Ecology and Sustainable Development

0. Introduction: The short history of human development
1. Ecology and ecosystems
2. Ecosystem functions
3. Concept of Sustainable Development
4. Environmental Pollution
5. Natural Resources
6. Climate Change
7. Socioeconomic Challenges
8. Third Industrial Revolution

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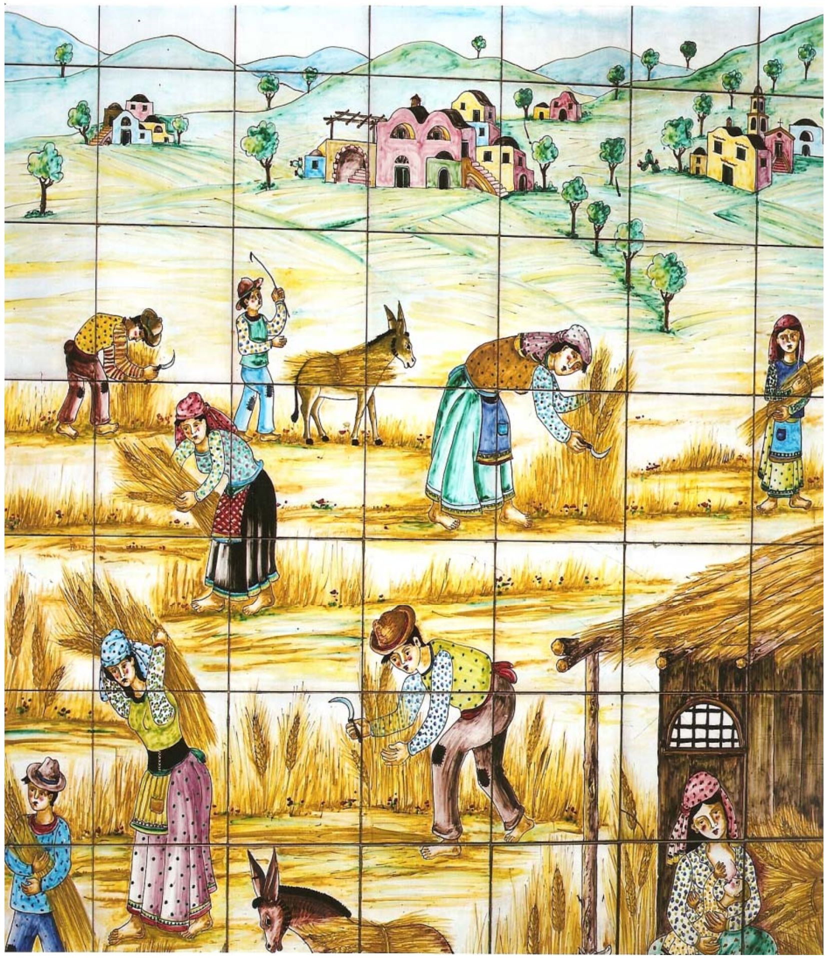
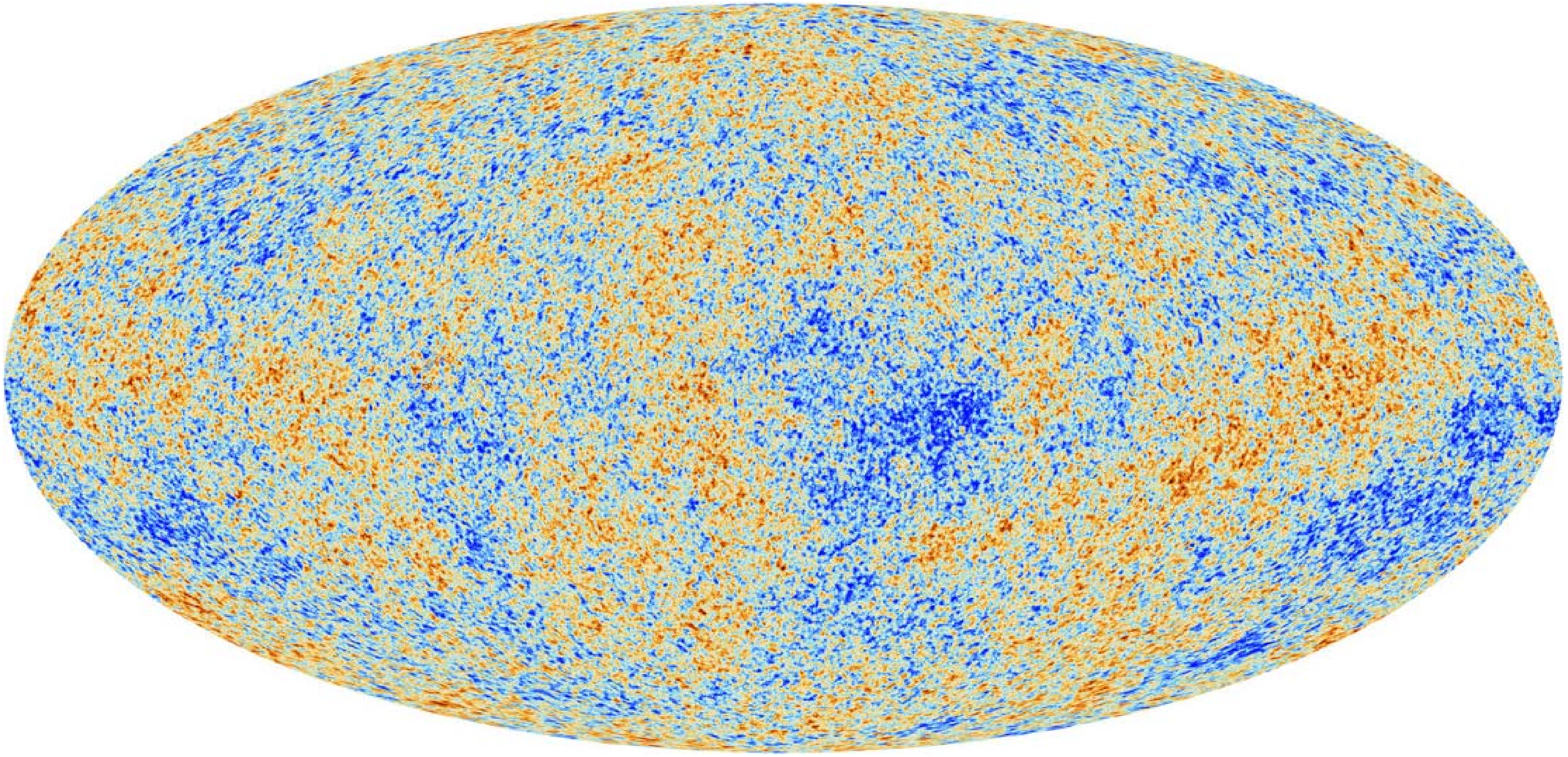


Literature, References and Acknowledgements

- **Recommended Literature:**
  - **Jay H. Withgott, Matthew Laposata:** Essential Environment: The Science behind the Stories, 6th Edition 2017, available printed volume ISBN-10: 0134204883, ISBN-13: 978-0134204888 ($ 159)
  - http://www.mypearsonstore.com/bookstore/essential-environment-the-science-behind-the-stories-9780321984579
  - **Wikipedia:** An very useful source of information on virtually all issues dealt with in the lecture course. Occasional inaccuracies may occur since the content of the articles is not validated.
- **References:**
  - Since this material is only for internal use by the student enrolled in the lecture course and not for public distribution the source of information is indicated on the slides in a general way, e.g. by listing the institution, but usually not the full bibliographical details. Photos where no specific indication of origin is given are generally from Wikipedia, where the specific citation can be found in full detail.
- **Acknowledgements:**
  - Material from this lecture course has been obtained from many different sources, particularly from international institutions active in this field like UNEP, the IPCCC, WHO, the European Environment Agency, The Joint Research Centre of the European Commission, etc., and also from Wikipedia which provides excellent articles on many topics of interest in this context. The possibility to obtain information from these sources for this course is gratefully acknowledged.

The Universe

•The **Universe**: the totality of existence, including planets, stars, galaxies, the contents of intergalactic space, subatomic particles, and all matter and energy.
•Began 13.82 billion years ago through the "Big Bang" which delivered all the energy contained in our present universe.



Source: ESA 2013

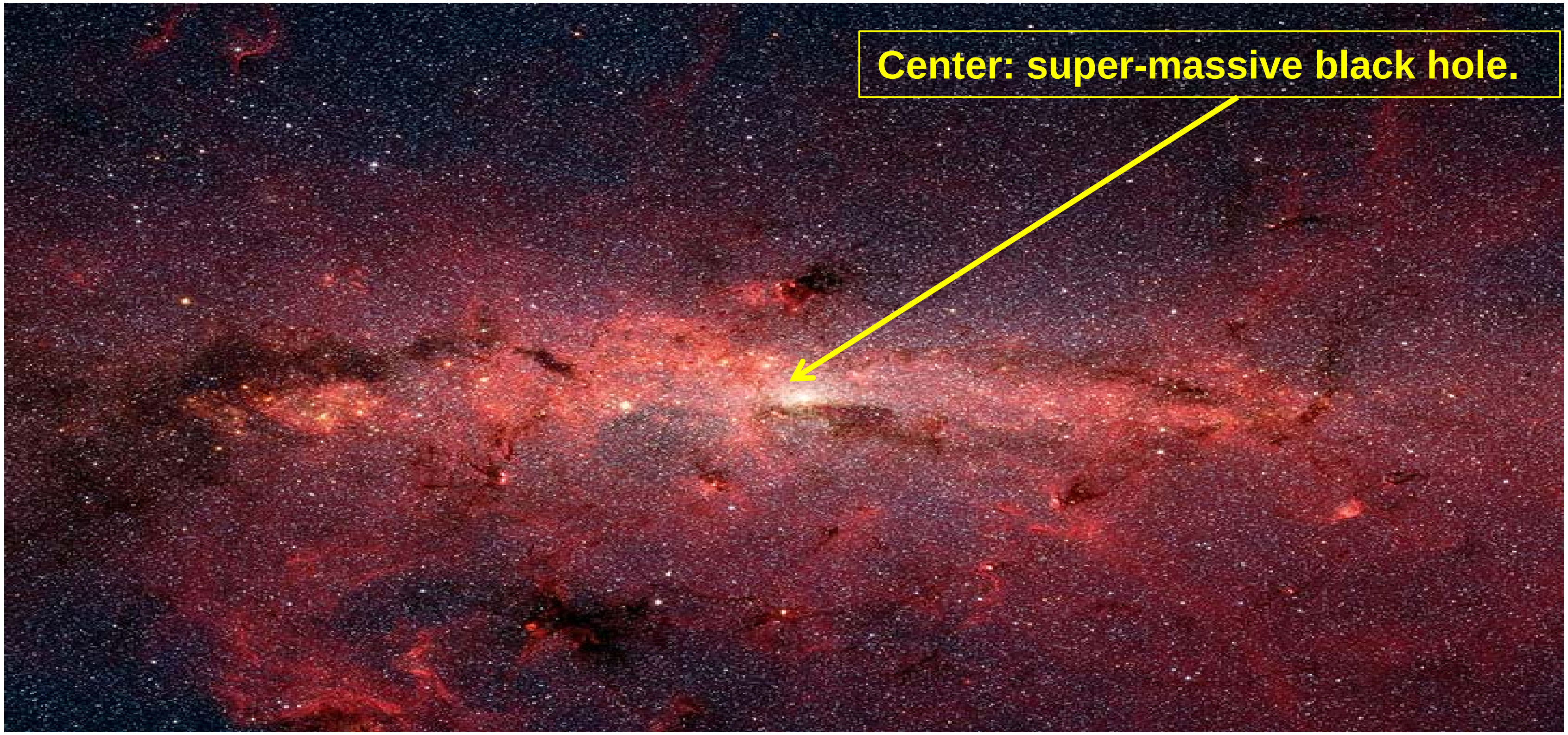
Space Telescope Planck (2009-2013): cosmic background radiation in range 30 und 857 GHz. Position 1,2 mio km distance from earth.

The Universe and our Galaxy

•There are probably more than 100 billion (10^{11}) galaxies in the observable Universe.

•**Our Galaxy:** the “Milky Way”

➢200-400 billion stars and at least as many planets, 10 billion of which could be located in the habitable zone of their parent star.

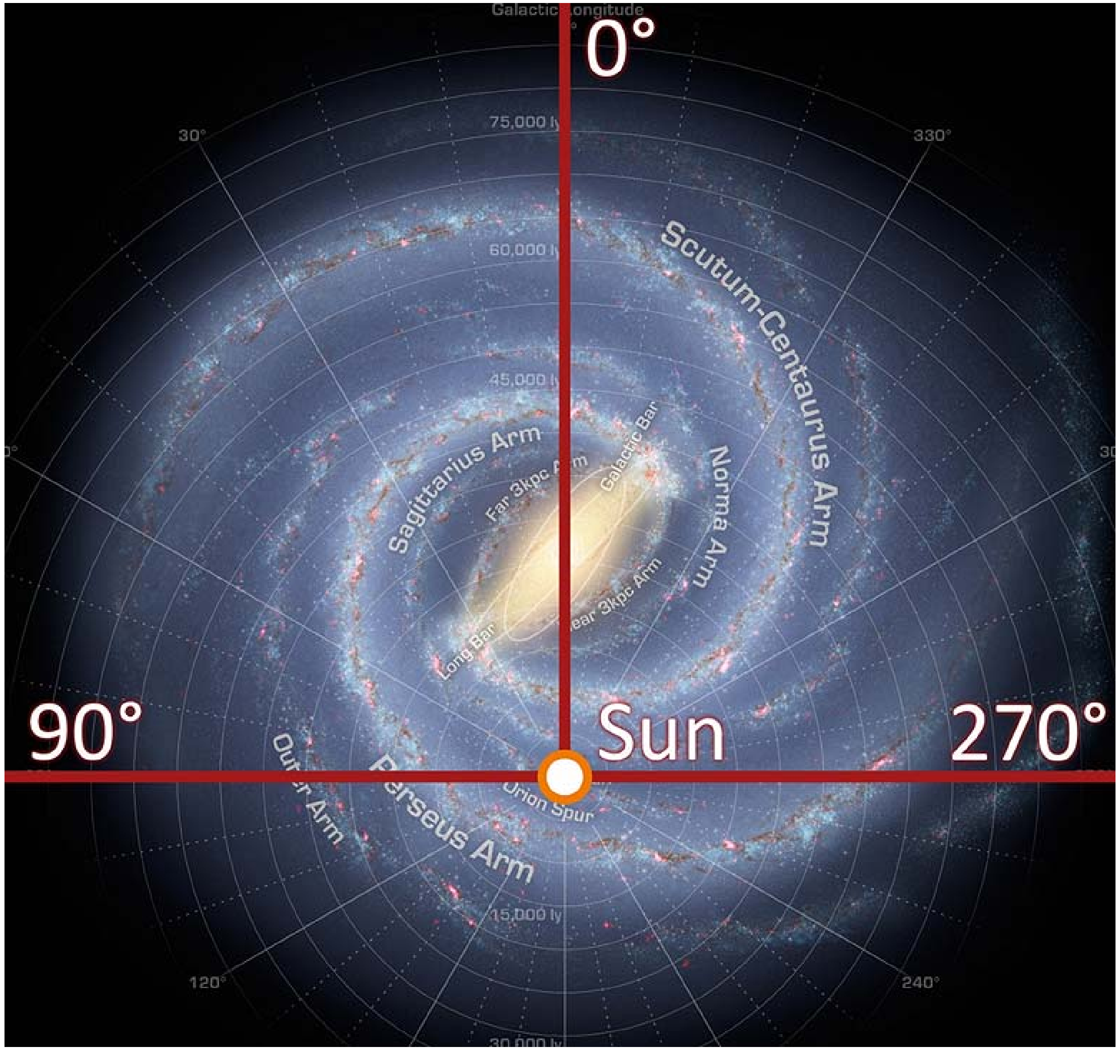


Source: NASA 2012, Wikipedia

Diameter 900.000.000.000.000.000 (9×10^{17}) km. Thickness: 9×10^{15} km.

Our Galaxy

- 13.2 billion years old, nearly as old as the Universe.
- The entire Galaxy moving with ca. 600 km per second (2 million km/h).



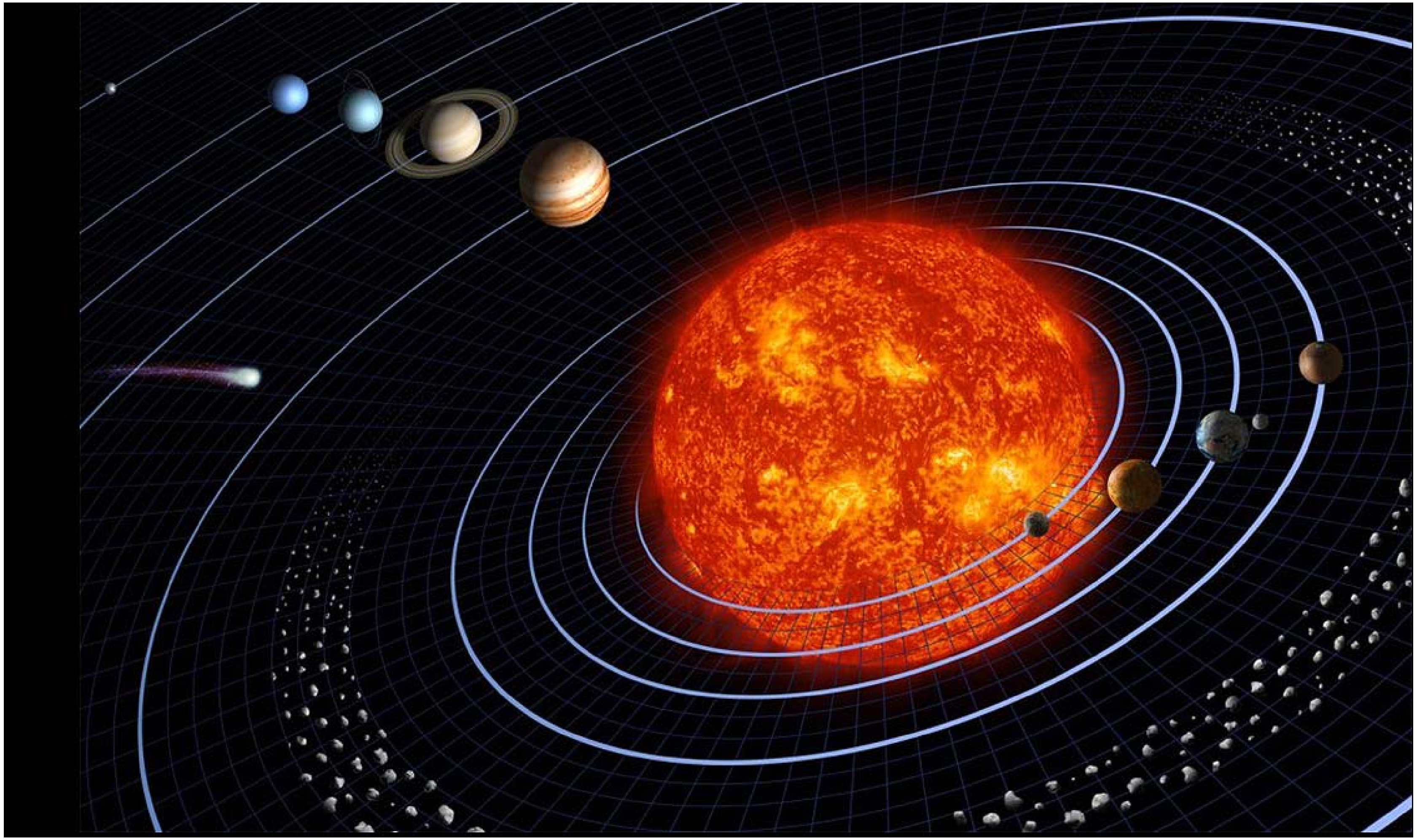
Sun location in the Milky Way Galaxy.

- Distance of sun from center ca. 3×10^{15} km.

- It takes the Solar System about 250 million years to complete one orbit around the Galaxy (a *Galactic year*).

Source: Wikipedia

Spaceship Earth



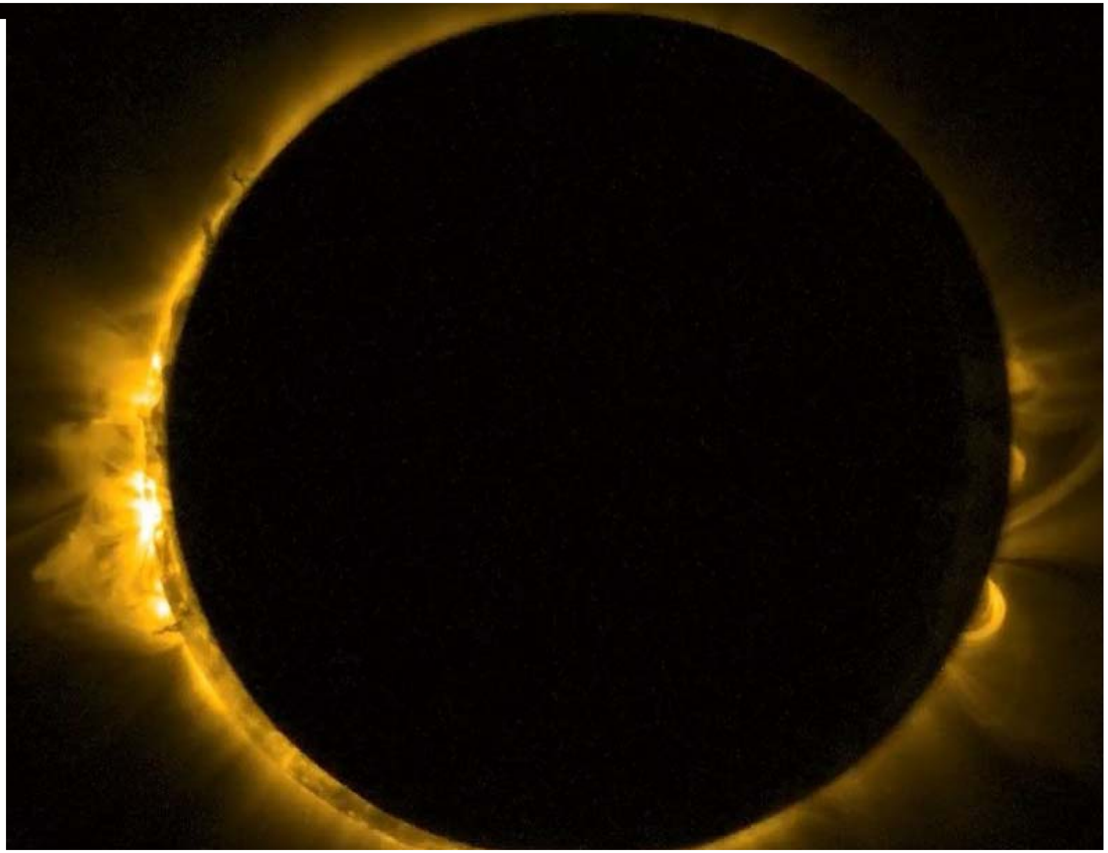
•Our solar system has 8 planets (Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune) and a diameter of 6.000.000.000 km.
•The diameter of earth is 12.000 km.
•Earth is the only planet with living objects.

Source: NASA 2012

Our Sun

- Ball of plasma consisting of hydrogen (73%) and helium (25%) formed ca 5 billion years ago from a collapsing molecular cloud.

- Radius 695.700 km
- Core temperature:
  15 million °C
- Reactions in core:
  nuclear fusion (proton chain)
  $^{1}H + ^{1}H = ^{2}H$
  $^{2}H + ^{1}H = ^{3}H$
  $^{3}H + ^{1}H = ^{4}He$
- Energy generated by fusion emitted at the surface as
  – radiation
  (50% IR, 40% VIS, 10% UV)
  – particles (solar wind)
- Surface temperature:
  5.500 °C (white color)
- Emissions of energy fluctuating



The turbulent surface of the Sun and its swirling corona captured during a solar eclipse on 20 March 2015 by Proba-2 satellite.
Source: ESA 2015

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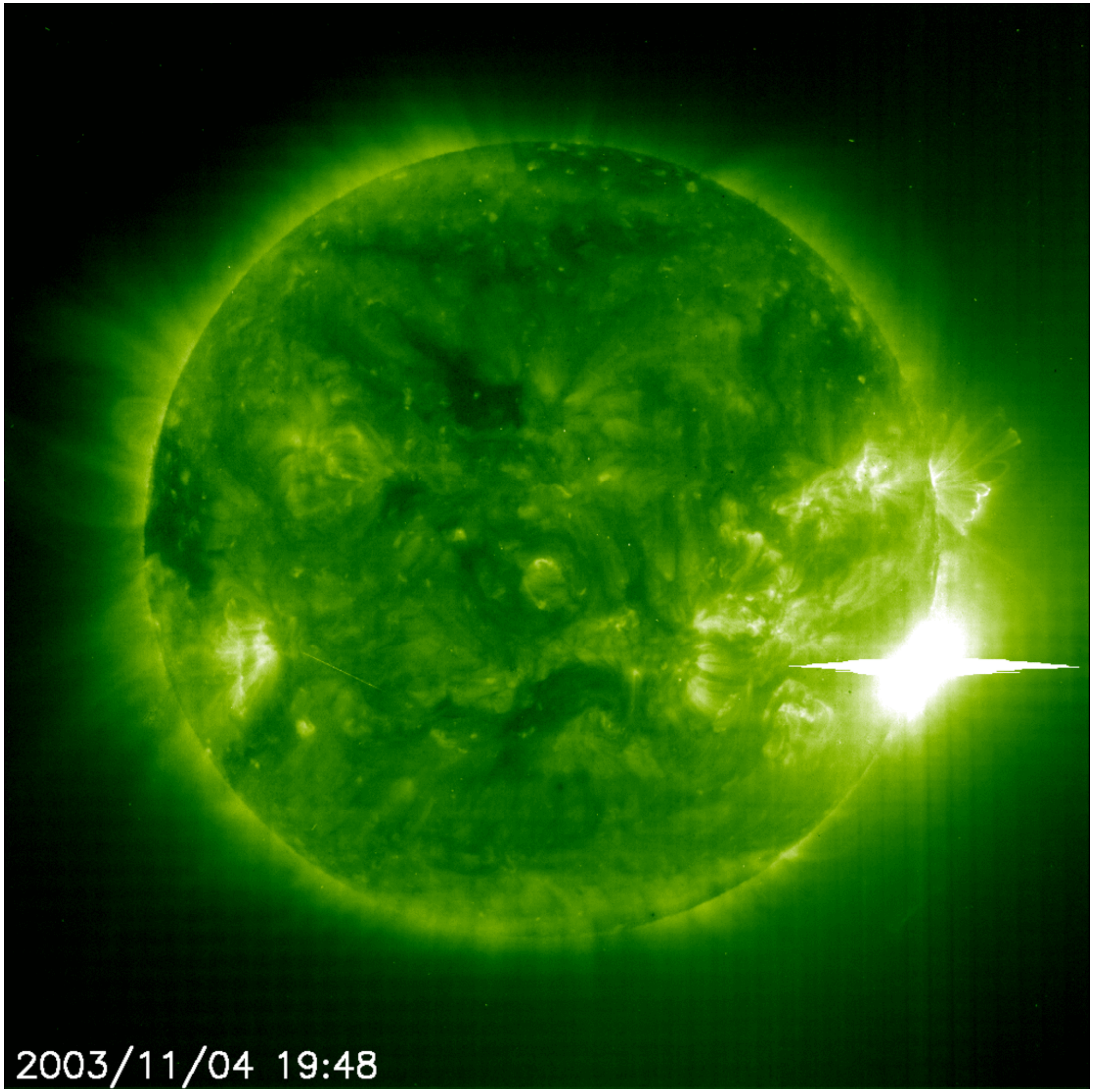
Giant Solar Flare



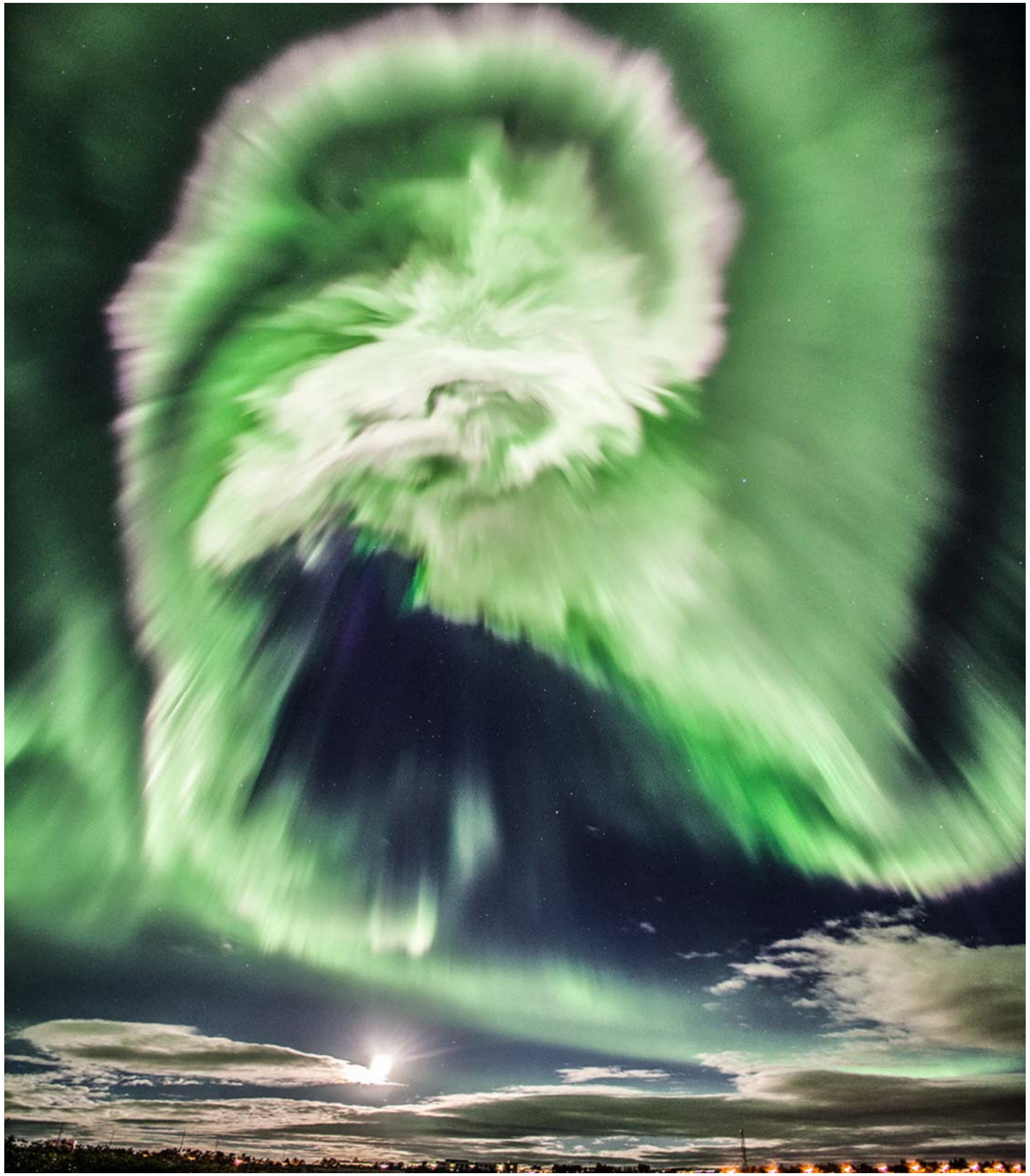
Near-instantaneous release of energy caused by a loop of magnetism snapping into a more stable configuration.

Energy of up to a thousand billion Hiroshima-sized atomic bombs can be released in just a few minutes.

A billion tonnes of the solar atmosphere was propelled into space at a speed of 2300 km/s (8.2 million km/h).

Source: ESA 2014

Aurora over Iceland



Solar particles hitting the earth‘s atmosphere.

The effect is seen only at polar and near-polar latitudes because the charged particles travel in towards Earth along magnetic field lines that meet our planet at its poles.

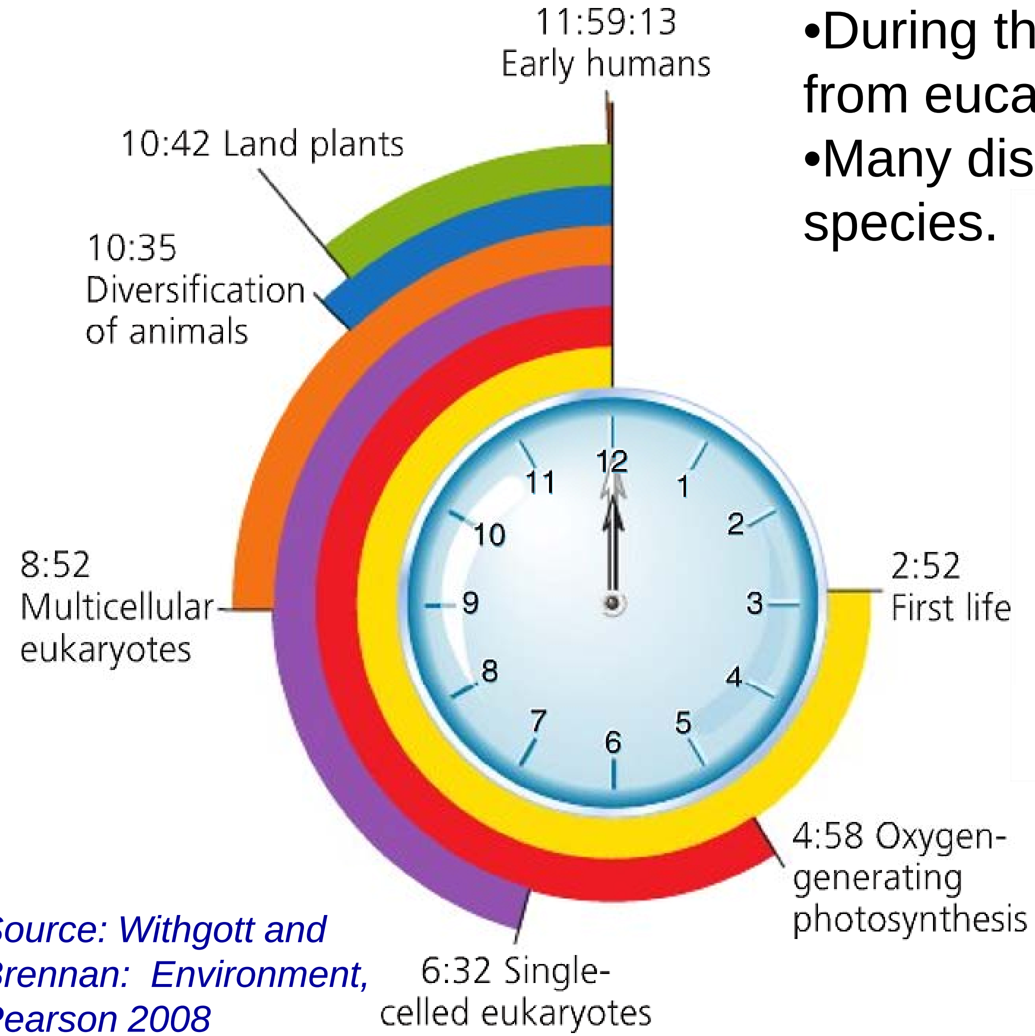
Earth magnetic field is protective but very strong solar particle streams can influence electrical fields on earth: 1980 power breakdown in Quebec

Source: ESA 2016

The Short History of the Human Development

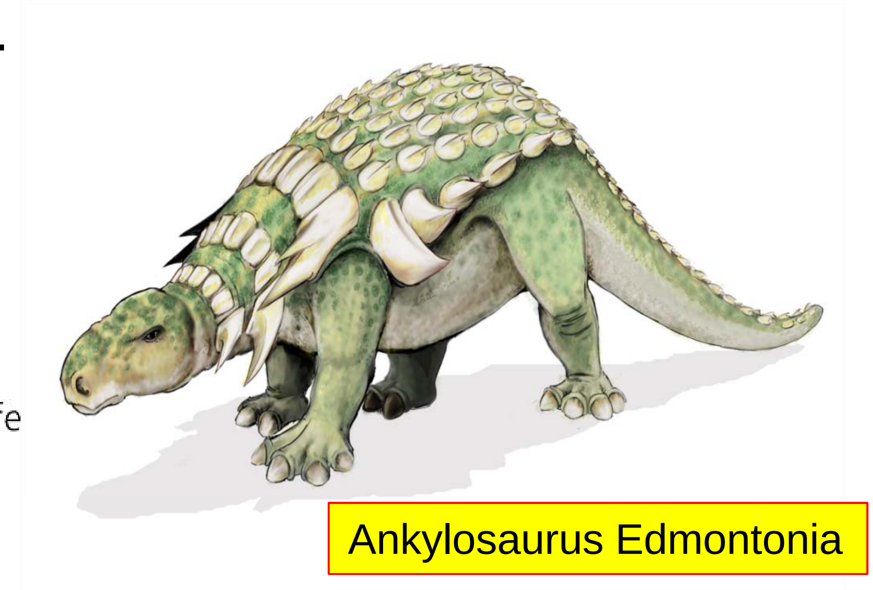
0. Looking back: The short history of the human development

•Our planet was born about 5 billion years ago.



Source: Withgott and Brennan: Environment, Pearson 2008

•During the ages many species developed – from eucariotic cells to mighty animals.
•Many disappeared and gave space for new species.



Ankylosaurus Edmontonia

•Humans arrived late as they are the most complex product of evolution.

Source: Wikipedia

The Short History of the Human Development

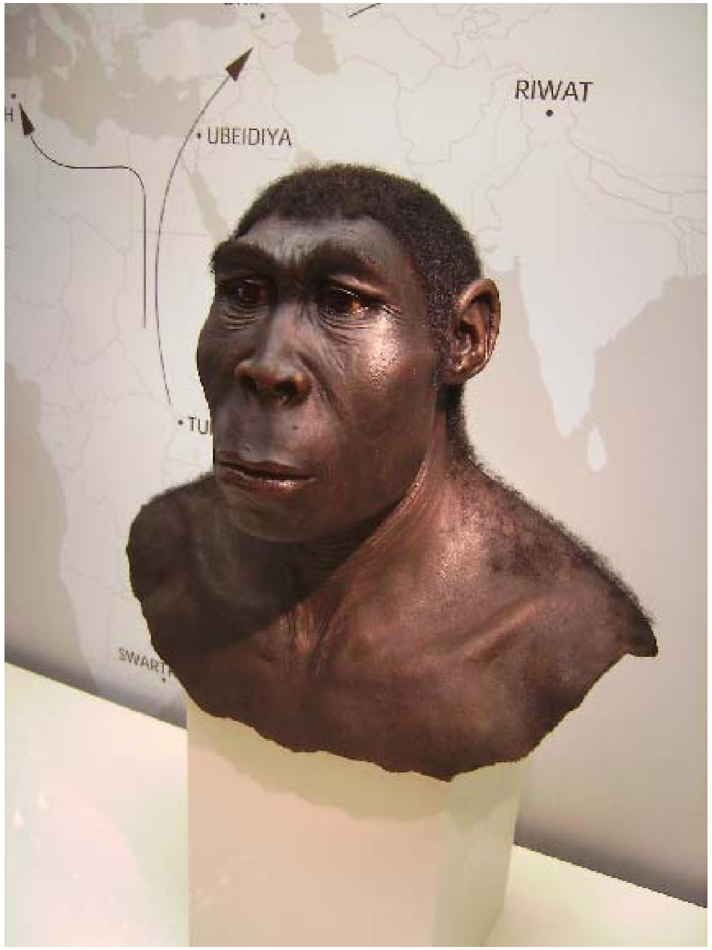
- ***Species Homininae:***
- 6 – 10 million years ago the separate evolution of hominins from the shimpanzees and gorillas started.
- hominins gradually developed bipedalism:
  - ability to detect wild animals across large distances by overlooking the grass in the African savannahs
  - development of hands and fingers gave new possibilities
- *Species Homininae however* lacked the large brains of modern humans.

A reconstruction of *Australopithecus afarensis,* size typically 1,2 m, lived 3 – 4 million years ago.

Source: Wikipedia

The Short History of the Human Development

- ***Homo erectus:***
- originally migrated from Africa 2 million years ago, and dispersed throughout most of the Old World, reaching as far as Southeast Asia.
- *H. erectus* was the first to control fire.
- Various species of homo erectus developed in different regions of the world:
  - *Homo erectus yuanmouensis (1,7 million years)*
  - *Homo erectus pekinensis (400.000 years)*
  - *Homo neanderthalensis (300.000 years)*

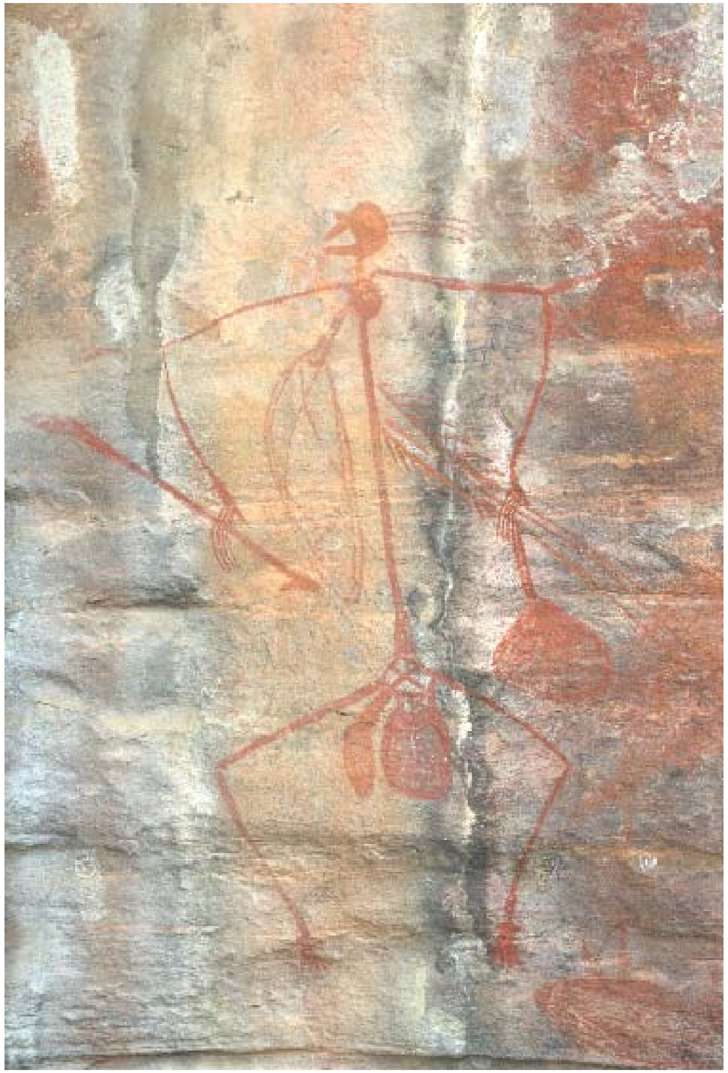


A reconstruction of *Homo erectus*. Typical height 1,80 m.

Source: Wikipedia

The Short History of the Human Development:
The Cognitive Revolution

- ***Homo sapiens:***
- seems to have developed some 200.000 years ago in Africa.
- Homo sapiens inhabited Eurasia and Oceania some 40.000 years ago, and the Americas some 10.000 years ago.
- The appearance of homo sapiens lead to the extinction of other homo species and many types of animals (large mammals like the mammoth).
- They hunted wild animals and gathered wild plants for food supply.
- *Homo sapiens* became the dominating species in nature.



Cave painting of a hunter in Northern Australia

Source: Wikipedia

The Short History of the Human Development:
The Cognitive Revolution

- **What is the reason for this supremacy of homo sapiens?**
  after all: 99% of the 23.000 genes of human beings are identical with those of the shimpanzees.

nerve cells in human brain

size of the brain:

– human brain has a weight of about 2 kg and is therefore 5 -10x larger than that of other animals (in relation to body weight)

– contains 100 billion cells connected in a complex 3-dimensional structure

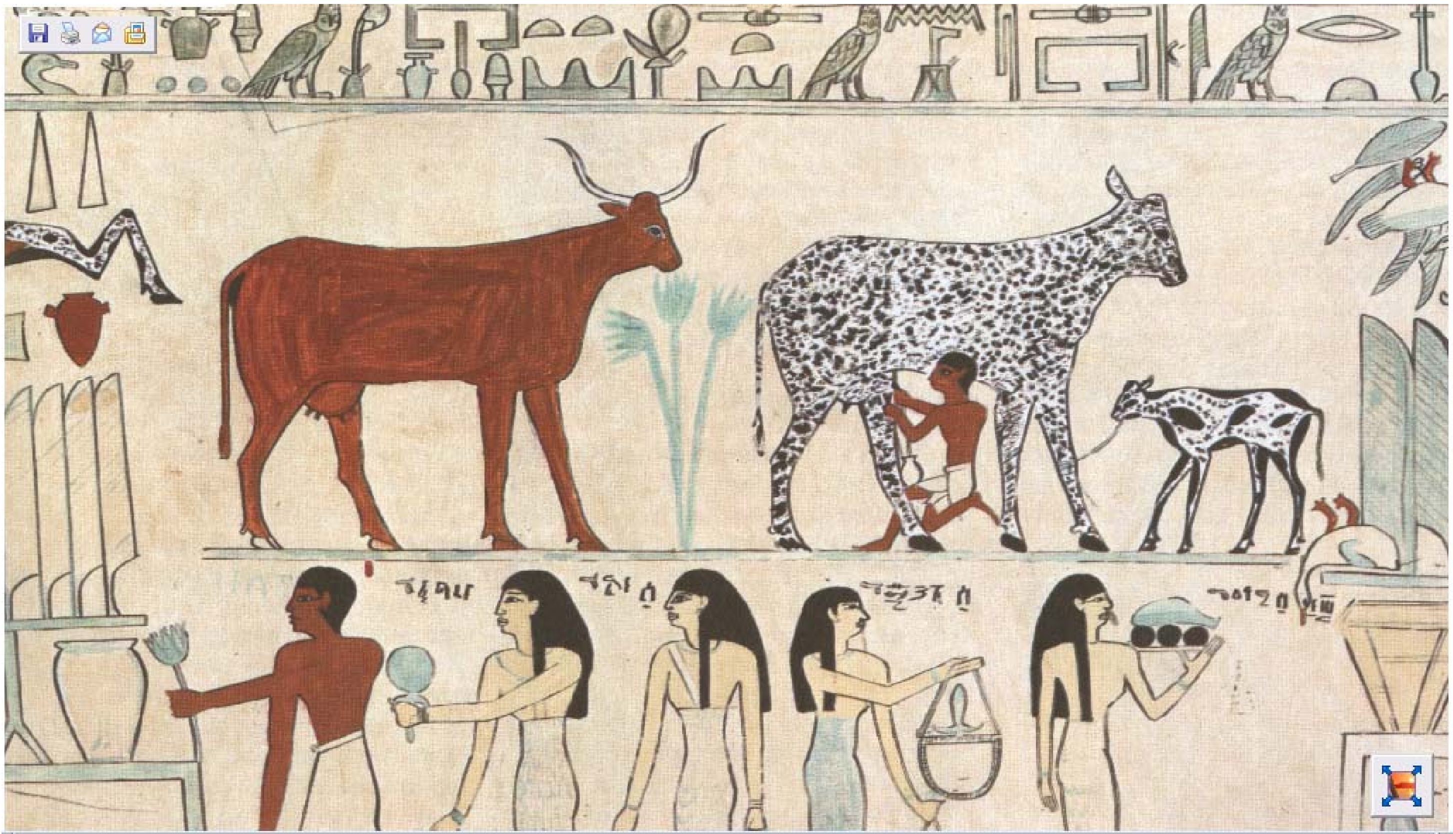
– consumes 25% of the energy uptake

Source: Yuval Noah Harari – Sapiens - A Brief History of Humankind, Vintage 2015

The Short History of the Human Development:
The Agricultural Revolution

•Until ca. 10,000 years ago most humans lived as hunter-gatherers in small eglitarian nomadic groups known as band societies.

•Then advent of agriculture led to permanent human settlements, the domestication of animals and the use of metal tools.



Early domestication: cow being milked in ancient Egypt.

Source: Wikipedia

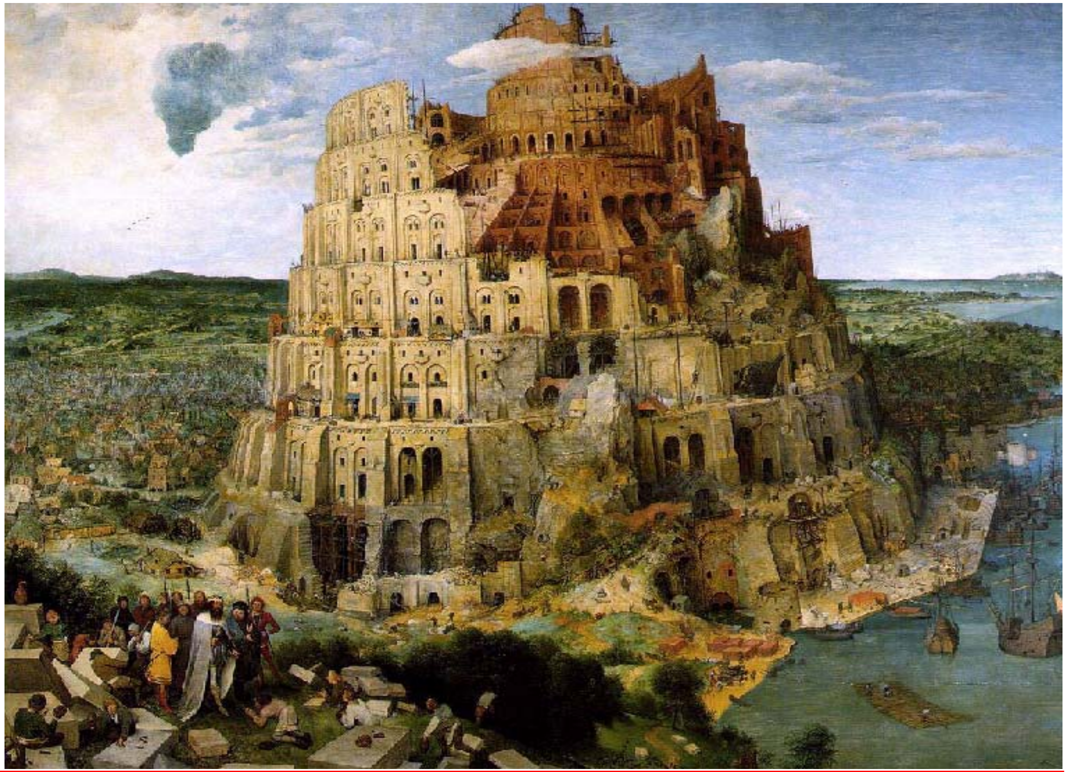
The Short History of the Human Development

•Agriculture encouraged trade and cooperation, and lead to a complex society, marking the begin of „civilization".

•Consequently the first proto-states developed in Mesopotamia, Egypt and the Indus Valley about 6,000 years ago.

•Cities were built, military forces were formed for protection, and government bureaucracies for administration.

•States cooperated and competed for resources, often in long wars.

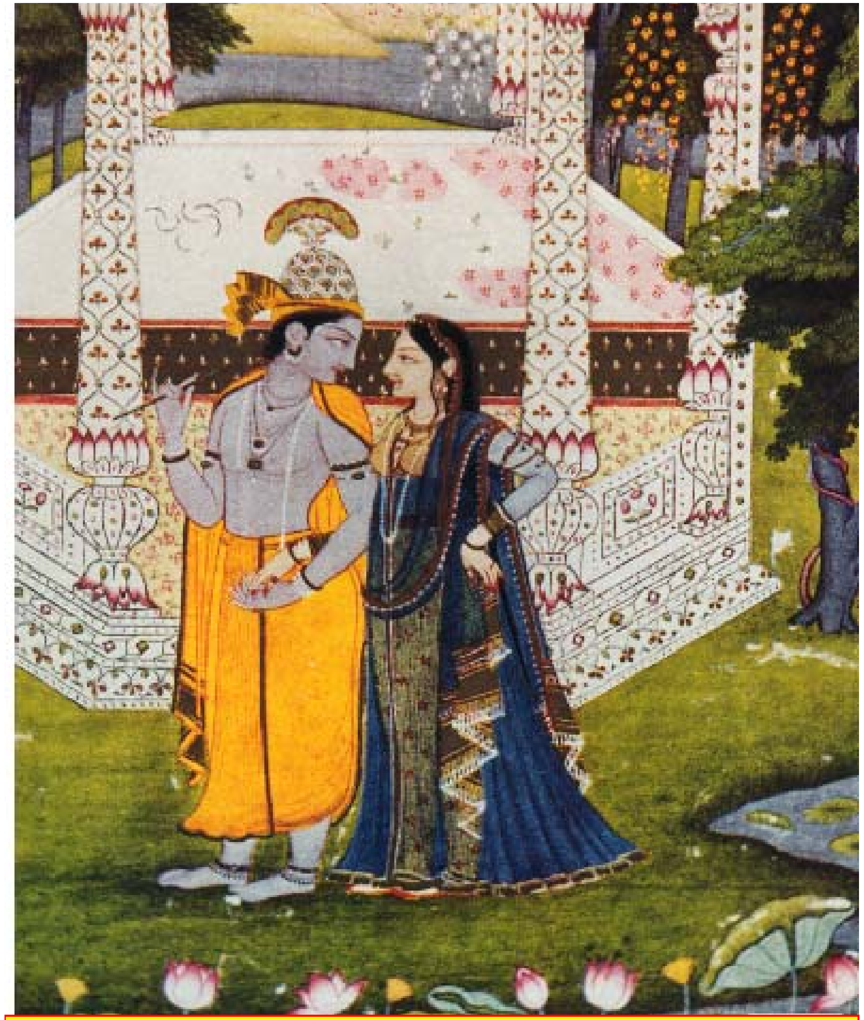


Tower of Babel by Pieter Bruegel de Oude.

Agamemnon (1.400 BC)

Source: Wikipedia

The Short History of the Human Development



Krishna (left), the eighth incarnation (avatar) of Vishnu, with his consort Radha

- Some 3.000 to 4.000 years ago major and influential religions emerged:
  - Hinduism, a religious tradition that originated in South Asia
  - Judaism, originating in the Middle East
- This was followed later by another 3 major religions:
  - Buddhism in Asia around 550 BC
  - Christianity originating in Judea around year zero, and
  - the Islam in the 7th century AD in Arabia.
  - These major religions have today close to 5 billion followers.

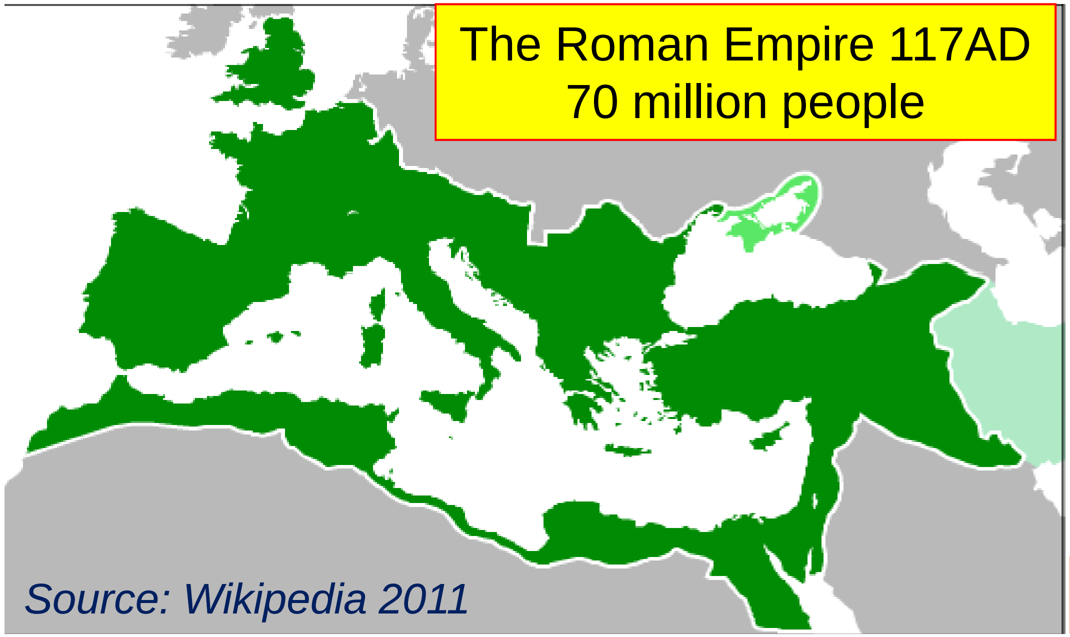
Source: Wikipedia

The Short History of the Human Development

Around 2,000 – 3,000 years ago the first large empires were established through conquest of neighbor territorries and populations:

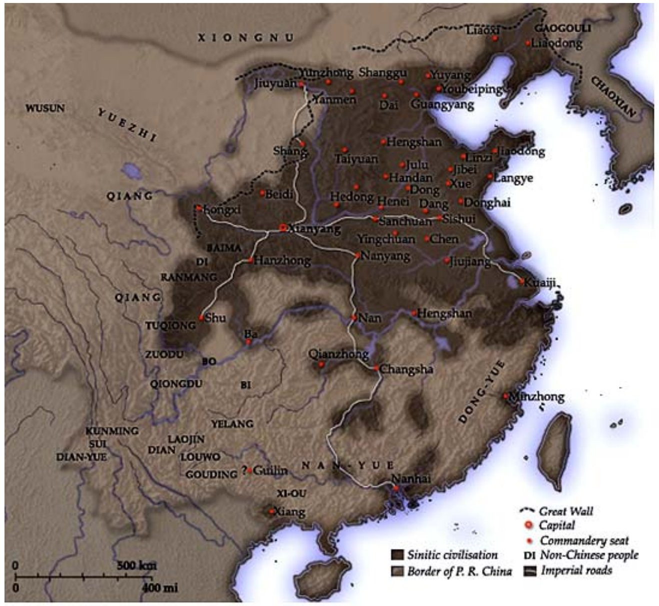
- *Persian Median Empire*
- *Qin Empire (China)*
- *Roman Empire*

Persian Median Empire 500BC – 50 million people



The Roman Empire 117AD
70 million people

Source: Wikipedia 2011



Source: Wikipedia

Qin Empire 215BC, 20 million people

The Short History of the Human Development

•The foundations of the Western civilization were largely laid in the philosophical schools of Greece between 500 and 100 BC.

The School of Athens founded by Plato in 385 BC.
Fresco by Raffaello Santi.

•The foundations of the governance systems of the Western world were developed in Rome from 500BC till 500AD.

A Roman aureus struck under Augustus AD 13–14

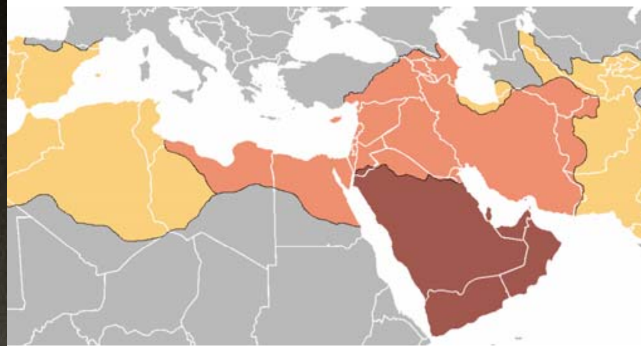
Photos: Wikipedia

The Short History of the Human Development

- The Middle Ages saw the rise of revolutionary ideas and technologies.
  - In China, an advanced and urbanized economy promoted fine arts and innovations such as printing and the compass.

A Chinese Tang Dynasty (618–907) sculpture of the Buddha.

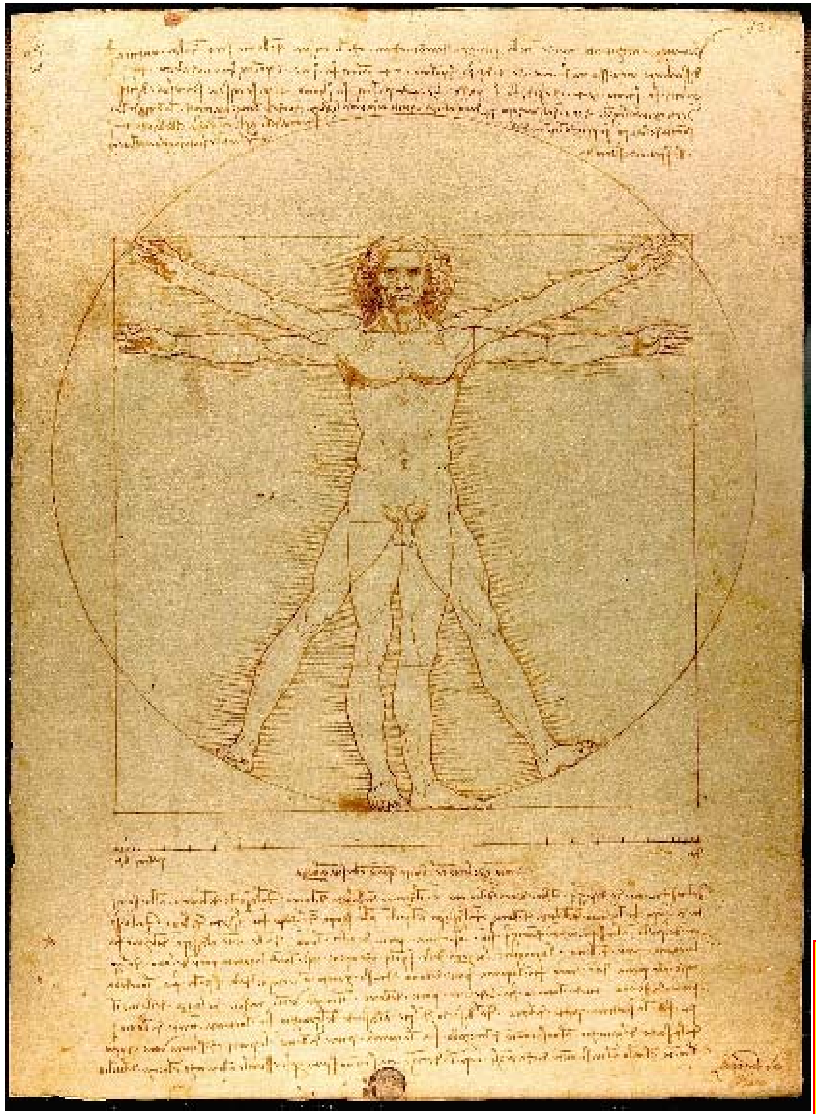
  - In the Mediterranean Region the Islamic Golden Age brought about major scientific advancements in the Muslim empires.



Jabir Ibn Hayyan (721-815) introduced the experimental method to chemistry. He also established the chemical industry and perfumery industry.

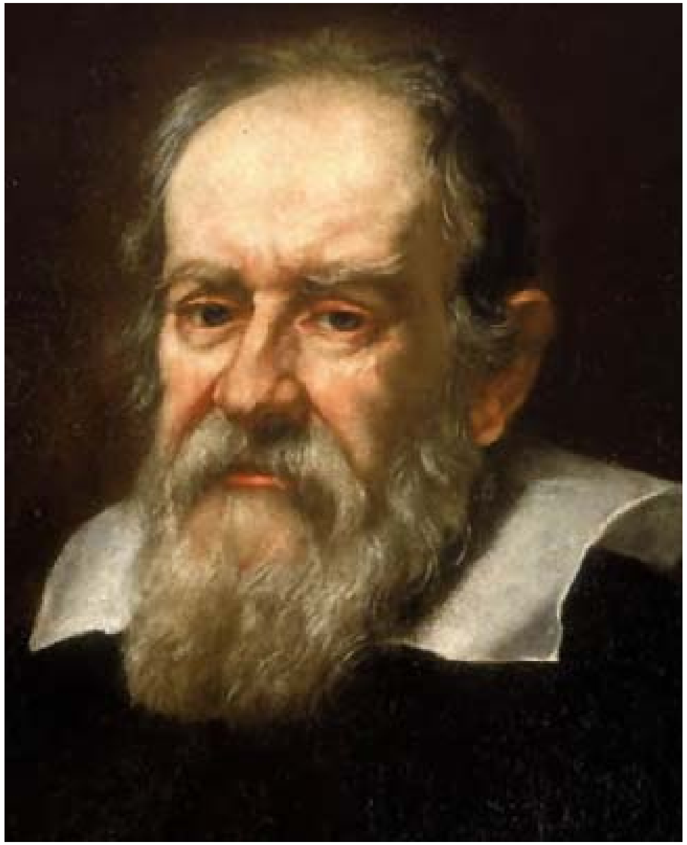
Photos: Wikipedia

The Short History of the Human Development



Leonardo da Vinci's Vitruvian Man of perfect proportions.

- The rediscovery of classical learning and inventions such as the printing press led to the Renaissance in the $14^{th}/15^{th}$ century.
- This „Golden Age“ of Europe produced the greatest masterpieces of art.
- Revolutionary scientific discoveries would provide the basis for our modern societies.



Galileo Galilei, born Pisa 1564 died Arcetri 1642

Photos: Wikipedia

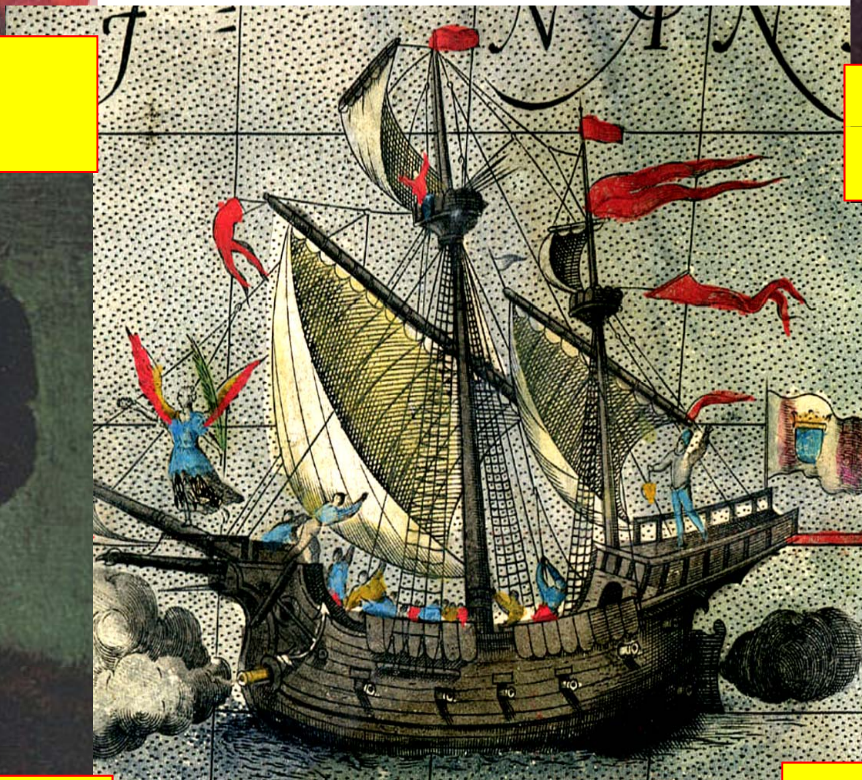
The Short History of the Human Development

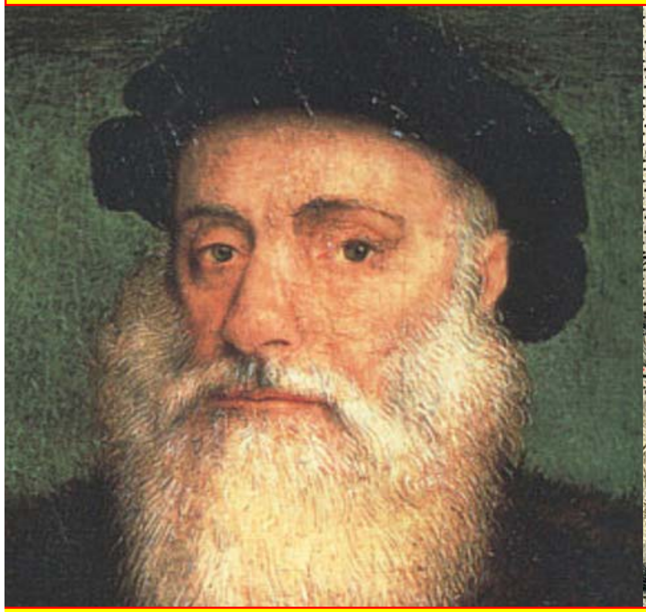
Cristoforo Colombo (1451-1506)

- Over the next 300 years, Europea seafarers set out to explore the unknown world and discover new continents.

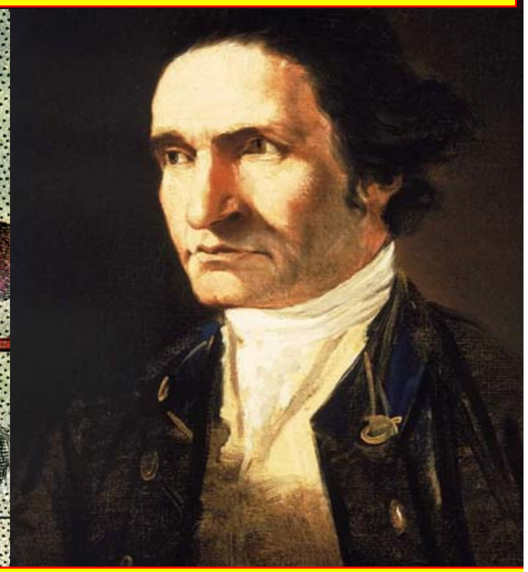
Fernão de Magalhães (1480-1521)

Victoria – only ship to return from Magalhães expedition.





Vasco da Gama (1469-1524)



James Cook (1728-1779)

Source: Wikipedia

The Short History of the Human Development

- Exploration and imperialistic conquest brought much of the Americas, Asia, and Africa under European control.
- First colony: the Aztec empire became New Spain

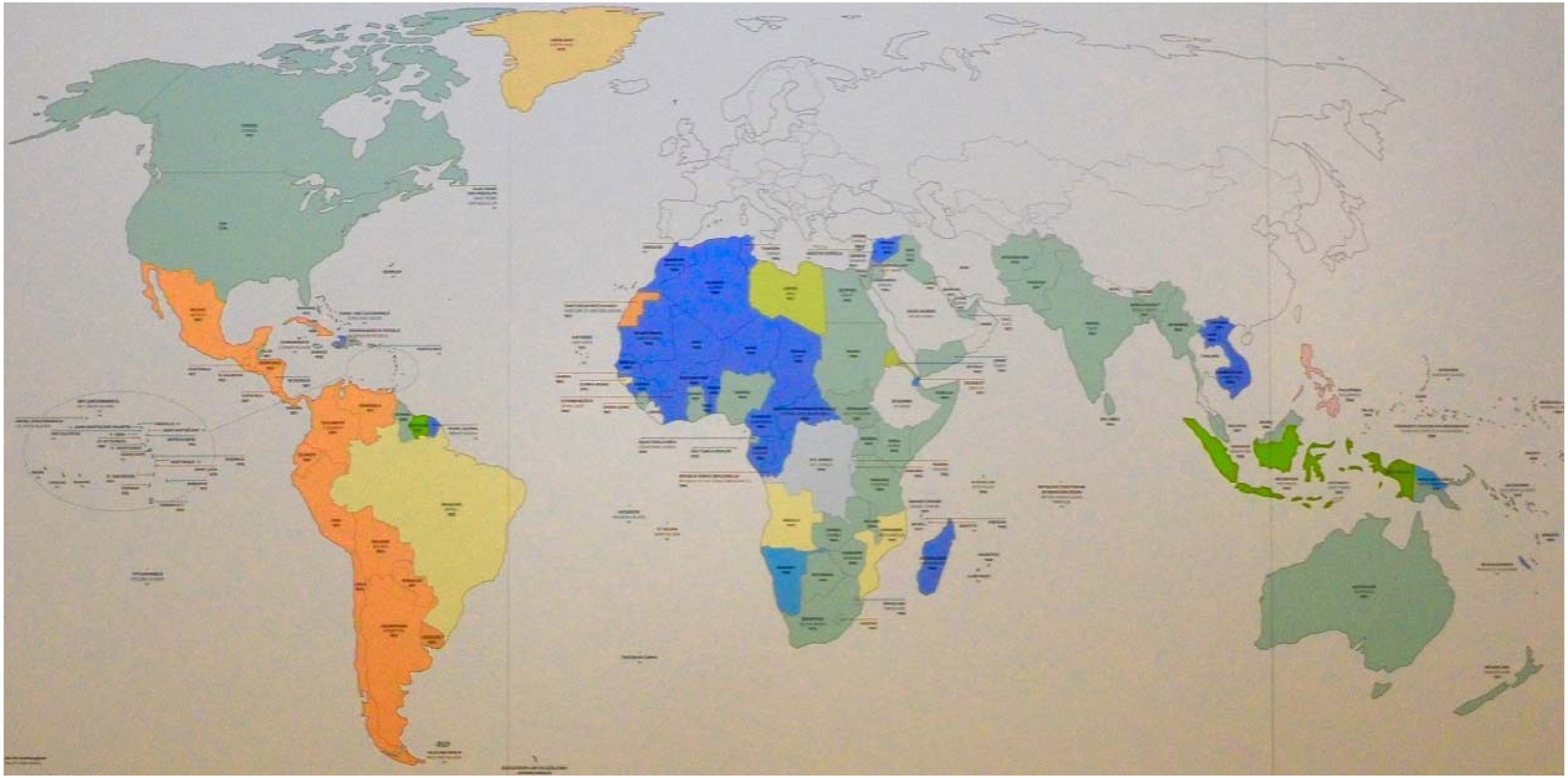
Hernando Cortes (1485-1547)

Quetzal feathered headdress, Mexico (Weltmuseum Wien)

Conquest of the Aztec Empire:
500 soldiers with horses and firearms defeated an Aztec army of more than 50.000 with the help of an uprising of other peoples suppressed by the Aztec rulers.

The Short History of the Human Development:
Map of Former European Colonies

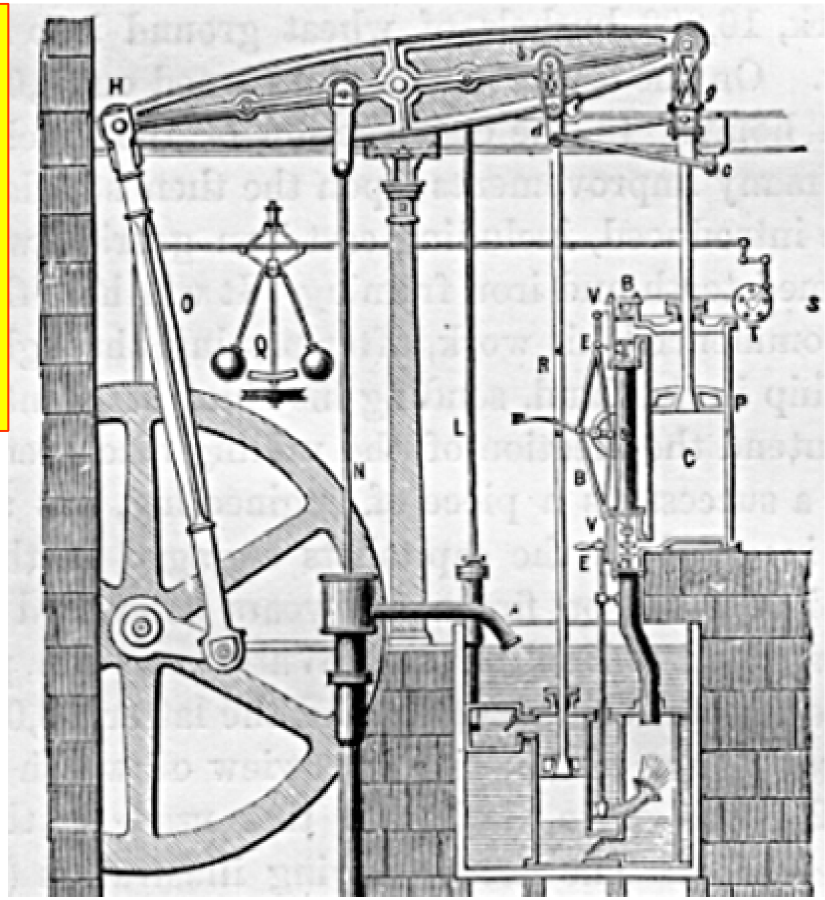
- England, Spain and France created huge colonial empires.
- Great Britain had more than 50 colonies largest empire ever: 40 million km^2
- Huge amounts of valuables brought from the colonies to Europe:
  South America: gold, silver; North America: furs; India: jewels, spices.



The Short History of the Human Development:
The (First) Industrial Revolution

•The First Industrial Revolution from 1750 till 1850 promoted major innovations: steam engine to introduce mechanical labour, mechanical transport, such as the railway and steam ships.

Steam engine designed by Boulton & Watt. Drawing from 1784.



Photos: Wikipedia

James Watt, born Greenock, Scotland 1736, died Handsworth, England 1819

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Lionel Feininger – Locomotive

The Short History of the Human Development

•Another key element of the the first Industrial Revolution is the development of chemical sciences providing the basis for new materials, new medicines, new forms of energy production and a better understanding of nature and its processes.

•**Justus von Liebig 1840:** „Die organische Chemie in ihrer Anwendung auf Agricultur und Physiologie.“

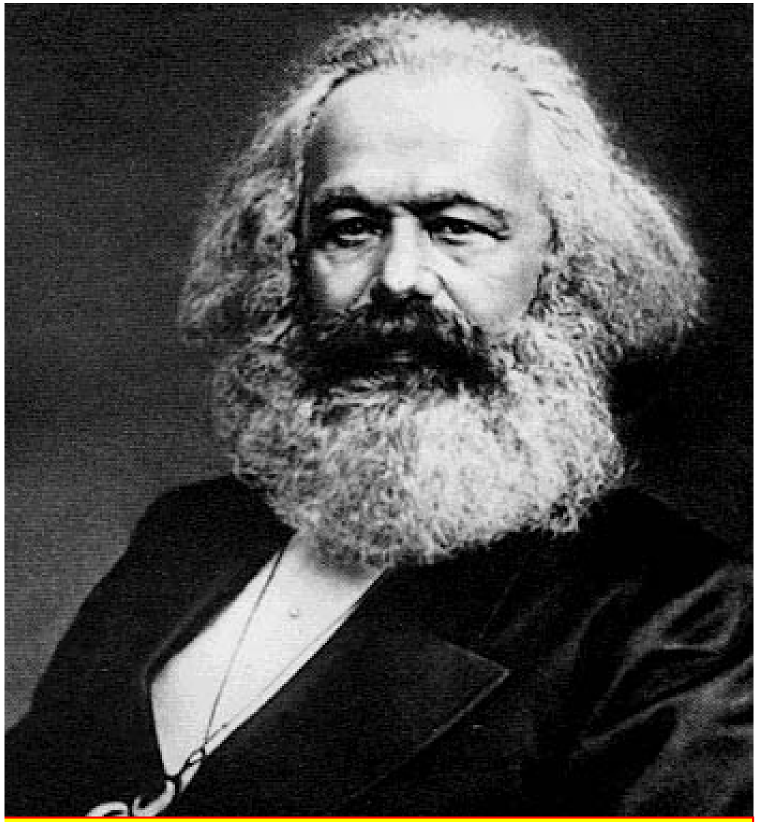
•Discovery of the role of nutrients for plant growth and development of the first chemical fertiliser allowed to combat hunger and starvation in a rapidly growing population.

Antoine Lavoisier,
born Paris 1743
died Paris 1794

Photos: Wikipedia

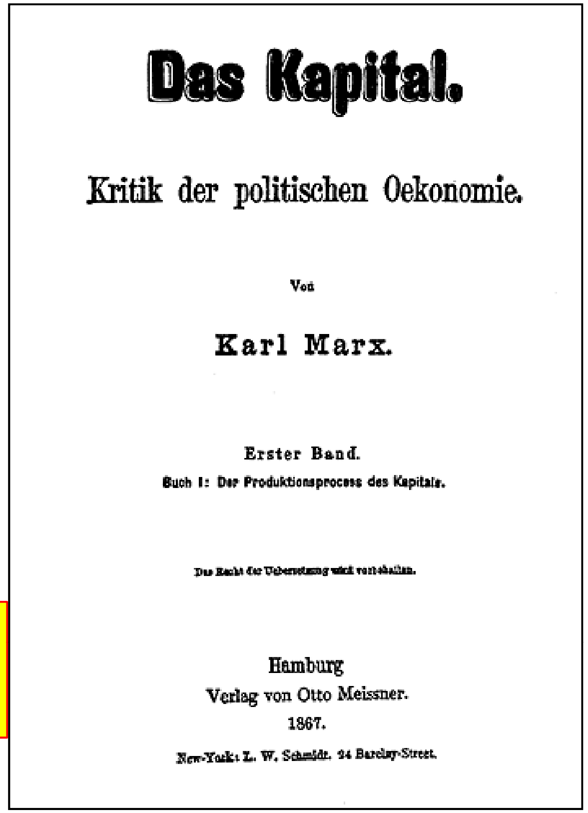
The Short History of the Human Development

- The industrial revolution brought about a massive increase in productivity, a general improvement of the economic and social standards, even great wealth for a limited group of people, but also serious societal disorders.
- New powerful philosophies and political streams developed as a response.



Karl Heinrich Marx,
born Trier 1818, died London 1883

- Karl Marx: *„The central driving force of capitalism is in the exploitation and alienation of labour"*.
- „Das Kapital" is one of the most important publications in human history.
- It provided the new political ideology of communism and later socialism.



Das Kapital.

Kritik der politischen Oekonomie.

Von

Karl Marx.

Erster Band.

Buch I: Der Produktionsprocess des Kapitals.

Das Recht der Uebersetzung wird vorbehalten.

Hamburg

Verlag von Otto Meissner.

1867.

New-York: L. W. Schmidt. 24 Barclay-Street.

Das Kapital, published 1867

Photos: Wikipedia

The Short History of the Human Development

•The second industrial revolution from 1850 till 1940 brought about major innovations, like:

•modern steel production ⟹ railways

•electricity ⟹ radio, electric lightening, telephone

•combustion engine ⟹ automobiles

•pharmaceuticals ⟹ modern medicine

European railway network 1850

Photos: Wikipedia

Syphilis caused by bakterium treponema pallidum treated with Arsphenamin (1910).

The Short History of the Human Development

•The first half of the 20th century is characterised by the extensive use of modern technologies for warfare leading to

–an up-to date unknown mass extinctions of human beings in a short time
(100 million people died),

–extensive poverty in many regions of the world,
and finally

– a massive shift of political power from Europe to America.

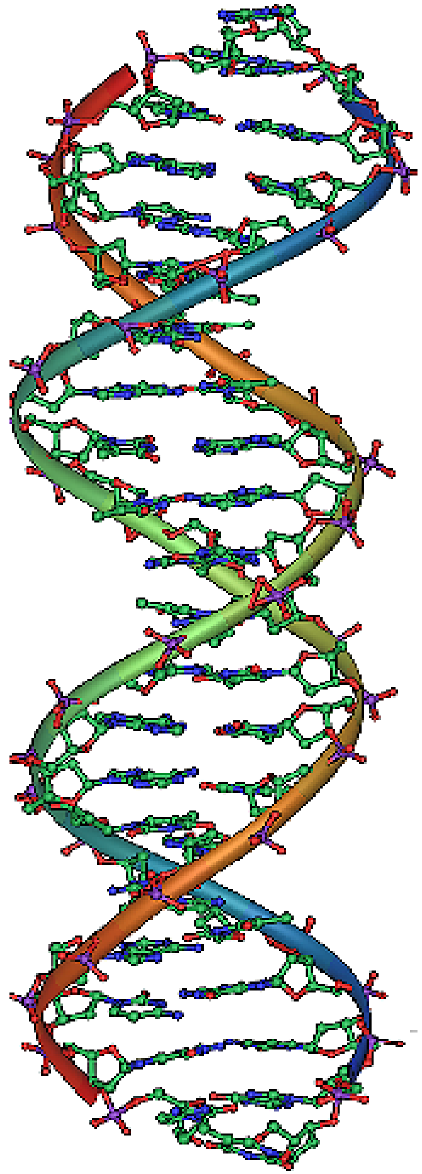
Iwo Jima, February 23, 1945
Raising the first flag.

The Short History of the Human Development

•The second half of the the 20th century is characterised by new revolutionary scientific achievements, like the invention of the transistor, or the clarification of the structure of the DNA, leading to the Third Industrial Revolution.

First transistor invented by William Shockley, John Bardeen and Walter Brattain at Bell Labs December 23, 1947.

Structure of DNA as discovered by James Watson, Francis Crick 1953 at Cambridge, UK



Photos: Wikipedia

The Short History of the Human Development

- The second half of the the 20th century is also characterised by
  - emergence of many new states from former colonies,
  - an expansion of the democratic political systems,
  - the rebuilding of much of Europe as a new entity called European Union, and
  - the rising of the USA to the global superpower with clear cultural, societal, military, financial, economic and political dominance.

Jean-Baptiste Nicolas Robert Schuman (* 29. Juni 1886 in Luxemburg; † 4. September 1963 in Chazelles bei Metz) was one of the founders of the European Union.

The Short History of the Human Development

THE 21ST CENTURY WILL OVERturn many of our basic assumptions about economic life. The 20th century saw the end of European dominance of global politics and economics. The 21st century will see the end of American dominance too, as new powers, including China, India and Brazil, continue to grow and make their voices heard on the world stage. Yet the century's changes will be even deeper than a rebalancing of economics and geopolitics. The challenges of sustainable development—protecting the environment, stabilizing the world's population, narrowing the gaps of rich and poor and ending extreme poverty—will render passé the very idea of competing nation-states that scramble for markets, power and resources.

Jeffrey Sachs, Director UN Millenium Project
Time Magazine, March 24, 2008

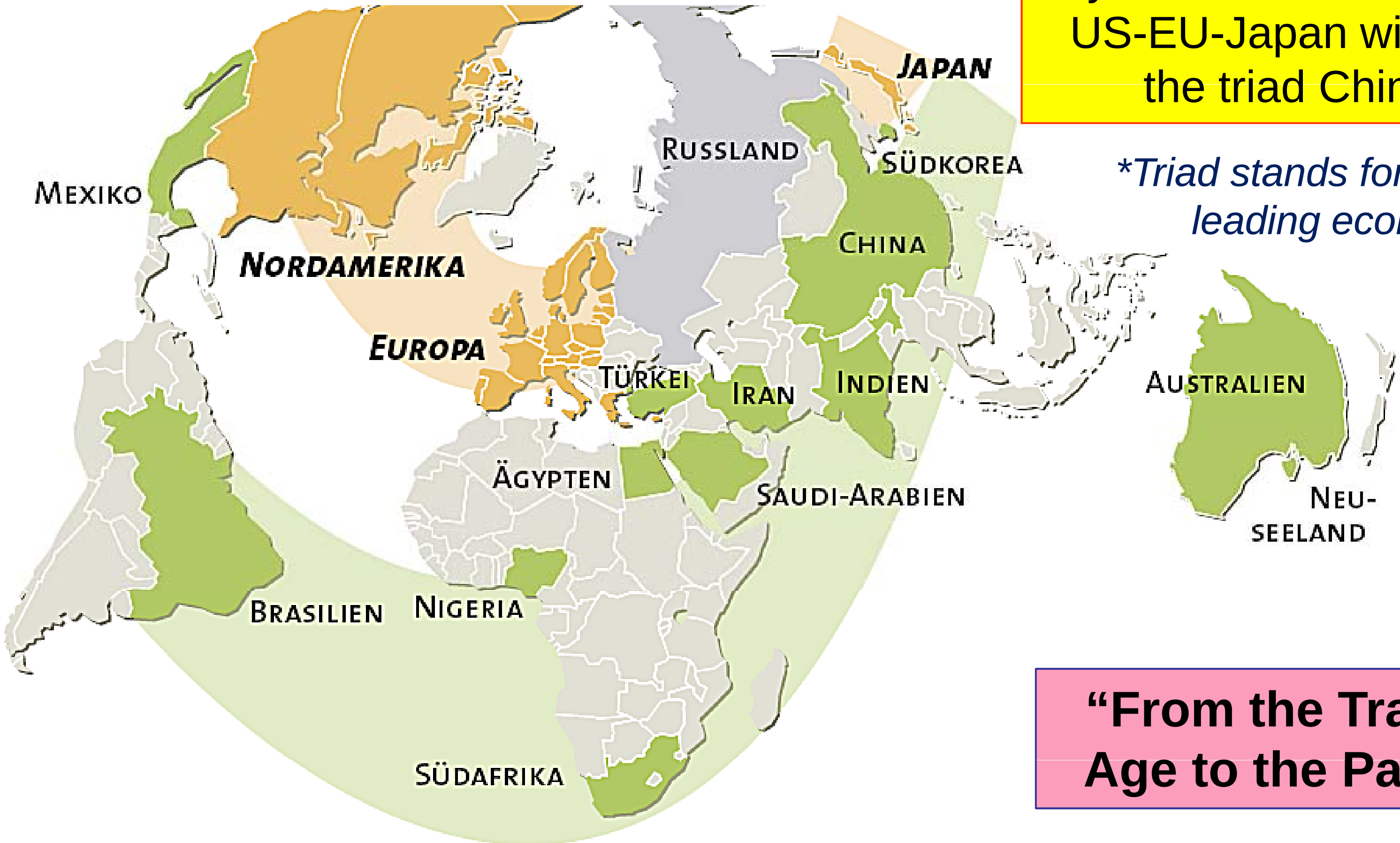
- The 21st century will be the period of globalisation.
- The prime drivers for globalisation are
  - the USA, Europe and Japan, who are looking for new markets for their industrial and service products, and
  - the dynamic developing countries of Asia, like China, India, who provide these markets and act as producers for most basic goods.
- The most important basis is the WTO agreement of 1995 which covers 95% of the global population.
  - Globalisation poses huge challenges for the human society.

The Short History of the Human Development

- Globalisation has a major economic and political impact.
- 21st century will see emergence of new powers and the development of a very different „multipolar and multicultural“ global economic and political system.
- Moving towards „The Gobal Village“.

By 2050 the now dominating triad* US-EU-Japan will be replaced by the triad China-India-USA

**Triad stands for the group of the 3 leading economic regions.*

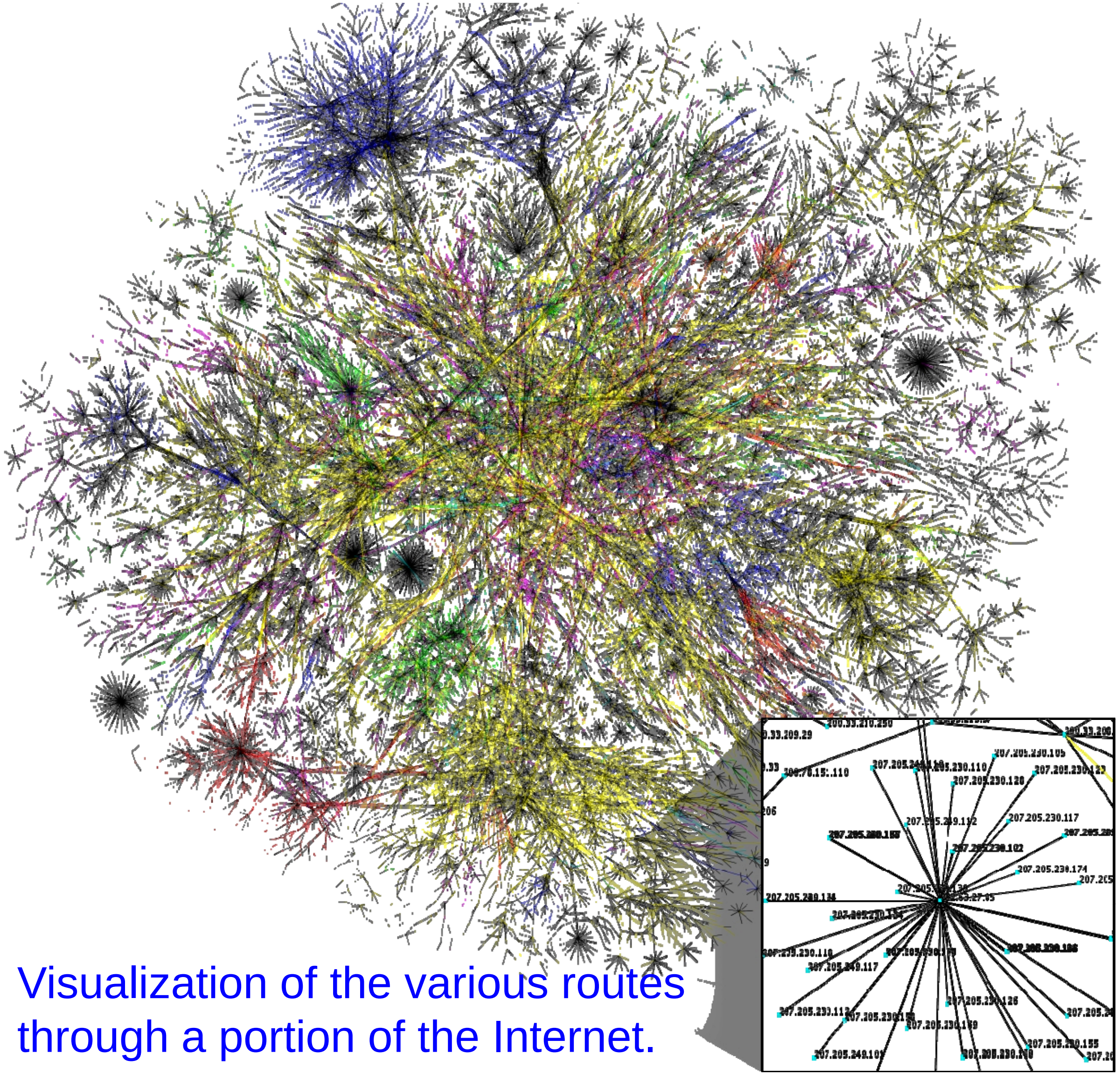


“From the Transatlantic Age to the Pacific Age.”

Power constellation in the 21st century. *Source: Le Monde Diplomatique 2007*

The Short History of the Human Development

•Globalisation means transcending classical geographical boundaries.
•ICT has largely impacted on individuals and societies across the globe.



Visualization of the various routes through a portion of the Internet.

•Tim Berners-Lee, a British scientist at CERN, invented the World Wide Web (WWW) in 1989.

•4,2 billion internet users in 2018
(40 million 20 years ago)

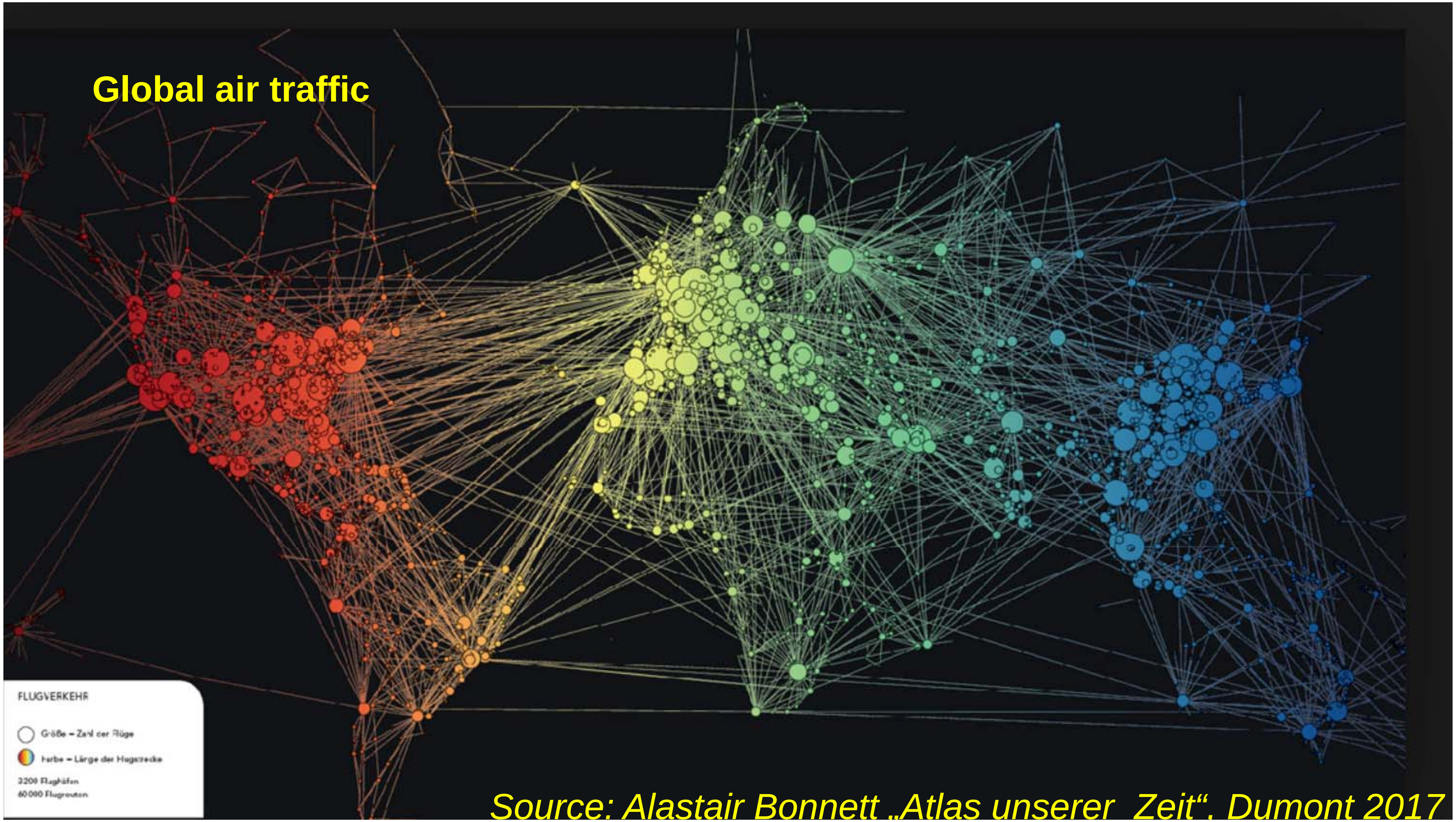
•4,5 billion smartphones

•2 billion Facebook users

•Today 7,7 billion people from 1.000 nations and 200 countries interact, many of them in real-time.

The Short History of the Human Development

A connected world:
40 million flights per year; 4,4 billion air passengers (2018)



The Short History of the Human Development

- **Human impact on planet Earth:**
  - **Transformation of half of the earth's surface.**
  - **10 fold increase in population during last 3 centuries.**
  - **15 fold increase in energy and resource consumption during last century.**
- **"Anthropocene"**

Source: Paul Crutzen: Anthropocene,and 3DNWorld web-site

The Future:
Six Major Transformations

Digital revolution
Artificial intelligence, big data, biotech, nanotech, autonomous systems

Human capacity & demography
Education, health, ageing, labor markets, gender, inequalities

Smart cities
Decent housing, mobility, sustainable infrastructure, pollution

Consumption & production
Resource use, circular economy, sufficiency, pollution

Food, biosphere & water
Sustainable intensification, biodiversity, forests, oceans, healthy diets, nutrients

Decarbonization & energy
Energy access, efficiency, electrification, decent services

Source: TWI2050.org, JMMüller IIASA 2018

Ecology and Sustainable Development

1. Ecology and Ecosystems:

1.1 Biology and the Environment: scope of ecology, Earth's ecological systems

1.2 Biosphere: lithosphere, atmosphere, hydrosphere, biogeochemical cycles

1.3 Ecosystem Dynamics: productivity, stability/vulnerability, ecological crisis

Photo: Michael Lange Geo 2011

Definition of Ecology

1.1 Biology and the Environment:

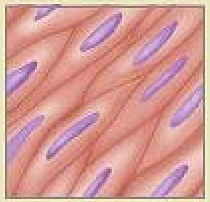
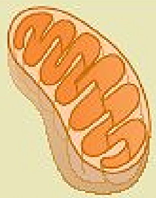
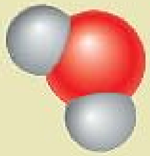
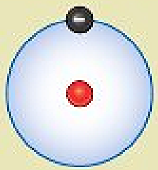
- **Ecology:**

– Multi-disciplinary science focussing on the relationship of organisms – usually of higher level - with the environment.

- **Environment of an organism:**
  - (local) abiotic factors such as insolation (sunlight), climate, and geology,
  - biotic factors, which are other organisms that share its habitat.
- **Organisms can be studied at many different levels**, from
  - proteins and nucleic acids (in biochemistry and molecular biology), to
  - cells (in cellular biology), to
  - individuals (in botany, zoology, and other similar disciplines), and finally at the level of
  - populations, communities, and
  - ecosystems, to the
  - biosphere as a whole.

Source: Wikipedia

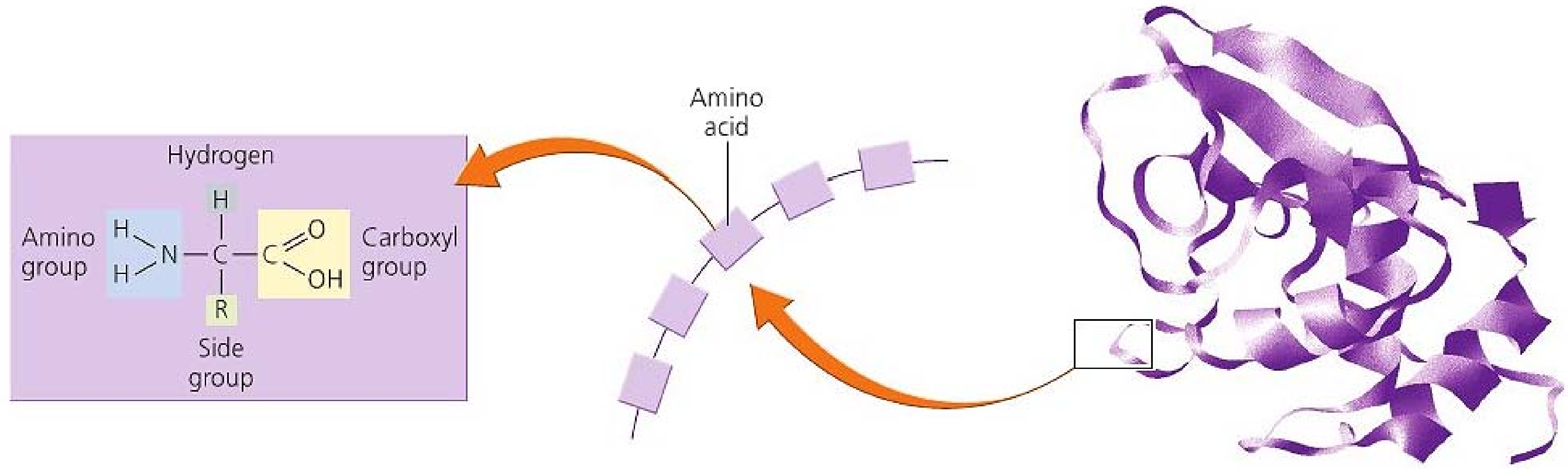
Hierarchy of Matter

Hierarchy of Matter within Organisms		
	Organism	An individual living thing
	Organ system	An integrated system of organs whose action is coordinated for a particular function
	Organ	A structure in an organism composed of several types of tissues and specialized for some particular function
	Tissue	A group of cells with common structure and function
	Cell	The smallest unit of living matter able to function independently, enclosed in a semi-permeable membrane
	Organelle	A structure inside a eukaryotic cell that performs a particular function
	Macro-molecule	A large organic molecule (includes proteins, nucleic acids, carbohydrates, and lipids)
	Molecule	A combination of two or more atoms chemically bonded together
	Atom	The smallest component of an element that maintains the element's chemical properties

Source: Withgott and Brennan: Environment, Pearson 2008

Hierarchy of Matter:
From Molecules to Living Cells

Makromolecules are the building blocks of life: proteins

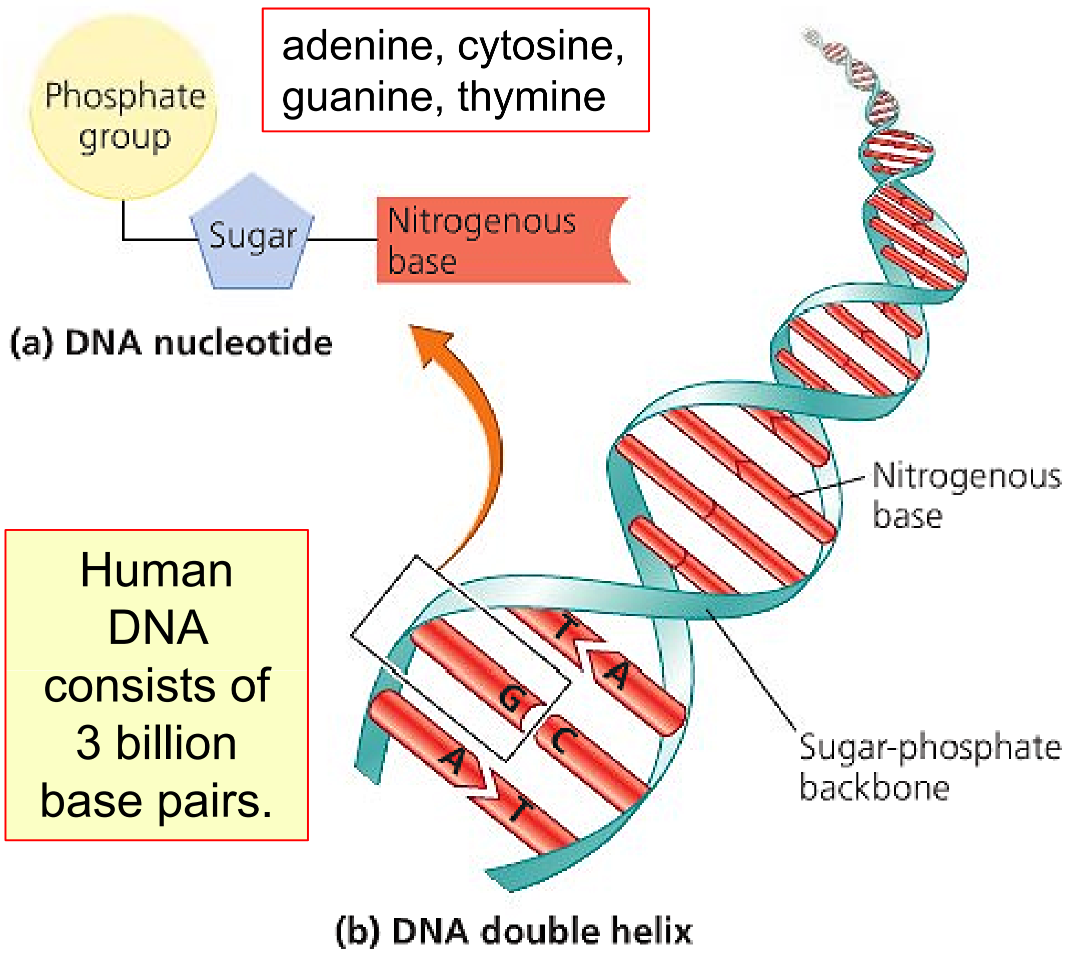


(a) General structure of an amino acid (b) Chain of amino acids (c) Protein

Source: Withgott and Brennan: Environment, Pearson 2008

Hierarchy of Matter:
From Molecules to Living Cells

Protein production is directed by the nucleic acids deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).



- The DNA contains all the hereditary information.
- This information is rewritten to a molecule of RNA which directs the order of amino acids in building a protein.
- Genetic information contained in the DNA is passed on from one generation to another as the DNA strands replicate during cell division and egg or sperm formation.

Source: Withgott and Brennan: Environment, Pearson 2008

Hierarchy of Matter:
From Molecules to Living Cells

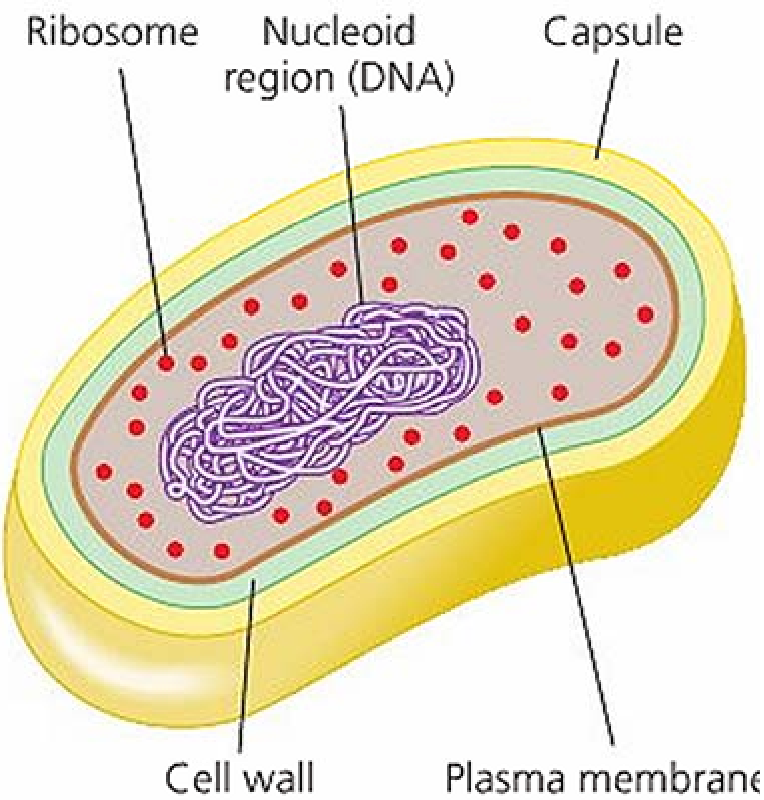
- Length of an individual DNA-strand (if pulled out to a one-dimensional string): 2m
- Total length of all DNA-strands in a human body: 1000x distance earth-sun (as the human body contains 7.10^{12} cells)
- Regions of the DNA which perform the particular coding functions are called „genes“.
- Humans have 23.000 genes (twice as many as a mosquito).
- The genome is the whole set of genes of an organism and is divided into chromosomes.
- 99,9% of DNA of all persons are identical.
- Hereditary influence determined by individual human genome:
size 90%, weight 70%, diabetes 70%, age 25%

Source: Withgott and Brennan: Environment, Pearson 2008

Hierarchy of Matter:
From Molecules to Living Cells

Cells are the smallest unit of life that can function independently.

Source: Withgott and Brennan: Environment, Pearson 2008



Prokariotic cell

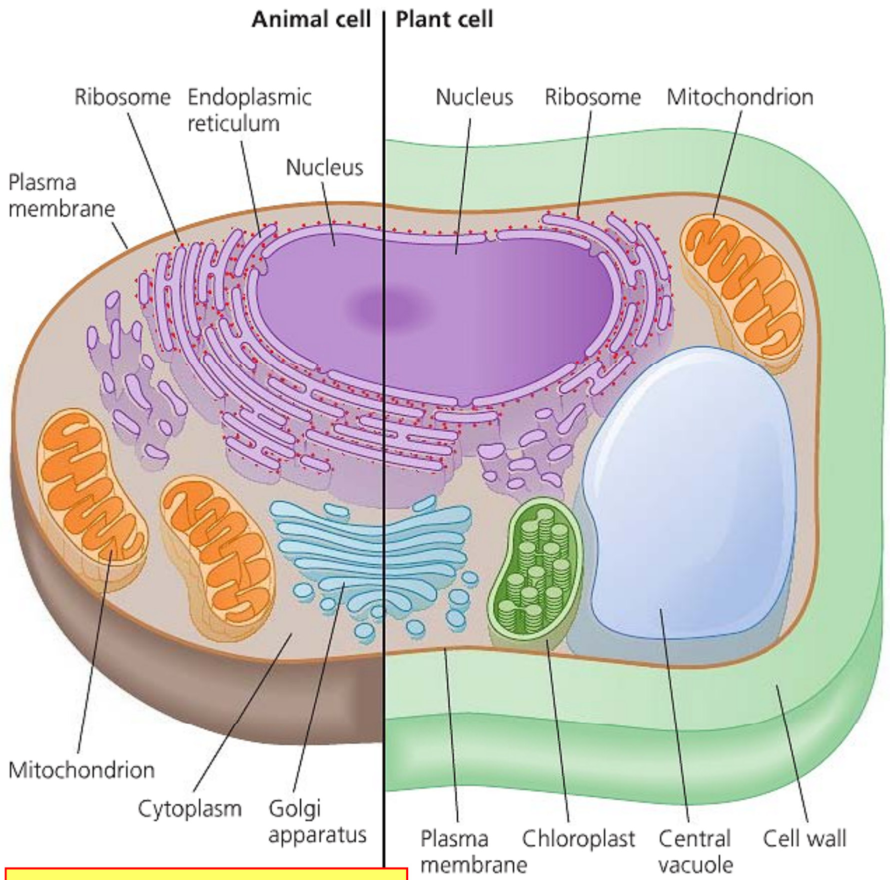
- Prokaryotes are single cell organisms like bacteria.
- Prokaryotic cells have a simple structure:
  - -cell wall of peptidoglycan (polysaccharide chains cross-linked with peptides),
  - -membrane of lipids,
  - -cytoplasm (cell fluid),
  - -ribosomes for the synthesis of proteins,
  - -a nucleoid region with the DNA.
- Bacteria are diverse and ubiquitous in the environment, vital for life, and often form colonies and live in symbiosis with other organisms.

The first living things on Earth were prokaryotes. The oldest ancient fossil microbe-like objects are dated to be 3.5 billion years old.

Hierarchy of Matter:
From Molecules to Living Cells

Source: Withgott and Brennan: Environment, Pearson 2008

Animals, plants, fungi have eukariotic cells.



Eukariotic cell

•Eucariotic cells have a more complex structure:

•Cell wall (peptides and/or carbohydrates) and an outer membrane of lipids.

•Cytoplasm containing organelles and an enclosed membrane-bound nucleus with the DNA.

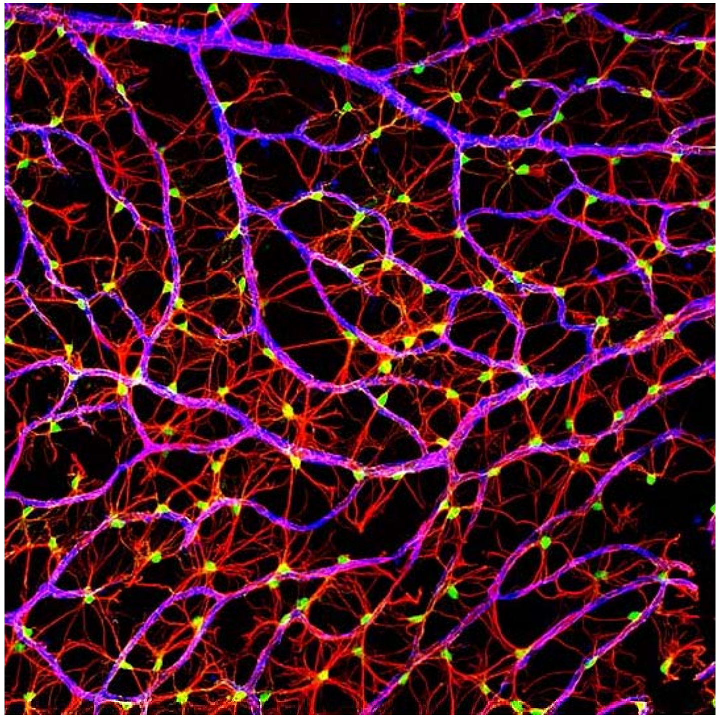
•Specific functions of organelles:

- -mitochondria extract energy from sugar and fat,
- -ribosomes synthesise proteins,
- -chloroplasts of plants with chlorophyll for photosynthesis.

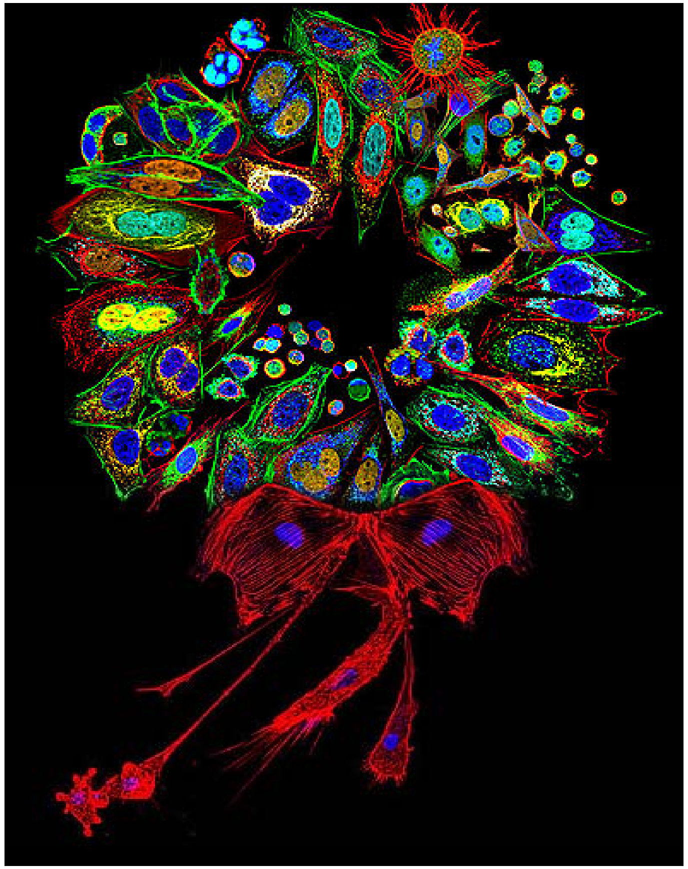
•Eukariotes: many and different cells.

Different cells perform different functions.
Cells of the same function form tissues and tissues make up organs.

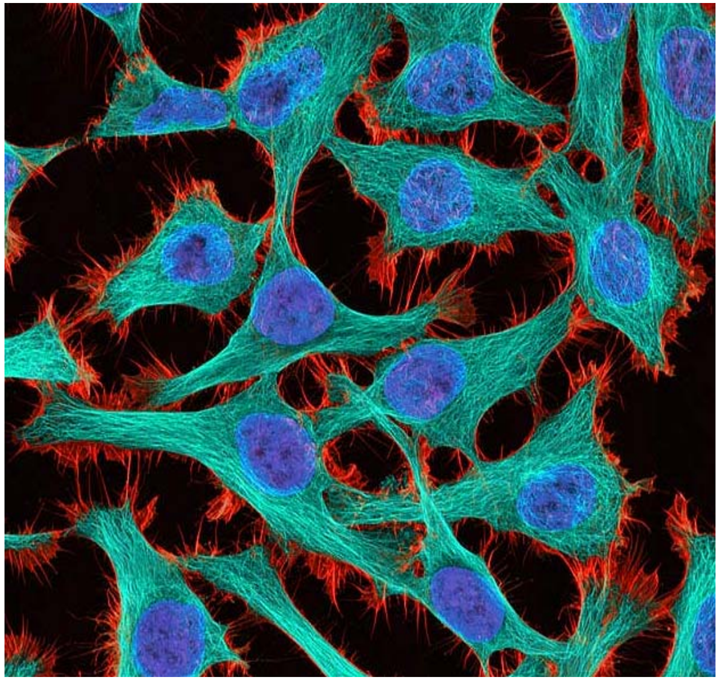
Cell Structures



Nerve cells
of a mouse (40x)
photo Gabriel Luna



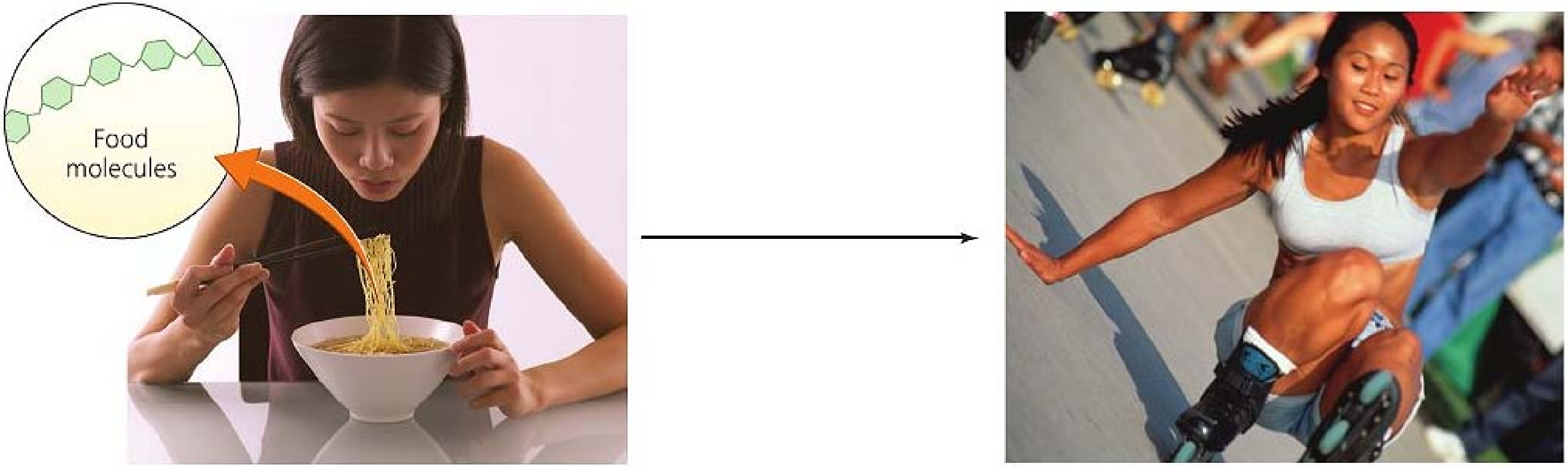
Different stained
mammal cells
(200-2000x)
photo Donna Stolz



Cancer cells (300x)
photo Thomas Deerinck

Source: Geo 2011

Energy:
Conversion from Potential into Kinetic Energy



Potential energy — **Kinetic energy**

oxygen uptake by respiration

$$C_6H_{12}O_6 + O_2 \longrightarrow CO_2 + H_2O + \text{Heat}$$

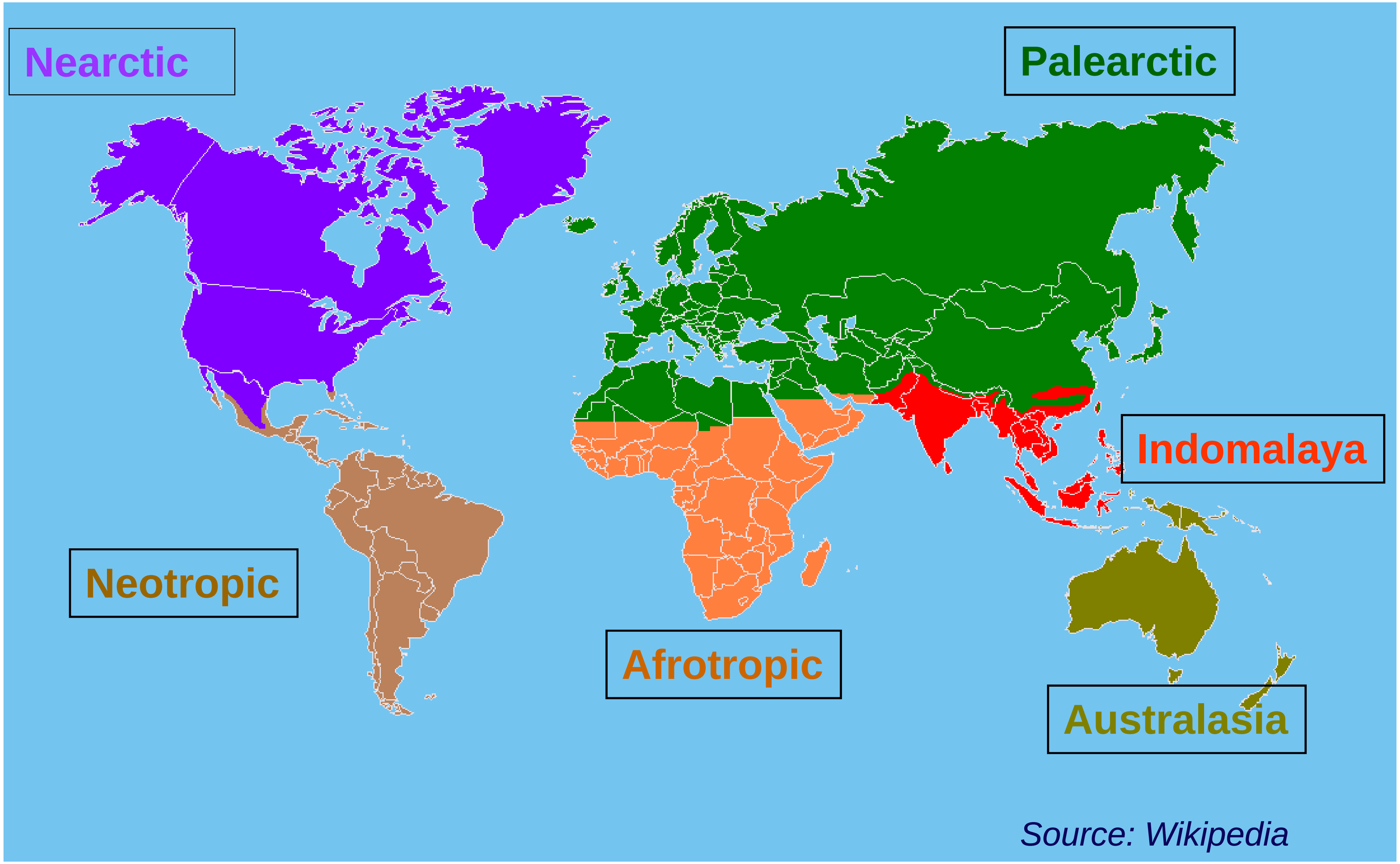
Glucose + Oxygen → Carbon dioxide + Water + Heat

Potential energy of chemical substances: energy the held in the bonds between the atoms. Breaking down larger molecules through a chemical reaction releases this potential energy as heat or kinetic energy.

Source: Withgott and Brennan: Environment, Pearson 2008

Spatial Classification of Earth‘s Ecological System: Ecozones

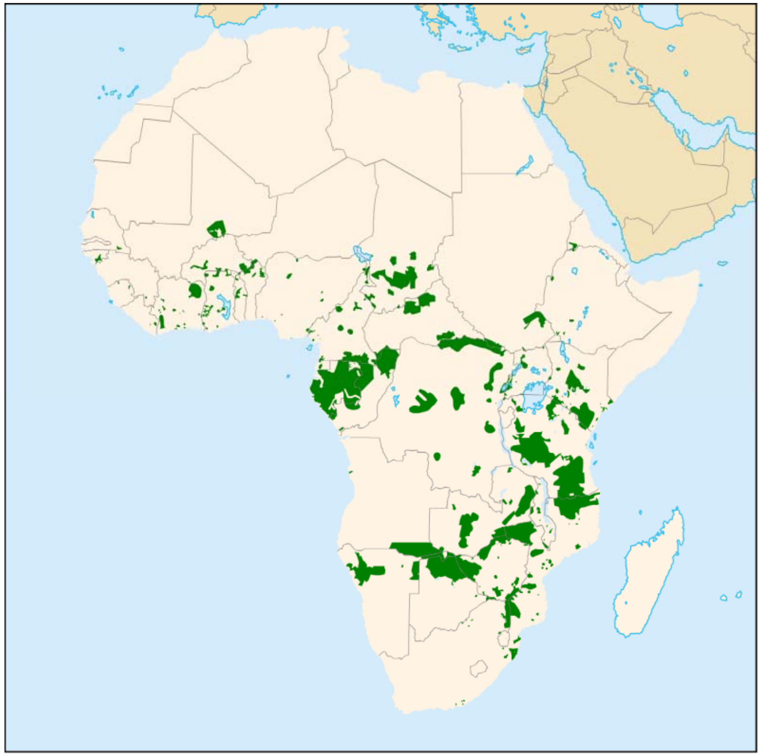
Largest scale biogeographic division of the earth's surface based on the historic and evolutionary distribution patterns of plants and animals.



Spatial Classification of Earth‘s Ecological System: Ecoregions and Habitats

- E**coregion** (**bioregion/biogeographic region)**:
  - ecologically and geographically defined area beneath an "ecozone“
  - contains a characteristic, geographically distinct assemblage of species.
- WWF identified 825 terrestrial ecoregions and approximately 450 freshwater ecoregions like Himalaya, Sahara, Australian coral reef, mangrove swamps.

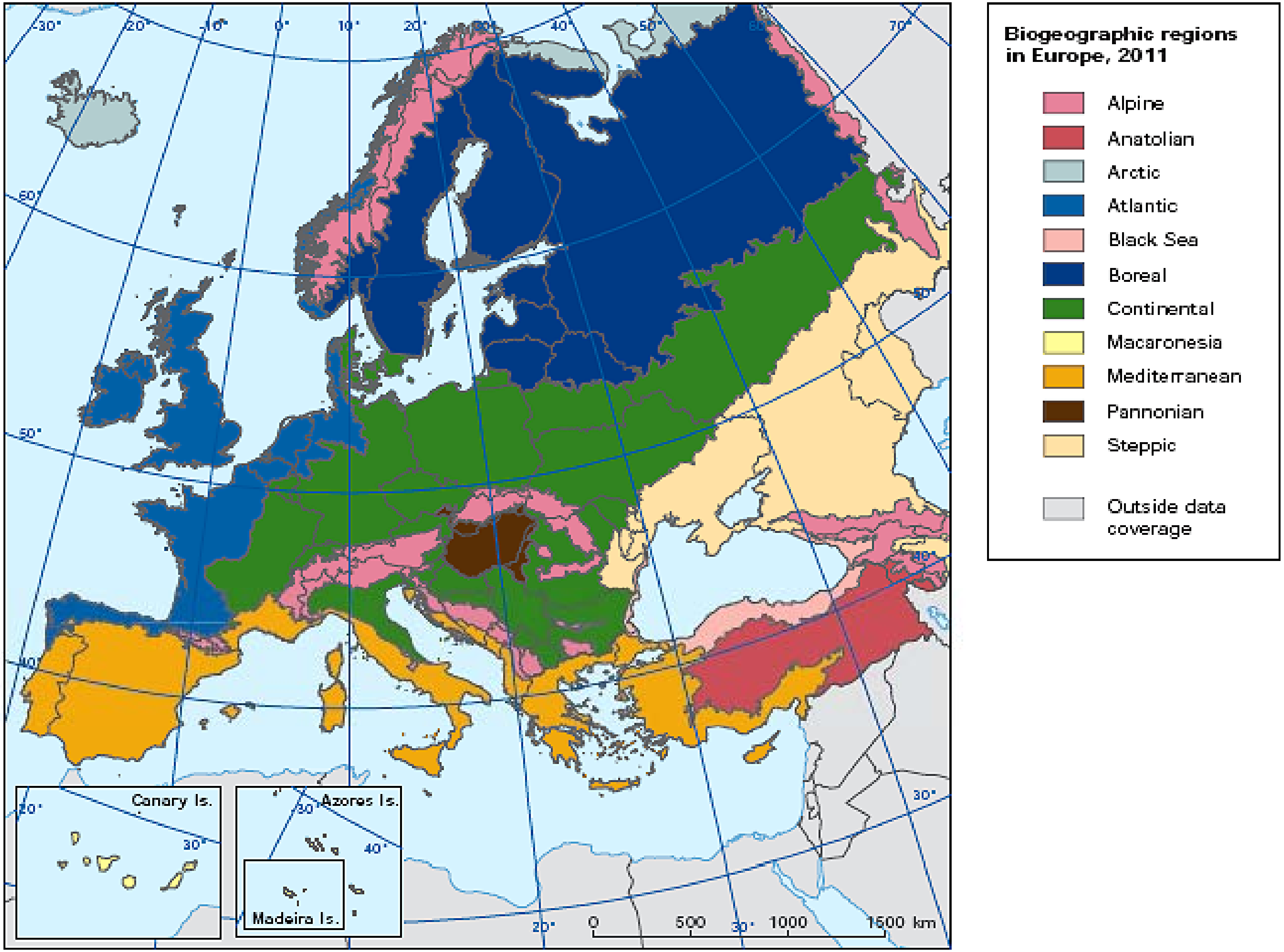
- **Habitat:** ecological or environmental area inhabited by a particular species.



The remaining fragmented habitats of the African Elephant

Source: Wikipedia

Biogeographic Regions of Europe



Source: EEA 2012, http://www.eea.europa.eu/publications/protected-areas-in-europe-2012

Spatial Classification of Earth‘s Ecological System: Biomes

- **Biome**: climatically and geographically defined area of ecologically similar communities of plants, animals, and soil organisms.

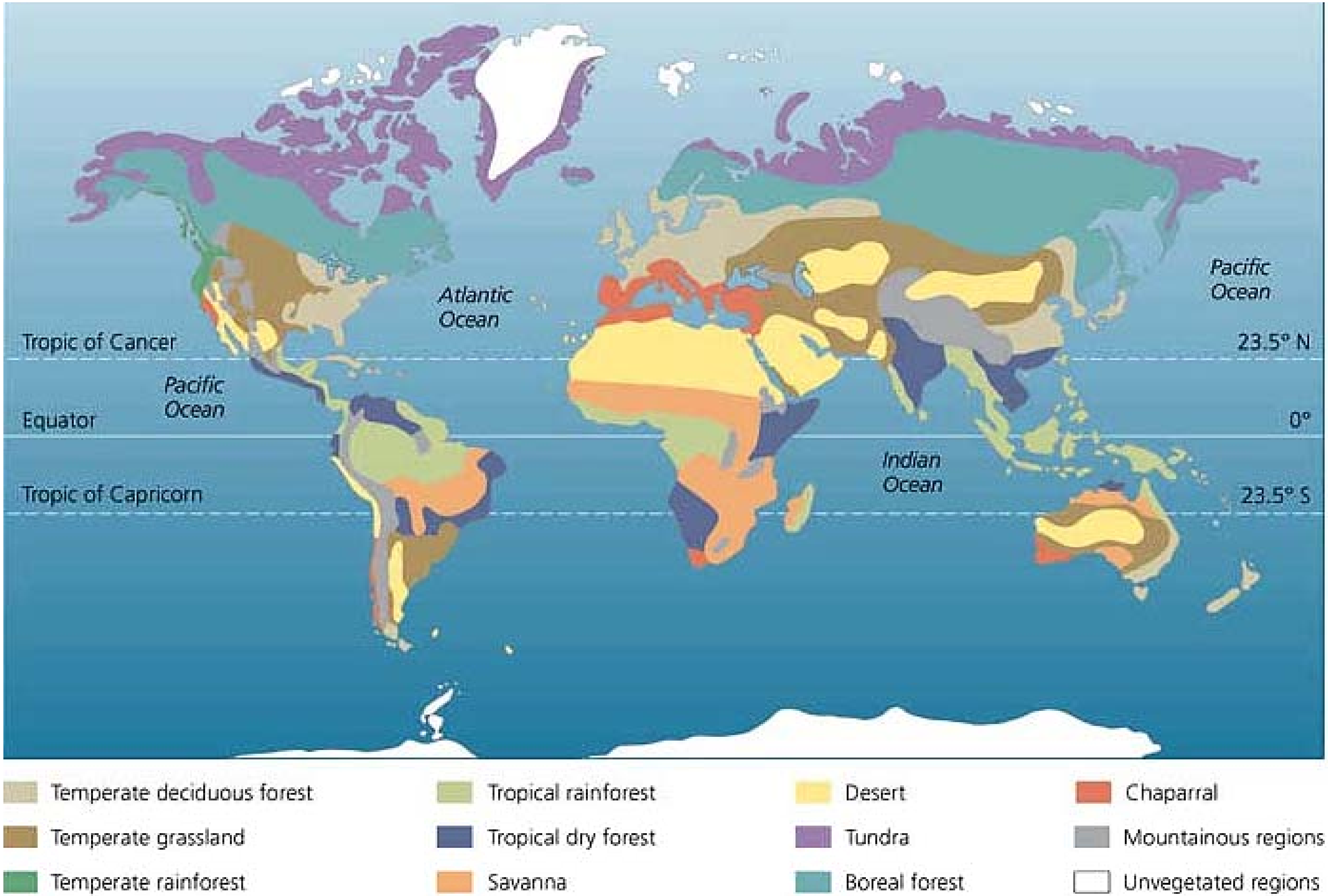
- **Terrestrial biomes:**
  - ➢ temperate deciduous forest, temperate grassland, temperate rainforest, tropical rain (cloud) forest, tropical dry forest, savanna, desert, tundra, boreal forest, chaparral.
  - ➢ climate is a major factor determining the distribution of terrestrial biomes.

- **Aquatic biomes:**
  - ➢ large lakes, river deltas, polar freshwaters, mountain freshwaters, tropical and subtropical rivers........
  - ➢ polar seas, temperate shelves and seas, tropical coral regions....

- The biodiversity characteristic of a biome is a function of abiotic factors and the biomass productivity of the dominant vegetation.

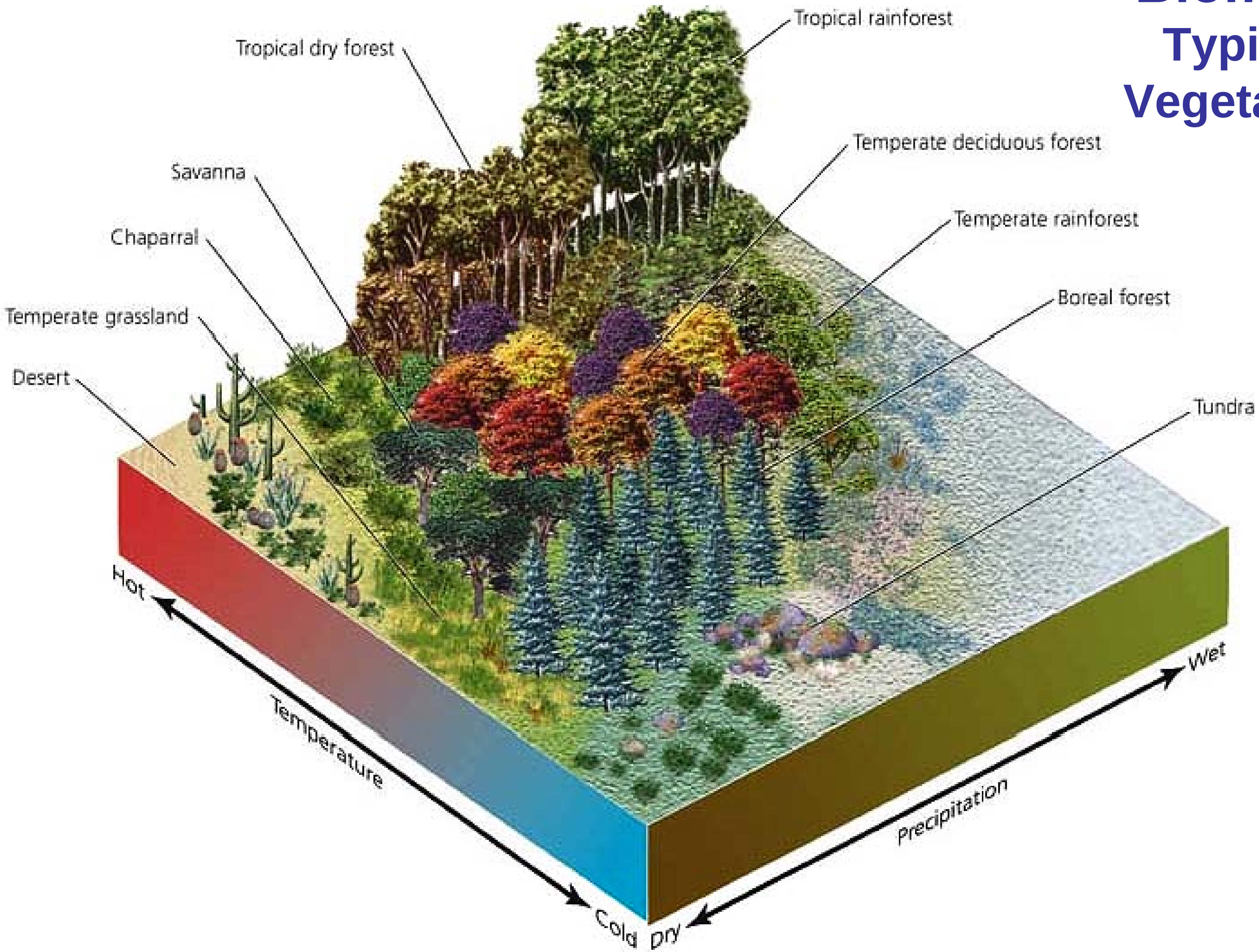
Source: Wikipedia

Biomes: Global Distribution



Source: Withgott and Brennan: Environment, Pearson 2008

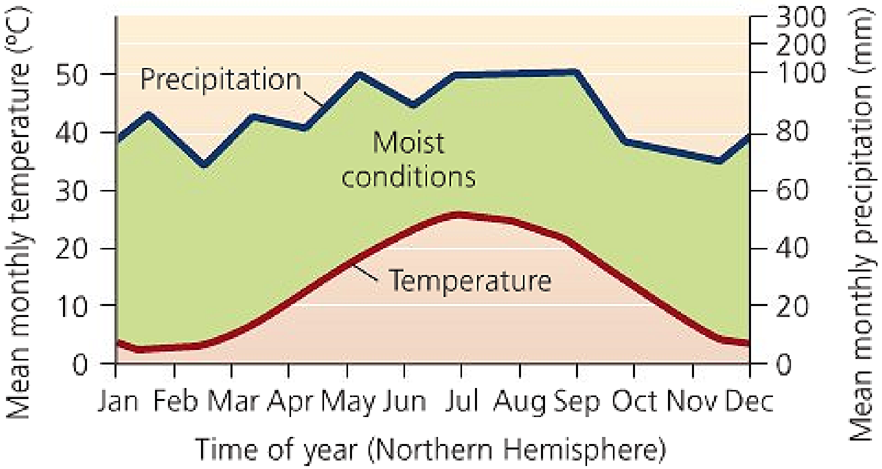
Biomes:
Typical Vegetation



Source: Withgott and Brennan: Environment, Pearson 2008

(a) Temperate deciduous forest

stable seasonal precipitation

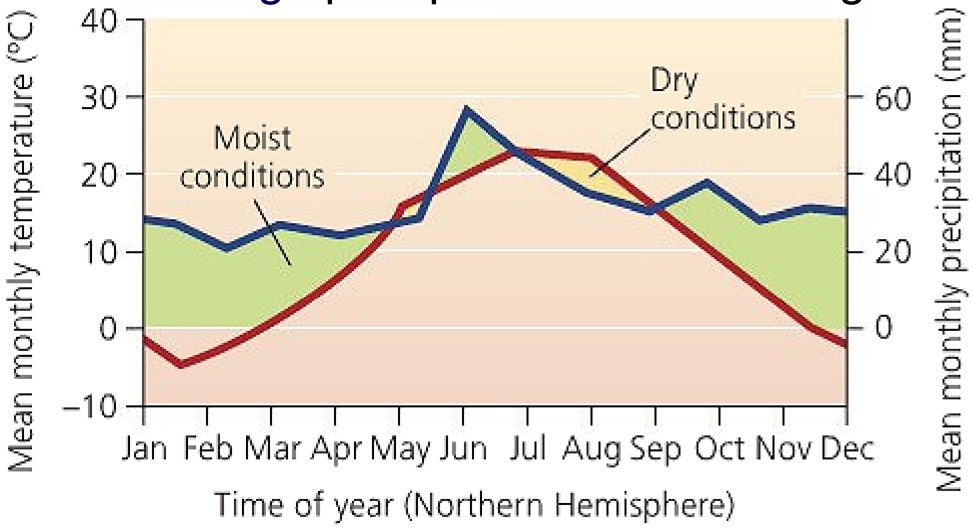


(b) Washington, D.C., USA

varied seasonal temperatures

(a) Temperate grassland

not enough precipitation for trees to grow



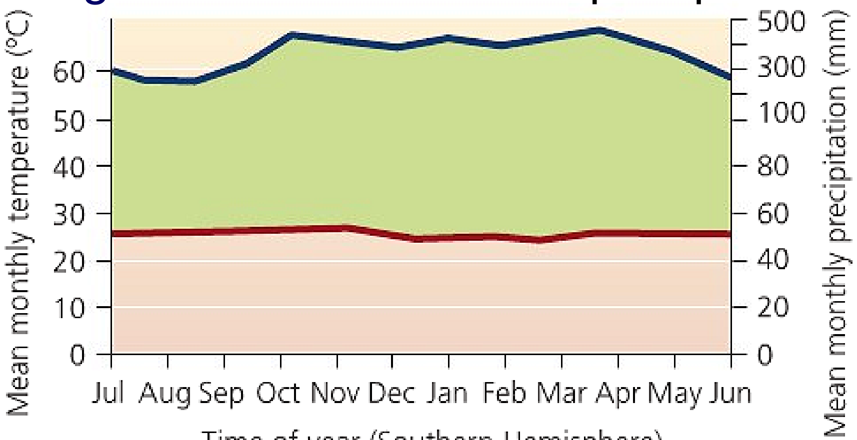
(b) Odessa, Ukraine

large temperature variations

Source: Withgott and Brennan: Environment, Pearson 2008

(a) Tropical rainforest

high and stable seasonal precipitation

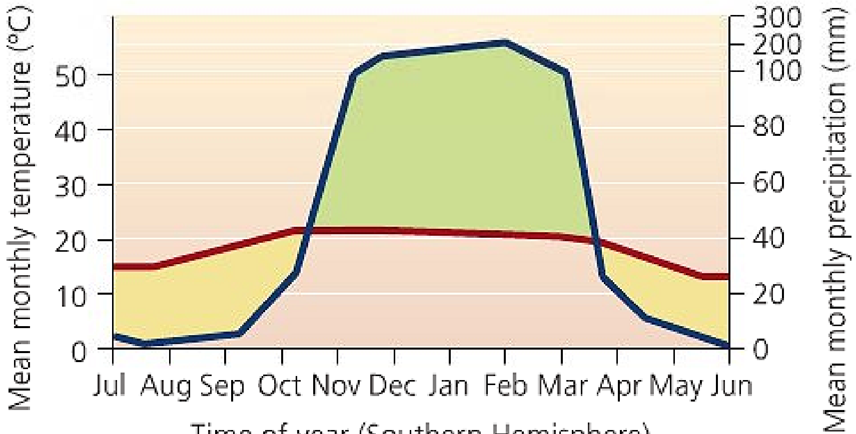


(b) Bogor, Java, Indonesia

stable high temperatures

(a) Savanna

high precipitation in summer



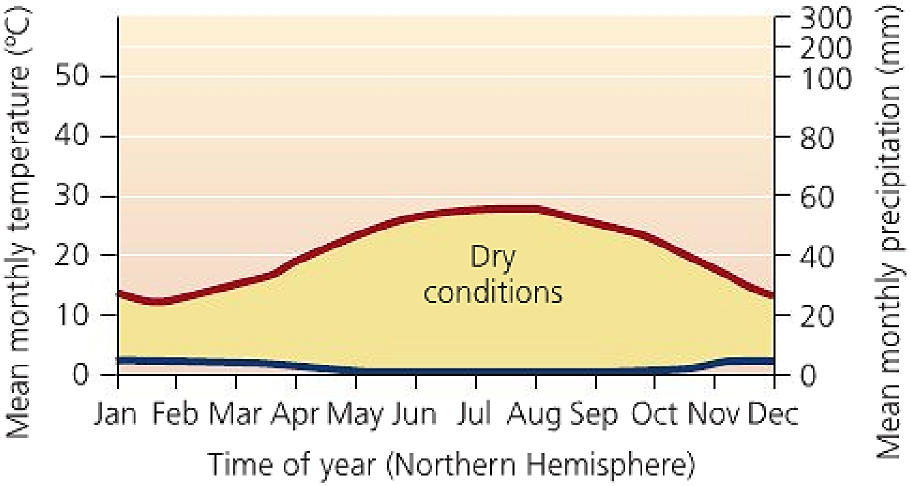
(b) Harare, Zimbabwe

stable lower temperatures

Source: Withgott and Brennan: Environment, Pearson 2008

(a) Desert

very little precipitation throughout the year

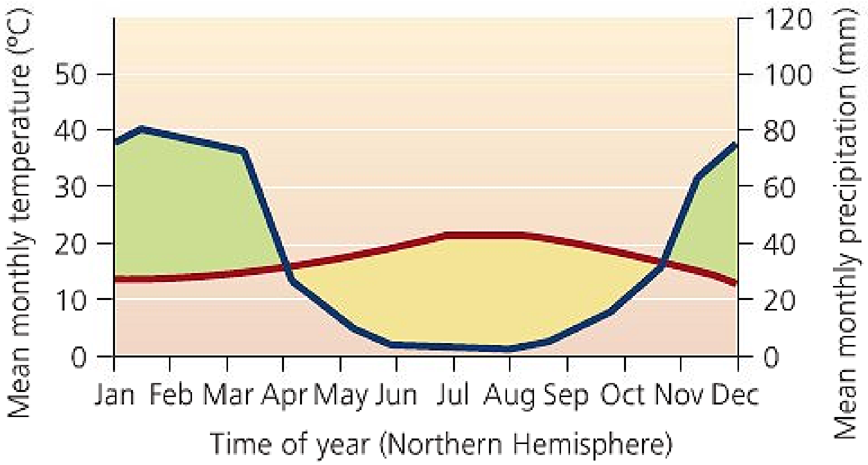


(b) Cairo, Egypt

varied seasonal temperatures

(a) Chaparral

high winter precipitation



(b) Los Angeles, California, USA

stable temperatures

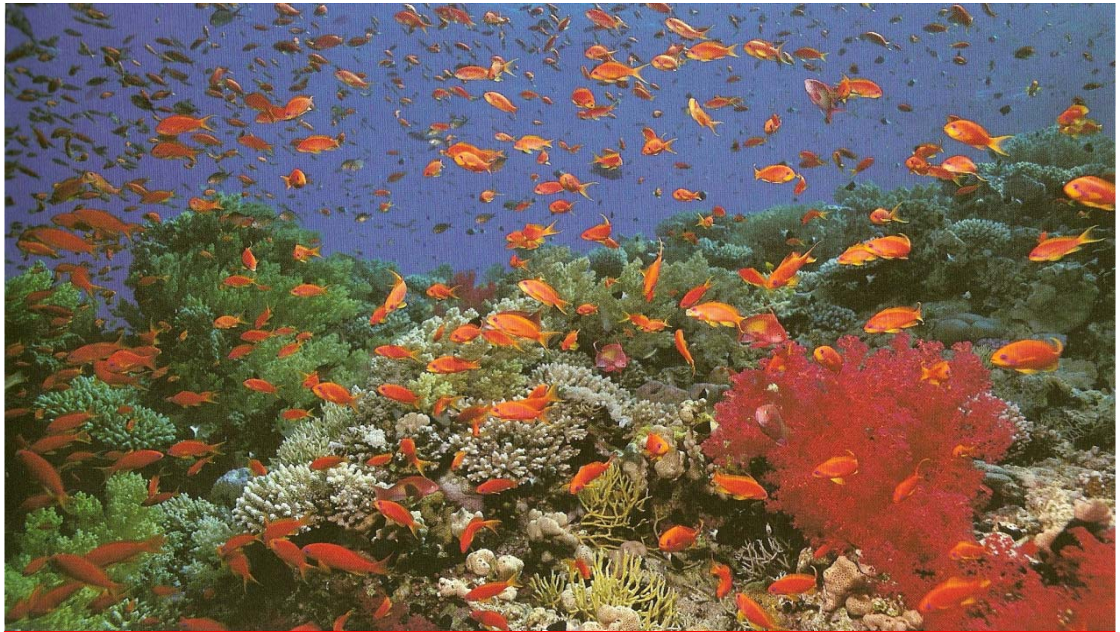
Source: Withgott and Brennan: Environment, Pearson 2008

Ecosystems

- **Ecosystem:** natural unit consisting of all plants, animals and micro-organisms (biotic factors) in an area functioning together with all of the non-living physical (abiotic) factors of the environment.
- **Ecosystem dynamics:**
- Primarily stochastic (chance) events.
- Introduction of new elements: possible disruptive effects, which in some cases, can lead to ecological collapse.

– Ecosystems have the (limited) ability to rebound from a disruptive agent.

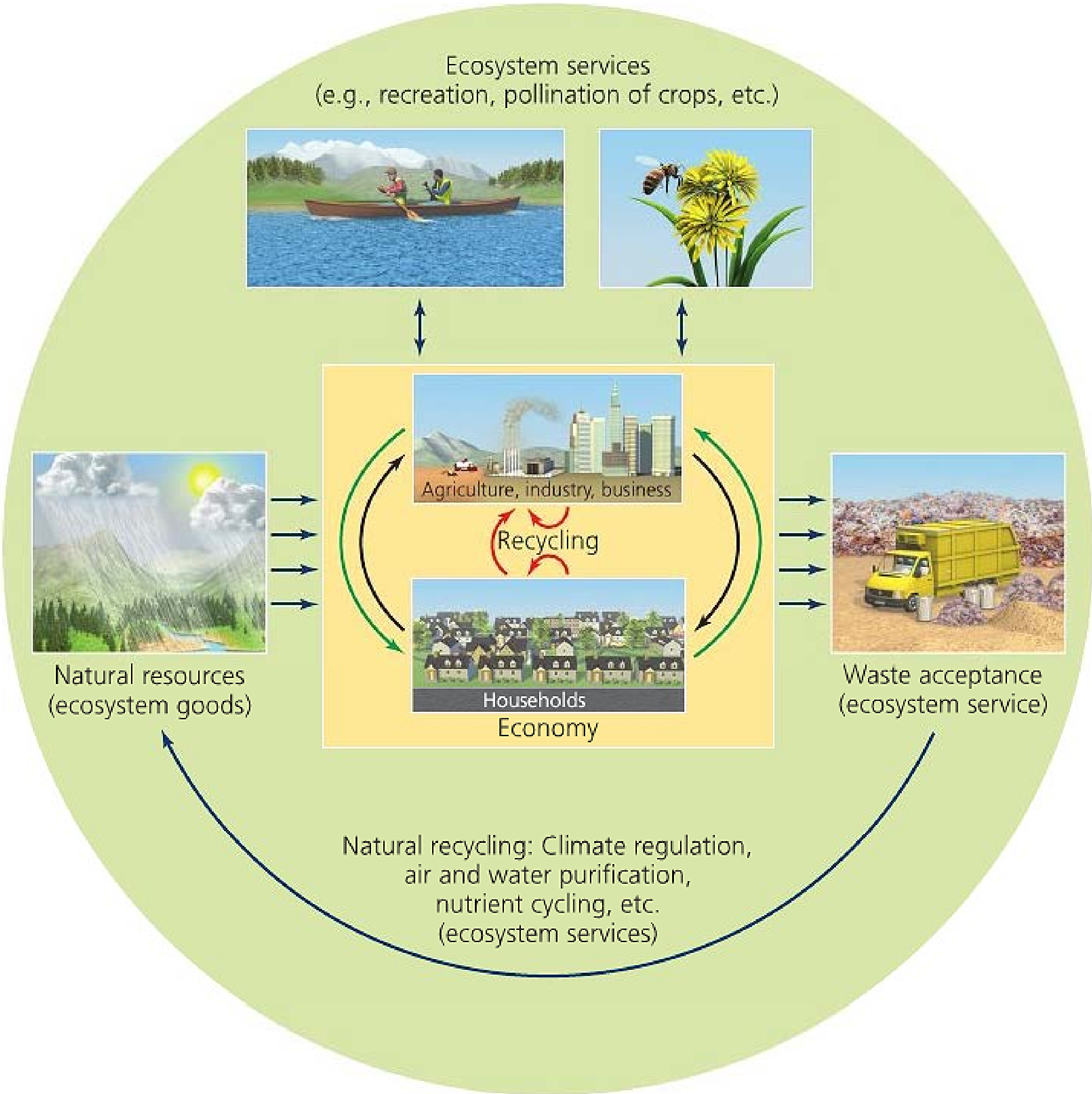
– Difference between collapse or rebound determined by the toxicity of the introduced element and the resilience of the original ecosystem.



Example of stressed ecosystem: The coral reefs.

Source: Wikipedia

Ecosystems: Human Interactions



(b) Economic activity as viewed by environmental and ecological economists

- Ecosystem services are "fundamental life-support services upon which human civilization depends".

- Human beings are part of the ecosystem and must interact with it in a sustainable manner.

- The Millennium Ecosystem Assessment (2005) concluded that in the past 50 years humans have altered the earth's ecosystems more than any other time in our history.

Source: Withgott and Brennan: Environment, Pearson 2008

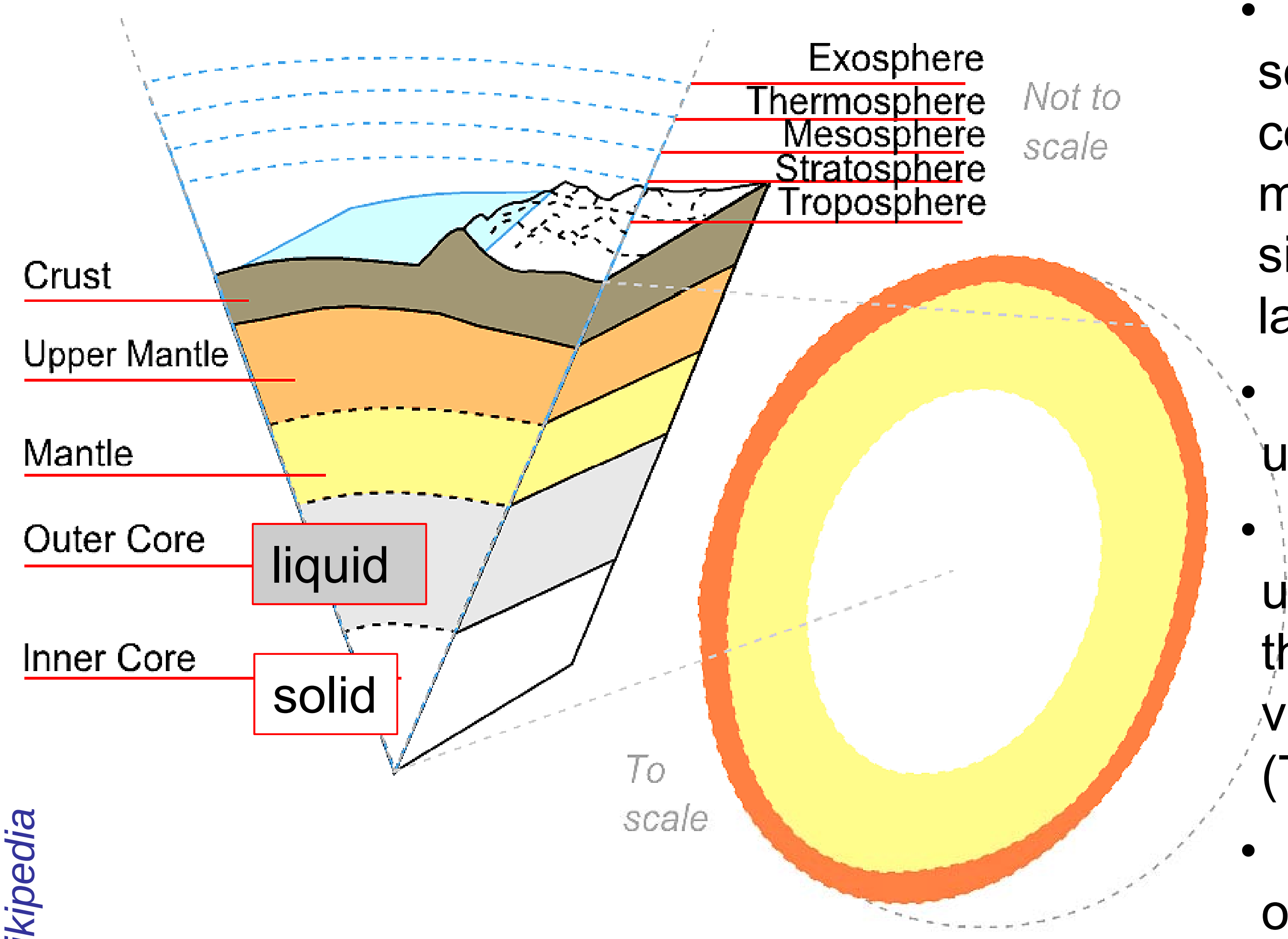
Biosphere

1.2 Biosphere

- **Biosphere:**
  - global ecological system integrating all living beings and their relationships, including their interaction with the elements of the lithosphere, hydrosphere, and atmosphere.
  - Evolution of our biosphere began through a process of biogenesis 3.5 billion years ago.
  - Biosphere comprises all of the Earth's biomes.
  - Biosphere is a very thin surface layer which extends from 11,000 meters below sea level to 15,000 meters above.
  - Live can be found in the deep seas and highest altitudes.

Source: Wikipedia

Structure of the Earth

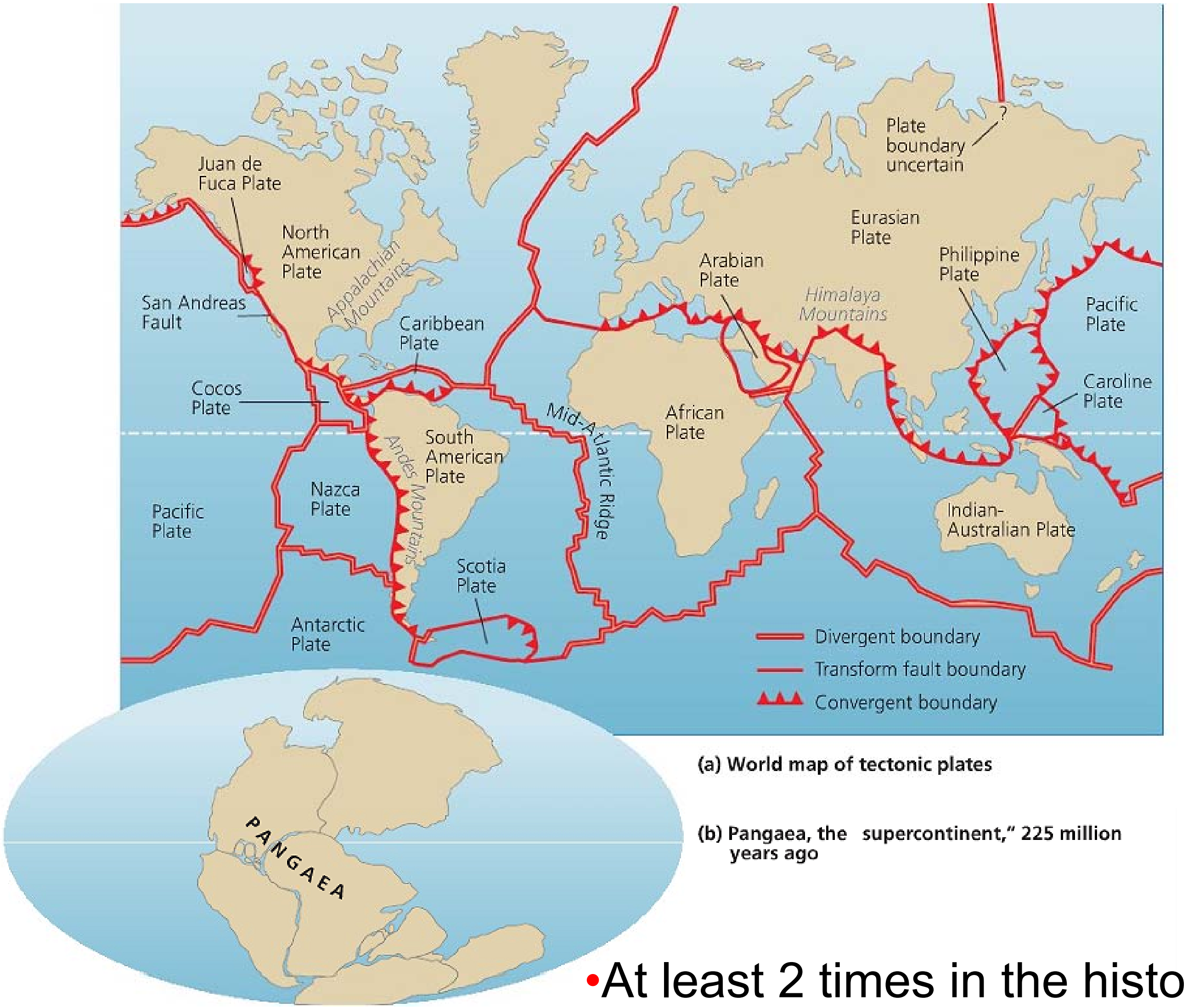


Source: *Wikipedia*

- **Crust (lithosphere)** : solid, 30–50 km thick, consisting mainly of magnesium-iron-silicates, on top thin layer of soil.
- **Upper mantle:** up to 200 km
- **Lower mantle:** up to 2.800 km below the surface, minerals viscous. (T = 1000 - 4000°C).
- **Core:** outer and inner core mainly iron and nickel (T = 4.000 - 6.100°C).

mass of earth: gravitational field
Fe-Ni-core: magnetic field

Lithosphere



(a) World map of tectonic plates

(b) Pangaea, the supercontinent," 225 million years ago

- Earth's crust: 15 major plates moving at rates of 2–15 cm/yr
- Movements have greatly influenced the evolution of climate and life.
- Plate movement leads to volcanic activity, earthquakes and tsunamis.
- At least 2 times in the history of earth all continents were combined in one supercontinent „pangea".

Source: Withgott and Brennan: Environment, Pearson 2008

R

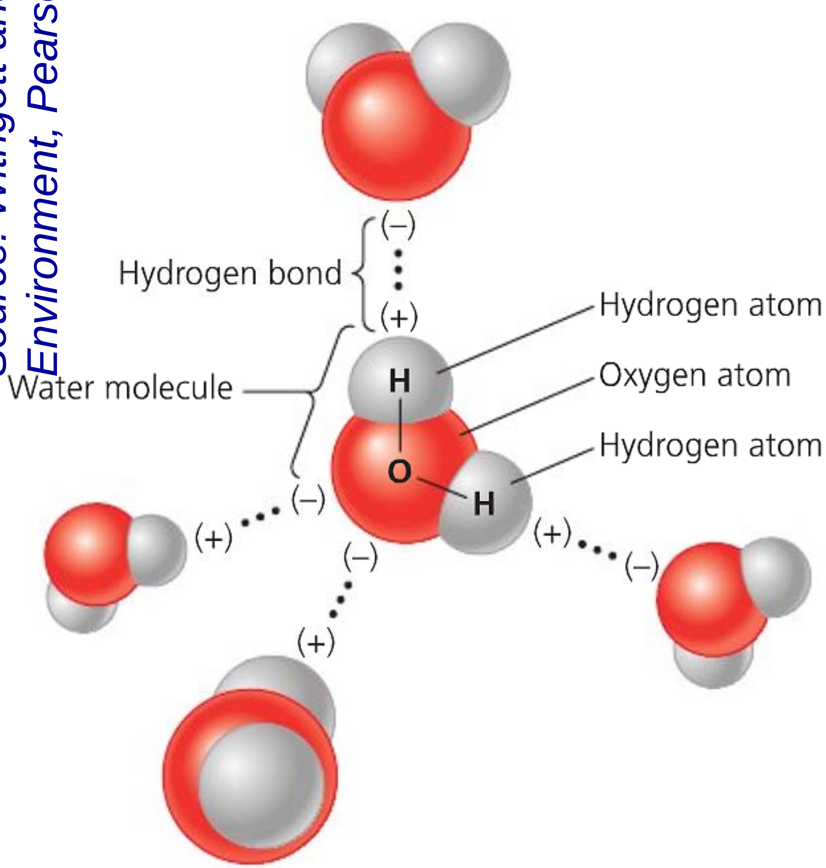
Hydrosphere

Photo: Wikipedia

Water in three states: Liquid, solid (ice), and (invisible) vapor in air. Clouds are droplets of liquid, condensed from water vapor.

Source: Withgott and Brennan: Environment, Pearson 2008

Hydrosphere:
The Structure and Properties of Water



•**Water molecule: very high dipole moment giving water special properties:**

-liquid state at normal environmental temperatures due to high cohesive forces,

-high solubility for nutrients and gases like oxygen due to strong interaction with other polar molecules,

-reduction of temperature extremes on earth due to high heat capacity allowing water bodies to absorb huge amounts of heat.

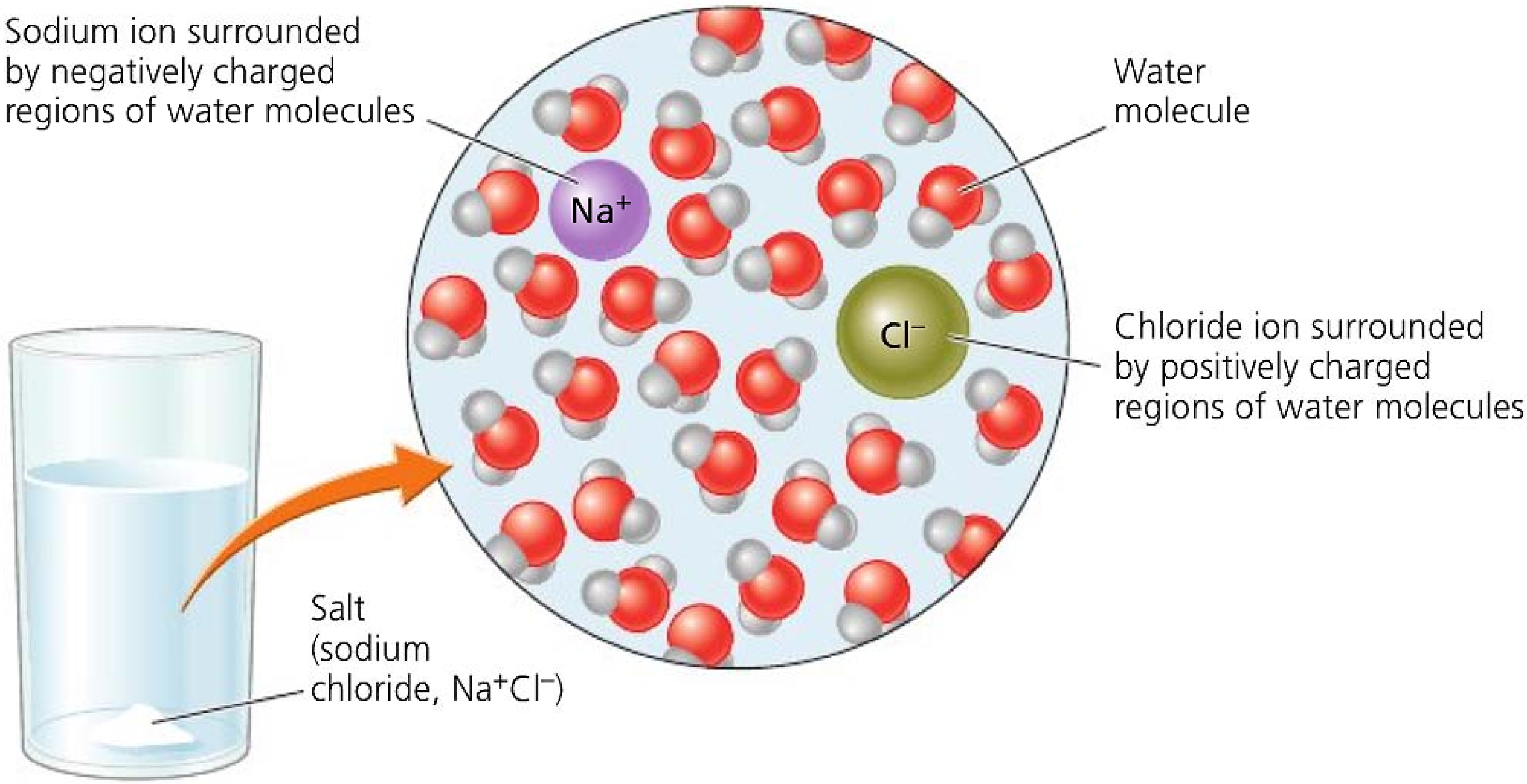
•**Maximum density of water at 4°C:**

-Cold water sinks to the bottom of water bodies and creates ciculation and supply of nutrients and oxygen for living species.

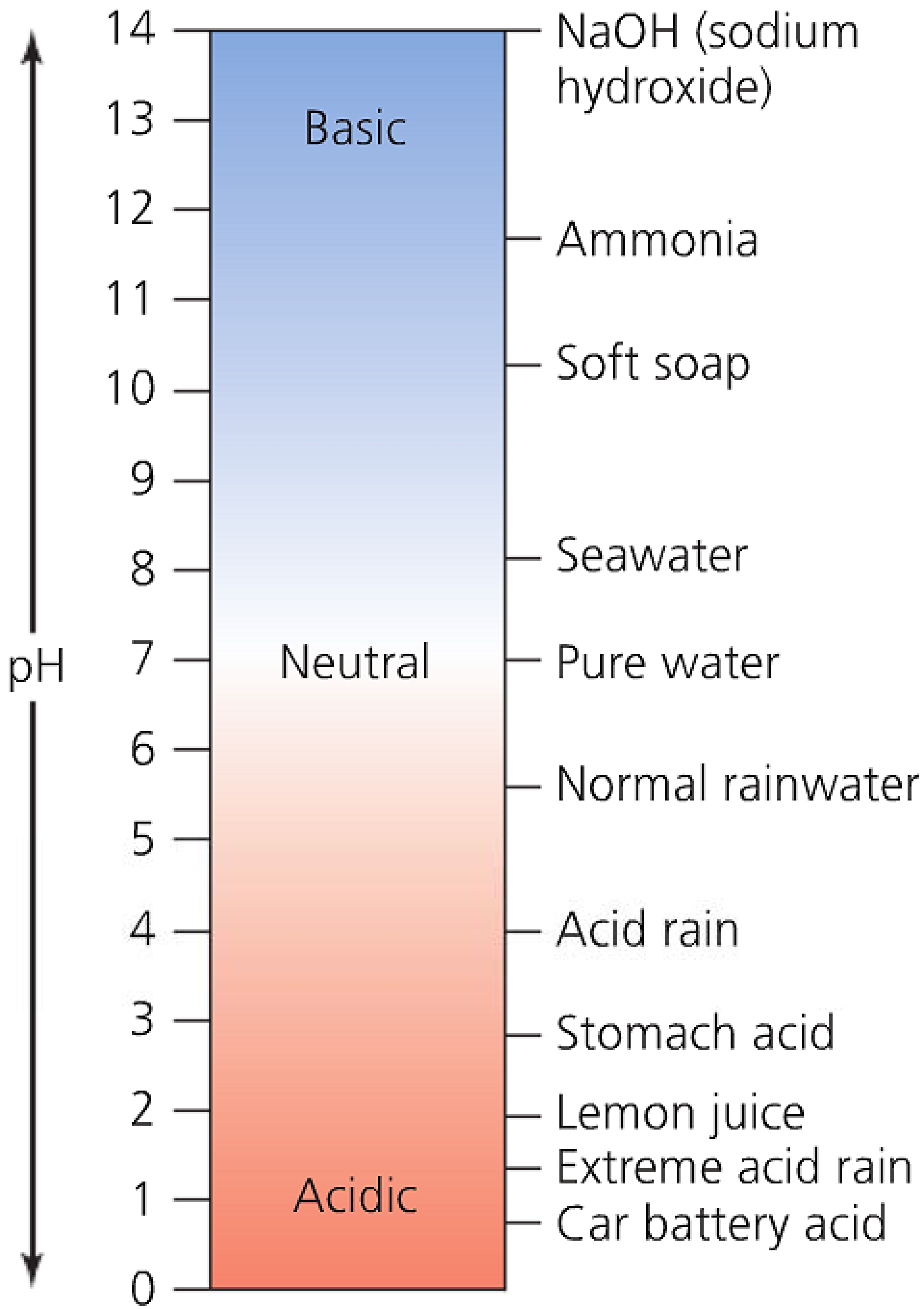
-Ice floats on water protecting lower layers from freezing.

Hydrosphere:
The Structure and Properties of Water

Water as a solvent.



Source: Withgott and Brennan: Environment, Pearson 2008



Hydrosphere:
The Structure and Properties of Water

•Chemical compounds dissolved in water determine the acidity of water.

•Acidity expressed as a pH value:

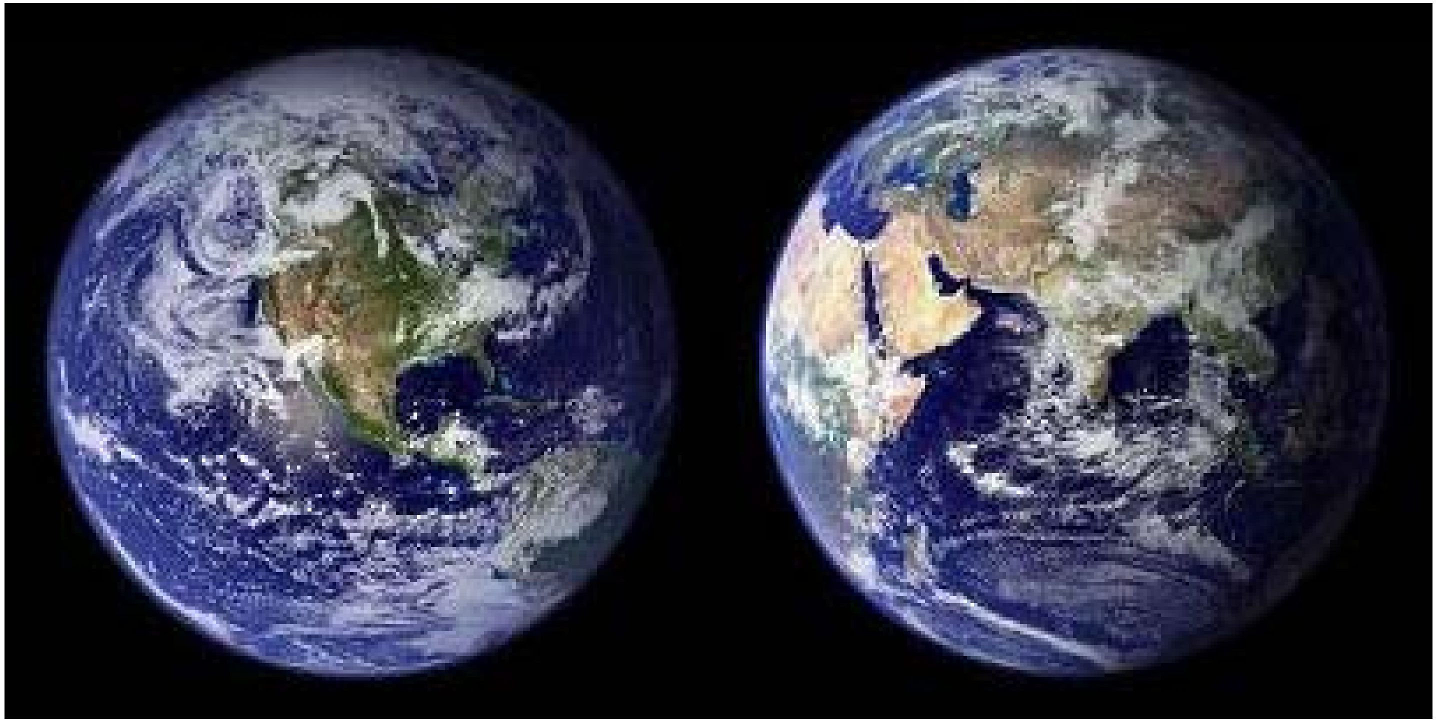
$$pH = -\log [H^+]$$

•pH scale comprises 14 orders of magnitude.

•Some substances make water acidic (pH<7), others basic (pH>7).

Source: Withgott and Brennan: Environment, Pearson 2008

Hydrosphere



- **Theories for Origin of Water on Earth:**
- „Classical Theory“: early earth subjected to a period of bombardment by comets and water-rich asteroids. Problem: $^{1}H/^{2}H$ ratio of outer space water as measured by Rosetta at comet 67P/Churyumov–Gerasimenko in 2014 is very different from water on earth.
- „New Theory“: Outgassing of water from the interior of the Earth. Minerals of mantles contain 2-5% water. Sufficient to form oceans during 1 bio years.

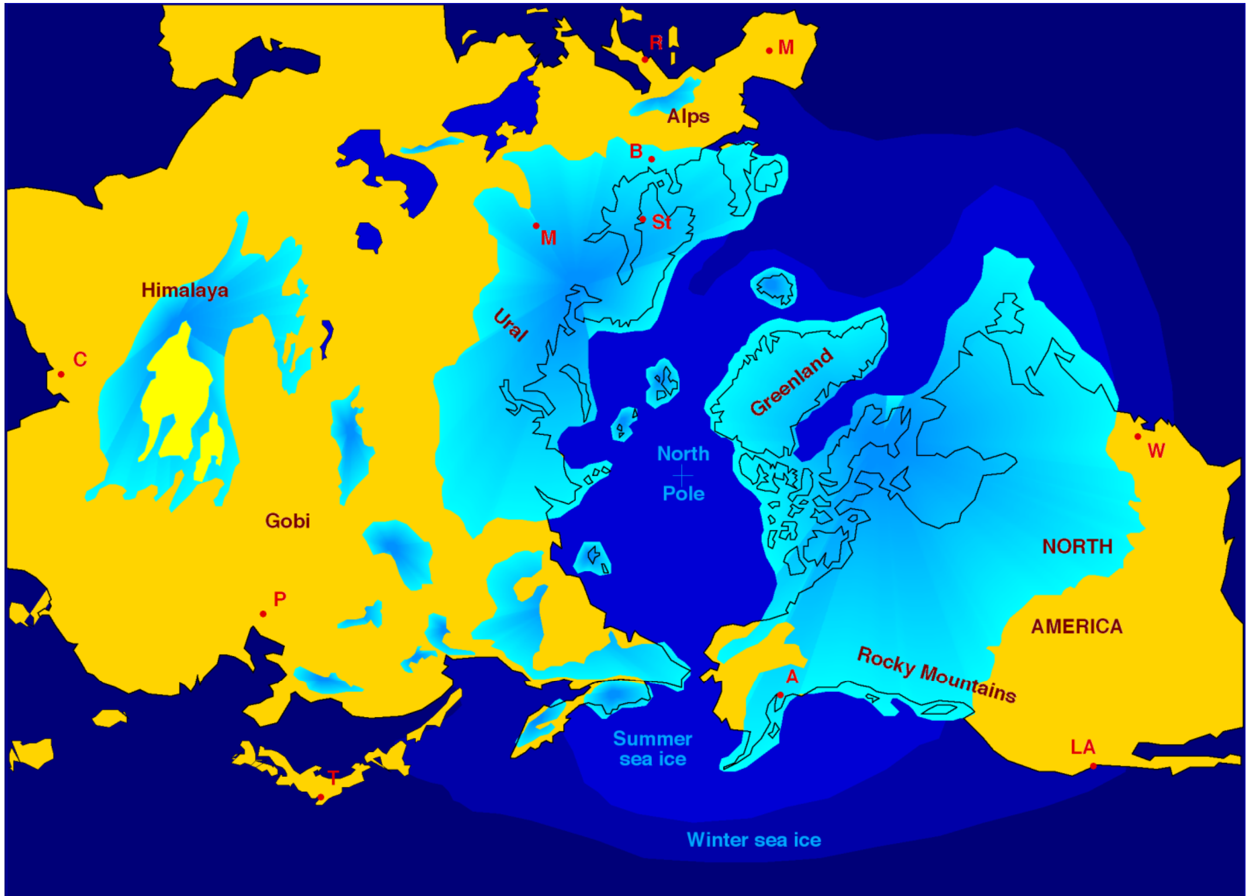
Hydrosphere

- The abundance of water on Earth is a unique feature that distinguishes our "Blue Planet" from others in the solar system.
- Approximately 70.8 percent of the Earth is covered by water and only 29.2 percent is landmass.
- 97% of the planets water resources are sea water and (only) 3% fresh water.
- Earth is actually beyond the outer edge of the orbits which would be warm enough to form liquid water.
- Without the greenhouse effect caused by water vapour Earth's average surface temperature would be - 15°C (as opposed to + 14°C) and all oceans frozen.
- Paleontological evidence indicates that at one point after blue-green bacteria (Cyanobacteria) had colonized the oceans, the greenhouse effect failed, and Earth's oceans may have completely frozen over for 10 to 100 million years („snowball Earth“ event).

Source: Wikipedia

Hydrosphere: The Ice Ages

•During the history of the Earth there have been a series of periods – probably four - in which a significant portion of the hydrosphere was locked up in the form of glacial ice.



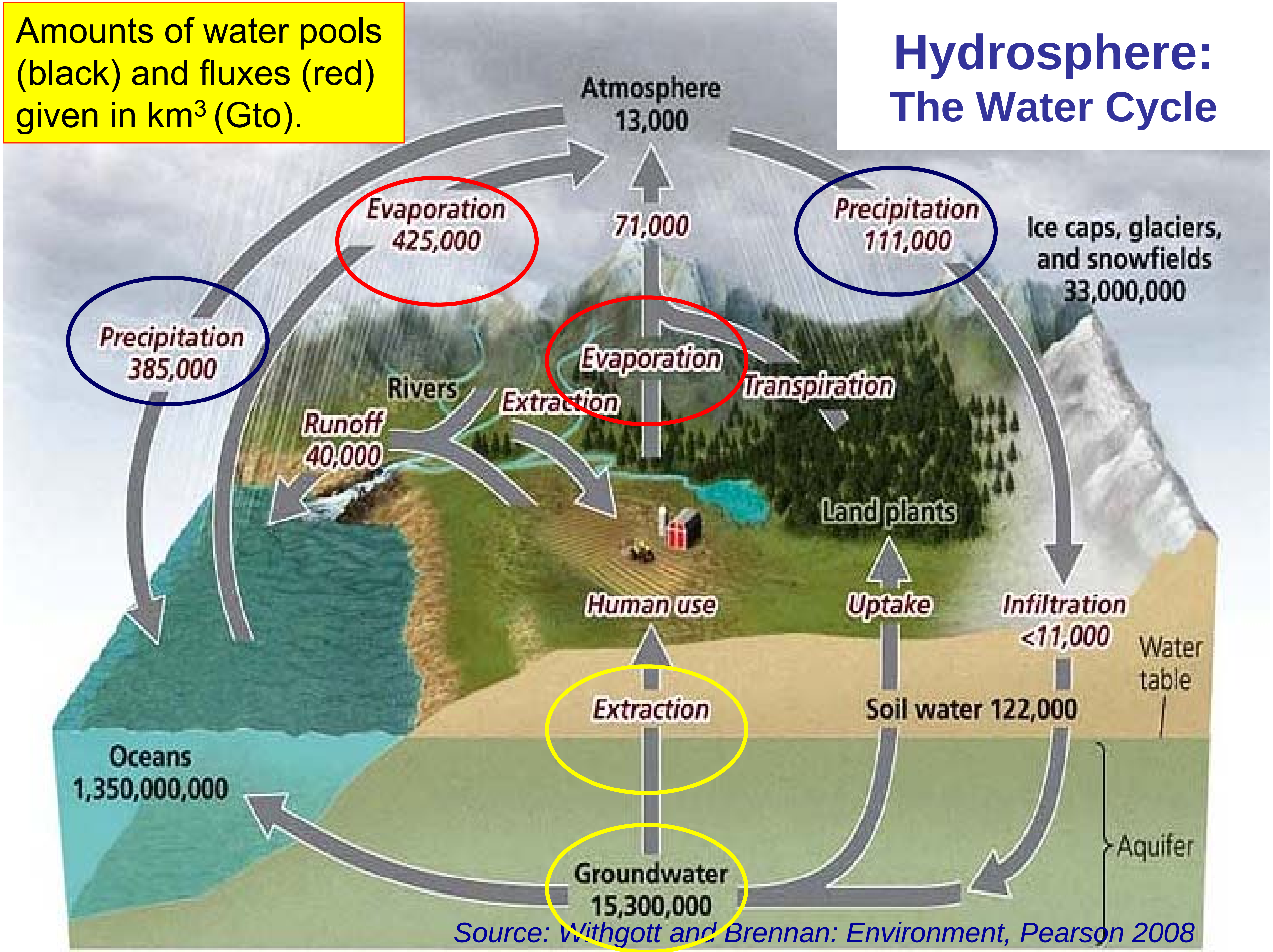
- –The last ice age began about 40 million years ago and ended about 10.000 BC.
- –In present interglacial period average global temperatures are typically 5°C higher.
- –Predicted changes in orbital forcing suggest that the next glacial period would not begin before about 50,000 years from now.

Source: Wikipedia

Northern Hemisphere Glaciation During the Last Ice Age. The set up of 3 to 4 km thick ice sheets caused a sea level lowering of about 120 m.

Hydrosphere:
The Water Cycle

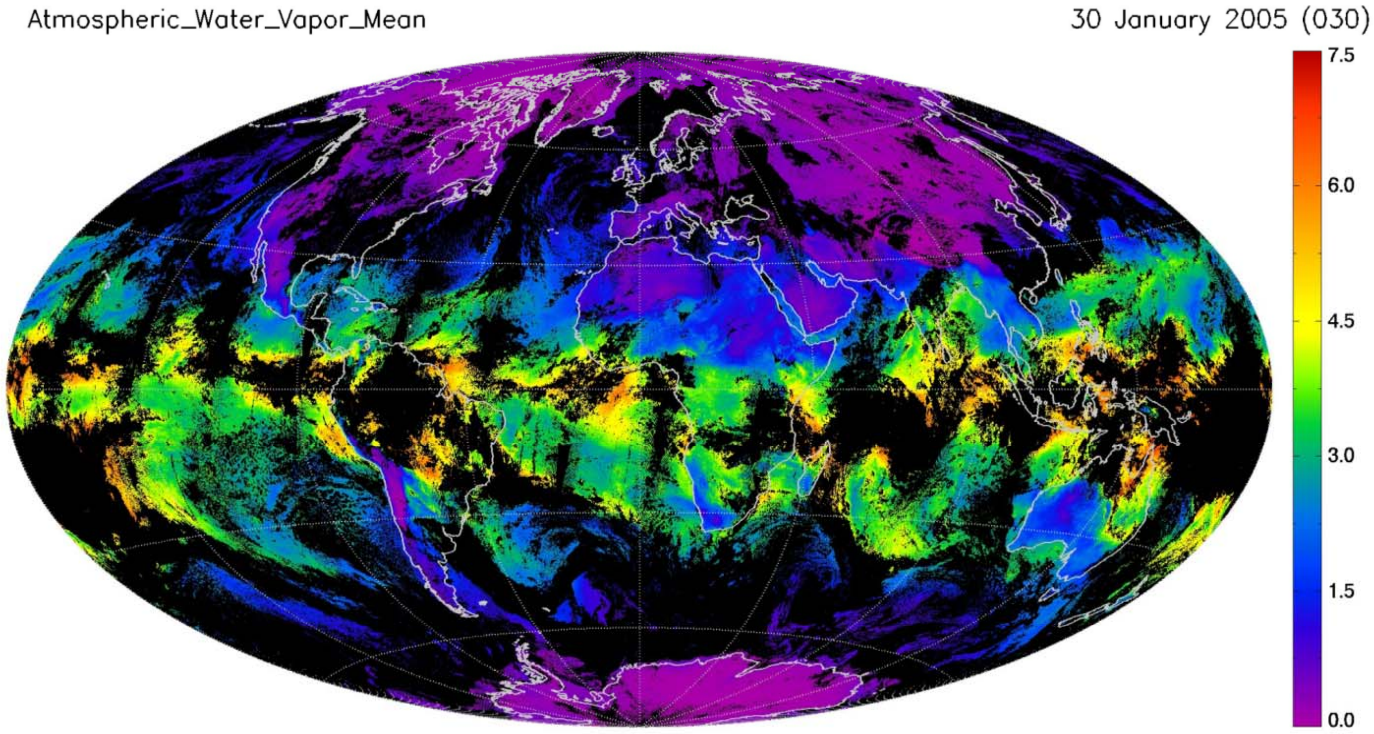
Amounts of water pools (black) and fluxes (red) given in km^3 (Gto).



Source: Withgott and Brennan: Environment, Pearson 2008

Hydrosphere: Water Cycle

- The water cycle describes the transport of water in the hydrosphere.
- All currently recognized forms of life rely on an active hydrosphere.
- Evaporation leads to significant amounts of water in the atmosphere (1%), which can form clouds by condensation and lead to precipitation.
- Evaporation of water from oceans and subsequent precipitation allow for the purification of salt water into fresh water.

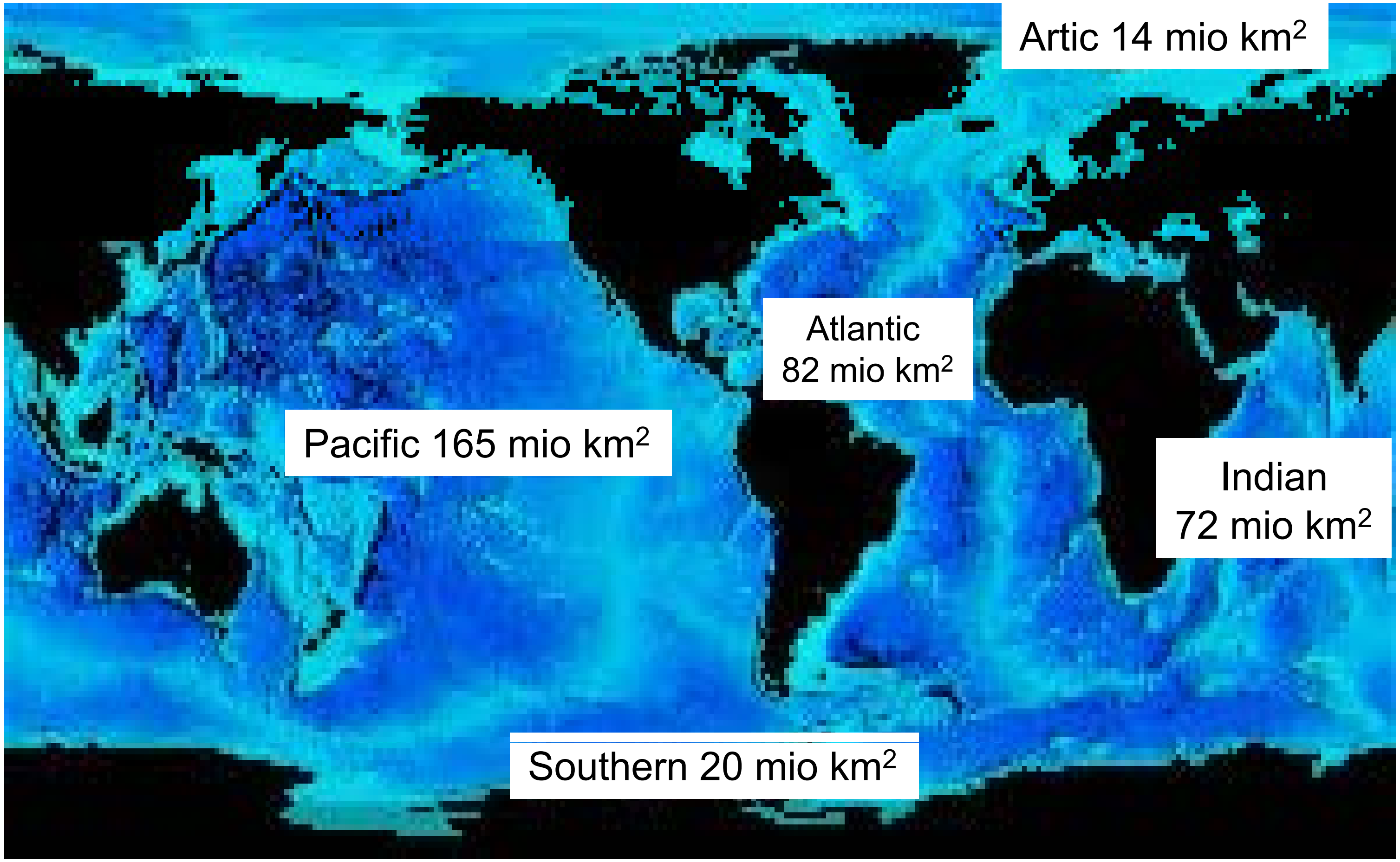


•Precipitation also removes a large portion of pollutants from the atmosphere.

Global distribution of atmospheric water measured as height of a water column (cm).

Hydrosphere: The World's Oceans

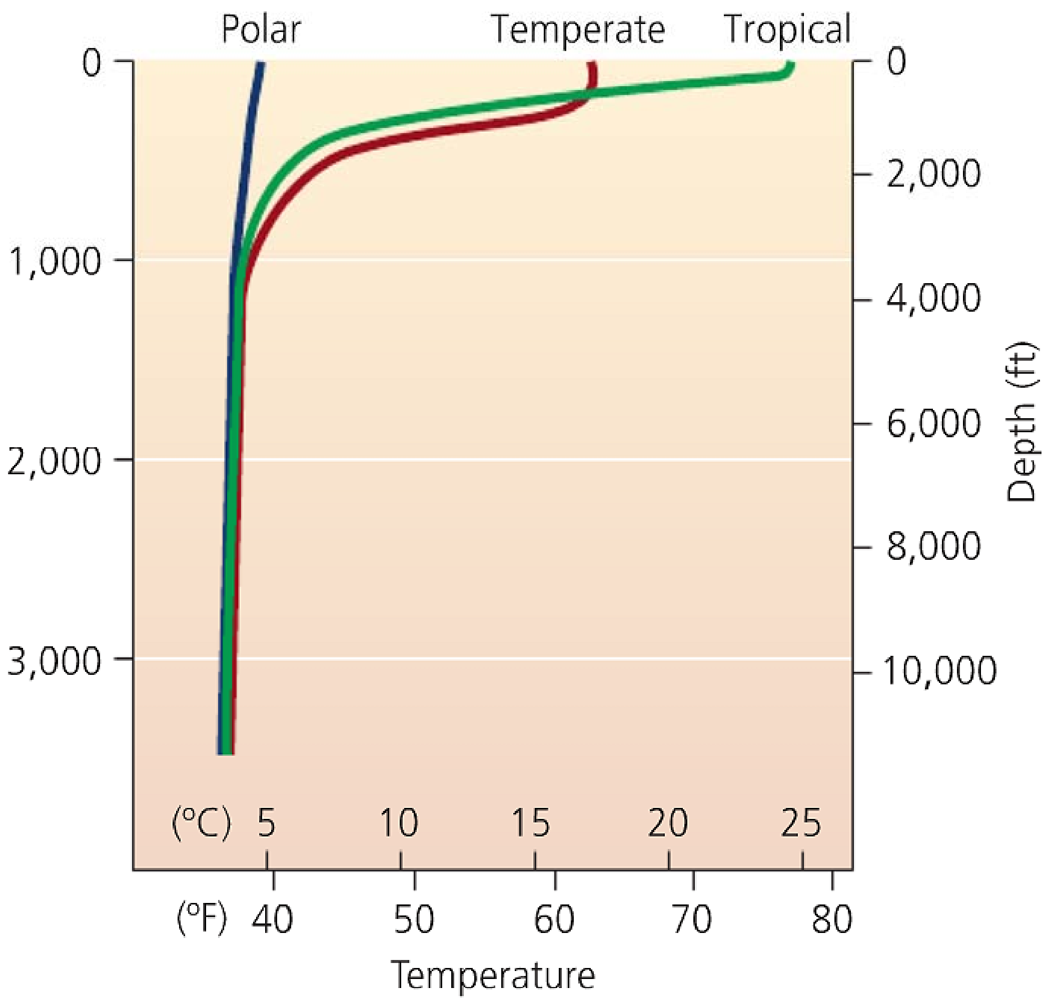
- Comprise 97% of the planet's water.
- The tremendous heat capacity of the oceans moderates the planet's climate.
- Absorption of gases affects the composition of the atmosphere (CO_2).



- Surface temperature: can range below freezing near the poles, up to 35°C in restricted tropical seas.
- Salinity can vary from 1.0-4.1%.

Photo: Wikipedia

Hydrosphere: Temperature Profile in Oceans



Source: Withgott and Brennan: Environment, Pearson 2008

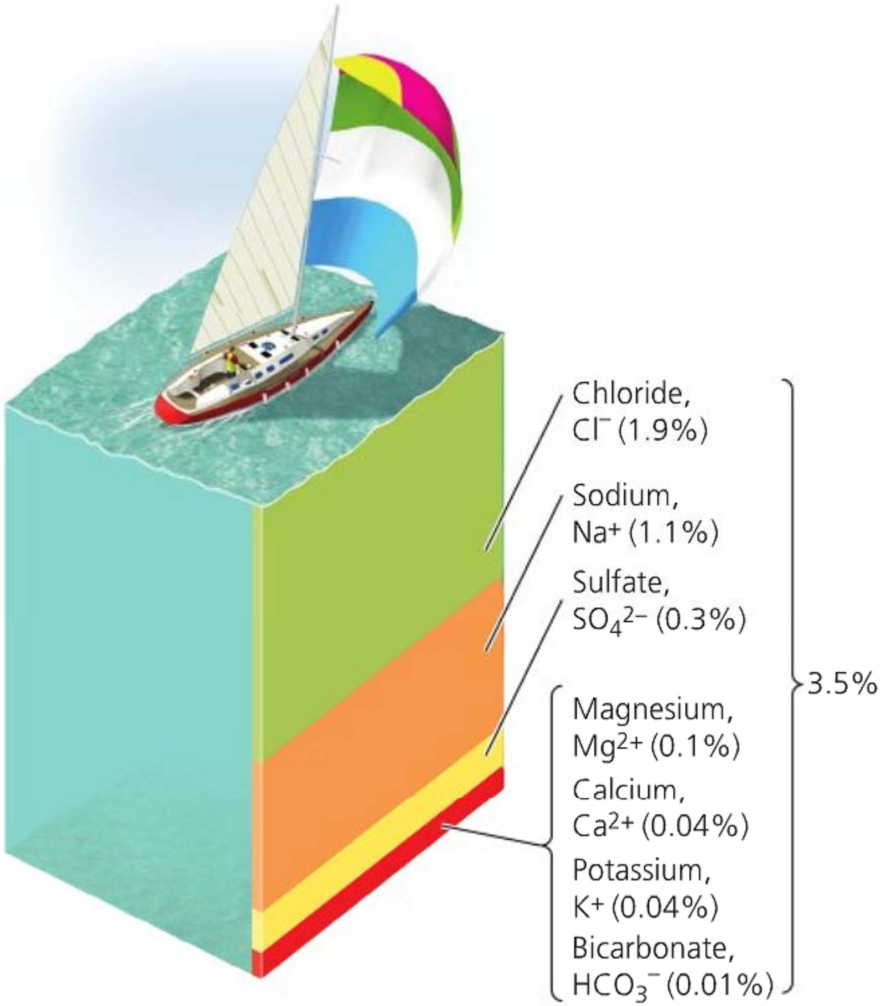
- Top 10 m surface zone absorbs 80 % of solar energy:
  - „photic zone“ - practically all of the primary production of biomass by phytoplankton
  - Phytoplankton is first step in the food chain and source of all life in the oceans.
- Beneath this layer the temperature falls rapidly:
  - „pycnoclyne zone“ till about 150 m depth rich in fish.
- Water below is nearly unaffected by winds, sunlight and temperature variations in the atmosphere.

- Density and salinity increasing with depth.

Hydrosphere:

Chemical Composition of Ocean Water

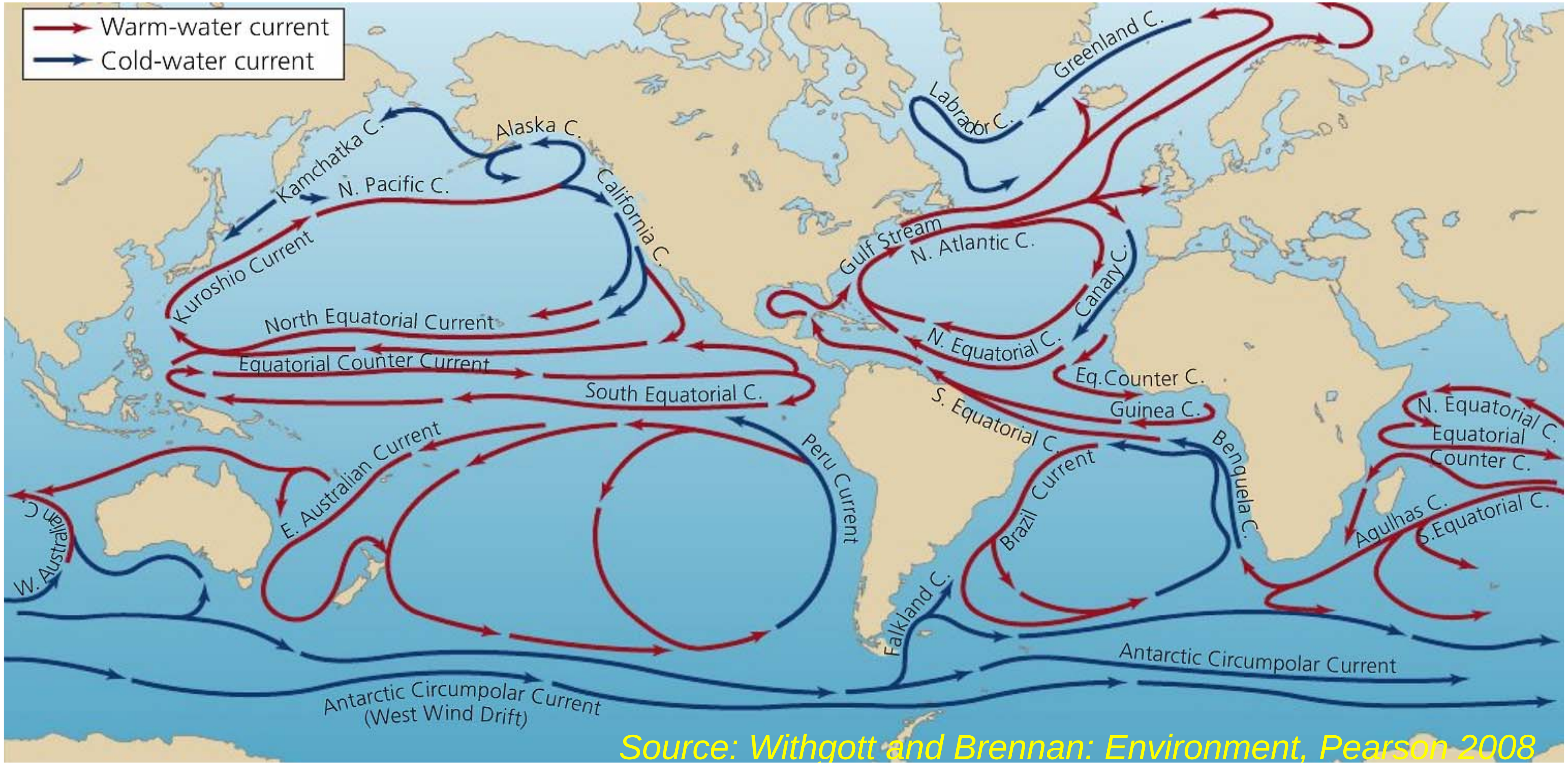
Source: Withgott and Brennan: Environment, Pearson 2008



- Ocean water contains on the average ca 3,5 % salt arising from permanent transport of salts from land masses through rivers and atmospheric deposition.
- The salt content increases the density of water and influences the ocean currents, like the gulf stream.
- In addition nutrients occur in sea water in trace amounts (important for life in the marine ecosystems).
- Sea water contains dissolved gases, like oxygen produced by photosynthetic processes of plants, and phytoplankton, and carbon dioxide, mainly from exchange processes with the atmosphere.

Hydrosphere: Ocean Circulation

- The earth's ocean is composed of huge river-like flows caused mainly by density differences, heating and cooling and wind.
- Horizontal currents flow in the upper 400 m over thousands of kms.
- Important for the transport of heat, nutrients, pollutants and marine species.
- Ocean currents were extremely important for shipping in the past.



Source: Withgott and Brennan: Environment, Pearson 2008

Hydrosphere: Ocean Circulation

R

- Significance of ocean currents for discoveries:

In 1488 Bartolomeu Diaz tried to reach India via the African Cape route but was only able to get around the Cape of Good Hope, and not to India due to the Aghulas current .

Therefore Columbus tried the Western route in 1992. His sailing was supported by the Canary and the North Equatorial currents leading him to La Gomera and Cuba.

Hydrosphere: Thermohaline Circulation

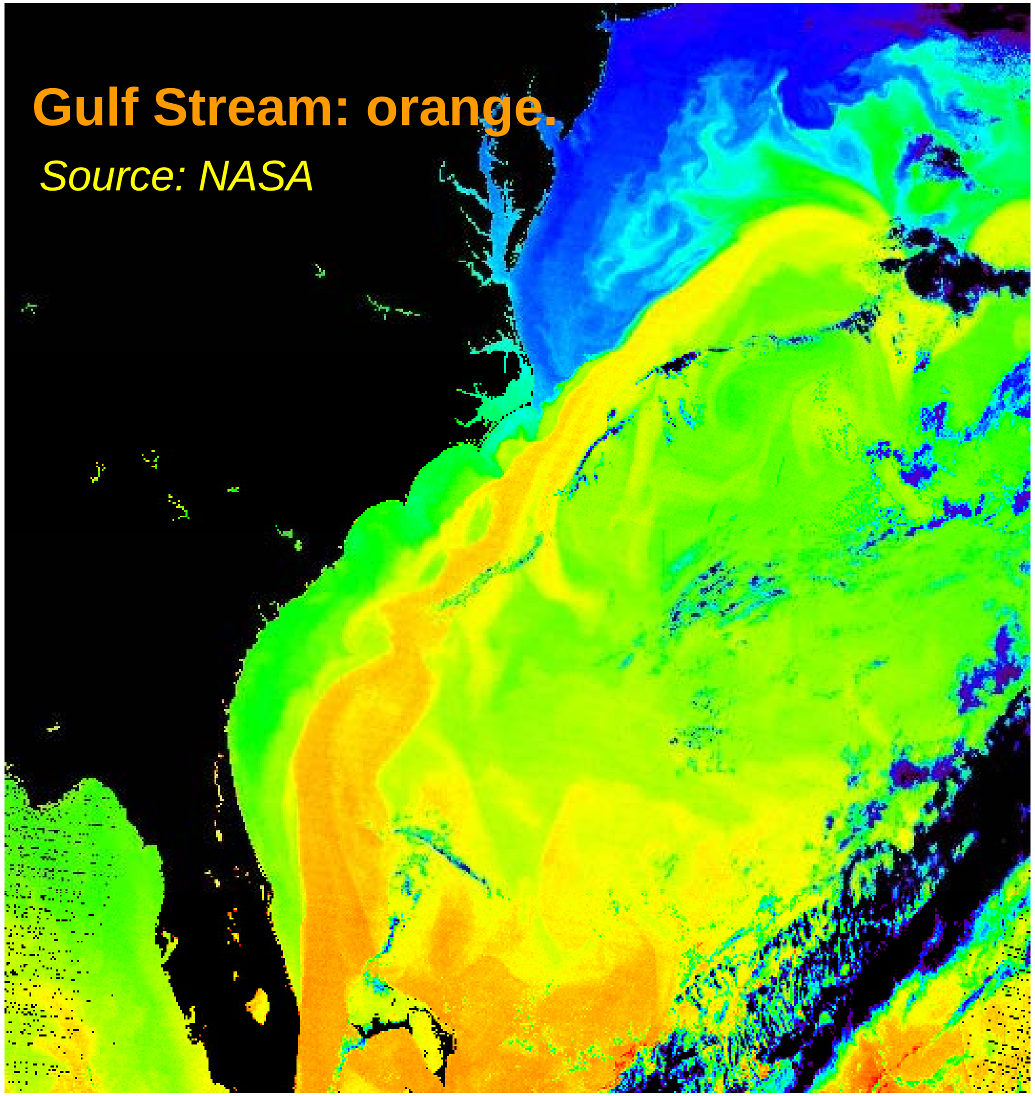
•The term thermohaline circulation (THC) refers to the part of the large-scale ocean circulation that is driven by global density gradients created by surface heat and freshwater fluxes.

•The THC is sometimes called the ocean conveyor belt.

Source: Wikipedia

A simplified summary of the path of the density driven thermohaline circulation. Darker arrows represent deep-water currents, while lighter arrows represent surface currents.

Hydrosphere: The Gulf Stream



- Surface current heading polewards from the equatorial Atlantic Ocean, cooling all the while and eventually sinking at high latitudes (forming North Atlantic Deep Water).
- This dense water then flows into the ocean basins and creates a southward flow of deep water.
- As these dense water masses sinking into the ocean basins displace the water below them, in the southern zone an upwelling of warm water must occur to maintain a balance.

- The Gulf Stream influences the climate of the east coast of North America from Florida to Newfoundland, and the west coast of Europe.

Source: Wikipedia

The Atmosphere

- The **Earth's atmosphere** is a layer of gases surrounding the planet Earth and retained by the Earth's gravity.

The Earth Seen from Apollo 17

Composition of Dry Atmosphere (Vol%)

Nitrogen	78,08 %
oxygen	20,94 %
argon	0,93 %
carbon dioxide	0,04 %
trace gases	0,01%

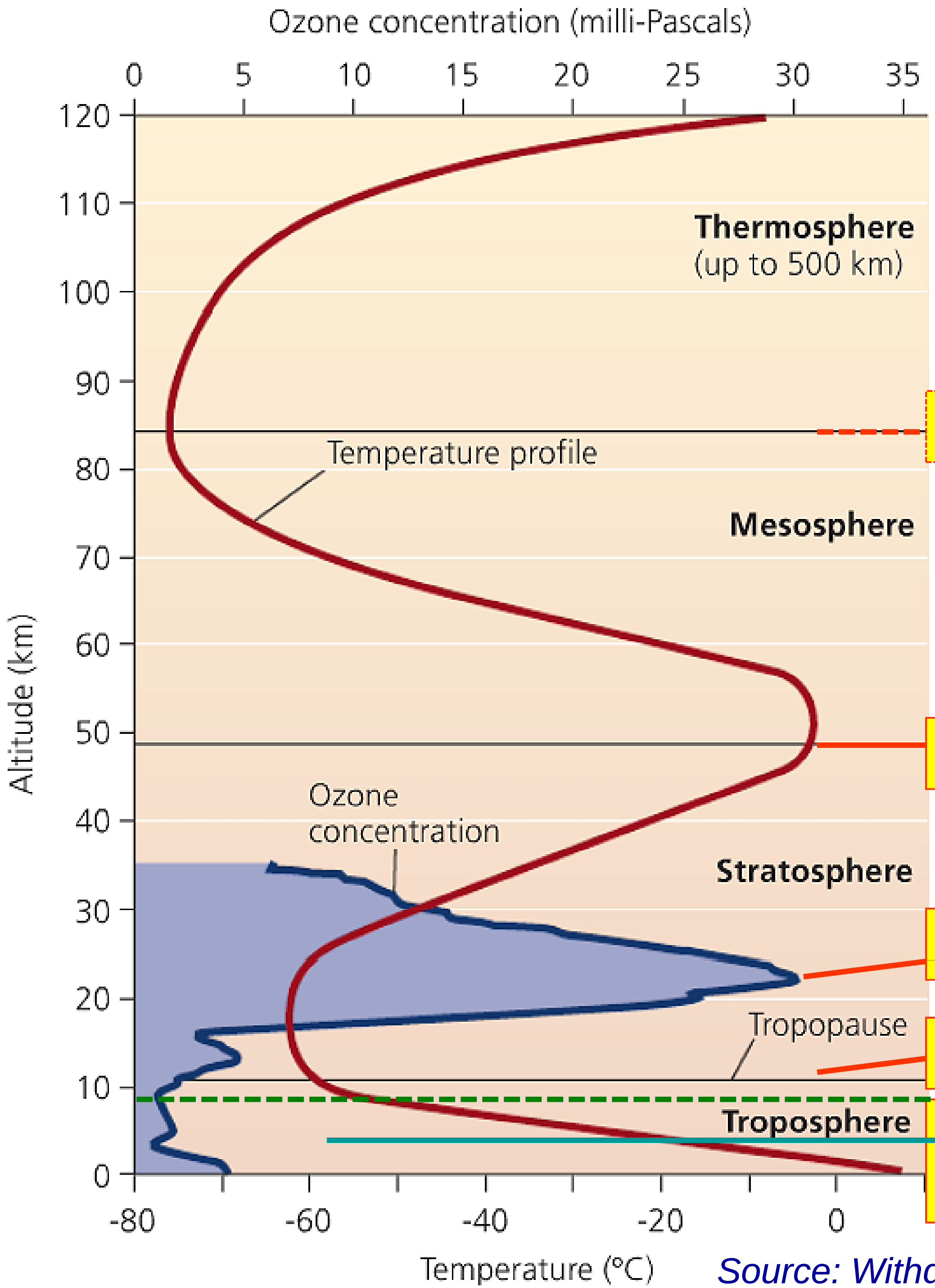
In addition: water vapour about 1% on the average

Source: Wikipedia

- The atmosphere protects life on Earth by absorbing ultraviolet solar radiation and reducing temperature extremes between day and night.

Atmosphere:
Vertical Structure

Meteosat: altitude 40.000 km
Galileo satellites: 22.000 km
ISS: 330 km



T = - 80 C in mesopause

T = + 10 C in stratopause

Statospheric ozone layer

T = - 60 C in stratopause

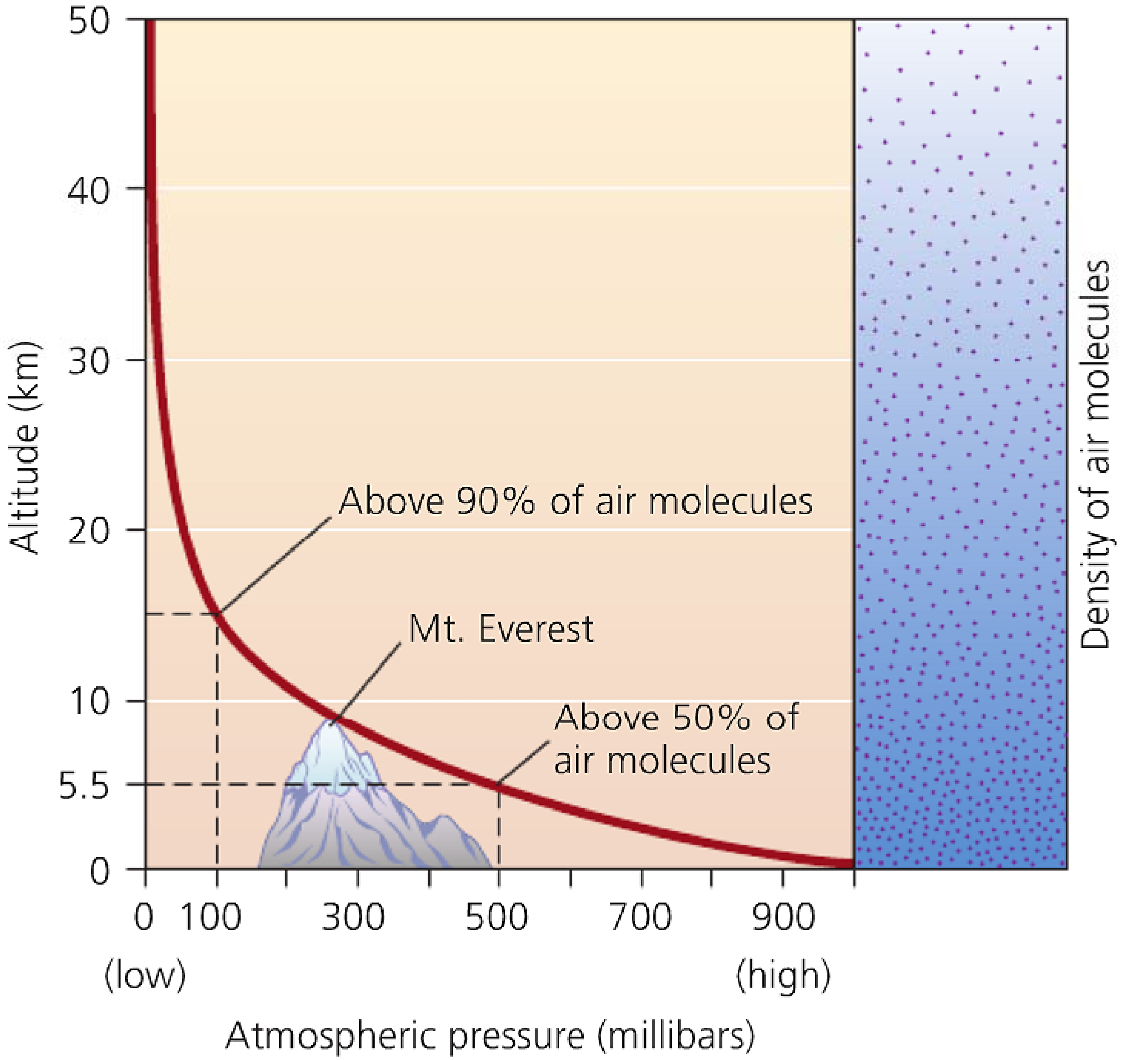
Jet airplane: 8-10 km

strong vertical mixing due to solar heating at the surface: weather

Source: Withgott and Brennan: Environment, Pearson 2008

Atmosphere: Atmospheric Pressure

- Total atmospheric mass is 5.1361×10^{18} kg or 1/1,200,000 the mass of Earth.
- Atmospheric pressure is a direct result of the total mass (weight) of the air above the point at which the pressure is measured.



-The average atmospheric pressure, at sea level, is about 101.3 kPa (kilopascal).

-Atmospheric pressure decreases with height.

-Air pressure varies with location and time leading to the formation of air streams and specific weather conditions (high pressure/low pressure areas).

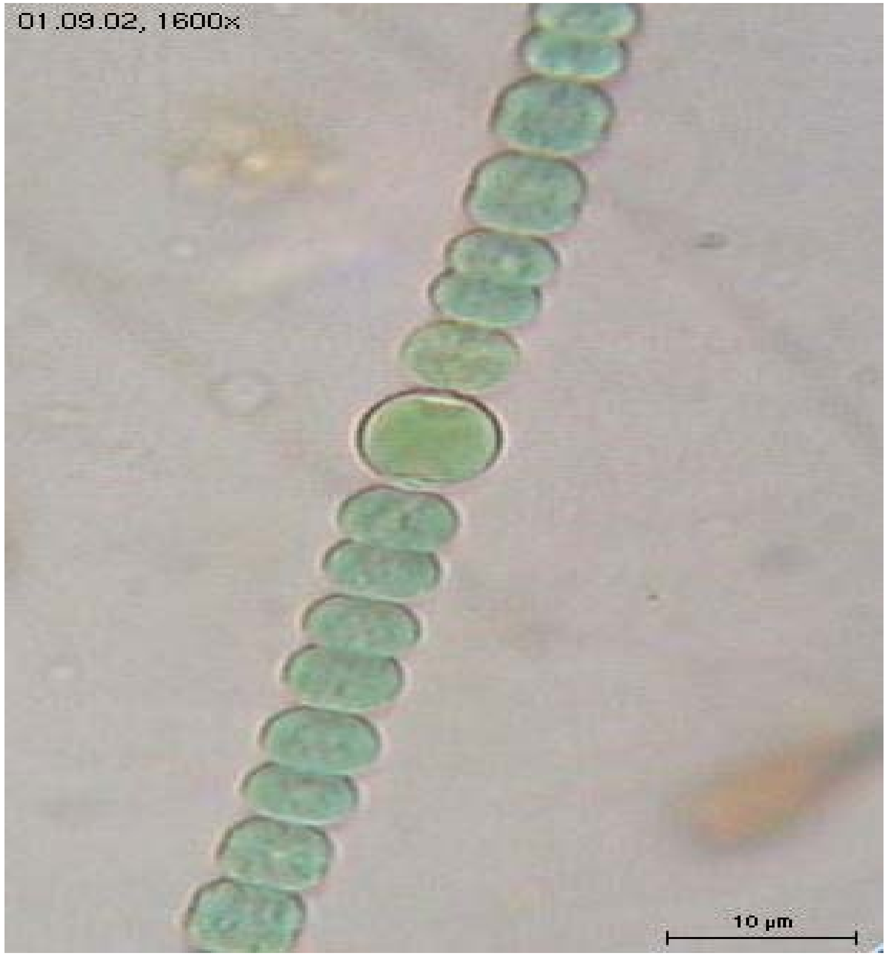
Source: Withgott and Brennan: Environment, Pearson 2008

Atmosphere - Evolution

- **Present atmosphere** is the Earth's "third atmosphere“.
- **First (original) atmosphere:** 5 billion years ago, primarily helium and hydrogen. Heat from the still-molten crust and the sun dissipated this atmosphere.
- **Second atmosphere:** formed 4.4 billion years ago. Surface had cooled enough to form a crust, still heavily populated with volcanoes which released steam, carbon dioxide, and ammonia leading to an atmosphere**,** which was primarily carbon dioxide and nitrogen-compounds (ammonia) but virtually no oxygen („anoxic state“).
  - This second atmosphere had approximately 100 times as much gas as the current atmosphere, but as it cooled much of the carbon dioxide was dissolved in the seas and precipitated out as carbonates.
- **Third atmosphere**: 3.3 billion years ago conversion of the earth's atmosphere from an anoxic state to an oxic state started, based on the activities of cyanobacteria. Cyanobacteria, also known as blue-green algae, were the first species with photosynthetic activity and thus the first producers of oxygen.

Source: Wikipedia 0

Atmosphere: Cyanobacteria



•In photosynthesis carbon dioxide and water are converted into glucose and oxygen with the energy provided by sunlight (endothermic reaction).

• Glucose is then the energy carrier for the living system and the base material for the formation of other organic molecules, like cellulose, proteins, carbohydrates.

•A certain amount of oxygen remains dissolved in the water and the rest is released into the atmosphere.

•The growth of cyanobacteria thus leads to a steady removal of CO_2 and enrichment of oxygen in the atmosphere, and finally to a switch from the anoxic to the oxic state..

Photo: Wikipedia

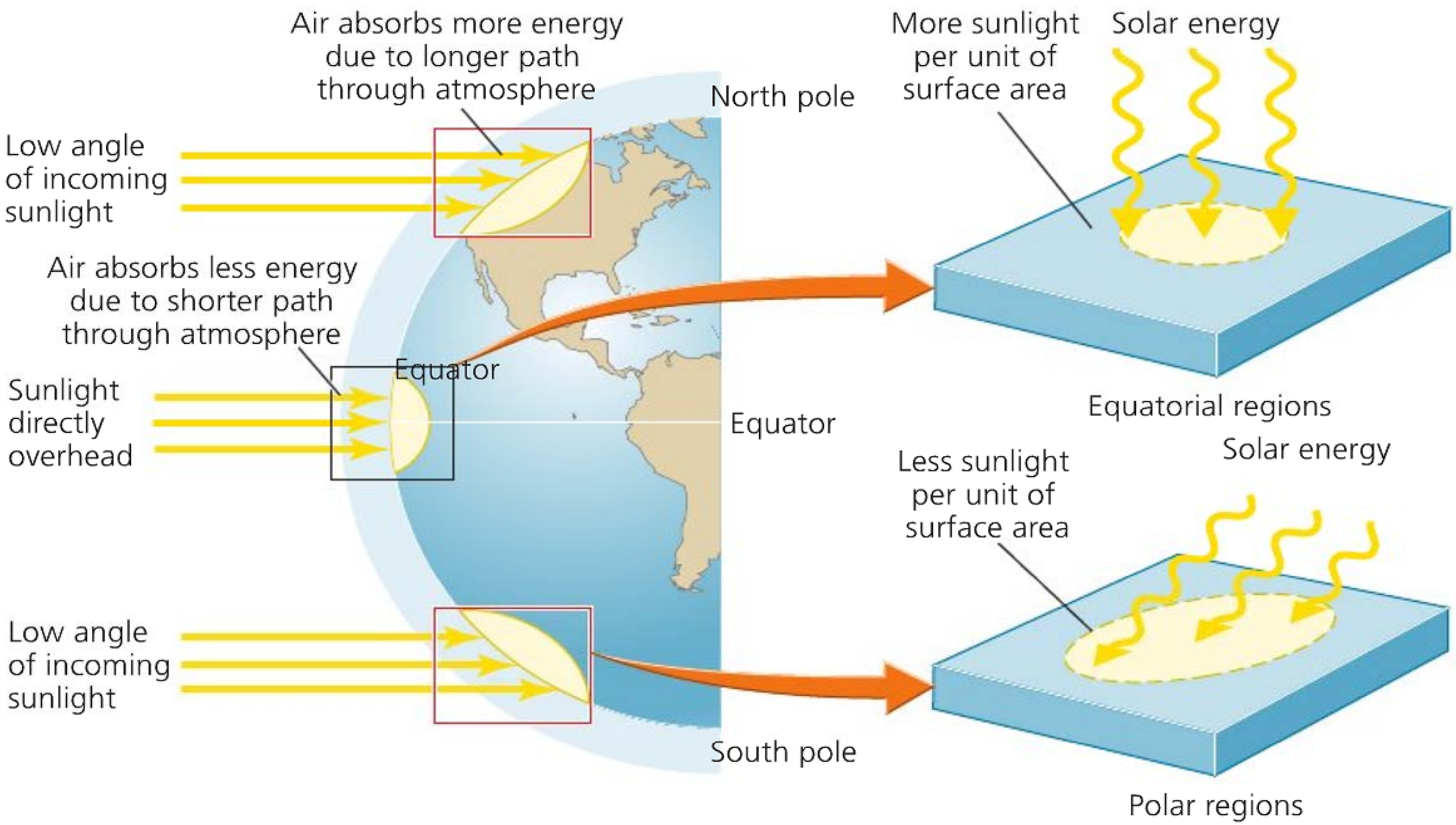
The Third Atmosphere

- Oxygen accumulated in the atmosphere resulted in mass extinctions of the anaerobic species some 2,4 billion years ago.
- Increase in oxygen in the atmosphere enabled the evolution of a totally different species (like eukaryotic cells) which use cellular respiration to produce the energy needed for a living system (and the building materials of living matter, like proteins).
- Respiration is the reverse process to photosynthesis as oxygen and glucose are consumed and CO_2 and water are formed (exothermic reaction).
- The energy gained comes essentially from the „burning“ of glucose.
- These aerobic organisms carry more energy than anaerobic organisms and thus dominate the biosphere through complex multicellular organisms.
- Oxygen reacted also with ammonia to release nitrogen thus producing the large concentration of nitrogen in the atmosphere.
  - Reaction: $4\ NH_3 + 3\ O_2 = 2\ N_2 + 6\ H_2O$
- Finally an oxygen-nitrogen atmosphere evolved towards the end of the Carboniferous era (about 300 million years ago).

Source: Wikipedia

Atmosphere: Atmospheric Circulation

•Large scale movement of air is the main mechanism by which heat is distributed on the surface of the Earth.

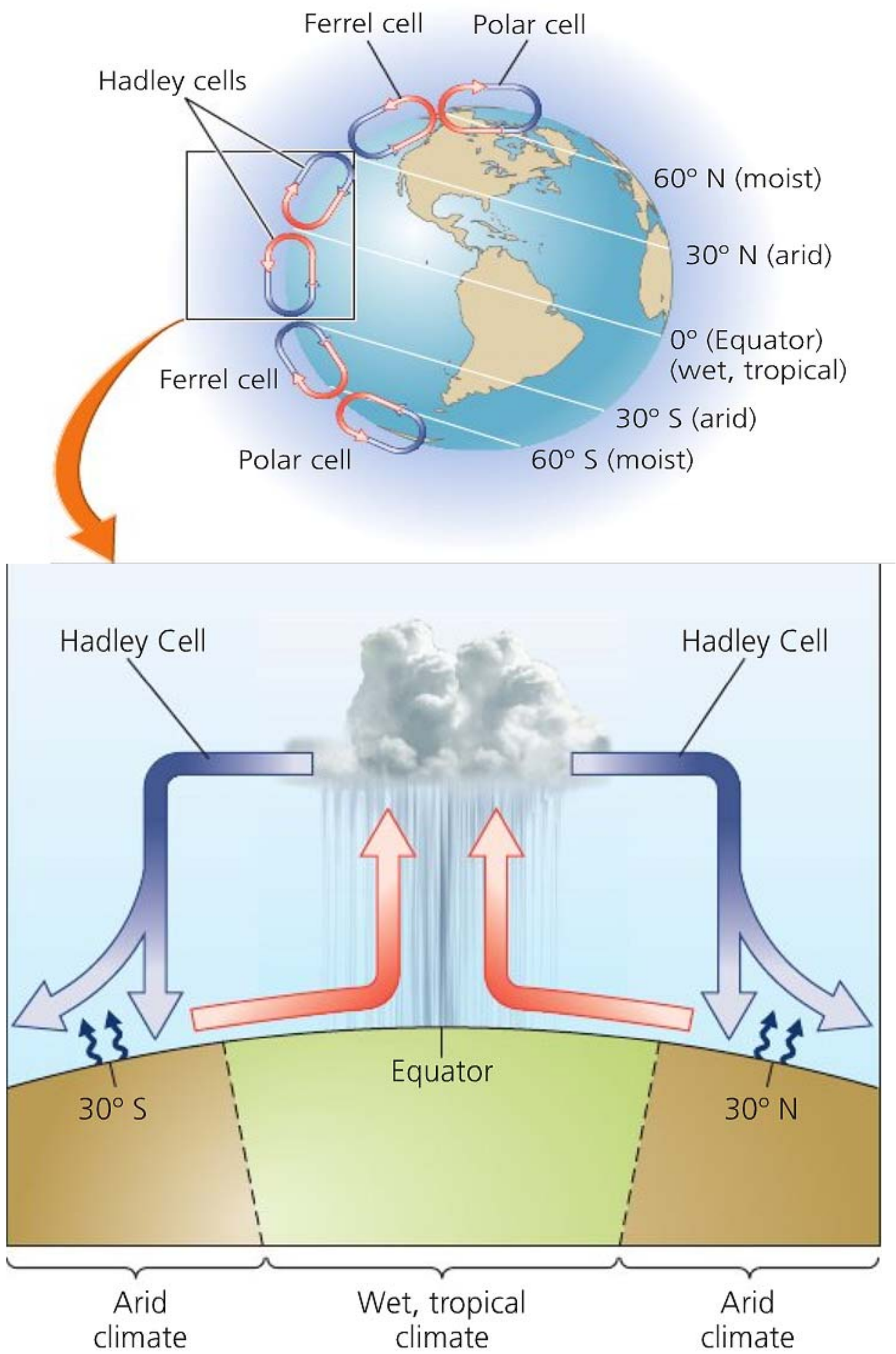


Source: Withgott and Brennan: Environment, Pearson 2008

•The major driving force of atmospheric circulation is solar heating, which on average is largest near the equator and smallest at the poles.

•The atmospheric circulation transports energy polewards, thus reducing the resulting equator-to-pole temperature contrast.

Atmosphere: Circulation

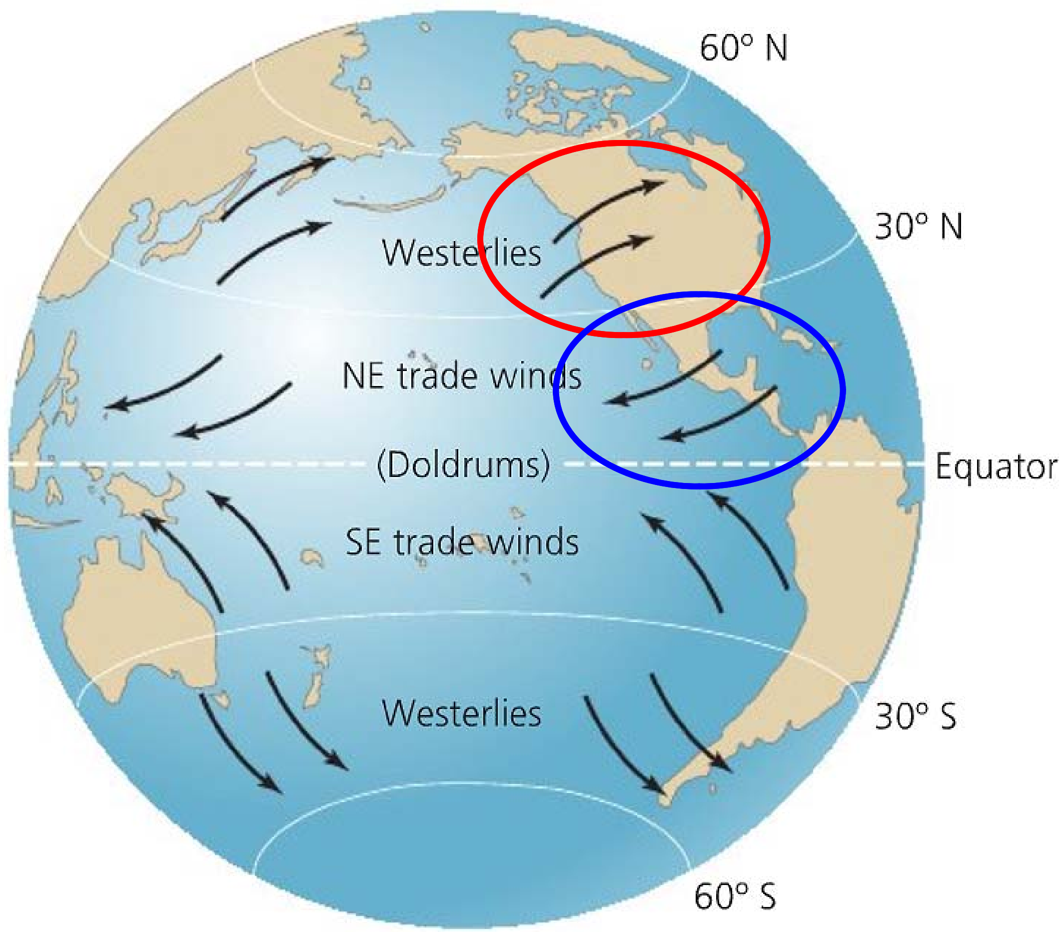


(a) Convection currents

- **Hadley cell:** circulation pattern dominating the tropical atmosphere, with rising motion near the equator, poleward flow 10-15 kilometers above the surface, descending motion in the subtropics, and equatorward flow near the surface.
- In the tropical zone the hot air picks up lots of moisture from the surface, cools when rising and releases much of the moisture in form of rain in the tropics.
- As the air flows towards the pole it is exposed to further cooling and therefore sinks to the ground as dry air. It warms during sinking due to (adiabatic) compression leading to a warm arid climate in these zones.
- The air then flows back to the tropical zone due to pressure differences.

Source: Withgott and Brennan: Environment, Pearson 2008

Atmosphere: Circulation



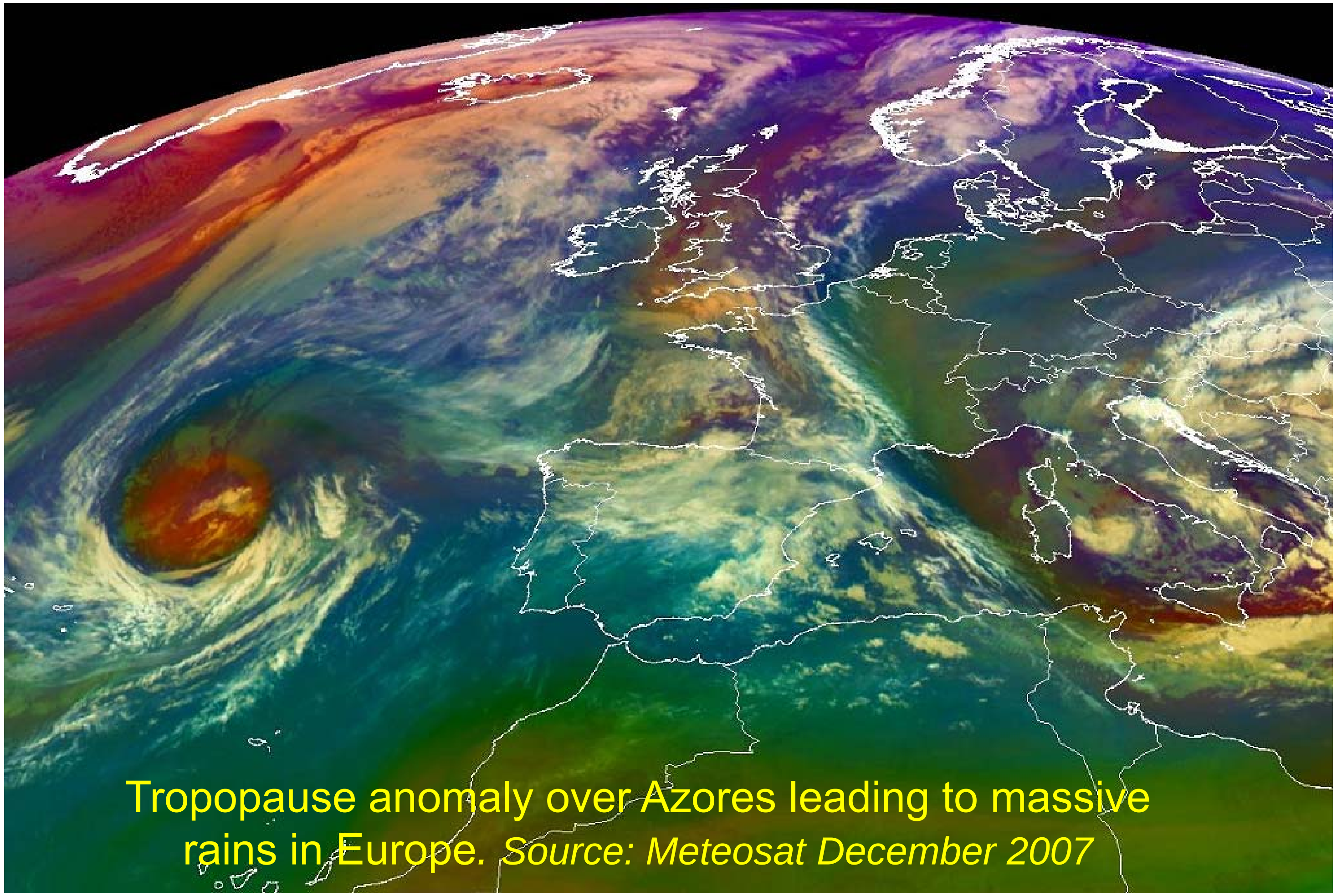
(b) Global wind patterns

Source: Withgott and Brennan: Environment, Pearson 2008

- Near the tropopause, as the air moves polewards in the Hadley cell, it is turned eastward by the Coriolis force creating the subtropical jet streams that flow from west to east in 10.000m altitude **(„Westerlies“).**
- Analogously, near the surface, the equatorward return flow is rotated to the west.
- These surface winds, with both an equatorward and a westward component, are referred to as the **trade winds.**

Atmosphere: The Weather

- The large-scale structure of the atmospheric circulation varies from year to year, but the basic structure remains fairly constant.
- However, individual weather systems - midlatitude depressions, tropical convective cells or tropopause anomalies - occur randomly.



Tropopause anomaly over Azores leading to massive rains in Europe. *Source: Meteosat December 2007*

- Therefore weather cannot be predicted beyond a fairly short limit: about ten days in practice.
- Nonetheless, the average of these systems, the climate, is quite stable.

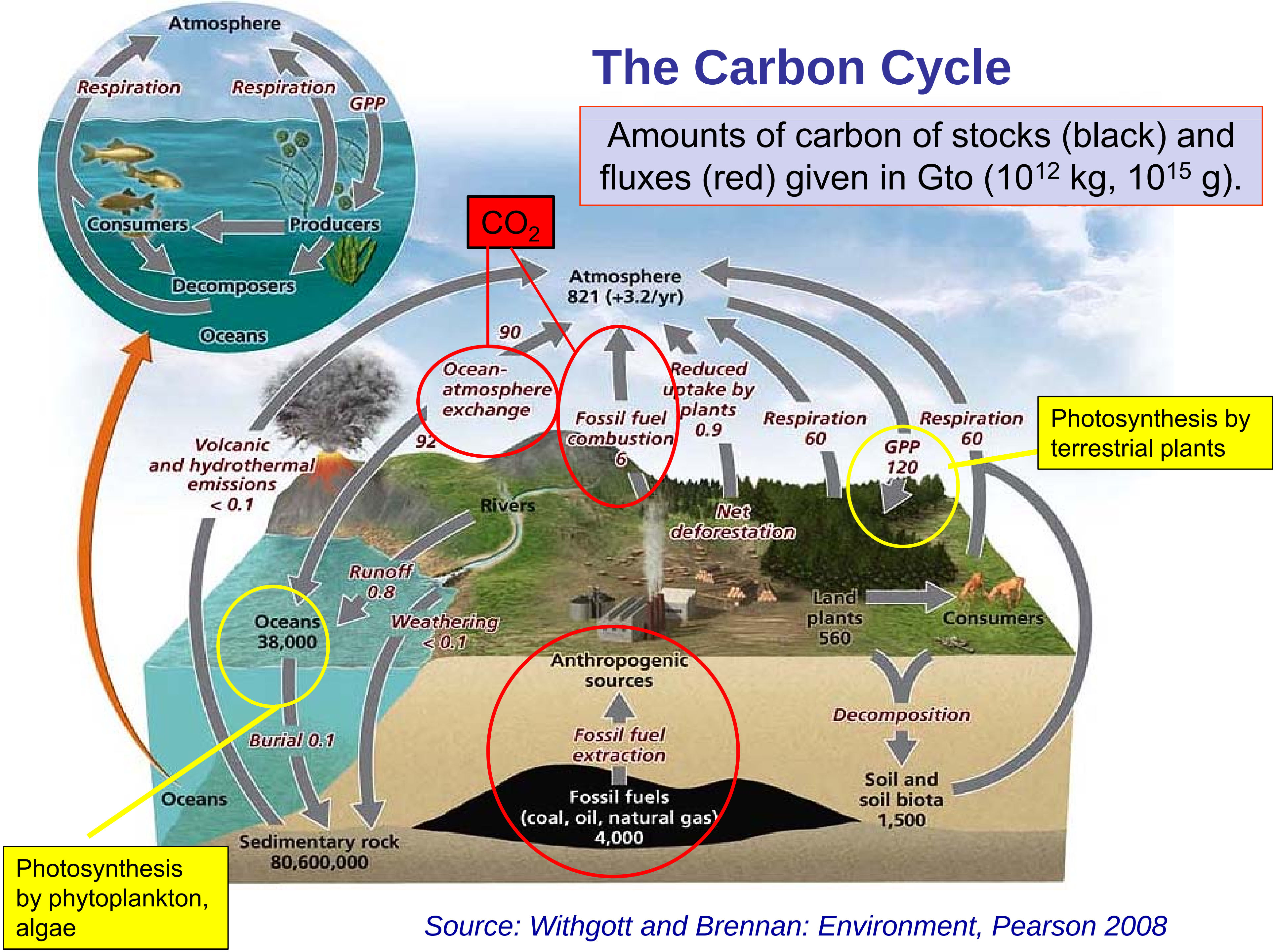
Biogeochemical Cycles

- The biosphere contains great quantities of elements such as carbon, nitrogen, hydrogen and oxygen.
- Other elements, such as phosphorus, calcium, and potassium, are also essential to life, yet are present in smaller amounts.
- At the ecosystem and biosphere levels, there is a continual recycling of all these elements, which alternate between the mineral and organic states.
- The most important biogeochemical cycles are:
  - The carbon cycle.
  - The nitrogen cycle.
  - The phosphorus cycle.
  - The oxygen cycle.

Source: Wikipedia

The Carbon Cycle

Amounts of carbon of stocks (black) and fluxes (red) given in Gto (10^{12} kg, 10^{15} g).



Source: Withgott and Brennan: Environment, Pearson 2008

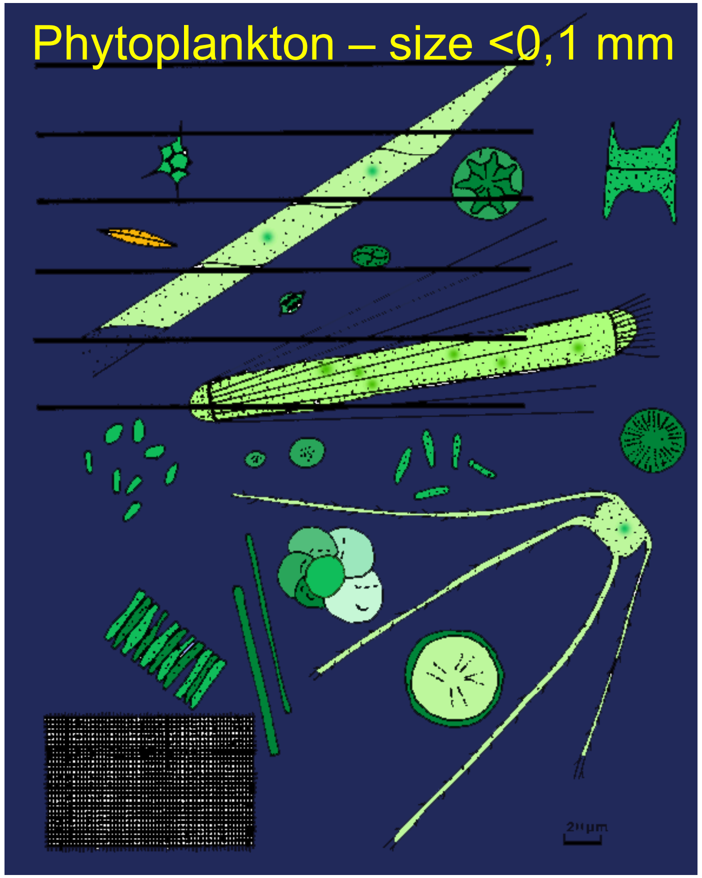
The Carbon Cycle

- The **carbon cycle** refers to the exchange of carbon between the carbon reservoirs, which are the atmosphere, biosphere, lithosphere and hydrosphere of the Earth.
- **Atmosphere:** carbon exists as carbon dioxide (CO_2) – raw material for photosynthesis thus basis for all plants.
- **Biosphere:** Carbon exists as living species (plants, animals) largely consisting of organic carbon compounds (carbohydrates, celluloses, proteins…..) and of inorganic carbonates (e.g. shells of animals).
- **Lithosphere**: Carbon exists as inorganic carbonate rocks and as carbon rich deposits of dead organic matter (coal, oil, natural gas).
- **Hydrosphere:** Carbon exists as dissolved carbon dioxide, suspended carbonates, dead organic matter.
- The annual movements of carbon, the carbon exchanges between reservoirs, occur because of various chemical, physical, geological, and biological processes.

Source: Wikipedia

The Carbon Cycle - Biosphere

- **Carbon in the biosphere:**
- Carbon is the major element in all organic compounds which are produced essentially from glucose through a multitude of biochemical reactions.
- Glucose is produced from CO_2 by autotroph organisms through the process of photosynthesis.



-The most important autotrophs are trees in forests on land and phytoplankton in the oceans.

–Through photosynthesis, phytoplankton is responsible for about half of the oxygen produced in the Earth's atmosphere.

-Its cumulative energy fixation in carbon compounds (primary production) is the basis for the vast majority of oceanic and also many freshwater food webs.

-Carbon is transferred within the biosphere as heterotrophs feed on other organisms or their parts (e.g. fruits).

Source: Wikipedia

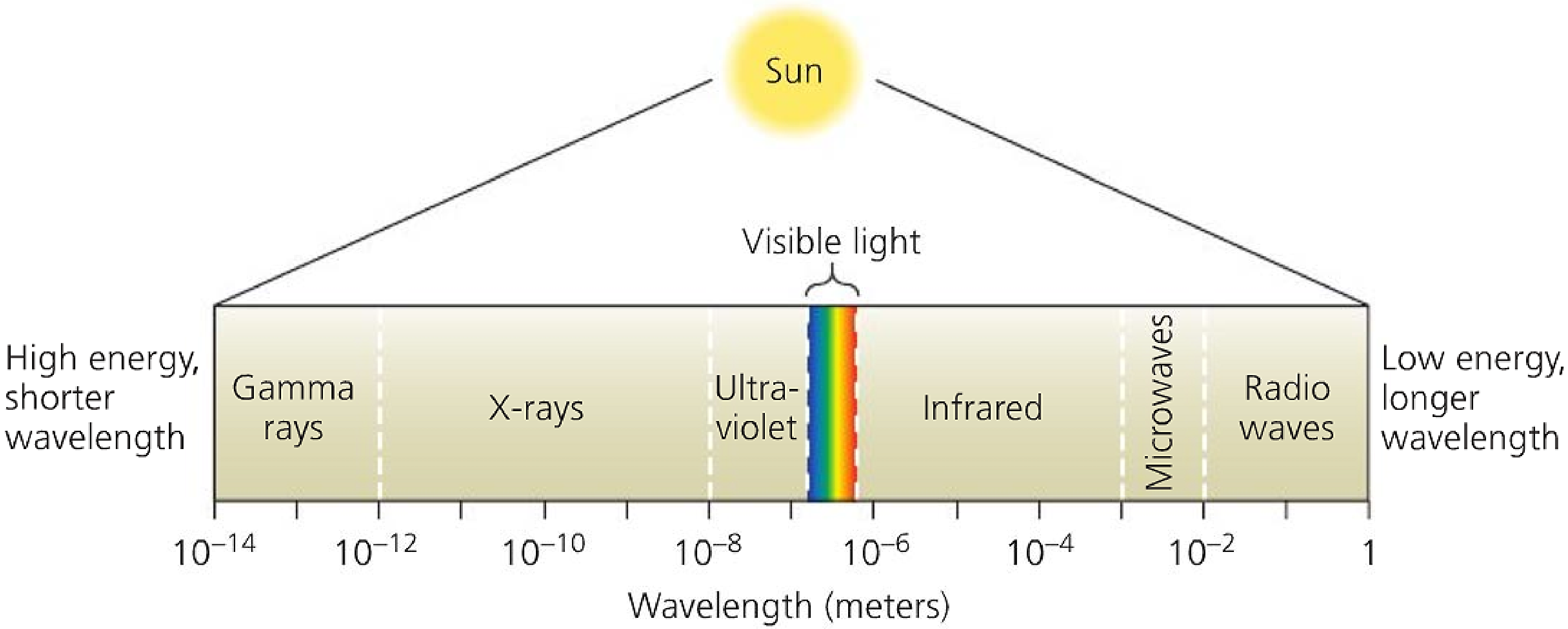
The Carbon Cycle: Biosphere

Photosynthesis

- Photosynthesis is the primary process for the origin of life on earth.
- It can be described by the summary reaction:

$$6CO_2 + 6H_2O + h\nu \rightarrow C_6H_{12}O_6 + 6O_2$$

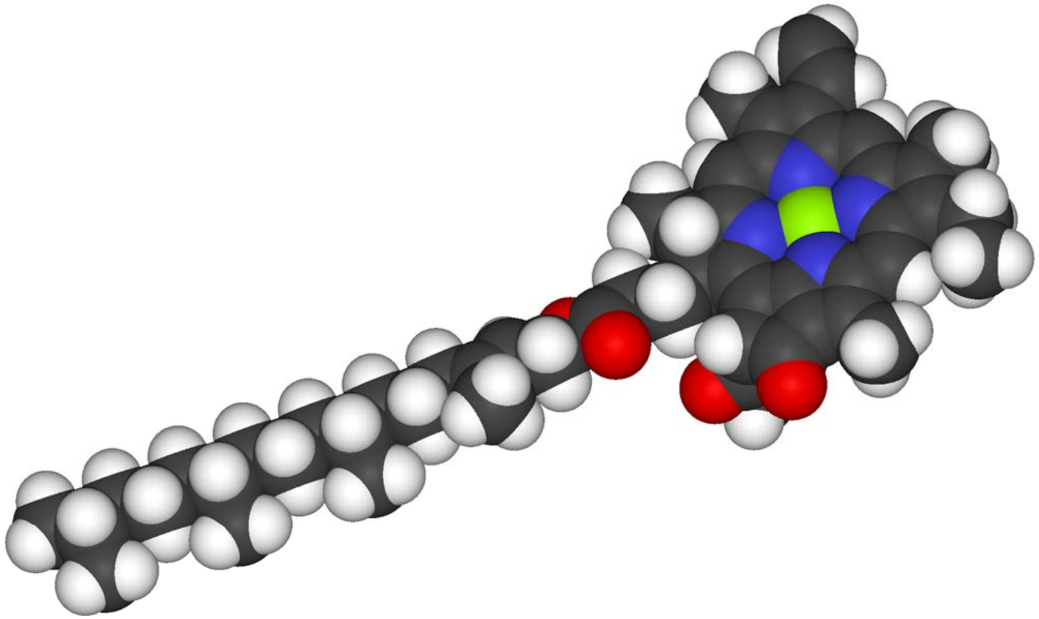
- Photons ($h\nu$) from the sun provide the energy for this endothermic reaction. Thus the sun powers most living systems.



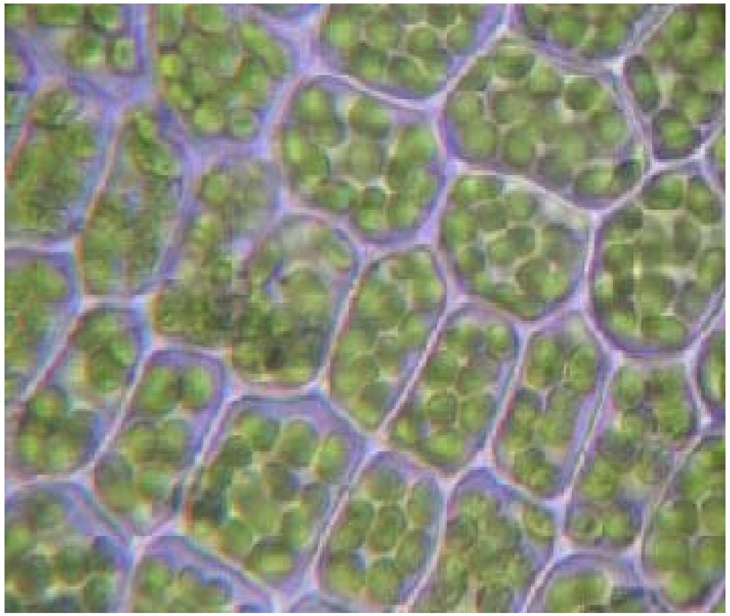
Source: Withgott and Brennan: Environment, Pearson 2008

The Carbon Cycle:
Photosynthesis

- Photosynthesis needs the involvement of a catalyst: chlophyll.
- Chlorophyll is present in cell organelles called chloroplasts.



Model of the chlorophyll a molecule



Chloroplasts of plant cells.

Photos: Wikipedia

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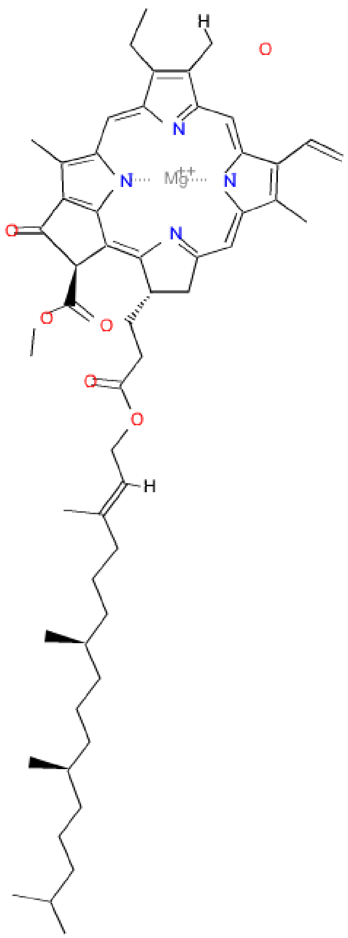
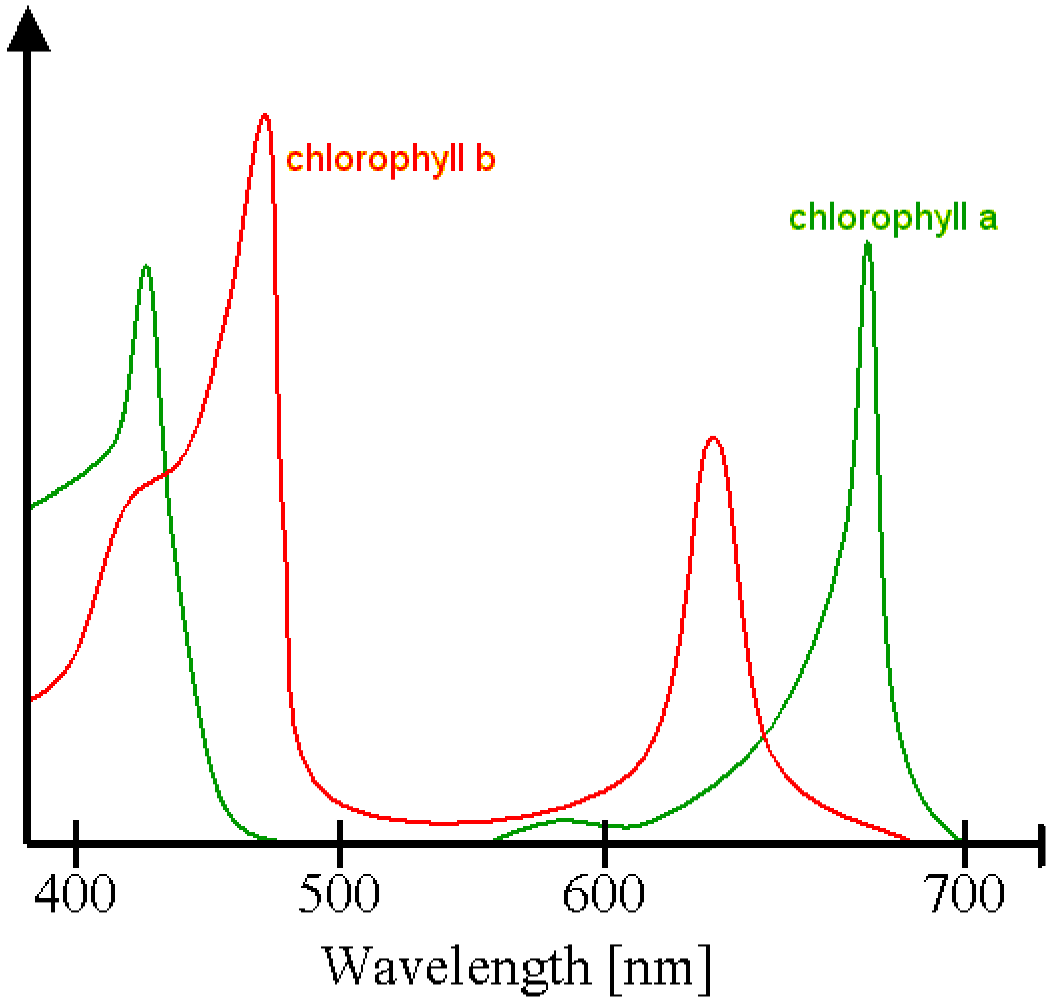
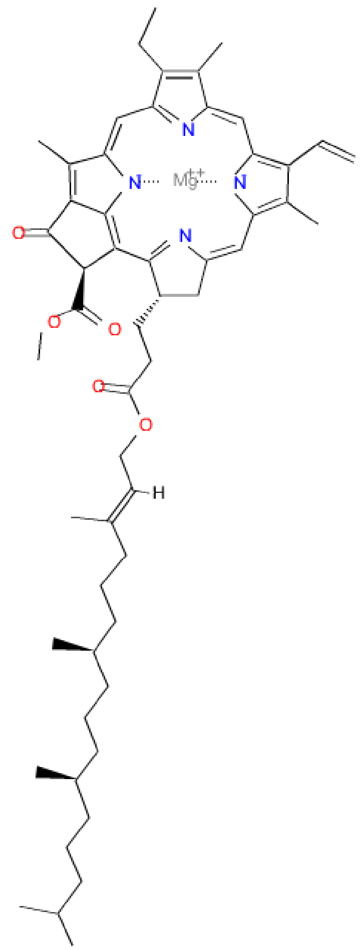
The Carbon Cycle:
Photosynthesis

Chlorophyll b





Chlorophyll a



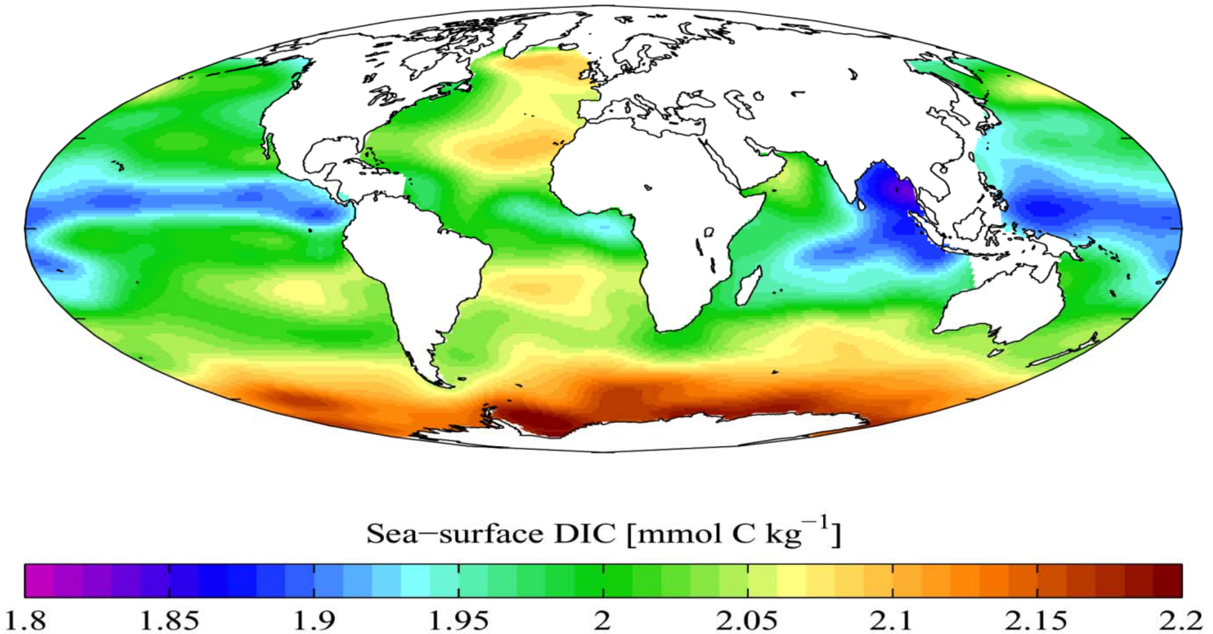
Absorbance spectra of free chlorophyll *a* (green) and *b* (red).

Photos: Wikipedia

The Carbon Cycle: Hydrosphere

Inorganic processes

- At the surface of the oceans carbon dioxide is readily exchanged with the atmosphere and dissolved in the water.
- This carbon exchange becomes important in controlling pH in the ocean and can also vary as a source or sink for carbon.
- Carbon dioxide reacts with water to form bicarbonate ions.
- Bicarbonate reacts with calcium to form limestone (calcium carbonate, $CaCO_3$), which precipitates to the ocean floor.



Sea Surface Dissolved Inorganic Carbon Concentration.
Colder regions hold more carbon due to higher solubility of CO_2.

Source: GLODAP climatology

The Carbon Cycle: Release into Atmosphere

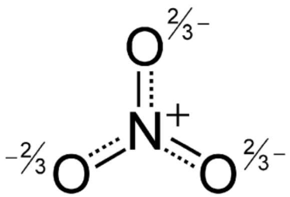
- **Respiration performed by animals**: This is an exothermic reaction and it involves the breaking down of glucose (or other organic molecules) into carbon dioxide and water.
- **Decay of animal and plant matter.** Fungi and bacteria break down the carbon compounds in dead animals and plants and convert the carbon to carbon dioxide if oxygen is present, or methane if not.
- **Combustion of organic material:** produces carbon dioxide (and other compounds, like water vapor). Burning fossil fuels such as coal, petroleum products, natural gas or biomass releases carbon that has been stored in the geosphere for millions of years.
- **Production of cement:** carbon dioxide is released when limestone (calcium carbonate) is heated to produce lime (calcium oxide), a component of cement.
- **Outgasing from oceans:** At the surface of the oceans where the water becomes warmer, dissolved carbon dioxide is released back into the atmosphere.
- **Volcanic eruptions:** release primarily water vapor, carbon dioxide and sulfur dioxide.

Source: Wikipedia

The Nitrogen Cycle

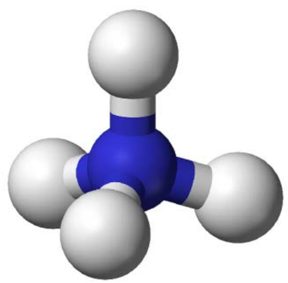
- Earth's atmosphere is about 78% nitrogen, making it the largest pool of nitrogen.
- Nitrogen is essential for many biological processes and is crucial for any life here on Earth.
- It is in all amino acids, is incorporated into proteins, and is present in the bases that make up nucleic acids, such as DNA and RNA.
- In plants, nitrogen is also used in chlorophyll molecules which are essential for photosynthesis and further growth.
- Important nitrogen compounds are:

Nitrates: NO_3^-



$NaNO_3$, KNO_3, NH_4NO_3

Ammonium salts: NH_4^+

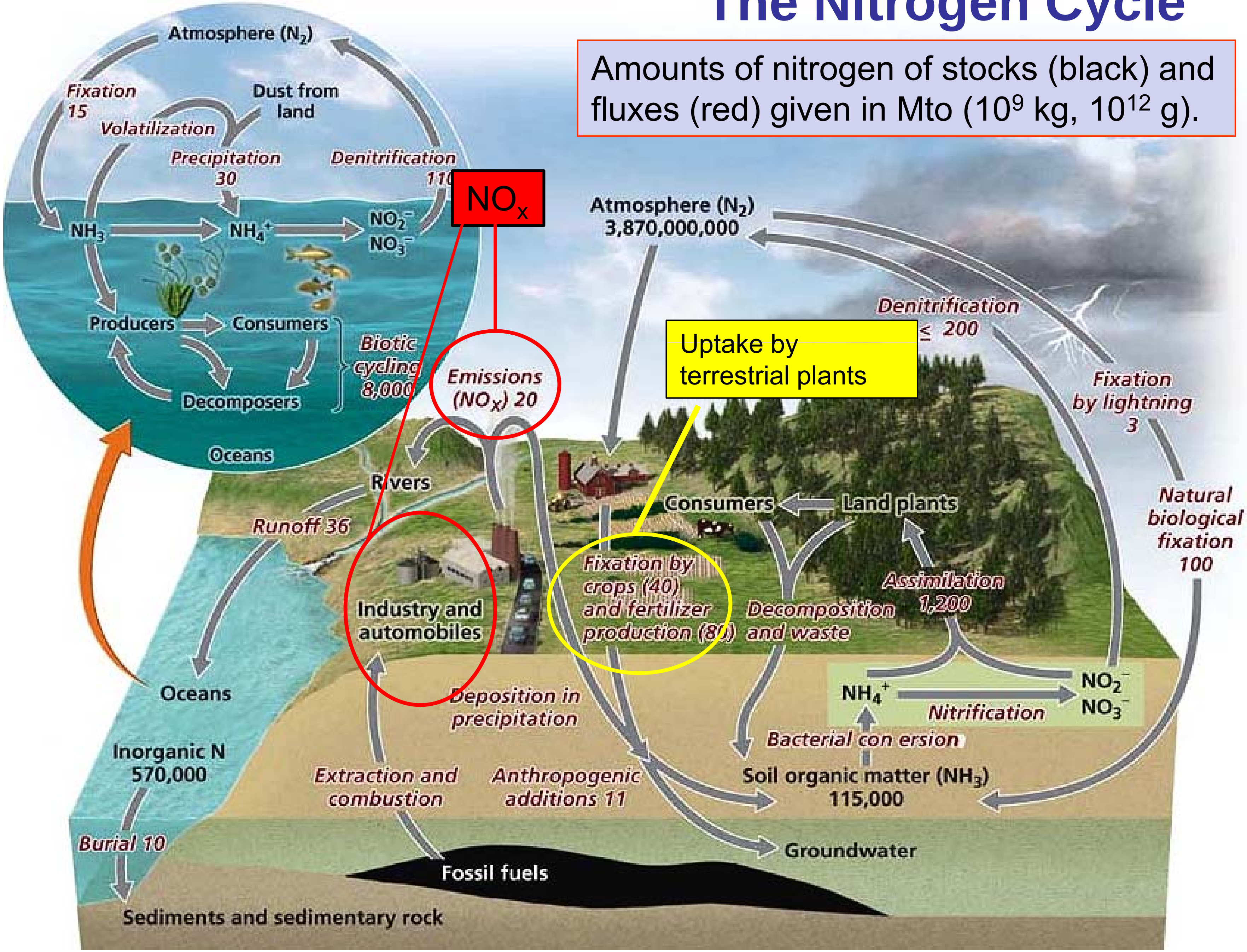


NH_4NO_3, NH_4Cl, $(NH_4)_2SO_4$

Source: Wikipedia

The Nitrogen Cycle

Amounts of nitrogen of stocks (black) and fluxes (red) given in Mto (10^9 kg, 10^{12} g).



Source: Withgott and Brennan: Environment, Pearson 2008

The Nitrogen Cycle:
Uptake of Nitrogen from the Atmosphere

- **Uptake of gaseous nitrogen (N_2) from atmosphere:**
- N_2 cannot normally be taken up by plants since it is a very stable molecule.
- Conversion of N_2 into forms usable by living organisms is done by bacteria endowed with the nitrogenase enzyme that combines gaseous nitrogen with hydrogen to produce ammonia, which is then further converted by the bacteria to make its own organic compounds.

Source: Wikipedia

– Some nitrogen fixing bacteria, such as *Rhizobium or Bradyrhizobium*, live in the root nodules of legumes (such as peas or beans).
– They form a mutualistic relationship with the plant, producing ammonia in exchange for carbohydrates.

Soybean root nodules, each containing billions of *Bradyrhizobium* bacteria.

The Nitrogen Cycle:
Uptake of Nitrogen from Soil

- **Assimilation**

- Most plants can absorb nitrate or ammonium ions from the soil via root hairs.
- If nitrate is absorbed, it is first reduced to nitrite ions and then to ammonium ions for incorporation into amino acids, nucleic acids, and chlorophyll.
- To achieve proper yields in plant growth these nitrogen compounds must be added to the soil (natural or chemical fertilisers).
- Typically fertilizers do not only provide nitrogen (nitrate, ammonium compounds,urea) but also other major plant nutrients like phosphorus and potassium, then secondary plant nutrients (calcium, sulfur, magnesium), and sometimes trace elements.
- Fertilisers are naturally occurring compounds such as manure, bird excretions („Chile-Salpeter“), peat or mineral deposits, or manufactured through natural processes (such as composting) or chemical processes (such as the Haber-Bosch process).

Source: Wikipedia

The Nitrogen Cycle:
Chemical Fertilisers

- **Chemical Fertilizers:**

- In the Haber-Bosch Process developed 1910 ammonia (NH_3) is produced through a high temperature (400°C)/high pressure (300bar) reaction between hydrogen (from natural gas) and atmospheric nitrogen:
  $N_2 + 3H_2 = 2\ NH_3$
- NH_3 is used to produce nitrogen fertilizers, mostly in the form ammonium nitrate and urea.
- The Haber-Bosch process now produces 100 million tons of nitrogen fertilisers per year.
- The growth of the world's population to its current figure has only been possible through intensification of agriculture associated with the use of fertilizers.
- That fertilizer is responsible for sustaining one-third of the Earth's population, but overfertilisation is considered a severe environmental problem.

Source: Wikipedia

The Nitrogen Cycle:
N-Compounds in the Atmosphere

- **NO_x (NO, NO_2):**
- NO_x (NO, NO_2) is produced by combustion of materials containing nitrogen compounds (biomass) or combustion of fossil fuels (coal, oil, gas) at high temperatures enabling a reaction between N_2 and O_2 (main components of air)
- Fossil fuel combustion dramatically increased in the industrial age and has contributed to a 6 or 7 fold increase in NO_x flux to the atmosphere (compared to preindustrial times).
- NO, NO_2 are acid gases forming nitric acid in cloud droplets leading to acid rain causing acidification of surface waters and excessive nitrogen input into sensitive ecosystems.
- NO, NO_2 react in the presence of UV-radiation with hydrocarbons to form tropospheric ozone, which is a major air pollutant and the main component of summer smog.

Source: Wikipedia

The Nitrogen Cycle:
N-Compounds in the Atmosphere

- **N_2O:**
- N_2O is a green house gas with a climate forcing factor 25x higher than CO_2
- Main source for N_2O is the application of chemical fertilizers which has been heavily increasing over decades since 1960.

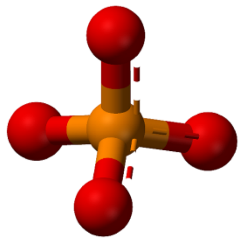
- **NH_3:**
- Concentration in the atmosphere has tripled mainly as the result of increased use of fertilisers.
- It reacts in the atmosphere with NO_x and SO_2/SO_3 forming ammonium nitrate and sulfate as an aerosol.
- These are components of acid precitation.

Source: Wikipedia

The Phosphorus Cycle

- **Significance of phosphorus:**
- Key component of all living matter (cell membranes) and molecules vital for life, like DNA, RNA, ATP, ADP.
- Vast amounts stored in rocks and sediments in the form of phosphates, but low solubility of these compounds and therefore small bioavailability.
- Additional supply through fertilisation for plants often necessary.

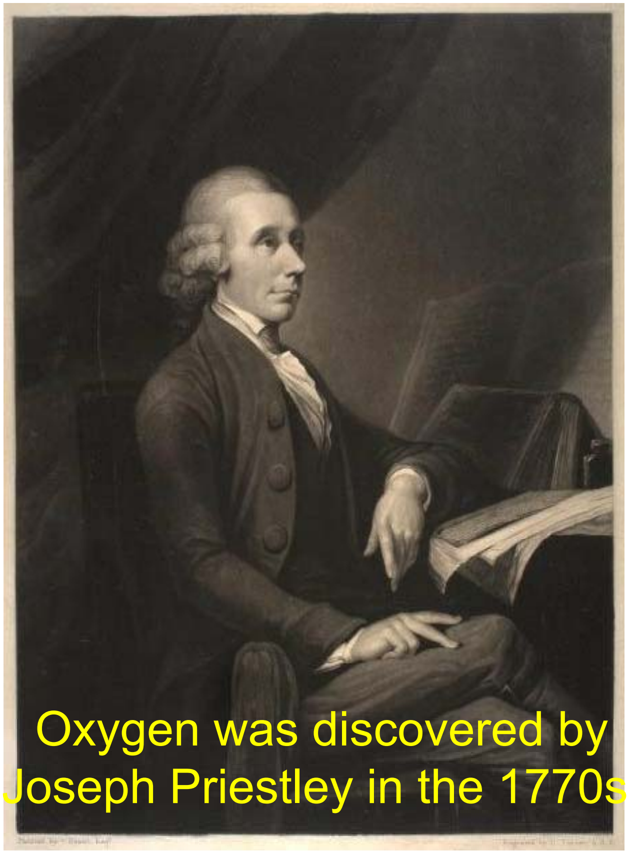
Major compounds: PO_4^{3-}



$Ca(H_2PO_4)_2$, $NH_4H_2PO_4$

- **Supply of phosphorus to waters and soil:**
  - Main input through fertilisation in agriculture
  - Effluents from households (detergents), human and animal excretions and decomposition of organic compounds.
- **Effects on the environment:**
  - Oversupply of waters with phosphorus contributes to eutrophication.

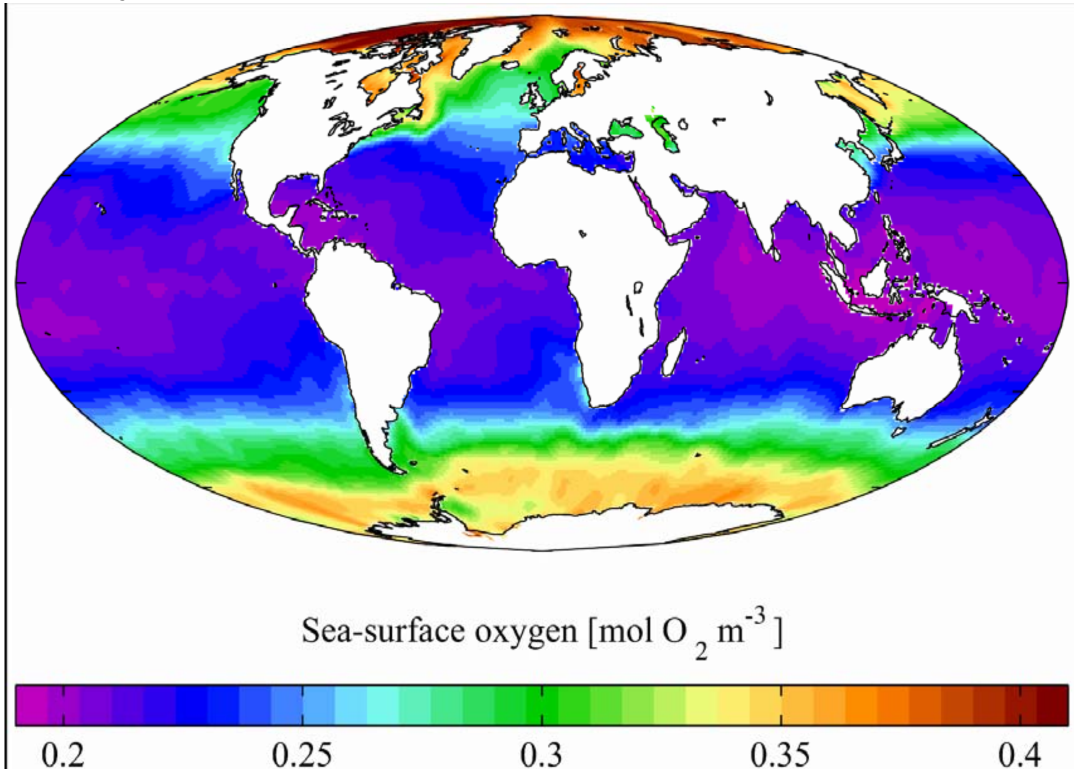
Source: Wikipedia



Oxygen was discovered by Joseph Priestley in the 1770s.

The Oxygen Cycle

- Oxygen reacts readily with almost all other elements forming oxides.
- Most abundant element by mass in the Earth's crust.
- Oxygen constitutes 20.9% of the volume of air.
- Free oxygen also occurs in solution in the world's water bodies.
- Solubility inceases with lower temperature.



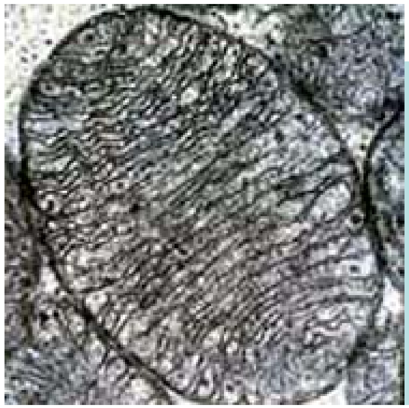
- Polar oceans support a much higher density of life.
- Polluted water may have reduced amounts of O_2 , depleted by decaying algae and other biomaterials (see eutrophication).

Photos: Wikipedia

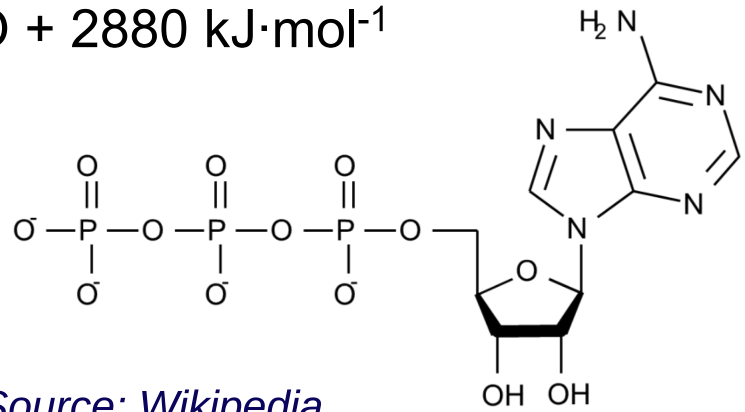
The Oxygen Cycle: Production and Consumption

- **Production of oxygen:**
  - The main source of oxygen within the biosphere and atmosphere is photosynthesis by plants and the phytoplankton of the oceans.
- **Oxygen consumption from the atmosphere:**
  - The main way oxygen is lost from the atmosphere is via respiration, mechanisms in which animal life and bacteria consume oxygen and release carbon dioxide.
  - Oxygen is used in mitochondria to help generate adenosine triphosphate (ATP), the chemical energy carrier, during oxidative phosphorylation.
  - The reaction for aerobic respiration is essentially the reverse of photosynthesis and is simplified as:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 2880\ \text{kJ}\cdot\text{mol}^{-1}$$



Mitochondrion, membrane-enclosed organelle found in most eukaryotic cells is the „cellular power“ plant. Size: 1–10 micrometers.



Source: Wikipedia

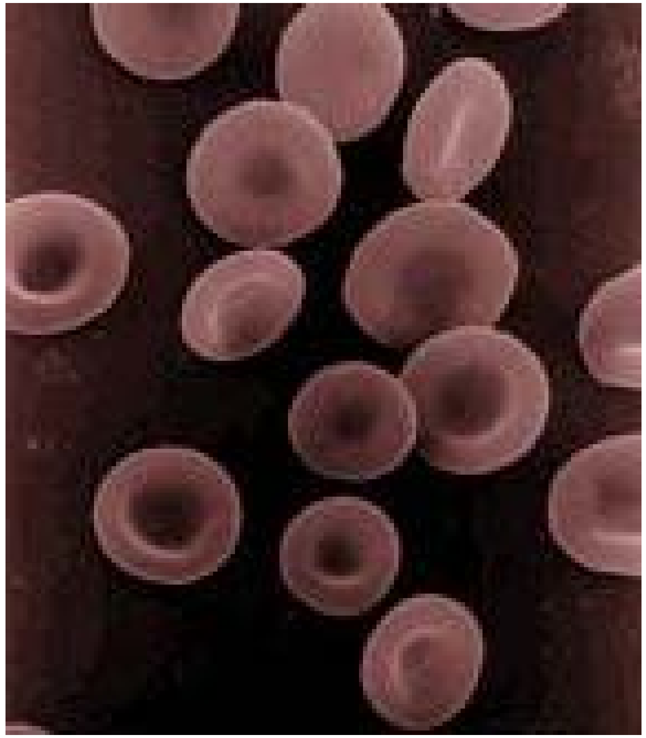
The Oxygen Cycle: Respiration

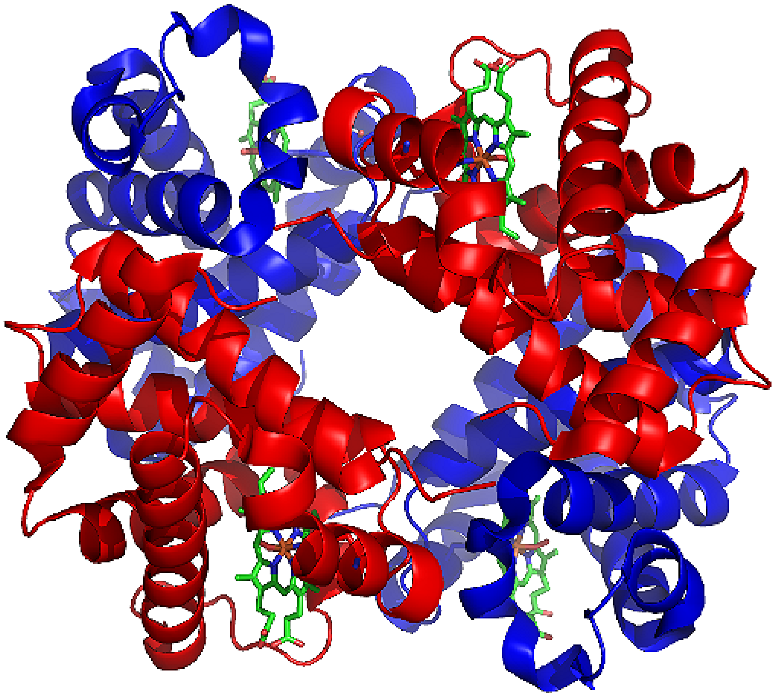
-In vertebrates, O_2 is diffused through membranes in the lungs and into red blood cells (erythrocytes).

-Diameter of human erythrocyte disk is 6–8 µm.

-Humans have roughly 4 to 6 billion erythrocytes.

-Oxygen can easily diffuse through the red blood cell's cell membrane.





Structure of human hemoglobin.

–Each erythrocyte contains millions of hemoglobin molecules.

–A hemoglobin molecule contains 4 heme groups whose iron atoms temporarily link to oxygen molecules in the lungs or gills and release them throughout the body.

Photos: Wikipedia

Ecosystem Productivity

1.3 Ecosystem Dynamics

- **Ecosystem productivity:**

– Living organism has a permanent relationship with their environment.

– These interactions make an ecosystem productive.

– Within the ecosystem, species are connected by food chains or webs.

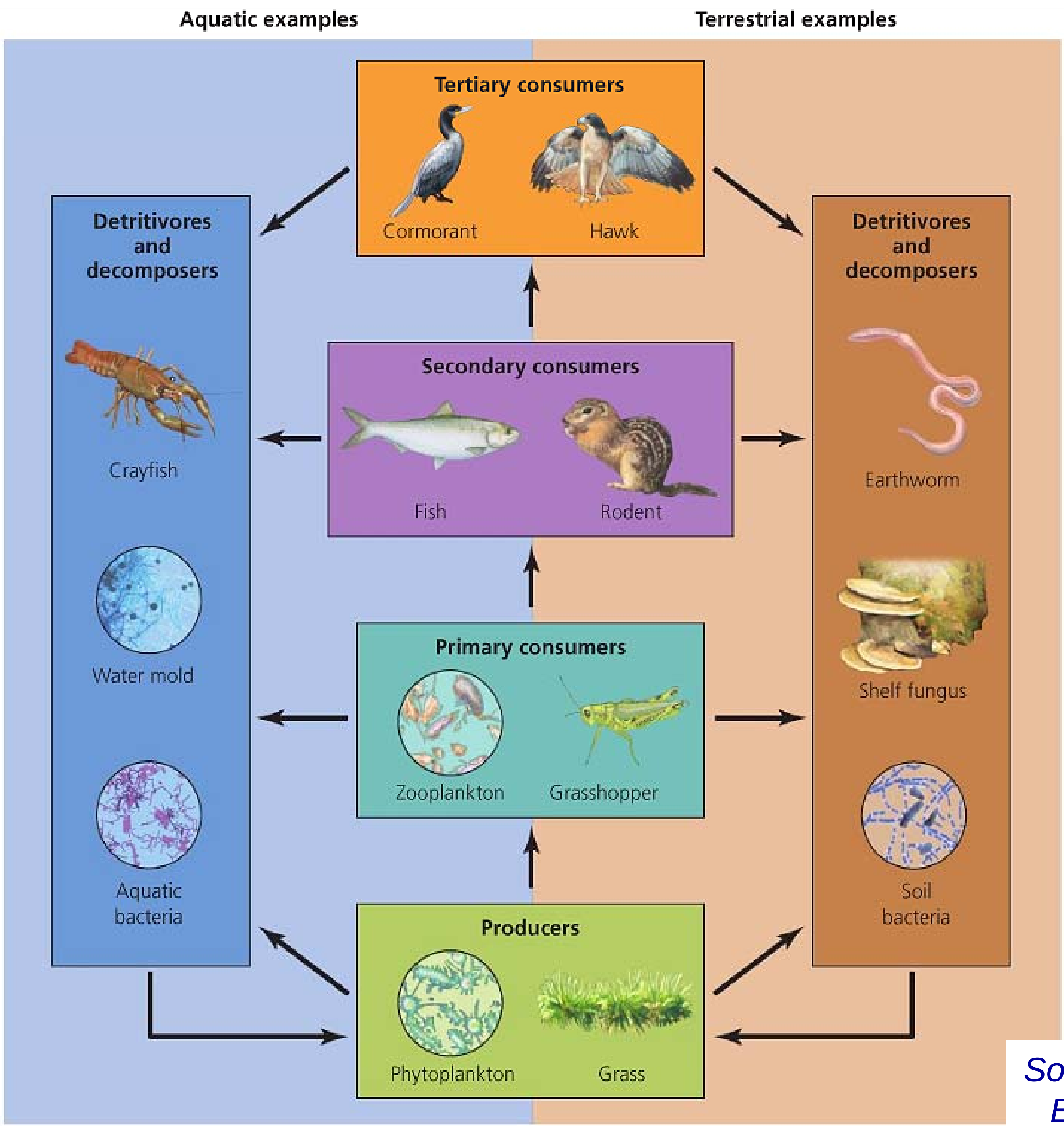
– Energy from the sun, captured by primary producers via photosynthesis, flows upward through the chain to primary consumers (herbivores), and then to (carnivores and omnivores), before ultimately being lost to the system as waste heat.

– On average, only 10% of the organism's energy are passed on to the next trophic level. The other 90% are used for the organisms life processes or are lost as heat to the environment.

– Therefore only a small amount of biomass is transferred to the next feeding level, thus showing a Pyramid of Biomass.

– As the chain is travelled along, the number of consumers at each level drops very significantly.

Source: Wikipedia



Ecosystem Productivity:

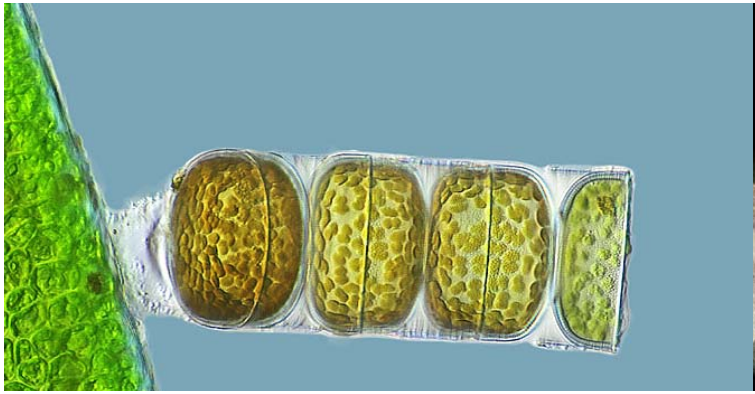
The Food Chain

- Various trophic levels of consumers and decomposing chains for aquatic and terrestrial food chains.

Source: Withgott and Brennan: Environment, Pearson 2008

Pictures of an Aquatic Food Chain

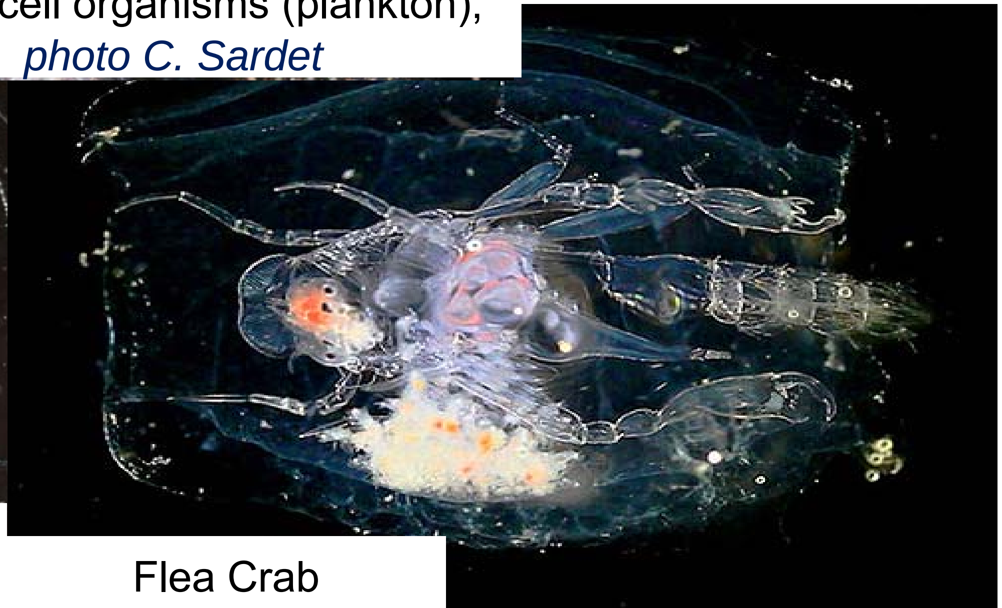
Source: http://www.planktonchronicles.org/......Geo 2011



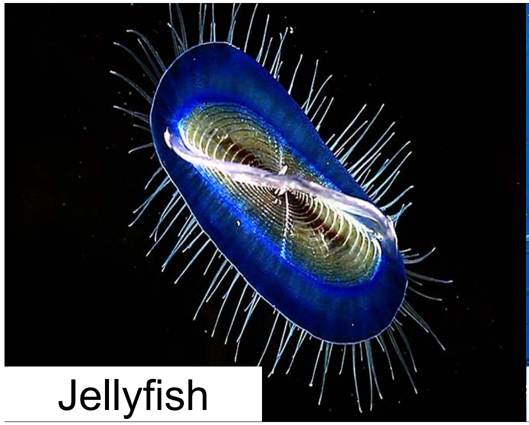
Phytoplankton *Melosira moniliformis* (320X), *photo Frank Fox*

Single cell organisms (plankton), *photo C. Sardet*

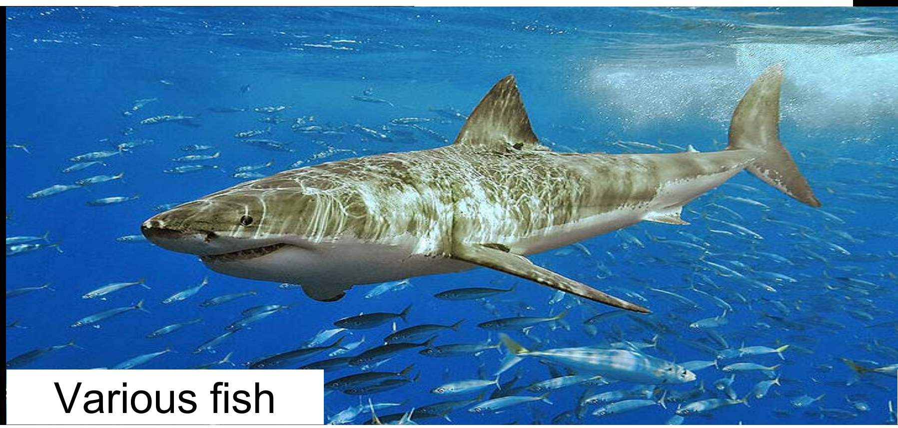
Multicellular organisms (plankton), *photo C. Sardet*



Flea Crab



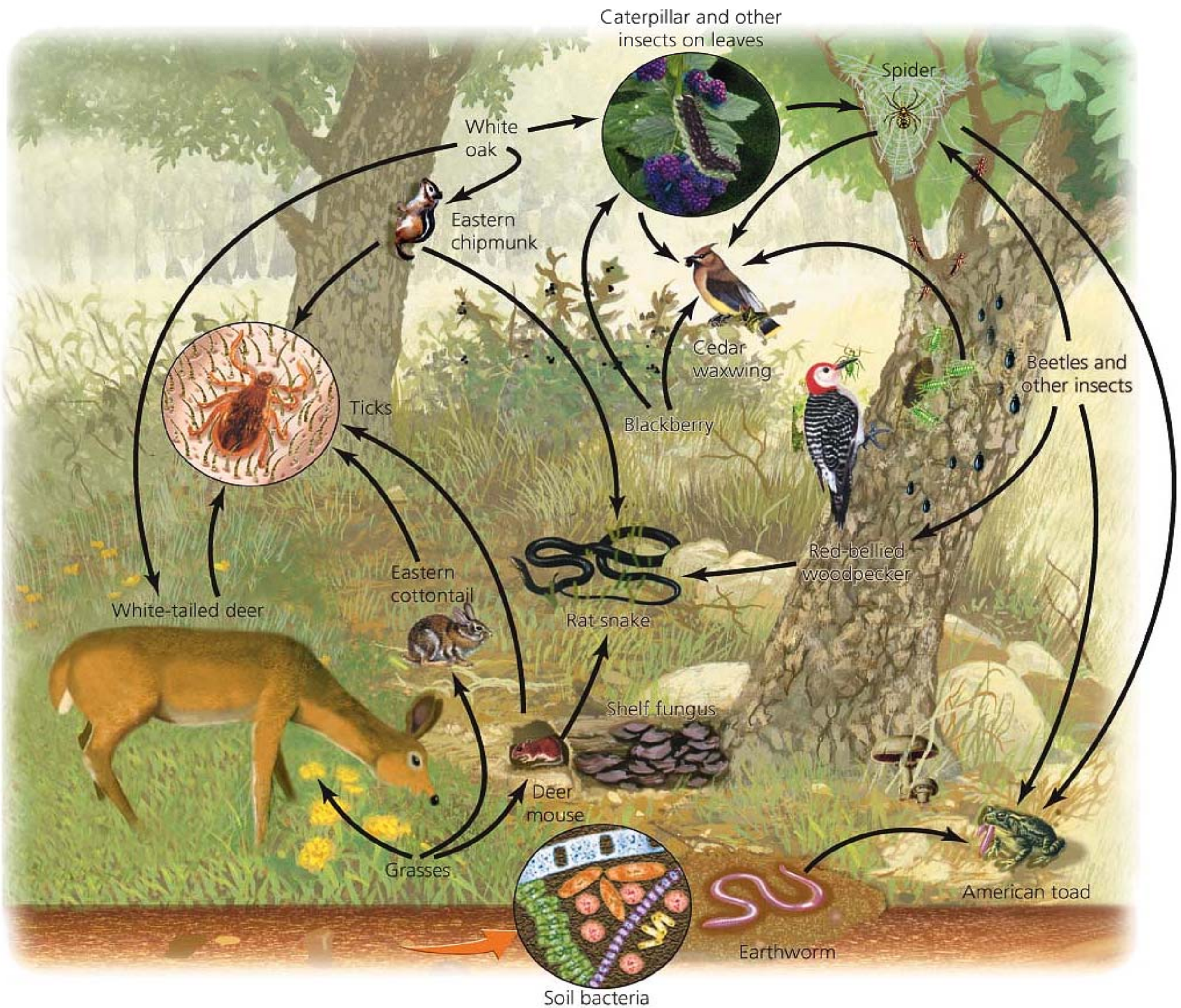
Jellyfish



Various fish

Various birds

Ecosystem Productivity:
The Food Web



-Linear food chains are overly simplistic as most consumers feed on multiple species.

-A food web extends the *food chain* concept from a simple linear pathway to a complex network of interactions.

-Food sources of most species in an ecosystem are very diverse, resulting in a complex *web* of relationships.

Food web for North America's deciduous forests.
Source: Withgott and Brennan: Environment, Pearson 2008

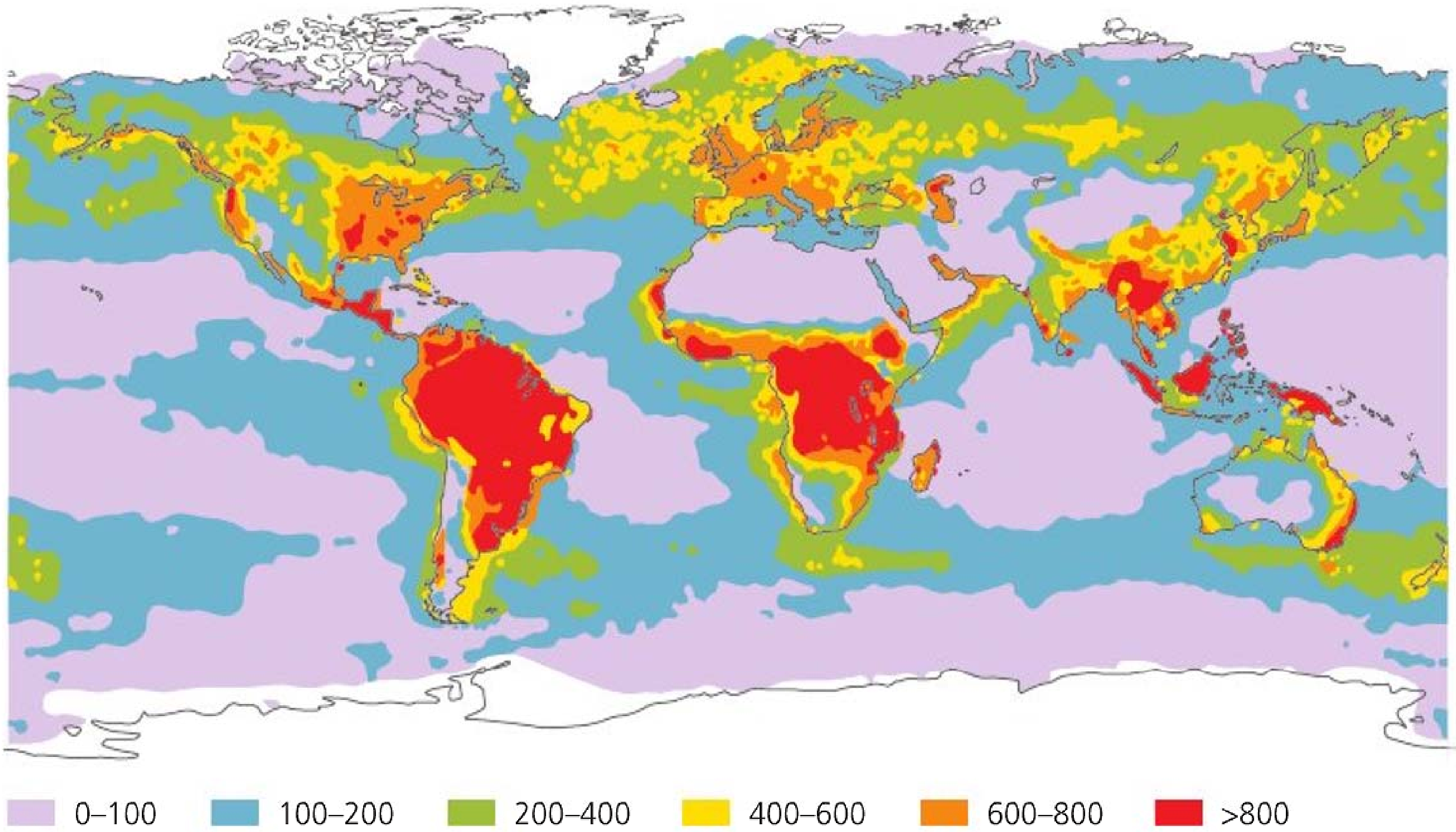
Ecosystem Productivity

- Biomass and primary productivity are key elements determining the load capacity, the number of organisms which can be supported by an ecosystem.
- An ecosystem(s) is unstable when the load capacity is overrun.
- The productivity of ecosystems is estimated by comparing three types of land-based ecosystems and the total of aquatic ecosystems:

- The forests (1/3 of the Earth's land area) contain dense biomasses and are very productive. The total production of the world's forests corresponds to half of the primary production.
- Savannas, meadows, and marshes (1/3 of the Earth's land area) contain less dense biomasses, but are productive. Represent the major part of what humans depend on for food.
- Extreme ecosystems in the areas with more extreme climates - deserts and semi-deserts, tundra, alpine meadows, and steppes - (1/3 of the Earth's land area) have very sparse biomasses and low productivity.
- Finally, the marine and fresh water ecosystems (3/4 of Earth's surface) contain very sparse biomasses (except coastal zones).

Source: Wikipedia

Ecosystem Productivity



(b) Global map of net primary productivity

Source: Withgott and Brennan: Environment, Pearson 2008

Stability and Vulnerability of Ecosystems

- **Ecological factors** which affect dynamic change in a population or species in a given environment are usually divided into two groups: abiotic and biotic.

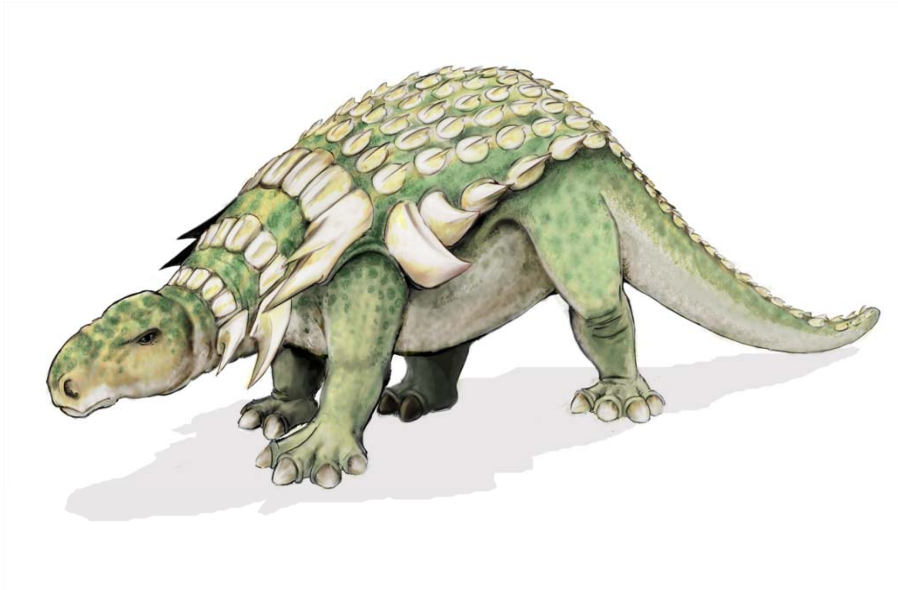
- **Abiotic factors** are geological, geographical, hydrological and climatological parameters:
  - Water, which is an essential element to life and a milieu.
  - Air, which provides oxygen, nitrogen, and carbon dioxide to living species and allows the dissemination of pollen and spores.
  - Soil, at the same time source of nutrient and physical support.
  - Temperature, which should not exceed certain extremes, even if tolerance to heat is significant for some species.
  - Light, which provides energy to the ecosystem through photosynthesis.
- **Biotic ecological factors:**
  - Relations within a population: co-operation or competition, with division of the territory, and sometimes organizational hierarchies.
  - Interaction between different species: predation (to eat or to be eaten), which leads to the essential concepts in ecology of food chains.

Source: Wikipedia

Ecological Crisis

- In the case of natural disasters or strong interferences by human activities, the delicate equilibria existing in ecosystem may be significantly disturbed.
- These disturbances may lead to gradual degradation of ecosystems and finally to ecological crisis situations.
- Ecological crisis can occur at a global, regional or local level.
- **Examples for present global ecological crisis are:**
  – Climate change
  – Loss of biodiversity
- **Examples for present regional ecological crisis are:**
  – Overpopulation, droughts, deforestation, desertification, extreme pollution of air, water, soil
- **Examples of past global ecological crises are:**
  - Permian-Triassic extinction event 250 million of years ago.
  - Cretaceous-Tertiary extinction event 65 million years ago.
- **Examples of past regional ecological crises are:**
  - The Exxon Valdez oil spill off the coast of Alaska.
  - The nuclear meltdown at Chernobyl.

Global Ecological Crisis:
The Permian-Triassic Extinction Event



Ankylosaurus Edmontonia

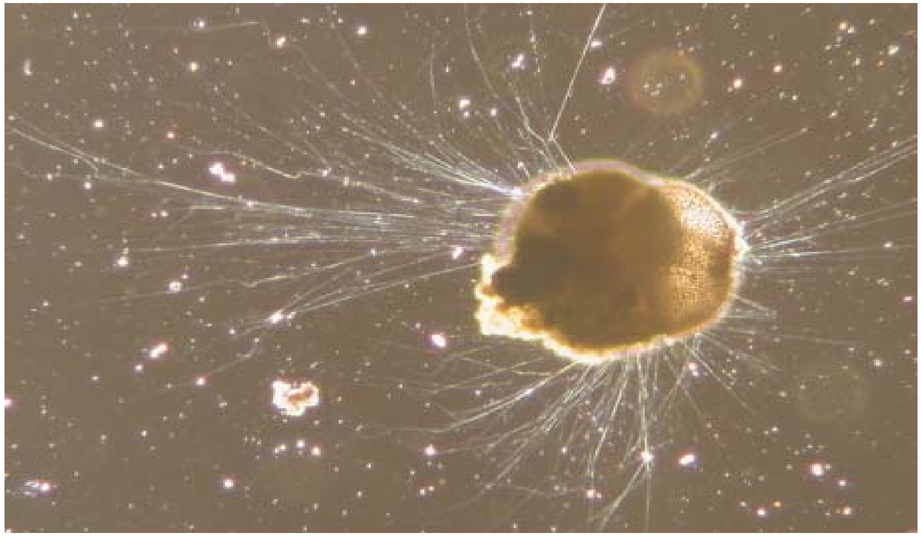
Pangea, the supercontinent that existed during the Paleozoic and Mesozoic eras about 250 million years ago, before each of the component continents were separated into their current configuration. *Source: Wikipedia 2010*

Global Ecological Crisis:
The Permian-Triassic Extinction Event

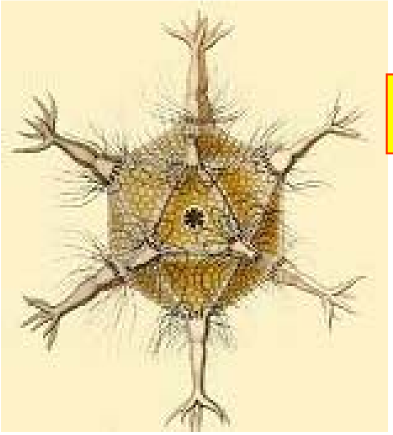
- The **Permian–Triassic (P–Tr) extinction event:**
- occurred 250 million years ago and was the Earth's most severe extinction event, with up to 96 percent of all marine species and 70 percent of terrestrial vertebrate species becoming extinct.
- Possible cause for the extinction event : increased vulcanism for long periods - „Siberian Traps" – lava fields of 2 million km^2:
  - release of huge amounts of CO_2 causing a global temperature increase of 5°C,
  - dust clouds reducing photosynthesis,
  - massive SO_2-emissions causing highly acids rains,
  - release of methane from frozen methane hydrates from the sea floor leading to a total temperature increase of 10°C, and as a consequence
  - gradualistic processes like sea-level change, anoxia, and increasing aridity.

Global Ecological Crisis:
The Permian-Triassic Extinction Event

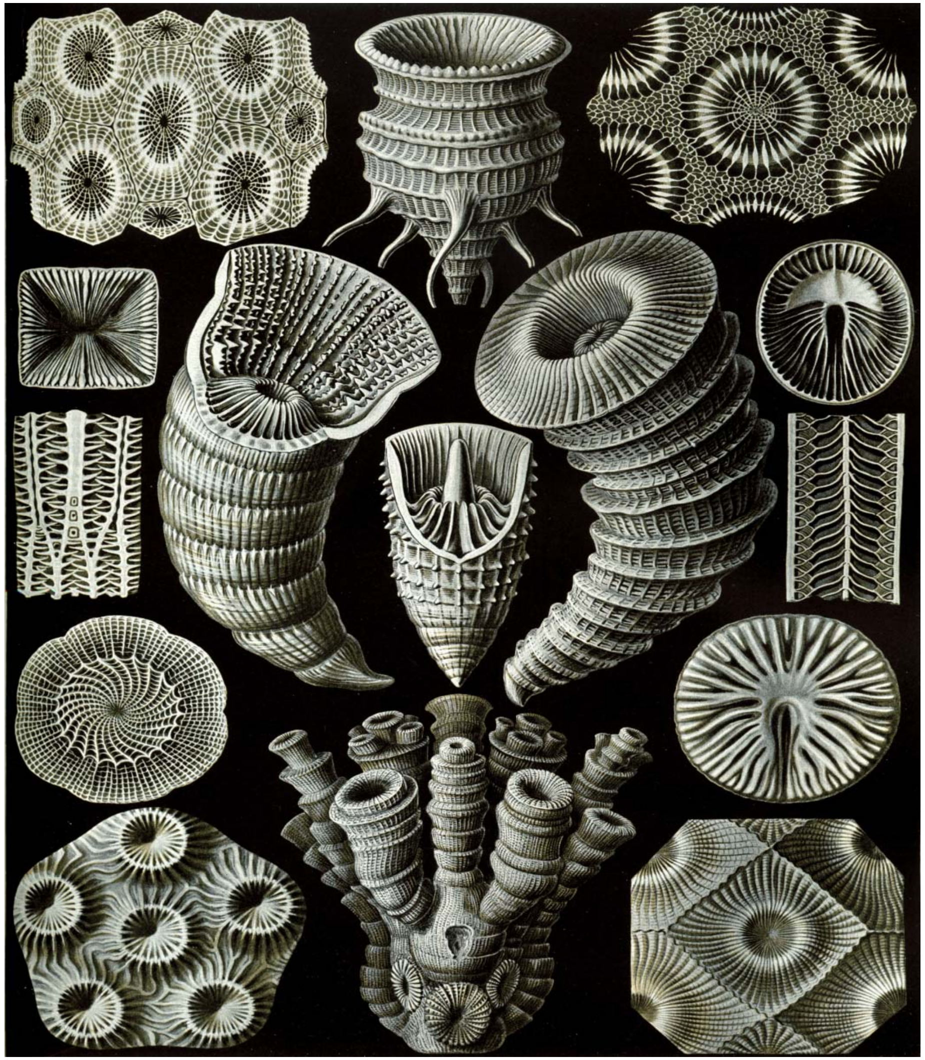
Marine organisms: suffered the greatest losses - only a few groups survived, like some brachiopods, some ammonites; and crinoids ("sea lilies").



Ammonia tepida **(Rotaliida)**



Circogonia icosahedra,

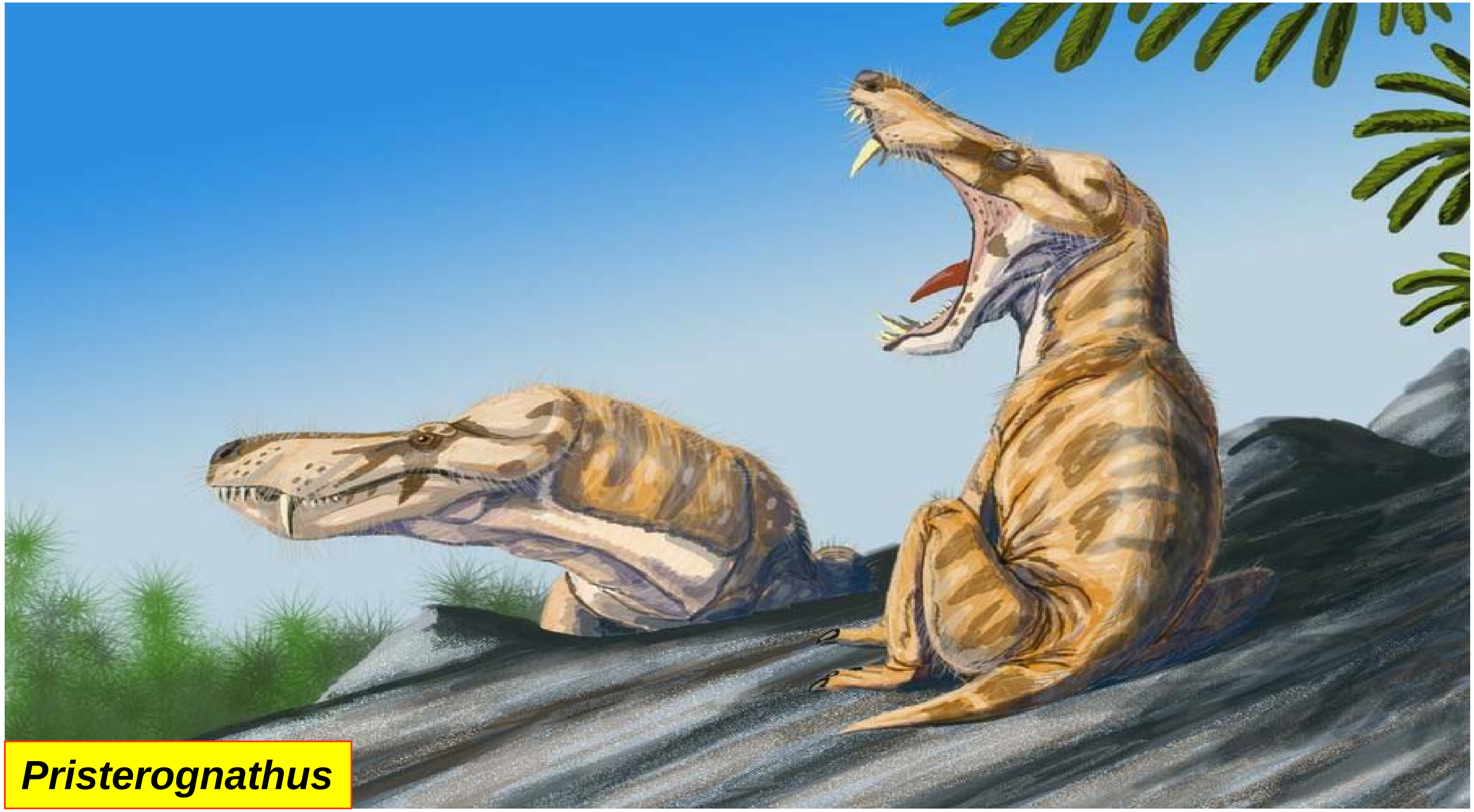


Rugose corals

Source: Wikipedia

Global Ecological Crisis:
The Permian-Triassic Extinction Event

Over two-thirds of terrestrial amphibian, sauropsid ("reptile") and therapsid ("mammal-like reptile") families, pelycosaurs became extinct.
Extinction enabled the development of the „modern mammals“.



Pristerognathus

Photo: Wikipedia

Global Ecological Crisis:
The Cretaceous-Tertiary Extinction Event

- The **Cretaceous–Tertiary extinction event**:
- Occurred 65,5 million years ago.
- Extinction of dinosaurs, mosasaurs, plesiosaurs, pterosaurs and many species of plants and invertebrates.
- Survivors were mammalian and birds.
- **Causes and effects:**
- Likely catastrophic events such as massive asteroid impacts or increased volcanic activity.
- Dust clouds reduced sunlight and species which depended on photosynthesis declined or became extinct.
- Reduction of phytoplankton and land plants which were the foundation of the food chain in the late Cretaceous.
- Marine species feeding on phytoplankton died out as well as herbivorous animals when the plants they depended on for food became scarce; consequently, top predators such as *Tyrannosaurus rex* also perished.

Global Ecological Crisis:
The Cretaceous-Tertiary Extinction Event

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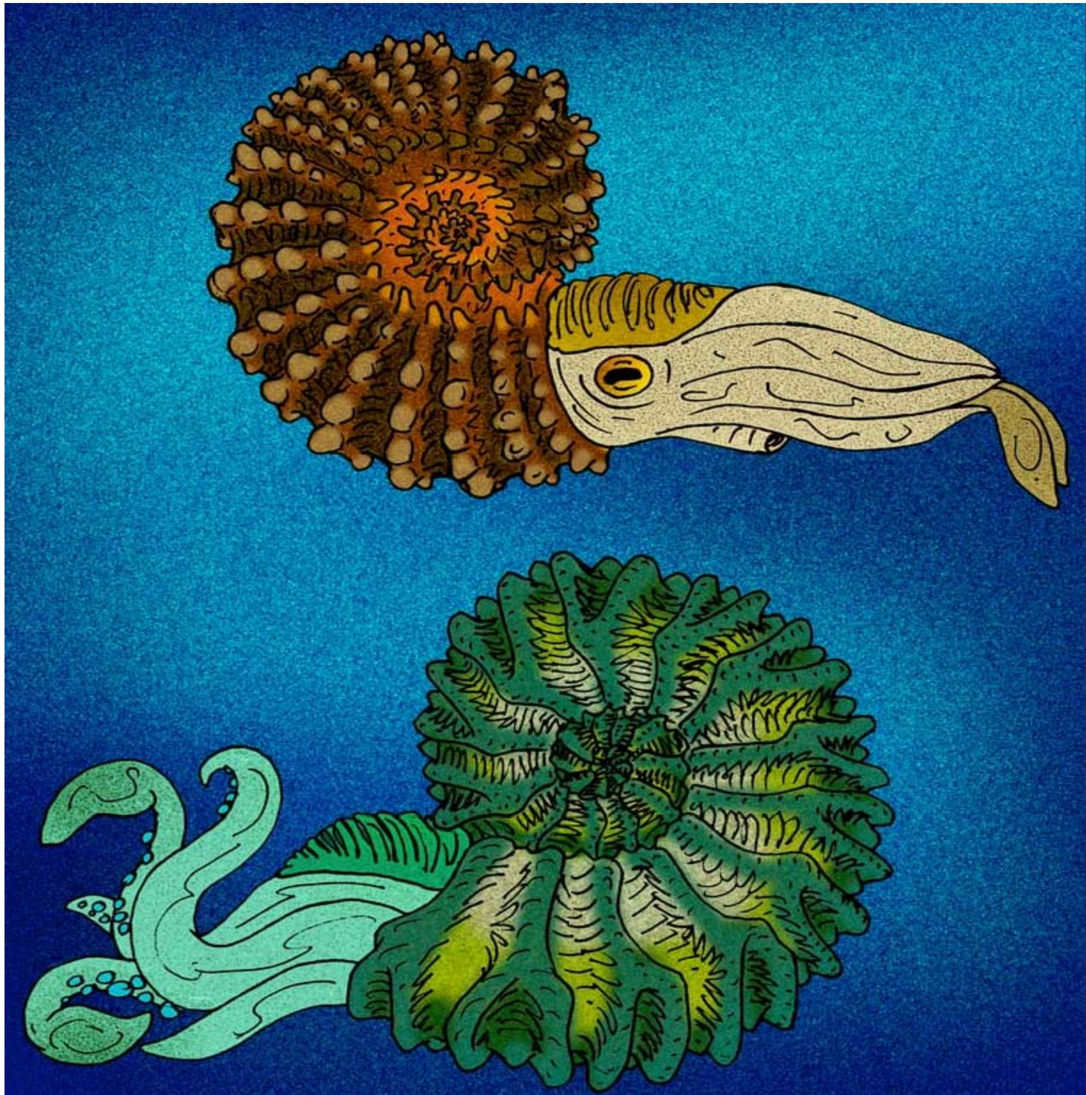
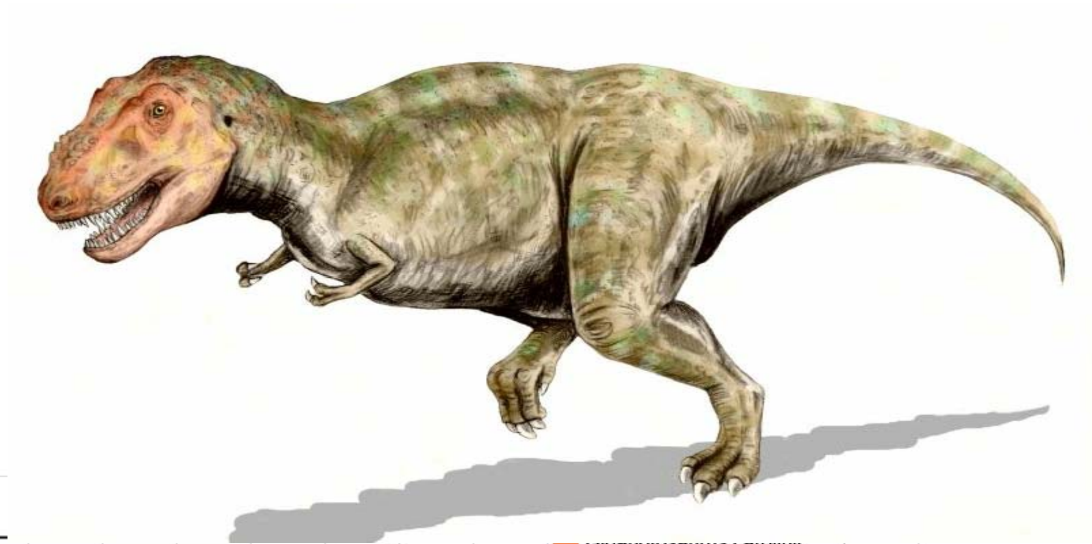
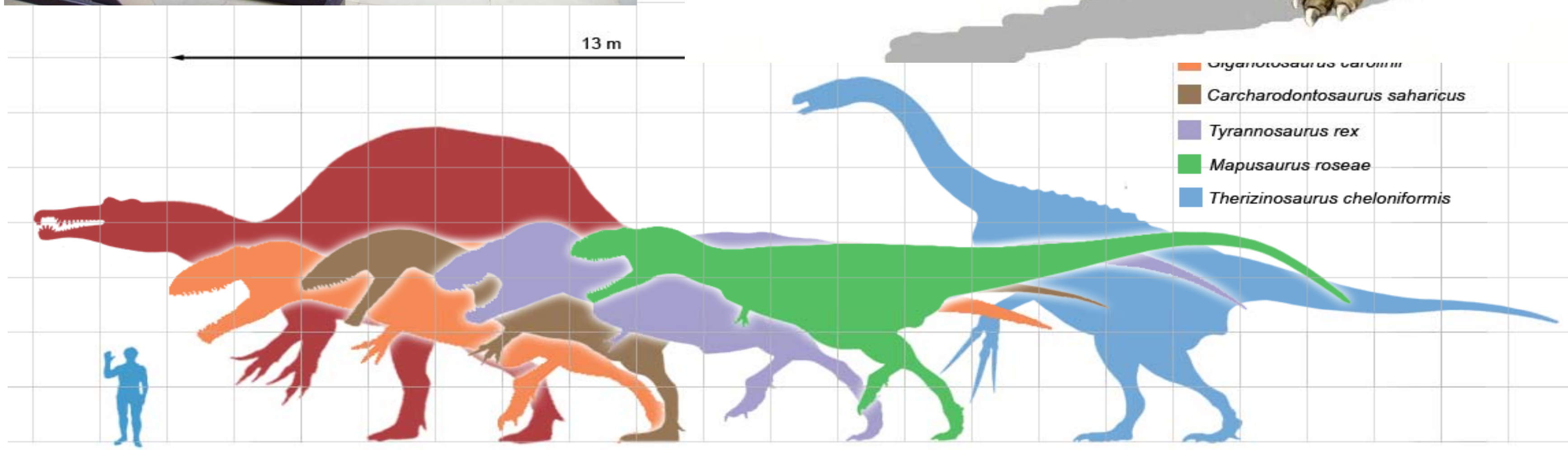


Ammonites

Coleoids

Global Ecological Crisis:
The Cretaceous-Tertiary Extinction Event





Photos: Wikipedia

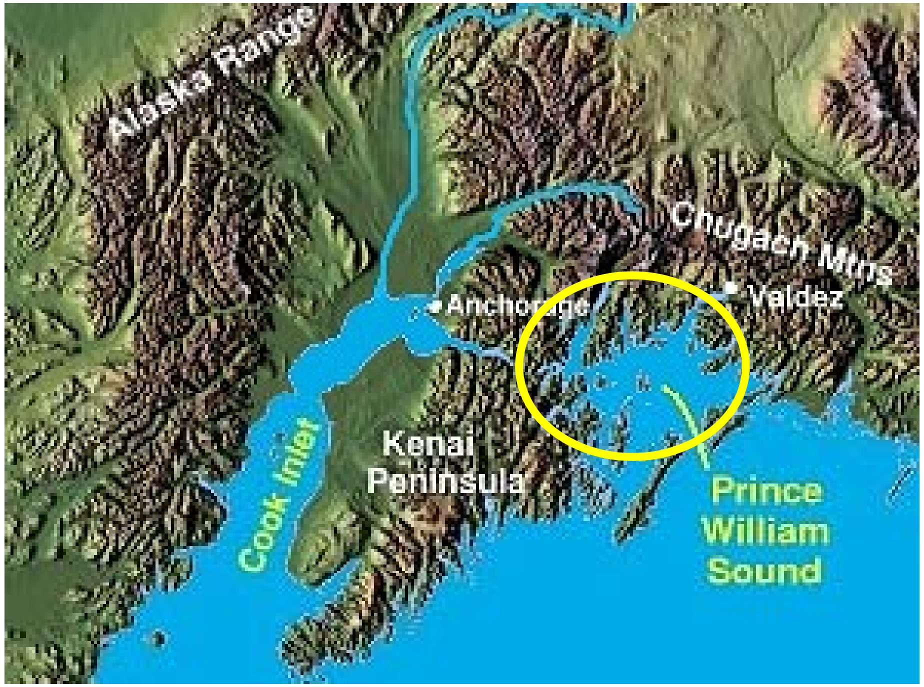
Size comparison of selected giant theropod dinosaurs,
Tyrannosaurus rex in purple. Due to the high oxygen content in the atmosphere (35%) the animals became much larger than today.

Local/Regional Ecological Crisis:
The Exxon Valdez Oil Spill of 1989

•*Exxon Valdez* struck Bligh Reef at around 12:04 am March 24, 1989 spilling 42 million liters of Prudhoe Bay crude oil into the sea at Prince William Sound in Alaska.

•During the first few days of the spill, heavy sheens of oil, covered large areas of the surface of Prince William Sound and coated 2.100 km of coastline.

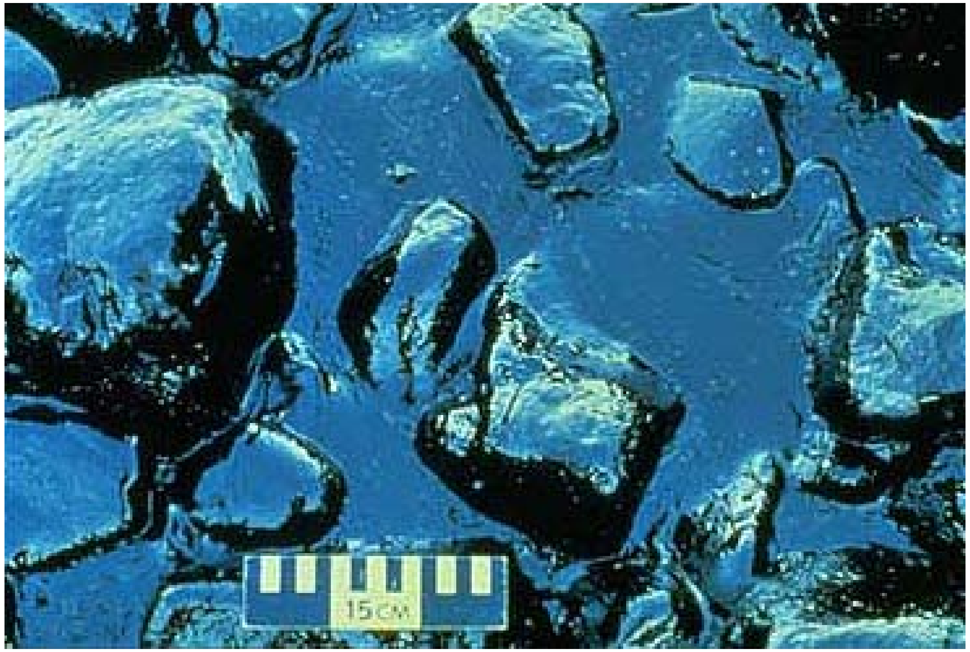
•The region was a habitat for salmon, sea otters, seals, sea birds and sharks.



Source: Wikipedia

Local/Regional Ecological Crisis:
The Exxon Valdez Oil Spill of 1989

- Thousands of animals died immediately.
  - 100,000–400,000 seabirds
  - 2,600–5,500 sea otters
  - 200 - 300 harbor seals
  - 250 bald eagles
  - 22 orcas
  - billions of salmon and herring eggs destroyed.



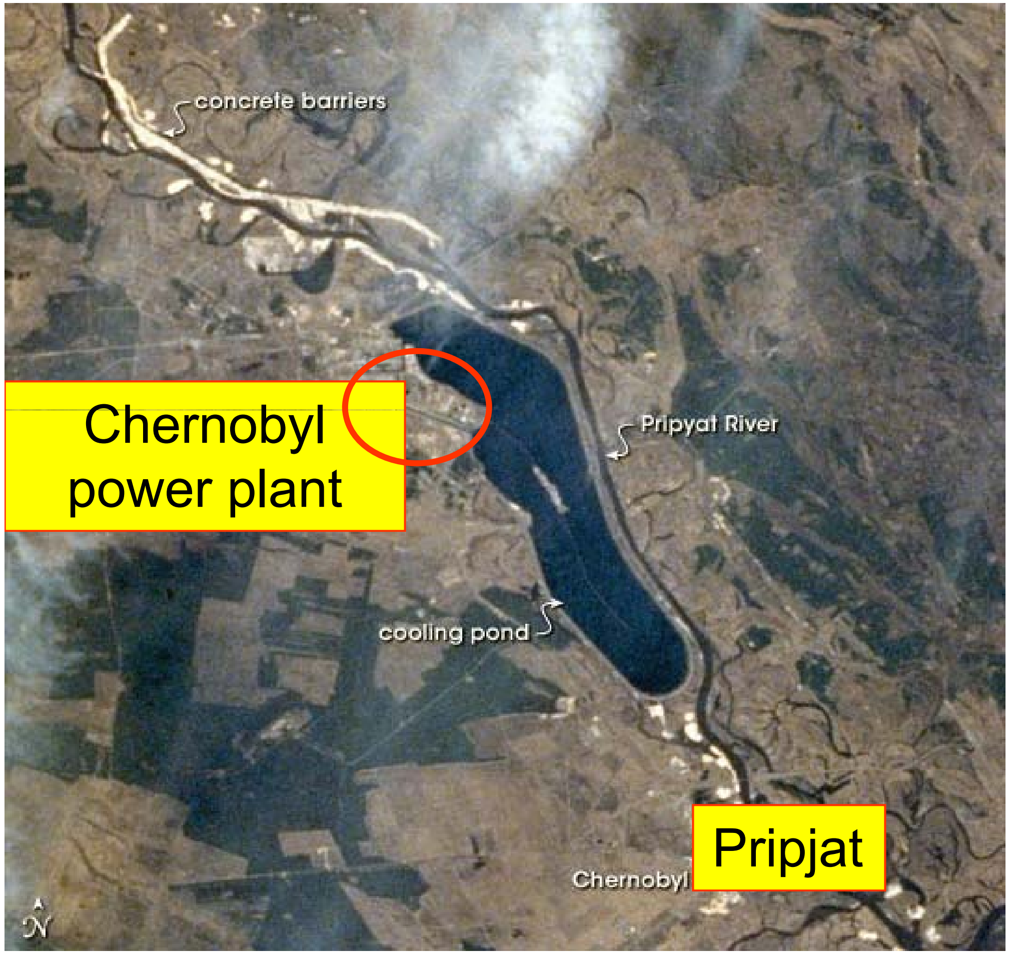
Some shoreline habitats take decades to recover.

Source: Wikipedia

Local/Regional Ecological Crisis:
The Nuclear Meltdown in Chernobyl of 1986

•**Chernobyl** is a large abandoned nuclear power plant in northern Ukraine, in the Kiev province near the border with Belarus, 10 km northwest of the city of Pripjat which had 45.000 inhabitants at that time.

Source: Wikipedia



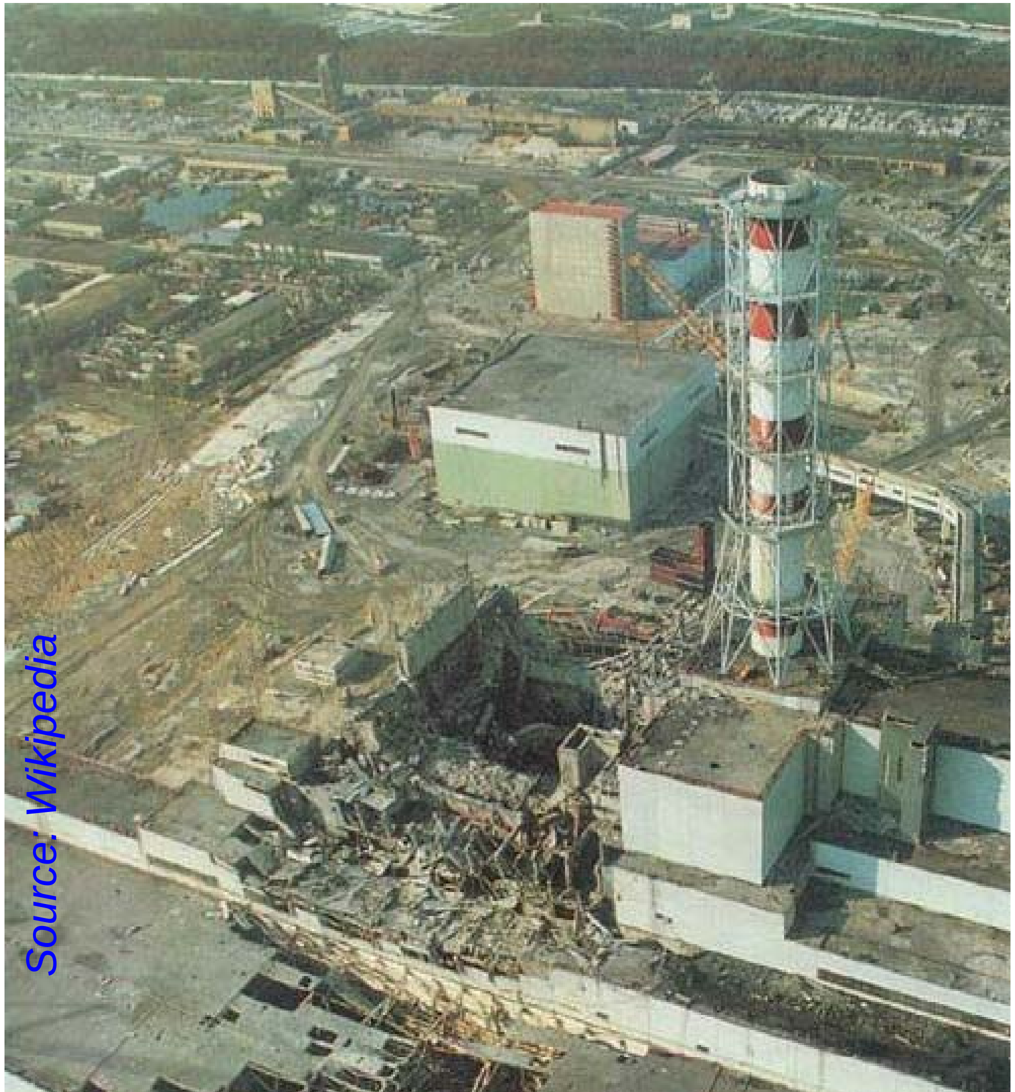
•On April 26, 1986 tests with the reactor were made during which the computer-controlled safety systems were disabled.

•Removal of the control rods, build up of heat and reinsertion of the control rods caused a run-away reaction.

•The reactor exploded at 01:23 AM local time.

•After the explosion, graphite fires broke out, due to the high temperatures of the reactor and the graphite's exposure to oxygen.

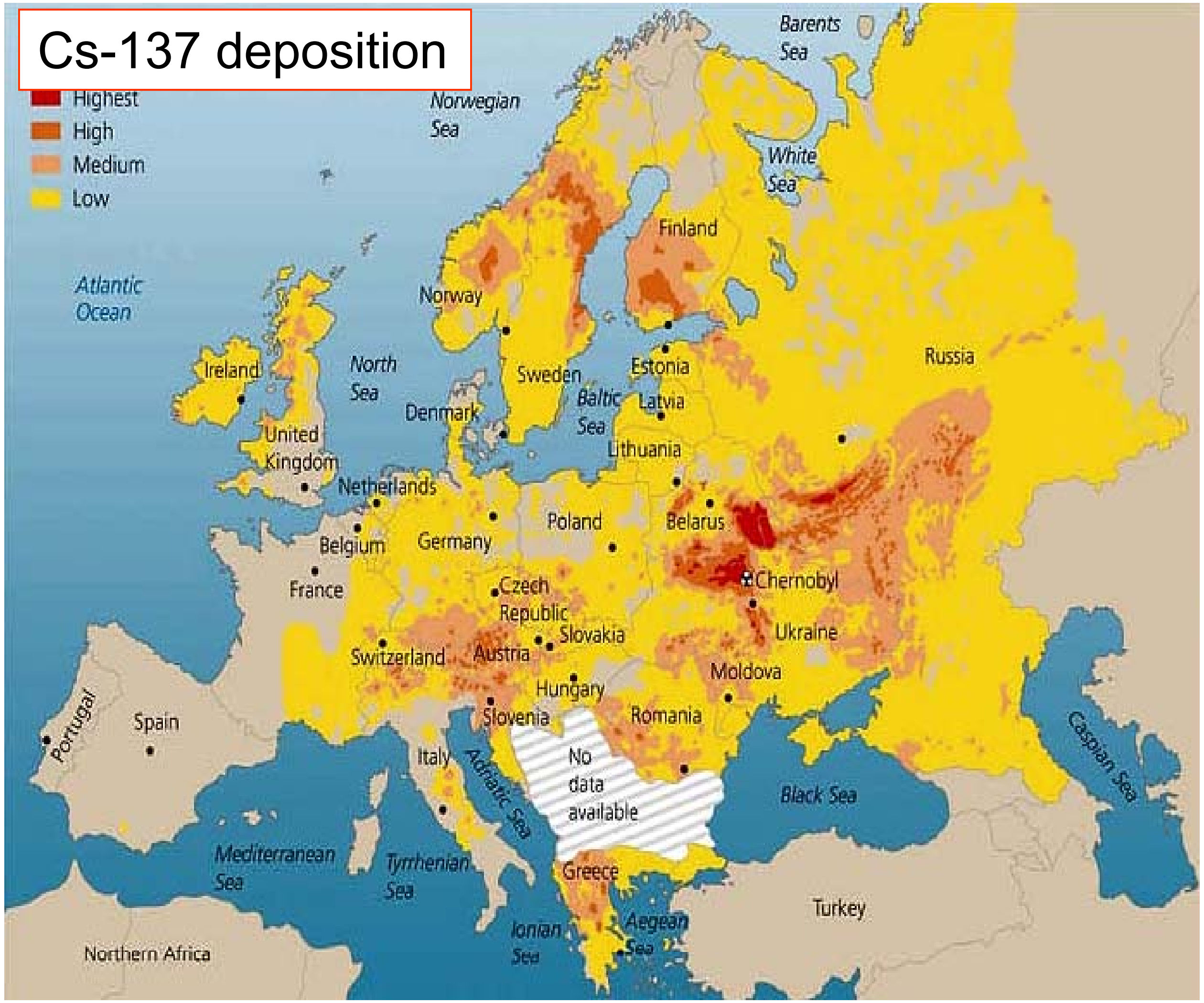
Local/Regional Ecological Crisis:
The Nuclear Meltdown in Chernobyl of 1986



- Due to the graphite fire radioactive debris were flung high up, smoke containing radioactive contaminants from the burning graphite traveled as far as Belarus.
- For the next 10 days the reactor spewed the equivalent of 400 Hiroshima bombs' worth of radioactivity across 300,000 km^2 of Europe.
- 120,000 people were evacuated and many villages were abandoned.
- Main fallout was Caesium-137, Strontium-90 and Iodine-131.

Chernobyl reactor number four after the disaster, showing the extensive damage to the main reactor hall (image center) and turbine building (image lower left).

Local/Regional Ecological Crisis:
The Nuclear Meltdown in Chernobyl of 1986



-Caesium-137 (beta and gamma emitter, half-life 30 years) is water-soluble and extremely toxic.

-Strontium-90 (beta emitter, half life of 28,8 years) is incorporated in the bones and bone marrow and can cause cancer.

-Iodine-131 (beta and gamma emitter, half life 8 days) is incorporated in the thyroid glands and causes cancer.

Map of Cs-137 deposition in Europe (fall out from Chernobyl explosion). Other elements show a similar pattern. *Source: Withgott and Brennan: Environment, Pearson 2008*

Local/Regional Ecological Crisis:
The Nuclear Meltdown in Chernobyl of 1986

•200,000 young soldiers and others were rushed in from all over the Soviet Union for „clean-up“.

Contaminated military vehicles and helicopters

•A 10 km^2 dump was filled with radioactive lorries, cement mixers, trains and helicopters.

•A concrete "sarcophagus" was hastily built over the stricken reactor showing quickly damages.

•Now a new new steel containment structure has been constructed.

•**Human damages according to IAEA and WHO 2005:**
56 direct deaths (47 accident workers, and 9 children with thyroid cancer)
an estimated 10,000 extra premature deaths due to cancer among the workers involved in clean-up and the population affected by the fall out.

Local/Regional Ecological Crisis:
The Nuclear Meltdown in Chernobyl of 1986

The city of Pripjat evacuated 24 hours after the explosion at the Chernobyl Nuclear Power Plant and „dead zone“ since that time.

Former dormitory for primary school children.

Source: Spiegel On-line
21 July 2008

Local/Regional Ecological Crisis:
The Nuclear Meltdown in Chernobyl of 1986

Abandoned Village near Chernobyl (2001)

•Numerous villages have been abandoned.
•Tens of thousands of square kilometers of agricultural land still cannot be used for farming until the soil has been remediated.
•Biodiversity has increased due to the removal of human influence.

300 people now live in the forbidden zone despite of the still heavy radioactive contamination.

Source: Spiegel On-line 21 July 2008

Ecology and Sustainable Development

2. Ecosystem Functions and Human Impact:

2.1 Biodiversity

2.2 Chemicals in the Environment

Biodiversity

2.1 Biodiversity

- **Biodiversity**:
  - Variation of life forms within a given ecosystem, biome or for the entire Earth.
  - Biodiversity found on Earth today consists of many millions of distinct biological species, the product of four billion years of evolution.
  - Flora and fauna diversity depends on climate, altitude, soils and the presence of other species.
  - Biodiversity is extremely rich in the tropics and very low polar regions.
- **Biodiversity hotspot:**
  - region with a high level of endemic species.
  - Brazil's Atlantic Forest contains roughly 20.000 plant species, 1.350 vertebrates, and millions of insects, about half of which occur nowhere else in the world.
  - Madagascar: high endemism since separated from mainland Africa 65 million years ago.

Biodiversity: Benefits

Source: Wikipedia

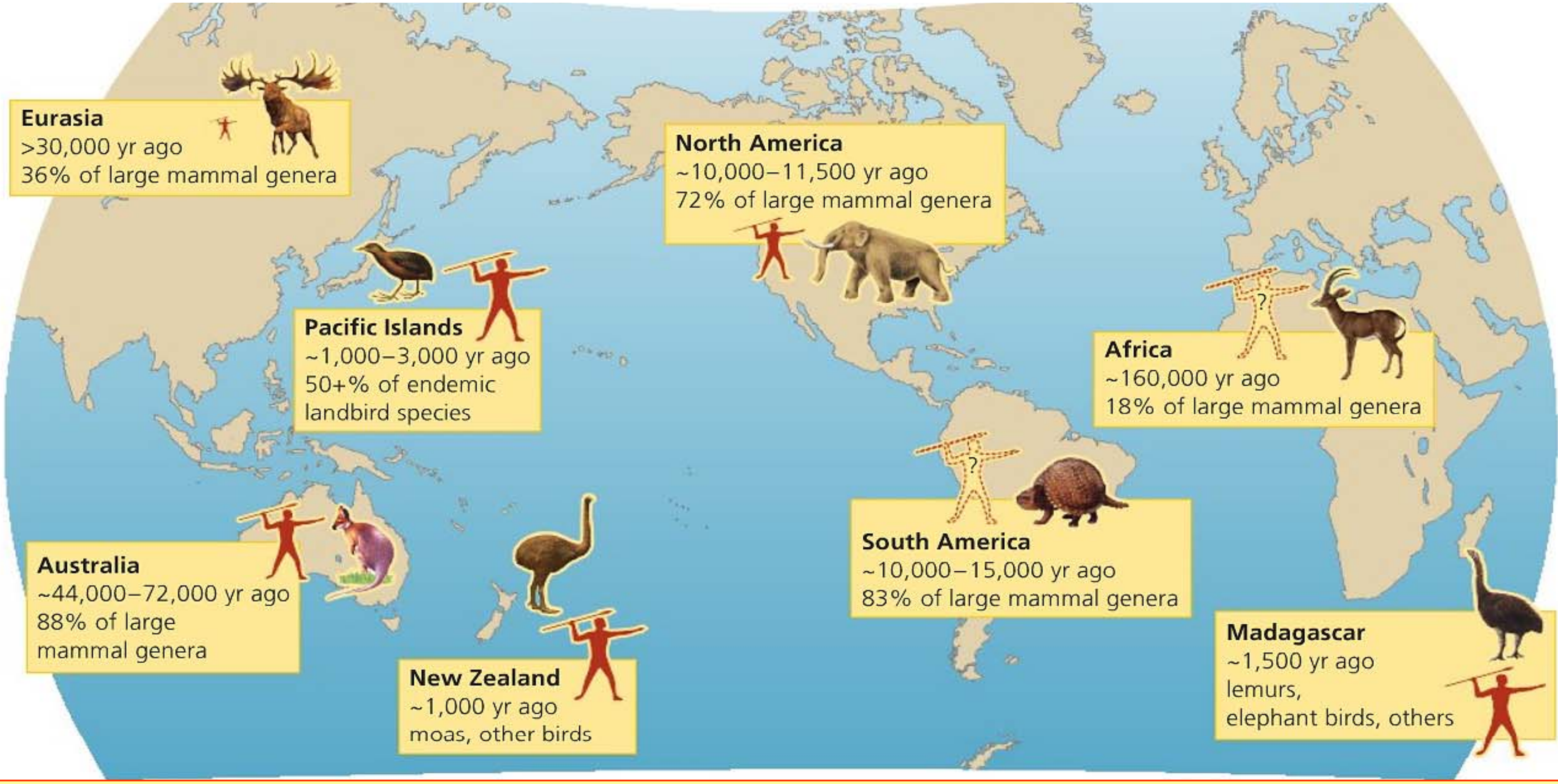
- **Resistance of crops to catastrophes:**
  - Monoculture, the lack of biodiversity, was a contributing factor to agricultural disasters, like the Irish Potato Famine of 1846 (population reduced by 20%) or the collapse of the European wine industry in the late 1800s (viteus vitifolie - „Reblaus“).
- **Resistance of crops to diseases:**
  - Higher biodiversity also controls the spread of certain diseases as viruses will need adapt to infect different species.
- **Provision of food and drink:**
  - Although about 80 percent of our food supply comes from just 20 kinds of plants, humans use at least 40,000 species of plants and animals a day.
- **Provision of medicines:**
  - About 40% of the pharmaceuticals used in the US are manufactured using natural compounds found in plants, animals, and microorganisms.
  - Many drugs are also derived from microorganisms (penicillin...).

Biodiversity: Benefits

- **Provision of industrial materials:**
  - A wide range of industrial materials are derived directly from biological resources: building materials, fibers, dyes, resins, gums, adhesives, rubber and oil.
- **Ecosystem services:**
  - Biodiversity important regulating the chemistry of our atmosphere and water supply.
  - Biodiversity is directly involved in recycling nutrients and providing fertile soils.
- **Intellectual value:**
  - Bionics – Nanotechnology
- **Leisure, cultural and aesthetic value:**
  - gardening
  - biodiversity has inspired musicians, painters, sculptors, writers......
- **Intrinsic value of biodiversity:**
  - Philosophically it could be argued that biodiversity has intrinsic aesthetic and/or spiritual value to mankind.

Biodiversity: Historic Anthropogenic Impact

- **Elimination of biological species:**
  - Anthropogenic evolution lead to extinction of large mammals and birds already thousands of years ago.
  - Homo sapiens was (is) an „ecological mass murder“ (Y. N. Harari)



Map shows for each region time of human arrival and the extent of the extinction. Size of human hunters in proportion to their contribution to the extinction of these species.

Source: Withgott and Brennan: Environment, Pearson 2008

Biodiversity:
Recent Anthropogenic Impact

- **Discovery and colonization:**
- Extinction of many bird species on remote islands after discovery and introduction of foreign species by man starting 500 years ago.
- **Industrialisation:**
- Industrialisation and change of land use beginning in the 19th century: Scientists estimate that during the last century, between 20,000 and two million species have become extinct.
- **Persistent threats from human activities:**
  - Land change activities.
  - Environmental pollution: atmosphere, soil and water.
  - Agricultural application of fertilizers, pesticides.
  - Climate change.
  - Hunting and fishing.

International Union for the Conservation of Nature (IUCN):
2015 assessment report lists 11.982 species identified as threatened out of 59.033 species evaluated using the IUCN Red List criteria.

Biodiversity: Extinct Species

Moa were flightless birds native to New Zealand. The largest species reached 3 m.

Photo: Wikipedia

Biodiversity: Existing Species

- **Numbers of species (Chapman 2009):**
  Earth's ecosystems contain an estimated 10 million species, of which 1,9 million have been documented.
- **300.000 plant species** , including
  - 120.000 fungi
- **1,5 million animal species**, including
  - 65.000 vertebrates:
    - 31.000 fish,
    - 6.500 amphibians,
    - 8.700 reptiles,
    - 10.000 birds,
    - 5.500 mammals.
  - 1,4 million invertebrates:
    - 1 million insects,
    - 90.000 mollusks,
    - 50.000 crustaceans,
    - 150.000 bacteria.

Biodiversity: Endangered Species

•The conservation of biological diversity has become a global concern and is addressed in the **Convention on Biological Diversity,** which is an international treaty of 1992 (Rio), signed by 196 parties with main goals: conservation of biodiversity, sustainable use of its components and fair sharing of such resources.

A long tailed Macaque sits chained awaiting sale at a bird market in Denpasar, Bali.

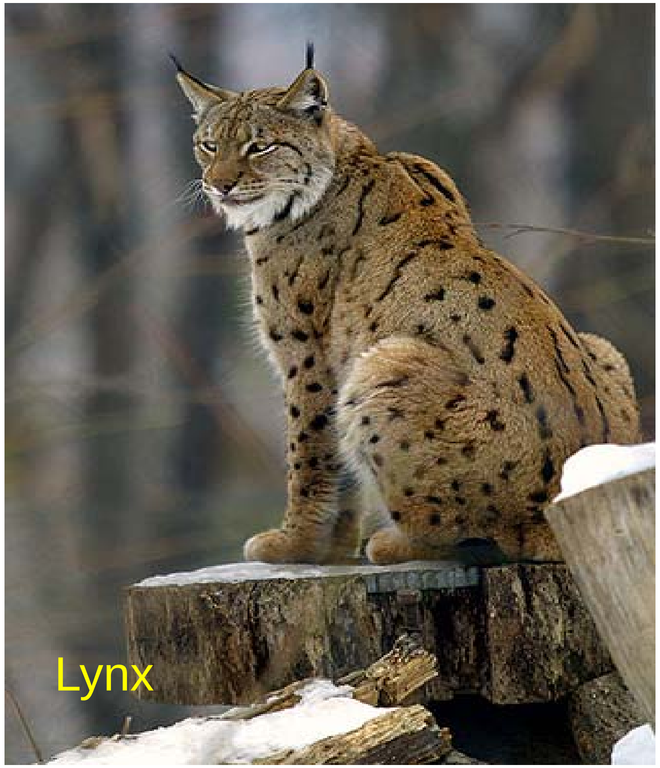
Photos: Wikipedia

Bengal Tiger:
survives only in protected areas

Biodiversity:
EU Red List

•**European Red List of endangered species (IUCN criteria):**
- 15% of Europe's 2.313 mammal species
- 13% of Europe's 1.000 bird species
- 9% of Europe's 440 butterfly species

•**Strict protection regime for certain animal species**



Source: EC DG ENV 2011

Biodiversity: EU Strategy

•**EU Biodiversity Stategy (1998, updated 2010):** to halt the loss of biodiversity and improve the state of Europe's ecosystems by better protection and restoration of ecosystems and sustainable agriculture, forestry and fisheries.

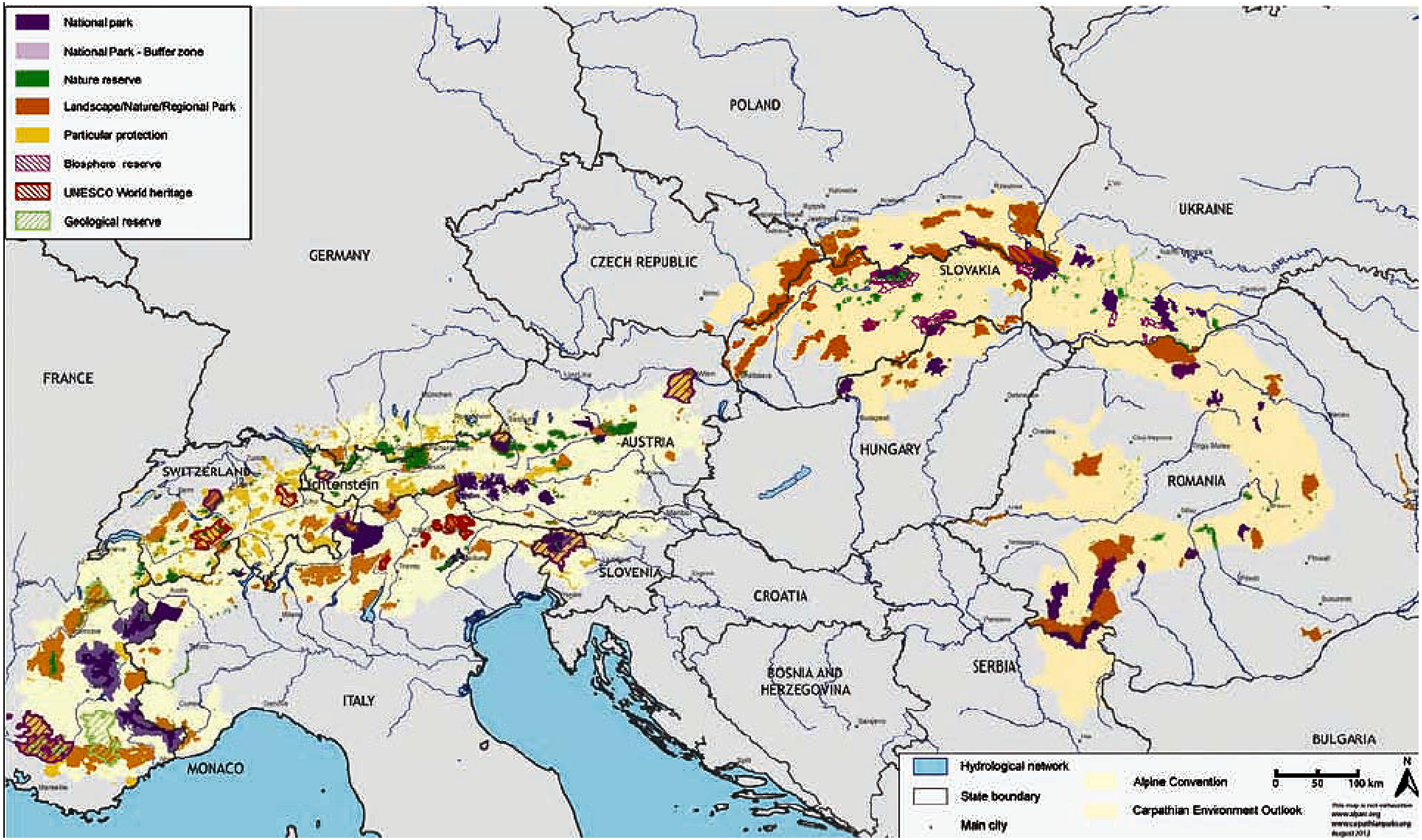
•**Natura 2000 areas:** comprise 18% of the European land area, based on

- Habitat Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora generating Special Areas of Conservation (SAC)
- Birds Directive 2009/147/EC creating a comprehensive scheme of protection for all wild bird species naturally occurring in the Union through Special Protection Areas.

March-Thaya-Wetlands of 150 km^2 are habitat for many protected species.

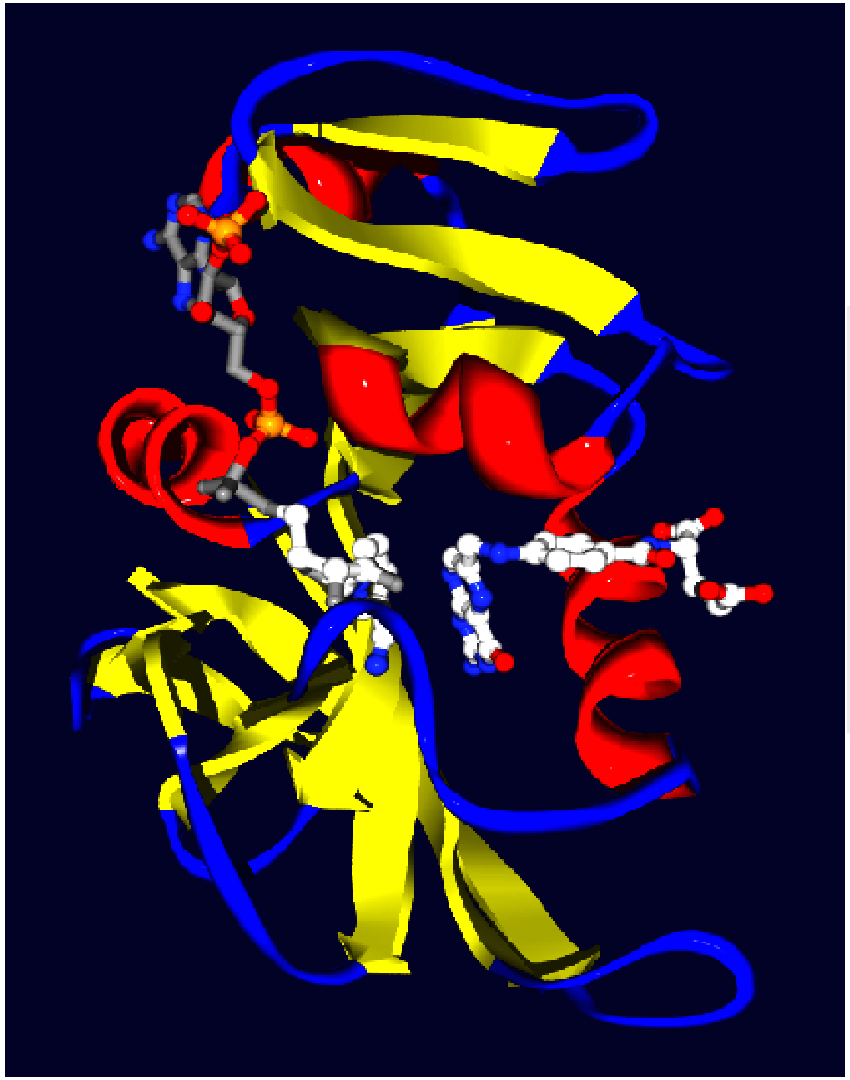
Photos:, Wikipedia

Biodiversity:
Large Alpine and Carpathian Protected Areas



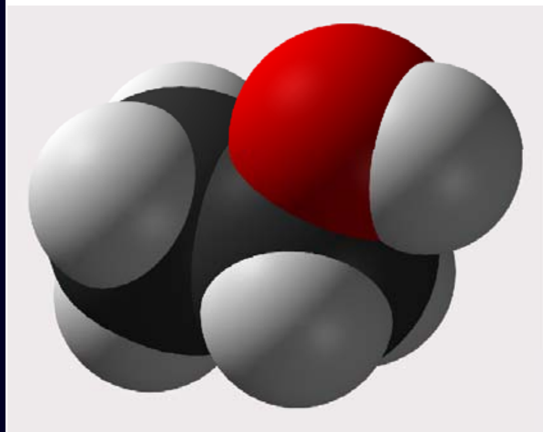
Source: EEA 2012, http://www.eea.europa.eu/publications/protected-areas-in-europe-2012

Chemicals in the Environment

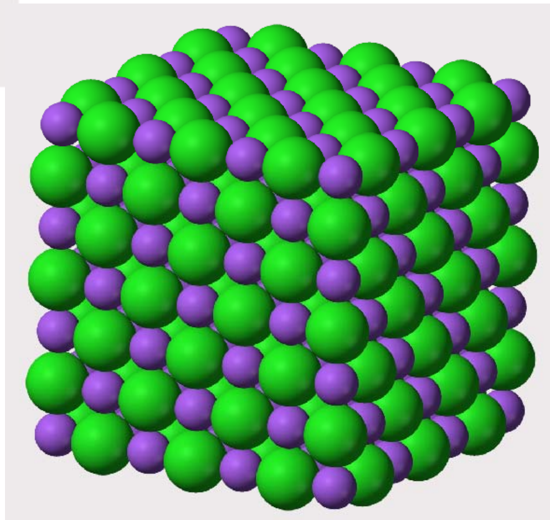


E. coli Dihydrofolat Reduktase

A **chemical substance** is a material with a definite chemical composition.



Ethanol (C_2H_5OH)



Natriumchlorid ($NaCl$)

Chemicals in the Environment

- Chemical substances have systematic names („IUPAC“ nomenclature) and sometimes an empirical name.
- For example, the compound 6-(hydroxymethyl)oxane-2,3,4,5-tetrol is commonly known as glucose (a sugar).
- Presently 144 million chemical compounds are known and registered by Chemical Abstracts Services (USA) and assigned a CAS registry number. More than 100.000 different chemical compounds are regularly produced by industry and enter the environmental system.
- Annual production: 400 million tons globally
- Polymers and plastics, especially polyethylene, polypropylene, polyvinyl chloride, polyethylene terephthalate, polystyrene and polycarbonate comprise about 80% of the industry’s output.
- The EU, U.S. and Japanese chemical companies are the world's largest producers: BASF, Dow, Shell, Bayer, INEOS, ExxonMobil, DuPont, SABIC, Aventis, Novartis, Mitsubishi.

Source: Wikipedia

Chemicals in the Environment:
Relevant Substances

- **The most important chemical substances in relation to the environment are:**
- **Fertilisers:** containing - in varying proportions – mainly compounds of nitrogen, phosphorus, potassium, calcium, sulfur, magnesium).
  - Annual use close to 100 million tons (50 million tons nitrogen).
  - Major source for input of nitrogen and phosphorous into water systems (eutrophication)
- **Plant protection chemicals** (pesticides, herbicides….): toxic compounds
- **Detergents:** provide phosphate input to water systems (eutrophication)
- **Waste materials** from human consumption and industrial processes, e.g. substances from use of industrial materials by consumers and storage, processing of waste: heavy metals (like Cd, Cr, Pb….., phosphates, chlorinated hydrocarbons, freons, dioxins)
- **Pharmaceuticals and agropharmaceuticals:** possible endocrine disruption

Chemicals in the Environment:
Risk Assessment

- All chemical compounds entering the environment have been registered at a proper authority.
  - USA: the US Food and Drug Administration – FDA
  - EU: National Competent Authorities, or European Chemicals Agency – ECA, based in Helsinki (under the REACH legislation).
- The US FDA registry contains some 5.000 substances classified as somehow toxic.
- Six types of toxicity data are included in the Registry:
  - Primary irritation, mutagenic effects, reproductive effects, tumorigenic effects, acute toxicity, other multiple dose toxicity.
- For all data the bibliographic source is listed. The studies are not evaluated in any way. Liability rests with the producer/distributor of the chemicals.

Examples for lethal toxicity: nicotin 2mg/kg body weight, 4 lt water in 1 hour

Chemicals in the Environment: Pesticides

A cropduster spreading pesticide

•A **pesticide** is a substance or mixture of substances used for controlling the damage caused by a pest.

•Application of pesticides in agriculture is necessary since large fractions of a crop can be destroyed by pests.

•Many pesticides are however poisonous to humans.

•Major classes of pesticides:

-Bactericides for the control of bacteria
-Fungicides for the control of fungi
-Herbicides for the control of weeds
-Insecticides for the control of insects
-Molluscicides for the control of slugs and snails
-Nematicides for the control of nematodes
-Virucides for the control of viruses (e.g. H5N1 „bird flu“)

Source: Wikipedia

Chemicals in the Environment: Pesticides

- **History**
- The application of pesticides in agriculture began in the 1940s.
- Pesticide use has increased 50-fold since 1950 and 2.5 million tons of industrial pesticides are now used each year.
- Seventy-five percent of all pesticides in the world are used in developed countries, but use in developing countries is increasing.
- **Regulations:**
- To use a pesticide, it must be approved by a government agency.
- UN‘s Food and Agriculture Organization (FAO) adopted an International Code of Conduct on the Distribution and Use of Pesticides in 1985.
- The UN Codex Alimentarius Commission seeks to create uniform standards for maximum levels of pesticide residues among participating countries.
- In the European Union an extensive legislative framework is in place controlling the use of pesticides in food and feed (Regulation 396/2005 of EP and Council on maximum residue levels of pesticides in or on food and feed of plant and animal origin).

Source: Wikipedia

Pesticides - Environmental Effects

- Use of pesticides can have unintended effects on the environment.
- Many of the chemicals used in pesticides are persistent soil contaminants which adversely affect soil conservation and decrease the general biodiversity in the soil.
- The amount of pesticide that migrates from the intended application area is influenced by the particular chemical's properties: its properties for binding to soil, its vapor pressure, its water solubility, and its resistance to being broken down over time.
- „Old“ pesticides like DDT or atrazin have very long residence times in soil and water due to their extraordinary chemical stability and have therefore been outphased in many countries.
- But: successful in wiping out malaria in India (6 million annual deaths in the 1960s)
- „Modern“ pesticides (like organophosphorus compounds) are chemicals which rapidly decay in soil and water and therefore have residence times of only weeks.

Source: Wikipedia

Pesticides - Environmental Effects

- **Environmental effects**

- Maximum limits of allowable concentrations for individual pesticides in public bodies of water are set by the Environmental Protection Agencies in industrialised countries.
- The EU set maximum concentrations of pesticides in water: Maximum Residue Limit (MRL) for ground and drinking water 0,1 μg/L.
- A major environmental effect is the damage to bees and other insects and the reduction of the pollination services provided by them.
- Reducing the use of pesticides and choosing less toxic pesticides may reduce risks.
- Integrated pest management, the use of multiple approaches to control pests, is becoming widespread in many countries.
- Genetic modification of crops may allow the use of less pesticides (e.g. Roundup Ready soybeans of Monsanto), is however under heavy criticism in the European Union.

Pesticides - Environmental Effects on Bees

•In recent decades there was a dramatic reduction in the number of honey bees in the U.S. (and to a lesser extent Europe) and a decline in the number of colonies maintained by beekeepers.

•Colony collapse disorder (CCD) is a phenomenon in which worker bees abruptly disappear.

•Major suspected causes are the enhanced use of pesticides and spreading of infections of bee hives by the *Varroa Destructor mite.*

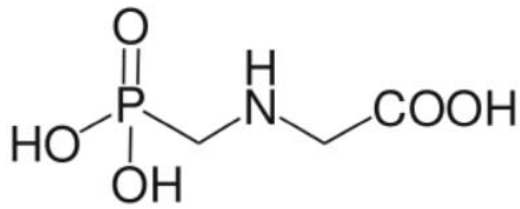
•Colony collapse is economically significant because many agricultural crops worldwide are pollinated by bees.

Contribution of insect pollinators to agricultural output: 200 billion $/year

(Source: UNEP 2011)

Pesticides:
Controversies about Toxicity

Glyphosate developed by Monsanto chemist John Franz in 1970 is a broad-spectrum herbicide. It is an organophosphorous compound killing weeds.



- Monsanto brought it to market for agricultural use in 1974 under the trade name Roundup. Glyphosate is the most used herbicide in the United States agricultural sector, with 80.000 tons applied.
- WHO, FAO, European Chemicals Agency, European Food Safety Agency, and the German Federal Insitute for Risk Assessment have concluded that there is no evidence that glyphosate poses a carcinogenic or genotoxic risk to humans (more than 1.000 studies evaluated).
- The International Agency for Research on Cancer (IARC), affiliated with the WHO, has made claims of carcinogenicity in research reviews but the IARC has been criticized for its assessment methodology.
- Due to a political initiative triggered by several NGOs the EP voted to ban glyphosate in 2017, but the European Council approved use until 2022.
- Austria plans a gradual exit from application of this pesticide.

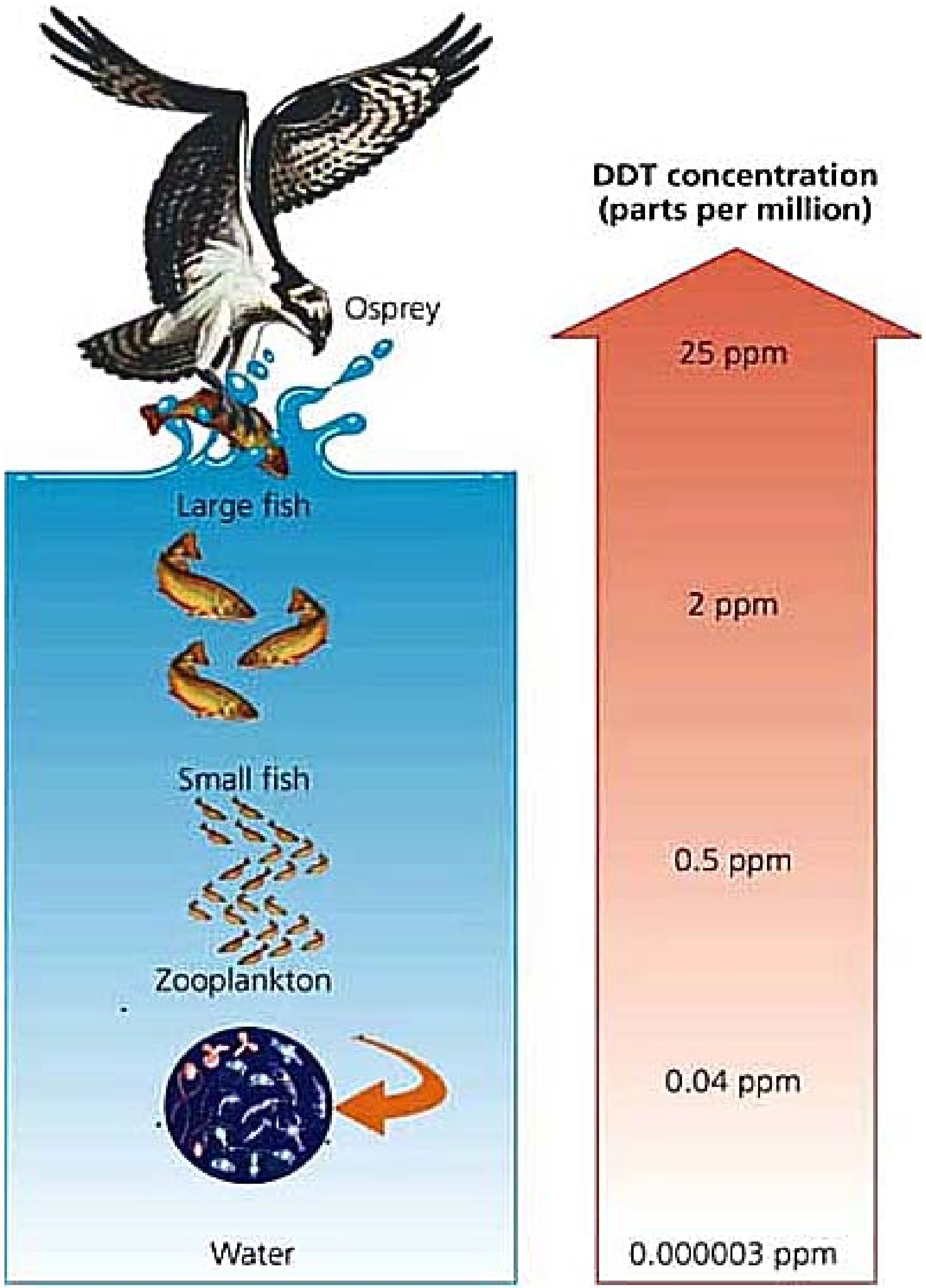
Chemicals in the Environment:
Persistent Organic Pollutants

- **Persistent organic pollutants**

- Persistent organic pollutants (POPs) are compounds that resist degradation and thus remain in the environment for years.
- POPs are frequently halogenated, usually with chlorine.
- The more chlorine groups a POP has, the more resistant it is to being broken down over time.
- Chemical characteristics of POPs: low water solubility, high lipid solubility, semi-volatility, and high molecular masses.
- The lipid solubility results in the ability to pass through biological phospholipid membranes and bioaccumulate in the fatty tissues of living organisms.
- Therefore these chemicals also have the ability to bioaccumulate and biomagnify, and can bioconcentrate.
- A prominent example of this class of compounds was DDT.

Source: Wikipedia

Chemicals in the Environment:
Persistent Organic Pollutants



Bioaccumulation of fat soluble persistent organic pollutants in the food chain.
Concentration enrichment factor 10.000.000.

DDT was preventing many fish-eating birds from reproducing, which was a serious threat to biodiversity.

Source: Withgott and Brennan: Environment, Pearson 2008

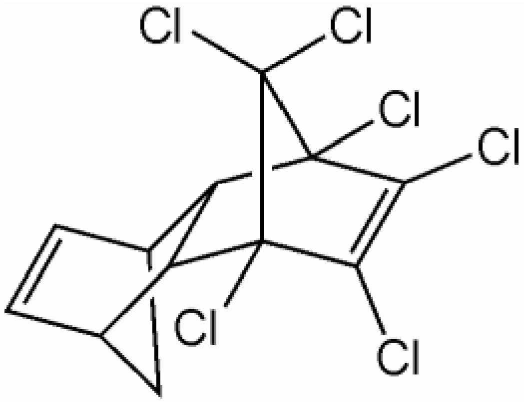
Chemicals in the Environment:
Persistent Organic Pollutants

- **Persistent organic pollutants**
- POPs may continue to poison non-target organisms in the environment and increase risk to humans by disruption in the endocrine, reproductive, and immune systems, although very little is currently known about these chronic effects.
- Due to their semi-volatility POPs have the ability to travel great distances through the atmosphere attached to particulate matter to become deposited in remote regions.
- Indirect routes include the food chain, which is the major source for exposure of humans and animals to POPs (dioxins in meat, PCBs in eggs).
- Thus POPs can be found all over the world, including in areas where they have never been used and remote regions such as Antarctica.
- Some POPs have been banned like chlorofluorocarbons, while others continue to be used.

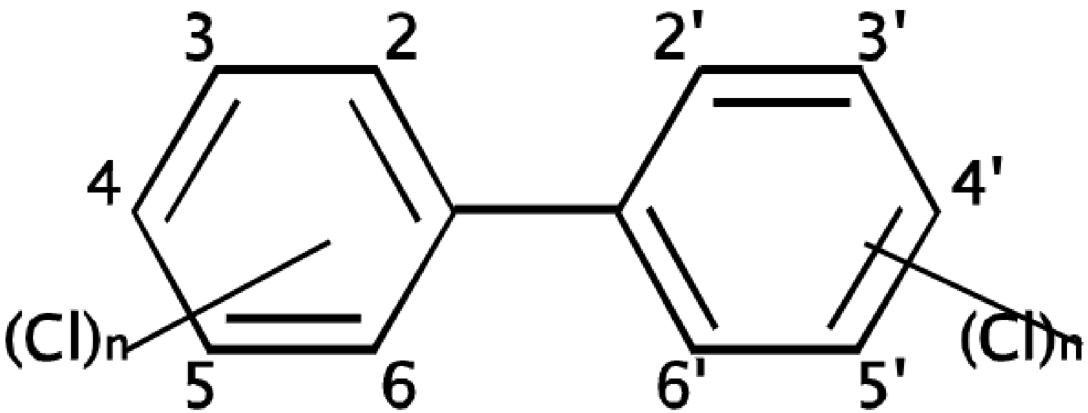
Source: Wikipedia

Chemicals in the Environment:
Persistent Organic Pollutants

- In 1995, the United Nations Environment Programme (UNEP) decided to begin investigating POPs, initially beginning with a short list of the following twelve POPs, known as the 'dirty dozen': aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, polychlorinated biphenyls, polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans, and toxaphene.



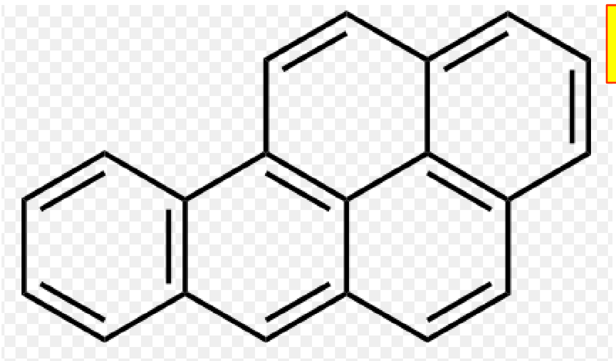
Aldrin



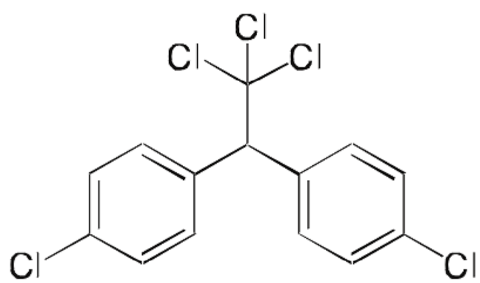
Polychlorinated biphenyls (PCBs) are a class of organic compounds with 1 to 10 chlorine atoms.

Chemicals in the Environment:
Persistent Organic Pollutants

- Since then, this list has been extended to include such substances as
- ➢ carcinogenic polycyclic aromatic hydrocarbons (PAHs), like Benzo-a-Pyrene (produced in smoking of meat),
- ➢ some brominated flame-retardants (used in polymers and textiles),
- ➢ some organometallic compounds such as tributyltin (TBT - used as antifouling painting for ships and boats).
- Many POPs are currently or were in the past used as pesticides (aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, and toxaphene), in industrial processes and in the production of a range of goods such as solvents, polyvinyl chloride, and pharmaceuticals.



BaP

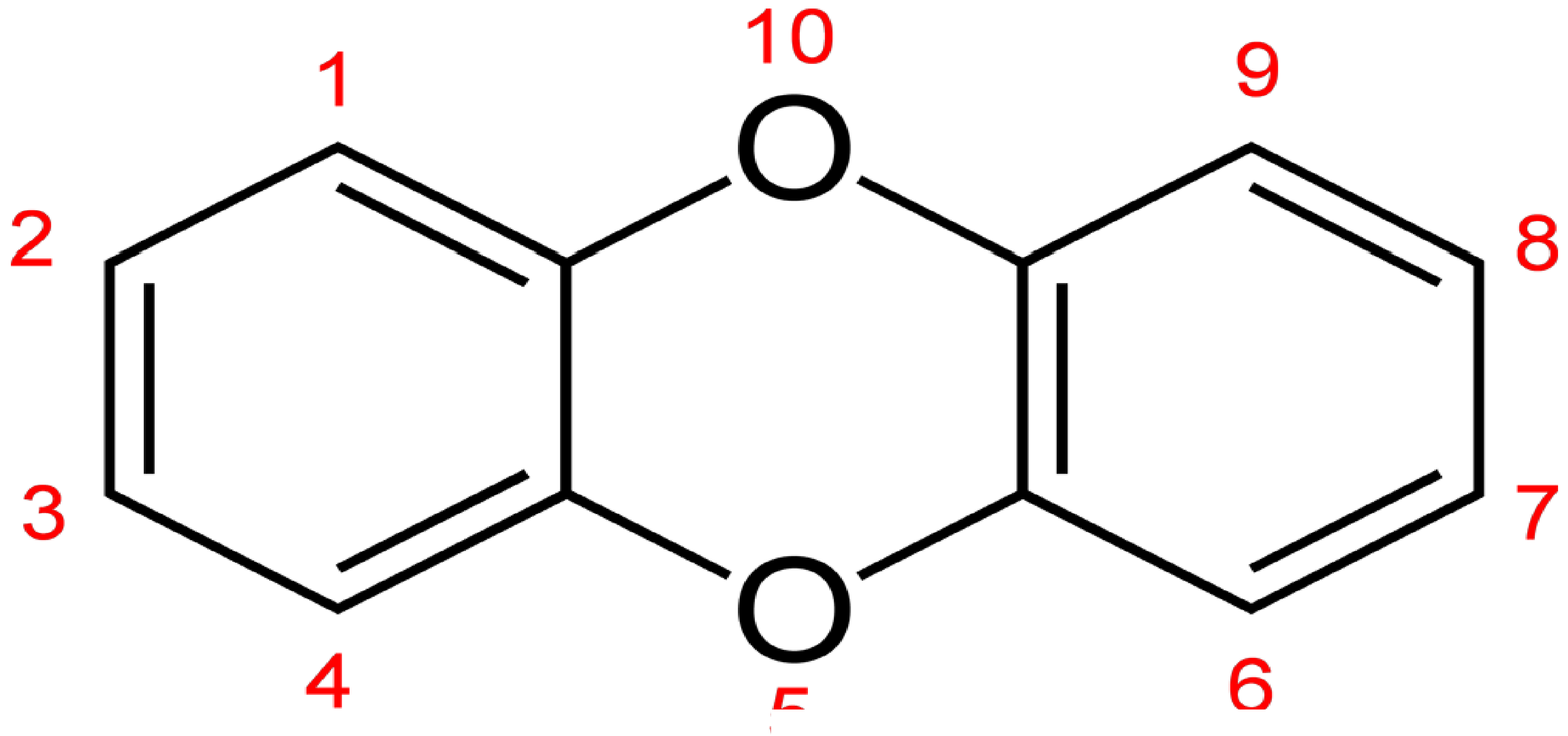


DDT = 1,1,1-trichloro-2,2-di(4-chlorophenyl)ethane

Source: Wikipedia

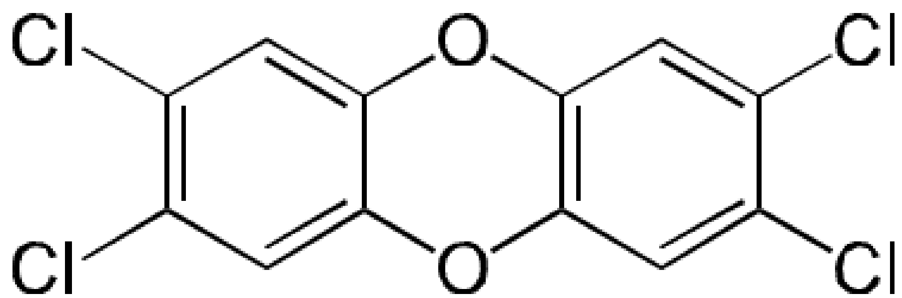
Chemicals in the Environment:

Persistent Organic Pollutants – Polychlorinated-dibenzo-dioxins (PCDDs)



The skeletal formula and substituent numbering scheme of dibenzo-*p*-dioxin,
the parent compound of PCDDs.

2,3,7,8-Tetra-chloro-dibenzo-dioxin.



Most toxic of the congeners.

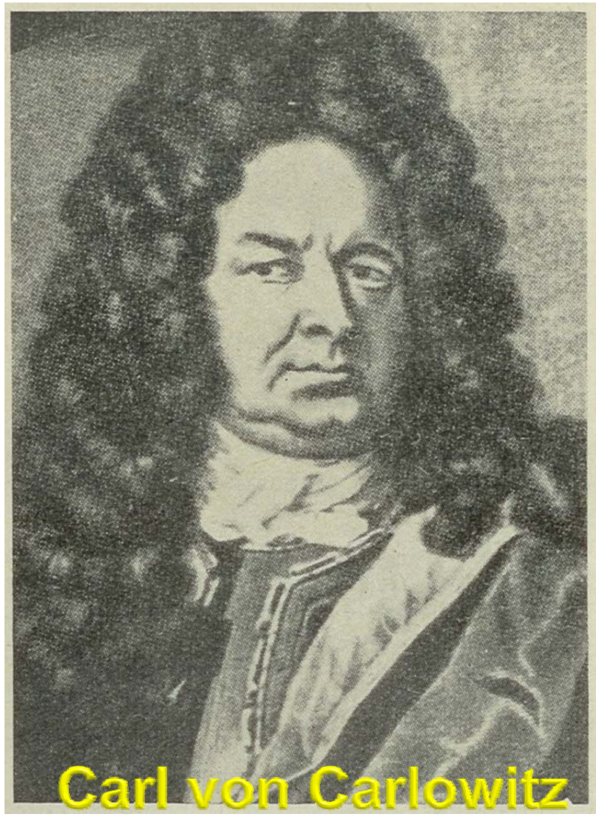
Ecology and Sustainable Development

3. Sustainable Development as a Concept for Societal Evolution:

- The origin of environmentalism and sustainability.
- The evolution of environmental policies at a global level.
- Milestones for EU policies on environmental protection and sustainable development.

The Evolution of Environmental Policies

- First appearance of term „sustainability“ 1713 in a publication of Carl von Carlowitz (1645 – 1714) „Oberberghauptmann“ in Saxonia in respect to the management of forests.



•He demanded that the forest should be managed in a „sustainable“ manner, meaning that not more would be extracted as would regrow.


Mit GOtt!
SYLVICULTURA OECONOMICA,
Oder
Haußwirthliche Nachricht und Naturmäßige
Anweisung
Zur
Wilden Baum-Zucht/
Nebst
Gründlicher Darstellung/
Wie zuförderst durch Göttliches Benedeyen dem allenthalben und insgemein einreissenden
Grossen Holtz-Mangel/
Vermittelst Säe- Pflantz- und Versetzung vielerhand Bäume zu prospiciren/
Alles zu nothdürfftiger Versorgung des Hauß- Bau- Brau- Berg- und Schmeltz-Wesens/
Worbey zugleich eine gründliche Nachricht von den in Churfl. Sächß. Landen
Gefundenen Turff
Dessen Natürliche Beschaffenheit/ grossen Nutzen/ Gebrauch und nützlichen Verkohlung.
Aus Liebe zu Beförderung des algemeinen Bestens beschrieben
Von
Hannß Carl von Carlowitz/
Königl. Pohl. und Churfl. Sächß. Cammer-Rath/ und Ober-Berg-Hauptmann.
Mit Königl. Pohl. und Churfürstl. Sächß. allergnädigsten PRIVILEGIO.
LEIPZIG/
verlegts Johann Friedrich Braun 1713.

Source: Wikipedia

•This lead to a decree of King of Saxonia for the sustainable management of forests and indeed deforestation could be stopped.

The Evolution of Environmental Policies

„Environmental Protection“ virtually unknown untill 1960s.

•Public awareness first raised massively in 1962 by Rachel Carson through her battle against the uncontrolled use of pesticides in agricultural production in the USA for which she coined the term „biocides“.

Rachel Carson “The Silent Spring” 1962:
“Now I truly believe that we in this generation must come to terms with nature, and I think we’re challenged, as mankind has never been challenged before…...”

•*Silent Spring* spurred a reversal in US pesticide policy—leading to a nationwide ban on DDT and other pesticides—and the grassroots environmental movement the book inspired led to the creation of the US Environmental Protection Agency (EPA).

Source: Wikipedia

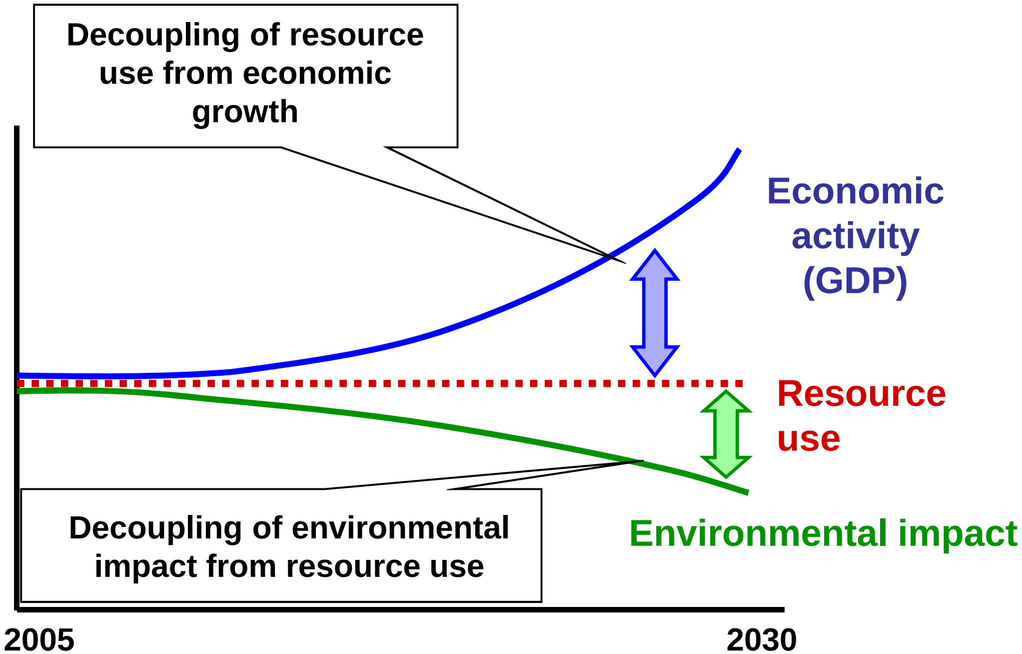
The Evolution of Environmental Policies:
First Man on the Moon 1968

Source: NASA

The Evolution of Environmental Policies

- 1972 the issue of sustainable use of the limited natural resources emerged: “The Limits to Growth - A Report of the Club of Rome’s Project on the Predicament of Mankind”

Dennis Meadows: “If the world's consumption patterns and population growth continue at the same high rates of the time, the earth will strike its limits within a century.”



Source: Wikipedia

- Meadows report caused a world wide debate on resource issues.

The Evolution of Environmental Policies:
Policy Measures

- Since the 1970s adoption of regulations on pollution control focussing on air, water and waste and control of toxic substances at national (e.g. Austria, Scandinavian countries, USA) and European level which achieved a substantial improvement of the environment.
- In 1972 environmental protection and sustainable development were for the first time placed on the international policy agenda at the Stockholm Conference organised by the UN.
- Stockholm Conference adopted fundamental principles, like:
  „***The natural resources of the earth, including air water, land, flora and fauna, must be safeguarded for the benefit of present and future generations through careful planning and management.***“

The Evolution of Environmental Policies:
Policy Measures

- **Establishment of the UN Environment Programme (UNEP) in 1972:**
- to coordinate the United Nations environmental activities with special focus on developing countries.
- Headquarter Nairobi with several regional offices all over the world.
- UNEP activities cover a wide range of issues regarding the atmosphere, marine and terrestrial ecosystems and funds environmentally related development projects.

– UNEP publishes important reports on global issues (like the Global Environment Outlook [GEO] series).

Protection of marshlands in Iraq:
90 % lost.

The Evolution of Environmental Policies:
Policy Measures

- **From environmental protection to Sustainable Development:**
- SD concept promoted by the World Commission on Environment and Development (WCED): commissioned report “Our Common Future” in 1983, published in 1987 (“Brundtland Report”).

Gro Harlem Brundtland presenting the report to the UN GA in 1987.

„Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.“

Source: Wikipedia

Core element of SD: integration of environmental policies into other policies.

The Evolution of Environmental Policies:
Policy Measures

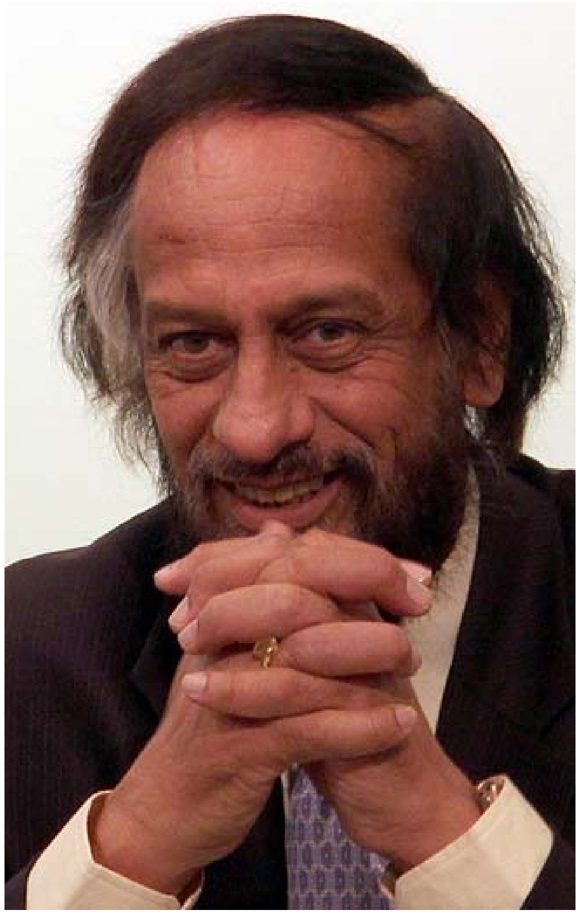
- The World Meteorological Organization and the UNEP established the Intergovernmental Panel on Climate Change (IPCC) in 1988.
  - IPCC is the scientific body tasked to evaluate the risk of climate change caused by human activity.

-The IPCC has so far published 6 assessments of climate change which are generally considered as the authoritative reports on the topic and therefore serve as the most important basis for policy making.

-The IPCC shared the 2007 Nobel Peace Prize with former Vice President of the United States Al Gore.

Photo: Wikipedia

Rajendra K. Pachauri, IPCC Chair since 2002



The Evolution of Environmental Policies:
Policy Measures

- **UN Conference on Environment and Development ("Earth Summit") in Rio 1992:**
- Follow-up action from the Brundtland report with 5 important documents produced:
- The Rio Declaration on Environment and Development with "Agenda 21" outlining the main tasks to be carried out for the achievement of SD.
- The Framework Convention on Climate Change (UNFCCC).
- The Convention on Biological Diversity (UNCBD).
- The Convention to Combat Desertification (UNCCD).
- The Forest Principles on the sustainable management of Forests.

Source: Wikipedia

The Evolution of Environmental Policies:
Policy Measures

- **Establishment of the Millennium Development Goals** at the Millennium Summit held at the UN Headquarters in New York in 2000.
- The **Millennium Development Goals** are eight goals that 189 United Nations member states have agreed to try to achieve by the year 2015.

- **The eight goals are:**

- Eradicate extreme poverty and hunger.
- Achieve universal primary education.
- Promote gender equality and empower women.
- Reduce child mortality.
- Improve maternal health.
- Combat HIV/AIDS, malaria, and other diseases.
- Ensure environmental sustainability.
- Develop a global partnership for development.

Source: Wikipedia

The Evolution of Environmental Policies:
Policy Measures

- **UN World Summit on Sustainable Development (WSSD or Earth Summit 2002),** Johannesburg:

- **The Johannesburg Declaration,** an agreement focussing particularly on the worldwide conditions that pose severe threats to the sustainable development of our people.
- **Fisheries agreement:** to restore the world's depleted fisheries.

- **UN World Summit 2012 (Rio+20 Conference):**

o Aim is to establish a green economy which will reduce poverty and slow consumption. The negotiated text was however severely inadequate to the task ahead. Evident how unproductively politicized the entire process had become.

- **UN 2030 Agenda for Sustainable Development 2015:**

o Successor programme of the Millenium Development Goals – now 17 goals focussing on the most important challenges for mankind providing a framework for global sustainable development.

The Evolution of Environmental Policies:
Policy Measures

Source: United Nations

The Evolution of Environmental Policies:
Milestones of European Union

- 1973: First Environmental Action Programme of EC
- 1996: Creation of the European Environment Agency in Copenhagen.
- 1997: Single European Act (Amsterdam) placed environmental protection on equal footing with economic growth and free trade.
- 2001 Gothenburg European Council Decision establishing EU Sustainable Development Policy:
  - *Integration of environmental considerations into all Community policies.*
- 2008: The Climate and Energy Package: a *series of Directives to combat climate change.*

Since 1970 ca 250 pieces of EU legislation have been produced and 7 Environmental Action Programmes established: Basis for the current policy guidelines of the European Union.

The Evolution of Environmental Policies:
The Policy Framework for the European Union

The Lisbon Agenda 2005

Economic Growth - Social Equilibrium - Environmental Quality

Sustainable Development is the Guiding Principle for the European Union.

EU Policy Priority Issues for Sustainable Development

Communication of European Commission to Council and Parliament COM (2005)658final

"On the Review of the Sustainable Development Strategy – a Platform for Action."

- **Management of Natural Resources: air, water, soil, forestry and agriculture.**
- **Climate Change and Clean Energy.**
- **Global Poverty and Development Challenges.**

Priorities also reflected in proposal for the General European Union Environment Action Programme to 2020

http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:354:0171:0200:EN:PDF

Ecology and Sustainable Development

4. Environmental Pollution:

4.1 Air

4.2 Water

4.3 Soil

EEA “The European Environment – State and Outlook 2015”

UNEP Global Environment Outlook 6 (2012)

Origin of Air Pollution

4.1 Air Pollution:

Major sources:

•Emissions from industry (production plants, power plants, waste incineration)
•Traffic (road, shipping)
•Small scale heating

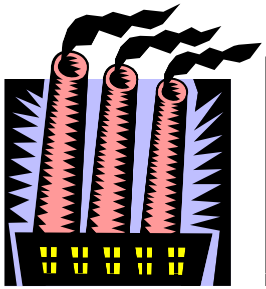
Transport of air pollutants:

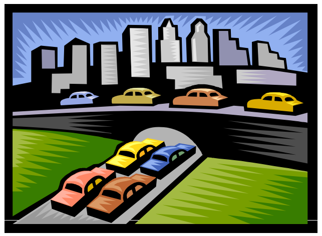
•Regional and global distribution of pollutants – effect depends on lifetime of a pollutant in the air.

Euro Emission Standards for Road Vehicles1970 – ….
Integrated Pollution Prevention and Control Directive 1996 and 2008
National Emission Ceilings Directive 2001 and 2016
Thematic Strategy on Clean Air for Europe 2005
Air Quality Directives 1996 – 2008

Clean Air for Europe:
Relation Emissions - Air Quality - Health

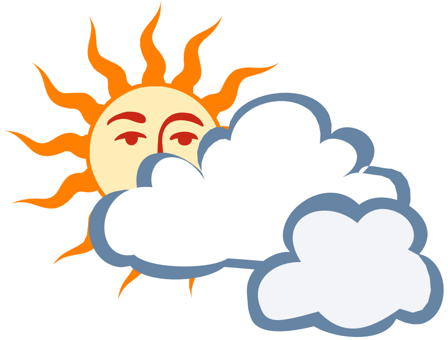
Emissions:
measured as amounts [tons/year]





•**Major primary air pollutants:**
SO_2, NO_x, Particulate Matter (PM), Volatile Organic Compounds (VOCs)

Air Quality:
measured as immission concentrations [$\mu g/m^3$]



•**Primary pollutants:**
•*SO_2, NO_x, PM, VOCs*

•**Secondary pollutants:**
O_3, ammonium sulfate and ammonium nitrate particles

Health Effects:
measured as percentage of population suffering from a specific disease

•**Chronic Diseases:**
asthma, allergies, cancer

•**Acute Diseases:**
bronchial, cardiovascular diseases

Source: JRC-IES

Clean Air for Europe:

National Emissions Ceiling Directive 2016/2284

The directive requires all Member States to report information annually concerning emissions and projections for four main air pollutants: nitrogen oxides (NO_X), non-methane volatile organic compounds (NMVOC), sulphur dioxide (SO_2) and ammonia (NH_3).

NECD sets pollutant-specific and legally binding emission ceilings for each of these pollutants and for each country, which must be met by 2010.

NEC Directive status report 2018 (emission data of year 2016)

https://www.eea.europa.eu/themes/air/national-emission-ceilings/nec-directive-reporting-status-2018

6 Member States exceeded one or more of the emission limits according to the data for 2016 reported to the EEA.

The pollutant for which most exceedances were registered was NH_3.

Austria exceeded the limit for NO_X which is 103.000 tons by 40%.

The road transport sector is the main factor affecting the NO_X exceedance which in general contributes approximately 40 % of total EU-28 NO_X emissions.

Clean Air for Europe:
Exposure of Urban Population to Air Pollutants

•**Major pollutants: Particulate Matter (PM_{10}, $PM_{2,5}$), Nitrogen dioxide (NO_2), Sulphur dioxide (SO_2), Ozone (O_3)**

•Pollution situation - percentage of ***urban*** population exposed to concentrations above EU immission limit values in period 2014-2016 (range indicates min and max):

-**Sulphur dioxide (SO_2):** <1% in this period, (EU limit value 125 μg SO_2/m^3 daily mean not to be exceeded more than three days a year).

-**Particulate Matter (PM_{10}):** 13-19% (EU limit value 50 μg/m^3 daily mean, not be exceeded more than 35 days a calendar year).

-**Particulate Matter ($PM_{2,5}$):** 6-8% (limit value 25 μg/m^3 yearly average)

-**Nitrogen dioxide (NO_2):** 7-8% (EU limit value 40 μg NO_2/m^3 annual mean).

-**Ozone (O_3):** 7-30% (EU target value 120 μg O_3/m^3 daily maximum 8-hourly average, not to be exceeded more than 25 times a calendar year).

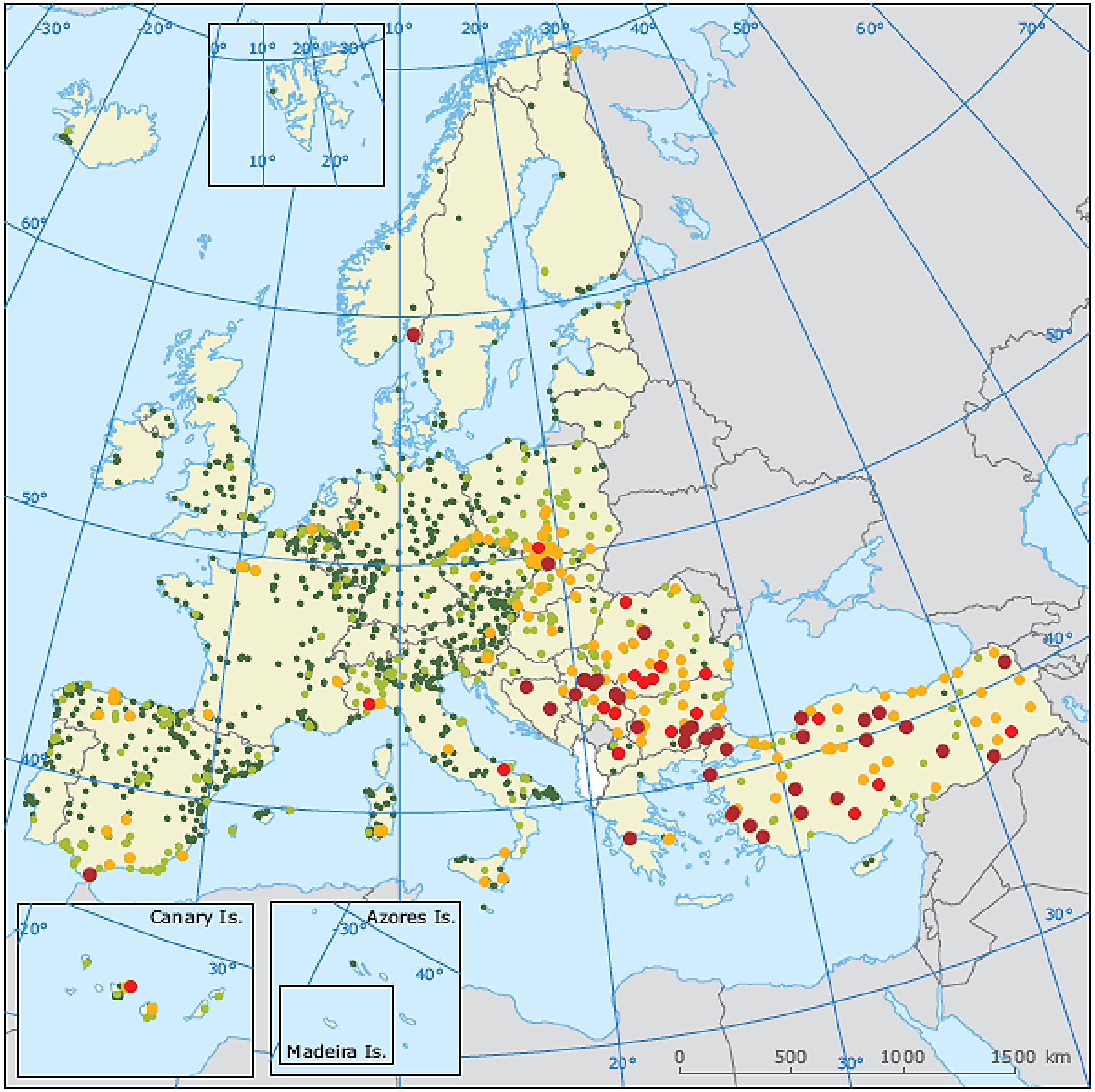
❖Note: ozone is not directly emitted, but formed by the reaction of hydrocarbons and nitrogen oxides under sunlight providing UV-radiation.

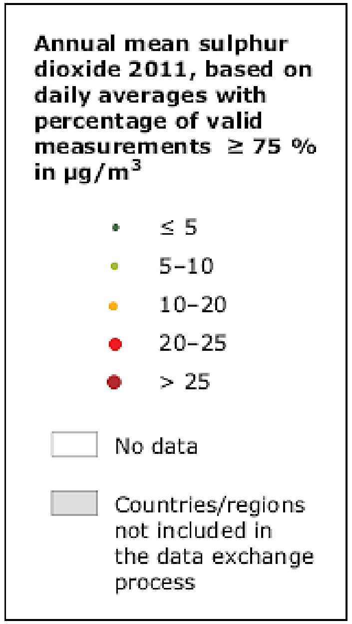
•Rural population usually not much effected by air pollution – „background immission concentrations“ below threshold levels.

•But: 80% of Europeans live in urban areas.

https://www.eea.europa.eu/publications/air-quality-in-europe-2018

Clean Air for Europe:
Regional Exposure to SO_2 in 2014





exceedance of a concentration of 20 $\mu g\ SO_2/m^3$ (WHO limit for daily average)

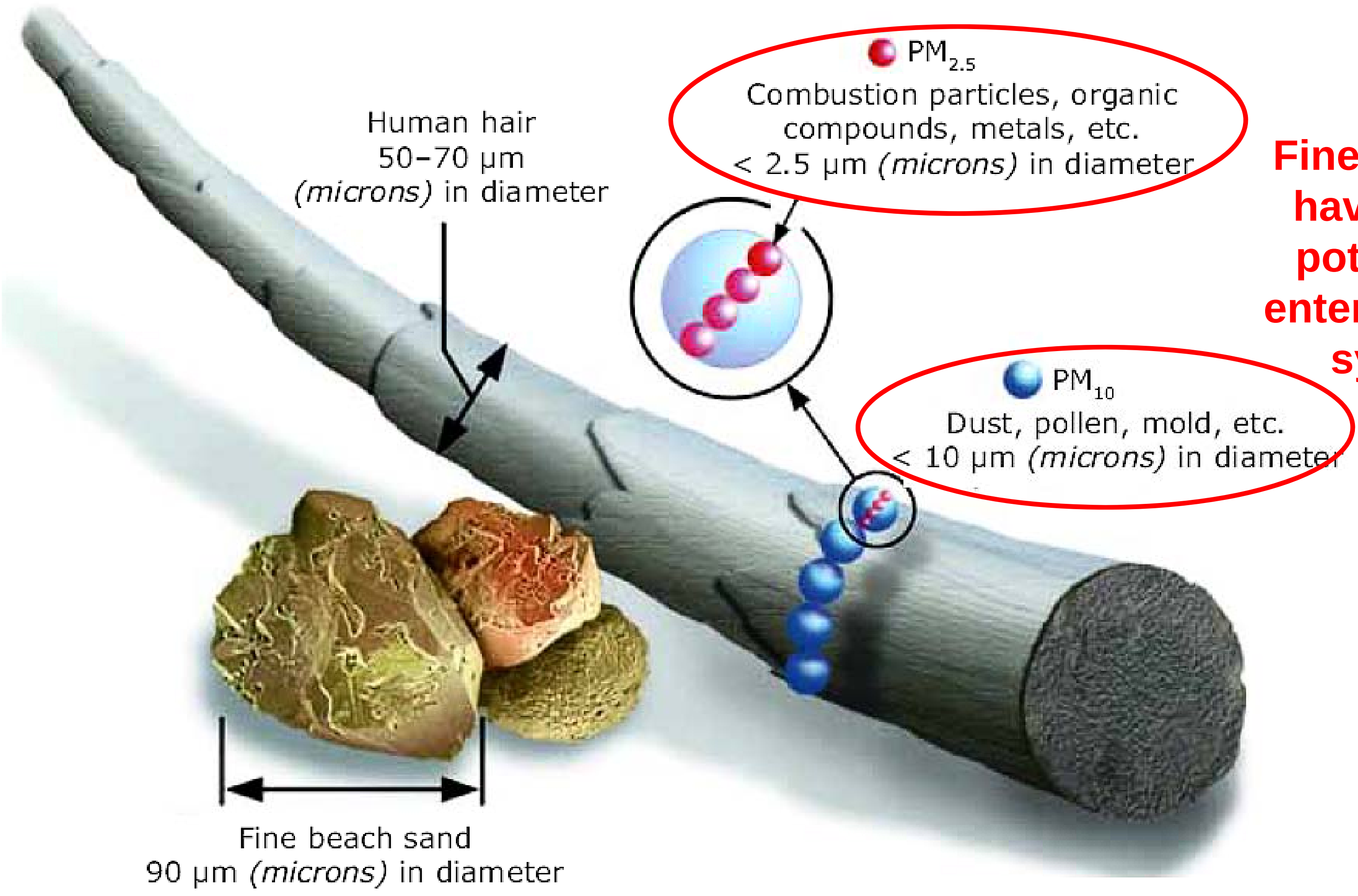
Major reasons for elevated SO_2 values:

•power stations (coal, oil)

•transport using sulphur-containing fuel (esp. shipping)

Source: http://www.eea.europa.eu/publications/air-quality-in-europe-2016

Clean Air for Europe: Visualisation of PM

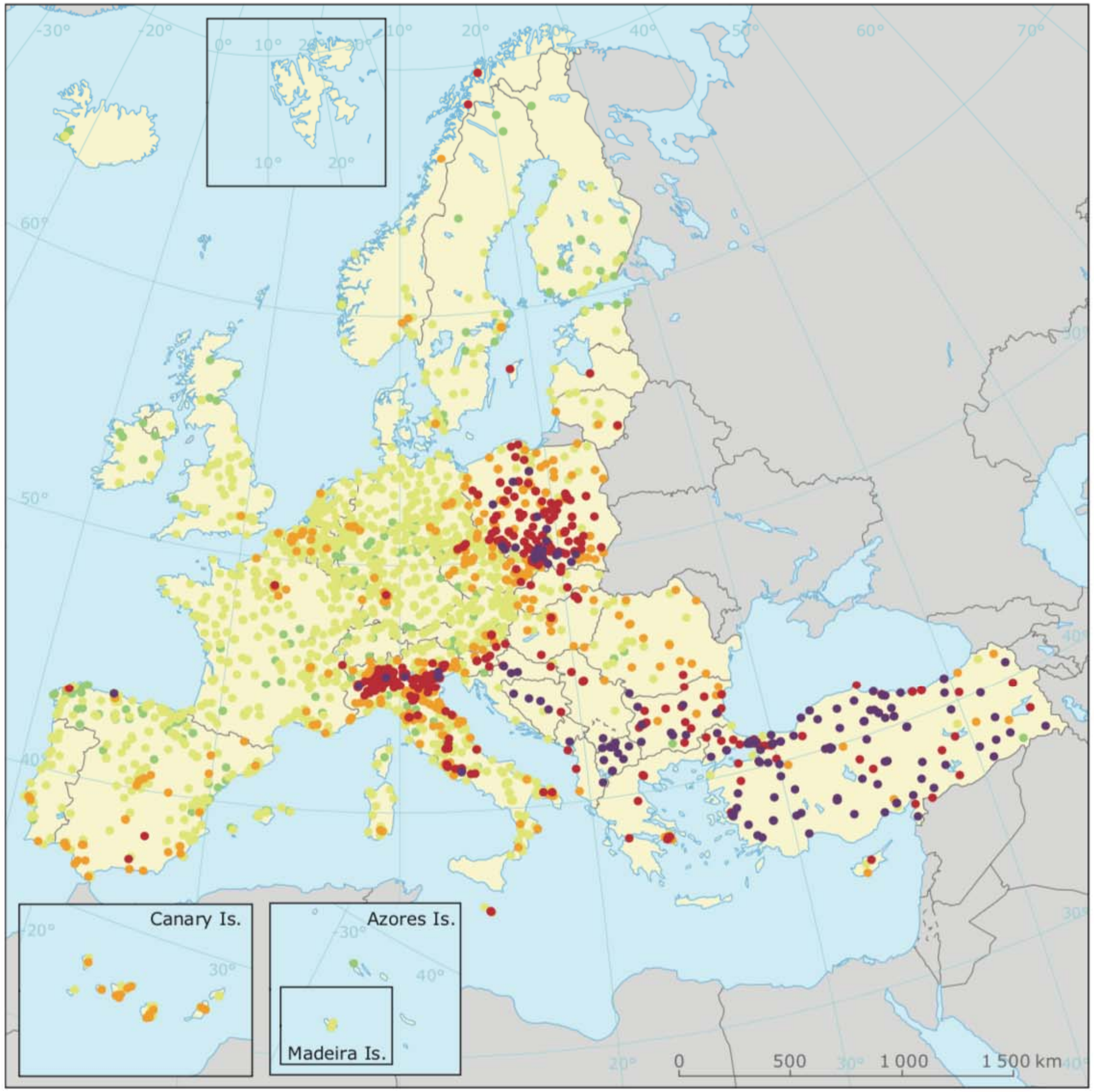


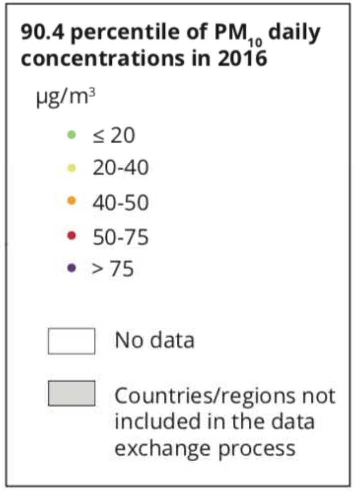
Fine particles have a high potential to enter the body system.

Source: http://www.eea.europa.eu/publications/air-quality-in-europe-2013

See also EEA Report 2012 „ Laying the foundations for greener transport — TERM 2011: transport indicators tracking progress towards environmental targets in Europe “
http://www.eea.europa.eu/publications/foundations-for-greener-transport

Clean Air for Europe:
Regional Exposure to PM_{10} in 2016





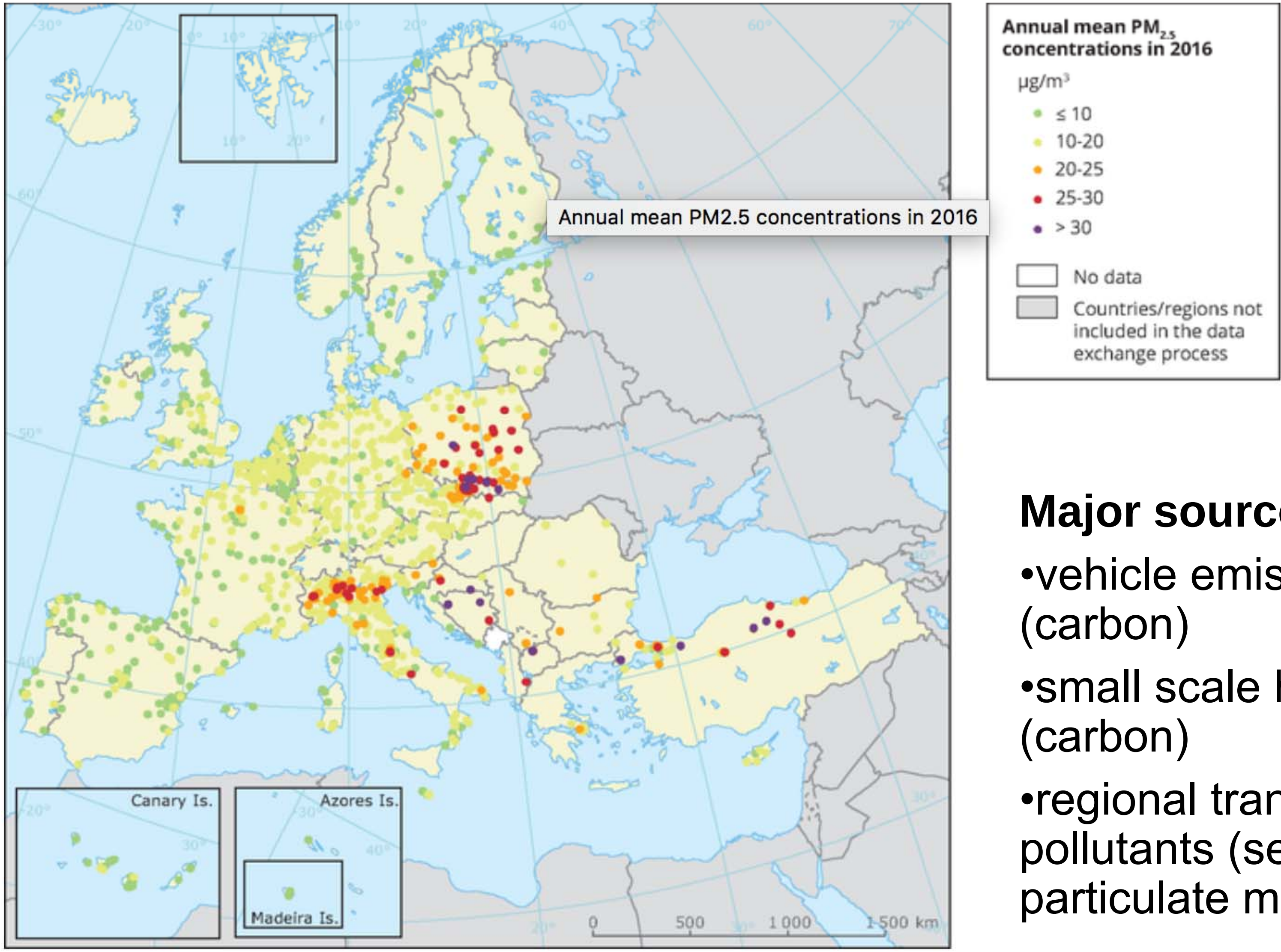
exceedance of annual limit value ($40\ \mu g/m^3$) – mainly in winter

http://www.eea.europa.eu/publications/ air-quality-in-europe-2018

Major sources for PM_{10}:

- •dust from road traffic (minerals)
- •vehicle emissions (carbon)
- •small scale heating (carbon)
- •regional transport of air pollutants (secondary particulate matter)
- •industrial emissions

Clean Air for Europe:
Regional Exposure to $PM_{2,5}$ in 2016



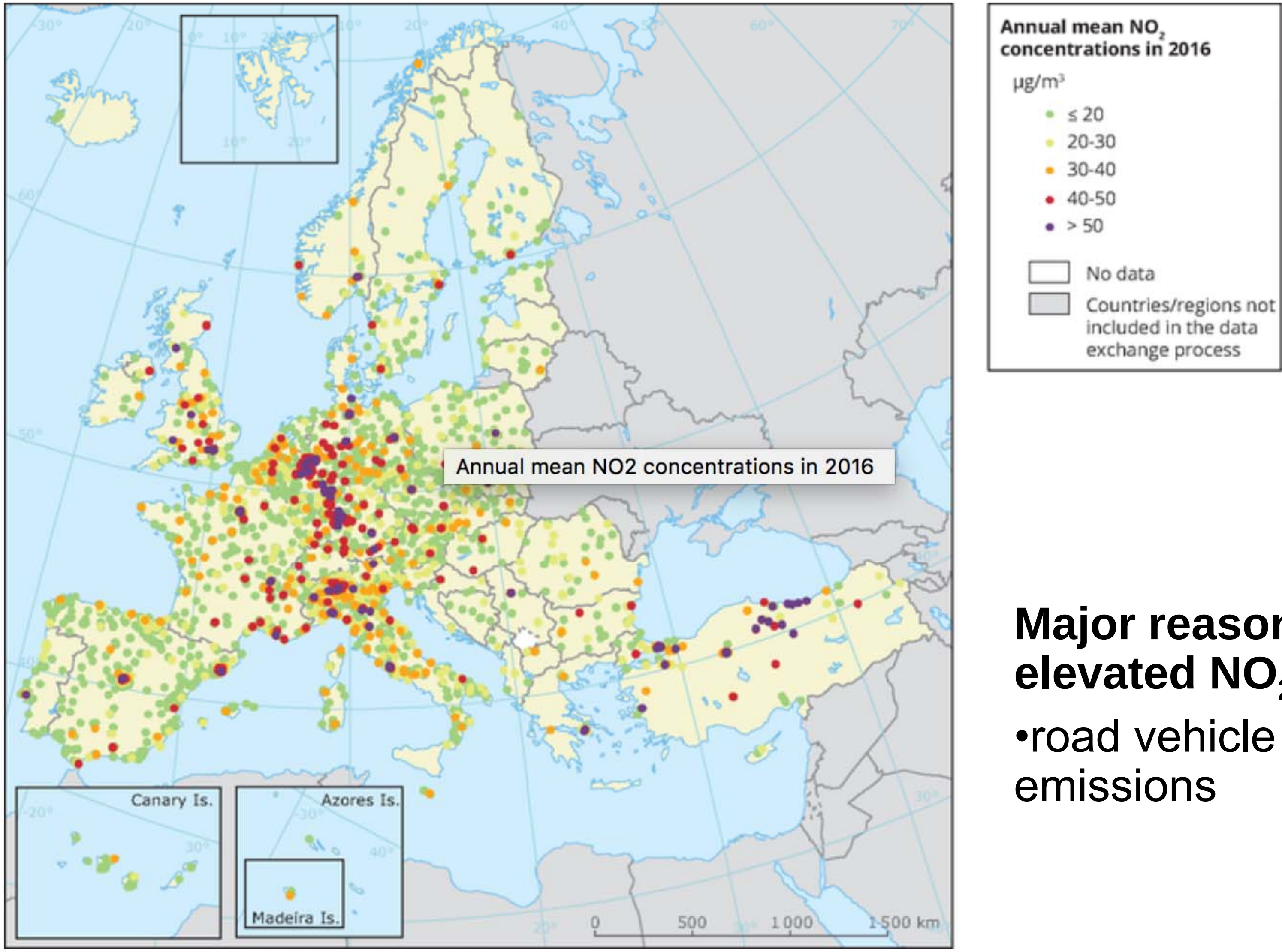
exceedance of annual limit value (25 µg/m^3)

Major sources for $PM_{2,5}$:

- vehicle emissions (carbon)
- small scale heating (carbon)
- regional transport of air pollutants (secondary particulate matter)

Source: http://www.eea.europa.eu/publications/air-quality-in-europe-2018

Clean Air for Europe:
Regional Exposure to NO_2 in 2016



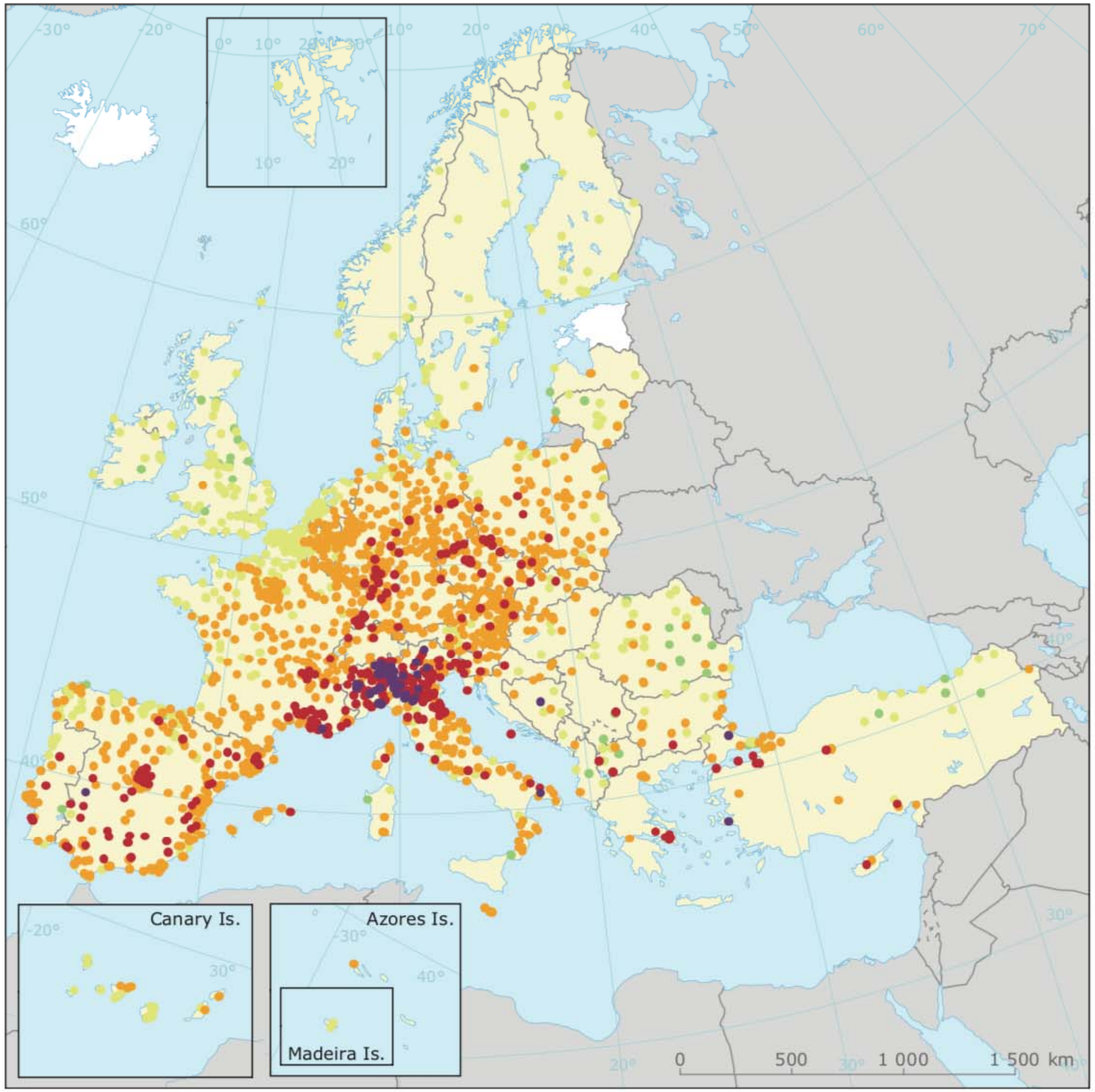
exceedance of the limit of 40 µg NO_2/m^3 annual mean

Major reasons for elevated NO_2 values:

•road vehicle and ship emissions

Source: http://www.eea.europa.eu/publications/air-quality-in-europe-2018

Clean Air for Europe:
Regional Exposure to Ozone in 2016



exceedance of the threshold and the number of allowed exceedances of the target value (120 μg/m³) – mainly in summer.

Major reasons for elevated O_3 values:

- road vehicle and ship emissions (VOCs and NO_x)
- high UV radiation

Source: http://www.eea.europa.eu/publications/air-quality-in-europe-2018

Clean Air for Europe:
Trends for Emissions of Major Air Pollutants in EU 1990-2014

- Emissions of major air pollutants have been significantly reduced due to the environmental protection activities of the EU.

➢ **SO_2/SO_3 reduction by 95%:**
  - industrial abatement measures (cleaning of flue gas)
  - elimination of sulfur from diesel and gasoline

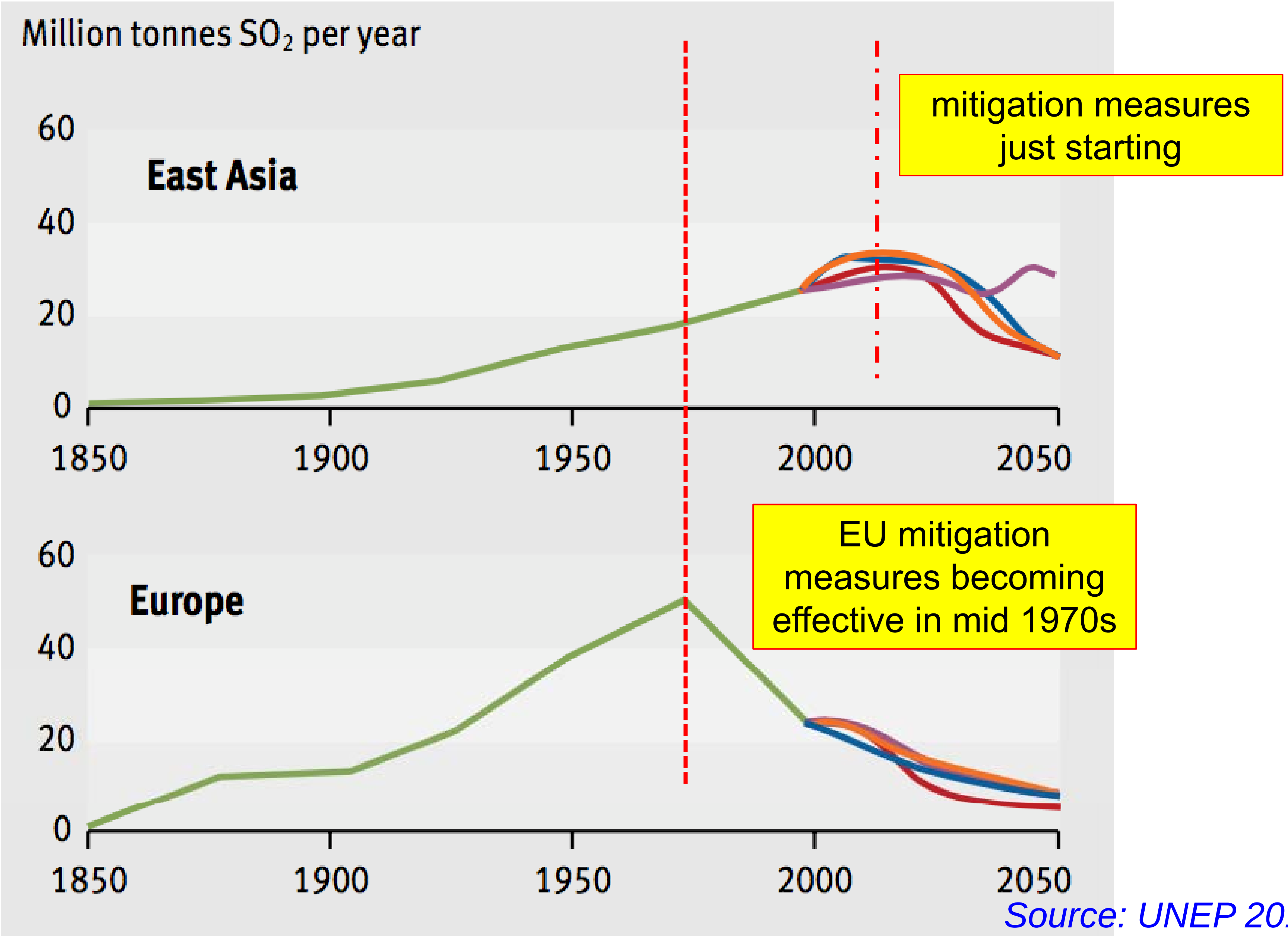
➢ **NO_X reduction 60% and NMVOCs (Non-Methane VOCs) 65%:**
  - reduction of small vehicle emissions (catalyst in gasoline cars):
    2005 Euro4 with 0,08*/0,25** gNO_x/km
    2011 Euro5 with 0,06*/0,18** gNO_x/km
    2018 Euro6 with 0,06*/0,08** gNO_x/km

* gasoline vehicles,
**diesel vehicles

➢ **PM10 and PM2,5 reduction 35%:**
  - industrial abatement measures (filters for smoke stacks)
  - reduced emissions for diesel passenger cars:
    2005 Euro4 mass limit 25 mg/km
    2011 Euro5 mass limit 5 mg/km
    2018 Euro6 mass limit 4,5 mg/km
  - improved road management
  - reduction of small scale heating and fuel switch from coal to gas

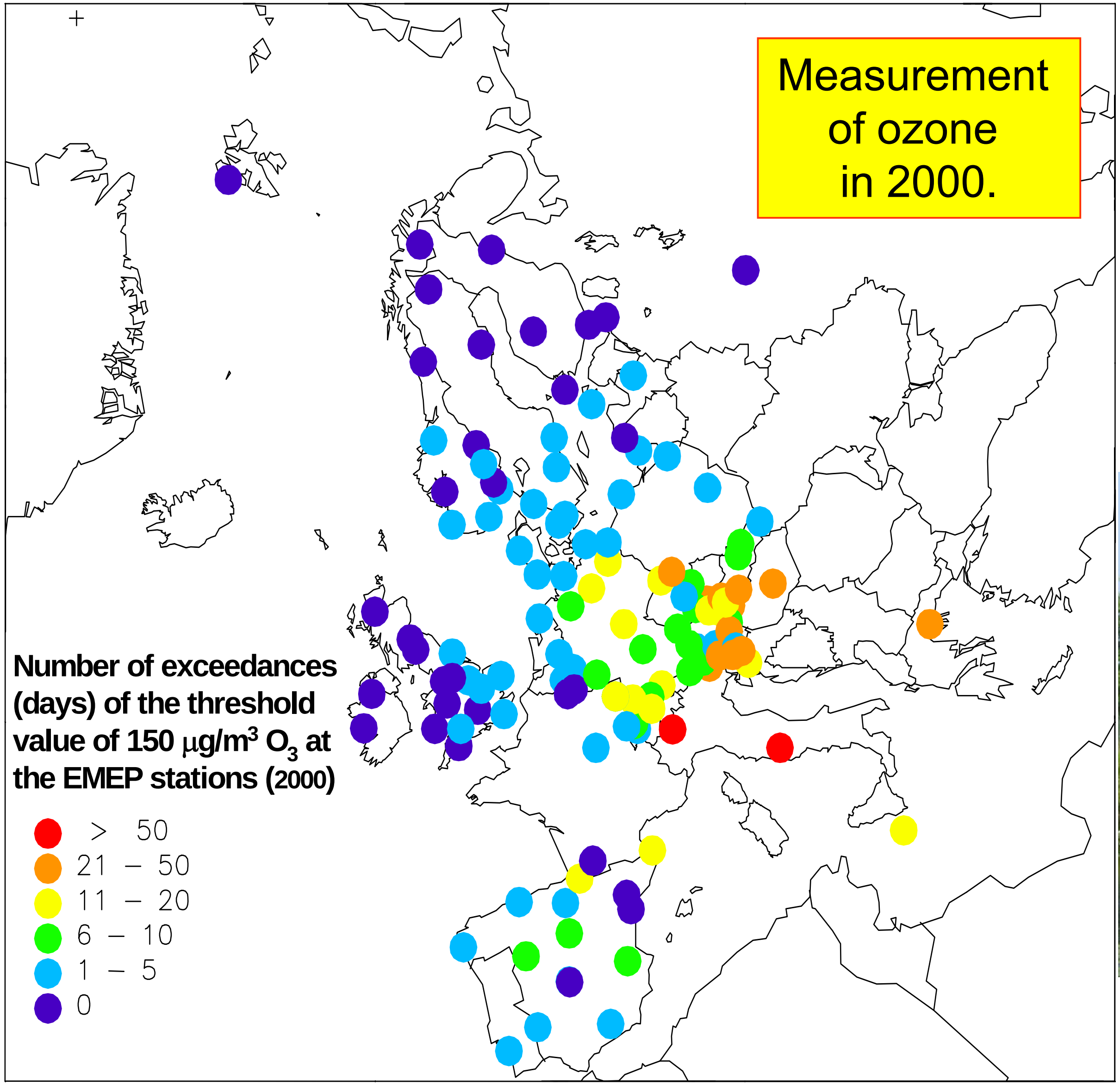
Source: EEA 2018

Regional Trends in SO_2 Emissions 1950 - 2050



Source: UNEP 2012

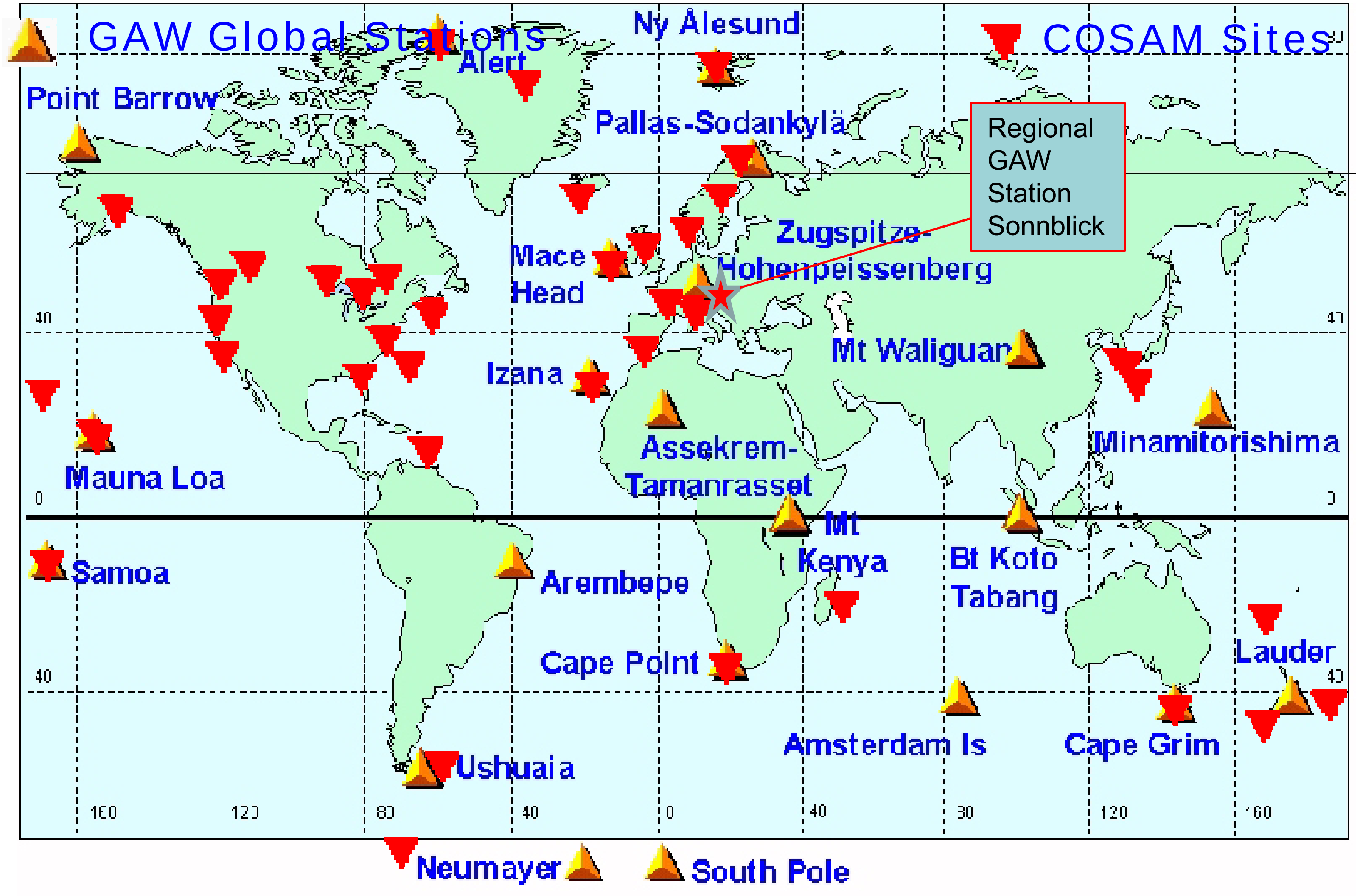
Regional and Hemispherical Transport of Air Pollutants



Source: JRC-IES

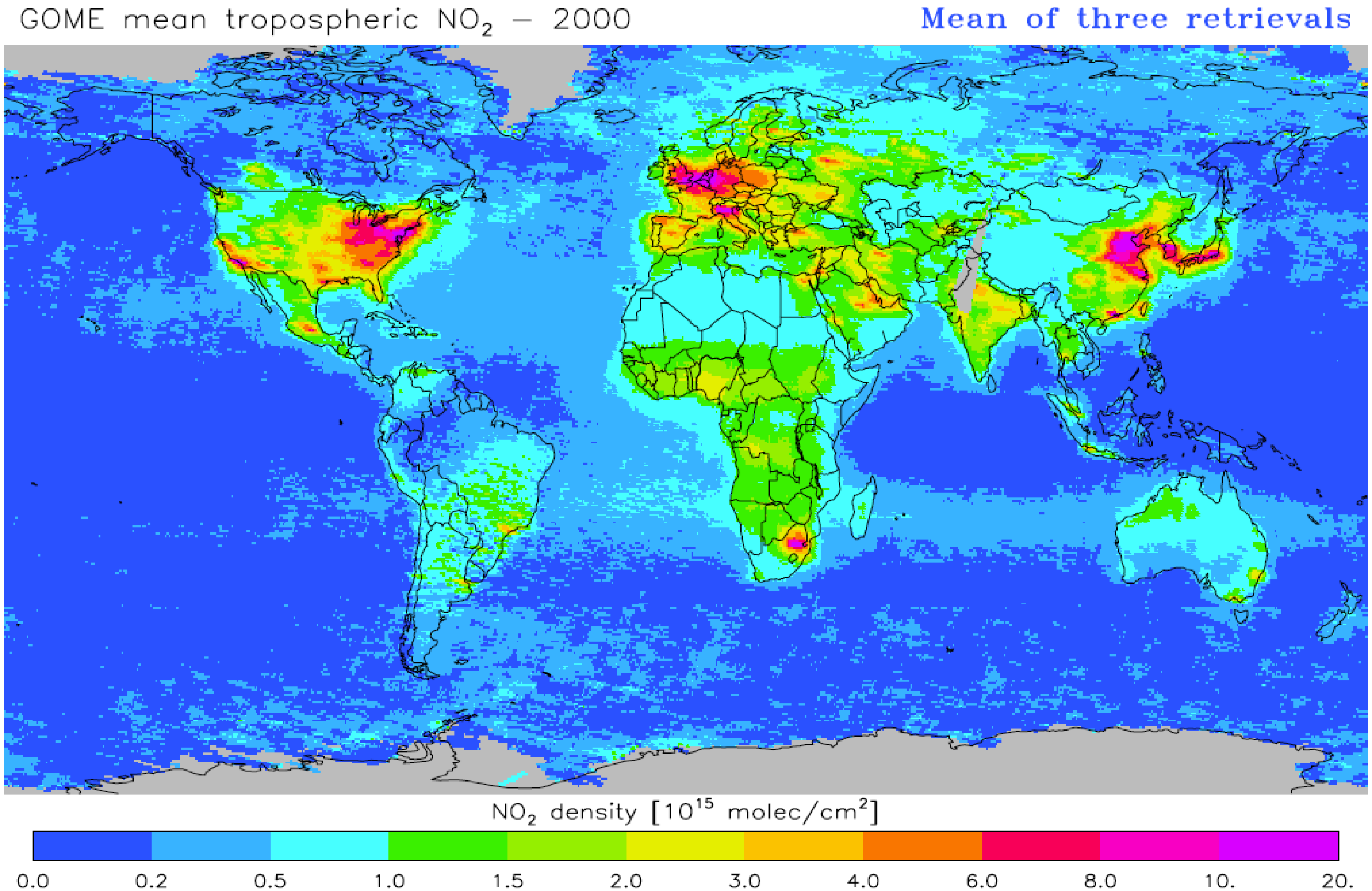
European Network for measuring the long range transport of air pollutants. See also EEA "European Union emission inventory report 1990–2014 under the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP)"

Hemispherical Transport of Air Pollutants



World Meteorological Organisation Global Atmospheric Watch Network
(WMO-GAW)

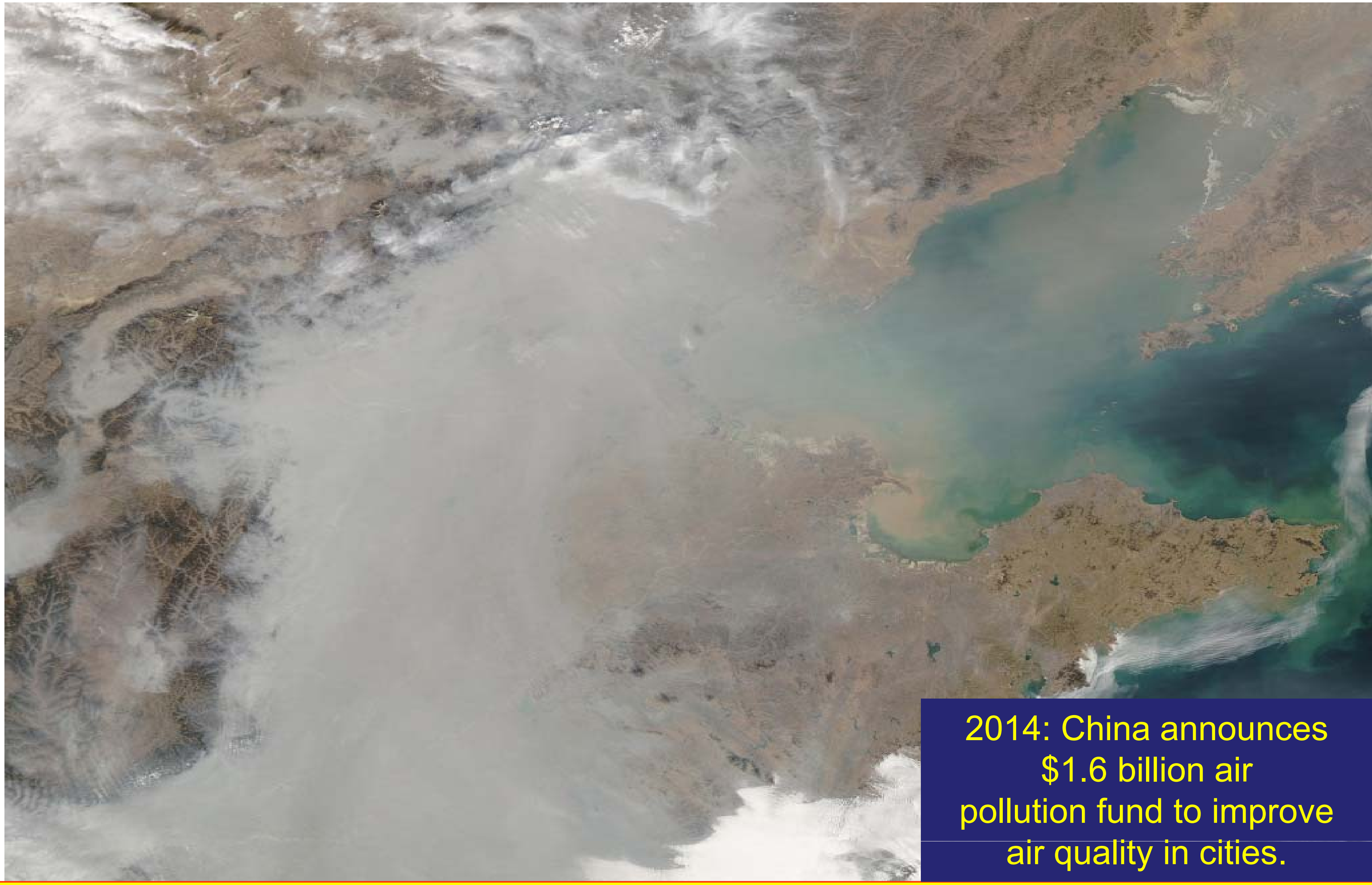
Hemispherical Transport of Air Pollutants



Source: Wikipedia 2010

Global air pollution: Nitrogen dioxide in atmosphere.
Lang range transport can increase ozone levels in Europe by a few ppb.

Global Air Quality



2014: China announces $1.6 billion air pollution fund to improve air quality in cities.

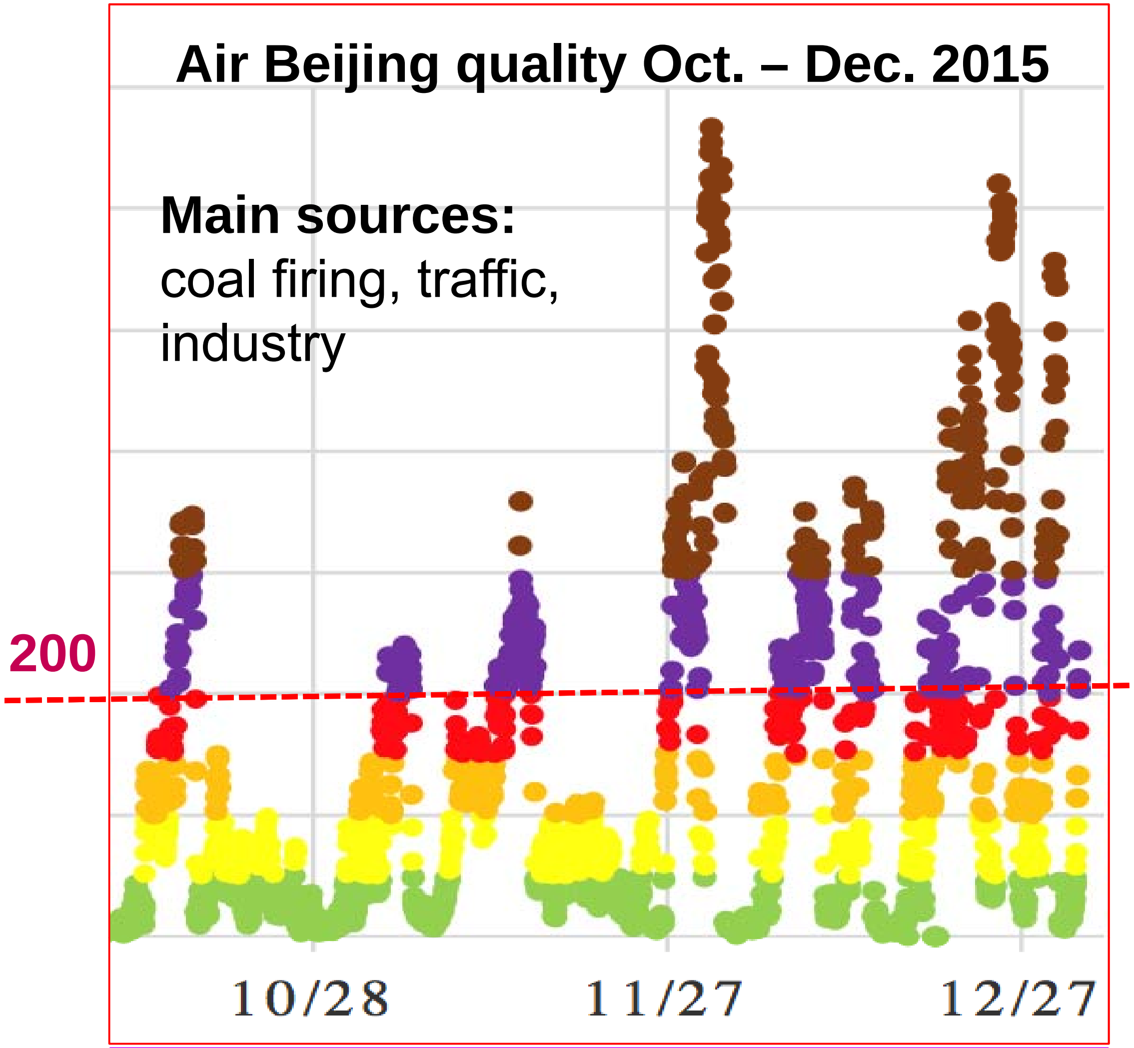
Global air pollution: Urban haze in Beijing area. „Brown clouds“ can travel from SE-Asia to North America and Europe. *Source: Meteosat 2006*

Air Pollution in Beijing

- Air quality indicated as Air Quality Index (AQI) based on the levels of $PM_{2.5}$、 PM_{10}, SO_2, NO_2, O_3 and CO. AQI related to health effects.

AQI	Air Pollution Level
0–50	Excellent
51–100	Good
101–150	Lightly Polluted
151–200	Moderately Polluted
201–300	slight irritations Heavily Polluted medium irritations
300+	Severely Polluted

Source: Wikipedia 2015



PM10: 900 μg/m³ in Jan. 2013 (EU limit 50)

Water Pollution

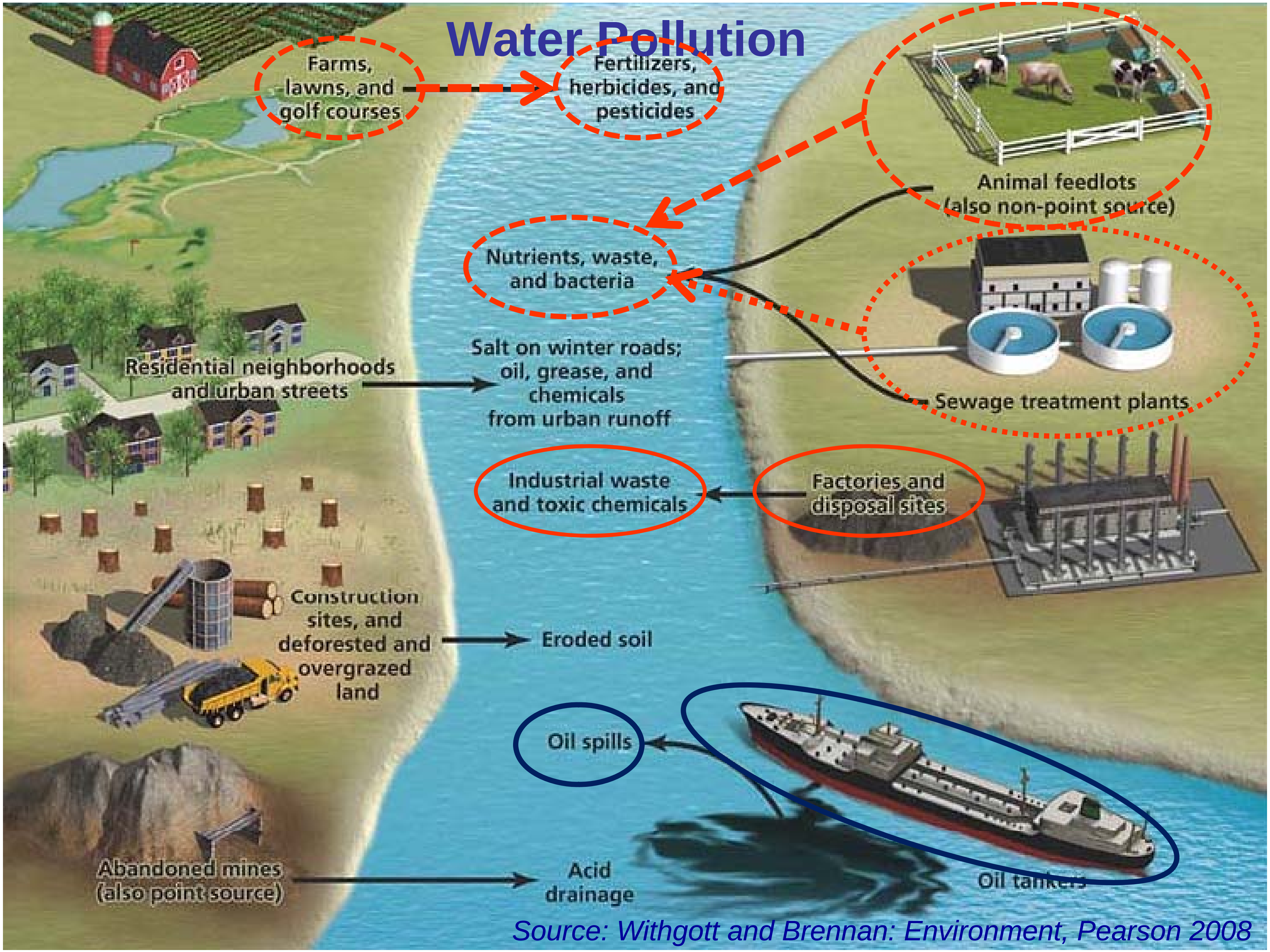
4.2 Water Pollution:

- **Most important causes:**

- ***Industrial waste water discharges:*** heavy metals, organic toxins and oils. Now largely eliminated in EU, USA, Japan. Still a major problem in emerging economies and developing countries.
- ***Agricultural effluents:*** pesticides, herbicides leading to ground water pollution, nutrients from fertilisation leading to eutrophication, manure leading to bacterial contamination.
- ***Human waste water discharge, unprocessed or processed in sewage plants:*** nitrates and phosphates leading to eutrophication and bacterial contamination.
- ***Oil discharges:*** oil spills due to accidents with tankers or in drilling or release of hydrocarbons due to intentional cleaning of oil tanks at the open sea.
- ***Excessive warming of surface waters:*** due to discharges of heated cooling water of thermal and nuclear power stations leading to a depletion of oxygen.

Source: Wikipedia

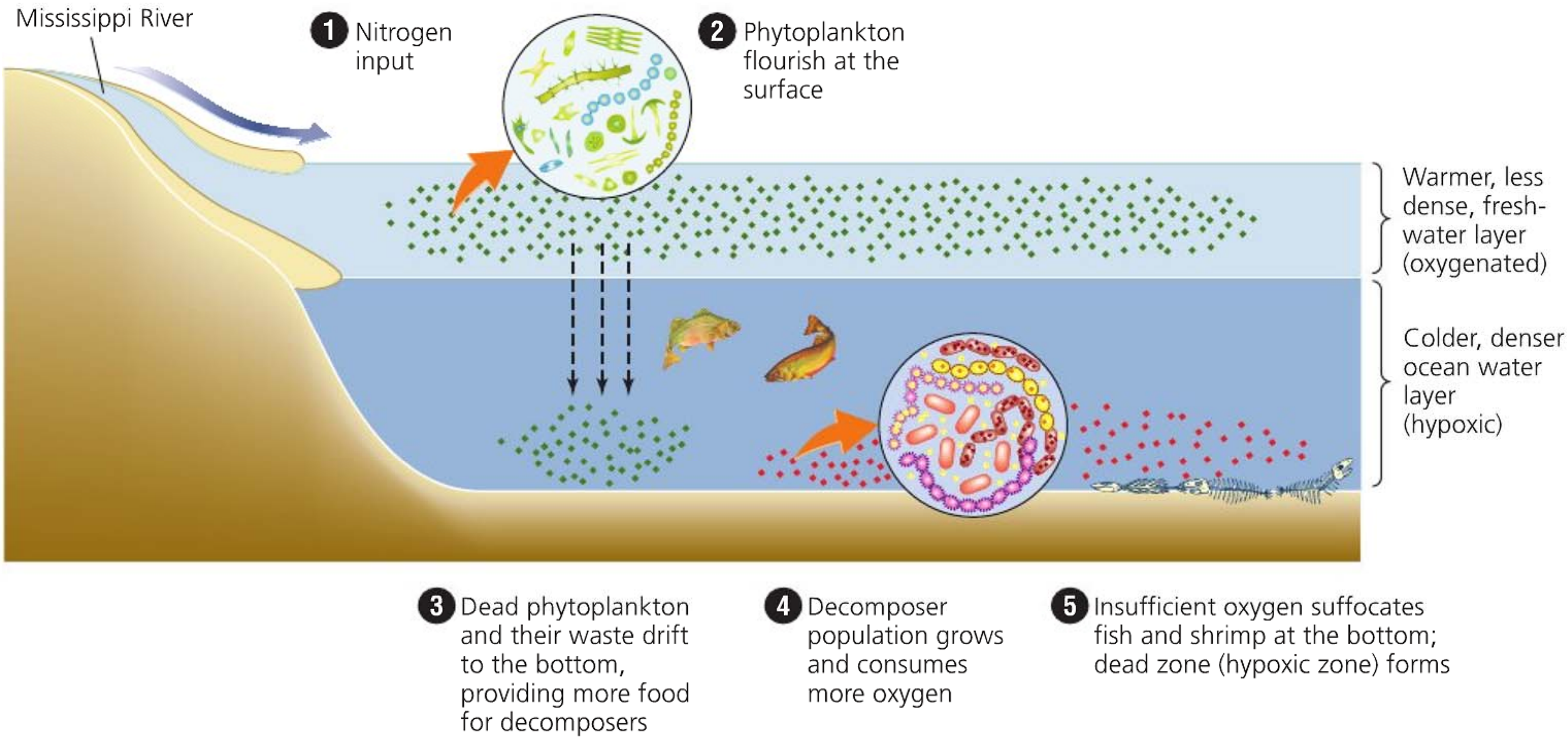
Water Pollution



Source: Withgott and Brennan: Environment, Pearson 2008

Water Pollution: The Eutrophication Process

•**Eutrophication:** high primary productivity (phytoplankton growth) due to a high nutrient input (particularly P and N from waste water and fertilizers).



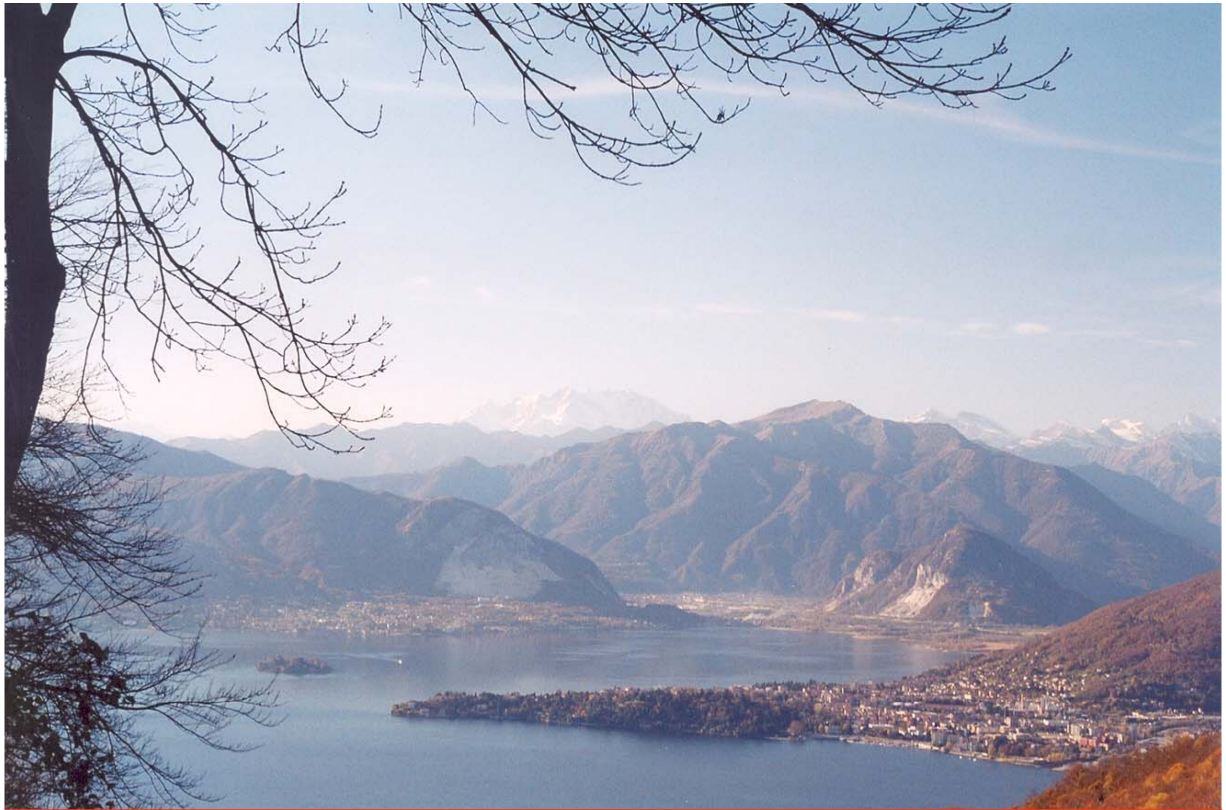
•Eutrophic lakes: excessive algal blooms, murky water and poor water quality.

•The bottom waters of such lakes is deficient in oxygen (no fish).

Source: Withgott and Brennan: Environment, Pearson 2008

Water Pollution: Eutrophication

- About half of the lakes in Europa, America and Asia show eutrification.
- In contrast an **oligotrophic lake** is a lake with low primary productivity, the result of low nutrient content.
- These lakes normally have very clear waters, some even with drinking-water quality.



Lago Maggiore

-The bottom waters of such lakes typically have ample oxygen; thus, such lakes often support many fish species.

-The oxygen content is likely to be higher in deep lakes, owing to their larger hypolimnetic volume.

Water Pollution: Sources of Nutrients

- **Point sources:**
  - Effluents of households and waste water treatment plants, mainly phosphates and nitrates.
  - Phosphates can be eliminated with chemical processing of waste water, nitrates by treatment with bacteria (reduction to nitrogen).
- **Diffuse sources:**
  - Nitrate and phosphate mainly from agricultural activity (manure, fertilisers).
  - Agriculture is main source for nitrate input into ground water, rivers, lakes and coastal waters.
  - Input subject to large spatial and temporal variations (season, precipitation, and other irregular events).
  - High density animal raising can cause massive local and regional pollution of gound water.
  - Use of ferlisers has dramatically increased in all parts of the world during the last 50 years to enhance agricultural yield.

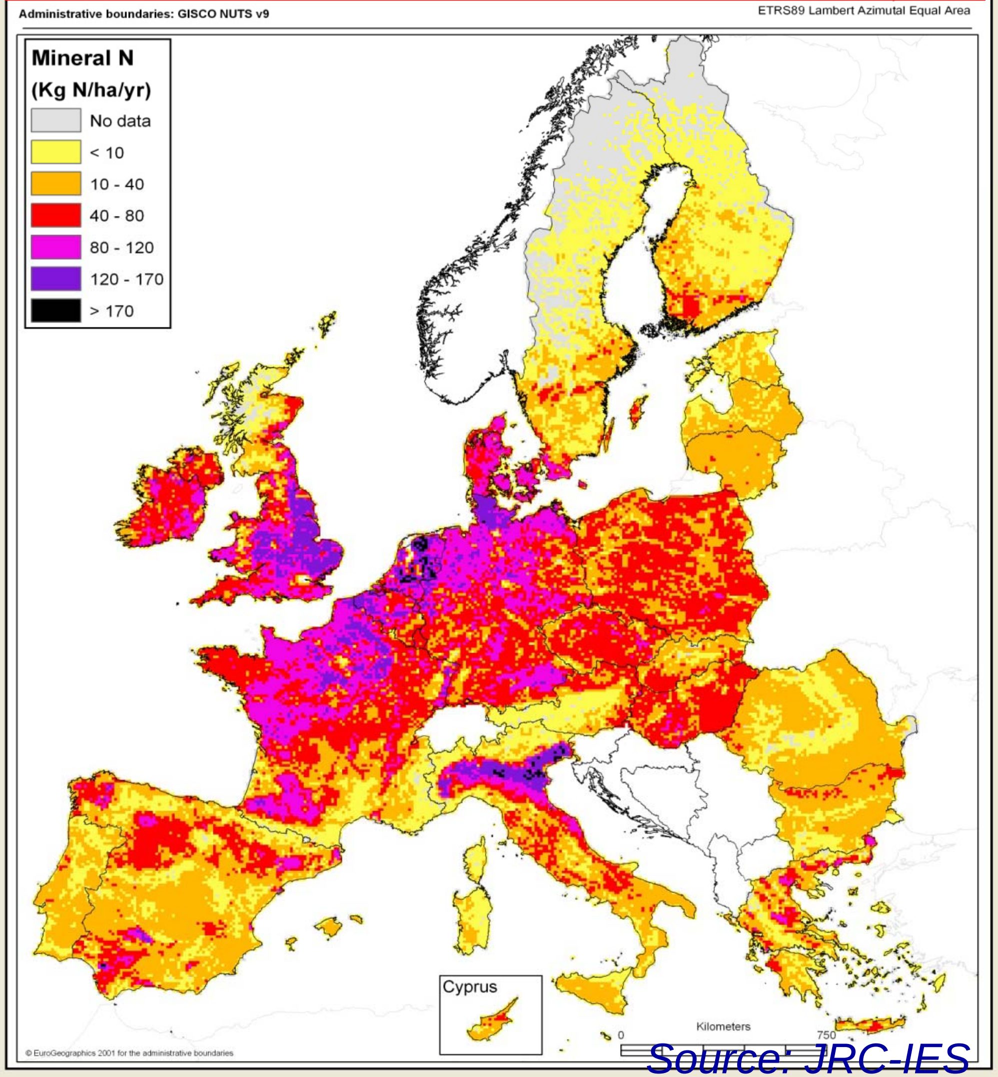
Water Quality and Quantity:
Pollution fromAgriculture

Use of nitrogen fertilisers has increased 10-fold in EU during last 50 years!

Agriculture is the main source of nutrients (and other chemicals) to surface waters leading to eutrophication and groundwater pollution.

- •Nitrates Directive 1991/676/EC
- •Drinking Water Directive 98/83/EC
- •Reform of Common Agricultural Policy (CAP)
- •Rural Development Policy 2006/114/EC

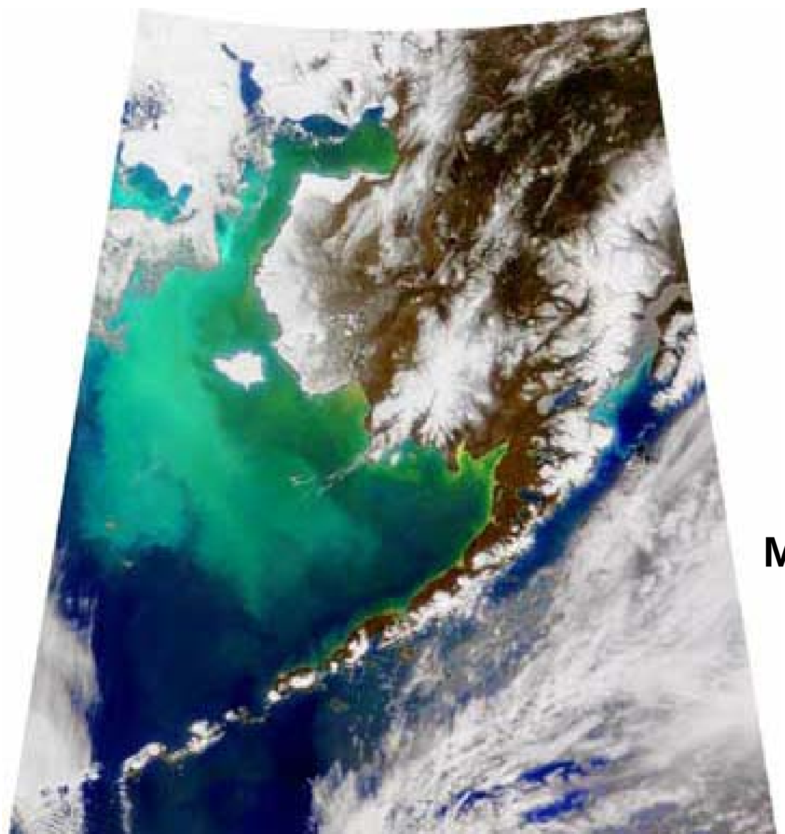
Average application of mineral nitrogen fertilisers in the European Union.



Source: JRC-IES

Water Pollution: Measuring Eutrophication

- A widely-used measure of eutrophication is the determination of algal and cyanobacterial biomass from the chlorophyll concentration.
- Peak values of chlorophyll *a* for an oligotrophic lake are about 1-10 µg/l, while in a eutrophic lake they can reach 300 µg/l.



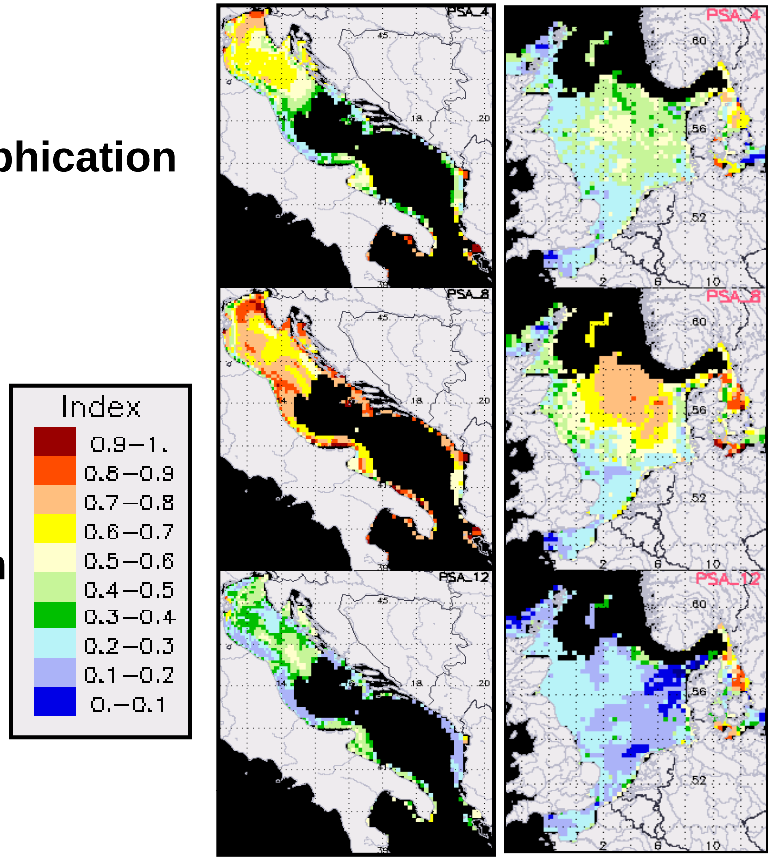
Satellite image of a large coccolithophore bloom in the Bering Sea in 1998.

Eutrophication

High

Medium

Low



April

August

December

Adriatic Sea North Sea

Source: ESA and JRC-IES

Water Pollution: Pathogens

Pathogens are protozoa, viruses or bacteria producing diseases.

- **Bacterial infections are most important:**
- *E. coli* – gastrointestinal disorders
- Campylobacteriosis – one of the most common causes of human bacterial gastroenteritis with fever, headache, and myalgias.
- Legionellosis - cause Pontiac fever and Legionnaires' disease
- Salmonellosis - due to many Salmonella species. Water/food/direct contact borne.
- Typhoid - Salmonella typhi bacteria - gastro-intestinal water/food borne.
- Cholera - Vibrio cholerae bacteria - gastro-intestinal often waterborne.

- **Diarrheal diseases:** are attributable to unsafe water supply, sanitation and hygiene and account for 4% of the total daily global burden of disease (WHO).

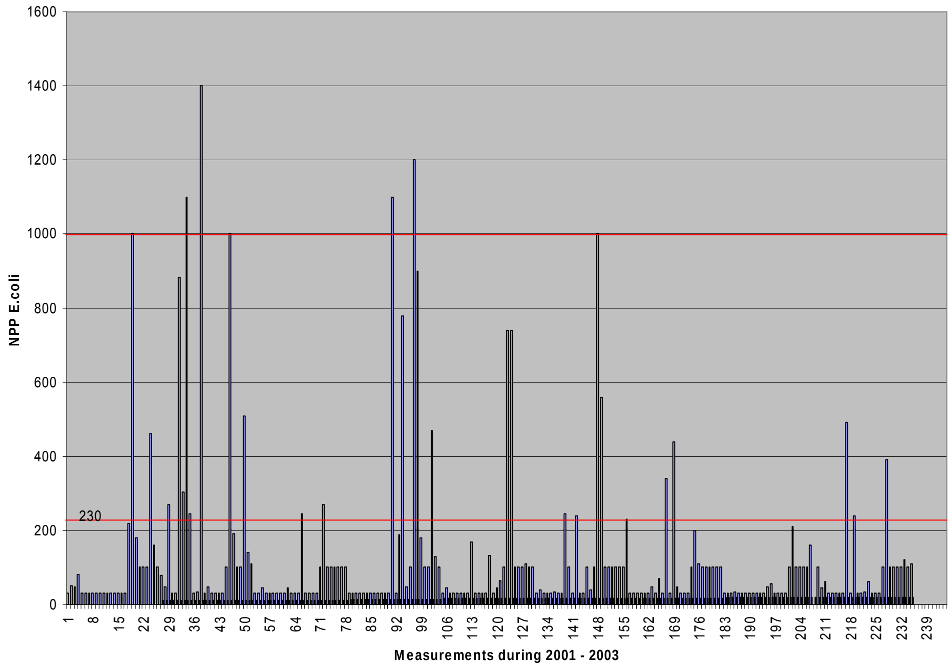
- **Sources for bacterial infections:**
- Mainly contaminated drinking water, used in the preparation of food.

Source: Wikipedia

Water Pollution:
Pathogens

- Coastal zone aquaculture is an important food production sector.
- Strong anthropogenic pressures: freshwater from river inputs rich in pollutants, extensive urbanisation with large amounts of waste wasters can lead to ecosystem functioning disruptions and food contamination.

E. Coli Bacterial Content of Oysters in Etang de Thau 2001 - 2003



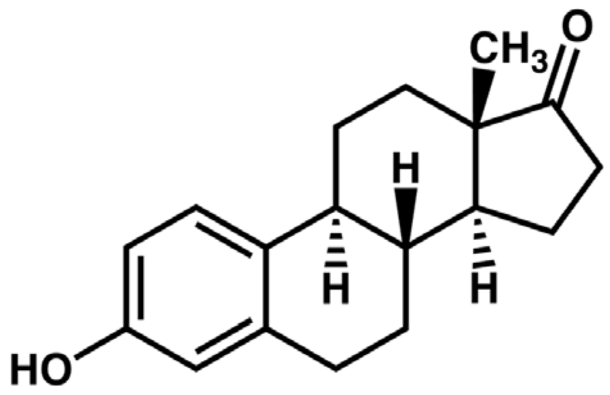
Source: IFREMER

Water Pollution: Chemicals

- **Chemical water pollution:**

- **Major inorganic contaminants:**
  - Nitrates and phosphates from human waste waters, manure and fertilisers.
  - Chemical waste as industrial byproducts.
  - Heavy metals including acid mine drainage (mainly accidents).

- **Major organic contaminants:**
  - Various toxic organic compounds used as insecticides and herbicides.
  - Detergents.
  - Various chemical compounds found in personal hygiene and cosmetic products.
  - Agropharmaceuticals.
  - Human medicines, like estrogens.
  - Petroleum hydrocarbons including fuels.



Water Pollution: Chemicals

- **Transport and chemical reactions of water pollutants**
- Most water pollutants are eventually carried by the rivers into the oceans.
- Many chemicals undergo reactive decay or chemically change especially over long periods of time in groundwater reservoirs.
- Toxins climb the foodchain. Each successive step up the food chain causes a stepwise concentration of pollutants such as heavy metals (e.g. mercury) and persistent organic pollutants such as DDT. This is known as biomagnification or bioaccumulation.
- Widespread chemical contaminations of food have occured with
– methyl mercury (fish – Minamata 1956, 1.800 people died)
– PCBs (chicken meat – Belgium 1999, no victims)
– dioxins (morzarella – Italy 2008, chicken products – Germany 2011, no victims)

Water Quality and Quantity:
General Problems in Europe

- About one quarter of all European ground water bodies are threatened by chemical pollution (particularly nitrate and pesticides).
- Widespread acidification of lakes in Northern Europe.
- Reduction of biodiversity in European water bodies.
- European seas threatened by eutrophication.
- Coastal zones under heavy pressure.
- Wide-spread over-consumption of water, particularly in the South of Europe.
- Water scarcity affects now already 100 million people in Europe.
- Climate change may enhance extreme weather events.

see also EEA Report 2018 "European waters - assessment of status and pressures"

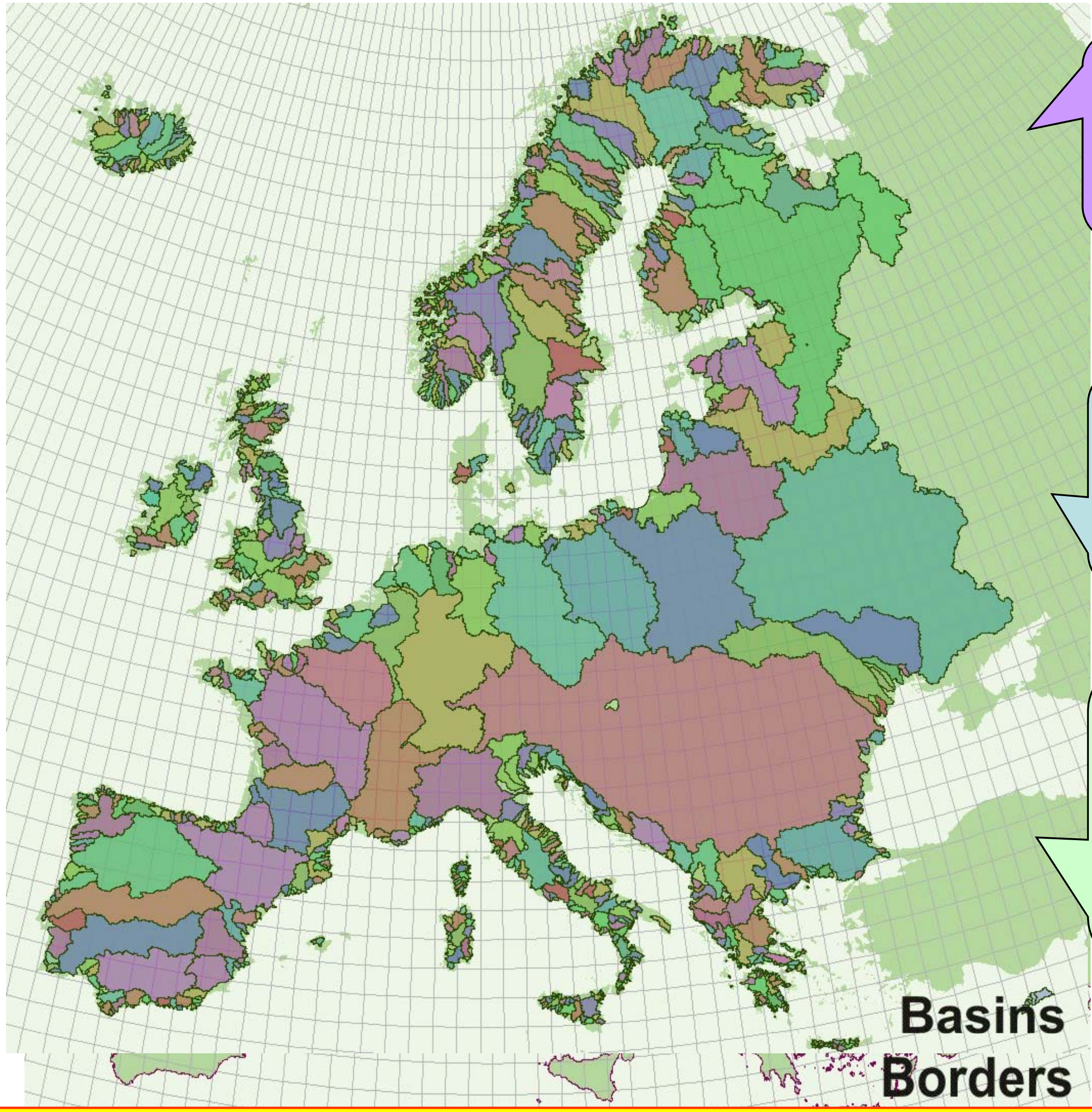
https://www.eea.europa.eu/publications/state-of-water (2018)

Water Framework Directive 2000/60EC
Marine Thematic Strategy 2006
REACH Directive 2006
PROTOCOL on Integrated Coastal Zone Management in the Mediterranean 2008

Water Quality and Quantity:
The Water Framework Directive

European Rivers.
Source: JRC-IES.

Water Quality and Quantity:
The Water Framework Directive



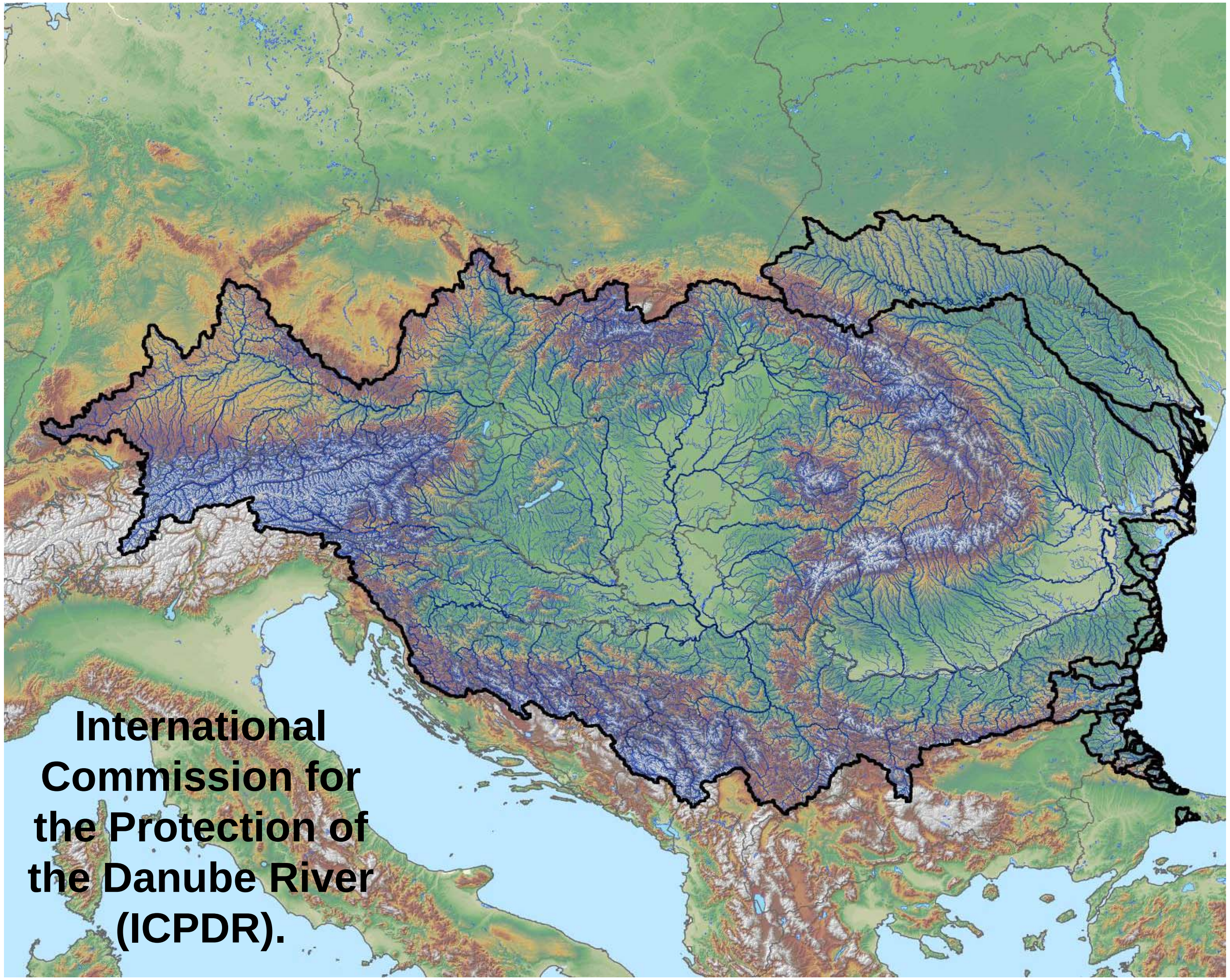
Integrated impact-based river basin management

Ecosystem approach: Holistic assessment of surface water status

Ambitious objectives: “good surface water status” by 2015, and prevention of deterioration

European River Basin Management. *Source: JRC-IES.*

Water Quality and Quantity:
The Water Framework Directive



Management for Danube River Basin.
801.463 km², 81 million inhabitants, 19 countries. *Source: JRC-IES*

Water Quality and Quantity:

The Water Framework Directive (WFD)

Chemical status
(surface and ground water)

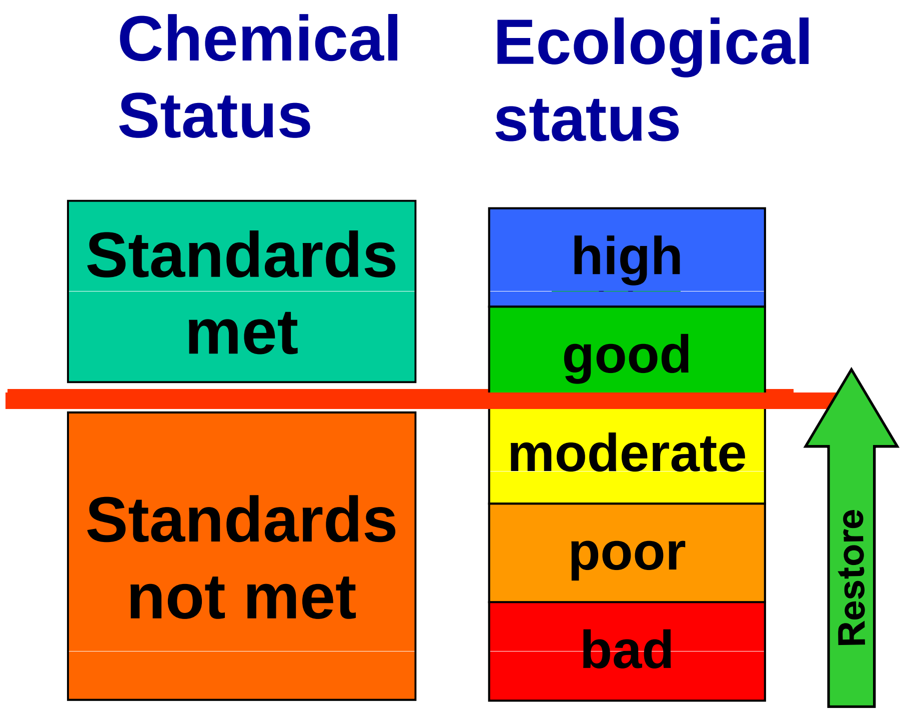
Levels of chemicals meet environmental quality standards in good status.

32.000 monitoring sites.

Ecological Status (surface water)

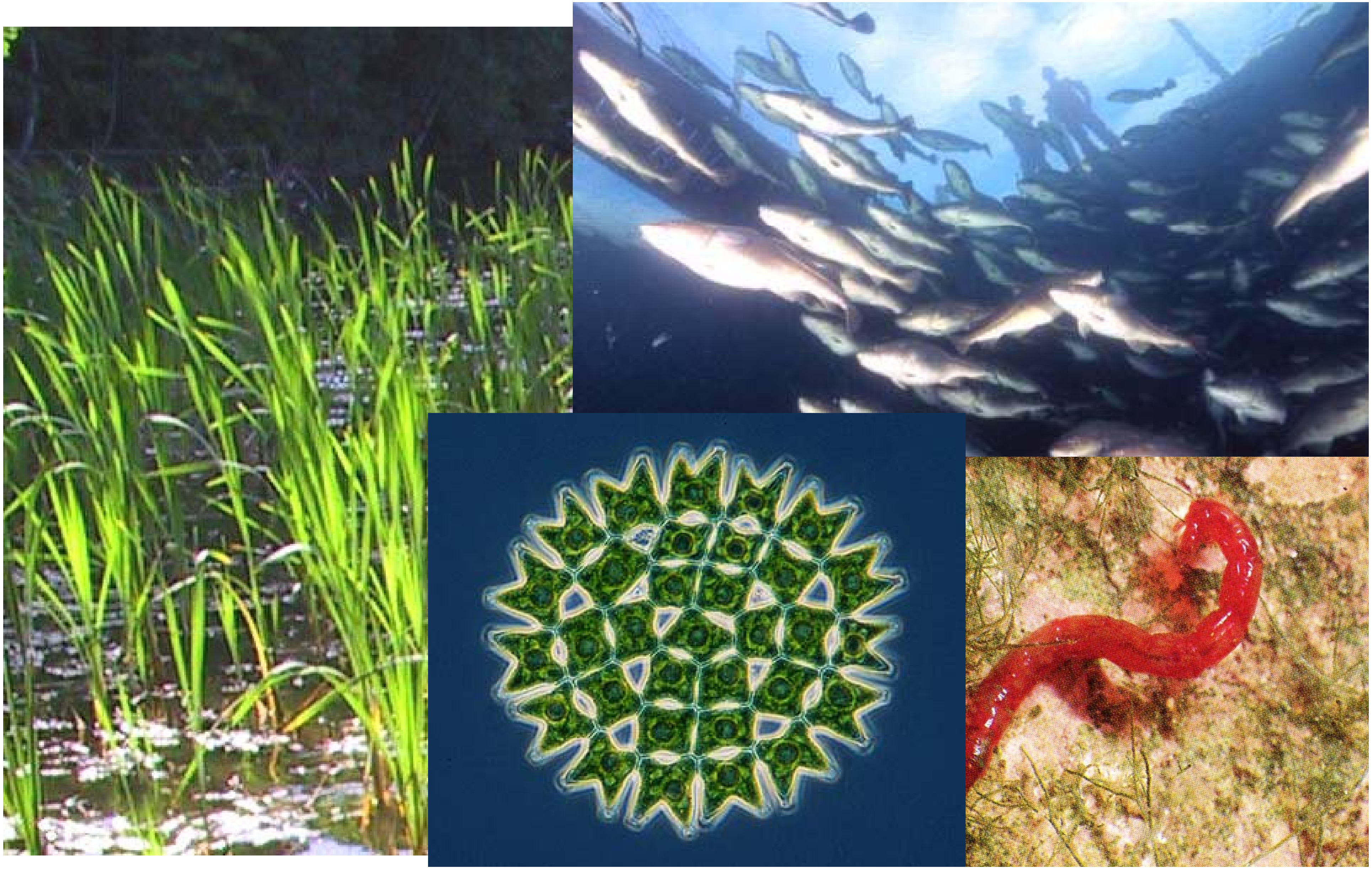
Based on biological quality indicators and ecological boundary setting.

52.000 monitoring sites.



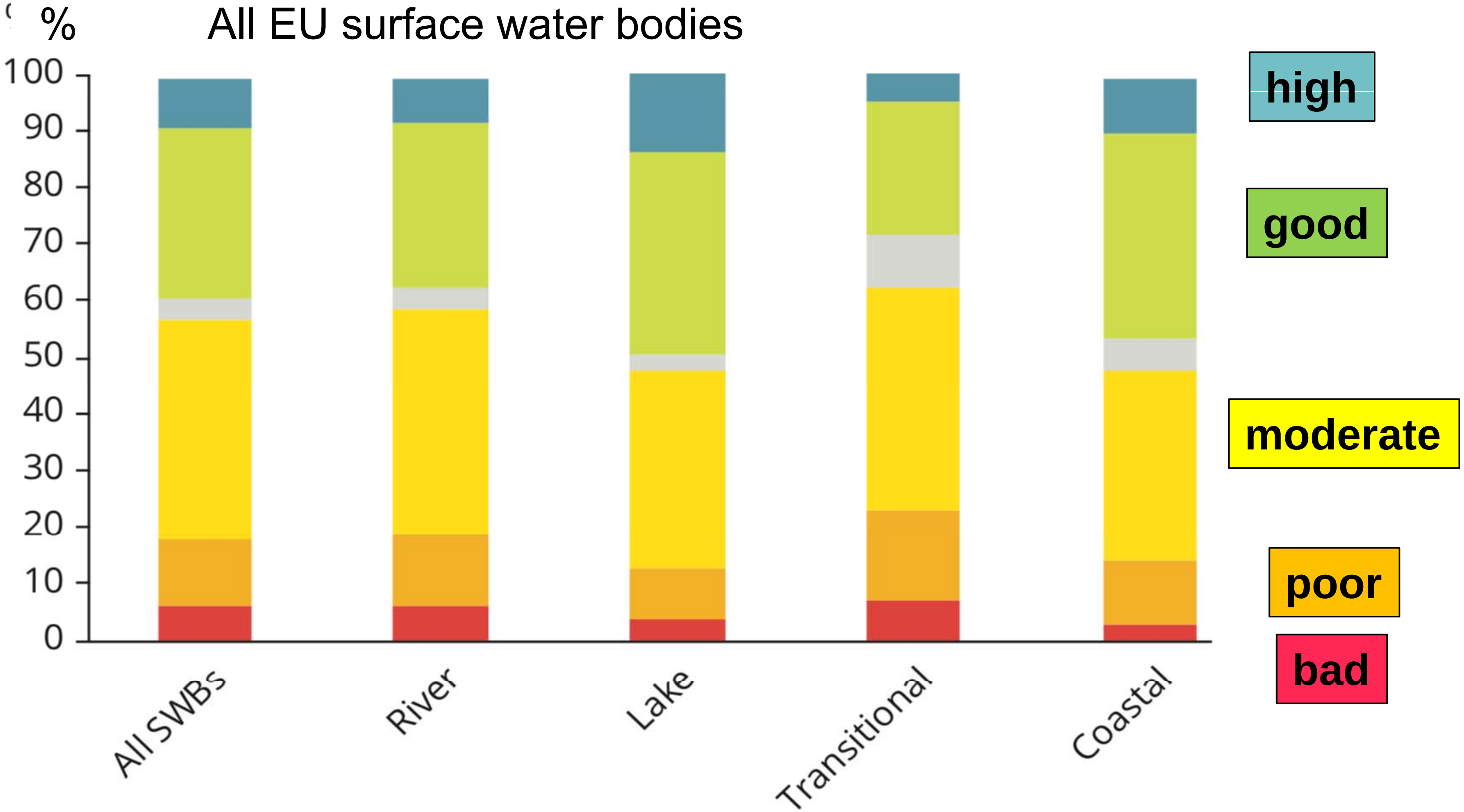
Water Framework Directive:
Ecosystem approach to water quality management.
Source: JRC-IES

Water Quality and Quantity:
Ecological Parameters



Water Quality and Quantity:

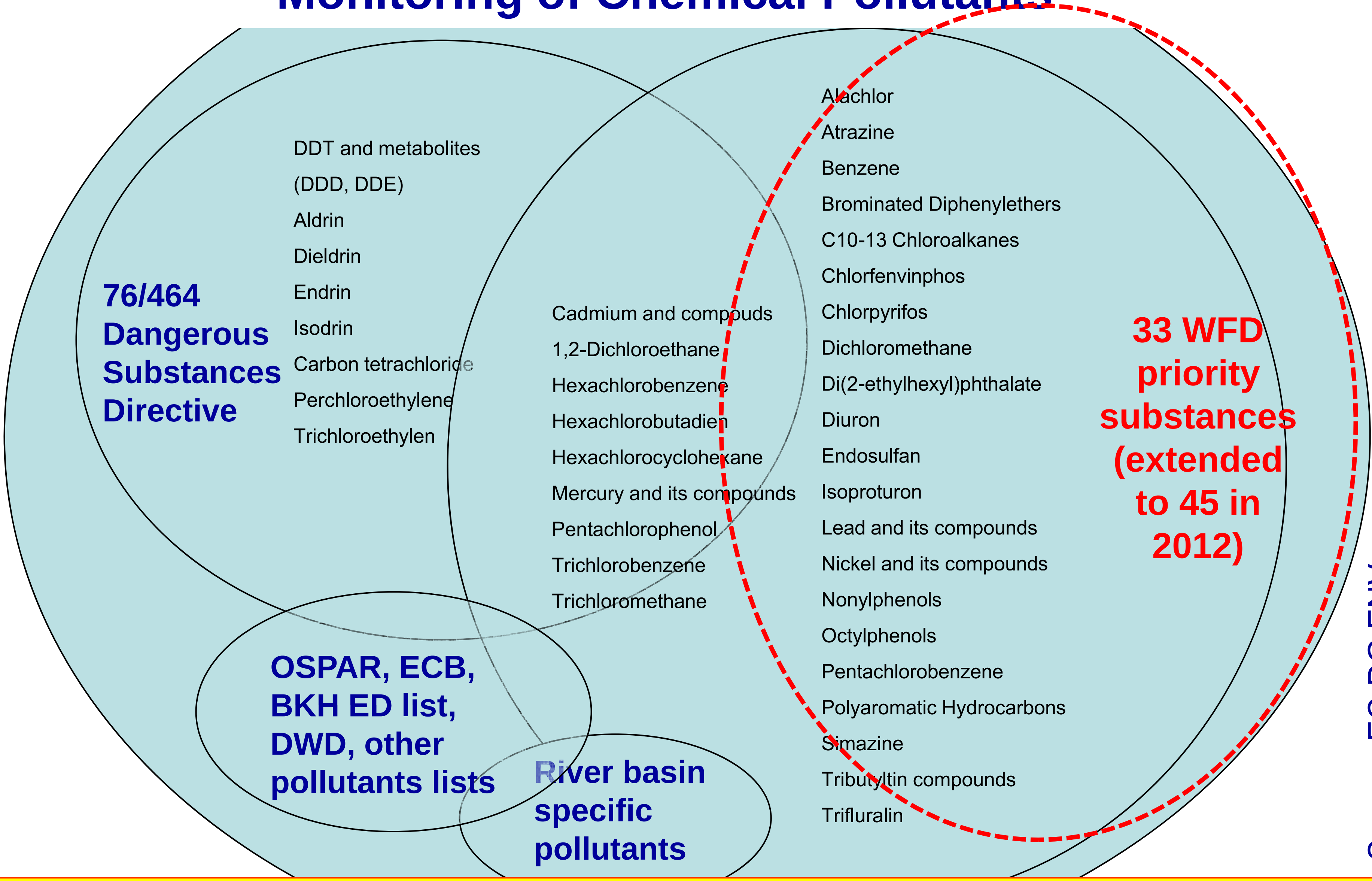
Ecological Status of Surface Waters 2016-2017



- Overall, around 40% of the surface water bodies are in good or better eological status, while 60% did not achieve good status.

https://www.eea.europa.eu/publications/state-of-water 2018

Water Quality and Quantity:
Monitoring of Chemical Pollutants



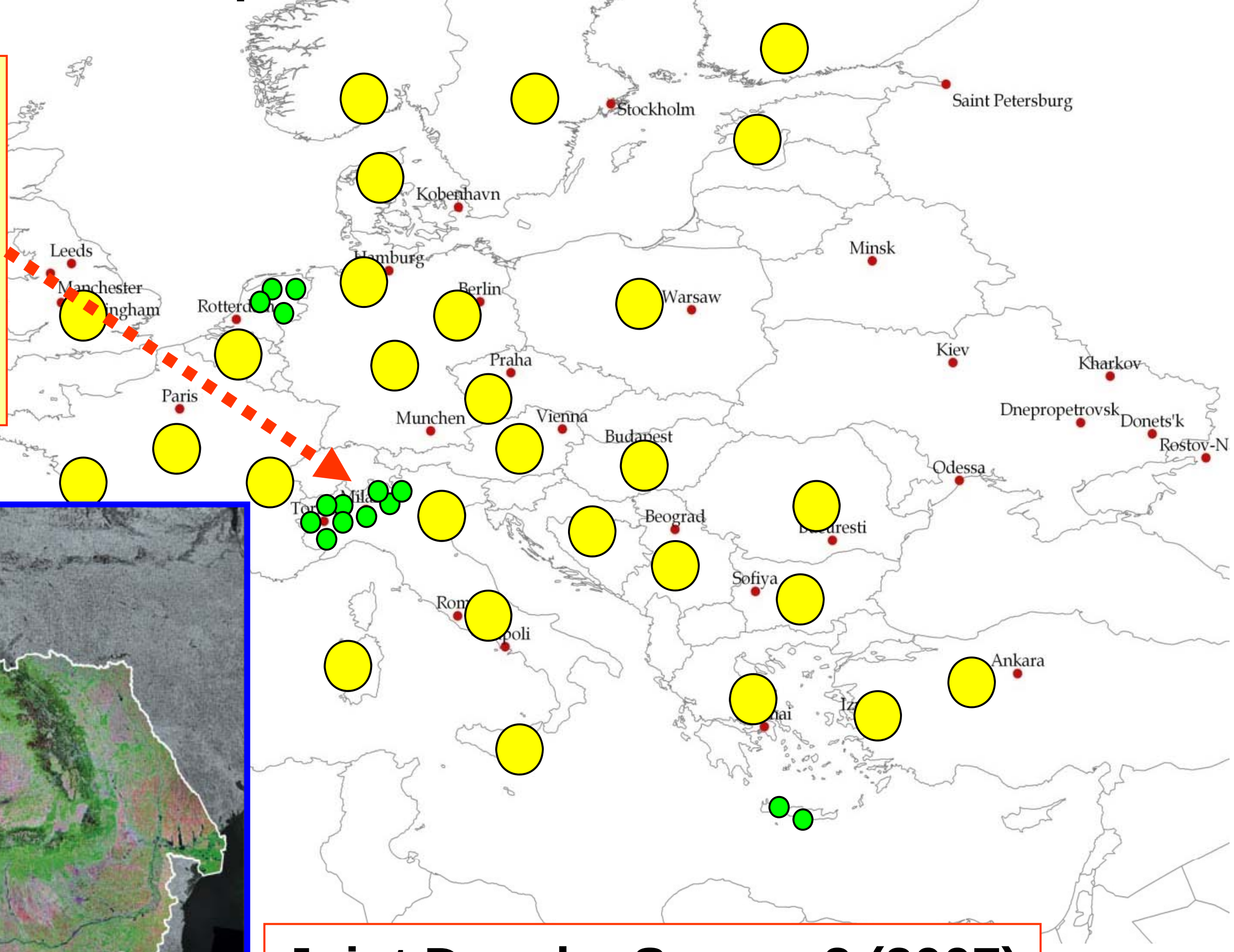
Source: EC-DG ENV

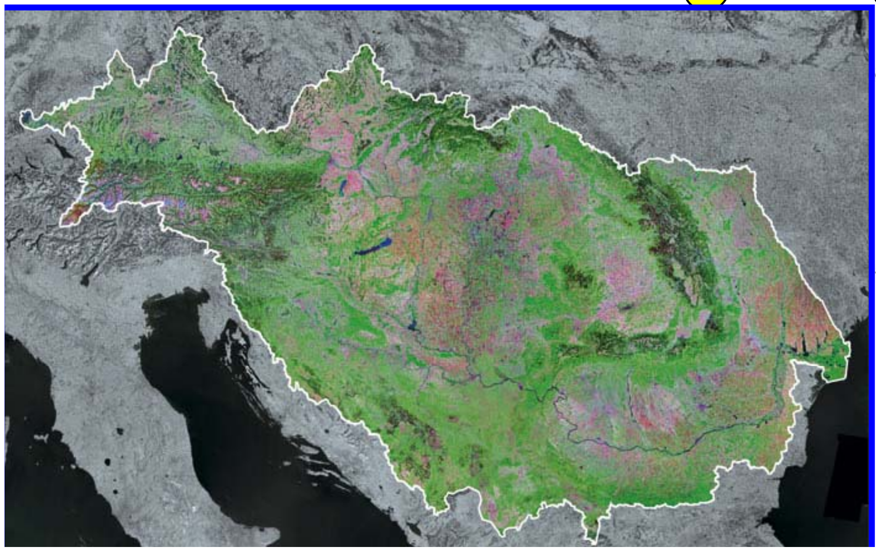
100 million tons of toxic chemicals produced in EU *(EUROSTAT 2008)*
>100.000 chemical compounds produced in industrial scale

Water Quality and Quantity:
Emerging Pollutants

Screening programme for the presence of “new substances” in European water bodies.

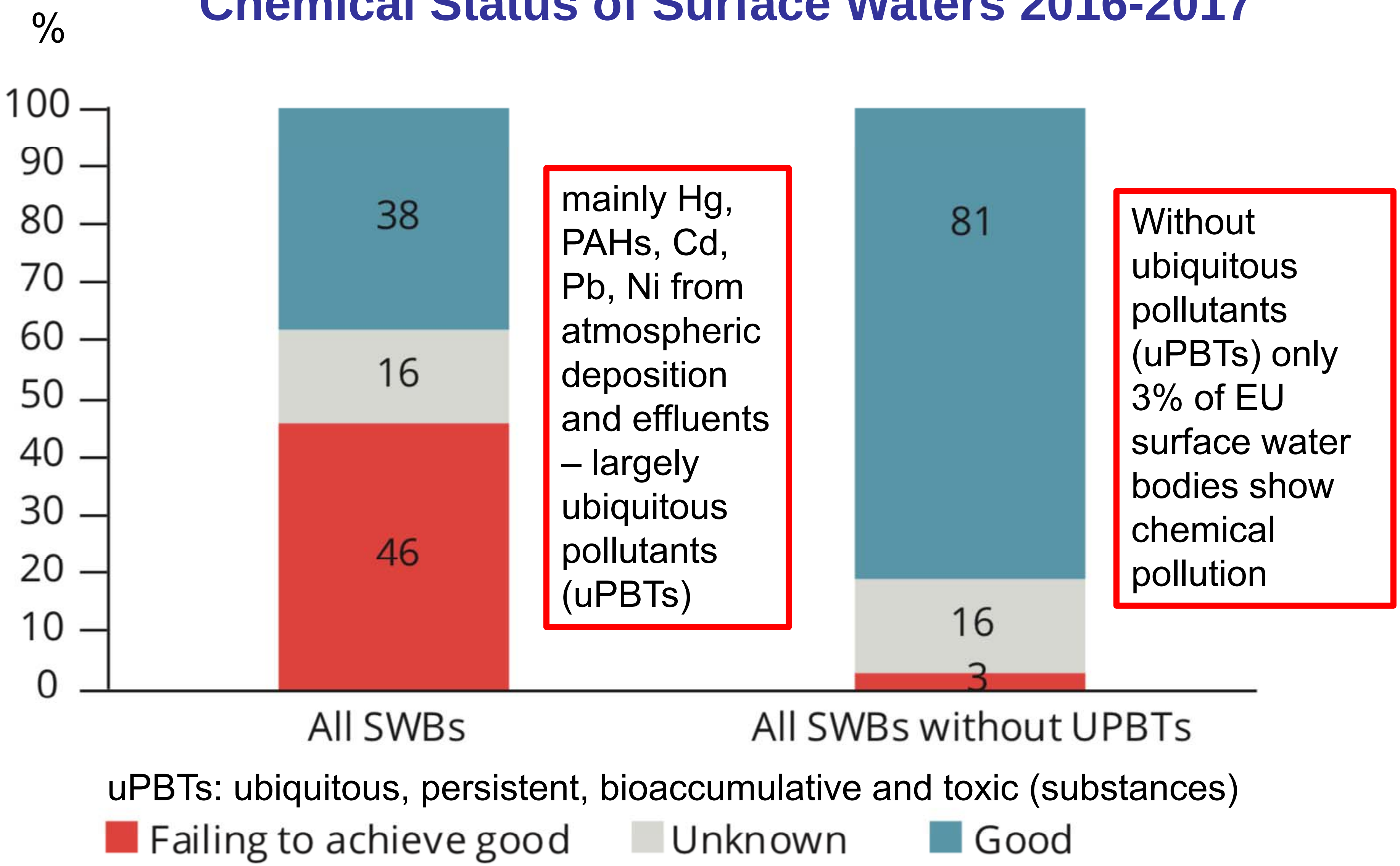
Po watershed a major source for Per-Fluoro-Octanoic Acid (PFOA):
4 tons per year discharged to the sea.
PFOA is carcinogenic.





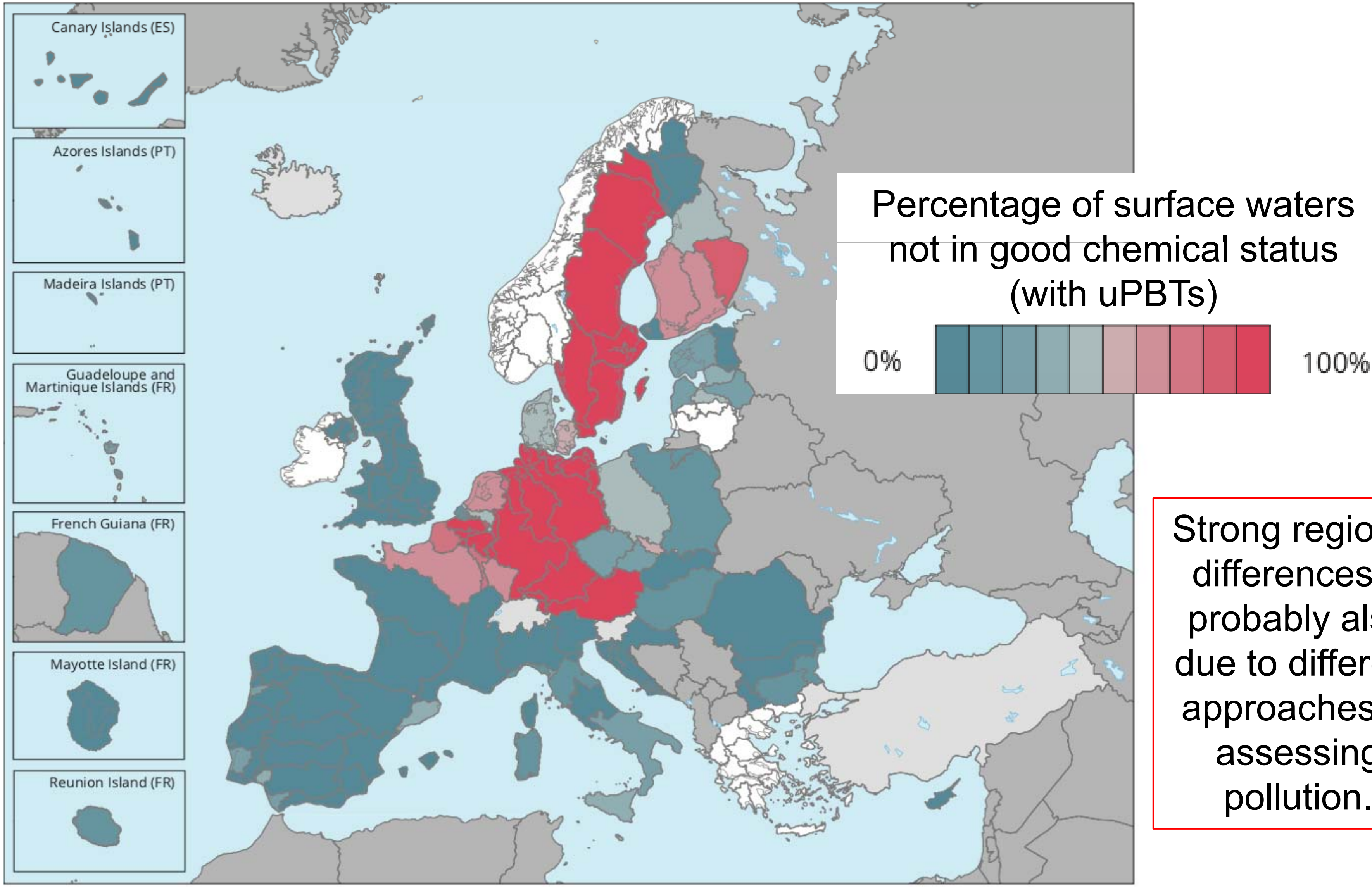
Joint Danube Survey 2 (2007)

Water Quality and Quantity:
Chemical Status of Surface Waters 2016-2017



https://www.eea.europa.eu/publications/state-of-water 2018

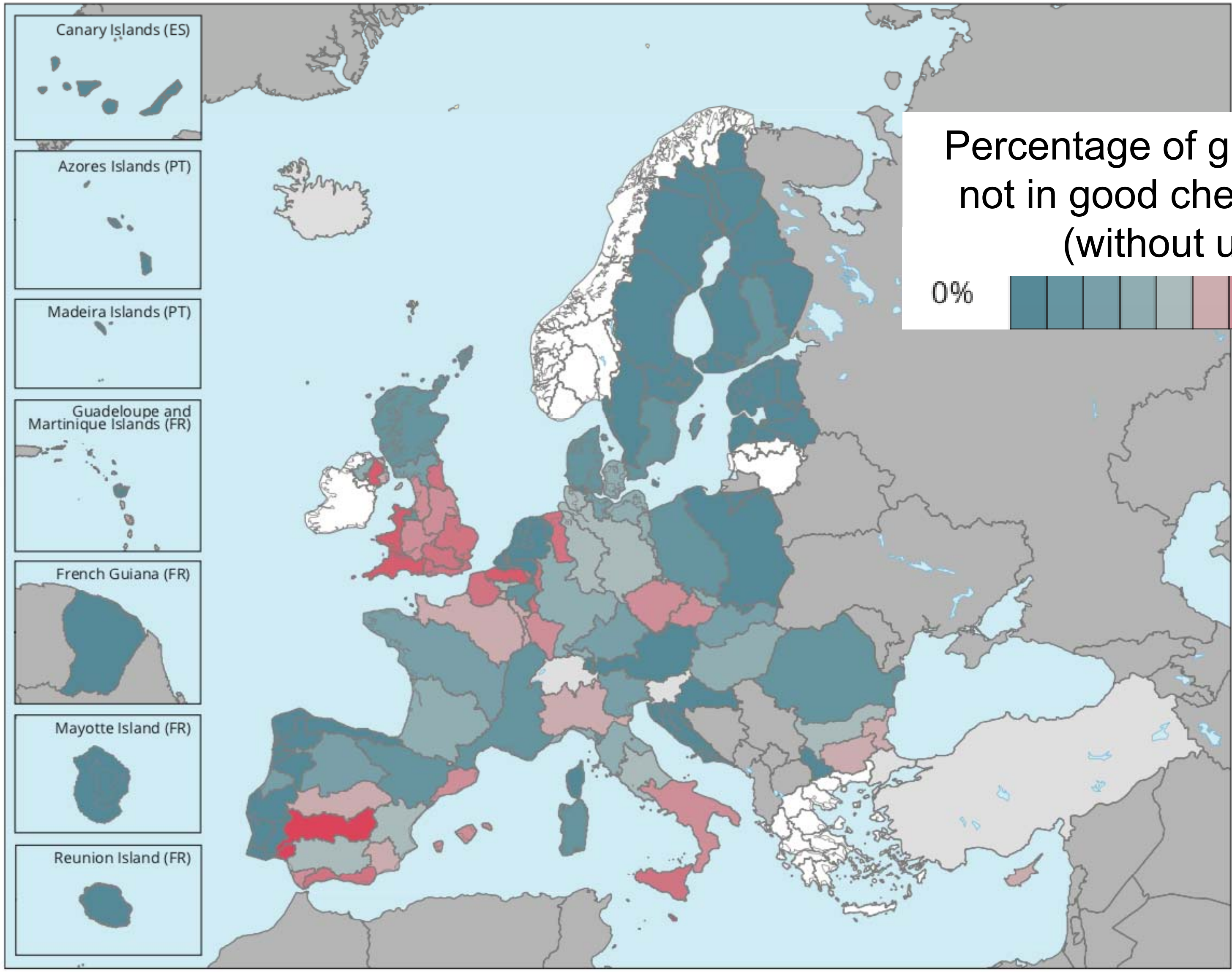
Water Quality and Quantity:
Chemical Status of Surface Waters 2016-2017



Strong regional differences – probably also due to different approaches in assessing pollution.

https://www.eea.europa.eu/publications/state-of-water 2018

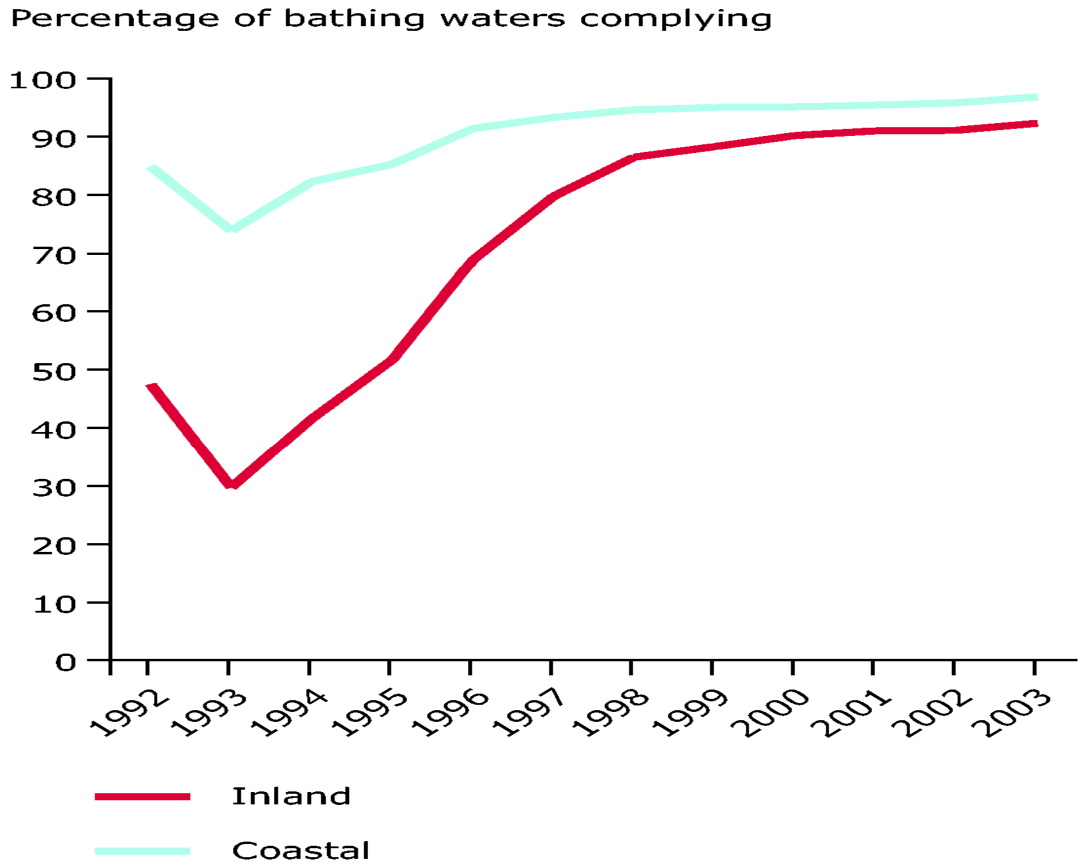
Water Quality and Quantity:
Chemical Status of Ground Waters 2016-2017



Overall only 26% of EU ground waters do not have good chemical status. Main pollutants: nitrates and pesticides. Locally other priority pollutants (160 different ones detected).

https://www.eea.europa.eu/publications/state-of-water 2018

Water Quality and Quantity:
Bathing Waters



- Bathing Water Directives 76/160/EC and 2006/7/EC

- The quality of water at designated bathing beaches in Europe (coastal and inland) has improved throughout the 1990s and early 2000s.

- Already in 2003, 97% of coastal bathing waters and 92% of inland bathing waters complied with the mandatory standards.

Source: EEA 2005.

See also EEA Report 2012 „ European bathing water quality in 2011"
http://www.eea.europa.eu/publications/european-bathing-water-quality-in-2011

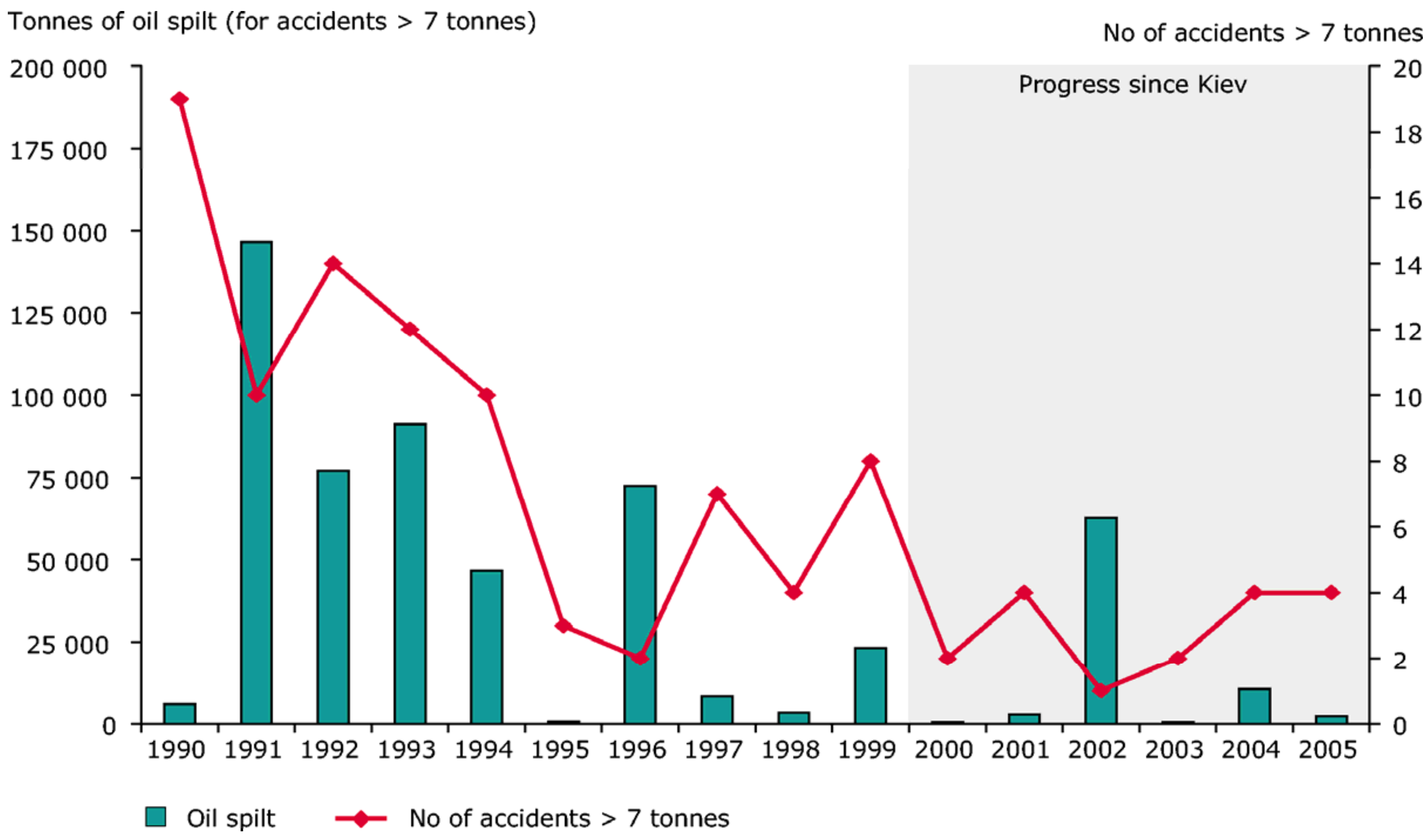
Percentage compliance of EU coastal and inland bathing waters with mandatory standards of the bathing water directive, 1992 to 2003 for EU-15.

Water Quality and Quantity: Coastal Zones

- **Strong anthropogenic pressures:**
  - –freshwater inputs rich in nutrients/pollutants leading to algal blooms,
  - –population growth/tourism in coastal areas,
  - –fish and shellfish farming (500.000 tons of molluscs annually), leading to anoxic crises.

Sustainable coastal zone management largely lacking.

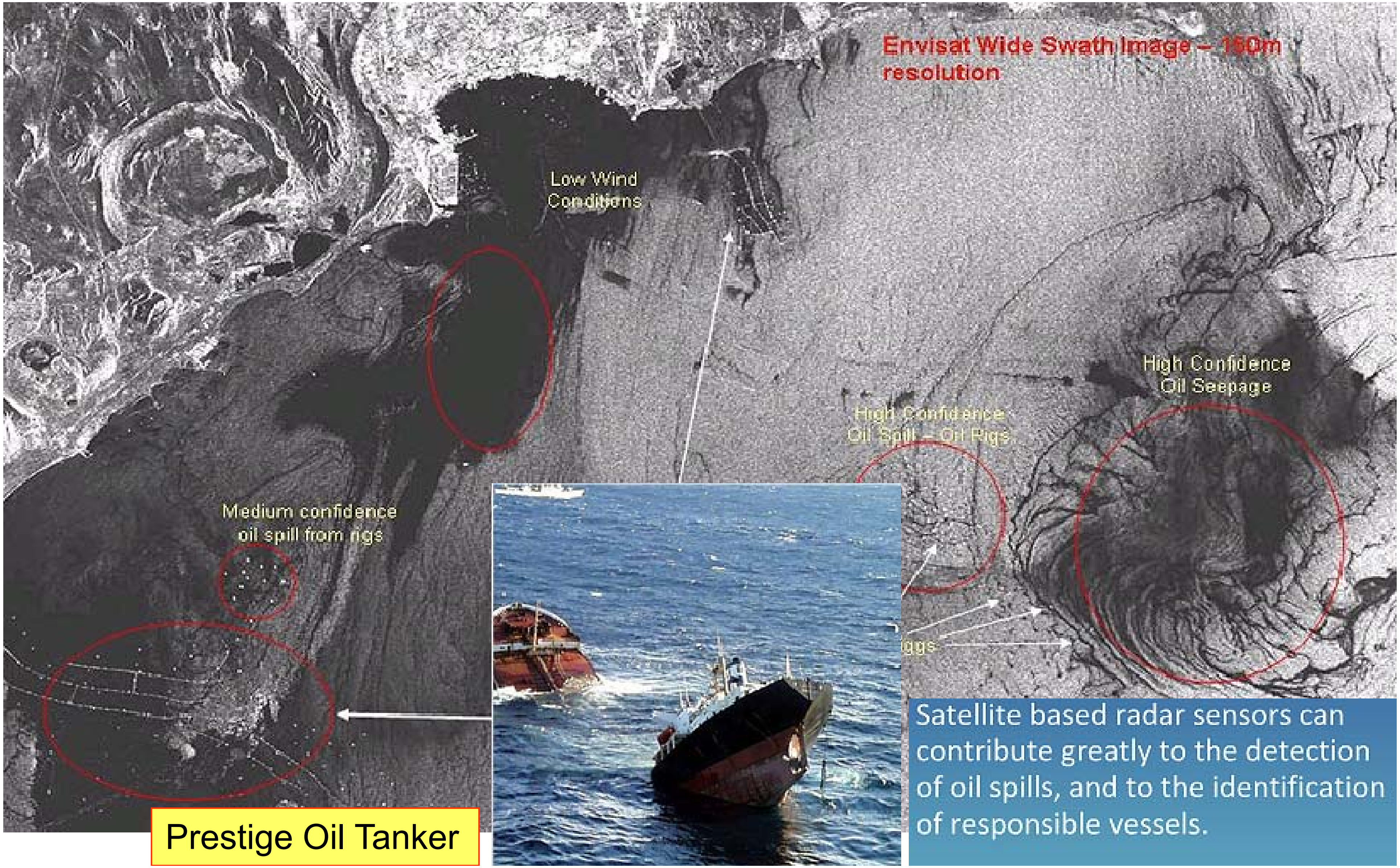
Water Quality and Quantity:
Oil Contamination



Accidental oil tanker spills in European seas.
Copyright EEA, Copenhagen, 2005.

Water Quality and Quantity:

Oil Contamination - Detecting and Monitoring Oil Spills



Prestige Oil Tanker

Satellite based radar sensors can contribute greatly to the detection of oil spills, and to the identification of responsible vessels.

Importance of Soil

4.2 Soil Pollution

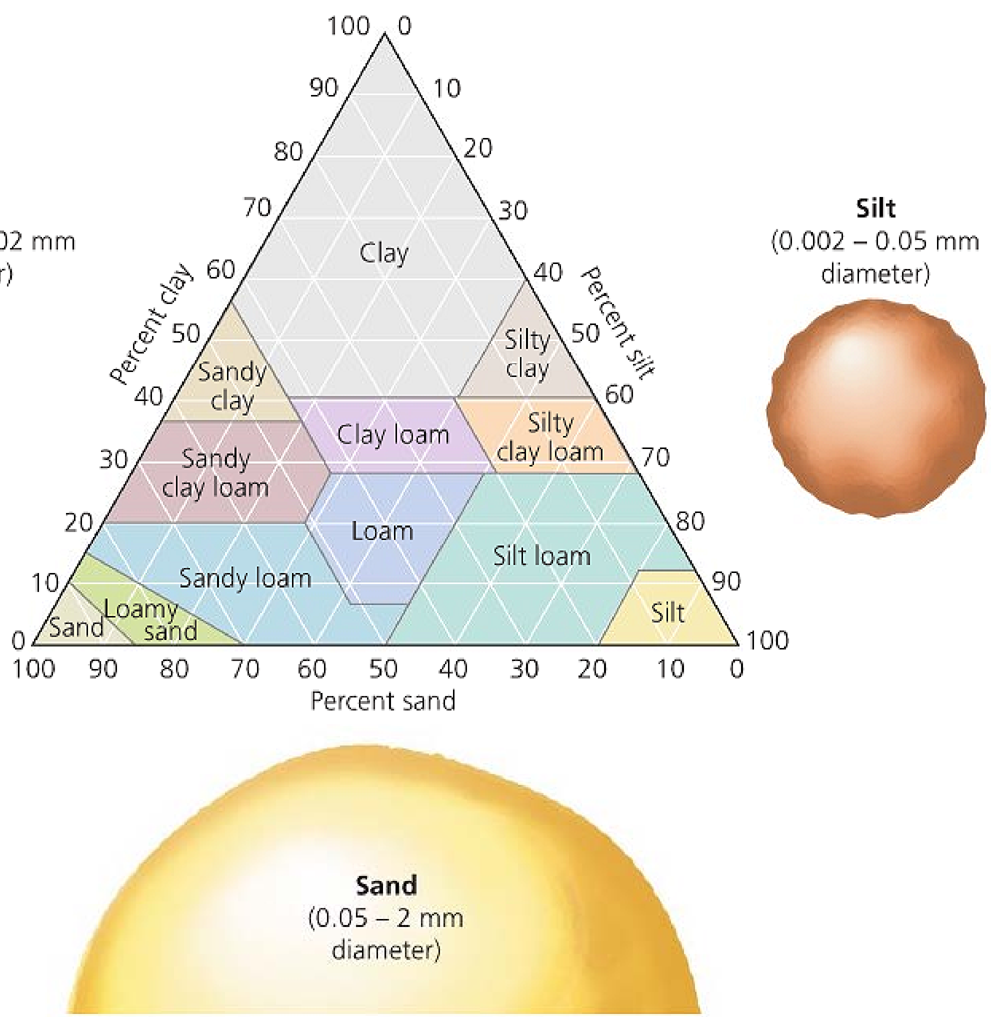
“Man…despite his artistic pretensions and many accomplishments, owes his existence to a thin layer of topsoil …and the fact that it rains”.
Old Chinese Proverb

The soil of Europe is a diverse, valuable and non-renewable resource that should be safeguarded.

Soil Texture

- Soil texture refers to sand, silt and clay composition affecting soil behavior, like the retention capacity for nutrients and water.

- Clay is the product of chemical weathering.
- Clay soil has high retention capacity for nutrients and water.



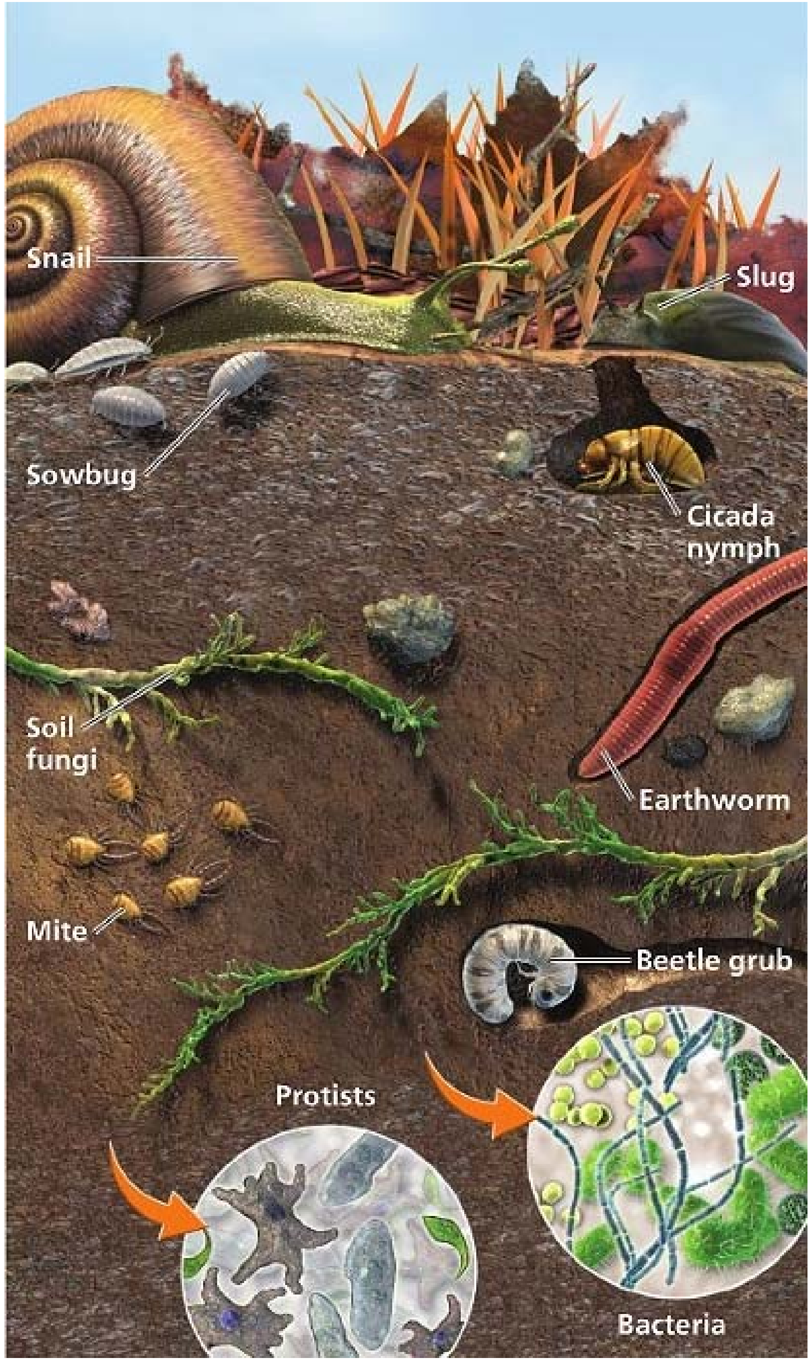
- Sand and silt are the products of physical weathering.
- Silty and sandy soils are more sensitive to erosion.

Source: Withgott and Brennan: Environment, Pearson 2008

Soil Functions

- **Soil performs a number of key environmental, social and economic functions that are vital for life.**
- Plants and crops depend on soil for the supply of water, nutrients and as a medium for growing.
- Soil stores, filters, buffers and transforms substances that are introduced into the environment, crucial in protecting water supplies and regulating greenhouse gases.
- Soil is a provider of raw materials.
- Soil is an incredible habitat and gene pool.

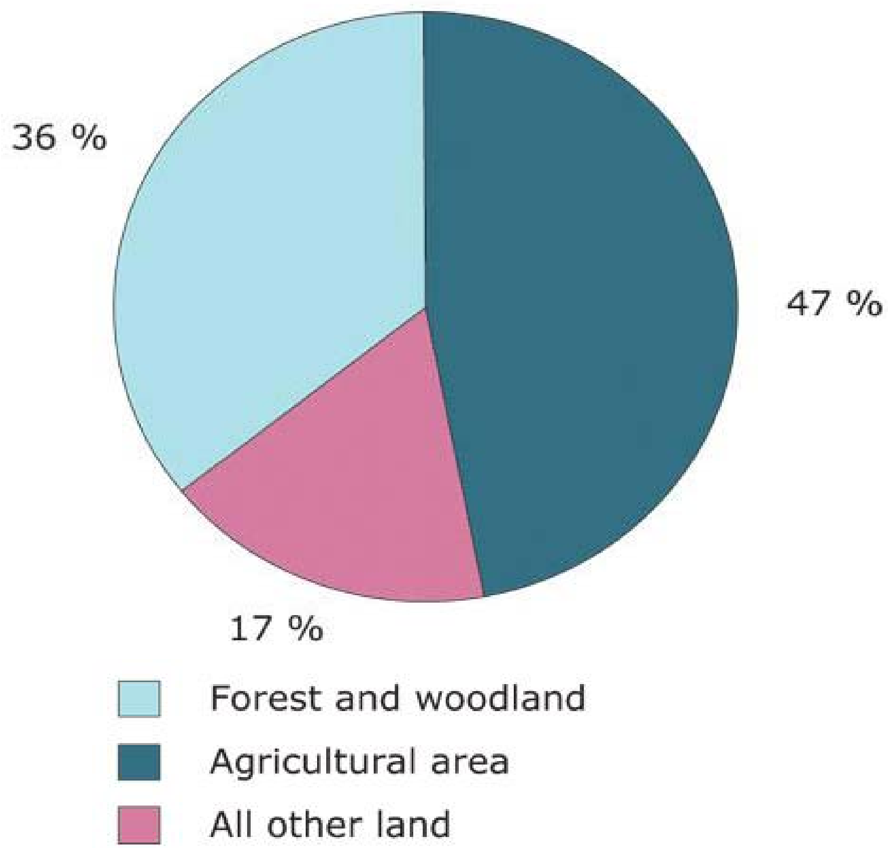
1 g of soil contains 100 million bacteria.
5 tonnes of live organisms can exist in
a hectare of soil.
Source: Withgott and Brennan:
Environment, Pearson 2008



Soil: Land Use and Problems

Source: JRC-IES/EEA

Land use in EU 15



- Soil erosion by water affects 12 % of Europe's surface and by wind 5 %.
- 45 % of European soils have a reduced organic carbon content (particularly in Southern Europe).
- Major land use changes: between 1990 and 2000 2,8 % of land area changed in use causing widespread sealing.
- Natural functions of soils and forests as carbon stocks and sinks changing.

See also EEA Report 2011 "Soil — SOER 2010 thematic assessment"
http://www.eea.europa.eu/soer/europe/soil

Climate Change is expected to enhance pressures on soil and natural vegetation.

Directive COM(2006)232 establishing a framework for the protection of soil.

Soil Contamination

•**Soil contamination** is the presence of man-made chemicals or other alteration in the natural soil environment.

- **Major causes:**
  - rupture of underground storage tanks
  - application of pesticides
  - leaching of wastes from landfills
  - direct discharge of industrial wastes.
- **Most common chemicals:**
  - petroleum hydrocarbons and solvents
  - pesticides
  - heavy metals.
- **Concerns:**
  - health risks due to contamination of water, crops, feed and food.

- There are about 150.000 contaminated sites within the European Union, many of these in the new Member States of the former Soviet block.

Source: Withgott and Brennan: Environment, Pearson 2008

Soil Contamination: Waste Management

- Each European produces on average 500 kg waste per year.
- Possible effects of waste deposition by landfill operations:
  - contamination of groundwater and/or aquifers by leakage
  - outgassing of methane (green house gas) from decaying organic wastes
  - harbouring of disease vectors such as rats and flies
  - simple nuisance problems (e.g. dust, odour).

•Mitigation:

–waste reduction and recycling

-incineration and pyrolysis

-composting and mechanical biological treatment

-banning of disposal of untreated waste in landfills (AT, DE, CH)

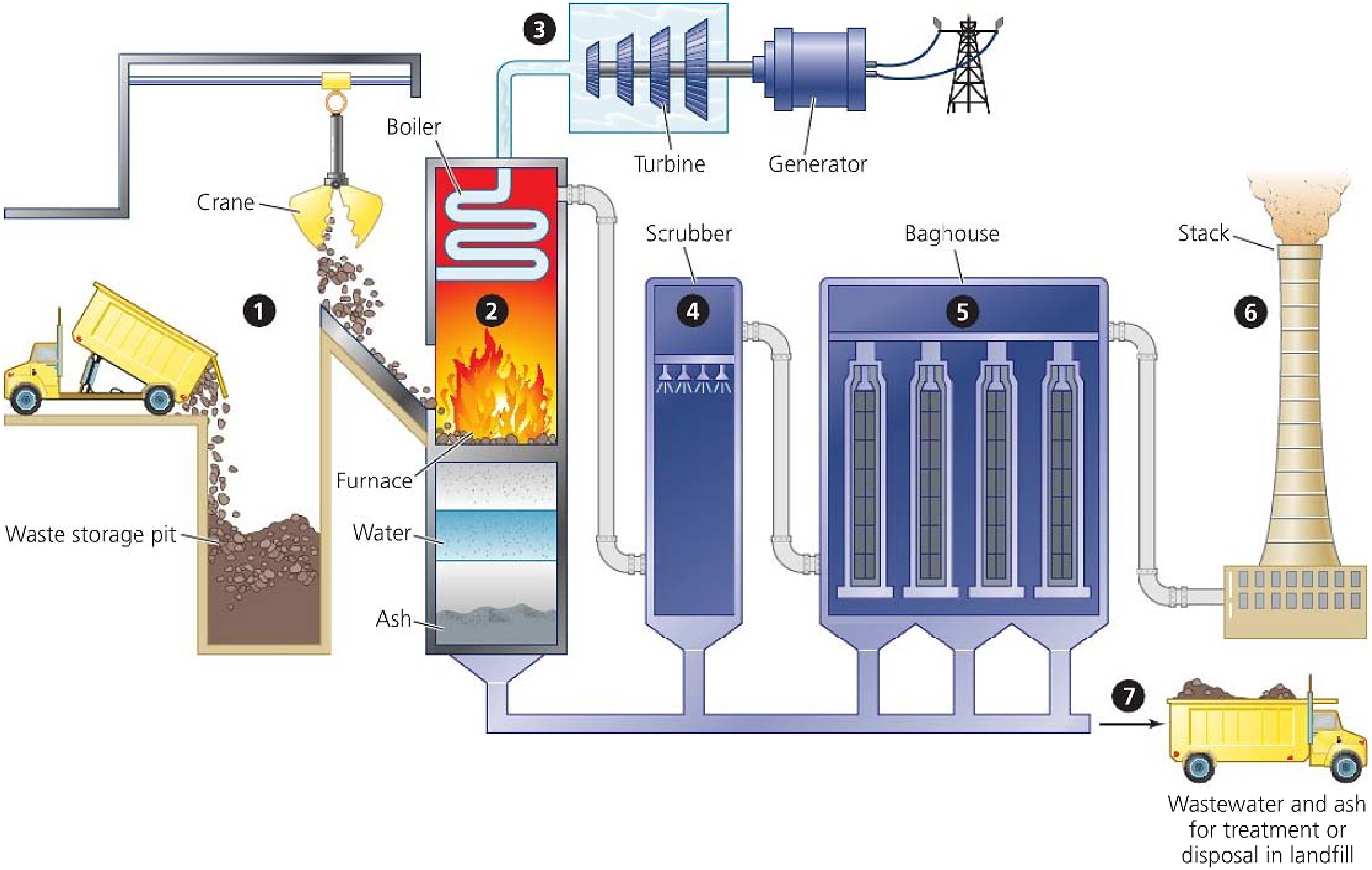
•EU actions:

-Thematic Strategy on the Prevention and Recycling of Waste COM(2005) 666 final and Directive 2006/12/EC on Waste.

See also EEA Report 2012 "Movements of waste across the EU's internal and external borders"
http://www.eea.europa.eu/publications/movements-of-waste-EU-2012

Soil Contamination: Waste Management

Waste incineration plant



Source: Withgott and Brennan: Environment, Pearson 2008

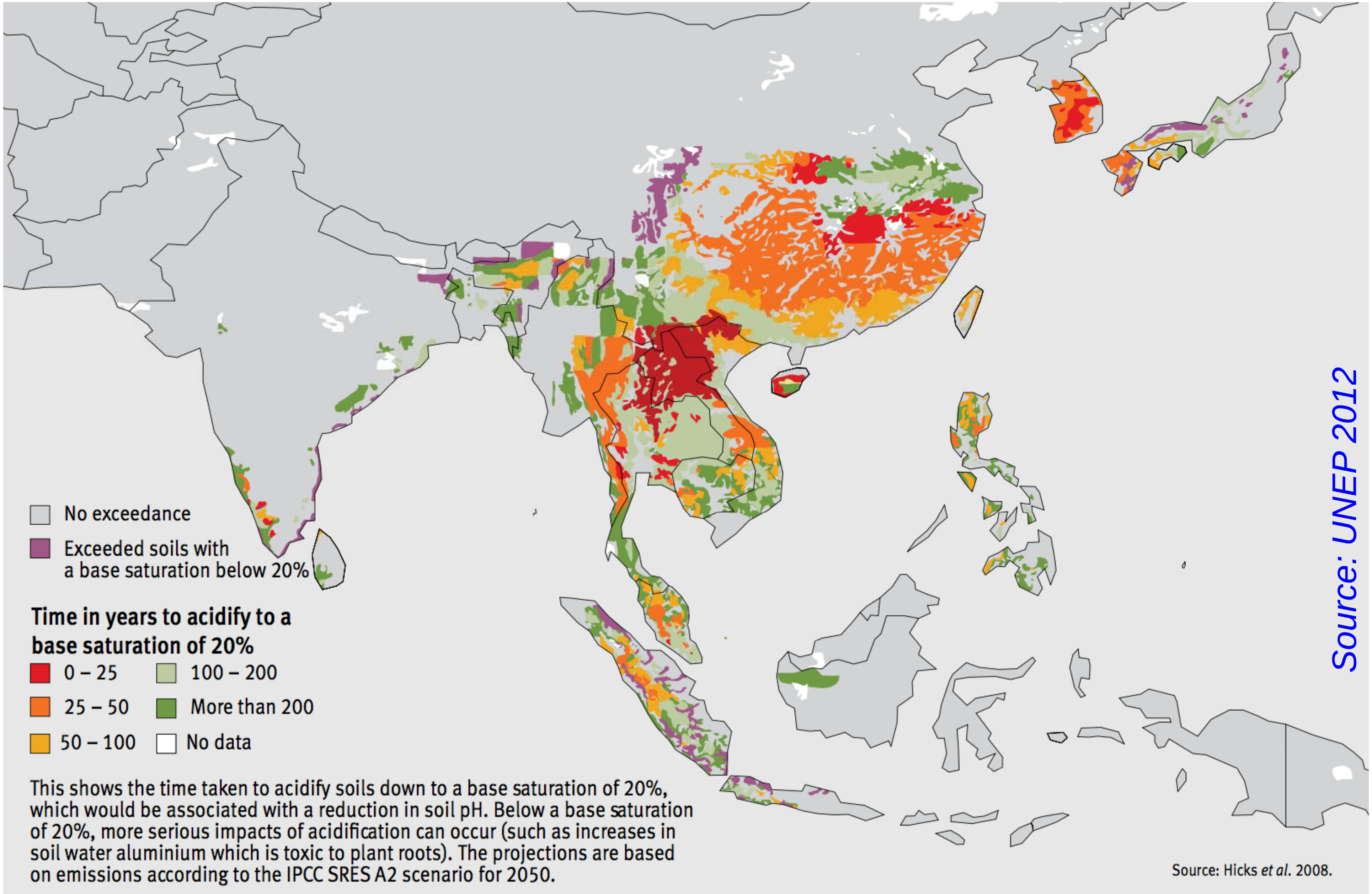
Soil Contamination:
Tiger Economies - Example China

- Economic growth without environmental protection resulted in massive soil pollution:
- Widespread damage of soil due to acid rain.
- 20% of China's cultivated land polluted with heavy metals.
- 60% of ground water contaminated.

->10 million tons of grain are contaminated by heavy metals every year, causing direct losses of US$ 2.5 billion.
-1.300 km^2 are covered or destroyed by solid waste.
-Contaminated areas account for one-tenth of China's cultivatable land, and concern mostly economically developed regions.

Source: Wikipedia

Soil Contamination:
Soil Acidification in SE-Asia



Source: UNEP 2012

Ecology and Sustainable Development

5. Natural Resources:

5.1 Forests

5.2 Crops and Food

5.3 Minerals, Metals and Fossil Fuels

Photo Florian Schulz 2009

Photo Keith Weller USDA 2013

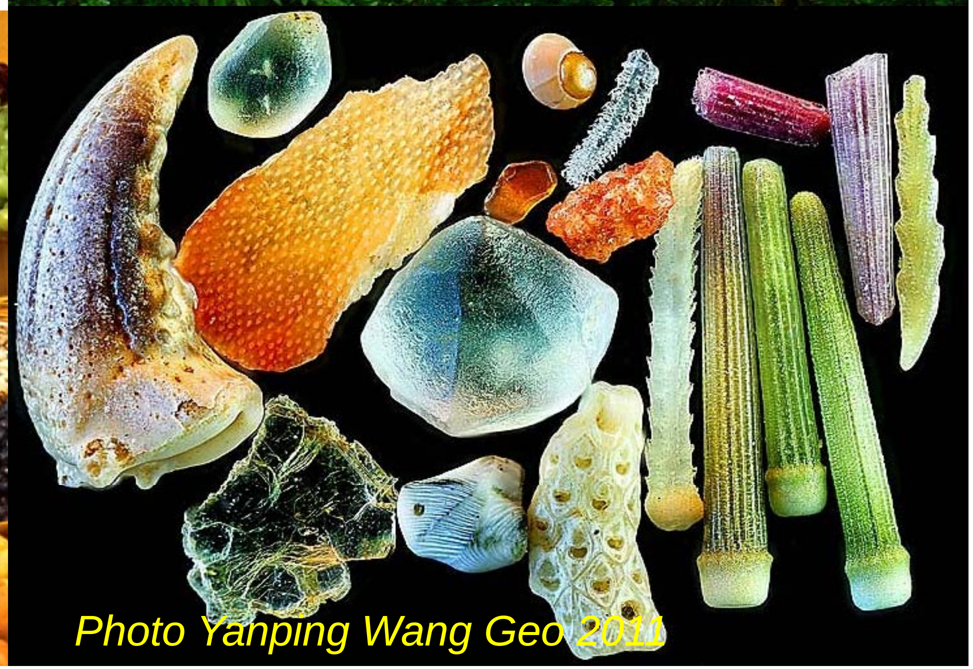
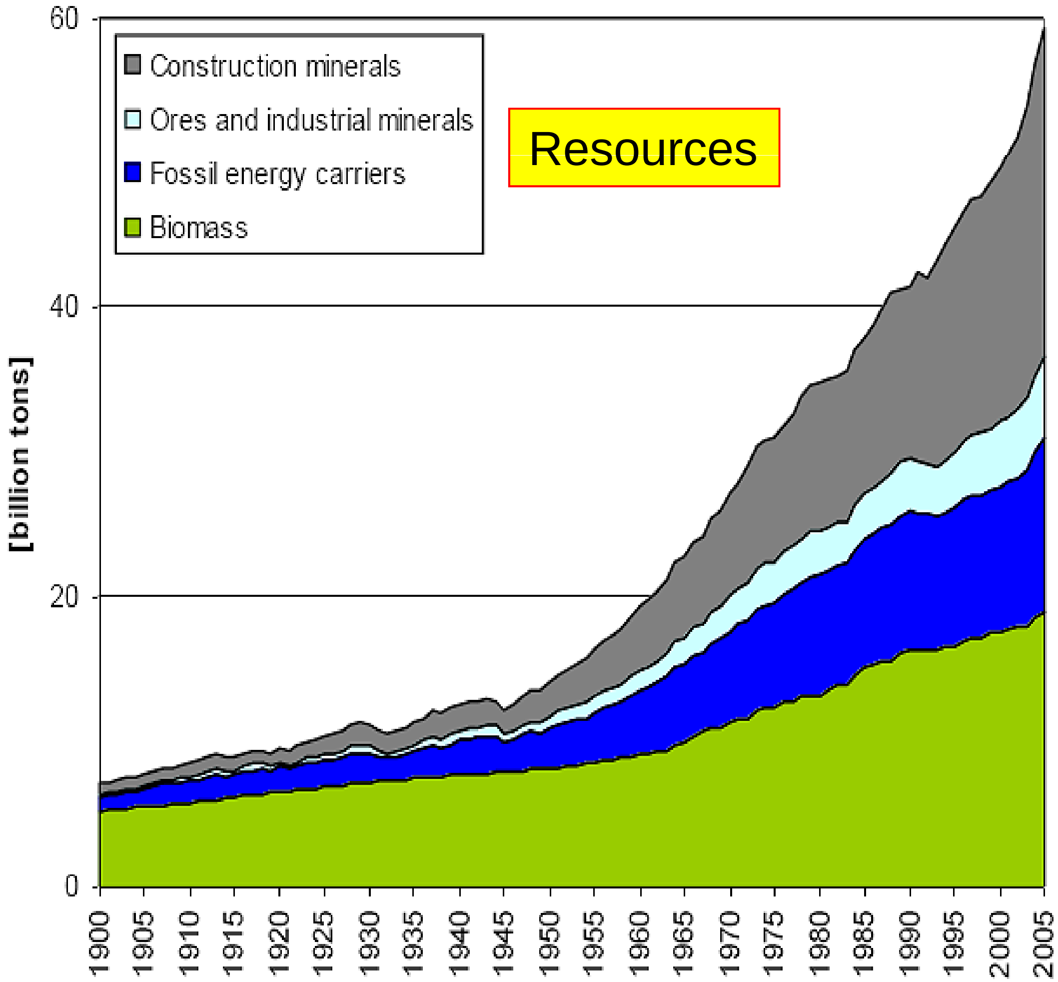


Photo Yanping Wang Geo 2011

Trends in Global Resource Consumption

•The last century has been characterised by a steeply rising consumption of natural resources and energy.

•Up to now there is no significant change in the global consumption trend.



Source: Krausmann et al, Fischer-Kowalski 2009

Drivers of increased resource (and energy) use:

•Population numbers

•"Development" in the sense of transition from an agrarian to an industrial regime:

➢Person in industrial regime uses 3-5x more energy and natural resources than a person in an agrarian regime.

•Rising income (GDP)

Significance of Forests

5.1 Forests

•About 30 % of the global land surface is covered by forests.
•Most of this consists of the boreal forests in the North and the tropical forests of South America and Africa.

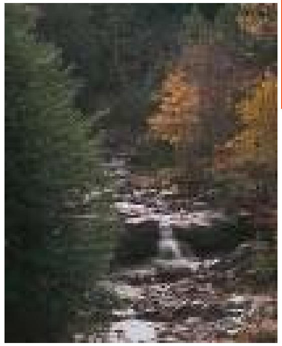
•Forest have a large economic value and perform provide a variety of necessary ecosystem services:

–timber production
–biodiversity conservation
–soil and water protection
–leisure services and tourism
–living space for indigenous people

Global map of forests.

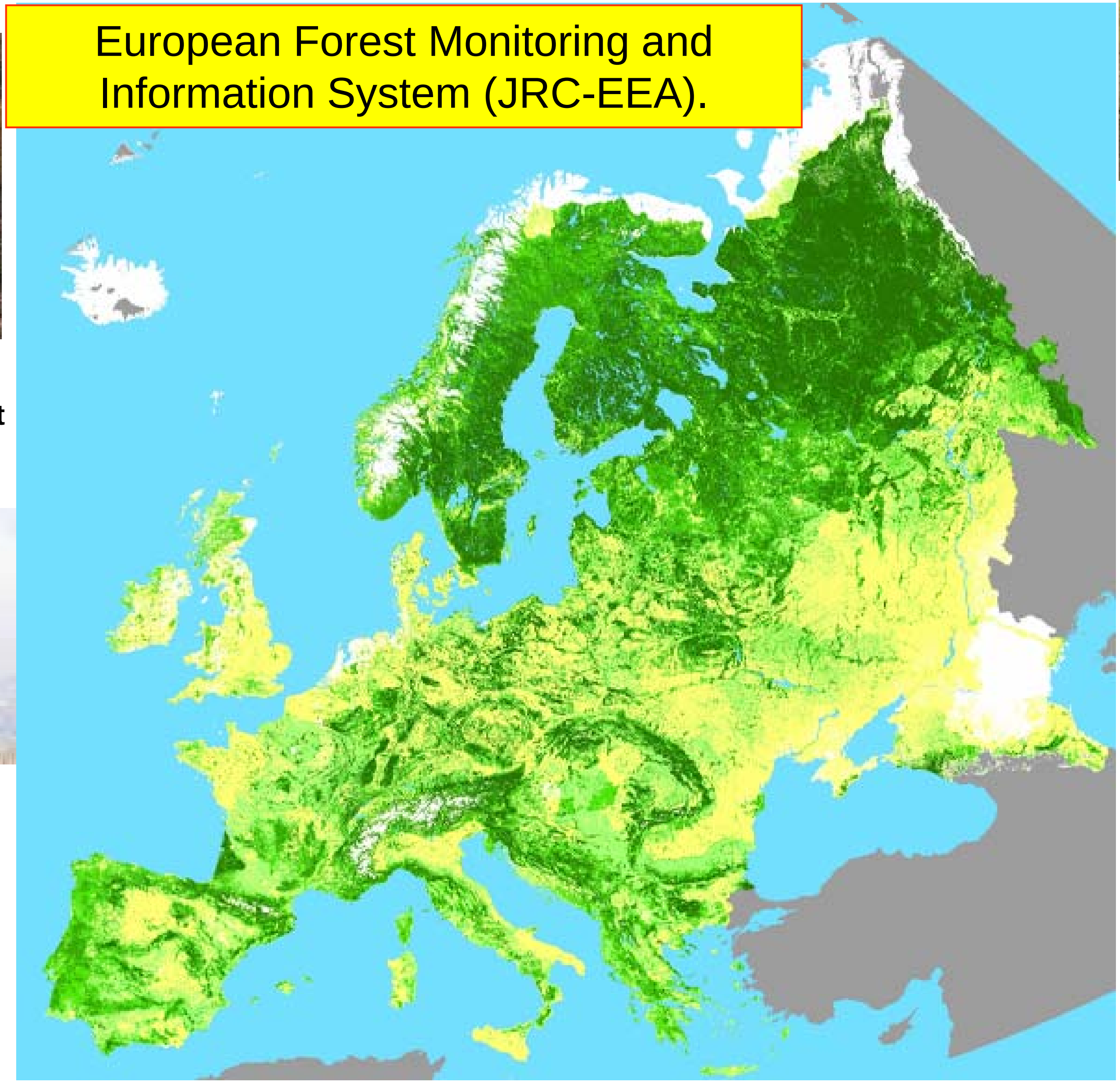
Source: Withgott and Brennan: Environment. Pearson 2008

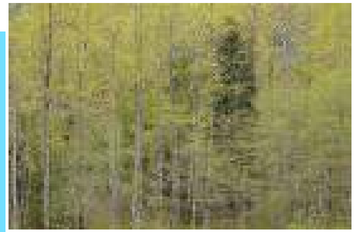
European Forests



Mountain forest

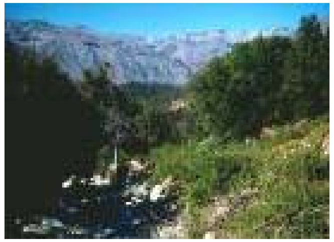
Mediterranean forest





Boreal forest

Alpine forest



Mediterranean protection forest

Source: JRC-IES.

Forests cover about 30% of the European land area.

Deforestation

- Conversion of forested areas to non-forest land for use such as arable land, pasture, urban use, logged area, or wasteland.
- **Deforestation in the historical context:**

- Deforestation has been practiced by humans since 10.000 BC by conversion into agricultural land (fields, pastures).
- Continuous reduction of forest areas over the centuries due to expanding human population, spread of agriculture, use of wood for housing and shipbuilding.
- Beginning of the industrial age widespread use of charcoal (DE, UK…).
- Since about the mid-1800s massive expansion of infrastructure (cities, roads, railways…).
- During the recent past and now deforestation is most pronounced in the rain forest regions for gaining agricultural land and timber production.

Source: Wikipedia

Deforestation: The Brasilian Rain Forests

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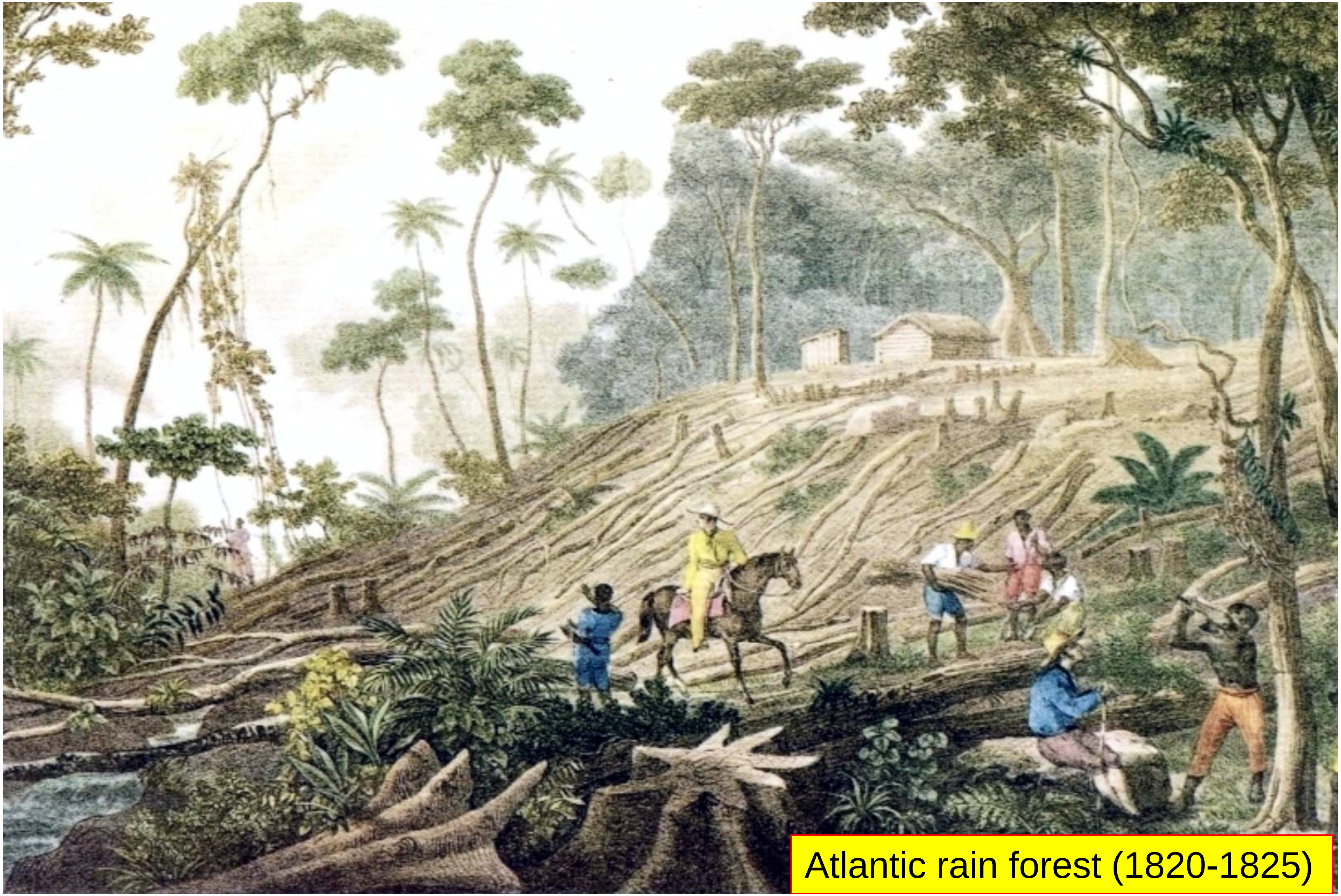


Deforestation: The Brasilian Rain Forests

- Atlantic Rainforest: less than 10% left.
- Amazon rainforest: largest biodiversity and sweet water reservoir on earth.
  - 14 percent of the Amazon rain forest has already been lost.
  - Only 3 % of the area are protected.
  - Deforestation there is ongoing at a rapid speed.

Amazon Basin

600 fires daily in the Amazon Rainforest.

- **Major driver:** increased demand for soybean has led to the displacement of beef ranches and farms of other crops, which, in turn, move farther into the forest.

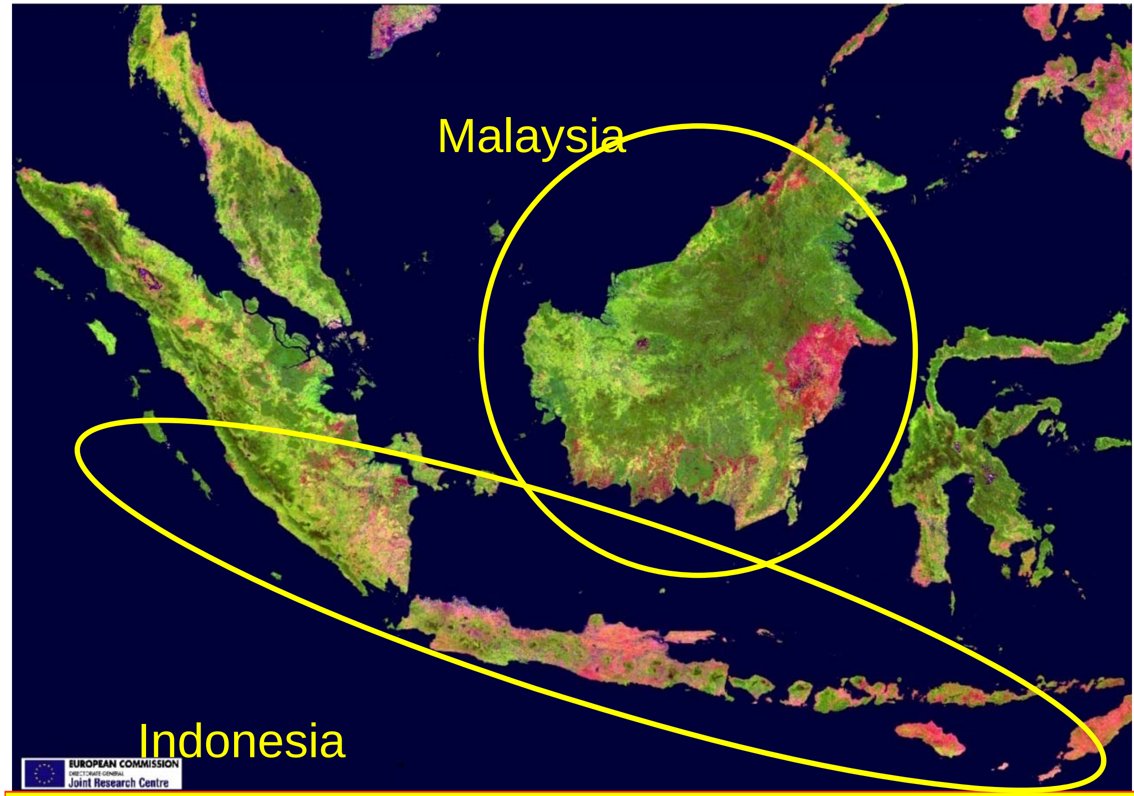
Source: National Geographic Society 2006, Wikipedia

Deforestation: The Brasilian Rain Forests.

Deforestation in Amazonia: Man-made fires around the Xingu National Park in northeast Brazil.
12th July 2007

Deforestation: The Forests of Asia

- Very large areas of Siberia have been harvested since the collapse of the Soviet Union.
- In the last two decades, Afghanistan has lost over 70% of its forests.
- 90% of the forests of the Philippine archipelago have been cut.



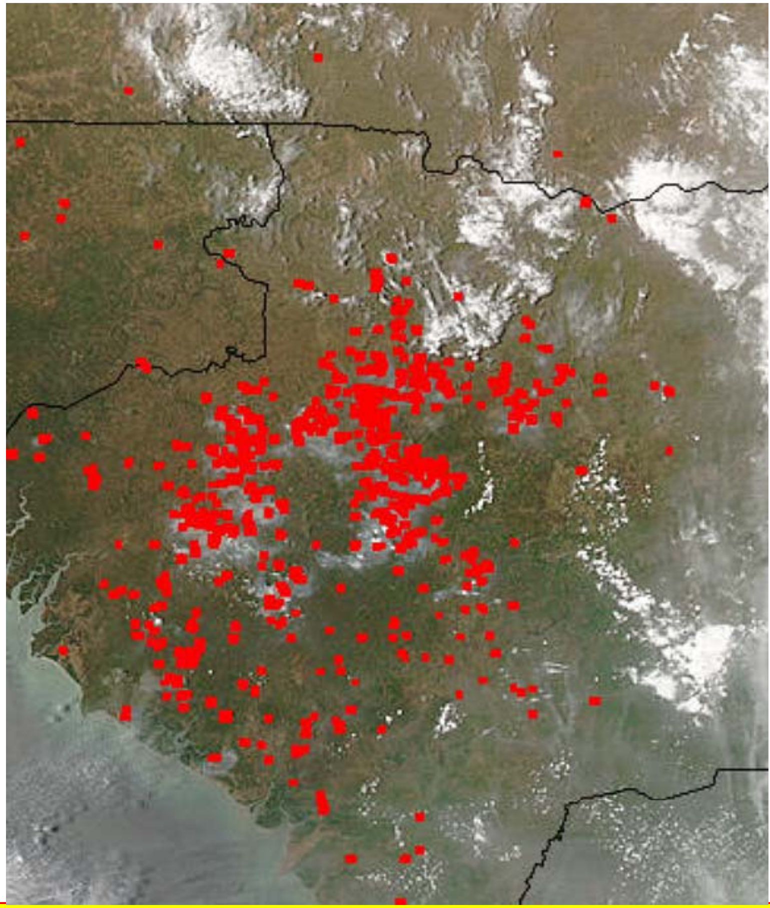
•In Indonesia and Malaysia native forest is cleared by large pulp and logging companies, many of them from China and Japan.

•Native rain forest is usually replaced by plantations with trees for paper or biofuel (palm oil) production.

Satellite image of Insular South East Asia 1998
Dark green: Tropical evergreen rainforest, Dark red: Burnt lowland rainforest
Source: NASA, Wikipedia

Deforestation: Forests of Africa

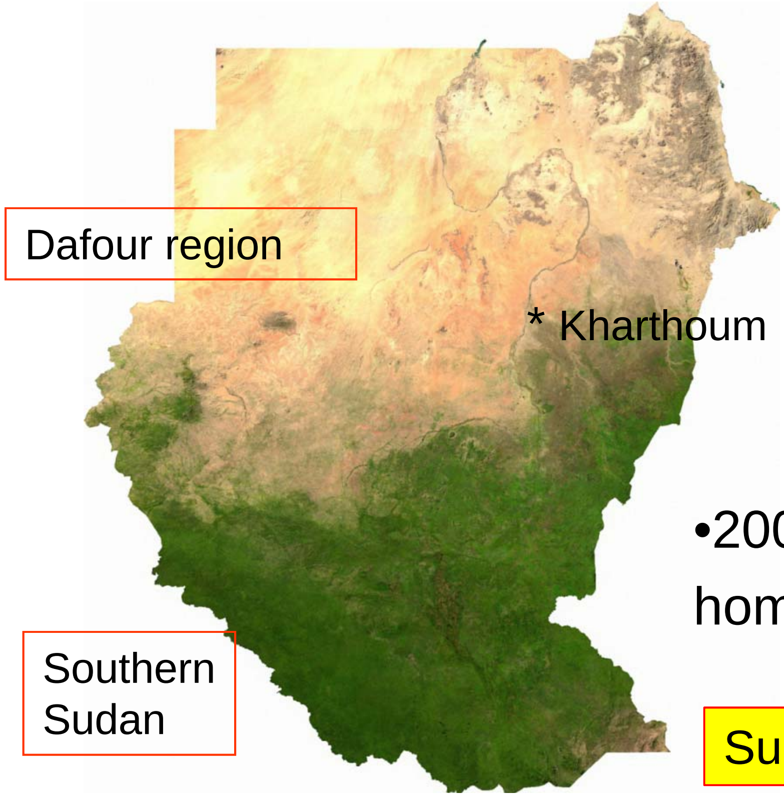
- From 1975 to 2000 Africa lost 16 % of its forests.
- Madagascar has lost 95% of its rainforests, Nigeria 80%.
- Annual loss of natural vegetation in Africa = 50.000 km^2
- Main drivers are logging activities for precious tropical wood and slash-and burn practices for gaining agricultural land.



Forest Fires in New Guinea, West Africa. *Source: NASA 2004*

Deforestation: Impact on the Environment

- Reduced biodiversity and loss of attraction for inhabitants and tourists.
- Reduction of storage of organic carbon in soil and of extraction of carbon dioxide and pollutants from the air.
- Enhancement of green house gas emissions due to burning of forests.
- Land degradation, drying of the soil layers, eventually desertification.
- Affects the amount of water in the soil and groundwater.



- Reduction of the landscape's capacity to intercept, retain and transport precipitation.
- Deforested areas become sources of surface water runoff which can lead to flash flooding.

- 2007 Sudan flash floods destryed of over 150.000 homes, leaving at least 750.000 homeless.

Sudan: 2,5 million km^2, 25 million people.

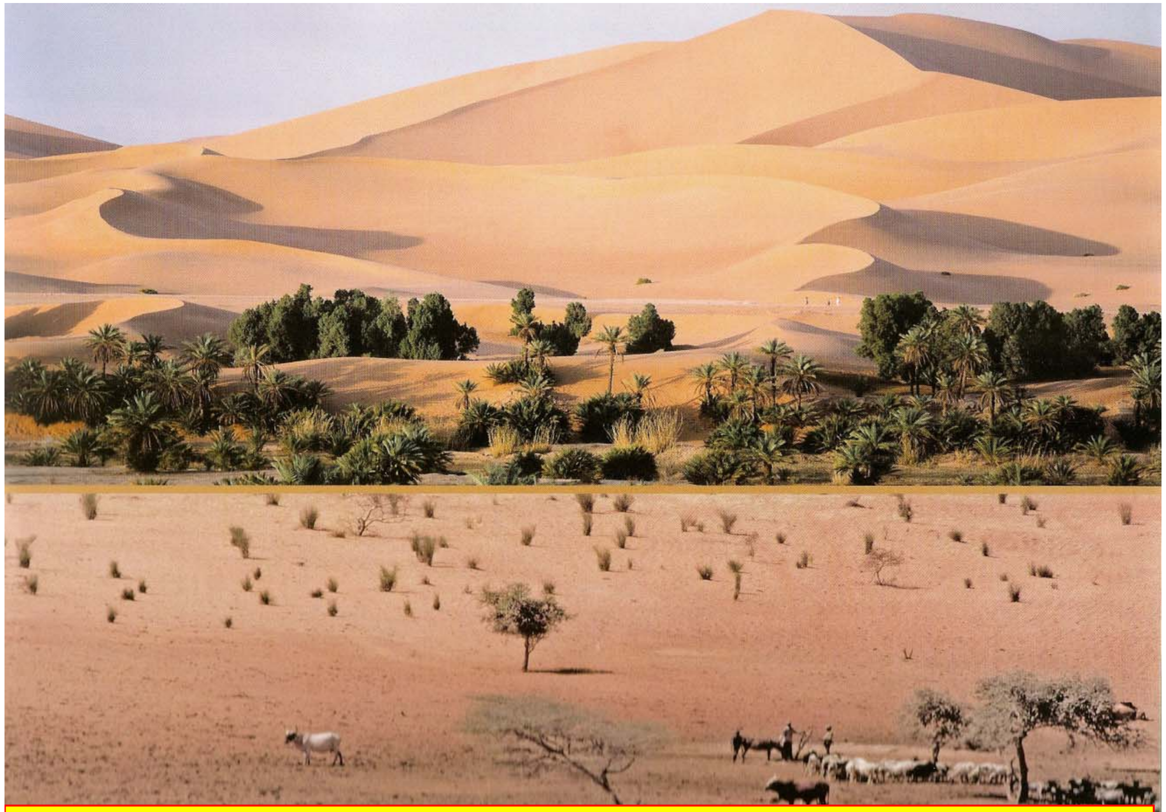
Source: Wikipedia

Deforestation: Consequences

Desertification

•**Desertification** is the degradation of land in arid and semi arid areas.

•The primary reasons for desertification, is overgrazing, overcultivation, incorrect irigation methods, deforestation, overdrafting of groundwater, increased soil salinity, and global climate change.



Desert fringes Karzaz, Algeria

•In marginal areas human activity may stress the ecosystem beyond its tolerance limit, resulting in degradation of the land.

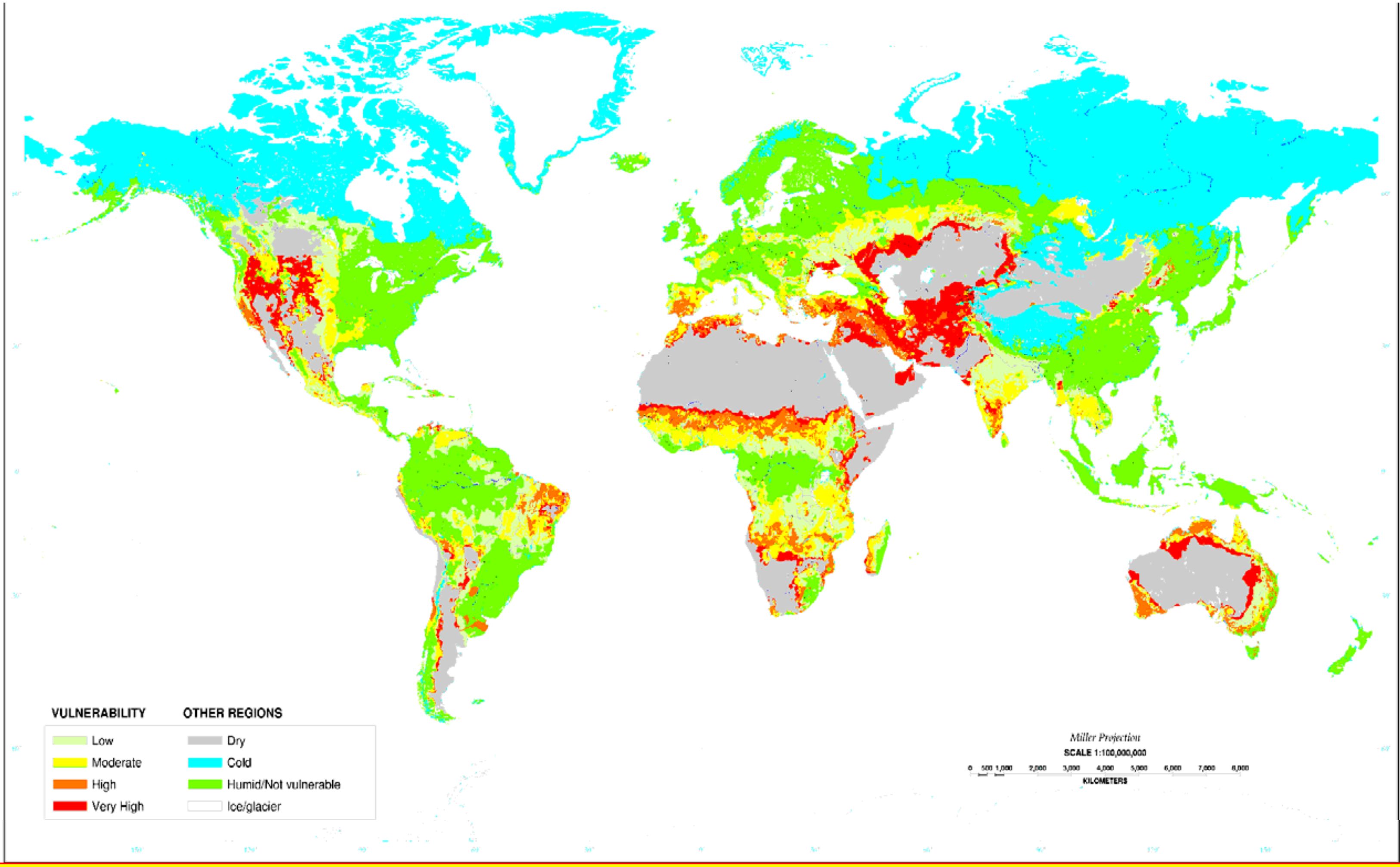
•The transition zones between deserts and the normal vegetation zones have fragile, delicately balanced ecosystems.

Photo: Wikipedia

Desertification: Vulnerable Zones

•Globally 10 – 20 % of the drylands are deserted.

•Global warming is leading to increased desertification in many areas.



Global map of desertification vulnerability.

Source: United Nations Convention to Combat Desertification (UNCCD)/USDA

Desertification

•A sequel to the deforestation is typically large scale erosion, loss of soil nutrients and sometimes total desertification.

•Examples of this extreme outcome can be seen on Madagascar's central highland plateau, where about seven percent of the country's total land mass have become barren, sterile land.

•Another region of desertification is the Sahel.

•The chief cause of desertification in the Sahel is slash-and-burn farming practised by an expanding human population.

•Drought is a contributing factor.

The Sahel zone – the buffer between the Sahara and savannas. *Source: Wikipedia*

Desertification: Historical and Current Events

(c) The shrinking Aral Sea, then and now

- In Kazakhstan, nearly half of the cropland has been abandoned since 1980.
- The Aral Sea situated between Kazakhstan and Uzbekistan had originally a surface area of 68.000 km^2.
  - Its water surface has shrunk to 10% of its original size.
  - The rest is now a salt desert.
  - Cause: Diversion of rivers feeding into the Aral Sea for irrigation of cotton fields in Kasachstan.

Source: Withgott and Brennan: Environment, Pearson 2008

Development of Agriculture

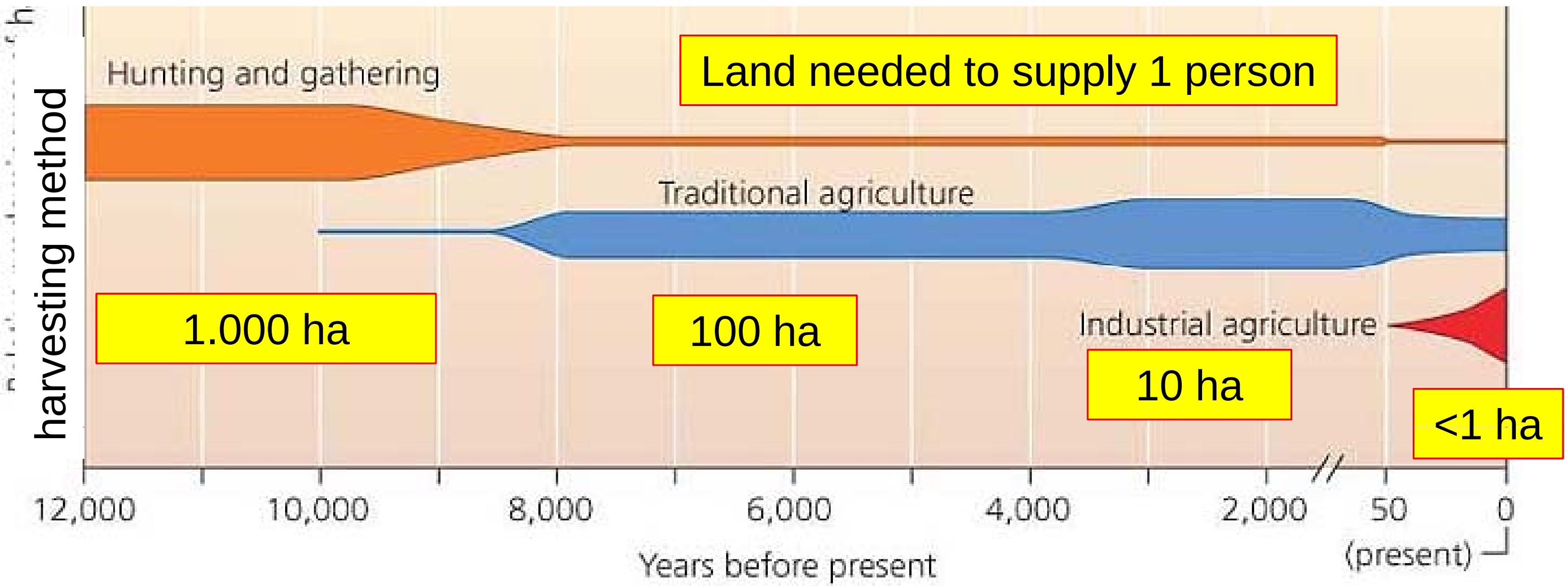
5.2 Crops and Food

•**Agriculture** is the artificial cultivation and processing of animals, plants, fungi and other life forms for food, fibers and other byproducts.

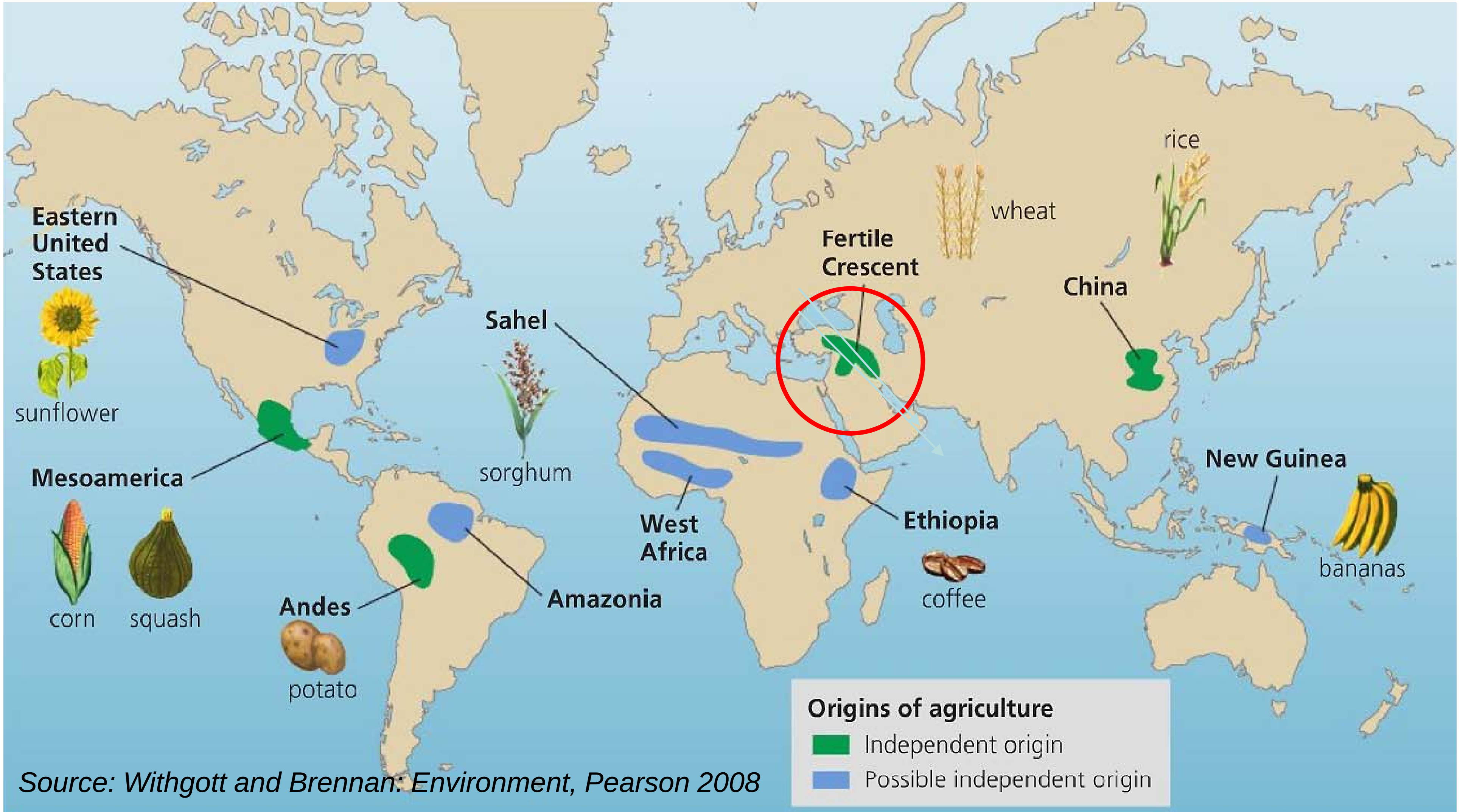
•Agriculture started 10.000 years ago in Mesopotamia (and in many other regions of the world).

•In Mesopotamia the eight so-called Neolithic founder crops of agriculture appear: wheat, barley, peas, lentils, bitter vetch, chick peas and flax.

•7.000BC farming spread to Egypt creating the basis for a new great culture.
•3.500BC the plough was developed.



Crops and Food:
Development of Agriculture



Source: Withgott and Brennan: Environment, Pearson 2008

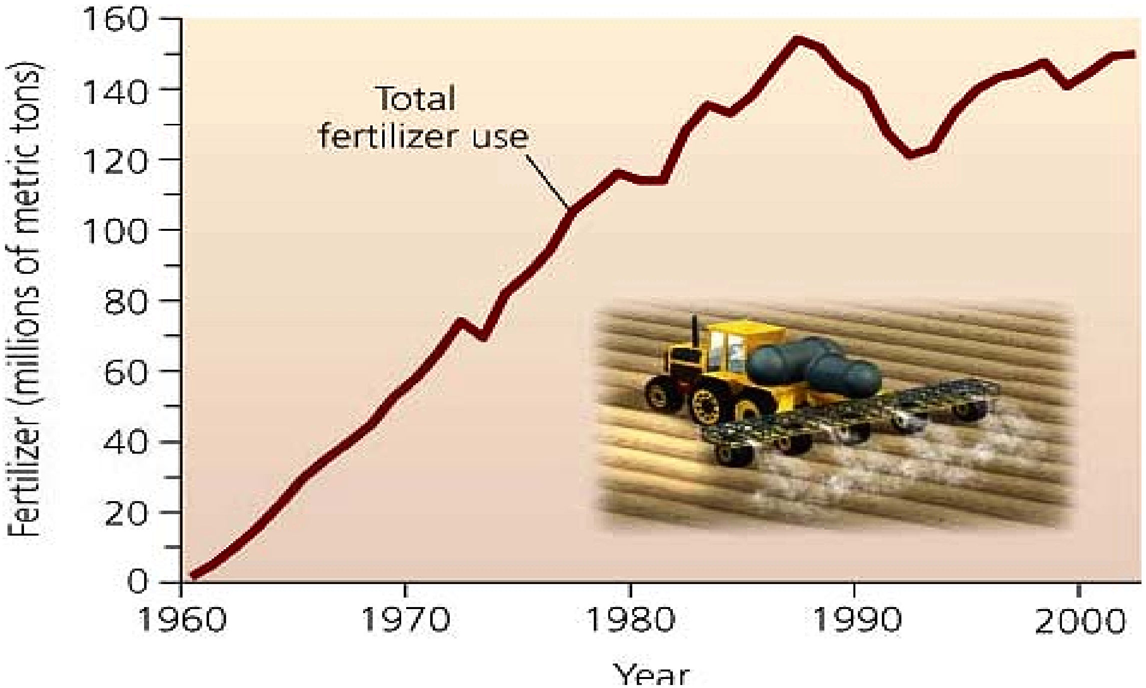
Agriculture developed independently in several regions of the world as certain civilisations domesticated wild plants and animals from species living in their environment.

Crops and Food:
Modernisation of Agriculture

•Until the first Industrial Revolution, the vast majority of the human population labored in agriculture.

•Since the 1940s, agriculture has dramatically increased its productivity, due to increased mechanization and the use of petrochemical derived pesticides and fertilizers.

•Modernisation of agriculture has allowed the world population to double over the last 50 years.



36% of the world's workers are employed in agriculture, but agricultural production accounts for less than five percent of the gross world product.

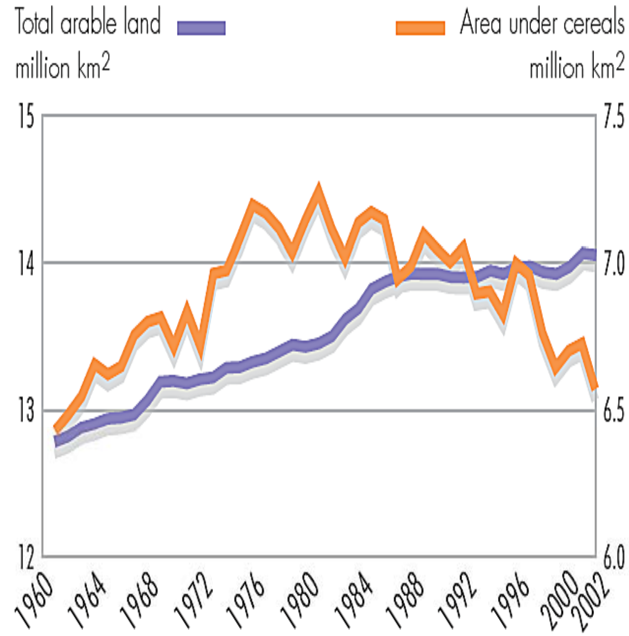
Source: Withgott and Brennan: Environment, Pearson 2008

Crops and Food: Land Use for Agriculture

- Area of arable land is still slightly increasing due to draining of wetlands, irrigation and deforestation.
- But area used for cereals is decreasing due to increase in meat production.
- Areas needed for crops and meat production:

–1 kg of vegetable 1 m^2
–1 kg of chicken 14 m^2
–1 kg of eggs 22 m^2
–1 kg of beef 250 m^2

Arable land (left scale) and area under cereals (right scale).
Source: UNEP GEO-4, 2006, FAOSTAT 2006



Source: FAOSTAT 2006

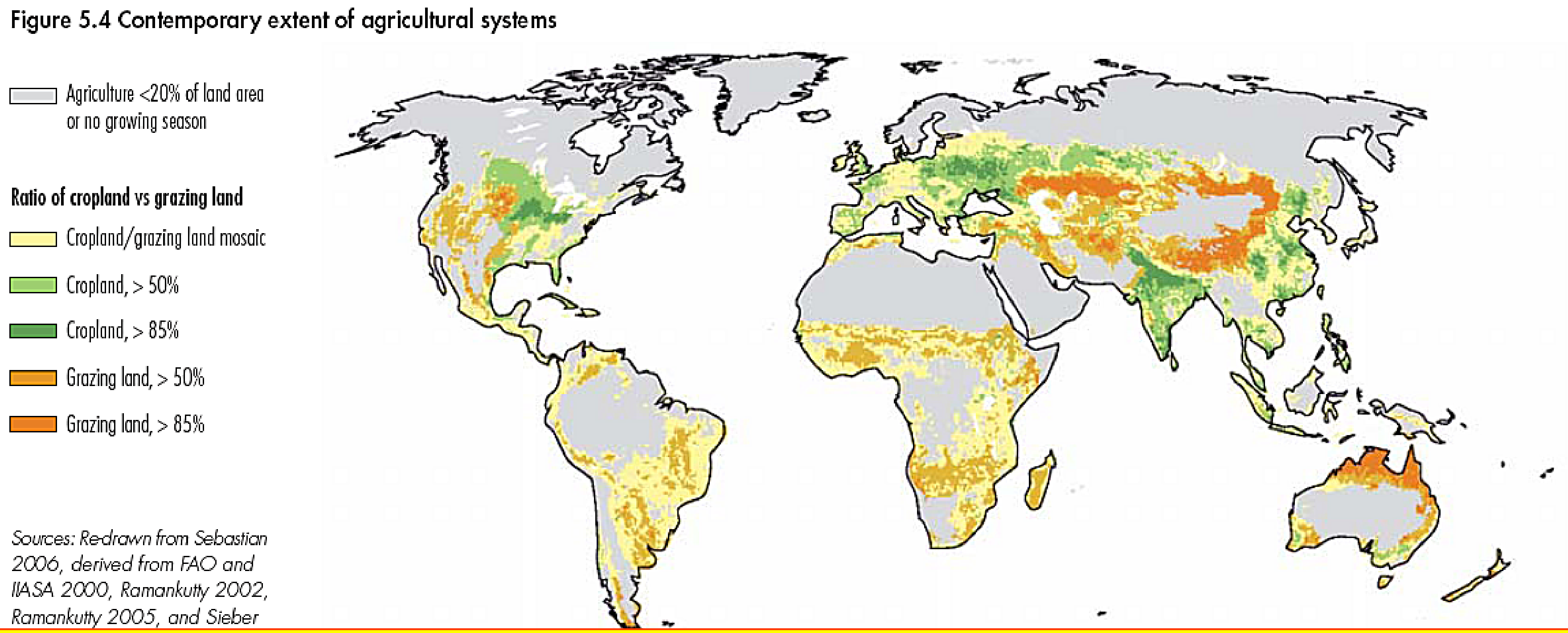
- **Top agricultural products in million tons (FAO 2012):**

-855 maize, 722 rice, 701 wheat, 262 soy beans,
-614 cow's milk, 95 water buffalo milk, 65 eggs
-373 potatoes, 256 cassava, ca 500 all vegetables
-107 bananas, 75 apples, 69 grapes, 38 mangos
-108 pig meat, 90 chicken meat, 63 beef

Meat makes up only ca 5 % of the global food production – but takes 2/3 of the agricultural land. Meat has only a slightly higher energy content than crops.

Crops and Food: Agricultural Areas

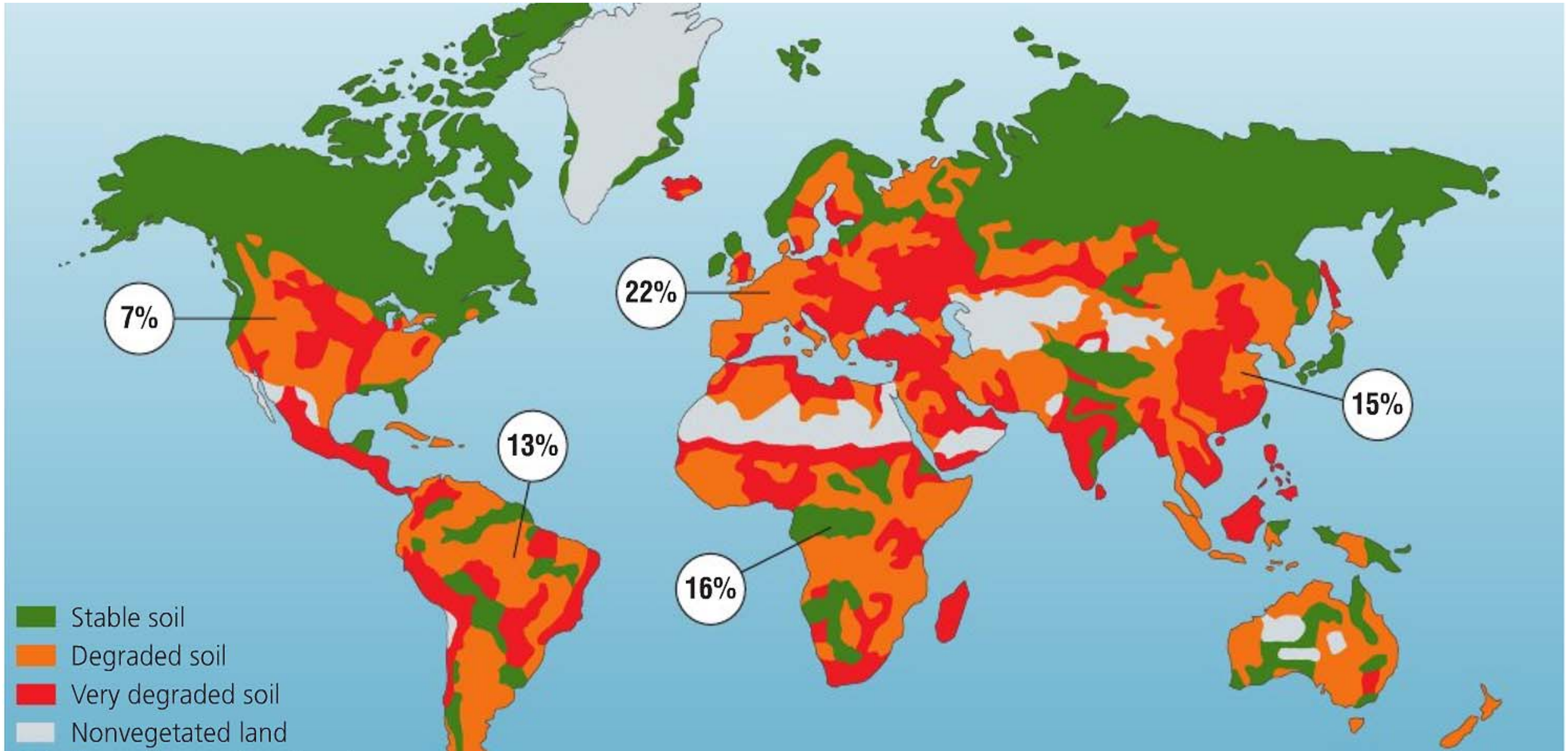
•Globally only 12 % of land surface usable for agriculture with only 2,5 % high value farmland and very unbalanced distribution between different regions.
•Arable land per capita decreasing due to population growth, but the agricultural yield can be increased: now 70% in industrialised countries, 20% in developing countries.
•Reduction of food waste in developed countries: per capita food waste in Germany is 146 kg annually *(Source: EP STOA 2013)*



Contemporary extent of agricultural systems. *Source: UNEP GEO-4, 2006, FAOSTAT 2006*

Crops and Food: Degradation of Agricultural Soils

- **Major threats to agricultural soils:**
  - degradation of soil quality due to overgrazing, overload with fertilisers and pesticides, overextraction of groundwater causing a lowering of ground water levels and rising of saline waters
  - soil erosion by wind and water leading to desertification



Percentage area of continent with very degraded soil.

Source: Withgott and Brennan: Environment, Pearson 2008

Crops and Food: Water Availability

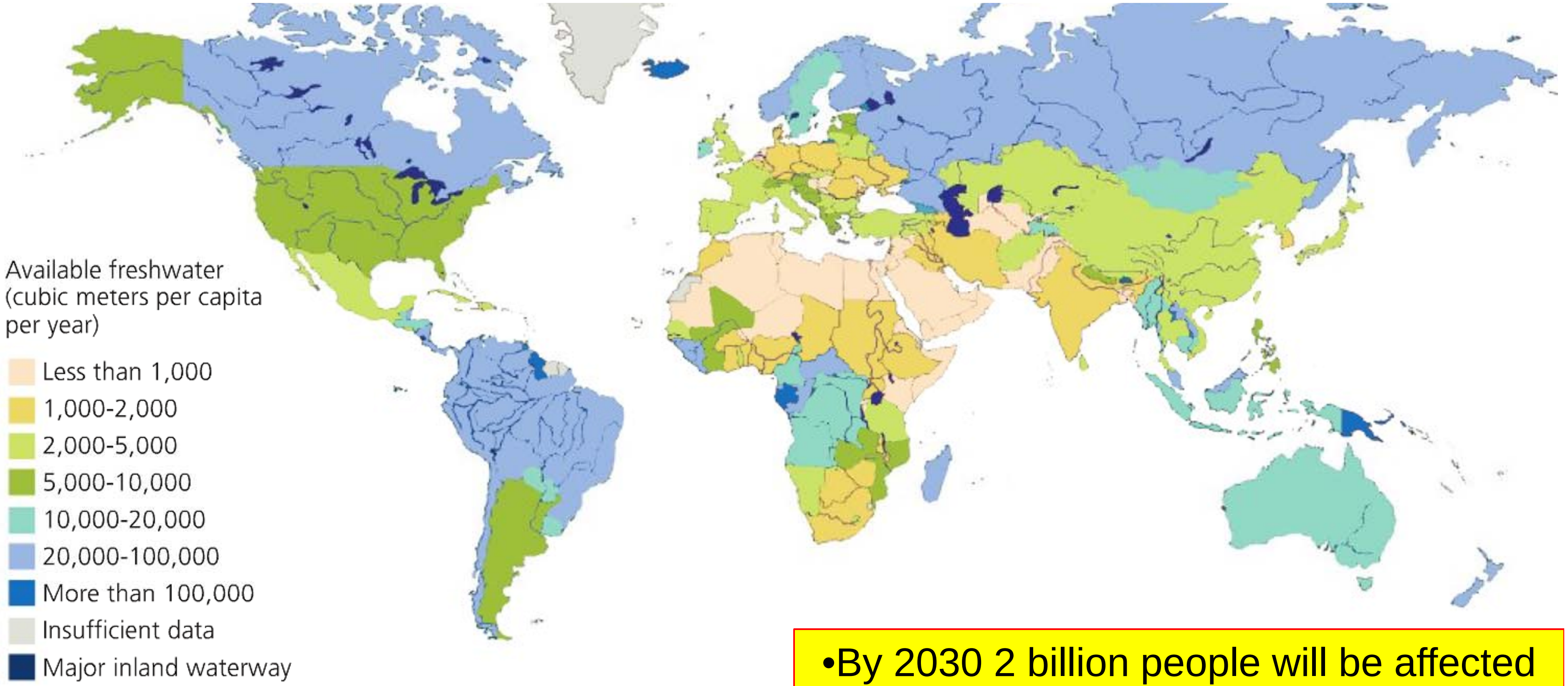
•Agriculture accounts for 70% of the global consumption of freshwater water.

•Globally 40% of crops are produced in irrigated fields.

•Water availability is very different in the various regions of the world.

•Water scarcity affects large parts of Africa, the Middle East and South Asia.

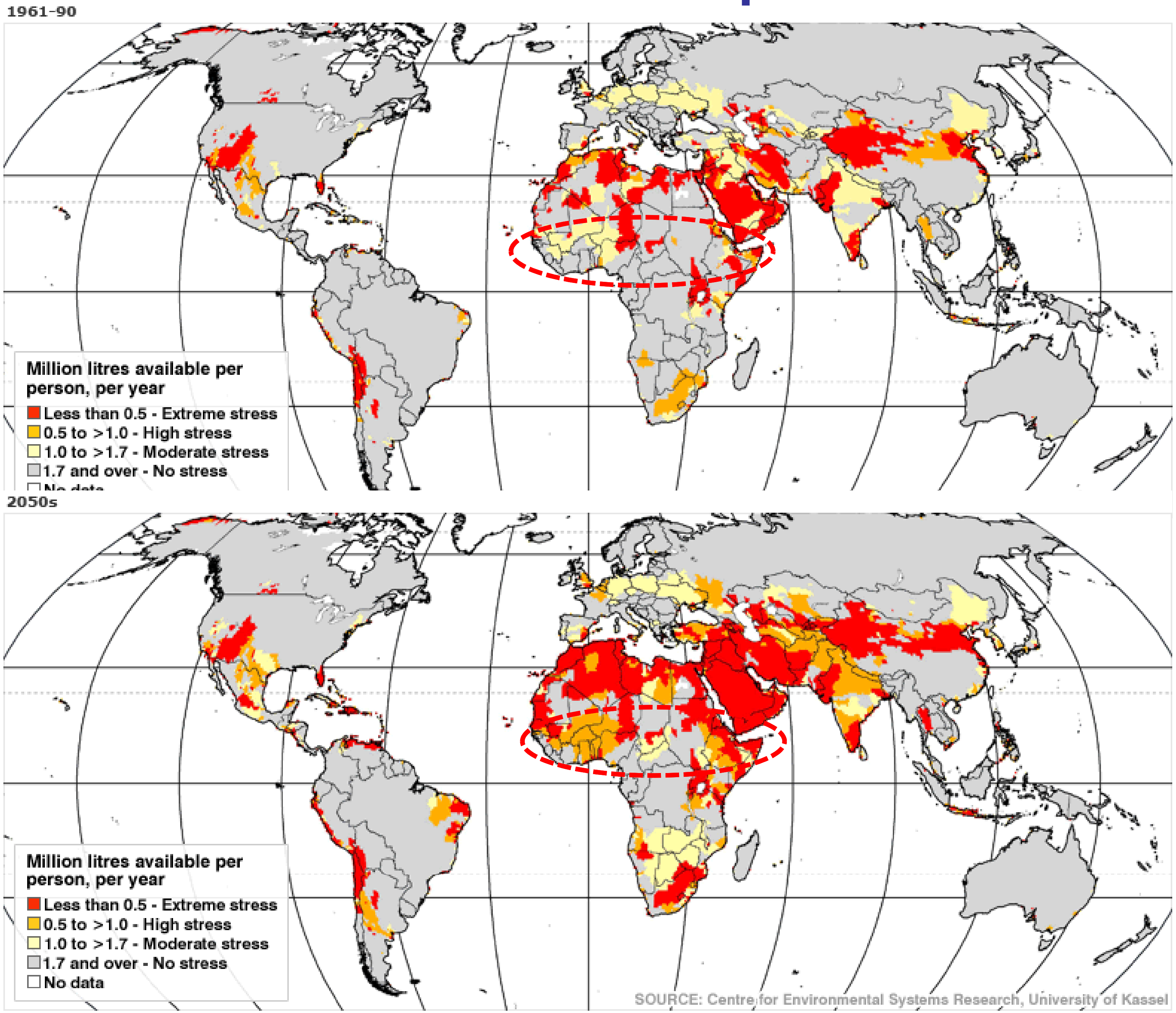
•Overextraction of ground water for land irrigation magnifies this problem.



Source: Withgott and Brennan: Environment, Pearson 2008

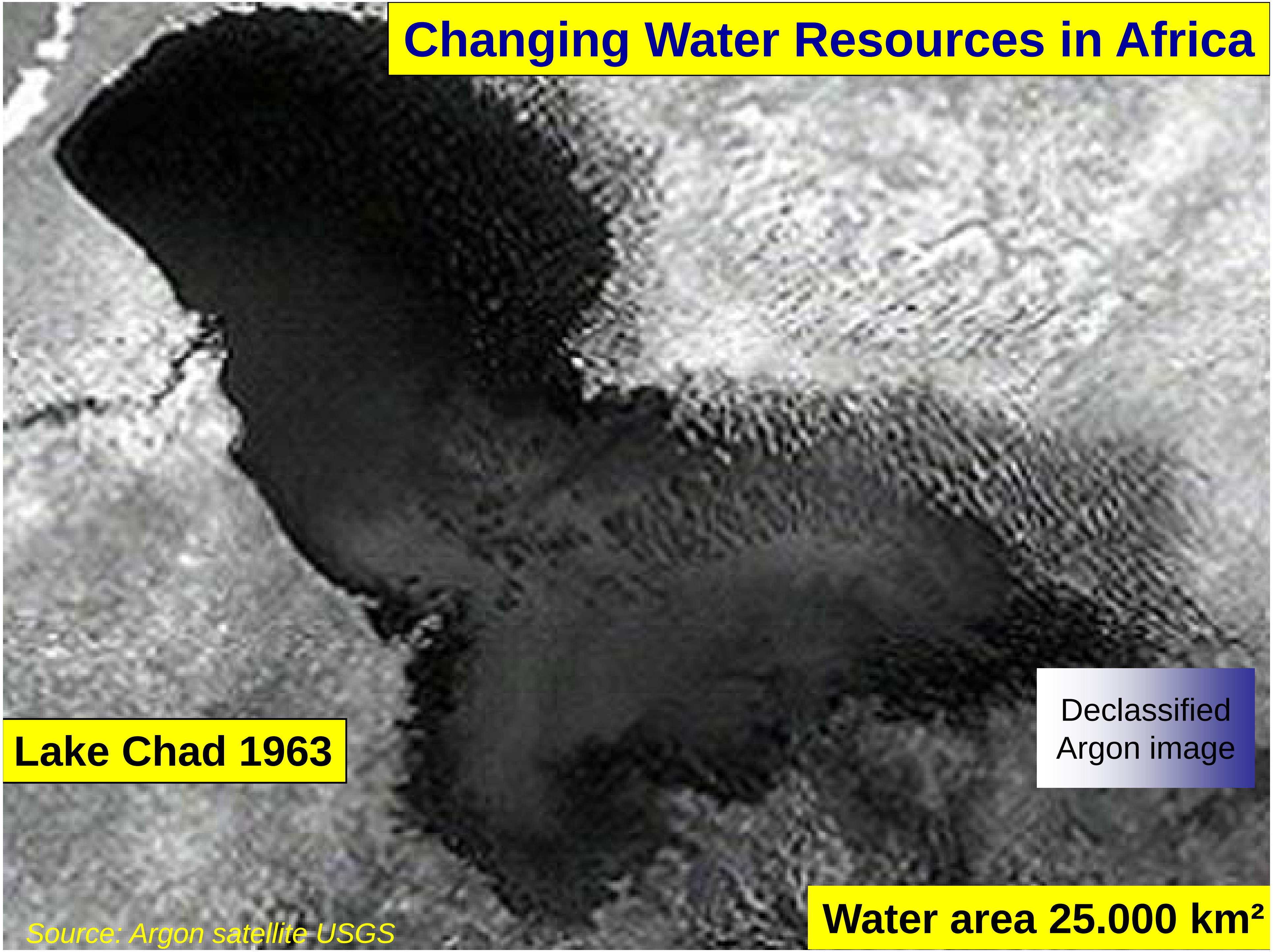
•By 2030 2 billion people will be affected by severe water shortage.

Global Water Consumption and Availability

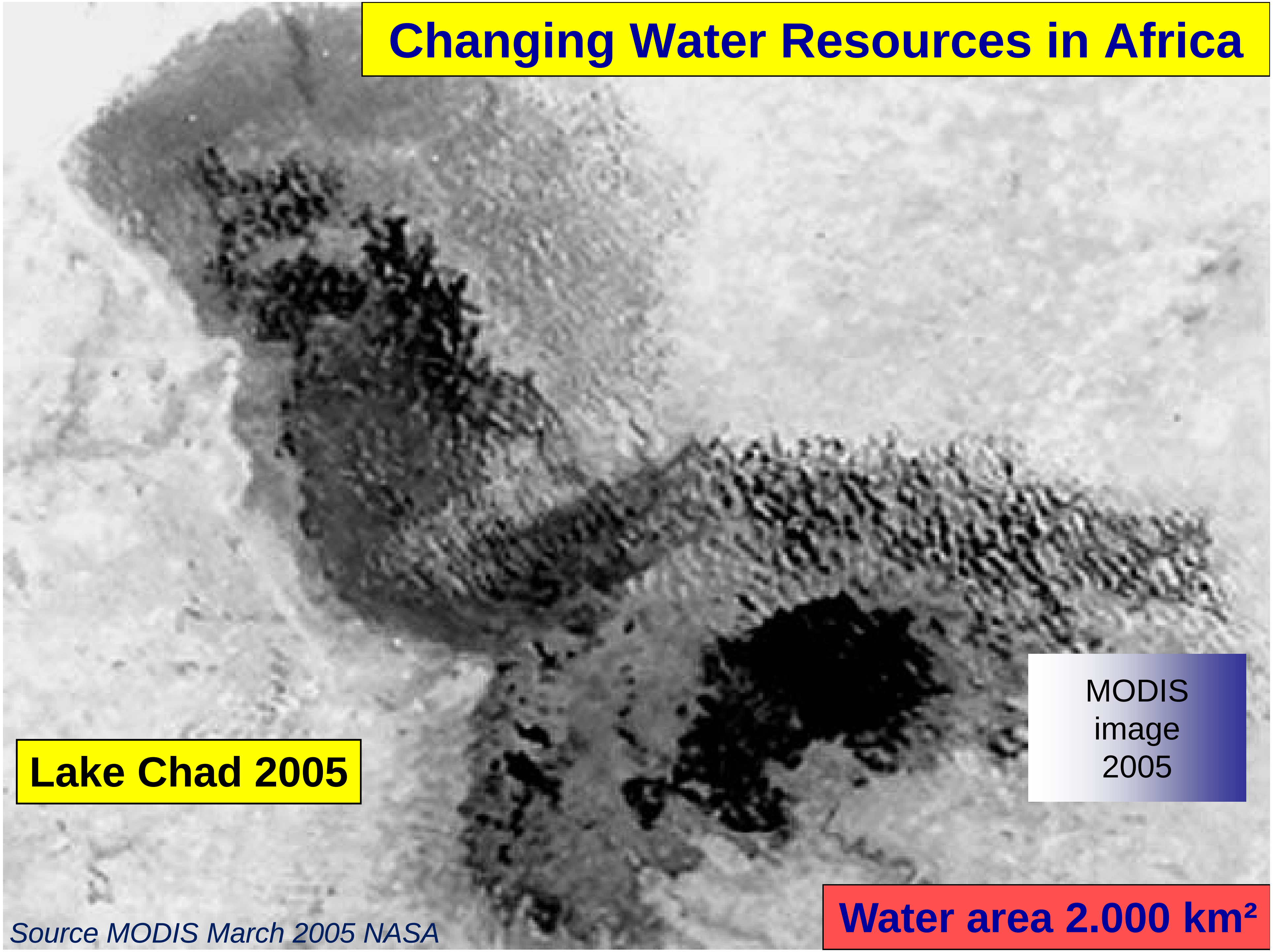


- Spreading of areas with insufficient water supply providing "water stress" for the populations and reduced agricultural productivity from the 1980s till the 2050.

Source: H. Kroiss TU Wien 2010


Changing Water Resources in Africa
Lake Chad 1963
Declassified Argon image
Water area 25.000 km²
Source: Argon satellite USGS

Changing Water Resources in Africa



Source MODIS March 2005 NASA

Crops and Food: Water Avaibaility

R

Farmers driving their cattle through the Amboseli Lake in Kenya of which only a dry ground is left.

Source: National Geographic Society 2006

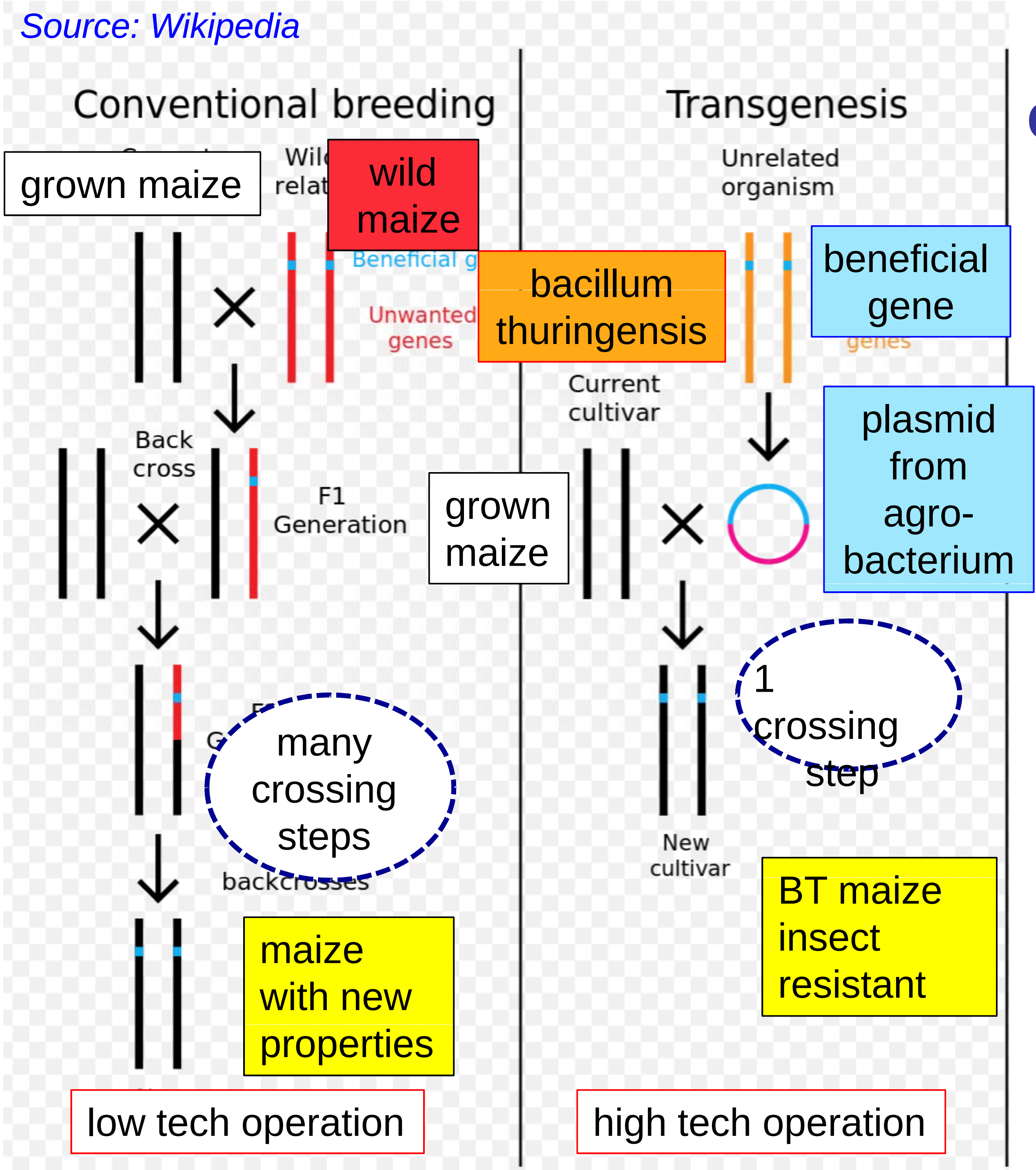
Crops and Food:
Fighting for Agricultural Land – Darfour/Sudan

Decades of drought, desertification, and overpopulation are the main causes of the Darfur conflict starting in 2003.

Map of destroyed villages as of Aug. 2004.

Baggara nomads searching for water have taken their livestock further south, to land mainly occupied by non-Arab farming communities.

In the conflict 400.000 died and 2,5 million people were displaced, and many of them now living in the Darfour refugee camps. *Source: UN and Wikipedia*



Crops and Food:
Genetically Modified Organisms (GMOs)

•Genetic modification of seed material allows to produce plants with new properties („Biocrops“):

-Enhanced resistance against insects (Bt-maize).

-Enhanced resistance against efficient broad band pesticides (RoundupReady Soy).

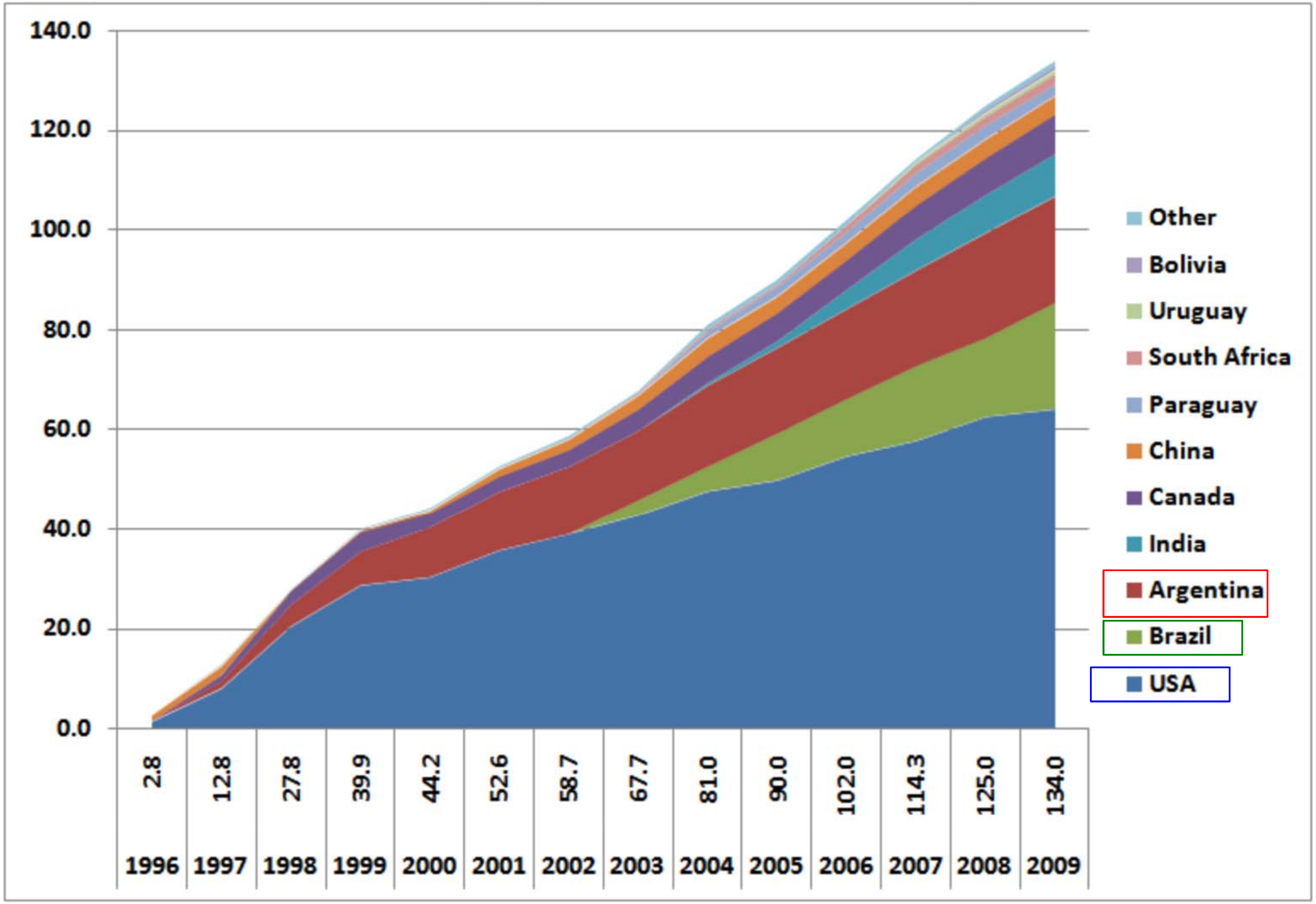
-Improved nutrient content.

-Higher drought resistance.

-Higher salt resistance.

Crops and Food: GMOs

GMOs are planted now in many regions of the world and provide a significant fraction of some major crops.

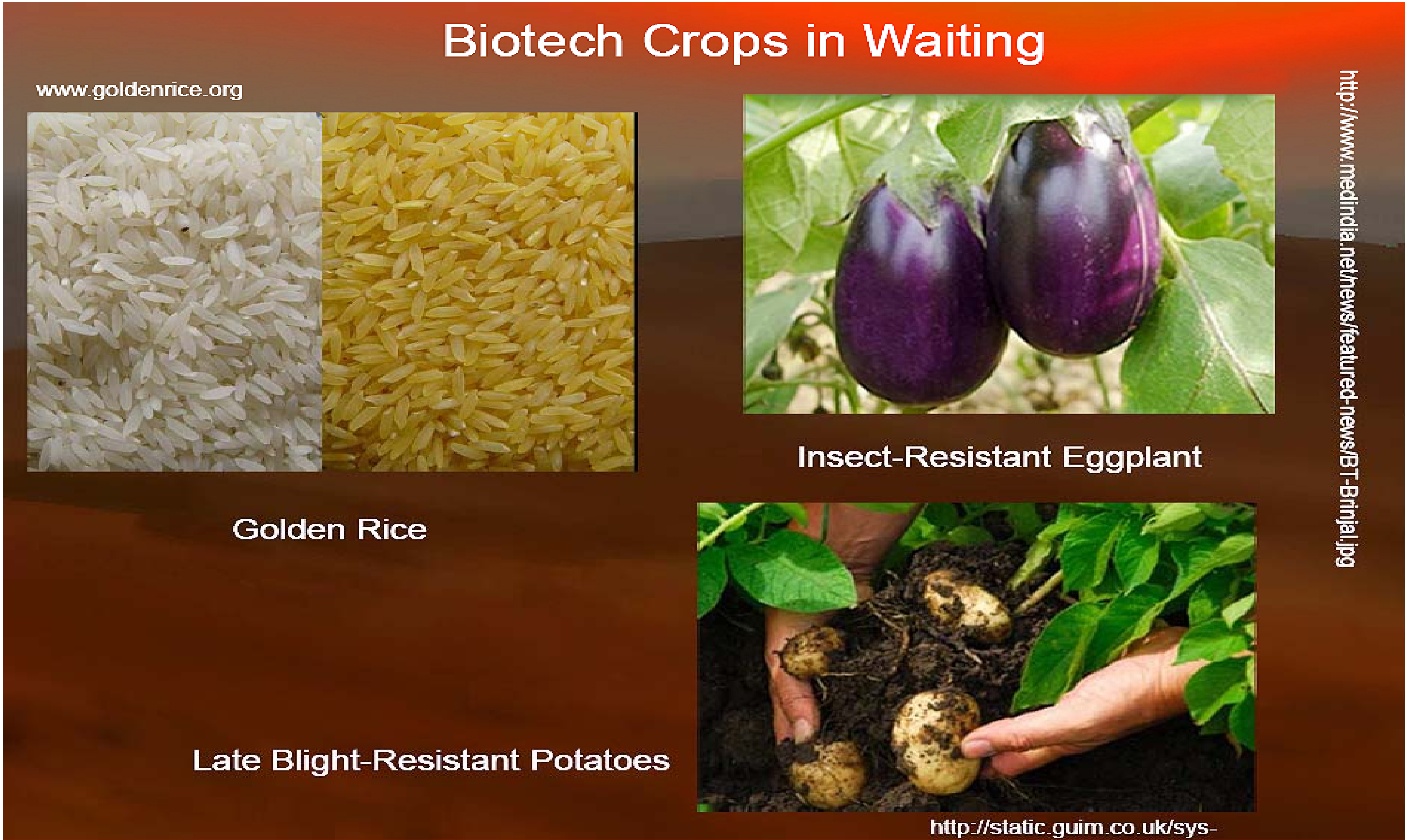


Global area of GM crops increased by a factor 100 since 1996.

- **Share of GM crops (2016):**
  - soy beans USA 94%, global 80%
  - maize USA 93%, global 35%
  - cotton USA 82%, global 70%
  - canola (rapeseed) USA 93%, global 25%

Source: Wikipedia

Crops and Food: Genetically Modified Organisms



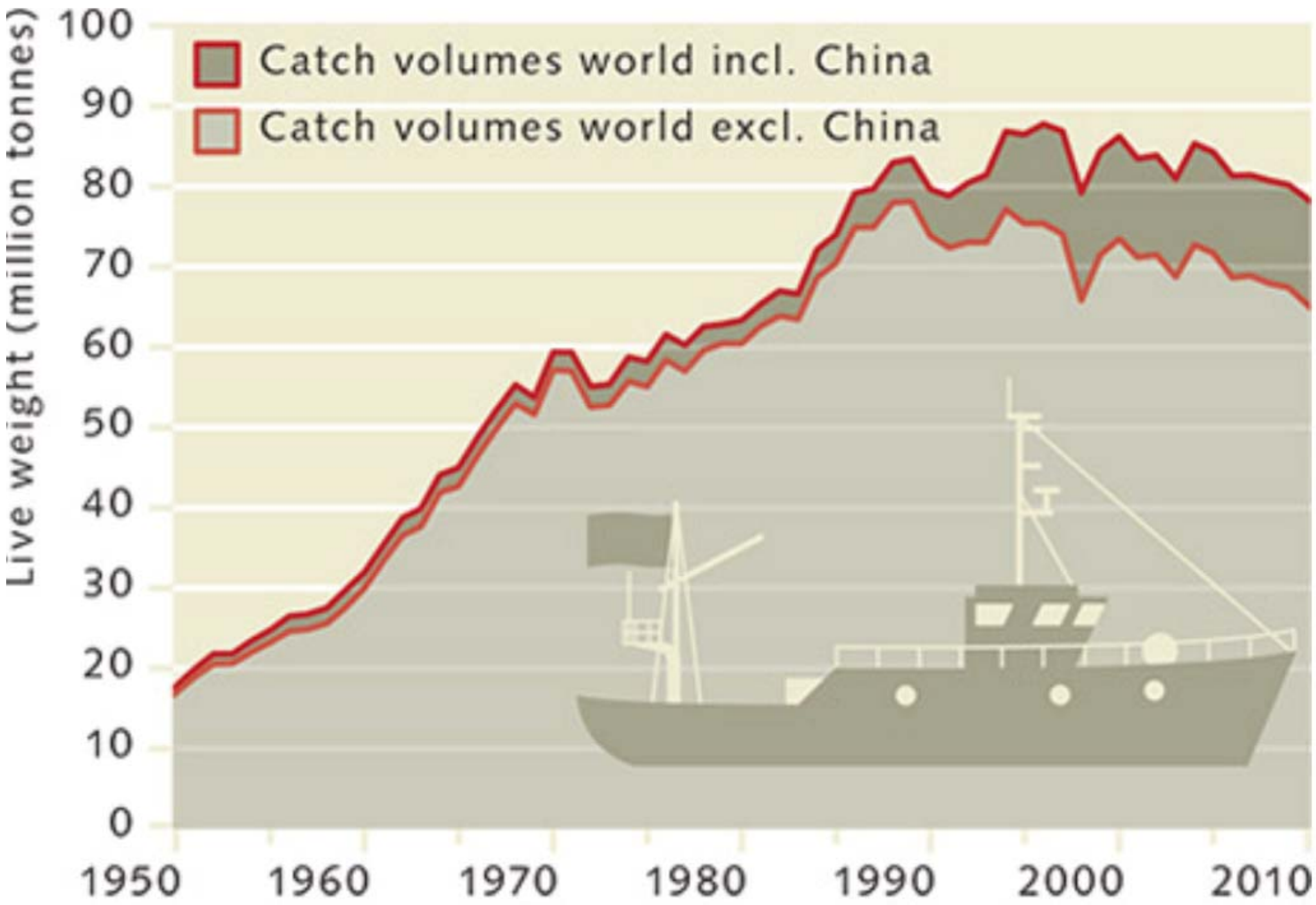
Genetic modification allows rapid cultivation of new crop varieties with improved properties. Conventional breeding techniques are much slower.

Crops and Food:
The European Position on GMOs

- In Europe the term "Frankenstein food" was coined.
- European consumer thoroughly dislike GMOs, are afraid of negative health effects and introduced labelling requirements.
- European Commission Report on GMO Biosafety (2010):
- ➢ Reports on 130 research projects covering a period of more than 25 years and involving 500 research groups:
- ➢ GMOs are not *per se* more risky than plants obtained with conventional breeding technologies.
- EU tried to ban imports of GM food and feed into the EU, but lost the WTO case:
- ➢ Only labelling acceptable.
- However many open questions remain:
- \- Dependence on large industry ?
- \- Pollination of non-GM plants ?
- \- Development of resistance of pests ?

Crops and Food: The Issue of Overfishing

- 14 fish species are important for the foodsupply of the humans.
- Global fish catch rose from 20 million tons in 1950s to 90 million tons in the 1990s due to the use of new technologies for commercial fishing, radar detection of fish swarms, trawling, purse sein....



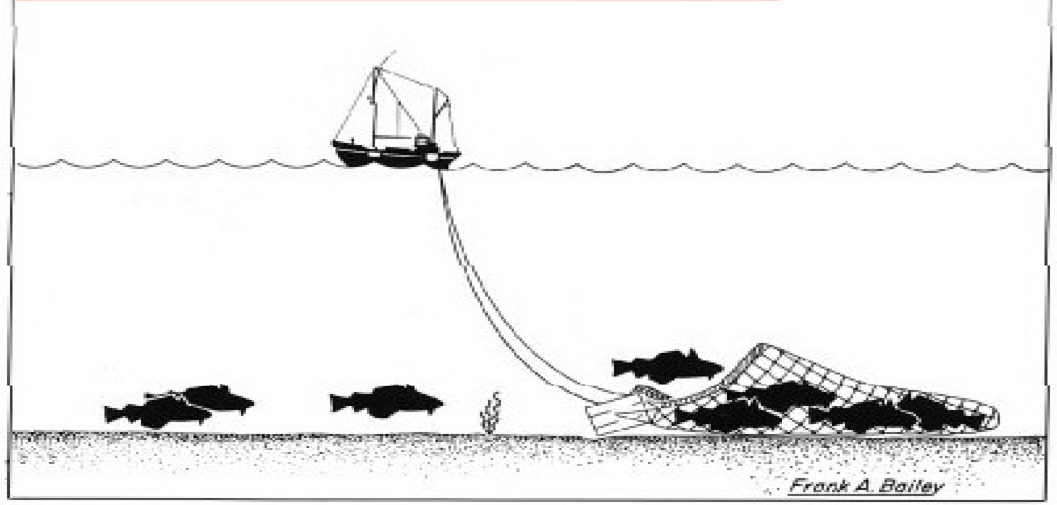
- Since then the global catches are slightly declining in spite of an extension of the fishing activities to the most remote regions.

Source: Wikipedia

Crops and Food:
Purse Seine and Trawling

- Purse Seine: Fish swarm is detected by sonar and an up to 200m deep net is layed around the fish. With this method whole swarms can be captured, inclusive all the small fish.
- Trawling: ship drags nets of up to 20.000 m^2 which allow to catch several hundred tons at once. Lack of selectivity.
- Bottom trawling: lack of selectivity and physical damage to the seabed.

Bottom trawling fishing technique.



Source: Wikipedia

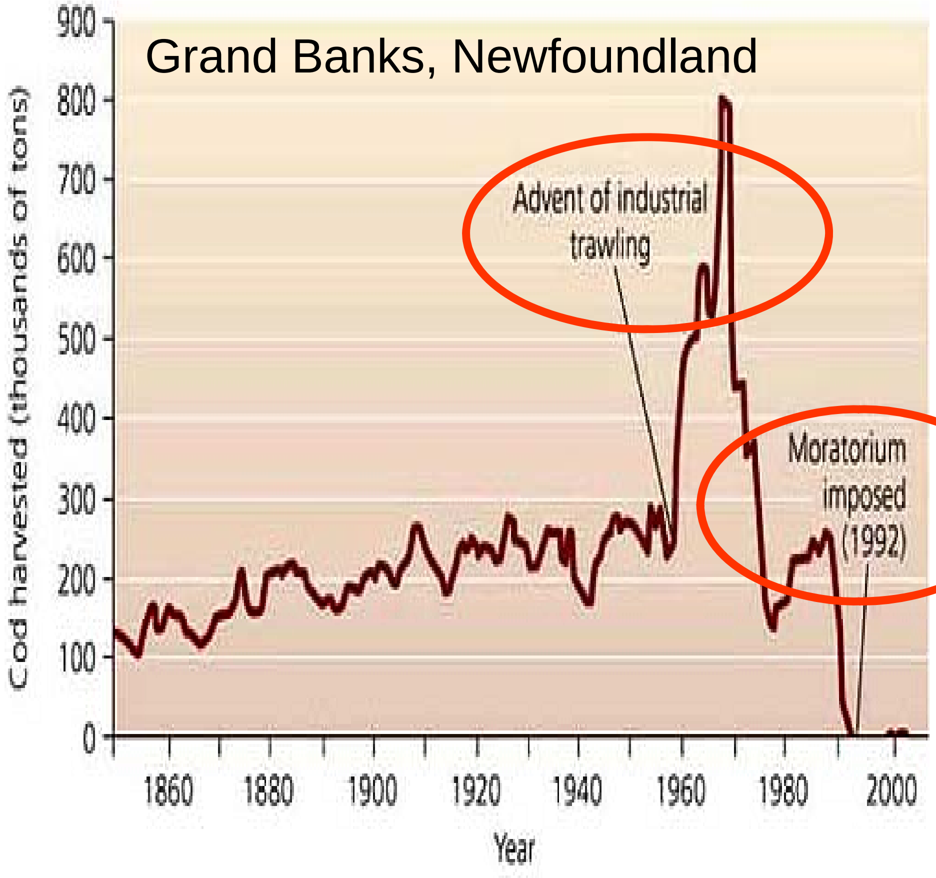
Purse Seine fishing technique.

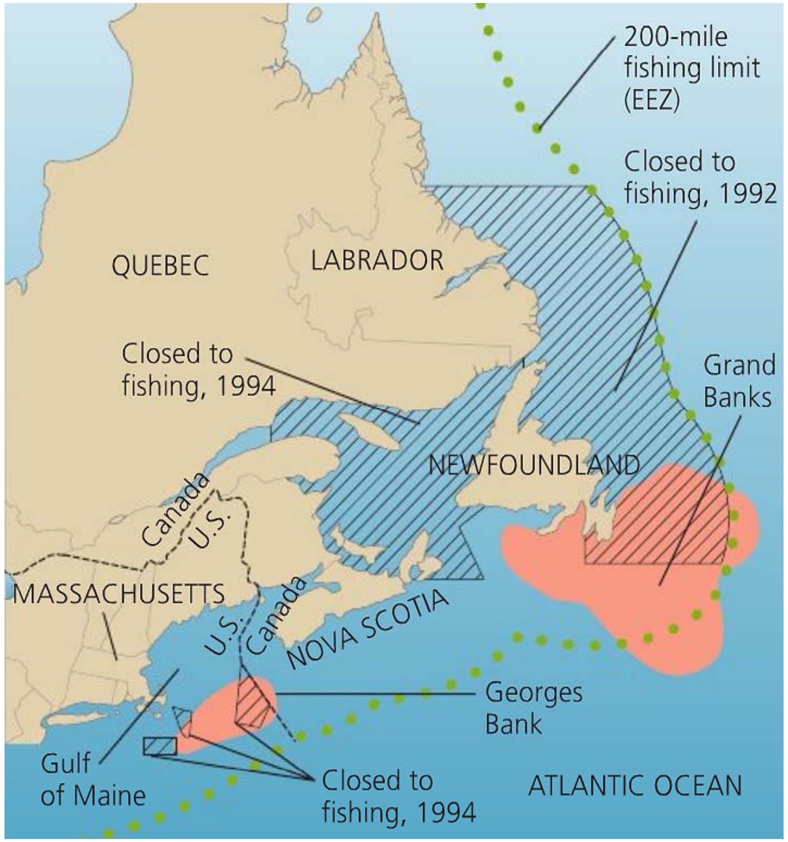

R

Crops and Food: Evolution of Cod Captures

•Fish catches of certain species and in specific regions have dramatically decreased due to reduction of the fish stocks: e.g. North Atlantic cod, salmon, tuna.

•Large areas had to be closed for fishing to enable recovery of cod stocks.

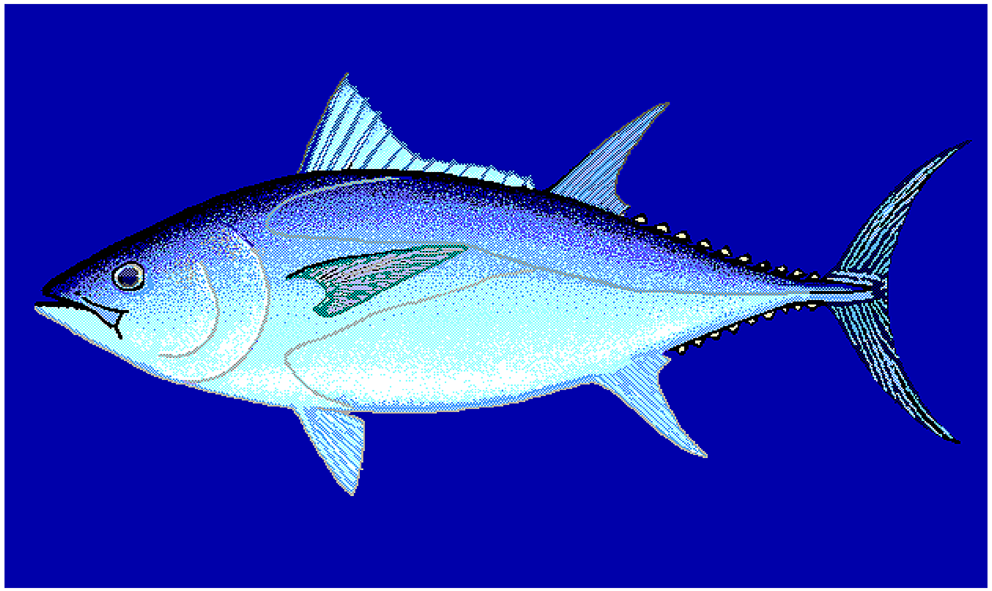




Source: Withgott and Brennan: Environment, Pearson 2008

Crops and Food: Tuna Fish

- In the 1960s, the annual world catch of tuna fish was about 1 million tons, most of it taken by hook and line.
- Now with purse seine catches are more than 4 million tons annually.
- 60%of the catch of the catch are skipjack tuna, 25% yellowfin tuna.
- Bluefin tuna, the most valuable species, amounts to only 1,5%
- 60.000 tons caught annually in the Mediterranean and Atlantic.
- Scientifically recommended catch of blue fin tuna is 15.000 tons maximum, consequently stocks were heavily reduced during the last decades.



- A 200 kg tuna fish can be sold for up to 600.000 $ on the Japanese market (2016).
- Extensive illegal fishing activities.

Bluefin tuna. *Source: Wikipedia*

Crops and Food: Decline of Fishery and Reactions

•Of our oceans' fish stocks, 50% are fully exploited and one third are overexploited

•Overfishing has not only proved disastrous to fish stocks but also to the fishing communities relying on the harvest causing a substantial drop in the number of fishers.

•Harvest Control Rule (HCR) management principles have been introduced in the main fisheries around the world.

•The "United Nations Convention on the Law of the Sea„ grants coastal states exclusive fishing rights for a 200 mile zone and requires all coastal states to ensure that the maintenance of living resources in their exclusive economic zones is not endangered by over-exploitation.

•Some States and Regions have enacted stringent fishing restictions (e.g. Canada, EU – Community Fishing Control Agency, Vigo).

Crops and Food: Aquaculture

•**Aquaculture production:**

-salmon, sea bass, cat fish, shell fish, tilapia, pangasius, trout, carp, oysters, shrimps, prawns……

-Totla production volume in 2016: 80 million tons with annual increase of 10 % (FAO)

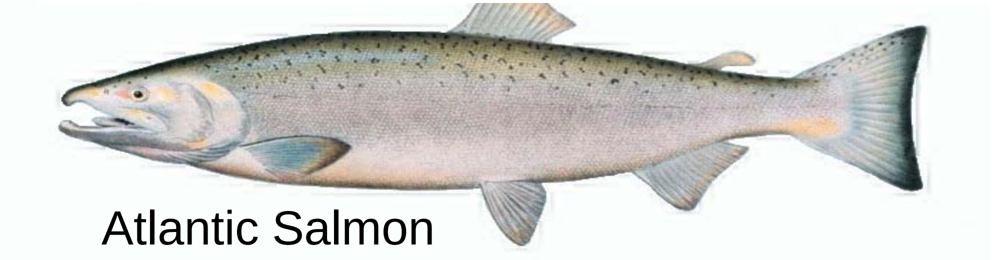
-30 years from now 80% of the fish consumed could come from aquaculture.

•**Environmental problems:**

-pollution with antibiotics and excrements

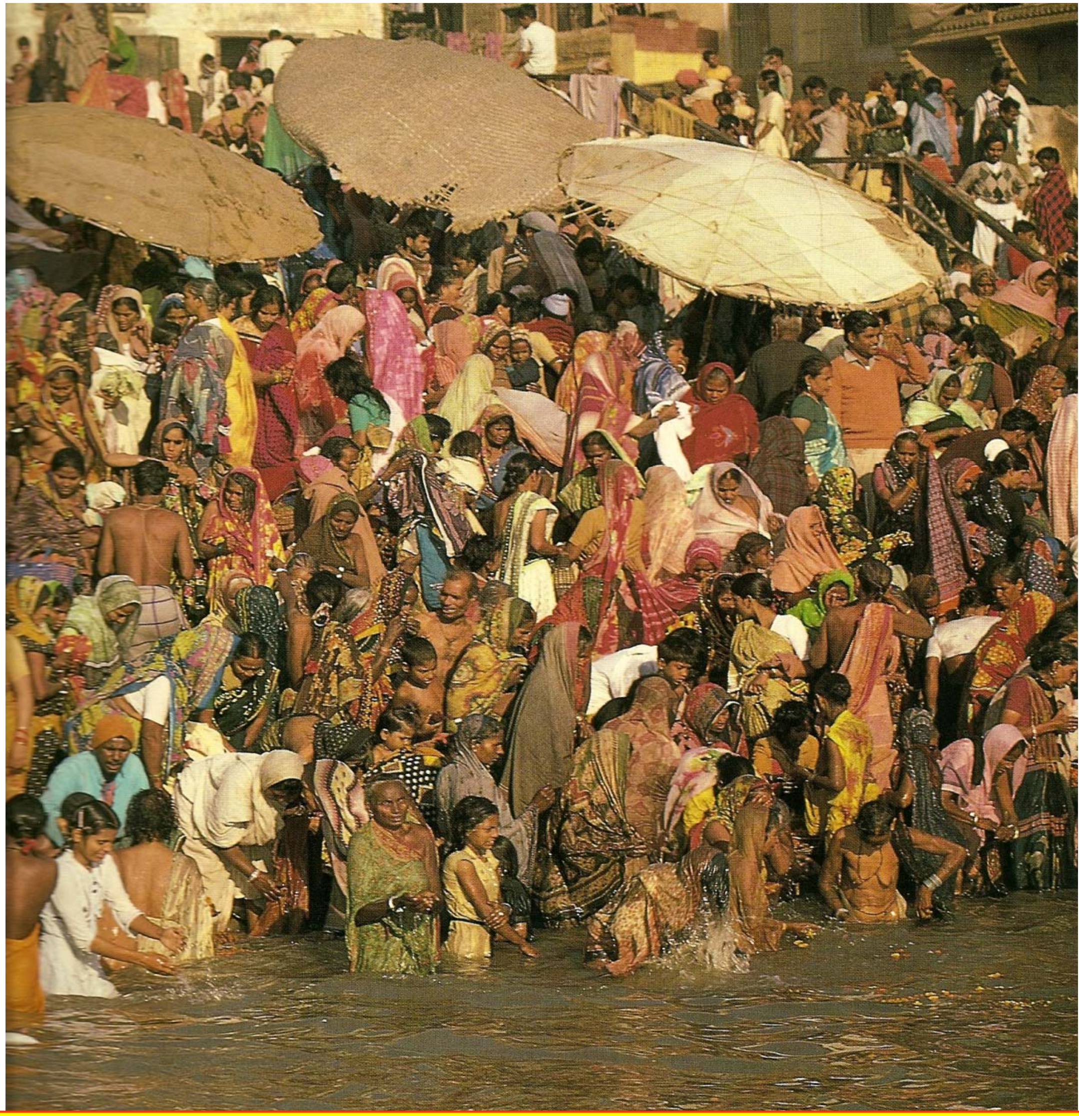
-breed fish escape and genetic crossing with wild species

-spread of parasites to wild species



Photos: Wikipedia

Crops and Food:
Global Population Growth and Food Supply



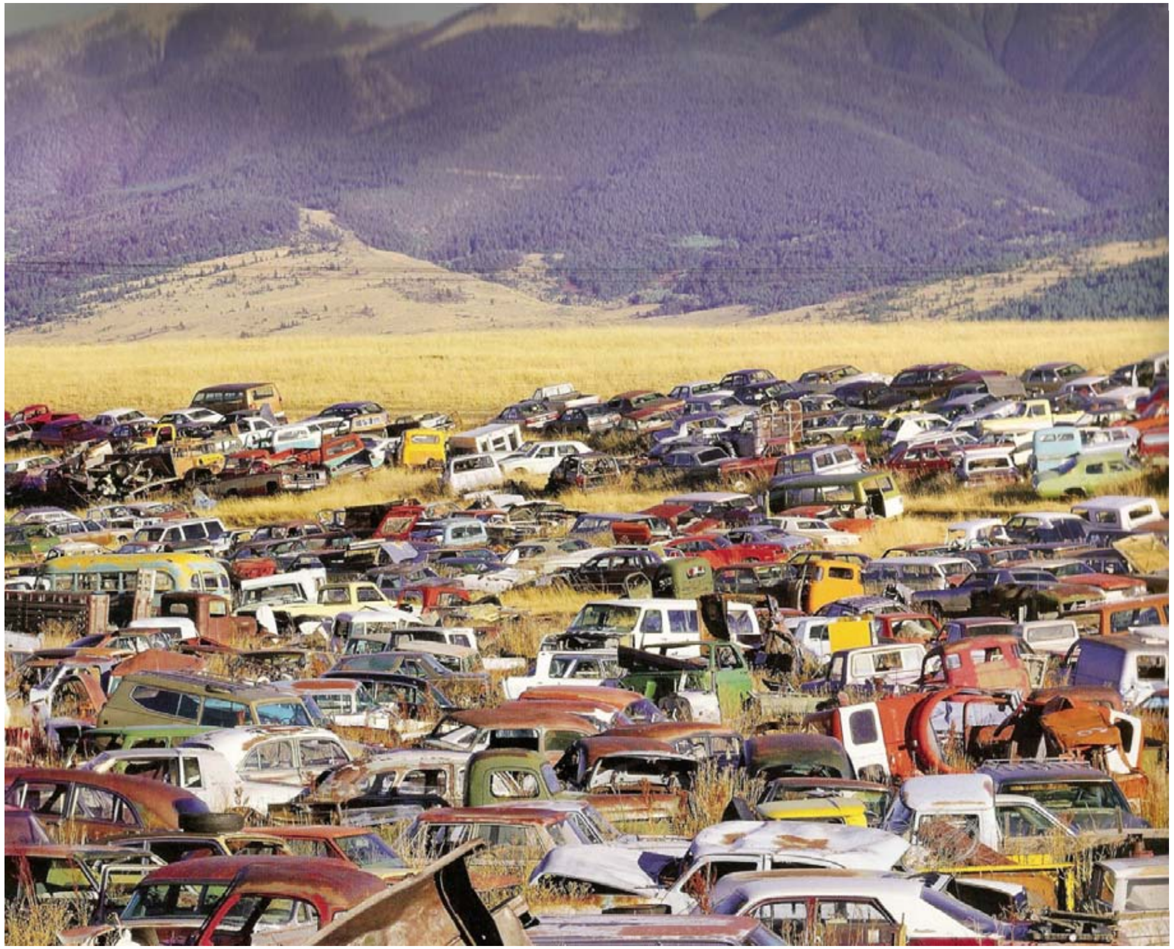
To supply the 10 billion people with food in 2050 a doubling of global food production deemed necessary,
but
available agricultural land per inhabitant
now 0,25 ha,
and
only 0,15 ha in 2050.

Varanasi at Ganges, India. *Source: Indien, RV Verlag*

Waste as a Resource

5.3 Minerals, Metals and Fossil Fuels

Source: National Geographic Society 2006



•**Car dumping site in the USA.**

•Each year about 20 million cars are taken out of service in the USA.

•In Europe ca 30 million become obsolete each year – many of these are sold to Africa.

See also EEA Report 2012 „ Material resources and waste”
http://www.eea.europa.eu/publications/material-resources-and-waste-2014

Minerals and Metals:
Waste as a Resource

- **Processing of imported electronic waste in Agbogbloshie in centre of Accra, Ghana.**

- In Europe each year about 100 million mobile phones and 20 million tv sets are taken out of service.
- Many of these are shipped to Africa for disassembling.

Photo: Kai Löffelbein Geo 2011

Minerals and Metals:
Waste as a Resource

The EU Resource Strategy:
Example: Waste as a resource – Towards a recycling society

Legal recycling targets to improve resource efficiency

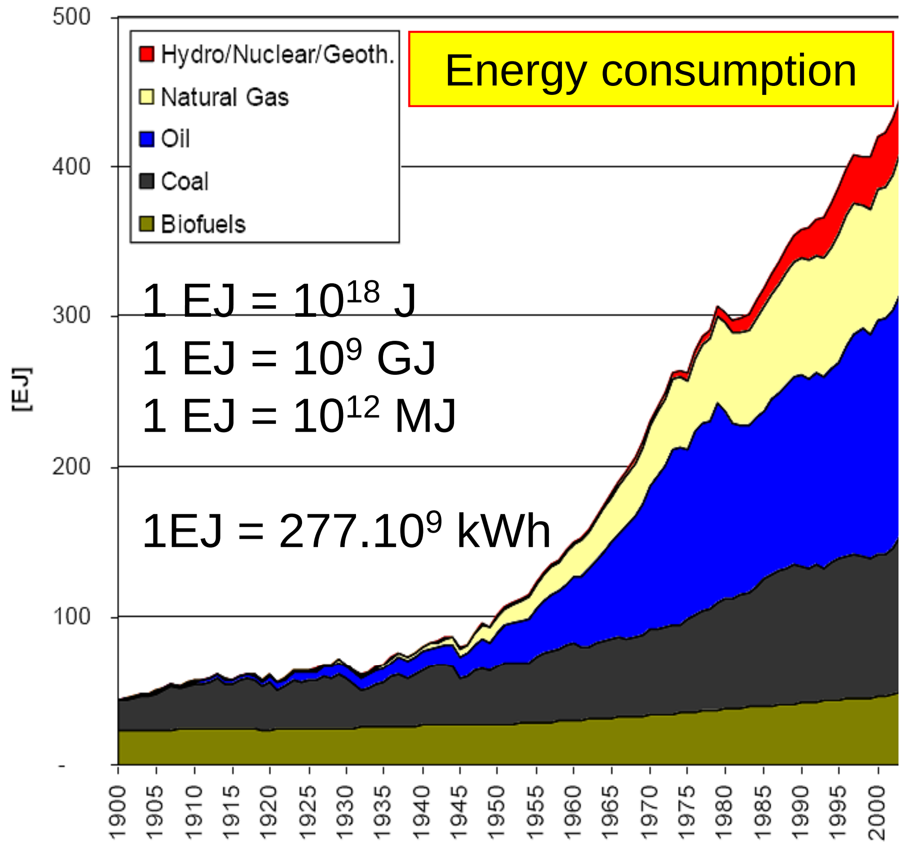
- **Household waste:** 50% (paper, metal, plastic & glass)
- **Construction and Demolition:** 70%
- **Electrical & Electronic Equipment (WEEE):**
  50 to 75% (collection requirement 4 → up to 16 kg/person/year)
- **End-of-Life Vehicles (ELV):** 85%
- **Packaging:** 55 to 80%

Source: T. Makela, uropen Commission 2009

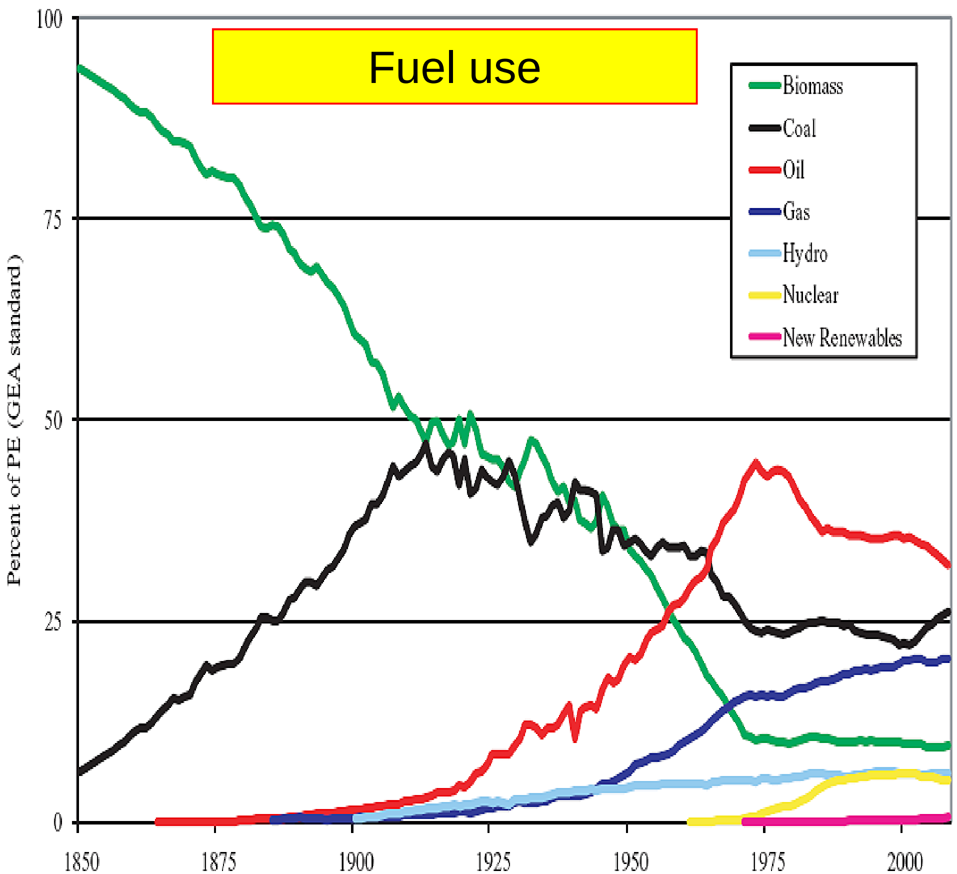
Each person in a highly developed region produces more than 500 kg of waste per year. “Circular economy” is now gaining impact as a model to transform today’s “take-make-dispose” economy into one that aligns business models with product and material design to decouple growth from resource. constraints.

Fossil Fuels:
Trends in Global Energy Consumption

- Steep increase in energy consumption



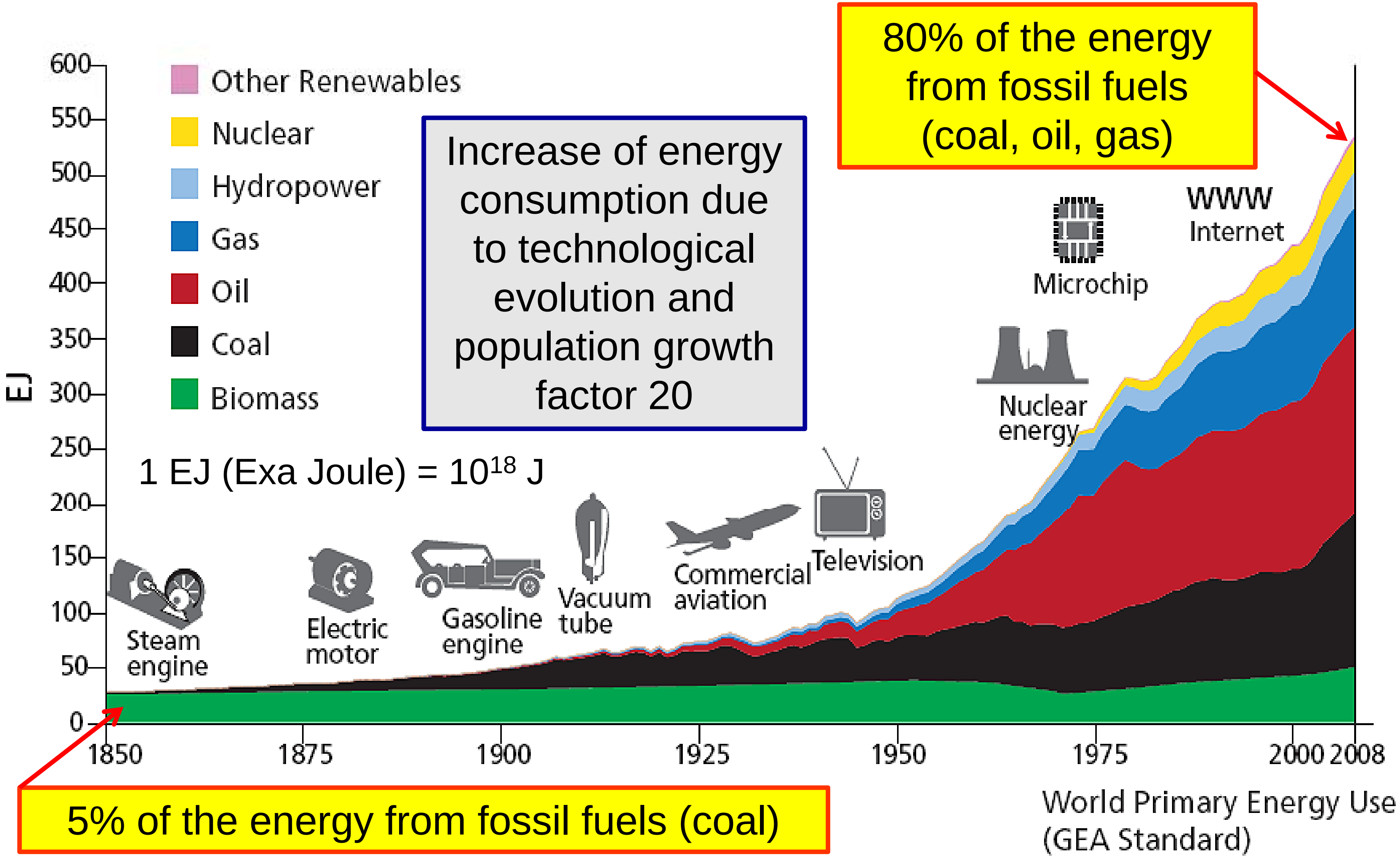
- Shift in fuel use:
from biomass to fossil fuels



Source: Krausmann et al, Fischer-Kowalski 2009

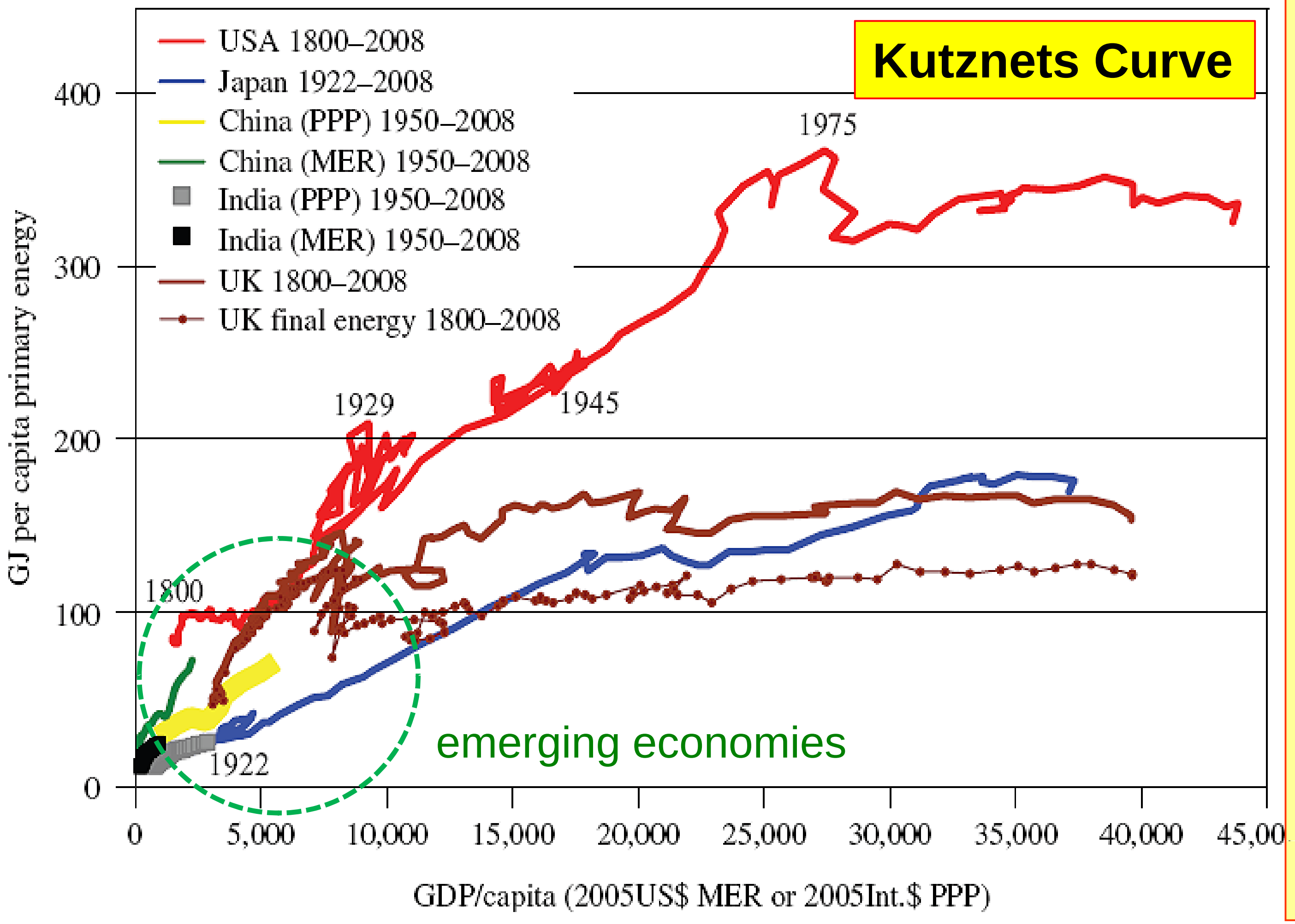
Source: IIASA 2011, http://www.iiasa.ac.at/web/home/research/researchPrograms/Energy/GEA_SPM.pdf

Fossil Fuels:
New Technologies and Energy Consumption



Quelle: IIASA 2011, http://www.iiasa.ac.at/web/home/research/researchPrograms/Energy/GEA_SPM.pdf

Fossil Fuels:
Relation Between GDP and Energy Consumption

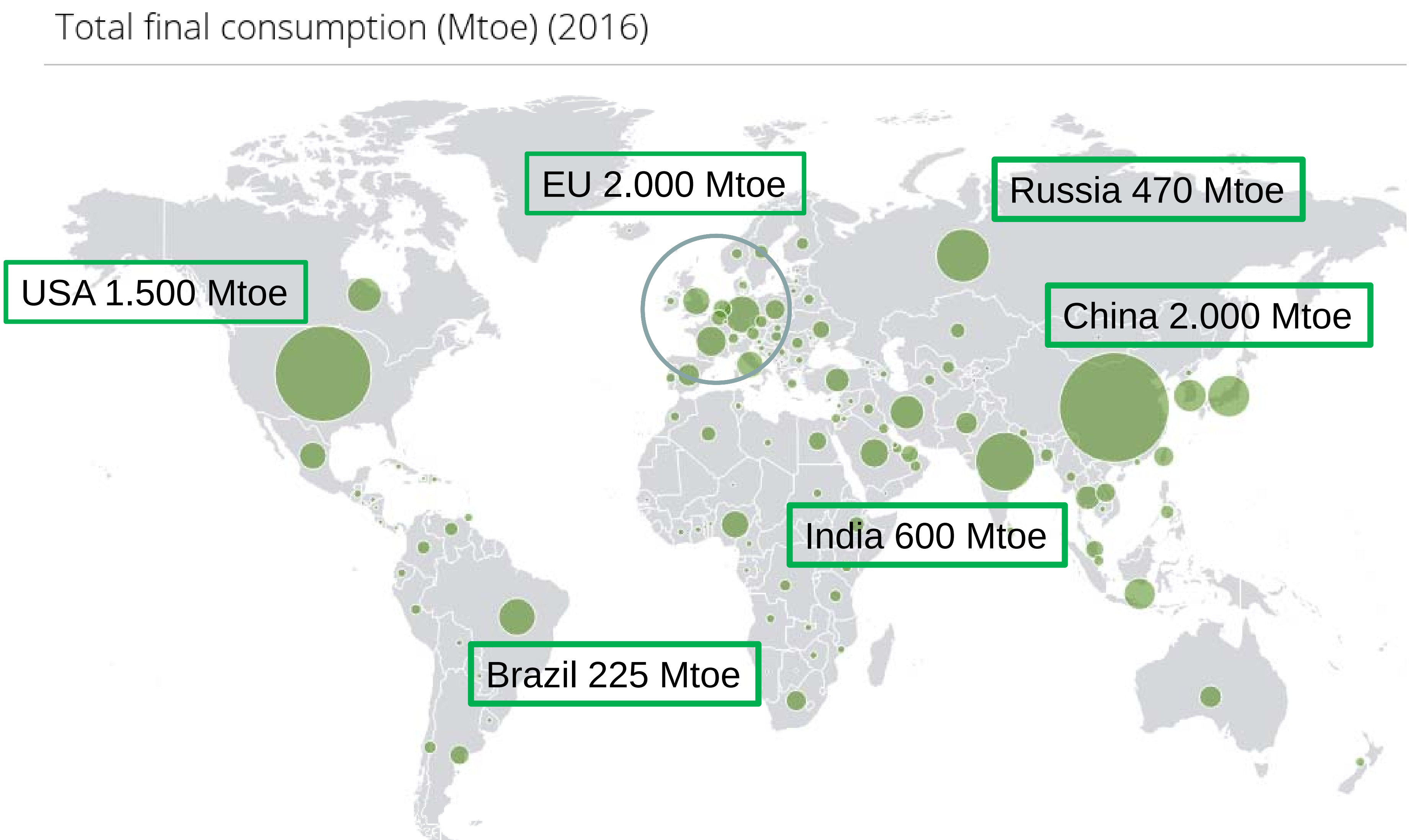


•Global energy consumption will more than double till 2050.

CO_2 emissions will rise from 36 Gto/yr in 2016 to 62 Gto/year by 2050 according to OECD/IEA analysis unless a technology change occurs.

Source: IIASA 2011, http://www.iiasa.ac.at/web/home/research/researchPrograms/Energy/GEA_SPM.pdf

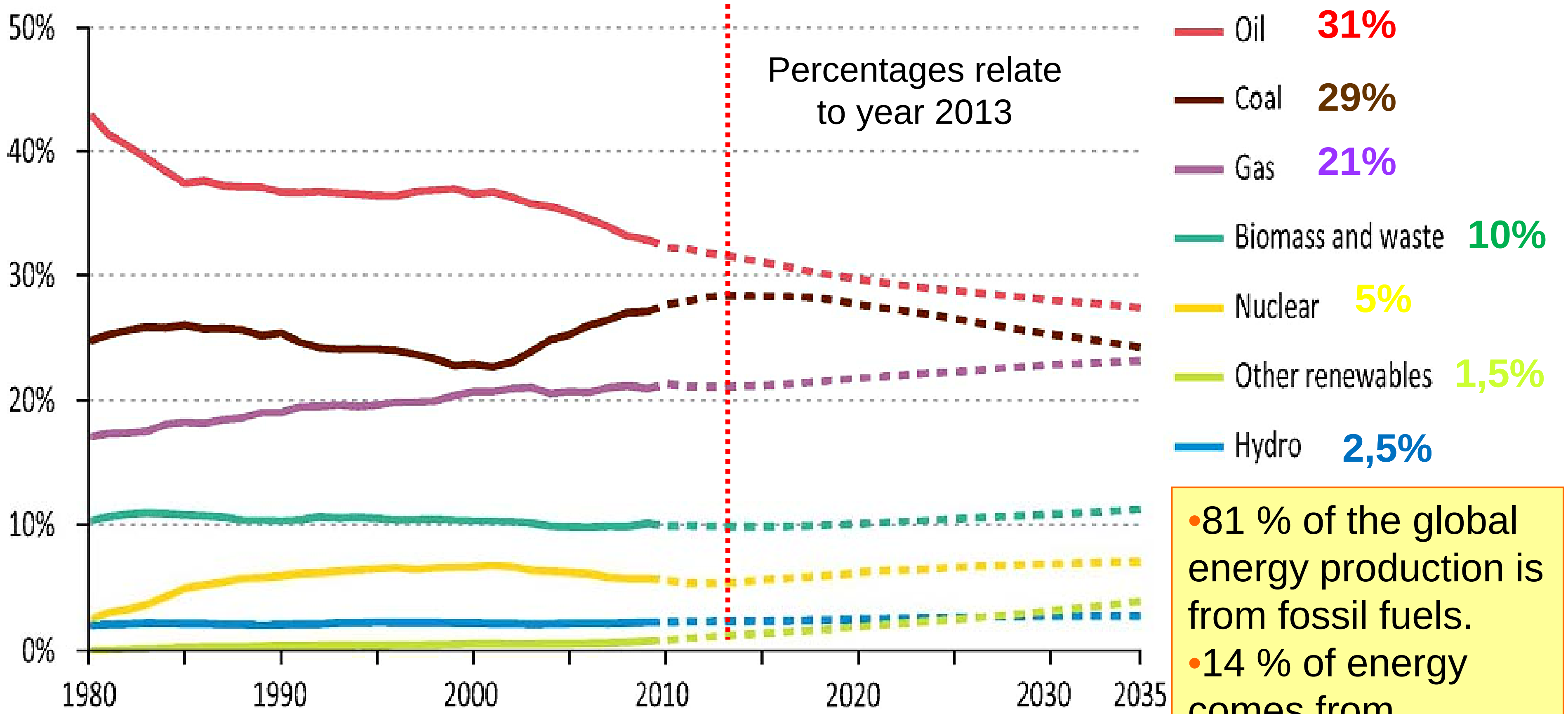
Total Energy Consumption per Country/Region



Source: IEA Atlas of Energy 2018

Energy conversions: 1 kWh = 3,6 MJ, 1 J = 1 Ws; 1 ton oil equivalent (toe) = 42 GJ
Global energy consumption: $21.300 \times 3{,}6.10^6 \times 7.10^9$ = 500 EJ (500.10^{18} J)

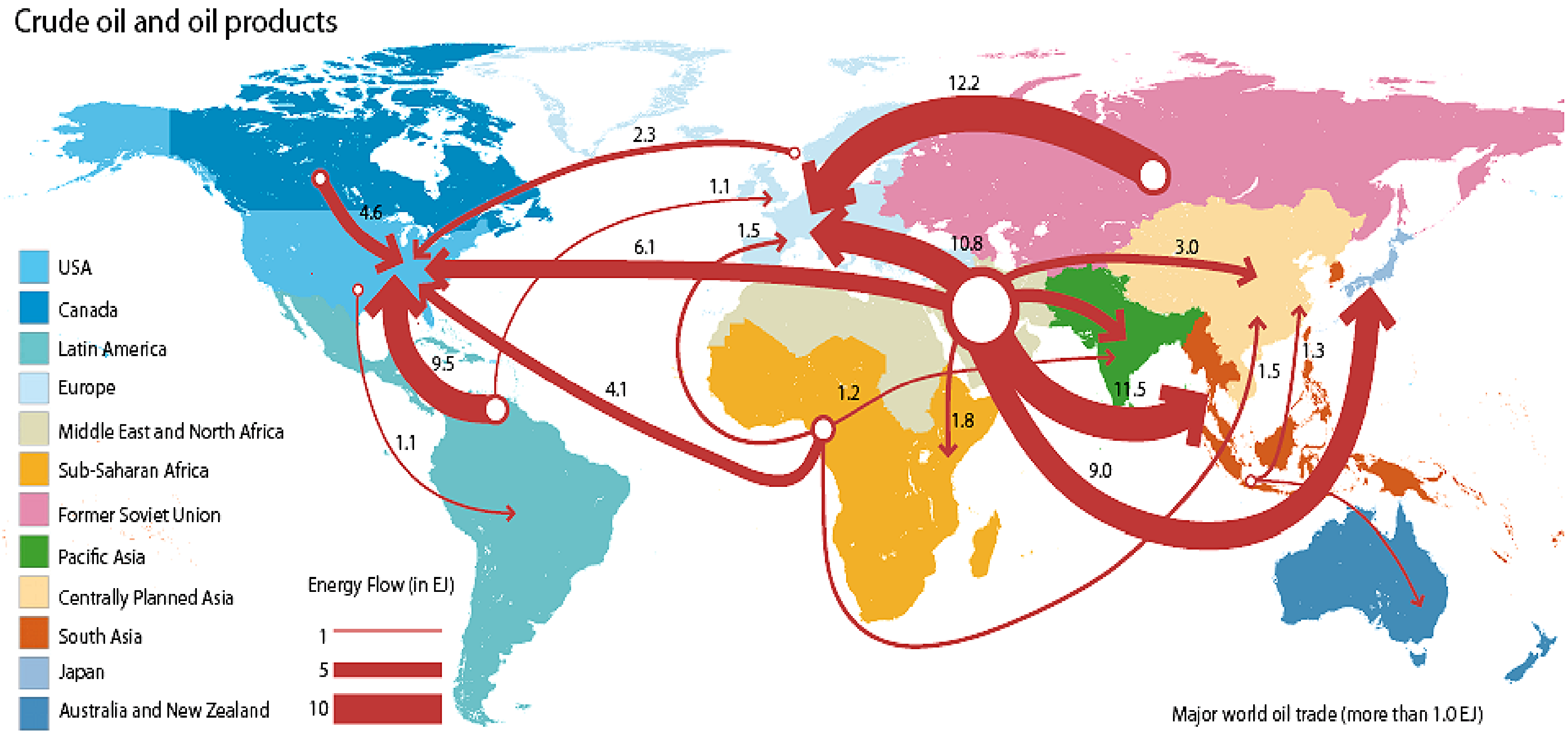
Energy Sources:
Shares of Energy Sources in World Consumption



- 81 % of the global energy production is from fossil fuels.
- 14 % of energy comes from renewable sources.

Total global energy demand now 500 EJ, 750 EJ in 2035 and 1.000 EJ in 2050. Oil remains the leading fuel though natural gas demand rises the most in absolute terms. *Source: IEA 2015*

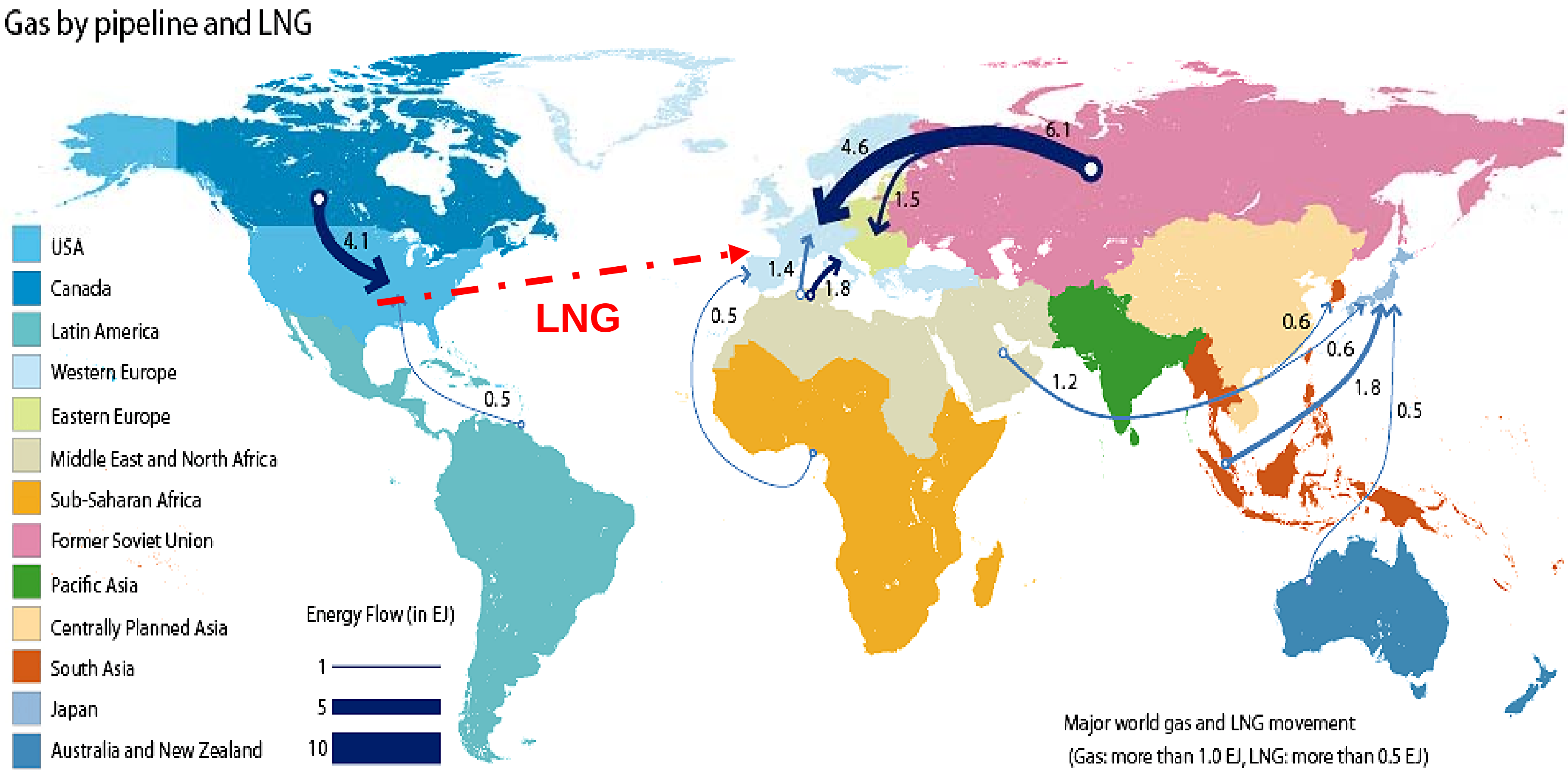
Fossil Fuels:
Global Oil Flows



Main oil suppliers: Saudi Arabia, Iran, Iraq, Kuwait, UEA, Qatar, Venezuela, Norway, Canada, Nigeria, Russia, Libya, Kazakhstan

Source: IIASA 2011, http://www.iiasa.ac.at/web/home/research/researchPrograms/Energy/GEA_SPM.pdf

Fossil Fuels:
Global Gas Flows



Main gas suppliers: Russia, Canada, Iran, Qatar, Saudi Arabia, Iraq, Turkmenistan, UEA, Venezuela, Nigeria, Algeria, Kazakhstan (plus USA with Liquid Natural Gas - LNG - in the future?)

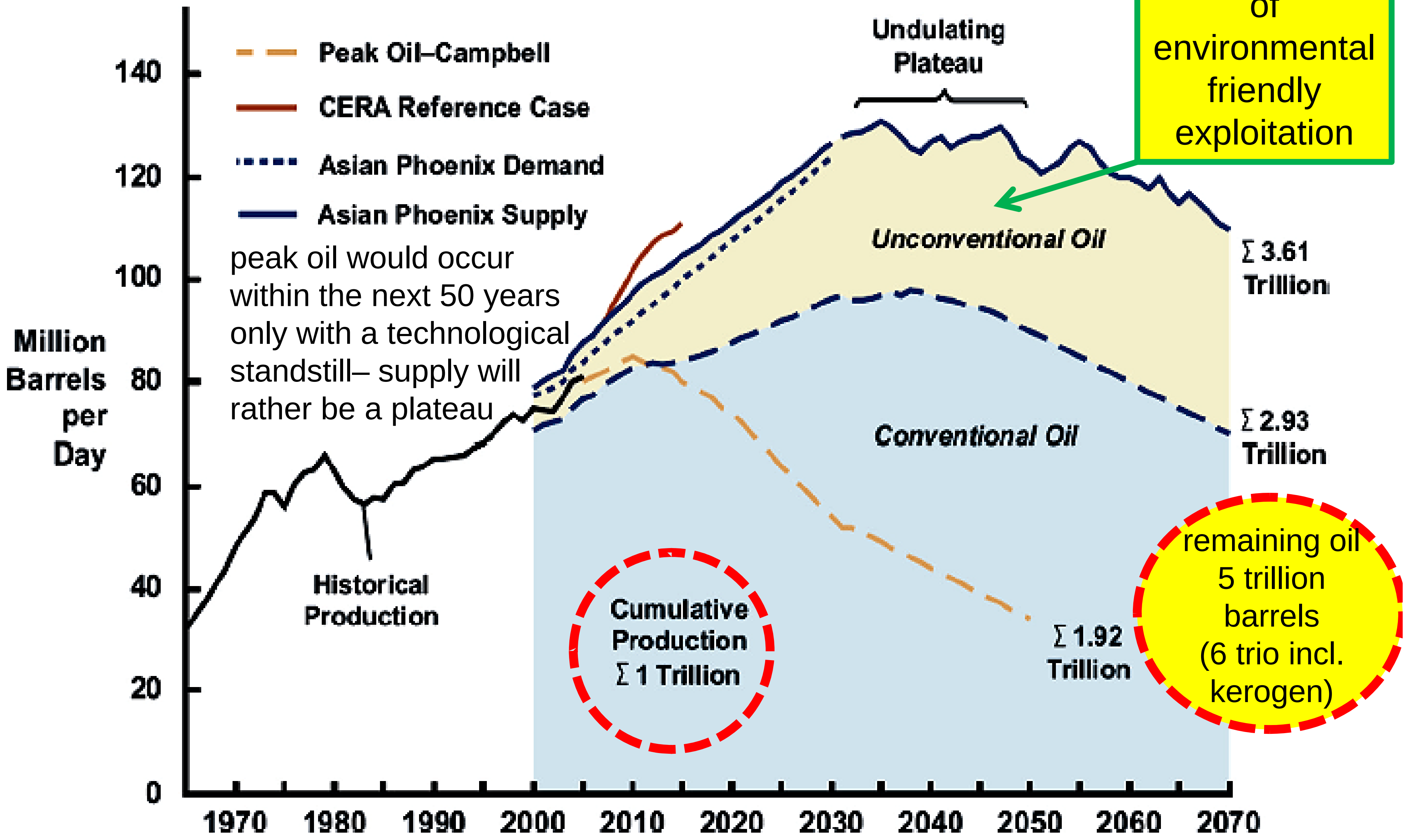
Source: IIASA 2011, http://www.iiasa.ac.at/web/home/research/researchPrograms/Energy/GEA_SPM.pdf

Fossil Fuels:
Global Consumption, Reserves and Resources

- **Oil:**
  – 50% of the global known *conventional* reserves now consumed
  – „*unconvential resources*" ca 3x the amount consumed by now :
  oil sands (bitumen-like materials which can be processed into synthetic crude oil) and oil shales (organic-rich fine-grained sedimentary rock containing significant amounts of kerogen, a solid mixture of organic chemical compounds). Exploitation causes environmental concerns!
- **Natural gas:**
  – 30% of the global known *conventional* reserves now consumed
  – „*unconvential resources*" ca 10-20x the amount consumed:
  shale gas. Exploitation causes also some environmental concerns
- **Coal:** nearly unlimited supply
- **Uranium:** practically unlimited supply

Source: IIASA 2011, http://www.iiasa.ac.at/web/home/research/researchPrograms/Energy/GEA_SPM.pdf

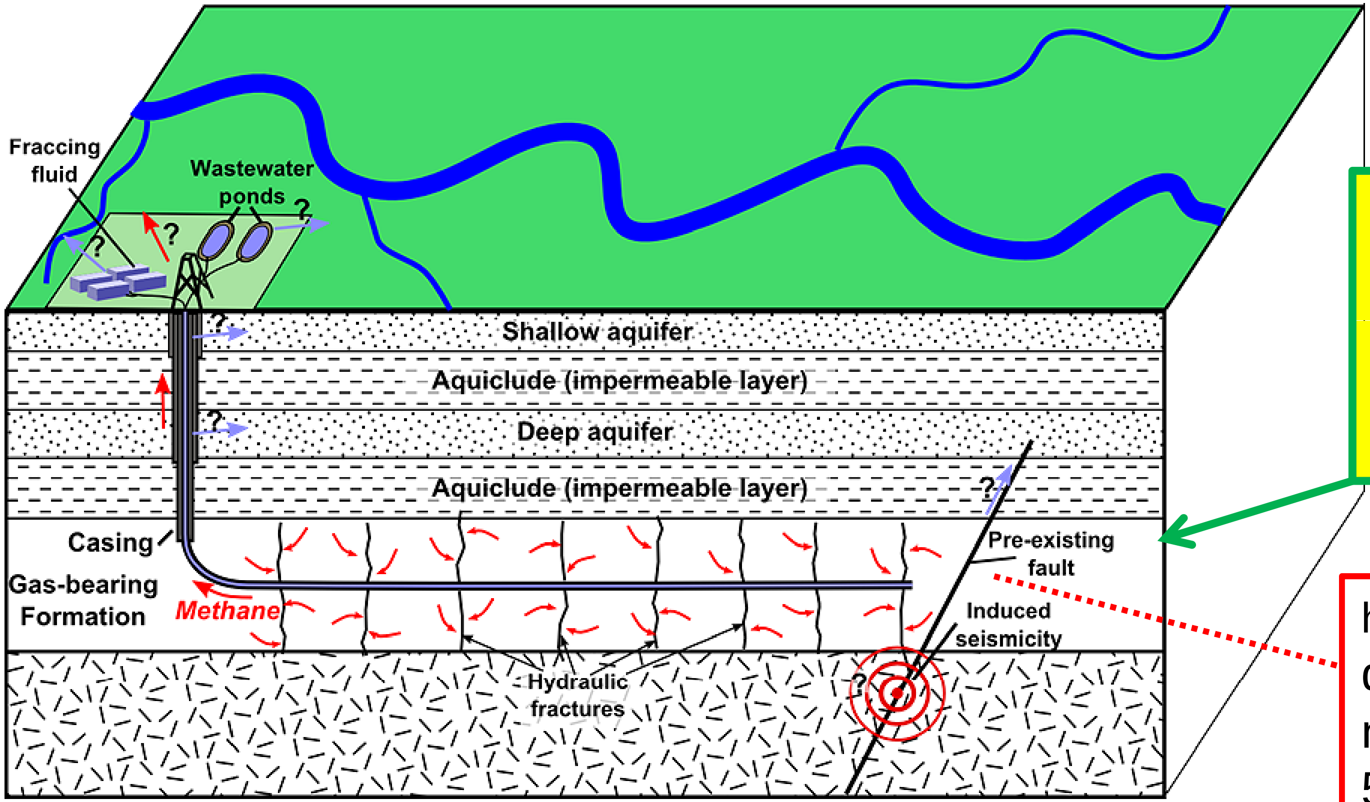
Fossil Fuels:
Possible Evolution of Global Oil Production



Source: IIASA 2011, IEA 2013

Fossil Fuels:
Unconventional Gas - Fracking

Source: IEA World Energy Outlook 2012



development of environmental friendly exploitation

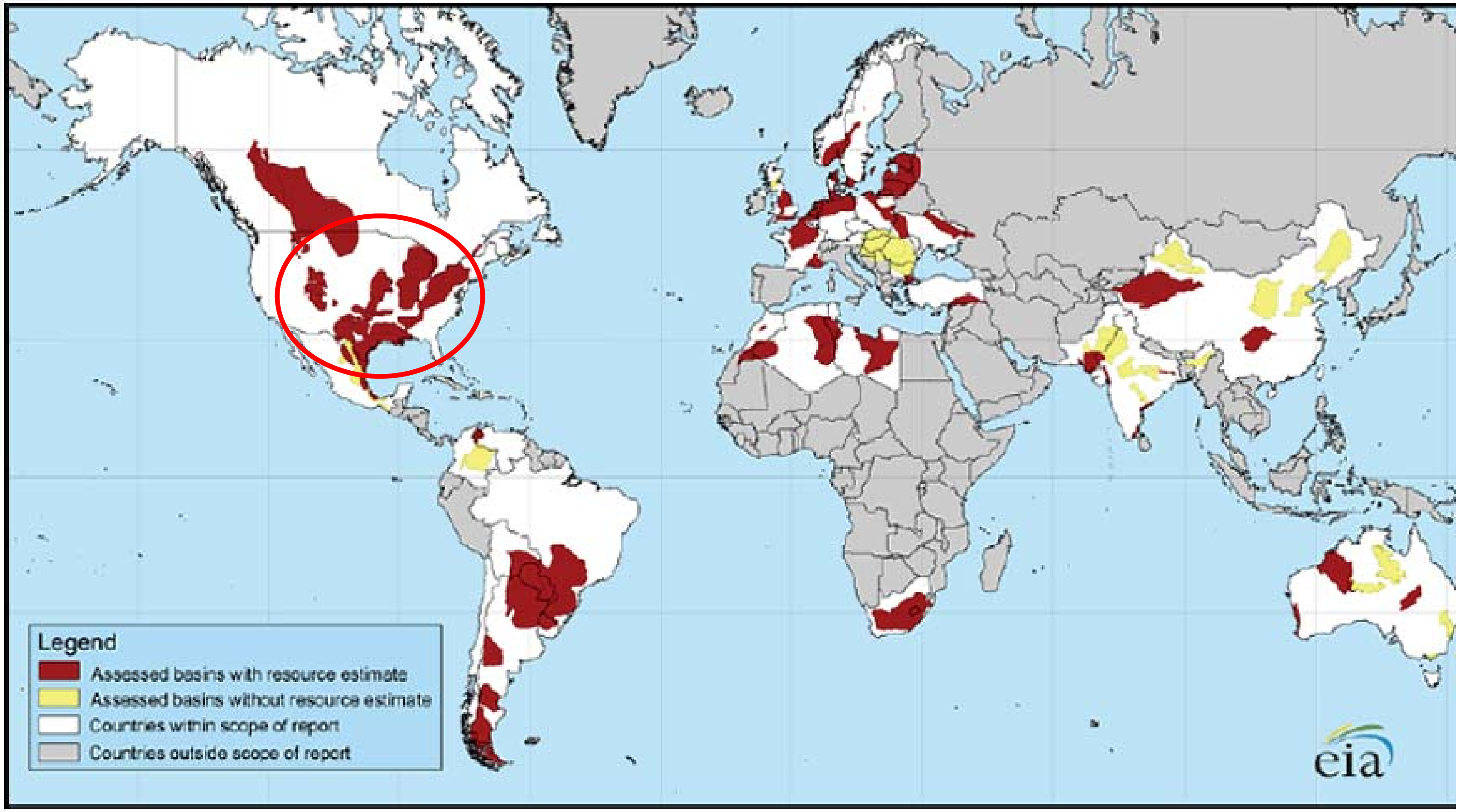
horizontal drilling now up to 500m

Induced hydraulic fracturing, commonly known as fracking, is a technique used to release petroleum or natural gas (including shale gas) for extraction.

Estimated resources are 10-20x the amount of natural gas consumed so far.

Environmental concerns focus on the contamination of ground water by the additives in the fracking fluids.

Fossil Fuels:
The New Gas World
World shale reserves

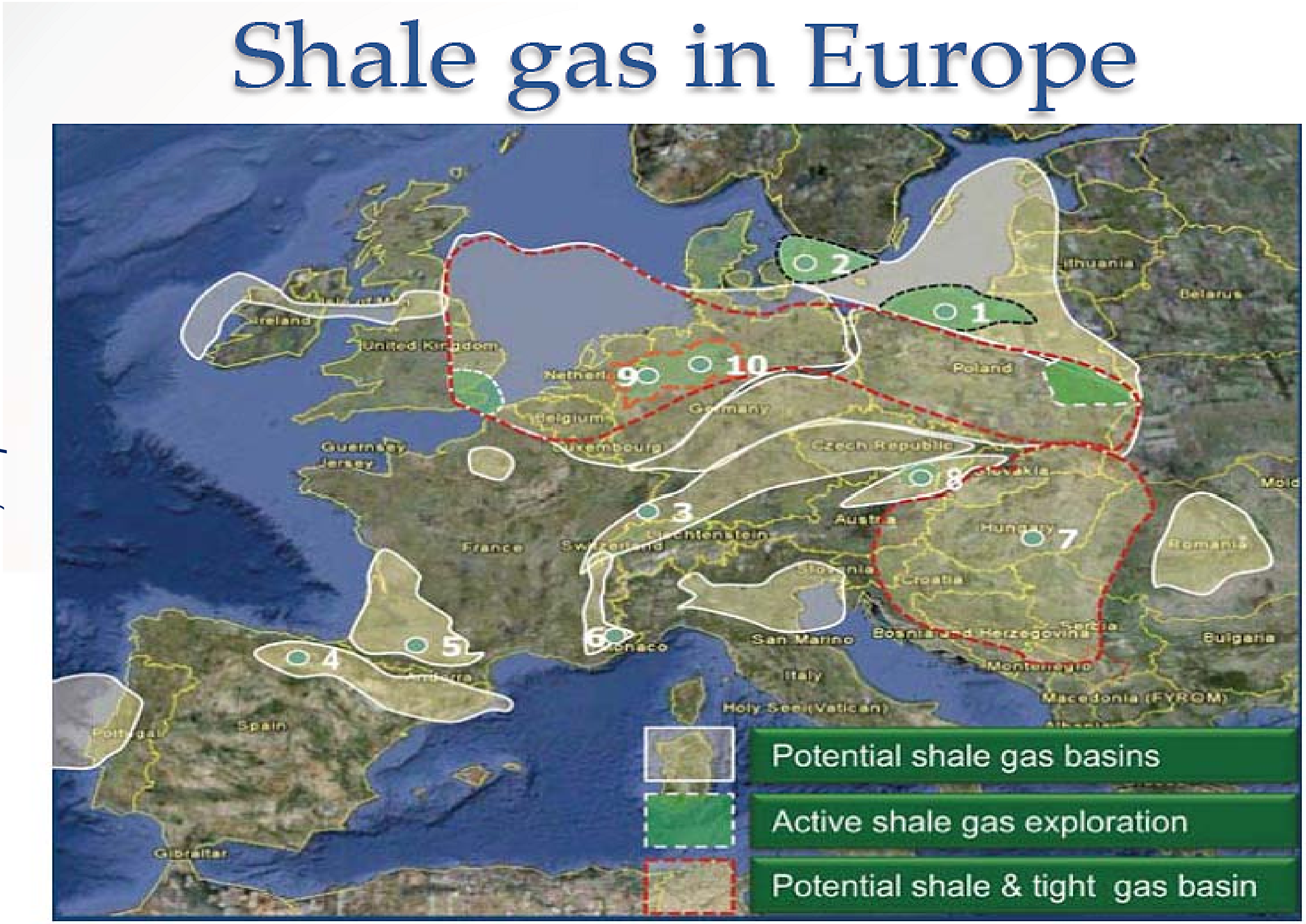


The USA is vigorously exploiting these reserves and is on track to become a major exporter for natural gas.

Source: Dieter Helm 2012, http://www.dieterhelm.co.uk/node/1328

Fossil Fuels: The New Gas World

Source: Dieter Helm 2012, http://www.dieterhelm.co.uk/node/1328



European reserves not very well defined and sometimes overestimated (e.g. Poland).

Exploitation difficult due to often rather complex geological formations.

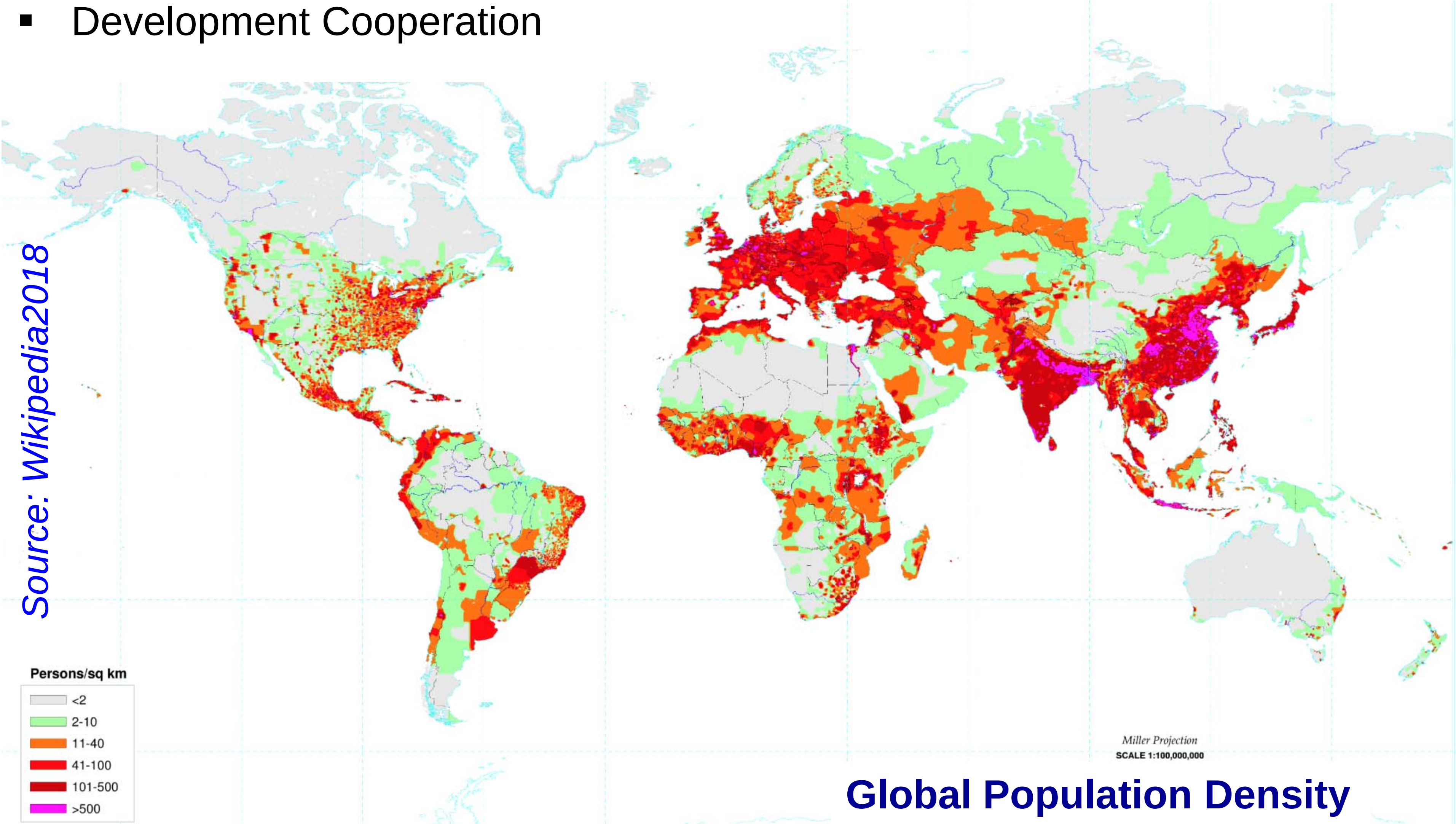
Fracking technology meets much suspicion in EU.
But: UK Roadmap of Department of Energy and Climate Change aims at shale gas production by 2020 which is 3 times larger than the present consumption.

Ecology and Sustainable Development

7. Socioeconomic Challenges:

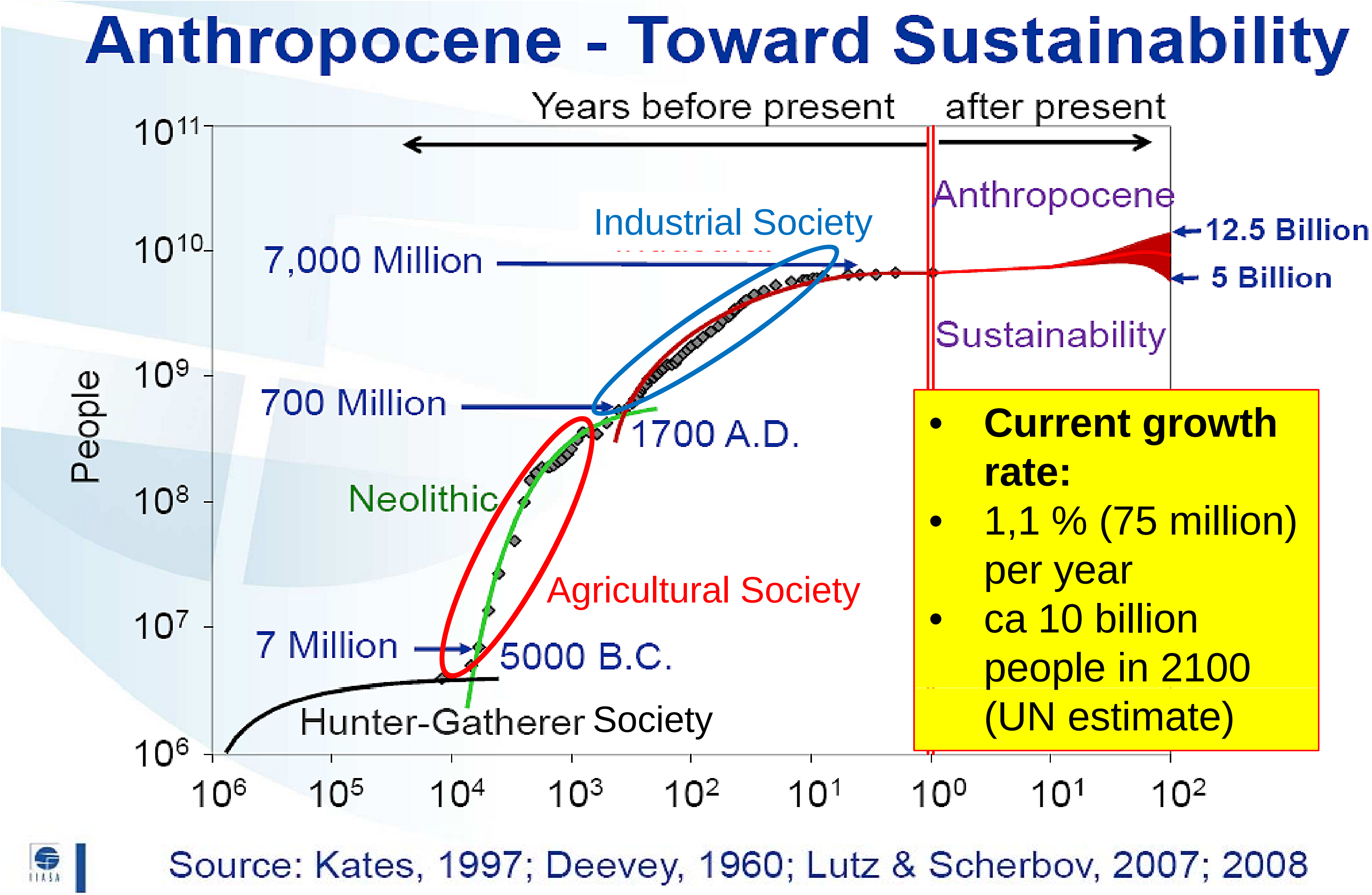
- Socioeconomic Trends
- Development Cooperation

Source: Wikipedia2018



Global Population Density

Evolution of World Population

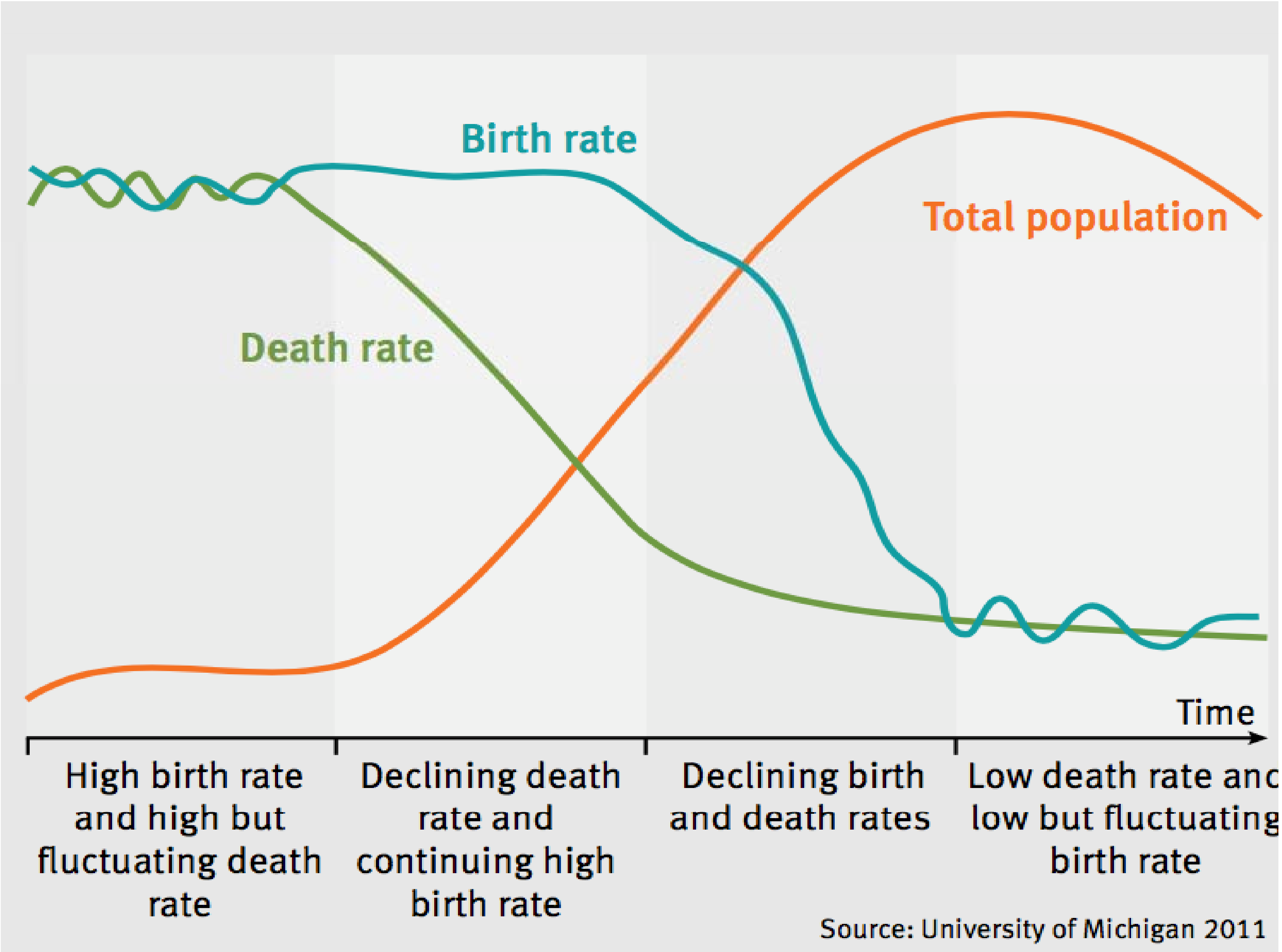


- **Current growth rate:**
- 1,1 % (75 million) per year
- ca 10 billion people in 2100 (UN estimate)

Source: Nakicenovic IIASA 2012

Around 30% of the world's population is below 15 years of age.

Evolution of the World Population:
The Demographic Transition



Source: UNEP 2012

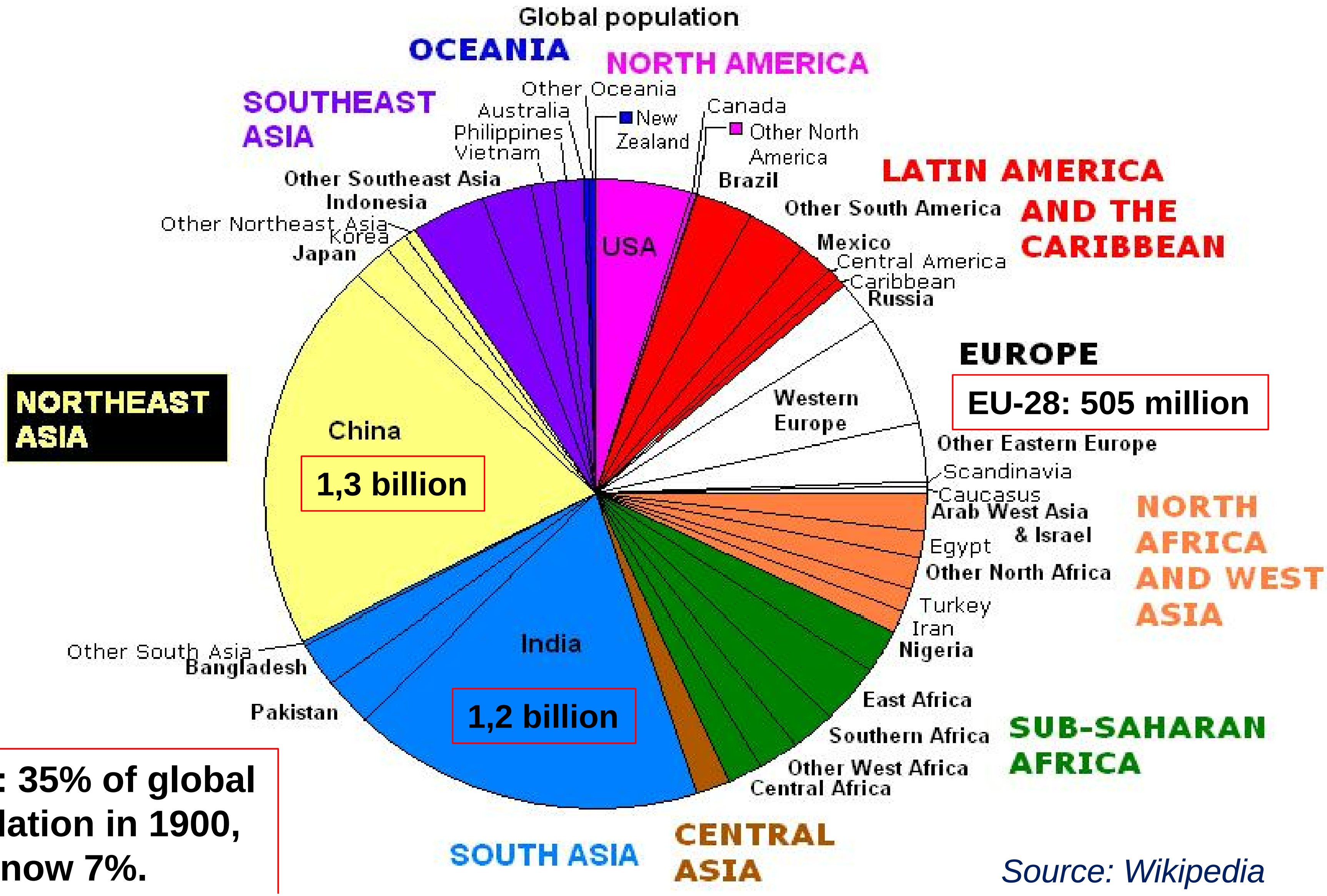
Developments in the Last Century…

- **Socio-economic indicators**:
  - life expectancy: x2
  - costs electricity: x0,1
  - costs transportation: x0,1
  - land productivity: x5 – 6
  - cost of food: x0,1
  - labor productivity: x200 – 300
  - poverty (<1.25€/day): 1 in 2 in 1900, 1 in 8 today

Source: Louise O. Fresco 2013

World Population by Region

- Global population: 7,7 billion (2018)



EU-28: 35% of global population in 1900, now 7%.

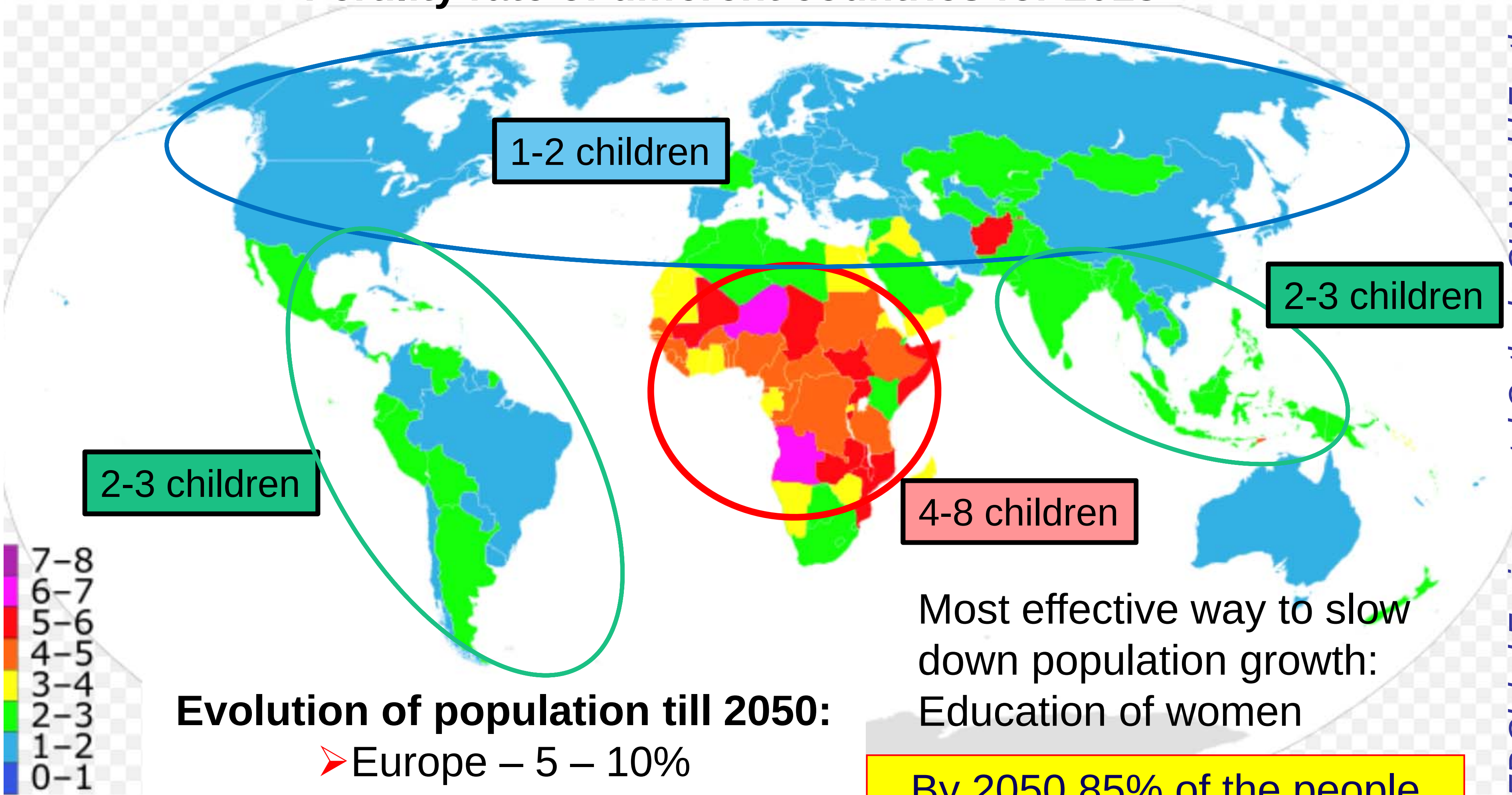
Source: Wikipedia

Features of World Population

- The Han Chinese are the world's largest single ethnic group, constituting over 19% of the global population in 2011.
- The world's most-spoken first languages are:
  - Mandarin Chinese (12.44% of the world's population)
  - Spanish (4.85%)
  - English (4.83%)
  - Arabic (3.25%) and
  - Hindustani (2.68%).
- The world's largest religions are:
  - Christianity (31% of the global population)
  - Islam (24.1%)
  - Hinduism (14%).

Population Evolution in Different Regions

Fertility rate of different countries for 2018



Evolution of population till 2050:

- Europe – 5 – 10%
- North America + 30%
- Asia + 30%
- Latin America + 50%
- Africa + 100%

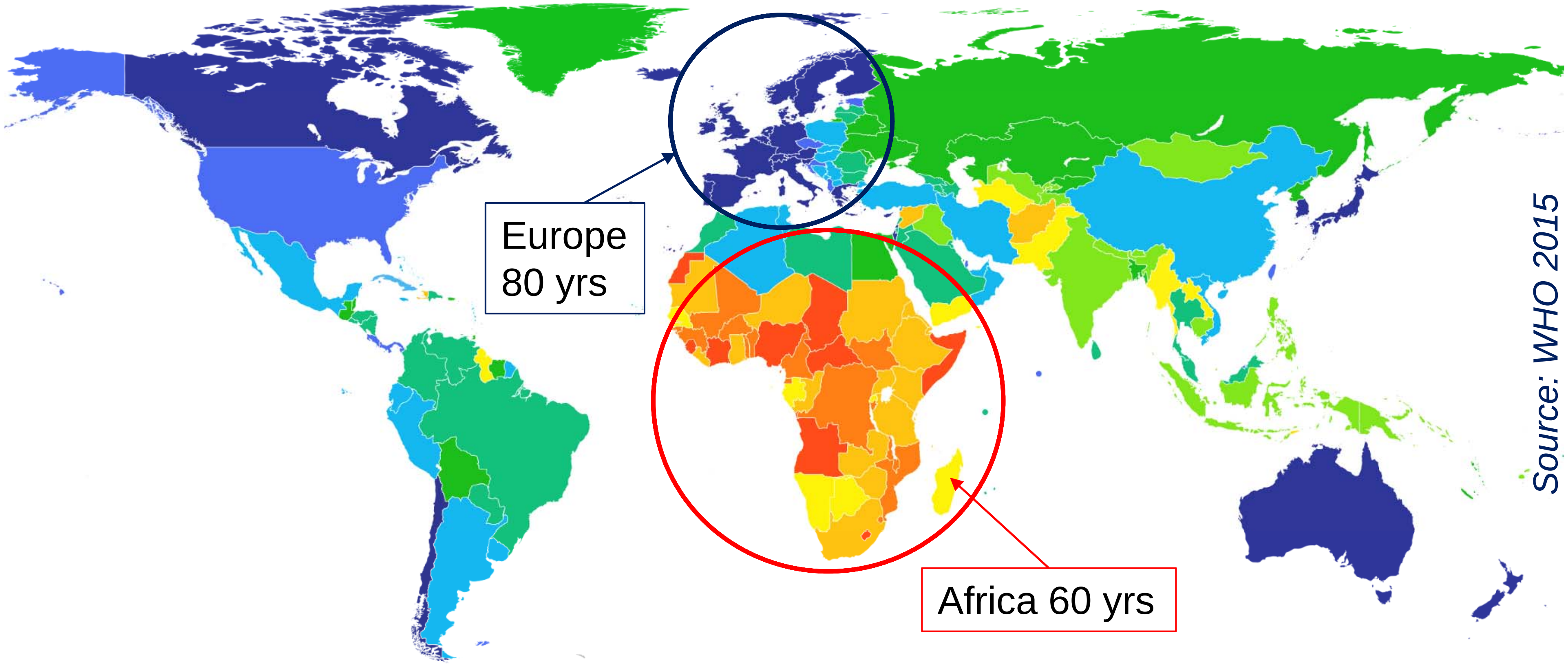
Most effective way to slow down population growth: Education of women

By 2050 85% of the people will live in developing countries/emerging economies.

Source: UNEP Global Environmental Outlook, CIA World Factbook 2018

Population Evolution in Different Regions

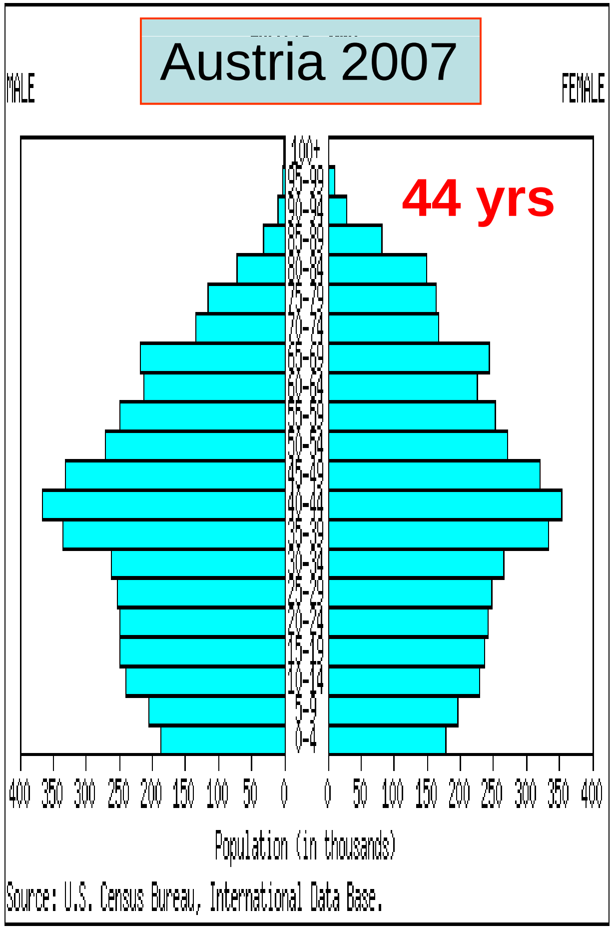
Life expectancy for 2015

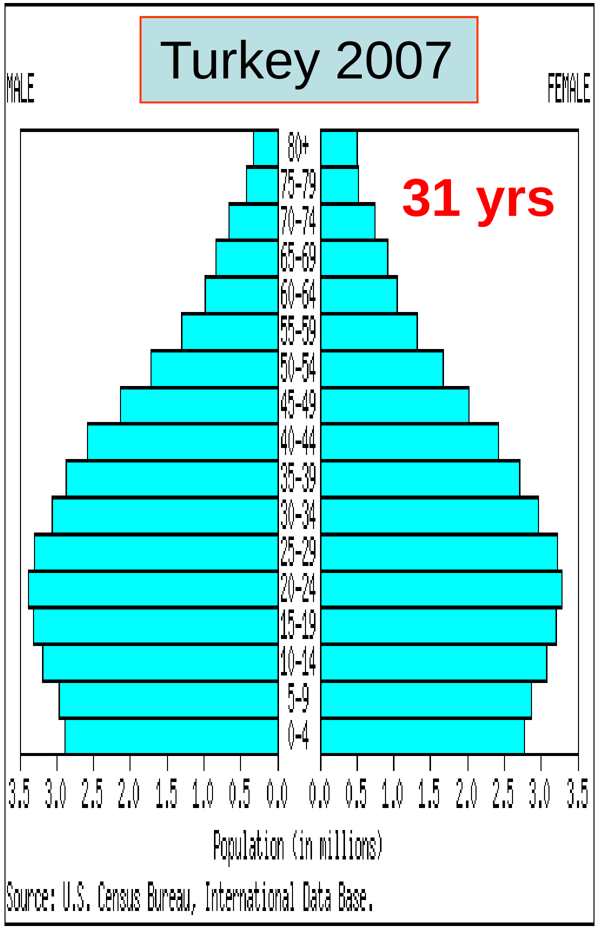


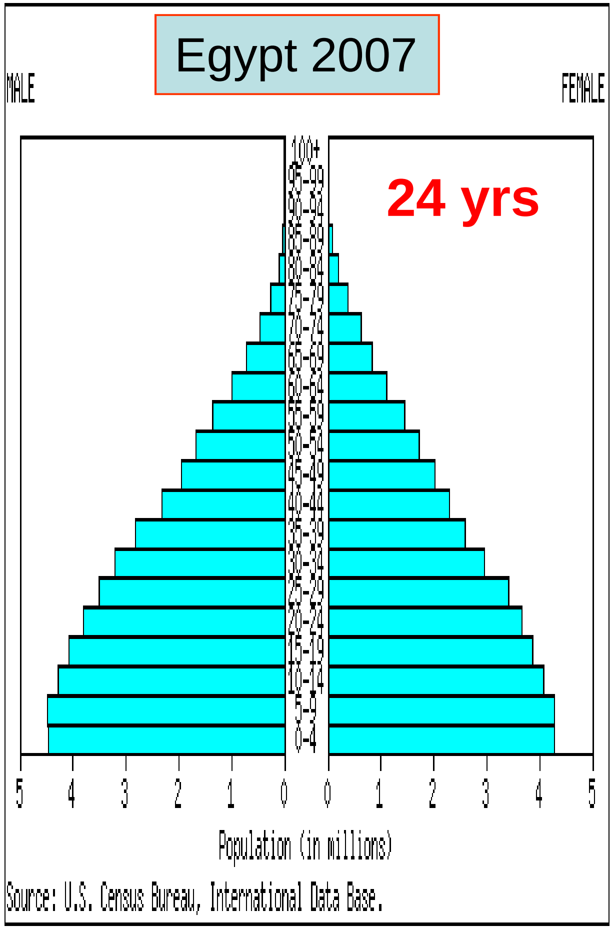
>80 77.5–80 75–77.5 72.5–75 70–72.5 67.5–70 65–67.5 60–65 55–60 50–55 2015 map showing average life expectancy by country in years. In 2015, the World Health Organization estimated the average global life expectancy as 71.4 years.[70]

Life expectancy equals the average number of years a person born in a given country is expected to live if mortality rates at each age were to remain steady in the future.

Age Distribution of Populations:
The Greying of Europe

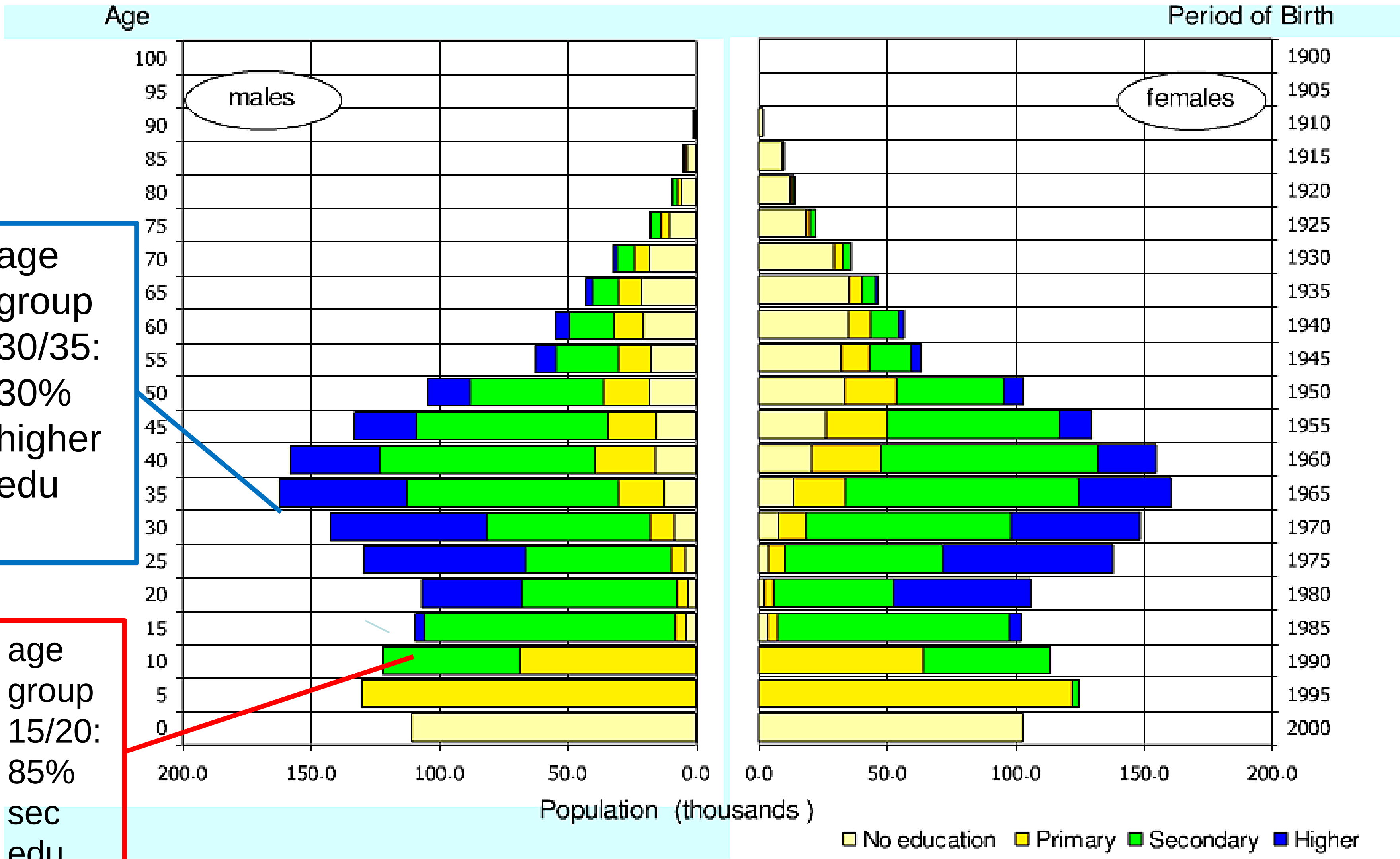






Population pyramids of Austria, Turkey and Egypt in 2007 and median age of populations in 2016 .

Educational Level of Populations:
Singapore 2000



age group 30/35: 30% higher edu

age group 15/20: 85% sec edu

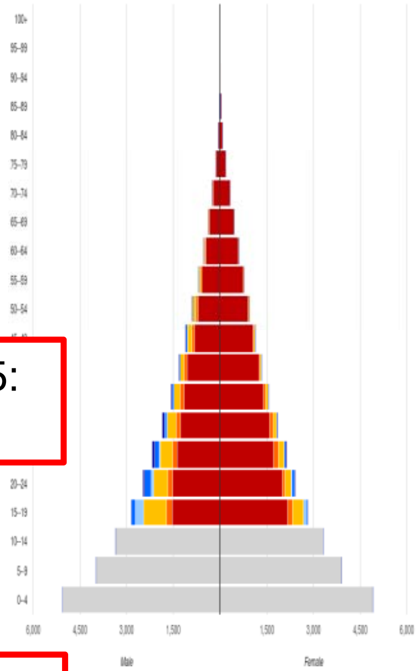
Source: Lutz 2009

Educational Level of Populations

Nigeria 1970 - 2010

Population
57 Million

1970

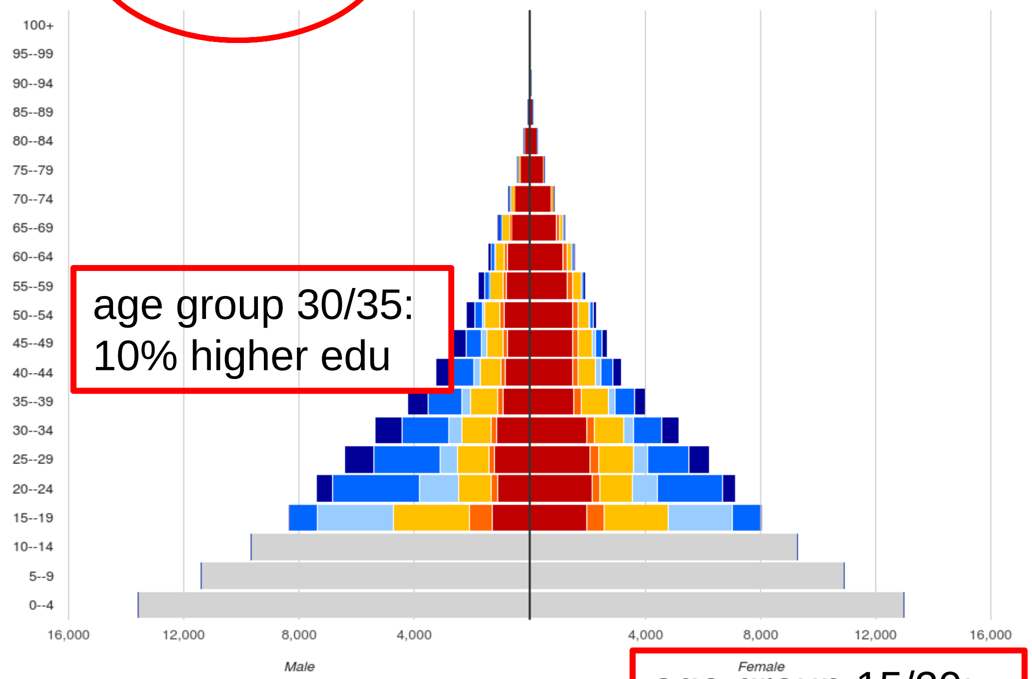


age group 30/35:
<1% higher edu

age group 15/20:
5% sec edu

Population
158 Million

2010



age group 30/35:
10% higher edu

age group 15/20:
30% sec edu

Under 15 | No Education | Incomplete Primary | Primary | Lower Secondary | Upper Secondary | Post Secondary

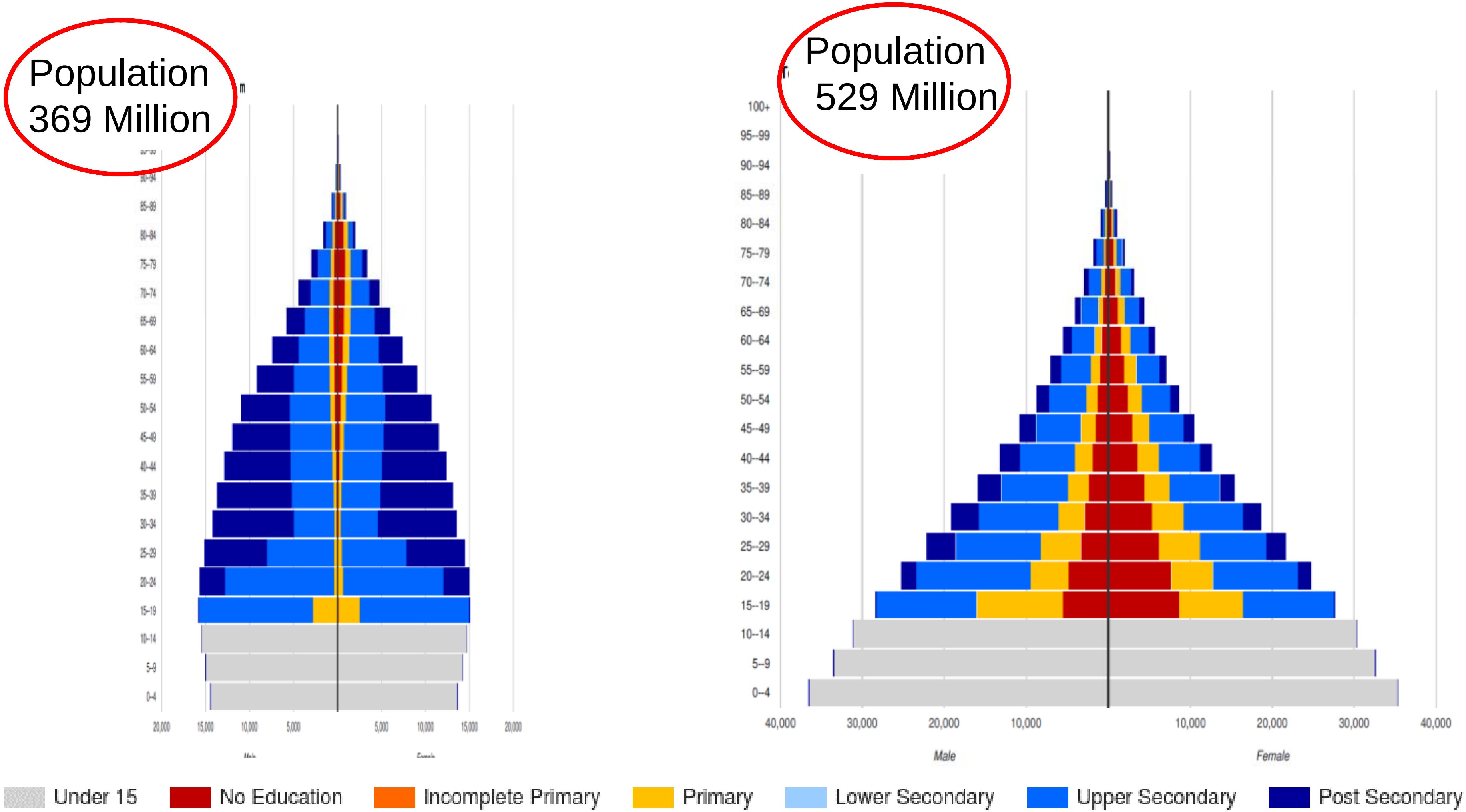
Source: Wittgenstein Centre Data explorer (2015), JMMüller IIASA 2018

Educational Level of Populations

Nigeria 2060

2060 Rapid Development –SSP1

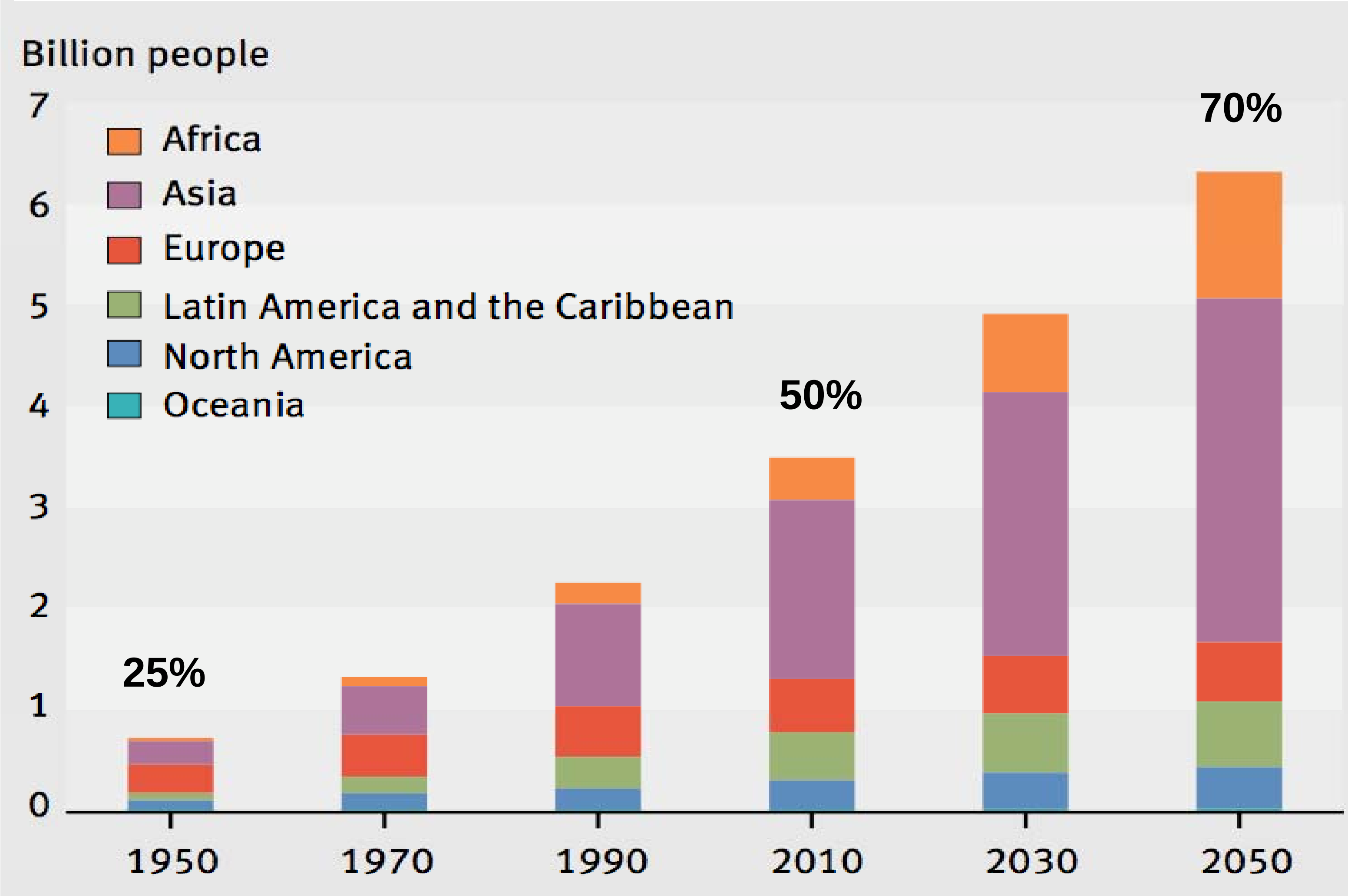
2060 Stalled Development – SSP3



Source: Wittgenstein Centre Data explorer (2015), JMMüller IIASA 2018

Urban Population 1950 - 2050

•Around 1800 only 3 % of the population lived in urban areas.

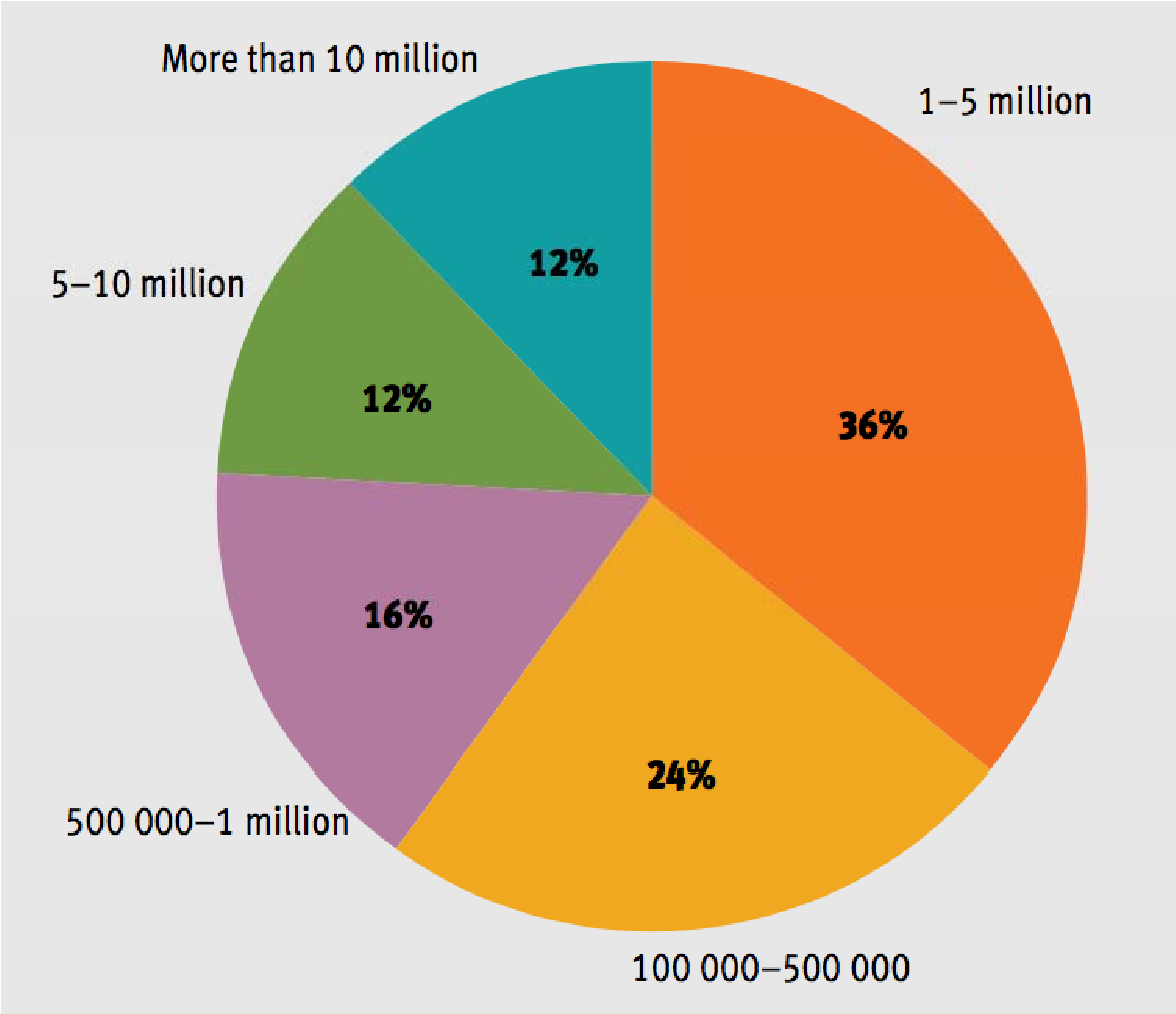


Source: UNEP 2012

In China each year 20 million people move to the urban areas.
By 2050 6 billion people will live in cities.

Urban Population in Developing Countries

Source: UNEP 2012



Some of the largest cities are in developing countries: extensive slums.

Jakarta 30 mio
Karachi 25 mio
Delhi 25 mio
Mumbai 20 mio
Dhaka 16 mio
Bangkok 15 mio

Lagos 21 mio
Kinshasa 14 mio

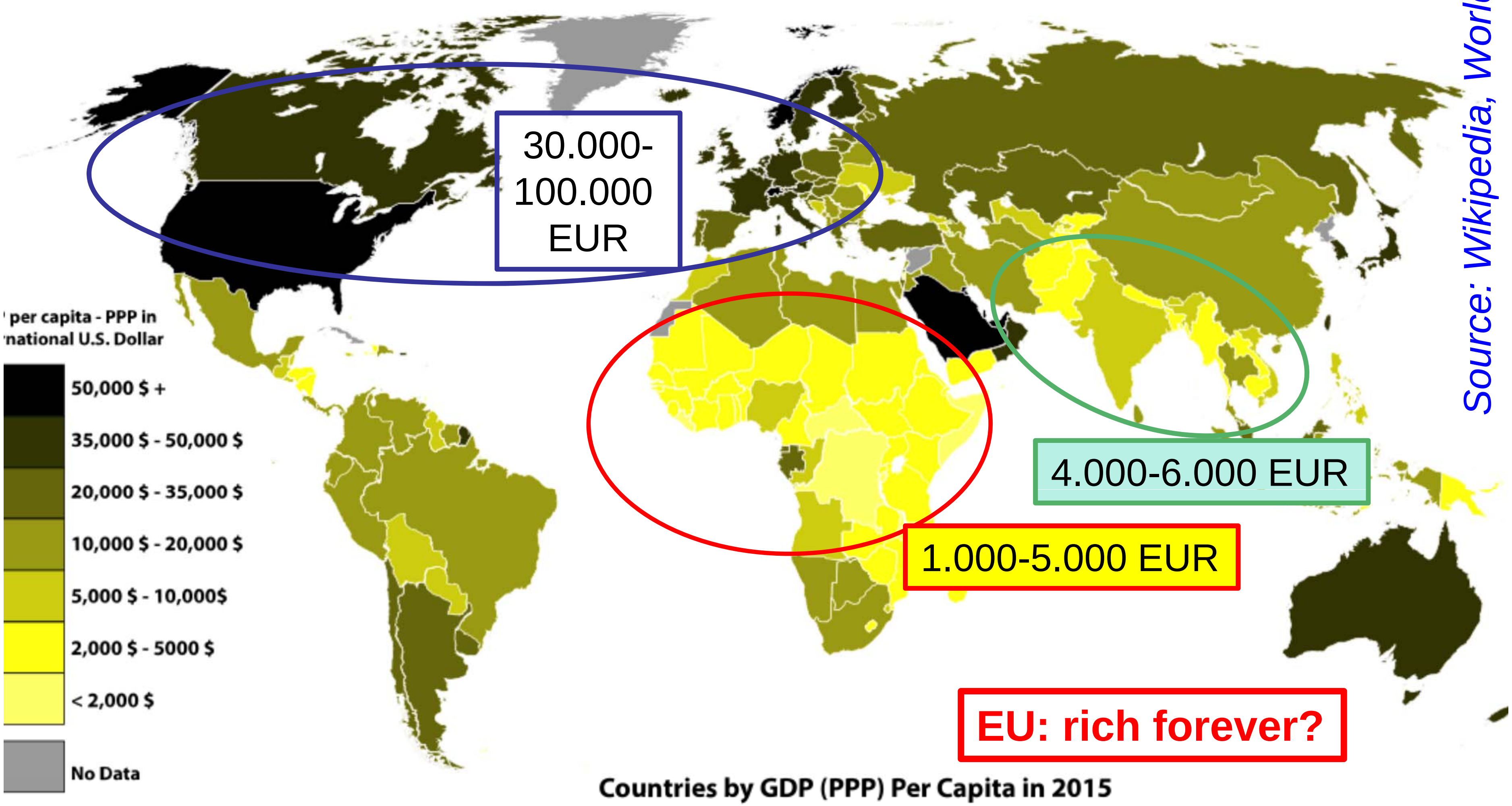
Mexico C. 20 mio

Distribution of the urban population of developing countries, by city size.

The Global Economic Situation

World map showing GDP per capita of the different countries.
Basis for comparison: Purchasing power parity exchange rate (PPP)

Source: Wikipedia, World Bank 2018



Countries by GDP (PPP) Per Capita in 2015

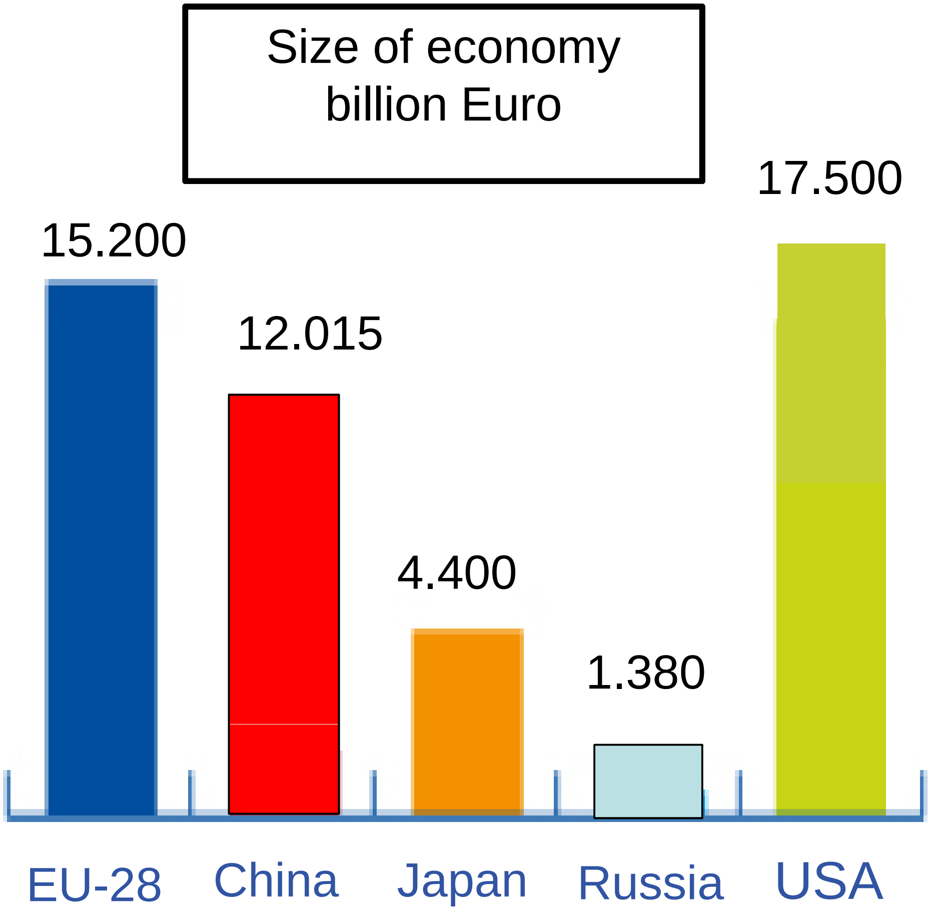
WTO agreement 1995: free global trade covers 95% of global production

The European Union: Competitive Strengths

- Europe has enjoyed a period of peace since 70 years now.
- It has stable political systems based on the principles of democracy.
- Involvement of the citizen in elections and other public affairs rather high.
- The EU has (in general) the best education system in the world.
- Europe has a very strong industry in some areas and many „hidden champions“ in specific areas (particularly SMEs)
- High integration of females in work force.
- High level social system (pensions, health insurance, unemployment services…)
- EU has become the second largest economic region of the world.
- The Euro has become a major currency (25% of global currency volume).
- The political „Leitmotiv“ of the EU - Sustainable Development“ – can serve as a model for the whole world.
- Untill recently very positive development with neighboring regions (Russia, Mid-Asia, Near East) – but now significantly disturbed.

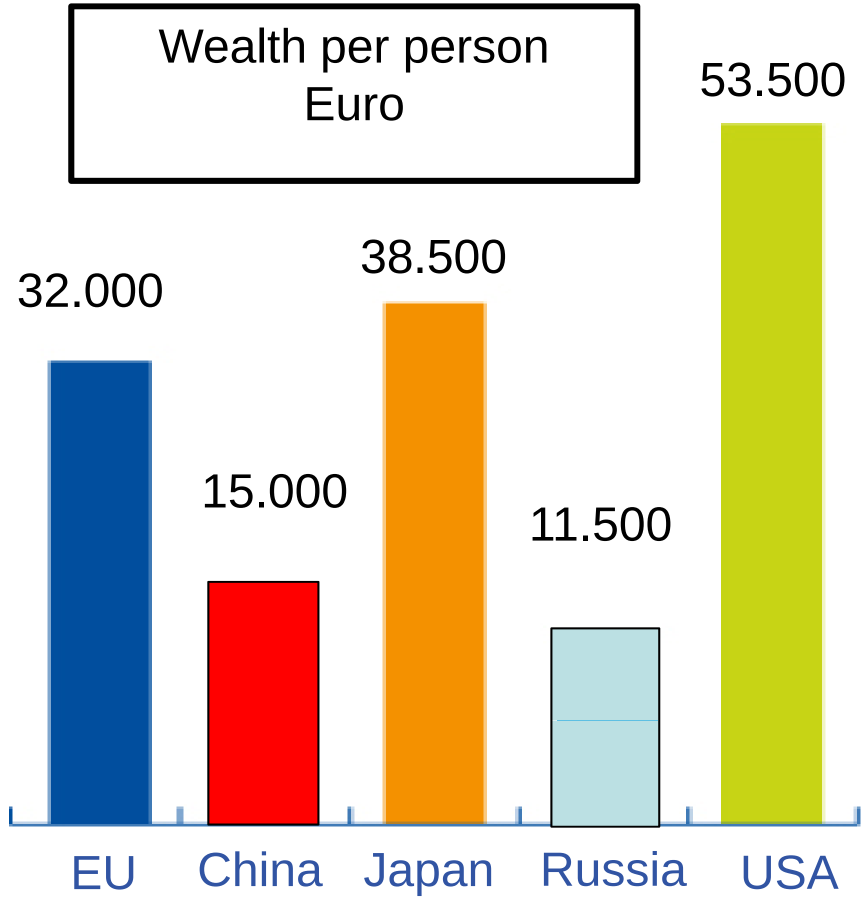
The European Union:
Competitive Strengths

How rich is the EU compared to the rest of the world?



Source: IMF 2018

<u>Nominal</u> Gross Domestic Product
based on current prices for 2017



Gross Domestic Product per capita
in <u>Purchasing Power Standard for</u> 2017

The European Union:
Competitive Strengths

Source: IMF 2017, EUROSTAT 2018

GDP per inhabitant (2017):

- –Luxemburg: 106.00 EUR PPP
- –Germany: 45.000 EUR PPP
- –Austria: 50.000 EUR PPP
- –Poland: 26.500 EUR PPP
- –Romania: 22.000 EUR PPP
- –Bulgaria: 19.700EUR PPP
- –EU average: 32.000 EUR PPP
- –World average: ca 10.000 EUR PPP

The spread of living standard between richest and poorest Member State is 4:1 measured as PPP GDP.

Note:
slightly different data are provided by different institutions like IMF, World Bank, Eurostat due to differences in the calculation methods.

- GDP growth rate: 1,5 - 2%
- Labour force by sector (2011):
  69,8% services; 25.2% industry; 5.0% agriculture
- GDP by sector (2015): 71,3% services; 24,5% industry; 1,6% agriculture
- Unemployment rate: 6,8% (Aug. 2018)

The European Union: Competitive Weaknesses

- Europe slower in innovation than USA, Japan, not enough R&D investments in future technologies (EU 1,8%, USA 3%, Japan 4% of GDP)
- Technology leadership in key areas not with Europe.
- Large and growing trade deficit with emerging economies:

  China 2000: 32 billion EUR, 2017:170 billion EUR
- Low mobility of work force and rather low attractivity for highly skilled immigrants e.g. from India.
- Low economic growth: typically 1- 3% (China 5-10%)
- Profit margins of EU-companies on the average 3% (USA 6%)
- Capital endowment of European companies typically 20% (USA 60%)
- Military expenses very high (60% of USA), but low efficiency of defense systems (20% of USA) due to lack of cooperation. EP 2013: annual loss 26 billion EUR. EU not able to protect its borders.
- High dependence on imports of energy and raw materials (>50% of primary energy is imported – 1 bio EUR/day, high energy costs for end user).

The Industrial Giant China

- **China‘s share in the global production of goods (2016):**
  - automobiles: 28%
  - ships: 41%
  - tv-sets: 60%
  - computers: 80%
  - mobile phones: 90%
- **China‘s ambitions for 2025:**
  - 70% of all components used for products produced in China
  - 80% of all electric cars made in China
  - 70% of all robots made in China
  - 80% of all wind and solar energy installations made in China
- **China‘s ambitions for 2050:**
  - **to be the number one industrial high tech nation in the world**
- **China‘s global economic policy:**
  - investments in high-tech in EU and other countries (where permitted)
  - building new intercontinental trade routes: silk roads
  - development of Africa (natural resources, infrastructure, new markets)

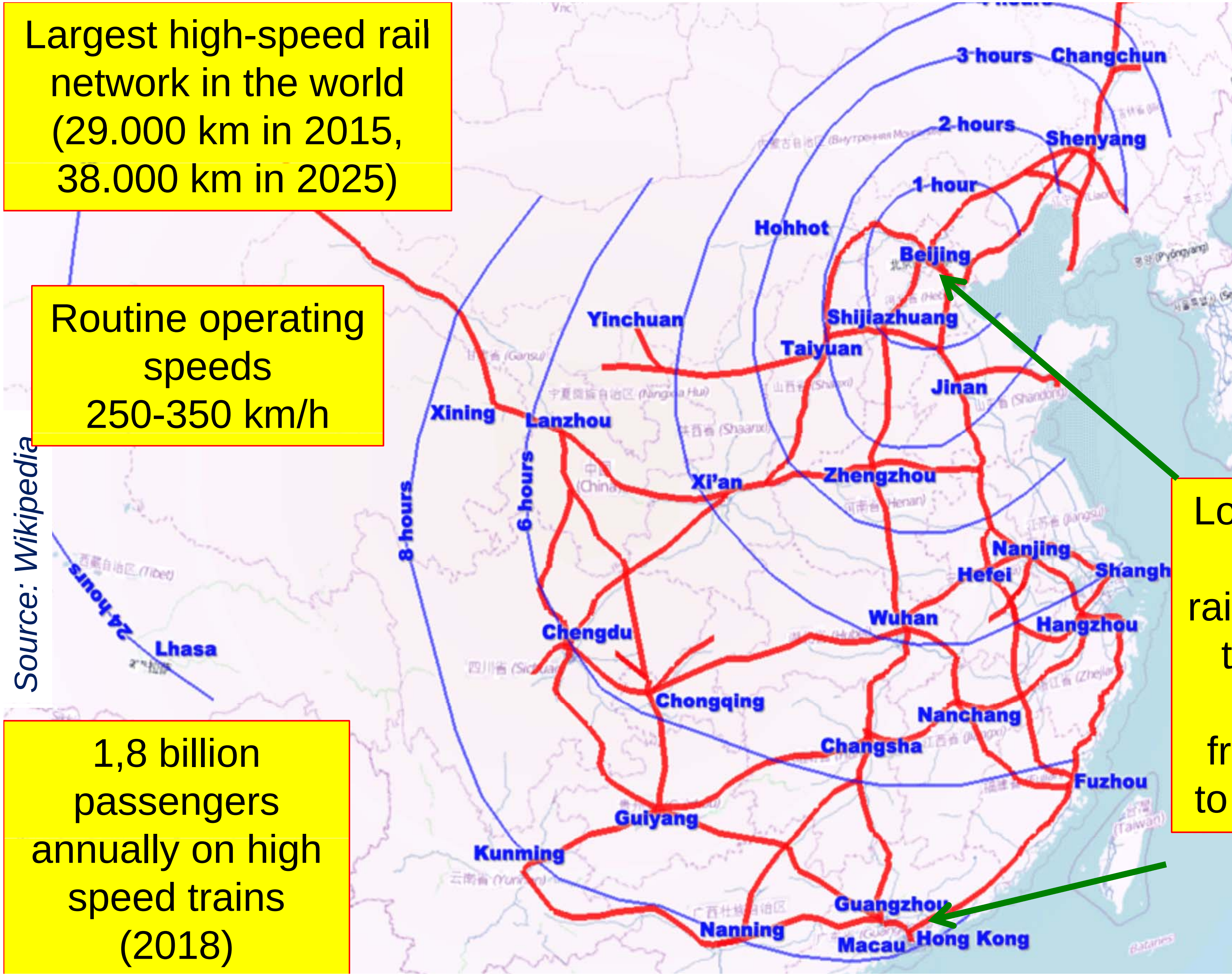
Source: Deutsche Handelskammer 2017, Die Presse 2017

China – The Global Player

Largest high-speed rail network in the world (29.000 km in 2015, 38.000 km in 2025)

Routine operating speeds 250-350 km/h

1,8 billion passengers annually on high speed trains (2018)



Source: Wikipedia

Longest high speed railway line in the world: 2.300km from Bejing to Hongkong

China – The Global Player

CRRC the largest producer of trains globally: business volume 30 billion EUR (2016). Siemens (ICE) plus Alstom (TGV) 15,2 billion EUR.

Source: Wikipedia

CRH 380 BL: operating speed 250 – 380 km/h; maximum speed 487 km/h
Originally based on Siemens ICE3

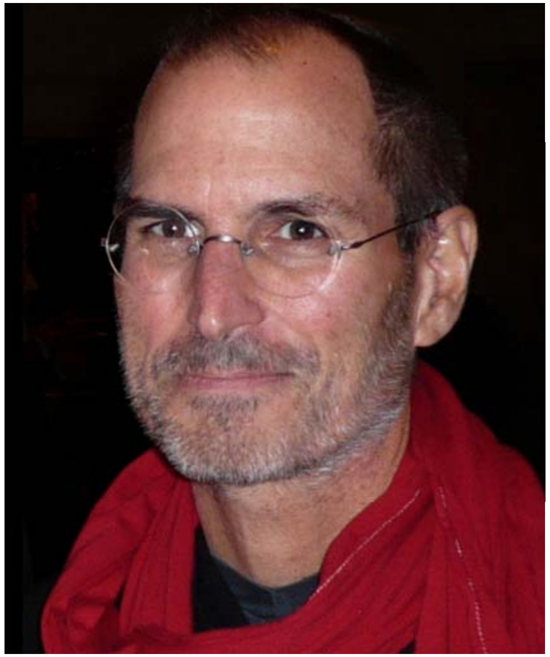
China – The Global Player

Shanghai – Busiest Container Harbour of the World. Turn-over 765 million tons of cargo annually - 35 million containers (2014).

The European Union: Competitive Weaknesses

- High taxes,high labor costs and high costs of state owned social security and health insurance systems. EU social expenses are 50% of all global social expenses! The European social model is not sustainable.
- Fairly large sovereign debts and budget deficits of most EU member states. Maastricht criteria for Eurozone countries have been massively violated in the past. Present stability and growth pact difficult to achieve for some countries (e.g. France, Italy). Eurocrisis not over.
- European Union has a complex structure with an often tedious decision making process and national interests of the member states often dominate over common interests:
  „EU politics is the science of muddling through“.
- Consequently up to now no common economic, social or foreign policy.
- Danger of re-nationalisation (Brexit, no solidarity in immigration crisis).
- Lack of dynamism compared to some other regions („Wellness Society“): Share of EU-27 in global GDP will drop from 20% to 14 % by 2050.

The New Global Players:
Apple



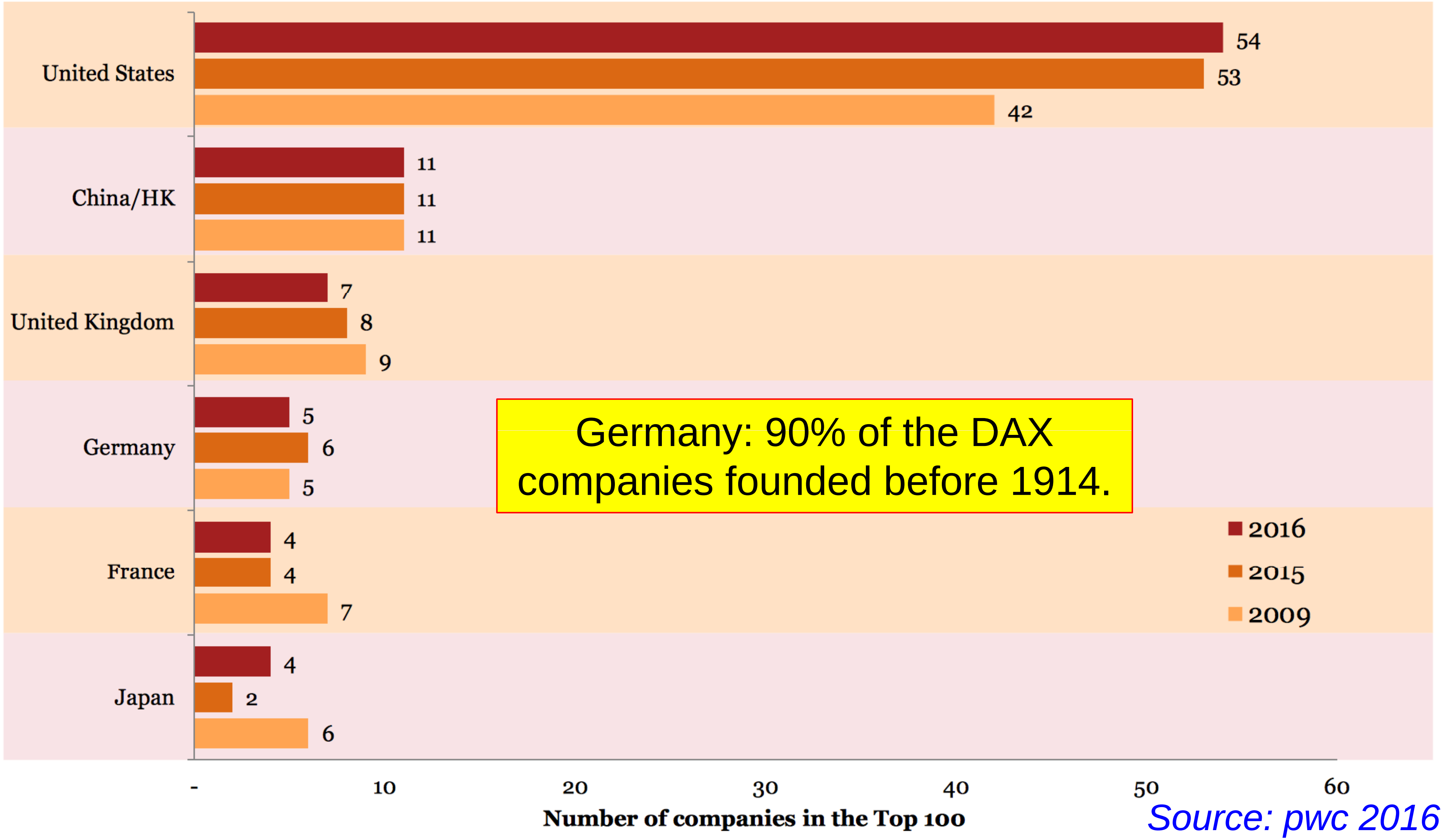
- Apple founded 1976 by Steve Jobbs, Steve Wozniak and Ron Wayne as garage company with a starting capital of 13.000$
- Development and design of PCs (Apple II 1977, Macintosh 1984 with graphical user interface and mouse, Macintosh Portable 1989, Macbook 2006), iPod (2001), iPhone (2003) and iPad (2010)
- Development center in USA (Cupertino, Cal.) with 25.000 staff
- Global staff: 110.000 (50% in retail)
- Production of components by 766 companies the world over (346 China, 126 Japan, 69 USA, 41 Taiwan)
- Assembly of Apple products in China by Foxconn (Taiwanese company)

The New Global Players:
Apple

- iPhone: plant in Zhengzhou with ca 300.000 staff (100 assembly lines, each 600 persons, 24 hours), 500.000 units/day, assembly costs ca 10 $
  - Most expensive component:
    display produced in USA, Korea, Japan and Taiwan ca 20 $
  - Total production costs: ca 40 $
  - Sales price of iPhone: 600-1.000 $
  - Turnover of Apple (2015):
    234 bio $, profit 53 bio $ (rate of return 23%)
  - Market value of Apple:
    900 bio $ (Nov. 2017)
- **Comparison with a top EU manufacturing company (Daimler-Benz):**
  - 300.000 staff, turnover 130 bio EUR, profit 6 bio EUR (rate of return 4,5%, market value 70 bio EUR

The European Union : Competitive Weaknesses

Top 100 companies per country of domicile – trends 2009-2016 (1/3)



Source: pwc 2016

The European Union as a Global “Soft Power”:
Political Values of European Soft Power

Pioneer in the Propagation and Implementation of the Concept of Sustainable Development for the Whole World

“Lissabon Agenda 2005”

- **Economic Growth**
- **Social Equilibrium**
- **Environmental Quality**

- Guiding Principle for the European Union and is being incorporated in all EU sectoral policies.
- Sustainable Development should be the guiding principle for all nations.
  - EU must apply this principle in negotiations at the level of the World Trade Organisation and thereby introduce environmental and social elements into the WTO scheme.

Development Cooperation:
Economic Situation in Different Regions of the World

Source: IMF 2018

• **Nominal GDP of different groups of economies for 2018:**

– **Advanced economies** (EU, USA, Japan, Canada, Australia, South Korea, Japan…..32 countries): 51.000 billion $ = **60% of global GDP**

– **Emerging and developing economies in Asia** (China, India, Indonesia, Thailand, Malaysia…..30 countries): 19.000 billion $ = **23% of global GDP**

– **Latin America and Caribbean economies** (Brasil, Argentina, Mexico, Colombia, Venezuela ….33 countries): 6.000 billion $ = **7% of global GDP**

– **Middle East, N-Africa, Pakistan** (Egypt, Iran, Saudi Arabia, VAE….23 countr.): 3.500 billion $ = **4% of global GDP**

– **Commonwealth of Independent States and Georgia** (Russia,...12 countries): 3.000 billion $ = **3,7% of global GDP**

– **Sub-Saharan Africa** (Nigeria, South Africa…..45 countries): 1.800 billion $ = **2,2% of global GDP (with 14% of global population)**

Globally huge socio-economic disparities:
ratio of nominal GDP per capita EU: Sub-Saharan Africa = 25:1

Development Cooperation

- **Poverty and lack of access to basic services:**

➢2,5 billion people without “improved” sanitation services (CDC 2018).

➢800 million people are without access to safe drinking water (CDC 2018).

– This number could increase to 2 billion by 2030.

– In developing countries 90 % of sewage waters enter into the ground waters without any purification.

– More than 5 million people die each year as a consequence of waterborne infectious diseases.

➢700 million people undernourished – but number sinking (World Bank 2018).

➢1 billion people without access to electricity (World Bank 2018).

➢Life expectancy (much) lower in developing countries:

60 years in Africa, 73 years in India, 83 years in Austria

Development Cooperation: EU Policies

•**Basis of EU policies for shaping a global partnership for sustainable development :**

-Johannesburg Declaration of 2002 and its Implementation Plan.

-Doha Development Agenda (Trade) of 2001.

-Monterrey consensus (Financing for Development) of 2002.

-Cotonou Partnership Agreement for Africa's Development, the Caribbean and Pacific (ACP) of 2000 involving 77 developing contries.

•2002 Communication of European Commission "Towards a Global Partnership for Sustainable Development" COM(2002)82:

-*Commitment of the EU to promoting sustainable development on a global level.*

•European Council Decision, 17Oct2002 "Putting into practice the European Union sustainable development strategy and the environmental dimension of the Johannesburg commitments".

Key element: Sustainable Development.

Development Cooperation: Financial Support

•**The development aid of the EU:**

➢The European Union is the largest donor of development aid in the world: it provides 60% of all development aid, which amounts to ca 40 billion EUR annually including all contributions from the member states directly paid to receiving countries (0,4% of the GDP, committment would be 0,7%).

➢The annual development aid of the EU per citizen is about 100 EURO compared to about 50 EUR of the United States or Japan.

•The high amounts of development aid given to different countries or regions do not necessarily secure political influence there:

➢EU annual aid to the Palestinian region is 600 million EUR, but the EU has little influence on the political peace making process there:
„The EU is a payer, but not a player in the Middle East.“

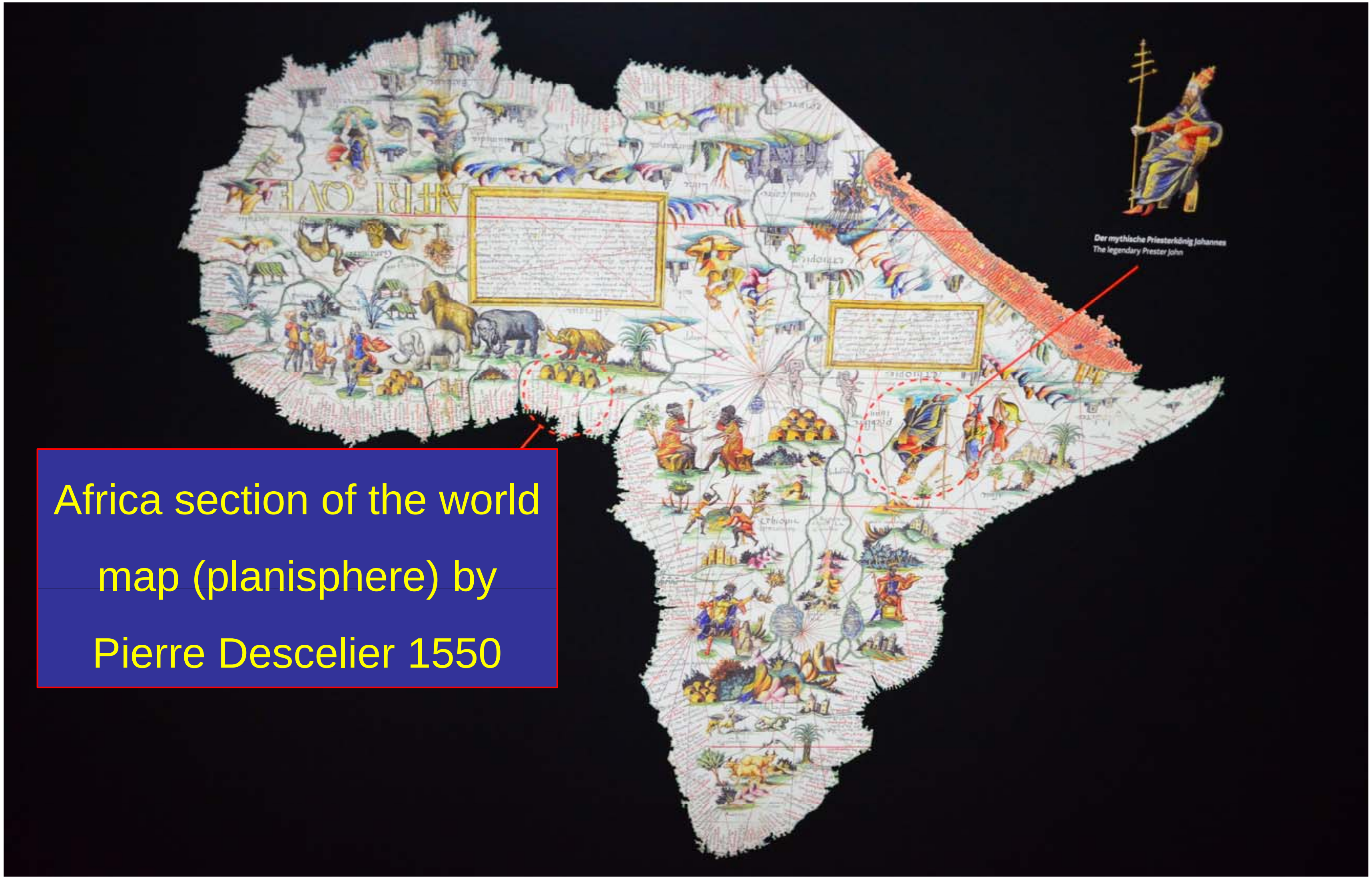
Development Cooperation: Financial Support

- **Humanitarian relief programmes of EU:**
- The European Community Humanitarian Aid Office, or "ECHO", provides additional humanitarian aid in crisis situations.
- Main support now for refugee camps and food supply.
- Budget 1,6 billion EUR (2017): Turkey 700 mio, Syria 280 mio, Iraq 82 mio, Yemen 77 mio, Africa 260 mio, SE-Asia 95 mio EUR

Rohynghia refugee crises: 700.000 fled from Myanmar to Bangladesh since Aug. 2017

Development Cooperation: Africa

The interest of Europe in Africa developed in the 15th and 16th century, mainly due to the many Portuguese expeditions launched by King Henry the Navigator, a.o. those of Bartolumeu Dias, Vasco da Gama.

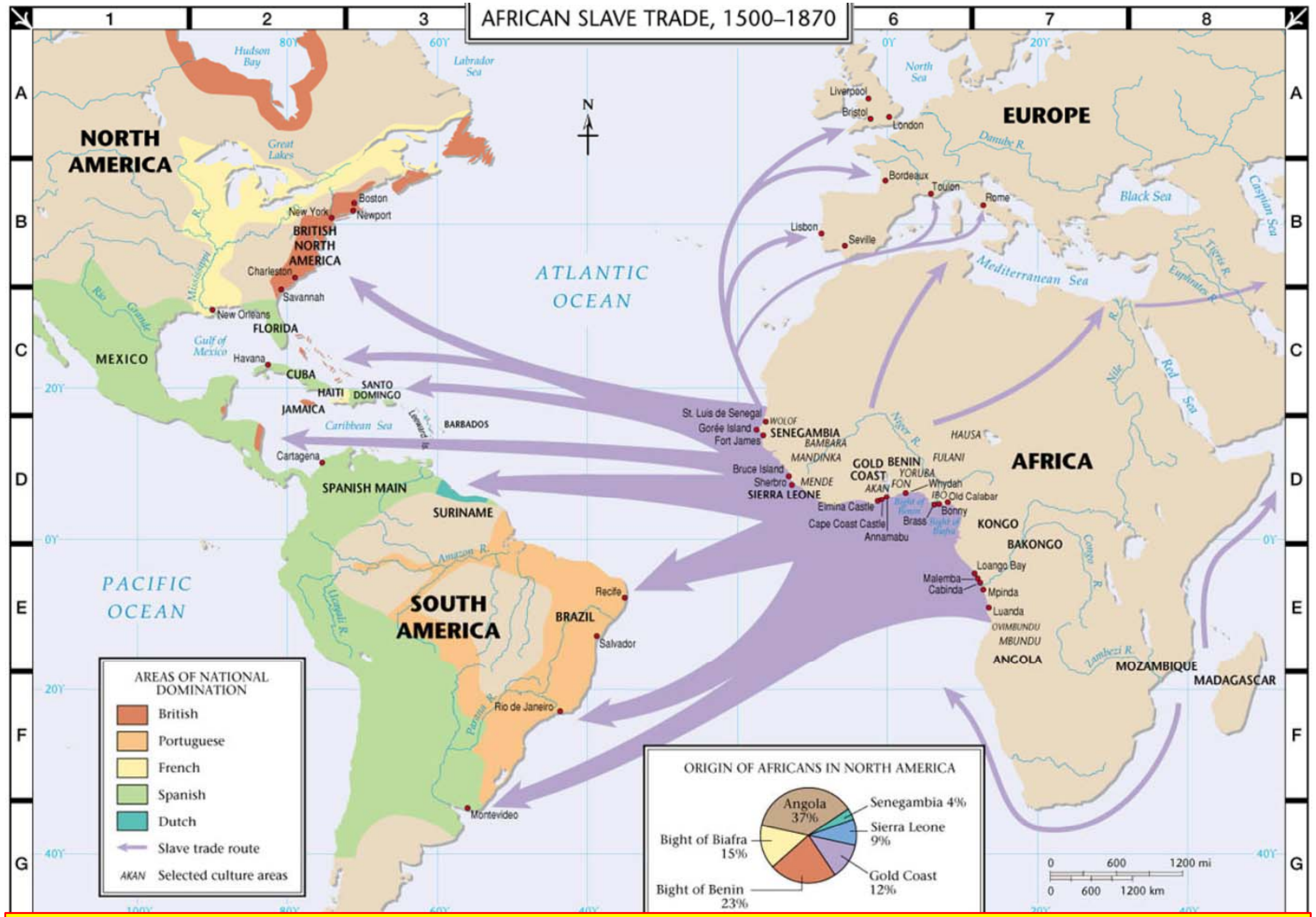


Africa section of the world map (planisphere) by Pierre Descelier 1550

Source: Weltmuseum Wien

Development Cooperation: Africa

- Colonisation of Africa started soon after the great discoveries and focused first on coastal zones.
- Later expeditions opened up the interior of this continent (e.g. Livingstone, Stanley).

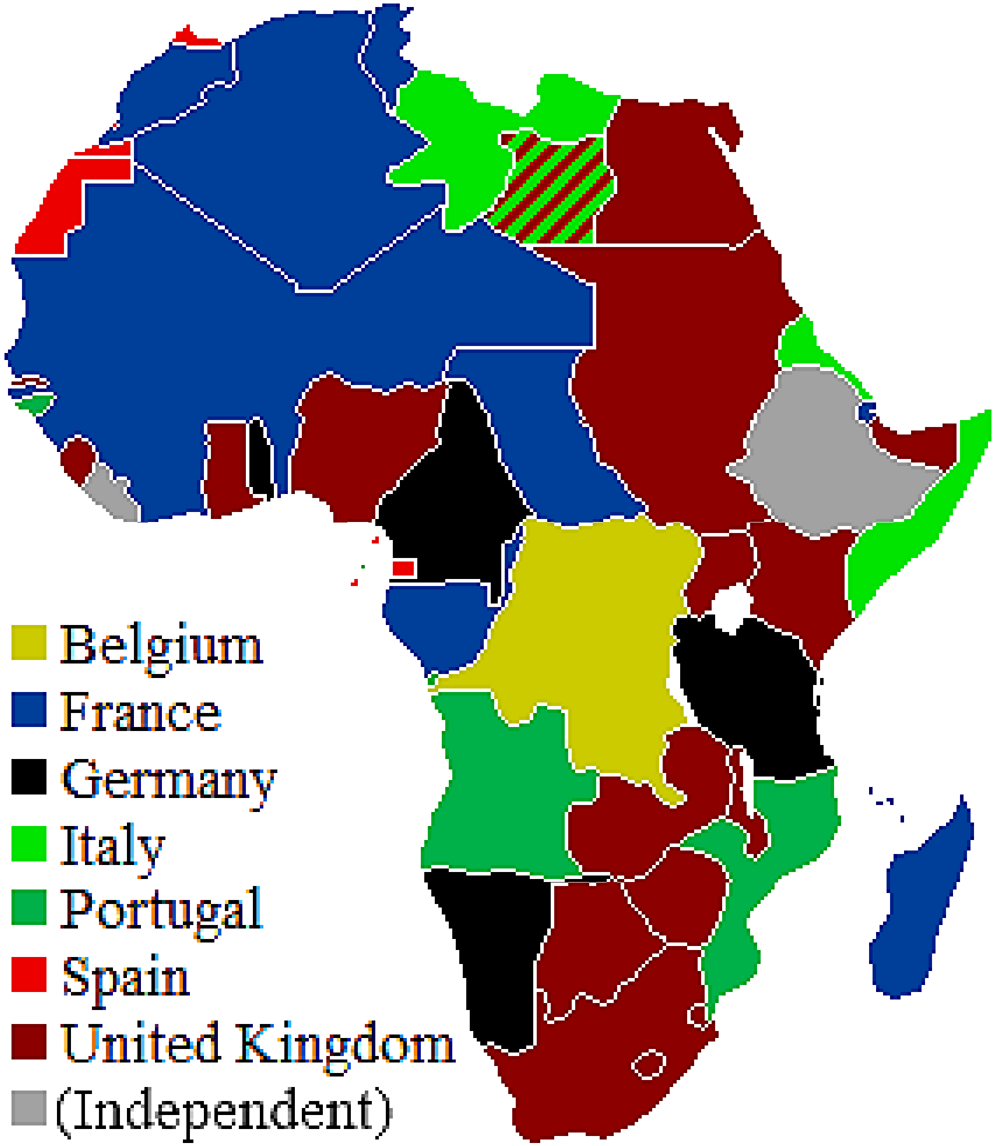


10-15 million slaves transported from West Africa to the Americas

Main driving forces were search for gold, slave trade and in general territorial gains by European nations, particularly England, France, Portugal, Belgium, Germany and Italy.

Source: Wikipedia

Development Cooperation: Africa



Africa 1914 under the control of colonial powers

- During the period of “New Imperialism“, between 1881 and 1914 the occupation, division, and colonization of African territory by European powers took place.
- While in 1870 only 10 percent of Africa was under formal European control by 1914 it had increased to almost 90 percent of the continent (only Ethiopia and Liberia were independent states).
- The Berlin Conference of 1884 regulated European colonisation and trade in Africa and lead to a stable system of European colonies which lasted until the 1960s.

Source: Wikipedia

Development Cooperation: Africa

•The decolonization of Africa took place in the mid-to-late 1950s and early 1960s, mostly very suddenly, with little preparation.

•There was widespread unrest and organised revolts in both Northern and sub-Saharan colonies, especially in French Algeria, Portuguese Angola, the Belgian Congo and British Kenya.

Patrice Lumumba, the first Prime Minister of the Republic of Congo (1960)

•Under the Treaty of Rome in 1957, the then colonies and overseas territories of member states had become associates of the Community.

•Decolonisation turned this link into a different kind of association, one between sovereign countries.

•The Lomé Convention, which was signed in 1975 in Lomé, the capital of Togo, and subsequently updated at regular intervals is the first formal agreement between the European Union and African States.

Source: Wikipedia

Development Cooperation: Africa

- It was followed by the Cotonou Agreement, signed in 2000 in Cotonou, the capital of Benin, marked a new stage in the EU's development policy.
- The basic aims of this agreement are
- to promote and expedite the economic, cultural and social development of the ACP states, and
- to consolidate and diversify their relations [with the European Union and its member states] in a spirit of solidarity and mutual interest.

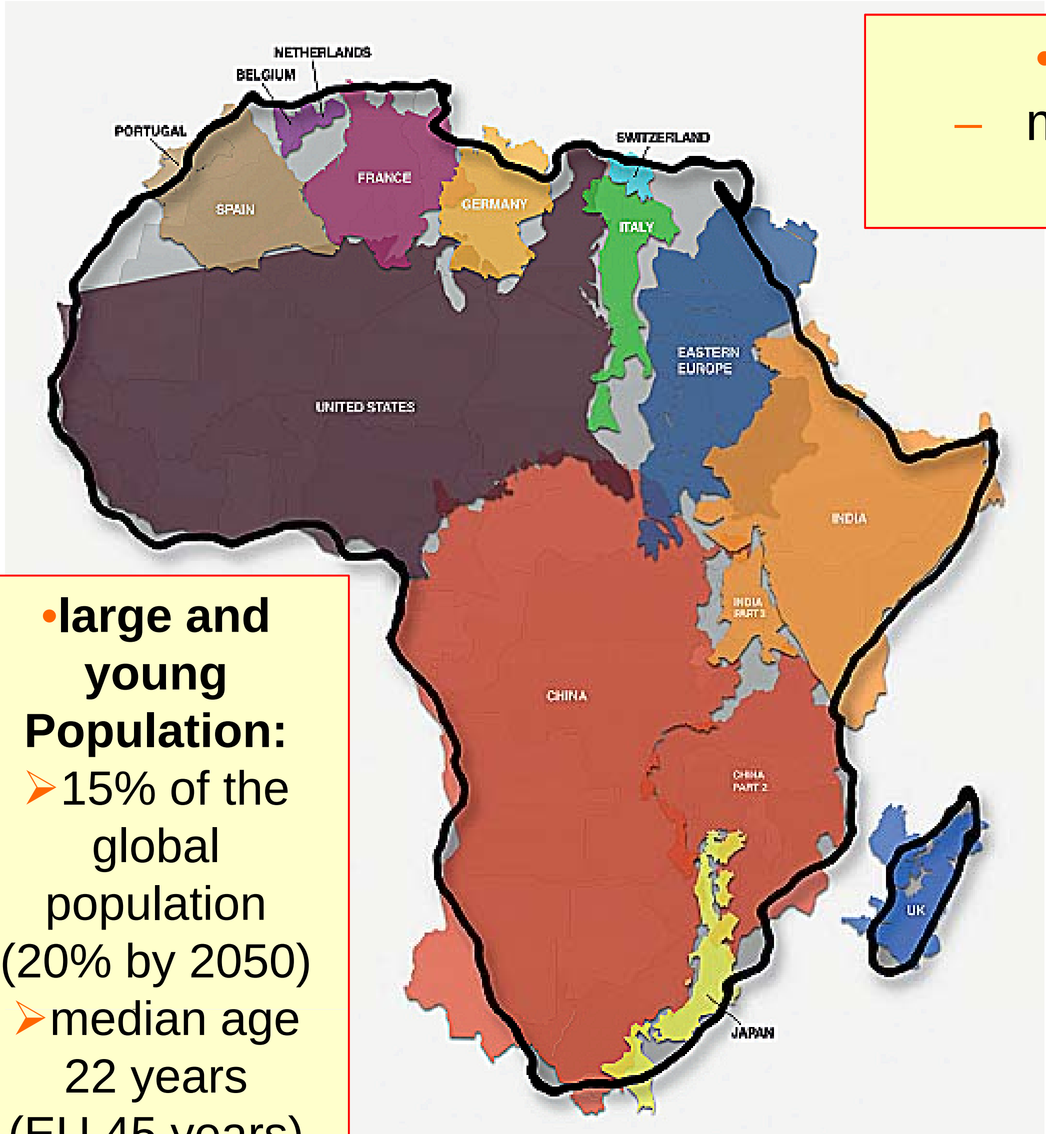
•The European Union has granted special trading concessions to the least developed countries, 39 of which are signatories to the Cotonou Agreement.

•The European Development Fund finances the ACP support programmes, paying out between two and three billion euro a year.

Photo: Wikipedia

The African Opportunities

•**Africa is a huge continent:** 30 million km^2 - 20% of the global land mass



•**rich in natural resources**

– minerals, oil, wood, agricultural products…….

•**Europe should**

➢provide technologies and aid for the development of infrastructure

➢invest in exploration and mining of valuable raw materials and development of local/regional industries, and

➢generate/develop markets for European products based on a rising purchasing power.

Photo: Wikipedia

•**large and young Population:**

➢15% of the global population (20% by 2050)

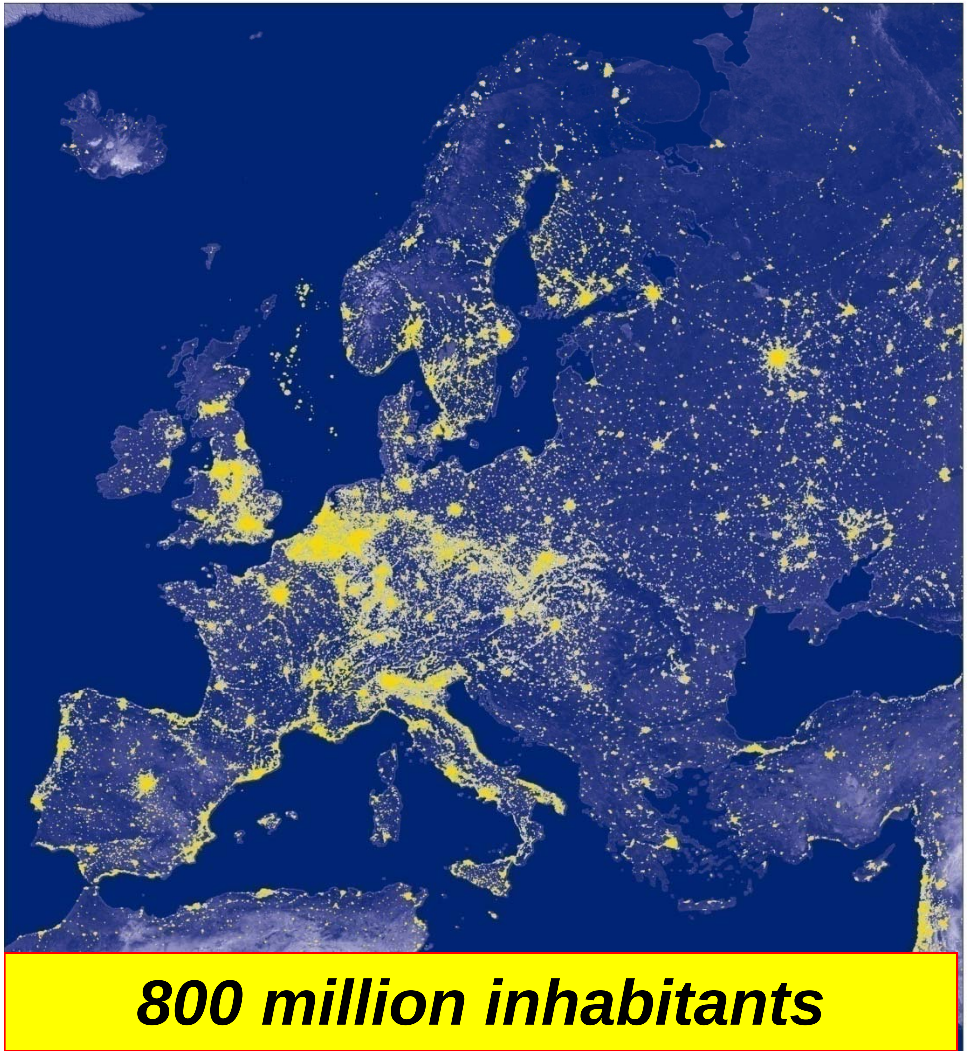
➢median age 22 years (EU 45 years)

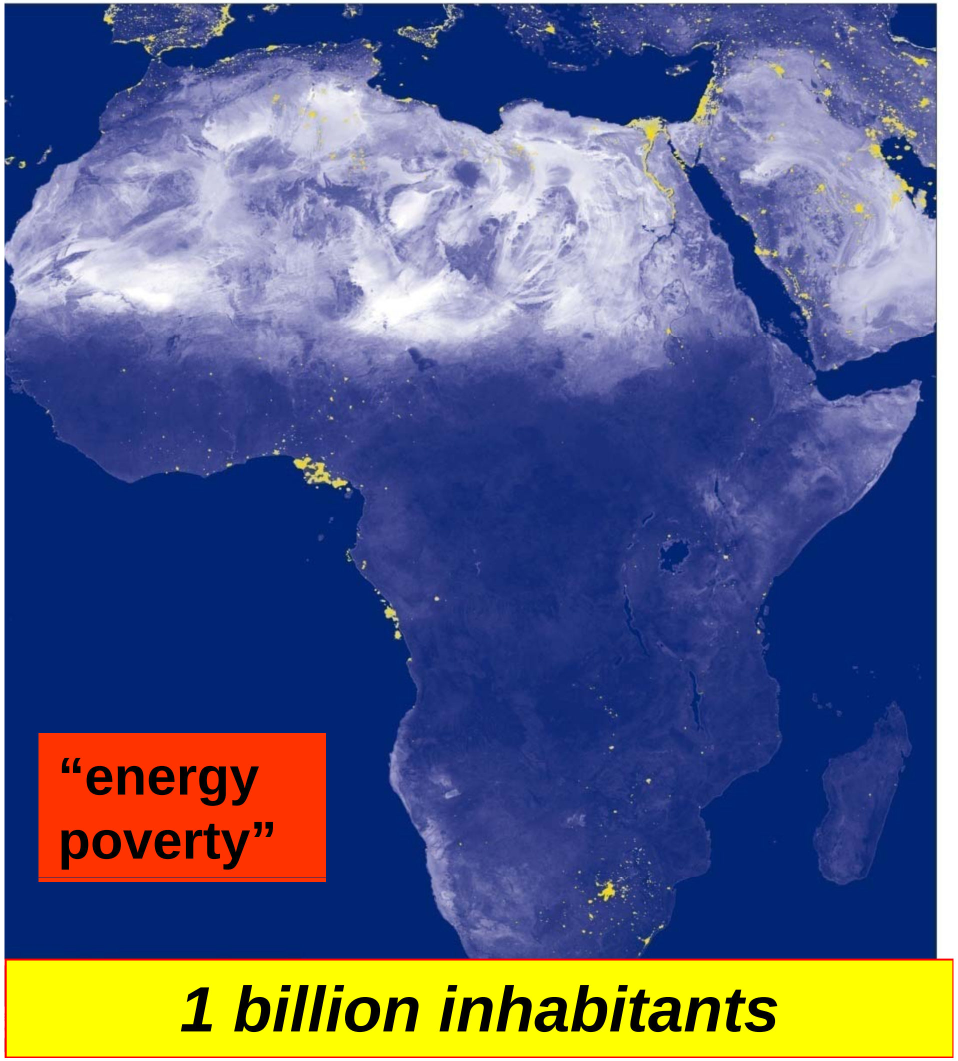
Africa:
Improving Infrastructure

Night-Lights over Europe and Africa

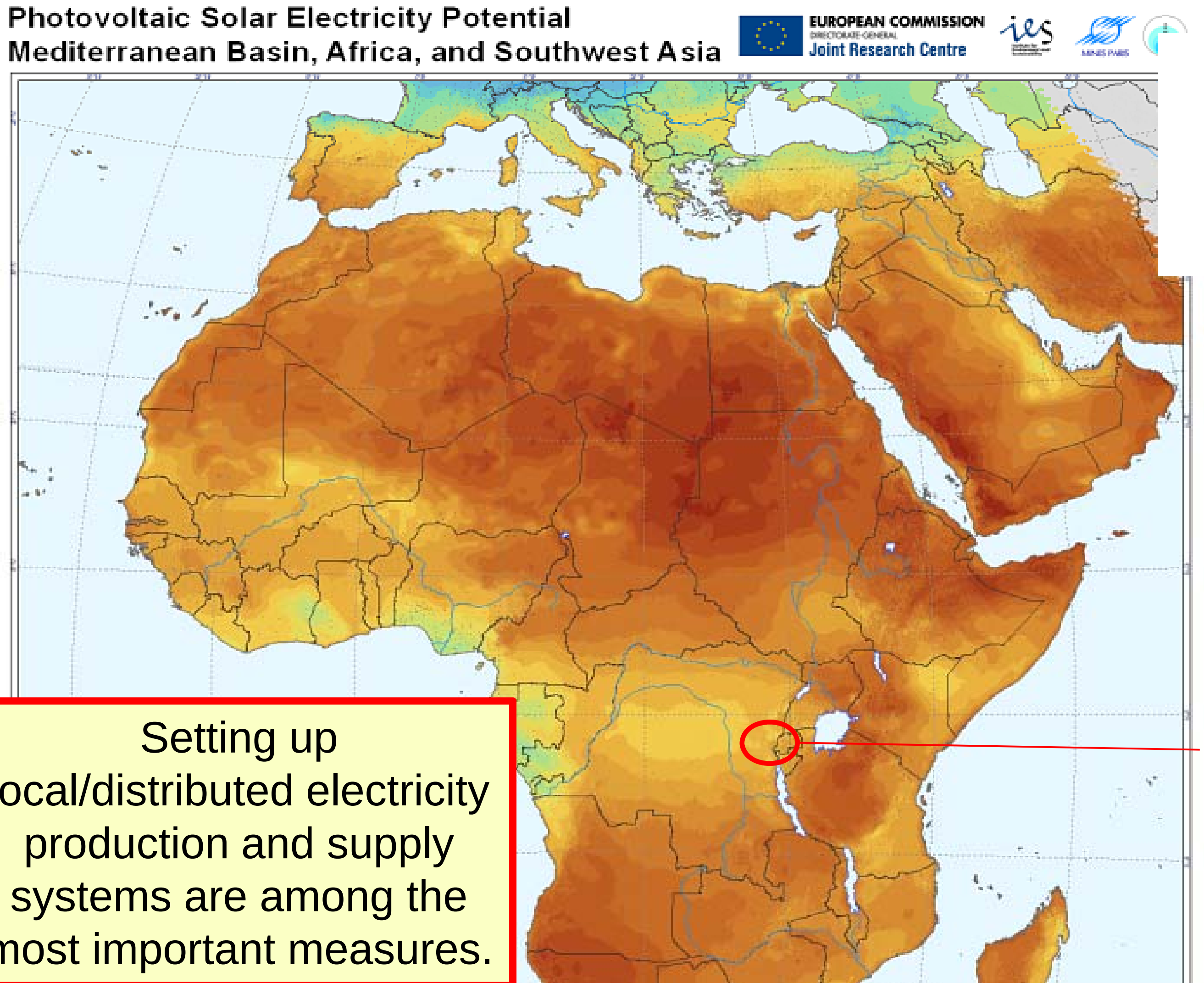
5000 Watt per capita

<500 Watt per capita





Africa: Improving Infrastructure



Potential of Solar Energy in Africa.
Source: JRC-IES

Setting up local/distributed electricity production and supply systems are among the most important measures.

2014 - Construction Begins on East Africa's First Utility-Scale Solar Field in Rwanda:
8.5 megawatt solar photovoltaic (PV) power plant will deliver 8% of the countries electricity consumption.
costs: 24 mio $

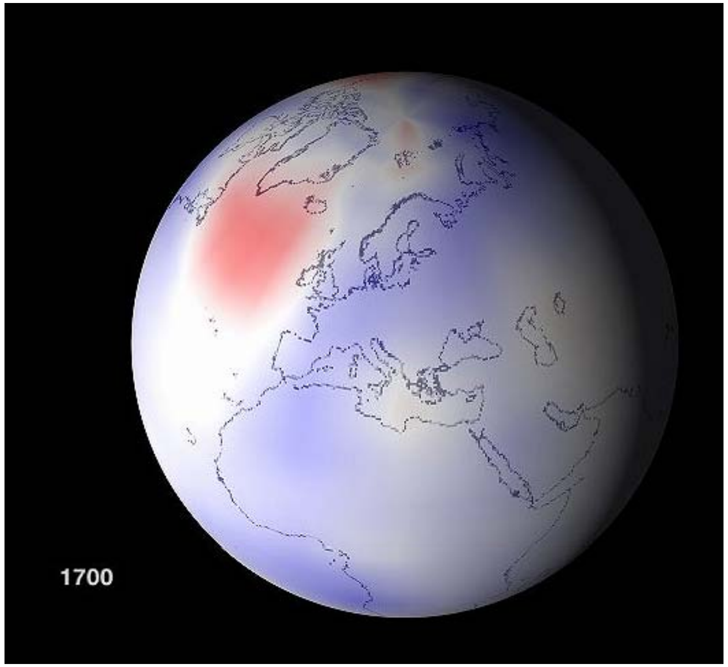
Ecology and Sustainable Development

8. Third Industrial Revolution:

8.1 Energy Technologies

8.2 Space Exploration

8.3 Global Earth Observation



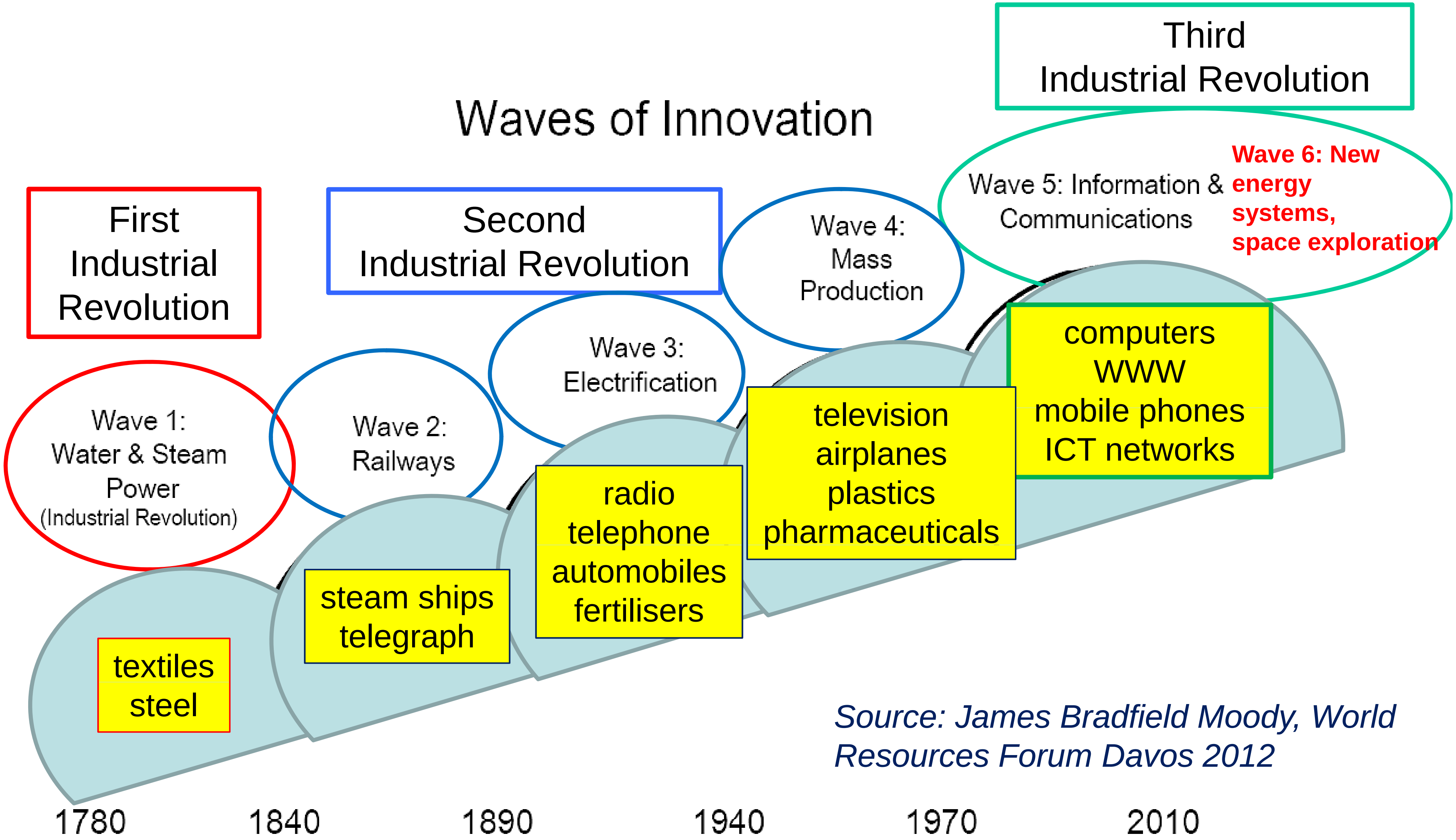
IIASA Global Energy Assessment 2012:

http://www.iiasa.ac.at/web/home/research/researchPrograms/Energy/Home-GEA.en.html

IEA World Energy Outlook 2016:

http://www.worldenergyoutlook.org/

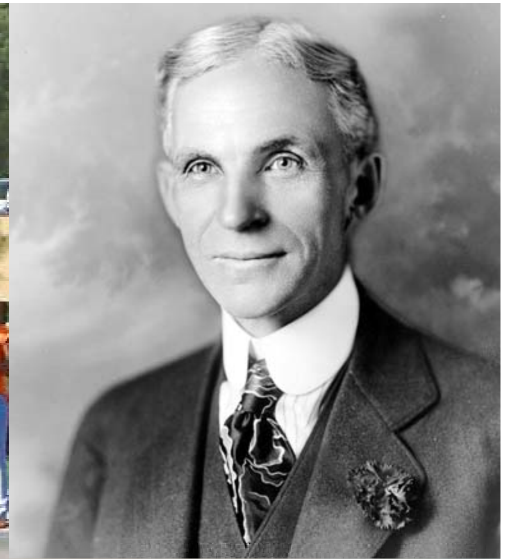
The Industrial Revolutions:
Six Waves of Innovation



Source: James Bradfield Moody, World Resources Forum Davos 2012

EU is the major political driver through its Climate and Energy Policy.
http://register.consilium.europa.eu/pdf/en/07/st07/st07224-re01.en07.pdf

Ford model T introduced 1908



Henry Ford 1863-1947

The Industrial Revolutions:
The Speed of Change

Source: Campanale, Carbontracker, JMMüller IIASA 2018

The “Third Industrial Revolution”:
Major Drivers of Technological Change

- **Major drivers of innovation today:**
– Sustainable production: reduced use of resources, less pollution
– Reduction of environmental pollution: „clean“ technologies
– Mitigation of global warming: new energy systems
– Extending frontiers of human activity: space exploration
– Sustainable management of the whole earth system: earth observation
– Cheaper and better production of goods: industry 4.0
- **New technologies on the rise supporting global sustainable development :**
  – recycling of materials
  - new efficient transport systems
  - low carbon electricity generation
  - new global monitoring techniques
  - artificial intelligence

…there is no limit to the phantasy of engineers and scientists !

The EU Climate and Energy Policy as a Driver of Change

•The heavy dependance of the EU on energy supply from other countries and the Climate Change agenda led to the introduction of a mandatory and comprehensive European energy policy by the European Council in 2005.

•***Key goals are:***

-enhance security of energy supply by diversification of energy resources
-reduce GHG emissions by 20% till 2020 and 40% till 2030 (comparison1990)

•***Major technical measures:***

oreduction of primary energy use (20 resp. 27% compared to projections made in 2007) in industrial processing and manufacturing, electricity production, lightning, heating, transport

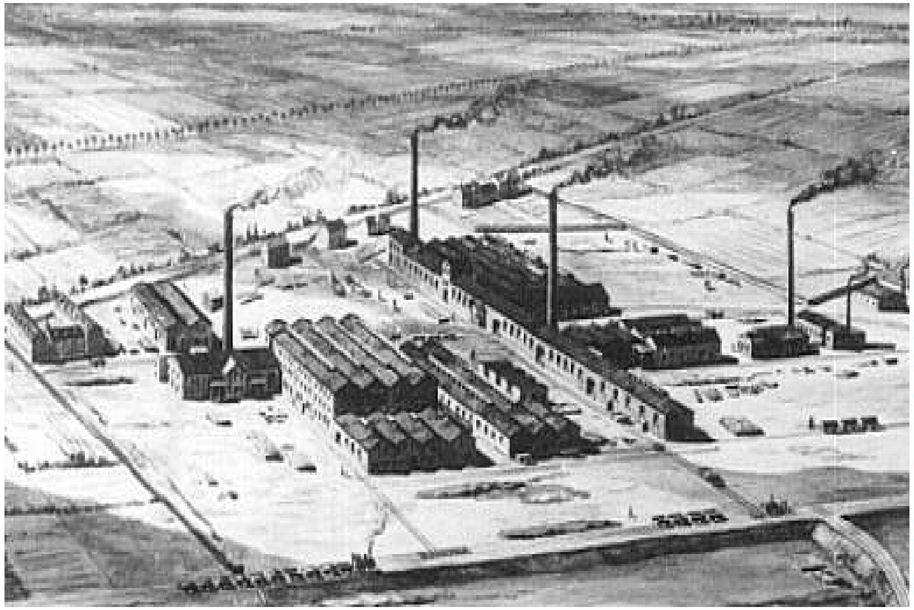
oreduction of CO_2 emissions of fossil fuel power plants: Carbon Capture and Storage (CCS).

o increase in renewable energy produced within the EU (20% resp. 27% of total energy market – now 13%), including decarbonisation of transport (10% biofuels from sustainable production, electromobility)

This policy will require massive research, development and innovation efforts involving all scientific disciplines.

Reduction of Primary Energy Use: Clean and Efficient Industrial Technologies

- Rigorous implementation “Best Available Technologies” (EU Directive).
- Emission trading system to stimulate investments in new technologies.



Source: BASF

•Development of highly integrated value chains for industrial products, including recycling (“Use every atom!”).
•Improved valorisation of coal, oil and natural gas as feedstocks in chemical industry through new catalytic pathways.

Reduction of Primary Energy Use:
High Efficiency Power Plants

•Electricity production accounts for about 30% of total energy consumption.
•Electricity consumption is expected to at least double till 2050.
•Globally ca 60 % of electricity produced is from fossil fuel or biomass.

•**EU electricity production (2016):**
49% fossil fuels, 26% nuclear, 12% hydro, wind 10%, solar 4%

•**Fossil fuels cannot be completely replaced.**

•Increasing conversion efficiency from fuel to energy.

•Efficiency for electricity production now 40%, but enhancement possible:

–New thermal conversion processes for coal involving pyrolysis, gasification and combustion

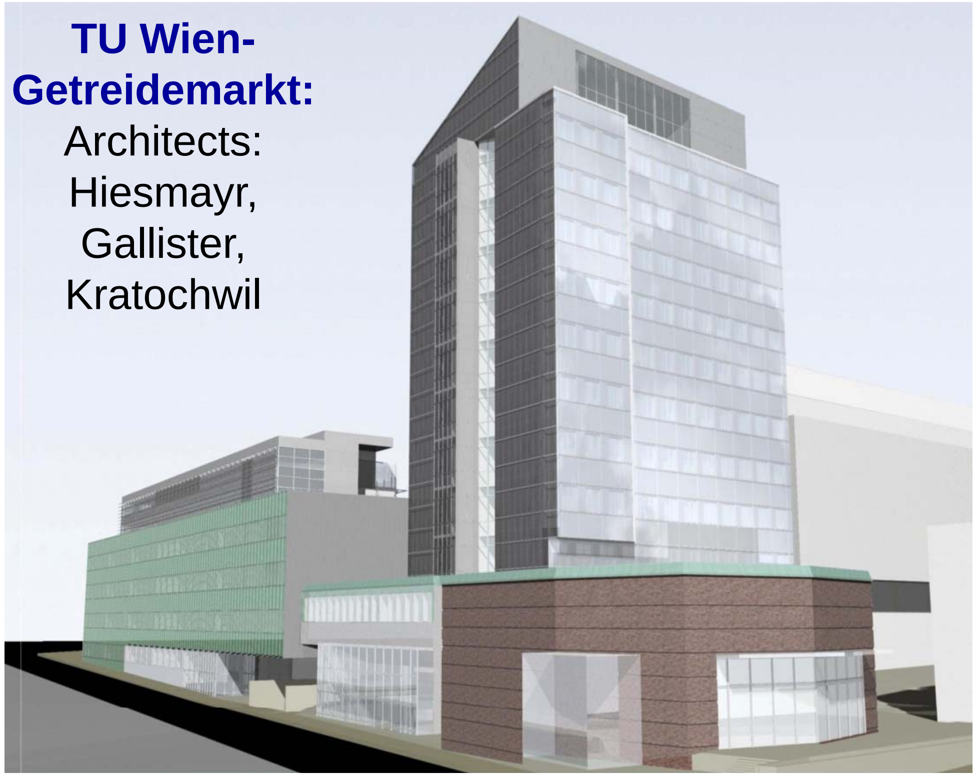
–New materials like Ni-Cr-base alloys for increased operational temperatures
(700°C, 350 bar: 50% efficiency).

Reduction of Primary Energy Use:
Lightning and Heating

- **Efficient Lightning:** Conventional light bulbs have a yield of only 4 %.
- ➢ Development of a new generation of lightning devices with high energy efficiency: especially LEDs with efficiency of up to 20 - 50% (Nobel-Prize 2014).
- **Development of a new generation of houses:**
- ➢ passive houses
- ➢ surplus houses

Solar house LISI (Karin Stieldorf, TU Wien)

TU Wien-Getreidemarkt:
Architects:
Hiesmayr,
Gallister,
Kratochwil



"Every house can become a power plant." (Robert F. Kennedy jun.)

Reduction of Primary Energy Use:
„The City of Tomorrow“

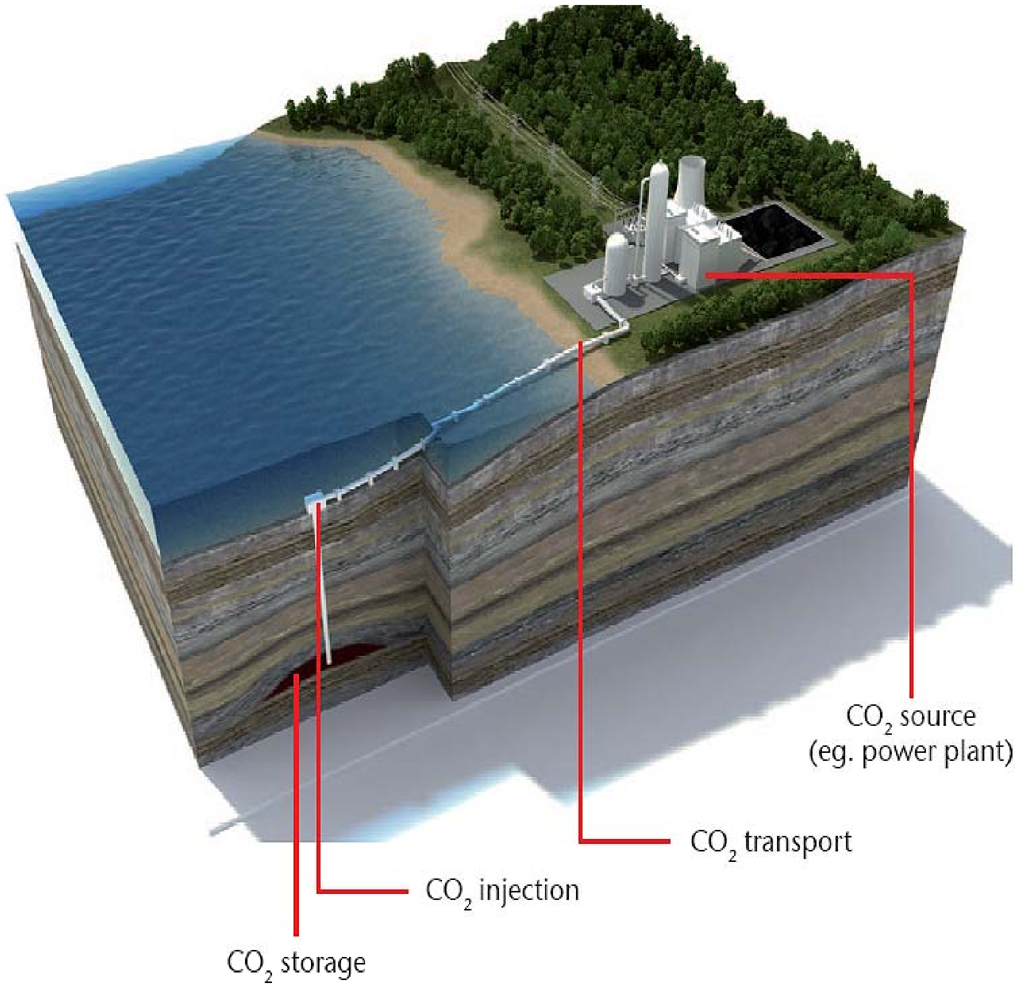
75% of energy consumed in urban areas.
50% of world population lives in cites with more than 1 million inhabitants.

“Carbon-neutral” ecocities:
Dongtan Ecocity planned for 500.000 inhabitants by 2050.

Emission Reductions from Power Generation:
Carbon Capture and Storage (CCS)

•Capture of emitted CO_2 in power plants burning fossil fuel.

•Liquification of emited CO_2 and storage in geological formations underground.



- ➢ Theoretically reduction of CO_2 80-90% possible, but increased fuel needs of a coal or gas fired plant with CCS by 25%-40%.
- ➢ Recycling of captured CO_2 for production of methanol or methane by reaction with H_2 .

EU SET-Plan: The EU CO_2 Capture, Storage and Transport Initiative (13 bio EUR)

Emission Reductions from Power Generation:
Carbon Capture and Storage (CCS)

R

Vattenfall Schwarze Pumpe 30 MW pilot plant

Source: Vattenfall 2010

Costs: ca 1 bio EUR for 1 GW power plant capturing ca 1 million tons CO_2 p.a.
Impact on electricity production costs: +100% *(Source: Daniel Yergin 2013)*

Emission Reductions from Road Transport

- Road transport responsible for 25% of EU GHG emissions.
- Tank-to-wheel efficiency of present cars ca 20%.
- Global vehicle fleet is set to increase from around 1 billion to between 2 and 3 billion by 2050. Most of this growth will take place in developing countries (China x10, India x5).

Measures:

- enhancement of efficiency for diesel and gasoline driven cars (maximum fuel consumption <4,5 l/100km for passenger cars by 2021, <3 l/100km by 2030)
- “CO_2-neutral” biofuels
- electric cars
- advanced public transport systems

Emission Reductions from Road Transport:
Biofuels

EU-Directive: 10% of fuel from renewable (bio)resources

First generation:
ethanol from cereals and sugar,
diesel from plant oils.

Biofuel factory Babilafuente produces annually 200.000 tons ethanol from cereals. In USA 40% of maize used for ethanol.

Abb.: Abengoa, Wikipedia 2010

Second generation:
ethanol from wood or energy plants

Fluidized Bed Gasifier in Güssing, Austria

EU SET-Plan: The European Industrial Bioenergy Initiative (9 Md EUR)

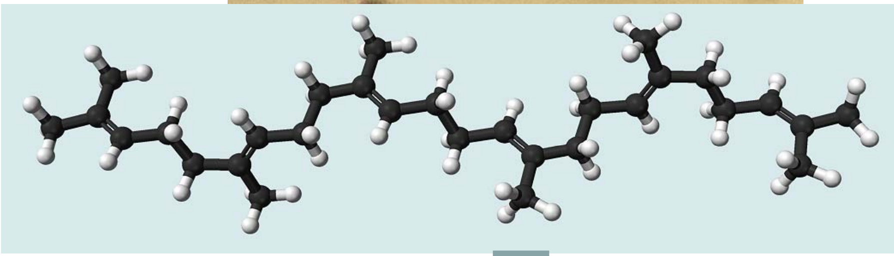
Emission Reductions from Road Transport:
Biofuels

Third generation:
hydrocarbons (gasoline, diesel) from algae.

Algae of the chlorophyceae class (like botryococcus braunii and chlorella vulgaris) produce hydrocarbons (mainly triterpenes), which can amount to 50 % of their mass ("Oilgae").

Abb.: Wikipedia 2013

$C_{30}H_{48}$



"Biorefinery"

Fourth generation:
Artificial photosynthesis

$$CO_2 + H_2O + \text{photons} \xrightarrow{\text{catalyst}} C_xH_y$$

- Genetically engineered photosynthetic microorganisms (cyanobacteria) - U.S. Patent #7,794,969 of Sept. 2010 on "HelioCultures" to Joule Unlimited, Cambridge, Mass.
- Inorganic photocatalysts:
exploratory project on "Artificial Photosynthesis" by EUCheMS study group.

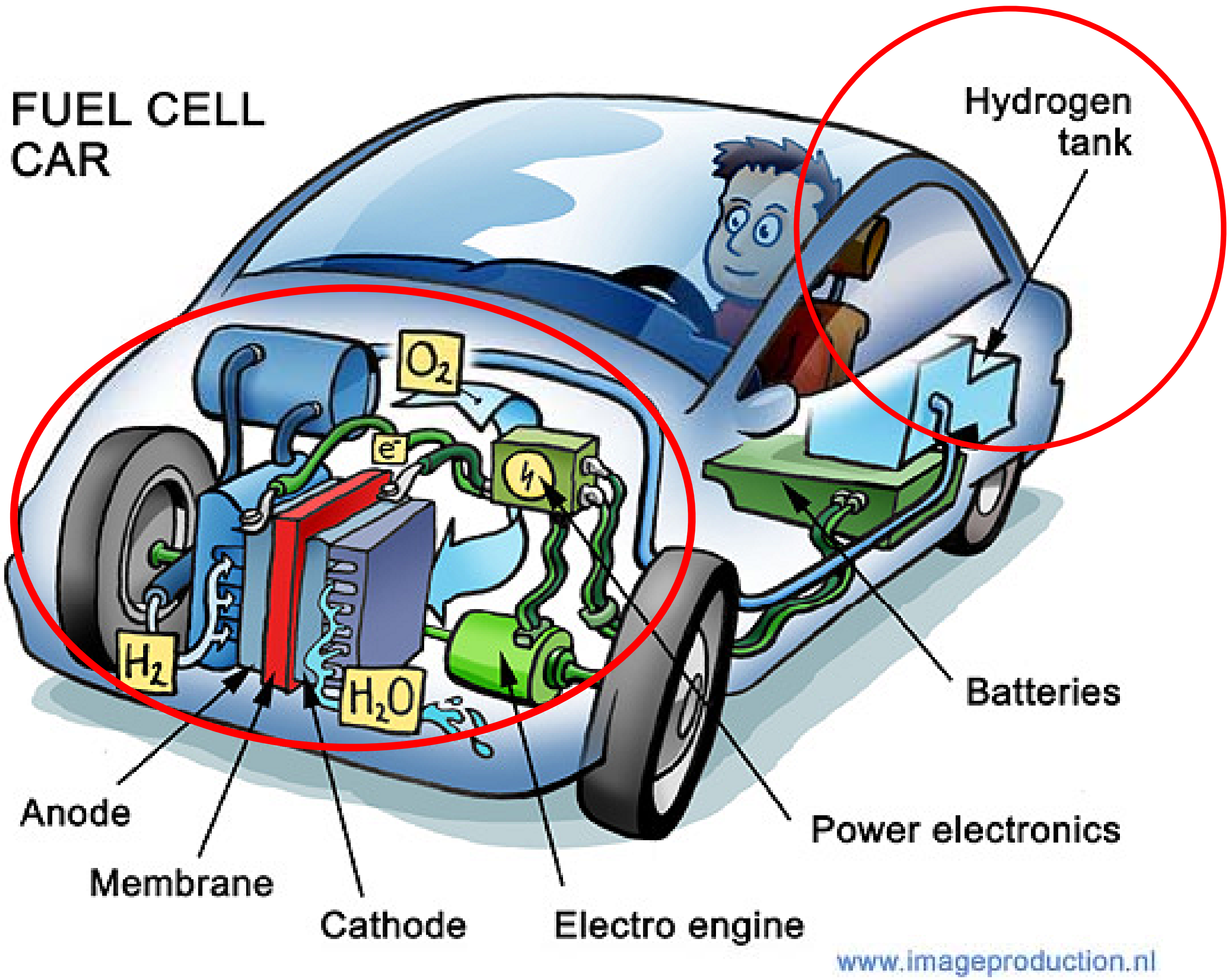
Emission Reductions from Road Transport:
Electromobility

- **Development of light weight electric cars:**
- – Tank-to-wheel efficiency of electric cars could reach 70 %.
- – New construction materials: high performance polymers, carbon fiber polymer composites, high performance ceramics…………….
- – High performance batteries and fuel cells (using hydrogen)

Renault Twizy:
„An all-electric vehicle aimed primarily at busy city dwellers who need to pick their way through the urban jungle."
Ultra-compact dimensions 2.30m in length, and just 1.13m wide.

..........................towards autonomous driving (Tesla, Google....)

Emission Reductions from Road Transport:
The Hydrogen Powered Electric Vehicle



Source: Imageproduction and Wikipedia

Emission Reductions from Road Transport:
The Hydrogen Powered Electric Vehicle

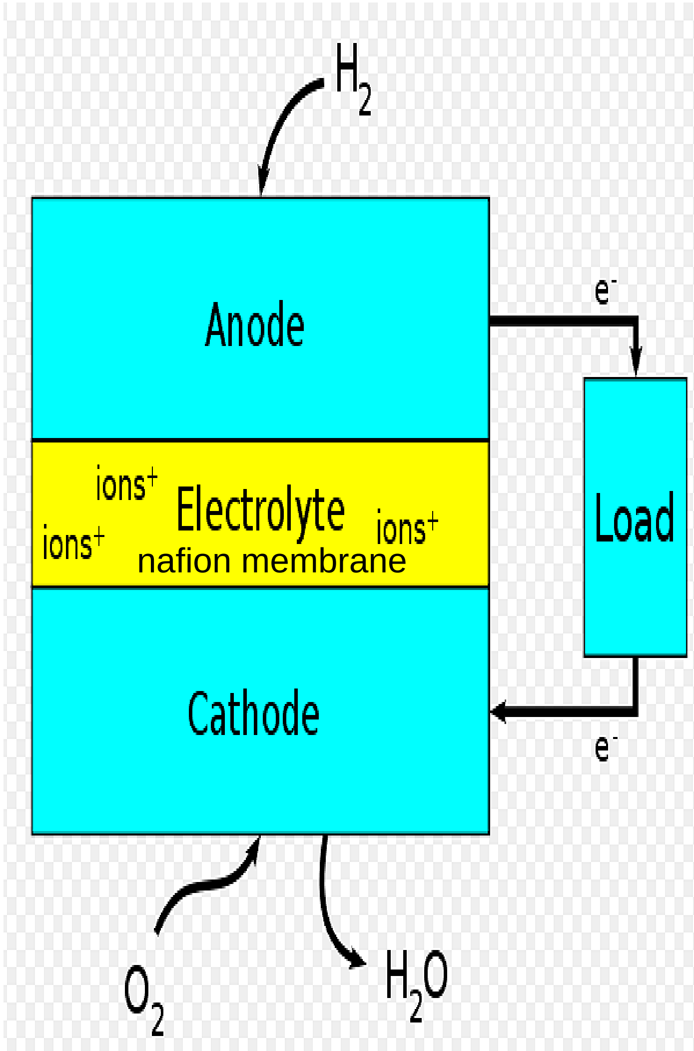
- **Fuel cells for electromobility:**
  - Proton exchange membrane (PEM) cells using hydrogen as fuel yield only water as emission product.
  - Tank-to-wheel efficiency ca 40 % in European driving cycle.

Reaction at anode:

$H_2 = 2\ H^+ + 2e$ (Pt-catalyst)

Reaction at cathode

$2\ H^+ + ½\ O_2 + 2e = H_2O$



Source: JRC, Institute for Energy 2010

Emission Reductions from Road Transport:
The Hydrogen Powered Electric Vehicle

Toyota FCHV PEM FC fuel cell vehicle

Mercedes Citaro fuel cell bus

Source: Wikipedia

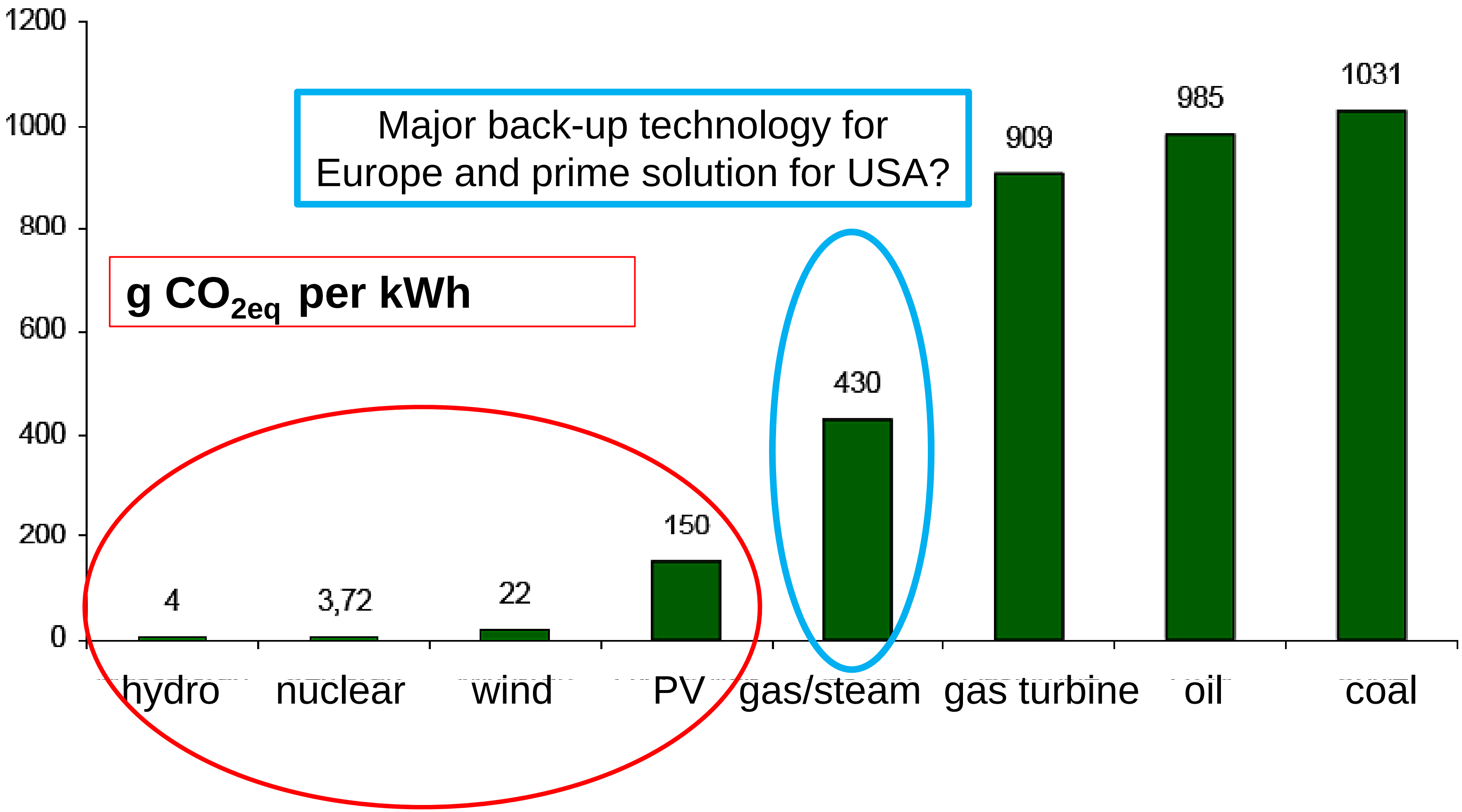
Emission Reductions from Road Transport:
Hydrogen as an Energy Carrier

- As an energy carrier, hydrogen can store and deliver energy in a widely useable form and is one of the most promising alternative fuels for future energy applications (“hydrogen economy”).
- Production of hydrogen from water:
  - high efficiency electrolysis at high temperatures (800°C) – electricity from wind and sun
  - catalytic thermochemical production, e.g. using concentrated solar power, high temperature nuclear reactors („generation4“)
- Underground storage in salt stocks, caverns:
  - large quantities of hydrogen as grid energy storage
- Storage in vehicles:
  - tanks for compressed hydrogen (350 – 700 bar) in vehicles
  - development of solid state hydrogen storage (such as MgH_2, $NaAlH_4$, …)

EU SET-Plan: The Fuel Cells and Hydrogen Joint Technology Initiative (1 bio EUR)

Source:
JRC, Institute for Energy 2010

Emission Reductions in Production of Electricity



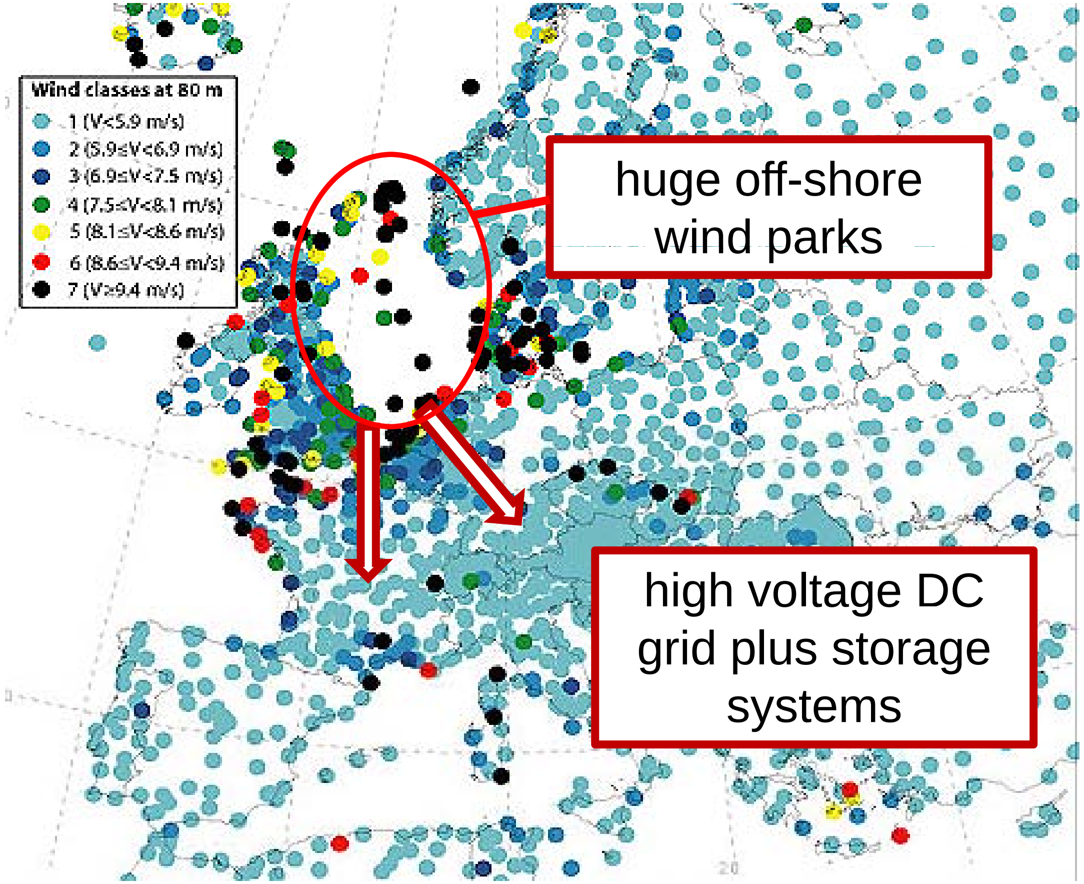
Attention: values are indicative only as they depend strongly on the assumptions and type of calculation made.

Source: EDF 2010, H. Rauch 2011

Renewable Energies: Wind Power

Share in electricity production 2016: 10 % in EU-28 (EUROSTAT 2018), estimated share 17 % in 2020.

Enercon E-126: 7.5 MW, height 198 m, diameter of rotors126 m



Source: JRC Institute for Energy,

>50.000 wind turbines installed in EU

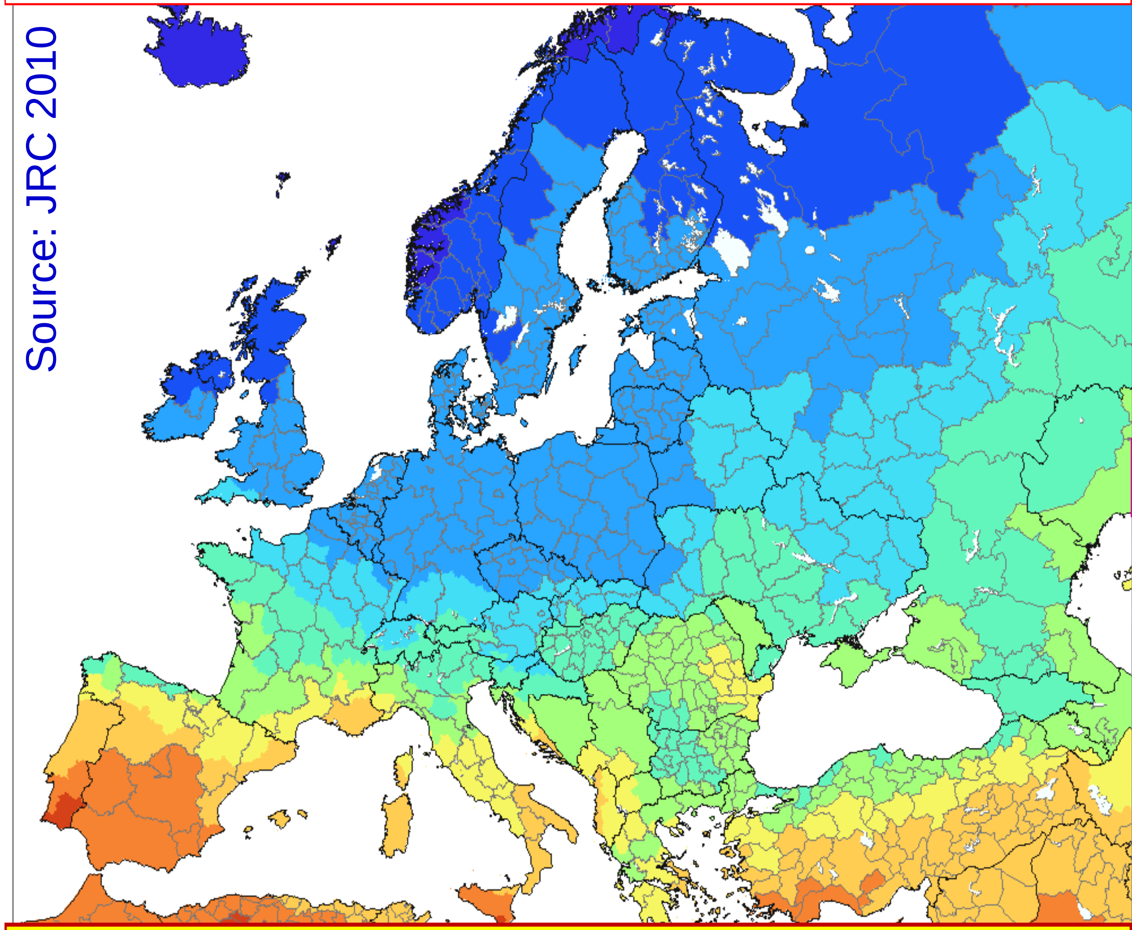
EU SET-Plan: The European Wind Initiative (6 bio EUR)

Renewable Energies: Solar Power

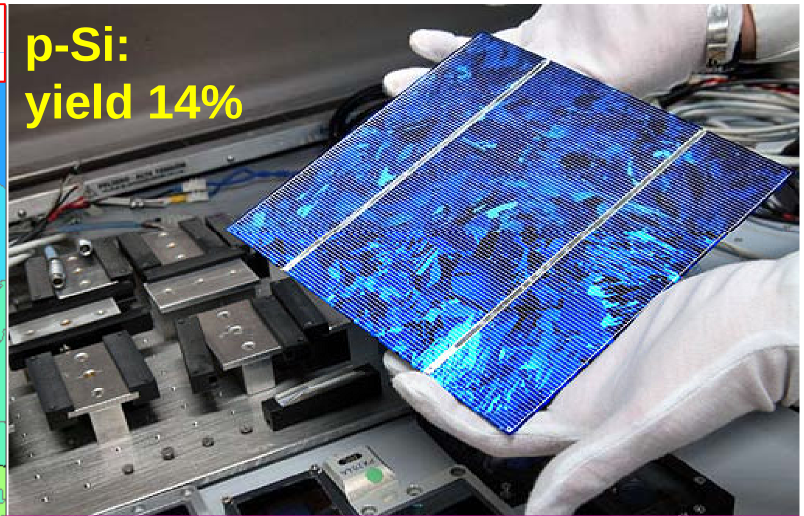
Share in electricity production 2016: 4 % in EU-28 (EUROSTAT 2018), estimated share 8 % in 2020.

European Potential for Solar Power

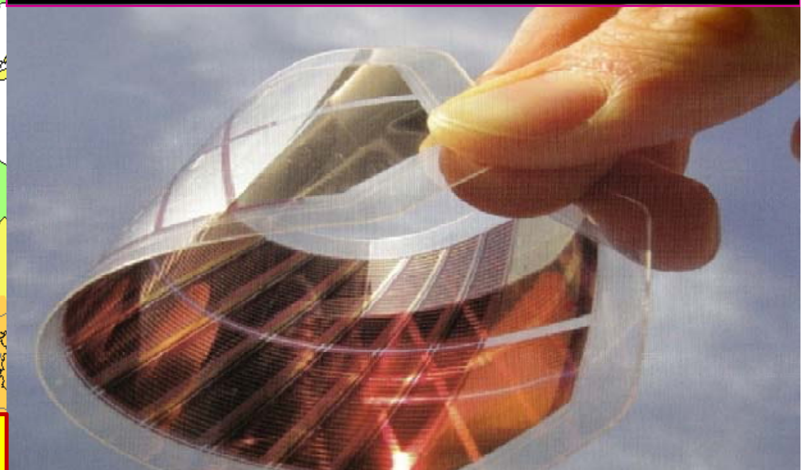
Source: JRC 2010



EU SET-Plan: The Solar Europe Initiative (16 bio EUR)



Multijunction devices: > 40 %



Solar foils and strings

Renewable Energies: Solar Power

R

Solar bikini (Andrew Schneider)

„Solar strings“ textile produce electrical energy for an MP3 player.

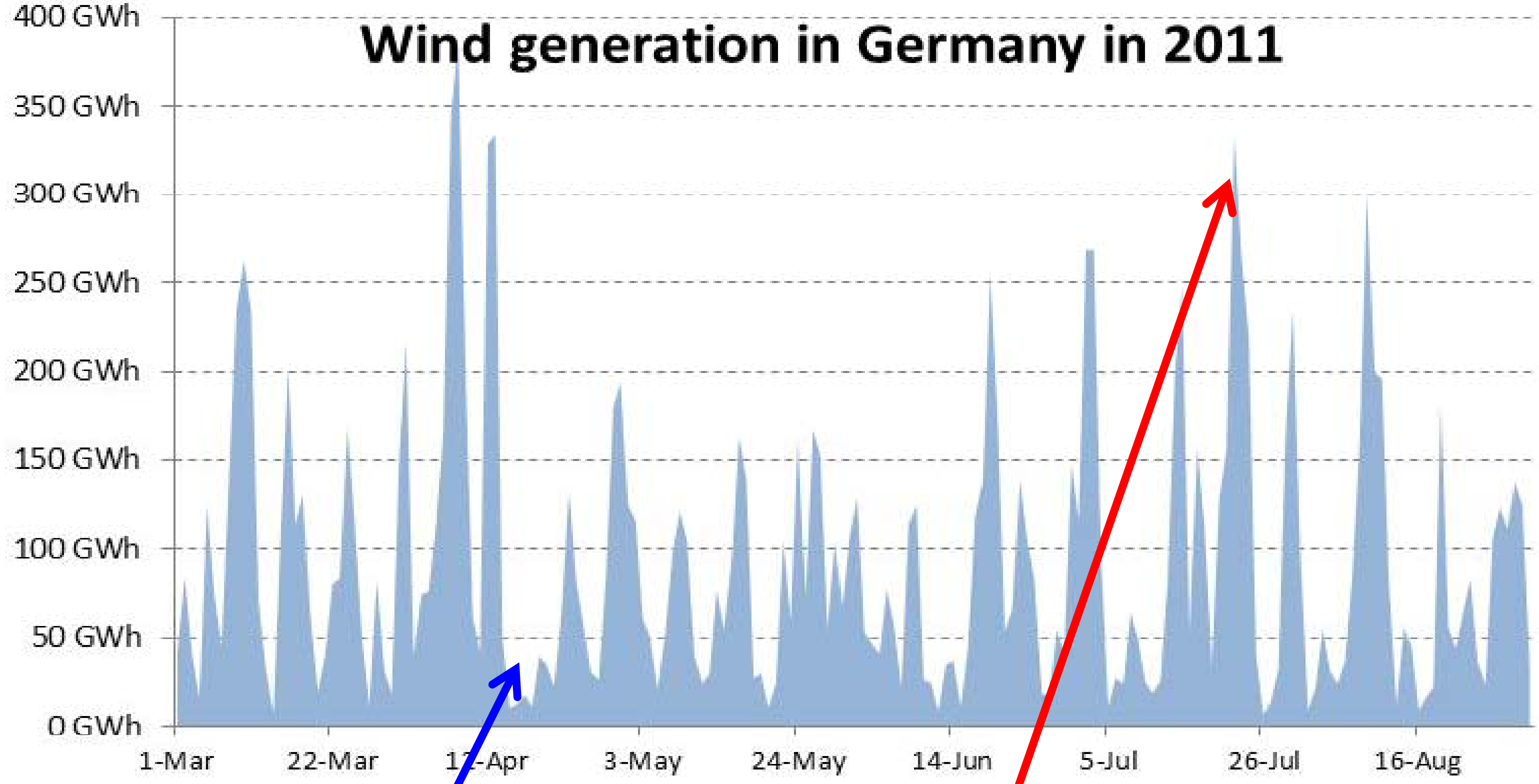
Solar Impulse 2
(Bertrand Piccard and André Borschberg)

Solar airplane:
17.200 solar cells. Wing span like Airbus A380.
First flight 2. June 2014
Airplane can stay in the air for 1 month.
Flew 40.000km around the world 2015/2016

Sources: Geo 2011 and http://www.solarimpulse.com/ 2016

Renewable Energies:
Volatility of Wind and Solar Energy

In Germany about 2 weeks per year practically no wind or solar electricity.

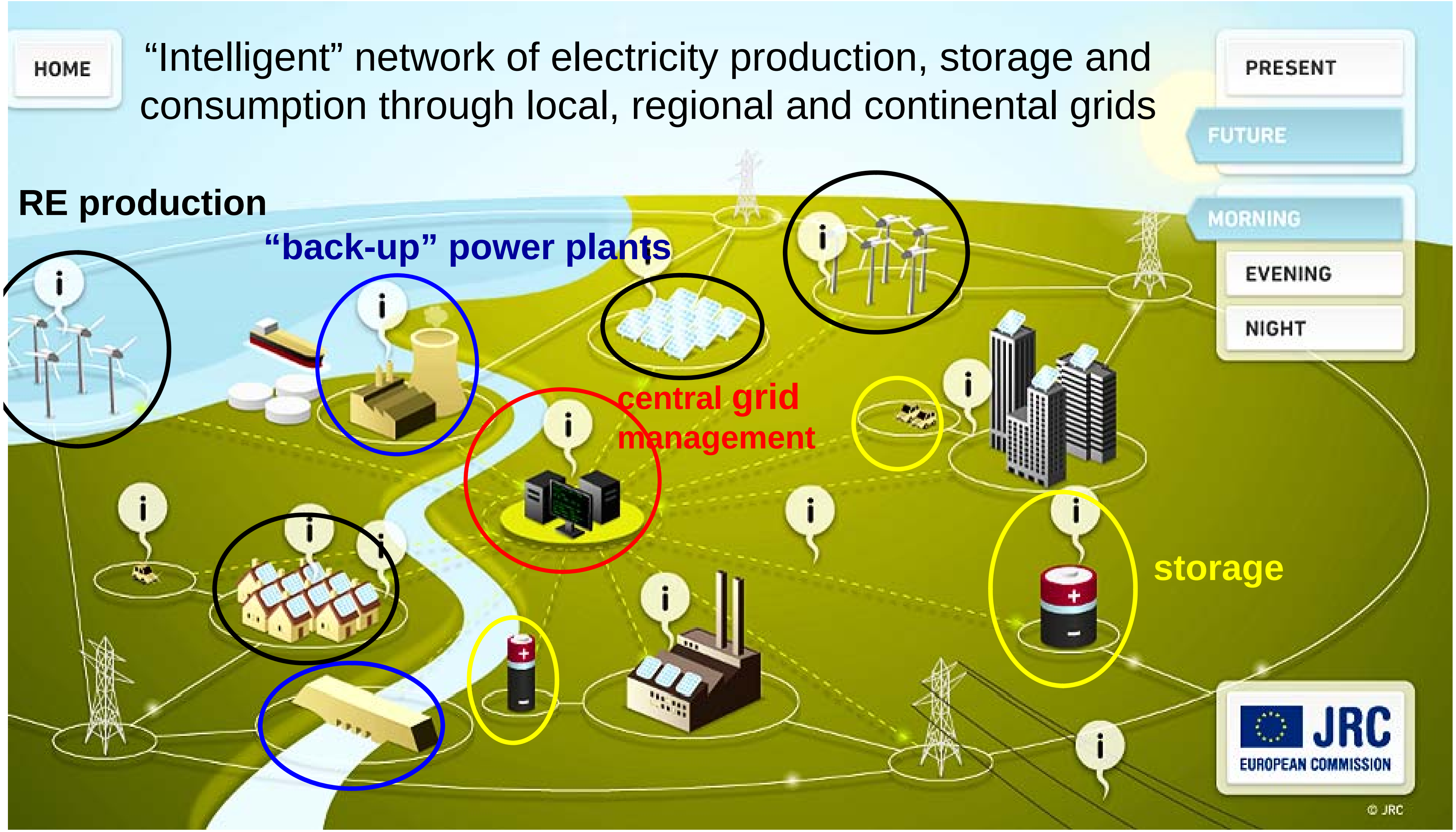


back-up power plants:
gas, coal, nuclear

storage of electricity:
hydro (Kaprun), batteries, hydrogen

Source : Enerdata 2012

Renewable Energies:
Storage of Electricity and „Smart Grids“



- **“Demand Side Management”:**
  - capacity driven pricing
  - capacity driven allocation of electricity

Source: JRC 2012

Economic Aspects of Energy Shift

- **Estimated global costs of energy shift:**
  - Stern Report, IIASA: 0,5-1,5% of global GDP = 300-900 billion EUR annually
  - Global investments in renewable energies in 2017: 200 billion EUR
  - Subsidies for RE in Austria: 100 EUR per person annually
- **Impact on job market:**
  - Globally up to now 8,1 million jobs created, among these 3,5 million in China, 800.000 in USA and 400.000 in Germany (IEA 2016)
  - Expected number of jobs created in China till 2020: 13 million (Chinese Energy Agency)
- **Impact on investments:**
  - Binding of large capital: German “Energiewende” costs 25 bio EUR annually
  - China has invested more than 100 bio EUR in RE within China
  - Chinese foreign investments in RE were 30 bio EUR in 2016

Source: Bloomberg 2018, IEA 2018

Global subsidies for fossil fuel production: 300 billion EUR annually

Renewable Energies:
Co-benefits

Co-benefits of energy shift:

- Reduction of energy imports of EU: now 350 billion EUR annually
- Reduction of air pollution (China!)

New entrepreneurial spirit in Europe?

J. F. Kennedy, Rice University 1962:
"We choose to go to the moon......that will serve to organise the best of our energies and skills."

2014: China announces $1.6 billion air pollution fund to improve air quality in cities.

- China is world leader in RE (solar, wind, hydro)
- 5 of the largest PV-producers are Chinese companies

Space Exploration: The Last Frontier

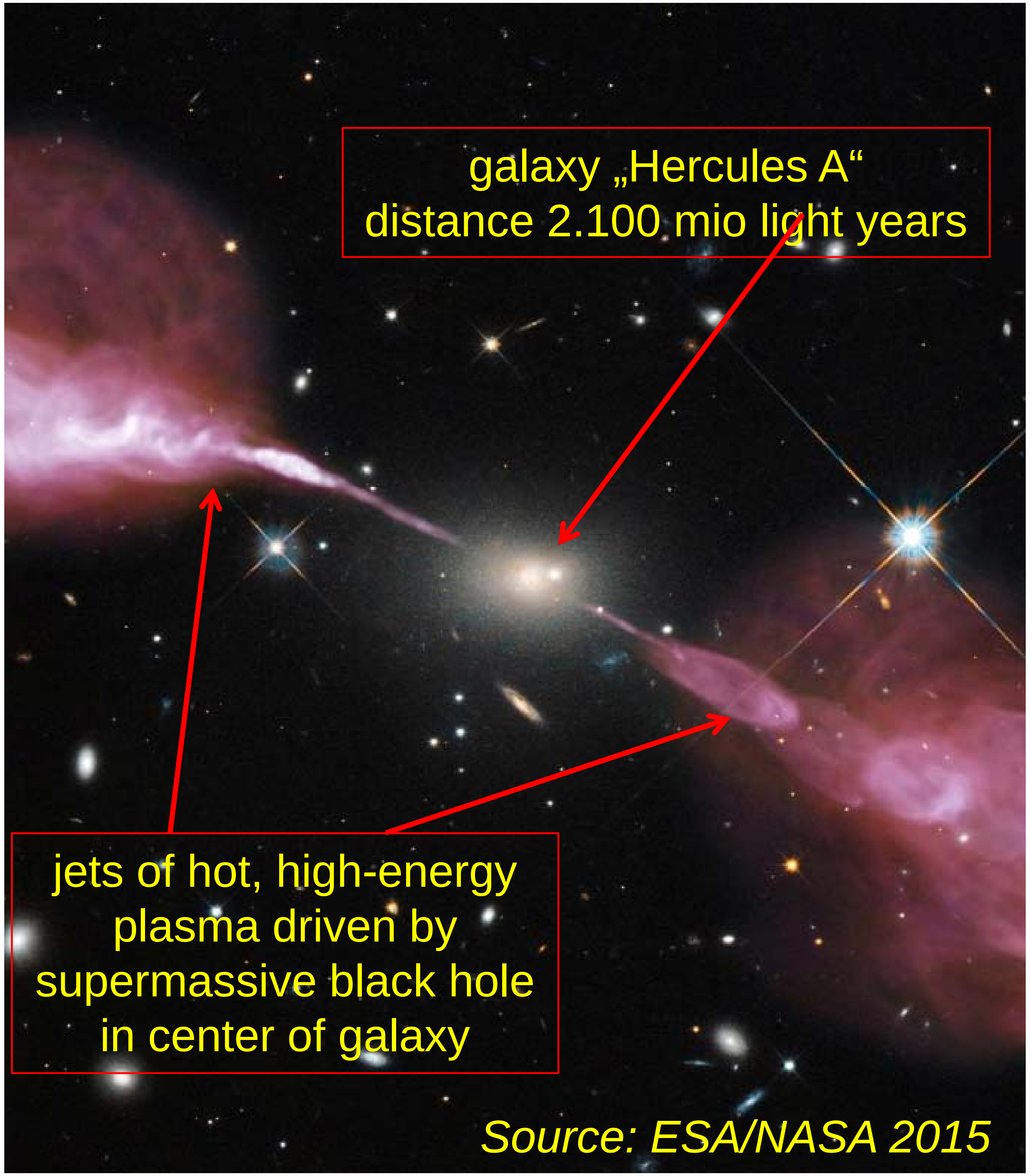
8.2 Space Exploration

- Unmanned robotic probes or human spaceflights
- Landmarks:
  - 1957 first human-made object to orbit (*Sputnik)*
  - 1969 first moon landing (*Apollo 11*)
  - 1970 landing of *Venera* on Venus
  - 1971 landing of *Mars 3* on Mars
  - 1971 first space station (*Salyut 1*)
  - 1977 *Voyager 2* to study outer planets
  - 1982 Space shuttle programme
  - 1998 International Space Station (ISS)
- Major launch vehicles:
  - *Saturn*
  - *Sojus*
  - *Ariane*

Ariane 6: will be able to lift 1.000 tons to geostationary orbit (40.000km altitude), 3 bio EUR development costs, 90 mio EUR/launch, operational by 2020 (Airbus Defence and Space)

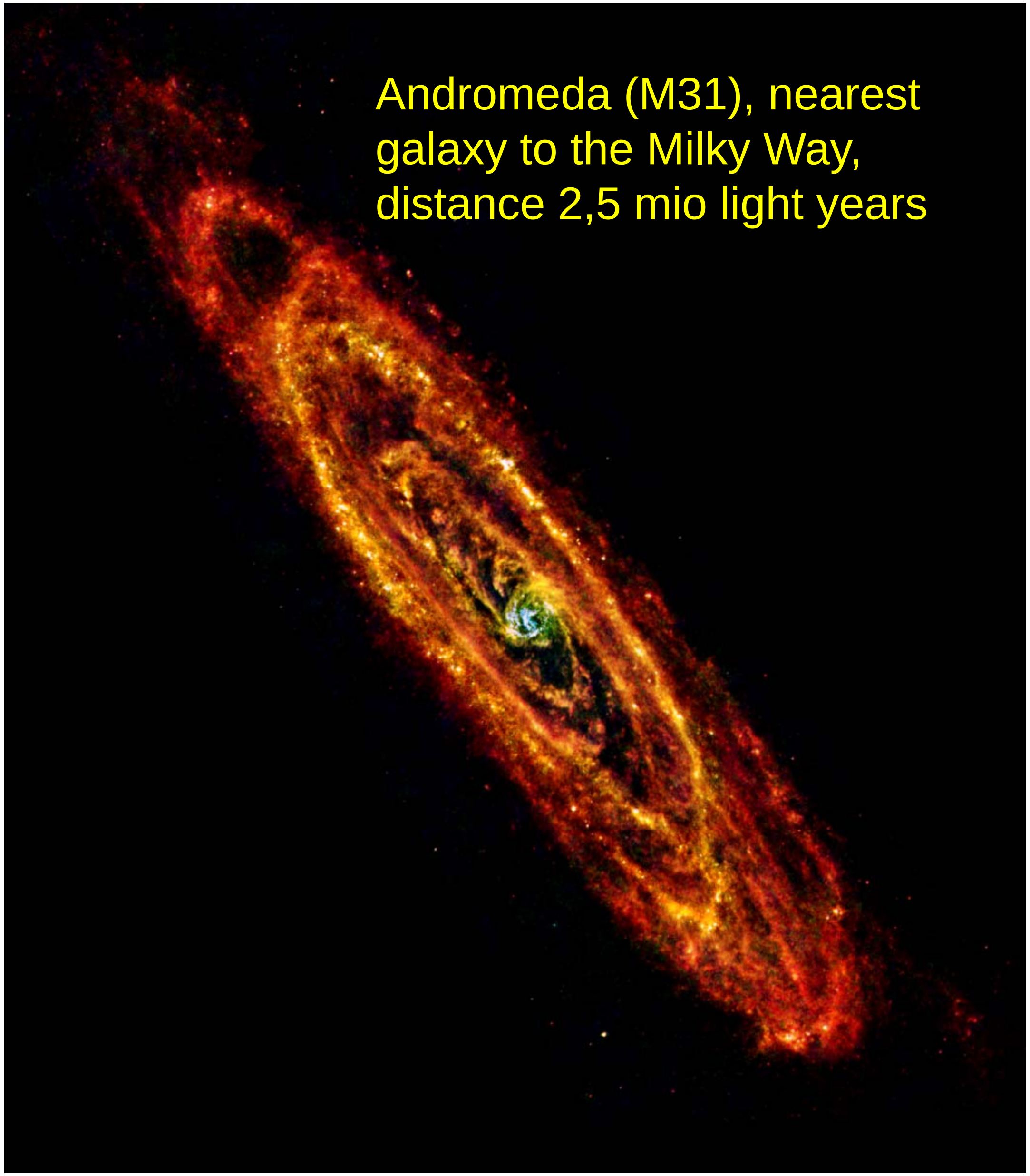
Space Exploration:
Search for Evolution of Universe - Hubble Space Telescope

- 2,4 m mirror telescope for high resolution imaging in IR, VIS, UV and radio wave range, positioned in low earth orbit (550km) to explore galactic evolution in the early Universe.
- active 1990 – 2009
- serviced by space shuttle missions
- Example: emission of plasma jets travelling at nearly speed of light from black hole in center of galaxy Hercules A and formation of huge „material clouds“ due to expansion and slowing down of the plasma jets.



Space Exploration:
Search for Life in Space - Herschel Space Observatory

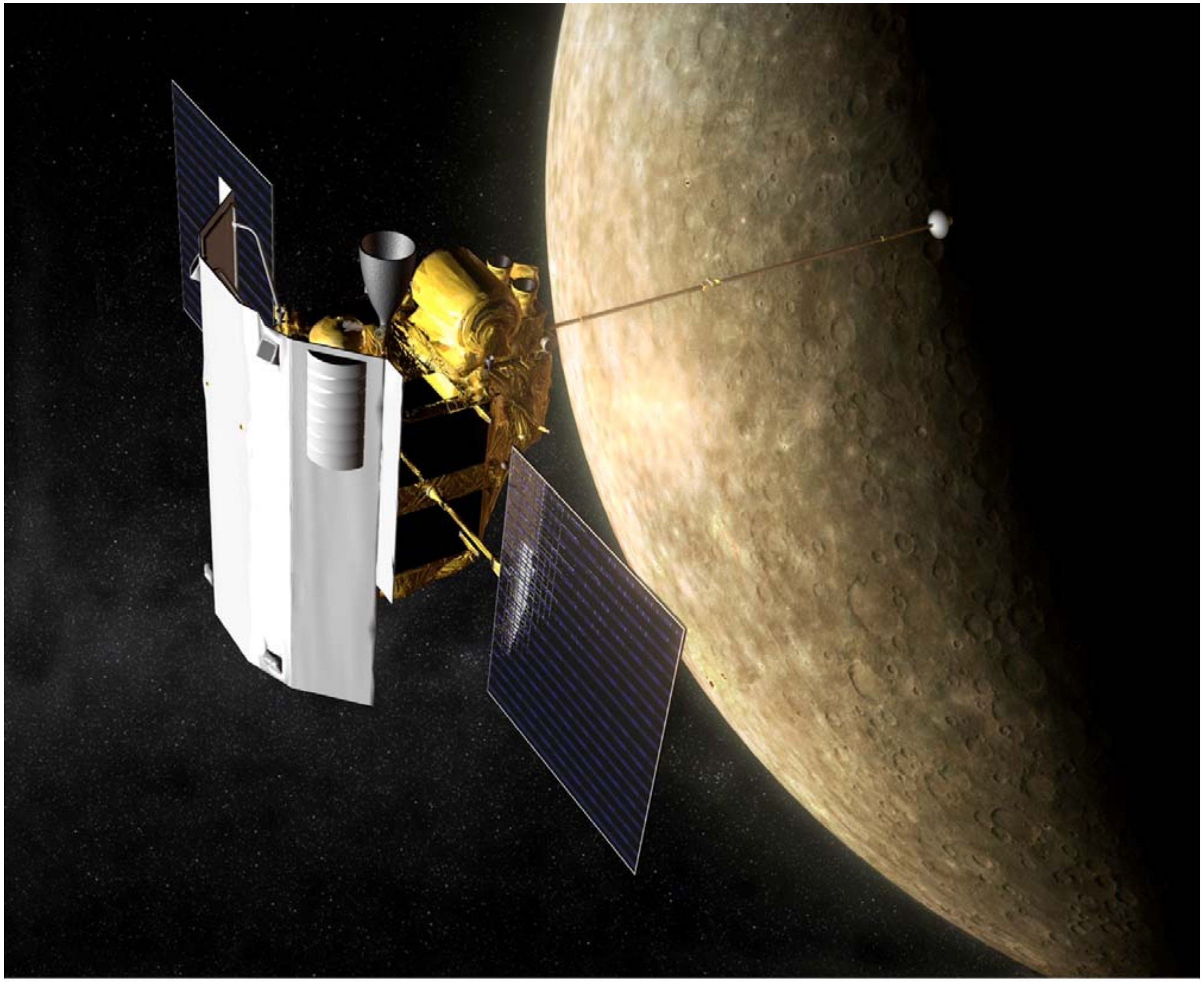
- Largest infrared telecope ever launched (diameter of mirror 3,5m) positioned 1,5 mio km from earth
- active 2009 – 2013
- imaging and spectrosopic measurements in IR and sub-mm-wave range
- search for oxygen, water ...in galactic and extragalactic objects
- studies of star and galaxy formation



Source: ESA 2015

Space Exploration:
Planets of our Solar System - Messenger

- Launched in 2004 Messenger was the first spacecraft to orbit Mercury (2011-2013).

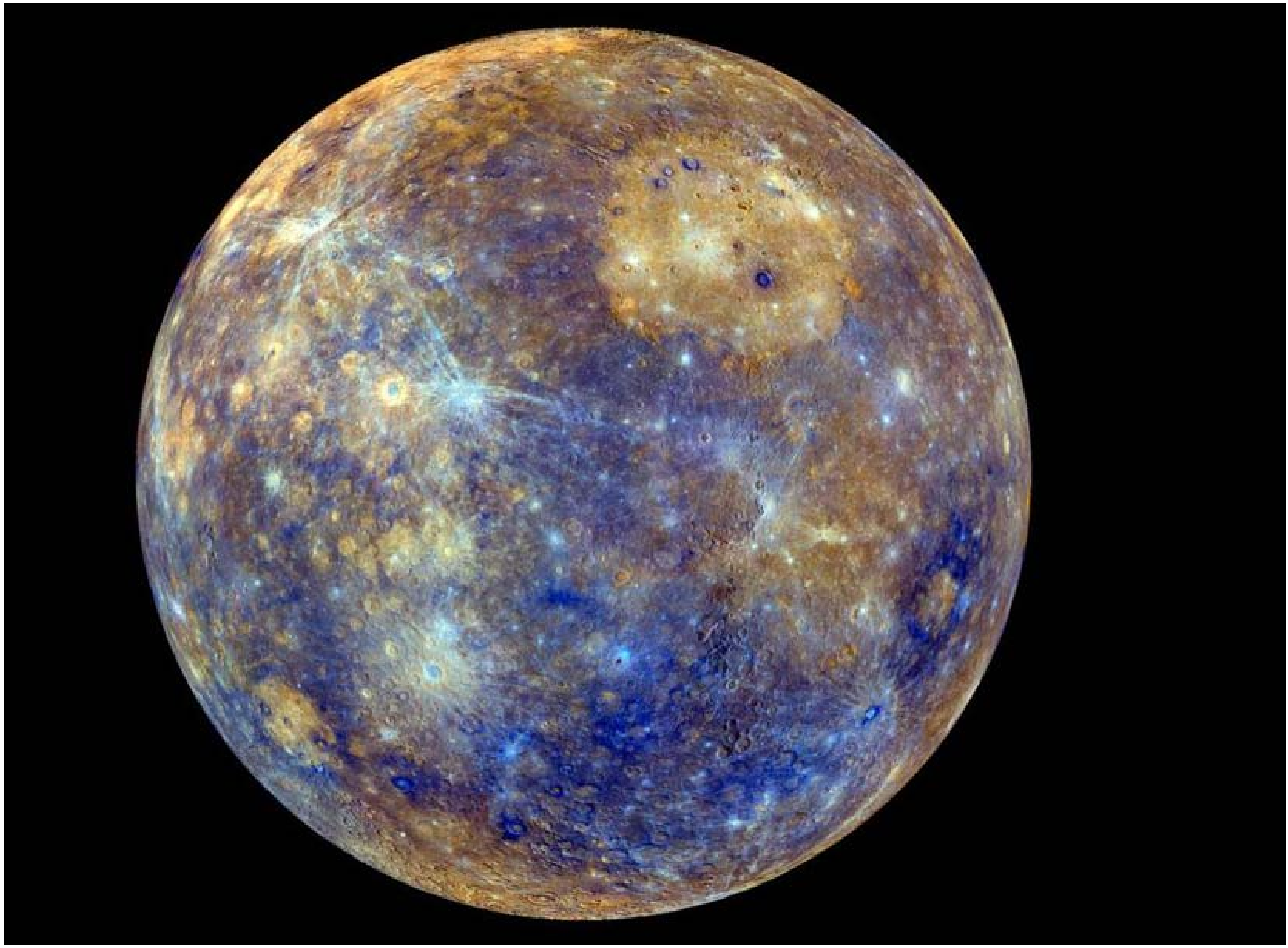


- Extremely complex flight path to minimize impact of gravity by the sun (swing-by maneuvers with Venus and Mercury).

Source: NASA 2015

Space Exploration:
Planets of our Solar System - Messenger

- MESSENGER achieved 100% mapping of Mercury and an extensive characterisation with instruments for imaging, analysis of atmosphere and surface material (IR, UV, gamma, neutron, plasma spectrometers....)



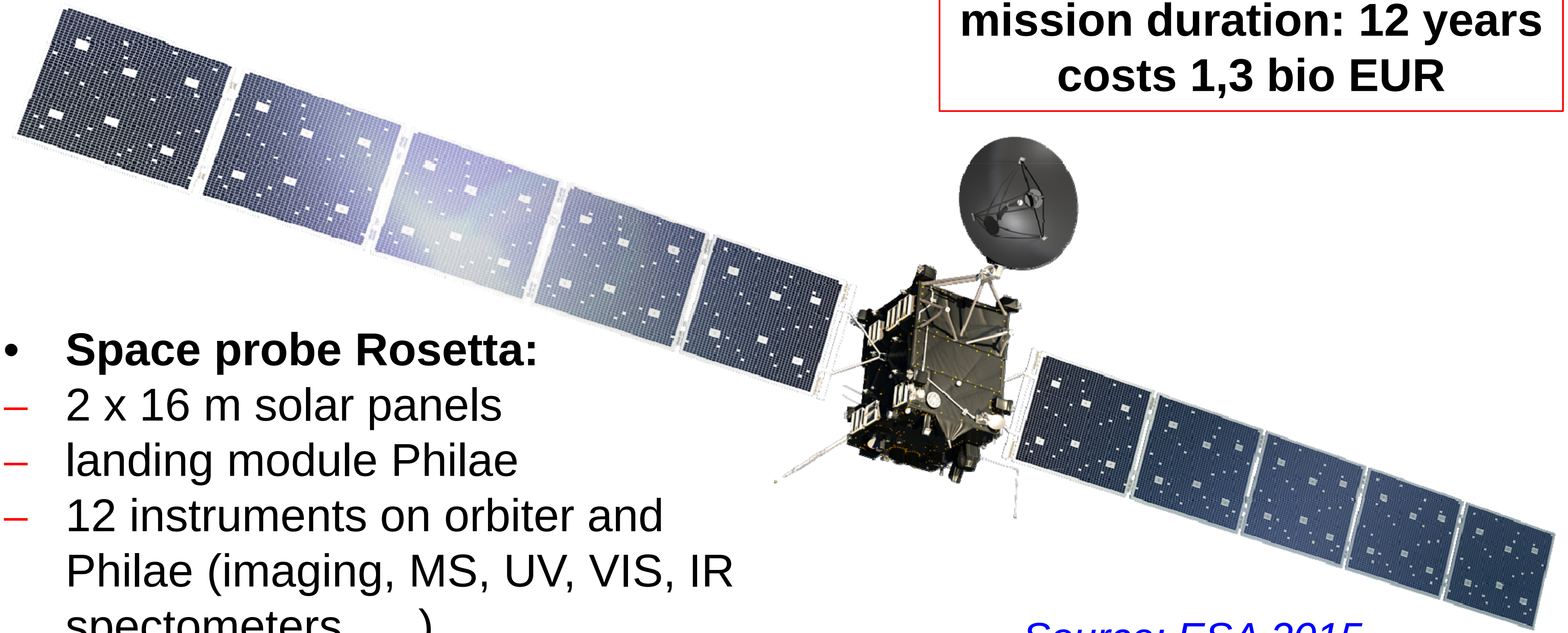
- The contrasting colours have been chosen to emphasise the differences in the composition.
- Discovery of water ice at the planet's north pole.

Source: NASA 2015

Space Exploration:
Search for Life in Outer Space - Rosetta

- **ESA mission to Comet 67P/Churyumov–Gerasimenko:**
– „Chury“ discovered 1969 on photographic plates (Kiev)
- **Comets:**
– „outer-space“ objects with size of a few km
– matter: mainly of H_2O (plus CO_2, trace organic compounds..... ?)
– could provide information on origin of solar system and formation of „early life“

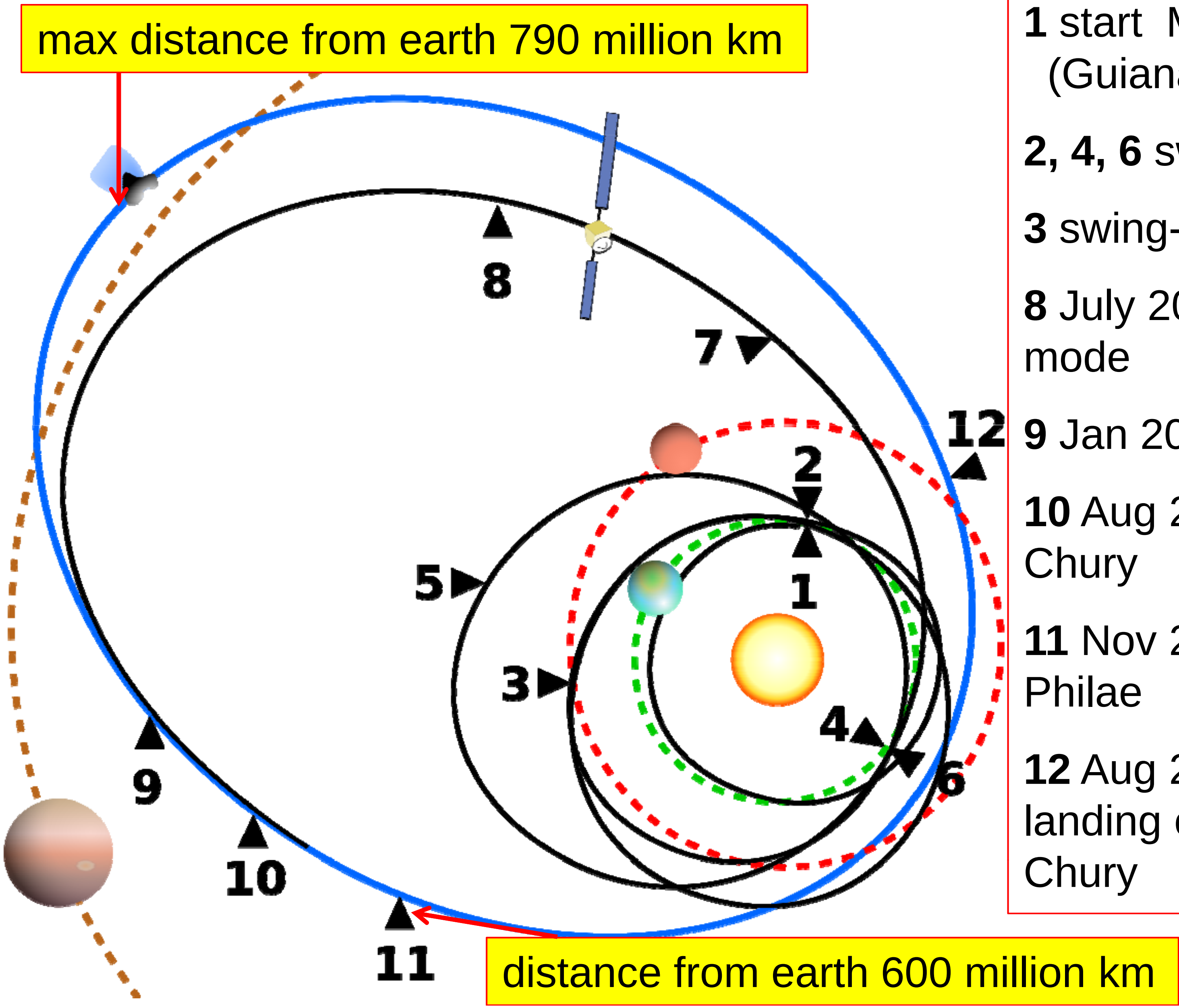
mission duration: 12 years
costs 1,3 bio EUR



- **Space probe Rosetta:**
– 2 x 16 m solar panels
– landing module Philae
– 12 instruments on orbiter and Philae (imaging, MS, UV, VIS, IR spectometers, ...)

Source: ESA 2015

Trajectory of Rosetta



1 start March 2004
(Guiana, Ariane 5)

2, 4, 6 swing-by earth -----

3 swing-by Mars ------

8 July 2011 hibernation mode

9 Jan 2014 wake-up

10 Aug 2014 swing-in Chury

11 Nov 2014 landing of Philae

12 Aug 2015 crash landing of spacecraft on Chury

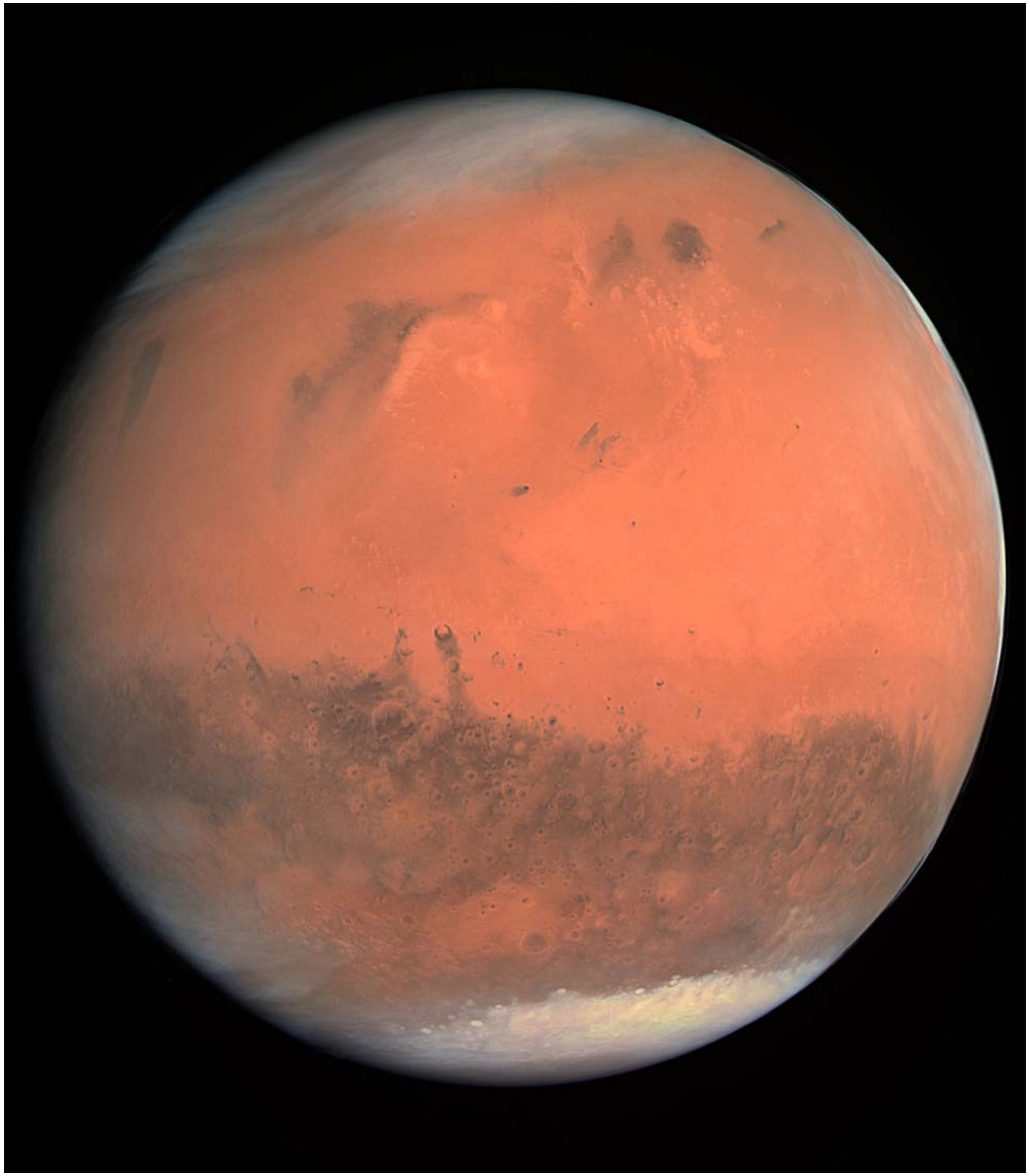
Source: ESA 2015

Swing-in of Rosetta at Mars

TRUE-COLOUR IMAGE OF MARS SEEN BY ROSETTA

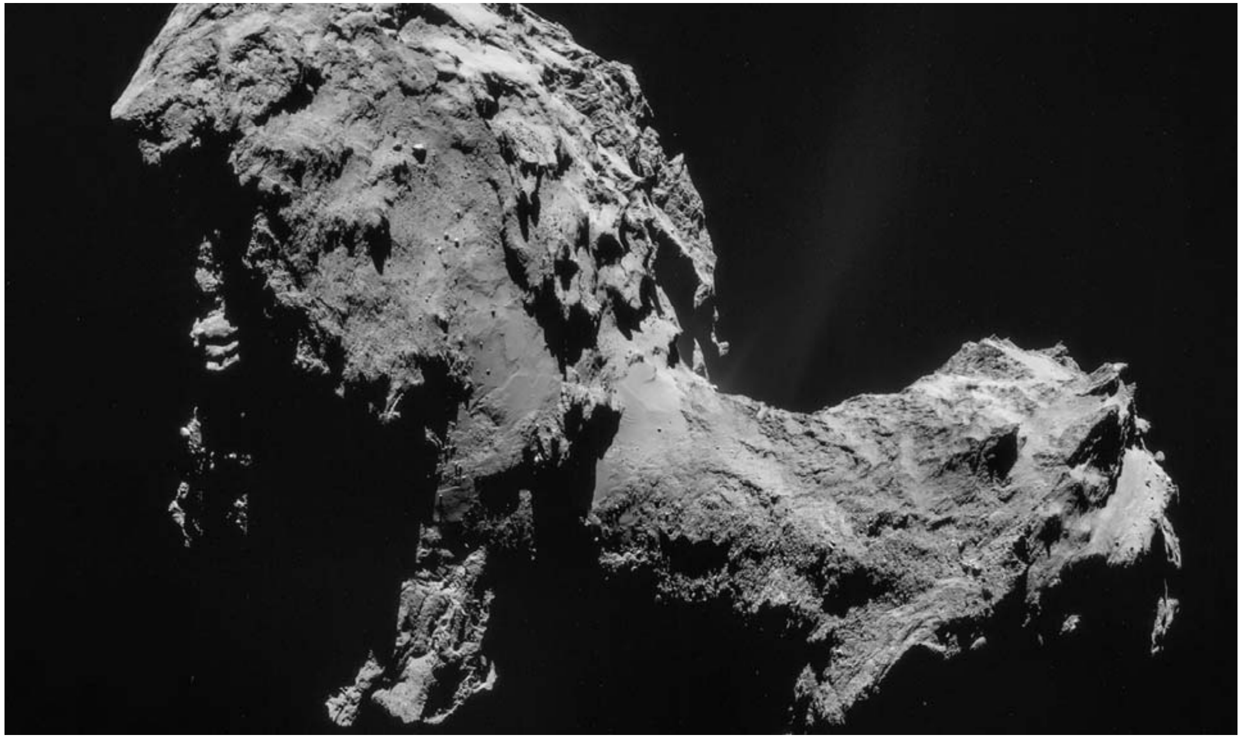
- The first true-colour image generated using orange (red), green and blue colour filters.
- The image was acquired on 24 February 2007 at 19:28 CET from a distance of about 240.000 km; image resolution is about 5 km/pixel.

Source: ESA 2007



Rosetta Orbiting Comet

- **Rosetta was first spacecraft to orbit a comet**
  - distance ca 30 km
  - duration of orbiting: 17 months



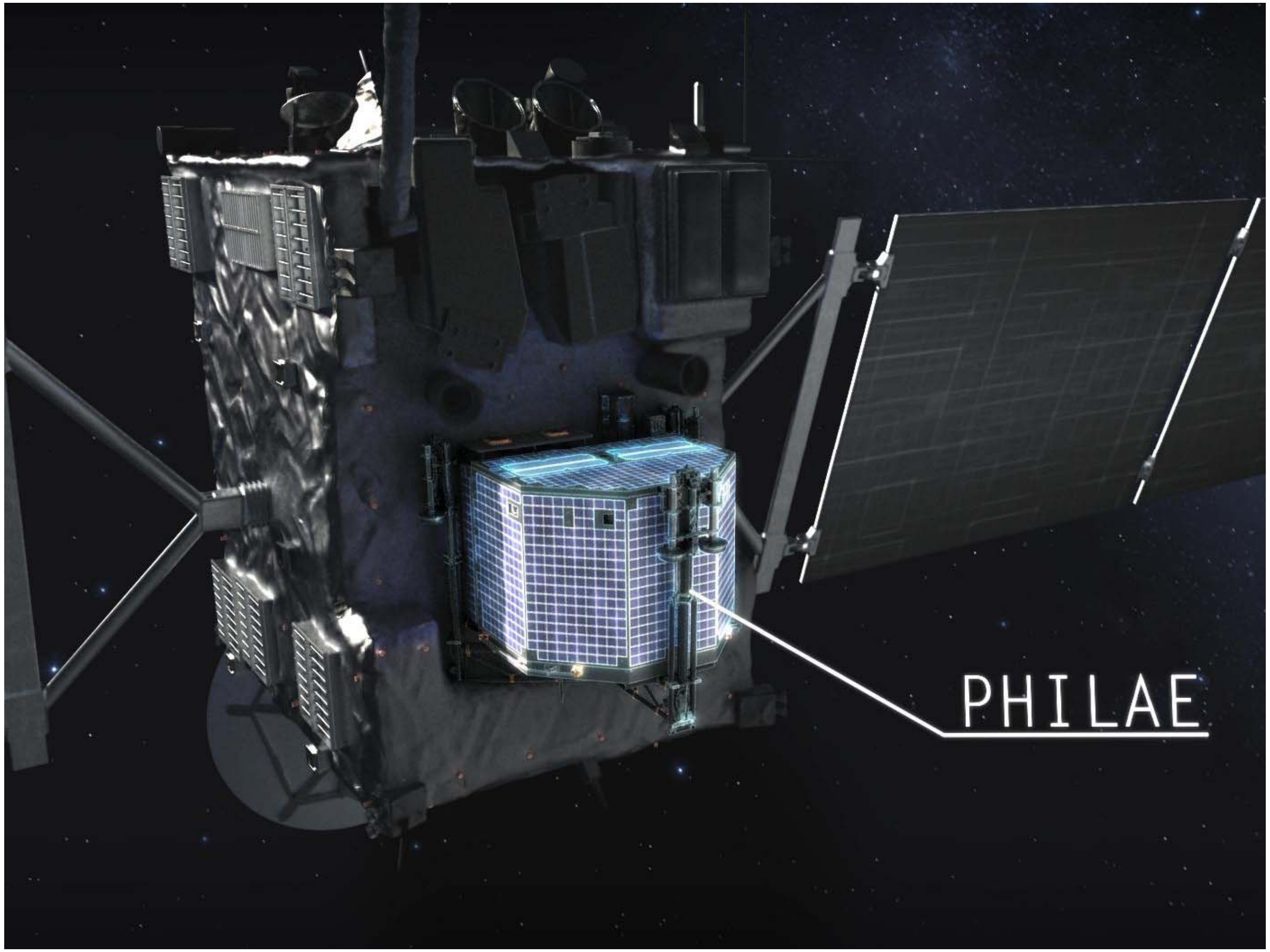
- **High resolution images**
- **First direct analysis of matter of comet:**
  - mass spectrometric analysis of particles emitted from comet due to solar impact
  - detection of a large number of small organic molecules: hydrocarbons up to C7, alcohols up to C5, aromatic compounds, sulfur compounds, aminoacid glycine....
  - detection of elements vital for life: Na, K, Mg, P.....
  - measurement of isotopic ratio $^{2}H/^{1}H$ in comet water: higher than on earth

Source: ESA 2014

Rosetta‘s Landing Module

- Rosetta dispatched Philae on 12 Nov. 2014.
  – Landing speed 1m/s due to low gravitational field of comet (actual weight of the 100kg lander was there 1g).

- Philae delivered data for about 20 hours (over a period of 8 months):
  – first images of a comet‘s surface
  – first *in situ* analysis of its composition.

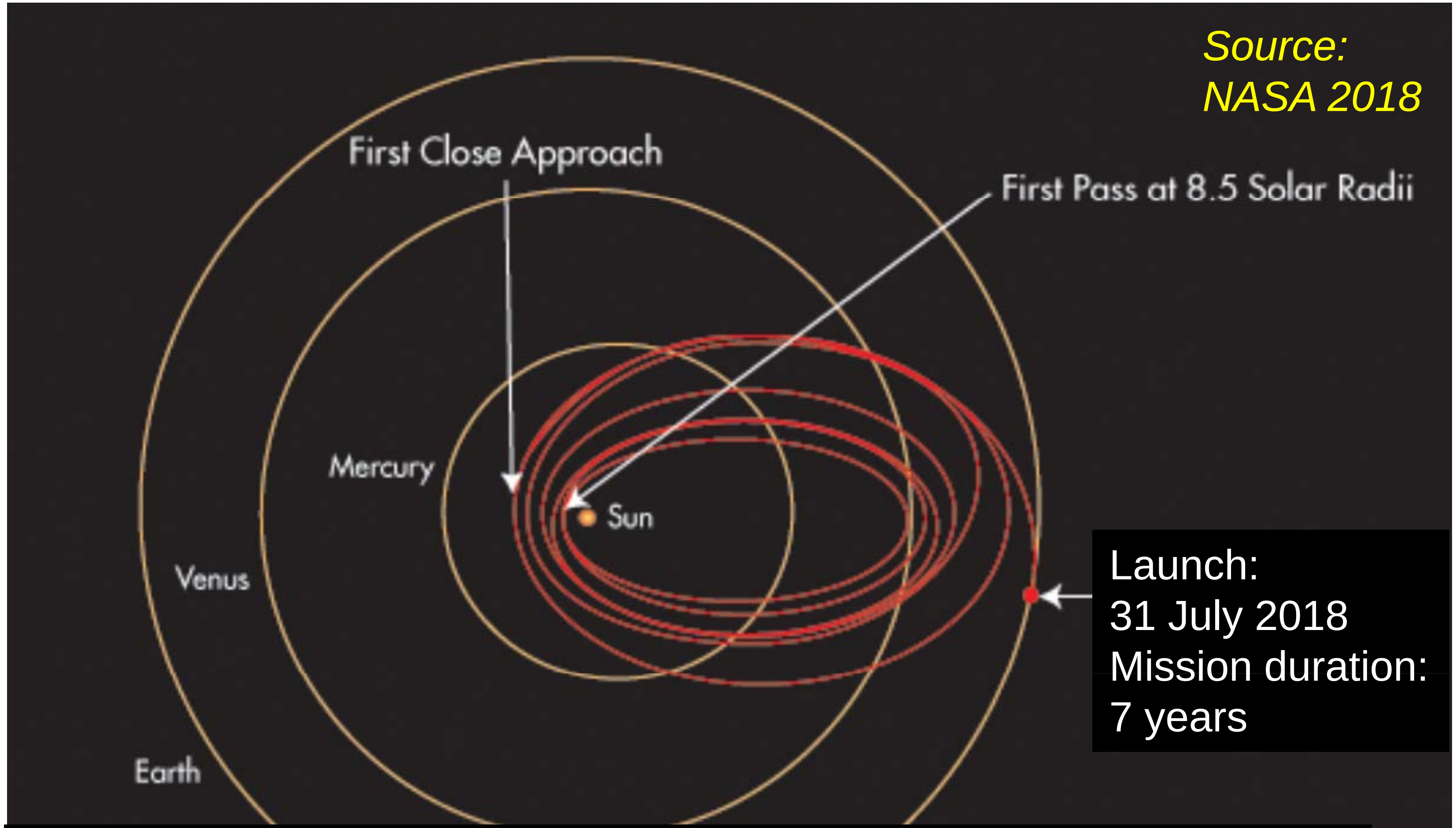


Source: ESA 2014

Space Exploration:

Particle Flows from the Sun – Parker Solar Probe

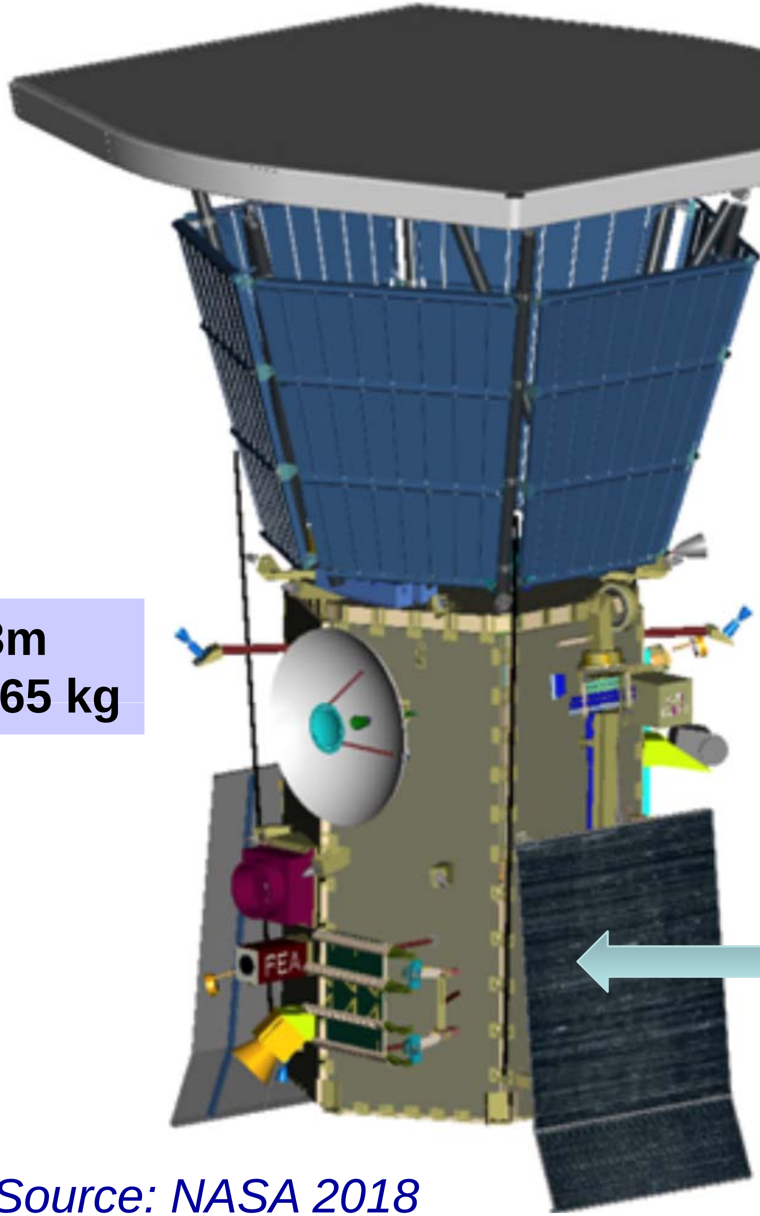
Unique mission to study the processes occuring at the surface of the sun leading to solar wind, corona, aurora in earth atmosphere......



Distance earth - sun: 150 million km
Closest distance to the sun: 5 million km
24 cycles around the sun (each 88 days), heliocentric speed 200 km/s

Space Exploration:
Particle Flows from the Sun – Parker Solar Probe

Height: 3m
Weight 865 kg



heat shield:
1.400°C surface temperature

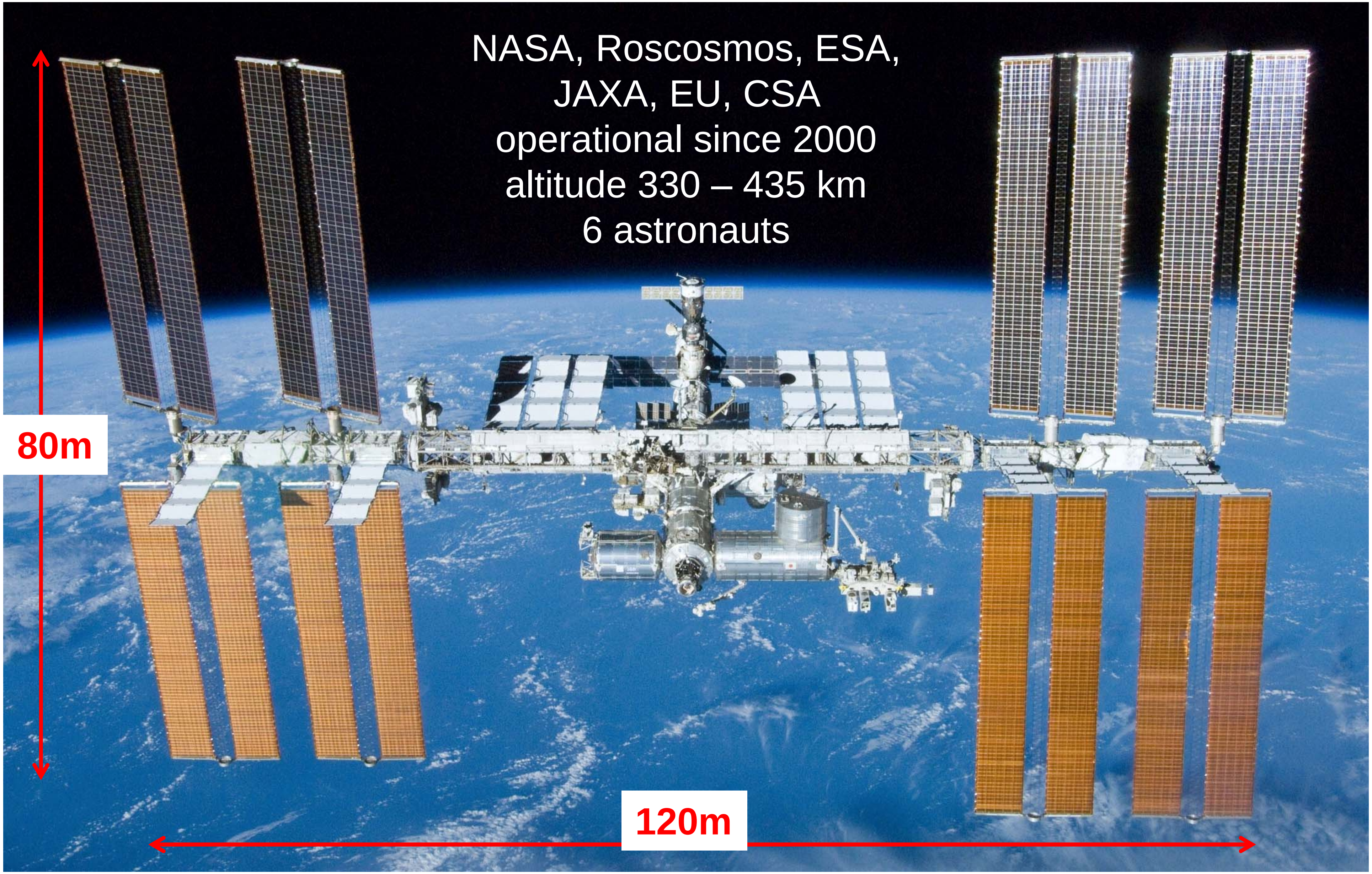
material carbon fiber composite

4 instruments:
to measure flow of electrons, alpha particles: data on electric and magnetic fields, plasma and electron density, velocity, density of particles in solar wind

PV panels for electricity supply

Source: NASA 2018

International Space Station:
Laboratory, Observatory, Factory



Global Earth Observation

8.3 Global Earth Observation

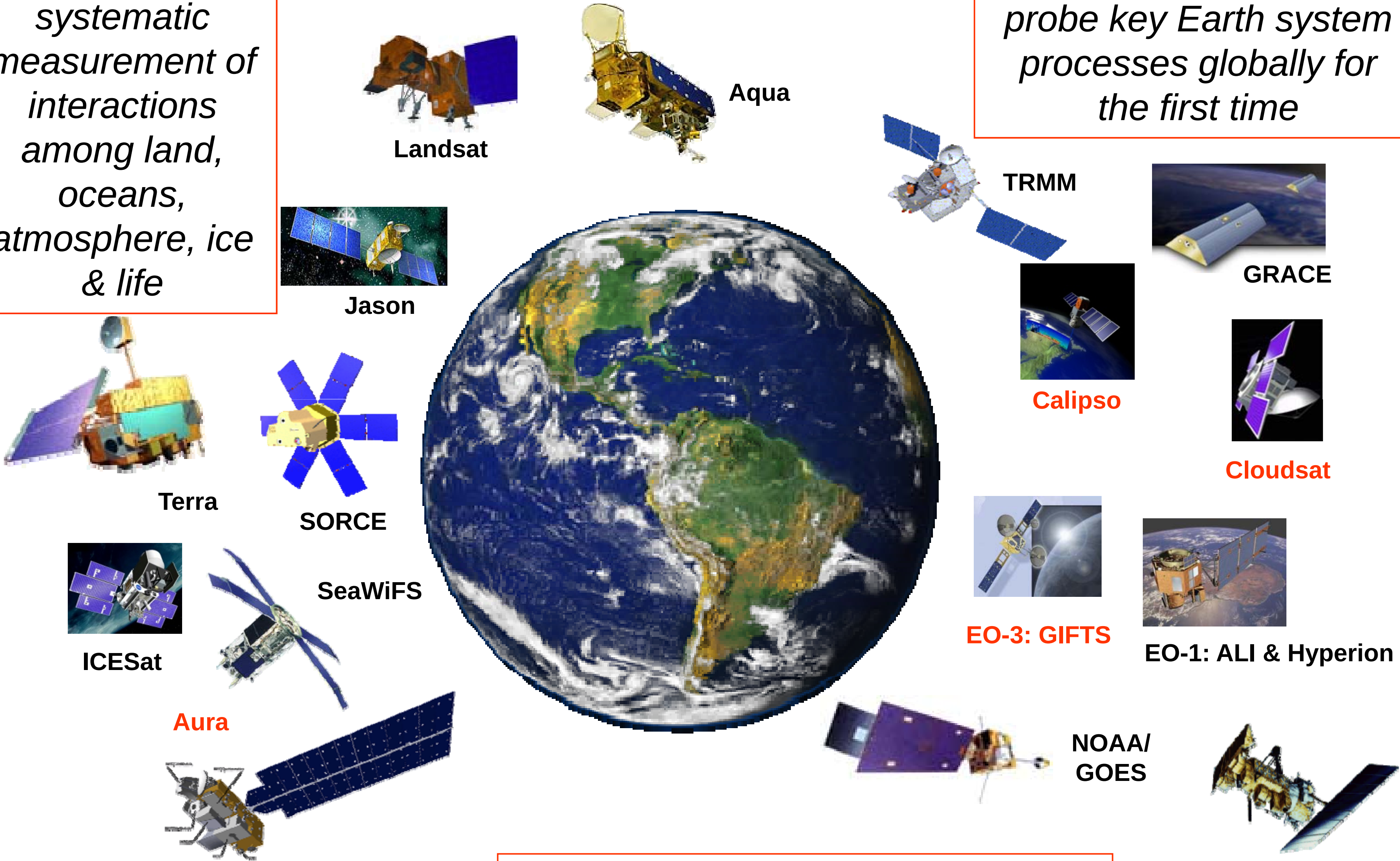
Source: NASA Space Shuttle

Globalisation Requires Monitoring the Whole Planet.

NASA's Earth Observing System

The Earth Observing System -- systematic measurement of interactions among land, oceans, atmosphere, ice & life

Exploratory missions to probe key Earth system processes globally for the first time



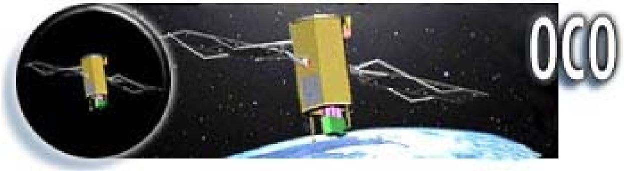
Weather services

Source: NASA

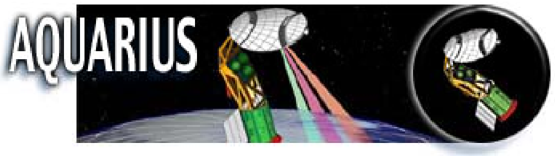
R

NASA's Earth Observing System:
Exploratory Missions (ESSP)

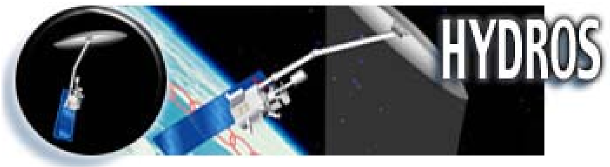
CALIPSO will provide key measurements of aerosol and cloud properties needed to improve climate predictions.



OCO (Orbiting Carbon Observatory) provides observations of atmospheric carbon dioxide, the principal anthropogenic driver of climate change.

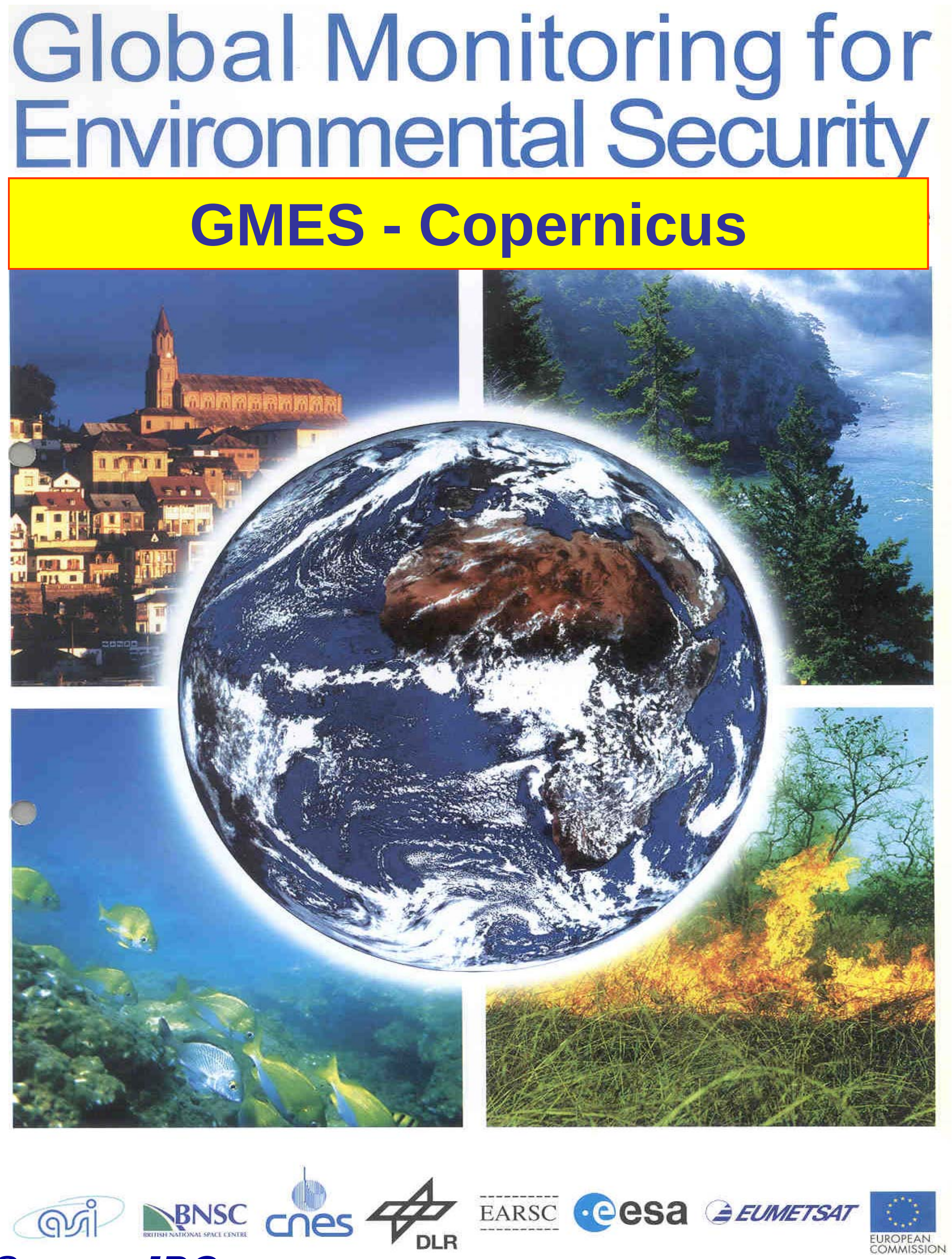


AQUARIUS will measure global Sea Surface Salinity (SSS) important for the water cycle, the climate, and the ocean.



HYDROS will measure soil moisture and land surface freeze/thaw conditions, leading to breakthroughs in the understanding of processes linking water, energy, and carbon cycles.

Source: NASA

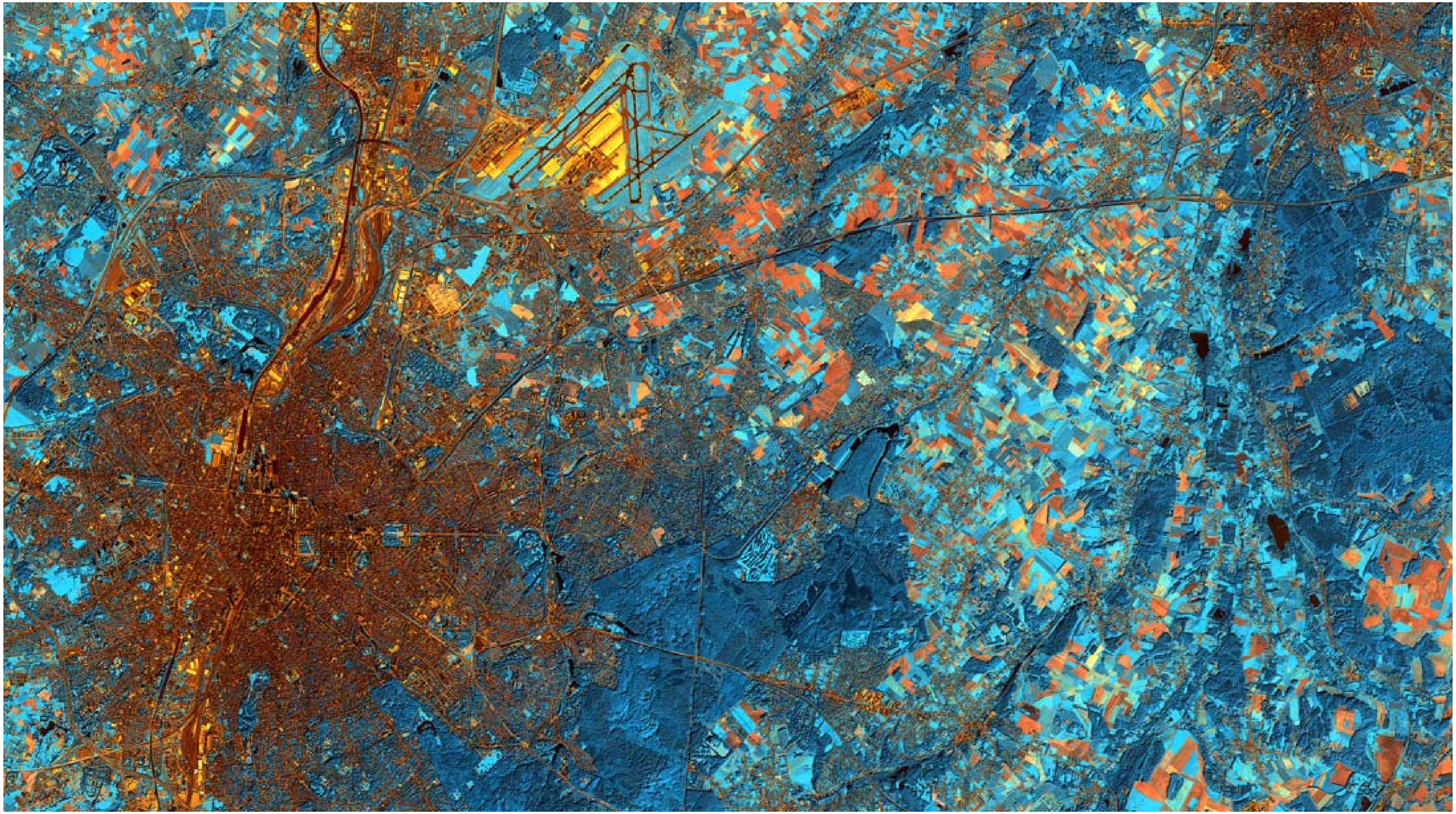


Source: JRC

- **Operational dimension:**
  - ***Land Monitoring:*** information on land use and land cover changes of interest for climate change, water management, biodiversity, agricultural production, urban planning.
  - ***Marine Services:*** delivers information on the state of the coastal and marine environment.
  - ***Atmospheric services:*** monitoring air pollution and climate change variables.
  - ***Crisis Management:*** delivers information important for response to crises and emergencies associated with natural and man made disasters, like floods, fires, earthquakes, landslides, tsunamis, industrial accidents.

http://www.copernicus.eu/

Copernicus Services:
Land Monitoring



BRUSSELS false-colour image from the Spot-5 (28 September 2011)

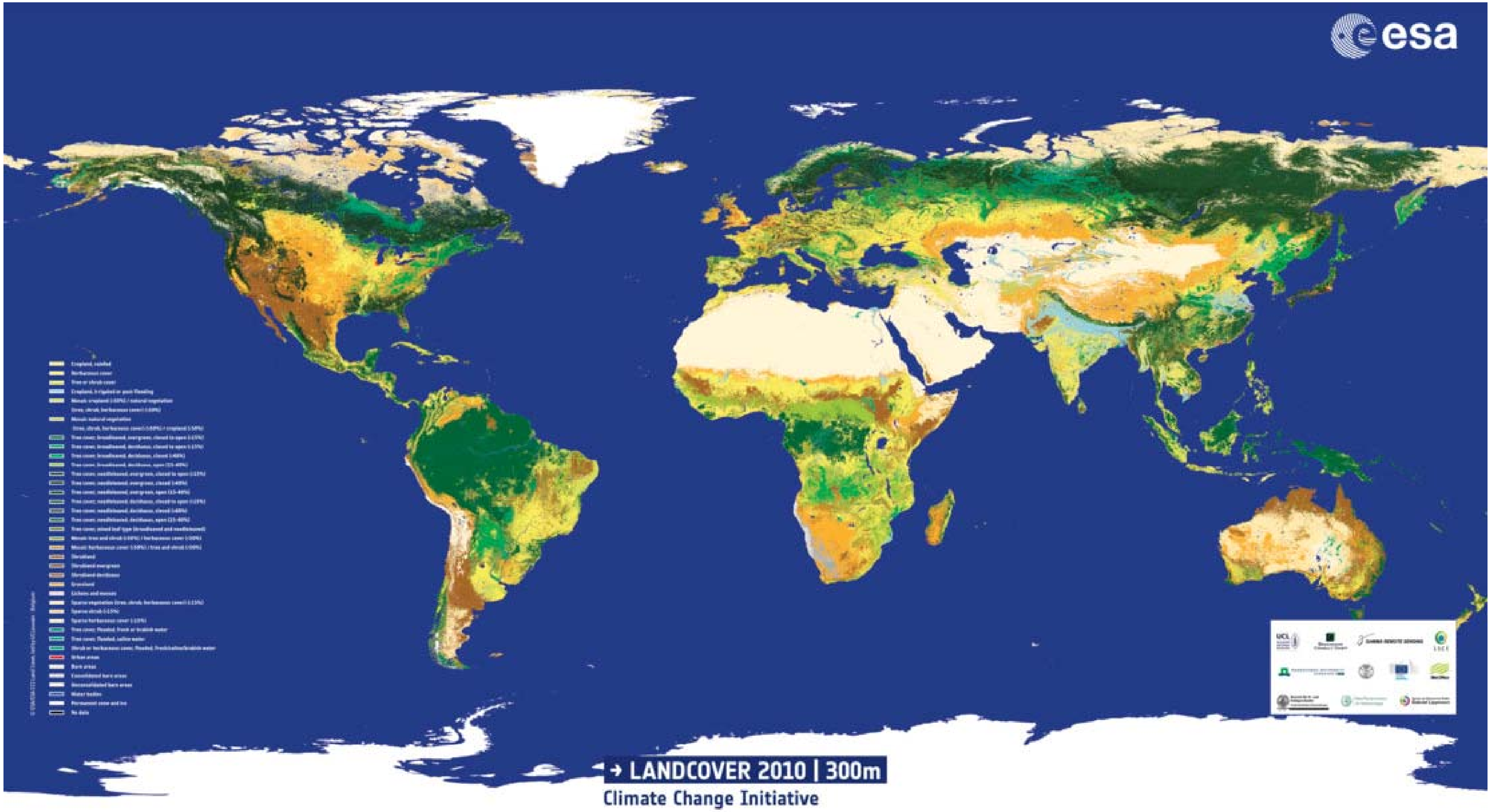
Source: Airbus/ESA 2015

Copernicus Services:
Land Monitoring

Source: ESA 2010

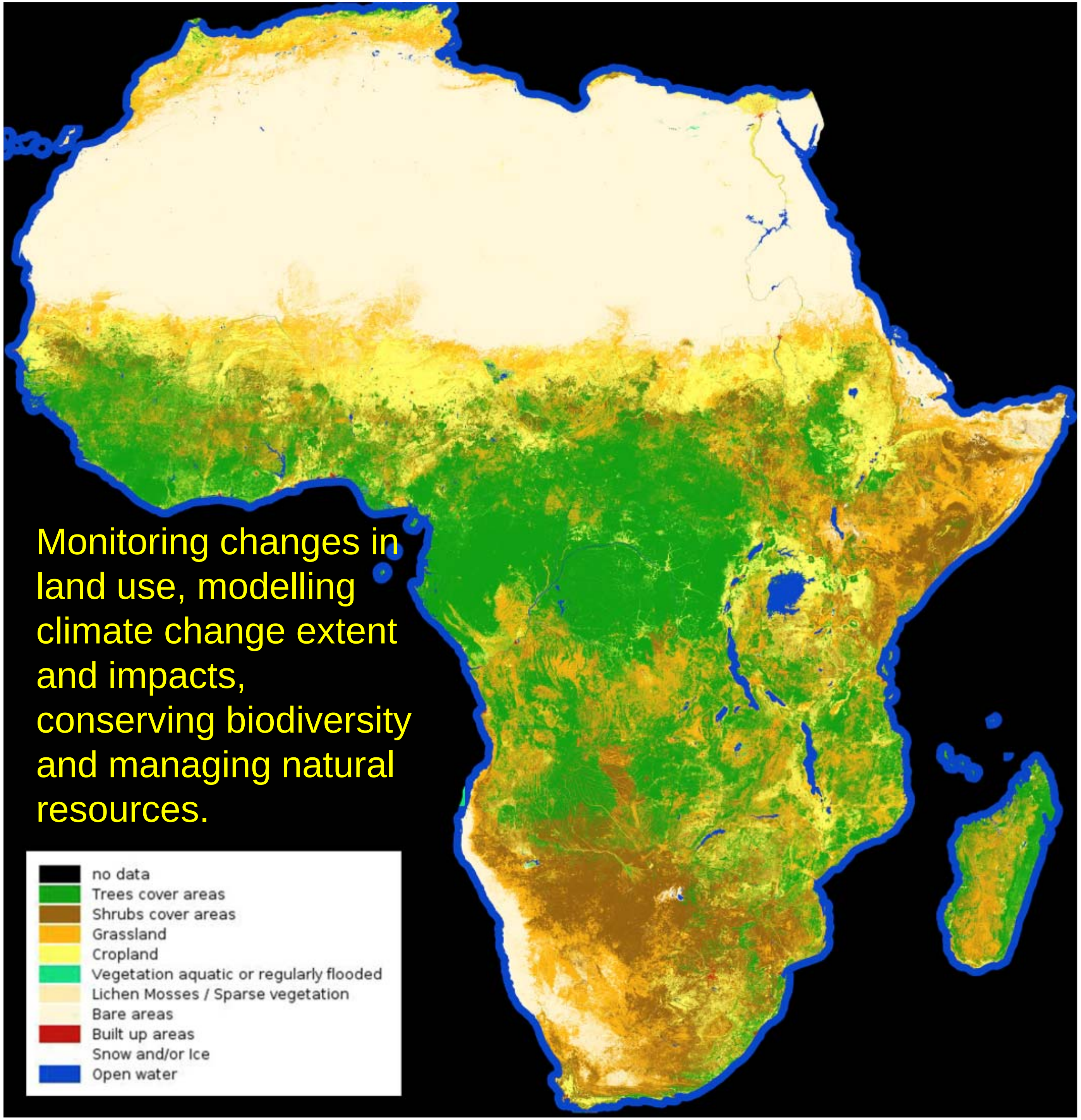
Copernicus Services:
Land Monitoring

Global Land Cover Map 2010



Source: JRC, ESA/CCI Land Cover/Université catholique de Louvain 2014

Copernicus Services:
Land Monitoring

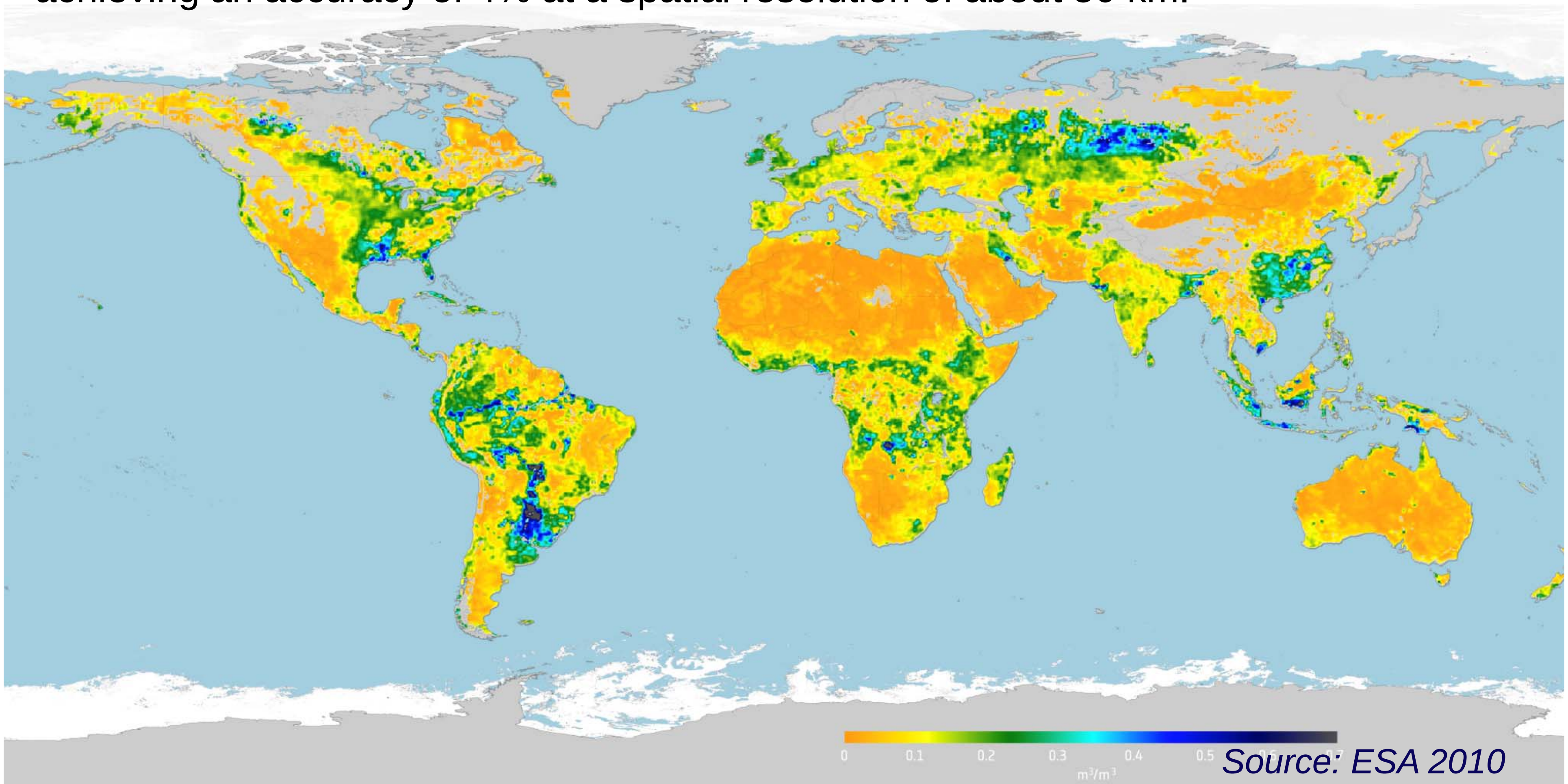


Land cover map of Africa:
Resolution 20m.
Created from180.000 Copernicus Sentinel-2A images captured between December 2015 and December 2016.
Land-cover mapping breaks down the different types of material on Earth's surface.
Important information for sustainable management of Africa.

Source: ESA 2017

Copernicus Services:
Land Monitoring

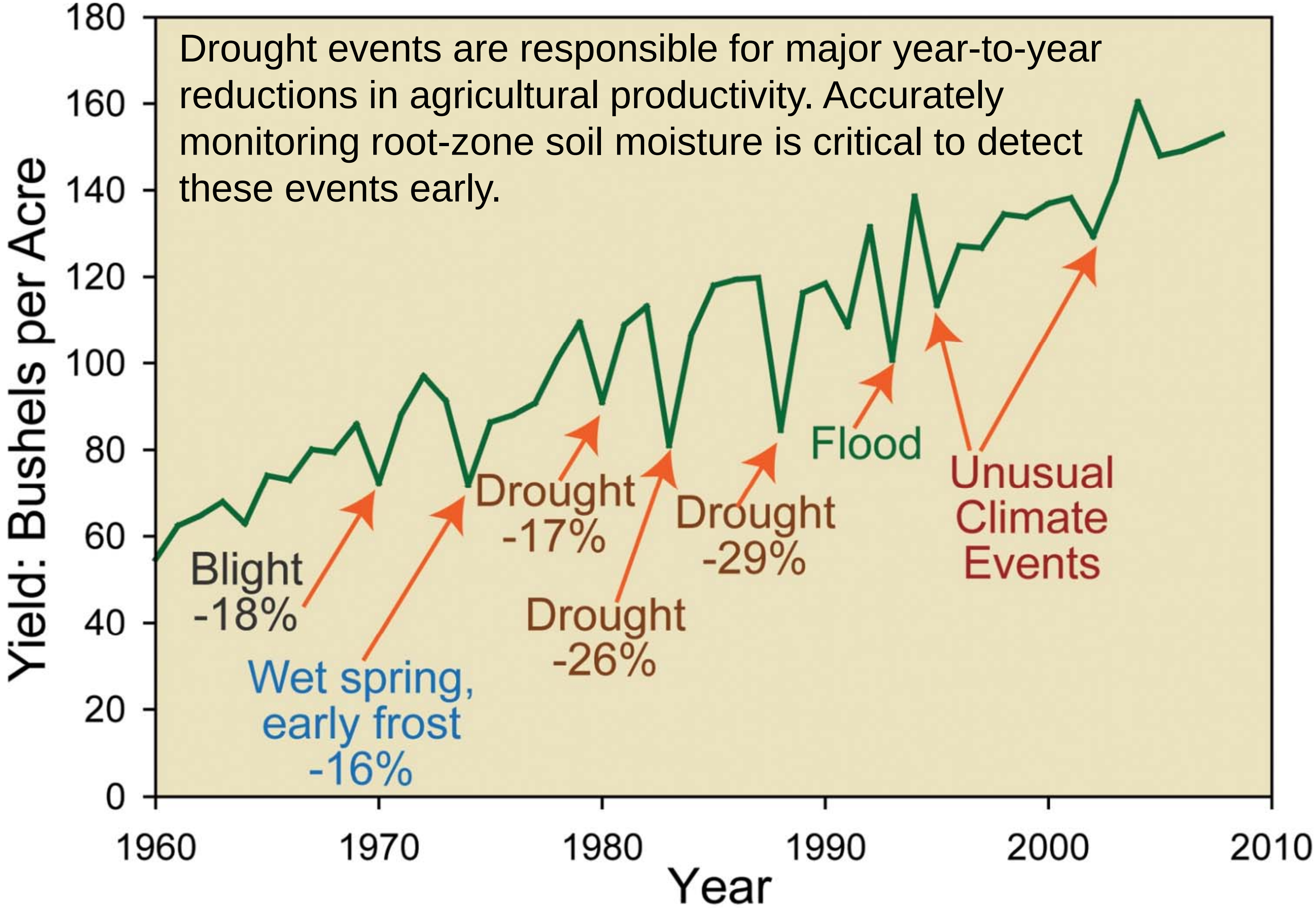
- **Global soil moisture map:**
  - –The ESA-SMOS satellite carries a novel interferometric radiometer that operates in the L-band microwave range to capture 'brightness temperature' images.
  - –These images are used to derive global maps of soil moisture every three days, achieving an accuracy of 4% at a spatial resolution of about 50 km.



Source: ESA 2010

Copernicus Services:
Land Monitoring

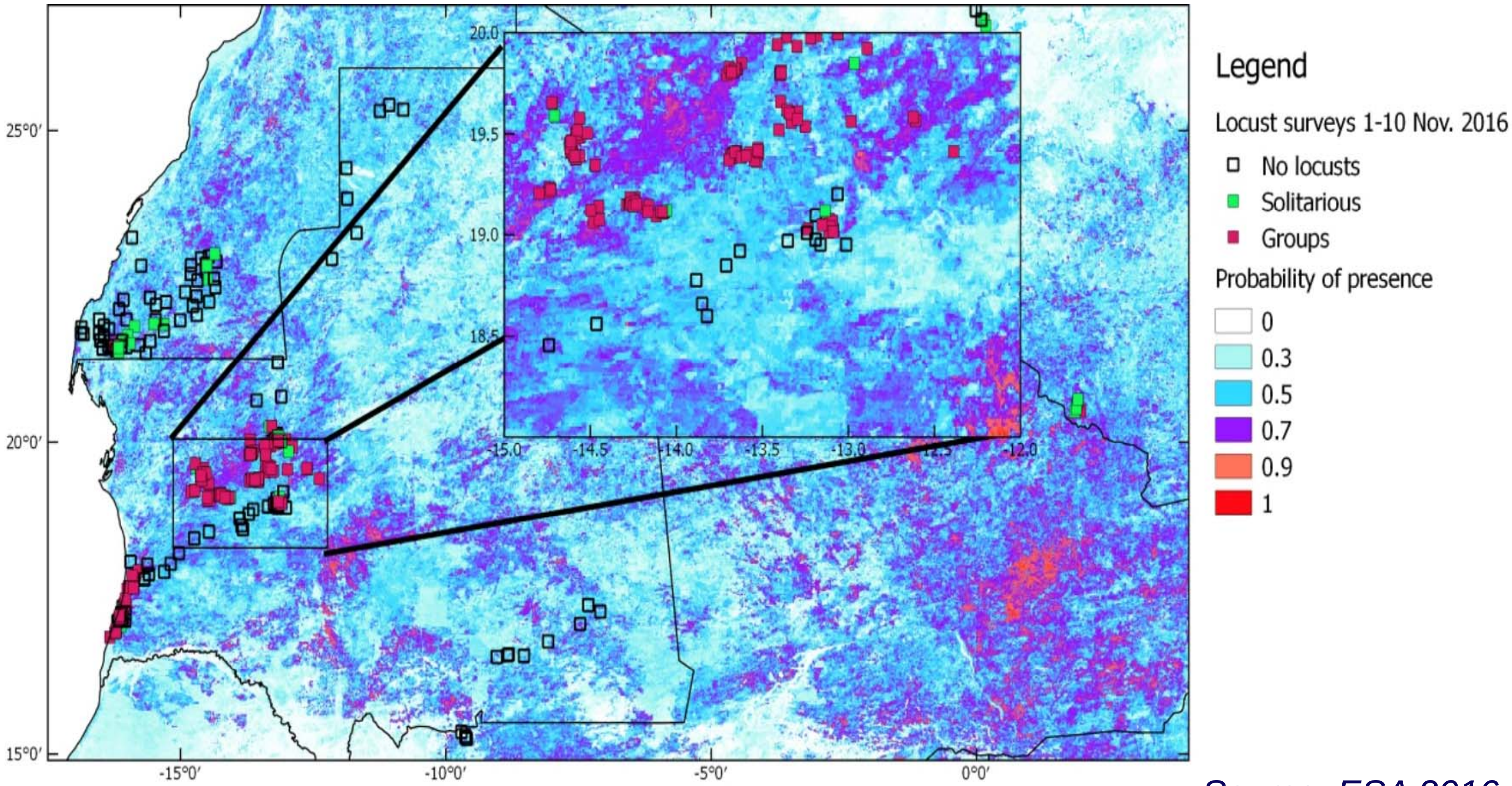
Impact of soil moisture on agricultural yields (USA):



Source: USGCRP NAST 2009

Copernicus Services:
Land Monitoring

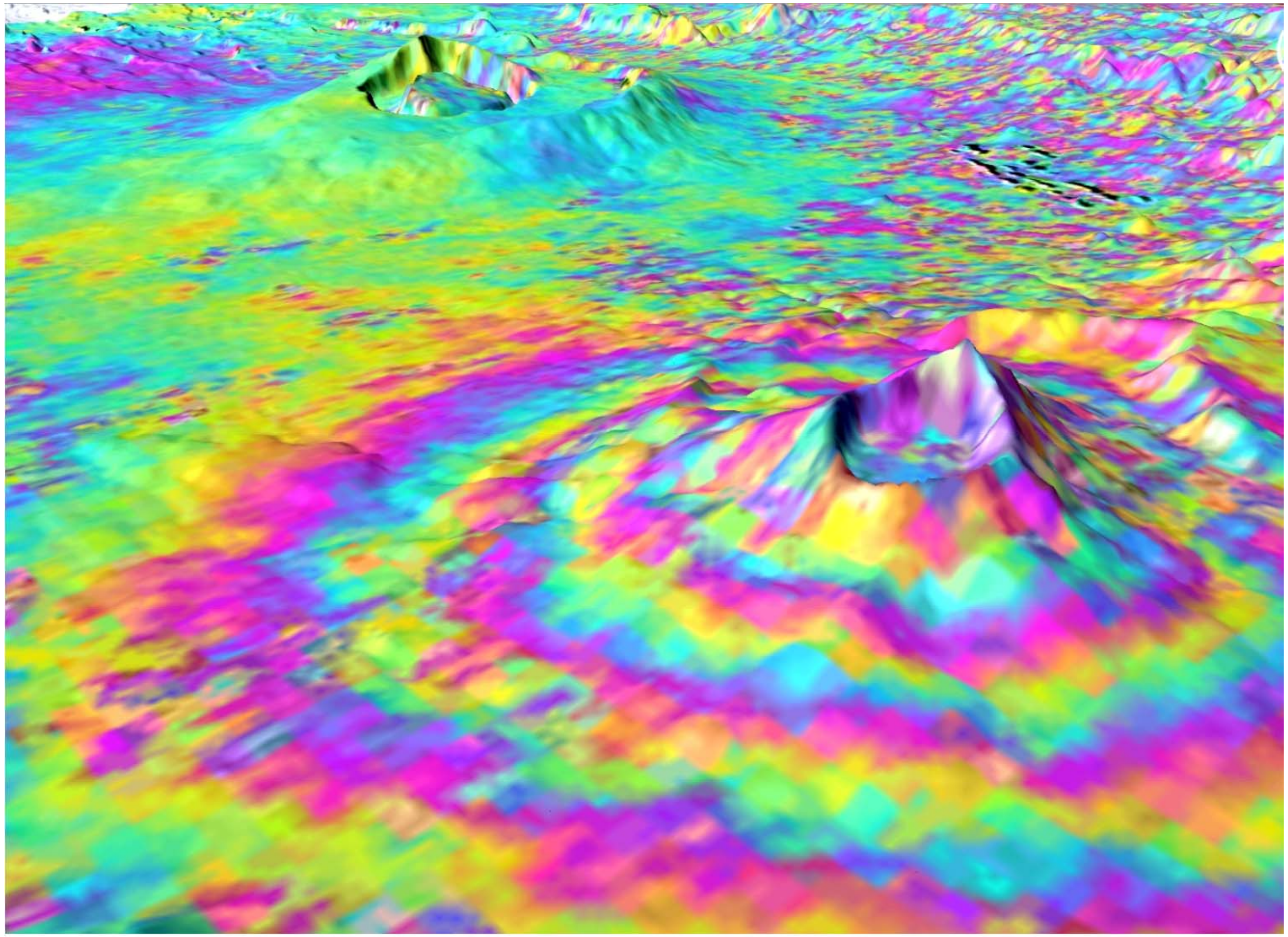
Identification of favourable areas for locust swarming (Africa):
Soil moisture data from the SMOS satellite were used to create this map showing areas with favourable locust swarming conditions (in red) during the November 2016 outbreak.



Source: ESA 2016

Copernicus Services:
Land Monitoring

Monitoring volcanic activities before eruptions (Kenya):
Envisat Advanced Synthetic Aperture Radar interferogram over the Kenyan section of the Great Rift Valley shows small surface displacements of the Longonot Volcano that are not visible to the naked eye (front right).

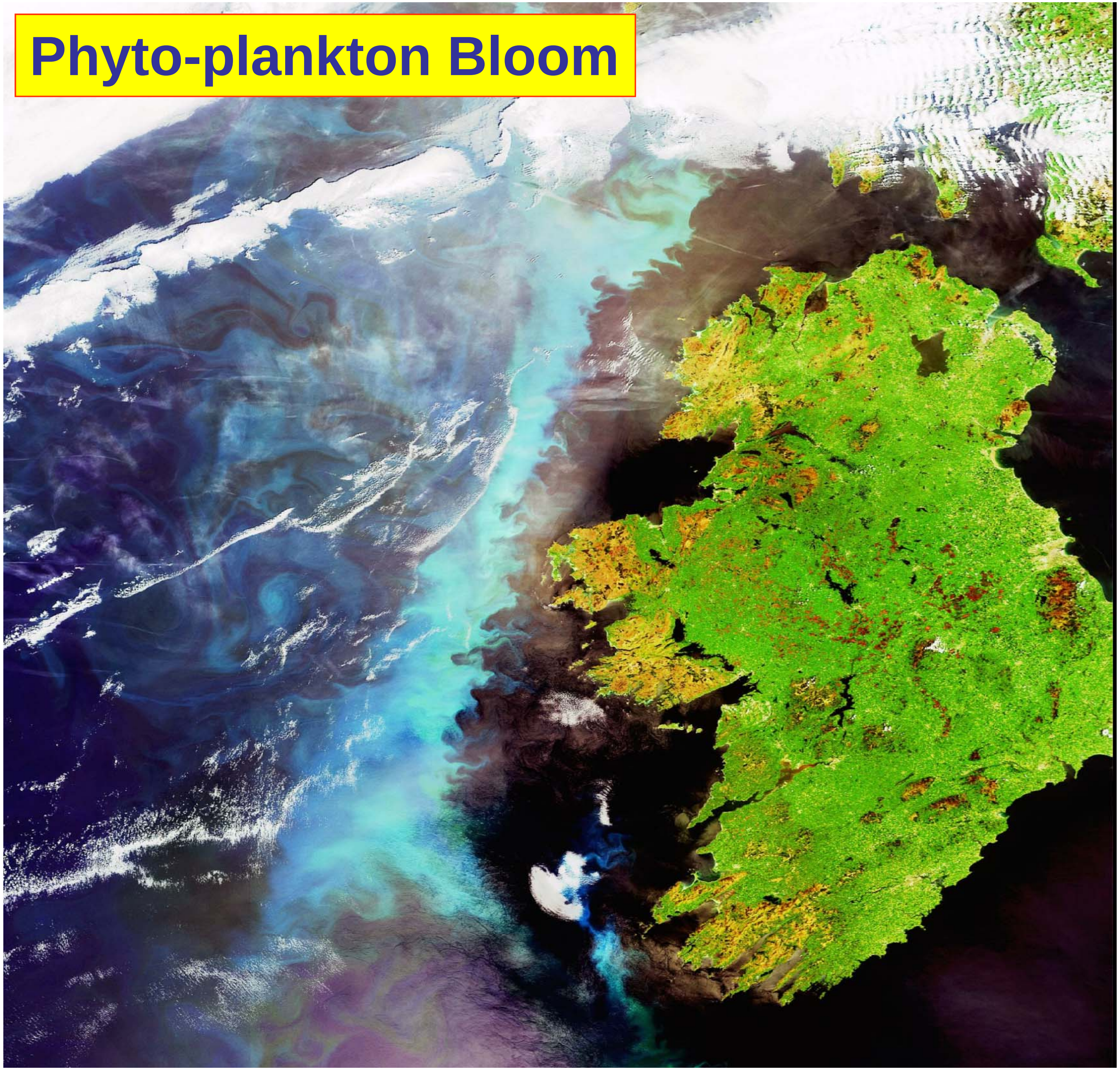


From 1997 – 2000 the Longonot Volcano experienced an uplift of around 9 cm. Interferogram images appear as rainbow-coloured interference patterns.

The Suswa volcano in the background was stable.

Source: ESA 2010

Phyto-plankton Bloom



Copernicus Services:

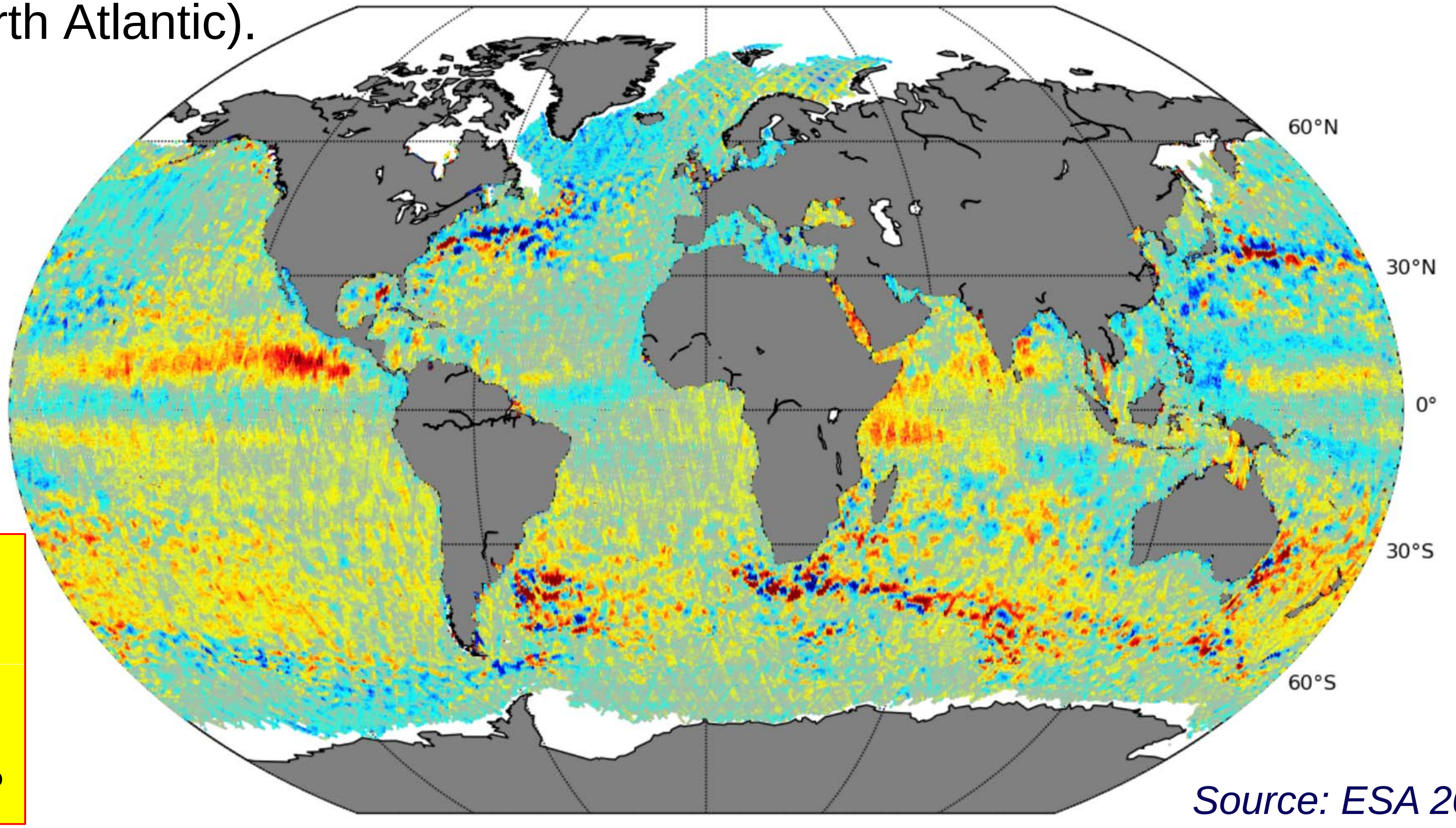
Marine Monitoring

A large aquamarine-coloured plankton bloom is shown stretching across the length of Ireland in the North Atlantic Ocean in this Envisat image.

Source: ESA 2006

Copernicus Services:
Marine Monitoring

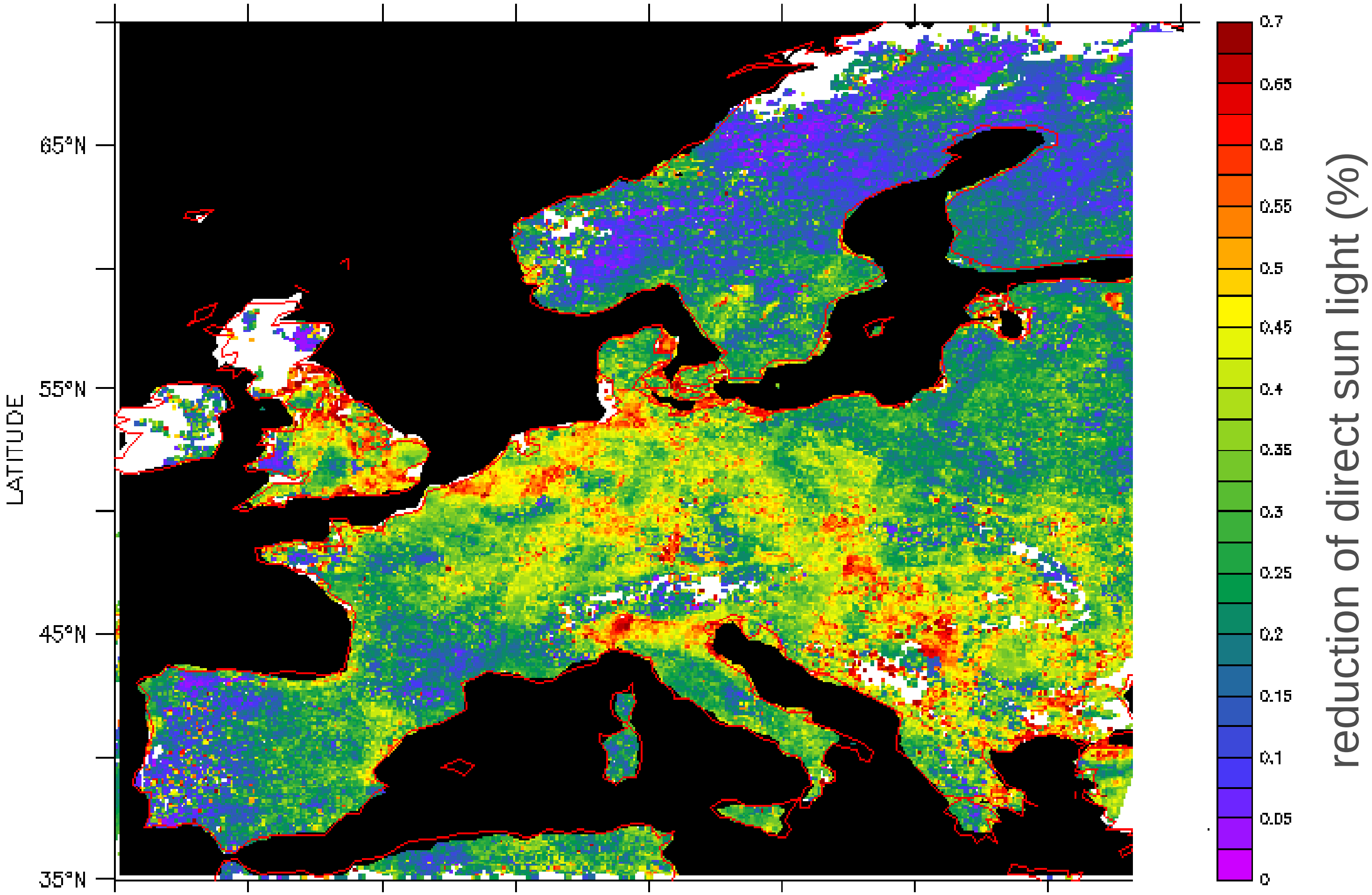
Measurement of sea level with Sentinel-3's altimeter:
Using local sea-level variations measured by and comparing them to a reference level, major ocean currents can be computed and mapped. Mesoscale local hills and valleys can be observed in the sea surface (e.g. associated with the strong western boundary currents of the Gulf Stream in the North Atlantic).



Global warming: impact on ocean currents?

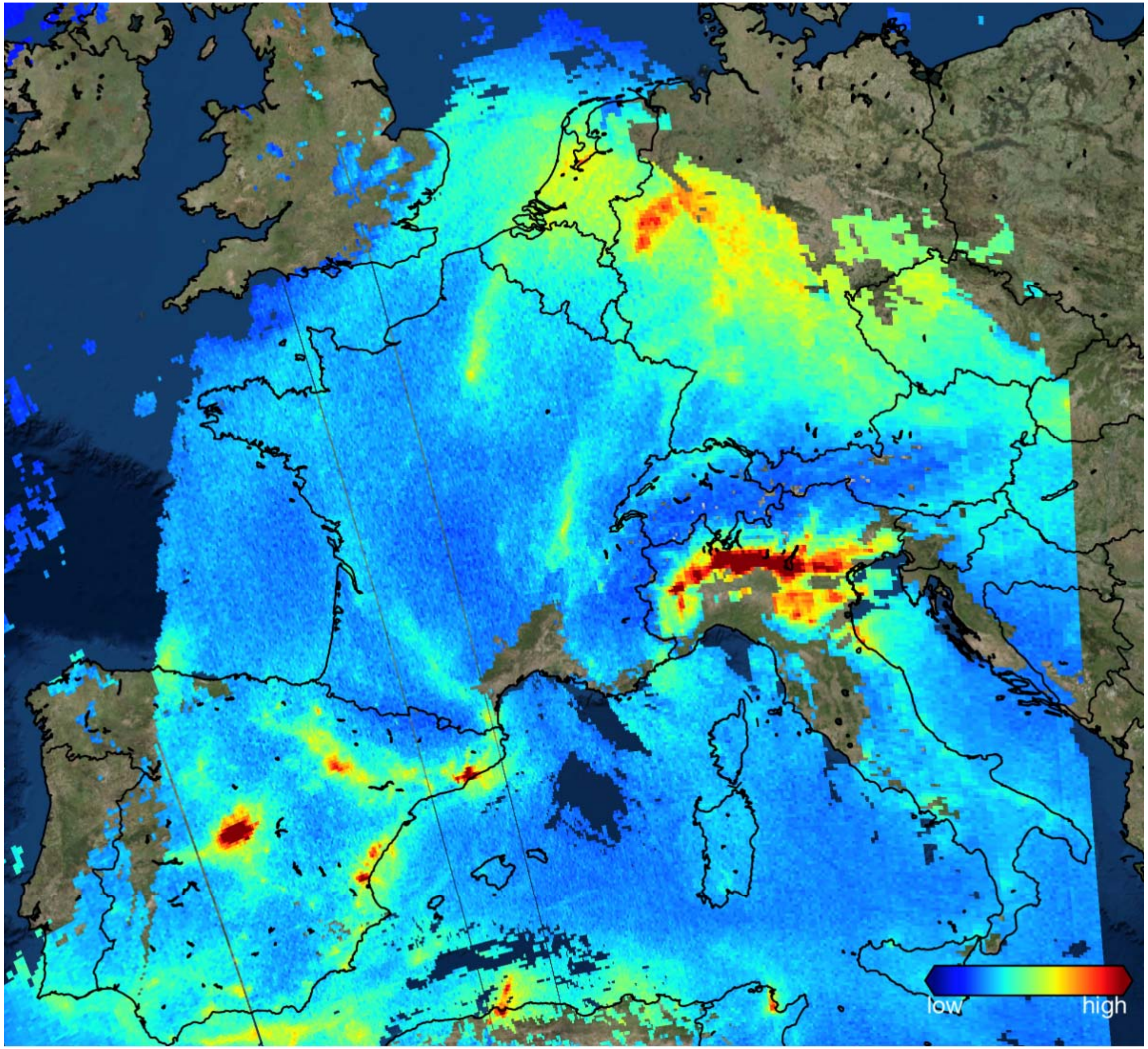
Source: ESA 2016

Copernicus Services:
Atmospheric Monitoring



Measurement of particulate matter from space. Monthly composite map of aerosol optical depth (August 1997). *Source: JRC-IES/TNO-FEL*

Copernicus Services:
Atmospheric Monitoring



Nitrogen dioxide over Europe:

Sentinel-5P measurements April 2018 (averaged).

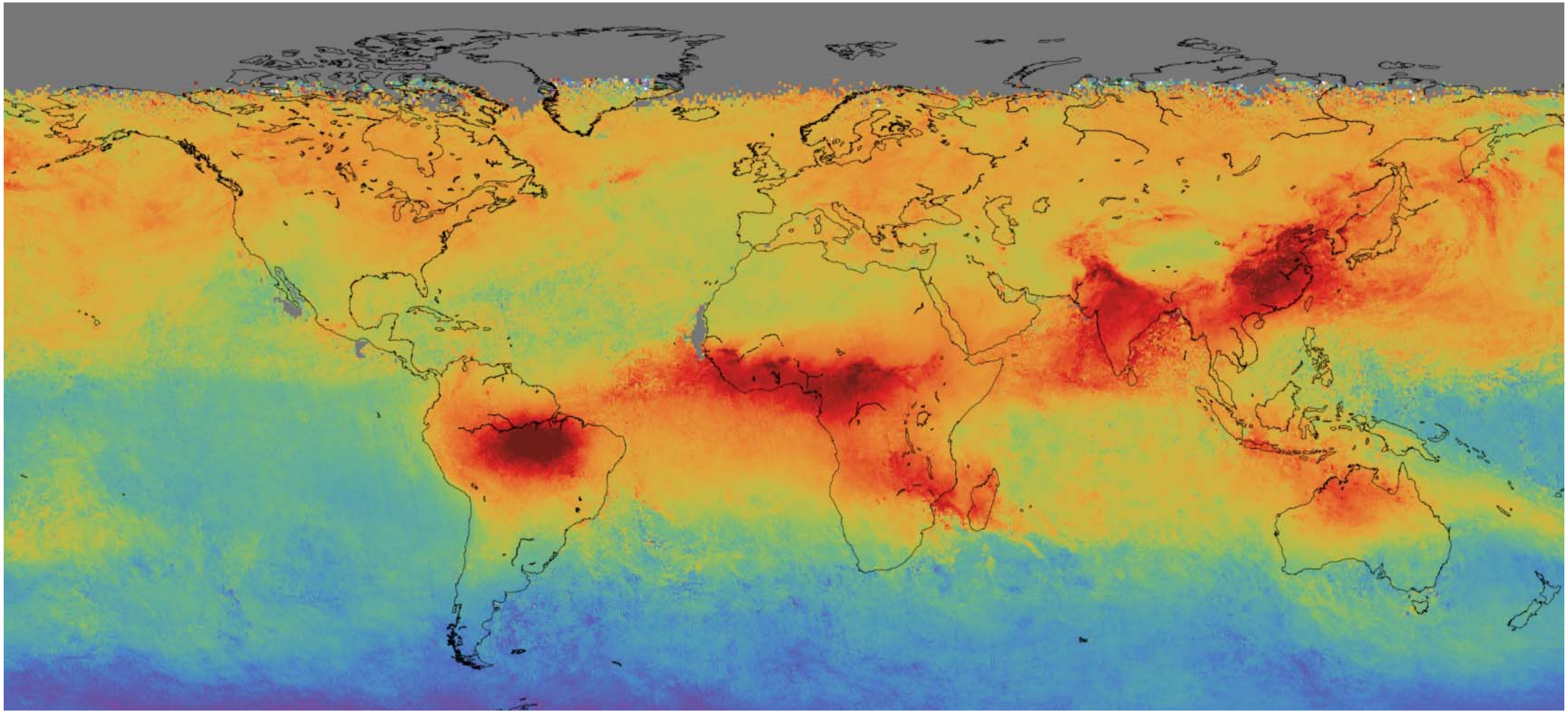
Air pollution emitted by big cities and shipping lanes is clearly visible.

With a resolution of up to 7 x 3.5 km, Sentinel-5P's Tropomi instrument can detect air pollution over individual cities.

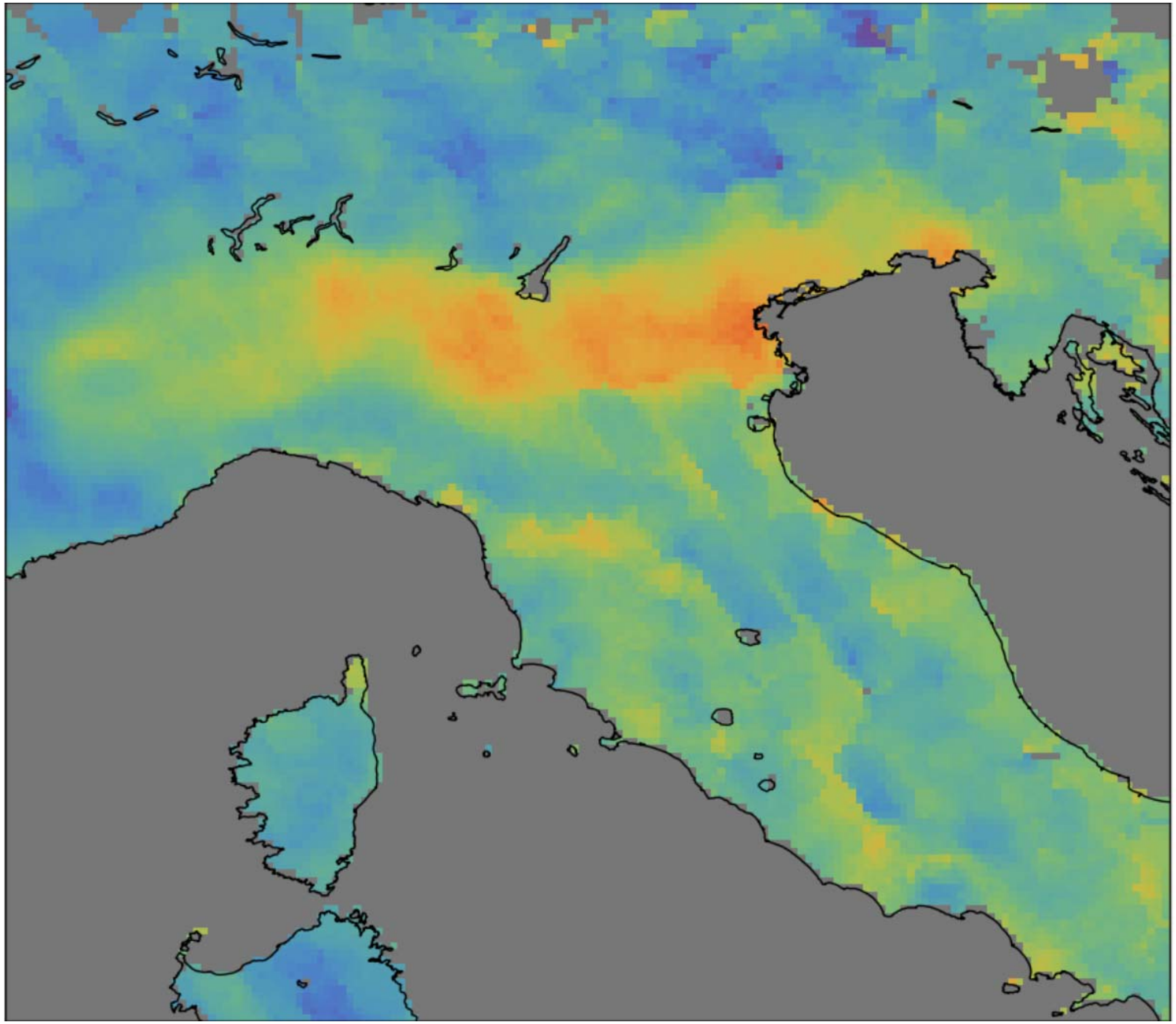
Source: ESA 2018

Copernicus Services:
Atmospheric Monitoring

Global carbon monoxide map (2017):
Copernicus Sentinel-5P satellite.
Image shows high levels of CO over parts of Asia, Africa and South America.
The mission has a swath width of 2600 km, which allows the whole planet to be mapped every 24 hours.



Copernicus Services:
Atmospheric Monitoring



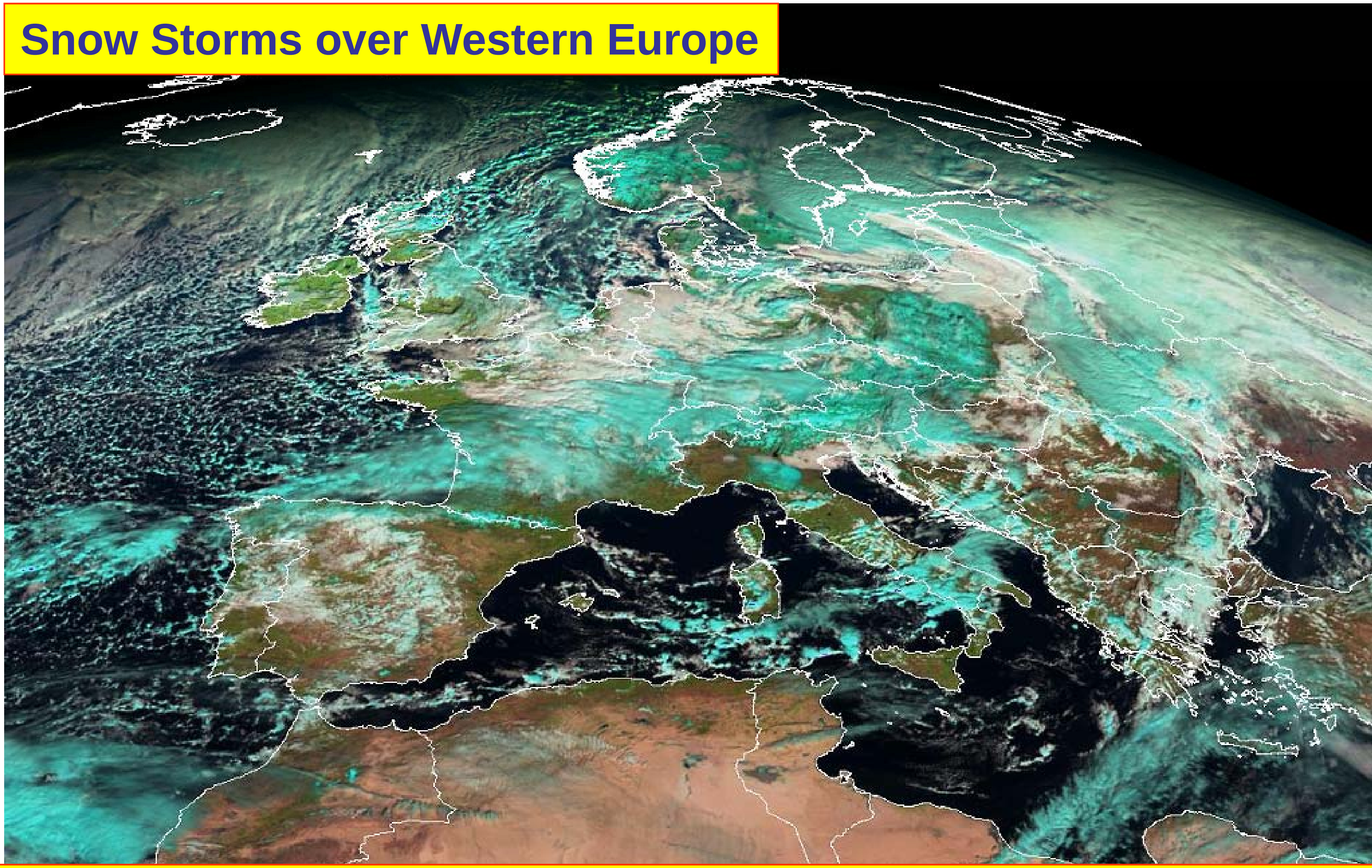
Carbon monoxide over Northern Italy (2017):

Copernicus Sentinel-5P satellite image shows high levels of CO over the Po valley and the industrial zones of Mestre and Trieste.
Main sources of CO are traffic and industrial activities.

Source: ESA 2017

Copernicus Services:
Crisis Management

Snow Storms over Western Europe

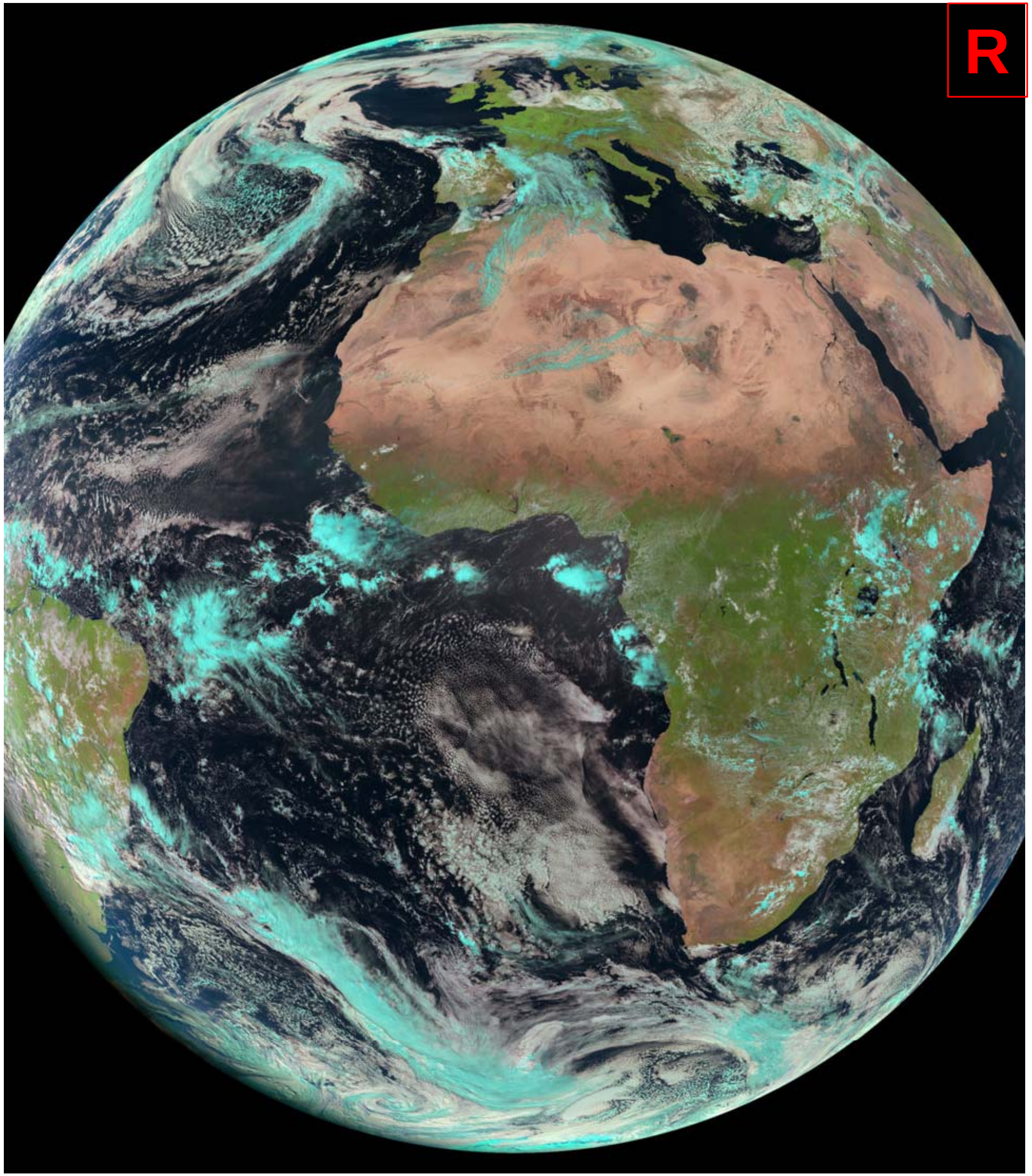


Severe winter weather swept over parts of Europe paralyzing public transport and roadways and cutting electricity for 250.000 people. *Source: Meteosat November 2005*

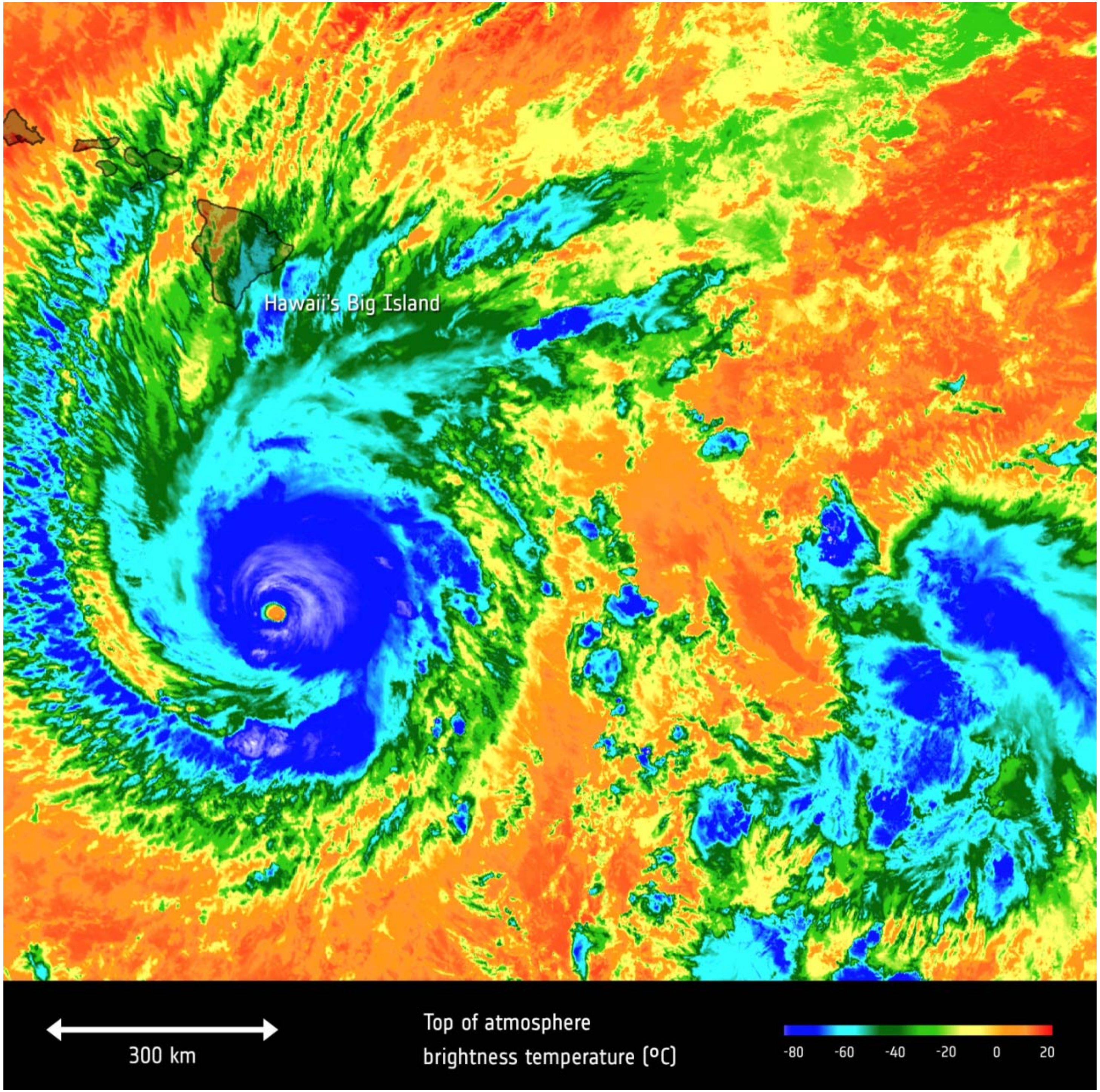
Copernicus Services:
Crisis Management

Global weather observation:

This full-disc image of Earth was acquired by the Spinning Enhanced Visible and Infrared Imager (SEVIRI) instrument on MSG-3 (now Meteosat-10 in operation) on 22 April 2015.



Source: ESA/EUMETSAT 2015



Copernicus Services:

Extreme Weather Events

Hurricane Lane near Hawai Aug. 2018

Radiative temperature at 15 km altitude:

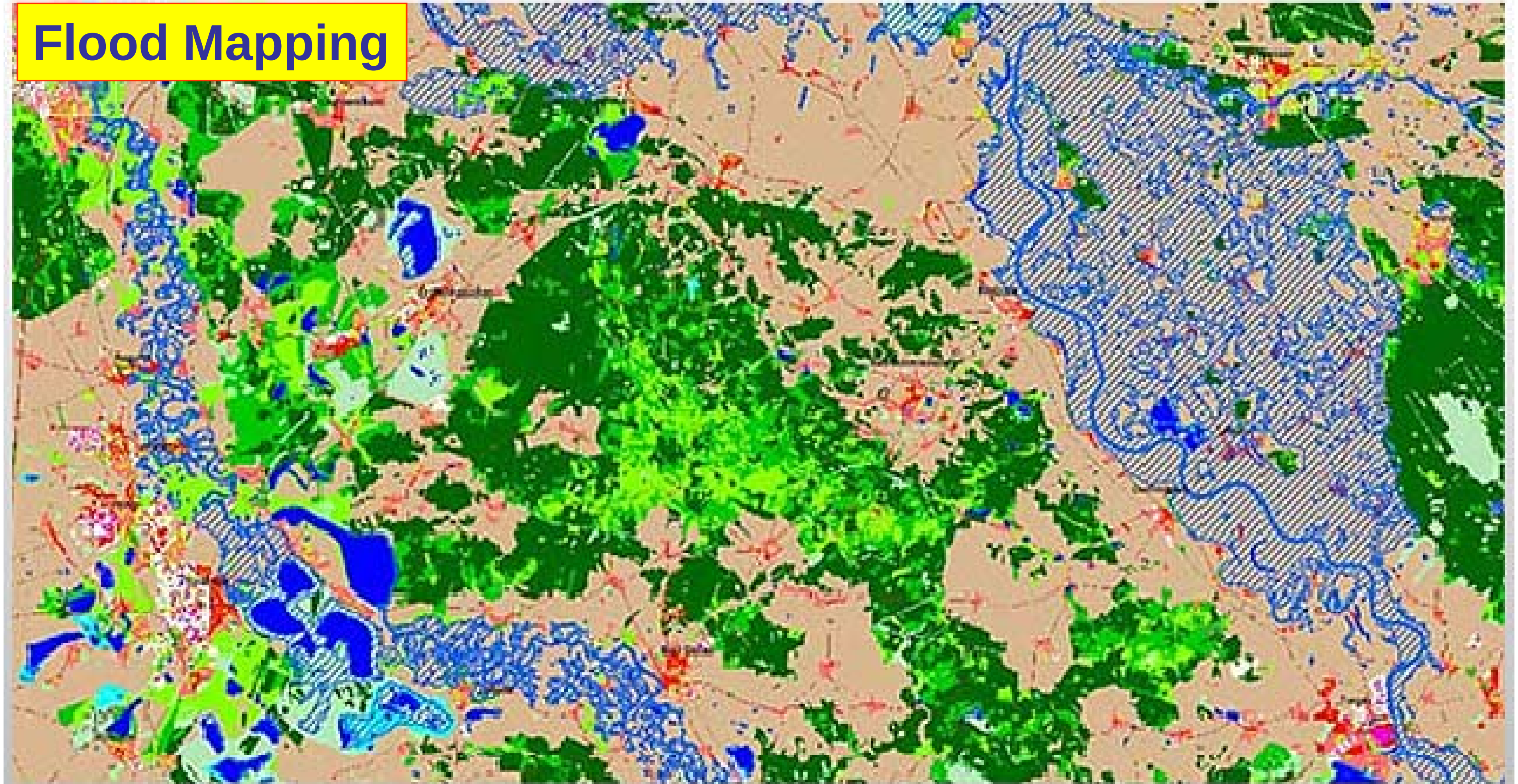
blue: -80°C

orange: + 15°C

Source: ESA 2018

Copernicus Services:
Crisis Management

Flood Mapping

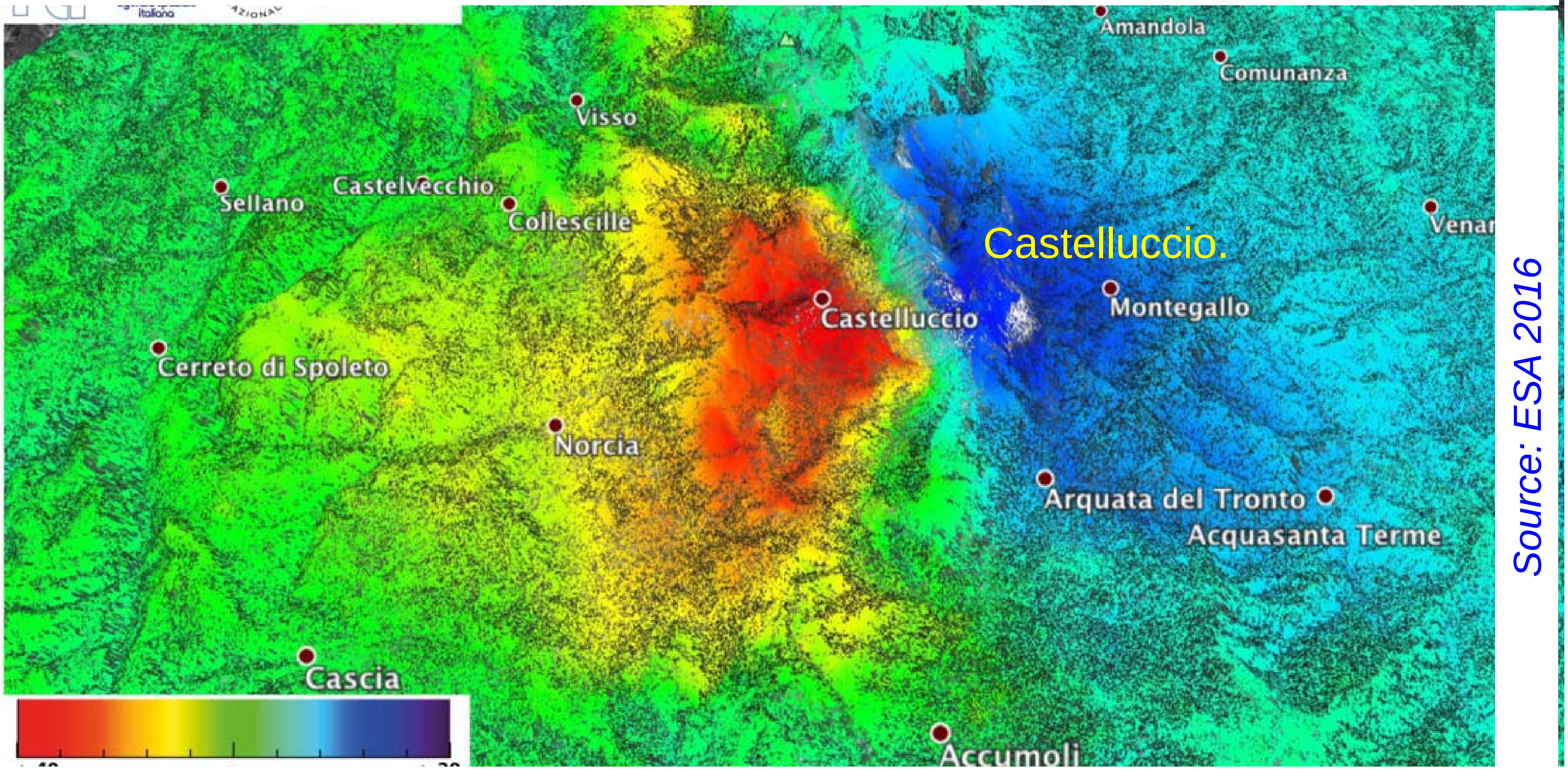


Past Floods Events Map, Elbe Flooding 2002

Source: Meteosat August 2002

Copernicus Services:
Crisis Management

EARTHQUAKE in ITALY 30 OCTOBER 2016 (magnitude 6,5)



Source: ESA 2016

The results show ground deformations extending across about 130 km^2 with a maximum displacement of about 70 cm (in the direction of the satellite).

Copernicus Services: Crisis Management

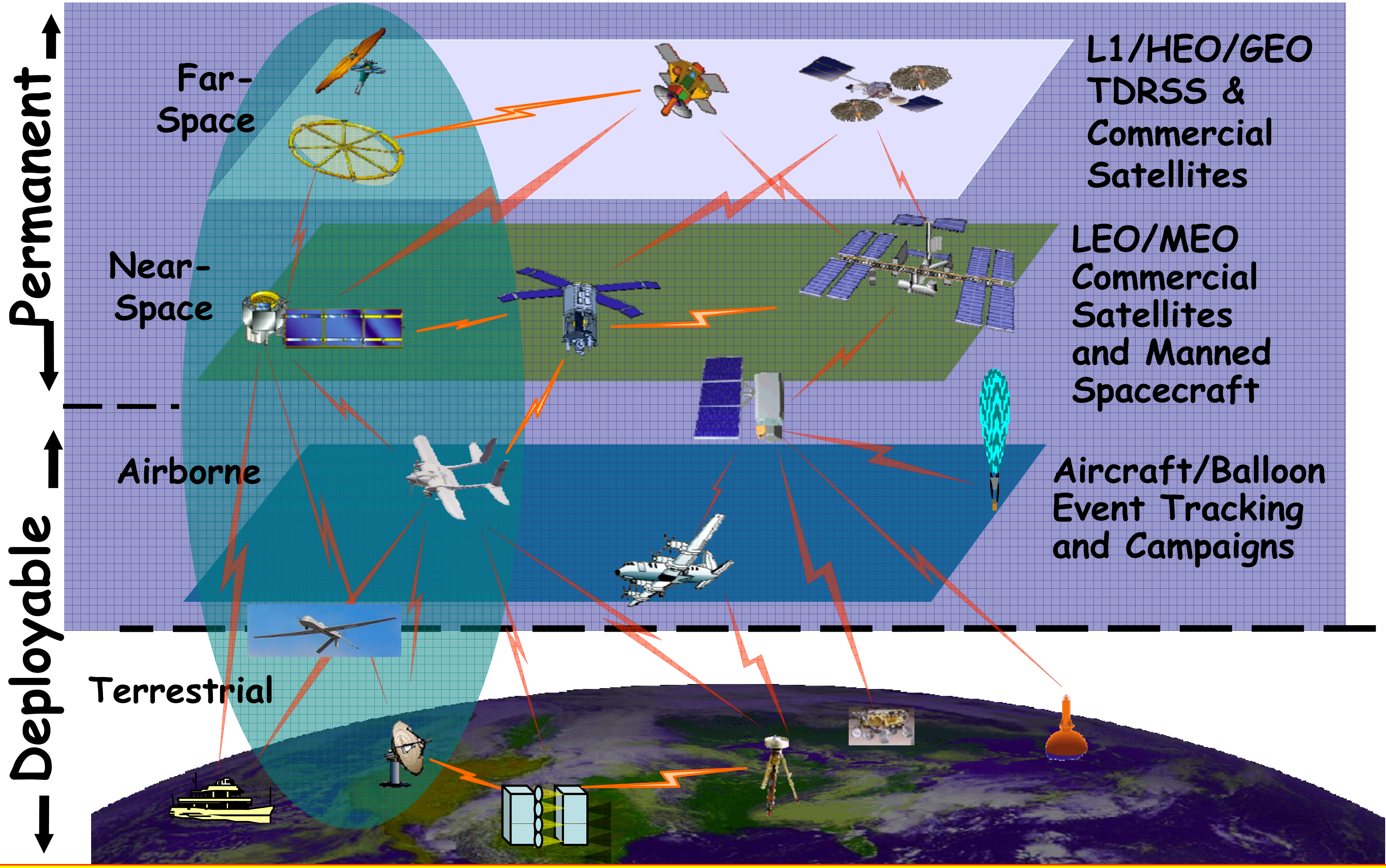
During the Rohingya crisis in Myanmar at least 288 villages were partially or totally destroyed by fire in northern Rakhine state after August 2017.
The imagery also shows that nearby ethnic Rakhine villages were left intact.

Satellite images show destroyed Rohingya village

Source: Human Rights Watch, Satellite image 21 September 2017

Source: BBC 2018

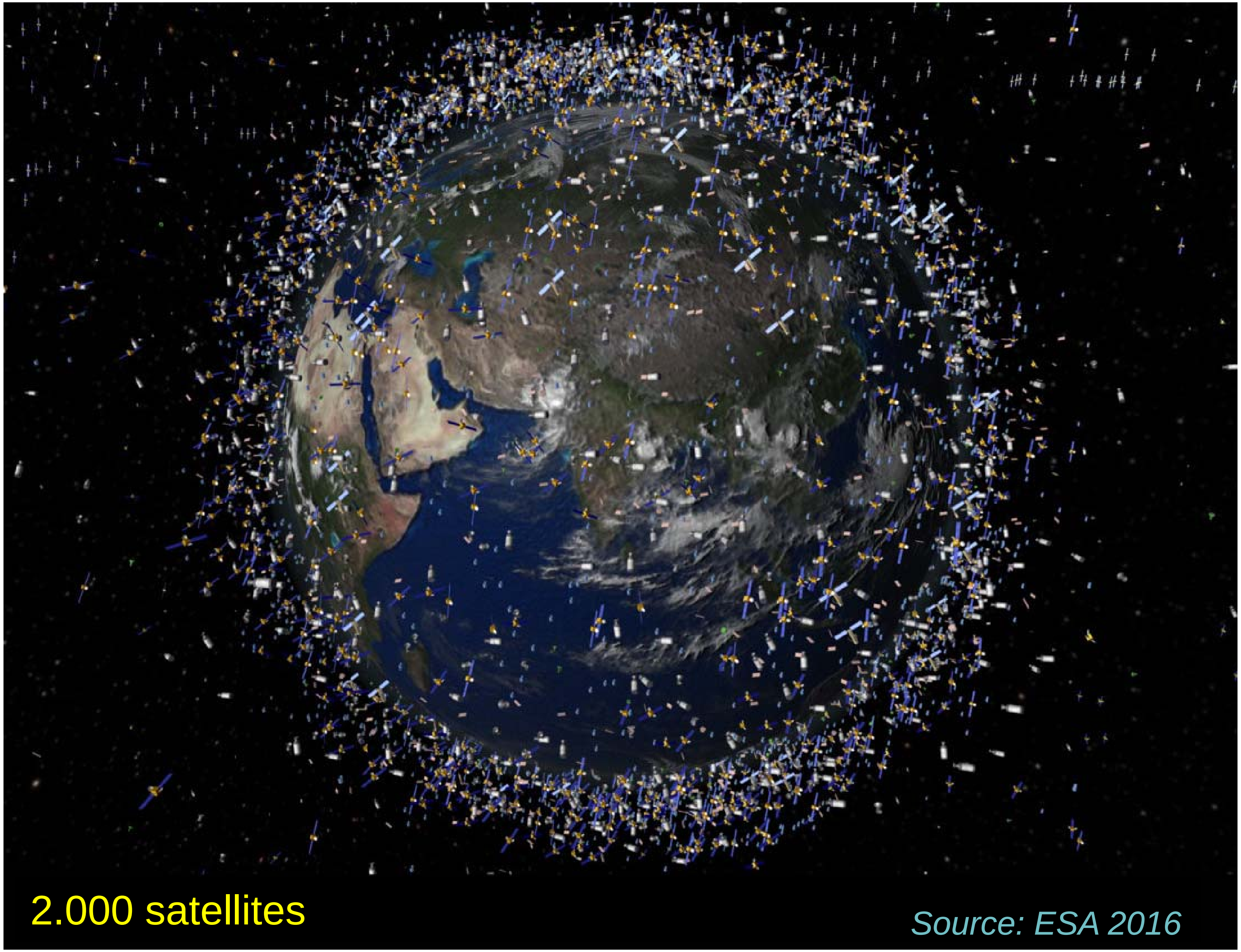
Global Earth Observation:
GEOSS



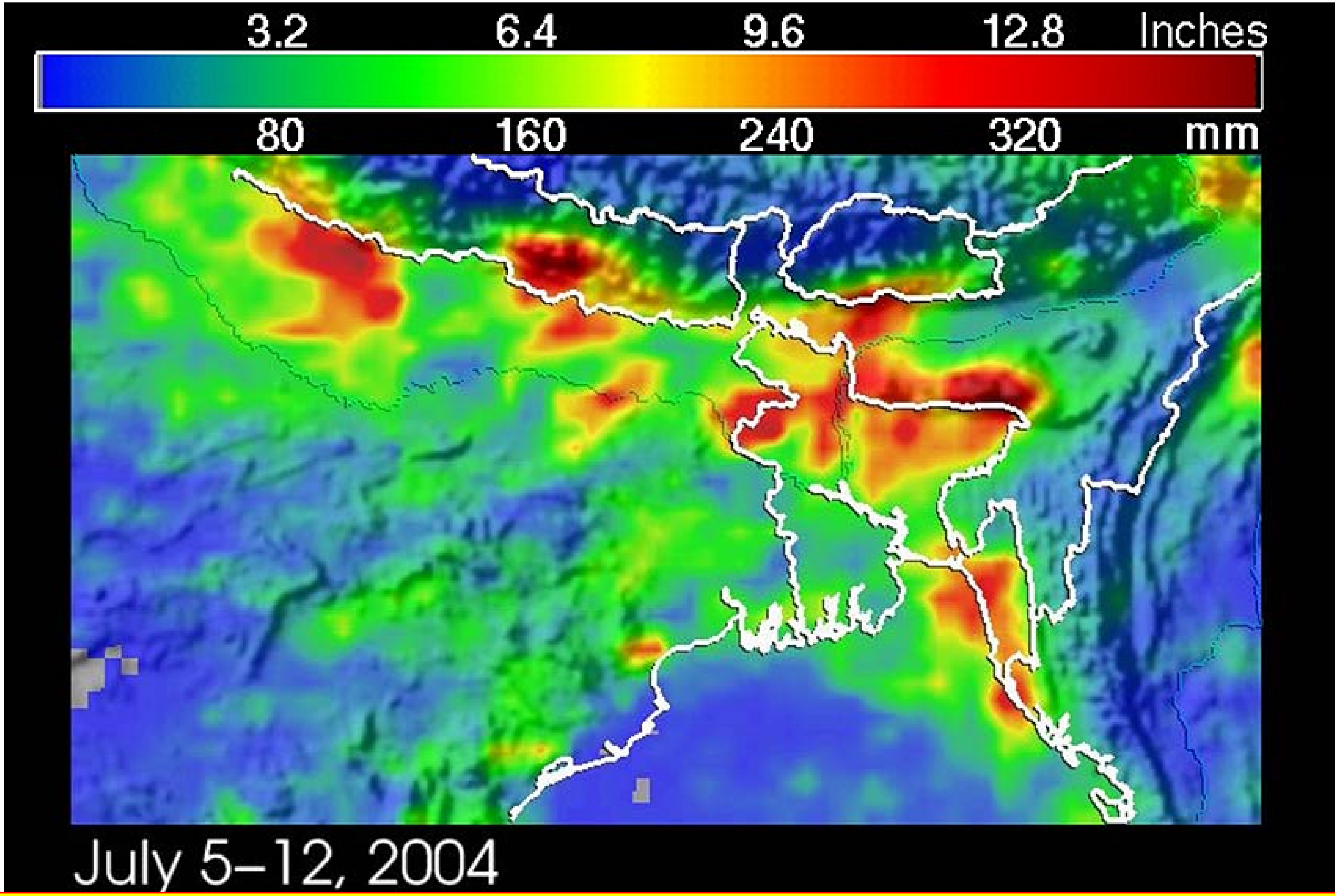
GEOSS: Global Earth Observation System of Systems
(USA, EU, Japan, China, India, Brazil, South Africa, Korea……). *Source: NASA*

Global Earth Observation:
GEOSS

R



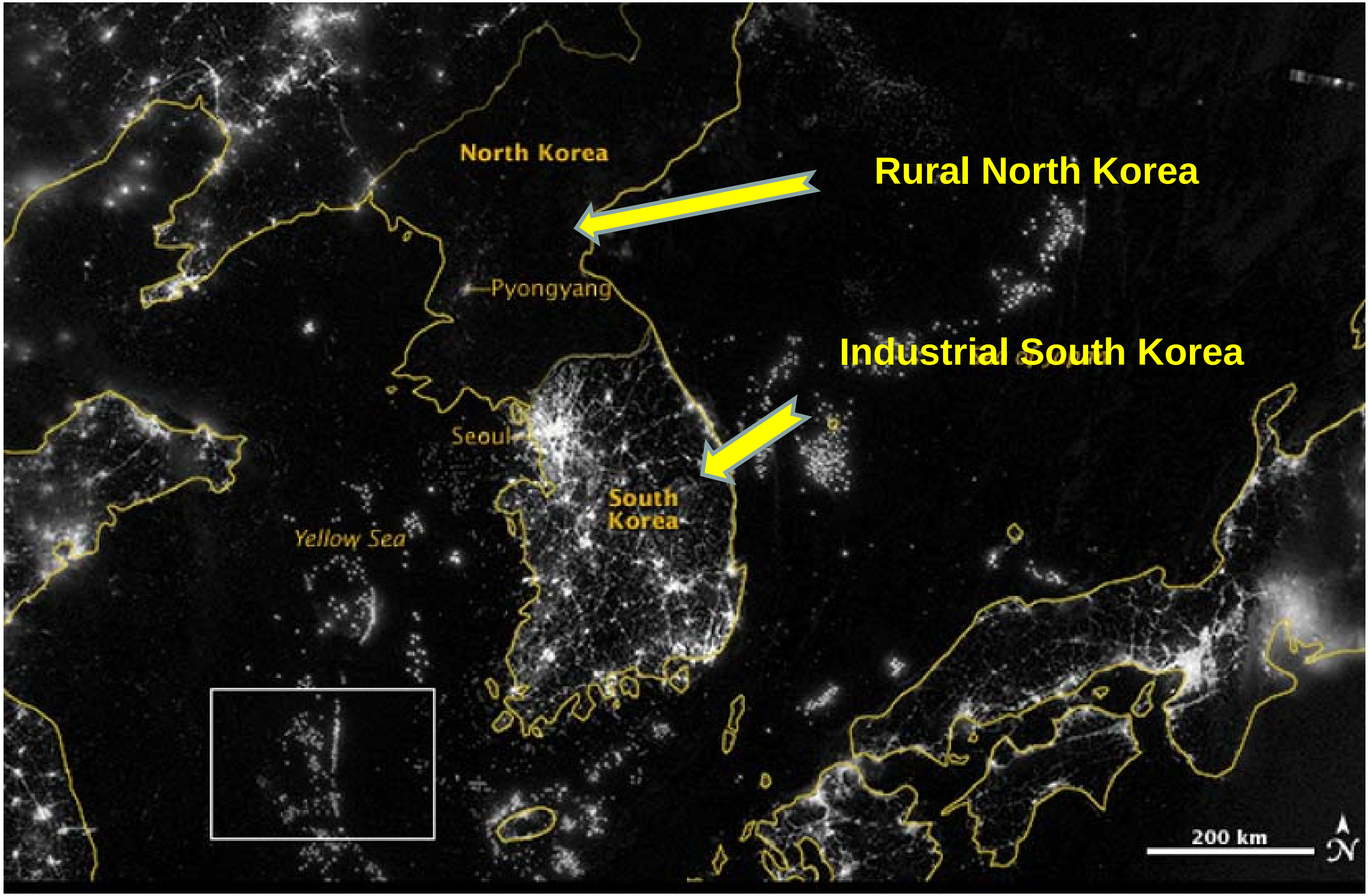
Monitoring Tropical Rainfalls



Source: NASA 2012

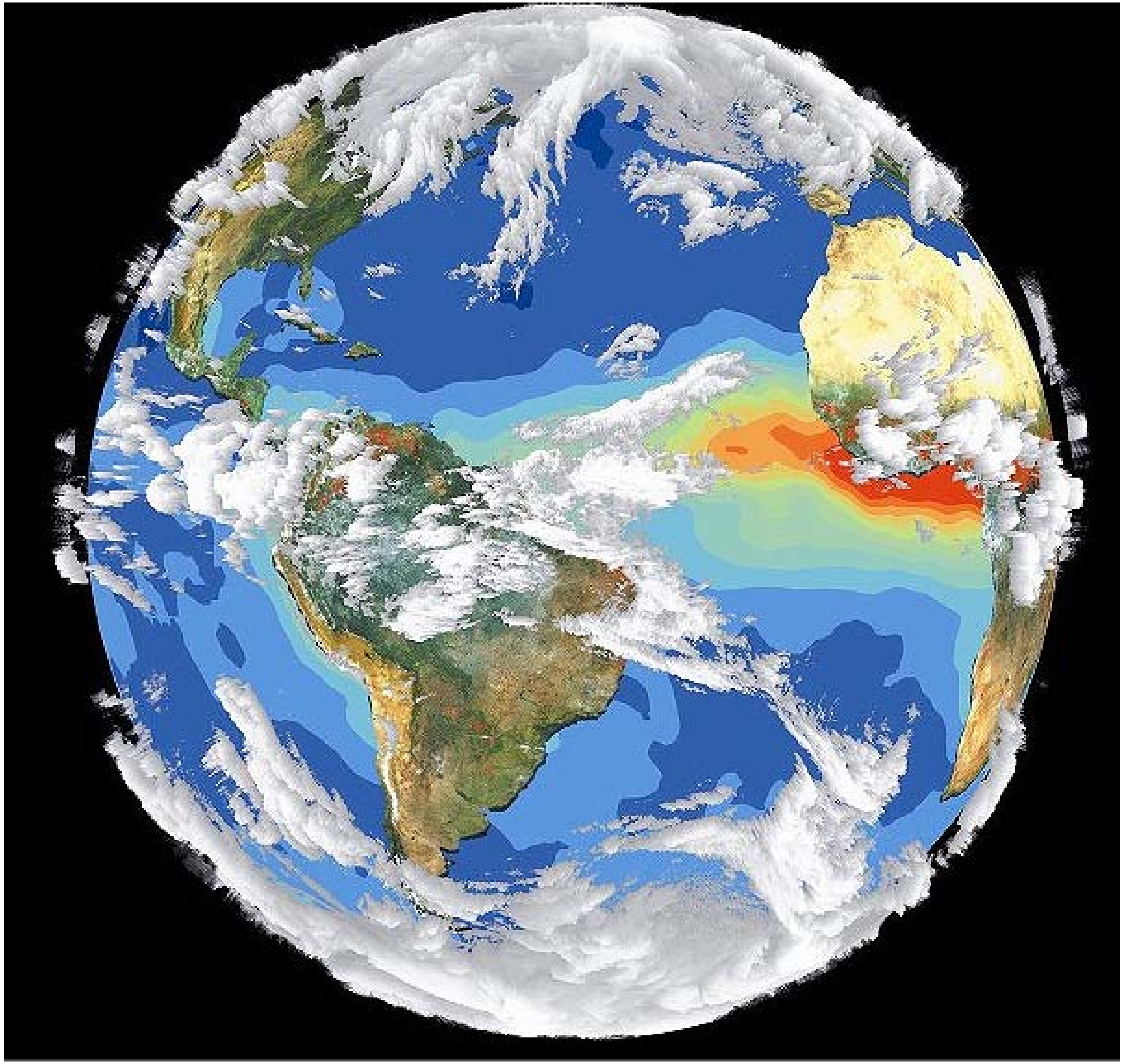
Tropical Rainfall Measuring Mission satellite (TRMM – NASA/Japanese space agency JAXA) monitored heavy rainfalls occurred along southern Nepal, northern India and northern and southeastern Bangladesh leading to widespread flooding.

GEOSS Services:
Activity Monitoring



Source: NASA 2012, http://earthobservatory.nasa.gov

Earth's Interrelated Systems and Climate



Composite image taken from 6 different satellites:

•Land image in true color from SeaWiFS of NASA.

•Oceanic aerosol caused by biomass burning and windblown dust over Africa by NOAA.

•Clouds from infrared images from four geostationary weather satellites (NOAA's GOES 8 and 9, the ESA’s METEOSAT, and Japan's GMS 5).

Source: NASA 2012


Thank you for your interest in this subject !