The Overall Impact of Climate Change on Renewable Energy

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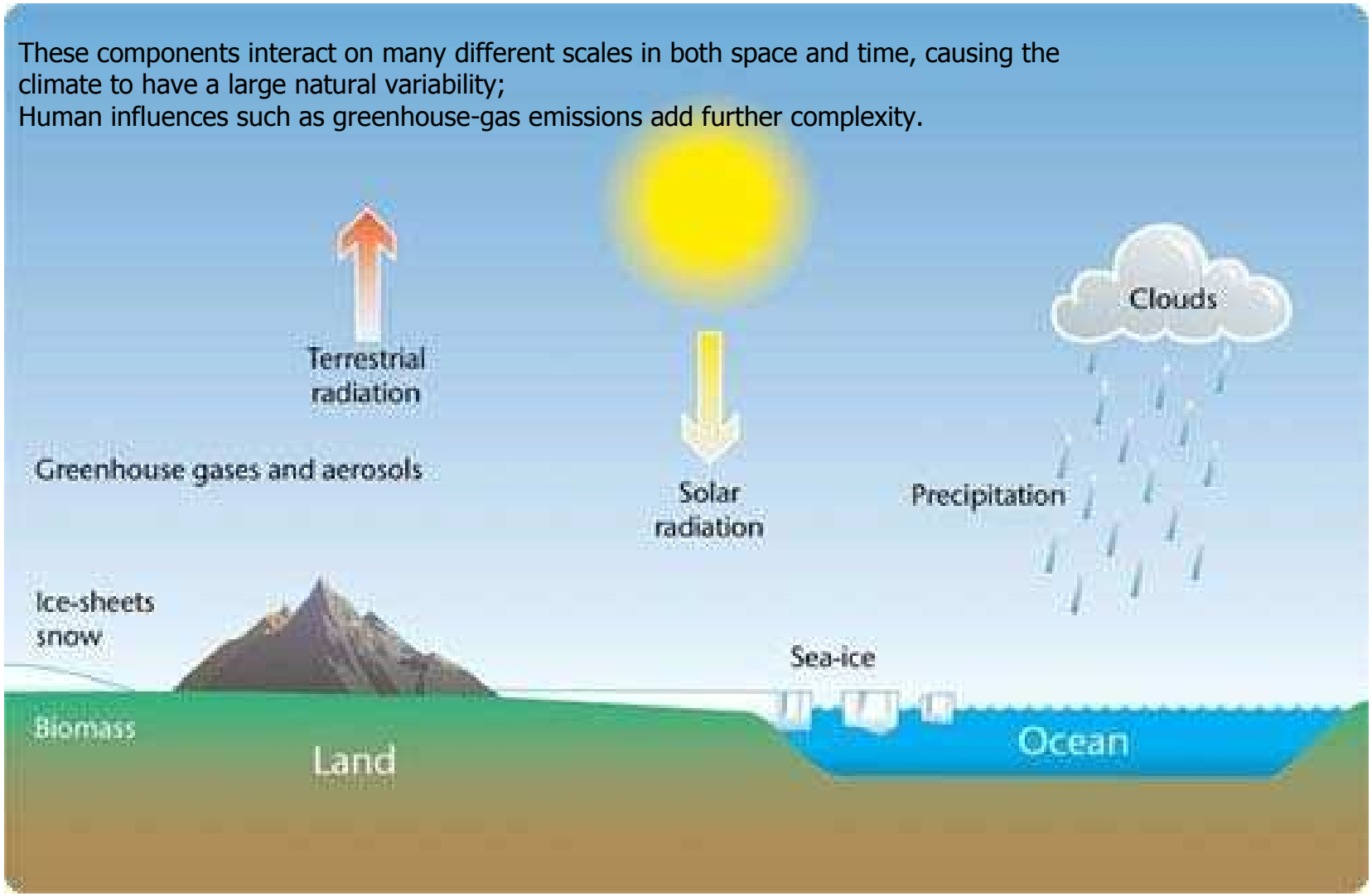
Perspectives of Renewable Energy in the Danube Region

The Earth System

These components interact on many different scales in both space and time, causing the climate to have a large natural variability;
Human influences such as greenhouse-gas emissions add further complexity.



Climate Change – a multidisciplinary issue

Complexity in natural sciences: meteorology, oceanology, hidrology, agriculture, geology, glaciology, ecology – on the basis of basic sciences (physics, chemistry, biology and mathematics)

Issue in social sciences: human behaviour, culture, ethics, teaching/education, migration, mobility, land-use, urbanization, architecture etc.

Schneider, S.H. (1977): Climate change and the world predicament: A case study for interdisciplinary research. *Climatic Change*

„The relationship between climatic change and issues of population, food, resources, environment and the human condition i.e., the world predicament, are explored. It is concluded that society is dangerously vulnerable to natural climatic variability at times of depleted food reserves (such as now) and that massive use of technologies (especially energy) to improve the human condition could well cause significant climatic change as early as the year 2000."

Climate Change – a global issue

World Climate Programme (WCP): The declaration of the First World Climate Conference held in 1979 called for the urgent development of a common strategy for a greater understanding of the climate system and a rational use of climate information, and proposed the establishment of the World Climate Programme (WCP).

The four main objectives adopted for the WCP were to:

- Determine the physical basis of the climate system that would allow increasingly skilful climate forecasts;
- Develop evermore useful applications of climate information benefiting economic efficiency, the human health of communities, food production and the prudent use of water resources;
- Determine socio-economic impacts and national vulnerabilities to climate variations and change; and
- Develop and maintain an essential global observing system fully capable of supporting the other three objectives.

Climate Change – a global issue

WCP was established as an interagency, interdisciplinary effort, with WMO, ICSU and United Nations Environment Programme (UNEP) initially as the co-sponsors. It comprised of four components:

- The World Climate Data Programme (WCDP)
- The World Climate Applications Programme (WCAP)
- The World Climate Impacts Programme (WCIP)
- The World Climate Research programme (WCRP)

The contributions of the WCP through these four components can be primarily framed under following core areas:

- Climate observations, monitoring and data management
- Operational climate information, prediction and analysis systems including user liaison
- Impact assessment and response systems
- Climate research, modelling and tools

Climate Change – a global issue

Intergovernmental Panel on Climate Change - IPCC (1988)

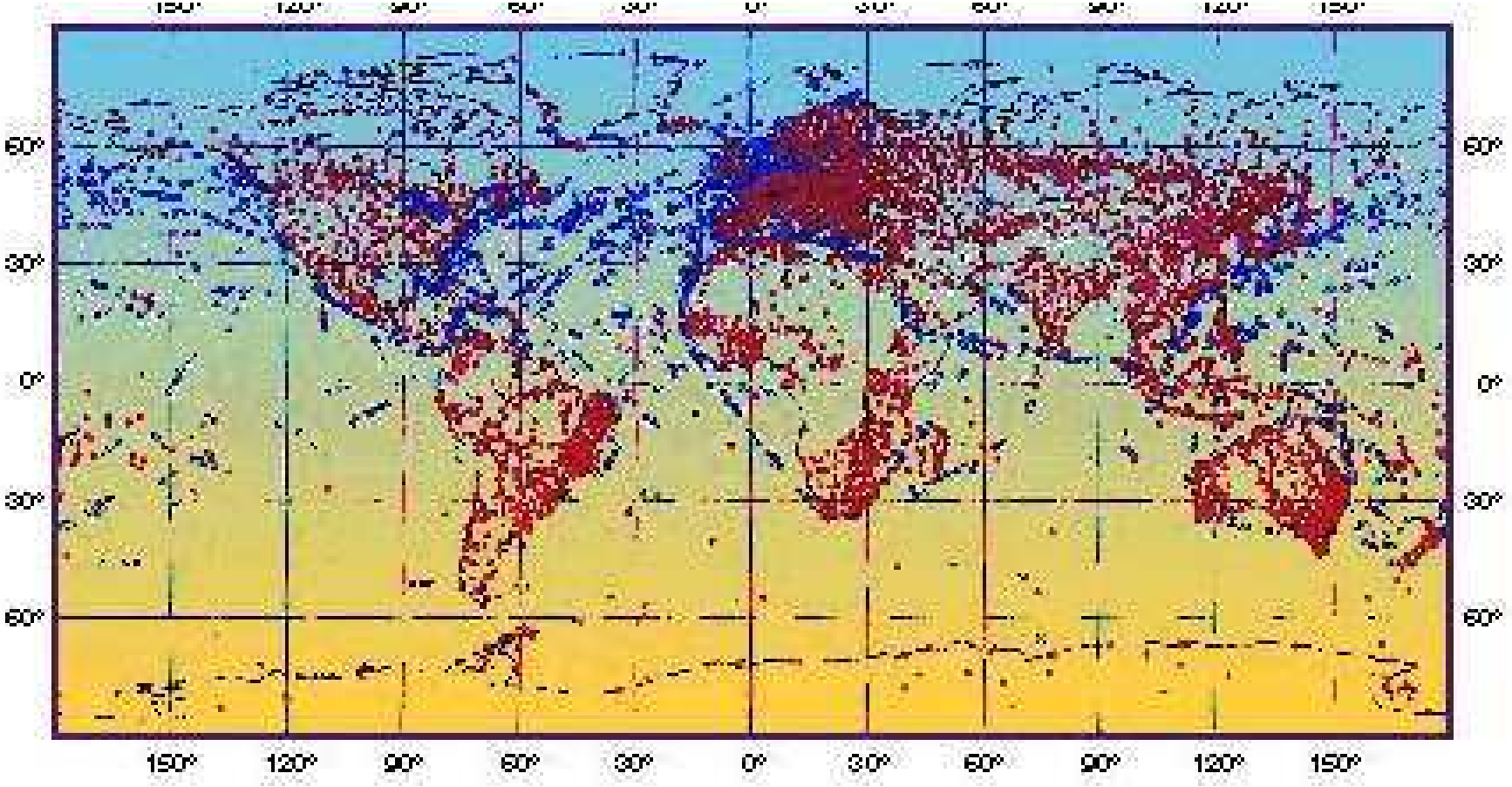
(Initiated by the cooperation between WMO and UNEP)

- summarizing current state of scientific knowledge, providing rigorous and balanced scientific information to decision makers (*policy-relevant yet policy-neutral*);
- compiling Assessment Reports regularly 1990- ;
- IPCC does not conduct any research nor does it monitor climate related data or parameters;

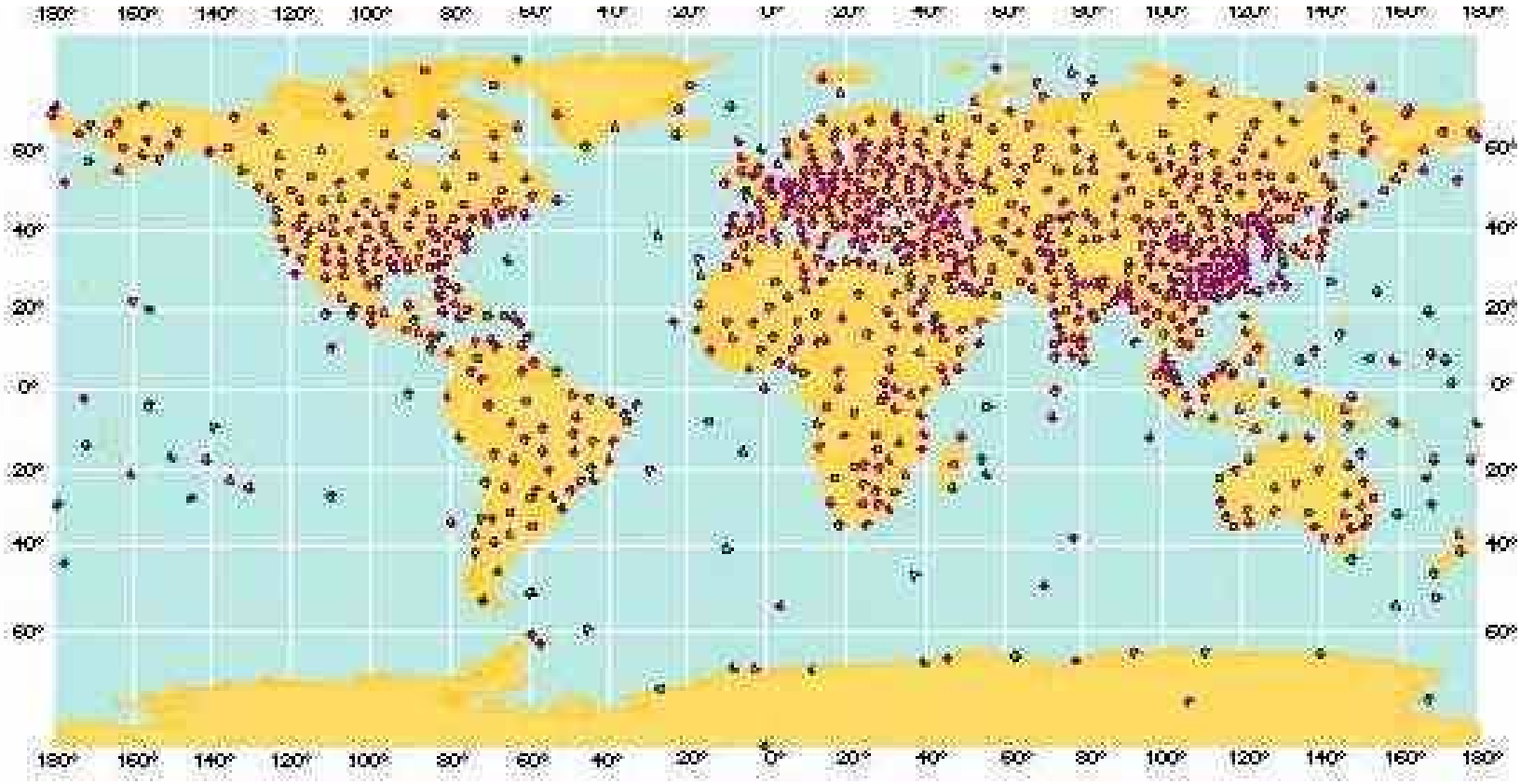
UN Framework Convention on Climate Change – UNFCCC (1992)

- in decision making precautionary principle is considered

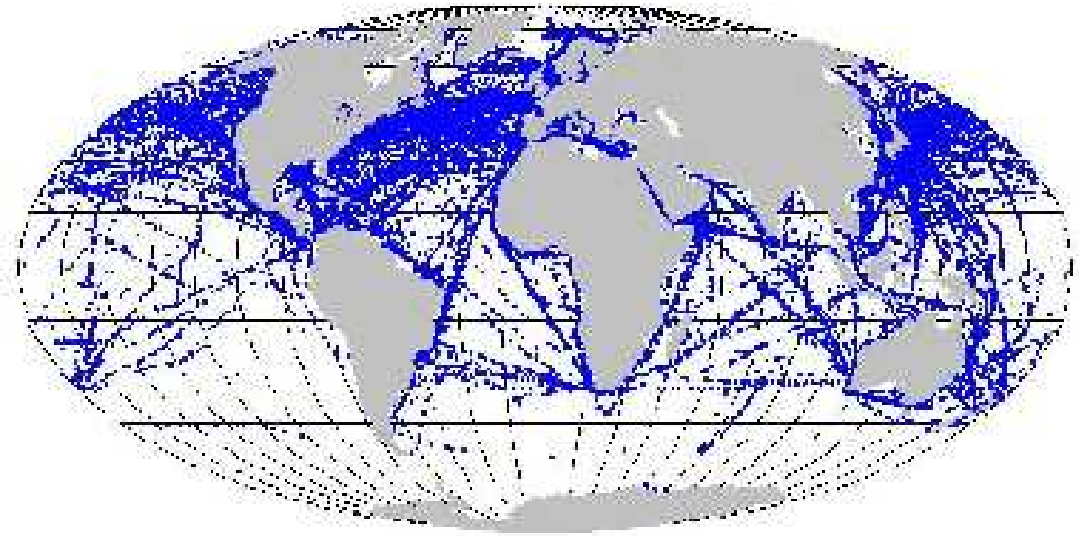
WMO – Surface Based Observations

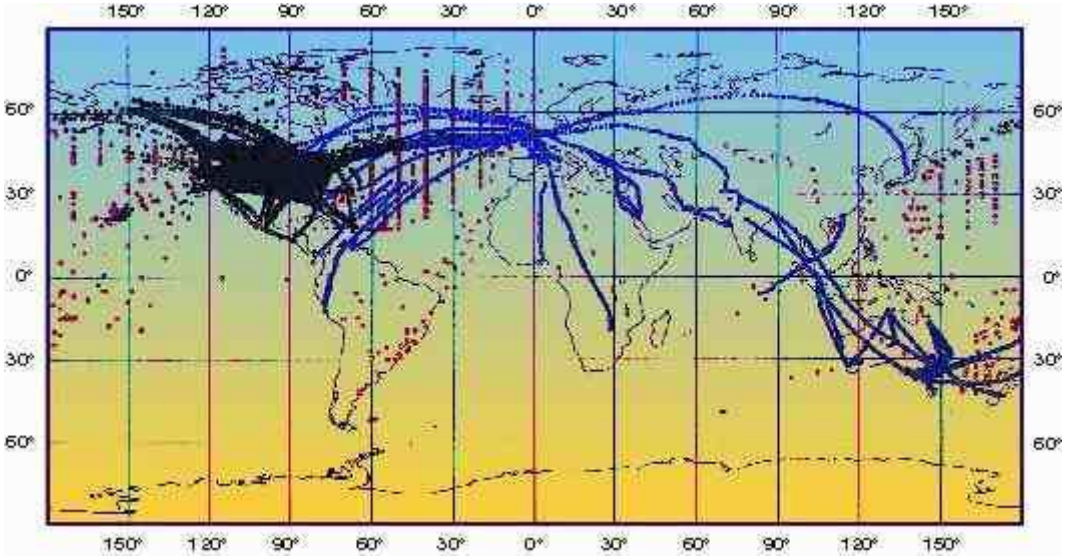


WMO – Upper Air Radiosonde Observations

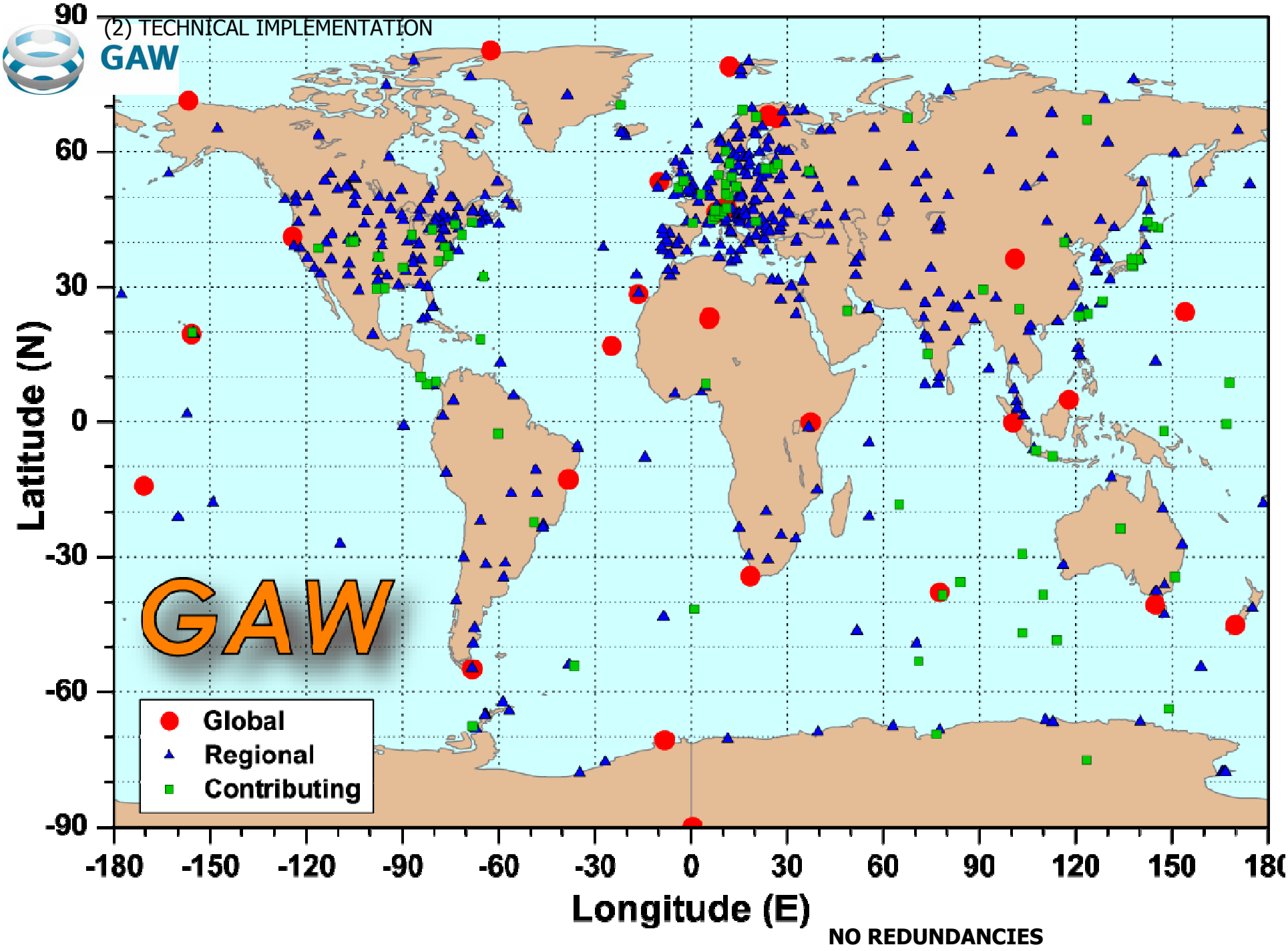


WMO – Ship and Airplane Based Observations



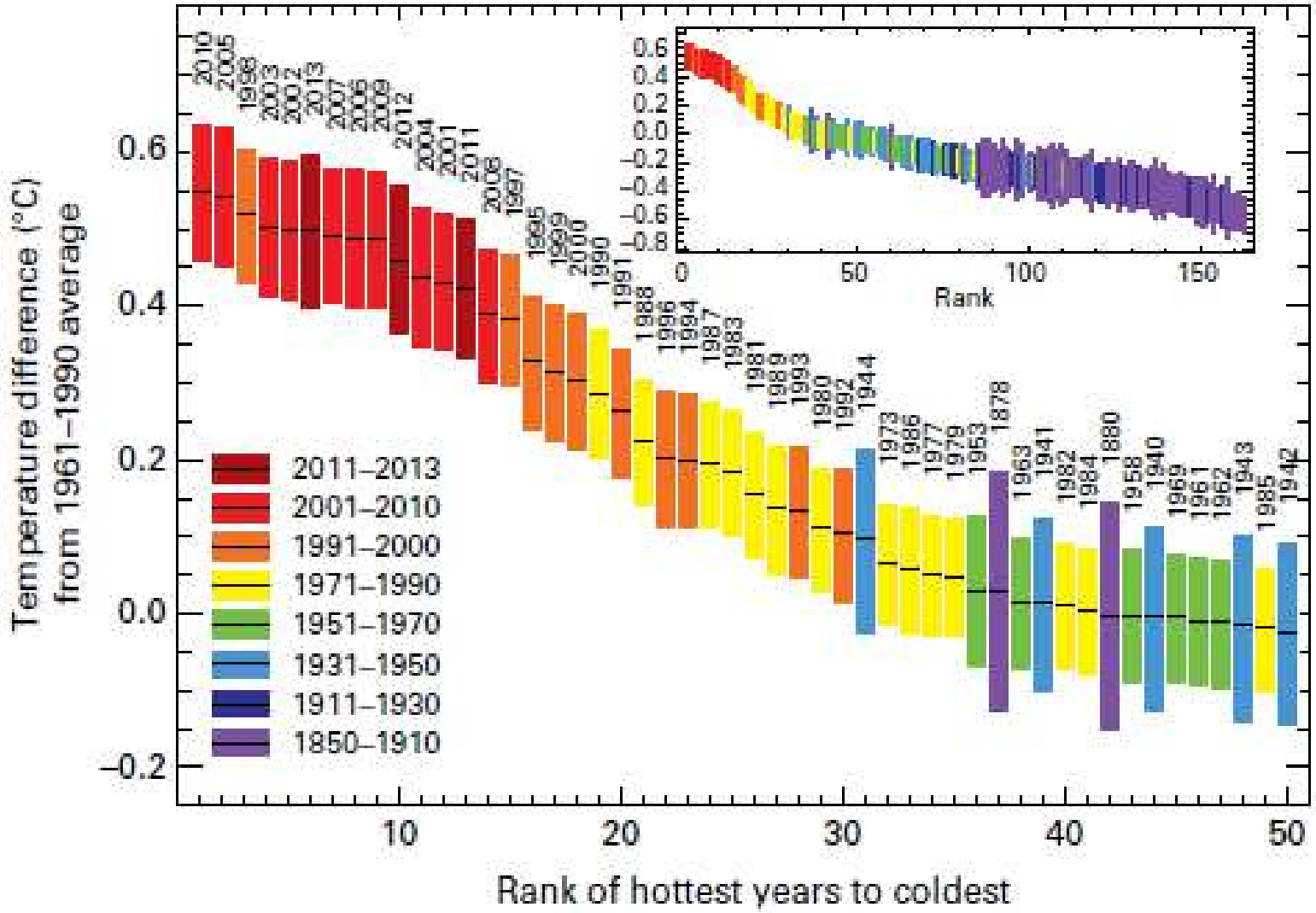


GAW



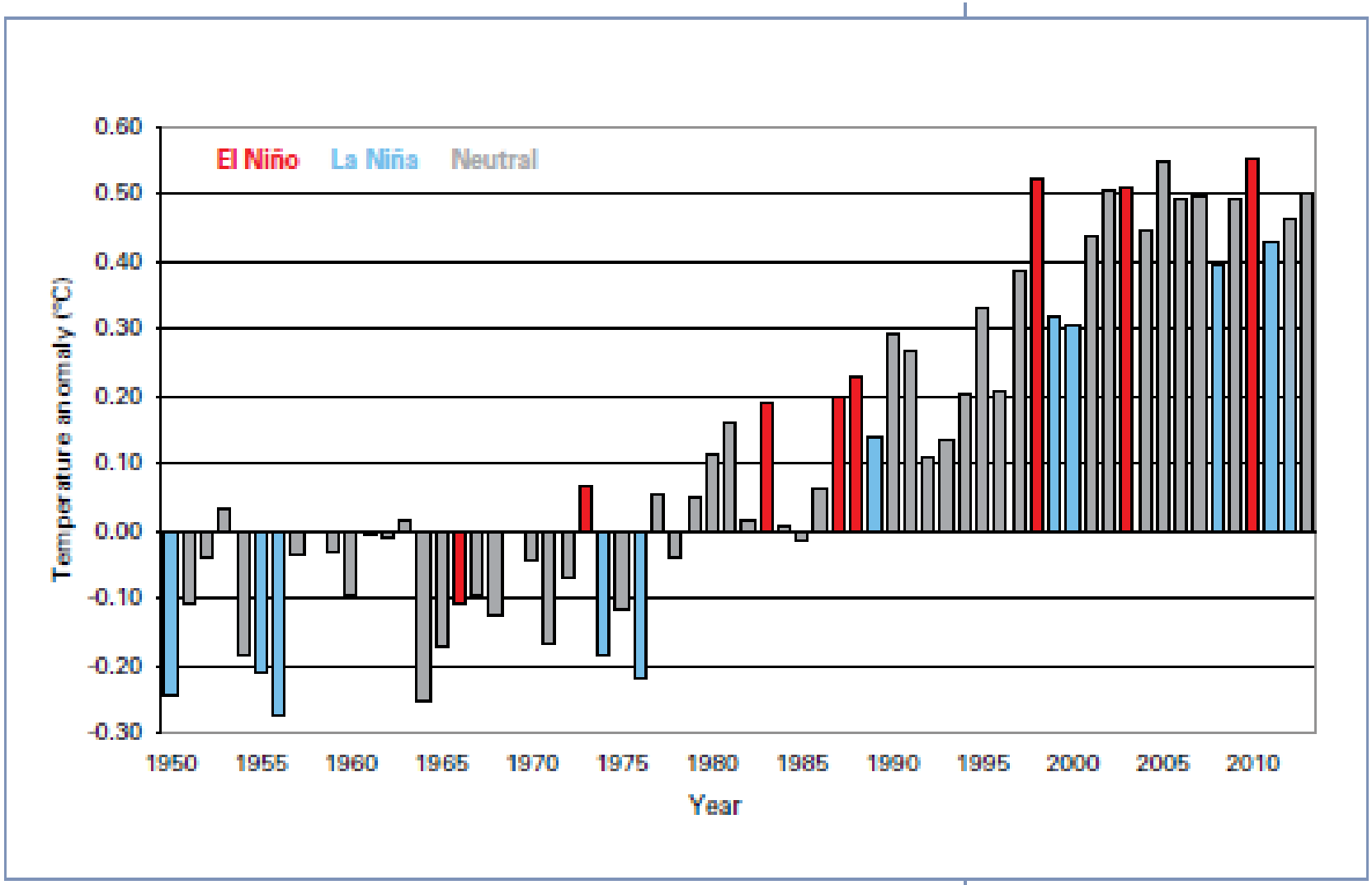
NO REDUNDANCIES

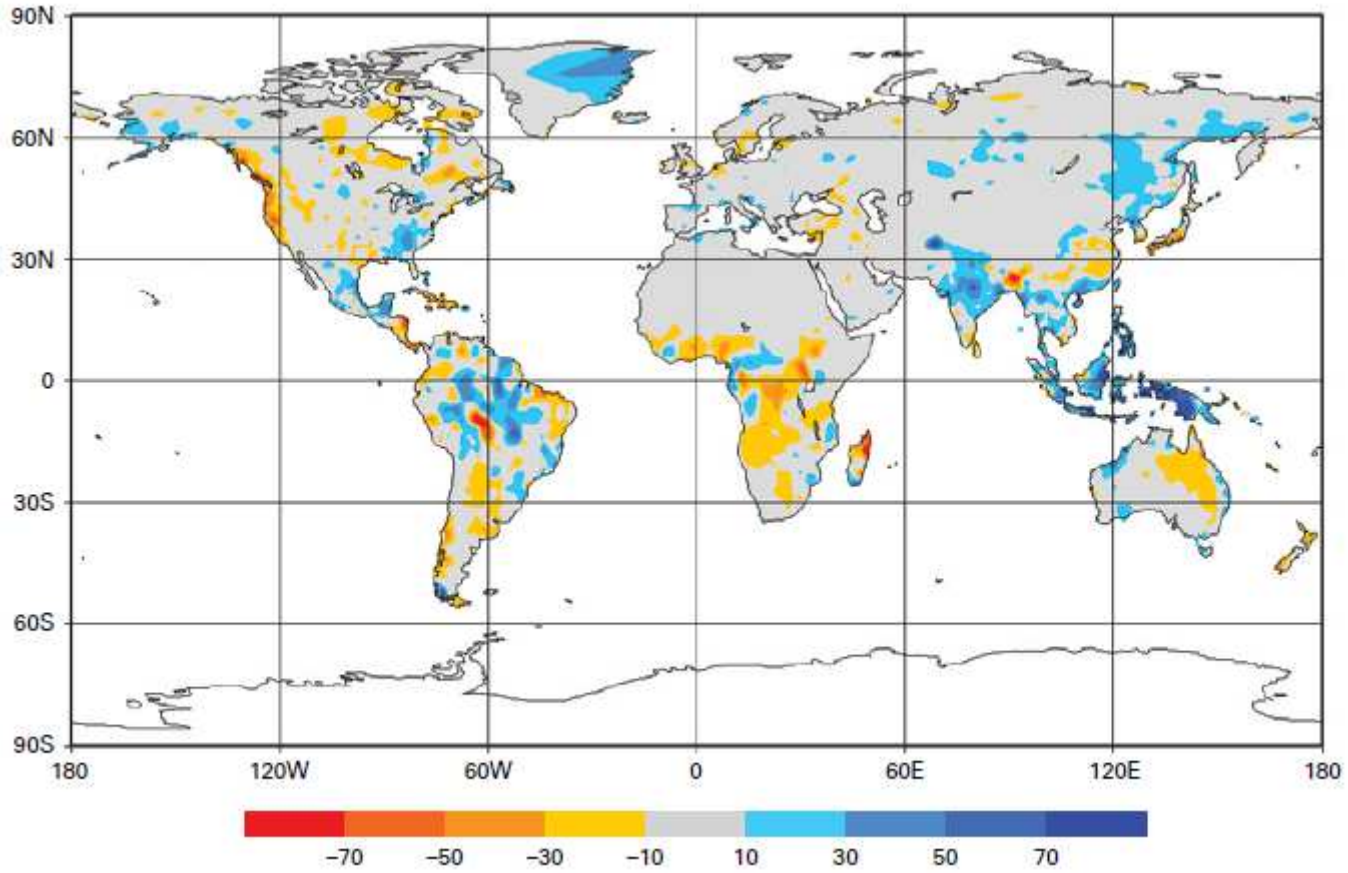
Anomaly of annual average temperatures



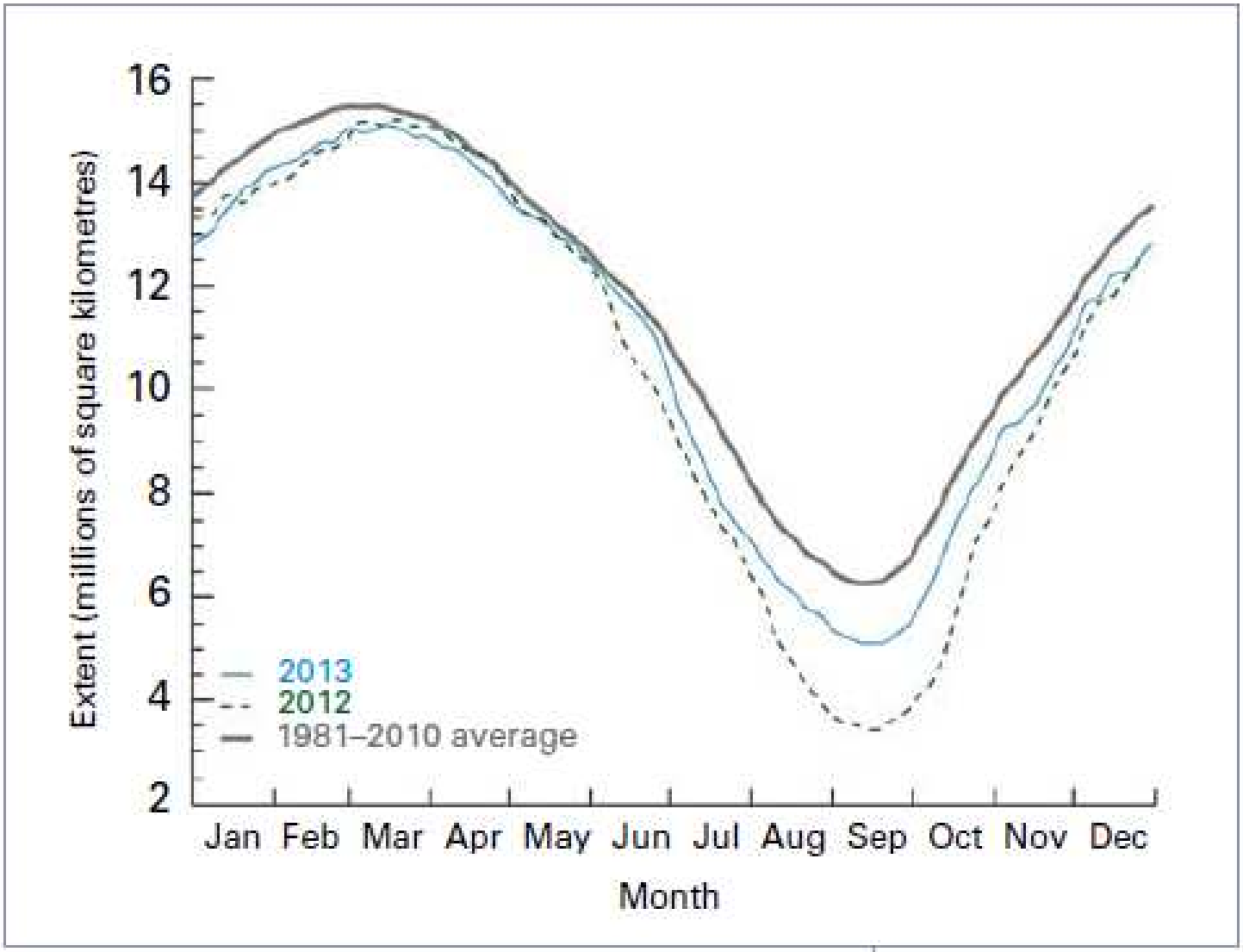
WMO, 2014

Anomaly of annual average temperatures





Annual precipitation anomalies for global land areas for 2013; gridded 1.0-degree raingauge-based in mm/month (relative to 1951–2000) *(Source: Global Precipitation Climatology Centre, Deutscher Wetterdienst, Germany)*

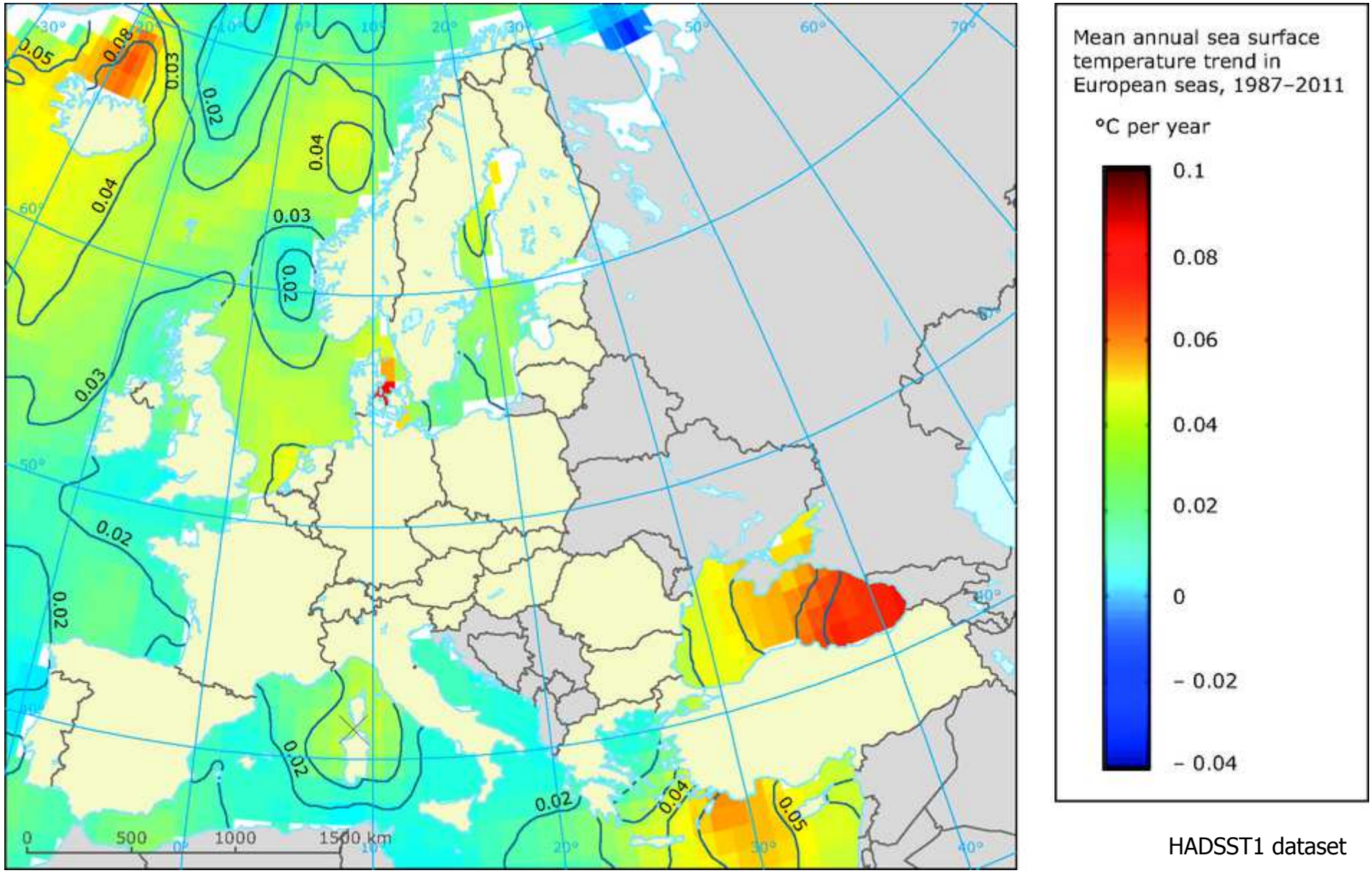


Arctic sea-ice extent in 2013, compared with 2012 and the 1981–2010 average *(Source: National Snow and Ice Data Center, United States)*

Meteorological extremes in 2013

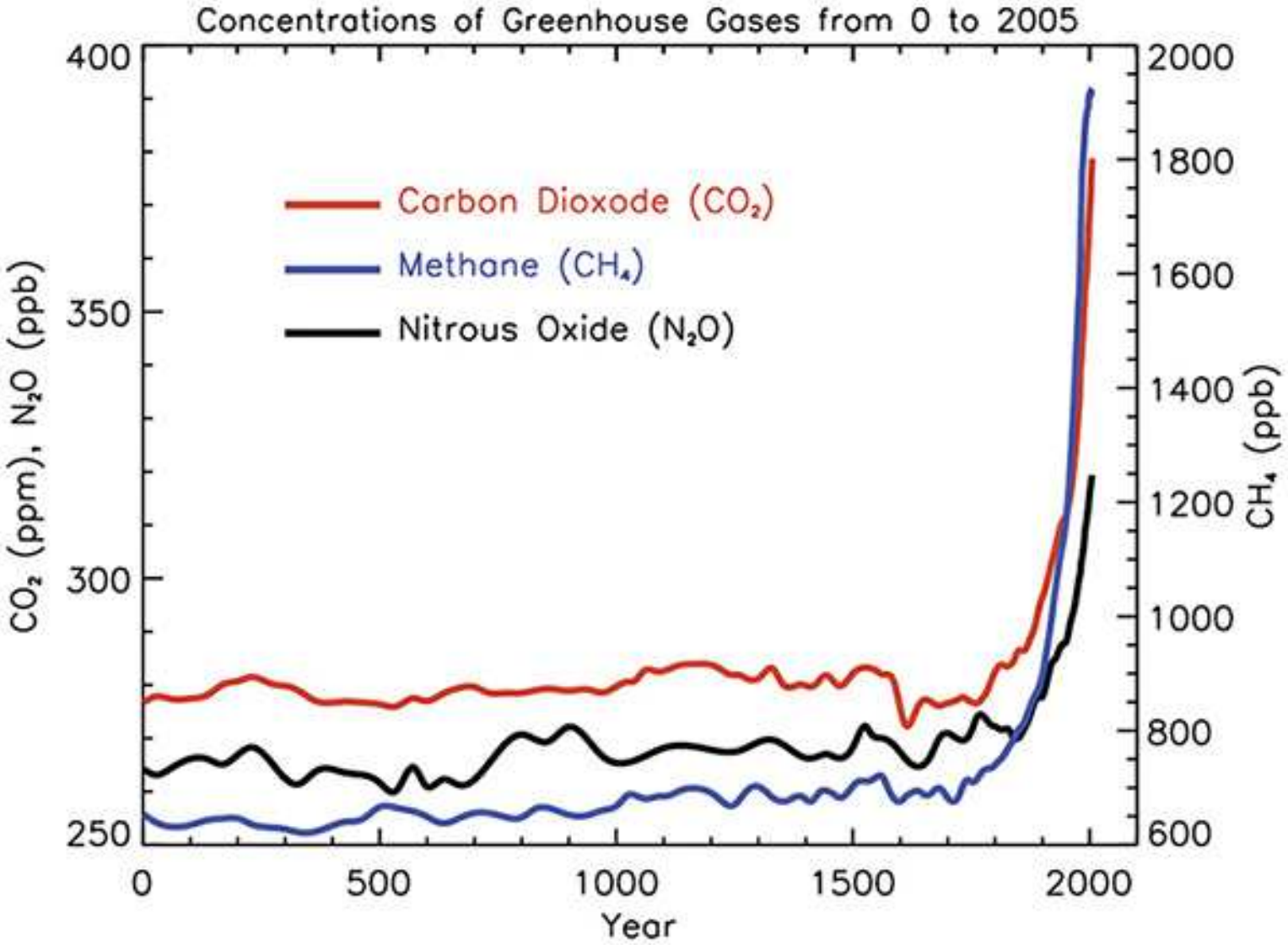
• Typhoon *Haiyan (Yolanda), one of the strongest storms to ever make landfall, devastated parts of the central Philippines.*
• Surface air temperatures over land in the southern hemisphere were very warm, resulting in widespread heatwaves; Australia saw record warmth for the year, Argentina its second warmest year and New Zealand its third warmest.
• Frigid polar air swept across parts of Europe and the south-eastern United States.
• Severe drought gripped Angola, Botswana and Namibia.
• Abundant rains and flooding impacted north-eastern China and eastern Russian Federation.
• Heavy rains and floods affected Sudan and Somalia.
• Major drought affected southern China.
• North-eastern Brazil experienced its worst drought in the past 50 years.
• The widest tornado ever observed hit El Reno, Oklahoma in the United States.
• Extreme precipitation led to severe floods in the Alps and in Austria, the Czech Republic, Germany, Poland and Switzerland.
• Israel, Jordan and the Syrian Arab Republic were struck by unprecedented snowfall.
• *Greenhouse gas concentrations in the atmosphere reached record highs.*
• *The global oceans reached new record high sea levels*.
• The Antarctic sea-ice extent reached a record daily maximum.

Mean annual sea surface temperature trend

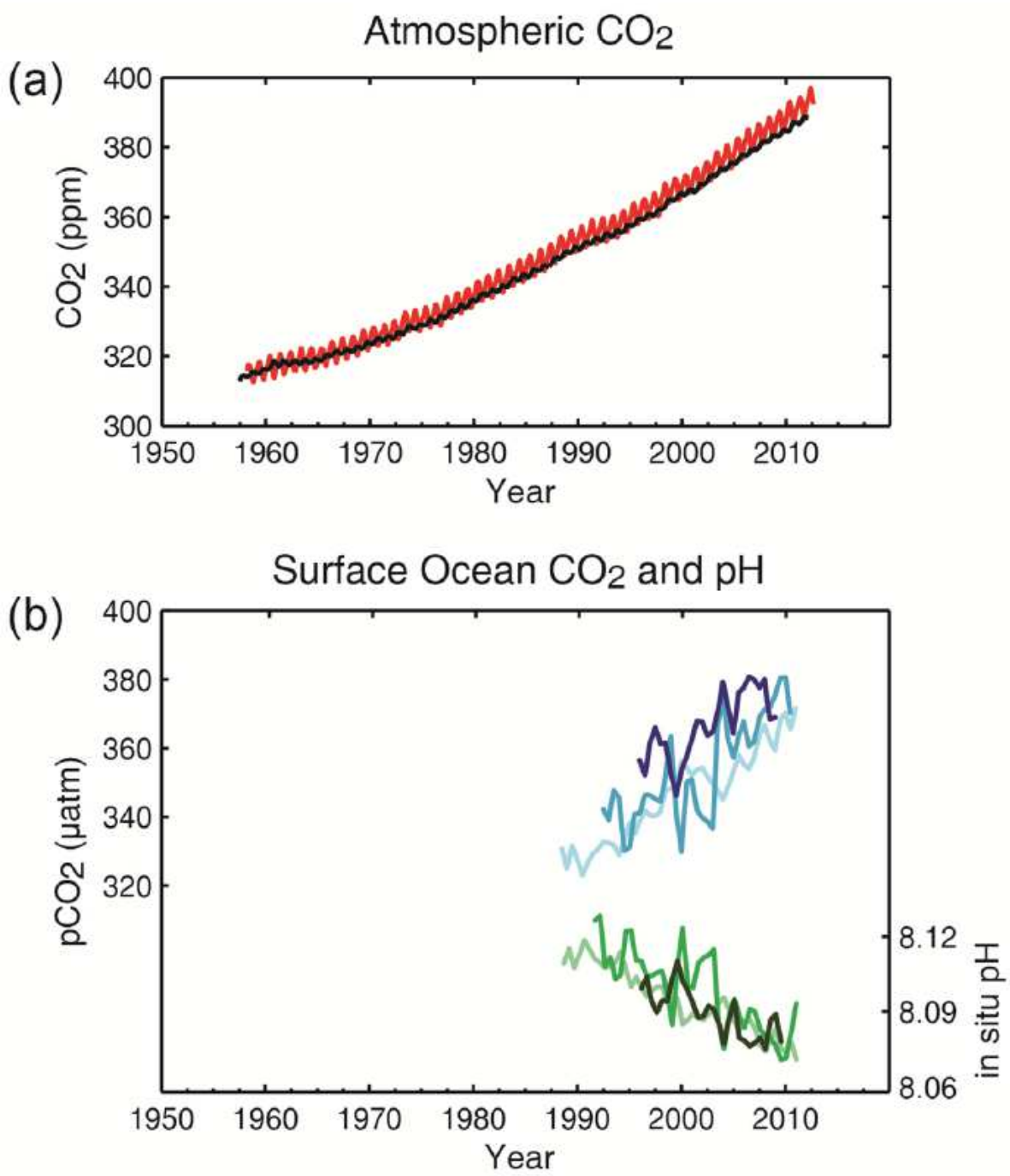


HADSST1 dataset

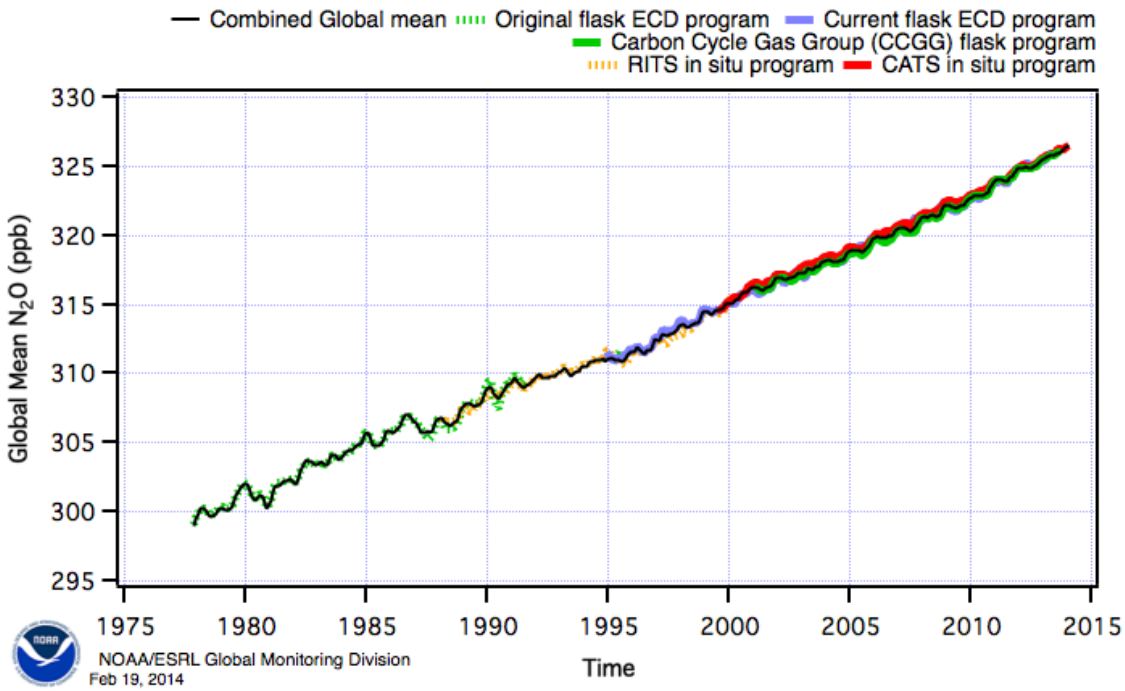
GHG concentration trends

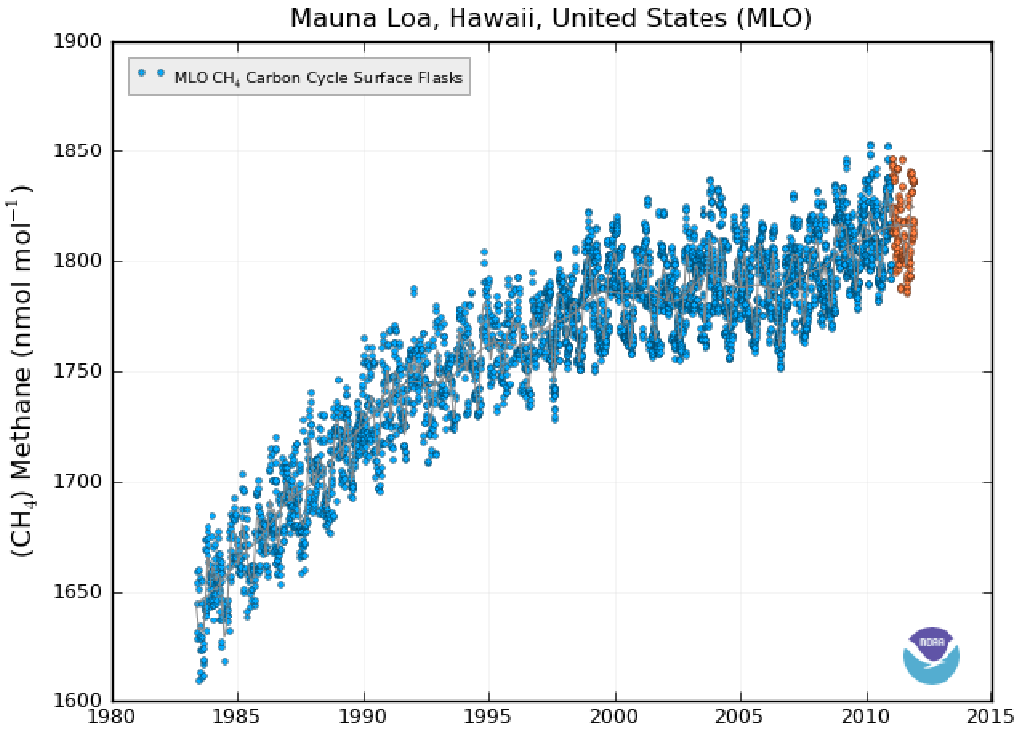


WMO, 2010


Atmospheric CO_2
(a)
400
380
360
340
320
300
CO_2 (ppm)
1950
1960
1970
1980
1990
2000
2010
Year
Surface Ocean CO_2 and pH
(b)
400
380
360
340
320
pCO_2 (µatm)
8.12
8.09
8.06
in situ pH
1950
1960
1970
1980
1990
2000
2010
Year

WMO, 2013





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Intercontinental transport of pollutants

- SO_2, SO_4 and H_2S content over Europe, N-America and The Atlantic(*Mészáros E.,* 1978).
- 3-D global modell (*Derwent et al.,* 2004) tropospheric ozone and precursors, 21 european receptor points.
- GLEMOS model: EMEP MSC-E, Hg and POPs global transport.
- Hemispheric Transport of Air Pollution (HTAP 2010), multi-modell (7-32) analyses: O3, PM, Hg, POPs

  ACCENT/PHOTOCOMP (*Dentener et al.,* 2006),

  AEROCOM (*Textor et al.,* 2006),

  TRANSCOM (*Law et al.,* 2008),

  RETRO (*Schultz et al.,* 2007).

Global (Hemispheric) Transport of Air Pollutants

Long-range Transboundary Air Pollution (LRTAP Convention)
TF on Hemispheric Transport of Air Pollutants (TF HTAP) 2005-

Regional air pollution problems have become hemispheric issue

Global emission, transport and deposition investigations:

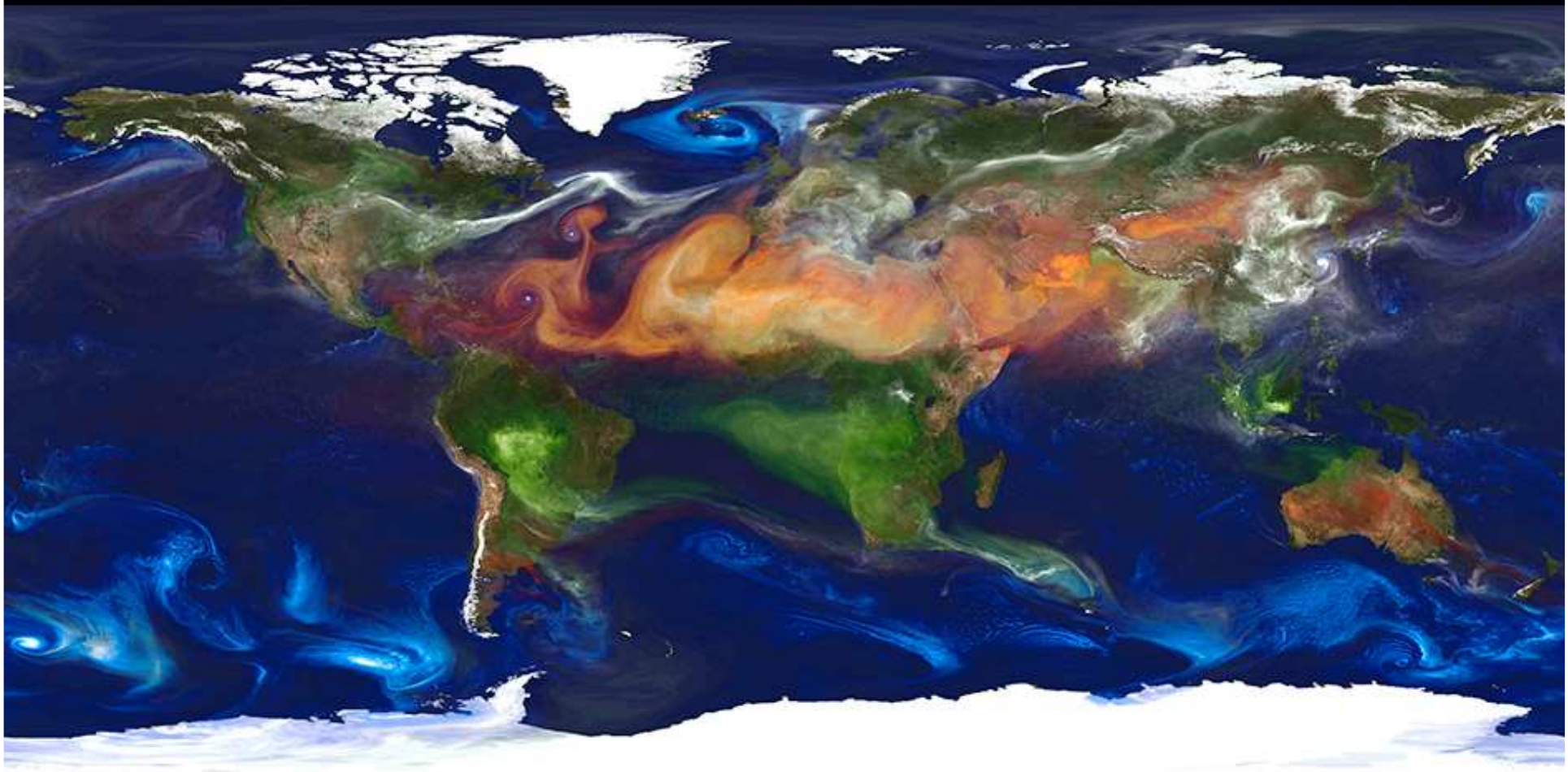
- surface ozone
- mercury
- PM
- persistent organic pollutants(POP)

National database update (monitoring and modelling)

Global *ensemble* modelling and environmental state assessment, inter-continental transport of air pollutants, source origin of North Pole regional pollution

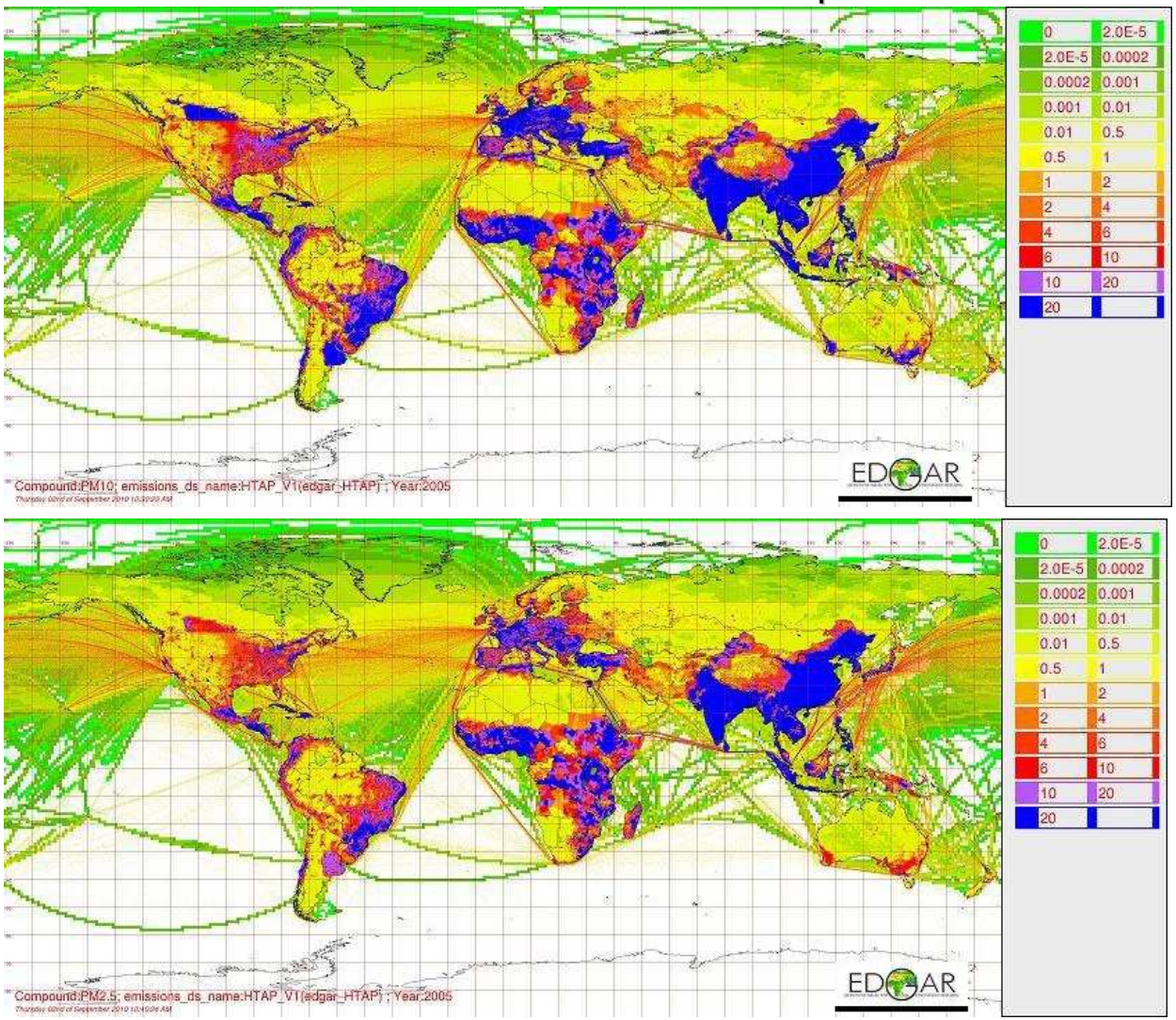
Global Transport of Atmospheric Aerosol Particles

NASA Goddard Earth Observing System Model GEOS-5, (*Putman W.*, 2012)

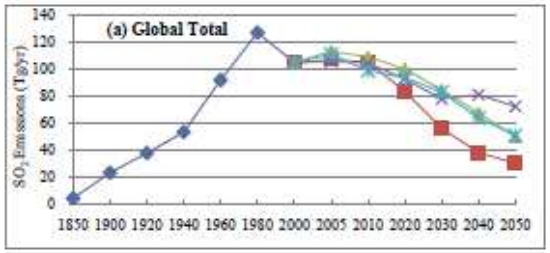


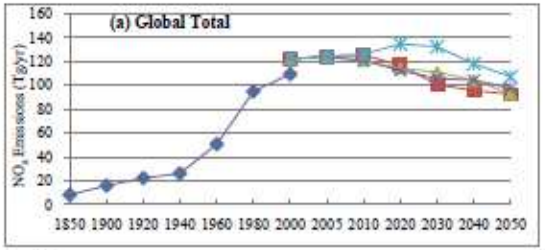
Global PM_{10} and $PM_{2.5}$ emissions (t/grid)

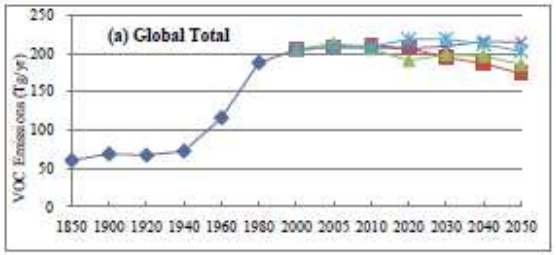
Emission Database for Global Atmospheric Research

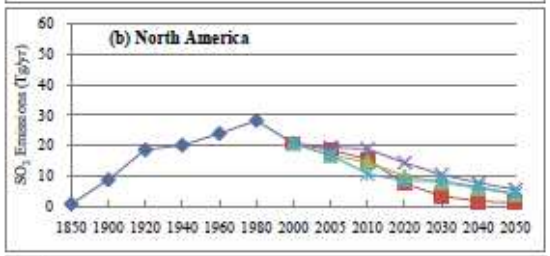


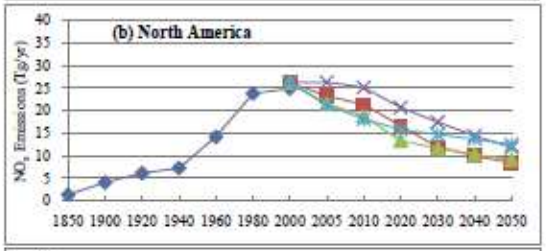
Global Sulfur Dioxide, Nitrogen Oxide and VOC Emissions (HTAP Report, 2010)

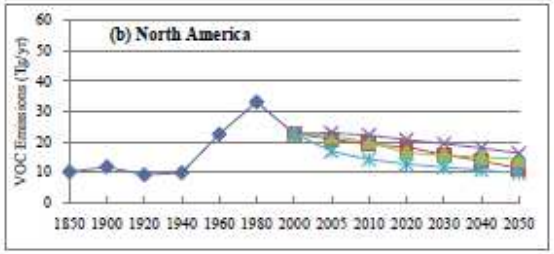


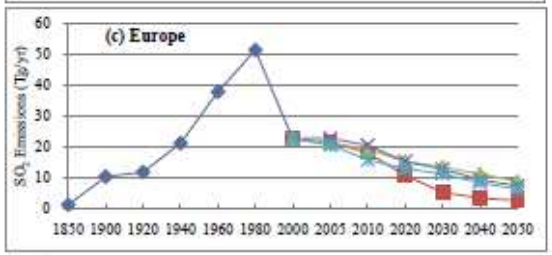


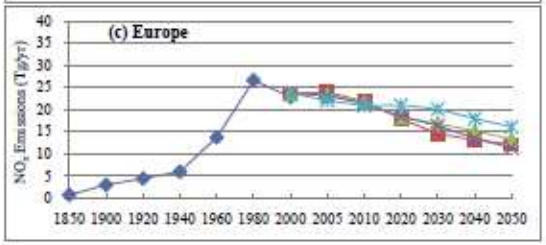


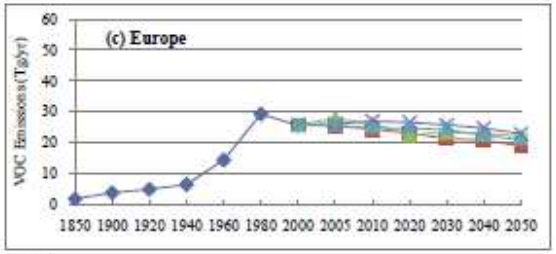


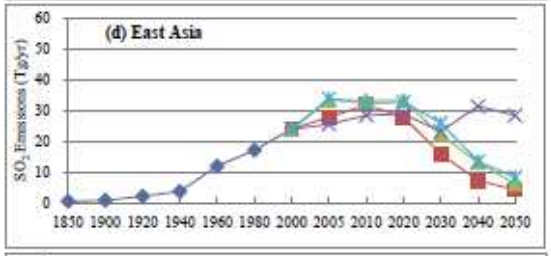


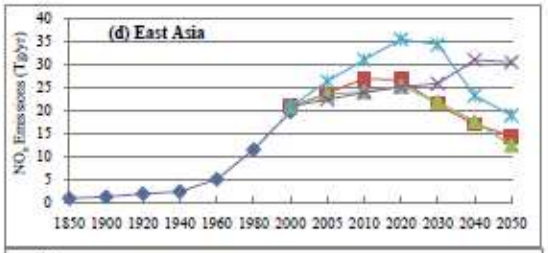


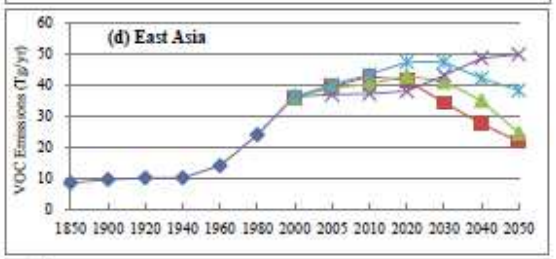


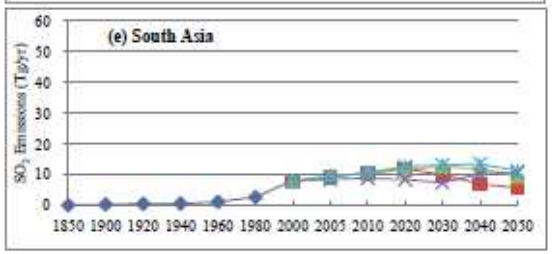


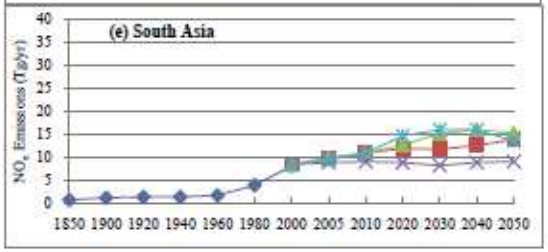


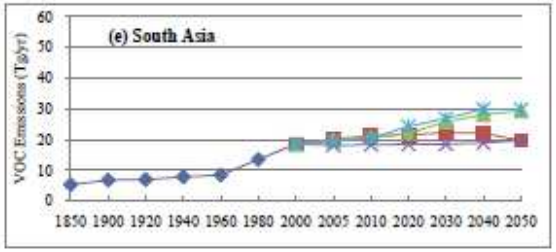




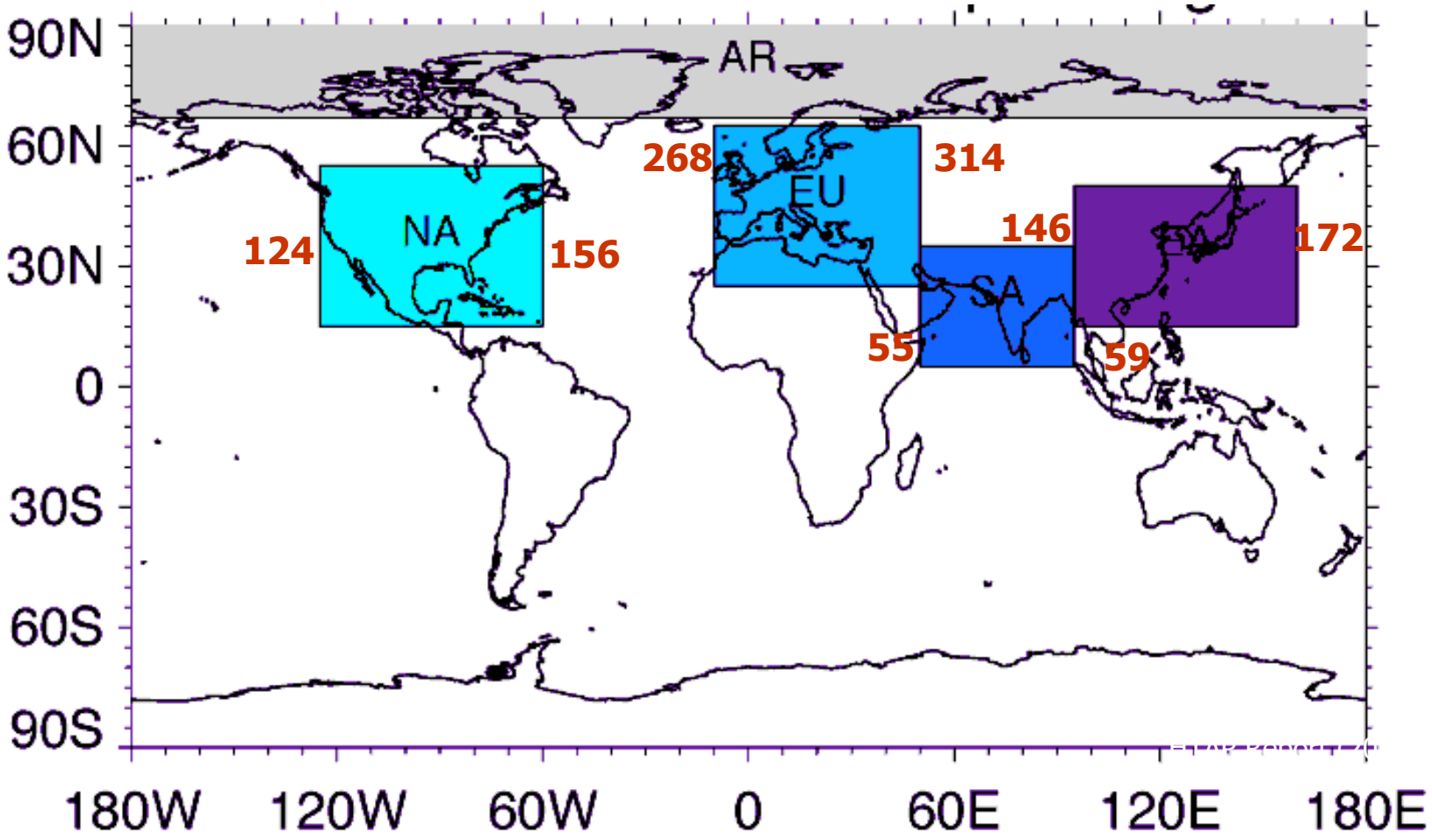




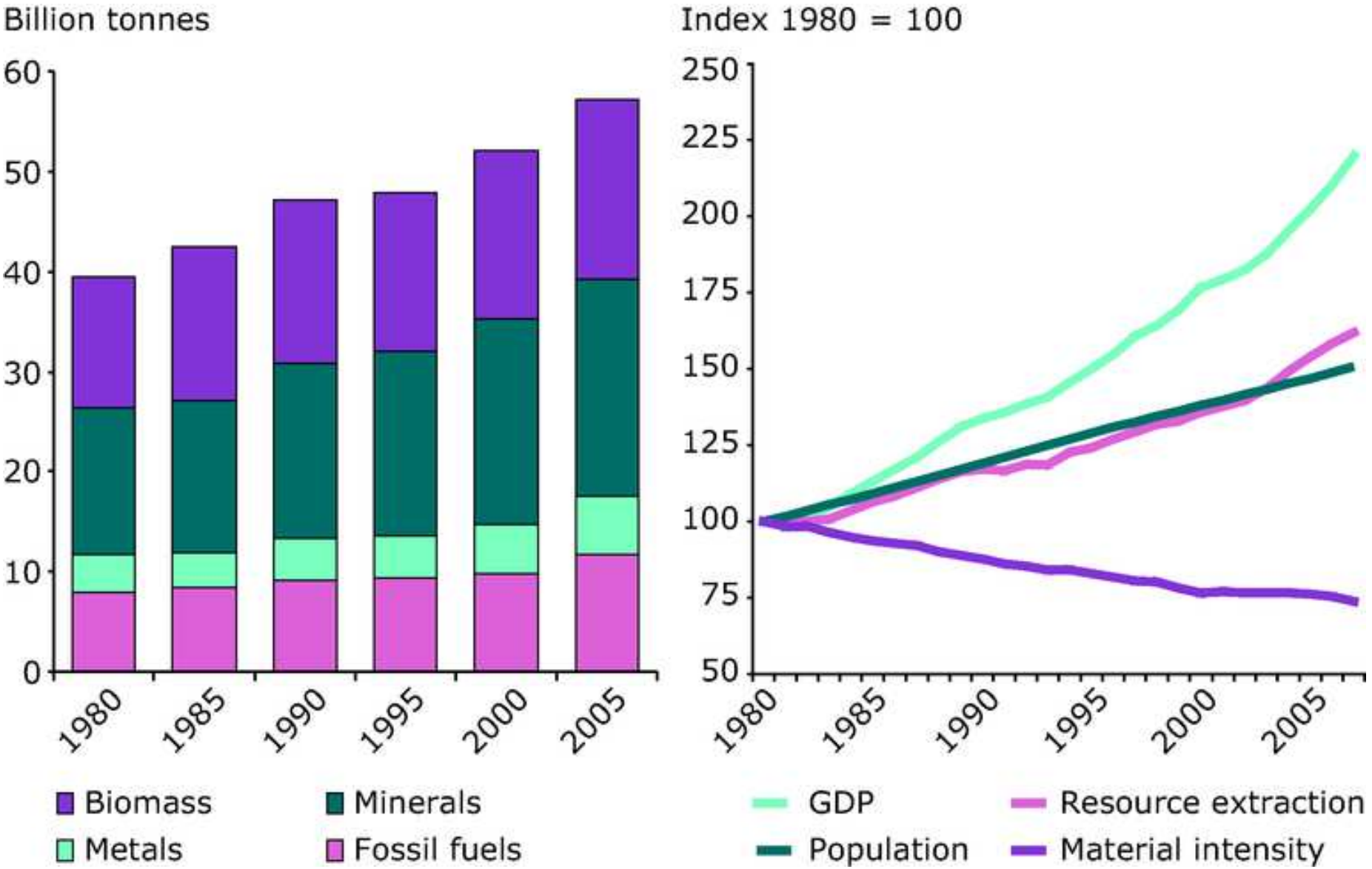




PM10 annual average zonal import/export fluxes in HTAP regions (Tg)



Extraction of Natural Resources (EEA, 2012)



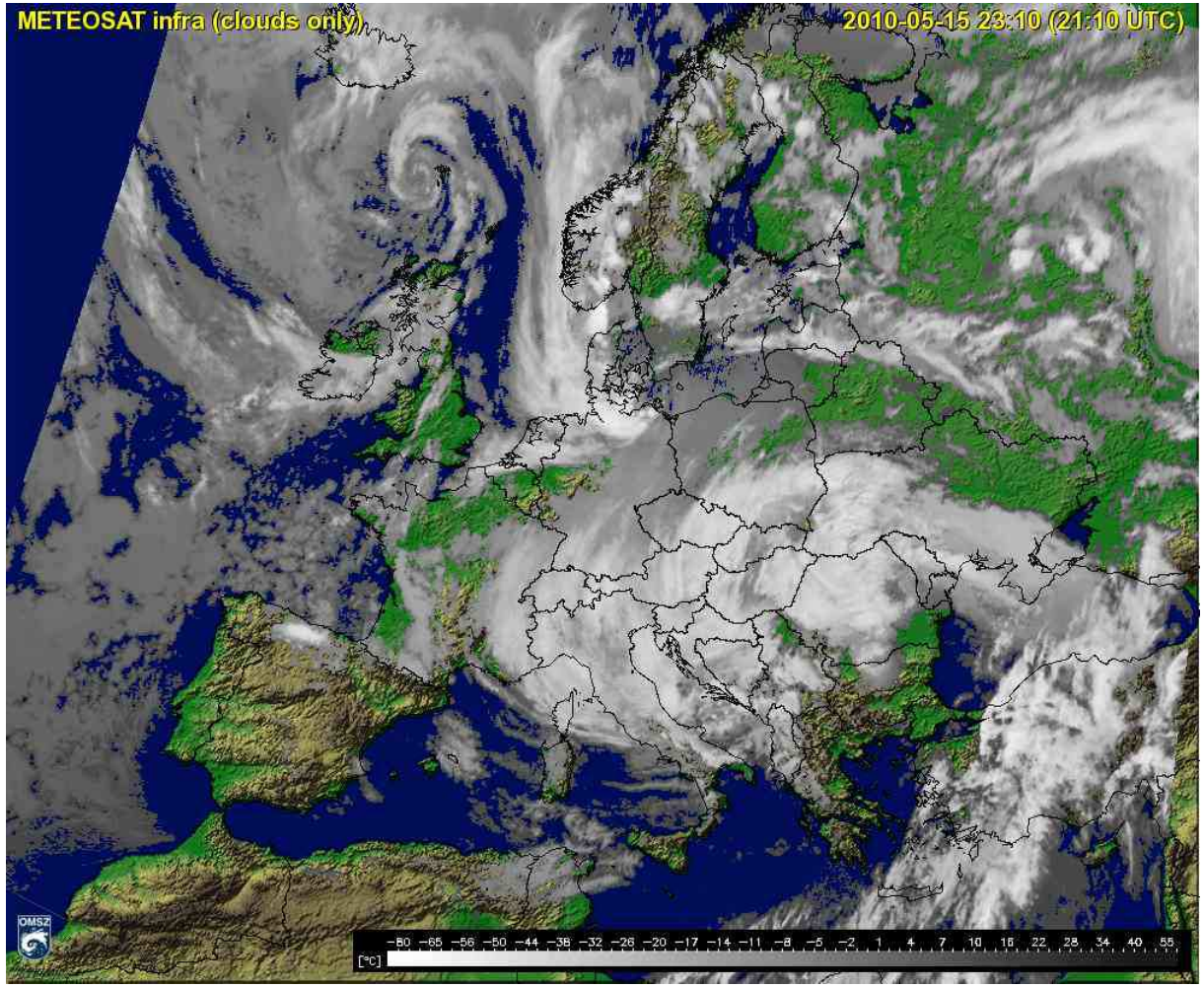
Impacts of Climate Change

Most of the impacts are connected with the water cycle.

- Long-term trend in precipitation amount, intensity and frequency;

- Increase in risks of droughts and floods affecting agriculture, food production, energy production, water reservoirs, sustainability of ecological systems and infrastructure development;

- Rising sea levels endangers the sea-shore communities, cities, water reservoirs and food production.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AP

Effects of Climate Change

Human Health

- Heat stress, cardiovascular diseases;

- Invazive allergenic species;

- Longer and more intense air pollution episodes;

- Flash floods endanger food and drinking water safety;

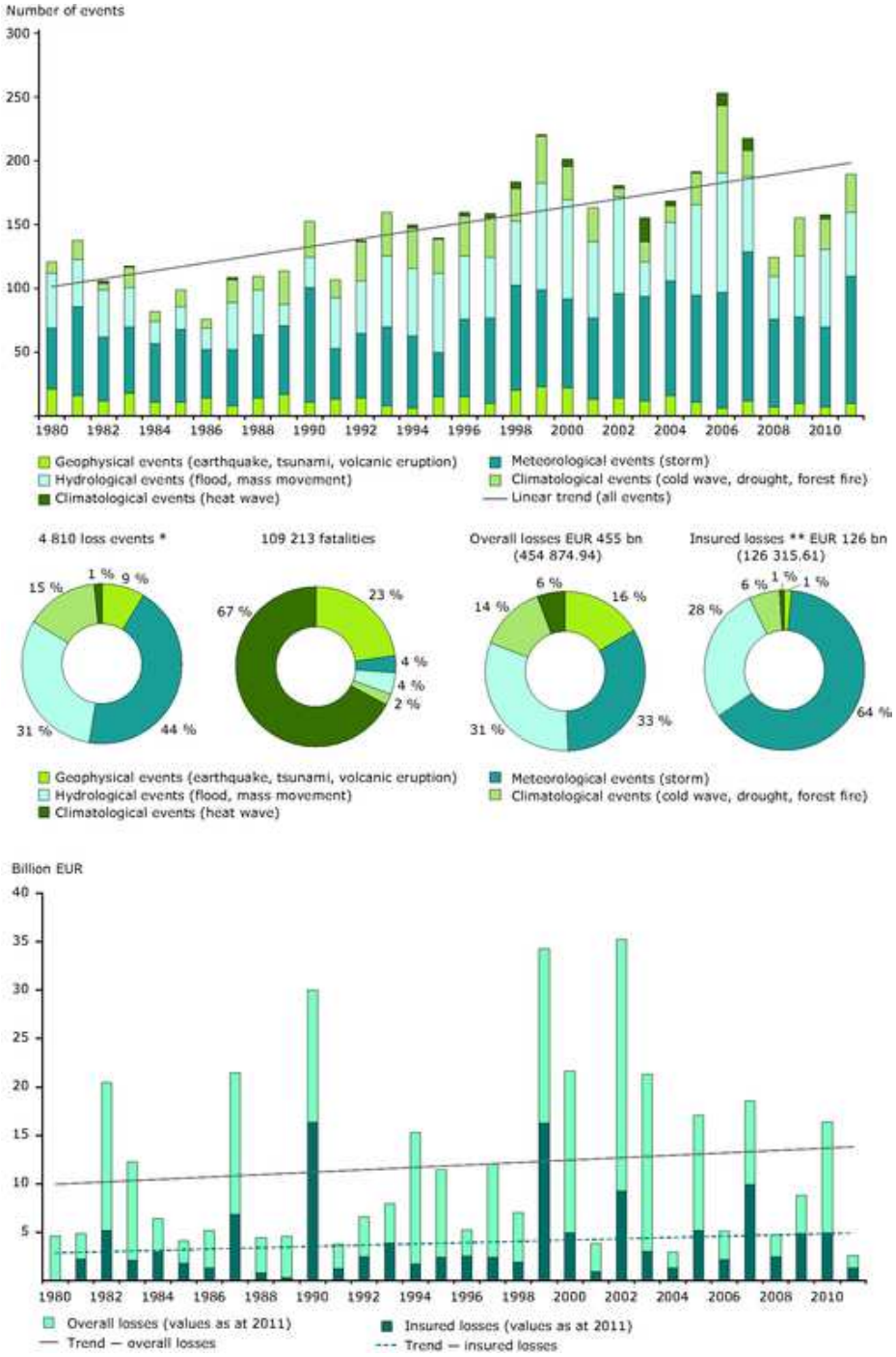
- Tropical and subtropical diseases emerging in northern areas

- Food safety, security and storage

Houses undermined by melting Permafrost

Number of events of natural disasters, and costs of insurance companies

EEA, 2012



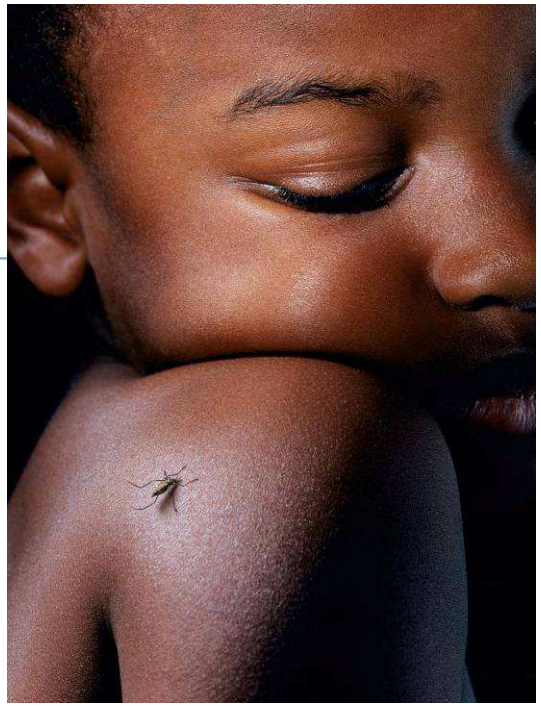
WMO Global Framework for Climate Services

GFCS provides a worldwide mechanism for coordinated actions to enhance the quality, quantity and application of climate services.

Science-based development of climate information system supporting adaptation policy on global, regional and local scales.

GFCS short term priorities

- ✓ **Water**
- ✓ **Reduce disaster risks**
- ✓ **Health**
- ✓ **Agriculture, food safety and security**



WMO Global Atmosphere Watch
WMO Strategic Plan 2016-2019

«Science for Service»

1. Reduce the risks of environmental disasters
2. Global Integrated Polar Prediction System (GIPPS)
3. Megacities
4. Global Framework for Climate Services (GFCS)
5. WMO Integrated Global Observing System (WIGOS), WMO Information System (WIS), GFCS

Integrated GHG Information System: Serving society and supporting policy

- CAS recognized that emission inventories and their reduction approaches require independent, scientific information to support verification and policy decisions.
- CAS noted that bottom-up, top-down and reanalysis should work together. What we do not measure, we cannot manage. Must separate human from natural influences to inform policy or engineering decisions. This requires an Integrated Greenhouse Gas Information System (IGIS) that is global in scale, but also addresses sub-continental, policy-relevant regions.
- CAS appreciated on-going work to establish IGIS, including the N American Carbon Program (NACP - USA, Canada, Mexico), the Integrated Carbon Observation System (ICOS) in Europe, expansions of observations in countries such as China and Brazil, initiatives involving commercial aircraft, and even work by private organizations.
- CAS noted that for IGIS requires a denser greenhouse gas observational network with more variety of observations, models for inversion, better coordination with the biosphere and oceans.
- CAS requested Members to take the necessary steps to develop these high-quality observations, to be compatible with the established GAW network and to improve the modelling tools to implement IGIS.
- CAS agreed that WMO Programmes have the capacity to develop the atmospheric part of IGIS.
- CAS stressed that full implementation of IGIS would require the established collaboration with other international organizations and coordination bodies, e.g., working together with GEO-Carbon.

Aerosols: Impacts on air quality, weather and climate

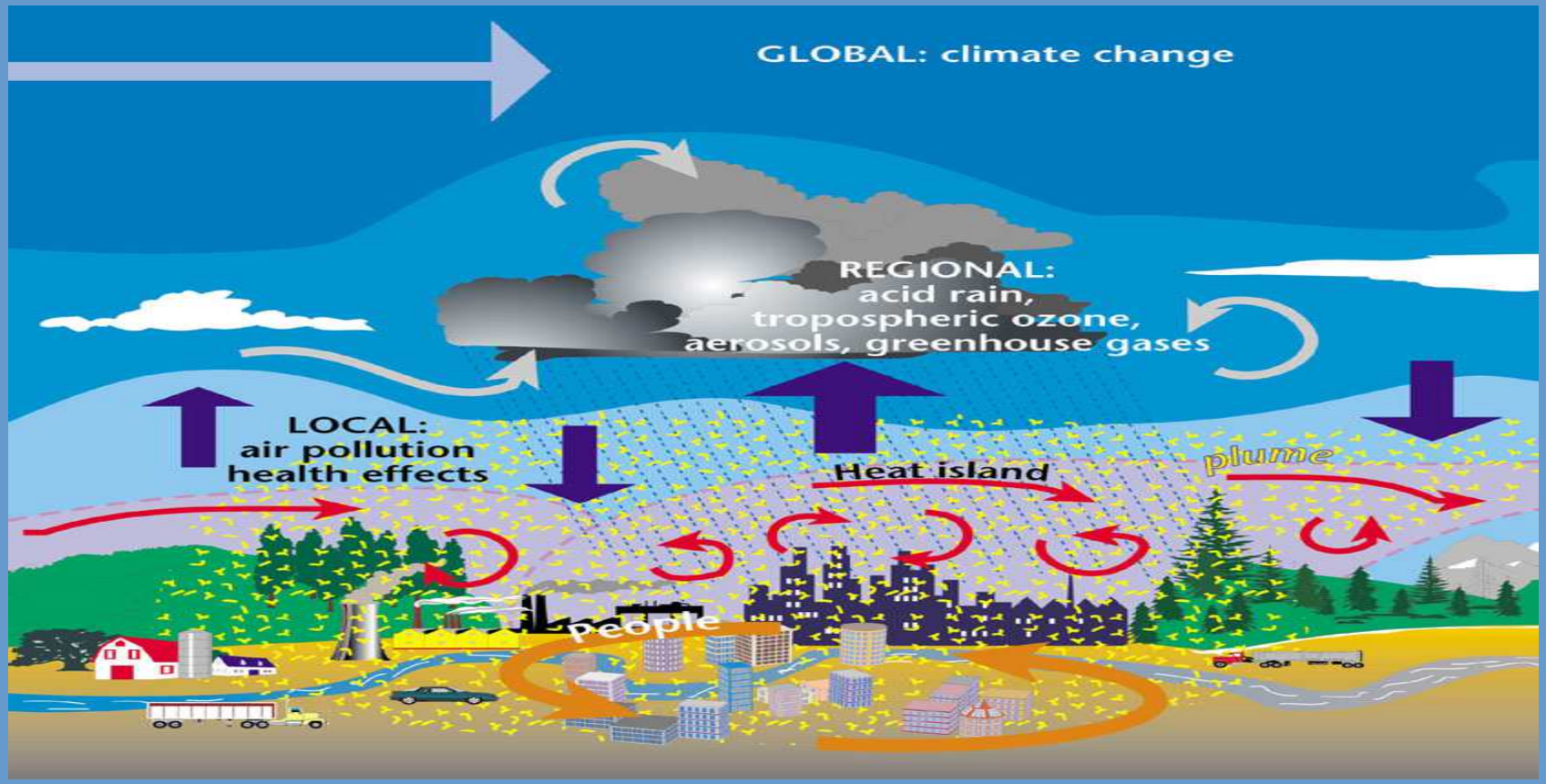
- CAS recommends to make use of advances in aerosol research, with new measurement methods like the aerosol mass spectrometer that recently has become available and allow performing source apportionment. Simplified versions, such as the aerosol chemical speciation monitor, allow for long-term operation and year-long data sets have been acquired at certain sites. Their long-term performance is currently tested within the European project ACTRIS; if successful these instruments should also be applied at GAW stations outside of Europe.
- CAS recommended to carry out vertical profiling for aerosols, also as a bridge between in-situ observations and satellite observations, using lidars, and strive for a 3-dimensional observed distribution of aerosols and their properties by integrating available measurement platforms - in situ, ground based and satellite borne remote sensing as well as aerosol properties observed from civil aircraft (IAGOS).
- CAS recommended to plan for an integrated global aerosol observation system. It should foster aerosol-related process studies, validation of satellite sensors, model development and evaluation, assimilation of aerosol data into operational models, and comprehensive aerosol climatology on a global scale.
- CAS recommended to learn from the MACC-II European project how it provides global environmental predictions and to try out the magnitude of the aerosol direct effects on numerical weather prediction in the ECMWF/IFS system.
- CAS underlined that the global air composition forecasting system needs to be complemented with higher resolution aerosol models covering regional and urban scales (megacities), which allow addressing air quality and health impacts in particular.
- MACC-II European project can provide a way forward. Aerosol modelling exercises and model intercomparisons, such as conducted in WGNE (aerosol-NWP), AEROCOM (global aerosol), SDS-WAS RC NA-ME-E (Dust) or AQMEII (air quality), are necessary for progress.

Urbanization: Research and services for megacities and large urban complexes

- CAS realized that it is essential to establish capabilities in urban areas for the provision of necessary environmental information for them to function safely and well. CAS noted that cross-cutting coordination and collaboration is required, as in many cases several wide ranging agencies have responsibilities for providing services that are impacted by weather and climate.
- CAS appreciated the initiative to develop comprehensive guidelines for establishing weather, climate, water and related environmental services for megacities and large urban complexes (referred to as Integrated Urban Weather, and Climate Services).
- CAS recommended that the service needs of cities be included in evolving priorities of the Global Framework for Climate Services. In this regard the Commission recommended that the coupled high resolution modelling requirements of the urban environment be considered by the Working Group on Numerical Experimentation in cooperation with the working groups on Mesoscale Meteorological Forecasting Research and Data Assimilation and Observation Systems, and GURME.
- CAS further requested that urban requirements be considered in future integrated observing systems and also by WWRP in the THORPEX legacy projects on High Impact Weather (HIWeather) and Sub-seasonal to Seasonal prediction (S2S).
- CAS viewed the collaboration between CAS and CBS as well as that between the RES and WDS Departments of WMO as critical elements towards establishing a collaborative activity on megacities and large urban areas. The Commission recommended for this activity to be brought up to the next Executive Council and then to the next WMO Congress.
- CAS noted that this initiative also offers opportunities to expand cooperation with WHO and other agencies. CAS requested for Members to consider establishing an international coordination office for the megacity and large urban complexes activity and seconding experts, and encouraged Members to make resources available for support to the project.

WMO

GURME – Research to Applications



Future Earth is a new 10-year international research initiative that will develop the knowledge for responding effectively to the risks and opportunities of global environmental change and for supporting transformation towards global sustainability in the coming decades.

IUGG IAMAS considered (Davos, 2013)

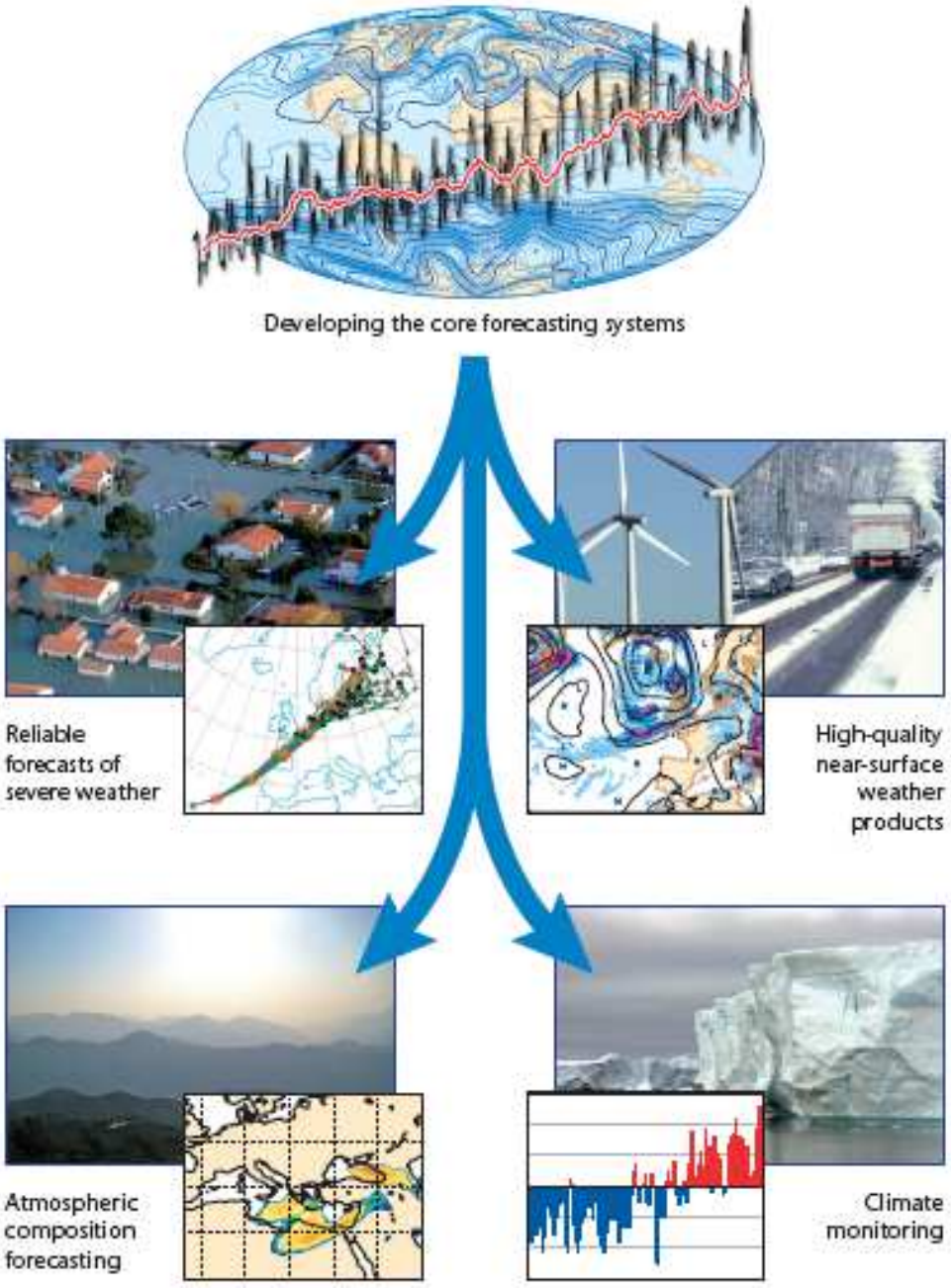
- Air quality and climate variability and trend;
- Complex air quality/climate models;
- Risks of climate engineering, geoengineering.

EUMETSAT EPS Program

Metop-A 2006
Metop-B 2012
Metop-C 2017

„Weather, Climate, Environment”

ECMWF Strategic Plan, 2011-2020



Monitoring Atmospheric Composition and Climate (MACC-II)

Thanks for your attention !