UNECE Group of Experts on Climate Change impacts and adaptation for international transport networks

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Climate change: an overview of the scientific background and potential impacts affecting transport infrastructure and networks

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Purpose and scope of the report

- To assist the work of the UNECE Group of Experts, in accordance with its agreed work programme and objectives

- Effective adaptation action for International Transport Networks (ITN) requires a good understanding of the potential climate change (CC) impacts, that may vary in type, range and distribution, depending on climate change factor as well as on

  - Region/local vulnerability
  - Mode of transport
  - Infrastructure, services, operation

- Report represents a first step to take stock of some of the available information on CC impacts on international transportation infrastructure

  - in the ECE region and beyond
  - including their type, range and distribution across different regions and transport modes

Structure of the draft report

- Short review of the scientific background of Climate Change and its implications on a global scale and in the UNECE region (Section 2).

- Review some of the potential impacts of climate change on international transport networks (Section 3),

  - identifying particularly issues pertinent to transport infrastructure in the UNECE region;
  - taking into account the different modes of transportation.

- Brief overview of some of the particularly pertinent studies relating to different modes of transportation (Section 4)

- Some additional literature of relevance to the further study of climate change impacts on international transport networks (Annex).

Synopsis

Climate Change: The Physical Basis

- Phenomenology: in which way is the climate changing?
  - Temperature, sea level rise and precipitation trends
  - Extreme events
- Mechanism: what are the processes involved?
- Feedbacks and tipping points: concerns about dangerous climate change

Climate Change Implications for Transport

- Impacts in polar areas
- Impacts on coastal areas
- Riverine floods
- Heat waves and Droughts
- Permafrost

Select studies on climate change impacts on transport

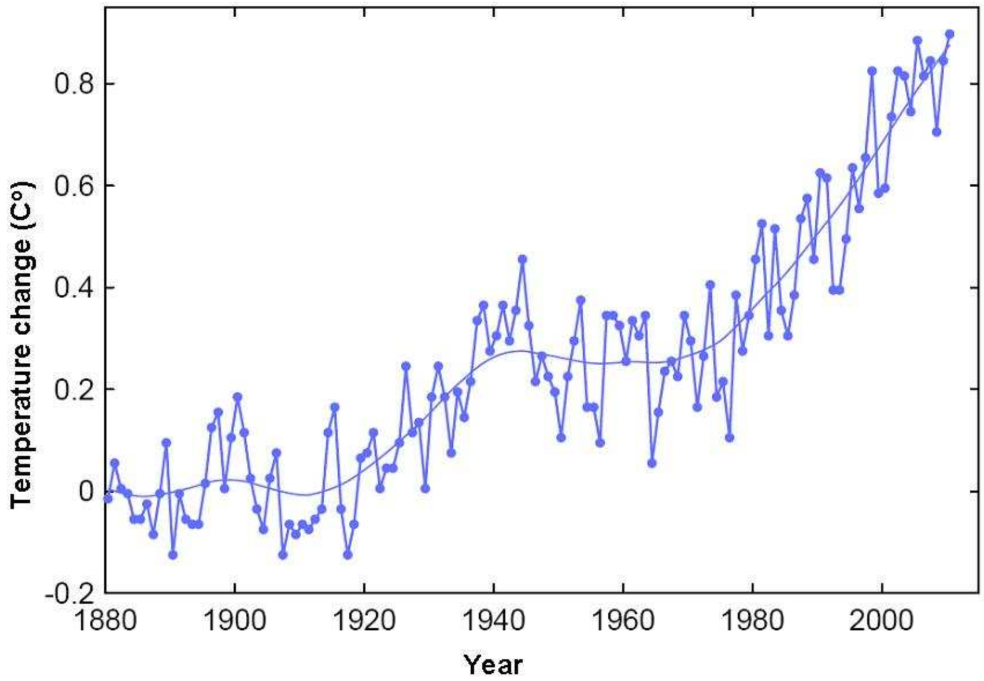
Phenomenology: how the climate is changing?

Climate Change (CC): defined as a change of climatic conditions relative to a reference period, i.e.:

- **Period with first accurate records (1850s-1860s) or**
- **Average climate of periods with accurate climatic information and infrastructure used today (e.g. 1961-1990 1980-1999**)

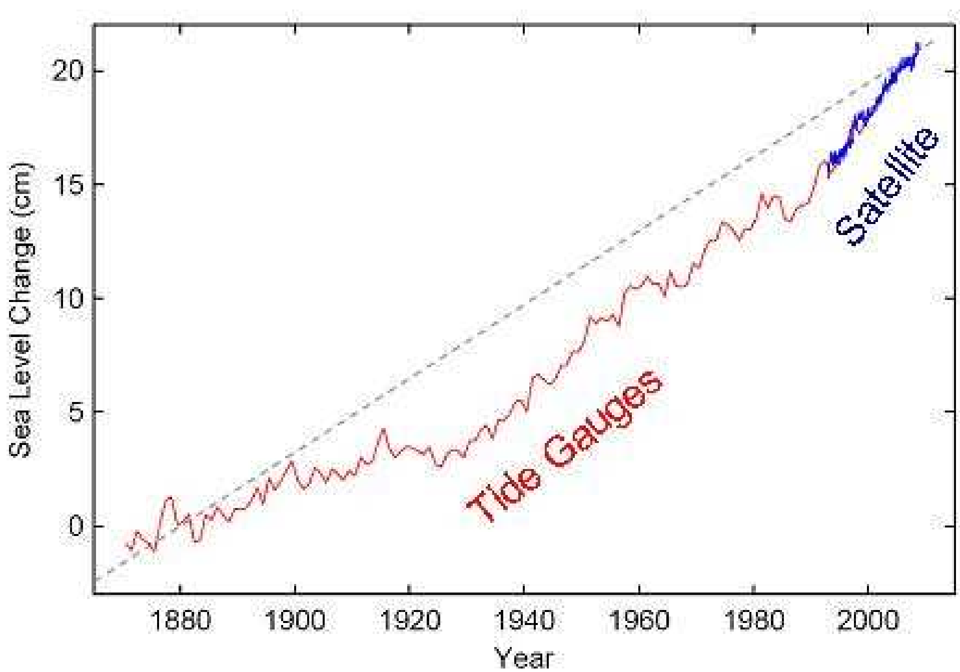
- **Temperature, sea level and precipitation trends**
- **Polar Ice loss**
- **Extreme climate events**

- **There are also feedbacks/tipping points. i.e trends can be changed by** reinforcing (or negative) feedbacks and if thresholds are crossed trends will not be linear and reversible, but abrupt, large and (potentially) irreversible in human temporal scales.



Mean temperature rise 1880-2010. NASA Data (Rahmstorf, 2011).

Projections for 2100:
- Increase 0.5 - >6.0 °C, depending on the scenario (IPCC, 2007)



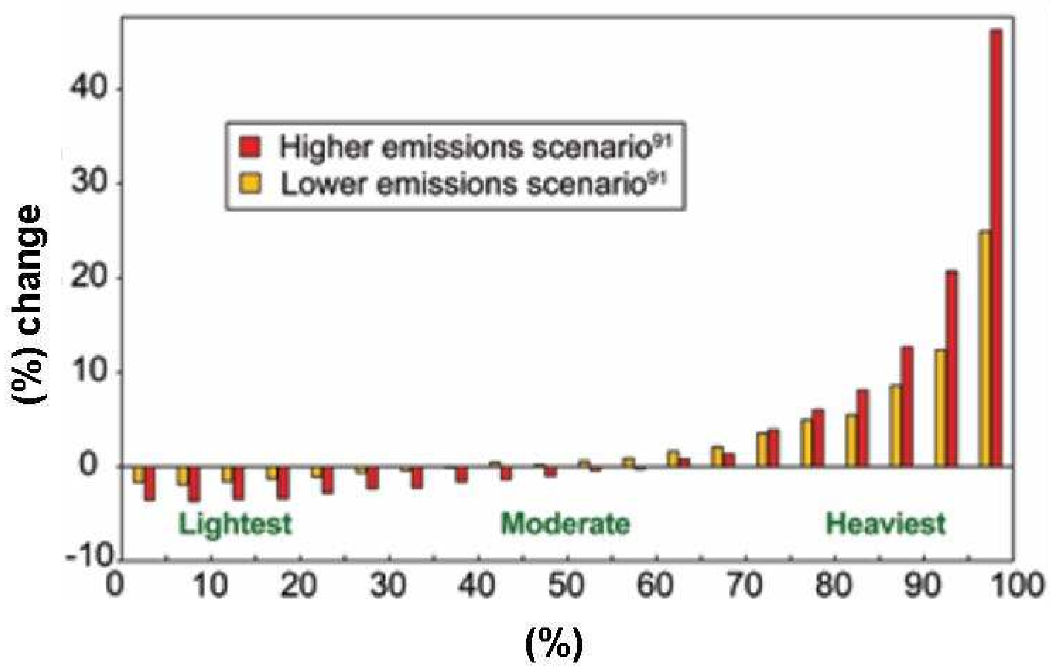
Global sea level changes 1860-2010 (Rahmstorf, 2011).

Projections for 2100:

- 0.22 - 0.60 m (IPCC, 2007)
- > 1 m if the melt of Ice sheets is included (Rahmstorf, 2007)

above the mean sea level of 1980-1999

Precipitation changes



***Projected changes in precipitation between 1990-1999 and 2090-2099 (N. America). Light, moderate and heavy events (Karl et al., 2009*).**

Spatial Variability (IPCC, 2007)

Mostly wetter to the north and dryer to the south of the UNECE region

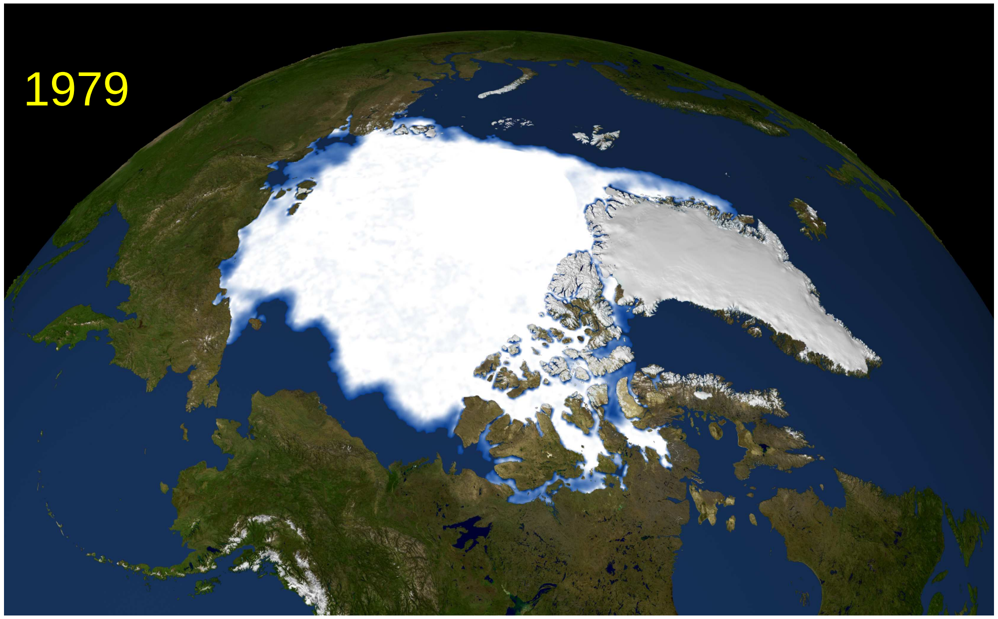
- <u>Very likely (> 90%)</u> increase in N. Europe, Canada, NE USA and N. Asia and decrease in S/ Europe

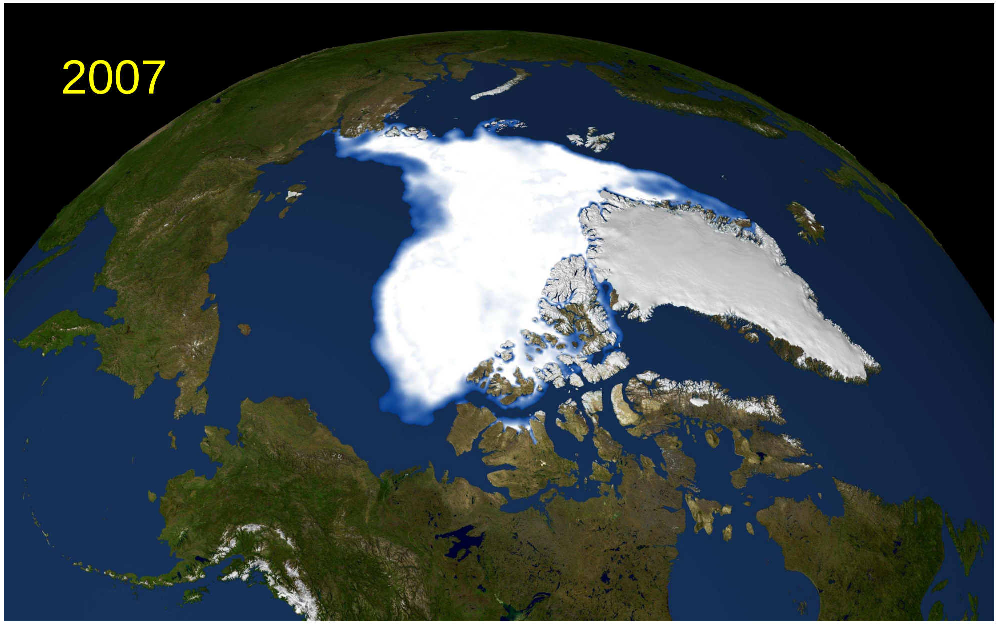
- <u>Likely (> 66%)</u> increase in extreme rainfall events in N. Europe and N. Asia and

- LIkely <u>(> 66%)</u> increase in draughts in S. Europe

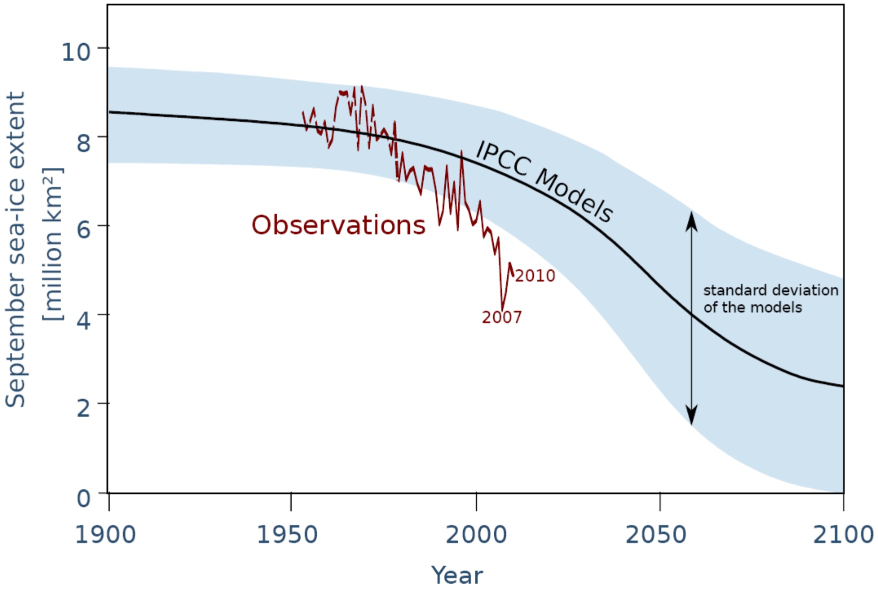
- <u>Very likely (> 90%)</u> snowfall derease in Europe and N. America

1979-2007: rapid summer Arctic ice loss





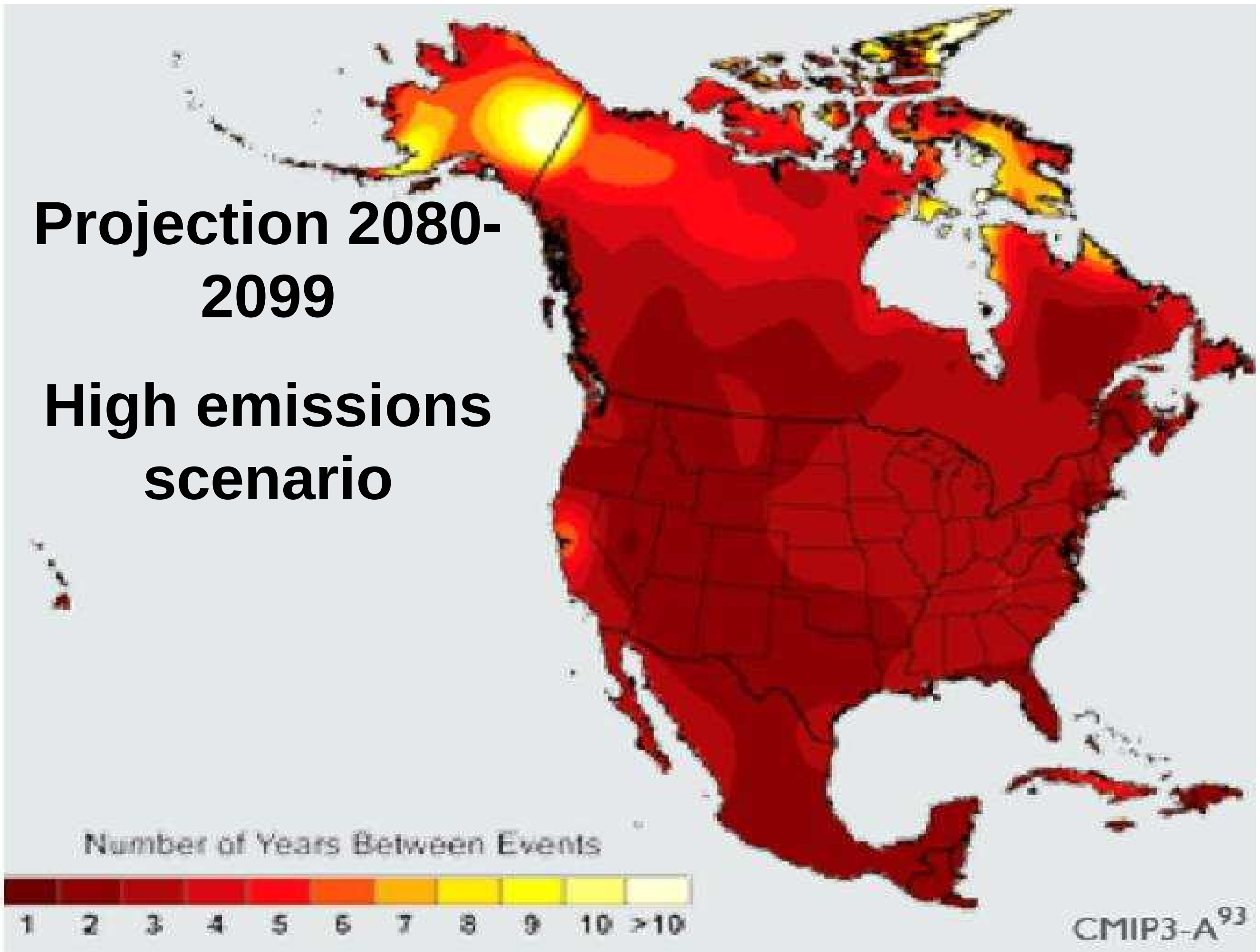
Trends from models (1990-2100) and observations (1950-2010) (Rahmstorf, 2011)



Likelihood of extreme events (IPCC, 2007)

Phenomenon/ trend	Likelihood that trend occurred in late 1900s (post 1960)	Likelihood of a human contribution to observed trend	Likelihood of future (2100) trends based on IPCC scenarios
Fewer cold days/nights over most land	Very likely	Likely	Virtually certain
More frequent hot days/nights over most land	Very likely	Likely (nights)	Virtually certain
Warm spells/heat waves frequency increases over most land	Likely	More likely than not	Very likely
Heavy precipitation event frequency increases over most areas	Likely	More likely than not	Very likely
Area affected by droughts increases	Likely in many regions since 1970s	More likely than not	Likely
Intense tropical cyclone activity/storm surge increases	Likely in some regions since 1970	More likely than not	Likely

Projections: More frequent extreme heat waves

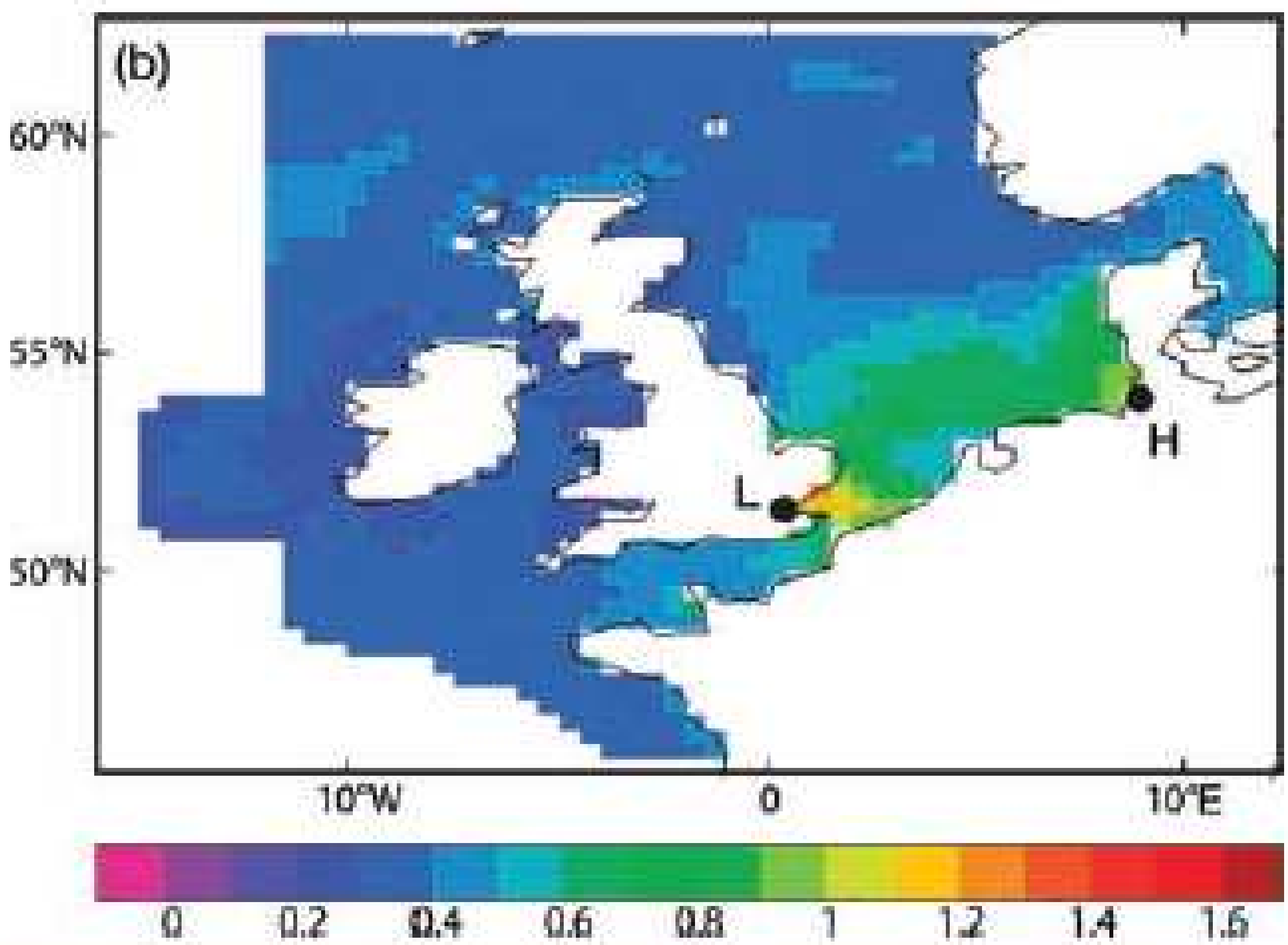


Projection 2080-2099

High emissions scenario

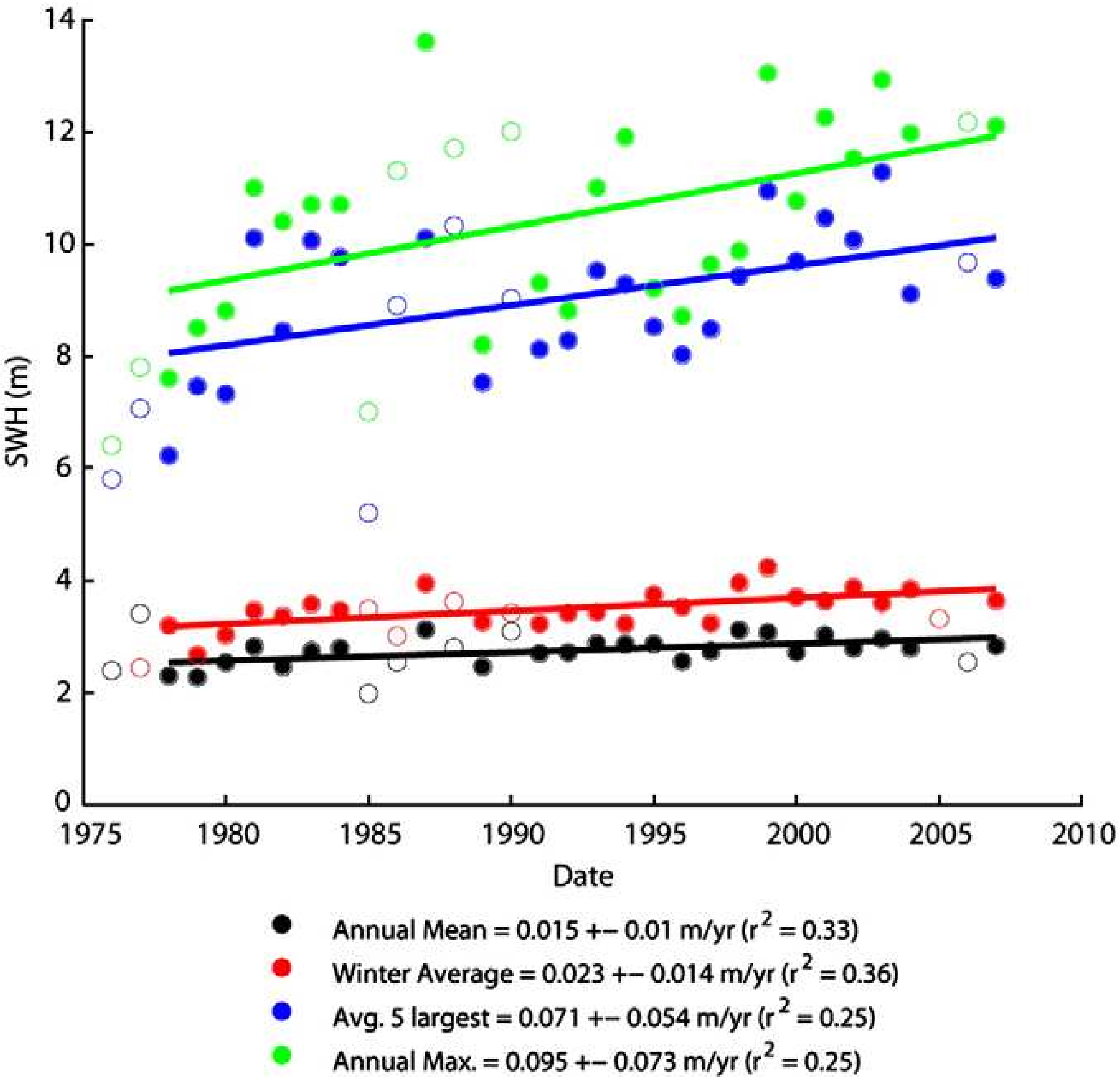
Extreme heat waves (1-in-20-year events) are projected to be more frequent in N. America (Karl et al., 2009)

Projections: More frequent extreme sea levels



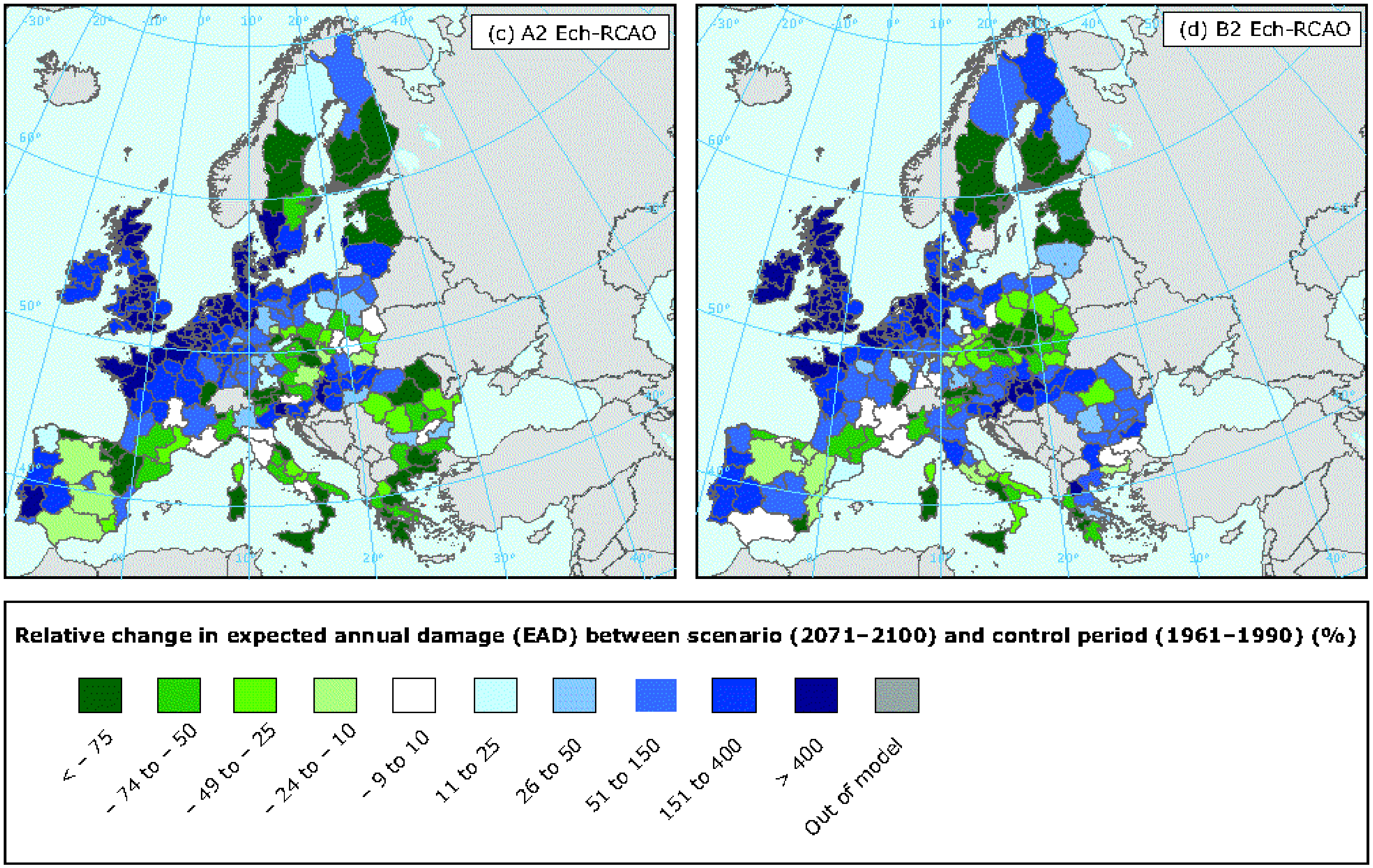
Projected increase in the 1-in the-50-year extreme sea level in 2080 (A2 scenario) (L – London; H – Hamburg) (after Lowe and Gregory, 2005).

Current trends: More energetic extreme waves



Increases in the annual mean, winter averages, mean of the highest annual waves and annual maxima significant wave heights at the NDBC #46005 platform (NE Pacific). The annual maximum significant wave height has increased 2.4 m! in the last 25 years. (Ruggiero et al., 2010).

Projections: Riverine Floods



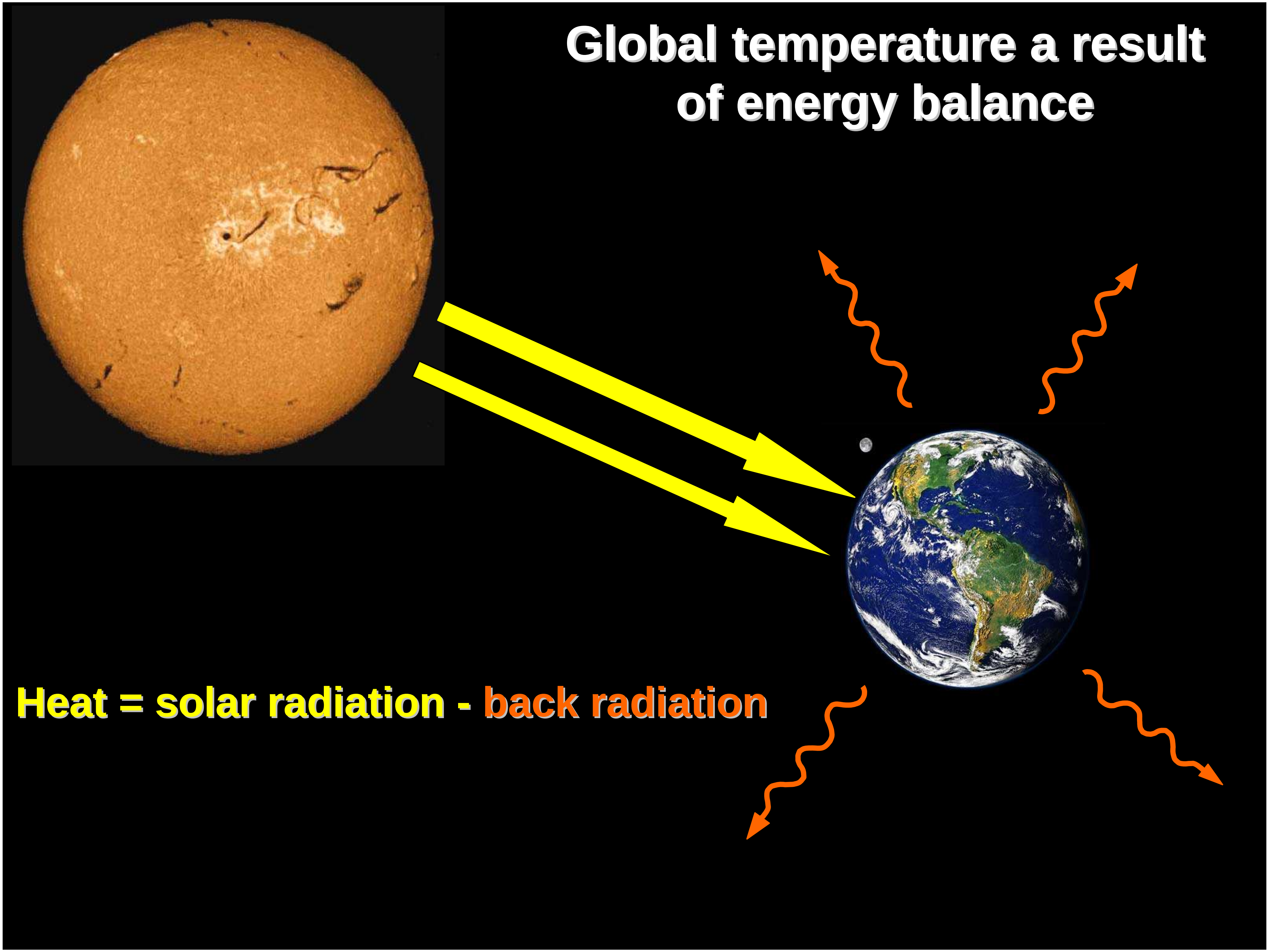
Relative changes in Expected Annual Damage (EAD) from riverine floods, between 2071–2100 and 1961–1990 in Europe (EC JRC, 2010)

Climate controls: what are the processes involved?

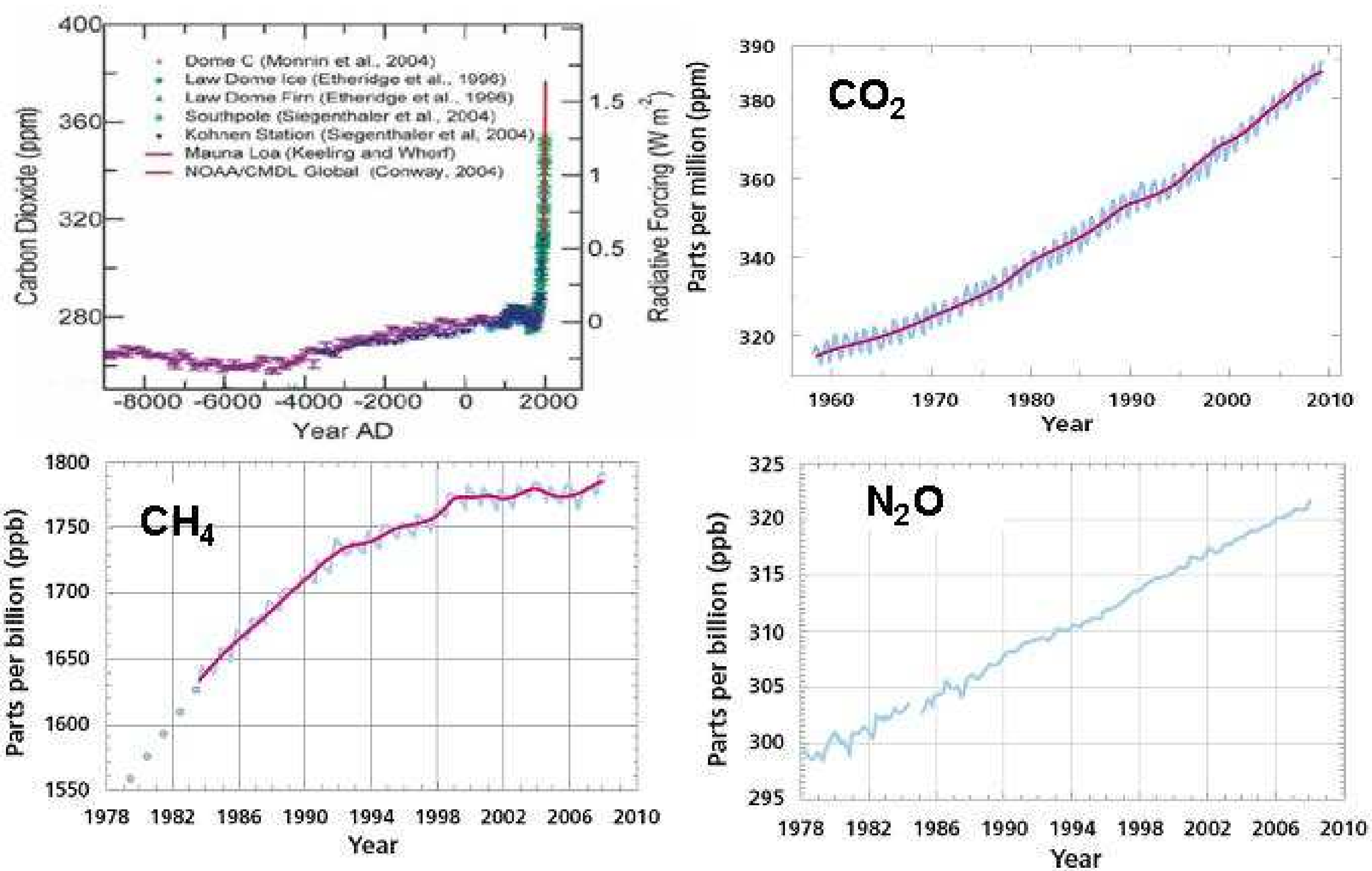
- **Climate is controlled by solar heat inflows/outflows**

- **A major cause of the observed increase in the planet's heat content is the increasing atmospheric concentrations of greenhouse gases (GHGs) that absorb heat reflected back from the Earth's surface**

- **Variability both natural and human induced**


Global temperature a result
of energy balance
Heat = solar radiation - back radiation

Trends in GHG atmospheric concentration



Atmospheric CO2 concentration (in parts per million) during the last 11000 years (Rahmstorf, 2011) and the last 50 years. The concentrations of the CH4 and N2O (in ppb-parts ber billion) since 1978 are also shown (Richardson et al., 2009).

International transport network sensitivity to Climate Change

Long lifetimes of key assets, sensitive to climate

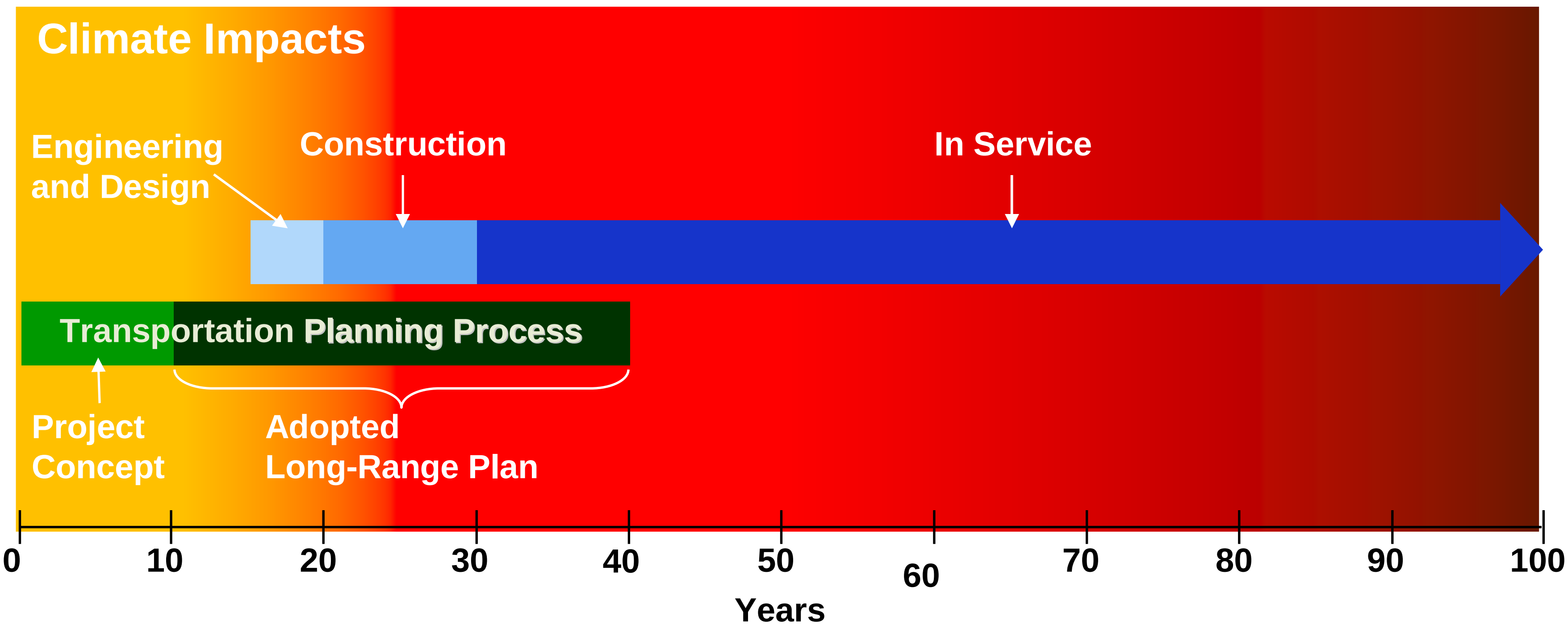
Locations of assets often exposed to climate impacts (ports, inland waterways, roadway and railway networks in flood plains etc)

Interdependence of transport and trade: transport is demand driven (indirect impacts, e.g. agriculture)

Relatively few studies, particularly in terms of adaptation measures, although large costs are expected

<u>Important: Understanding of key vulnerabilities to CC</u>

Transportation Timeframes vs. Climate Impacts



Source: Savonis, 2011

CC impacts study Coverage for European sectors

Sector	Coverage	Cost estimates	Benefit estimates
Coastal zones	Very high — infrastructure/erosion for Europe, regions, several countries as well as cities/local examples.	√√√	√√√
Energy	Medium — cooling/heating demand (autonomous adaptation) for Europe, some countries. Less on planned adaptation and supply *.	√√	√√
Infrastructure	Medium — adaptation cost estimates in several countries for flooding, but lower coverage of other infrastructure risks.	√√	√
Agriculture	High — coverage of farm-level autonomous adaptation benefits, but much less on costs and on planned adaptation.	√	√√
Health	Low/medium — adaptation costs for heat alert systems and food-borne disease, but less coverage of other health risks.	√	
Water	Low/medium — limited number of national, river basin or sub-national studies on water supply.	√	
Transport	Low/medium — some national and individual sector case studies.	√	
Tourism	Low — studies of winter tourism (Alps) and some of autonomous adaptation from changing summer tourism flow *.	√	√
Forestry and fisheries	Low — limited number of quantitative studies.	√	
Biodiversity/ecosystem services	Low — limited number of quantitative studies.	√	
Business and industry	Very low — no quantitative studies found.		
Building adaptive capacity	Low — selected studies only and only qualitative descriptions of benefits.	√	

Note: * can be considered an impact or an adaptation. See Watkiss and Hunt (2010) for extra notes and caveats.

Key: √ Low coverage with a small number of selected case studies or sectoral studies.
√ √ Some coverage, with a selection of national or sectoral studies.
√ √ √ More comprehensive geographical coverage, with quantified cost or benefit estimates at aggregate levels.

Source EEA, 2010

Climate Change Implications for Transport

Significant impacts on transport infrastructure and operations expected

In polar areas

- longer shipping season in Arctic, shorter shipping routes-NWP/less fuel costs, but, possibly, higher costs for new support services

In coastal areas

In river flood plains

Due to heat waves and droughts

Due to permafrost

Coastal areas

- **Increased coastal flood and inundation risks;**
- **erosion of coastal areas and damages to port infrastructure, equipment and cargo;**
- **increased port construction and maintenance costs;**
- **changes in port/navigation channel sedimentation patterns;**
- **relocation of people/business, labour shortages and insurance issues**

Impacts on coastal areas: roads

Source: P. Peduzzi, 2011

Impacts on coastal areas: roads

Impacts on coastal areas: airports e.g. Kingston (Jamaica)

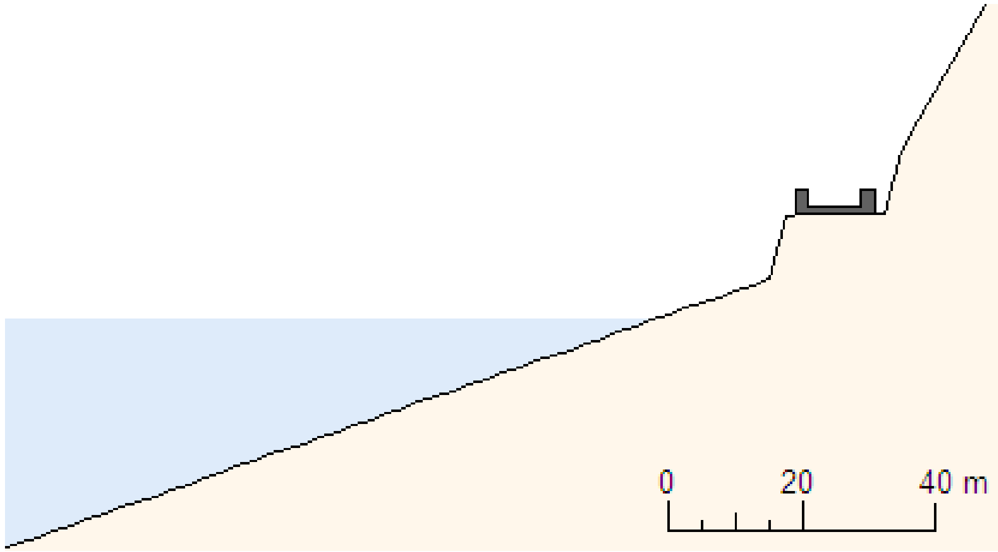
Impacts on coastal areas: railways

Impacts on coastal areas: railways

Retreat projection
18.8 m

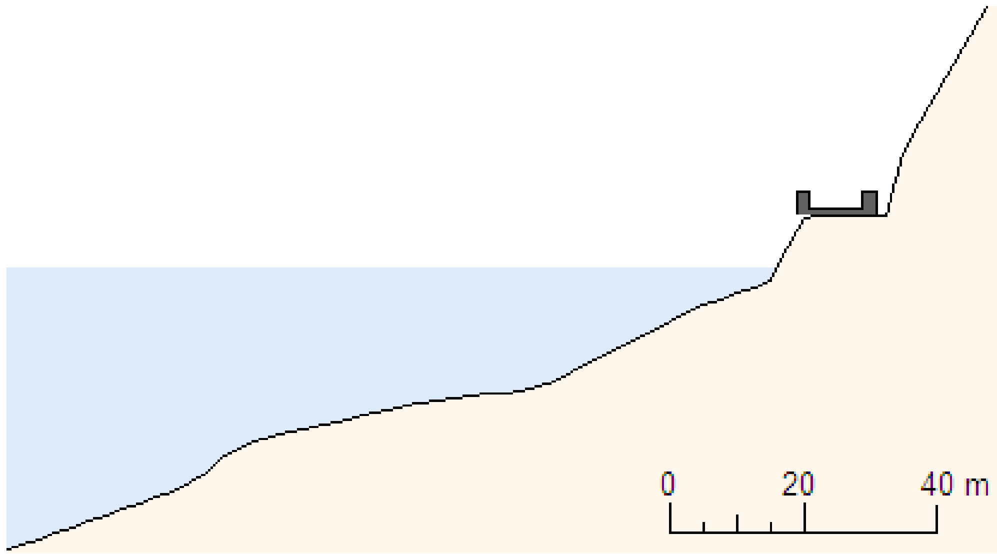
Coastal retreat-inundation under 1 m sea level rise (mean + storm surge. Beach slope: 1/15; offshore wave height (H): = 4 m/; Period (T) = 7.9 sec, sediment median diameter d_{50} = 0.8 mm

Leont' yev Model



Present normal conditions

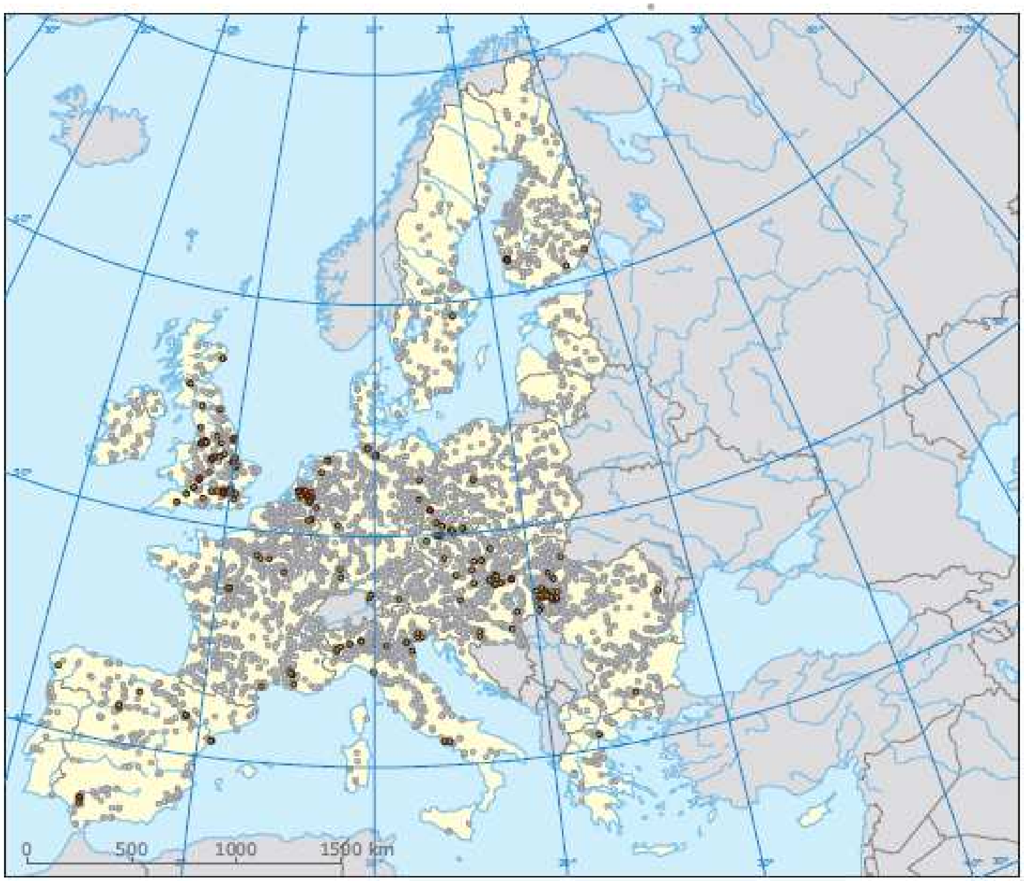
Storm surge 1 m

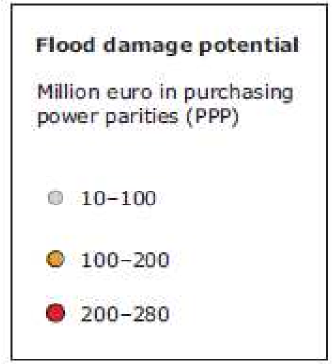


River flood plains

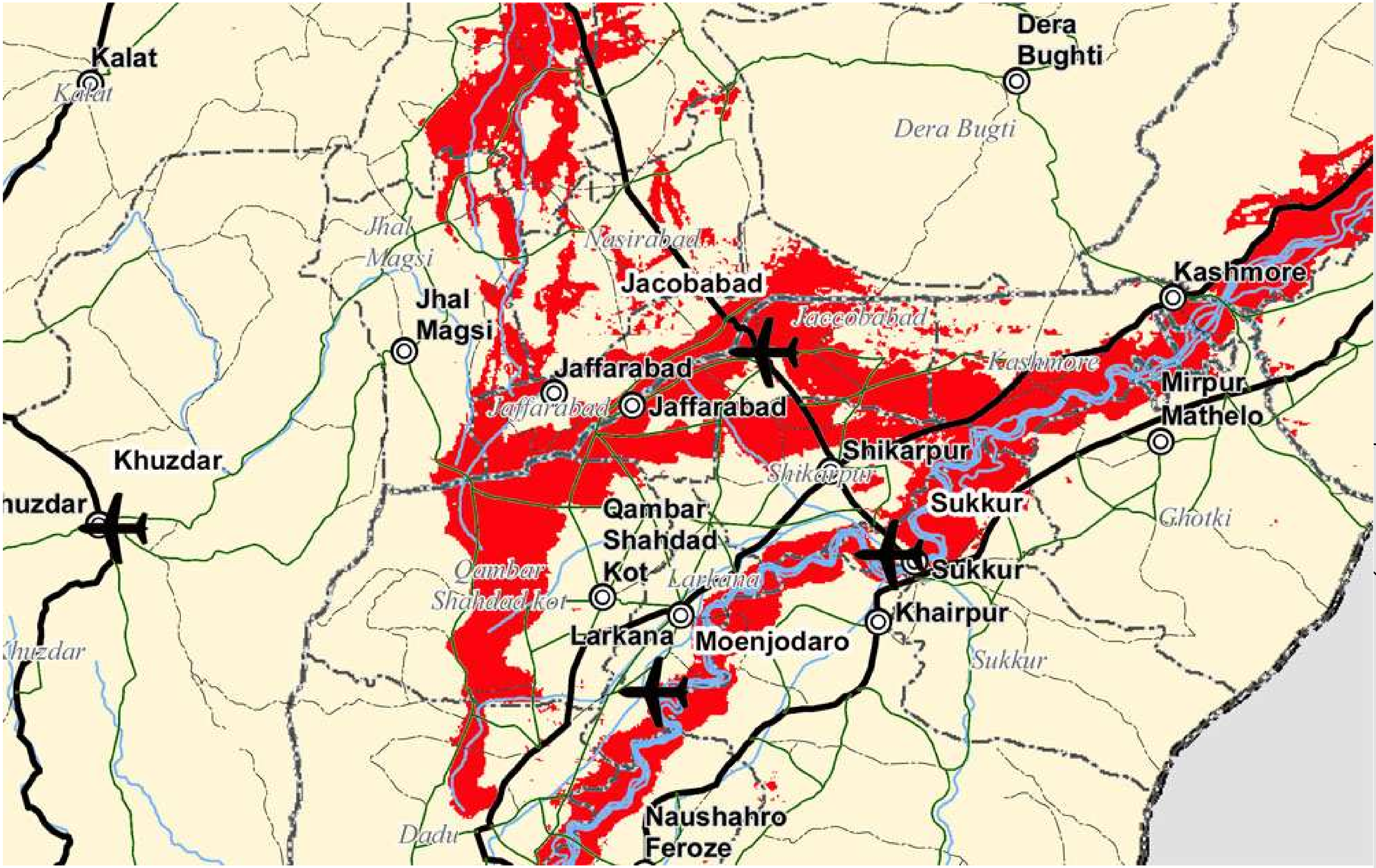
- Increased flooding/inundation risks for transport networks;
- impacts on inland waterway navigation;
- damages and/or destruction of vital transport nodes (e.g. bridges)

Impacts on river flood plains





Flood damage potential in Europe (EEA, 2010). The estimations have been based on the assumption of a 100-year return period event (i.e. the record flood in 100 years), present climate and no defences. Catchments of less than 500 km2 are not included.



Source(s): MapAction; United Nations Office for the Coordination of Humanitarian Affairs (OCHA)
P.l Peduzzi, UNEP (2010). UNECE-UNCTAD Workshop

Source: P. Peduzzi, 2010
UNECE-UNCTAD
Workshop presentation.

Due to heat waves and droughts

- dilatation of badly designed railways;
- forest fire impacts on land and air transport;
- increased landslide risks affecting mountainous road and rail networks;
- damage to infrastructure, equipment and cargo and increased construction and maintenance costs;
- higher energy consumption in ports and other terminals;
- challenges to operations in inland waterways and service reliability

Impacts due to heat waves: rail dilatation

Drought & inland waterway transport

Permafrost areas

Permafrost degradation will lead to damage to

- railways, roads, bridges and pipelines;
- building foundations and airports;
- coastal infrastructure

and lead to increased construction and maintenance costs

Permafrost distribution

Melting permafrost: impacts on roads

Alaska

Melting permafrost: impacts on roads

Alaska

Melting permafrost: impacts on coasts

Alaska

Select studies on CC impacts on transport

The US Gulf Coast Study
- **Gulf Coast Study, Phase I**
- **Gulf Coast Study, Phase II**

PIANC Study

Scottish Road Network Climate Change Study

Climate change and the railway industry: a review

Future Resilient Transport Networks (FUTURENET)

Rail safety implications of weather, climate and climate change

Climate Adaptation of Railways: Lessons from Sweden

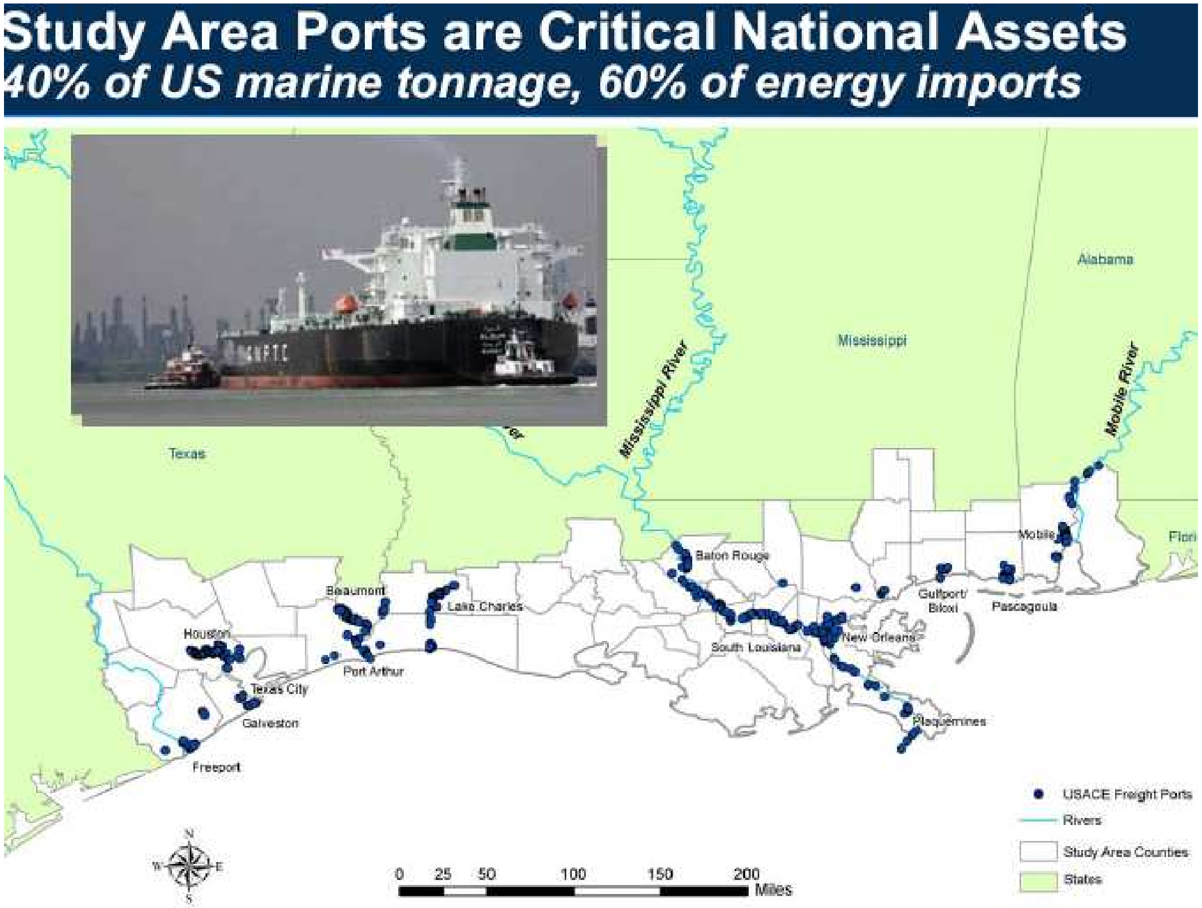
Railway construction techniques in permafrost regions

Quantifying the effects on rail of high summer temperatures

ARISCC Adaptation of Railway Infrastructure to Climate Change

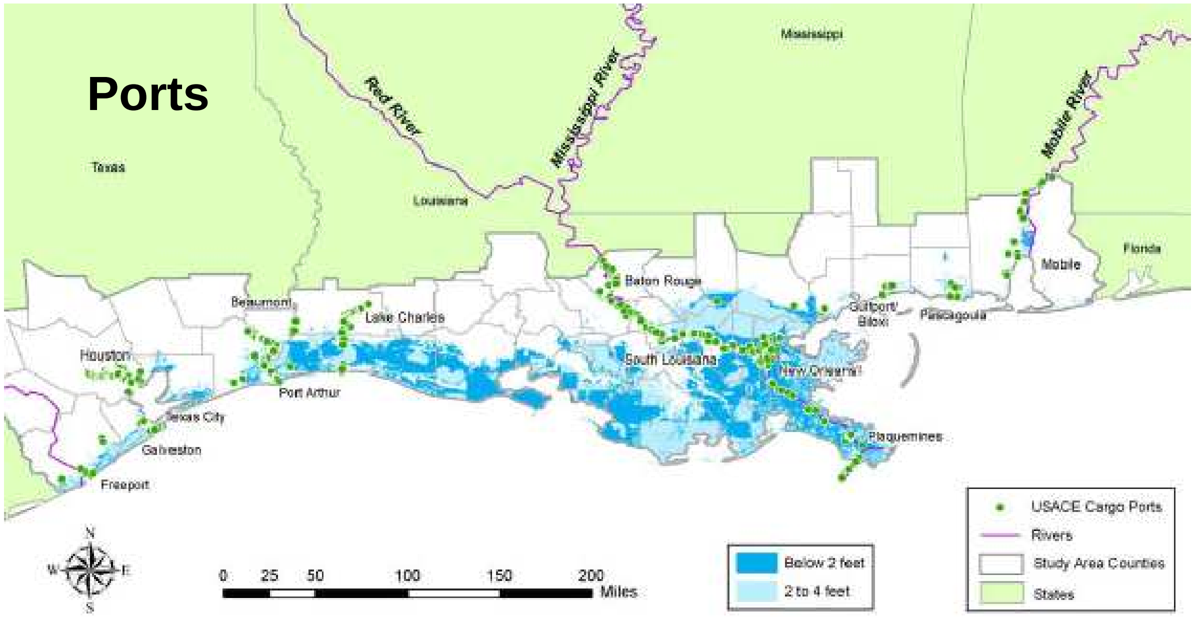
Climate Risk and Business: Ports

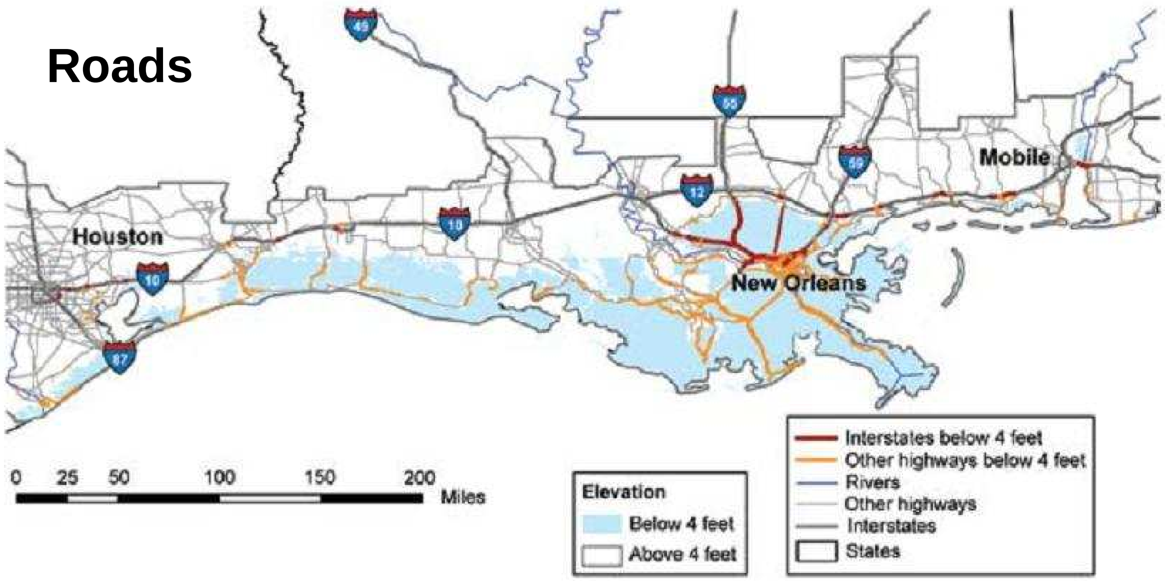
US Gulf Coast study



Ports and other infrastructure assets at risk along the US Gulf coast (US Gulf Coast Study (Savonis 2009))

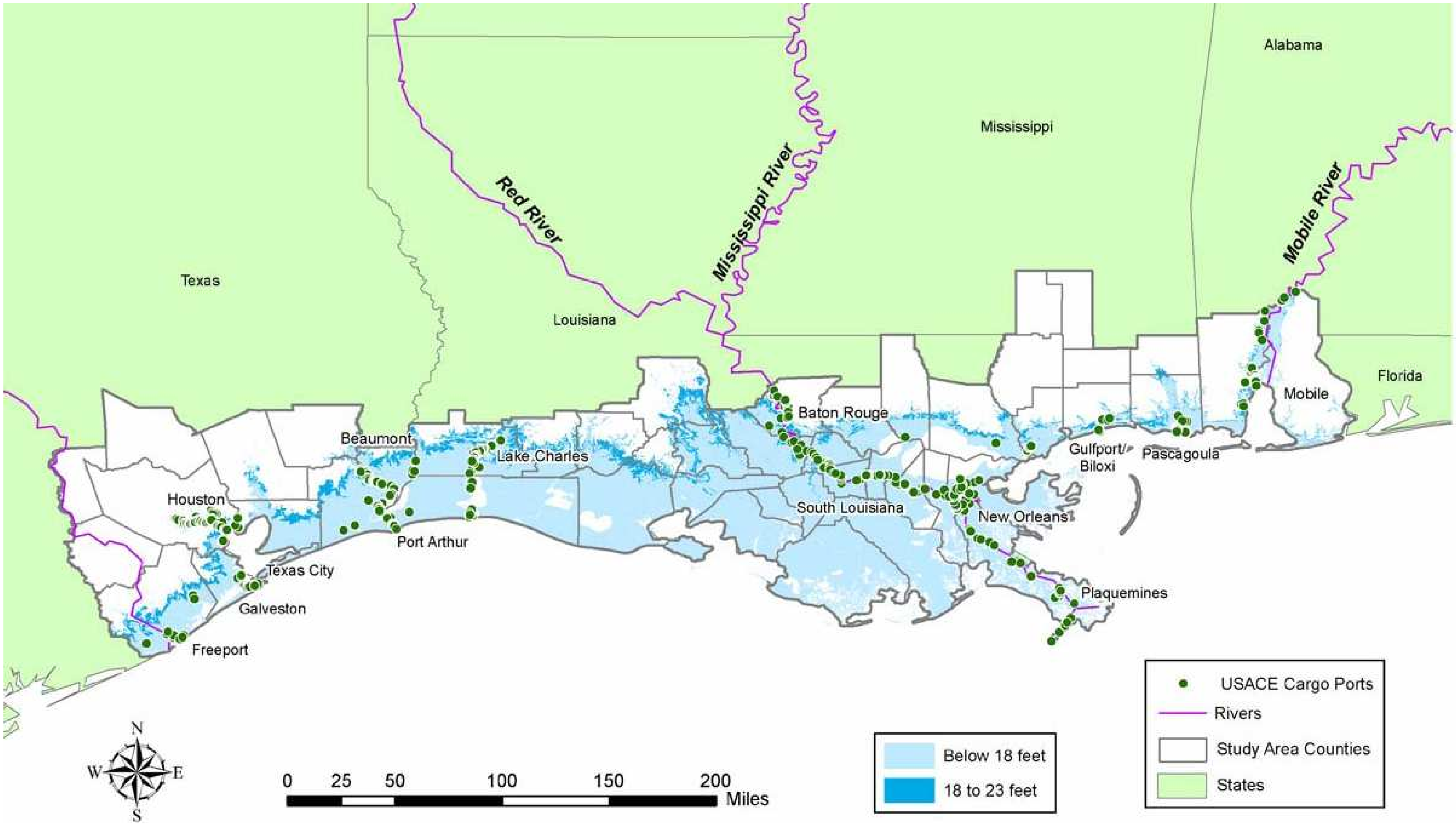
US Gulf Coast study





Flood risk at US Gulf coast under sea level rise 0-6-1.2 m (MSL + storm surge). Relative sea level rise of ~1.2 m (4 feet) could inundate more than 2400 miles of roads, over 70% of the existing port facilities, 9% of the railway lines and 3 airports;

US Gulf Coast study



In the case of a ~5.4-7 m storm surge, more than 50% of interstate and arterial roads, 98% of port facilities, 33% of railways and 22 airports in the US Gulf coast would be affected (CCSP, 2008).

Thank you!