UNECE Group of Experts on Climate Change Impacts and Adaptation for Transport Networks and Nodes, 22nd June 2017, Geneva

Overview of Recent Climate Change Trends and Projections Affecting Transportation in the ECE Region

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Presentation Synopsis

Chapter 1: Climate Change: Recent Trends and Projections

- Phenomenology: how is the climate changing?
- Recent climate projections
- Climate Change Implications for Transport
- Conclusions

Questionnaire: Overview of the responses

The way forward

Phenomenology: How does the climate vary and change?

Climate Variability and Change (CV & C): variability and sustained change of climatic conditions relative to a reference period (e.g. 1961-1990 1980-1999. 1986-2005)

Evidence presented in the IPCC AR5 (2013) suggests a consistent change of climatic factors →

Recent evidence suggests that transport affecting climatic factors are 'deteriorating'

- Temperature: Long-term and most recent trends →
- Precipitation →
- Arctic ice, snow and permafrost melt →
- Sea level →
- Extreme climate events →

Note: Potential feedbacks/tipping points

Most recent climate projections

Temperature projections

Snow and permafrost projections

Mean sea level projections

Extreme event dynamics

Climate Change challenges for Transport

Significant impacts on transport infrastructure/operations expected in ECE:

From extreme temperatures, heat waves and droughts

From extreme precipitation and river floods

In Arctic areas due to permafrost melt, but also opportunities due to longer shipping season and shorter shipping routes

In coastal areas due the MSL and storm waves/surges

Summary

Ample evidence to suggest a significant and, in some cases, accelerating change

The period 2011-16 was the warmest 6-year period on record for most of the ECE region

Under both low-moderate and high emission scenarios, large increases in land temperatures projected, particularly for the northern ECE region

The already diminishing sea ice/permafrost areas will be very significantly reduced

Global MSL rise in 2081–2100 projected to increase by up to 1 m; however there will be significant spatial variability

In the ECE region, very hot summers will occur much more frequently under all scenarios

Increases in heavy precipitation projected for central and NE Europe; increases in river flooding are also projected

Large increase in heat wave frequency are projected for Europe

Projections show higher ESLs for all European seas; Wave power will also increase paricularly in the Baltic and the NE and NW Pacific

Questionnaire: Overview

Few (15) responses received; limited information that could be statistically analysed

- Perceived importance of climate change: 61% low or moderate and 39 % high (15 responses)

- Critical infrastructure arteries and nodes useful for mapping: 8 responses, but numbers for ports and airport are skewed

- Perceived climatic impacts on critical infrastructure by factor and mode: information primarily for road and rail (9 responses)

- Perceived change over time of climatic impacts on critical infrastructure by mode and factor: Very limited information for roads only (10 responses)

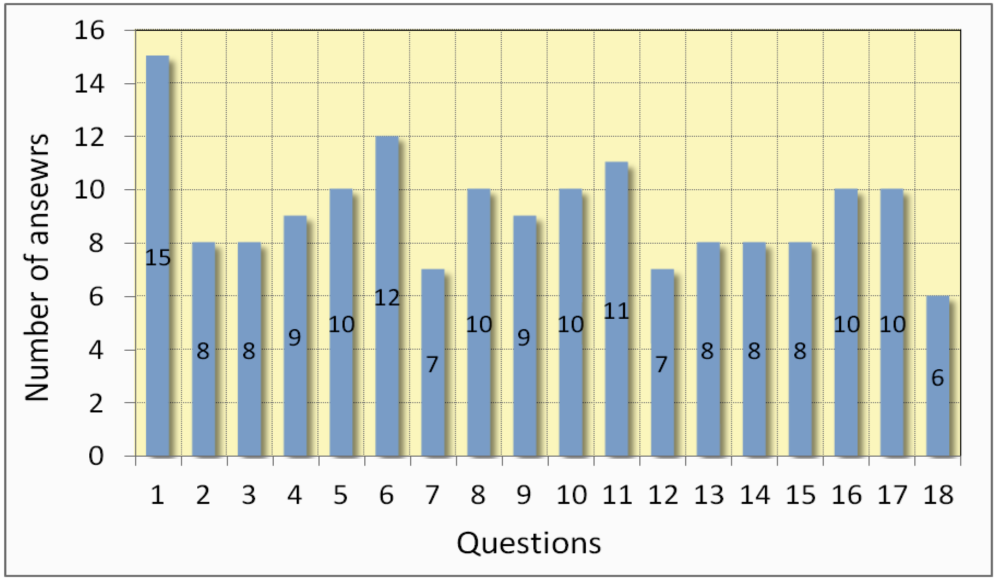
- User requests for effective response measures: 42 % yes and 42 % no (12 responses)

- Availability of information on climate change impacts by modal infrastructure: Varied answers (10 responses)

- Basis for weather/climate information used: most respondents reported both observations and modelling 10 Responses

- Availability of downscaled forecasts/assessments for critical infrastructure: where available mostly up to 50 years (11 responses)

Questionnaire: Responses received



Number of answers for each question

15 questionnaires were analysed

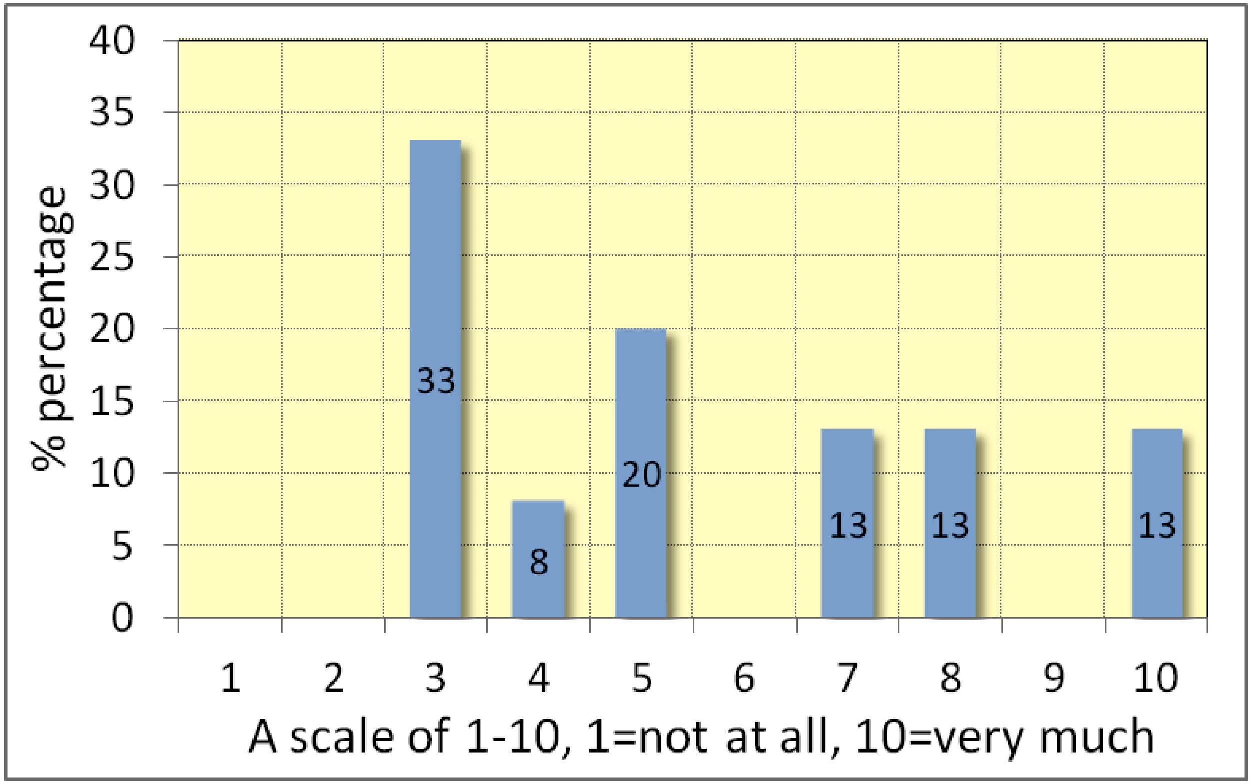
Questions statistical analysed: 1, 2, 4, 5, 6, 8, 10 and 11

Questions difficult to plot or not sufficiently answered: 3, 9, 12, 13, 14 and 15

Descriptive questions: 7, 16, 17 and 18

Perceived importance of climate change and/or extreme weather events

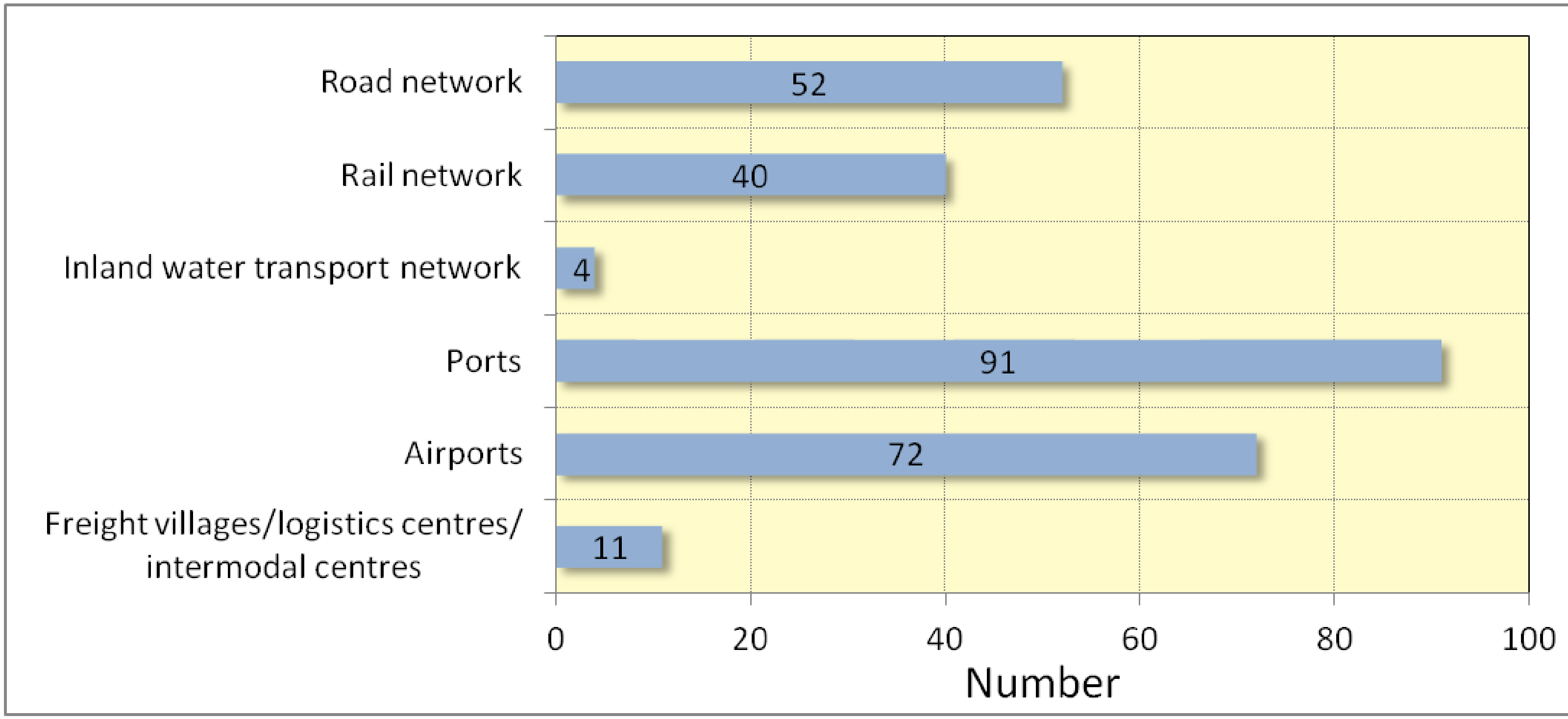
QUESTION 1: To which extent do you consider climate change and/or extreme weather events to be a problem for transport in your country/region (on a scale of 1–10)



15 Respondents

Critical infrastructure arteries and nodes

QUESTION 2: Critical transport infrastructure: Please list below the transport arteries (road, rail, inland water transport) and nodes (ports, airports, freight villages/ logistics centers/ intermodal centers) considered as critical in your country/region and specify their criticality.

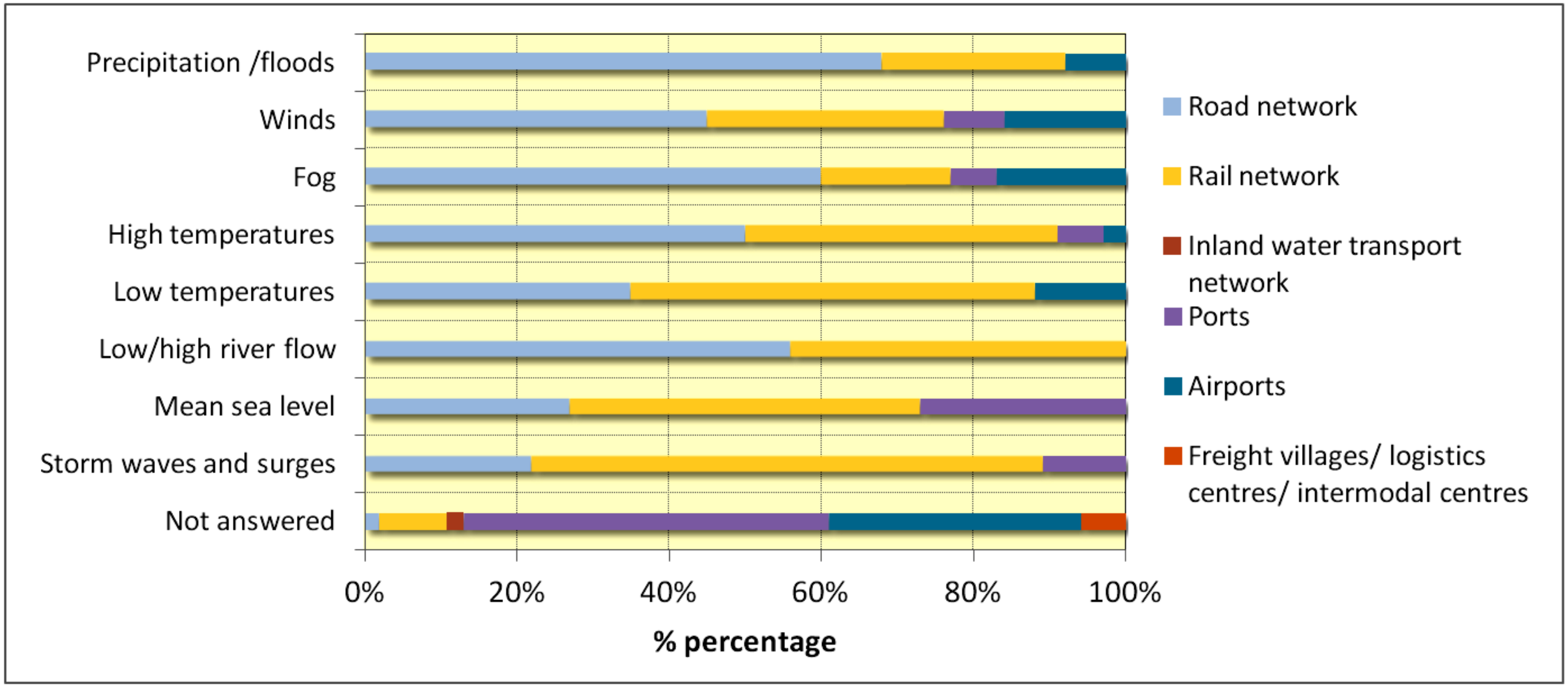


8 Respondents

Critical assets recorded. One respondent gave 2 Annexes with the list of airports (55) and seaports (71) but did not specify if they are all critical (all included here)

Perceived Climatic impacts on critical infrastructure by factor and mode

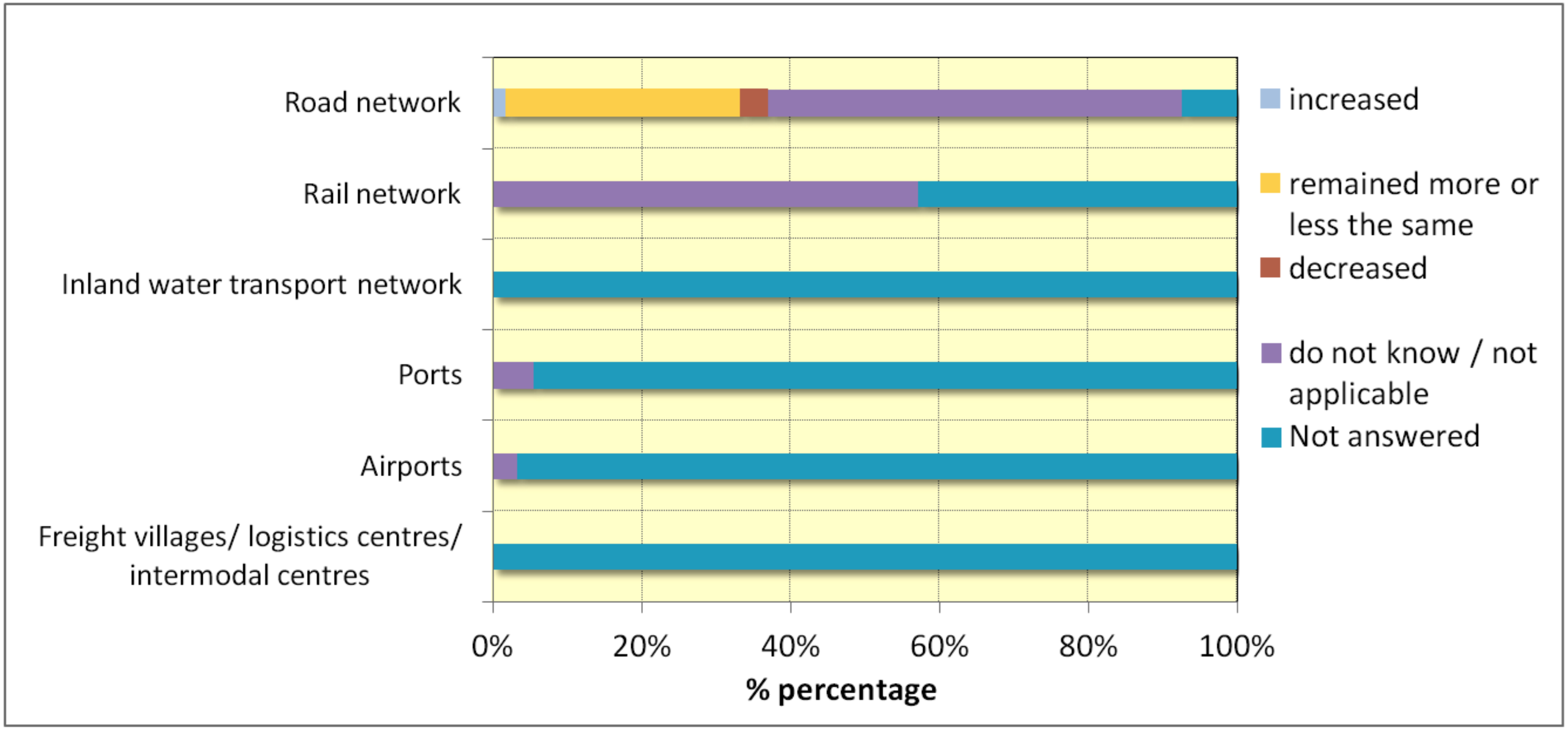
QUESTION 4: Which of the following weather or climate related factors have impacted your critical infrastructure mentioned above (check all that apply)



9 Respondents

Perceived change over time of climatic impacts on critical infrastructure by mode and factor

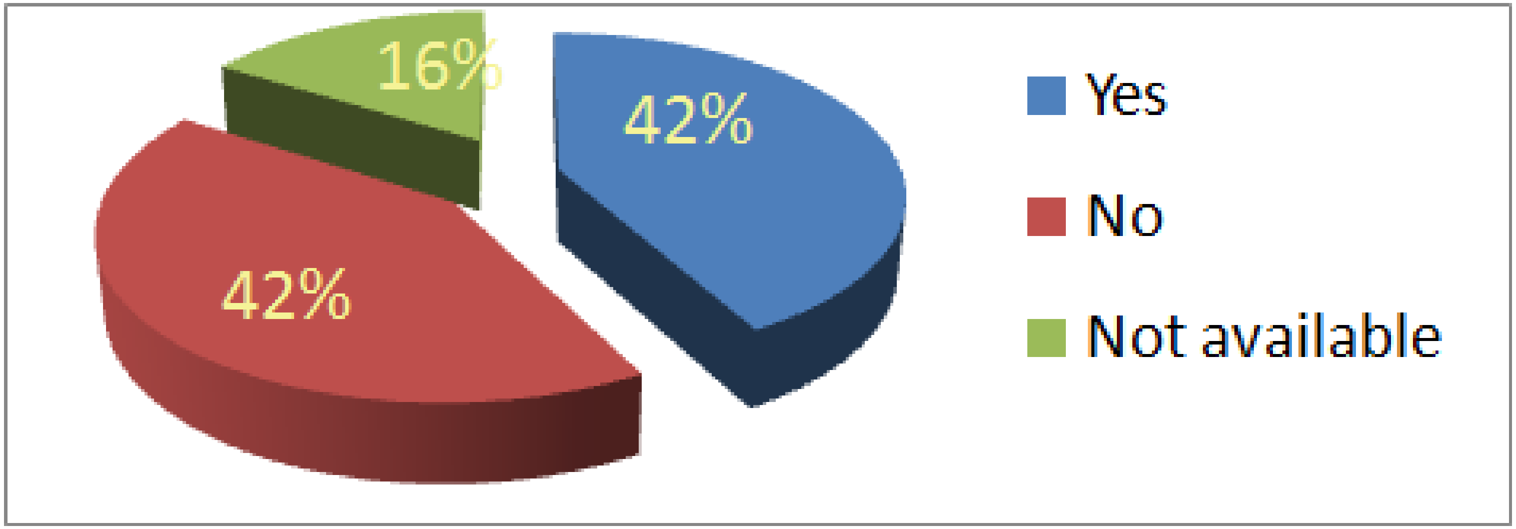
QUESTION 5: Over time, has the magnitude of damage and/or disruption caused by weather or climate related events:



10 Respondents

User requests for effective response measures

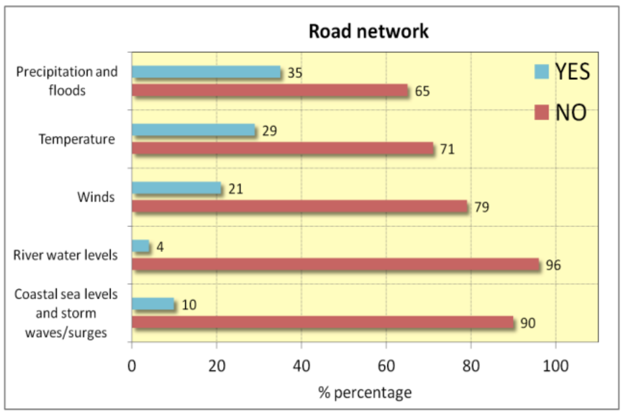
QUESTION 6: Have users of the critical infrastructure requested implementation of effective response measures?

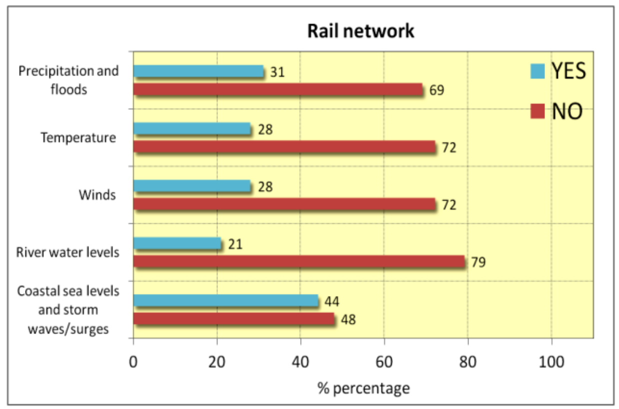


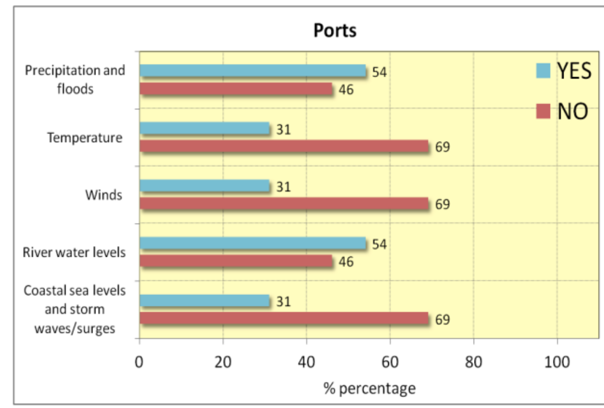
12 Respondents

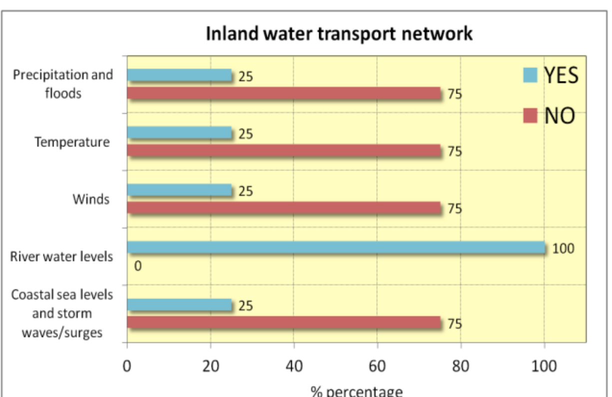
Availability of information on climate change impacts by modal infrastructure

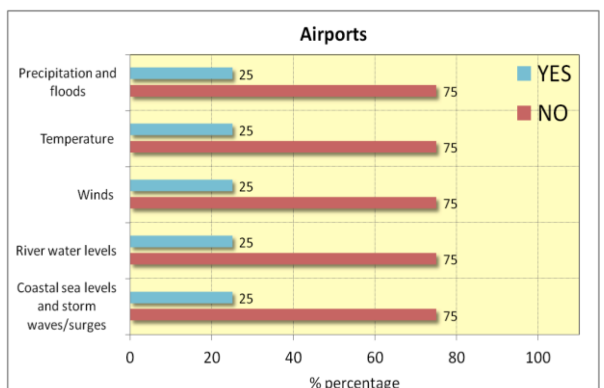
QUESTION 8: Is there information available on the following climate change impacts that have affected or will potentially affect critical infrastructure in your country/region/organization?







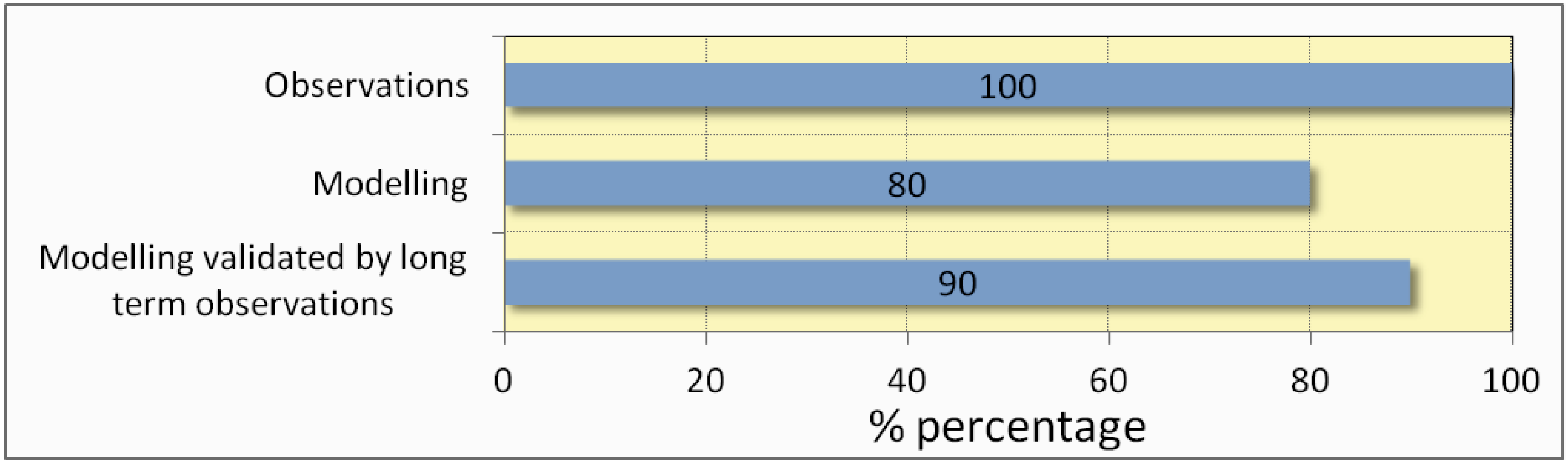




10 Respondents

Basis for weather/climate information used

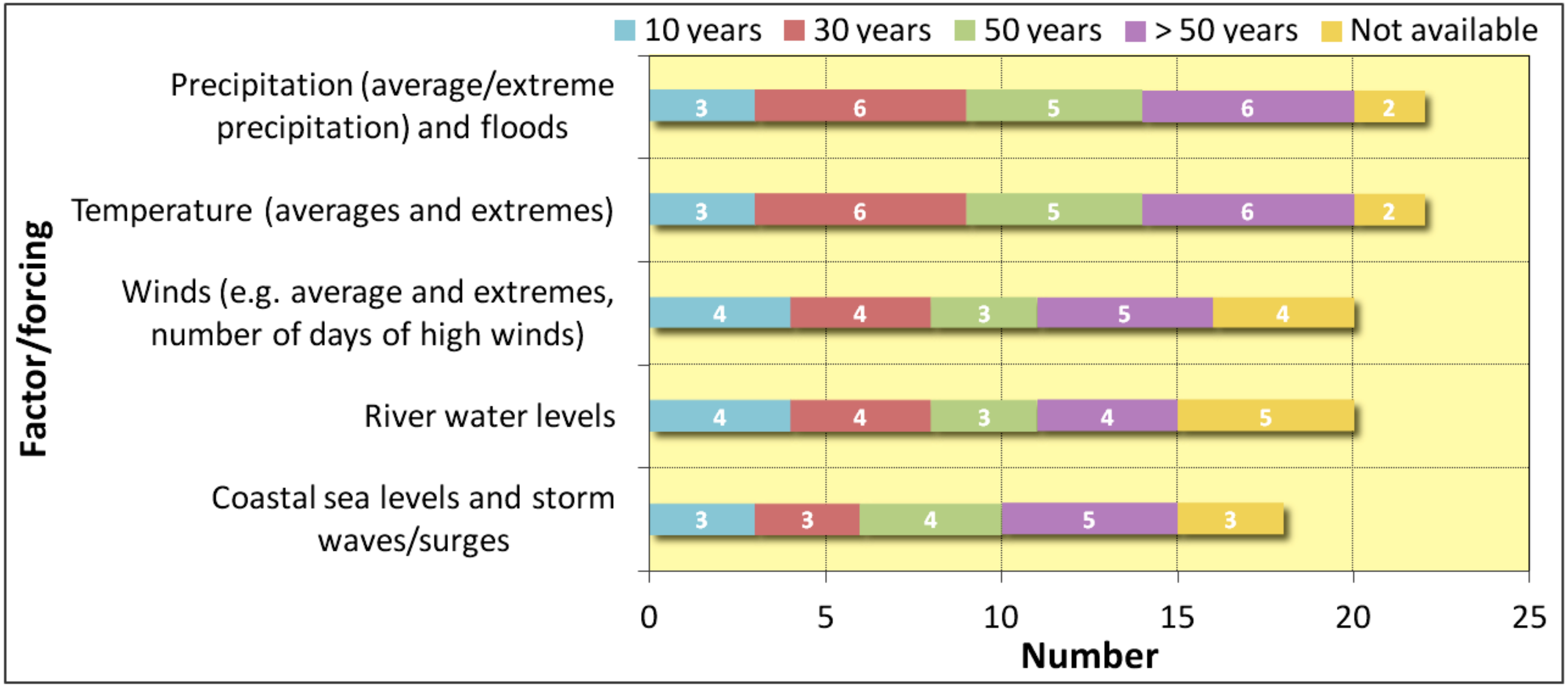
QUESTION 10: Please indicate the basis for weather/climate information used in the estimation of impacts and the design of response measures regarding your critical infrastructure (check all that apply)



10 Respondents

Availability of downscaled forecasts/assessments for critical infrastructure

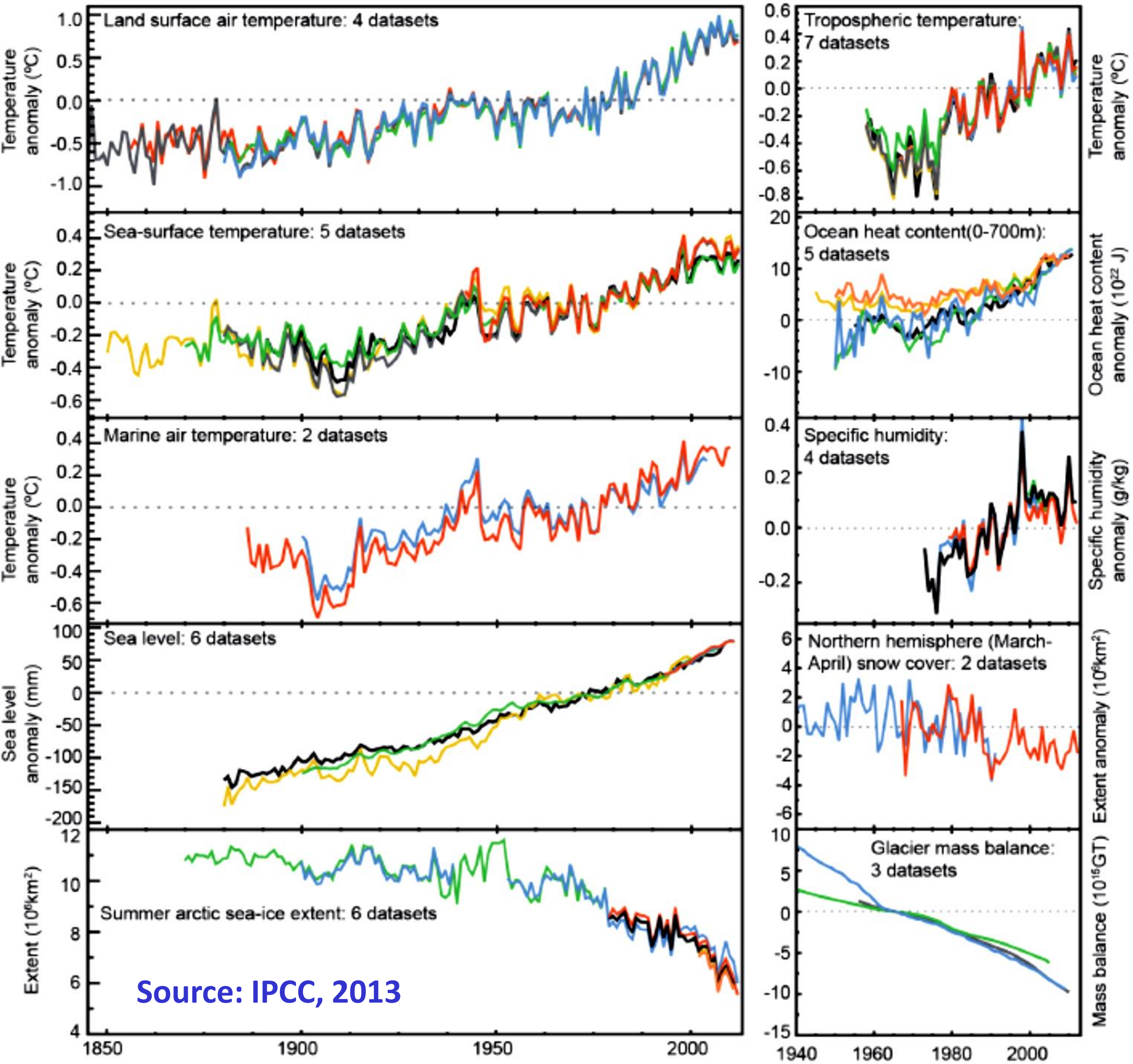
QUESTION 11: Are downscaled forecasts or assessments available for your critical infrastructure regarding the following climate forcing and factors? If so, at which time scale?



11 Respondents

The way forward?

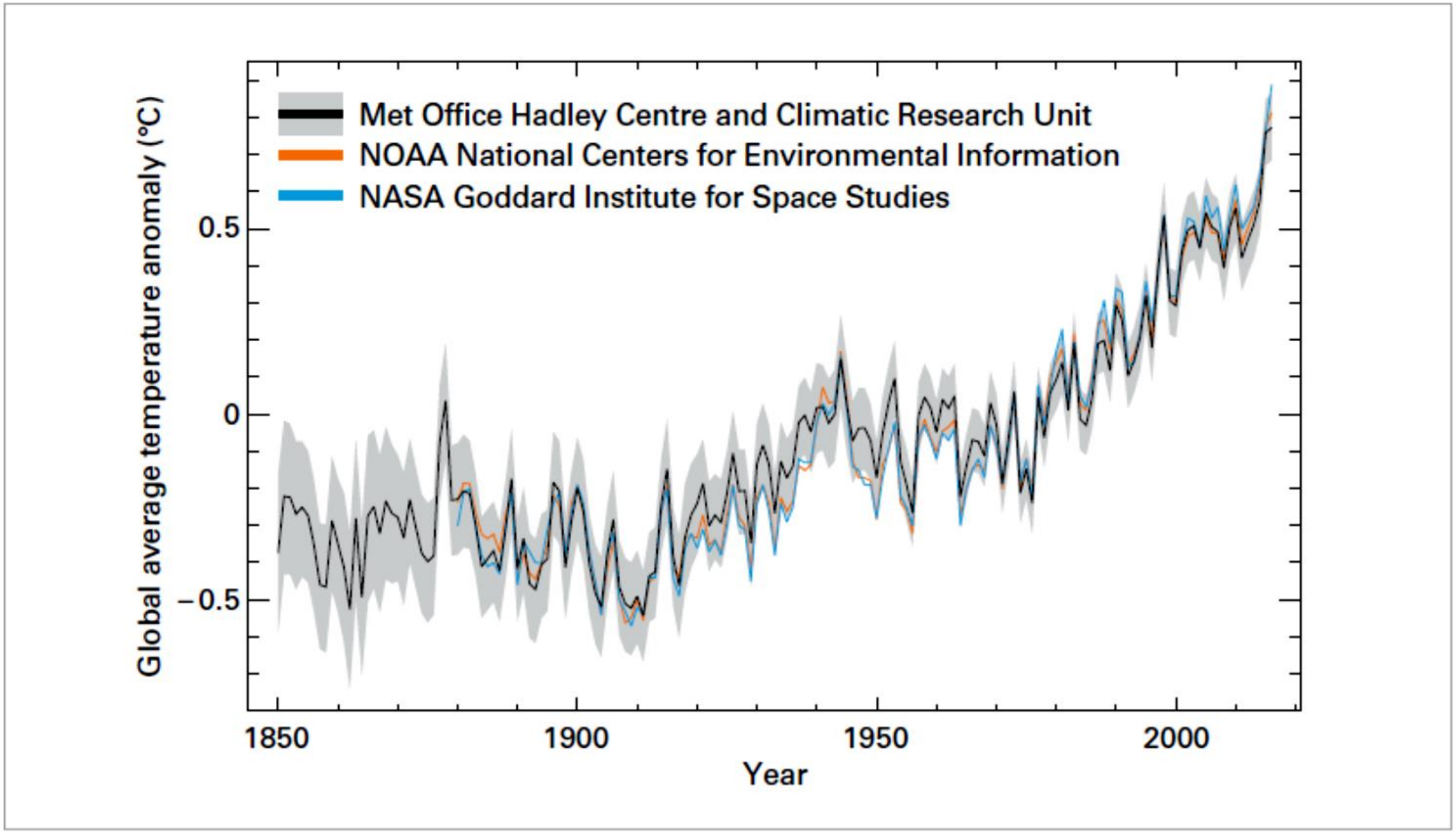
Climatic factor change



The dynamics of several climatic factors (e.g. land and sea surface temperature, sea level, Arctic ice extent, glacier mass balance) suggest:

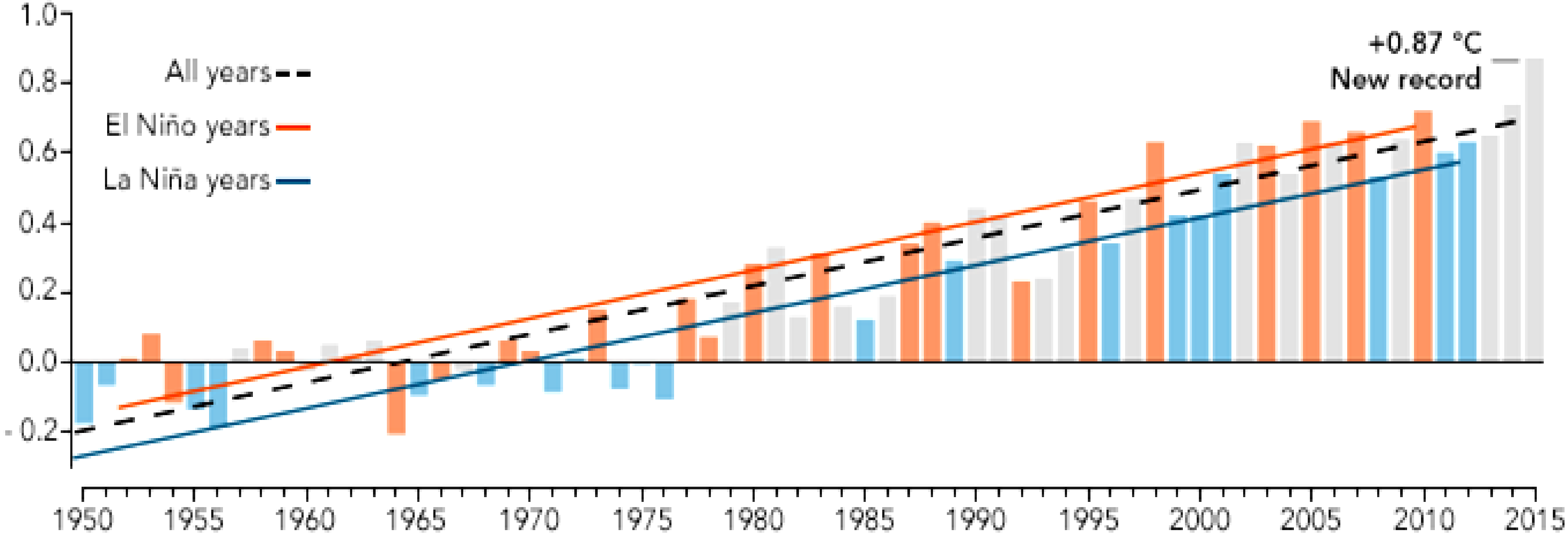
A significant and, in some cases, accelerating climatic change

Trends: Land and ocean temperature anomalies 1880-2014



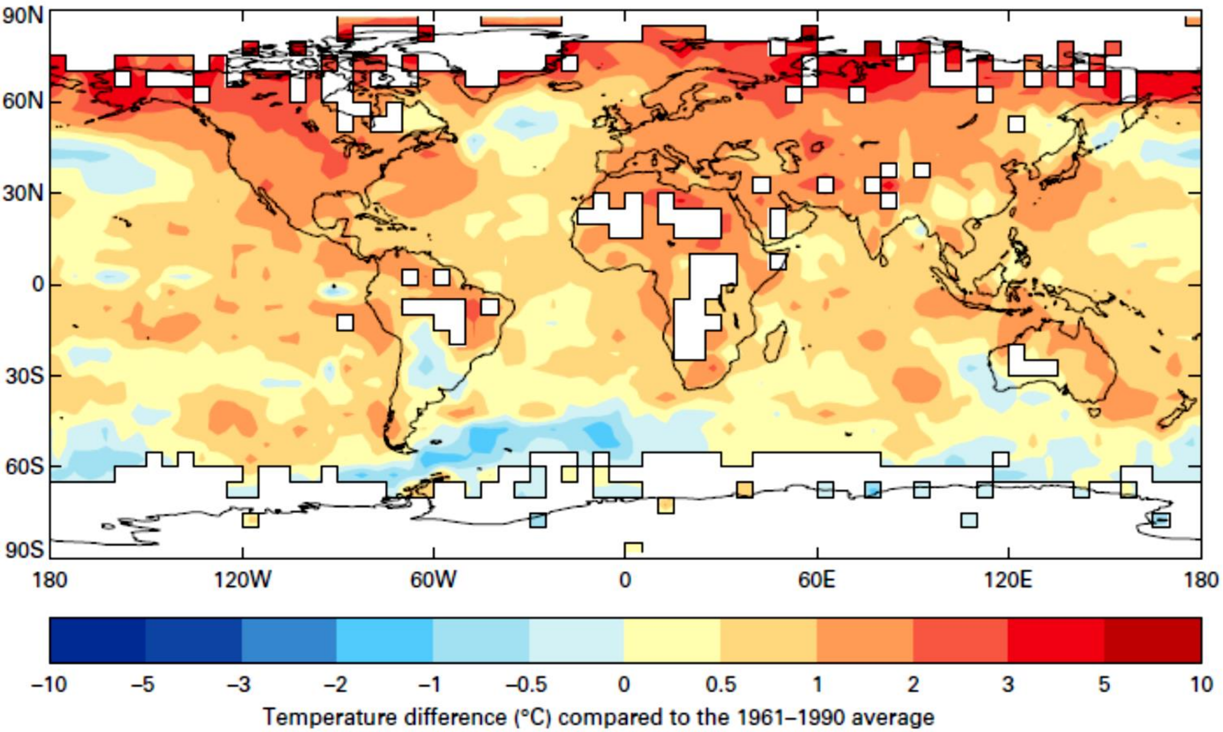
Global average temperature anomalies for the period 1850-2016 relative to the period 1961–1990 for 3 major datasets. Grey shading indicates the uncertainty in the HadCRU dataset (UK Met Office Hadley Centre) (From WMO, 2017). .http://library.wmo.int/opac/doc_num.php?explnum_id=3414).

Trends: Effects of large climatic modulations (ENSO)



Annual temperature anomalies (compared to 1951-1980 average). Blue and red bars represent El Niño and La Niña years, respectively. Blue and red lines are the respective trends; neutral years in grey; the dashed line represents the overall trend (NASA, 2016).

Trends: 2016 Temperature anomalies



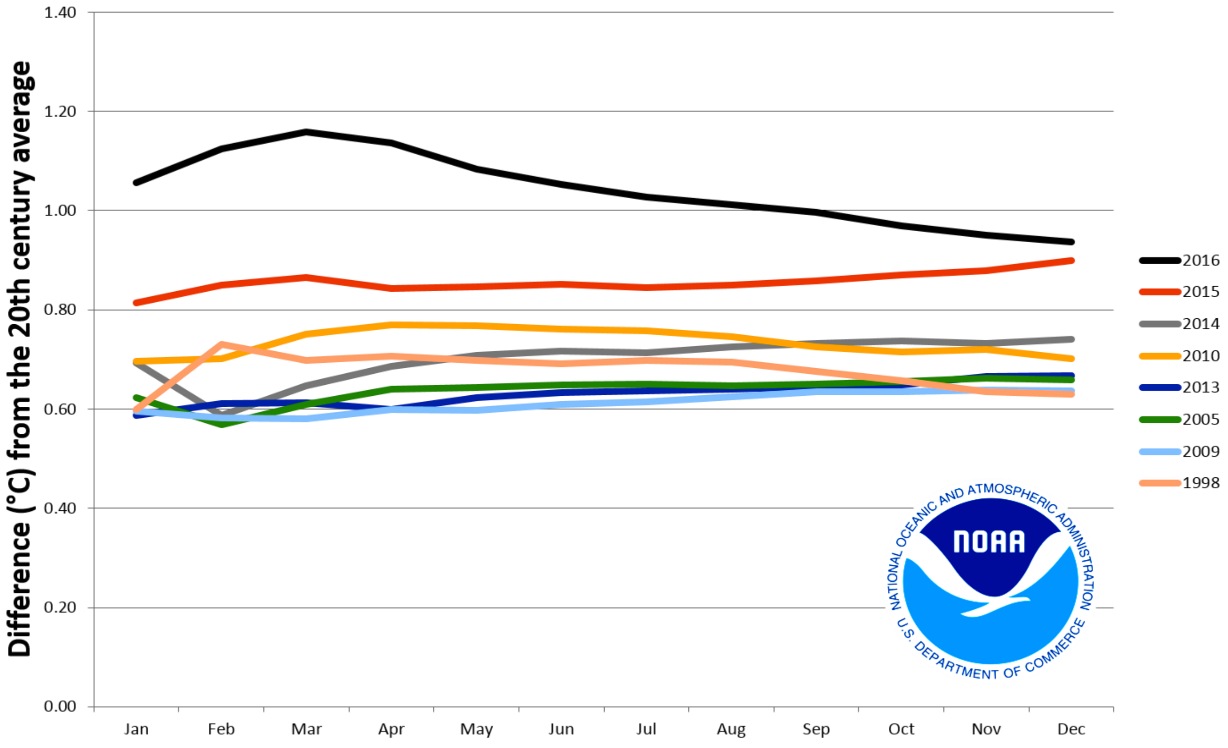
Spatial distribution of the global temperature anomalies in 2016 (relative to the 1961–1990) (WMO, 2017).

<u>2016 was the warmest year on record</u> (0.83 ± 0.10 °C warmer than the average of the 1961–1990 period)

It surpassed the previous records of 2015 and 2014.

Temperatures in the ECE region soared, particularly in the Arctic areas

Trends: 2011-2016 Temperature anomalies



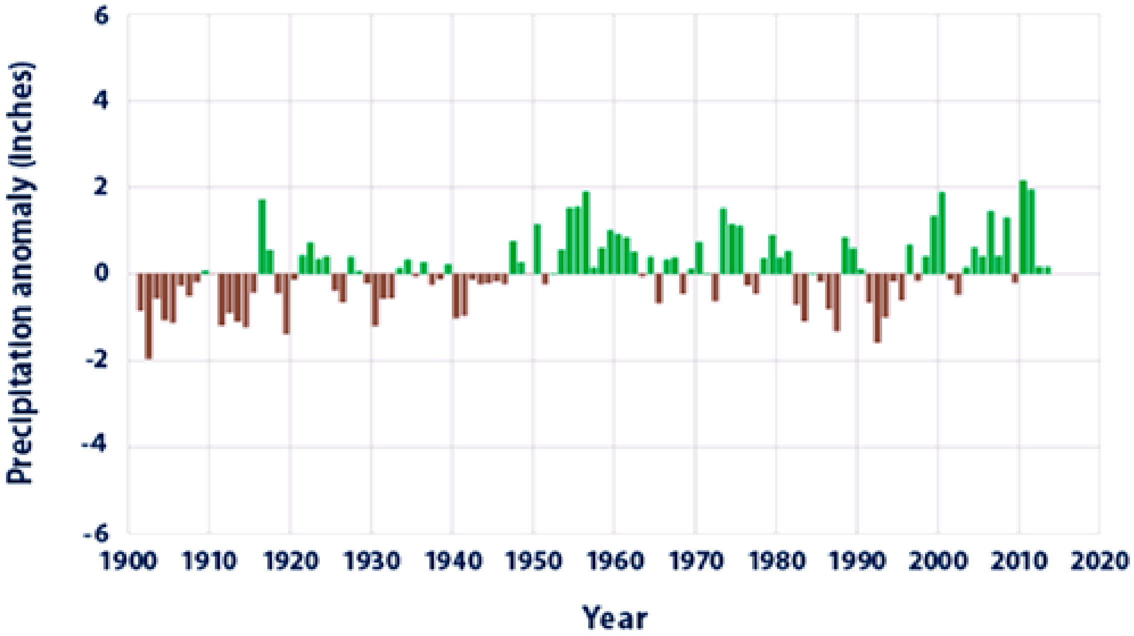
The 2011-16 period was the warmest period on record, with temperatures (NOAA, 2017b).

2011-16 the warmest 6-year period on record,

Land temperatures were > 1°C above the 1961-90 average over most of Europe, the SW USA and the Asian sector of the Russian Federation and in the arctic areas (NOAA, 2016)

Global ocean temperatures were also unprecedented

Precipitation: Trends

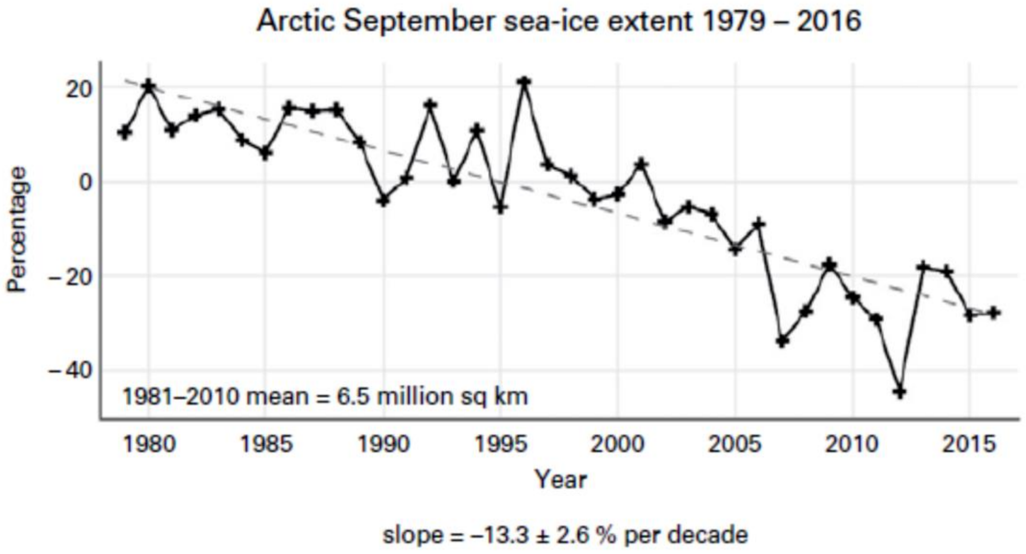


Total annual global land precipitation for the period 1901-2013 in relation to the 1901-2000 (EPA, 2015).

Land precipitation shows large spatio-temporal variability and strongly influenced by the (ENSO)

A major feature of the most recent 6-year period is the presence of persistent multi-year rainfall anomalies over several regions (WMO, 2017).

Sea ice: Trends

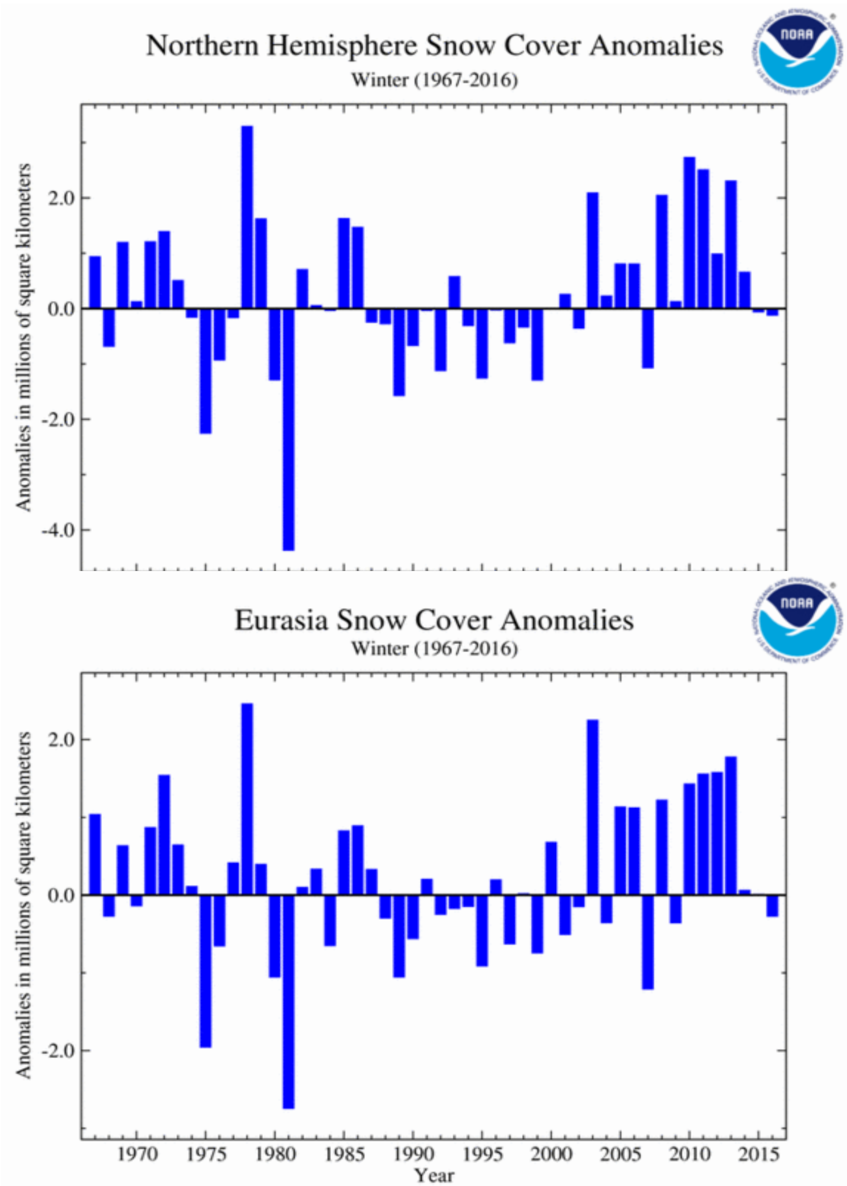


September sea-ice extent for the Arctic: Percentage of long-term average of the reference period 1981–2010 (WMO, 2017).

Arctic sea-ice extent was well below average in 2016.

The seasonal maximum of 14.52 million km^2 (on the 24th March) was the lowest seasonal maximum in the 1979–2016 satellite record

Snow: Trends

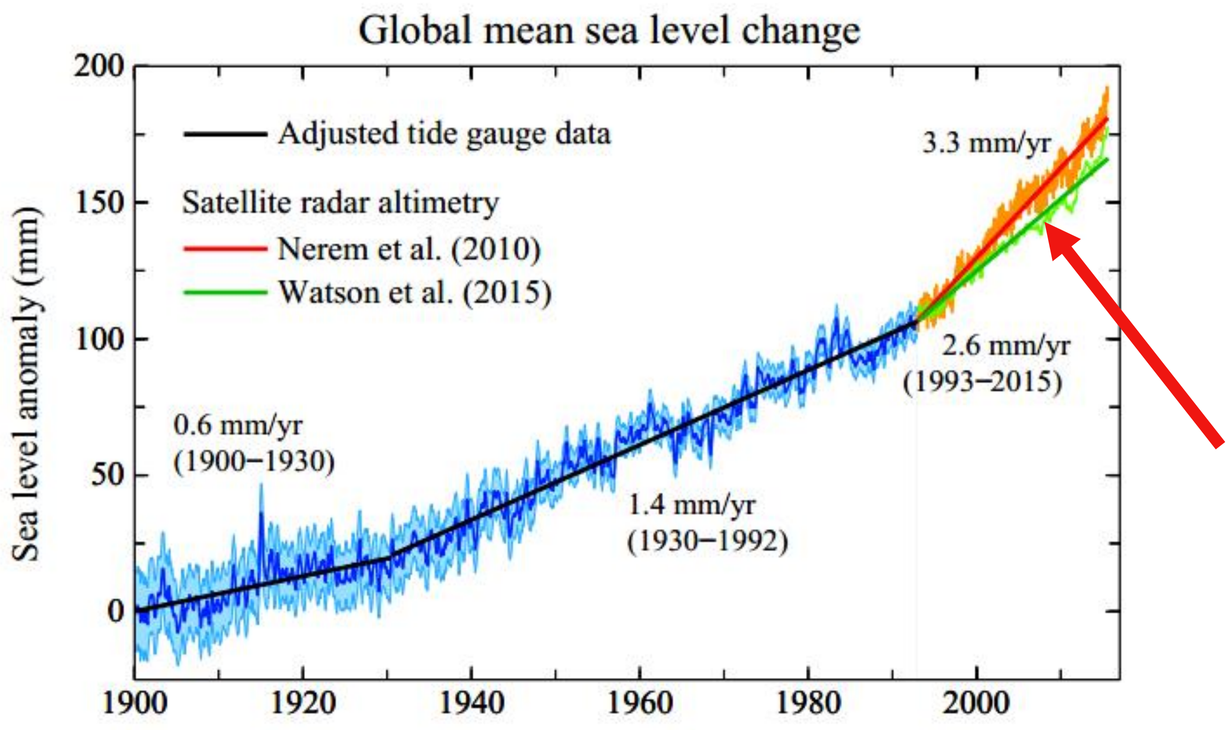


Winter Snow Cover Extent in N. America (top) and Eurasia (bottom) (NOAA 2017).

NH winter snow cover extent (SCE) has changed slightly in the 50-year record (NOAA, 2017).

In 2016, the winter SCE (December 2015-February 2016) was about 120,000 km2 below the 1981-2010 average

Sea level: Trends



Increasing trends

Estimated sea level change (mm) since 1900 (Hansen et al., 2016).

Extreme events 2011-2016

Many extreme weather/climate events, including hurricanes, heat/cold waves, floods and droughts

Events caused large economic losses (> 20 billion US$): Hurricane *Sandy (2012)*, the 2011 SE Asian floods, droughts in the southern/central United States (2012-2013), and floods in central Europe (2013) and the UK (2014-2015)

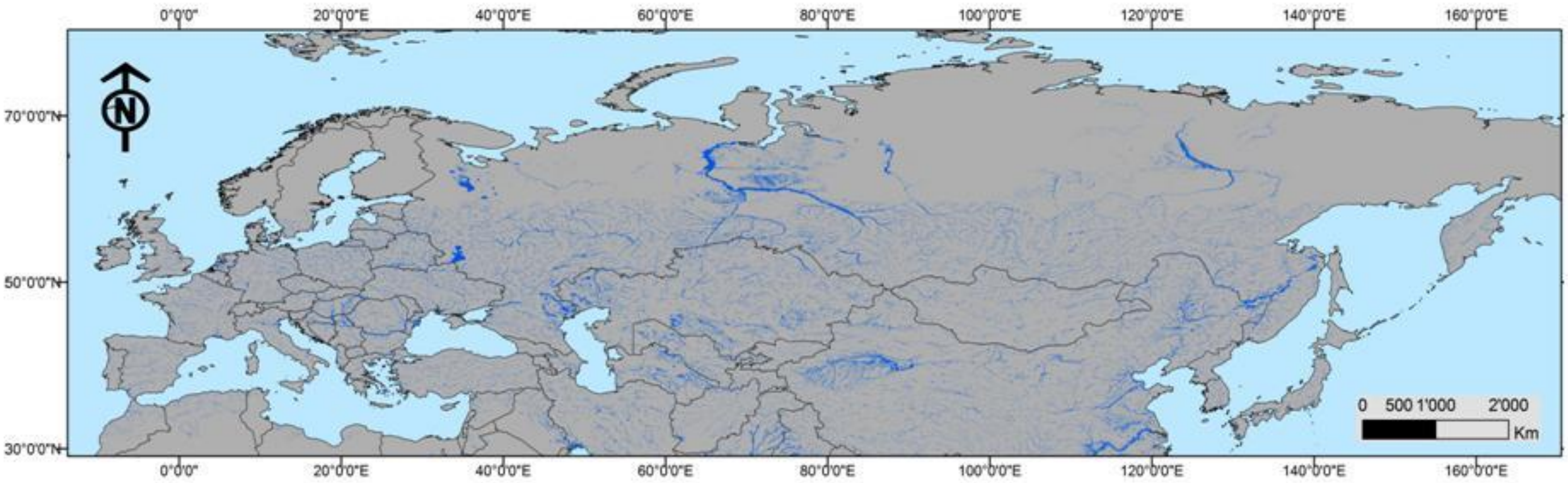
Significant annual wet anomalies in NE Europe (2012) and SE Europe (in 2014)

Major heatwaves (July 2015 set several records in Europe)

Prolonged period of extreme cold in Europe (February 2012)-temperatures remained below 0°C continuously for 2 weeks or more in most of central Europe

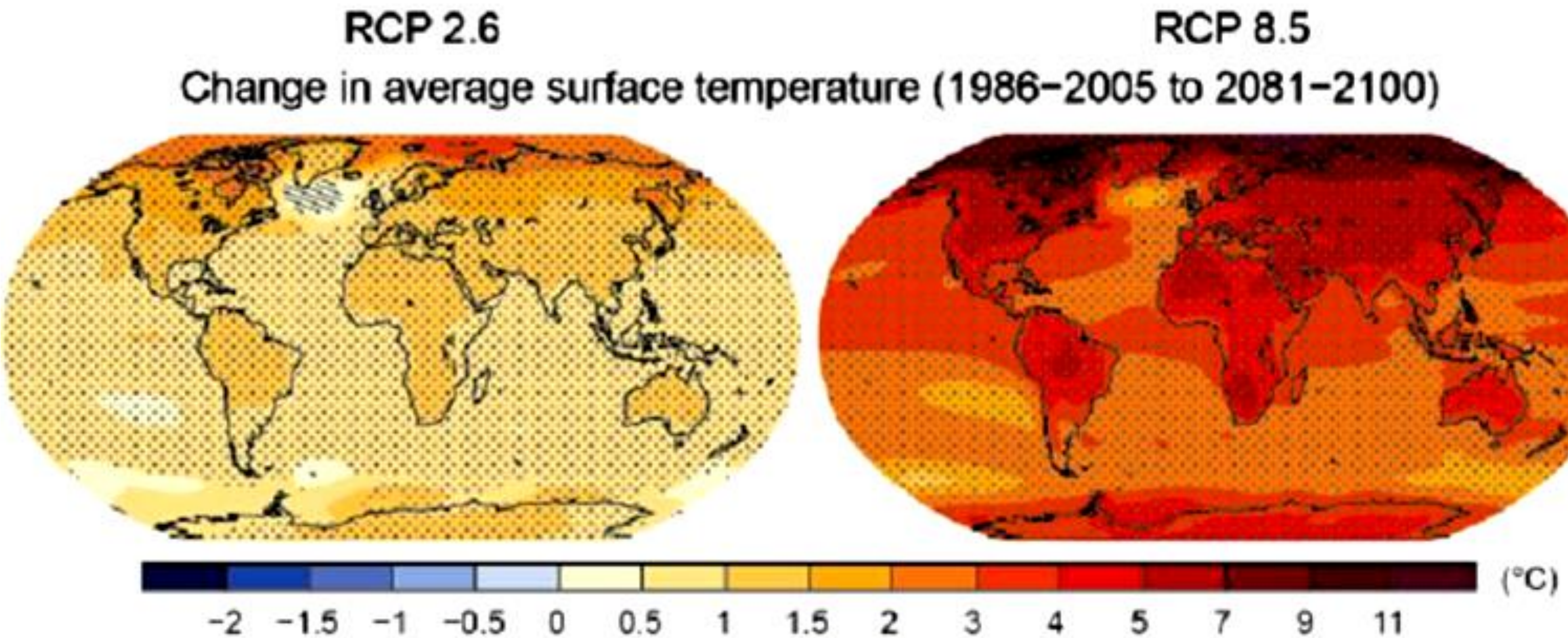
Flooding in the Danube and Elbe basins (May-June 2013) caused huge economic losses

Flood hazard



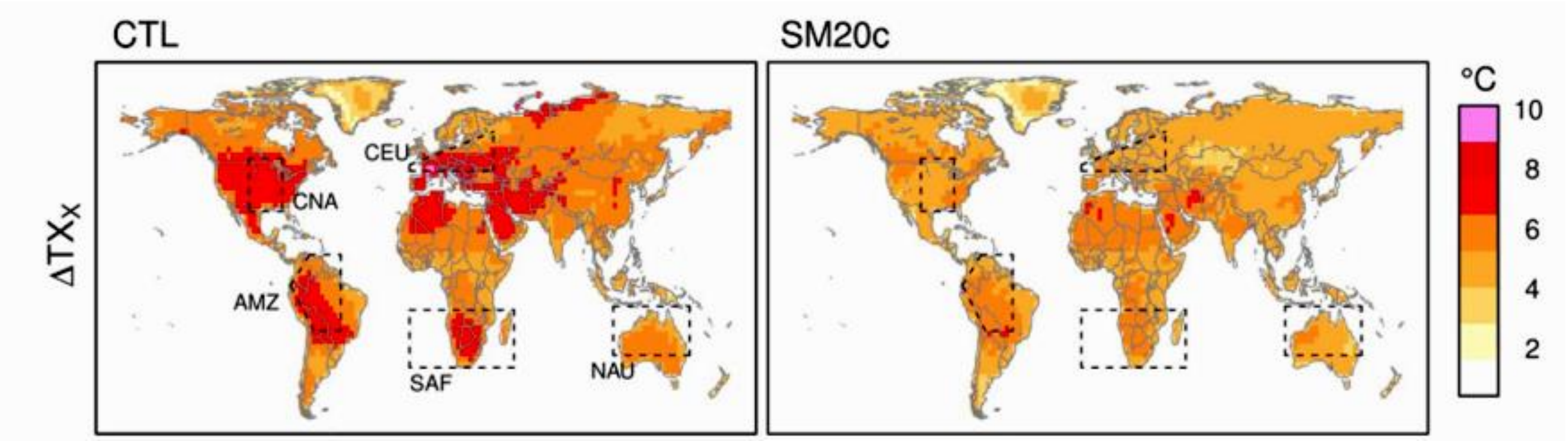
Current flood hazard (95 % probability) in the Eurasian region of the ECE for the 100-year flood from a global GIS model based on river discharge time-series. DEM resolution 90 m. Areas over 60 ^{0}N are not fully covered (From UNEP-GRID and UNISDR, 2008). (ECE, 2013)

Temperature: Projections



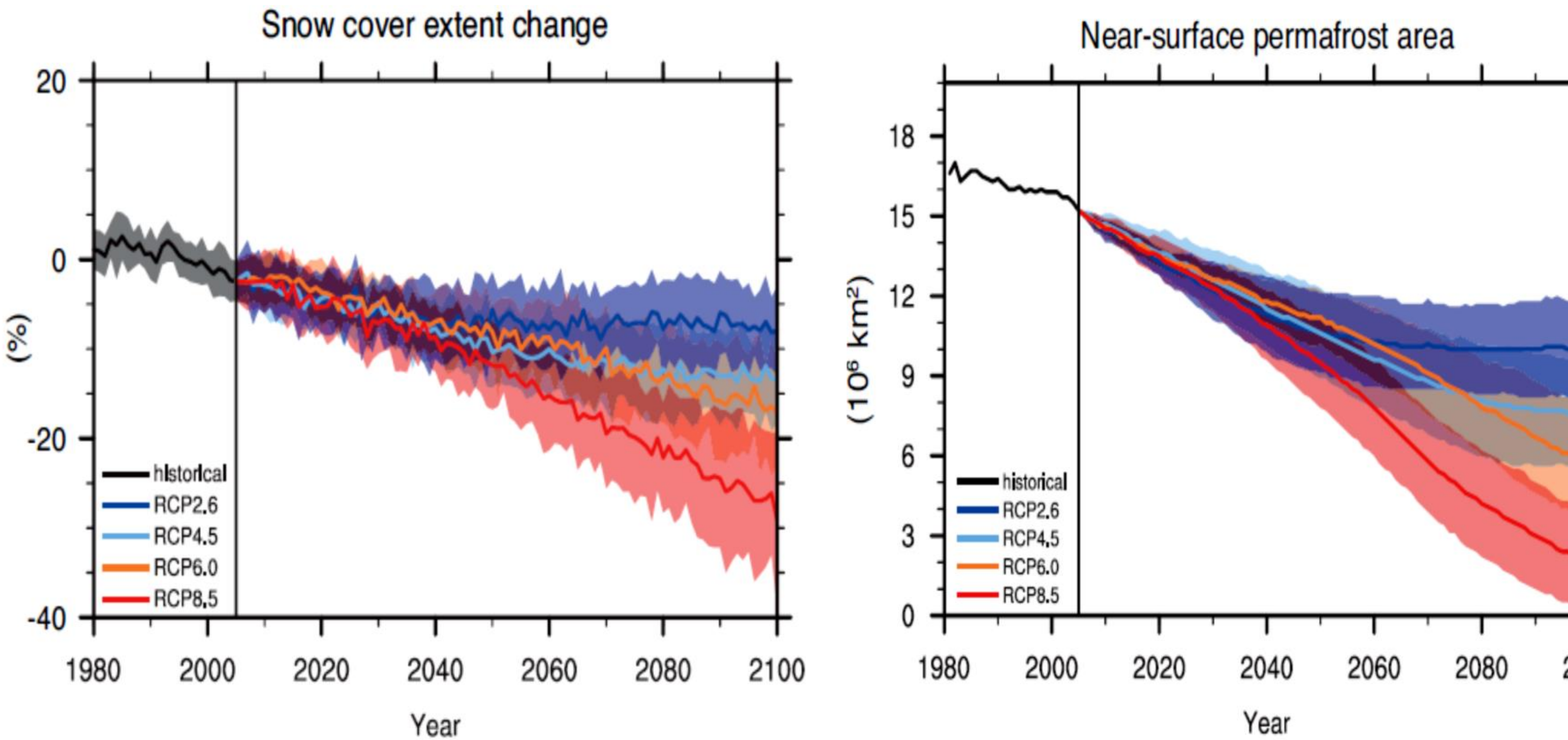
Projected changes in average temperatures in 2081-2100 relative to 1986-2005 for low (RCP2.6) and high emission (RCP8.5) scenarios (IPCC, 2013)

Maximum temperature: Projections



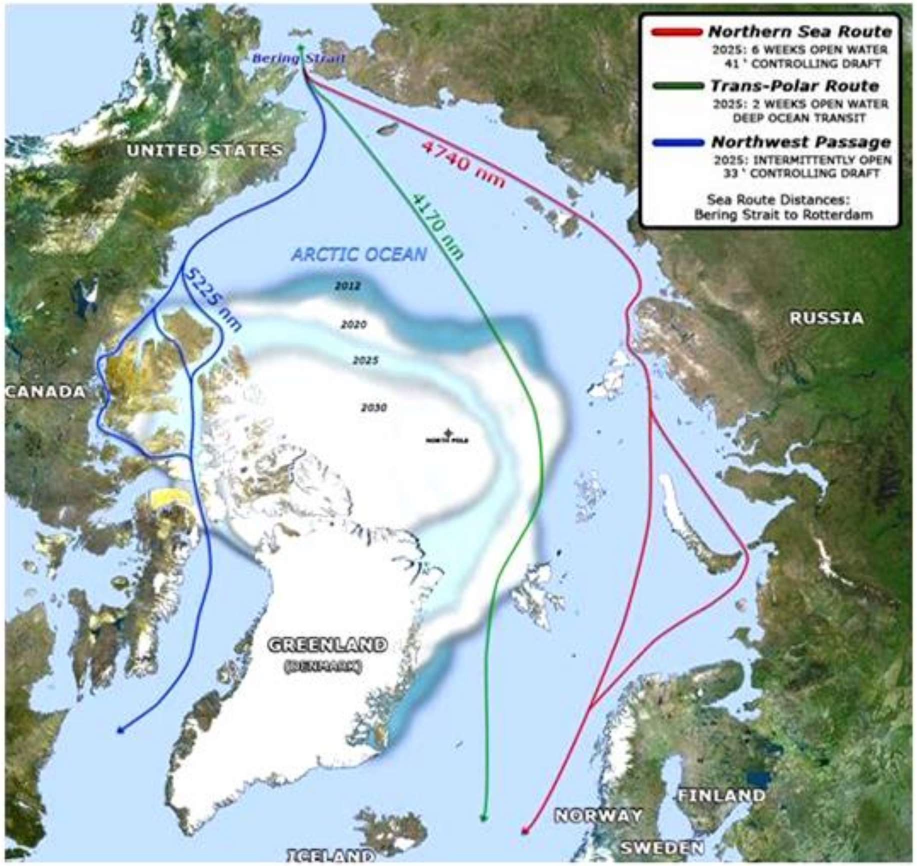
Projected changes in TXX (multimode mean of daily maximum temperature) between 2081–2100 and 1951–1970 for CTL (left) and SM20c (right). Grey color denotes insufficient model agreement (Vogel et al., 2017).

Snow cover and permafrost: Projections



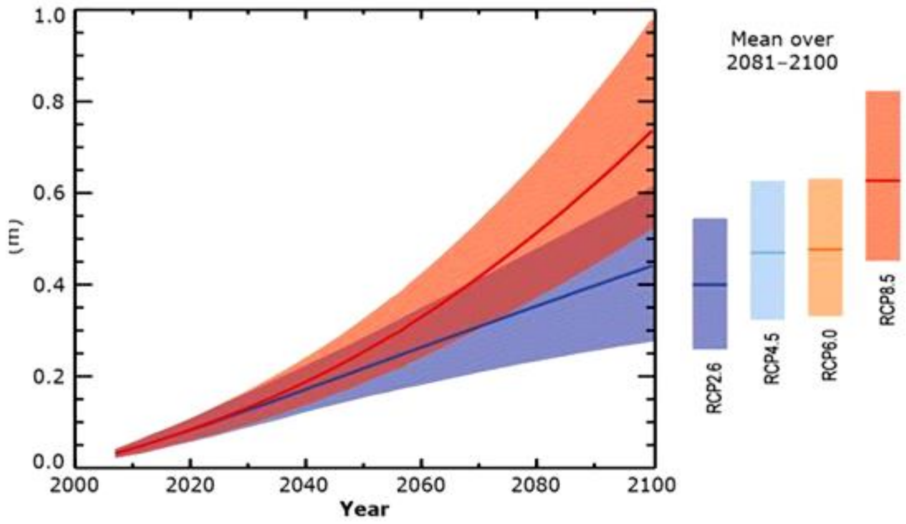
Projected (a) snow cover extent and (b) near-surface permafrost changes for 4 Representative Concentration Pathways-RCPs (from CMIP5 model ensemble) (IPCC, 2013)

Arctic ice: Projections

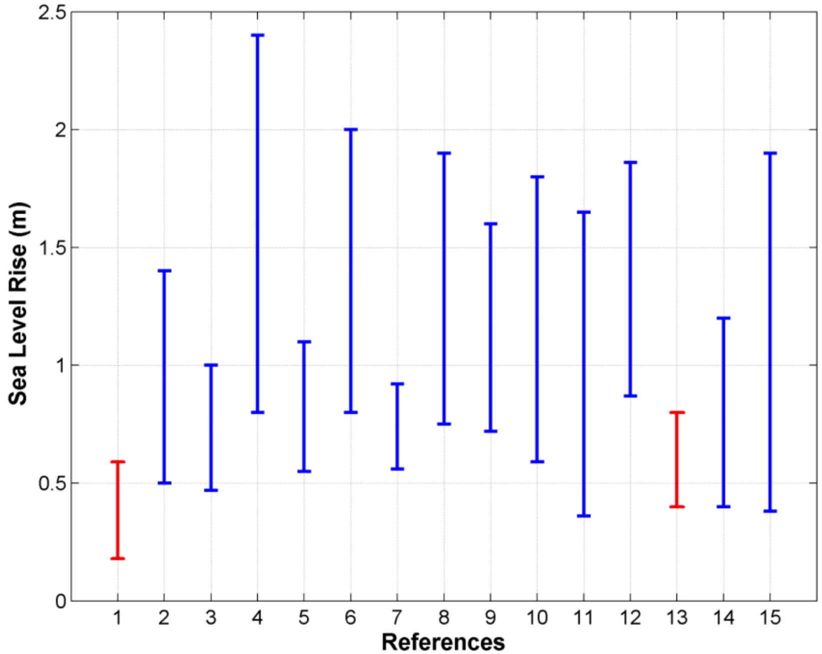


Potential new Arctic shipping routesby 2025 (U.S. Climate Resilience Toolkit, 2015)

Sea level: Projections

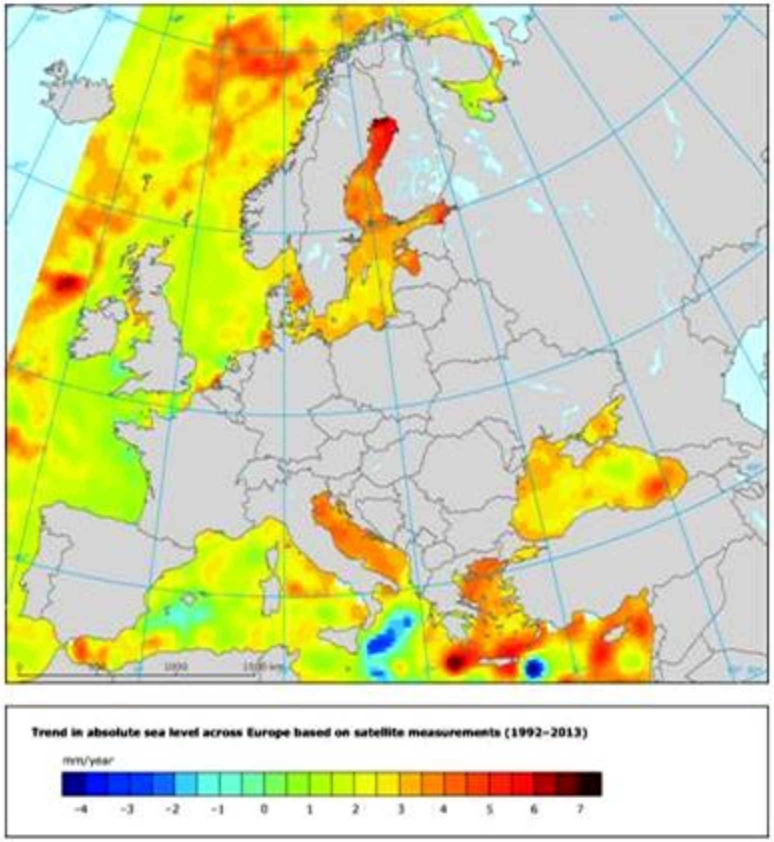


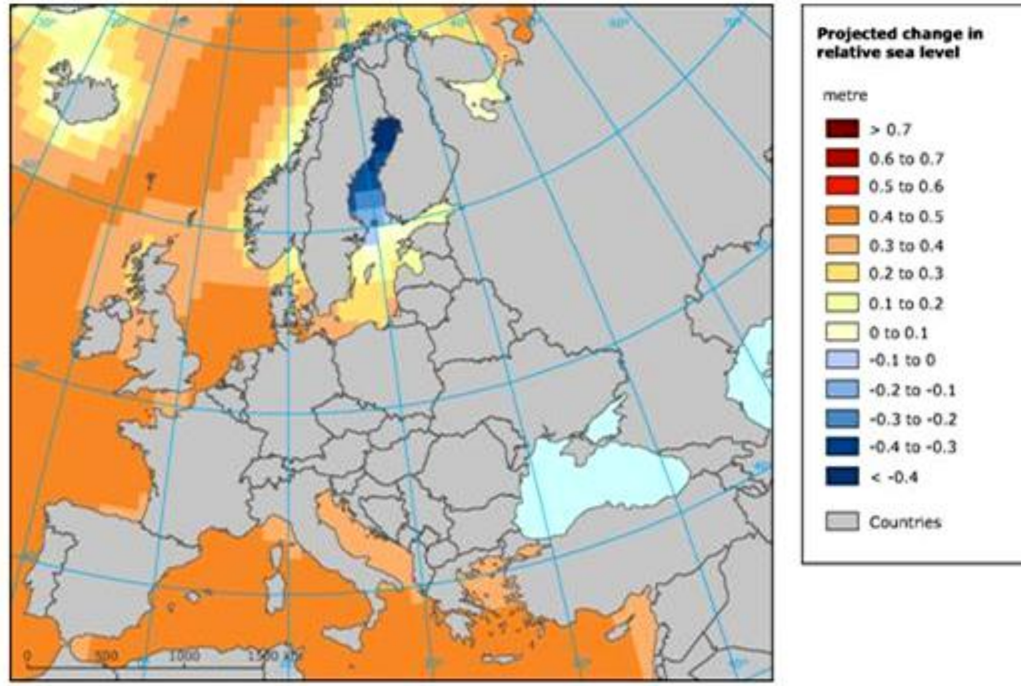
Projected global MSLR over the 21st century relative to 1986-2005 (IPCC, 2013)



Recent sea level rise projections for 2100 compared to that of IPCC (2007) 0.18-0.59 m (first red bar) by other researchers (2007-2015) including that of the IPCC (2013) (second red bar)

Sea level Projections: Large spatial variability

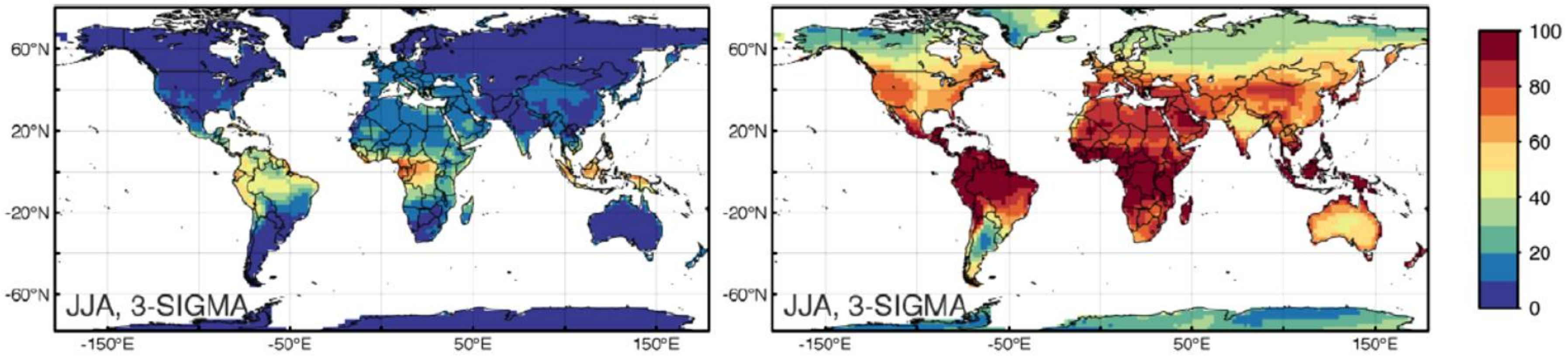




Trends in absolute sea level in European Seas from satellite measurements (1992–2013) and projected change in 2081-2100 compared to 1986-2005 for RCP4 (EEA, 2014)

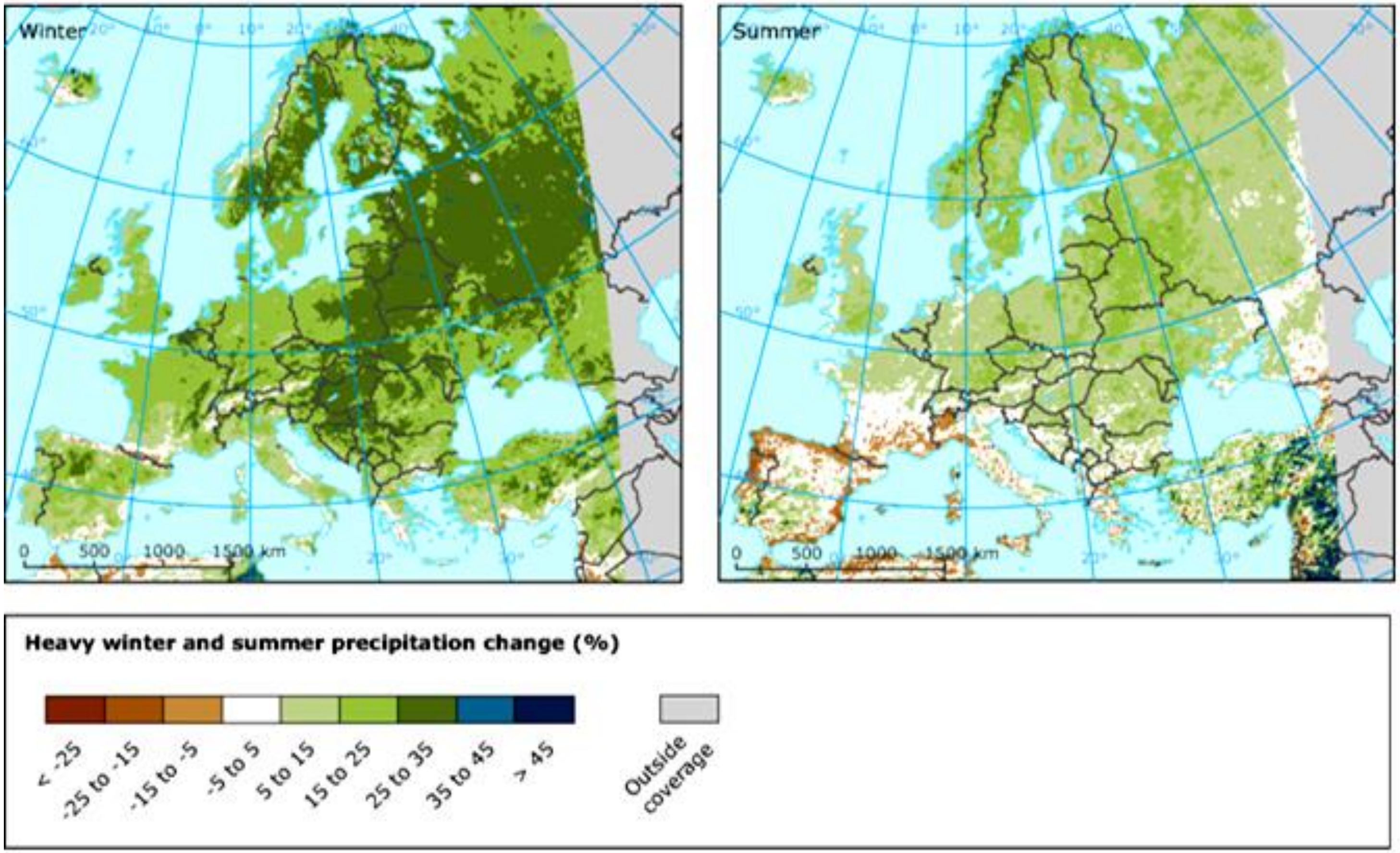
Extreme event Projections: Heat

Increases for all scenarios, but particularly for the high scenarios



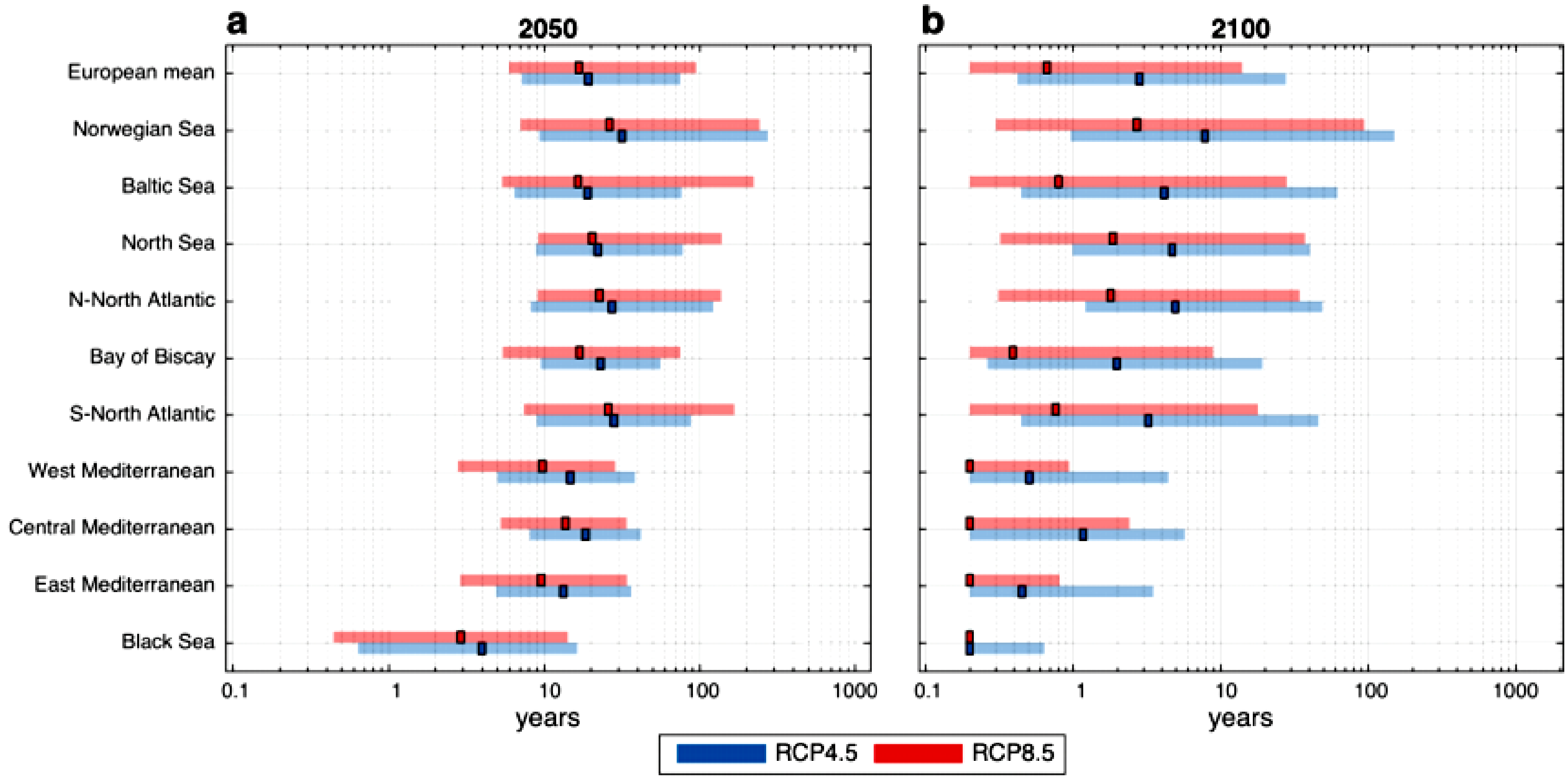
Projected changes in hot seasonal temperature extremes in 2071-2100 for RCPs 2.6 and 8.5. Yellow, orange/red areas show regions where (at least) 1 every 2 summers will be warmer that the warmest summer in 1901-2100 (Coumou and Robinson, 2013)

Extreme event Projections: Precipitation

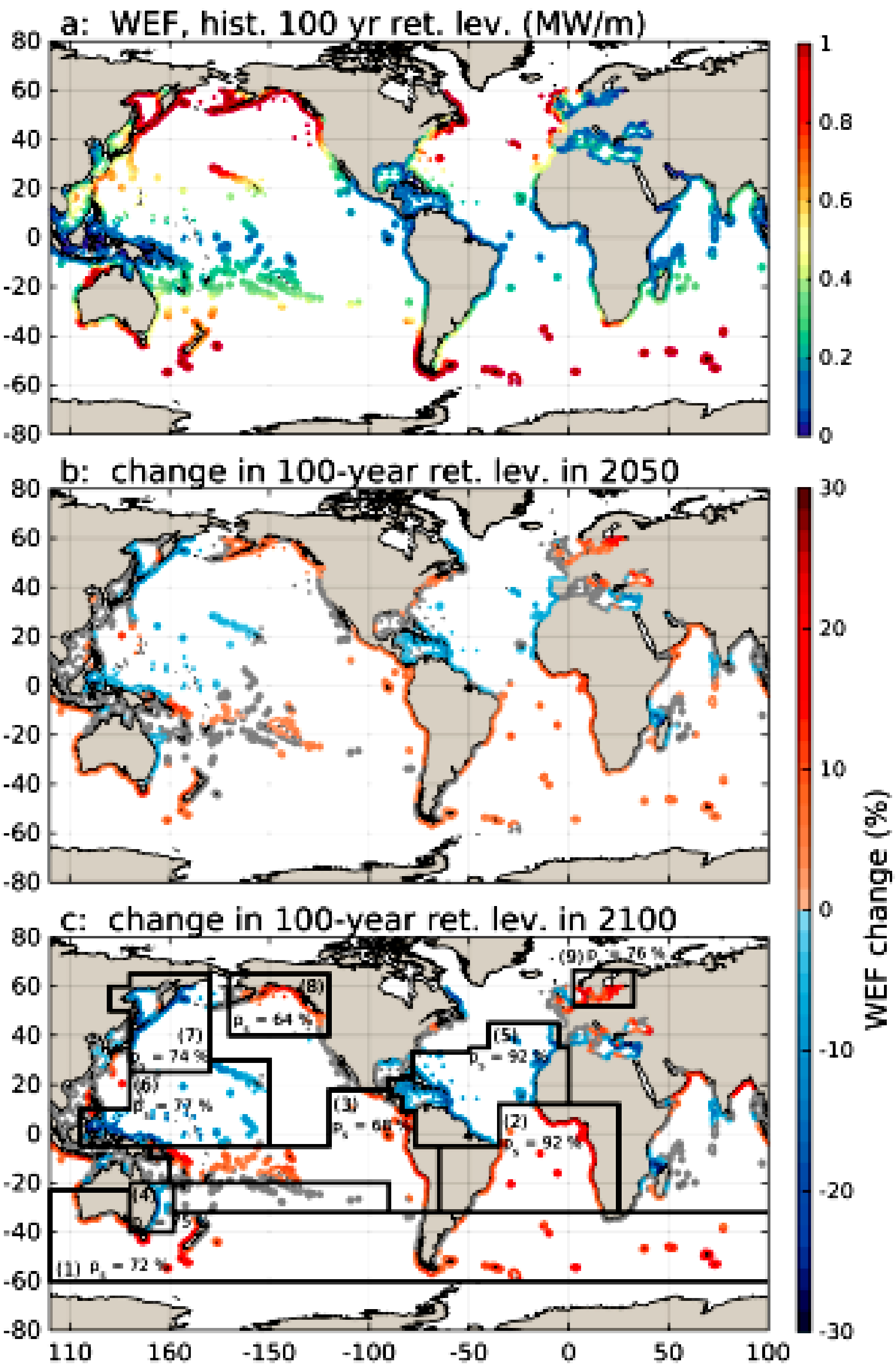


Projected changes in heavy precipitation (in %) in winter and summer from 1971-2000 to 2071–2100 for the RCP8.5 scenario based on the ensemble mean of regional climate models (RCMs) nested in general circulation models (GCMs) (EEA, 2015c)

Extreme event Projections: Extreme Sea levels (ESLs)



Return period of the present day 100-year ESLs under RCP4.5 and RCP8.5 in 2050 (a) and 2100 (b). Colored boxes express the ensemble mean value and colored patches the inter-model variability (best-worst case). The values shown are averages along the European coastline and along the coasts of 10 regions (Vousdoukas et al., 2017).



Extreme wave power: Projections

Larger increases in the Baltic, North and Black Seas, and the NW and NE Pacific

Projections of wave energy flux-WEF along the global coastline: (a) baseline 100-year return level and relative change of the 100-year WEF for the year (b) 2050, and (c) 2100. (Mentaschi et al., 2017).