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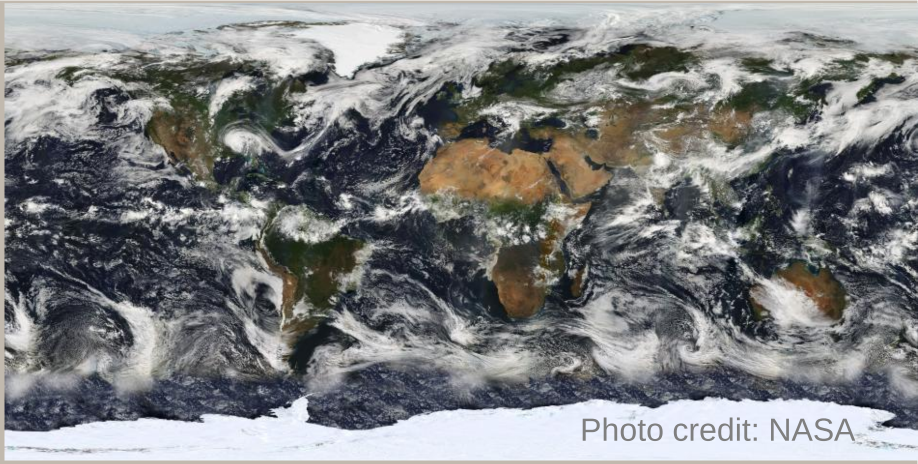
Photo credit: NASA

Climate change in the Arctic region

Stefan Fronzek

Finnish Environment Institute (SYKE)

SYKE

Arctic Wood Building and Circular Economy Forum
May 23-24, 2018

KEMI
Arctic Bio Capital

Outline

- Introduction
- Climate change in the Arctic
- Impacts on nature
- Responses: mitigation + mitigation

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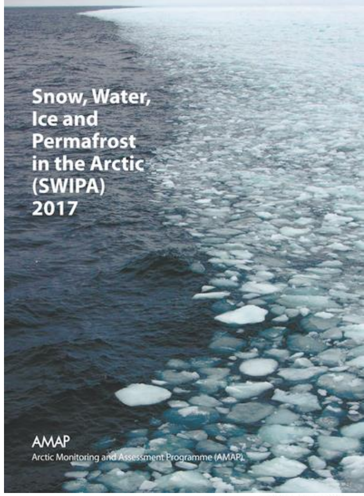
Assessment reports about climate change in the Arctic

2017: SWIPA report

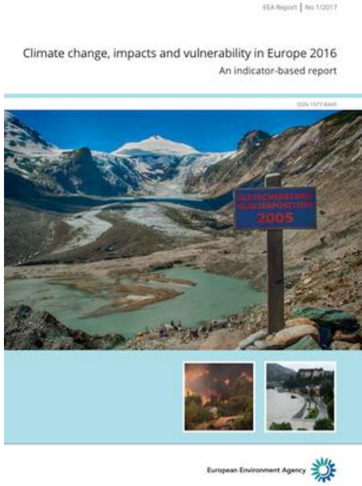
AMAP, 2017. Snow, Water, Ice and Permafrost in the Arctic (SWIPA): Climate Change and the Cryosphere. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xiv + 269 pp.



2017: EEA climate change indicators

European Environment Agency 2017. Climate change, impacts and vulnerability in Europe 2016 an indicator-based report. EEA report 1/2017. 424 pp

Chapter 3.3 (Cryosphere)



2013: IPCC AR5, WGI

IPCC 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Chapters 4 (Observations: Cryosphere) and 12 (Long-term Climate Change)

2014: IPCC AR5, WGII

IPCC 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Chapters 21 (Regional context) and 28 (Polar regions)

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Global energy budget

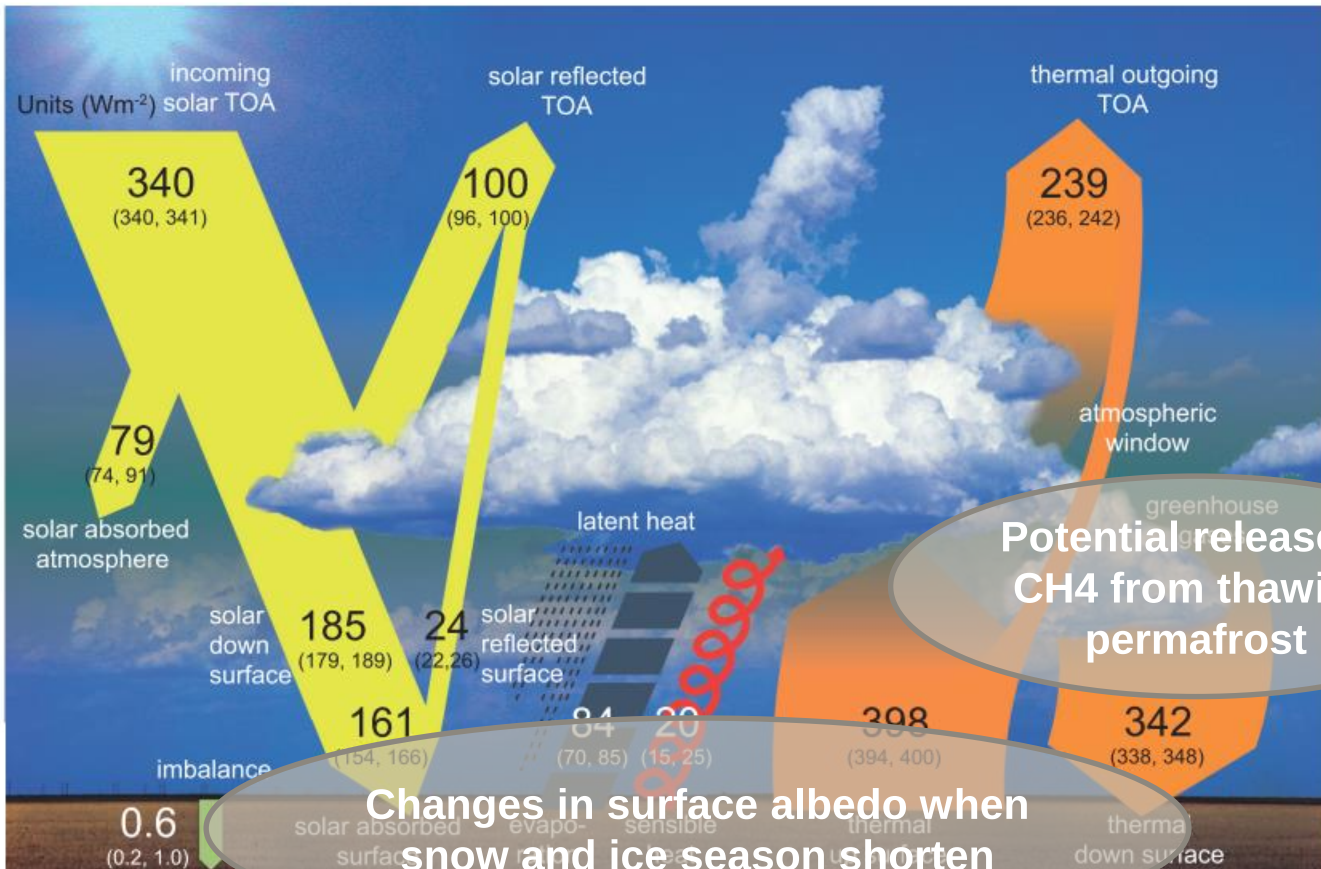

Figure 2.11: | Global mean energy budget under present-day climate conditions. Numbers state magnitudes of the individual energy fluxes in W m^{-2}, adjusted within their uncertainty ranges to close the energy budgets. Numbers in parentheses attached to the energy fluxes cover the range of values in line with observational constraints. (Adapted from Wild et al., 2013.)

Climate feedbacks in the Arctic

Source: IPCC 2013, Ch. 2; see also Chapin et al. 2011, Fig. 2.3

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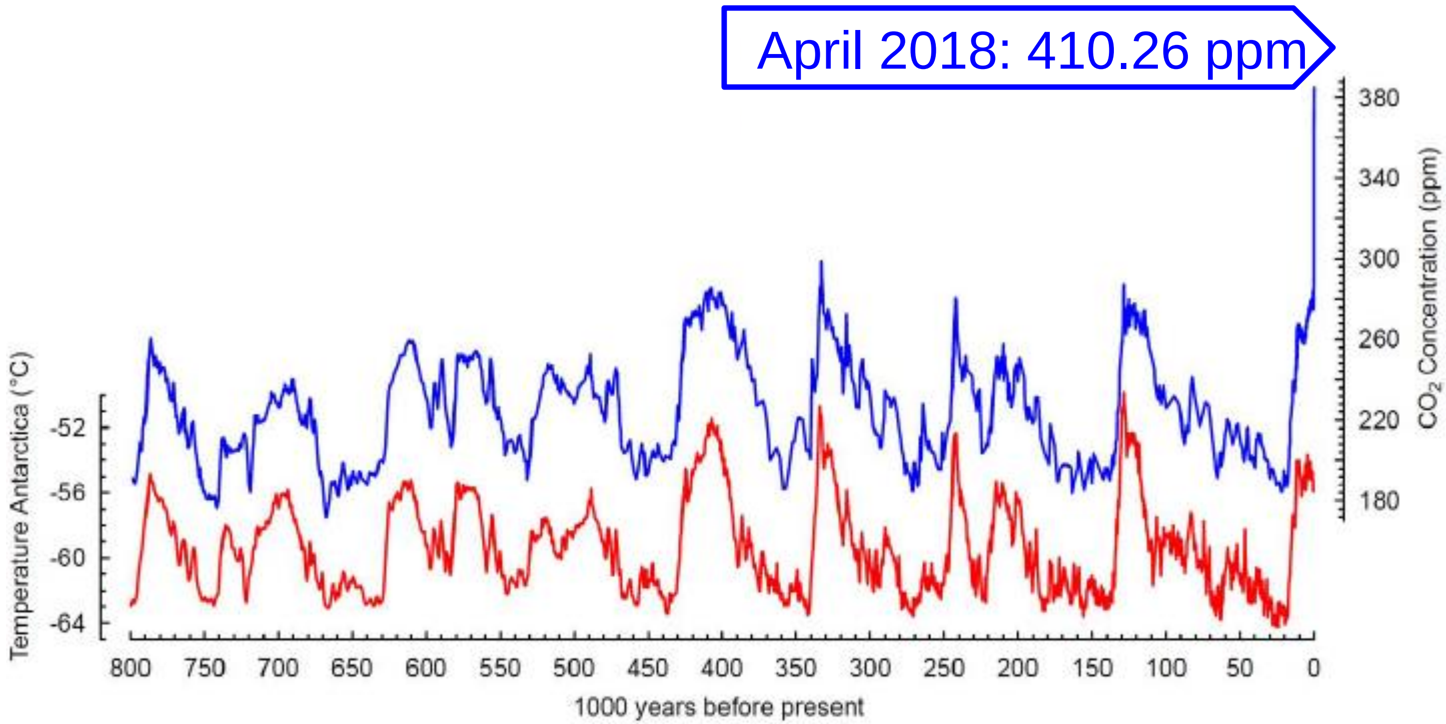
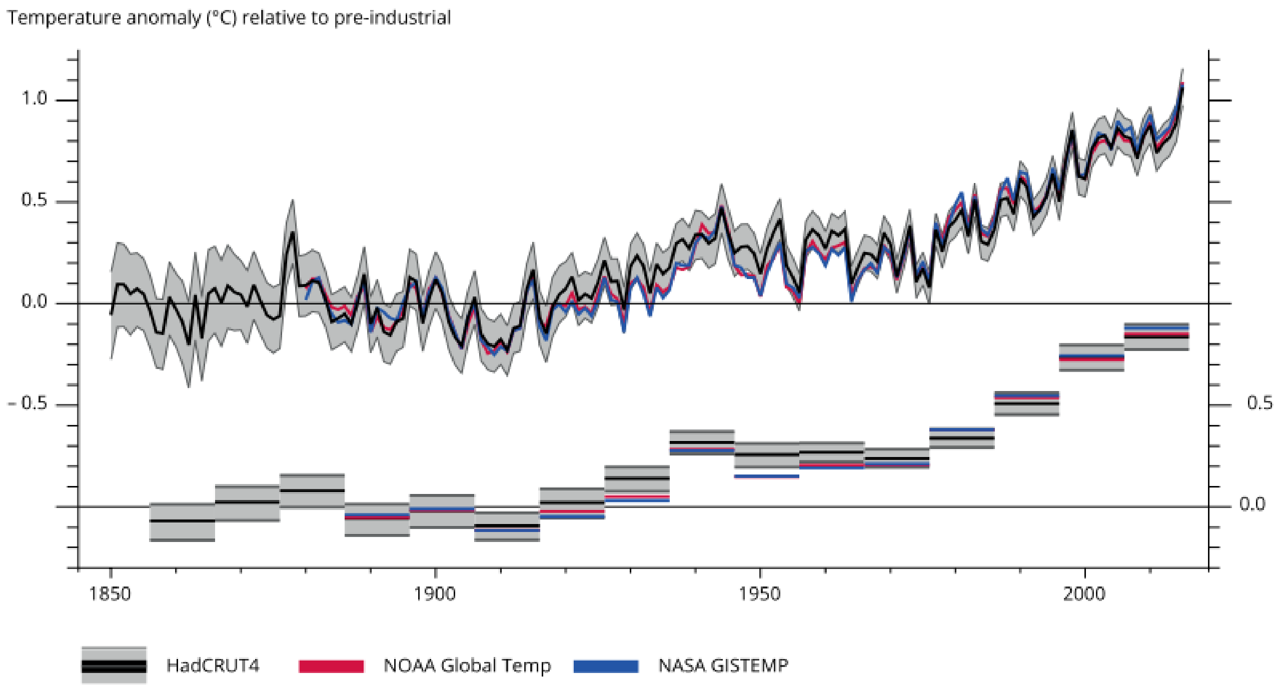
Atmospheric CO_2 concentrations from ice cores and measurements



Source: Siegenthaler et al., 2005; Lüthi et al., 2008, NOAA; www.ipcc.ch

Global warming since the pre-industrial period has reached 1°C

Figure 3.6 **Global average near-surface temperatures between 1850 and 2015 relative to the pre-industrial period**



Note: Three sources of data are used for the mean annual change (upper panel) and mean decadal (10-year) change (lower panel) relative to the pre-industrial period. The uncertainty ranges (values between 2.5 and 97.5 percentiles) for the HadCRUT4 dataset are represented by grey shading.

Source: EEA and UK Met Office, based on HadCRUT4 (Morice et al., 2012), NOAA Global Temp (Karl et al., 2015) and GISTEMP (Hansen et al., 2010).

Source: EEA 2017

COP21: The Paris agreement

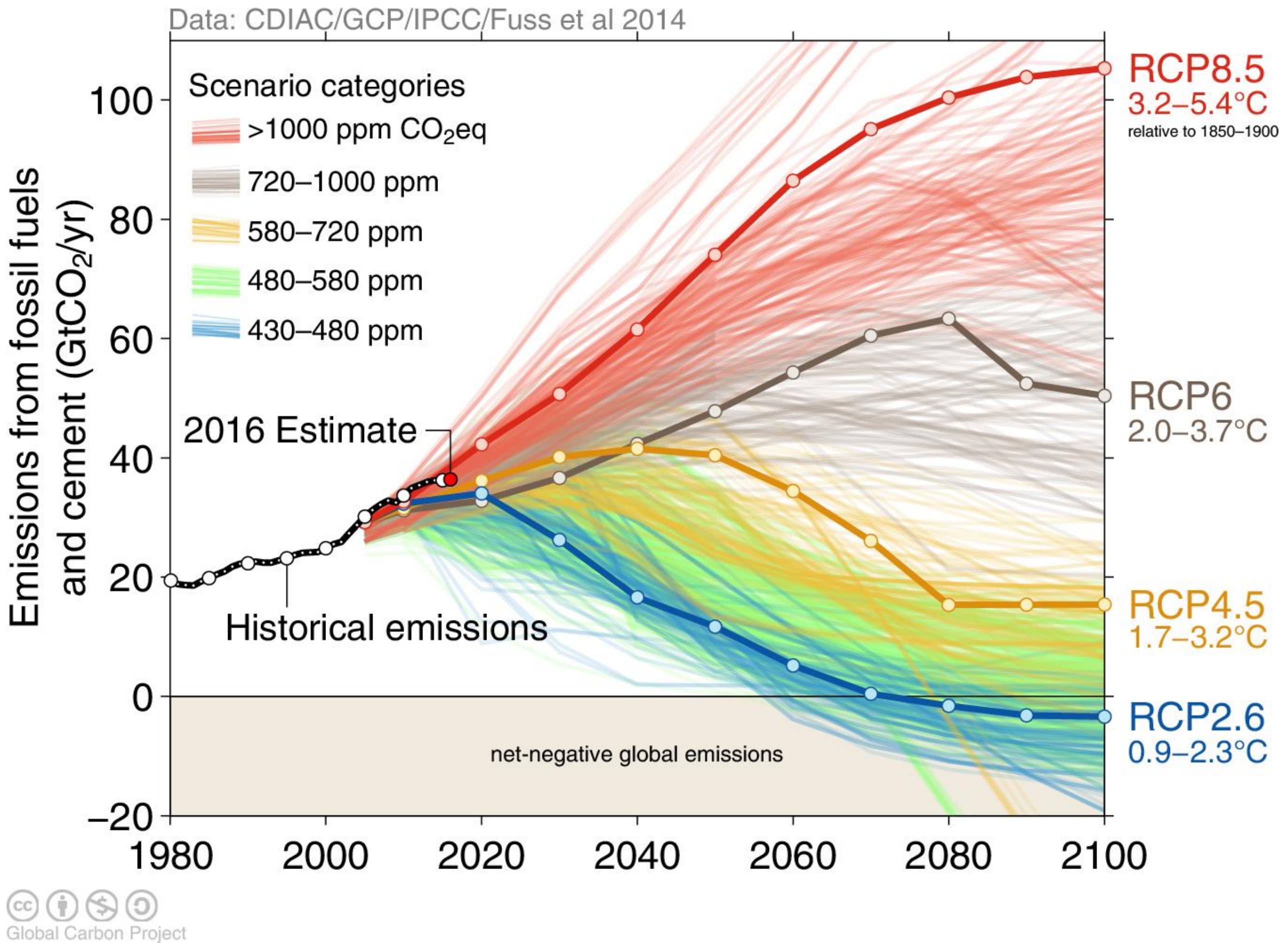
PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

12 December 2015: Secretary-General Ban Ki-moon (second left), UNFCCC's Christiana Figueres (left), French Foreign Minister Laurent Fabius and President of the UN Climate Change Conference in Paris (COP21), and President François Hollande of France (right), celebrate historic adoption of Paris Agreement. UN Photo/Mark Garten

"… holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change"

Observed emissions and emissions scenarios

The emission pledges to the Paris Agreement avoid the worst effects of climate change (4-5°C)
Most studies suggest the pledges give a likely temperature increase of about 3°C in 2100



The IPCC Fifth Assessment Report assessed about 1200 scenarios with detailed climate modelling on four Representative Concentration Pathways (RCPs)

Source: Fuss et al 2014; CDIAC; IIASA AR5 Scenario Database; Global Carbon Budget 2016

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Climate change in the Arctic

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Observed warming strongest in the Arctic

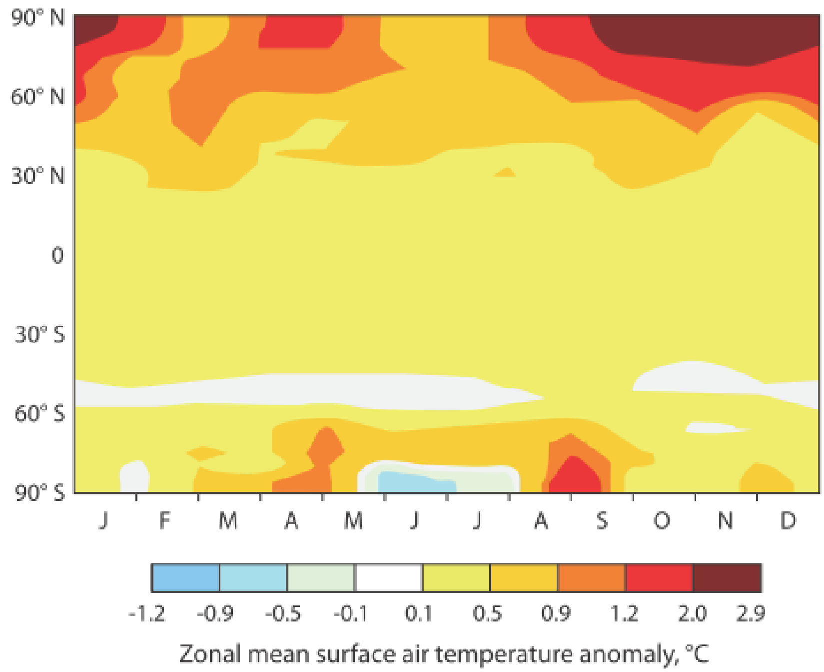

Figure 2.3. Monthly surface air temperature anomalies averaged over the period 2001 to 2009 (relative to the mean for 1951 to 2000) shown as a function of latitude. Source: NASA Goddard Institute for Space Studies (http://data.giss.nasa.gov/gistemp).

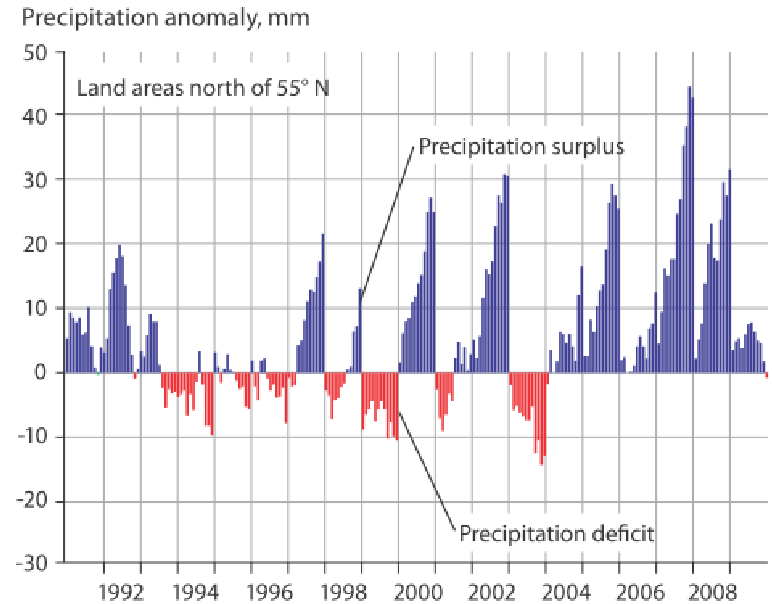

Figure 2.10. Monthly-accumulated anomalies of precipitation for the period 1991 to 2009 (relative to the corresponding monthly means for 1951 to 2000) averaged over land areas north of 55° N. Source: Global Precipitation Climatology Center / World Meteorological Organization / Deutscher Wetterdienst (Courtesy of B. Rudolf).

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Source: AMAP 2011

Future warming in the Arctic >2 as strong as global average

Temperature change | Precipitation change

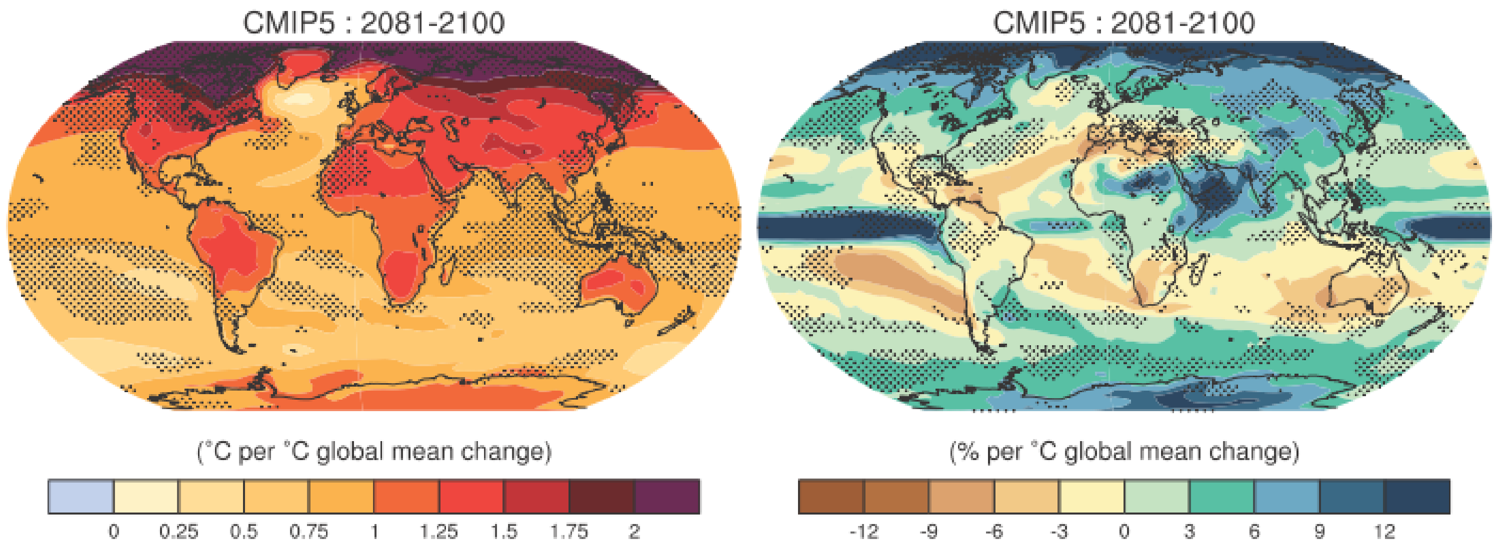

Figure 12.41 | Patterns of temperature (left column) and percent precipitation change (right column) for the CMIP3 models average (first row) and CMIP5 models average (second row), scaled by the corresponding global average temperature changes. The patterns are computed in both cases by taking the difference between the averages over the last 20 years of the 21st century experiments (2080–2099 for CMIP3 and 2081–2100 for CMIP5) and the last twenty years of the historic experiments (1980–1999 for CMIP3, 1986–2005 for CMIP5) and rescaling each difference by the corresponding change in global average temperature. This is done first for each individual model, and then the results are averaged across models. For the CMIP5 patterns, the RCP2.6 simulation of the FIO-ESM model was excluded because it did not show any warming by the end of the 21st century, thus not complying with the method requirement that the pattern be estimated at a time when the temperature change signal from CO_2 increase has emerged. Stippling indicates a measure of significance of the difference between the two corresponding patterns obtained by a bootstrap exercise. Two subsets of the pooled set of CMIP3 and CMIP5 ensemble members of the same size as the original ensembles, but without distinguishing CMIP3 from CMIP5 members, were randomly sampled 500 times. For each random sample we compute the corresponding patterns and their difference, then the true difference is compared, grid-point by grid-point, to the distribution of the bootstrapped differences, and only grid-points at which the value of the difference falls in the tails of the bootstrapped distribution (less than the 2.5 percentiles or the 97.5 percentiles) are stippled.

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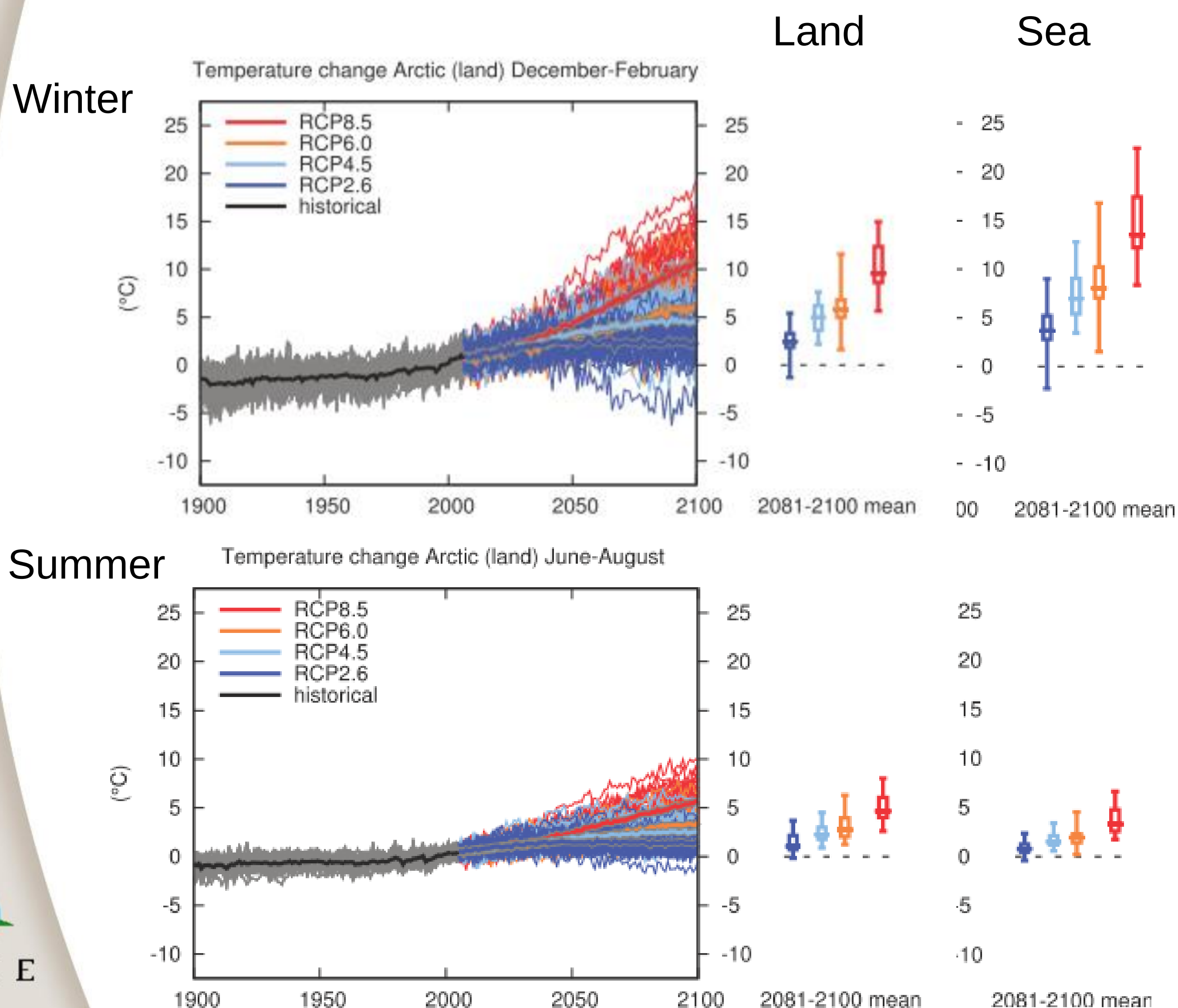
Source: IPCC 2013

Projected warming in the Arctic (relative to 1986–2005)



Source: IPCC 2013

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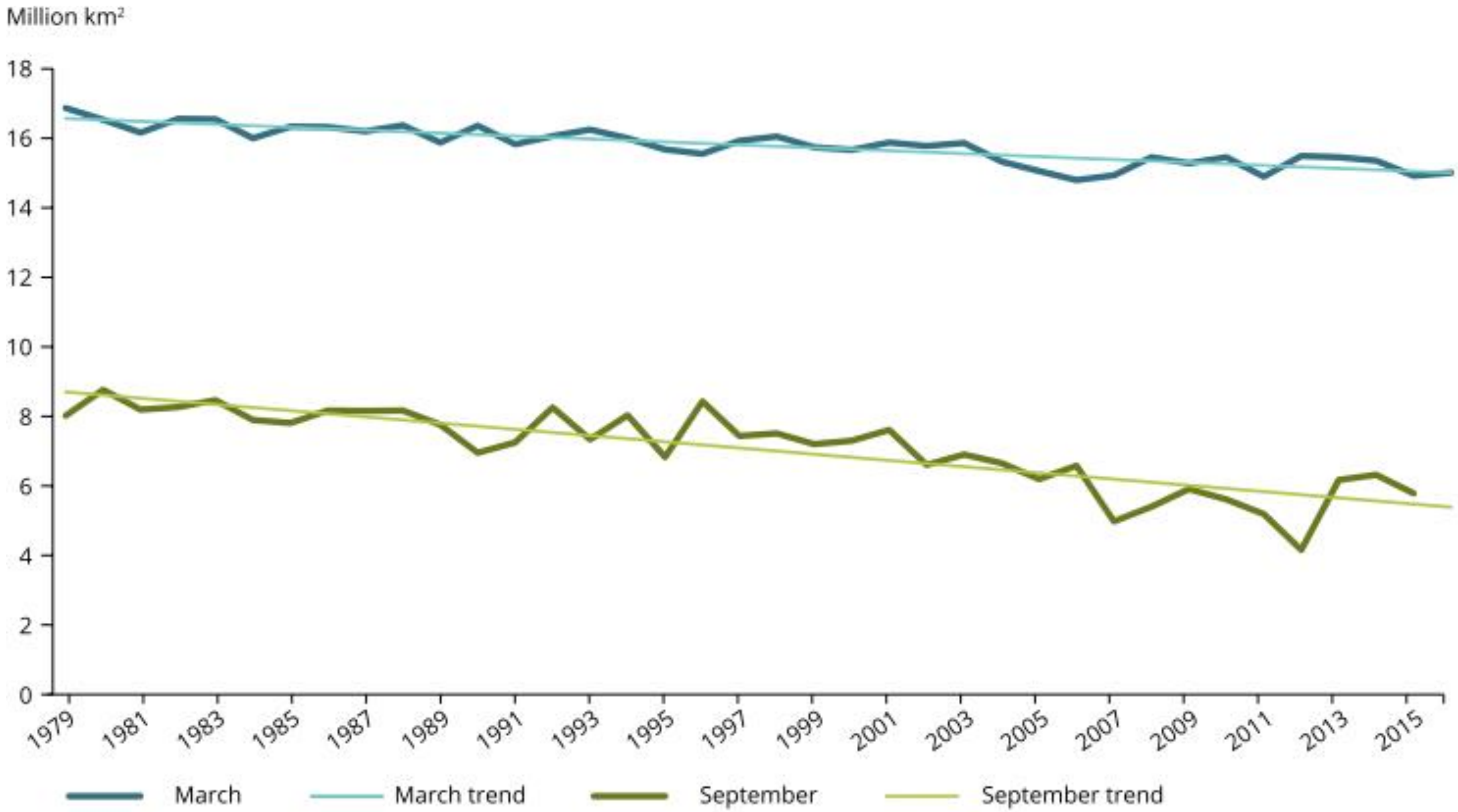
Arctic sea ice extent 1979-2016



Note: Trend lines and observation points for March (the month of maximum sea ice extent) and September (the month of minimum sea ice extent) are indicated. This figure does not reflect the reduction of sea ice thickness, which has also been declining over the same period.

Source: EUMETSAT Satellite Application Facility on Ocean and Sea Ice (OSI SAF) and CryoClim. Data delivered through Copernicus Marine Environment Monitoring Service.

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Source: EEA 2017

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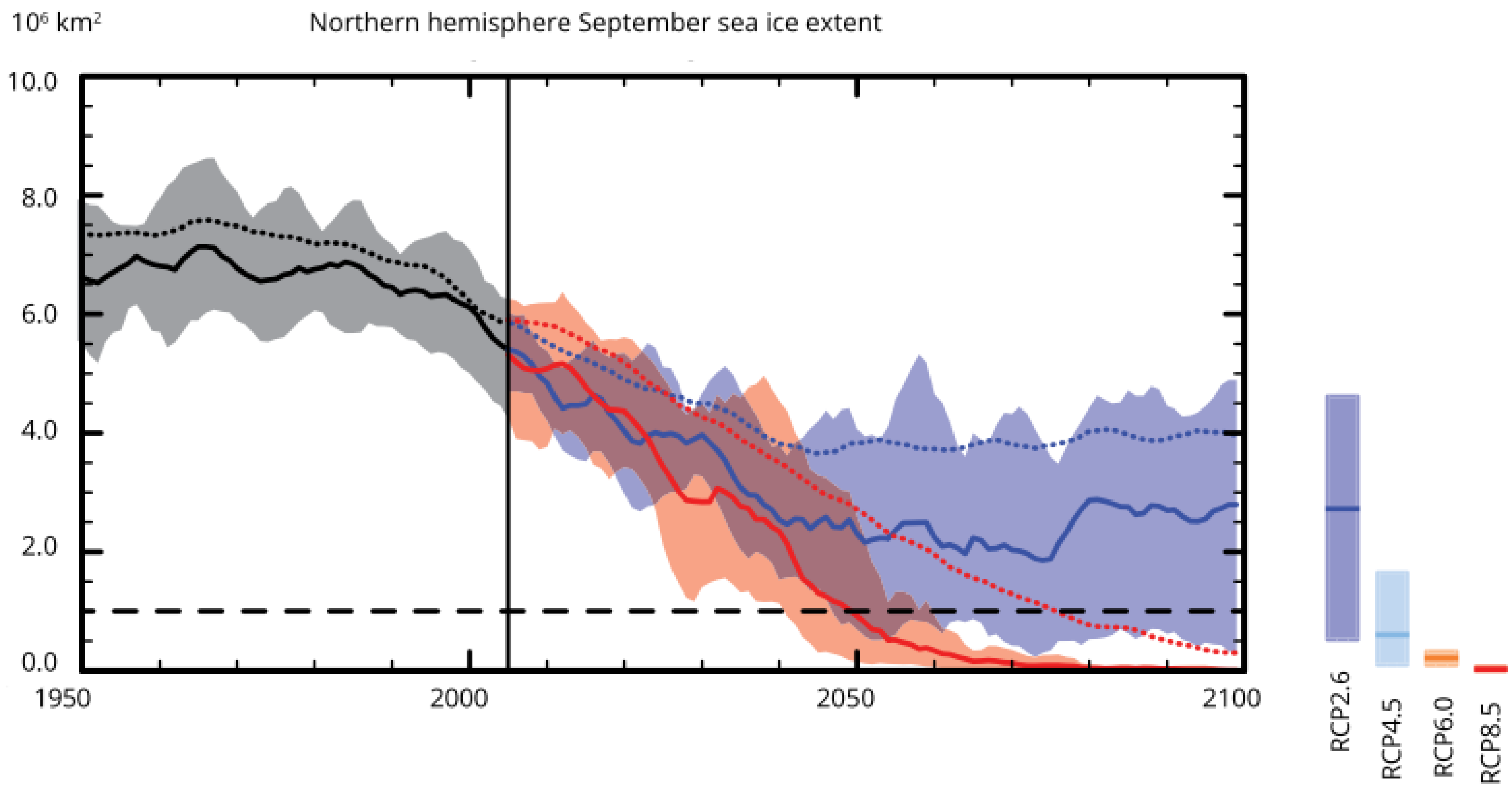
Northern hemisphere September sea ice extent 1950-2100



Note: This figure shows changes in northern hemisphere September sea ice extent as simulated by CMIP5 models over the 21st century under different emissions scenarios (RCPs). Sea ice extent is defined as the total ocean area in which sea ice concentration exceeds 15 % and is calculated on the original model grids. The solid lines show the five-year running means under the emissions scenarios RCP2.6 (blue) and RCP8.5 (red), based on those models that most closely reproduce the climatological mean state and 1979–2012 trend of the Arctic sea ice, with the shading denoting the uncertainty range. The mean and associated uncertainties averaged over 2081–2100 are given for all RCP scenarios as coloured vertical bars (right). For completeness, the CMIP5 multi-model mean for RCP2.6 and RCP8.5 is indicated with dotted lines. The black dashed line represents nearly ice-free conditions.

Source: Adapted from IPCC, 2013b (Figure SPM-7(b)).

Source: EEA 2017

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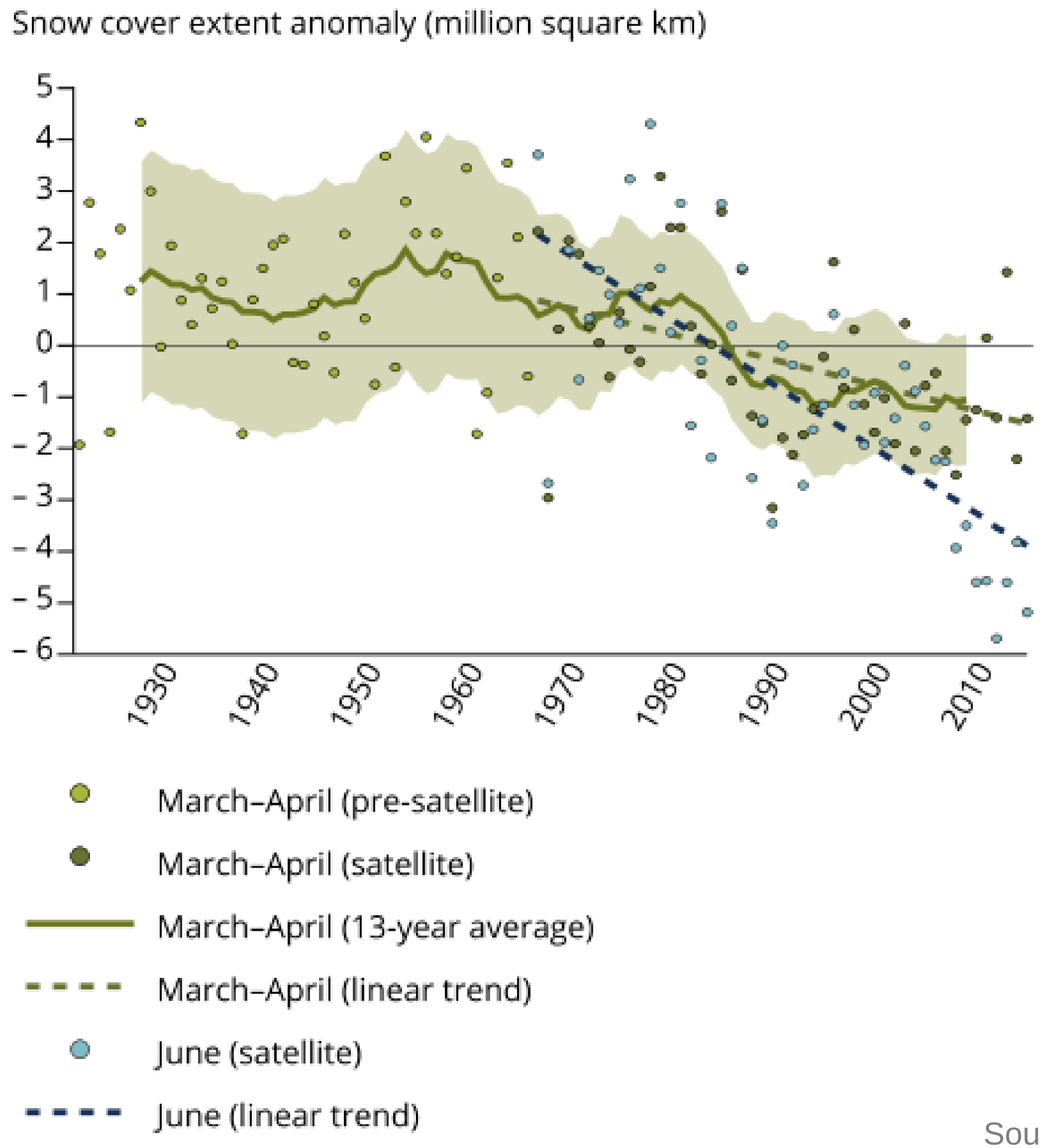
Observed snow cover trends over the northern hemisphere, 1922-2015



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Source: EEA 2017

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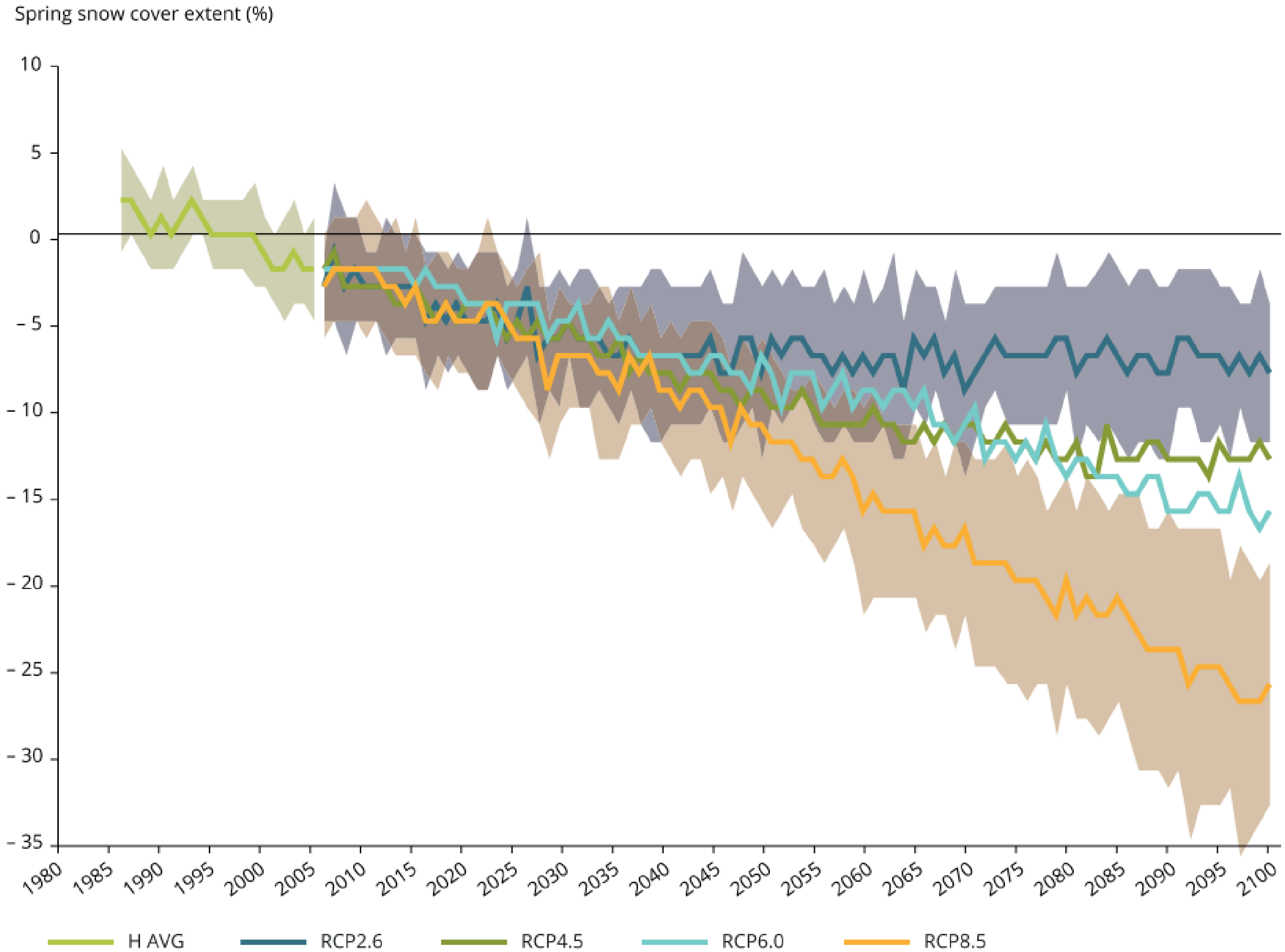
Projected snow cover extent over the northern hemisphere



Note: This figure shows the northern hemisphere spring (March to April average) snow cover extent based on the CMIP5 ensemble for actual emissions (up to 2005) and different forcing scenarios (RCPs). Values are given relative to the 1986–2005 reference period (H AVG). Thick lines mark the multi-model average and shading indicates the inter-model spread (one standard deviation).

Source: Adapted from IPCC (2013a, Figure 12.32). Data were provided by Gerhard Krinner (Laboratoire de Glaciologie et Géophysique de l'Environnement, France).

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Source: EEA 2017

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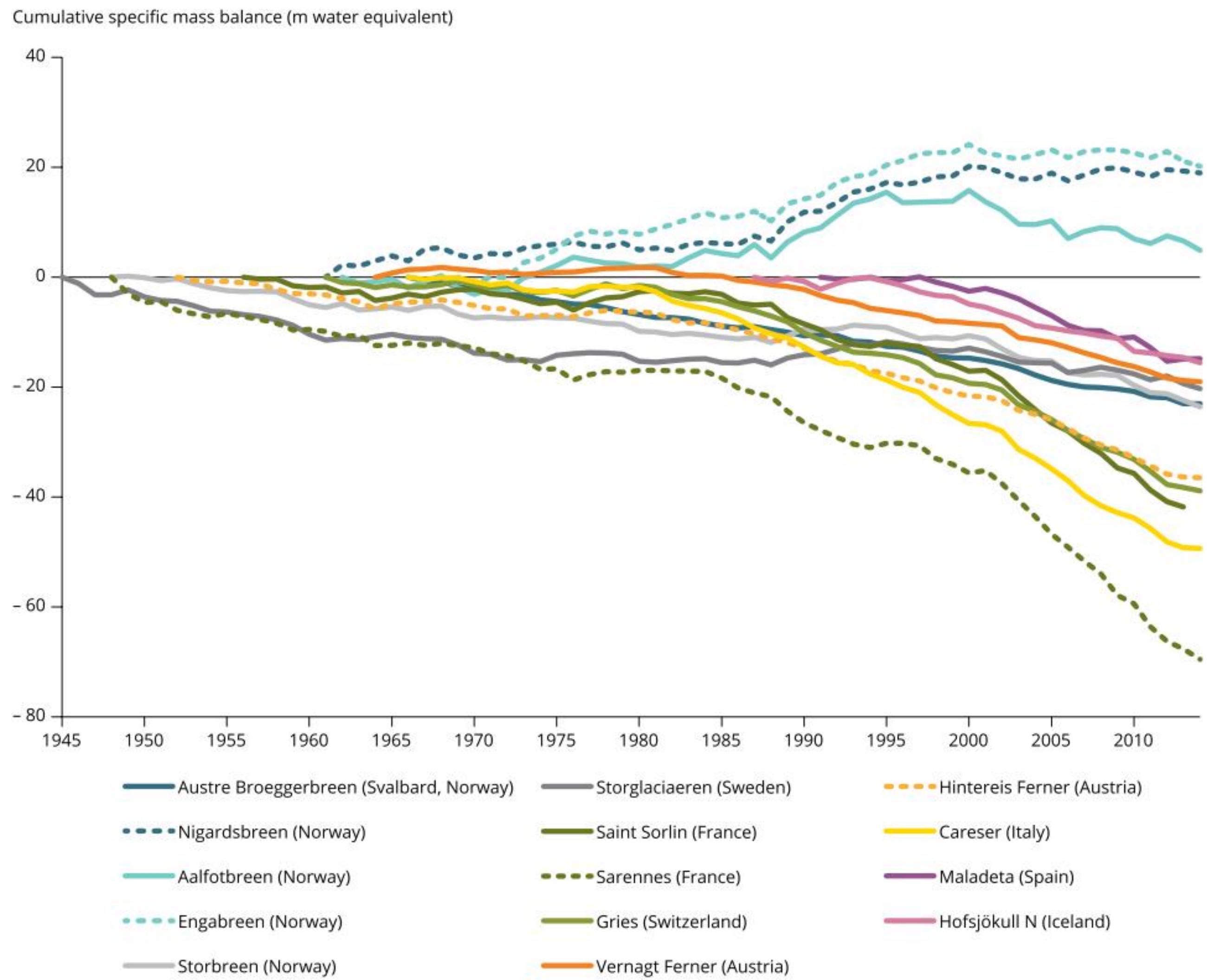
Cumulative mass balance of glaciers in Europe

Some Norwegian glaciers increased in mass until the 1990s due to precipitation increases.



Note: The figure shows cumulative specific net mass balance (m water equivalent) of European glaciers in the period 1946–2014.

Source: Fluctuation of Glaciers Database (FoG), World Glacier Monitoring Service.

Source: EEA 2017

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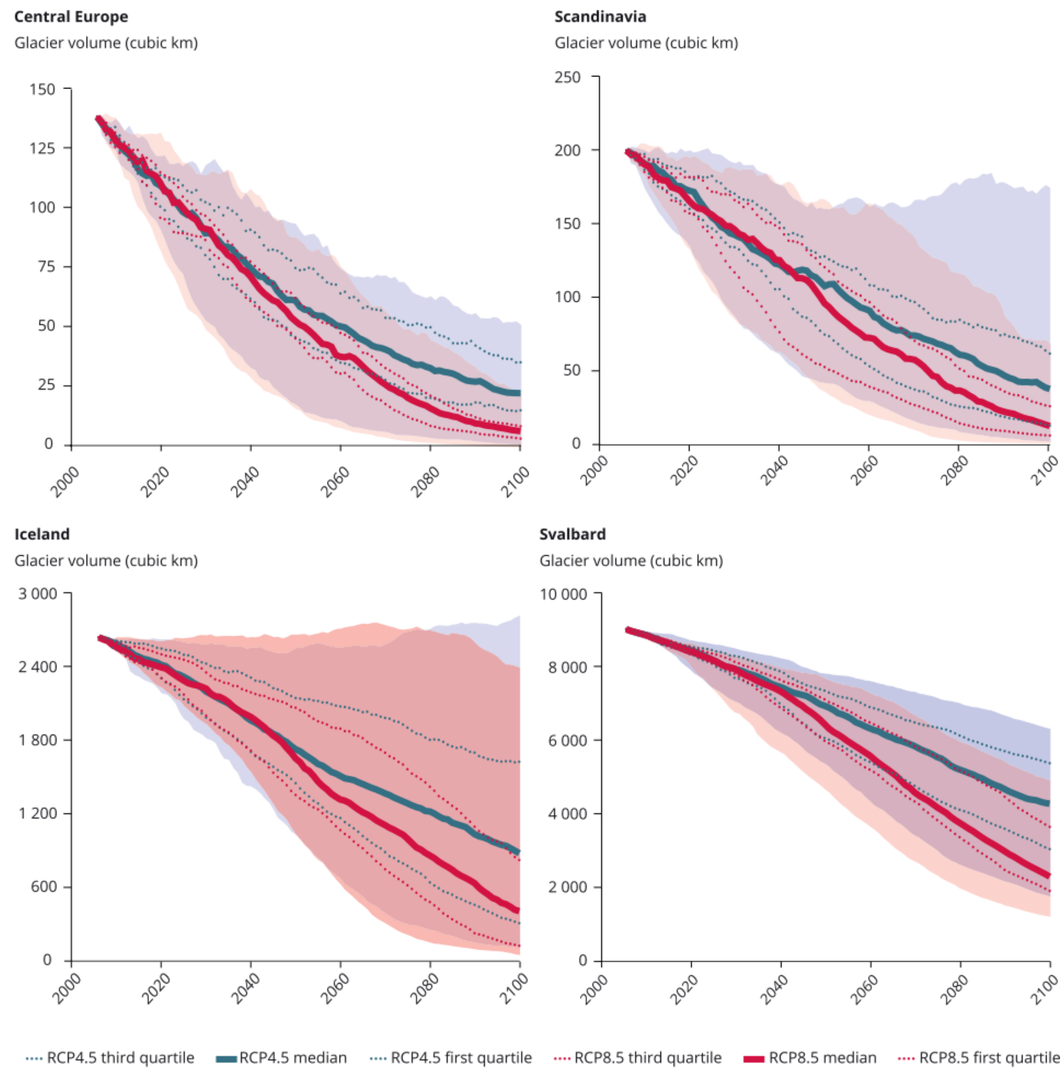
Glacier volume projections



Note: The figure shows the projected volume for 2006–2100 of all mountain glaciers and ice caps in the European glaciated regions, derived using a mass balance model driven with temperature and precipitation scenarios from 14 GCMs, in central Europe, consisting of the European Alps and Pyrenees (top left), Scandinavia (top right), Iceland (bottom left) and Svalbard (bottom right).

Source: Radić et al., 2014.

Source: EEA 2017

Changes in permafrost

- Increases in soil temperature, active layer depths and permafrost thaw

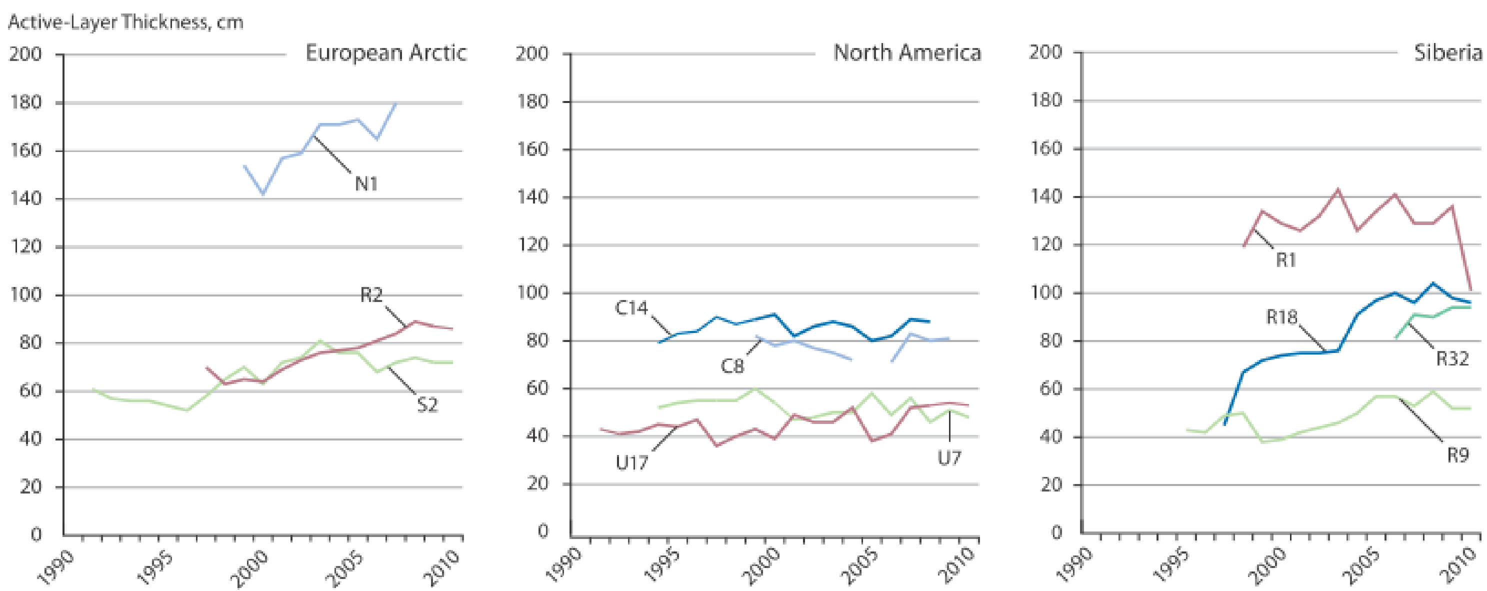
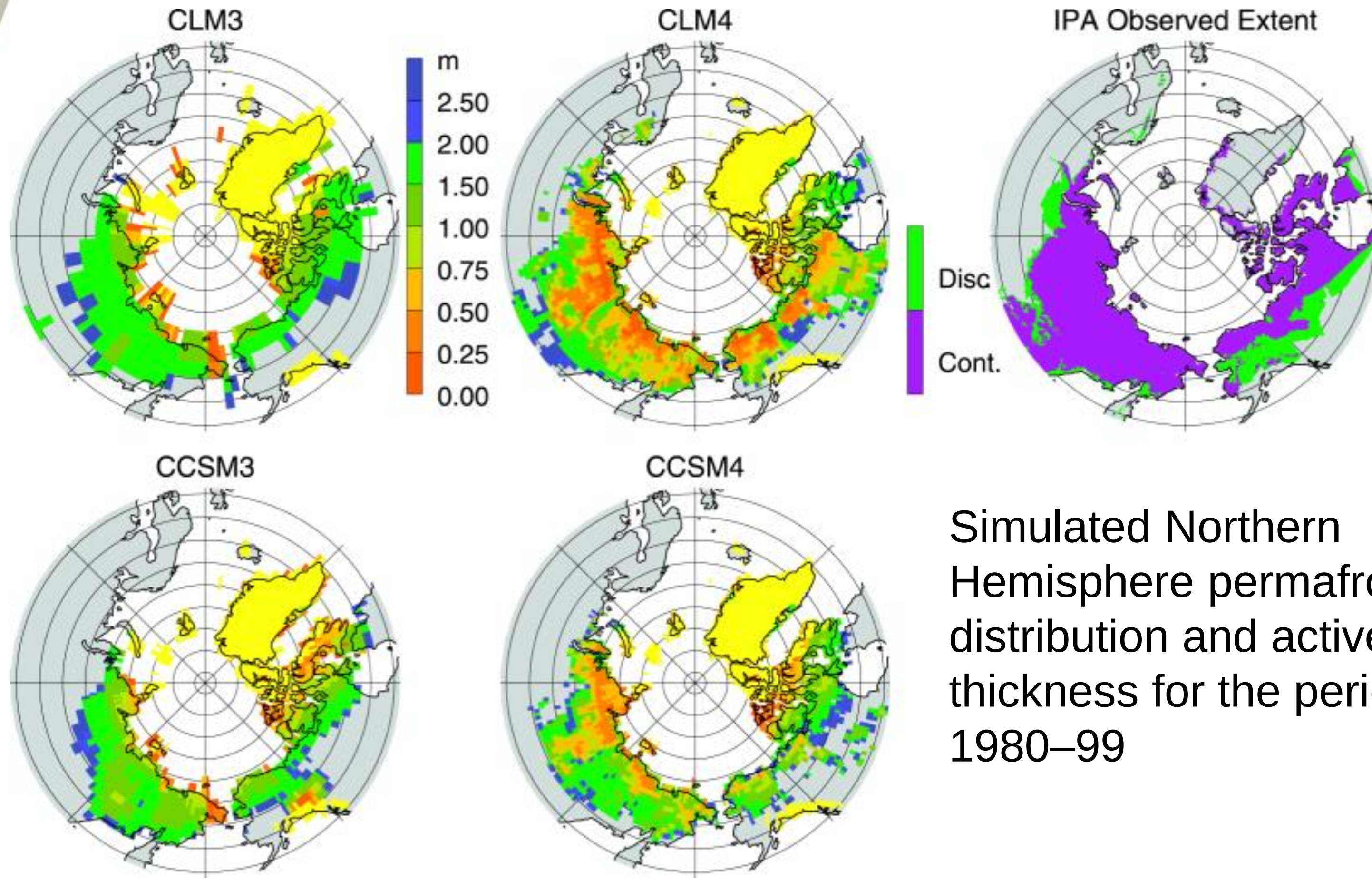


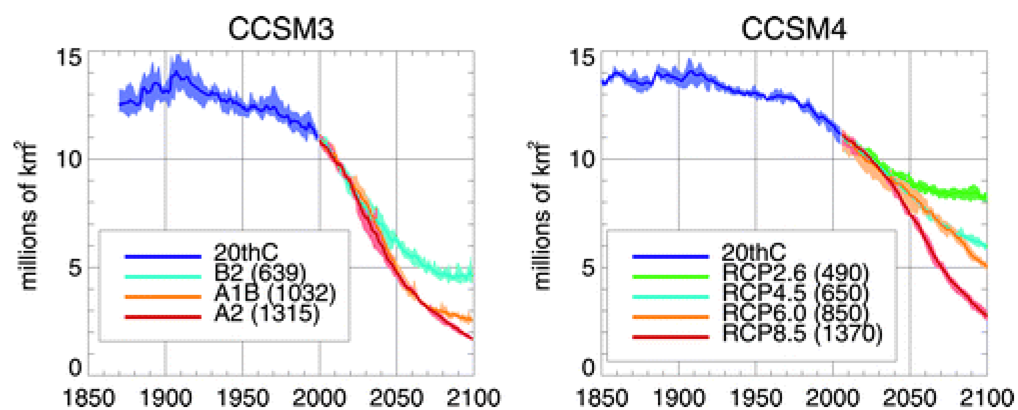
Figure 5.8. Distribution of northern hemisphere CALM sites (see Figure 5.4 for detailed permafrost map) and examples of the trends in active-layer thickness at a selection of sites (indicated by red dots). The active-layer measurements were obtained from bedrock, sediment and organic-rich sites. Site numbers correspond to the CALM nomenclature and the entire CALM data archive is available at www.udel.edu/Geography/calm/data/data-links.html.

Source: AMAP 2011



Simulated Northern Hemisphere permafrost distribution and active-layer thickness for the period 1980–99

Northern Hemisphere near-surface permafrost extent



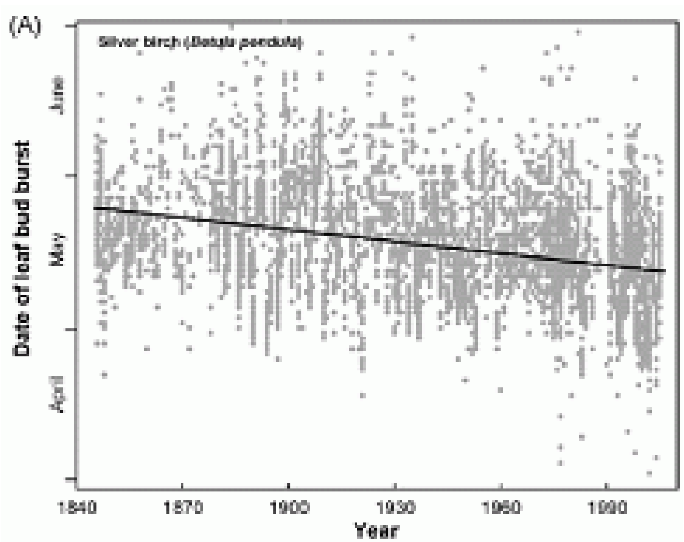
Source: Lawrence et al. 2012

Impacts permafrost thaw on infrastructure

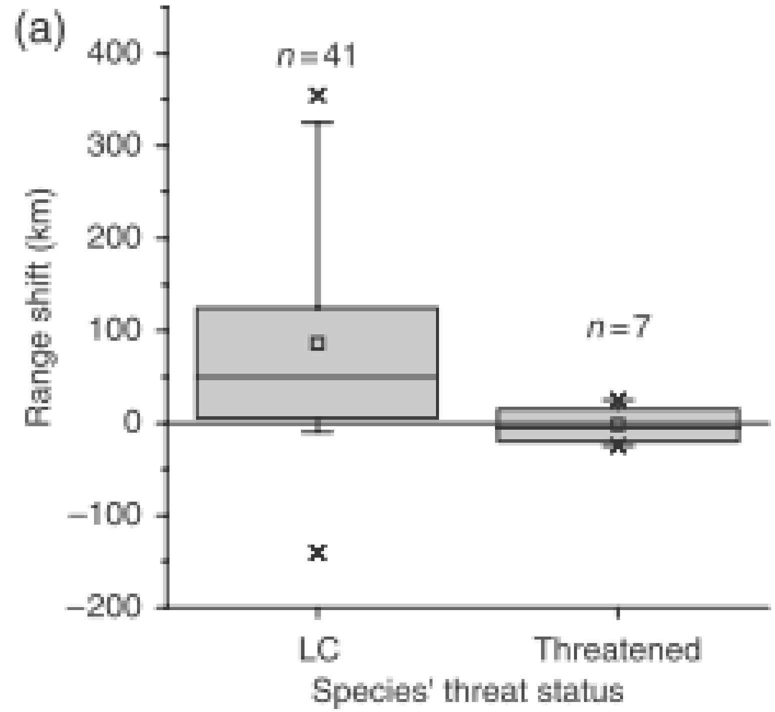
Human settlements in permafrost regions and their foundation dates.

Impacts on the Arctic nature

Observed impacts – examples of “fingerprints” of climate change: trees and butterflies in Finland



Observed dates of leaf bud burst of silver birch. Source: Linkosalo et al. 2009.



Range shift of 48 butterfly species in Finland between 1992–1996 and 2000–2004
(measured as change in the average latitude in 10 northernmost grid squares with a positive atlas record).
Source: Pyöry et al. 2009.

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Bird species ranges are shifting northwards

Changes in population density in Finnish bird atlas data between 1981-1999 and 2000-2009

Northern bird species

Southern bird species

6 *Virkkala & Rajasärkkä* • BOREAL ENV. RES. Vol. 16 (suppl. B)

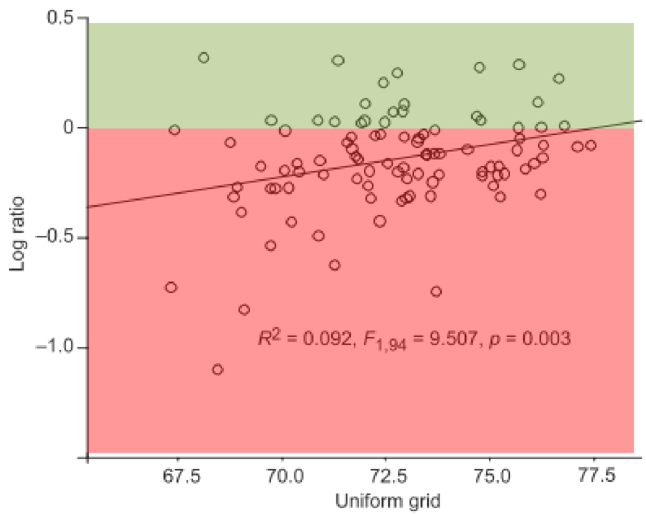

Fig. 2. Population density change (linear regression) for northern bird species from 1981–1999 to 2000–2009, based on log ratio [log ratio = log(density in 2000–2009/density in 1981–1999)] in each protected area according to location from south to north (for uniform grid details, *see* Fig. 1).

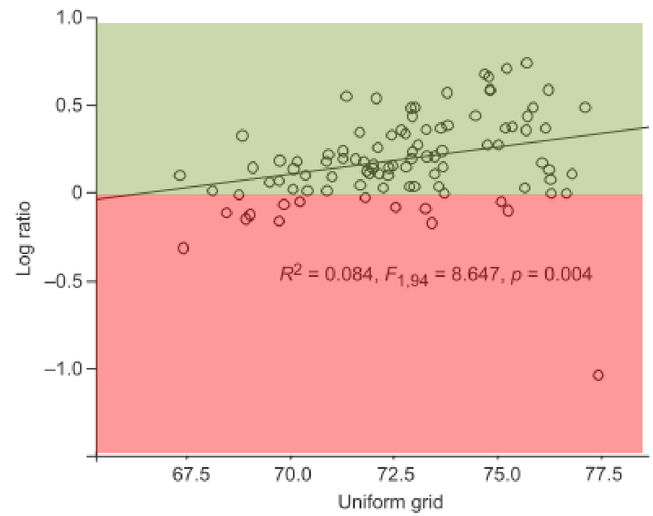

Fig. 3. Population density change (log ratio) for southern bird species in each protected area, according to location from south to north (uniform grid); linear regression presented.

Source: Virkkala & Rajasärkkä 2011

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Modelled bird species probability for present-day (x-axis) and 2051-2080 (y-axis)

Southern boreal zone

Middle boreal zone

Northern boreal zone

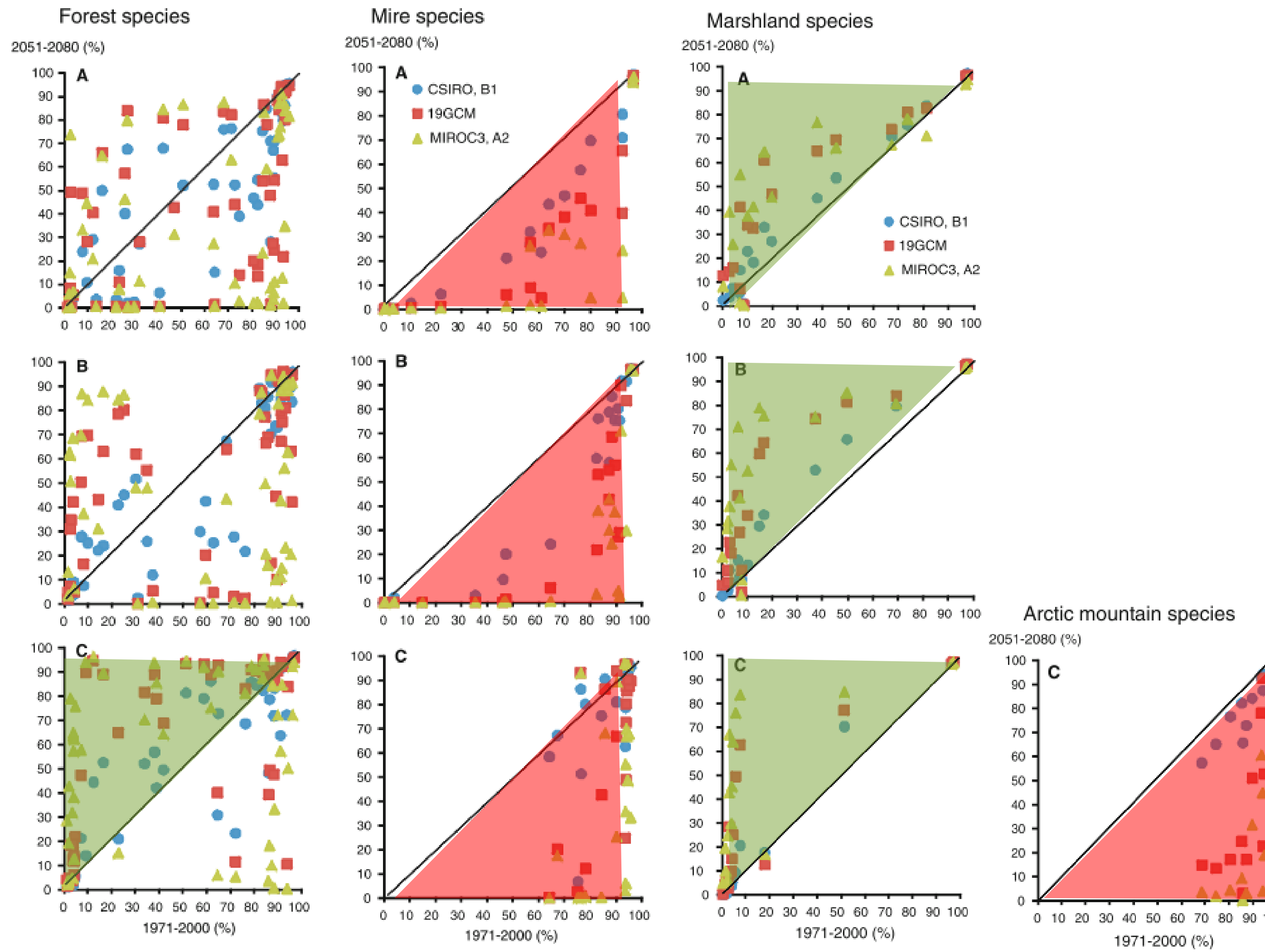

Fig. 3 Probability (in %) of occurrence of species in protected squares in 1971–2000 and in 2051–2080 based on the three climate scenarios. a southern boreal, b middle boreal, c northern boreal zone. Species probability of occurrence is predicted to decrease below the diameter line and to increase above the line

Source: Virkkala et al. 2013

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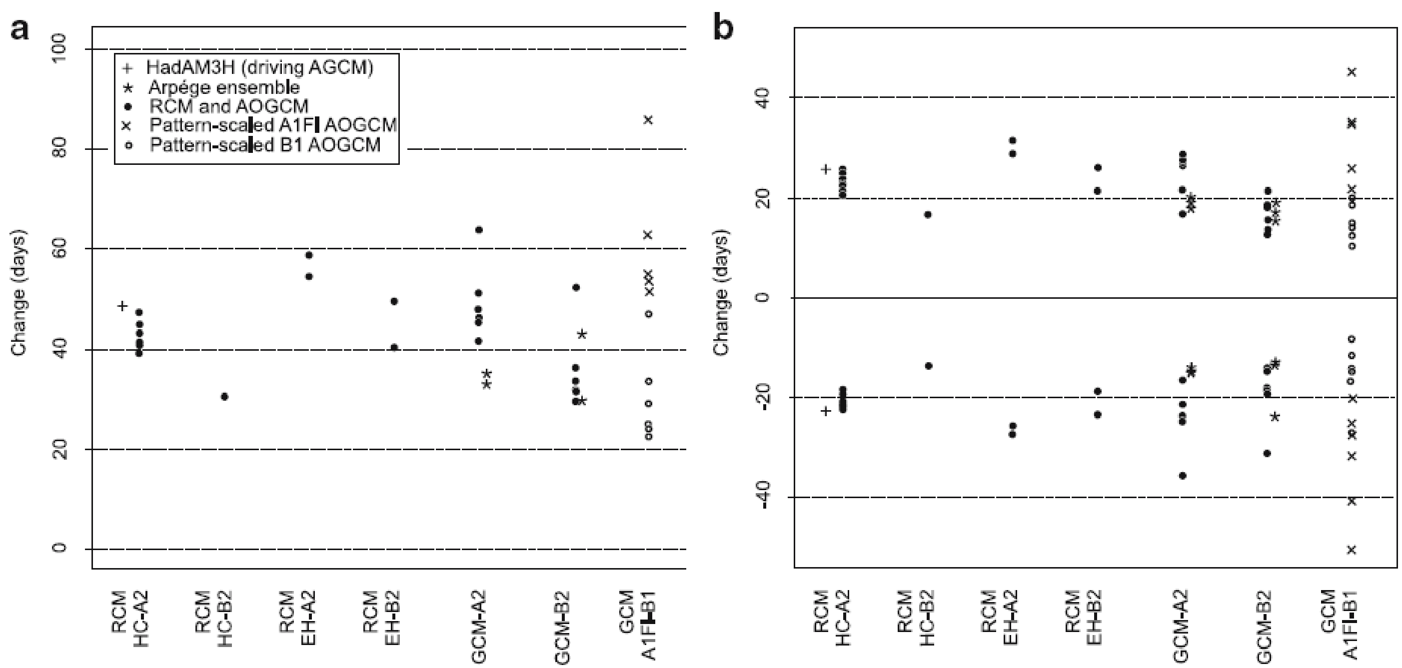
Lengthening of the growing season

- 3 to 10 weeks longer growing season in N Europe by the end of the 21st century

Fig. 4 Regionally-averaged changes in **a** the length, and **b** the start (*bottom*) and end (*top*) of the thermal growing season in northern Europe (see footnote 3) for different groups of climate scenarios from RCM, AGCM and AOGCM simulations for the period 2071–2100 compared with the baseline (1961–1990). All scenarios are applied as delta changes to the CRU baseline temperatures



Source: Fronzek & Carter 2007

Thermal suitability of grain maize

136 Climatic Change (2007) 81:123–143

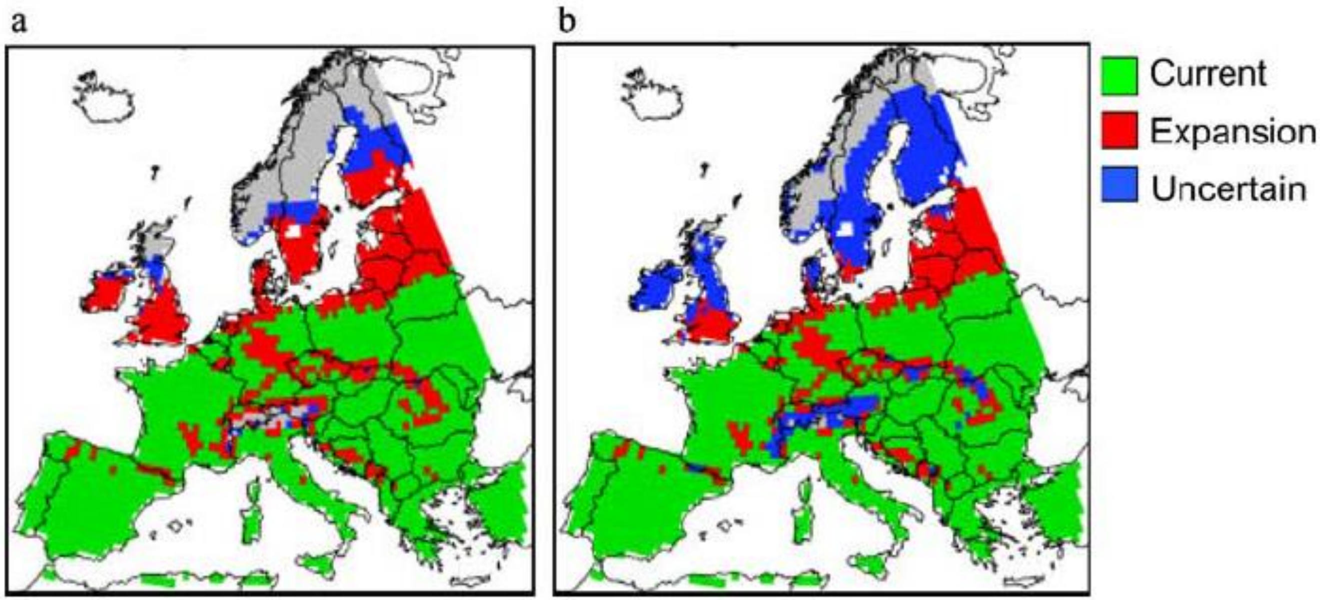


Fig. 4 Modelled suitability for grain maize cultivation during the baseline (1961–1990) and future (2071–2100) periods for: **a** 7 RCM scenarios driven by HadAM3H for the A2 emissions scenario and **b** 24 scenarios from 6 GCMs for each of the A1FI, A2, B1 and B2 emissions scenarios. *Green areas* show the suitable area for the baseline, *red* depicts the expansion common under all scenarios and *blue* the uncertainty range of the respective scenario group. *Grey areas* are unsuitable under all scenarios

Source: Olesen et al. (2007). *Climatic Change*, **81**, 123–143.

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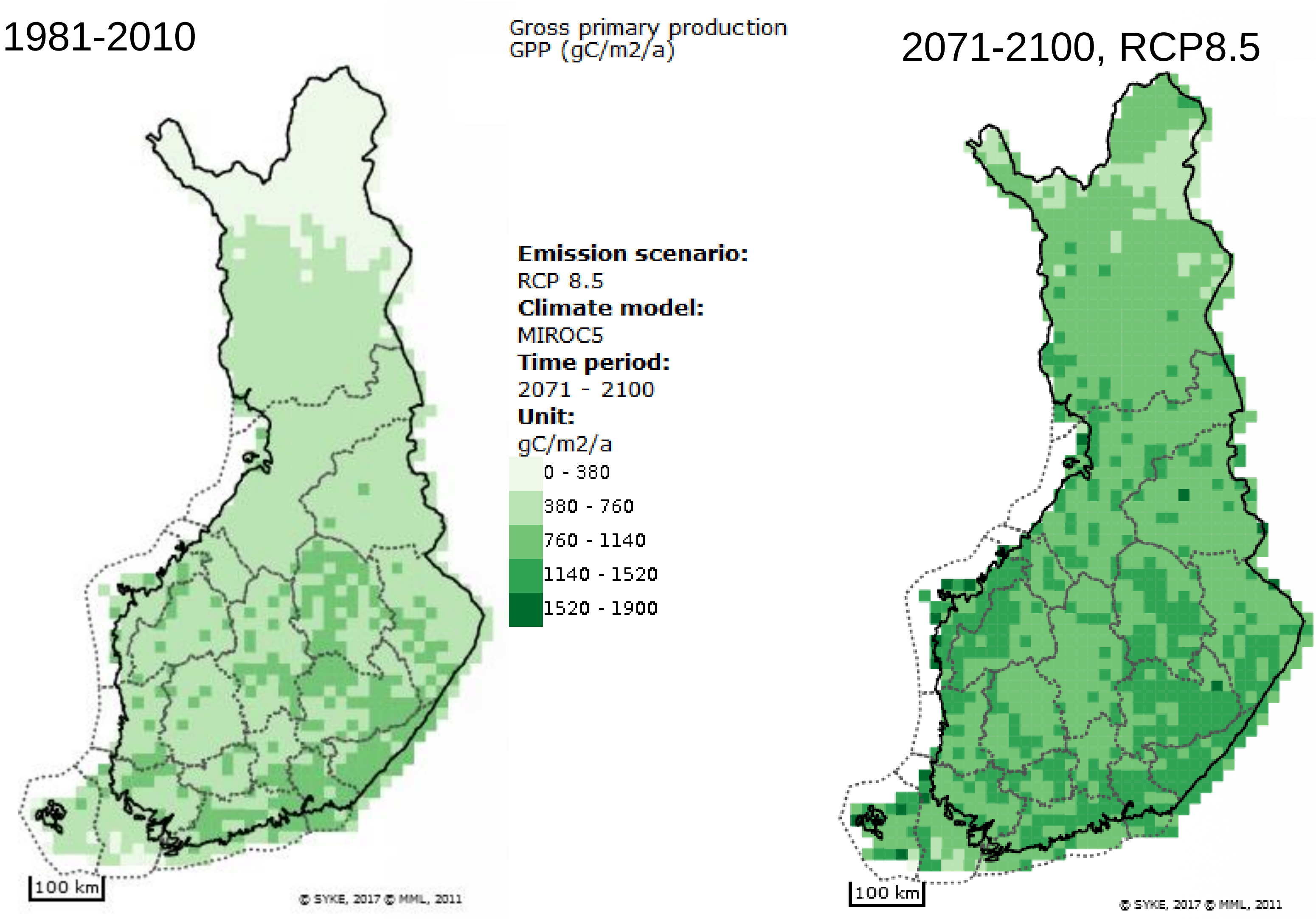
Forest productivity increases



Source: Peltoniemi et al. 2015, http://climateguide.fi

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Climateguide.fi

Responses to climate change

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Mitigation and Adaptation

- **<u>Mitigation</u> is the reduction of greenhouse gas emissions in order to prevent dangerous climate change**

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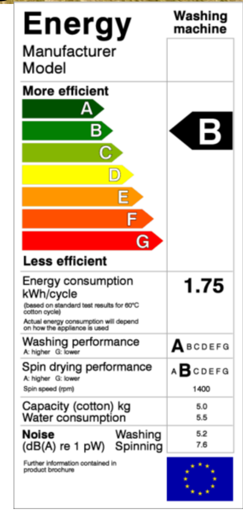
Mitigation and Adaptation

- Mitigation is the reduction of greenhouse gas emissions in order to prevent dangerous climate change
- **Mitigation alone is not enough. The earth is already committed to some climate warming**

Mitigation measures

Photo credits: Wagner Christian



EU energy label

- Alternative energy sources
- Energy efficiency and conservation
- Carbon sequestration (CO_2 removal from the atmosphere)
  - Reforestation
  - Wetland restoration
  - Geoengineering (e.g. carbon capture and storage, seeding oceans with iron; solar radiation management)

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Mitigation by wooden construction

- Accounting for net life cycle carbon emissions
  - Emissions from material production
  - Substitution of fossil fuels from biomass (logging residues and waste wood from end-of-life demolition)
  - Cement process reactions
  - Carbon stock changes and carbon sequestration in wood products

- GHG saving potential: single Finnish building (Gustavsson et al. 2006)
  - 4 stories, wooden frame and façade, 1175 m^2 floor area, building life cycle 100 years
  - Net CO2 emissions (tonnes of C)

Wood frame		Concrete frame	
Coal	Natural Gas	Coal	Natural Gas
-76,2	-30,6	75,3	72,3

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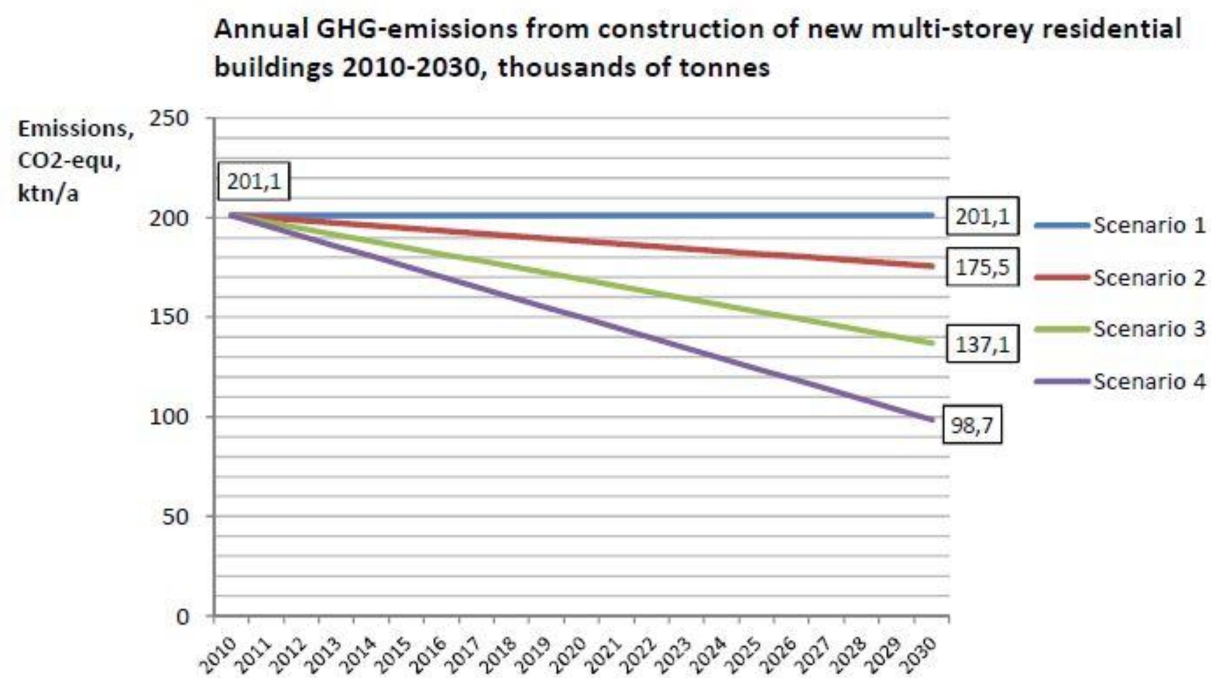
Slide prepared by David Lazarevic, SYKE

GHG saving potential of the multi-storey wooden building market in Finland

- Ruuska & Häkkinen 2012:
  - Scenario 1: 2%; Scenario 2: 20%; Scenario 3: 50%; Scenario 4: 80% of new wooden buildings per year by 2030



Slide prepared by David Lazarevic, SYKE

CLIMATE CHANGE PROGRAMME

Mitigation and Adaptation

- Mitigation is the reduction of greenhouse gas emissions in order to prevent dangerous climate change
- **Mitigation alone is not enough. The earth is already committed to some climate warming**
- Adaptation is the alteration of activities in order to avoid or minimise the consequences of climate change

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Examples of adaptations in the Arctic

Arctic region	Adaptation	Stressors	Publication
Alaska	Construction a new school in sheltered location away from settlement. Road to school provides an evacuation route during extreme weather; school may serves as pioneer infrastructure for community relocation.	Sea level rise and coastal erosion, extreme events	(Bronen and Chapin 2013)
Northwest Territories	The Women's Community Kitchen project—effort to educate about nutritional cooking with store foods to ameliorate projected declines in country food availability	Changing sea ice dynamics, decreasing snowfall, food insecurity	(Pearce *et al* 2012)
Yukon	The Whitehorse Community Adaptation Project—multi partner project to develop scenarios for planning in the context of climatic and social change.	General climate-related concern, changing socio-economic conditions	(Hennessey 2010)
Nunavut	Altering location and timing of hunting; additional preparation, including GPS, monitoring weather forecasts, extra emergency equipment	Changing sea ice dynamics, environmental conditions uncertainty, weather uncertainty, economic stress	(Ford *et al* 2013)
Nunatsiavut	Changing climate, changing health, changing stories–participatory approach to understanding and promoting human health in the context of complex social and ecological interactions	Rising temperatures, seasonality change, weather uncertainty, decreasing rainfall, changes in wildlife, health related concerns, cultural change	(Harper *et al* 2012)
Lapland	Constructing more weather resistant roads into logging areas to overcome access challenges related to thawing roads	Rising temperatures, weather uncertainty, environmental conditions uncertainty, economic stress	(Keskitalo 2008)
Fennoscandia	Moving reindeer by truck due to poor land conditions, supplementary winter feeding due to frozen pasture	Rising temperatures, seasonality change, environmental conditions uncertainty, marginalization, resource development related concerns, economic stress	(Furberg *et al* 2011)
Greenland	Altering location and timing of hunting; additional preparation, including GPS, monitoring weather forecasts, extra emergency equipment; women's employment playing a larger role in finance hunting activities	Changing sea ice dynamics, weather uncertainty, changing wildlife distributions, rigid wildlife management programs, economic stress	(Ford and Goldhar 2012)
Siberia	Changing livestock grazing patterns, decreasing heard size to promote flexibility	Vegetation change, rain on snow events, environmental conditions uncertainty, resource development related concerns, marginalization	(Forbes *et al* 2009)
Beringia	State and federally funded coastal erosion control efforts	Sea level rise and coastal erosion, extreme events,	(Marino 2012)
Pan-Arctic	The development of the International Maritime Organization's International 'Polar Code' for Arctic shipping	Changing sea ice dynamics, resource development related concerns, increased shipping in Arctic waters	(Hovelsrud *et al* 2011)

Source: Ford et al. 2014

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Summary and conclusions

- ~1°C global warming since pre-industrial conditions
- Arctic region warms more, 2x in the future
- Observed decrease of snow cover, shrinking of glaciers, declining area and thinning of Arctic sea ice; further reductions in the future.
- The melting of ice and snow and the thawing of permafrost cause positive feedback loops that can accelerate climate change further.
- Changes in the cryosphere affect global sea level, many species, ecosystems and their services, forest productivity increases.
- Wooden buildings decrease GHG emissions.
- Adaptation is needed.

Blue glacier ice, Northwest Greenland.
Photo credit: Lars Witting/ARC-PIC.COM