CES Nordic Project on Climate and Energy Systems

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Climate and Energy Systems

A Nordic Project providing climate-parameter scenarios for the energy sector until 2050

Presentation based on input from working groups led by:

Árni Snorrason, Birger Mo, Deborah Lawrence, Erik Kjellström, Jari Schabel, Niels-Erik Clausen, Seppo Kellimäki, Sten Bergström and Tómas Jóhannesson

Presented by: **Þorsteinn Þorsteinsson**
Icelandic Meteorological Office

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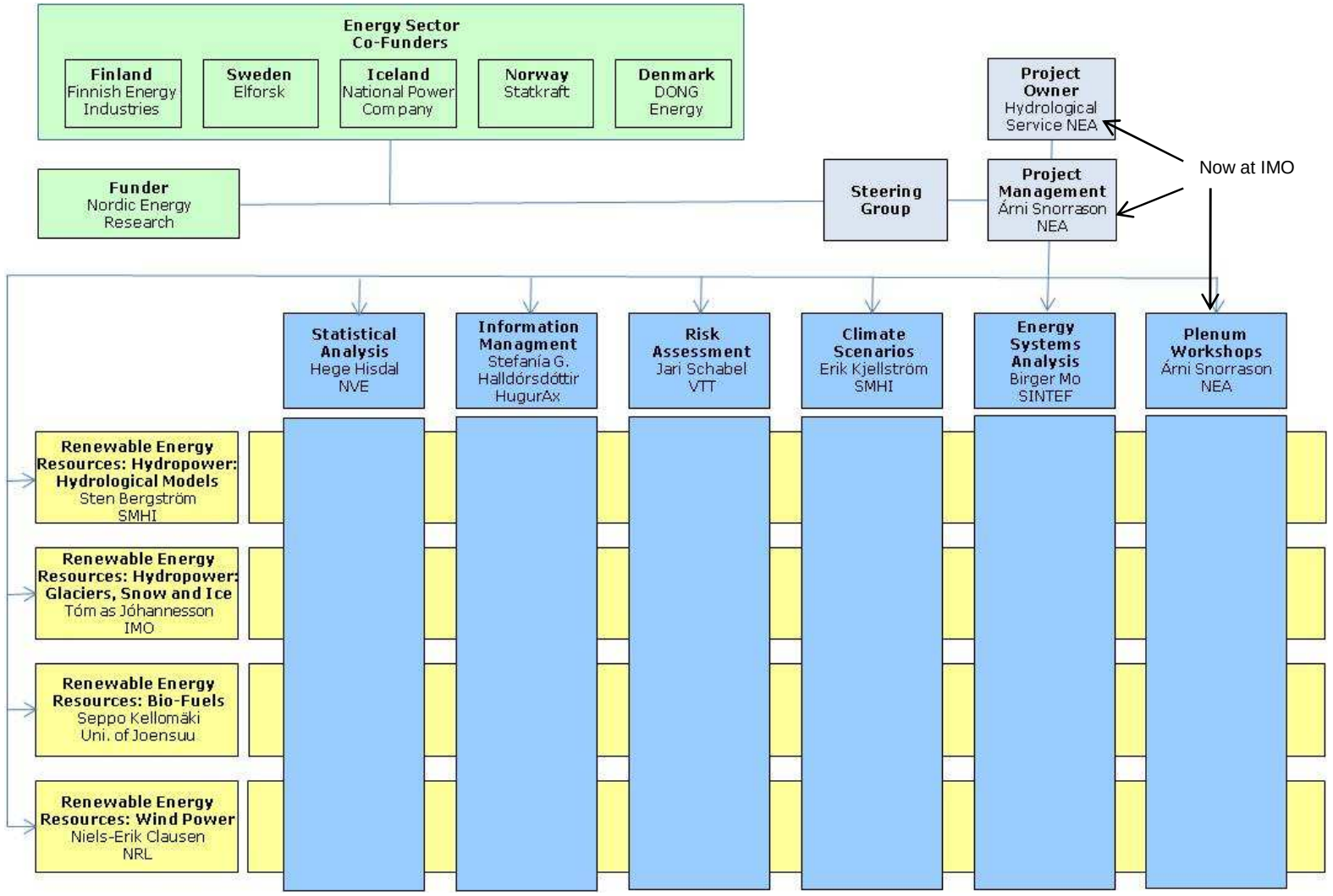
The Nordic Project *Climate and Energy Systems*

- **Objective: To improve the decision framework of the energy sector with regard to climate change impact on renewable energy resources and the energy system**
- **Project period 2007-2010**
- **30+ partners from the 5 Nordic + the Baltic countries**
- **Focus on hydropower, wind energy and biomass**
- **Supported by Nordic Energy Research and the Nordic Energy Industry (DONG Energy Denmark, Statkraft Norway, Elforsk Sweden, the Finnish Energy Industries and the National Power Company, Iceland)**

Partners, organisation



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Statistical analysis group

Sets the scene for future climate scenarios through studies of patterns of change in historical data

PI: Deborah Lawrence, Norges Vassdrags og Energidirektorat (NVE)

- **Analyses of regional series and trends in climate parameters and streamflow/runoff for the individual countries**
- **Analyses of changes in the occurrence of extreme events**
- **Analyses of links between atmospheric processes and local variables of interest to the energy sector; i.e. streamflow and wind**

Statistical analysis: Example from Denmark

Analysis of regional trends in precipitation and runoff based on data from:

- 8 climate stations
- 18 river discharge stations

Period studied: 1917-2000

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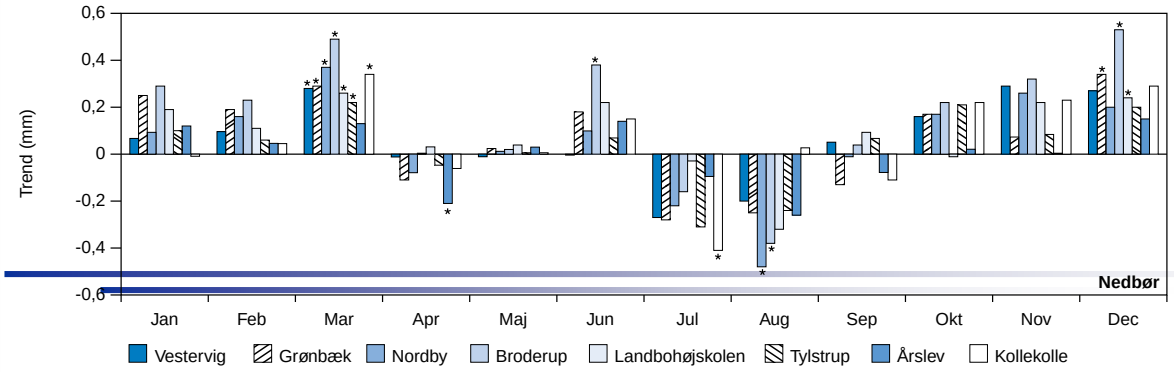
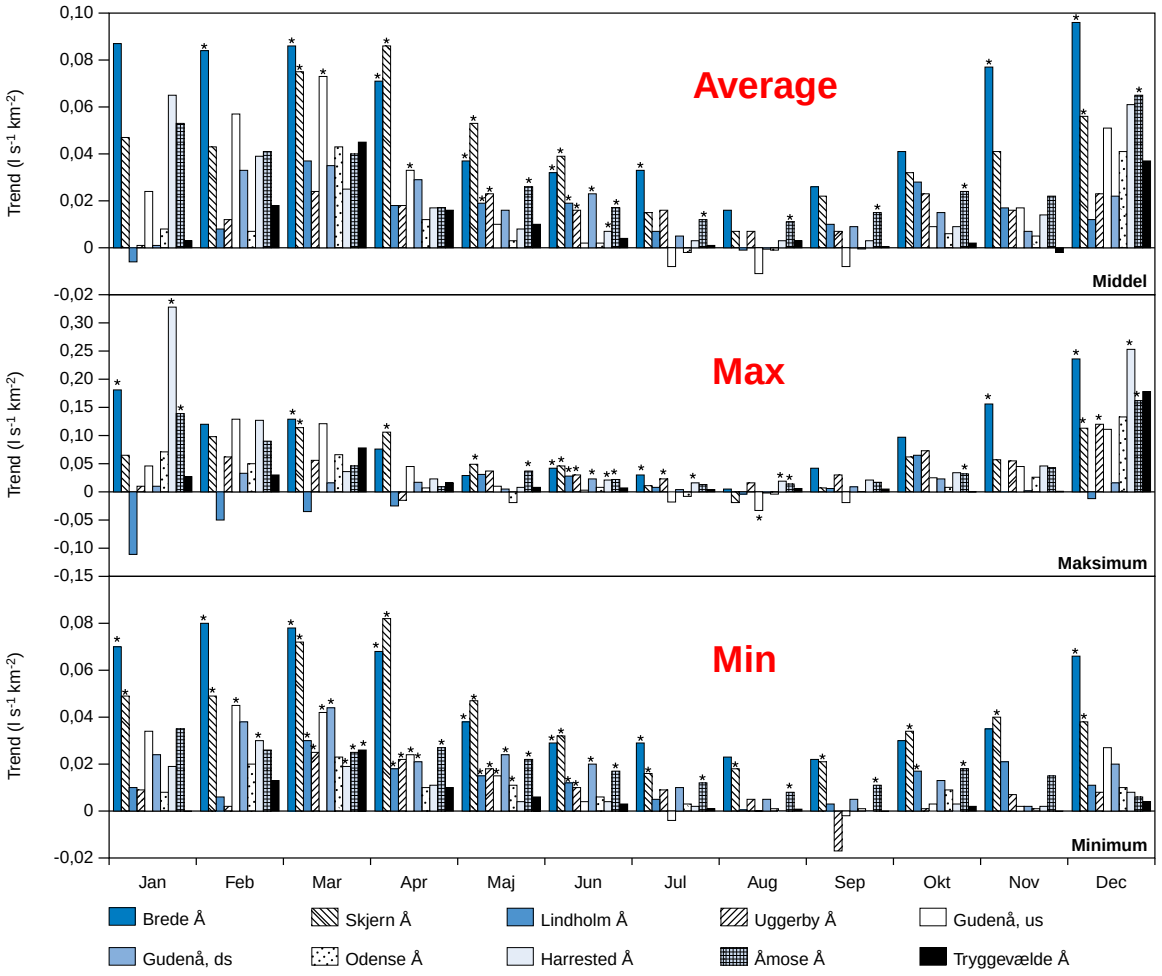


Increase in annual precipitation observed at 7 out of 8 stations. Trend towards wetter winters and drier summers.

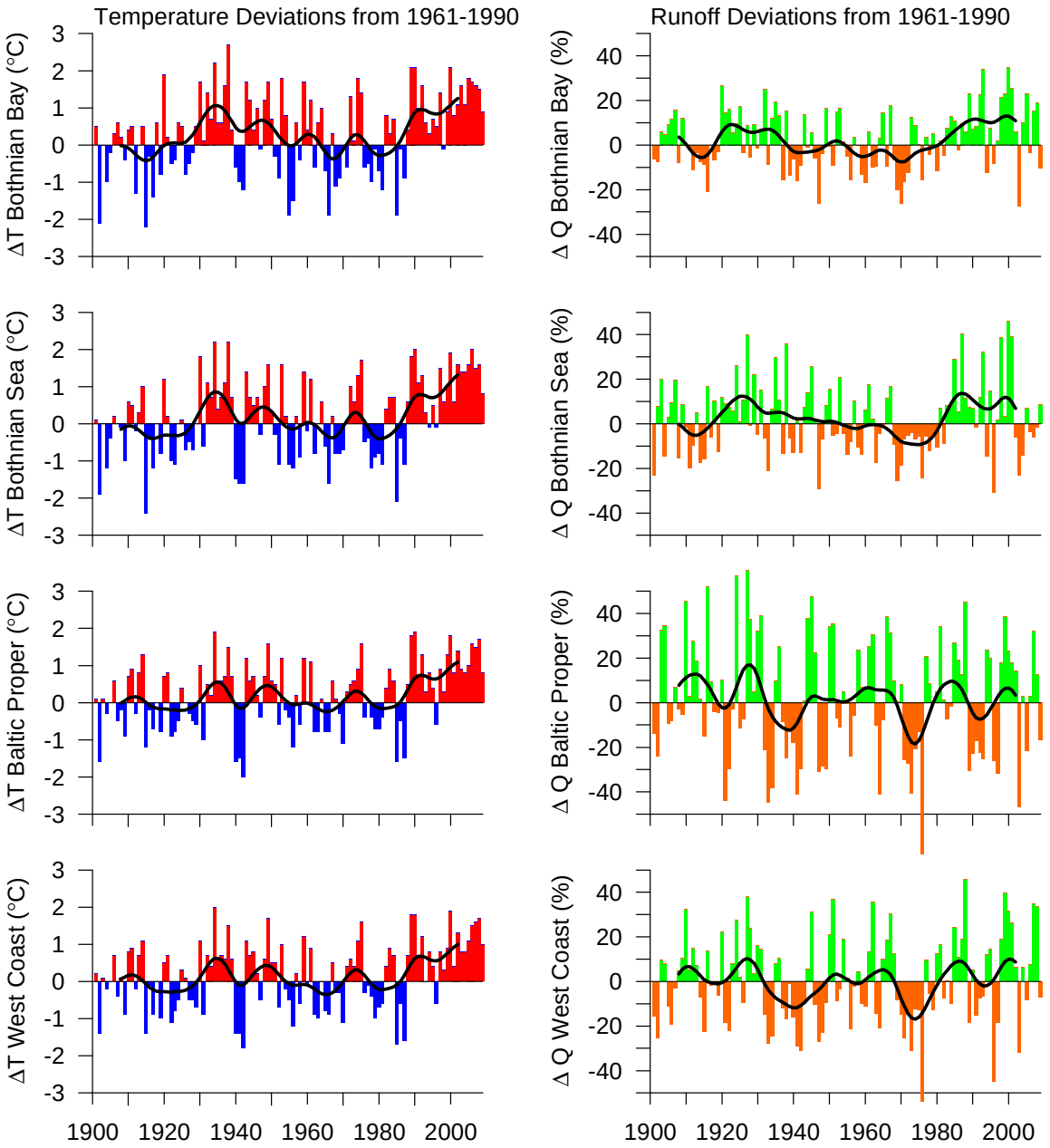


Annual runoff increases at all stations.

Monthly values show clear seasonal pattern in trends:

Largest positive trends in winter half-year.

Time series of temperature and runoff from Sweden 1901-2009



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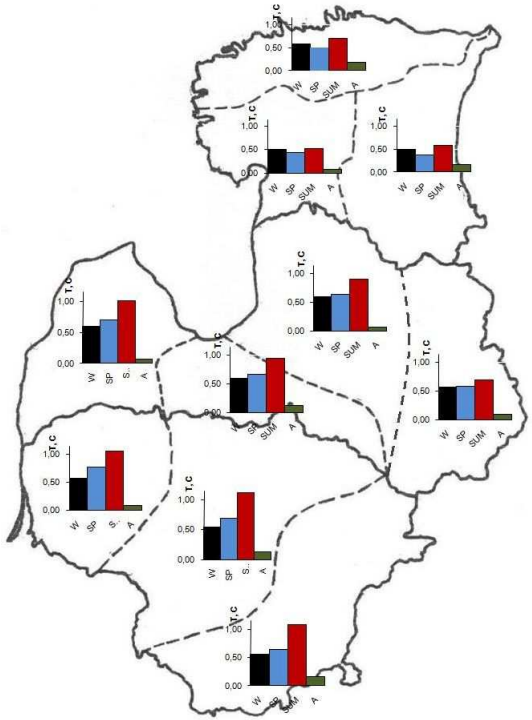
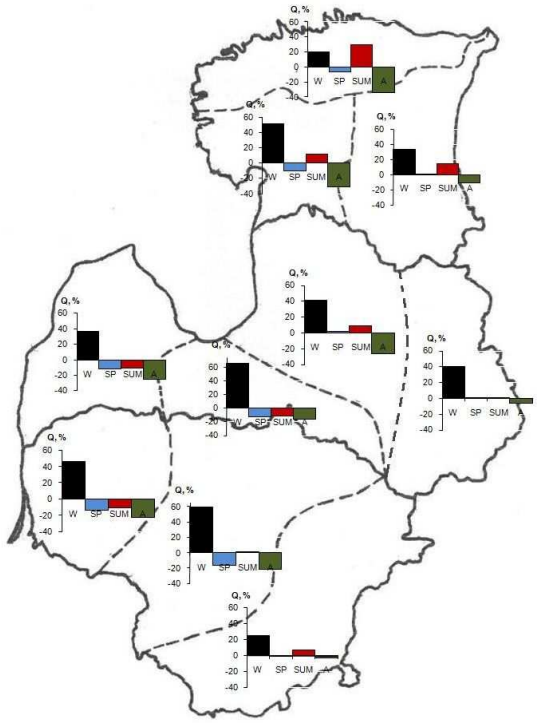
Recent temperature and runoff changes in the Baltic countries

Period 1991-2007 compared with reference period 1961-1990



Seasonal anomalies in temperature (°C)



Seasonal anomalies in runoff (%)

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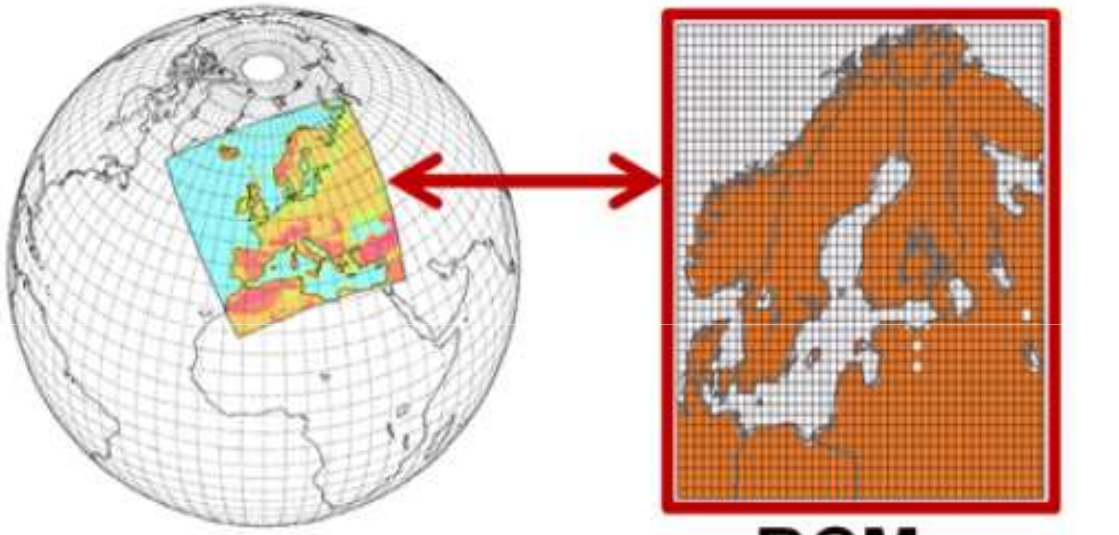
The Climate Modelling and Scenarios Group

Uses output from global Atmosphere Ocean General Circulation Models (AOGCMs) to forecast future climate of the Nordic region

PI: Erik Kjellström, Sveriges Meteorologiska och Hydrologiska Institut (SMHI)

- **Provides regional climate scenarios at 25 km resolution for the CES groups**
- **High-resolution climate change scenarios at 1-3 km horizontal resolution for selected areas**
- **Evaluates the range and probabilities of modelled mean climate and climate variability, for the period 2010-2050**
- **Analyses regional climate scenarios in terms of impact-relevant indices**

Approach: Downscale output from Global Climate Models to regional/local scale



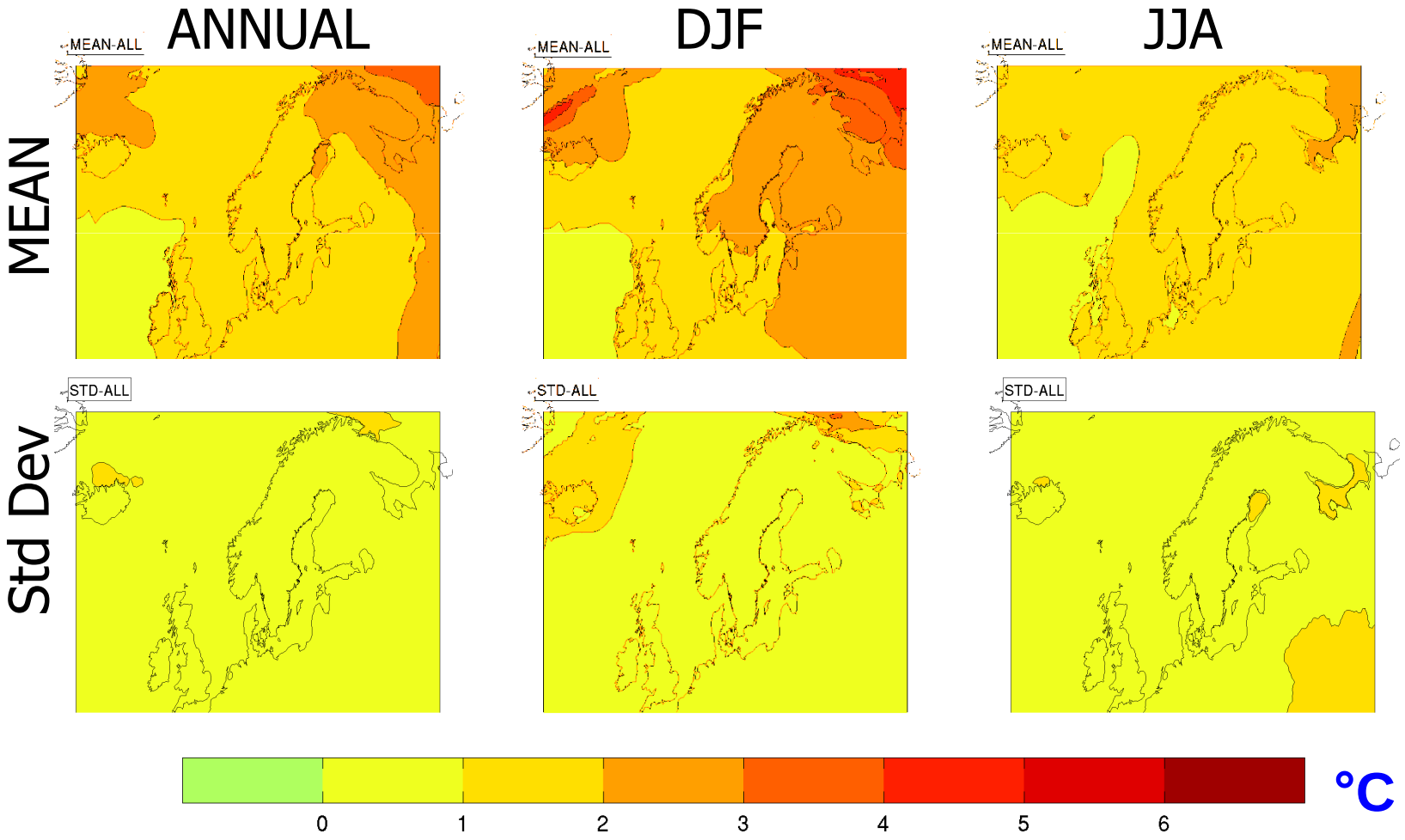
AOGCM
Whole globe
Lower resolution

RCM
Smaller domain
Higher resolution
Lateral boundaries from AOGCM

Illustration from: Pryor et al. Climate Dynamics (2005)

Regional climate change simulations: ensemble mean

15-member ensemble mean change (2021-2050 vs 1961-1990) in T2m



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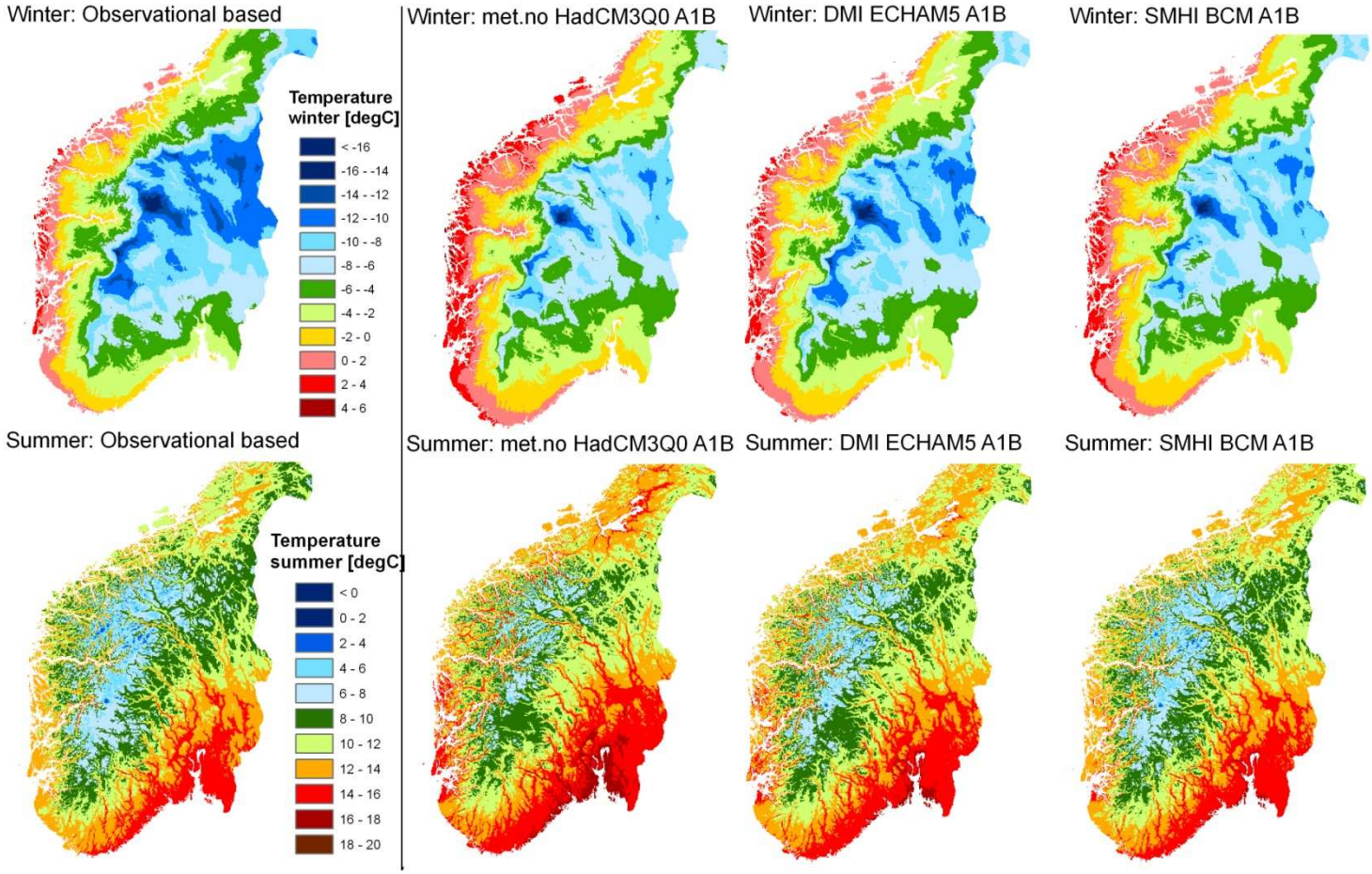
Downscaling of RCM output to 1km horizontal resolution by a statistical method

Projections of temperature for southern Norway for 2021-2050 as compared with 1961-1990.

Observed **Projected**



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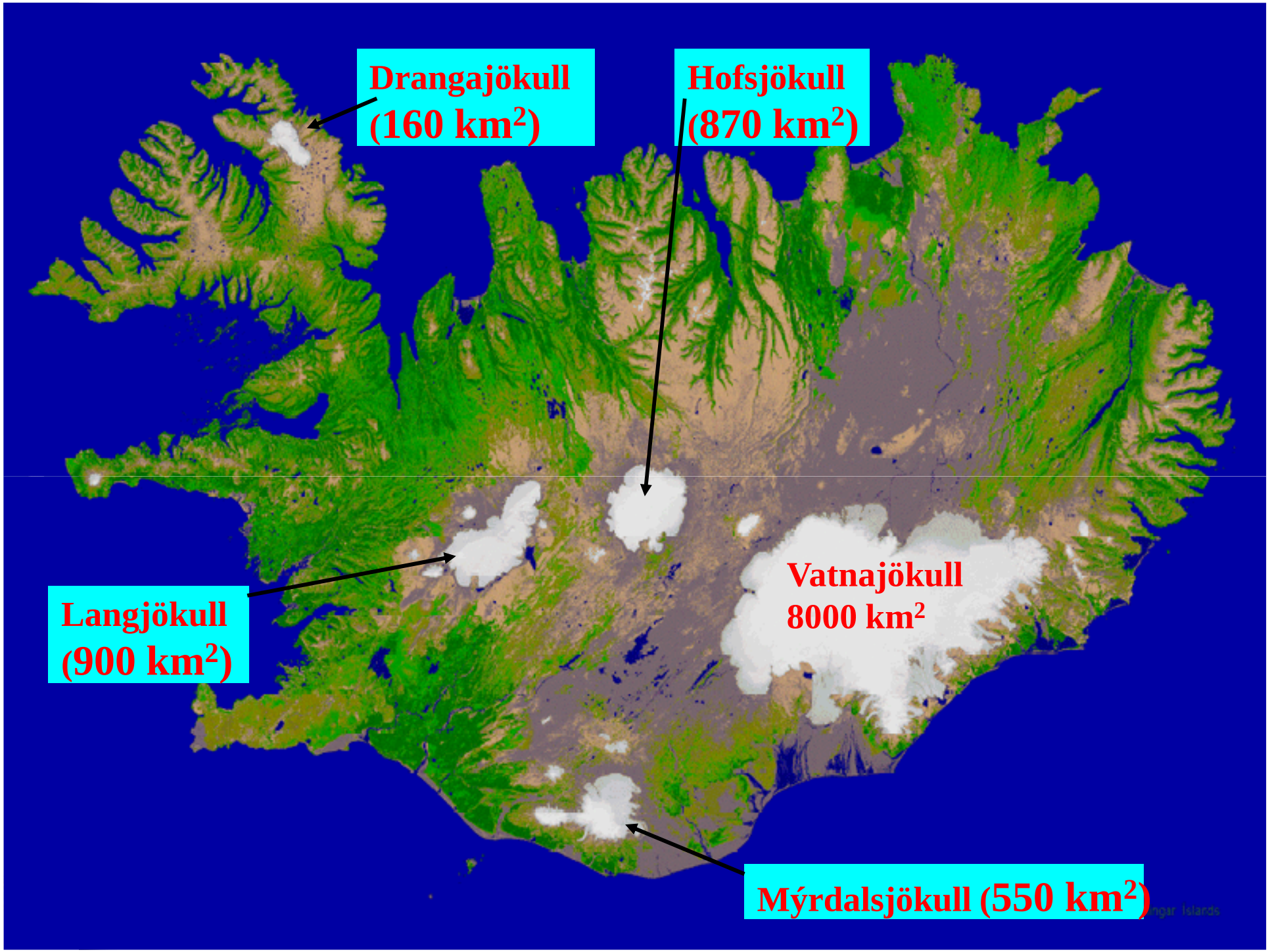
Hydropower, snow and ice group

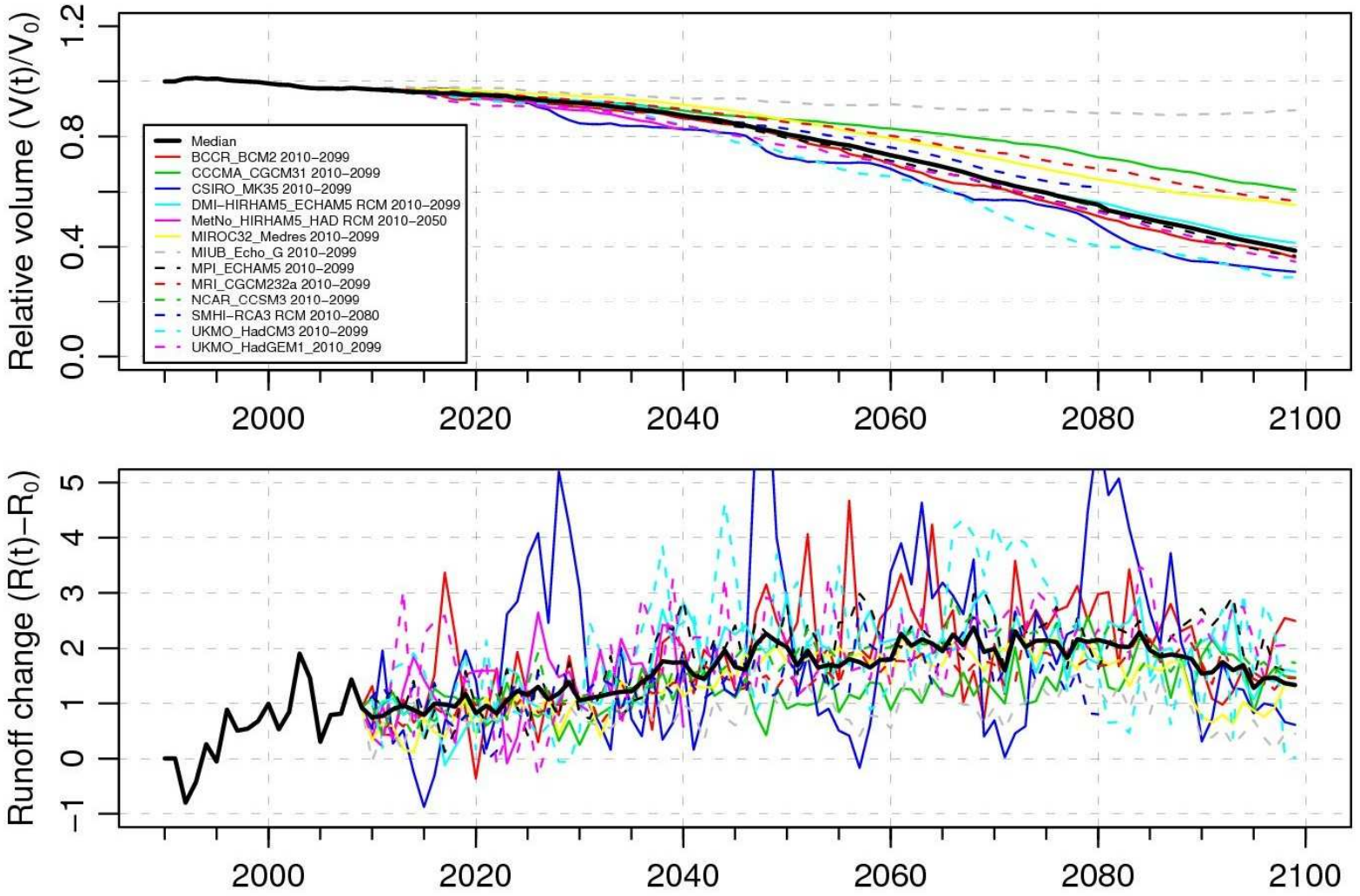
Uses the climate scenarios along with extensive data sets on glacier mass balance in Scandinavia and Iceland to model future changes in glacier volume and meltwater delivery from glaciers

PI: Tómas Jóhannesson, Veðurstofu Íslands (Icelandic Meteorological Office, IMO)

- **Mass balance and dynamic modelling of glaciers in Iceland, Norway and Sweden**
- **Precipitation downscaling in Iceland and Scandinavia**
- **Coupled glacial runoff – dynamic glacier modelling in Iceland and Norway**
- **Meteorological downscaling and mass balance modelling of a glacierized watershed in Greenland**


Drangajökull
(160 km²)
Hofsjökull
(870 km²)
Langjökull
(900 km²)
Vatnajökull
8000 km²
Mýrdalsjökull (550 km²)

Hofsjökull, coupled model



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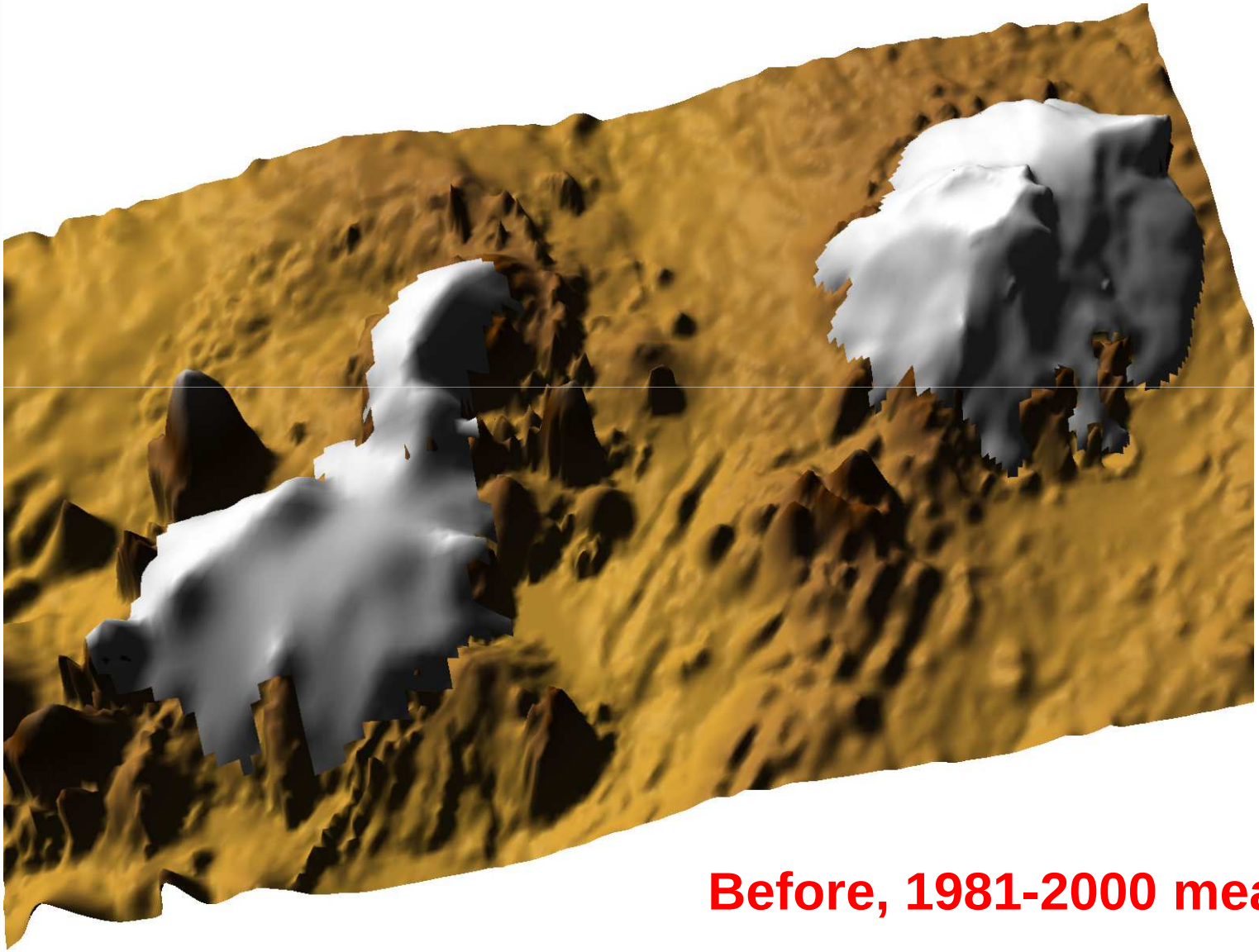
Modelling the development of the Langjökull and Hofsjökull ice caps in Iceland 2000-2100



Before, 1981-2000 mean

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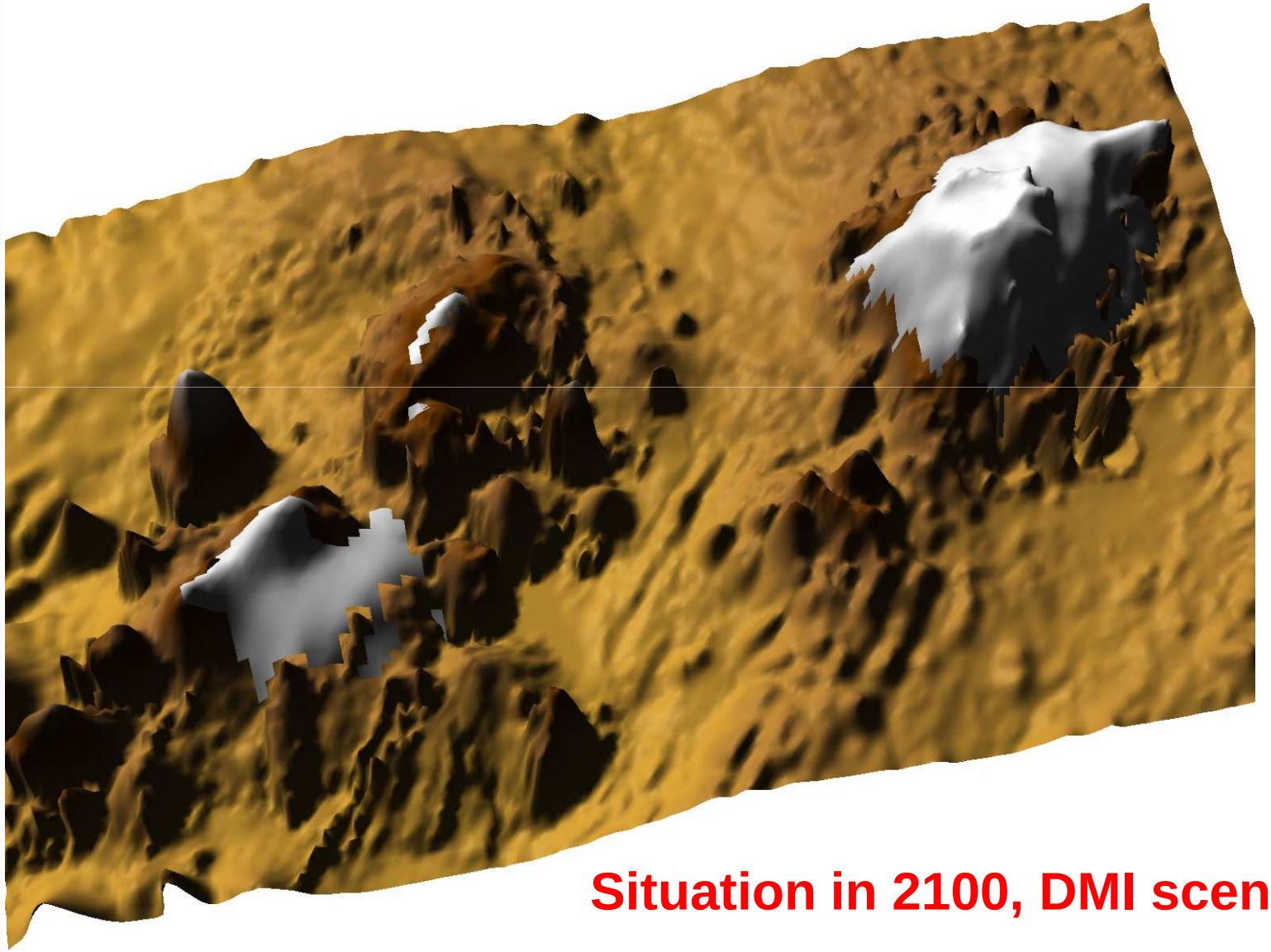

Situation in 2100, DMI scenario

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Some conclusions from the snow and ice group

- Many glaciers and ice caps, except the Greenland ice sheet, are projected to disappear in 100-200 years.
- Runoff from ice-covered areas in the period 2020-2051 may increase by on the order of 50% with respect to the 1961-1990 baseline
- There will be large changes in runoff seasonality and in the diurnal runoff cycle
- The runoff change may be important for the design and operation of hydroelectric power plants and other utilisation of water
- There is a large uncertainty associated with differences between the modelled climate development by different GCMs and RCMs

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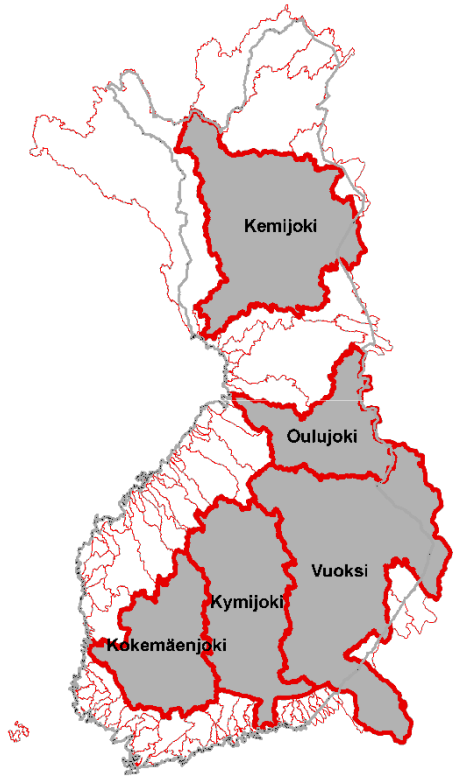
Hydropower, hydrology group

Uses the CES climate scenarios to investigate effects of runoff changes on the production of hydropower, the most important renewable energy source for electricity in the Nordic area

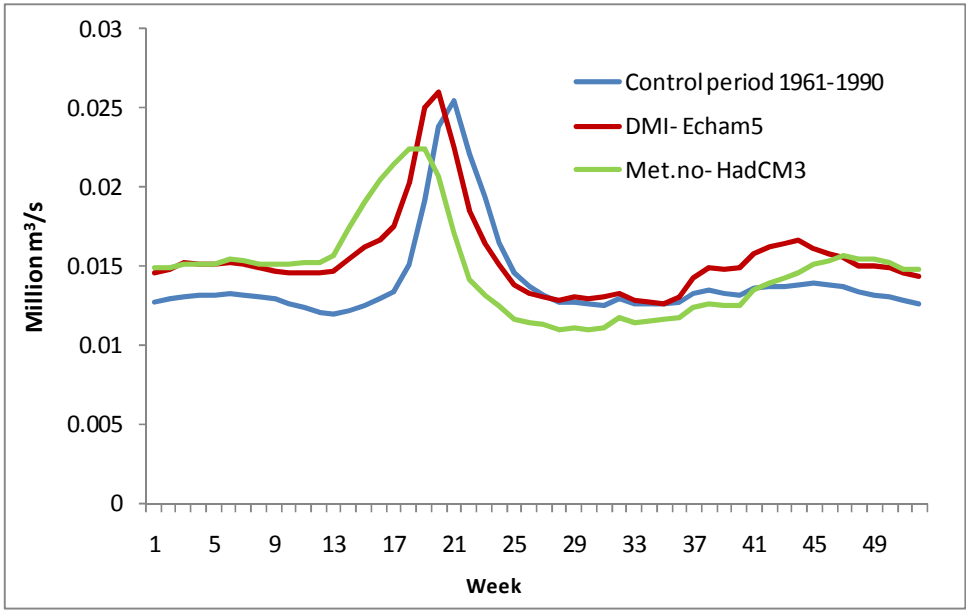
PI: Sten Bergström, Sveriges Meteorologiska och Hydrologiska Institut (SMHI)

- **Climate change effects on hydropower production**
- **Dam safety studies**
- **Improving interfaces between climate models and hydrological models**
- **Improve methodology to cope with impacts on lake and river regulation in a changing climate**
- **Compare Nordic design flood standards under present and future climate conditions**

Predicted runoff changes: Example from Finland



Location of five most important rivers in Finland harnessed for hydropower production



Discharge (weekly average) in the control period 1961-1990 and in 2021-2050 based on two scenarios. The scenarios indicate a 5-10% increase in annual runoff and a clear increase in winter runoff.

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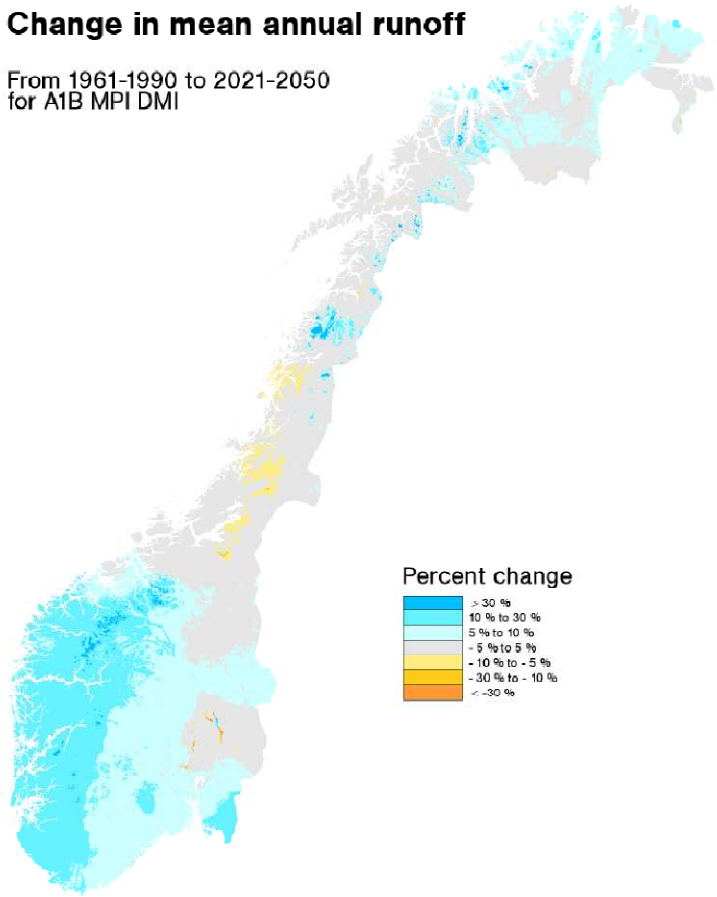
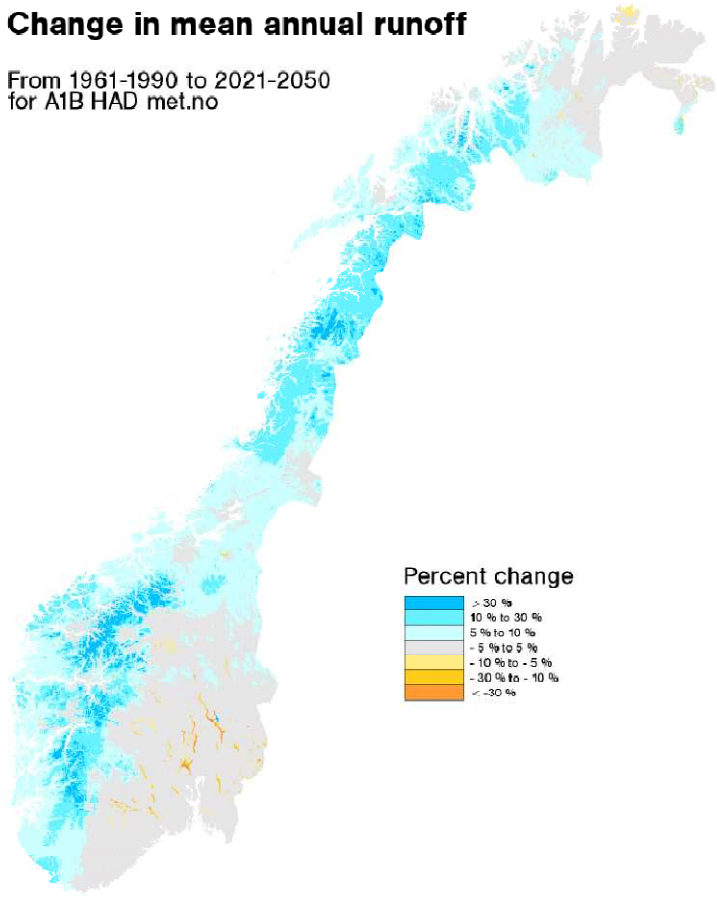
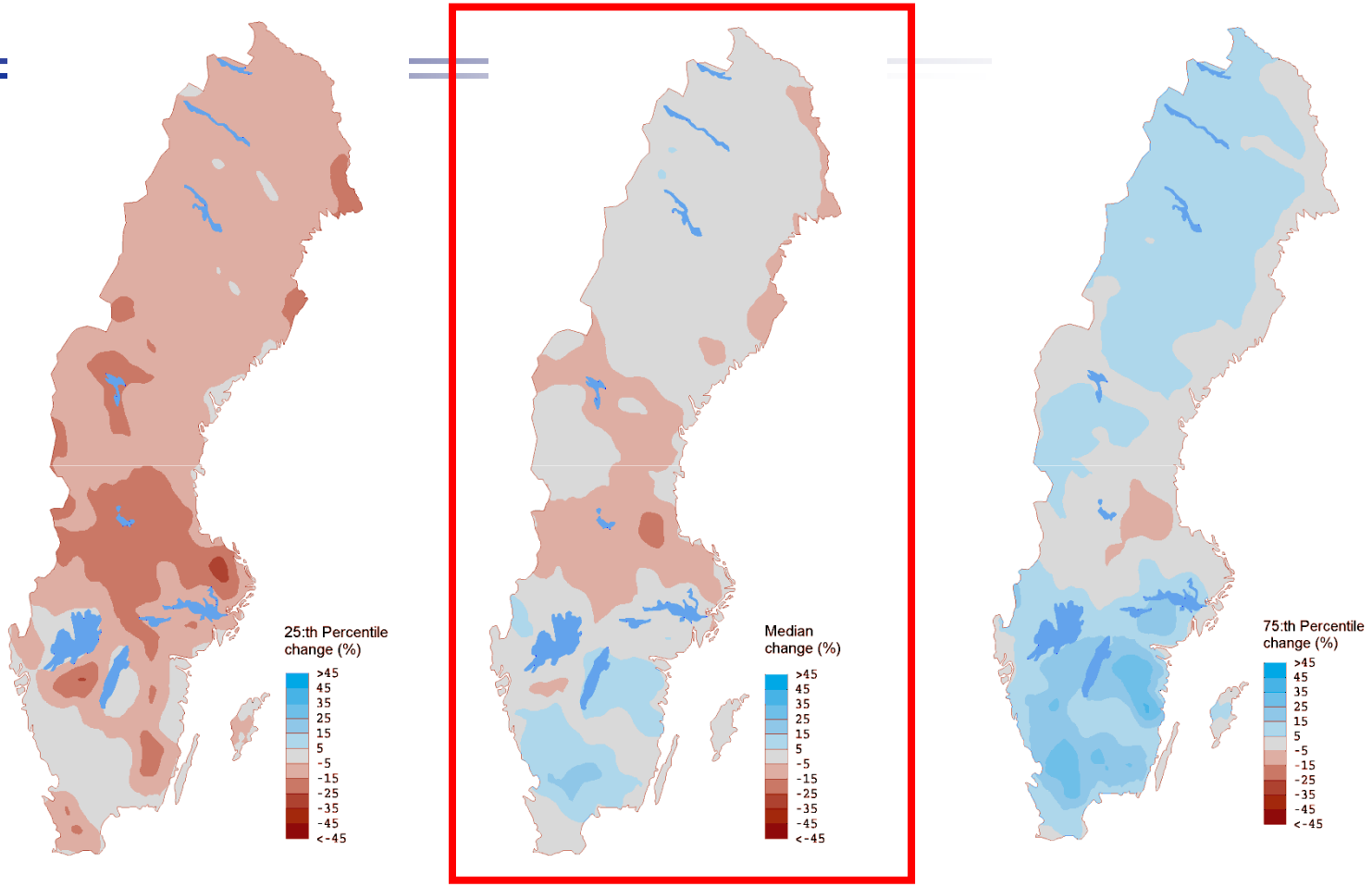
Predicted runoff changes: Example from Norway





100-year floods in Sweden



Change in 100-year floods (%) in Sweden from the period 1963-1992 to the period 2021-2050. (Left and right diagrams indicate span of possible outcomes from 16 models).

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Some conclusions from the hydrology group

- **Little doubt that Nordic and Baltic hydropower systems will be affected strongly by a changing climate**
- **Seasonality of inflow into reservoirs changes – milder and wetter winters**
- **Large snowmelt floods likely fewer, but larger rain floods may occur**
- **Potential for hydropower production will generally increase**
- **Considerable uncertainty, regional scenarios vary greatly**

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The Wind Energy Group

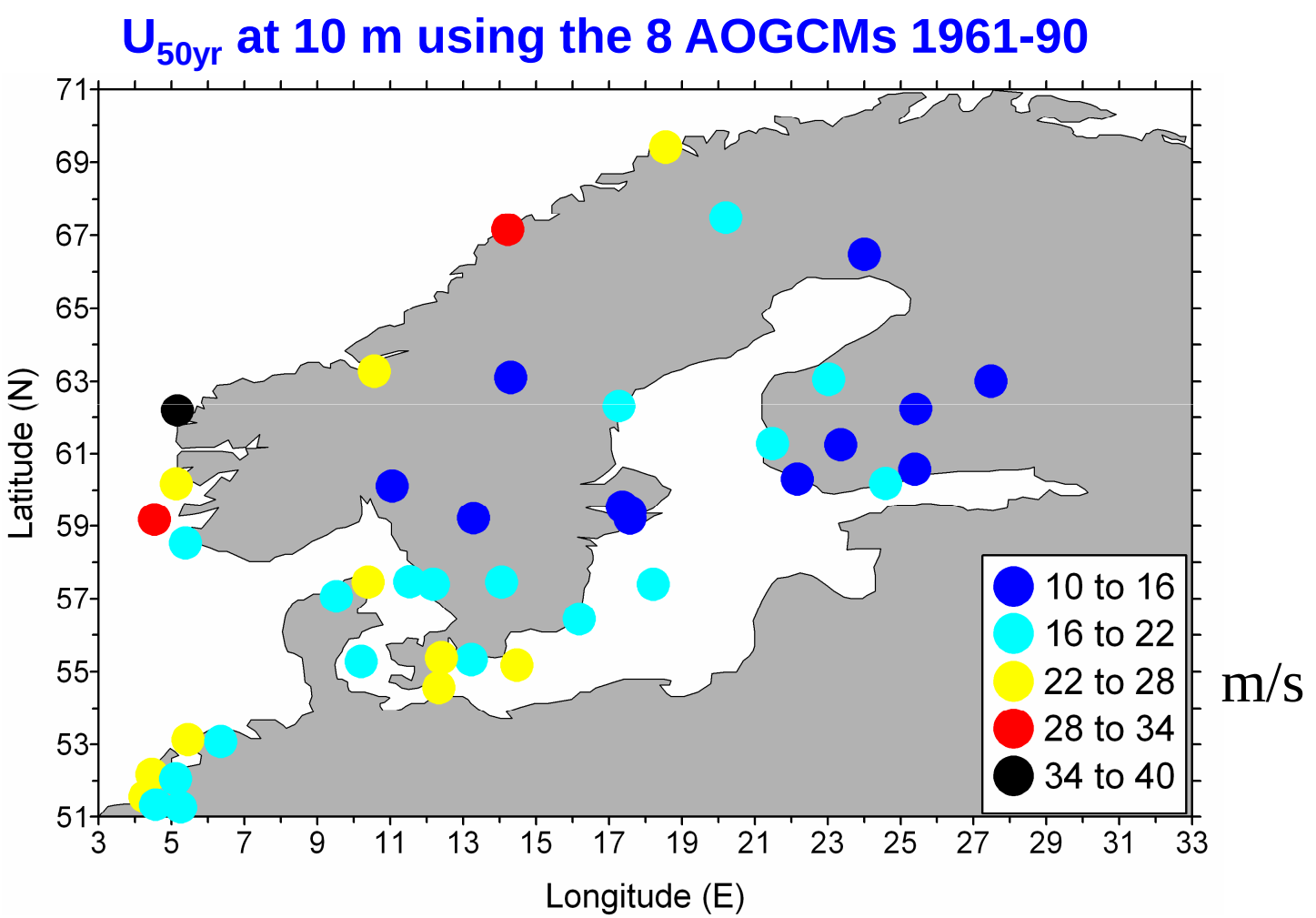
Forecasts future wind climates, analyses climate change impacts on extreme wind and contributes to forecasts of the development of the Nordic electricity system in the coming 20-30 years.

PI: Niels-Erik Clausen, Risø Nationallaboratoriet, Danmarks Tekniske Universitet

- **Develop and evaluate tools for forecasting changes in wind climates**
- **Extreme wind atlas of the Nordic countries (50-year wind in 100 m height)**
- **Investigate climate change impact on extreme wind**
- **Development of a sea-state model to estimate fair-weather windows for offshore wind farms - will climate changes lead to increased operation and management costs of offshore wind farms and changes in wind farm availability?)**

Empirical downscaling of eight models, control period

-



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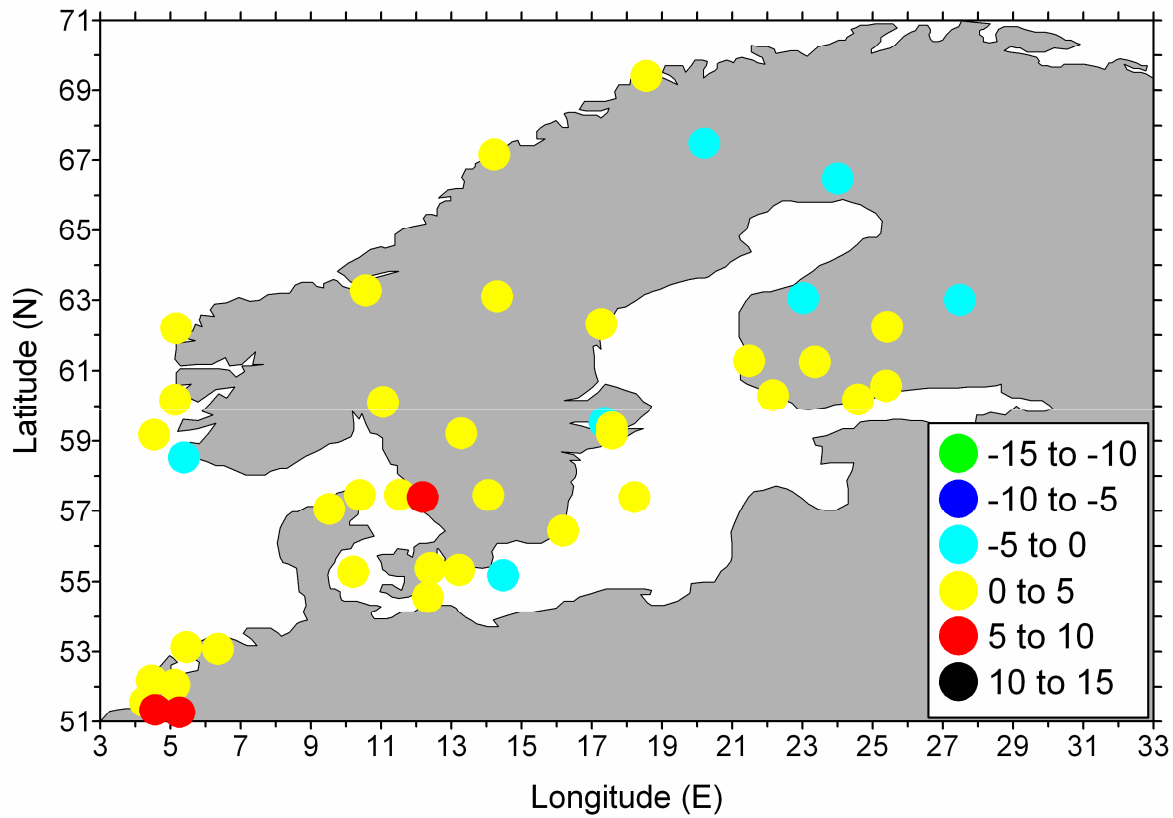
Change compared to 1961-90

The ensemble average change (%) in U_{50yr} using 8 AOGCMs



Δ%

% change; 43 stations	2046-65	2081-2100*
<1%	26 stations	14 stations
>1%	17 (1-5%)	27 (1-10%)

* 2 show decrease

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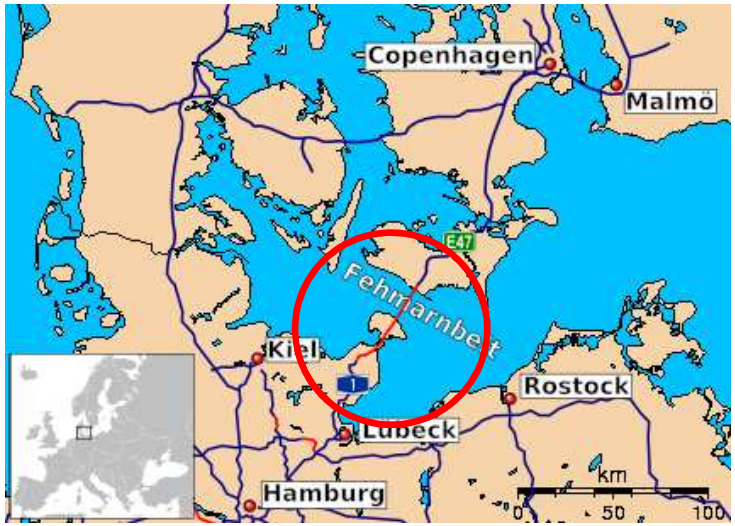
Associated work relating to climate robust design of infrastructures

Storebælt bridge Denmark



Definition of design basis for Fehmern Belt fixed link

Results from the wind group

- In Northern Europe there are indications that we will see 0-10% increase of U_{50yr} in 2100 (63% of stations)
- 33% of stations show < 1% change
- 4% show decrease
- Extreme wind is sensitive to choice of model
- Extreme wind appears less sensitive to emission scenario
- Essential to use multiple models (AOGCMs) for analysis of climate impact of extreme wind

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The Biofuels Group

Utilization of various sources of bioenergy will increase in the Nordic countries in the future. What is the biomass production potential of forests at present and in the future, under likely climate scenarios?

PI: Seppo Kellomäki, University of Joensuu, Finland

- **Understanding the natural variability and predictability of bioenergy production**
- **Assessment of potential production of forest biomass for energy**
- **Assessment and development of forest management regimes and bioenergy production to substitute fossil fuels**

Results indicate that bioenergy production potential will have increased by the mid-21st century.

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The Risk Analysis Group

Uncertainty translates into riskier decisions within the energy sector – methods and tools for climate change risk assessment and adaptation strategies must be realised.

PI: Jari Schabel, VTT Technical Research Centre of Finland

- **An evaluation of risk under increased uncertainty to improve decision making in a changing climate**
- **Develop a Risk Assessment Framework (RAF) for use in climate change management within the energy sector**
- **General decision support regarding climate issues for the energy sector**
- **Support development of adaptation strategies and Adaptation Plan**

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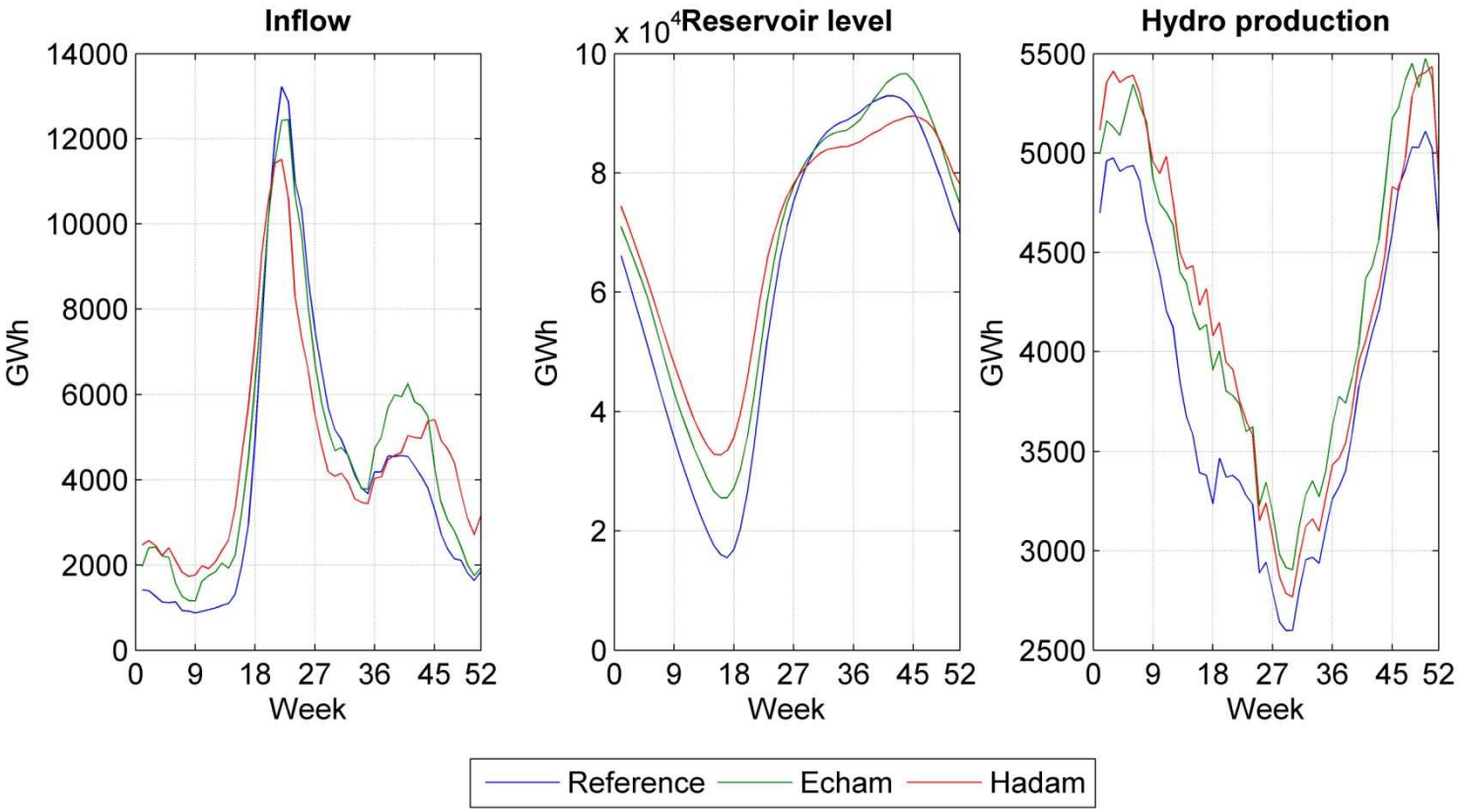
The Energy Systems Analysis Group

Uses present climate data and future scenarios to simulate the operation of a given electricity system. Identifies and quantifies changes in generation of and demand for electricity resulting from changing climatic conditions.

PI: Birger Mo, SINTEF Energy Research, Norway

- **How do power generation, demand and transmission characteristics respond to expected changes in reservoir inflow and temperatures?**
- **SINTEF Energy Research´s EMPS model used to simulate the electricity system by 2020, taking into account forecasts of production and transmission capabilities, electricity demand, input fuel costs and CO_2 quota prices.**

Average annual hydropower characteristics for the NordPool area – reference period and 2 scenarios



- **Greater inflow predicted, particularly in winter**
- **Less variation in reservoir levels over the year**
- **Increased hydropower potential predicted**

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Some key results for 2020 (energy systems analysis)

- Average annual inflow will have increased by 12-13 %
- More inflow during winter, less or unchanged during summer
- Higher temperatures causes demand to decrease by 2-3%
- Thermal production is substituted by hydro production
- Less imports from and more export to continental Europe

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Thank you for your attention!