Climate model simulations of snow and related variables in northern Europe

Kirsti Jylhä\textsuperscript{1}, Jouni Räisänen\textsuperscript{2} and Anna Parvio\textsuperscript{1}

\textsuperscript{1} Finnish Meteorological Institute, 
Climate change and applications
\textsuperscript{2} University of Helsinki, 
Dep. of Physical Sciences, Div. of Atmospheric Sciences

Regional Science Team Meeting
devoted to the High Latitudes of the NEESPI domain
June 2-6, 2008 Helsinki
Organization 1.1.2008

Under the Ministry of Transport and Communications

Personnel:
- 571 person-years
  - Research 248
- women 40% - men 60%
- 55% academic degree
  - 15% researcher training

<table>
<thead>
<tr>
<th>WEATHER AND SAFETY</th>
<th>RESEARCH AND DEVELOPMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather and Safety Centre</td>
<td>Climate Change</td>
</tr>
<tr>
<td>Commercial Services</td>
<td>Air Quality</td>
</tr>
<tr>
<td>Development of Services</td>
<td>Meteorology</td>
</tr>
<tr>
<td>Information Management Services</td>
<td>Earth Observation</td>
</tr>
<tr>
<td>Observation Services</td>
<td>Arctic Research</td>
</tr>
<tr>
<td></td>
<td>Kuopio Unit</td>
</tr>
<tr>
<td></td>
<td>Consulting Services</td>
</tr>
</tbody>
</table>

ADMINISTRATION
Climate Change research unit

- Climate Research and Applications
- Socio-economic Impacts of Climate and Weather
- Greenhouse Gases
- Aerosols and Climate
- Modelling and Observation of the Atmosphere

Average date of snow melting off

Yksikössä 56 henkeä, johtajana professori Ari Laaksonen

Measurements of greenhouse gases and aerosols
Outline

• Projected changes in frost and snow
  - regional climate model simulations
    (ECA&D observations and INTAS/SCCONE data)

• Processes involved in changes in snow cover
  - global climate model simulations

• Model performance in simulating snow cover
  - ECHAM5, ERA40-reanalysis, INTAS/SCCONE data
Projected changes in frost and snow

Output from PRUDENCE regional climate model (RCM) simulations:
• Seven RCMs with a resolution of about 50 km
• Lateral boundary conditions from HadAM3H atmospheric general circulation model (GCM) (or from ECHAM4/OPYC3)
• SRES A2 or (B2) emission scenario
• Two 30-year periods 1961–1990 and 2071–2100

For comparisons:
• European Climate Assessment daily station data for daily min and max temperatures
• INTAS/SCCONE data for snow cover

The number of frost days (Tmin<0ºC)

ECA&D observations 1961-1990

Model performance for frost:

- Observed gradients
  - from SW to NE,
  - from the coast to inland areas and
  - from low- to high-elevation sites generally captured well.

- 66% of the cases in a correct interval of 30 days

- The main area of overestimation in Romania

- Large deviations at some mountain stations <= differences in altitude between the station and the corresponding grid-box average.

Dots: observations
Contours: the mean of seven RCM-H simulations

Ref: Jylhä et al. (2008)
Decreasing number of frost days (Tmin<0ºC)

ECA&D observations 1961-1990

Projected changes by 2071-2100

Ref: Jylhä et al. (2008)
More frequent freezing point days* in Scandinavia in Dec-Feb

ECA&D observations 1961-1990

Projected changes by 2071-2100

*Min<0°C, Tmax>0°C

Ref: Jylhä et al. (2008)
Days with snow cover

INTAS/SCCONE observations 1961-1990

Model performance for snow cover

- Observations reasonably well simulated by the multi-model average.
- 76% of the cases in a correct interval of 30 days

Dots: observations
Contours: the mean of seven RCM-H simulations

Ref: Jylhä et al. (2008)
Fewer days with snow cover

INTAS/SCCONE observations 1961-1990

Ref: Jylhä et al. (2008)
Percentage reductions in the annual mean SWE > in # of days with snow

Northern Europe, annual

Climate model simulations
- HIRHAM HC A2 (3)
- HIRHAM EC A2
- HIRHAM EC B2
- RCAO HC A2
- RCAO EC A2
- RCAO EC B2
- CHRM HC A2
- CLM HC A2
- REMO HC A2

Change in # of days with snow (%) vs Change in mean SWE (%) for 1961-90 => 2071-2100

Emissions
- A2
- B2
Outline

• Projected changes in frost and snow
  - regional climate model simulations
    (ECA&D observations and INTAS/SCCONE data)

• Processes involved in changes in snow cover
  - global climate model simulations

• Model performance in simulating snow cover
  - ECHAM5, ERA40-reanalysis, INTAS/SCCONE data

THE WCRP CMIP3 MULTIMODEL DATASET
A New Era in Climate Change Research

by Gerald A. Meehl, Curt Covey, Thomas Delworth, Mojib Latif, Bryant McAvaney, John F. B. Mitchell, Ronald J. Stouffer, and Karl E. Taylor

Open access to an unprecedented, comprehensive coordinated set of global coupled climate model experiments for twentieth and twenty-first century climate and other experiments is changing the way researchers and students analyze and learn about climate.
Changes in March mean snow water equivalent (SWE) relative to 1950–1999

Simulated 20-model mean changes under the A1B scenario

Ref: Räisänen (2008)
Changes in November-March mean temperature, total precipitation and snowfall
Simulated 20-model mean changes under the A1B scenario

- Warming everywhere
- Mostly increases in total precipitation
- Both increases and decreases in snowfall

Ref: Räisänen (2008)
Decomposition of changes in snow water equivalent

Changes in SWE
= changes in total precipitation \((\Delta P)\)
+ changes in the fraction of precipitation that falls as snow \((\Delta F)\)
+ changes in the fraction of accumulated snowfall that has not melted away \((\Delta G)\)
+ a nonlinear term involving a combination of the changes in above-mentioned factors.

Finland \((62.5^\circ\text{N}, 27.5^\circ\text{E})\)
- \(\Delta F\) dominates in autumn and early winter,
- \(\Delta G\) from March onward

Eastern Siberia \((62.5^\circ\text{N}, 130^\circ\text{E})\)
- \(\Delta P\) from autumn to spring except from September \((\Delta F)\) and May \((\Delta G)\)

Ref: Räisänen (2008)
Warmer climate: less or more snow?

The average borderline between increasing and decreasing midwinter SWE coincides broadly with the –20°C isotherm in late 20th century November–March mean temperature.

The strong temperature dependence of the simulated SWE changes suggests that projections of SWE change could be potentially improved by taking into account biases in simulated present-day winter temperatures.

Ref: Räisänen (2008)
Outline

• Projected changes in frost and snow
  - regional climate model simulations
    (ECA&D observations and INTAS/SCCONE data)

• Processes involved in changes in snow cover
  - global climate model simulations

• Model performance in simulating snow cover
  - ECHAM5, ERA40-reanalysis, INTAS/SCCONE data


Thanks to Lev Kitaev (RAS Institute of Geography, Moscow, Russia), Petri Räisänen (FMI)
Snow water equivalent in March based on ERA40 reanalysis

Average (in m) in 1971-2000

Largest values in western Siberia and in Uralian and Scandinavian mountains

Standard deviation (in m) in 1971-2000

Largest inter-annual variation in northern Europe

Ref: Parvio (2008)
Spatial average of snow water equivalent from Jan 1986 to Dec 1990 based on ERA40 reanalysis and ECHAM5-simulations for northern Eurasia (40-85°N, 0-180°E).

Coloured curves: 10 ensemble simulations forced by observed sea surface temperature
Black curve: ERA40 analysis

Ref: Parvio (2008)
Spatial average of snow water equivalent from Jan 1986 to Dec 1990 based on ERA40 reanalysis and ECHAM5-simulations

northern Eurasia (40-85°N, 0-180°E)

Red curve: average of 10 ensemble simulations forced by observed SST
Black curve: ERA40 analysis

Ref: Parvio (2008)
Spatial average of snow water equivalent from Jan 1986 to Dec 1990 based on ERA40 reanalysis and ECHAM5-simulations for northern Europe (55-72°N, 3-40°E).

- Red curve: average of 10 ensemble simulations forced by observed SST
- Black curve: ERA40 analysis

Ref: Parvio (2008)
Annual maxima of SWE in 1987 and 1989 based on daily INTAS/SCCOME data* and monthly ERA40 data

*Acknowledgements to Lev Kitaev

Ref: Parvio (2008)
Snow Mapping of Boreal and Sub-Arctic Zones: Earth Observation Data-Based Multi-Source Information Systems and Application to Climatic Studies (SNOW-CLIM)

Snow melt in northern Eurasia for 2005 as derived from AMSR-E microwave radiometer data. The map indicates the on-set of snow melt (days after the first of March).

For more information:
research professor Jouni Pulliainen, +358 50 589 5821, firstname.lastname (a) fmi.fi
Thank you ...

... for your attention!