Assessment of Snow Water Equivalent Estimates of CMIP5 Climate Model Simulations and Satellite-Based Data

Kari Luojus, Jouni Pulliainen, Juval Cohen, Matias Takala, Juha Lemmetyinen, Tuomo Smolander, Jaakko Ikonen
(Finnish Meteorological Institute)
& Chris Derksen & Ross Brown (Environment Canada)

6 February 2014 – Bern, EARSeL LISSIG

Contents

1) Overview on satellite retrieved SWE
   - ESA DUE GlobSnow SWE

2) CMIP5 simulations

3) Snow Extent

4) Hemispherical SWE / snow mass

ESA DUE GlobSnow

• ESA DUE GlobSnow project: Production of novel hemispherical **snow extent** (SE) and **snow water equivalent** (SWE) climate data records.

• **Generation of long time-series employing FMI supercomputing facilities at Helsinki** (daily, weekly and monthly maps of SE and SWE for northern hemisphere) **+ NRT processing**

• Consortium members: Finnish Meteorological Institute (FMI) with ENVEO IT GmbH (Austria), GAMMA Remote Sensing (Switzerland), Norwegian Computing Center, Finnish Environment Institute (SYKE), and Environment Canada (EC). + Univ. Bern, MeteoSwiss, ZAMG & Norut

• GlobSnow-1 (3.5 years): 11/2008 – 11/2011 (36 months)
• GlobSnow-2 (2 years): 05/2012 – 05/2014 (24 months)

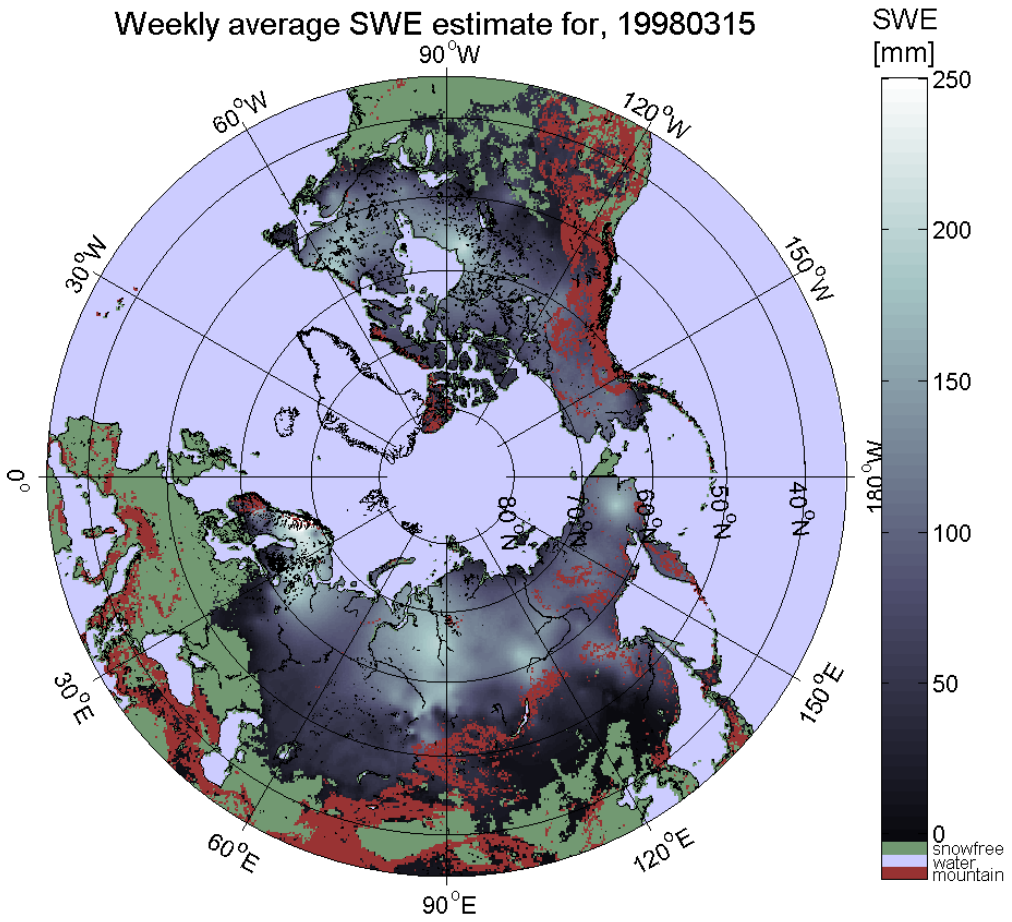
• Details and products available at **www.globsnow.info**

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

esa due data user element GLOBSNOW

34 year-long CDR time-series on snow conditions of Northern Hemisphere

- First time reliable daily spatial information on SWE (snow cover):
  - Snow Water Equivalent (SWE)
  - Snow Extent and melt (+grain size)
  - 25 km resolution (EASE-grid)
  - Time-series for 1979-2013
- Passive microwave radiometer data combined with ground-based synoptic snow observations
  - Variational data-assimilation
- Available at open data archive (www.globsnow.info)
- Demonstration of NRT processing since October 2010



Takala, M., Luojus, K., Pulliainen, J., Derksen, C., Lemmetyinen, J., Kärnä, J.-P, Koskinen, J., Bojkov, B., "Estimating northern hemisphere snow water equivalent for climate research through assimilation of spaceborne radiometer data and ground-based measurements", Remote Sensing of Environment, Vol. 115, Issue 12, 15 December 2011, doi: 10.1016/j.rse.2011.08.014

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

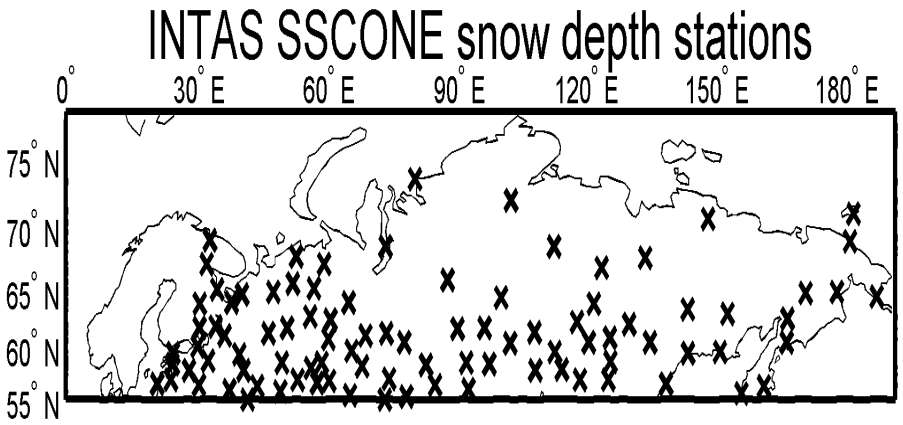
esa due data user element GLOBSNOW

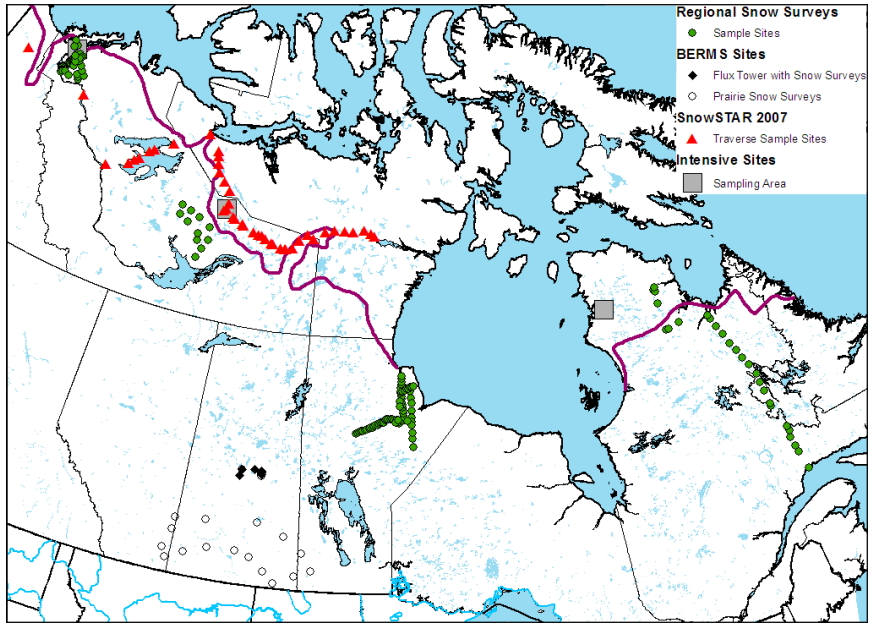
Distributed validation data, e.g. Northern Eurasia & Canada

Snow Survey data (from the former USSR and Russia)

- There are 517 snow path stations with data for (1979 – 2009)
- Manual ground-based measurements on snow depth/SWE
- 1 - 2km snow transects, measurements every 100m - 200m

Land Cover	Reference Dataset	Year	n	Mean SWE (mm)
Tundra	Intensive Sites; SnowSTAR 2007	2006-2008	28	120
Northern Boreal	EC Snow Surveys	2006-2007	105	135
		SWE <150 mm	73	134
Southern Boreal	EC Snow Surveys	2005-2007	57	75
Southern Boreal	BERMS Towers	2005-2008	468	70
Prairie	EC Snow Surveys	2005-2007	41	44



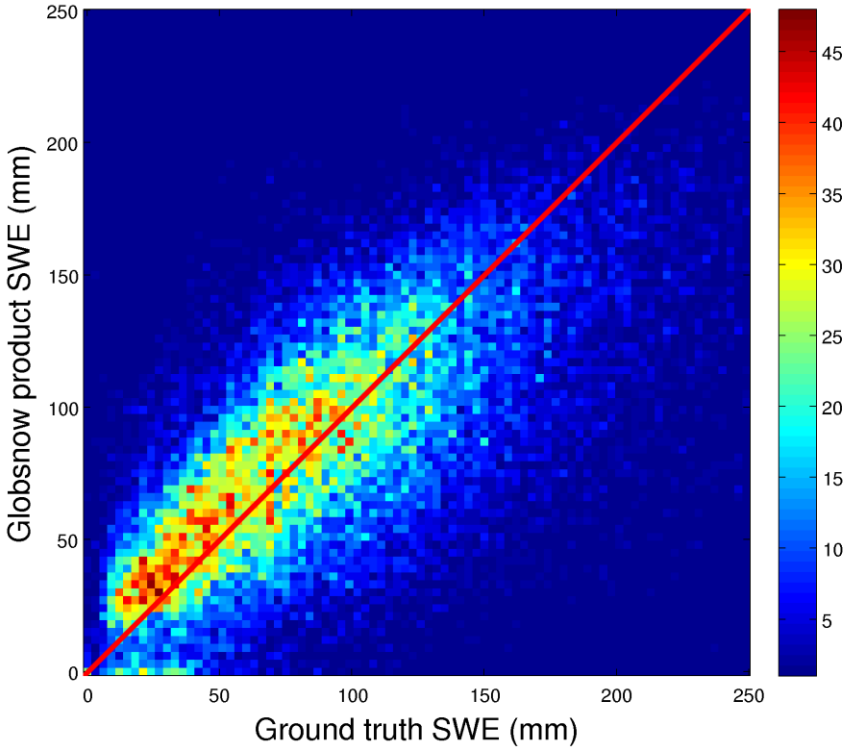


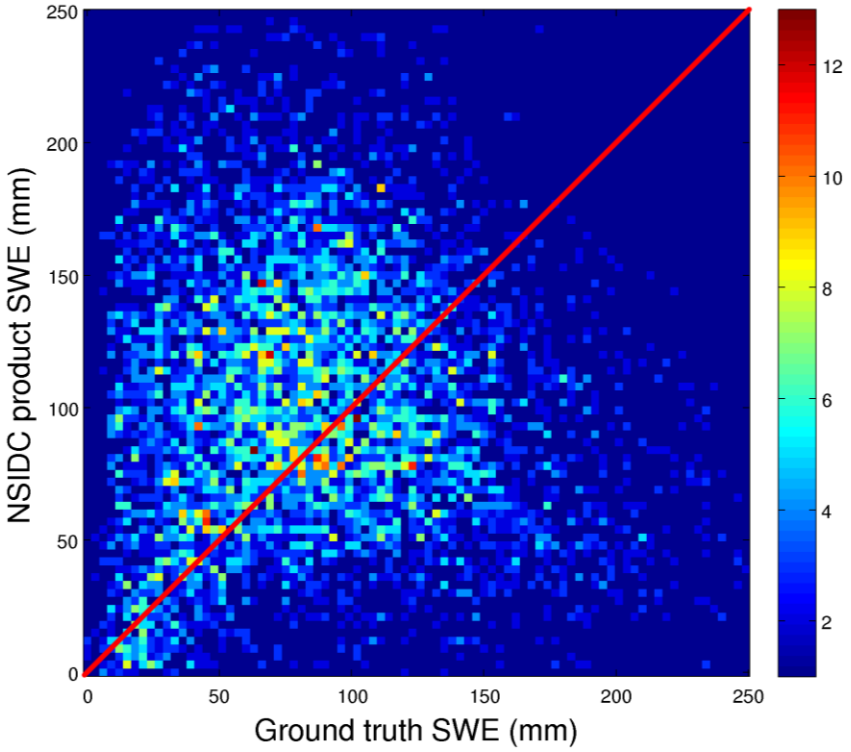
ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

esa due data user element GLOBSNOW

SWE retrieval (data assimilation vs. channel diff.)

- Density scatterplot (assimilated vs. satellite only SWE)
- Russian INTAS SCCONE **SWE transect data** as reference



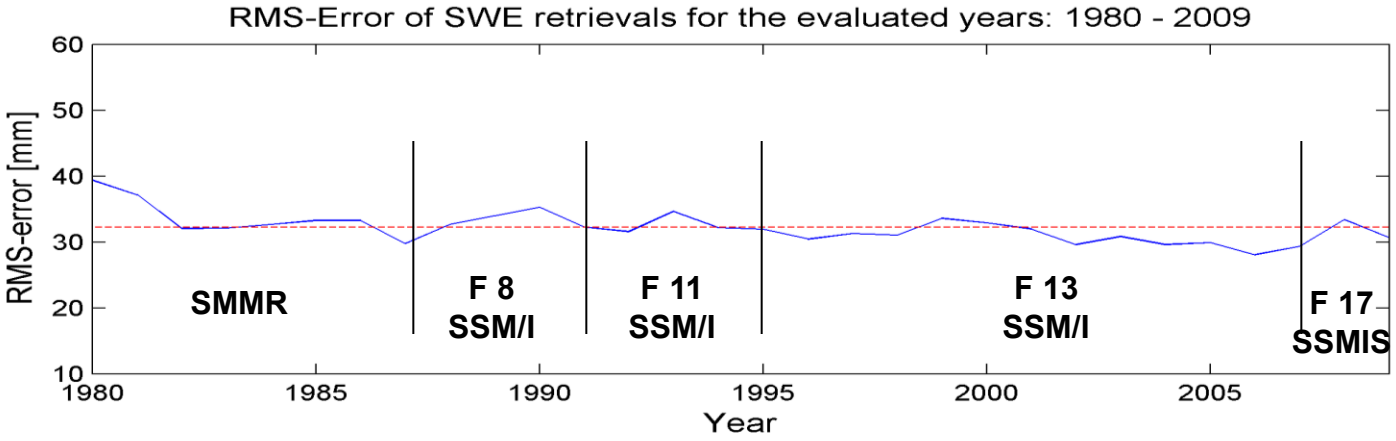


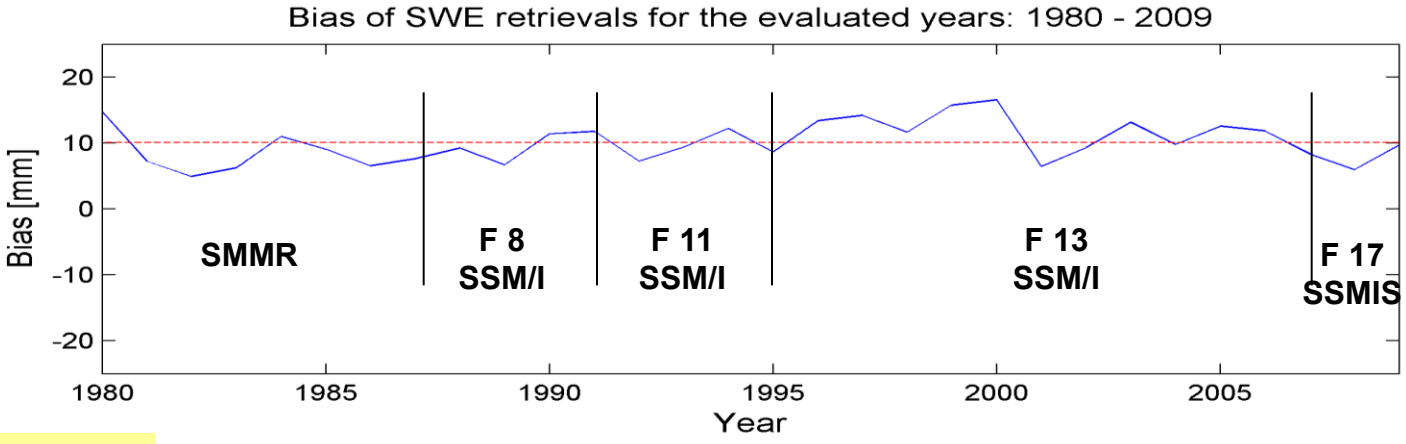
ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

esa due data user element GLOBSNOW

Long term consistency of SWE v2.0 FPS

- RMS error and retrieval bias calculated independently for each year 1980-2009
- Reference data: snow transects from Russia (INTAS-SCCONE)





SWE<150 mm

2) CMIP5 simulations

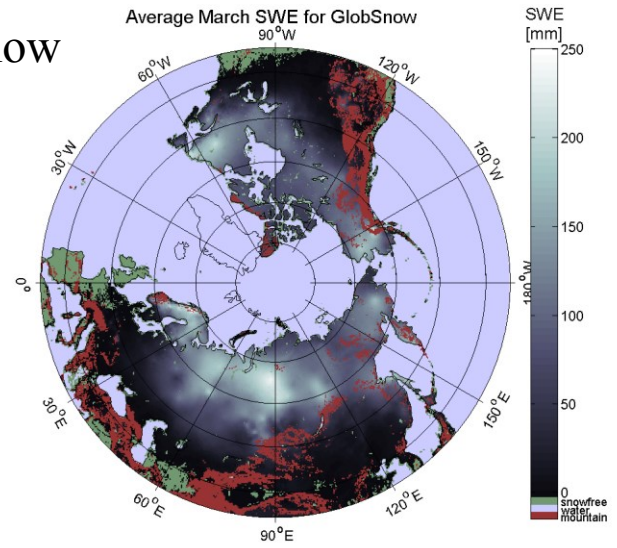
CMIP5 simulations

- **CMIP5 = Coupled Model Intercomparison Project 5**
- **Latest set of global atmosphere-ocean climate model simulations, to be used in the upcoming IPCC 5th Assessment Report (2013)**
- **Historical (1850-2005) simulations for model testing and interpretation of observed climate changes**
  - Anthropogenic forcing: greenhouse gases, aerosols, land use..
  - Natural forcing: solar variability + volcanic eruptions
- **Future simulations (2006-2100/2300) based on a wide range of emission scenarios**
- **20+ models with variable resolution and physical parameterizations**
- **In many cases: several realizations of the same simulation with different initial conditions, to study the impact of unforced natural variability**
  - Typically only one realization per model used here

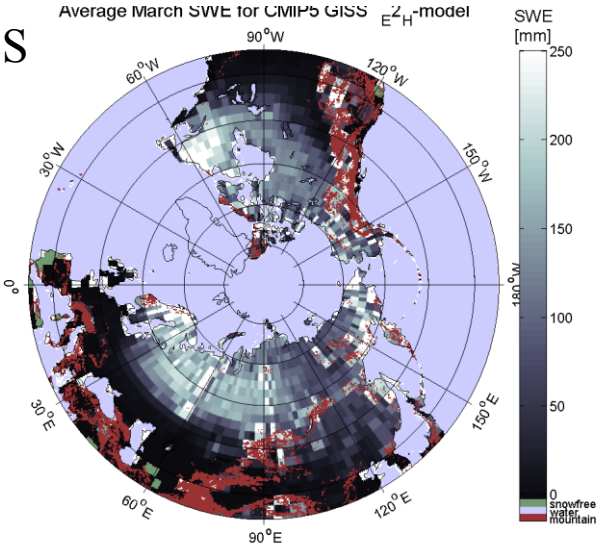
ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

CMIP5 Examples – mean March SWE

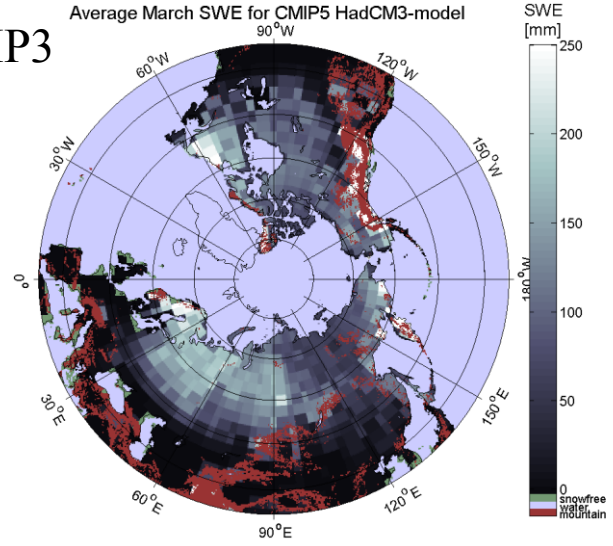
GlobSnow



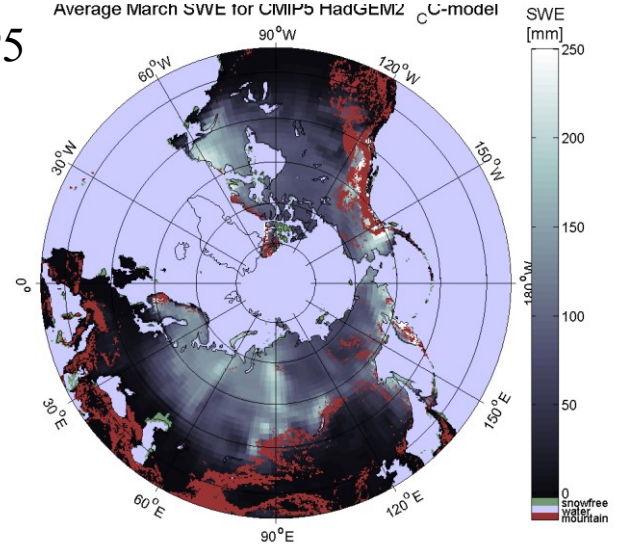
NASA/GISS



Had CMIP3



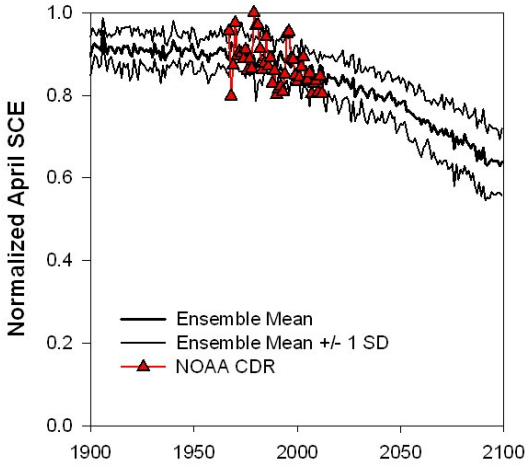
Had CMIP5

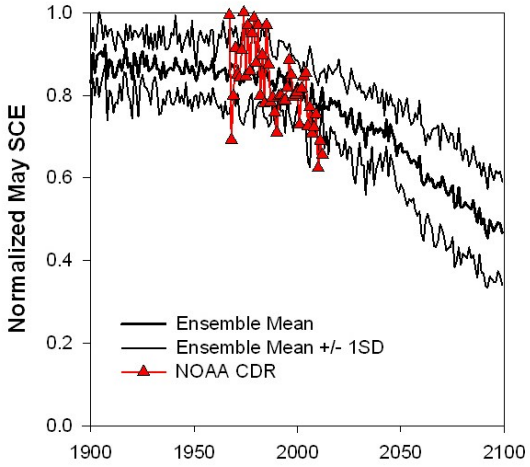


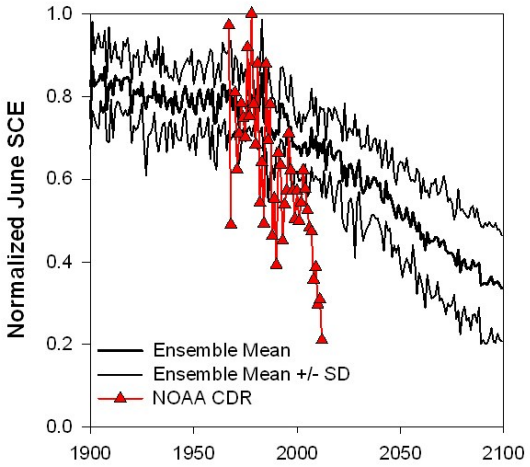
3) Changes in Snow Extent
(NOAA snow chart CDR & CMIP5 archive)

- Investigations & material by:
C. Derksen, R. Brown (EC)

Simulated vs. Observed Arctic Snow Cover





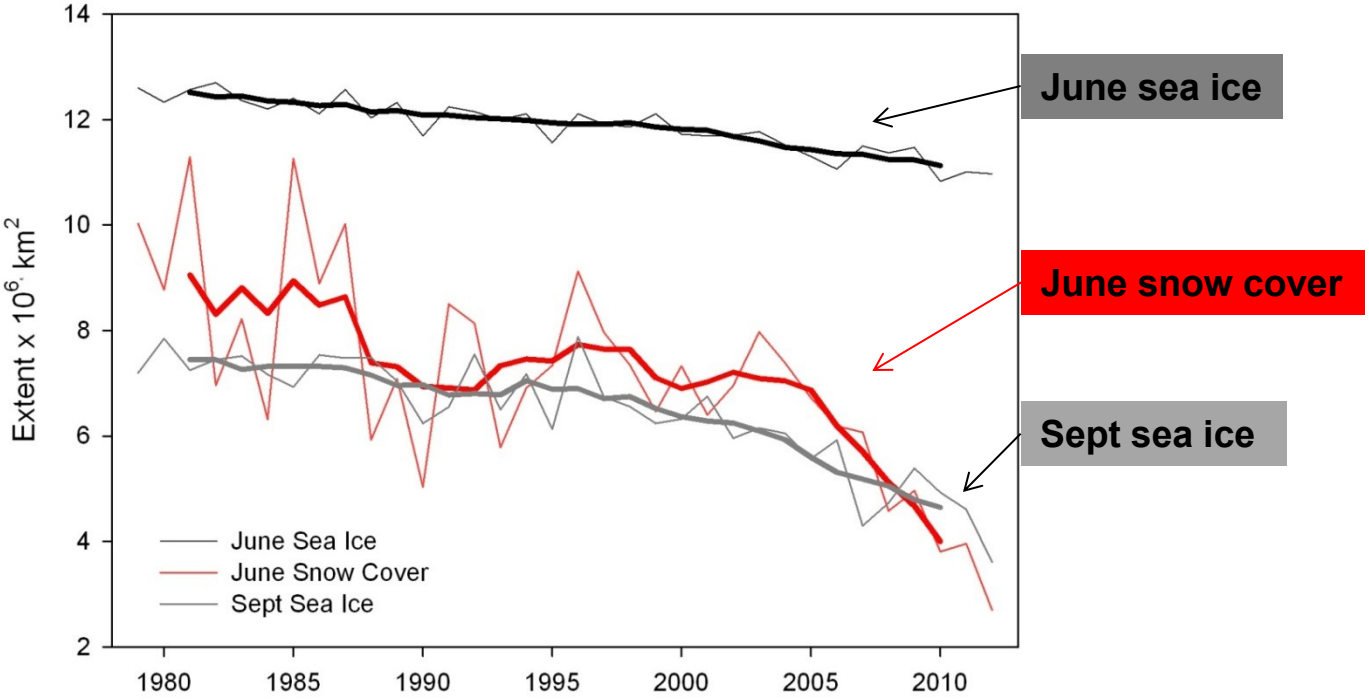


Historical + projected (**8 CMIP5 models; rcp85 scenario**) and observed (**NOAA snow chart CDR**) snow cover extent for April, May and June for land areas north of 60°. Snow covered area is normalized by the maximum area simulated by each model.

- NOAA observations are mostly within ±1 standard deviation of the multi-model ensemble in April and May, but start to diverge from the model consensus in recent years.
- Marked reductions in June SCE observed since 2005 fall below the zone of model consensus defined by +/-1 standard deviation from the multi-model ensemble mean.

Changes in Snow vs. Sea Ice Extent

Northern hemisphere June snow cover and Arctic sea ice extent, 1979-2012



- For 1979–2012, June SE decreasing at rate of -17.6% per decade (relative to 1979-2010 mean)
- September sea ice extent is decreasing at -13.0% per decade. ***Derksen, C Brown, R (10.10.2012) GRL***

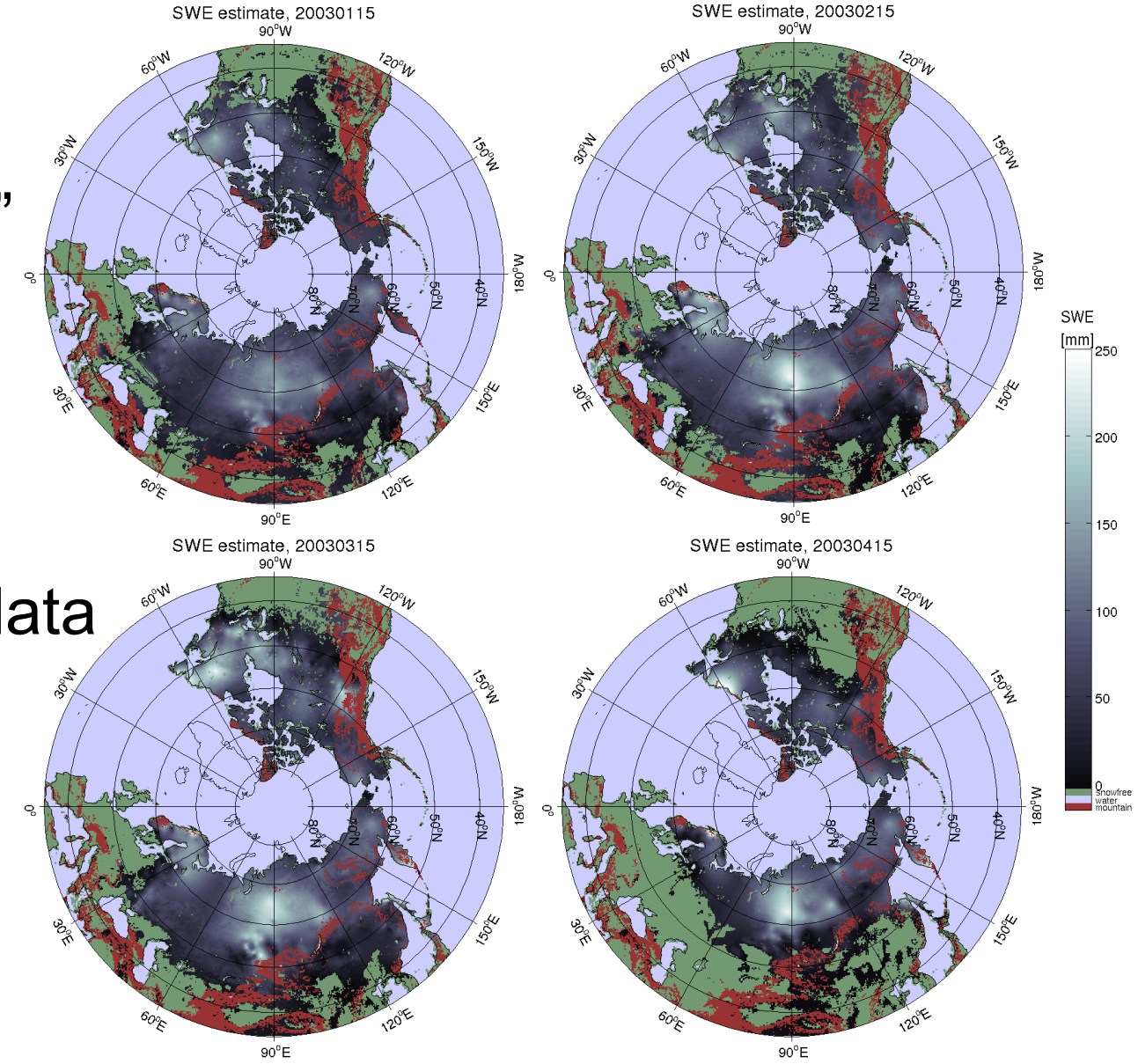
- **Estimated decay in radiative forcing (cryospheric cooling) receive nearly equal contributions from land snow cover and sea ice**
  (Flanner et al. 2011 – *Nature Geoscience Letters, March 2011*)

4) Hemispherical SWE / snow mass

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

GlobSnow SWE ”observation data” available as daily/weekly/ monthly products

CMIP5: monthly data

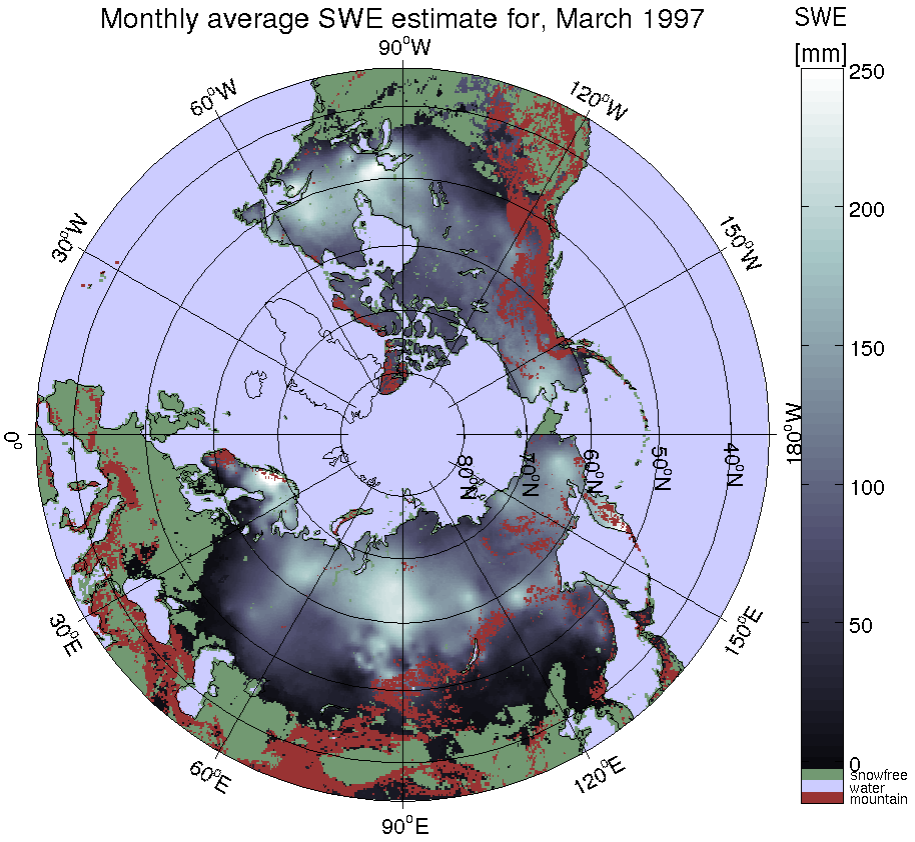


ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

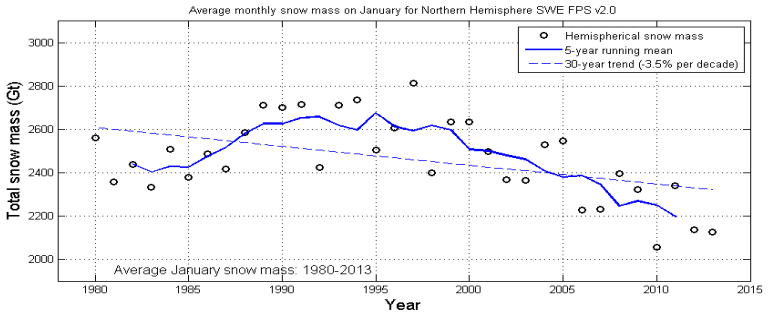
Monthly aggregated SWE product

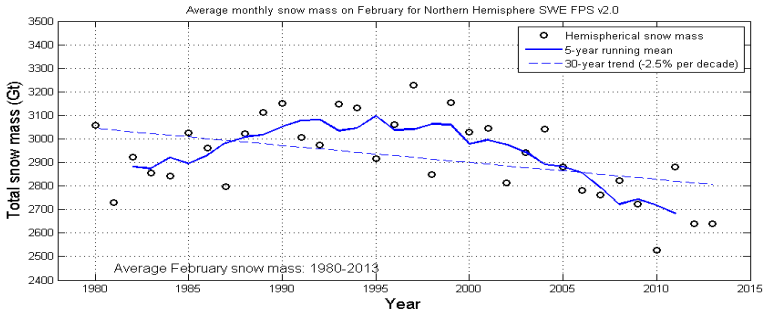
+ an utilization example for climate monitoring

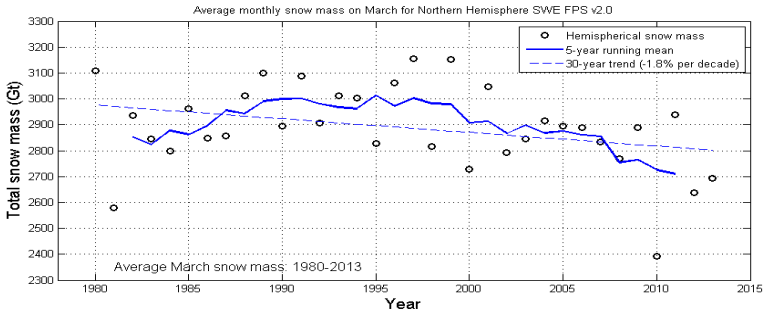
Average SWE for March 1997



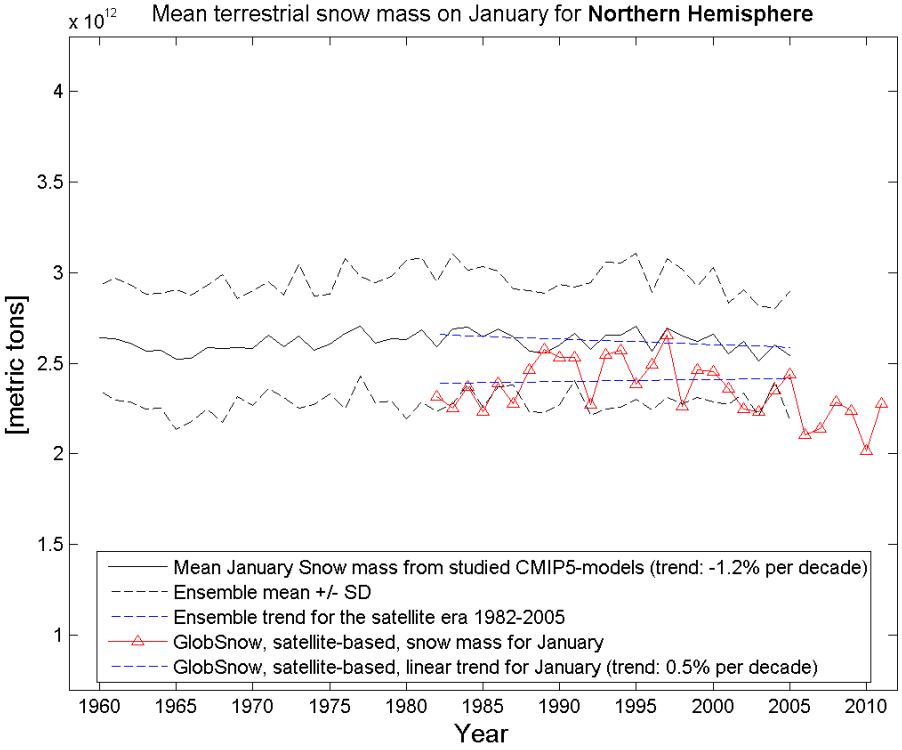
30 years NH SWE trends

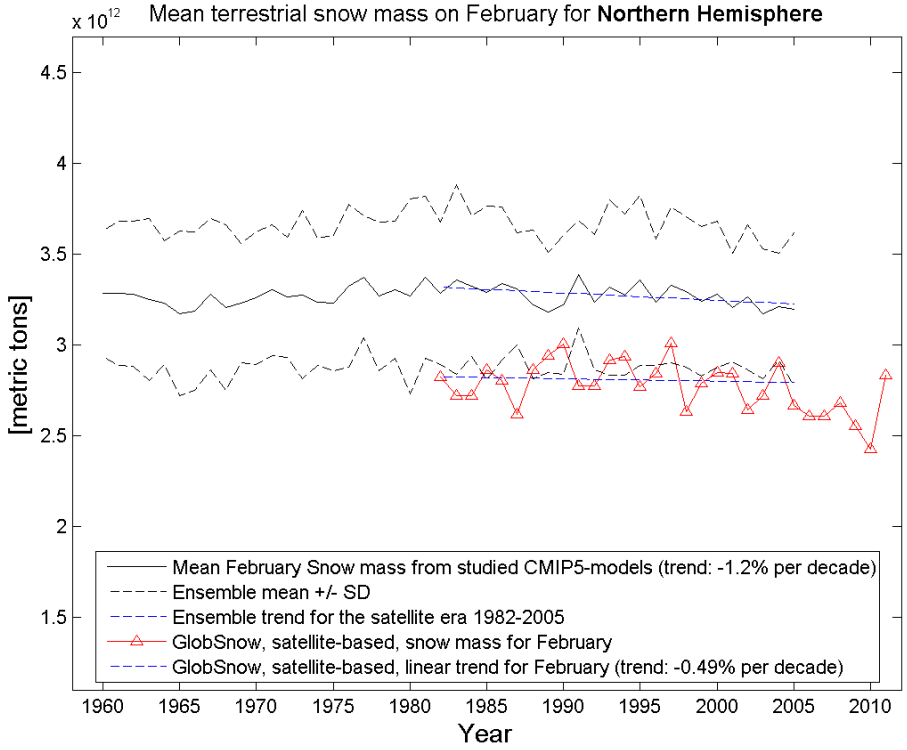




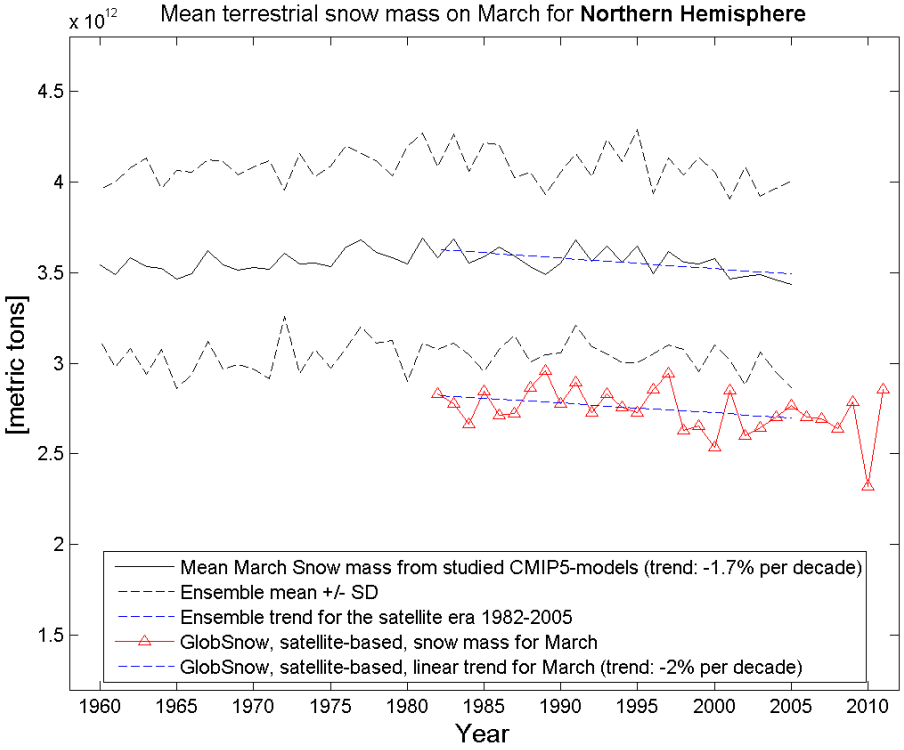


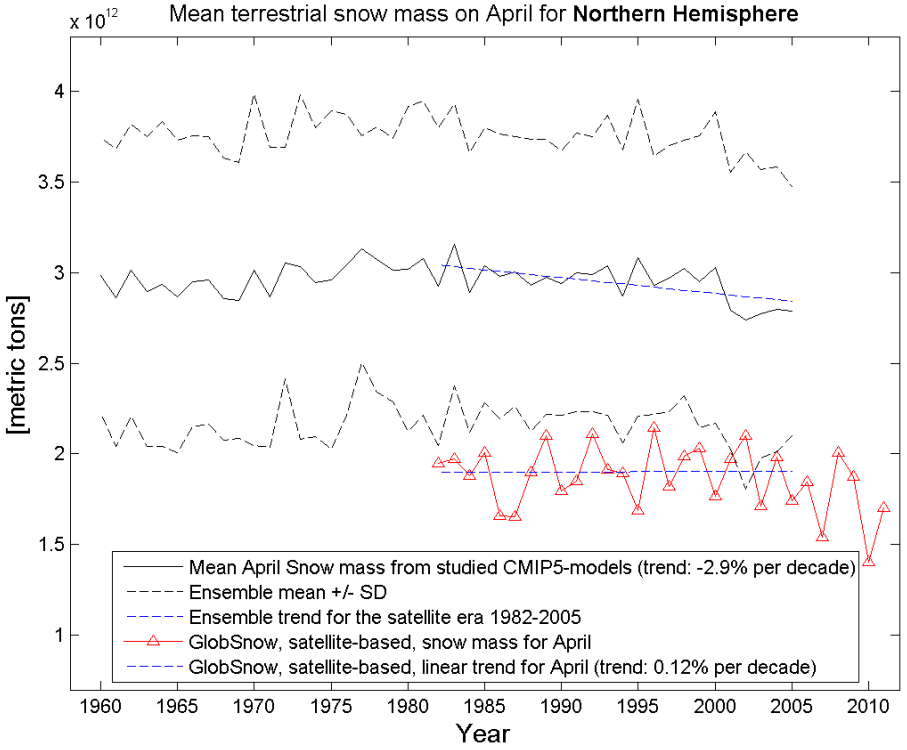
CMIP5 vs. GlobSnow historical SWE (Jan. & Feb.)



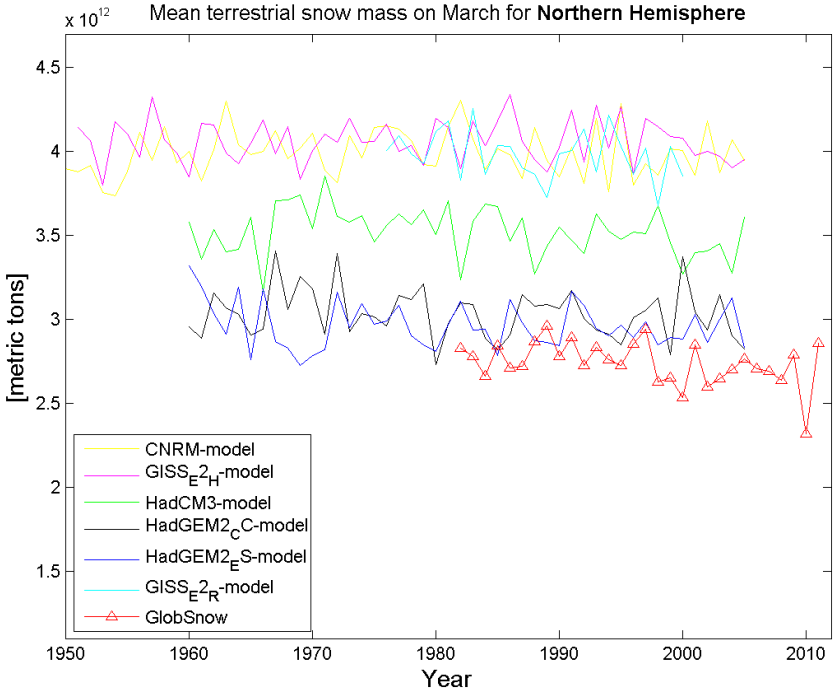


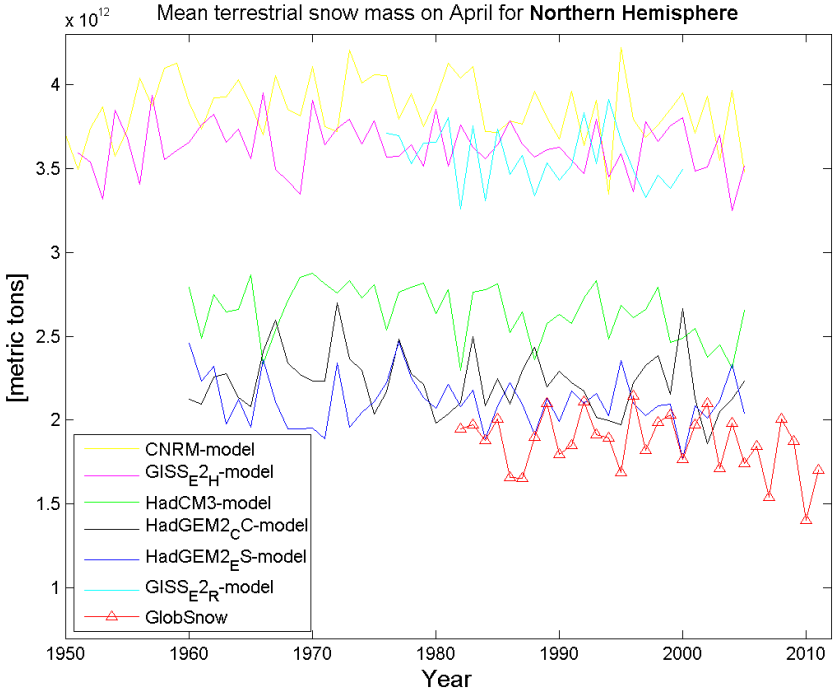
CMIP5 vs. GlobSnow historical SWE (March & April)



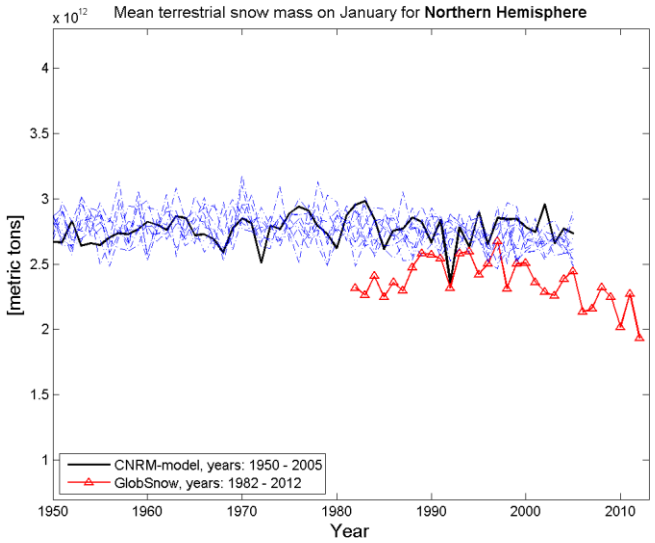


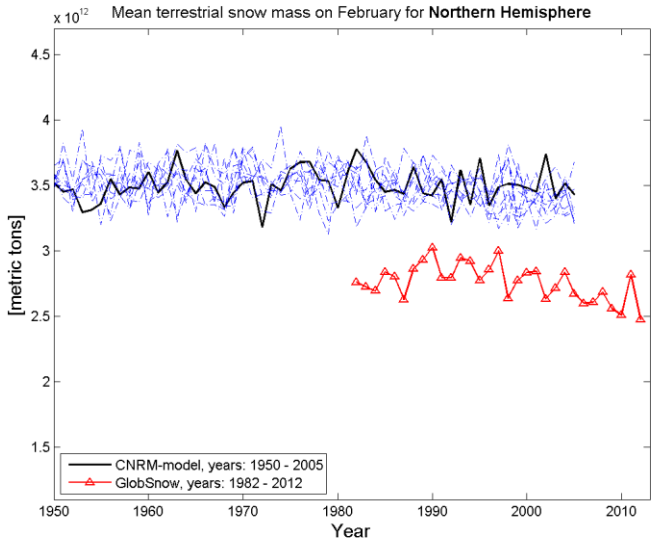
CMIP5 vs. GlobSnow historical SWE (March & April)

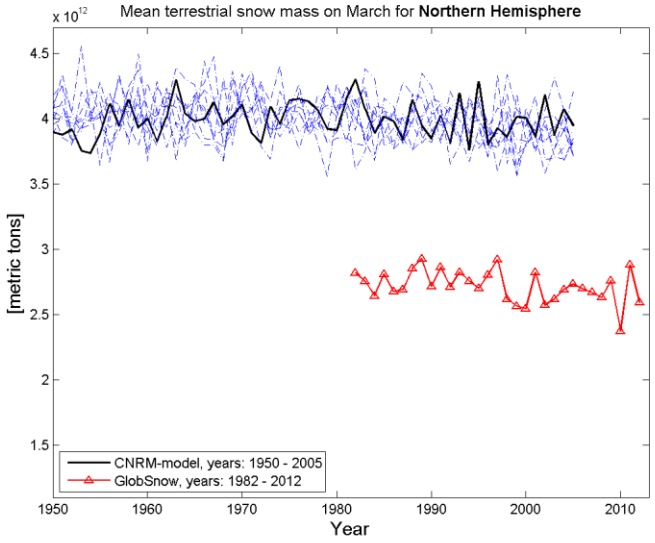


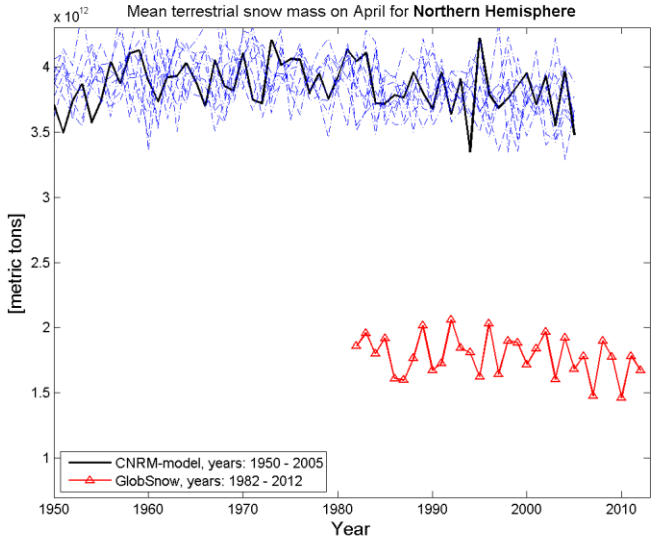


GlobSnow SWE vs. CNRM & different realizations









Conclusions & Future plans

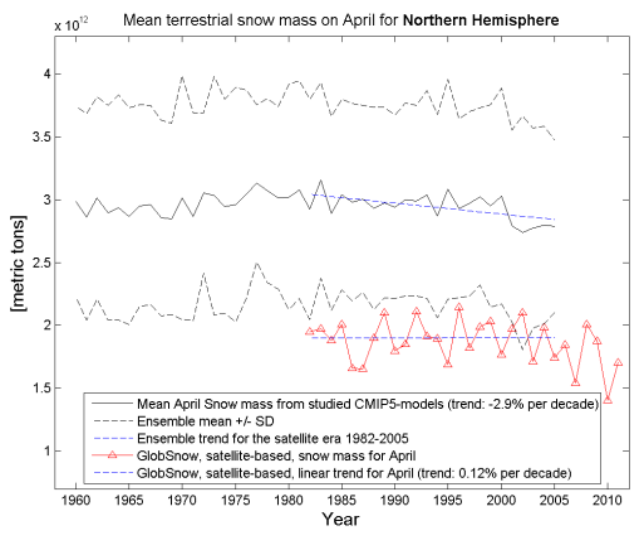
Conclusions:

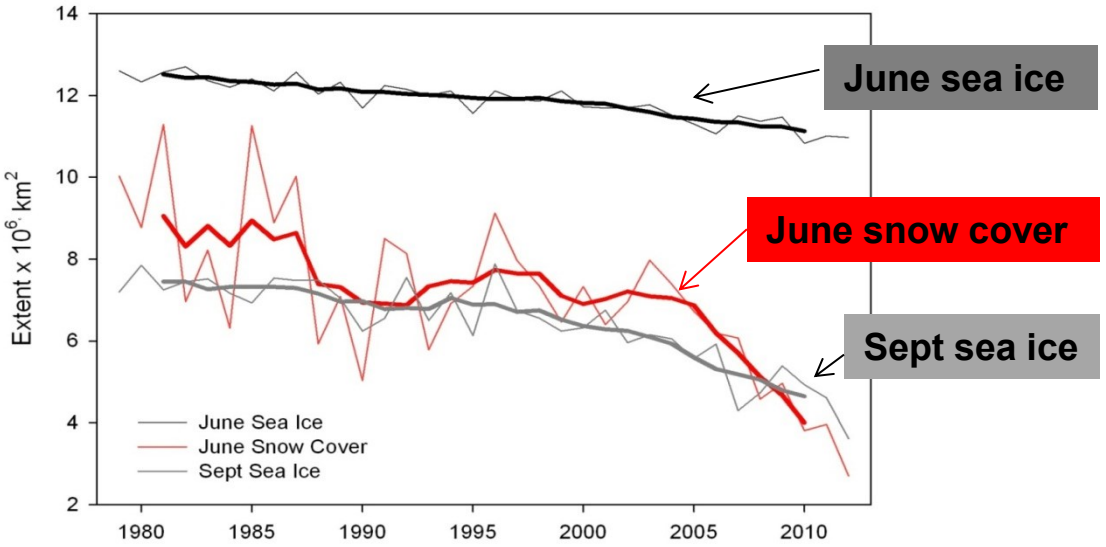
- **GlobSnow–2**
  - NH SWE v2.0 time series for 1979 – 2013 (released Dec. 2013)
  - NH SE v2.0 time series for 1995 – 2012 (release Dec. 2013)

- **SWE time series (30+ years) is applicable for comparison with climate model data**
  - However, need to keep track of number of observations – summer months & early autumn not necessarily representative

- **Investigations for SWE & CMIP5 comparisons still largely on-going**

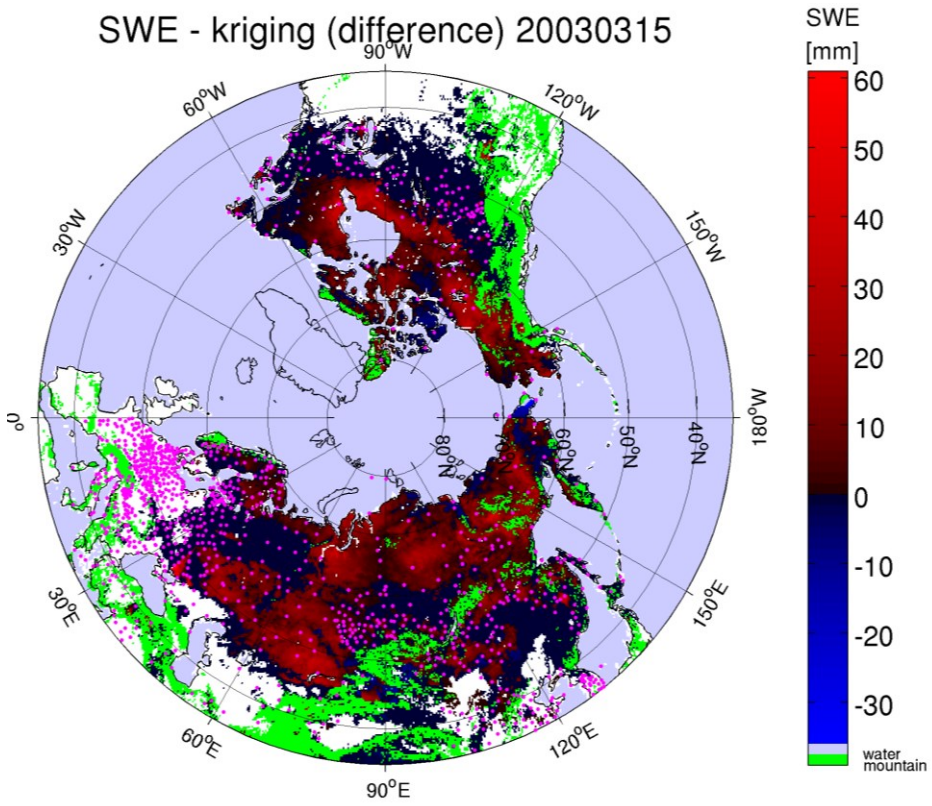
Thank You for Your Attention!

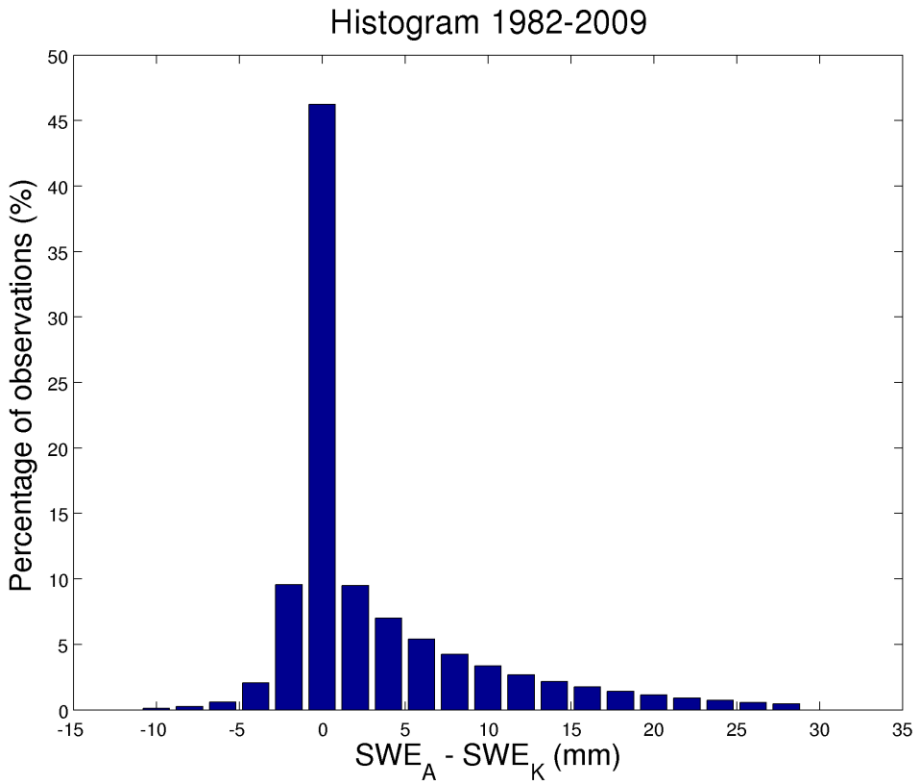




ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Impact of Radiometer Derived Information





Difference between final assimilated SWE and background SWE from interpolated synoptic weather station data.