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ASSESSMENT OF NORTHERN HEMISPHERE SNOW WATER EQUIVALENT DATASETS IN ESA SNOWPEX PROJECT

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Environment Canada Environnement Canada

Outline

- **Assessment of SWE datasets in ESA SnowPEx project**

  1) Uncertainties in observed and modelled NH SWE conditions

  2) Comparison of Satellite-based SWE datasets

  3) Comparison of Model-based SWE datasets

  4) Constraining SWE products using optical SE data

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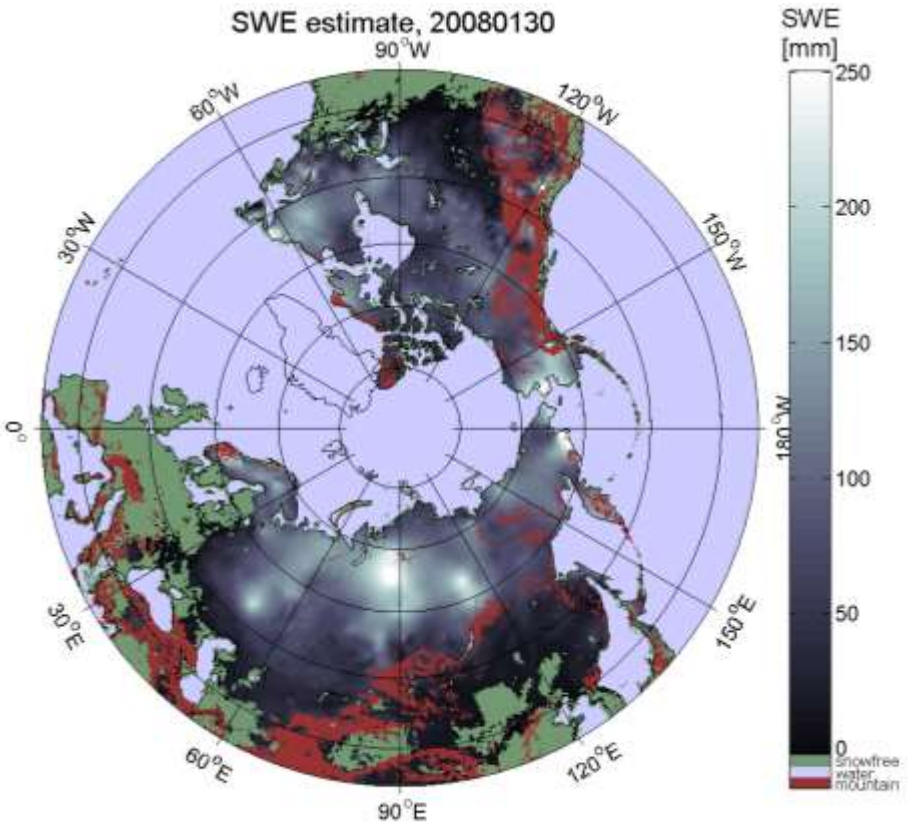
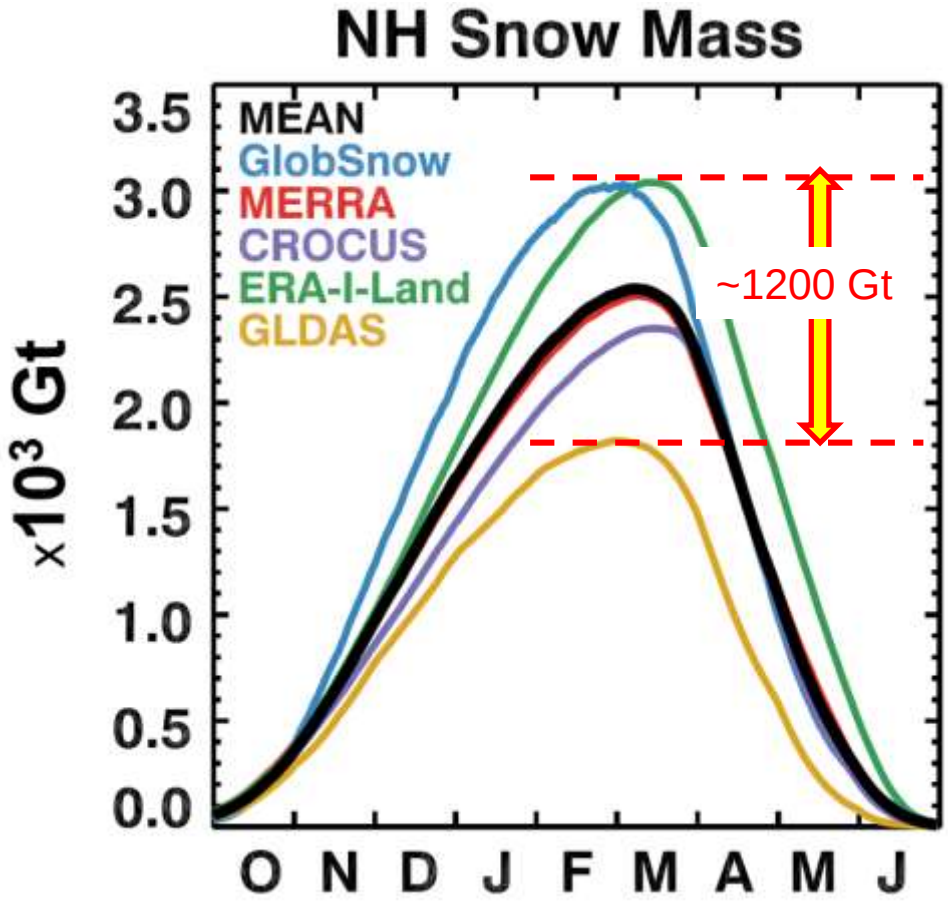
Uncertainty in NH Seasonal Snow mass

Spread in NH snow mass between **model-based** and **Satellite-based** estimates!



“Satellite-based“ GlobSnow SWE estimate



Models vs. “Satellite-based“ data

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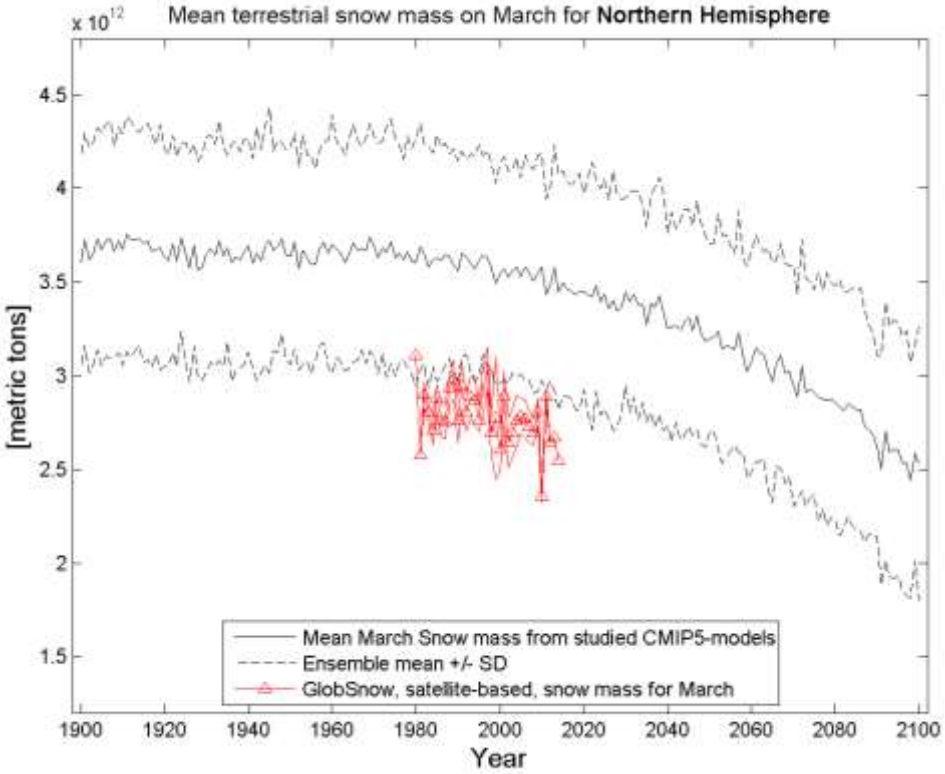
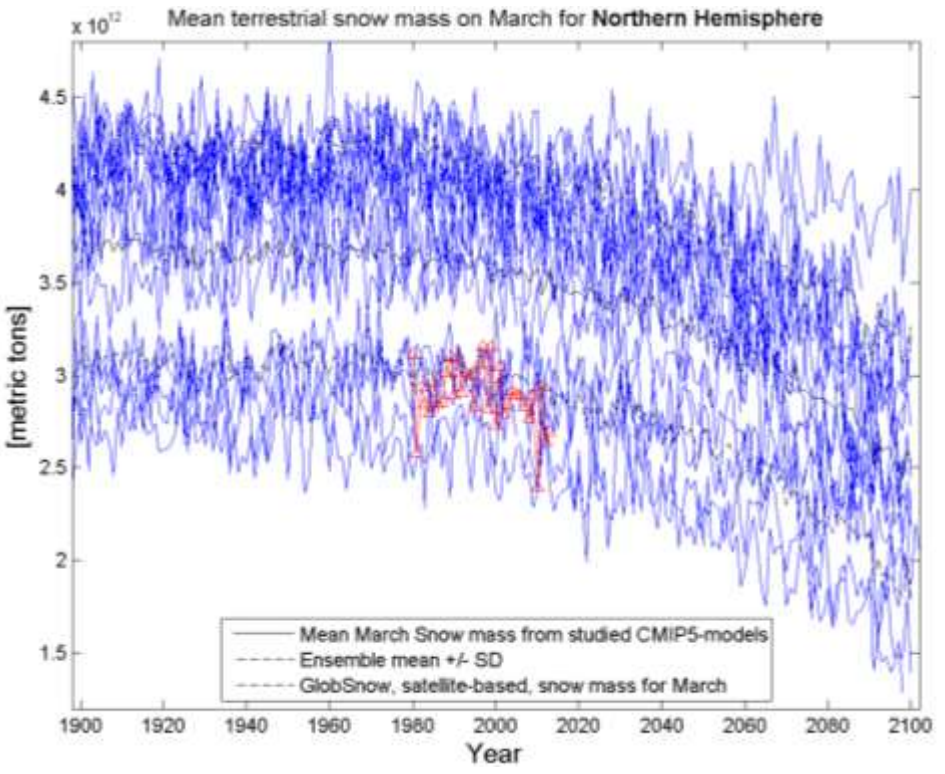
GlobSnow ensemble vs. ensemble historical & RCP8.5 ”forecast”

March & April, Preliminary: 16 models

- Significant over-estimation of spring-time snow mass in CMIP5 model simulations
- CMIP5: Historical + RCP8.5 forecasts





GlobSnow mean: 2900 Gt
CMIP5 mean: 3600 Gt (~25% over-estimation)

March spread in CMIP5: **2600 – 4300** Gt

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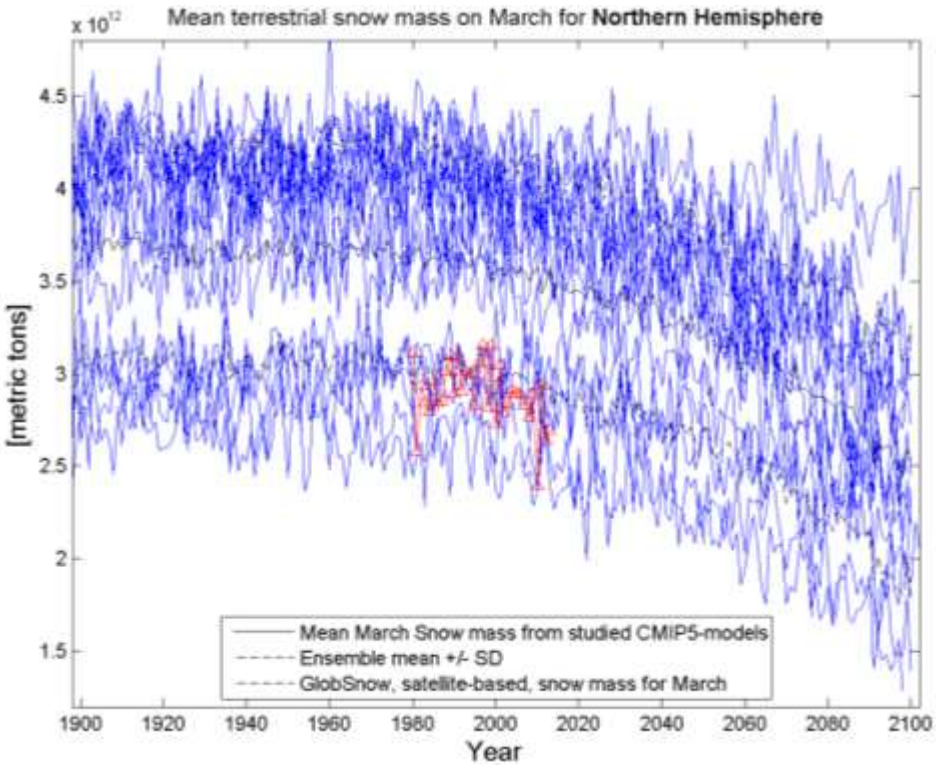
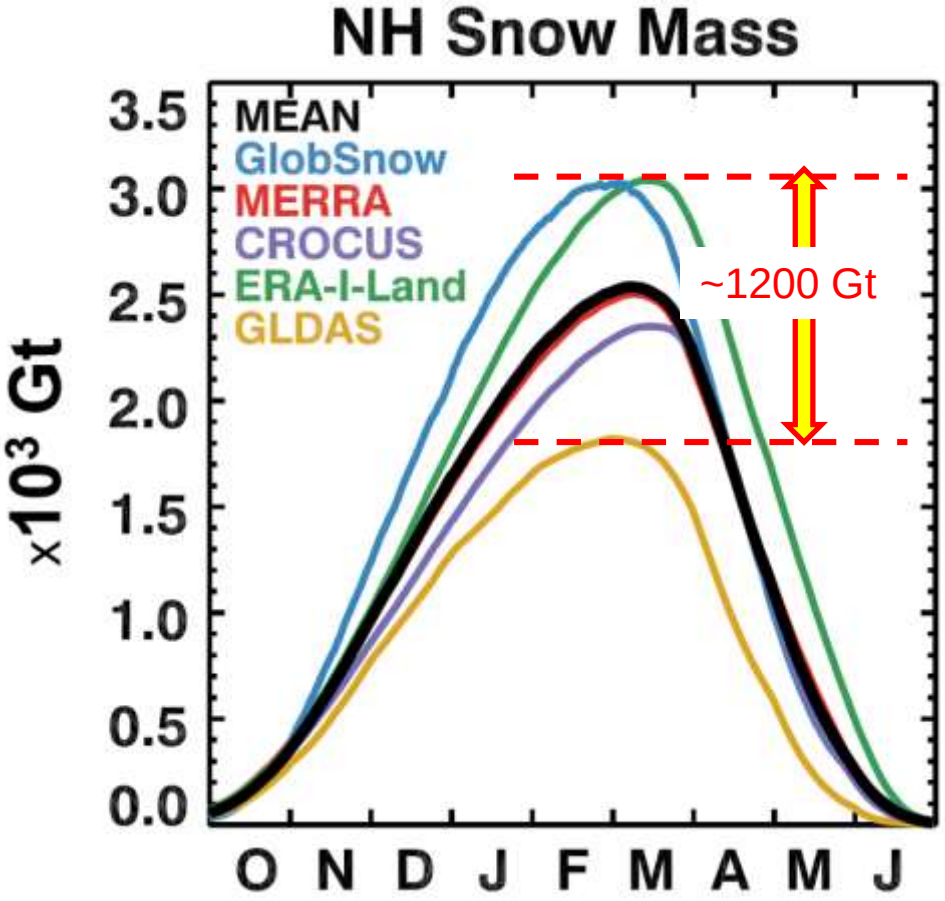
Uncertainty in Mass of Seasonal Snow

Wide spread in NH total snow mass between model-based and Satellite-based estimates!





CMIP5 (March) 2600 – 4300 Gt:

Re-analysis driven snow-models (March) 1800 – 3000 Gt

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Comparison of Satellite-based SWE datasets

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ESA SnowPEx project
SWE Inter-Comparison Objectives

- **Intercompare and evaluate hemispheric passive microwave derived SWE products generated by different algorithms, assessing the product quality by objective means.**
- **Evaluate and intercompare temporal SWE trends in order to achieve well-founded uncertainty estimates for climate change monitoring.**
- **Identify recommendations and needs for further improvements in monitoring seasonal snow parameters from EO data.**

SnowPEx considerations for SWE:

1. **Limited number and time series (AMSR-E) of EO-derived NH SWE products**
2. **Inclusion of non-EO gridded products**
3. **Challenges for alpine areas**

ISSPI-1 (Washington DC 07/2014): *community consensus* on datasets, protocols, metrics, work plan, etc.

ISSPI-2 (Boulder, Colorado 09/2015): Initial results, focus on finalizing analyses and publishing

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SnowPEx SWE Datasets (Oper., NH-domain)

Dataset	Method	Ancillary/ Forcing Data	Resolution	Time Series	Reference
GlobSnow	Passive microwave + in situ	Weather station snow depth measurements	25 km	1979-2015	Takala et al (2011)
NASA AMSR-E standard	Standalone passive microwave		25 km	2002-2011	Kelly (2009)
NASA AMSR-E prototype	Microwave + ground station climatology	Weather station snow depth climatology	25 km	2002-2011	TBD
ERAint-Land	HTESSEL land surface model	ERA-interim	0.75° x 0.75°	1981-2010	Balsamo et al (2013)
MERRA	Catchment land surface model	MERRA	0.5° x 0.67°	1981-2010	Rienecker et al (2011)
Crocus	ISBA land surface + Crocus snow model	ERA-interim	1° x 1°	1981-2010	Brun et al (2013)
GLDAS-2	Noah 3.3 land surface model	Princeton Met.	1° x 1°	1981-2010	Rodell et al (2004)

SWE analysis – Russian snow transect data

Evaluated satellite SWE datasets:

- **GlobSnow-2 (FPS v2.0)** **01/1980 – 12/2014**
- **NASA AMSR-E standard** **06/2002 – 10/2011**
- **NASA AMSR-E prototype** **10/2002 – 04/2011**

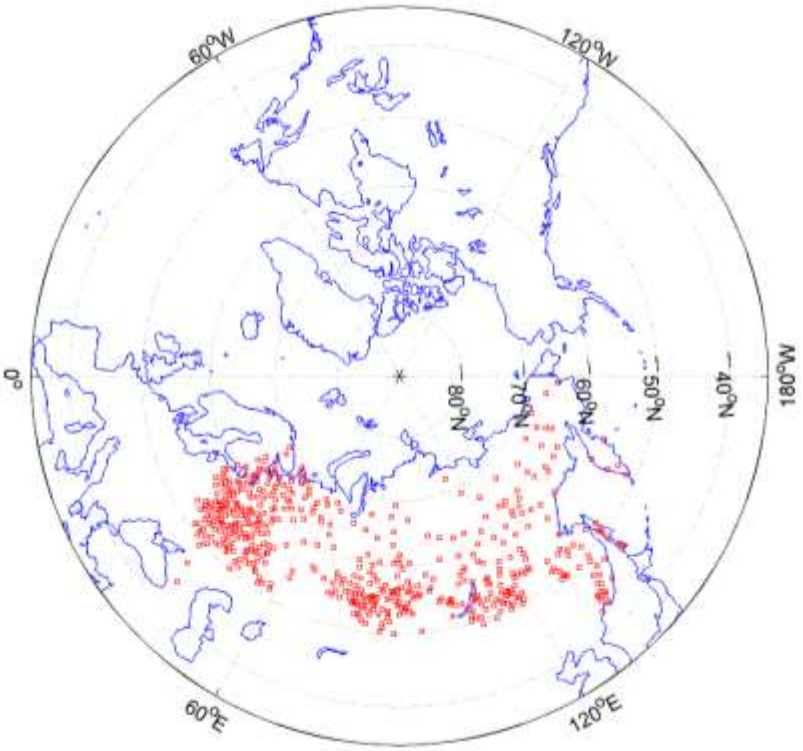
Reference data:

RIHMI WDC snow course data **2002 – 2011**

- **38 197** samples (only the coinciding samples from all products used)

Dataset covering the vast Russian domain, different regions & conditions

Satellite SWE vs Russian snow transect data



- Independent reference data, extensive Northern Eurasia coverage
- 517 snow courses, 1 - 2km snow transects, (data for 1979 – 2011)

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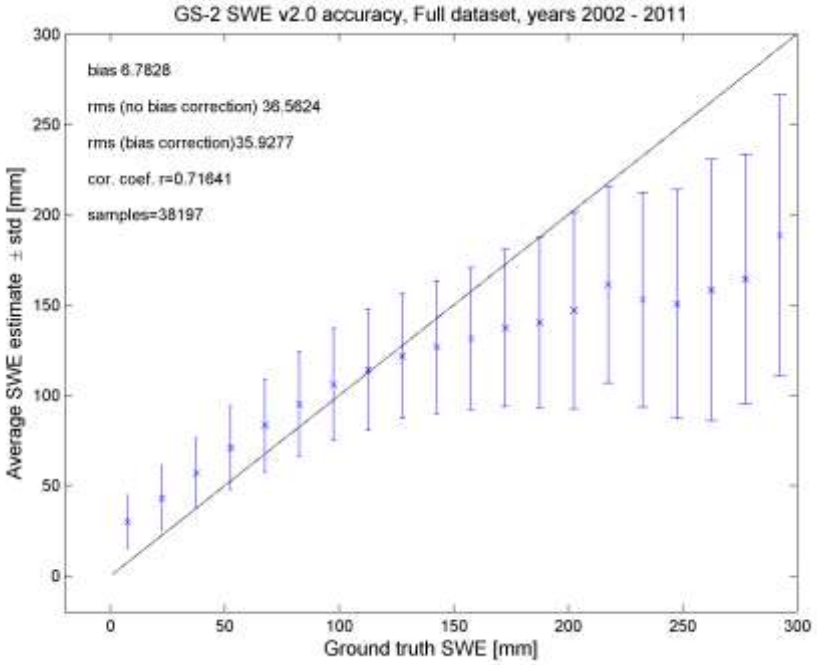
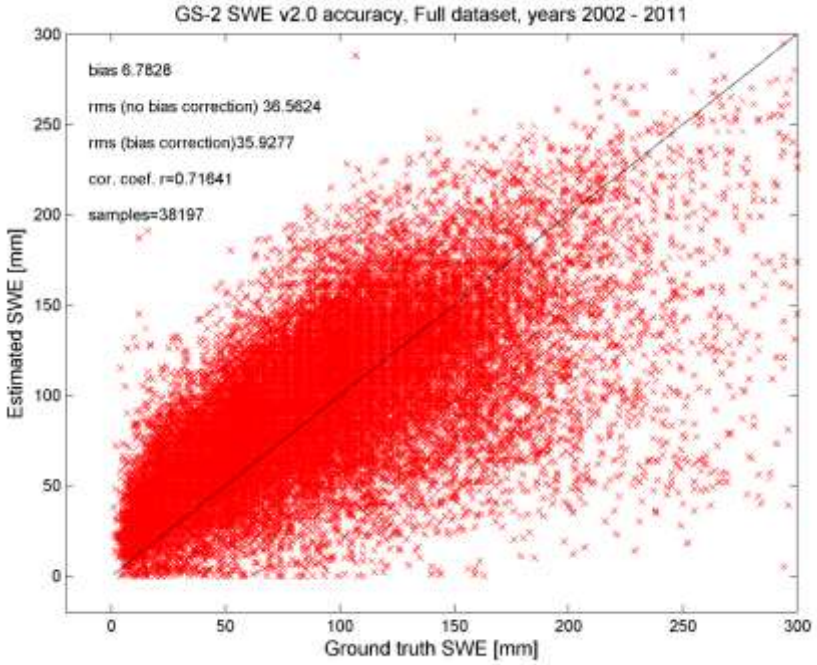
GlobSnow-2 SWE vs. RIHMI WDC (2002-2011)

38197 Coinciding samples of GlobSnow, NASA Standard and NASA prototype SWE

Evaluations for the samples available in all 3 products!



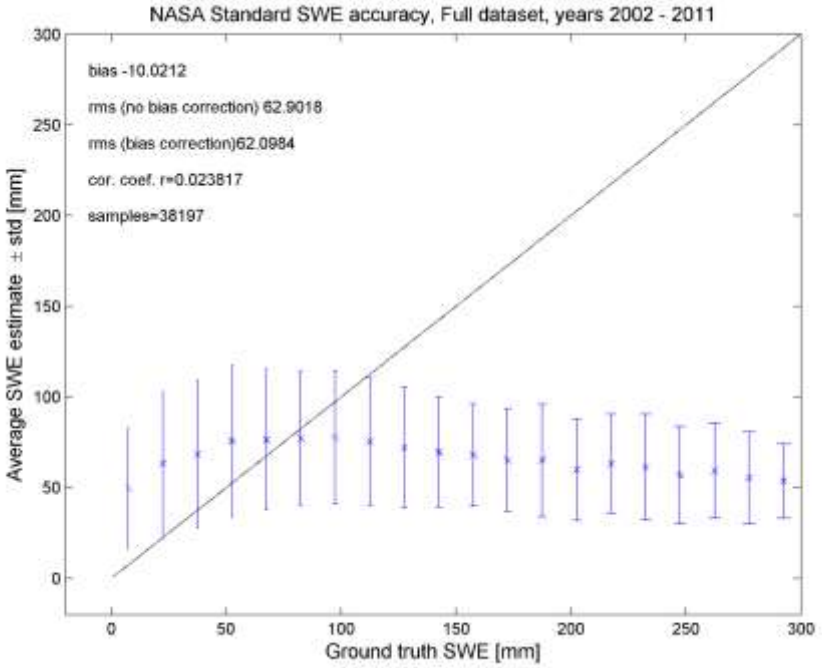


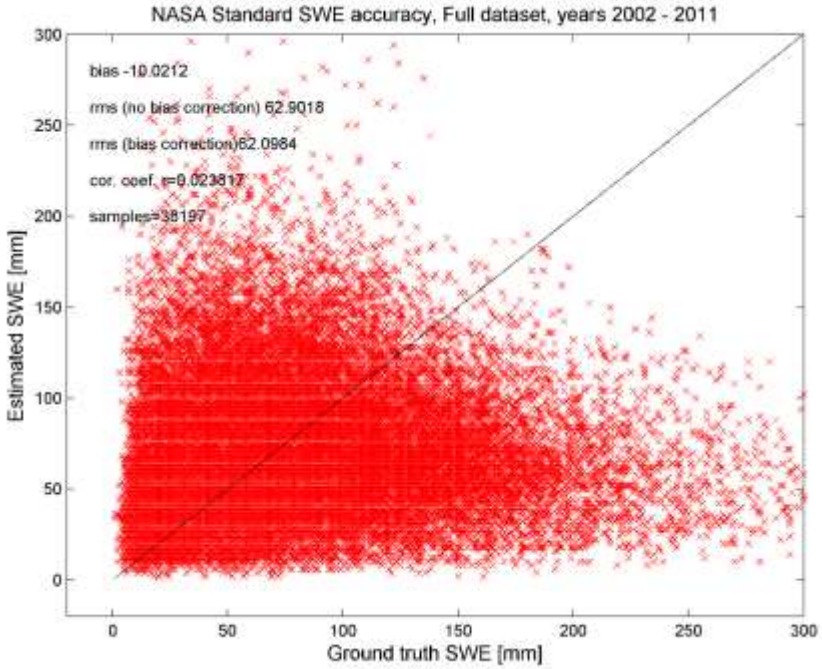
”Blended product” = combines satellite and ground-based WS-data

NASA Standard SWE vs. RIHMI WDC (2002-2011)

38197 Coinciding samples of GlobSnow, NASA Standard and NASA prototype SWE

Evaluations for the samples available in all 3 products!



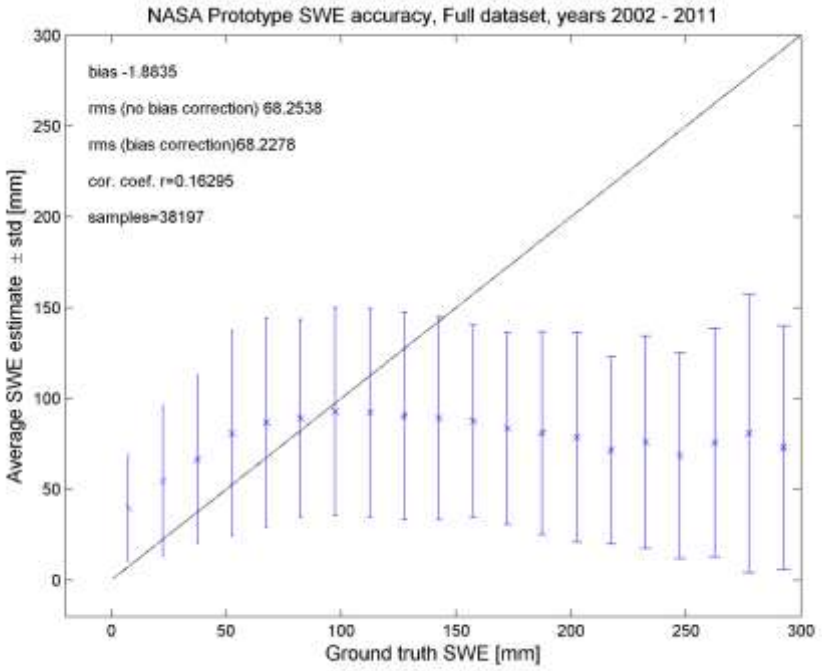


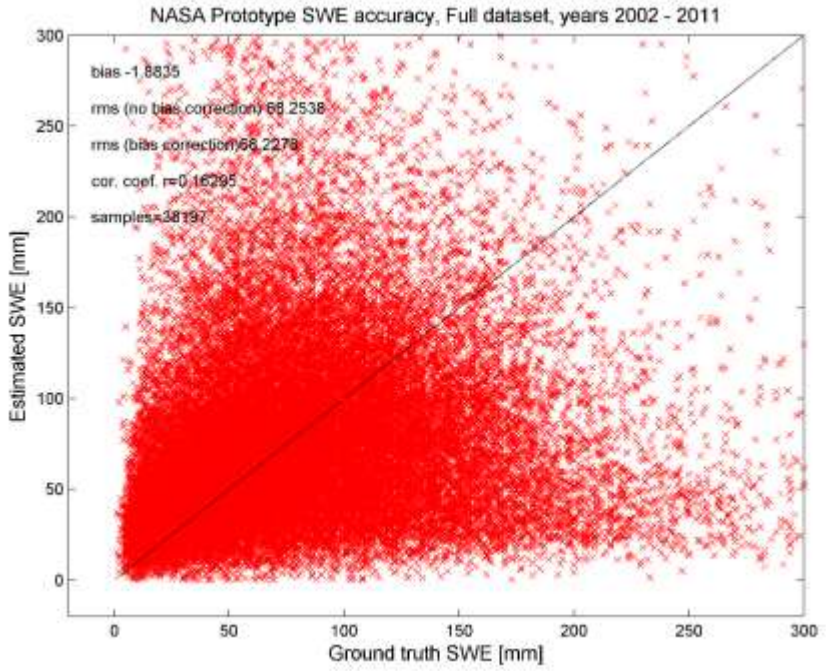
”Pure satellite product” = utilizes only satellite data for retrieval

NASA Prototype SWE vs. RIHMI WDC (2002-2011)

38197 Coinciding samples of GlobSnow, NASA Standard and NASA prototype SWE

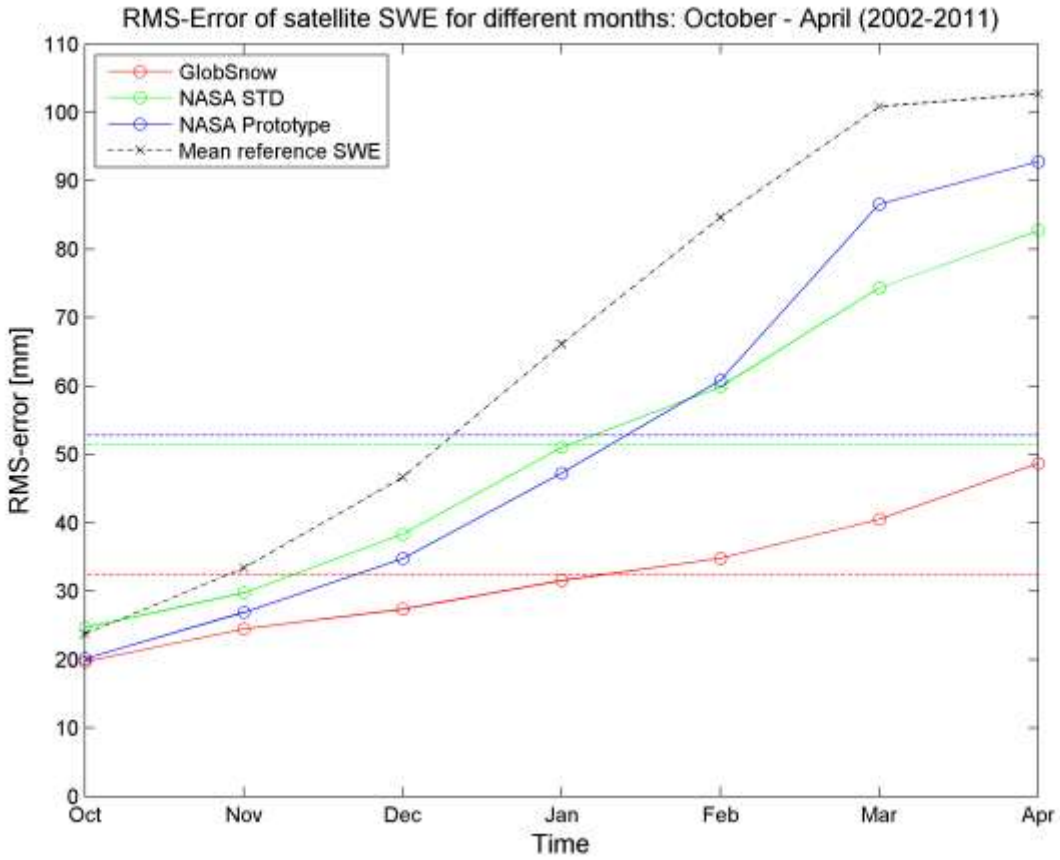
Evaluations for the samples available in all 3 products!





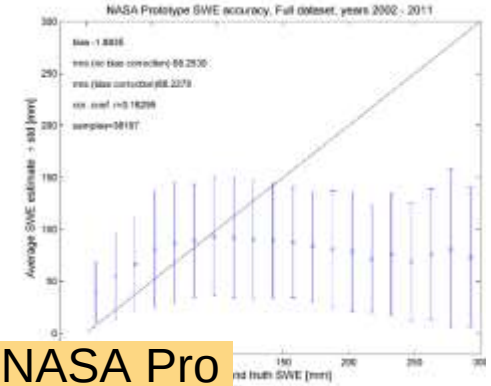
”Pure satellite product” = utilizes only satellite data for retrieval

SWE analysis on a monthly basis, RMSE

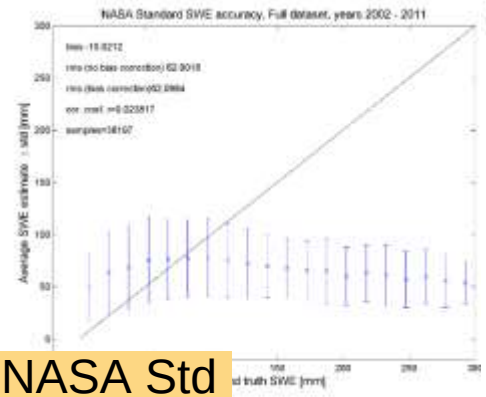


- Differences increase towards the end of the snow accumulation season

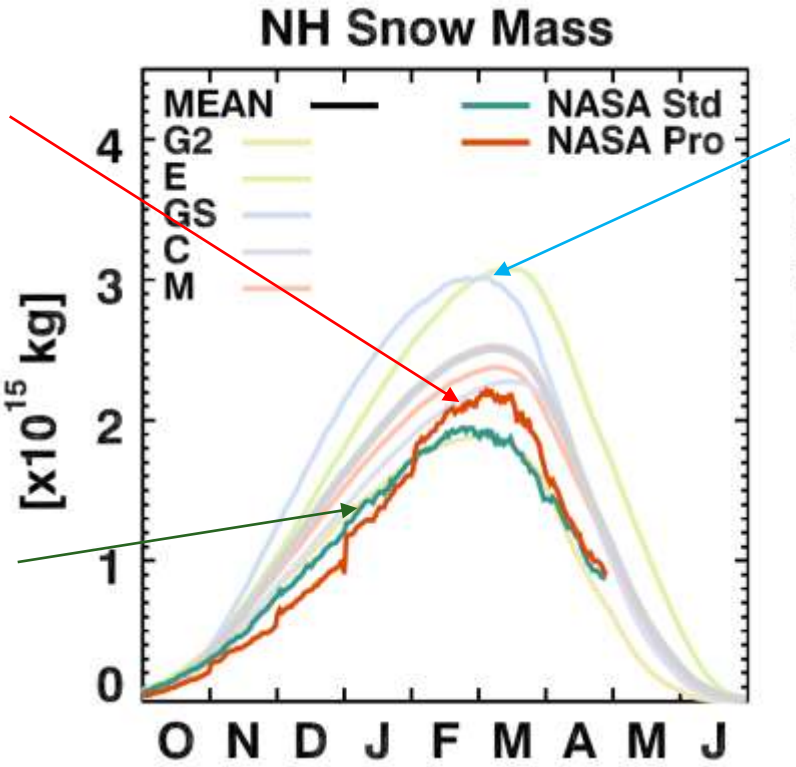
Conclusions (satellite-based SWE)

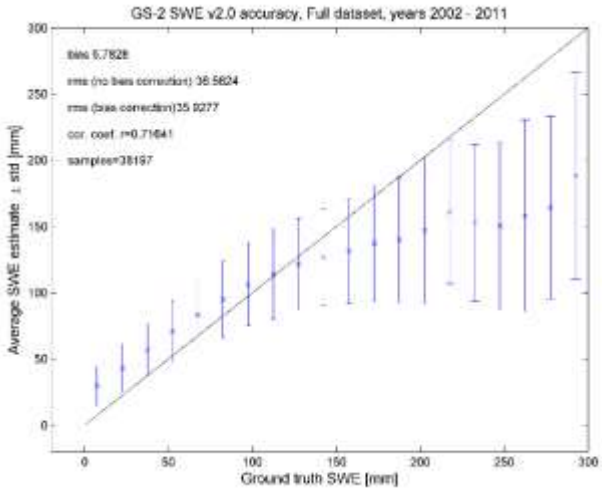


NASA Pro



NASA Std





GlobSnow

Observed under-estimation of NASA SWE products due to high negative bias with deep snow. Total snow estimates of GlobSnow for NH are more accurate.

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Comparison of Model-based SWE datasets

Model-based gridded SWE datasets

Analyses:

1) ERA-Interim-HTESSEL (ERA-land)

2) CROCUS/ISBA forced by ERA-Interim

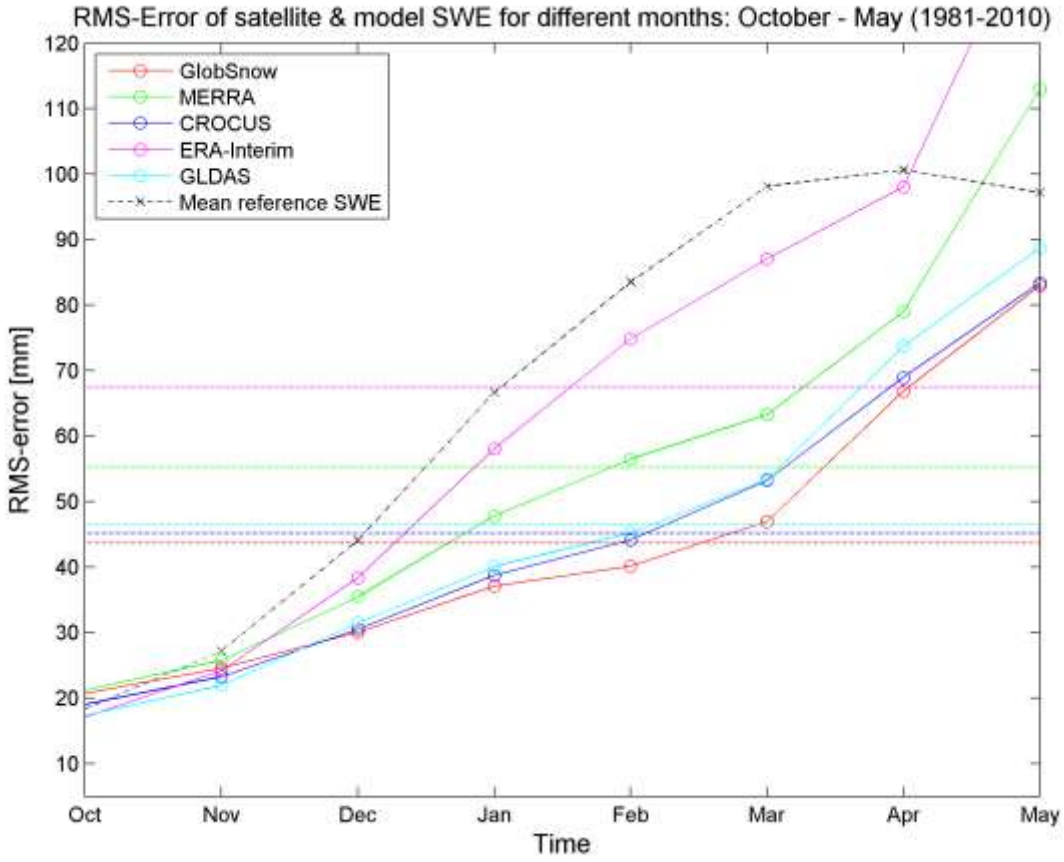
3) GLDAS2.0-Noah

4) MERRA-Catchment (MERRA-standard)

+) GlobSnow SWE v2.0 as a benchmark

- **Common assessed timeframe (1981 – 2010)**
- **Compared with Russian (& Finnish snow) course data**

SWE analysis on a monthly basis, RMSE



- Differences increase towards the end of the snow accumulation season

Conclusions (model-based SWE)

(GS-2); ERA-land; ERA-Int-CROCUS; GLDAS-Noah; MERRA-Catchment;

RMSE:(44.9mm), 74.7mm, 48.0mm, 49.5mm, 57.9mm

Bias: (-4mm), +42mm, +5mm, -11mm, +15mm

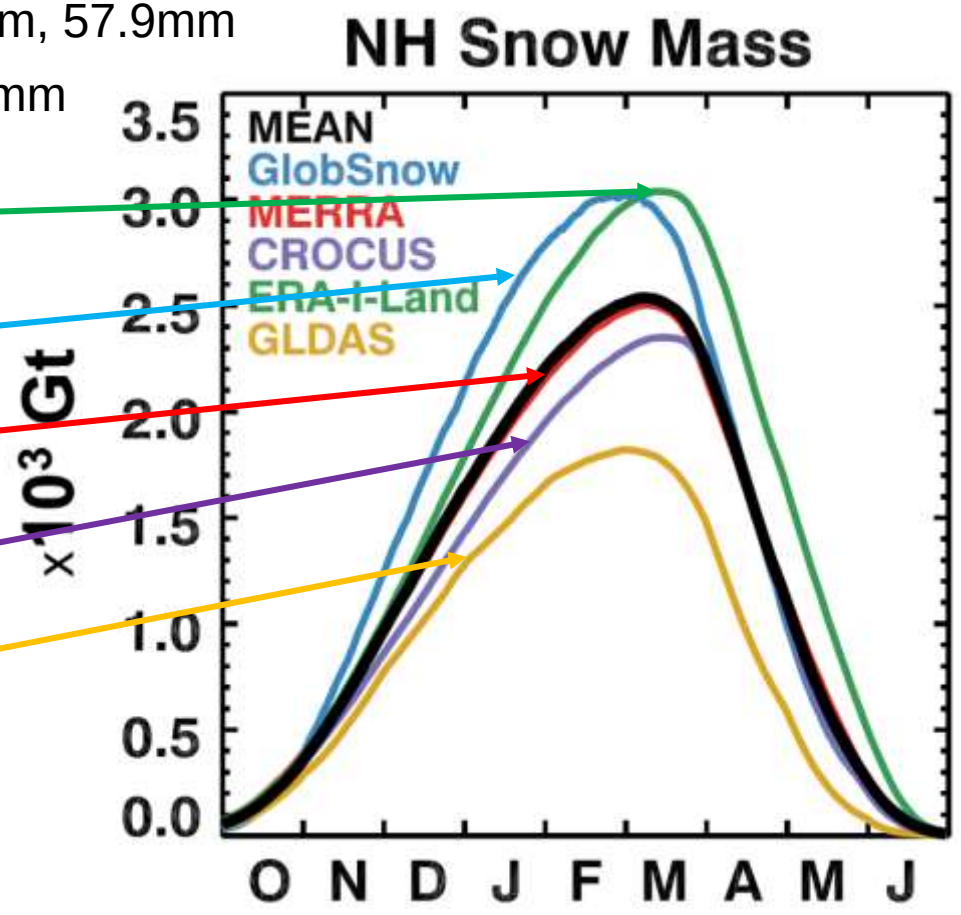
ERA-land: +42mm bias, high RMSE

GlobSnow: -4mm bias, low RMSE

MERRA: +15mm bias, mod. RMSE

CROCUS: +5mm bias, low RMSE

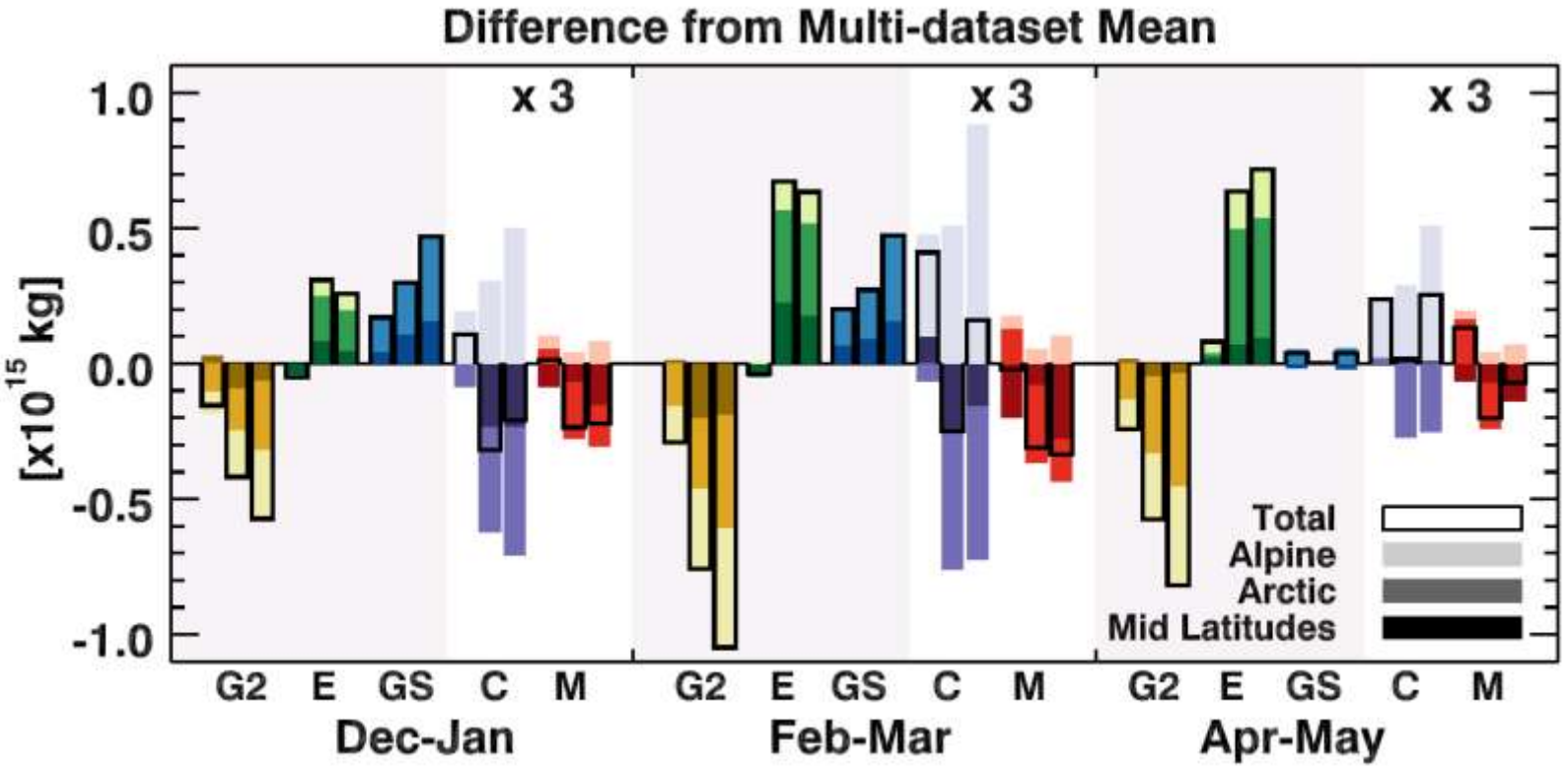
GLDAS: -11mm bias



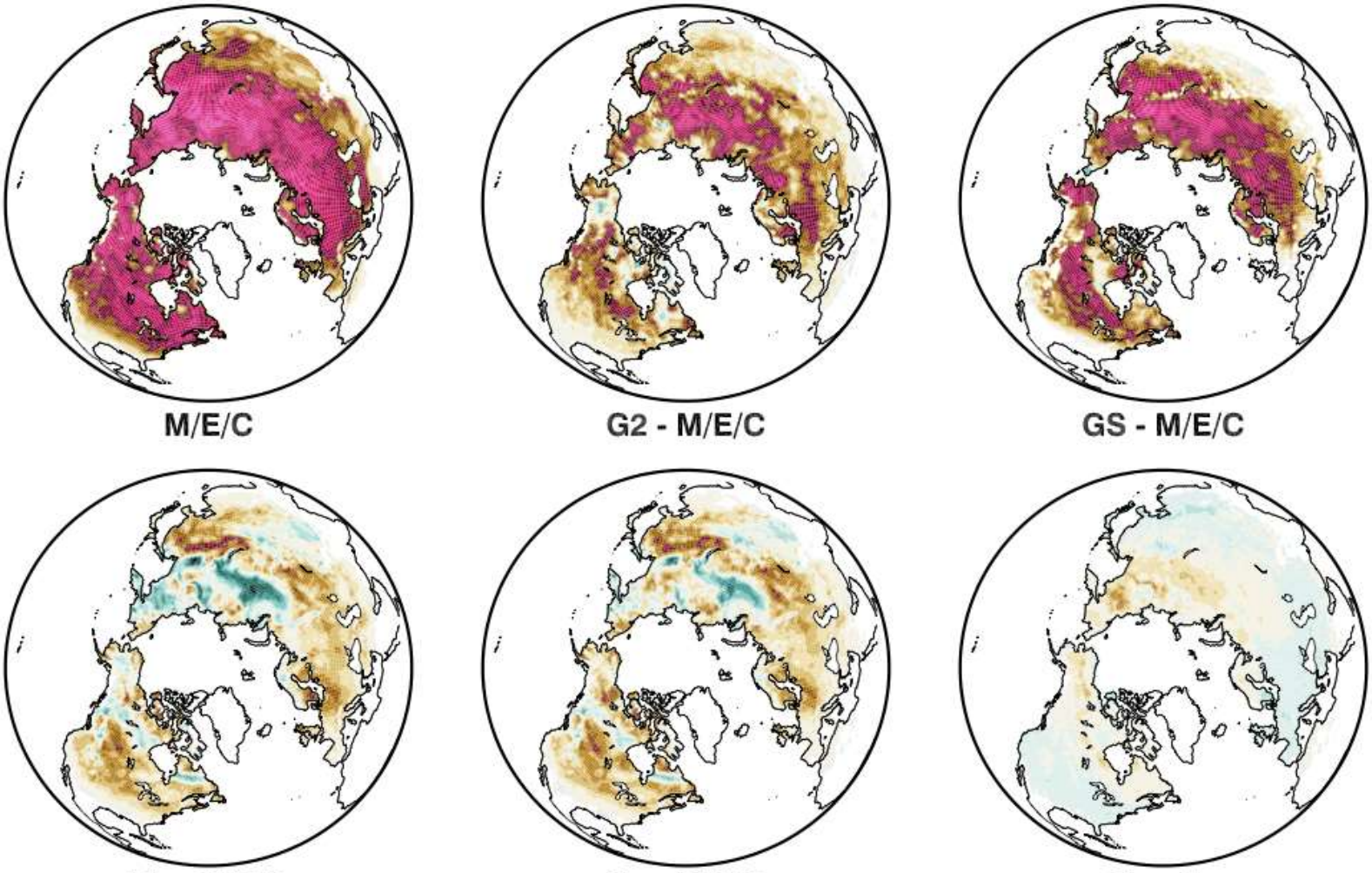
Overall behaviour is complex, additional alayses (month to month, landcover, etc…) on-going…

Gridded product multi-dataset comparison

- **Assessments for**
  - ***climatology***
  - ***individual product difference from multi-dataset mean by region and season***
  - ***temporal and spatial signal-to-noise***
  - ***anomaly consistency (including signal-to-noise)***
  - ***temporal and pattern correlation***



Spatial anomaly correlation
multi-dataset ensemble vs. individual products



Summary – All SWE products

- **Assessed for an uniform time period, ranked by retrieval performance (RMSE)**
- Time period 2002-2010, Russian snow course data as reference

Datasets	Dataset availability	Retrieval performance (RMSE) 2002-2010	Bias 2002-2010	Retrieval performance (RMSE) 1981-2010	Bias 1981-2010
GlobSnow v2.0	**1979-2015**	**42.6 mm**	**-3.8 mm**	44.9 mm	-4.3 mm
CROCUS-Era-Interim	**1981-2010**	**45.8 mm**	**+1.1 mm**	48.0 mm	+4.7 mm
GLDAS2.0-Noah	**1981-2010**	**48.0 mm**	**-8.4 mm**	49.5 mm	-10.8 mm
MERRA (Standard)	**1981-2010**	**54.9 mm**	**+12.9 mm**	57.9 mm	+15.2 mm
ERA-Interim (ERA-Land)	**1981-2010**	**67.3 mm**	**+35.4 mm**	74.7 mm	+42.4 mm
NASA Standard	**2002-2011**	**67.4 mm**	**-24.3 mm**	-	-
NASA Prototype	**2002-2011**	**72.4 mm**	**-19.9 mm**	-	-

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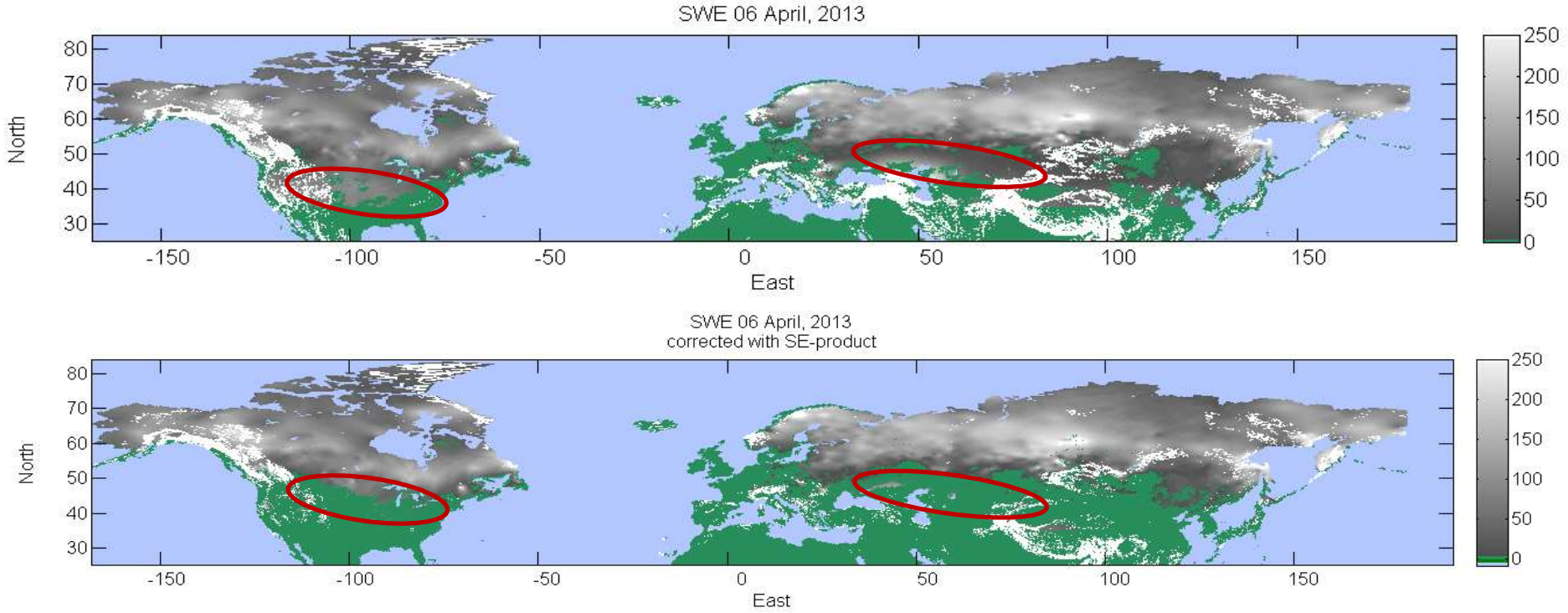
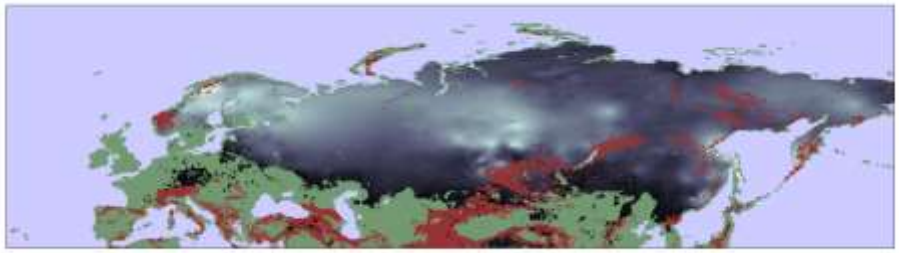
Constraining SWE products using optical SE data

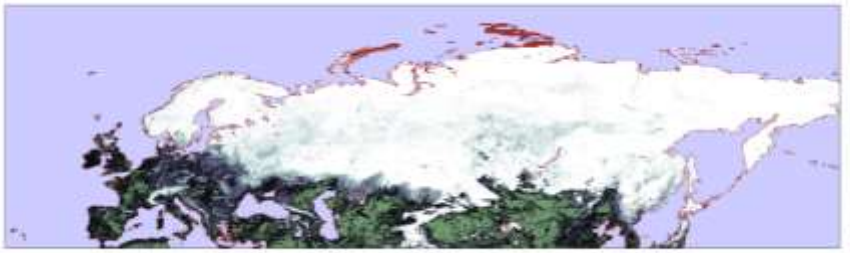
Fusion of GlobSnow SE and SWE

GlobSnow SWE NRT-product has difficulties in detecting snow line during spring melt season -> snow line identification from SE-product



Fusion with optical data (***GlobSnow SCAmod VIIRS***)
-> more realistic snow line during the melt season





SWE map from SSM/I (S) and weather station-observed SD

SE map from MODIS/VIIRS

SE-value averaging to coarse resolution SWE grid and thresholding to binary map (e.g. FSC >25%)

Snow exists in SWE product for pixel i

No

Yes

SE product missing

Yes

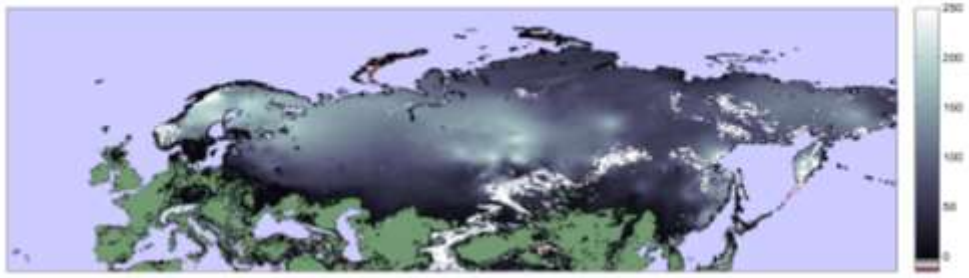
Snow exists in SE product for pixel i

No (or SE product missing and SWE product indicating no-snow)

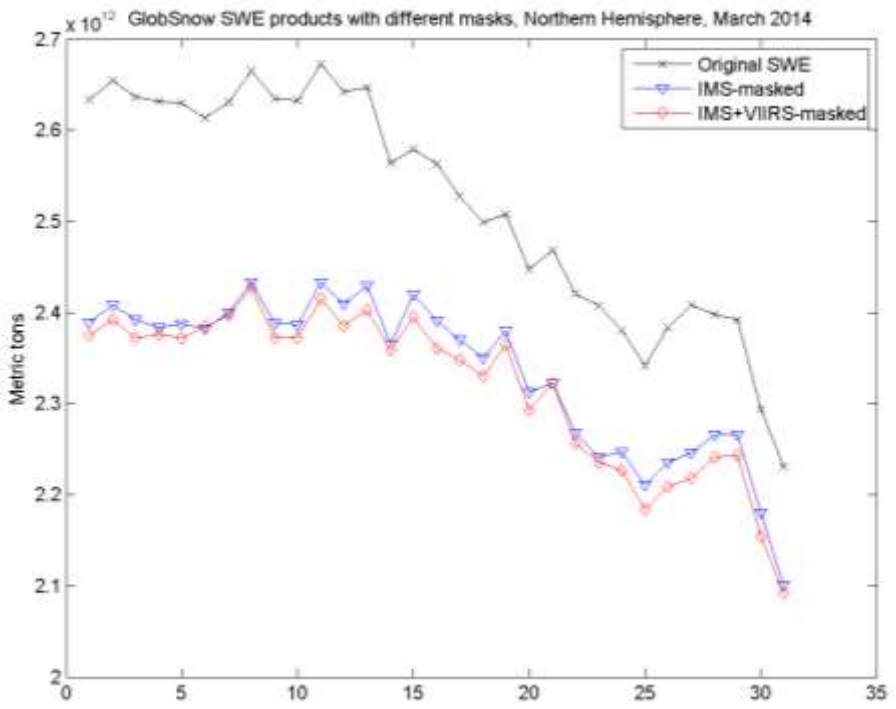
Snow cover with given SWE

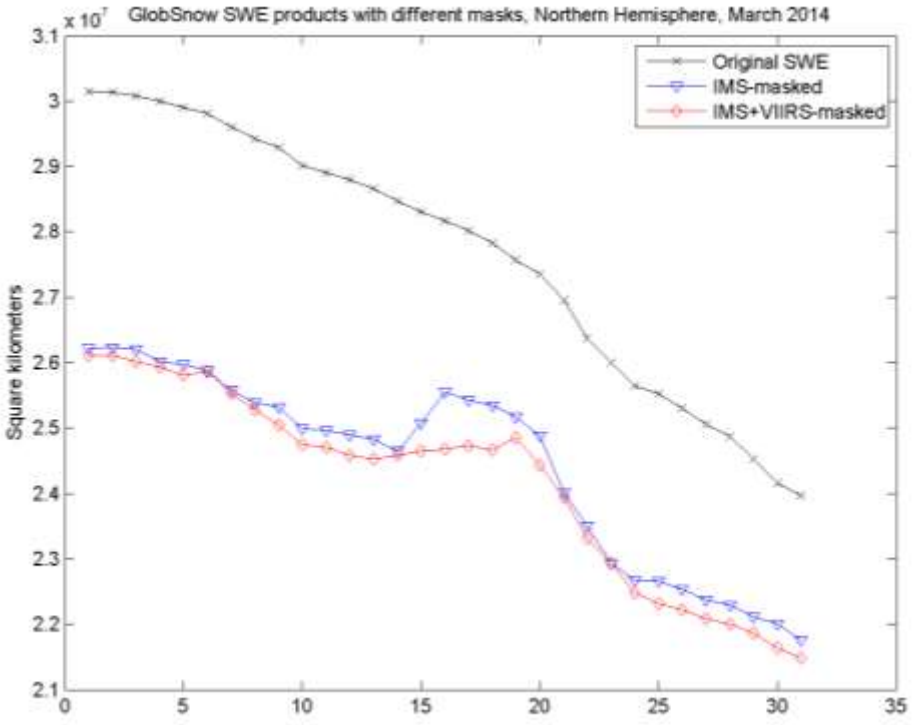
Wet or thin snow cover

No snow



Change in NH snow mass & area (March 2014)





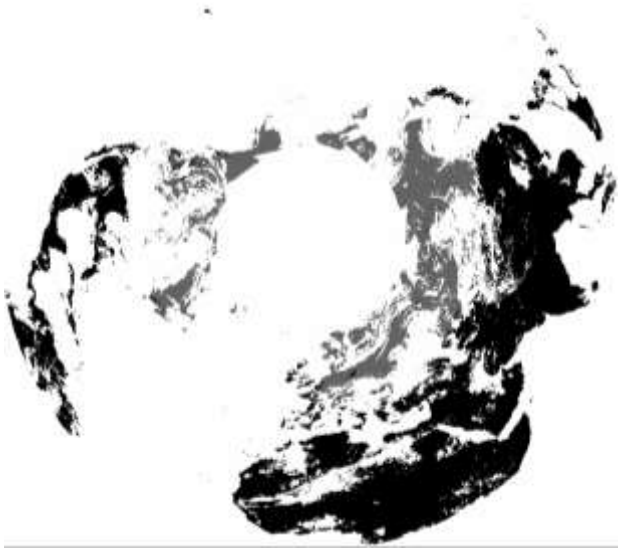
IMS+VIIRS masked
<u>8,0% decrease</u> in **<u>mass</u>**

IMS+VIIRS masked
<u>12,7% decrease</u> in **<u>area</u>**

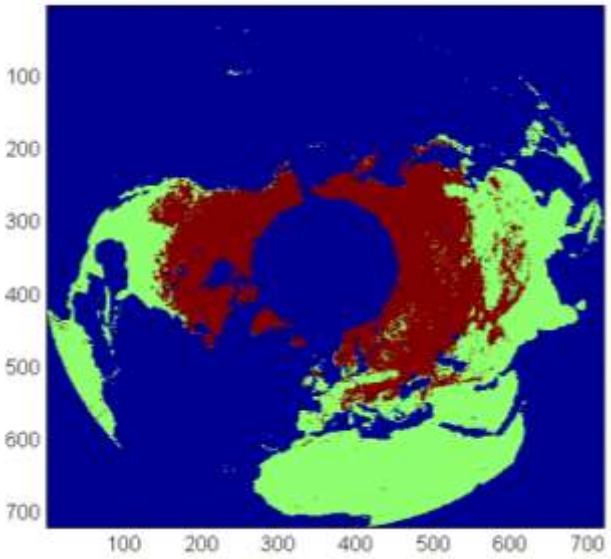
JXAM5 daily (5km) FSC -> cumulative daily (25km) SE

- Data from 1997-2013 acquired from JAXA and converted to 25km EASE-grid 2.0
- Daily FSC data were combined into a cumulative daily SE mask, using 25% cutoff value
- GlobSnow SWE masked (corrected) using daily composite SE-data

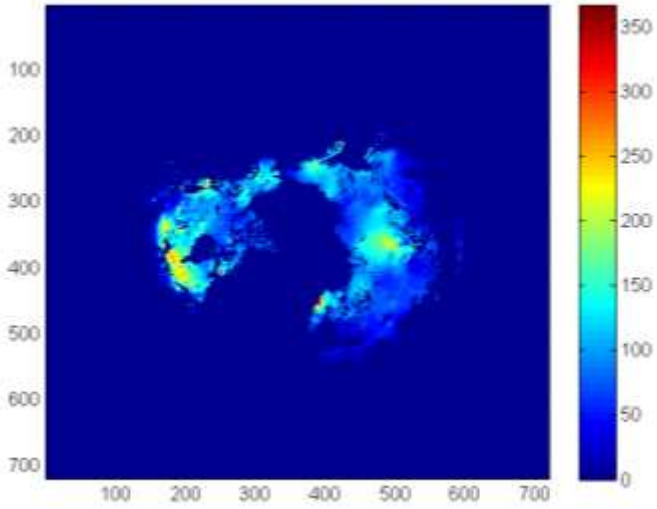
Single day JXAM5 FSC (gaps)



Cumulative SE map (no gaps)



SE masked SWE product



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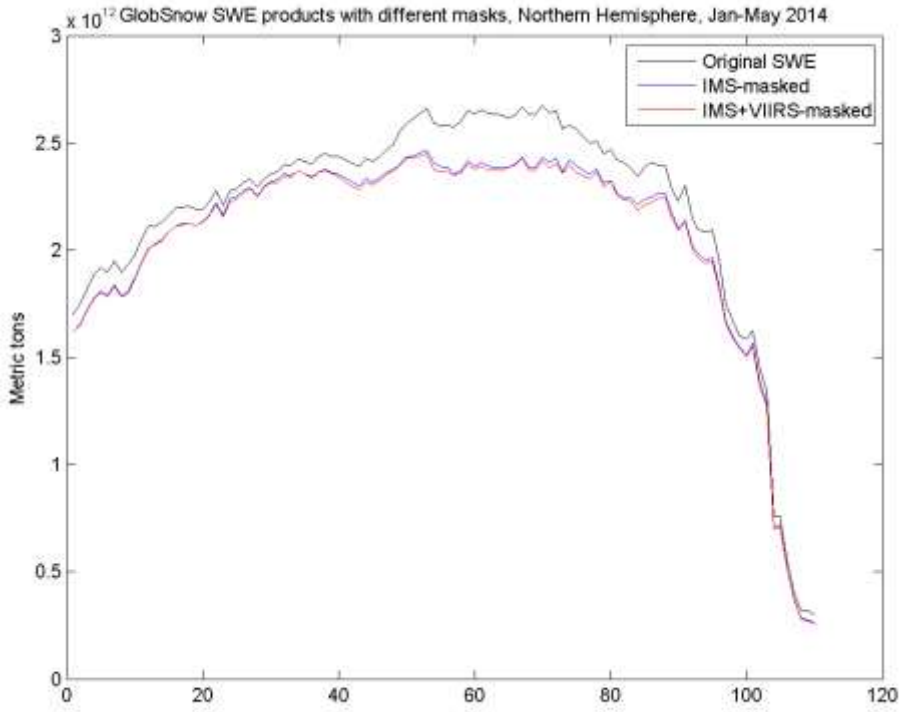
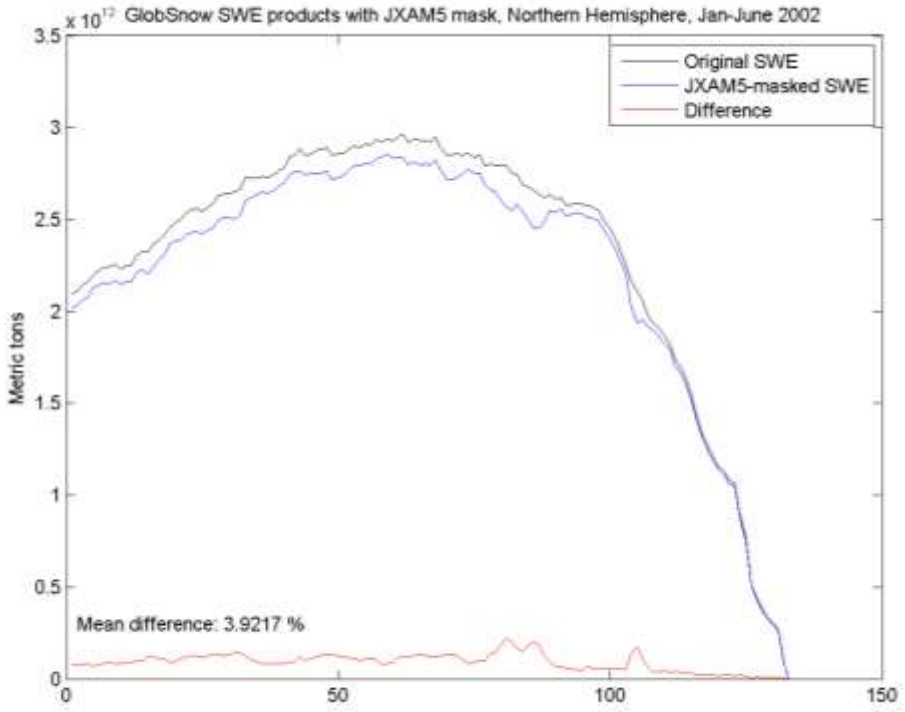
JXAM5 daily (25km) SE-masked GlobSnow SWE - Spring

- IMS+VIIRS-masked data shows significantly higher decrease in HN snow mass, than JXAM5 masked SWE data





IMS+VIIRS masking -> 8,0% decrease in mass

JXAM5 -> 3,9% decrease in mass (<u>at most</u>)

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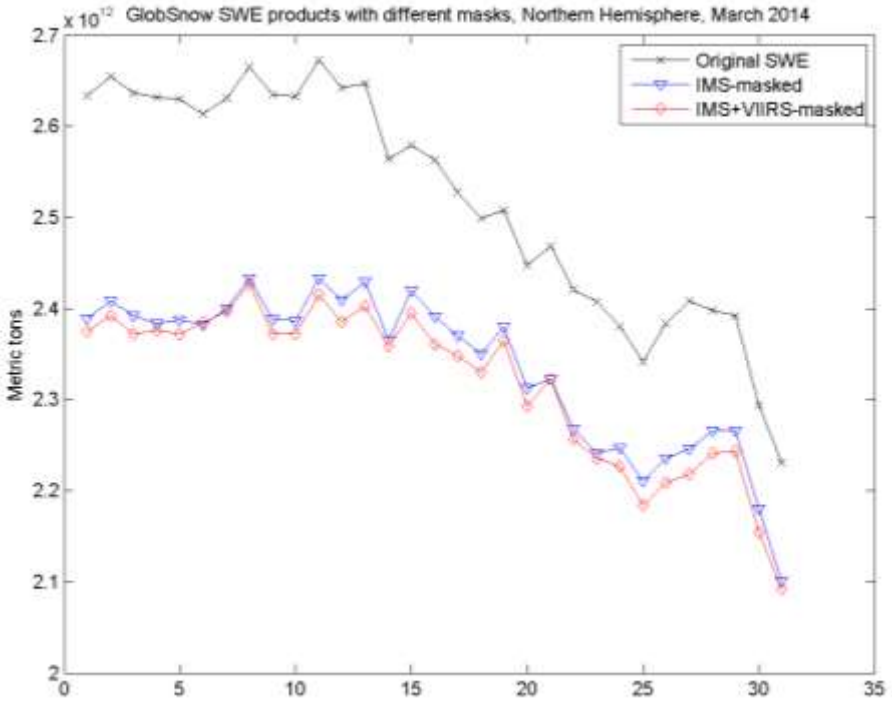
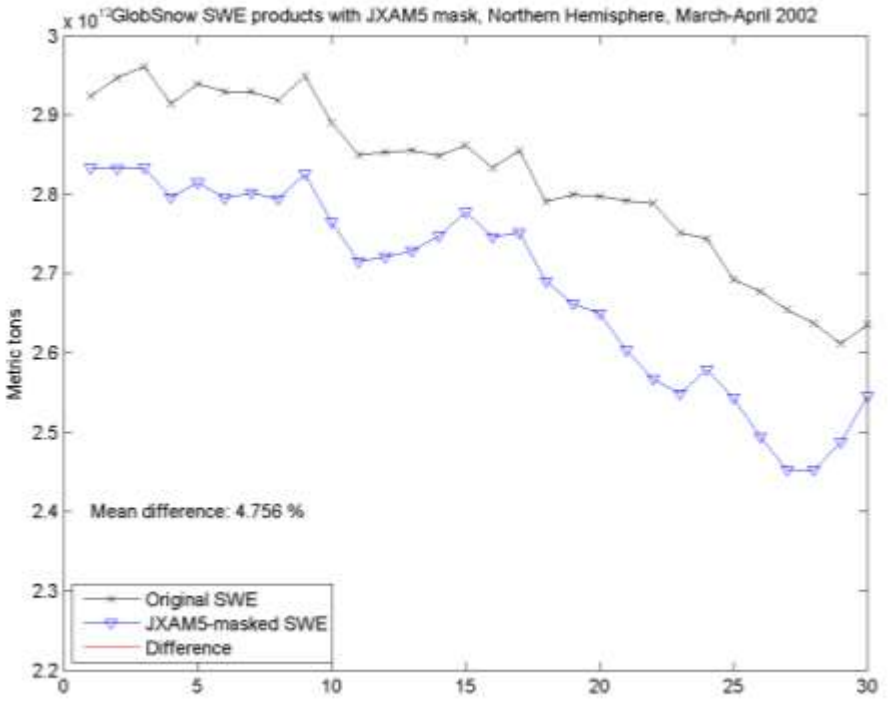
JXAM5 daily (25km) SE-masked GlobSnow SWE - March

- IMS+VIIRS-masked data shows significantly higher decrease in HN snow mass, than JXAM5 masked SWE data



IMS+VIIRS masked -> 8,0% decrease in mass

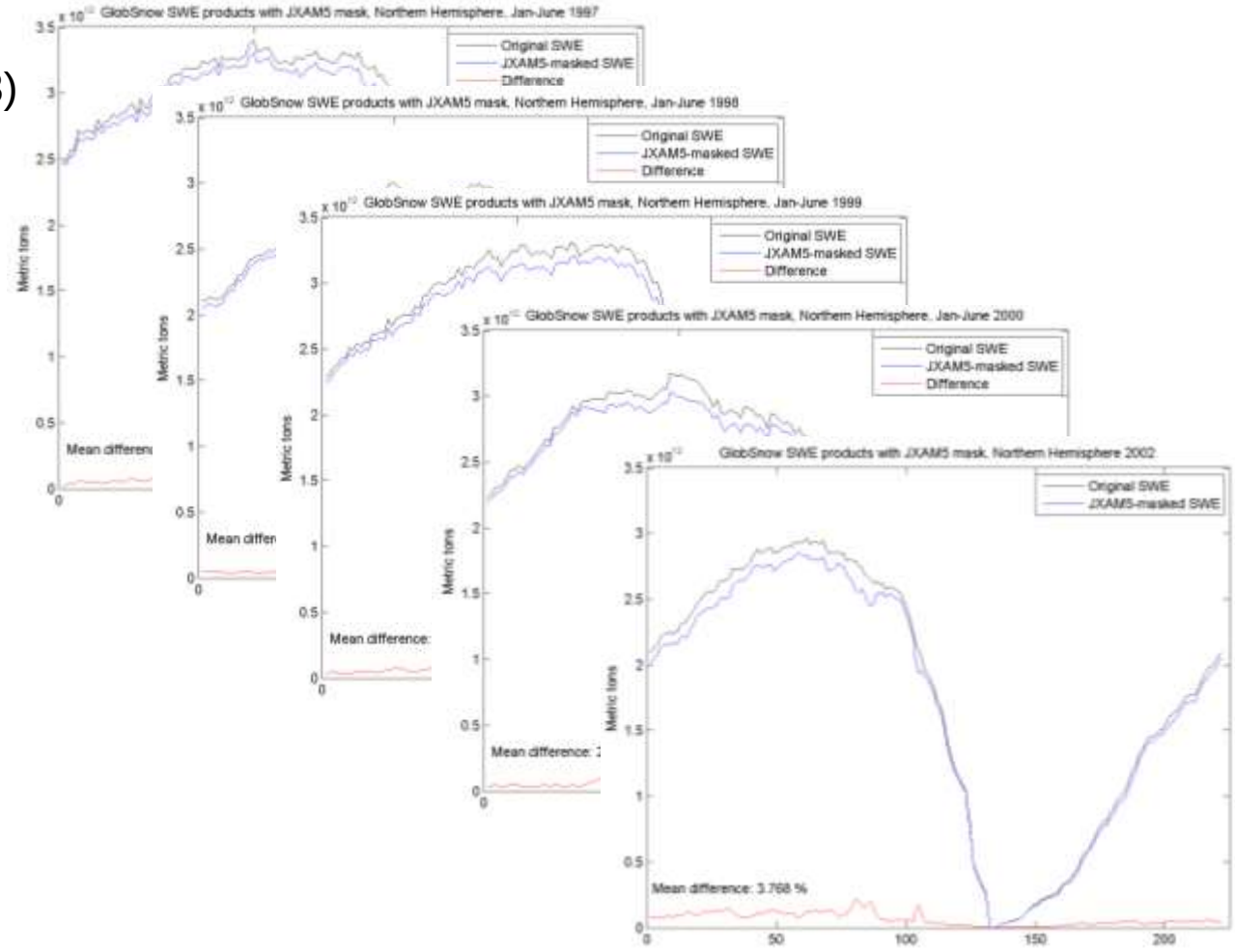


JXAM5 -> 4,8% decrease in mass (<u>at most</u>)

JXAM5 masked GlobSnow SWE – Average yearly (snow mass)

Average changes: (1997-2013)

- Jan.-March: -2.76%
- March: -2.92%
- Spring: -2.81%
- Autumn: -2.37%
- Whole year: -2.73%



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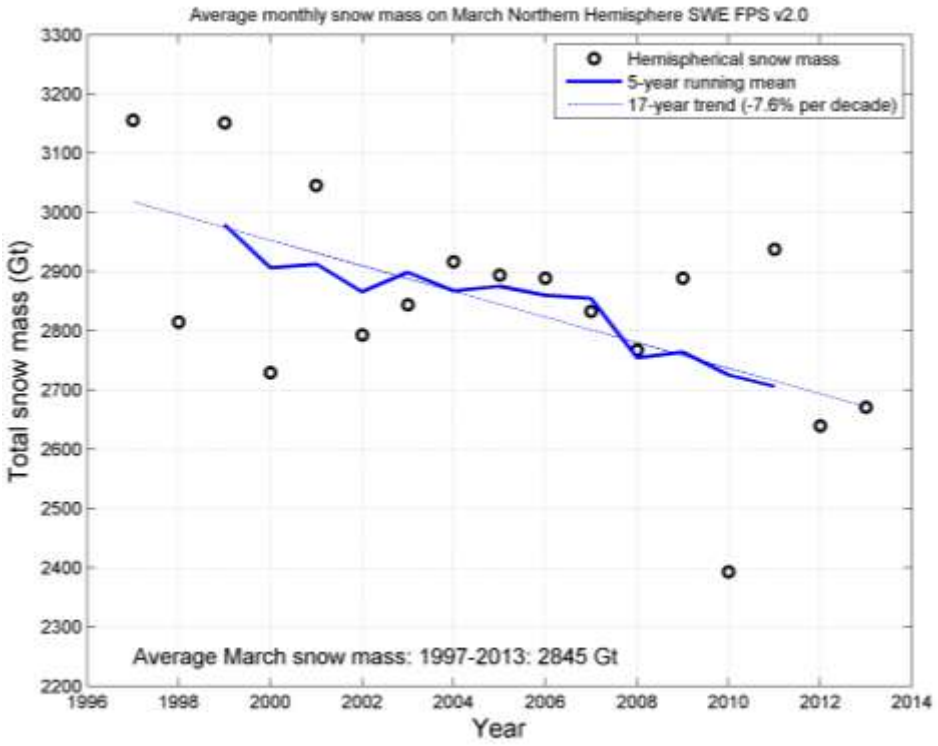
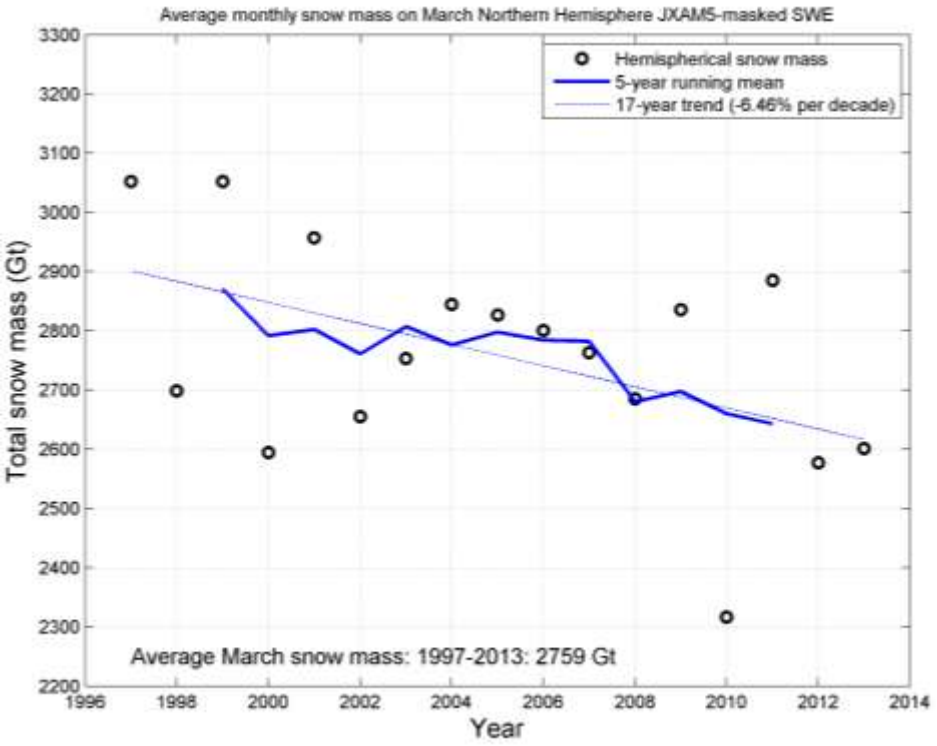
JXAM5 daily SE–masked GS SWE – Trends – March

(Jan, Feb, April -> trends about the same)



-7.6%



-6.5%

JXAM5-masked GlobSnow SWE
Slightly decreased trend

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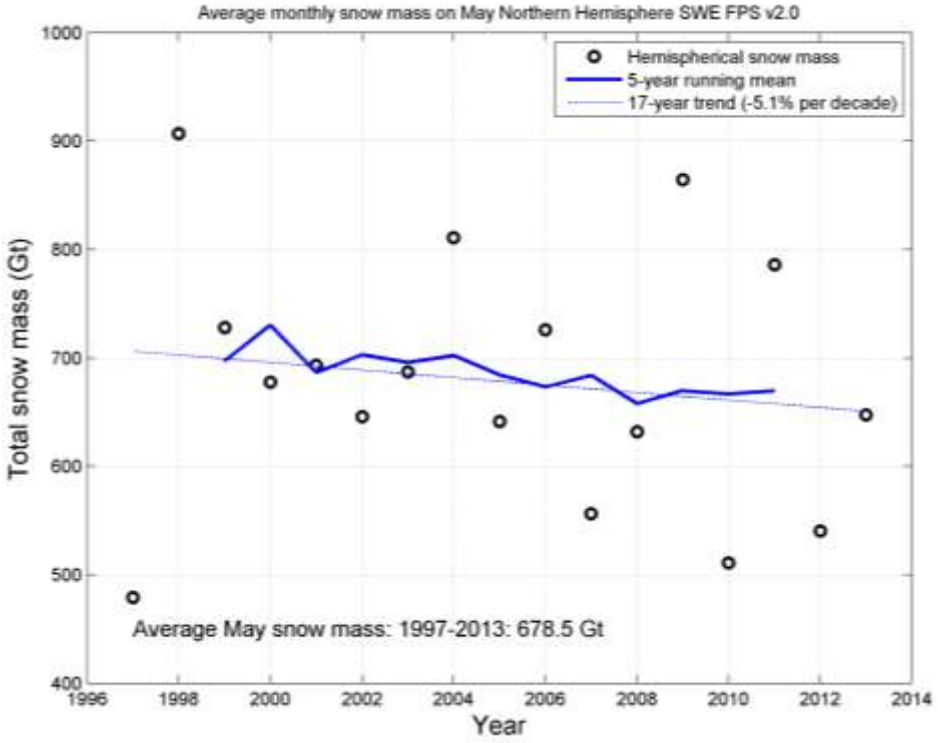
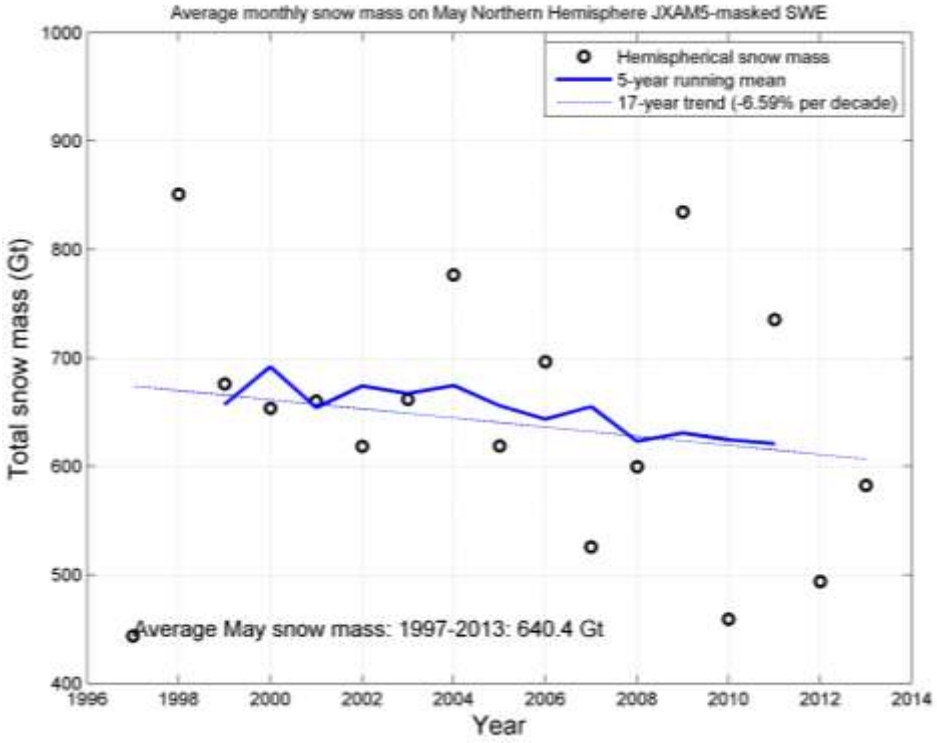
JXAM5 daily SE–masked GS SWE – Trends - May



-5.1%

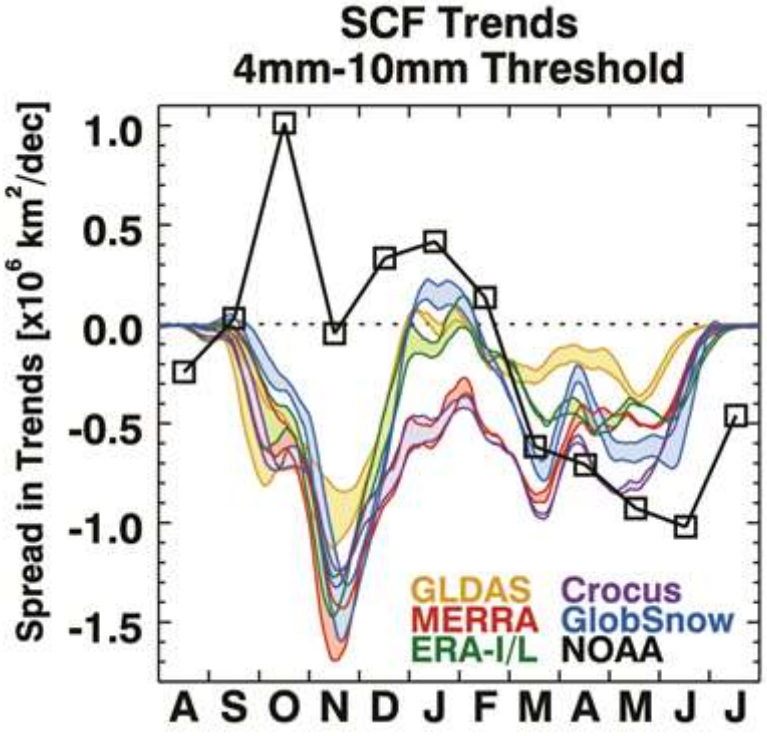


-6.6%

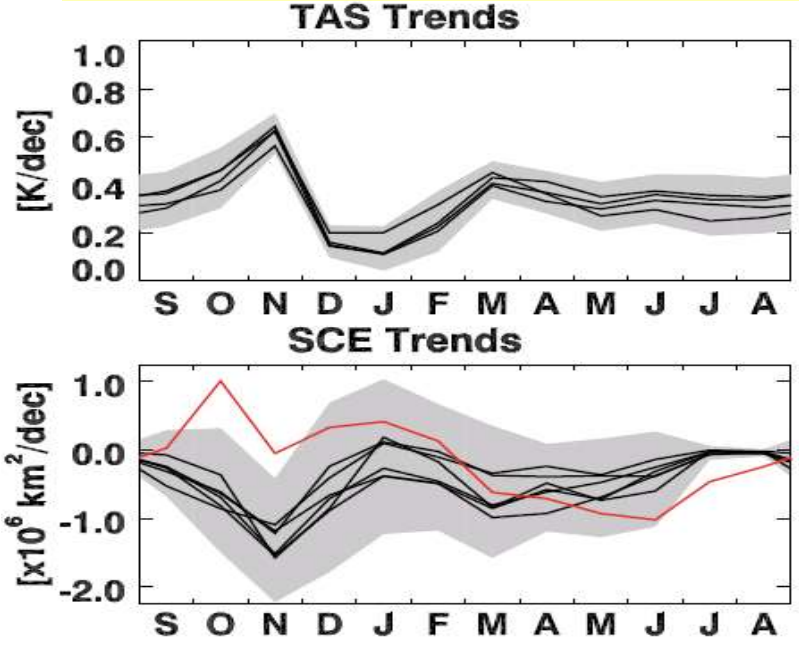
JXAM5-masked GlobSnow SWE
Slightly increased trend

Assessment of SE trends using SWE data (Remaining issues)

- Trend analysis:
  -Integration of SCE and SWE products: SE used to limit SWE (GlobSnow & JXAM5)
  -SWE products converted to SCE, 1981-2010; monthly spatial trend maps at 1x1 deg; temporal trend statistics.
  -Snow Extent trends from SWE data vs. NOAA_CDR long term trend!



Monthly NH surface temperature trends from CRU, NCDC, GISS and NCEP2m



NOAA-CDR is an outlier, esp. Oct/Nov

Monthly NH SCE trends from MERRA, ERA-I-Land, Crocus, GLDAS-2, Brown, GlobSnow, and NOAA-CDR