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Validation of satellite derived snow cover data records with surface networks and multi-dataset inter-comparisons

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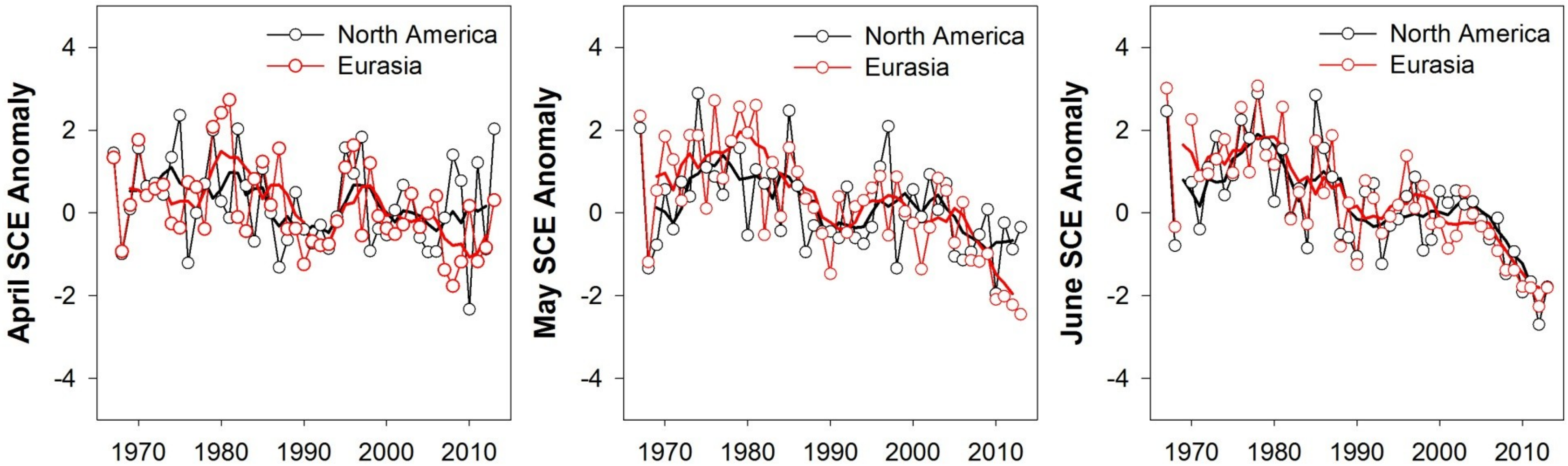
Thanks to our data providers:
Rutgers Global Snow Lab ● National Snow and Ice Data Center ● World Climate Research Programme Working Group on Coupled Modelling ● University of East Anglia – Climatic Research Unit ● NASA Global Modeling and Assimilation Office ● European Centre for Midrange Weather Forecasting

Outline

1. Challenges and approaches to validating snow datasets
   - -point in situ measurements
   - -gridded dataset inter-comparisons

3. Why quantifying spread in snow products matters

Snow – A Key Climate Variable



Snow cover extent (SCE) anomaly time series (with respect to 1988–2007) from the NOAA snow chart CDR. Solid line denotes 5-yr running mean.

- Over the 1979 – 2013 time period, NH June snow extent decreased at a rate of -19.9% per decade (relative to 1981-2010 mean).
- September sea ice extent decreased at-13.0% per decade.

 Derksen, C Brown, R (2012) Geophys. Res. Letters (updated)

Snow – An Important Hydrological Resource

NASA Earth Observatory

Hemispheric Snow Datasets

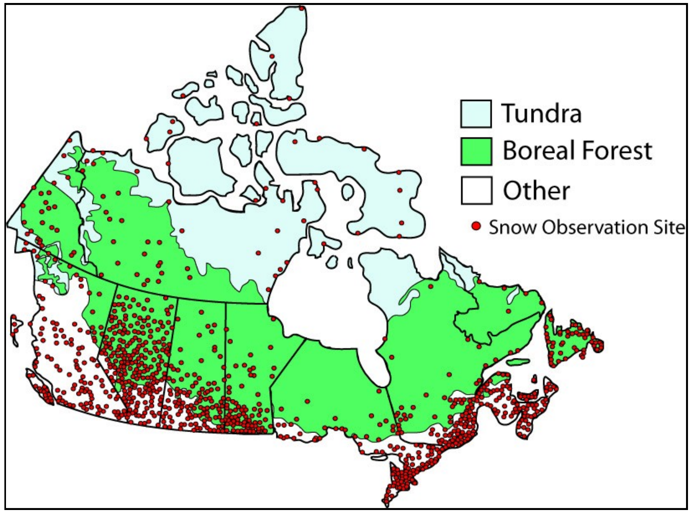
There are a lot of snow datasets out there…

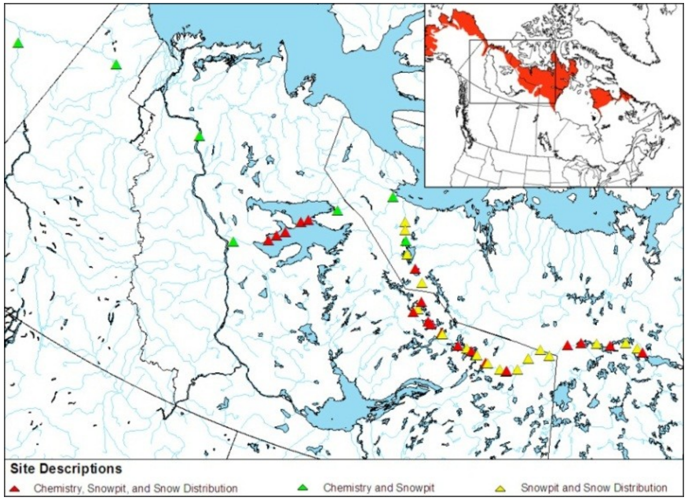
Description	Period	Resolution	Data Source
NOAA weekly ***snow/no-snow***	1966-2013	190.5 km	Rutgers University, Robinson et al [1993]
NOAA IMS daily 24 km ***snow/no-snow***	1997-2004	24 km	National Snow and Ice Data Center (NSIDC), Ramsay [1998]
NOAA IMS daily 4 km ***snow/no-snow***	2004-2013	4 km	NSIDC, Helfrich et al [2007]
AVHRR Pathfinder daily ***snow/no-snow***	1982-2004	5 km	Canada Centre for Remote Sensing, Zhao and Fernandes, [2009]
MODIS 0.05° ***snow cover fraction***	2000-2013	~5 km	NSIDC, Hall et al [2006]
ERA-40 reconstructed ***snow cover duration*** (temperature-index snow model)	1957-2002	~275 km (5 km elev. adjustment)	Environment Canada, Brown et al [2010]
QuikSCAT derived ***snow-off date***	2000-2010	~5 km	Environment Canada, Wang et al [2008]
Daily ***snow depth*** analysis (in situ obs + snow model forced by GEM forecast temp/precip fields)	1998-2013	~35 km	Canadian Meteorological Centre, Brasnett [1999]
Daily ***snow depth*** analysis (in situ obs + snow model forced by reanalysis temp/precip fields)	1979-1998	~35 km	Environment Canada, Brown et al [2003]
MERRA reanalysis ***snow water equivalent*** (CATCHMENT LSM)	1979-2013	0.5 x 0.67 deg	NASA, Rienecker et al [2011]
ERA-interim reanalysis ***snow water equivalent*** (HTESSEL LSM)	1979-2010	~80 km	ECMWF, Balsamo et al [2013]
GLDAS reanalysis ***snow water equivalent*** (Noah LSM)	1948-2000 1948-2010	1.0 x 1.0 deg 0.25 x 0.25 deg	NASA, Rodell et al [2004]
SnowModel driven by MERRA atmospheric reanalysis ***snow water equivalent***	1979-2009	10 km	Colorado State, Liston and Hiemstra [2011]
GlobSnow ***snow water equivalent*** (satellite passive microwave + climate station obs)	1978-2013	25 km	Finnish Meteorological Institute, Takala et al [2011]

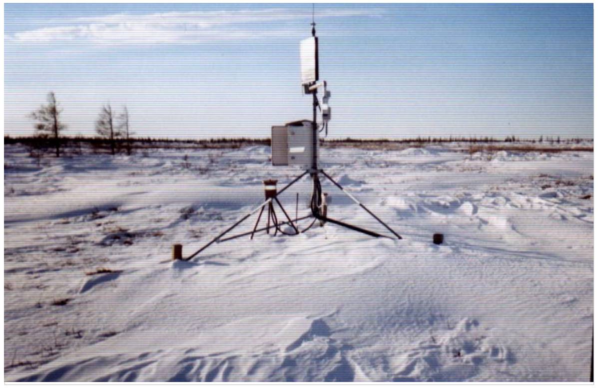
Challenges and Approaches to Validating Snow Datasets

Approaches to Validating Snow Products

Approach	Strengths	Weaknesses
1. Assessments with point observations (climate stations)	-Time series	-Sparse networks -Point vs. area comparison -Measurement and reporting deficiencies
2. Targeted field campaigns	-Measurements where/when needed	-Cost -'Snapshot datasets'
3. Multi-dataset comparisons	-Statistical characterization of uncertainty	-Definition of the authoritative baseline for assessment
4. High resolution EO for snow extent	-sub-pixel information	-Temporally and spatially limited

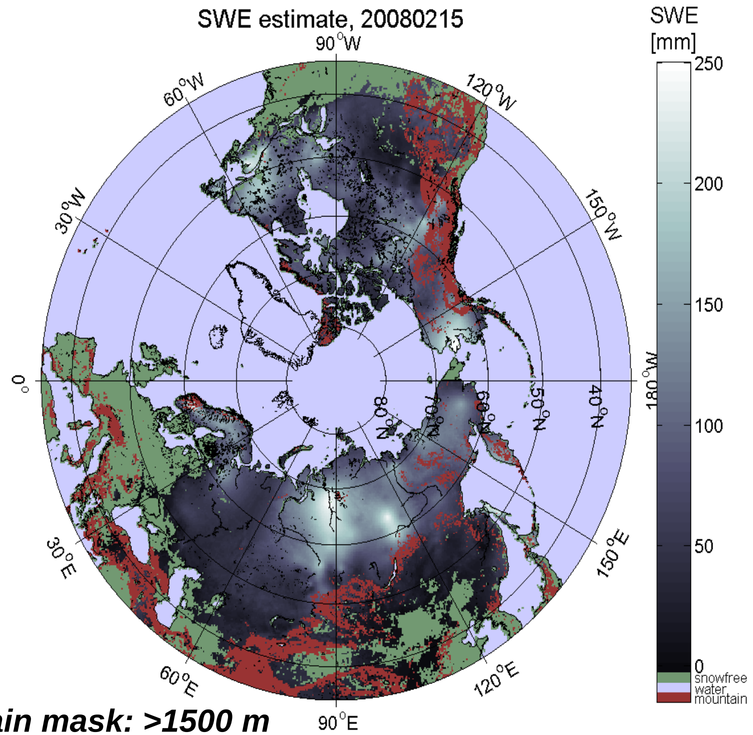


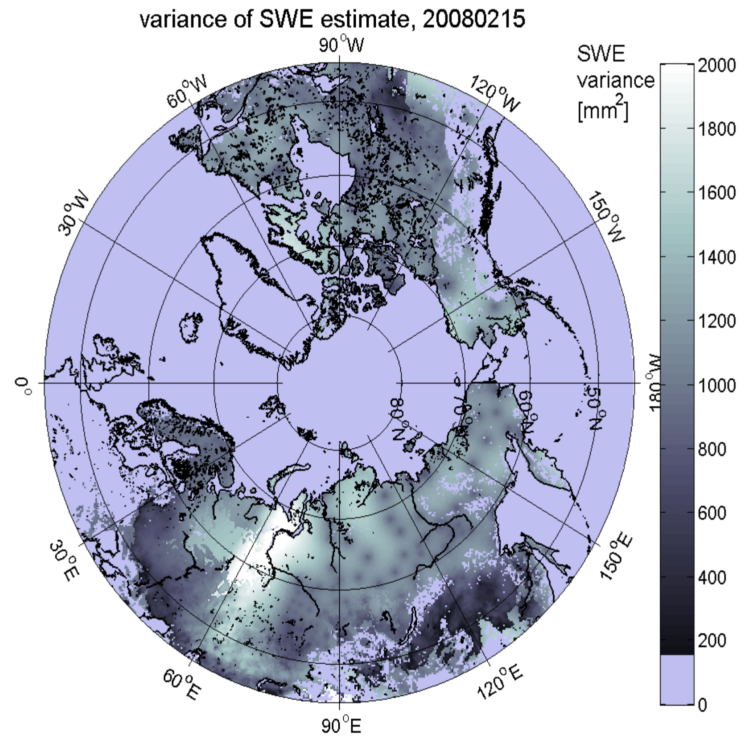




GlobSnow SWE Algorithm

Based on Pulliainen (2006) the method combines climate station snow depth observations with SWE estimates derived from satellite passive microwave measurements and microwave snow emission modelling within an assimilation framework.





Mountain mask: >1500 m

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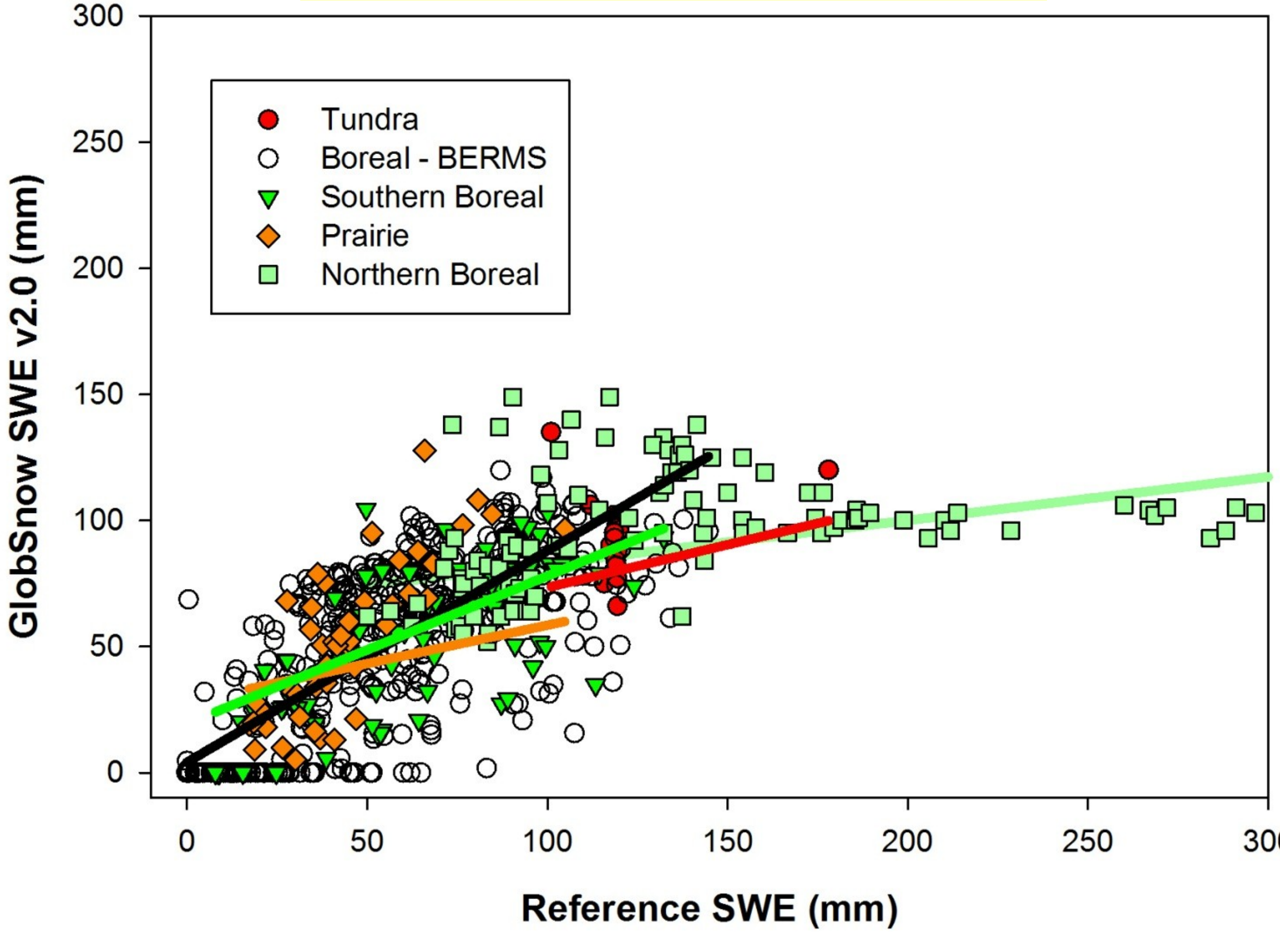
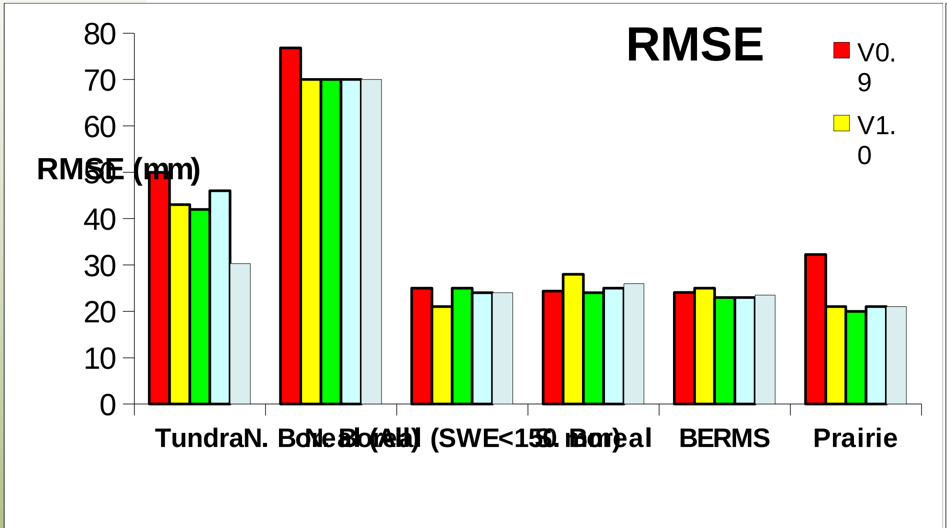
1. Assessment with Point Observations:
GlobSnow SWE v2.0 versus Canadian Reference Data

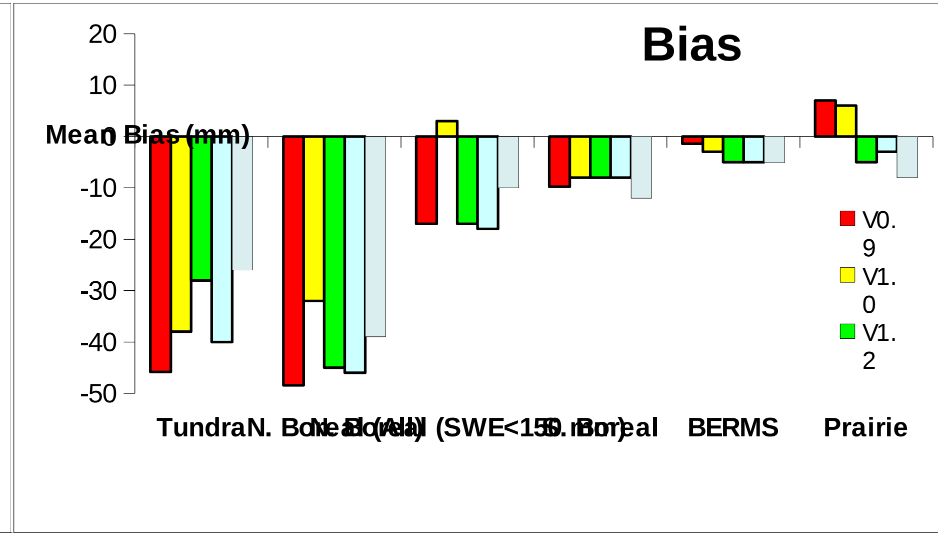
150 mm is the critical threshold…

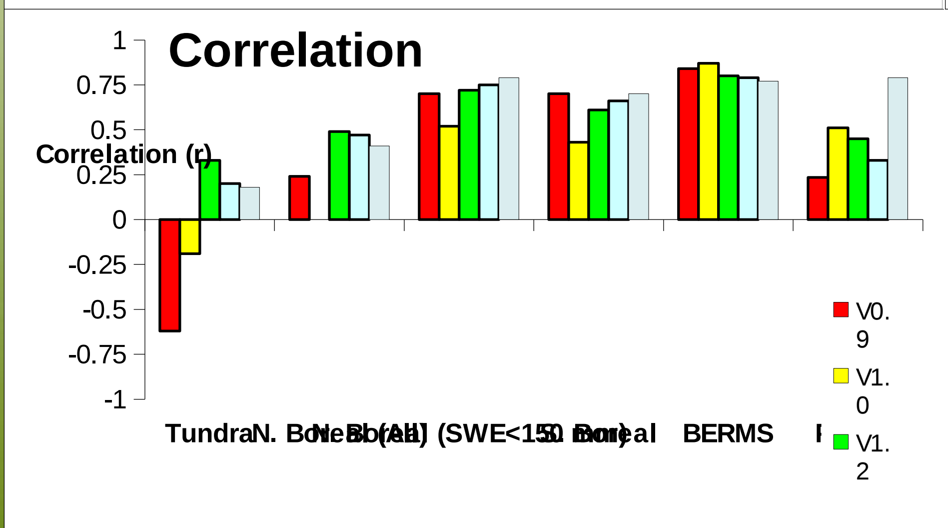


1. Assessment with Point Observations:

Development Sequence of GlobSnow SWE versus Canadian Reference Data





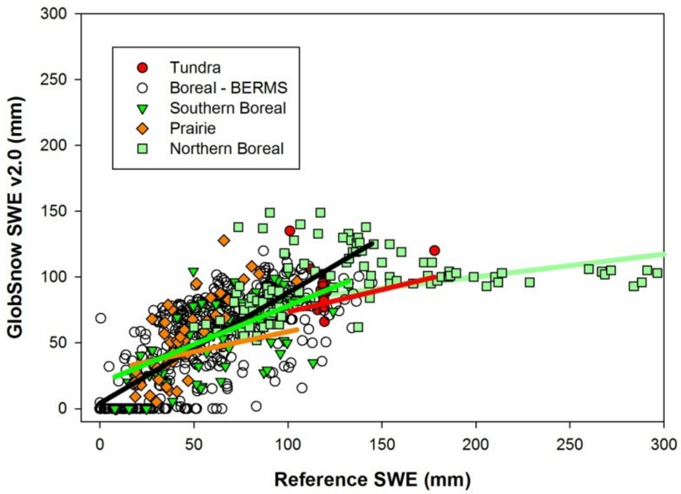


Change Relative to FPS1.3	RMSE	Bias	Correlation
Tundra	-16	-14	-0.02
N. Boreal SWE<150 mm	0	-8	0.04
S. Boreal	1	4	0.04
BERMS	1	0	-0.02
Prairie	0	5	0.46

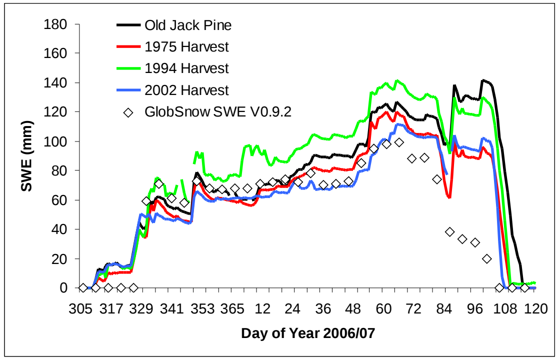
Notable improvement relative to v1.3 at tundra and prairie sites.

Challenges to Validating Gridded Snow Products with Ground Measurements

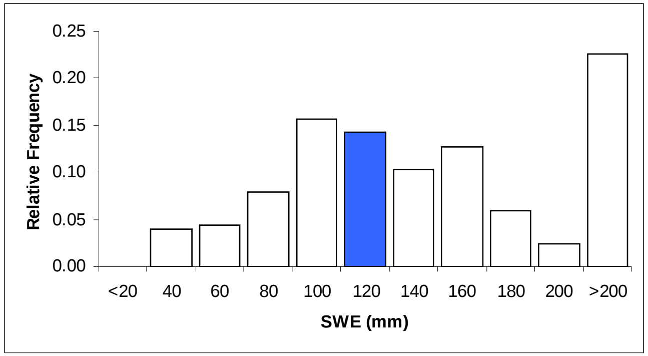
This is what product users want to see:



This is the reality:



Time series for the former BERMS sites



Spatial sampling across one grid cell

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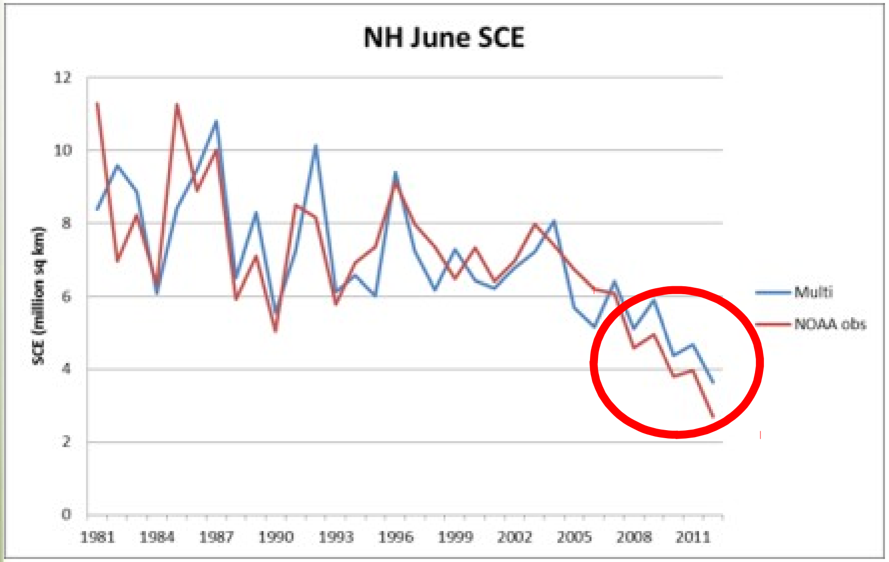
2. Targeted field campaigns for product validation

	Boreal to Boreal	Tundra to Tundra	Boreal to Tundra
Mean distance between sites (km)	20.3	17.5	24.6
n	63	22	9
Δ Density (%)	2.6	1.4	46.0
Δ Depth (%)	-2.6	-18.2	-57.0
Δ SWE (%)	0.1	14.1	-34.7

% change in bulk snow properties at the scale of adjacent PMW grid cells using long transect snow surveys

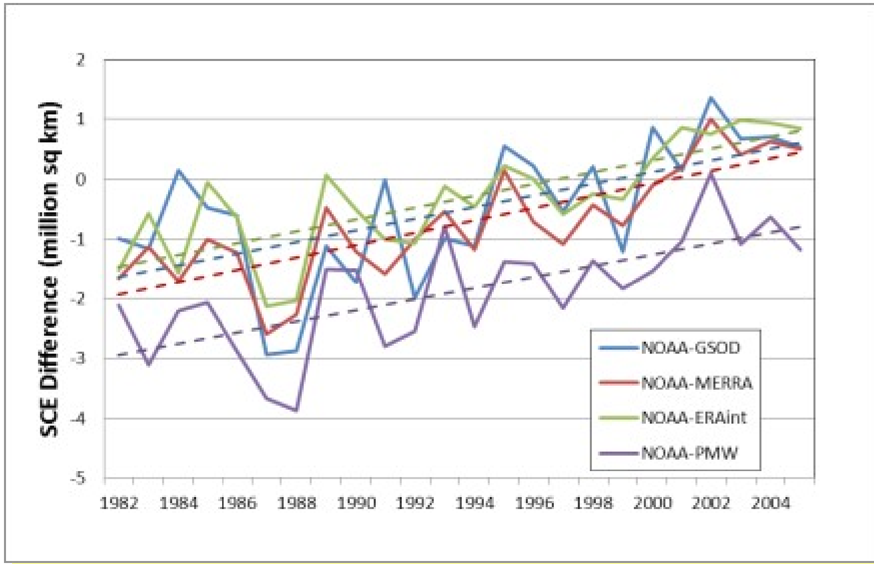
- Changes in tundra snow depth are higher over the tundra compared to the boreal forest partly due to high tundra snow depth variability due to wind redistribution
- Depth decreases by >50% across the transition from forest to tundra

3. Multi-dataset comparisons



NH June SCE time series, 1981-2012 NOAA snow chart CDR (red); average of NOAA, MERRA, ERAint (blue)

- Tendency for NOAA to consistently map less spring snow (~0.5 to 1 million km2) than the multi-dataset average ***since 2007***.
- Accounting for this difference reduces the June NH SCE trend from -1.27 km2 x 106 to -1.12 km2 x 106



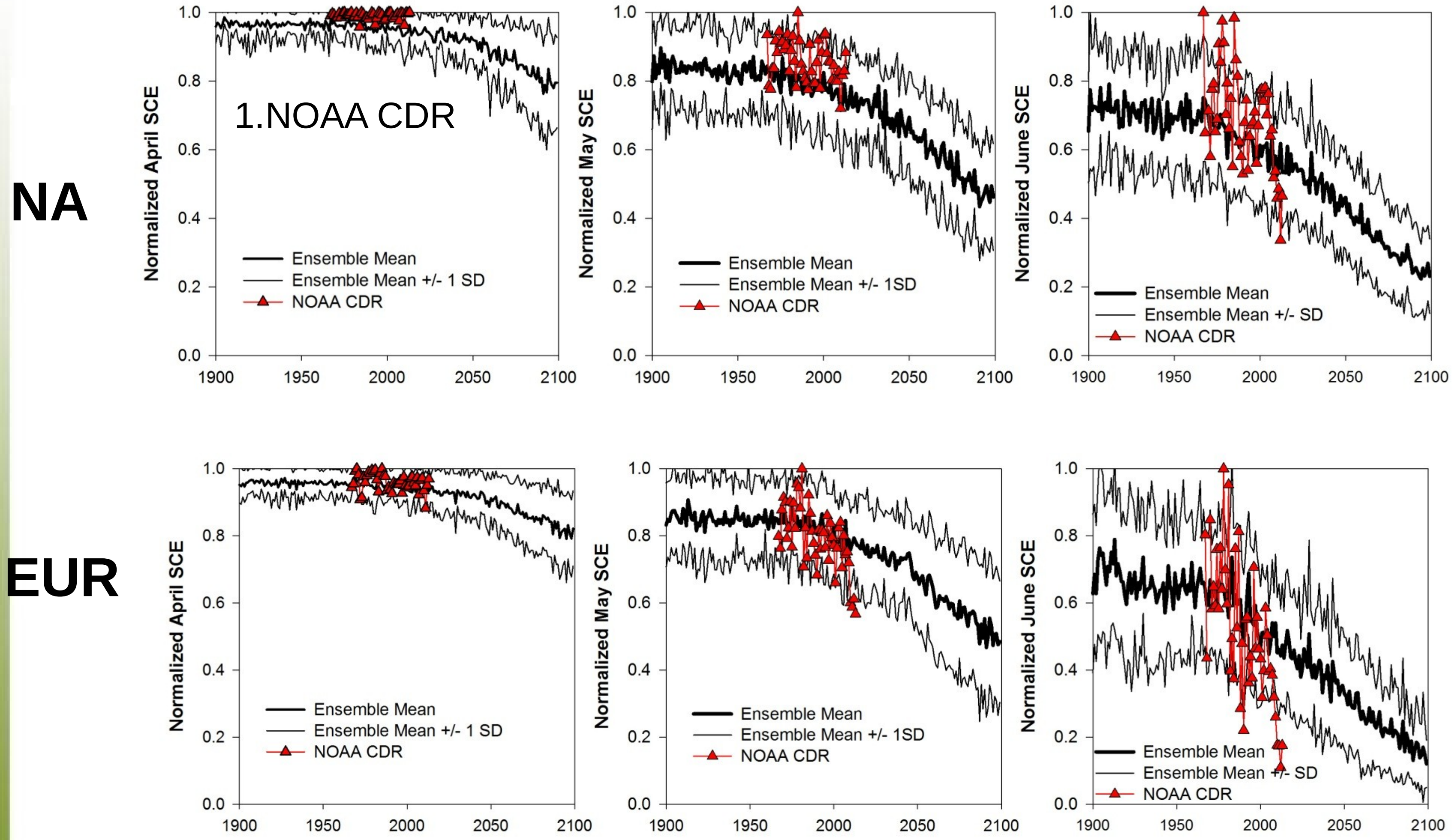
EUR Oct SCE: difference between NOAA snow chart CDR and 4 independent datasets, 1982-2005

- Evidence of an artificial trend (~+1.0 million km2 per decade) in October snow cover.

Brown, R Derksen, C (2013) Env. Res. Letters

Why quantifying spread in snow products matters…

Simulated vs. Observed Snow Cover Extent



Historical + projected (16 CMIP5 models; rcp85 scenario) and observed (NOAA snow chart CDR) snow cover extent for April, May and June.
SCE normalized by the maximum area simulated by each model.

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Updated from Derksen, C Brown, R (2012) Geophys. Res. Letters

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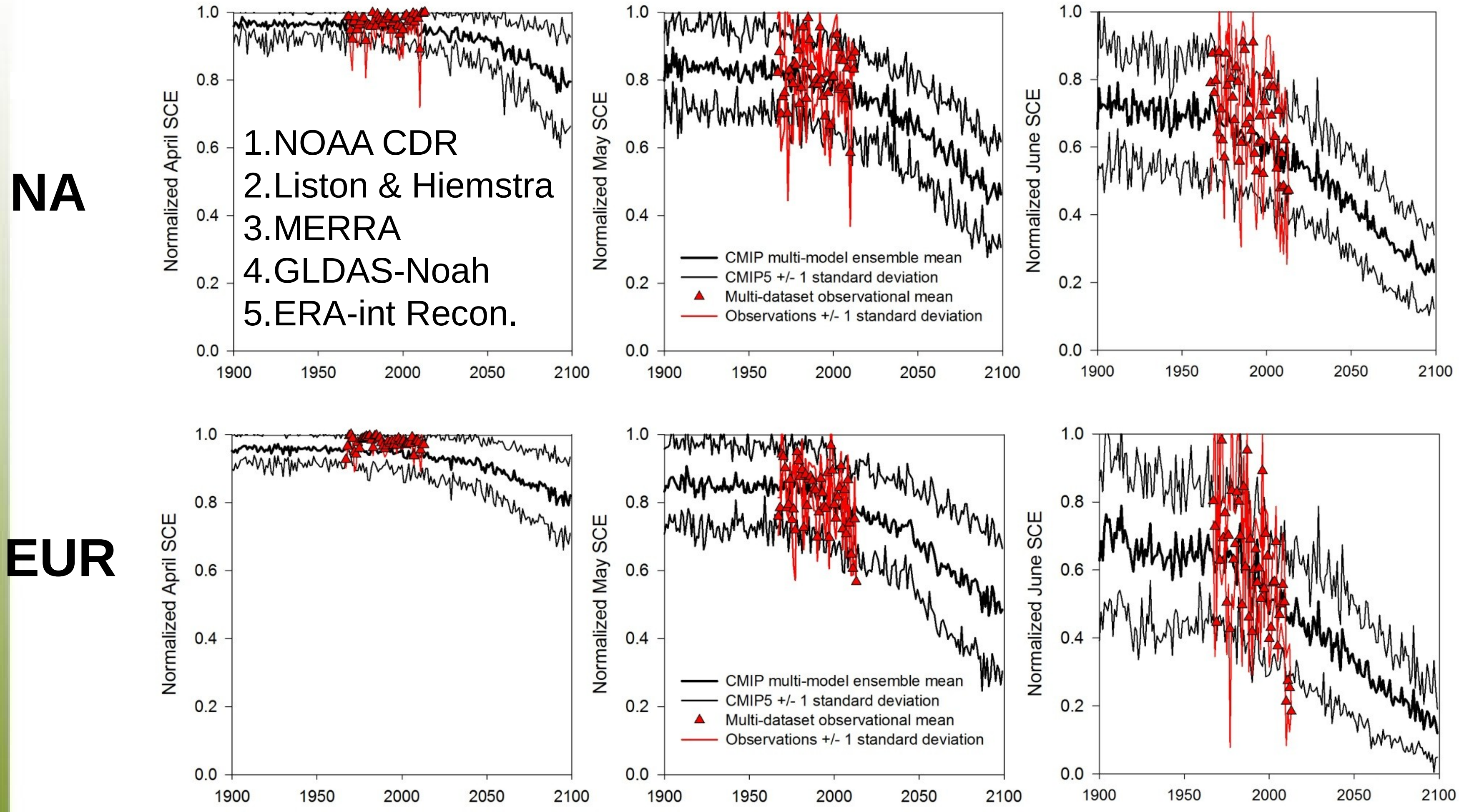
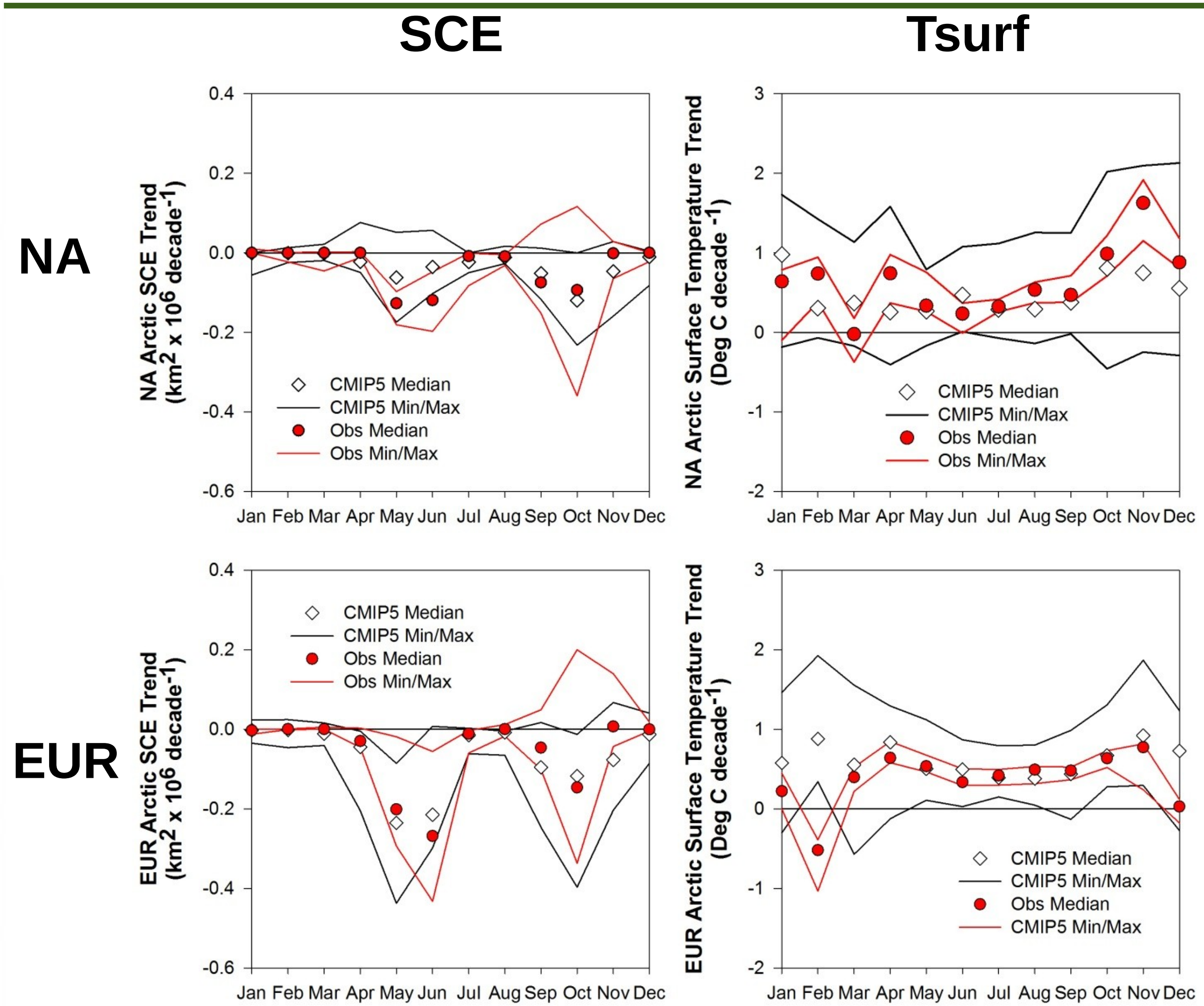
Simulated vs. Observed Snow Cover Extent



Historical + projected (16 CMIP5 models; rcp85 scenario) and multi-observational snow cover extent for April, May and June.
SCE normalized by the maximum area simulated by each model.

Arctic Snow Cover Extent and Surface Temperature Trends: 1980-2009



1. CRU 2. GISS
3. MERRA 4. ERA-int

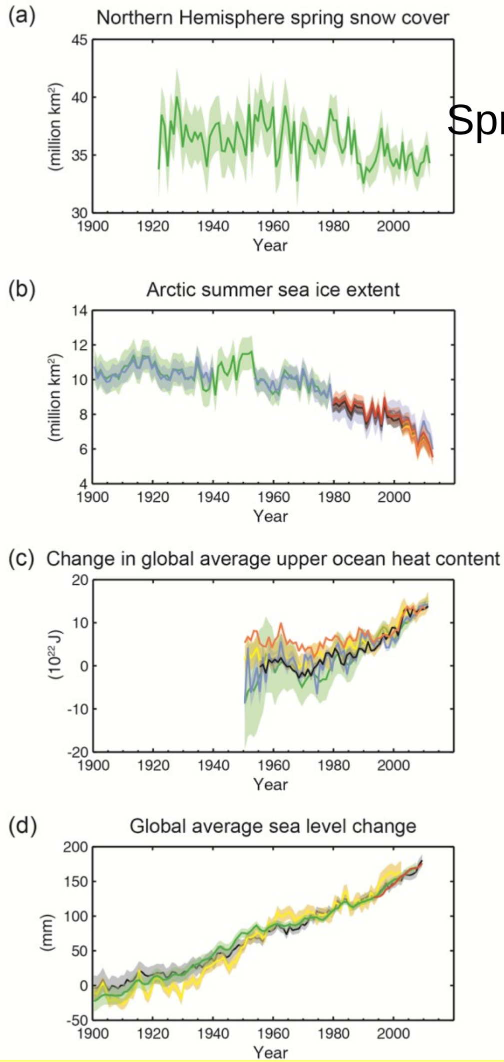
- Simulations slightly underestimate observed spring SCA reductions
- Similar range in observed versus simulated SCA trends
- Observed Arctic temperature trends are captured by the CMIP5 ensemble range

Conclusions

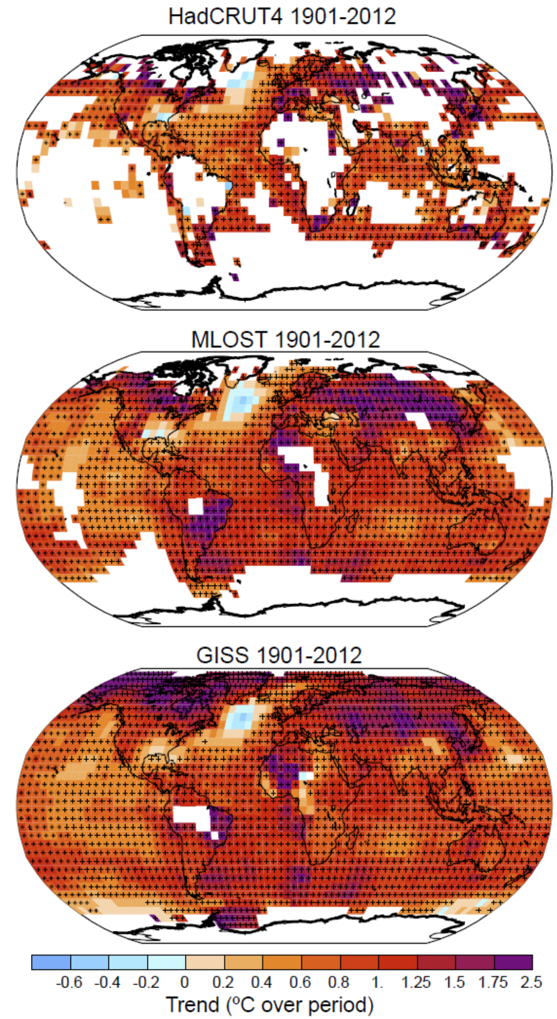
- Observations show rapid reductions in spring snow cover extent over the past decade – it is important to robustly characterize these t rends with validated observations.
- Point climate station observations play an important role in SWE product validatio n, but are hampered by the disconnect between the heterogeneity in snow distribu tion versus the spatial resolution of current products.
- The spread between 5 'observational' SWE datasets (mean; variability) is approxi mately the same as across 16 CMIP5 models.
- Quantifying observational uncertainty in gridded snow products is important for mo deling applications at all time scales:
  - -Land surface data assimilation for NWP
  - -Land surface initialization for monthly/seasonal forecasting
  - -Multi-decadal climate projections
- High spatial resolution snow water equivalent with sensitivity to deep snow requir es a new EO measurement concept (LiDAR; Radar)

Questions?

Climate Change and the Cryosphere



Spring snow cover



Observational time series
IPCC AR5 Summary for Policy Makers Figure 3

Trends in surface temperature 1901–2012
IPCC AR5 WG1 Chapter 2 Figure 2.21

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