Consistency and Uncertainty Among Gridded SWE Products

Comparison with 3 Satellite Based Products:
obSnow, NASA AMSR-E Standard, NASA AMSR-E Prototy

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SnowPEX Workshop 2
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Motivation

- Provide a SWE product for climate monitoring/estimatio of SWE trends: hemispheric, continental, elevational

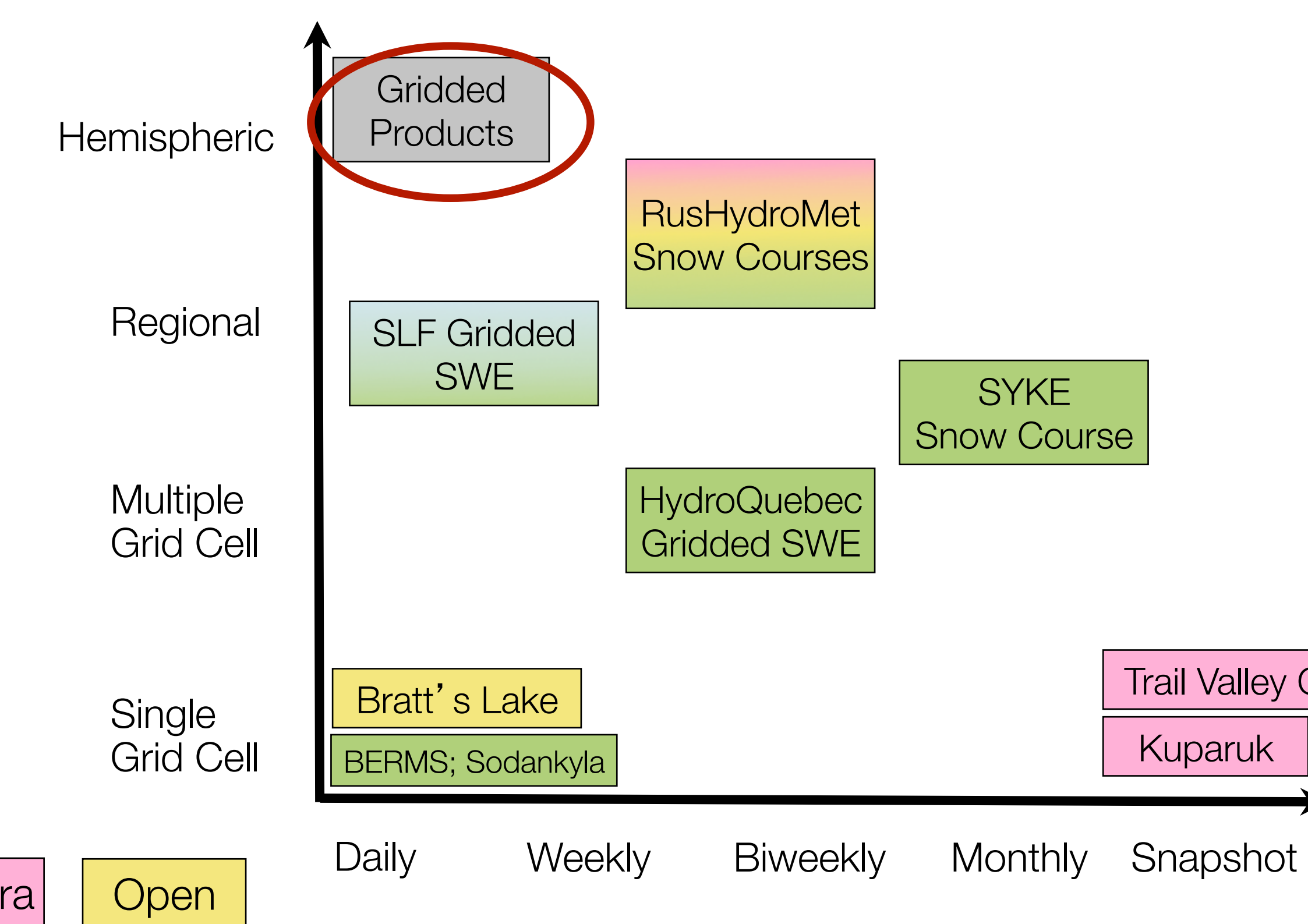
- Provide a product for climate model evaluatio climatology, variability

Outline

1. Comparison of Gridded SWE Products (daily, hemispheric)
    - Climatologies
    - Anomalies

Initial goal was not to evaluate accuracy of gridded data, or
consistency and obtain a sense of spread/uncertainty.

2. How do the satellite products compare?


Hemispheric
Regional
Multiple Grid Cell
Single Grid Cell
Gridded Products
RusHydroMet Snow Courses
SLF Gridded SWE
SYKE Snow Course
HydroQuebec Gridded SWE
Bratt's Lake
BERMS; Sodankyla
Trail Valley C
Kuparuk
Daily
Weekly
Biweekly
Monthly
Snapshot
ra
Open

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

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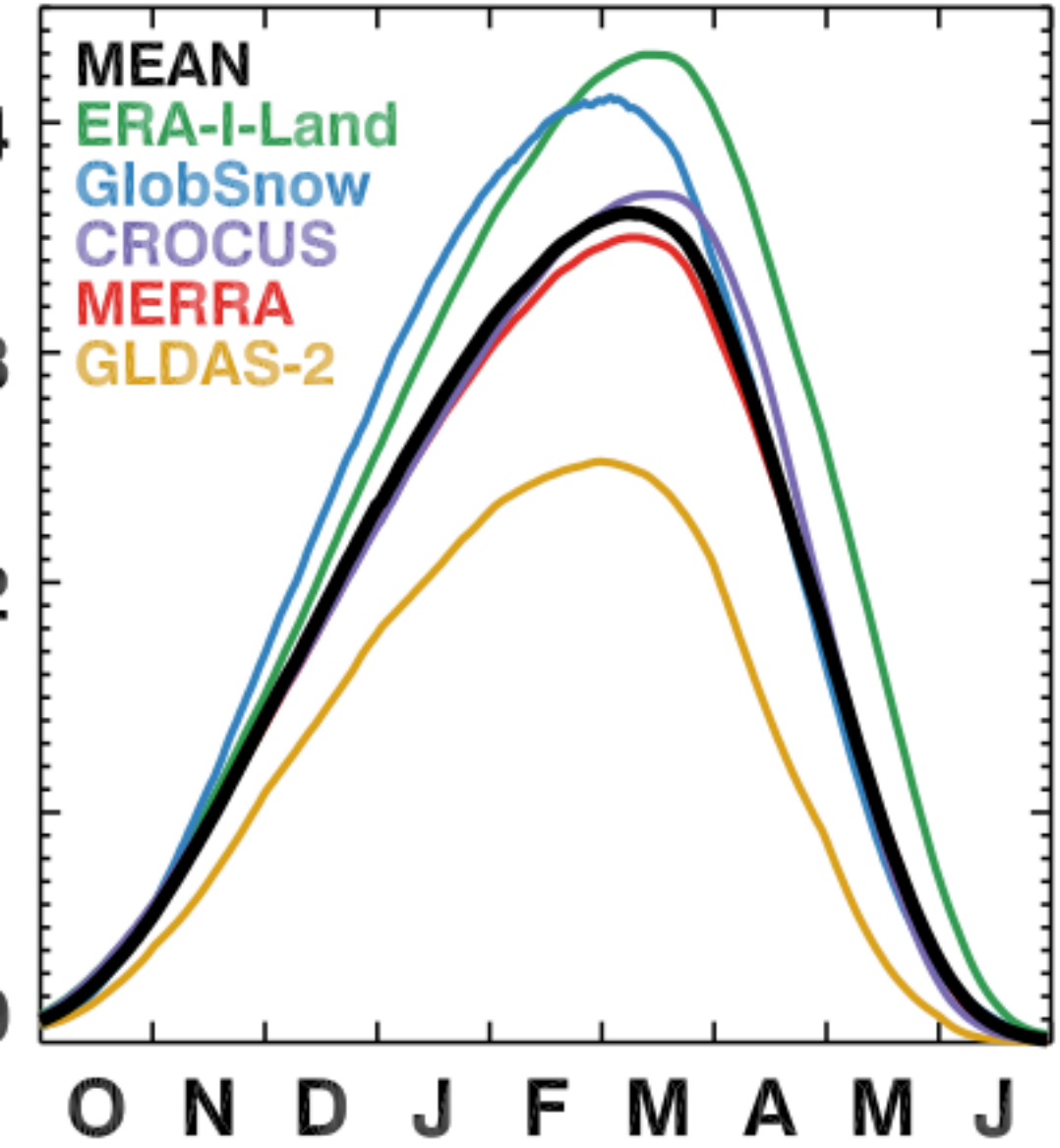
nsistency and obtain a sense of spread/uncertainty

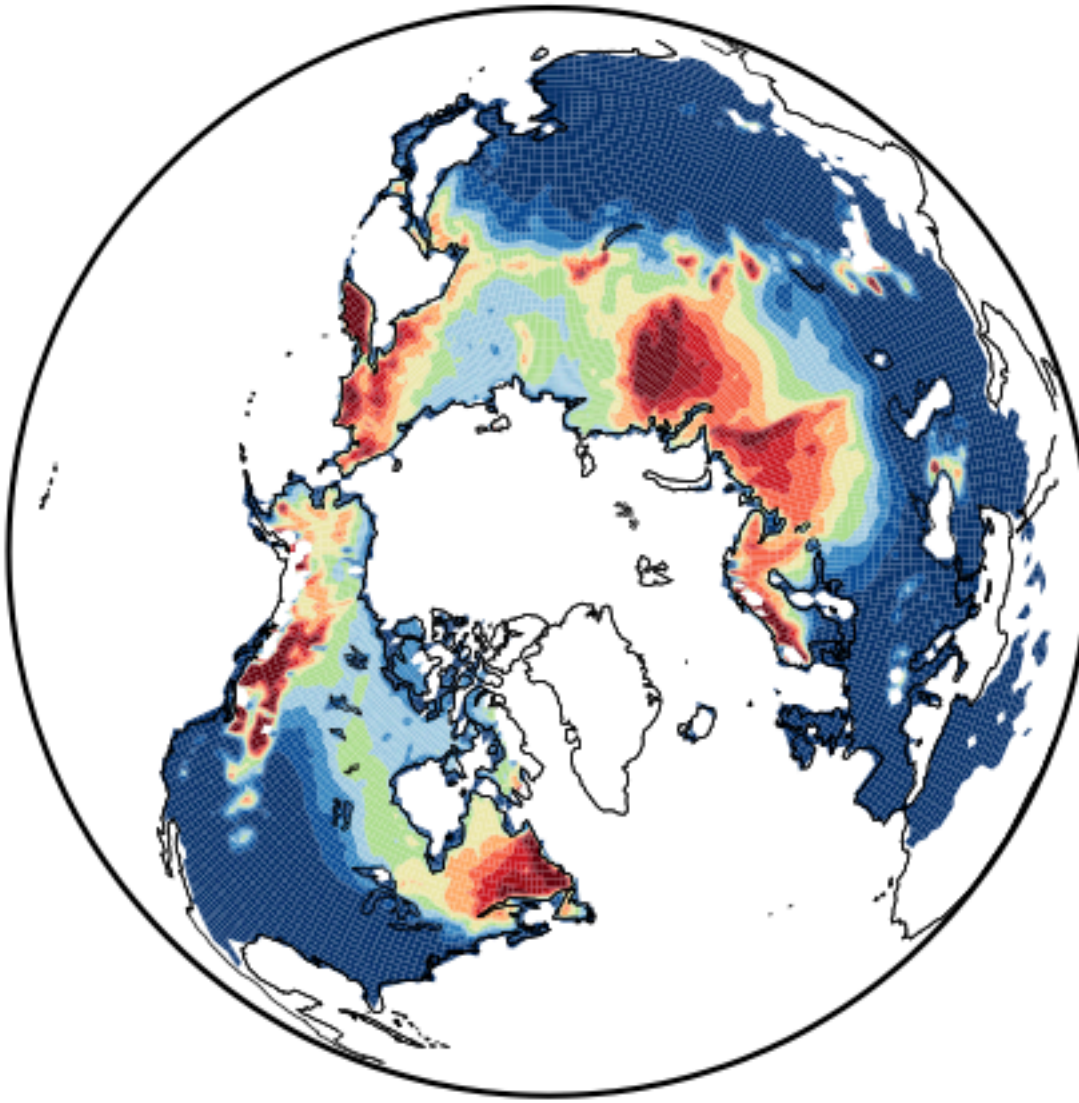
ataset	Forcing Data	Land Model	Snow Model	Resolution	Reference
RRA	MERRA	Catchment	Intermediate	⅔° x ½°	NASA Rienecker et al,
-I Land	ERA-Interim (GPCPv2.1 adj)	HTESSEL	Simple	¾° x ¾°	ECMWF Balsamo et al, 2
DAS-2	Princeton Met. Dataset	Noah	Simple	1° x 1°	NASA Rodell et al, 20
OCUS	ERA-Interim	ISBA	Complex	1° x 1°	Meteo-Franc Brun et al, 20
	satellite passive microwave				Finnish Met Inst

Comparison of Climatological SWE/SW

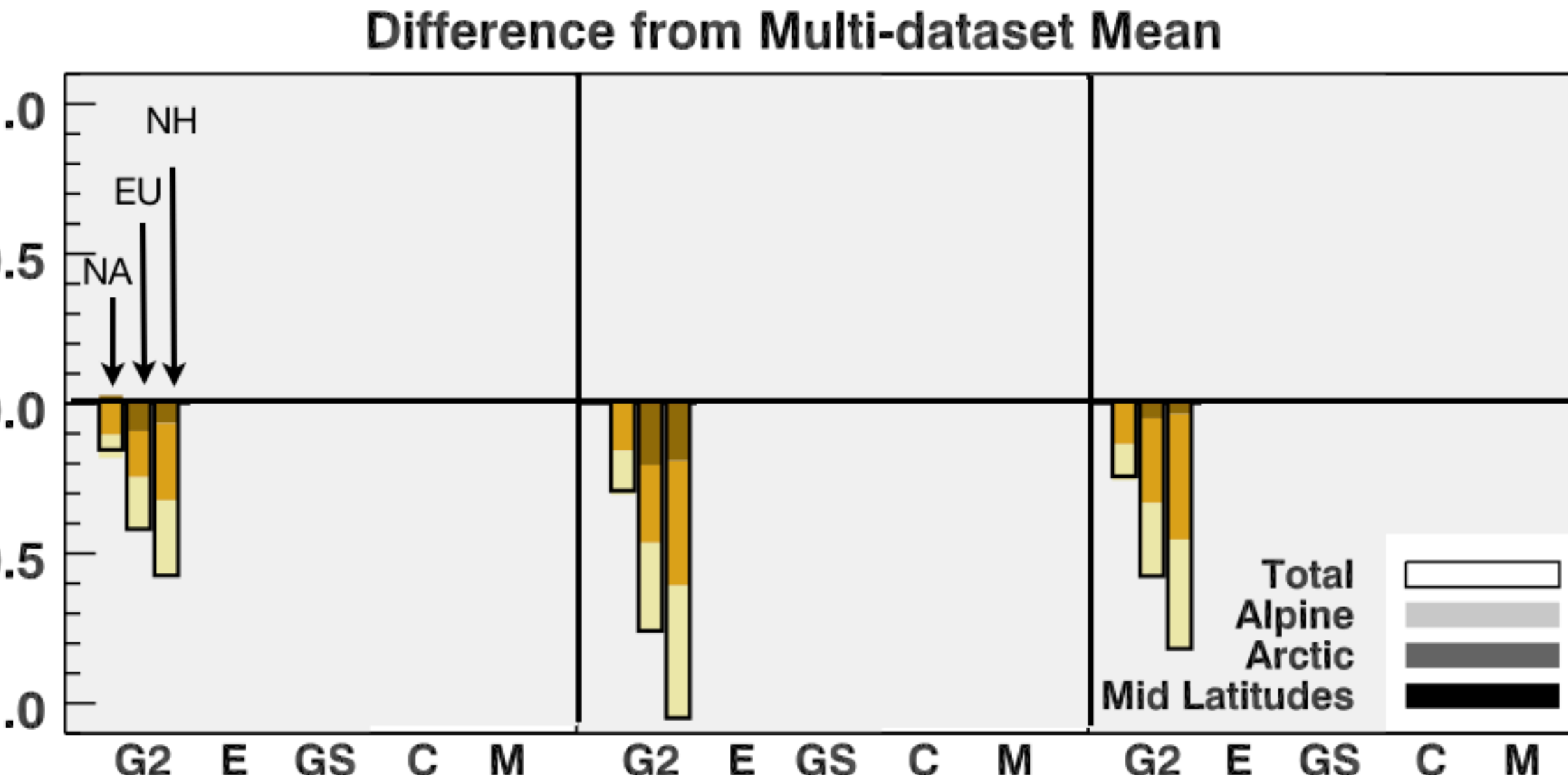
NH Snow Mass



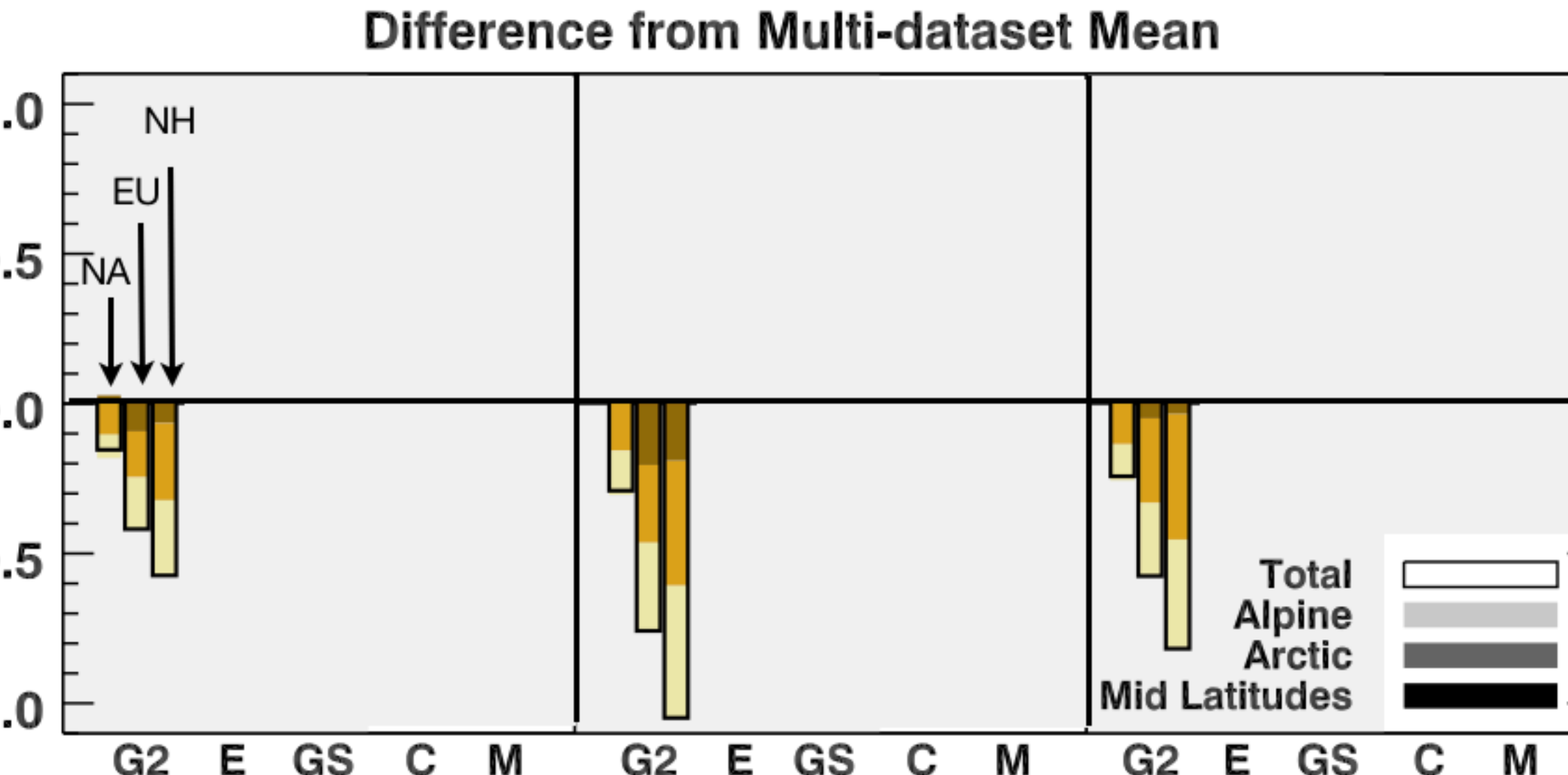
Multi-Dataset Mean SWE



matological SWE by Land Type + Continer



and alpine

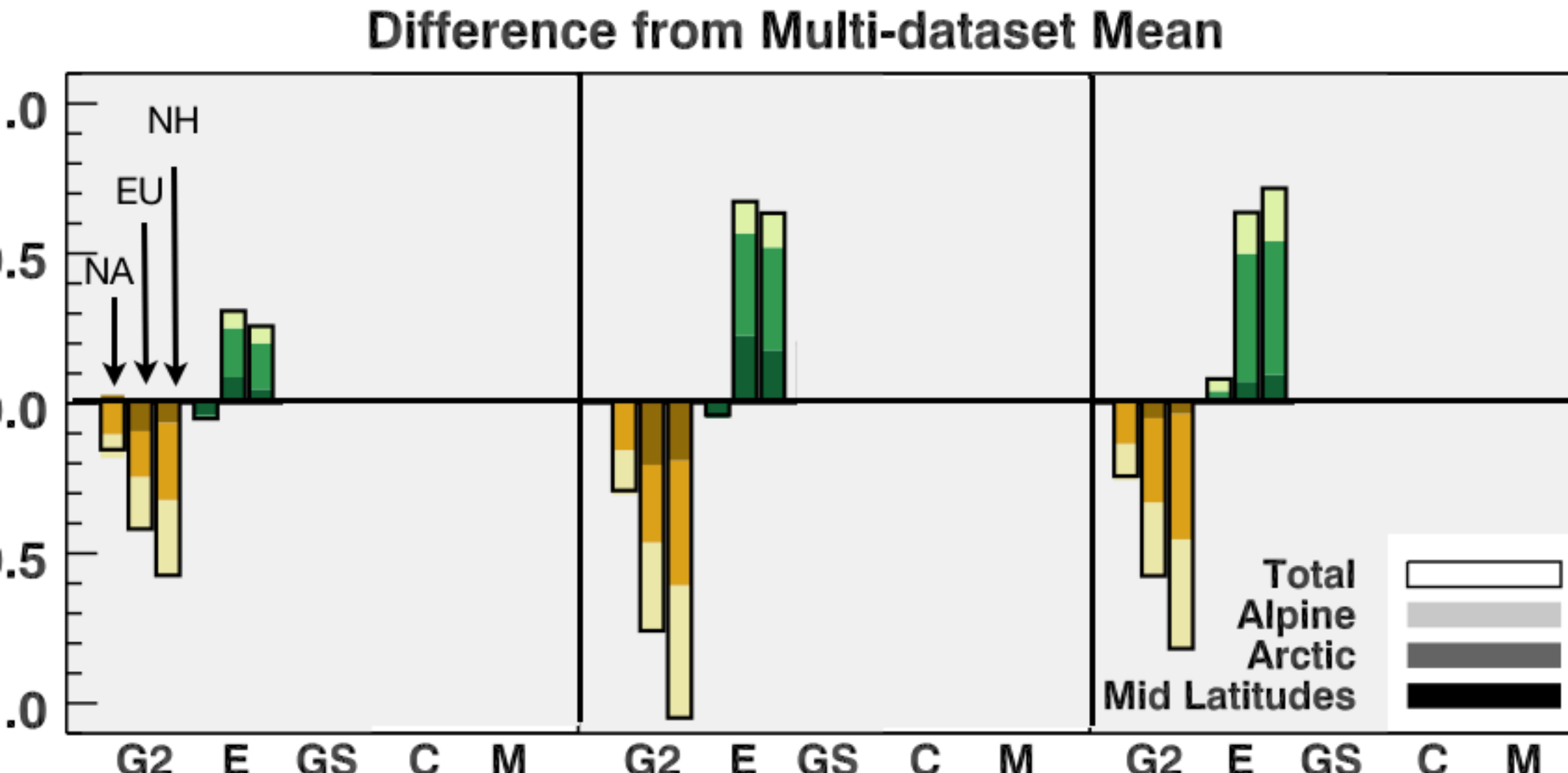

Difference from Multi-dataset Mean
.0
.5
.0
.5
.0
NH
EU
NA
Total
Alpine
Arctic
Mid Latitudes
G2
E
GS
C
M
G2
E
GS
C
M
G2
E
GS
C
M

DAS-2

A-I-Land

and alpine

- more SWM than mean product over Eurasia but not NA



DAS-2

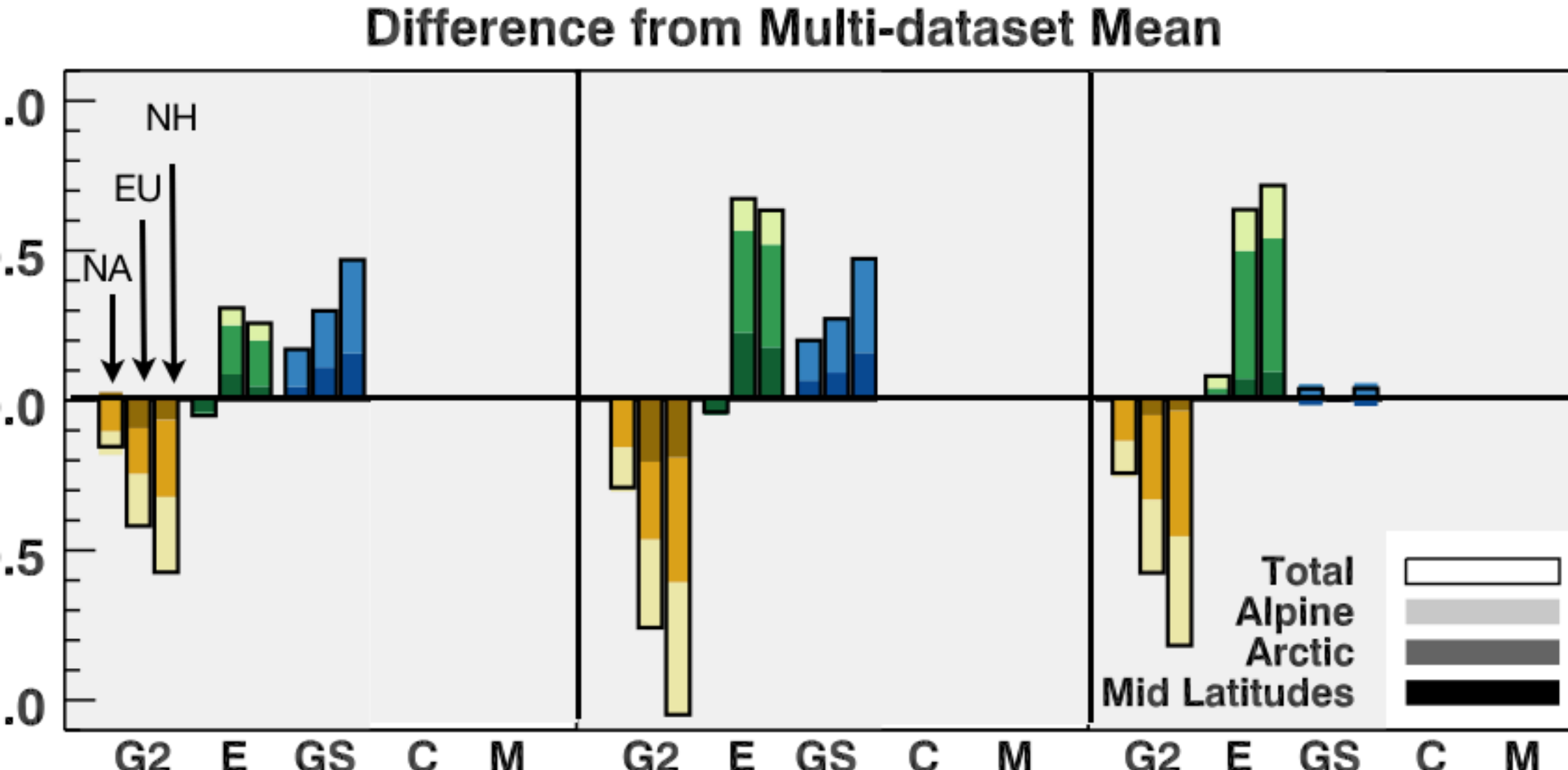
and alpine

A-I-Land

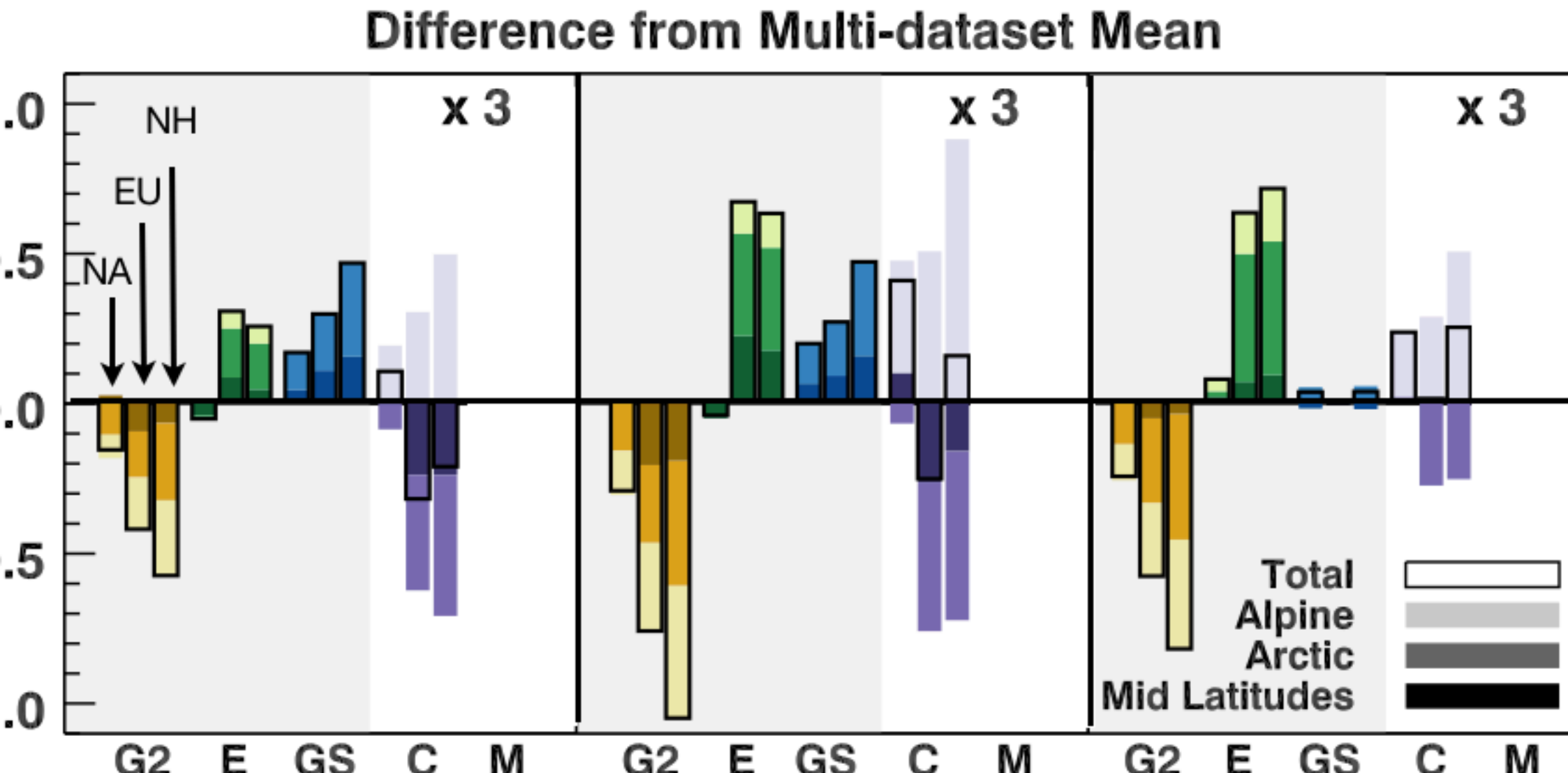
- more SWM than mean product over Eurasia but not NA

obSnow

- earlier peak SWM than other products, but reduced by Ap



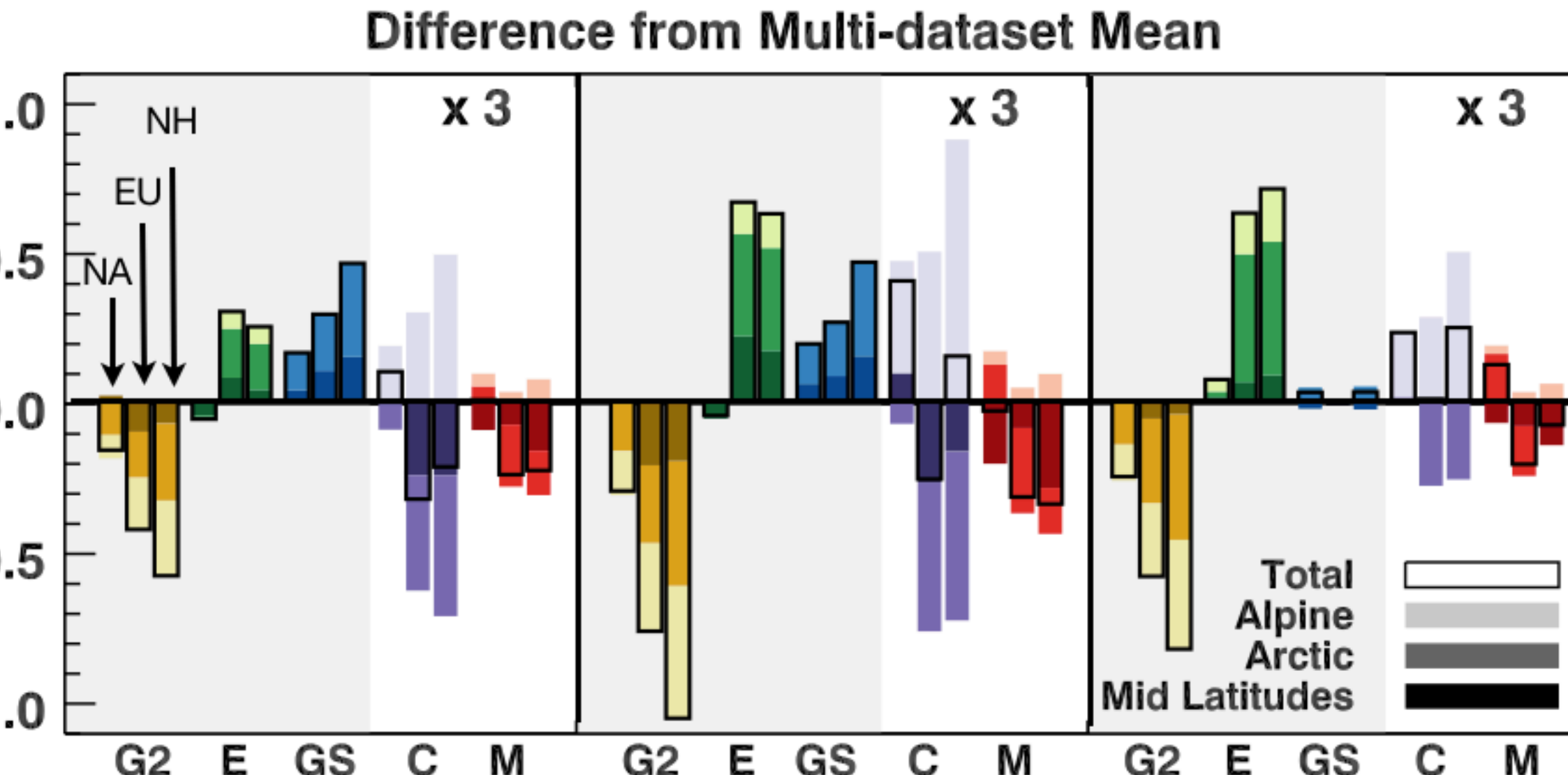
differences cancel out between Arctic/alpine; tracks less SWM in Arctic regions; more SWM in alpine regions



differences cancel out between Arctic/alpine; tracks less SWM in Arctic regions; more SWM in alpine regions

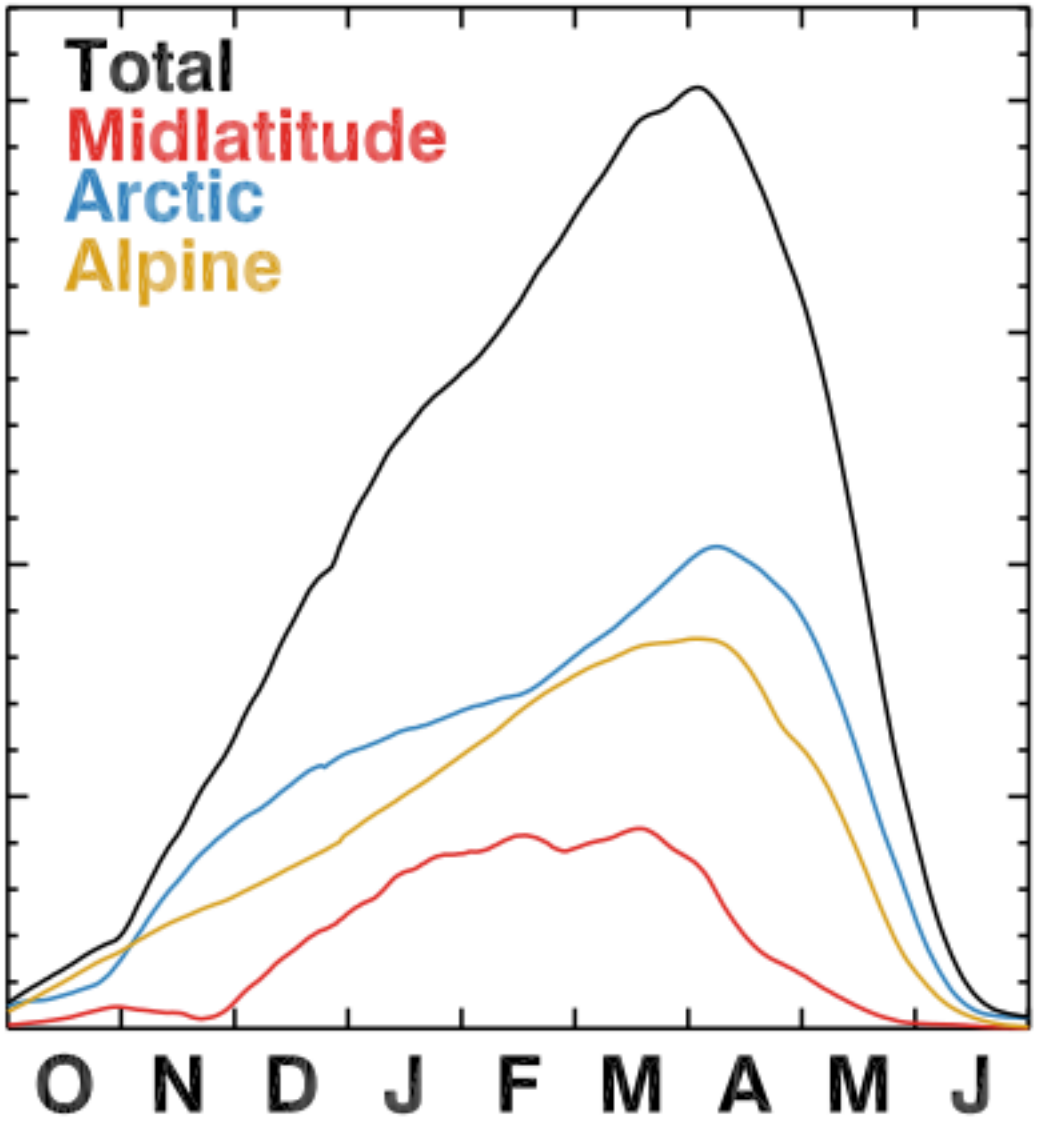
ERRA

- MERRA show smallest difference from mean; along with GlobSnow tracks more snow in NA

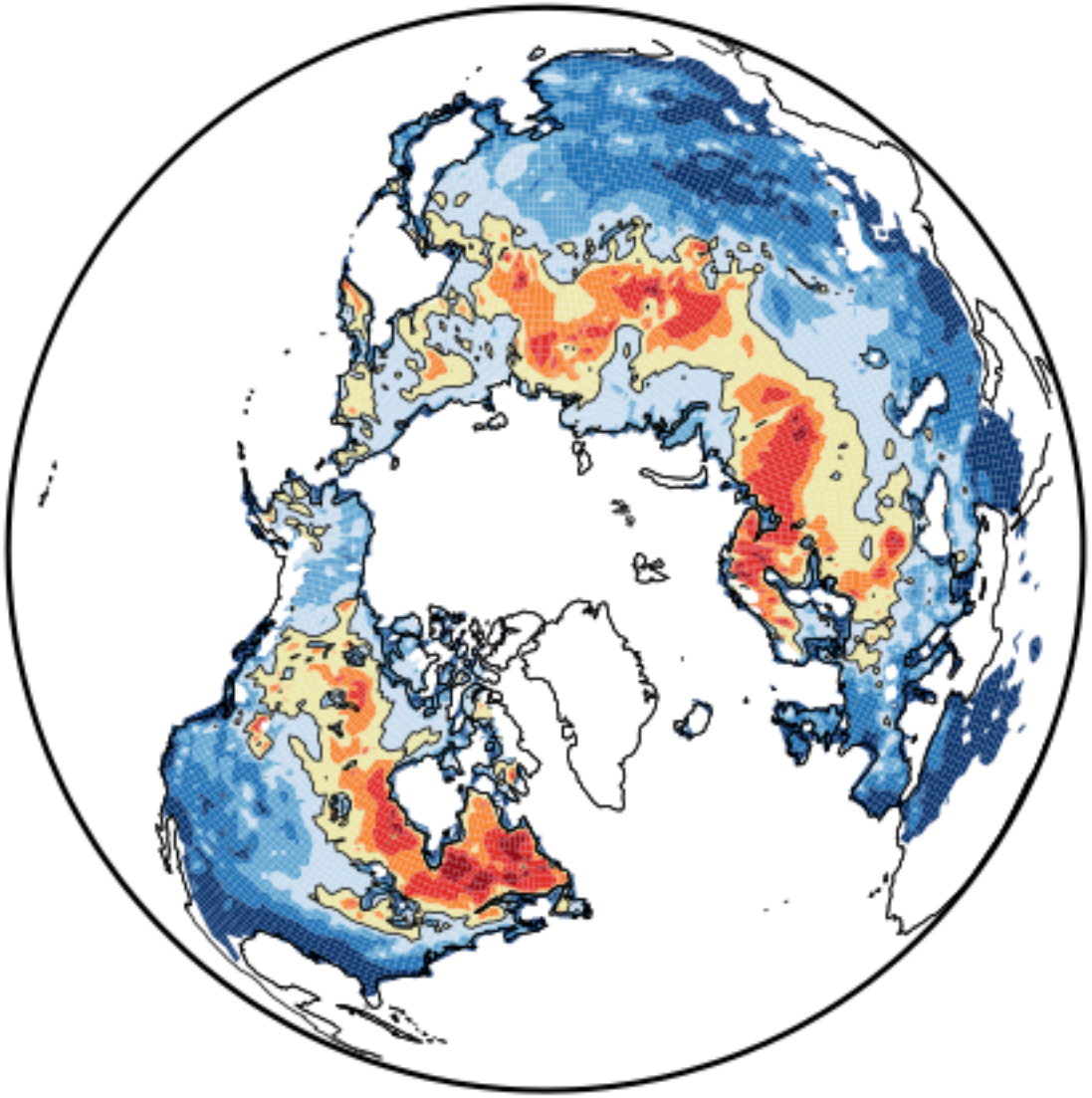


Uncertainty in Climatological SWE

Total NH Snow Mass Spread



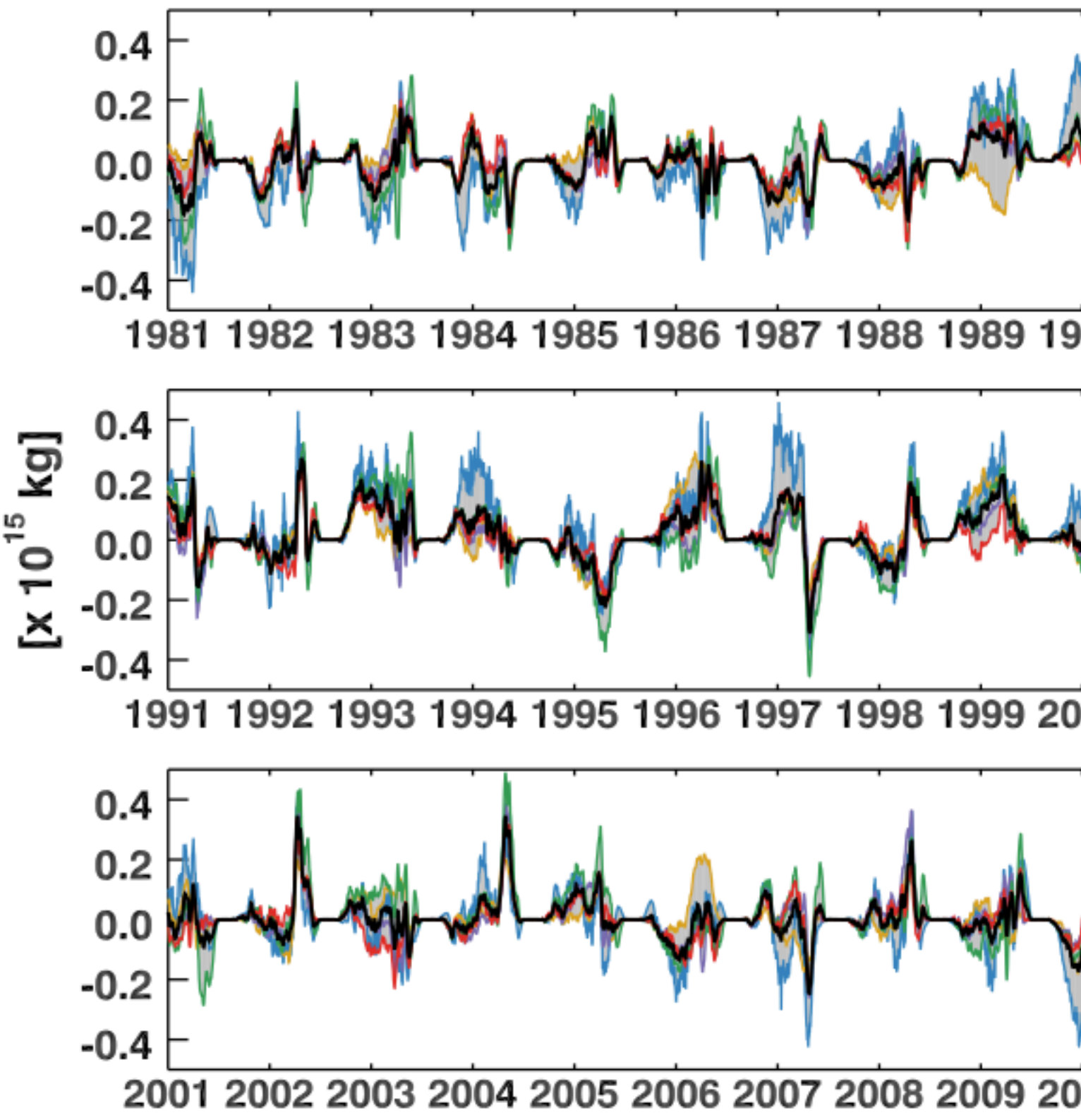
Mean SWE / Spread



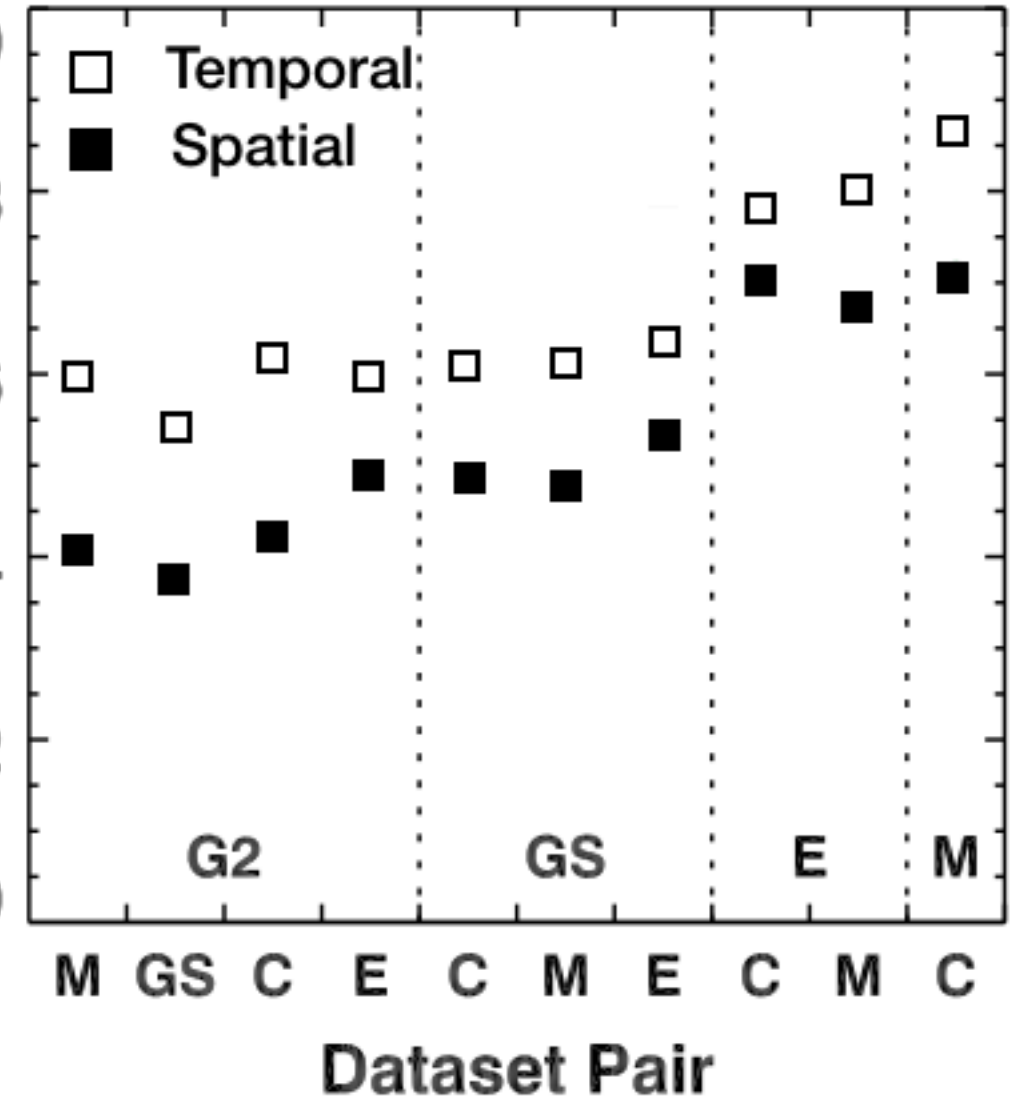
Anomalies

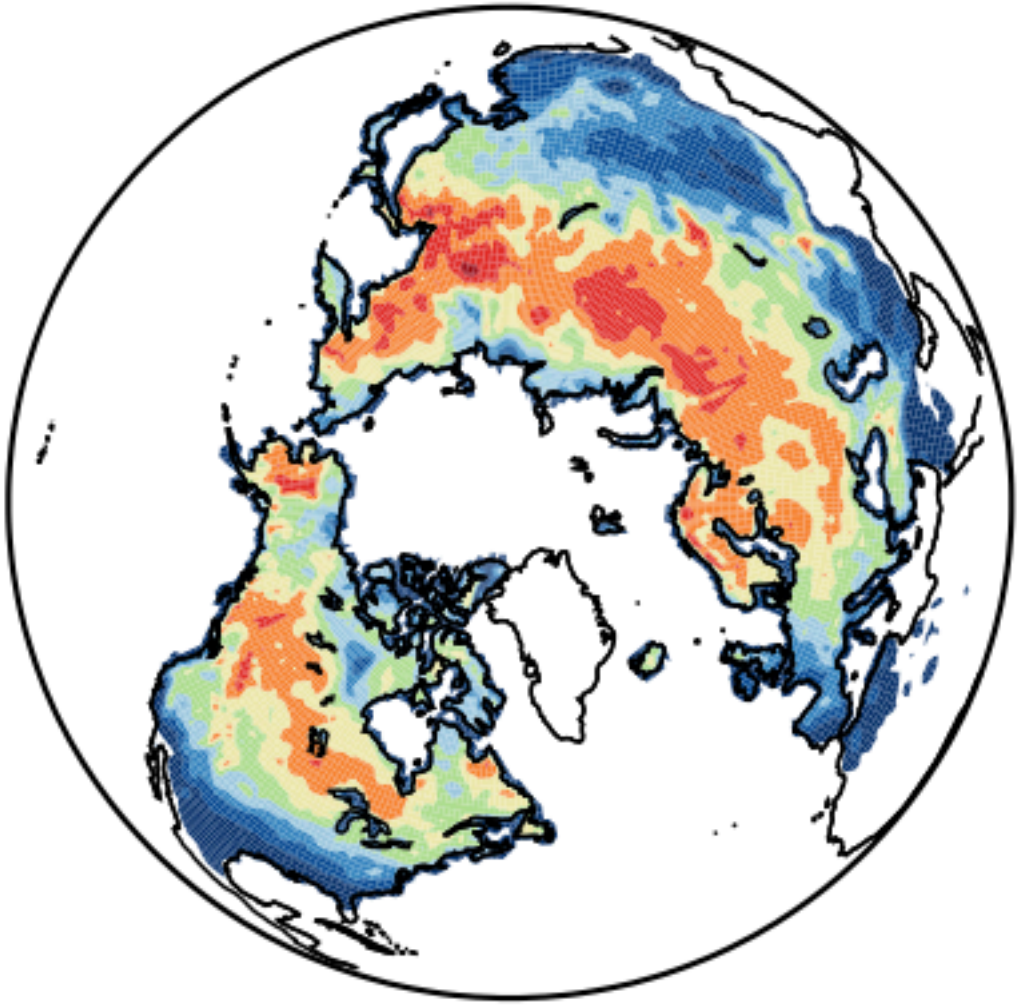
omaly spread marked
grey shading

used by different
oducts during different
ars



Pairwise Correlation

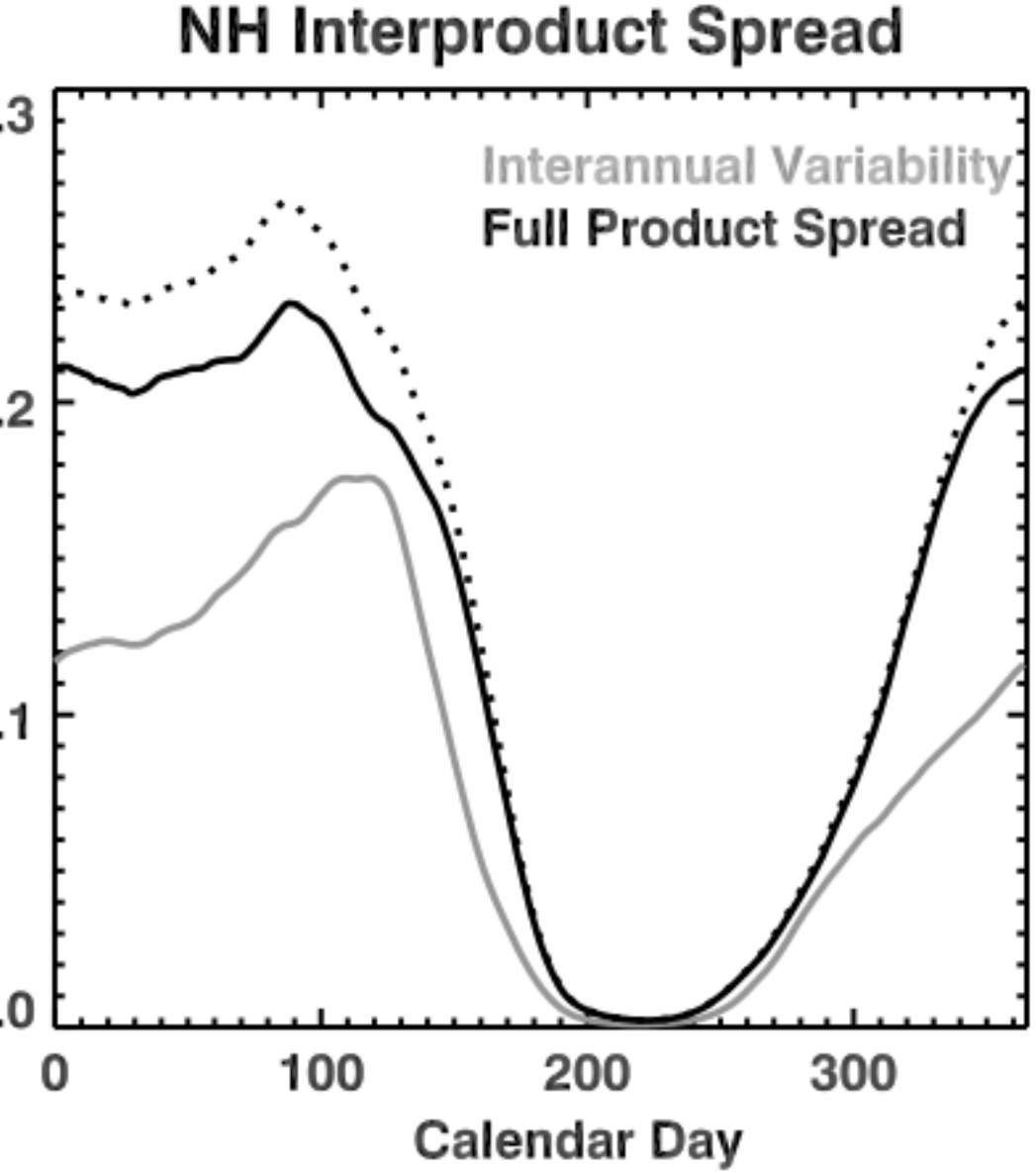


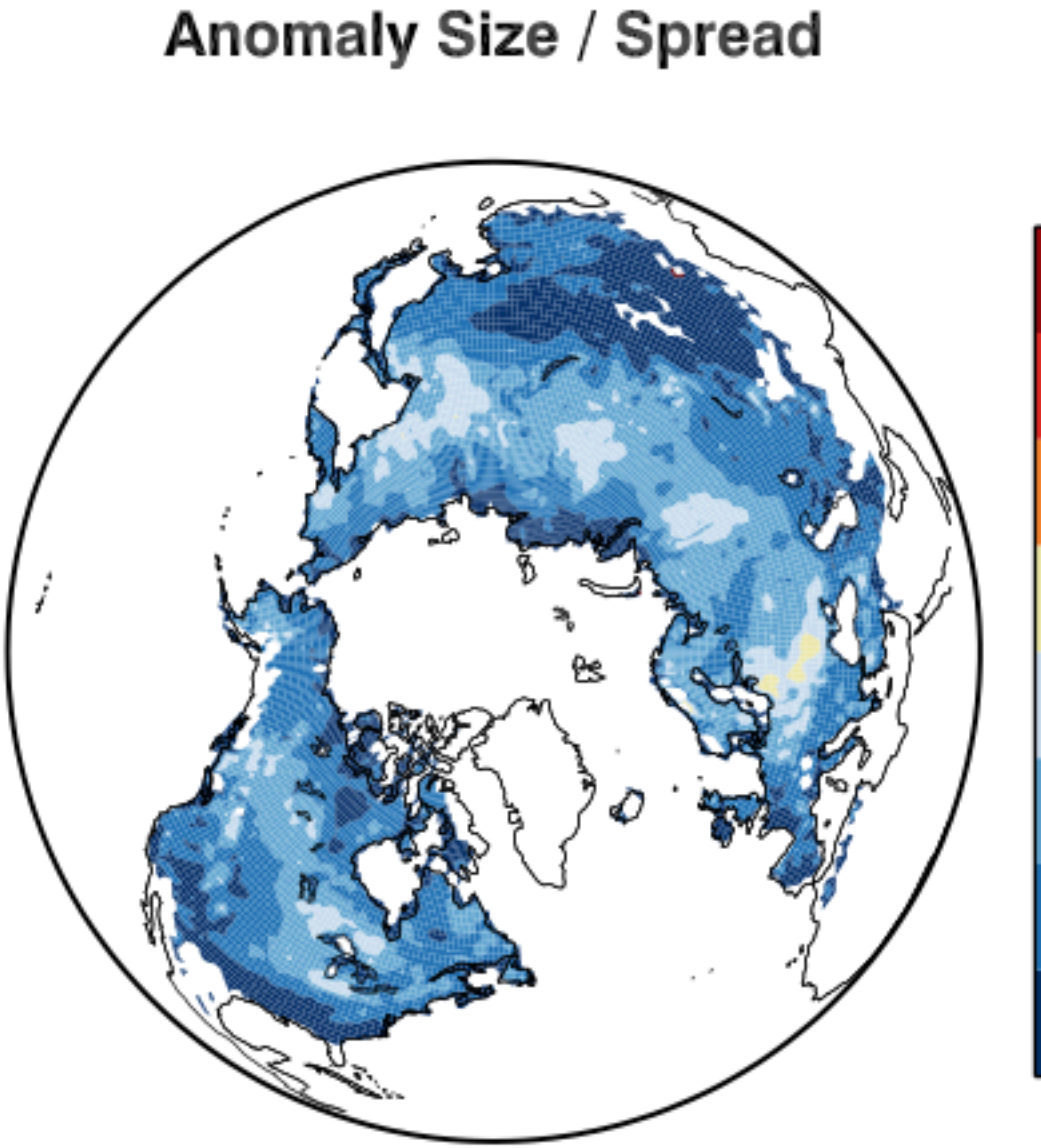


r a given pair of SWM time series we

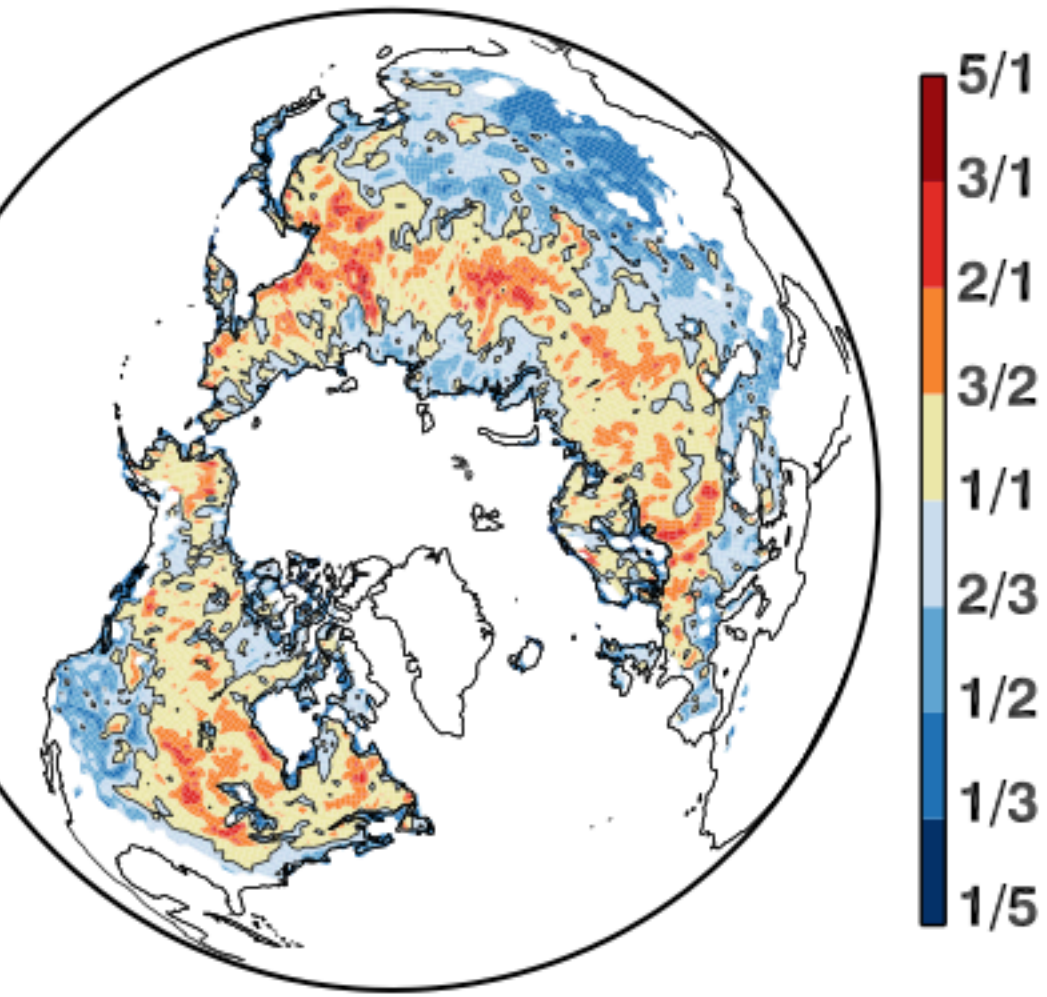
- Products show best correlatio

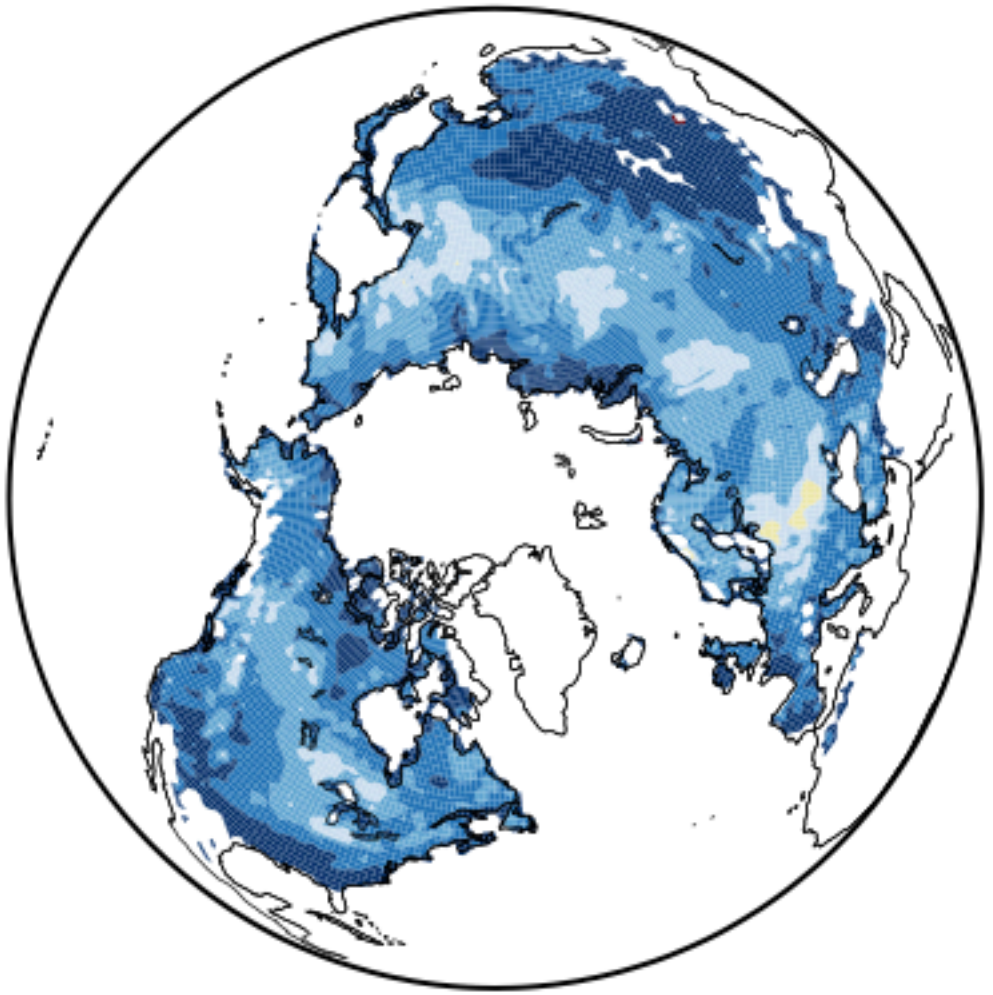
Uncertainty in Anomalous SWE



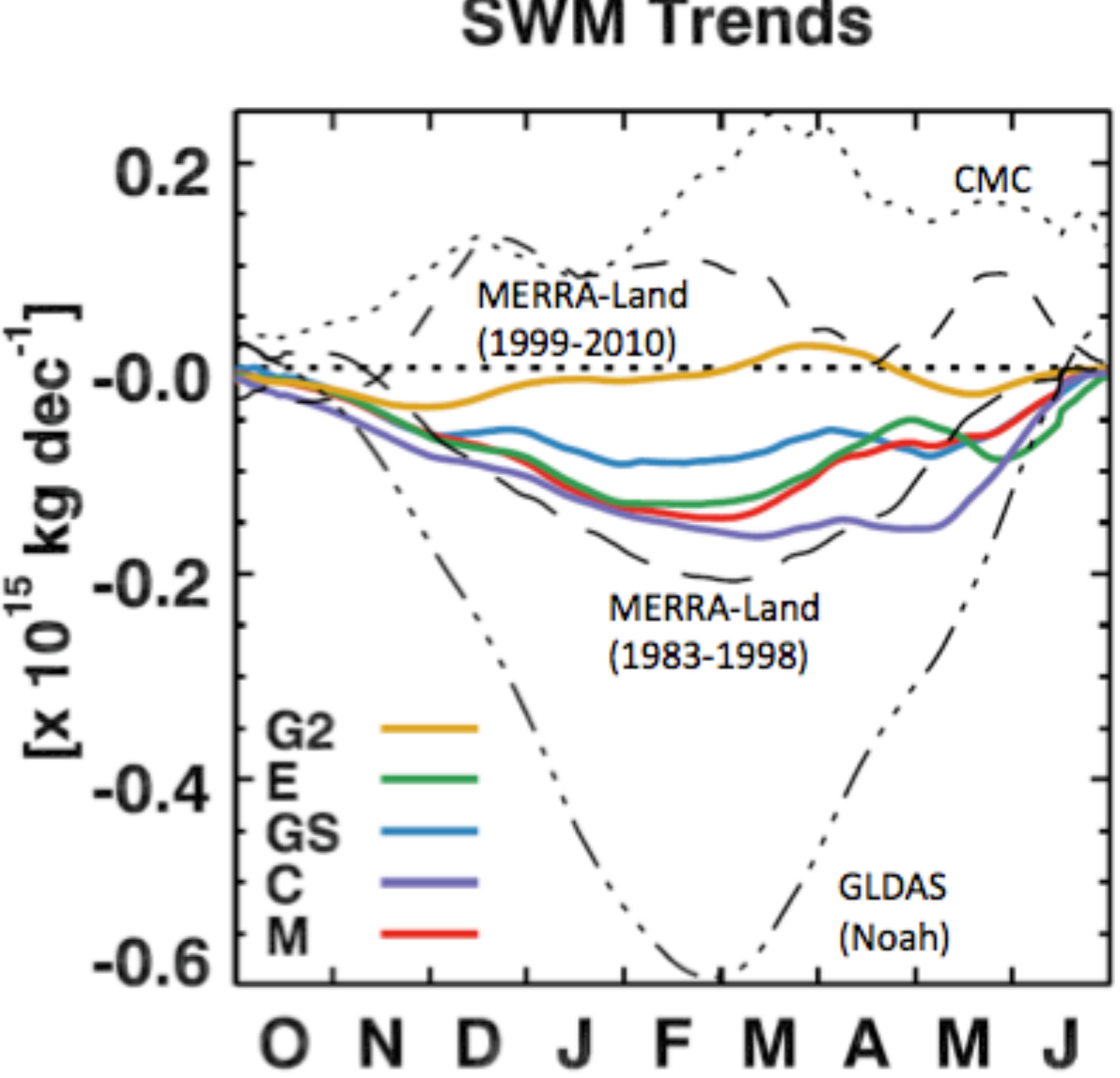


Uncertainty in Anomalous SWE





Lower spread among ERA,


SWM Trends
0.2
-0.0
-0.2
-0.4
-0.6
[x 10^15 kg dec^-1]
O
N
D
J
F
M
A
M
J
CMC
MERRA-Land
(1999-2010)
MERRA-Land
(1983-1998)
GLDAS
(Noah)
G2
E
GS
C
M

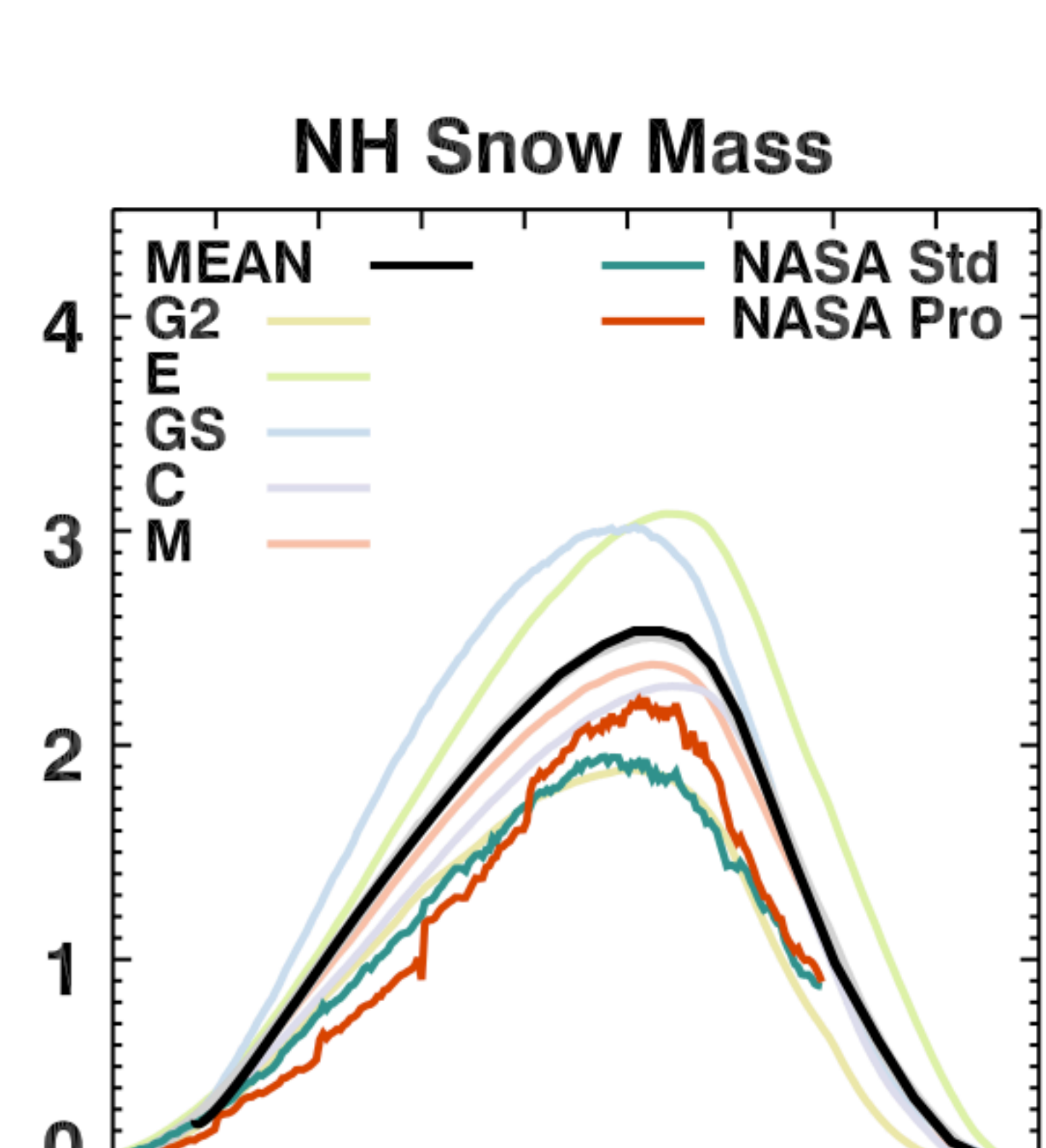
Large spread in product climatologies (~ 50%) primarily resulting from **differences over Arctic and alpine regions**, however gener agreement in the climatological pattern.

Anomalies also have large spread, comparable to or greater than nterannual variability

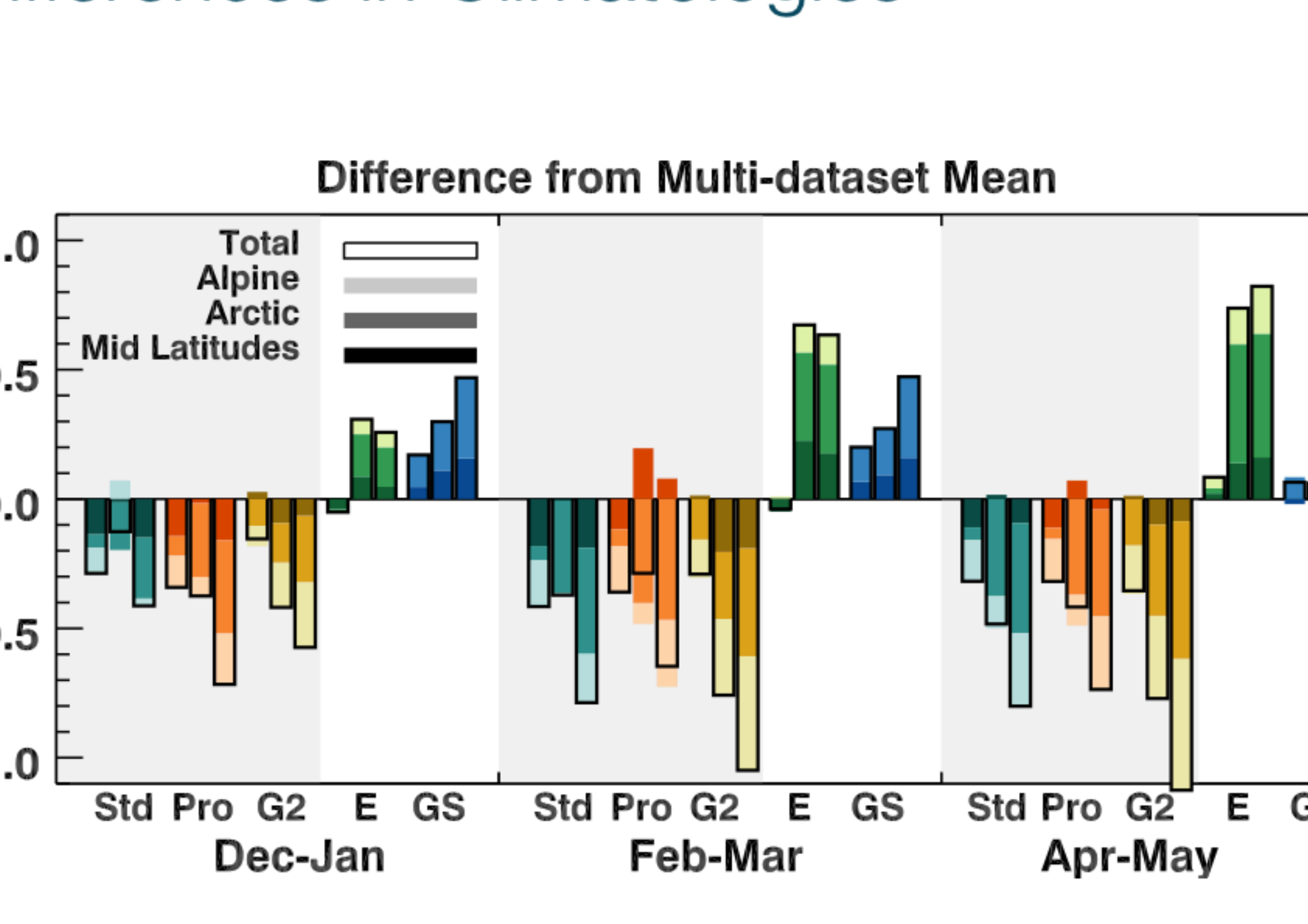
Boreal regions show the highest signal to noise for both climatoloical SWE and anomalous SWE as well as largest tempora correlations among the datasets

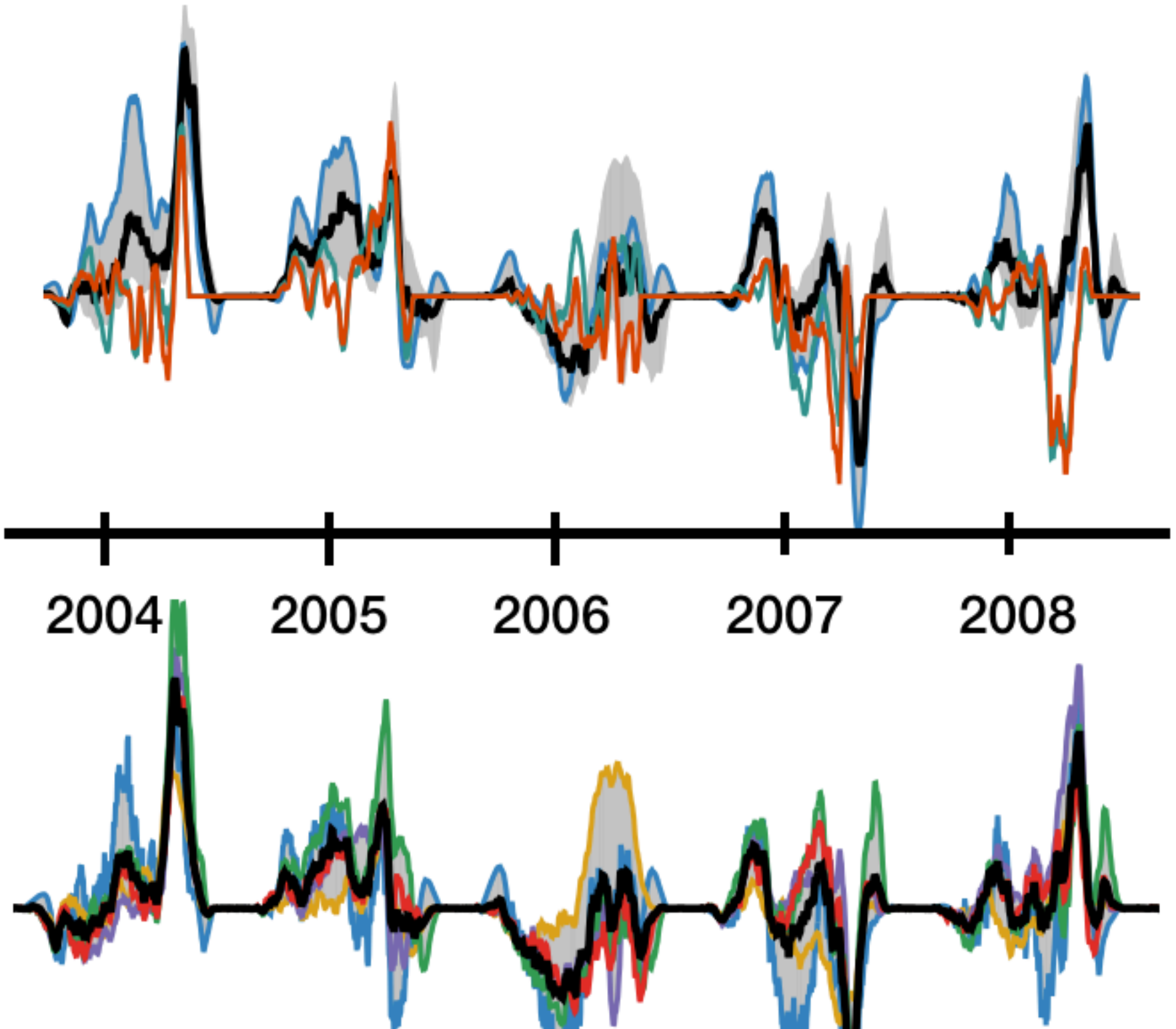
Most consistency/least spread seen among MERRA, ERA-I-Land and Crocus datasets

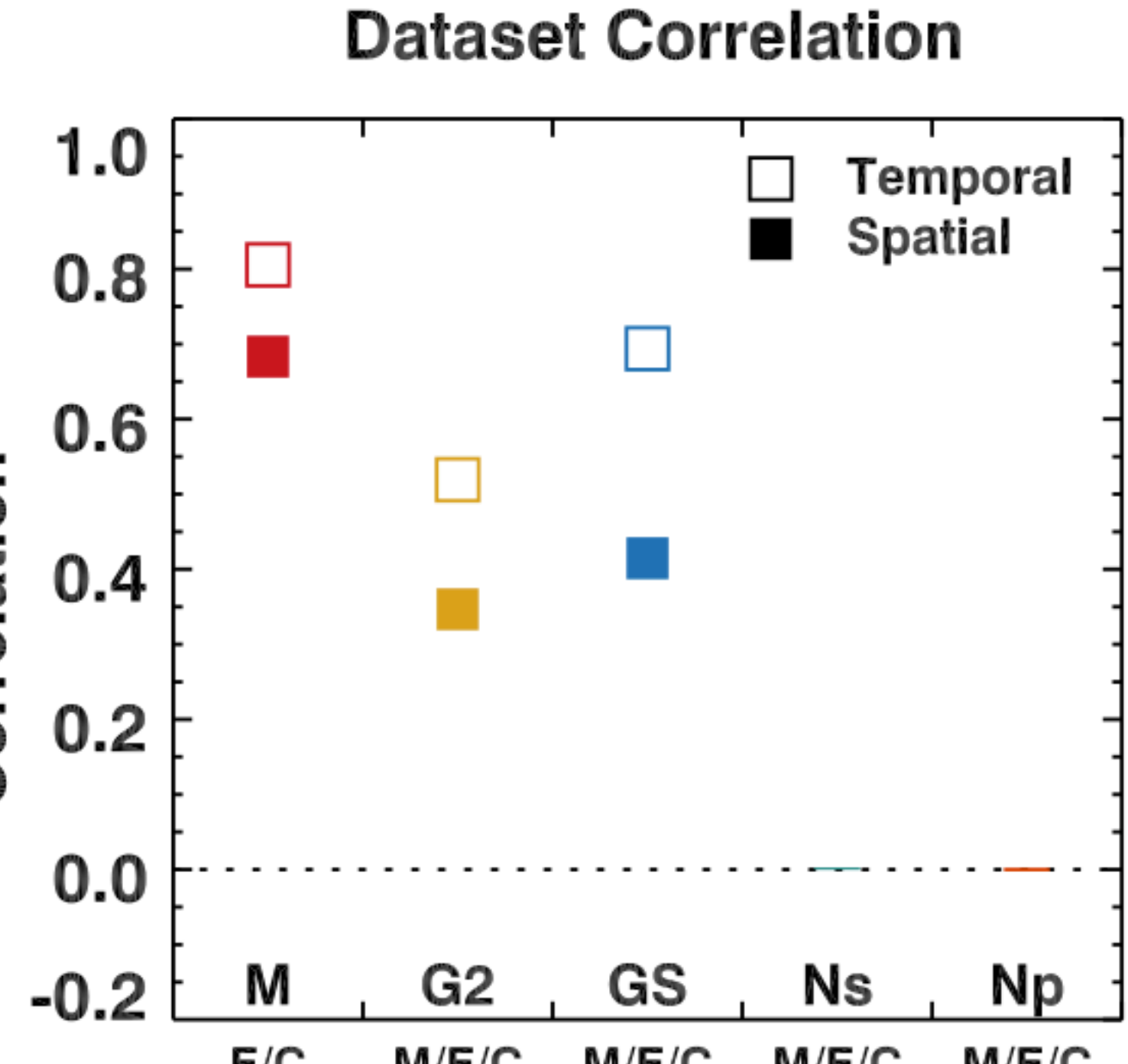
Details available in Mudryk et al., J. Climate (in press)

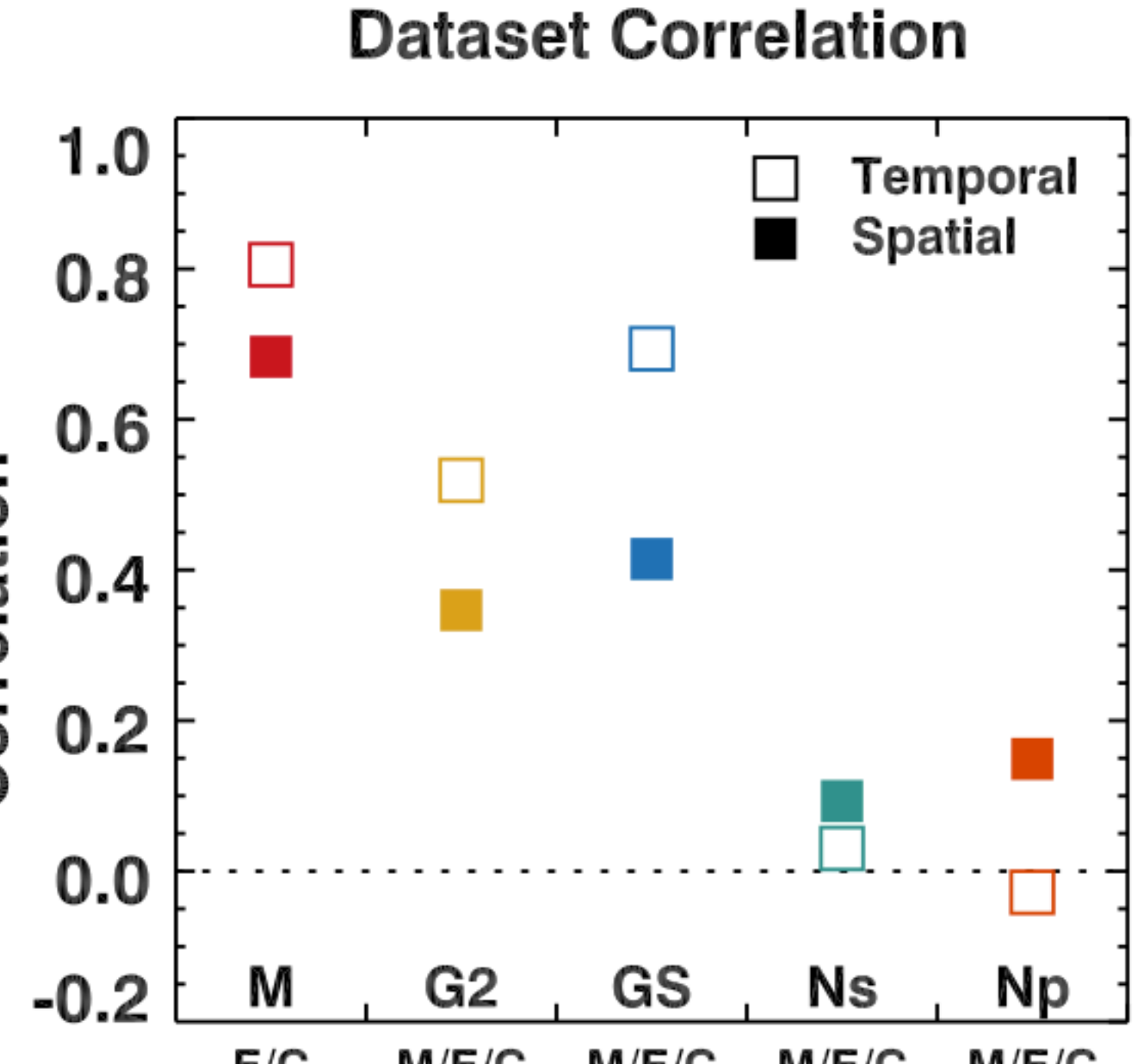


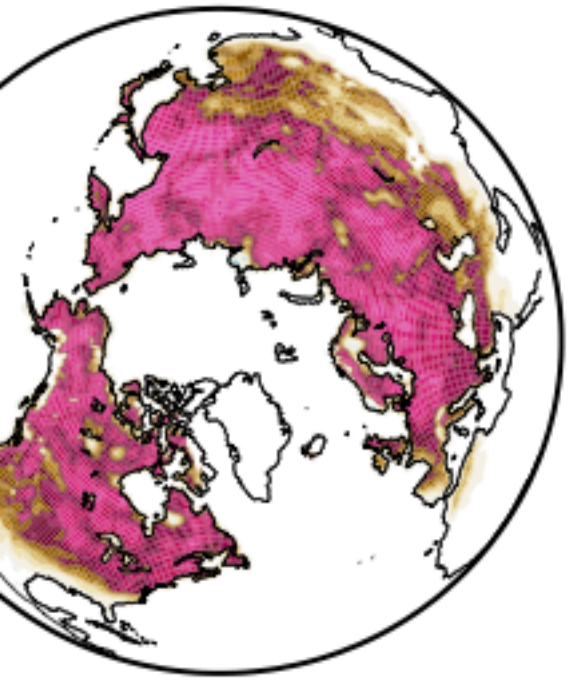
- lower SWE overall in b NASA products
- somewhat higher for prototype product dur February/March
- abrupt changes to algorithm parameters between adjacent mo


Difference from Multi-dataset Mean
Total
Alpine
Arctic
Mid Latitudes
.0
.5
.0
.5
.0
Std Pro G2 E GS
Std Pro G2 E GS
Std Pro G2 E
Dec-Jan
Feb-Mar
Apr-May

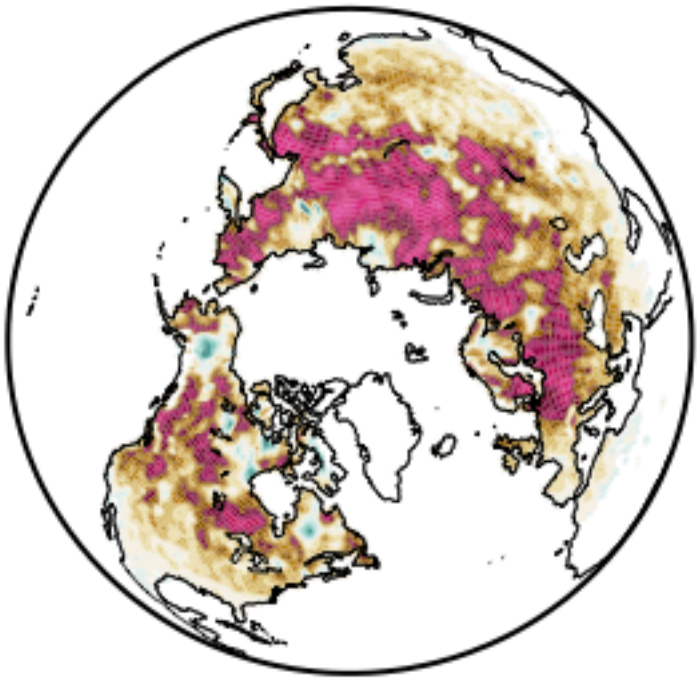

Mean
GlobSno
NASA-st
NASA-p
2004
2005
2006
2007
2008
Mean
GlobSn
MERRA
ERA-I-L
Crocus
GLDAS


Dataset Correlation
Temporal
Spatial
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
M
G2
GS
Ns
Np
F/C
M/F/C
M/F/C
M/F/C
M/F/C

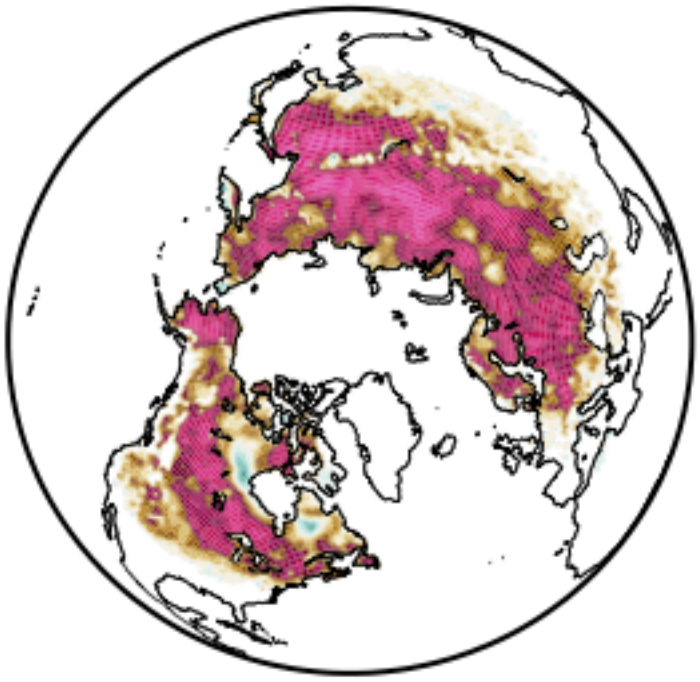

Dataset Correlation
Temporal
Spatial
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
M
G2
GS
Ns
Np



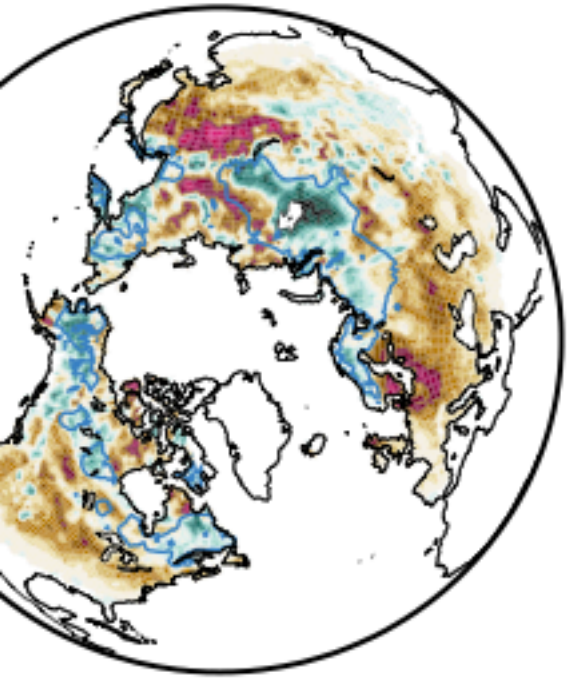
M/E/C

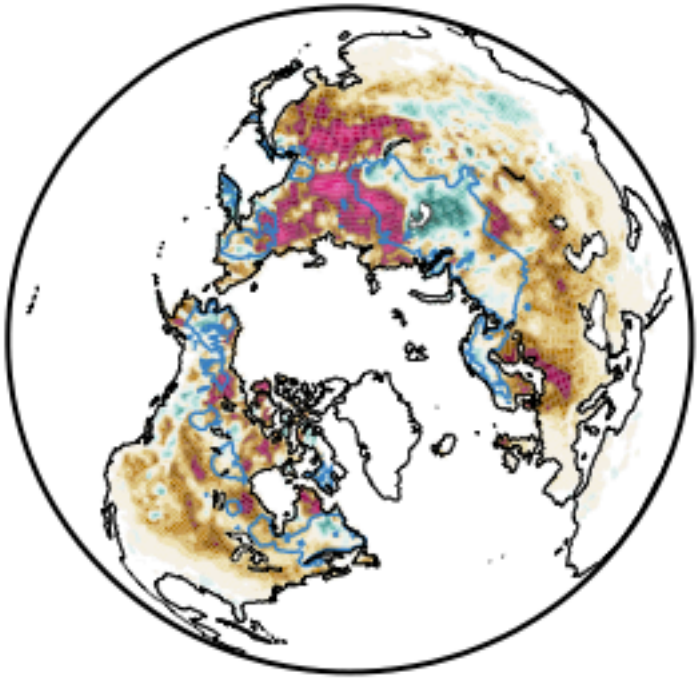


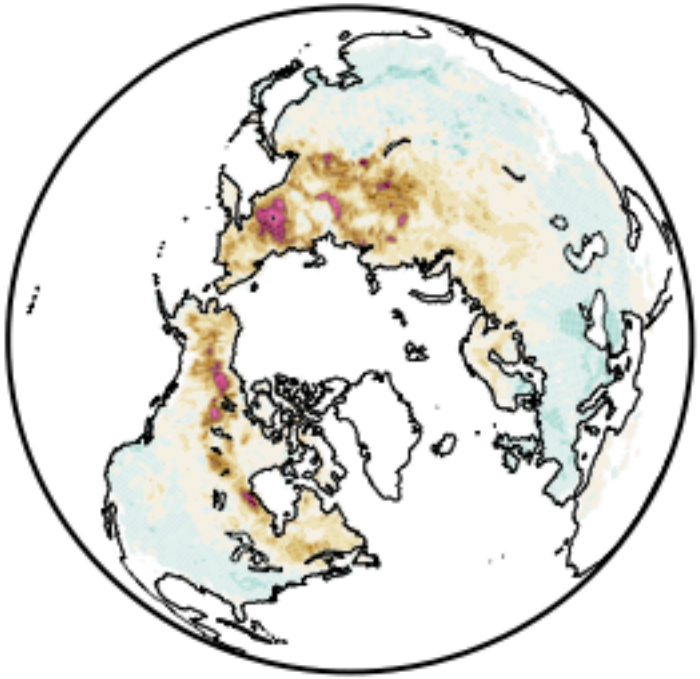
G2 - M/E/C

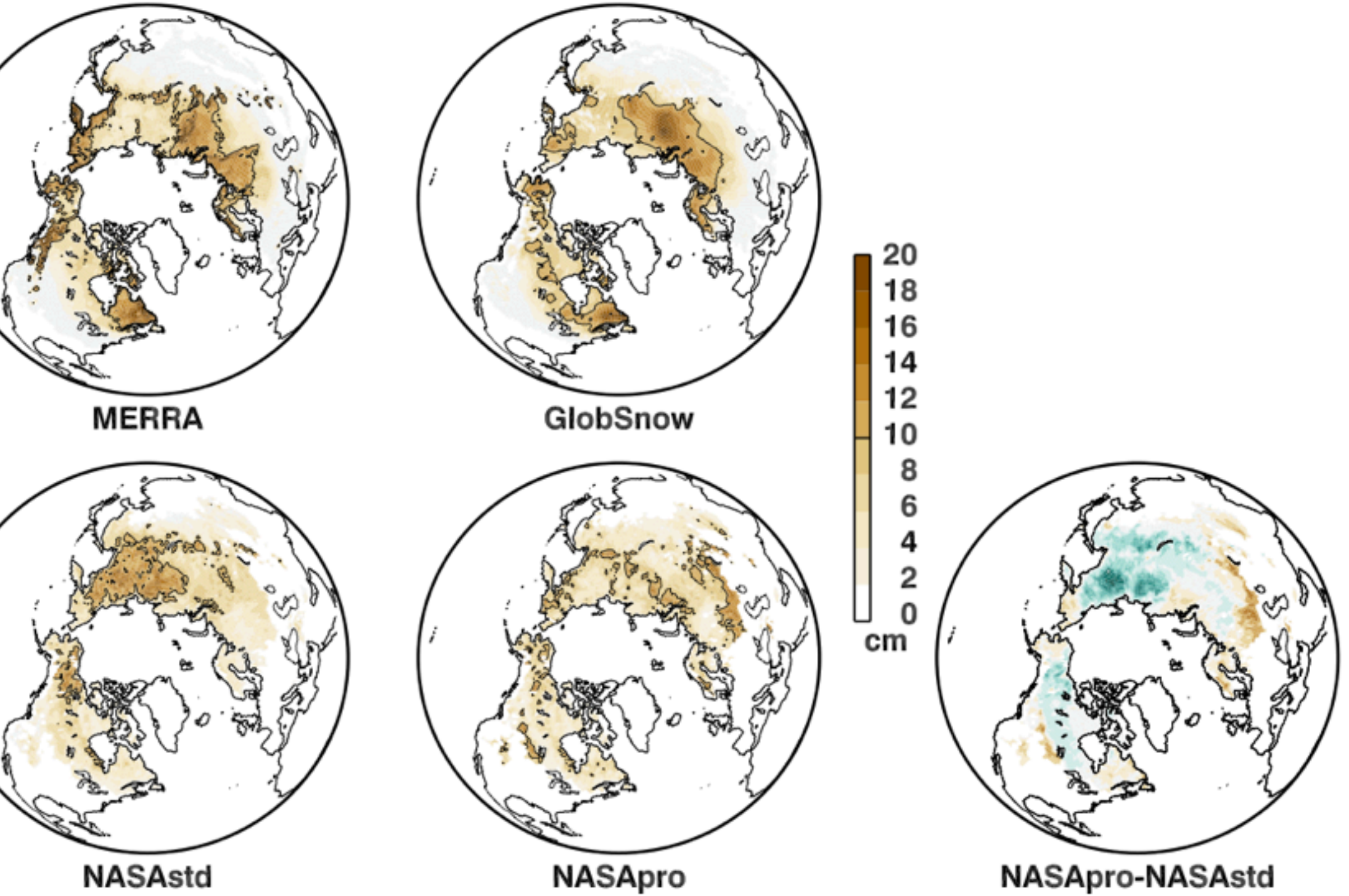


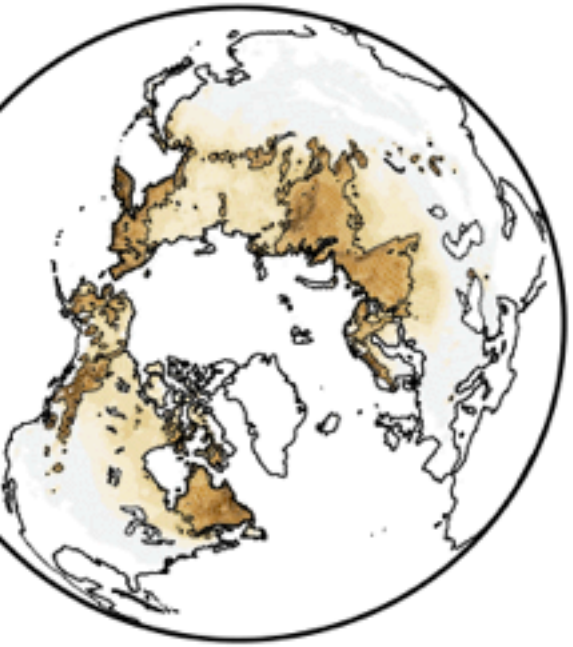
GS - M/E/C



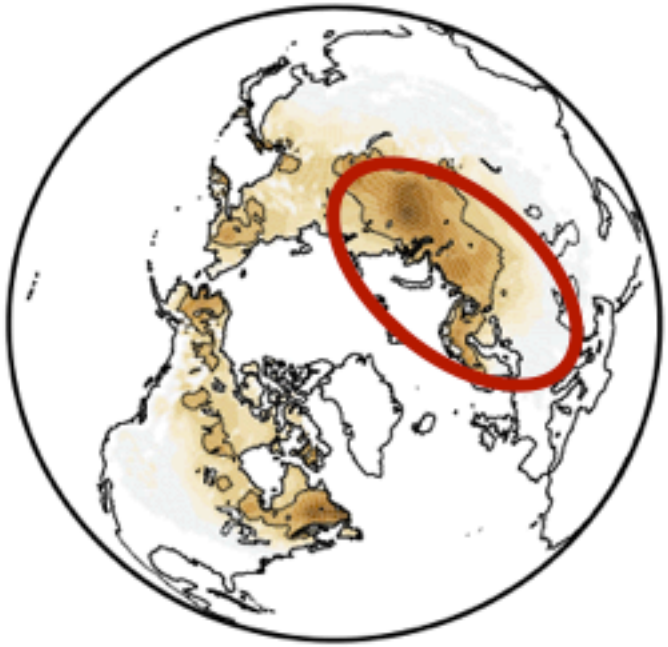





MERRA
GlobSnow
NASAstd
NASApro
NASApro-NASAstd
20
18
16
14
12
10
8
6
4
2
0
cm

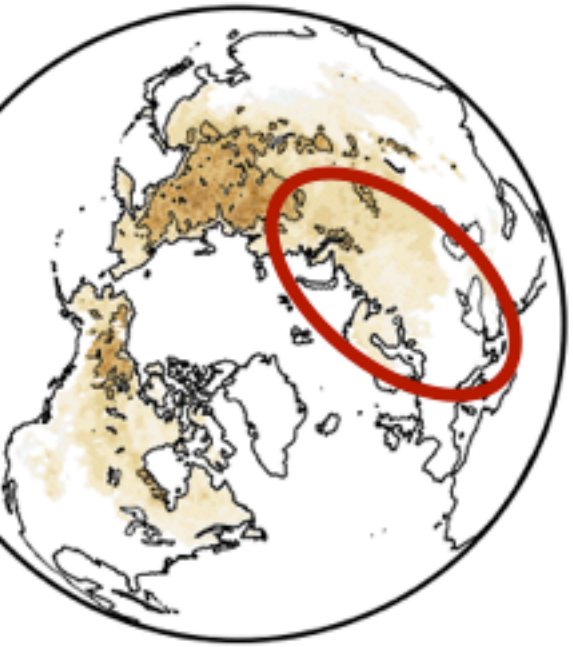


MERRA



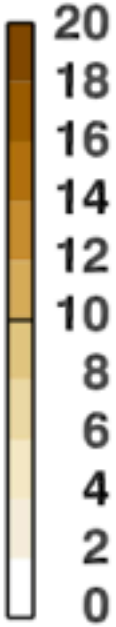
GlobSnow

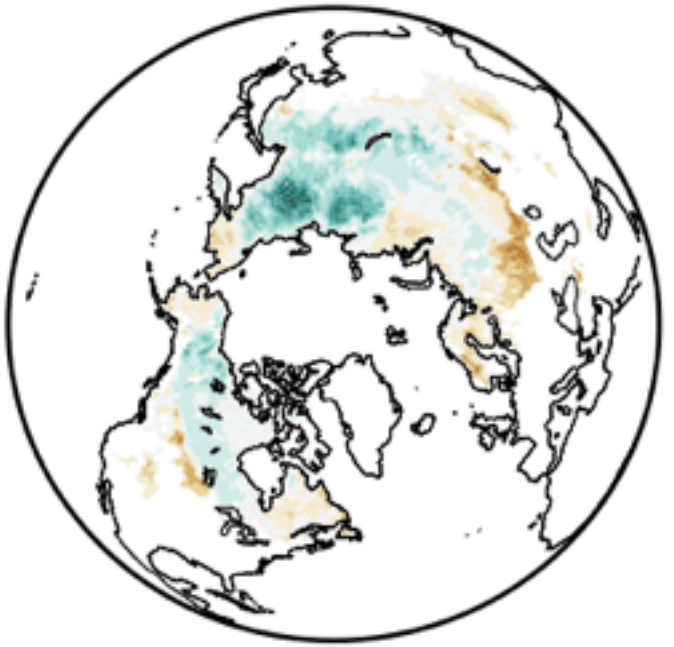
- GlobSnow retains sens
because of the inclusio
the background depth
from climate stations.



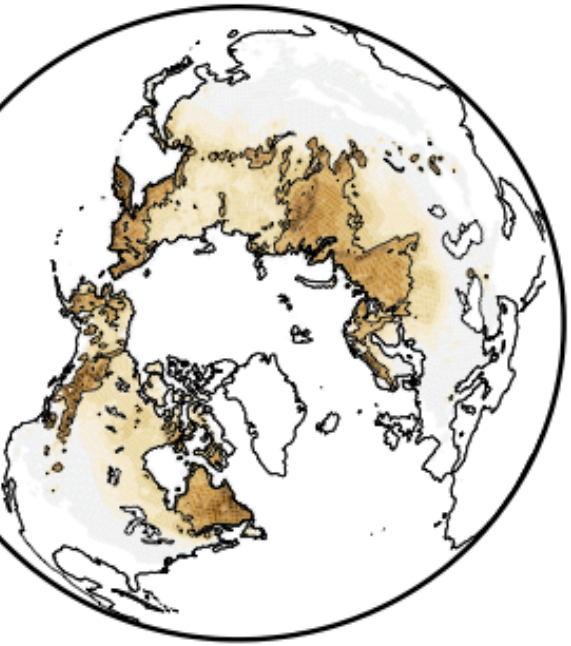
NASAstd

NASApro

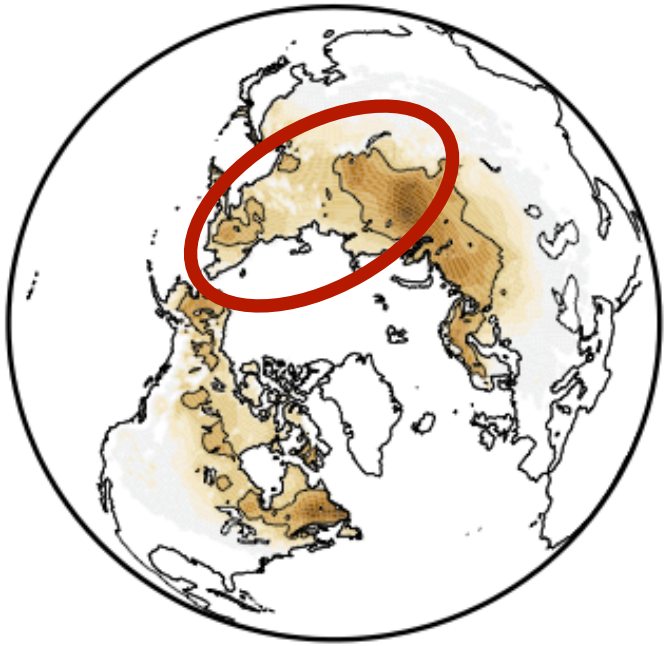




NASApro-NASAstd

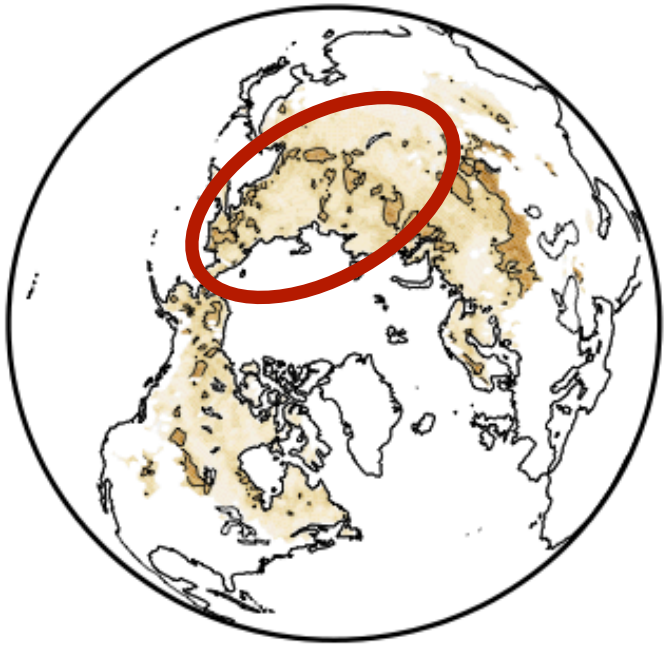


MERRA

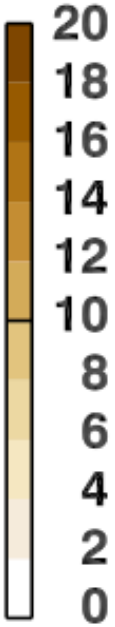


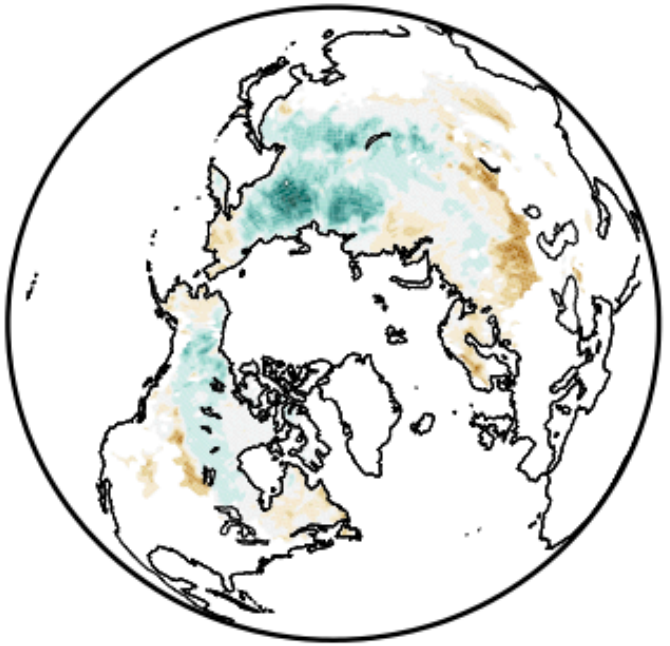
GlobSnow

NASAstd



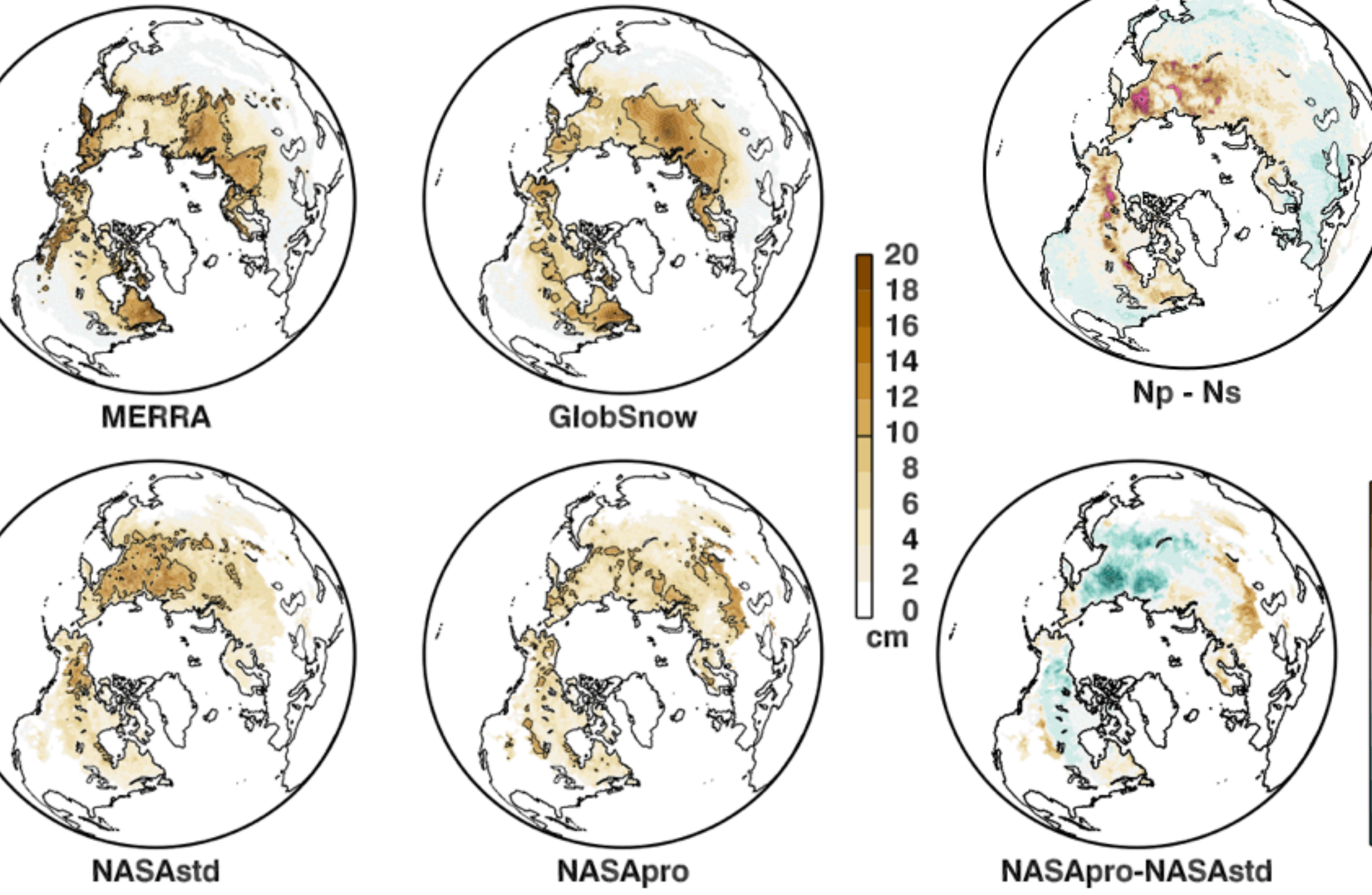
NASApro





NASApro-NASAstd

- SWE in this region is fit
  thin snow with large gra
  GlobSnow and NASAp
  unlike for NASAstd


MERRA
GlobSnow
Np - Ns
20
18
16
14
12
10
8
6
4
2
0
cm
NASAstd
NASApro
NASApro-NASAstd

Both NASA algorithms track less climatological SWE than GlobSnow and most other gridded products.

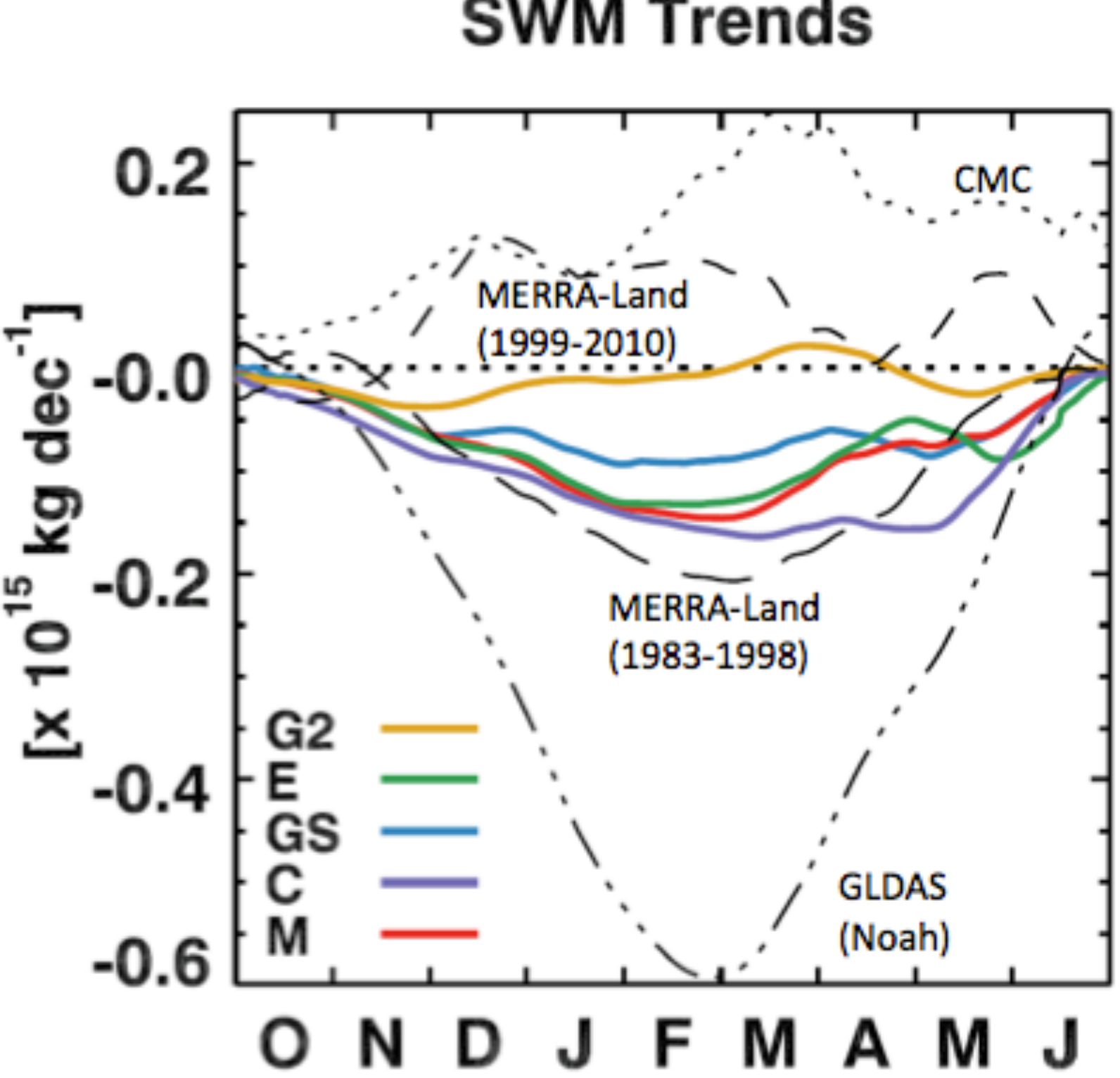
NASA SWE anomalies correlate poorly with those of GlobSnow ar the gridded SWE datasets.

Poor anomaly correlation appears to be due to differences in climatological patterns; NASA-prototype climatology is closer to that of GlobSnow and gridded products and shows better anoma correlations.

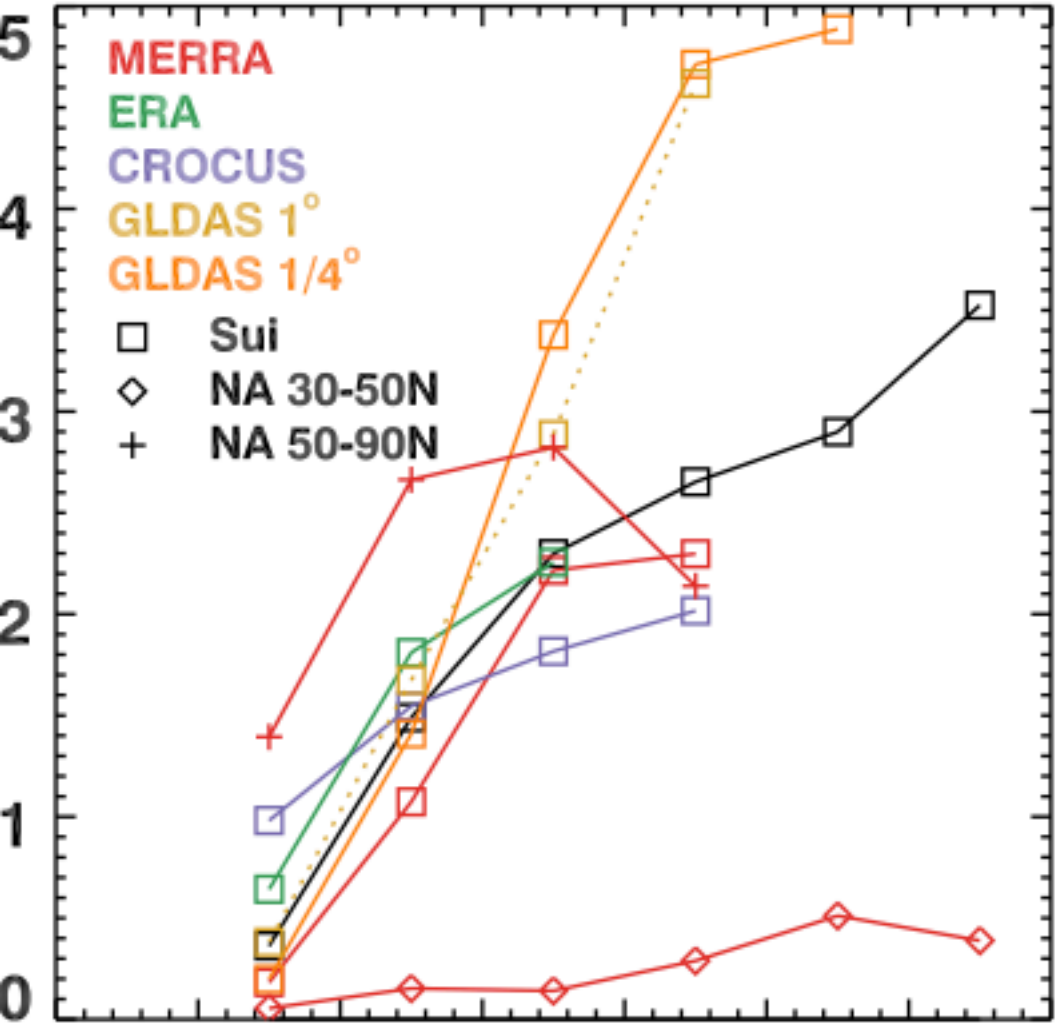
...ture work

- Accuracy of gridded products is currently under assessment through Eurasian and North American in situ data
- Alpine assessment is underway using SLF data, but how representative is this of other alpine regions?

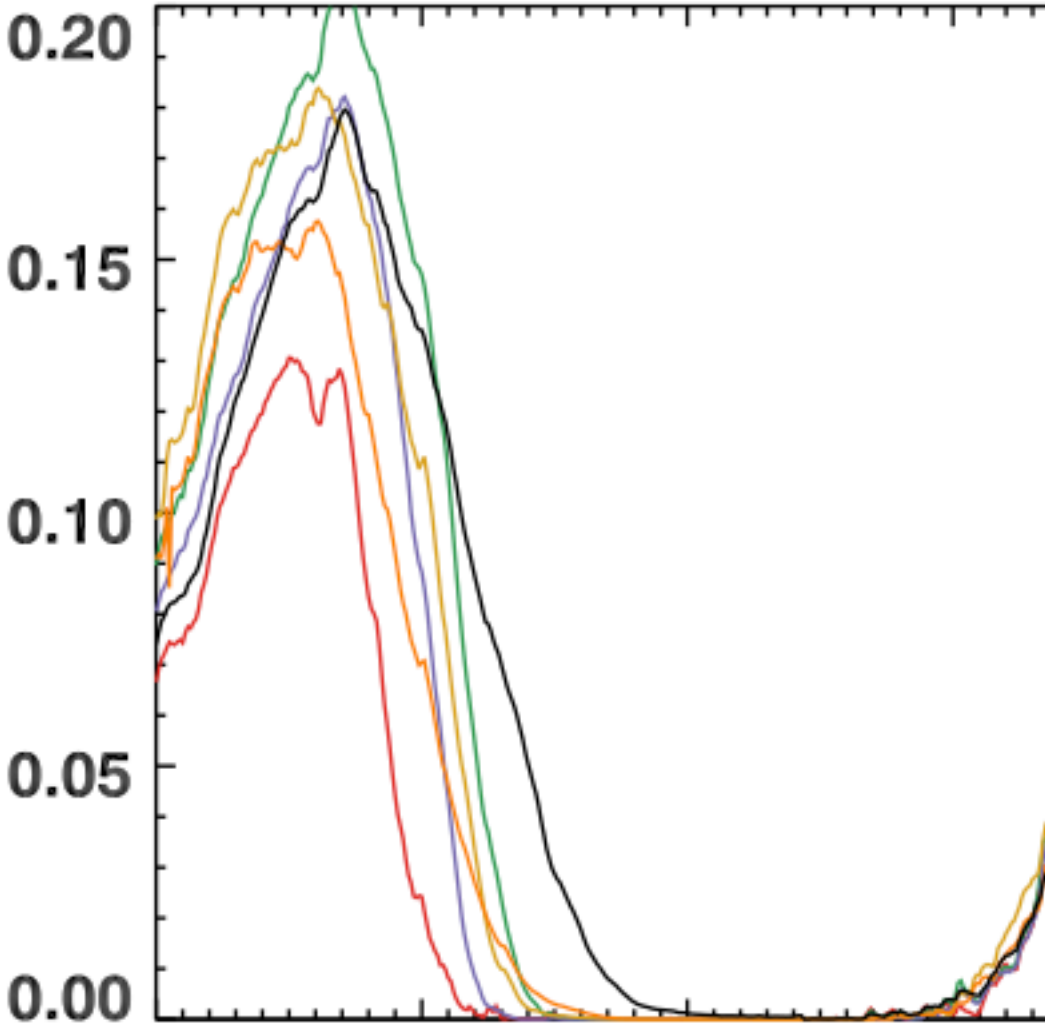
Thanks for your attention!

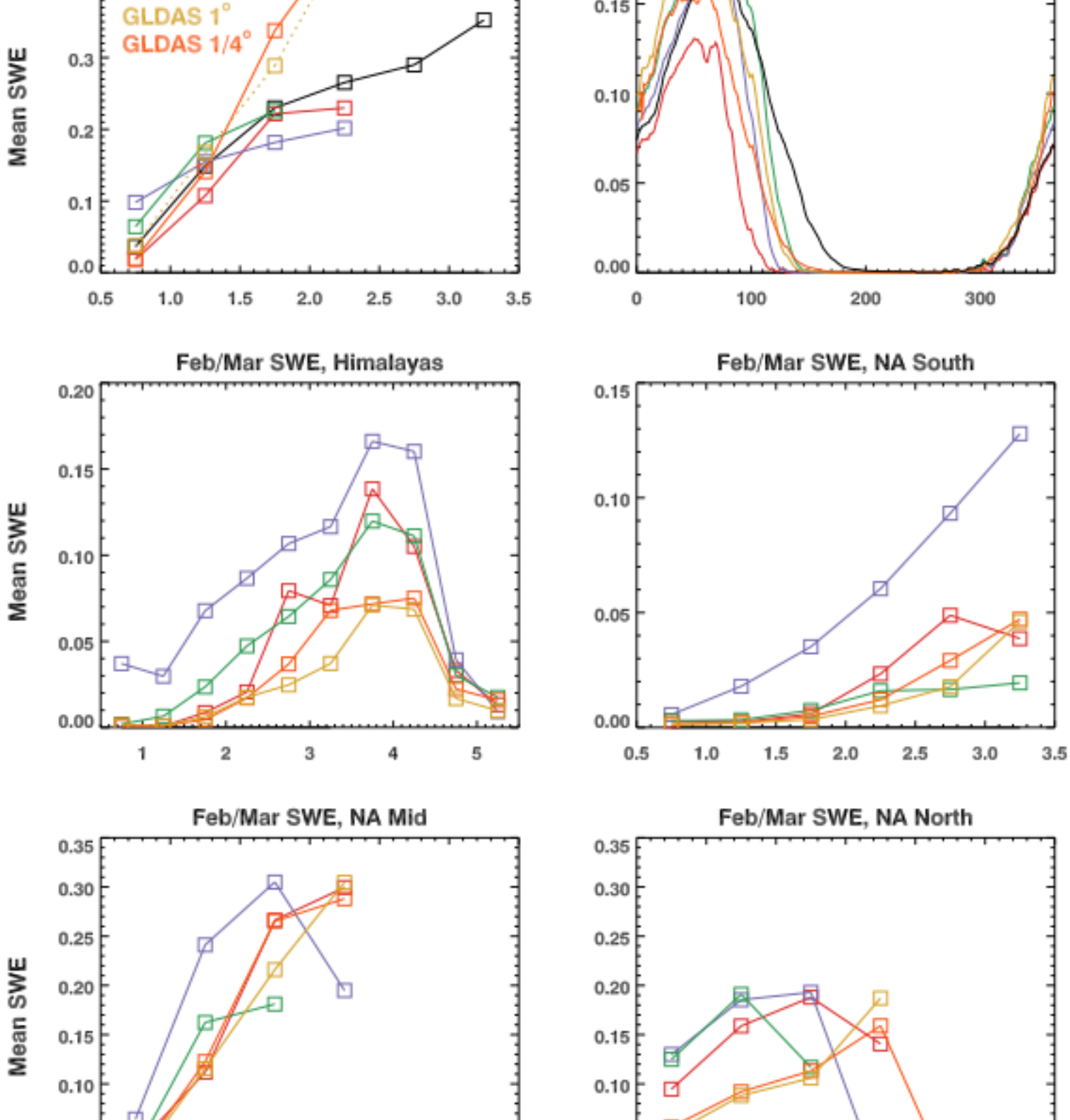

SWM Trends
0.2
-0.0
-0.2
-0.4
-0.6
[x 10^15 kg dec^-1]
O
N
D
J
F
M
A
M
J
CMC
MERRA-Land
(1999-2010)
MERRA-Land
(1983-1998)
GLDAS
(Noah)
G2
E
GS
C
M

Feb/Mar SWE by Elevation



SWE Climatology

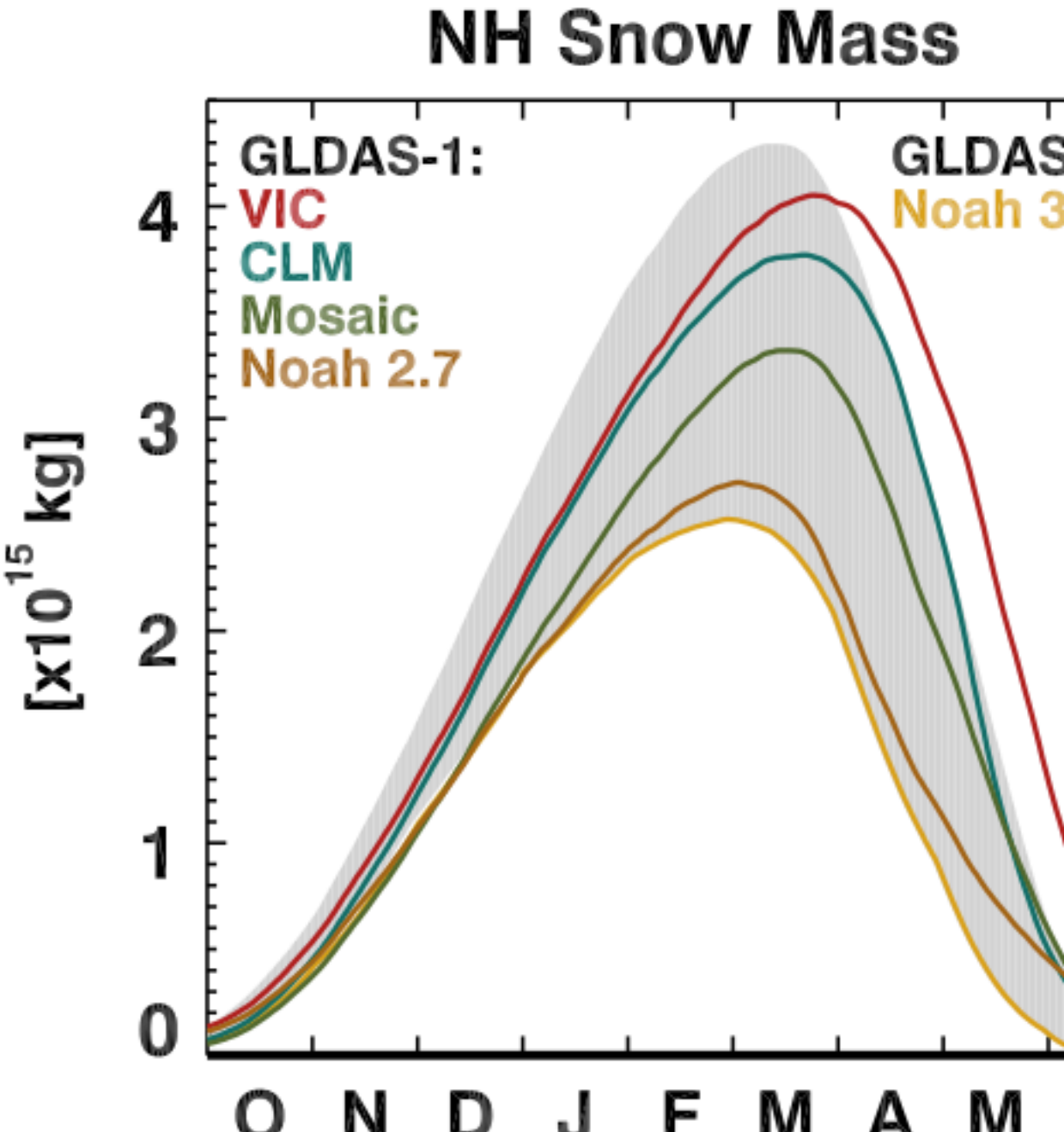



GLDAS 1°
GLDAS 1/4°
Mean SWE
Feb/Mar SWE, Himalayas
Feb/Mar SWE, NA South
Feb/Mar SWE, NA Mid
Feb/Mar SWE, NA North

Spread in climatologies
onnected to the particular
and model used

Shading shows spread
mong MERRA, Crocus,
ERA-I-Land, GlobSnow,
GLDAS-2

Curves show spread
mong GLDAS-1 data

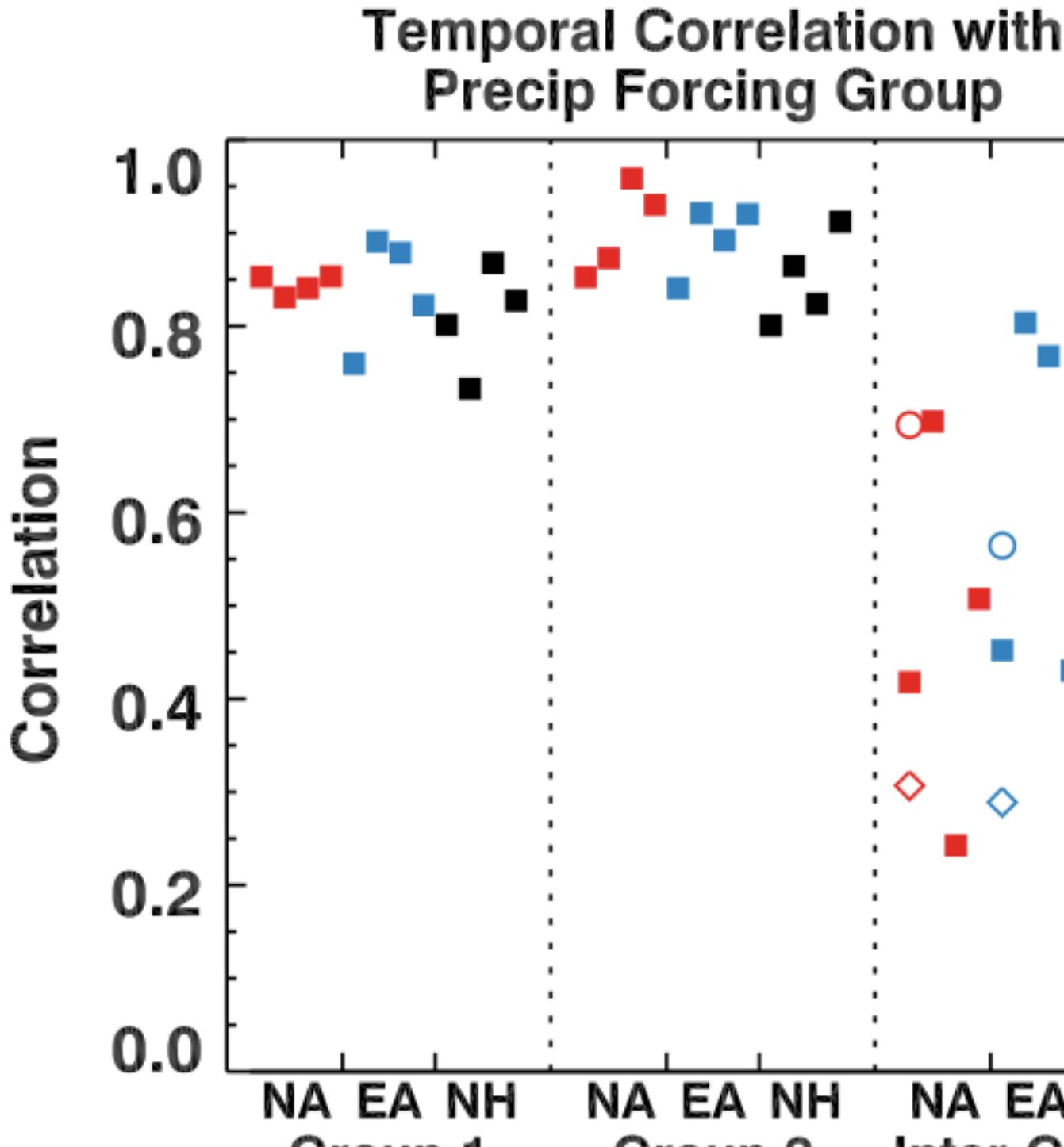


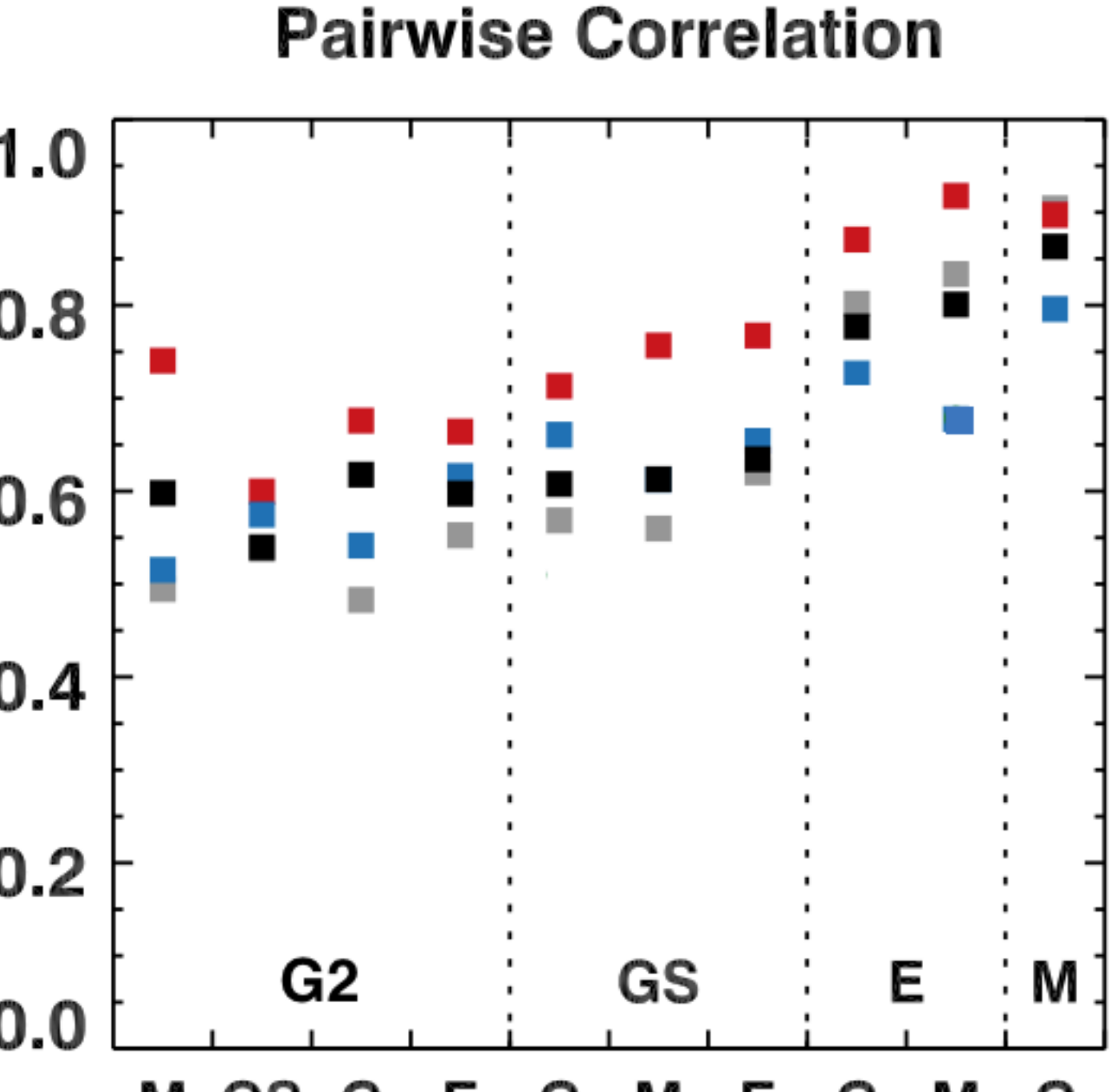
RA/MERRA/CROCUS SWM
ne series are correlated
0.85

LDAS-1 products (4) SWM
ne series are correlated
0.9

orrelations between the two
oups are substantially lower
d show best agreement
er mid-latitudes

roup 1 (newer forcing
eteorologies) shows better
greement with GlobSnow





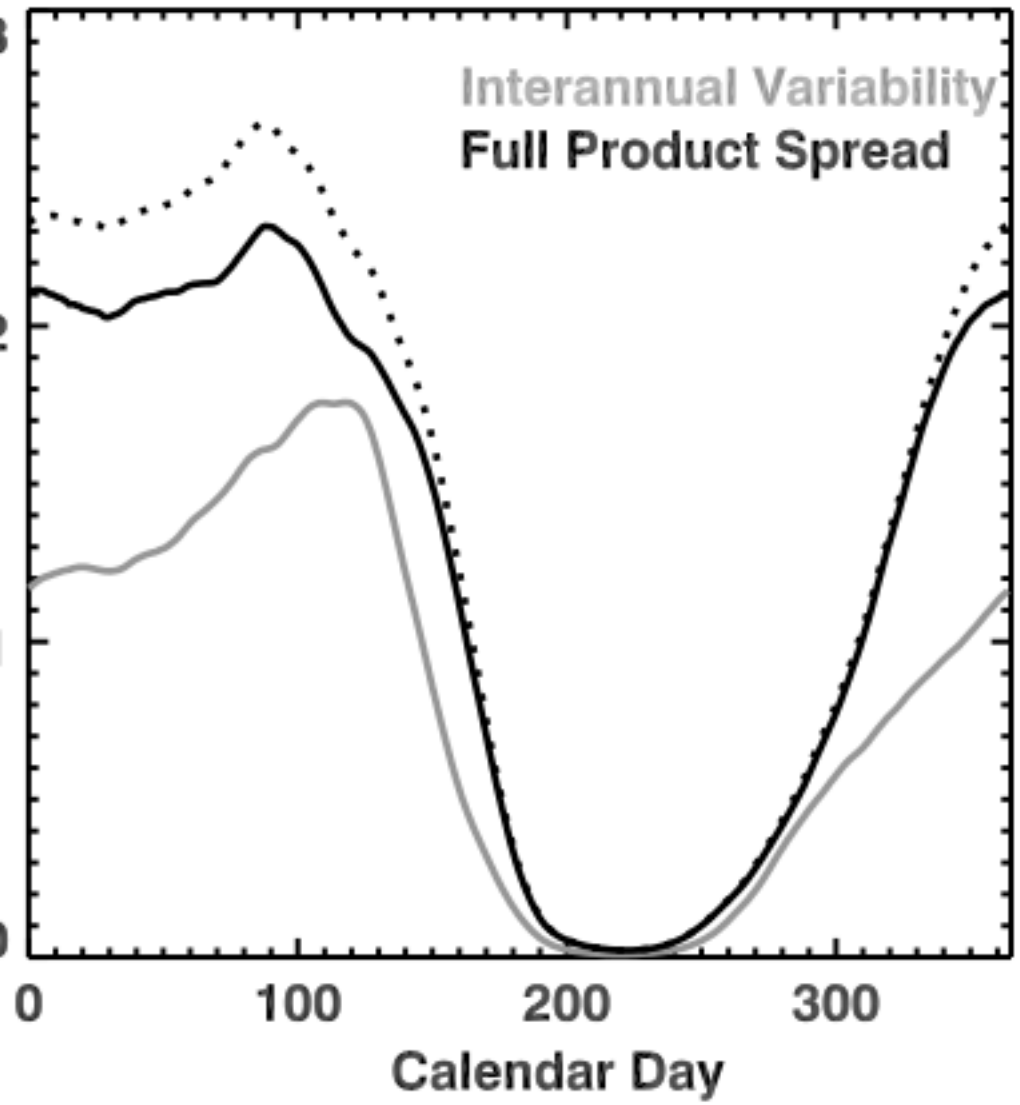
- Correlations are bette
  North America than c
  Eurasia

detrended

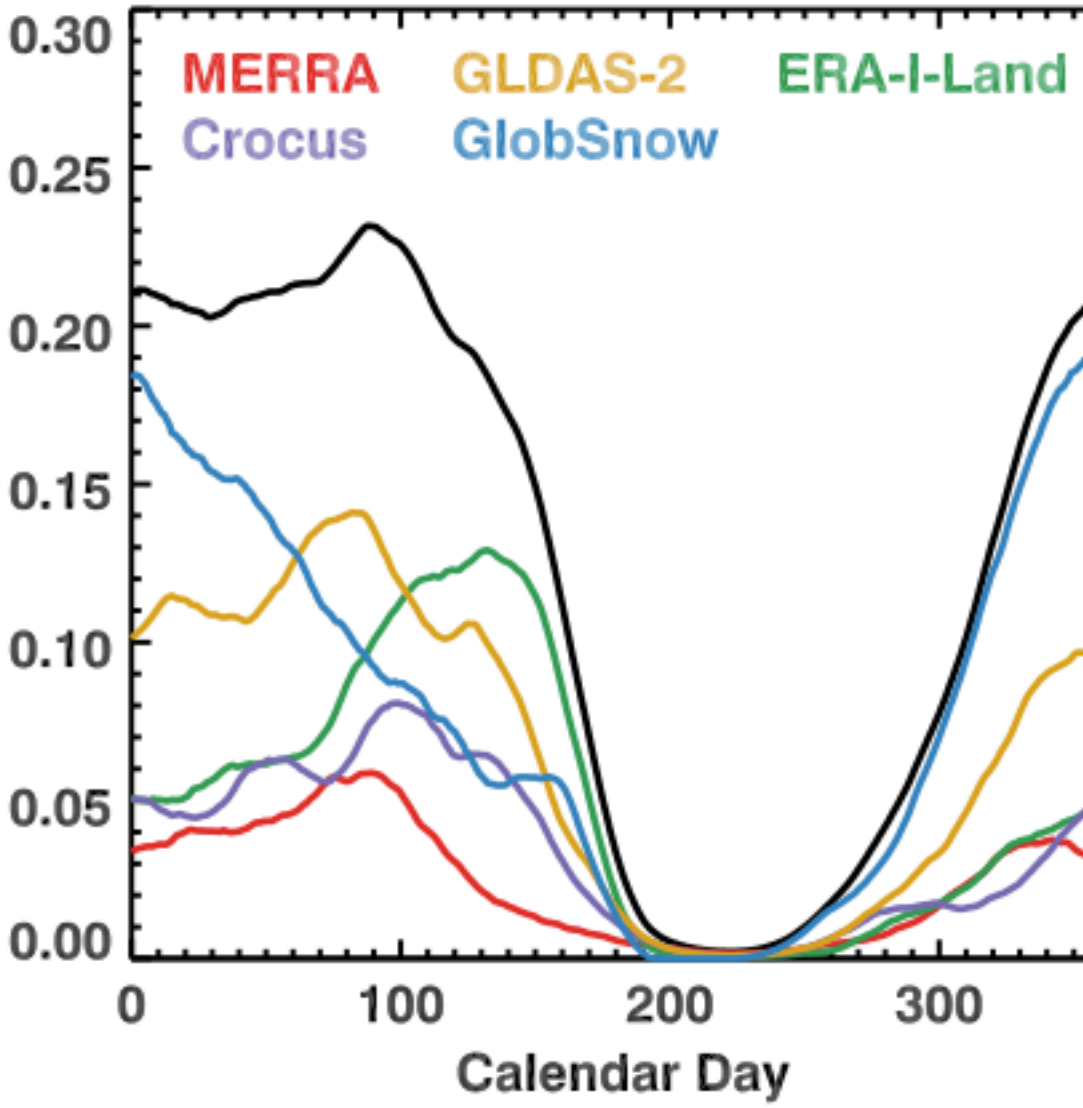
NA

EU

NH Interproduct Spread

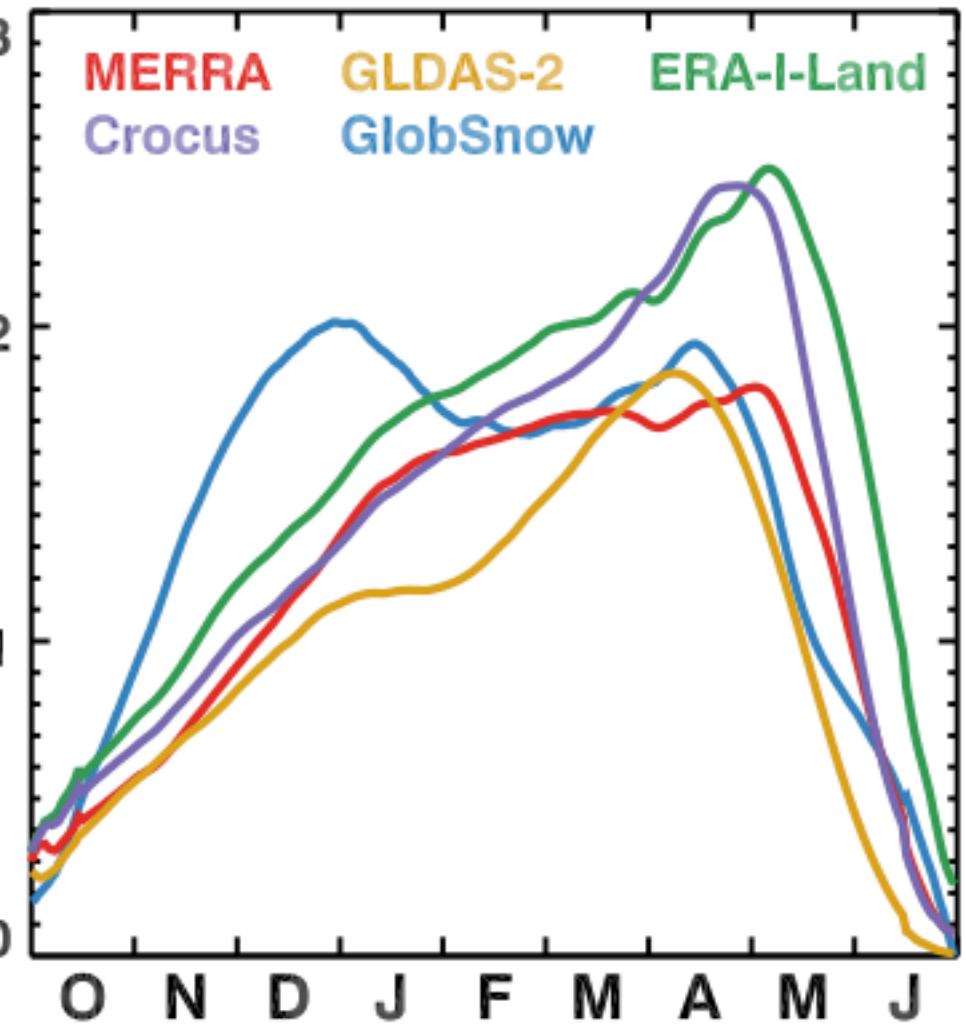


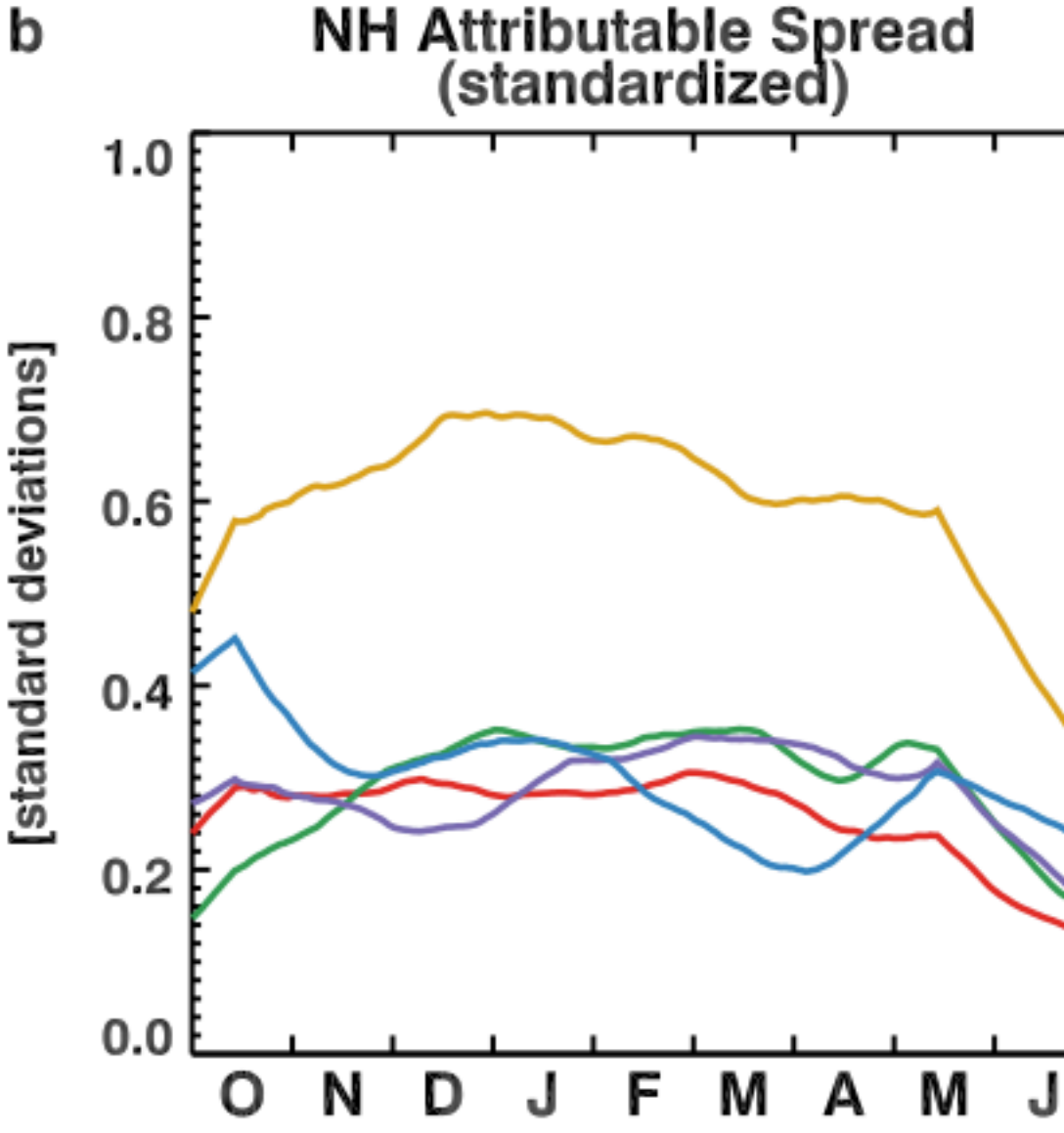
NH Attributable Spread



Spread among products is

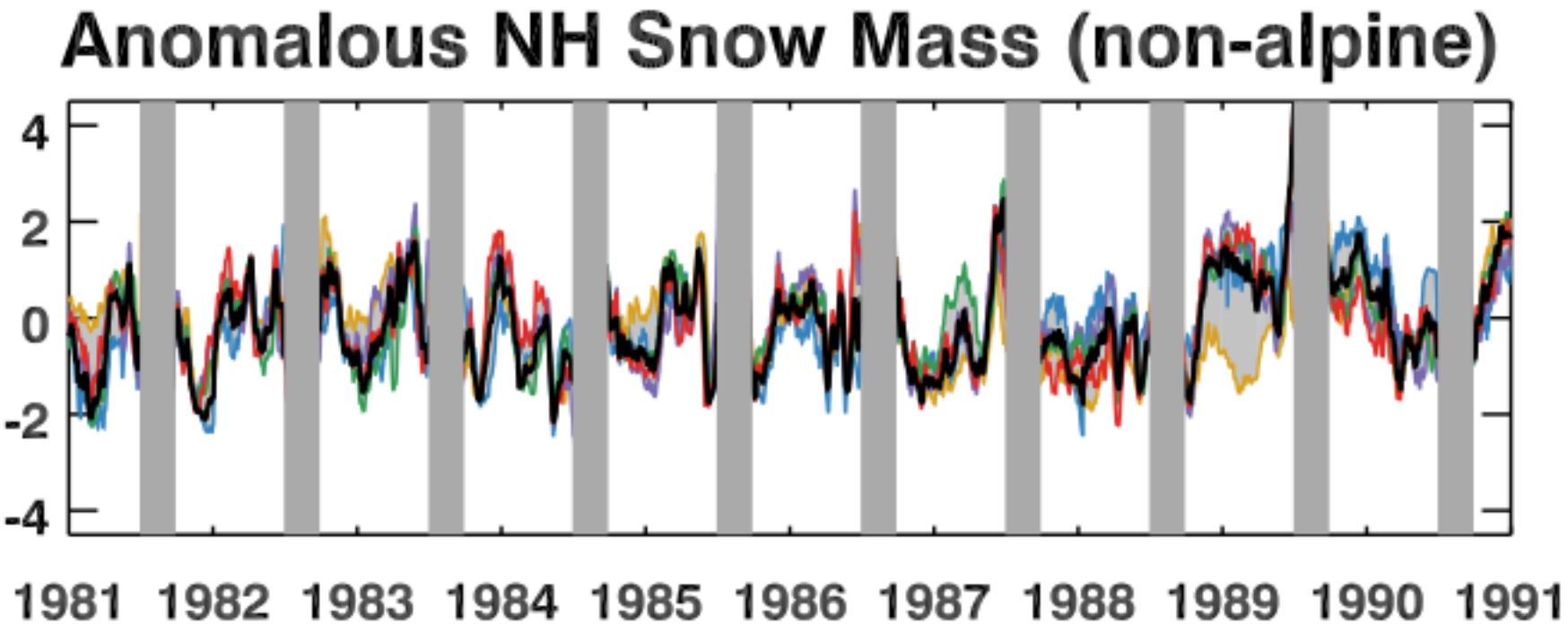
- GLDAS and GlobSnow togeth

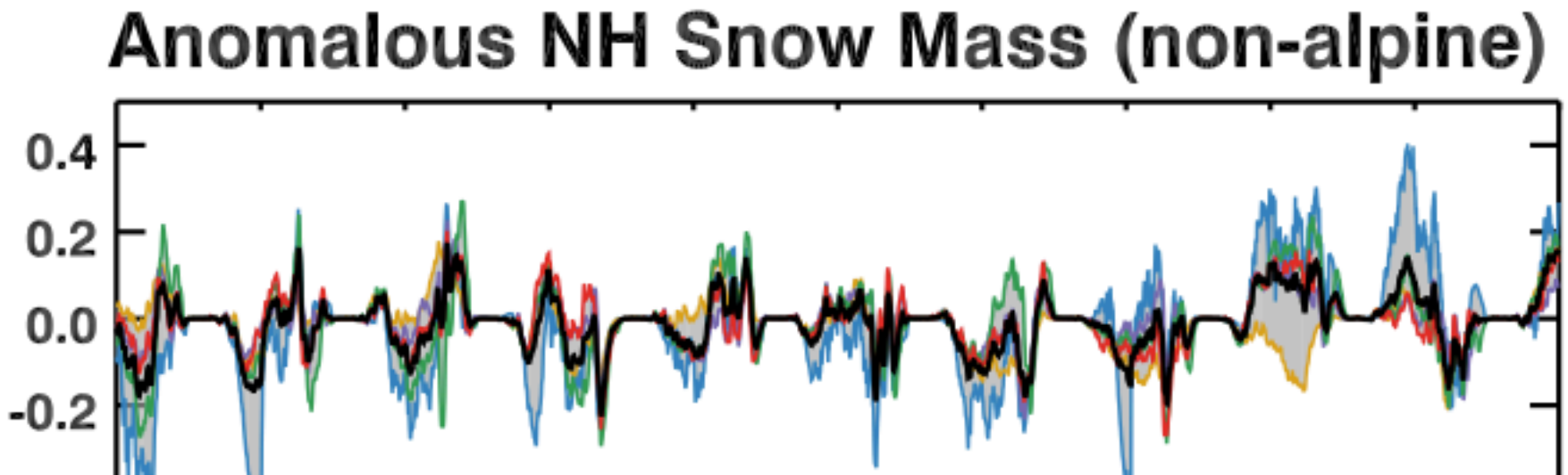




- Accounting for relative sizes o

Standardized vs Raw Anomalies



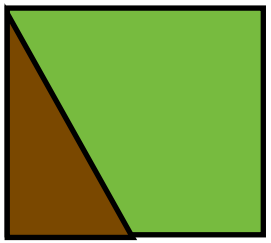


eatment of Alpine vs Non-alpine Regions

obSnow is unreliable in complex terrain like Alpine regions

non-alpine grid cell

mixed grid cell



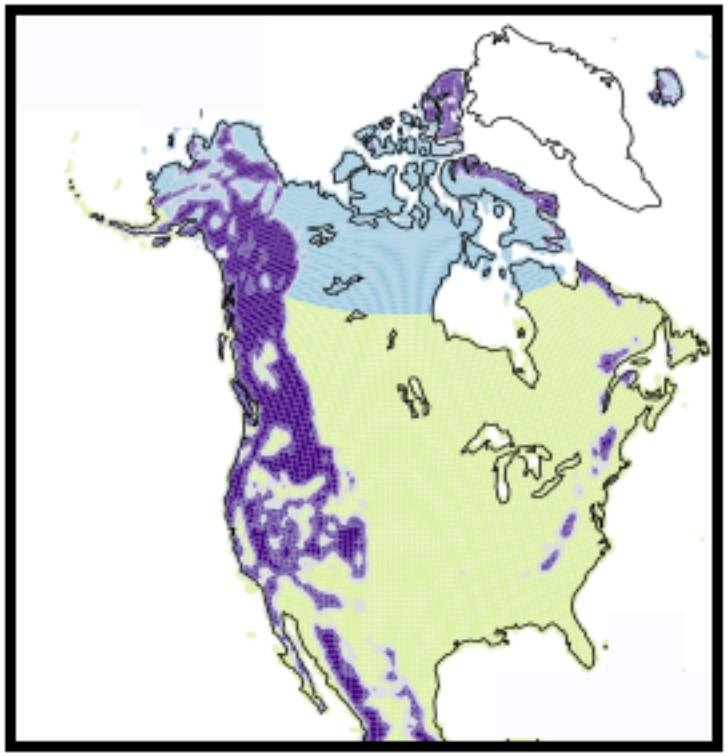
alpine grid cell

nweighted average
cluding GlobSnow

Unweighted averag
excluding GlobSno

1. partition snow by area into alpine + non-alpine
2. average SWE in each land type

Total Snow Water Mass
summed over continent



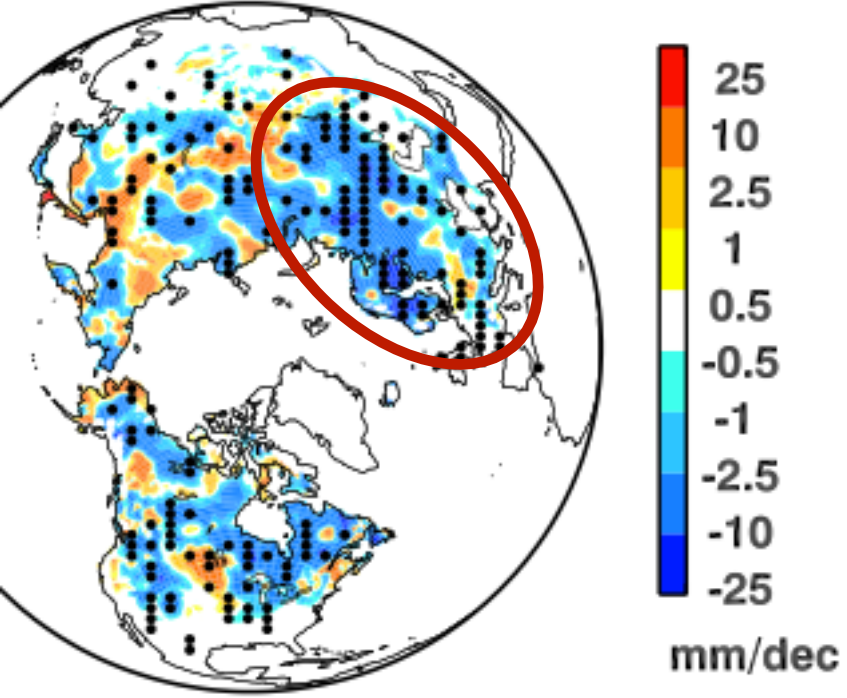
Northern Hemisphere
North America
Eurasia

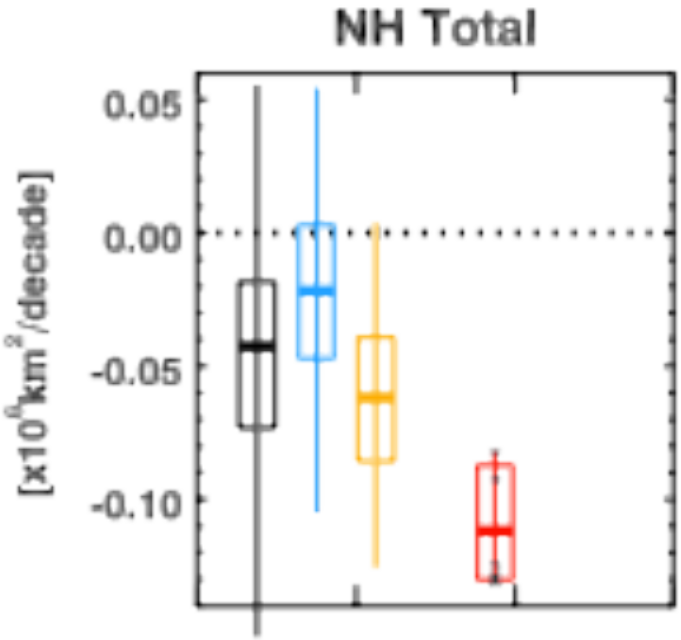
3 land types:

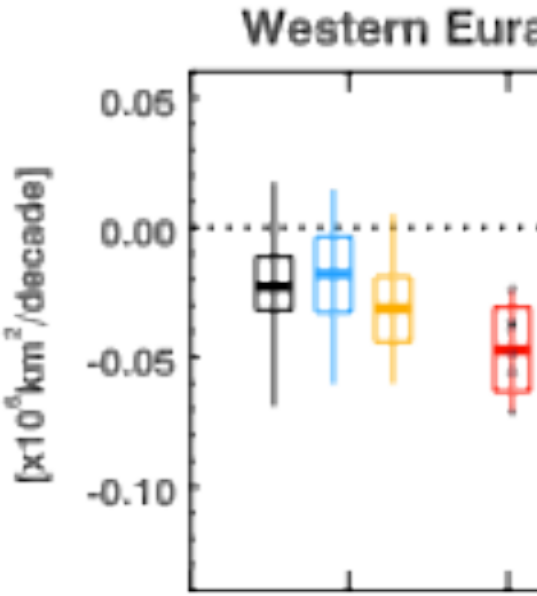
mid-latitudes
arctic
alpine

For a given SWM time series we construct daily climatologies, anomalie

comparisons with model output



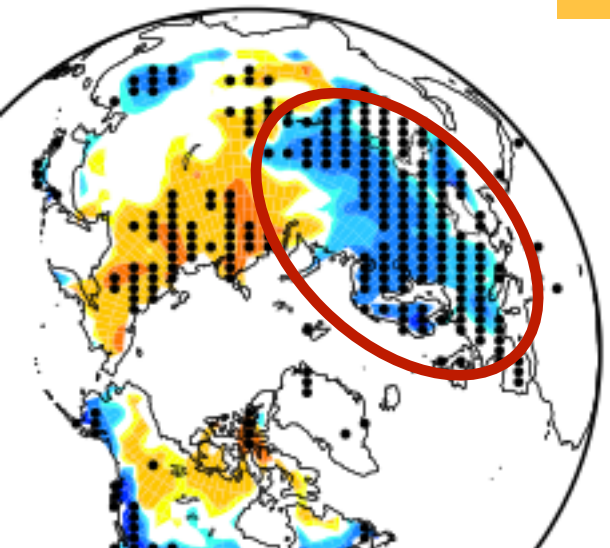


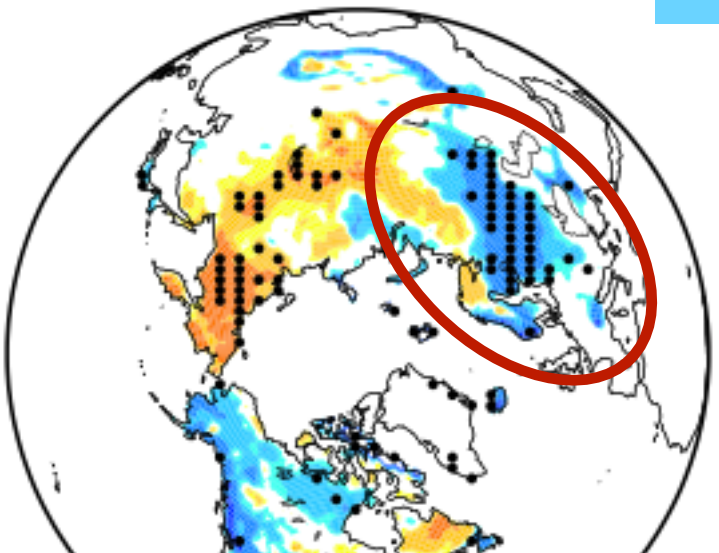


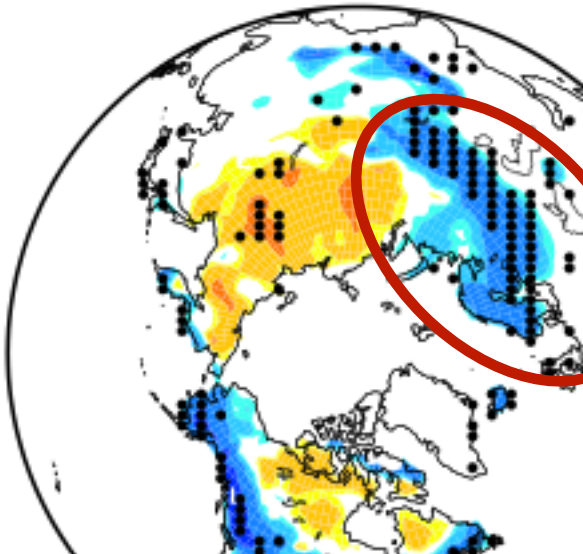
CanESM (50)

CESM (30)

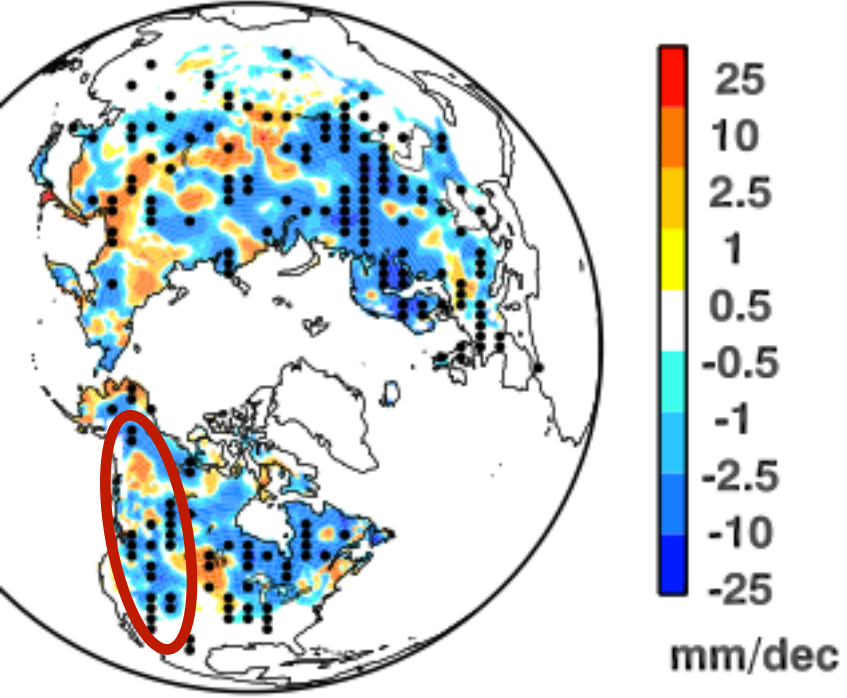
CCSM (40)

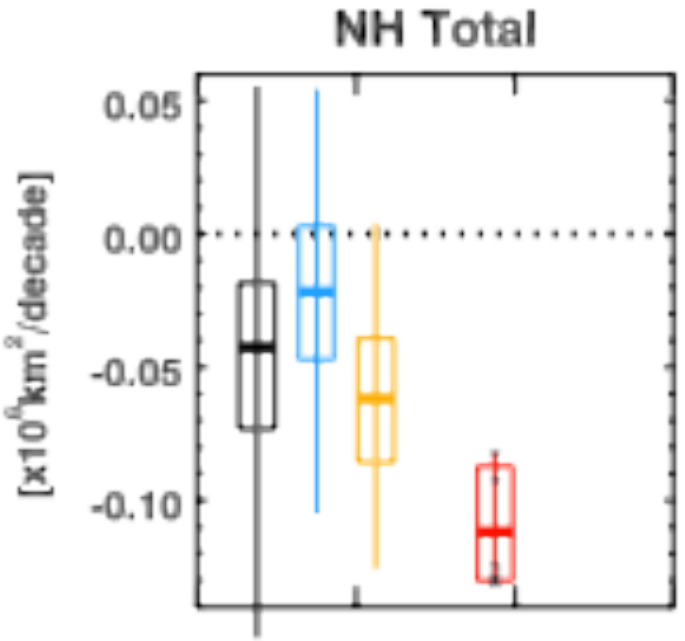


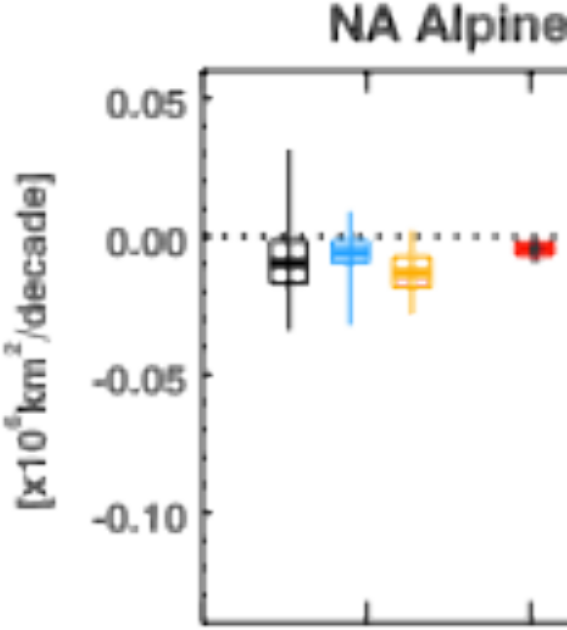




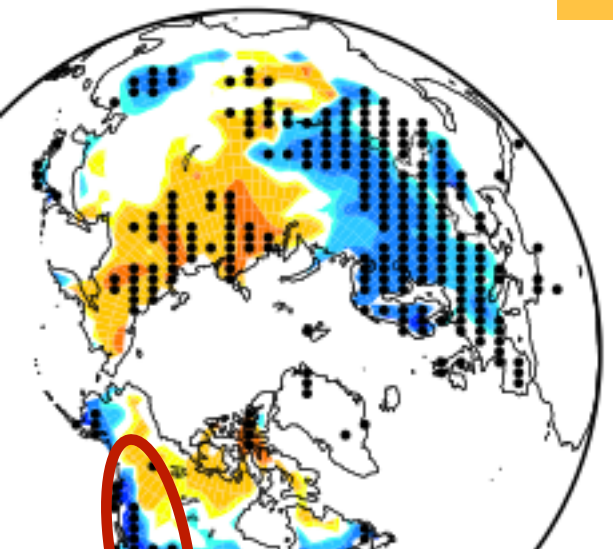
comparisons with model output



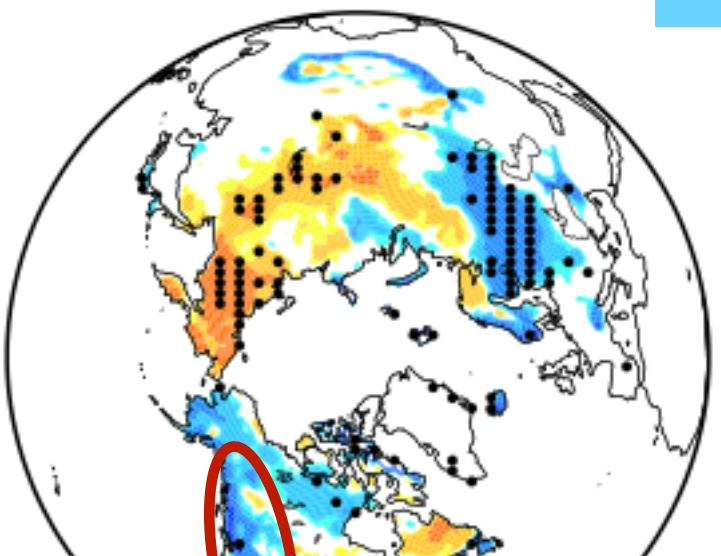




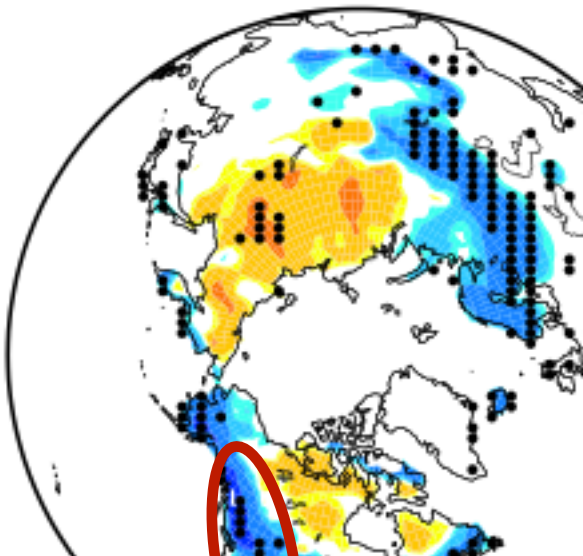
CanESM (50)



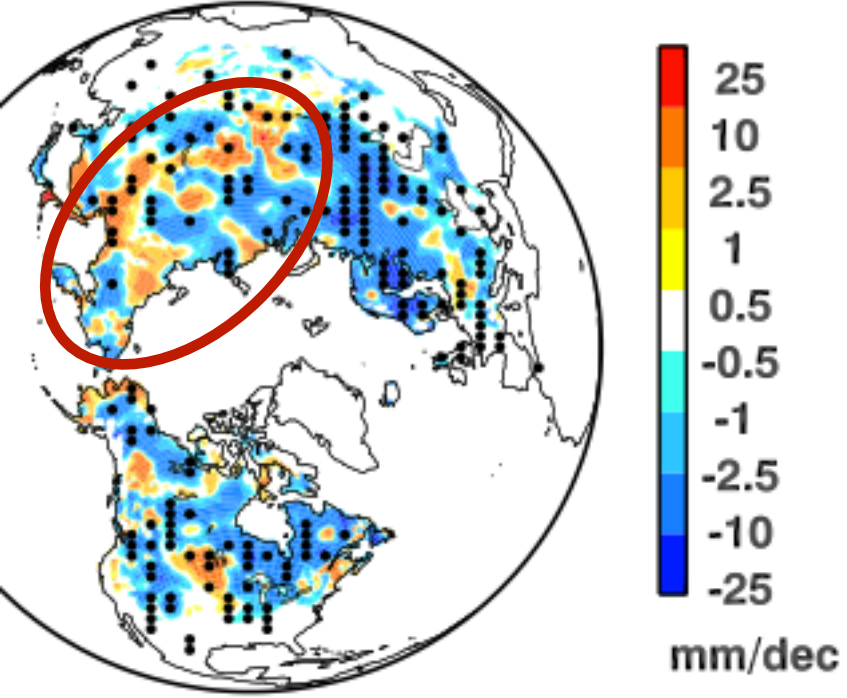
CESM (30)

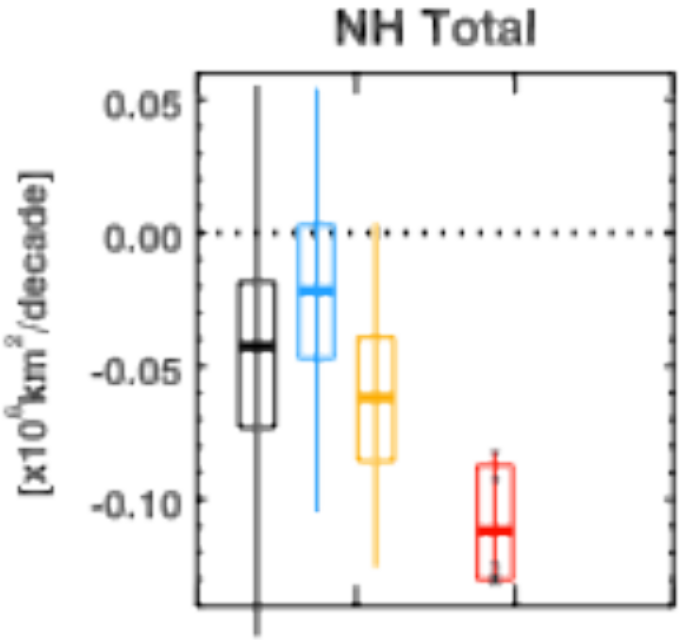


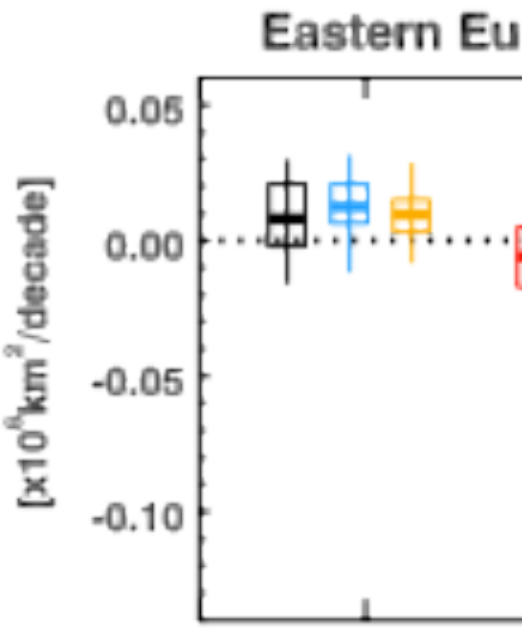
CCSM (40)



comparisons with model output



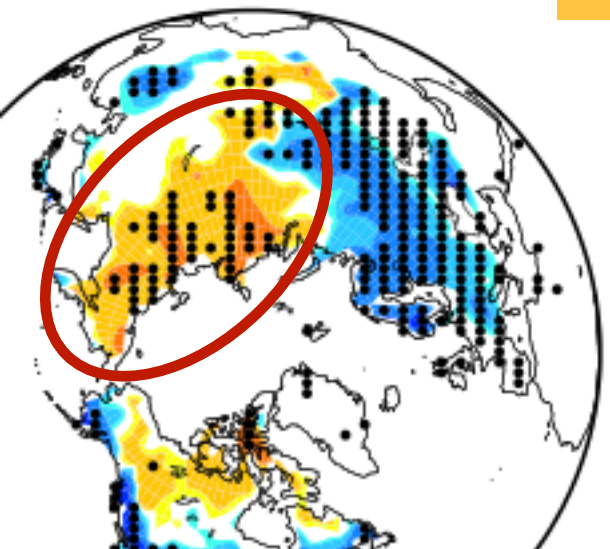


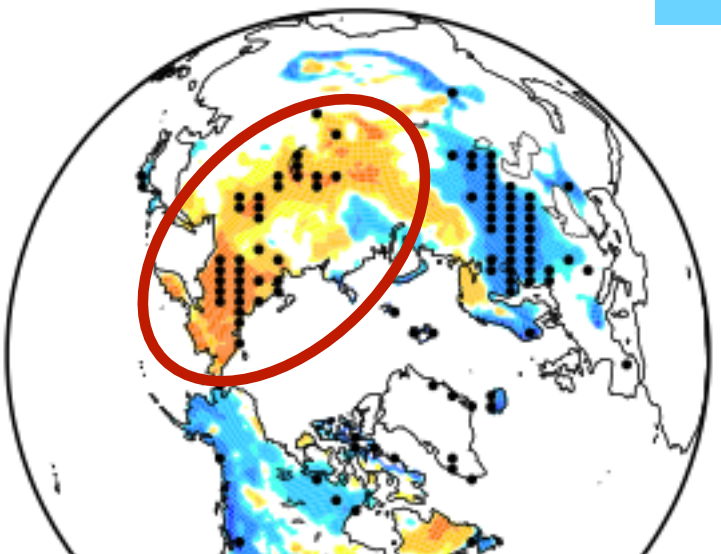


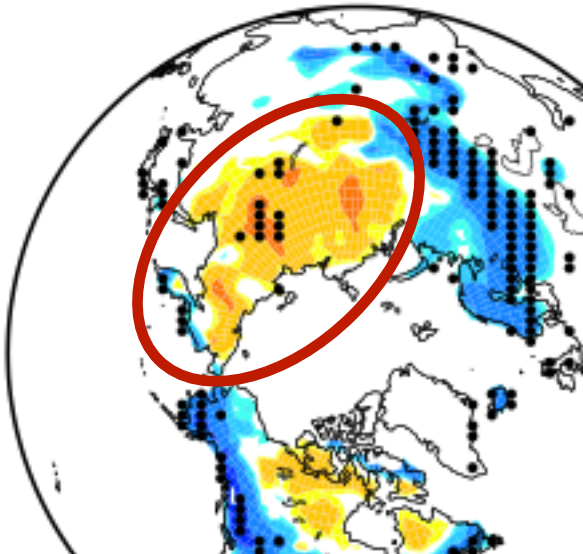
CanESM (50)

CESM (30)

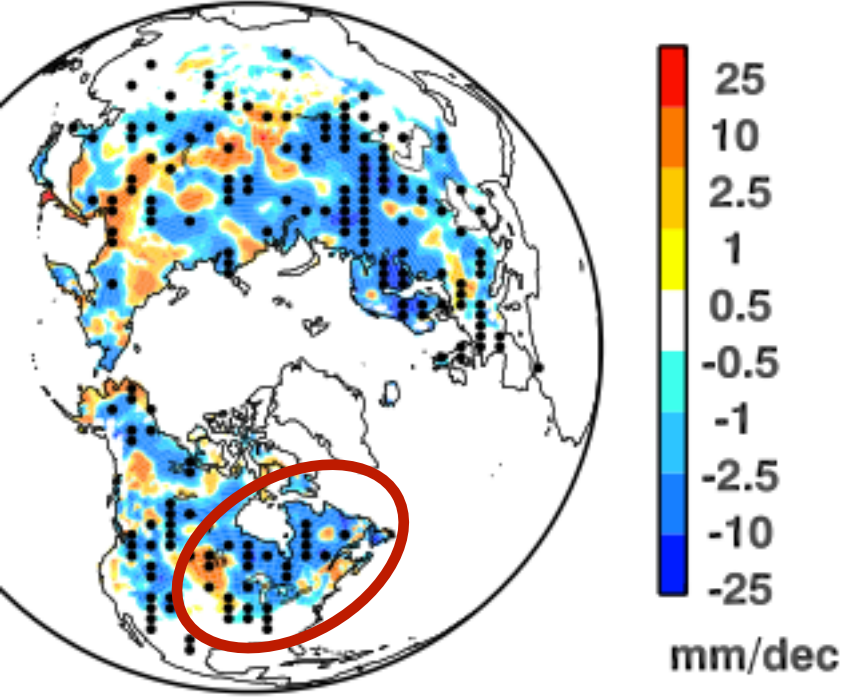
CCSM (40)

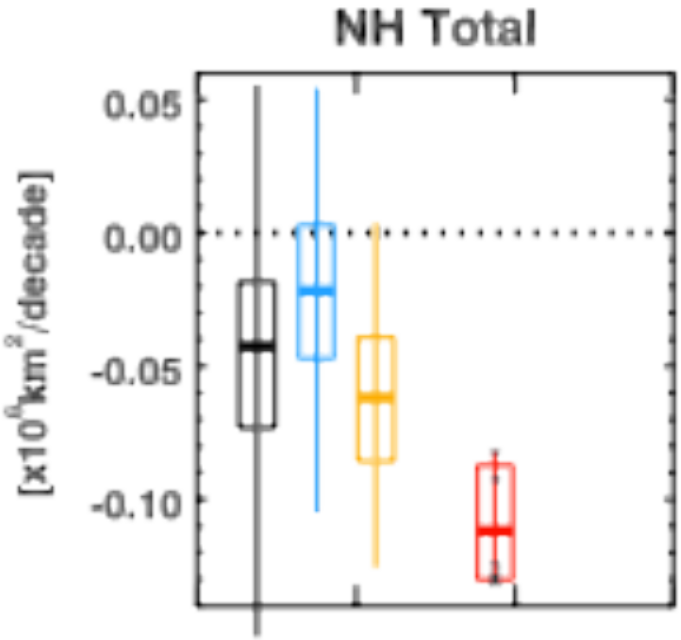


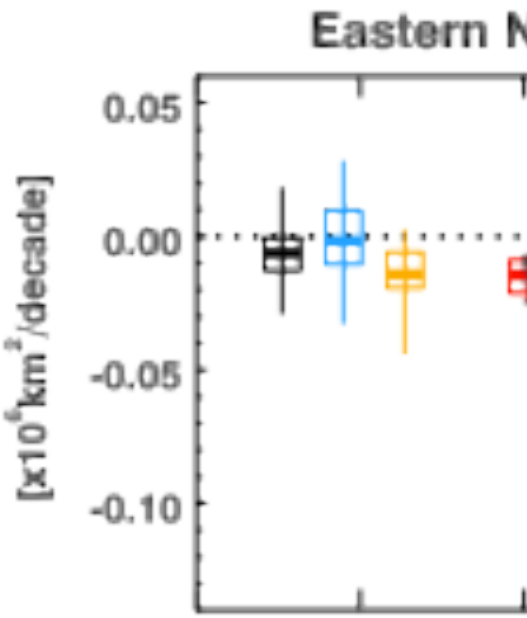




comparisons with model output



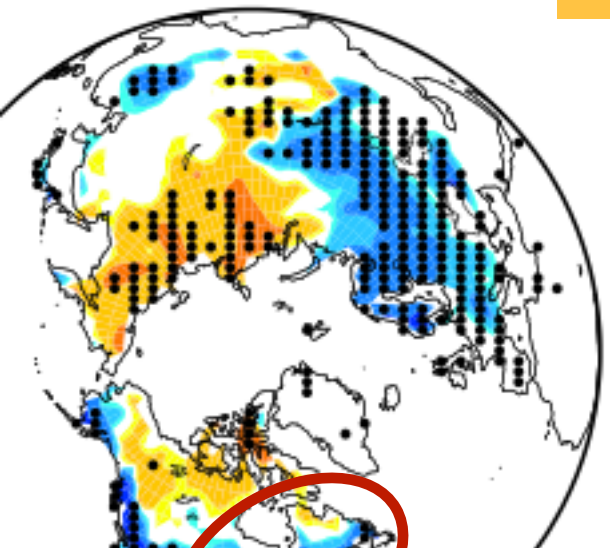


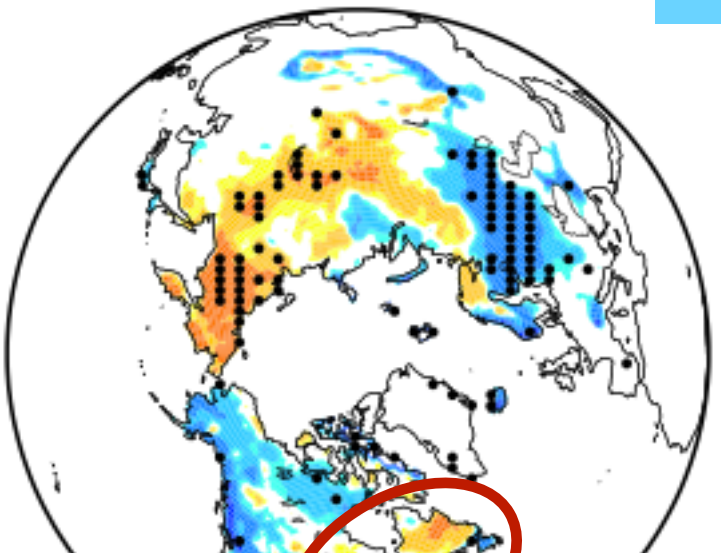


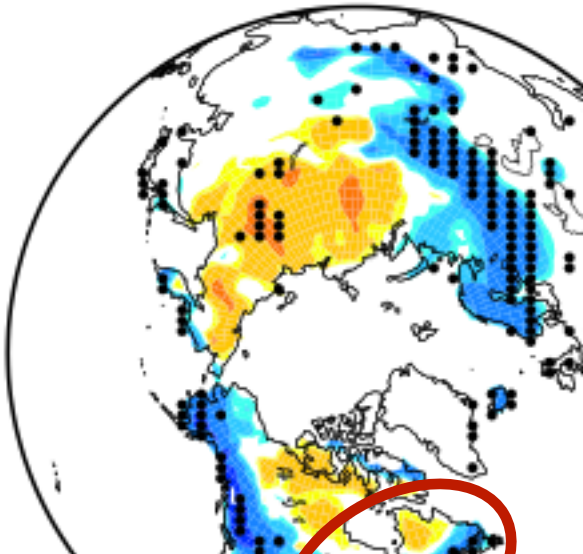
CanESM (50)

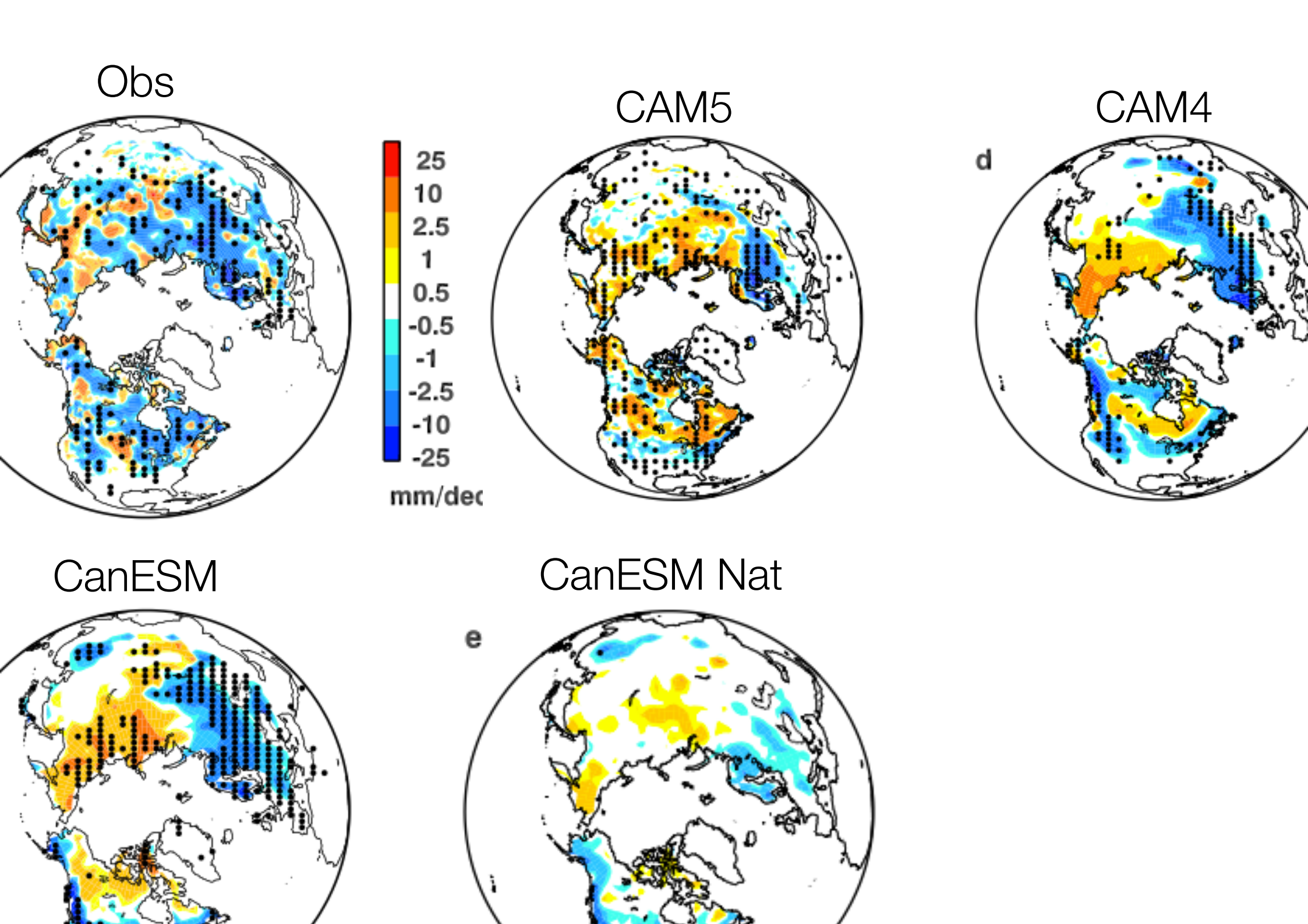
CESM (30)

CCSM (40)








Obs
CAM5
CAM4
d
25
10
2.5
1
0.5
-0.5
-1
-2.5
-10
-25
mm/dec
CanESM
CanESM Nat
e

LDAS-2 problems