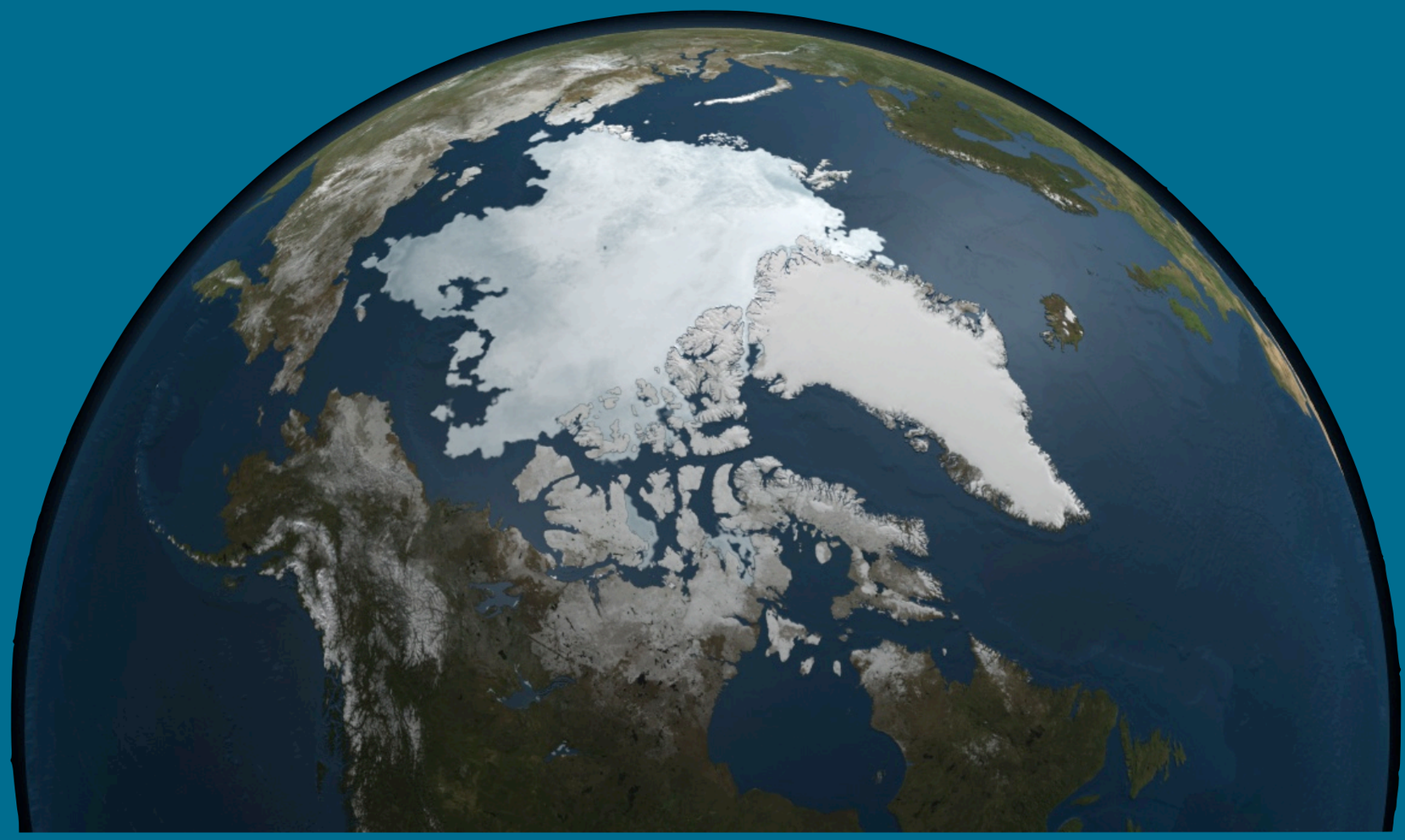
Seasonal predictions of Arctic sea ice

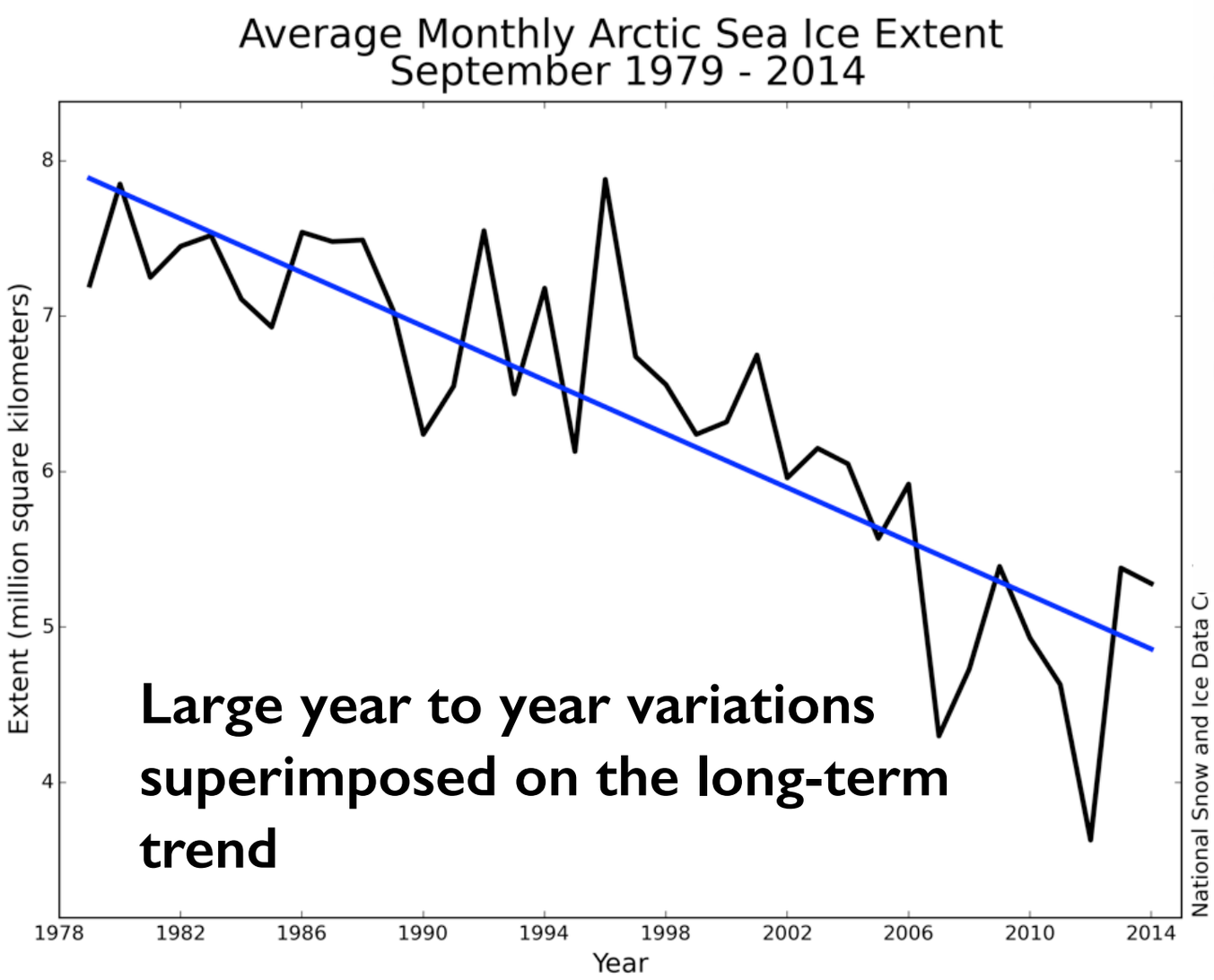
Rym Msadek NOAA/GFDL

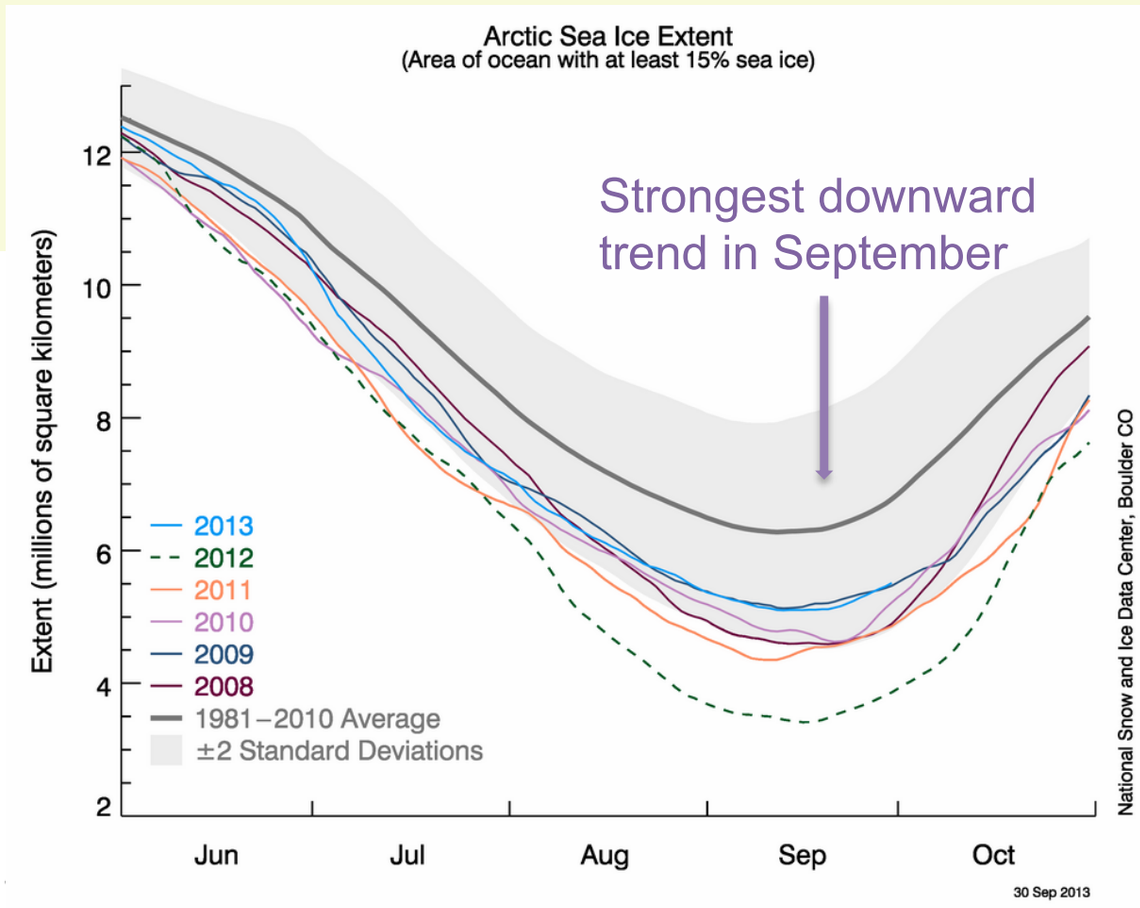
Collaborators: Gabe Vecchi (GFDL), Mike Winton (GFDL), Steffen Tietsche (Univ. Reading/ECMWF)



Application of seasonal to decadal climate predictions for marine resource management workshop - June 3-5

Motivation

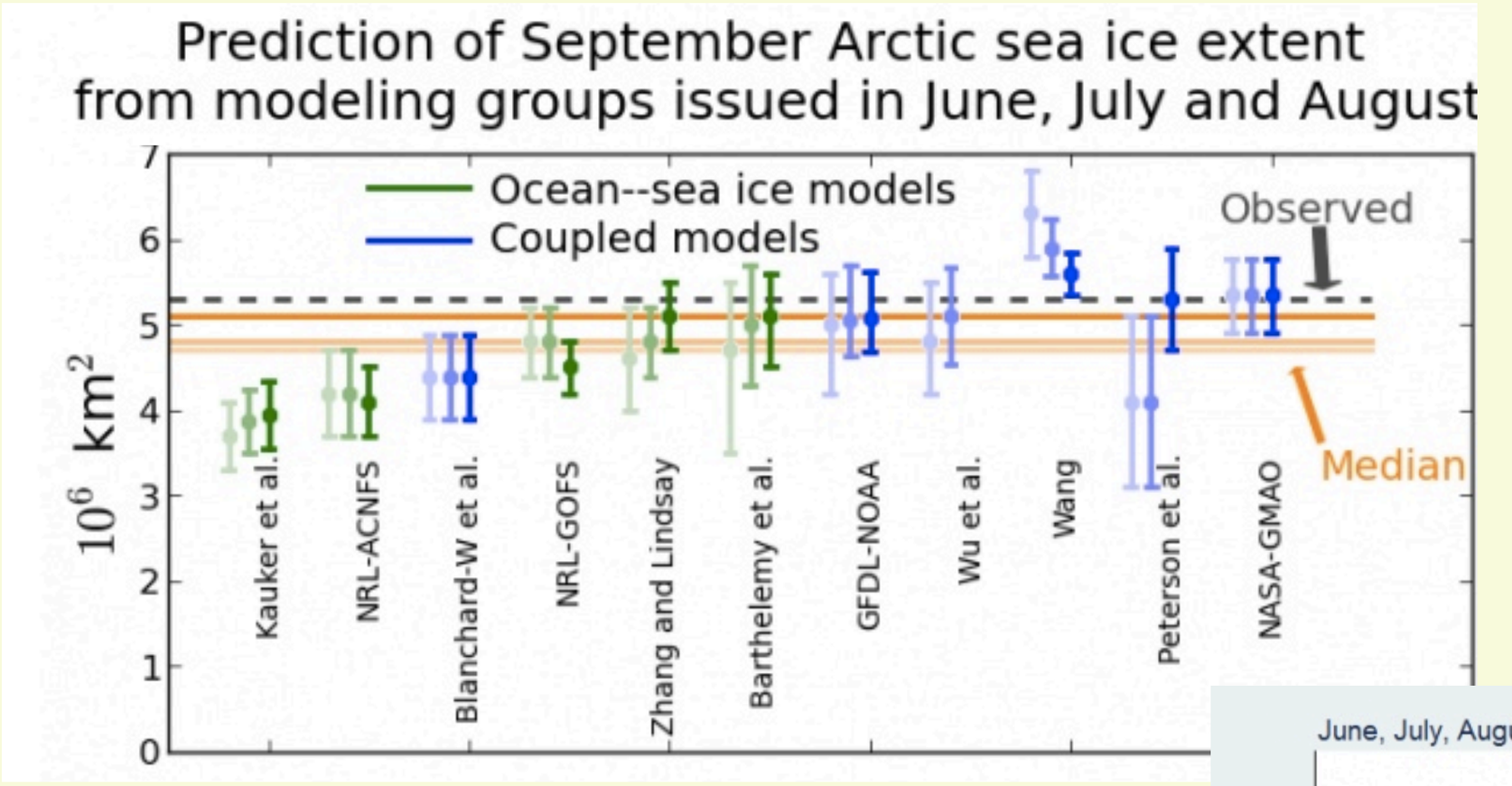




Are these variations predictable?
What are the driving mechanisms?

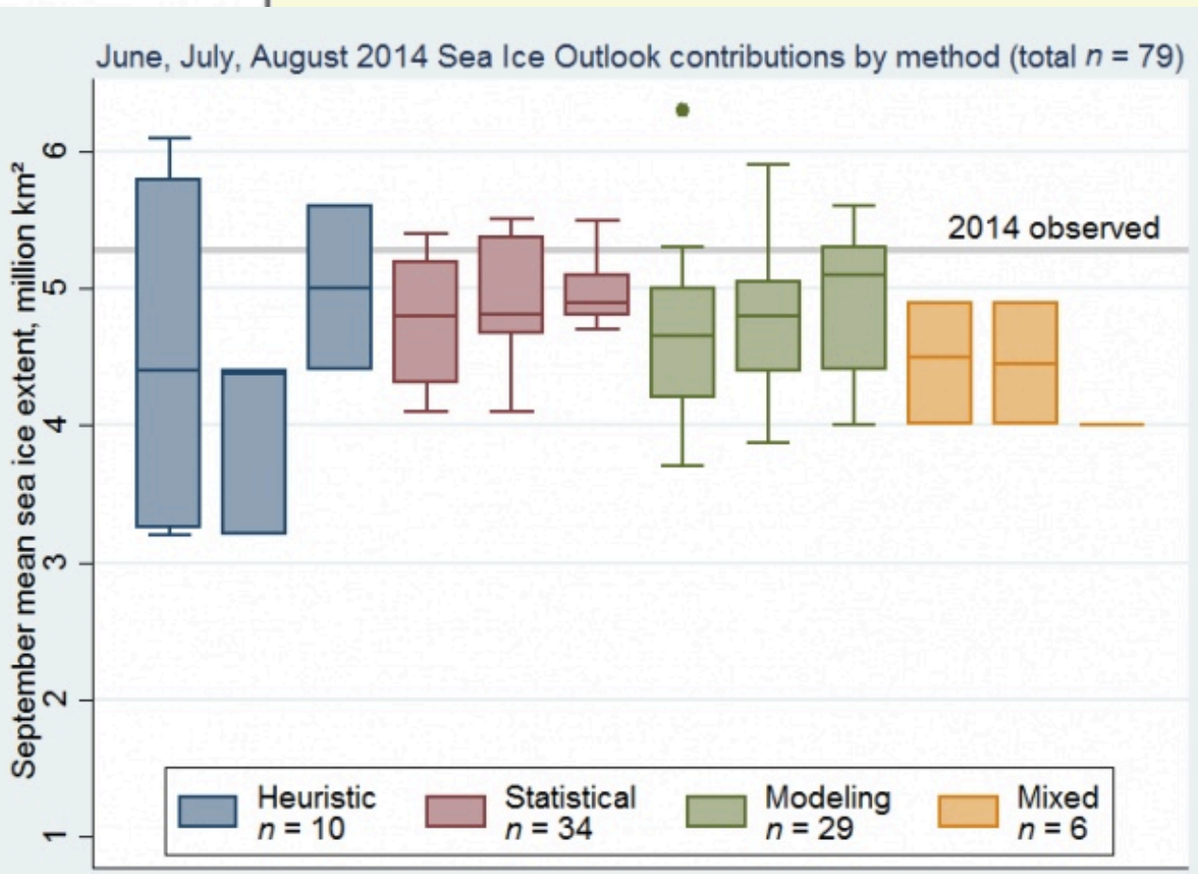
Sea Ice Prediction Network

Networking scientists and stakeholders to improve sea ice prediction in a changing Arctic



Contribution to the 2014 sea ice outlook

The median of the outlooks is a good prediction when the observed value is close to the trend (Stroeve et al. 2014)



http://www.arcus.org/sipn

GFDL forecast systems

Two suite of retrospective coupled predictions initialized every month (Jan. 1) since 1982 and run for 1 yr:

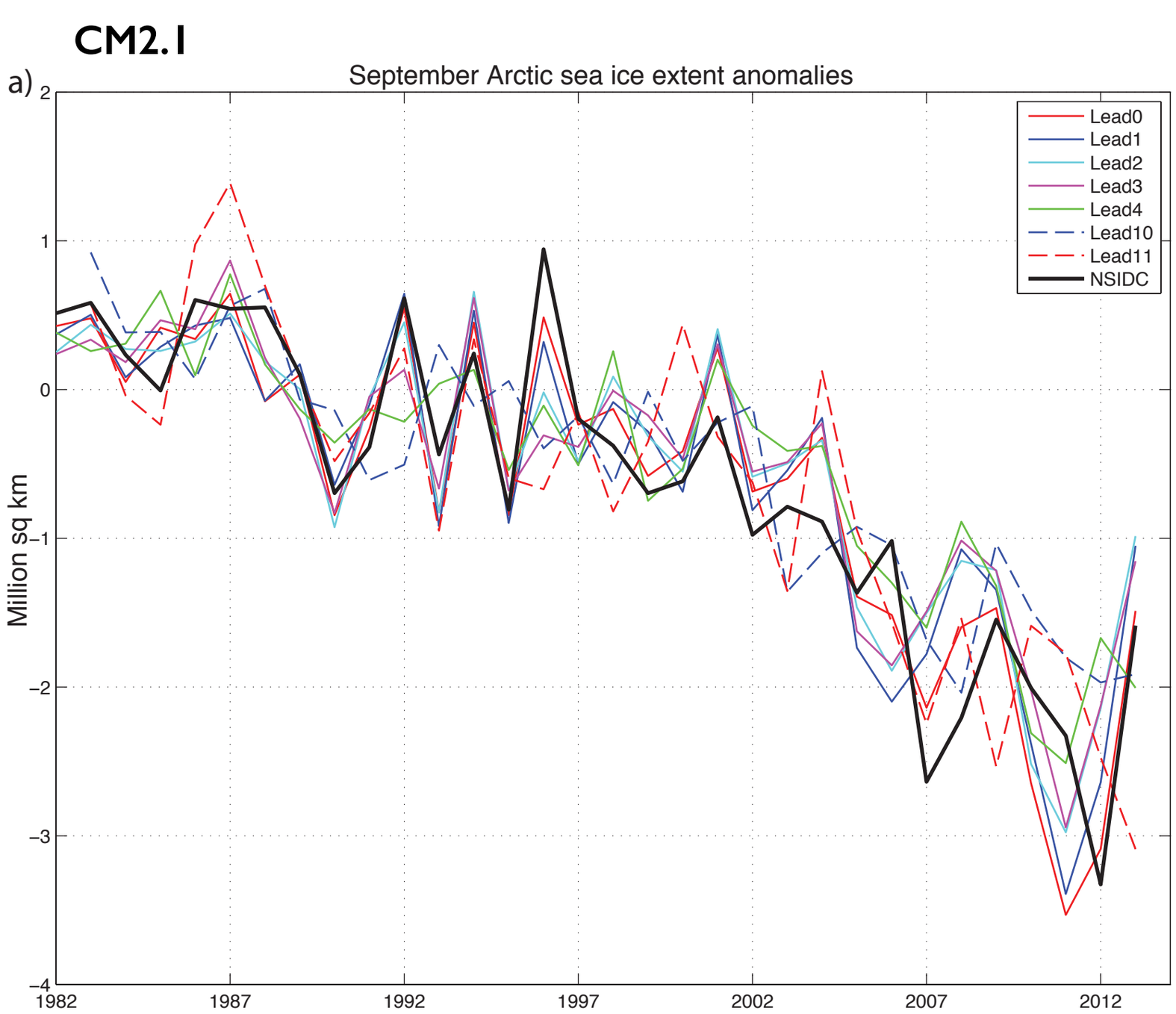
Same ocean (MOM4) and sea ice model (SIS), but different atmosphere:
-GFDL-CM2.1 low-res atmosphere (2°)
-GFDL-FLOR high-res atmosphere (50km cubed sphere)

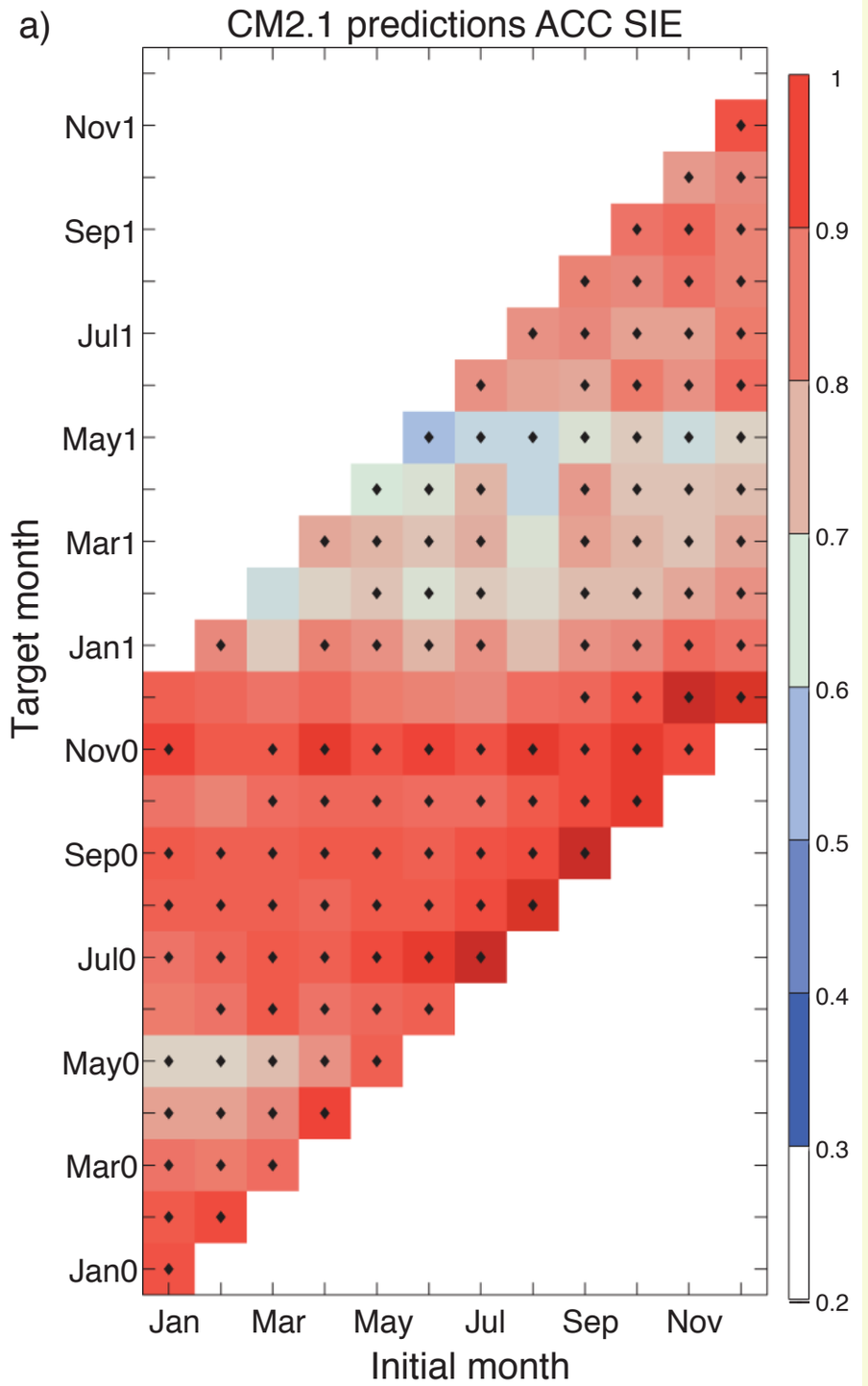
Same ocean/ice initial conditions:

Full field initialization using the GFDL ensemble coupled data assimilation ECDA (Zhang et al. 2007).
Ocean constrained by XBT, CTD, Argo, satellites.
Atmosphere constrained by NCEP.
Sea ice not directly assimilated

10-member ensemble
Historical radiative forcing prior to 2005. RCP4.5 after 2005

Skill of Pan Arctic sea ice extent



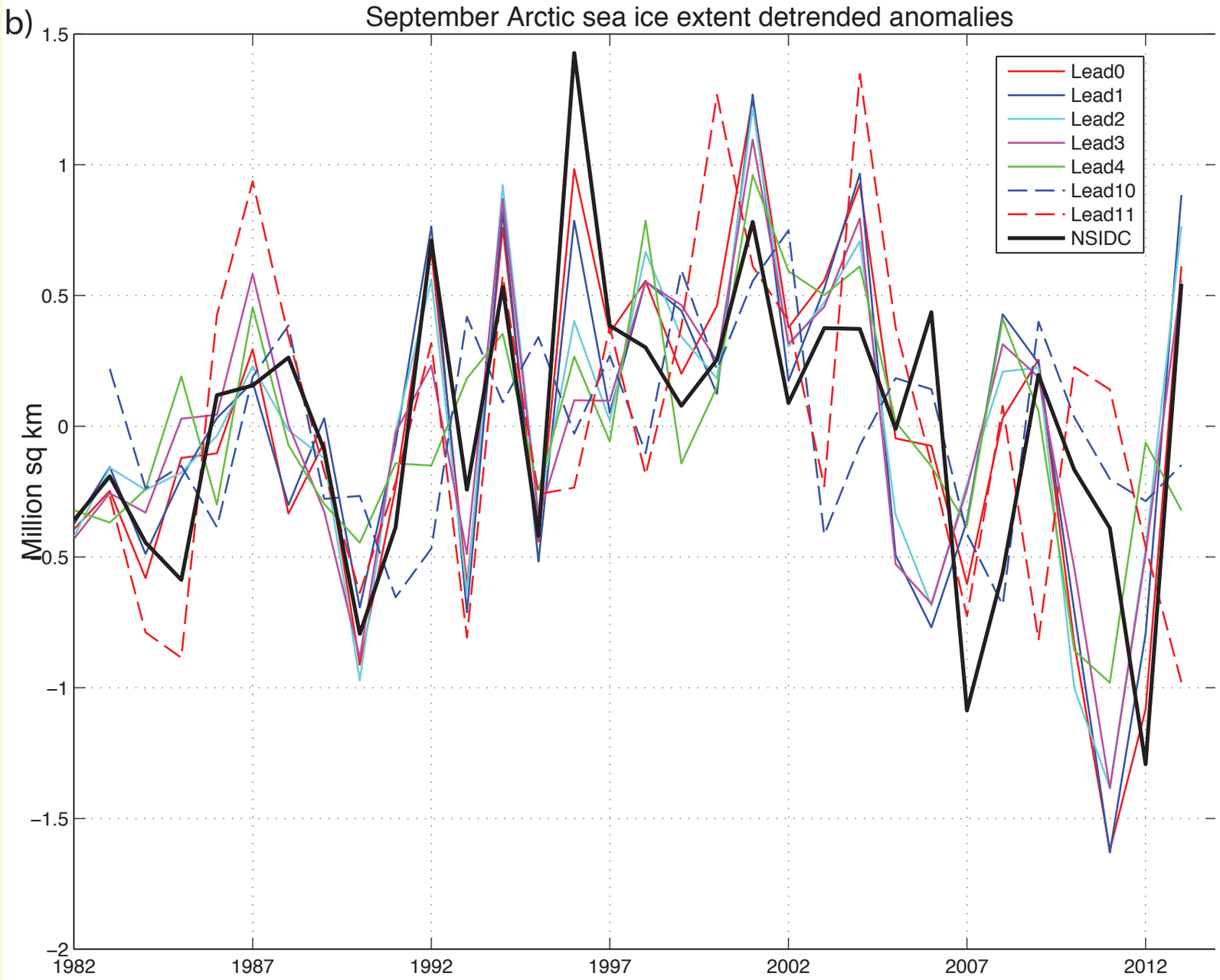


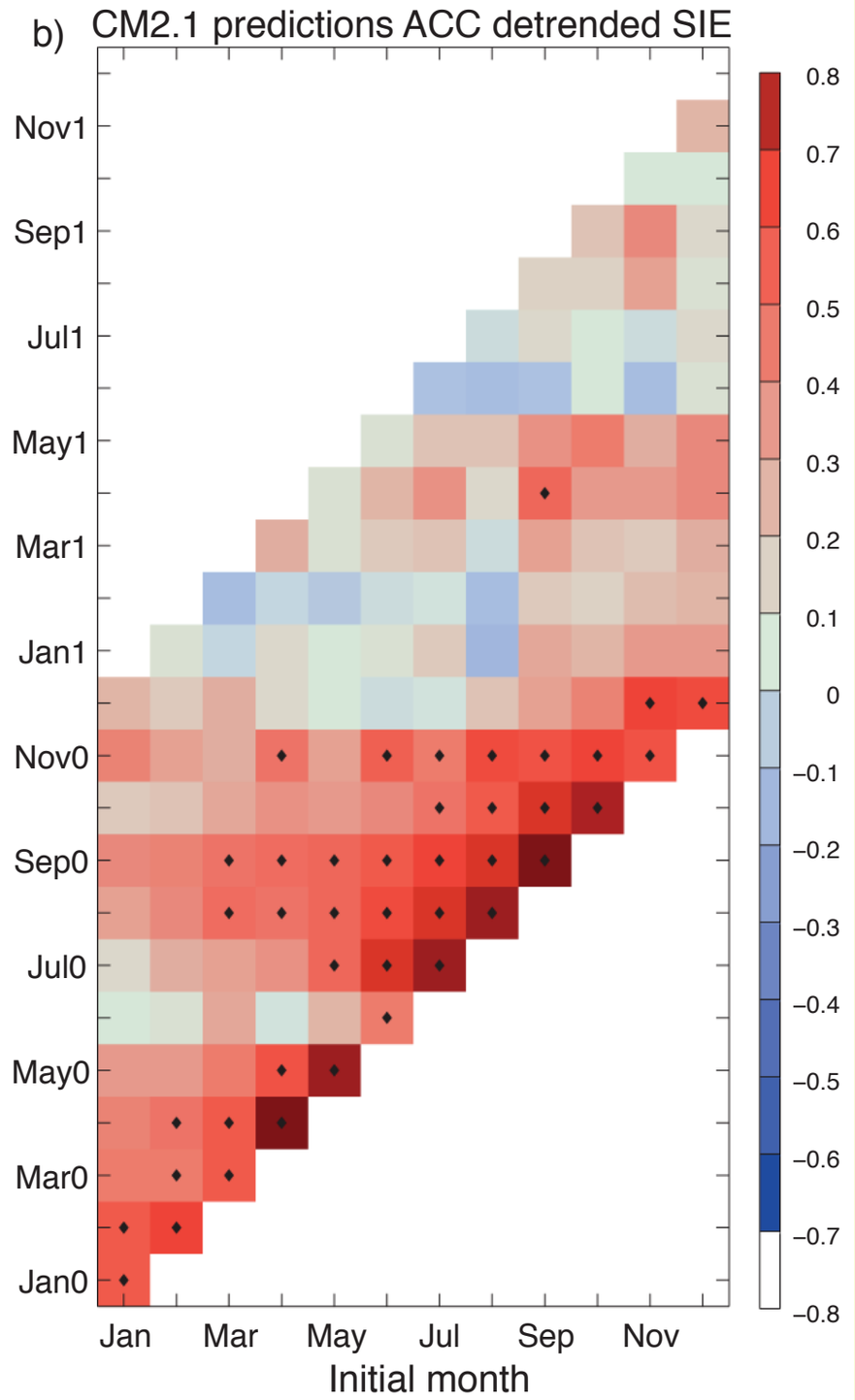
Most of the skill comes from the trend

Msadek et al. 2014

Skill of Pan Arctic sea ice extent

CM2.1

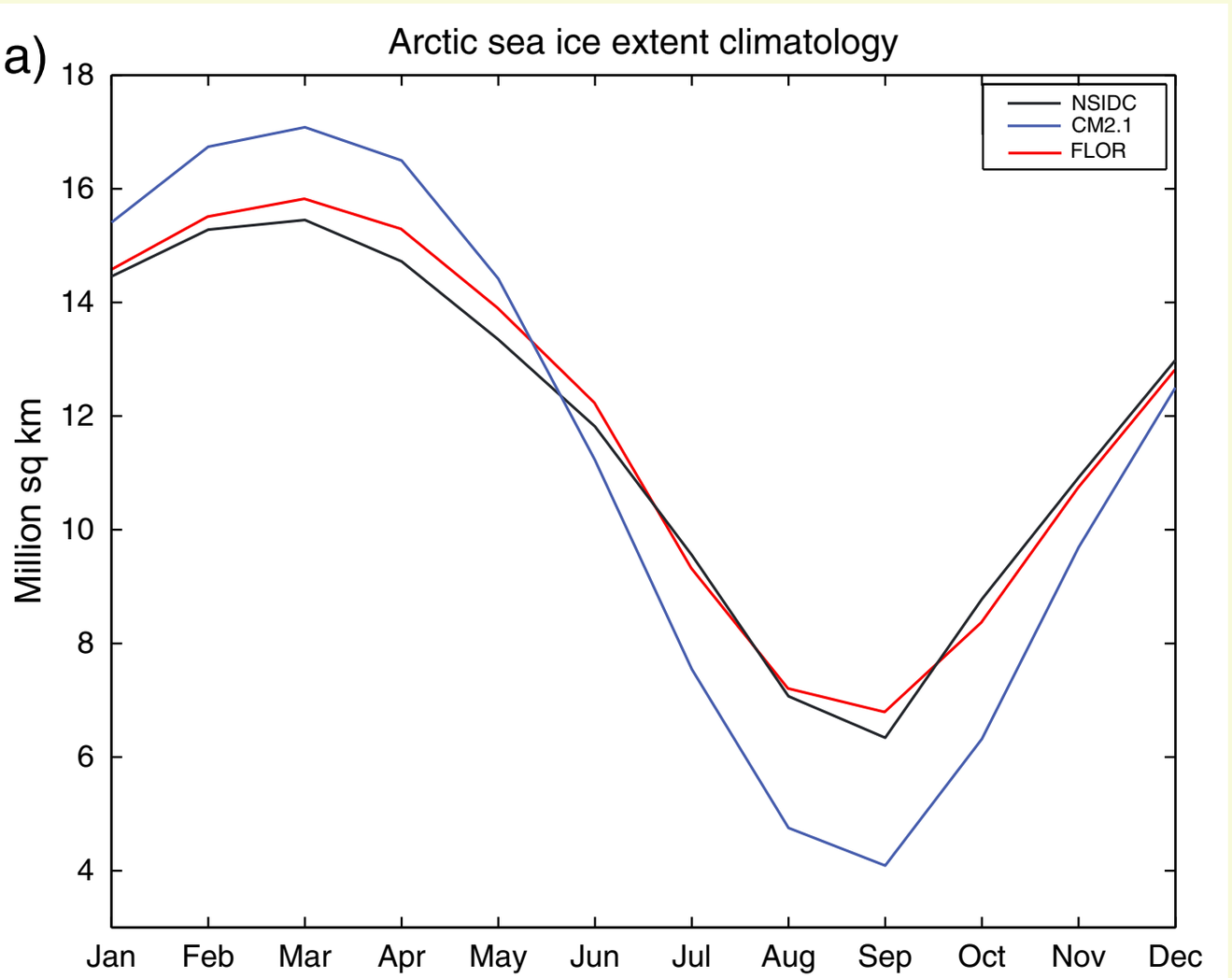




Msadek et al. 2014

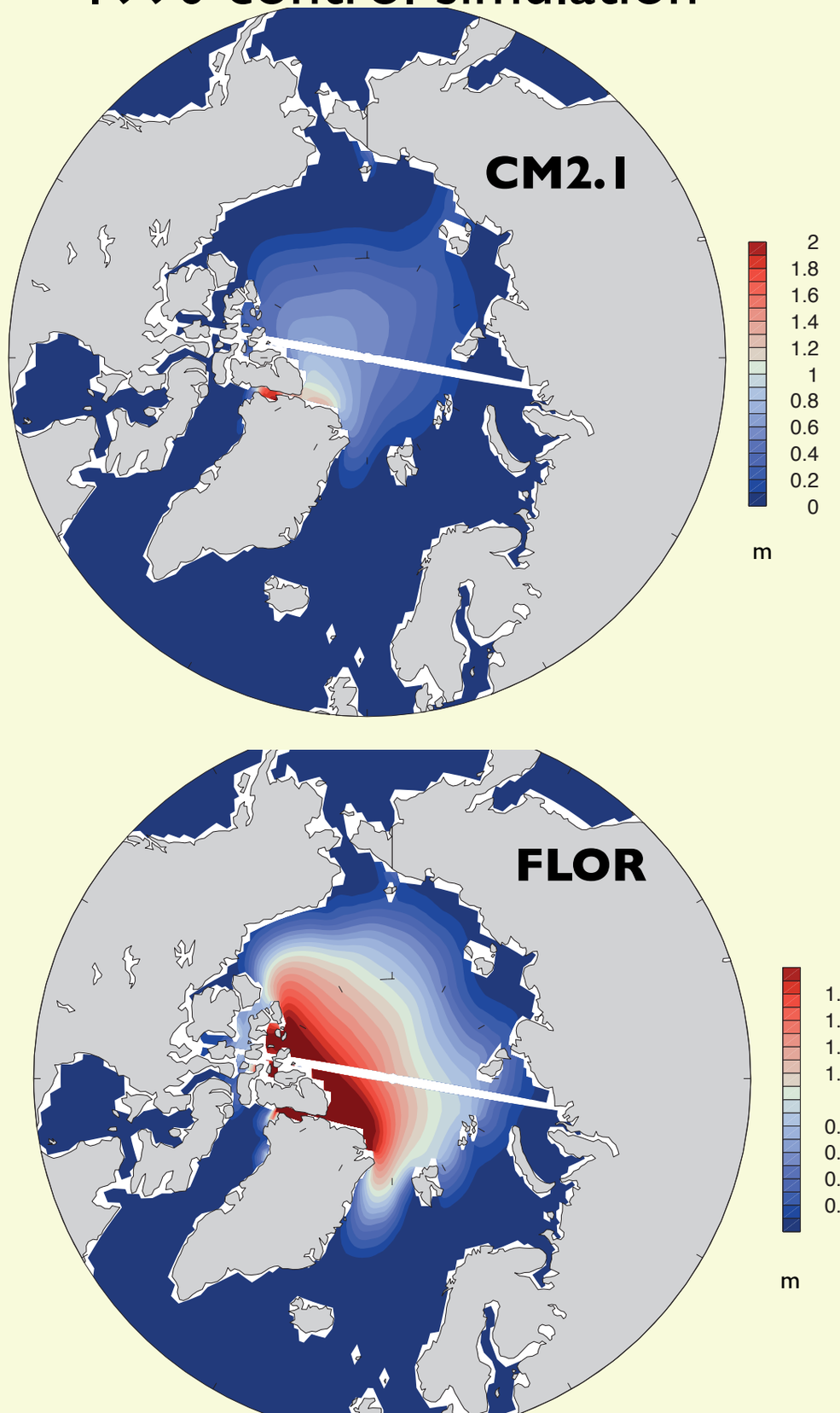
Significant skill in the year to year variations up to 6 month ahead for summer SIE

Mean state of CM2.1 and FLOR



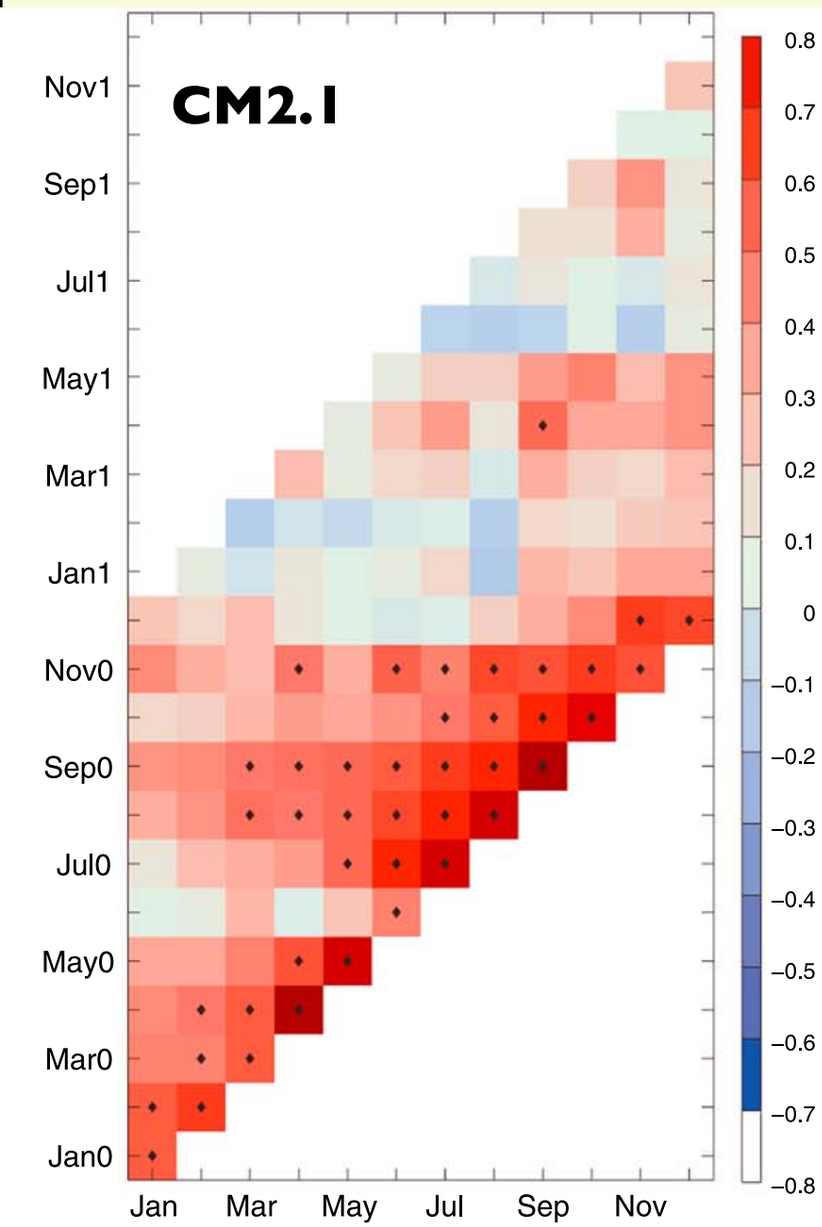
Better climatology of sea ice extent and thickness in the high-res model. Does it imply higher skill?

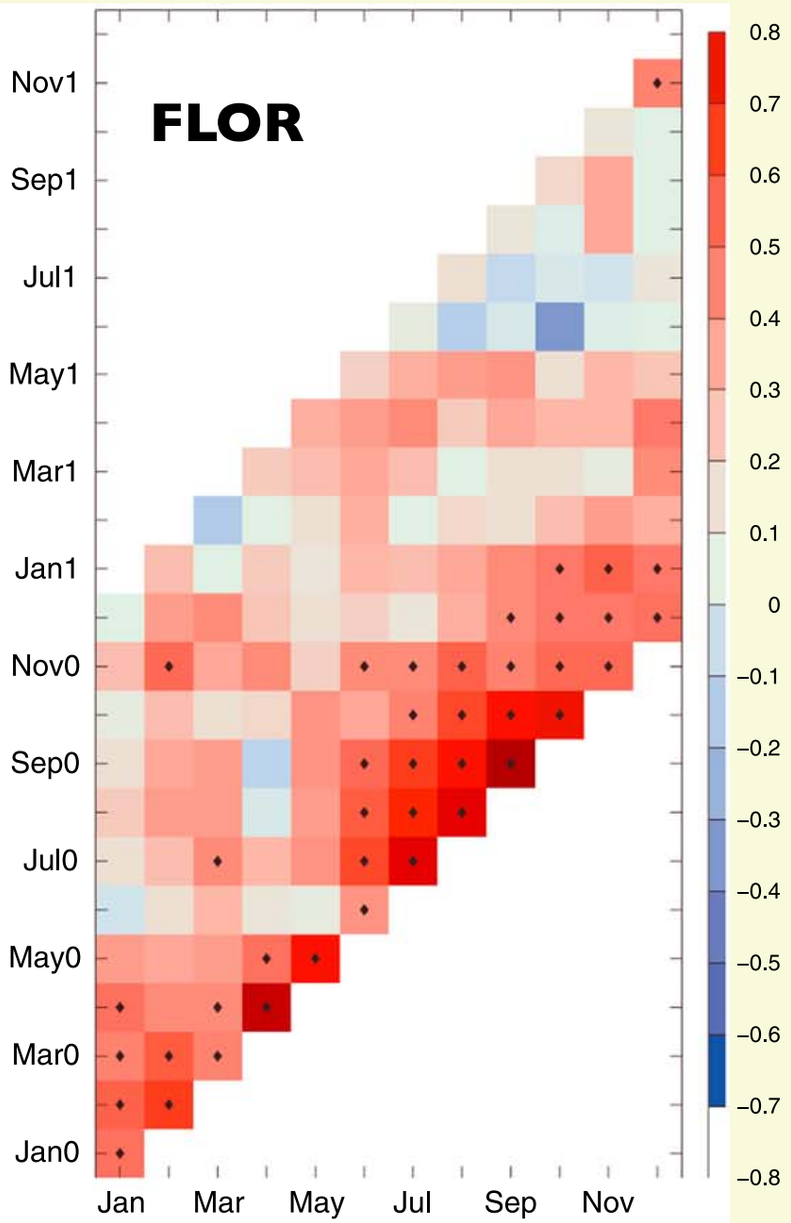
September thickness.
1990 control simulation



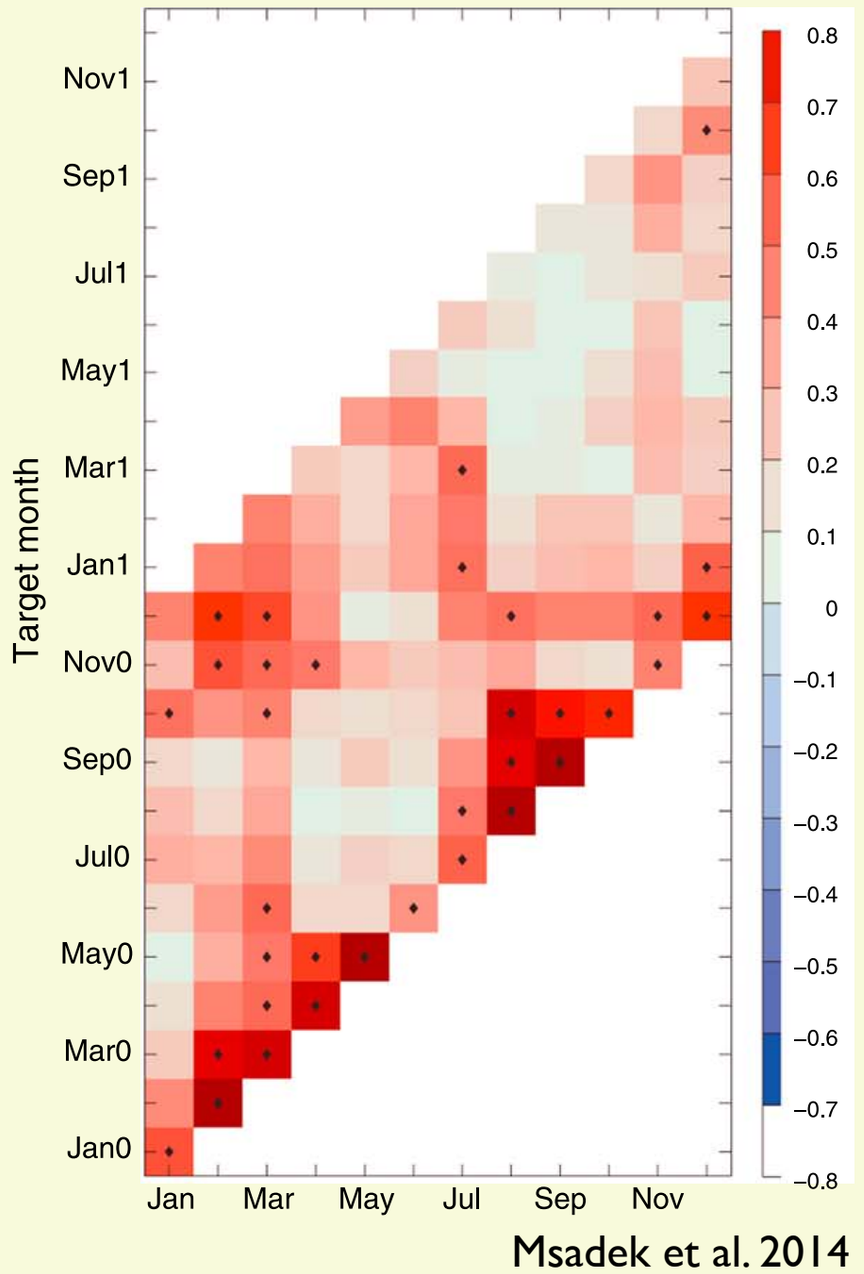
Skill of Pan Arctic sea ice extent

Biased corrected
Anomaly correlation





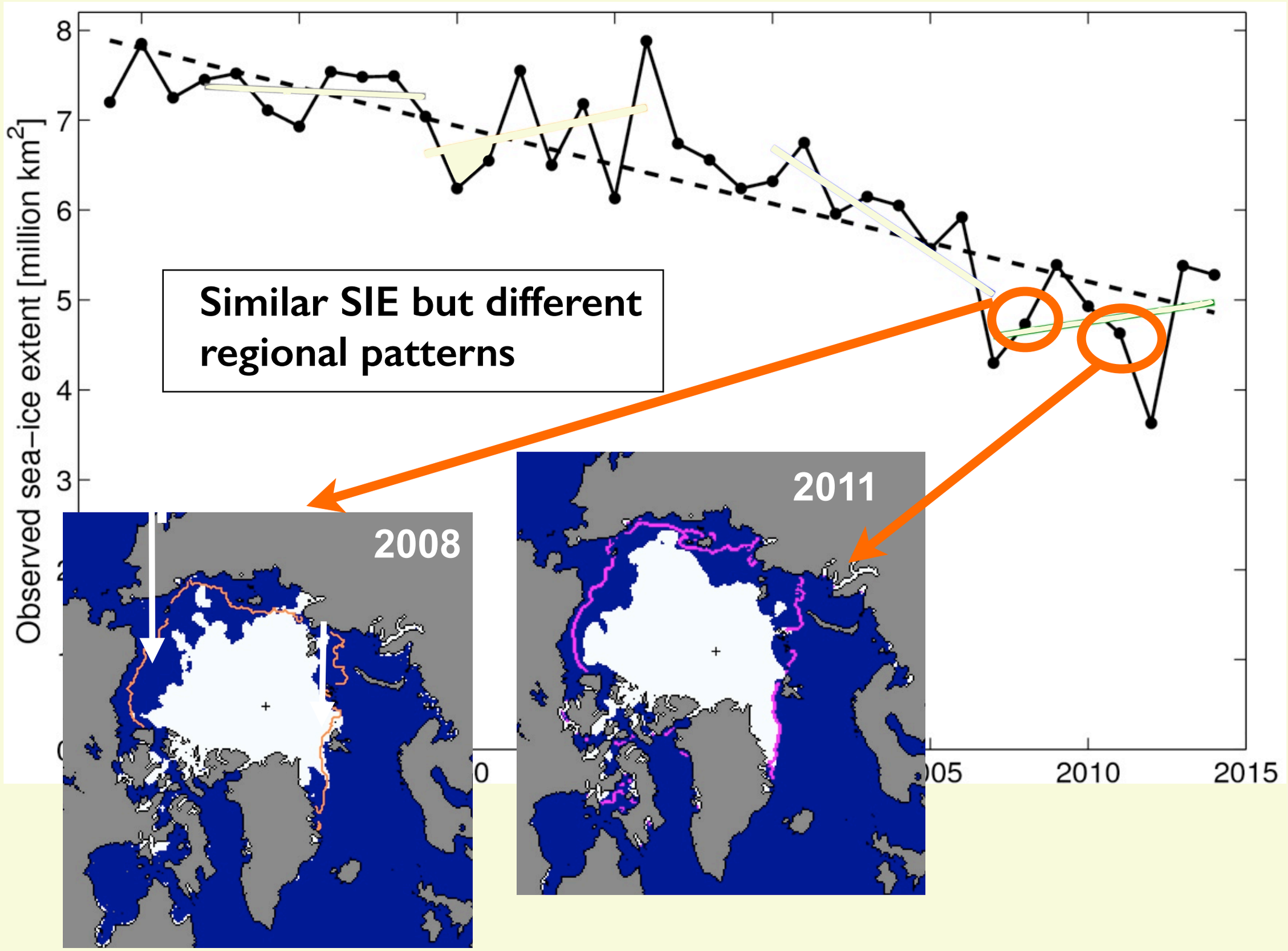
Persistence forecast



Msadek et al. 2014

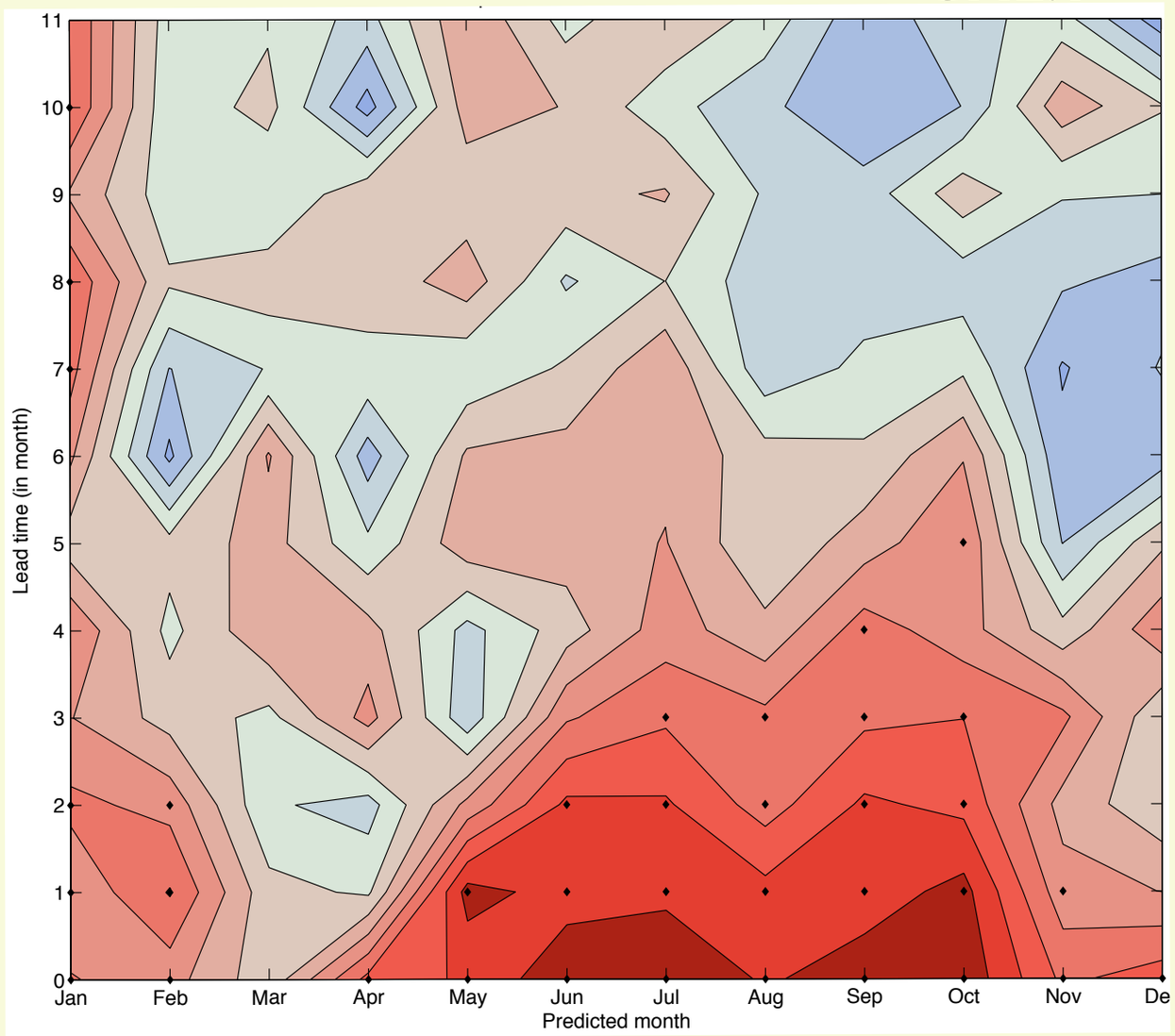
Some of the skill comes from persistence but dynamical models do a better job
The higher-res model does not perform better (for these lead times and for total extent)
=> Importance of initial conditions (similar in the two systems)
What about regionally?

Importance of regional assessments

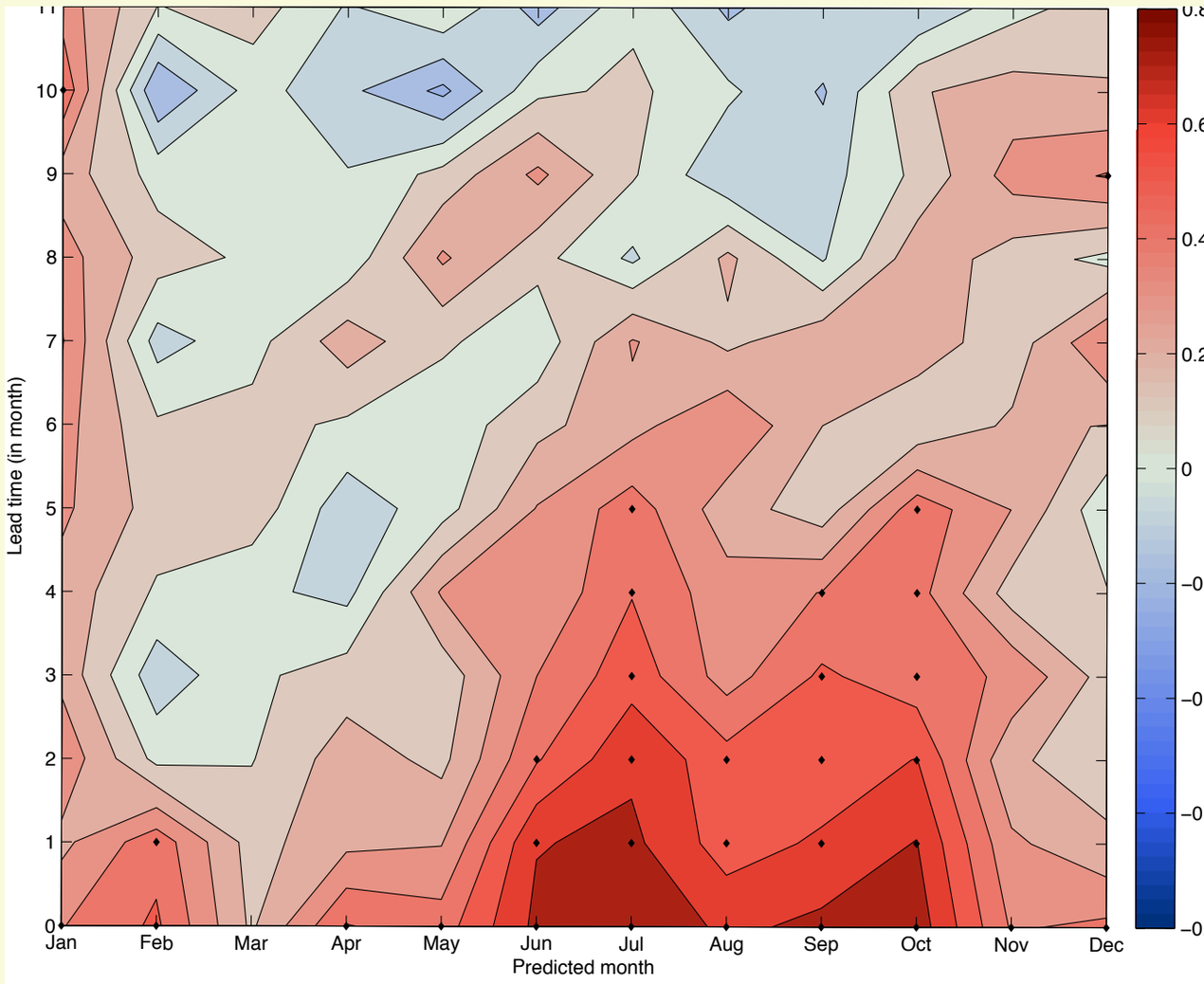


Anomaly correlations of detrended sea ice extent in the Eastern Arctic

CM2.1



FLOR

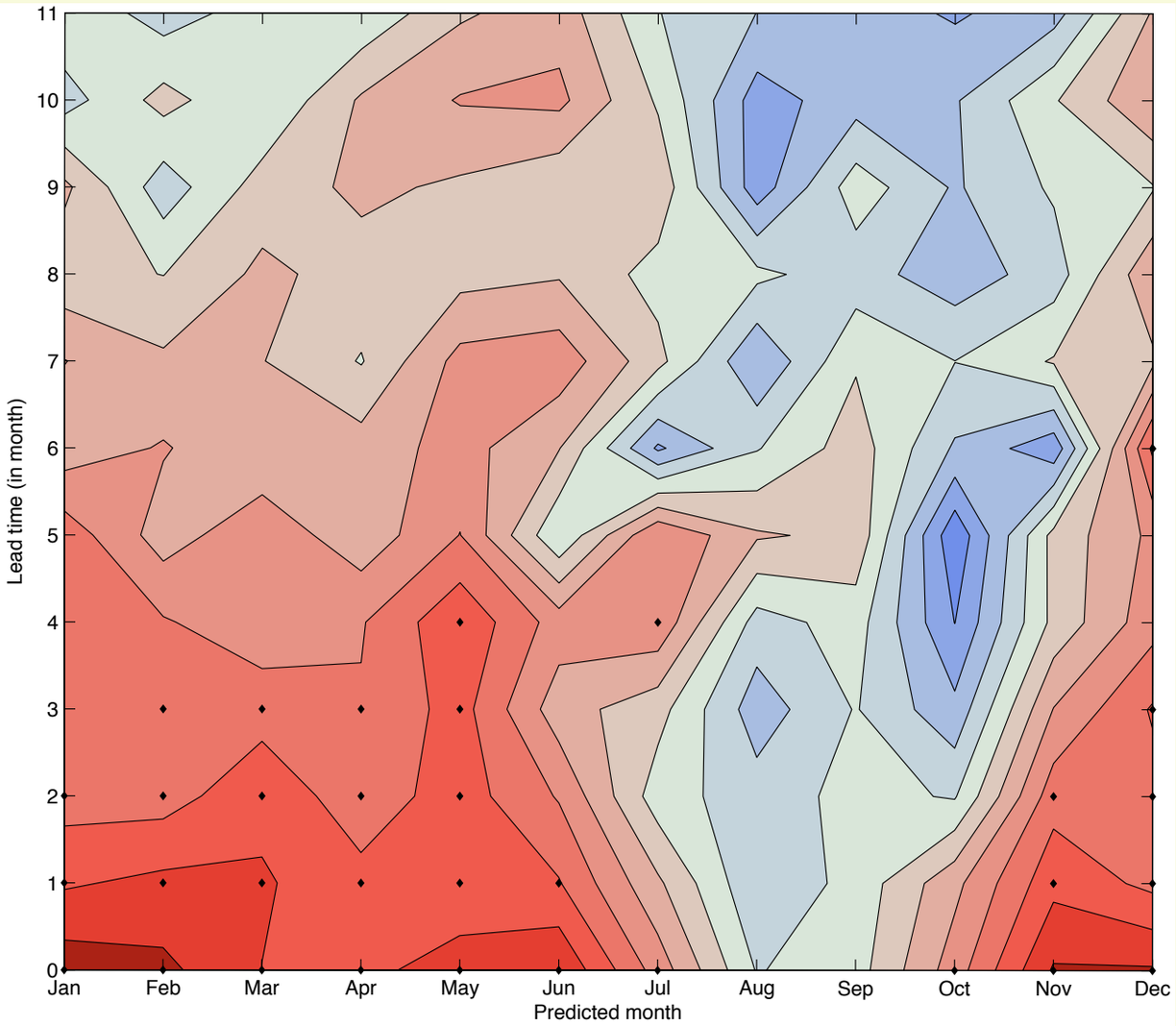


Significant skill in summer for few months

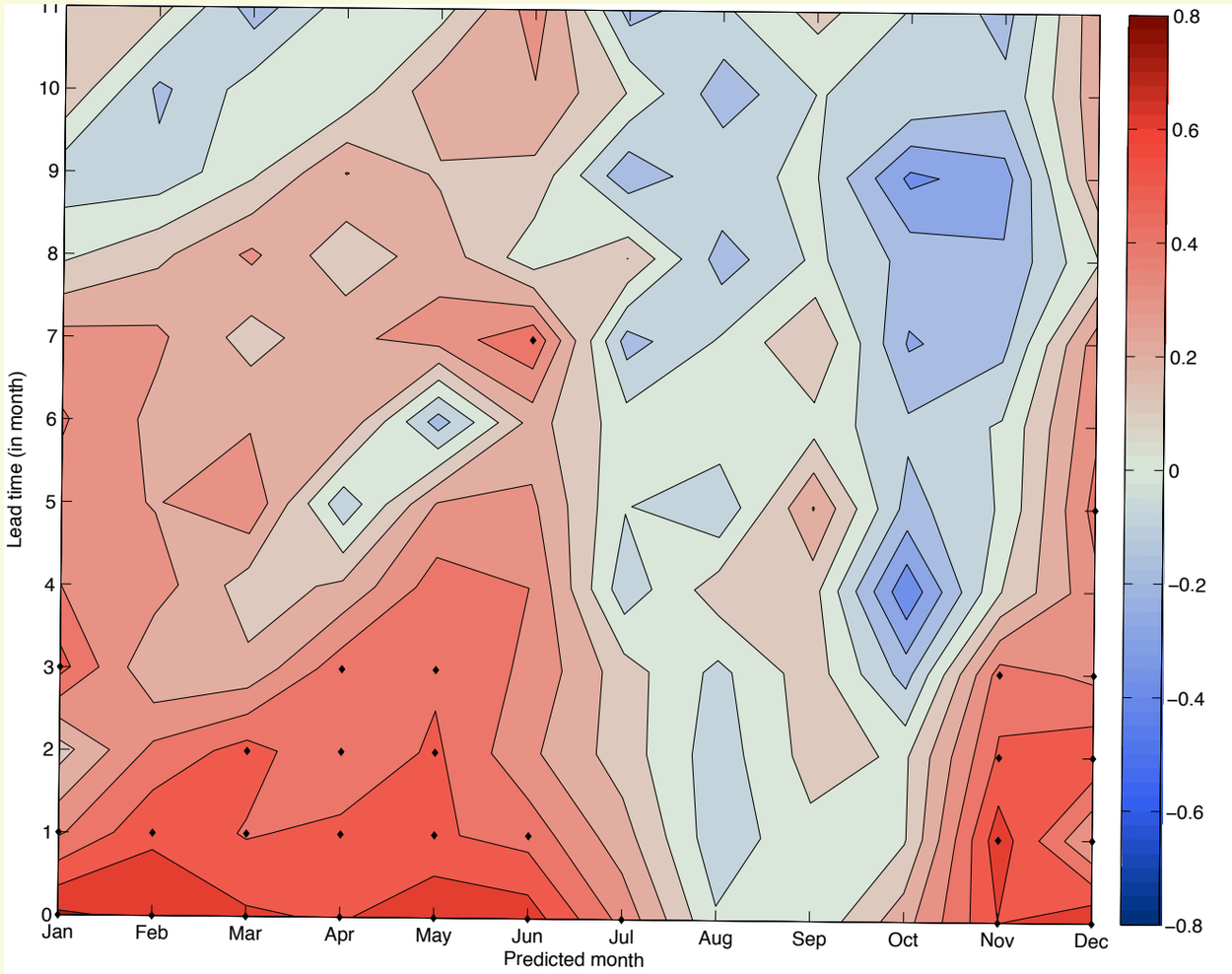
Comparable in the two models

Anomaly correlations of detrended sea ice extent in the Labrador Sea

CM2.1



FLOR

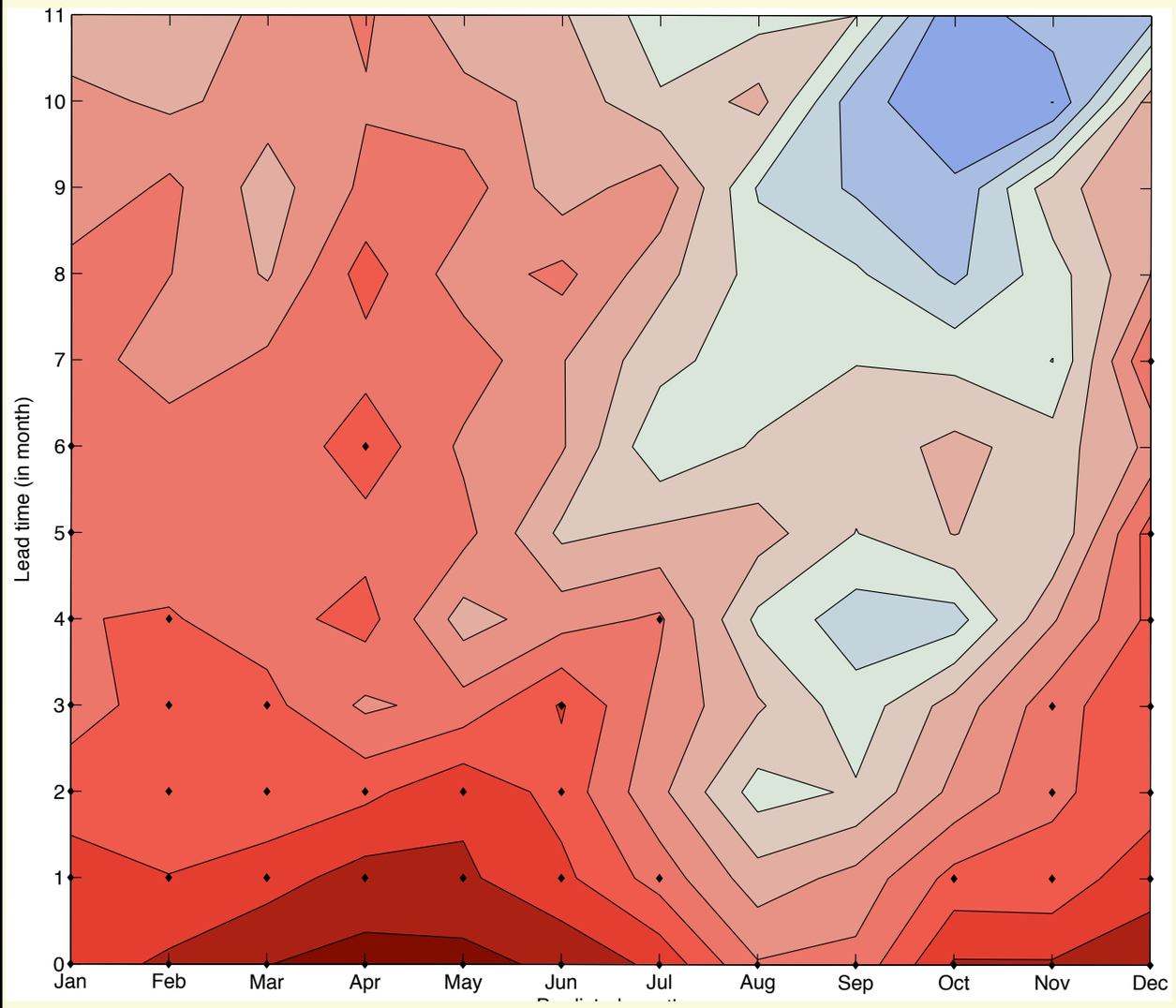


Significant skill in winter/spring for few months

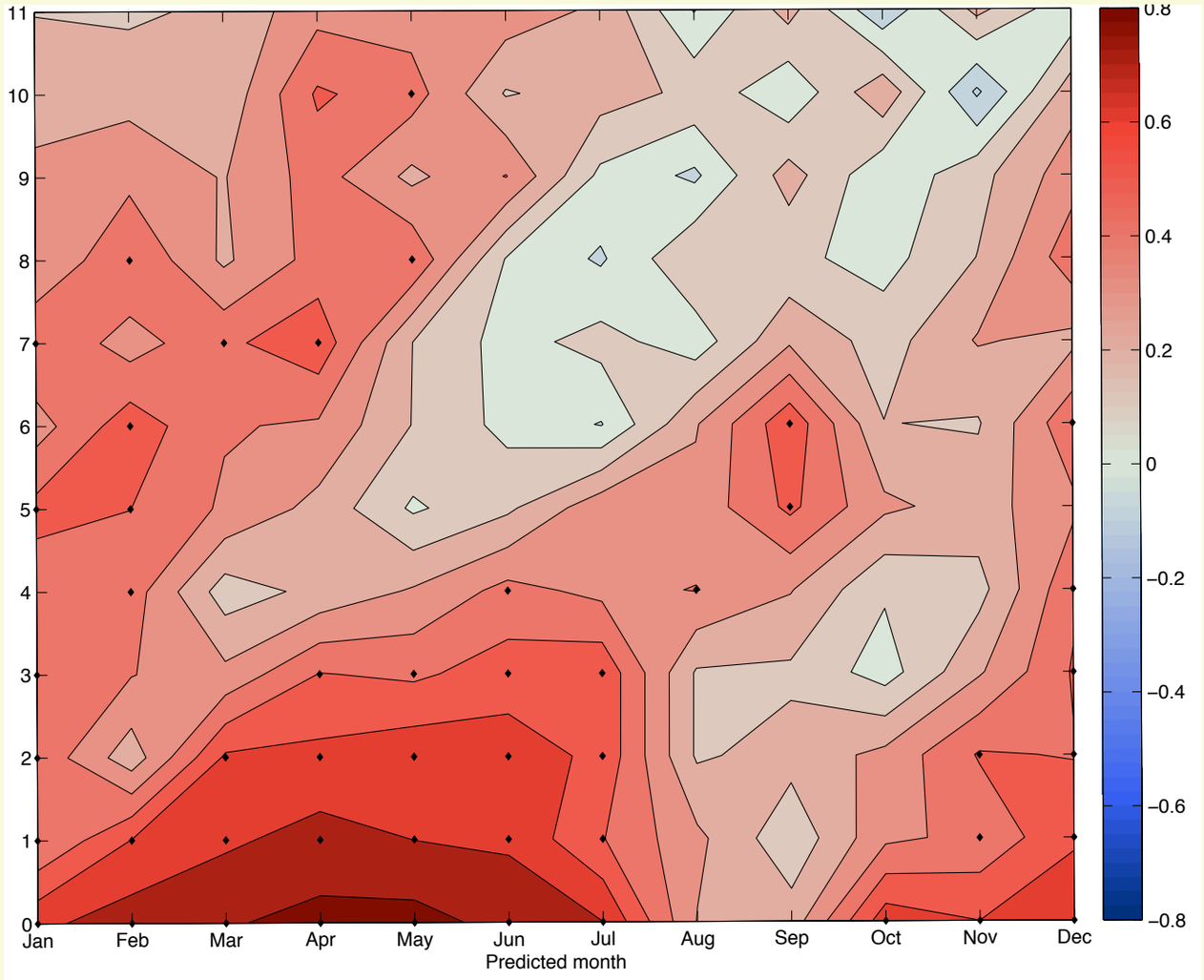
Comparable in the two models

Anomaly correlations of detrended sea ice extent in the Barents Sea

CM2.1



FLOR

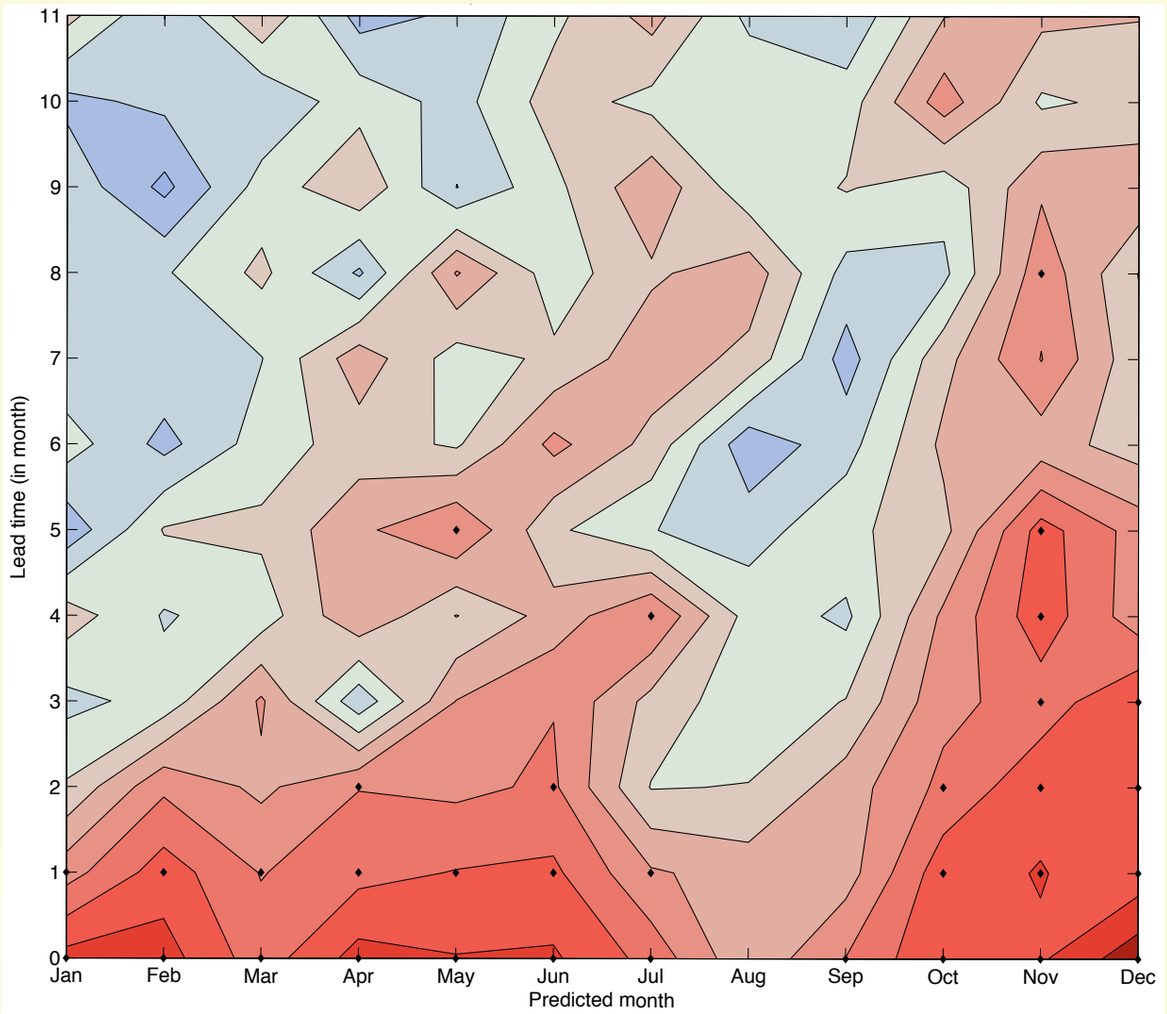


In FLOR: slightly higher skill in winter at longer lead times. More evidence of reemergence

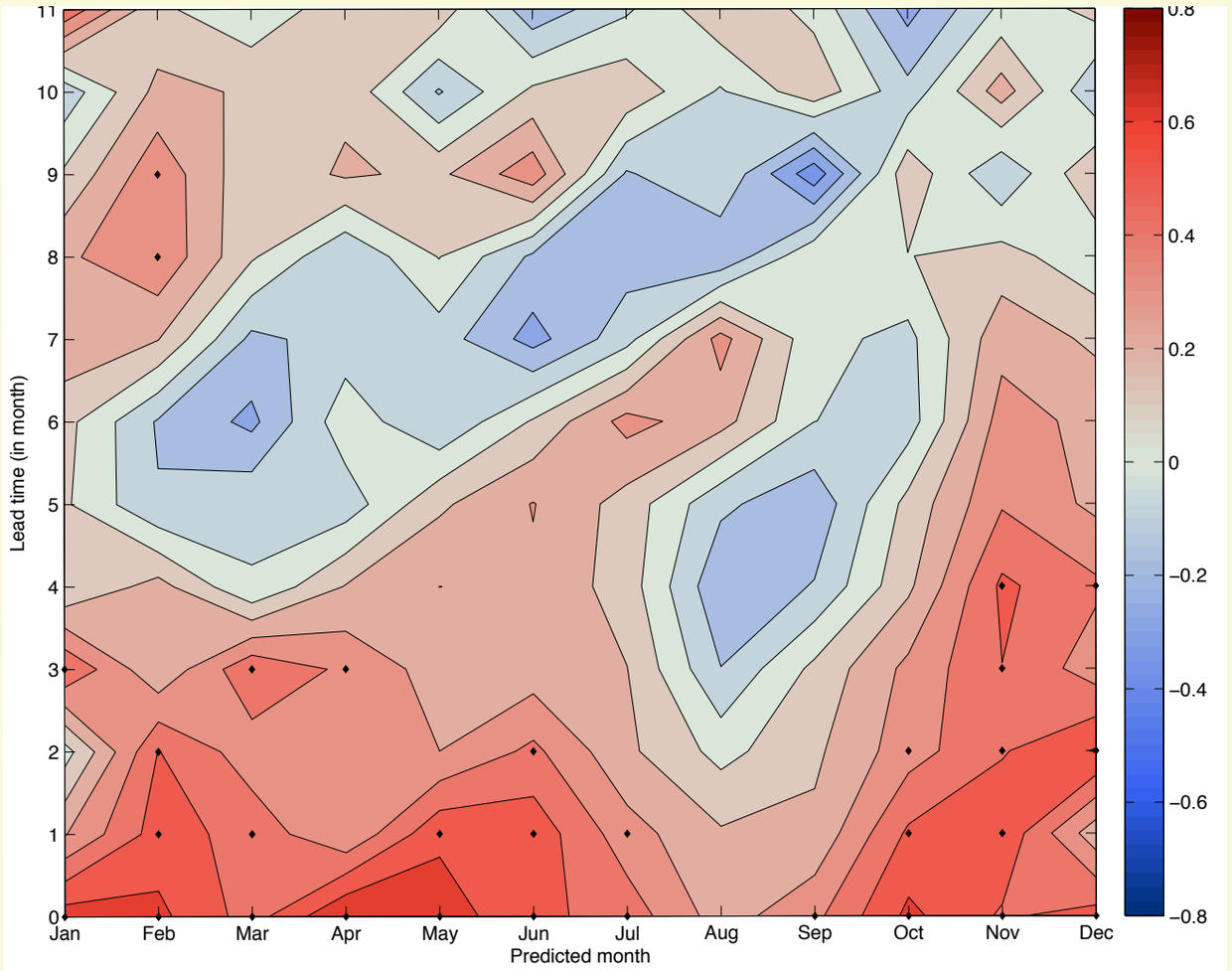
Better ocean heat flux convergence?

Anomaly correlations of detrended sea ice extent in the Pacific Arctic

CM2.1



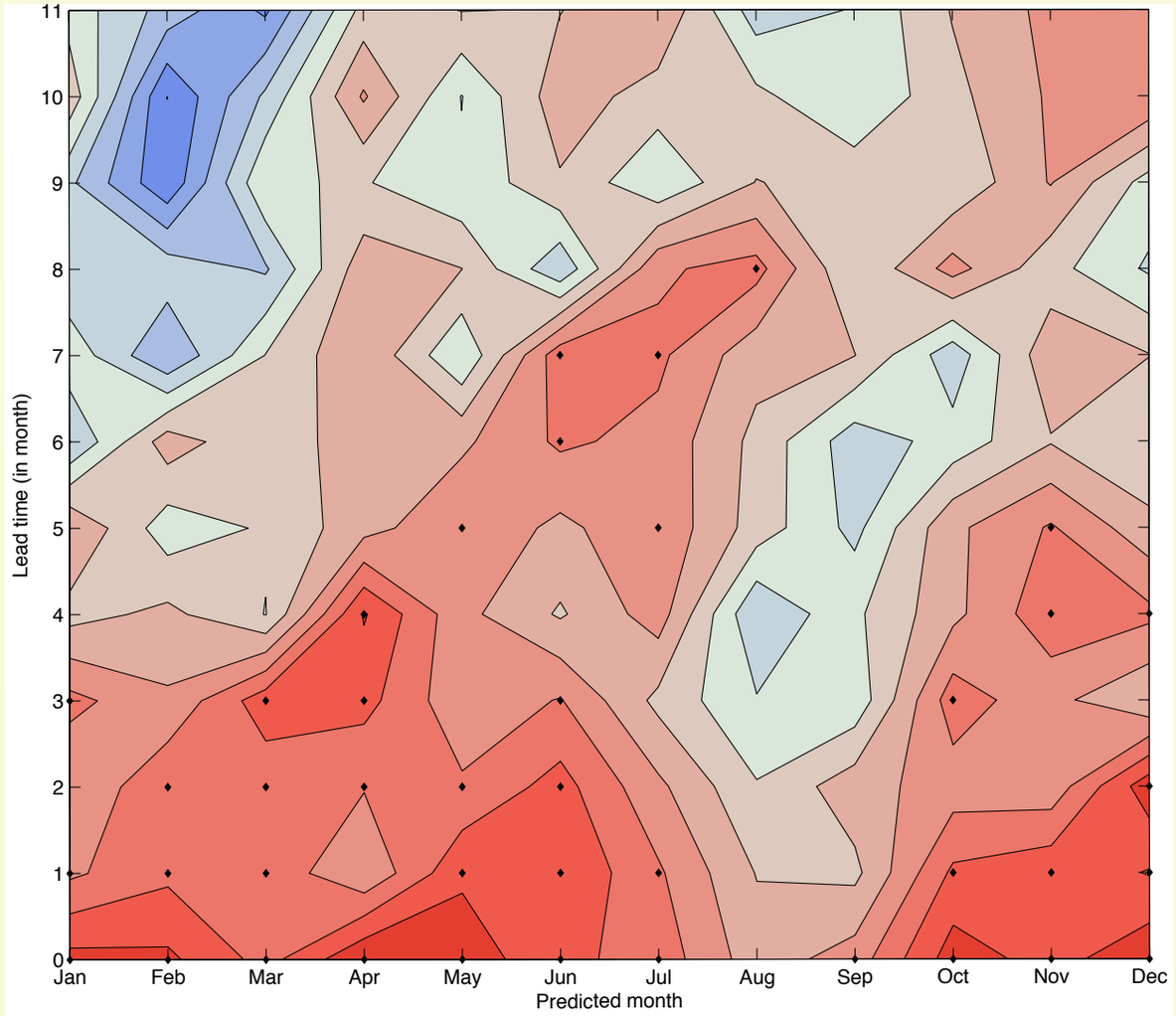
FLOR



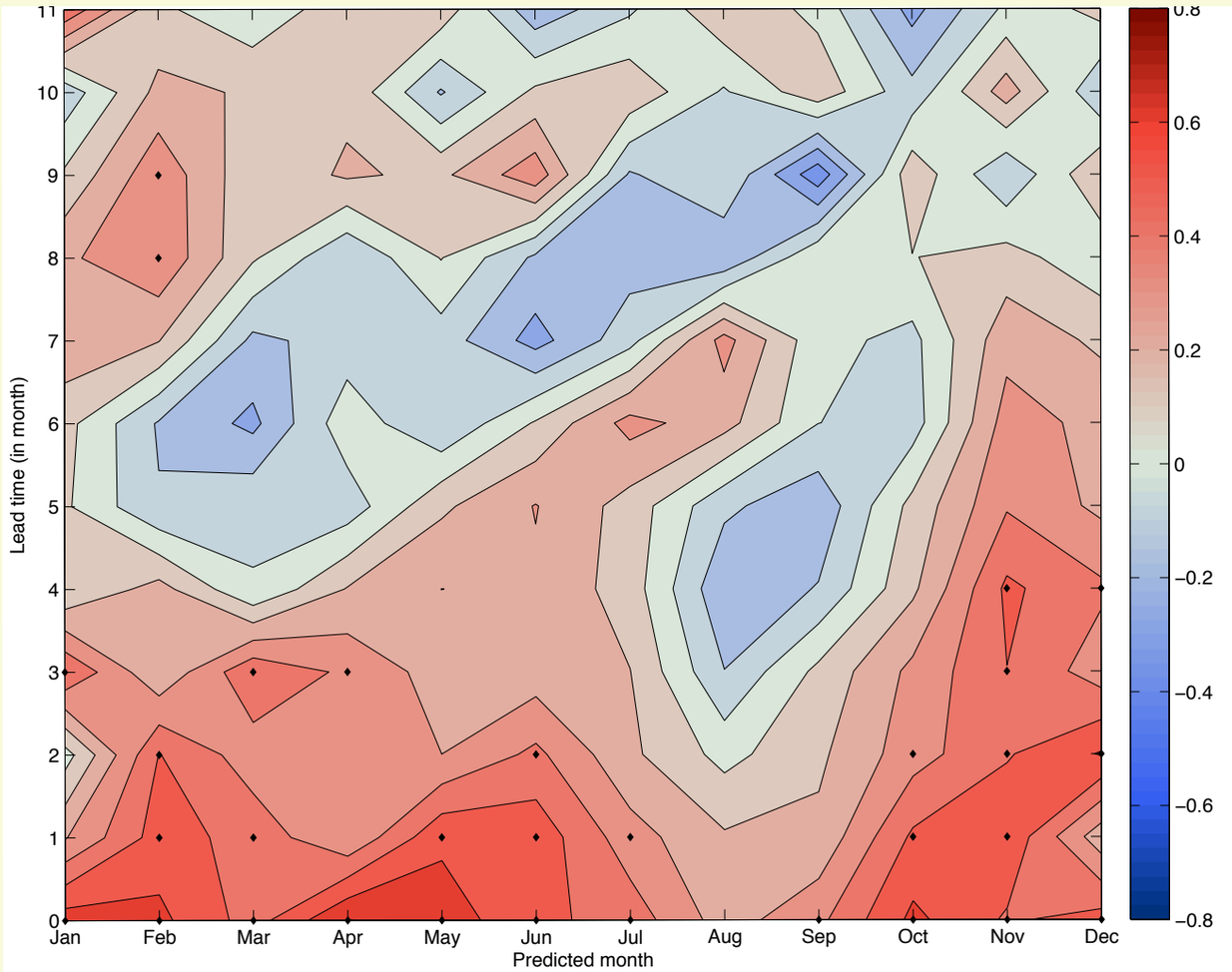
Comparable skill in the two models

Anomaly correlations of detrended sea ice extent in the Pacific Arctic

Flux adjusted FLOR



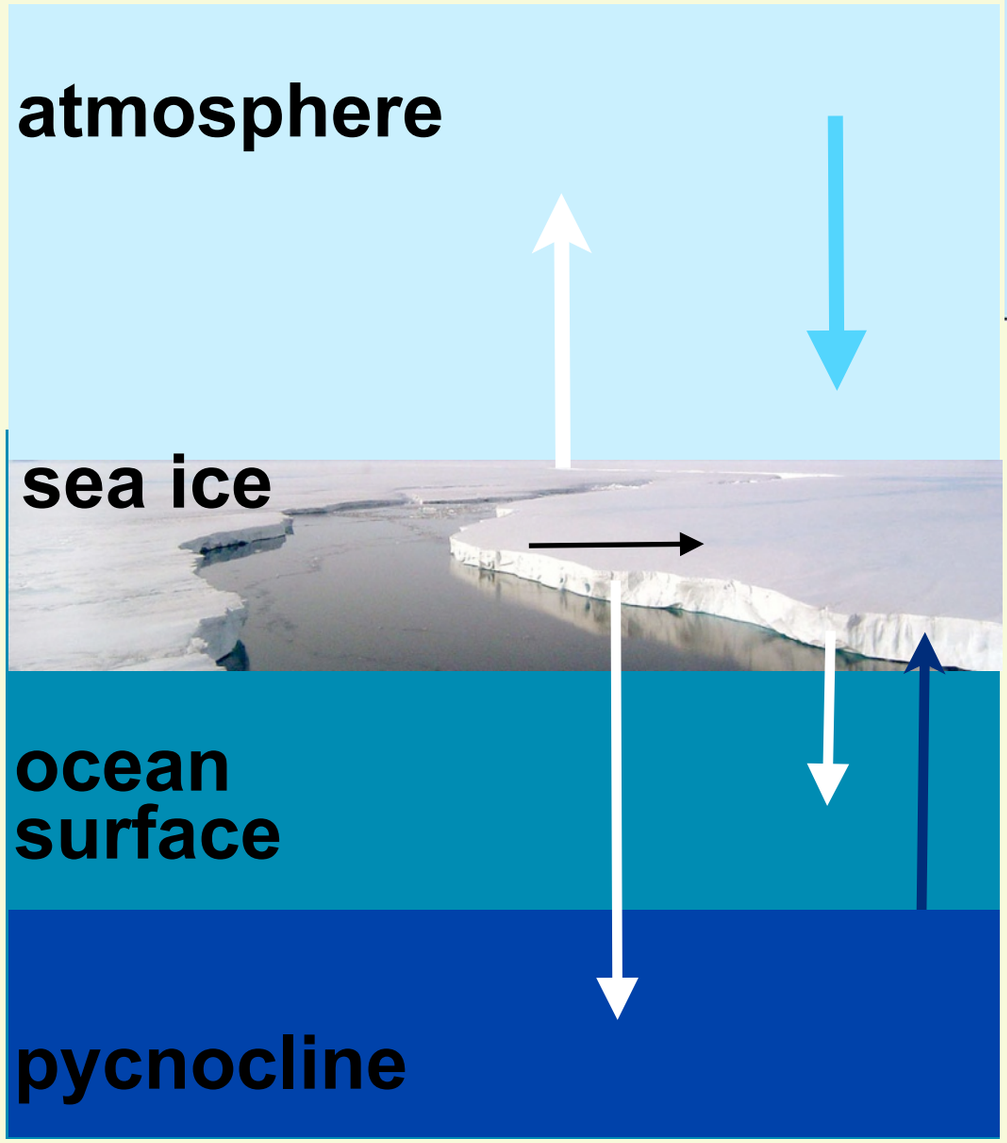
FLOR

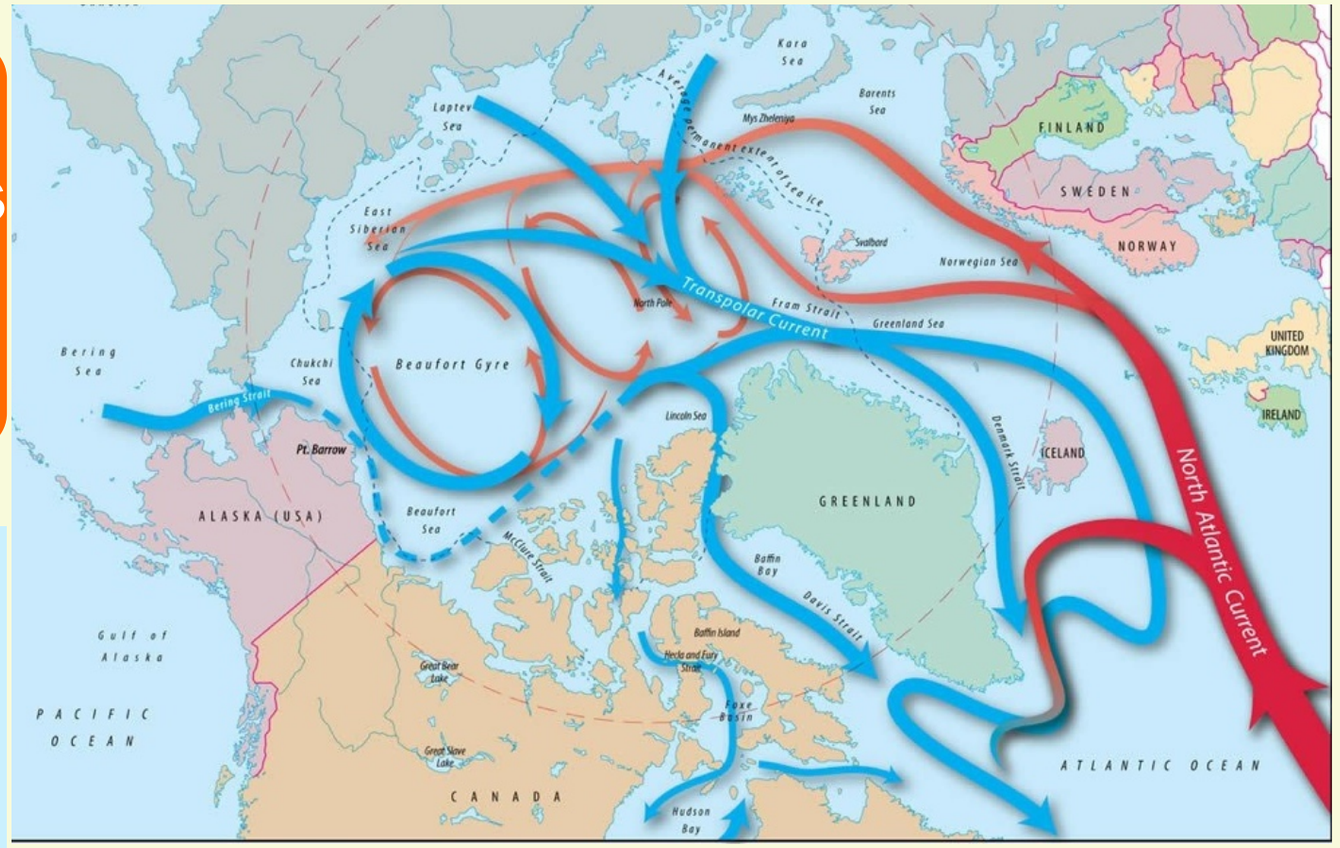


Better representation of the reemergence with a better SST climatology

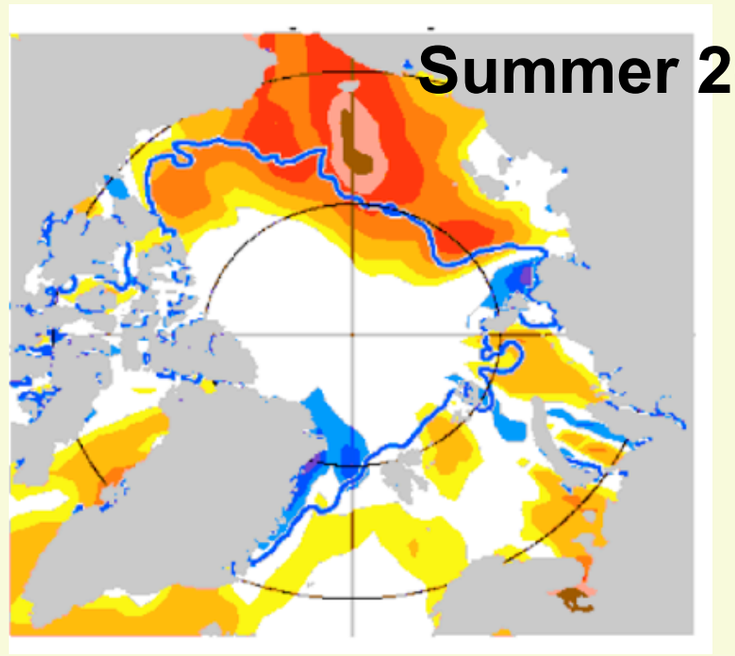
Complex mechanisms

Heat transport from the Atlantic and Pacific oceans contribute to the year to year variations of sea ice



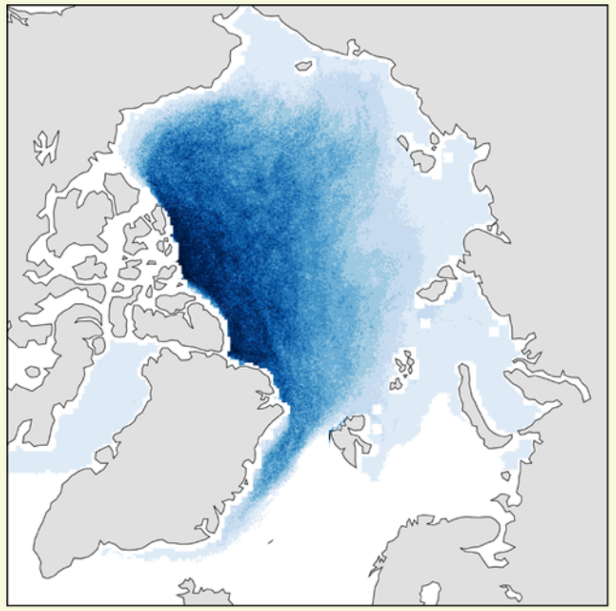


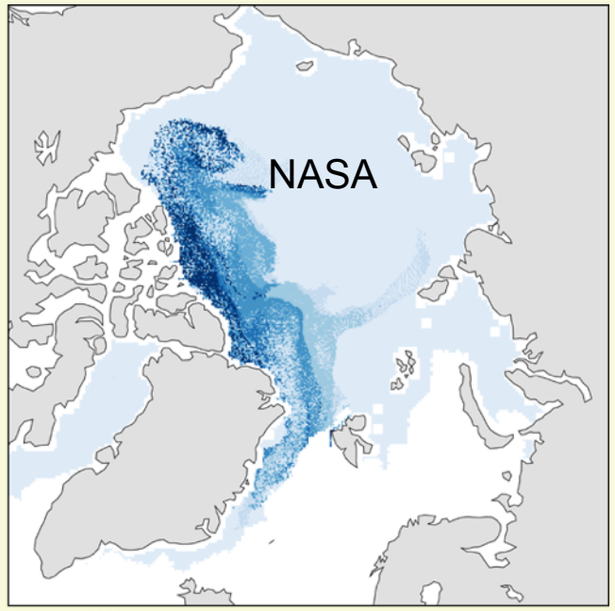
SST anomalies



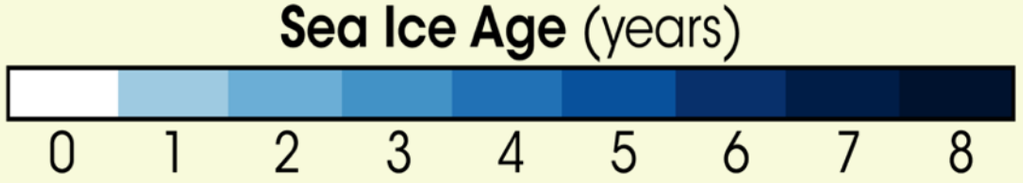
Complex mechanisms

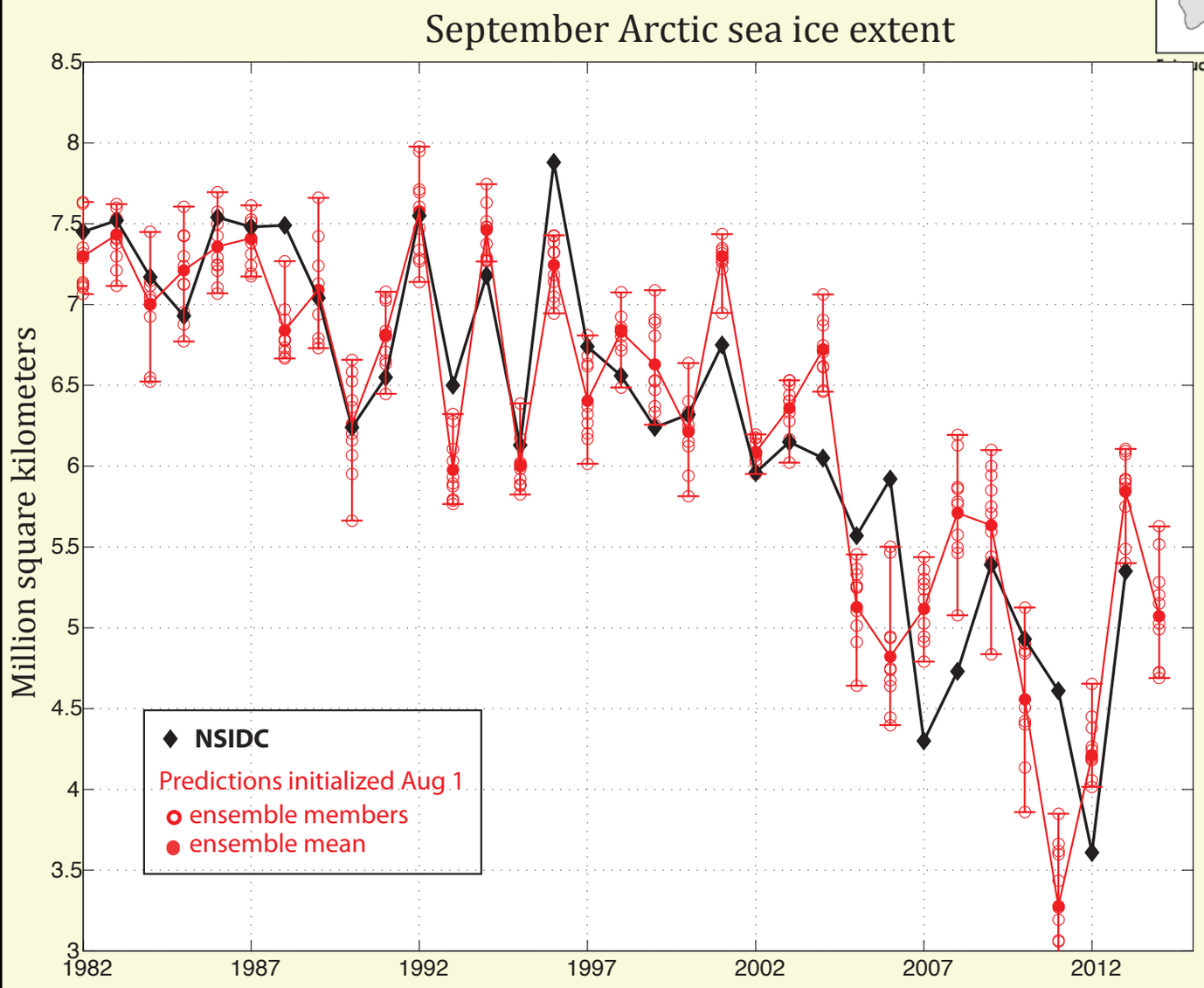
Thickness is a source of skill for summer sea ice extent.
Is predictability decreasing as ice gets thinner?





February 2008

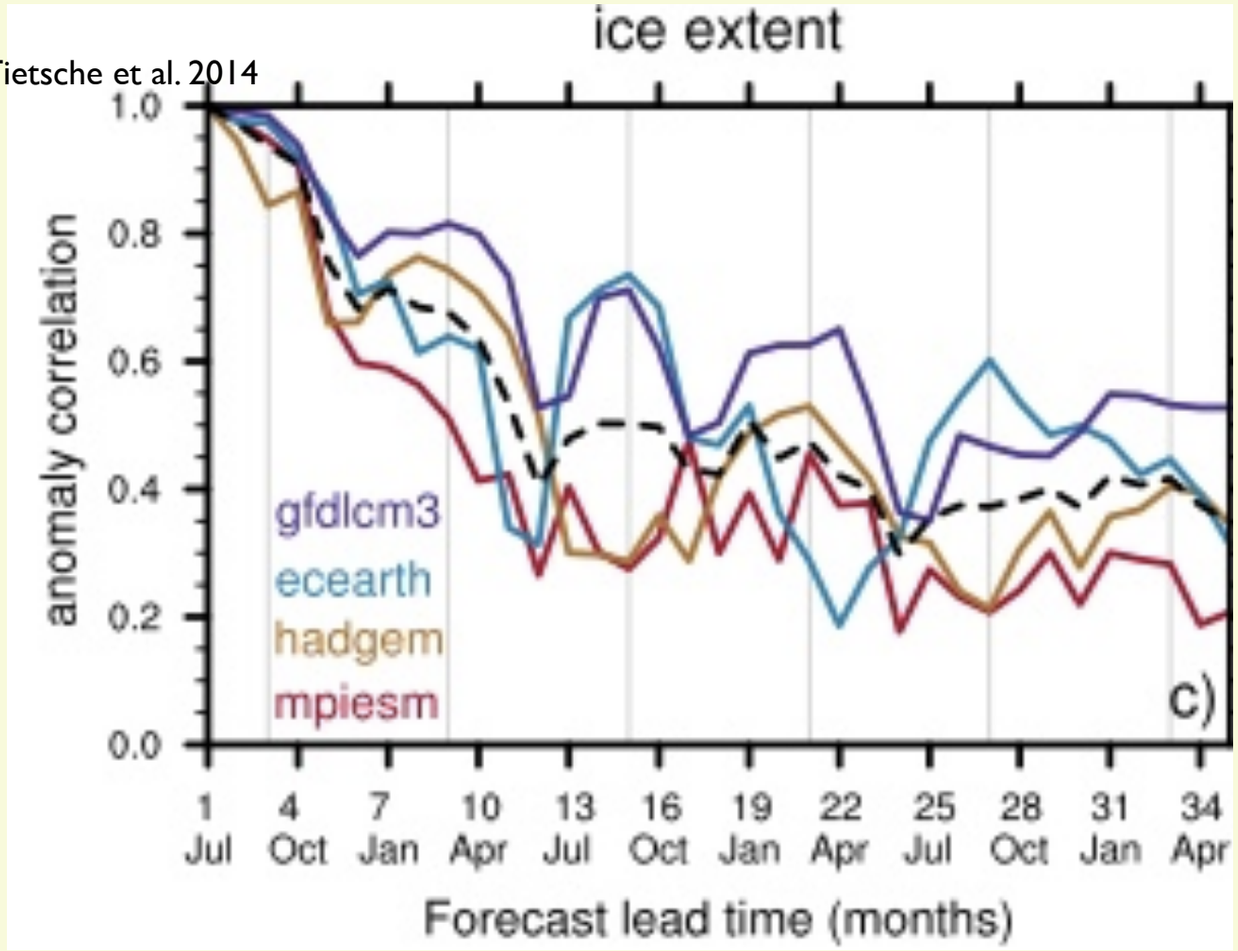




Better year-to-year predictability in the 1990s than in the 2000s.
But record too short to assess the effect of thinning

Current limitations

Tietsche et al. 2014



Potential predictability of sea ice extent ~1yr in perfect model experiments
(Blanchard et al. 2011, Tietsche et al. 2014)

Skill limited to few months in operational-like systems
(Sigmond et al. 2013, Chevallier et al. 2013, Wang et al. 2013, Msadek et al. 2014)

Potential predictability studies suggest that we could extend the skill for longer
What are we missing?

(Some) current limitations for seasonal sea ice predictions:

-Biased models (missing dynamical ice processes e.g. melt ponds, atmosphere, ocean)

-Uncertain initial conditions (especially thickness): lack of data to assimilate.

-Poor understanding of the mechanisms contributing to predictability

Summary

Seasonal sea ice predictions are challenging due to the variable nature of weather and ocean on this timescale as well as the current limitations in data and modeling capabilities

Higher atmospheric resolution does not necessarily imply higher skill in Arctic for lead times less than 12 months, even regionally.

Our results suggest that improving initial conditions is key for improving skill.

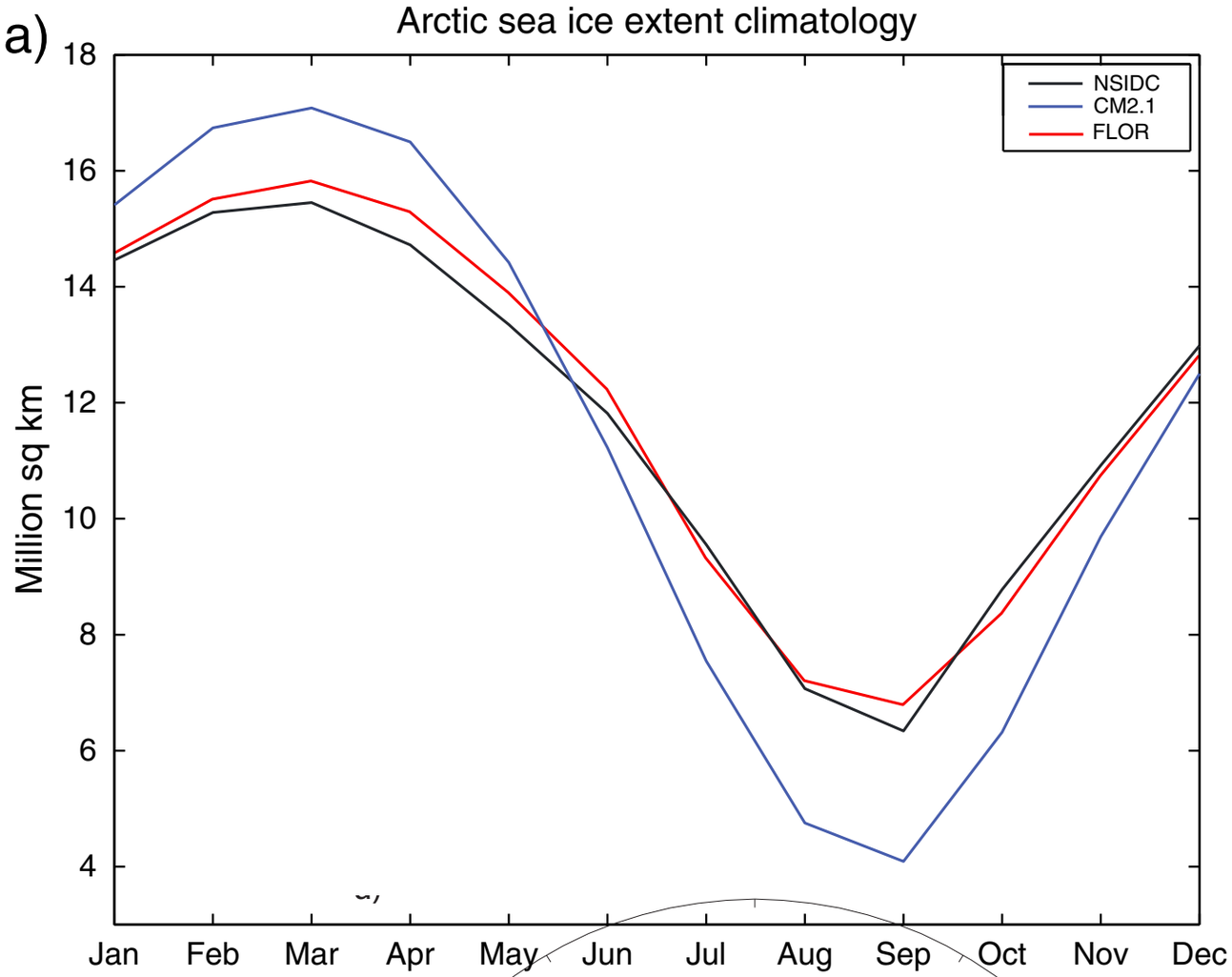
Reduced SST biases can lead to higher correlations in the regions where reemergence mechanisms play a role (Bering Sea, Atl.)

There are interesting regional differences in the structure of the lead-dependent skill, which reflects different mechanisms that are seasonally dependent

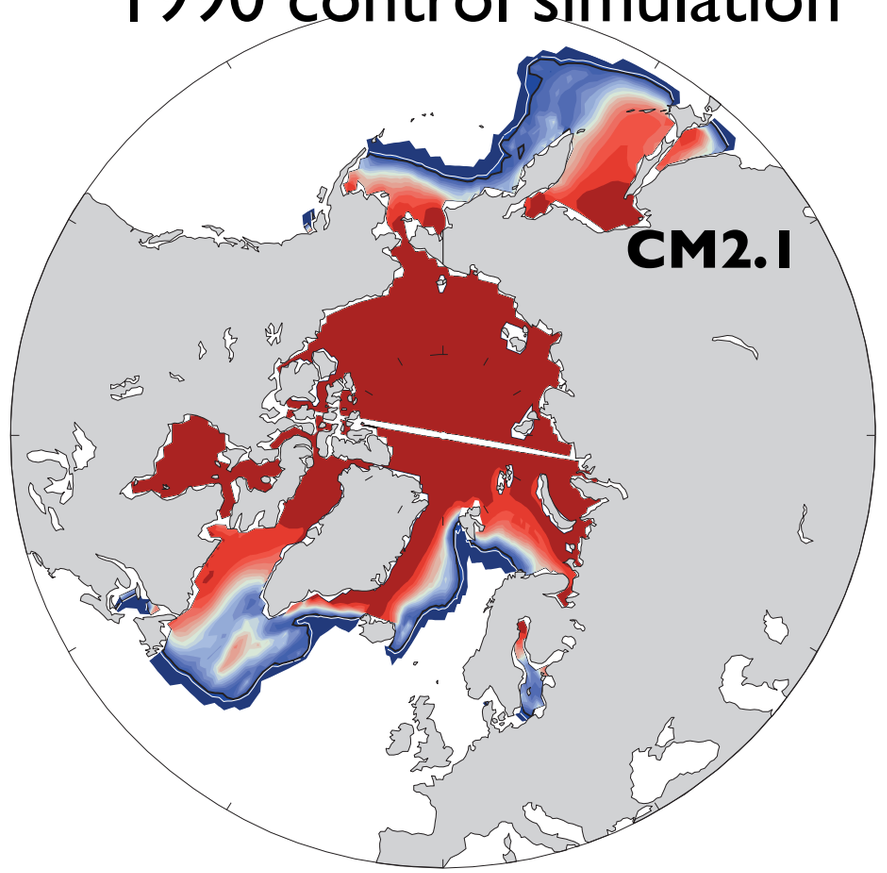
=> Need to identify the processes (ocean, atmosphere, ice) that contribute or limit skill for each region of the Arctic and assess the model dependence

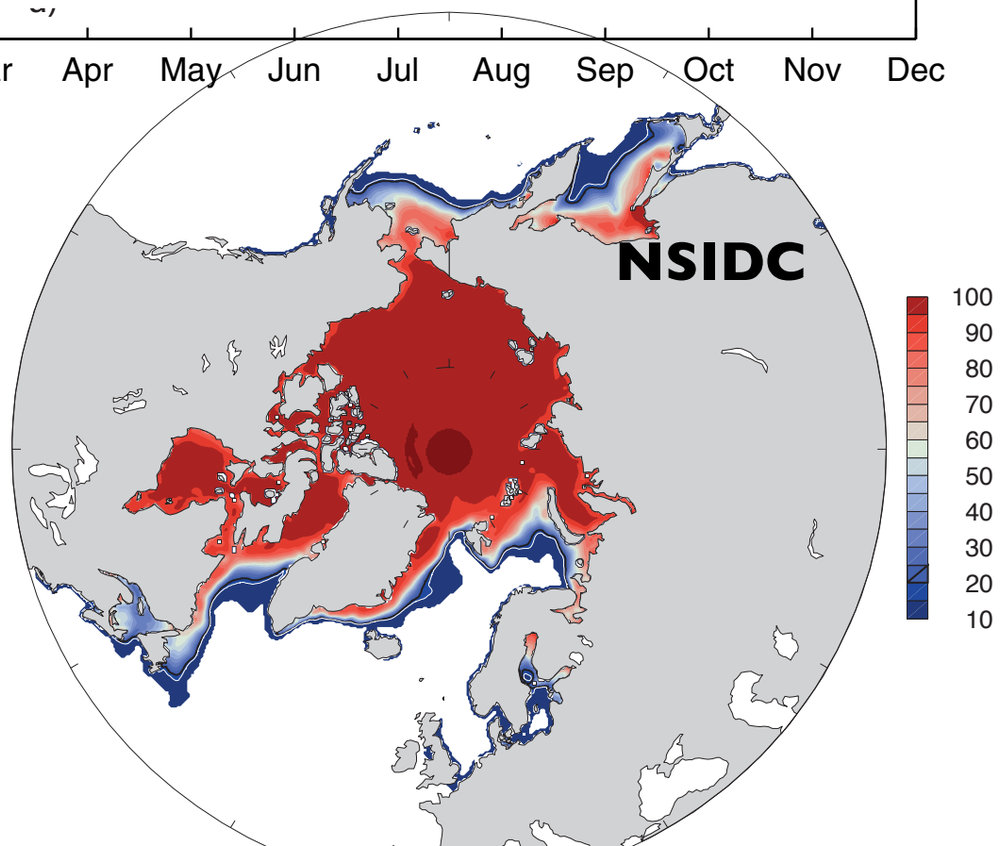
extra slides

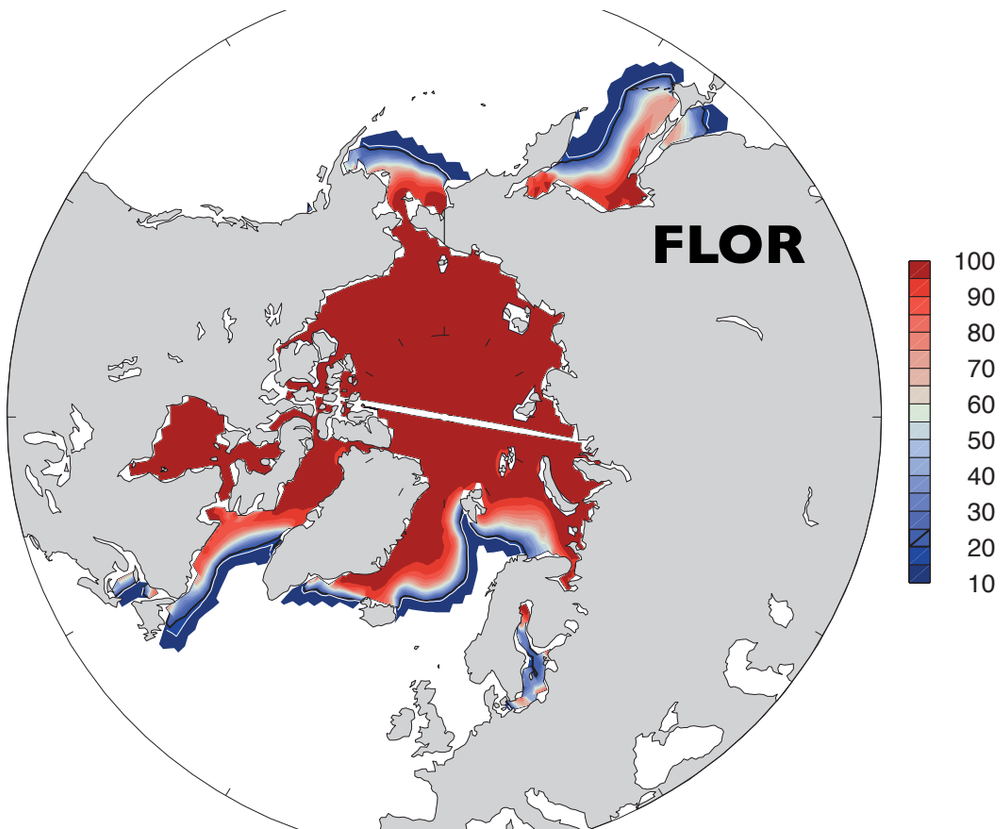
Mean state of CM2.1 and FLOR



March concentration
1990 control simulation

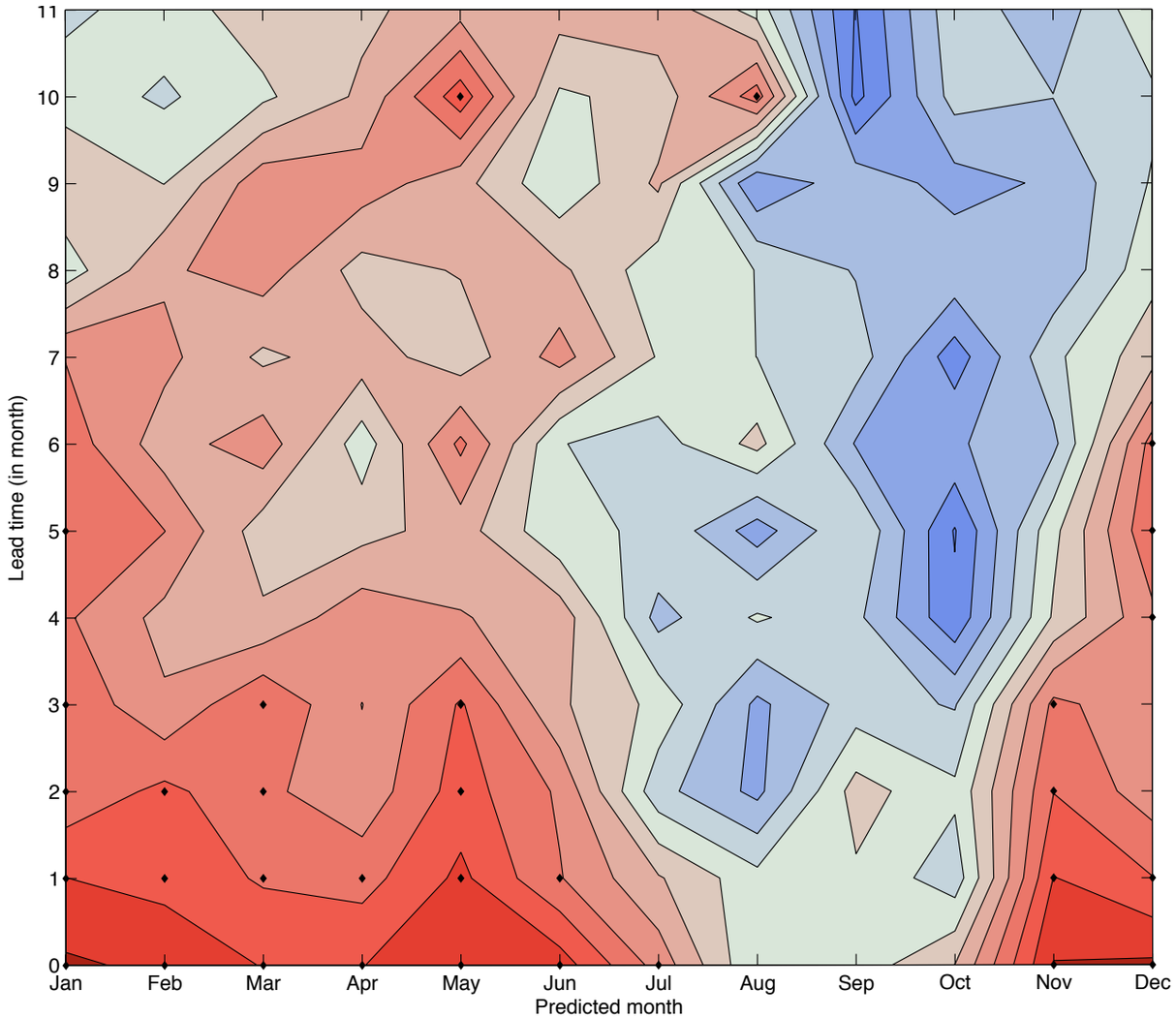




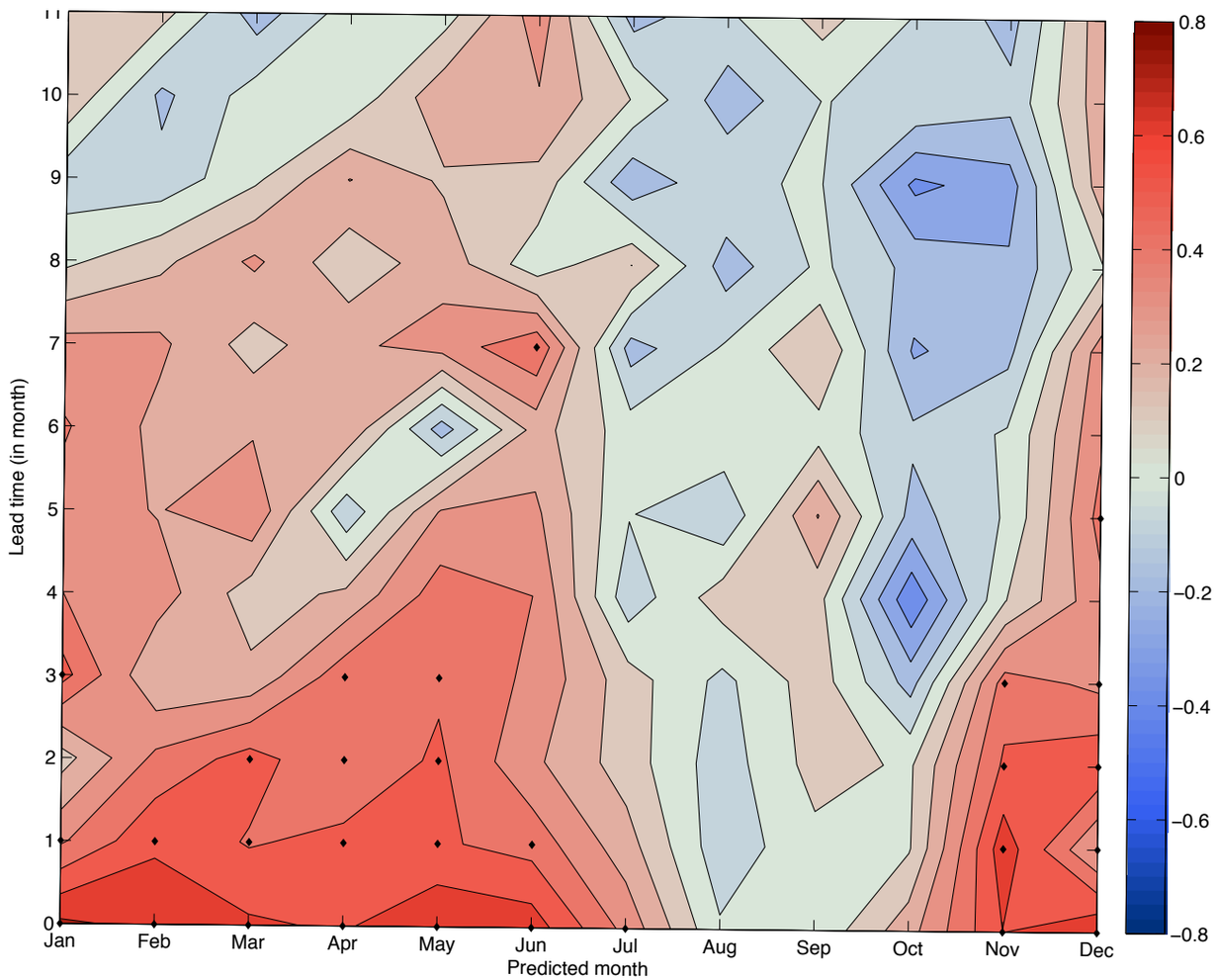


Anomaly correlations of detrended sea ice extent In the Labrador Sea

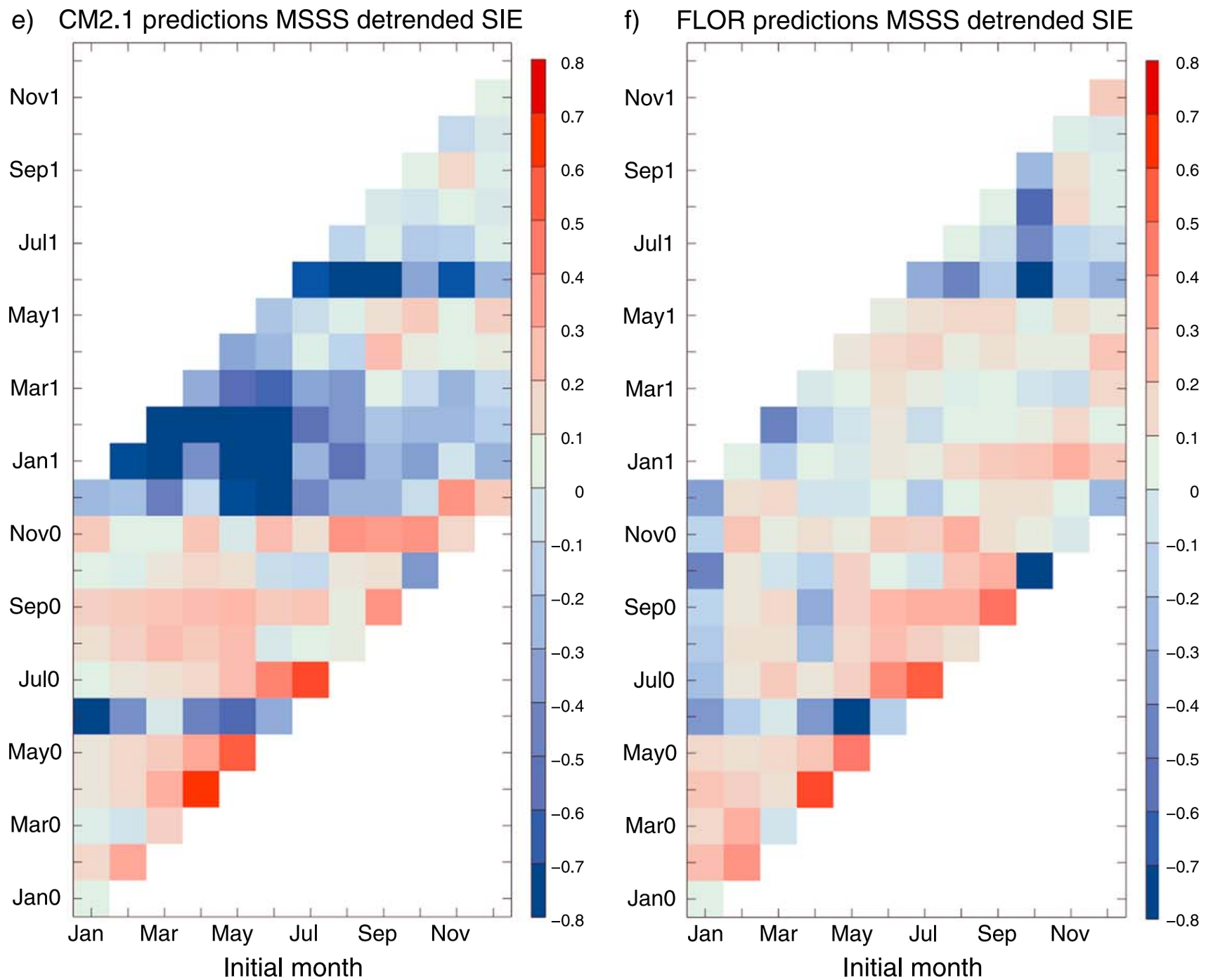
Flux adjusted FLOR



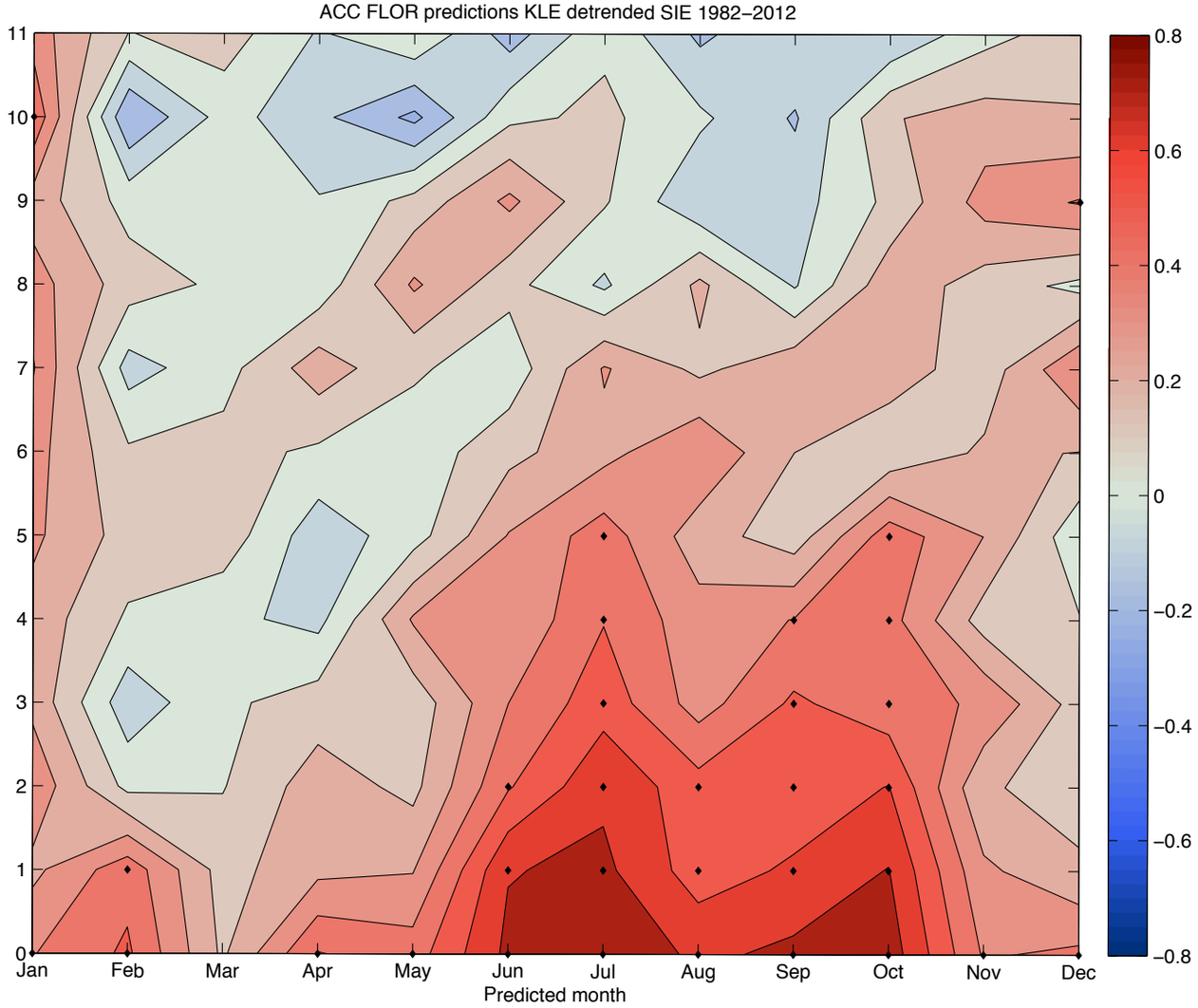
FLOR



Small effect of a better climatology of SST



Smaller error at longer lead times in the high res model


ACC FLOR predictions KLE detrended SIE 1982–2012
11
10
9
8
7
6
5
4
3
2
1
0
Jan
Feb
Mar
Apr
May
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Jul
Aug
Sep
Oct
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Dec
Predicted month
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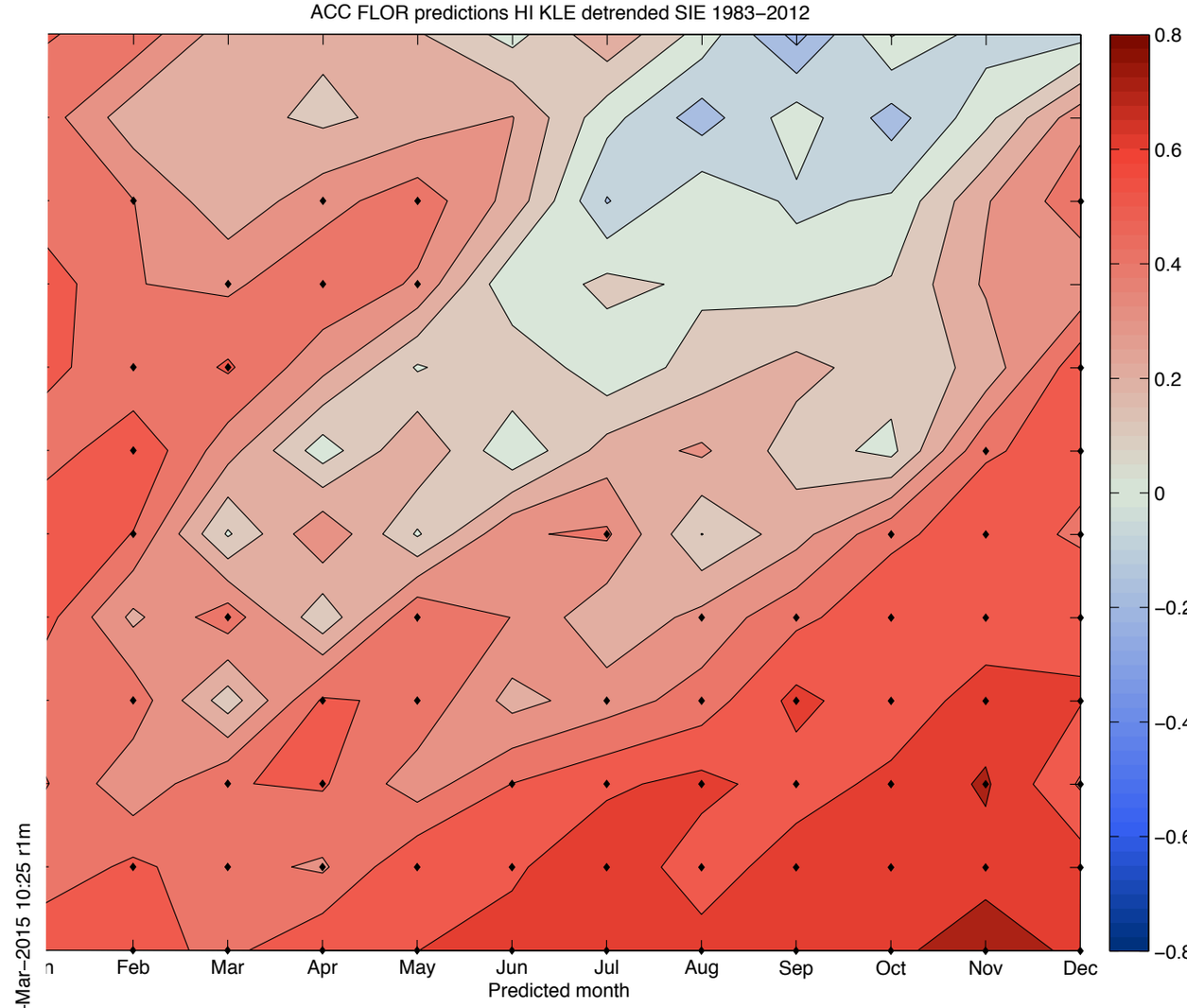
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8


ACC FLOR predictions HI KLE detrended SIE 1983–2012
20–Mar–2015 10:25 r1m
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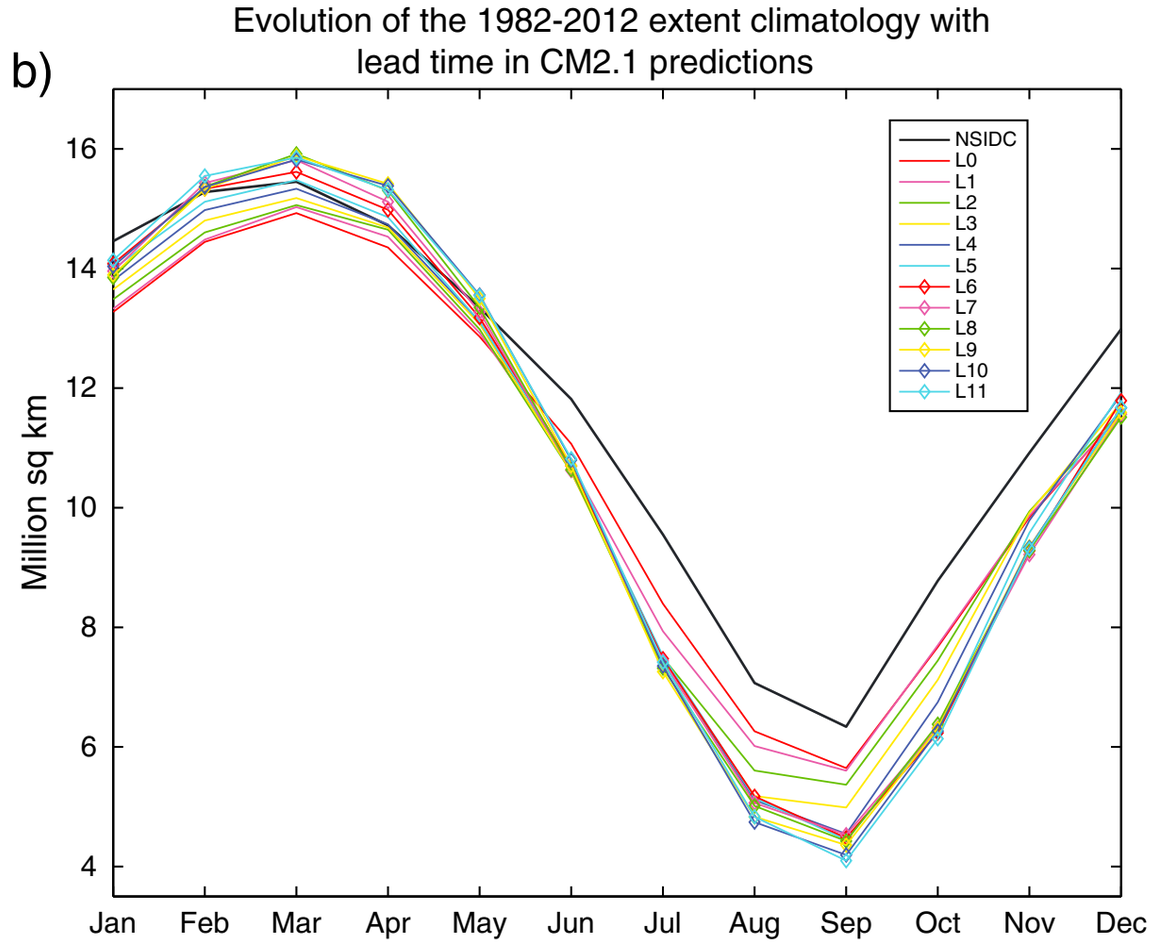
Sep
Oct
Nov
Dec
Predicted month
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8

b)


Evolution of the 1982-2012 extent climatology with
lead time in CM2.1 predictions
Million sq km
16
14
12
10
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Nov
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NSIDC
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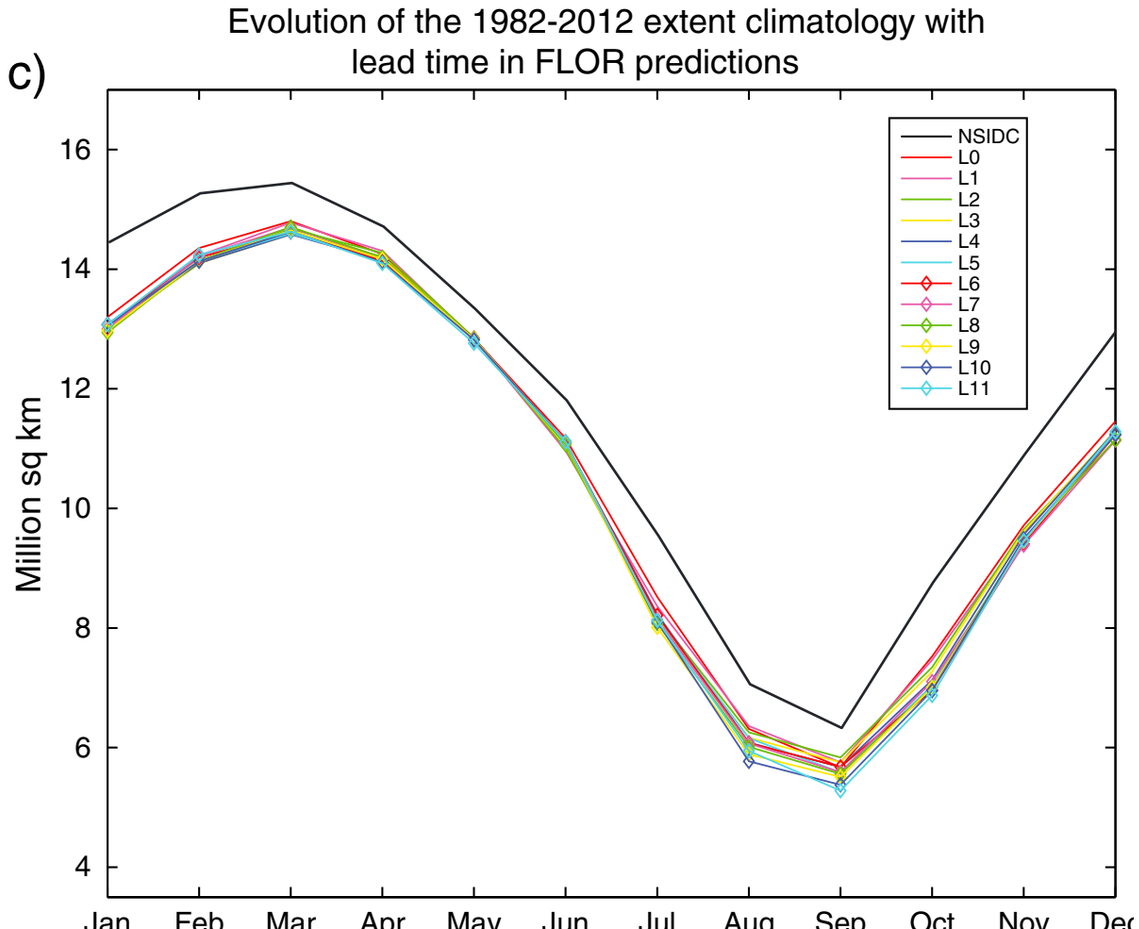
L10
L11

c)


Evolution of the 1982-2012 extent climatology with
lead time in FLOR predictions
Million sq km
16
14
12
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Dec
NSIDC
L0
L1
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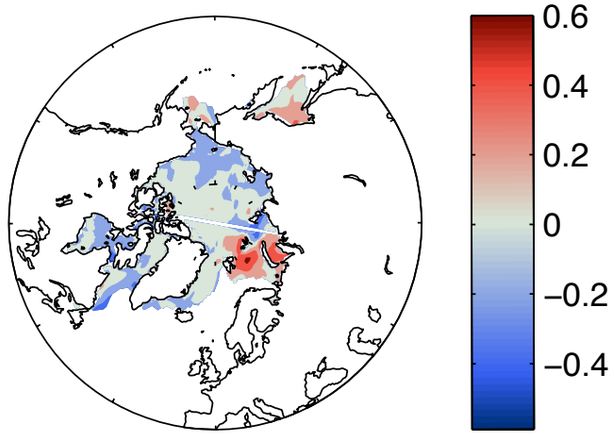
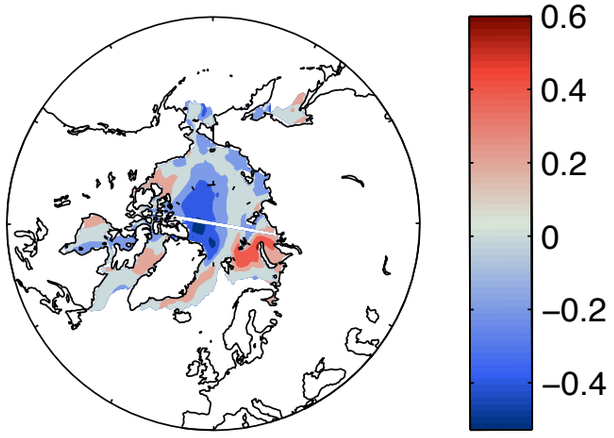
L11

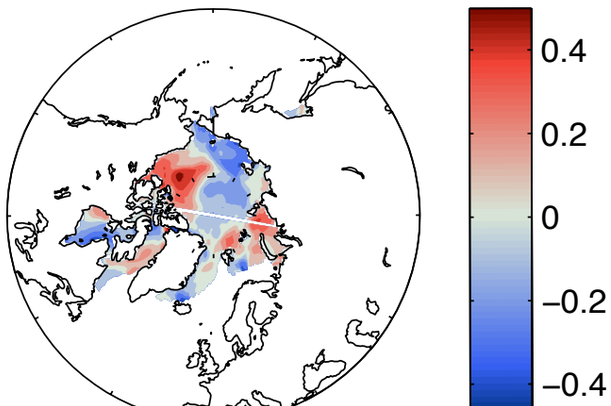
Correlation May 1982–2012 cn –mht BSO L0 FLOR



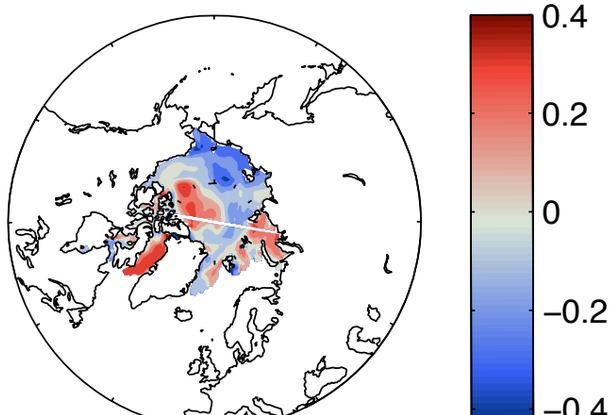
Correlation Jun 1982–2012 cn/mht BSO L1 FLOR



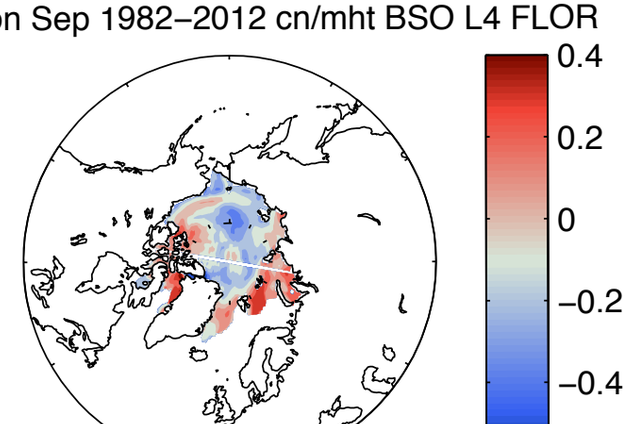
Correlation Jul 1982–2012 cn/mht BSO L2 FLOR



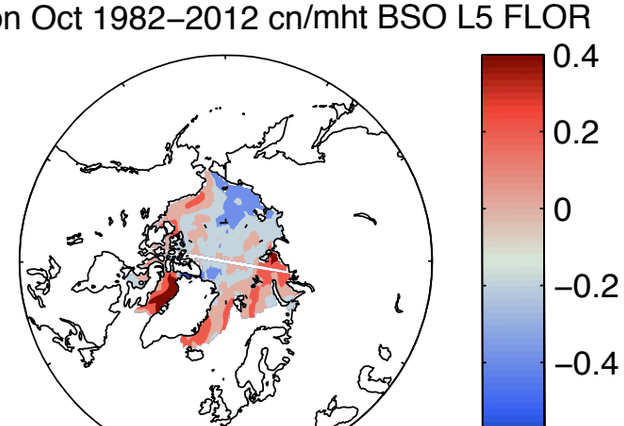
Correlation Aug 1982–2012 cn/mht BSO L3 FLOR

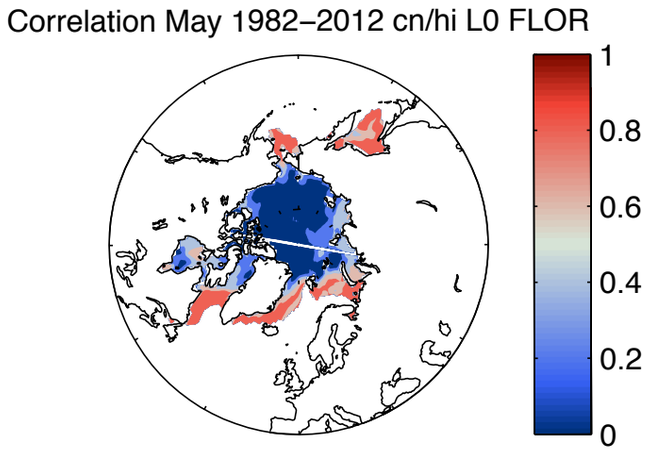


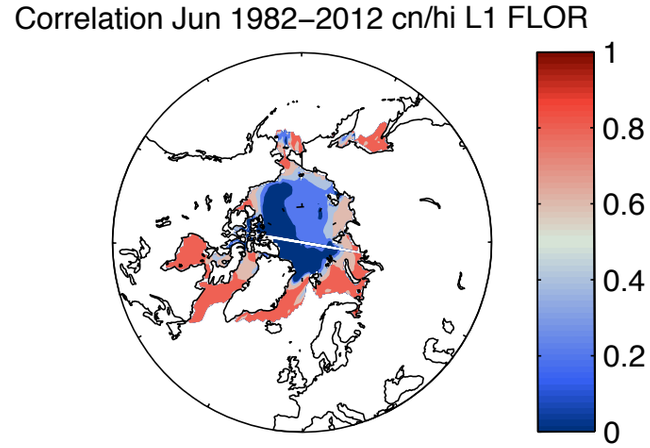
Correlation Sep 1982–2012 cn/mht BSO L4 FLOR

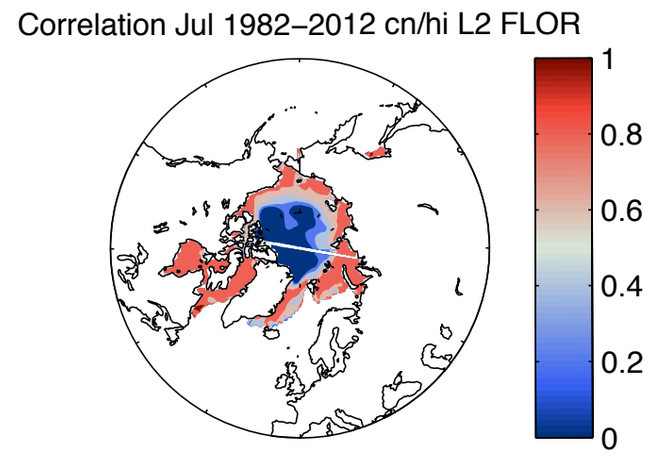


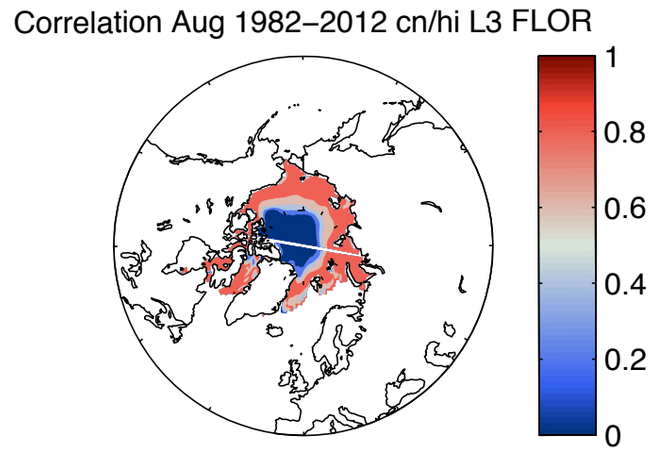
Correlation Oct 1982–2012 cn/mht BSO L5 FLOR

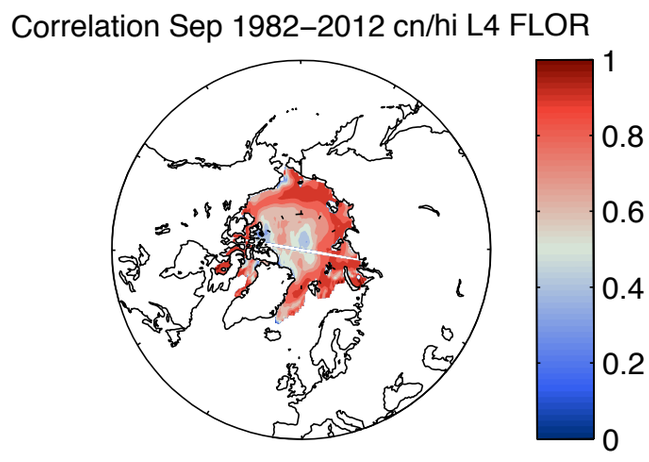


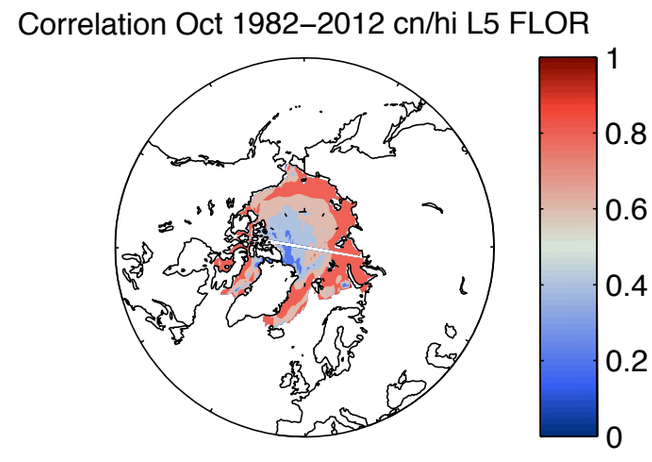








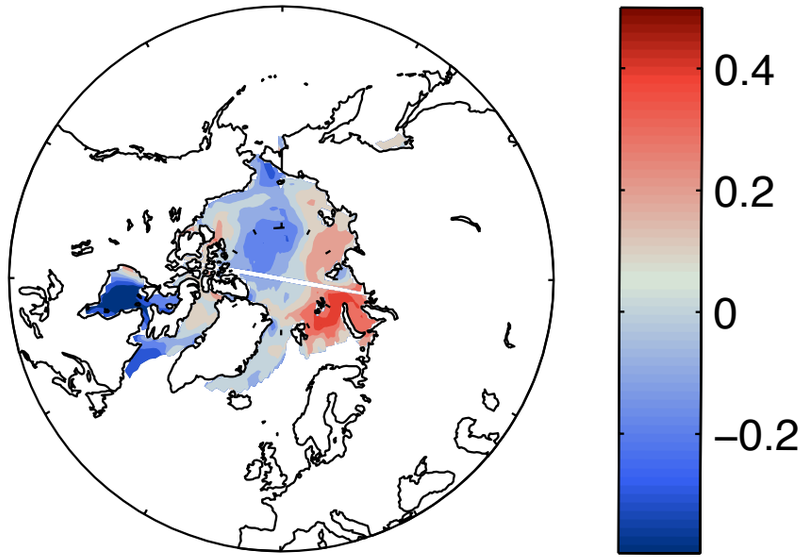




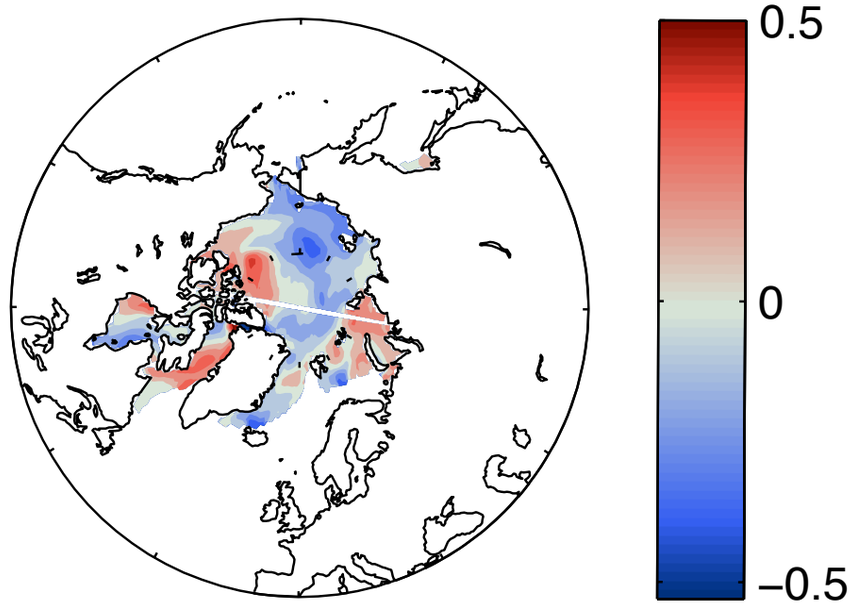
What is the mechanism that contributes to skill on regional scale?
Correlation between predicted concentration and predicted thickness
May initialization.

26–Mar–2015 12:16 r1m

Correlation JAS 1982–2012 cn/mht May BSO init May FLOR

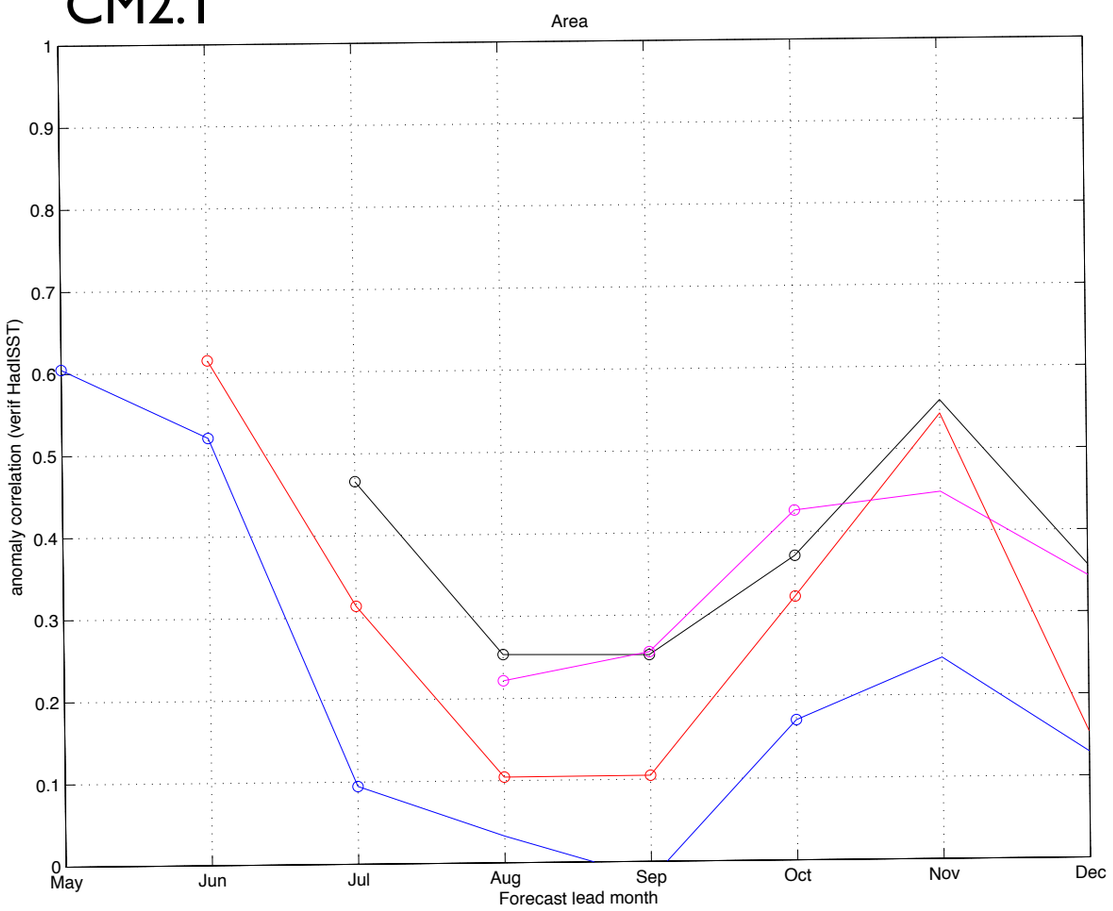


Correlation JAS 1982–2012 cn/mht BSO init May FLOR



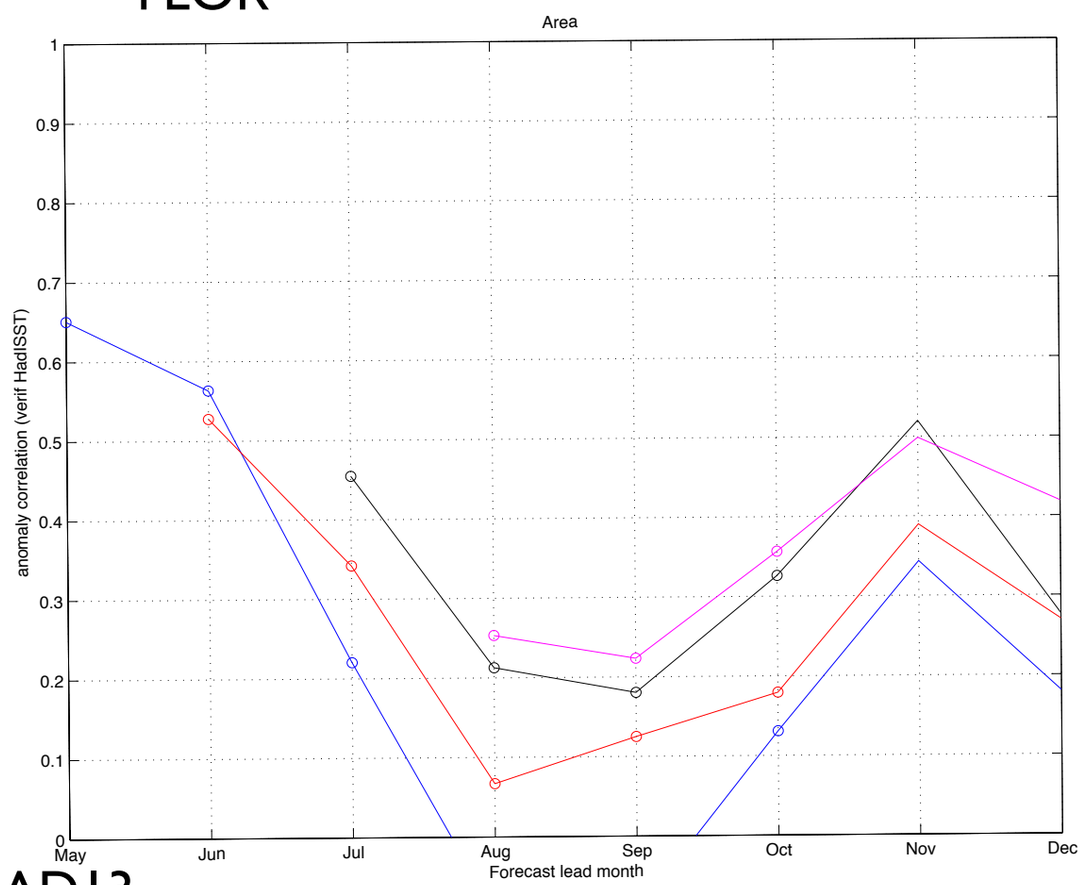
Pacific

CM2.1



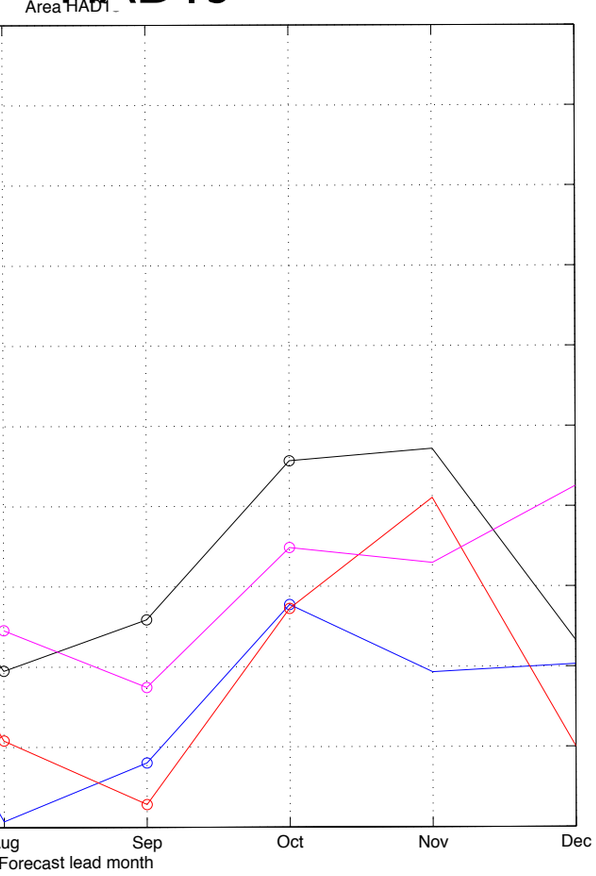
02–Apr–2015 12:20 r1m

FLOR



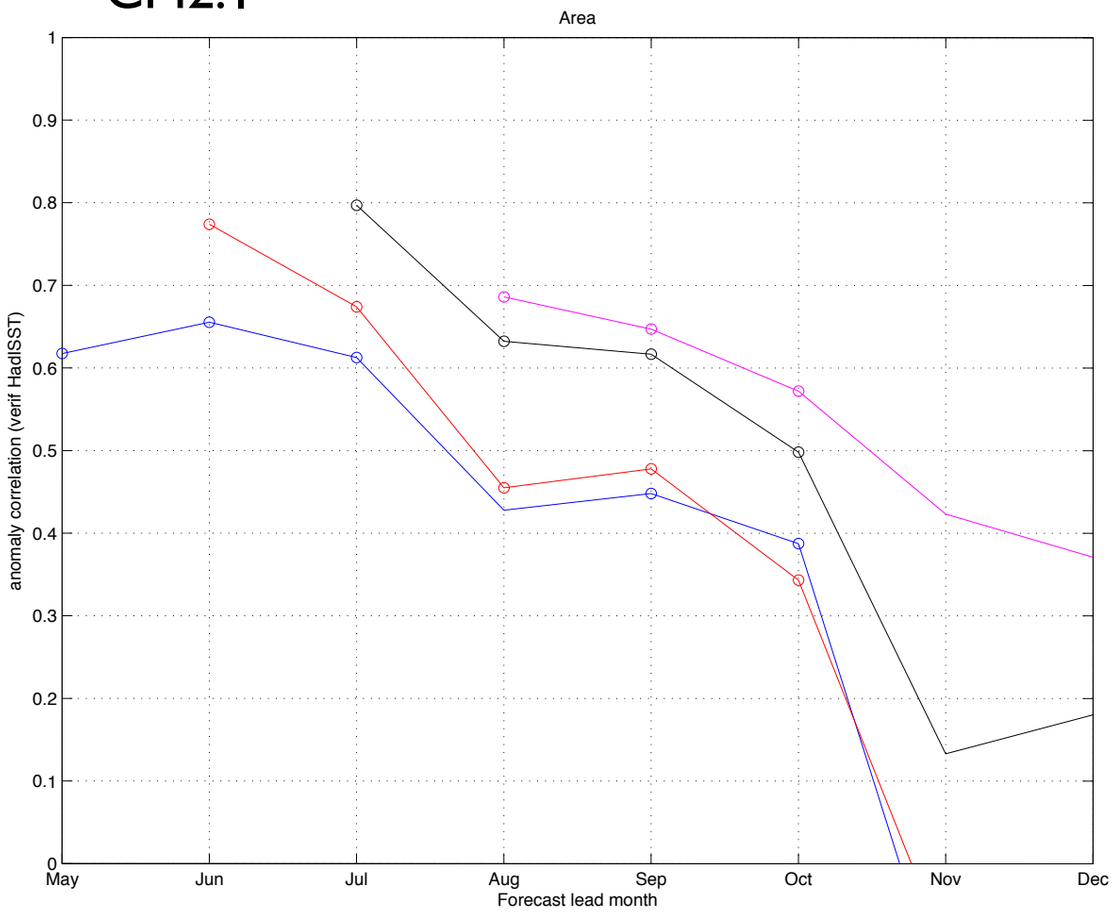
02–Apr–2015 12:15 r1m

HAD13



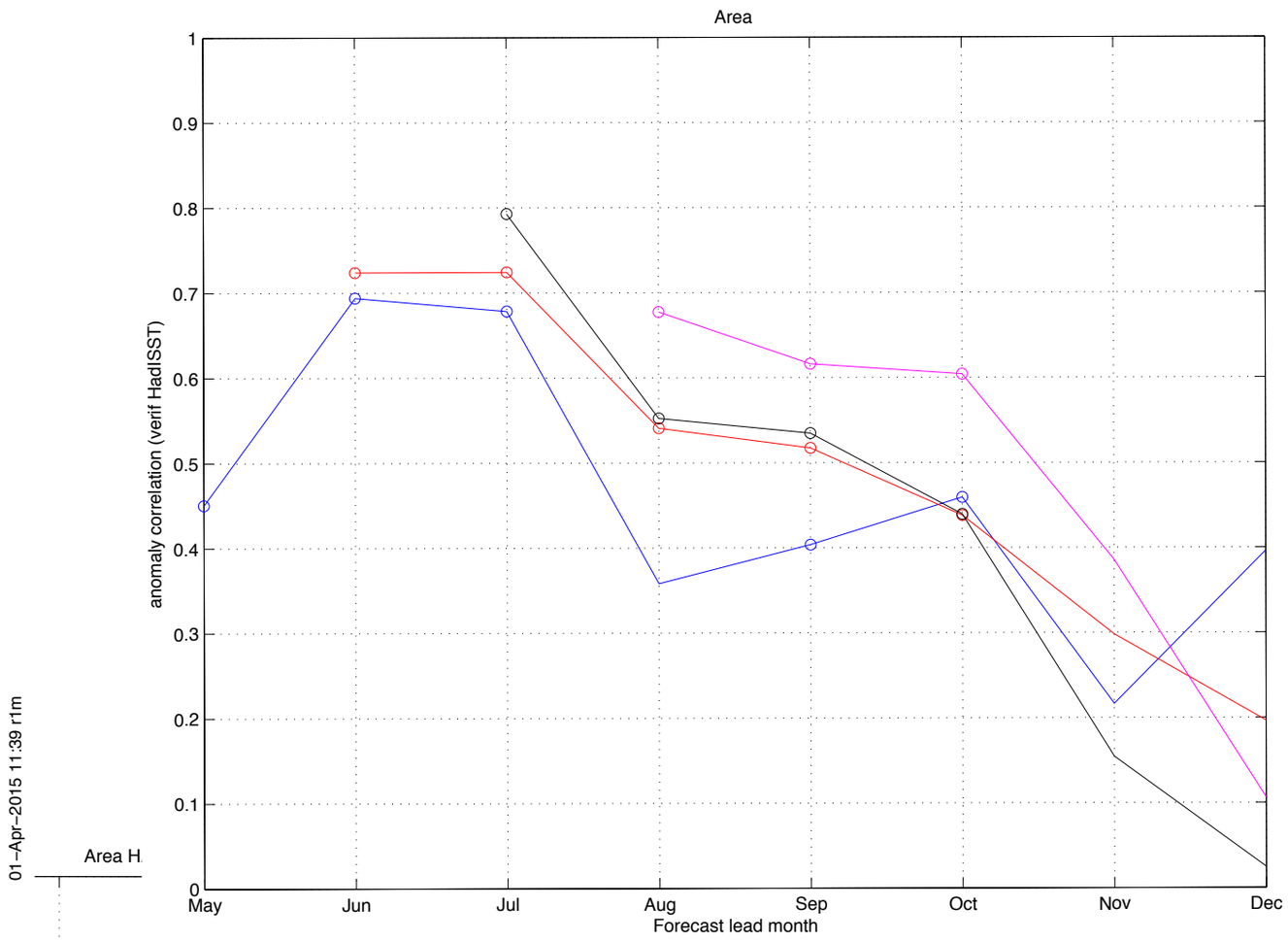
02–Apr–2015 12:27 r1m

CM2.1

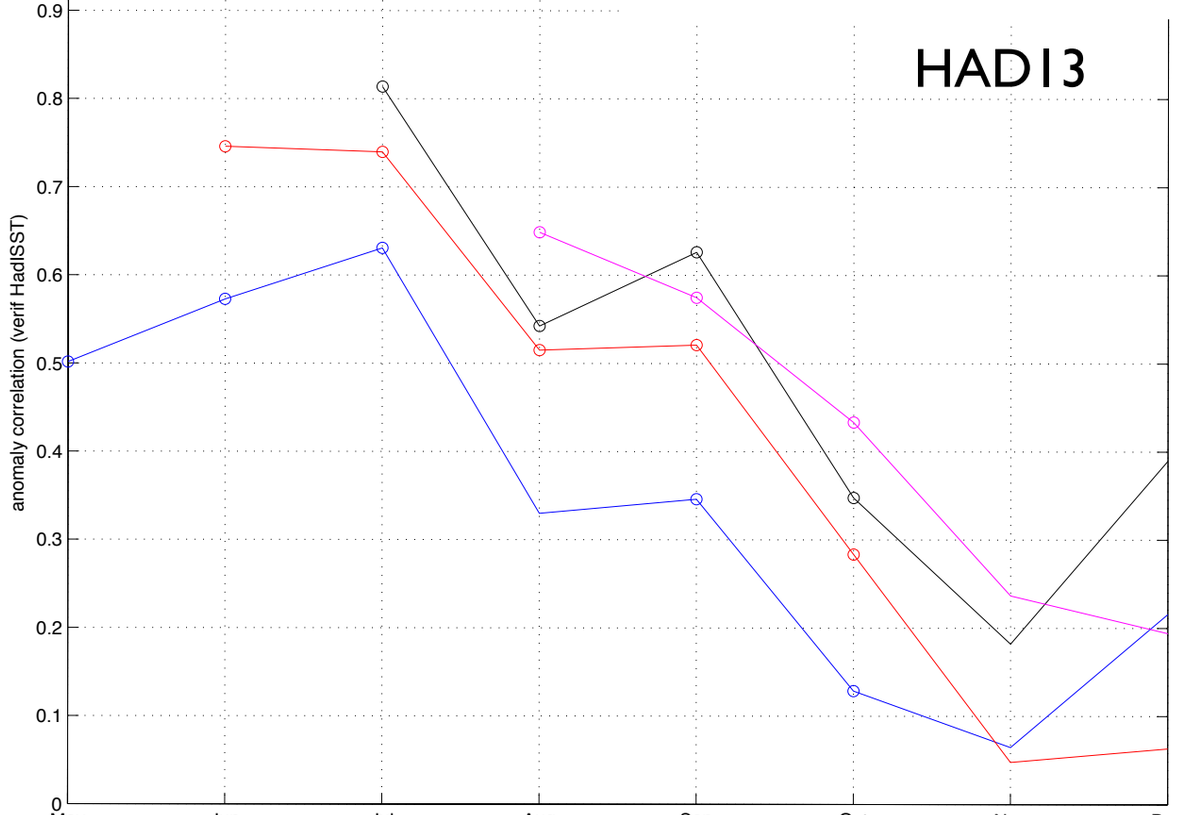


LKE

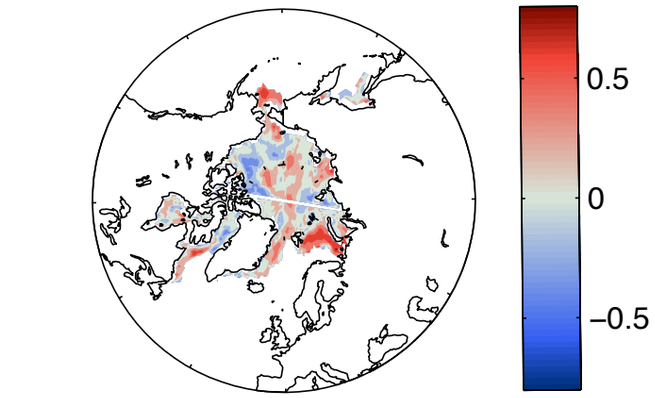
FLOR

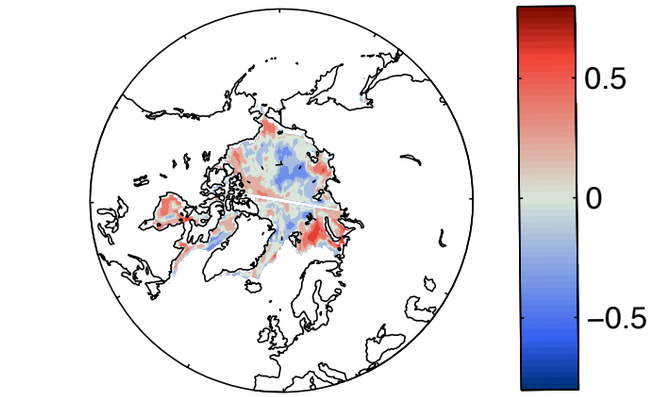


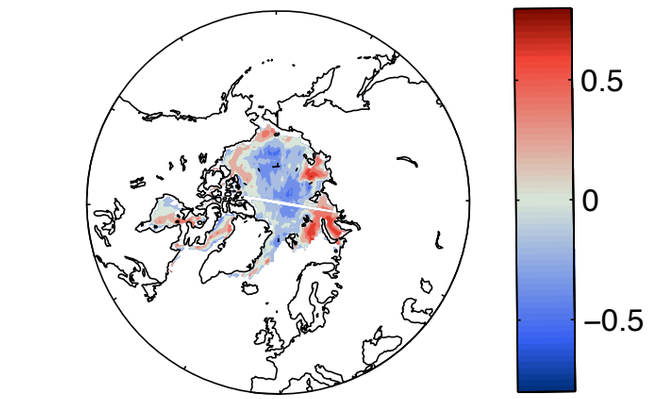
HAD13

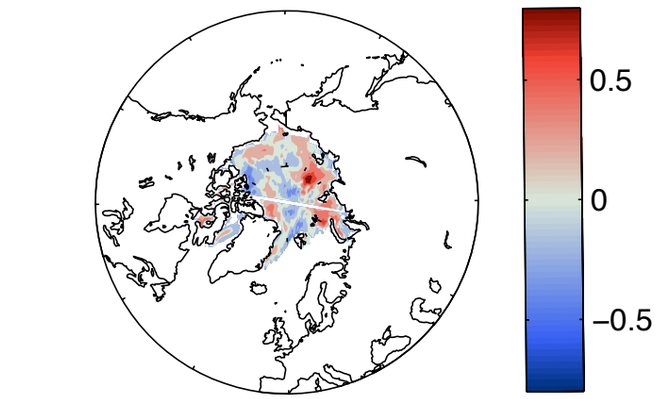


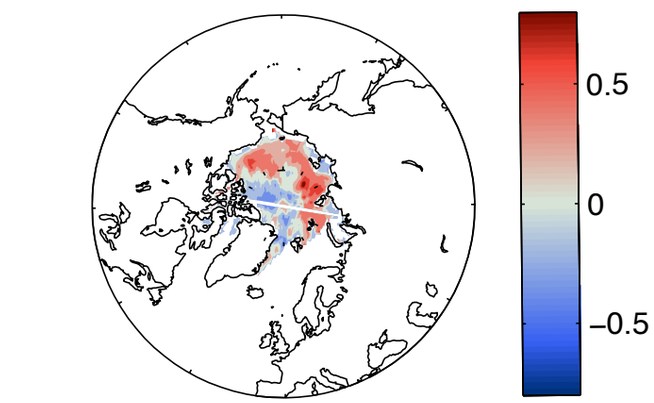
Correlation between the predicted concentration initialized in May and obs.
We see skill for Aug-Sep-Oct concentration in the Laptev/Kara/East Siberian regions

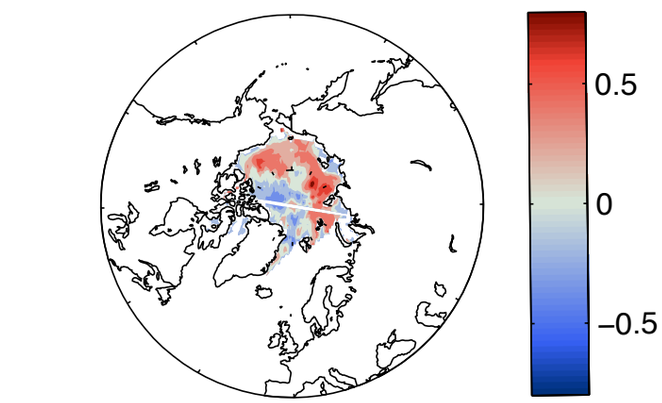






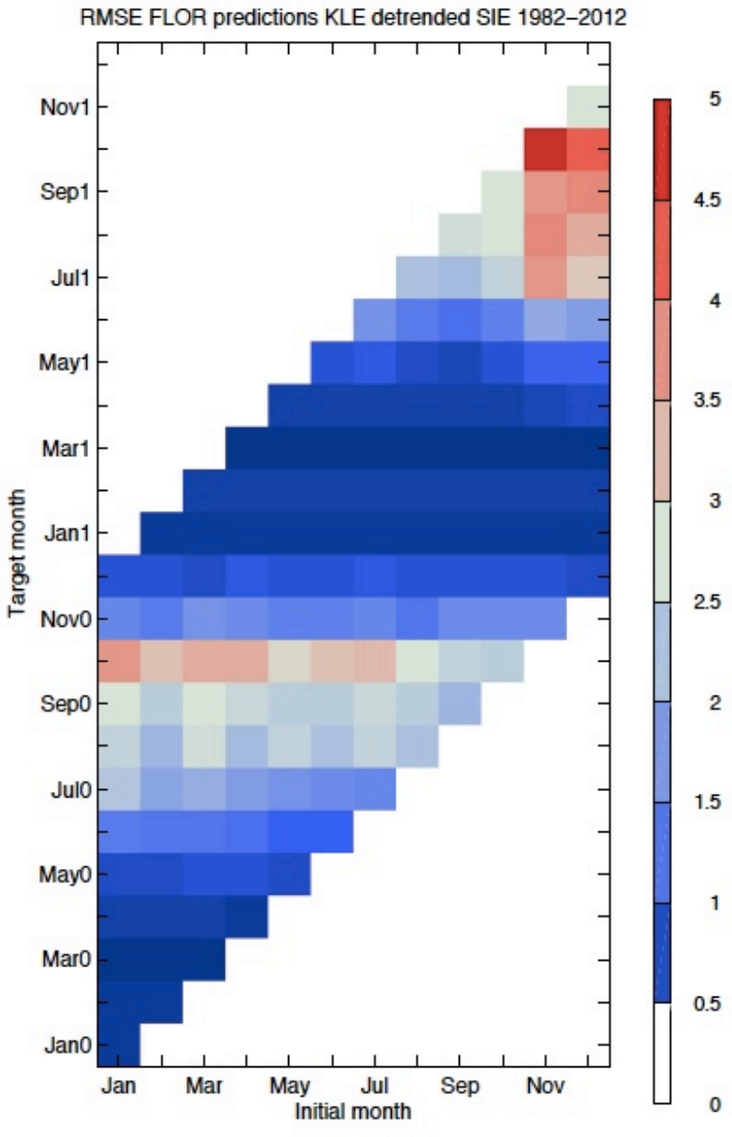


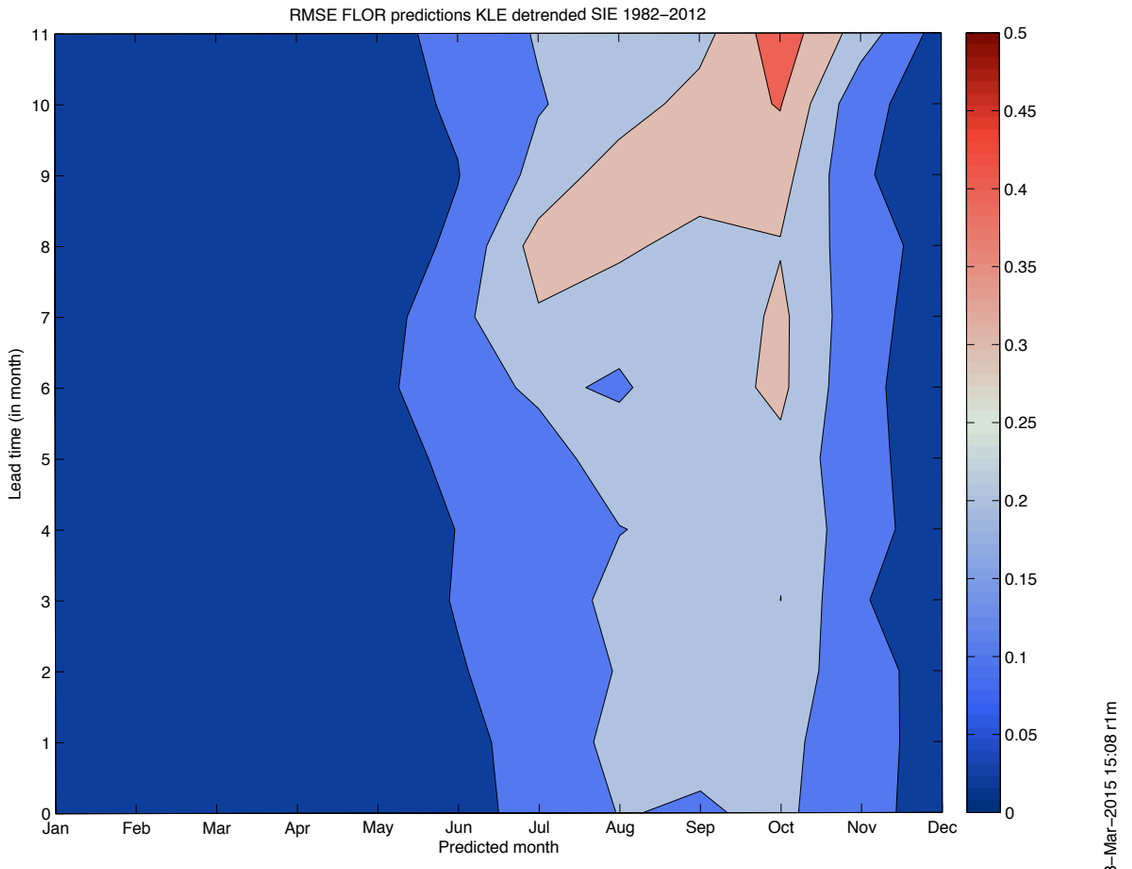




20–Mar–2015 17:16 r1m

RMSE of sea ice area averaged over the Laptev/Kara/East Siberian (LKE) regions

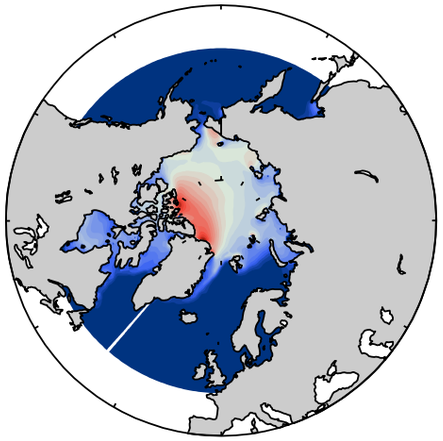




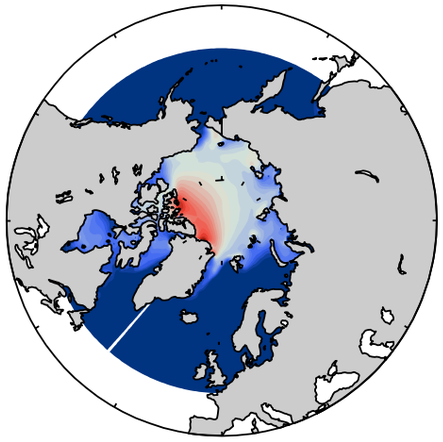
The rmse in summer remain quite small until lead 6-8 months

PIOMAS thickness

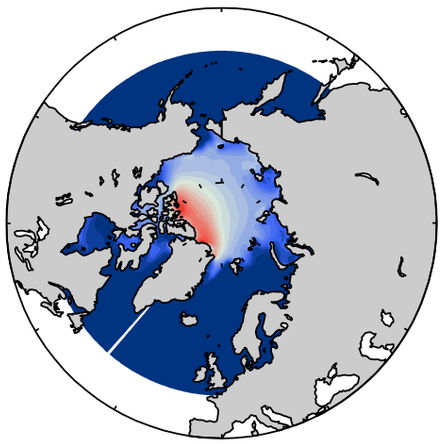
May 1983–2012 Thickness PIOMAS



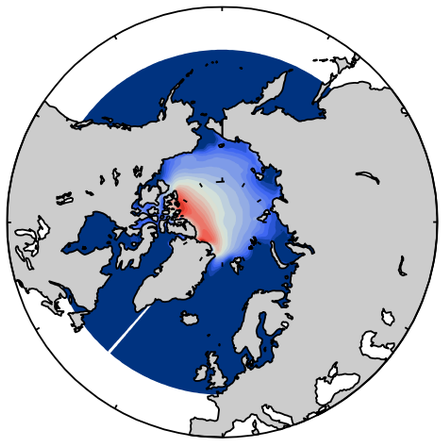
Jun 1983–2012 thickness PIOMAS



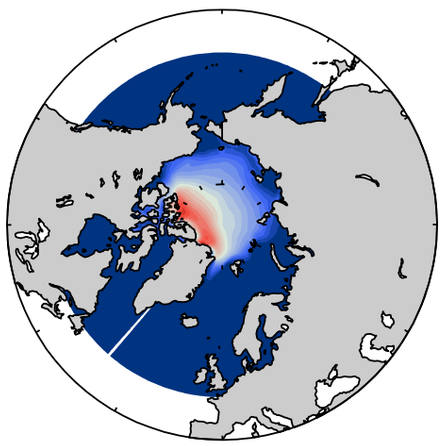
Jul 1983–2012 thickness PIOMAS



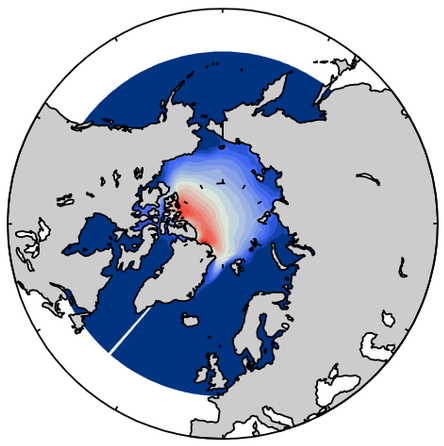
Aug 1983–2012 thickness PIOMAS



Sep 1983–2012 thickness PIOMAS



Oct 1983–2012 thickness PIOMAS



Mar–2015 10:59 r1m