Impact of declining Arctic sea ice on Northern Hemispheric weather

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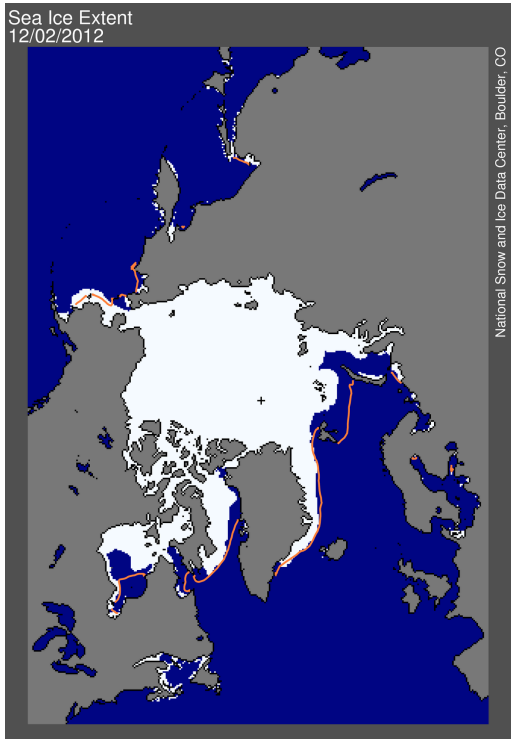
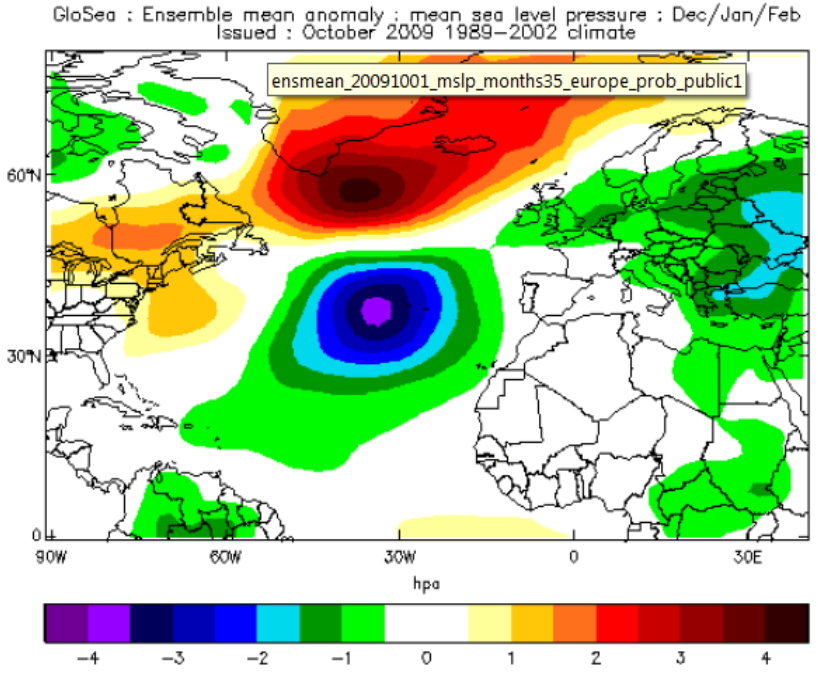
Georgia Institute of Technology





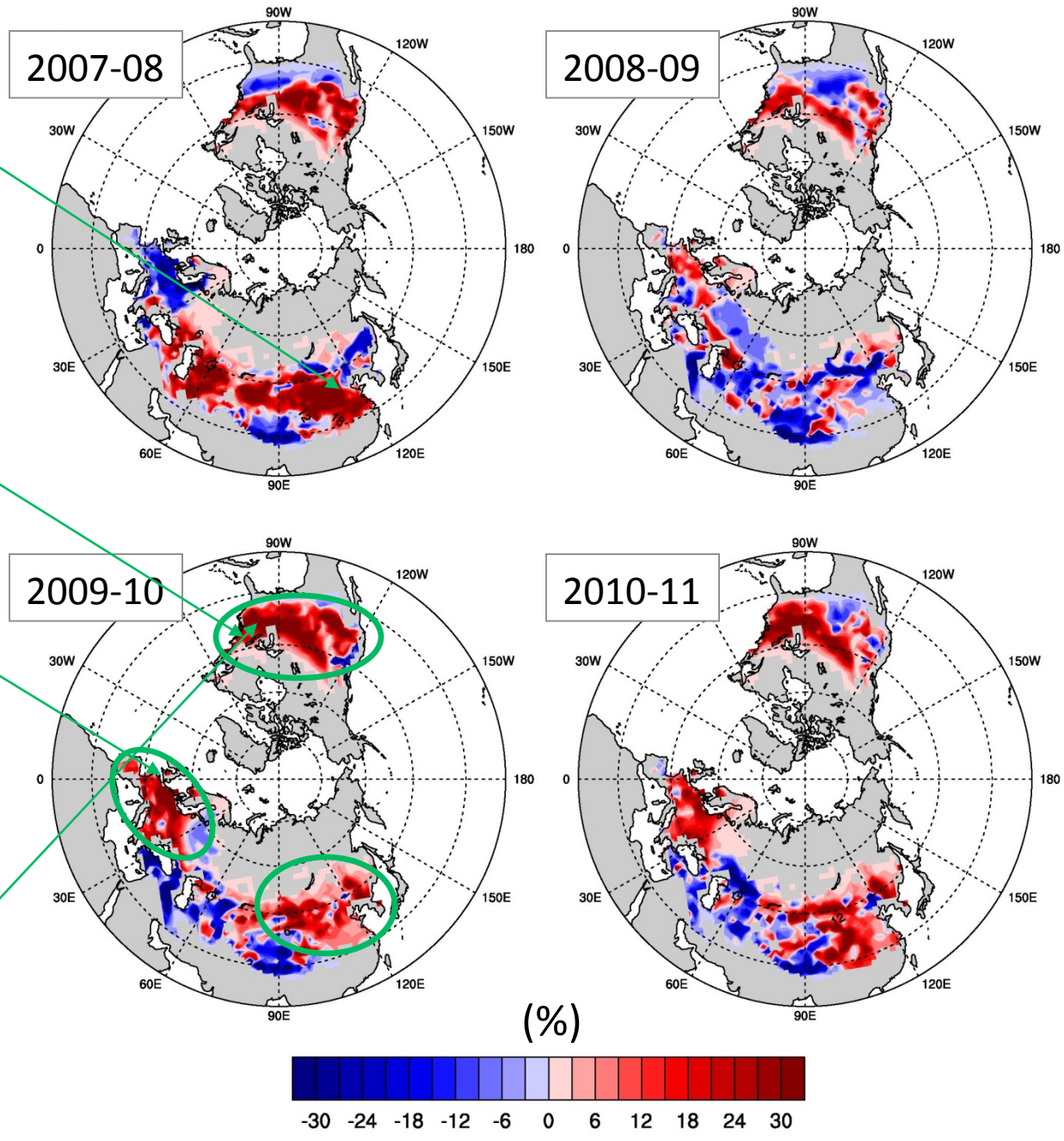
Part I: NH snow cover

Liu, J. J.A. Curry et al. 2012: Impact of declining sea ice on Arctic snowfall. PNAS, 109, 4074-4079

Part II: US surface temperature

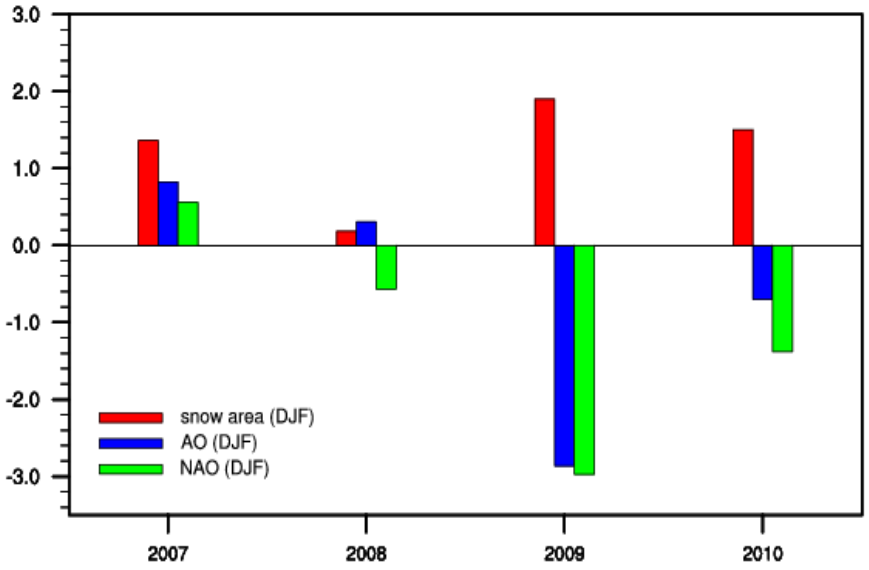
Winter season forecasts

Recent (2007-2010) winter snow cover anomalies

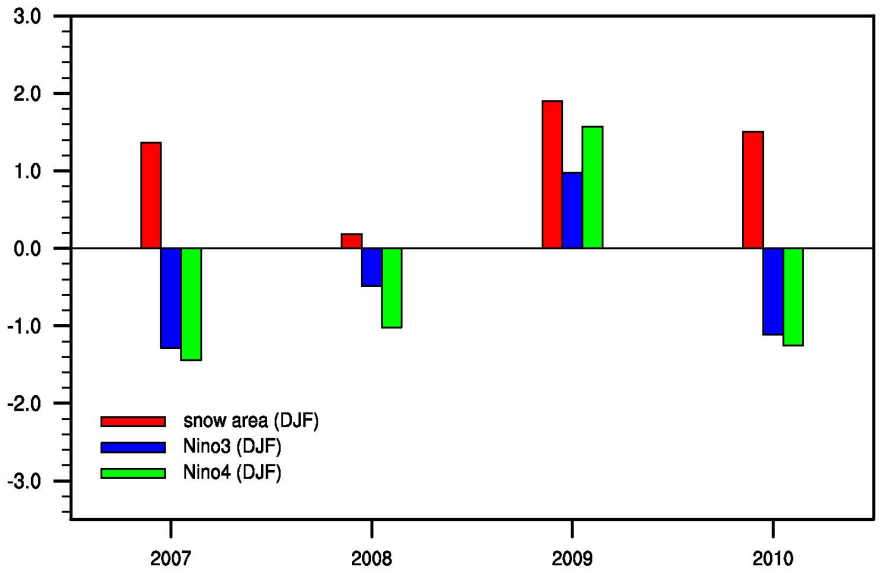


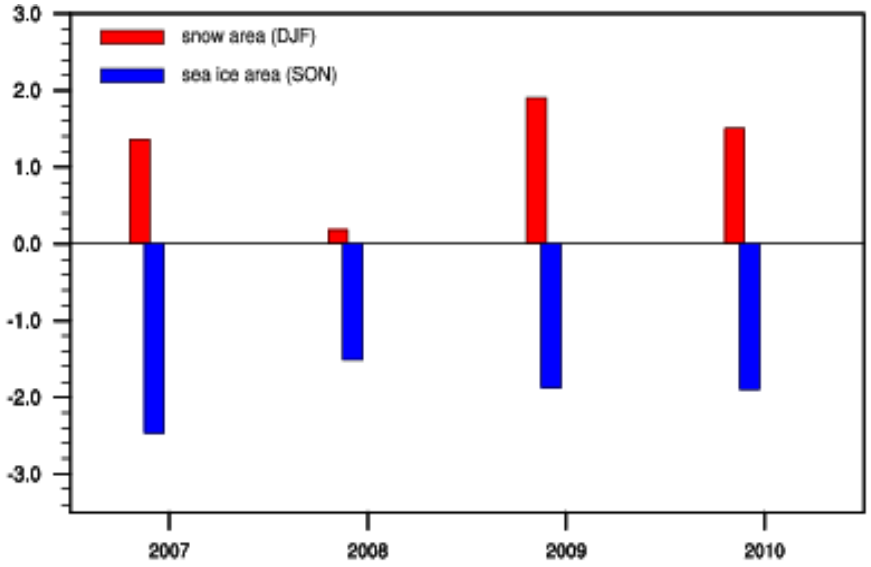
Winter snow area versus

NAO/AO



Nino3/Nino4

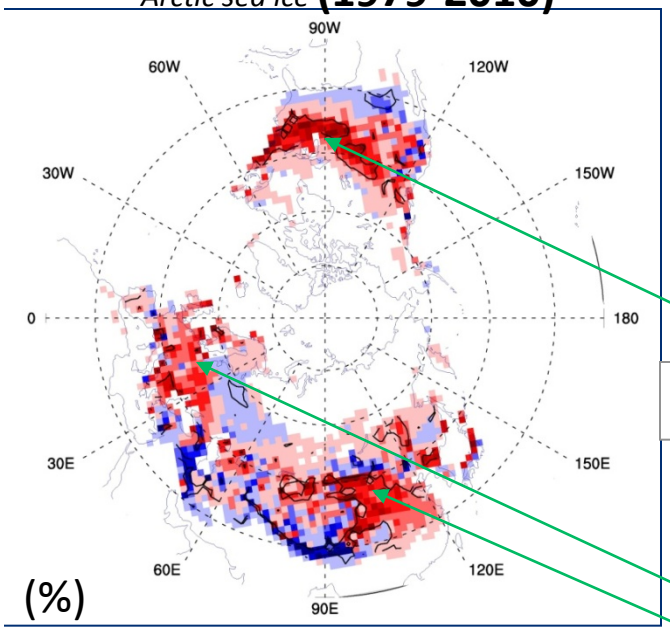




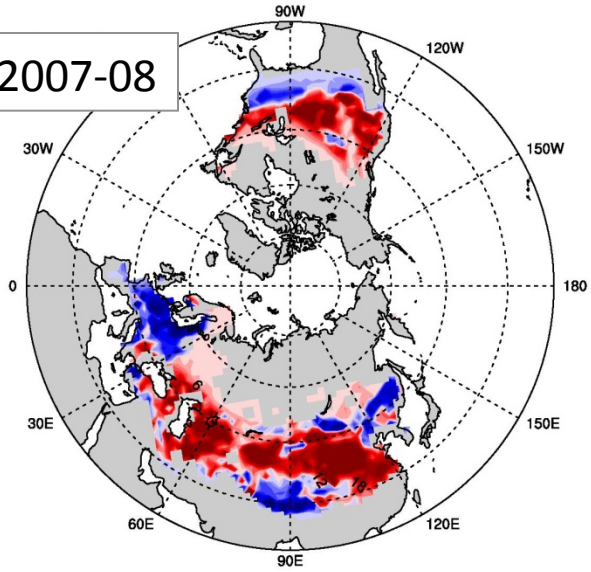
Autumn sea ice extent

Recent (2007-2010) winter snow cover anomalies

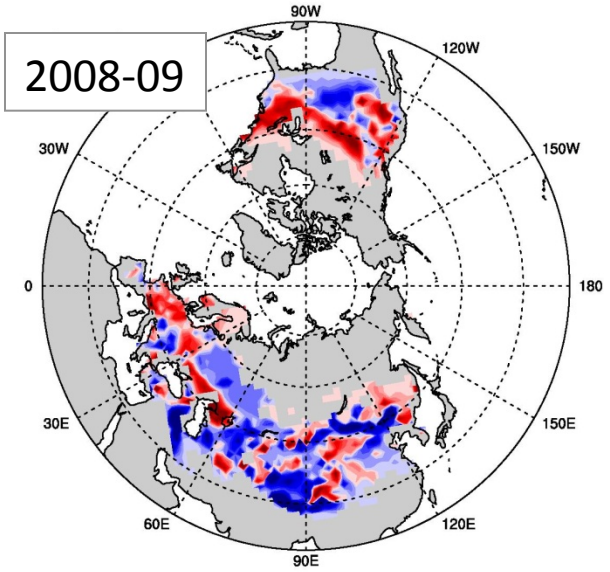
Regression of winter snow cover anomalies *on detrended index of autumn Arctic sea ice* **(1979-2010)**



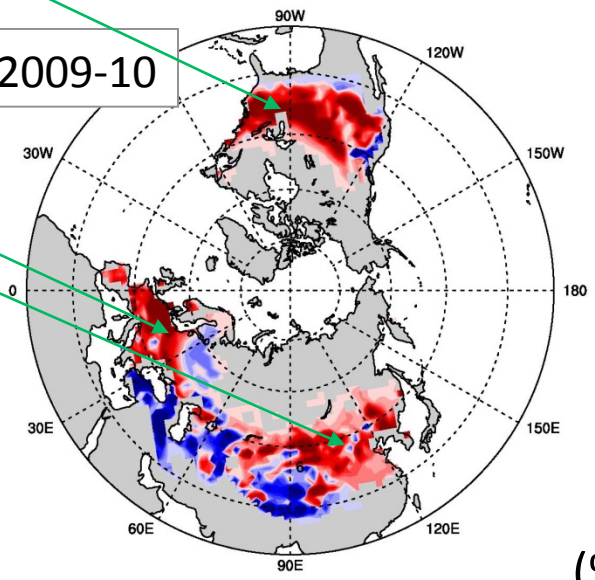
2007-08



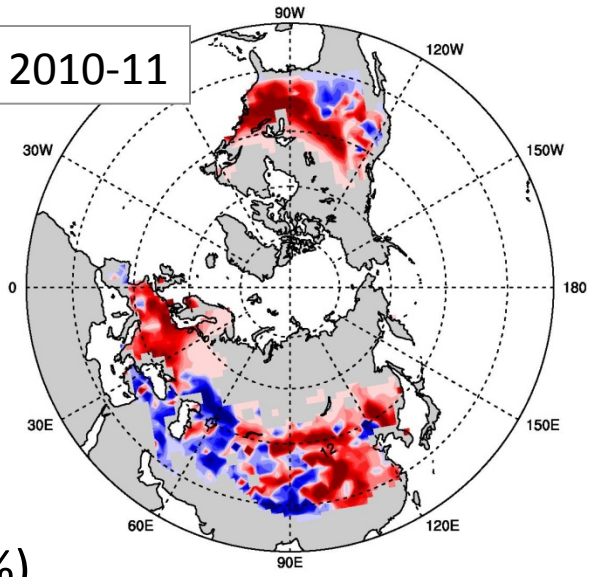
2008-09



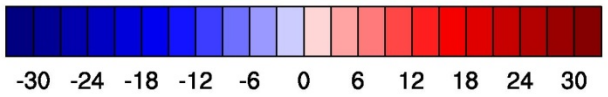
2009-10



2010-11



(%)



Hypothesized mechanism between decline of Arctic sea ice and anomalously snowy winters

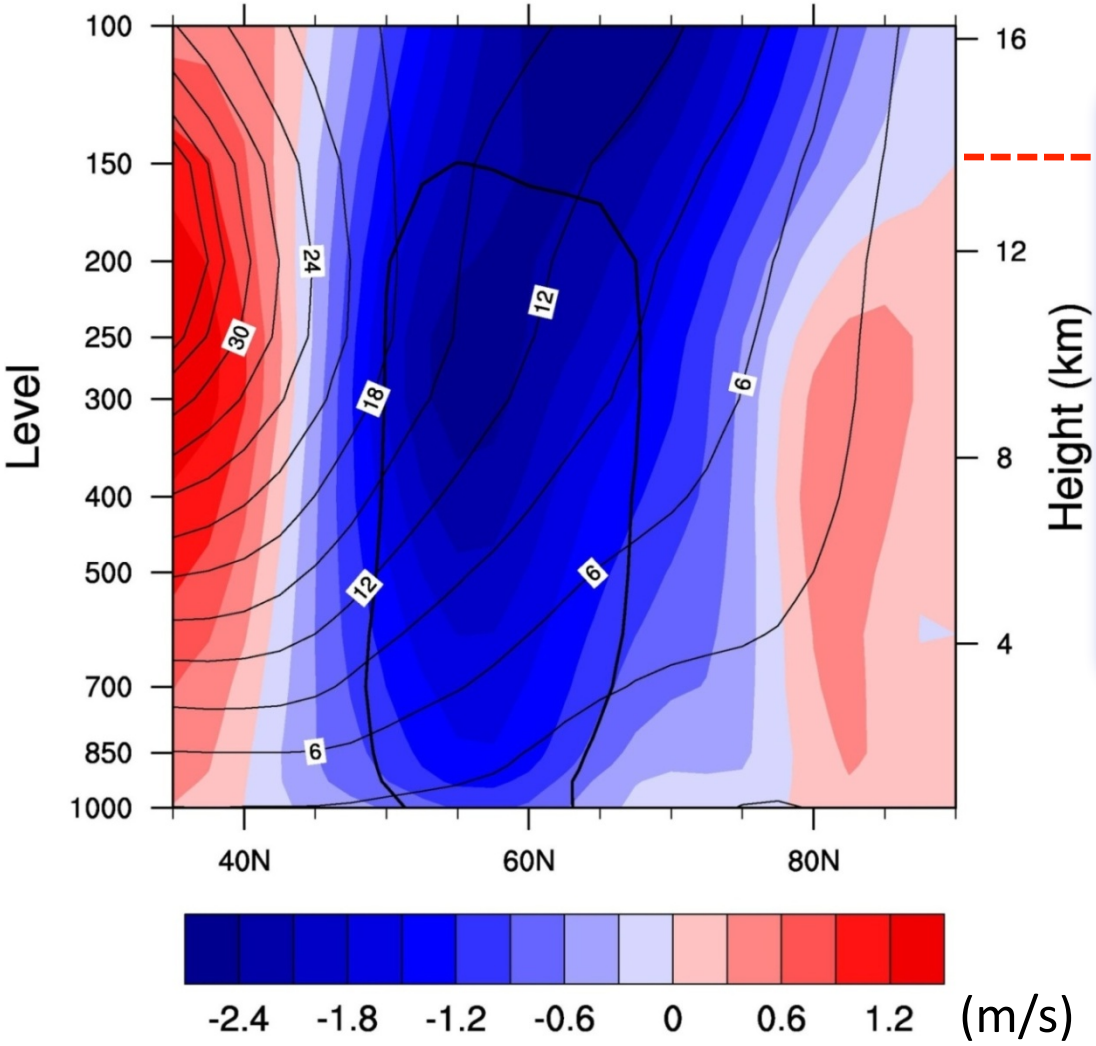
When sea ice is replaced by open water, substantial solar heat input directly into the ocean, increasing the heat stored in the upper ocean.

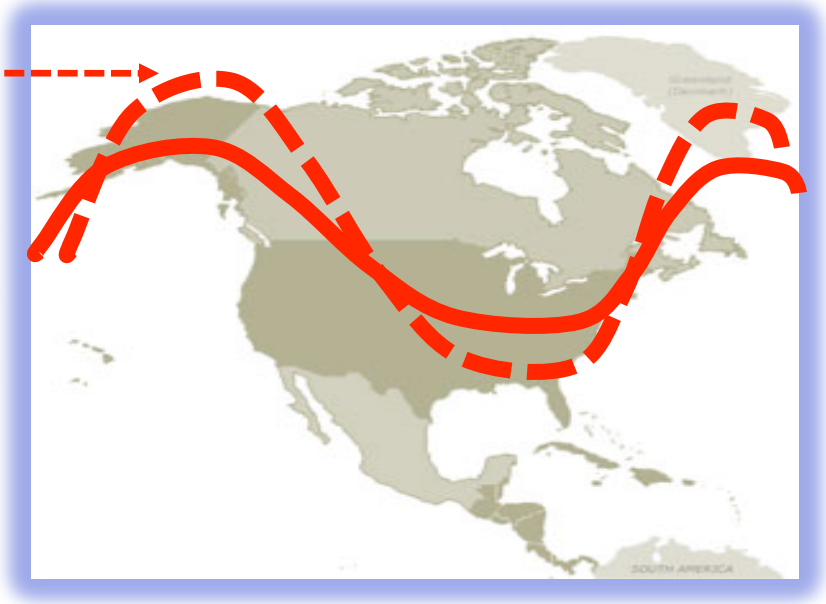
Warming of the upper ocean retards the recovery of sea ice during the freeze-up period.

Warm, ice-free ocean increases ocean surface flux of heat/moisture into atmosphere in late autumn/early winter, which has substantial impacts on winter atmospheric circulation.

Snowy Winter

Vertical cross-section of regression of winter zonal-mean zonal wind anomalies on detrended index of autumn Arctic sea ice **(1979-2010)**



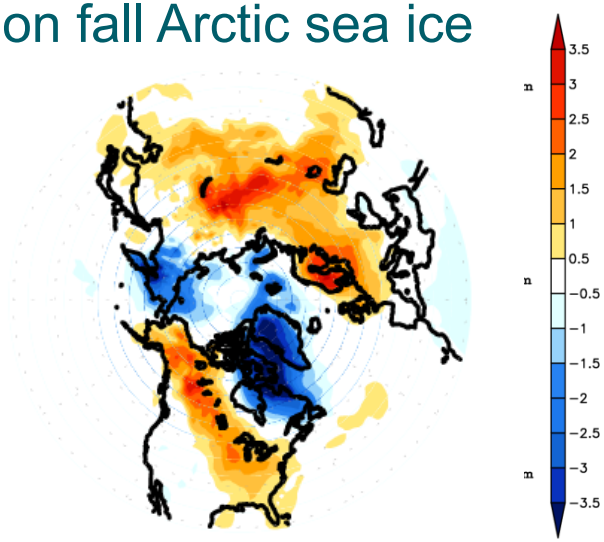


- Wave amplitude increases
- Rossby waves progress more slowly
- More blocking circulation

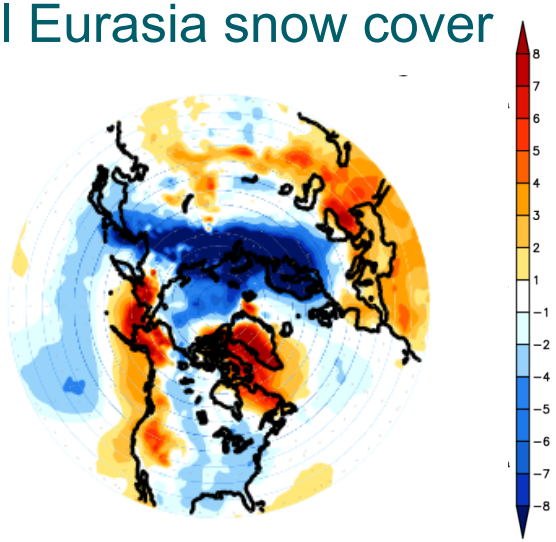
Causality question: is this being driven by the Arctic sea ice, or are both being driven by changes in hemispheric circulation regimes?

New Statistical Model for US Winter Temperatures

Winter temperature regressed on fall Arctic sea ice



Winter temperature regressed on Fall Eurasia snow cover



- Arctic sea Ice extent and snow cover impact mid-latitudes surface temperatures
- Reduced Fall Sea Ice cover >> Colder U.S. Winter
- Increased Fall Eurasia Snow Fall extent >> Colder U.S. Winter (Judah Cohen)

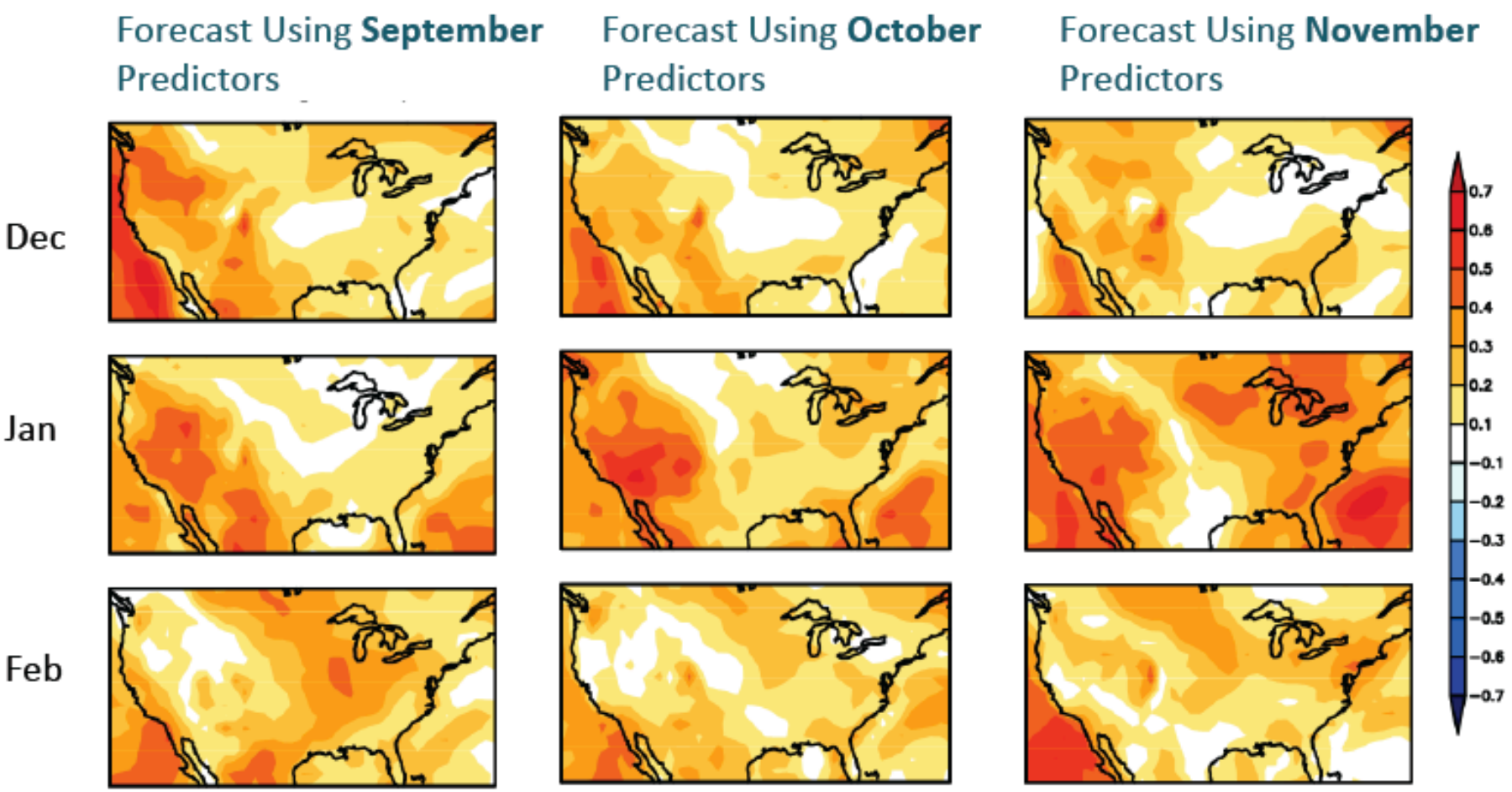
Predictors:
Arctic Sea Ice
Eurasia Snow cover

Multi-linear Regression Model

Surface Temp Prediction for U.S. and Europe

Regression Model Evaluation

Correlations between Observed and Forecasted Temperatures (1981-2010)

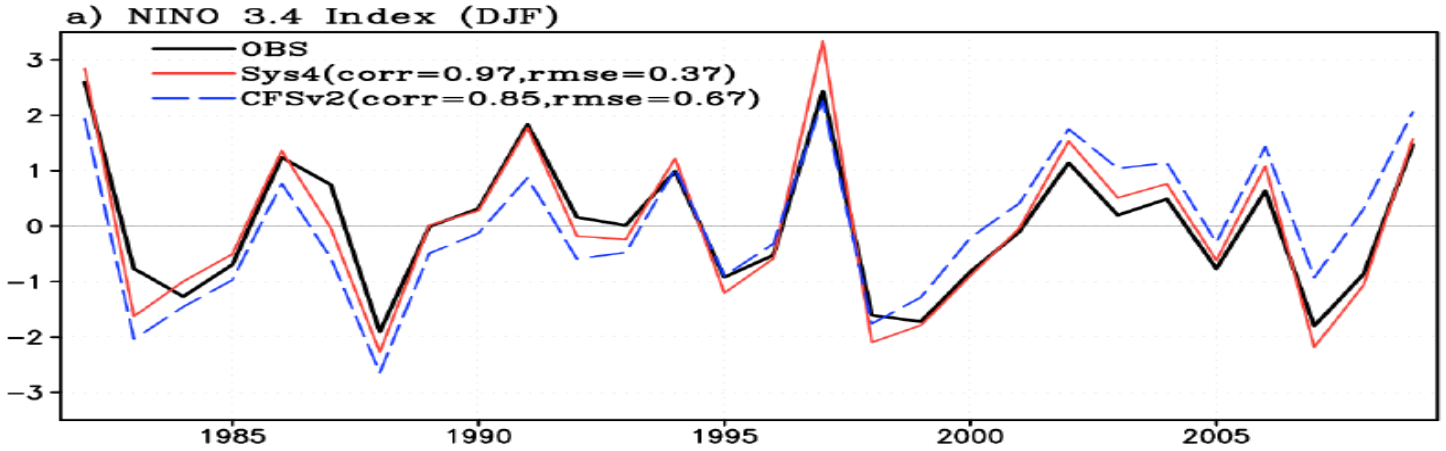


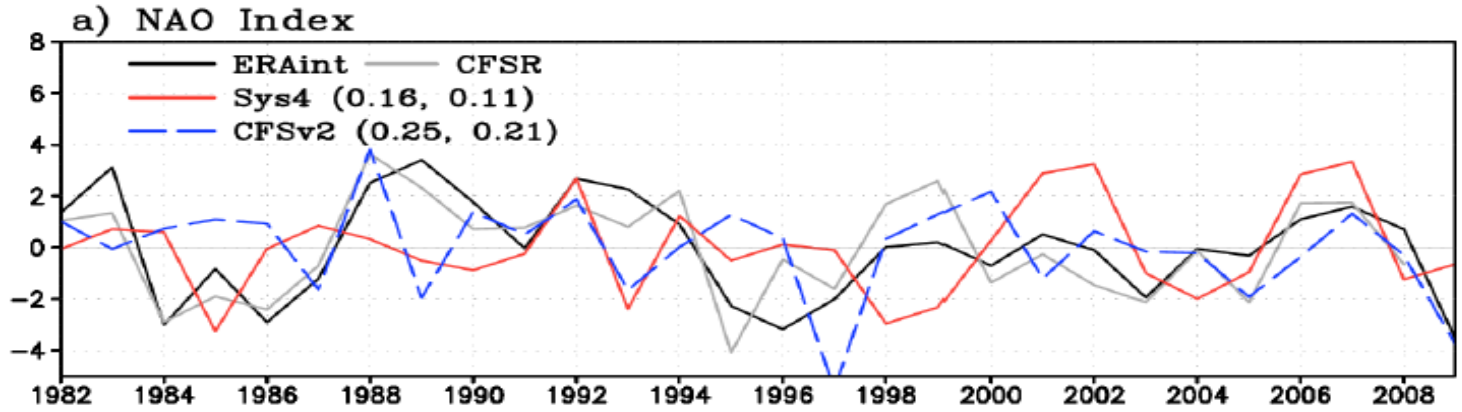
Winter Seasonal Forecast Skill: U.S. Surface Temperatures

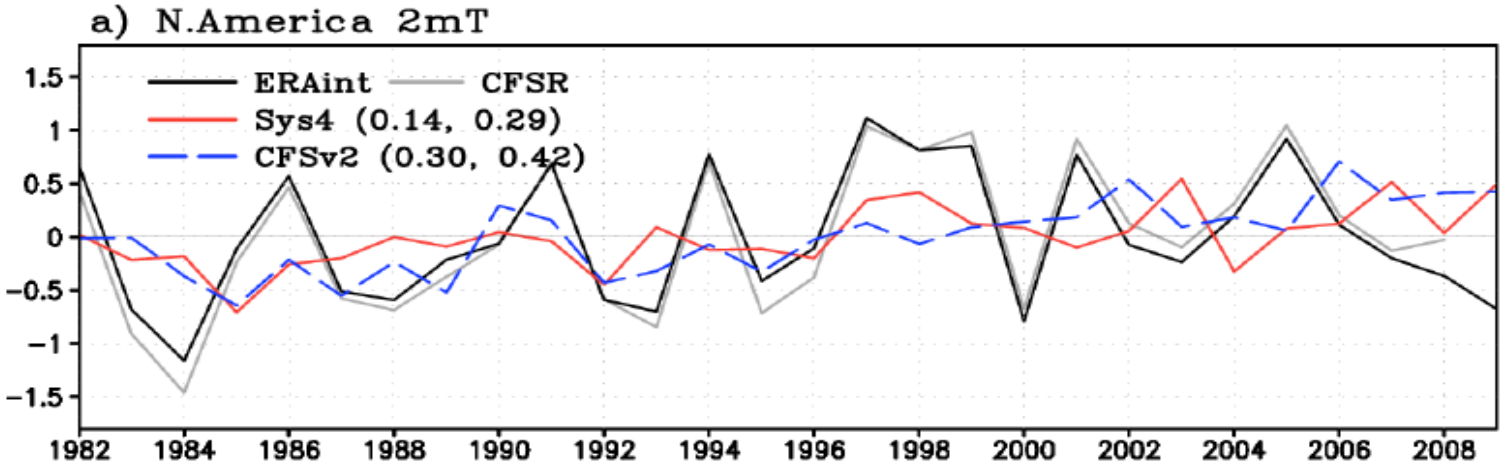
Empirical models

Coupled A/O GCM ensemble forecast systems

- NOAA NCEP CFSv2 (interactive dynamical sea ice)
- ECMWF System 4 (specified sea ice)
- UKMO GLOSEA 4 (interactive CICE)







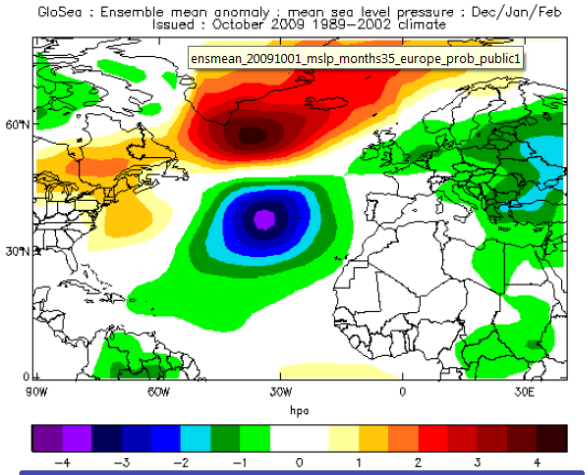
IC: Nov for DJF

Kim, Webster, Curry 2012

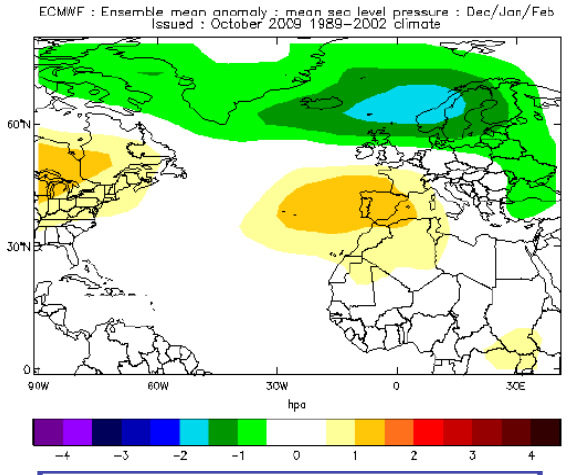
Importance of sea ice model & data assimilation

- 2009/2010 Winter Forecast

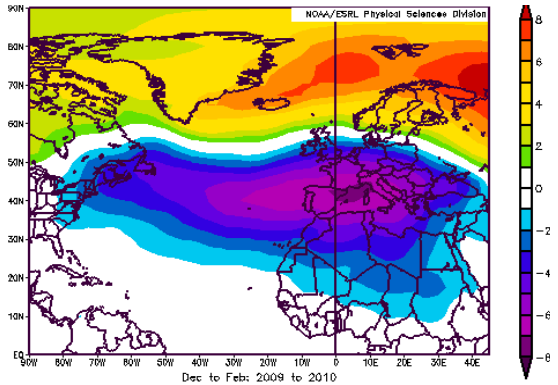
IC: October 2009 pmsl anomalies for DJF



UKMO GLOSEA 4



ECMWF System 3



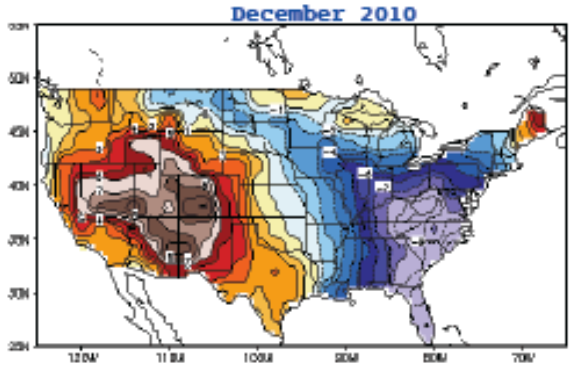
Observations

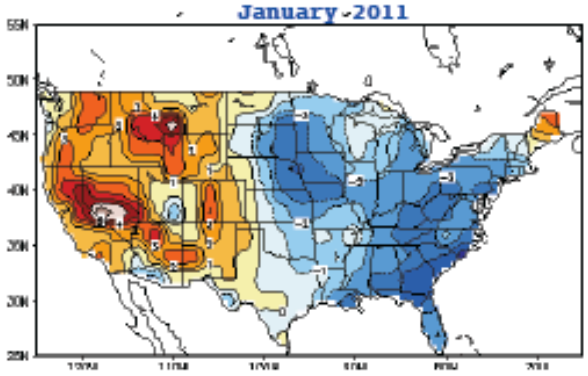
✓**GLOSEA 4: Sea ice model and assimilation of data**

http://www.ecmwf.int/newsevents/meetings/workshops/2011/MOS13/presentations/Hewson.pdf

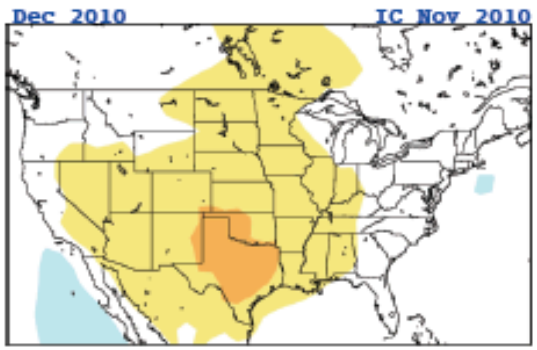
Winter 2010/2011

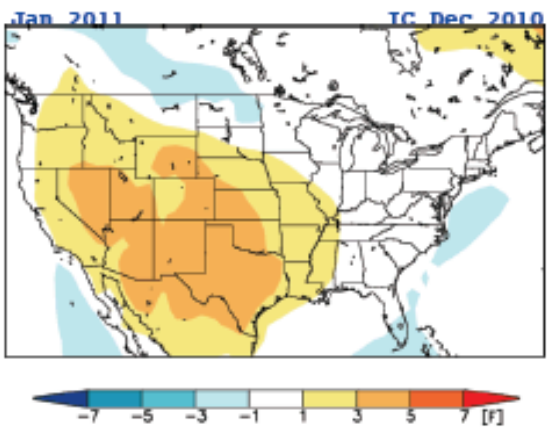
Observations



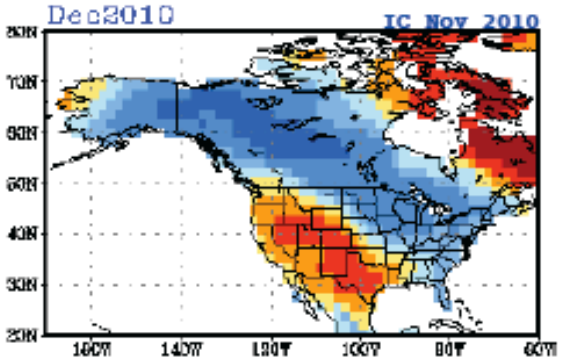


ECMWF System 3

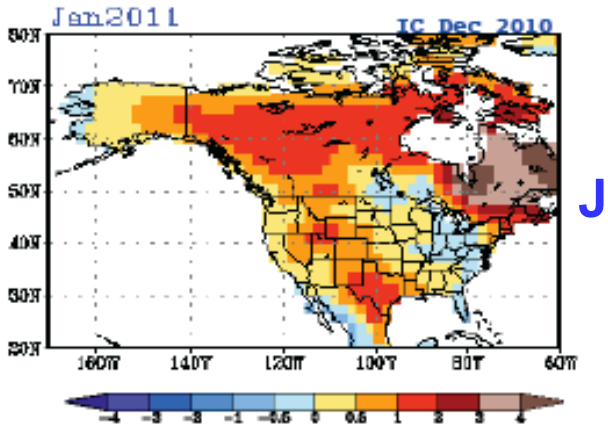




NCEP CFS

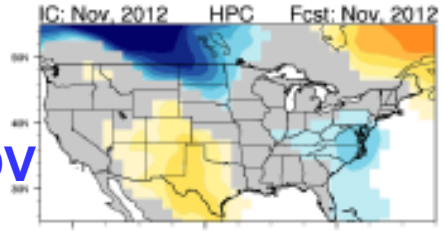
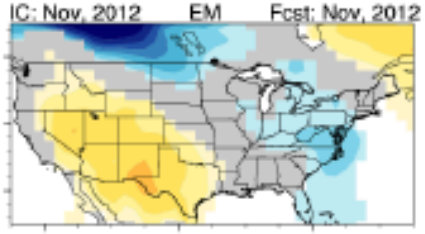
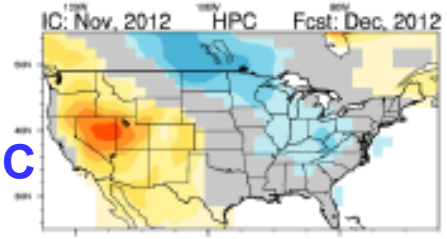
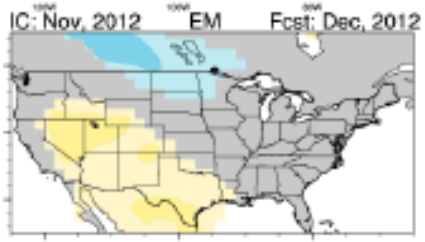
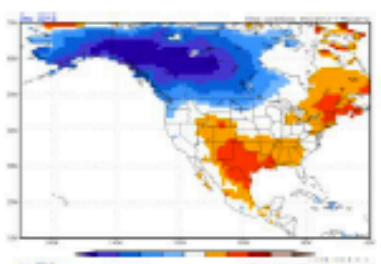
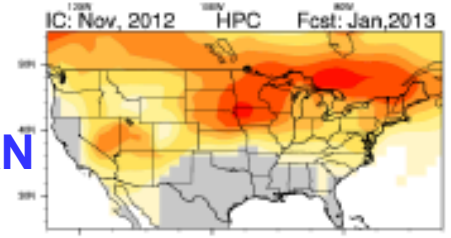
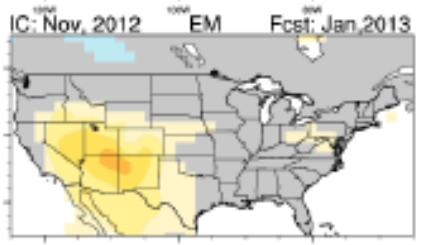
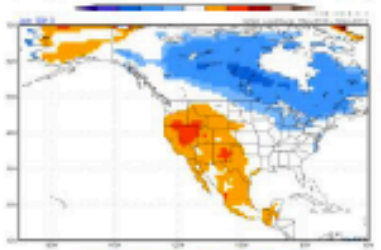
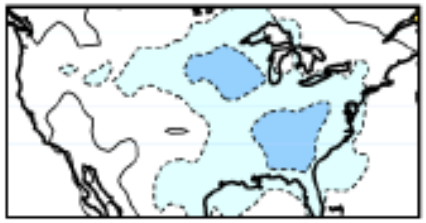
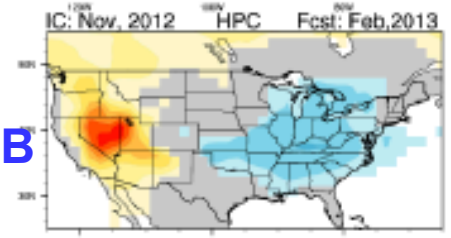
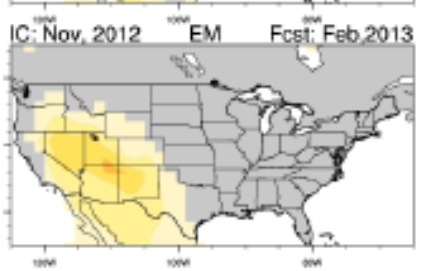
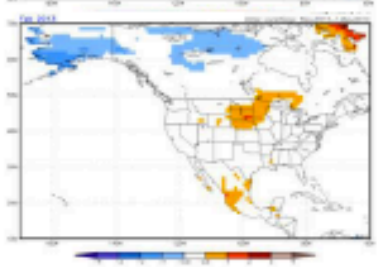
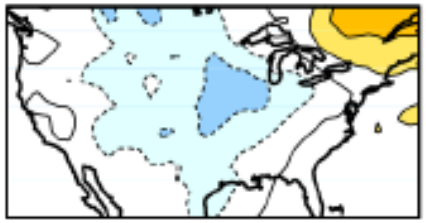


DEC



JAN

Winter 2012/2013 Forecast:
US Surface Temperature Anomalies

	ECMWF High Predictability Cluster*	ECMWF Ensemble Mean (IC 11/01)	CFSv2 Ensemble Mean (IC 11/04 – 11/14)	Statistical Model Nov. Predictors
NOV			N/A	N/A
DEC				
JAN				
FEB				

*made on Nov. 15

Conclusions

- Sea ice variations impact circulation regimes and surface weather
- Chicken and egg: sea ice, teleconnection regimes and the multidecadal oscillations have complex interactions
- Seasonal forecast models are getting interesting; interactive sea ice
- In the absence of high amplitude ENSO event, winter season forecasts (initialized in Oct, Nov) are highly uncertain
- Empirical models (network theory) have potential for seasonal forecasting, but need a longer data record (sea ice, circulation regimes) back to the 1930's.