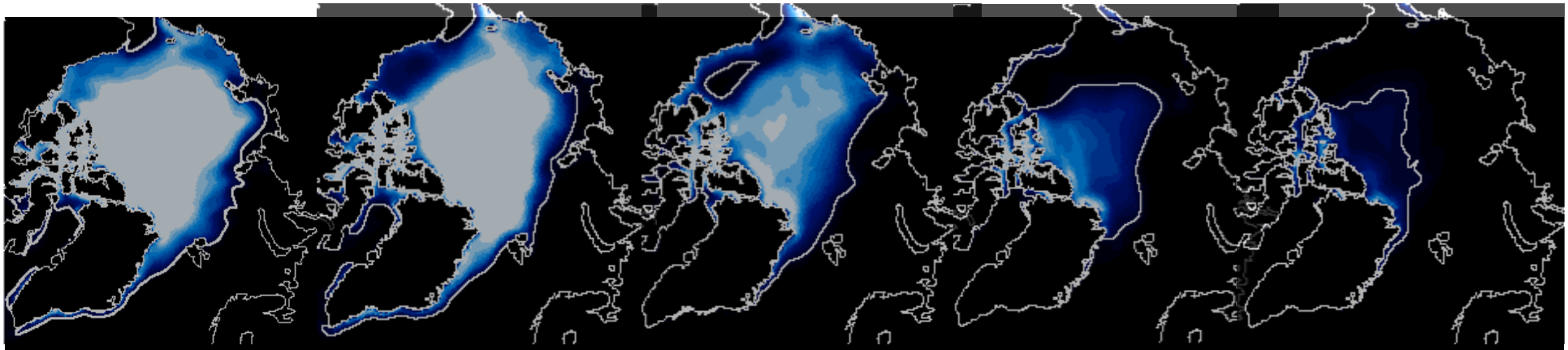

Mechanisms Influencing Arctic Sea Ice Predictability

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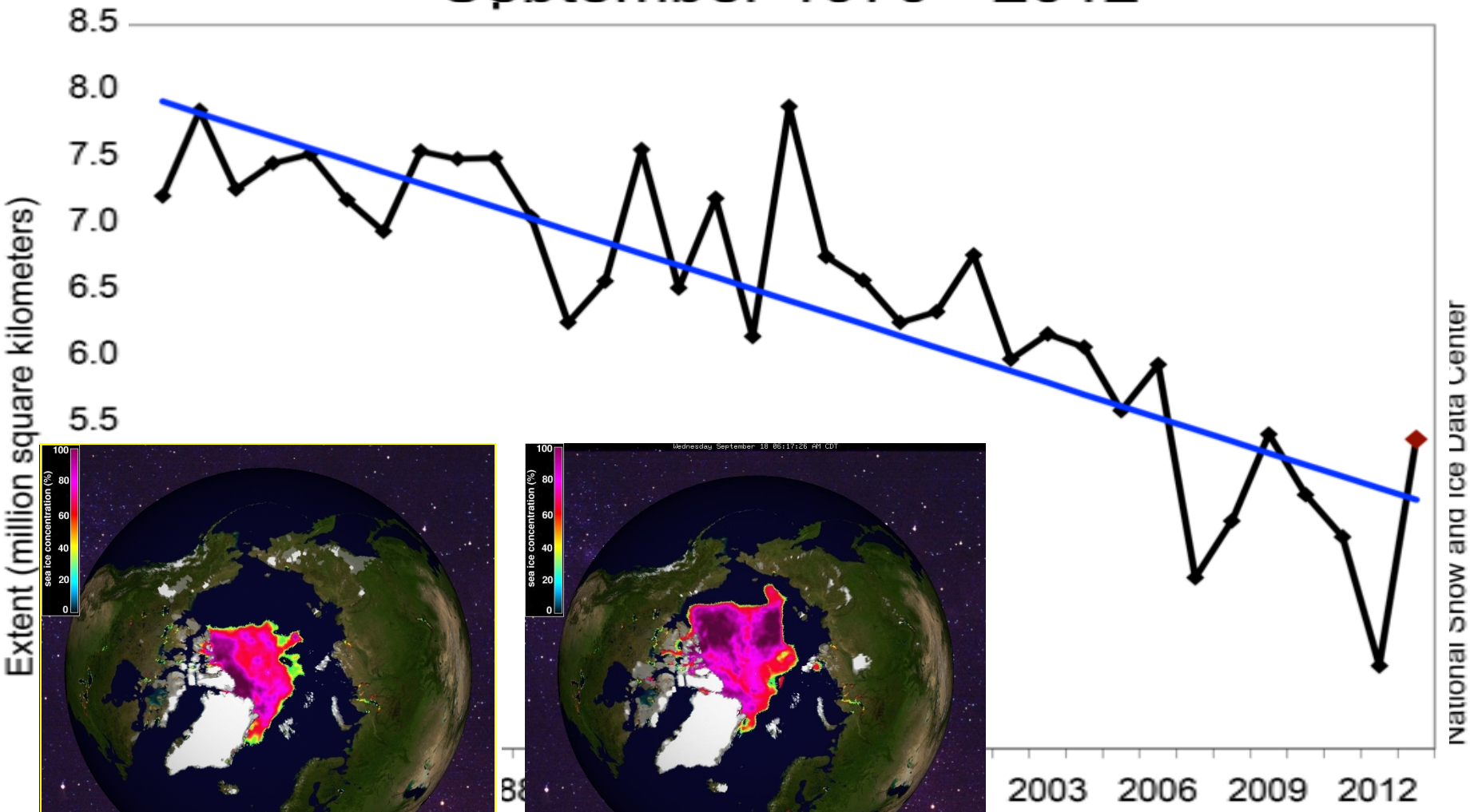
Collaborators:

David Bailey (NCAR), Steve Vavrus (U.WI), Julienne Stroeve (NSIDC), Ed Blanchard-Wrigglesworth (U. WA), Cecilia Bitz (U. WA), Jennifer Kay (NCAR)

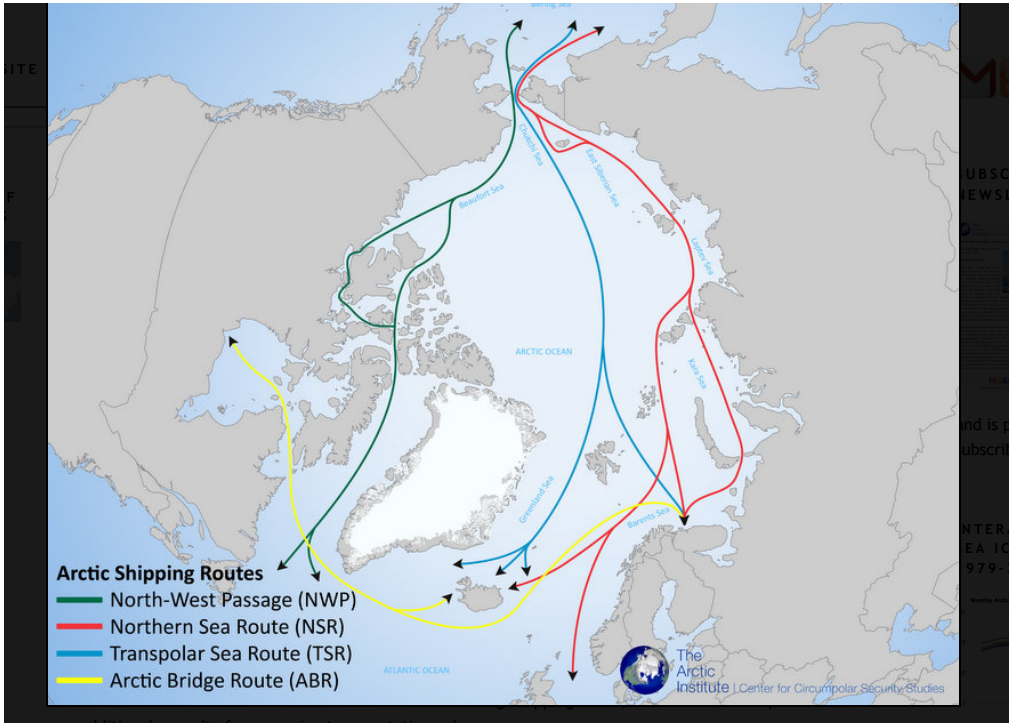
NCAR is sponsored by the National Science Foundation

Average Monthly Arctic Sea Ice Extent
September 1979 - 2012



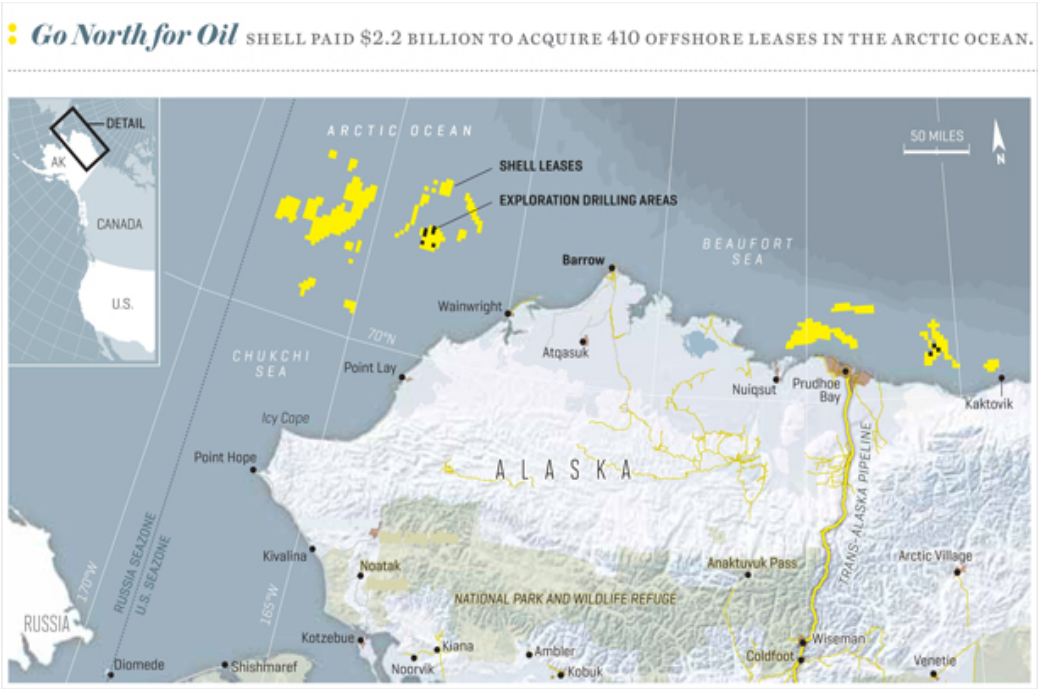
From The Cryosphere Today, U. IL

~13% per decade linear trend



46 vessels through Northern Sea Route

Barents Observer



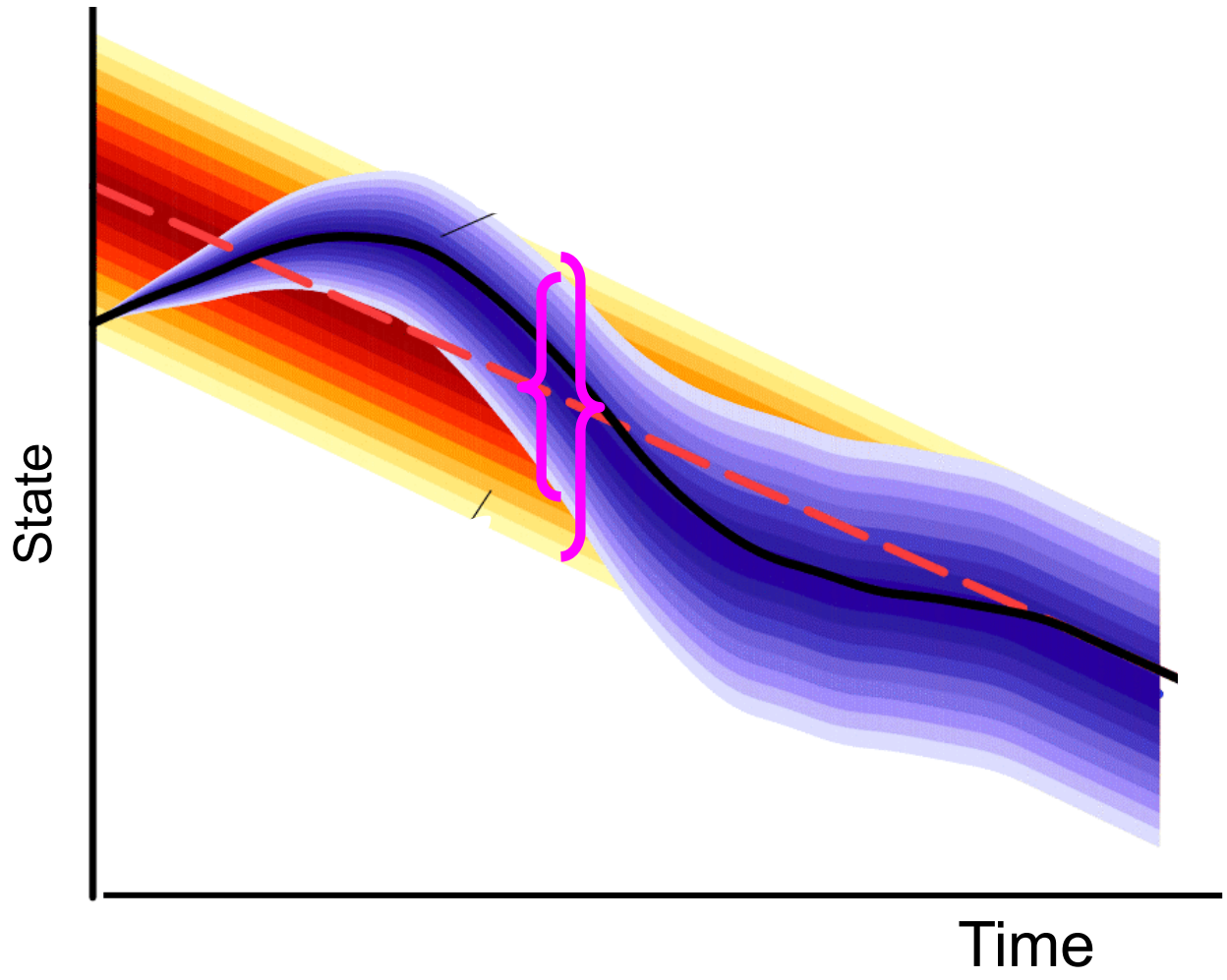
Predictability

Of the First Kind:

- Initial value problem
- Sensitive dependence on initial conditions limits predictability
- Timescale depends on system

Of the Second Kind:

- Boundary value problem
- Prediction of statistical properties of the climate system subject to some external forcing



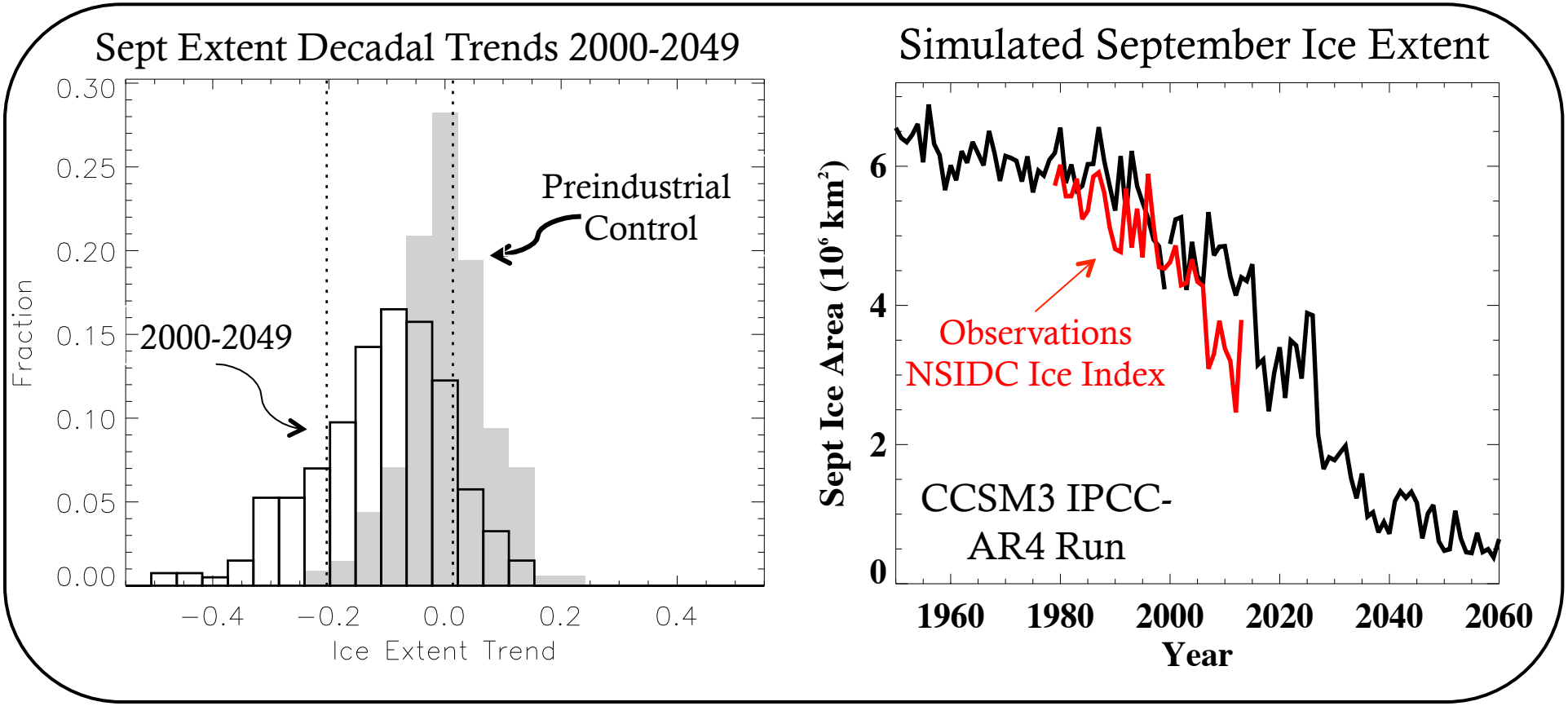
Total: Combination of the two

(Adapted From Branstator and Teng, 2011)

Using climate models to investigate sea ice predictability

Simulated September Sea Ice 20th-21st Century

- Exhibit rich natural variability (e.g. Kay et al., 2011)
- Including rapid ice loss events (similar to obs), instances of positive trends even within 21st century

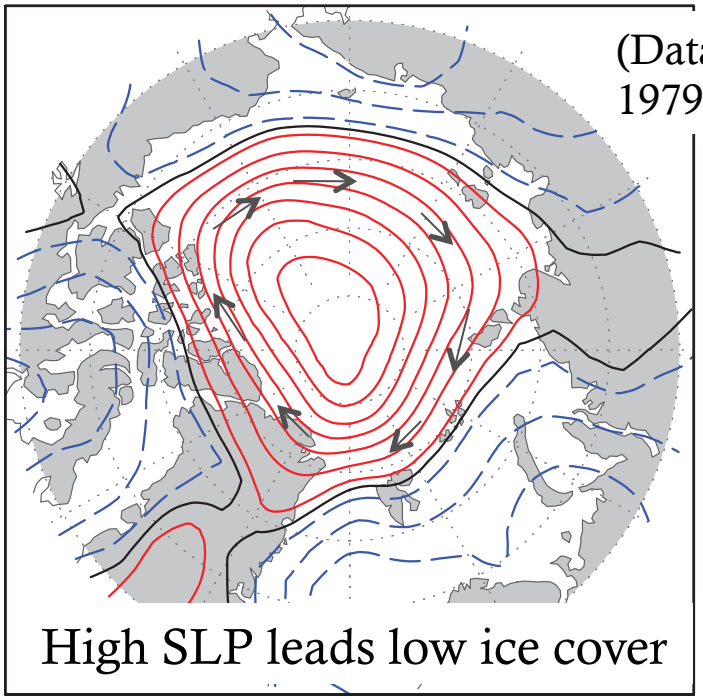


Using climate models to investigate sea ice predictability

Simulate Realistic Statistical Relationships

Example: Sept Extent and Summer Atmospheric Circulation

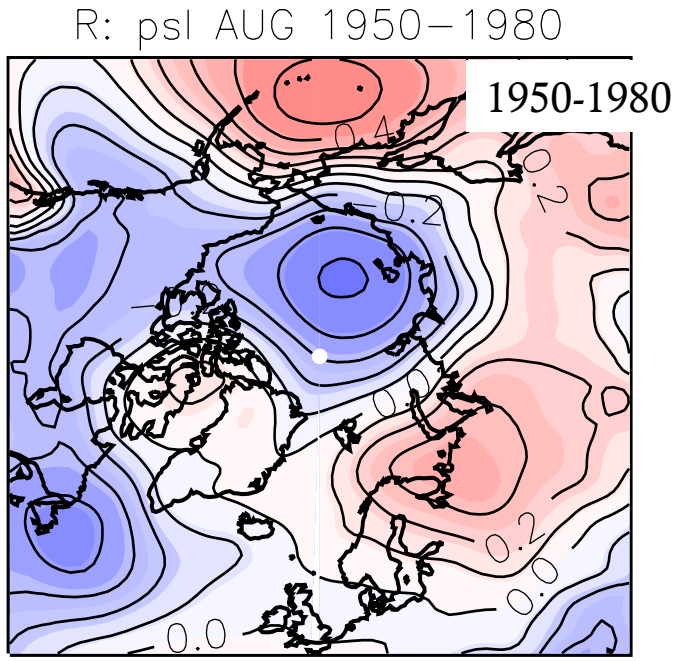
Observations



Regression:
Summer SLP on Sept ice extent
Ekman transport of sea ice results in net ice convergence

(Ogi and Wallace, 2007)

Climate Model

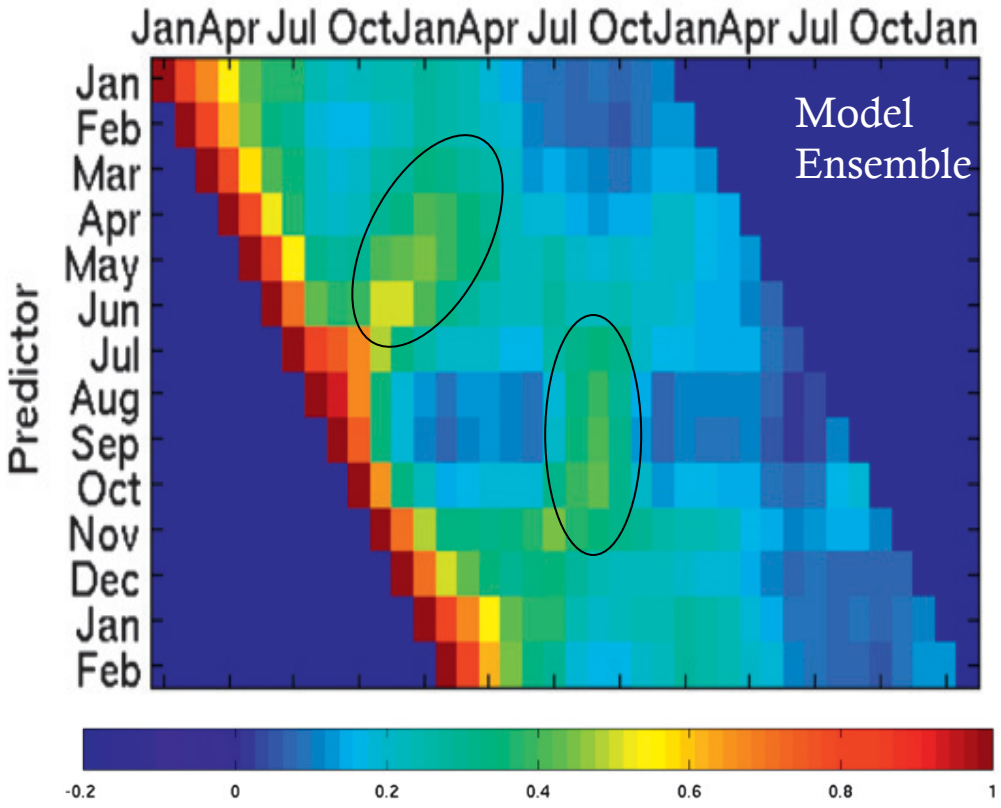


Correlation:
August SLP and Sept ice extent
High SLP leads low sea ice

From 8-members of CCSM3

(Holland and Stroeve, 2011)

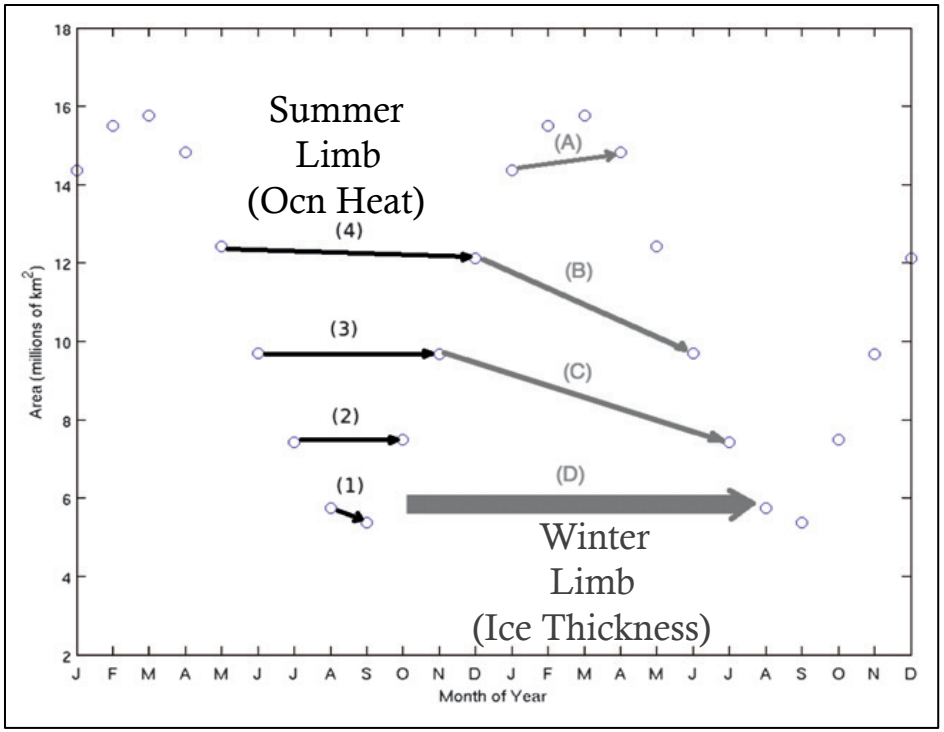
Lagged Correlation Ice Area Climate Model Ensemble



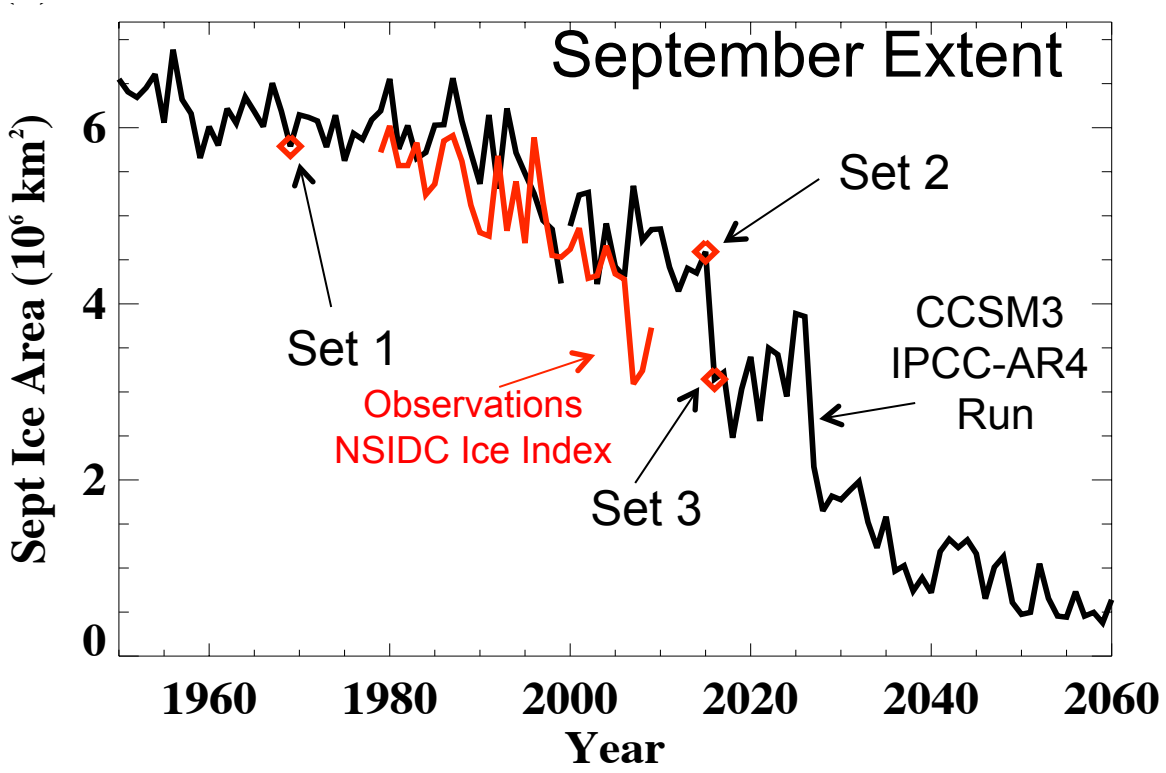
Model Evidence of Seasonal-Interannual Predictability

(Blanchard-Wrigglesworth et al., 2011)

CCSM3 Ice Area Annual Cycle

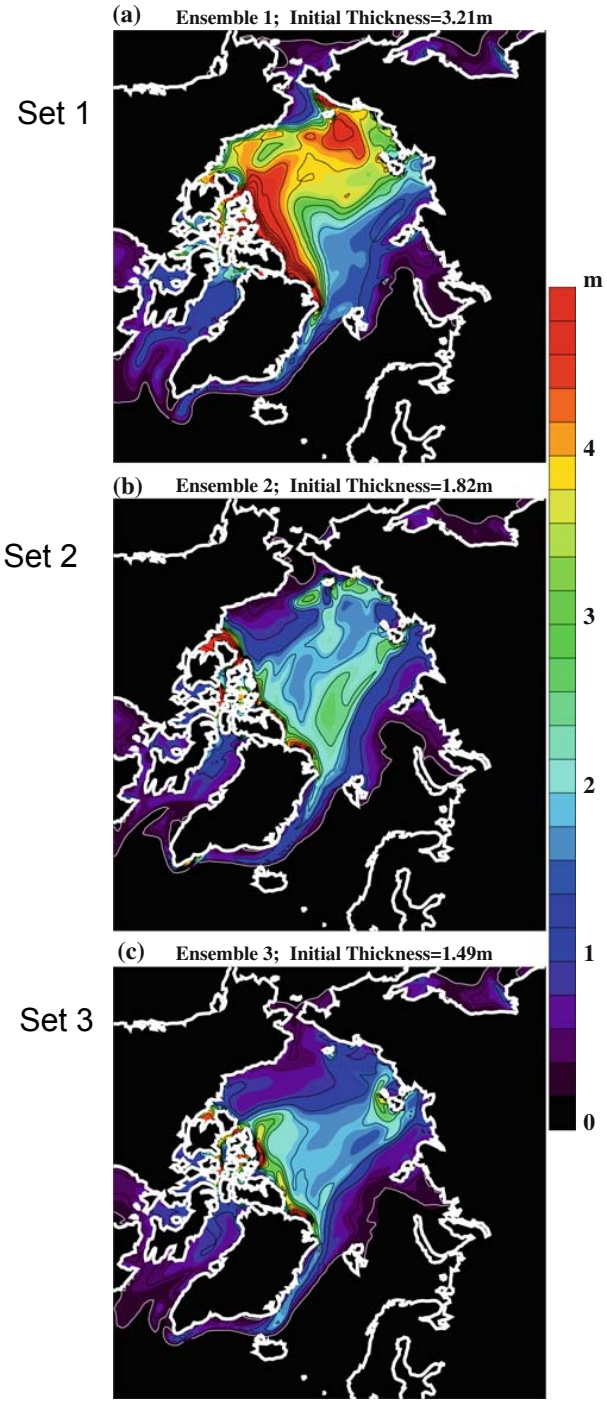


Predictability Ensemble Model Integrations

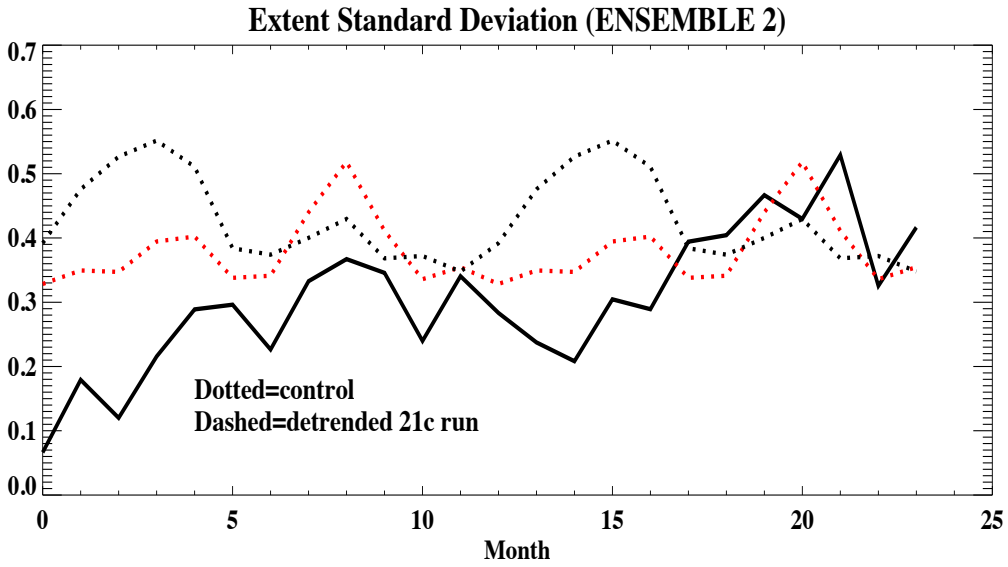


- Initialize runs with identical ice-ocean-land conditions from CCSM3
- Use 3 sets of Jan 1 initial conditions
- Each ensemble set has ~20 members
- Run forward 2-years

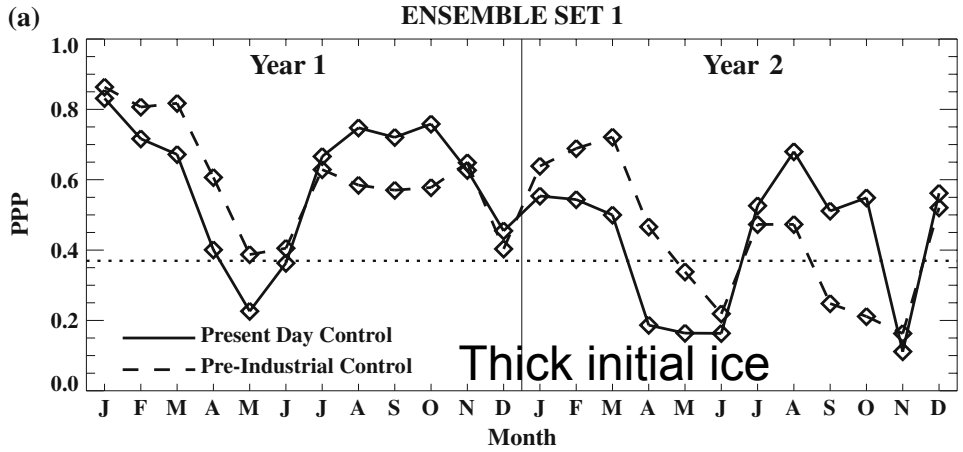
(Holland et al., 2011)



Assessing Predictability



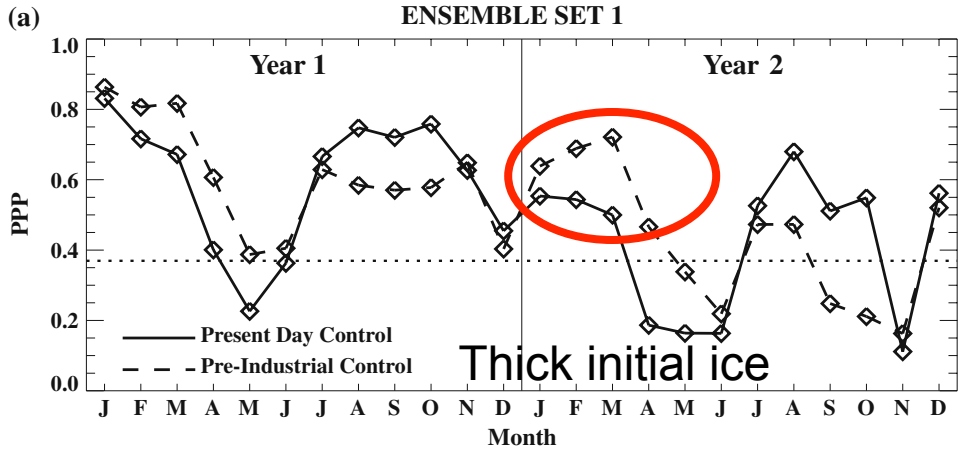
- Examine how ensemble members diverge over time
- Compare to the natural variability of the system
- When these are indistinguishable, predictability associated with initial state is lost



Ice Area

Potential Predictability

- PPP = $1-\sigma^2_t(\text{ens})/\sigma^2(\text{cont})$
- PPP decreases during spring, regained during summer and following winter

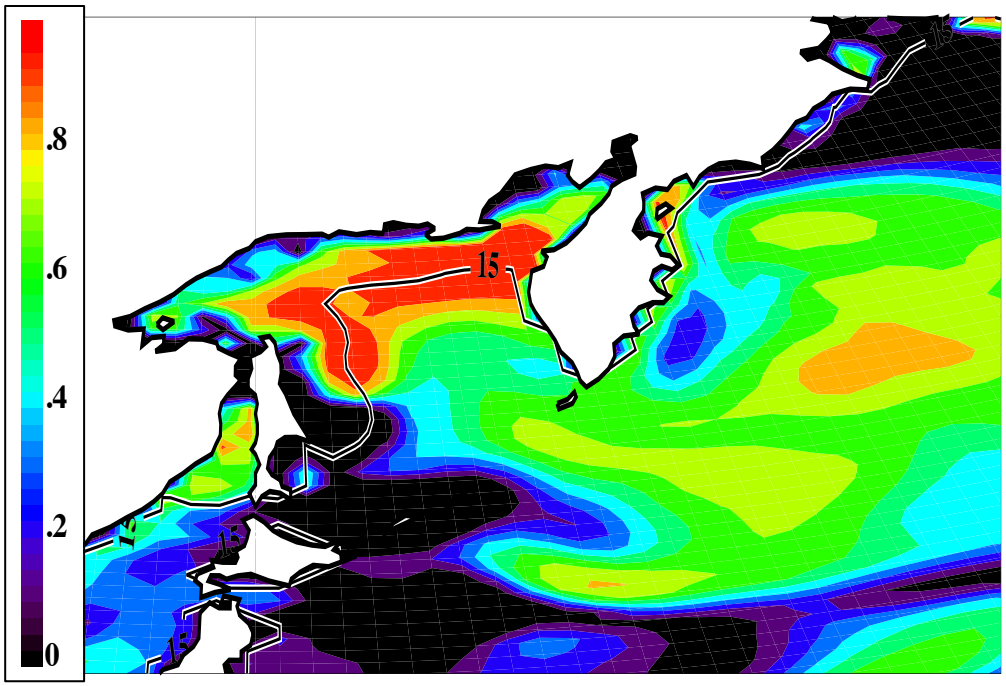


Ice Area

Potential Predictability

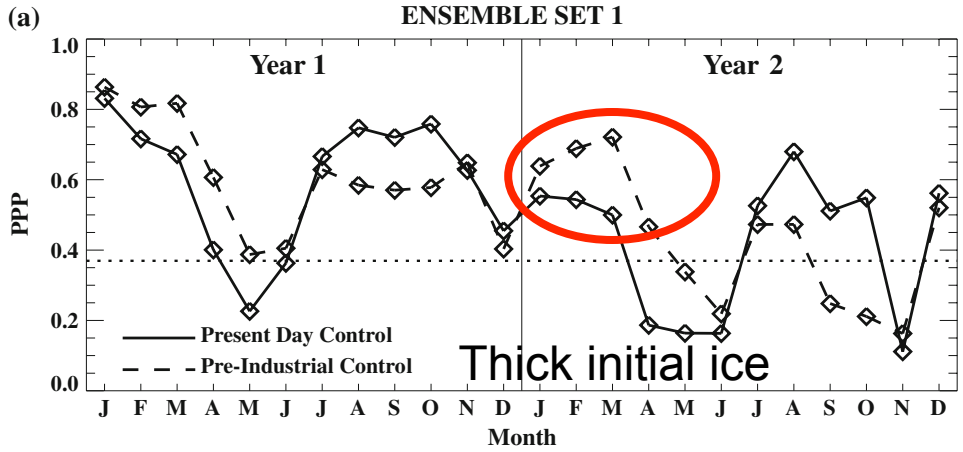
- PPP = $1-\sigma^2_t(ens)/\sigma^2(cont)$
- PPP decreases during spring, regained during summer and following winter
- Significant winter predictability - memory in ocean heat content

January SST PPP



Memory of ice edge location associated with SST predictability

Consistent with results from Blanchard-Wrigglesworth et al., 2011



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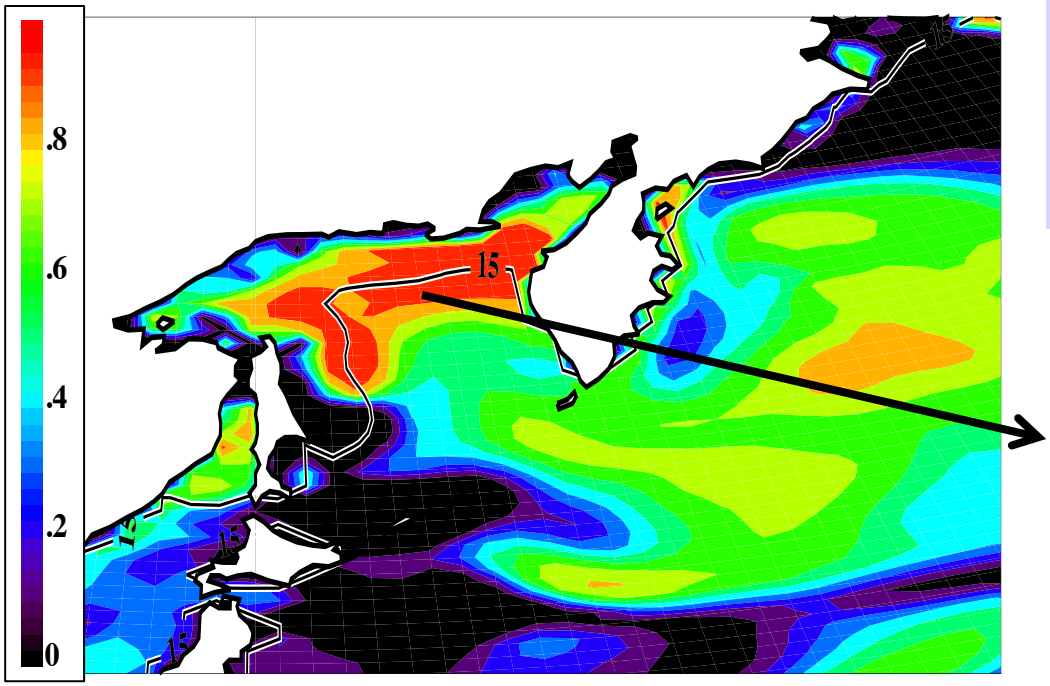
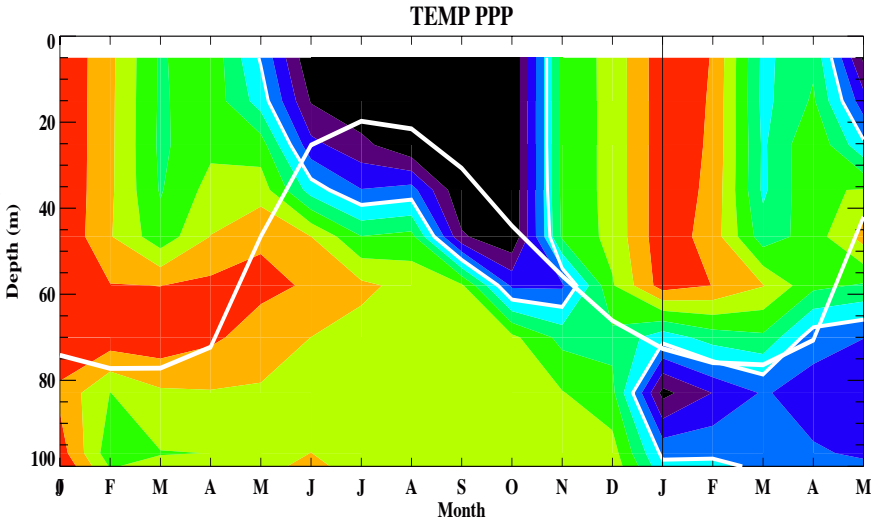
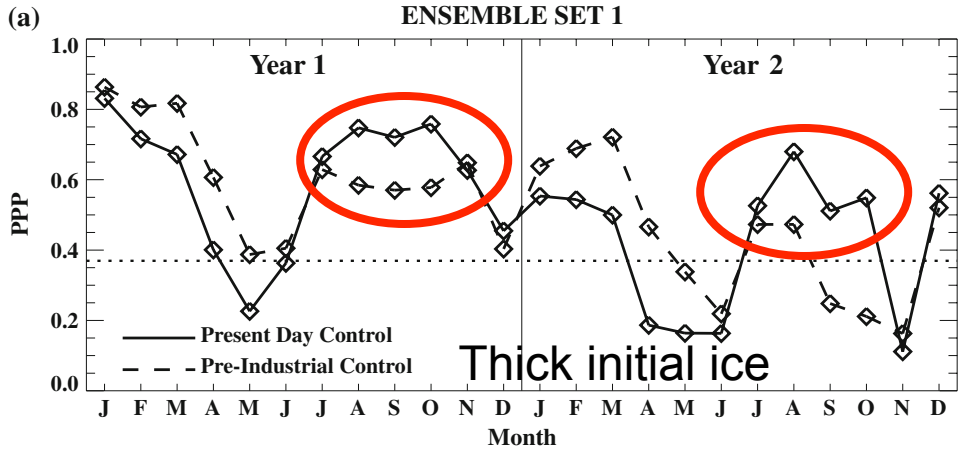
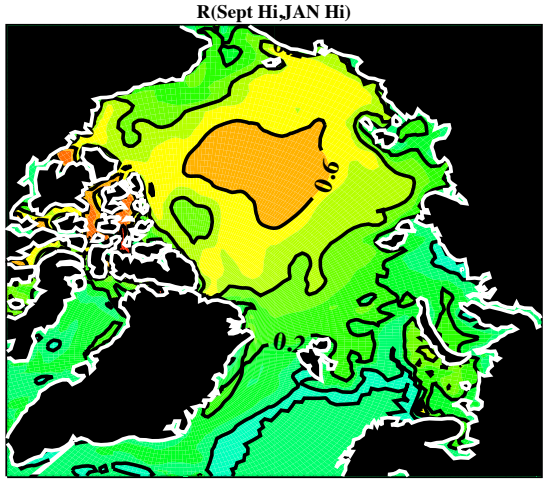


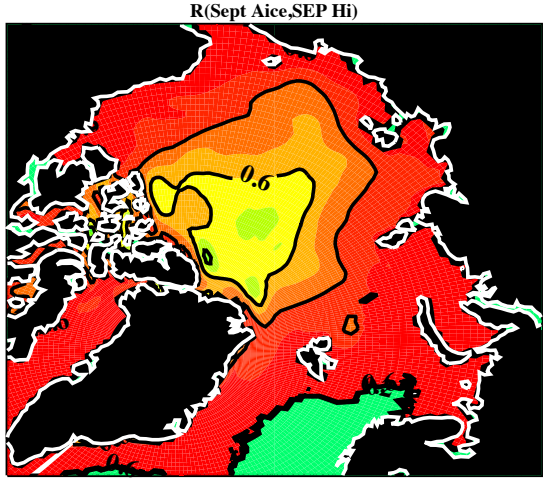






Ice Thickness "Memory"

Correlation: Jan Ice Thickness and Sept Ice Thickness



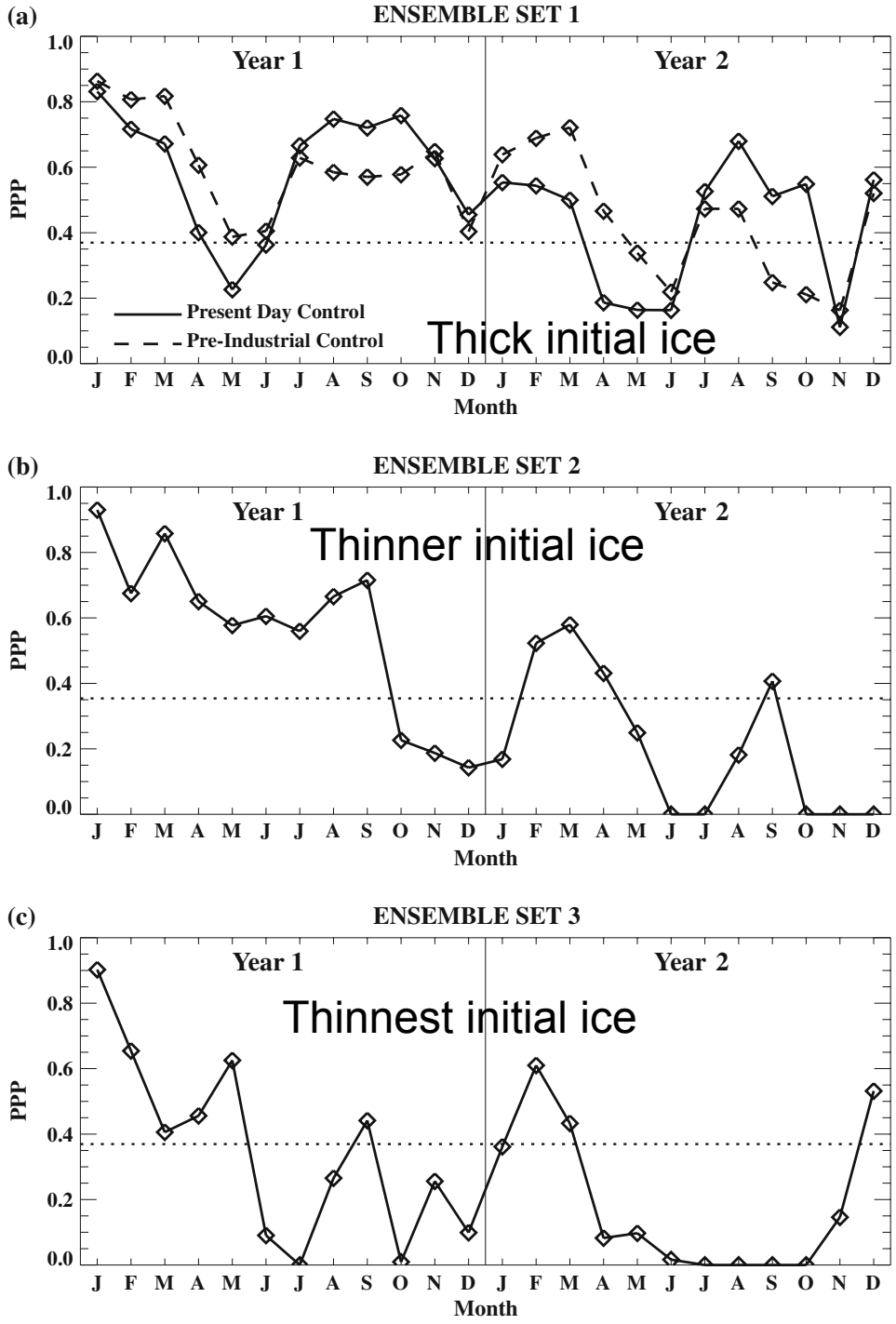
Ice Thickness/Area Coupling

Correlation: Sept Ice Thickness and Sept Ice Concentration

Ice Area

Potential Predictability

- PPP = $1-\sigma^2_t(ens)/\sigma^2(cont)$
- PPP decreases during spring, regained during summer and following winter
- Significant winter predictability - memory in ocean heat content
- Significant summer predictability – memory in ice thickness and strong ice area-thickness coupling



Ice Area

Potential Predictability

- PPP = $1-\sigma^2_t(\text{ens})/\sigma^2(\text{cont})$
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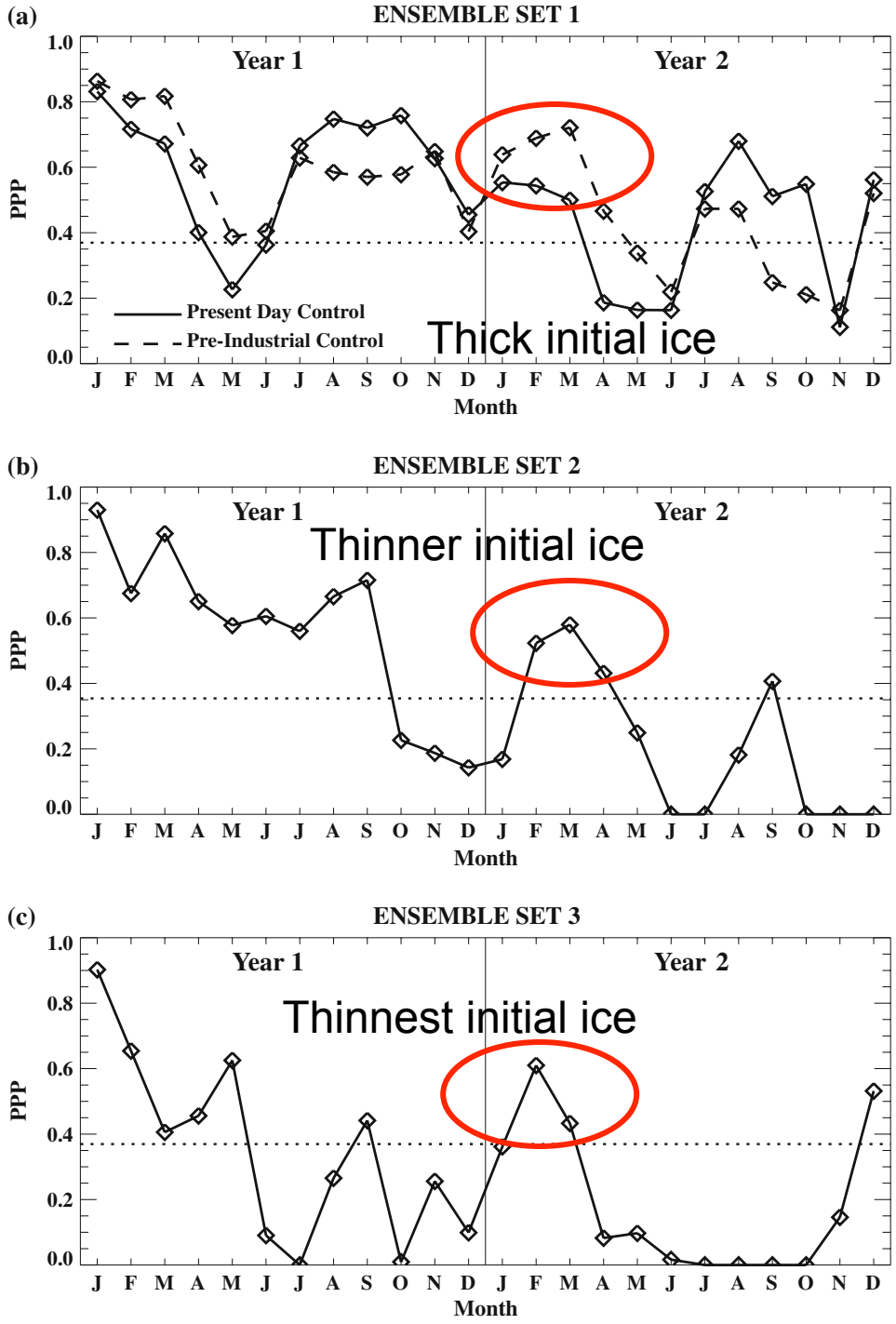

Ice Area

Potential Predictability

- PPP = $1-\sigma^2_t(\text{ens})/\sigma^2(\text{cont})$
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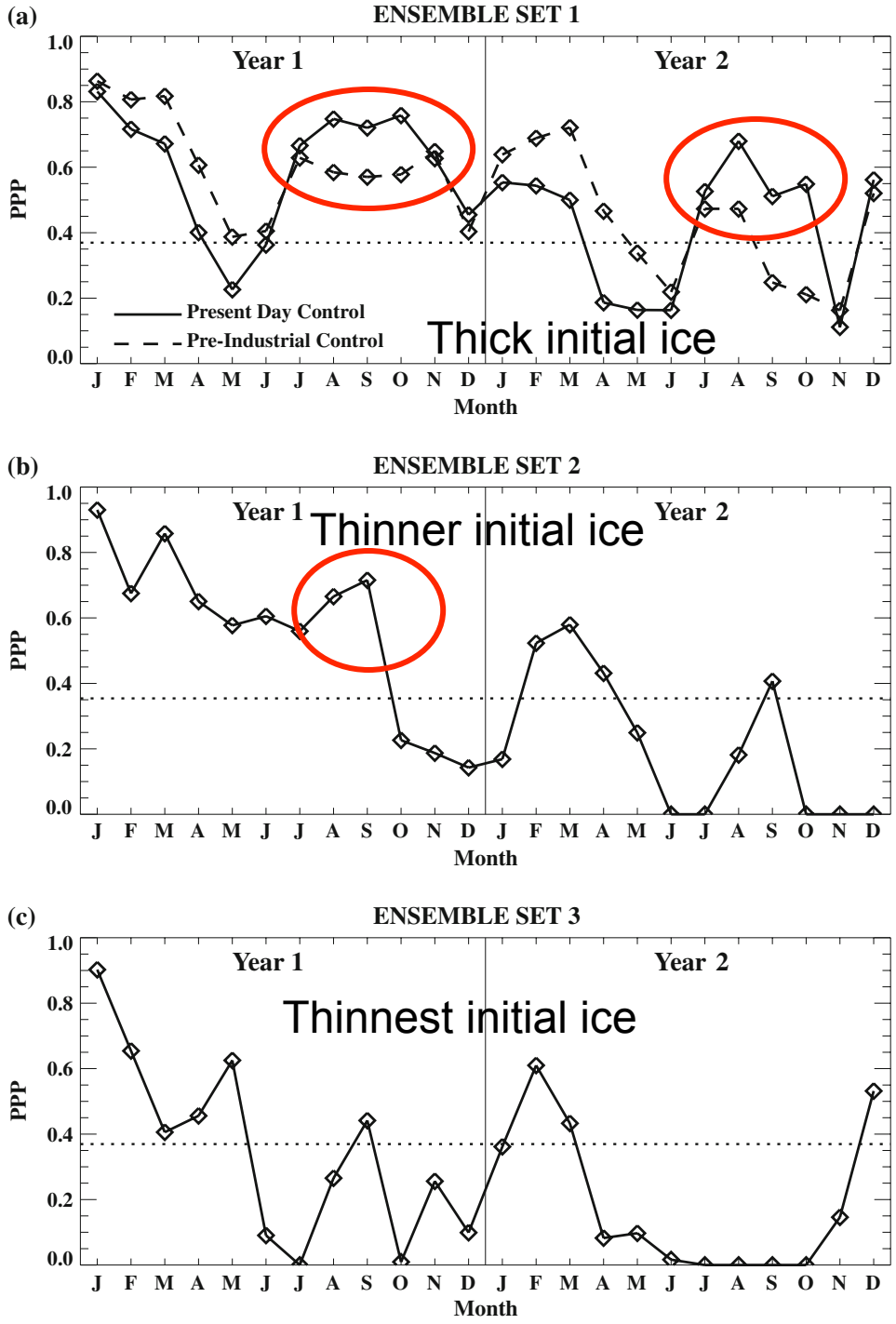


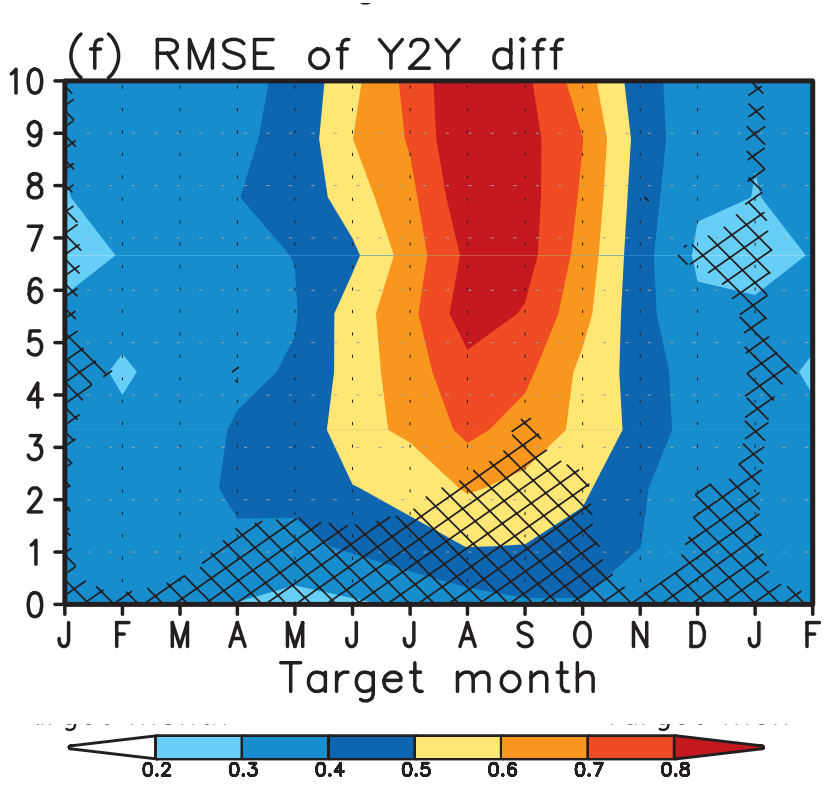
Ice Area

Potential Predictability

- PPP = $1-\sigma^2_t(ens)/\sigma^2(cont)$
- PPP decreases during spring, regained during summer and following winter
- Significant winter predictability - memory in ocean temperature
- ~~Significant summer predictability – memory in ice thickness and strong ice area-thickness coupling~~

Reduced summer predictability in thin ice conditions

Initialized forecast studies



Wang et al., 2013
From NCEP Climate Forecast System, v2

Much of forecast skill a result of the trend

For interannual variations, these studies generally obtain predictive skill for only a few month lead time

Other examples:
Chevallier et al., 2013
Sigmond et al., 2013
Merryfield et al., 2013

Conclusions and Thoughts on Paths Forward

- Idealized studies suggest predictive capability for 1-2 yrs
  - seasonally dependent mechanisms
  - predictability characteristics may change with large-scale ice loss
- Forecasting systems obtain skill for only ~months
- Need better understanding of
  - What predictability we can expect to realize given initial state information, model uncertainties
  - Where improvements are most beneficial (how this informs observing networks, model developments)
  - Predictability characteristics of regional information, different aspects of the ice cover


Questions?

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