The Predictability of Arctic Sea Ice

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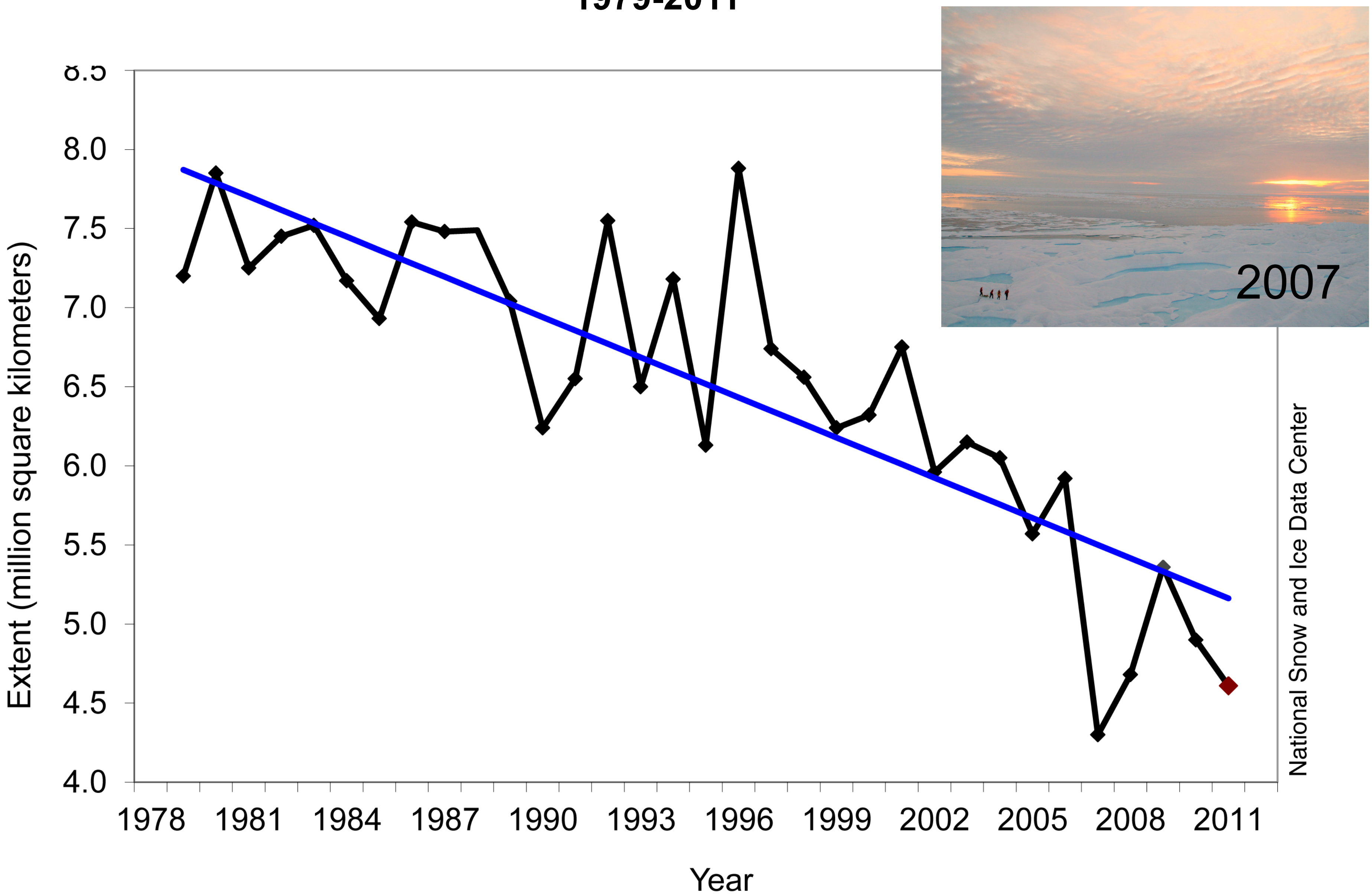
Thanks to Marika Holland, NCAR

September Arctic Sea Ice Extent
1979-2011



STUDY OF ENVIRONMENTAL ARCTIC CHANGE

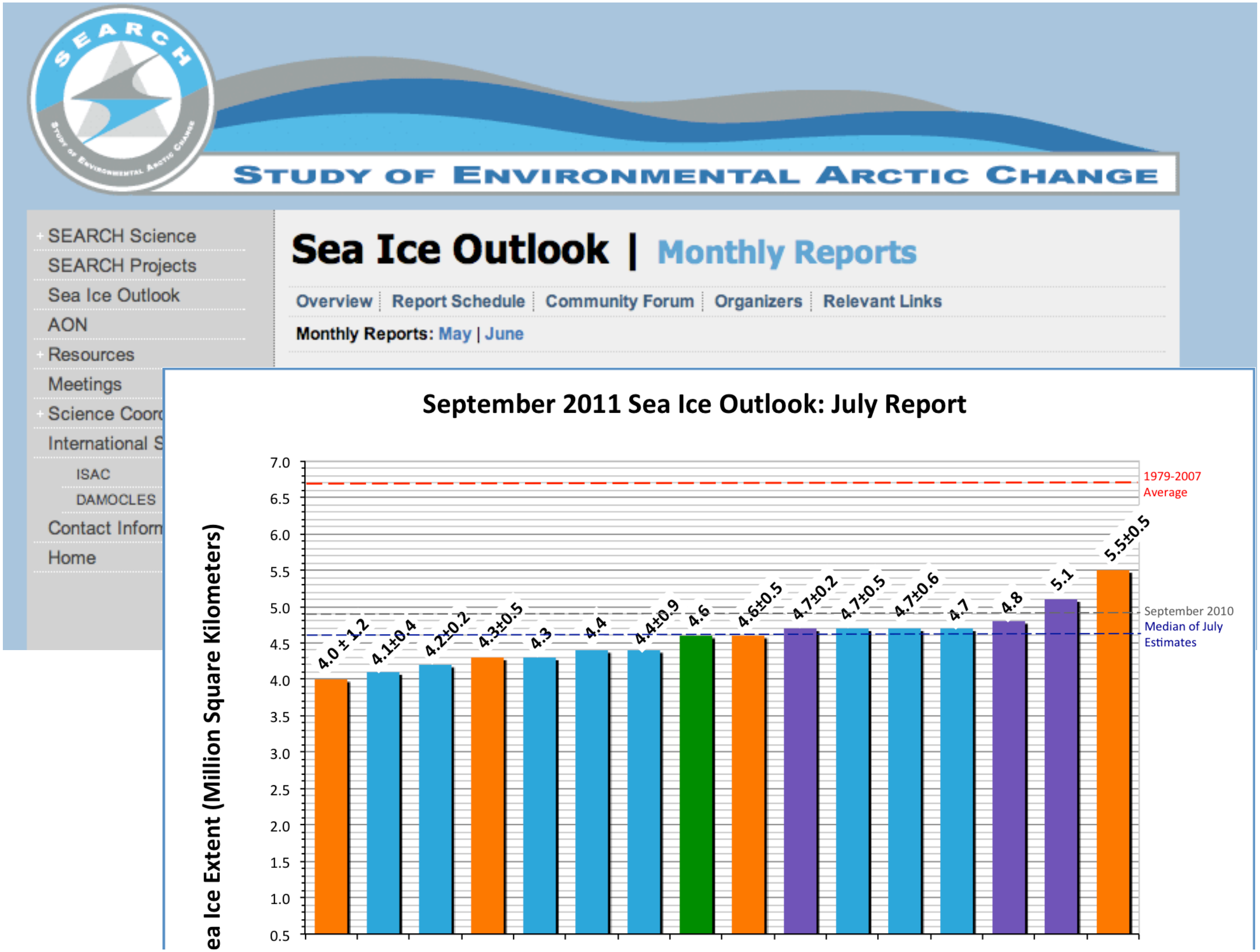
Sea Ice Outlook | Monthly Reports

June Report: Outlook Based on June Data

Report Released 16 July 2008

SUMMARY

The outlook for the pan-arctic sea ice extent in September 2008, based on June data, indicates a continuation of dramatic sea ice loss. The June Sea Ice Outlook report is based on a synthesis of 17 individual projections, utilizing a range of methods. Projections based on June data are similar to those of the May report, with no indication that a return to historical sea ice extent will occur this year.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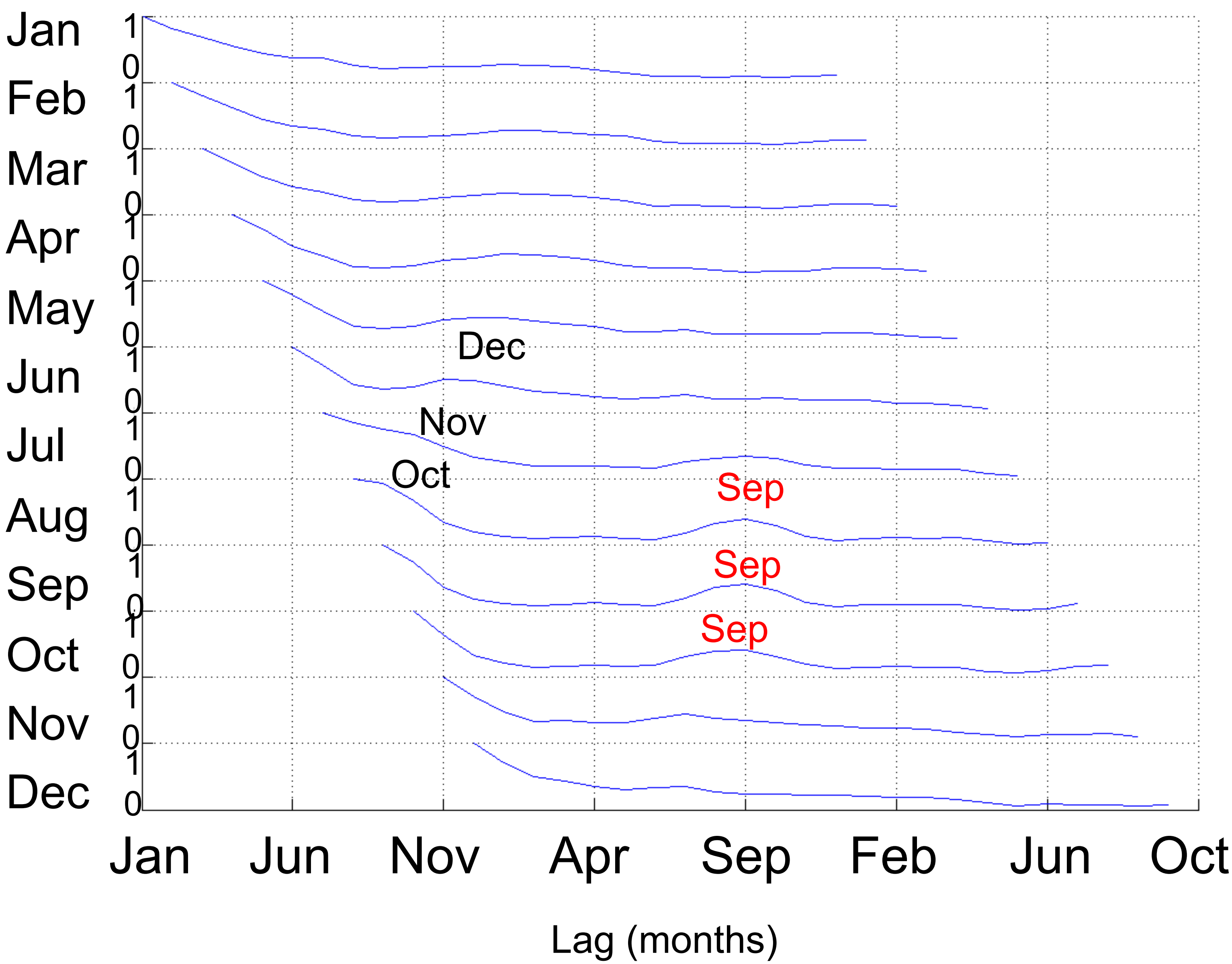
Monthly Reports: May | June
September 2011 Sea Ice Outlook: July Report
ea Ice Extent (Million Square Kilometers)
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
1979-2007 Average
September 2010
Median of July Estimates
4.0 ± 1.2
4.1±0.4
4.2±0.2
4.3±0.5
4.3
4.4
4.4±0.9
4.6
4.6±0.5
4.7±0.2
4.7±0.5
4.7±0.6
4.7
4.8
5.1
5.5±0.5

Lagged Correlation of pan-Arctic Sea Ice Area from 900 Years



Blanchard-Wrigglesworth, Armour, Bitz, and DeWeaver, 2011, J. Clim.

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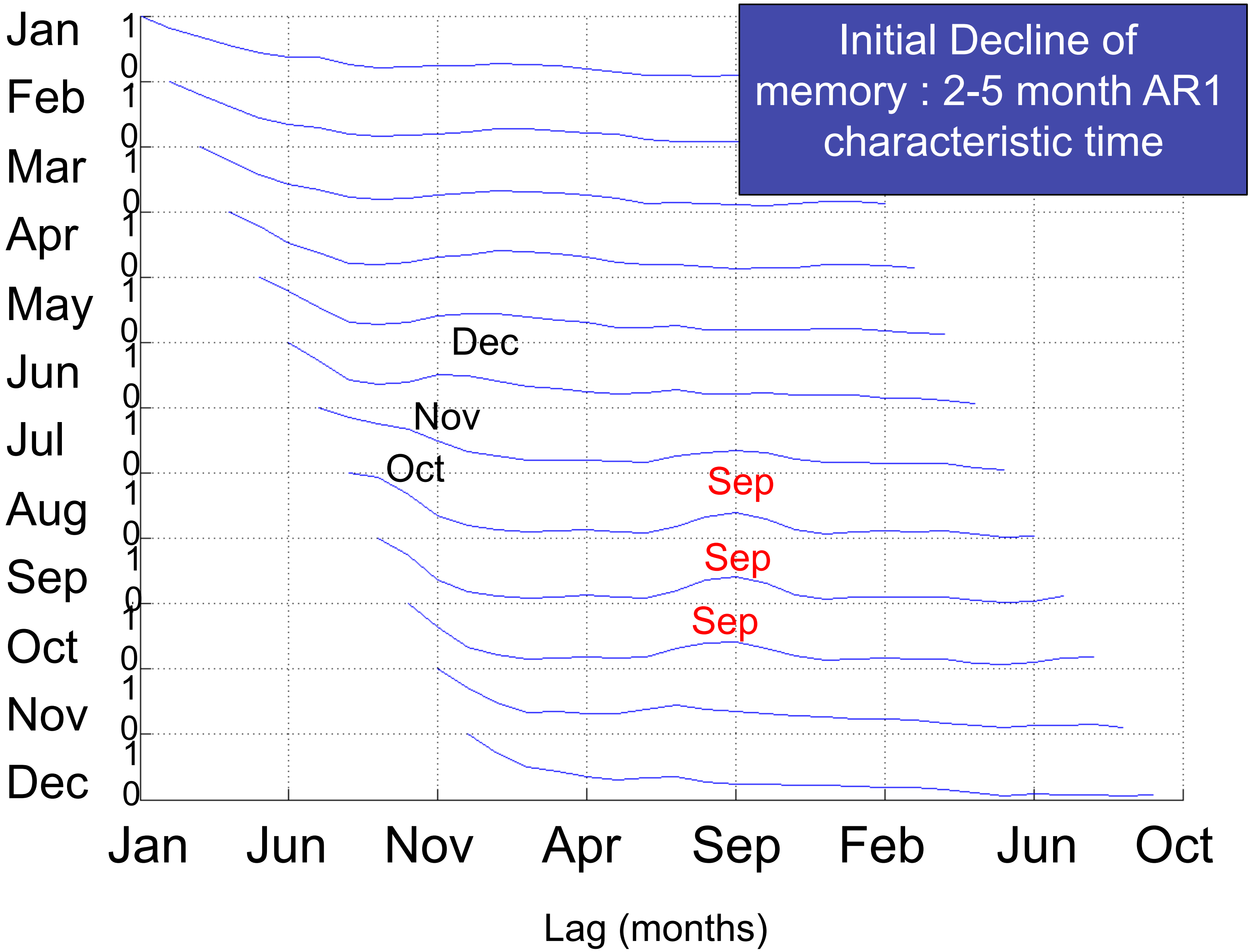

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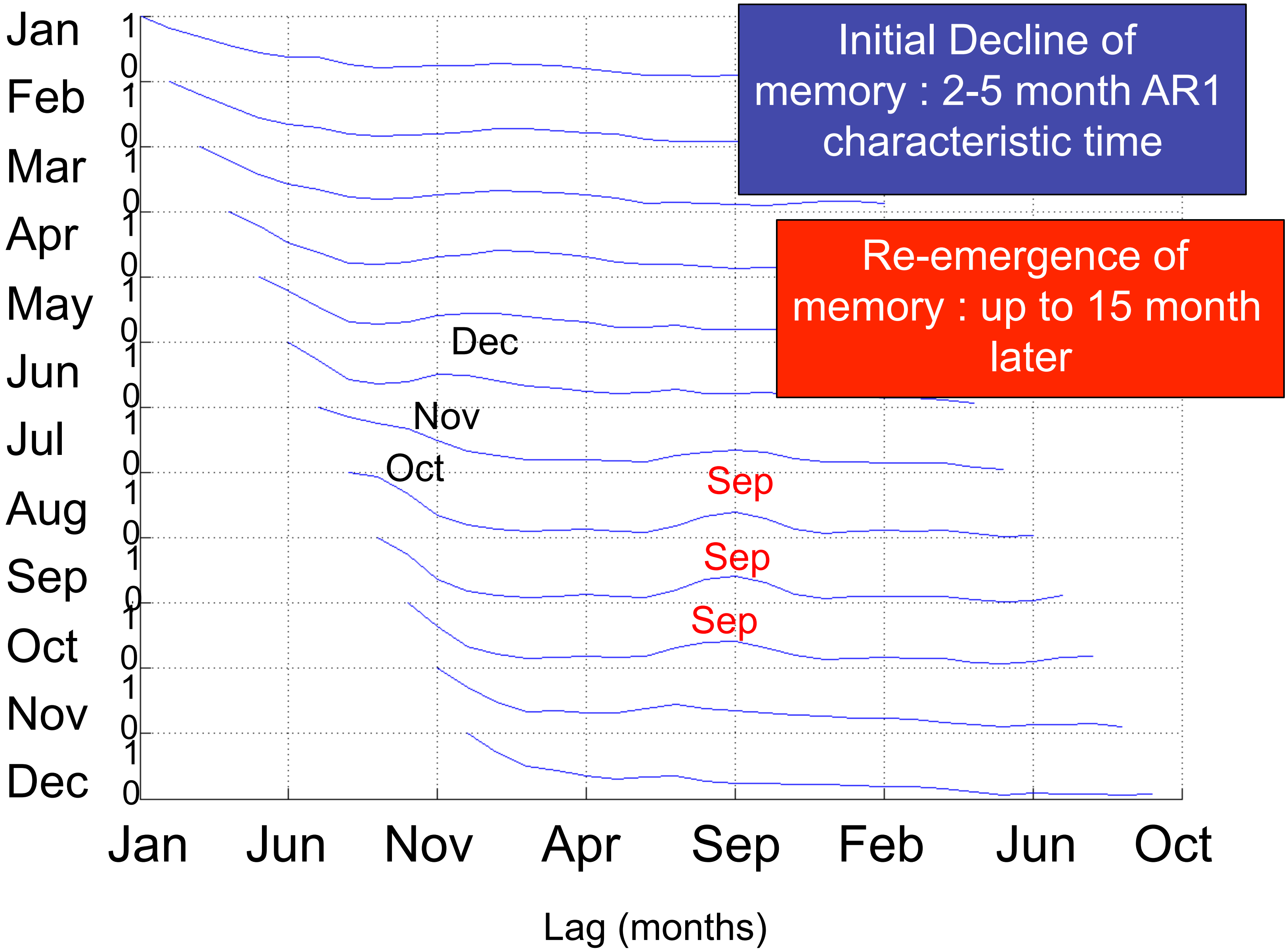

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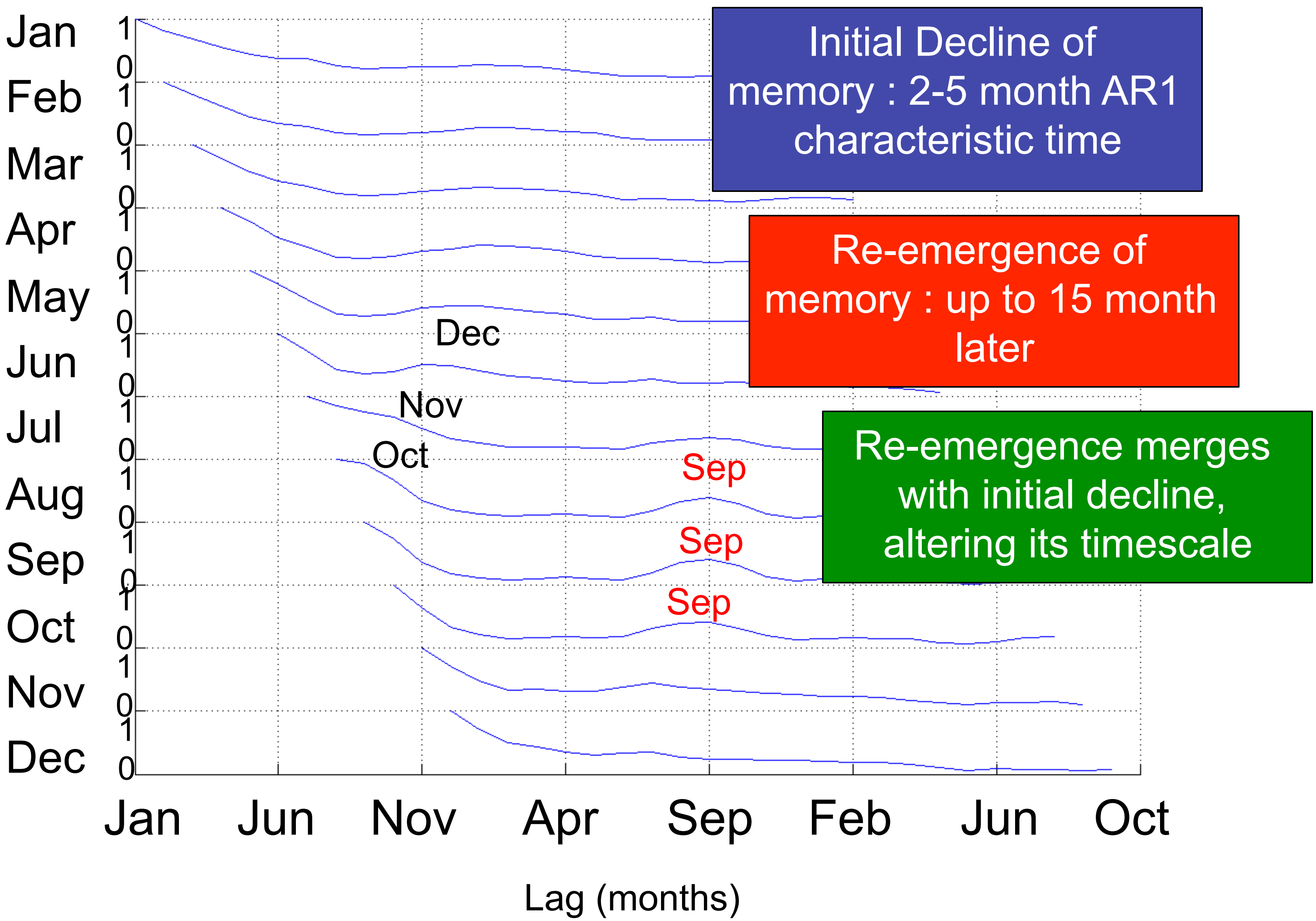
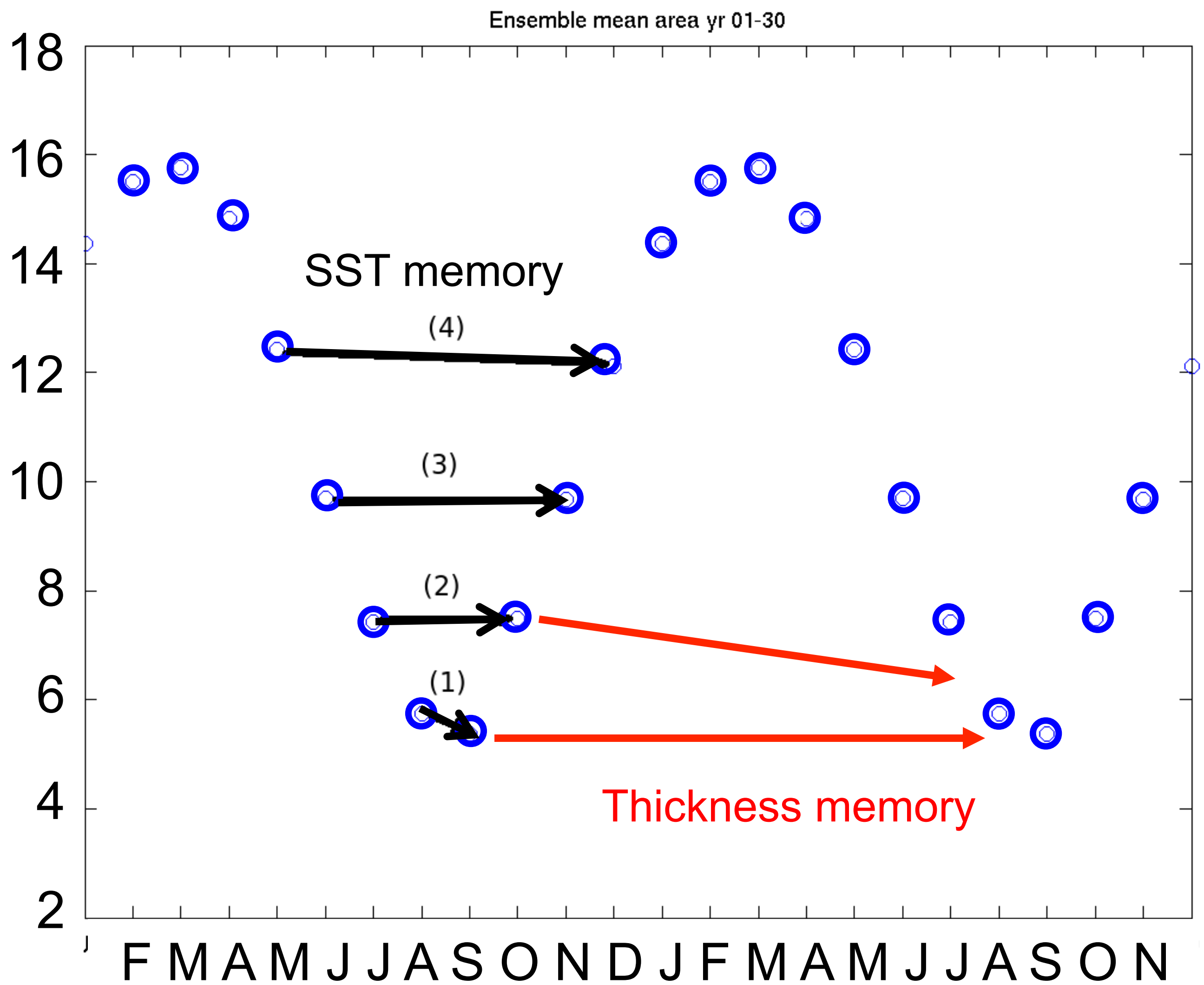


Blanchard-Wrigglesworth, Armour, Bitz, and DeWeaver, 2011, J. Clim.

Sea ice Area Climatology in 10^6 km^2



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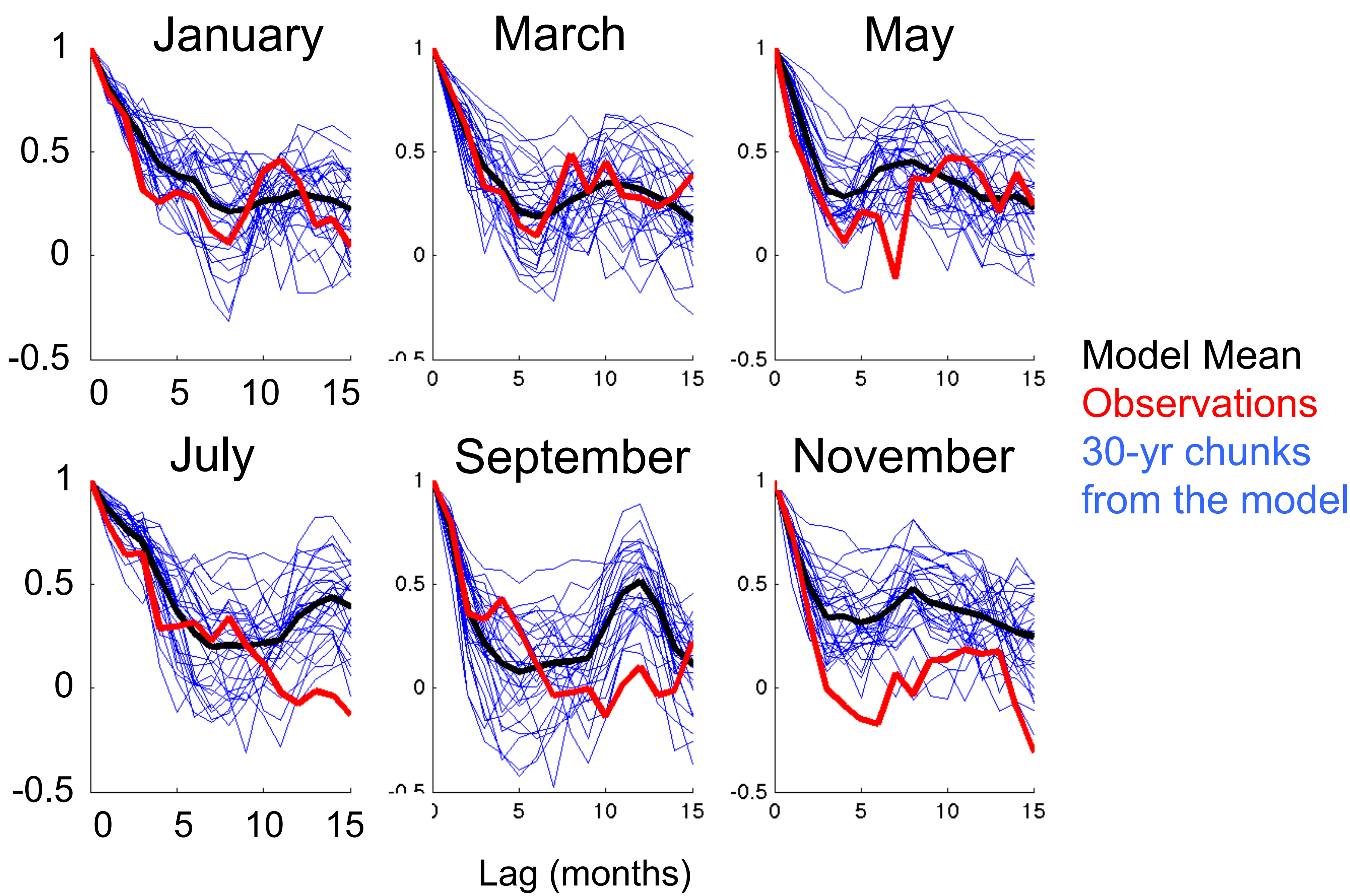
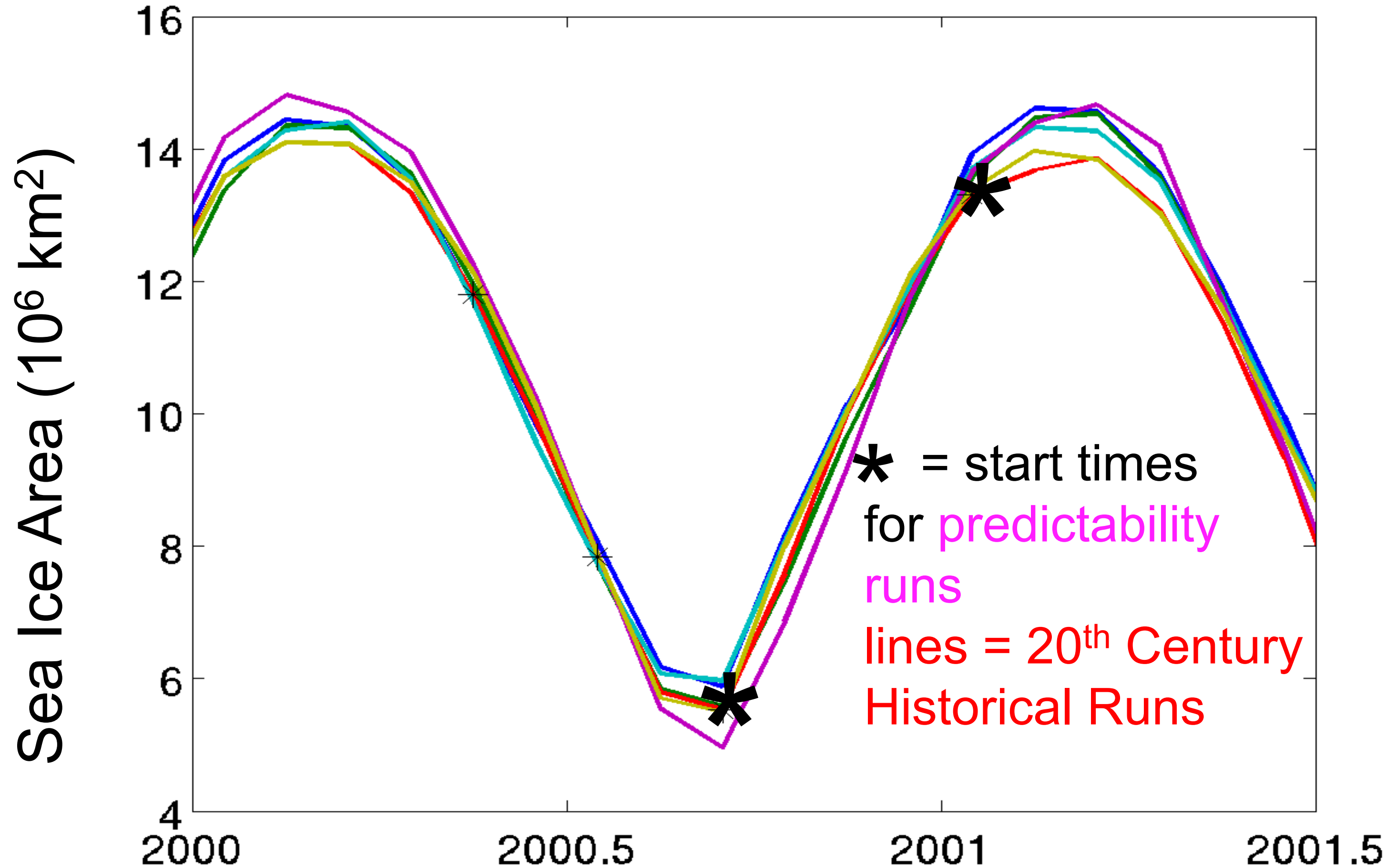
Lagged Correlation of pan-Arctic Sea Ice area

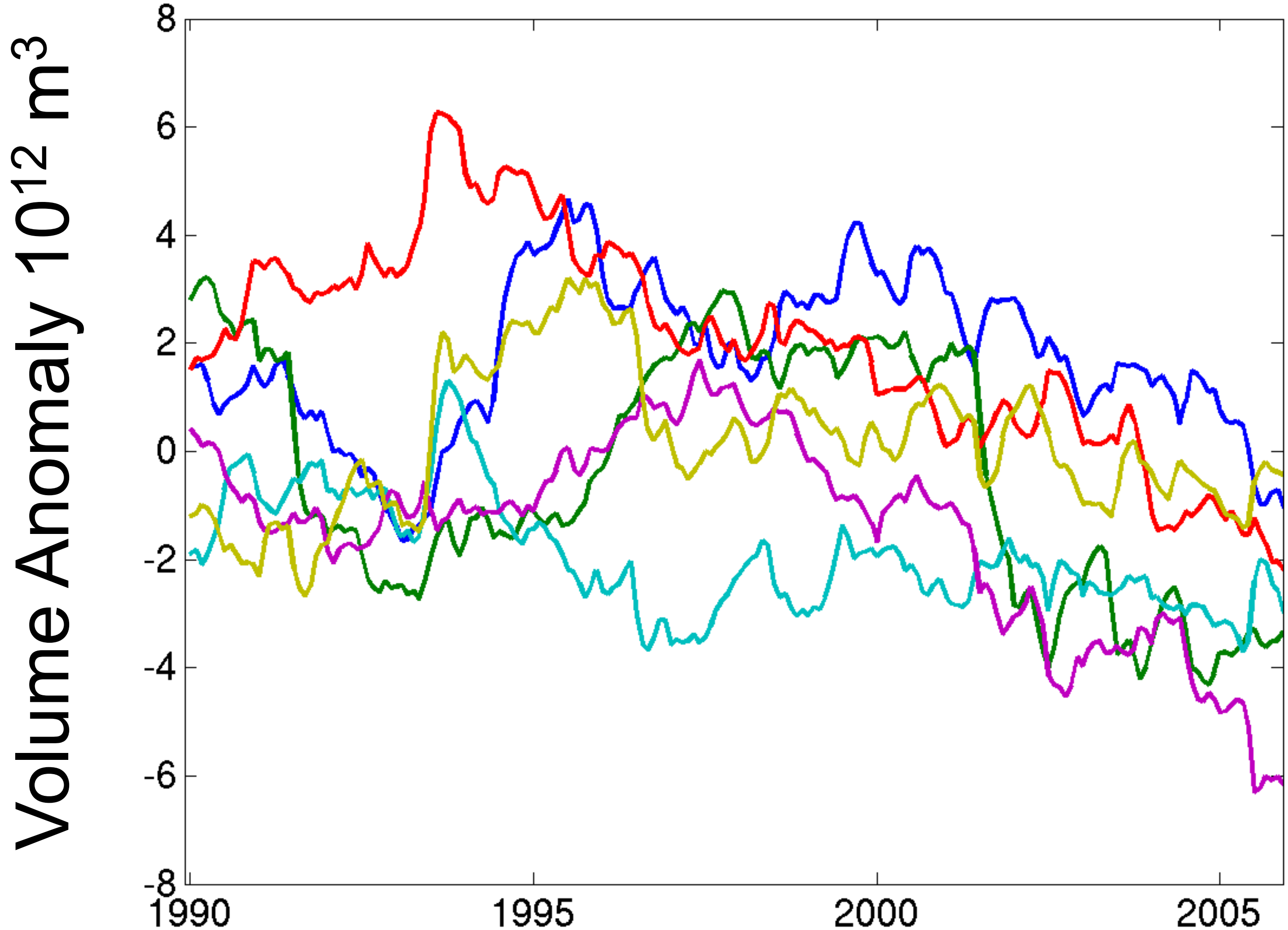


Prognostic Predictability
"Perfect Model" Studies with CCSM4



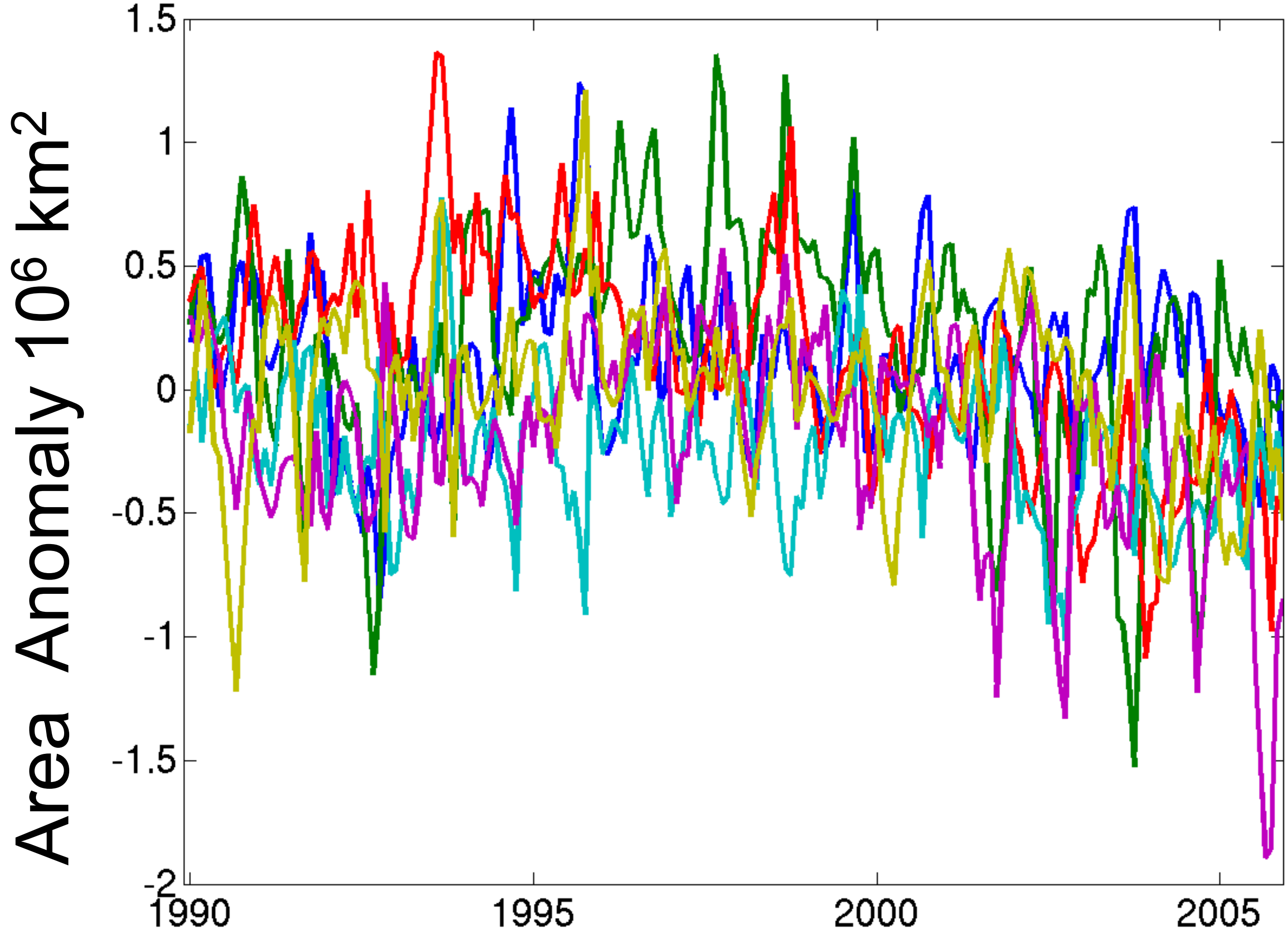
Initialized in year ~2000 of a 20th century run
for various start times

Issue 1: Large Trend



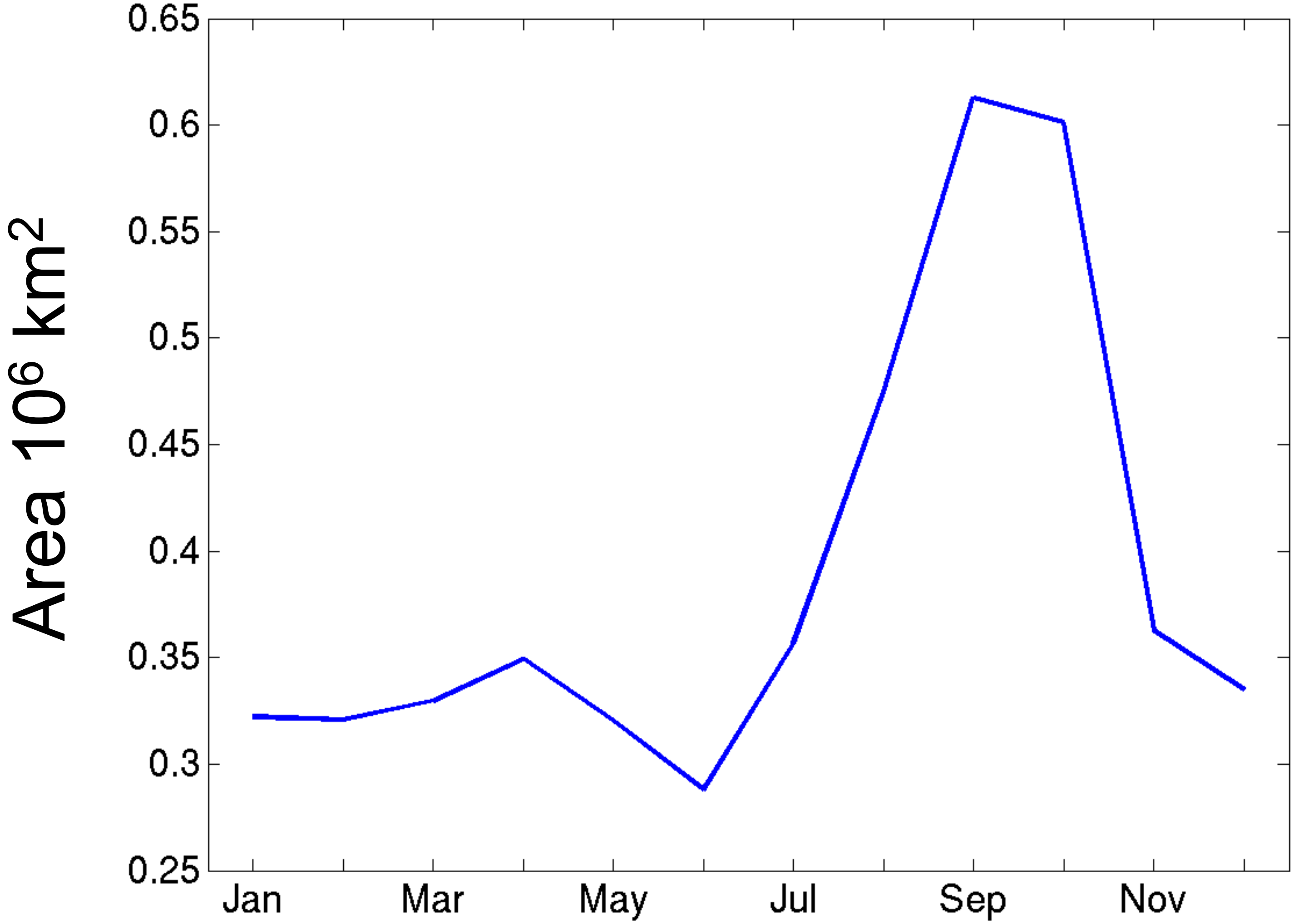
6 ensemble members of 20th Century Historical run

Issue 2: Seasonal Cycle in Area Anomaly



6 ensemble members of 20th Century Historical run

Standard Deviation of Area by Month



6 ensemble members of 20^{th} Century Historical run

Prediction Run Details

60 Ensemble members for each initial value start date (2 start times = 120 total runs)

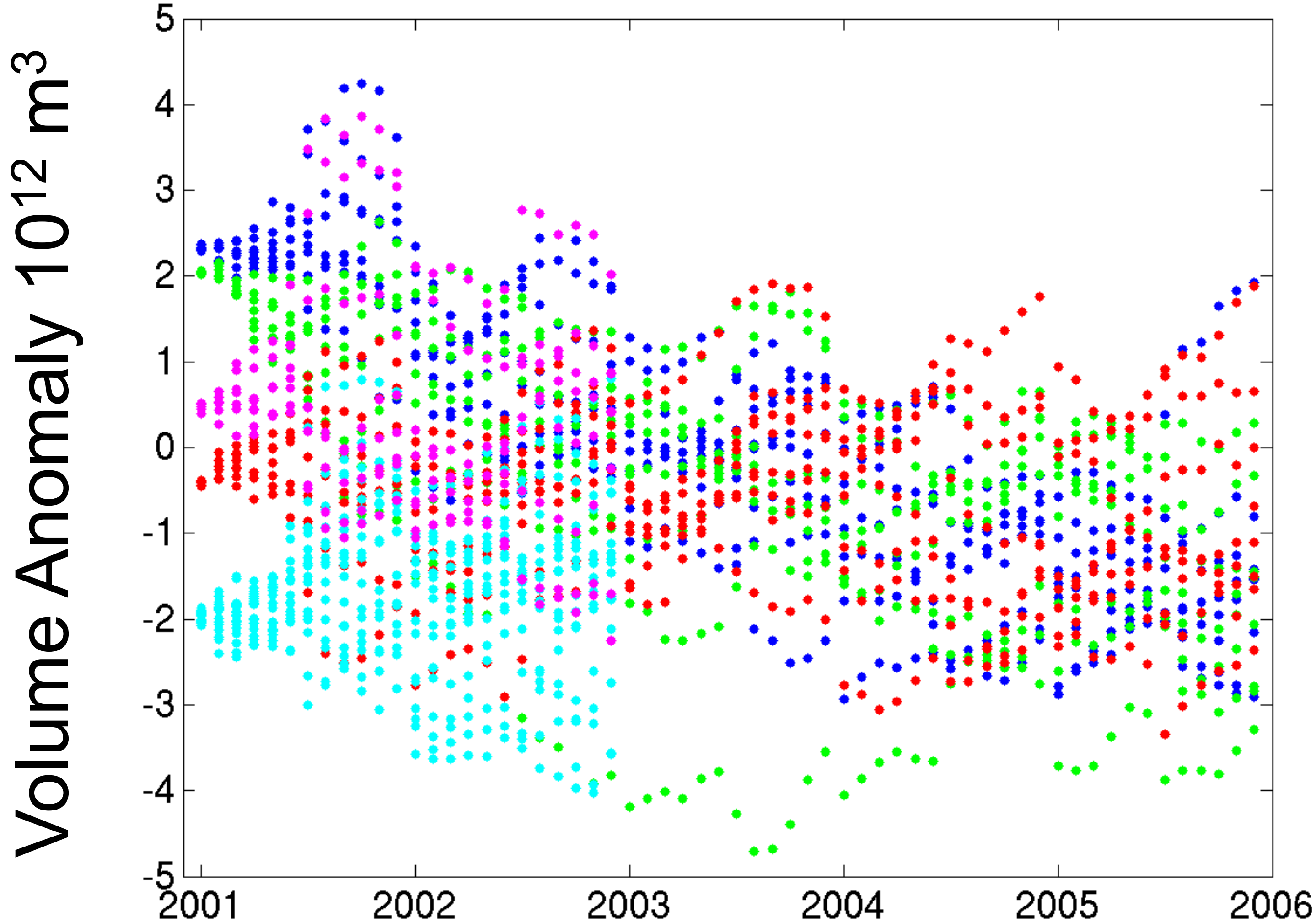
Initial values from 6 members of 20th century historical runs near year 2000, make 6 "subsets" of the ensemble for each start date

Perturbed using adjacent days in atmosphere, same sea ice, ocean, land in each "subset"

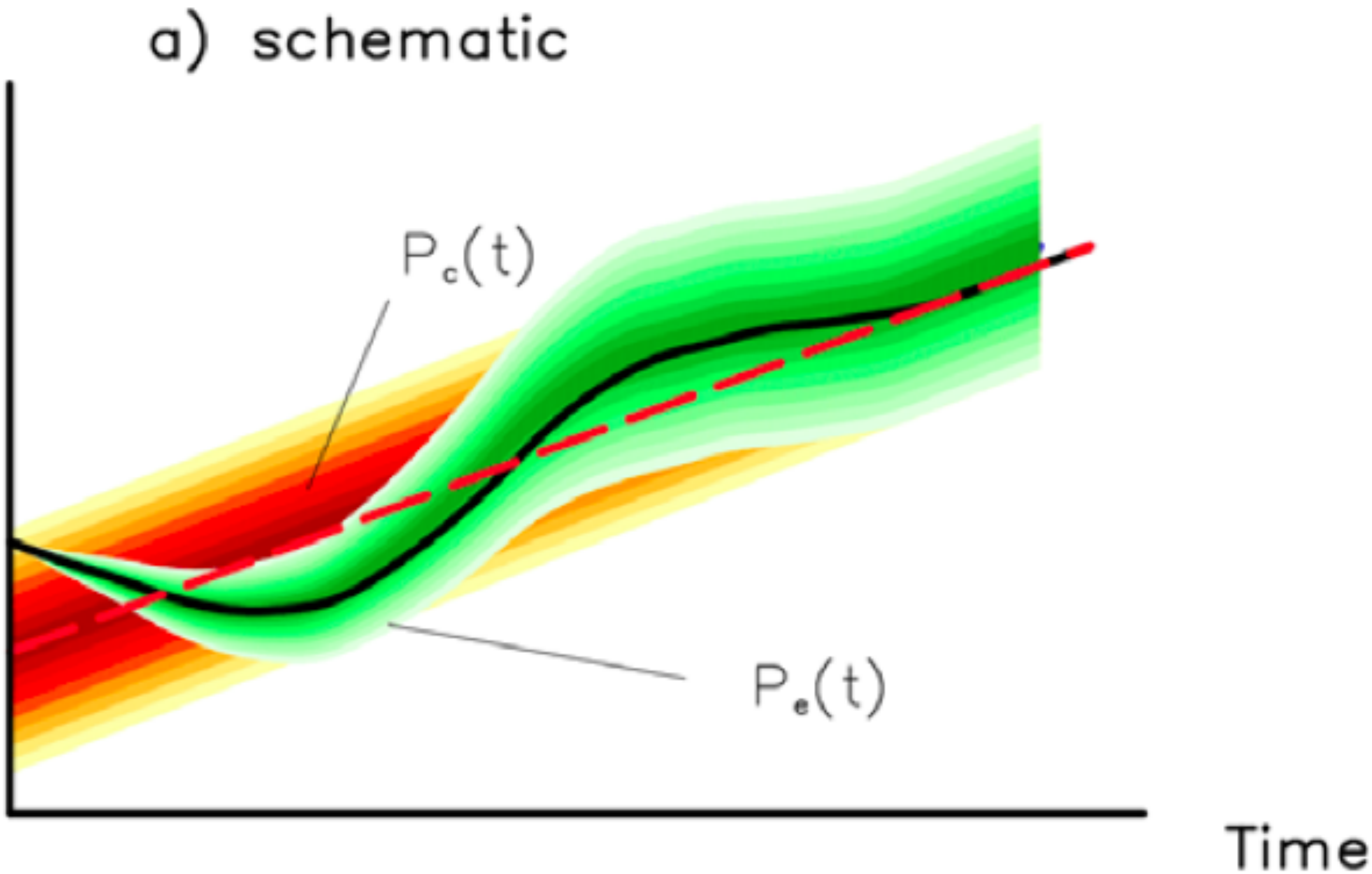
Runs are 2-5 years long

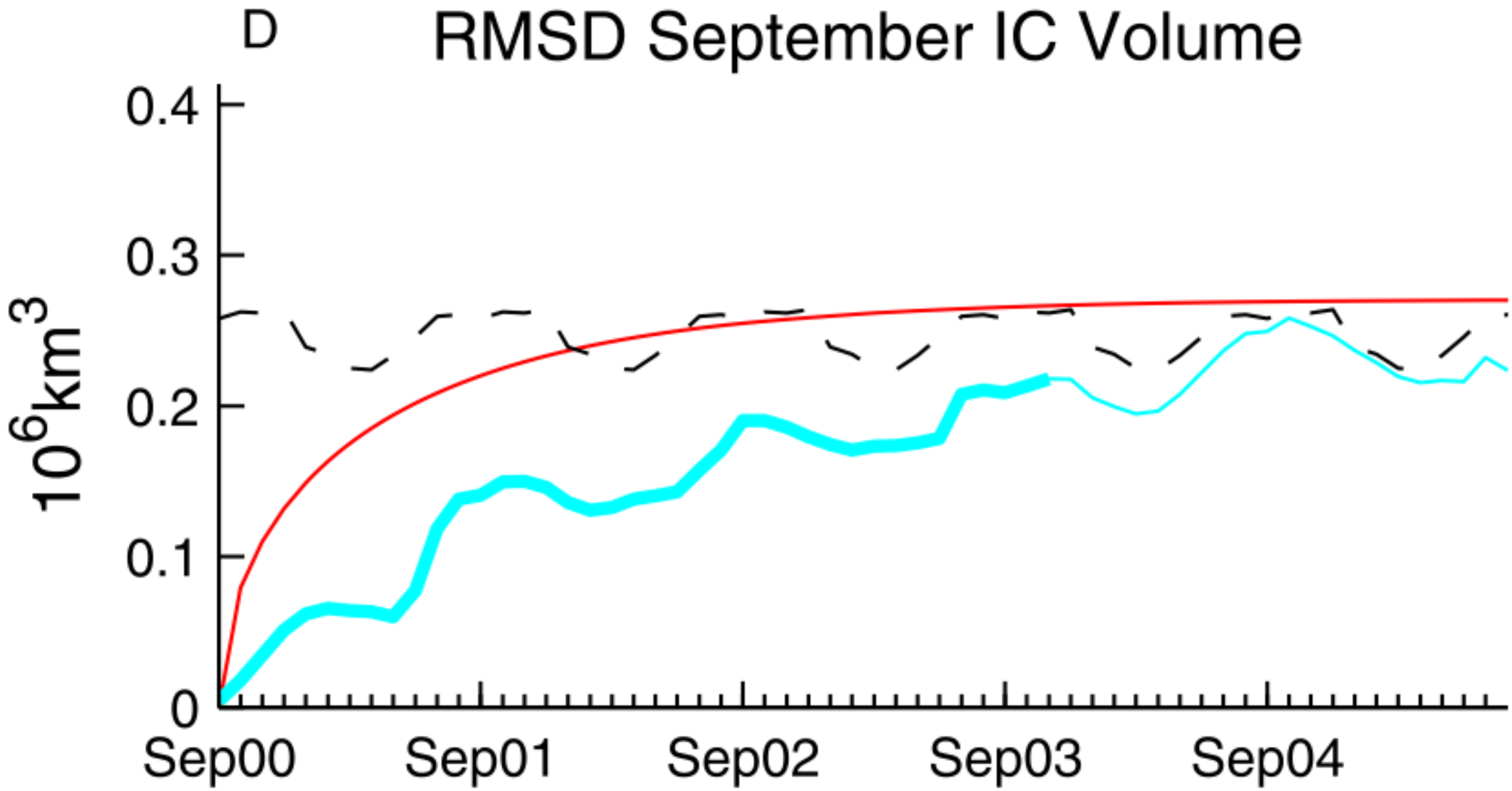
CCSM4 1° resolution

Ensemble starting January 2001



Branstator and Teng (2010) Two limits of Initial Value Predictability in a GCM





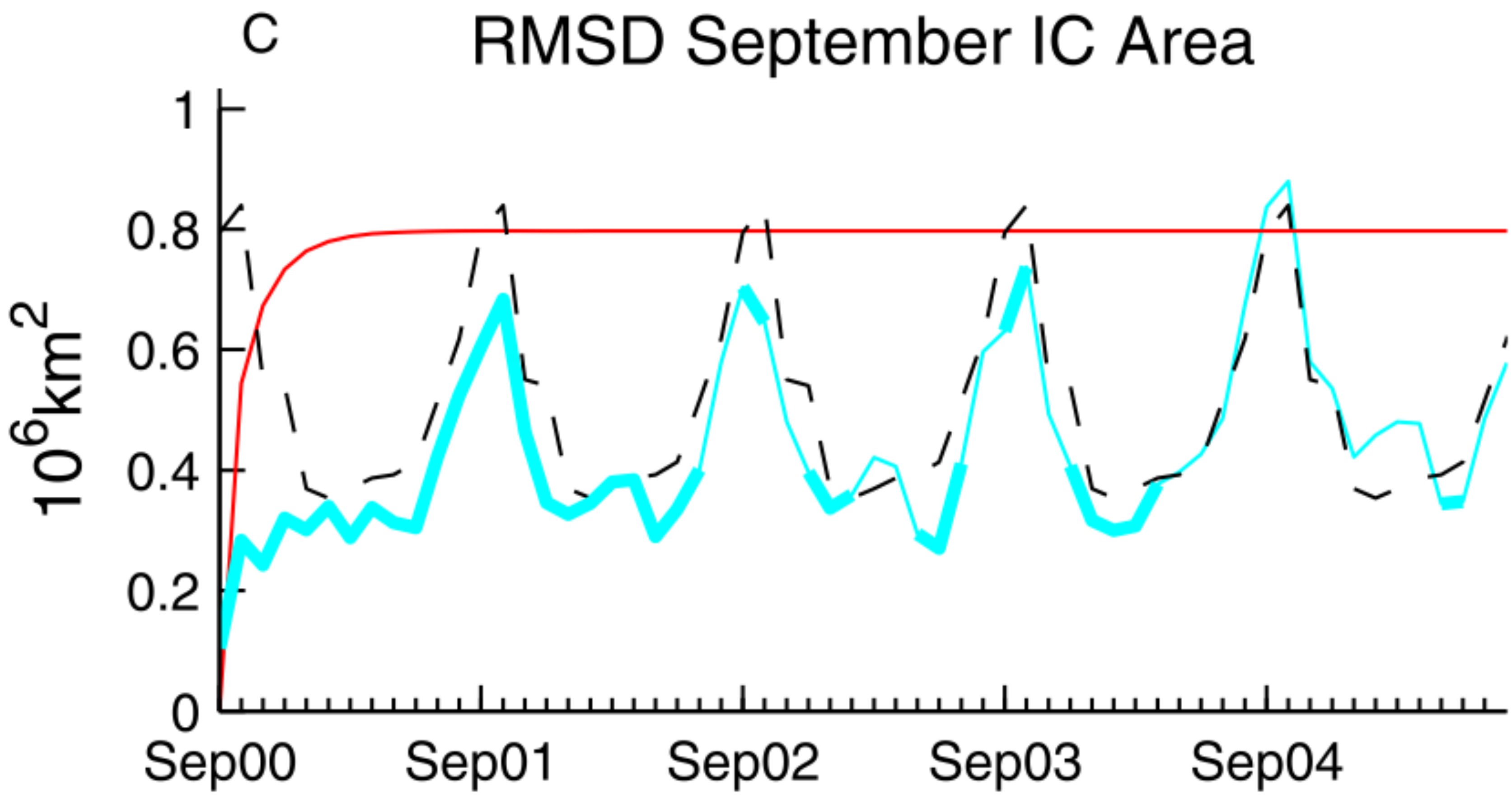
Initialized Ensemble on September 2000

Baseline from detrended 20th Century Historical Runs

AR1 model estimate

RMSD = rms of differences of all combinations of runs across subsets

Blanchard-Wrigglesworth, Bitz, and Holland, 2011, GRL



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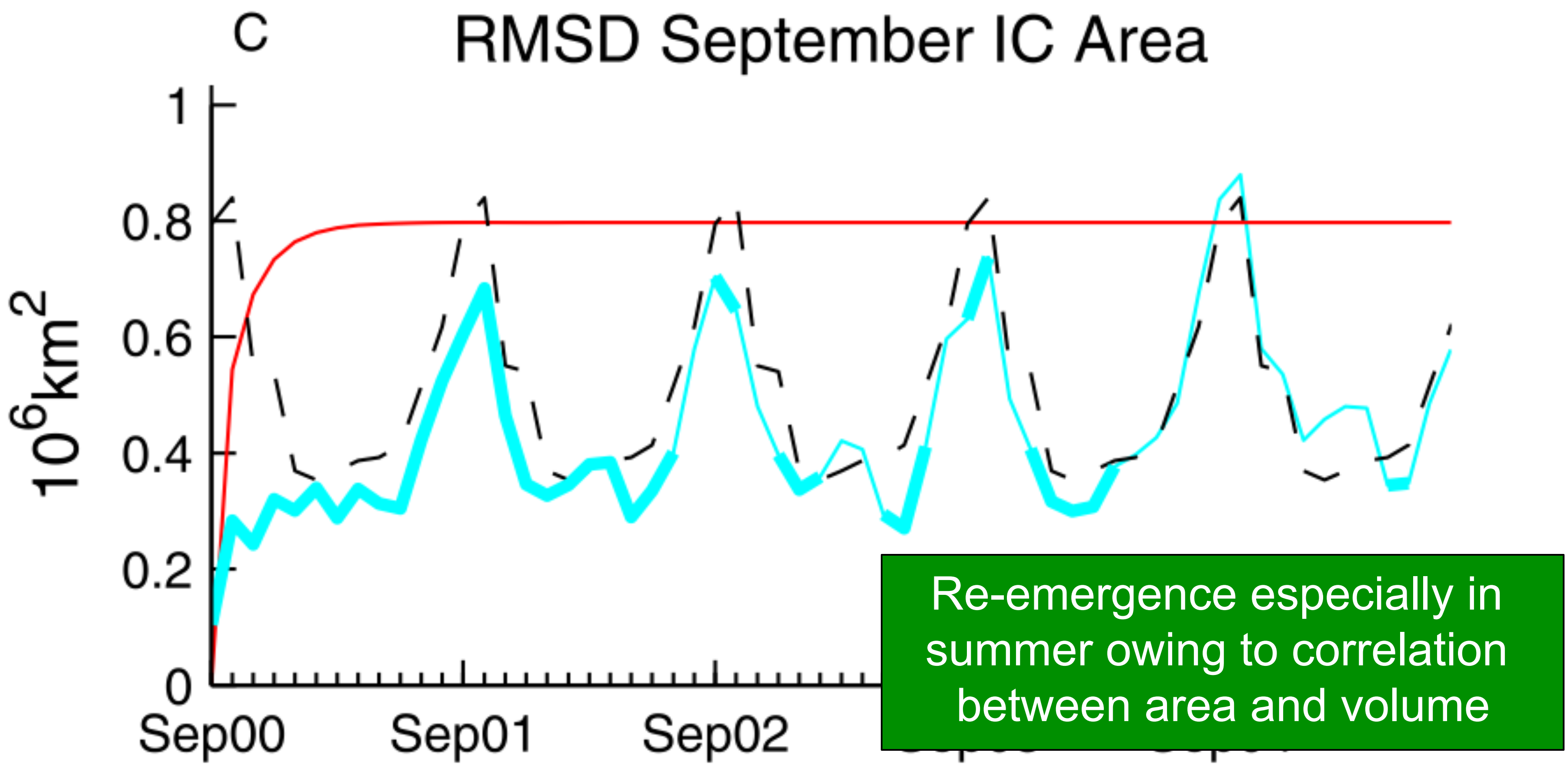


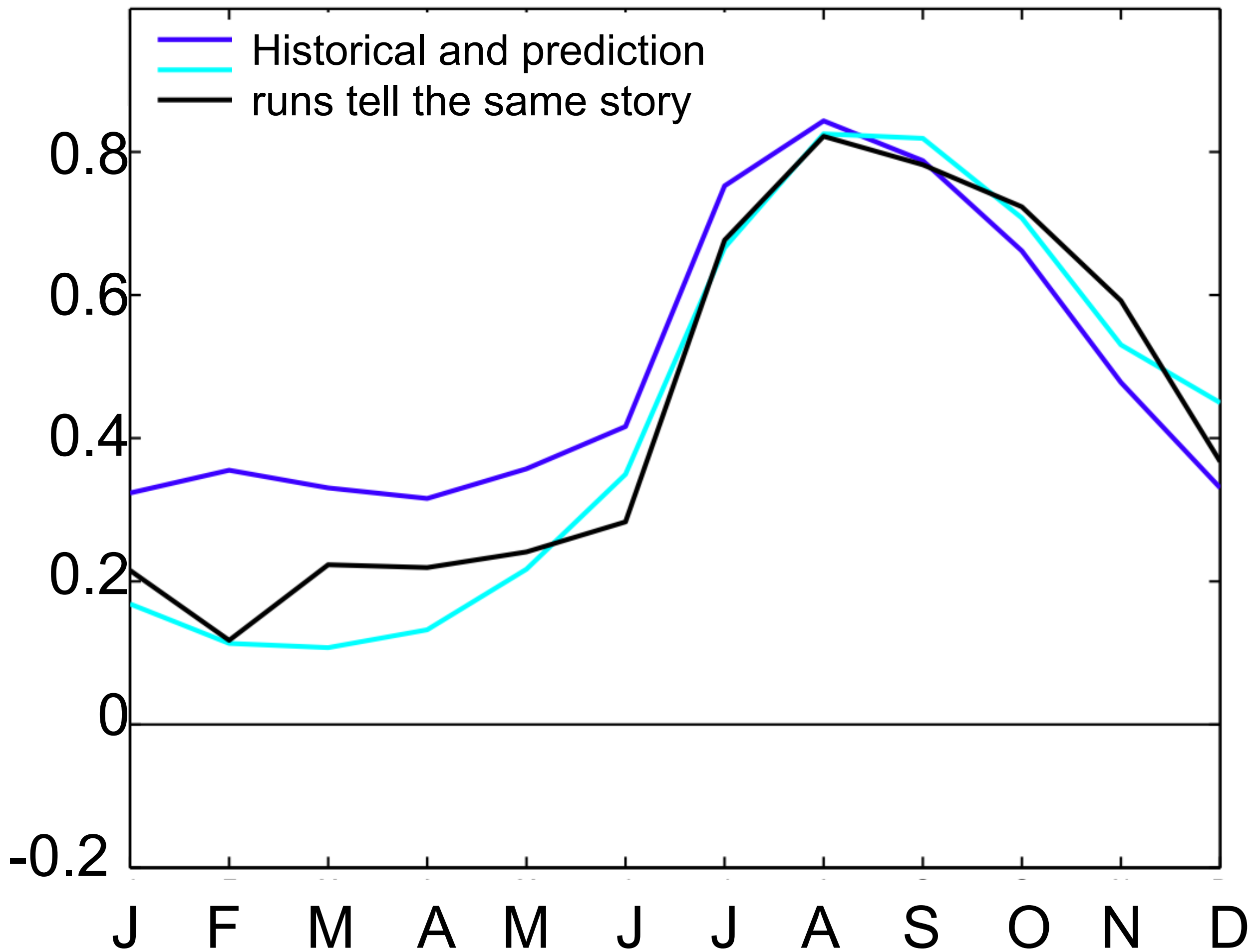
Initialized Ensemble on September 2000

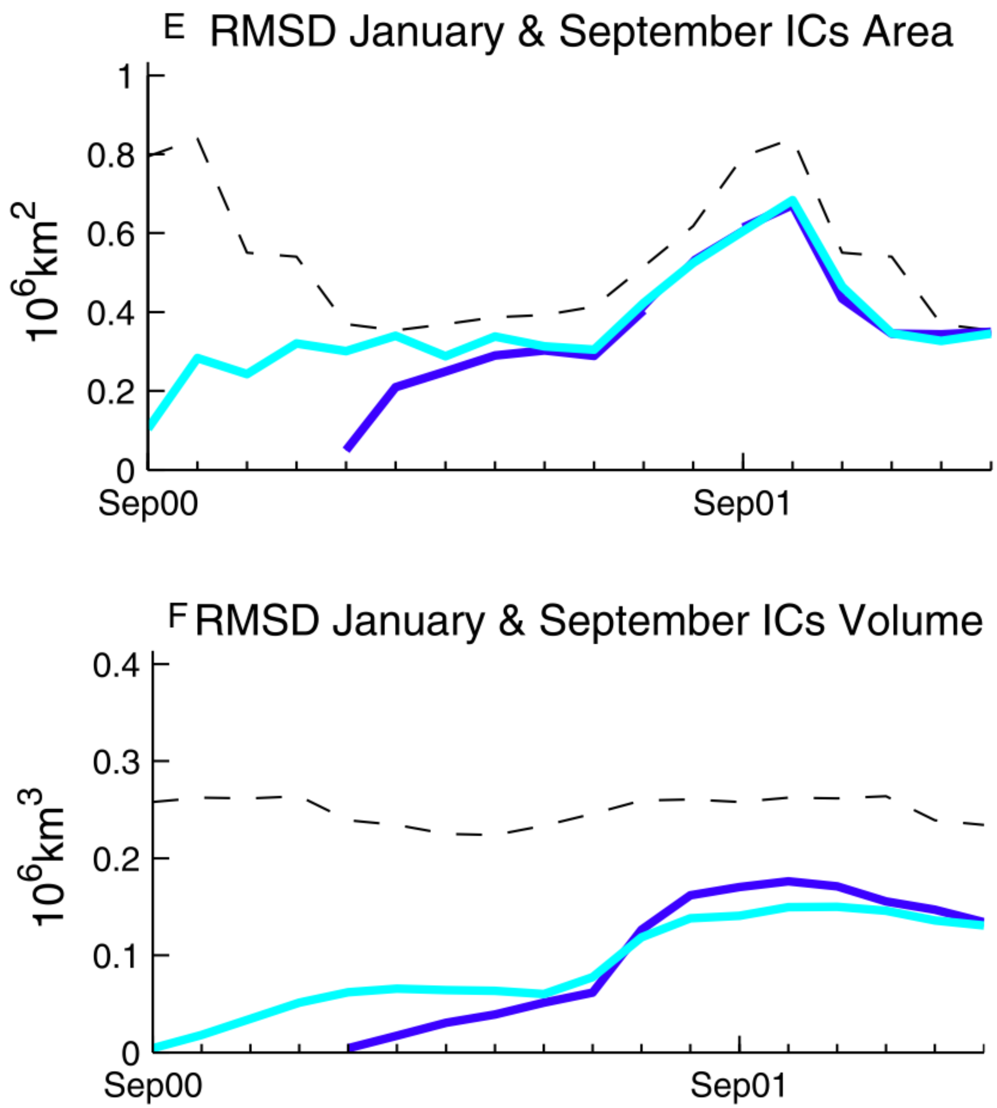
Baseline from detrended 20th Century Historical Runs

AR1 model estimate

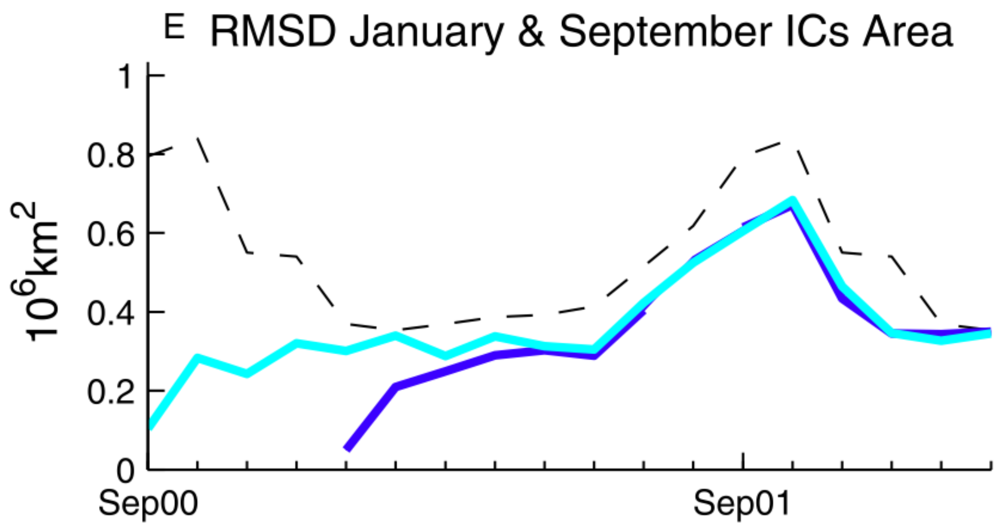
Blanchard-Wrigglesworth, Bitz, and Holland, 2011, GRL

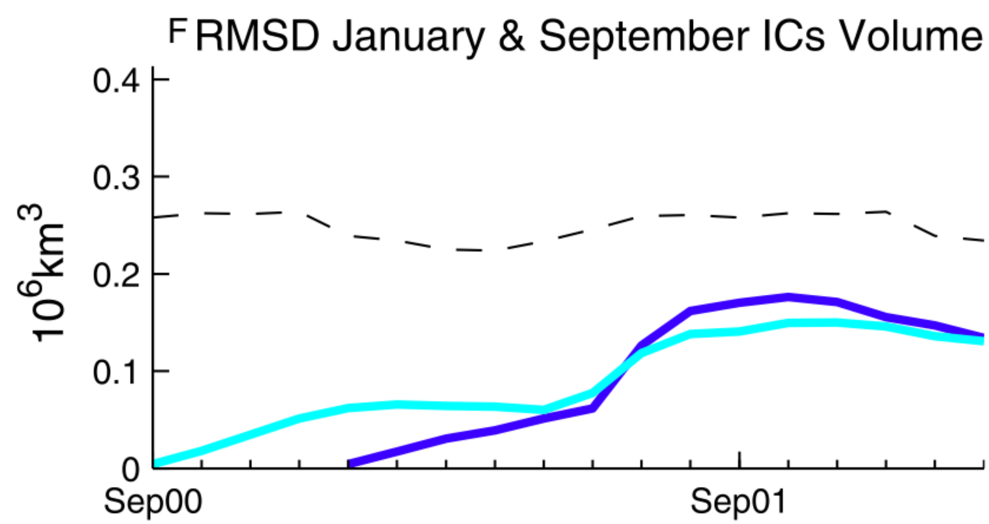
Correlation between Area and Volume by Month



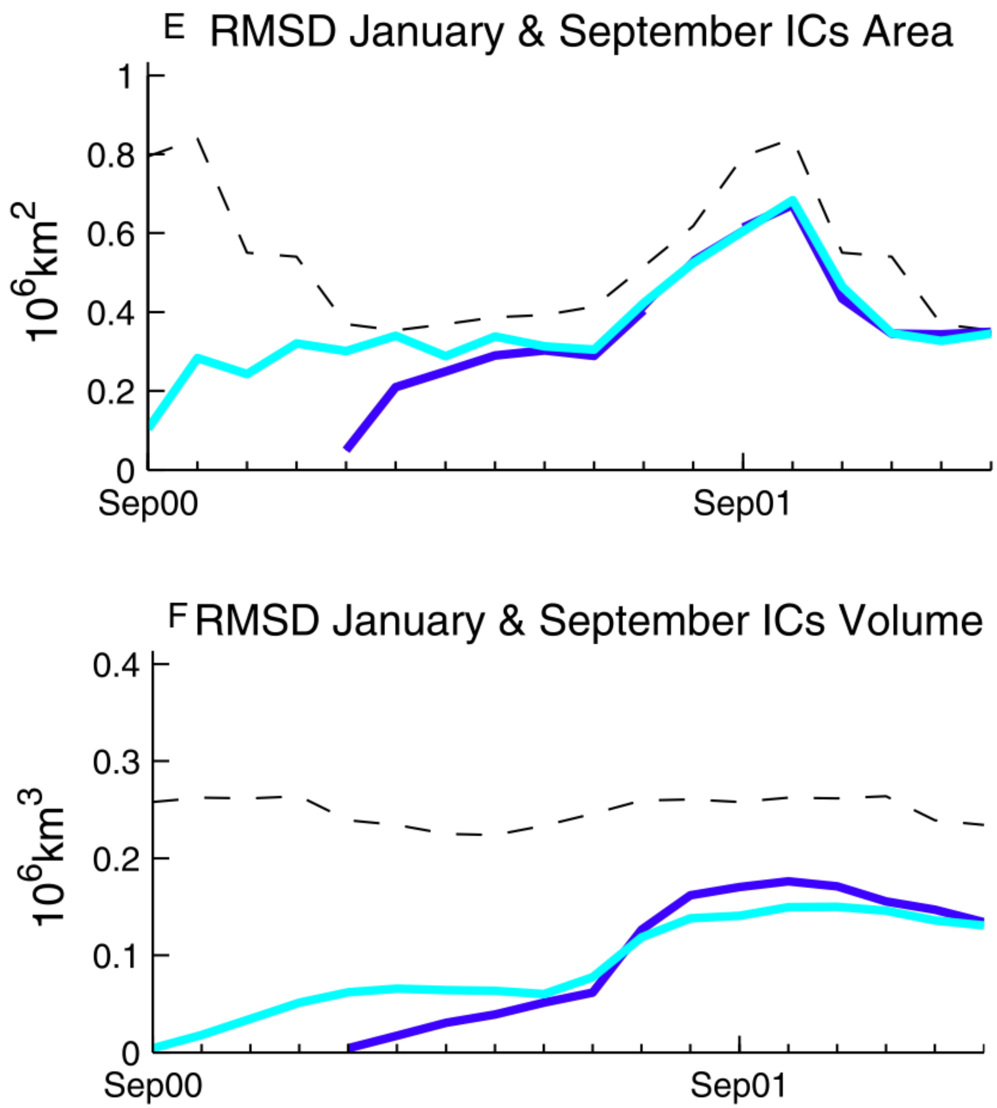


E RMSD January & September ICs Area
$10^6 km^2$
1
0.8
0.6
0.4
0.2
0
Sep00
Sep01
F RMSD January & September ICs Volume
$10^6 km^3$
0.4
0.3
0.2
0.1
0
Sep00
Sep01





Equally good summer forecast from prior September or January



Equally good summer forecast from prior September or January

Partial "Barrier" to volume predictability in spring from ice-albedo feedback

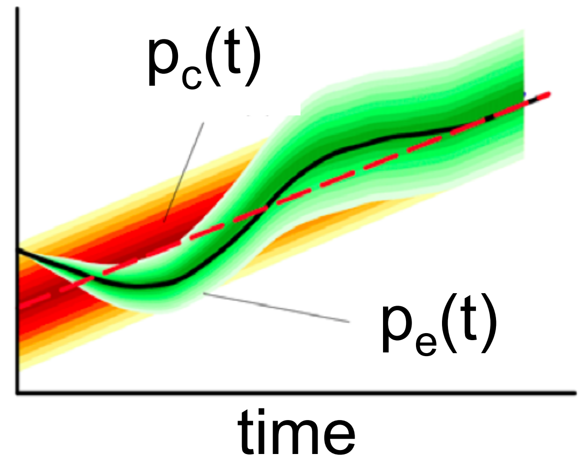
Relative Entropy

$$RE = \int p_c(x)\ ln\ (\frac{p_c(x)}{p_e(x)})\ dx$$

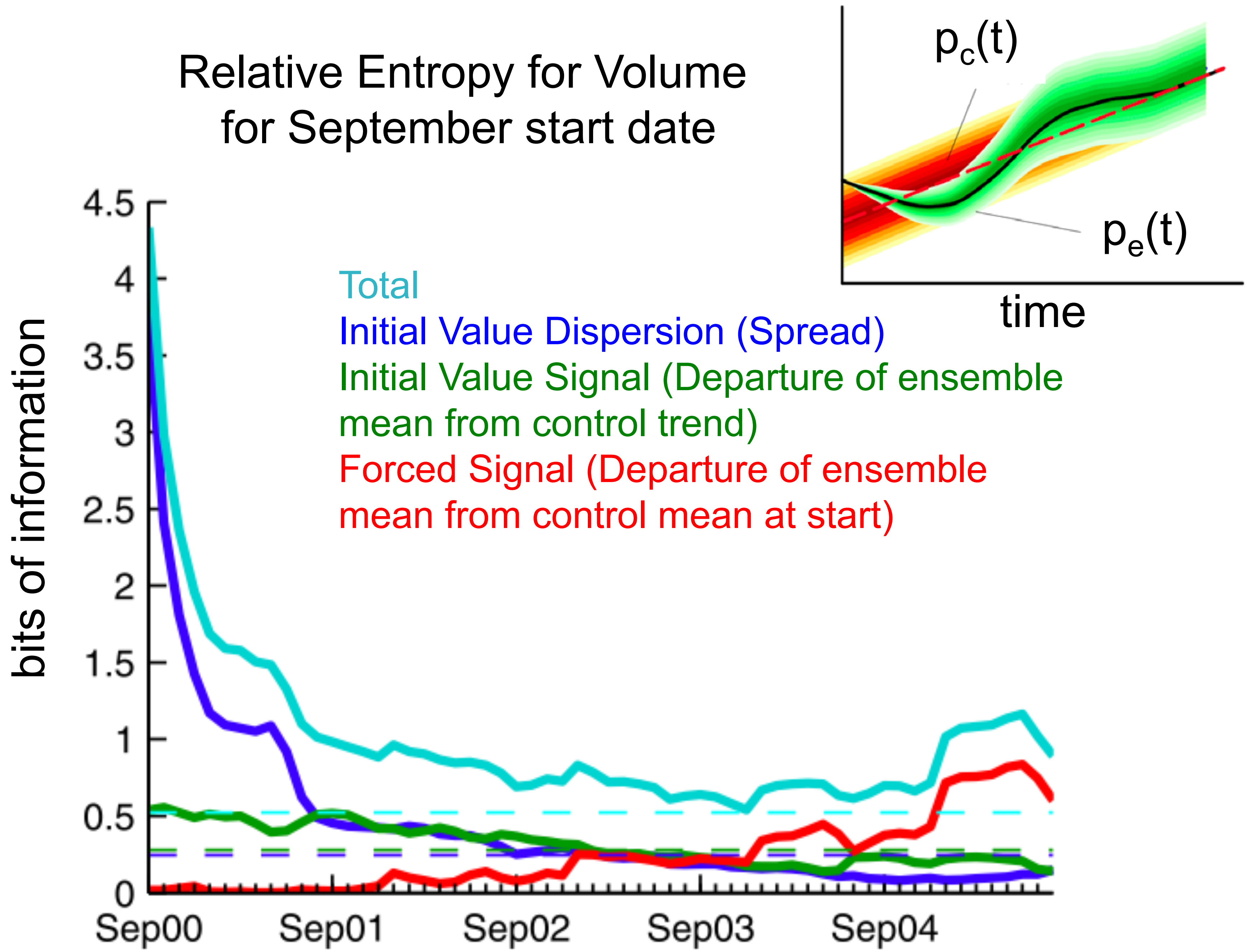
For 1D variable (e.g., x=sea ice area)
assuming Gaussian distributions

$$RE = \frac{1}{2}[ln(\frac{\sigma_c^2}{\sigma_e^2}) + \frac{\sigma_e^2}{\sigma_c^2} + \frac{(\mu_e - \mu_c)^2}{\sigma_c^2} - 1],$$

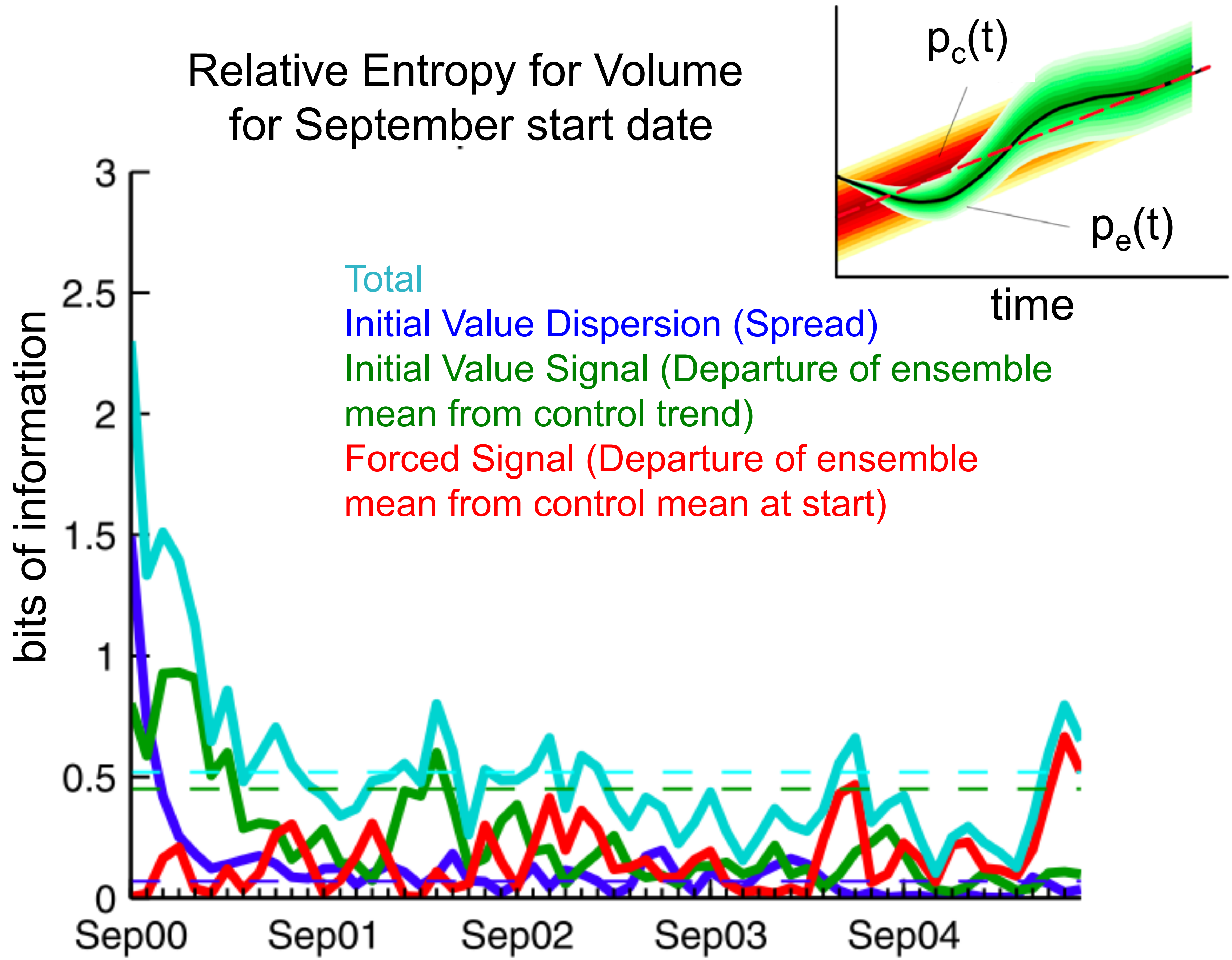
"dispersion" "signal"



Measuring dynamical prediction utility using relative entropy, Kleeman (2002)
and
Information theory and predictability for low-frequency variability, Abramov, Majda, Kleeman (2005)



Relative Entropy for Volume
for September start date
bits of information
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Sep00
Sep01
Sep02
Sep03
Sep04
Total
Initial Value Dispersion (Spread)
Initial Value Signal (Departure of ensemble mean from control trend)
Forced Signal (Departure of ensemble mean from control mean at start)
$p_c(t)$
$p_e(t)$
time



Relative Entropy for Volume
for September start date
bits of information
3
2.5
2
1.5
1
0.5
0
Sep00
Sep01
Sep02
Sep03
Sep04
Total
Initial Value Dispersion (Spread)
Initial Value Signal (Departure of ensemble mean from control trend)
Forced Signal (Departure of ensemble mean from control mean at start)
$p_c(t)$
$p_e(t)$
time

Summary

In perfect model study from Initial Values ~

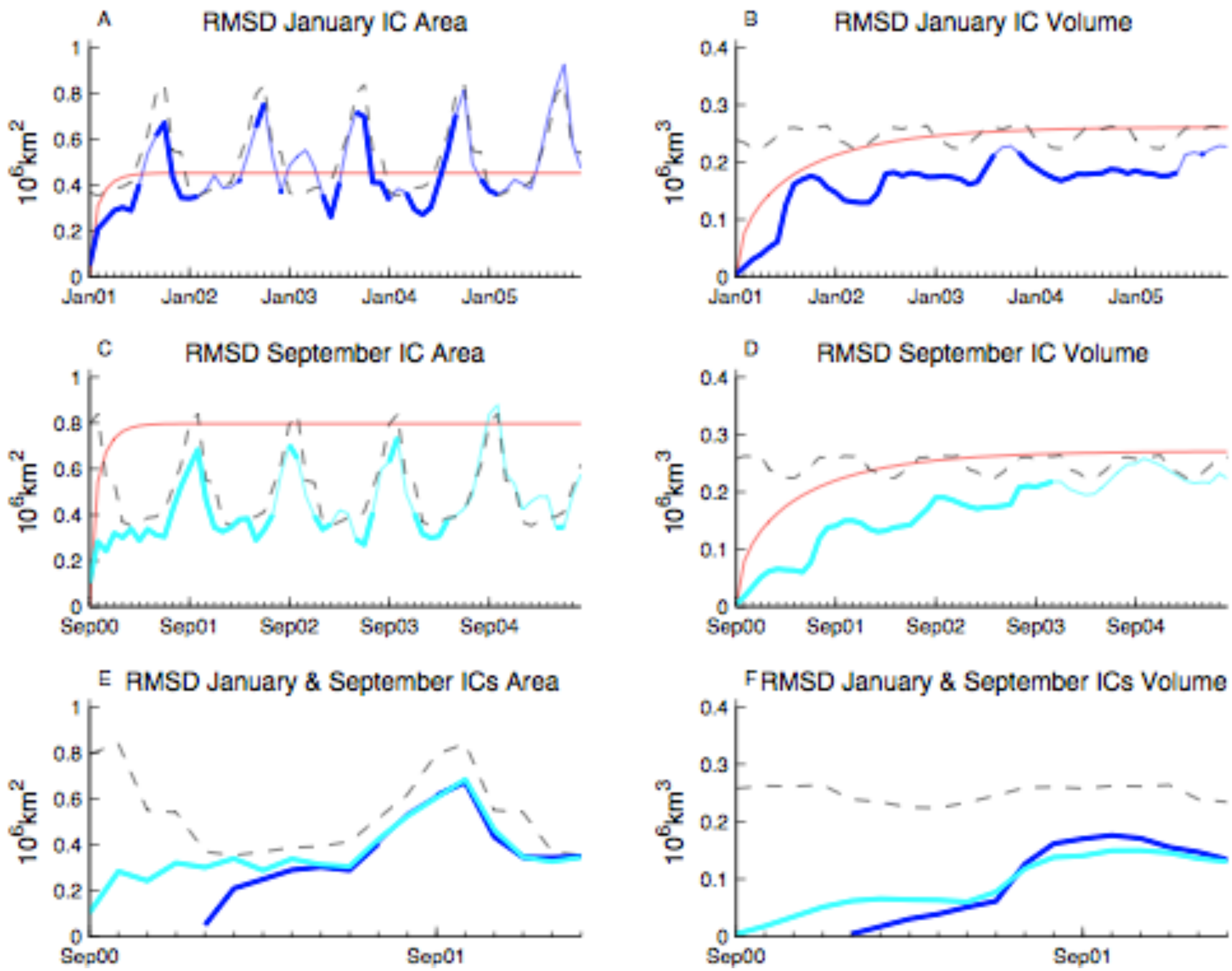
Pan-Arctic sea ice area is intermittently predictable for several years

Volume is predictable for 3-4 years, couples to area

Climate forcing overwhelms initial value predictability at about ~3 years

Summer predictions begun the prior September equal those begun in January

Partial barrier to predictability in spring from ice-albedo feedback


A RMSD January IC Area
B RMSD January IC Volume
C RMSD September IC Area
D RMSD September IC Volume
E RMSD January & September ICs Area
F RMSD January & September ICs Volume
$10^6 km^2$
$10^6 km^3$
Jan01
Jan02
Jan03
Jan04
Jan05
Sep00
Sep01
Sep02
Sep03
Sep04

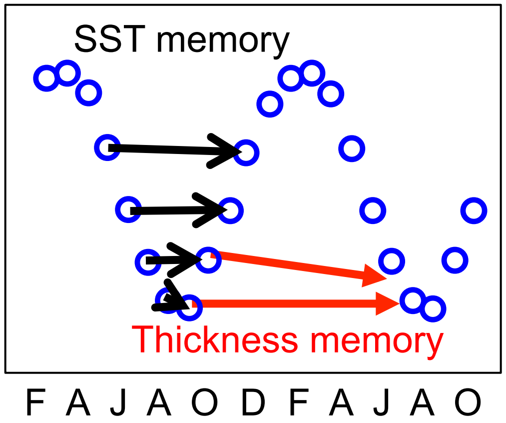
Part 1 Summary

Arctic sea ice area month-to-month persistence (decorrelation timescale) of 3-5 months, depending on the reference month

Arctic sea ice area re-emergence mechanism

Spring to Fall re-emergence is due to SST, seen in model and observations

Summer to Summer is due to thickness, only seen in model



Re-emergence mechanism modulates seasonal cycle of initial decorrelation timescale. Longest persistence is seen following an anomaly in July, strong all the way to October.

Most predictable month of total area given total area anomaly is September, can explain at least 20% of the variance starting a year in advance but this value raises to 70% one month in advance. October has greatest few-month predictability.

Lagged Correlation of Arctic Sea Ice area