How predictable is the North Pacific?

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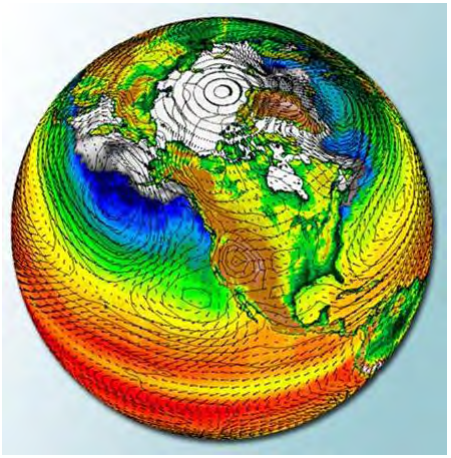
PICES-2013
Nanaimo, Canada
15 Oct 2013

Thanks to: Woo-Sung Lee, Slava Kharin, George Boer…

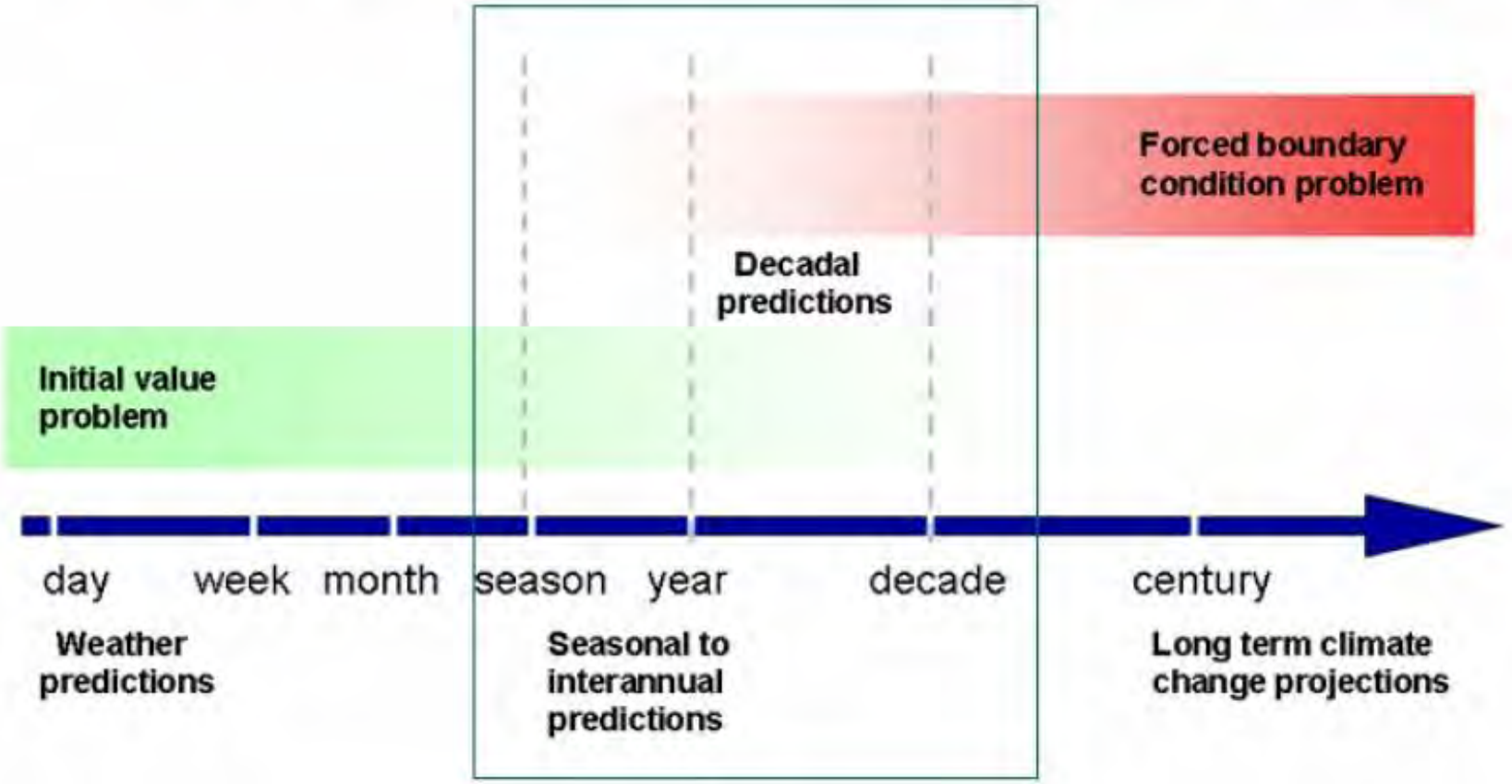
How predictable is the North Pacific…

…in *theory*, as a property of the climate system:

…in *practice*, using prediction tools available today:



Seasonal to Decadal Prediction



IPCC AR5 WG1 report
Chapter 11: Near-term Climate Change

Focus on two time scales

- **1-12 months: Seasonal Prediction**

ENSO + …

- **1-10 years: Decadal Prediction**

Pacific Decadal Variability + Forced Response (including Greenhouse Gases) + …

Canadian Seasonal to Interannual Prediction System (CanSIPS)

CanCM3

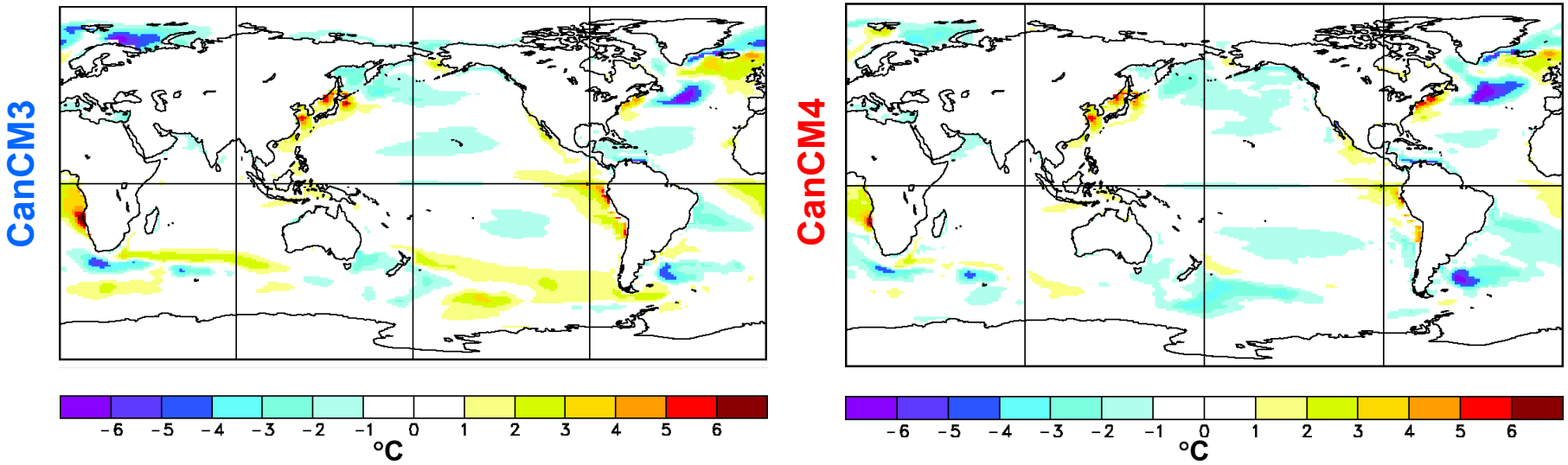
CanAM3 *Atmospheric model*
- T63/L31 (≈2.8° spectral grid)
- Deep convection scheme of Zhang & McFarlane (1995)
- No shallow conv scheme
- Also called AGCM3

CanOM4 *Ocean model*
- 1.41°×0.94°×L40
- GM stirring, aniso visc
- KPP+tidal mixing
- Subsurface solar heating climatological chlorophyll

CanCM4

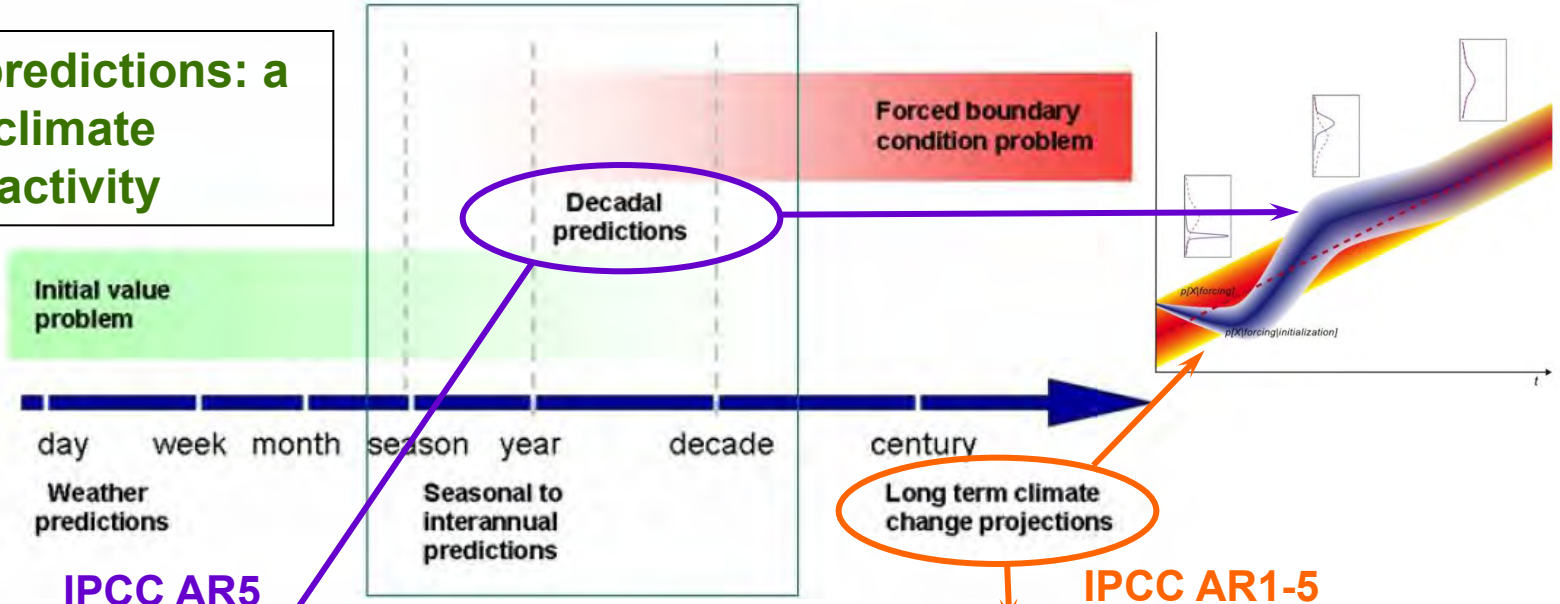
CanAM4 *Atmospheric model*
- T63/L35 (≈2.8° spectral grid)
- Deep conv as in CanCM3
- Shallow conv as per von Salzen & McFarlane (2002)
- Improved radiation, aerosols

Model SST biases vs obs (OISST 1982-2009)

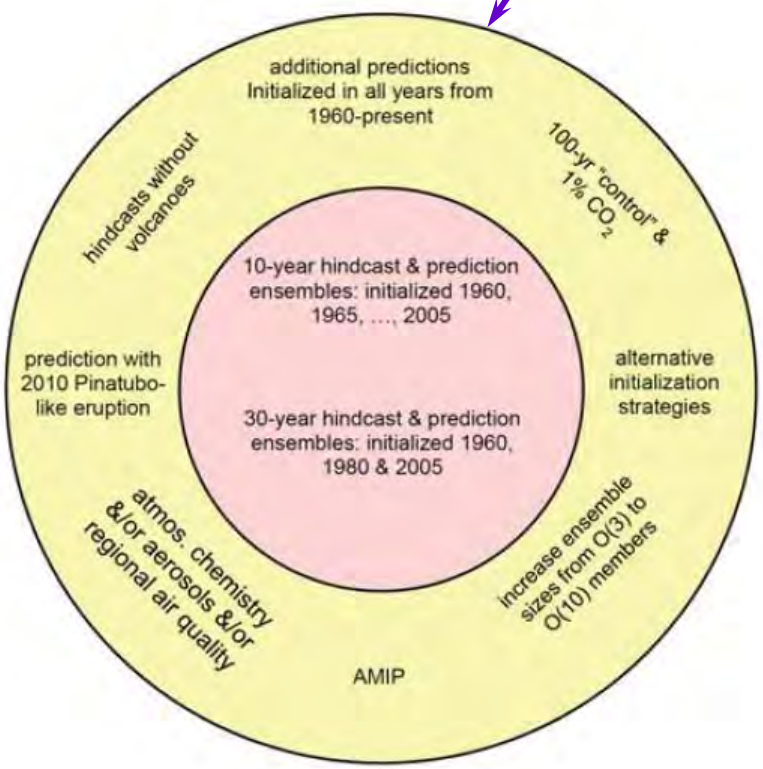


Merryfield et al. MWR 2013

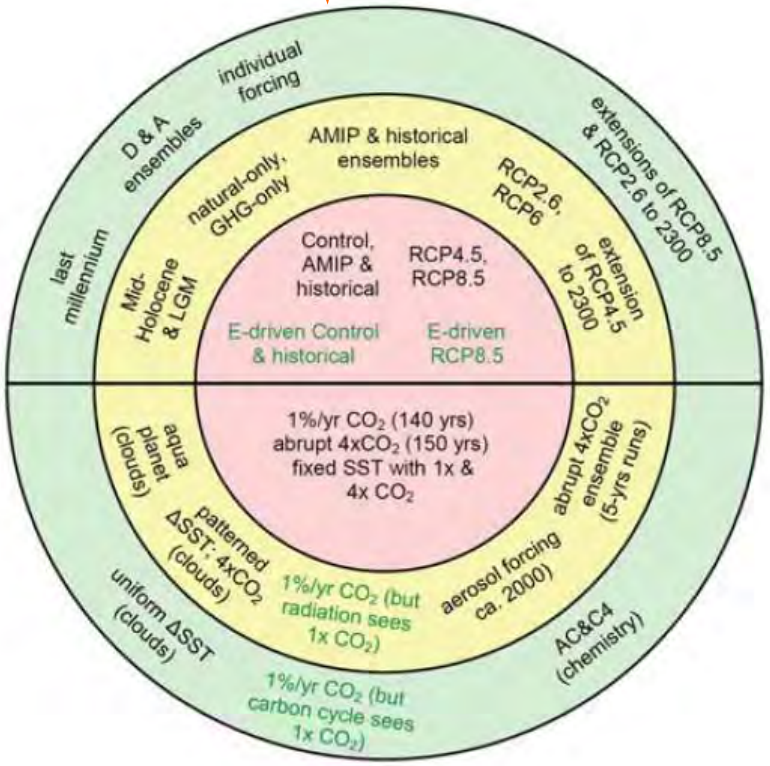
Intialized predictions: a new IPCC climate modelling activity



IPCC AR5



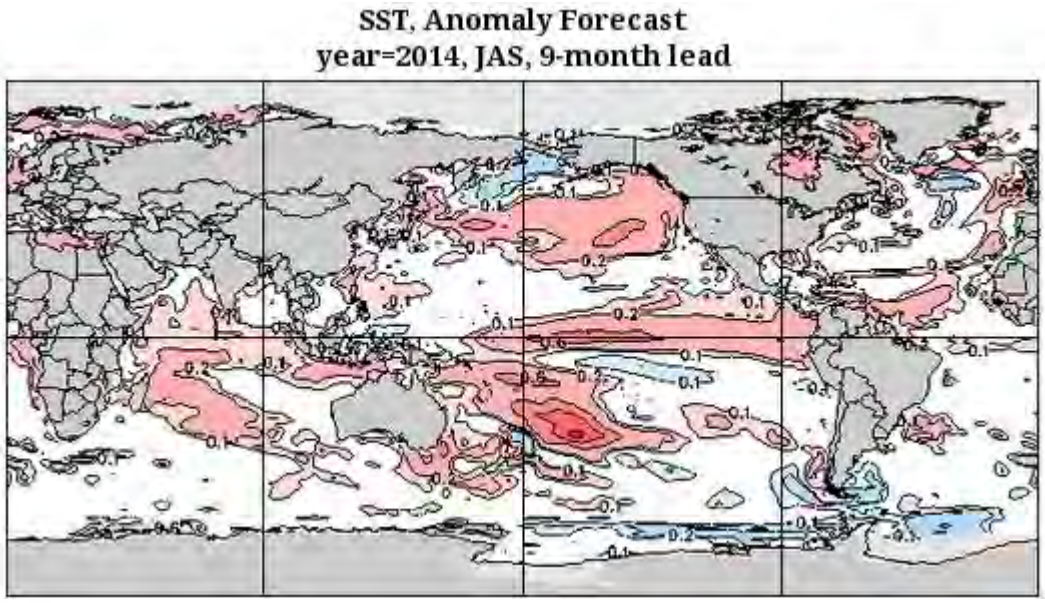
IPCC AR1-5



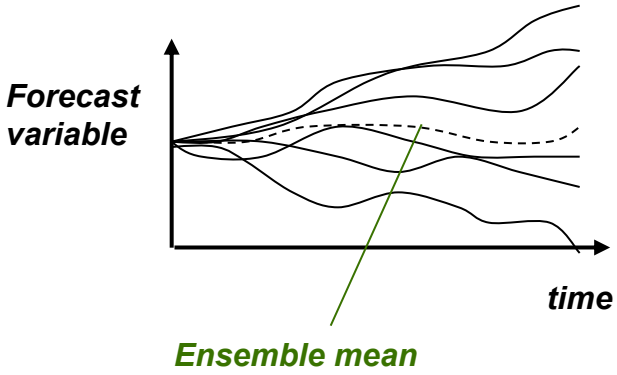
Fundamentals of Climate Forecasting

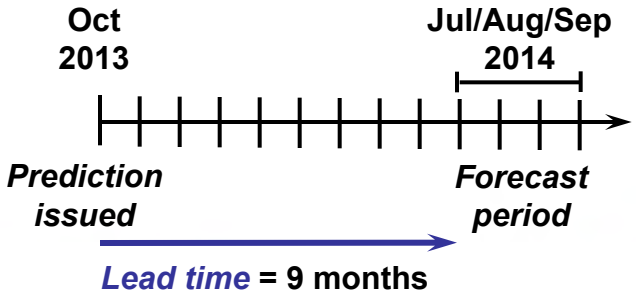
- Objective is to predict ***anomalies*** = departures from "normal"
- Climate forecasts are inherently *probabilistic*

  → due to "butterfly effect" need ***ensembles*** of predictions



Ensemble mean forecast





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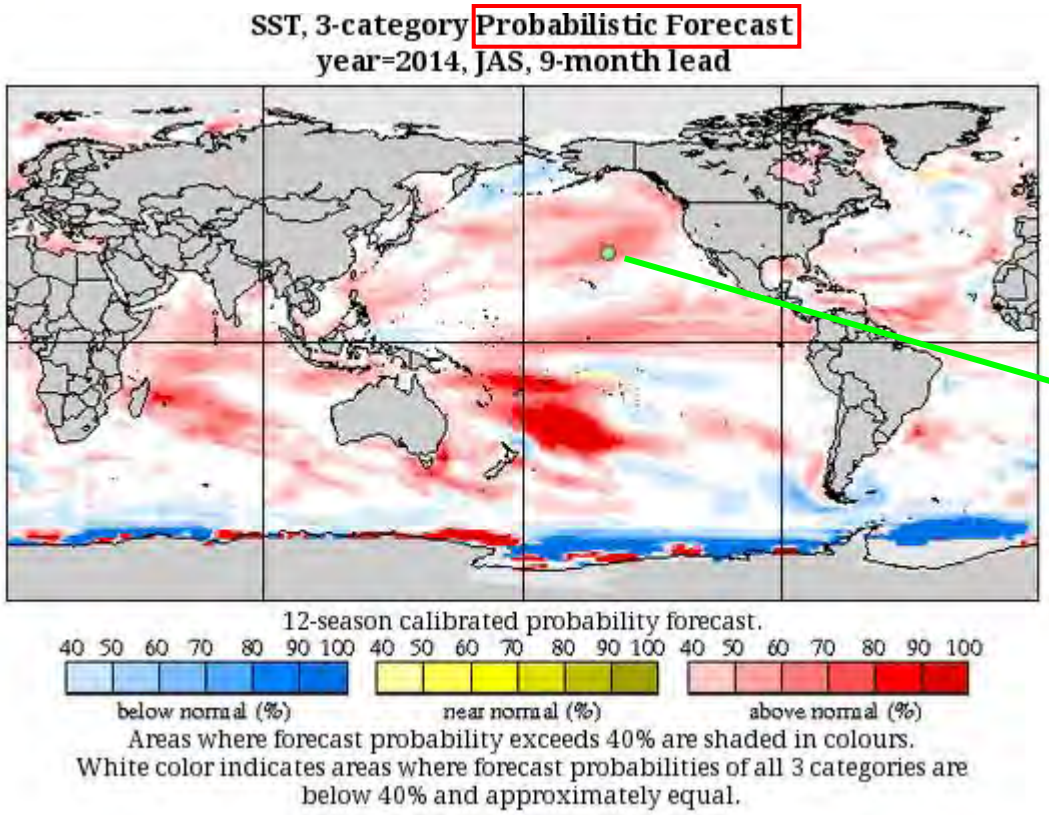
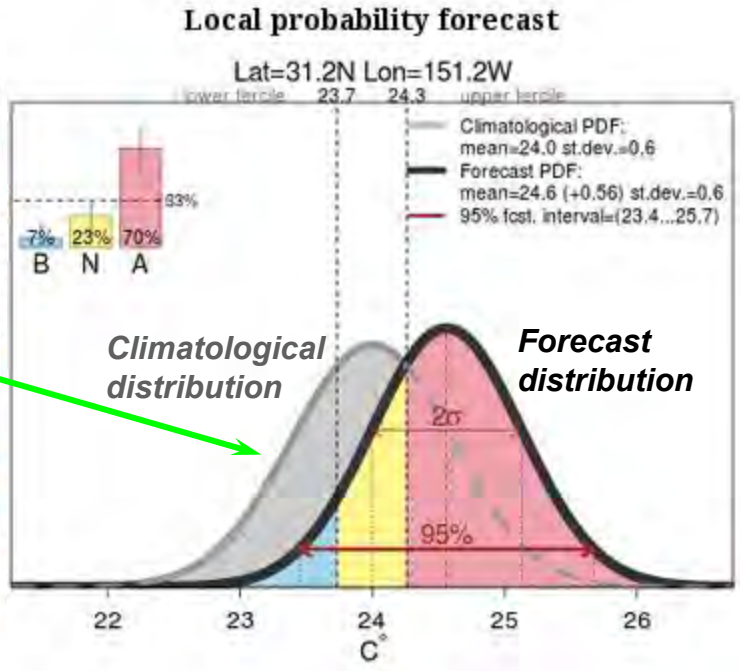
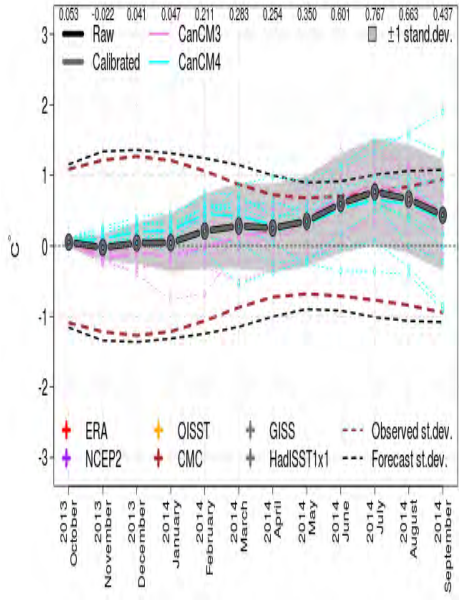




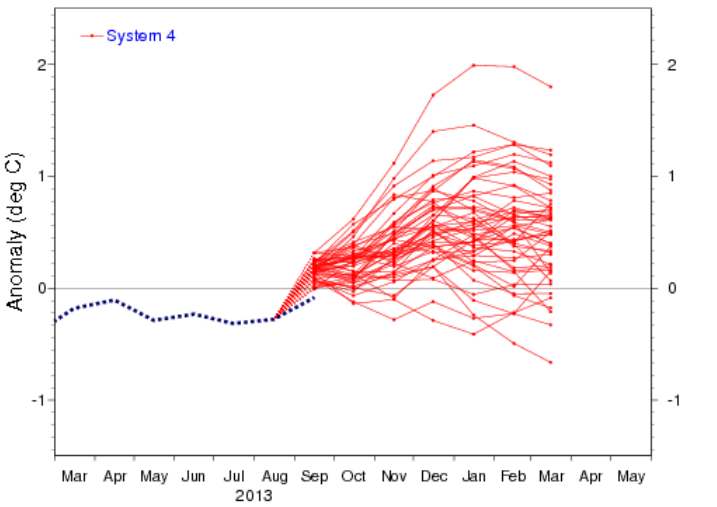
Latest ENSO forecasts from various centers

Canada



Last update: Sun Oct 13 2013
Initial conditions: 22Sep2013–10ct2013

EU

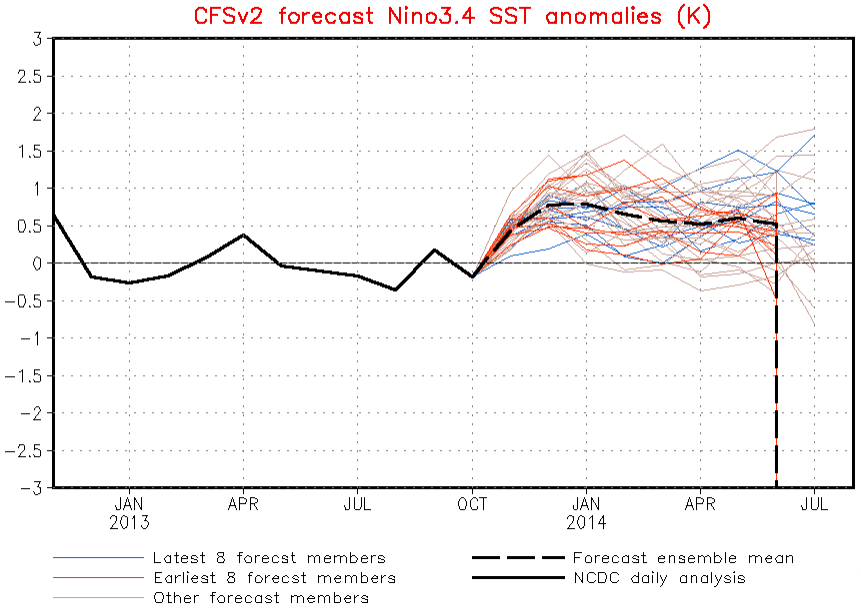


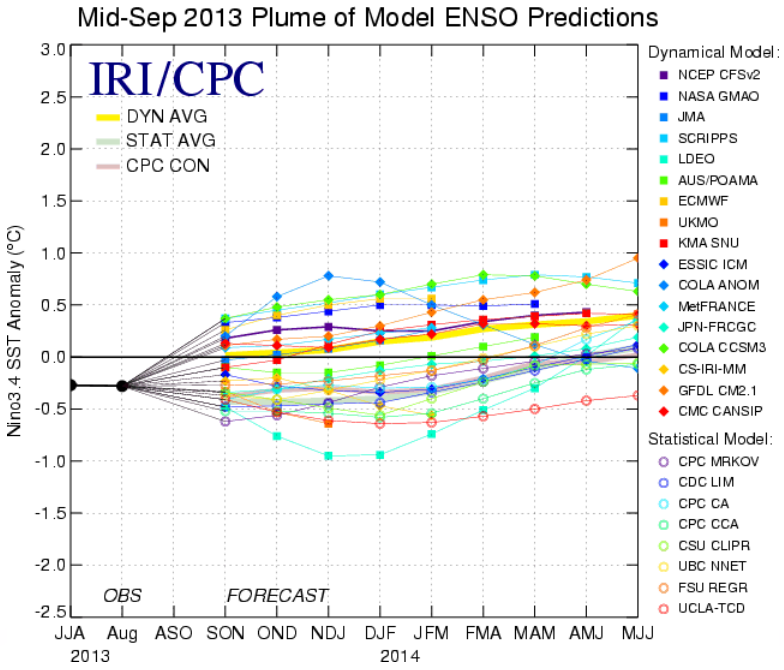
©ECMWF

Nino3.4 index

US

NWS/NCEP/CPC





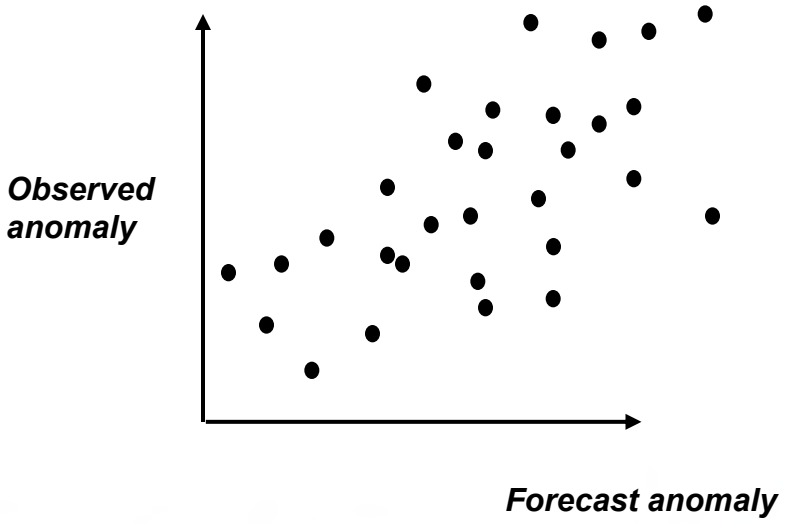
Fundamentals of Climate Forecasting

- Objective is to predict ***anomalies*** = departures from "normal"
- Climate forecasts are inherently *probabilistic*

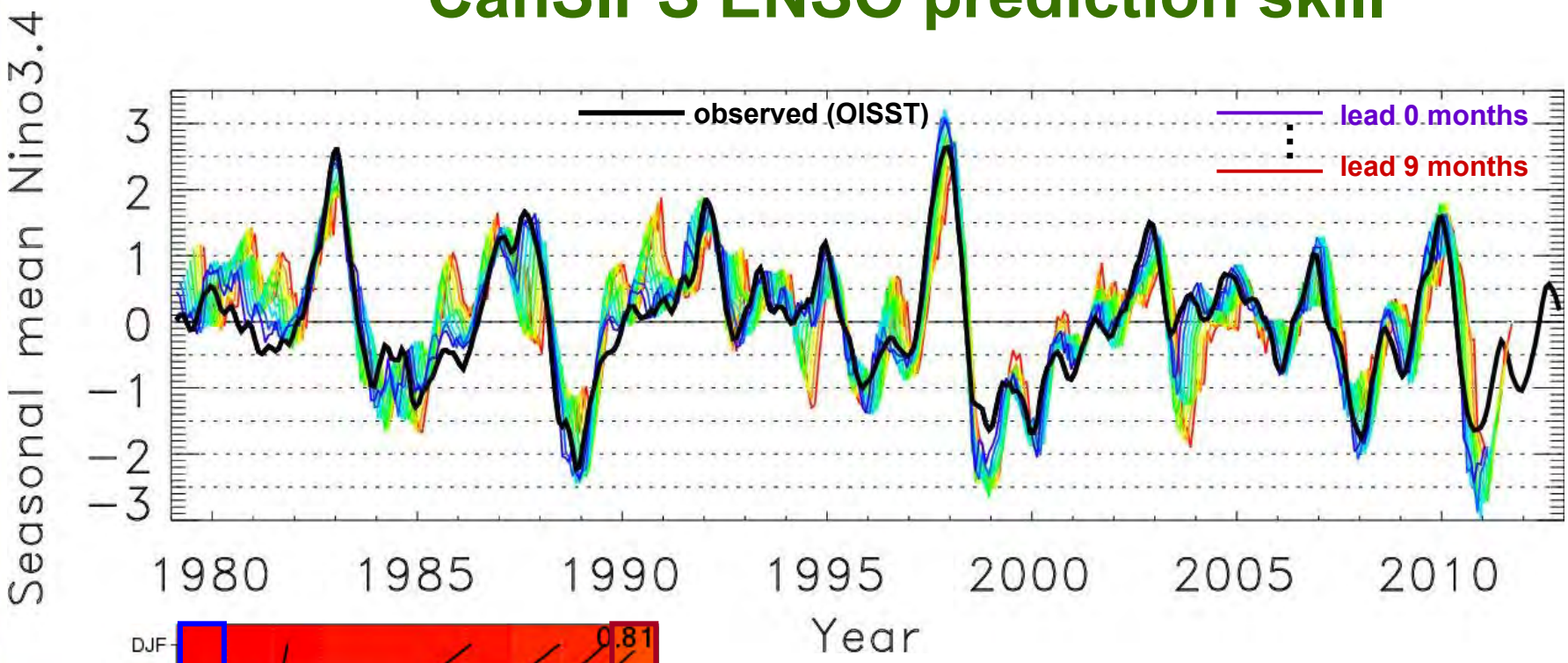
  → due to "butterfly effect" need ***ensembles*** of predictions

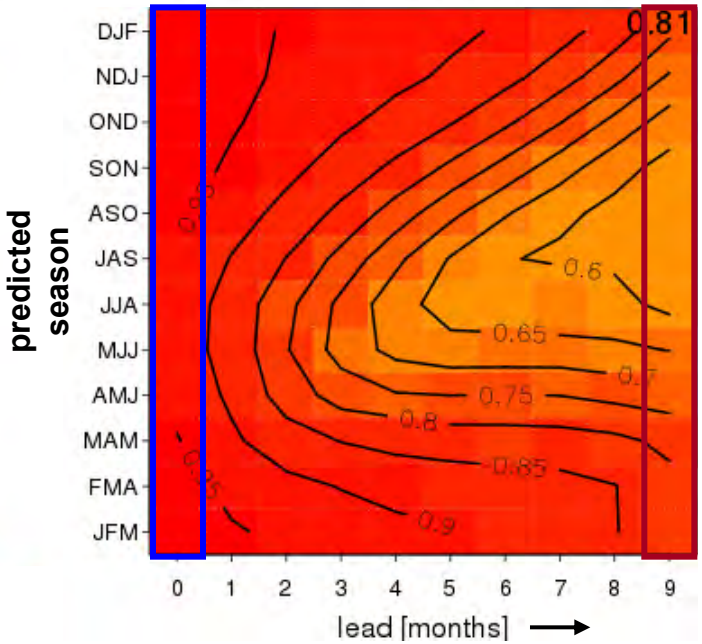
- ***Forecasts are useful only if past performance ("skill") is known***

Many skill measures are used, here will consider ***anomaly correlation*** = correlation of predicted and observed anomalies in past forecasts



CanSIPS ENSO prediction skill





Nino3.4 anomaly correlation (AC) skill:

0.94 < AC < 0.98 at 0-month lead

⋮

0.55 < AC < 0.84 at 9-month lead

How predictable is the North Pacific?

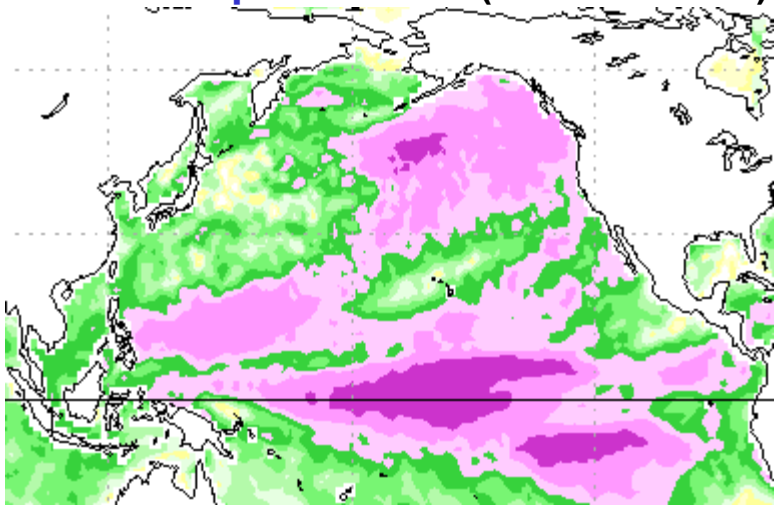
Months to seasons

North American Multi-Model Ensemble

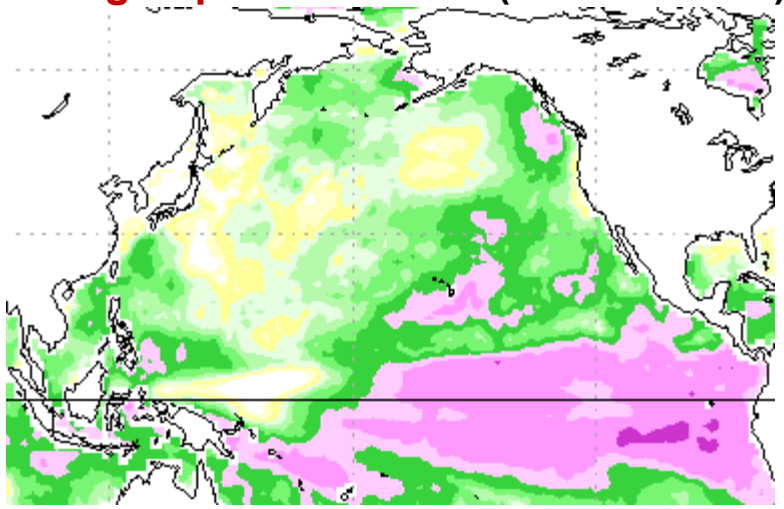
www.cpc.ncep.noaa.gov/products/NMME

NMME

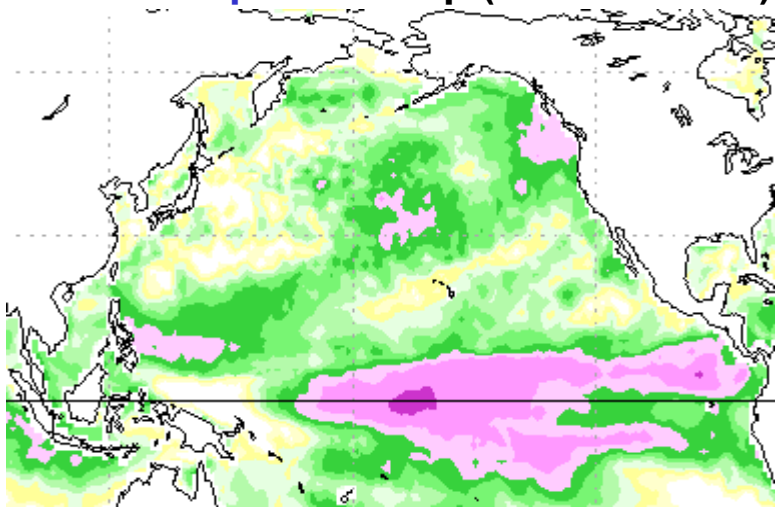
Feb/Mar/Apr from Jan (1 month lead)



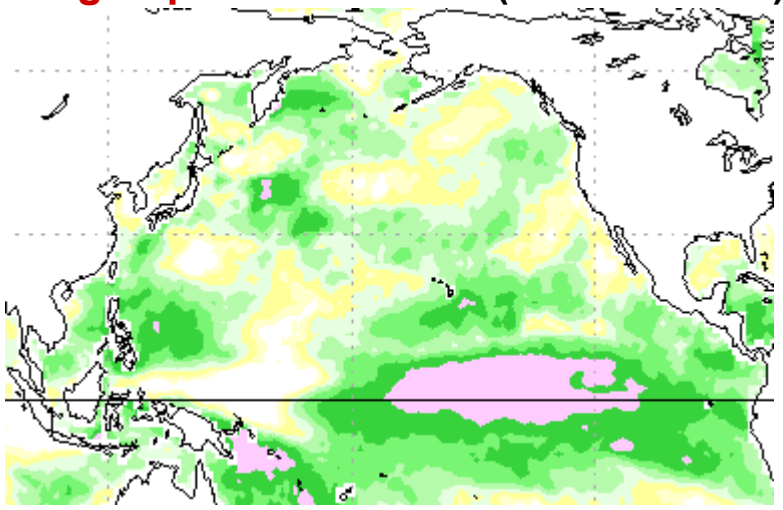
Aug/Sep/Oct from Jul (1 month lead)



Feb/Mar/Apr from Sep (5 month lead)

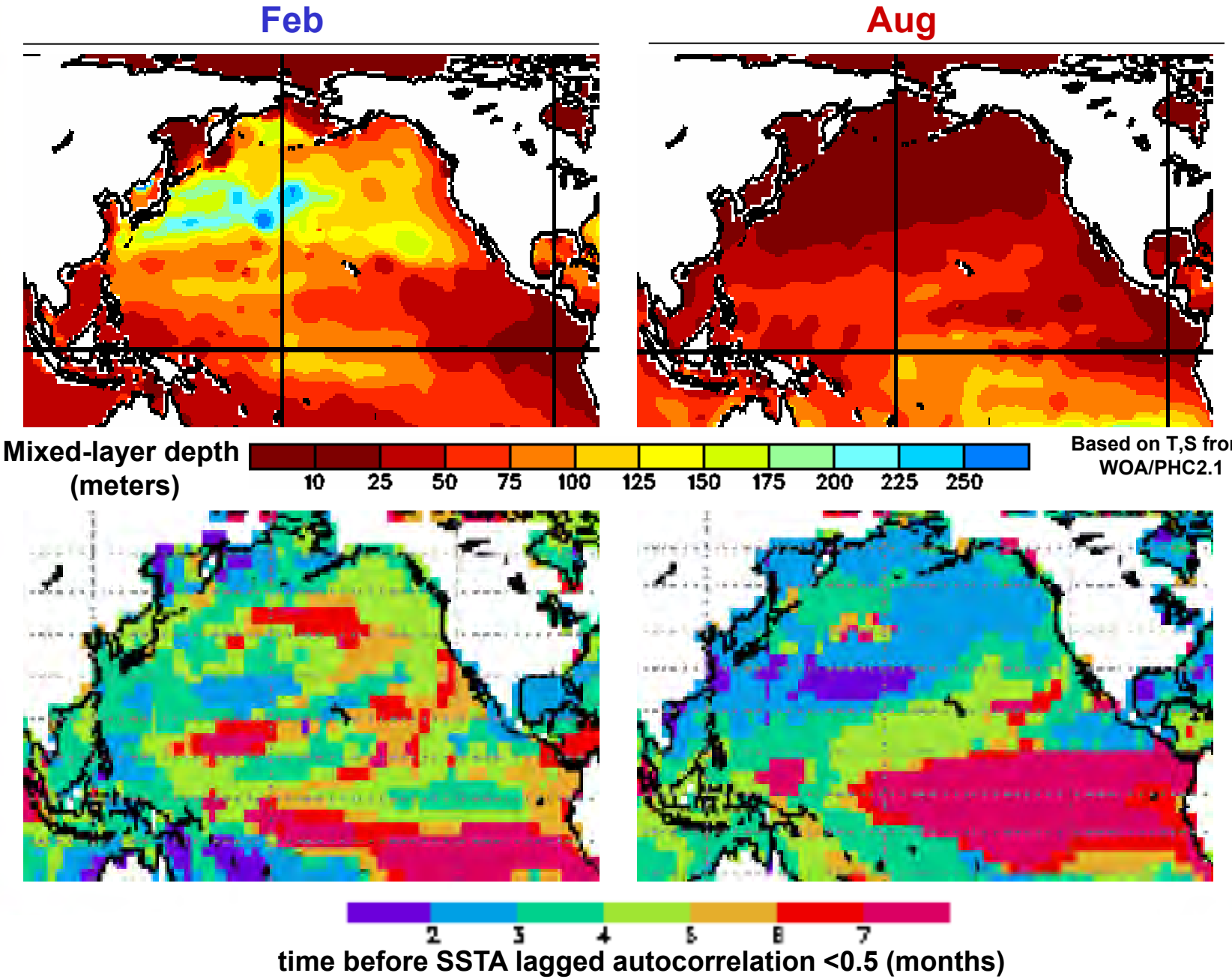


Aug/Sep/Oct from Mar (5 month lead)



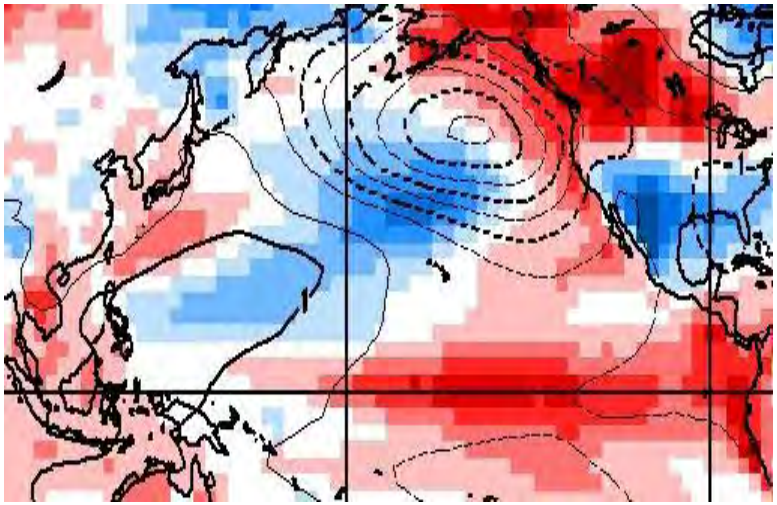
Anomaly correlation skill (%)

Seasonality of mixed-layer depth + SSTA autocorrelation

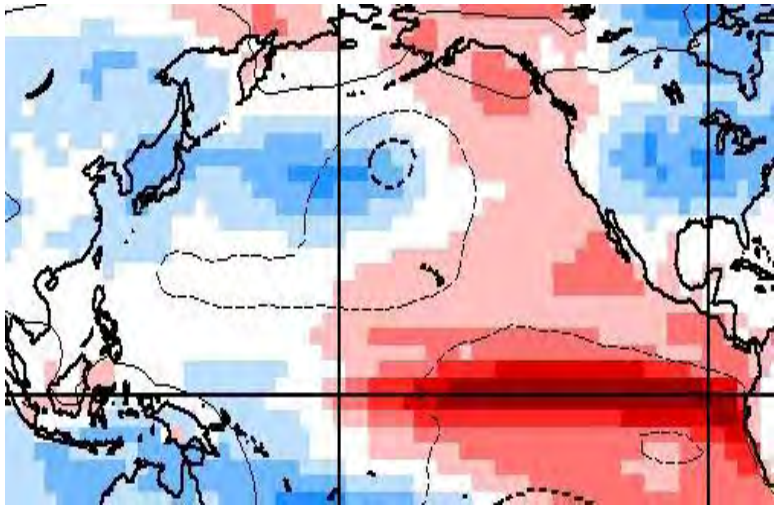


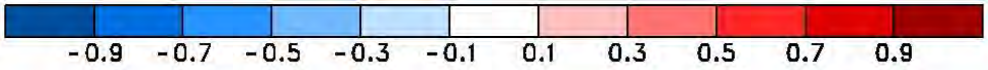
Seasonality of ENSO teleconnections

Feb/Mar/Apr



Aug/Sep/Oct





Colors: regression of near-surface temperature on Nino3.4 index (°C)
Contours: regression of sea level pressure on Nino3.4 index (CI 0.5 hPa)

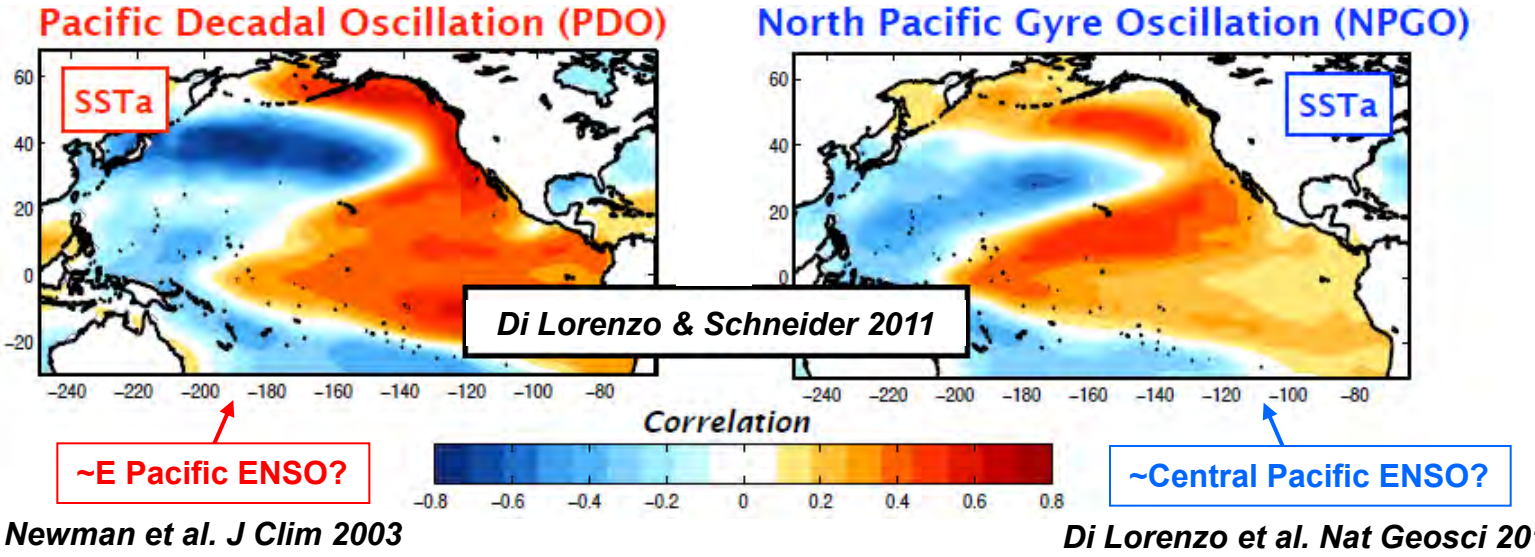
→ **both SST persistence and ENSO influence is lower in late summer vs late winter**

How predictable is the North Pacific?

Years to a decade

What is Pacific Decadal Variability?

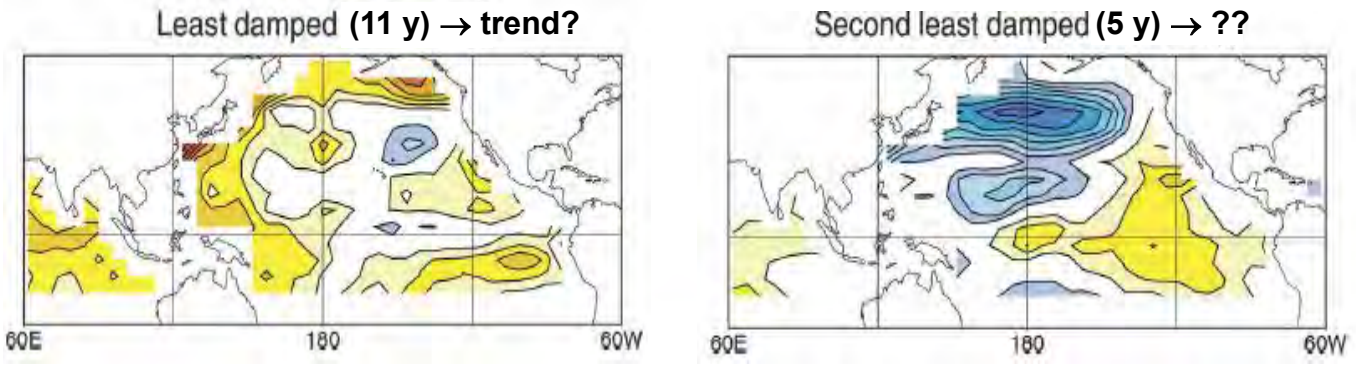
- Modeling studies give model-specific results (as for Atlantic)
  → ***focus on empirical results***
- First 2 North Pacific EOFs:



Newman et al. J Clim 2003

Di Lorenzo et al. Nat Geosci 2010

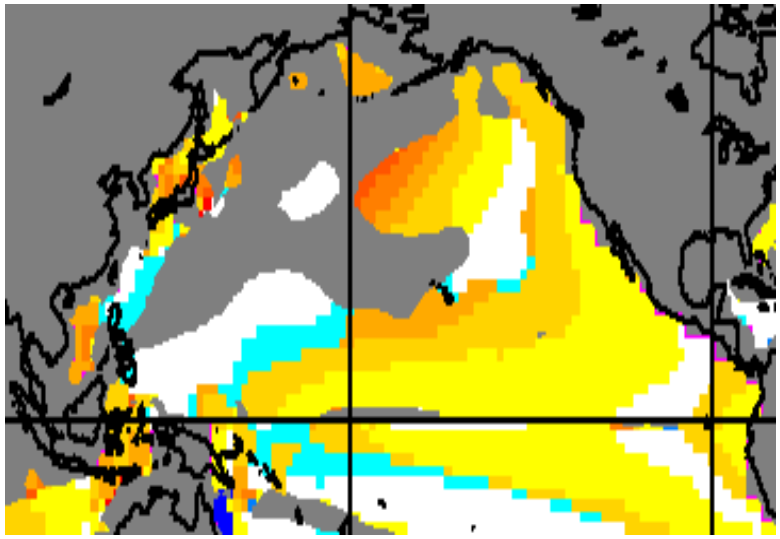
- PDV as a superposition of red noise processes (Newman 2007)



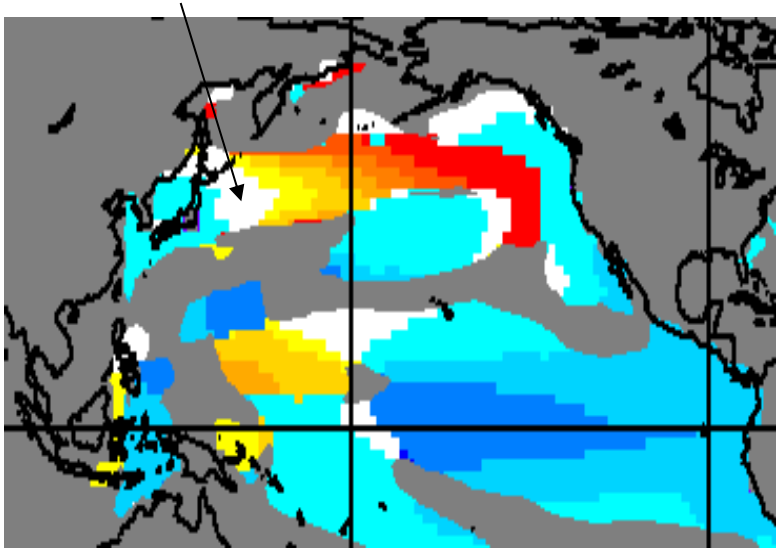
What is predictable in the North Pacific on time scales of years?

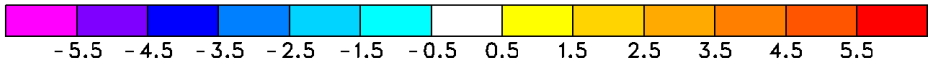
Consider *lag of maximum correlation* in 1000-year climate model run to explore causal relationships

Index: NINO3 **Field: v at 450m depth**



Index: KOE SST **Field: heat content to 330m**





lag of maximum correlation (years)

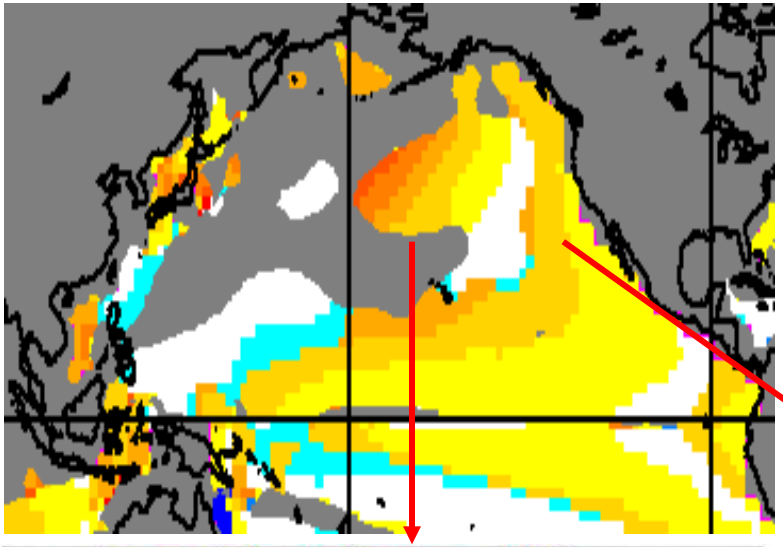
max(corr)<0.2

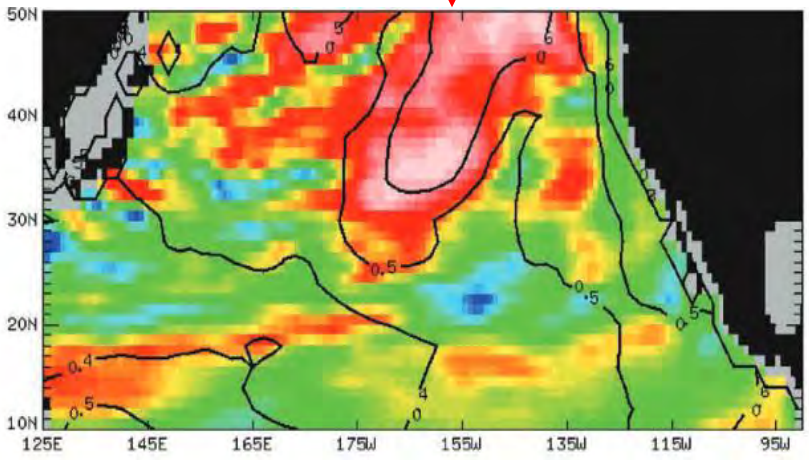
Is there empirical support for these model results?

What is predictable in the North Pacific on time scales of years?

Consider *lag of maximum correlation* in 1000-year climate model run to explore causal relationships

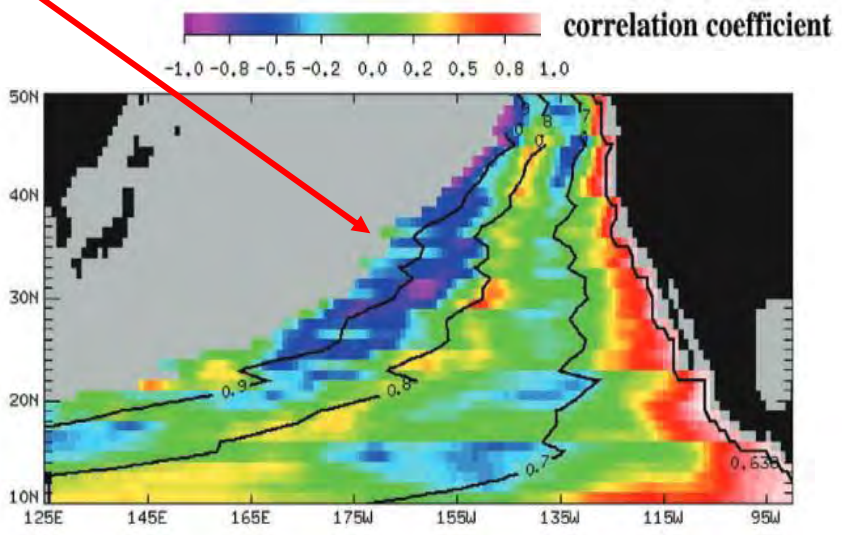
Index: NINO3 Field: v at 450m depth





Fu & Qiu (JGR 2002) correlated SSH obs with wind- and boundary-driven Rossby waves in model

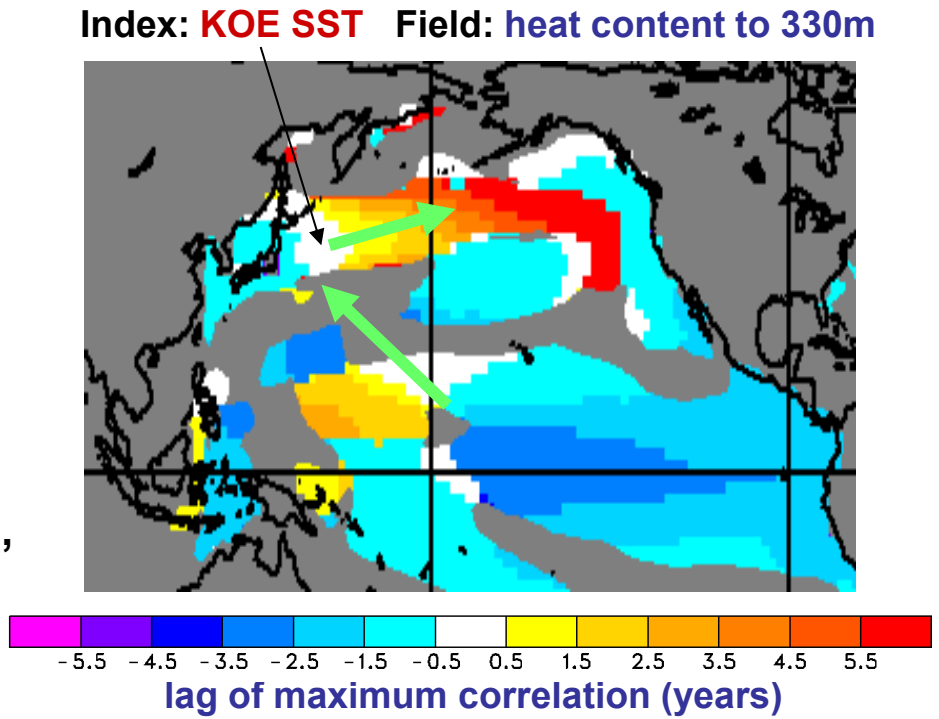
→ both features seen, but wind-driven Rossby waves are dominant in the ocean interior



What is predictable in the North Pacific on time scales of years?

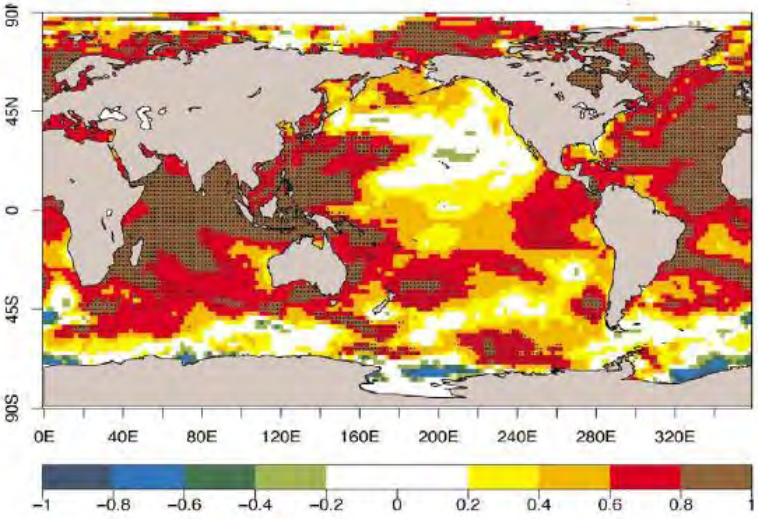
Consider *lag of maximum correlation* in 1000-year climate model run to explore causal relationships

- **Equatorial Pacific heat content leads KOE SST by 2-3 years**
- **KOE heat content anomalies then advected westward by North Pacific Current**
- **Some possible evidence for this process (e.g. Guemas et al. JGR 2012), but many questions remain**

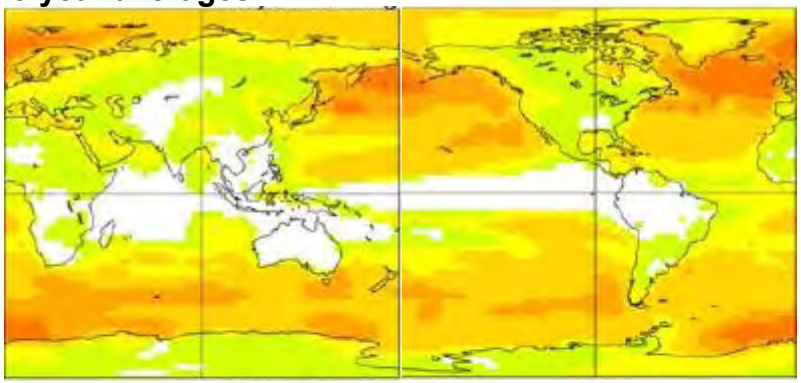


Diagnosed potential predictability

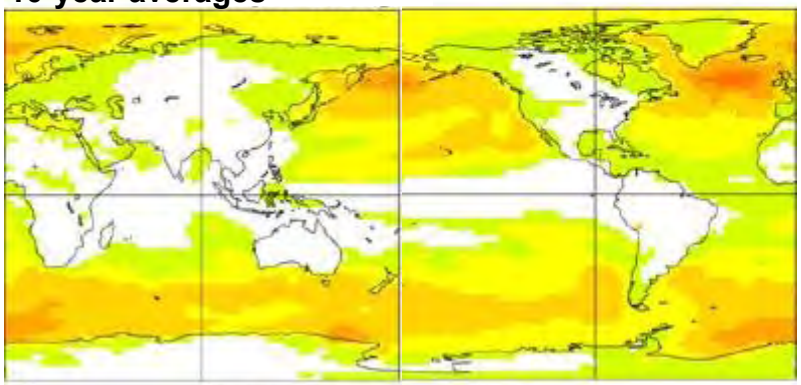
- **Boer & Lambert (GRL 2008) diagnosed fraction of *N*-year averaged surface temperature that is *potentially predictable* in 8000 years of climate simulations**
- **Perhaps surprisingly, *North Pacific nearly as predictable as North Atlantic***
- **However, actual decadal prediction skills look like this:**

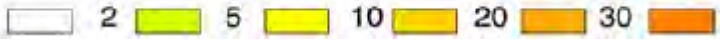


5-year averages



10-year averages

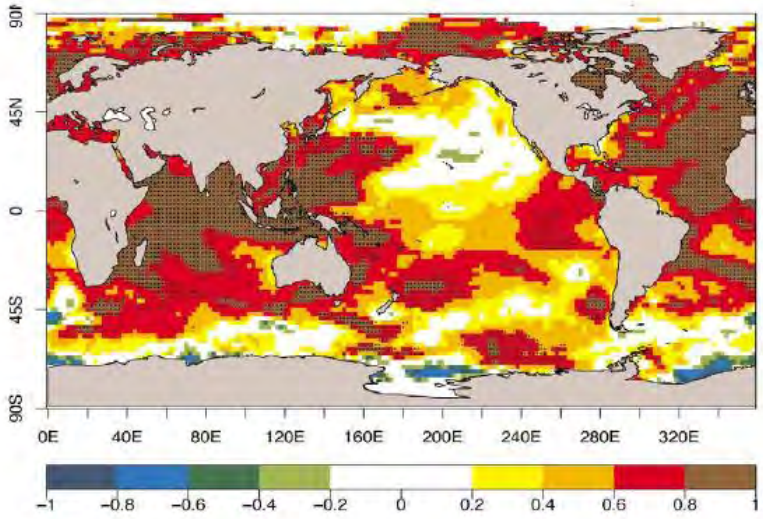




potentially predicable variance (% of total variance)

← **Anomaly correlation, Years 2-5 of forecasts from 5 IPCC decadal prediction models initialized in 1961-2006 *(Guemas et al. JGR 2012, also Kim et al. GRL 2012, Doblas-Reyes et al. Nature Comm. 2013)***

Why are actual and potential predictability so different?



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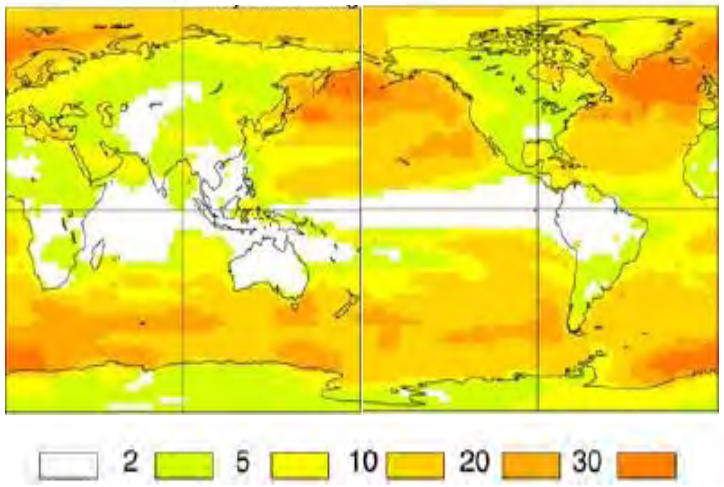

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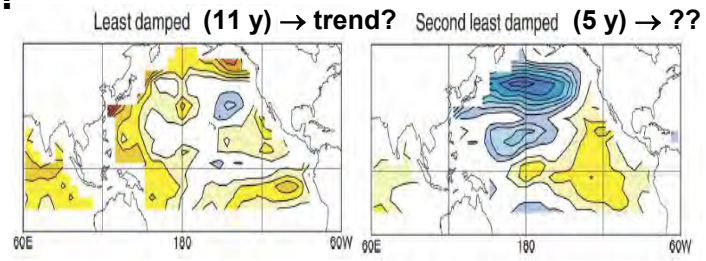
Some possibilities:

- **Climate models used to compute potential predictability are wrong?**
- **Warming trend (absent in potential predictability analysis) matters →**
  yes, but *increases* predictability especially in tropics (Boer, Clim Dyn 2011)
- **Empirical analysis (Newman 2007) is a better indication of predictability**
  → maybe: first (trend) mode somewhat resembles skill
  → explore role of second mode by removing trend?



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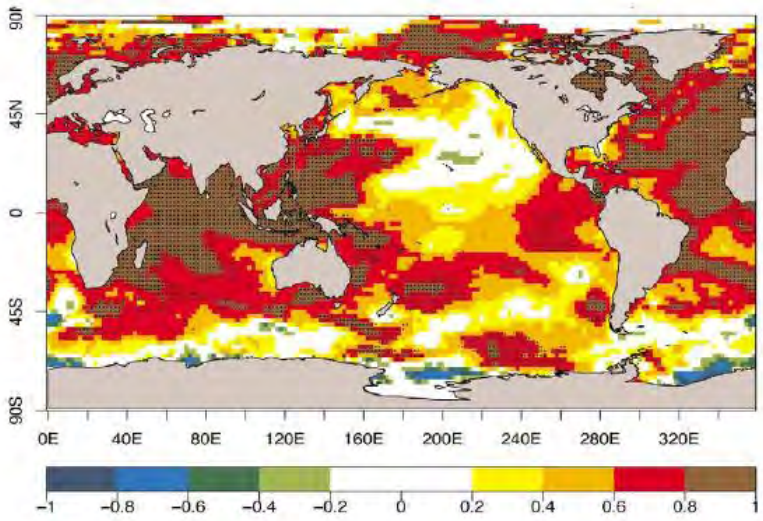

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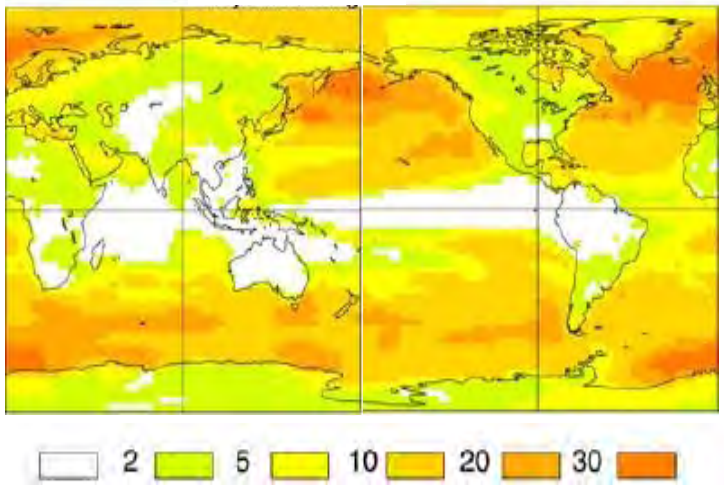

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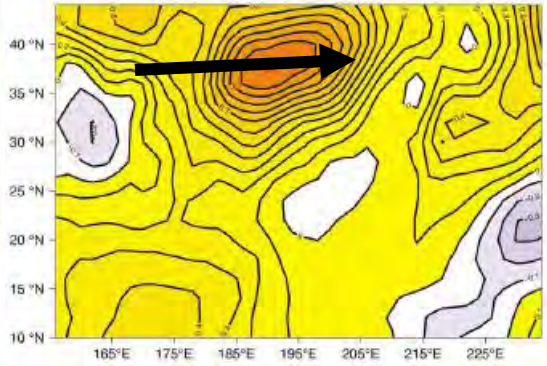
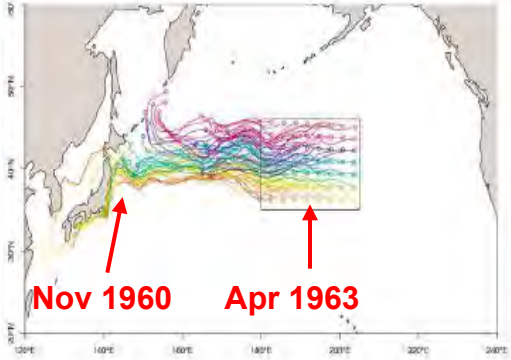
Some possibilities (continued):

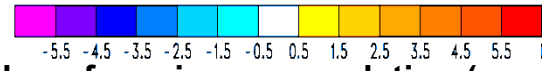
- **Guemas et al. (JGR 2012) suggest much of skill deficit caused by predictions missing large westward migrating warm anomalies in 1960s:**

1963 ERSST anomalies
(155-235°E, 10-45°N)

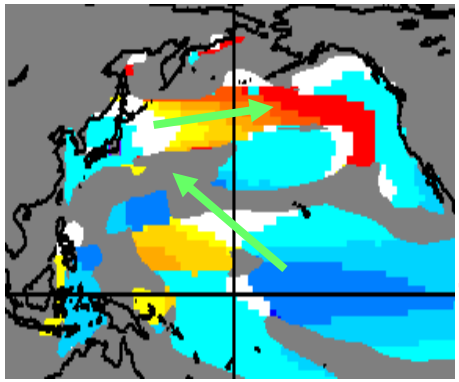


Backward trajectories launched
in 180-205°E-35-45°N in April 1963





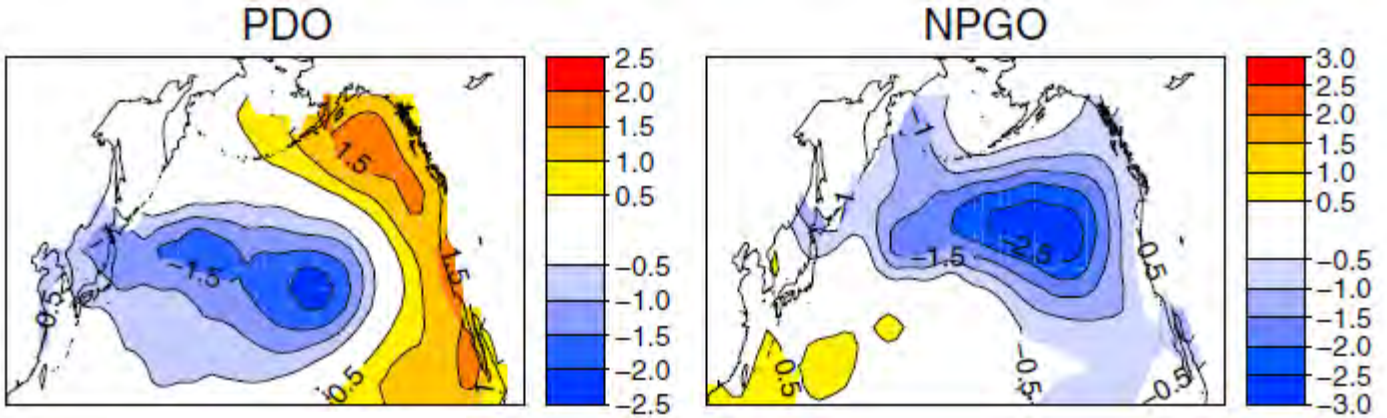
lag of maximum correlation (years)



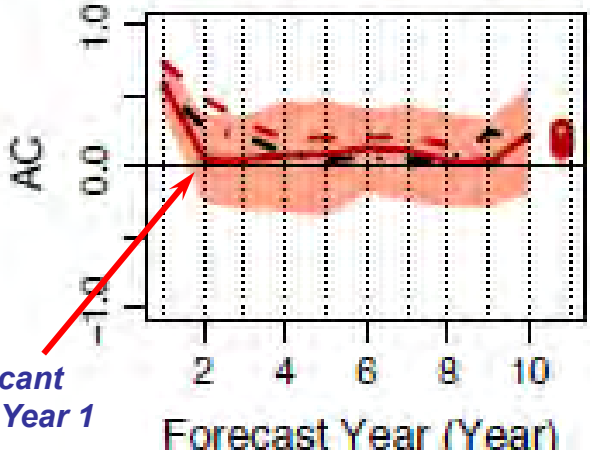
1958 El Nino?

Prediction of PDO and NPGO indices

- Lienert & Doblas-Reyes (JGR 2013) evaluated decadal predictions of PDO and NPGO indices
- PDO/NPGO defined as 1st and 2nd EOFS of detrended N Pacific SST

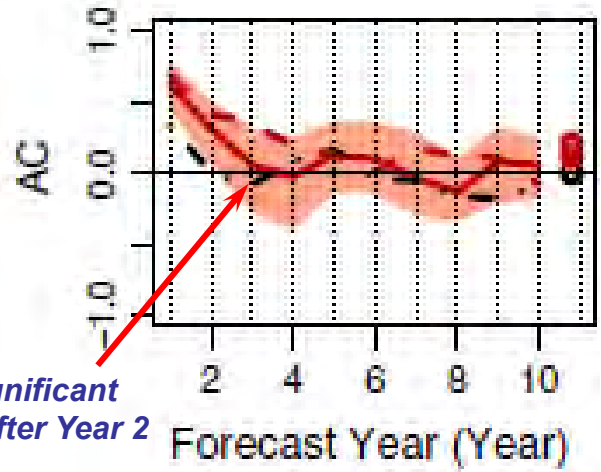


Skill in predicting detrended PDO



No significant skill after Year 1

Skill in predicting detrended PDO



No significant skill after Year 2

Conclusions

- Climate models are now being applied to near-term *prediction,* as well as long-term *projection*
- Seasonal prediction is relatively mature (can forecast ENSO and its impacts several seasons in advance), much to be done in developing ocean applications (currents, coastal upwelling,…)
- Decadal prediction is still in its infancy, ultimate potential still not well known
- Decadal predictions perform relatively poorly in the North Pacific, reasons being explored
- This does not stop scientists from making these predictions →

Real time multi-model decadal prediction (Smith et al. Clim Dyn 2012) issued early 2013