Environment Canada Environnement Canada

Canada

The Coupled Historical Forecast Project, version 1: Formulation, results, and progress towards CHFP2

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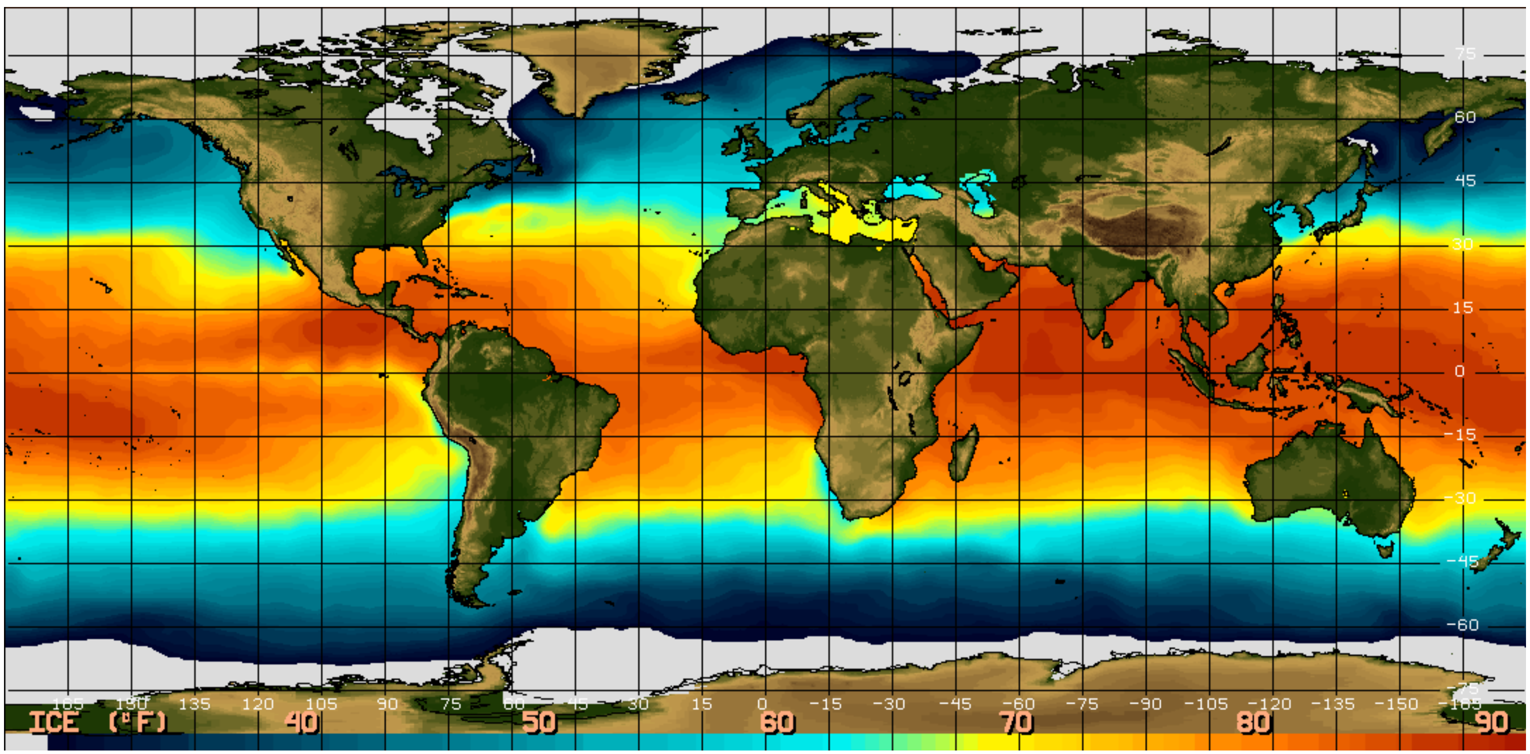
Canadian Foundation for Climate and Atmospheric Sciences (CFCAS)
Fondation canadienne pour les sciences du climat et de l'atmosphère (FCSCA)

GOAPP

Basis for Seasonal Forecasting

- Although *weather* not predictable beyond ~10 days, *climate statistics* contain predictable component due to forcing by slowly evolving boundary conditions:



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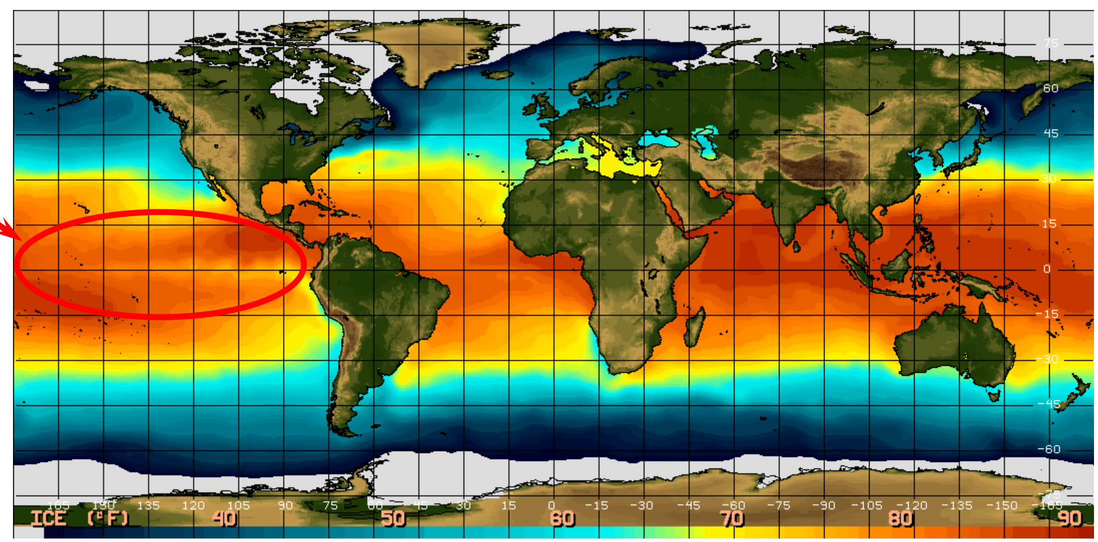
- SST



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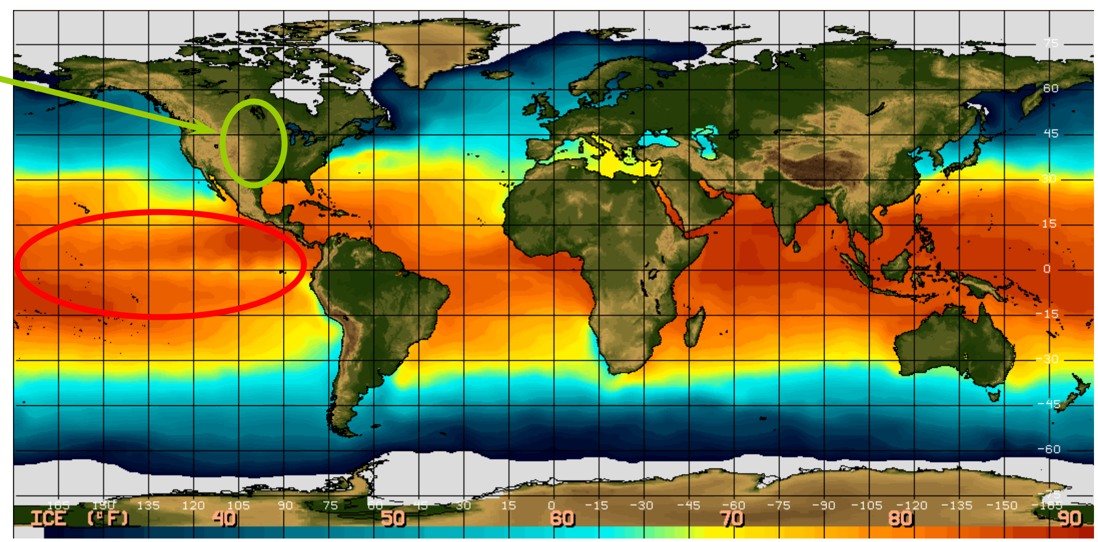
- Soil moisture



Basis for Seasonal Forecasting

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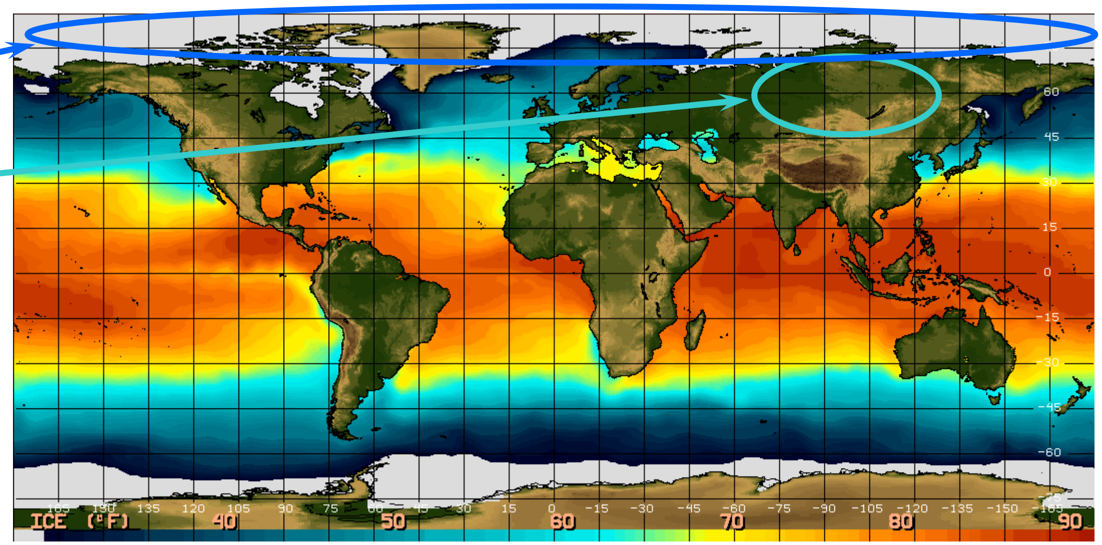
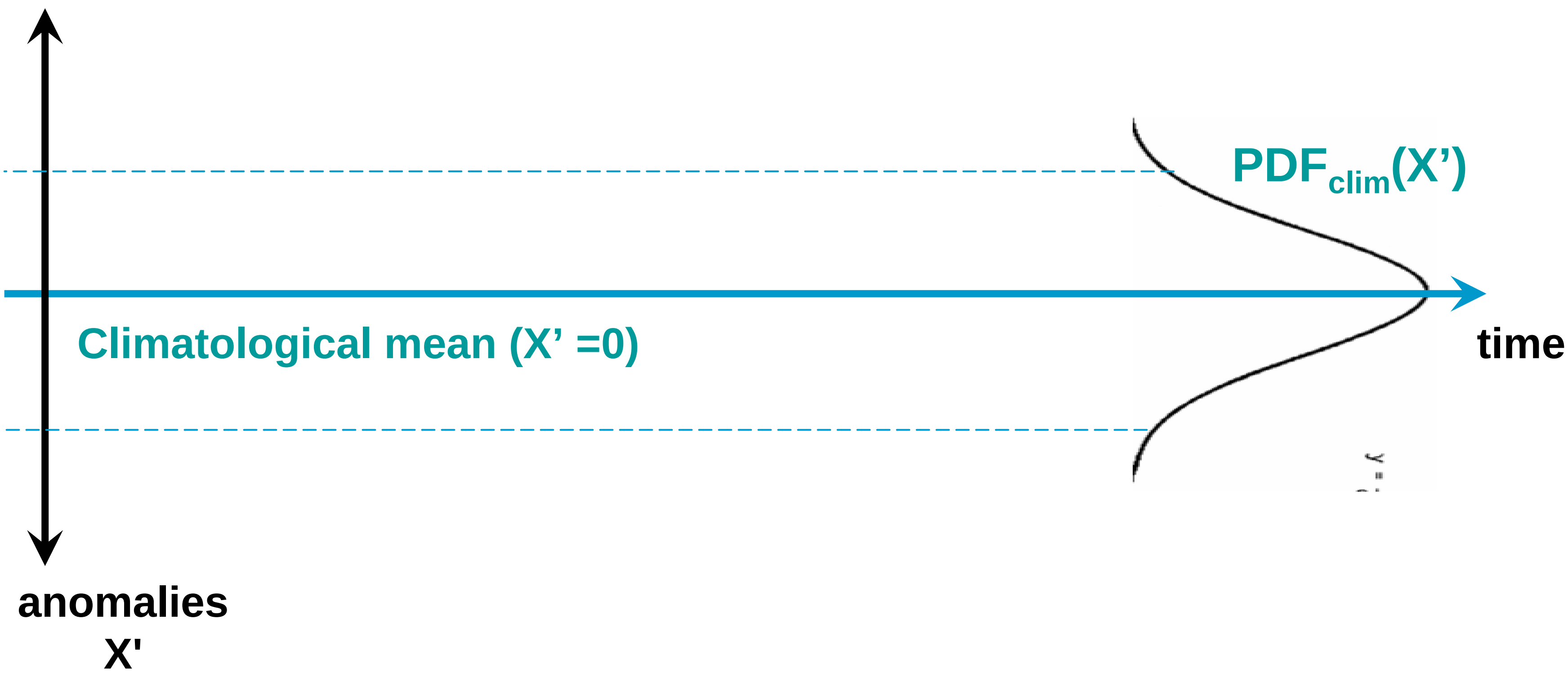
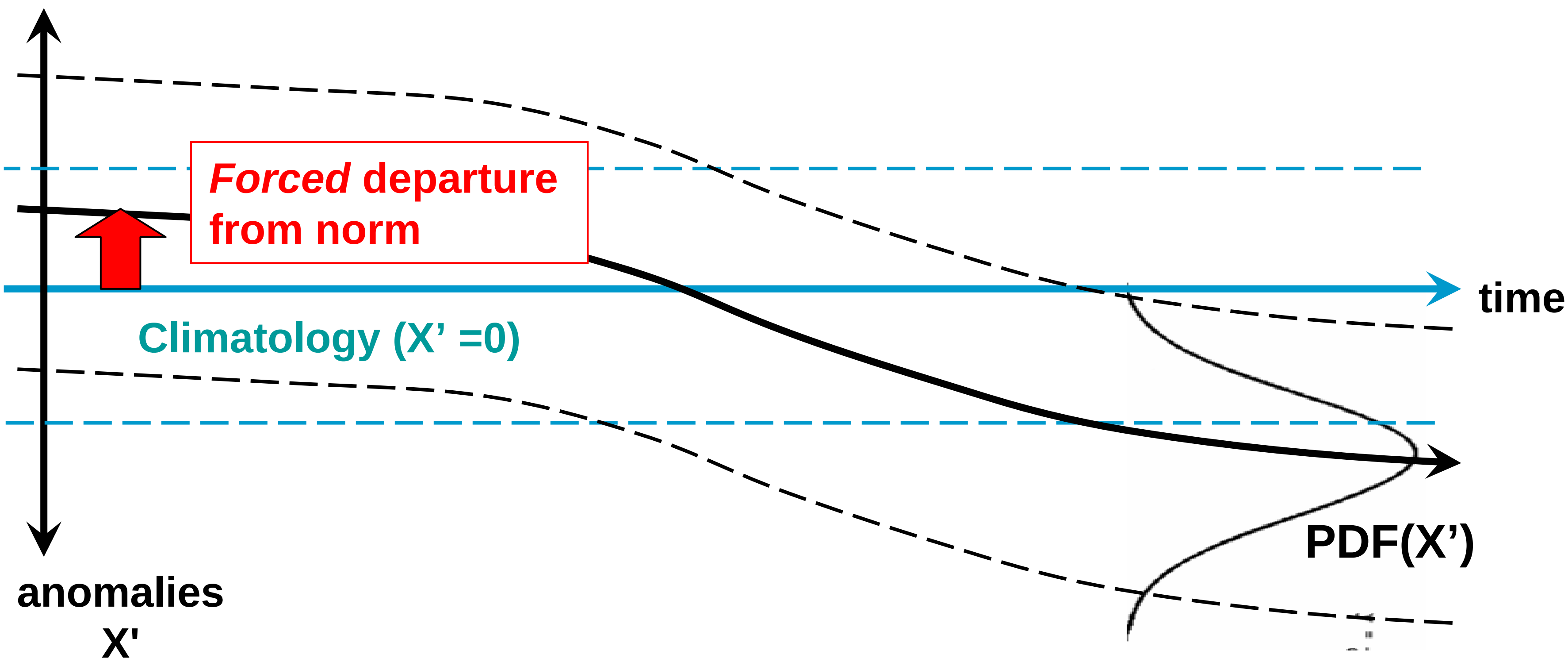
- SST
- Soil moisture
- Sea ice?
- Snow?



Climatological PDF

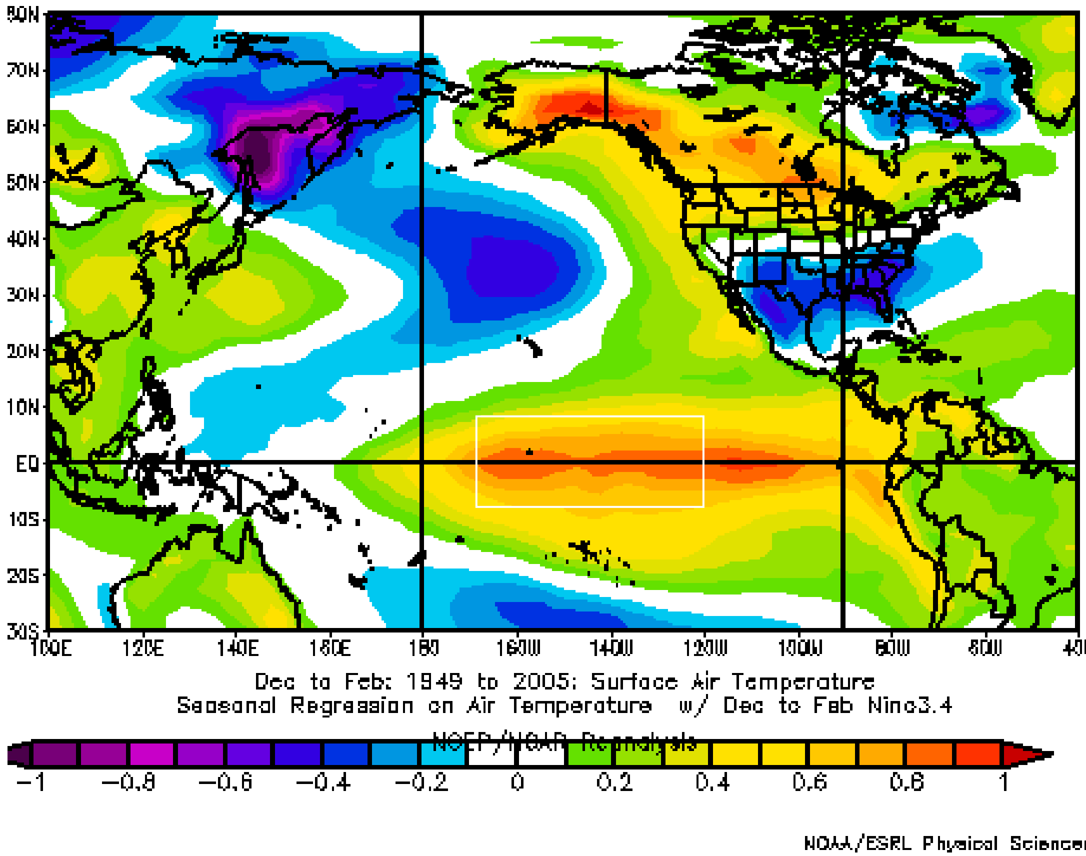


Evolving PDF under boundary forcing



ENSO effect on North American Climate

DJF Surface Temperature regression on NINO3.4



Ensemble forecasts a "must"

- Estimation of PDF $\rightarrow$ probabilistic forecasts

- Ensemble means more skillful than ensemble members

Why retrospective forecasts?

- Retrospective forecasts are crucial for
  - establishing forecast skill
  - providing forecast climatology for bias correction
  - guiding forecast calibration and post-processing
- Current EC operational system:
  - 4 AGCMs x 10-ensemble
  - validated by 2nd Historical Forecast Project (HFP2)
  - 4-month retrospective forecasts initialized each month 1969-2003
- Validate coupled forecasts by *CHFP*

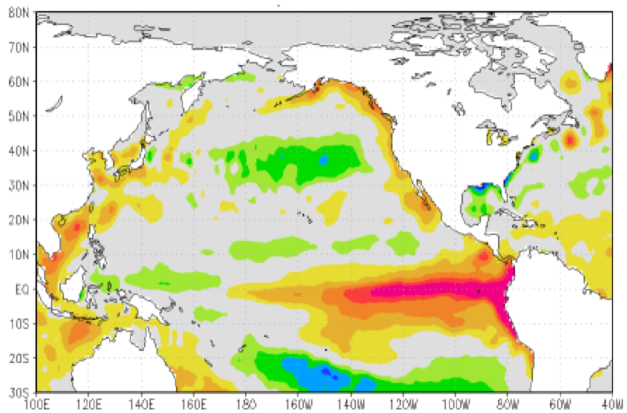
Motivation for *coupled* forecast model

2-tier forecast

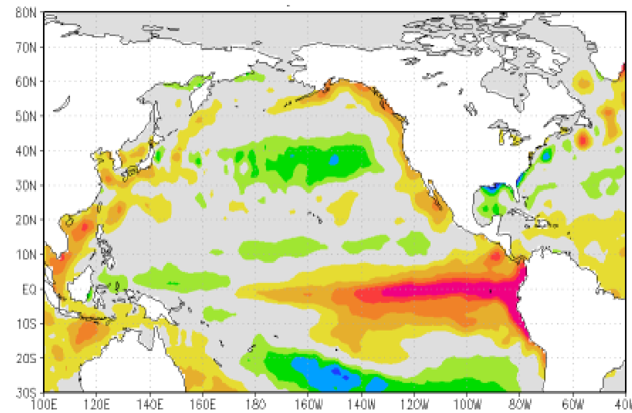
(AGCM + *specified* SSTA)

SSTA

Mar 1998

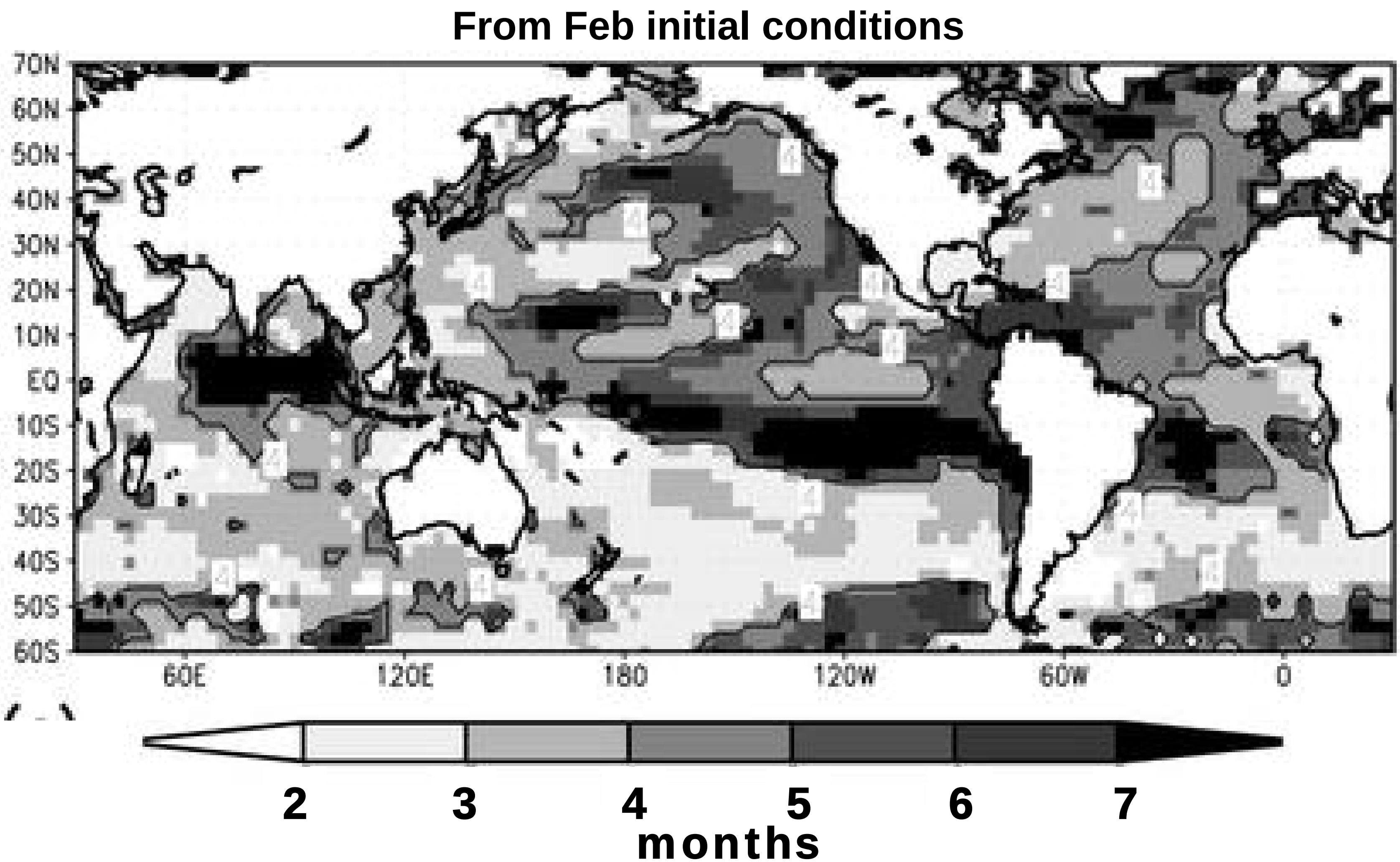


Sep 1998



Persistence of SSTA

Autocorrelation timescale of SST



Goddard and Mason (*Clim Dyn* 2002)

Motivation for *coupled* forecast model

Mar 1998

SSTA

Sep 1998

2-tier forecast

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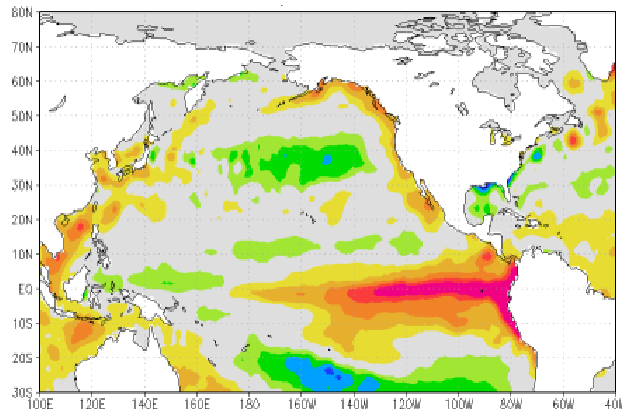
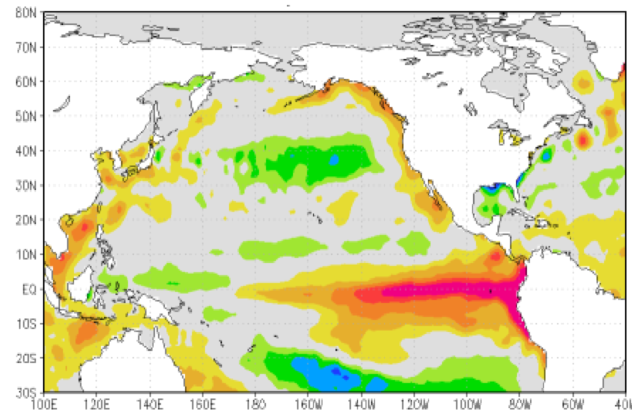
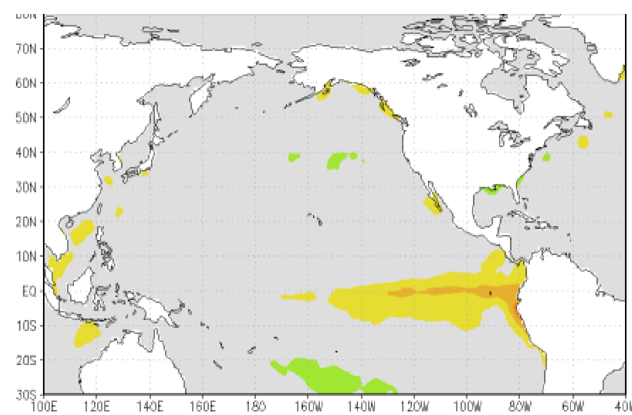




Persistent SSTA

(alternatively)



Damped persistence

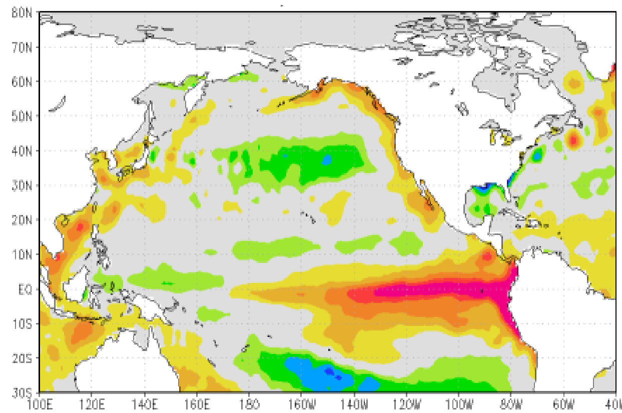
Motivation for *coupled* forecast model

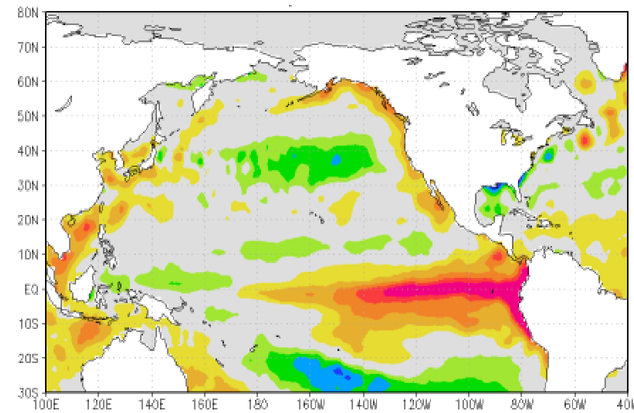
SSTA

Mar 1998 **Sep 1998**

2-tier forecast

(AGCM + *specified* SSTA)

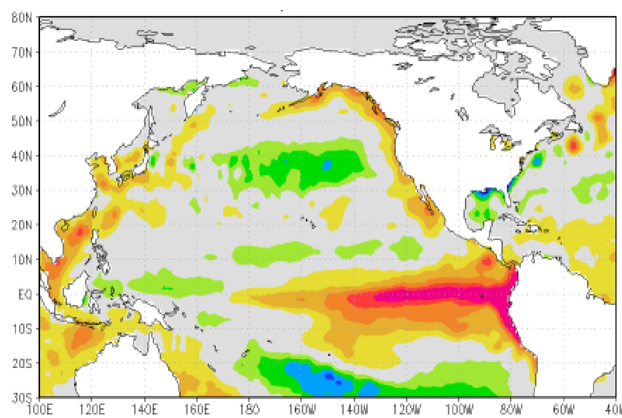


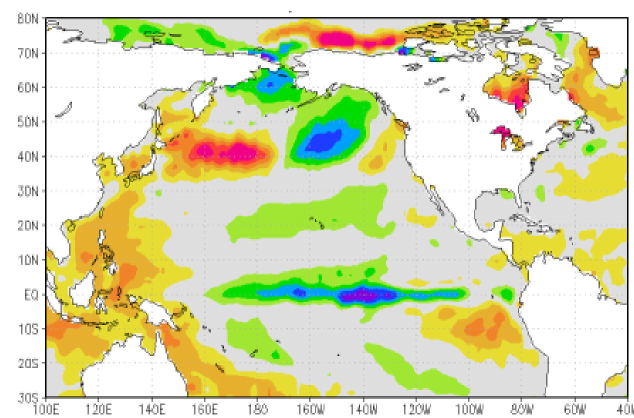


Persistent SSTA

1-tier forecast

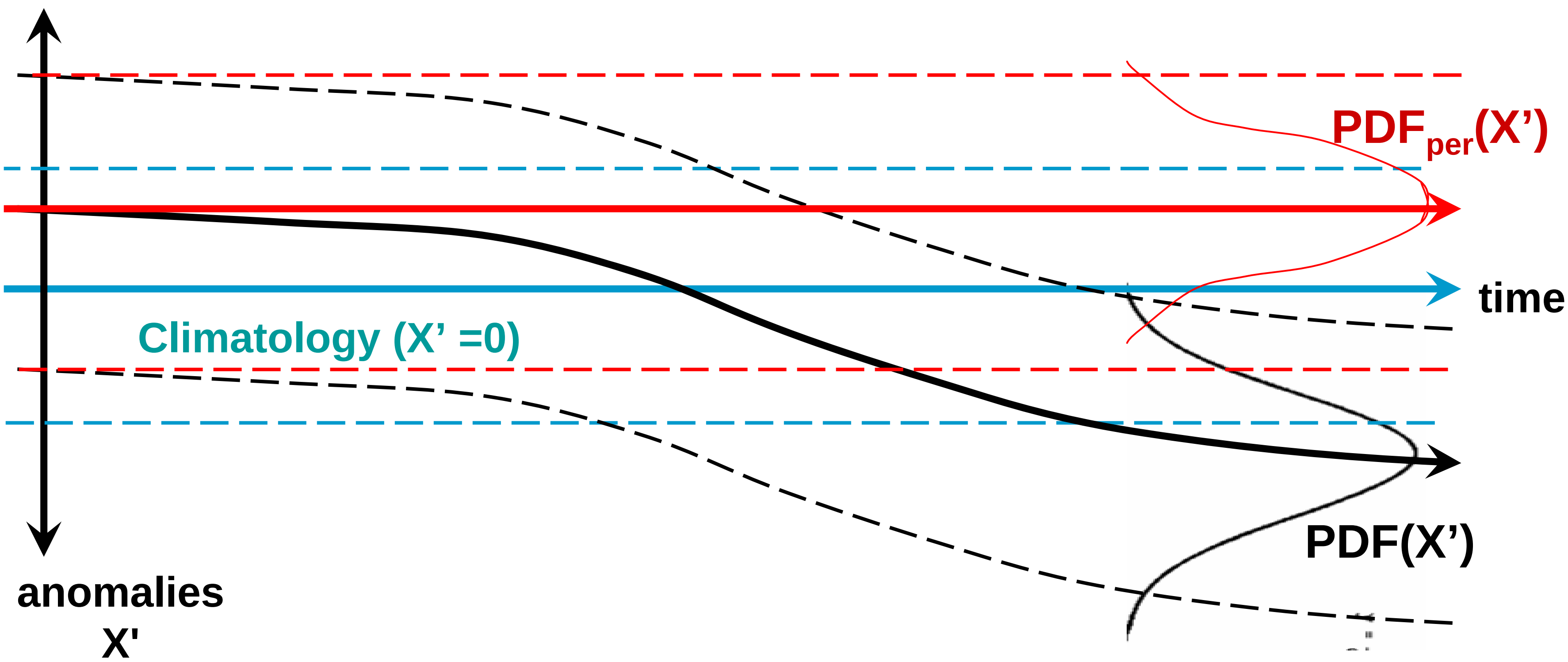
(CGCM)





Prognostic SSTA

PDF under persistent forcing

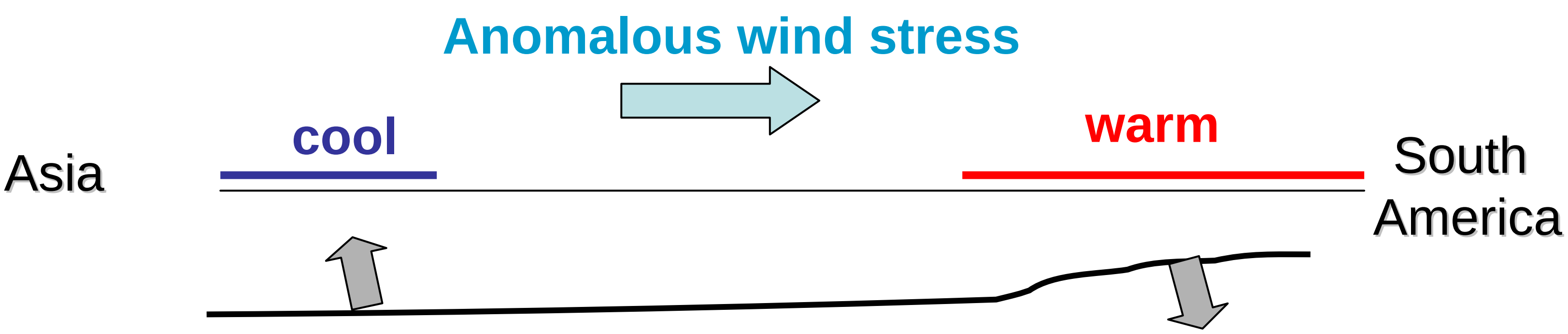


Pilot Project: CHFP1

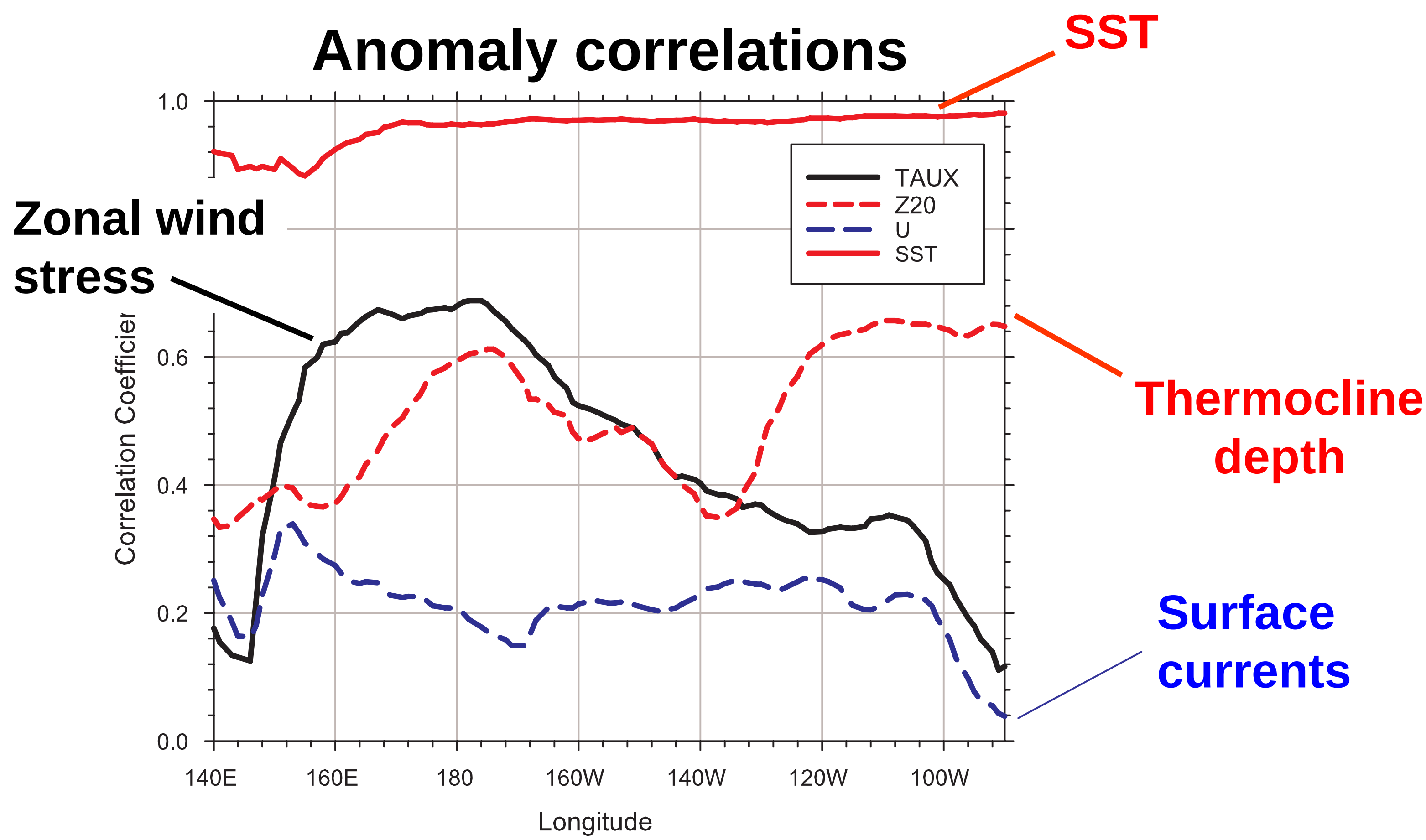
- Based on CGCM3.1/T63 (IPCC AR4)
- Simple SST nudging initialization after Keenlyside et al. (*Tellus* 2005):

  - Strongly relax SST to observed 1970-2001 time series

  - Anomalous wind stress tends to set up correct equatorial thermocline configuration:



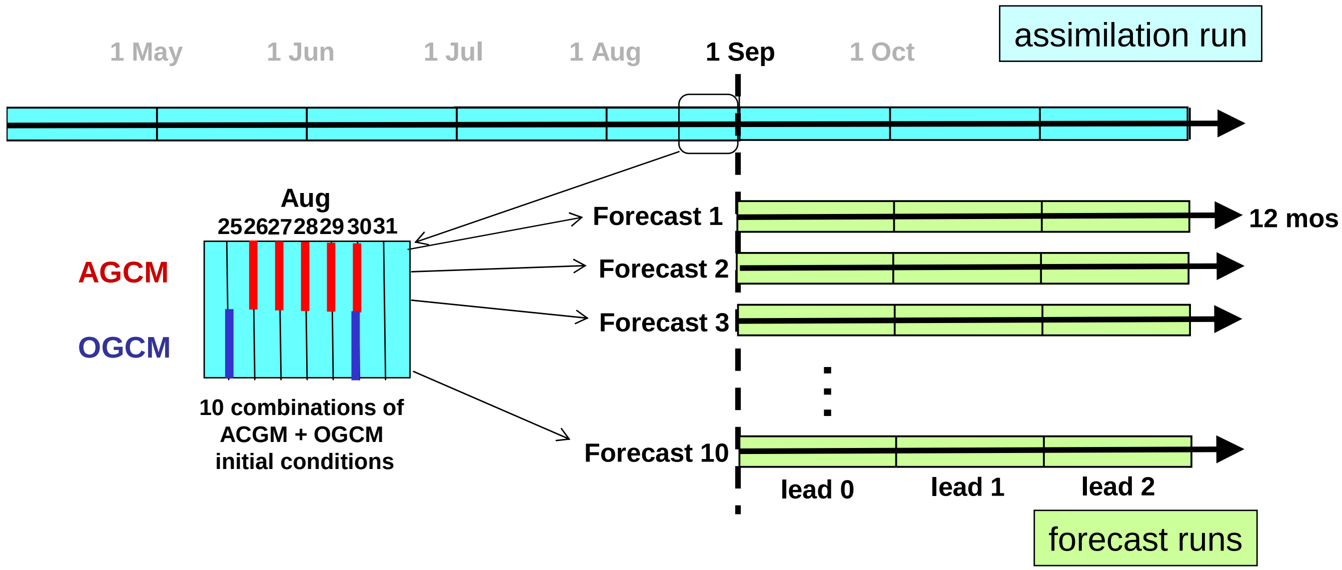
Skill of initialization procedure in equatorial Pacific



→ **Method shows modest skill initializing winds & subsurface ocean**

CHFP1 Ensemble Generation

- Construct 10 initial conditions for 1 Sep (e.g.) by combining atm and ocn states from preceding week:

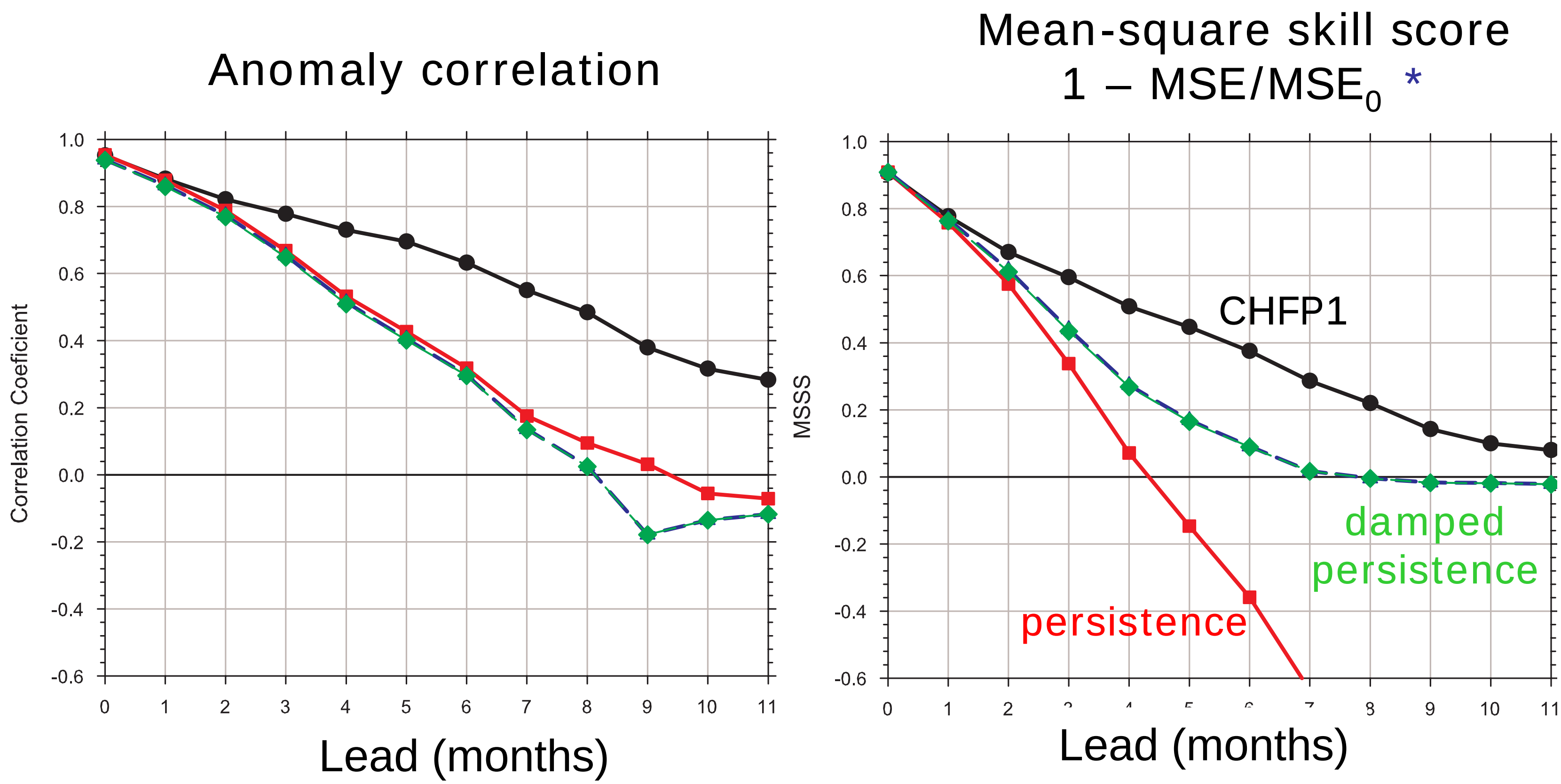


- Launch forecasts 1 Feb, 1June, 1 Sep, 1 Dec 1971-2000
- (10 ensemble members) x (4 initializations yr^{-1}) x 30 yrs

  → *1200 years of coupled model integration*

Forecast results: *Nino3.4 skill scores*

All seasons



* MSE = mean square error of forecast

MSE_0 = mean square error of reference forecast (=climatology)

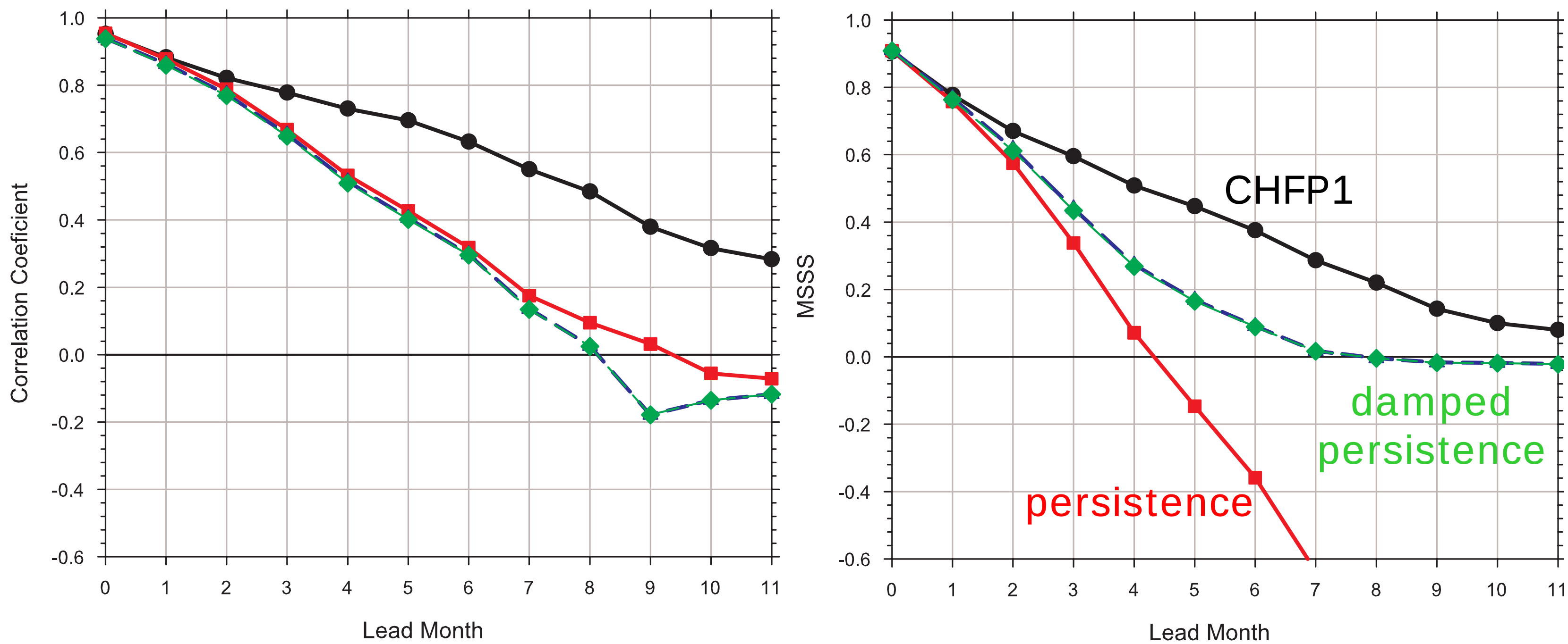
Forecast results: *Nino3.4 skill scores*

<0 if less skillful than climatological 'forecast'

All seasons

Anomaly correlation

Mean-square skill score $1 - MSE/MSE_0$ *



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Forecast results: ST over Canada

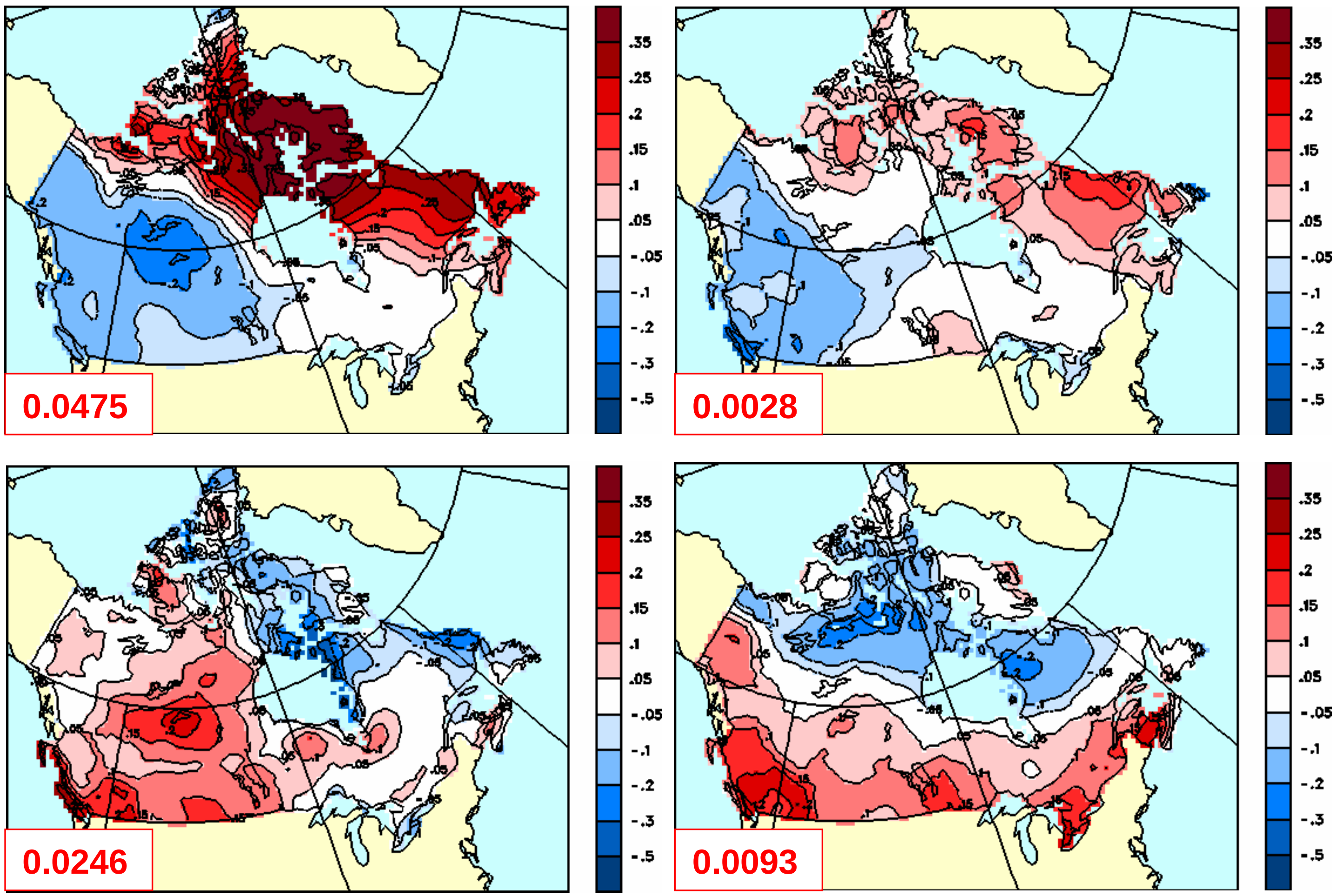
Seasonal forecasts, 1 month lead 1972-2001

Lead 1

CHFP1 **MSSS** **HFP2** **MSSS**

OND forecast

JFM forecast



Forecast results: ST over Canada

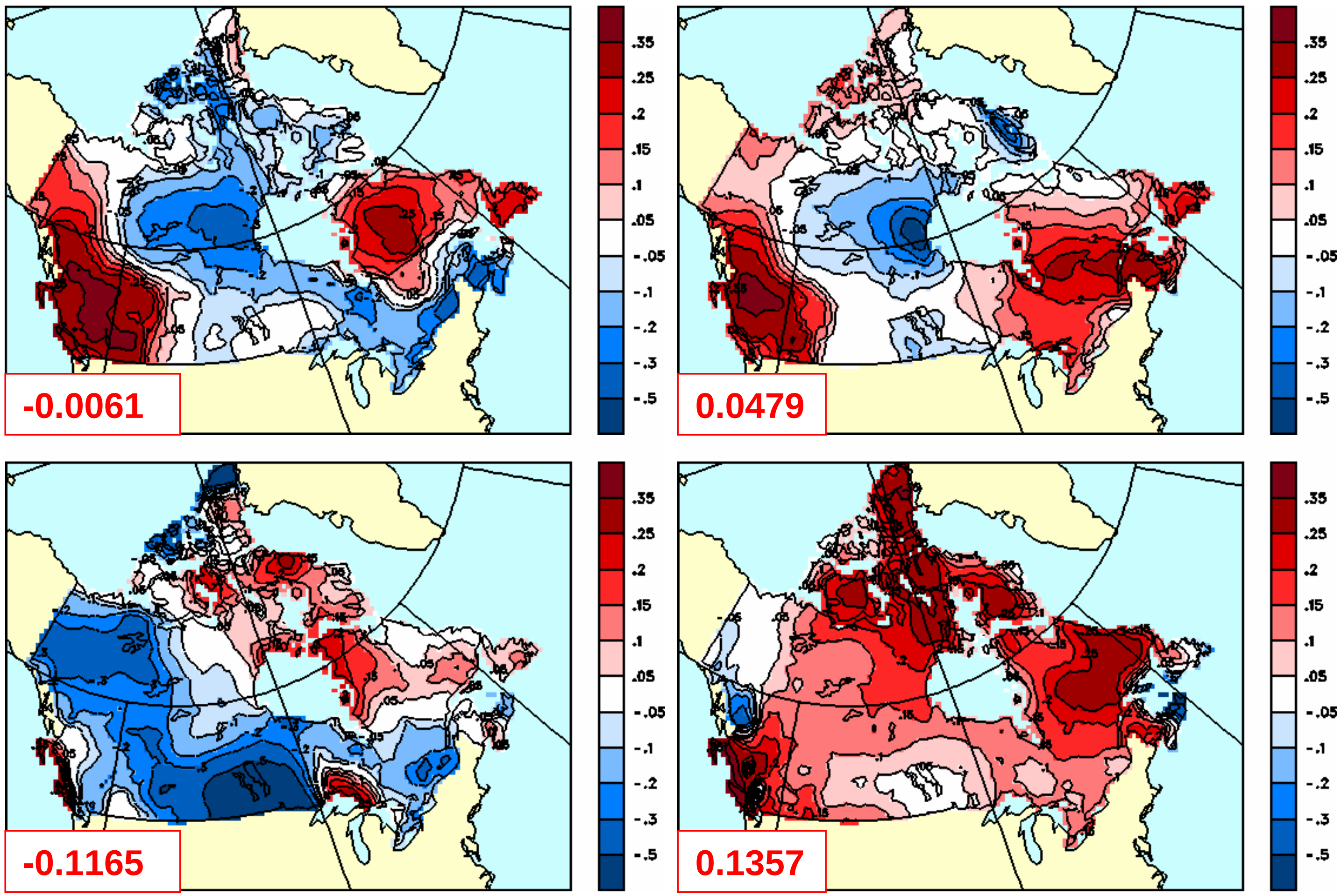
Seasonal forecasts, 1 month lead 1972-2001

Lead 1

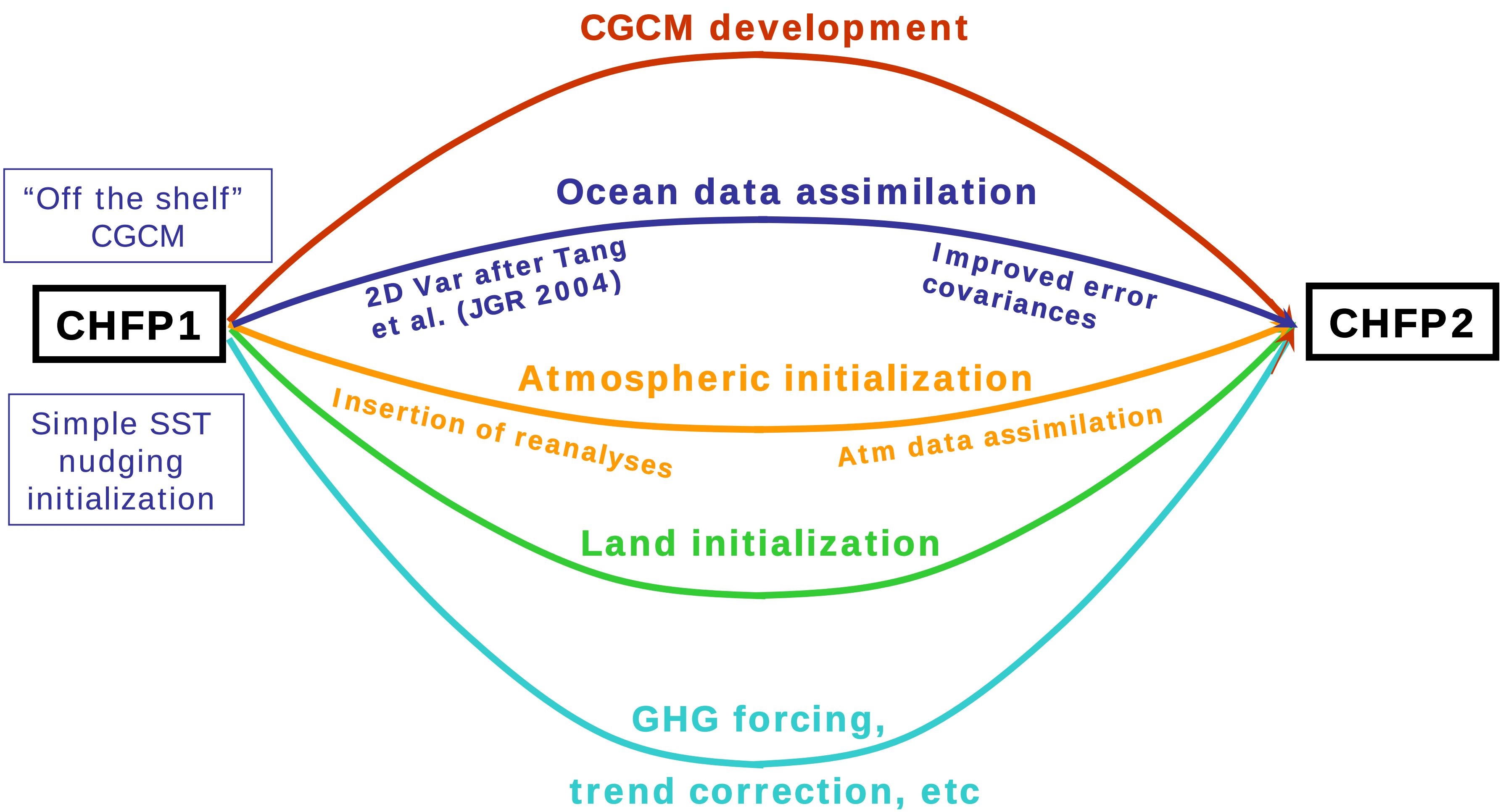
CHFP1 | **HFP2**

AMJ forecast

JAS forecast



Coupled Forecast System Development Path



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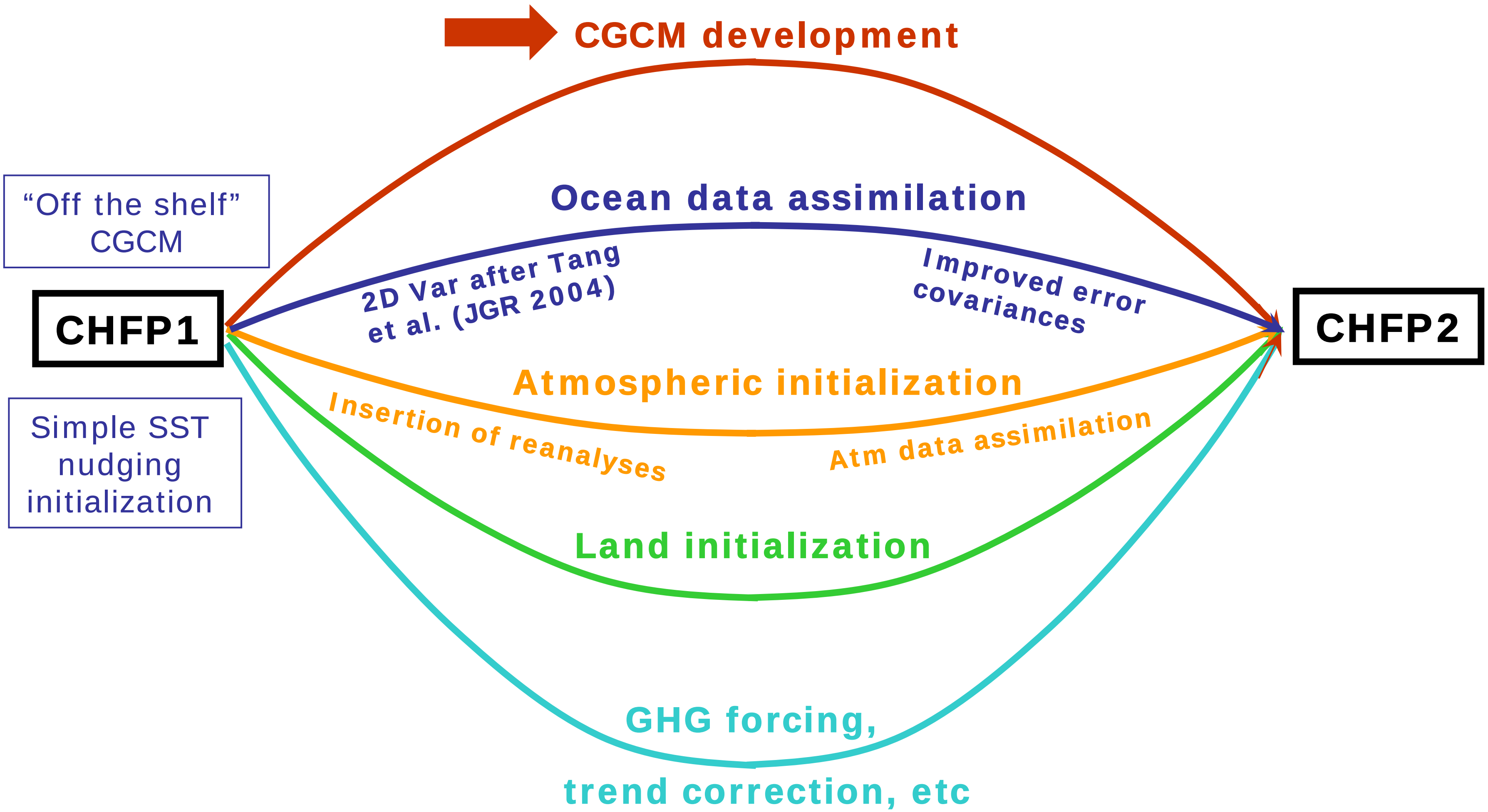
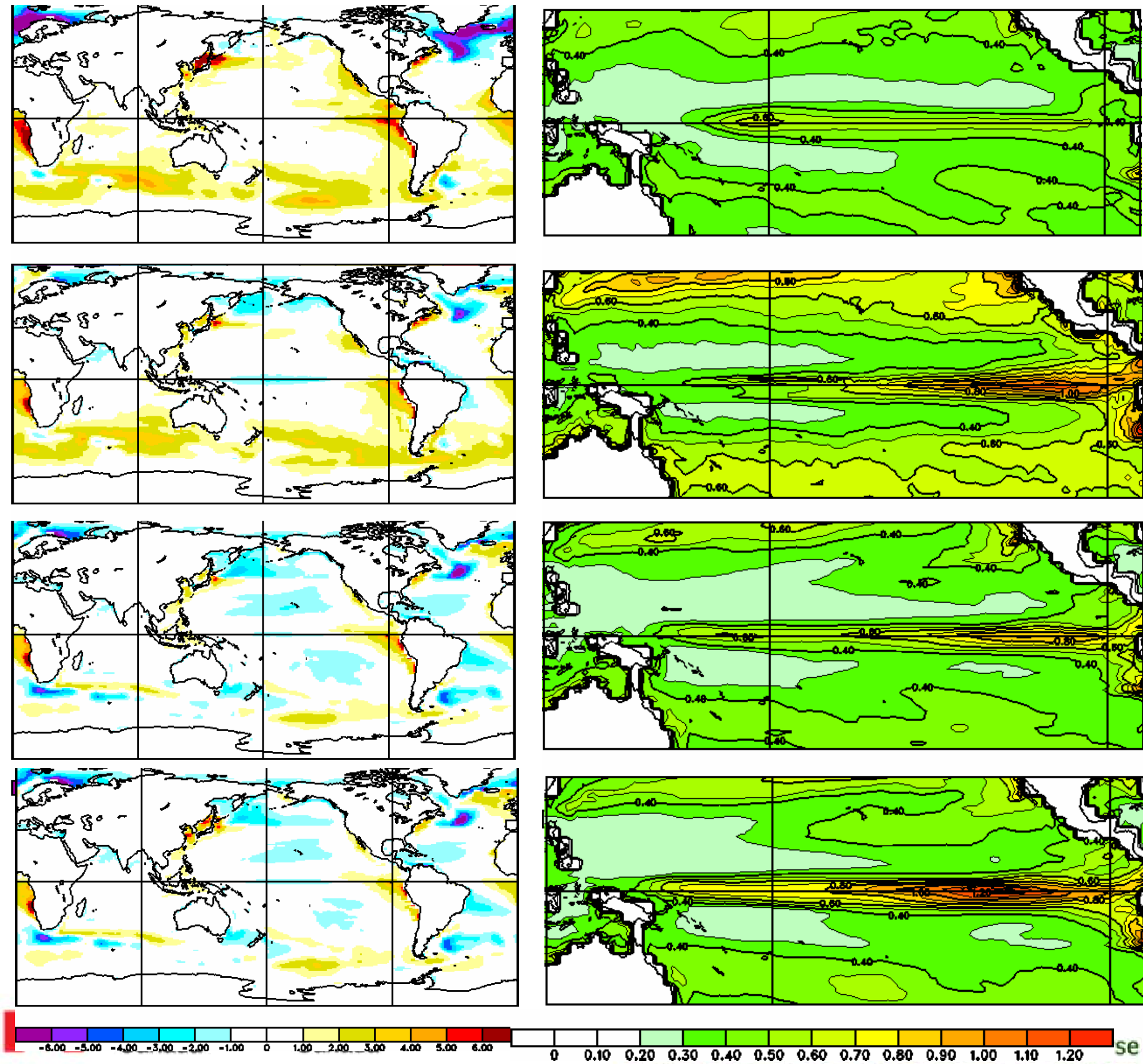


CGCM Development

SST Bias

SST standard deviation



CGCM3.1

IPCC/CHFP1

CGCM3.6

15m OGCM vertical res
KPP mixed layer
Anisotropic visc

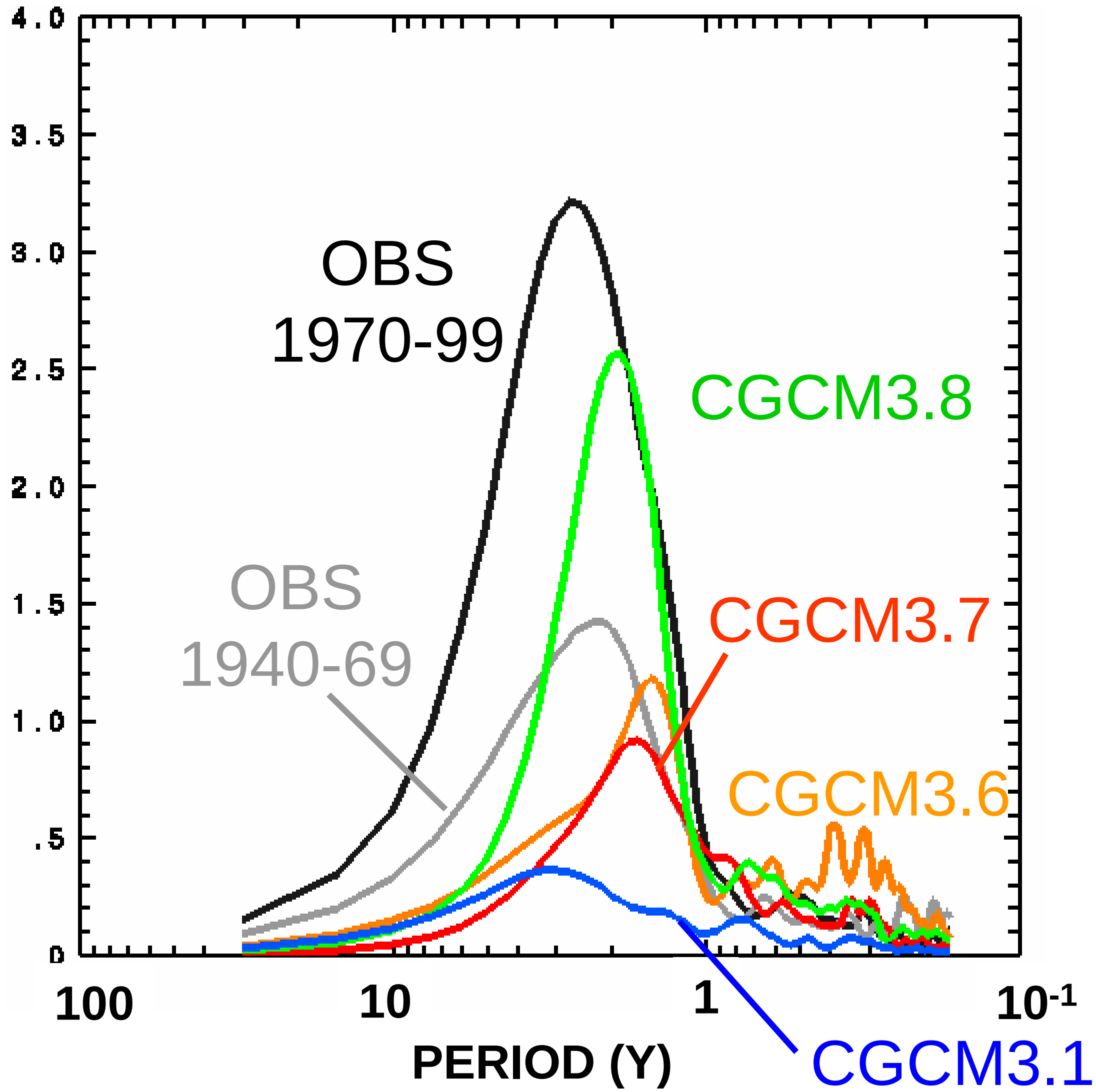
CGCM3.7

Penetrative solar radiation
AGCM physics filter

CGCM3.8

10m OGCM vertical res

NINO3 Power Spectrum



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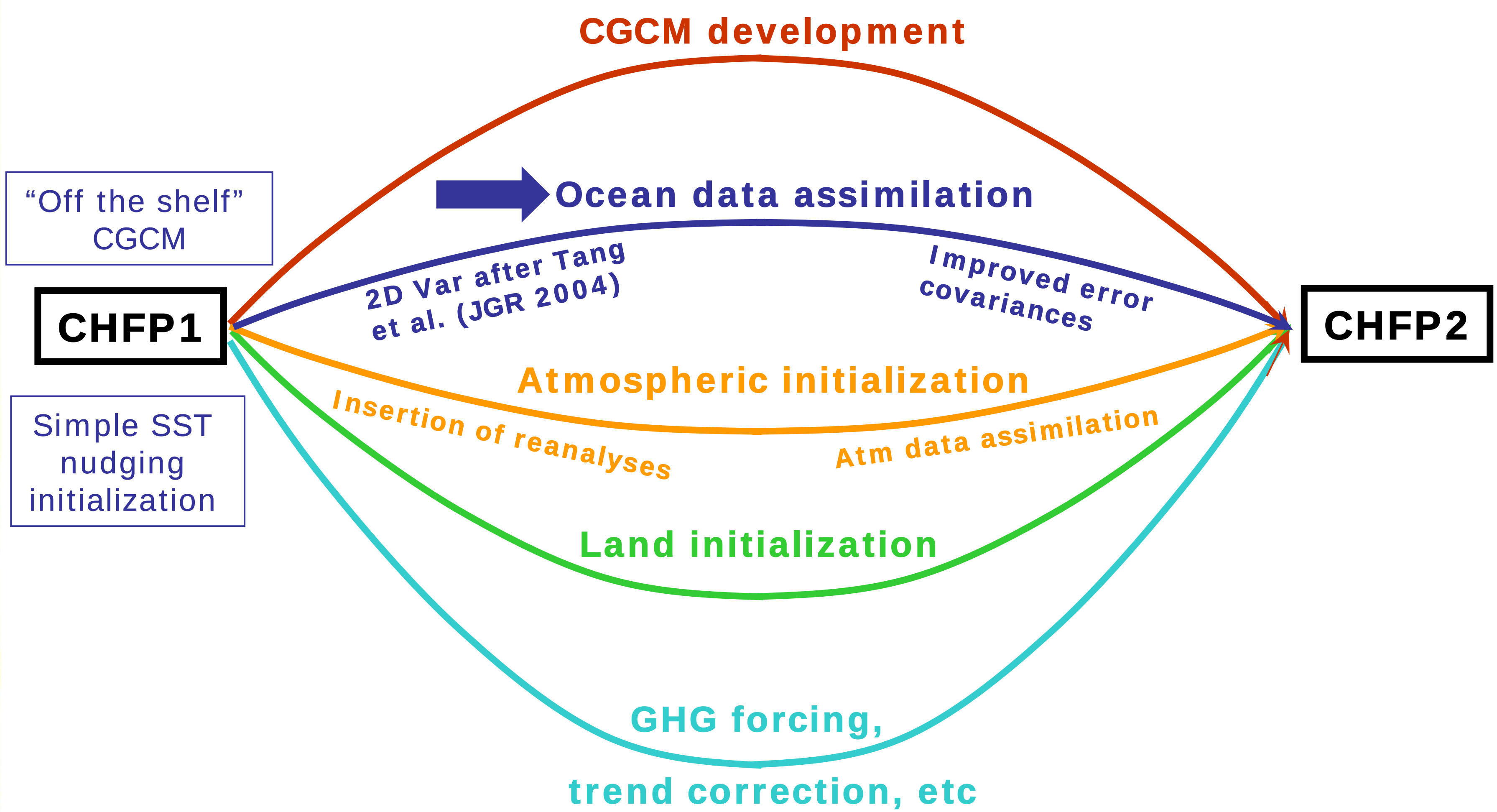
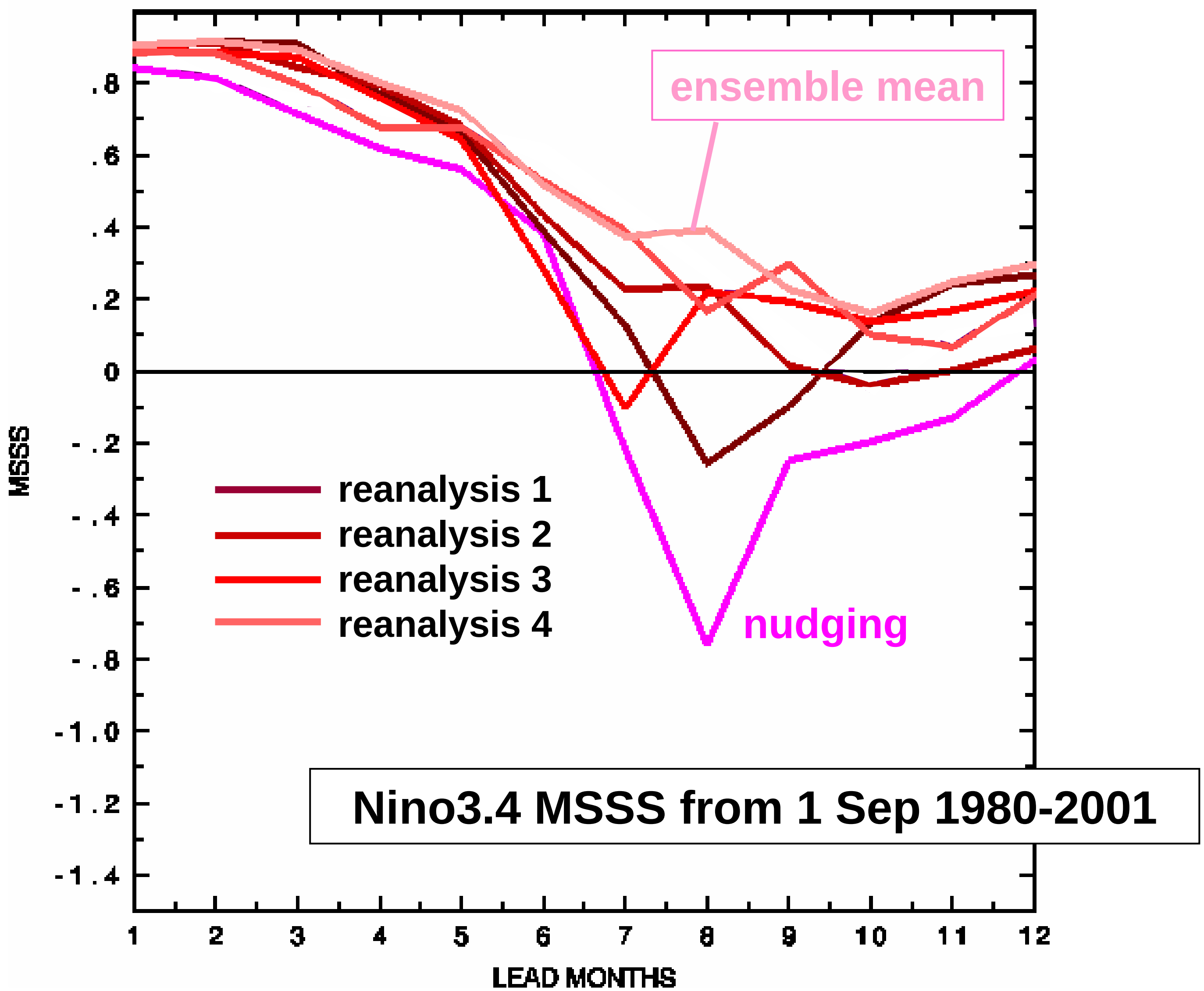


Ocean Data Assimilation

- Initially use approach of Tang et al. (JGR 2004):
  - input ocean *reanalysis* in lieu of observations
  - simple variational assimilation level-by-level (2D Var)
  - background error covariances of Derber & Rosati (*JPO*, 1989)
- Assimilate multiple ocean analyses
- Explore methods to improve error covariances

Initial Data Assimilative Forecasts with CGCM3.6



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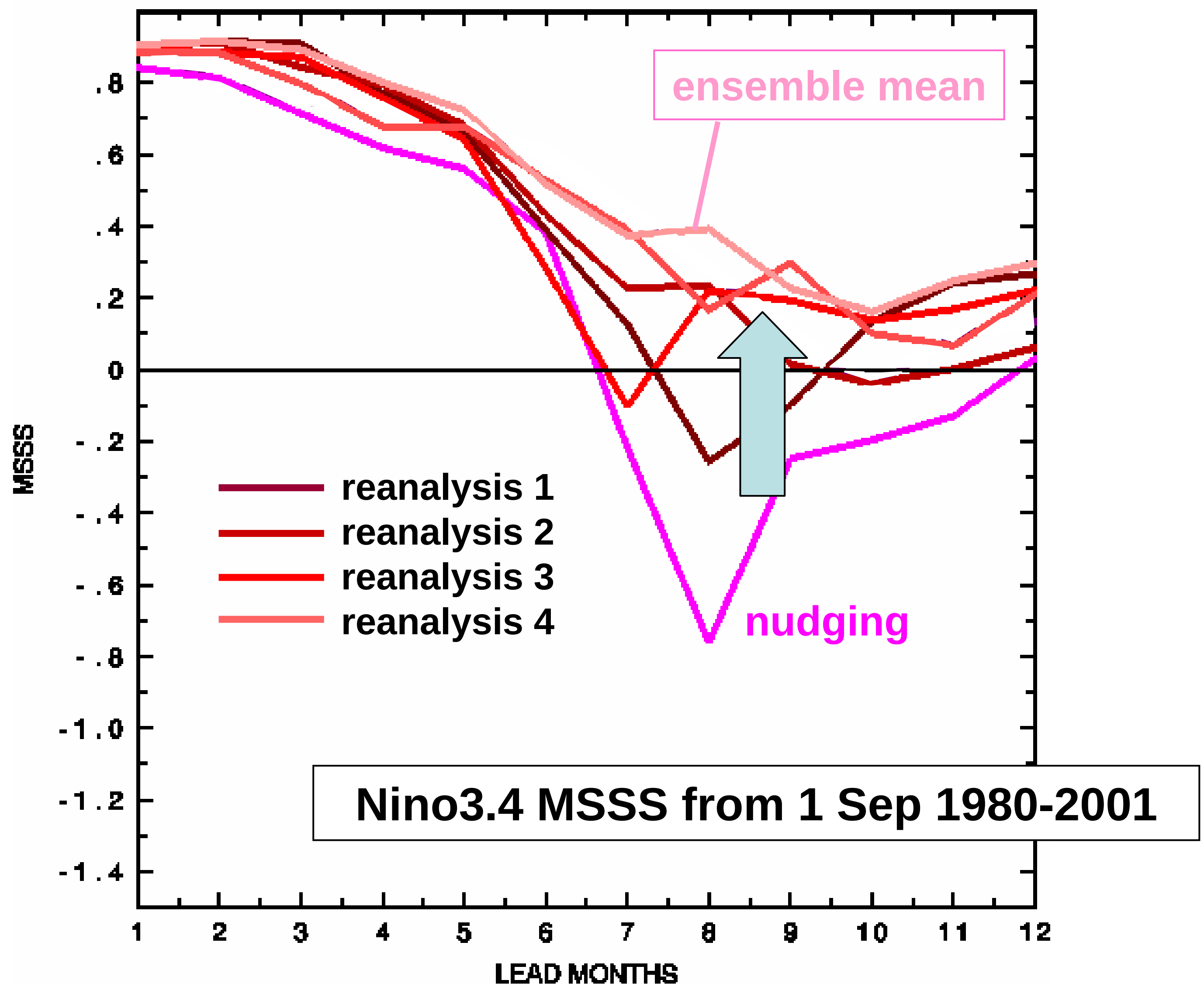
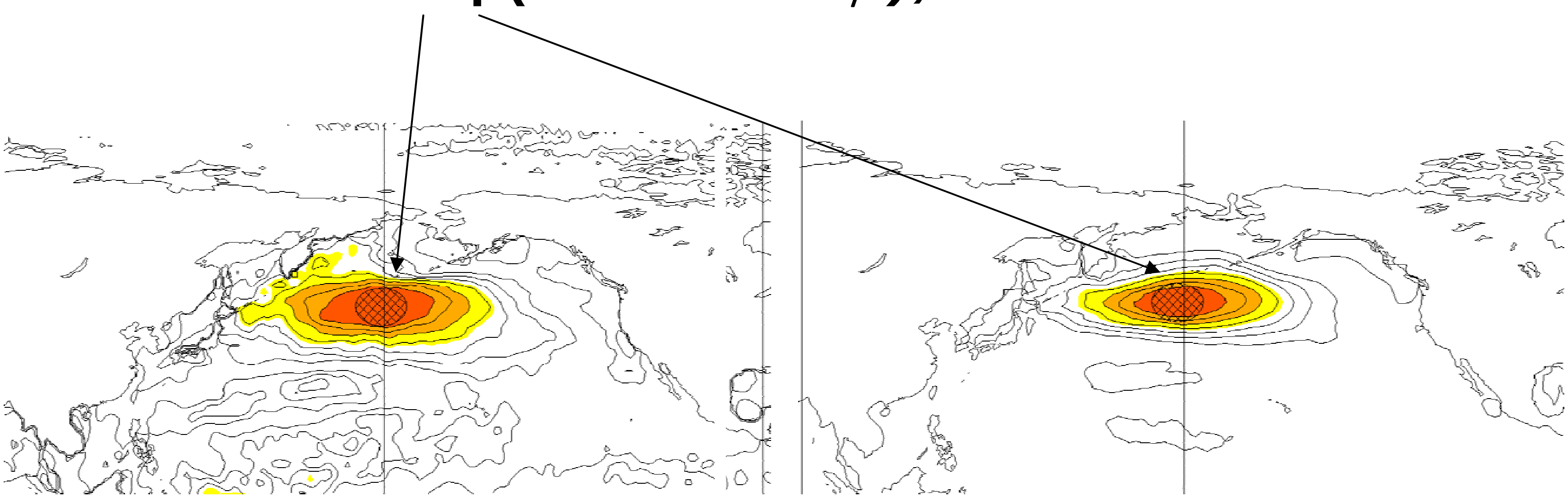


Improving background error covariances

- Good estimates of error covariances are critical to fidelity of assimilation scheme

- Tang et al. used simple Derber & Rosati parameterization:

$$\mathbf{Cov} \propto \exp(-r^2 \,/\, b^2 \cos\phi), \qquad b = 570\ \text{km}$$



Obs **Model**

Next step: improve background error covariances

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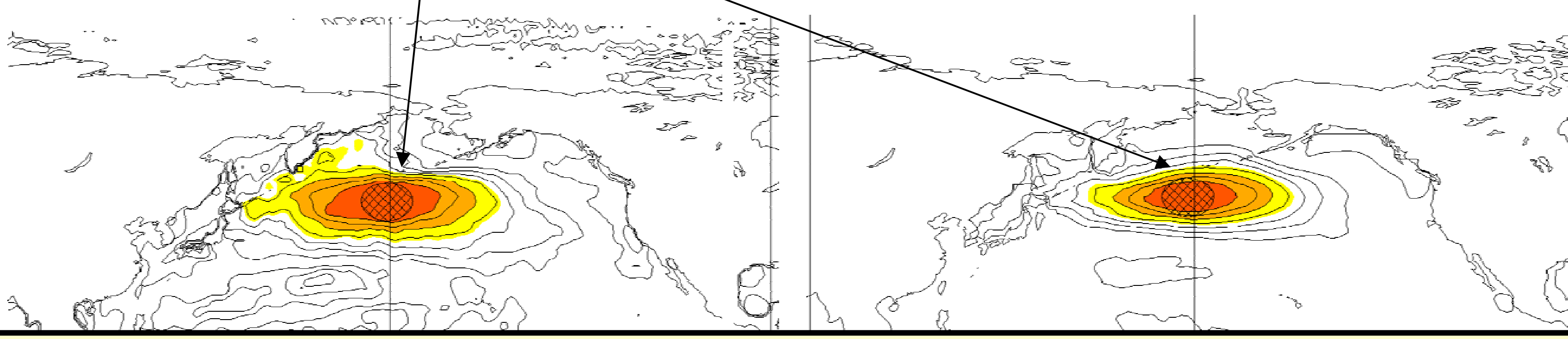
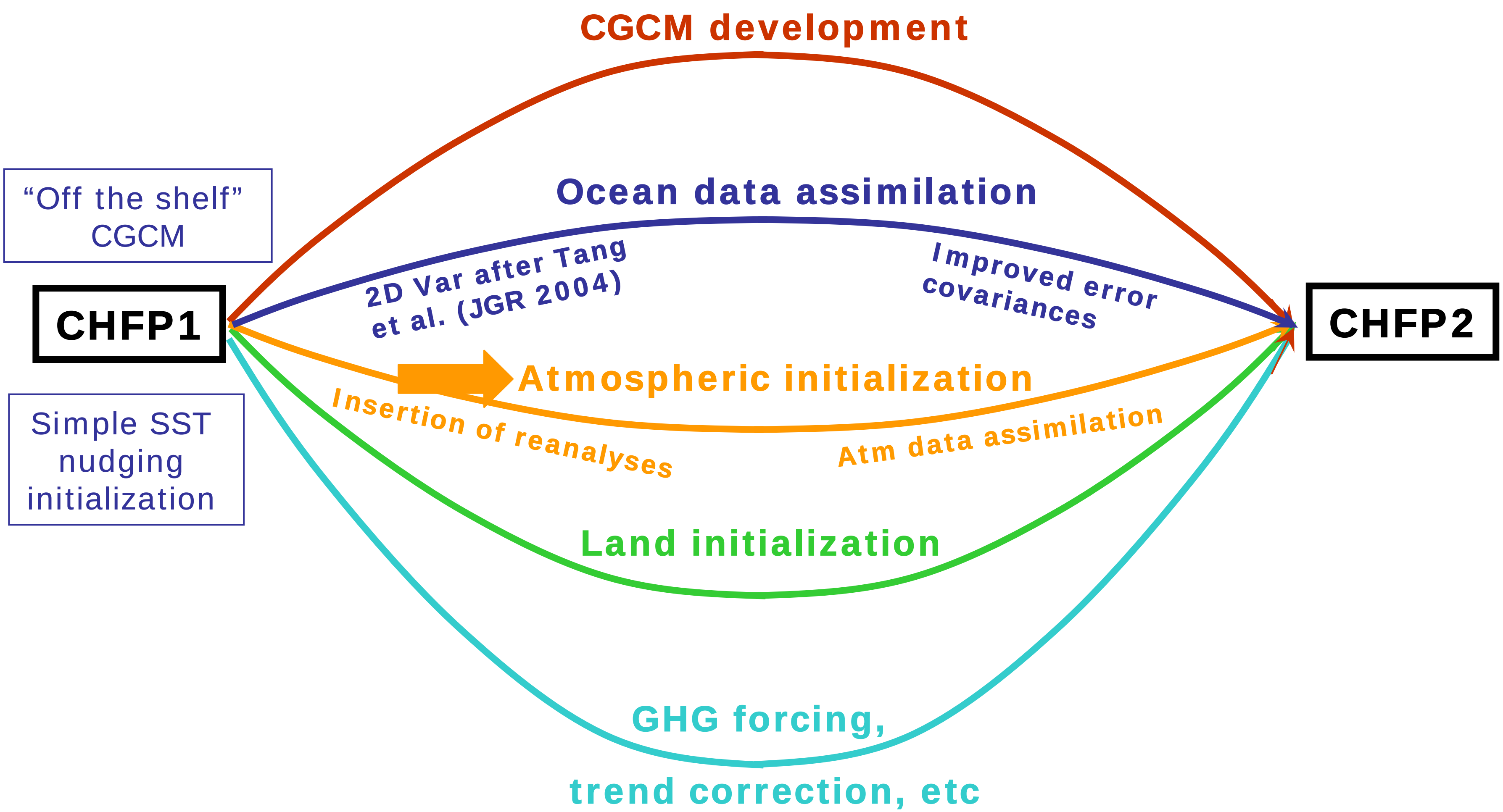


***New approach*: fit to model covariance structure at each (x,y,z) (e.g. Smith & Murphy JGR 2007, Fu et al. Adv Atm Sci 2004)**

Coupled Forecast System Development Path



Atmospheric Initialization

- SST nudging informs AGCM of boundary forcing, but not correct synoptic configuration, i.e. weather

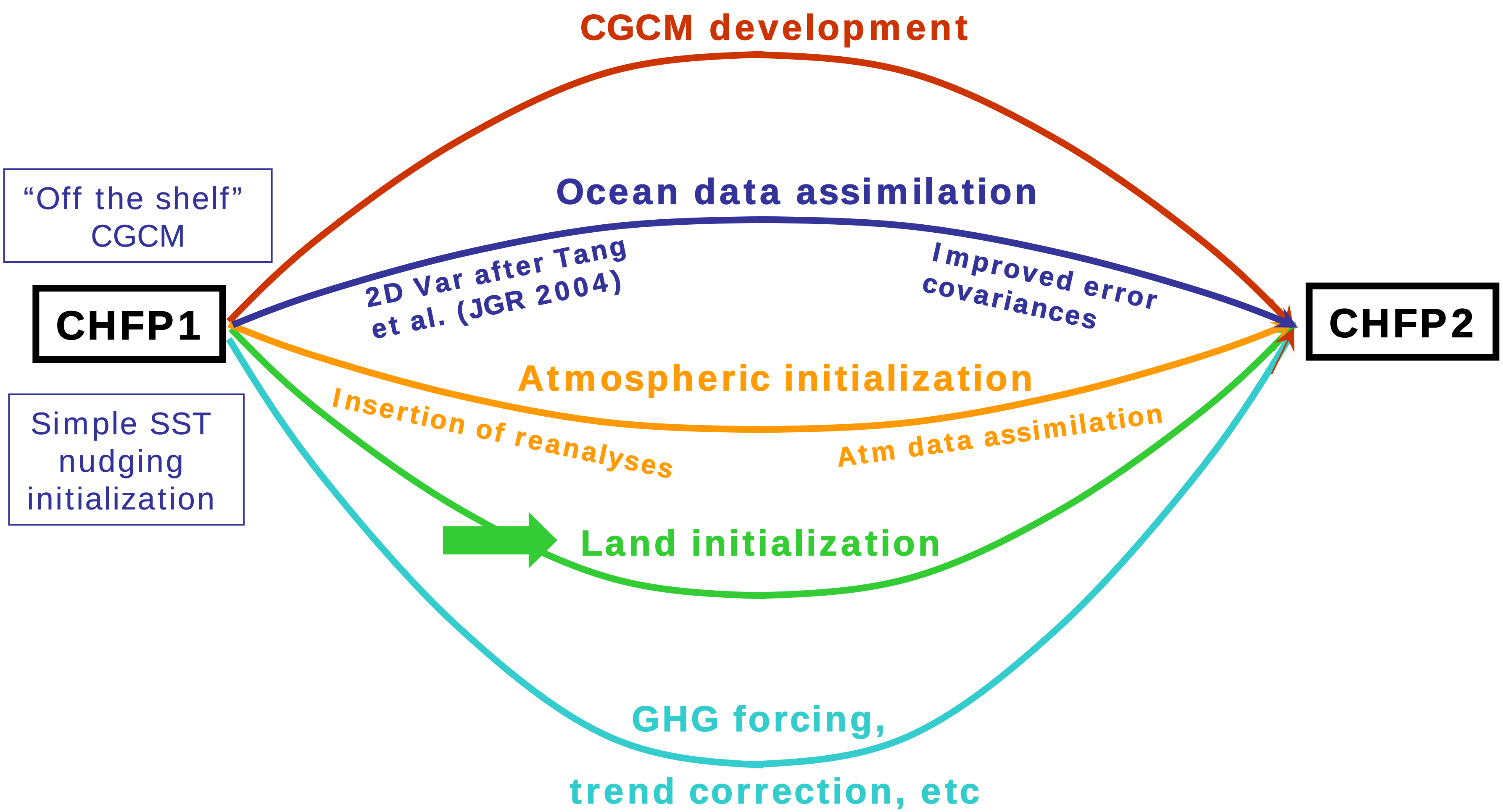
  $\rightarrow$ *major loss of skill in first month of forecast*

- Two approaches are being pursued:

  - Direct insertion of atmospheric analysis (cf. HFP2)

  - Simple assimilation of analysis into AGCM

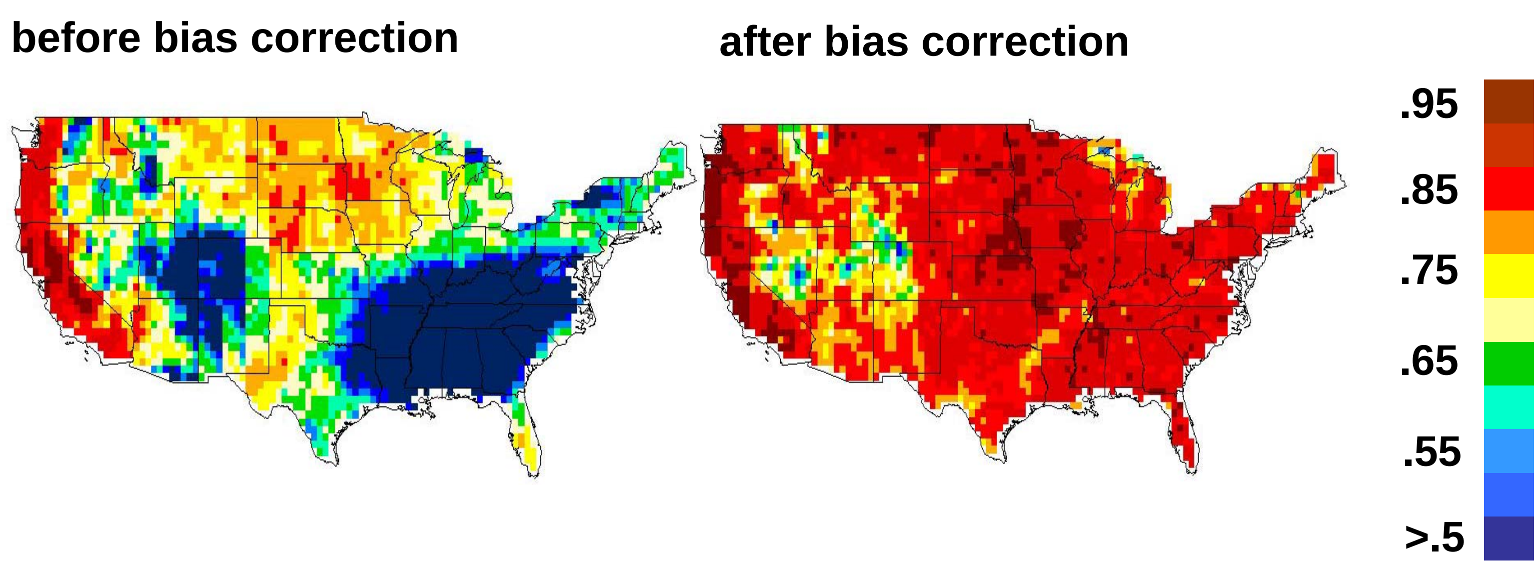
Coupled Forecast System Development Path



Land Initialization

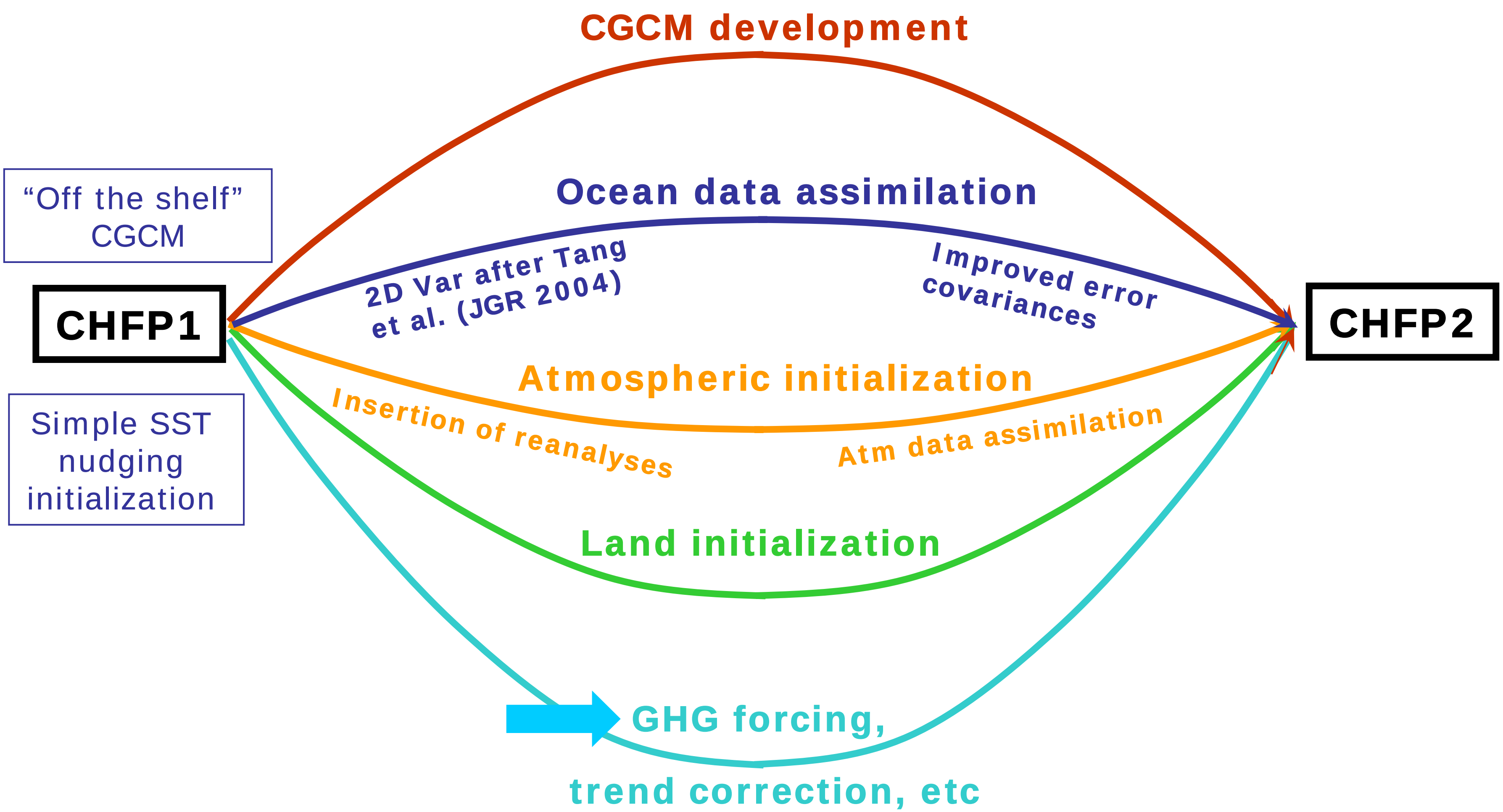
- CFCAS/GOAPP funded collaboration with A. Berg (Guelph)
- Force land surface model with *bias-corrected* reanalyses after Berg et al. (Int J Clim 2005)

Correlation of NCEP monthly precip with gauge-based measurements in USA:



Berg et al., 2003: 2005

Coupled Forecast System Development Path



Summary

- Coupled forecasts offer means for seasonal forecasting at longer leads, where future evolution of SSTA is critical
- Prototype CHFP1 competitive with 4-model HFP2 at 1-month lead, but has only simplest initialization
- CHFP1 provides a benchmark against which model and initialization improvements leading to CHFP2 can be assessed
- CCCma participation in international CHFP through CLIVAR/WGSIP