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Environnement  
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# Theme II Overview

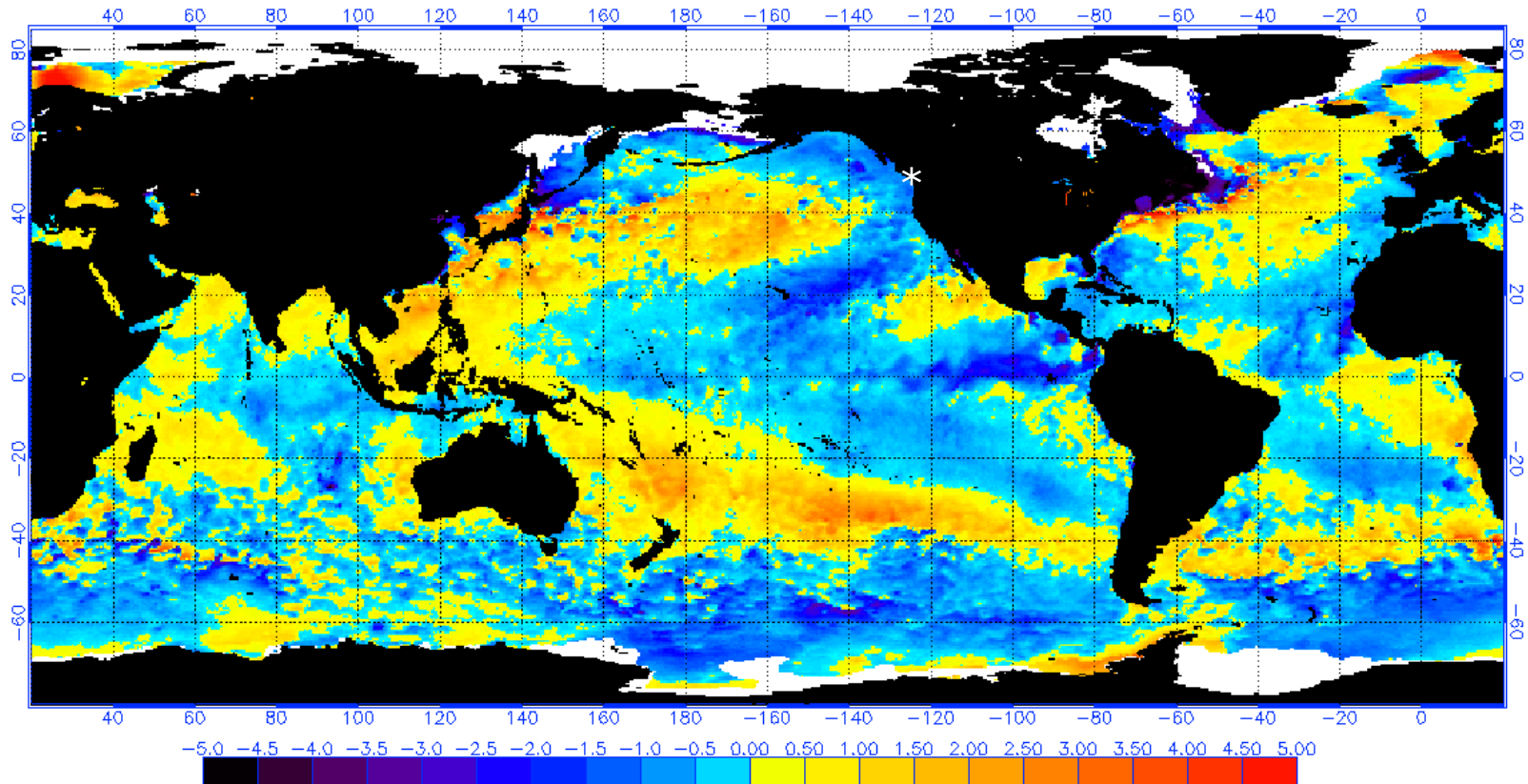
**Bill Merryfield**

**Canadian Centre for Climate Modelling and Analysis  
Environment Canada**

GOAPP Science Day 2009 March 12 Victoria

# Welcome to Victoria

NOAA/NESDIS 50 KM GLOBAL ANALYSIS: SST Anomaly (degrees C), 3/9/2009  
(white regions indicate sea-ice)



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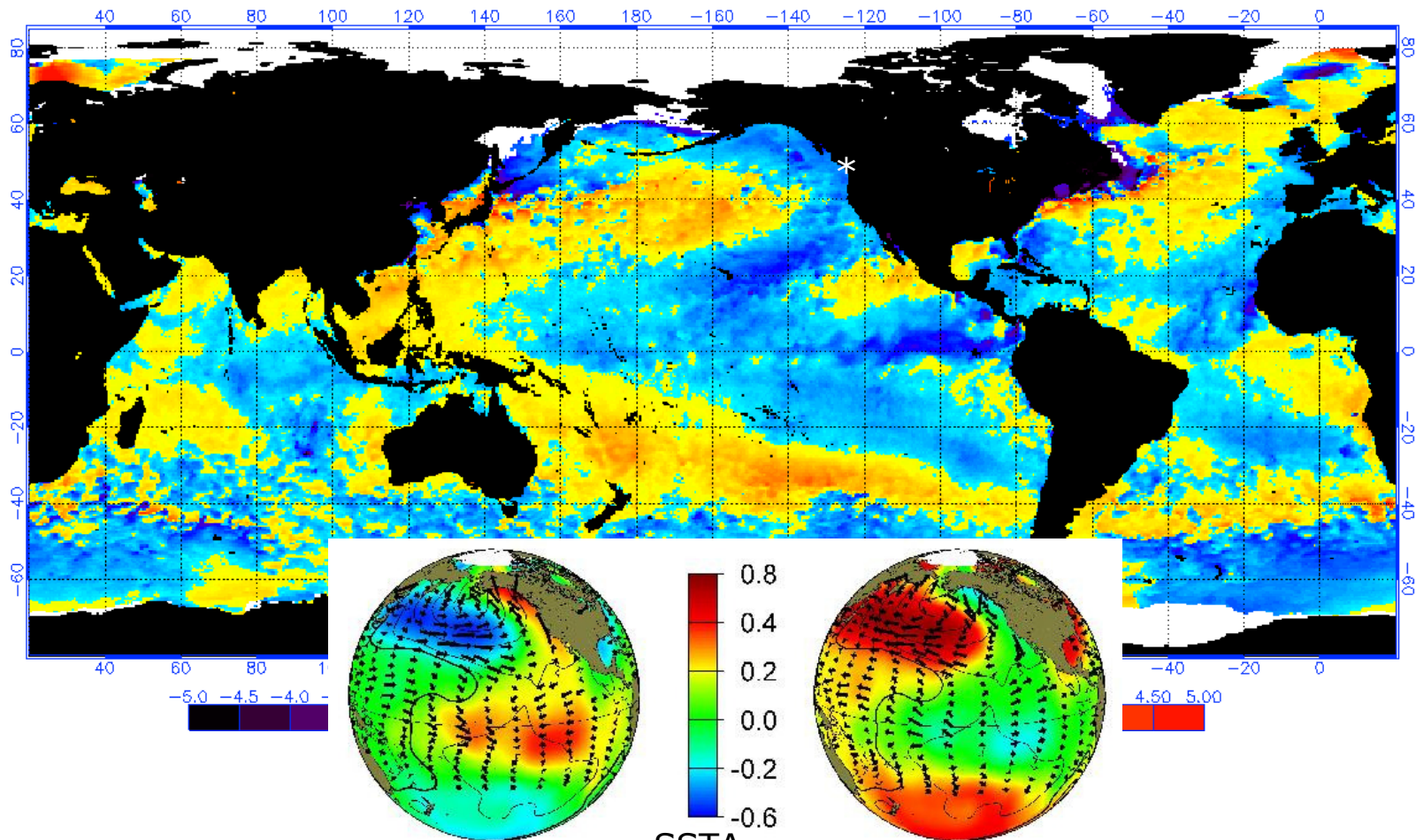
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# Welcome to Victoria

NOAA/NESDIS 50 KM GLOBAL ANALYSIS: SST Anomaly (degrees C), 3/9/2009  
(white regions indicate sea-ice)



**PDO warm phase**

**PDO cool phase**



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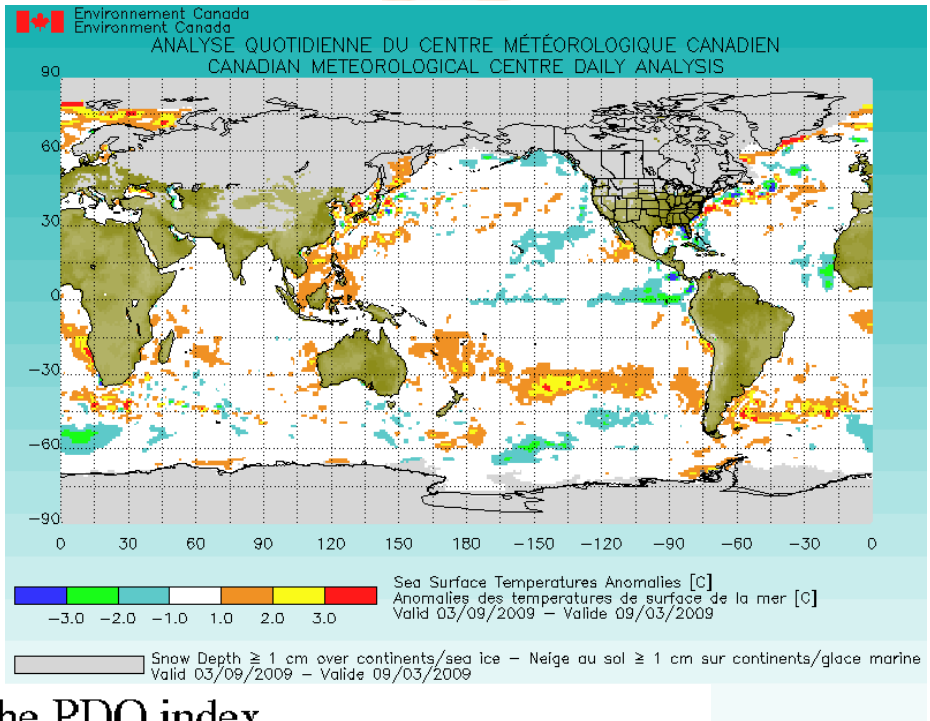
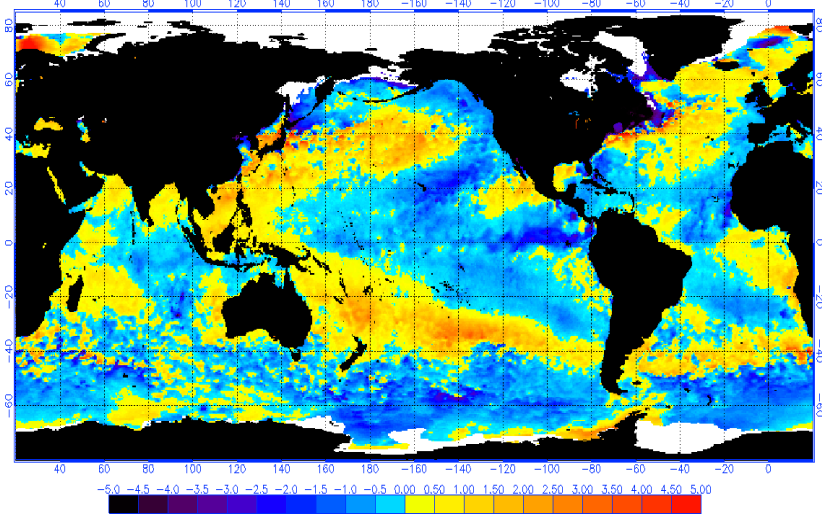
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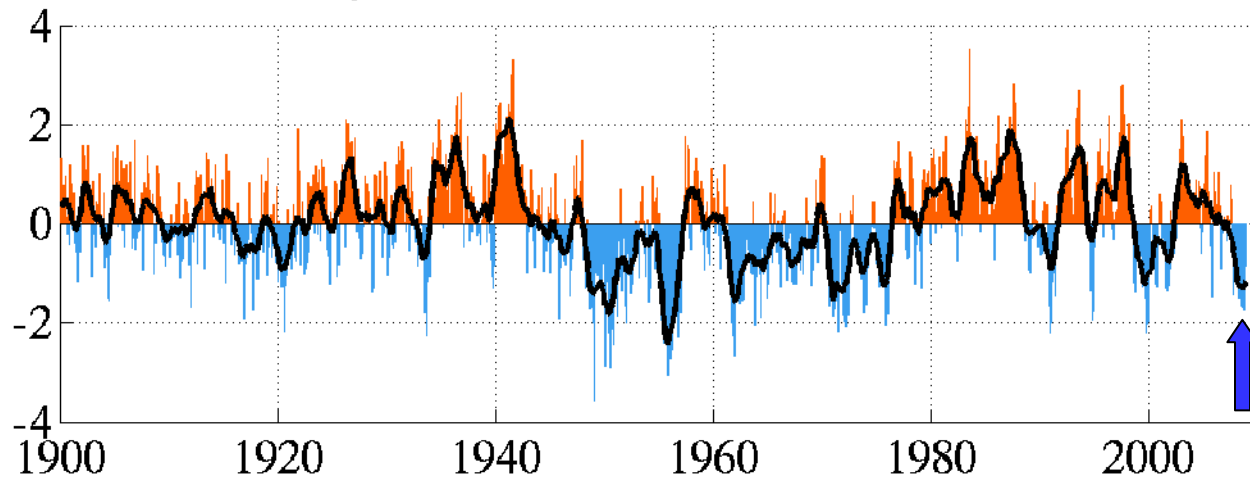
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NOAA/NESDIS 50 KM GLOBAL ANALYSIS: SST Anomaly (degrees C), 3/9/2009  
(white regions indicate sea-ice)



### monthly values for the PDO index



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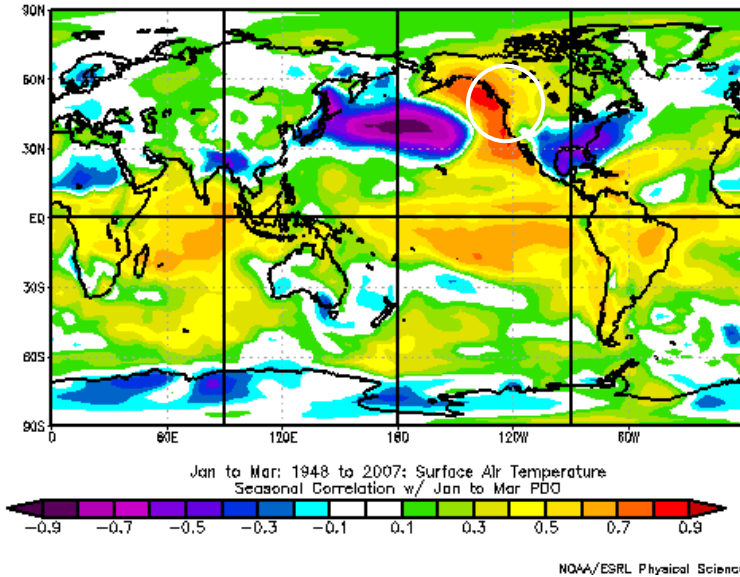
<http://jisao.washington.edu/pdo/>

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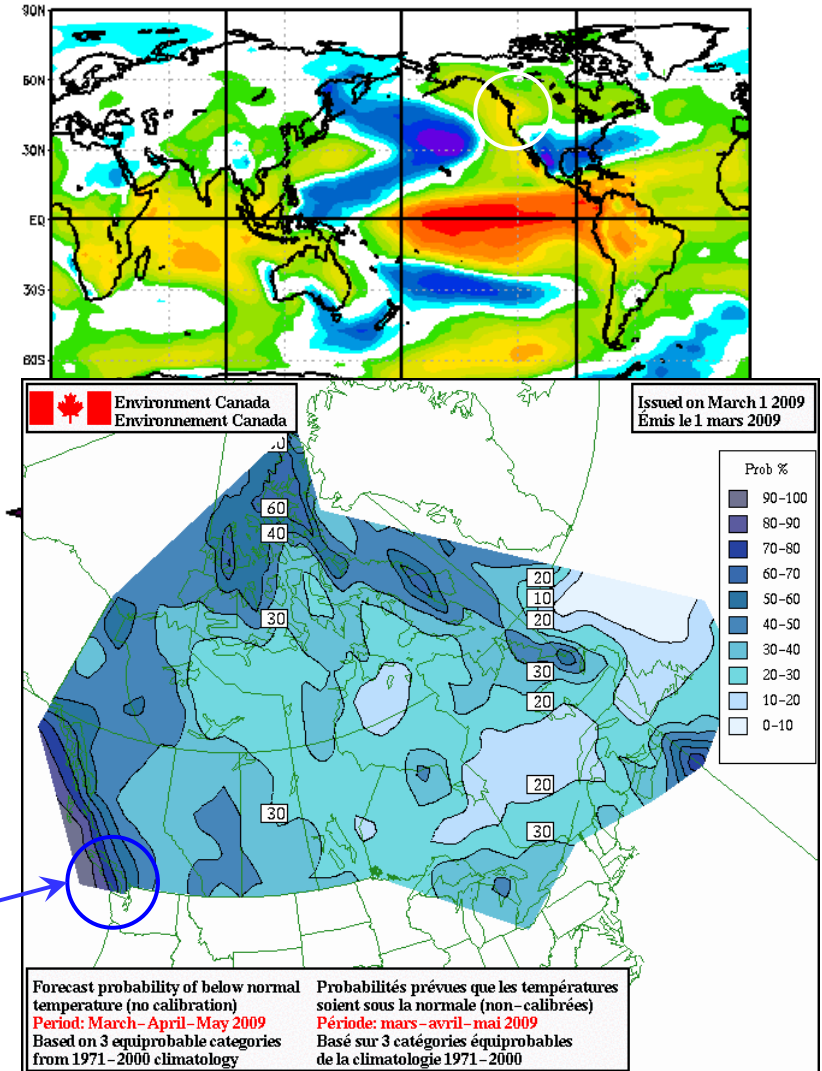
## ST correlation with PDO (JFM)

NCEP/NCAR Reanalysis



## ST correlation with Nino3.4 (JFM)

NCEP/NCAR Reanalysis



EC March-April-May forecast issued March 1

60-70% chance of below normal temperatures in Victoria



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# Seasons to Decades

- **Sub-Theme II.1 Analysis and Mechanisms**

*What are the origins of predictability?*

- **Sub-Theme II.2 Predictability of the Coupled System**

*What are the limits of predictability?*

- **Sub-Theme II.3 Prediction**

*How well can we predict in practice?*

- **Sub-Theme II.4 Land surface initialization**

*What is impact on prediction skill?*





- **Sub-Theme II.1 Analysis and Mechanisms**

- **Northern Annular Mode** *Fyfe morning talk*

- **Pacific Decadal Oscillation in climate models**

- *model biases*

- *relation to ENSO*

- Lienert afternoon talk*





- **Sub-Theme II.2 Predictability of the Coupled System**

- Predictability in a warming world
- 21<sup>st</sup> century decadal predictability
- Likelihood and predictability of cooling episodes in a warming climate
- Regional impacts of air-sea coupling on climate variability and predictability
- Prognostic predictability of large ensembles

→ *Merryfield/Tang morning talks*

→ *Ravindran afternoon talk*



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- **Sub-Theme II.3 Prediction**

- **II.3.1 Coupled Model Initialization**

*Flato morning talk*

*Deng afternoon talk*

- **II.3.2 The Coupled Model Historical Forecasting Project**

- **II.3.3 Forecast Combination, Calibration and Verification**



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# Spectral nudging: A tie-in with Theme I

- ***Spectral nudging*** developed under Theme I suppresses OGCM biases wrt climatological mean and seasonal cycle while leaving variability on other bands unfettered
- In Theme I interesting variability = eddies
- In Theme II interesting variability is seasonal/interannual
- ***Spectral nudging implemented in CCCma OGCM*** in collaboration with Dan Wright (BIO) & Fred Dupont (Dal)
- Coupled test runs underway



## • Sub-Theme II.3 Prediction

- II.3.1 Coupled Model Initialization
  - *Flato morning talk*
  - *Deng afternoon talk*
- II.3.2 The Coupled Model Historical Forecasting Project
- II.3.3 Forecast Combination, Calibration and Verification
  - *Kharin morning talk*
  - *Finnis afternoon talk*



# The Coupled Model Historical Forecasting Project (CHFP)

- For forecast systems, libraries of *retrospective forecasts* are essential for
  - *correcting forecast bias*
  - *assessing forecast skill from past performance*
  - *guiding optimal calibration*
- Previous and current EC operational systems based upon
  - **HFP**: 2 AGCMs, persisted SSTA (ensemble size 6)
  - **HFP2**: 4 AGCMs, persisted SSTA (ensemble size 4×10)

AGCM2  
AGCM3  
SEF  
GEM



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# The Coupled Model Historical Forecasting Project (CHFP)

- Under GOAPP, develop *coupled* forecast system → *SSTA part of forecast*
- **CHFP1**: modest pilot project
- **CHFP2**: incorporate model + initialization + calibration improvements
  - contribution to international CHFP (“*Climate-system Historical Forecast Project*”) organized by Clivar Working Group on Seasonal to Interannual Prediction





# CHFP Data Server (ensembles.ecmwf.int)

## Catalog

<http://ensembles.ecmwf.int/thredds/ensembles/stream1/atmospheric/monthly>

Dataset	Size	Last Modified
<a href="#">Geopotential</a>		--
<a href="#">Air temperature</a>		--
<a href="#">Zonal wind positive to the east</a>		--
<a href="#">Meridional wind positive to the north</a>		--
<a href="#">Mass fraction of water vapor in moist air</a>		--
<a href="#">SST over sea, soil temperature over land and ice temperature over sea ice</a>		--
<a href="#">Snow depth in metres of water equivalent</a>		--
<a href="#">Heat exchange between the surface and the air by motion of air</a>		--
<a href="#">Heat exchange between the surface and the air by water phase changes</a>		--
<a href="#">Mean sea-level pressure</a>		--
<a href="#">Cloud area fraction for the whole atmosphere column</a>		--
<a href="#">10-metre zonal wind positive to the east</a>		--
<a href="#">10-metre meridional wind positive to the north</a>		--
<a href="#">2-metre temperature</a>		--
<a href="#">2-metre dewpoint temperature</a>		--
<a href="#">Solar radiation incident at the surface</a>		--
<a href="#">Longwave radiation incident at the surface</a>		--
<a href="#">Difference of solar radiation from above and from below at the surface</a>		--
<a href="#">Difference of longwave radiation from above and from below at the surface</a>		--
<a href="#">Difference of solar radiation from above and from below at the top of the atmosphere</a>		--
<a href="#">Difference of longwave radiation from above and from below at the top of the atmosphere</a>		--
<a href="#">Near-surface maximum temperature in the previous 24 hours computed from 6-hourly (6, 12, 18 and 24 GMT) data</a>		--
<a href="#">Near-surface minimum temperature in the previous 24 hours computed from 6-hourly (6, 12, 18 and 24 GMT) data</a>		--
<a href="#">Total precipitation accumulated in the previous 24 hours</a>		--



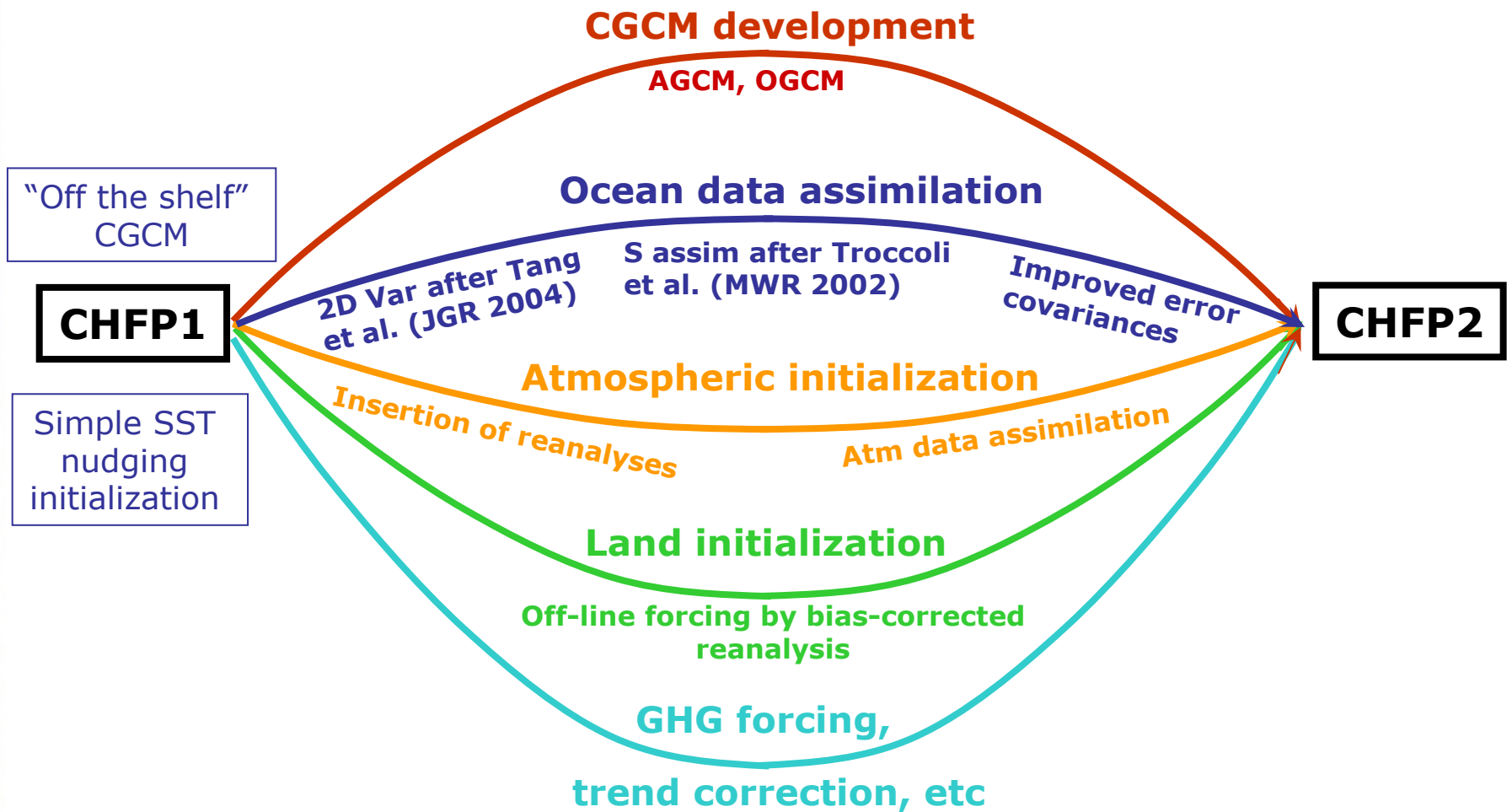
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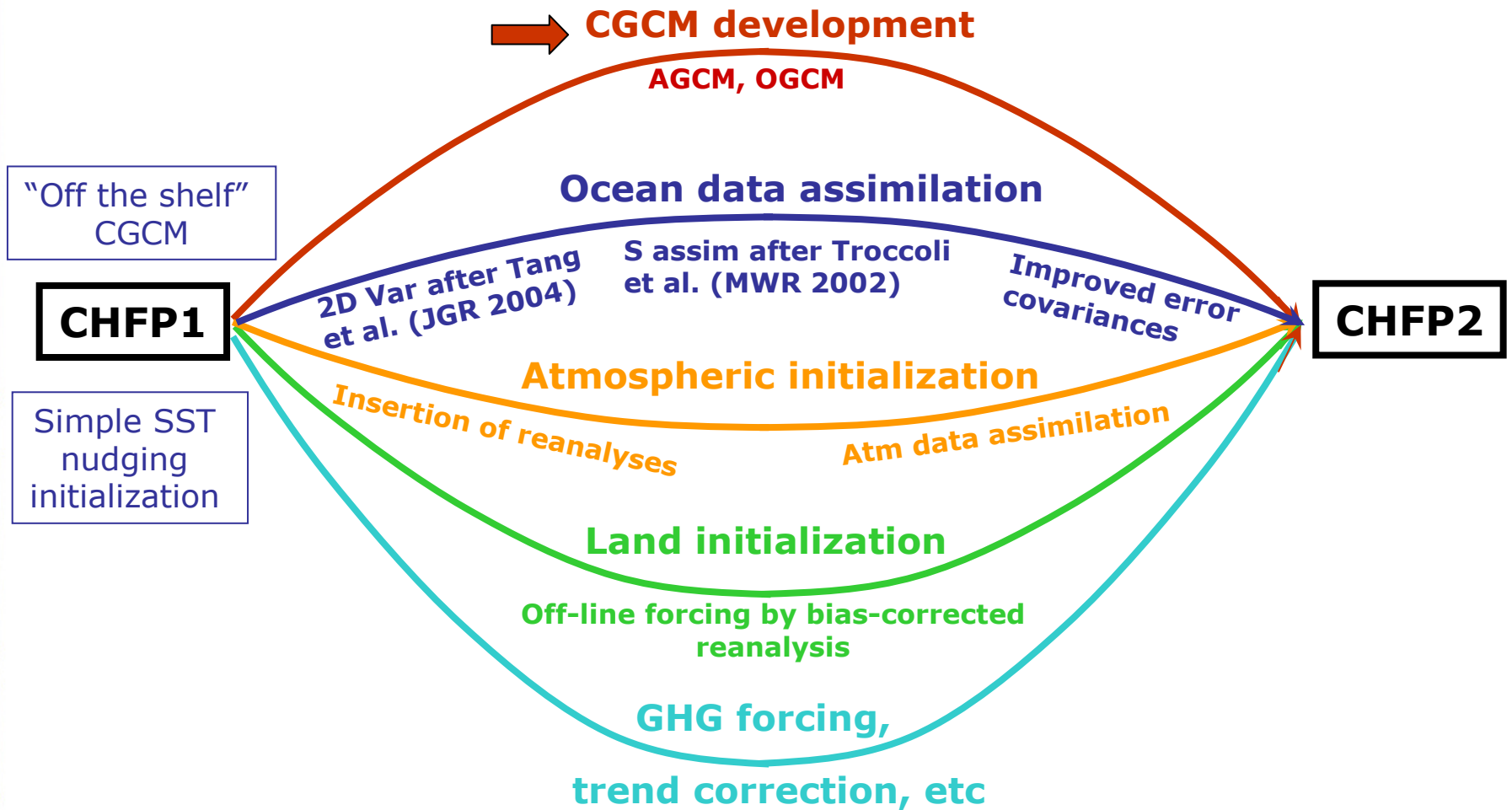
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# Coupled Forecast System Development Path



# Coupled Forecast System Development Path



# Forecast model configurations

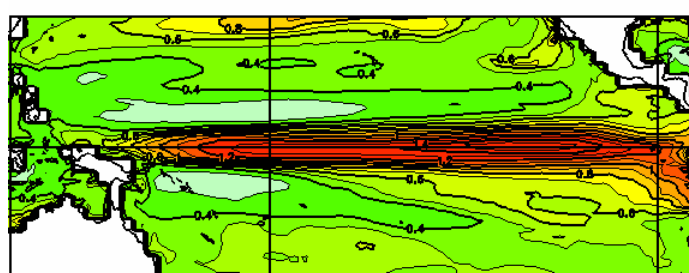
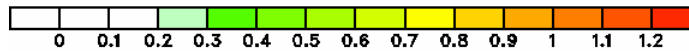
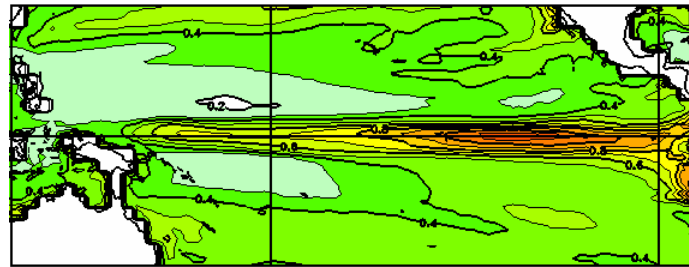
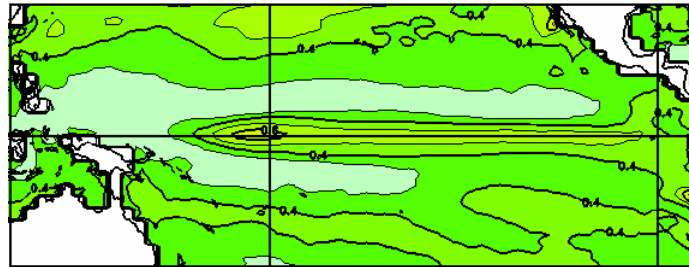
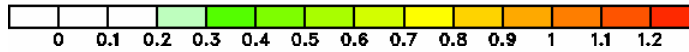
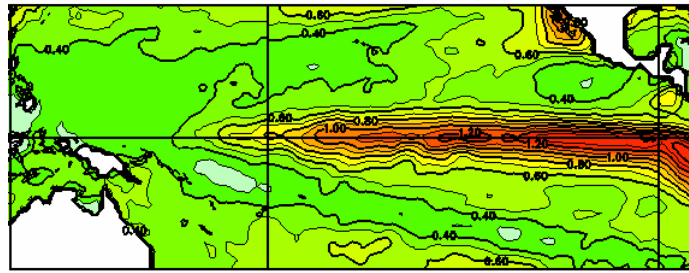
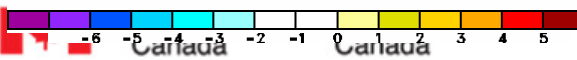
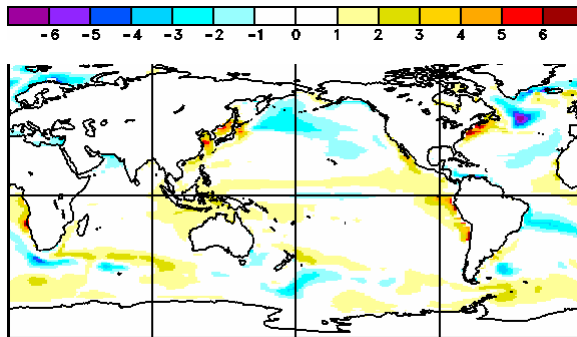
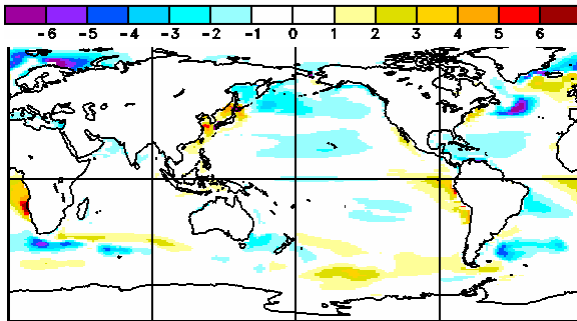
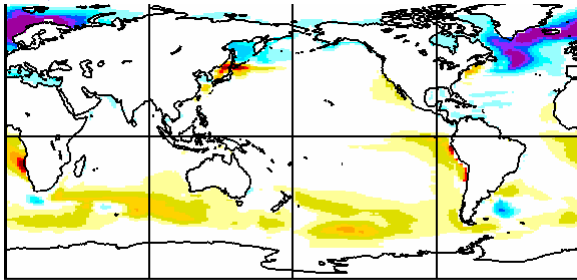
	AGCM3	AGCM4
OGCM3	CHFP1	—
OGCM4	CHFP2 <sub>1</sub>	CHFP2 <sub>2</sub>

- **OGCM4**: higher vertical resolution (10m in upper ocean), new physics
- **AGCM4**: many new physical parameterizations, prognostic aerosols...
- Same horizontal resolution ( $\approx 2.8^\circ \times 2.8^\circ$  AGCM,  $1.4^\circ \text{lon} \times 0.9^\circ \text{lat}$  OGCM)



# SST Bias

Monthly SSTA  
standard deviation →



Observations:  
HadISST 1970-99

AGCM3+OGCM3  
CHFP1

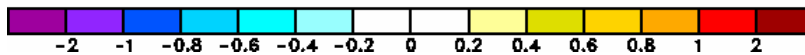
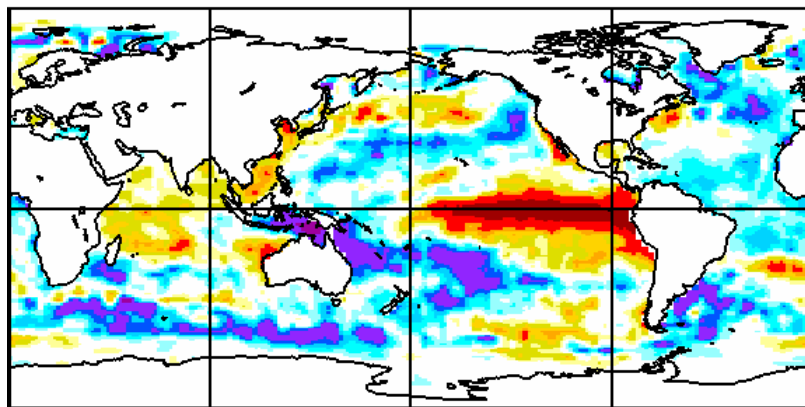
AGCM3+OGCM4  
CHFP2<sub>1</sub>

AGCM4+OGCM4  
CHFP2<sub>2</sub>

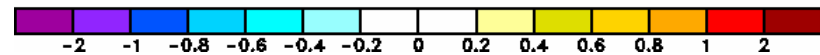
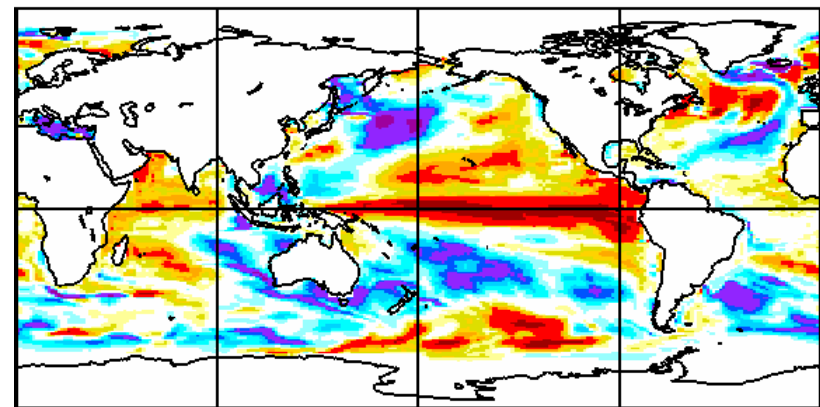


- Potential for improved prediction skill exemplified by “hit” for 11-month lead prediction of 1982/83 El Nino:

Obs SSTA Nov 1982



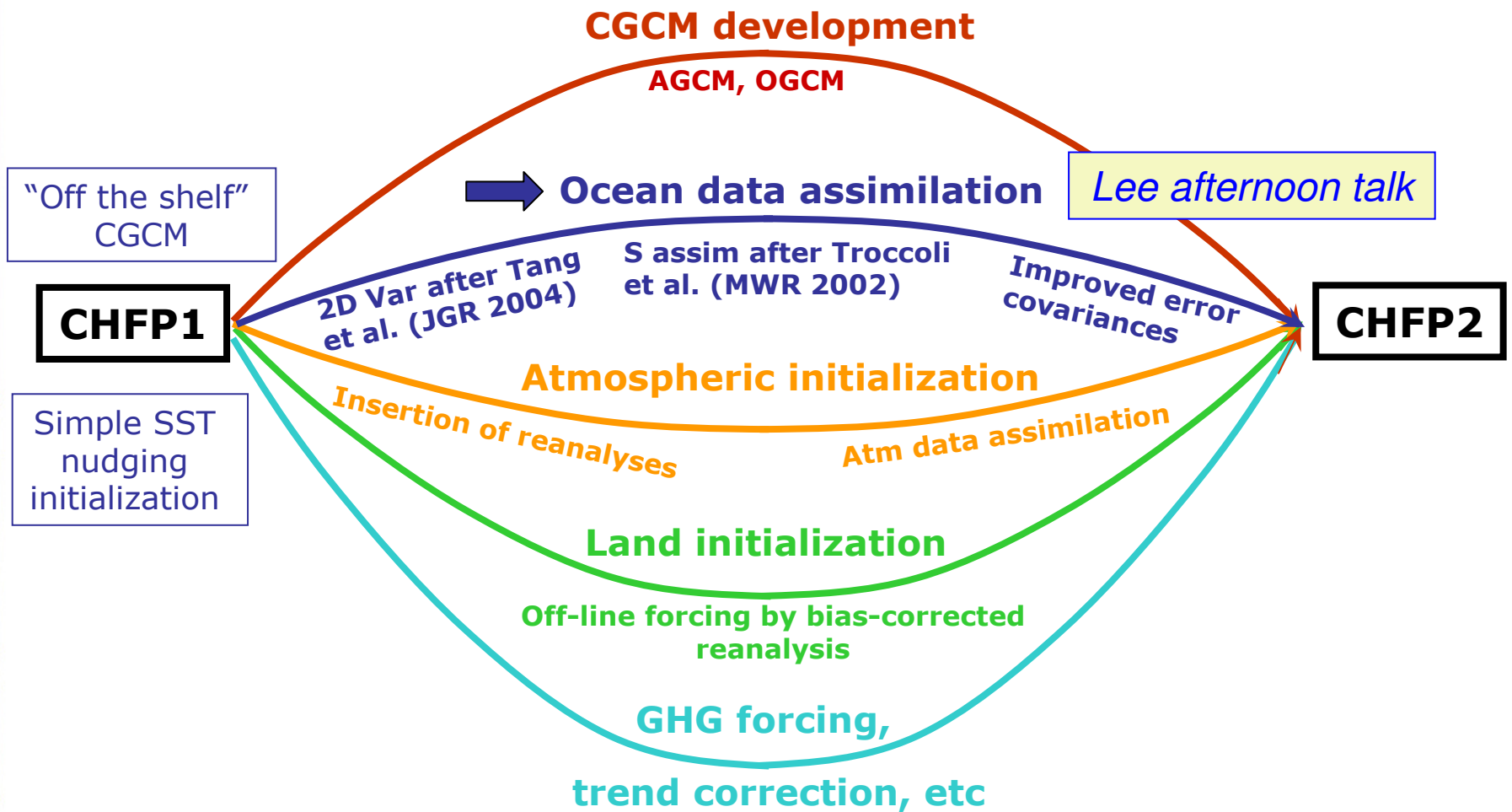
Deterministic forecast SSTA Nov 1982  
AGCM4 + OGCM4 Lead=11 mo



- While such outcomes not always possible (even in theory), a *strong El Nino is now within the range of possibilities admitted by the model*



# Coupled Forecast System Development Path



# Ocean Initialization by multi-analysis assimilation

- ❖ Experiment: compare NINO3.4 *skill* and *ensemble spread* for three ensemble initialization strategies:
  - *Multi-analysis*: off-line assimilation of 6 ocean analysis products (same atm)
  - *Exp\_atmos*: 6 AGCM states from consecutive days prior to forecast start (same ocn)
  - *Exp\_ocean*: 6 OGCM states from consecutive days prior to forecast start (same ocn)

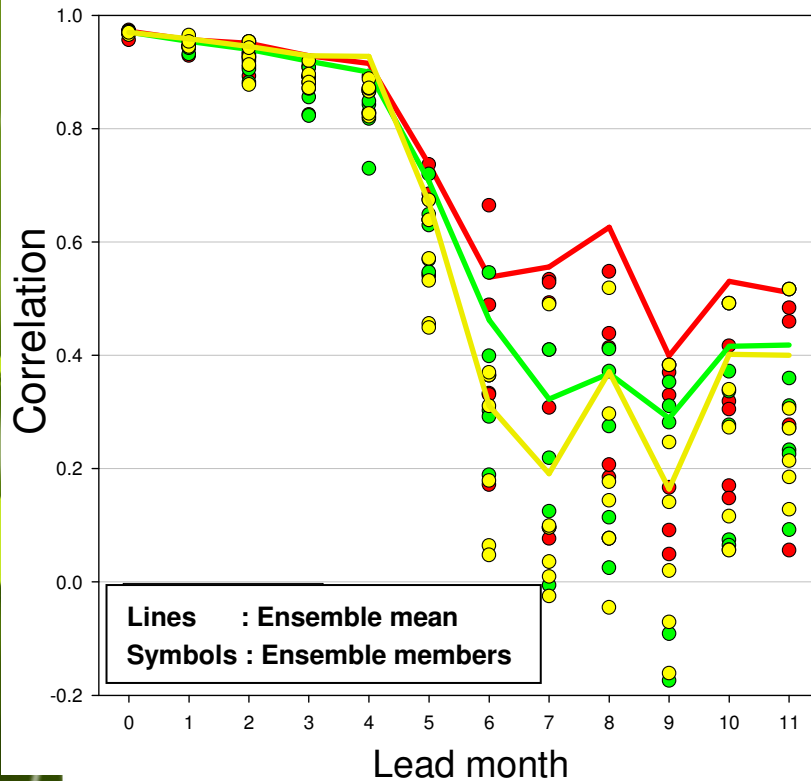
	MULTI-ANALYSIS						EXP_ATMOS						EXP_OCEAN					
Ensemble member	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Atmosphere Initial State	8/31						8/31	8/30	8/29	8/28	8/27	8/26	8/31					
Ocean Initial state	8/31						8/31						8/31	8/30	8/29	8/28	8/27	8/26
Used Reanalysis Data for ocean assimilation	GODAS	ECMWF	GFDL	SODA	INGV	METUK	GODAS						GODAS					

- ❖ **1980-2001**: 22 years of Sep 1–initialized forecasts

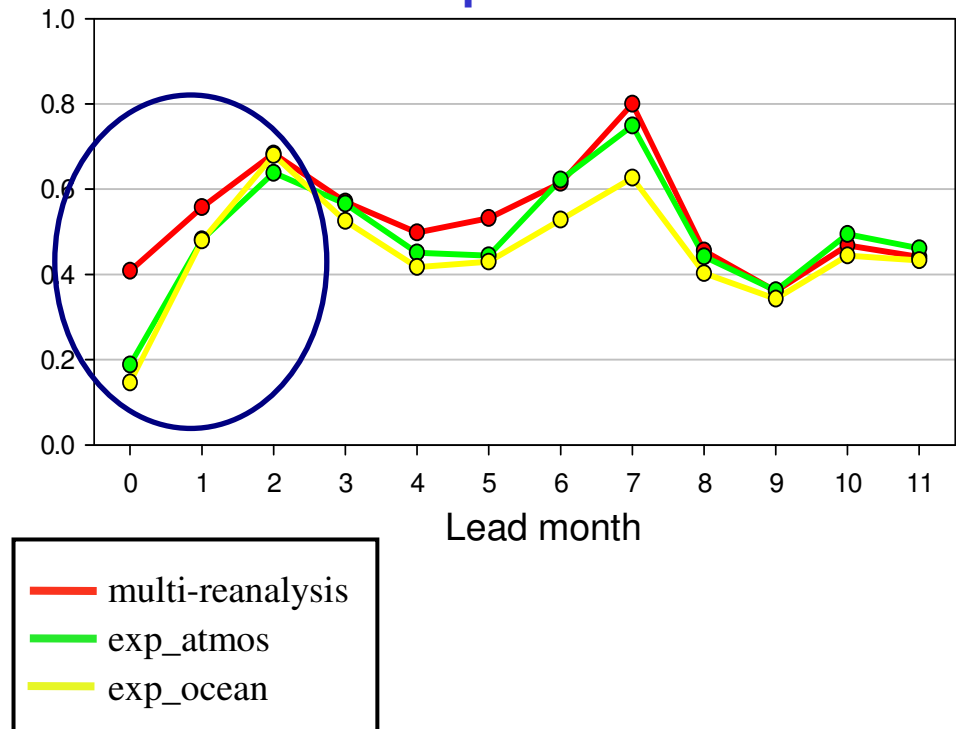


# NINO3.4 skill and ensemble spread

## SST Forecast Skill



## Ensemble Spread ÷ RMS Error

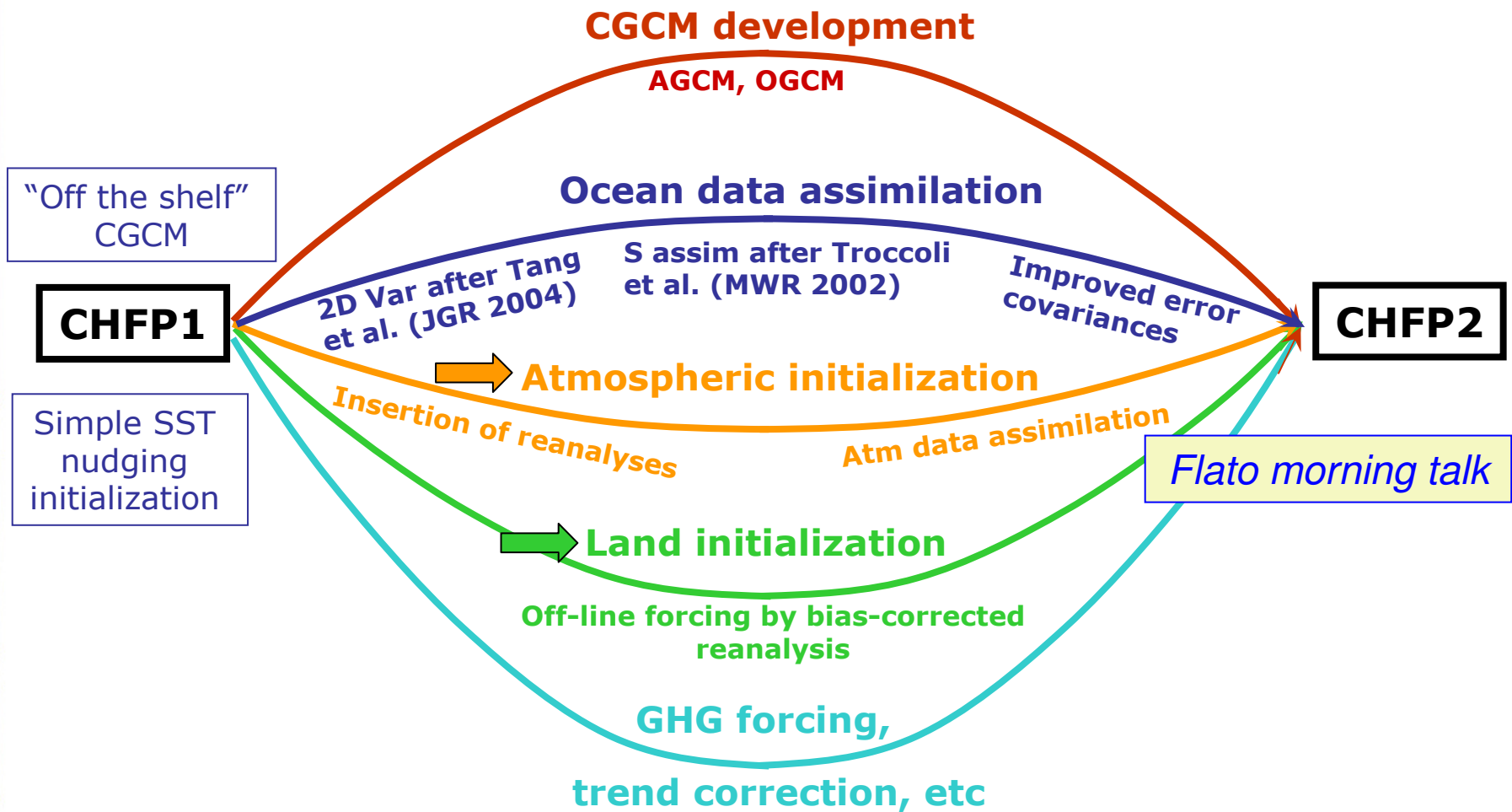


➔ Multi-analysis ocean initialization leads to

- Improved skill at longer leads
- Larger ensemble spread in first two months

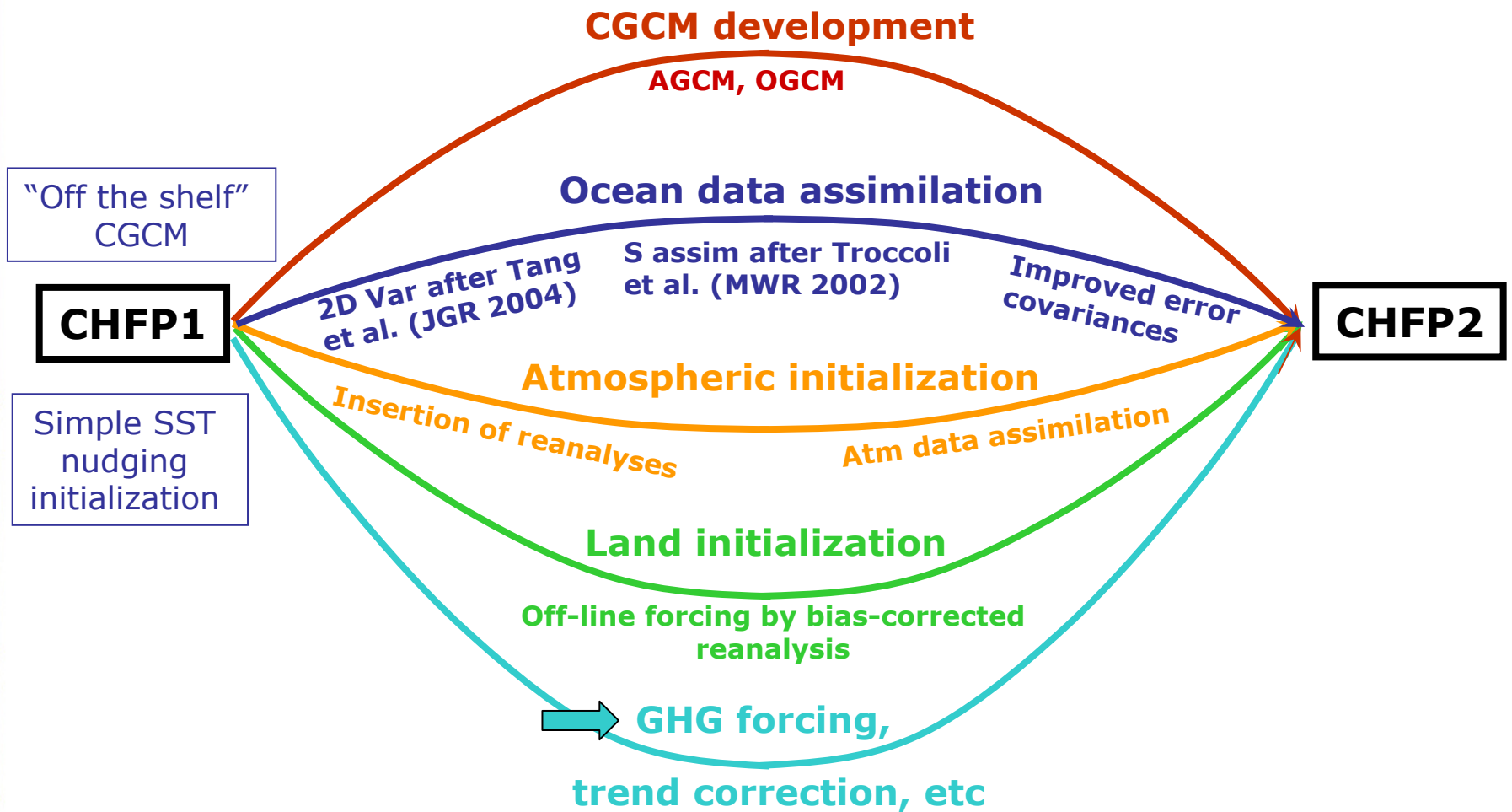


# Coupled Forecast System Development Path



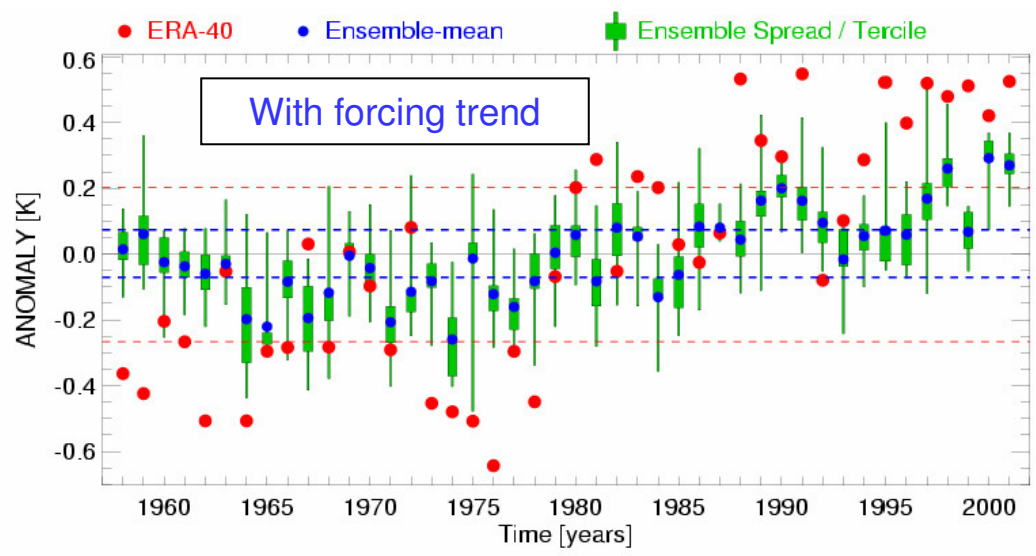
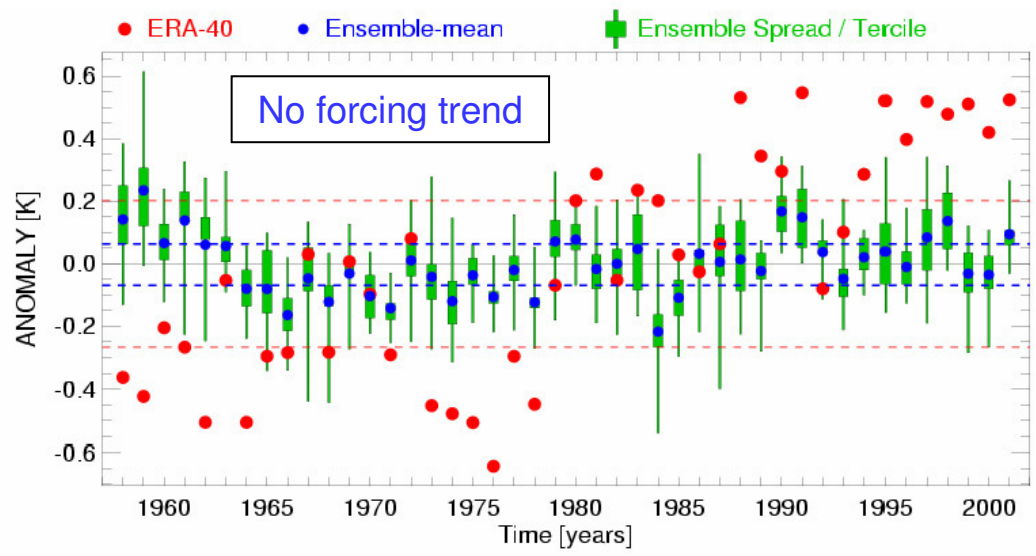


# Coupled Forecast System Development Path



# Importance of radiative forcing for Seasonal Forecasts

Global-mean temperatures: **Red** = obs    **Blue/green** = forecasts



← May start  
Month 4-6 forecasts)

Corr skill\*

Forecast month(s)	No forcing trend	With forcing trend
1	0.78	→ 0.80
2-4	0.49	→ 0.73
4-6	0.27	→ 0.63

\*averaged over May and Nov starts

Doblas-Reyes et al. *GRL* 2006



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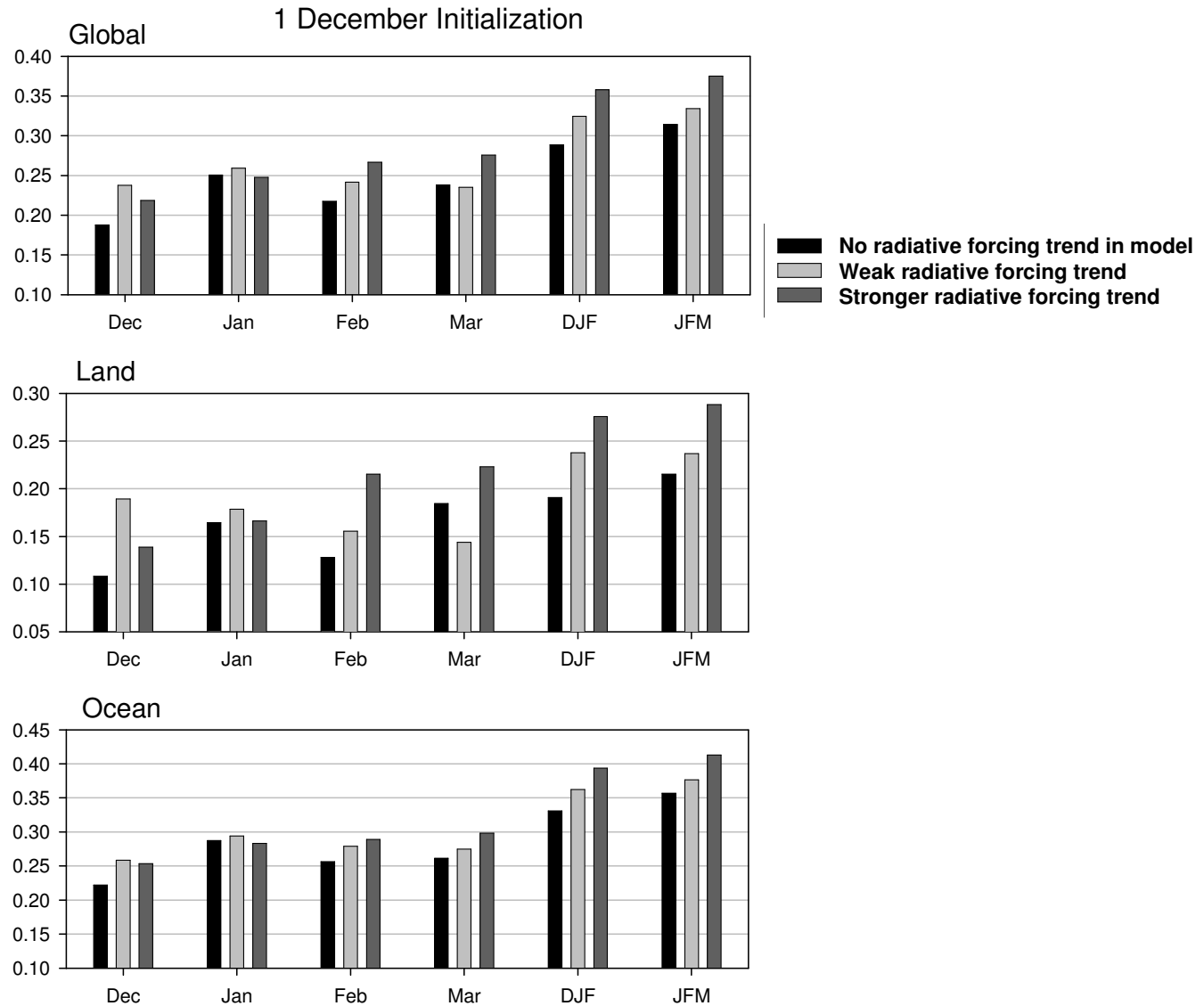
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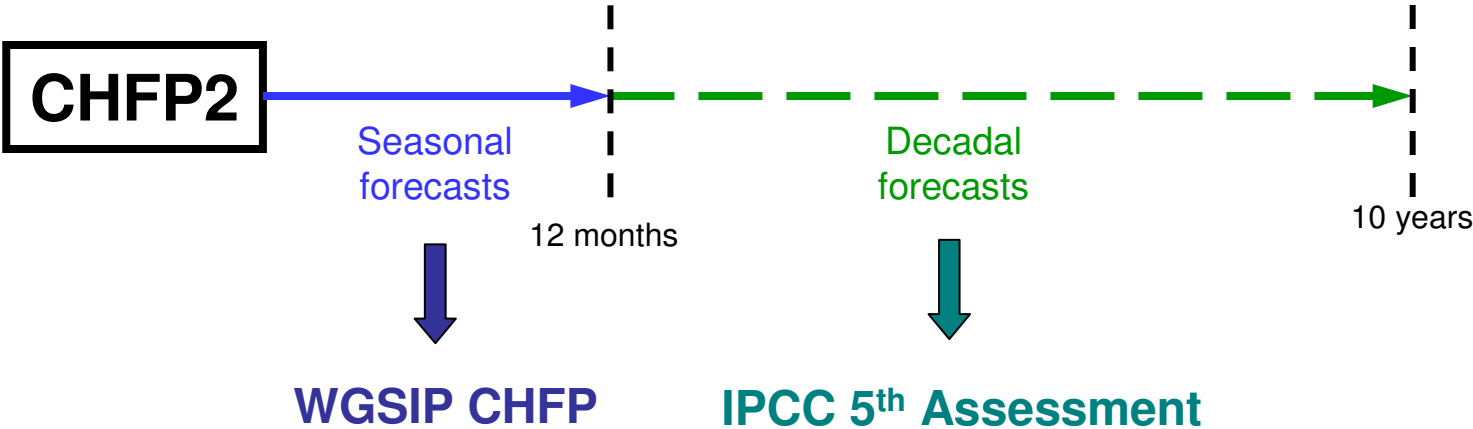


# Impact of radiative forcing trend on forecast skill

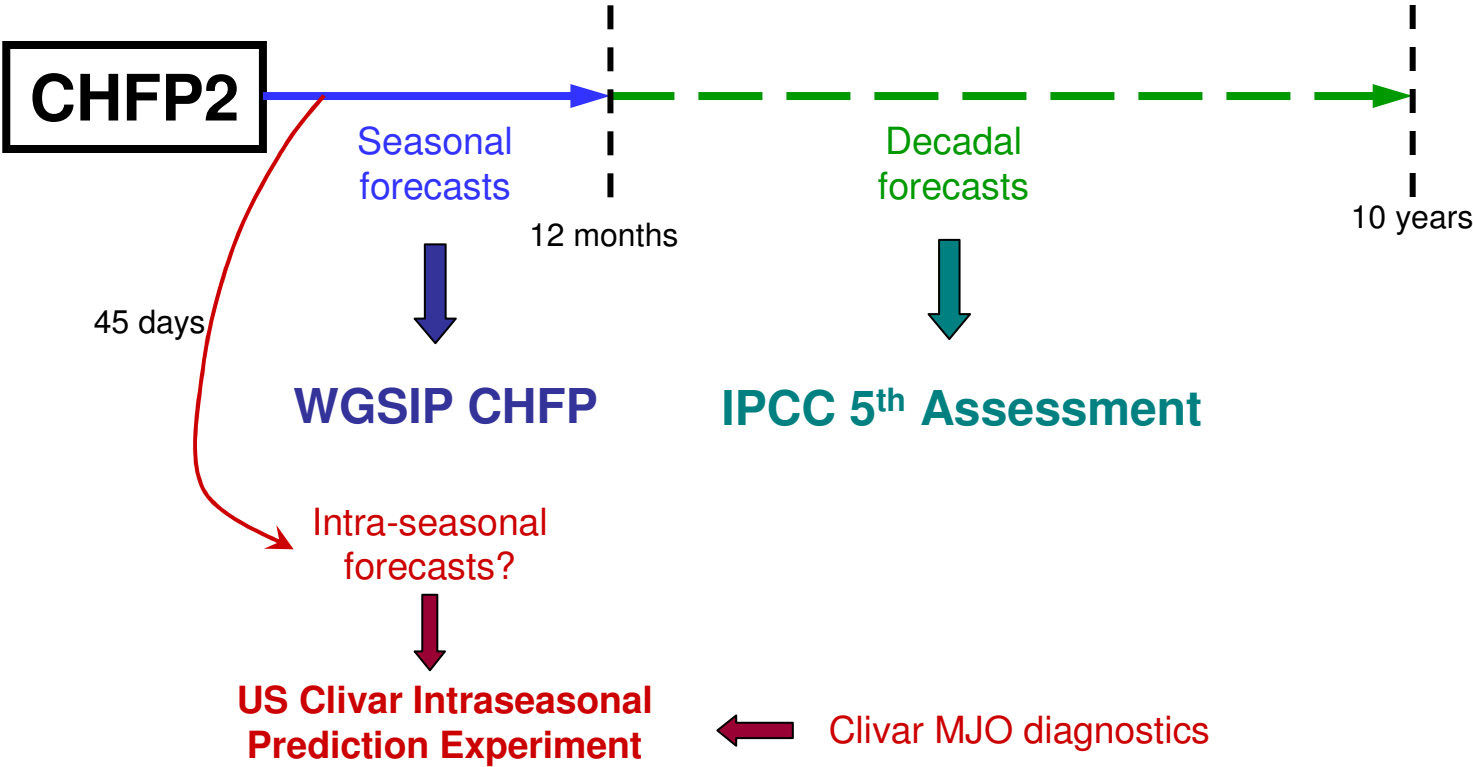
CHFP1: Temperature at 850hPa (T850) Anomaly Correlation



# CHFP2 potential contributions



# CHFP2 potential contributions



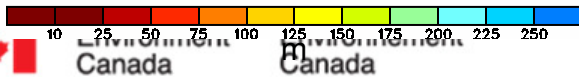
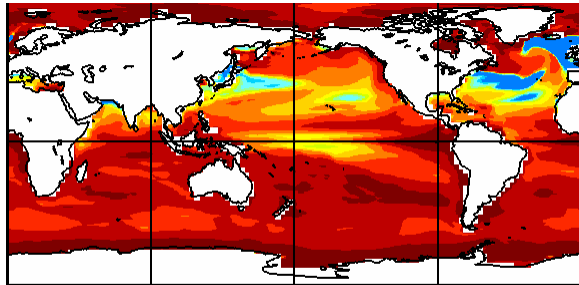
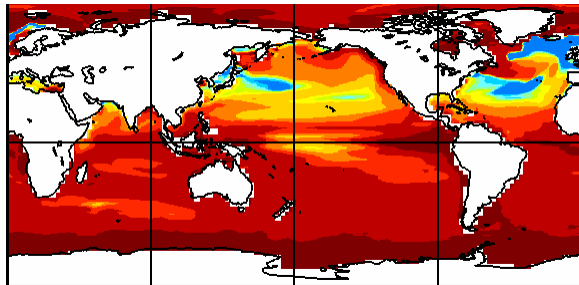
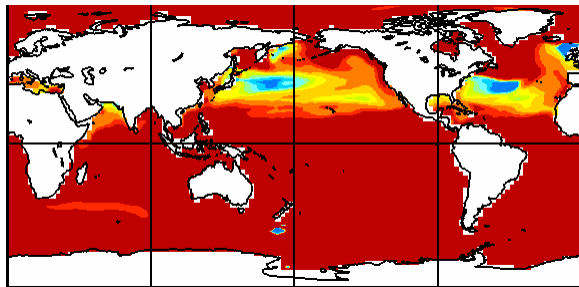
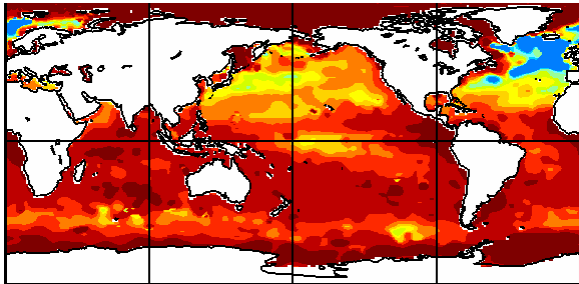
# Conclusions

- Several aspects of Theme II as originally proposed are being exceeded. These include
  - multimodel CHFP
  - initialization of AGCM/sea ice/land surface/ocean S
- CHFP2 must start soon
  - techniques and technologies that are ready and have been sufficiently tested will be incorporated
  - research will continue on effectiveness of others

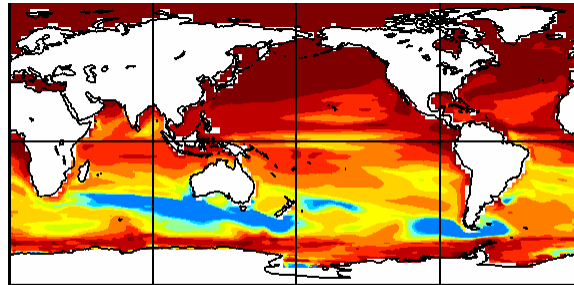
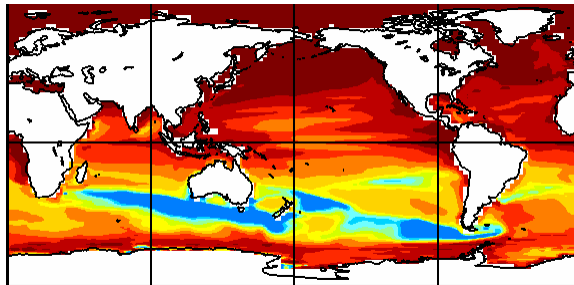
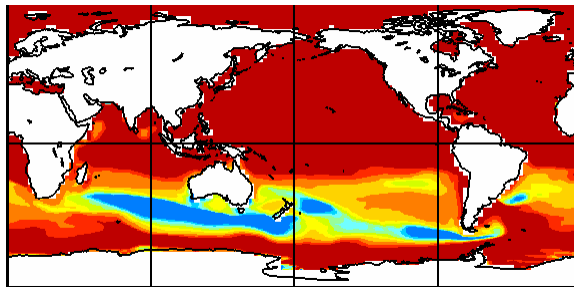
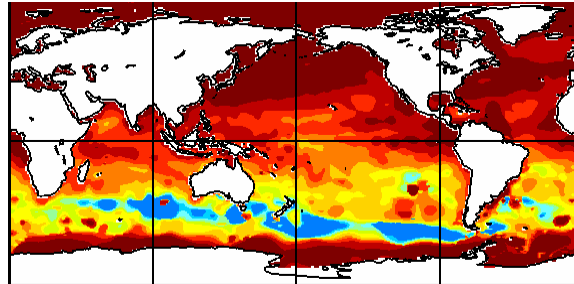




### Jan mixed layer depth



### Jul mixed layer depth



**Observations:  
WOA/PHC**

**AGCM3+OGCM3**

**AGCM3+OGCM4**

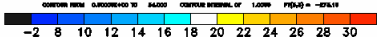
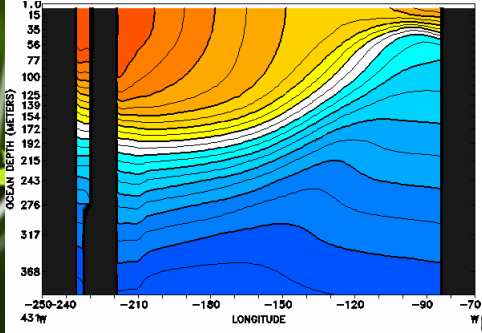
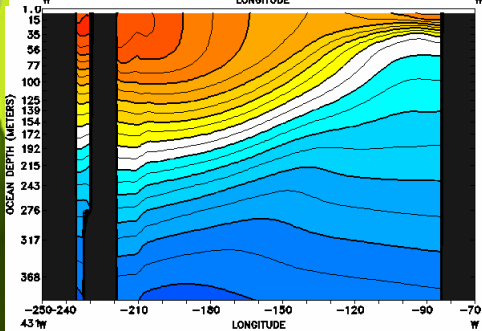
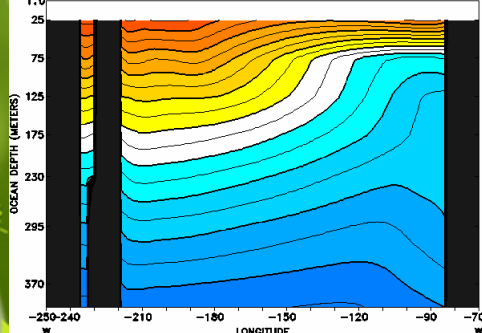
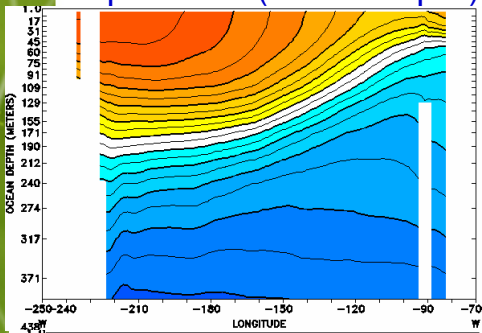
**AGCM4+OGCM4**



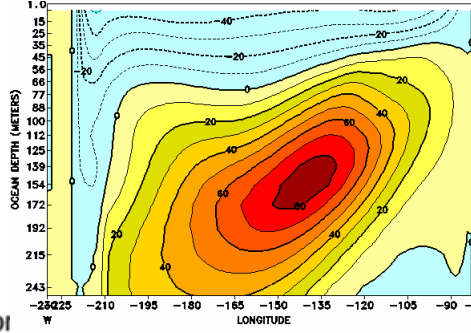
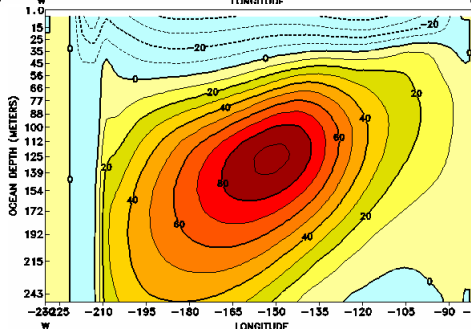
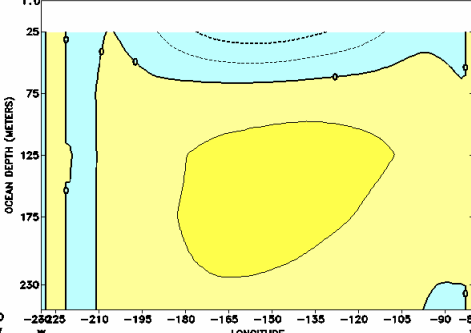
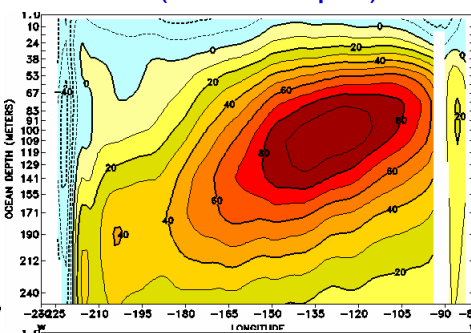
Canada

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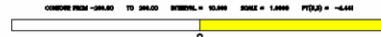
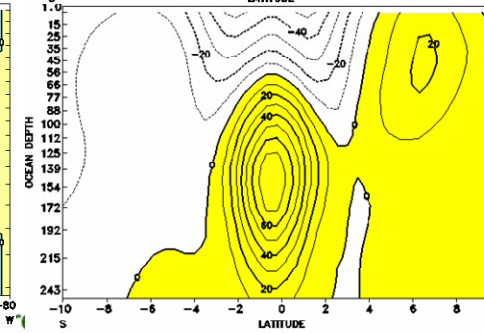
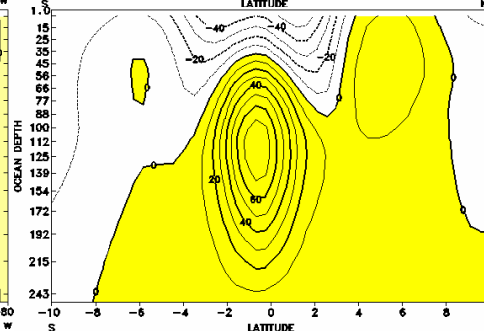
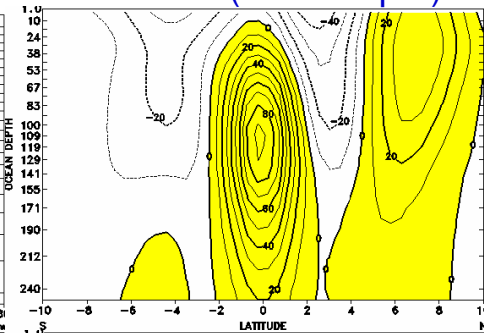
Temperature (lon vs depth)



U (lon vs depth)



U at 140°W (lat vs depth)



Equatorial Pacific

Observations: SODA

CGCM3.5

CGCM3.8

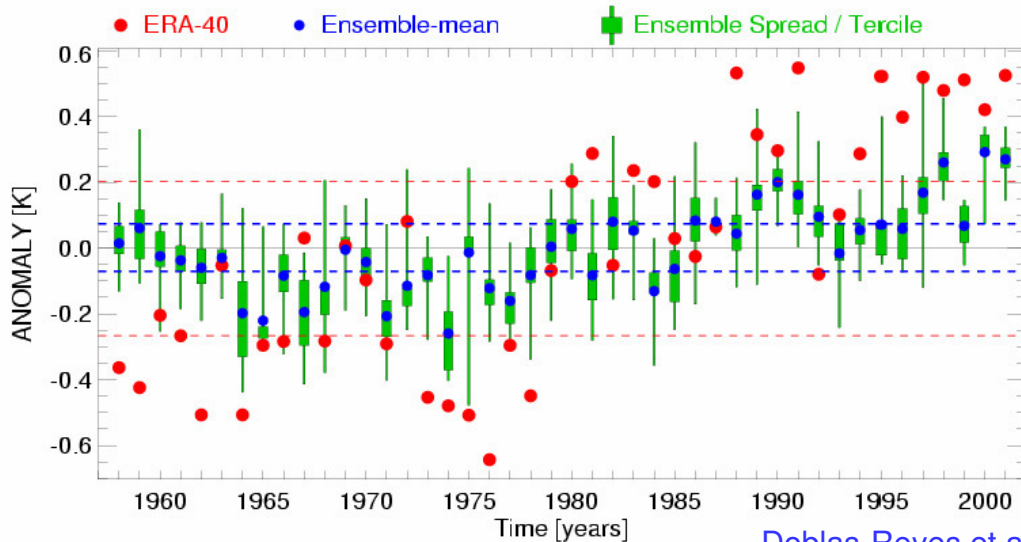
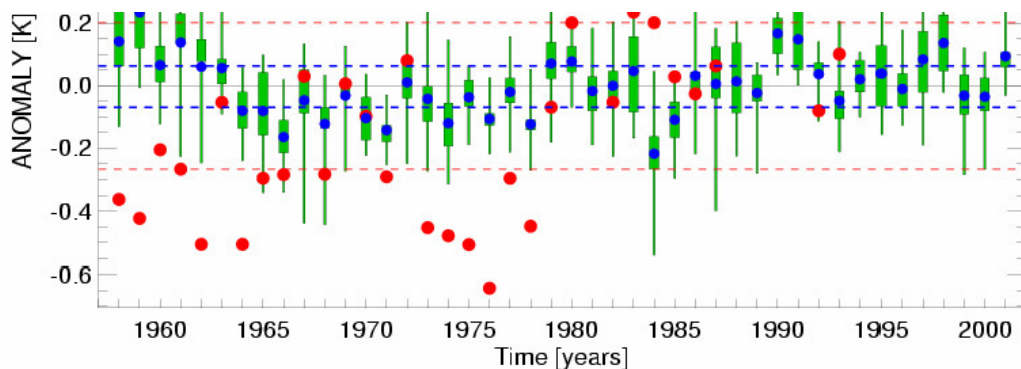
# Importance of radiative forcing for Seasonal Forecasts

First Month, May Start (M)	1-Month Lead, May Start (JJA)	3-Month Lead, May Start (ASO)	First Month, Nov Start (N)	1-Month Lead, Nov Start (DJF)	3-Month Lead, Nov Start (FMA)
<i>CONS Corr</i>					
(G) 0.79	0.52	0.29	0.76	0.46	0.25
(L) 0.63	0.30	0.13	0.59	0.46	0.33
(O) 0.86	0.71	0.39	0.60	0.25	0.13
<i>VARI Corr</i>					
(G) 0.81	0.79	0.68	0.79	0.67	0.58
(L) 0.71	0.70	0.58	0.66	0.56	0.60
(O) 0.81	0.80	0.69	0.77	0.50	0.45

**= forecasts**

**Corr skill\***

Forecast month(s)	No forcing trend	With forcing trend
1	0.78	0.80
2-4	0.49	0.73
4-6	0.27	0.63



\*means over May and Nov starts

Doblas-Reyes et al. *GRL* 2006



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