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Initialization of Coupled Seasonal Forecasts by Assimilation of an Ensemble of Ocean Reanalyses

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Global Ocean-Atmosphere Prediction and Predictability

Background

Factors that limit the skill of SST seasonal forecasting

- Unpredictable nature of atmospheric synoptic variability
- Coupled model error
- Error in the estimate of the atmosphere initial state
- *Error in the estimate of the ocean initial state*
  - Ocean Data Assimilation

    (Ji and Leetma, 1997; Rosati *et al.*, 1997; Alves *et al.*,2004 …..)

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Objectives

Ocean Data Assimilation

- Off-line 2 Dimensional Variational Scheme (Tang *et al.*, 2004) using existing reanalysis products
- Several ***ocean reanalysis datasets*** are available
  - Test the sensitivity to the assimilation
  - Contribute to generate an ensemble of ICs

Implement and Verify the initialization scheme by ocean data assimilation of multi-reanalysis.

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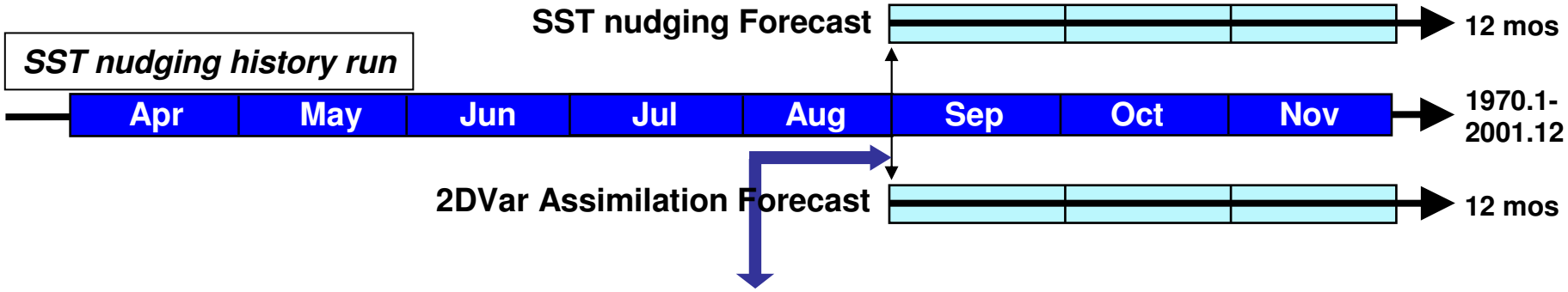
Seasonal Retrospective Forecasts

- Model : CCCma CGCM3 (AGCM: T63L31 OGCM:1.4x0.94xL33)
- Period : 1980-2001(22-year) Aug-initialization Forecast
- Experimental Design



Off-Line 2DVar Assimilation

- Variable : 3D Temperature
- Background Error Covariance : $a\ exp(-r^2/b^2)$ with b = 570 km
- Background field : Snapshots of history run
  (initial condition for SST nudging forecast)
- Observation field : Reanalysis Data

Used Ocean Reanalysis Products

Acronym	Organization	Resolution				Scheme /Model	Reference
		Time	Longitude	Latitude	Depth		
GODAS (Global Ocean Data Assimilation System)	NOAA NCEP EMC CMB(Climate Modeling Branch)	Monthly (1980.1-2007.8)	DX = 1 (0.5E-0.5W)	DY=0.33 (74.5S-64.5N)	40 levels (5 -4478m)	3DVar/ MOM3	Behringer, D. W., and Y. Xue, 2004
SODA 1.4.2 (Simple Ocean Data Assimilation Reanalysis)	UMD/TAMU Reanalysis Product	Monthly (1958.1-2001.12)	DX = 0.5 (0.25E-0.25W)	DY = 0.5 (75.25S-89.25N)	40 levels (5-5374m)	POP	Carton, J.A., and B.S. Giese, 2006
SODA 1.4.3		Monthly (2000.1-2004.12)					
GFDL	GFDL Ocean Data Assimilation Experiment	Monthly (1960.1-2006.12)	DX= 1 (0.5E-0.5W)	DY= 1 – 0.33 (81.5S-89.5N)	50 levels (5-5316m)	3DVar/ MOM3	http://data1.gfdl.noaa.gov/nomads/forms/assimilation.html
INGV	Instituto Nazinale di Geofisica e Vulcanologia	Monthly (1962.1-2001.12)	DX= 1 (0.0E-1.0W)	DY=1 (89S-89N)	33 levels (0-5500m)	OI/ OPA	-ENACT project (http://www.ecmwf.int/research/EU_projects/ENACT/ocean_analyses/index.html)
ECMWF	European Center for Medium-range Weather Forecast	Monthly (1962.1-2003.12)				OI/ HOPE-E	
METUK	The Meteorological Office	Monthly (1960.1-2004.12)				Objective Analysis	

*** 3D-ocean temperature, Grid data, at least over 20 year**

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How different are the reanalyses to be assimilated ?

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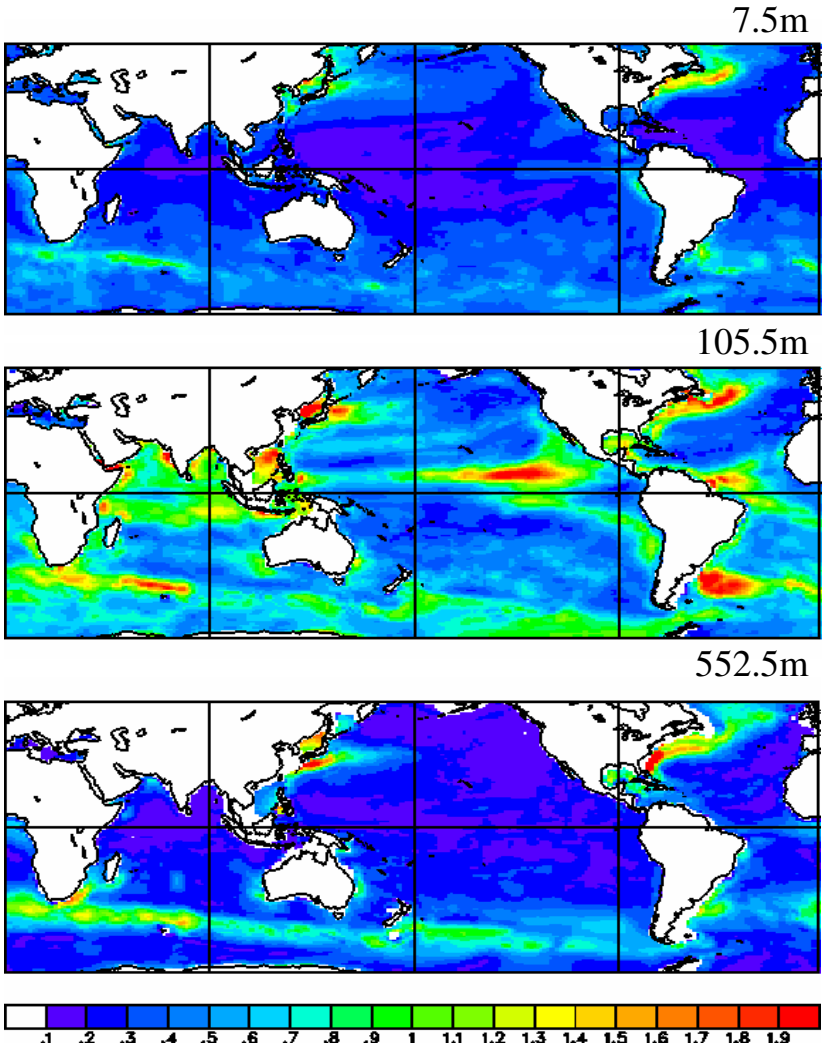
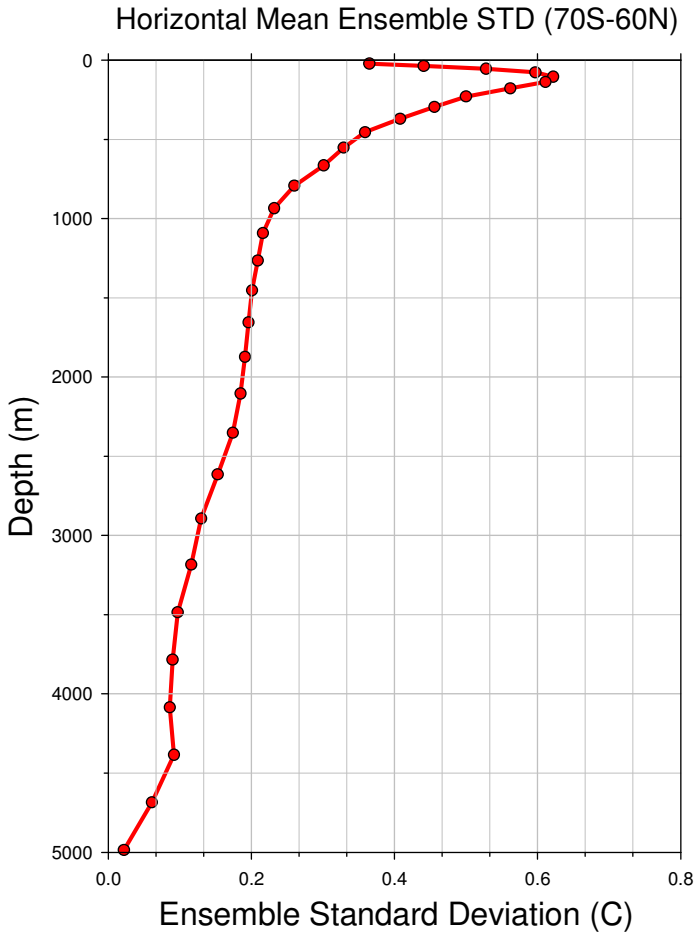
Intercomparison of Ocean Reanalysis Products

Time Mean Ensemble Standard Deviation(1980-2001)





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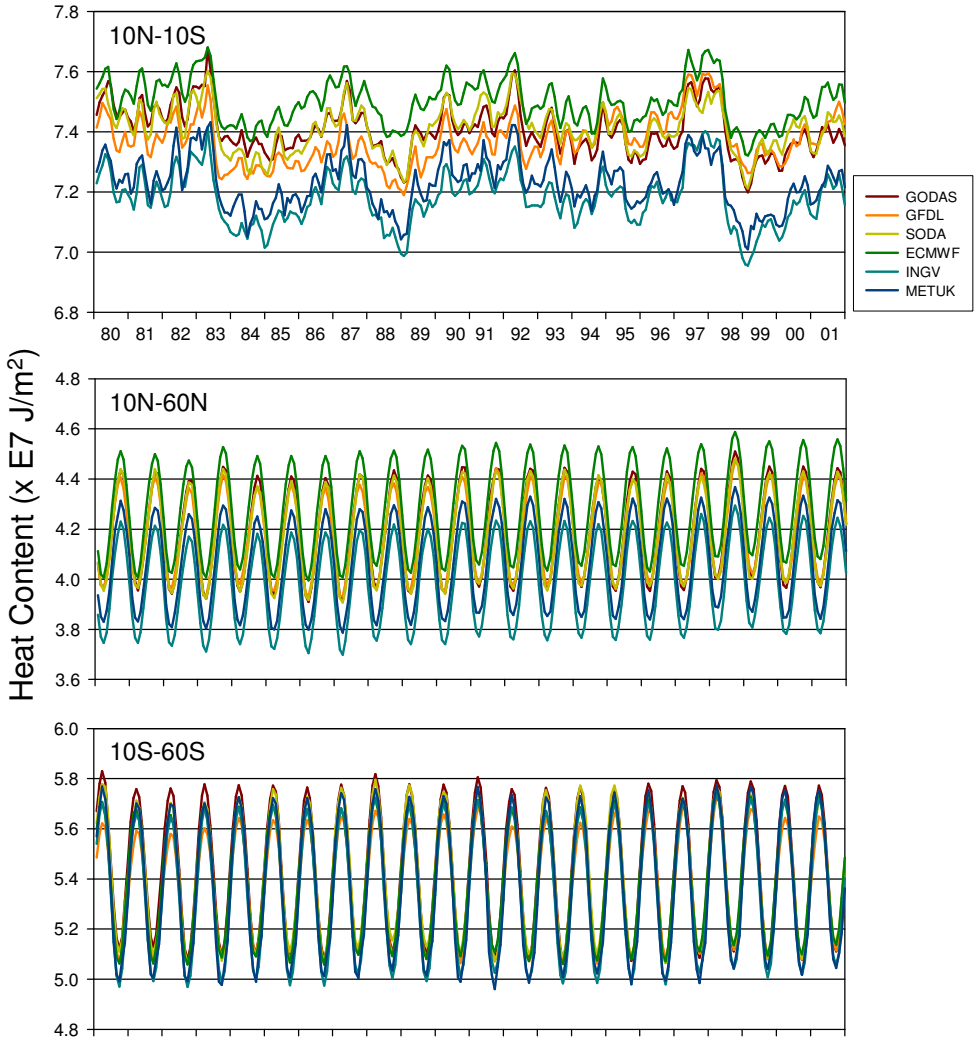
Intercomparison of Ocean Reanalysis Products

Variability of Upper Ocean(125m) Heat Content

Multiple reanalysis can provide a diversity of ocean initial condition, within observational constraints



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What is impacts of ocean assimilation on forecast skill ?

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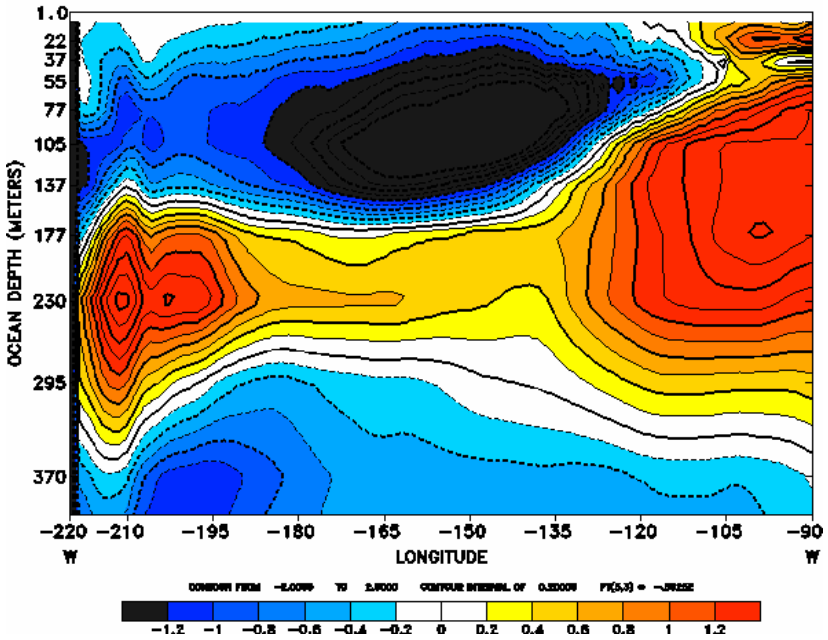
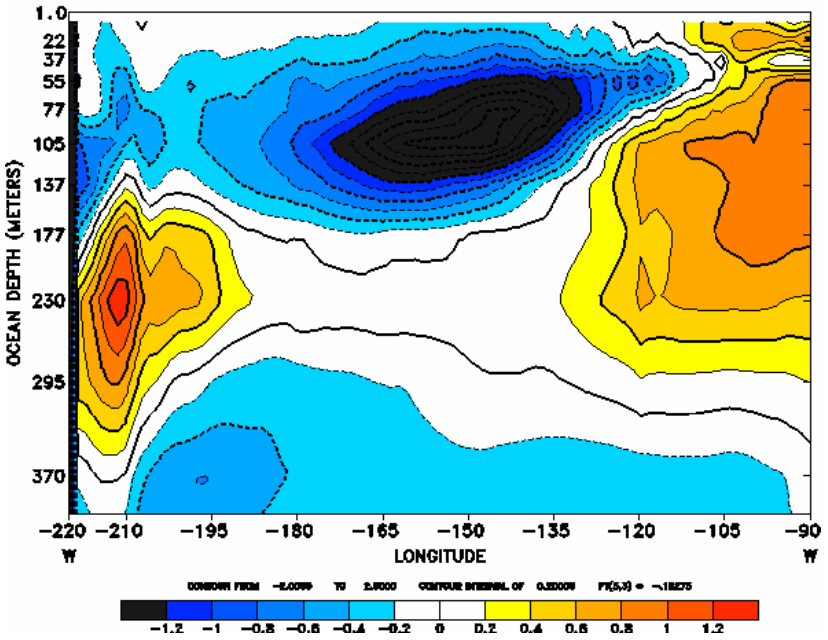
Impact of ocean assimilation on forecast skill

Equatorial Pacific Temperature Bias vs Depth
Nudging vs Assimilation Initial Conditions

SST nudging - GODAS



2DVar Assimilation - GODAS



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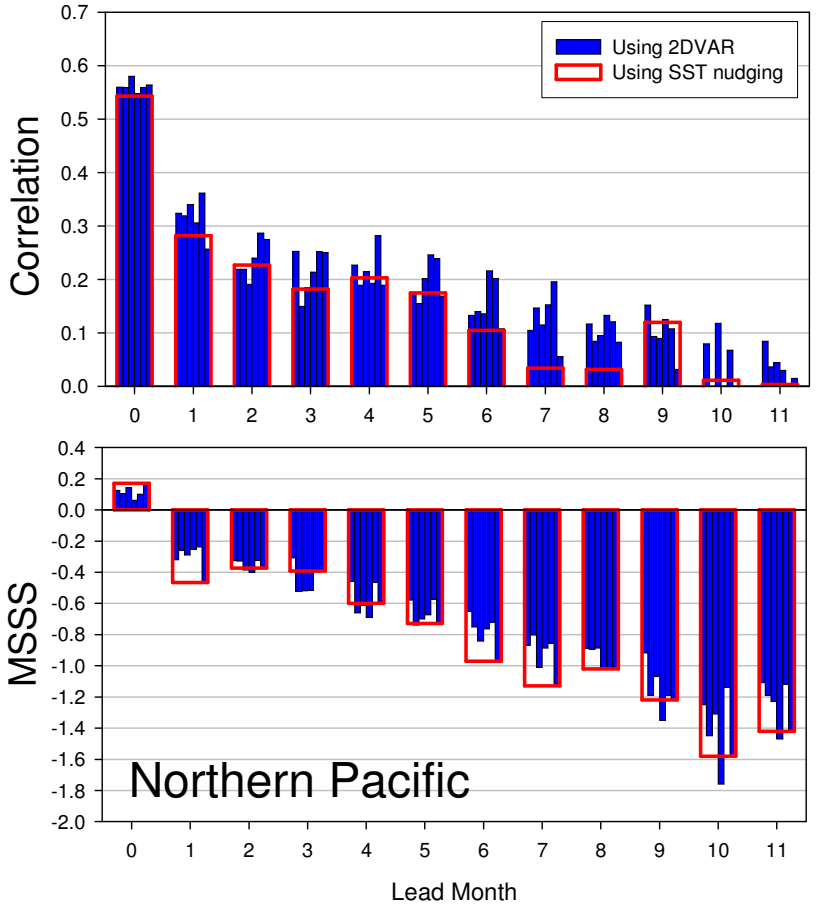
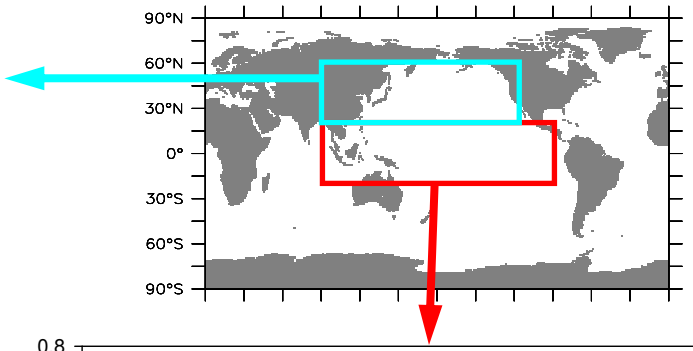
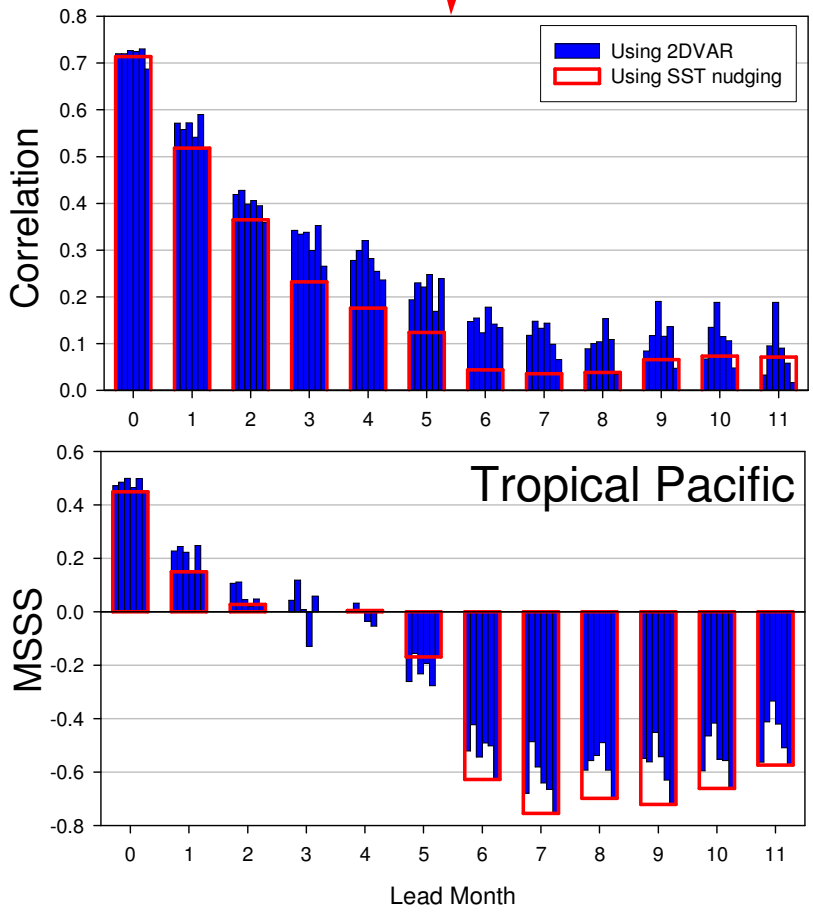
Impact of ocean assimilation on forecast skill

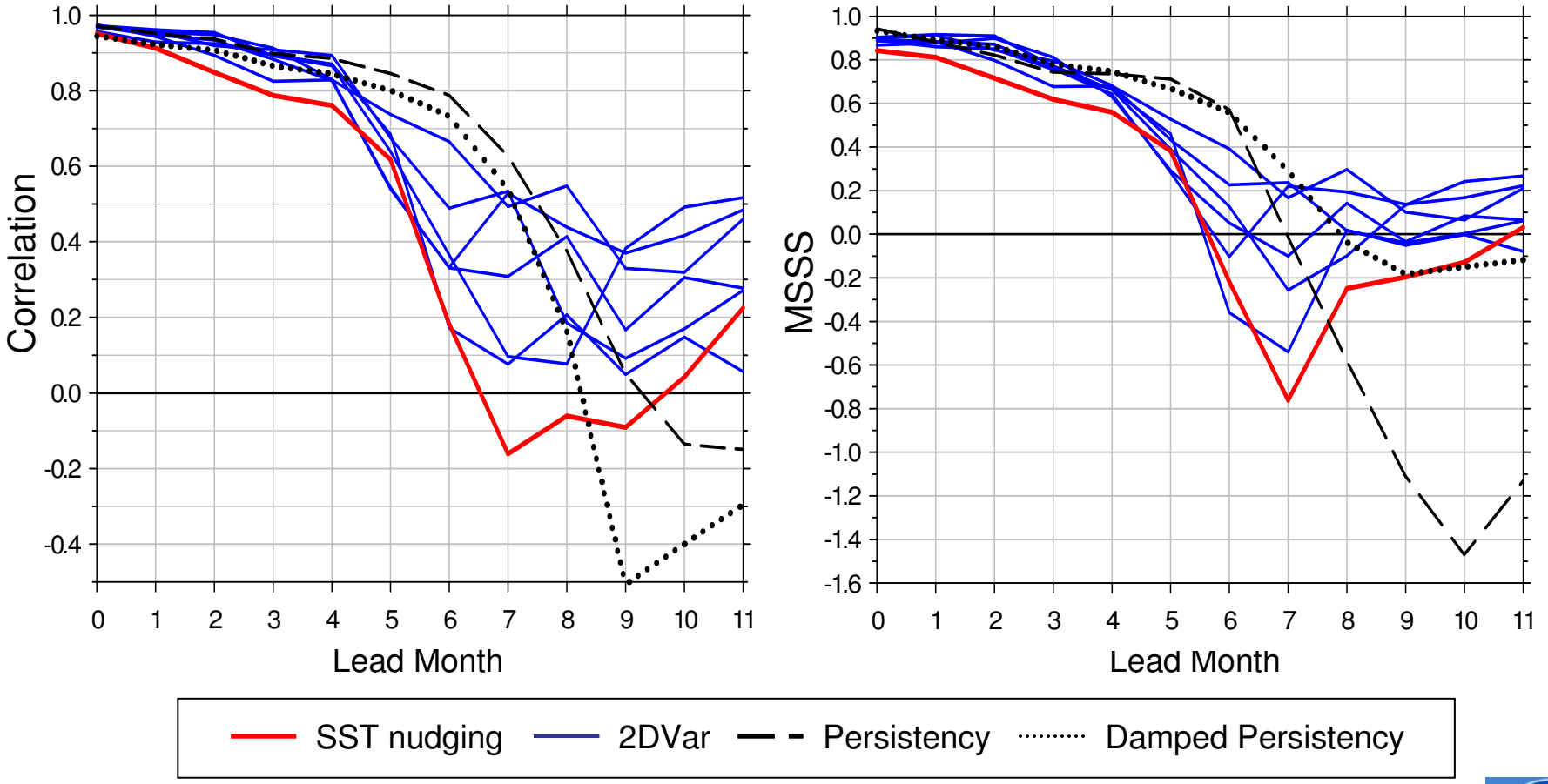






Impact of ocean assimilation on forecast skill

Skill in SST Anomaly Prediction
Nino 3.4 (1980.9-2001.8)



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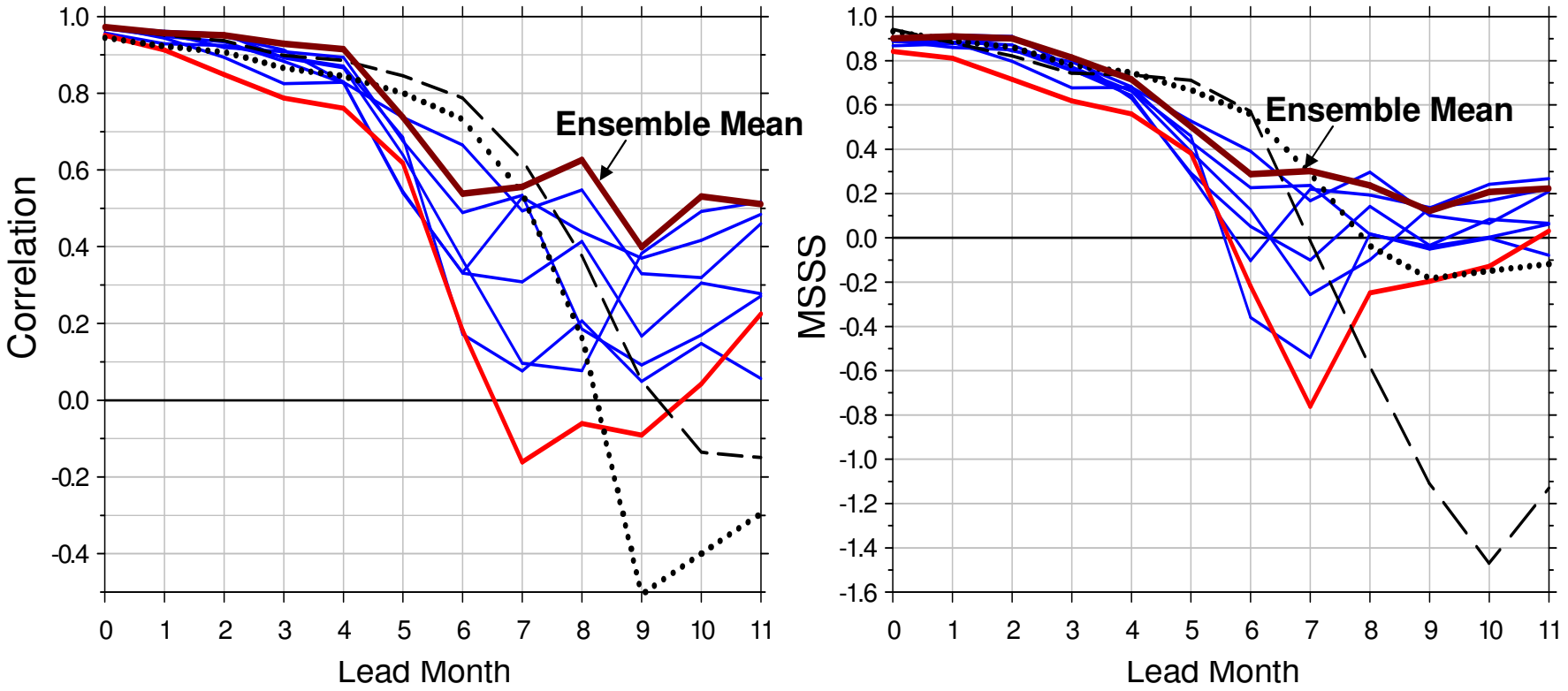

Multi-reanalysis ensemble forecast

Impact of different ensemble generation strategies on quality of ensemble forecast ?

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Evaluate of multi-reanalysis initialization

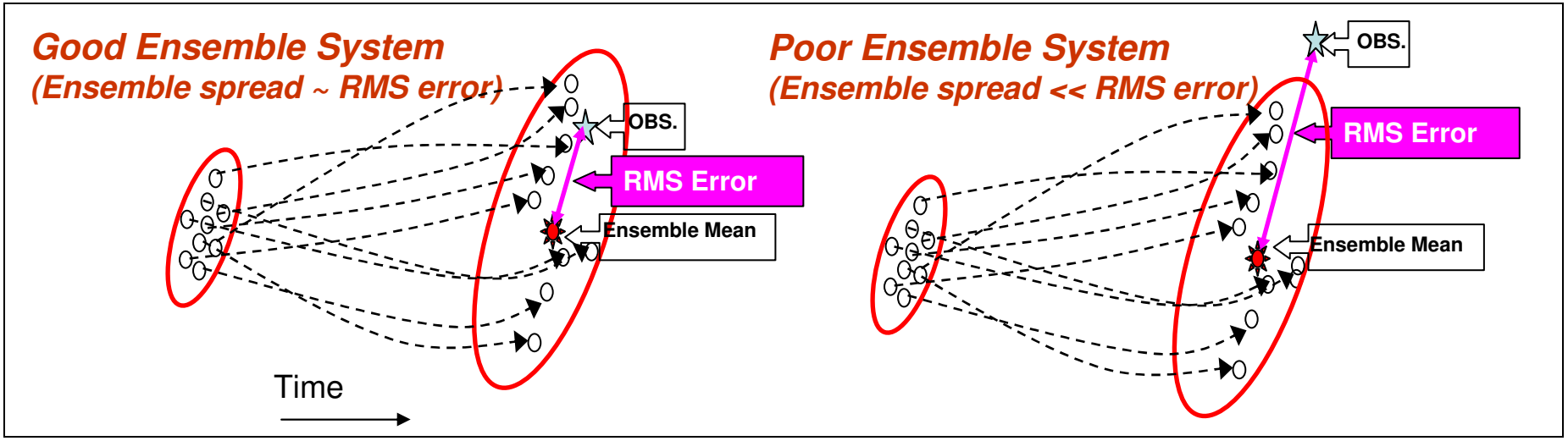
- Model : CCCma CGCM3 (AGCM: T63L31 OGCM:1.4x0.94xL33)
- Period : 1980-2001(22-year) Aug-initialization Forecast
- Experimental Design

	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					

Evaluate of multi-reanalysis initialization

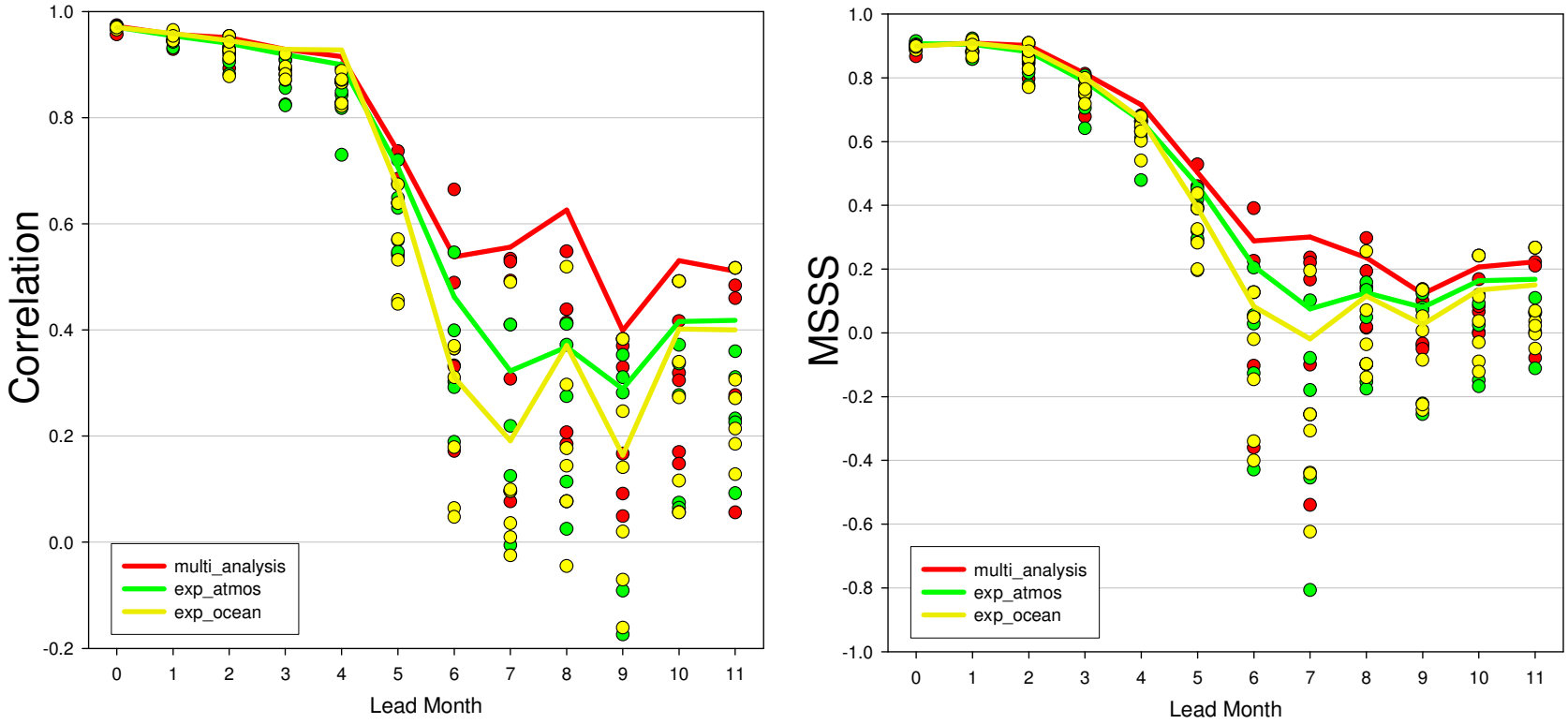
Desirable properties of a reliable ensemble system

- ❖ **Superiority of ensemble mean forecast to individual ensemble members**
- ❖ **Ensemble spread -skill relation**
  - **- Ensemble (RMS) spread ~ RMS Error of Ensemble mean**
  - **- Small (Large) spread should indicate low forecast uncertainties more (less) confidence are given to the forecast**



Evaluate of multi-reanalysis initialization

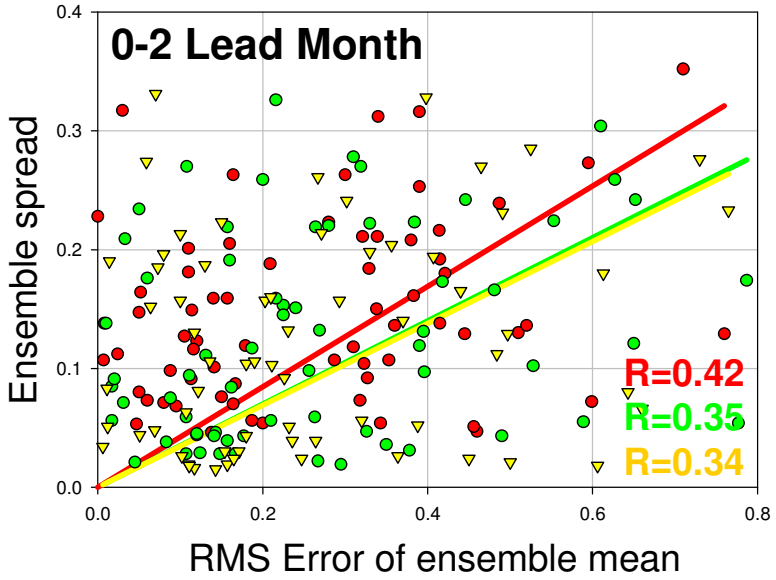
Skill in SST Prediction : Nino3.4

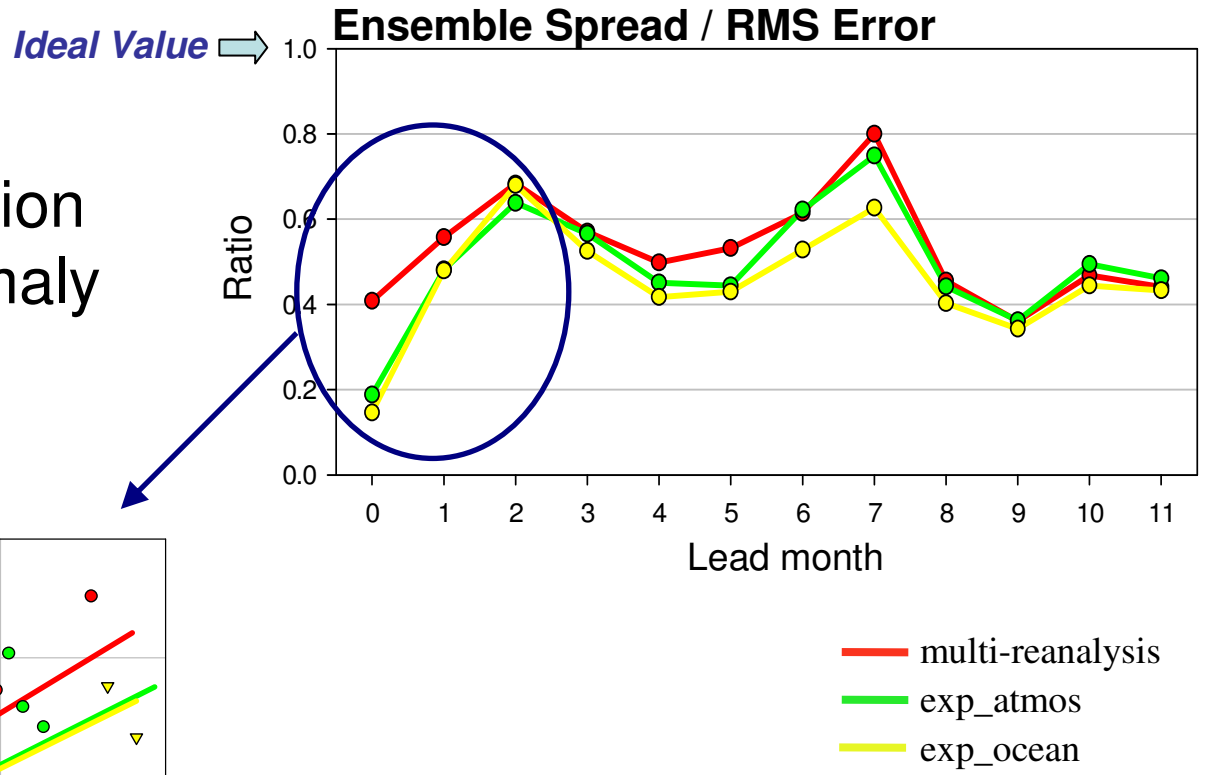


Lines : Ensemble Mean, Symbols : Ensemble members

Evaluate of multi-reanalysis initialization

Skill-Spread Relation
Nino3.4 SST Anomaly





Multi-reanalysis initialization improves ensemble spread early in forecast

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Summary

- 6 ocean reanalysis products are used as input for 2DVar ocean data assimilation for providing diversity in ocean initial condition.
- Ocean data assimilation improves the forecast skill.
- Initialization by assimilation of multi-reanalysis ensemble improves ensemble spread and skill, compared to traditional ensemble generation strategies.

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