GOAPP Network Workshop
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Previous Research & Future Plans

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Introduction

❖ Research Experience

"Mechanism of ENSO using CGCM"

2000	2001	2002	2003	2004	2005	2006	2007

Yonsei Univ. (2000–2001)

- Develop YONU CGCM
- Research on the ENSO Mechanism
- Prediction of the Global Warming at Times of doubled CO_2

Climate Res. Lab/ APCC KMA (2002–2005)

- Develop the High-Resolution KMA Model
- Evaluation of APCC MME System
- Develop the MME Tech.
- Produce the Deterministic /Probabilistic Seasonal Prediction

Yonsei Univ. (2006–2007)

- Investigate the Characteristics of Typhoon Simulated by CGCM
- Research on Oceanic Variability (MLD, Vertical mixing, Heat Contents) using OGCM

Main Interest

- **Development of Climate System Model**
  - Improvement of dynamical & physical processes in OGCM
  - Development of coupling-technique and data assimilation method

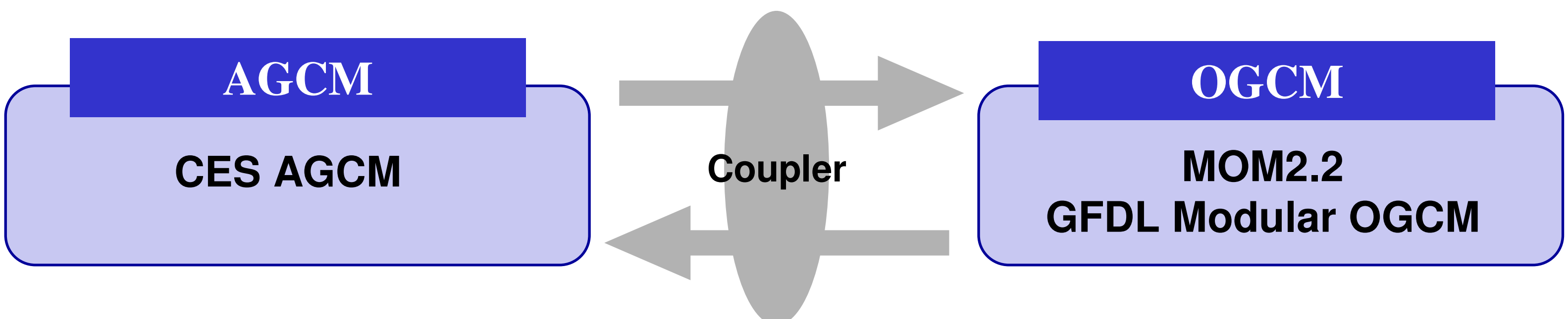
- **Climate Change**
  - Estimation the future global warming according to CO^2 doubling
  - The influence of greenhouse warming on the Typhoon climatology in CGCM (intensity, frequency and track)

- **Dynamics of Atmosphere/Ocean Interaction**
  - Mechanism of ENSO
  - The spatial-temporal variability of MLD, vertical mixing, and heat contents
  - The impact of atmospheric forcing on MLD

- **Long-Time Prediction**
  - Production and Verification of seasonal prediction by dynamical and Statistical Model

Structure of CES CGCM

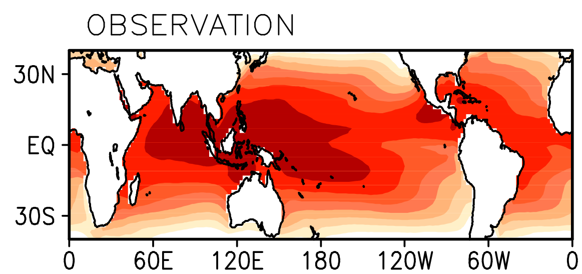
<table>
<tr><th>CGCM</th><th>AGCM</th><th>OGCM</th><th>Coupling Strategy</th></tr>
<tr><td rowspan="2">CES CGCM
(Ver. 2)</td><td>CES AGCM
T42, 21 levels
(2.8125X2.8125)</td><td>MOM2.2 OGCM
+ Ocean mixed layer model
Uneven Grid
(1 lon. X 1/3 lat. near equator)</td><td>1-day Mean Exchange
(SST, Heat Flux, Wind stress, Fresh Water Flux)
No Flux Correction</td></tr>
<tr><td colspan="3">Mixed Layer Model (Noh and Kim, 1999)
- To simulate the correct vertical ocean structure
Vertical Eddy Viscosity : $K_M = S_M ql$ where S_M, S_H : empirical Constant
Vertical Eddy Diffusivity : $K_H = S_H ql$ $q^2/2$: TKE
l : the length scale of turbulence</td></tr>
</table>

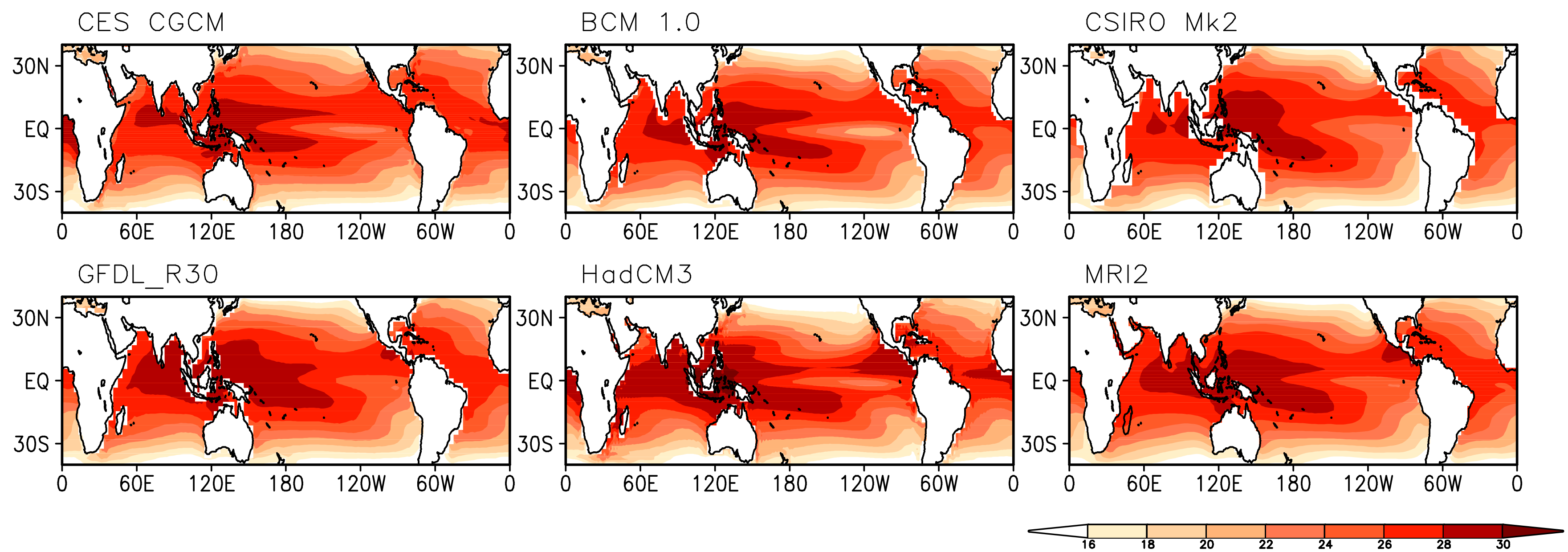


Mixed Layer Model
Noh and Kim, 1999

Results of CES CGCM

SST /
CMIP Simulations



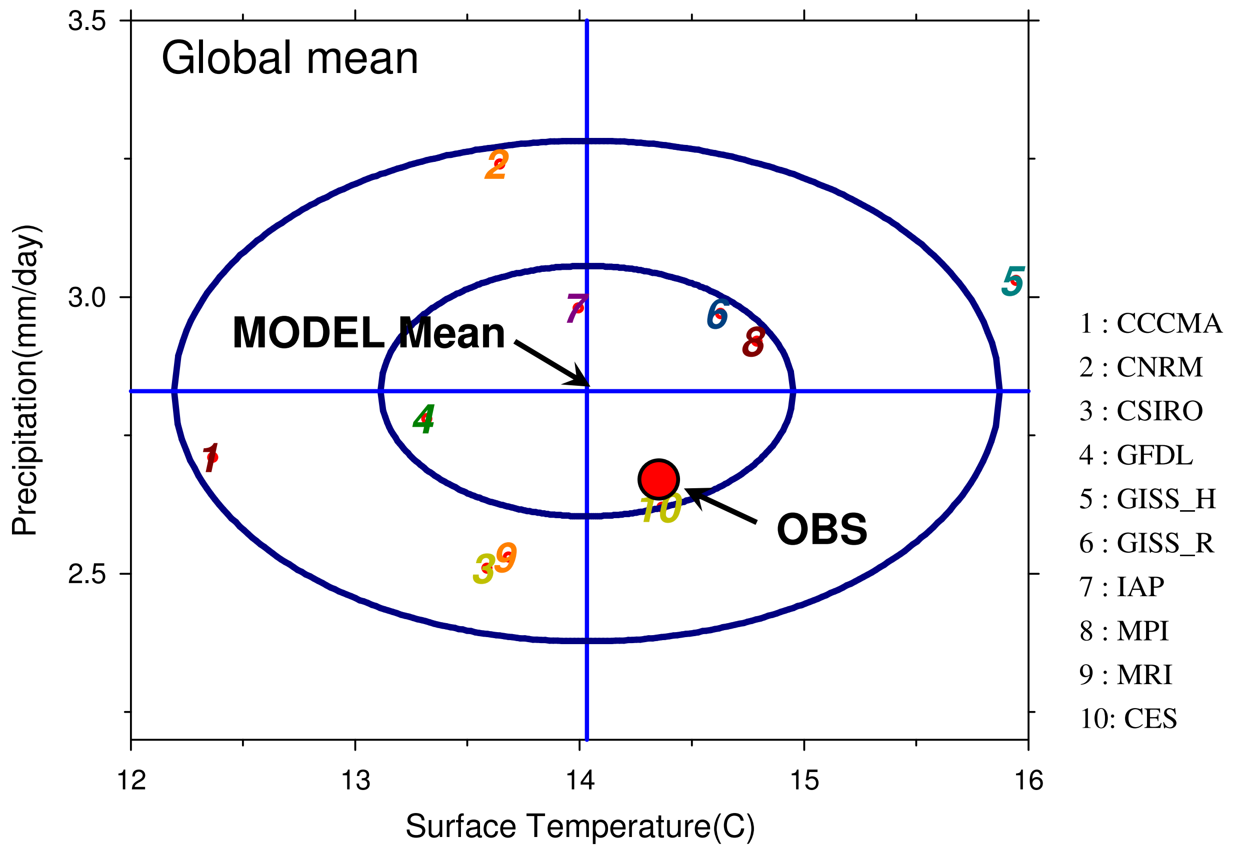


❖ Common Problems in CGCM Simulations

- Warm Bias at Eastern Edge of the Equatorial Pacific
- Too strong Cold tongue
- Kuroshio Extension region

Results of CES CGCM

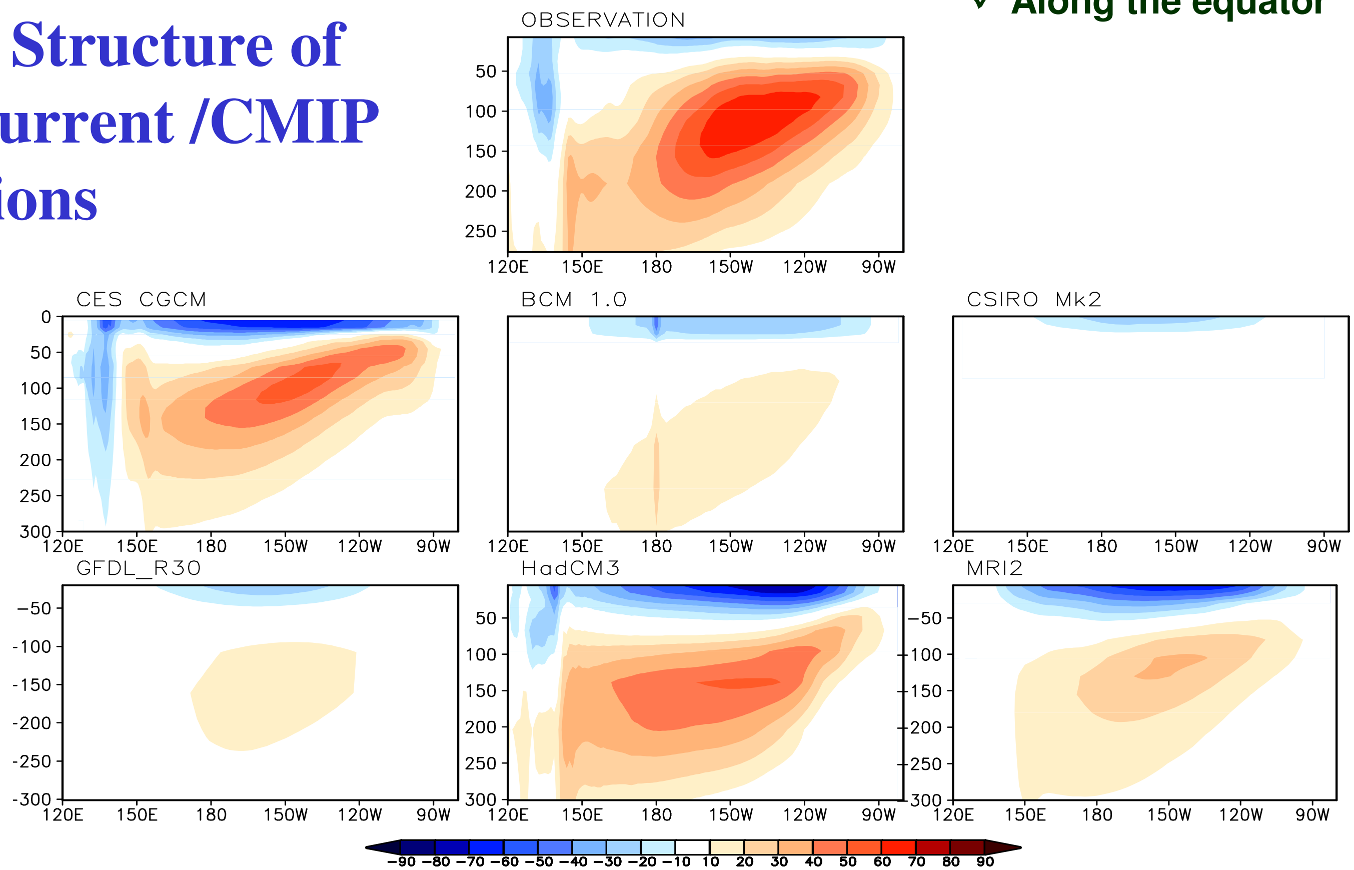
Scatter-Plot of global mean Temp. and Prec.



Results of CES CGCM

✓ **Along the equator**

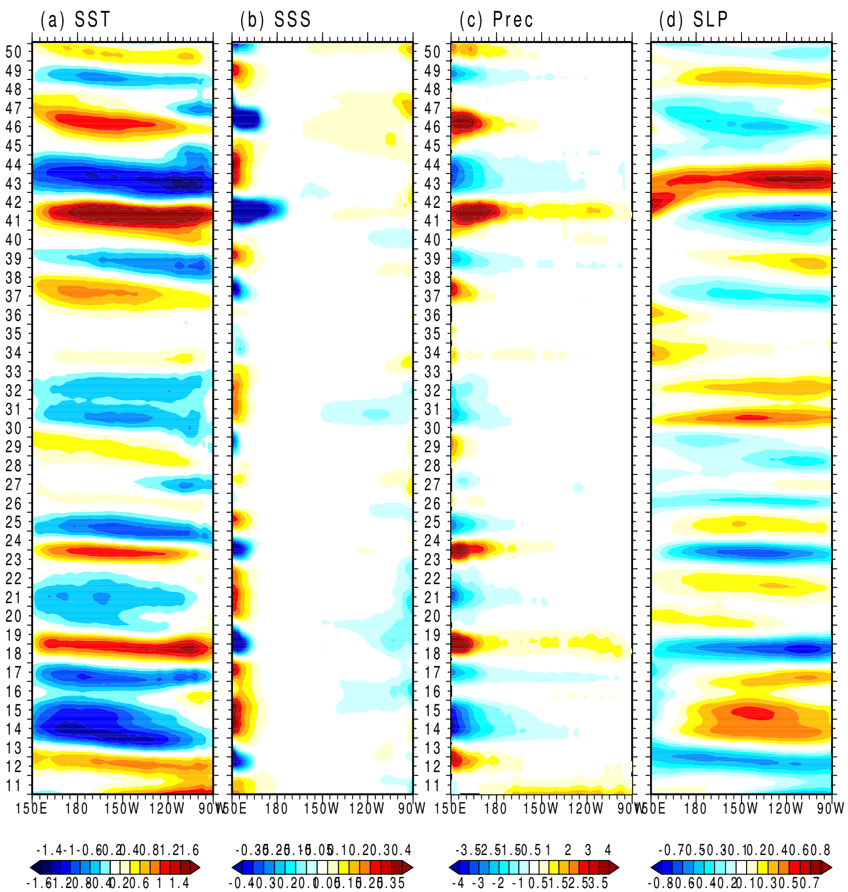
Vertical Structure of Zonal Current /CMIP Simulations



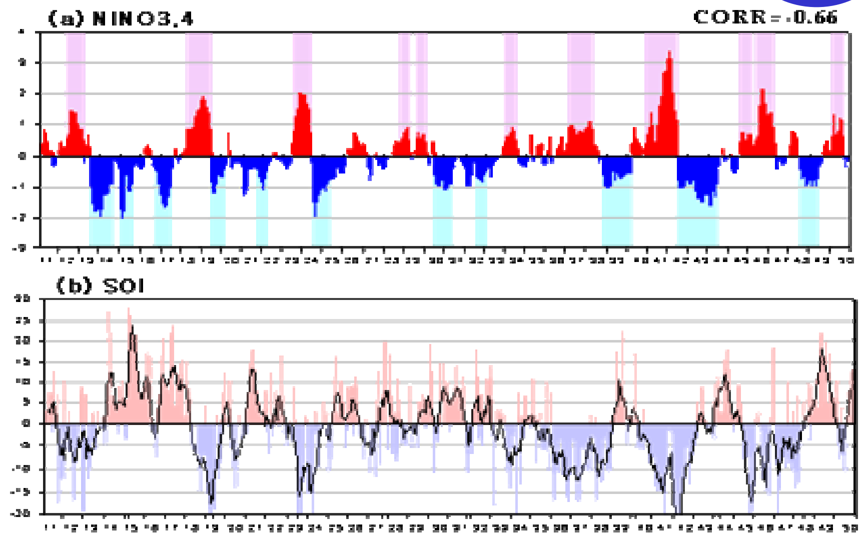
❖ **Common Problems in CGCM Simulations**

- Mostly simulate weak equatorial undercurrents
- Strong easterly surface currents
- Some models have a critical problem to simulate oceanic vertical structure

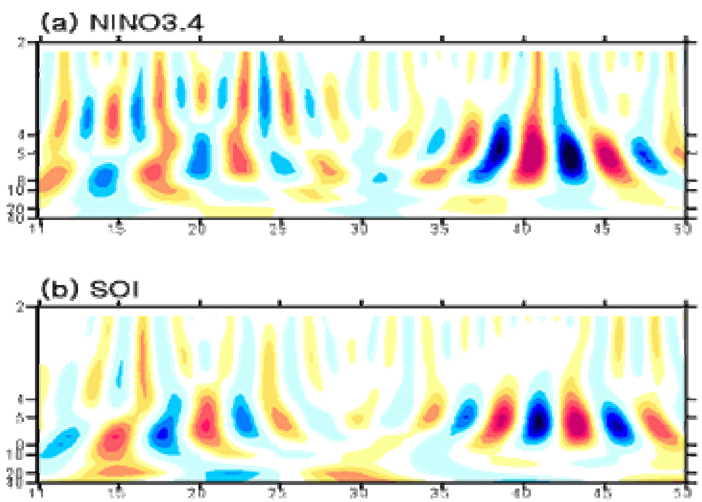
Results of CES CGCM



Hovmoller diagram of 5ºN-5ºS averaged simelated (a) SST, (b) SSS, (c) precipitation, and (d) sea level pressure.



The time series of (a) NINO3.4 index, and (b) SOI



Wavelet of (a)NINO3.4 index and (b)SOI

- Study the influence of greenhouse warming on the Typhoon climatology (intensity, frequency and track)
- Investigate a variability of Typhoon
- Investigate a relationship between climatic variability (ENSO, PDO, Ocean Heat contents, MLD…) and Typhoon variability

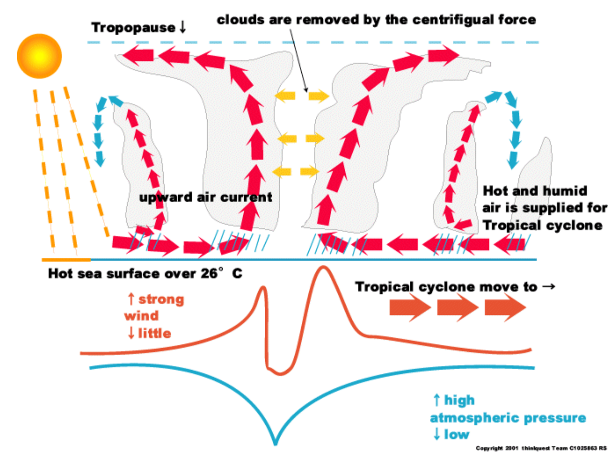
Typhoon simulated by CGCM

Criteria for detecting Tropical Cyclone

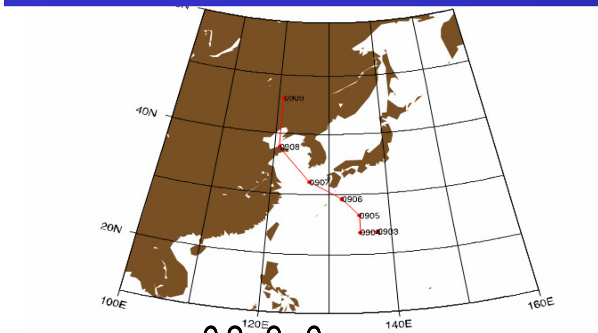
Variable	Wu and Lau(1992)	Bengtsson et al.(1995)	Matsuura (2003)
Minimum MSLP	Minimum relative to the 8 surrounding points	Minimum relative to the 8 surrounding points	≤ 1008hPa
Maximum wind speed	≥ 17.2 m/sec (at 950hPa)	≥15.0 m/sec (at 850hPa)	≥17.0 m/sec (at 850hPa)
Relative vorticity	Cyclonic at 950hPa	$\geq 3.5\times10^{-5}$ s^{-1} (at 850hPa)	$\geq 1.2\times10^{-4}$ s^{-1} (at 850hPa)
Geopotential Height	- Minimum Z1000 relative to the 8 surrounding points - Maximum thickness relative to the 4 surrounding points		
Temperature		- The sum of the anomalies at 700, 500, 300hPa > 3°C - The anomalies at 300hPa > The anomalies at 850hPa	
Velocity	0 ≤ U200<5m/sec 0 ≤ U950	|V| at 850hPa > |V| at 300hPa	
Vertical motion	Upward at 500hPa		
divergence	Convergence at 950hPa		
Relative humidity	≥ 70% (at 950hPa)		
etc	Region : 40.5S - 40.5N	Duration ≥ 1.5 days	Region : 120E-180,0-40N

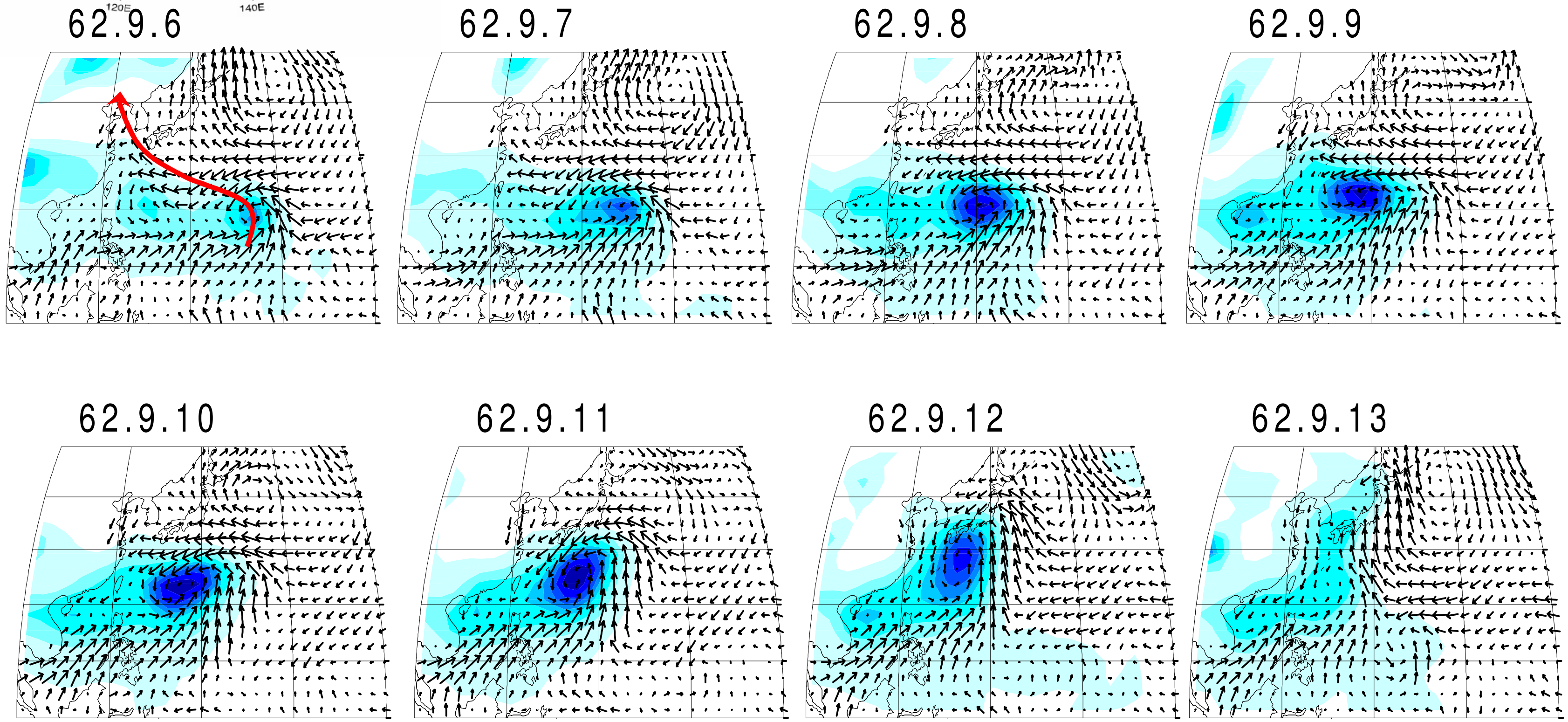
DATA : CGCM daily data (20year)

Criteria : by matsuura(2003)



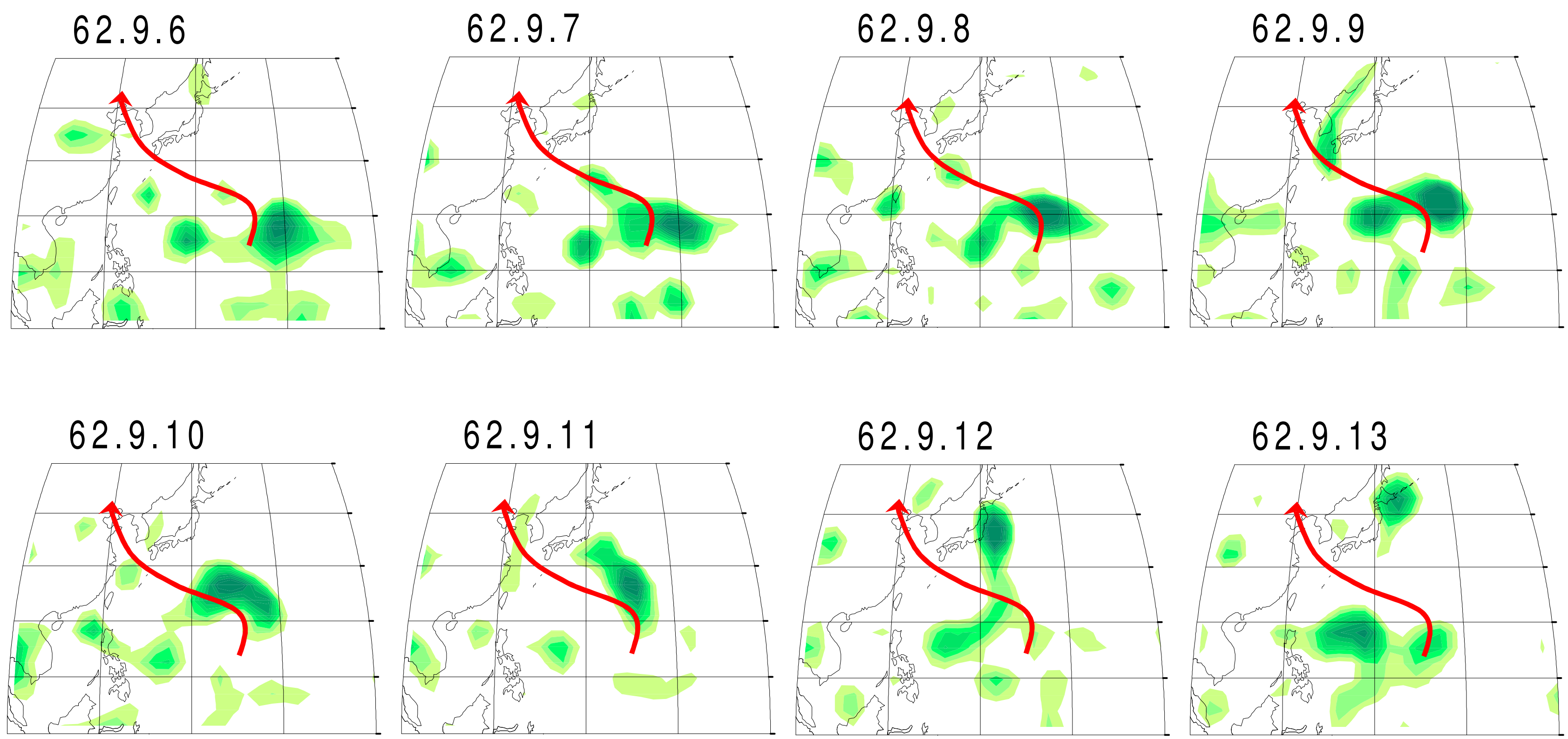
Typhoon simulated by CGCM





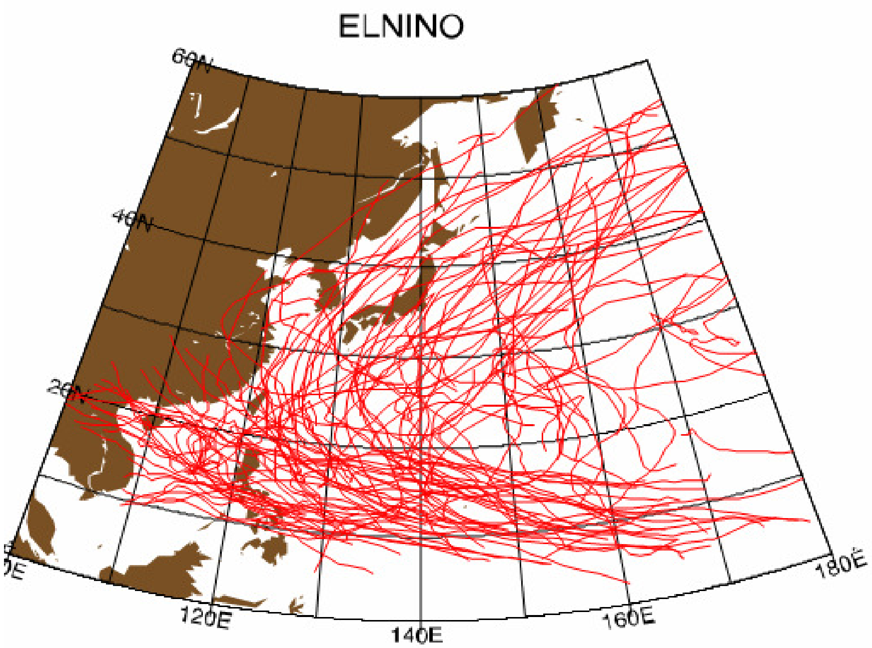
SLP(<1008hPa) and Surface Wind

Typhoon simulated by CGCM



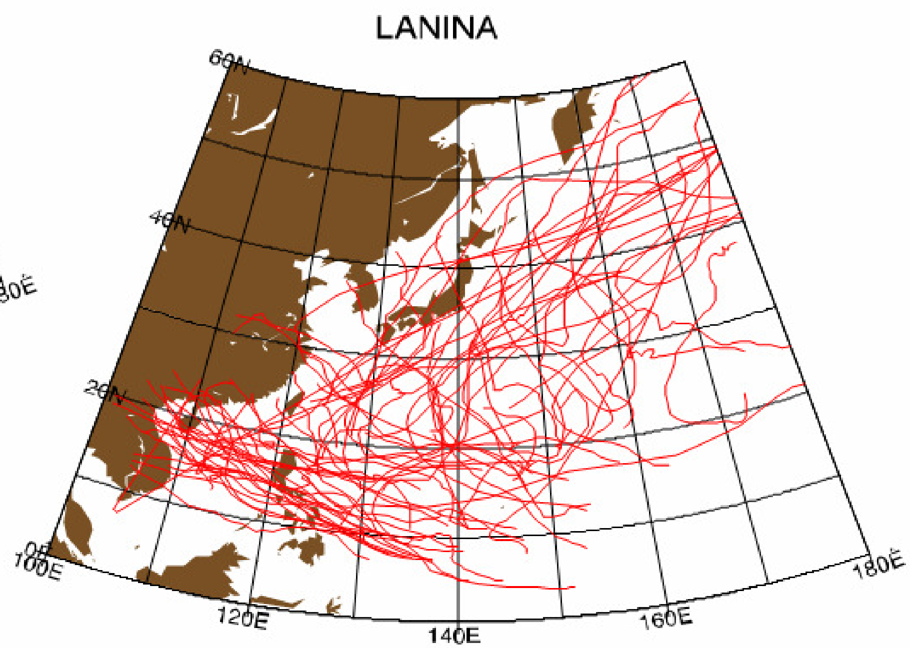
Precipitation (>20mm/day)

Typhoon simulated by CGCM

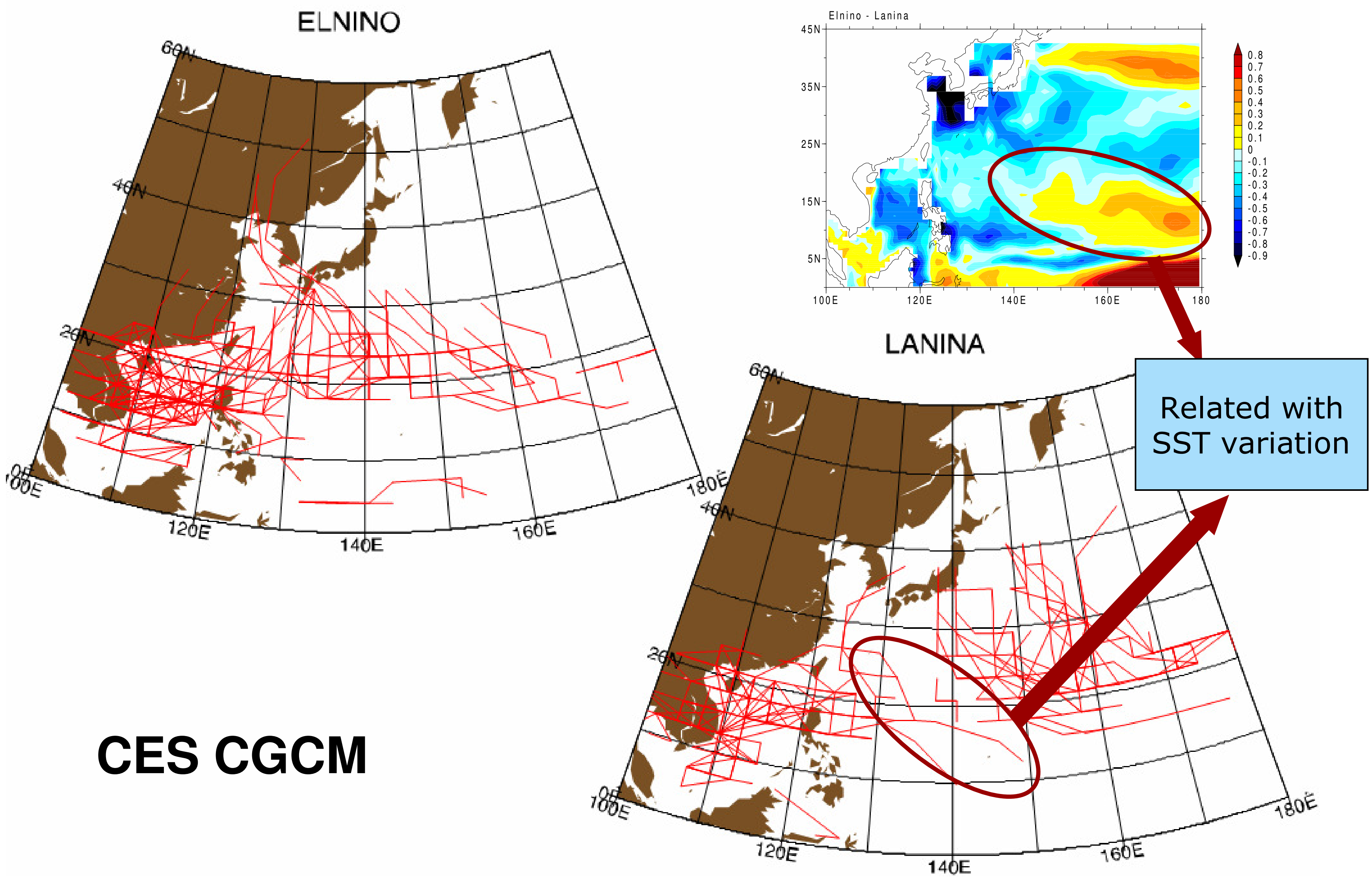


During El Nino, Typhoons more frequently move on a long track toward Korean peninsula

Observation (JTWC)



Typhoon simulated by CGCM



CES CGCM

Multi-Model Ensemble

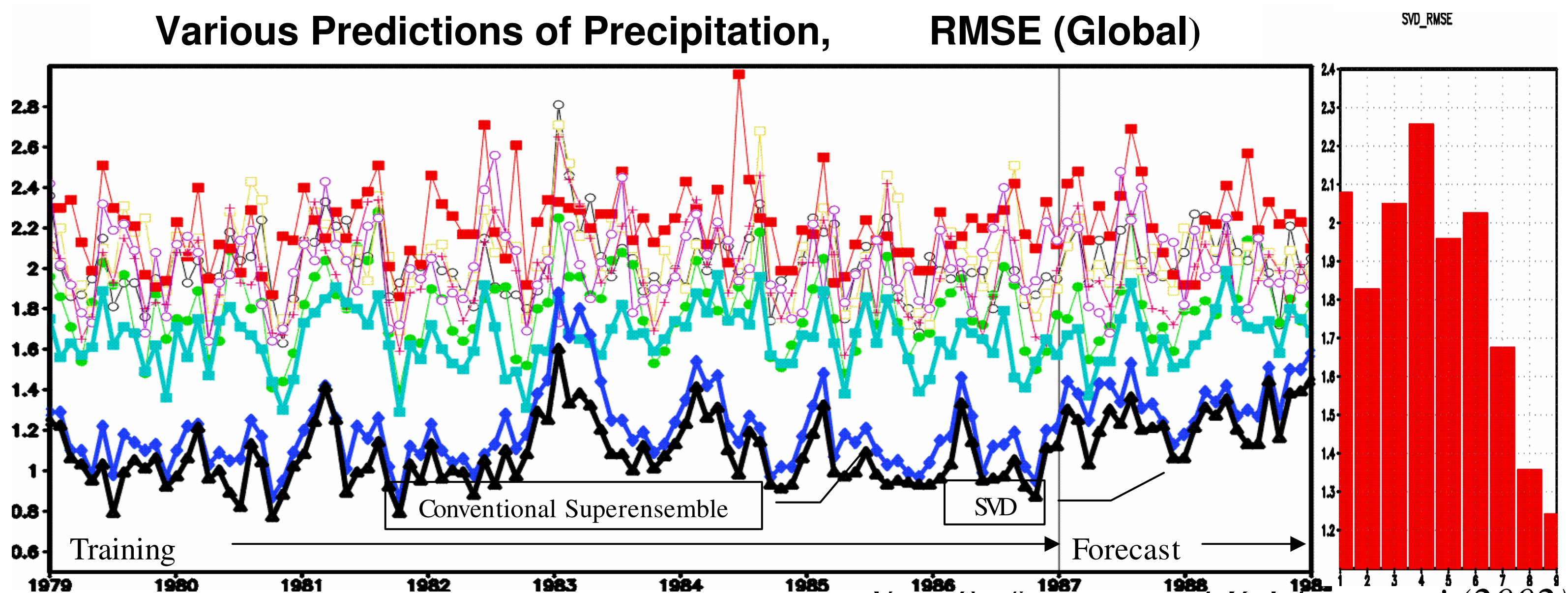
Multi-model Ensemble

Reduce systematic bias in model formulation	Reduce random error in Initial condition

Scientific Basis of MMES

- Superiority of a multi-model ensemble prediction compared to any of single prediction
- Applicability of superensemble technique to climate prediction

Various Predictions of Precipitation, RMSE (Global)



Yun, Stefanovar and Krishnamurti (2002)

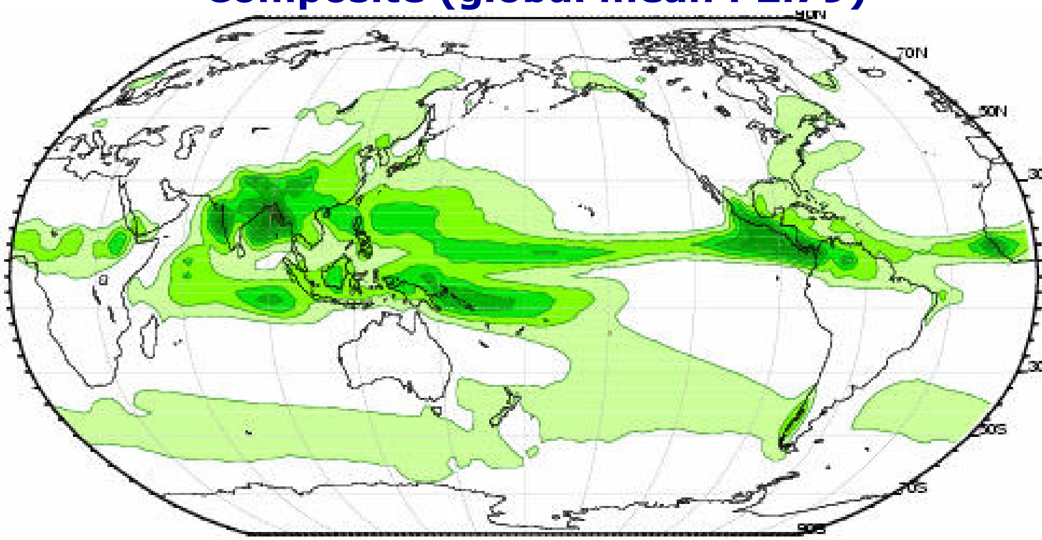
Is multi-model ensemble prediction superior to single model prediction ?

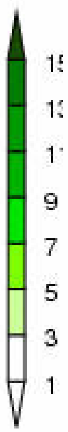
Multi-Model Ensemble

Member Economies	Acronym	Organization	Model Resolution	Hindcast Data
China	NCC	National Climate Center /CMA	T63L16	
	IAP	Institute of Atmospheric Physics	4 ° × 5 ° L2	
Chinese Taipei	CWB	Central Weather Bureau	T42L18	1979-1999
Japan	JMA	Japan Meteorological Agency	T63L40	1979-1999
Korea	GDAPS/KMA	Korea Meteorological Administration	T106L21	1979-1999
	GCPS/KMA	Korea Meteorological Administration	T63L21	1979-1999
	METRI/KMA	Meteorological Research Institute / KMA	4 ° × 5 ° L17	
Russia	MGO	Main Geophysical Observatory	T42L14	
USA	COLA	Center for Ocean-Land-Atmosphere Studies	T63L18	
	IRI	International Research Institute for Climate Prediction	T42L?	1979-1999
	NCEP	Climate Prediction Center/NCEP	T63L17	1979-1999
	NSIPP/NASA	National Aeronautics and Space Administration	2 ° × 2.5 ° L34	1979-1999

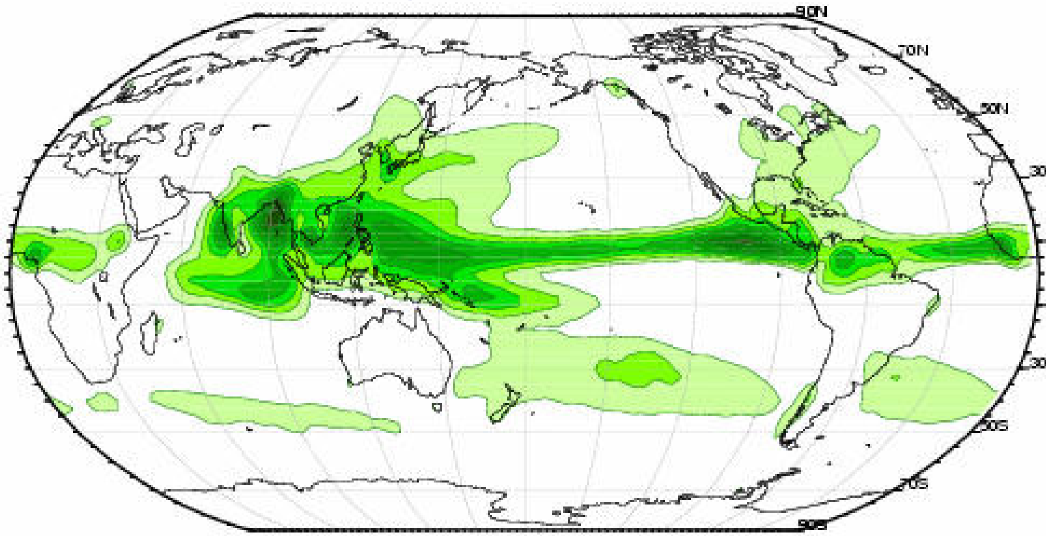
Multi-Model Ensemble

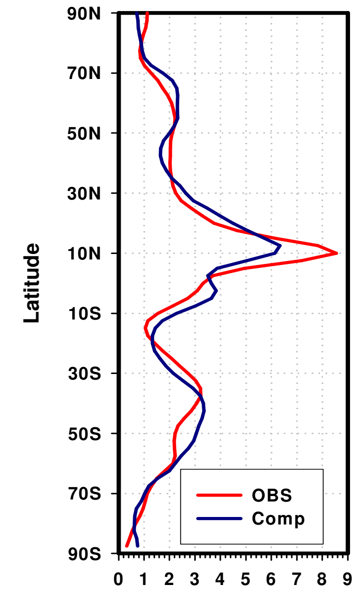
Composite (global mean : 2.79)





OBS (global mean : 2.77)



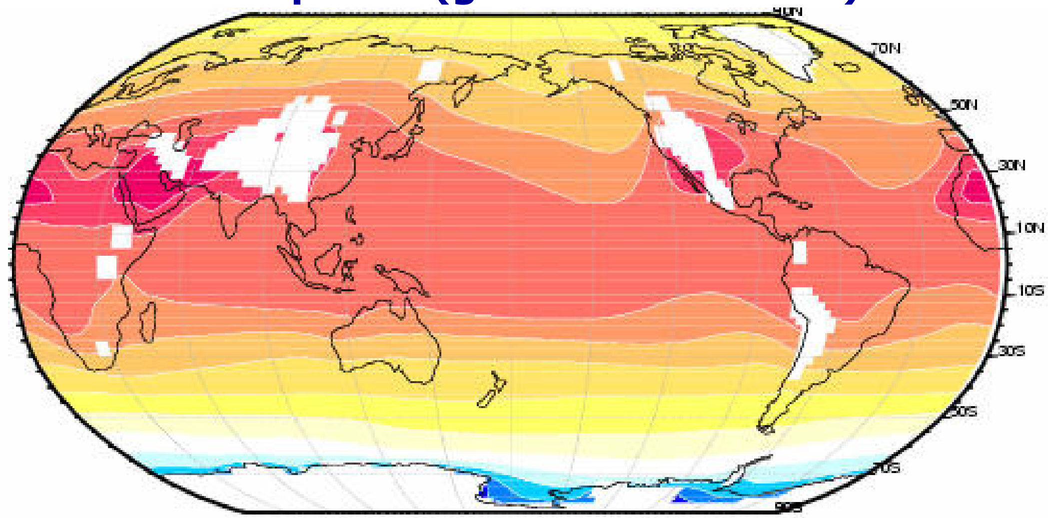


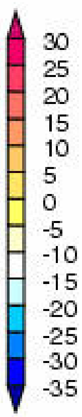
	Global Mean	Bias
Individual Model	3.25	0.48
	3.19	0.42
	2.91	0.14
	2.81	0.04
	2.72	-0.05
	2.66	-0.11
	2.49	-0.28
	2.32	-0.45
Composite	2.79	0.02

JJA mean Precipitation

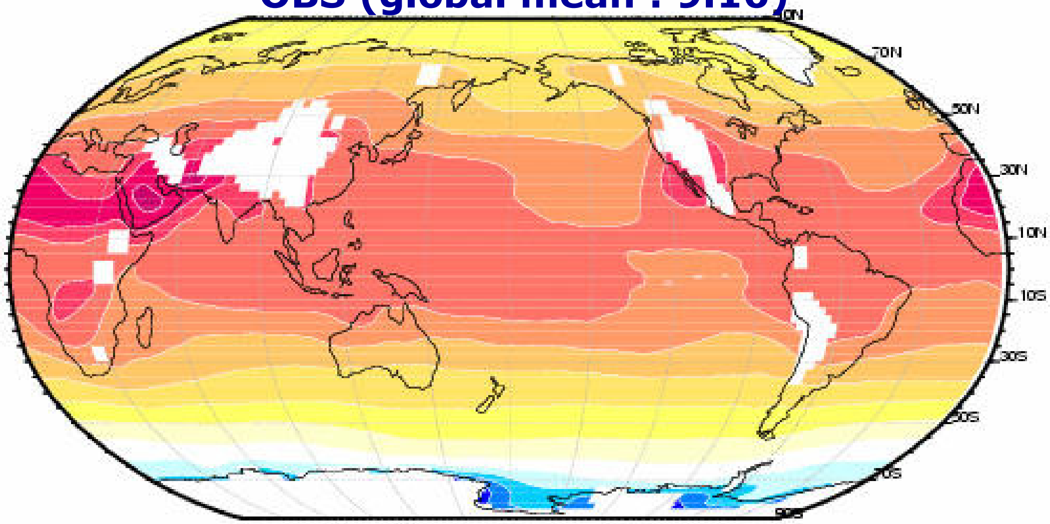
Multi-Model Ensemble

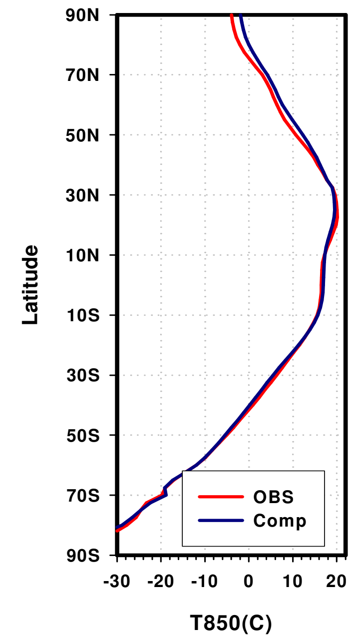
Composite (global mean : 9.14)





OBS (global mean : 9.16)

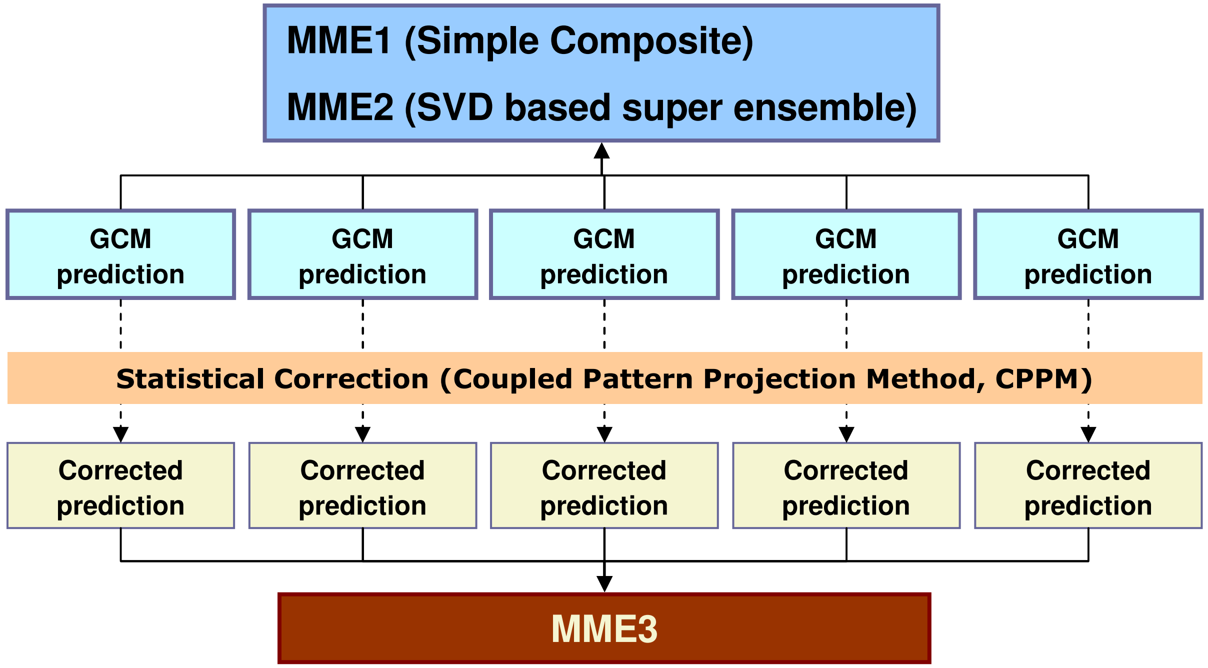




	Global Mean	Bias
Individual Model	11.09	1.93
	10.03	0.87
	9.07	-0.09
	9.07	-0.09
	8.58	-0.58
	8.42	-0.74
	7.73	-1.43
Composite	9.14	-0.02

JJA mean 850hPa Temperature

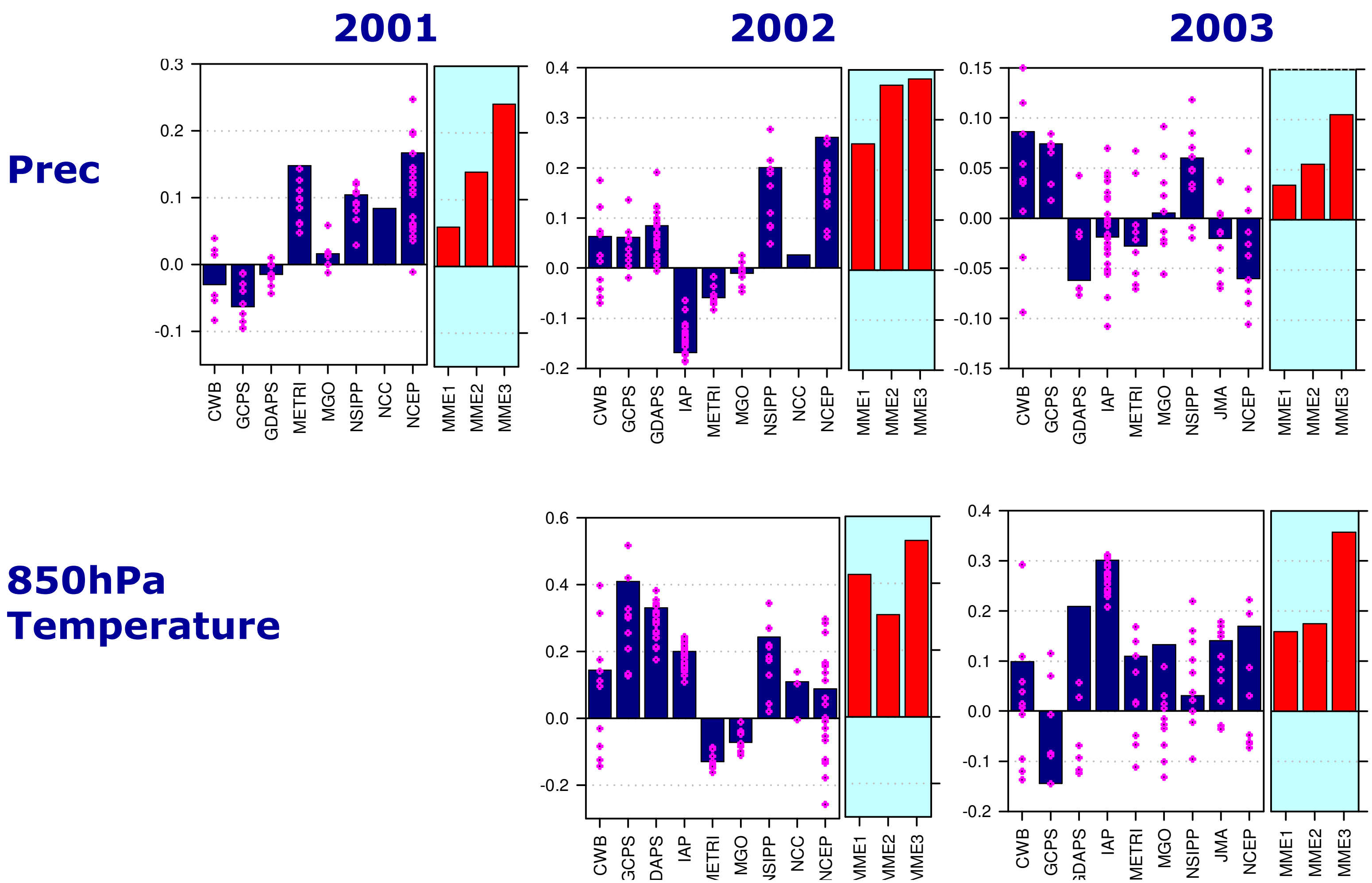
Multi-Model Ensemble



Used Model	**CWB, NSIPP GCPS, NCEP, JMA, GDAPS**
Period	• 21-year hindcasts from 1979 to 1999 • 2001/2002/2003 summer forecasts
Variable	**Precipitation, 850hPa Temperature**

Ensemble procedure

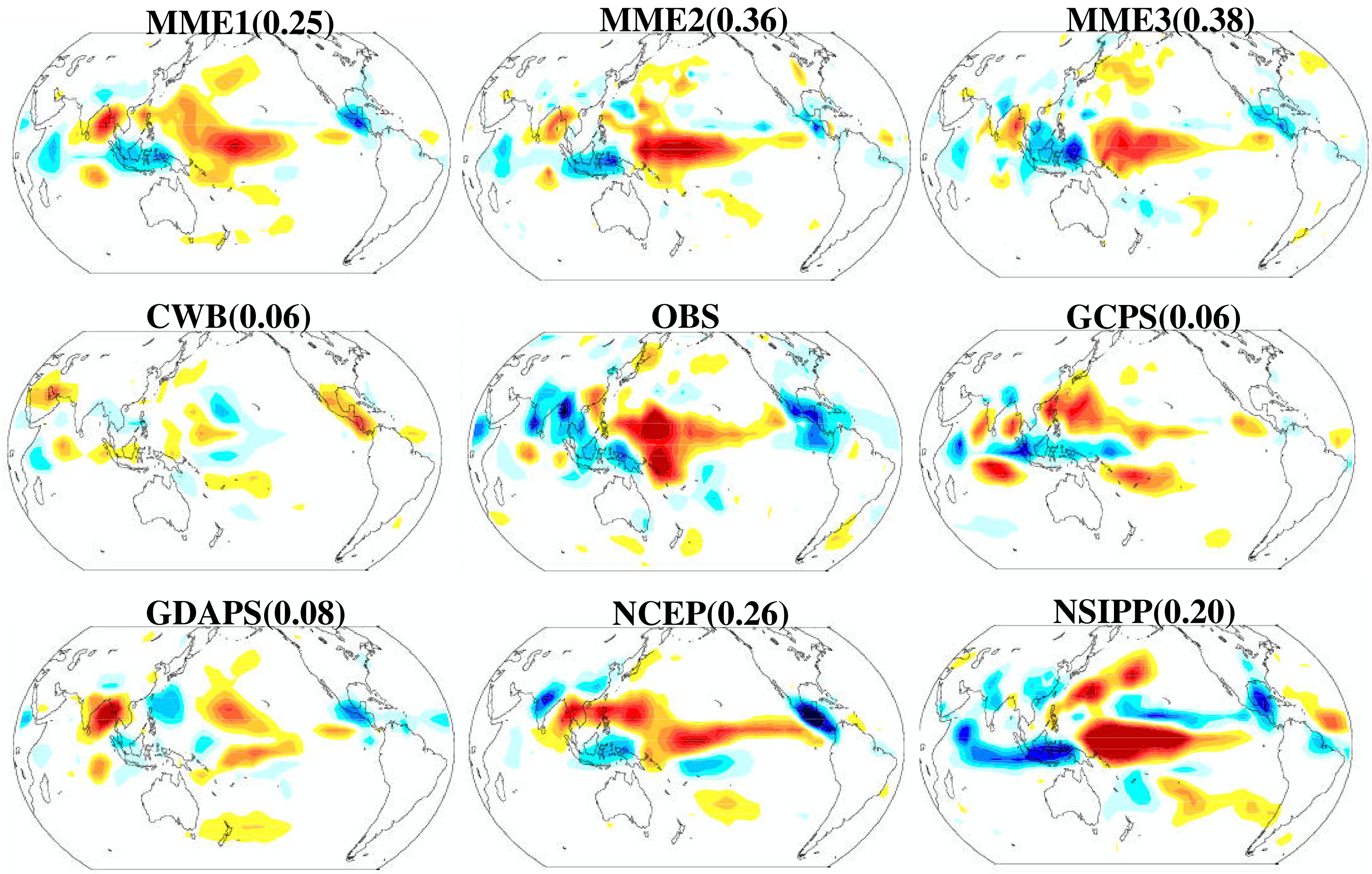
Multi-Model Ensemble



Pattern Correlation : 2001-2003 JJA Forecast

Multi-Model Ensemble

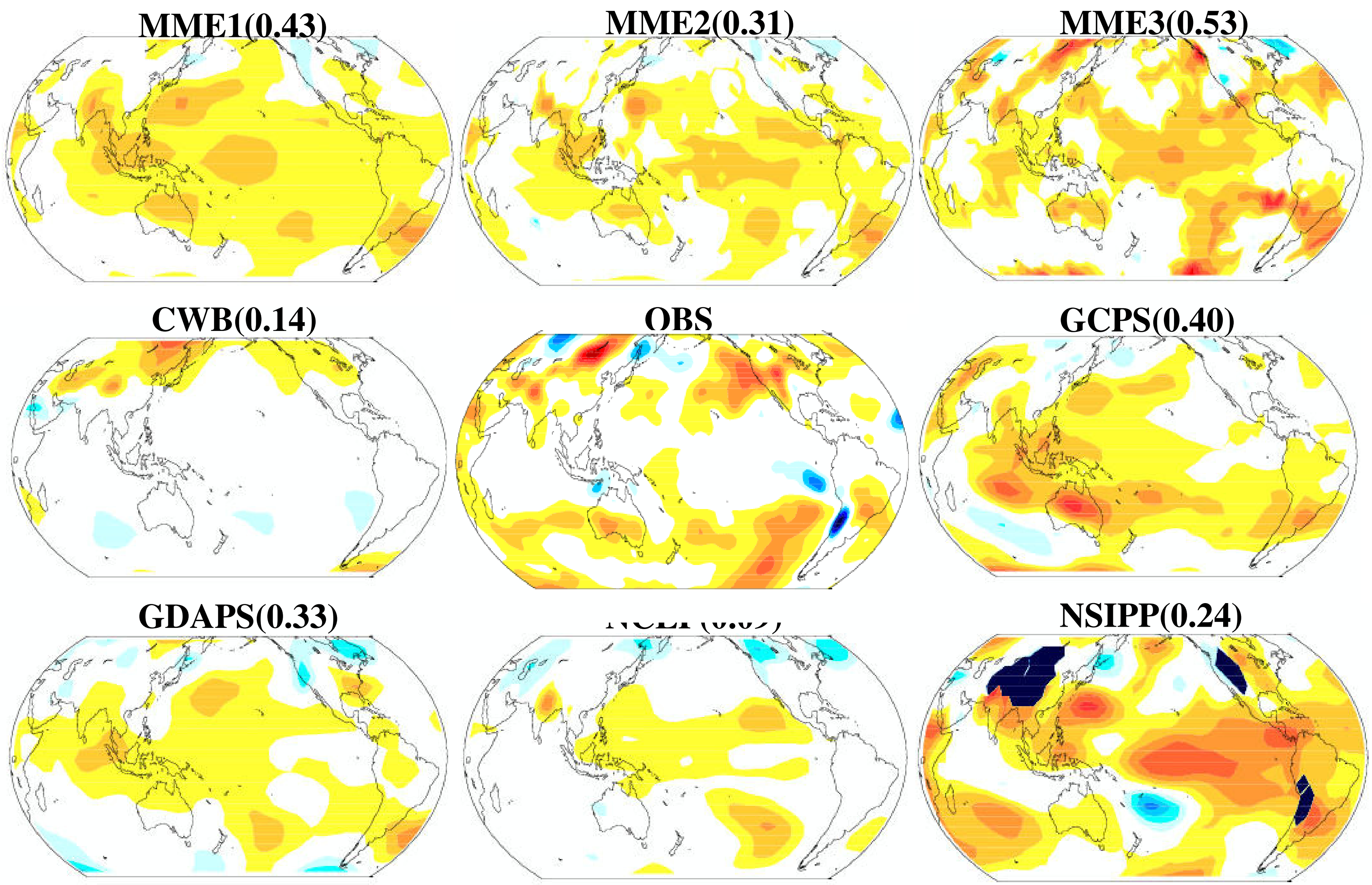
Precipitation Anomaly (JJA mean)



2002 Summer Forecast

Multi-Model Ensemble

850hPa Temperature Anomaly (JJA mean)



2002 Summer Forecast

Nonlinear Multi-Model Ensemble

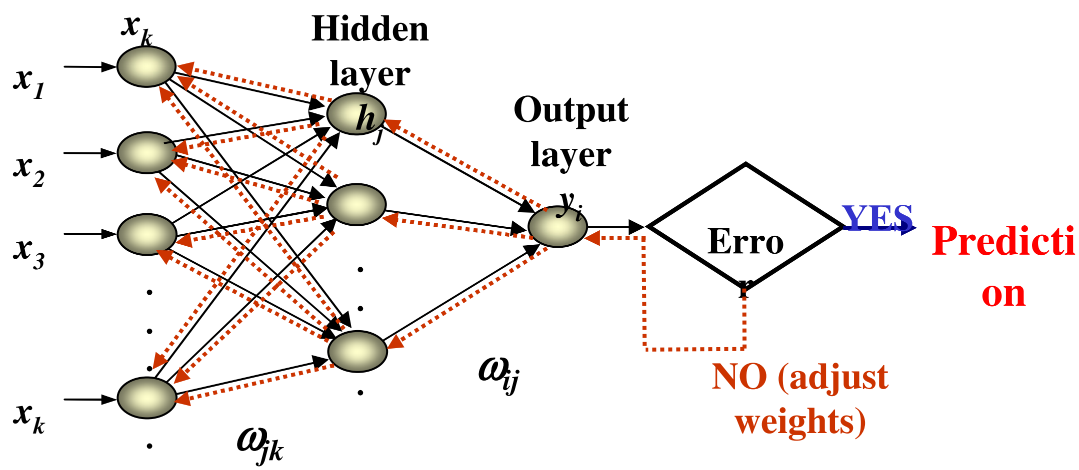
Climate system involves many nonlinear processes.

Will a nonlinear statistical model improve the prediction skill?

There have been studies applying neural networks, a nonlinear statistical method, to seasonal climate prediction (e.g., Derr and Slutz 1994; Tang et al. 1994; Hastenrath et al. 1995; Tangang et al. 1997; Hsieh and Tang 1998).

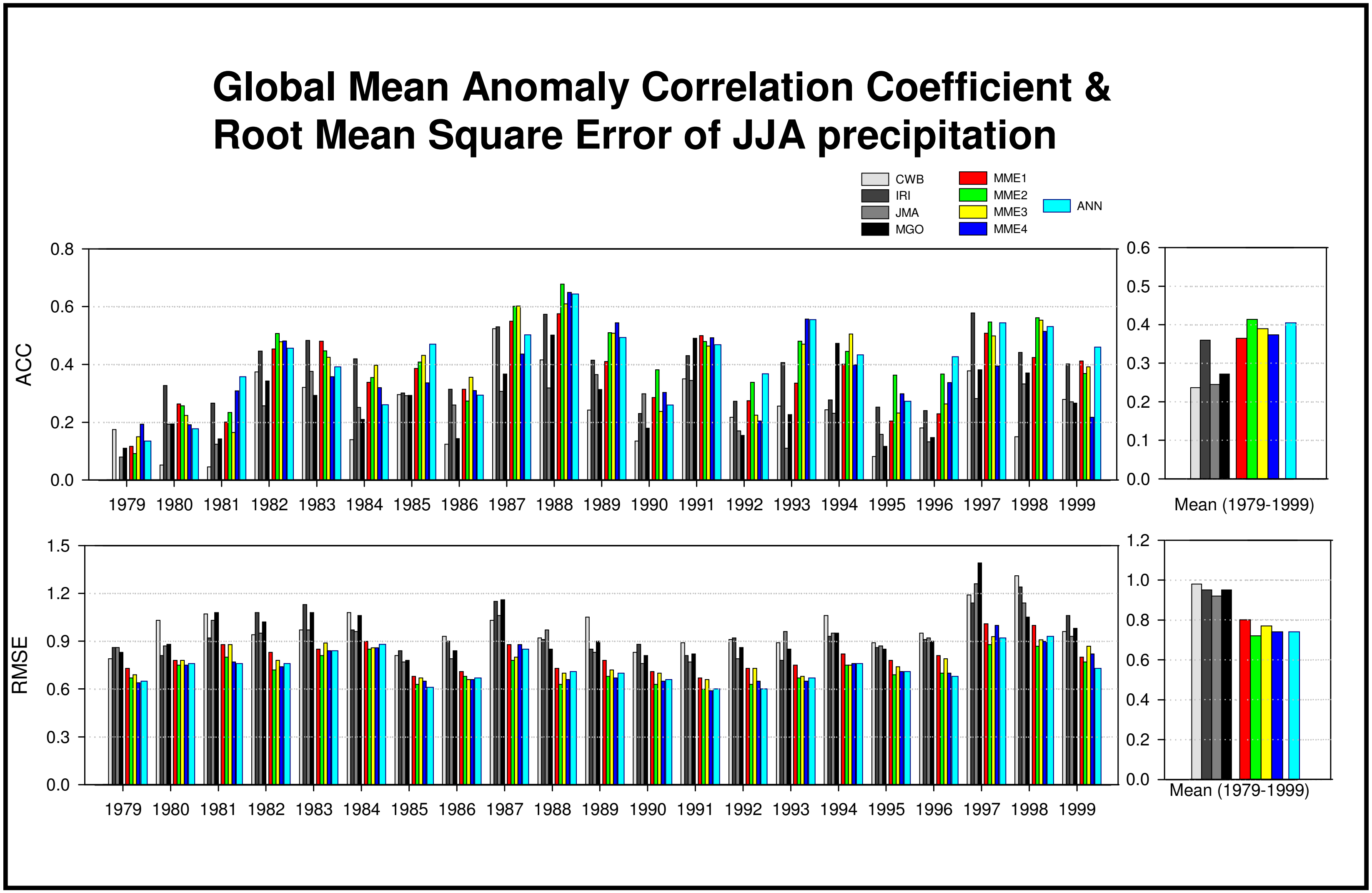
The algorithm adjusts the optimal weights such that E is minimized.

$E = (\text{network output}, y_i - \text{true})^2$



A feed-forward neural network with one hidden layer

Nonlinear Multi-Model Ensemble



Future Plan

Initialization

- Investigating ocean assimilation Schemes

Experiment

- Construction of multi-seasonal ensemble forecast system
- Running the model using initialization methods

Analysis

- Assessment of impact & improvement from initialization methods
- optimization of initialization method

CHFP

- Production of CHFP seasonal forecast(1980-2009)
- investigating the ensemble generation method

run

- Before coupling,

  - AGCM was integrated for 1 year forced by the observed SST.

  - OGCM was spun up for 10 years from motionless state initially with

    January mean temperature and salinity distributions by Levitus (1982)

    Net heat flux(Q) : $Q = Q_{ncep} + \gamma(SST_{lev} - SST_{model})$, combined

    (the restoring time scale of 11.5 days)

    the monthly heat flux and wind stress from NCEP reanalysis data.

Multi Model Ensemble prediction schemes

- **MME1** : Simple composite of individual forecast with equal weighting. (special case of MME2)

$$P = \frac{1}{M}\sum_i F_i$$

- **MME2** (Superensemble) : Optimally weighted composite of individual forecasts. The weighting coefficient is defined by regression of forecasts and observation during training period.

$$P = \sum_i a_i F_i$$

- **MME3** : Simple composite of individual forecasts, which was corrected by statistical post process

$$P = \frac{1}{M}\sum_i \hat{F}_i$$

□Determination of weighting coefficients of models for each grid point

- **Weighting coefficient (a_i)** of each model is defined by multiple regression of forecasts($F_i(t)$) and observation ($O(t)$) in the training period.

Minimizing mean square error (MSE)

$$MSE = \overline{\left(\sum_i a_i F_i(t) - O(t) \right)^2}^{Training} \longrightarrow C \cdot a = \tilde{o}$$

- covariance matrix of forecasts $$C_{i,j} = \sum_t^{train} F_i(t) F_j(t) = (UWV)_{i,j}$$

- covariance vector of observation and forecasts $$\tilde{o}_j = \sum_t^{train} O(t) F_j(t)$$

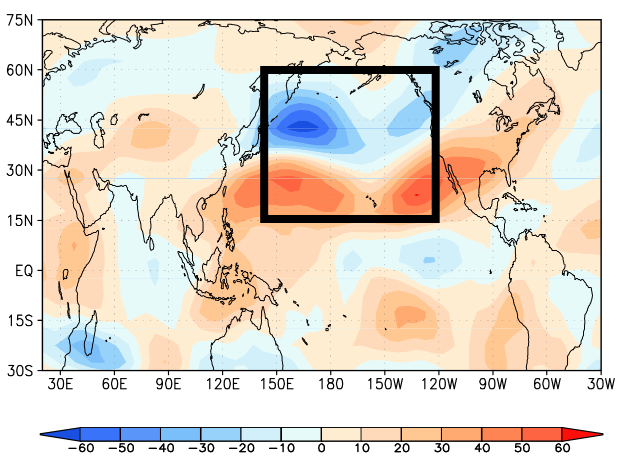
- **SVD technique** which removes the singular matrix problem is used to computes the weighting, (Yun et al. 2003)

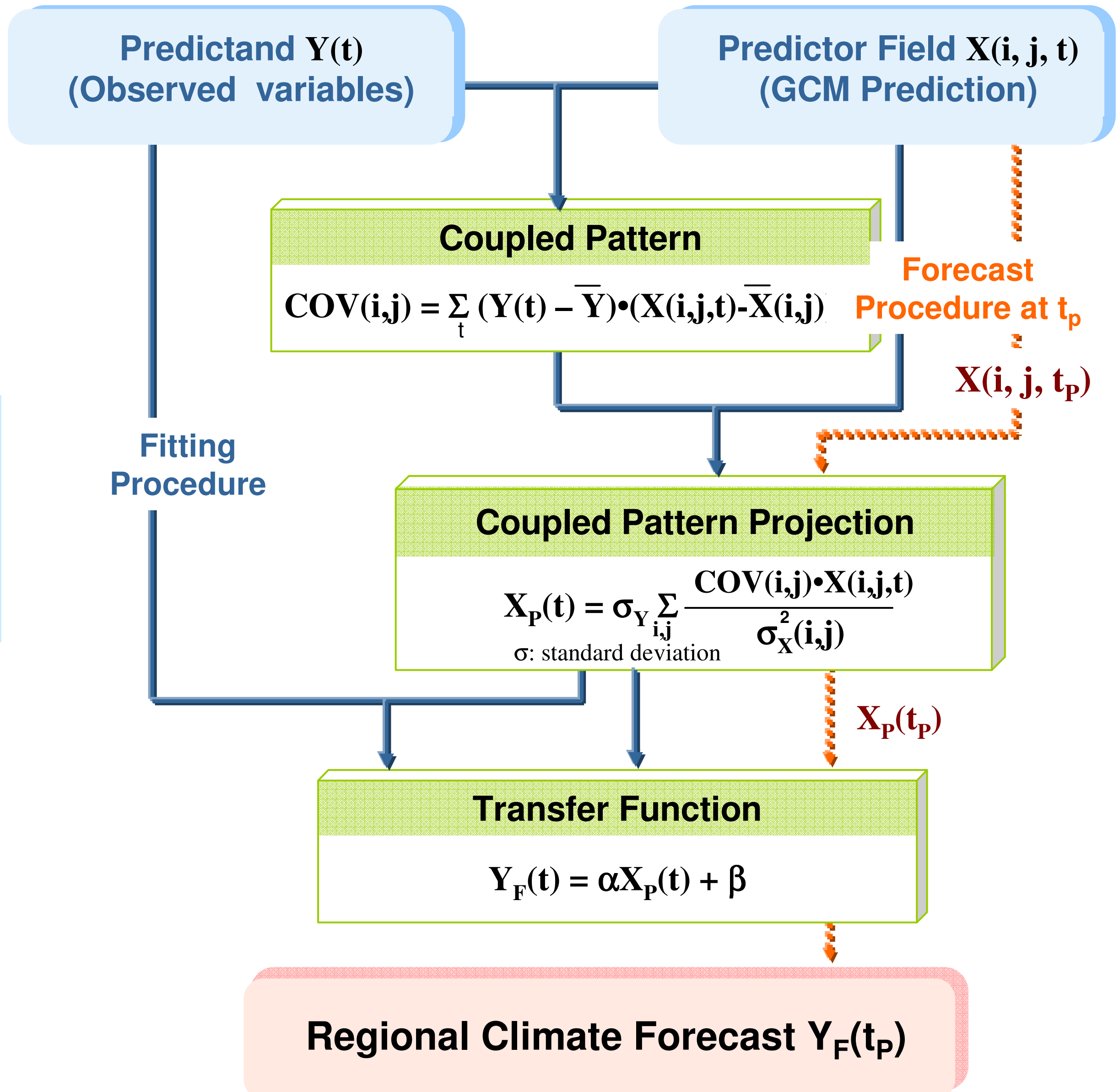
$$a_j = V \left[diag\left(\frac{1}{w_j} \right) \right] \cdot (U^T \cdot \tilde{o}_j)$$

Statistical Downscaling : Procedure

Statistical Correction :
Coupled Pattern Projection Model

The Predictor Field Example :January mean temperature in Korea is predicted using covariance pattern between January mean temperature in Korea and 200 hPa zonal wind for the period 20-year from 1978 to 1997.





Multi-Model Ensemble