JMA Ensemble Prediction System for Long-range Forecast

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DEFINITIONS OF METEOROLOGICAL FORECASTING RANGES

1. Nowcasting
   0 -2 hours
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3. Short-range weather forecasting
   Beyond 12 hours and up to 72 hours
4. Medium-range weather forecasting
   Beyond 72 hours and up to 240 hours
5. Extended-range weather forecasting
   Beyond 10 days and up to 30 days
6. Long-range forecasting
   From 30 days up to two years
7. Climate forecasting
   Beyond two years

Difference between Short- and Long-range Forecast

- Long-range weather forecast (from 30 days up to two years) describes averaged weather parameters, expressed as a departure (deviation, variation, anomaly) from climate values for that period.

- On the other hand, forecast up to 10 days, such as nowcasting, very short-range weather forecast, short-range weather forecast, and medium-range weather forecast, describe weather parameters (not deviation, not averaged).

- Note that extended-range weather forecasting (beyond 10 days and up to 30 days) describes weather parameters, *usually* averaged and expressed as a departure from climate values for that period.

Different Aspects of Long-range Forecast Model from numerical weather prediction (NWP) model.

Long-range Forecast Model *Short-range Forecast Model*

- Equilibrium State (Climate) <--------> Transient State (Weather)
- Cumulus and SST anomaly <--------> Cumulus and Disturbances
- Ocean and Land Process<--------> Initial Condition in Atmosphere

2. Predictability

Uncertainty of Forecast

- Errors in Initial Condition
  - Errors in Raw Observational Data
  - Errors in Objective Analysis Procedure
  - Sparse Observation over Ocean
- Errors in Forecast Model
  - Limitation in the Spatial Resolution
  - Errors in Physical Processes

Concept of the Ensemble prediction

Multi-Initials within Errors in Observation

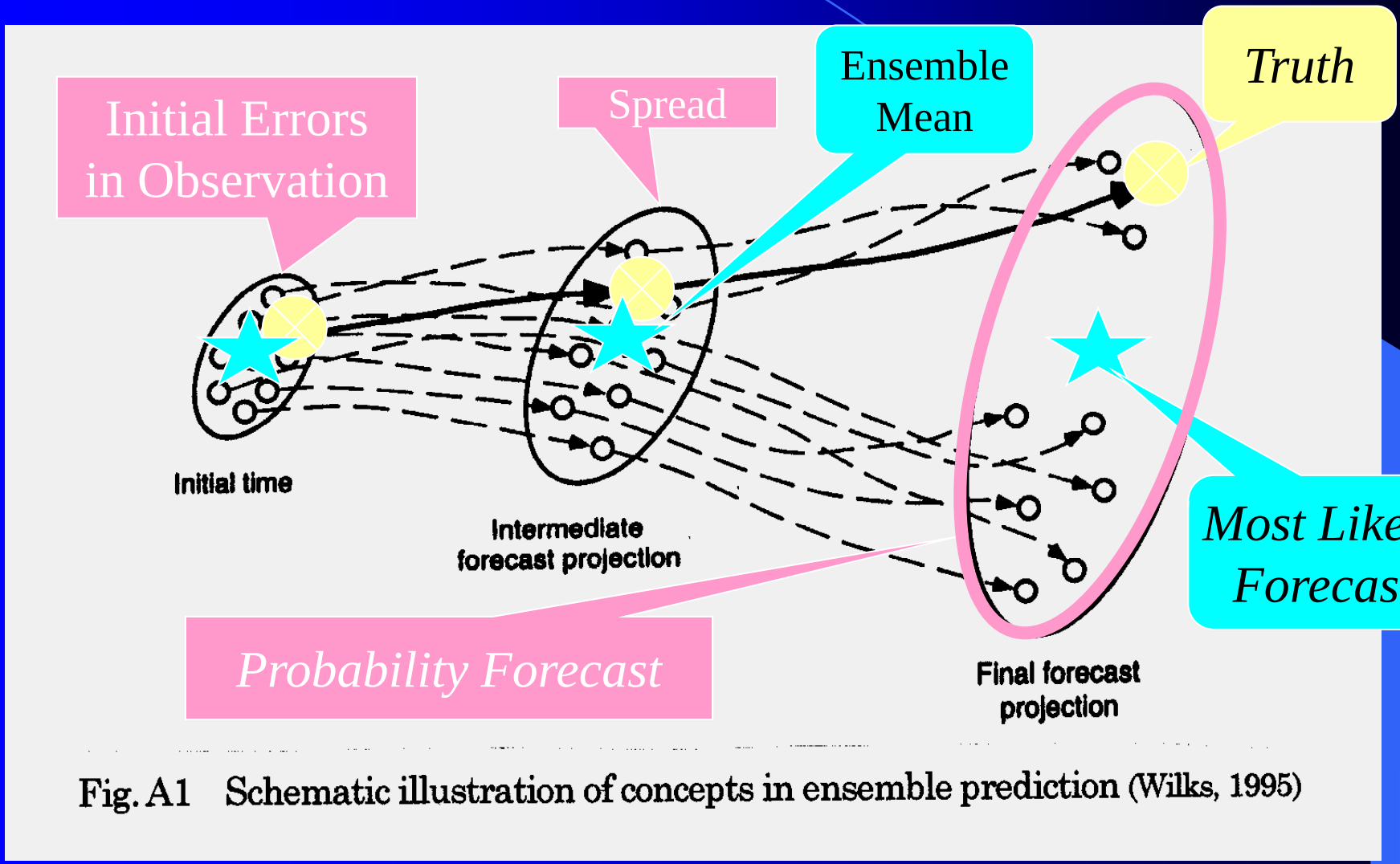


Fig. A1 Schematic illustration of concepts in ensemble prediction (Wilks, 1995)

Two kinds of Predictability

< Predictability of 1st kind >

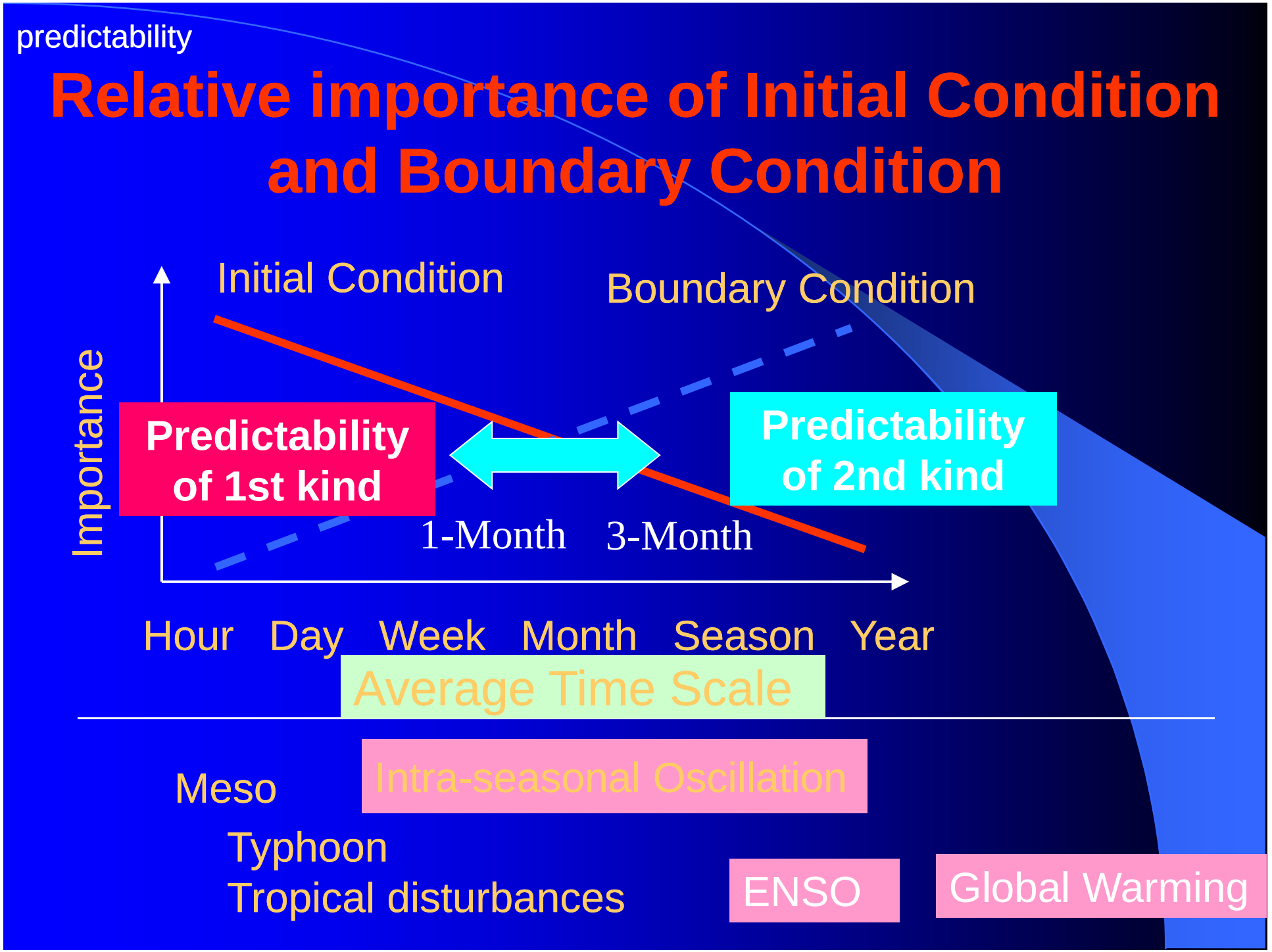
Originates from **Initial condition**

Deterministic forecast fails beyond two weeks due to the growth of errors contained in the initial states. Chaotic behavior of atmosphere comes from its strong non-linearity.

< Predictability of 2nd kind >

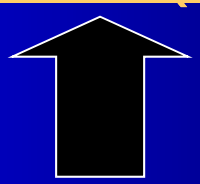
Originates from **lower boundary condition**

Effective for longer time scale; Month to season


predictability
Relative importance of Initial Condition and Boundary Condition
Initial Condition
Boundary Condition
Importance
Predictability of 1st kind
Predictability of 2nd kind
1-Month
3-Month
Hour
Day
Week
Month
Season
Year
Average Time Scale
Meso
Intra-seasonal Oscillation
Typhoon
Tropical disturbances
ENSO
Global Warming

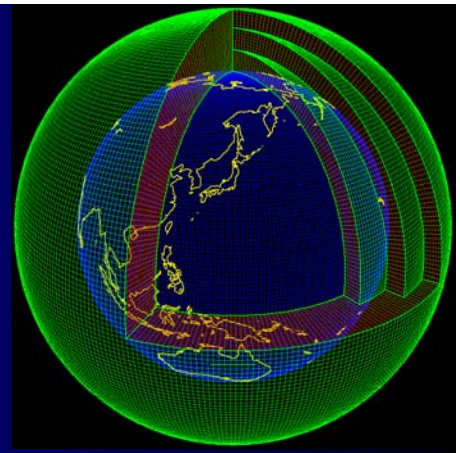
Lower Boundary Condition of Atmosphere

- **Ocean**
  - Sea Surface Temperature (SST)
  - Sea Ice
- **Land Surface**
  - Soil Temperature
  - Soil Moisture
  - Snow Cover, Snow Depth
  - Vegetation (Grass, Tree etc.)



Most IMPORTANT to the atmospheric variability !

Advantage of Ensemble Prediction System (EPS) over Statistical method



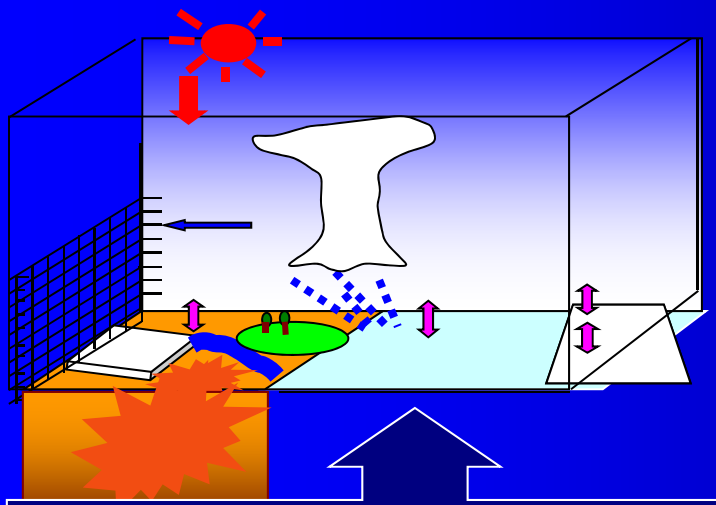
- Probability forecast
  - Intrinsically stochastic behavior of atmosphere can be predicted with ensemble technique .
- Forecast with physical consistency
  - NWP model can represent global circulation in a physically consistent way.
- Improvement based on advance of technology
  - Observation, Study on climate system, Model, Computational power, …….

3. Forecasting model

AGCM and CGCM

Two-Tiered Way

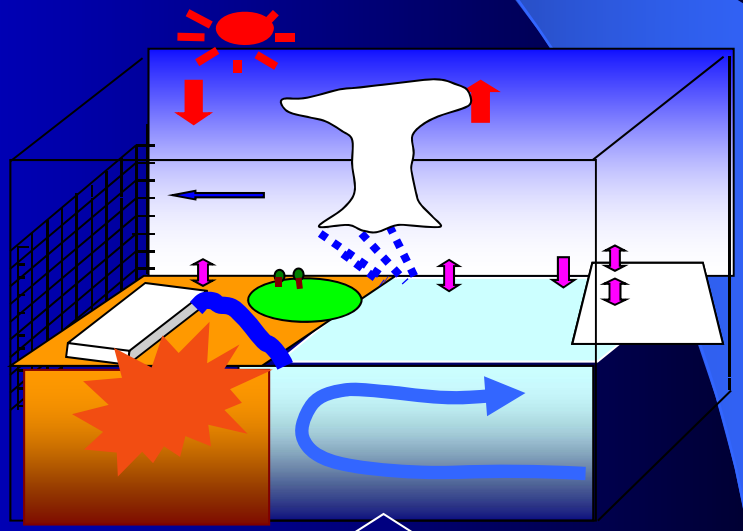
Atmospheric General Circulation Model (AGCM)



Separately predicted SST is prescribed as boundary

One-Tiered Way

Coupled ocean-atmosphere General Circulation Model (CGCM)



Ocean model is coupled

Merits and Defects of Two Methods

Method 1 One-tiered method (Use of CGCM)

Merit : Ideal if SST prediction is correct.

Defect :

(1) SST errors cannot be corrected.

(2) Needs large computer resources.

Method 2 Two-tiered method (Use of AGCM)

Merit :

(1) Predicted SST can be corrected.

(2) computer resources can be saved.

Defect :

Air to sea interactions are neglected

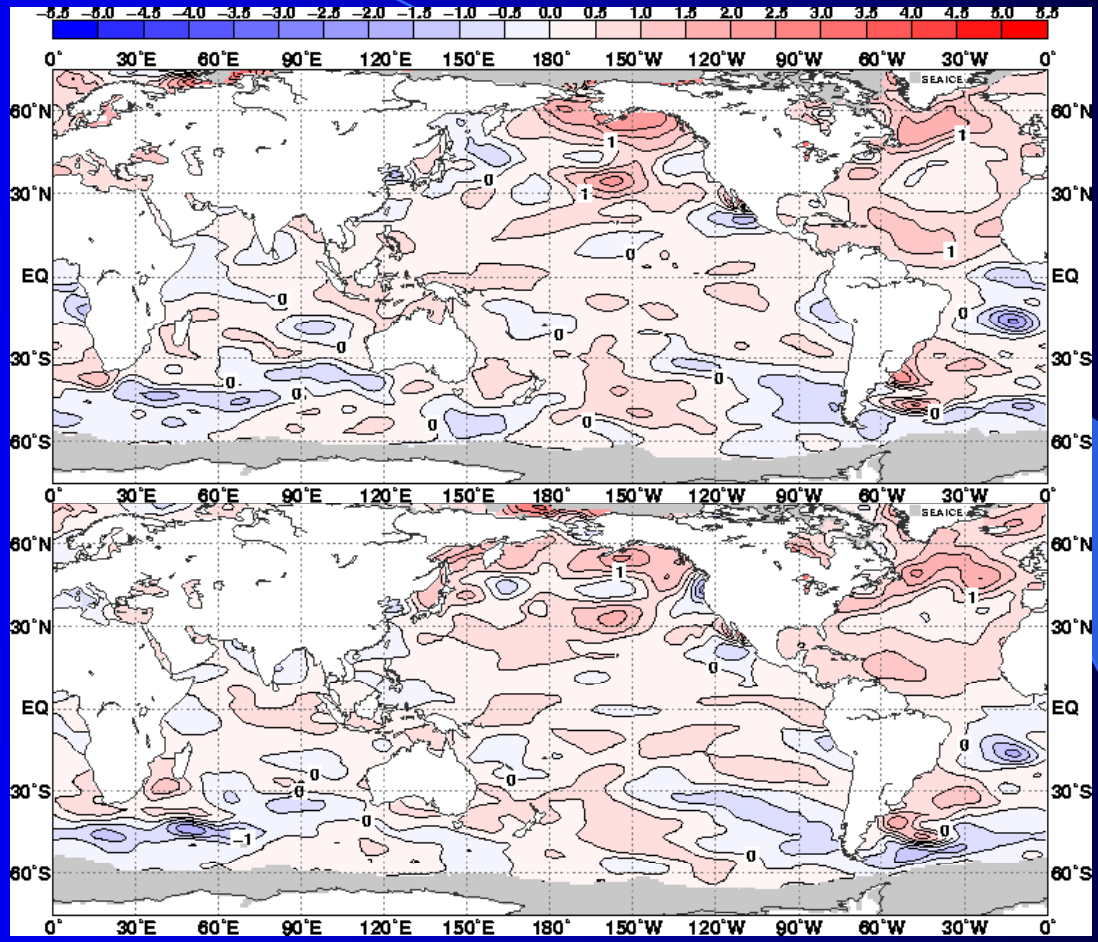
for atmospheric prediction.

Persisted anomaly of SSTs (1)

Jul. 2005

1 month later

Aug. 2005



SST changes slowly compared to atmosphere.

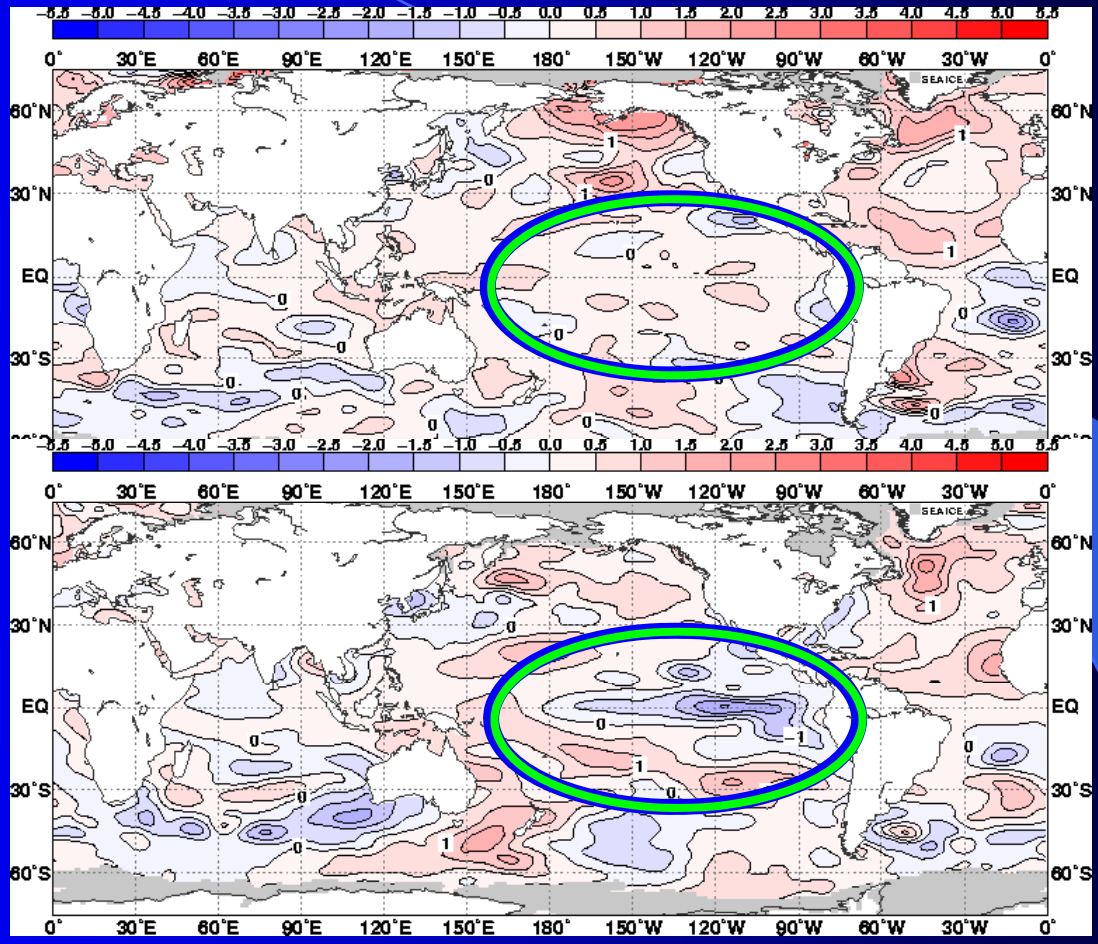
-> Persisted anomaly is useful for extended-range forecasting.

Persisted anomaly of SSTs (2)

Jul. 2005

5 months later

Dec. 2005

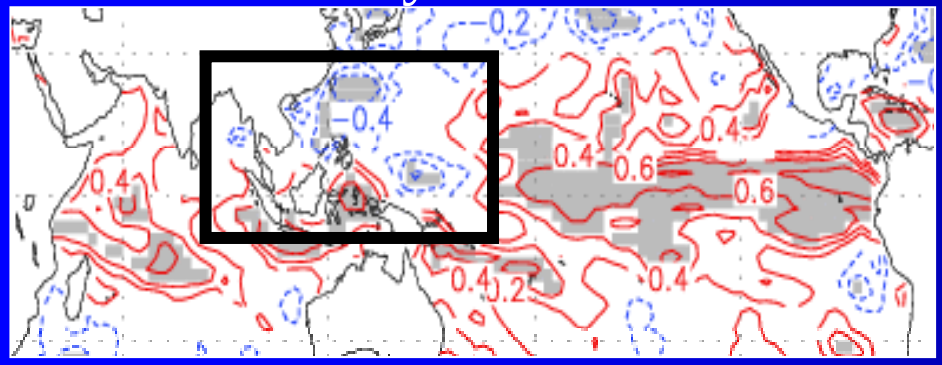


- When there is a time lag of over 3 month, Persisted anomaly is not necessarily useful.

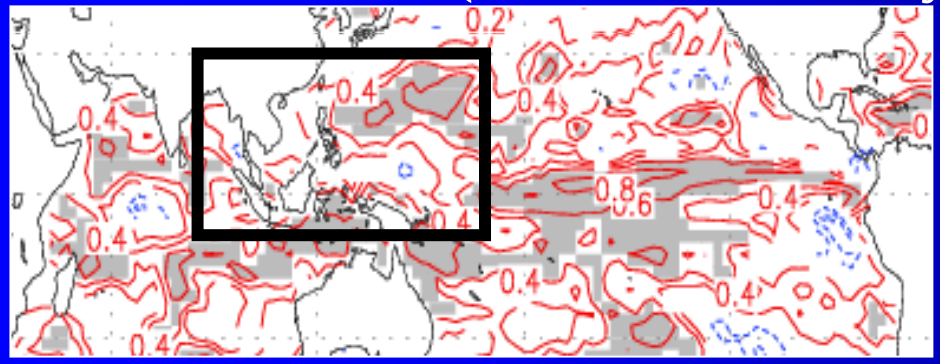
Importance of air to sea interactions

Maps show correlation coefficient between precipitation and SST in summer.

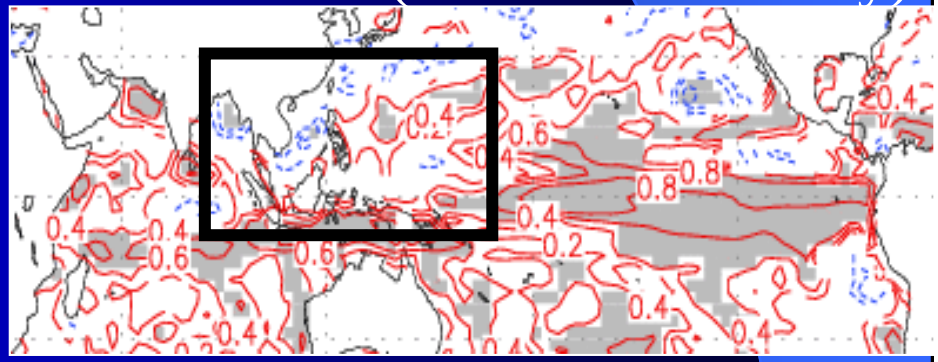
Analysis



JMA-AGCM (initial month: May)



JMA-CGCM(initial month: May)



JMA-CGCM reduces the overestimated positive correlation coefficient in the Western North Pacific.

What can a model predict ?

Circulation in Tropics and mid- and high-latitudes

Where does the signal of long-range forecast come from ?

Response of atmosphere to the slowly varying boundary conditions

Especially, the deviation of SST in the tropics such as ENSO

→ Deviation of convective activity of large scale

→ Deviation of divergence of large scale

→ Deviation of tropical circulation

direct and indirect influence
on the circulation in the mid- and high- latitudes

An example of forecast in the tropics

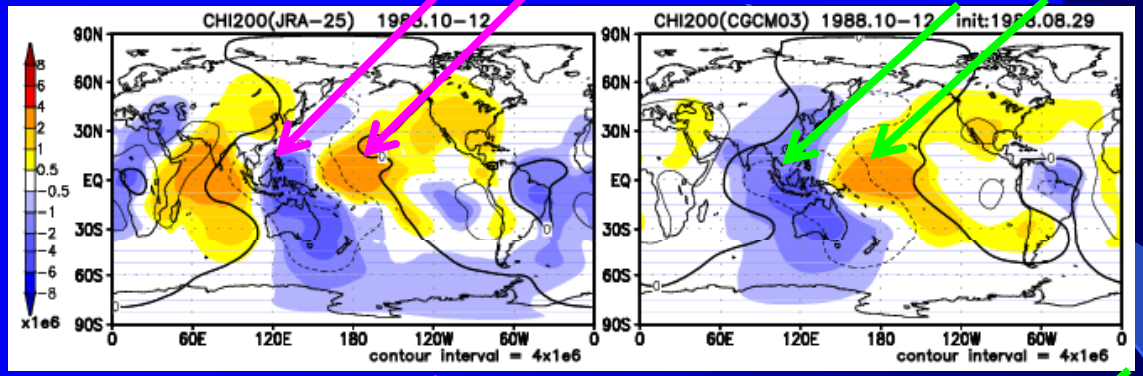
1988 Aug 29 initial, 90-day mean (1-month lead time)

In a case of La Nina

analysis

forecast

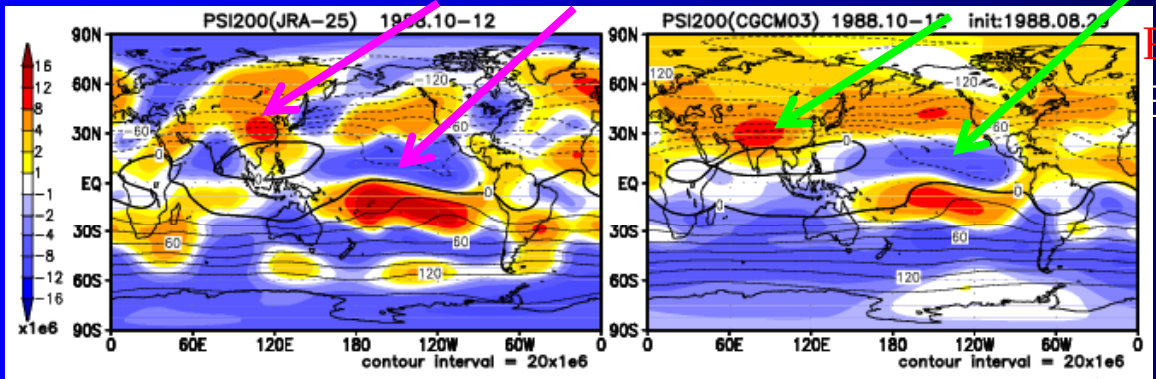
anomaly of velocity potential 200hPa



Red:convergence

Blue:divergence

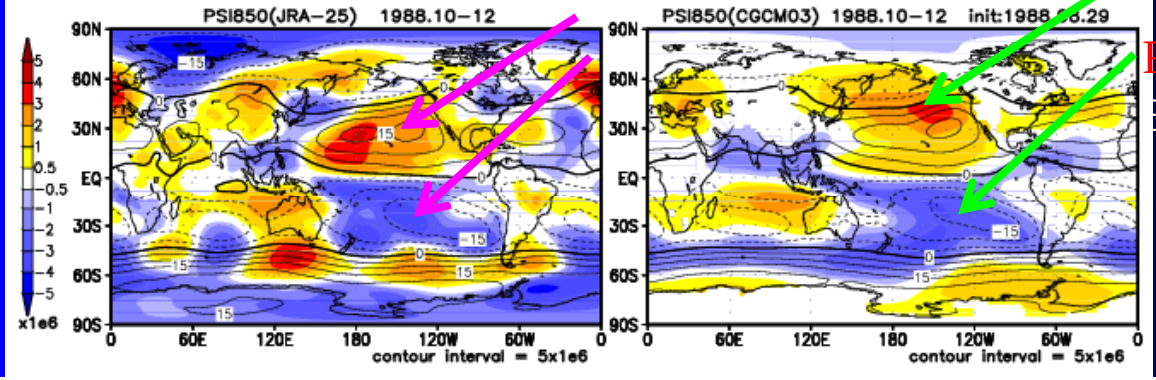
anomaly of stream function 200hPa



Red:clockwise

Blue:counter-clockwise

anomaly of stream function 850hPa



Red:clockwise

Blue:counter-clockwise

An example of forecast in the mid- and high-latitudes

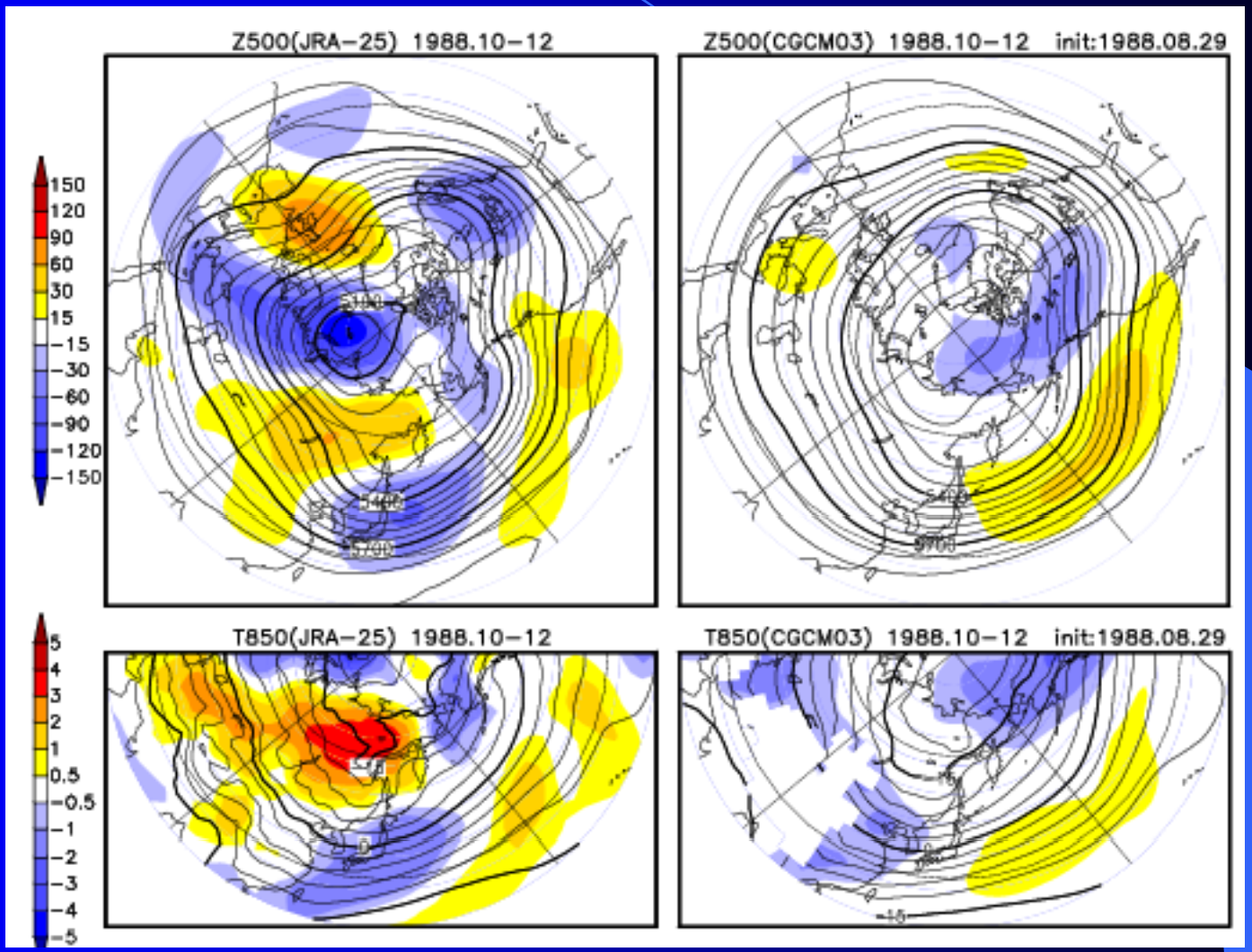
In a case of La Nina

1988 Aug 29 initial, 90-day mean (1-month lead time)

analysis forecast

anomaly of geopotential height at 500hPa

anomaly of temperature at 850hPa



JMA's Dynamical Seasonal Forecast makes use of numerical weather prediction model

- Dynamical seasonal forecast makes use of a reduced horizontal resolution version of NWP model (AGCM) for short-range and medium range forecast: TL159 version for one-month forecast, and TL95 version for 3-month and cold/warm season forecast.
- The same physical processes such as cumulus parameterization, radiation and cloud, boundary layer, gravity wave drag, and so on are used.
- Development of the NWP model is cooperation of Numerical prediction Division, Climate Prediction Division, and Meteorological Research Institute.

5. JMA’s Ensemble Prediction System (EPS) for seasonal forecast

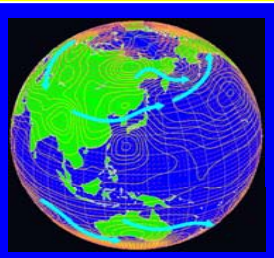
Introduction of a CGCM

- The long-range forecasting model was changed from an AGCM (two-tiered method) to a CGCM (one-tiered method) and unified with the El Niño prediction model in February 2010.

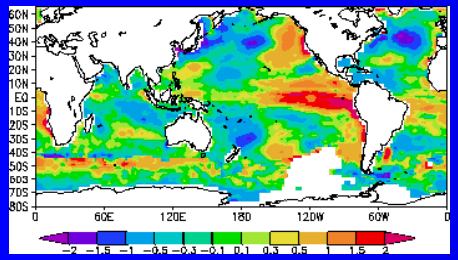
	descriptions
Old model	JMA-GSM (AGCM): T_L95L40, Prescribed SST anomaly, SV (51 mem) Periods: max. 7 months
Current model	JMA/MRI-CGCM , JMA-GSM (AGCM): T_L95L40, MRI.COM(OGCM): lon 1.0° x lat 0.3-1.0° , L50 BGM+LAF (51 mem) Periods: 7 months

The JMA's EPS for Long-range Forecast Outlook

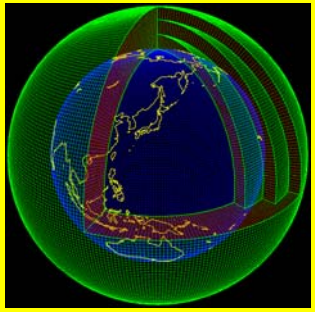
JMA Climate Data Assimilation



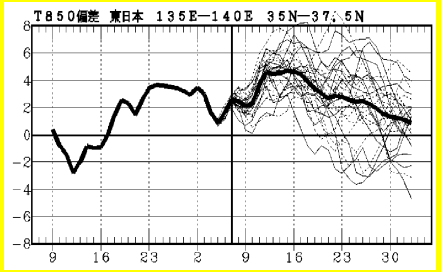
Ocean Data Assimilation



JMA CGCM



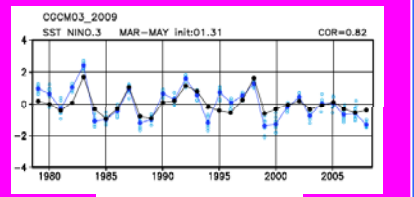
Ensemble Products

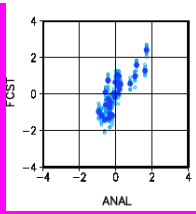


Calibration

Verification

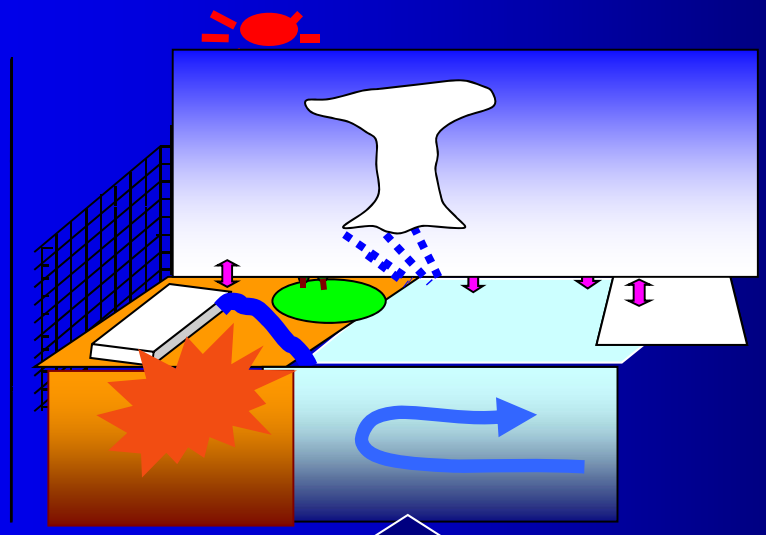
Hindcast





JMA Long-range Forecasting Model

Coupled ocean-atmosphere General Circulation Model (CGCM)

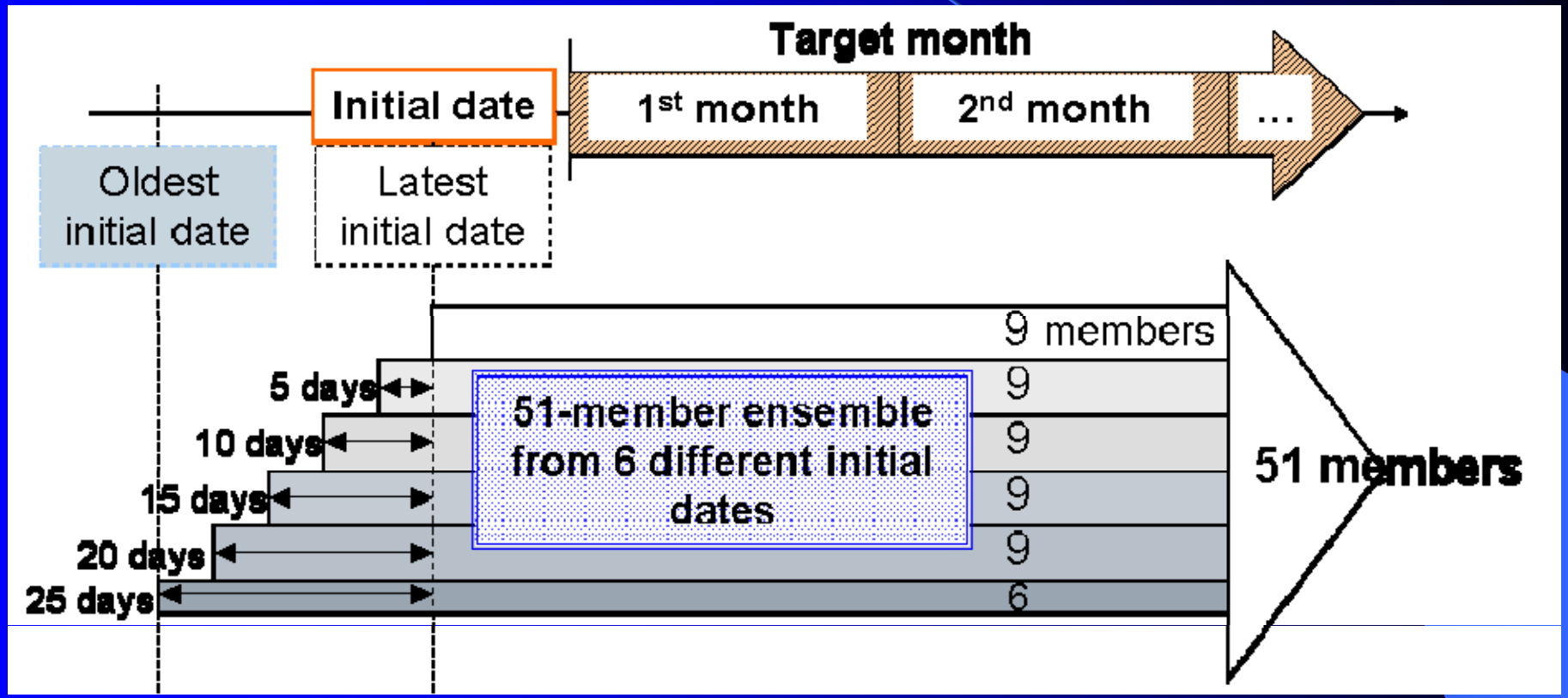


Ocean model is coupled

Specifications of the NWP model for Long-range forecast

Model	JMA/MRI-CGCM
Horizontal resolution	AGCM: TL95 (about 1.875º Gaussian grid ~180km) OGCM: 1.0deg in lon. X 0.3-1.0 deg in lat.
Vertical Layers	AGCM: 40 (Top Layer Pressure:0.4hPa) OGCM: 50
Time integration range	7 months
Executing frequency	Every five days (9 members for each initial date)
Ensemble size	51 members from six different initial dates.
Perturbation method	Breeding Growing Mode (BGM) & Lagged Average Forecast (LAF) method
SST	One-tiered method
Land surface Parameters	Climatology
Note	

Schema of aggregation for the ensemble members in the EPS for long-range forecasting



6. Hindcast

Hindcast

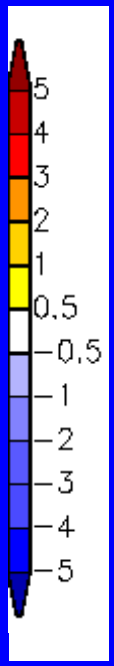
- “Hindcast” is a set of systematic forecast experiments for past cases.
- Hindcast is performed to estimate systematic bias and skill of the model.

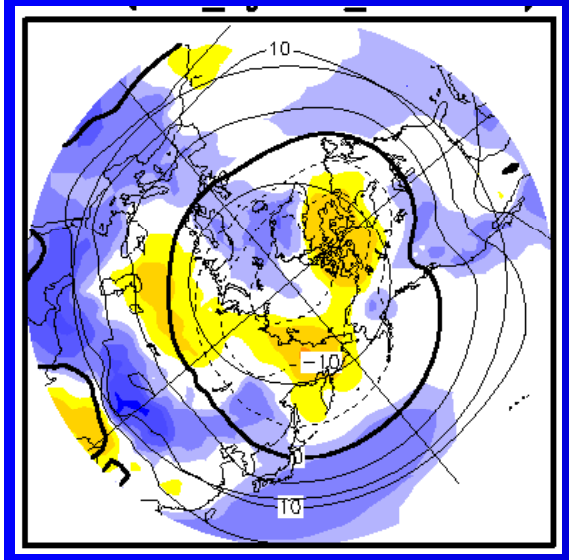
Specification of 7-month EPS Experiment (Hindcast for Long-range Forecast)

Model	JMA/MRI-CGCM (TL95)
Target years	1979 to 2008, 30 years
Target months	All months (initial date is the middle and end of every month)
Integration time	7 months
Ensemble size	10 (5 BGM & 15-day LAF)
Initial condition	
Atmosphere	JRA-25/JCDAS (JMA Climate Data Assimilation System)
Ocean	MOVE/MRI.COM-G (Ocean Data Assimilation)
Land surface	Climatology
Verification data	JRA-25/JCDAS, COBE-SST, GPCP

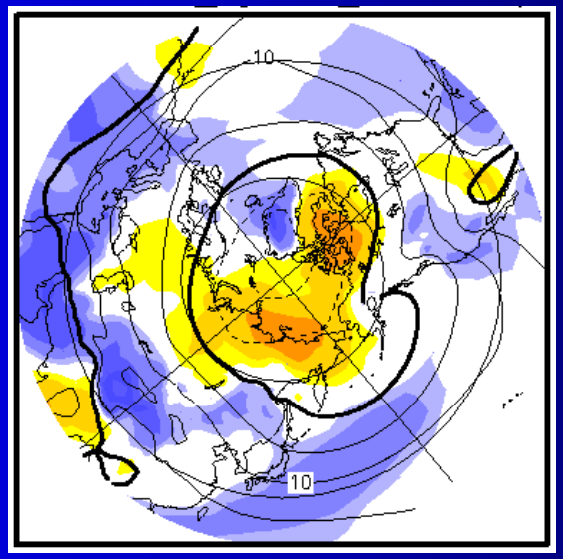
Systematic Bias

- Systematic Bias = Model climate – Observed Climate
- Model climate, which is estimated from hindcast data, is not necessarily in agreement with observed climate.
- The longer execution time of forecasting model is, the larger departure form observed climate is.

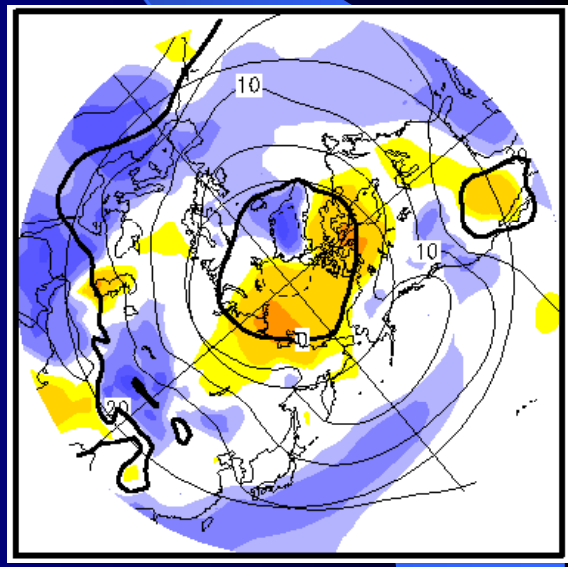




1st month



2nd month



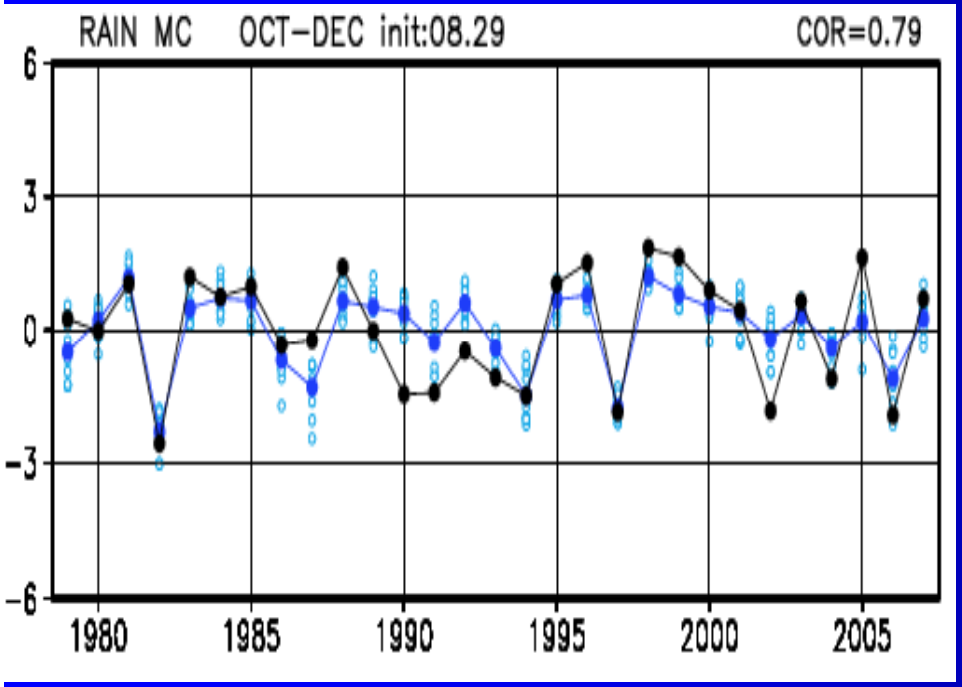
3rd month

T850 Systematic Bias of JMA-CGCM (an example)

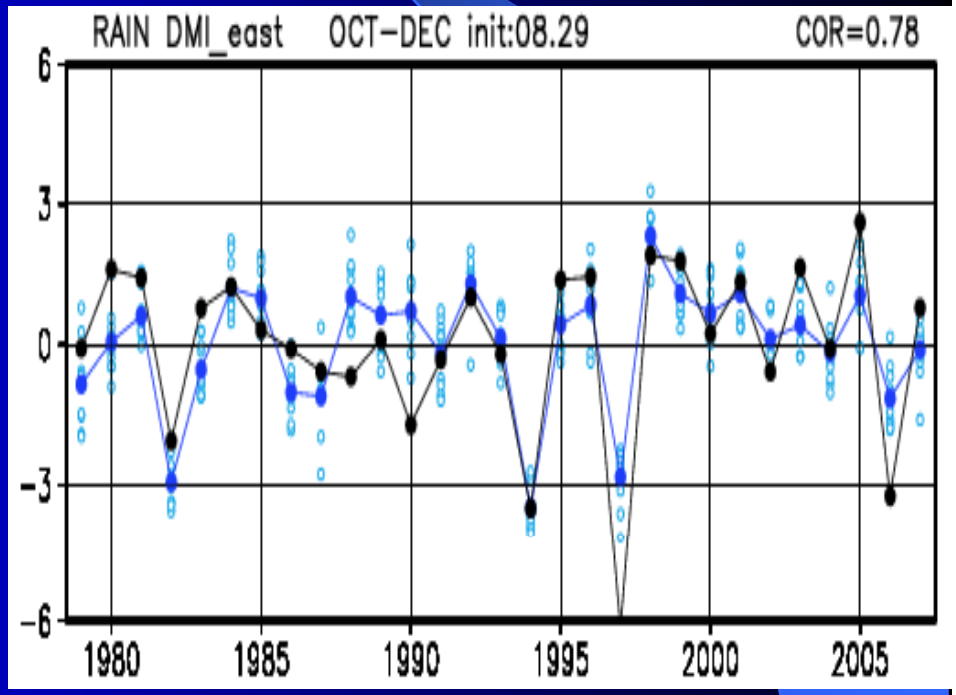
Time Series of Spatial Correlation in Hindcast

Aug. 29 initial, 90-day mean (1-month lead time)

Precipitation of the Maritime Continent COR=0.79



Precipitation of the eastern Indian Ocean COR=0.78

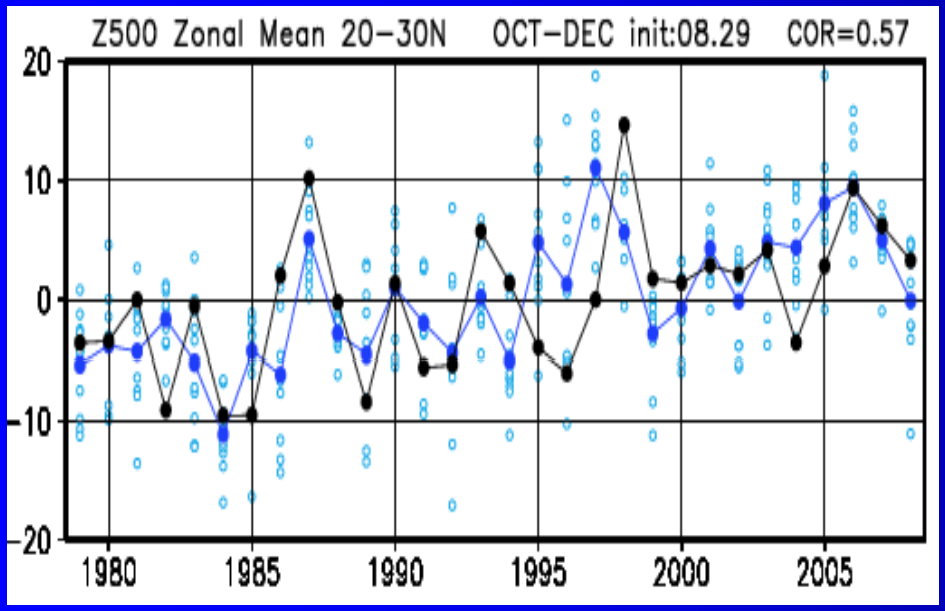


black: analysis
Blue: forecast

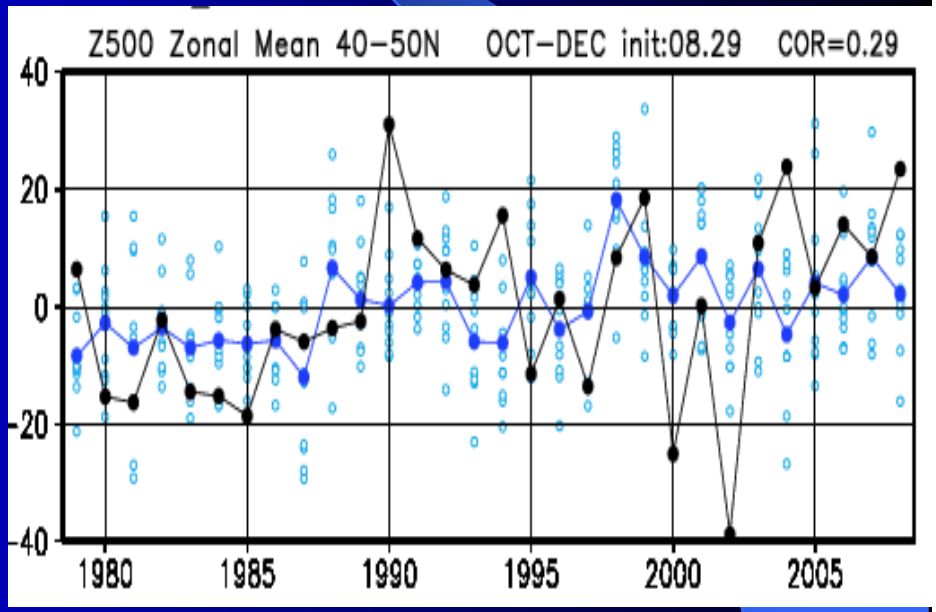
Time Series of Spatial Correlation in Hindcast

Aug. 29 initial, 90-day mean (1-month lead time)

Z500 Zonal Mean 20-30N
COR=0.57

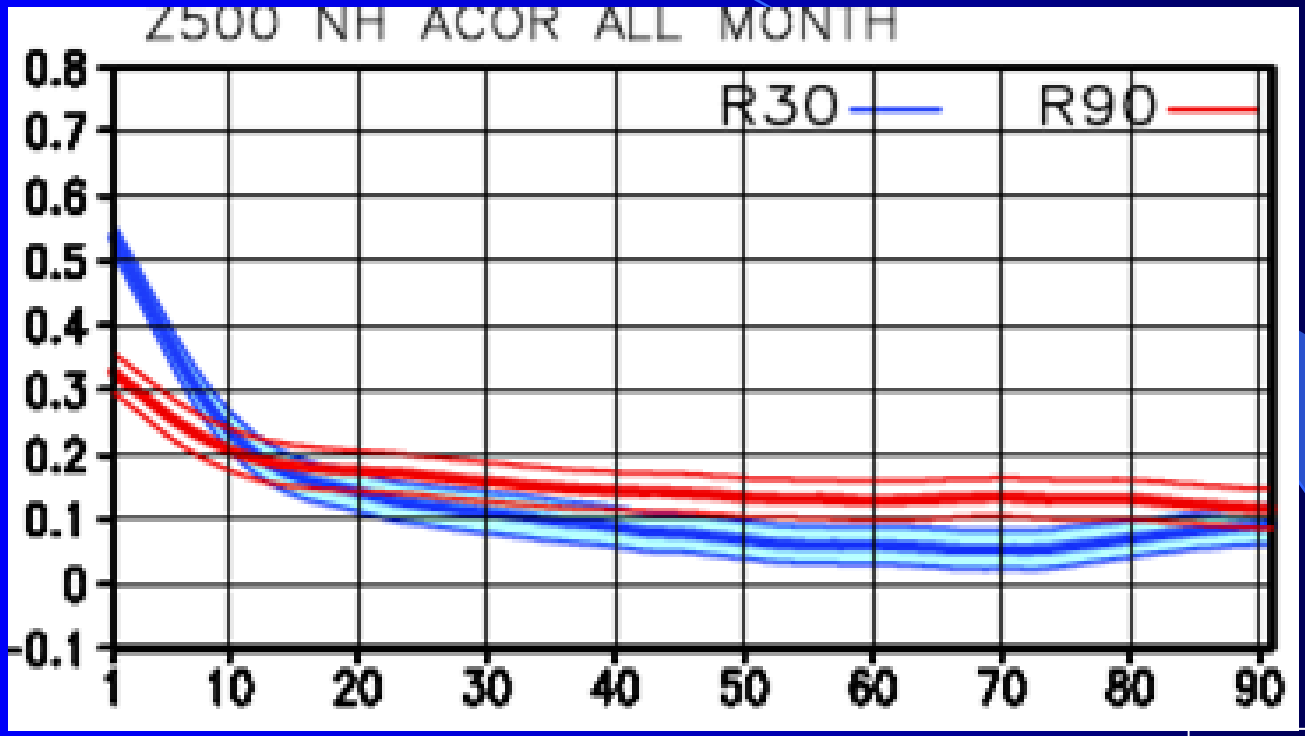


Z500 Zonal Mean 40-50N
COR=0.29



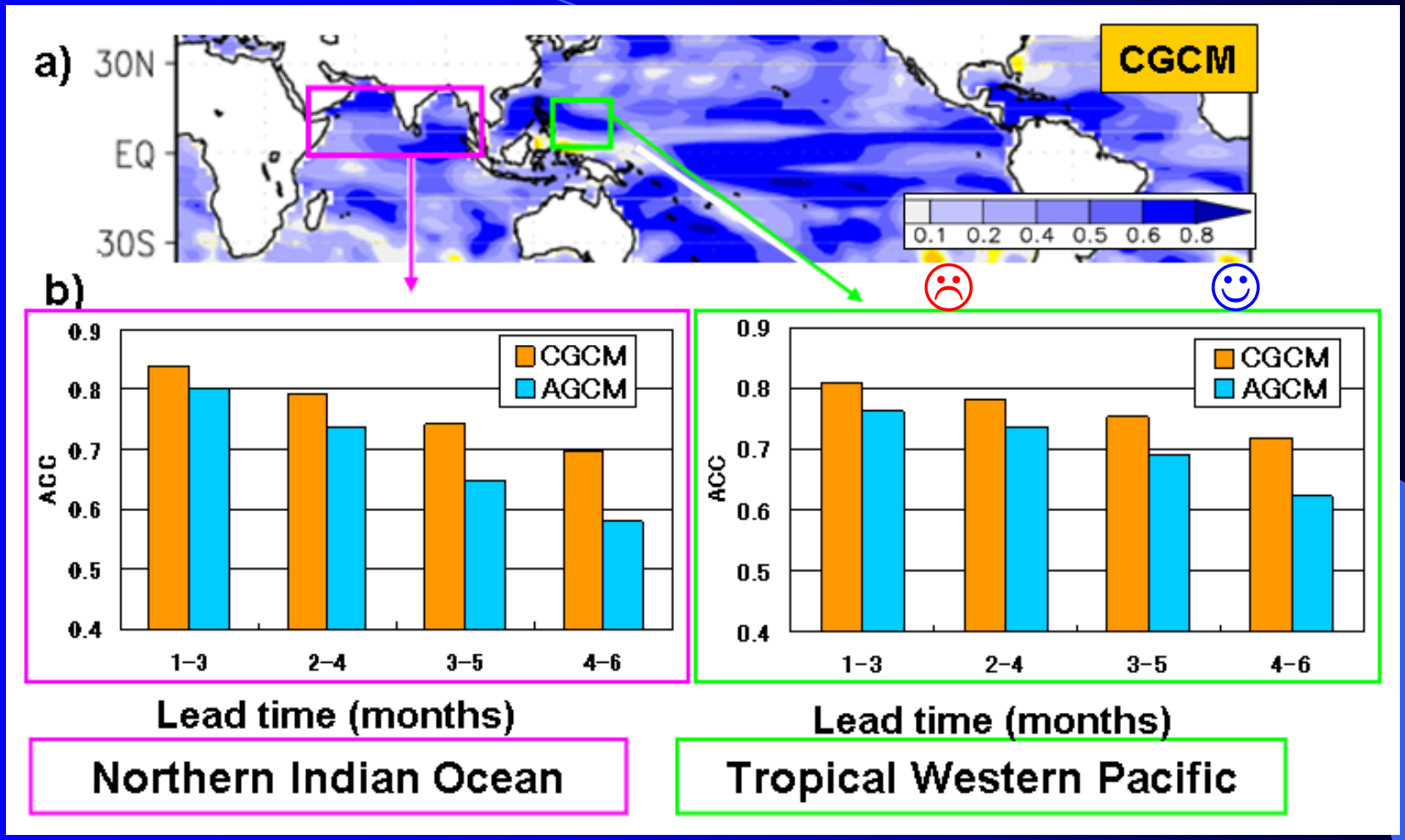
black: analysis
Blue: forecast

Skill of forecasting model and lead-time



- The map show time series of ACC on Z500 in the Northern hemisphere .
- R30 indicates 1-month mean Z500. R90 indicates 3-month mean Z500.
- Period of the retrospective forecast is 22 years (1984-2005).

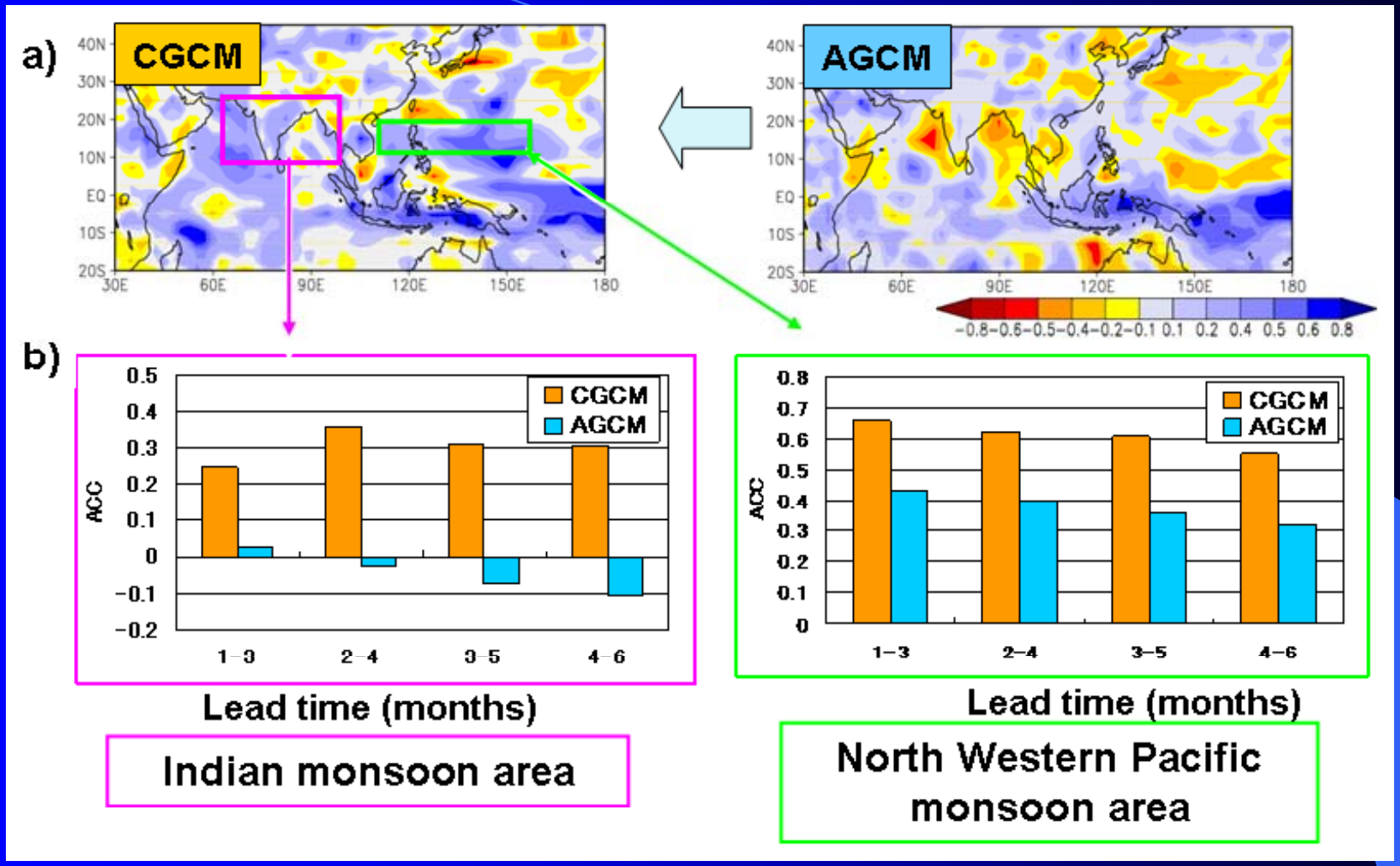
Skill of 3-month mean SST (ACC)



- a) show ACCs with a four-month lead time for Jun-August.
- b) and c) show time series of ACCs (average for 12 initial months).
- Period of the retrospective forecast is 22 years (1984-2005).

The JMA/MRI-CGCM shows better skill than JMA's two-tier old model.

Skill of 3-month mean Precipitation (ACC)



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- b) and c) show time series of ACCs (average for 12 initial months).
- Period of the retrospective forecast is 22 years (1984-2005).

The JMA/MRI-CGCM shows better skill than JMA's two-tier old model.

Remarks

1) Prediction skills should be checked before you use the products.

2) Improvement of the EPS for seasonal forecast is required.

Thank you!