Issues on Seasonal Prediction

In-Sik Kang

Seoul National University

Issues on Dynamical Seasonal Prediction

1. Model Development

- Dynamics: High resolution
- Physics: Better parameterization

2. Seasonal Prediction System

- Tier2 vs Tier1
- Initialization

3. Multi-Model Ensembling

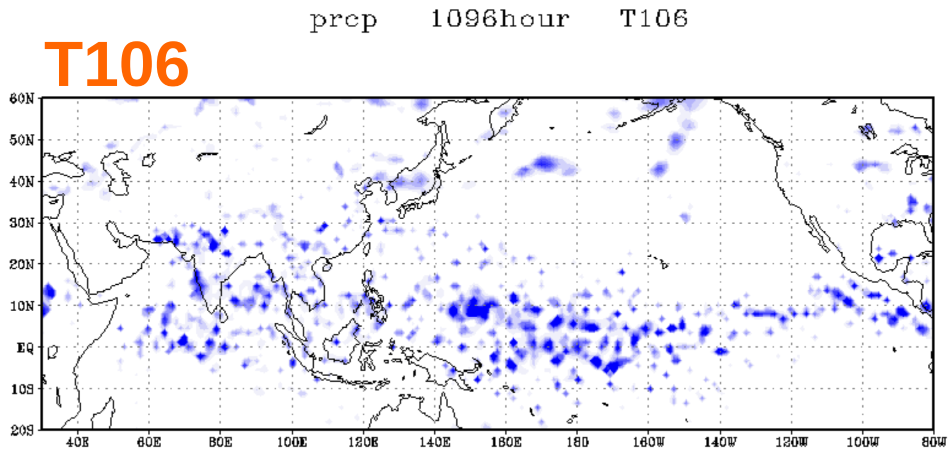
- Determinstic and Probabilisitc forecasts
- Prediction of daily or Pentad variations

Resolution Issue

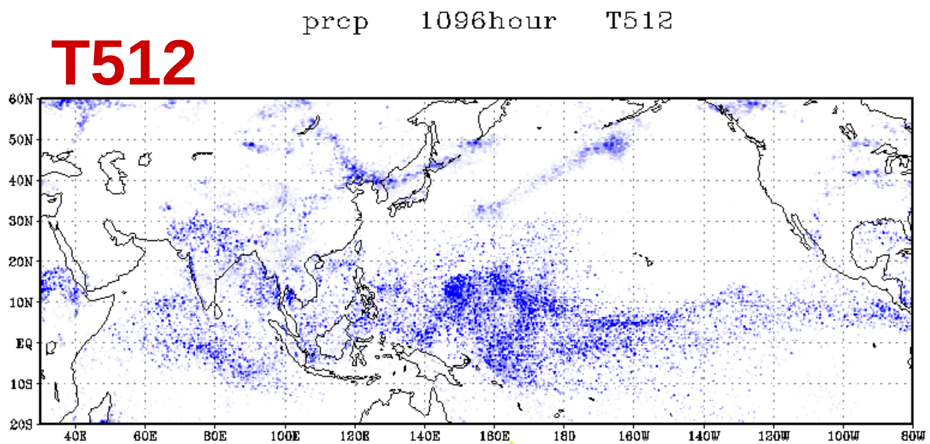
Very high-Resolution Global Model (1997.7.20~31)

SNU AGCM

T106

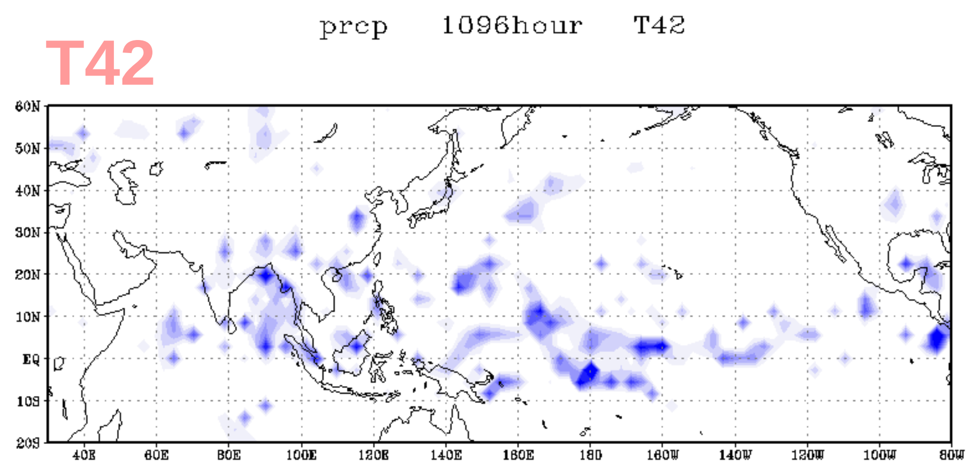


T512

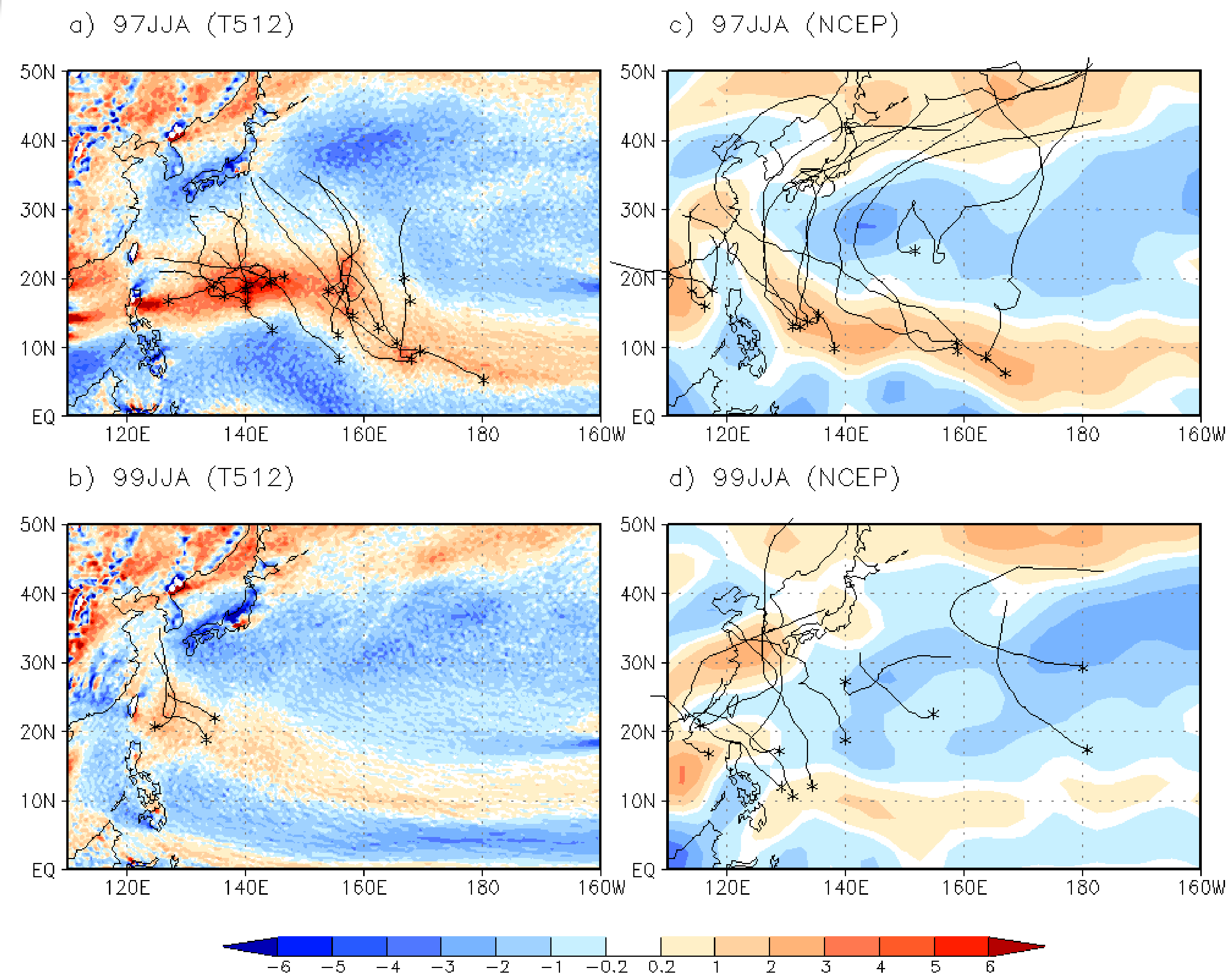


Very expensive!
It takes 4 hours to integrate 1day using 60 CPUs of CRAYX1E

T42

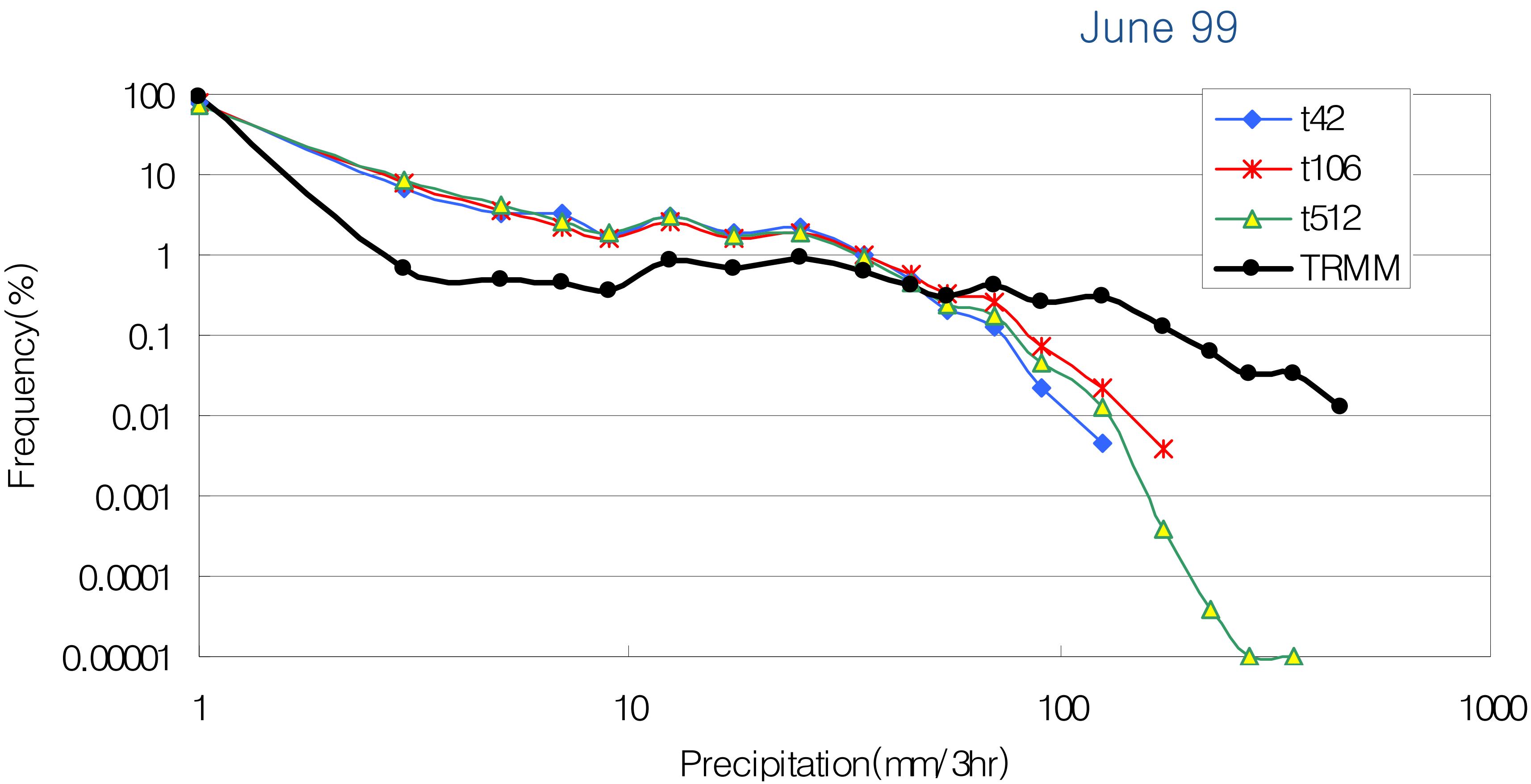


Typhoon (Vorticity)



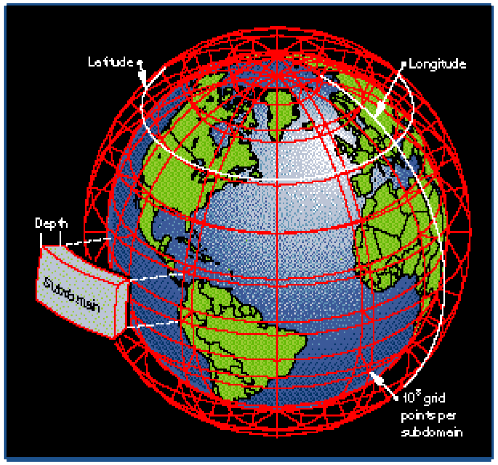
High-Resolution Model

Frequency of event



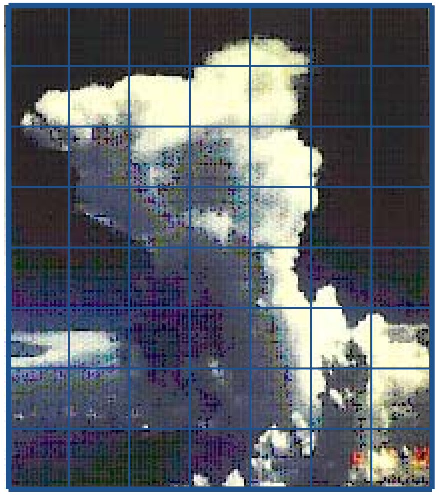
Next Generation Climate Prediction Model

GCM



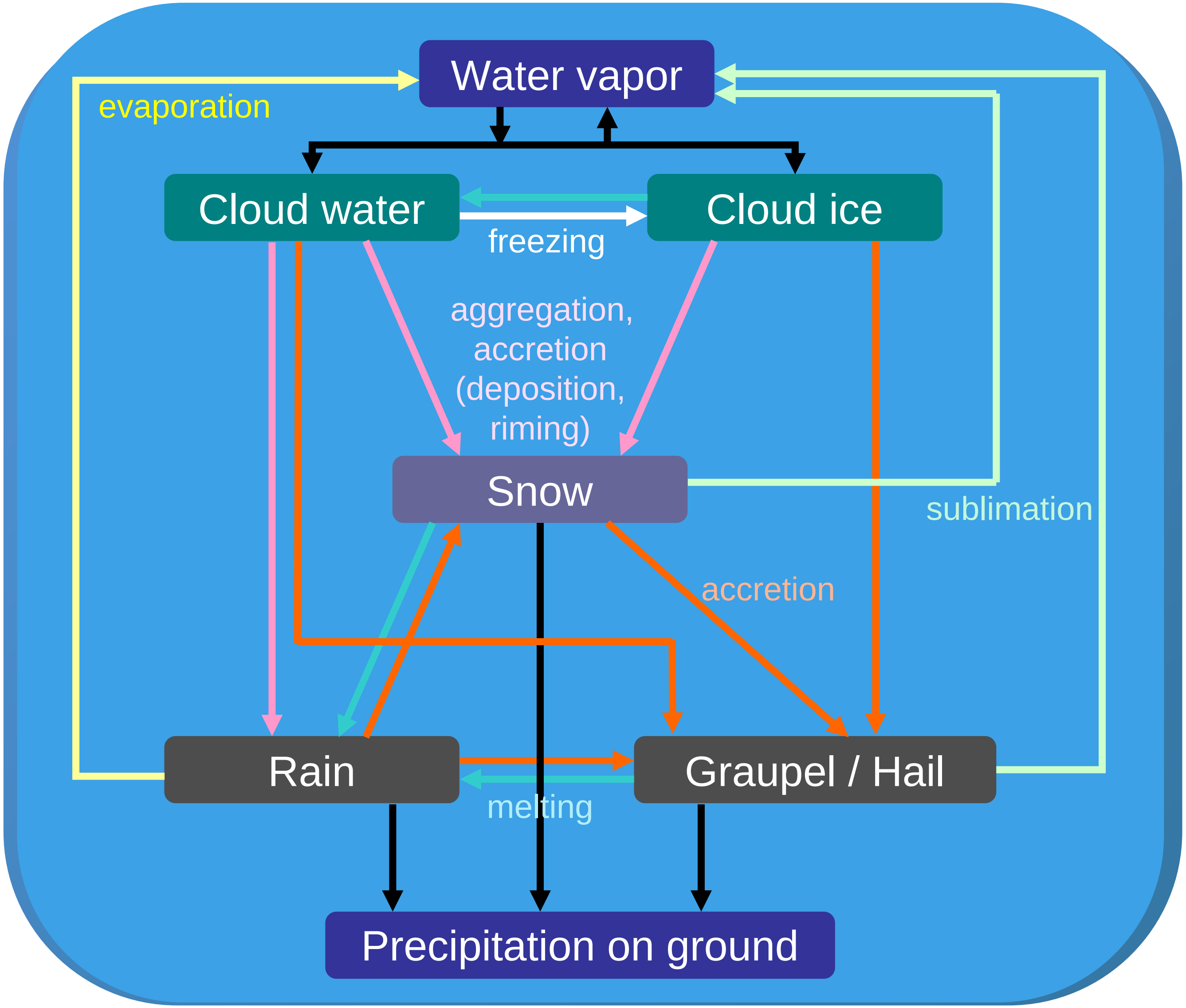
- 1-grid box
- Parameterization
- Uncertainty of the number and position of the clouds

High resolution GCM + Microphysics



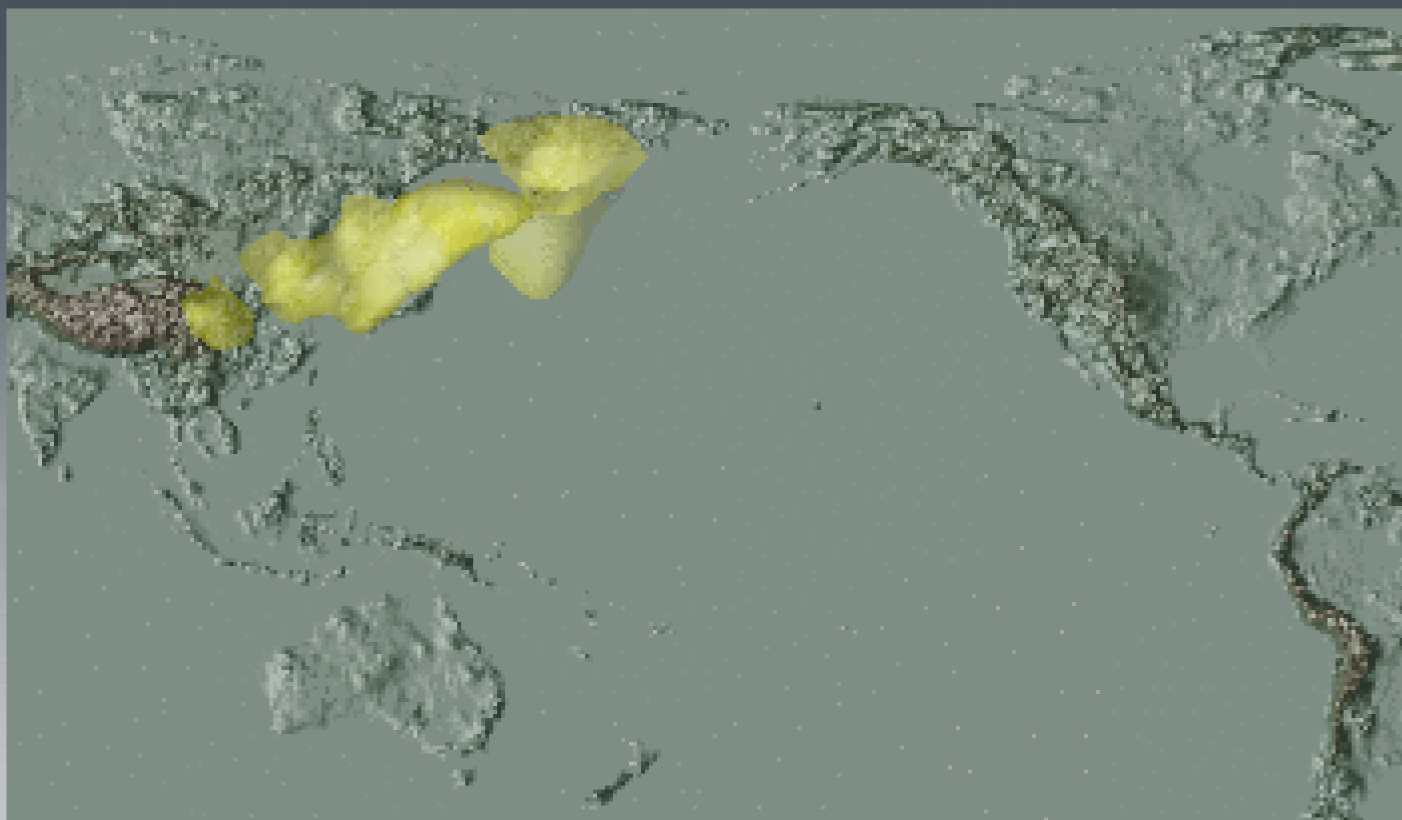
- High-resolution grid box
- Cloud resolving more correctly
- improvement of the precipitation prediction in global model

Microphysics



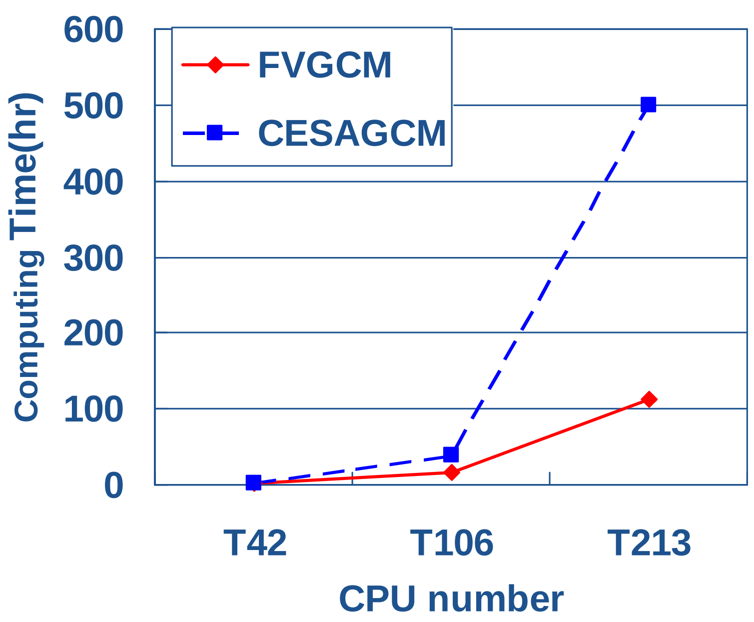
Climate-Environment System Model

Daily evolution of Dust, Spring 2001

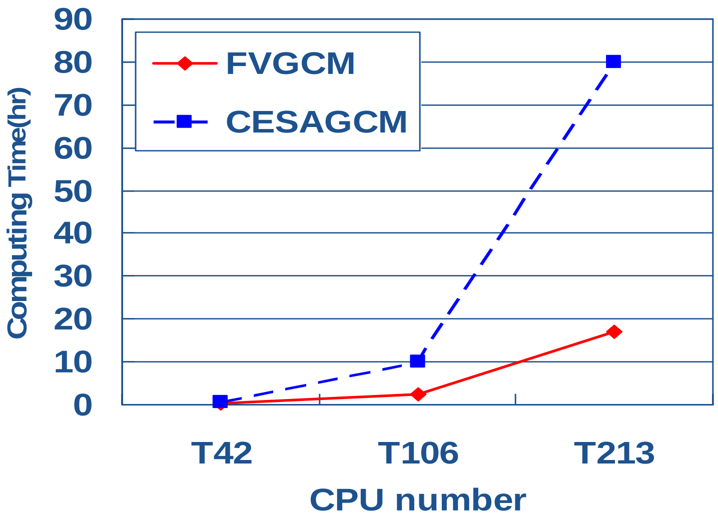


Computational Efficiency

Single CPU(1month)



8 CPU(1month)



- FVGCM is 5 times as fast as CESAGCM at T213
- Longer time step in FVGCM(30min at T213)
- In supercomputer, It is expected that the total computing time will decrease as twice as linux cluster

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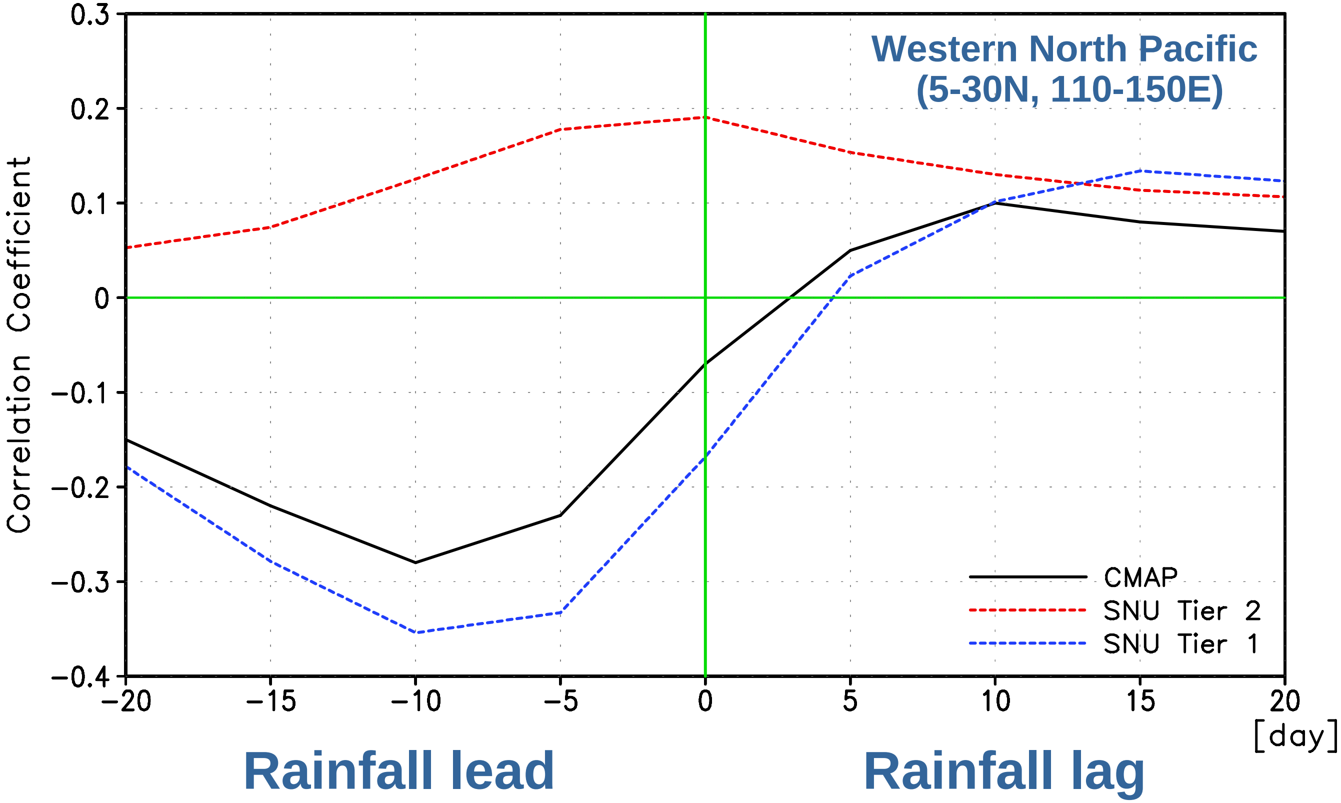
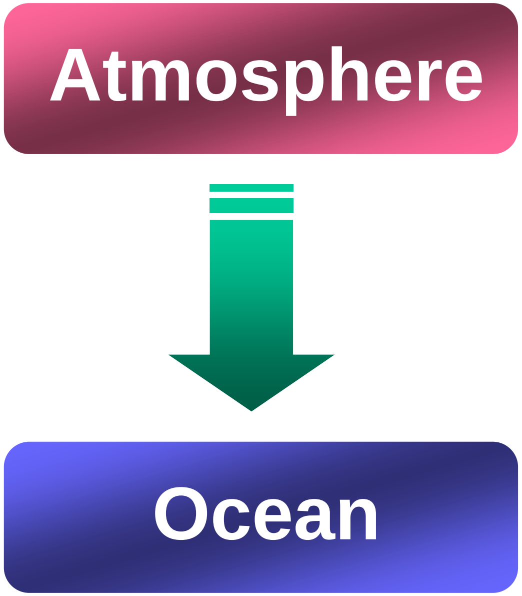
Tier1 vs. Tier2

Lead-Lag Correlation between SST and Precipitation





- MJJAS for 21 years of 1981-2001

Tier1 → Initialization Problem

Prediction Memory

2-tier system (AGCM) : Predicted SST
Land Initial Condition

1-tier system (CGCM) : Ocean Initial Condition
Land Initial Condition

Initial Drift

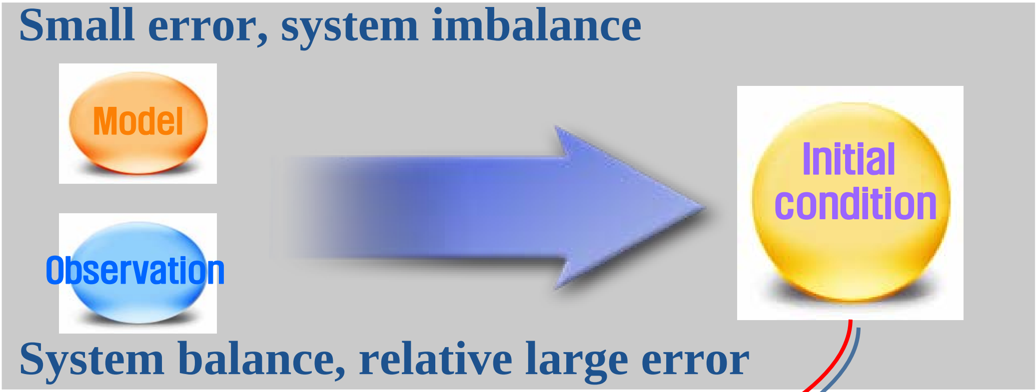
Imbalances < between Atmosphere and Ocean
between Initial condition and Model Physics

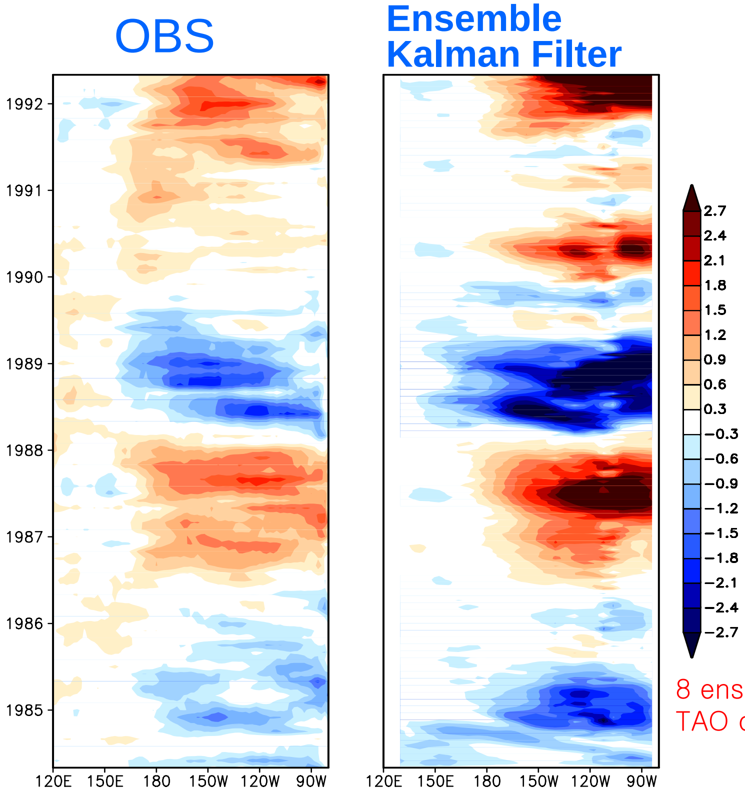
→ Cause serious initial drift

Current Approaches

- Ocean spinning up (SNU, MAXP)
- Coupled SST nudging (SINTEX)
- 3DVAR/4DVAR (DEMETER, COLA, GFDL)
- Ensemble Kalman Filter (GFDL, SNU)

Initialization





8 ensemble members are used.
TAO data (SST & isothermal depth) is used for assimilation.

Initial Condition of Model Simulation for Climate Prediction

Benefit :

- Maintain memory longer
  (More similar to OBS than Backgraound)
- Reduce Initial Drift
  (More balanced than OBS)

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Multi-Model Ensemble (MME)

$$x_i = y + e_i + \varepsilon_i$$

Forecast = True + Error + Noise

E_M : Error variance of Multi-Model Ensemble $E_M = \frac{1}{M}\left[\overline{V}(e) + \frac{2}{M}\sum_{ij} COV(e_i, e_j) + \overline{V}(\varepsilon)\right]$

E_S : Error variance of Single Model $E_s = \overline{V}(e) + \overline{V}(\varepsilon)$

For example : Two Models (M=2)

Error variance of Multi-Model Ensemble $E_M = \frac{1}{2}\left[\overline{V}(e) + COV(e_1, e_2) + \overline{V}(\varepsilon)\right]$

Error variance of Single Model $E_s = \overline{V}(e) + \overline{V}(\varepsilon)$

Mean Square Error $E = E_M - E_s = \boxed{-\frac{1}{2}\overline{V}(e) + \frac{1}{2}COV(e_1, e_2)}\boxed{-\frac{1}{2}\overline{V}(\varepsilon)}$

Reduction of Systematic Error

Reduction of Random Noise

For Improvement ➔ E < 0

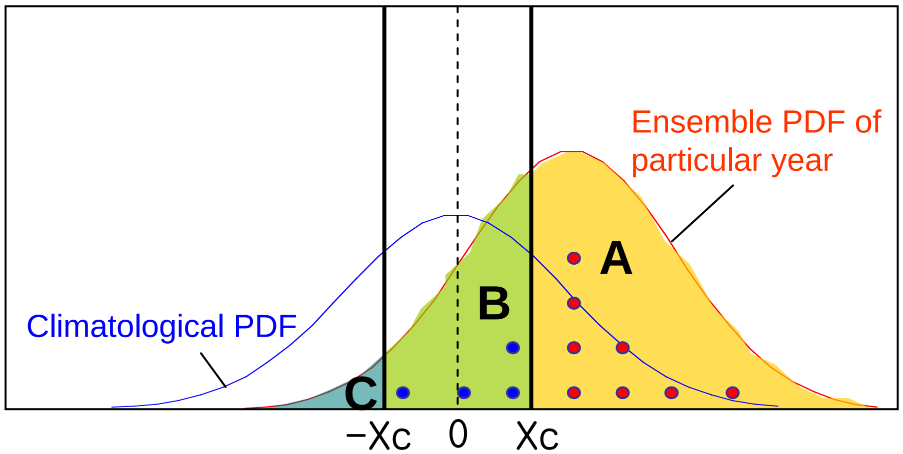
Where Models are independent each other ➔ $COV(e_i, e_j) = 0$

MME schemes

1. Deterministic forecast
2. Probabilistic forecast

Testing probabilistic MME schemes in a simple model

Simple Pooling method



A	Probability of ABOVE normal
B	Probability of Near normal
C	Probability of BELOW normal

Bayesian based MME scheme (IRI)

$$P_i^{new} = a_i P_c + b_i P_i$$

$$P_{MME} = a' P_c + b' \left(\sum_i \frac{a_i}{\sum_k a_k} P_i \right)$$

Another scheme (FSU: SPENS)

$$w_i = \frac{c_i^k}{\sum_{i=1}^{N} c_i^k}$$

K=3

$$c_i = \frac{\alpha}{\alpha+\gamma} + \frac{\delta}{\beta+\delta}$$

α : number of hit (fcst-yes, obs-yes)

β : number of false alarm (fcst-yes, obs-no)

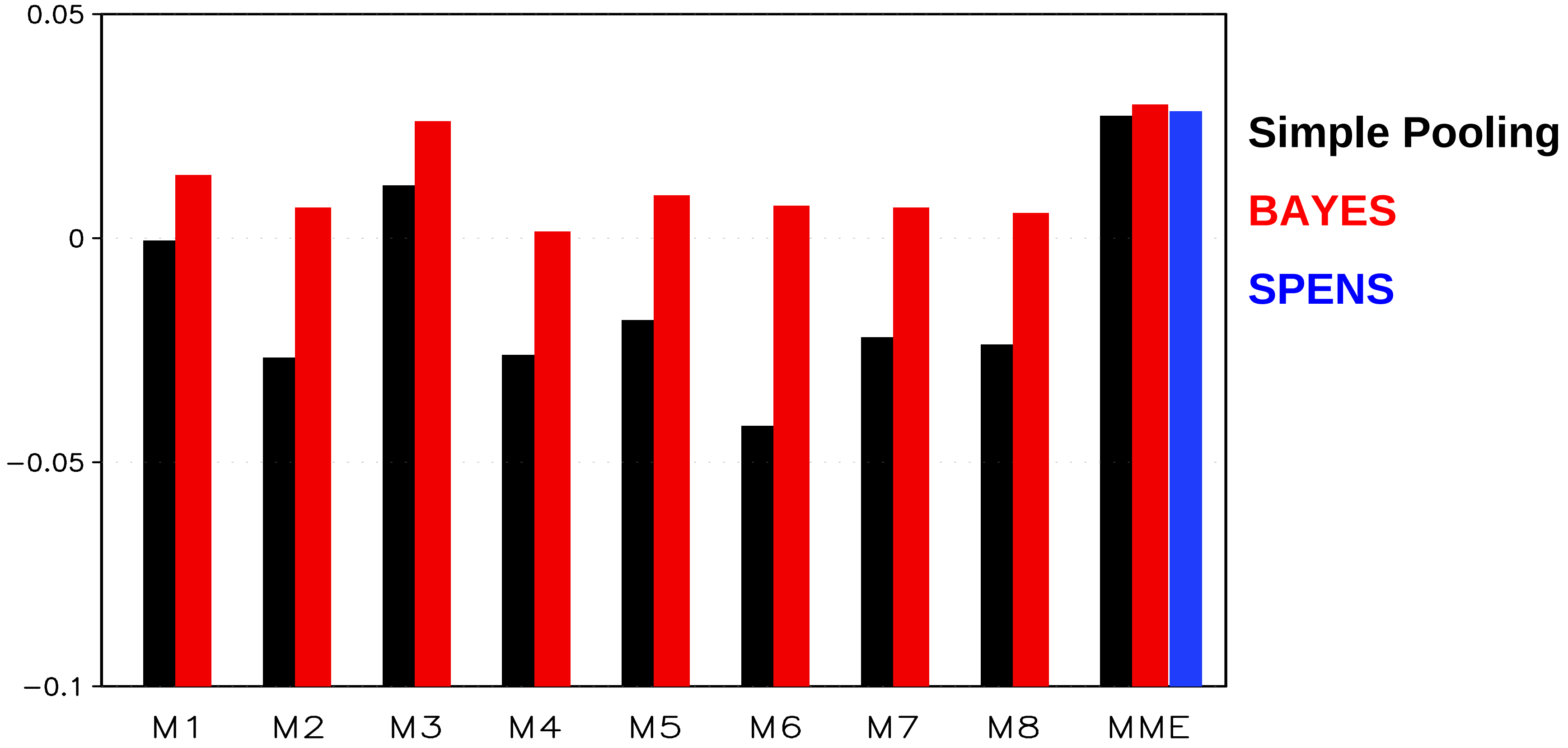
γ : number of miss (fcst-no, obs-no)

δ : n. of correct rejection (fcst-no, obs-yes)

Mean RPSS

seasonal mean upper level streamfunc. / 20 members / total 240 seasons

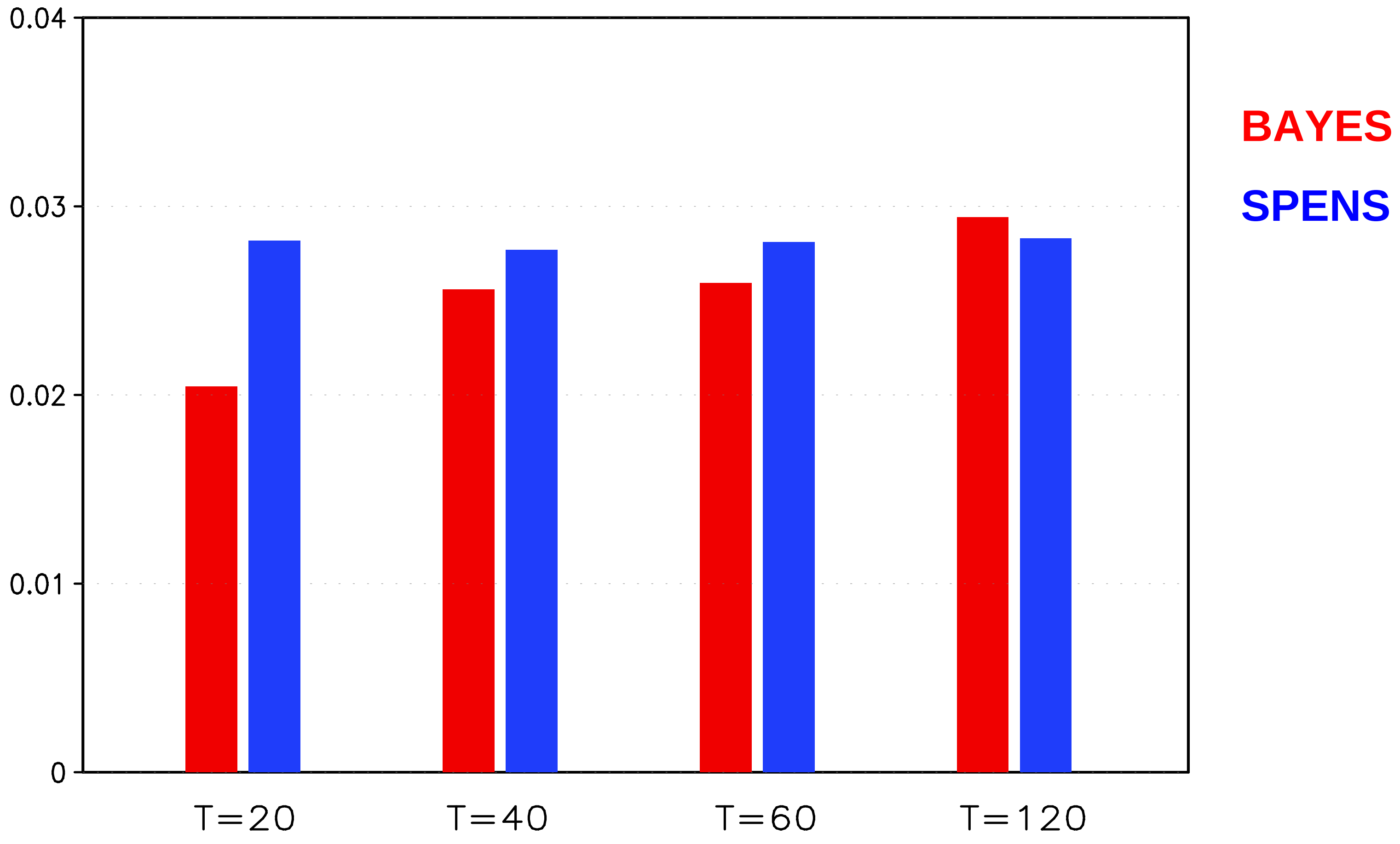
Training: 120 seasons, Verification: 120 seasons



Very good simple pooling MME : either of Impact of ensemble size or well distributed different model

Weighted MME is better than/comparable to the pooling

Mean RPSS w.r.t. different training sample size (year)



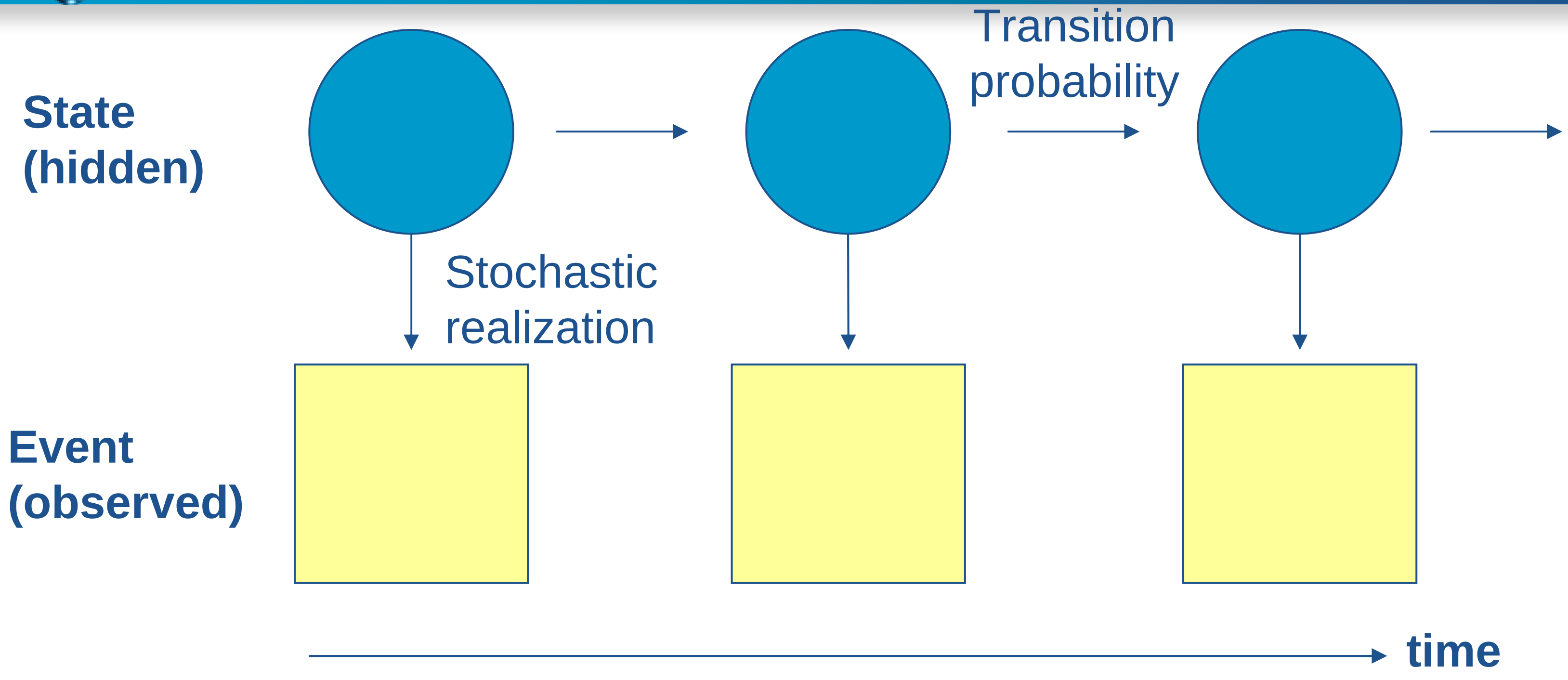
Seasonal Prediction

- Seasonal mean

- Daily or pentad variations for a season

Frequency vs Intensity

Hidden Markov Model



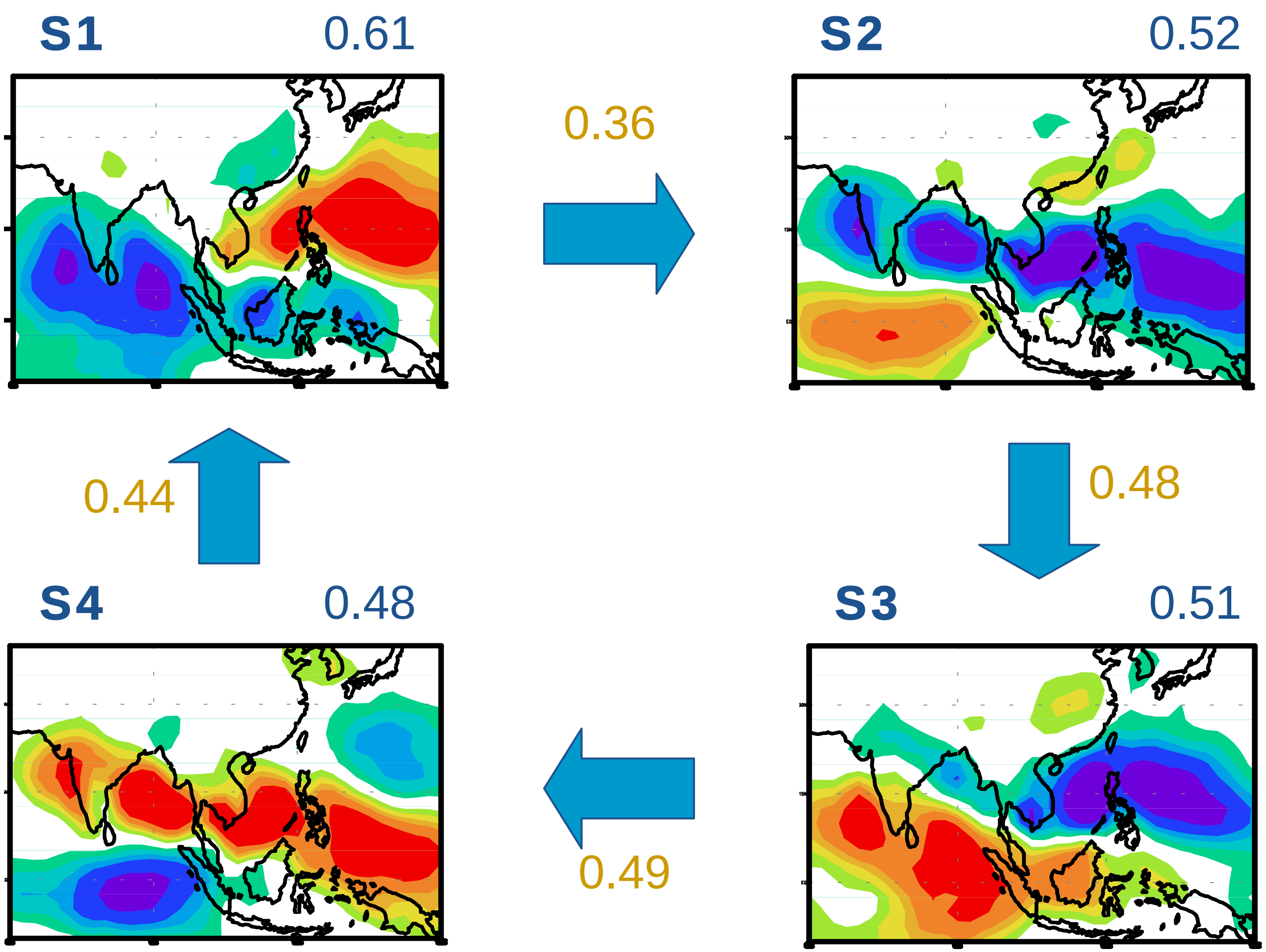
Cluster analysis + transition property among clusters

Application of HMM to ISO

- **Statistical analysis of ISO**
- **Link to dynamical seasonal forecast : Utilize as a post-process**

Estimated States & transition probabilities

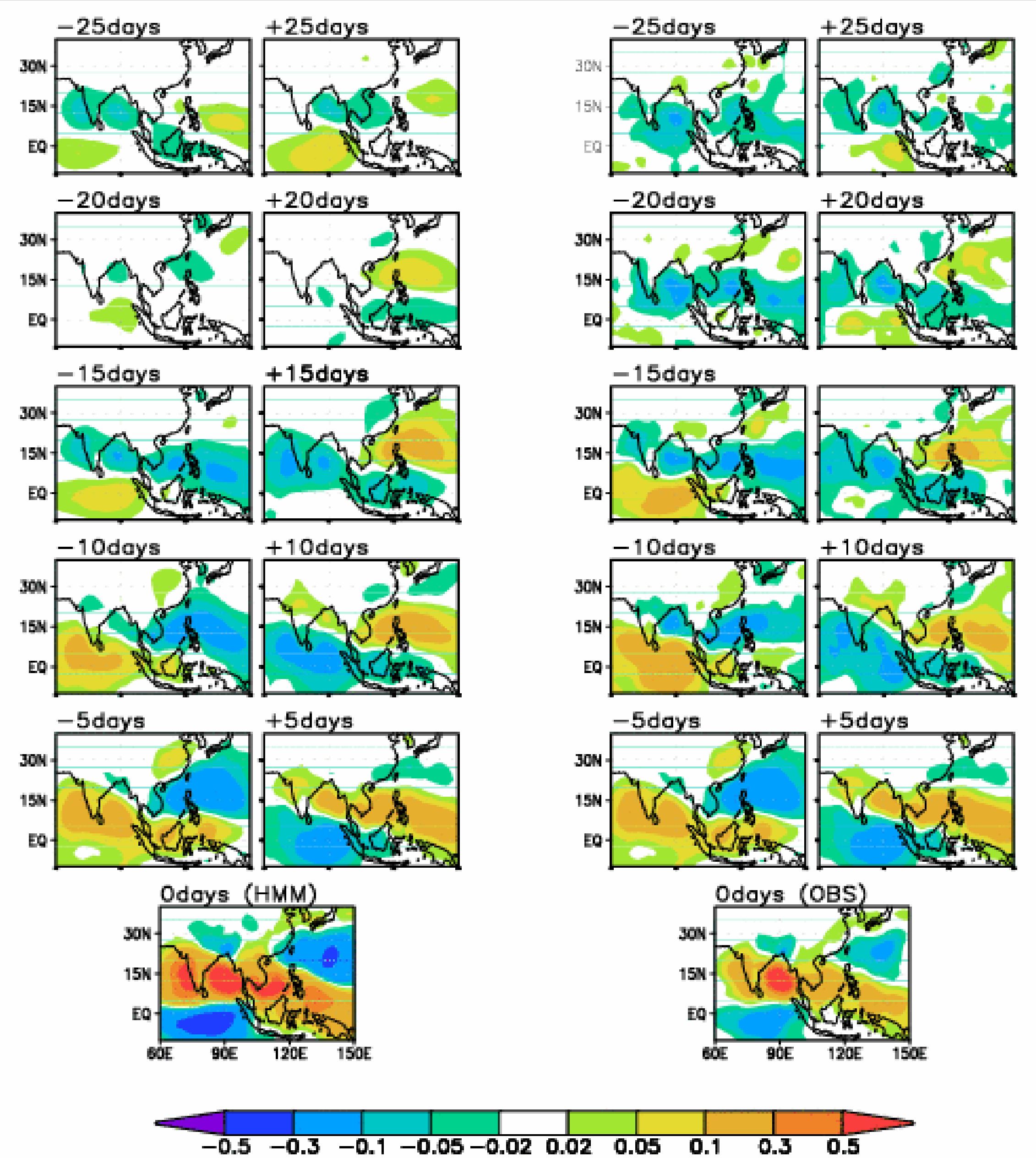
Map: Pentad Precipitation anomaly corresponding to each state



Stochastic simulation of ISO with HMM

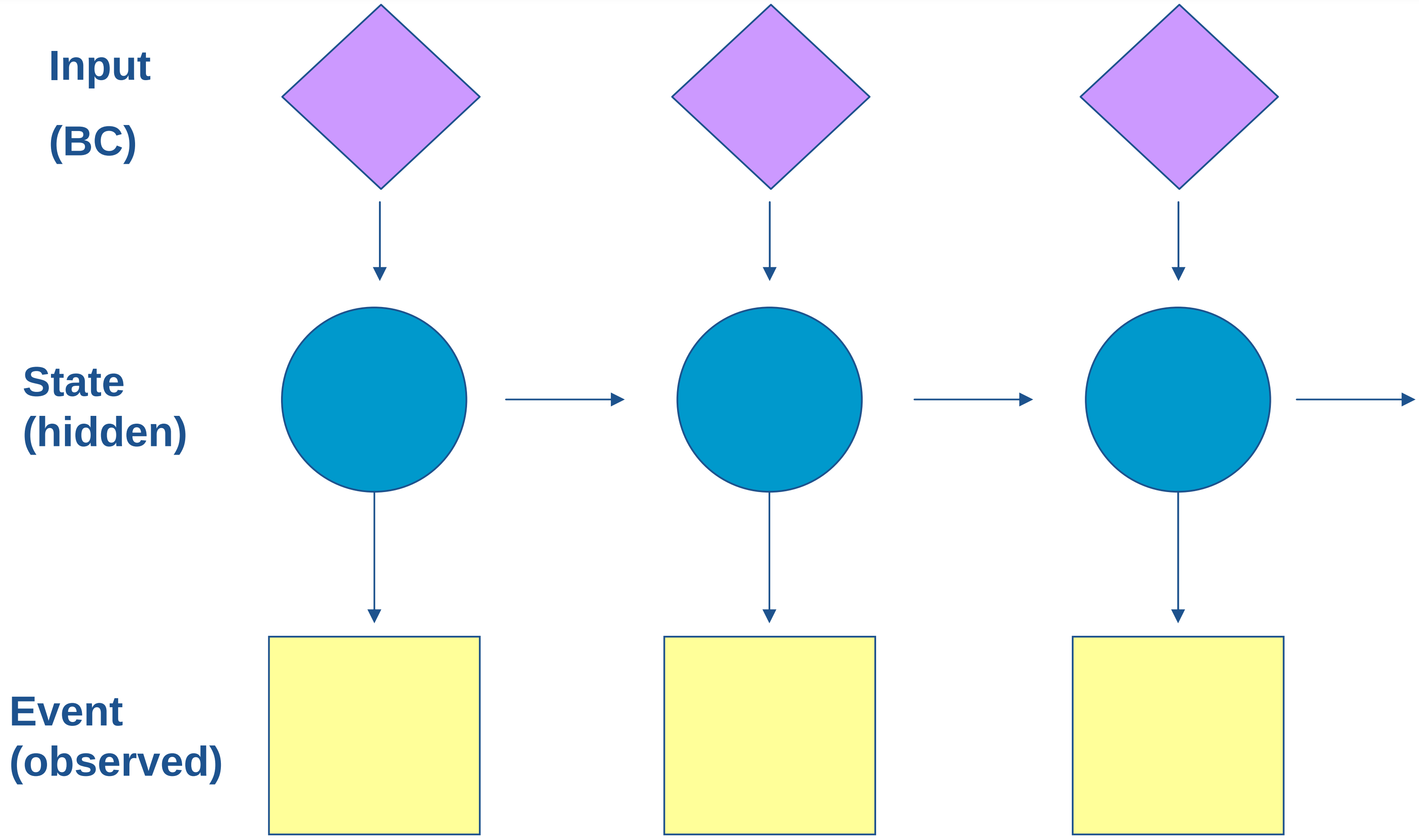
HMM

OBS



Lead-Lag one point regression map

Nonhomogeneous HMM (NHMM) with input

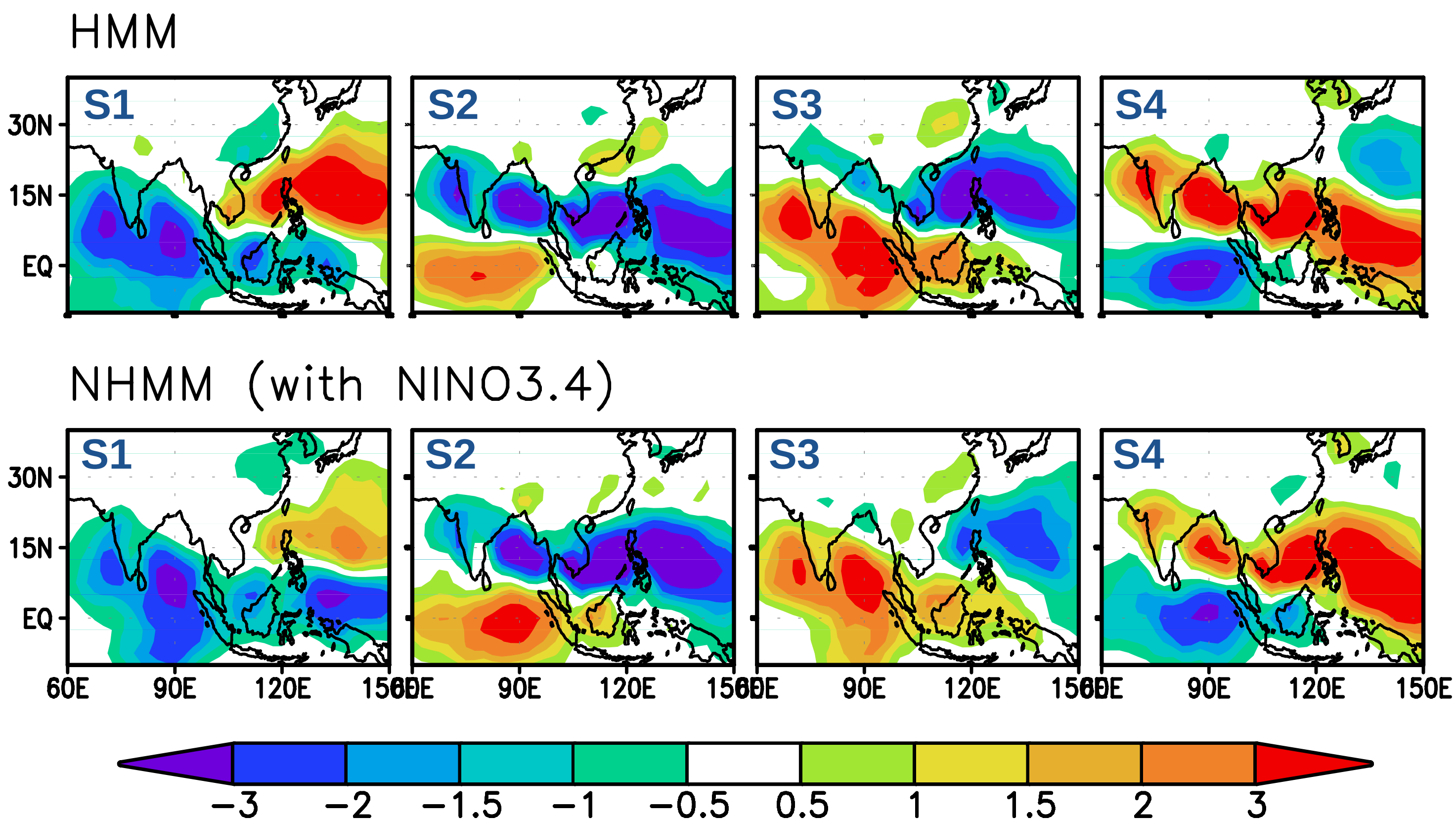


Considering impact of Input(BC) in transition probability / states occurrence

→ Linkage to GCM forecast

NHMM with summer mean Nino3.4 SSTA

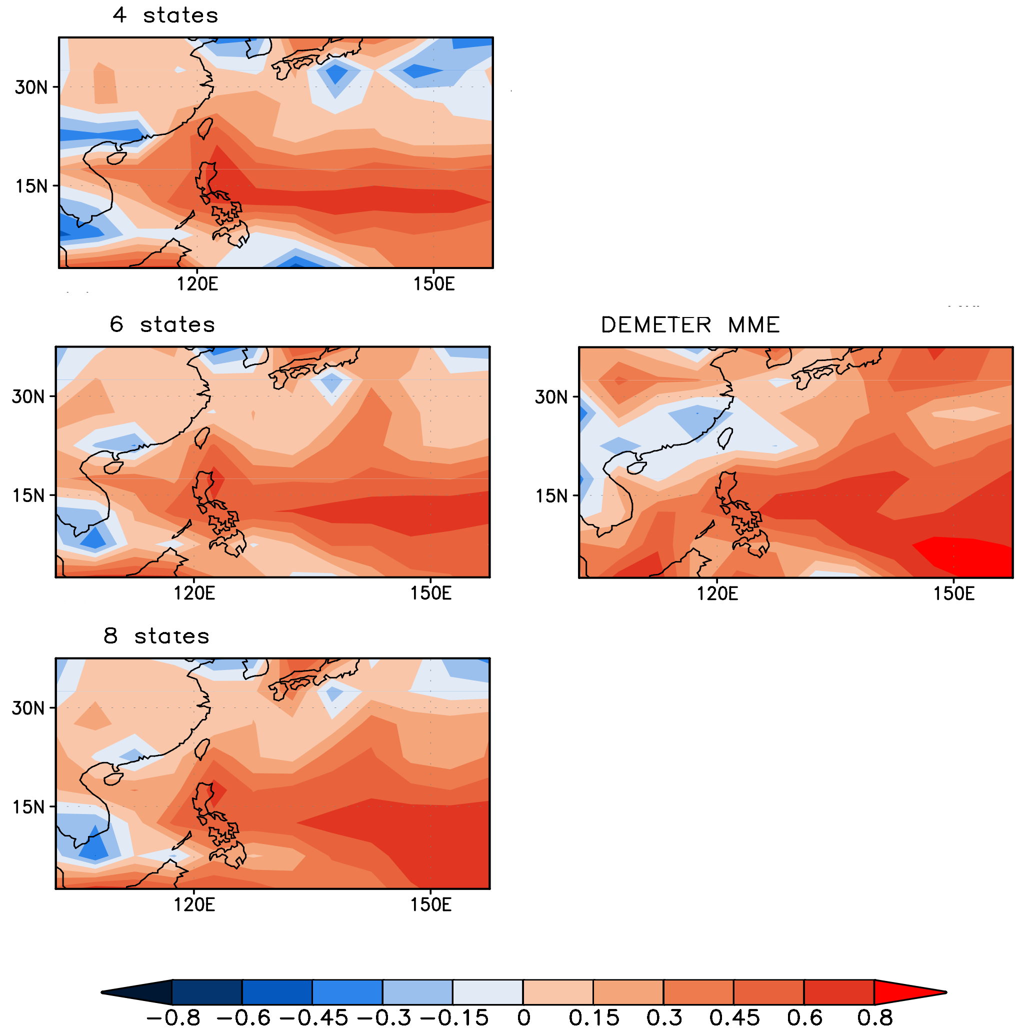
Map: Pentad Precipitation anomaly corresponding to each state



States picked up by NHMM resembles those of HMM

First attempt of post-process : anomaly correlation skill

seasonal mean precip. generated by NHMM with GCM forecast as a input



Input variable of NHMM : 3 leading PCs of GCM (DEMETER) MME monthly mean forecast of precipitation over same domain

Simulating Pentad precipitation anomalies with NHMM and make seasonal average of them

Cross-validation

Thank You !