Intraseasonal (MJO) Prediction and Predictability: Impact of Initialization

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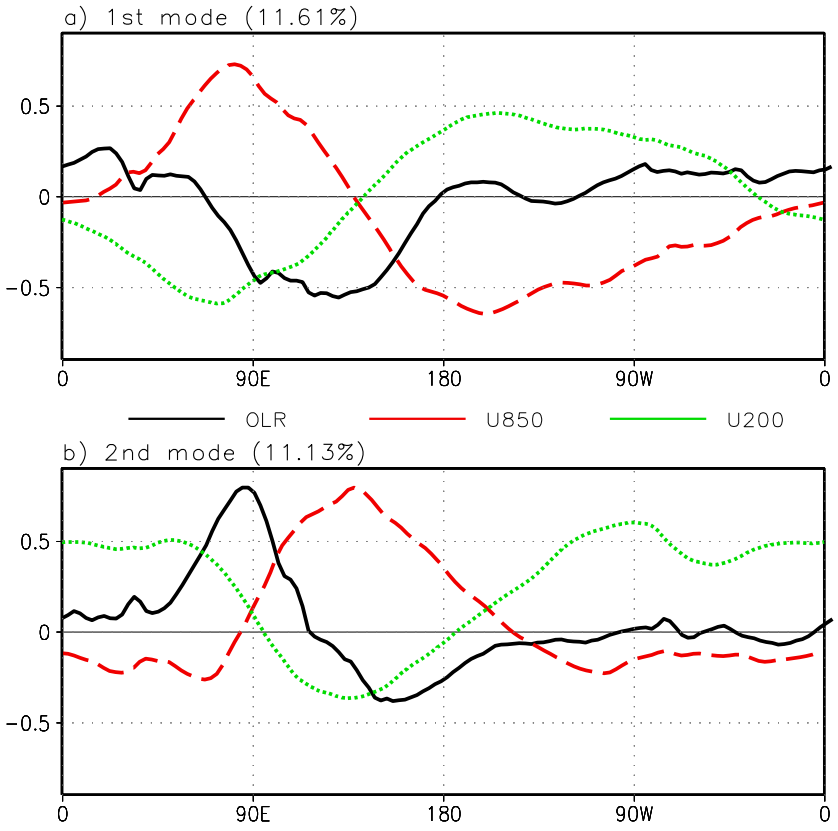
Predictand: RMM index

Real-time Multivariate MJO index (RMM):

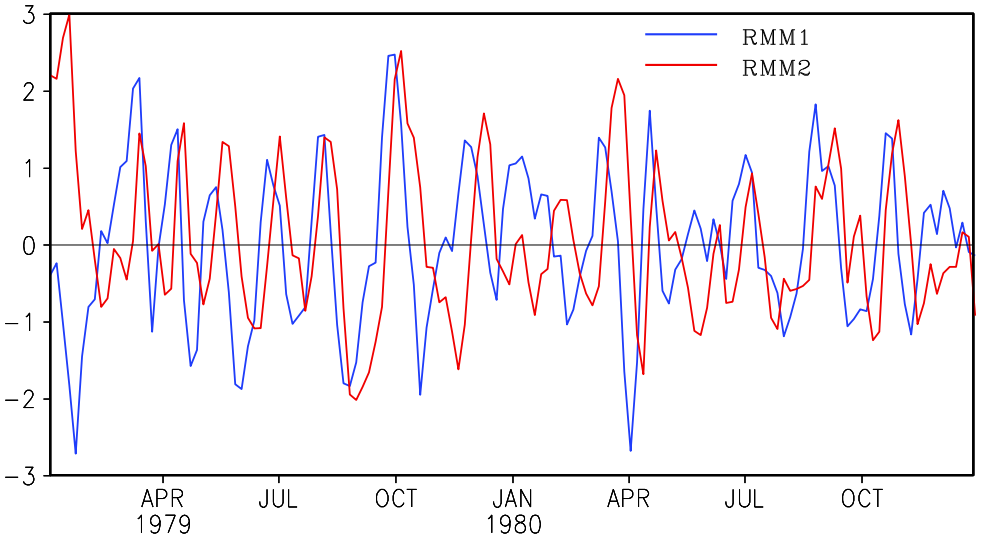
The PCs of combined EOFs (Equatorial OLR, U850, U200)

(Wheeler and Hendon 04)

- **EV of Combined EOF**



- **PCs: RMM1 and RMM2**



1. Annual cycle removed;

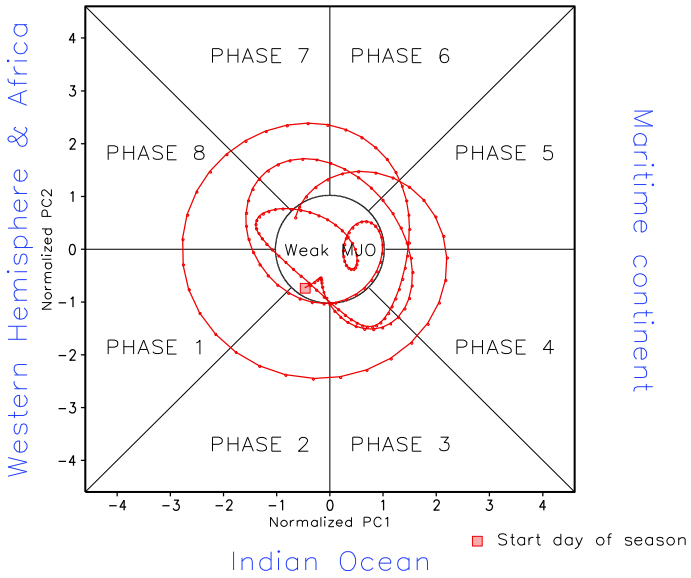
2. Interannual variability removed:

- Mean of previous 120 days

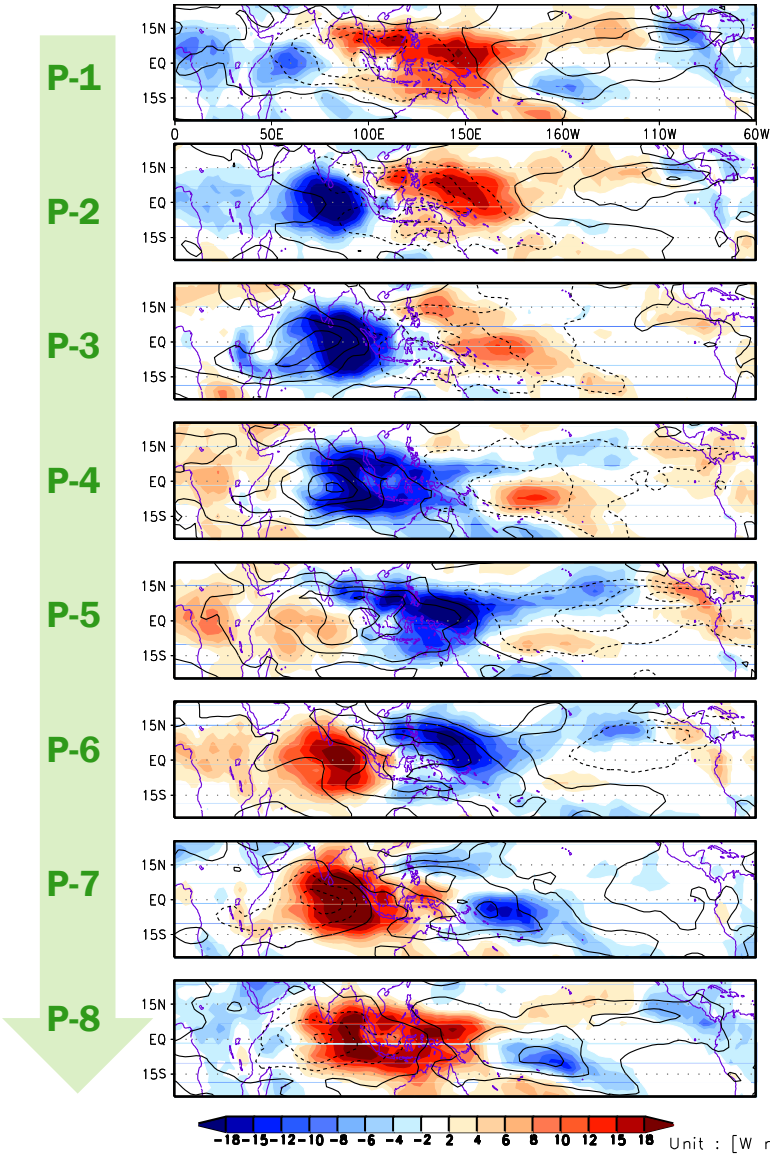
Advantages of RMM index

1. Avoid the typical Filtering problem in real-time use
2. Convenient for application (monitoring and prediction):
   Reduction of parameters
3. Represent the MJO in individual phase

Phase diagram (RMM1, RMM2)
: Nov1979-Apr1980



Composite: OLR & U850



Contents

- **Statistical and dynamical models of MJO**

  Kang and Kim (2010, J. Climate)

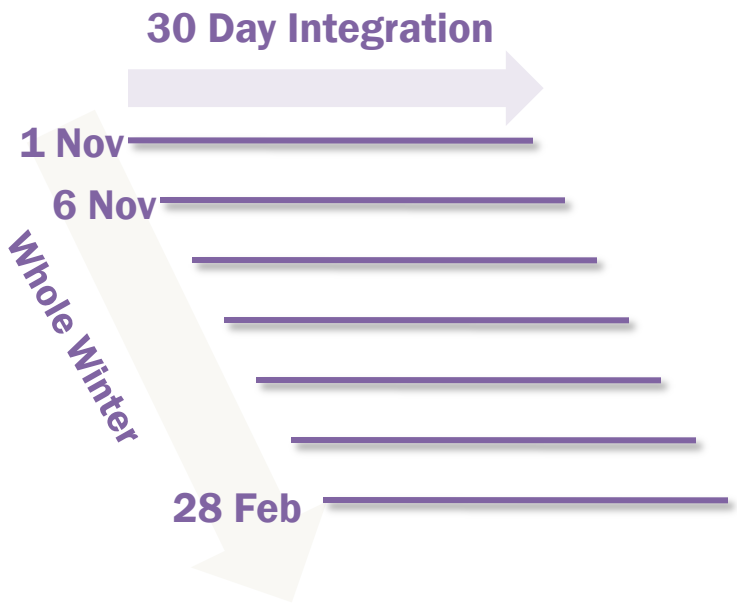
- **NECP vs ERA40 for MJO initialization**

- **Various initializations (replacement, nudging, ensemble methods, ESV)**

- **Improvements of AGCM & CGCM**

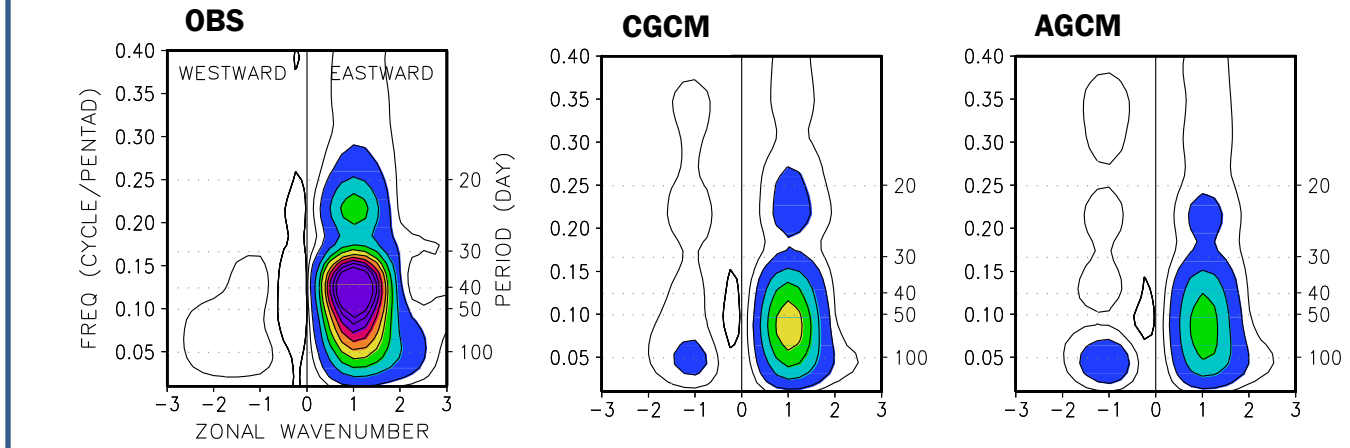
- **Ongoing and future studies**

Serial integration for MJO forecasts



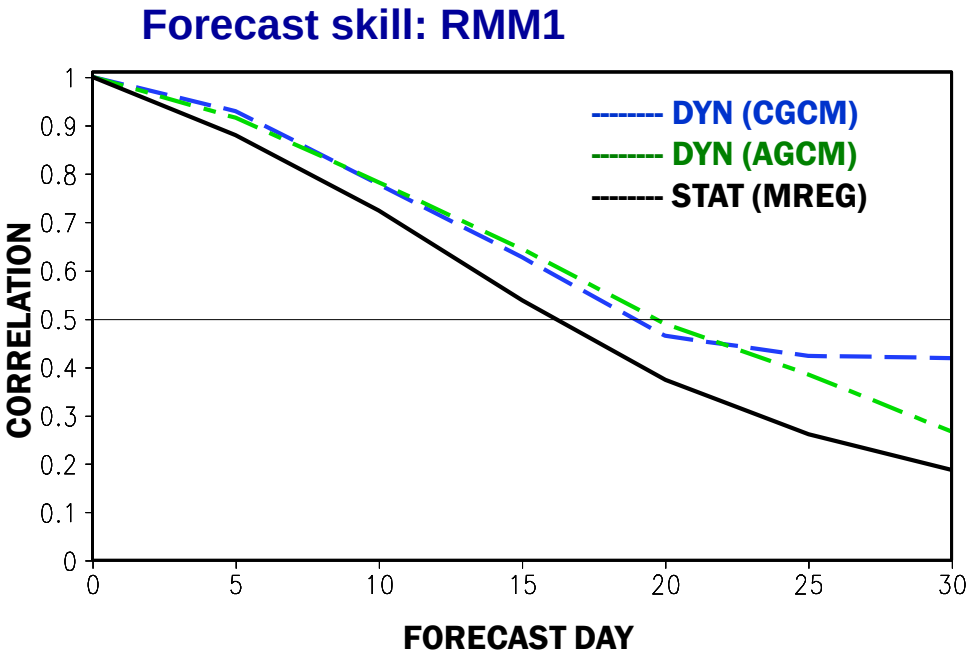
Serial run with SNU GCM

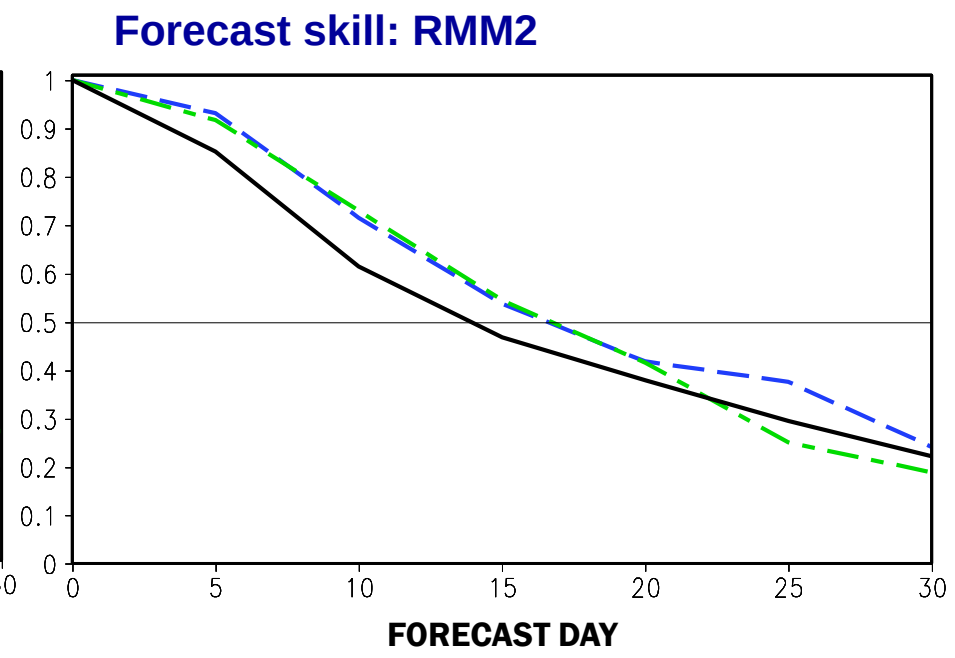
EXP	Period	Total 30-day forecasts	Using 1-CPU
AGCM (Persistent SST)	27-year (79-05)	621	4 month
CGCM	15-year (91-05)	345	4 month



Space-time power spectrum (VP200 10S-10N, 1-30 day FCST)

Forecast skills of RMM index



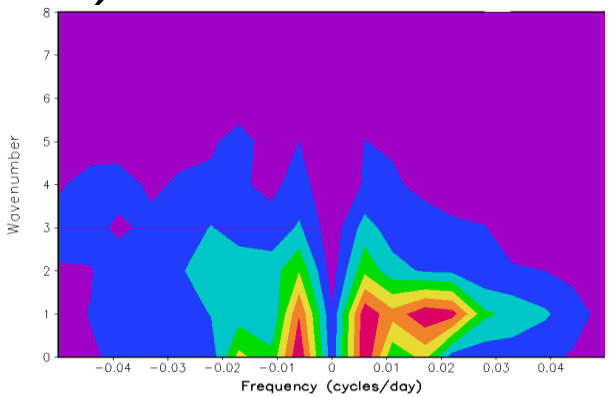


Correlation 0.5 at (day)		
	RMM1	RMM2
DYN (CGCM)	19-20	16-17
DYN (AGCM)	19-20	16-17
STAT (MREG)	16-17	14-15

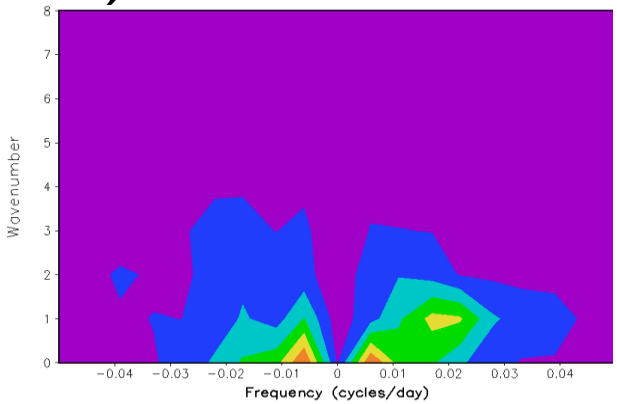
Impact of observation data :
ERA40 v.s NCEP reanalysis data

Equatorial space-time spectrum of
low-level specific humidity (10S-10N averaged)

a) ERA40



b) NCEP



*winter season (Nov.- Apr., 1981-2000)

Forecast skill of RMM index : NCEP/NCAR v.s ERA40

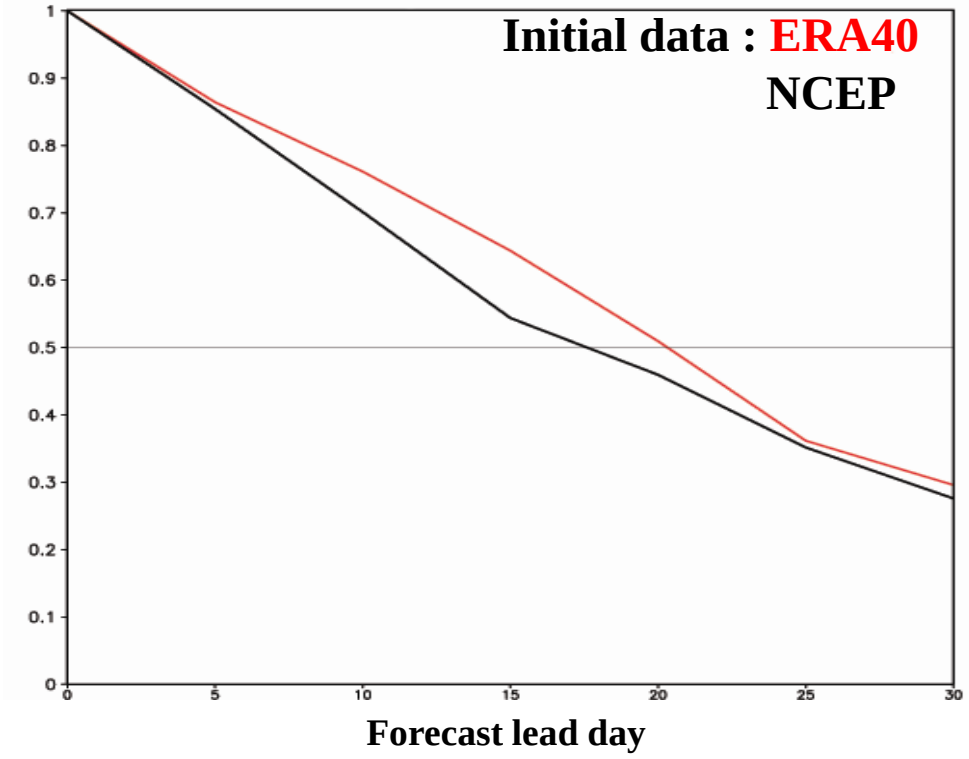
$$\text{Cor of RMM index } (\tau) = \frac{[\sum_{i=1}^{N} a_{1i}(t)\cdot b_{1i}(t) + a_{2i}(t)\cdot b_{2i}(t)]}{\sqrt{\sum_{i=1}^{N}[a^2{}_{1i}(t) + a^2{}_{2i}(t)]}\cdot\sqrt{\sum_{i=1}^{N}[b^2{}_{1i}(t) + b^2{}_{2i}(t)]}}$$

$a_{1i}(t), a_{2i}(t)$: observed RMM1,2 at day t

$b_{1i}(t), b_{2i}(t)$: simulated RMM1,2 at day t

τ : Forecast lead day

N : Number of forecasts



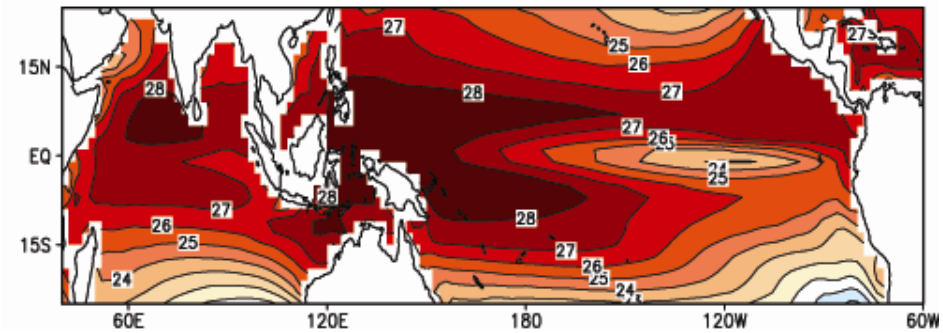
	Red	Black
Observation	ERA40	NCEP
Observation	Replace	
Initialized variable	3-dimensional U,V,T,q Surface pressure (Ps)	
Ensemble member	1	
Model	CGCM v.2	
Prediction period	1981.11.6-2000.2.24 (Total : 437 cases)	

Selection of initial data : NCEP → ERA40

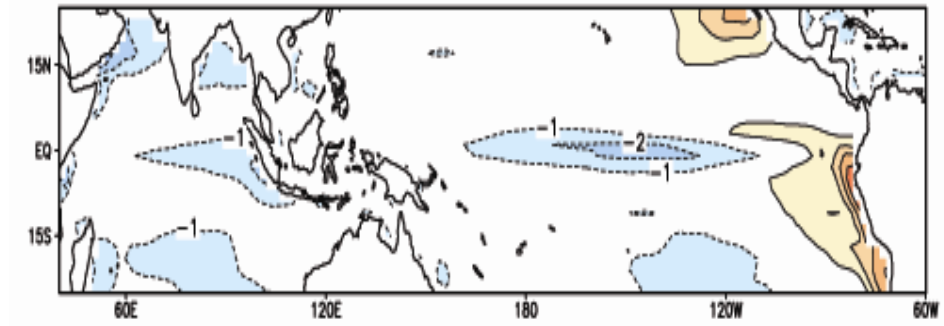
CGCM improvement

CGCM v.1

Annual mean SST

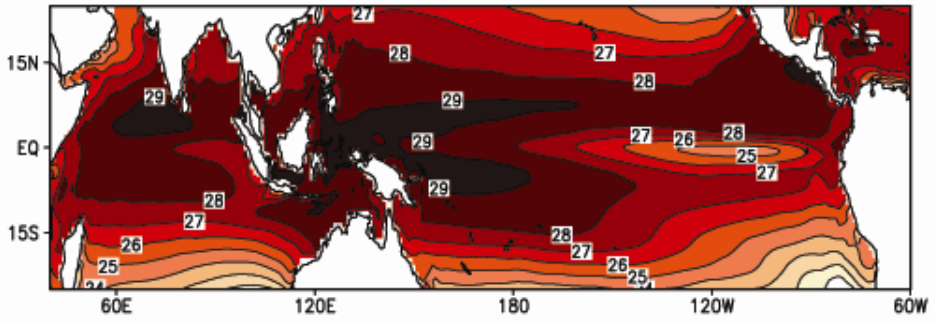


Bias

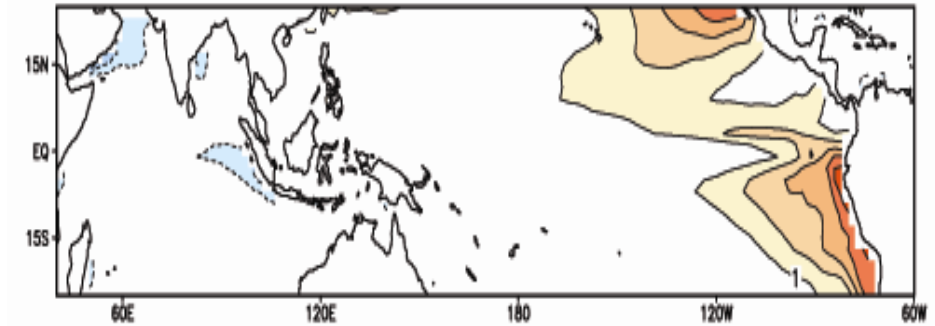


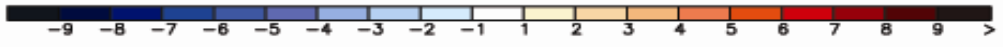
CGCM v.2

Annual mean SST



Bias



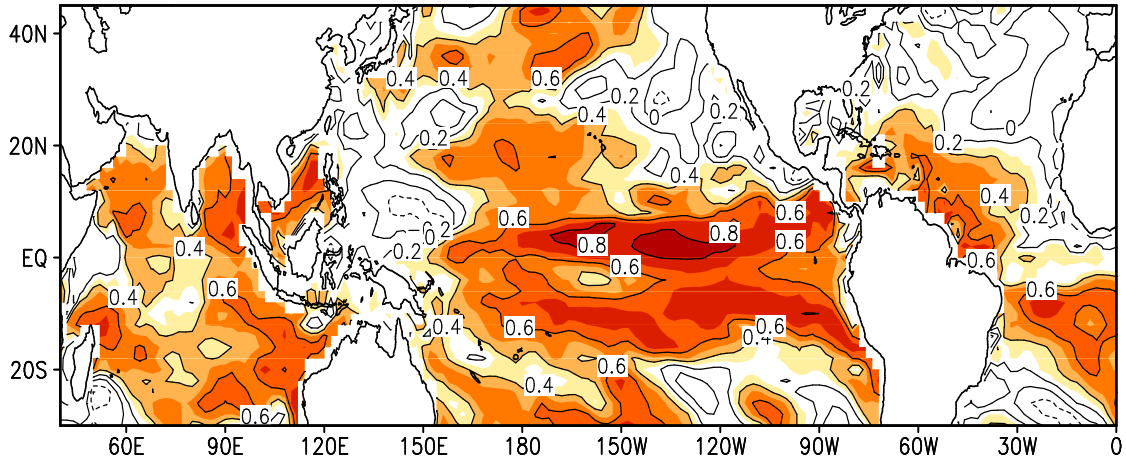


- Convective momentum transport
- Diurnal coupling
- Tokioka constraint (alpha=0.1)
- Auto conversion time scale (3200s)

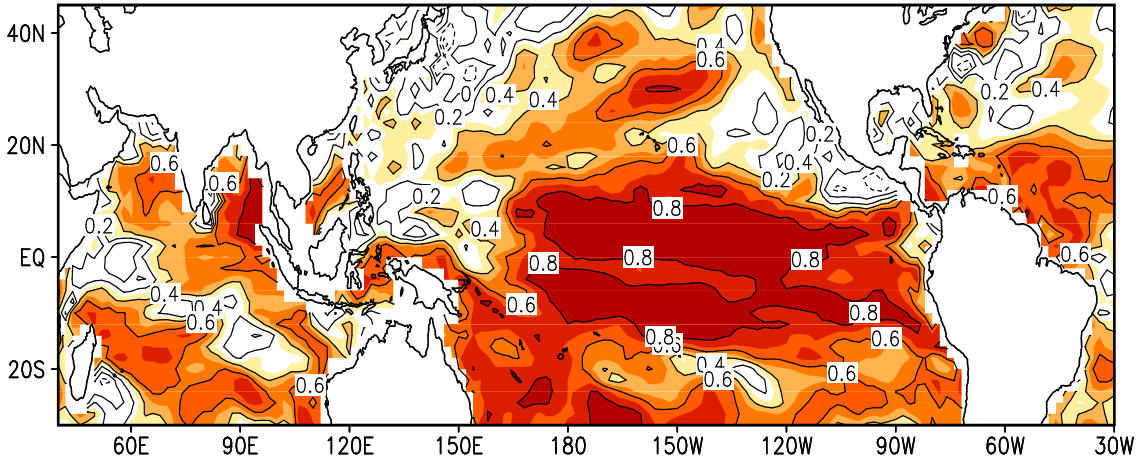
Seasonal prediction

Correlation skill for JJA SST (Start from 1st May)

CGCM v.1



CGCM v.2



Model improvement
➔ Significant impact
(Seasonal prediction)

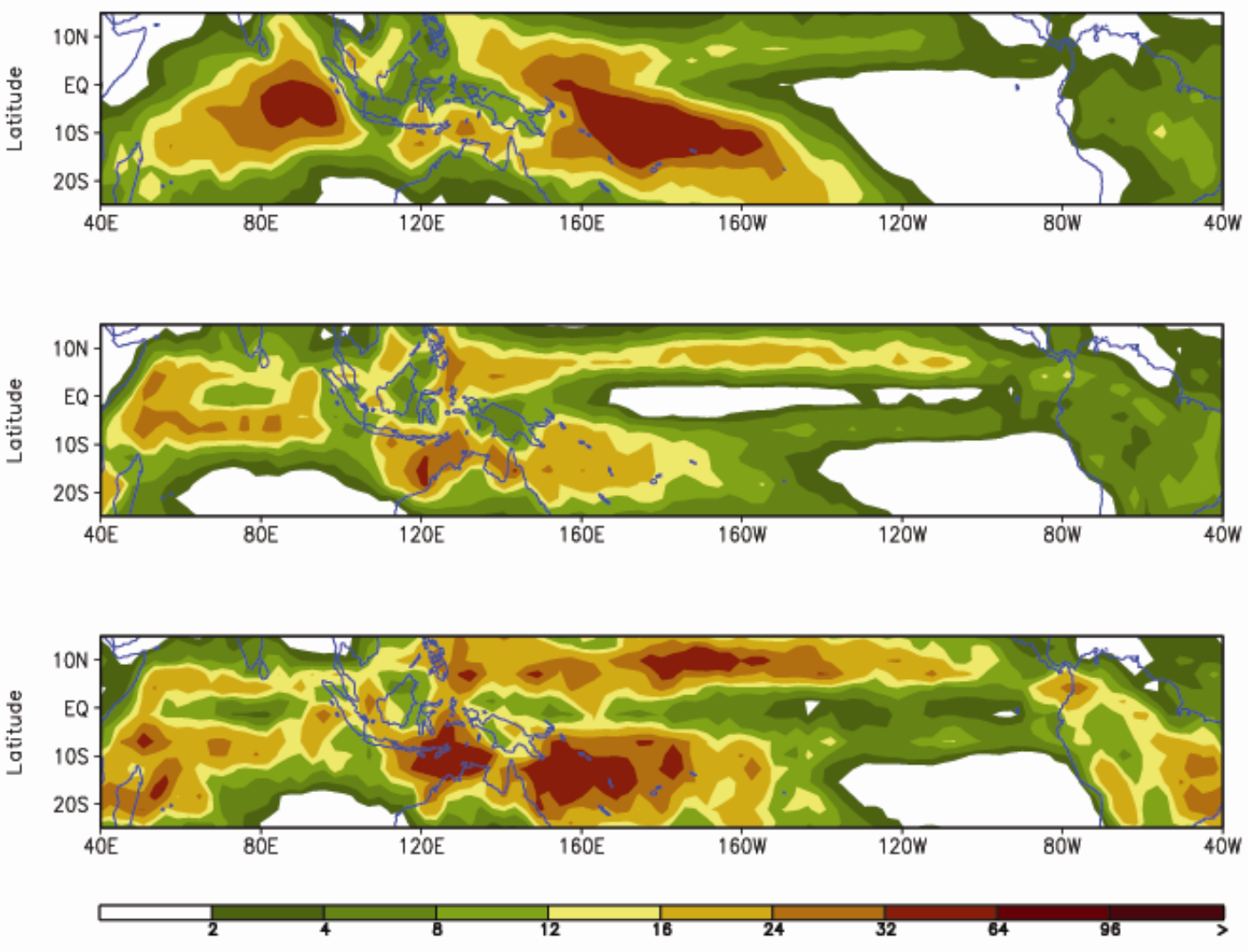
Initialization: Nudging
(OCN only)

Sub-seasonal (20-100 day filtered) variability of PRCP

GPCP

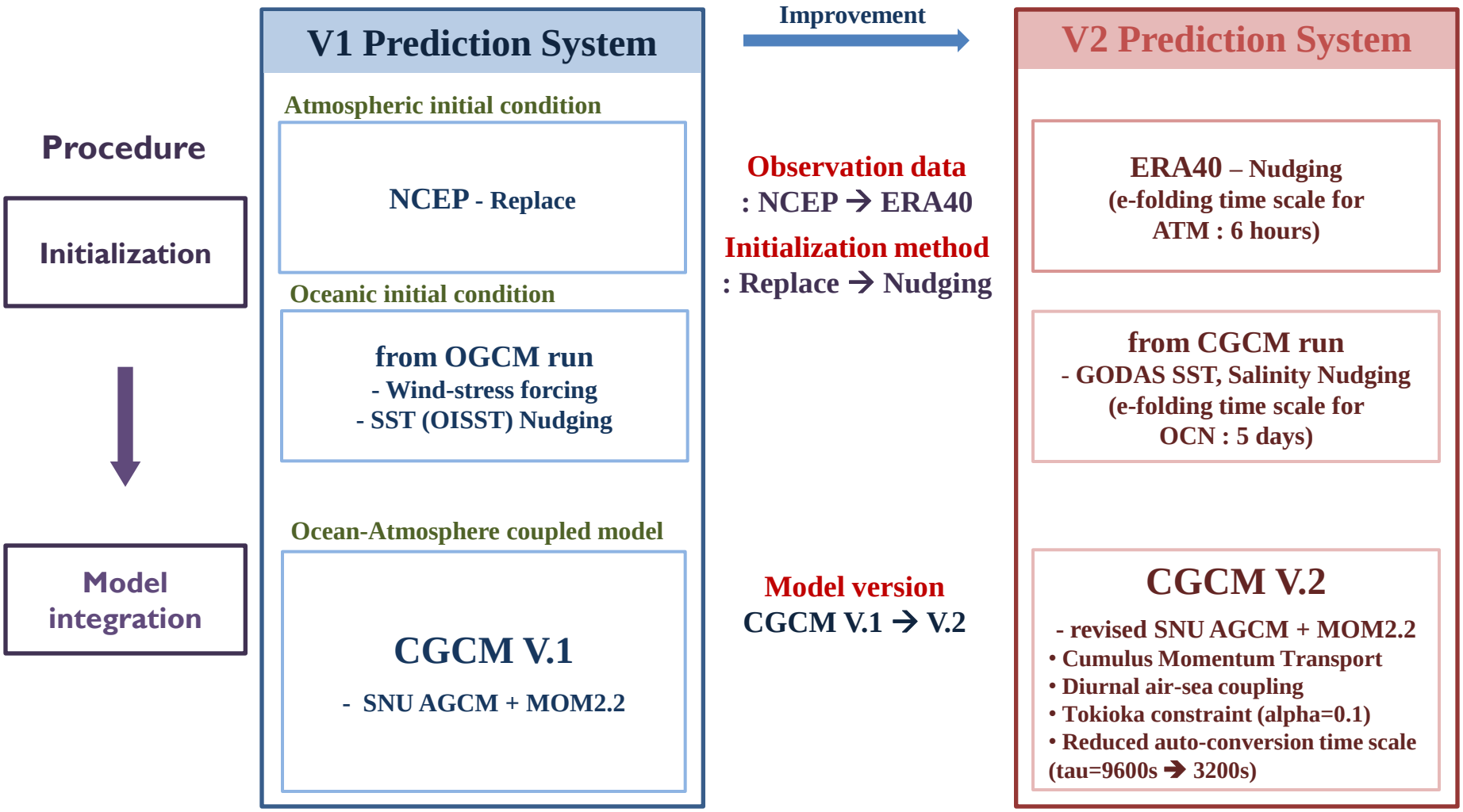
CGCM v.1

CGCM v.2

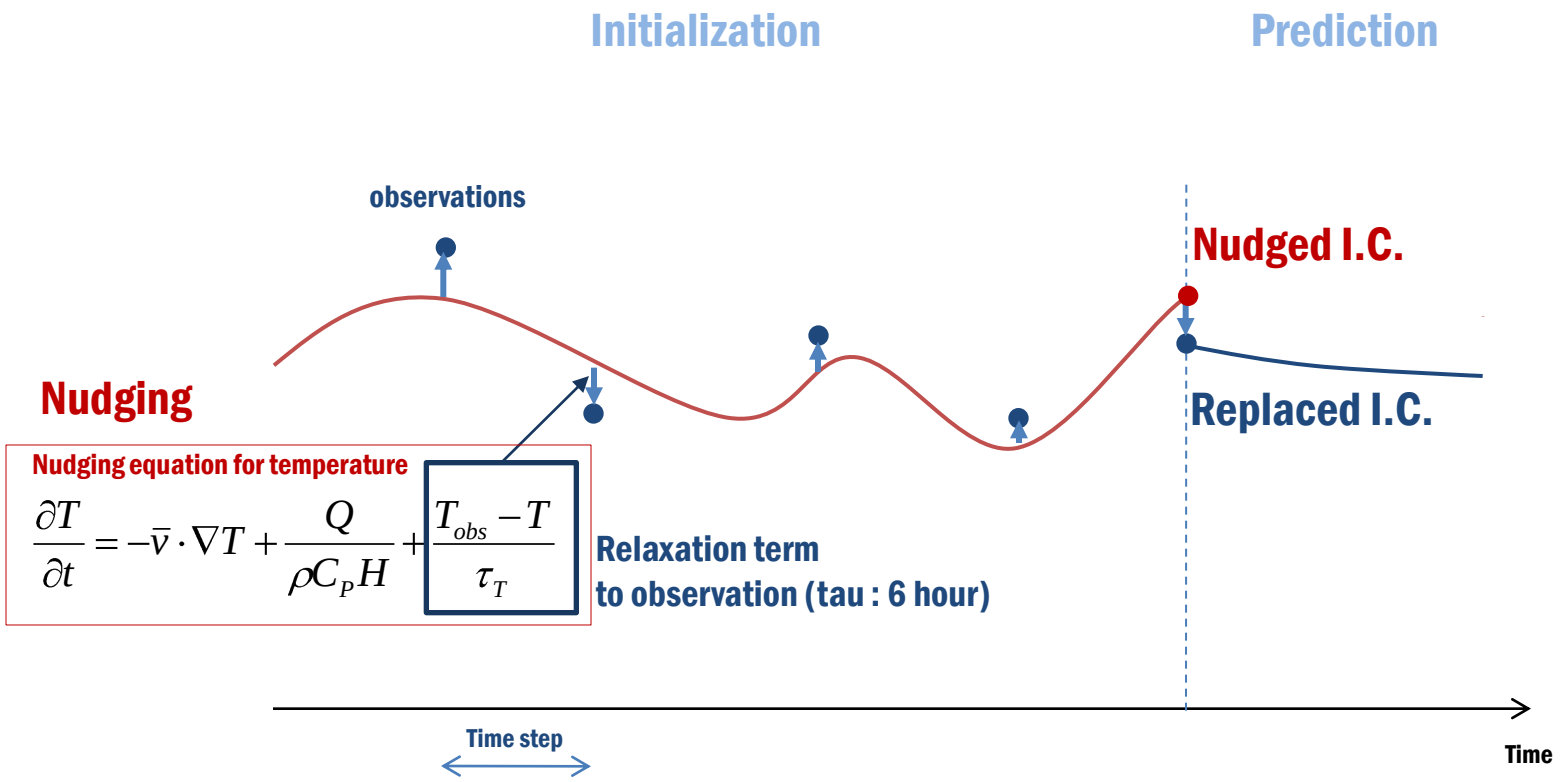


*November-April

Dynamical MJO prediction system with CGCM

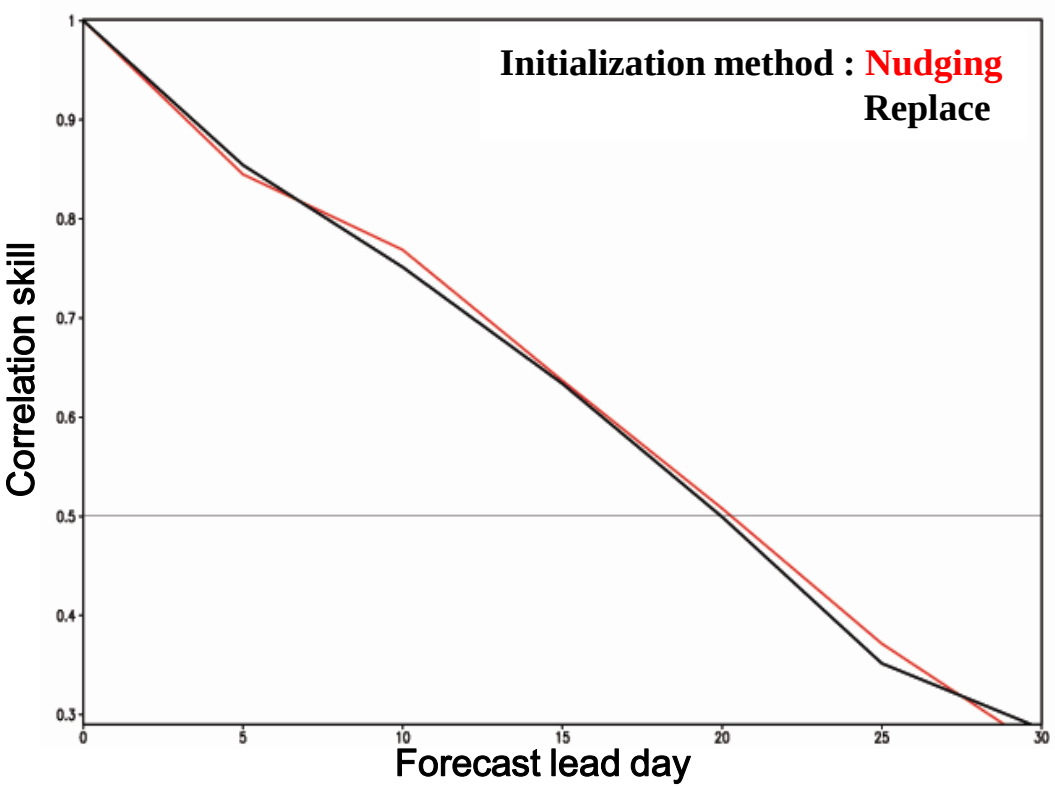


Coupled Initialization with the atmosphere nudging



Coupled vs non-coupled initialization

Correlation skill of RMM index



	Red	Black
Initialization	**Nudging** (rescaling time : 6 hour)	**Replace**
Observation	ERA40	
Initialized variable	3-dimensional U,V,T,q Surface pressure (Ps)	
Ensemble member	**1**	
Model	CGCM v.2	
Prediction period	1981.11.6-2000.2.24 (Total : 437 cases)	

Ensemble prediction

Procedure

Initialization

Atmospheric initial condition

ERA40
- Nudging

+

Oceanic initial condition

from CGCM run-
Temperature, Salinity (GODAS) Nudging

+

Ensemble perturbation

Ensemble generation method

Empirical Singular Vector (ESV) for MJO related variable

Time regression to other variables

ESV related field to all prognostic variables of ATM & OCN

Model integration

Ocean-Atmosphere coupled model

CGCM V.2

- revised SNU AGCM + MOM2.2
- **Cumulus Momentum Transport**
- **Diurnal air-sea coupling**
- **Tokioka constraint (alpha=0.1)**
- **Reduced auto-conversion time scale (tau=9600s ➔ 3200s)**

Fast-growing perturbations for optimal ensemble prediction

Two well-known methods

	Breeding method	Singular Vector (SV)method
Description	Repeat breeding and rescaling in the model integration	Linear Stability of linearized model
Usage	NCEP for medium-range prediction	ECMWF for medium-range prediction
Drawbacks	Additional computation is required	Linearized model is required

⇩

Modifications for wide / easy application is needed

Empirical Singular Vector for optimal perturbations (Kug et al, 2009)

Define initial (X) & final (Y) variables with forecast data

Y = X (t + 10days)

Formulate the Linear Operator (L)

Linear inverse modeling (L_{linear})

$$Y = L \cdot X$$

$$L = YX^{T}(XX^{T})^{-1}$$

Find fast growing perturbation using SVD

$$L_{linear} = USV^{T}$$

Fast growing perturbations :

→ Right singular vectors whose singular value is maxima

Sensitivity test of initial & final variables

Initial time variable	Final time variable	Detection of Unstable mode

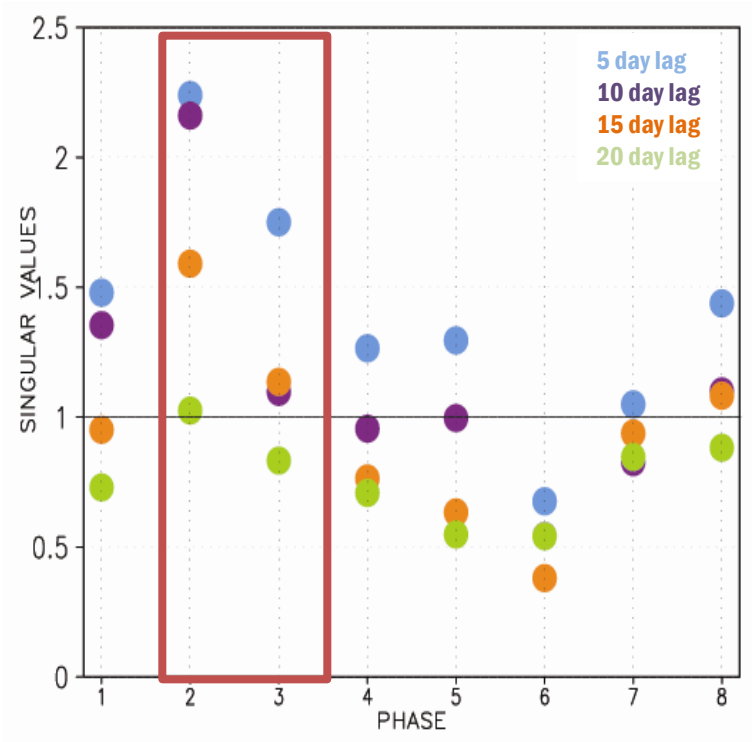
Selection of initial & final variables for detecting growing perturbations related to MJO

Specific humidity at 925mb	U850, U200, VP200 (Combined EOF is used)	O

Unstable modes related to MJO

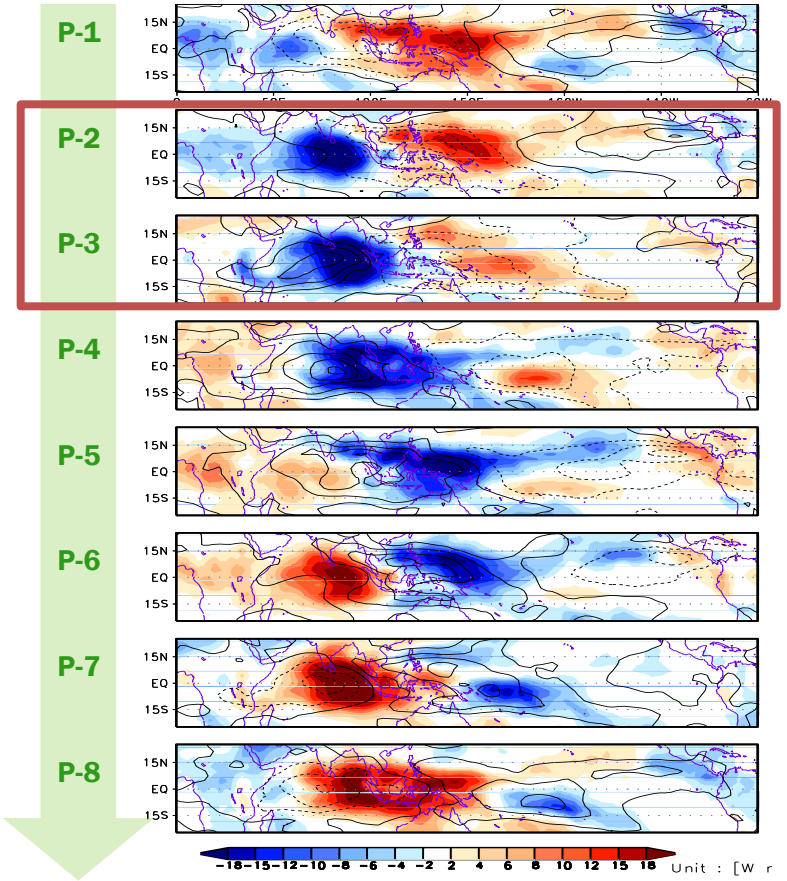
Singular value

(When SV is greater than 1: Unstable mode)



Phase 2,3 : Most unstable phase

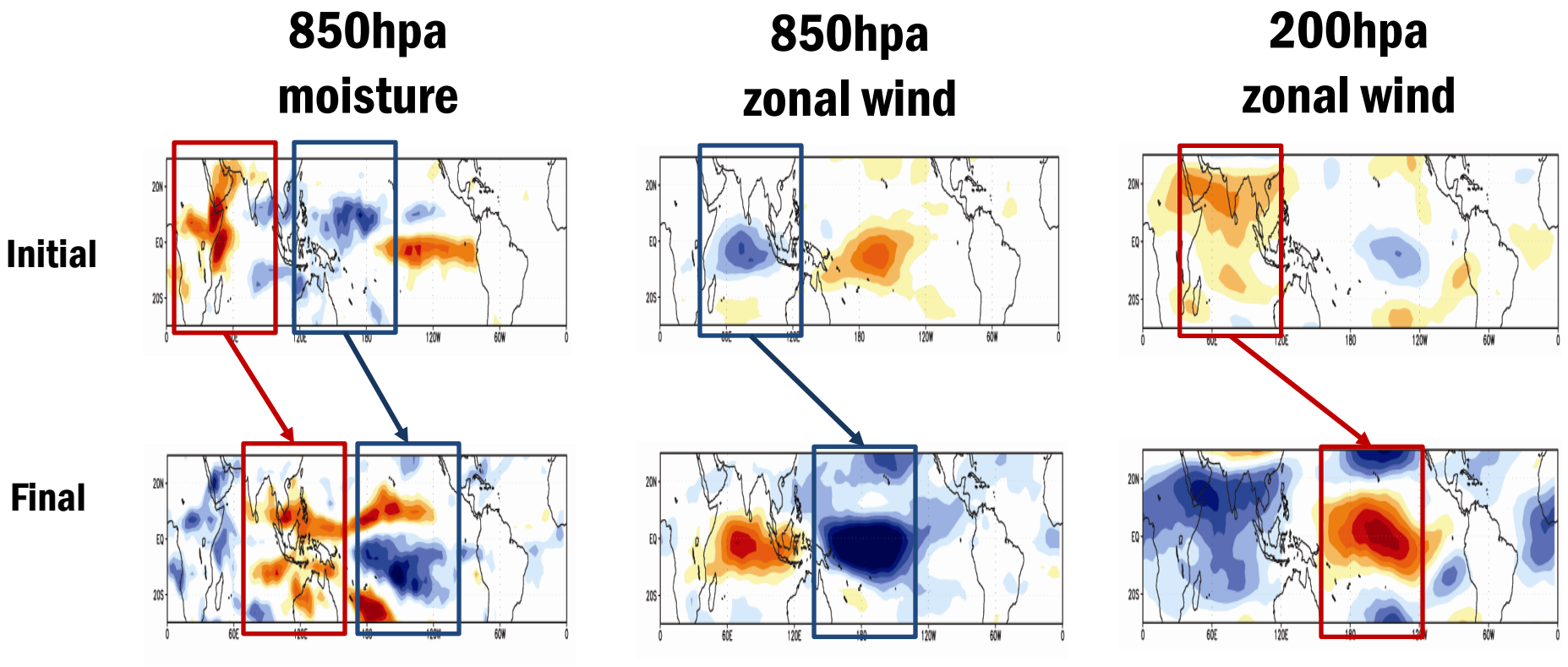
MJO lifecycle composite: OLR (shading) & U850 (contour)



Phase 2,3
MJO signal intensifies over Indian Ocean- Maritime continent

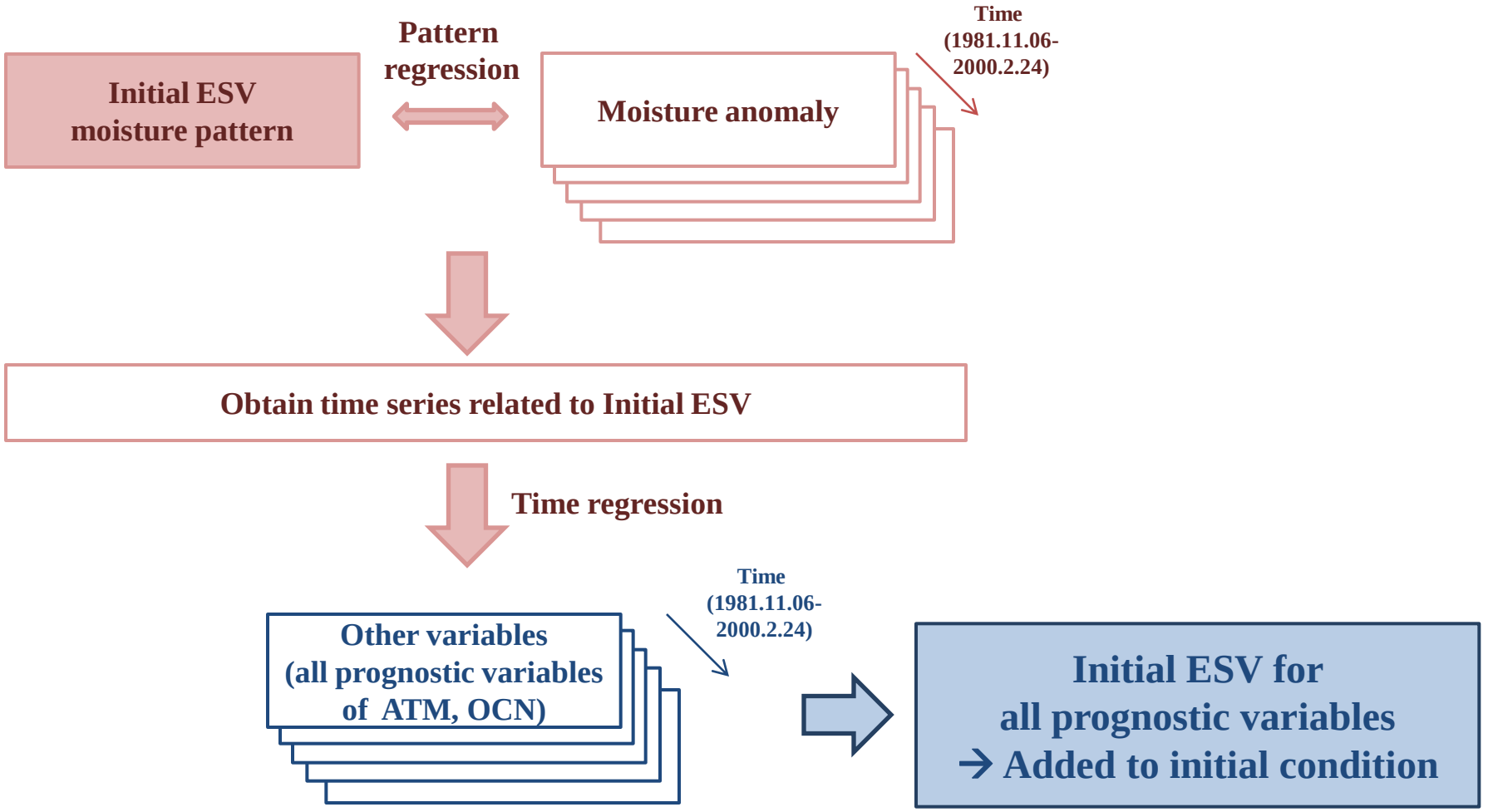
Empirical Singular Vector : Phase 3

*Obtained from model forecasts

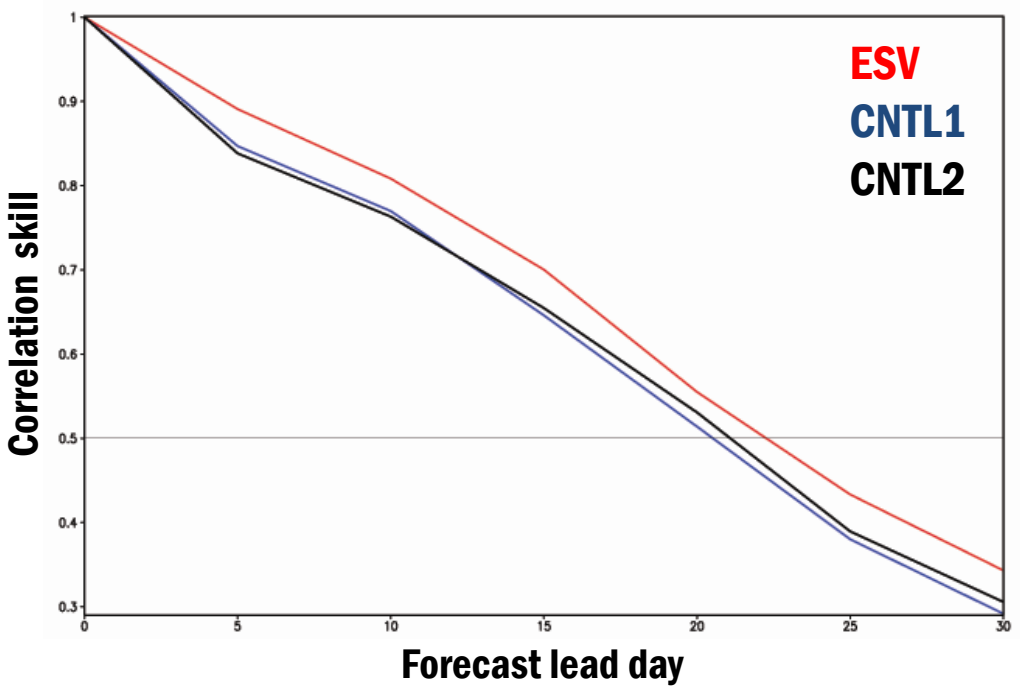


ESV mode : Eastward propagating

Generating initial perturbations for all variables



Correlation skill 2 ensemble members

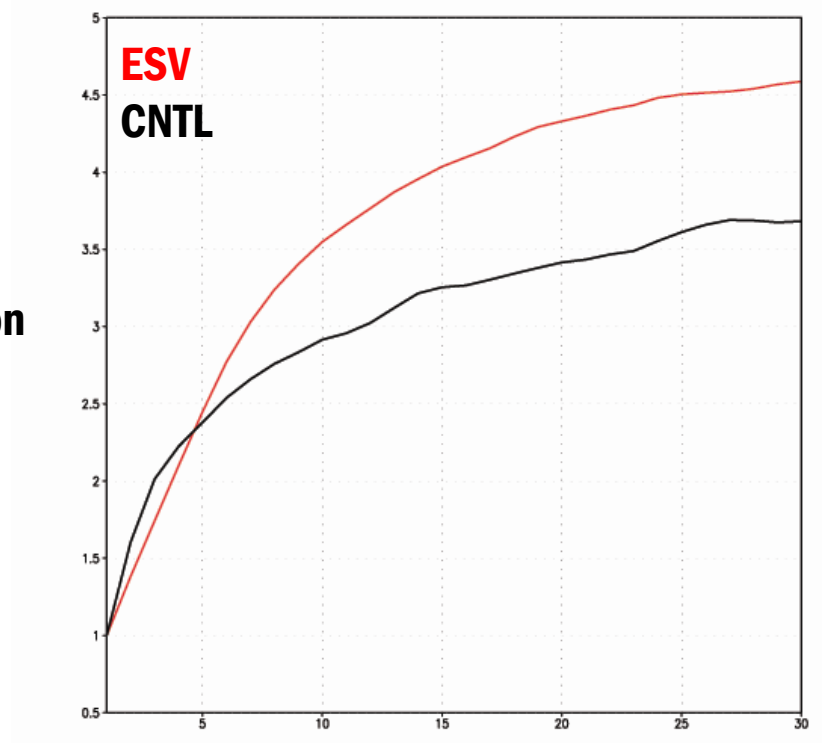


		ESV (RED)	CNTL1 (BLUE)	CNTL2 (BLACK)
Number of ensemble member		2		
Observations		ERA40		
Model		CGCM V.2		
Ensemble member Description	1st	ERA40 Nudging + Positive ESV pert.	Nudging - on time	Nudging - on time
	2nd	ERA40 Nudging + Negative ESV pert.	Replace - on time	Nudging - 6 hour lag

Ensemble perturbation growth rate : U850

Ensemble perturbation :
Averaged RMS U850 ensemble perturbation over equator

$$\text{Growth rate at } T^{th} \text{ day} = \frac{\text{Ensemble perturbation at } T^{th} \text{ day}}{\text{Ensemble perturbation at initial day}}$$



ESV perturbation grows faster than LAF (CNTL) perturbations
→ ESV : fast-growing perturbations which guarantees skillful climate prediction

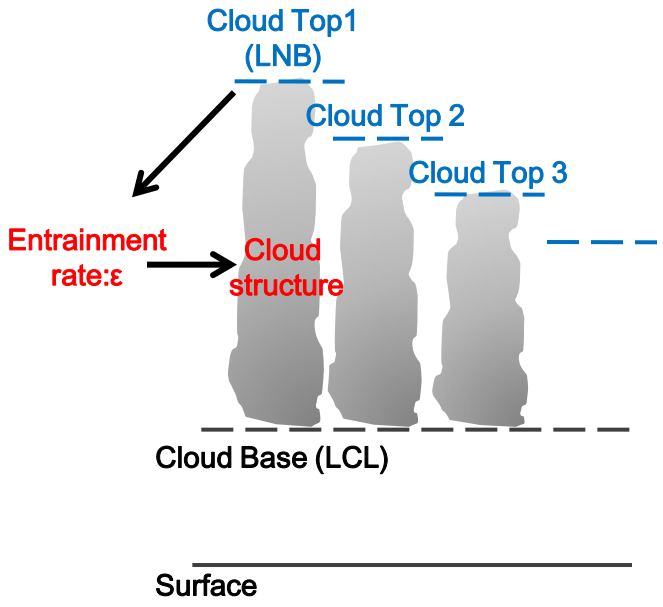
- Impact of Model Improvement

Representation of cumulus cloud

Spectral method

Top-oriented / spectrum

e.g. Arakawa and Schubert (1974)

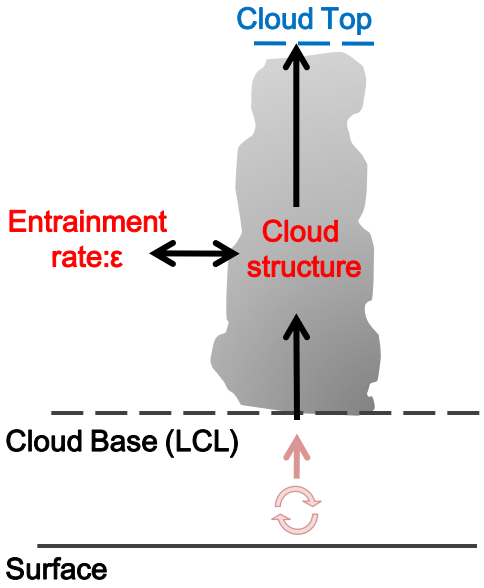


❖ **Cloud top determination**
➔ **deterministic**

Bulk method

Bottom-oriented / Bulk

e.g. Tiedtke (1989)



❖ **Cloud top determination**
➔ **depends on environment**

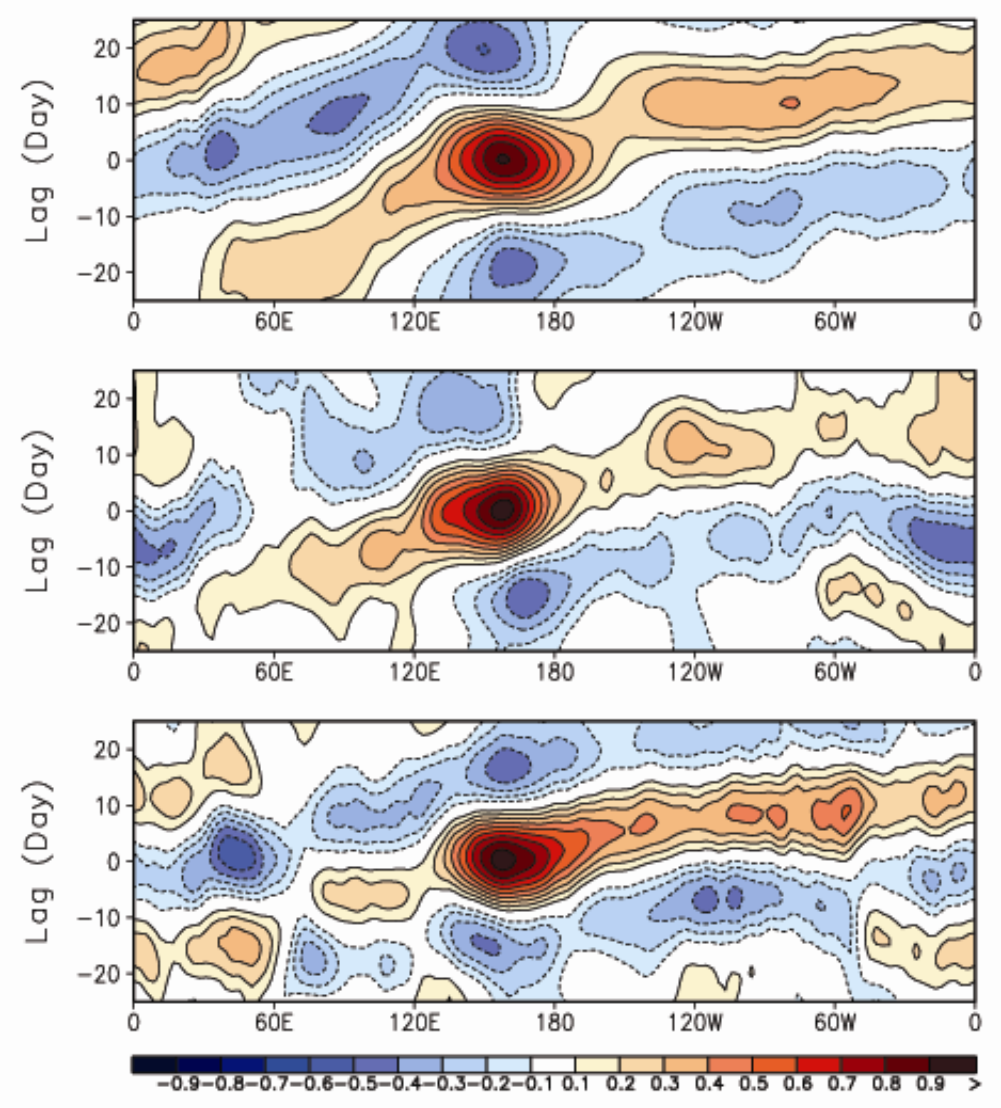
Lag-correlation diagram

(U850, 20-100day filtered)

NCEP

CGCM v.2

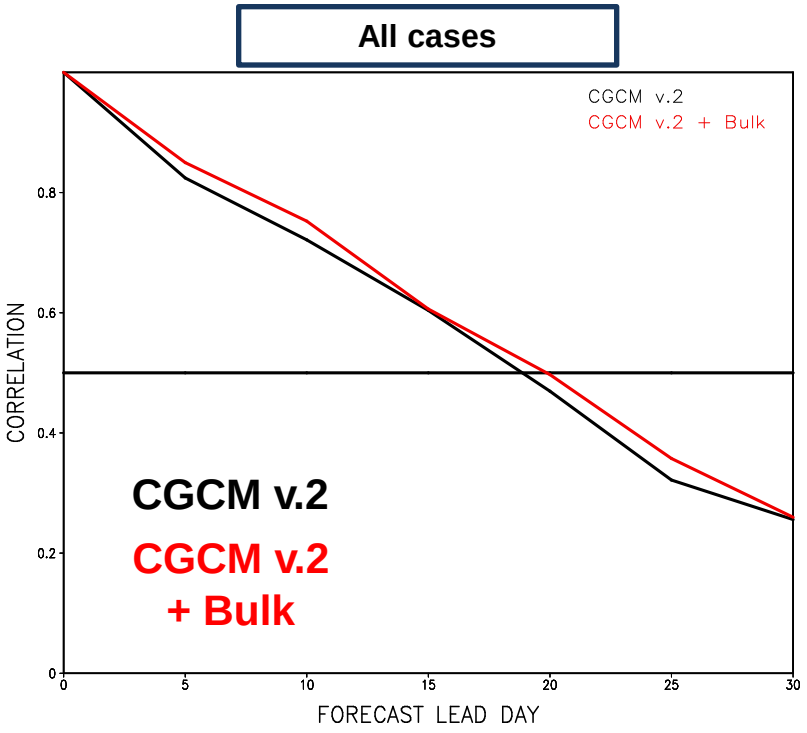
CGCM v.2 + Bulk

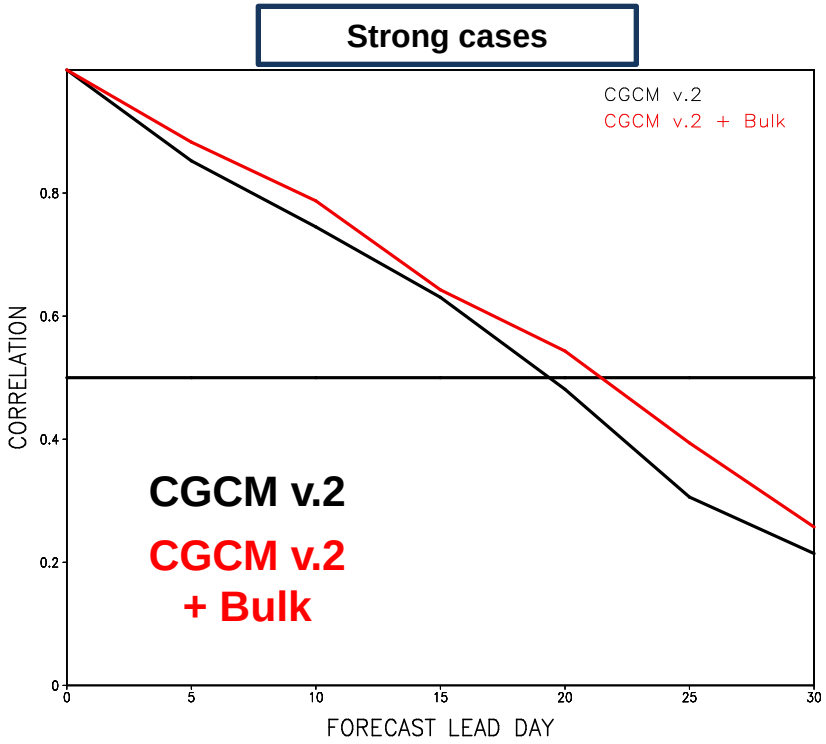


➢ Reference point

: 155-160°E, 5°N-5°S averaged

RMM prediction skill

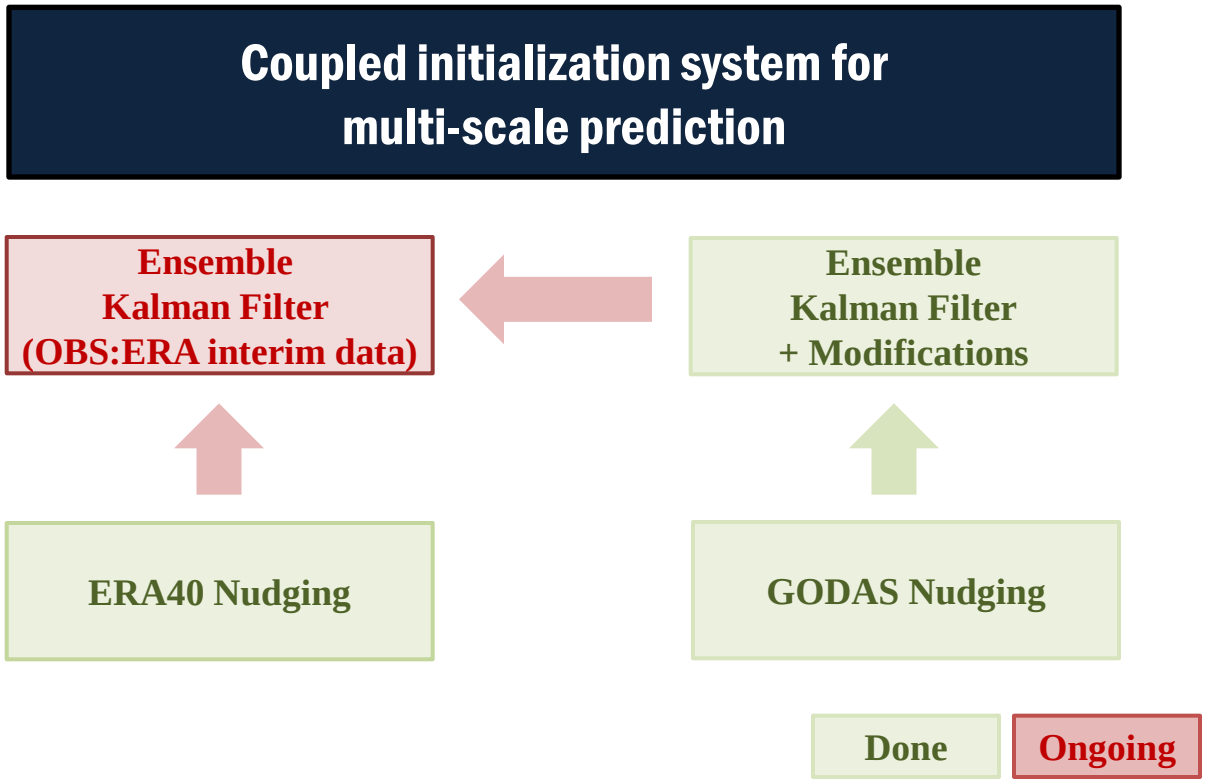




- Number of cases

	CGCMv.2	CGCM v2. + Bulk
All	437	437
Strong	291	278
weak	146	159

Initialization development strategy

	Atmos Initialization	Ocean Initialization
Target	MJO forecasts	Seasonal forecasts
Method		

Thank you!