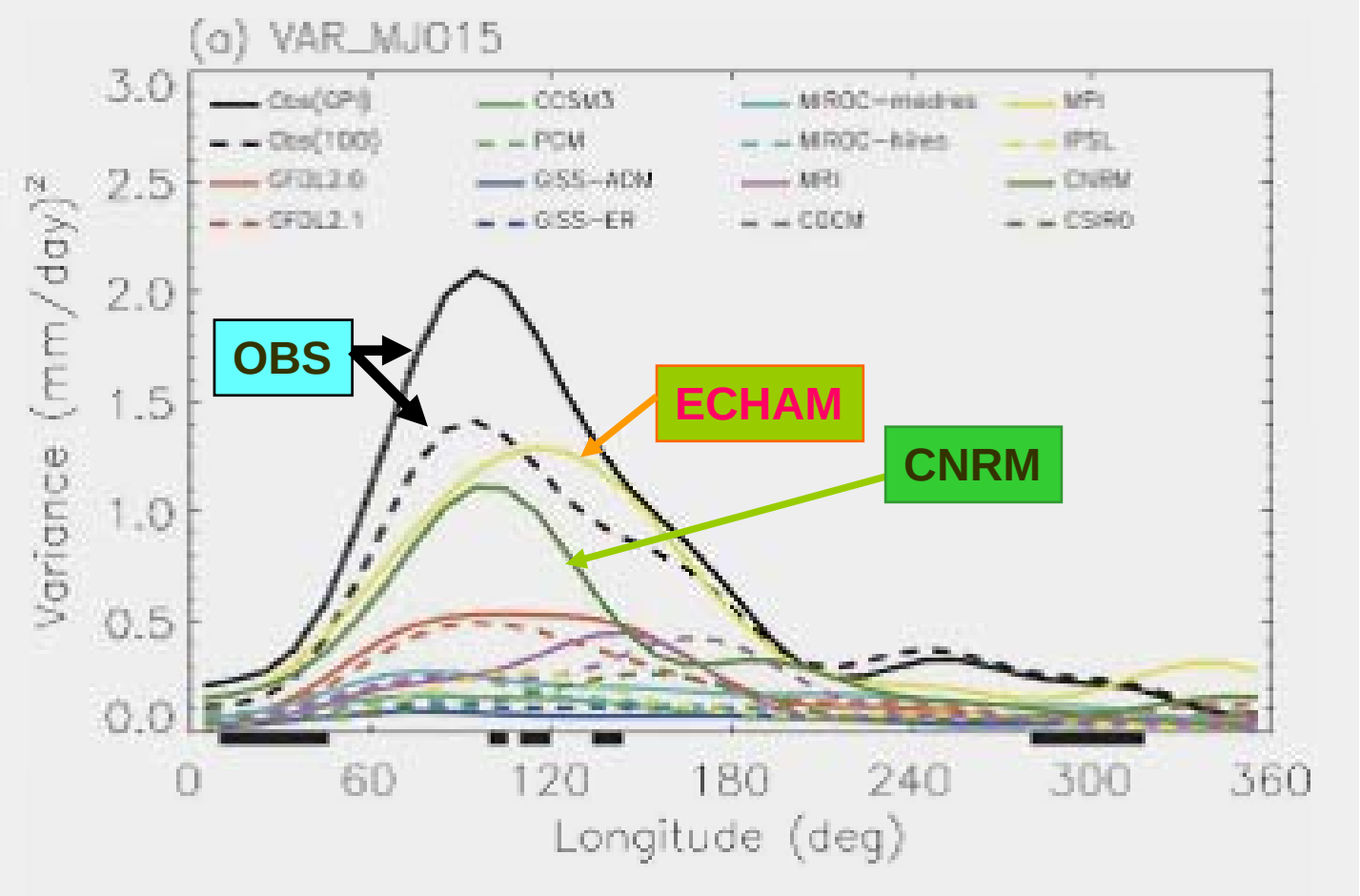
Data assimilation, Real-time forecasting and high-resolution simulation during the 2011 CINDY/DYNAMO field campaign

Tim Li and X. Fu (UH), Kunio Yoneyama and Tomoe Nasuno (JAMSTEC)

- Real time observational support
  - Real-time MJO prediction using U. Hawaii hybrid coupled GCM
  - Hindcast experiments during 2004-2008 have been conducted (Fu et al. 2009, 2010) → A new initialization strategy
- WRF 3DVar/4DVar data assimilation during CINDY/DYNAMO campaign period
  - Strategy: Combine in-situ observations with remotely sensing satellite measurements to generate regular grid (~10km) data
  - A similar attempt during TCS-08 campaign was conducted using WRF 3DVar/4DVar (Li et al. 2009)
- NICAM global cloud-resolving (3.5km ~ 7 km) simulations
  - JII: Initial condition and validation from the assimilation products
  - Process-oriented study to reveal MJO initiation mechanisms (extratropical forcing vs. encircunavigation mode vs. local processes)

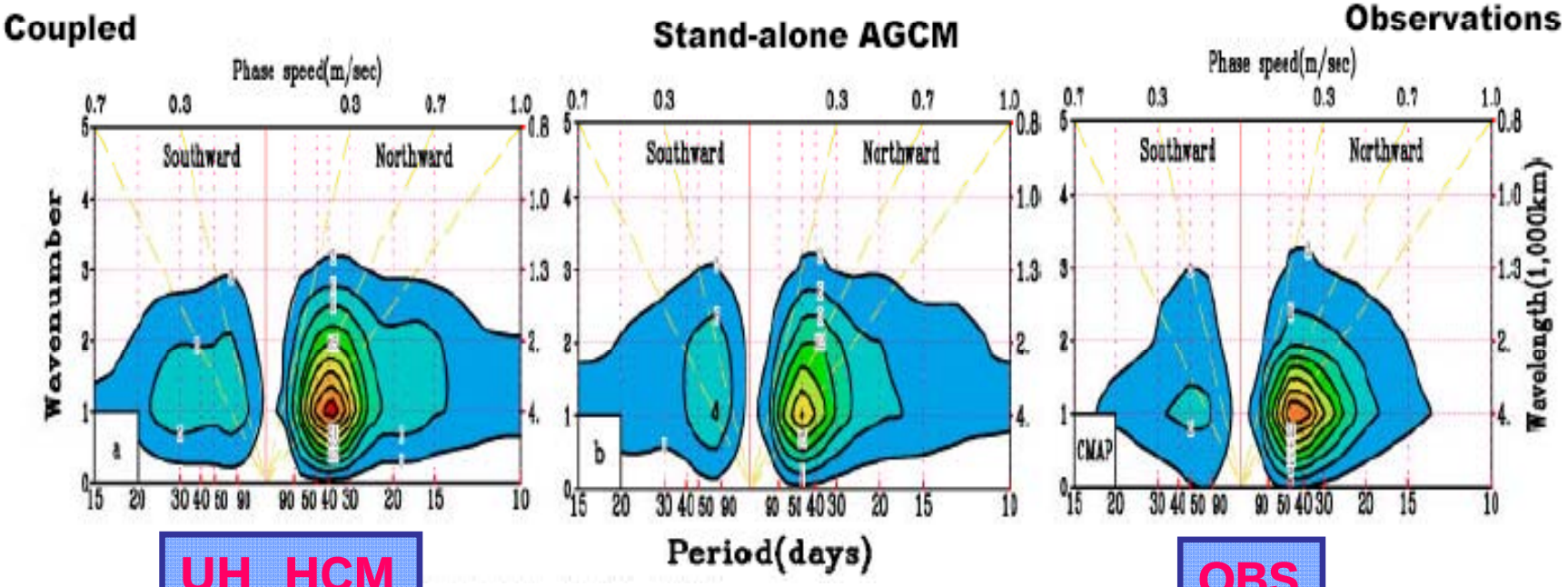
ISO Intensity in 14 IPCC AR-4 Climate Models



East-West Direction

Lin et al. (2006)

NP-ISO is well Simulated by UH_HCM



UH_HCM

OBS

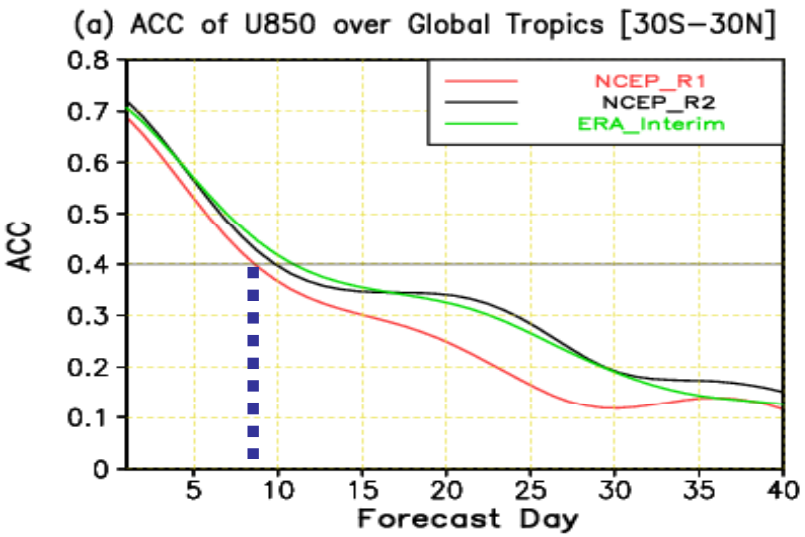
ECHAM-4 AGCM + UH_IOM

Fu, Wang, Li, and McCreary, 2003, J. Climate

Experimental ISO Forecasts with UH_HCM

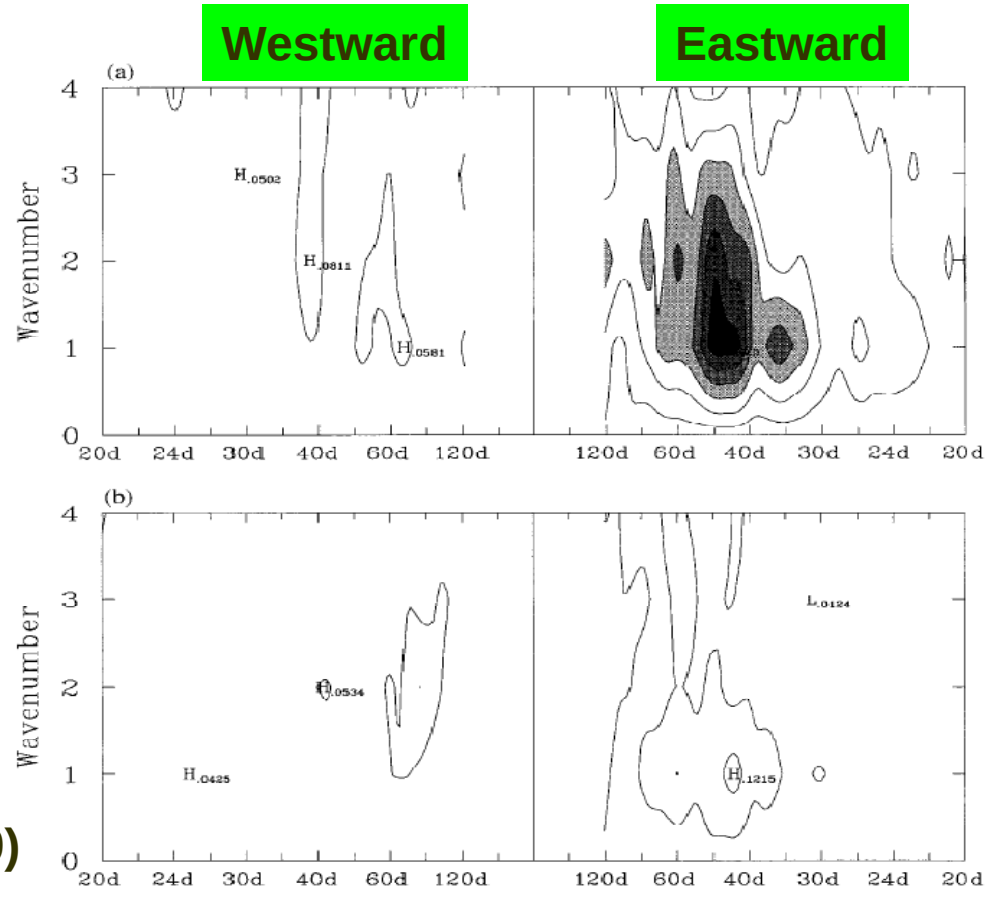
- **Target Period:** May-October 2004-2008
- **Forecast Interval:** Every 10 days, totally 16 forecasts
- **10 Ensembles:** Perturbations are 10% of daily differences
- **Integration Length:** 60 days
- **Initial Conditions:** NCEP R1/R2; ERA-Interim and modified reanalyses
- **Skill Measure:** **A**nomaly **C**orrelation **C**oefficient over Southeast Asia and global tropics.

ISO Forecast Skills in 2004 Summer



(1 July 1986 – 30 June 1993)

Observed OLR



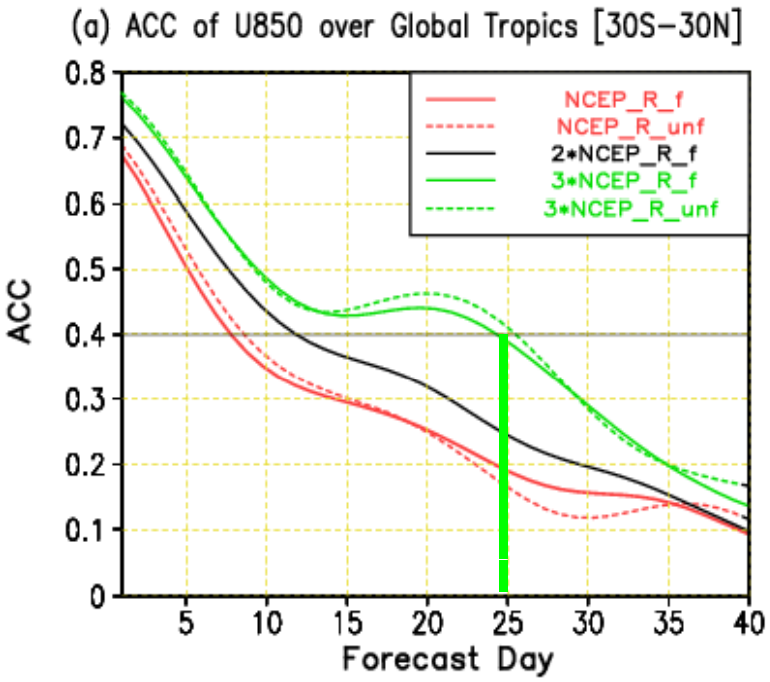
ISO intensity in the NCEP reanalysis is 2-3 factors smaller !

NCEP Reanalysis OLR

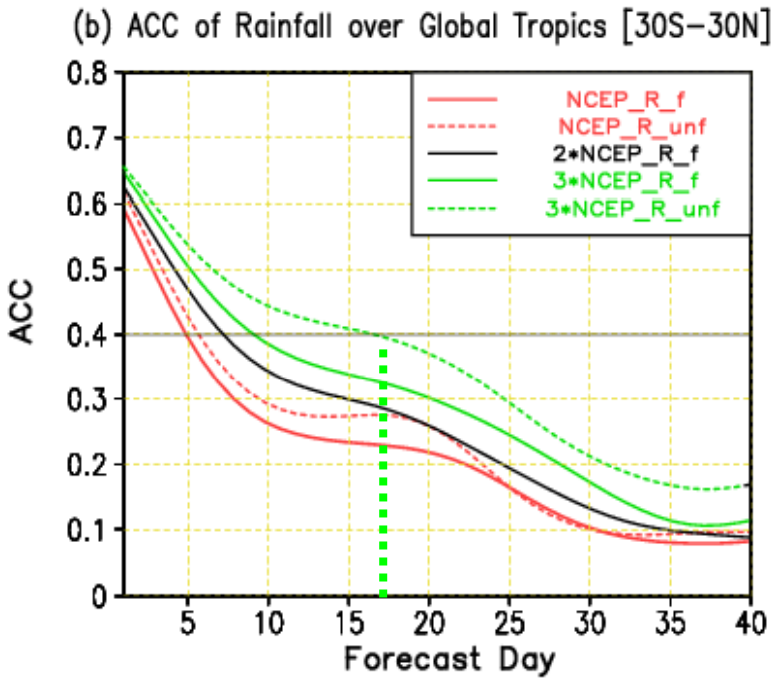
Shinoda et al. (1999)

ISO Forecast Skills in 2004 Summer (May-October)

ACC of Filtered U850



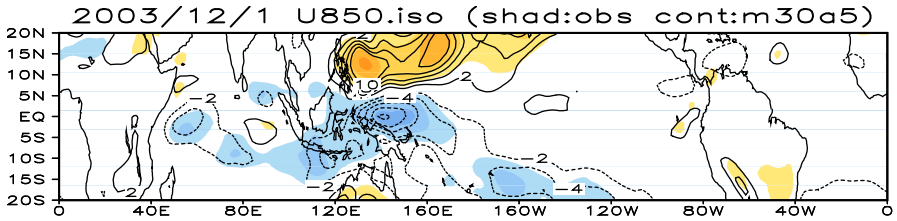
ACC of Filtered Rainfall

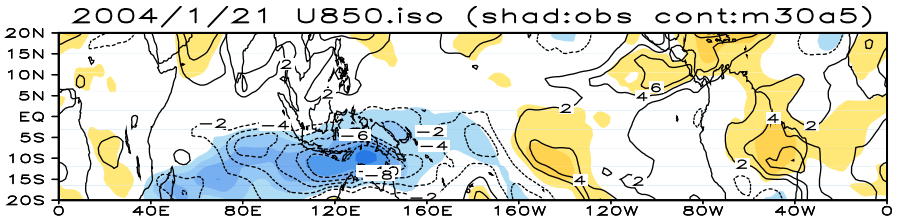


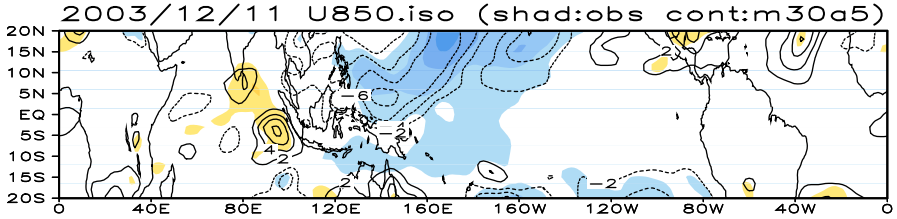
Fu et al. (2009, GRL)

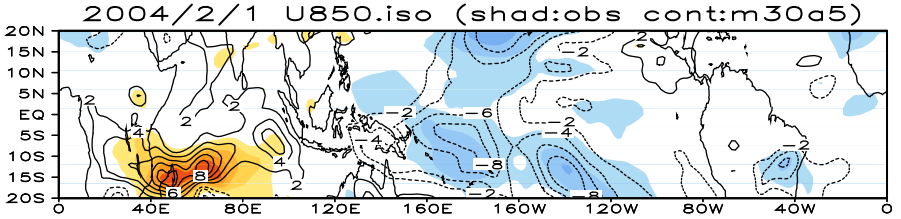
Challenge in real-time application: no time filtering !

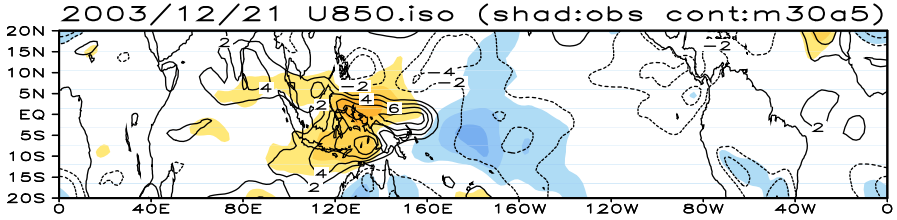
filtered (shad) vs. non-filtered (cont) DJF MJO_U850

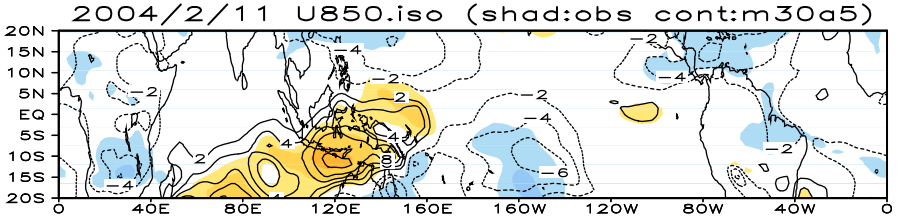


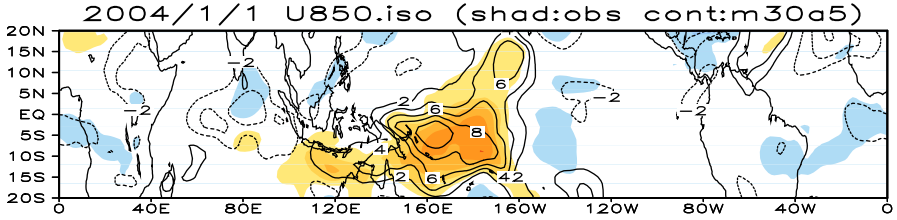


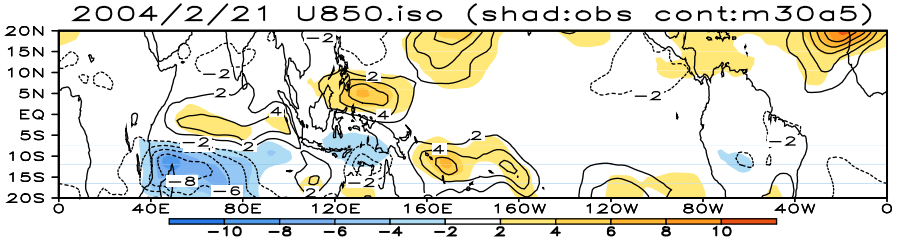


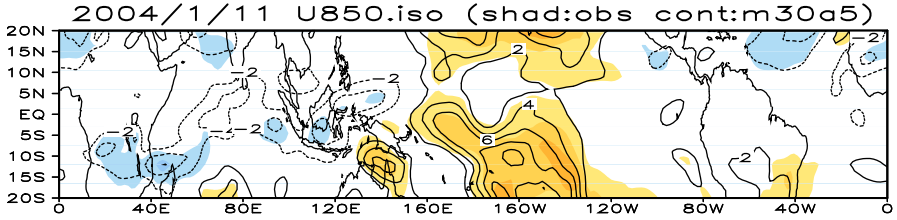












1990-2009 Pattern corr. = 0.81

RMSE = 1.6 m/s

WRF 3DVar Data Assimilation during TCS-08 Field Campaign

Case:

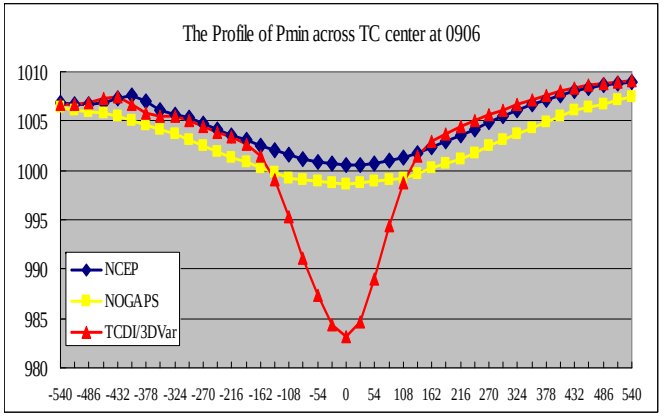
Super-typhoon Sinlaku, Sept. 7-21, 2008 (minimum pressure: 929hPa)

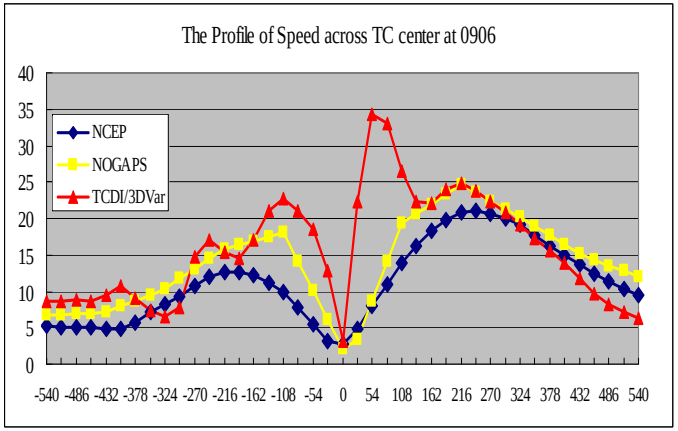
Date:

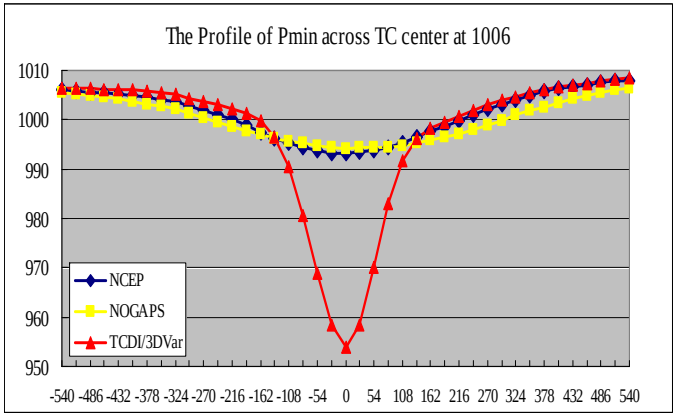
- **In-situ data:**
  USAF C-130 dropsonde data(including T, Td, RH, U-wind, V-wind)
  NRL P-3 dropsonde data (including T, Td, RH, U-wind, V-wind)
  DLR Falcon Doppler Wind Lidar data (including U-wind, V-wind)
  DLR Falcon flight level data (including T, Td, RH, U-wind, V-wind)

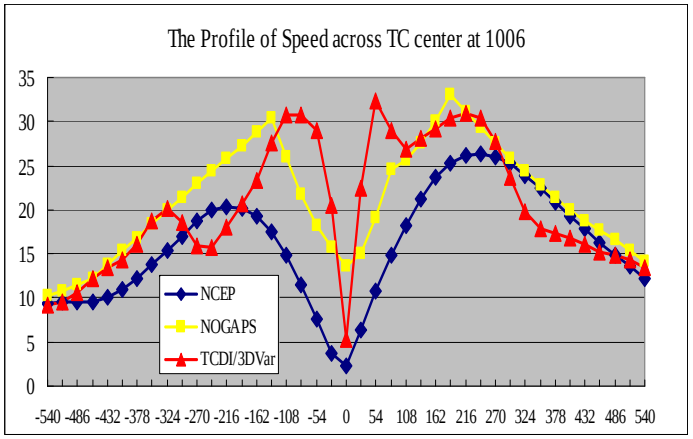
- **Satellite data:**
  AIRS temperature and humidity
  QSCAT surface wind derived from Seawinds instrument
  AMSU temperature
  TRMM rainfall rate

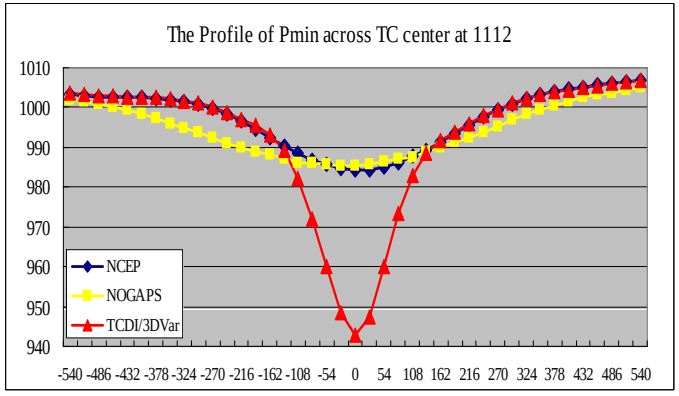
- **Other data:**
  Synthetic observations
  NCEP final analysis (1 degree by 1 degree)

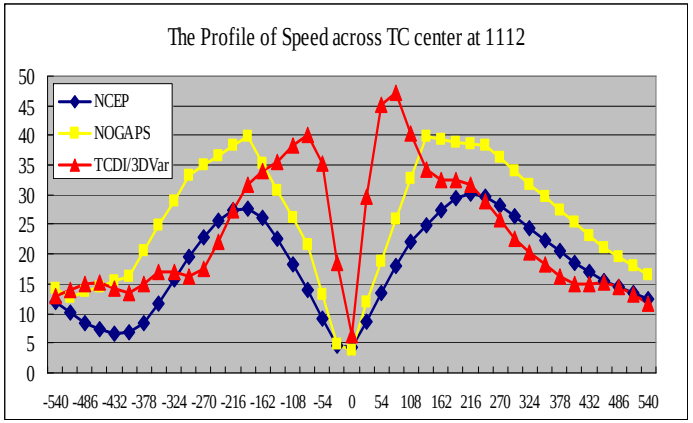

The Profile of Pmin across TC center at 0906
1010
1005
1000
995
990
985
980
NCEP
NOGAPS
TCDI/3DVar
-540 -486 -432 -378 -324 -270 -216 -162 -108 -54 0 54 108 162 216 270 324 378 432 486 540

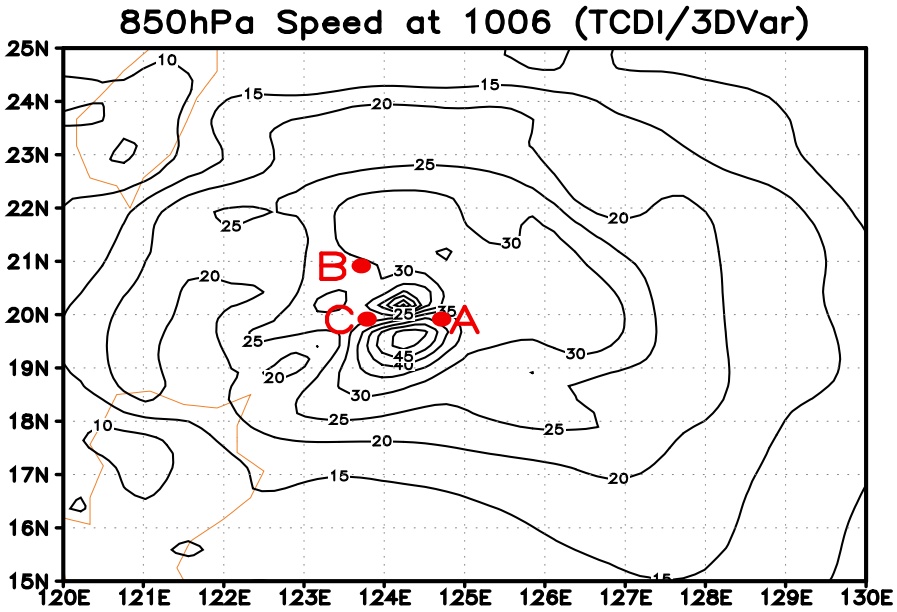

The Profile of Speed across TC center at 0906
40
35
30
25
20
15
10
5
0
NCEP
NOGAPS
TCDI/3DVar
-540 -486 -432 -378 -324 -270 -216 -162 -108 -54 0 54 108 162 216 270 324 378 432 486 540

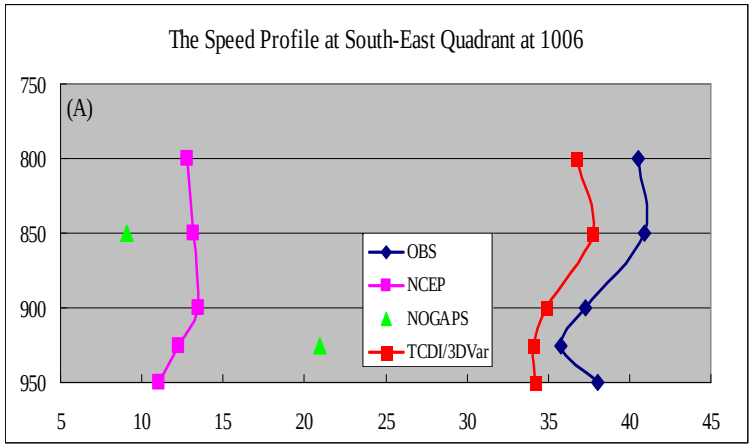

The Profile of Pmin across TC center at 1006
1010
1000
990
980
970
960
950
NCEP
NOGAPS
TCDI/3DVar
-540 -486 -432 -378 -324 -270 -216 -162 -108 -54 0 54 108 162 216 270 324 378 432 486 540

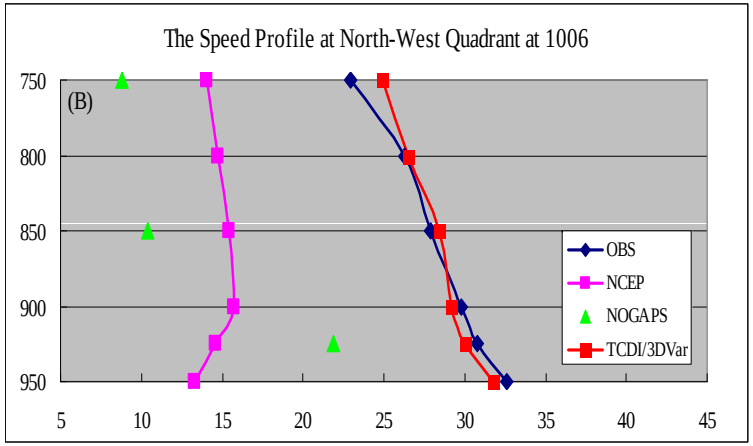

The Profile of Speed across TC center at 1006
35
30
25
20
15
10
5
0
NCEP
NOGAPS
TCDI/3DVar
-540 -486 -432 -378 -324 -270 -216 -162 -108 -54 0 54 108 162 216 270 324 378 432 486 540

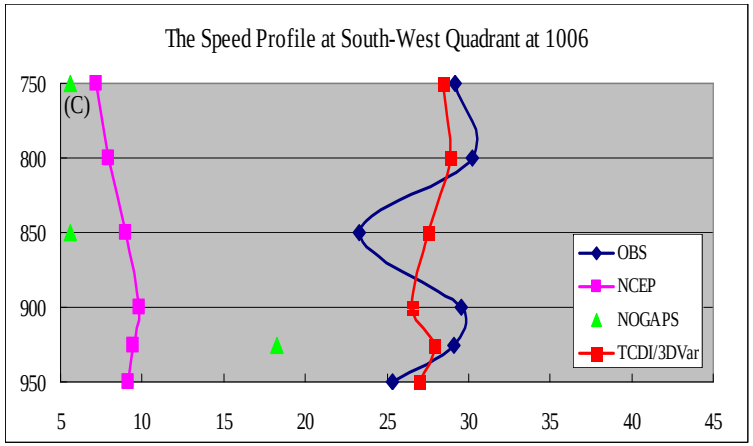

The Profile of Pmin across TC center at 1112
1010
1000
990
980
970
960
950
940
NCEP
NOGAPS
TCDI/3DVar
-540 -486 -432 -378 -324 -270 -216 -162 -108 -54 0 54 108 162 216 270 324 378 432 486 540


The Profile of Speed across TC center at 1112
50
45
40
35
30
25
20
15
10
5
0
NCEP
NOGAPS
TCDI/3DVar
-540 -486 -432 -378 -324 -270 -216 -162 -108 -54 0 54 108 162 216 270 324 378 432 486 540



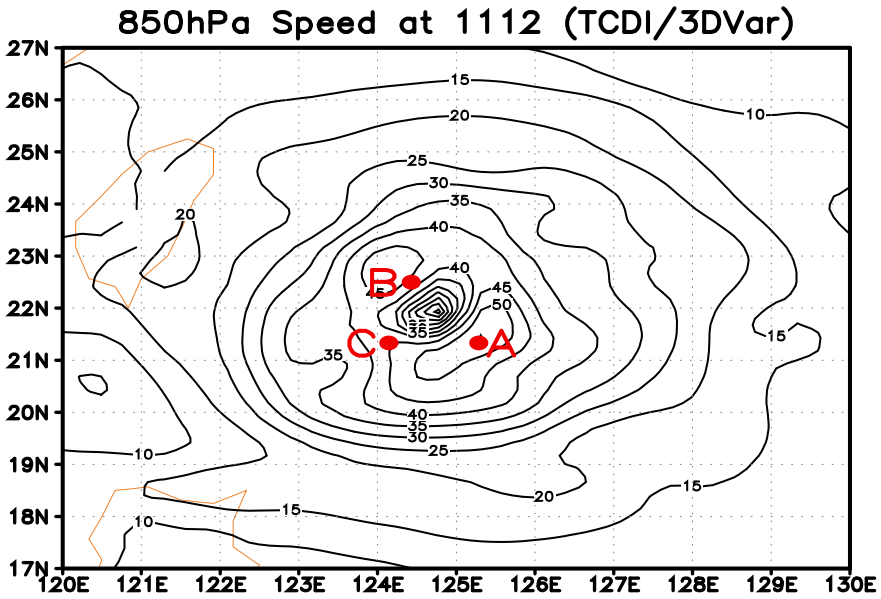






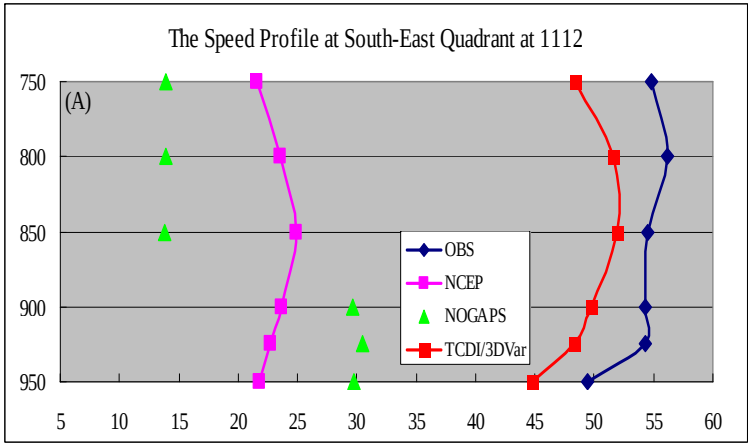
Top: 850hPa total wind speed

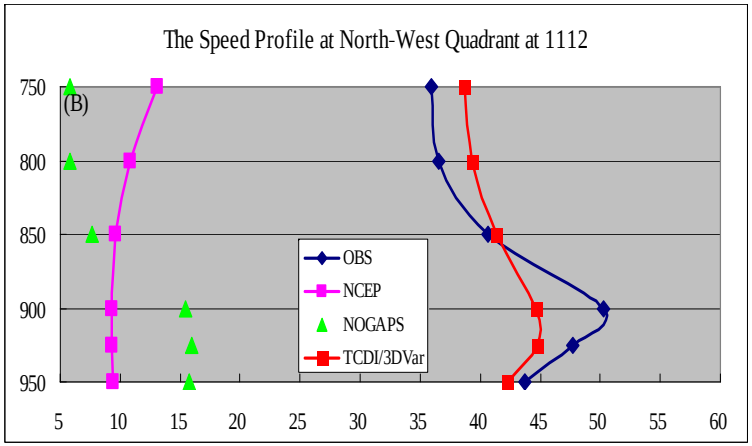
Right: comparison of wind speed profile at 1006

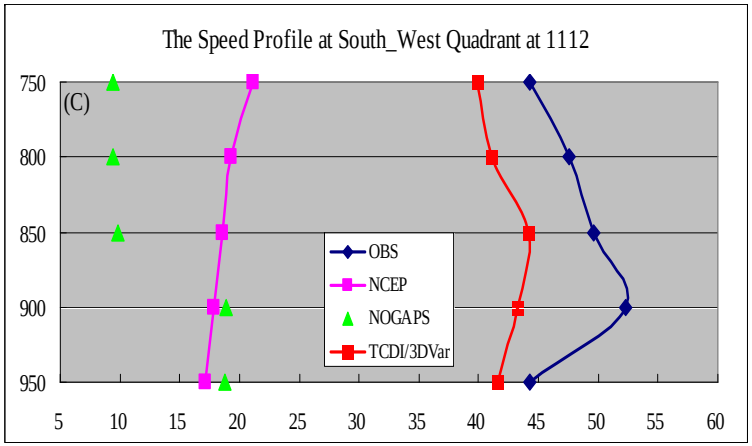


Top: 850hPa total wind speed

Right: comparison of wind speed profile at 1112



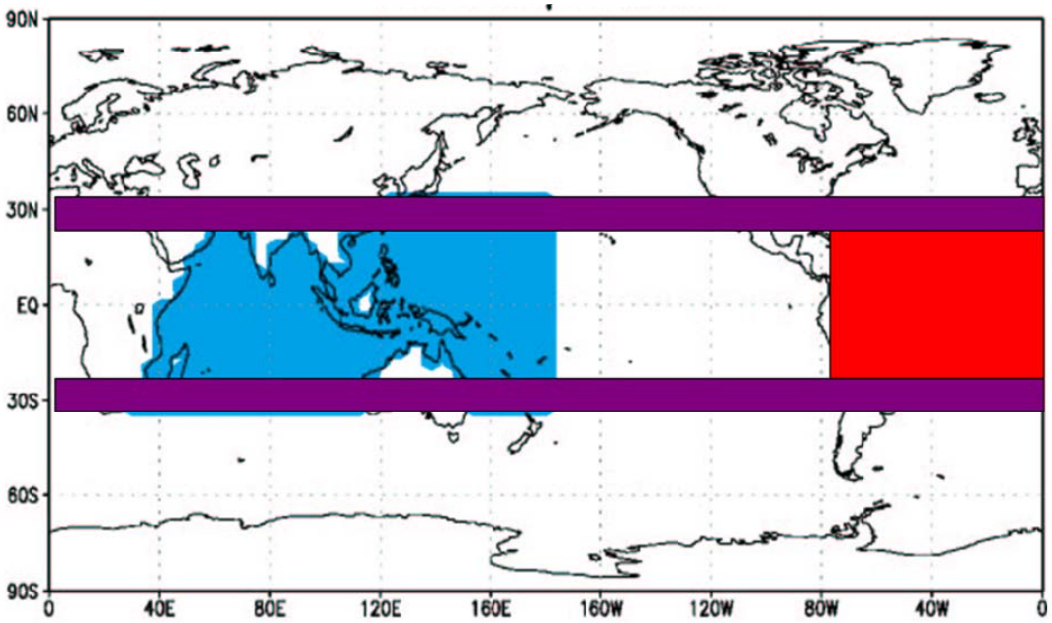




Data Assimilation Strategy:

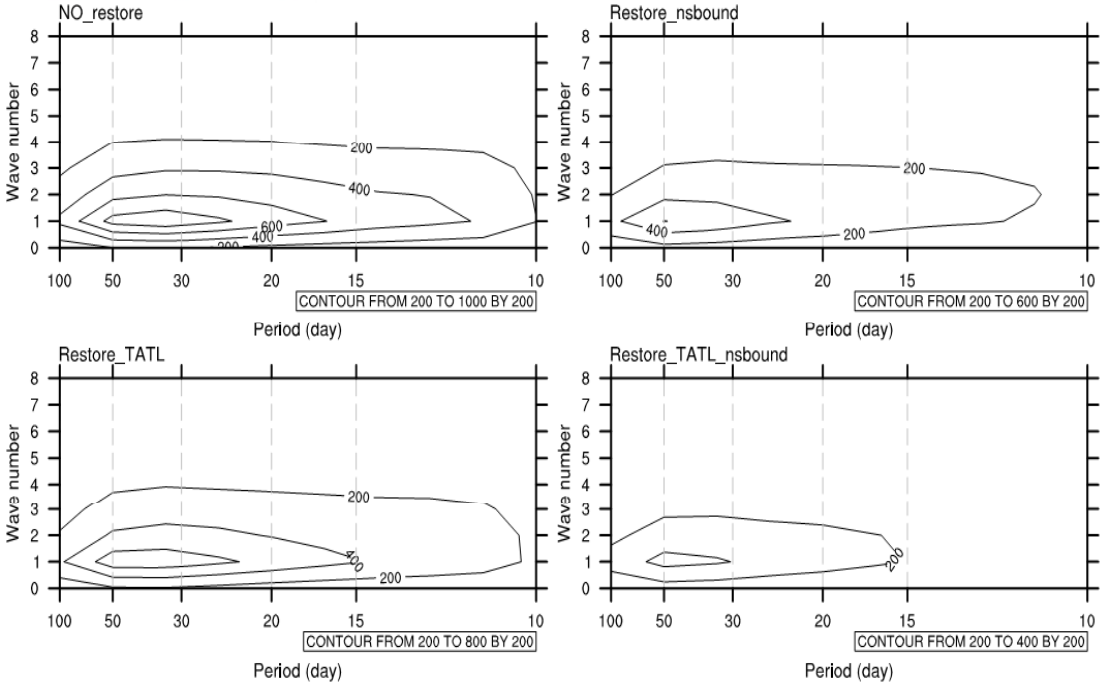
- Combine in-situ ship/island/flight observations and satellite observations
- Cover the entire campaign period
- Provider regular-grid (~10 km) 3-hourly reanalysis products for analysis, model initialization, and validation

Idealized AGCM experiments: What initiates MJO in IO?



sensitivity experiments:

No_restore: control exp
Restore_nsbound
Restore_TATL
Restore_TAL_nsbound



Bottom: Eastward-propagating MJO energy spectrum

Thanks

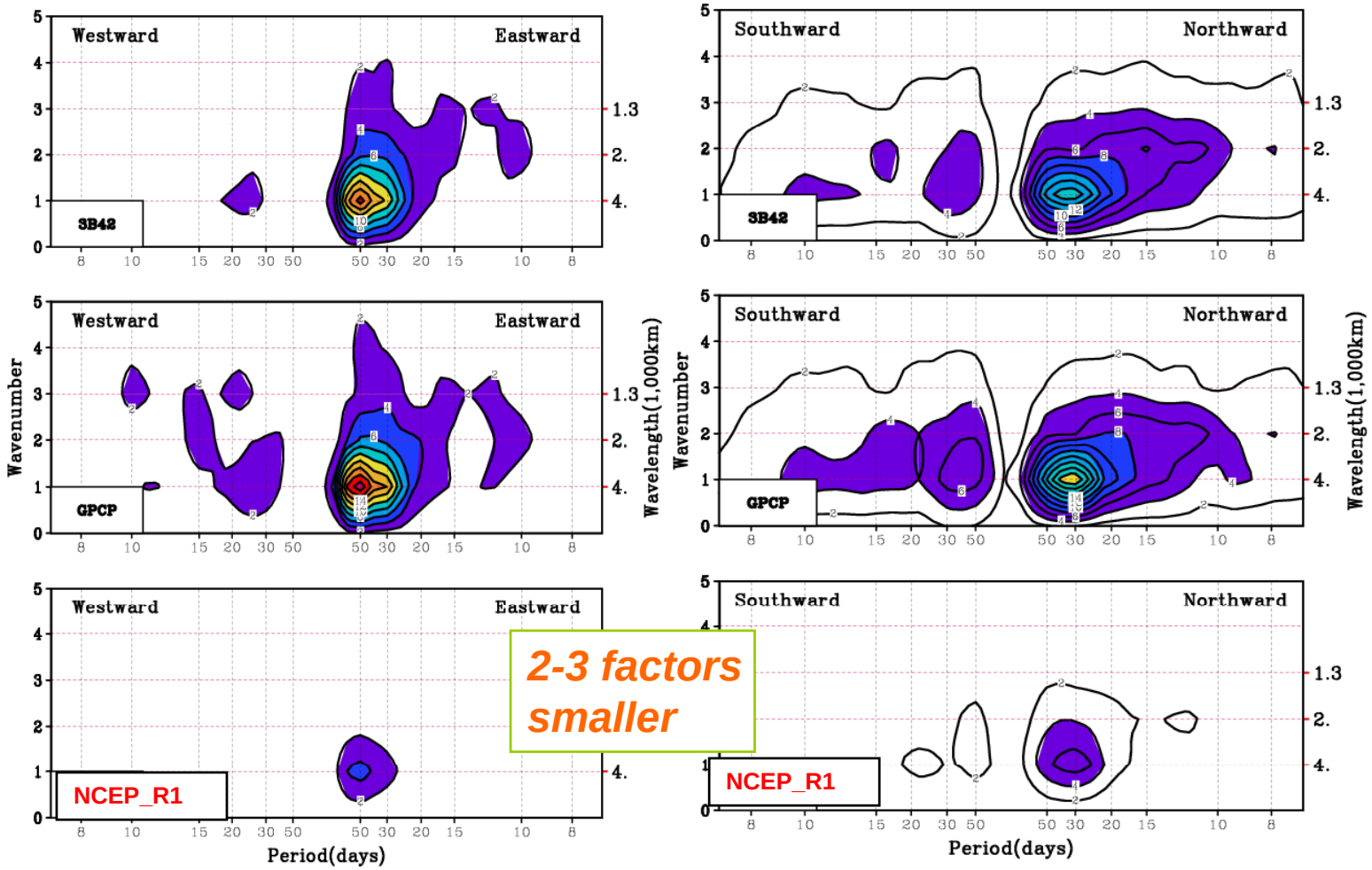
NCEP Reanalysis-1 underestimates ISO

(2004 Summer)

TRMM 3B42

GPCP

NCEP Reanalysis Rainfall



Eastward Propagation

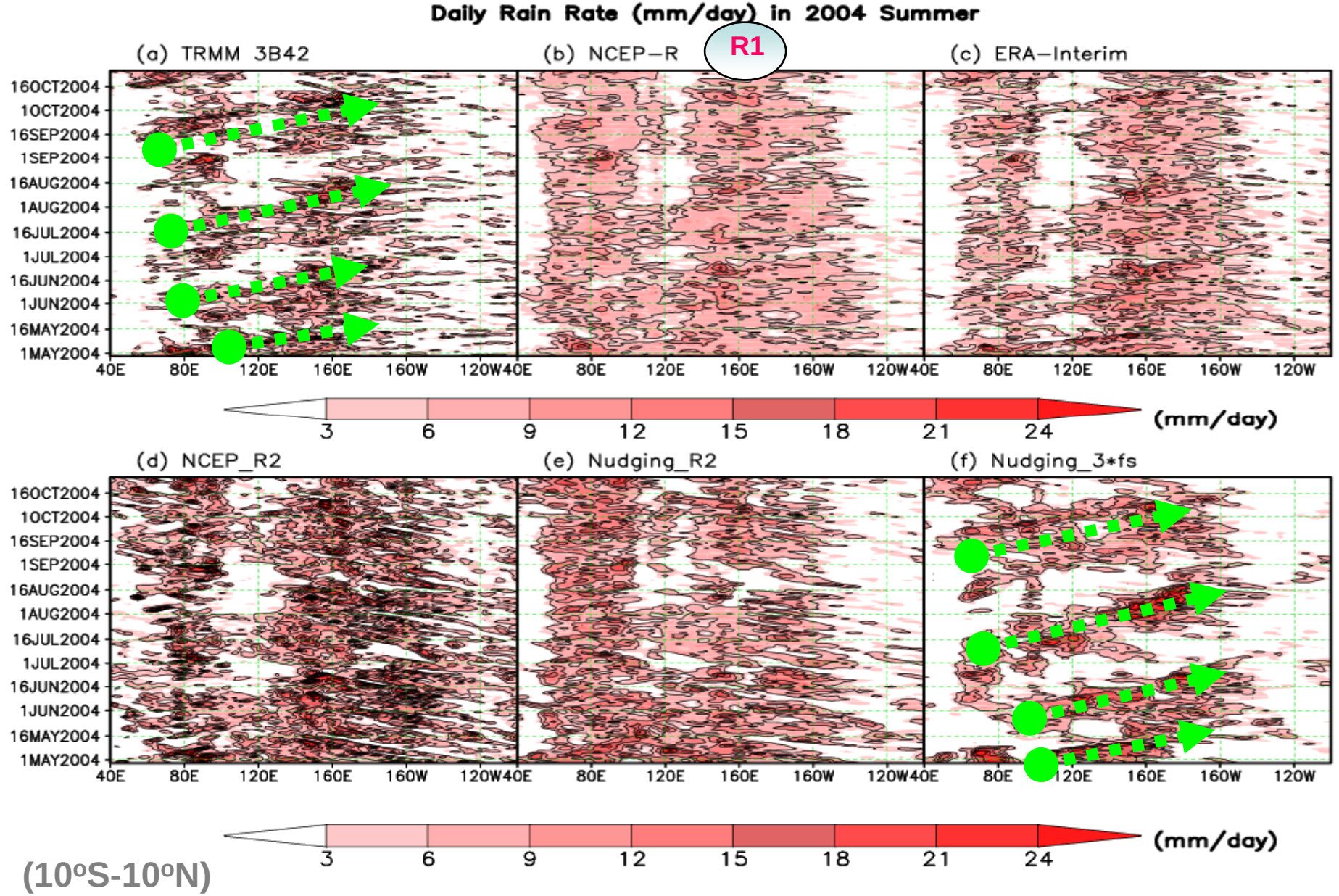
Northward Propagation

Forecast Sensitivity Experiments

EXP.	Initial Conditions
NCEP_R_f	AC[1] + Filtered[2]
NCEP_R_unf	AC + Filtered + High-frequency[3]
2*NCEP_R_f	AC + 2*Filtered
3*NCEP_R_f	AC + 3*Filtered
3*NCEP_R_unf	AC + 3*Filtered + High-frequency

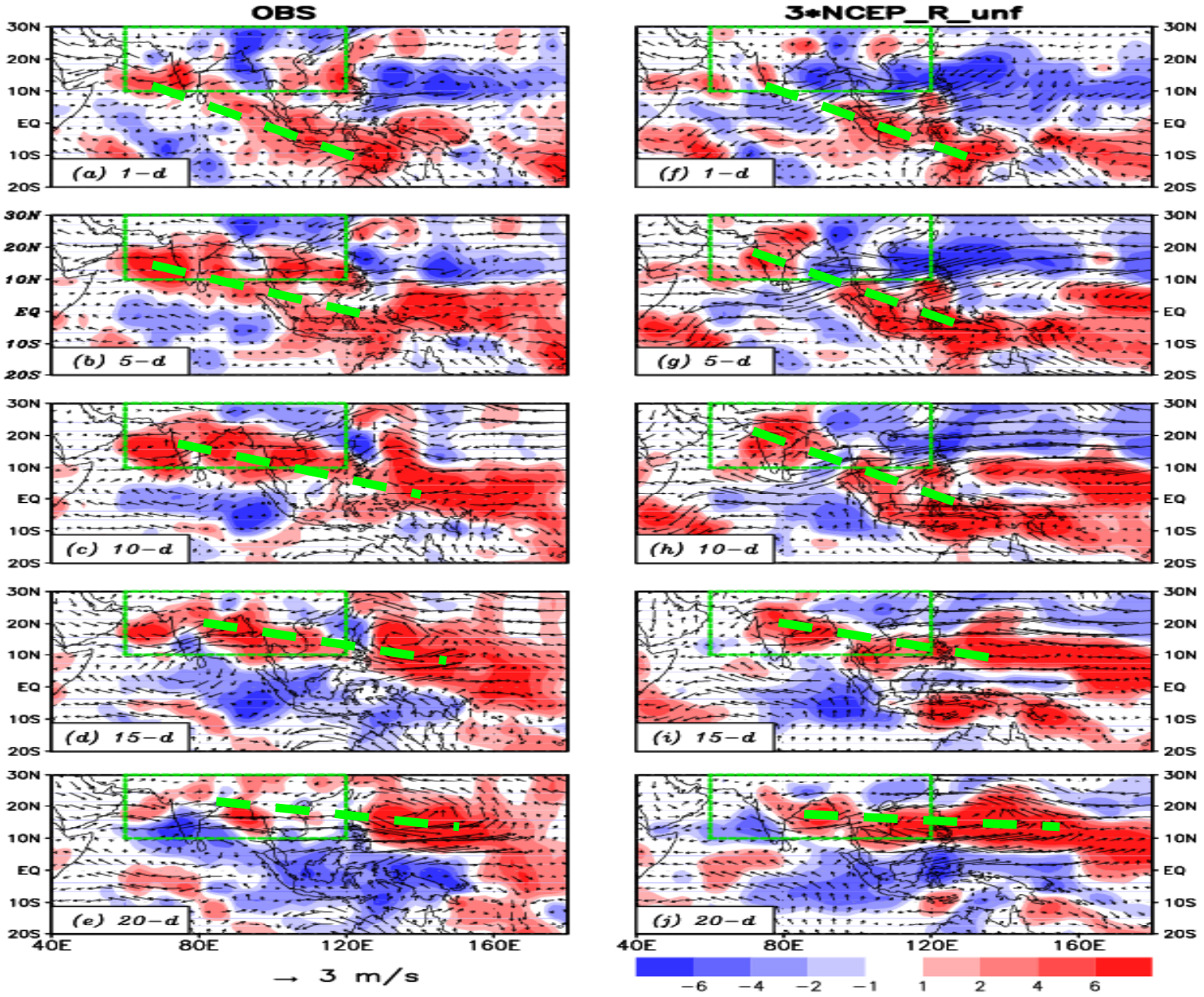
[1]AC (Annual Cycle) => mean + first three harmonics
[2]Filtered => 30-90-day variability
[3]High-frequency => Total - AC - Filtered

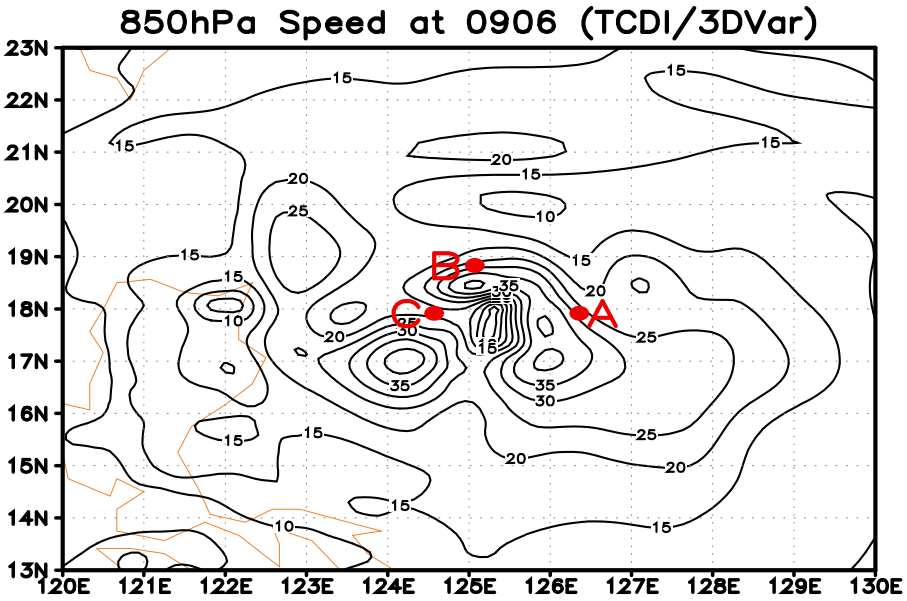
Daily Rainfall in 2004 Summer along the Equator



INTERNATIONAL PACIFIC RESEARCH CENTER

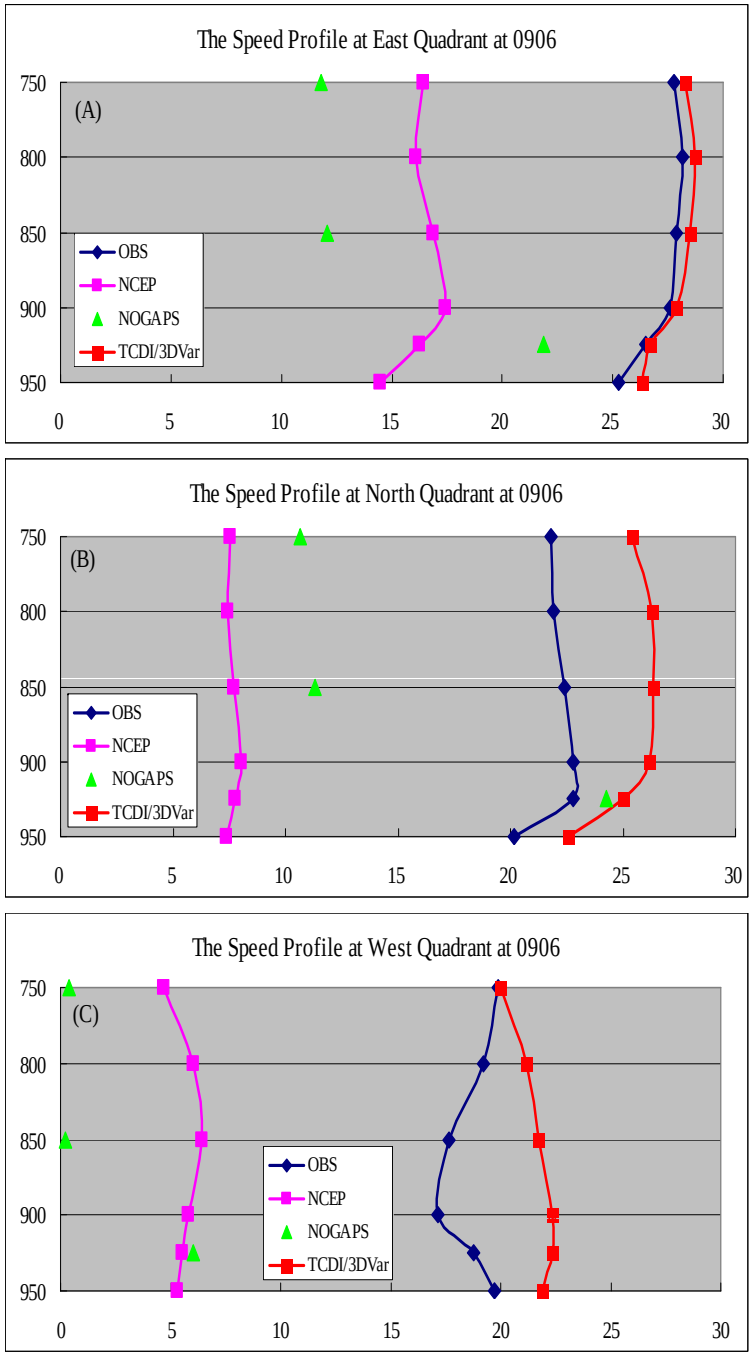
Initialized on May 31, 2004 with Enhanced ISO in NCEP R1



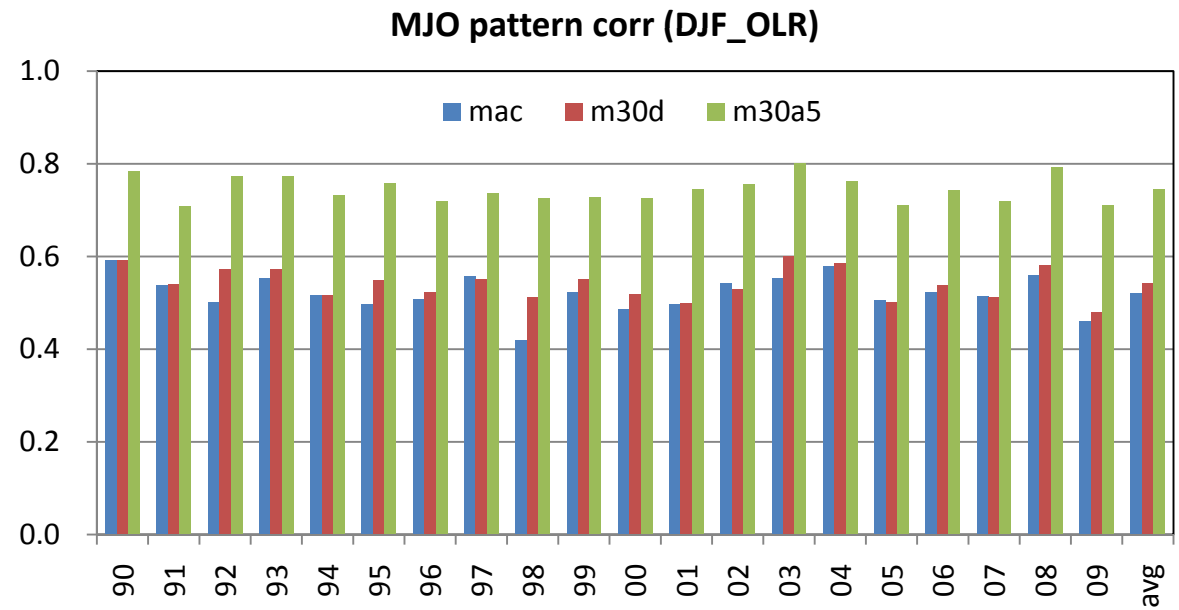


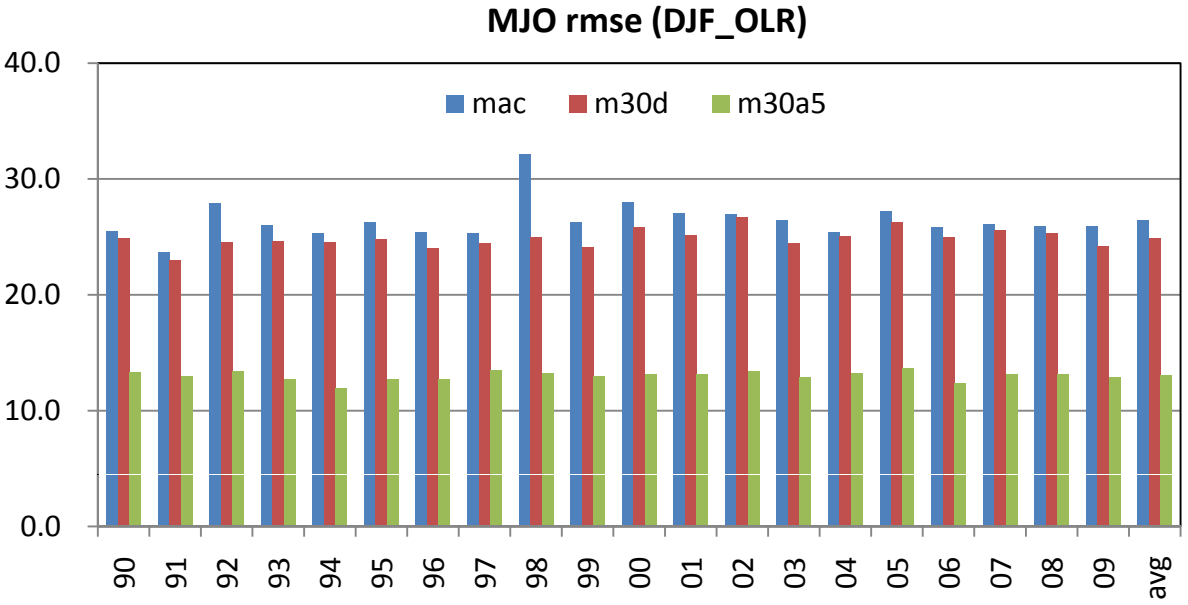
Top: 850hPa total wind speed

Right: comparison of wind speed profile at 0906



1990-2009 DJF MJO OLR forecast skill



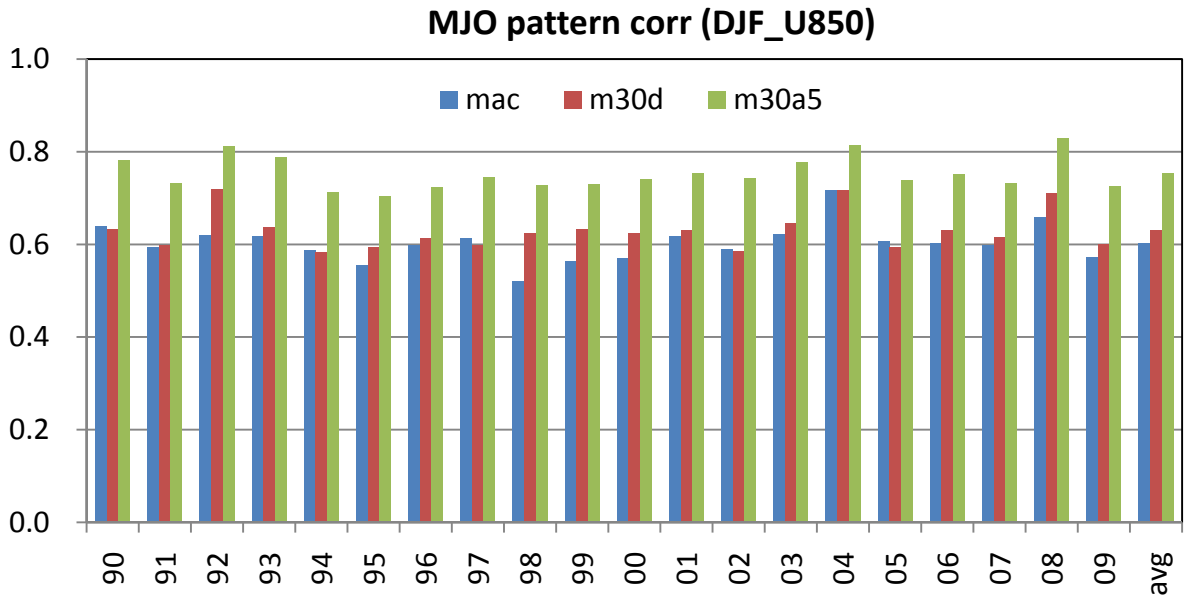


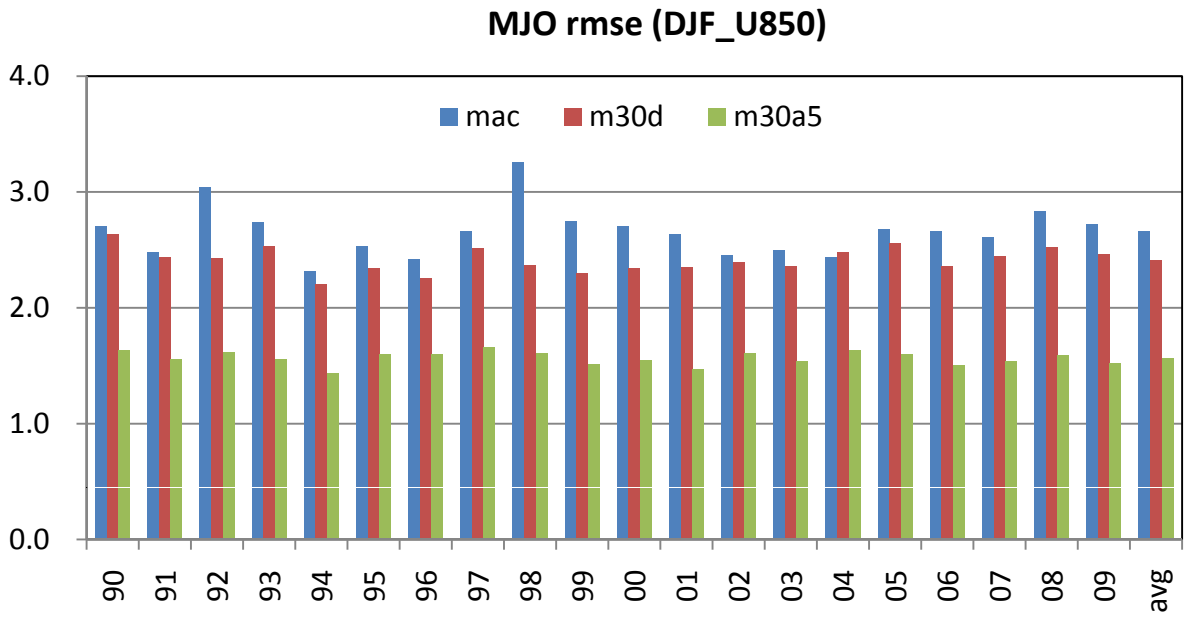
- Year “90” indicates forecast period from Dec 1989 to Feb 1990.

- mac: remove annual cycle (minus 90d low-pass filrering)
- m30d: remove interannual component (minus previous 30d average)
- m30a5: remove synoptic component (previous 5d average)

- Process of removing interannual components shows significant impact on the forecast skills in El Nino years (1991/1992 and 1997/1998).

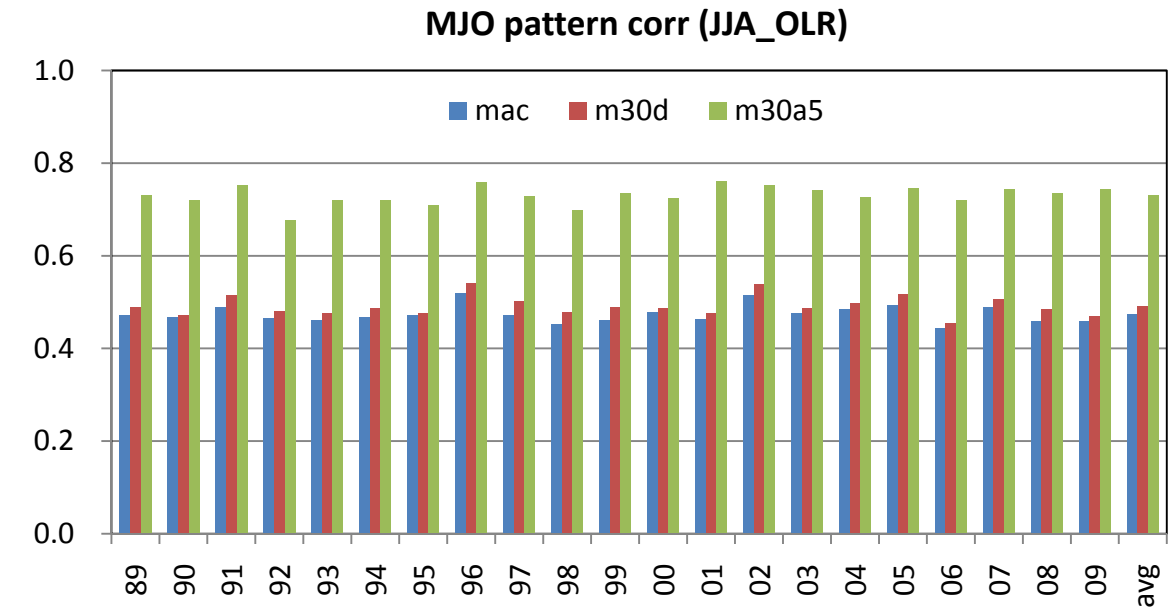
1990-2009 DJF MJO U850 forecast skill

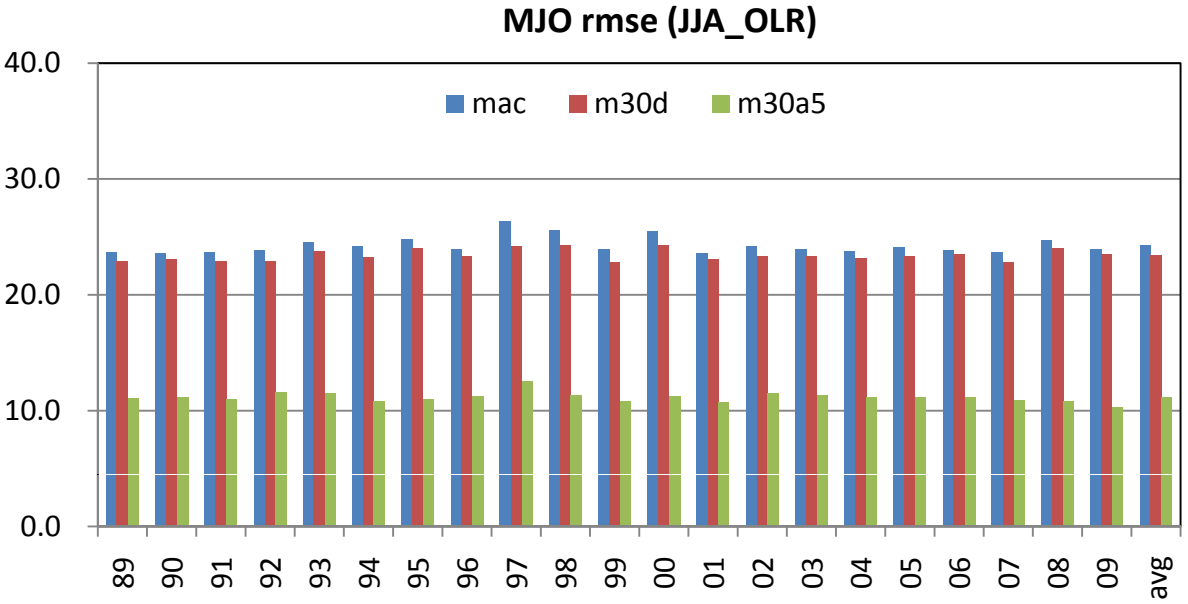




- MJO U850 forecast shows similar results to OLR.
- Removing interannual components are important for El Nino years.

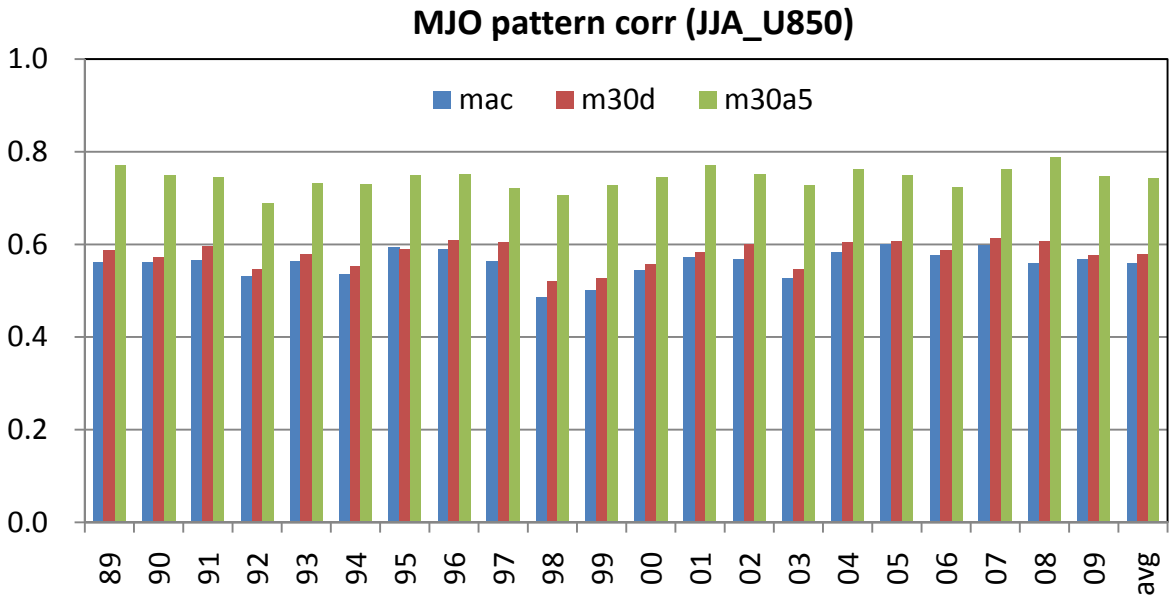
1990-2009 JJA MJO OLR forecast skill

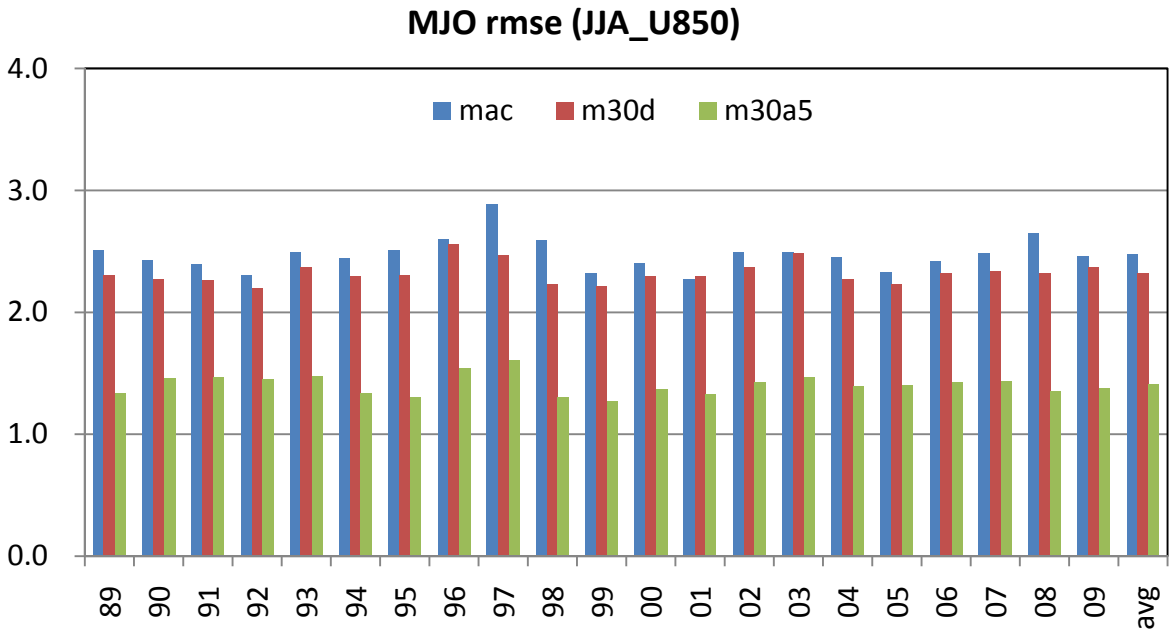




- For the MJO forecast in boreal summer, the effects of removing interannual components is not as large as it in wintertime.

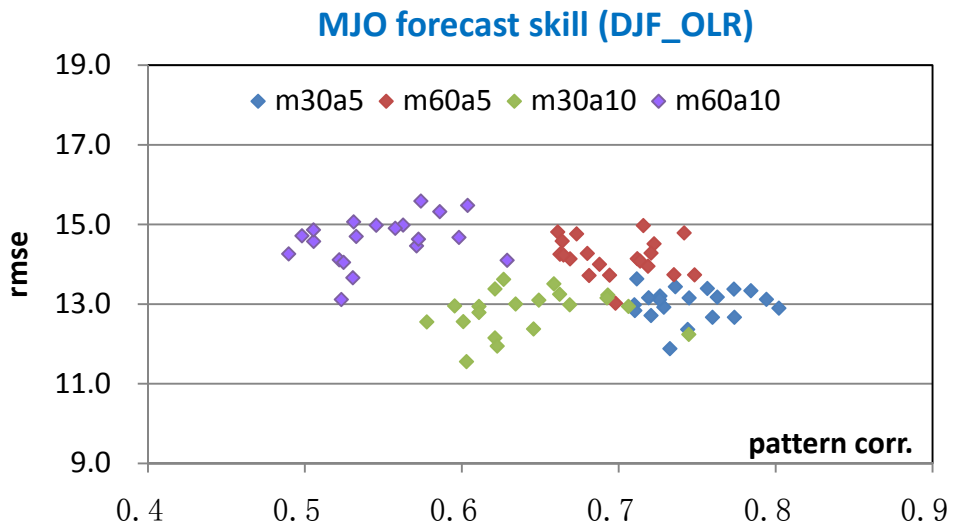
1990-2009 JJA MJO U850 forecast skill

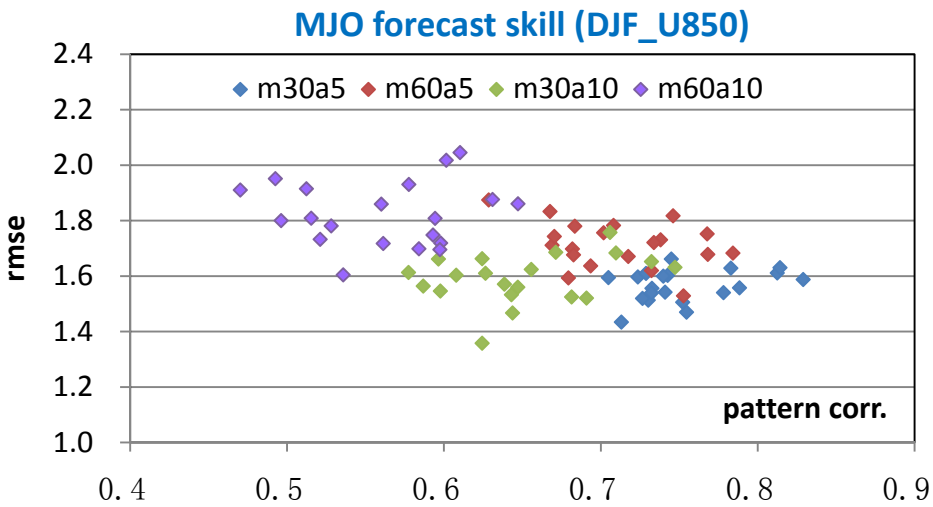


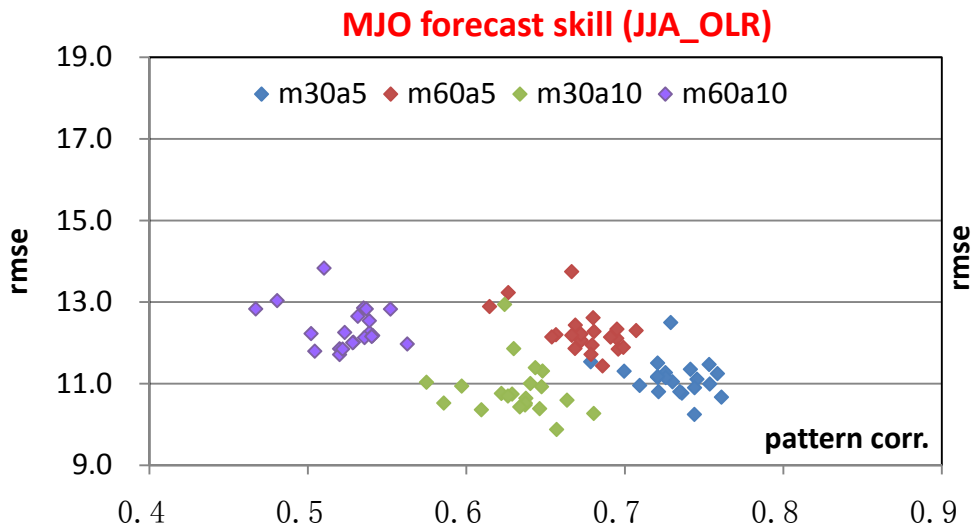


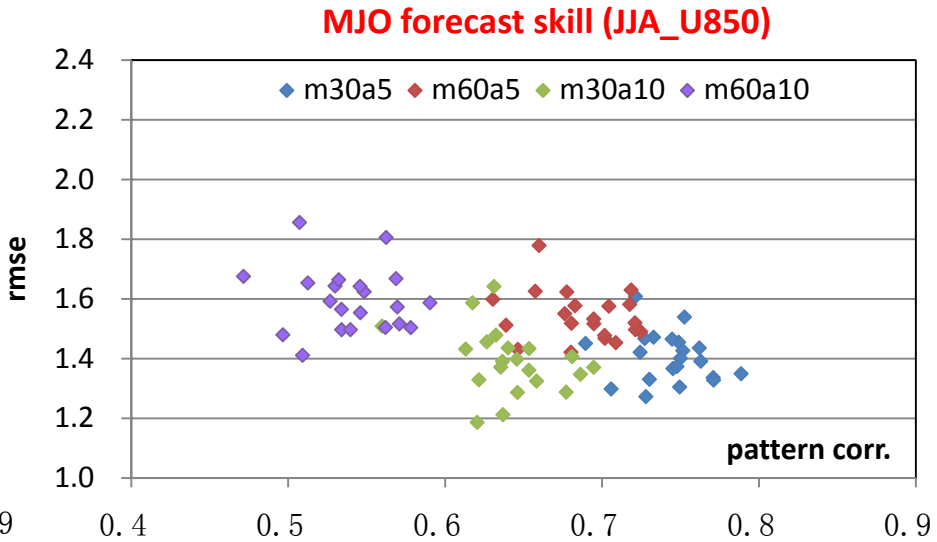
- MJO U850 forecast shows similar results to OLR.
- During summertime, removing interannual components for the MJO forecast is not such important as it in winter.

Test of averaged periods for interannual and synoptic components



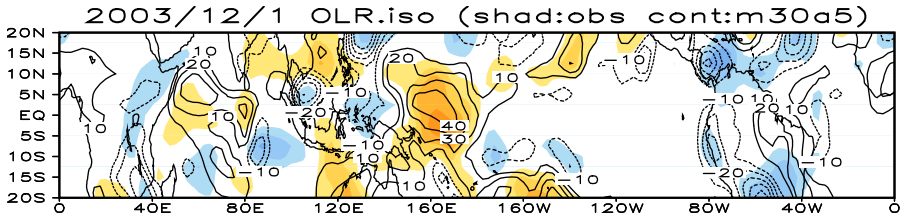


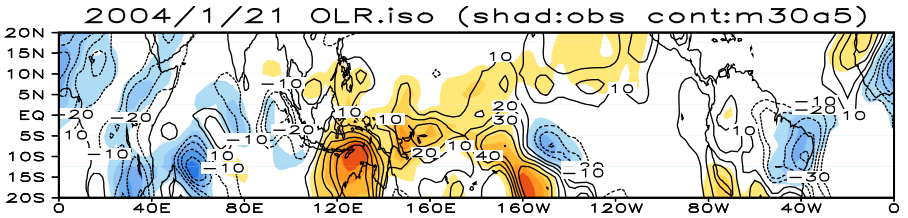


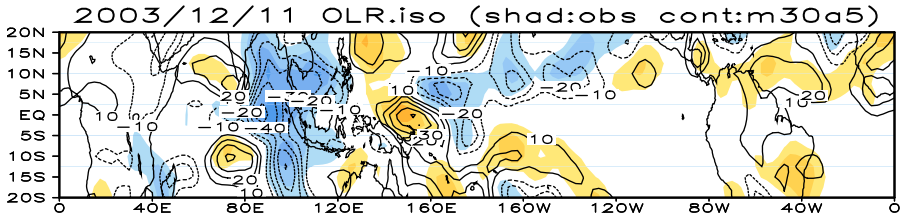


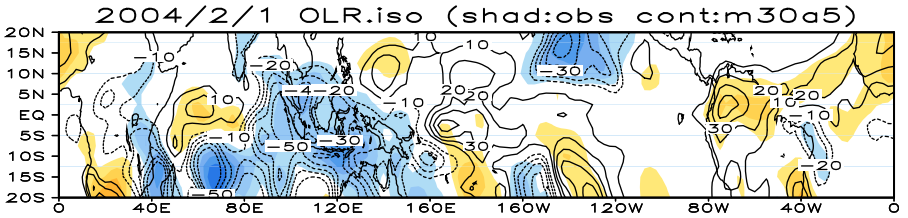
Optimal periods for interannual and synoptic components are previous 30day and previous 5day averages, respectively.

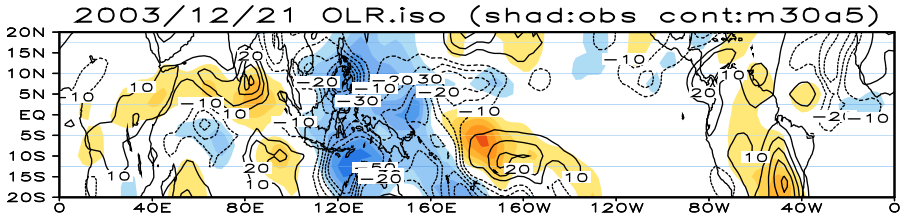
filtered (shad) and non-filtered (cont) DJF MJO_OLR

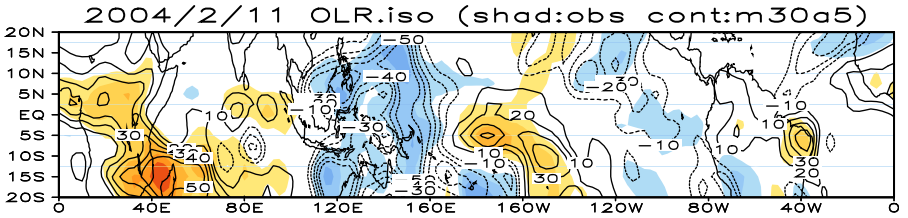


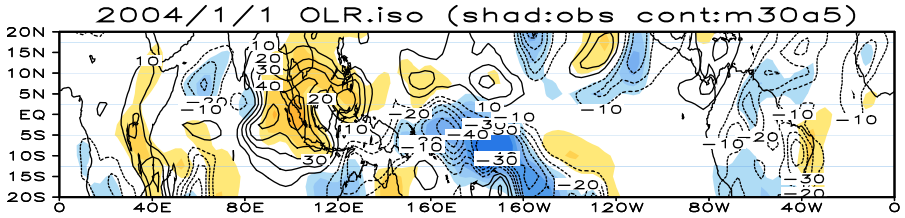


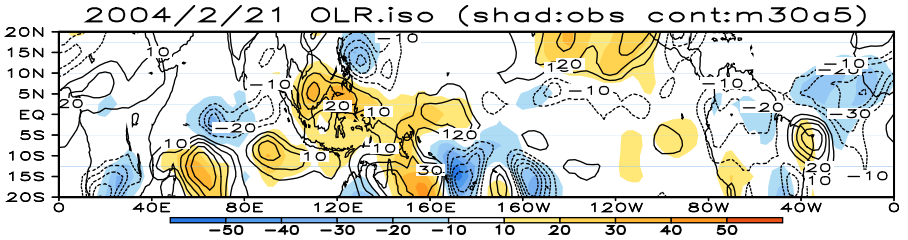


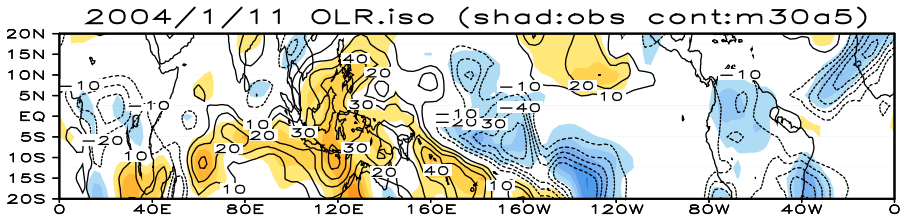






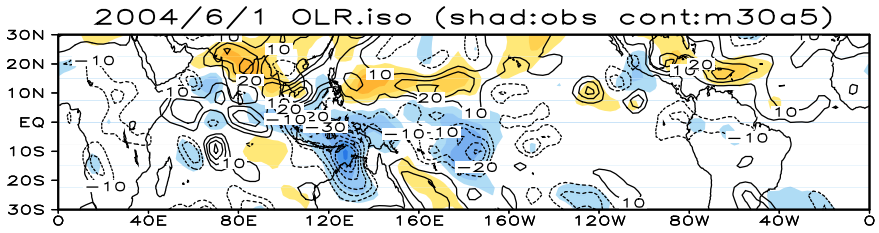


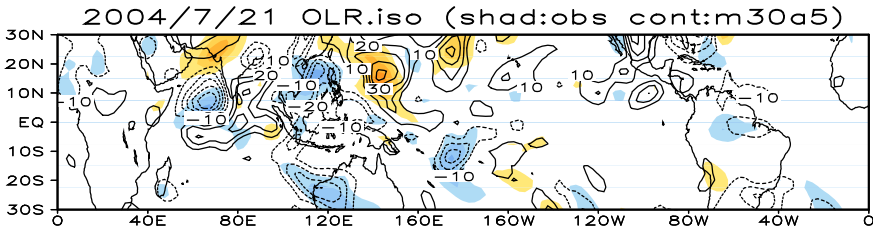


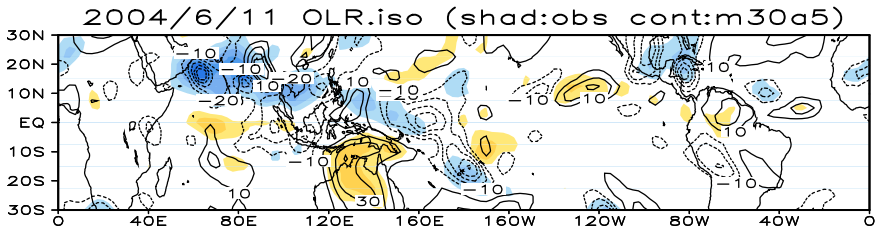


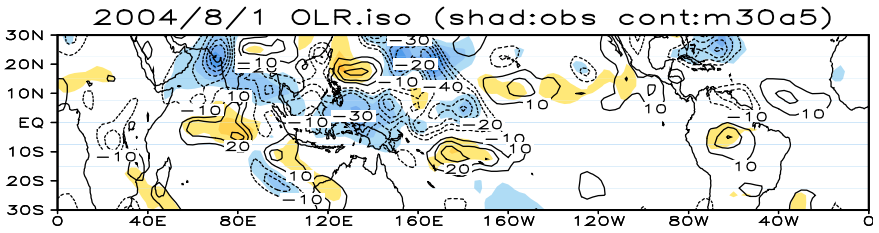
1990-2009 Pattern corr. = 0.76

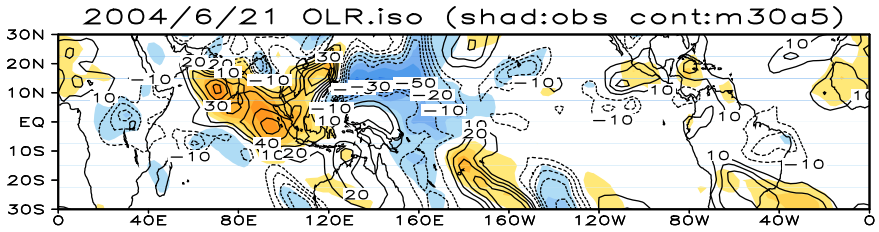
filtered (shad) and unfiltered (cont) JJA ISO_OLR

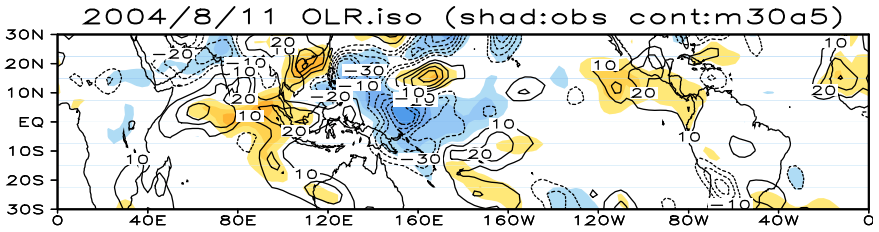


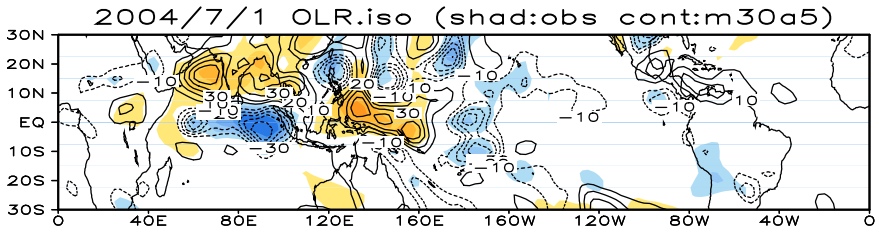


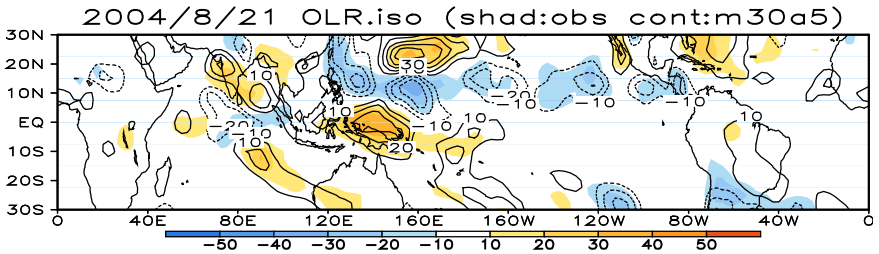


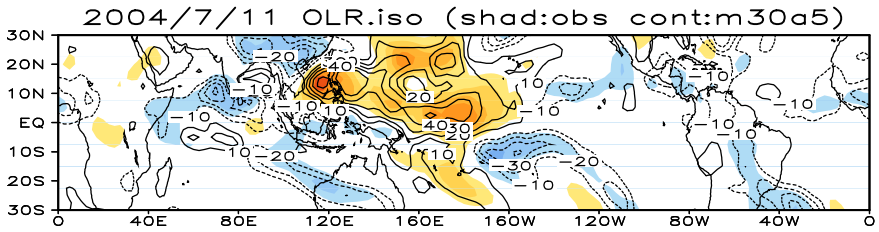








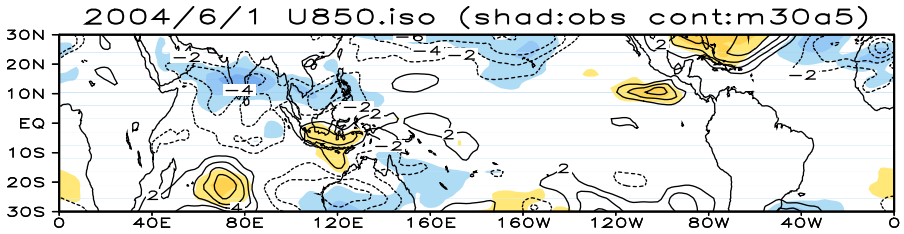


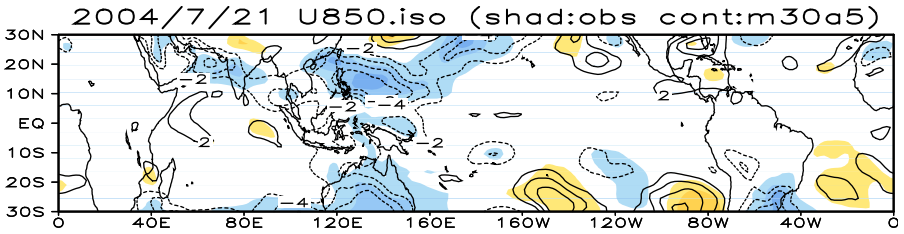


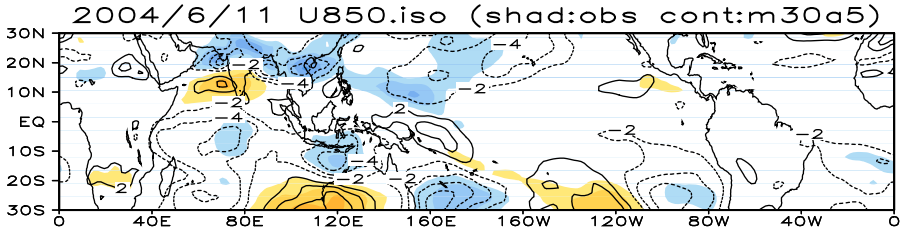
Pattern corr. = 0.73

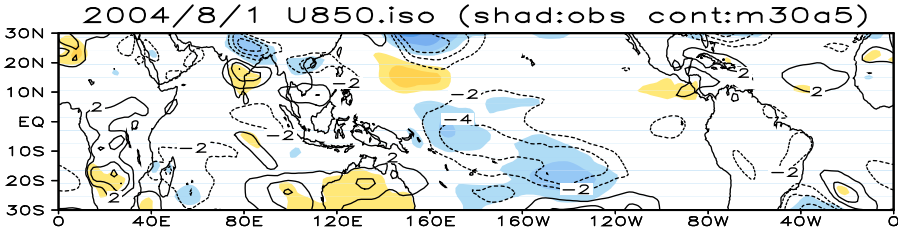
RMSE = 11.15 W/m2

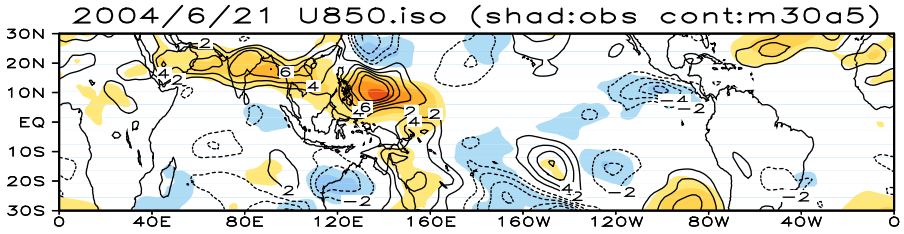
filtered (shad) and unfiltered (cont) JJA ISO_U850

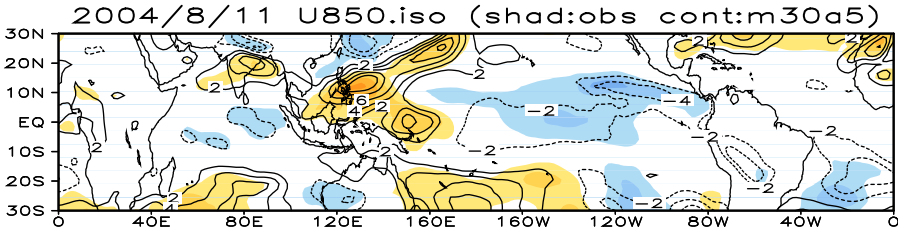


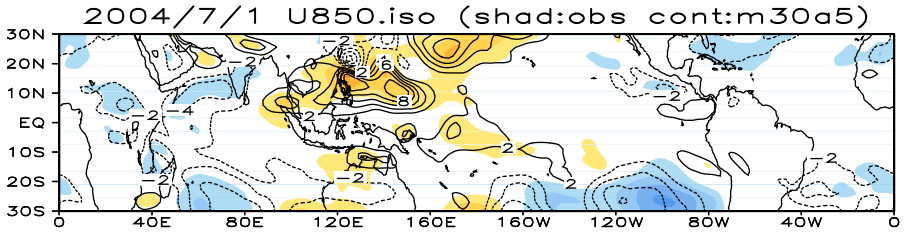


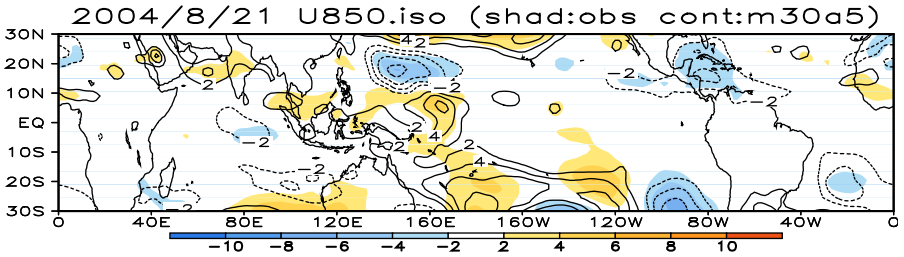


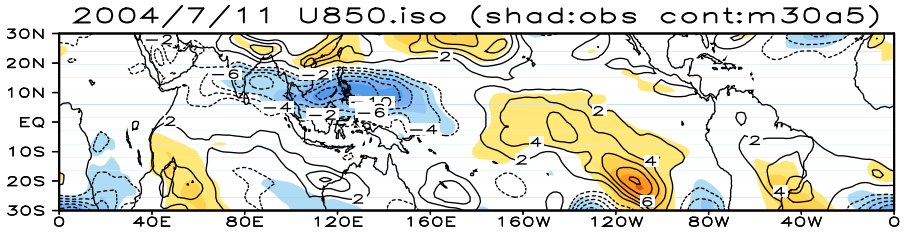












Pattern corr. = 0.76

RMSE = 1.39 m/s