Performance of the NCEP Climate Forecast System in predicting the Madden-Julian Oscillation

Wanqiu Wang, Meng-Pai Hung, Scott Weaver, Arun Kumar
Climate Prediction Center

Xiouhua Fu
University of Hawaii

Background

- MJO Prediction and predictability have been analyzed in many studies. These studies were based on forecasts that
  I. Cover a short forecast history period, or
  II. Are initialized at a long time interval (e.g., weekly or monthly), or
  III. Use outdated initializations or outdated models

- CFSv2 provided a unique data set of 45-day hindcasts
  I. Relatively long period (1999-2010),
  II. New initial conditions from CFSR and latest version of CFS, and
  III. Initialized daily.

- An assessment of CFSv2 hindcasts will
  I. Complement earlier studies
  II. Help reveal deficiencies of the system for further improvement

Aspects to be analyzed

1. MJO prediction skill
   A. Dependence on initial phase and target phase
   B. Variability of the prediction skill

2. Maintenance of the MJO
   A. Amplitude and phase speed
   B. Initial phase dependence

3. Prediction of the MJO during the DYNAMO period
   A. Forecast from operational GFS and CFSv2
   B. Experiments to test convection schemes

Data

1. Variables
   U850, U200, OLR

2. CFSv2 hindcasts
   Initial dates: 1 Jan 1999 – 31 Dec 2010
   Forecast length: 45 days
   Ensemble size: 4 runs from each day

3. Observation
   U850/U200: CFSR
   OLR: NOAA/AVHRR

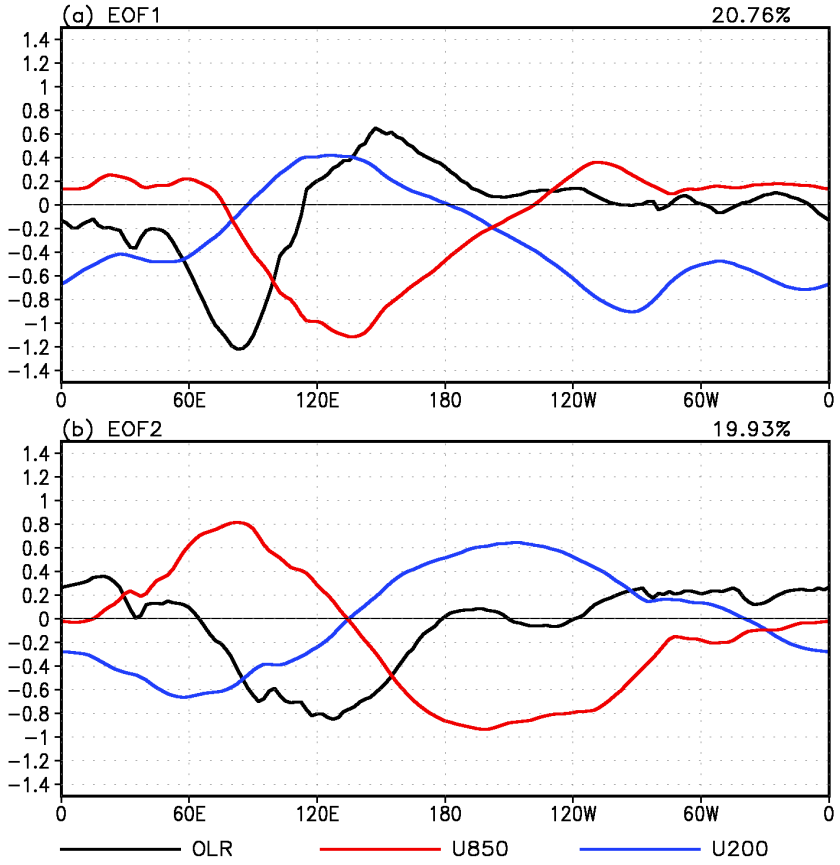
4. Intraseasonal anomalies

$F' = F - F_c - F_L$

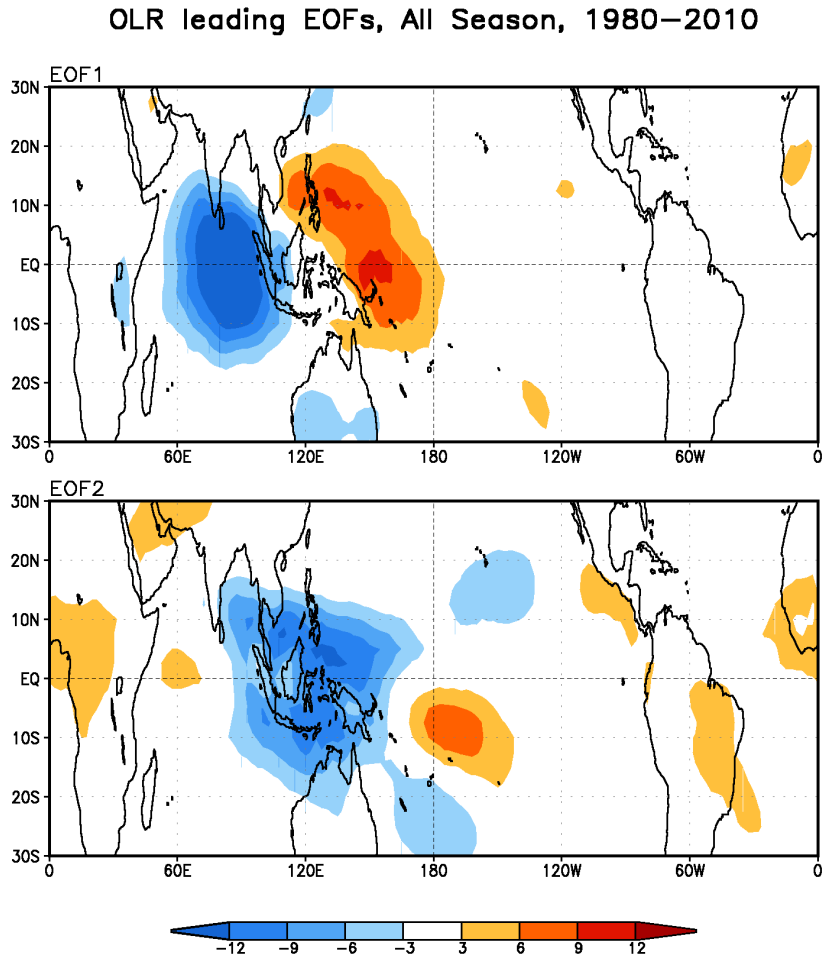
Where F : Total field
F_c : Daily climatology
F_L: Low frequency (previous 90-day average of $F - F_c$)

Definition of MJO

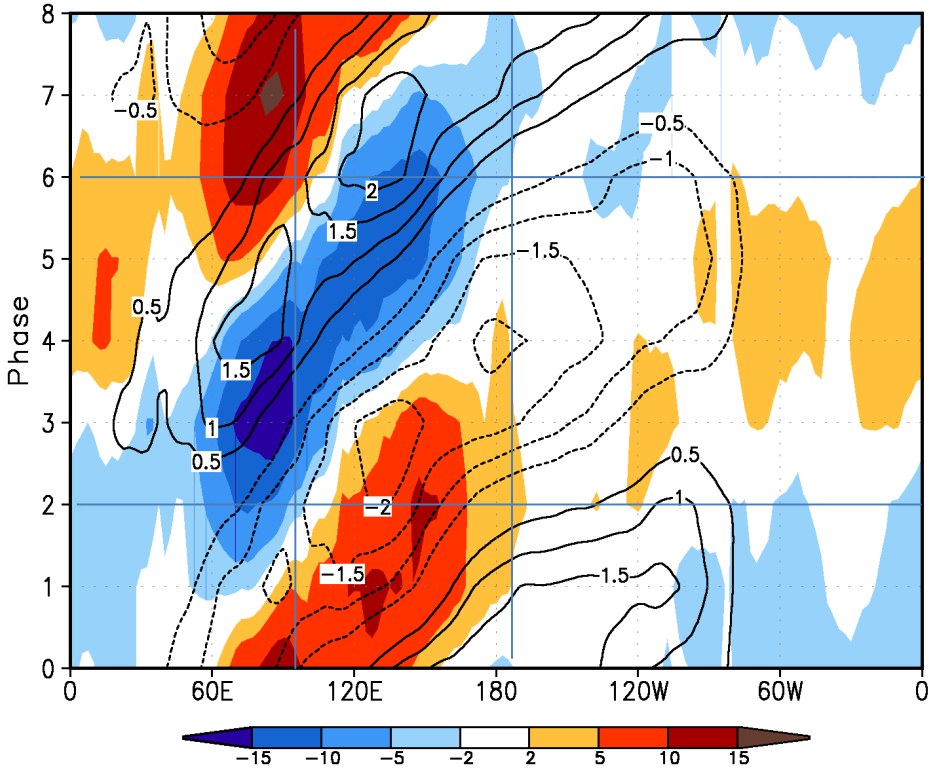
Combined EOFs (U850, U200, OLR)
Ave(15S:15N), 20-100-day filtered



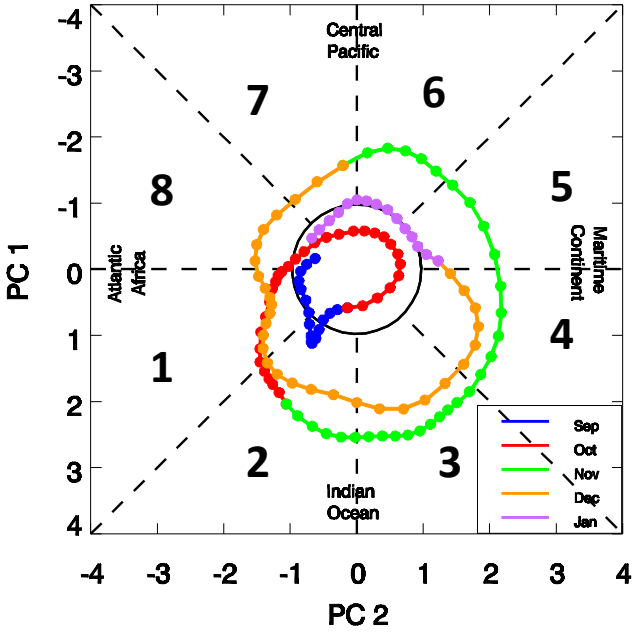
OLR EOFs (30S-30N)



Composite MJO lifecycle



Shadings: OLR (Wm^{-2})
Contours: u850 (m/s)



Results

1. MJO prediction skill
   A. Dependence on initial phase and target phase
   B. Variability of the prediction skill
2. Maintenance of the MJO
   A. Amplitude and phase speed
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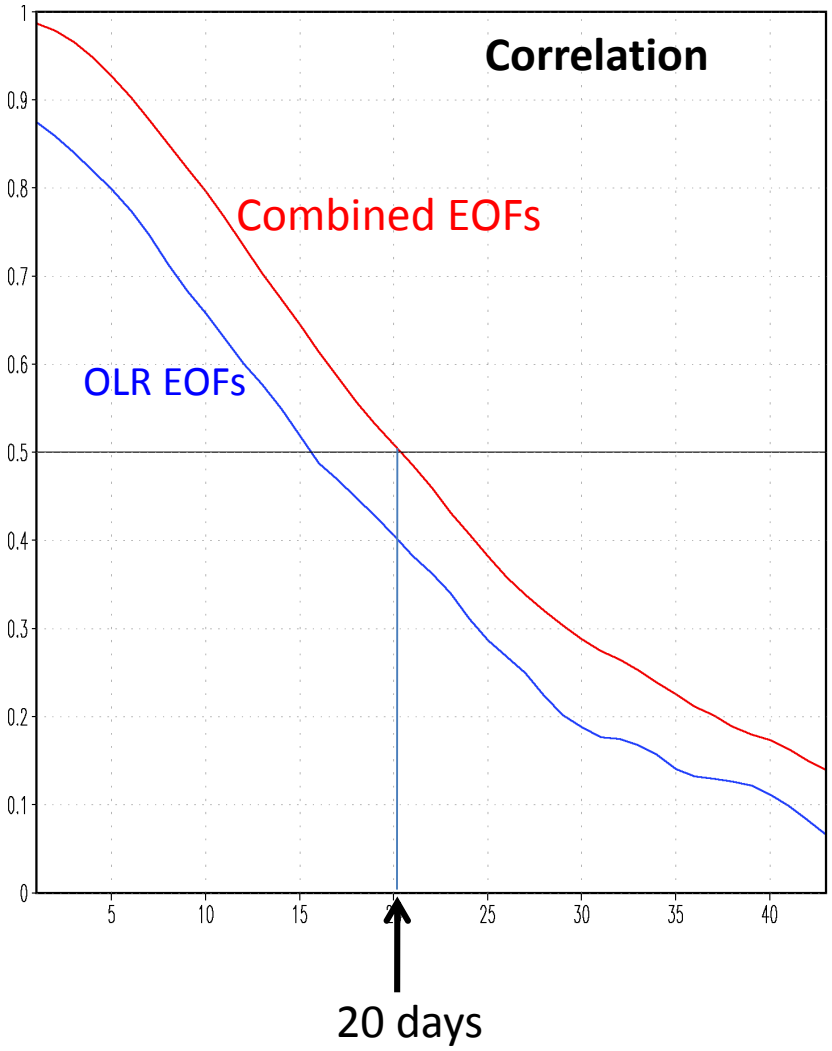
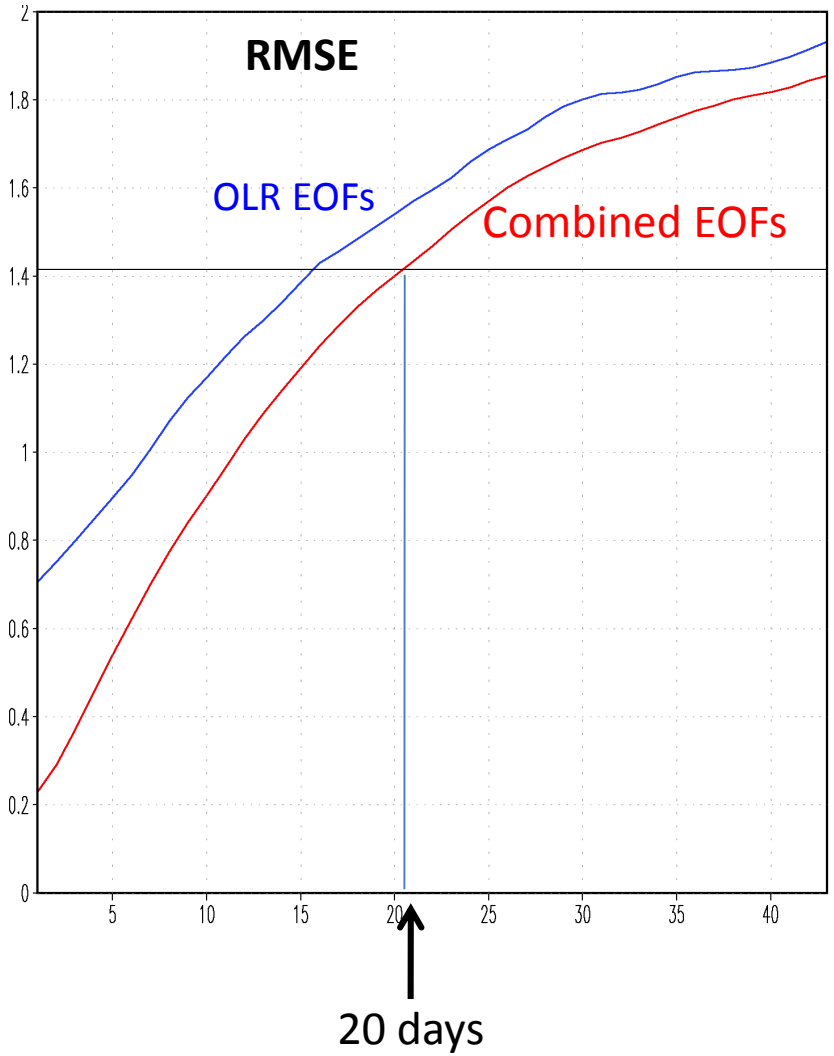
3. Prediction of the MJO during the DYNAMO period
   A. Forecast skill
   B. Comparison of CFSv2 with other models

Bivariate correlation and RMSE of PCs





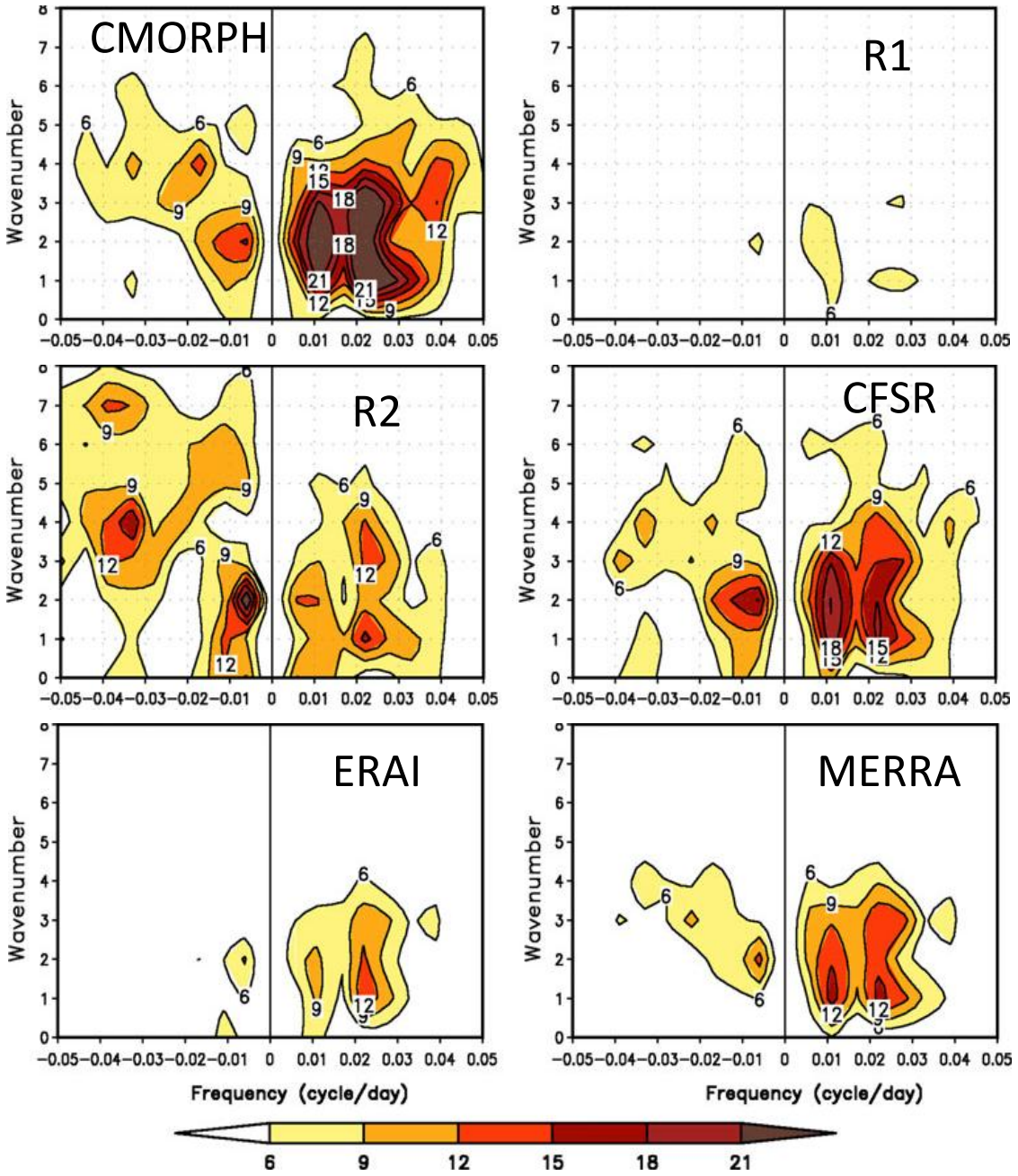
<u>Analysis after this will be for combined EOFs</u>

Anomaly correlation coefficient of MJO PCs

Model	Initial conditions	0.5 ACC	Reference
CCCma GCM3	NCEP/NCAR R1	6 days	Lin et al. (2008)
RPN GEM	NCEP/DOE R2	10 days	Lin et al. (2008)
CFSv1	NCEP/DOE Reanalysis (R2)	10-15 days	Seo et al (2009)
POAMA 1.5b	ERA-40 relaxation	21 days	Rashid (2010)
ECMWF Cy32r3	ERA-40, ECMWF operational analysis	23 days	Vitart et al. (2010)
CFSv2	CFSR	20 days	Wang et al. (2013)

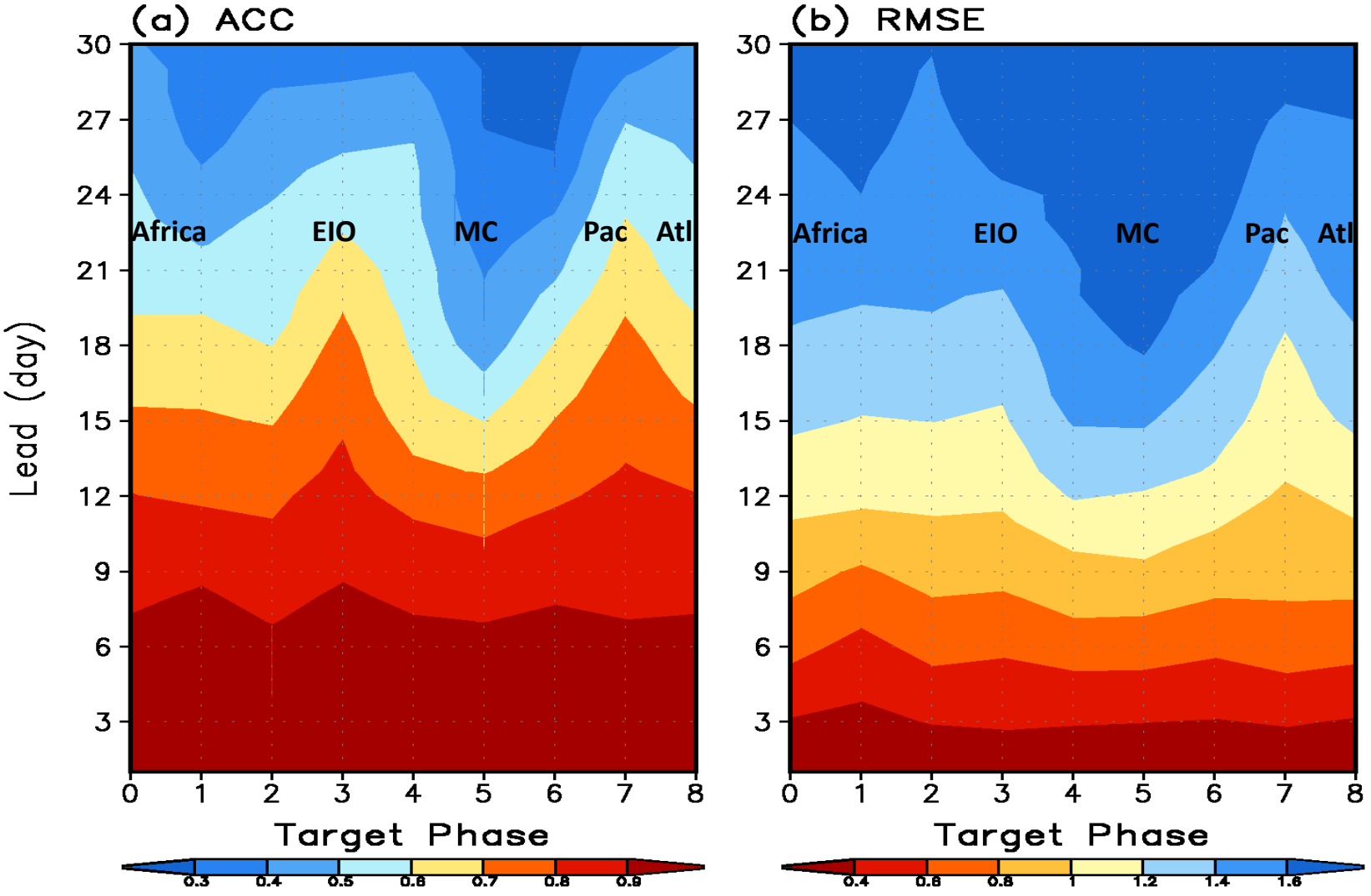
Rainfall wavenumber-frequency spectra (10S–10N average)

The new reanalyses (CFSR, MERRA, ERAI) produced better eastward/westward contrast

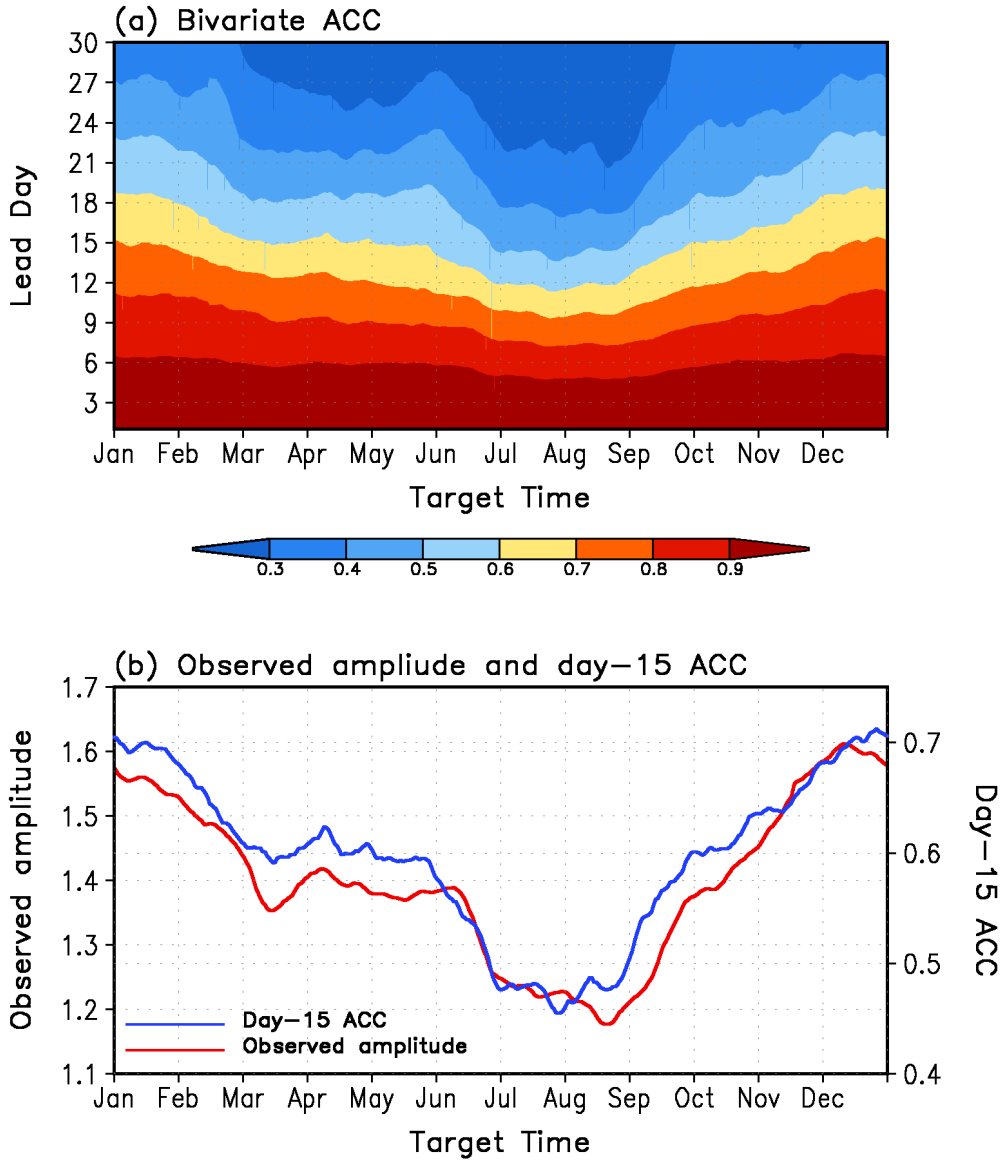


Wang et al. (2012, Climate Dynamics)

CFSv2 prediction skills



Seasonal variation of ACC



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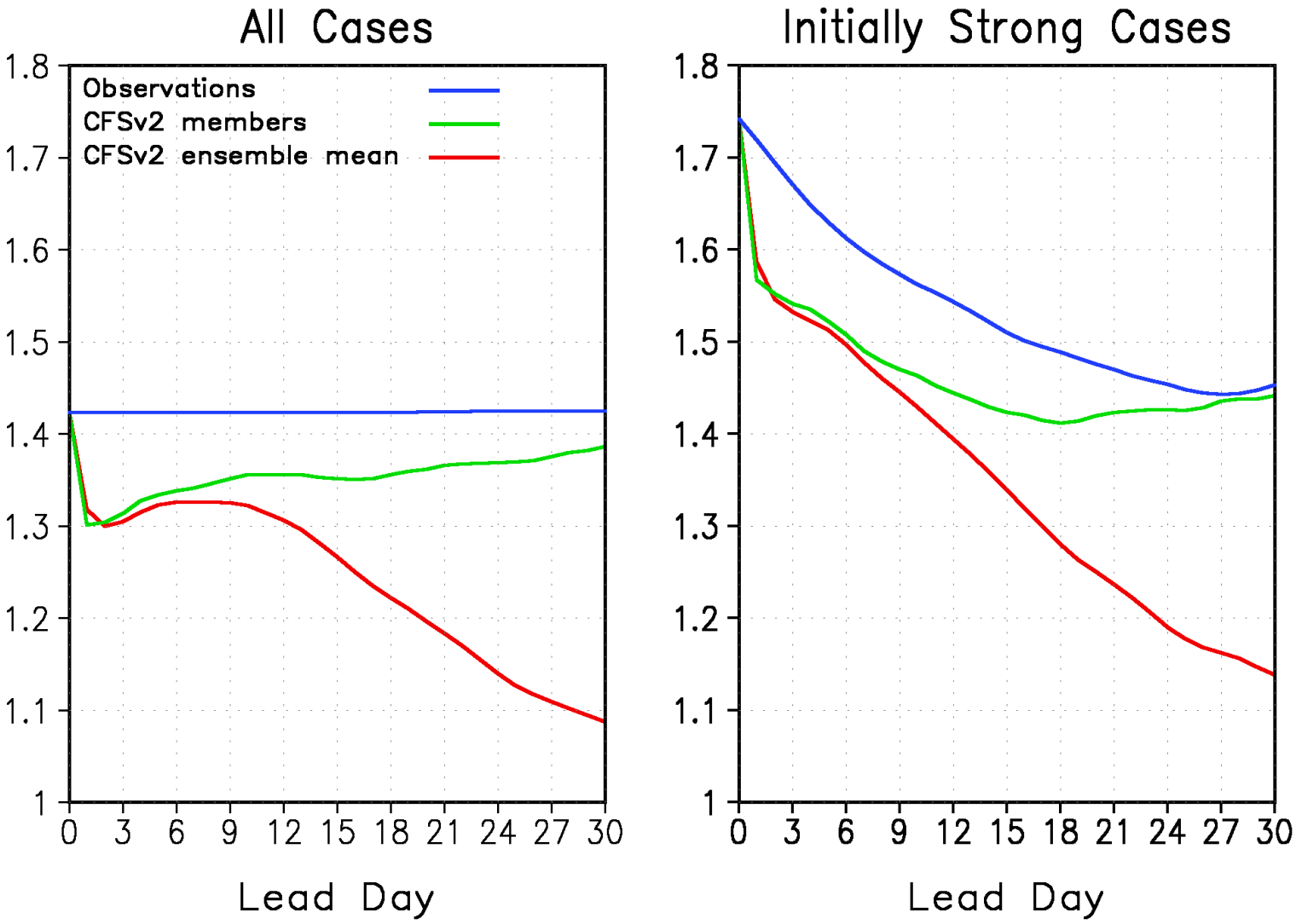
Evolution of amplitude

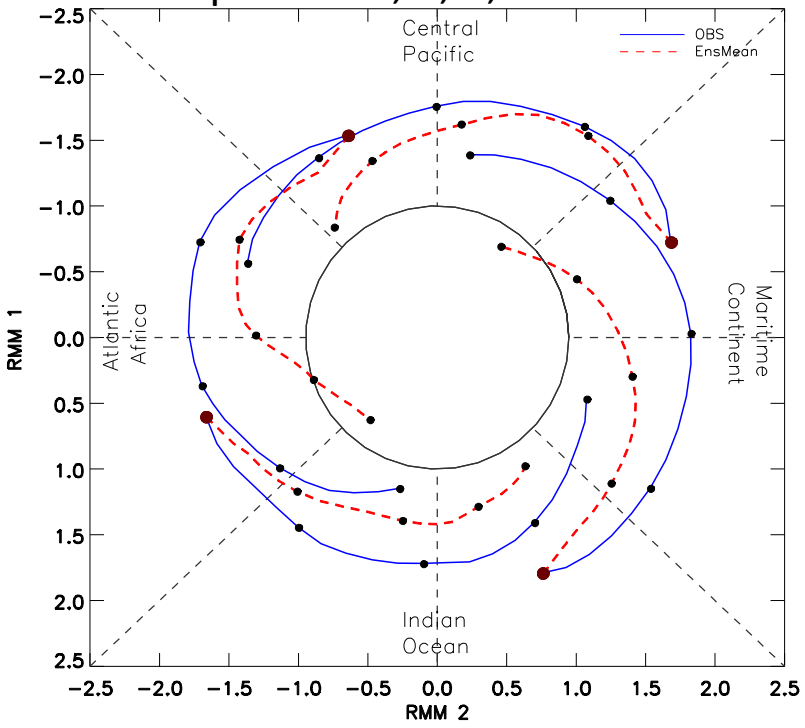


Composites forecast for each initial phase.

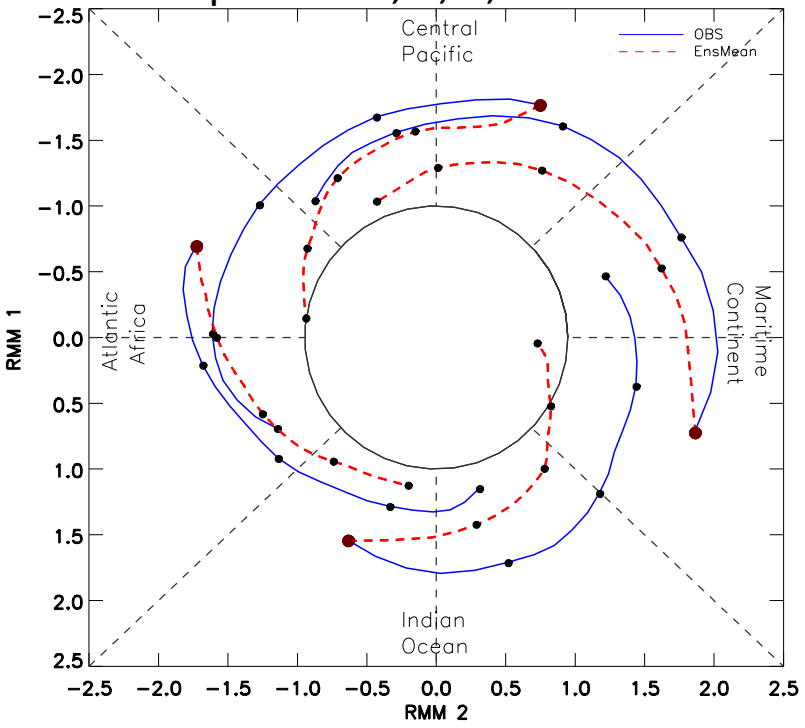
Observation

CFSv2

Initial phases: 1, 3, 5, 7



Initial phases: 2, 4, 6, 8

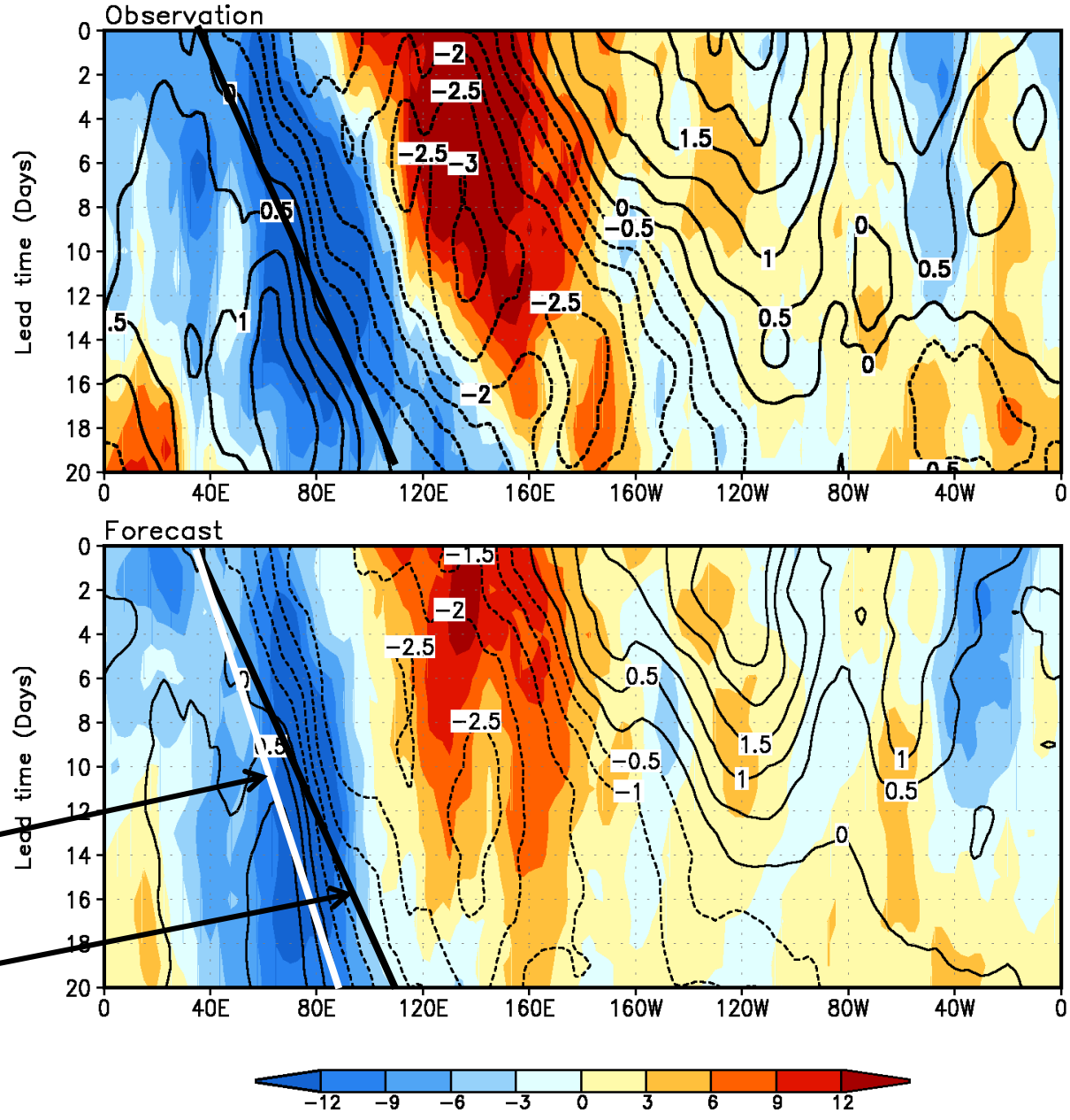


Phase speed: Degree/day)

Initial Phase	1	2	3	4	5	6	7	8
Obs (CFSv2-obs)	6.9 (-1.7)	6.7 (-1.2)	7.4 (-1.2)	7.6 (-0.5)	6.7 (-1.3)	7.2 (-2.0)	7.2 (-1.2)	6.4 (-1.3)

- The MJO propagates too slowly while becoming weaker than observed.

Composite for initial phase 1



Contours: u850
Shadings: OLR

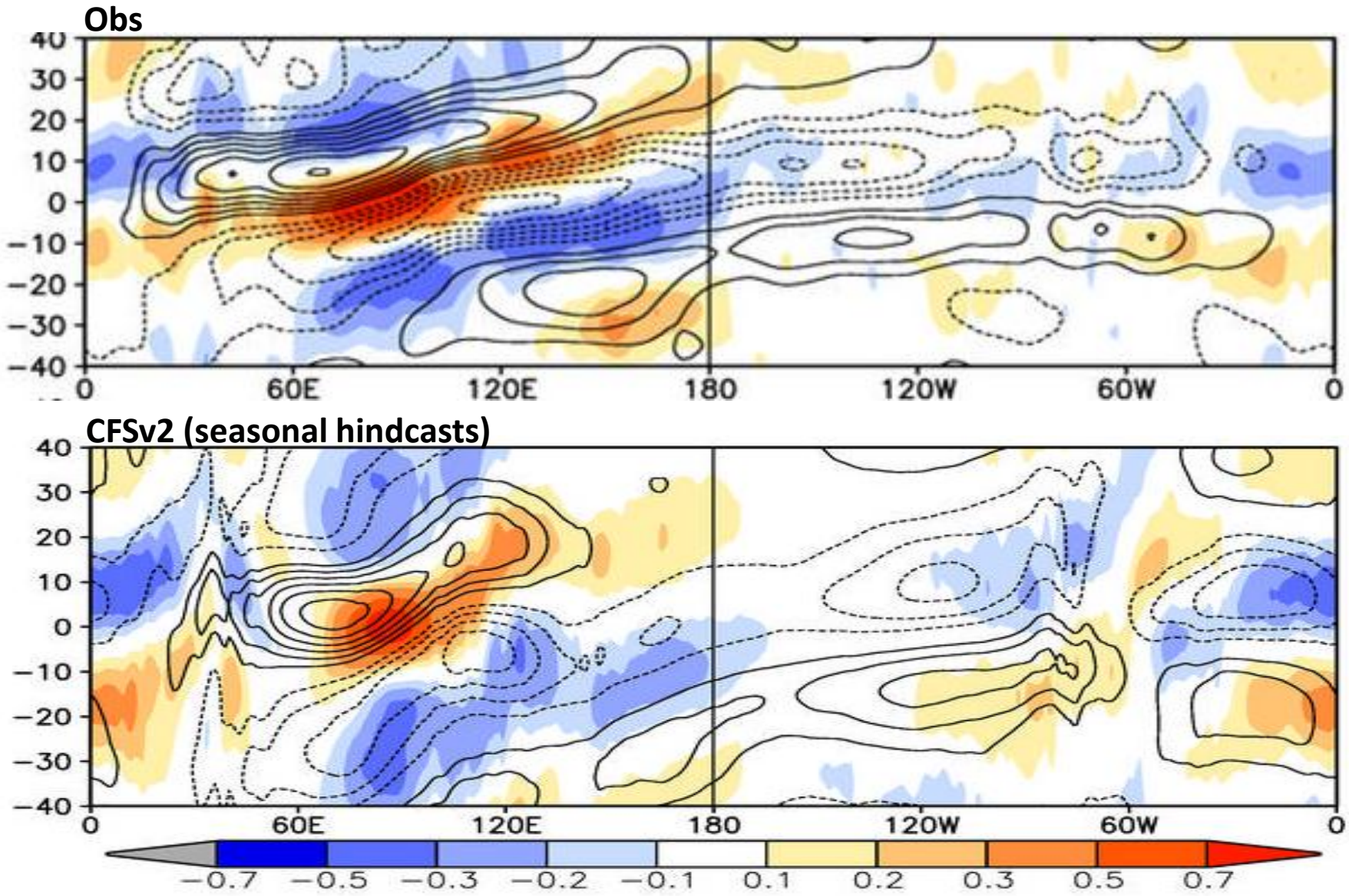
Thick lines:
u850=0

Forecast

Observation

Slow propagation in CFSv2 seasonal runs

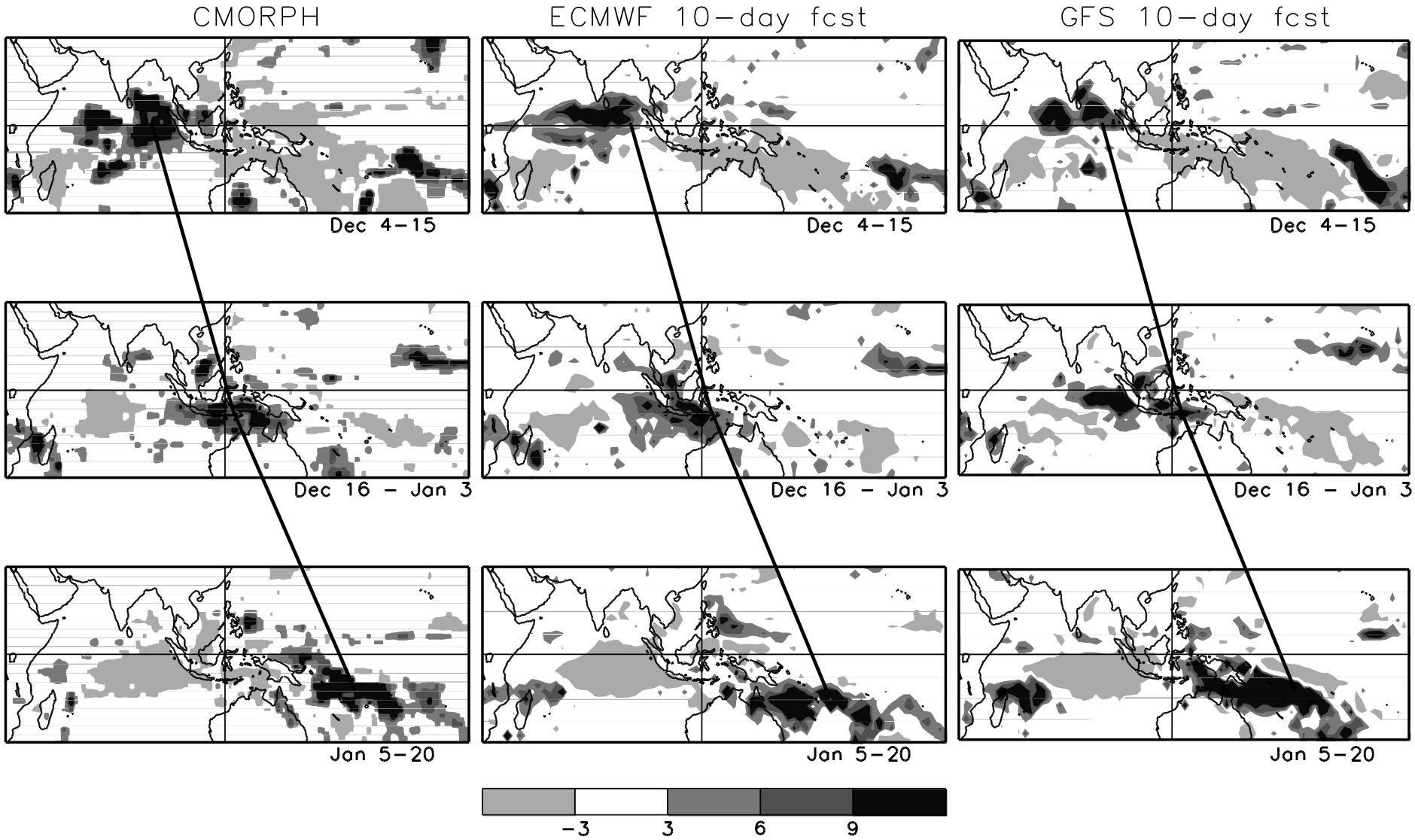
Lag correlations Indian Ocean precipitation index (70E-100E, 10S-10N)
precipitation (shaded); 850 hPa zonal winds (contoured)



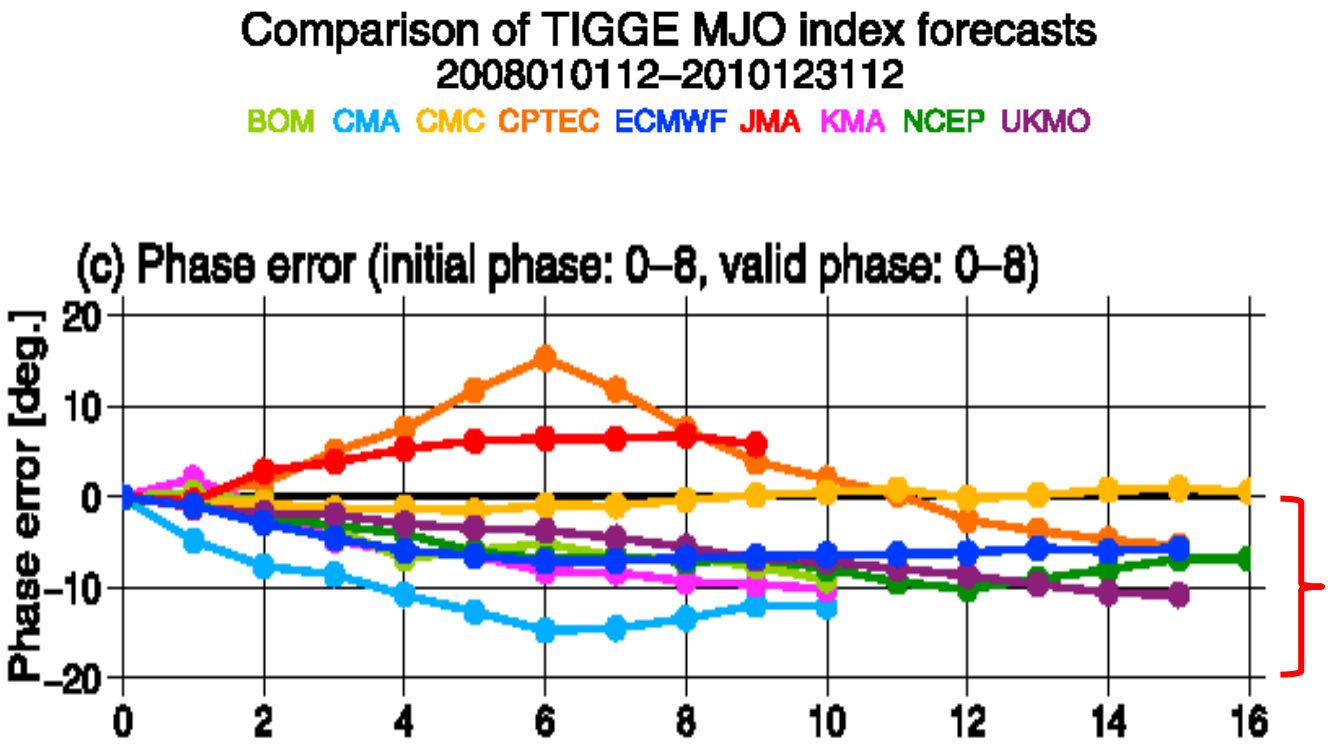
Weaver et al. (2011, J. Clim)

Slow propagation in other forecast models

Prediction of Dec-Jan 2007/2008 MJO event



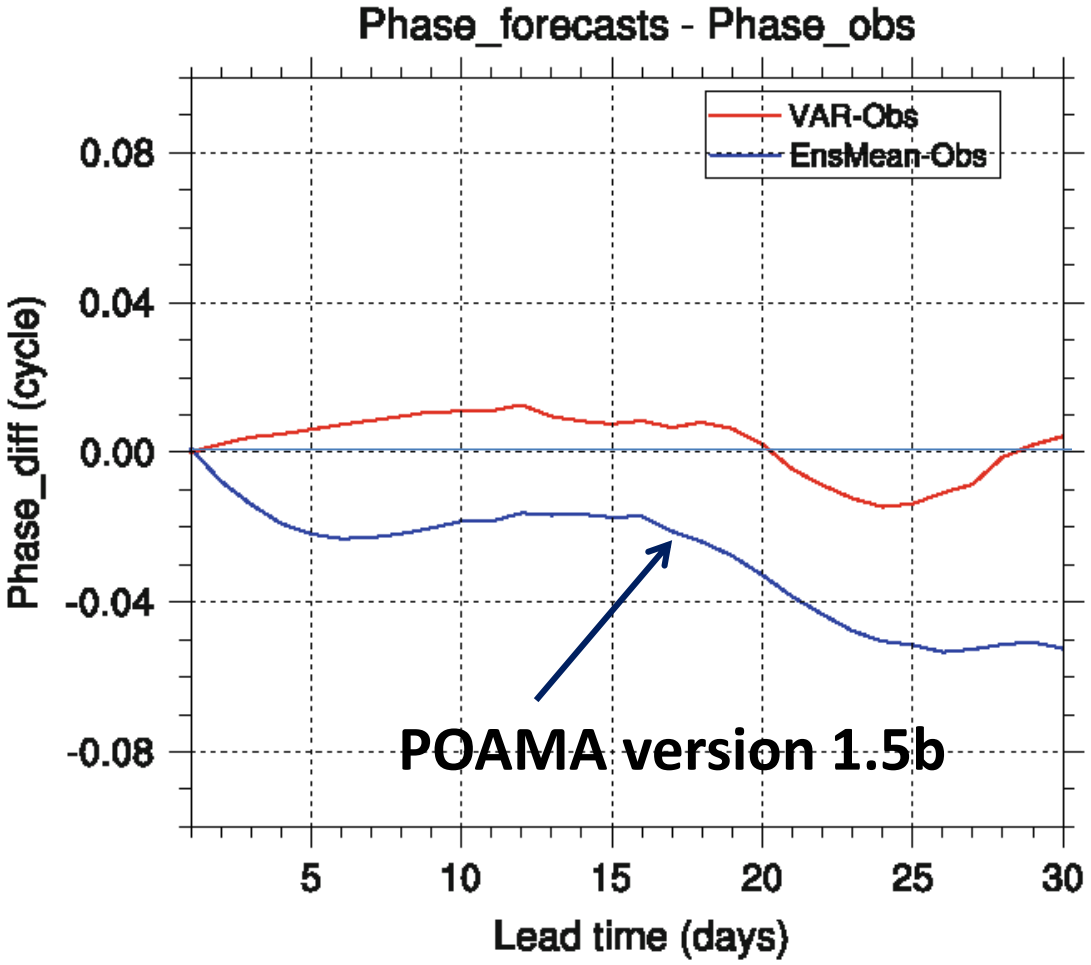
Janowiak et al. (2010, MWR)



Phase speed too slow

Matsueda and Endo (2011,GRL)

Phase speed error in POAMA version 1.5b



Rashid et al (2010, Climate Dynamics)

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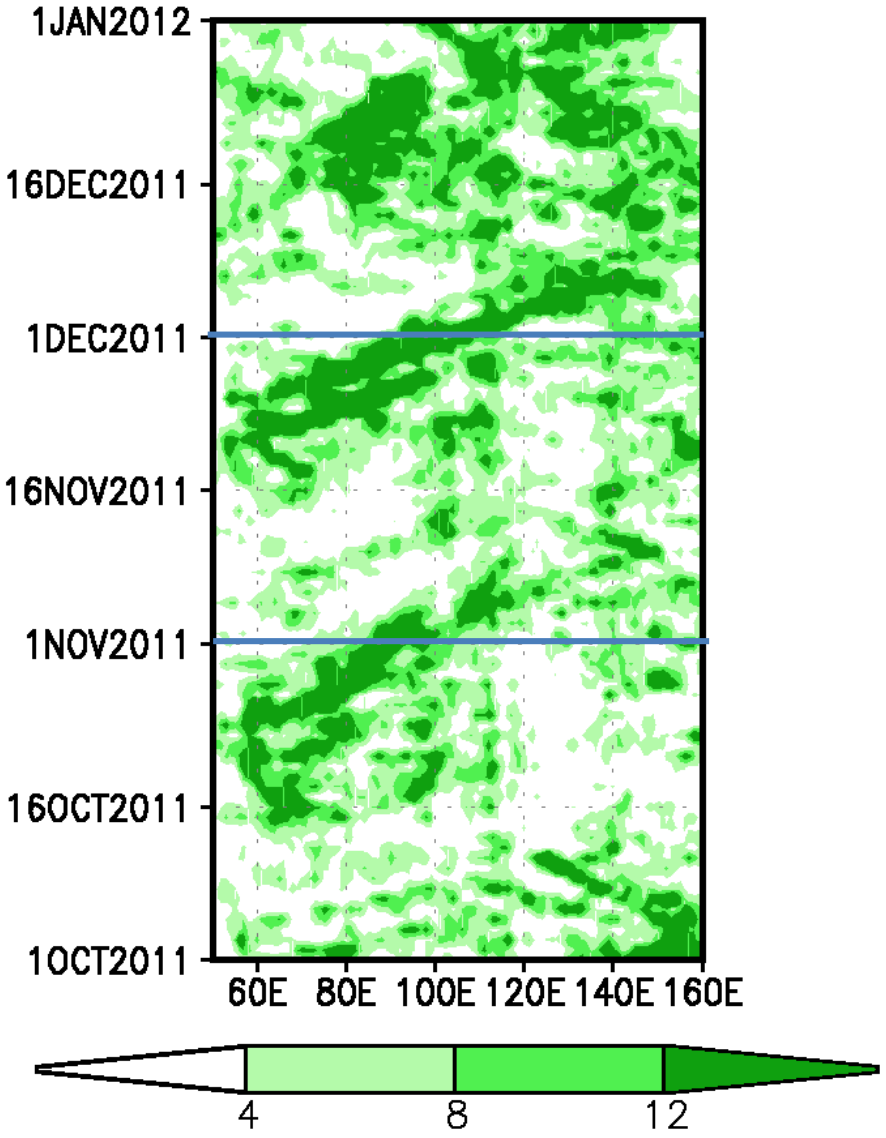
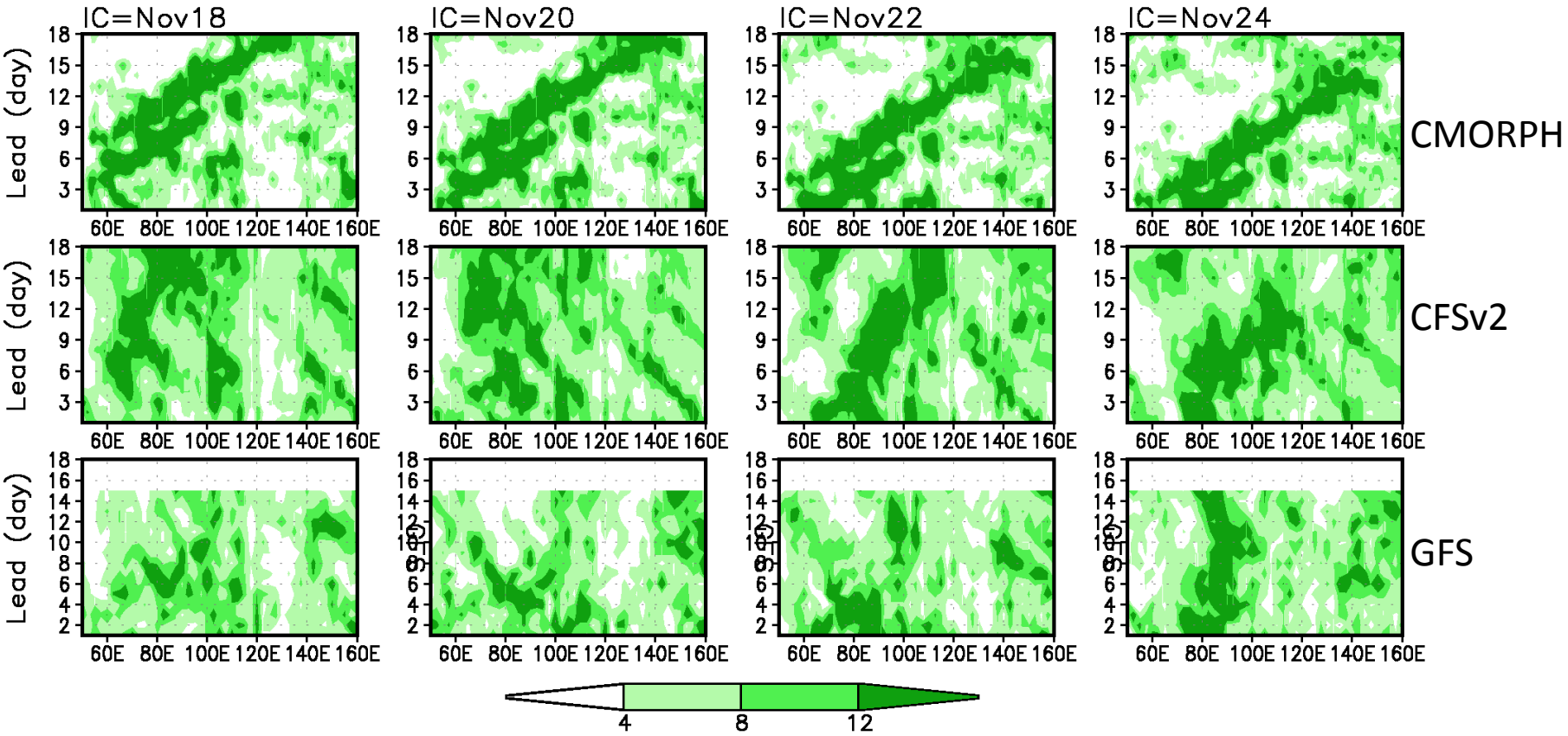
CMORPH rainfall (mm/day)

Ave(10S-10N)

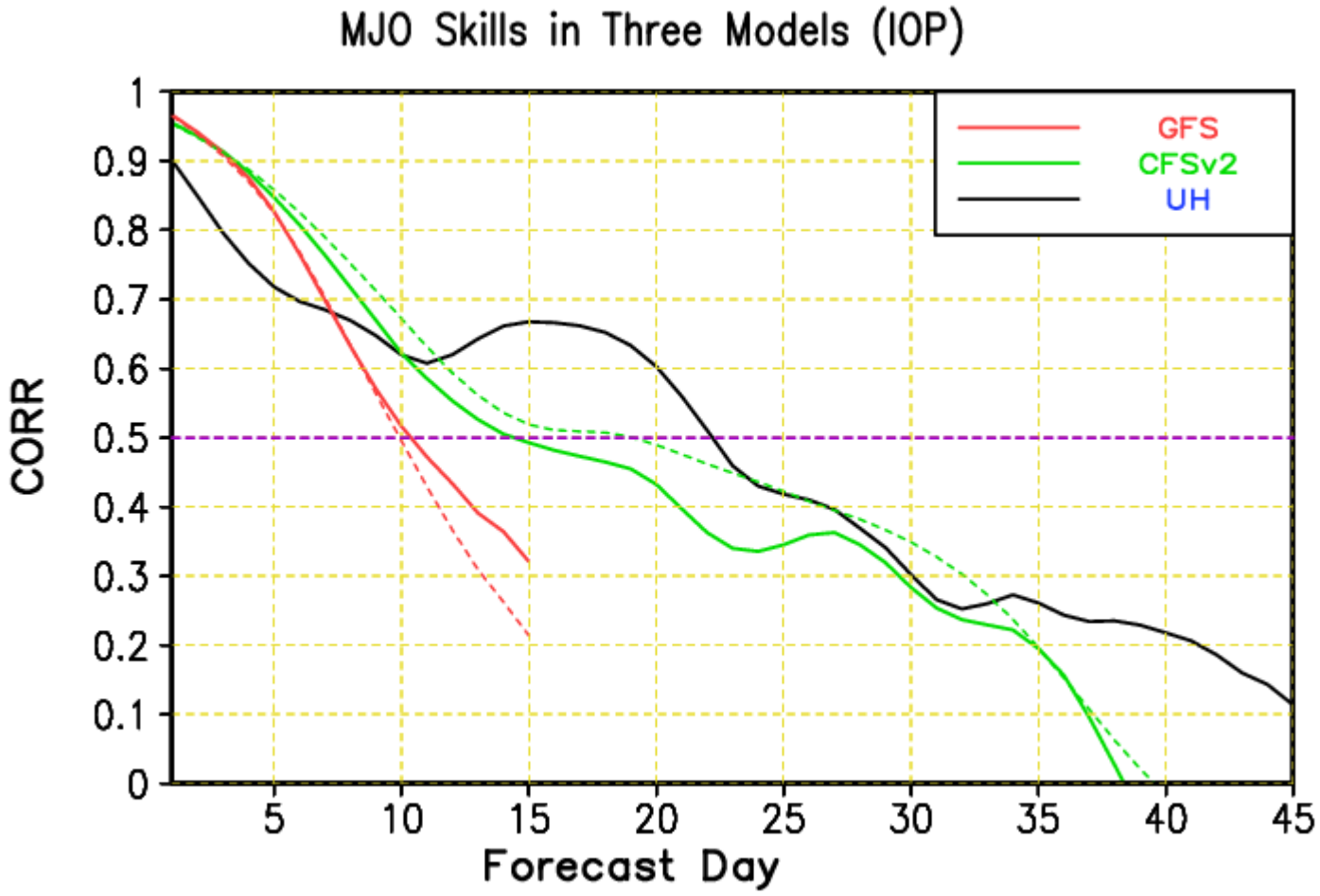


10S-10N average rainfall (mm/day)



Anomaly correlation of MJO for DYNAMO/CINDY IOP period

(Sep01, 2011-Jan15, 2012)



Fu et al (2013, Climate Dynamics)

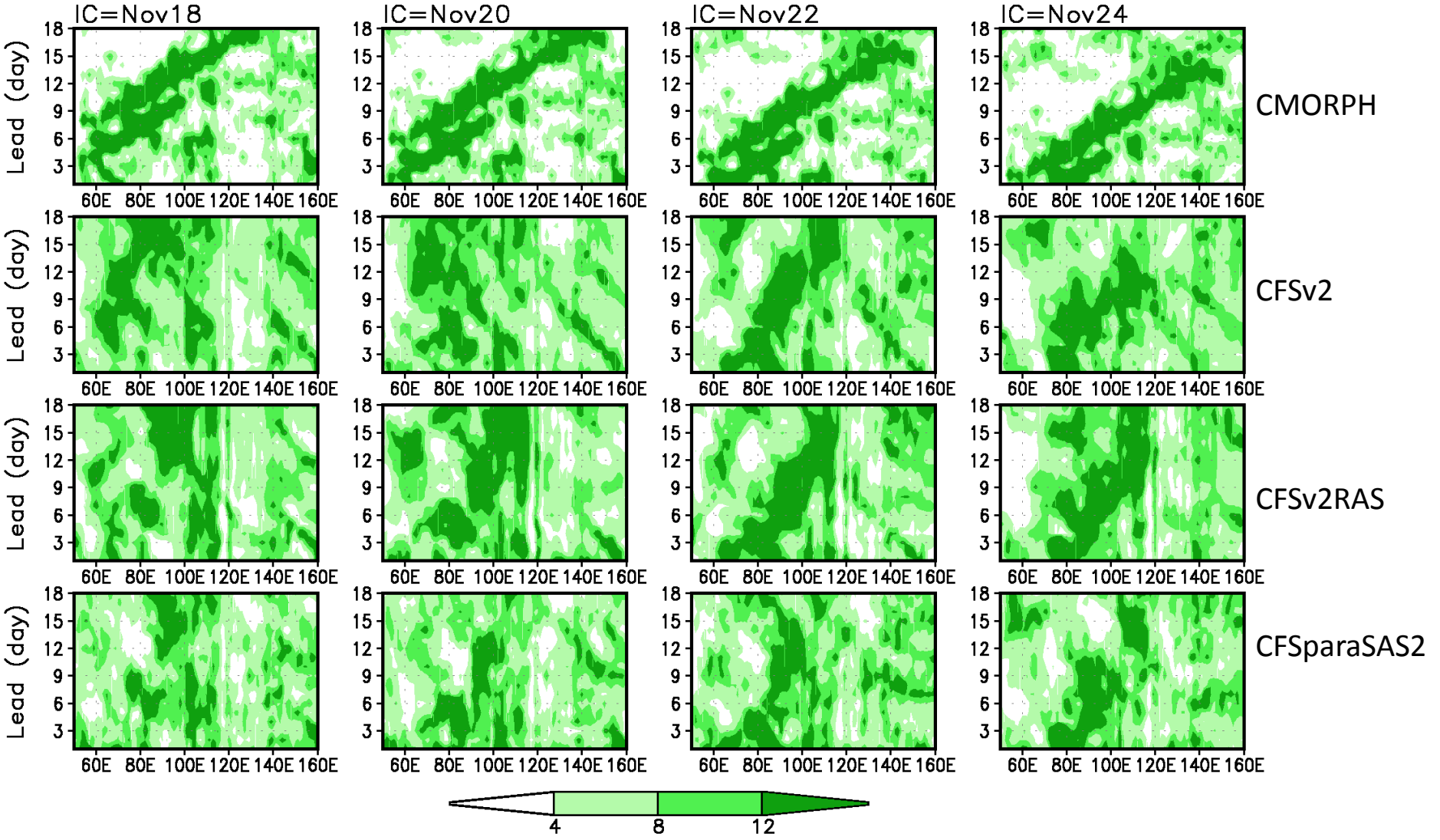
What are the causes of the forecast errors?

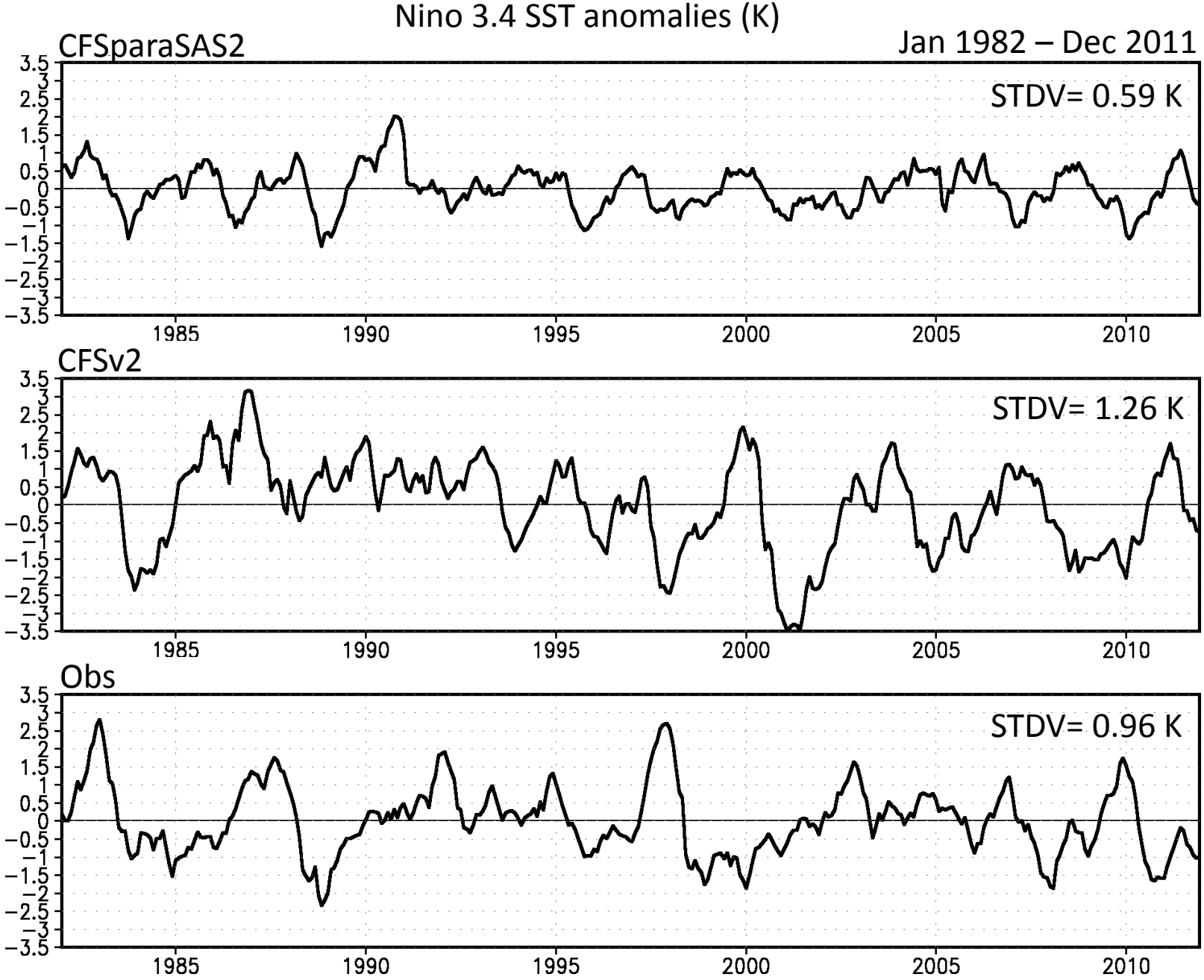
- Convection parameterizations
- Inaccurate SSTs
- Resolutions
- ….

Experiments to test convection schemes with CFSv2

CFSv2:	Operational CFS (using SAS convection scheme)
CFSv2RAS:	CFSv2 with RAS convection scheme
CFSparaSAS2:	Parallel CFS with SAS2 convection scheme

10S-10N average rainfall (mm/day)



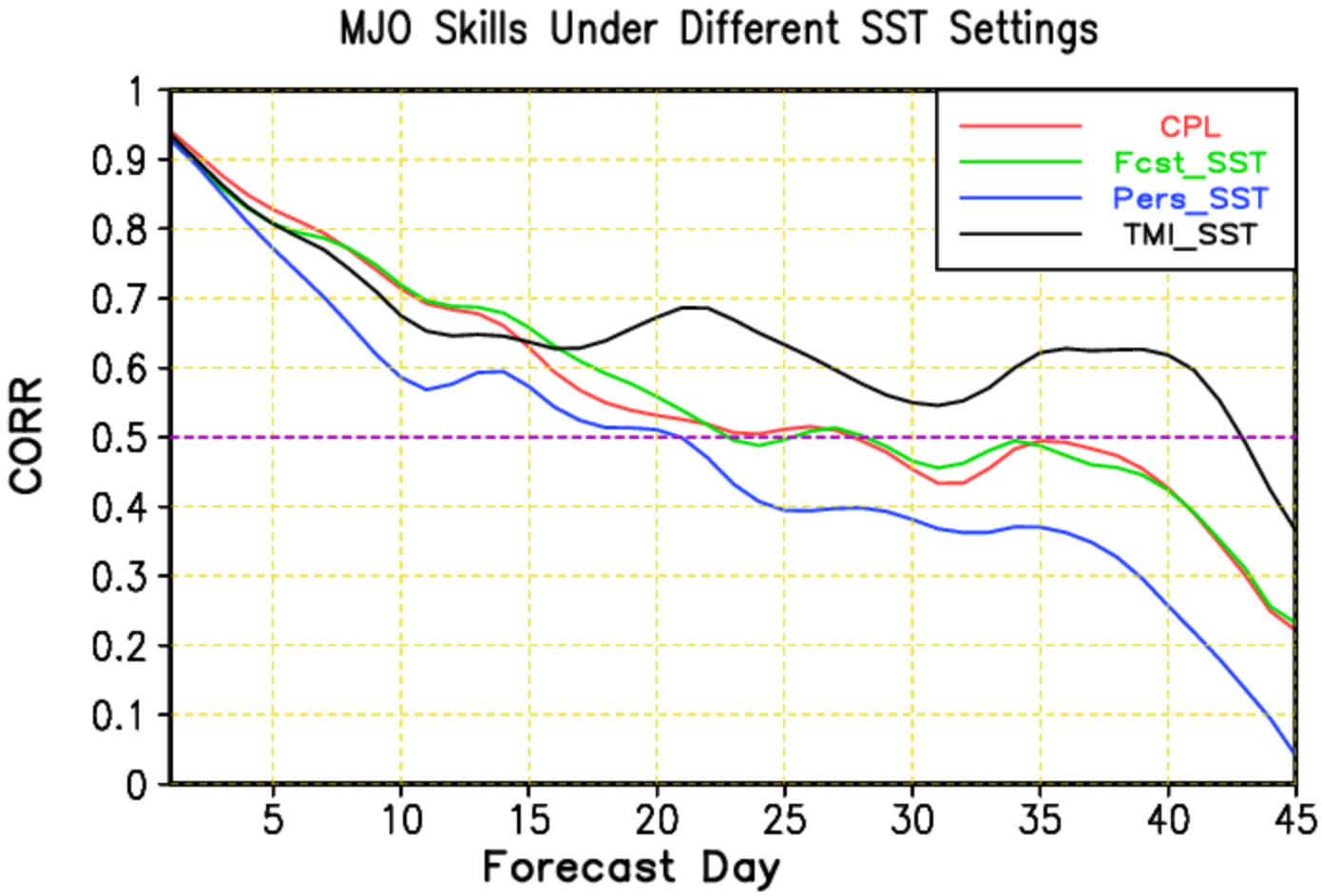

Nino 3.4 SST anomalies (K)
CFSparaSAS2
Jan 1982 – Dec 2011
STDV= 0.59 K
CFSv2
STDV= 1.26 K
Obs
STDV= 0.96 K
3.5
3
2.5
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−2.5
−3
−3.5
1985
1990
1995
2000
2005
2010

Experiments to test SST with UH model

CPL	Atmosphere-ocean coupled forecasts
Fcst_SST:	Atmosphere-only forced with SSTs from the CPL
Pers_SST:	Atmosphere-only driven by persistent initial SST anomalies
TMI_SST:	Atmosphere-only forced with TMI SSTs

Anomaly correlation of MJO for DYNAMO/CINDY IOP period

(Sep01, 2011-Jan15, 2012)



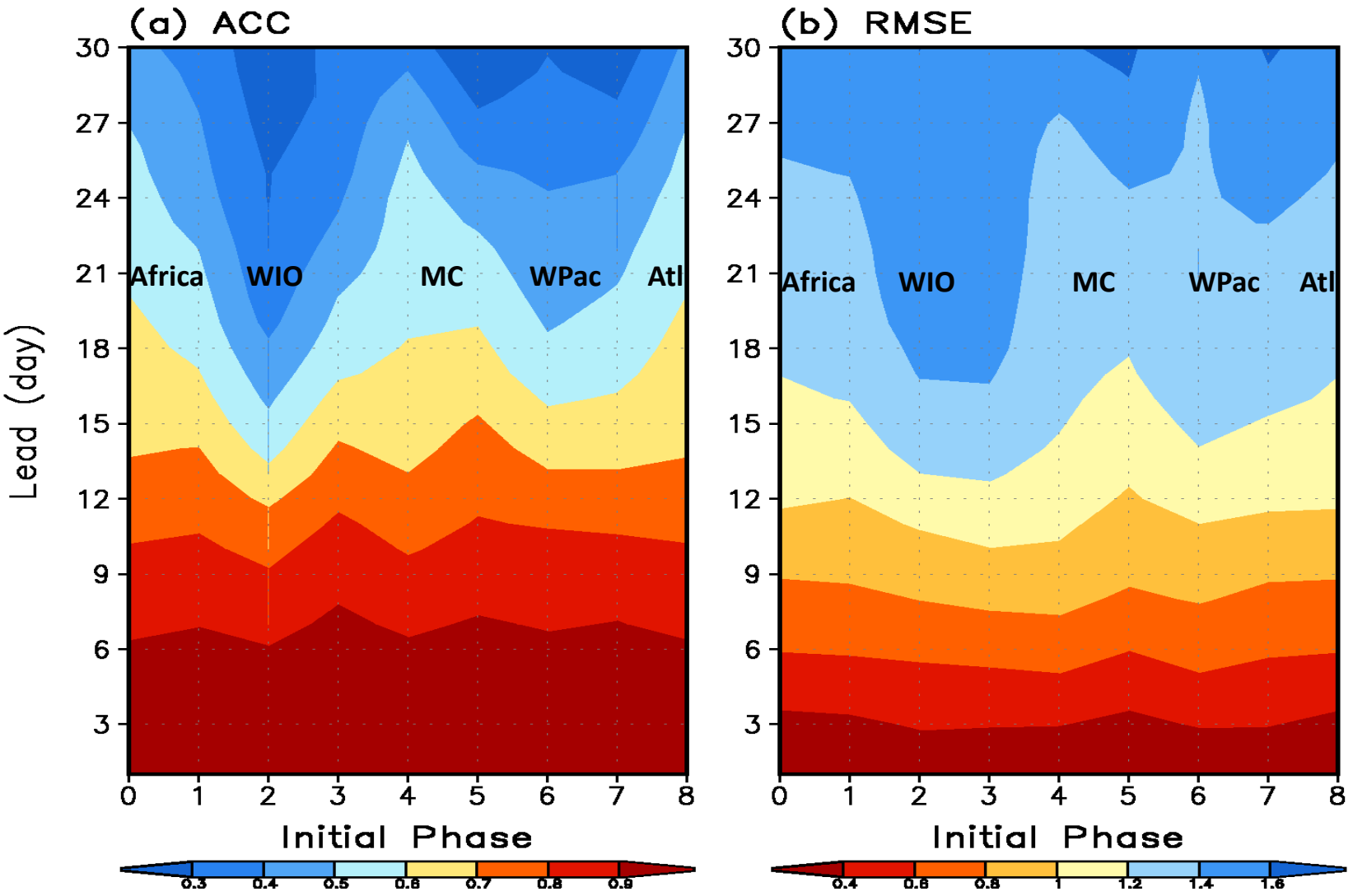
Fu et al (2013, Climate Dynamics)

Summary

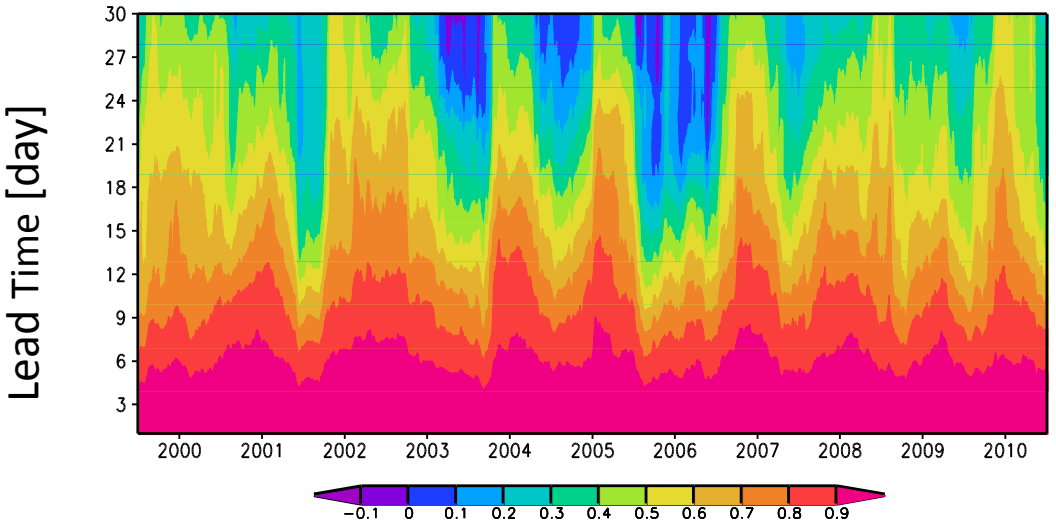
- CFSv2 is improved (compared to CFSv1, and GFS)
- Major deficiency: Propagation too slow (Not only in CFSv2)
- More work needed (convection schemes, convection parameters, ocean models, …)

Extra slides

CFSv2 prediction skills as a function of lead time & initial phase



Temporal variation of MJO bivariate ACC



181-day running window

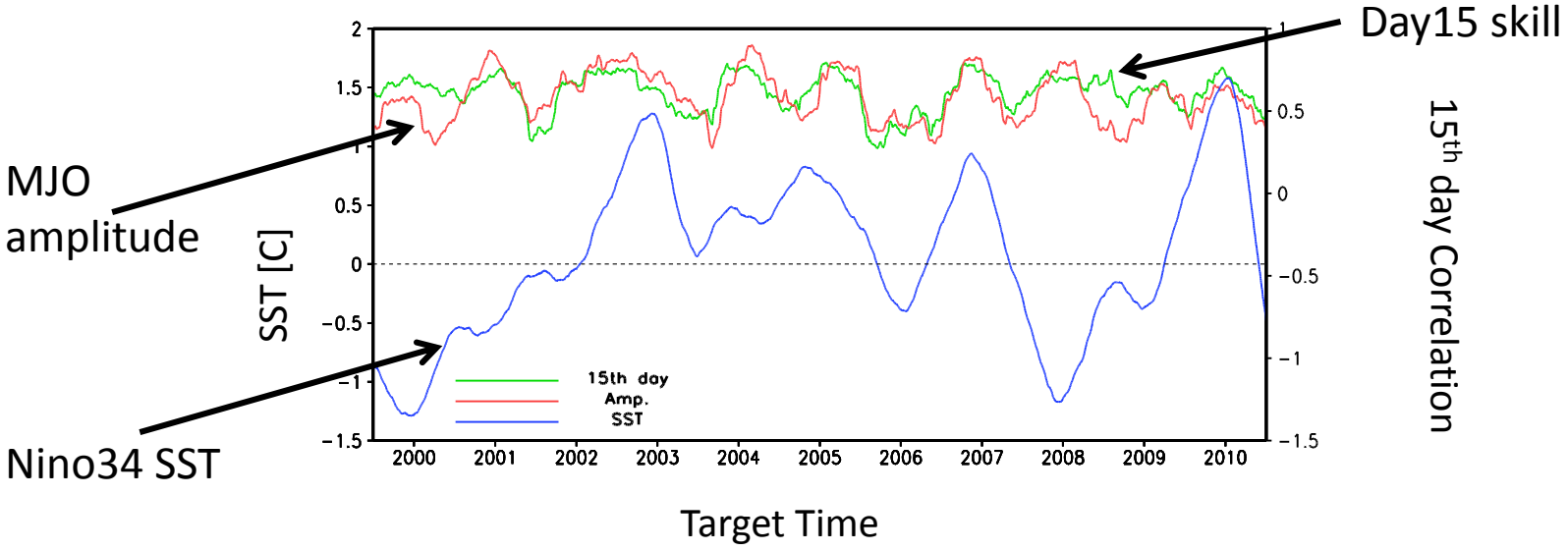


Fig. 5. Variation of MJO forecast skill

10S-10N average rainfall (mm/day)
IC: 22Nov2011