# Coupled ocean-atmosphere variability - MJO

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European Centre for Medium-Range Weather Forecasts

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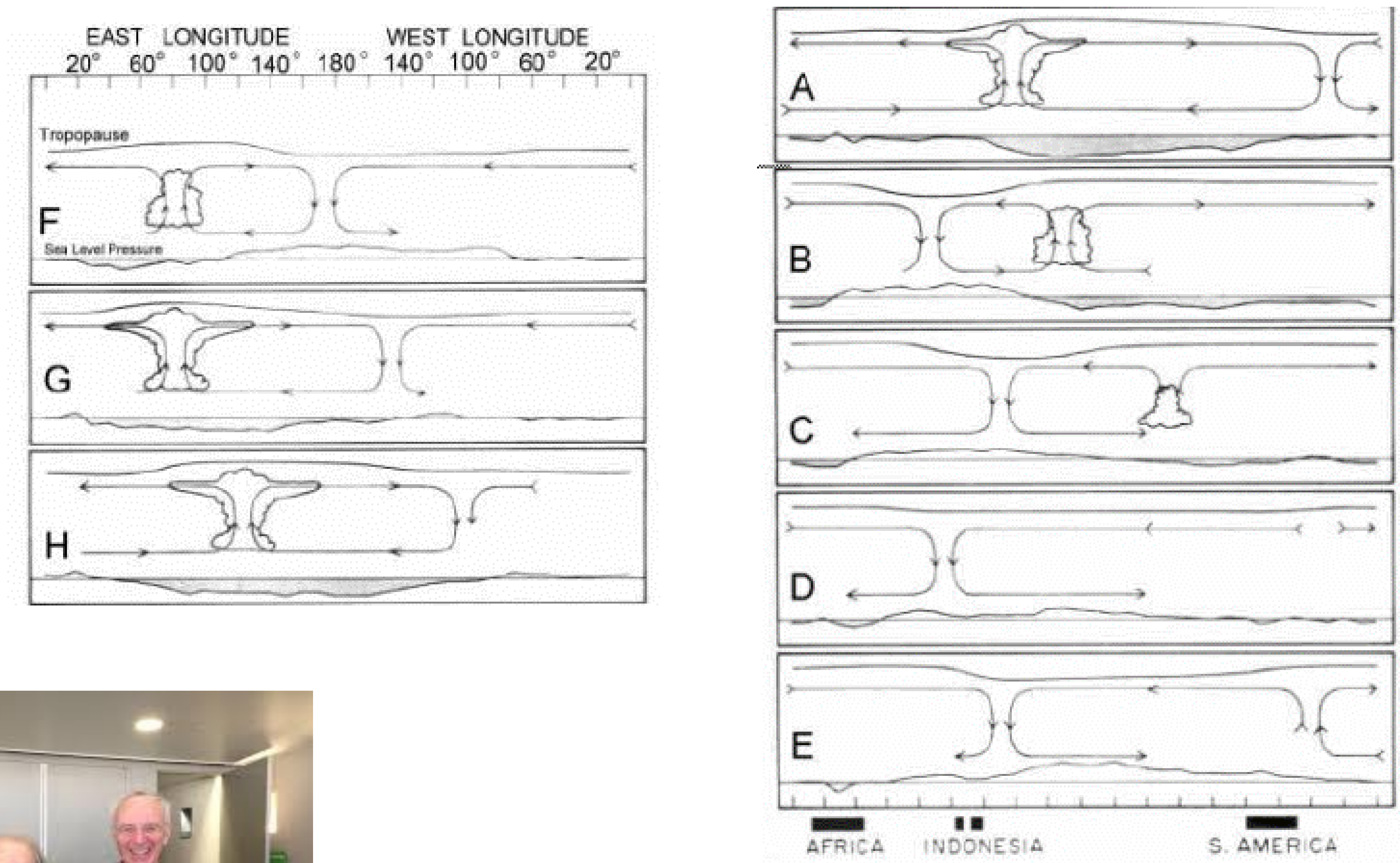
- Description of the MJO and its impacts
- Prediction of the MJO
- Air-sea Interaction

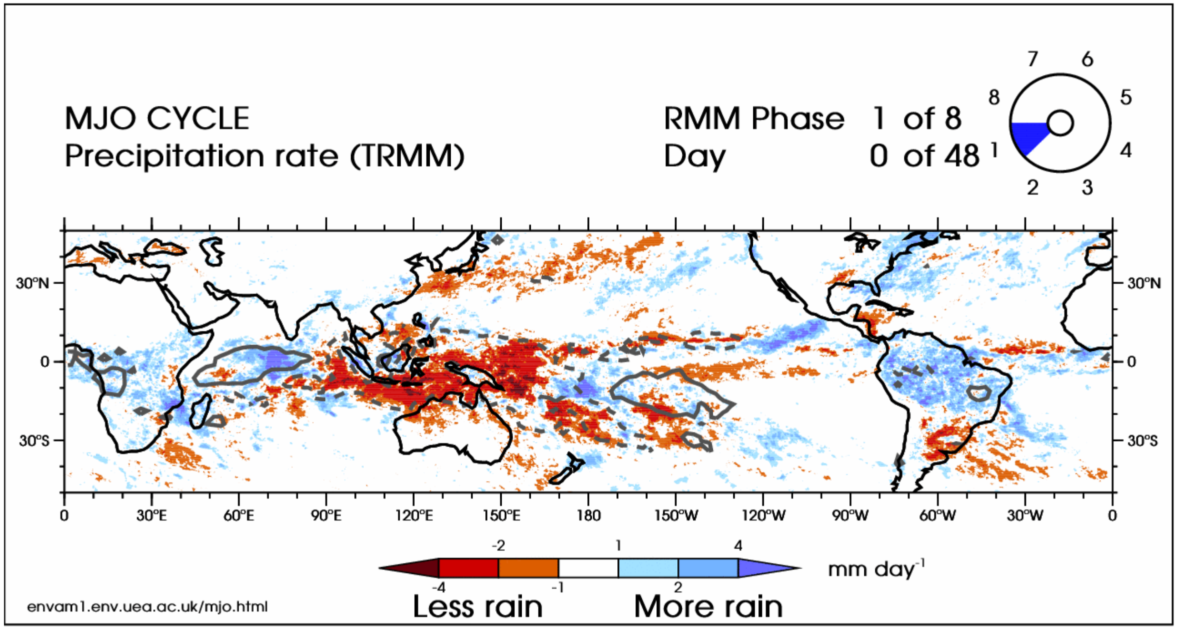
# *The Madden-Julian Oscillation (MJO)*



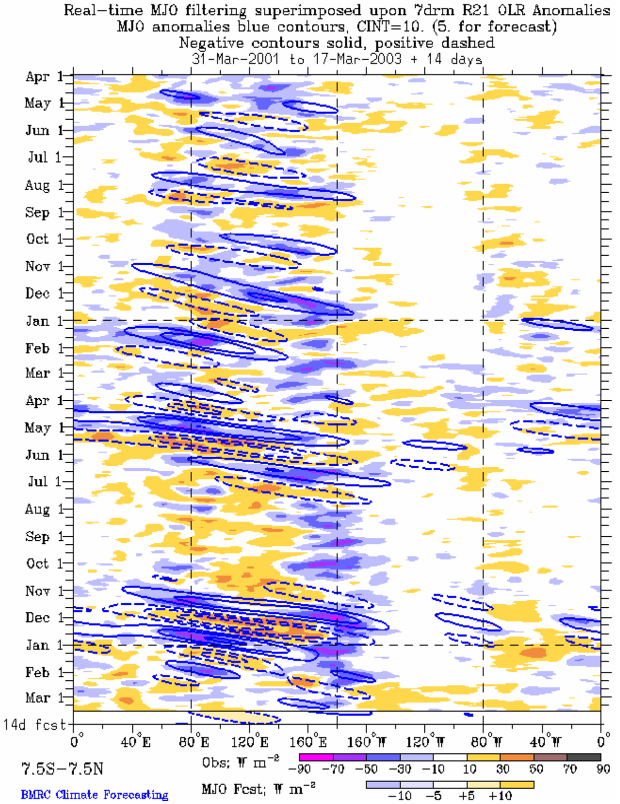

**From Madden and Julian (1972)**

# The Madden Julian Oscillation (MJO)

MJO life cycle




From http://envam1.env.uea.ac.uk/mjo.htm




**From http://www.bom.gov.au/bmrc/clf**

# The Madden Julian Oscillation (MJO)

- The MJO is a 40-50-day oscillation
- The MJO is a near-global scale, quasi-periodic eastward moving disturbance in the surface pressure, tropospheric temperature and zonal winds over the equatorial belt (4 to 8 m/s).
- The Madden-Julian Oscillation (MJO) is the dominant mode of variability in the tropics in time scales in excess of 1 week but less than 1 season.
- The MJO has its peak activity during Northern winter and spring.

# Theories for the onset of an MJO event

- **Local recharge/discharge processes** ( e.g. Hendon 1988, Blade and Hartmann 1993, Hu and Randall 1994…)
- **Upstream effects of circumnavigating waves** ( e.g. Knutson et al 1986, Knutson and Weickmann 1987, Lau and Peng 1987)
- **Stochastic forcing** (Wilson and Mak 1984, Neelin and Yu 1994, Yu and Neelin 1994)
- **Extratropical influences** (e.g. Lau and Peng 1987, Hsu et al 1990, Lin et al 2007, Ray et al 2010, Wedi and Smolarkiewicz 2010..)

# *The Madden Julian Oscillation (MJO)*

## Why is the MJO so important?

- Impact on the Indian and Australian summer monsoons (Yasunari 1979), Hendon and Liebman (1990)

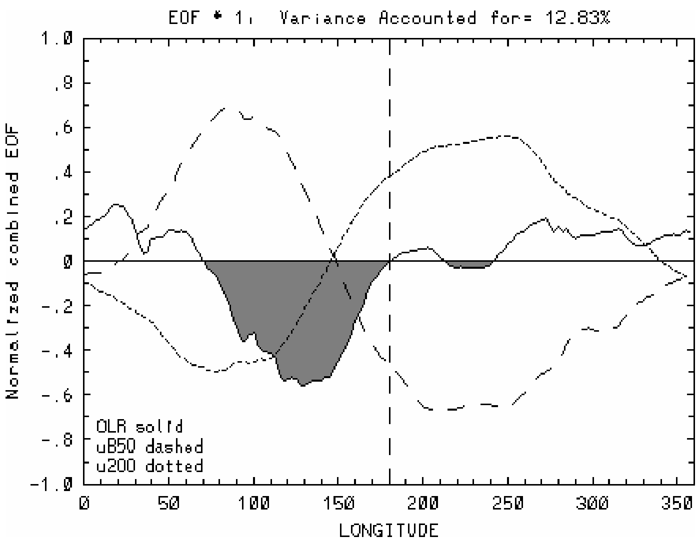
- Impact on ENSO. Westerly wind bursts produce equatorial trapped Kelvin waves, which have a significant impact on the onset and development of an El-Niňo event. Kessler and McPhaden (1995)

- Impact on tropical storms (Maloney et al, 2000; Mo, 2000)

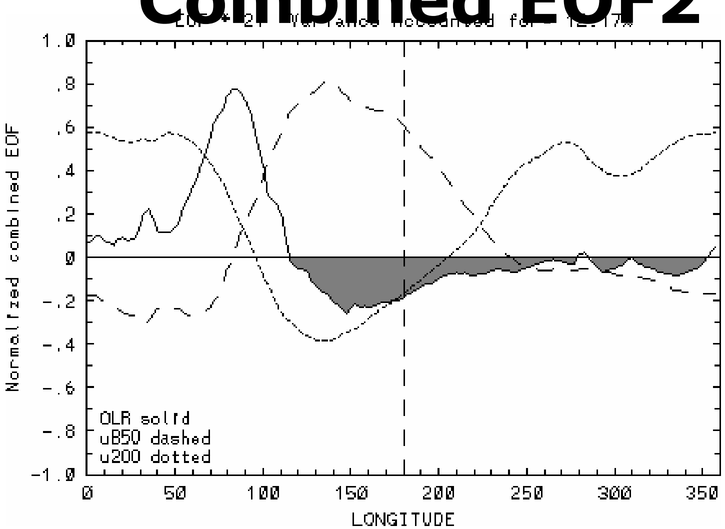
- Impact on Northern Hemisphere weather

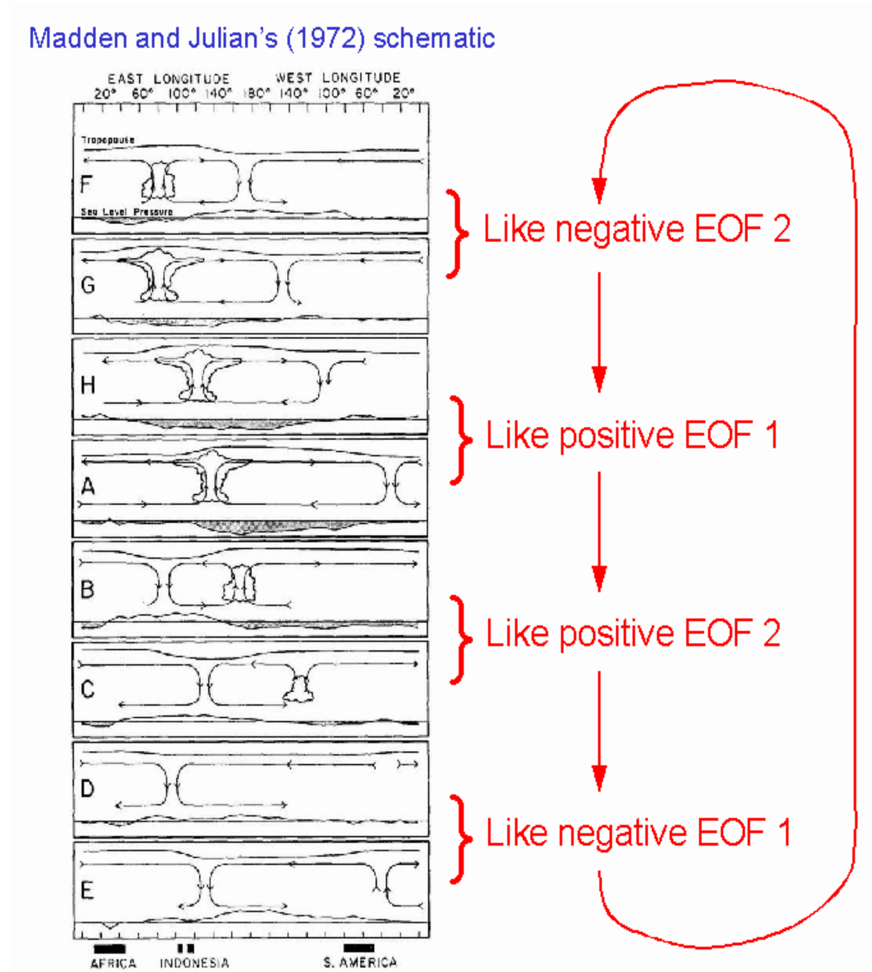
# MJO Index

## Combined EOF1



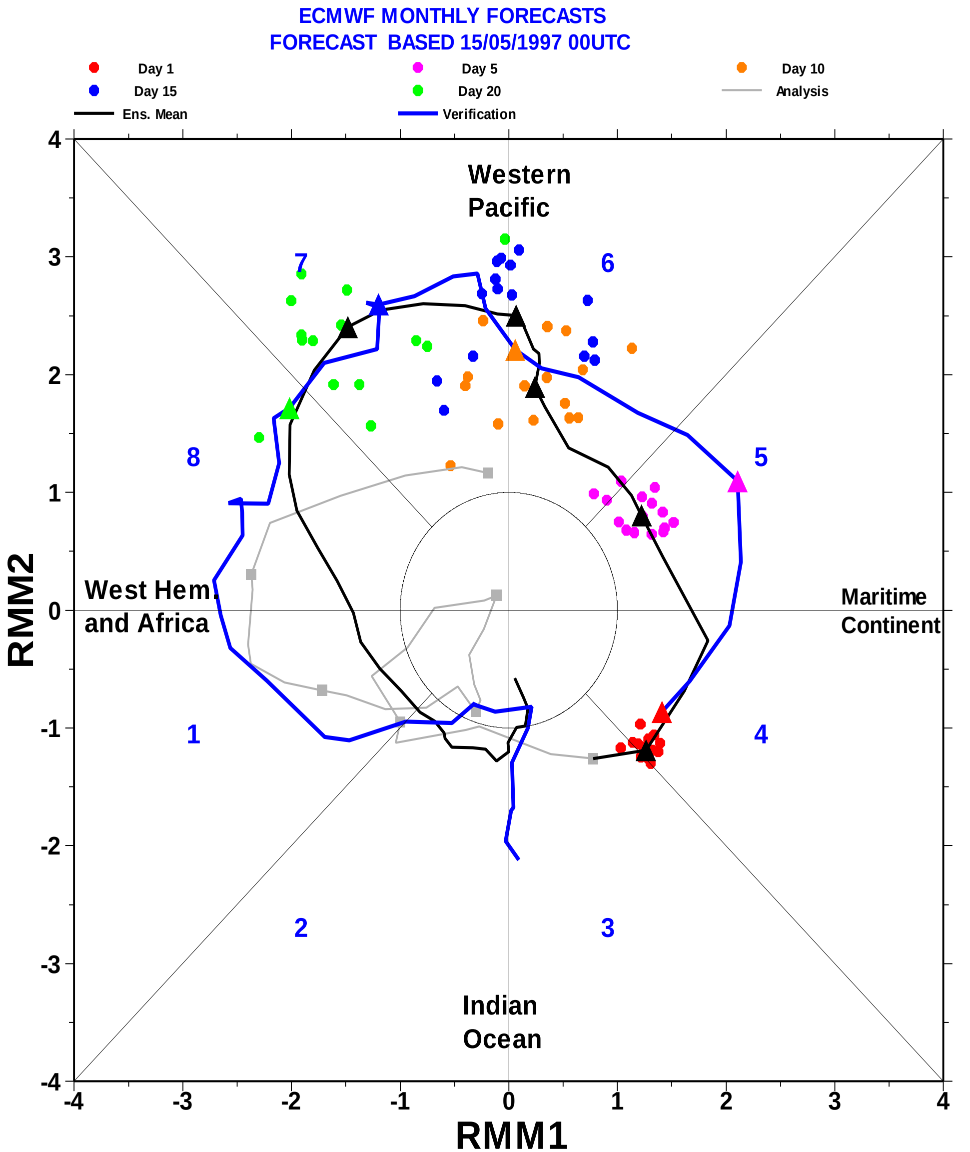

## Combined EOF2



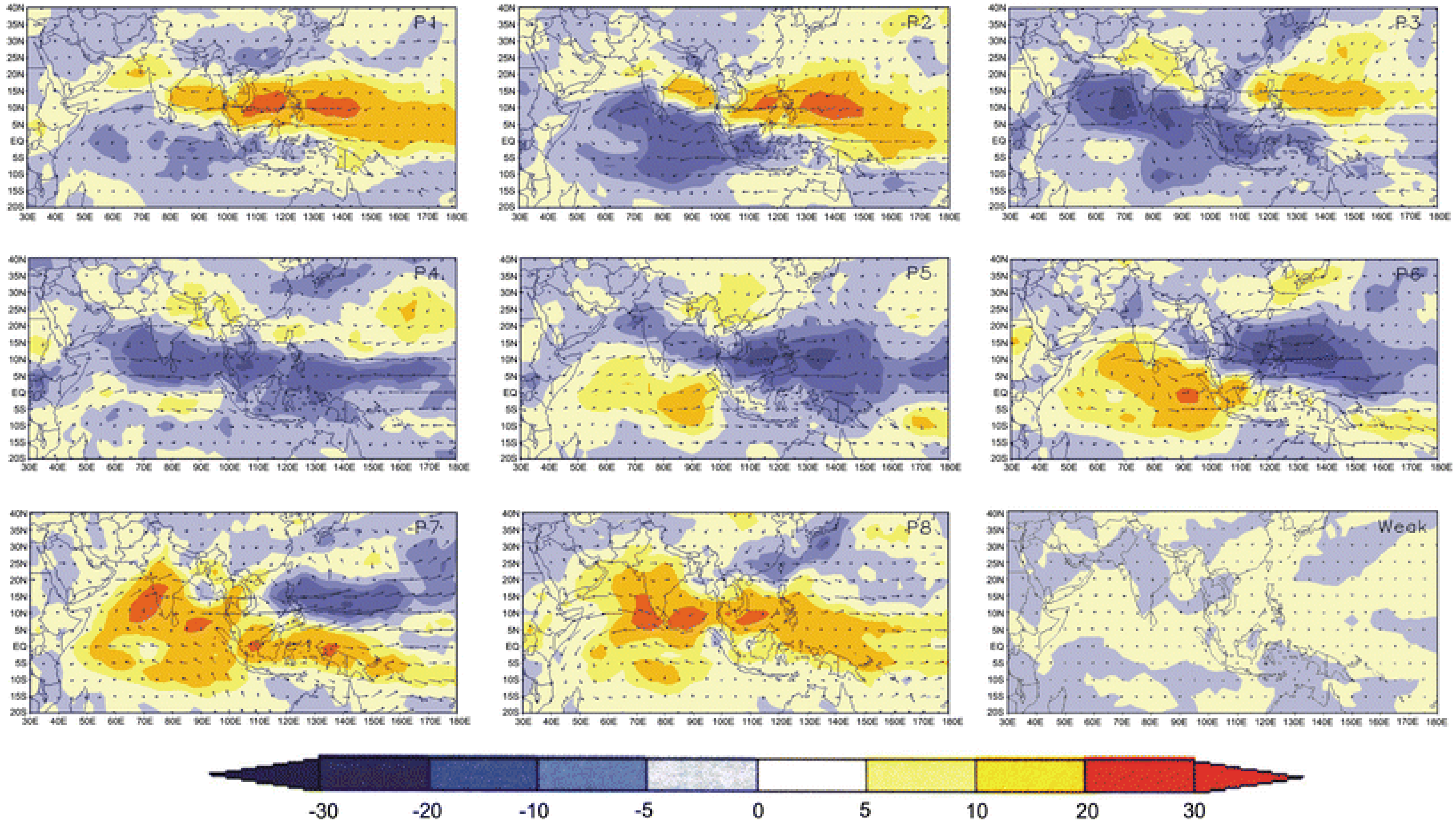

**From Wheeler and Hendon, BMRC**

# MJO FORECAST



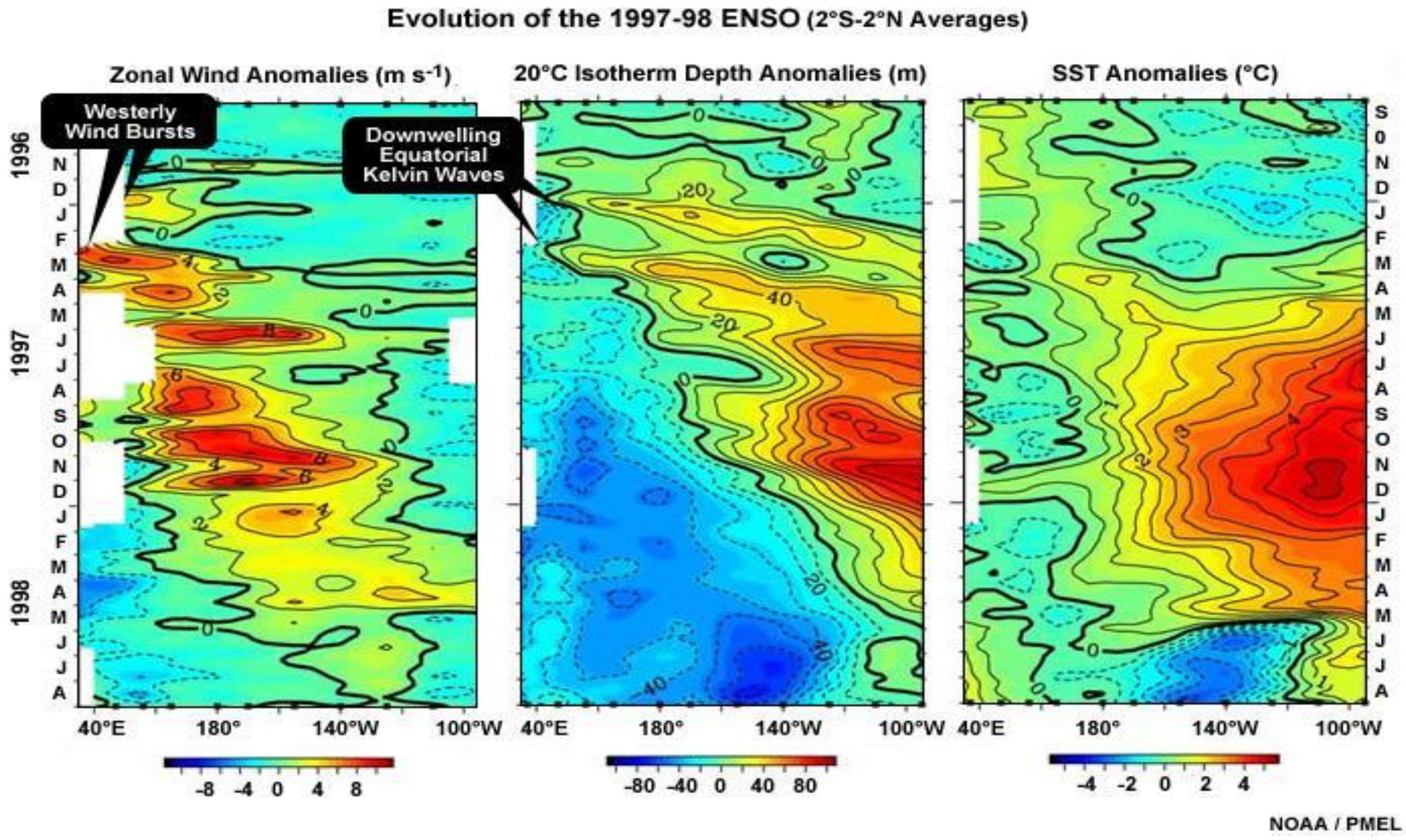
# Impact of MJO on Indian Monsoon

Composite daily OLR and 850hPa wind vector anomalies for various MJO phases : 1974 - 2008

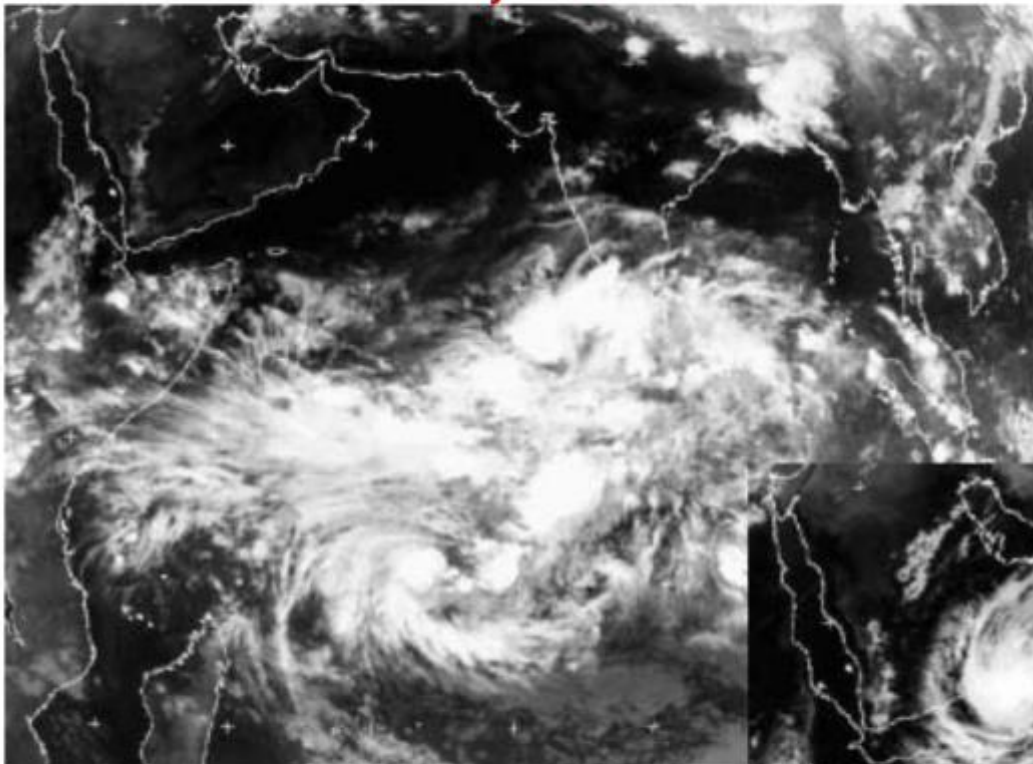



Pai et al, 2009

# Impact of MJO on ENSO

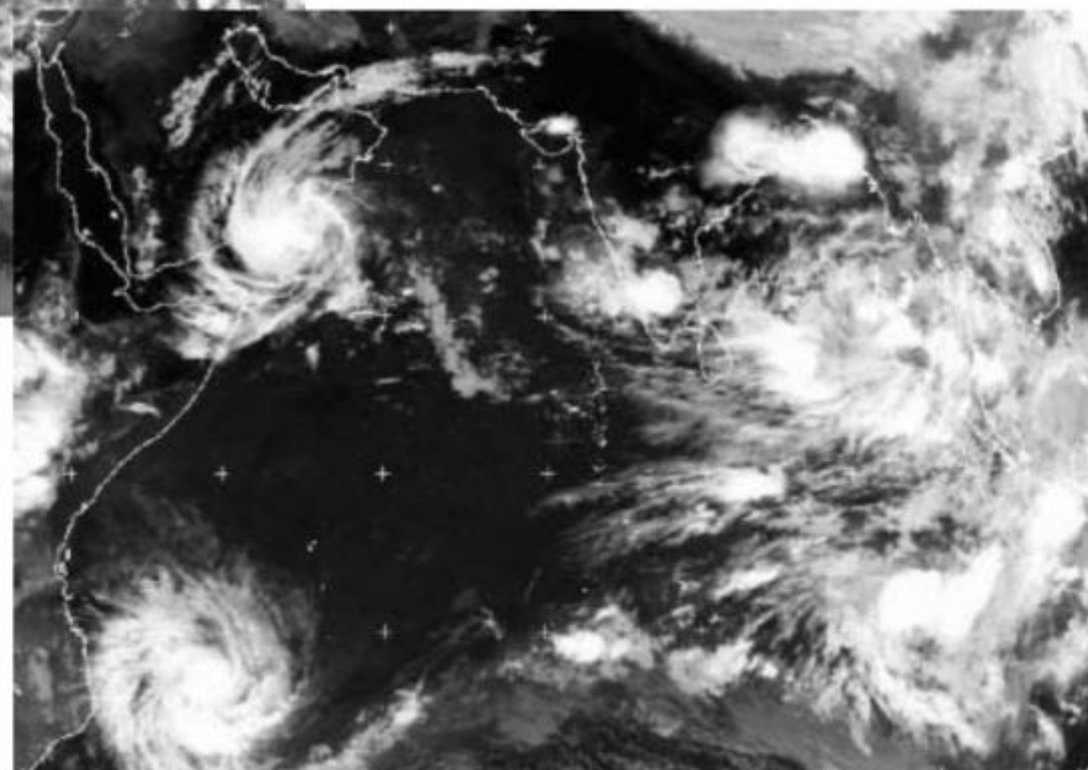


2 May 2002



## Madden Julian Oscillation

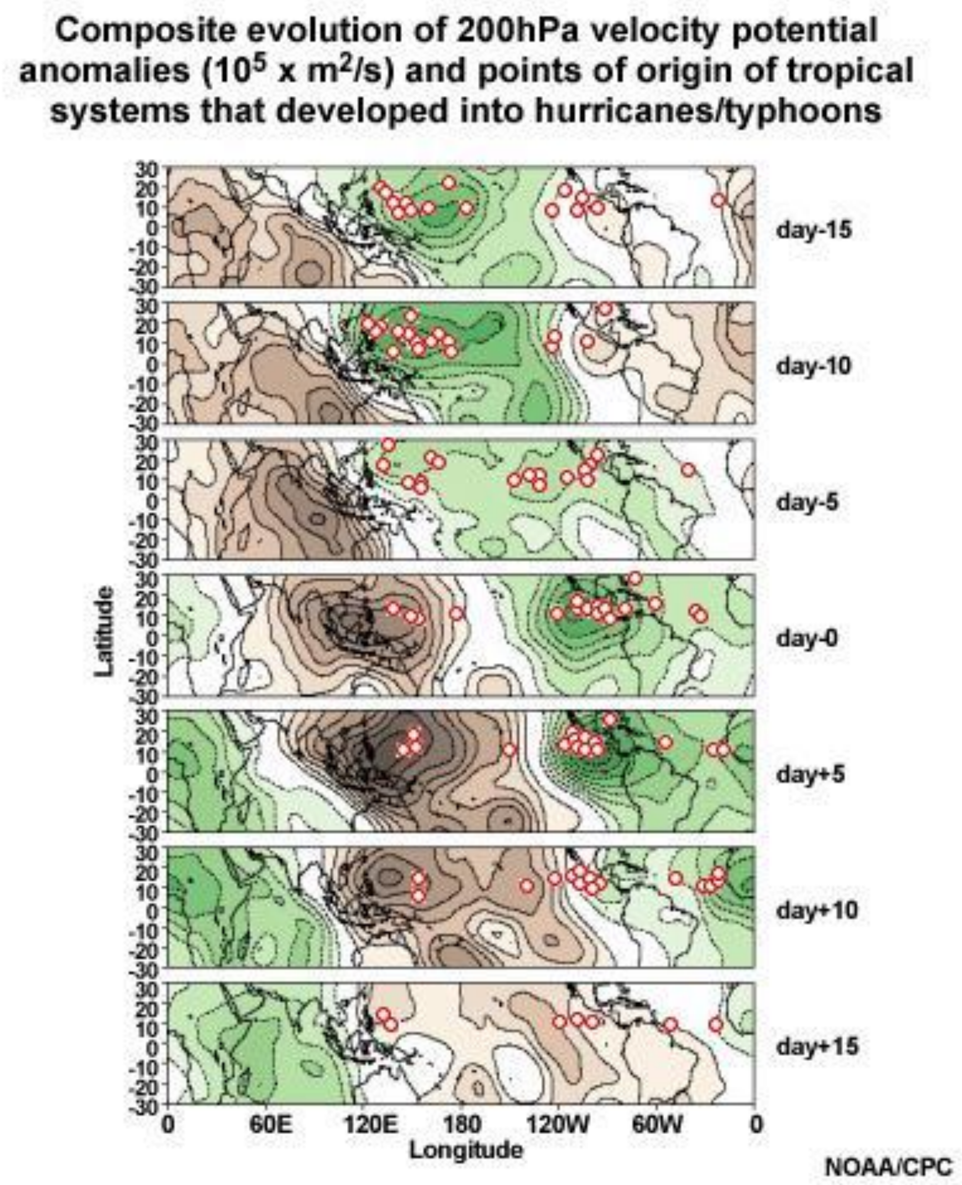
Upper panel shows active MJO over Indian Ocean. A week later (right panel) the convection has moved east, spawning two westward moving cyclones.



9 May 2002

From Slingo et al., 2003

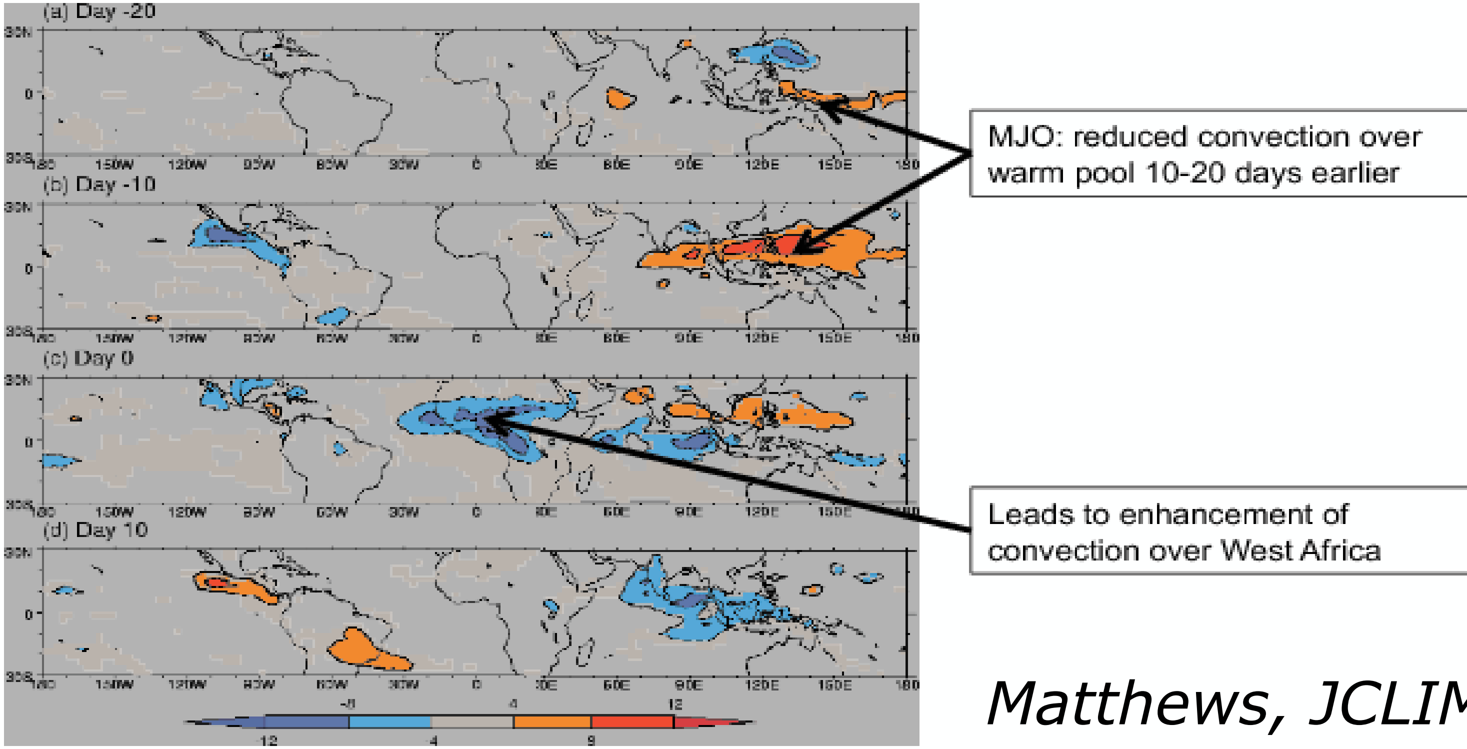
# Impact of MJO on tropical cyclones



# Impact of MJO on African Summer precipitation

## Response of the West African monsoon to the MJO

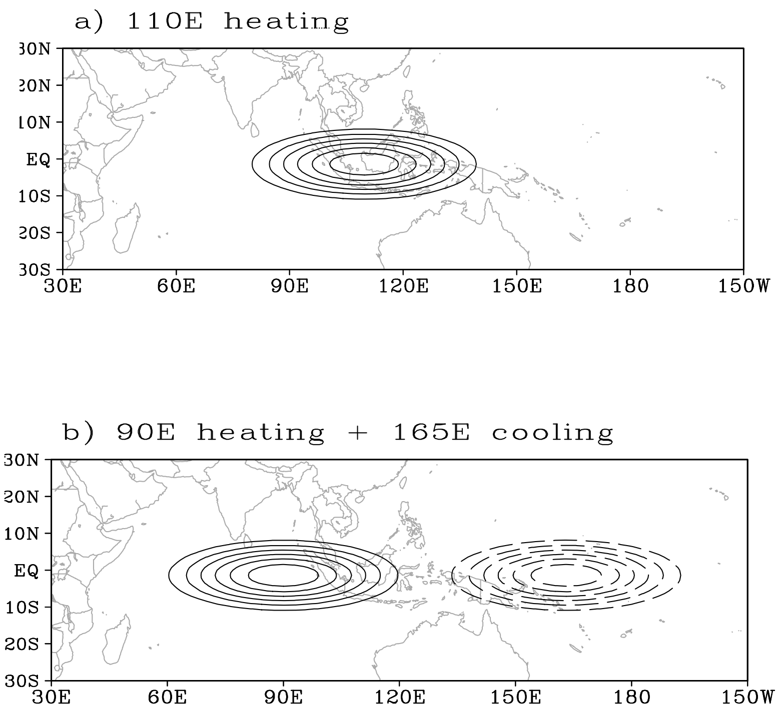
### Observed OLR: JJAS

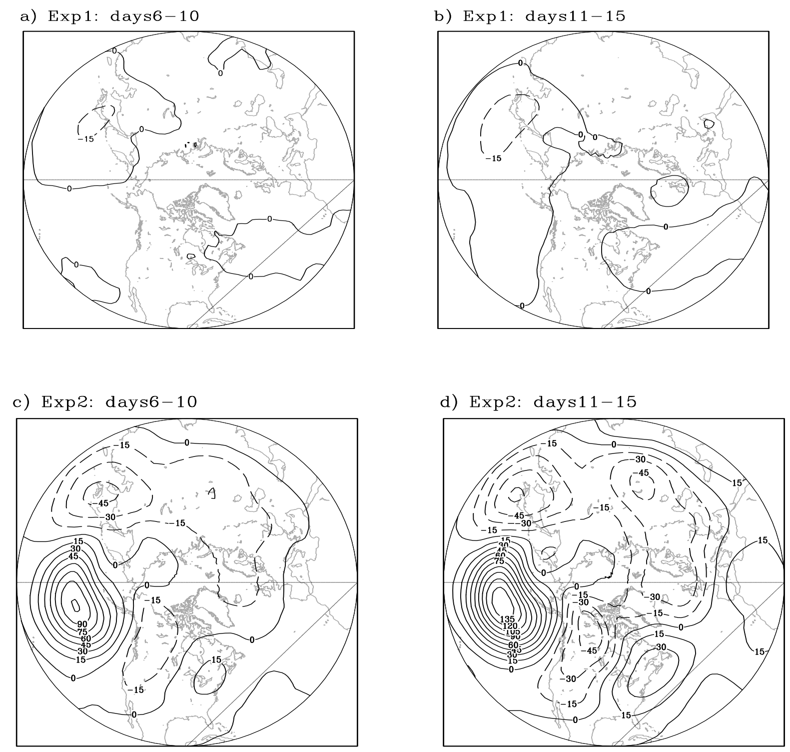



*Matthews, JCLIM 2004*

Matthews AJ, 2004: Intraseasonal variability over tropical Africa during northern summer. *J. Climate*, **17**, 2427-2440

# Impact of the MJO on Extratropics



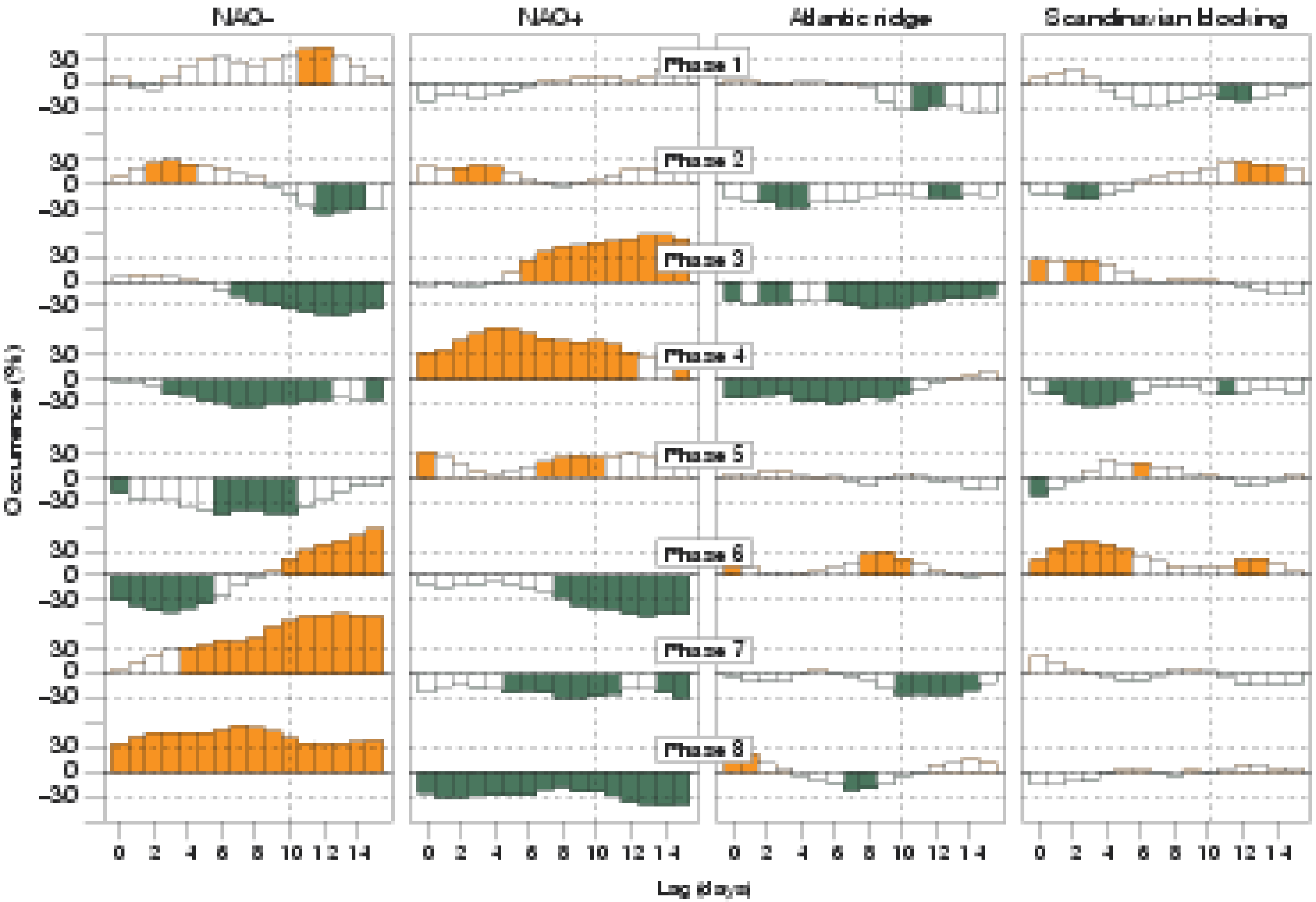

*Lin et al, MWR 2010*

See also

*Simmons et al JAS 1983*

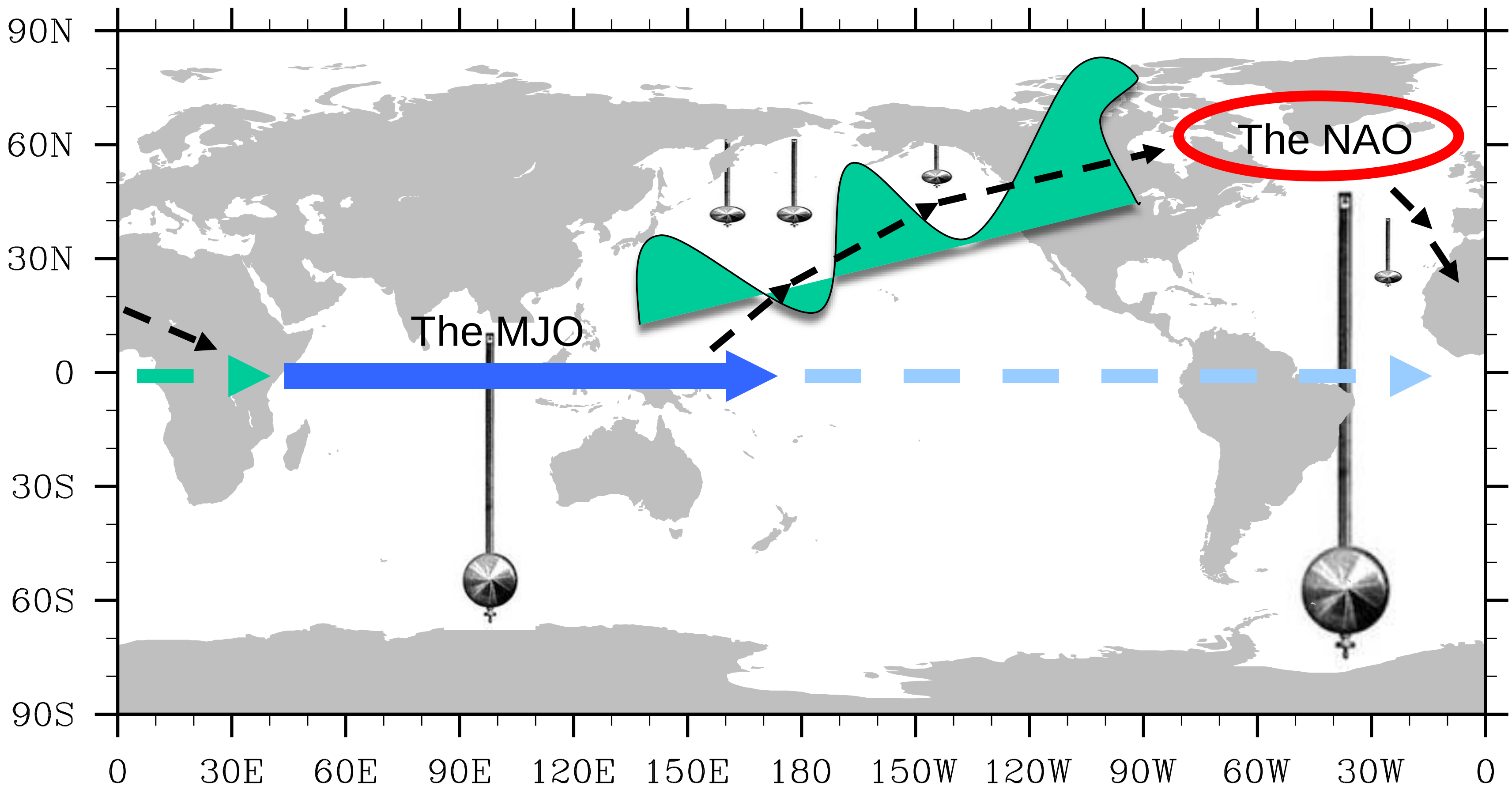
*Ting and Sardeshmukh JAS 1993*

# Impact over Europe




**Cassou (2008)**

The multi-scale organisation of tropical convection and its two-way interaction with the global circulation.

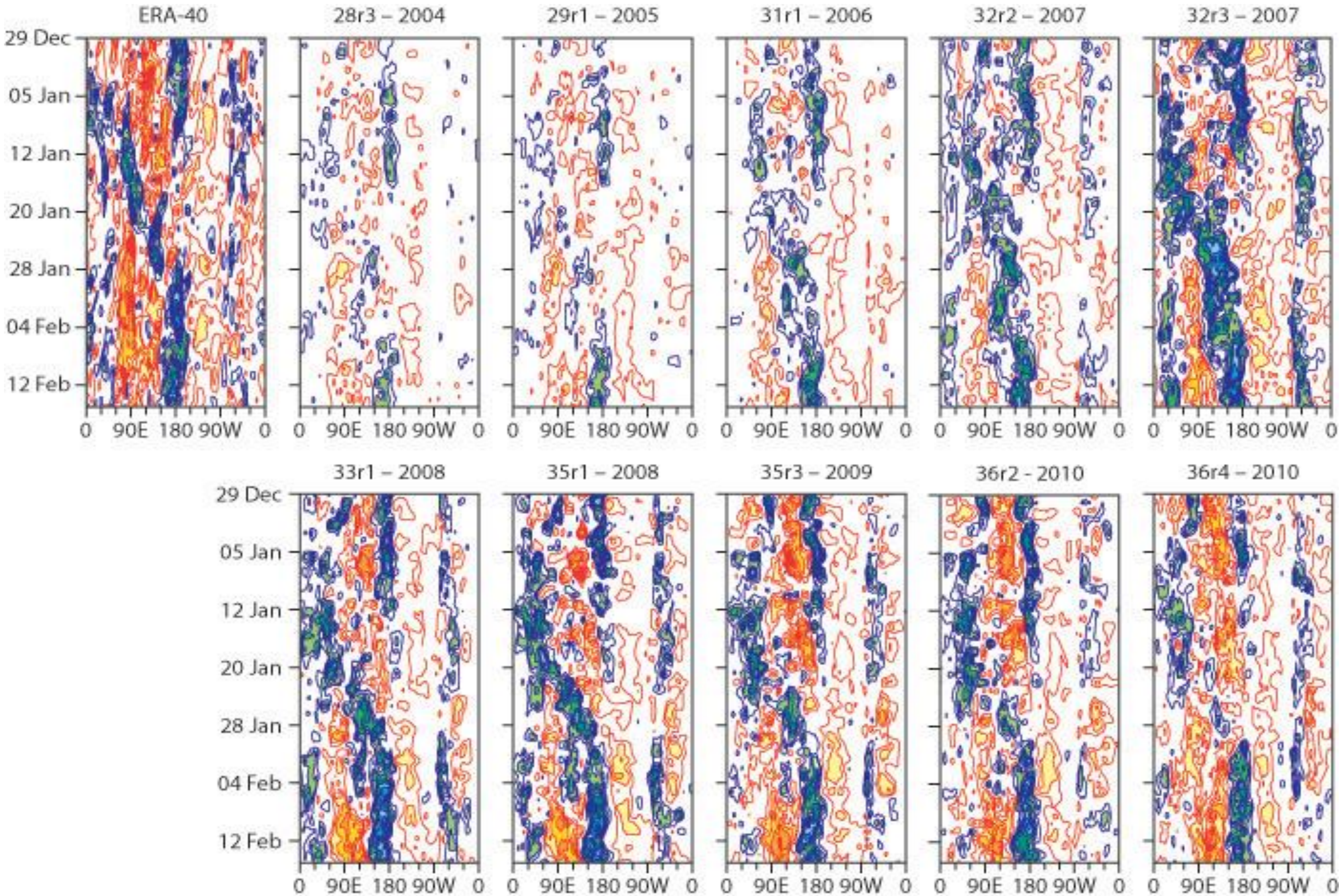



large scale oscillations interact?

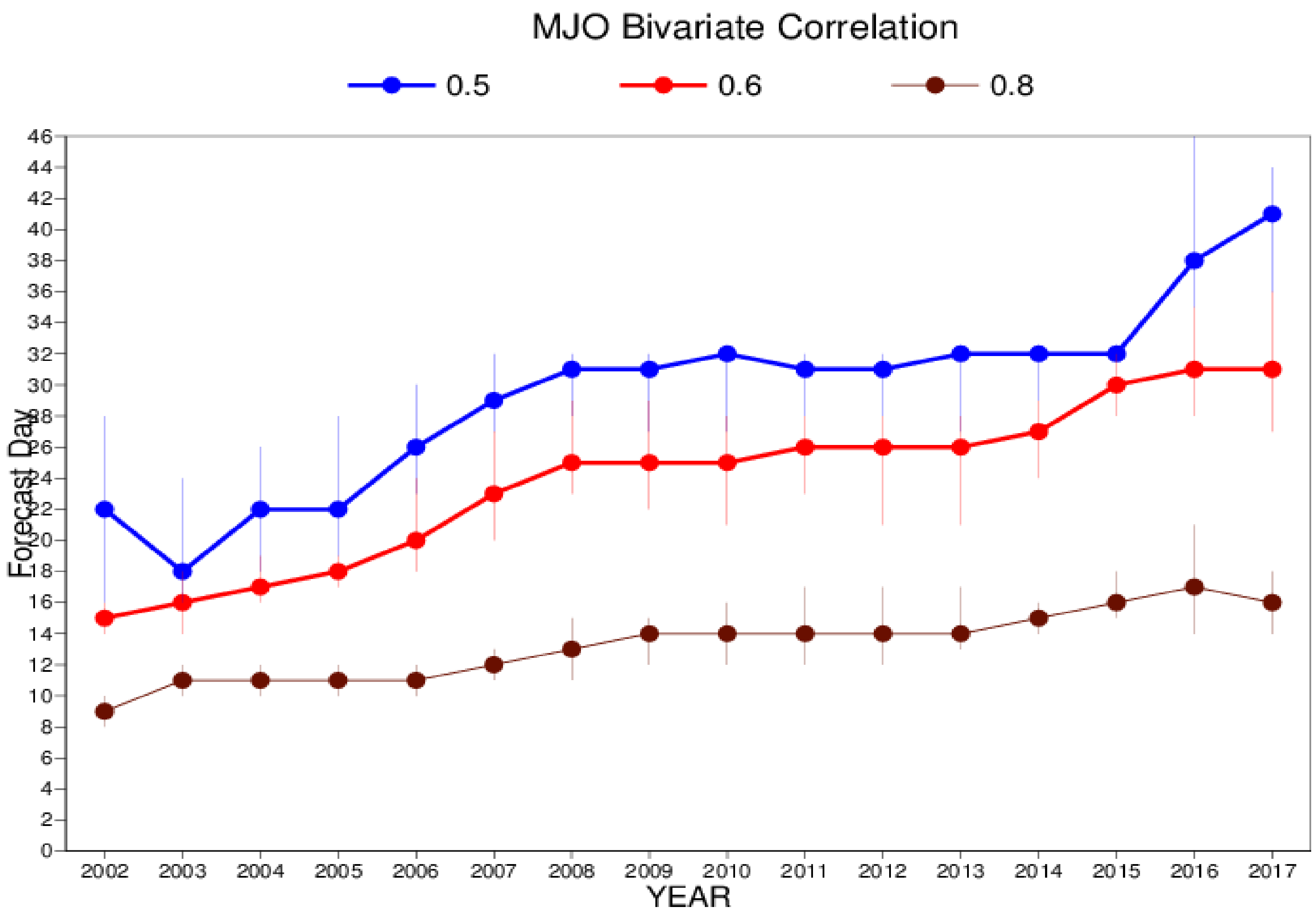
From Brunet, 2015

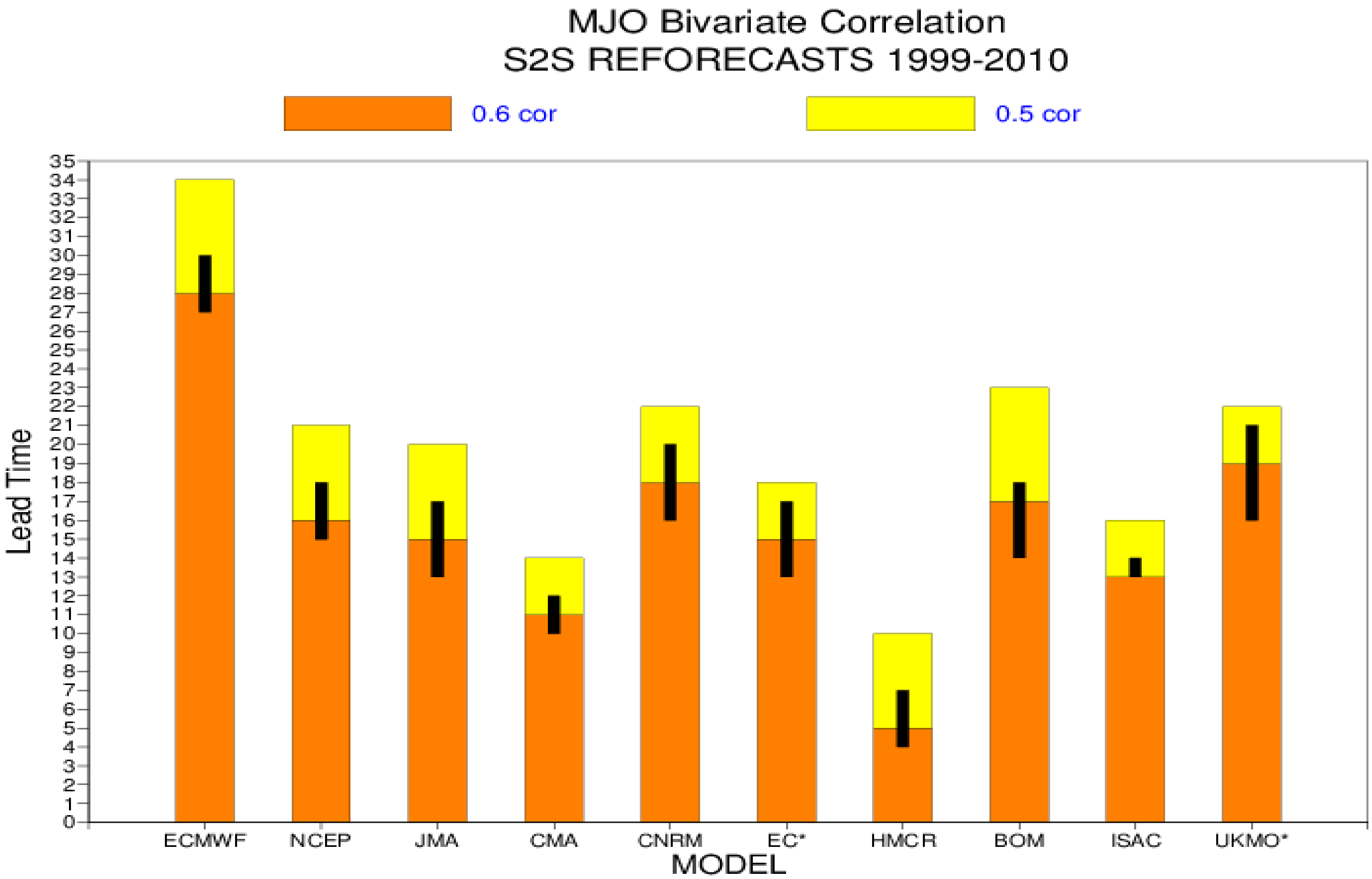
# MJO Prediction

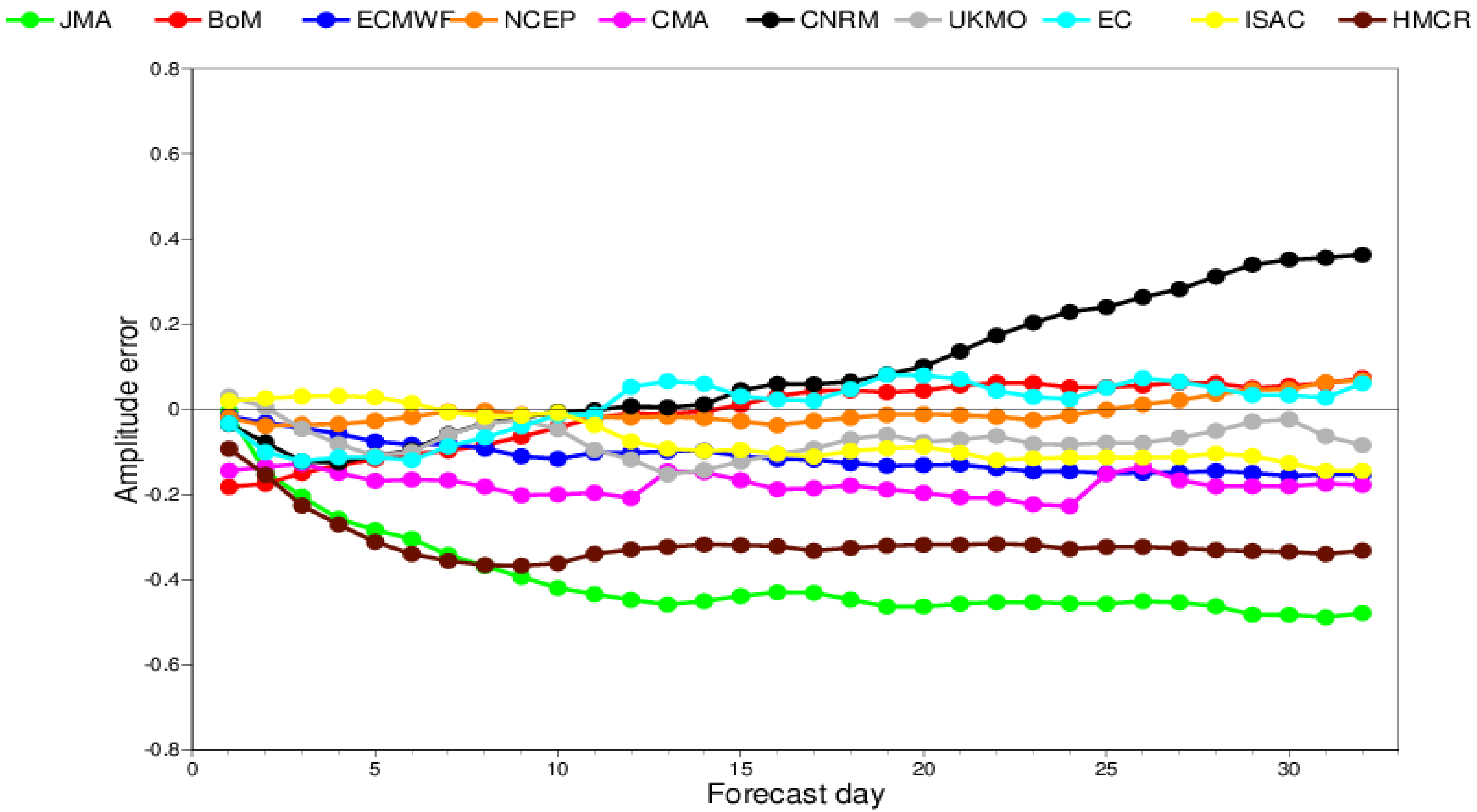
# OLR anomalies - Forecast range: day 15



# *MJO skill scores*

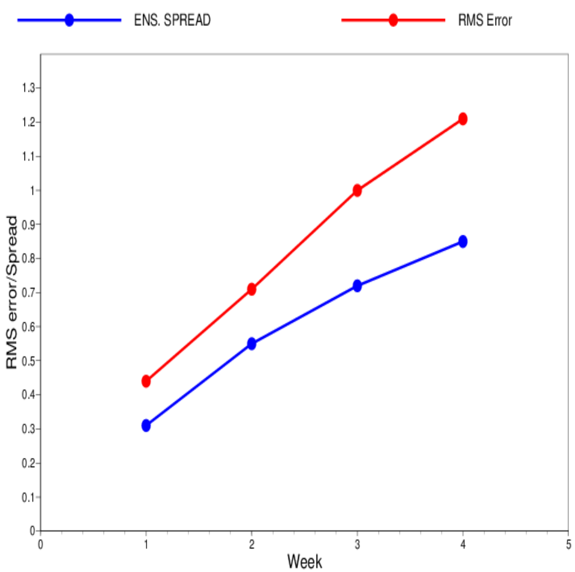



MJO Bivariate Correlation
S2S REFORECASTS 1999-2010
0.6 cor
0.5 cor
Lead Time
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
ECMWF
NCEP
JMA
CMA
CNRM
EC*
HMCR
BOM
ISAC
UKMO*
MODEL

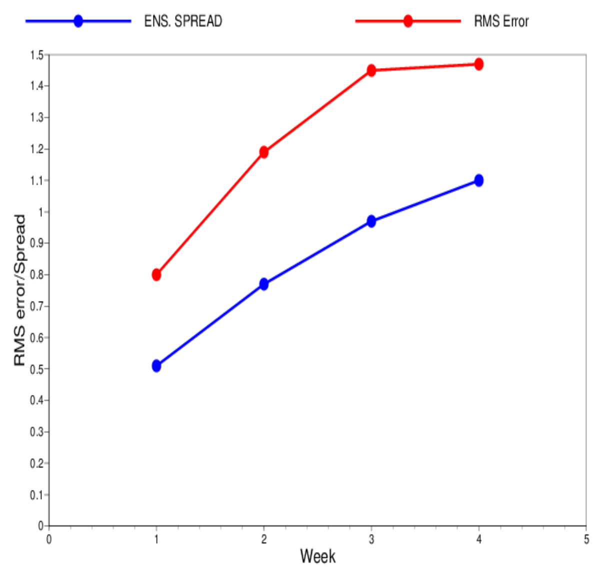

JMA
BoM
ECMWF
NCEP
CMA
CNRM
UKMO
EC
ISAC
HMCR
Amplitude error
Forecast day
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
0
5
10
15
20
25
30

# Spread/Skill relationship

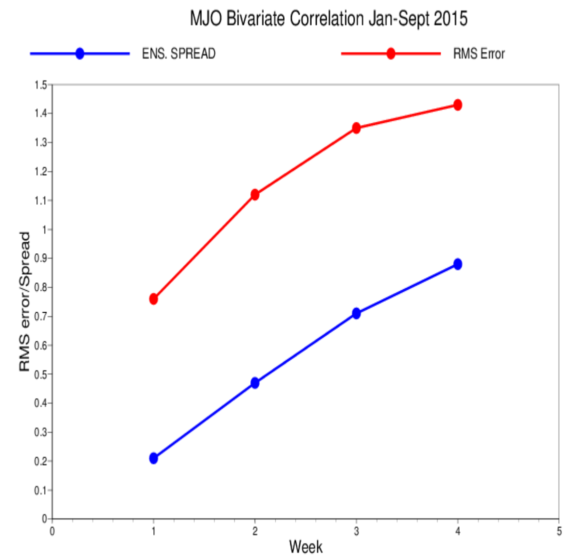
## ECMWF




## BoM



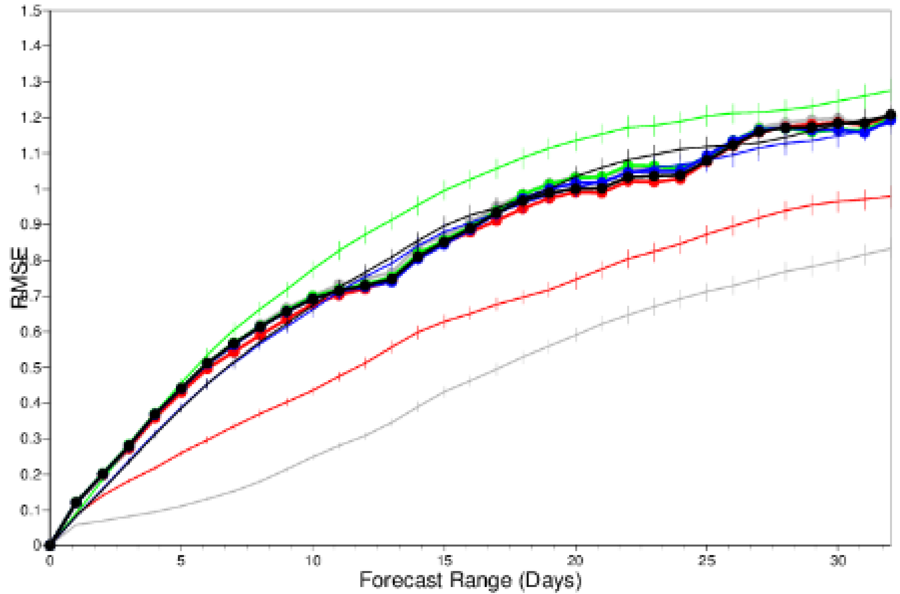

## NCEP




IP only

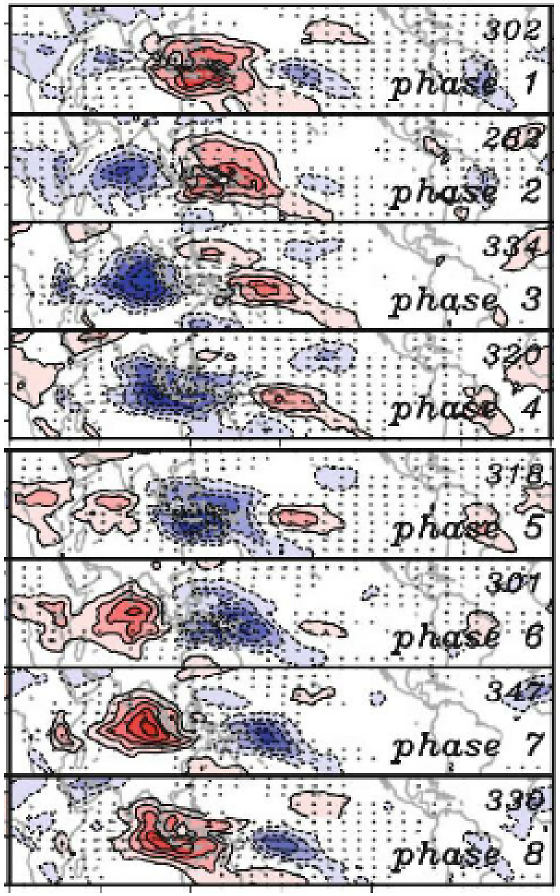
42R1

45r1

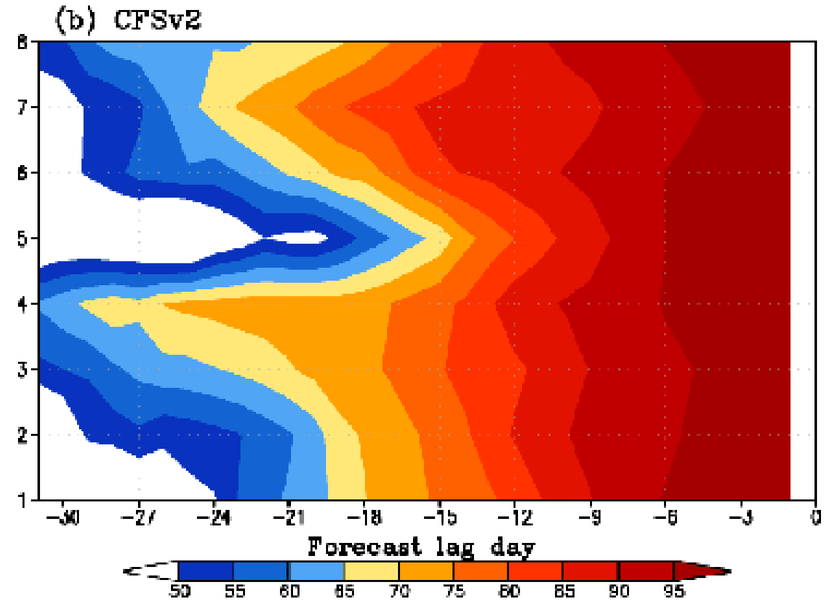


# MJO Maritime Continent Prediction barrier

MJO composite




MJO Prediction skill by target MJO phase



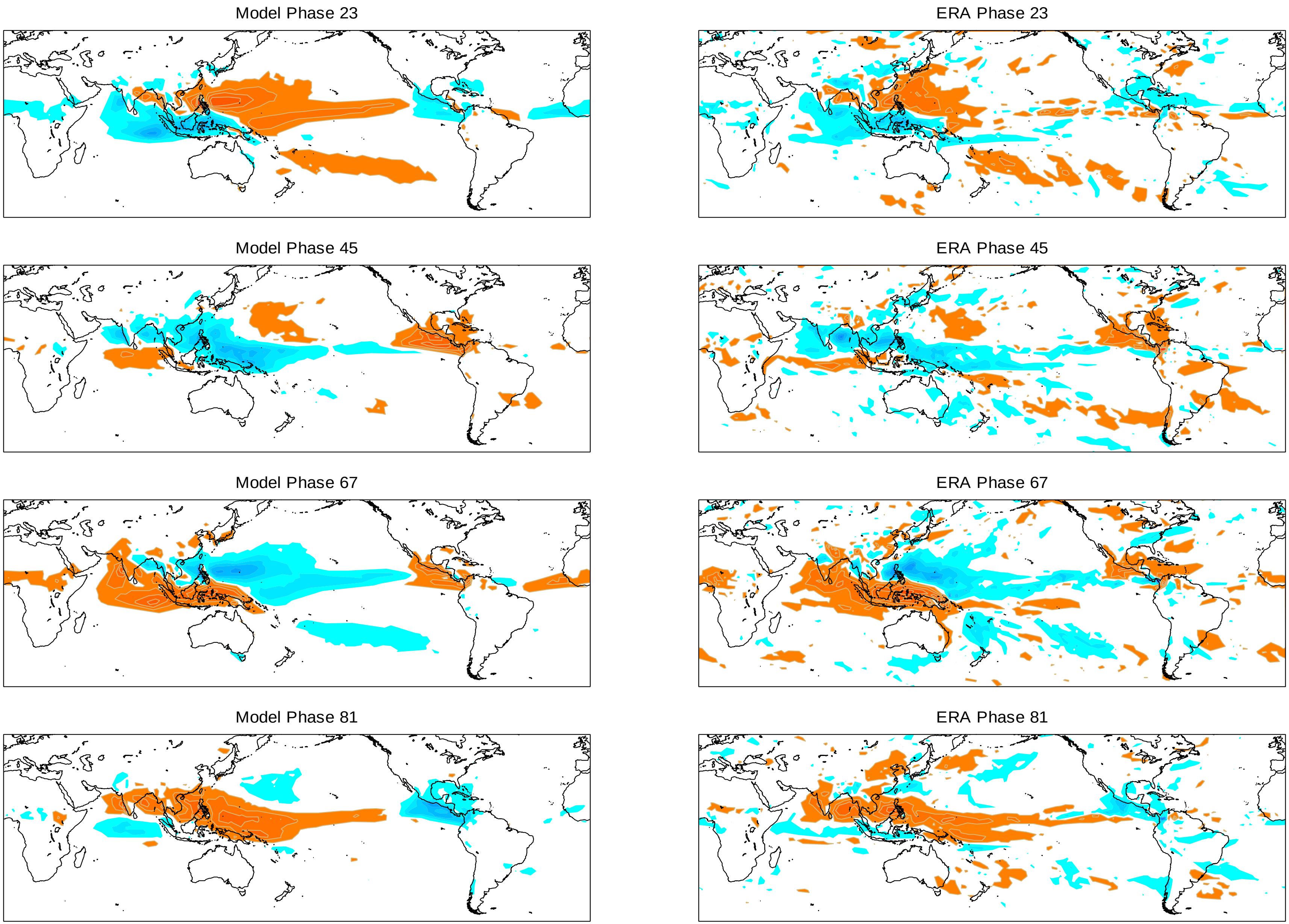

- CFSv2 shows sharp decrease in skill at phase 1 and 5

→ deficiency in predicting the enhanced (or suppressed) convective signal associated with the MJO over the Maritime Continent.

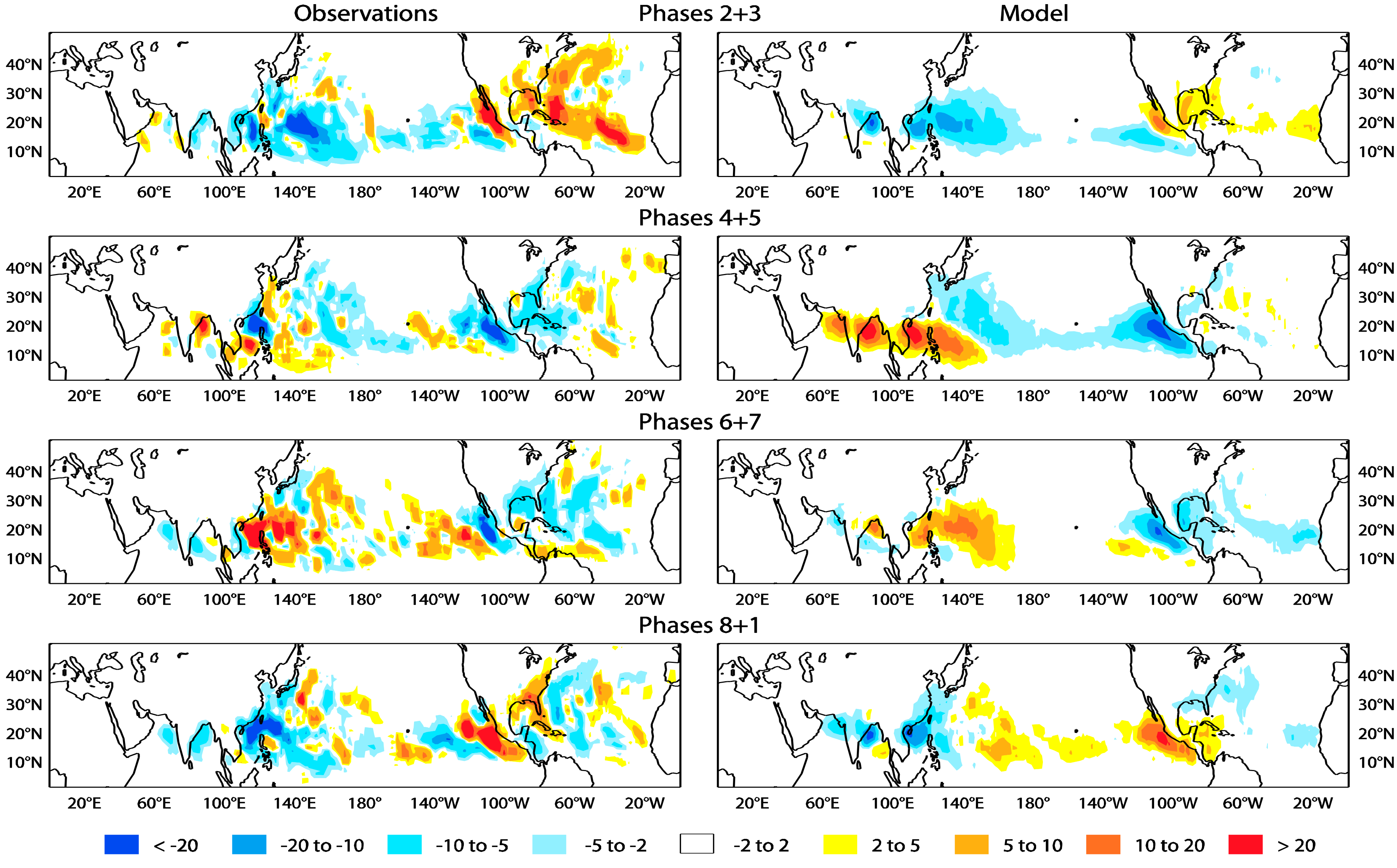
Kim et al. (2014)

# *Impact of the MJO on precipitation*

## JJA



# *Impact on Tropical Cyclone Density (Summer)*

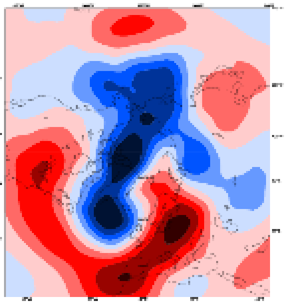



**Vitart, GRL 2009**

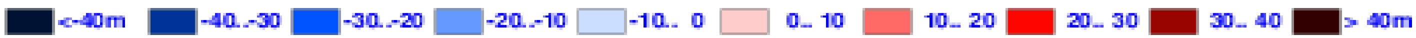
# Impact of the MJO on the N. Extratropics

## 3 pentads after MJO in phase 3

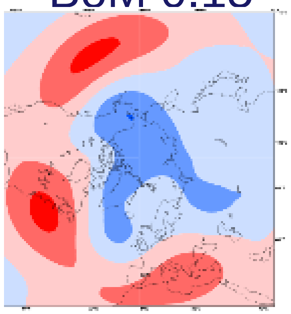
EI 0.48



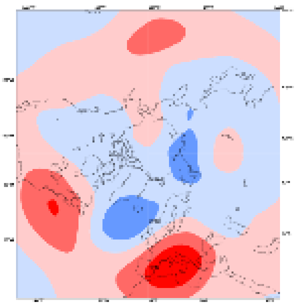
NAO Index: mean=0,
std=1.02



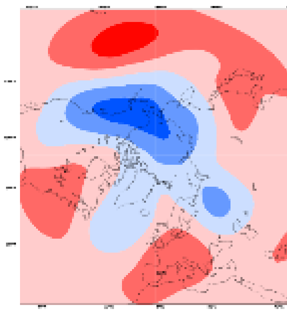

BoM 0.15



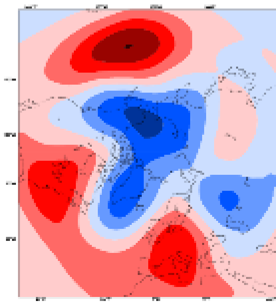
CMA 0.14



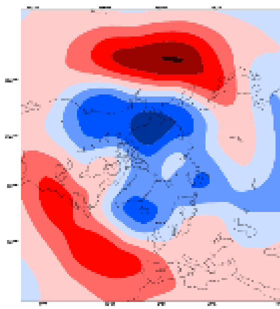
HMCR 0.13



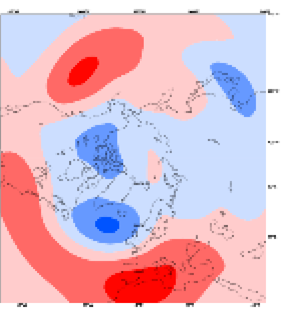
NCEP 0.32



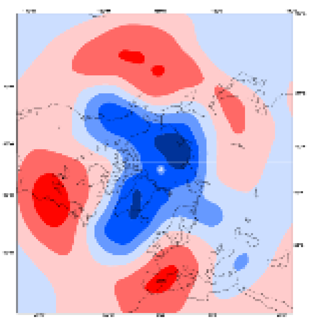
ISAC 0.25



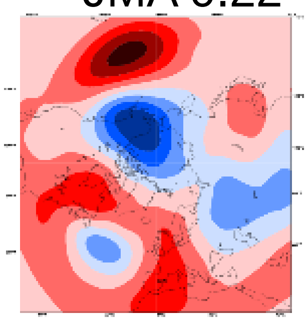
CNRM 0.15



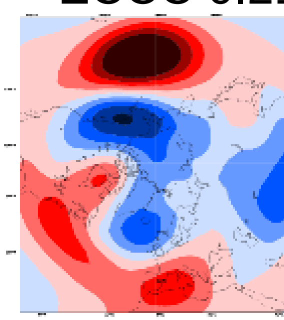
UKMO 0.28



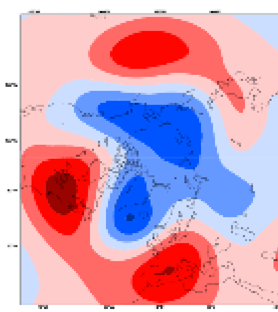
JMA 0.22



ECCC 0.21

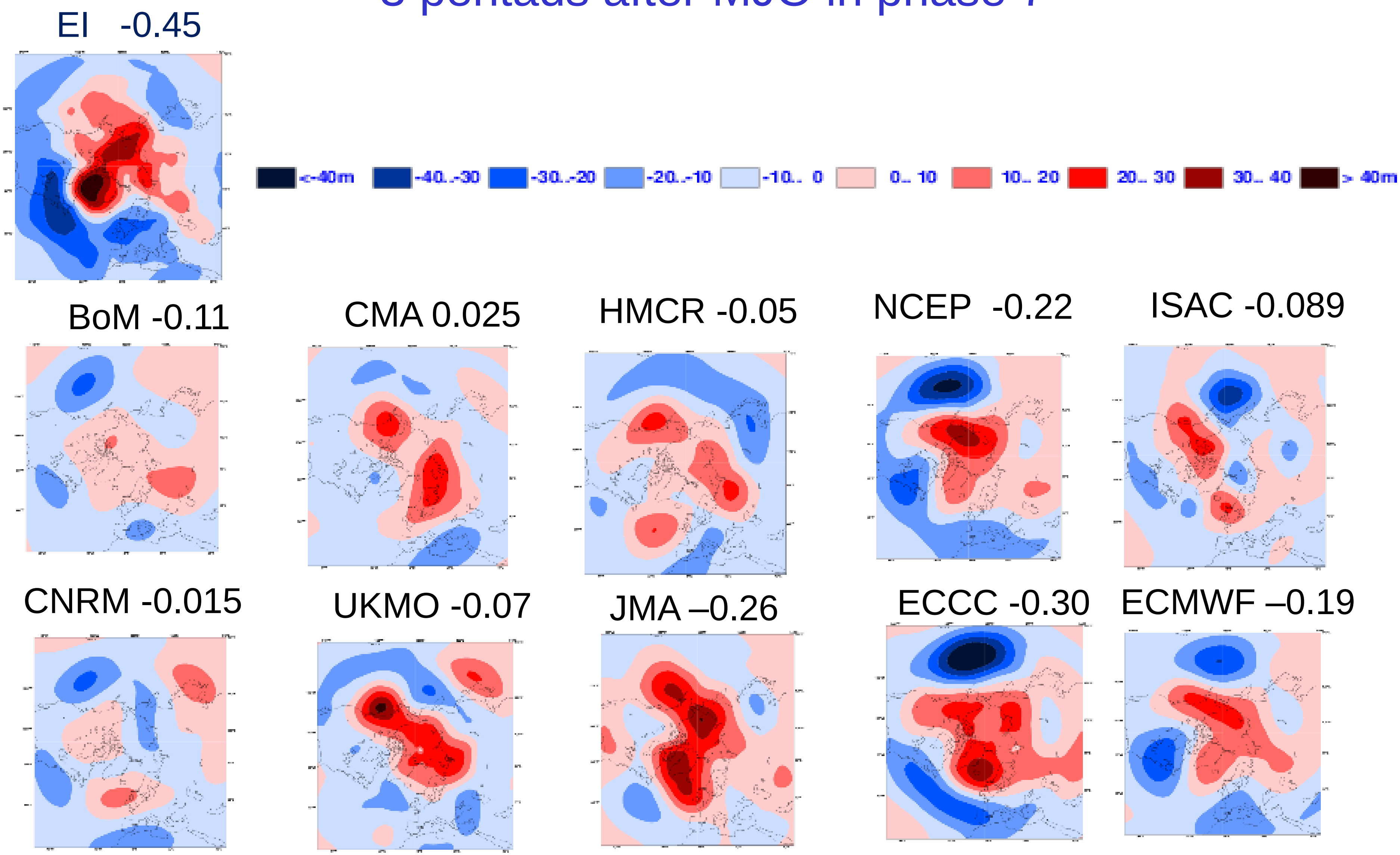


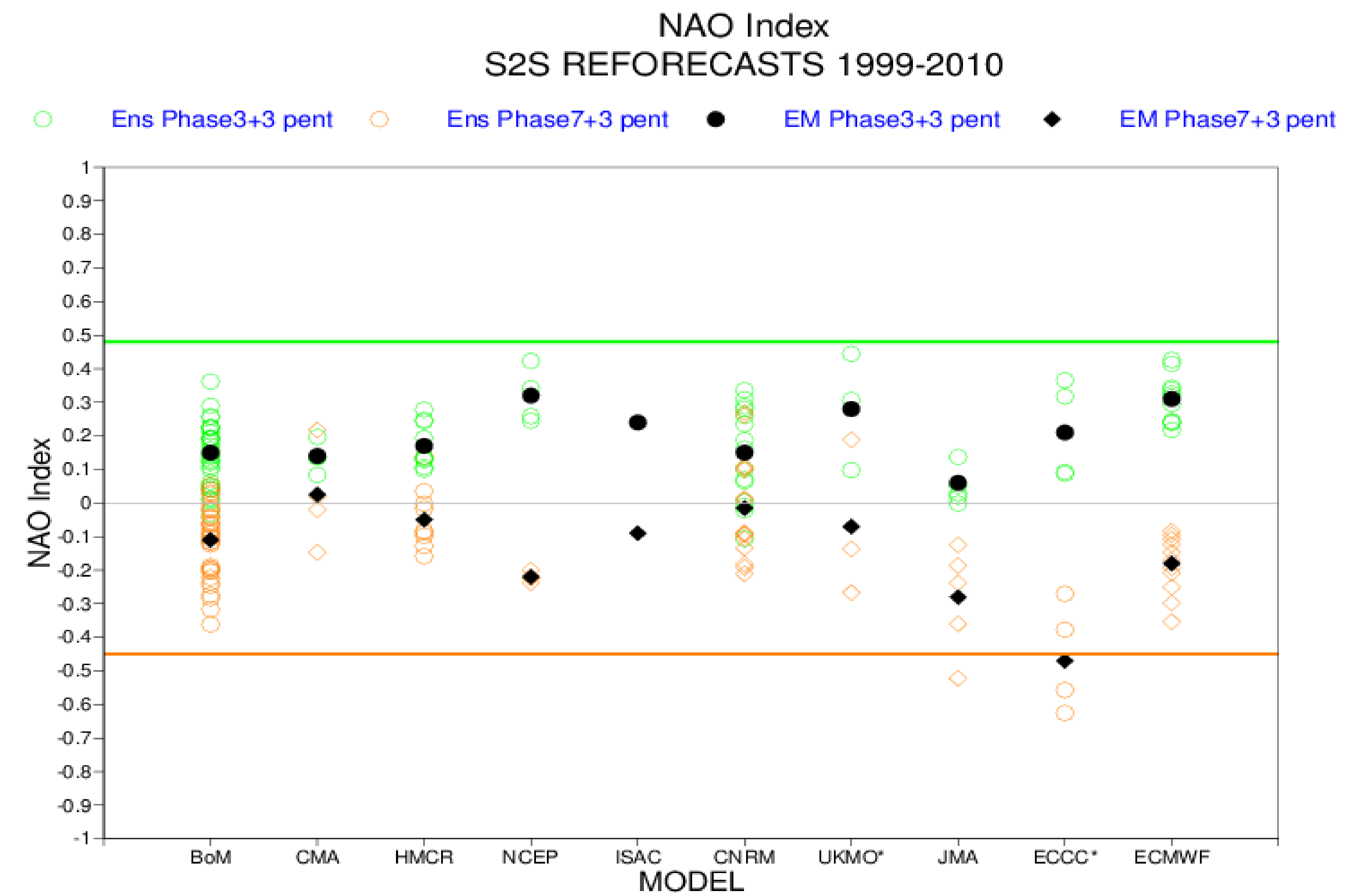
ECMWF 0.31



# Impact of the MJO on the N. Extratropics

## 3 pentads after MJO in phase 7





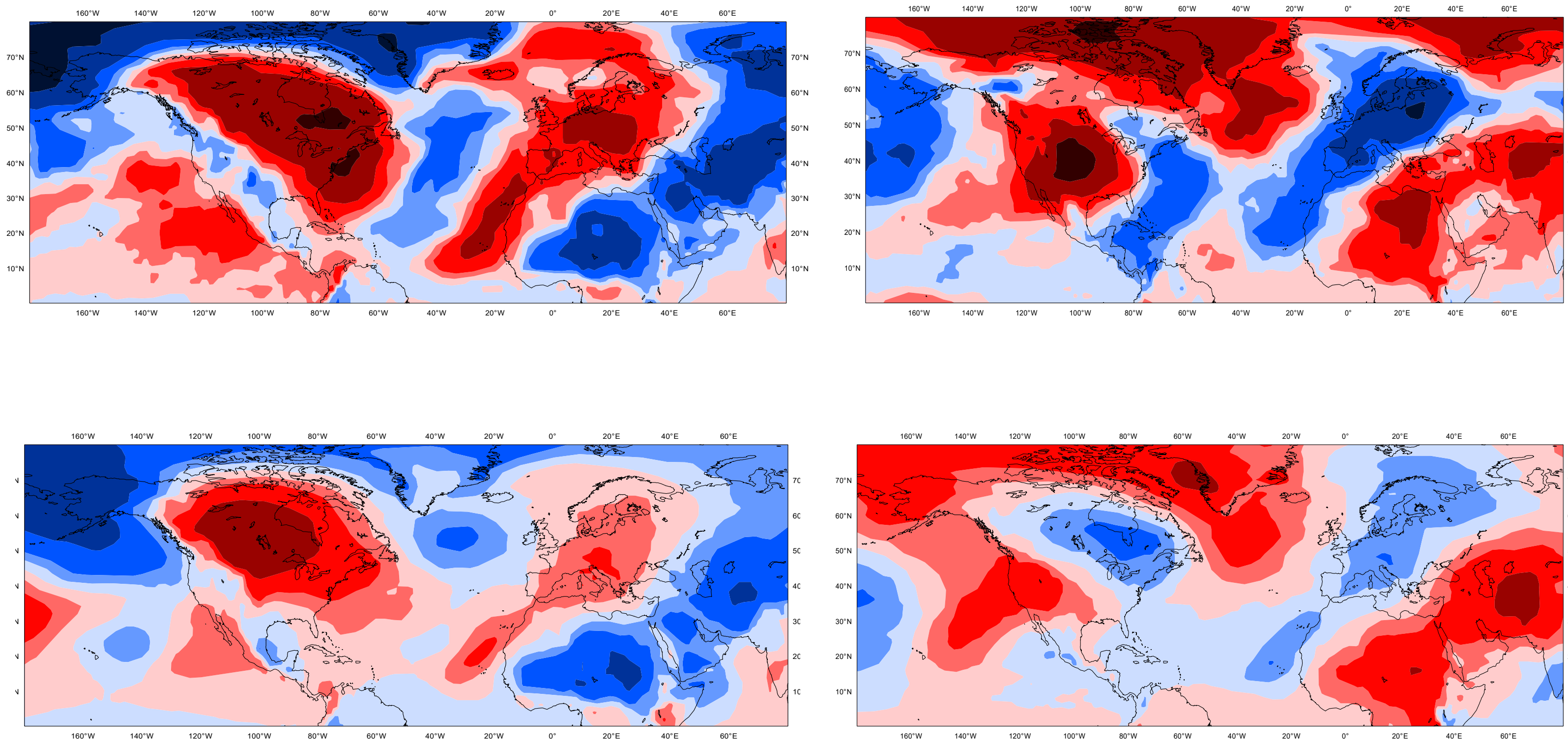
NAO Index
S2S REFORECASTS 1999-2010
Ens Phase3+3 pent
Ens Phase7+3 pent
EM Phase3+3 pent
EM Phase7+3 pent
NAO Index
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
BoM
CMA
HMCR
NCEP
ISAC
CNRM
UKMO*
JMA
ECCC*
ECMWF
MODEL

# T850 anomalies – NDJFM 1989-2008

**Phase 3 + 10 days** | **Phase 6 + 10 days**

**ERA**

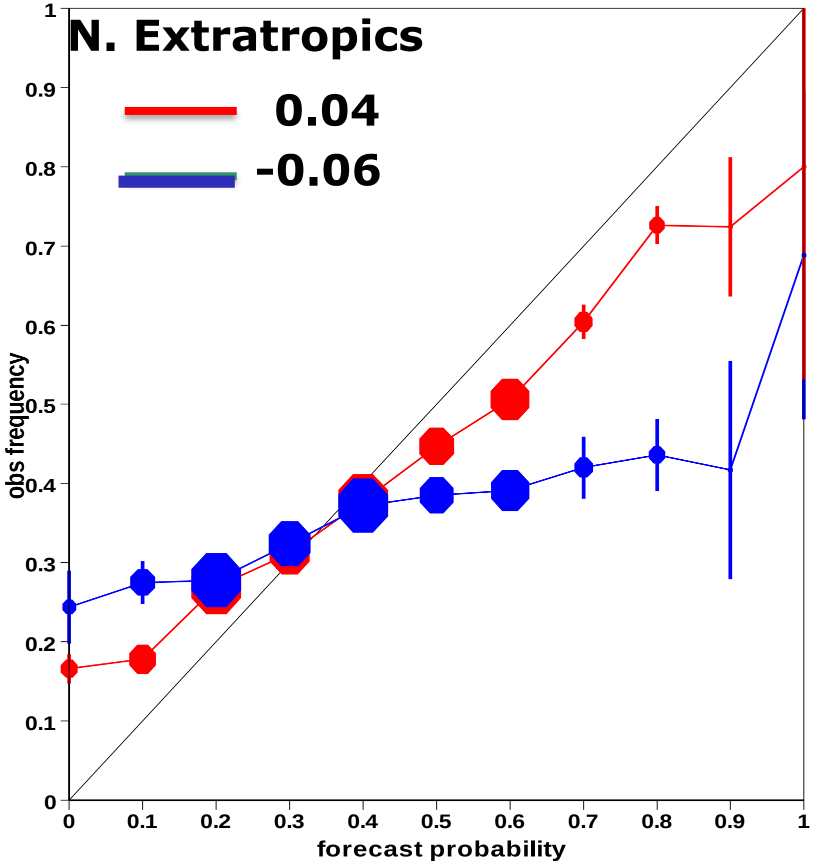
**MODEL**

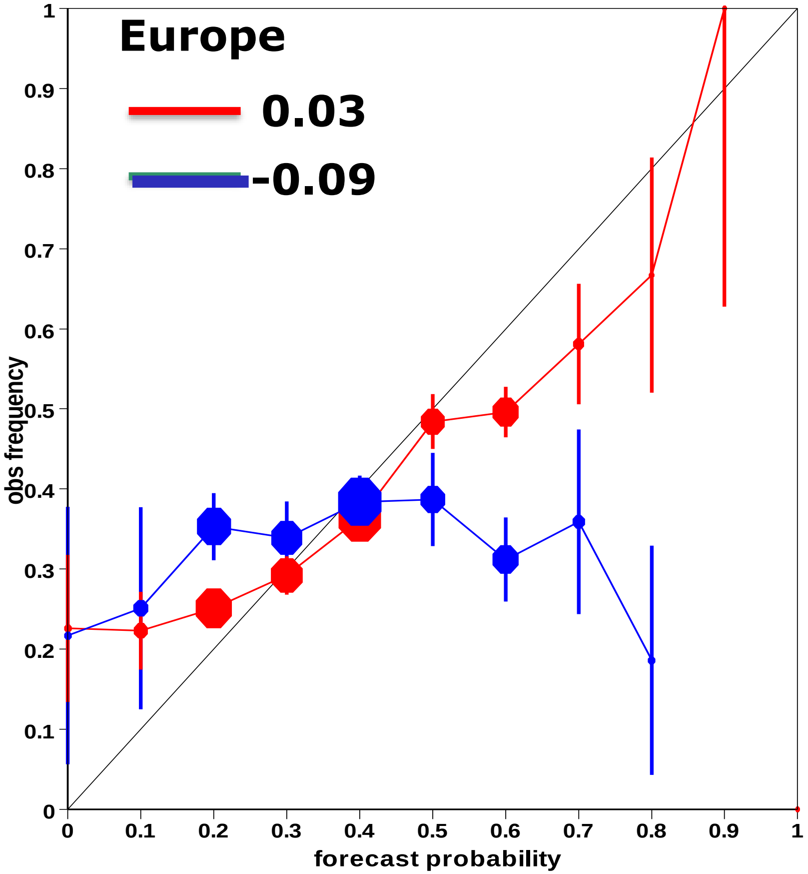


<-1.6 | -1.6..-0.8 | -0.8..-0.4 | -0.4..-0.2 | -0.2.. 0.0 | 0.0.. 0.2 | 0.2.. 0.4 | 0.4.. 0.8 | 0.8.. 1.6 | > 1.6 **Degree C**

# Probabilistic skill scores – NDJFMA 1989-2008

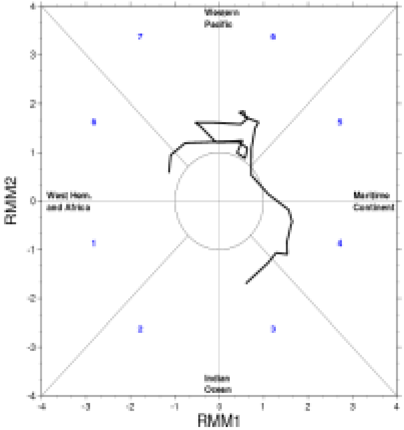
## Reliability Diagram
## Probability of 2-m temperature in the upper tercile
## Day 19-25

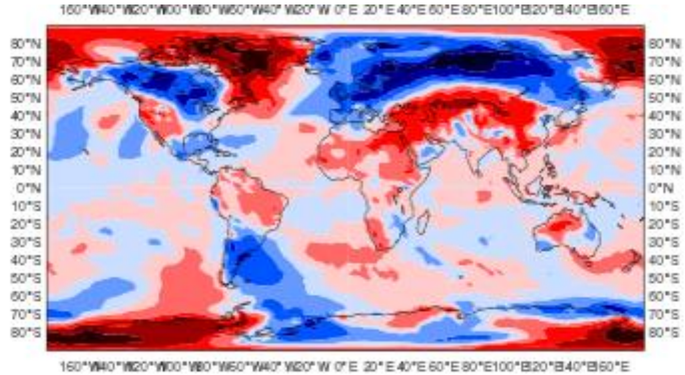


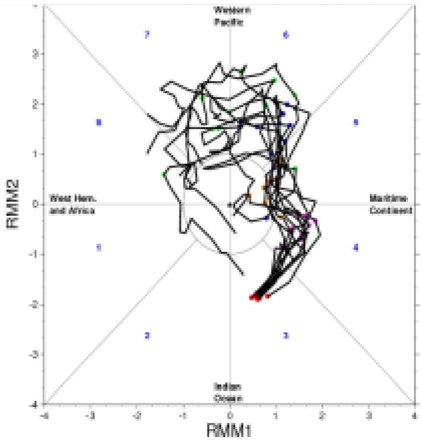



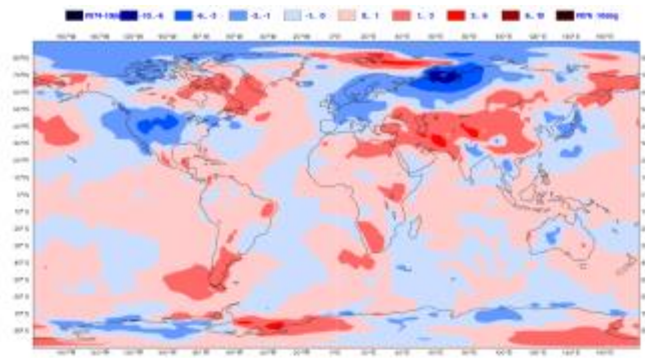

MJO in IC    NO MJO in IC

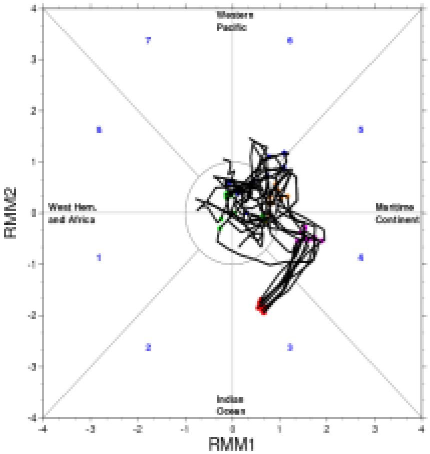
# 14 Feb 2013 -Day 26-32

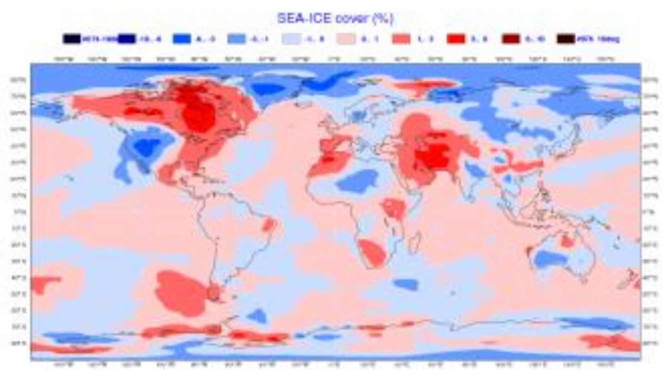






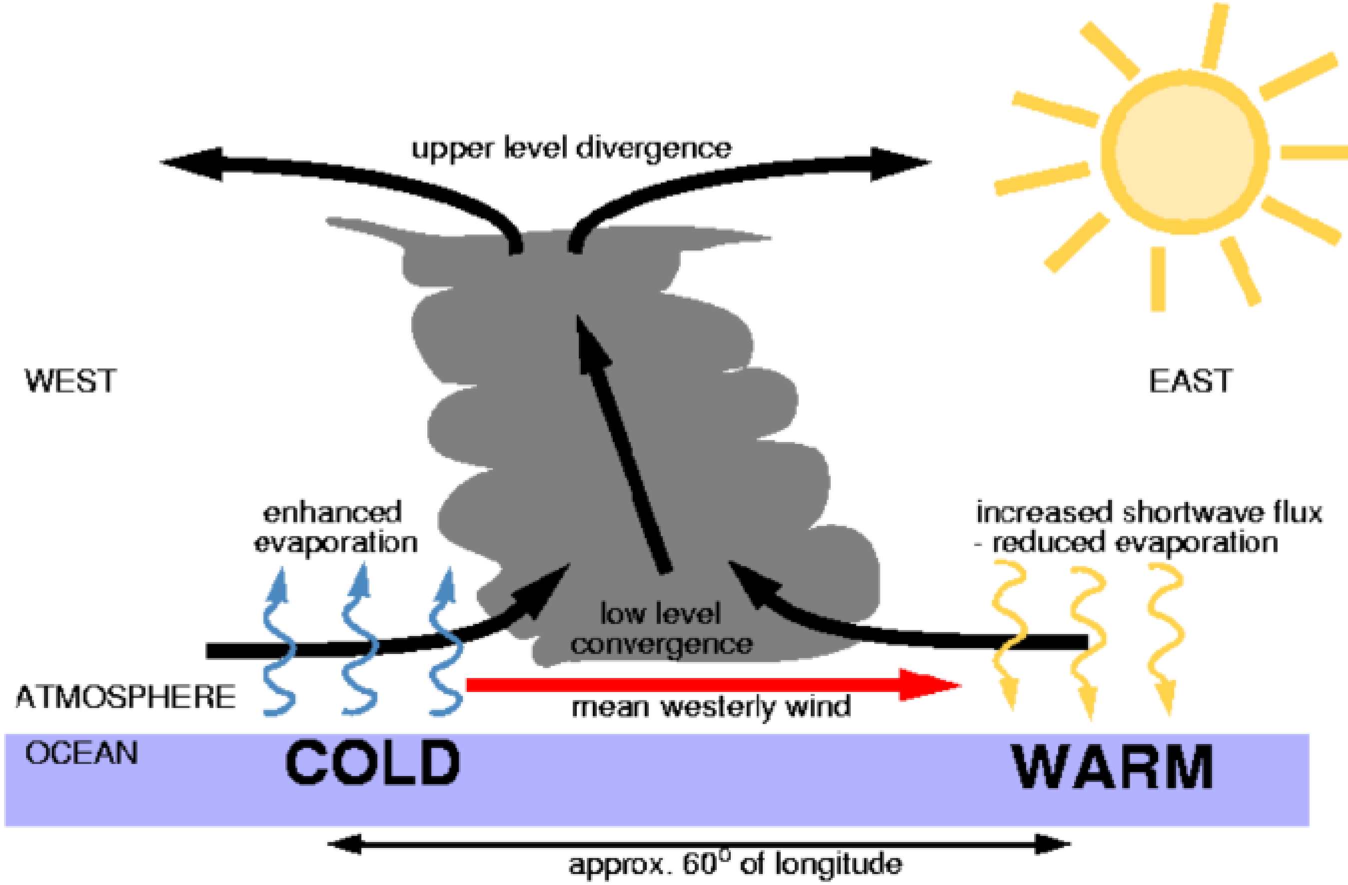



# Simulation of the MJO in climate models

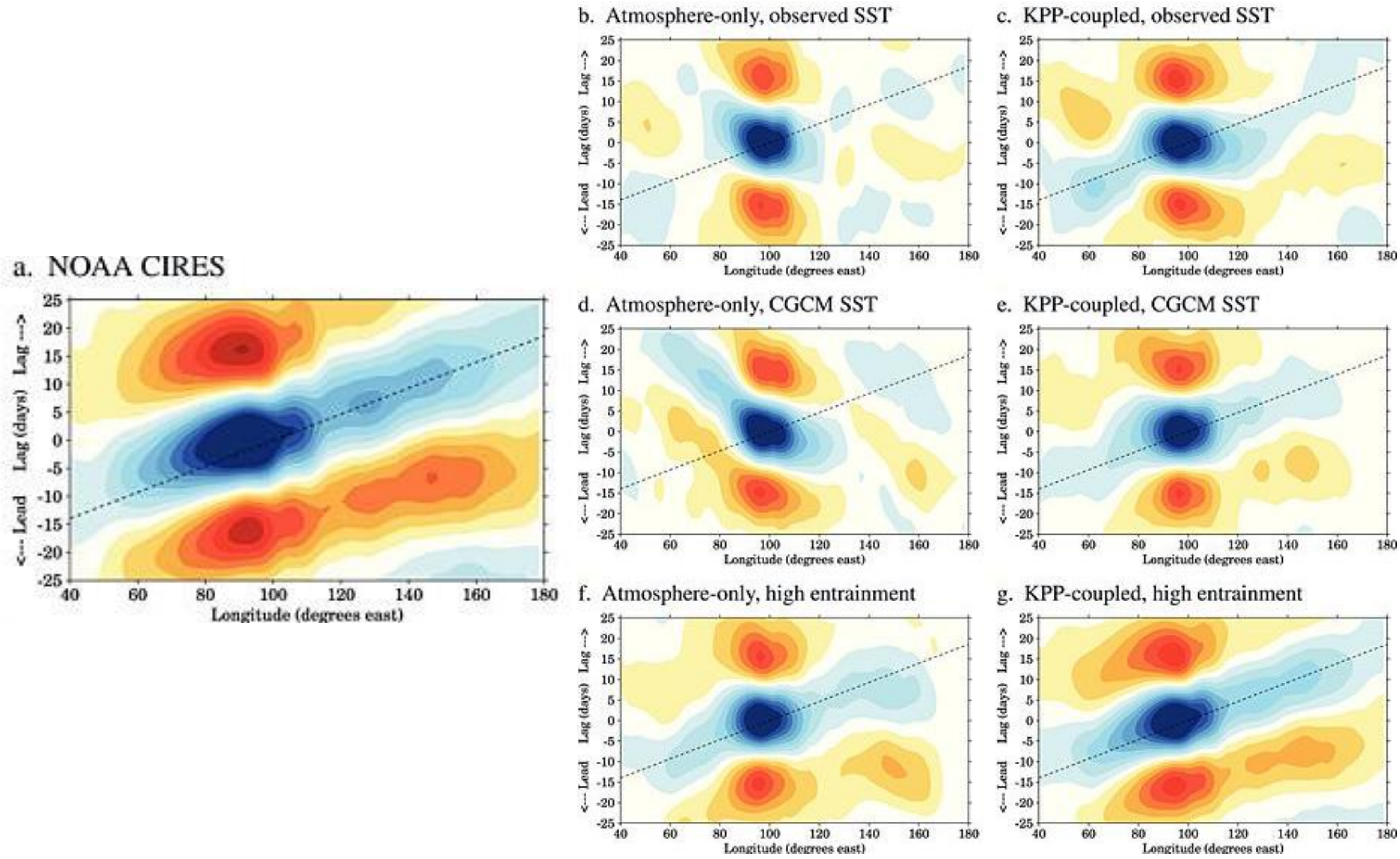
- Horizontal resolution: not important
- Vertical resolution: positive impact
- Air-sea coupling: Positive impact  but not crucial
- Convection scheme: crucial

# Air-sea Interaction

## Air-sea interaction and the MJO

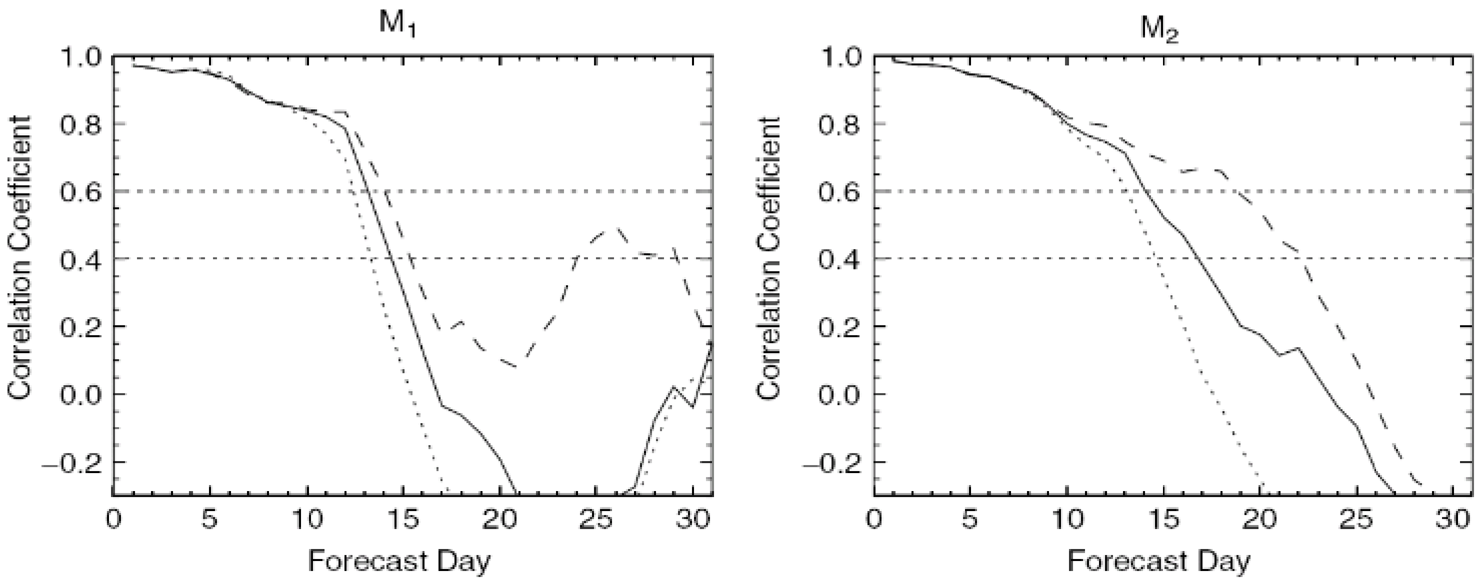



*Courtesy: Pete Inness*




Klingaman and Woolnough 2014

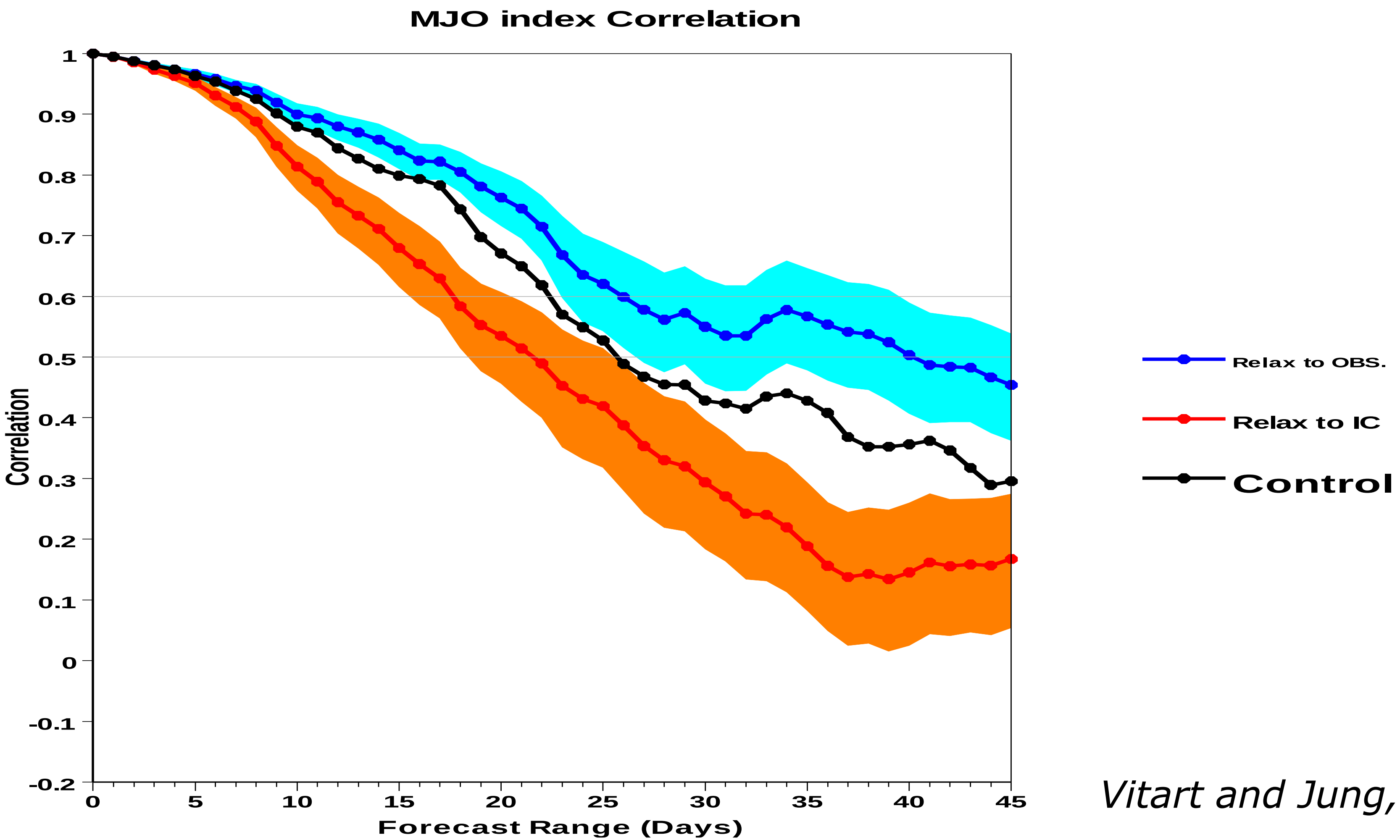
# Improvement of MJO Skill with Ocean Coupling




**CONT : solid line**
**ML : dashed line**
**PERS : dotted line**

Woolnough et al. (2007,QJRMS)

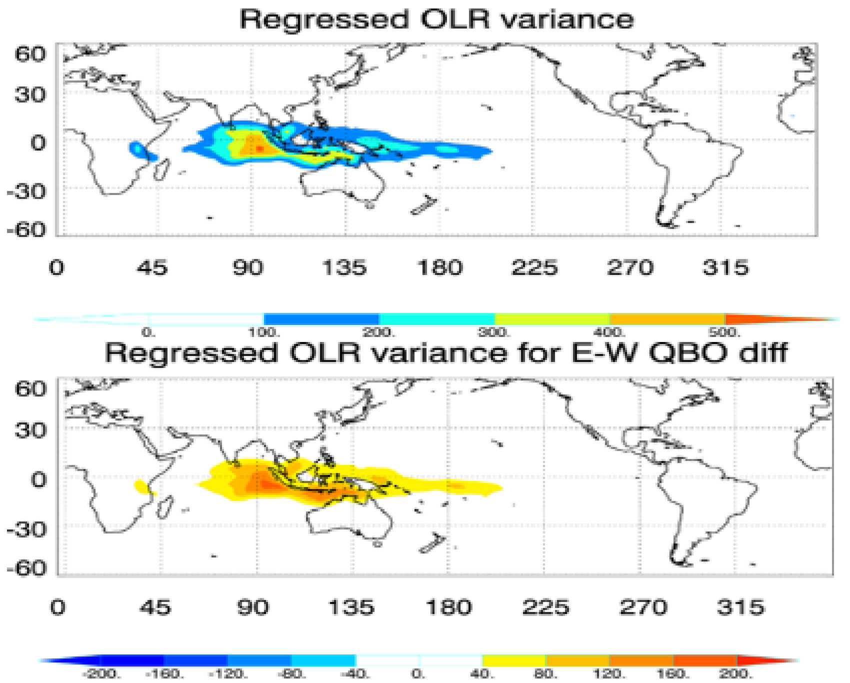
# Impact of N. Extratropics on MJO forecast skill



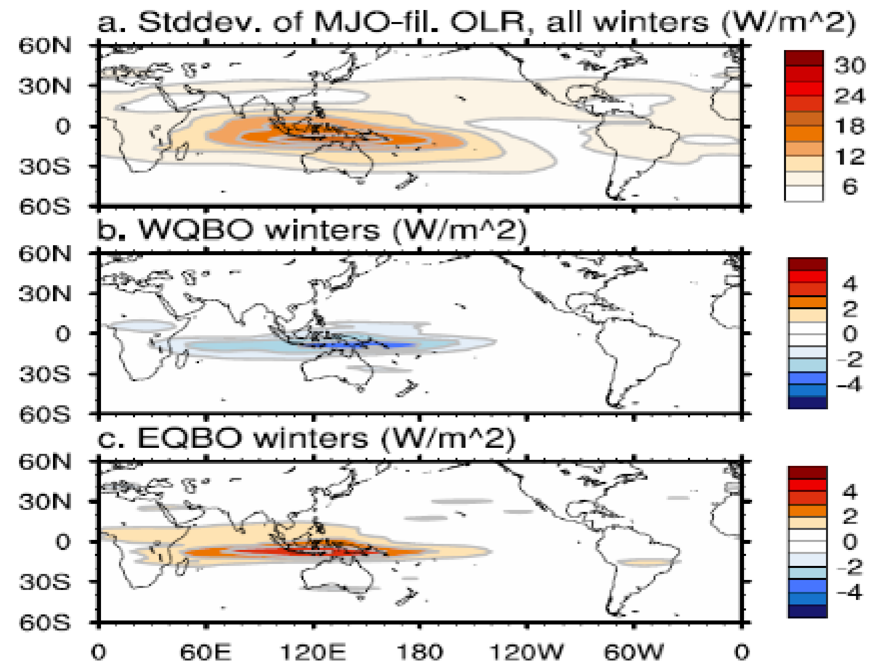

*Vitart and Jung, 2010*

# Impact of the QBO?

MJO OLR Variance (DJF ) from reconstruction onto RMM




East waves 1-5 periods 30-80 days

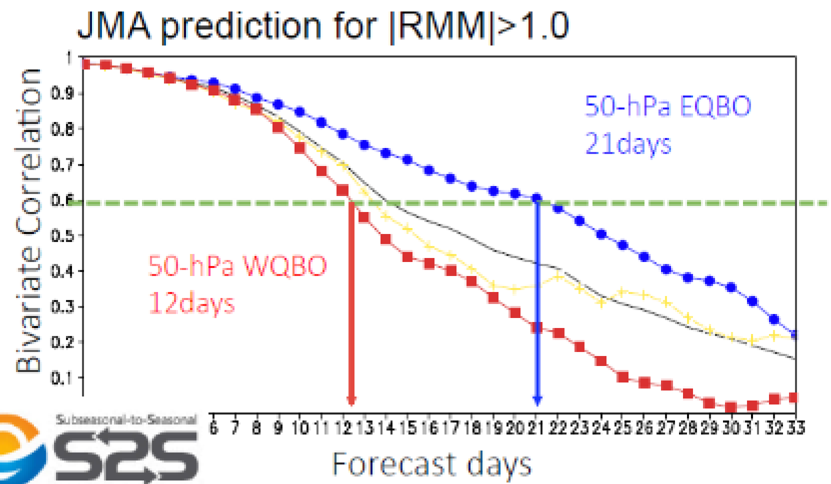



**Yoo and Son 2016**

**2 proposed mechanisms for impact on tropical convection**

1**) Changes in static stability at tropopause**: more stable and lower tropopause in west phase> convection lower (and maybe less top heavy heating profile based on Nie and Sobel 2015)
2) **Changes in vertical shear of zonal wind at tropopause**: less shear at tropopause over equatorial IO/West Pac in easterly phase, favors increased convection in easterly phase?

# Impact of the QBO?



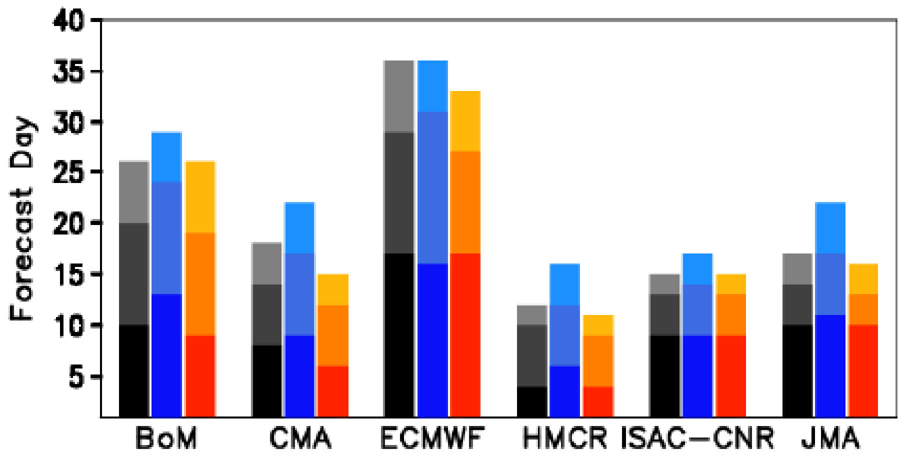




Figure 4. MJO prediction skill for six models. Light, medium, and Dark bars indicate respectively day when the MJO bivariate correlation reaches 0.5, 0.6, and 0.8

**Yoo and Son 2016**

# Conclusions

- MJO is the main source of tropical variability between a week and a season
- Global Impact of the MJO including over Europe. Main source of sub-seasonal predictability.
- MJO prediction: success story – Significant improvement in the prediction of MJO over the past decade. Operational systems show predictive skill up to week 3
- Importance of SST coupling, although not crucial
- Extratropics can also impact MJO