

Coupled ocean-atmosphere variability: the Madden-Julian Oscillation (MJO)

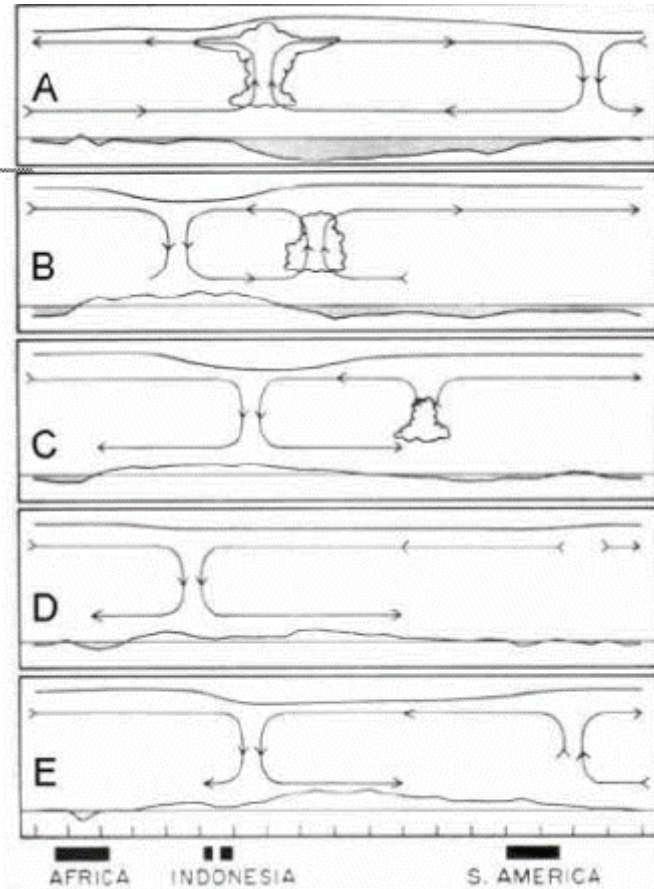
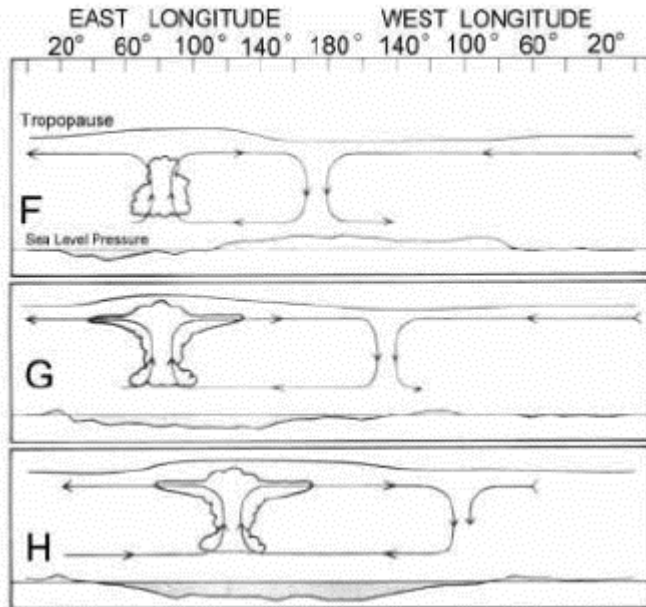
Frédéric Vitart

European Centre for Medium-Range Weather Forecasts

INDEX

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

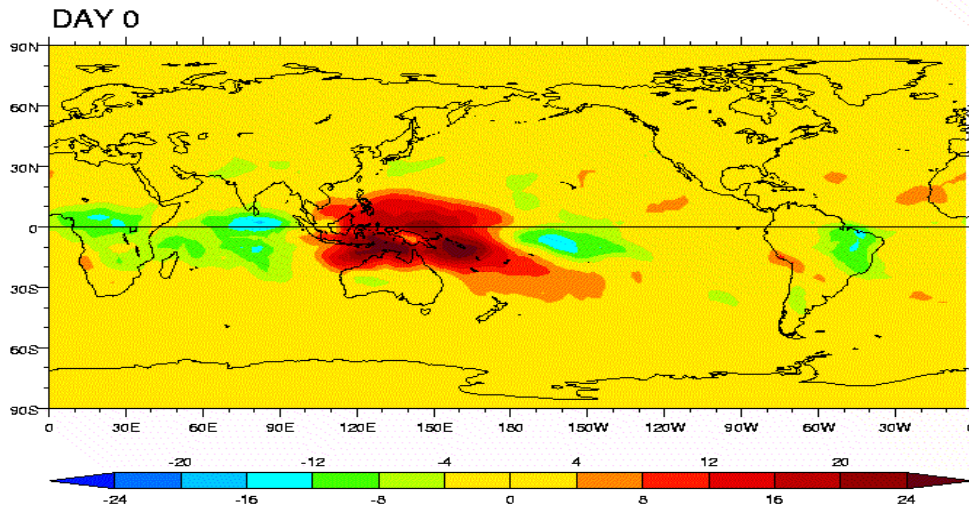
The Madden-Julian Oscillation (MJO)



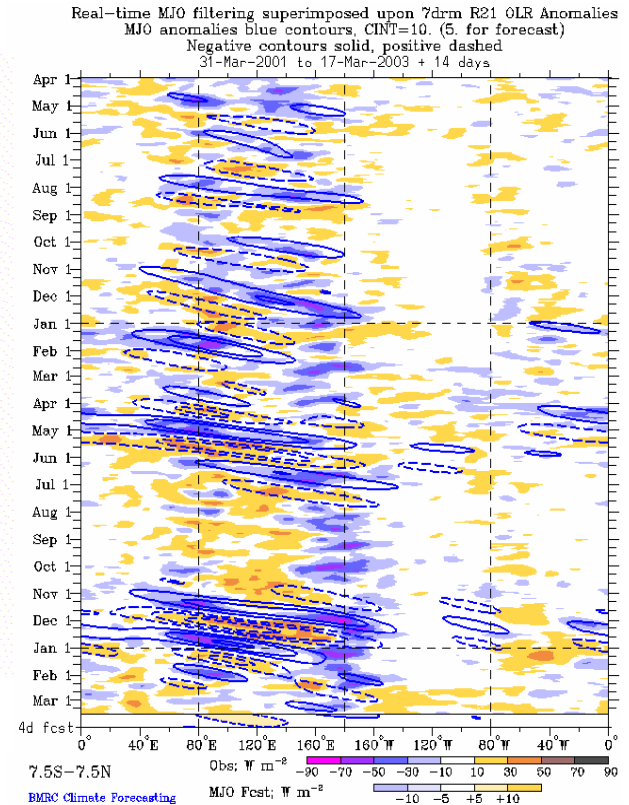
From Madden and Julian (1972)

The Madden Julian Oscillation (MJO)

MJO life cycle



(From NASA)



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..)

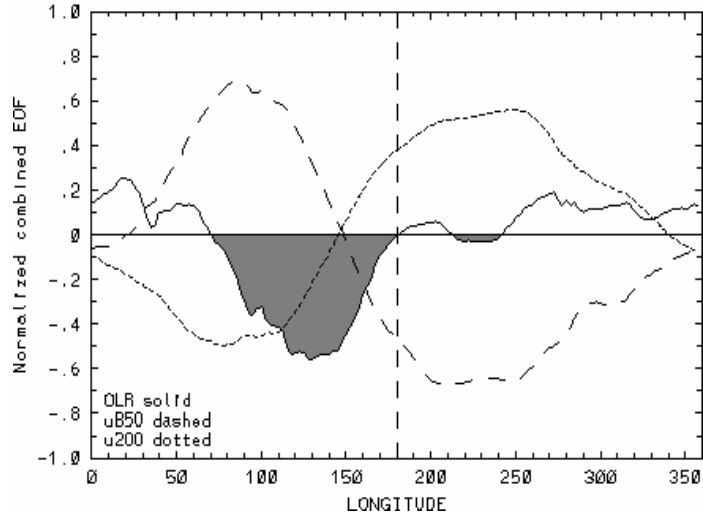
Why is the MJO so important?

- 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-Niño event. Kessler and McPhaden (1995)
- Impact on tropical storms (Maloney et al, 2000; Mo, 2000)
- Impact on Northern Hemisphere weather

MJO Index

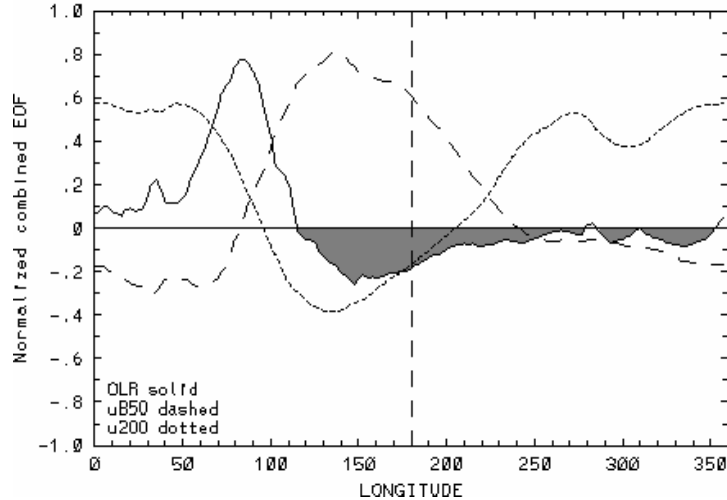
Combined EOF1

EOF # 1, Variance Accounted for= 12.83%

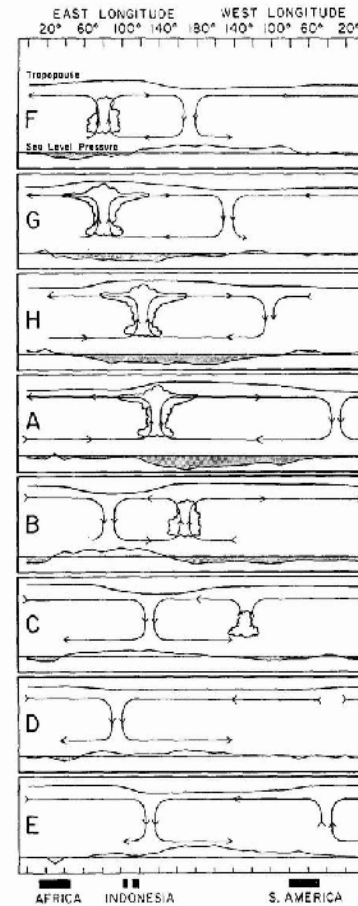


Combined EOF2

EOF # 2, Variance Accounted for= 12.17%

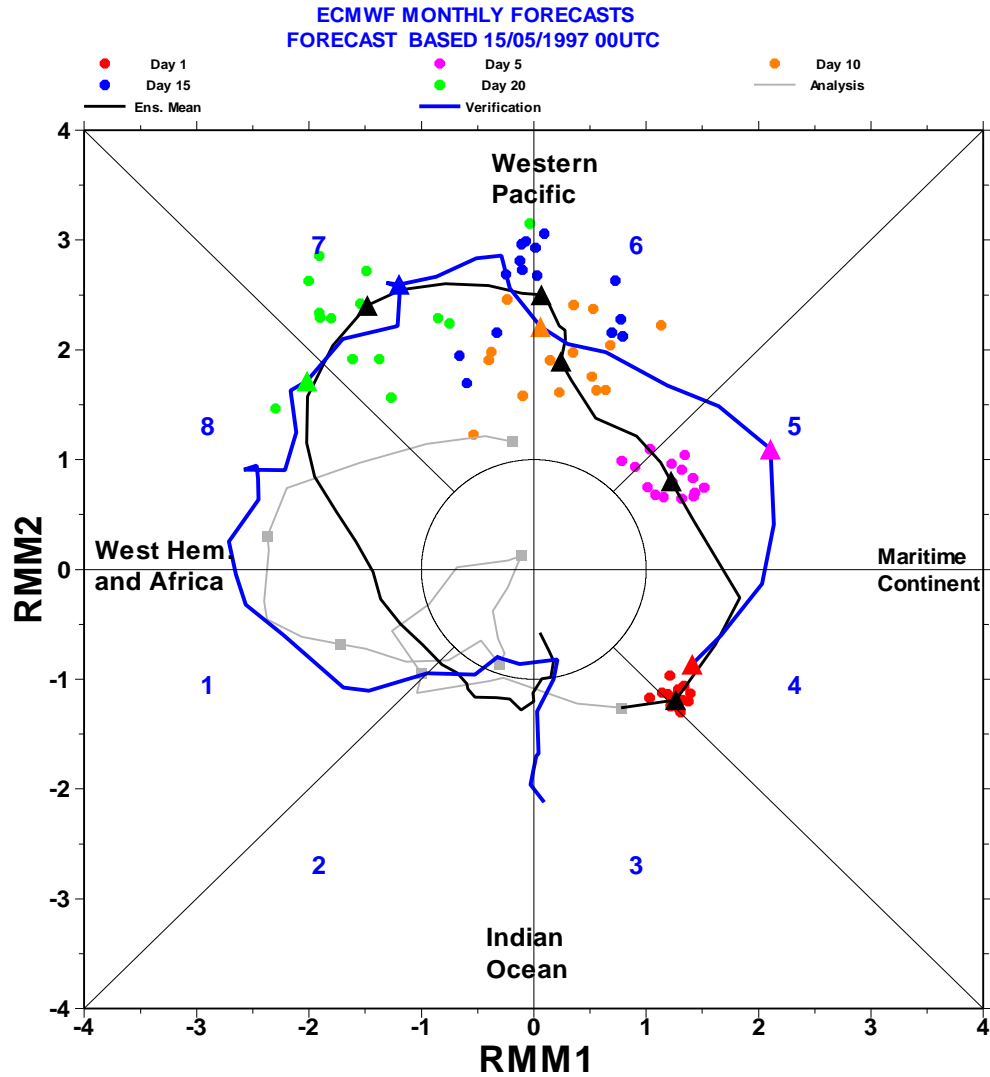


Madden and Julian's (1972) schematic



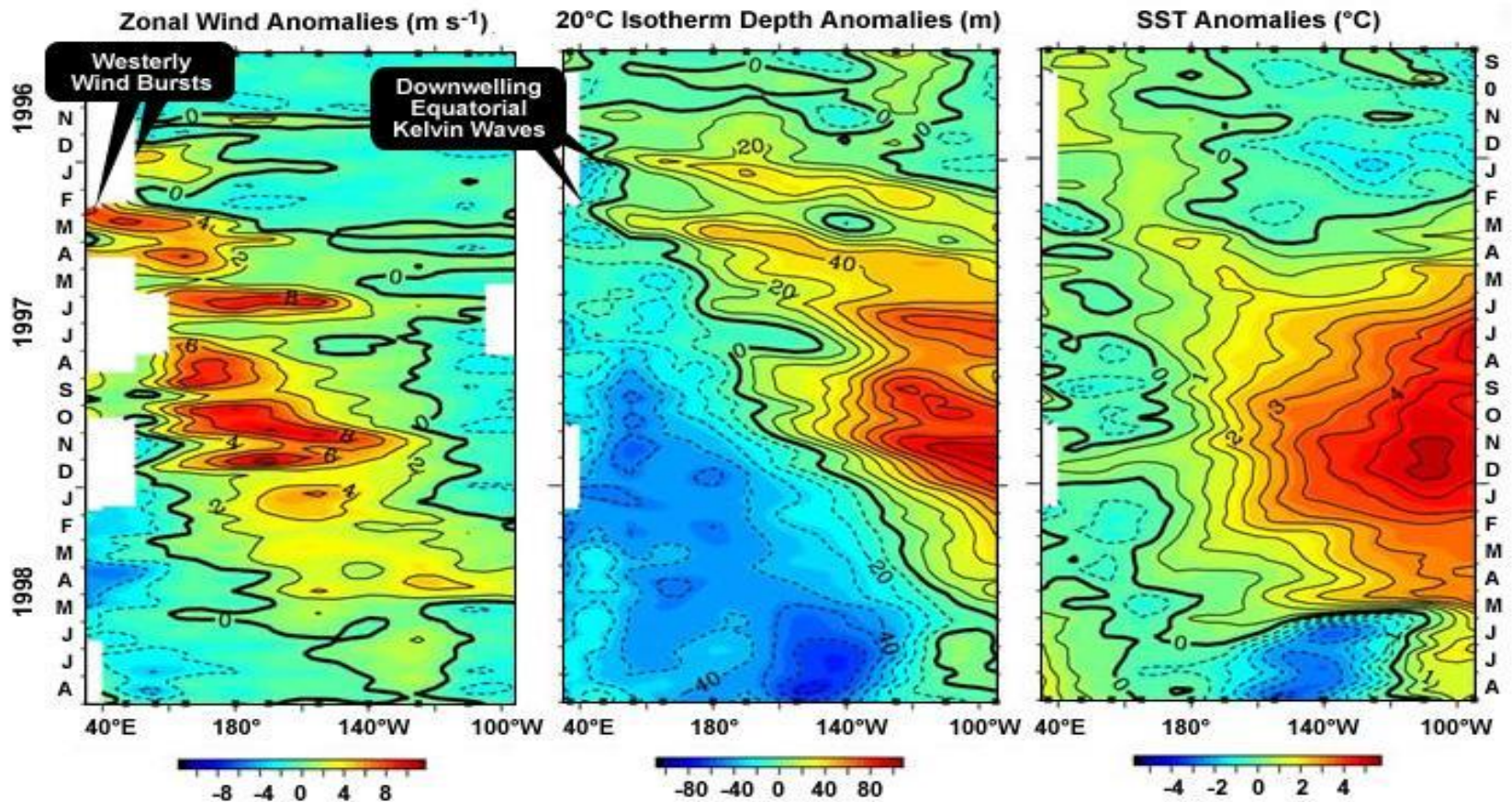
From Wheeler and Hendon, 2004

MJO FORECAST



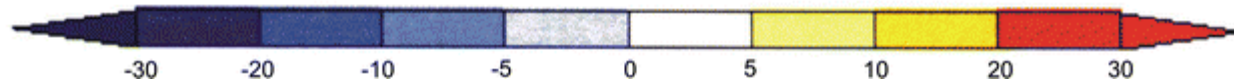
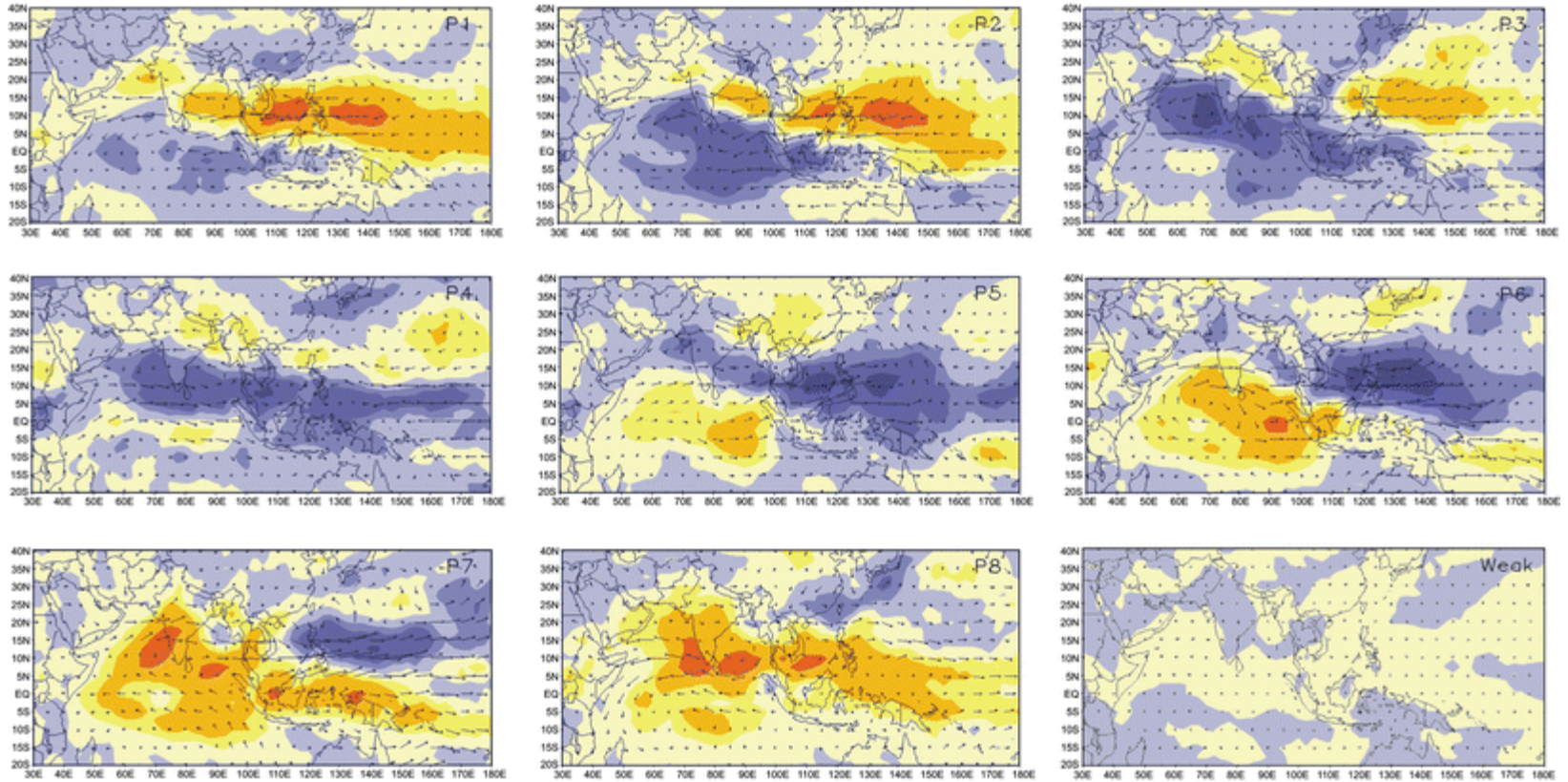
Impact of MJO on ENSO

Evolution of the 1997-98 ENSO (2°S-2°N Averages)



Impact of MJO on Indian Monsoon

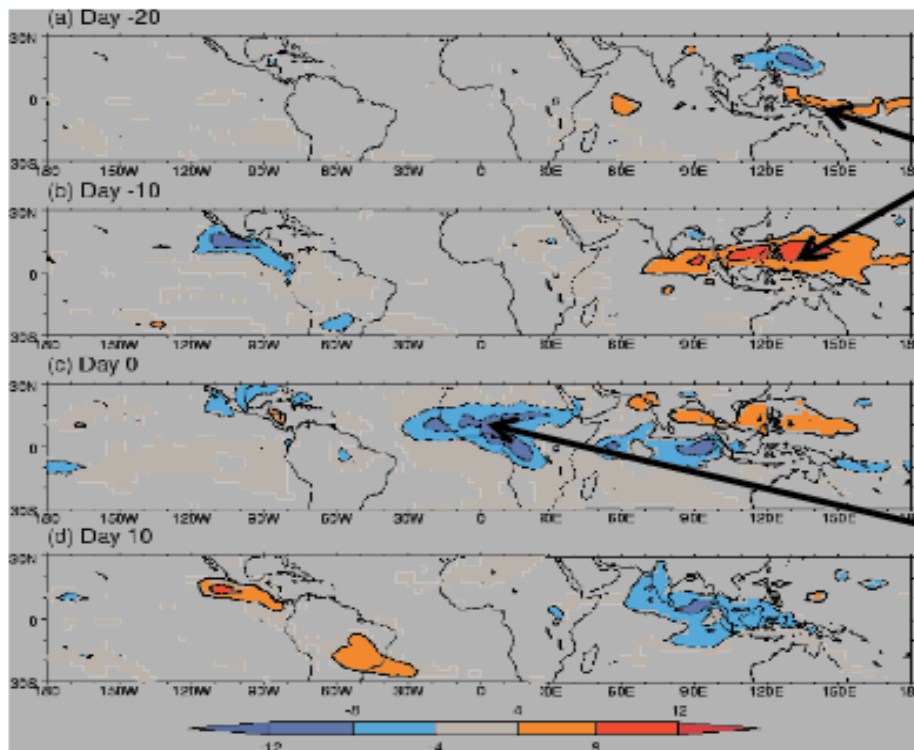
Composite daily OLR and 850hPa wind vector anomalies for various MJO phases : 1974 - 2008



Pai et al, 2009

Impact of MJO on African Summer precipitation

Response of the West African monsoon to the MJO Observed OLR: JJAS



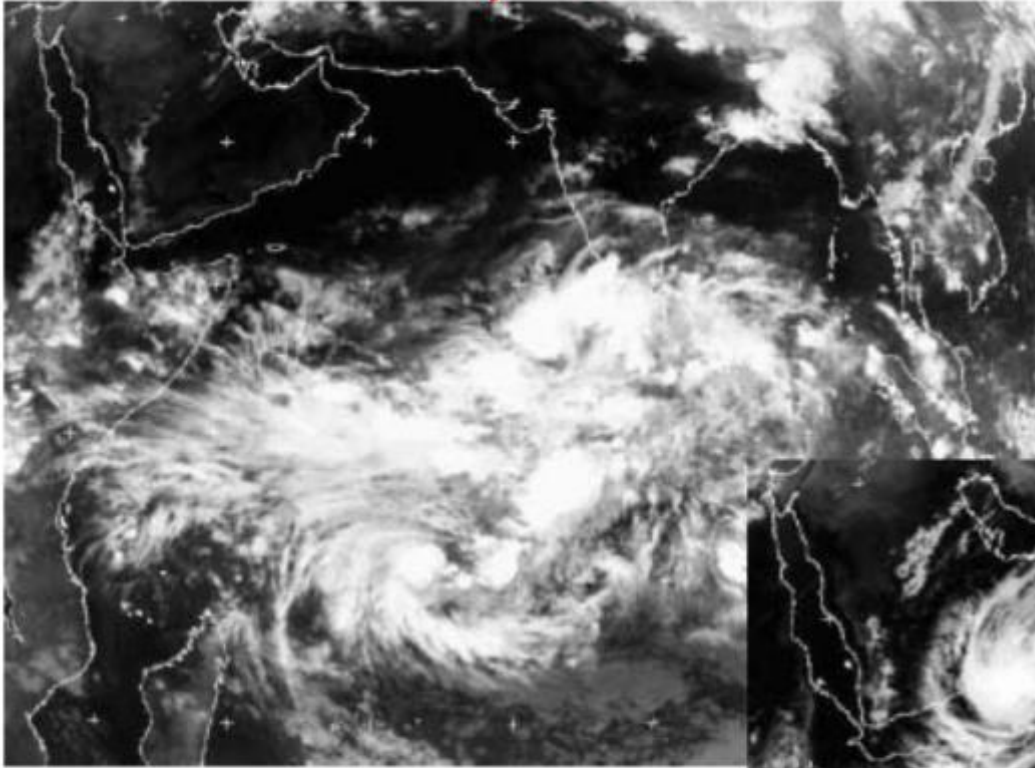
MJO: reduced convection over warm pool 10-20 days earlier

Leads to enhancement of convection over West Africa

Matthews, JCLIM 2004

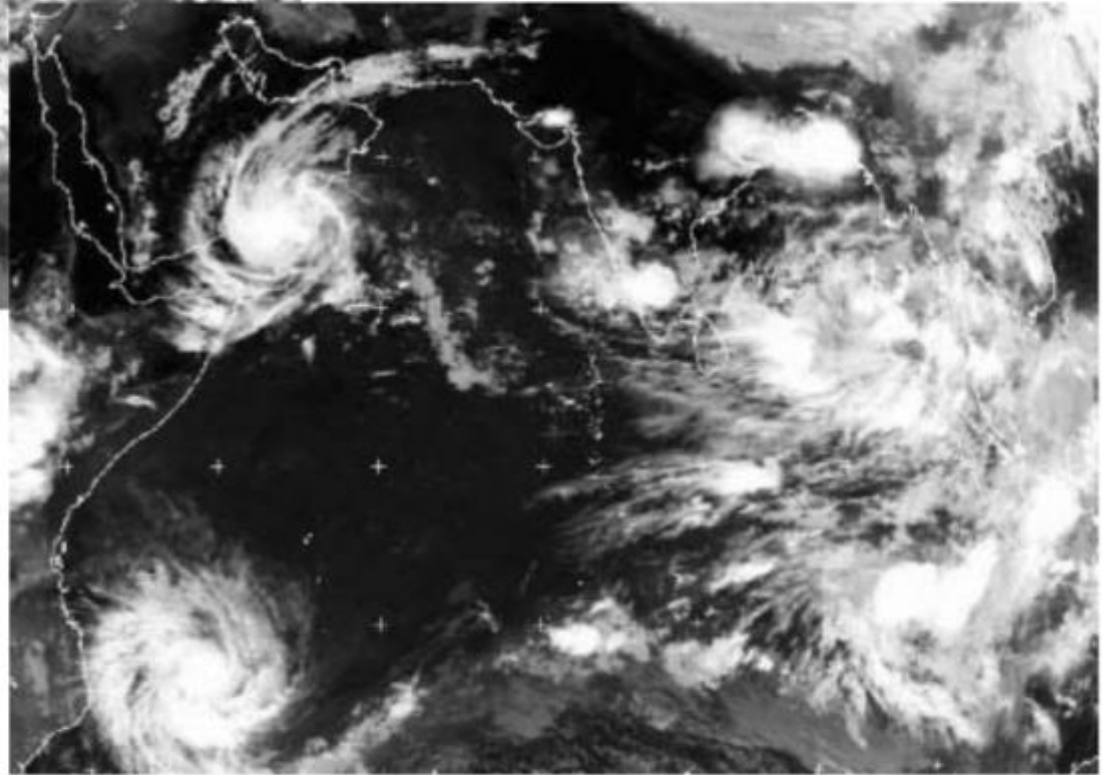
Matthews AJ, 2004: Intraseasonal variability over tropical Africa during northern summer. *J. Climate*, 17, 2427-2440

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.

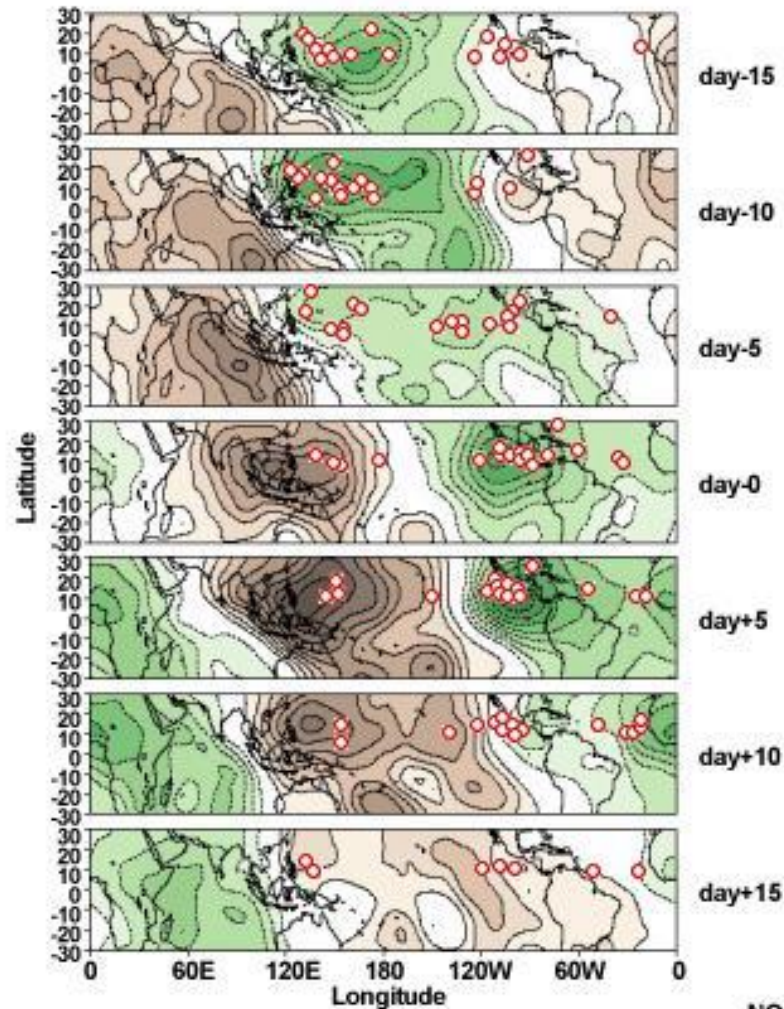


From Slingo et al., 2003

9 May 2002

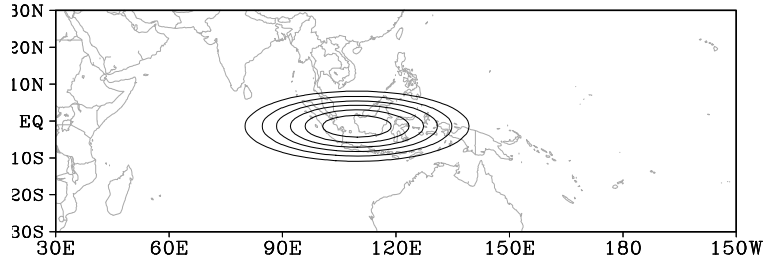
Impact of MJO on tropical cyclones

Composite evolution of 200hPa velocity potential anomalies ($10^5 \times \text{m}^2/\text{s}$) and points of origin of tropical systems that developed into hurricanes/typhoons



Impact of the MJO on Extra-tropics

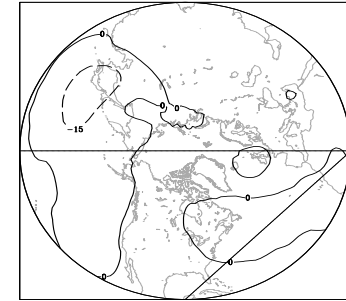
a) 110E heating



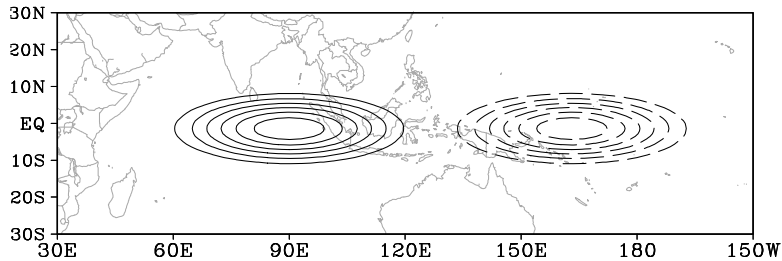
a) Exp1: days6-10



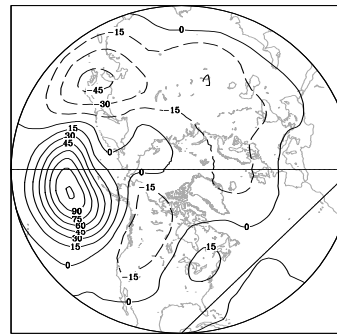
b) Exp1: days11-15



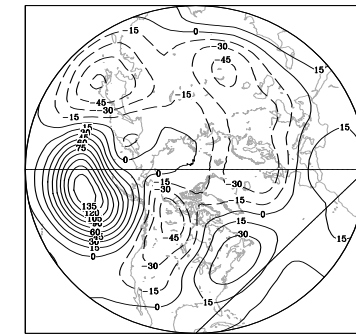
b) 90E heating + 165E cooling



c) Exp2: days6-10



d) Exp2: days11-15



Lin et al, MWR 2010

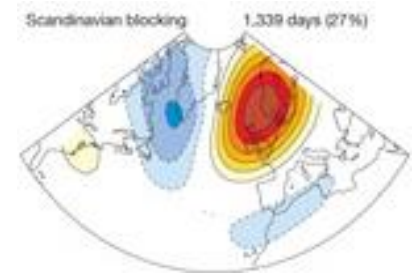
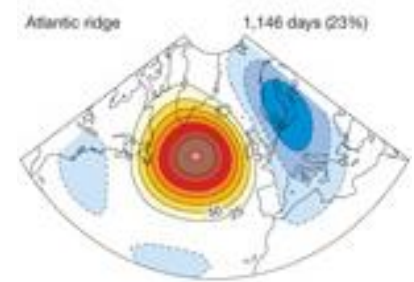
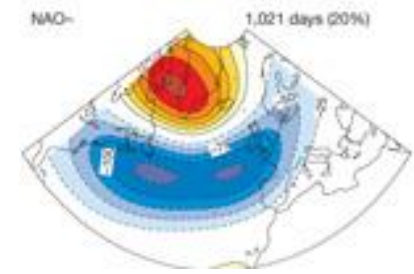
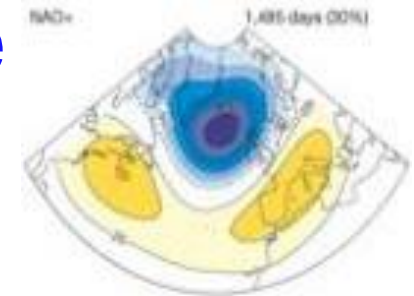
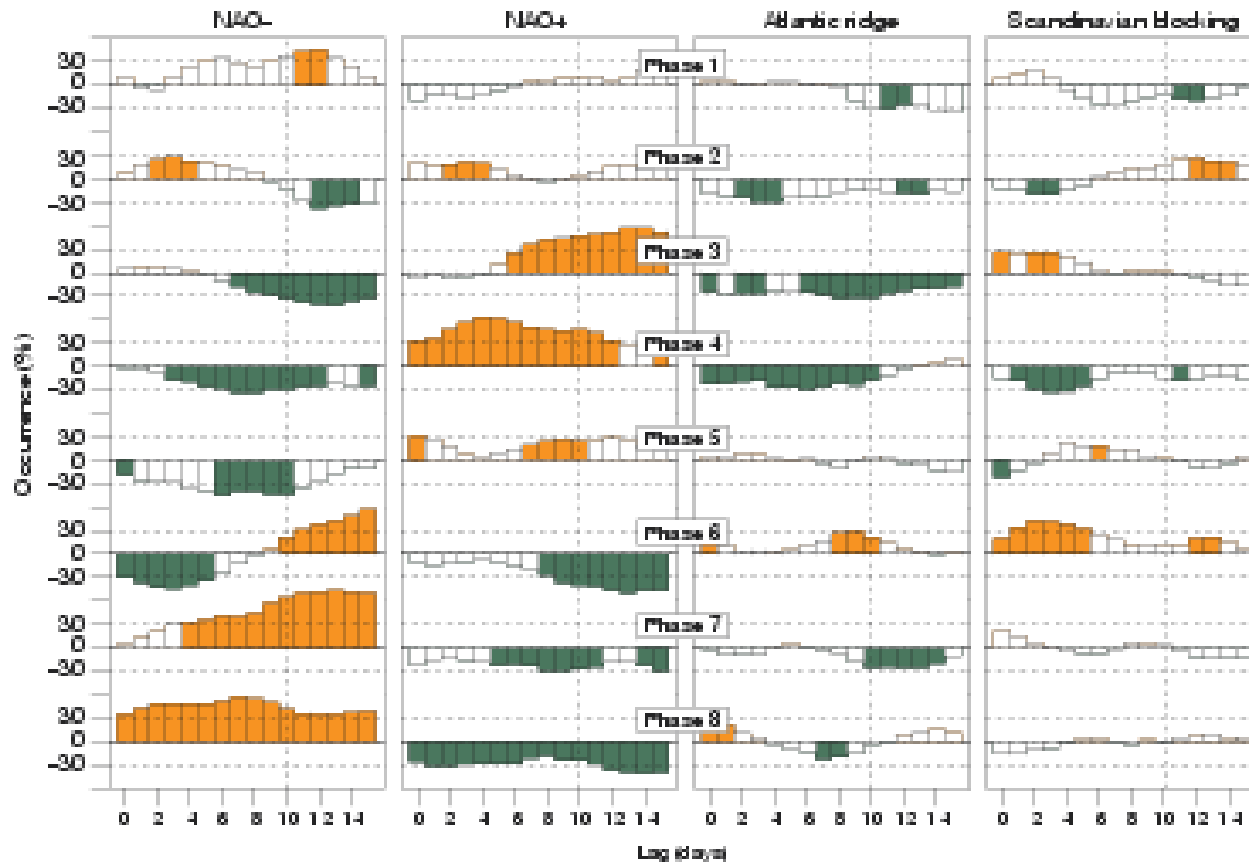
See also

Simmons et al JAS 1983

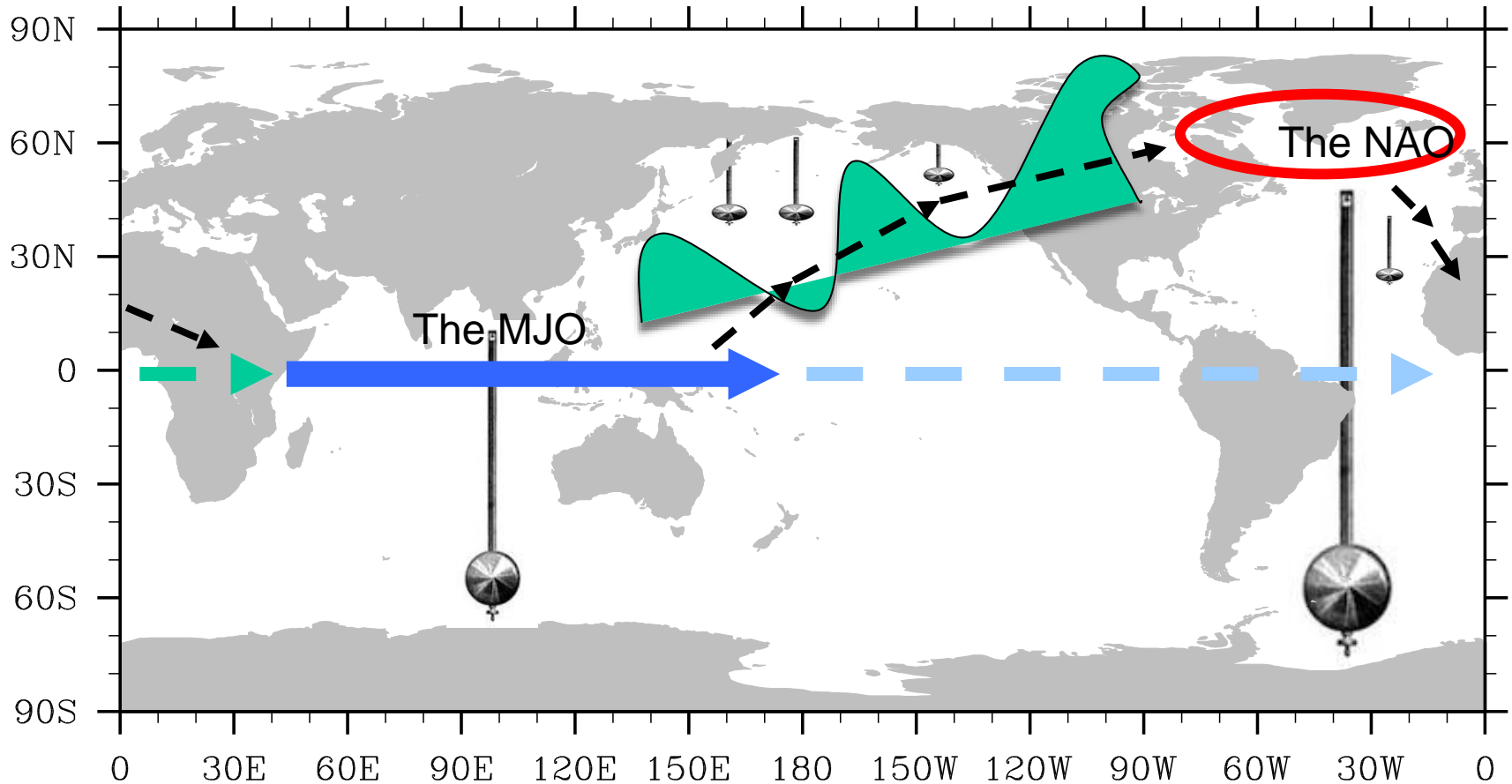
Ting and Sardeshmukh JAS 1993

Impact over N. Atlantic / Europe

(Cassou 2008)



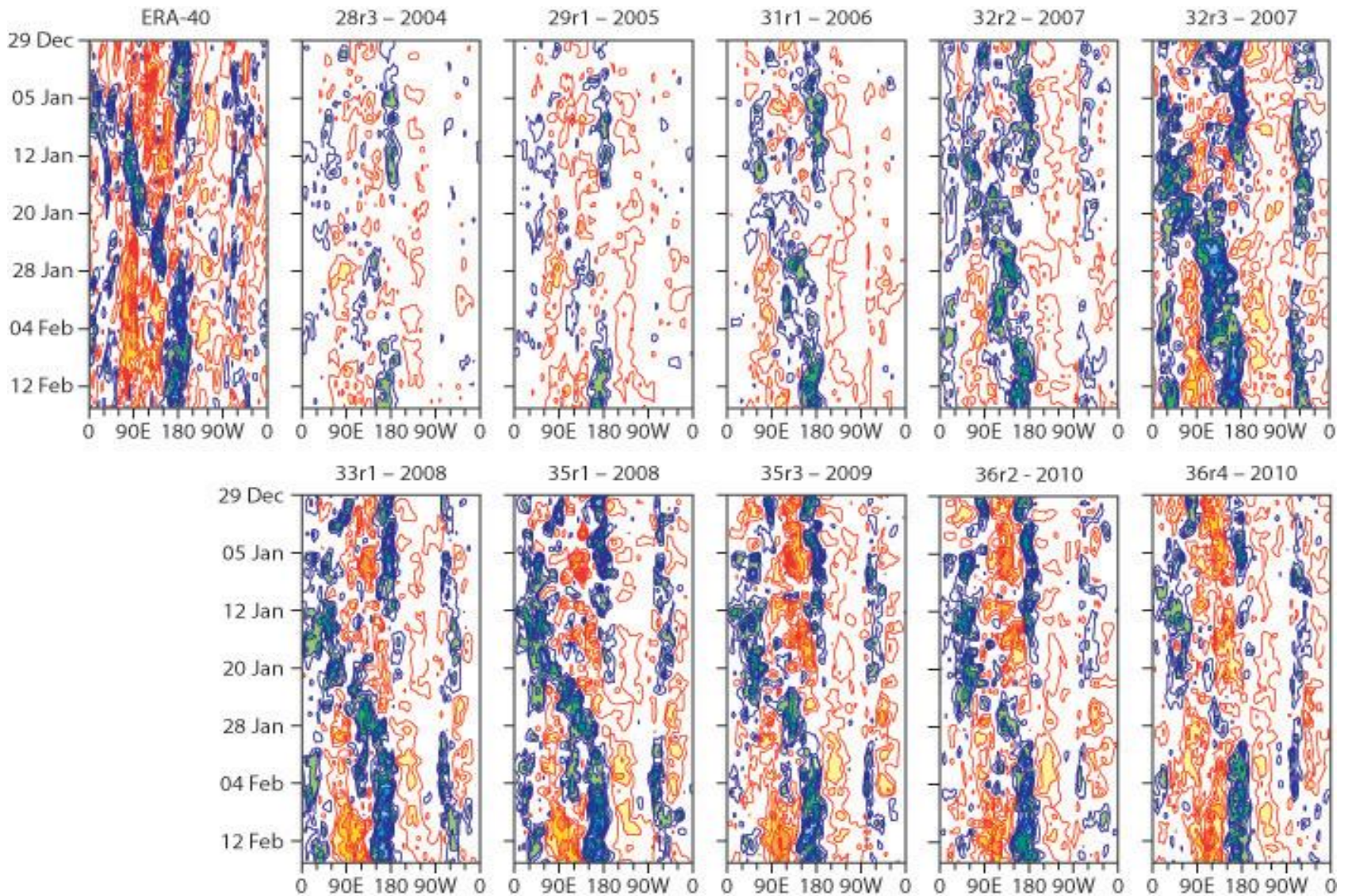
The multi-scale organisation of tropical convection and its two-way interaction with the global circulation



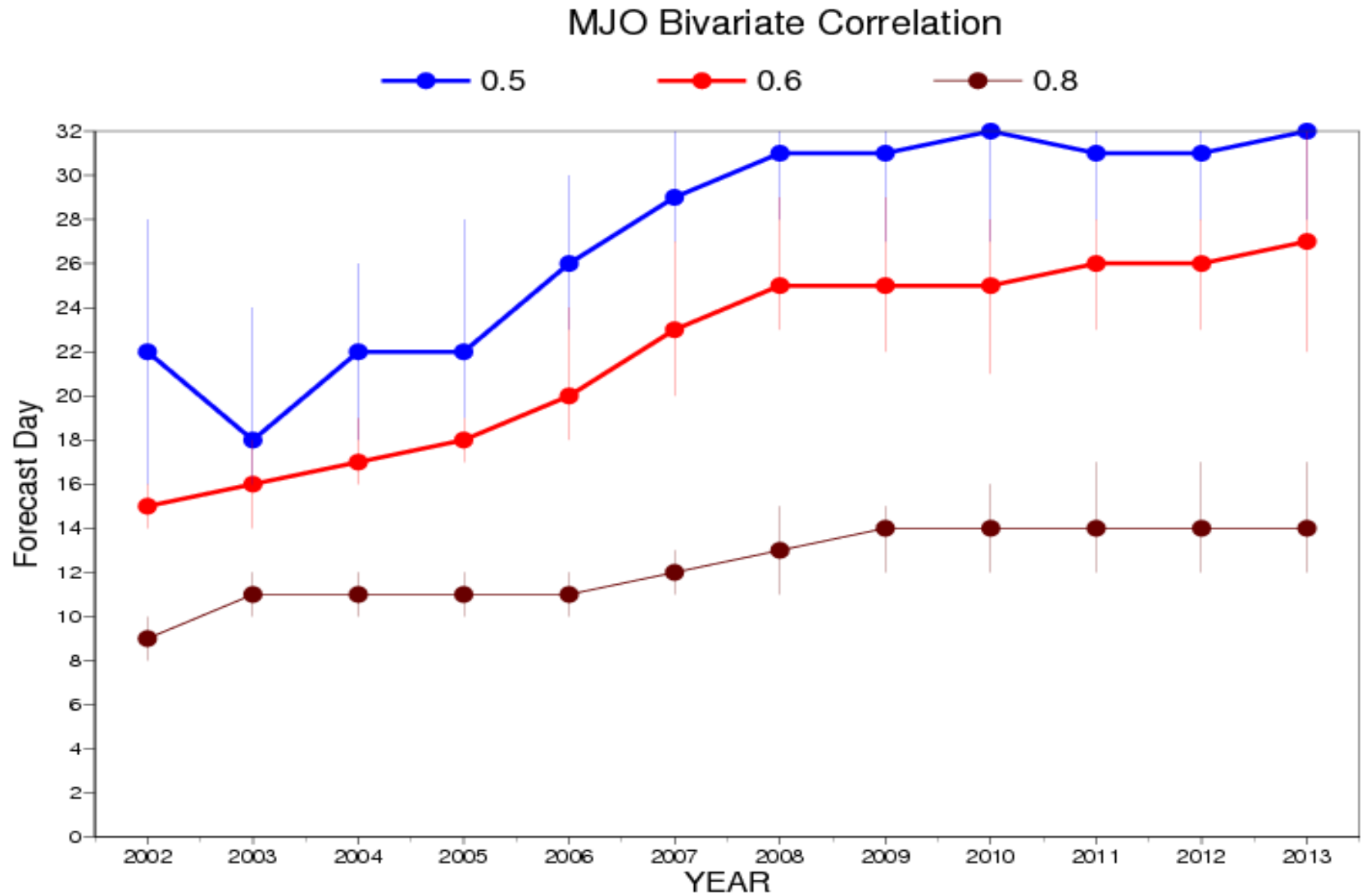
large scale oscillations interact?

MJO Prediction

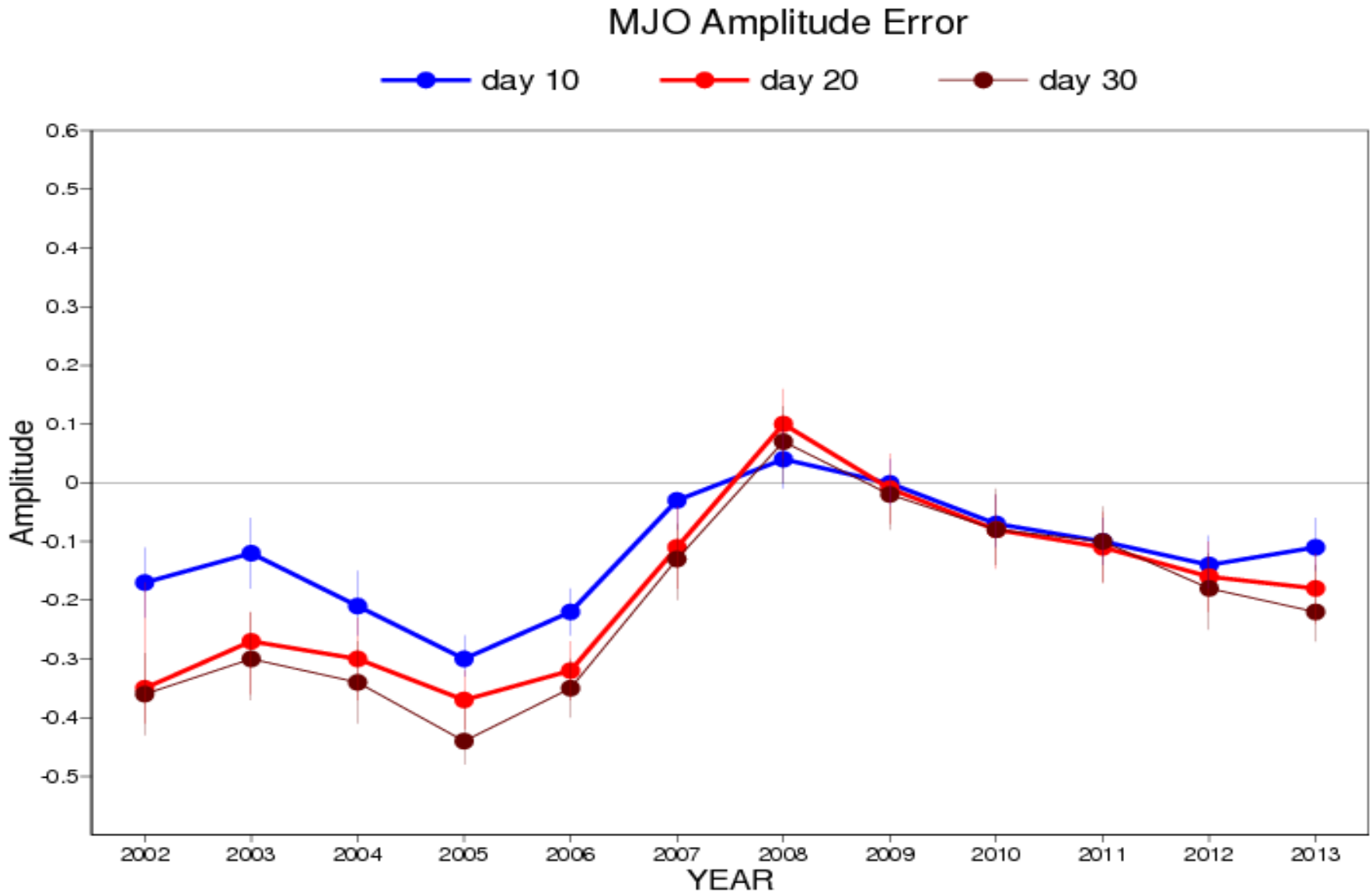
OLR anomalies - Forecast range: day 15



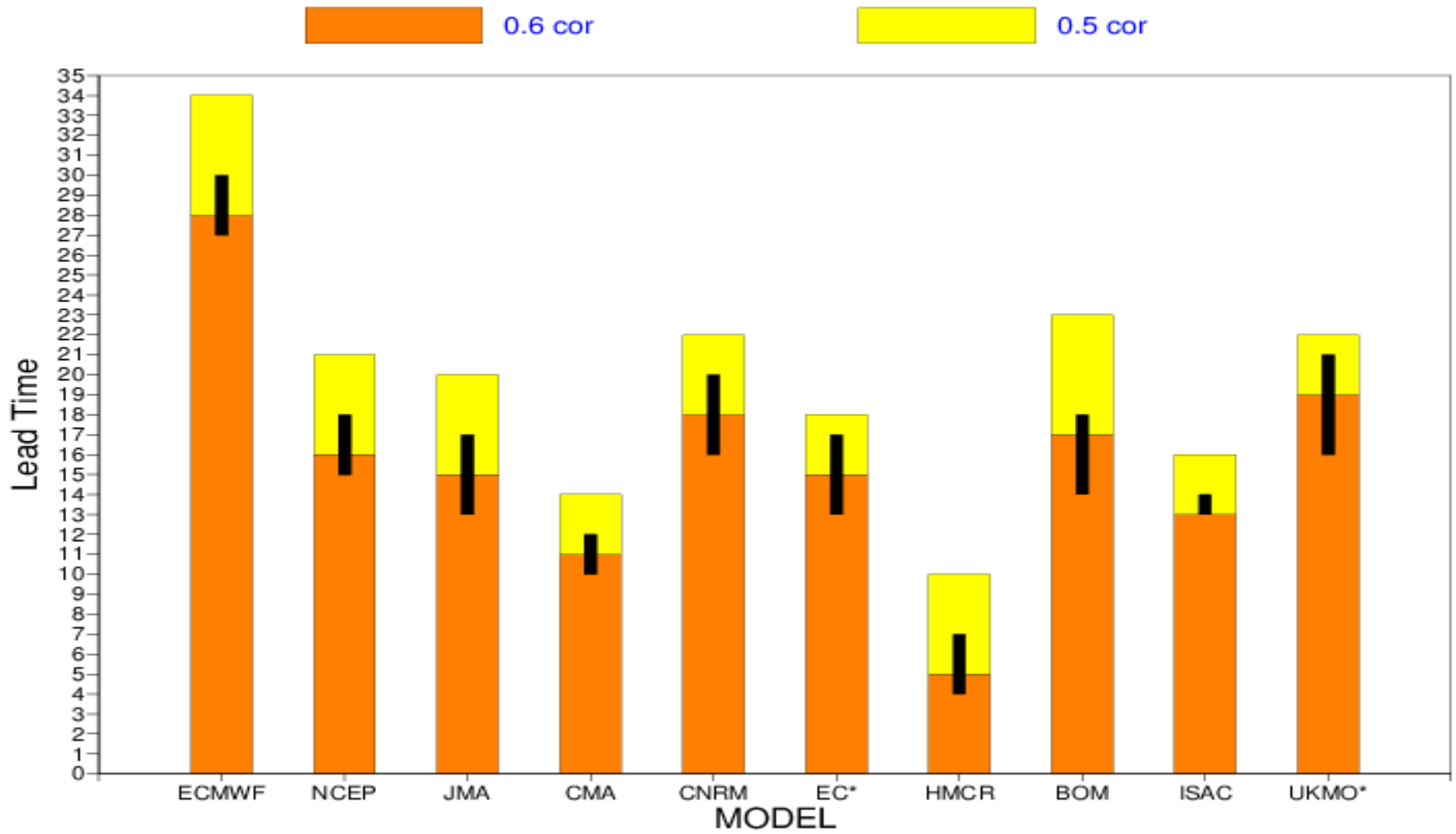
MJO skill scores



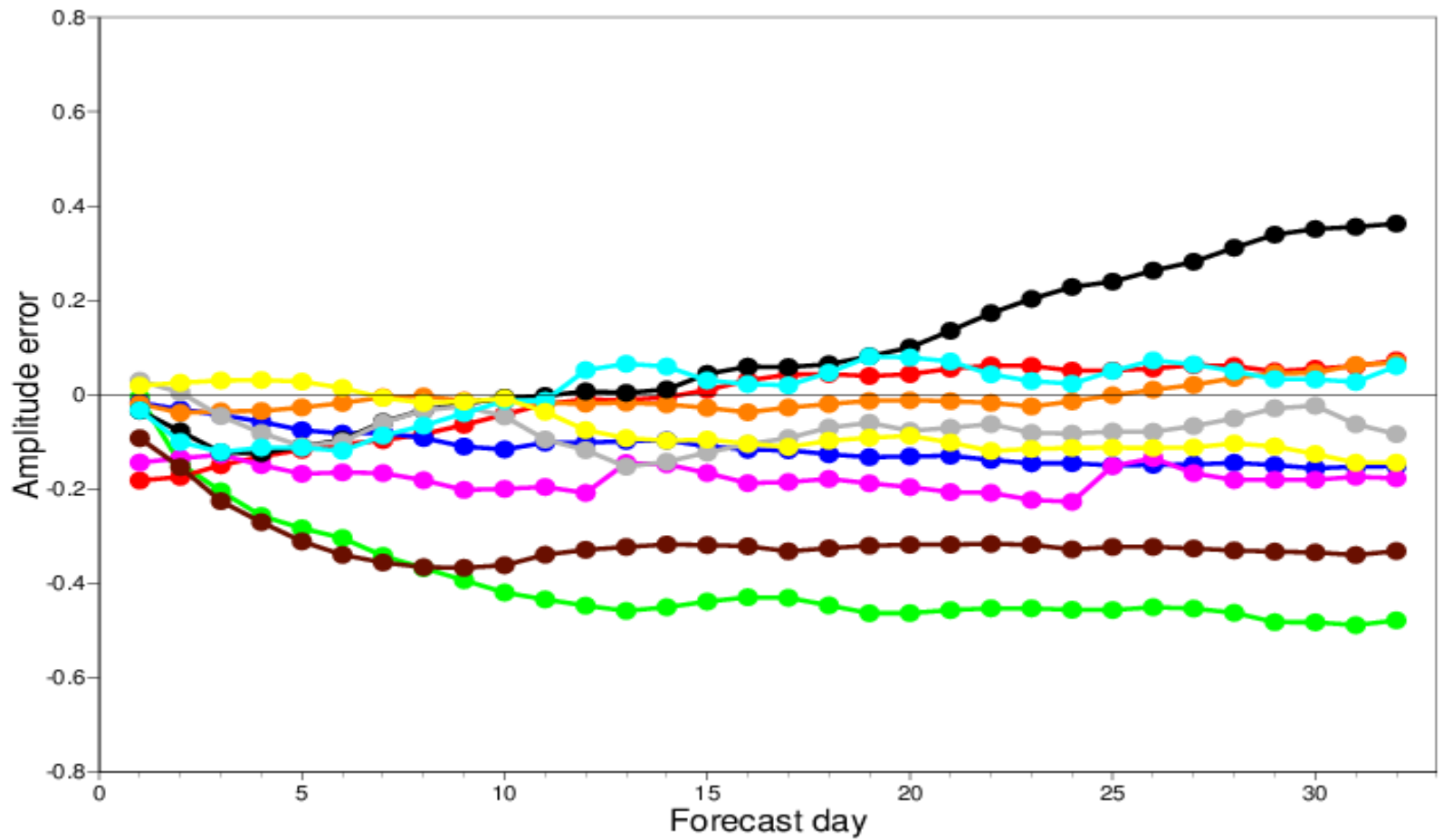
MJO amplitude



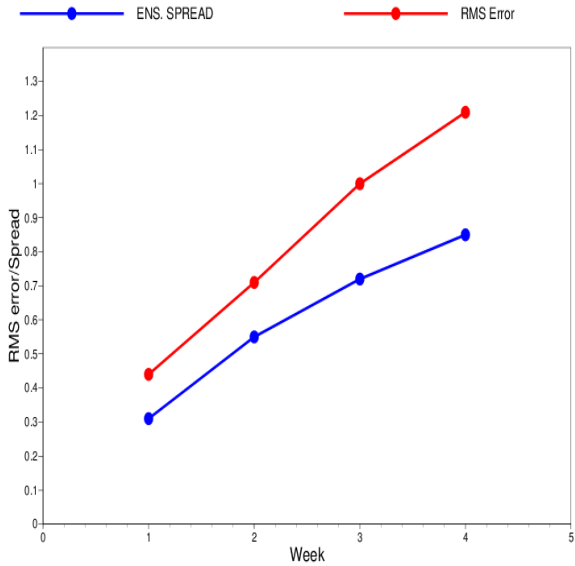
MJO Bivariate Correlation S2S REFORECASTS 1999-2010



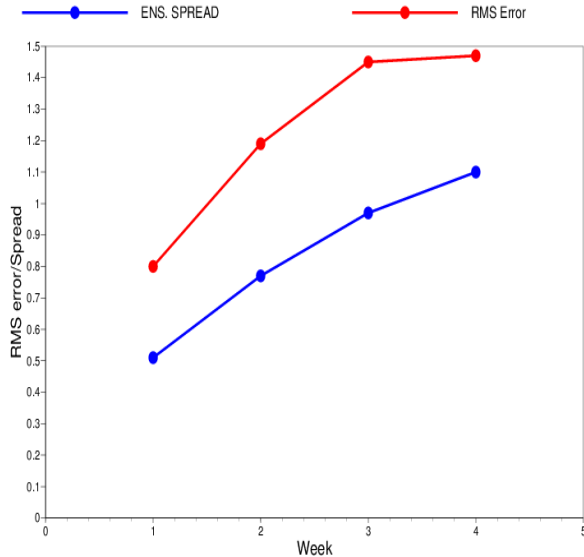
—●— JMA —●— BoM —●— ECMWF —●— NCEP —●— CMA —●— CNRM —●— UKMO —●— EC —●— ISAC —●— HMCR



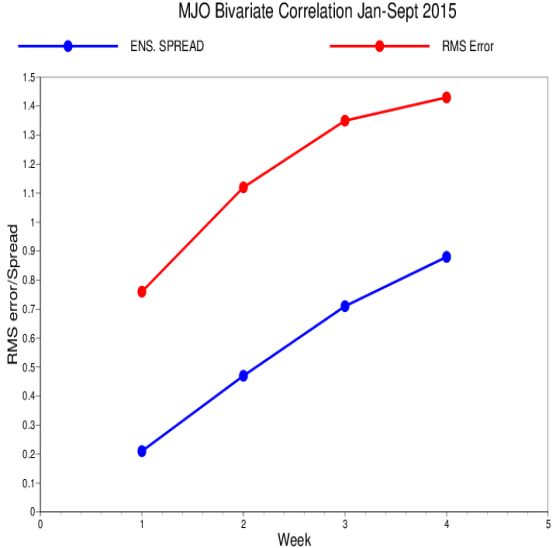
ECMWF



BoM

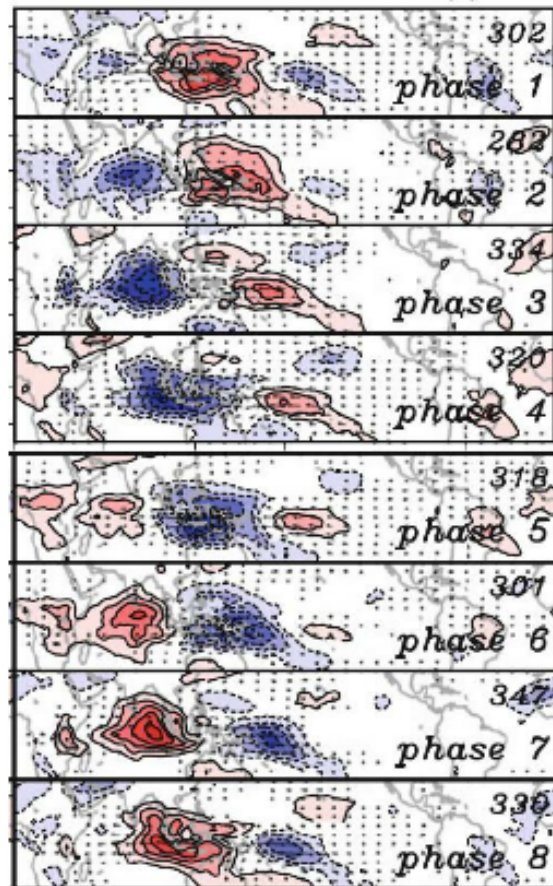


NCEP

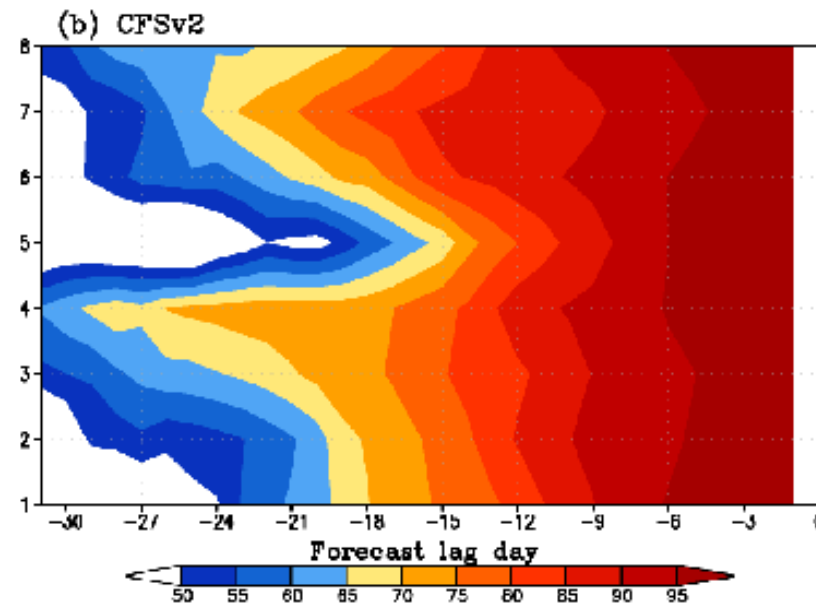


MJO Maritime Continent Prediction barrier

MJO composite



MJO Prediction skill by target MJO phase

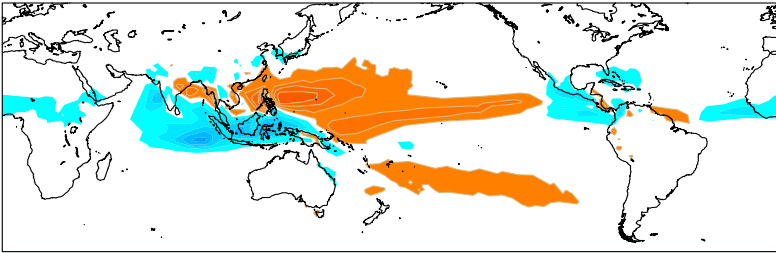


- CFSv2 shows sharp decrease in skill at phase 1 and 5
→ deficiency in predicting the enhanced (or suppressed) convective signal associated with the MJO over the Maritime Continent.
- Kim et al. (2014)

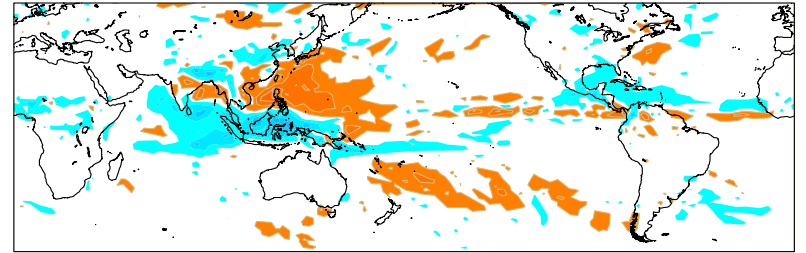
Impact of the MJO on precipitation

JJA

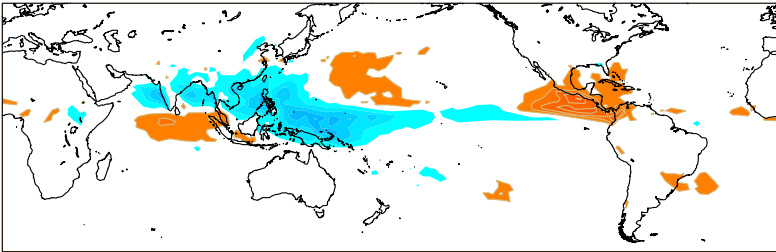
Model Phase 23



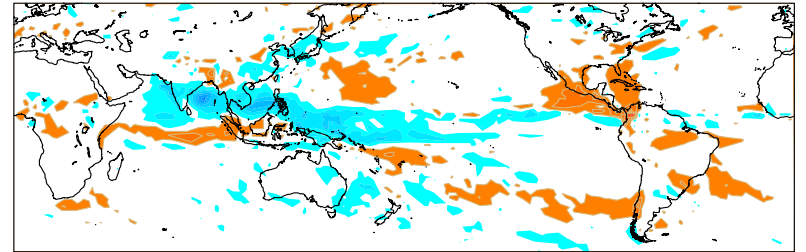
ERA Phase 23



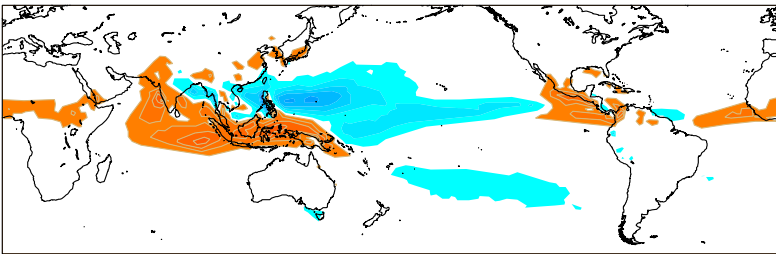
Model Phase 45



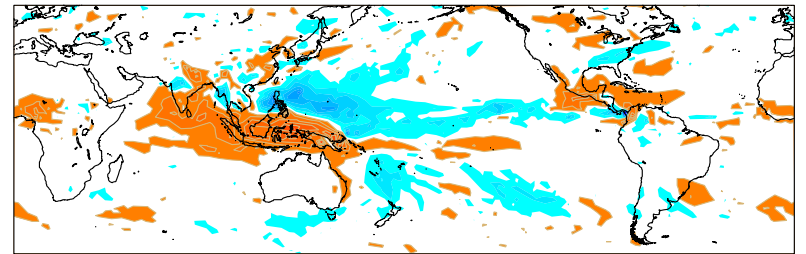
ERA Phase 45



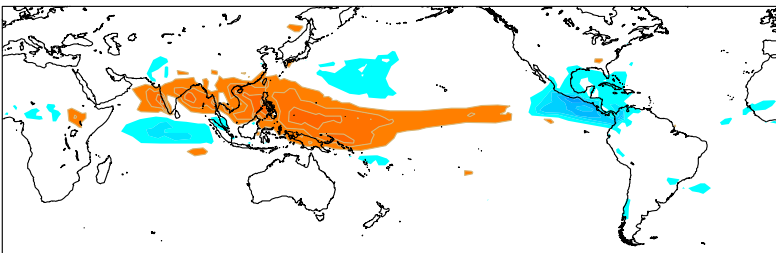
Model Phase 67



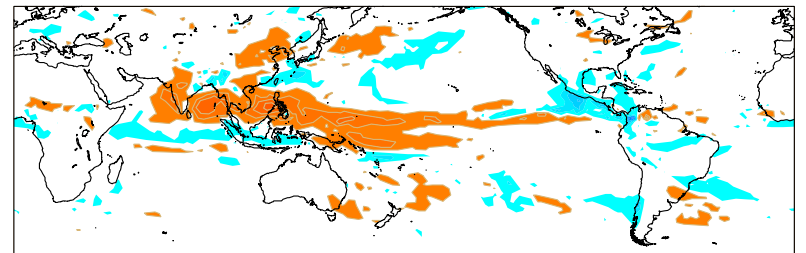
ERA Phase 67



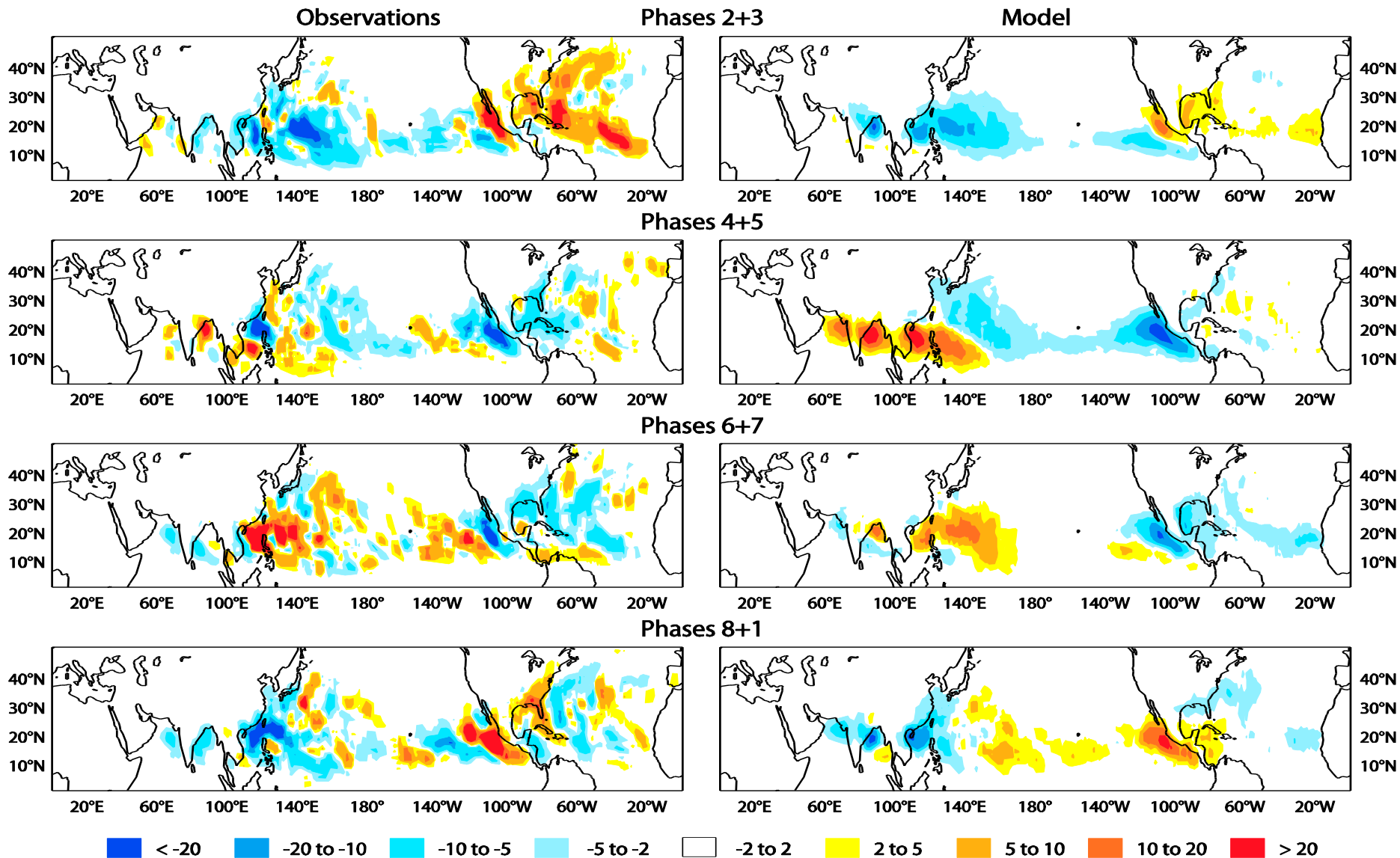
Model Phase 81



ERA Phase 81

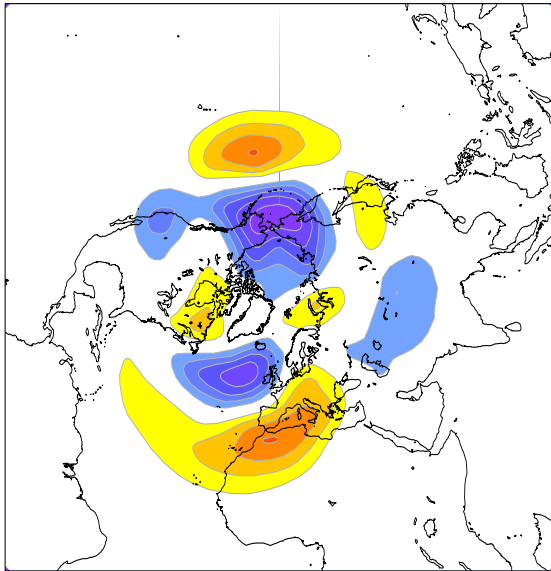


Impact on Tropical Cyclone Density (Summer)

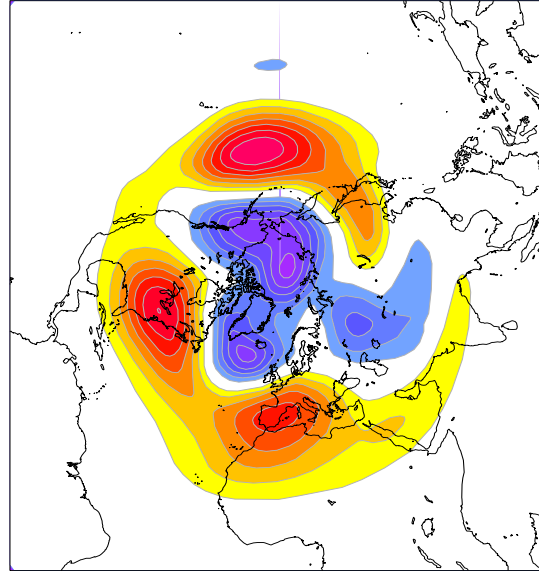


Impact of the MJO on the N. Extratropics

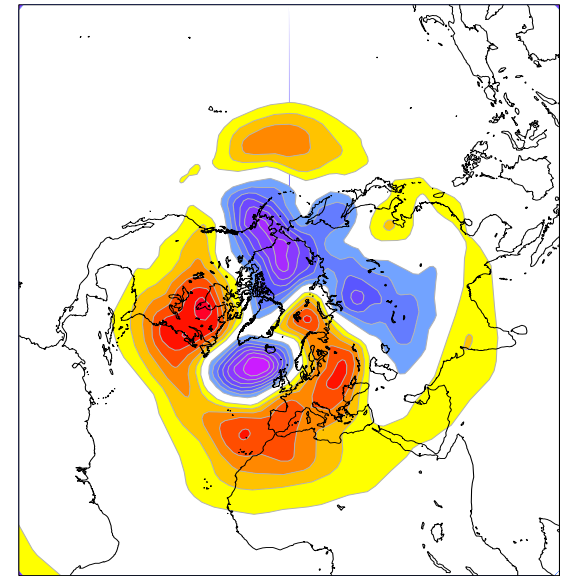
**2002 MOFC
hindcasts**



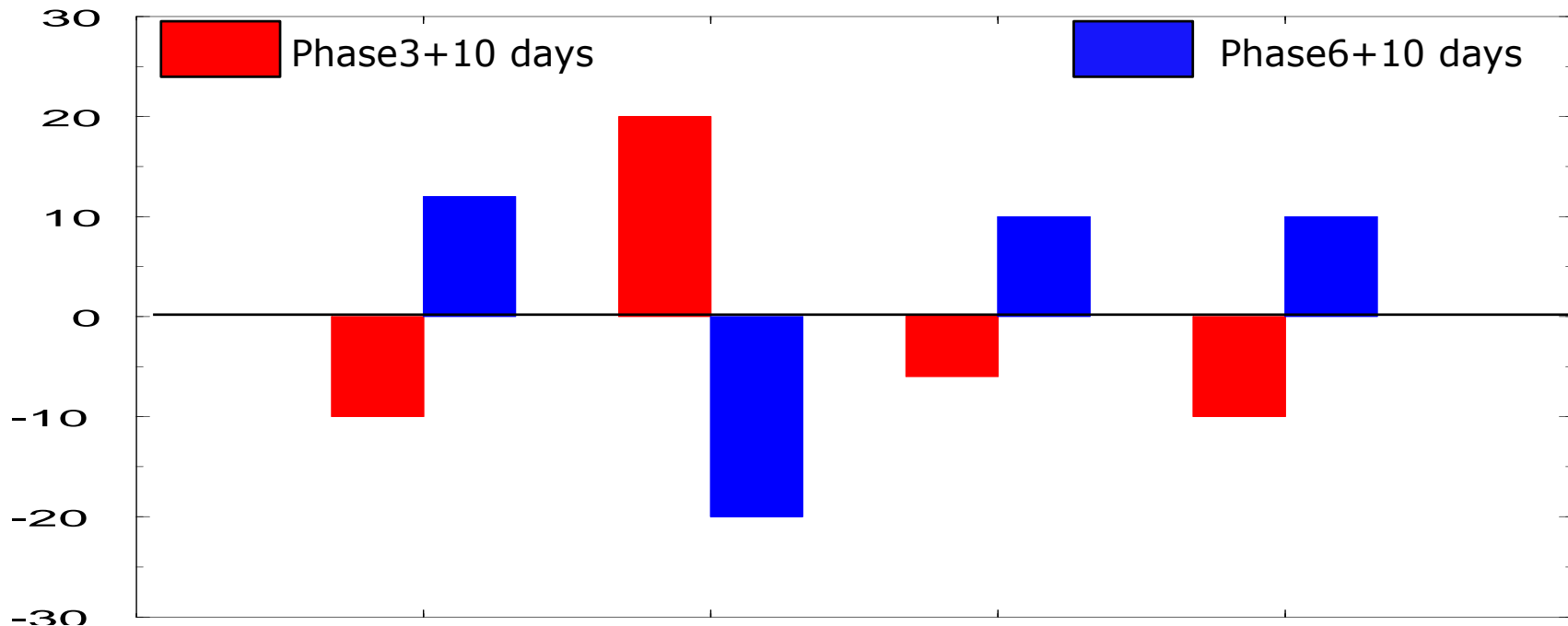
**2012 MOFC
hindcasts**



ERA Interim



Impact on weather regimes in hindcasts

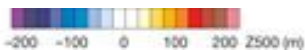
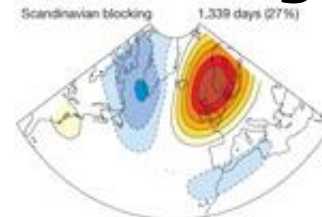
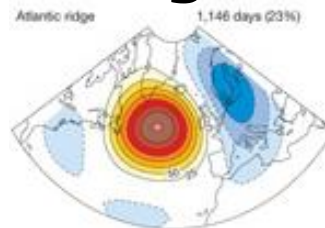
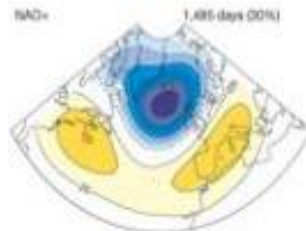
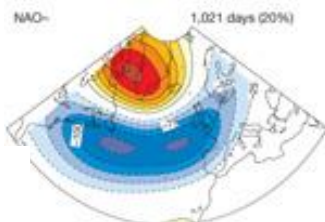


NAO-

NAO+

Atlantic ridge

Scandinavian blocking

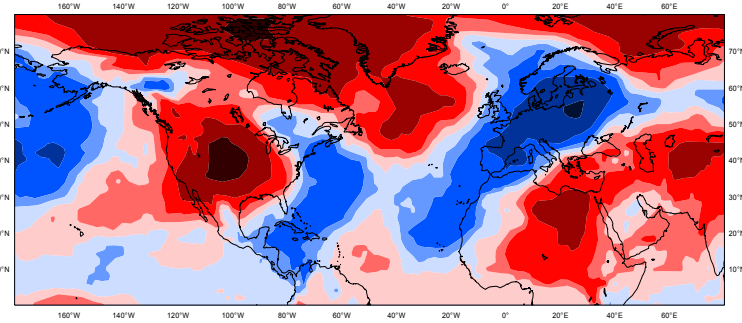
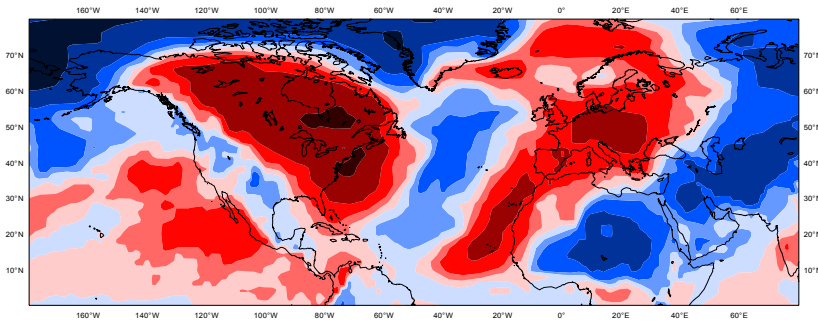


T850 anomalies – NDJFM 1989-2008

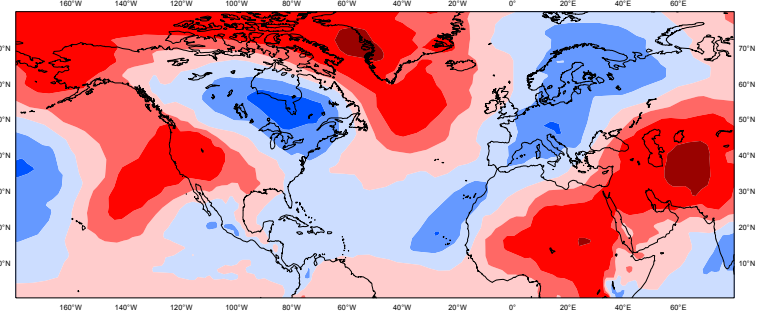
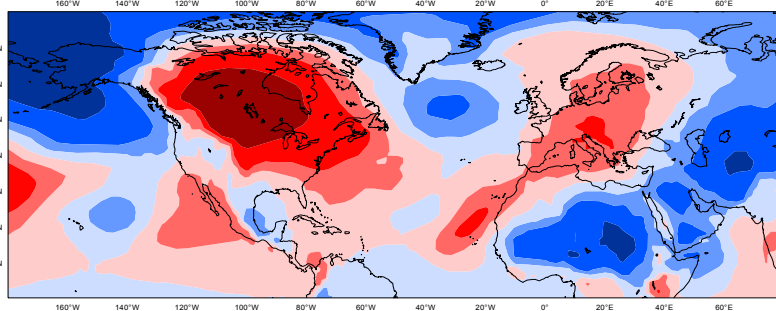
Phase 3 + 10 days

Phase 6 + 10 days

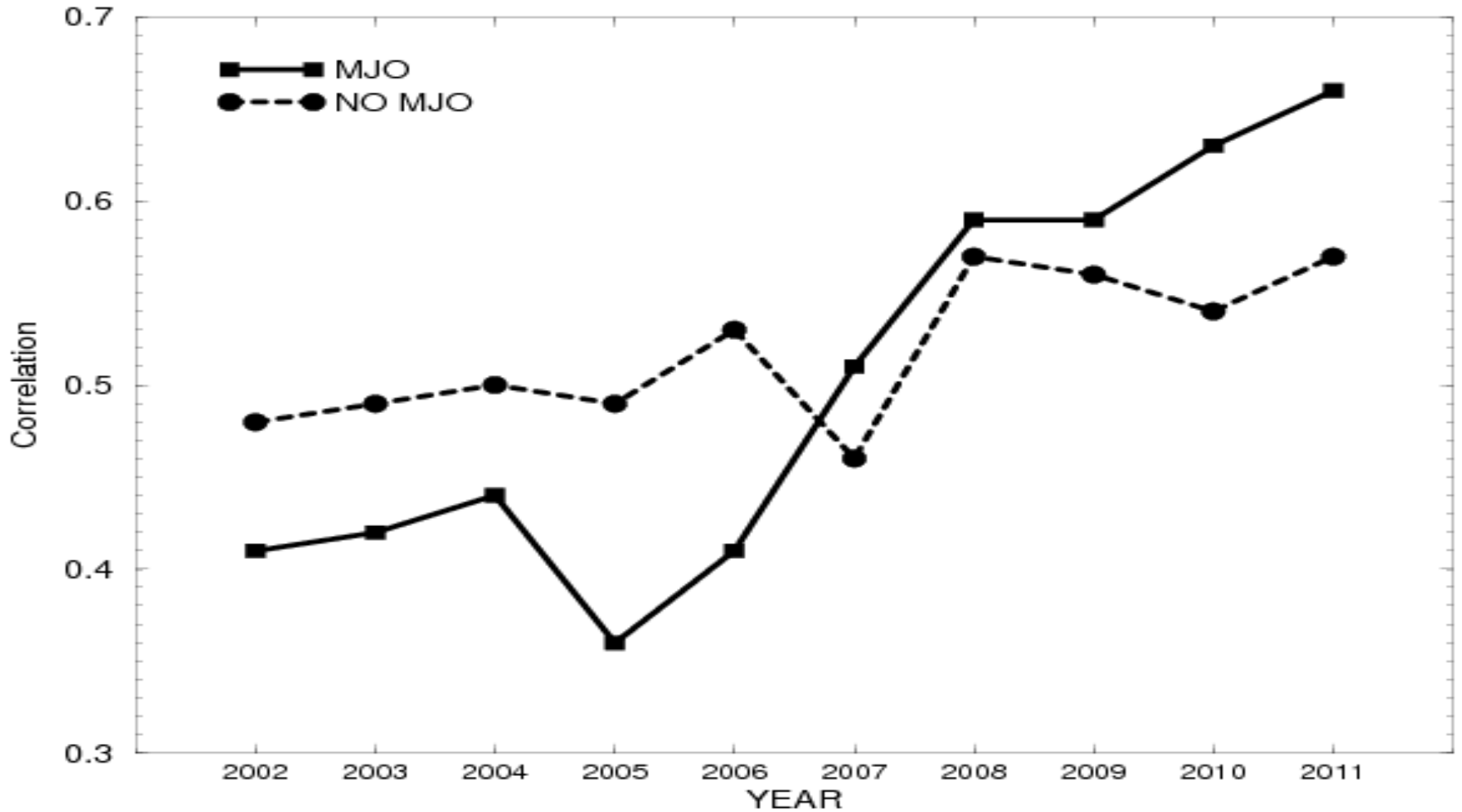
ERA



MODEL

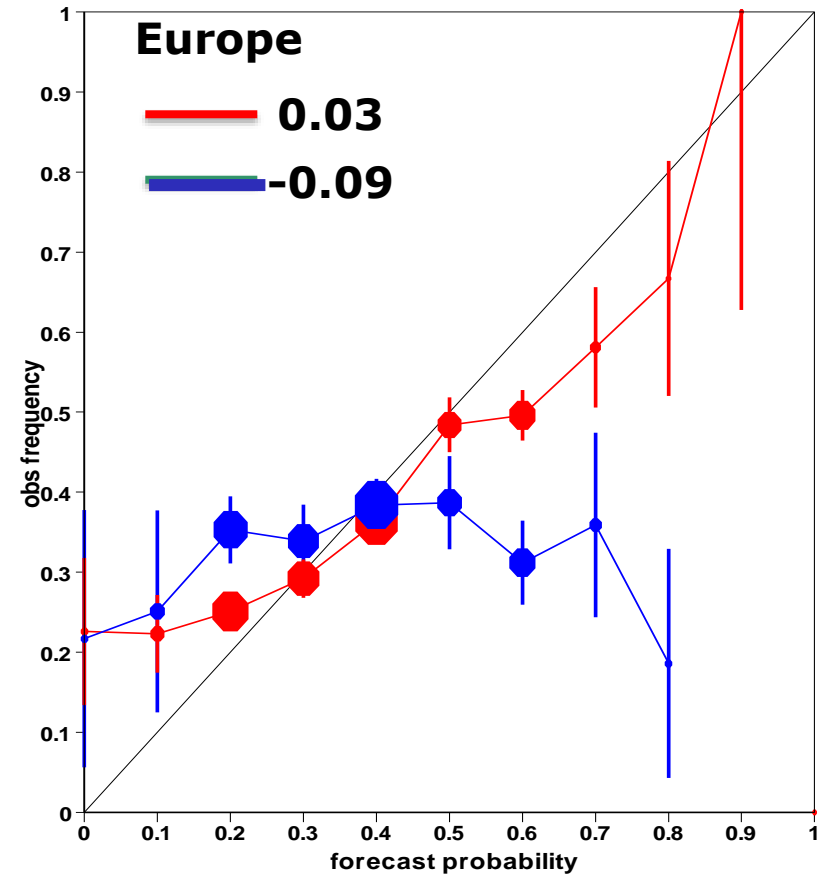
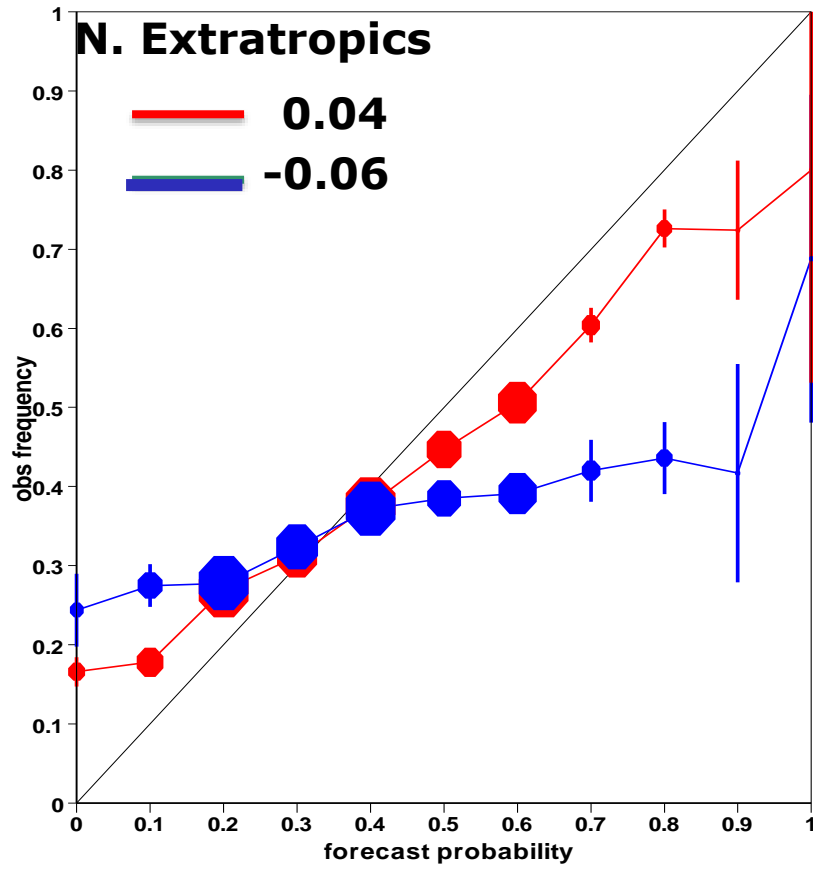


NAO skill scores – Day 19-25



Probabilistic skill scores – NDJFMA 1989-2008

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



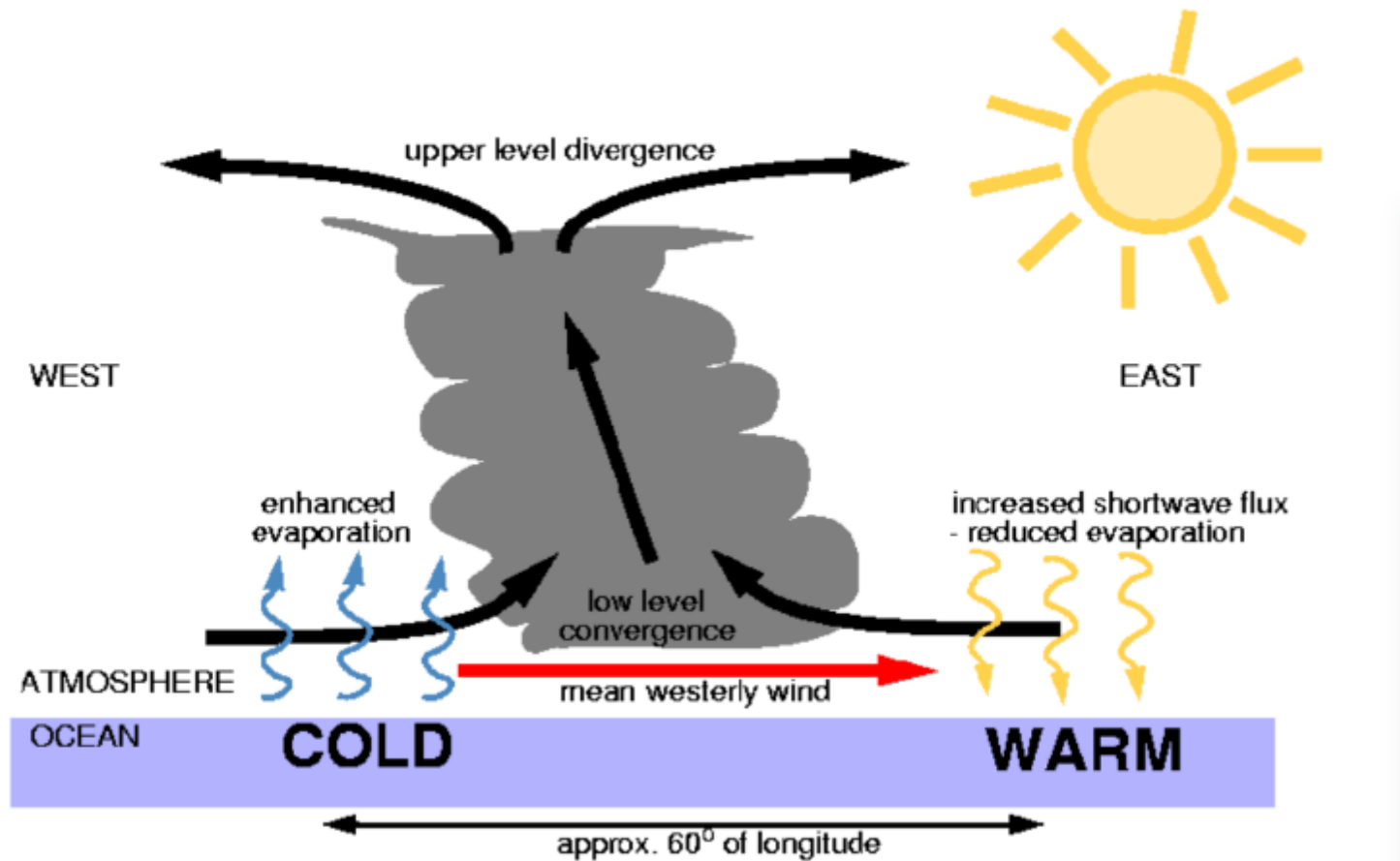
— MJO in IC **— NO MJO in IC**

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

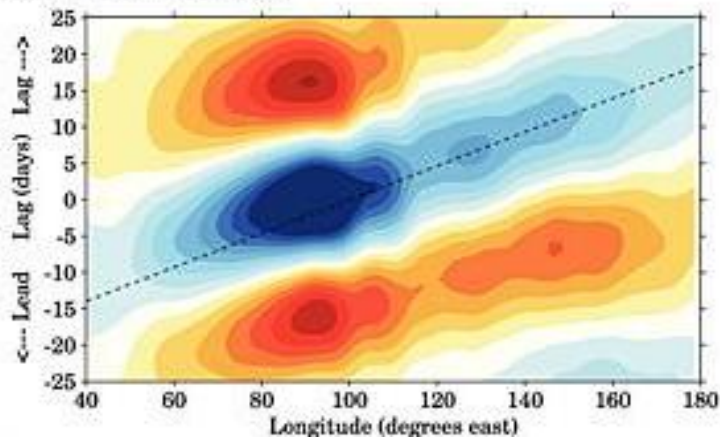
Air-sea Interaction

Air-sea interaction and the MJO

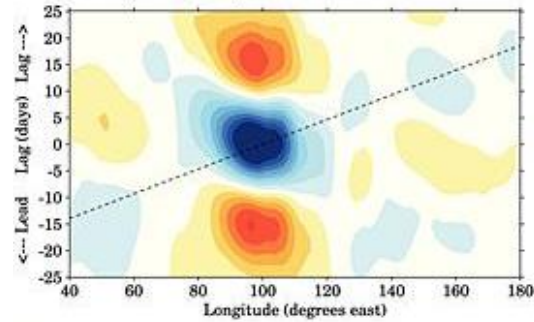


Courtesy: Pete Inness

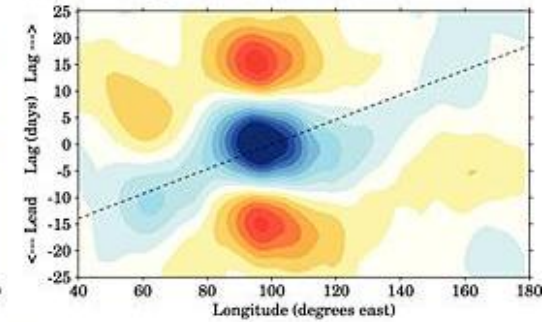
a. NOAA CIRES



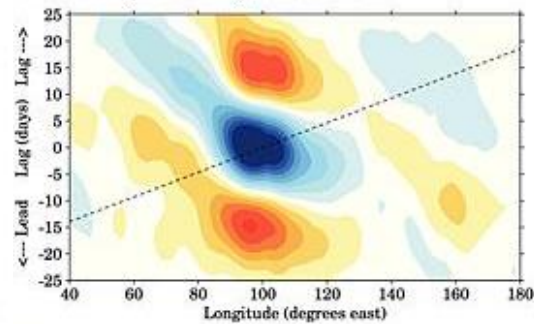
b. Atmosphere-only, observed SST



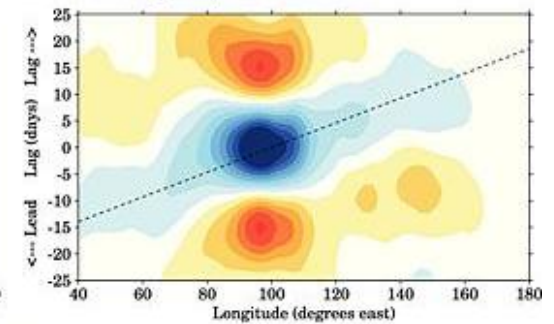
c. KPP-coupled, observed SST



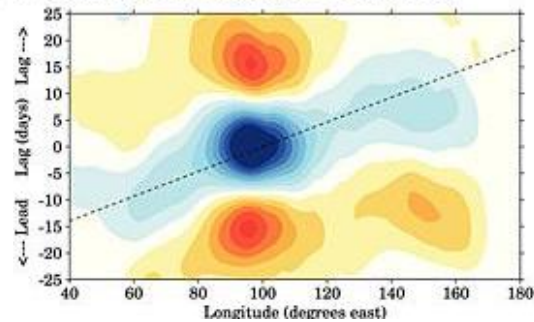
d. Atmosphere-only, CGCM SST



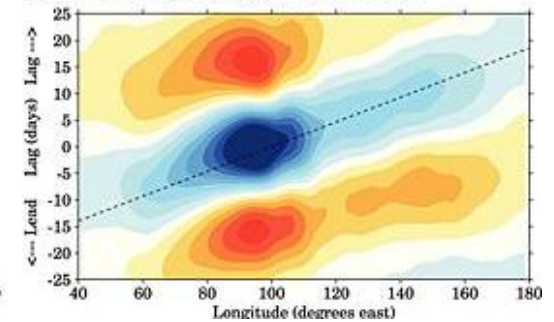
e. KPP-coupled, CGCM SST



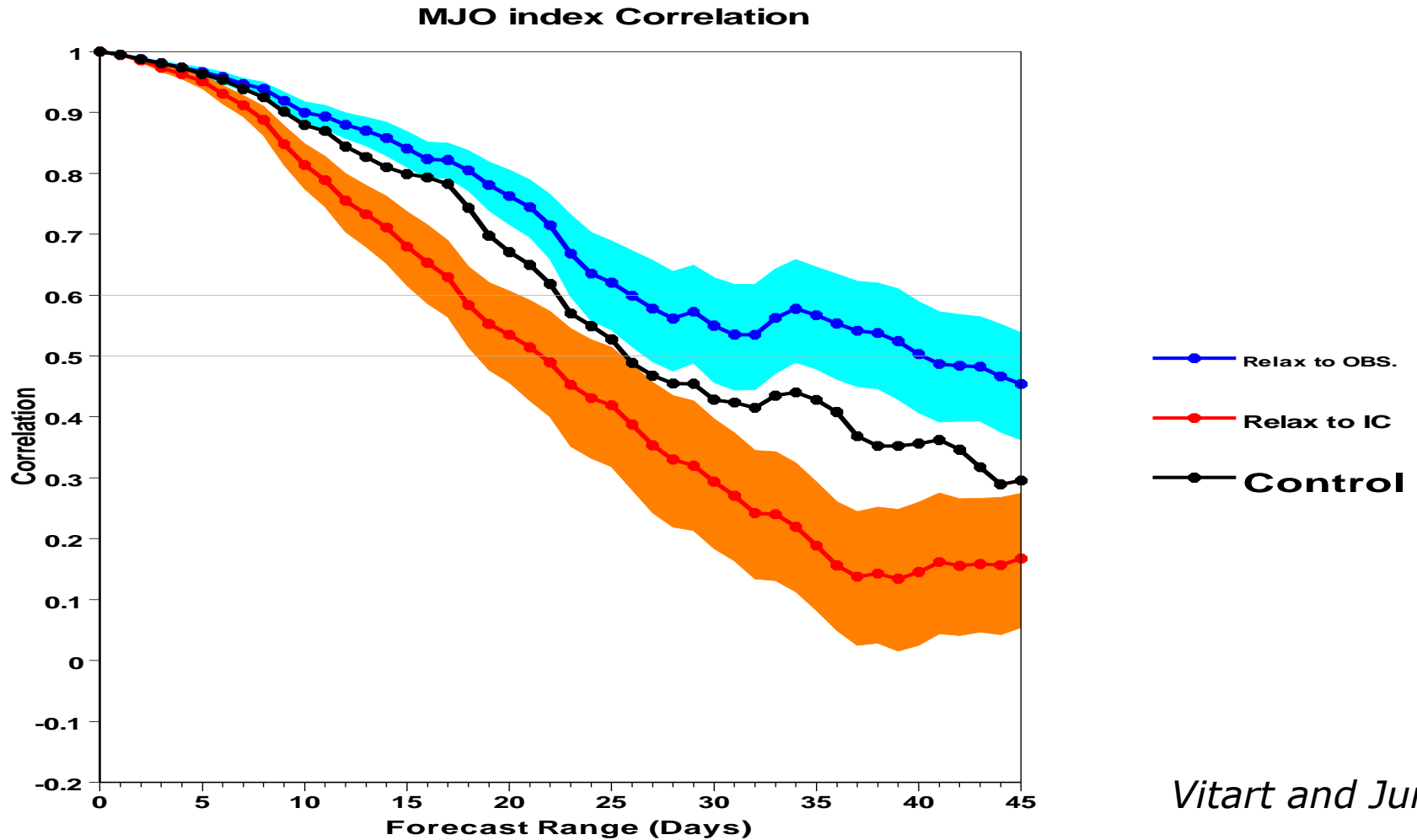
f. Atmosphere-only, high entrainment



g. KPP-coupled, high entrainment



Impact of N. Extratropics on MJO forecast skill

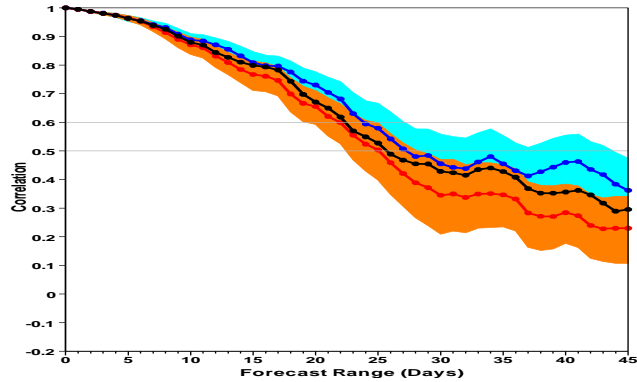


Vitart and Jung

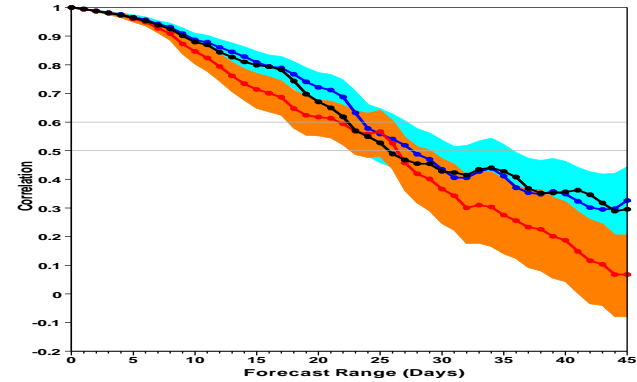
Impact of N. Extratropics on MJO forecast skill



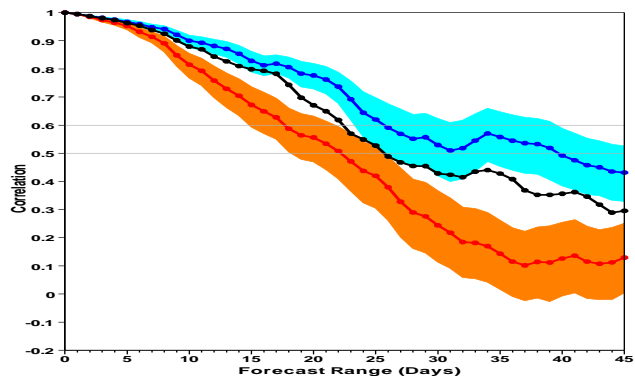
North Atlantic



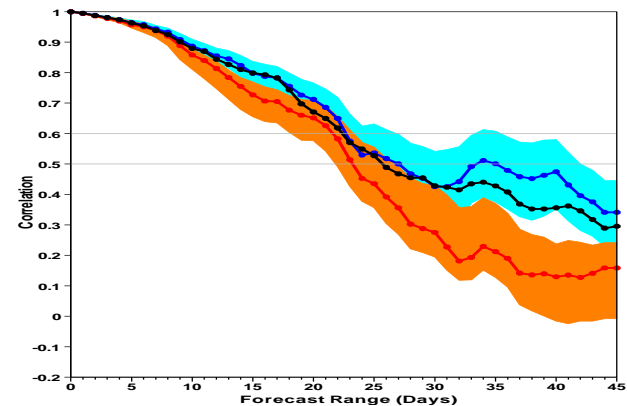
Eurasia



West Pacific



East Pacific



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