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# Sub-seasonal prediction of Tropical Cyclones


## Working Group

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Link: 8th WMO International Workshop on Tropical Cyclones (IWTC), Dec- 2014

# Main Progresses during the past 4-5 years

- Improved understanding of the impact of the intra-seasonal modes (MJO/BSISO, equatorial waves, MJO-ENSO) on TC activity.

- Improvement in the simulation and prediction of the intra-seasonal modes and its impact on TC activity.

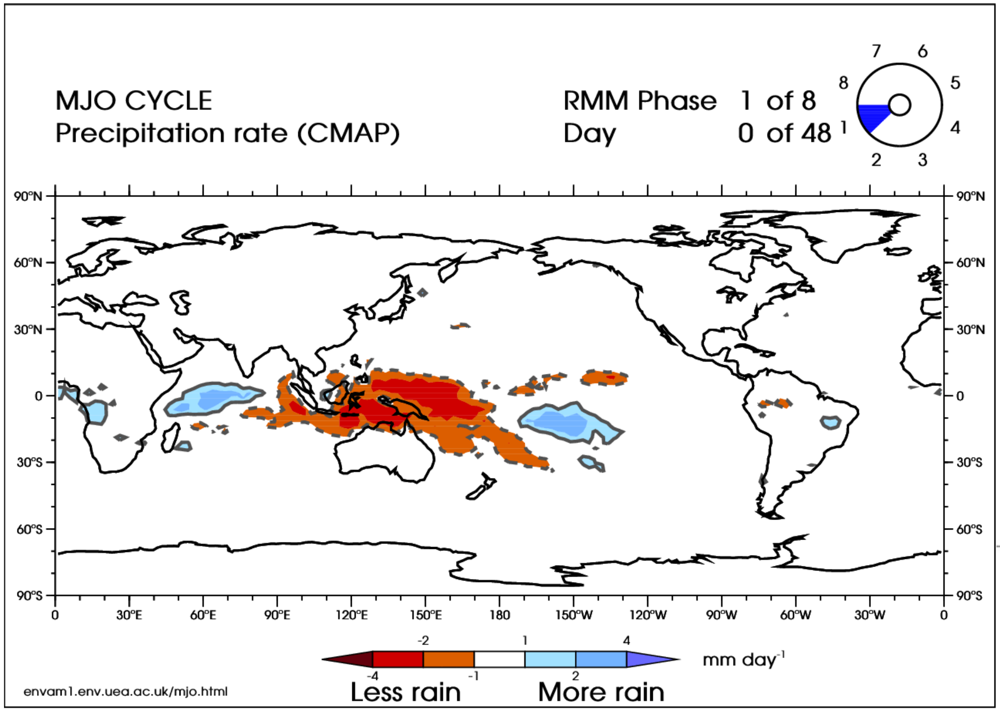
- Operational sub-seasonal TC forecasts.

# Main sources of intraseasonal TC predictability

- Madden Julian Oscillation (MJO)
- Boreal Summer ISO (BSISO)
- Equatorial waves
- Quasi-biweekly oscillation (QBWO)
- Combined effects (MJO-ENSO)

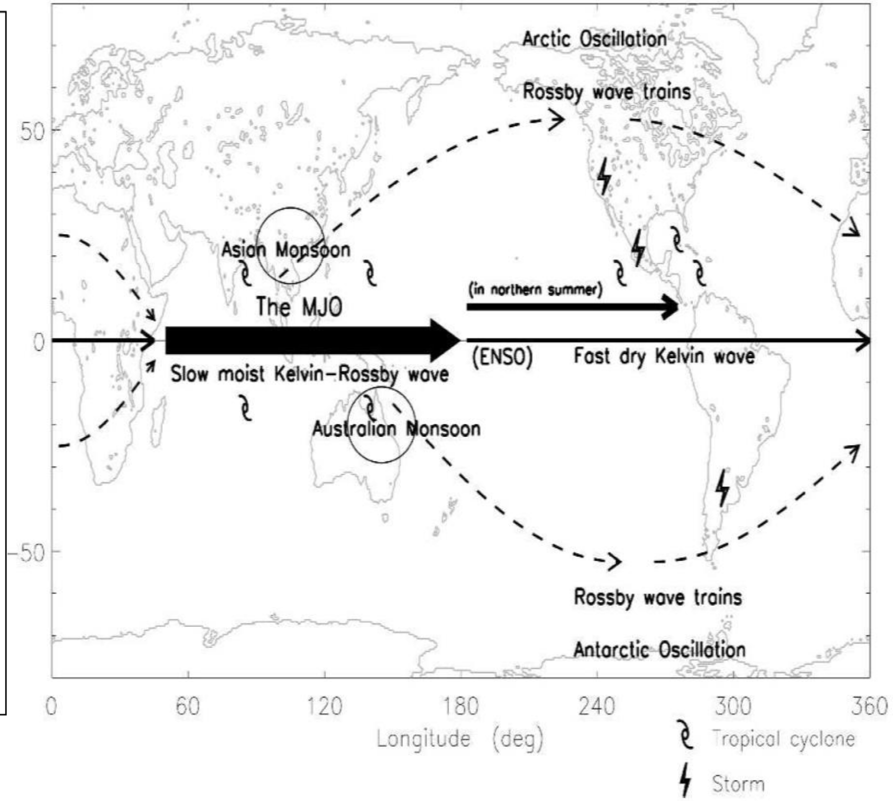
# Madden Julian Oscillation (MJO)

**MJO cycle: Precipitation**




Dr. Adrian Matthews webpage:
http://envam1.env.uea.ac.uk/mjo.html

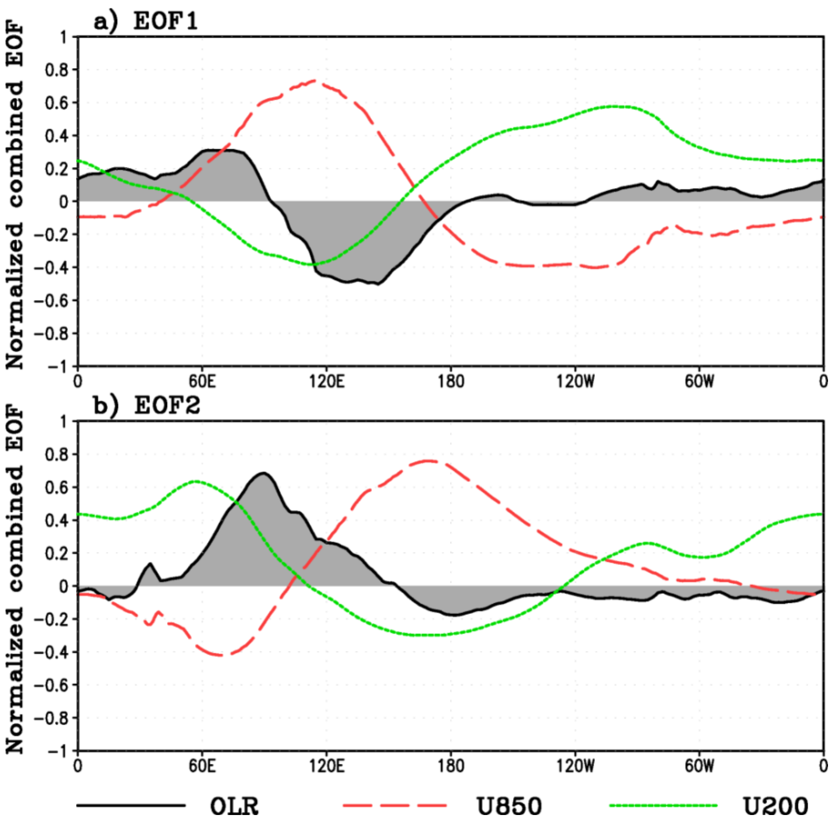
**MJO teleconnection**

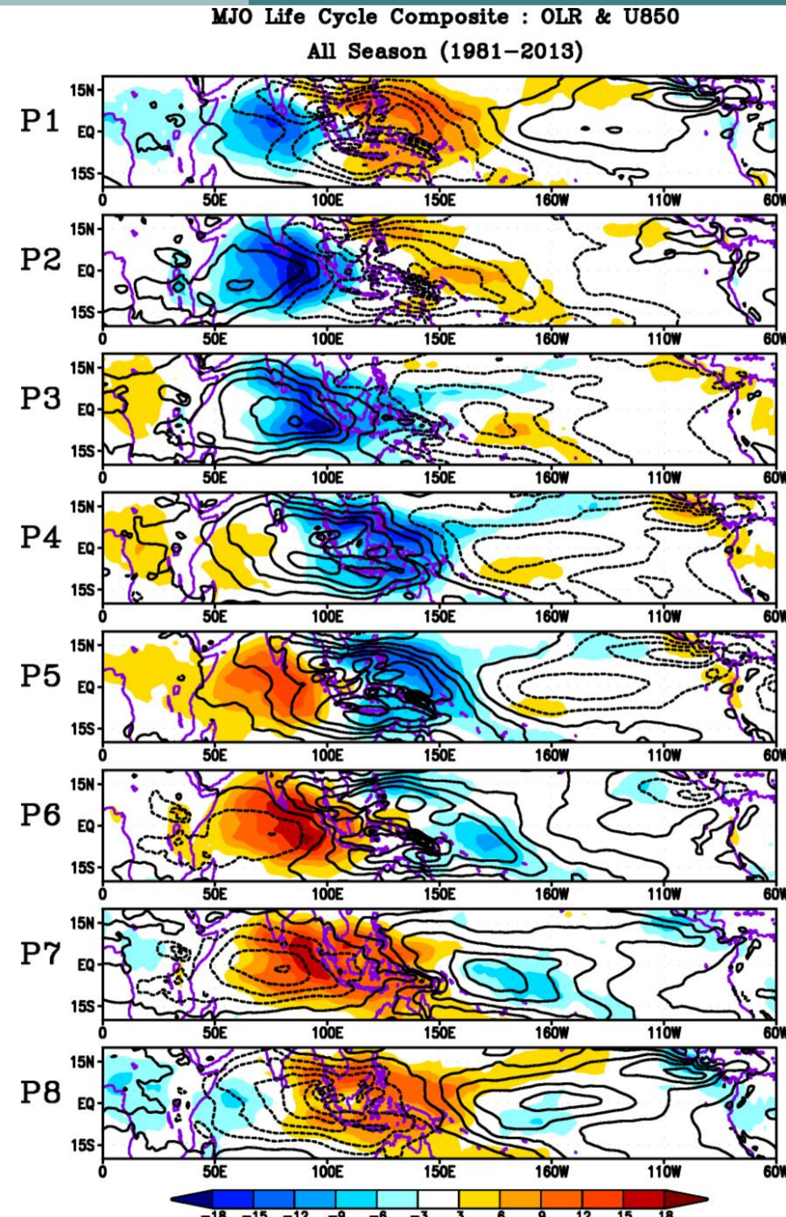



Lin et al. (2006)

# Definition of MJO

## Eigenvector of 1st and 2nd EOF



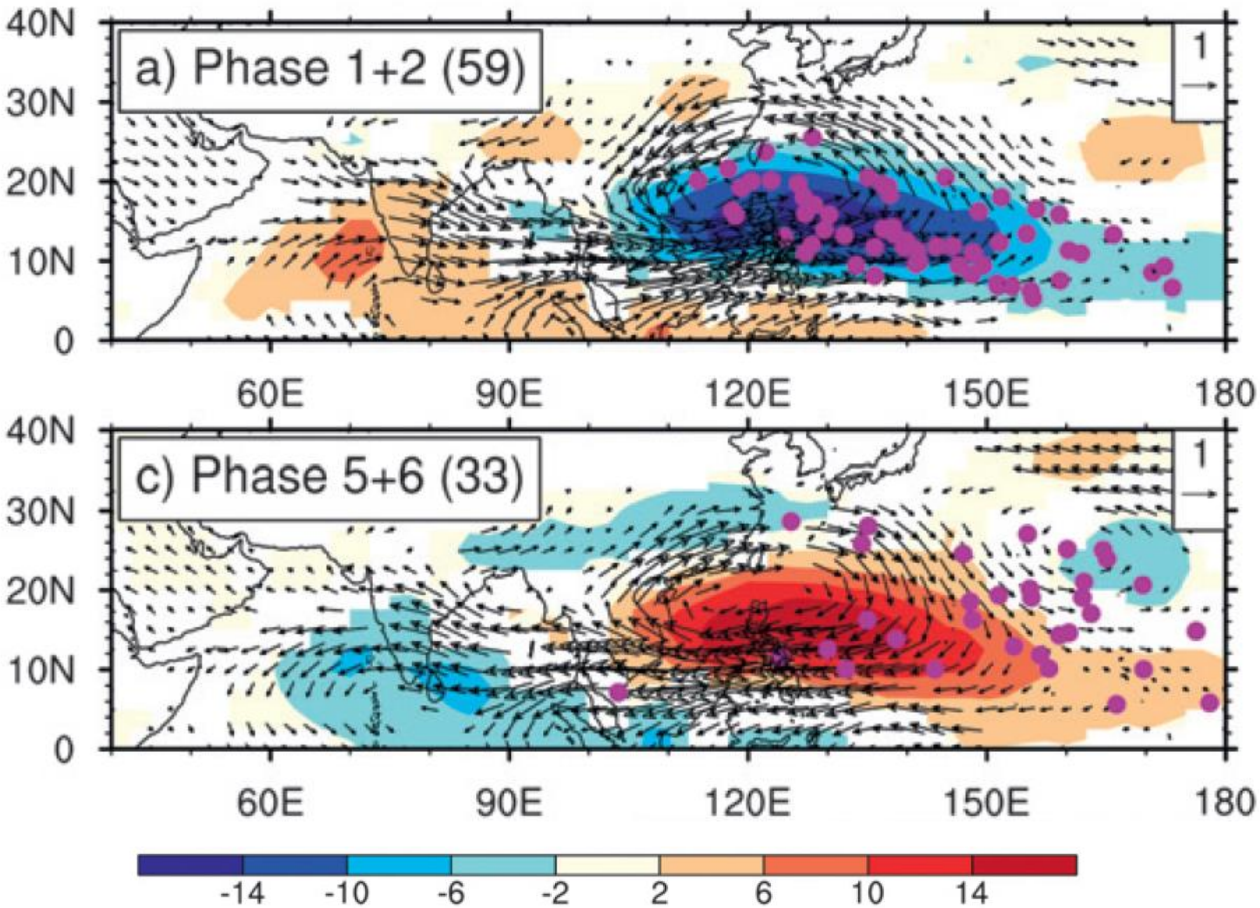

**Real-time Multivariate MJO (RMM) index, Wheeler and Hendon (2004)**

- Variables: 15°S-15°N mean OLR, u850, and u200 (unfiltered)
- Minimal prior removal of lower-frequency variability
- **The PCs of leading EOFs are RMM1 and RMM2**

# Western North Pacific: TC-MJO

## TC genesis

**OLR and 850-hPa wind anomalies (30–60-day filtered)**




● Cyclogenesis

Parenthesis: # of TCs

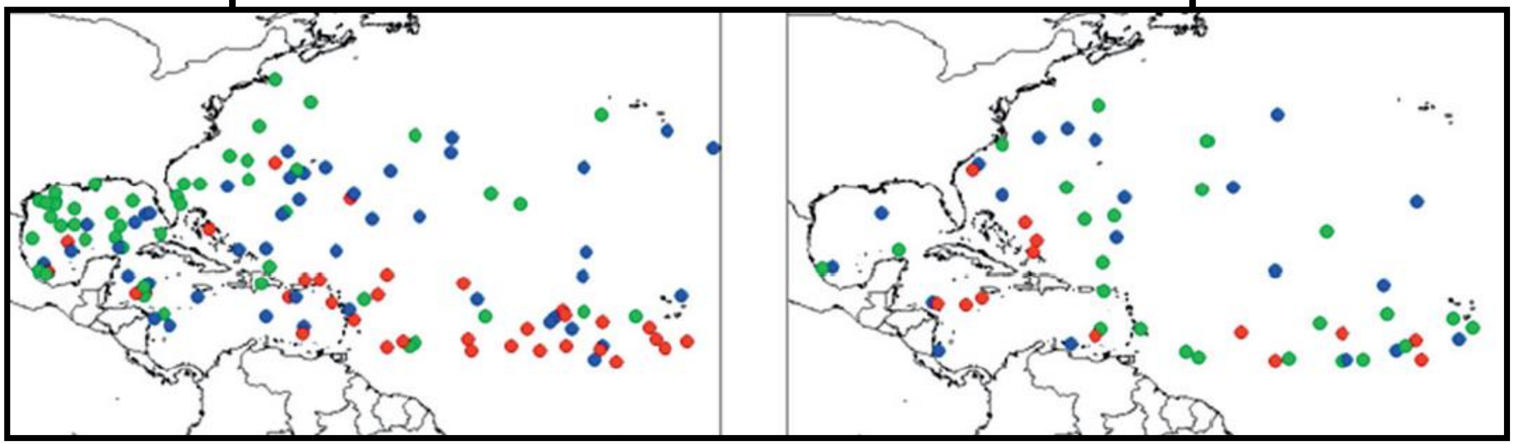
- Cyclogenesis is statistically enhanced in the convective phases of the MJO, while it is suppressed in the non-convective phases.

Li and Zhou (2013a)

# North Atlantic: TC-MJO

## Genesis locations for storms

**MJO phase 1-2** **MJO phase 6-7**



Green dots: storms <64 kt
Red dots: major hurricanes

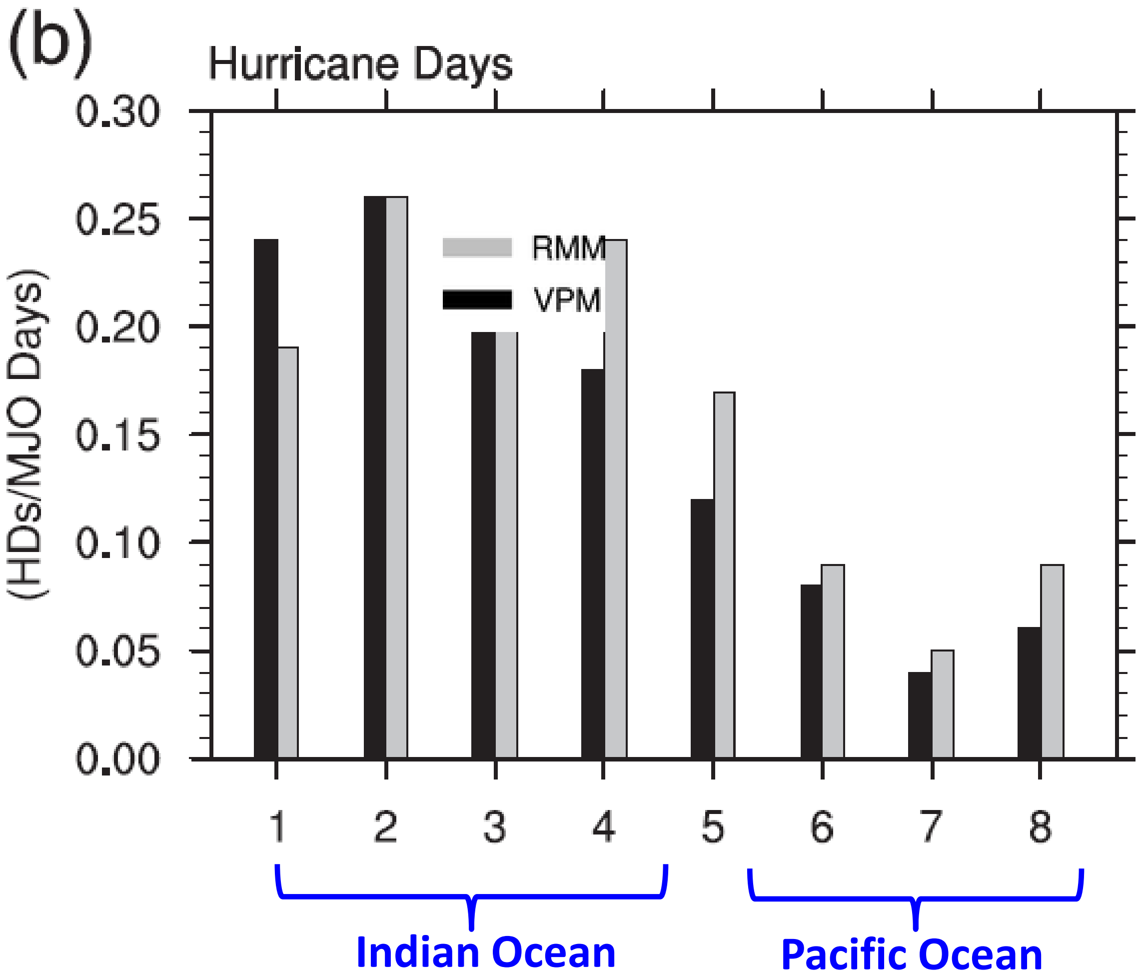
Klotzbach (2010)

General consensus is that TC activity in the Atlantic is enhanced in MJO Phases 1-3, while it is suppressed in MJO Phases 5-7

(Maloney and Hartmann 2000, Camargo et al. 2009, Belanger et al. 2010, Klotzbach 2010, 2014, Ventrice et al. 2011, 2013)

Klotzbach and Oliver (2015)

# North Atlantic: TC-MJO

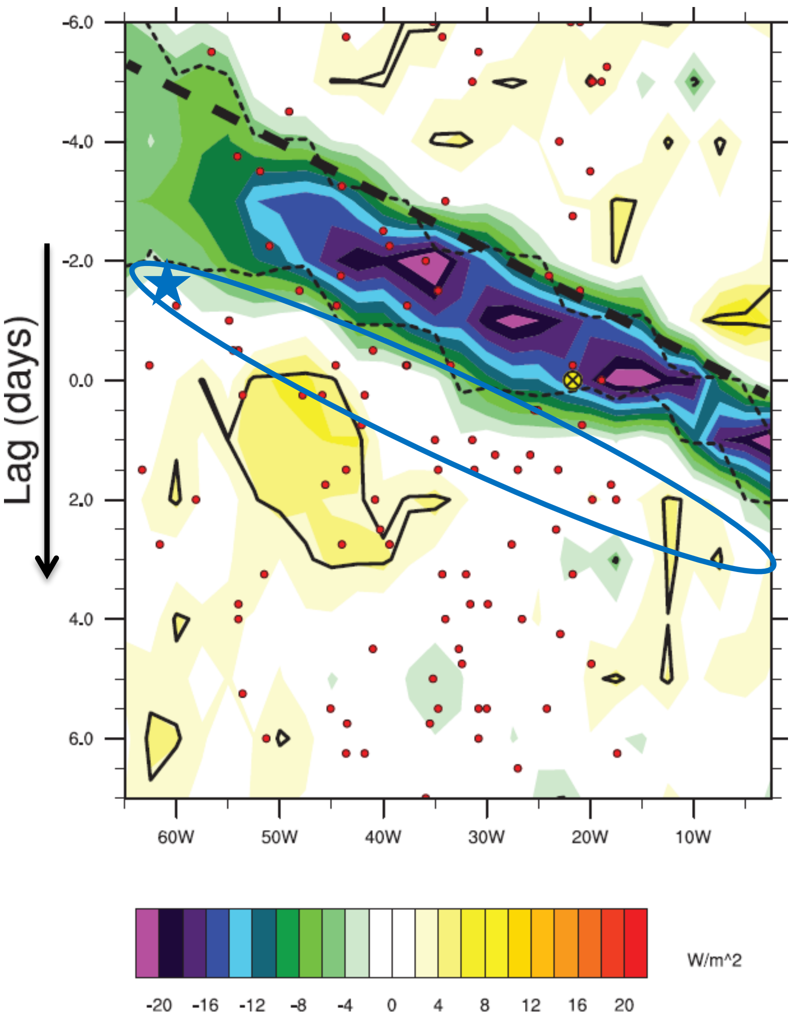



- Hurricanes are four times more likely when the MJO is located over the Indian Ocean than over the Pacific.

Ventrice et al. (2013)

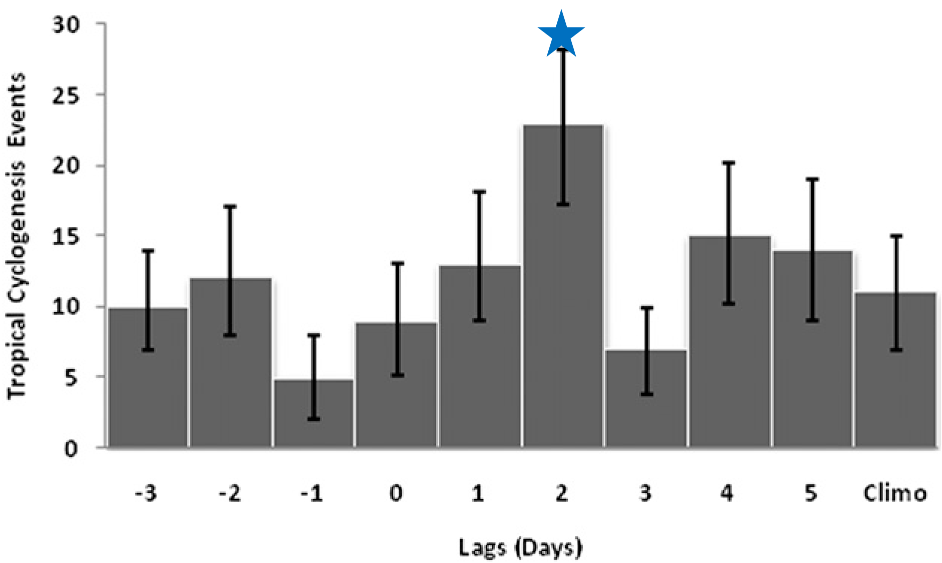
# North Atlantic: TC-CCKW

## OLR anomaly composite (1979-2009)




Shading: OLR anomalies averaged along 10°N
Dot: Tropical cyclogenesis

## Tropical cyclogenesis relative to the Kelvin wave




- While tropical cyclogenesis can occur within the convective envelop of the CCKW, it is most often observed approximately 2 days after its passage.

Ventrice et al. (2012)

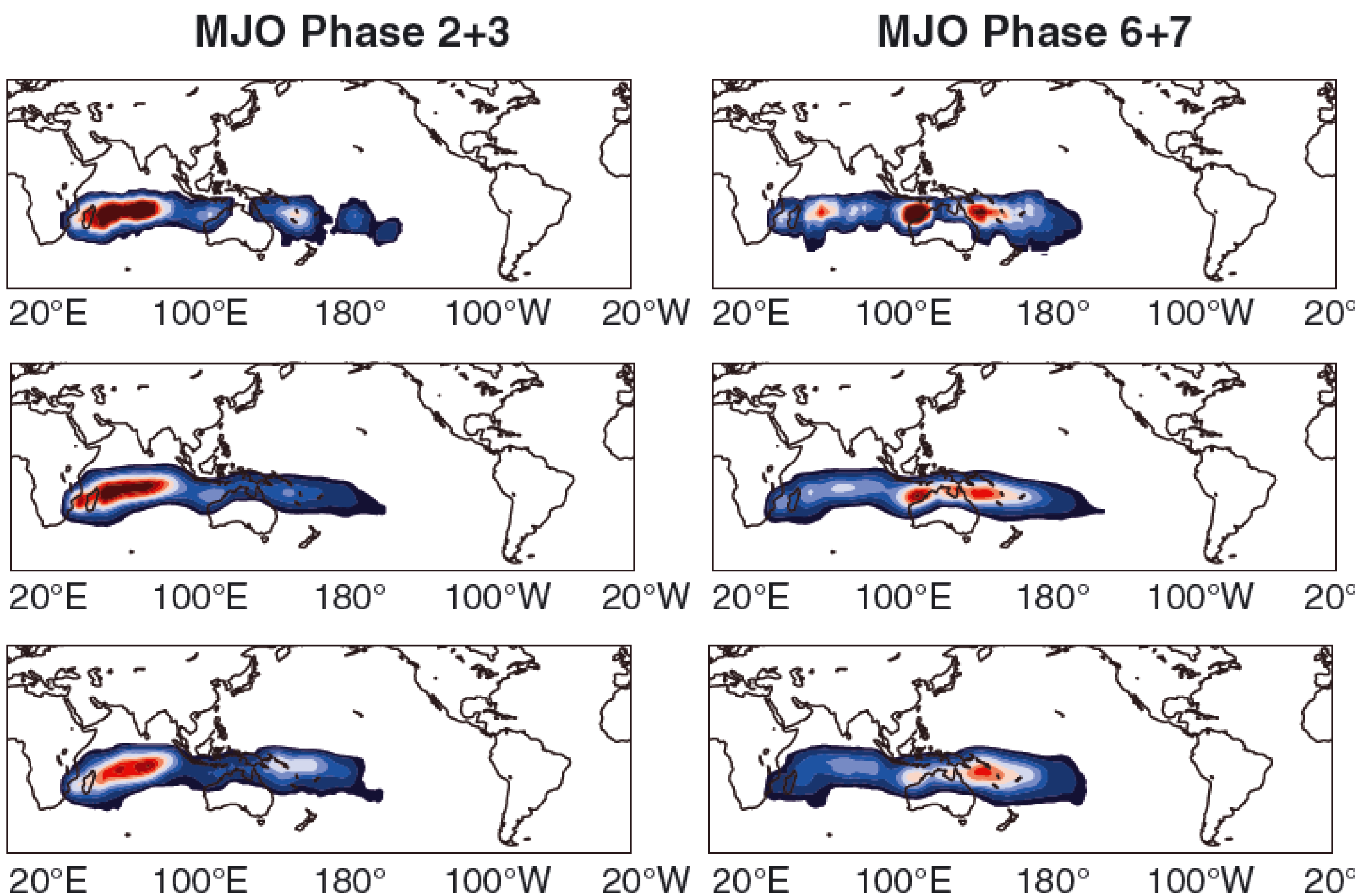
# Simulation: ECMWF

## Tropical storm density (Oct-Mar, 1995-2001)

**Observation**

**Reforecast produced in 2011**

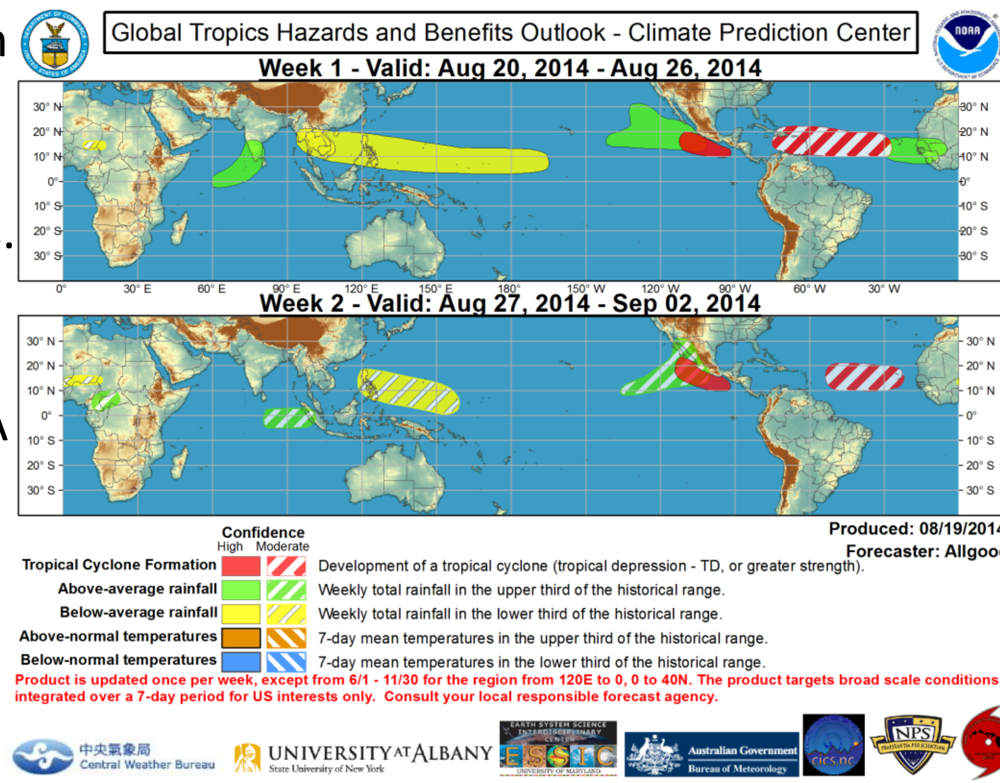
**Reforecast produced in 2002**




Vitart (2014)

# Sub-seasonal TC forecasts: NHC

- **Week 1-2 forecast**: NHC participates in the CPC's bi-weekly Global Tropical Hazards Assessments by providing guidance on the likelihood of TC genesis.
- Predictand: TC genesis
- Major tools: MJO forecasts from NOAA CPC, long-range ECMWF and GEFS ensemble forecasts, CCKW, circulation anomalies, climatology.
- Forecast process is largely subjective and relies on large-scale pattern (MJO).

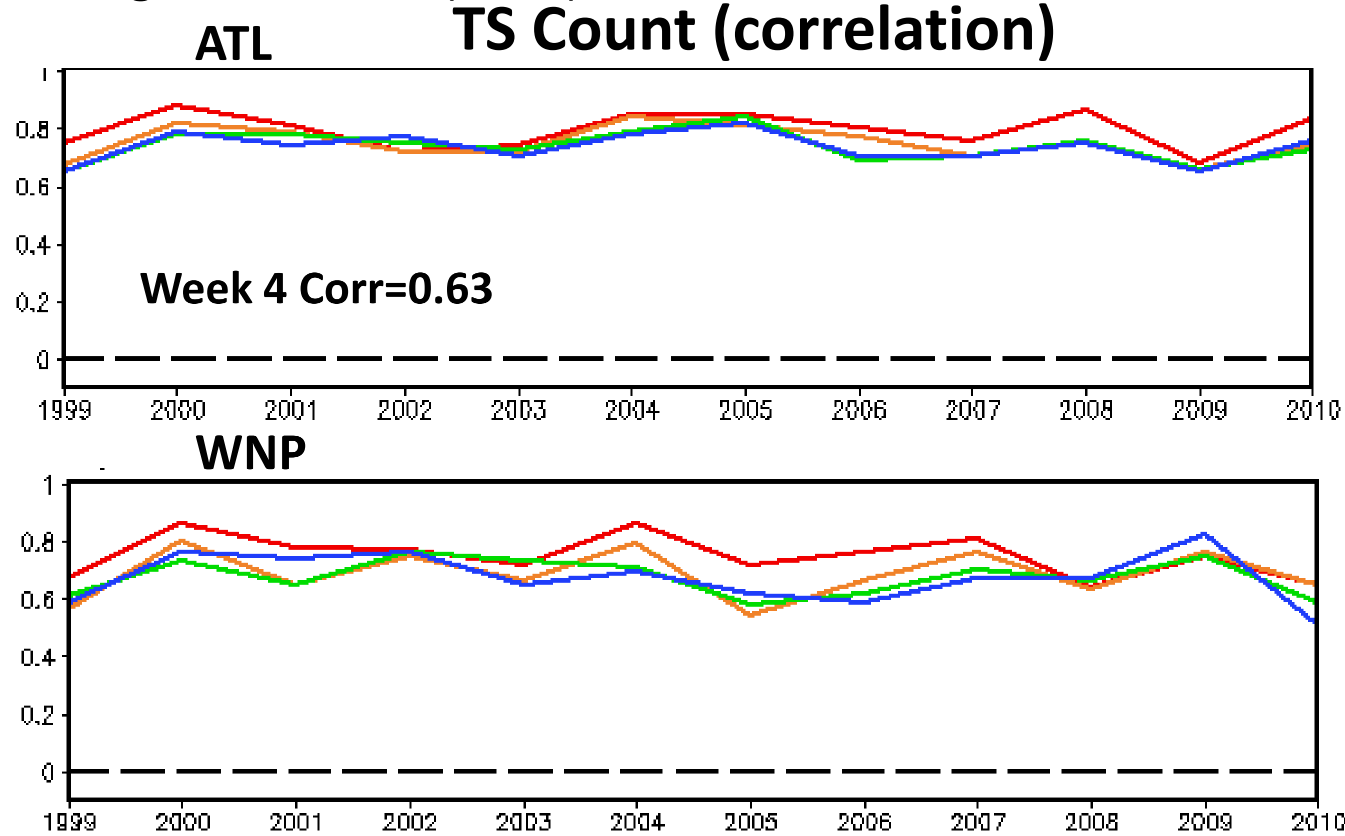



http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ghazards/ghaz.shtml

# NOAA/CPC

- **Week 1-4 forecast**: Global basins (provide an input for the Global Tropical Hazards Outlook )
- Predictand: Number of storms, track location
- Major tools: CFSv2 16-member ensemble forecasts produced daily
- TC detection/tracking: Camargo and Zebiak (2002)

## TS Count (correlation)


- CFSv2 45day hindcasts (1999-2010)

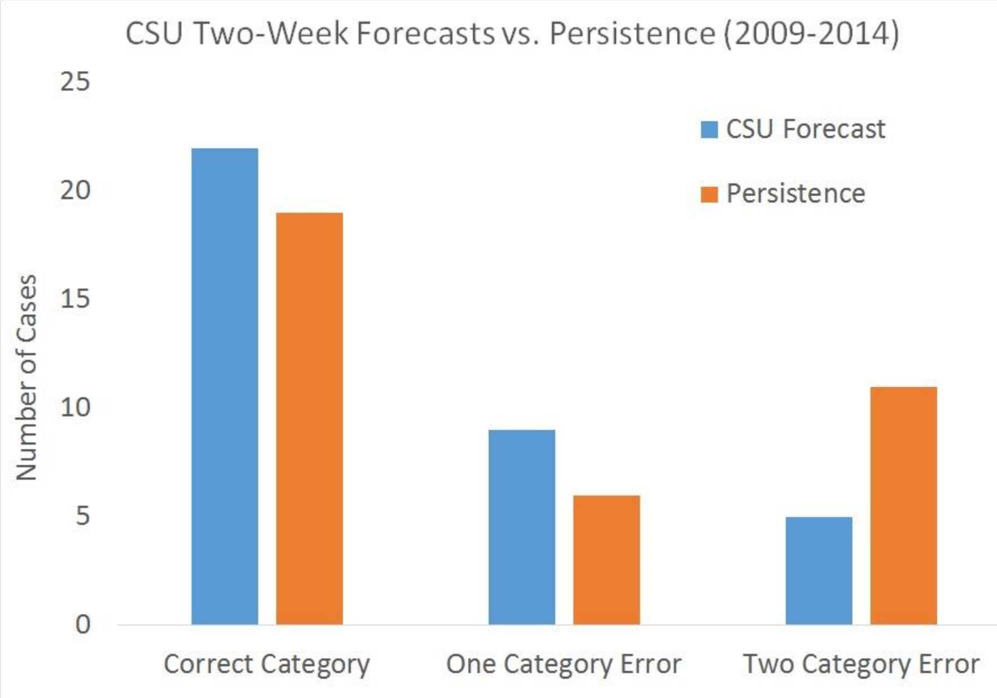
# Tropical Meteorology Project (CSU)

- **Two-week forecast**: North Atlantic (since 2009)
- Predictand: ACE during two-weeks target period
- Major tools:

  **< 7days**: Pre-existing storm activity, NHC tropical weather outlooks, TC predictions from global models

  **8-14 days**: MJO prediction
- 32 % improvement over persistence.

**Two-week Forecasts**



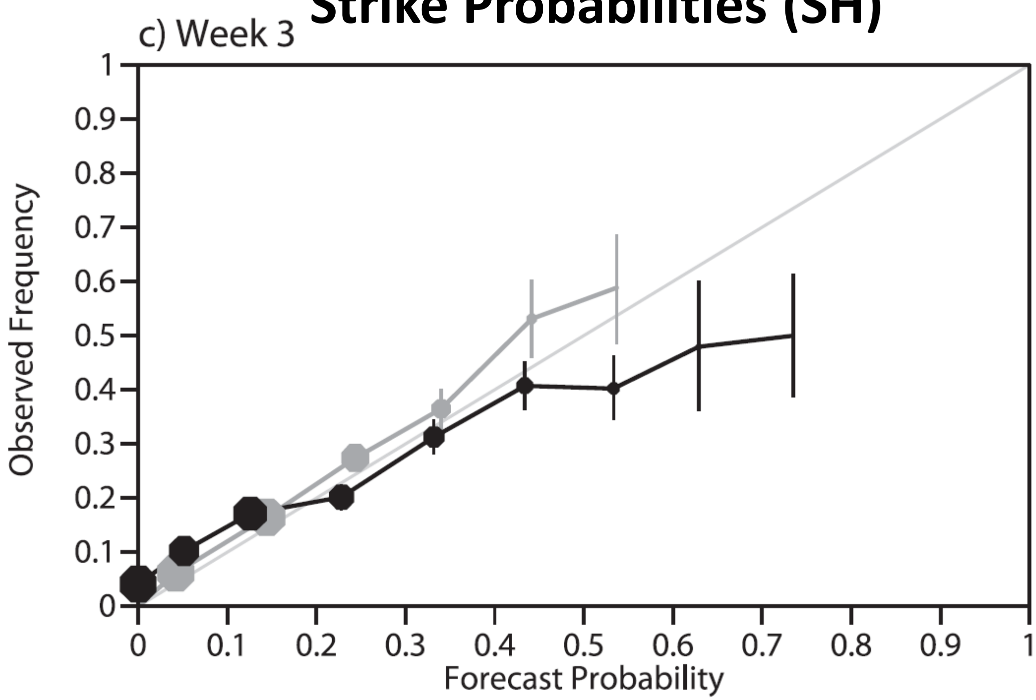

** Courtesy of P. Klotzbach*

http://hurricane.atmos.colostate.edu/

# ECMWF

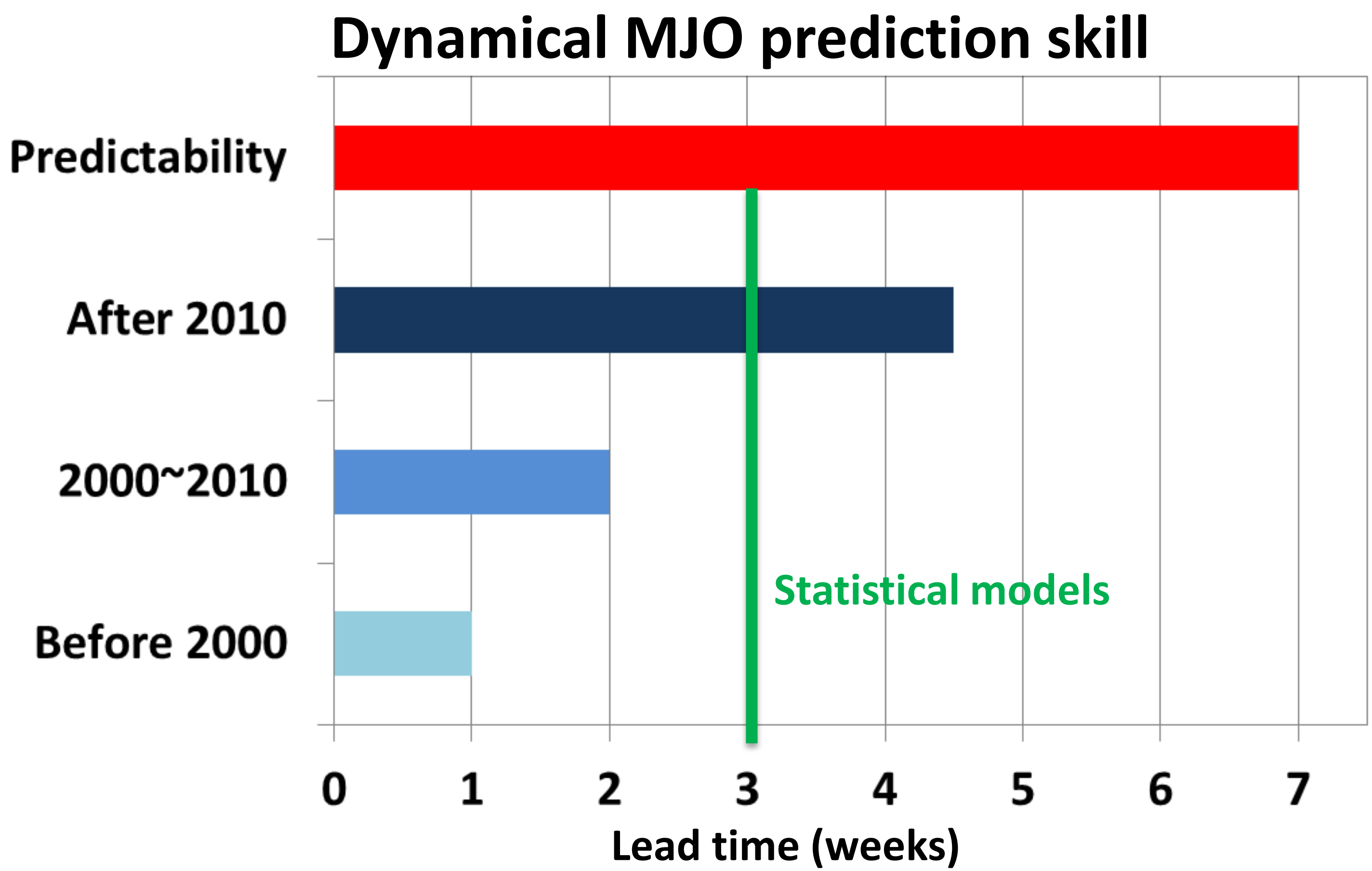
- **Week 1-4**, Global basin (since 2010)
- Frequency: Twice a week (Mon/Thu)
- Predictand: Strike probability (probability of a TC passing within 300 km), ACE, number of TCs, hurricanes, depressions
- Major tools: ECMWF 32-day sub-seasonal forecasts (Vitart et  al. 1997, 2003).

**Strike Probabilities (SH)**



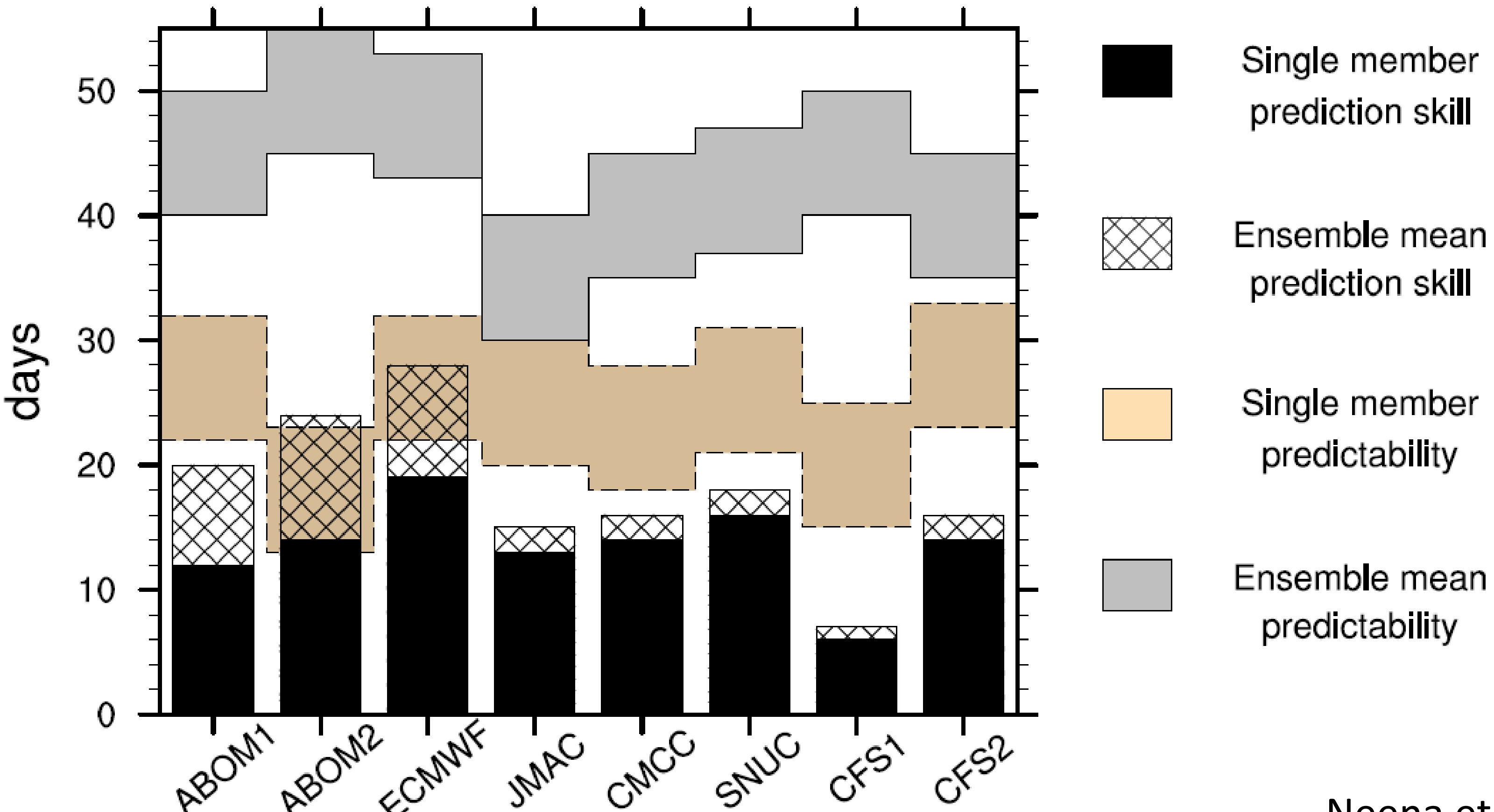

Vitart et al. (2010)

# Capability of MJO forecast




(Chen and Alpert 1990, Jones et al. 2000, Hendon et al. 2000, Waliser et al. 2003, Seo et al. 2005, 2009, Pegion and Kirtman 2008, Lin et al. 2008, Vitart and Molteni 2010, Weaver et al. 2011, Arribas et al. 2011, Fu et al. 2011, 2013, Rashid et. al.,2011, Kang et al. 2013, Ham et al. 2013, Kim et. al. 2014, Neena et al. 2014, Vitart 2014, Wang et al. 2014)

# Capability of MJO forecast




~ 2 weeks

~ 2-4 weeks

~ 3-5 weeks

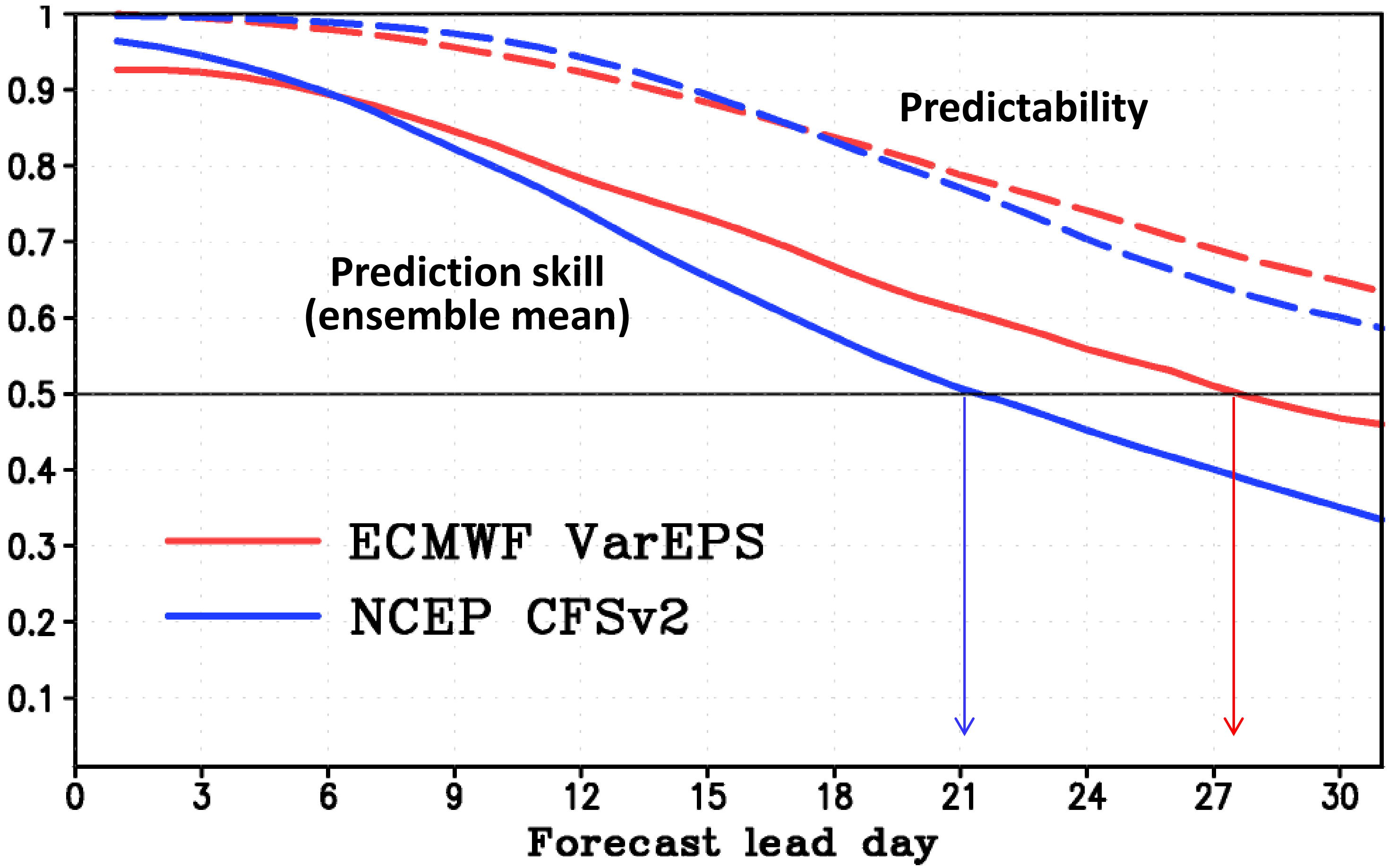
~ 5-7 weeks

Neena et al. (2014)

* ISVHE (Intraseasonal Variability Hindcast Experiment)

# Capability of MJO forecast

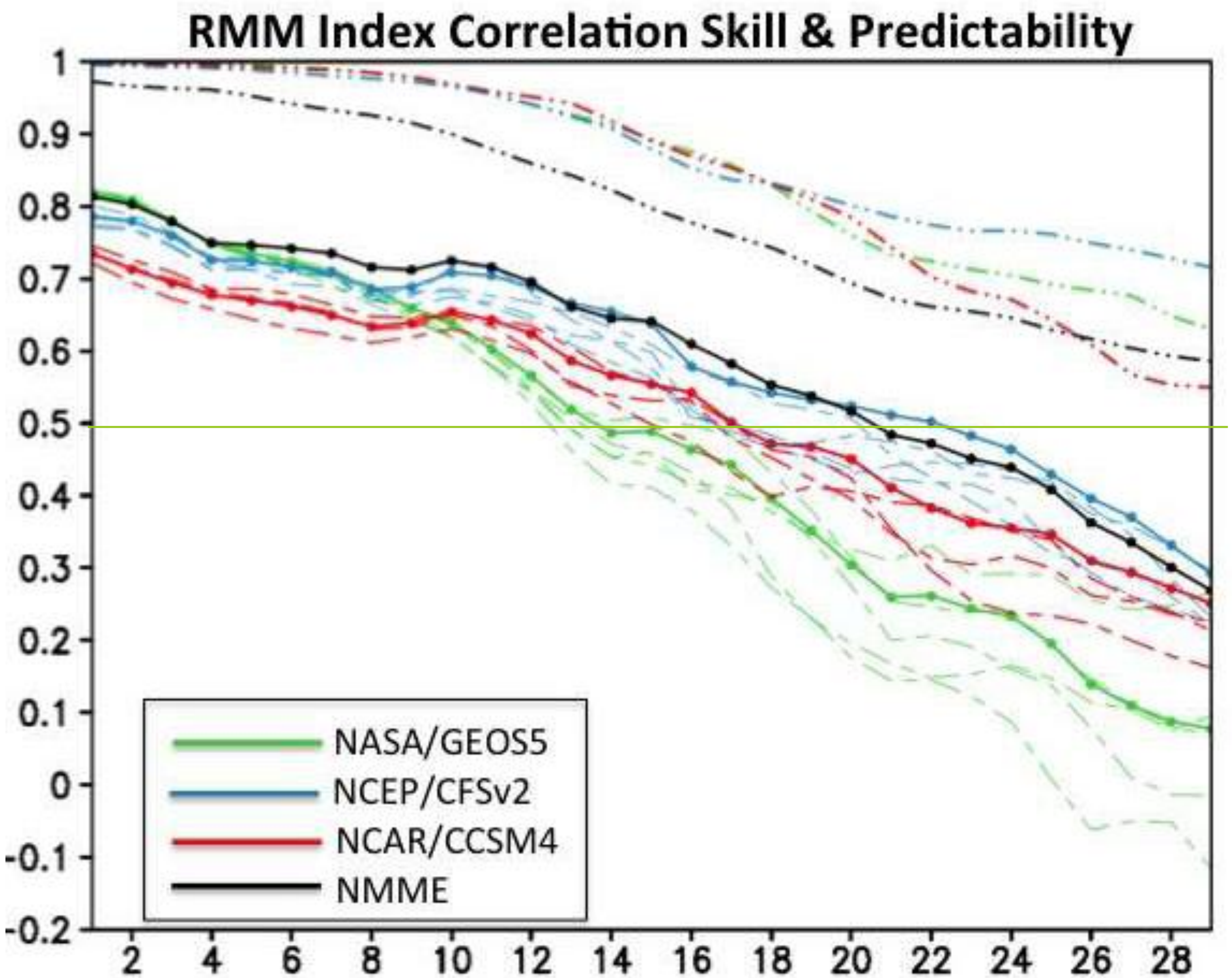
## MJO prediction skill (RMM index)




Kim et al. (2014)

# Capability of MJO forecast

## MJO prediction skill




**NMME Subseasonal Experiment**

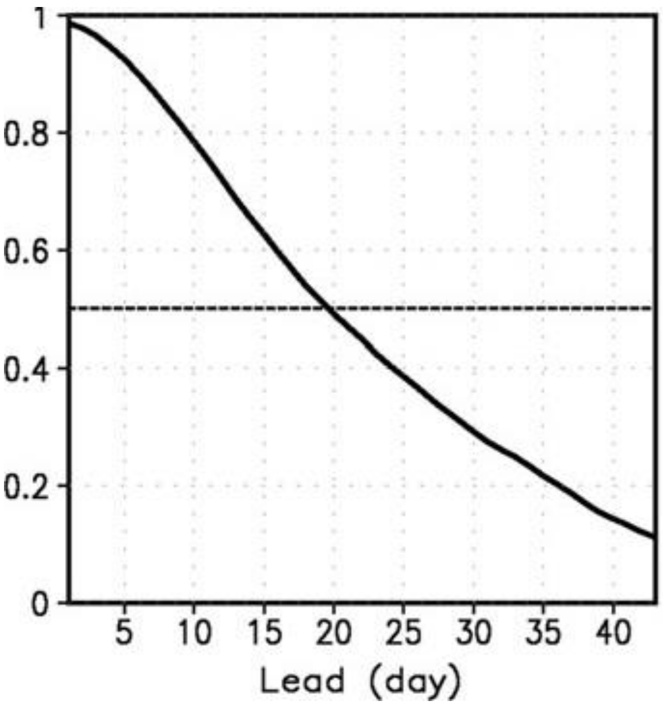
(1999-2012, Initialization Dates: November only on the 2, 7, 12, 17, 22, 27th)

*Source: S2S NMME workshop, K. Pegion*

# Capability of MJO forecast

## MJO prediction skill (RMM index)

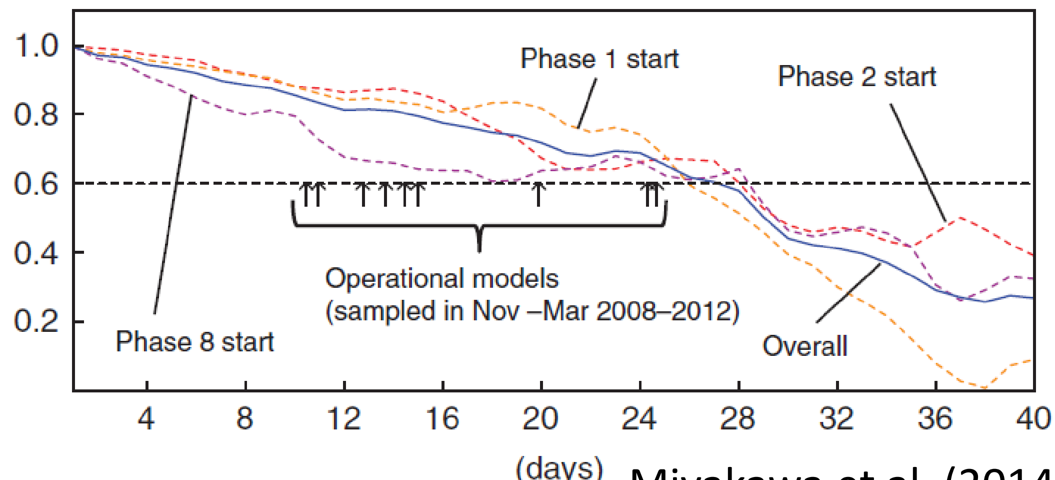
### NCEP CFSv2




(Wang et al. 2014)

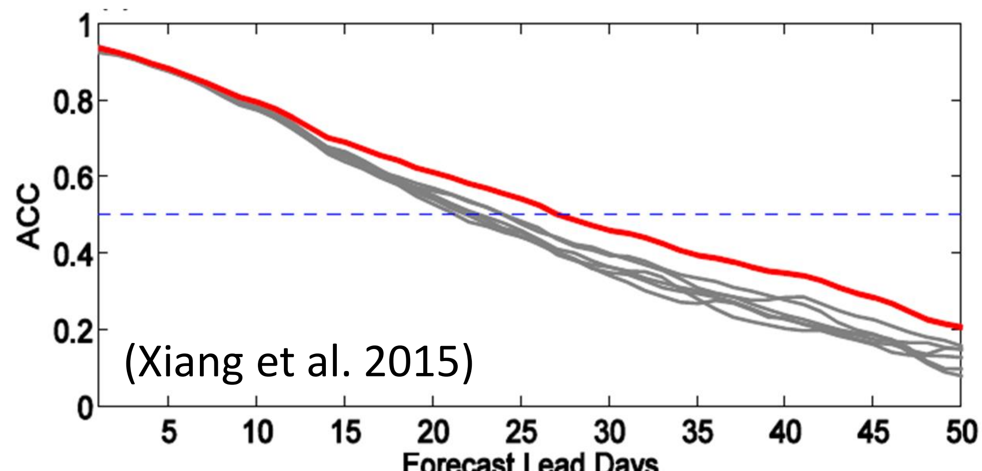
CFSv1 : ~15 days
(Seo et al. 2009)

### NICAM



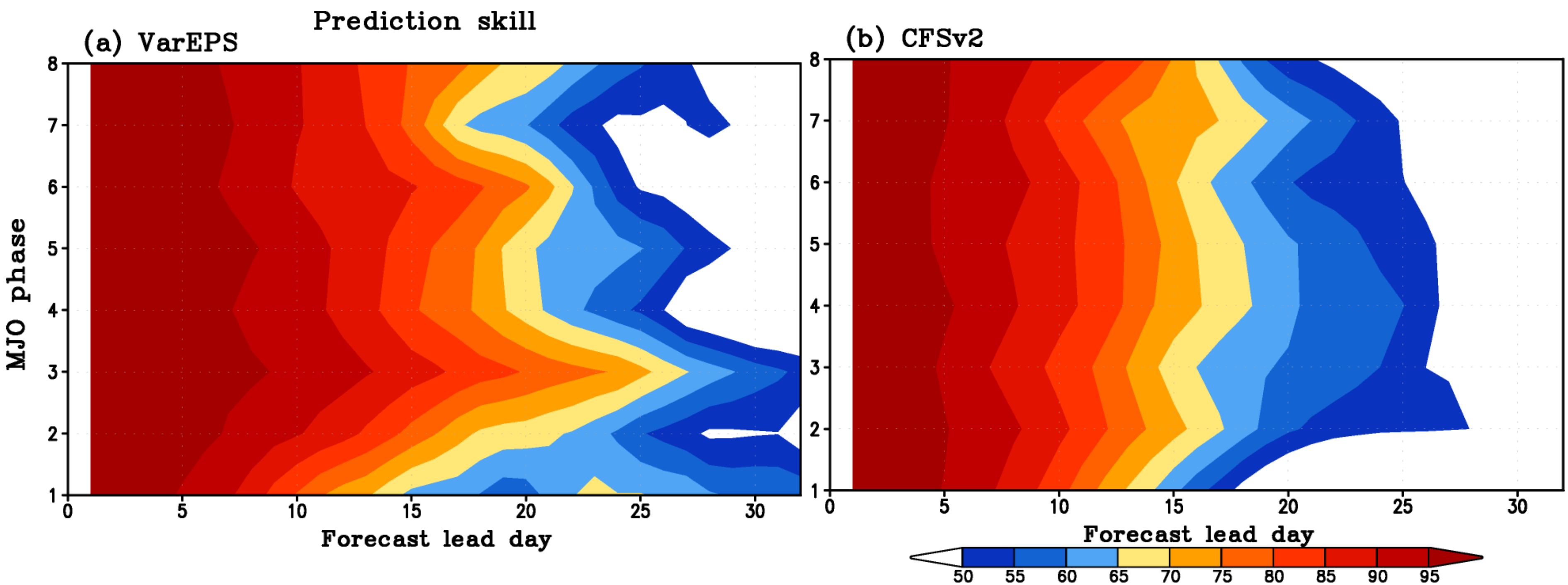

Miyakawa et al. (2014)

### GFDL FLOR




(Xiang et al. 2015)

# Prediction skill by initial MJO phase

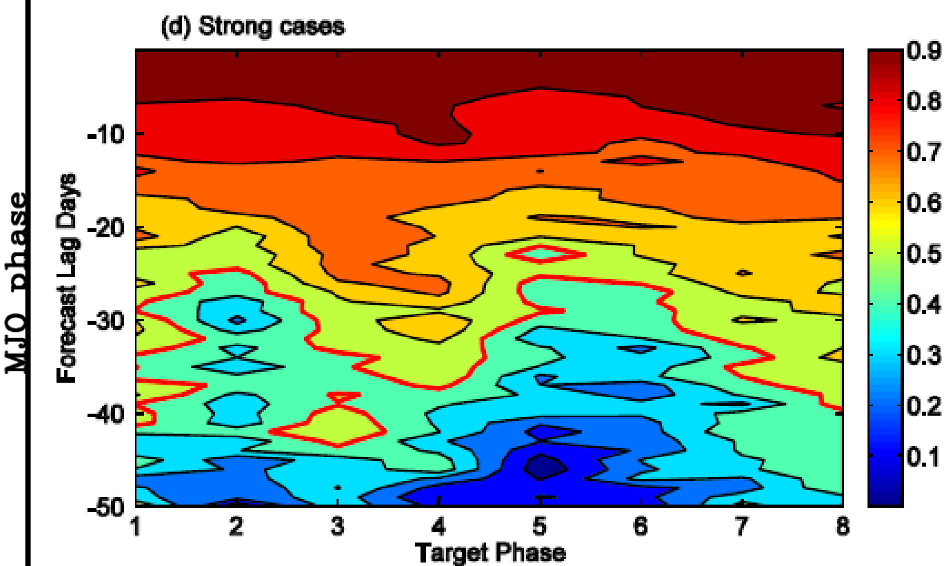



- Skill decreases relatively quickly in phase 1

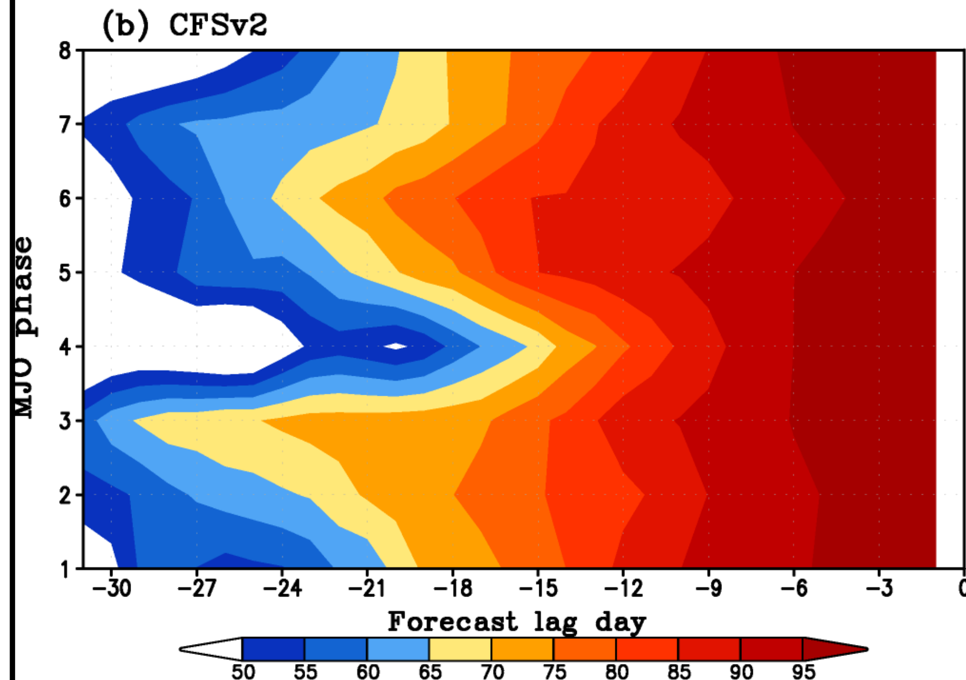
Kim et al. (2014)

# Prediction skill by target MJO phase

GFDL FLOR



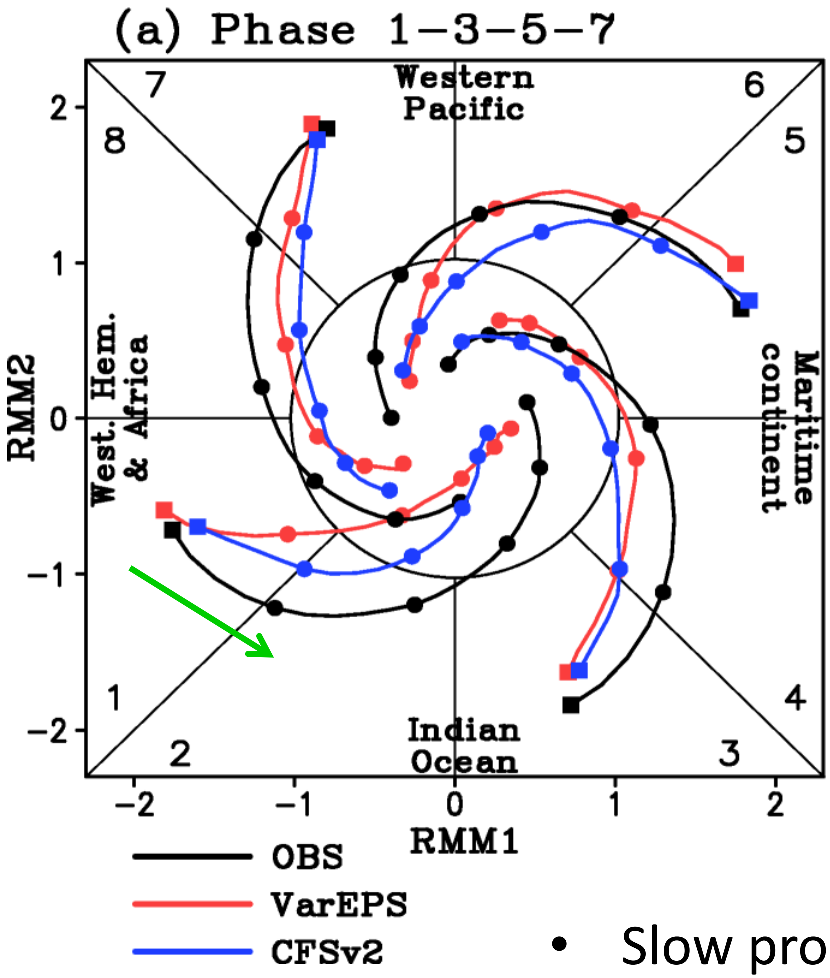

(Xiang et al. 2015)




Kim et al. (2014)

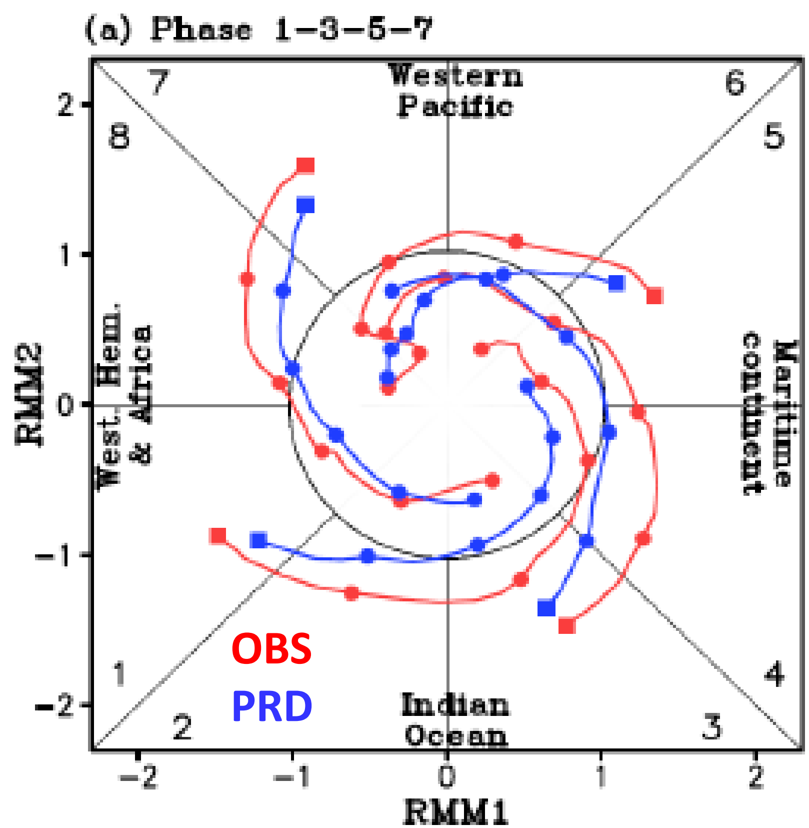
- CFSv2 shows sharp decrease in skill at phase 4 , 8→ deficiency in predicting the enhanced (or suppressed) convective signal associated with the MJO over the Maritime Continent
- In VarEPS, the barrier is not clearly represented → MC barrier strongly depends on the forecast systems (Rashid et al. 2011, Neena et al. 2014).

# MJO propagation and amplitude




Kim et al. (2014)

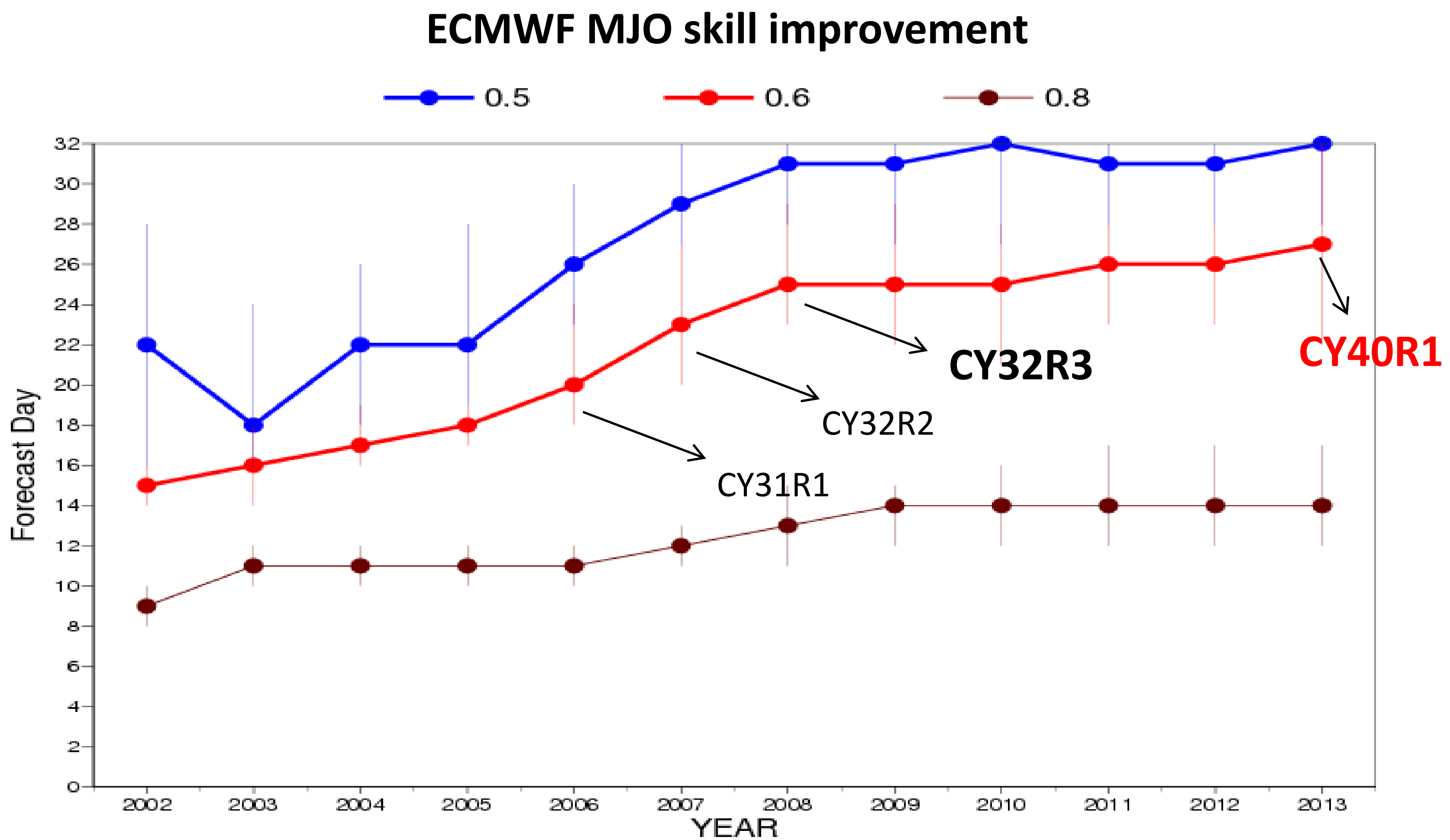
**GFDL FLOR**




(Xiang et al. 2015)

- Slow propagation speed
- Rapid drop of MJO amplitude

# Continuous MJO skill improvement




CY31R1: Parameterisation of ice supersaturation
CY32R2: McRAD (radiation scheme)
CY32R3: Changes in convective scheme (Bechtold at al. 2008)
CY40R1: Improved diurnal cycle of precipitation …

** Courtesy of F. Vitart*

# Discussion

**Summary**

- Intraseasonal modes, MJO and others, have been shown to influence TC activity in virtually all basins.
- Improvement in the simulation of the MJO and its impact on TCs activity.
- Skill in predicting these modes has improved dramatically (significant skill to 3-4 weeks).

# Discussion

**<u>Recommendation (from  WMO, IWTC-VIII)</u>**

- Are MJO and convectively coupled wave diagnostics being used to greatest benefit in all centers' genesis forecasts?

- **Needs for comparison of subseasonal TC forecasts in common framework. How best to be done?**

- "We recommend that the community make use of the forecast model output databases from the WWRP S2S project to systematically evaluate the skill of these forecasts. "

- "IWTC also recommends accelerated research into the best ways to communicate the value, uncertainties, and limitations of these forecasts to users."