Experimental Dynamical Multi-week Prediction of the MJO

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Australian Government
Bureau of Meteorology

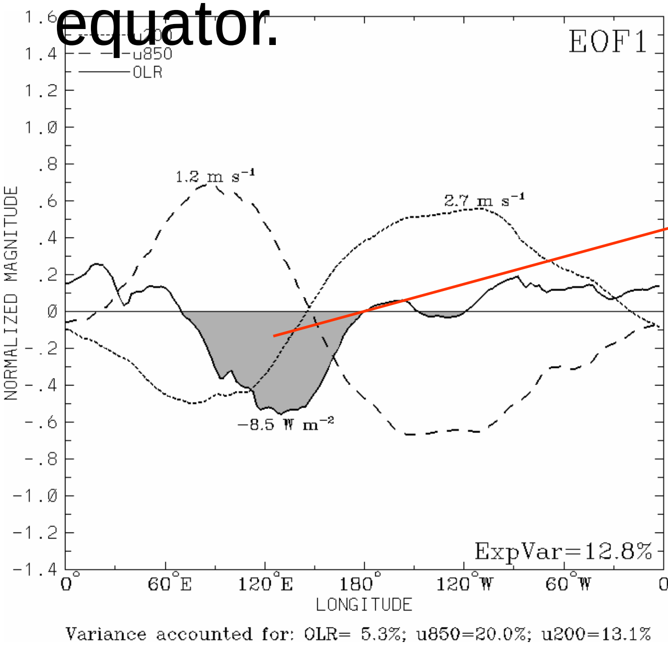
CSIRO

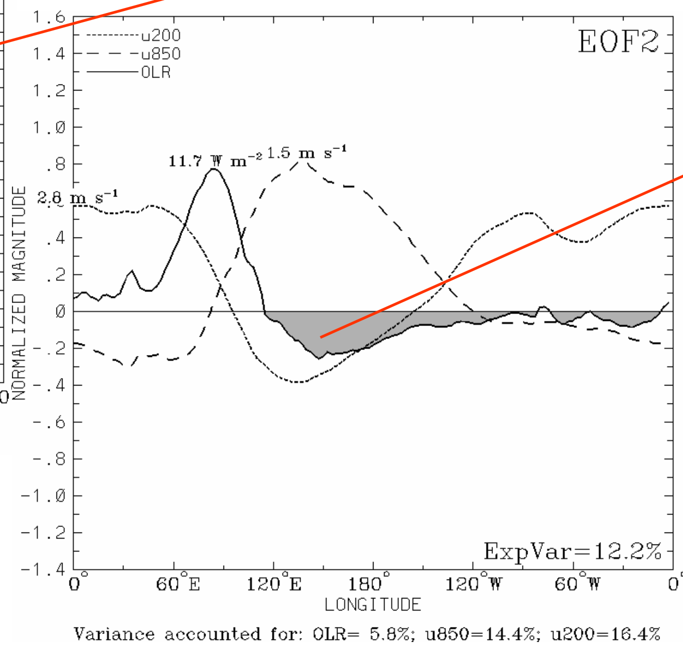
Outline

- **Prediction of the MJO is a key component in developing multi-week forecasting capability**
  - directly modulates weather throughout tropics (active/breaks, TC activity)
  - source of extratropical climate variability/predictability
- **Introduce method to monitor and assess forecasts of the planetary-scale aspects of the MJO based on Wheeler/Hendon RMM**
  - Focus on BoM POAMA model but compare with ECMWF (F. Vitart)
- **Issues of translating forecast of planetary-scale MJO to regional climate**
  - Requires a good simulation of the 3-d, time evolving structure of the MJO and ability to simulate teleconnection
  - MJO is not only source of multi-week predictability: SAM, ENSO, IOD
- **International project to assess operational real-time forecasts of the MJO**
  - What's the current capability of operational models?
  - Are there common problems?
  - Can we monitor improvement as systems are evolved?
  - Explore multi-model forecasts
  - Develop applications (e.g., forecasts of TC activity; active/break monsoon)

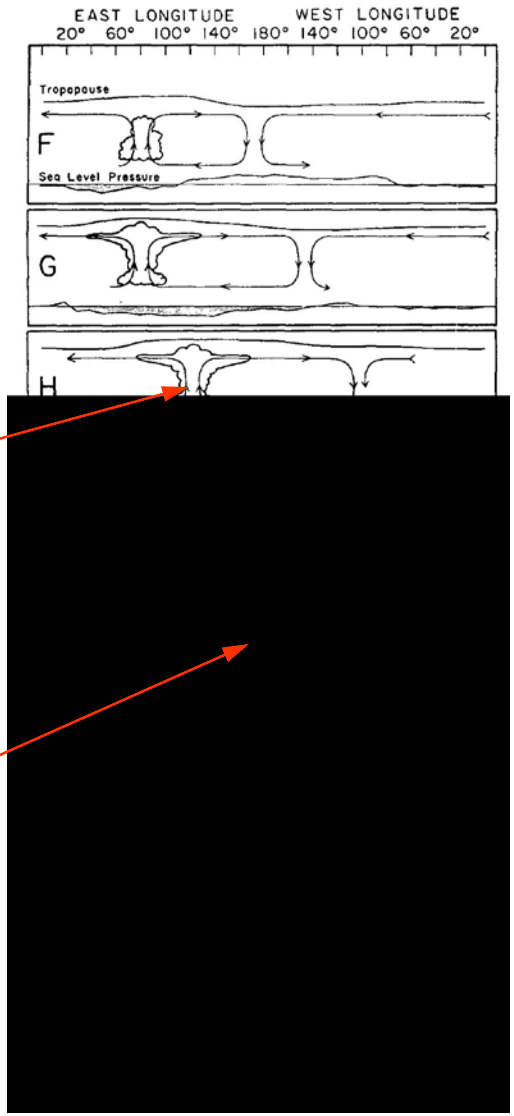
Diagnosing planetary-scale MJO

(Wheeler and Hendon): The leading pair of EOFs of equatorially averaged U850, U200, and OLR describe the convectively-coupled vertically-oriented circulation cells of the MJO that propagate eastward along the equator.



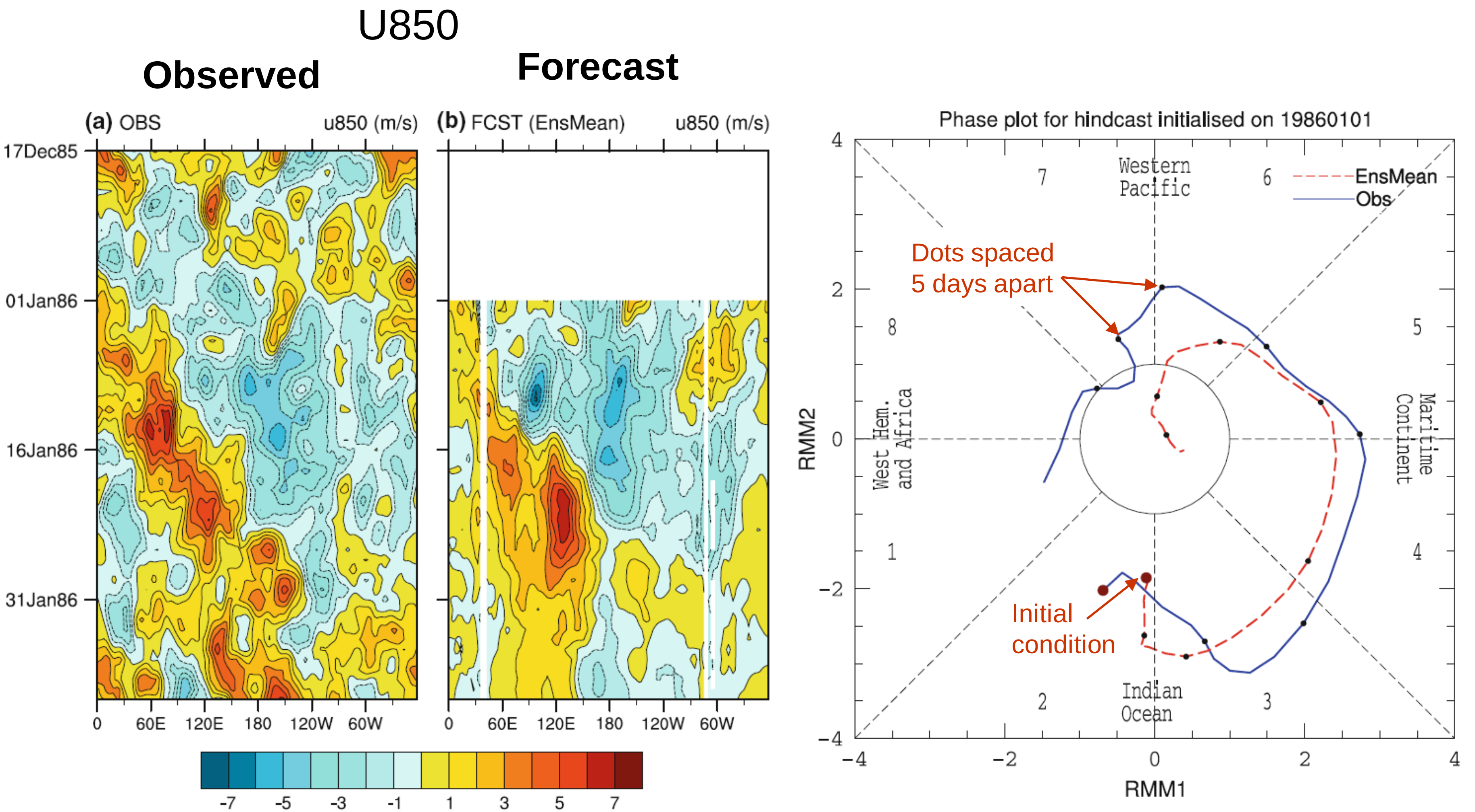


Wheeler and Hendon (2004)



Madden and Julian (1972)

Example behaviour of the RMM indices for monitoring and forecast from 1st Jan 1986 using POAMA



Note: Computation of RMM uses 15°S to 15°N averaged OLR, u850, and u200 (Wheeler and Hendon, 2004).

Evaluating forecasts of the MJO with RMM

1) Remove most recent 120d mean analysis/forecast
2) Project U850, U200, OLR onto observed EOFs
3) Score with bivariate correlation and rmse (Lin et al 2008)

$$COR(\tau) = \frac{\sum_{t=1}^{N}\left[a_1(t)b_1(t,\tau) + a_2(t)b_2(t,\tau)\right]}{\sqrt{\sum_{t=1}^{N}\left[a_1^2(t) + a_2^2(t)\right]}\sqrt{\sum_{t=1}^{N}\left[b_1^2(t,\tau) + b_2^2(t,\tau)\right]}}$$

$$RMSE(\tau) = \sqrt{\frac{1}{N}\sum_{t=1}^{N}\ [a_1(t) - b_1(t,\tau)]^2 + [a_2(t) - b_2(t,\tau)]^2}$$

$a_1(t)$ and $a_2(t)$ observed rmm_1 and rmm_2

$b_1(t,\tau)$ and $b_2(t,\tau)$ are forecast rmm_1 and rmm_2

POAMA1: Predictive Ocean-Atmosphere Model for Australia

T47 L17 atmosphere, tuned for a good MJO.

ACOM2 ocean (MOM2): 0.5°(lat) x 2°(lon) resolution near equator.

Ocean ICs: ocean data assimilation scheme

Atmospheric ICs: nudge to ERA-40 reanalyses.

Hindcasts: 10-member ensemble from 1st of each month for 1980-2006.

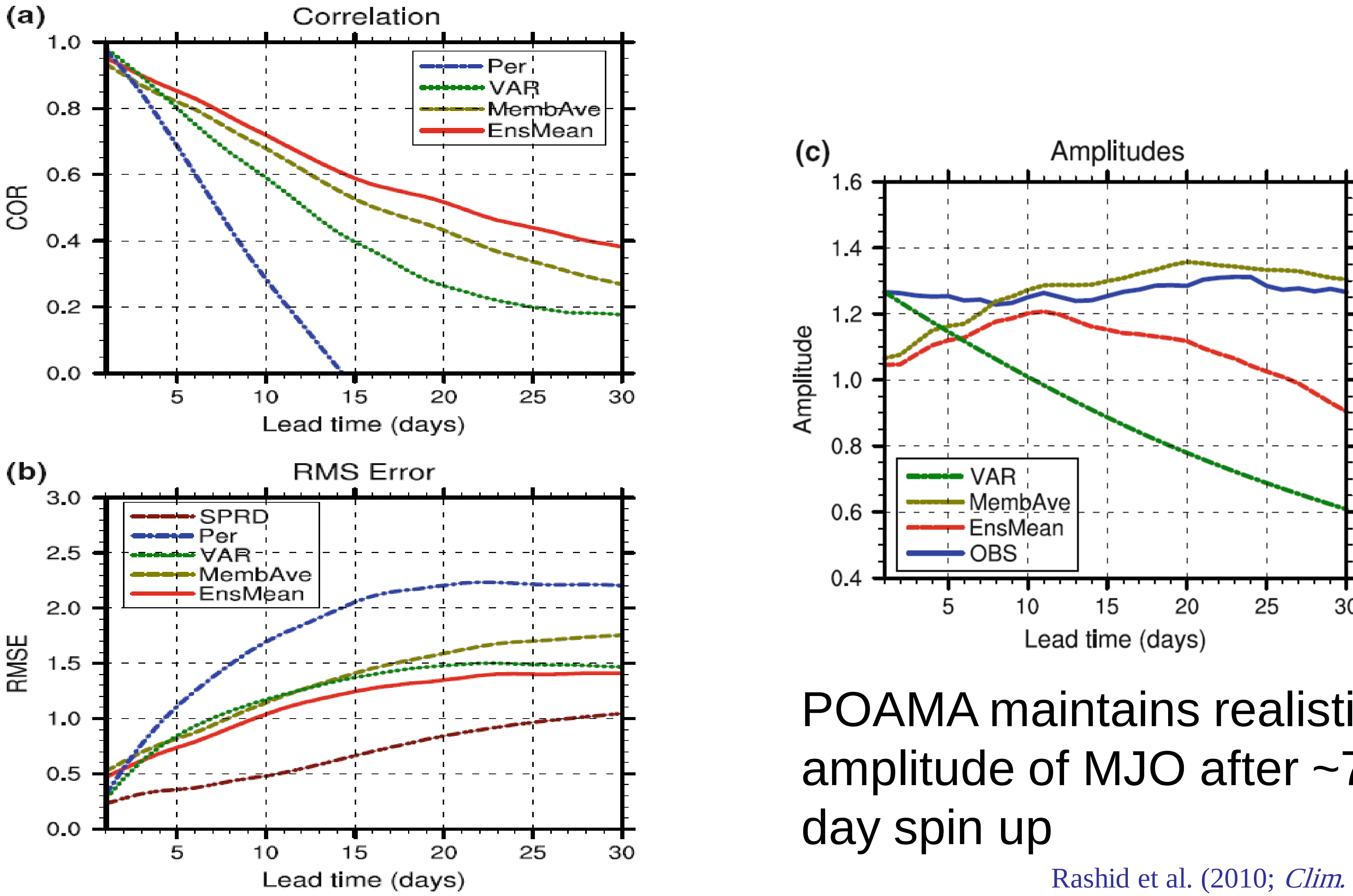
Lagged ensemble is generated using atmospheric ICs from successively 6 hours earlier.

Accounting for the lag (2.5 days) is important for skill assessment

POAMA hindcasts 1982-2006

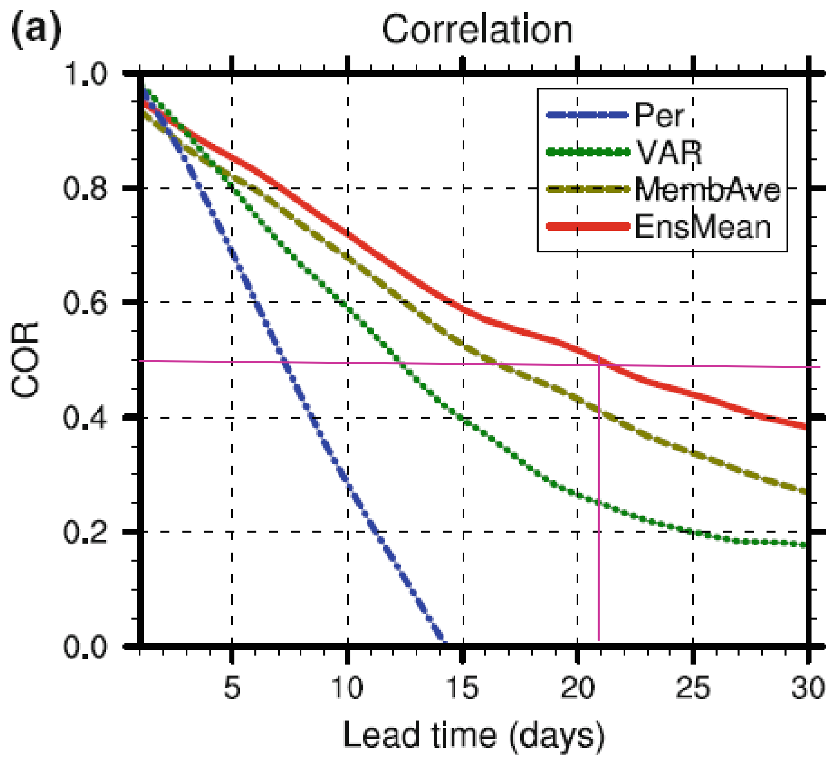
bivariate correlation, bivariate RMSE, bivariate amplitude

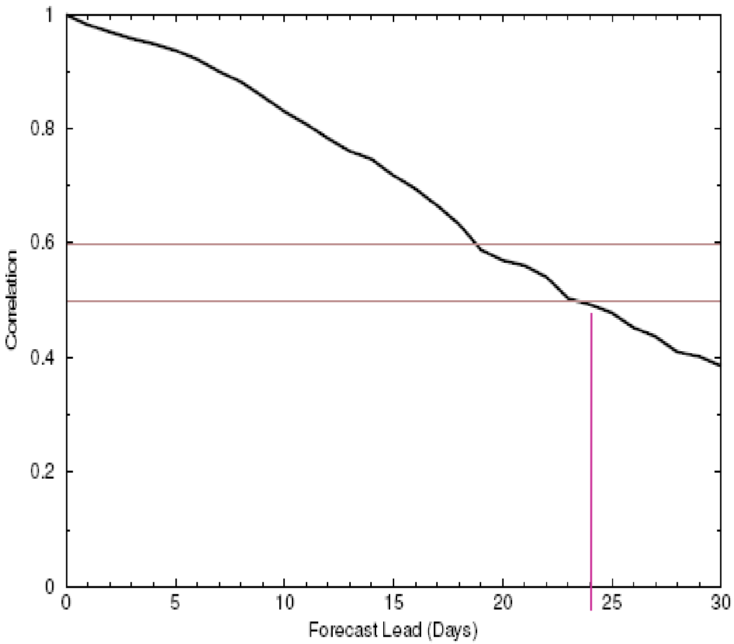
Method adapted from Lin et al. (2008),



POAMA maintains realistic amplitude of MJO after ~7 day spin up

Rashid et al. (2010; *Clim. Dyn.*)





T47L17 POAMA

Rashid et al. 2010

T399/T255 EC Monthly

Vitart et al. (2010)

POAMA skill at 21 days is achieved by EC monthly at 24 days

How does this “good” prediction of the planetary MJO translate into skilful predictions of regional weather/climate?

This depends on how well the forecast model simulates 3-d, time evolution of the MJO, especially rainfall (diabatic heating)

MJO composite NDJFMA season

Fcst lead

week 3-4

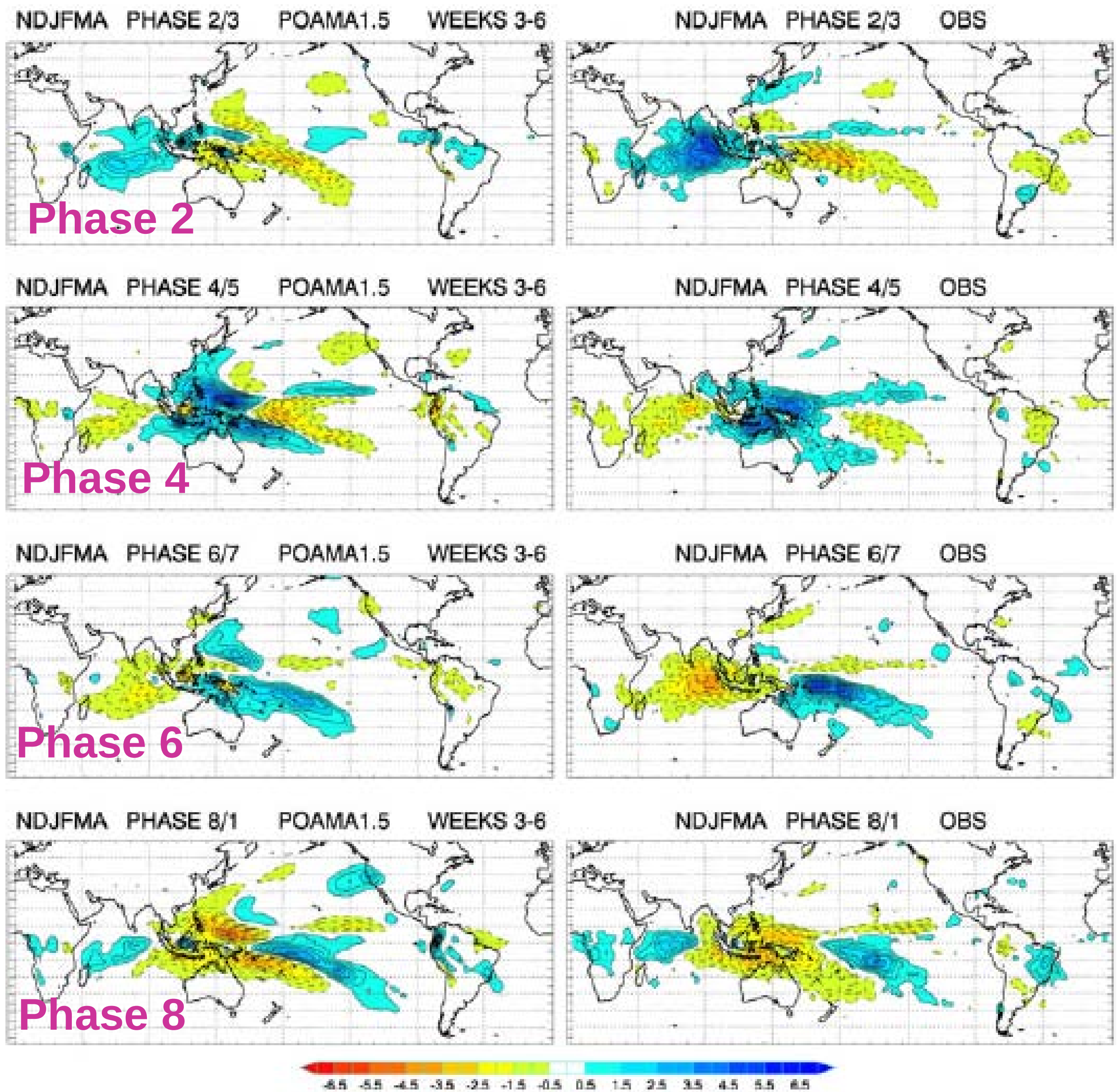
Marshall et al 2010

.

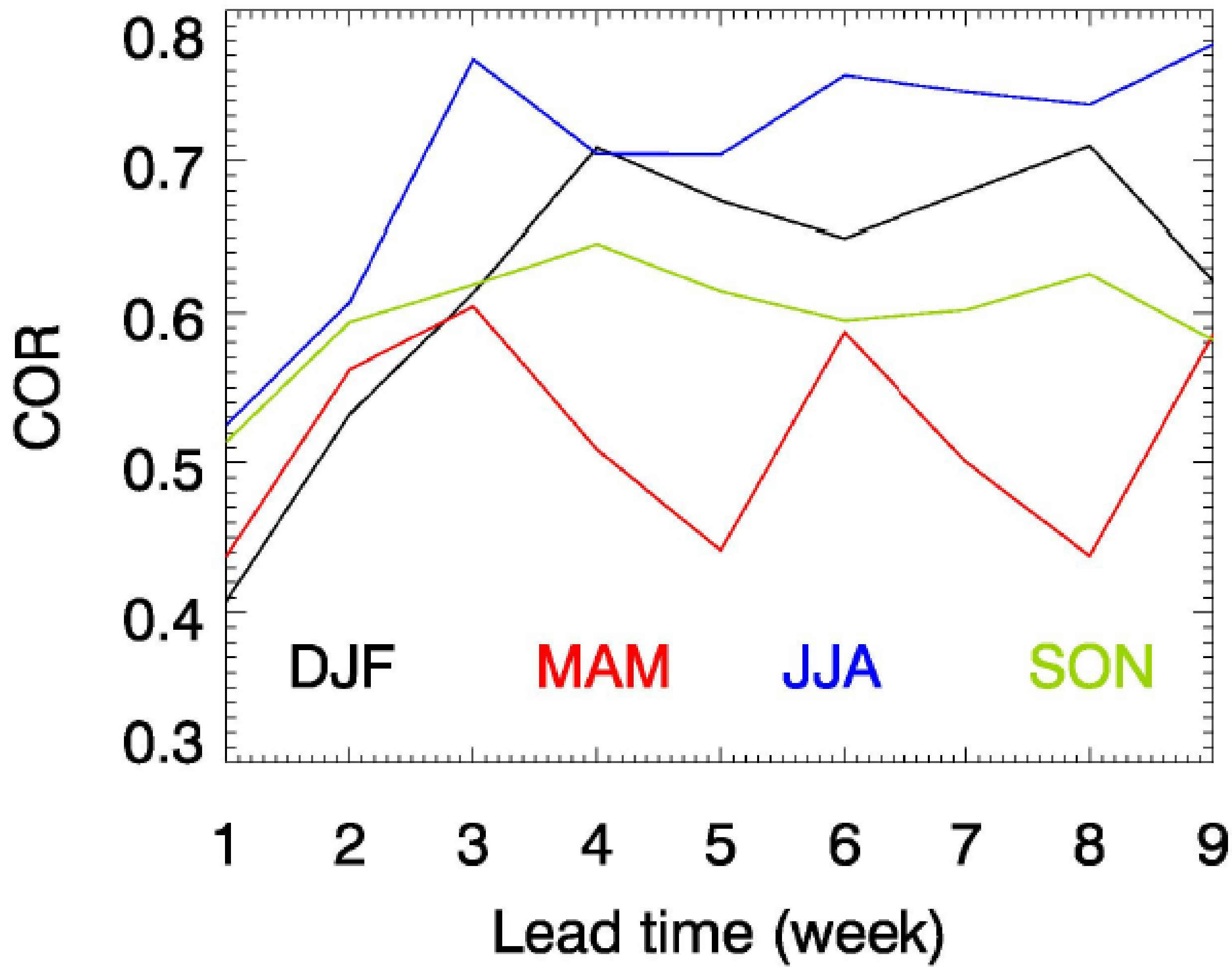
interval = 0.5 mm/

POAMA precip

CMAP observations



POAMA 1982-2008 Correlation of Composite MJO structure with observed in Indo-Pacific

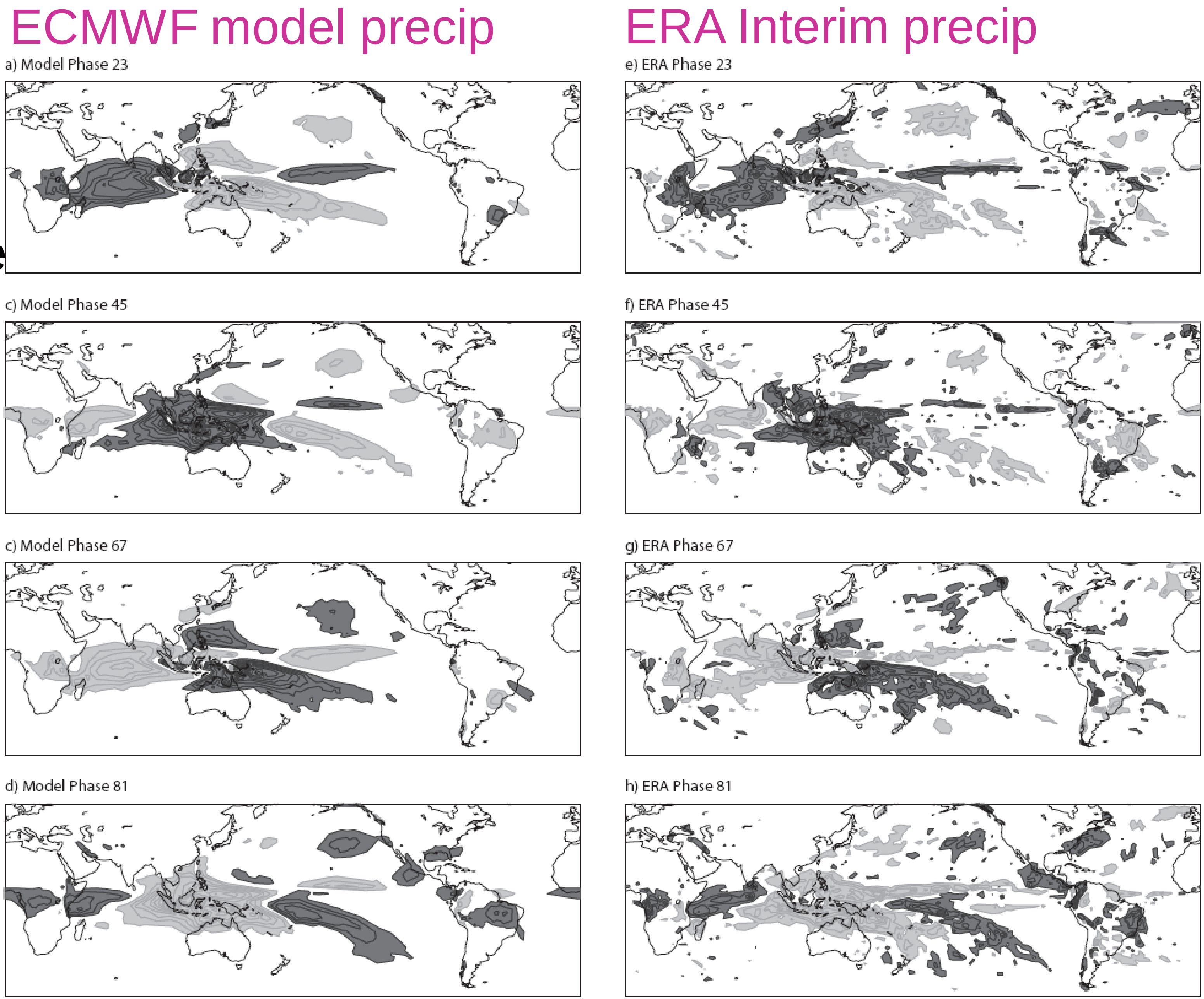


Amplitude spin-up associated with a “structural’ spin-up

ECMWF monthly system (Vitart and Molteni, 2010)

Nov-Apr

Week 3-4 composite



interval = 0.5 mm/day

POAMA precip CMAP observations

Same thing for JJA season

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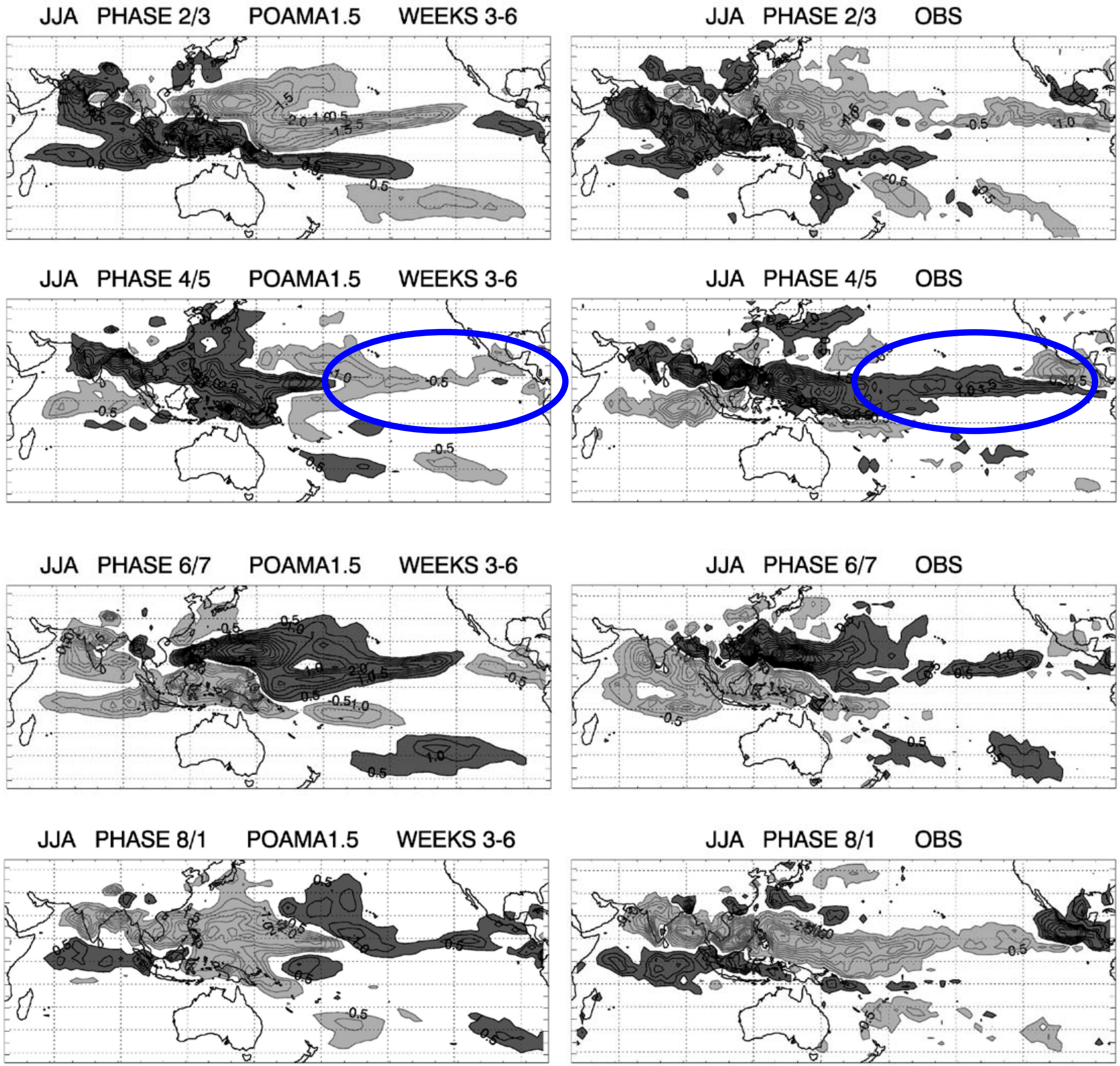


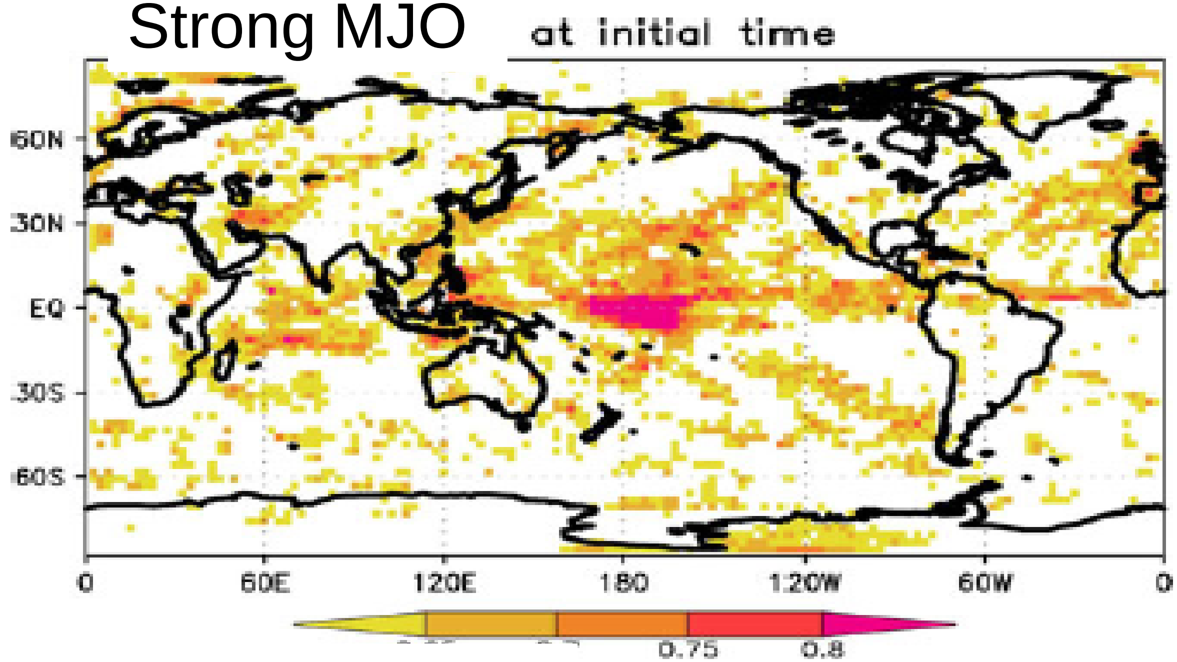
interval = 0.5 mm/day

MJO is also a source of global multi-week predictability

POAMA 1982-2008

ROC score upper tercile rainfall weeks 2-3

Strong MJO



Weak MJO

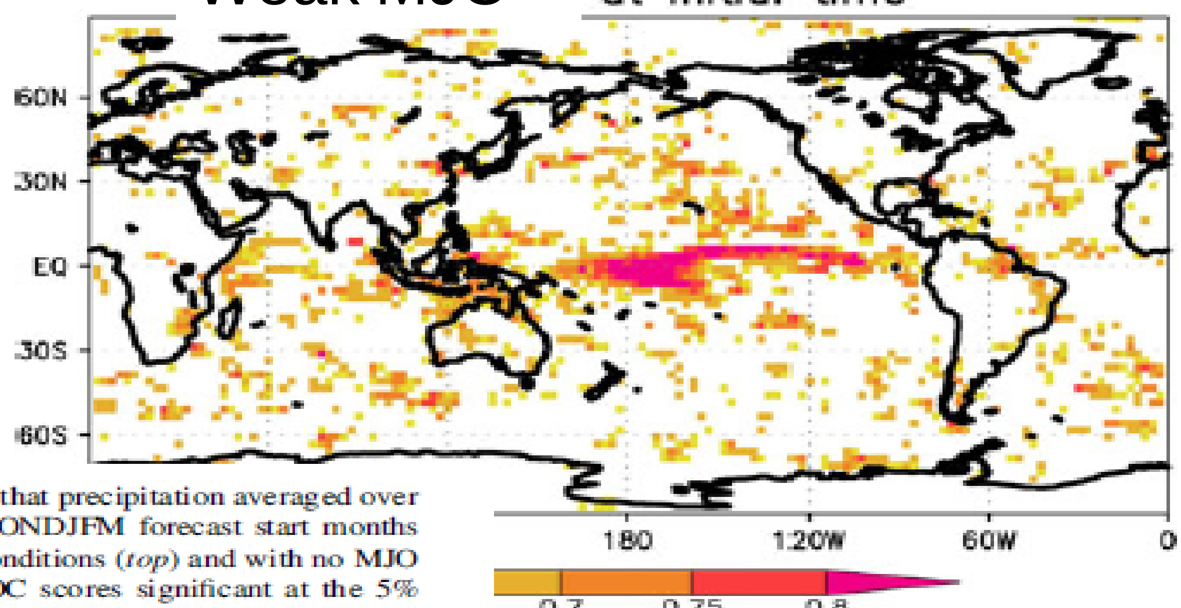


Fig. 8 ROC scores of the probability that precipitation averaged over days 8–21 is in the upper tercile for ONDJFM forecast start months for cases with an MJO in the initial conditions (*top*) and with no MJO in the initial conditions (*bottom*). ROC scores significant at the 5% significance level using a Mann–Whitney *U* test are shaded

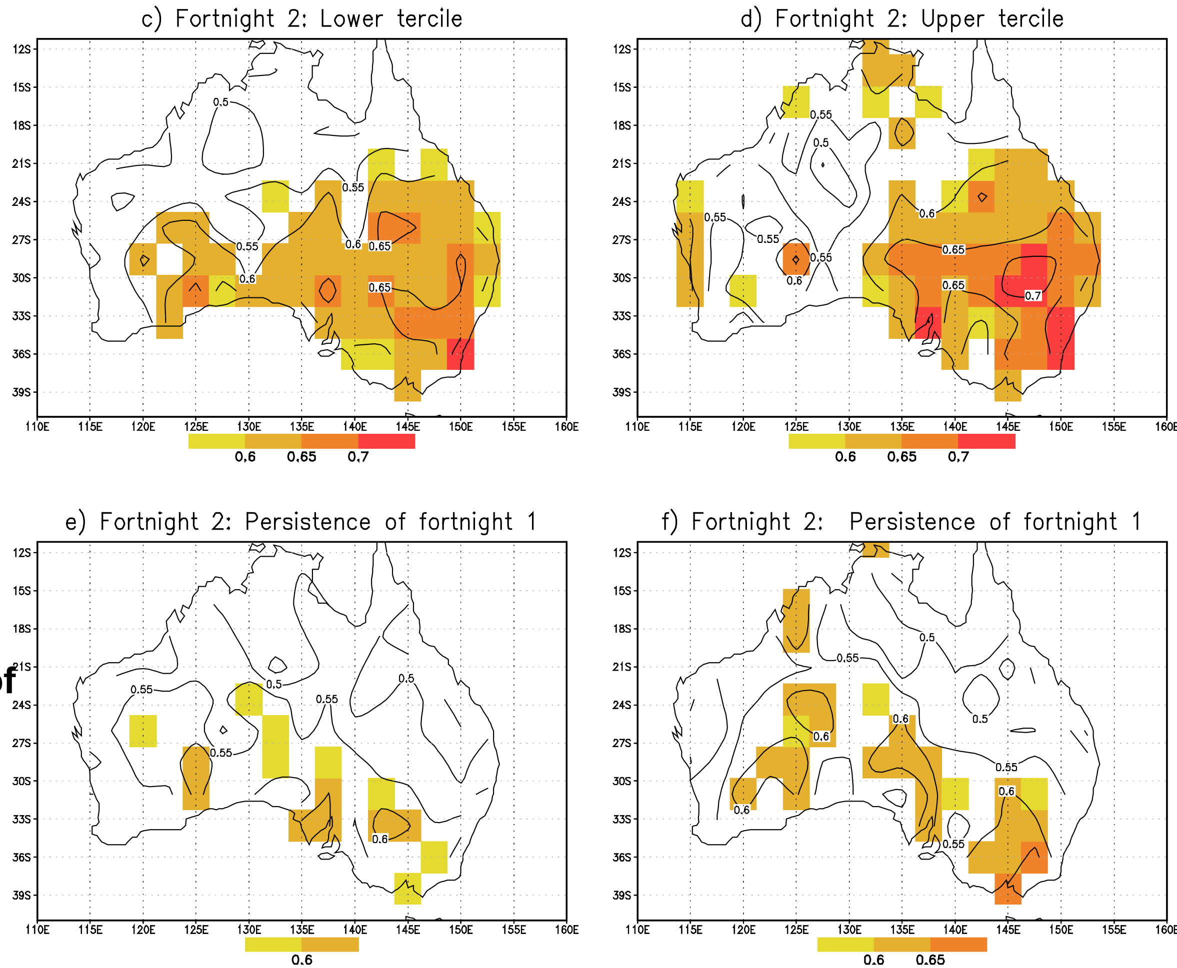
POAMA hindcasts 1982-2008

Area under the ROC curve (probabilistic skill): JJASON forecast start months

Lower tercile rainfall | **Upper tercile rainfall**

Forecast for week 3-4

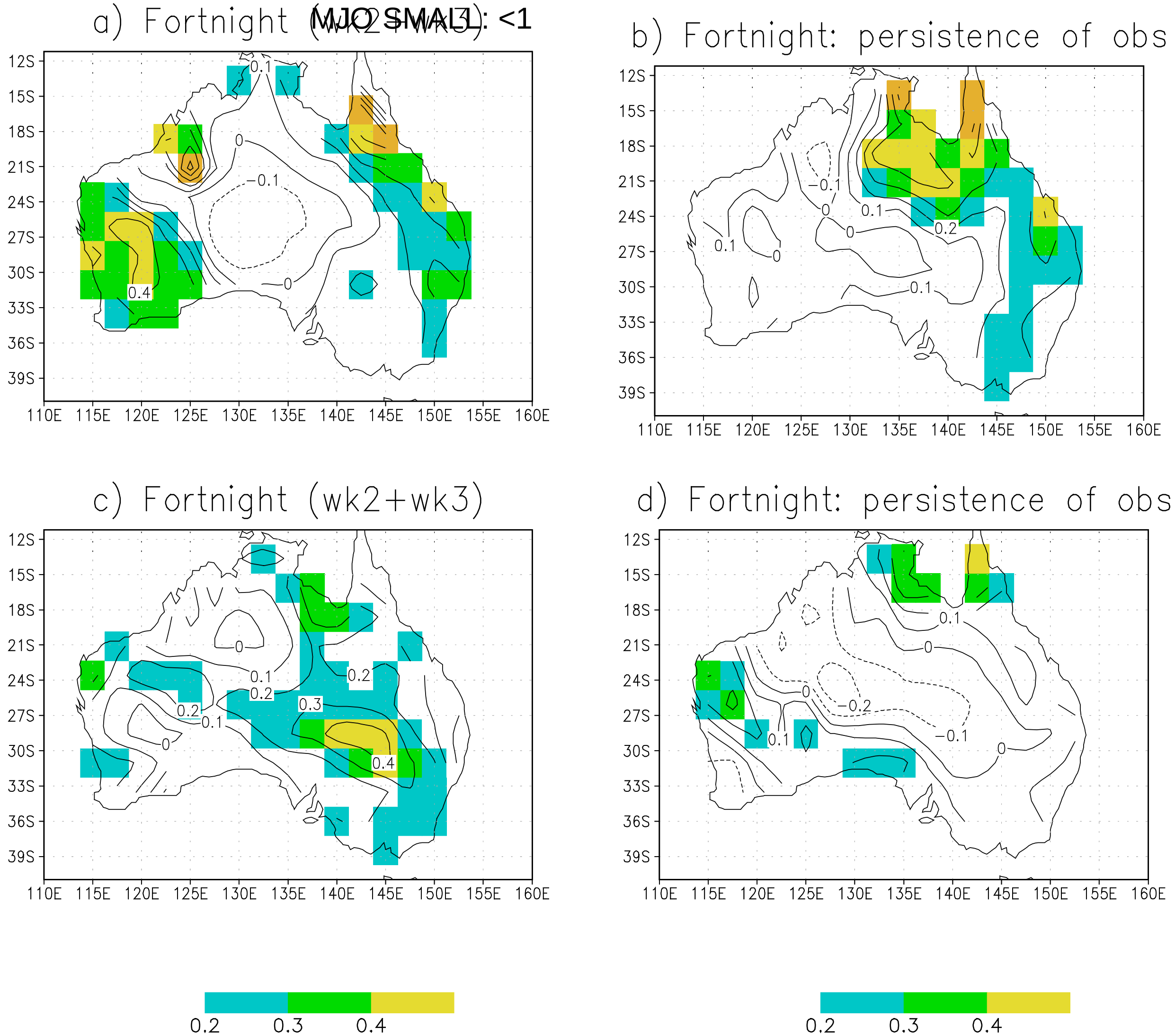
Persistence of week 1-2



ROC areas significant at the 5% significance level are shaded (Mann-Whitney U test)

JJASON forecast lead week 2 and 3
Rainfall anomaly correlation

Fortnight: AVERAGING WKS 2 and 3
window = 7: average the obs MJO amplitude over the 7 day period starting on the IC date
MJO BIG: >1
MJO SMALL: <1



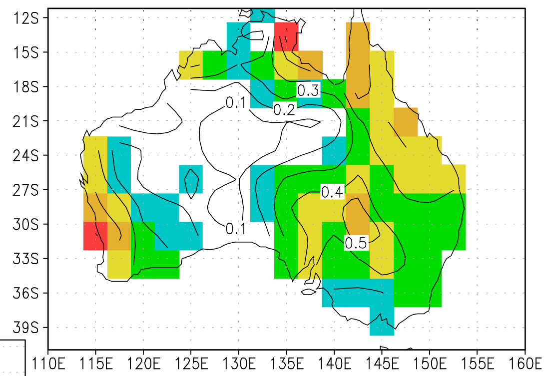
MJO big (n=85)

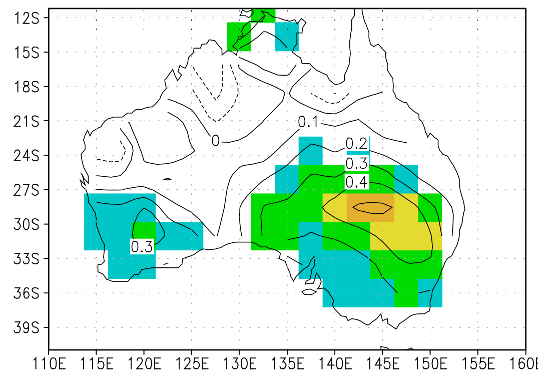
MJO small (n=77)

Other sources of multi-week predictability: ENSO & IOD

Dependence of rainfall forecast skill JJASON for weeks 3-4 on strength of ENSO/IOD

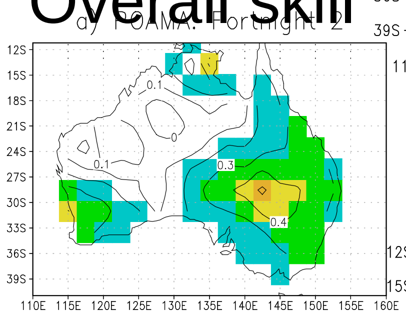
El Nino/La Nina strong



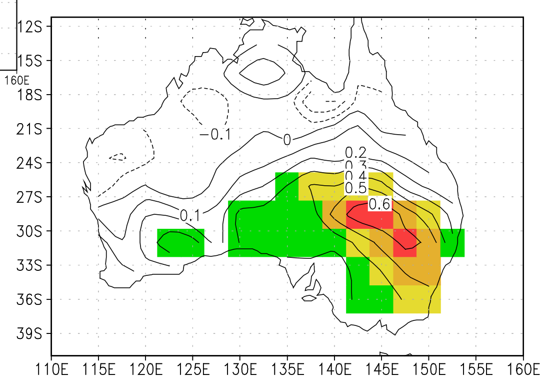


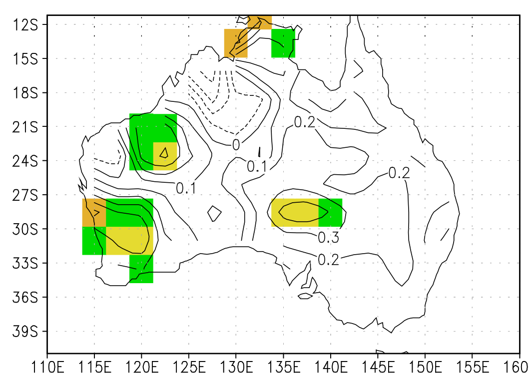
Neutral

Overall skill

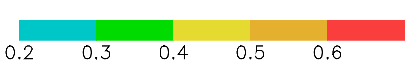


IOD is strong





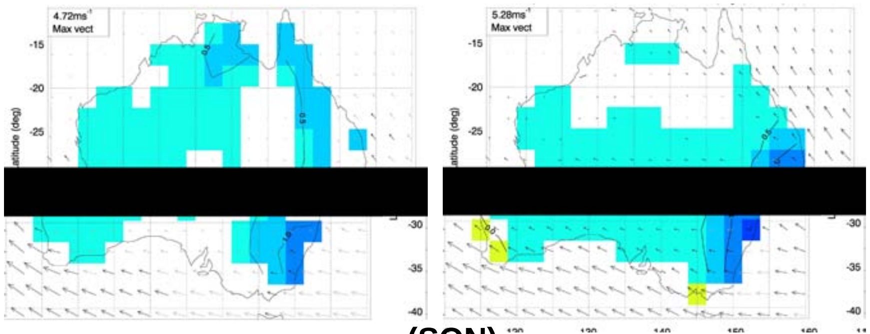
IOD weak



Modes of predictability: Southern Annular Mode

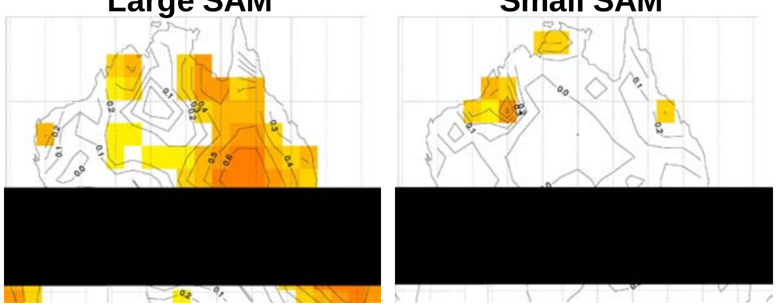
POAMA welol simulates weekly rainfall anomalies associated with the SAM (lead weeks 3-6) JJASON

OBS rain | POAMA rain (wks 3-6)



(SON)

Large SAM | Small SAM



(Anomaly correlations, JJASON, wks 2&3)

JJASON forecast lead weeks 2-3 anomaly correlation

SAM contributes to intra-seasonal rainfall prediction skill in POAMA over south-eastern Australia in JJASON

Proposed Structure for Multiweek Hindcasts and Real-time System POAMA2

Hindcasts:

- 30 member (10 from p24a/b/c) ensemble
- generated on the 1st, 11th and 21st of each month
- 1989-2008 (20yrs)
- 3 month (90d) forecasts

Compatible with the International ISO Hindcast Experiment

I.C.s: Ensemble ocean assimilation/atmosphere-land nudged ERA-40

Real-time:

- 30 member (10 from p24a/b/c) ensemble
- generated once per week (forecasts available 0z Friday)
- 3 month forecasts

(to be compatible with ECMWF)

Perturbed atmosphere/ocean initial conditions generated via coupled breeding method

A Framework for Assessing Operational Model MJO Forecasts

MJO Task Force Forecast Metric Team**

AMS Annual Meeting
January 24-28, 2011
Seattle, WA

** Jon Gottschalck / Augustin Vintzileos: NOAA / CPC
Matt Wheeler / Harry Hendon: Australia BOM
Frederic Vitart: ECMWF
Hai Lin: Environment Canada
Ann Shelly: UK Met Office
Duane Waliser: NASA / JPL
Ken Sperber: DOE / LLNL
Cristiano Prestrelo: CPTEC
Gopal Raman Iyengar: NCMRWF
Jyh-Wen Hwu: Taiwan CWB
Masashi Ujiie: JMA

Project Background

- The U.S. CLIVAR MJO Working Group (MJOWG) designated a team to adopt a uniform diagnostic for MJO identification and skill metrics

- Standard measures allow for consistent evaluation and display of MJO forecasts from multiple sources over time

- Invitation letter from the MJOWG and Working Group on Numerical Experimentation (WGNE) was distributed to operational centers around the world to introduce the project and request participation

- The U.S. CLIVAR MJOWG term has ended and this work is being carried on by the MJOTF sponsored by WCRP - WWRP/THORPEX YOTC

Center Participation

US – NCEP

ECMWF

United Kingdom

Brazil

US – NRL

India

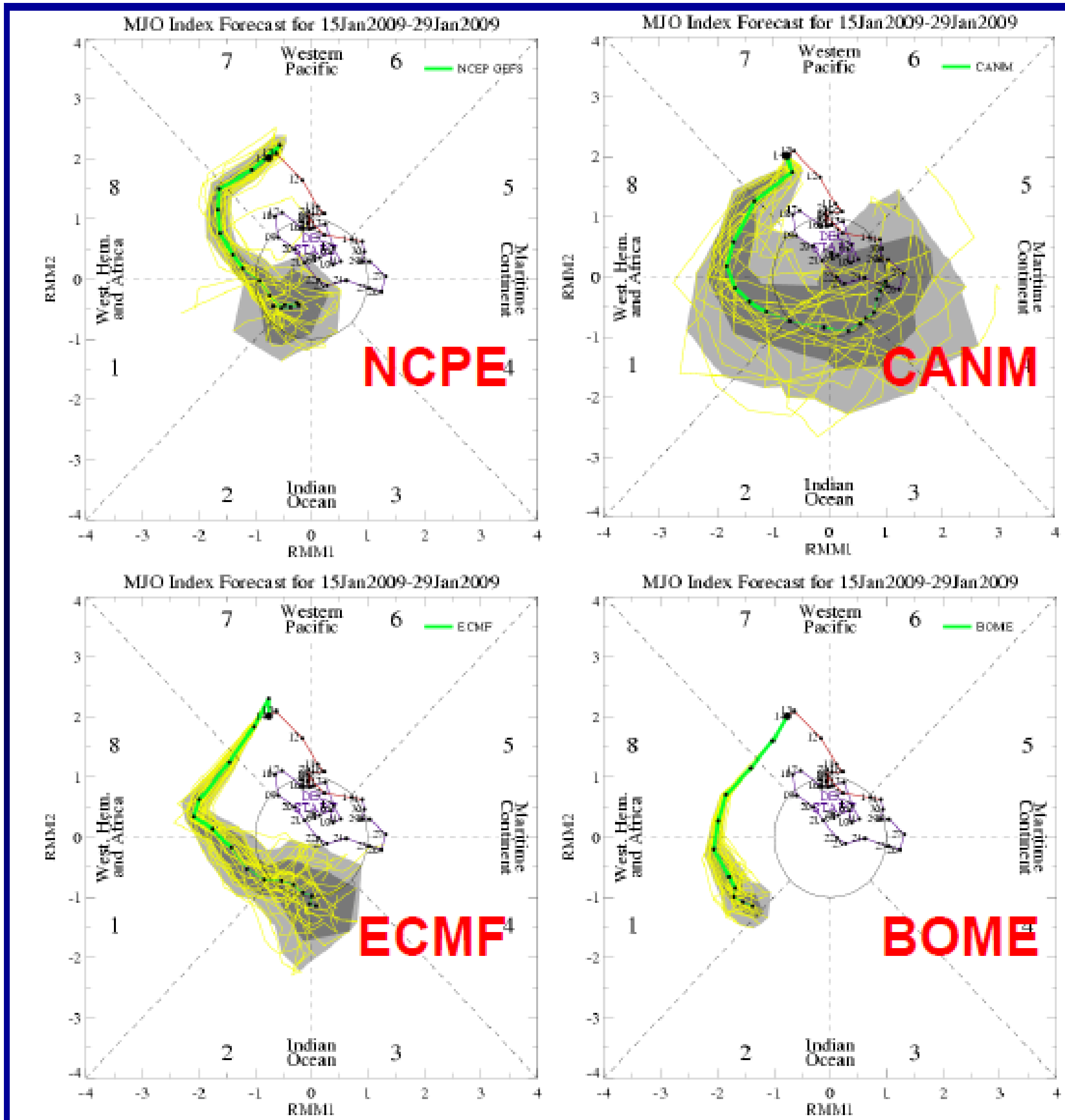
Taiwan

Australia

Japan

Canada – CMC

http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/clivar_wh.shtml



Differences in:

(1) Ensemble spread
(2) Propagation speed
(3) Amplitude

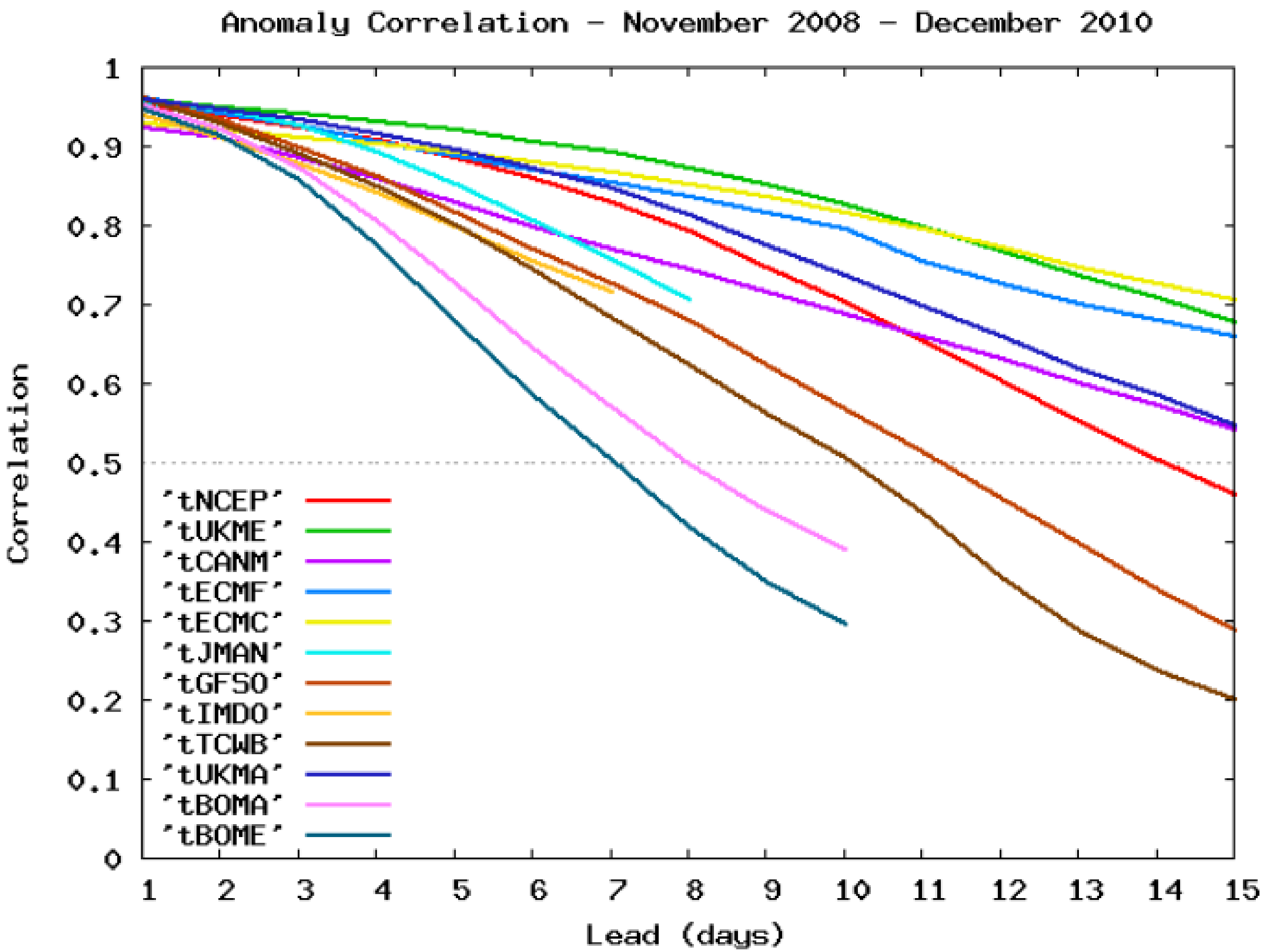
Verification

$$COR(\tau)=\frac{\sum_{t=1}^{N}\left[a_1(t)b_1(t,\tau)+a_2(t)b_2(t,\tau)\right]}{\sqrt{\sum_{t=1}^{N}\left[a_1^2(t)+a_2^2(t)\right]}\sqrt{\sum_{t=1}^{N}\left[b_1^2(t,\tau)+b_2^2(t,\tau)\right]}}$$

$$RMSE(\tau)=\sqrt{\frac{1}{N}\sum_{t=1}^{N}\ [a_1(t)-b_1(t,\tau)]^2+[a_2(t)-b_2(t,\tau)]^2}$$

- November 2008 – December 2010 time period
- Some forecast data is missing, but not much
- Calculate using NCEP Reanalysis first as one benchmark (shown here)
- Calculate using a “multi-model analysis” for the final measure (ongoing)

Preliminary Verification



Near-Term Next Steps

(1) Continued development and display of realtime verification statistics

- Complete verification as a function of MJO phase
- Statistical model as a benchmark
- Verification of the MMEF (equal weights)

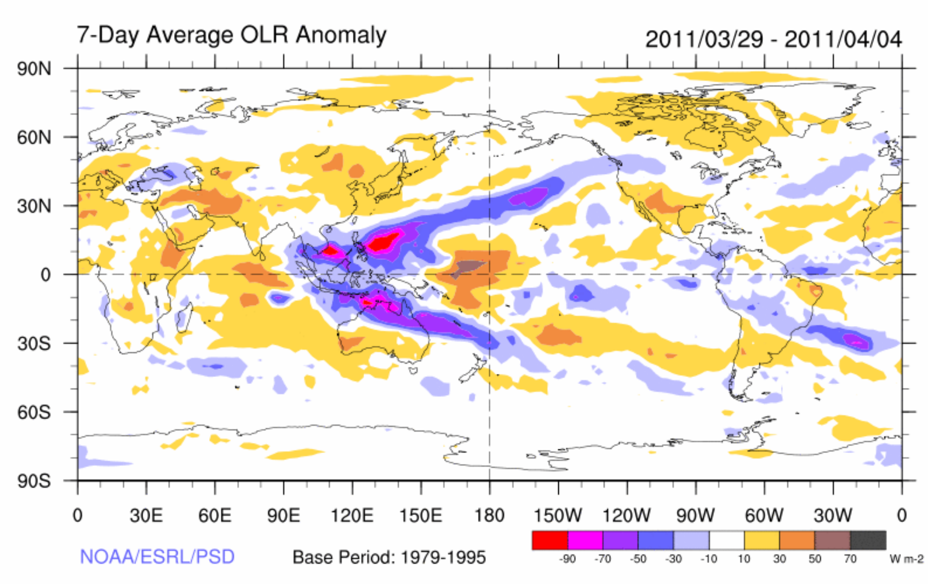
(2) Quantify bias between model data and obs

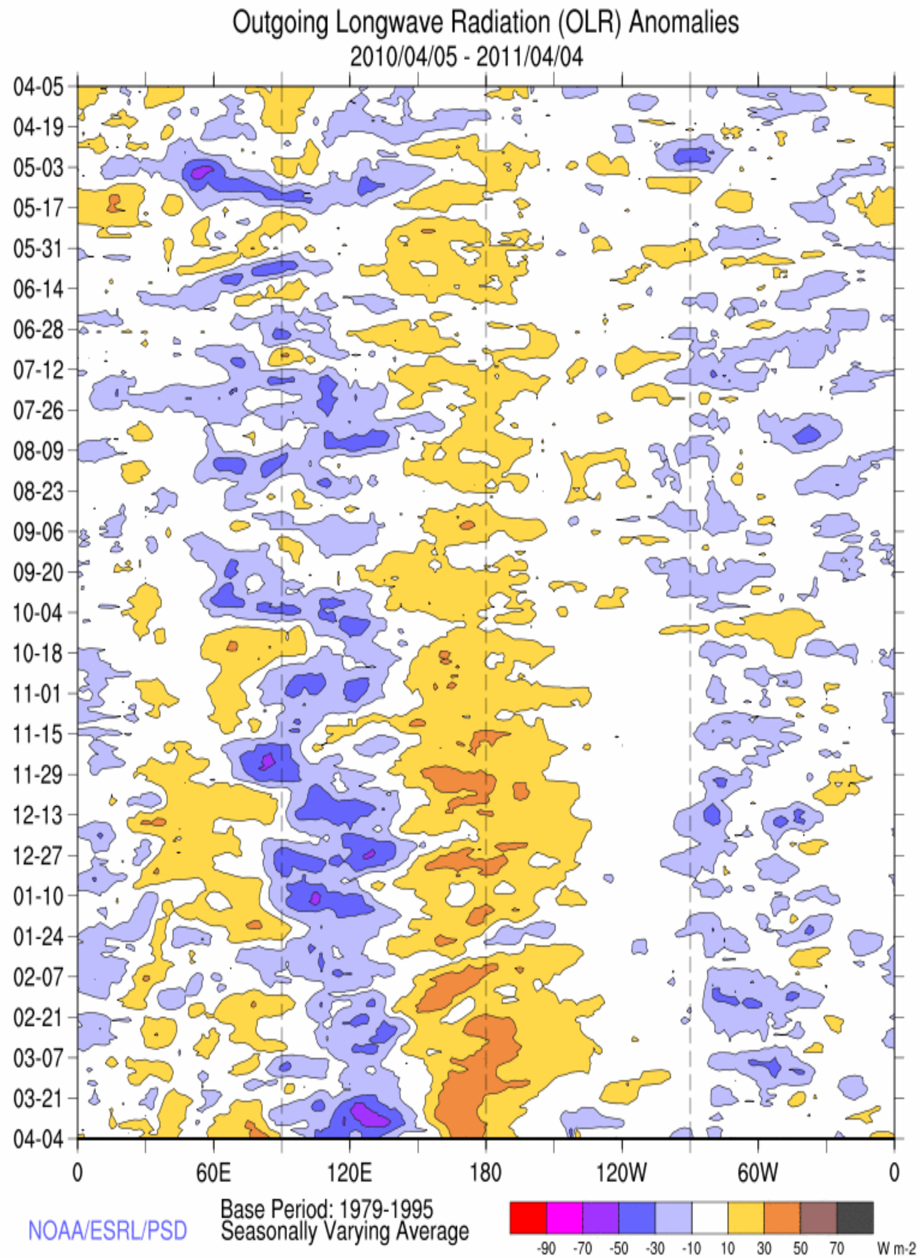
- Function of MJO strength and phase, model and seasonal cycle
- Evaluation is ongoing and products are being developed to quantify the biases and display in realtime to aid users

- Develop products (TC activity, active/break)

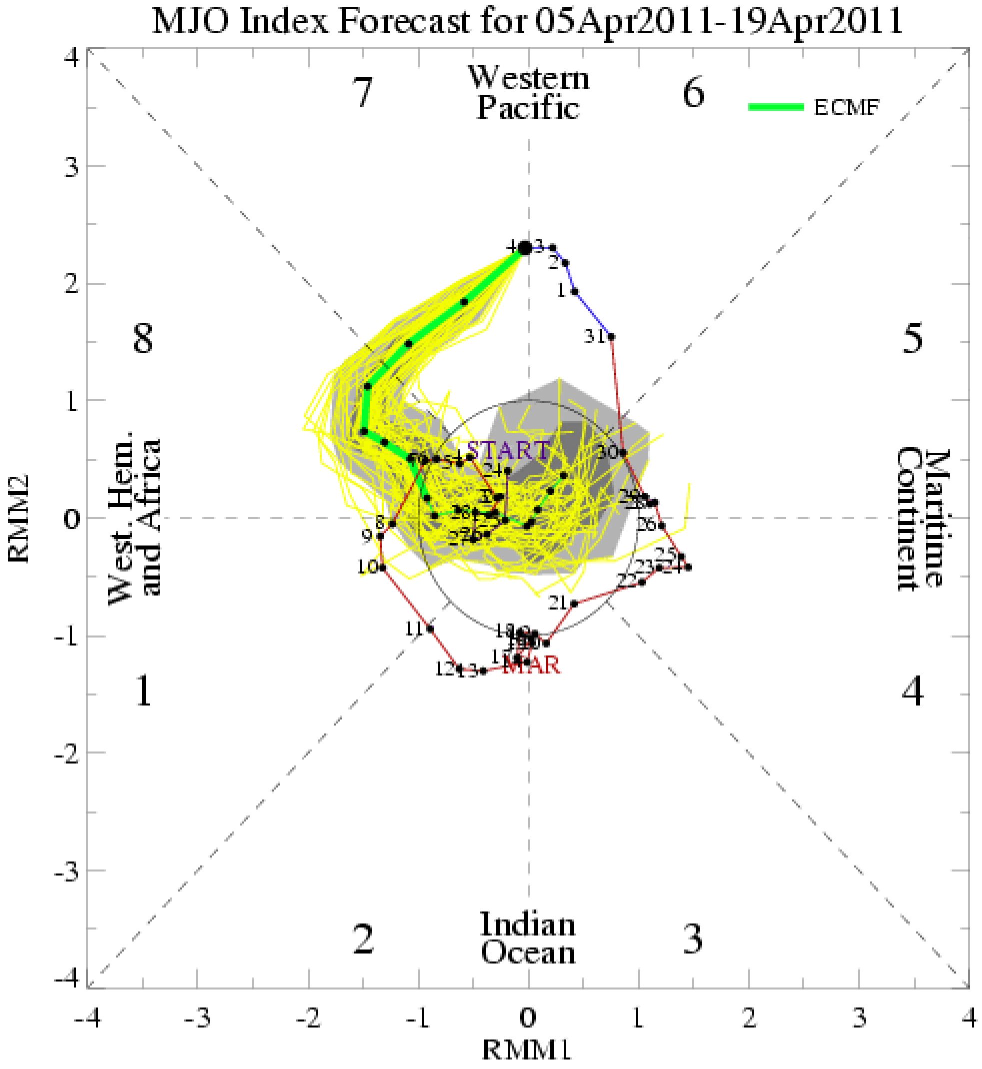
Current Status of MJO/convection

As of 5 April 2011

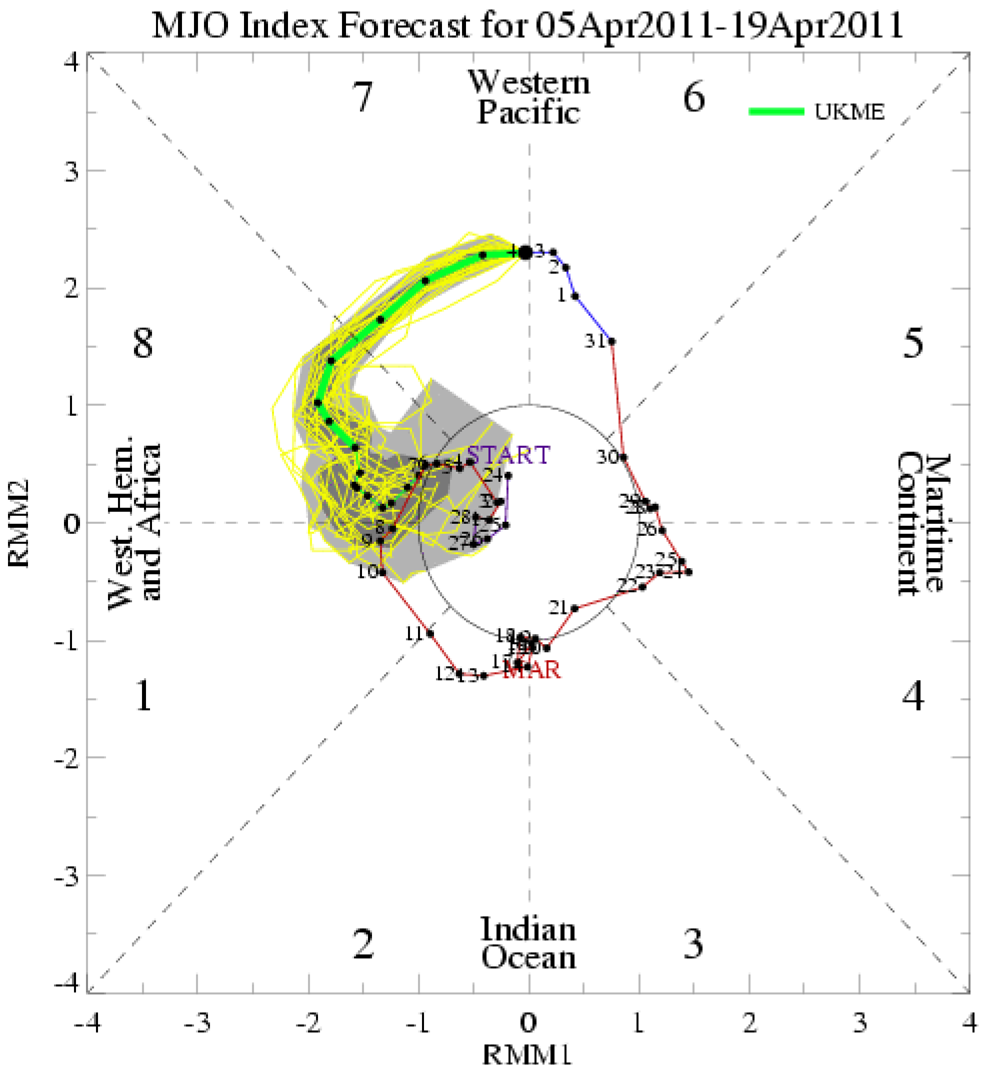


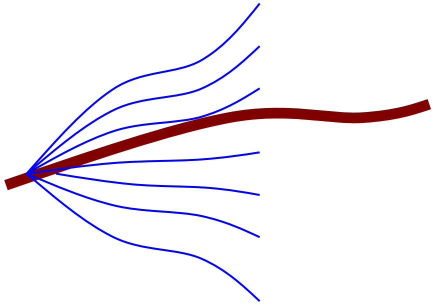


5 April 2011 Forecast
EC monthly



5 April 2011
Forecast
UKME
MOGREPS





Development of the POAMA multi-week prediction system

	POAMA-1.5	POAMA-2 (Seasonal)	POAMA-2 (Multi-week)
Data assimilation	PODAS ALI	PEODAS ALI	PEODAS ALI
Ensemble generation	Hindcast: lagged atmos (6hr); no ocean perturbations (10 members) Real-time: daily lagged ensemble (hindcast-realtime inconsistent)	Hindcast and real-time :: burst from first of the mnth, perturbed ocean intial condition); 30 members Ocean perturbations from PEODAS; no atmosphere perturbations	Hindcasts and real time burst from mulitple statts per mnth) Perturbed atmos initial conditions from coupled breeding).

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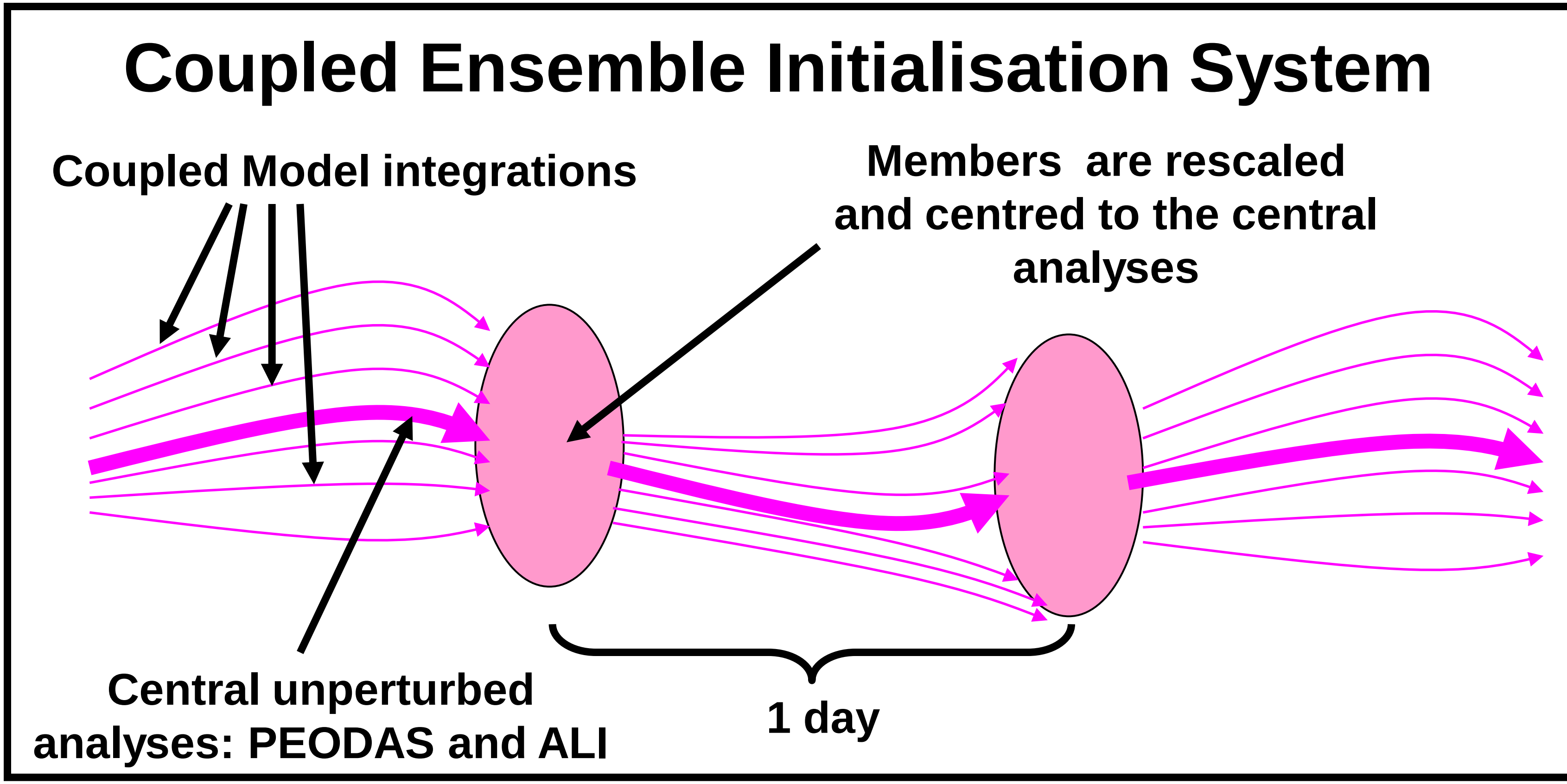
(to be compatible with ECMWF)

Perturbed atmosphere/ocean initial conditions generated via coupled breeding method

Initial conditions for the Multi-week system

Towards Coupled Assimilation...

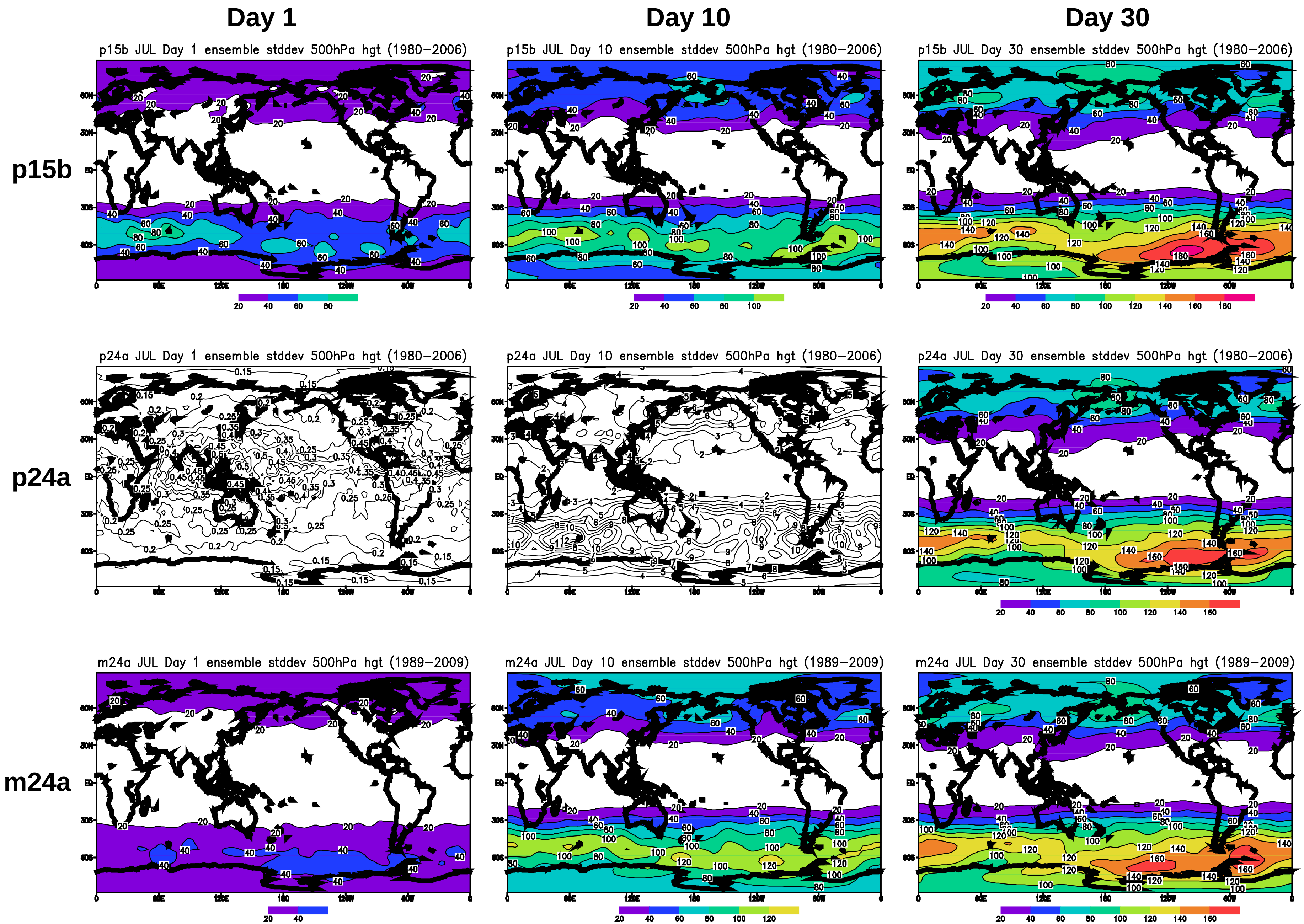
Based on the PEODAS infrastructure



→ **Generates coupled perturbations of both the atmosphere and ocean based on the breeding method**

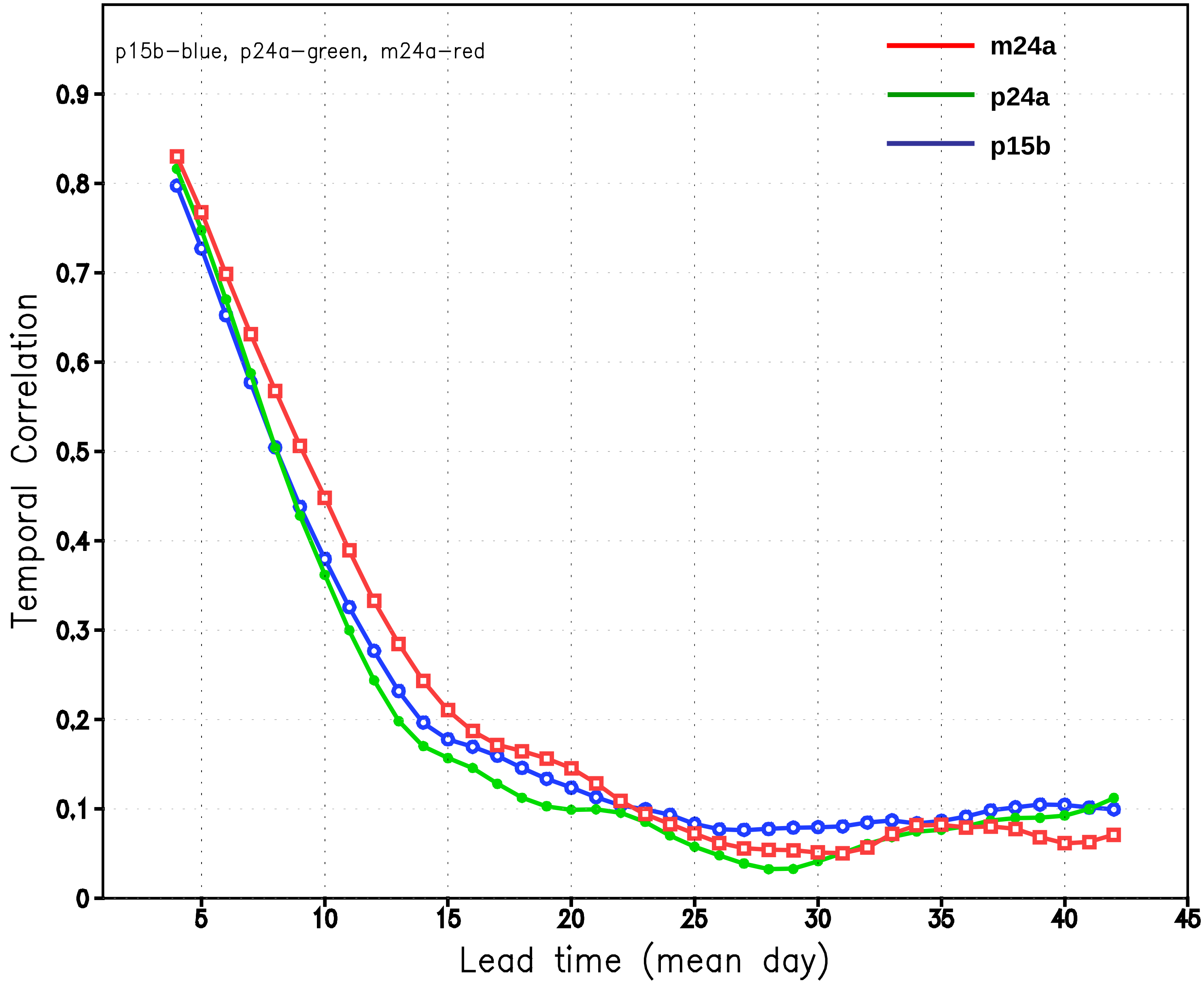
Yonghong Yin

JULY Ensemble Spread (stddev): 500hPa heights



500hPa Geopotential Heights: Correlation skill (7-day running mean applied to forecasts)

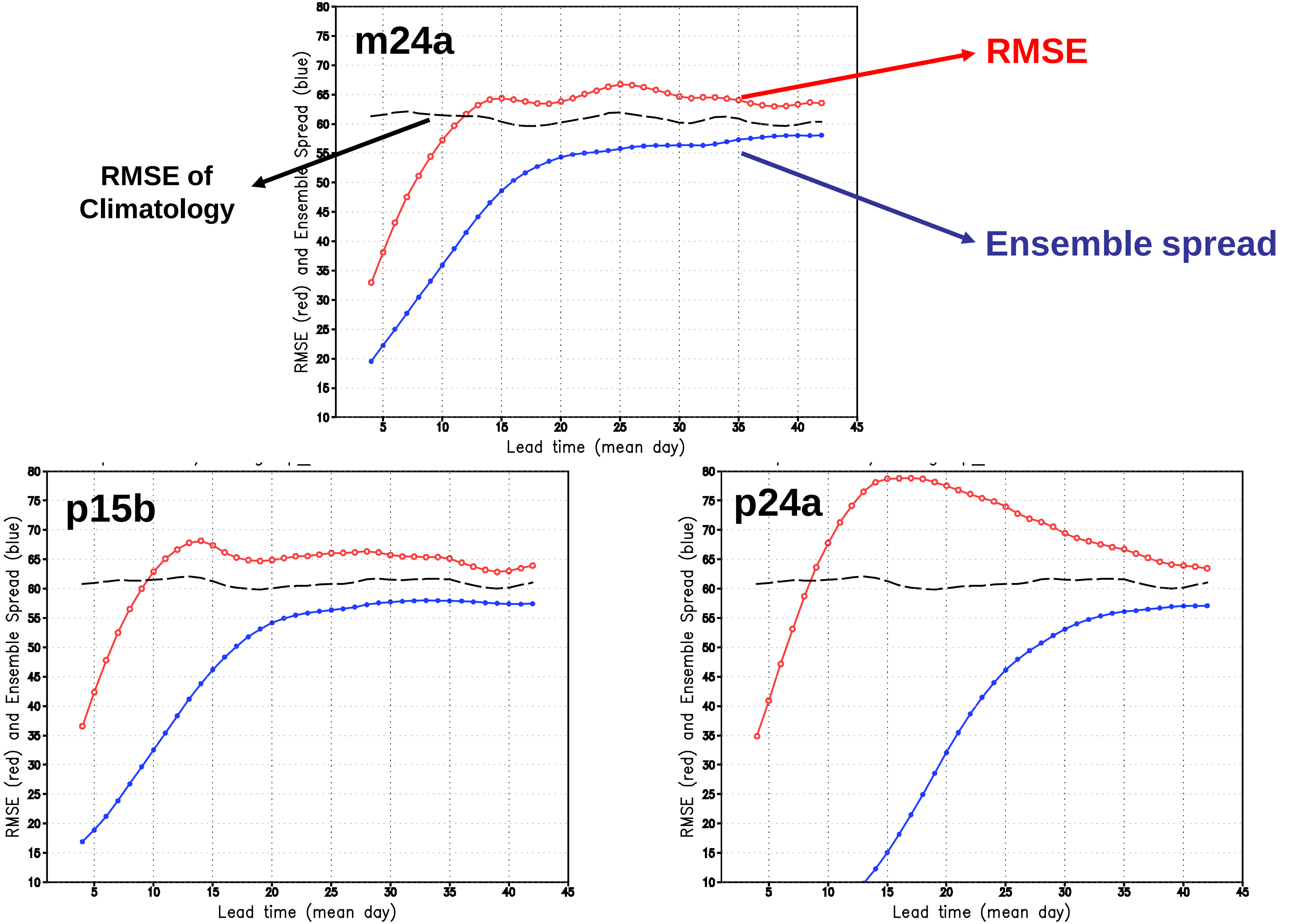
Jan and Jul forecast starts; Region=SHEM 20-60ºS



Current capability of POAMA multi-week system for predicting Australian climate weeks 2-8

500hPa Geopotential Heights: RMSE & Spread (7-day running mean applied to forecasts)

Jan and Jul forecast starts; Region=SHEM 20-60ºS



Current status of Multiweek System based on POAMA2

- First version of the Coupled Ensemble Initialisation System (CEIS) has been run 1989-2009
- First trial hindcast set has been run (to evaluate the CEIS):

  m24a: Jan and Jul starts, 1989-2009, 10 member ensemble

- m24a in the process of being analysed
- Technical structure of the CEIS and forecasts have been implemented in operations

Next steps

- Complete the analysis of m24a
- Finalise decision on coefficients required for CEIS and re-run if required
- Run hindcasts from the 1st of the month
- Run real-time forecasts
- Extend hindcasts to 11th and 21st of the month