WCRP /WWRP-THORPEX
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Overview of the MJO and convectively-coupled equatorial waves during YOTC

Matthew Wheeler

Centre for Australian Weather and Climate Research
A partnership between the Bureau of Meteorology and CSIRO
Melbourne, Australia

Australian Government
Bureau of Meteorology

CSIRO

Outline

YOTC = May 2008 to April 2010

1. Overall view of tropical convection during YOTC

2. MJO cases during YOTC

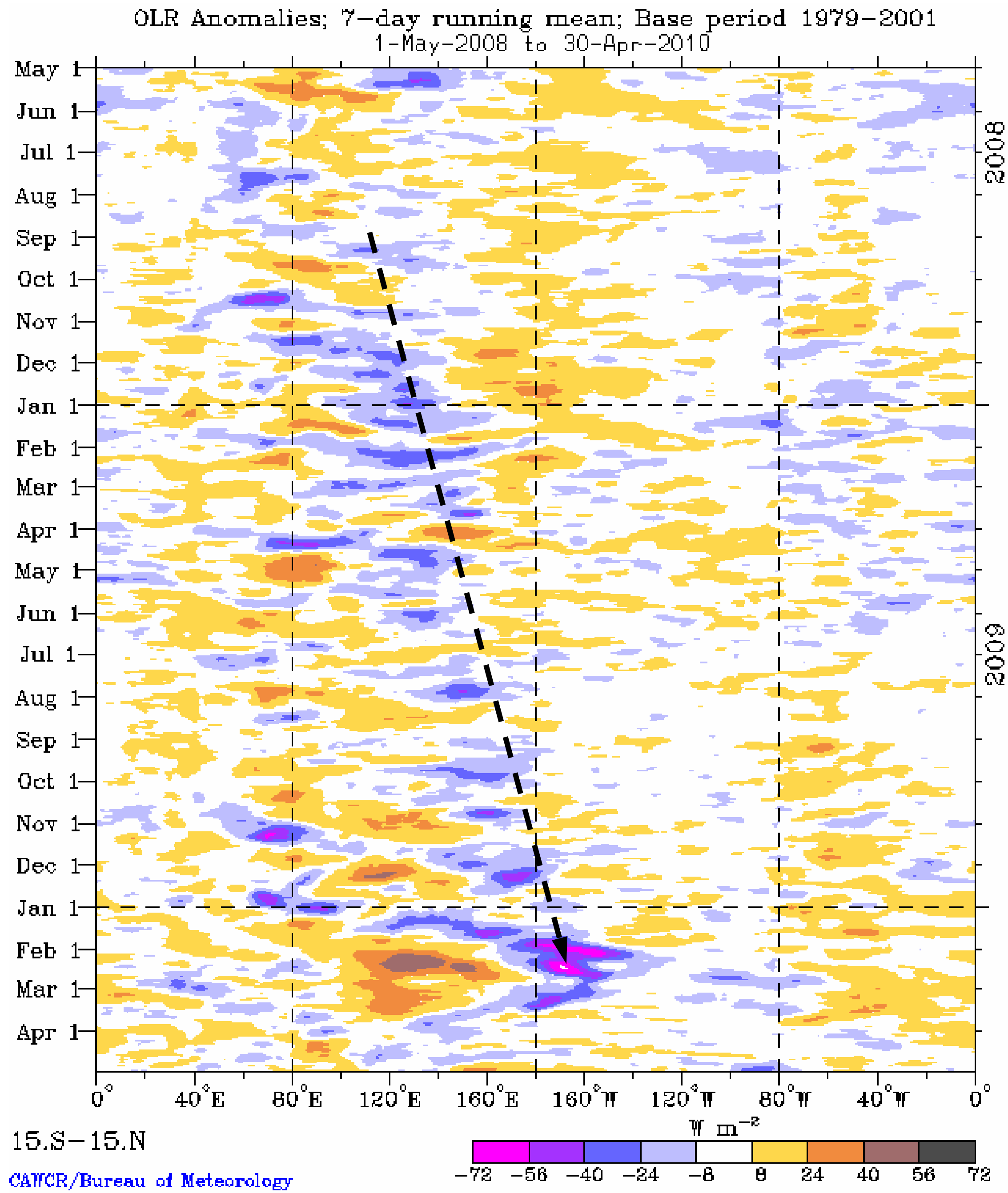
3. Convectively-coupled equatorial wave cases

4. Dynamical model MJO forecasts during YOTC

5. Summary and Discussion

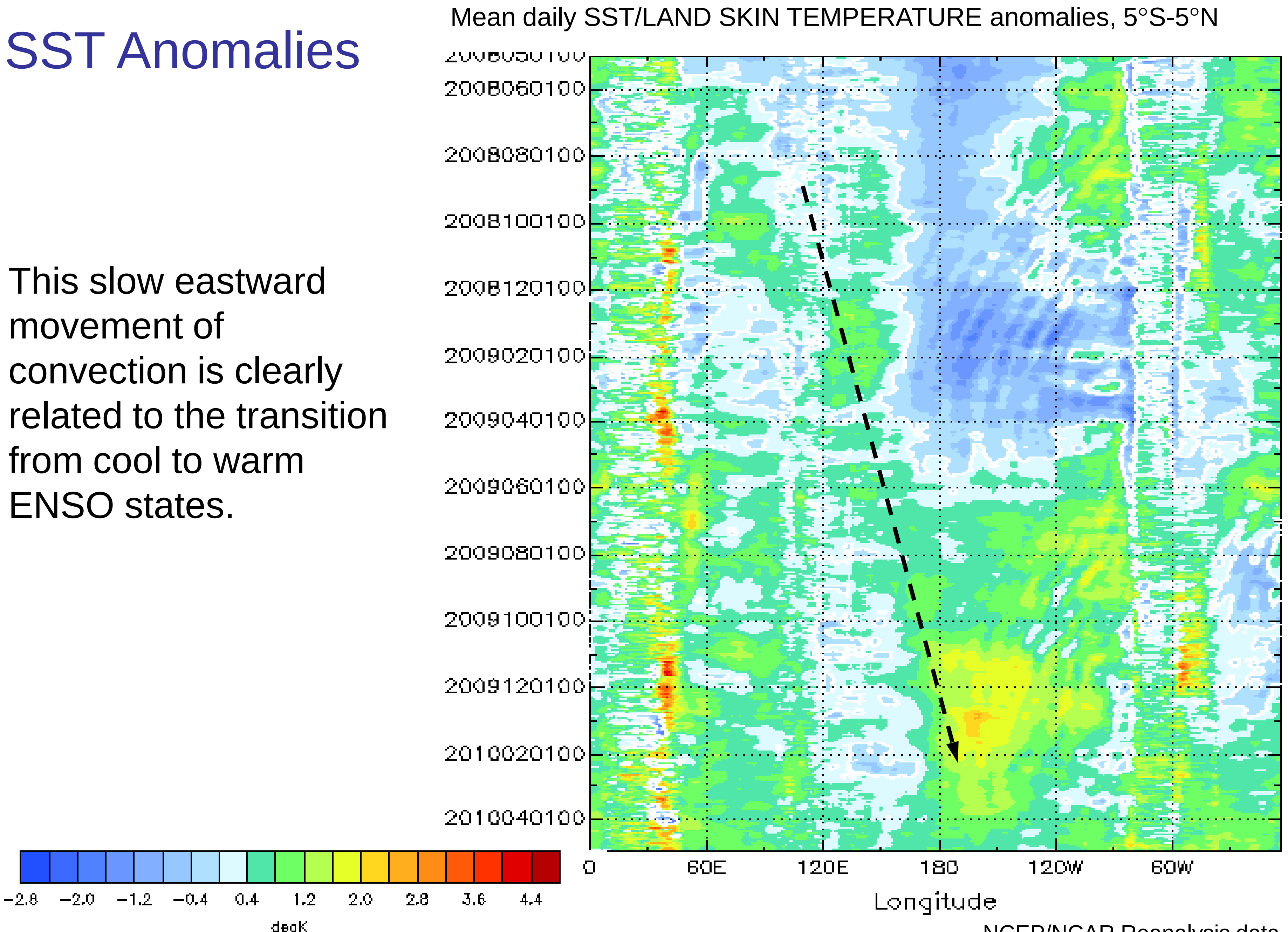
1. Overall view

On the longest time scale, the most prominent feature is the slow eastward movement of the most intense anomalies of enhanced convection.



SST Anomalies

This slow eastward movement of convection is clearly related to the transition from cool to warm ENSO states.



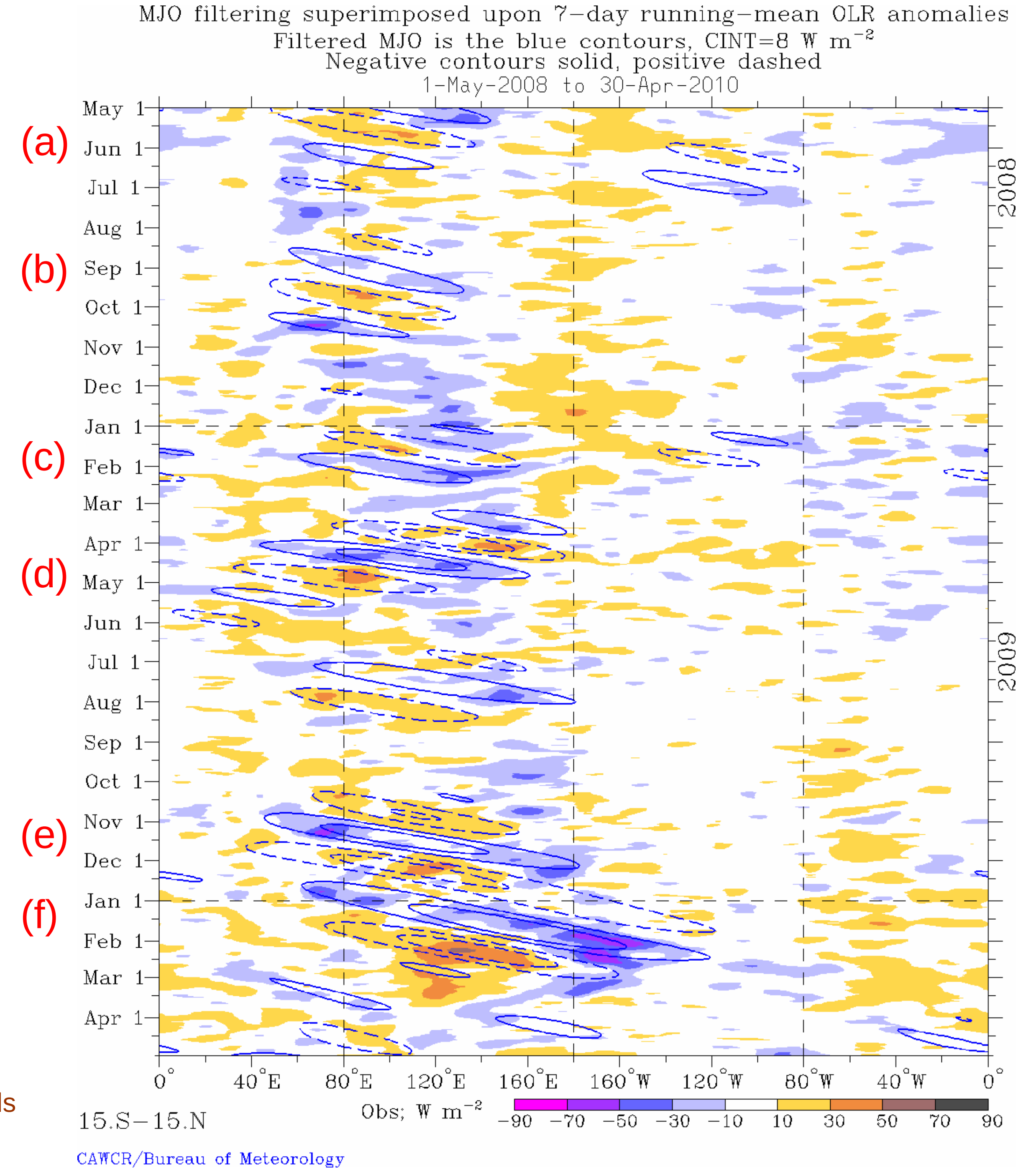
NCEP/NCAR Reanalysis data

2. MJO cases

Six cases of MJO variability can be identified.

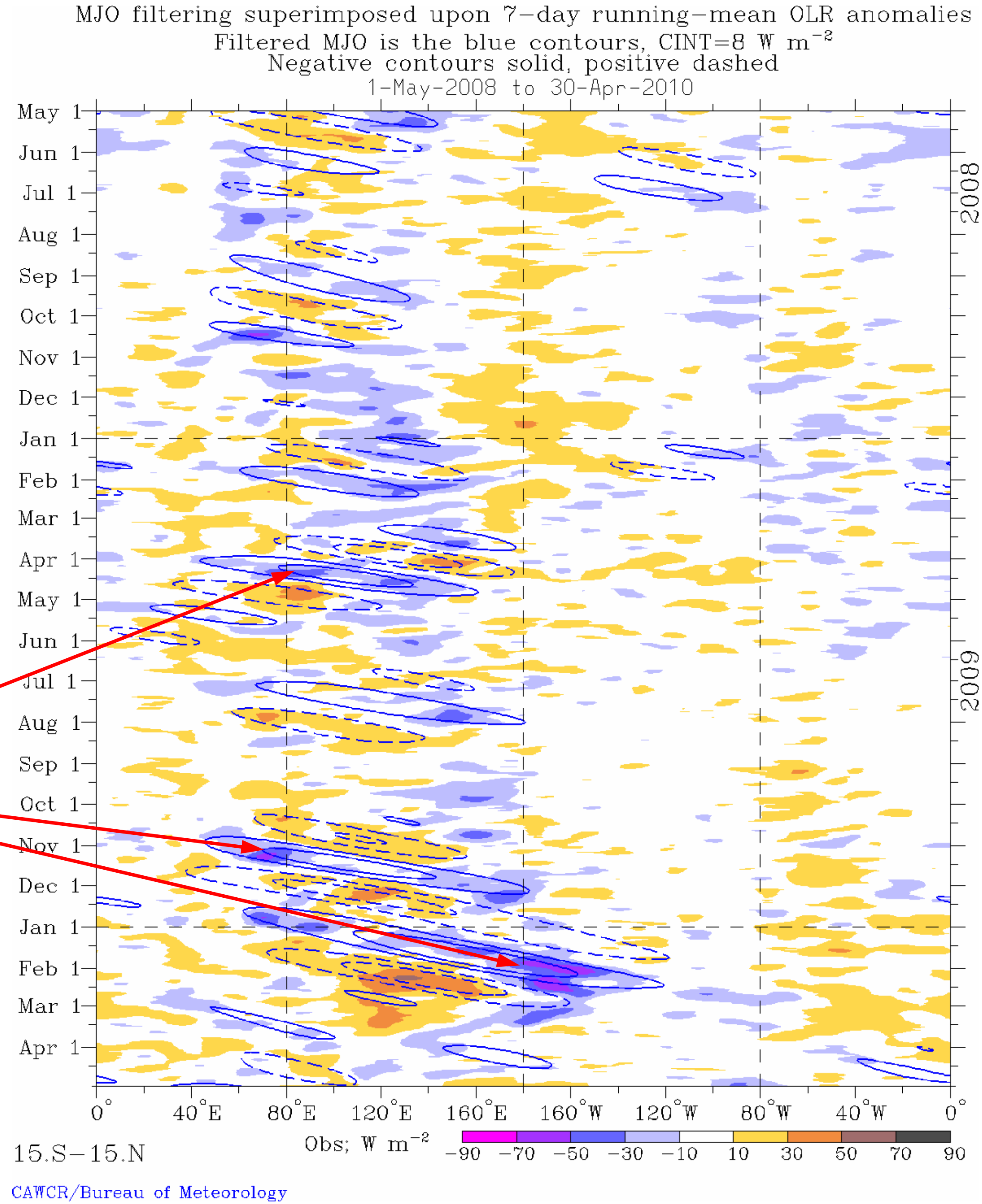
Labelling of MJO cases consistent with Waliser et al. (BAMS, submitted).

"MJO" defined in this plot through filtering of OLR anomalies for eastward waves 1-5, periods 30-96 days (Wheeler and Weickmann 2001)



3 strongest cases of MJO-related enhanced convection

(d) (e) and (f)



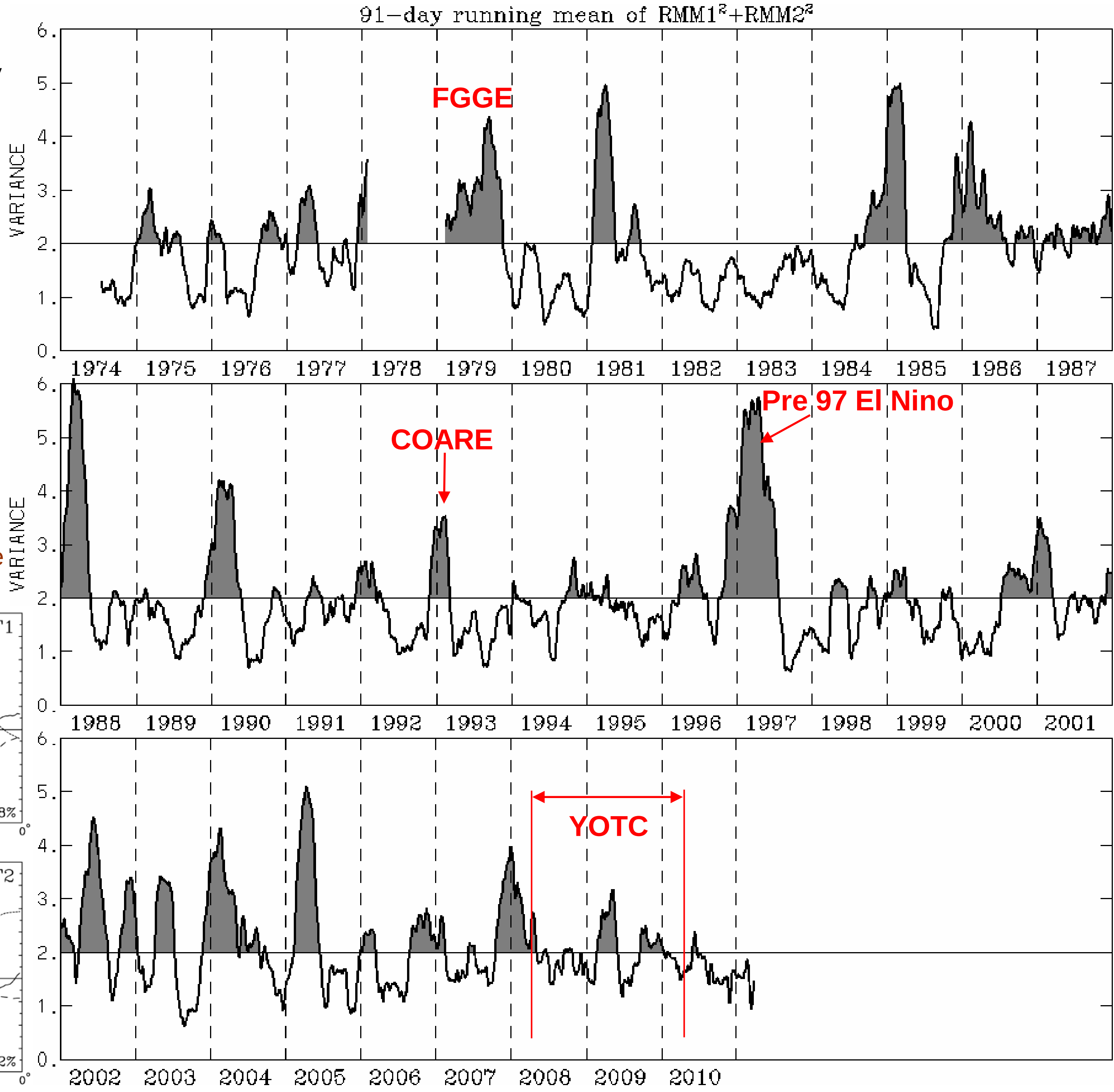
“MJO” defined in this plot through filtering of OLR anomalies for eastward waves 1-5, periods 30-96 days (Wheeler and Weickmann 2001)

How does the YOTC MJO activity compare to other memorable periods?

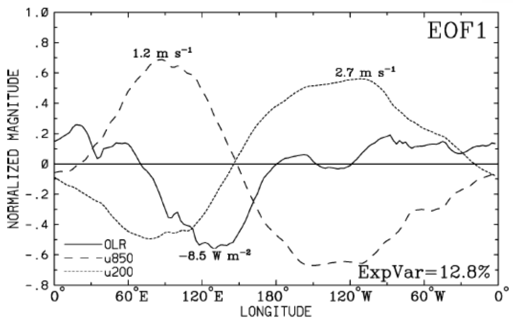
FGGE: 1979

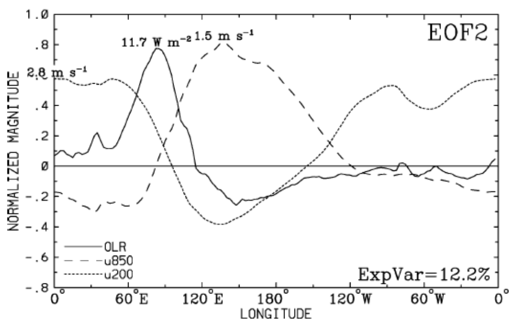
COARE: 1992/93

Pre 97 El Nino



Measured as the variance of the Wheeler-Hendon EOFs

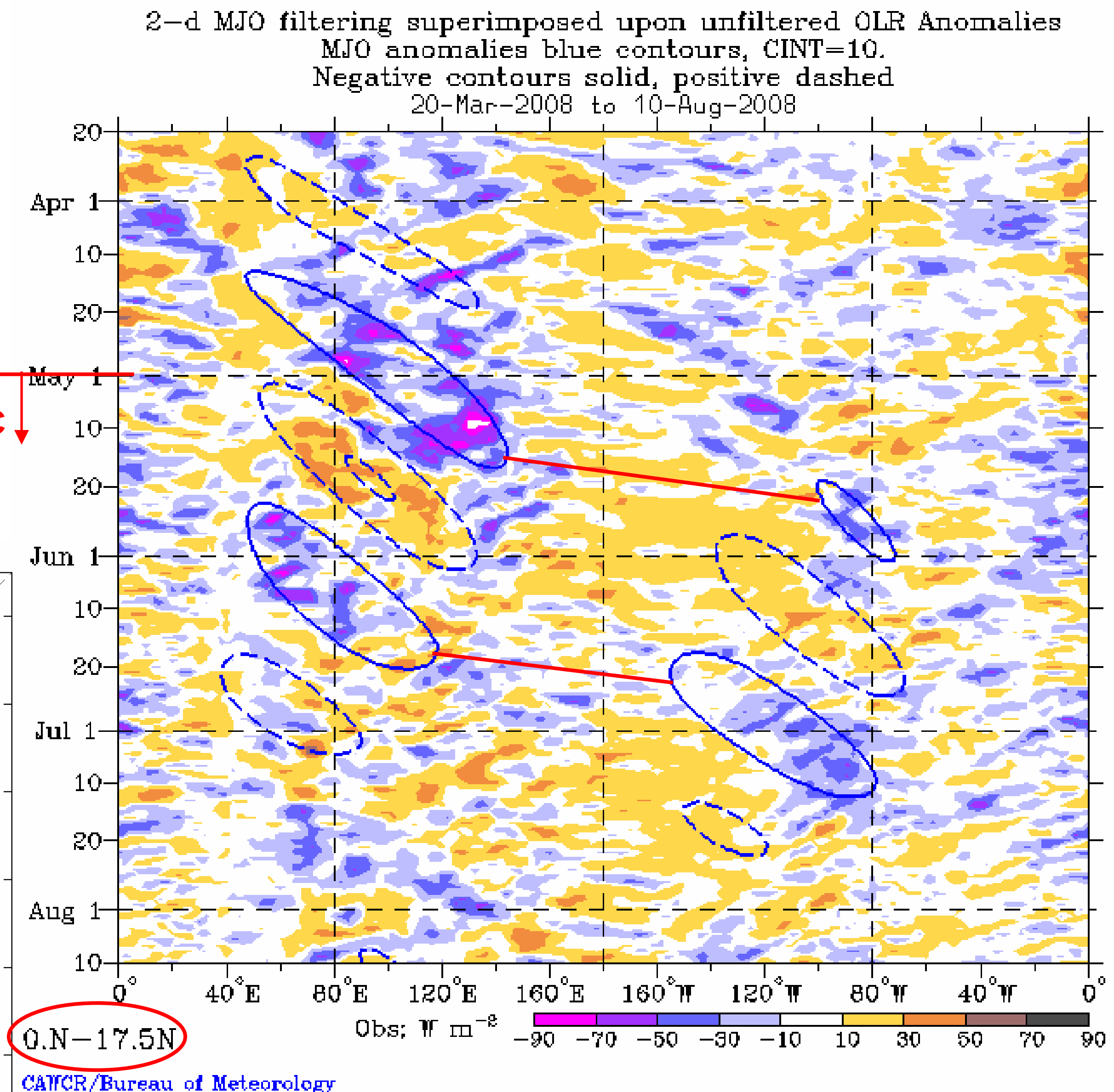


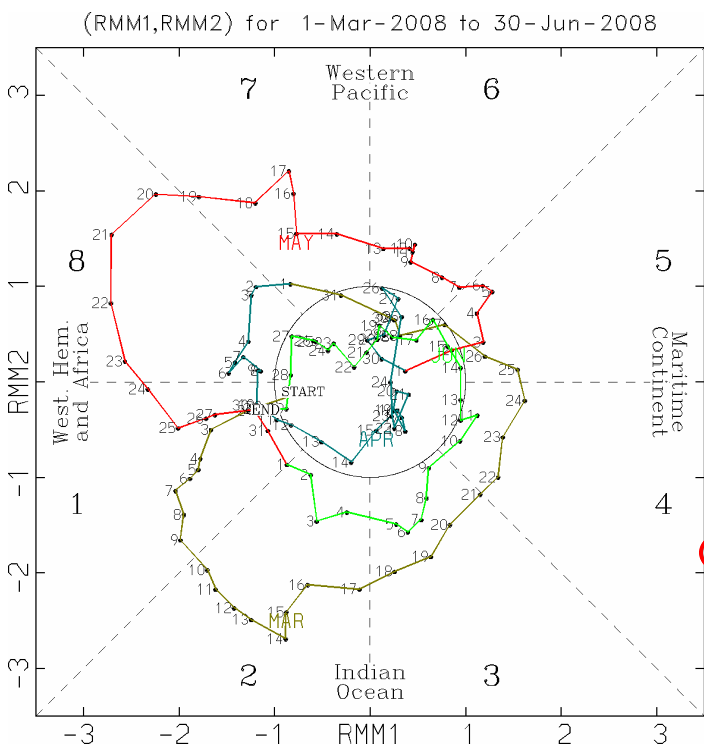


MJO case: (a) May-June 2008

Involved in monsoon onset over India (Kerala onset ~ 31st May).

Caused strong modulation of East Pacific ITCZ, including the formation of several TCs (Boris, Cristina, Douglas, Elida), and impacts on North American monsoon.

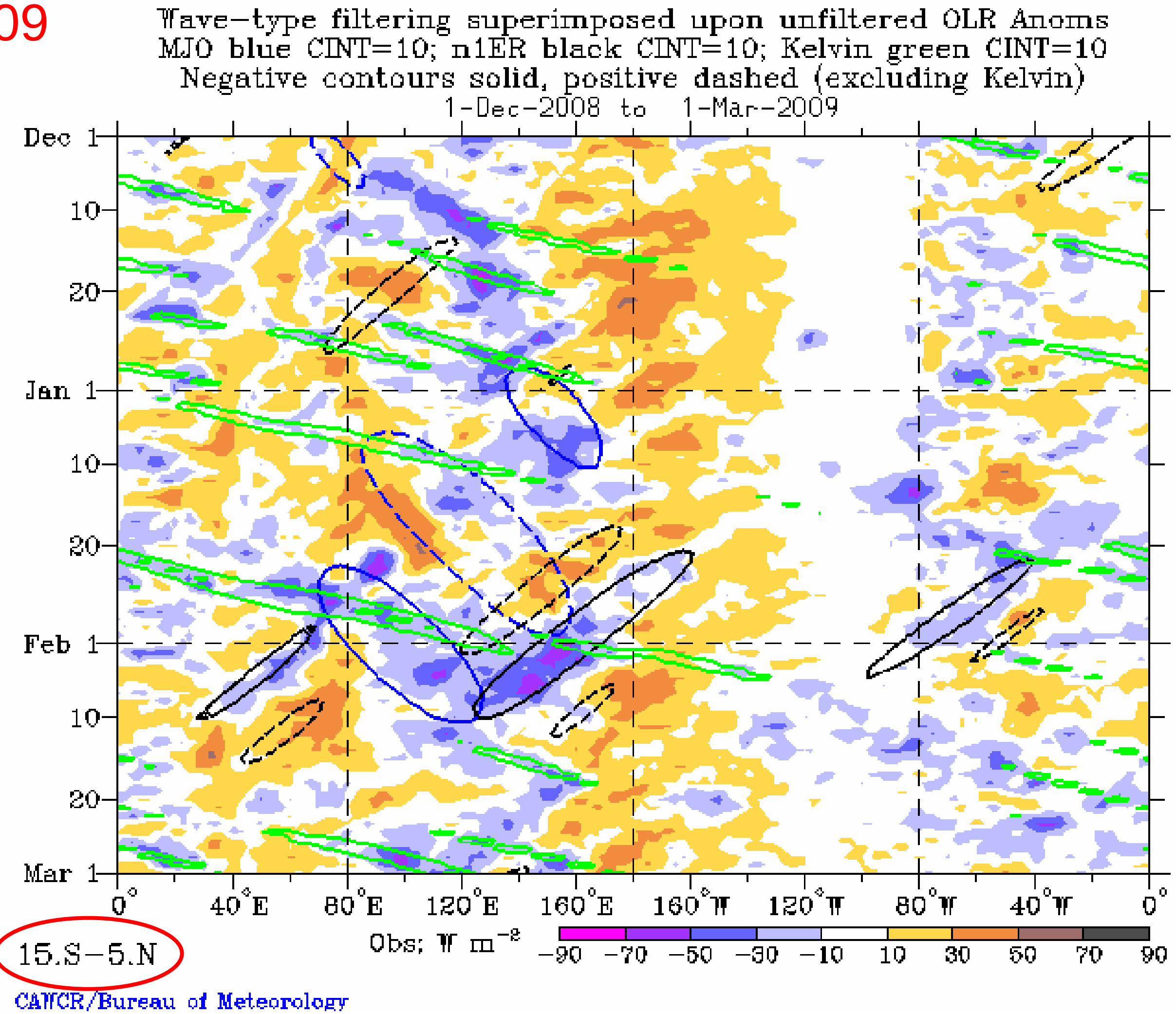


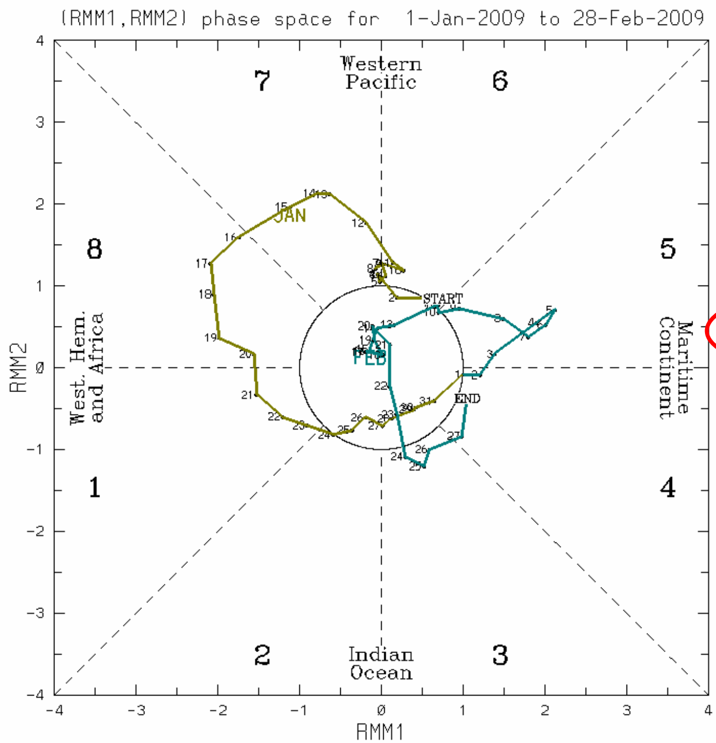


MJO case: (c) Jan-Feb 2009

A weak MJO event that involved interactions with CC Kelvin and Rossby waves.

Southern Hemisphere TCs Dominic, Hettie, Ellie and Freddy.





Note: The Australian monsoon onset occurred in most places by late December, seemingly un-related to the MJO.

However, the monsoon burst in early February appeared to be MJO-related, and was associated with much flooding in Queensland (~145°E) and disastrous heat-waves and fires in south-eastern Australia.

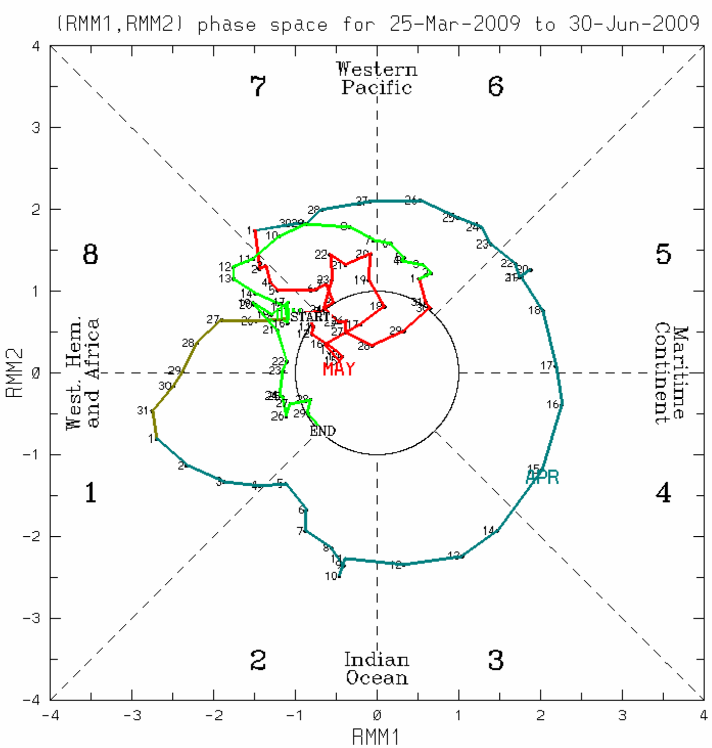
MJO case: (d) April-May 2009

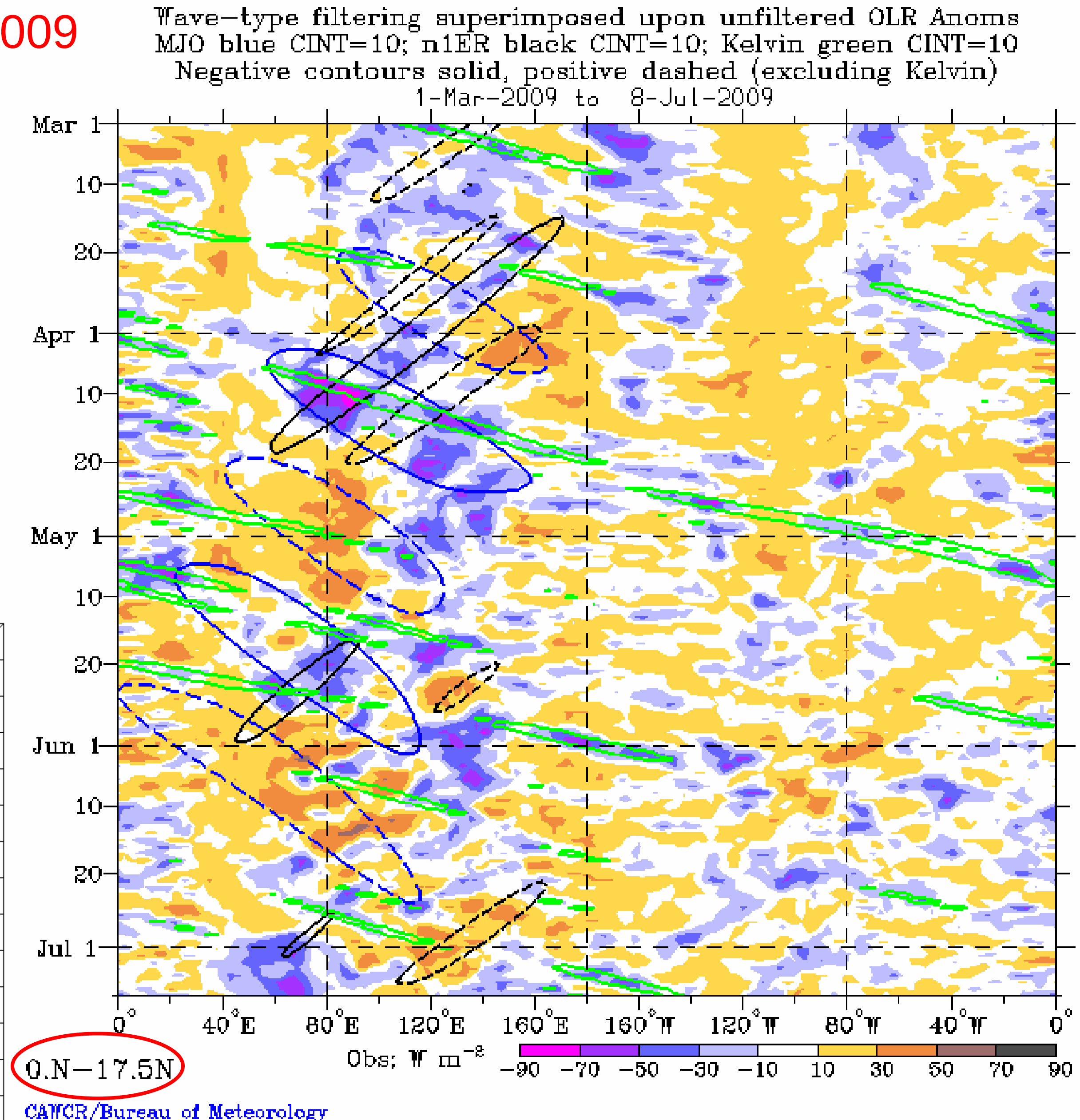
One of the 3 strongest MJO cases.

However, unlike activity of boreal spring/summer of 2008, had no discernible East Pacific ITCZ signal.

Kelvin and Rossby waves also involved.

April envelope had relatively fast propagation.

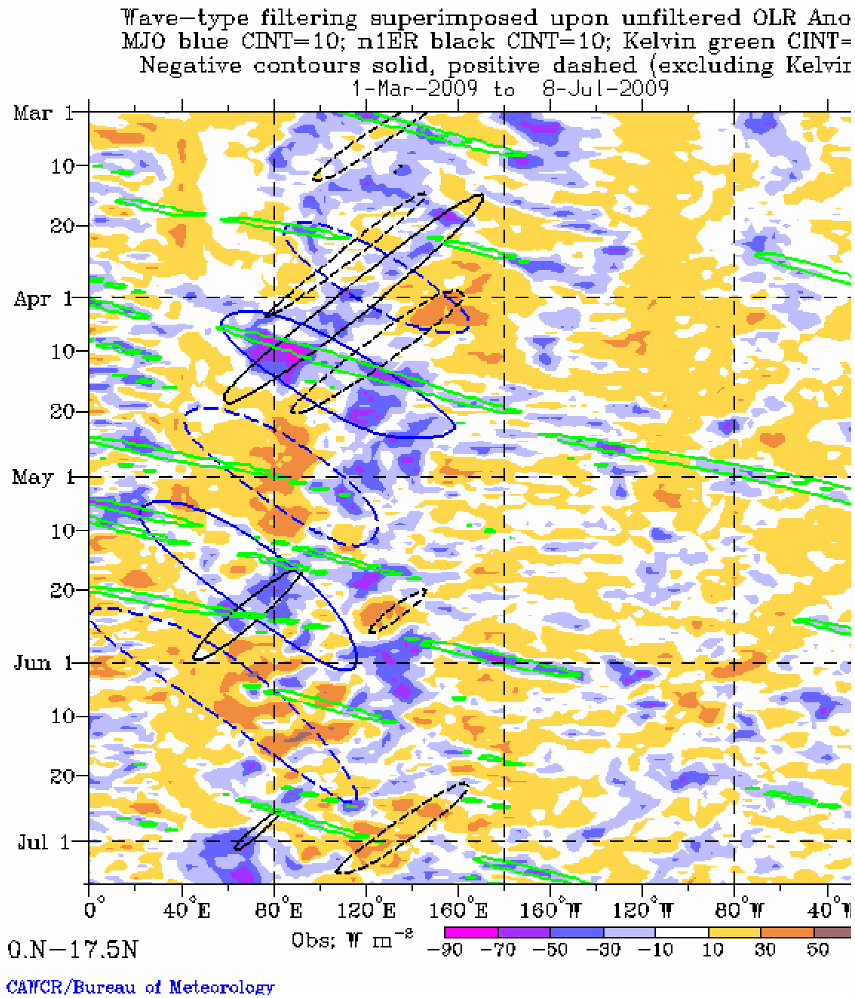


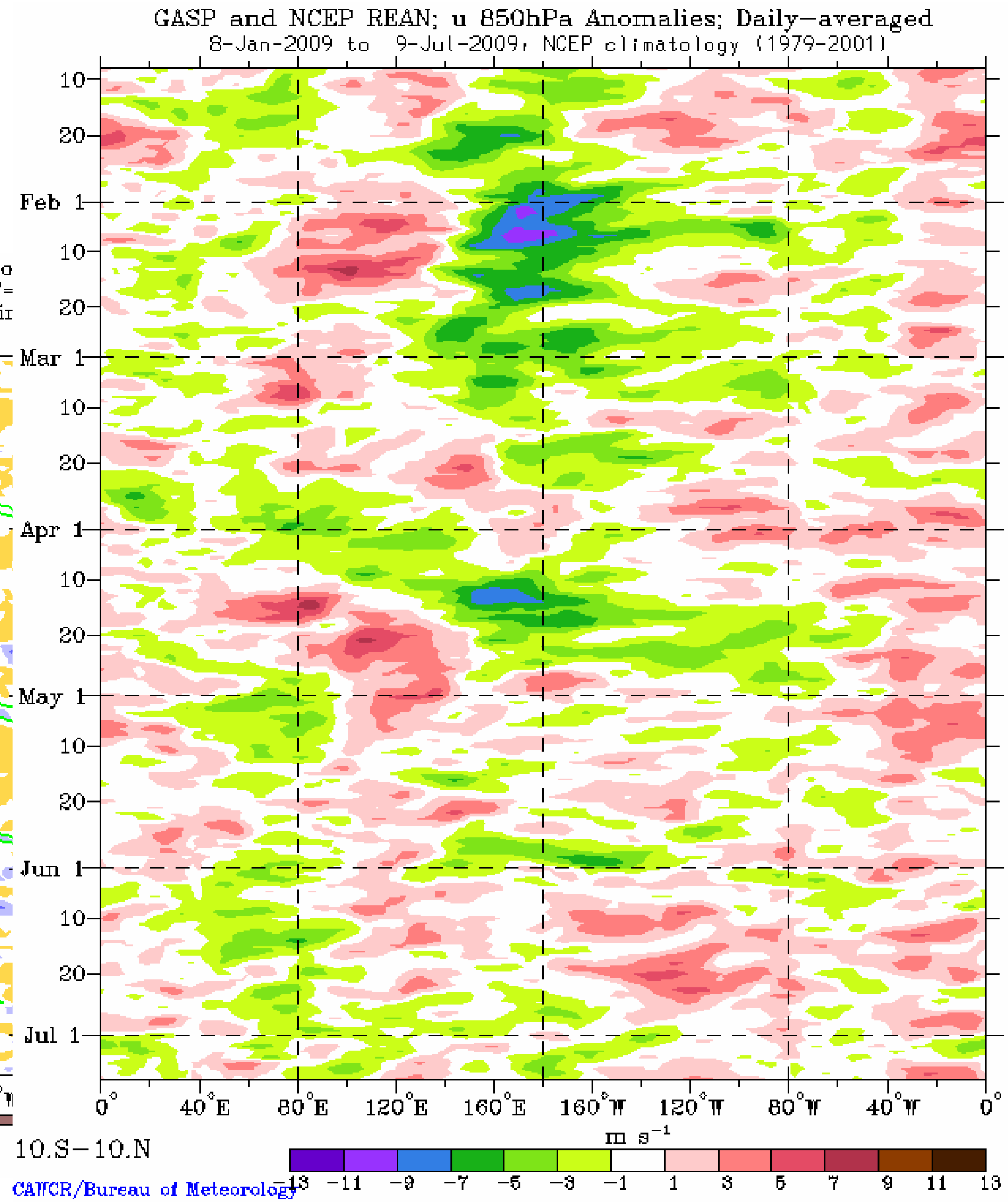


Indian monsoon onset at Kerala ~23rd May 2009

MJO also somewhat involved in June monsoon break over India

April 2009 MJO/Kelvin wave event was important for the shift from easterly to westerly anomalies across the Pacific, and subsequent basin-wide rise in SSTs.





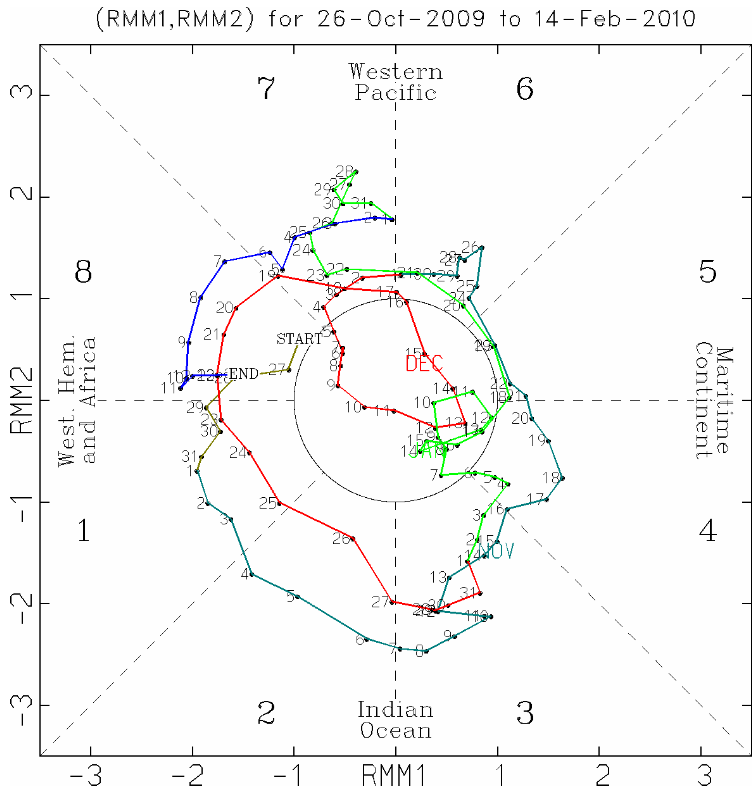
MJO cases: (e) Oct-Dec 2009

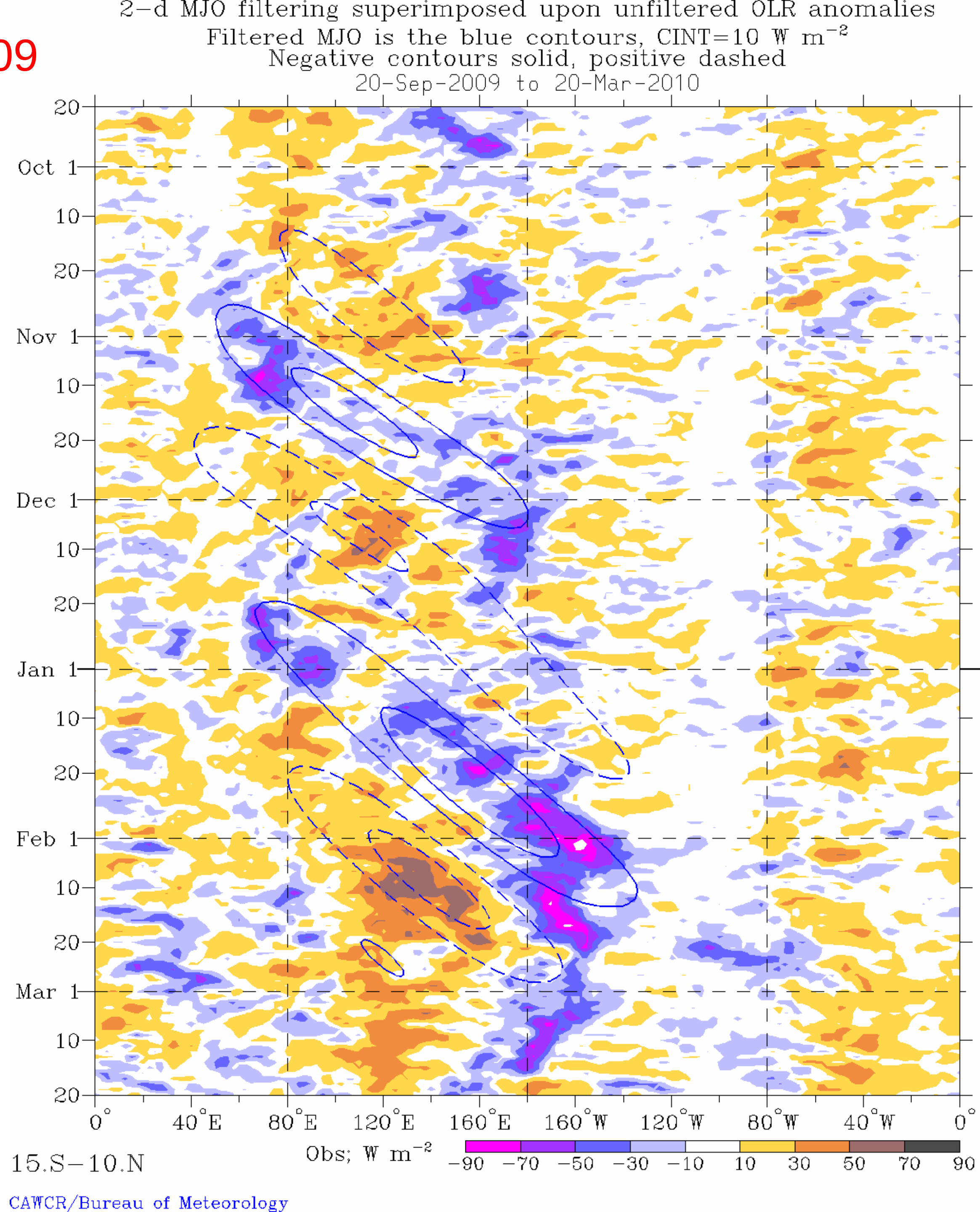
(f) Dec 2009-Feb 2010

Together, these cases comprise more than two full cycles of the MJO.

Convection associated with 2nd MJO cycle reached further eastward.

Main amplification of both events occurred well before the initiation of convection in the Indian Ocean.





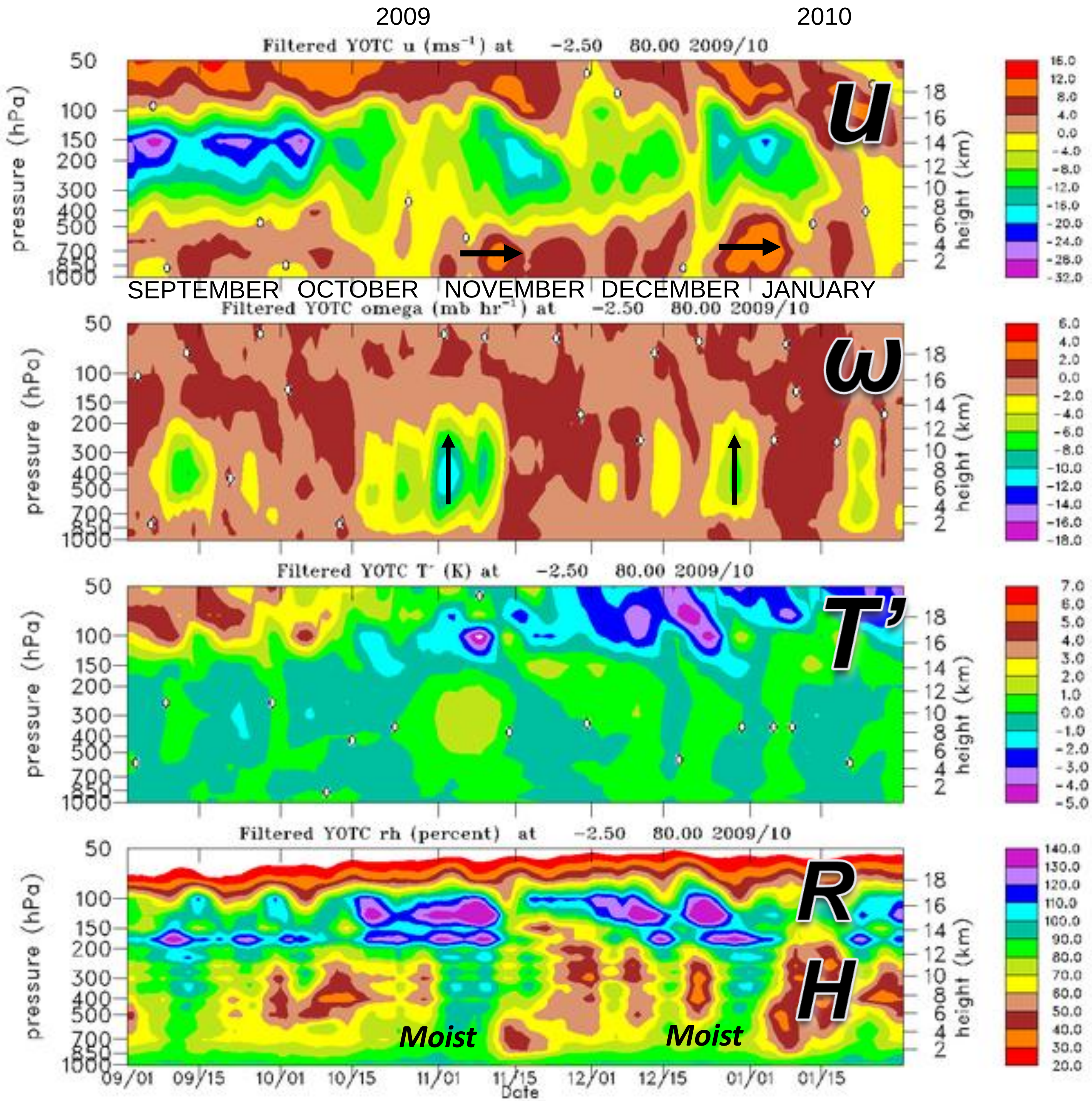
YOTC ECMWF high-res analyses

5° square centered at 2.5°S, 80°E.

Filtered to remove diurnal cycle.

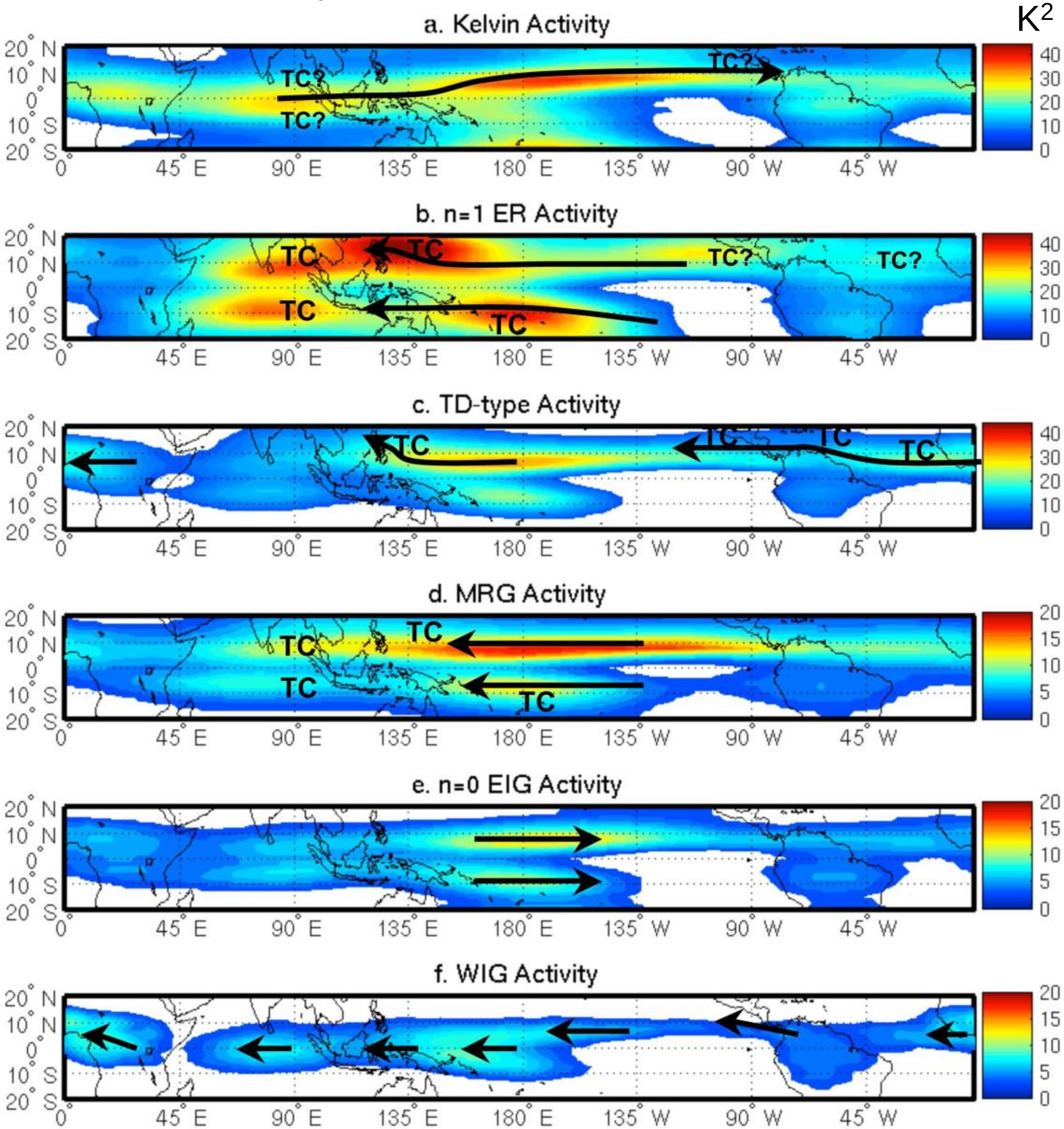
Low-level moisture leading convection.

Dick Johnson
Colorado State Uni

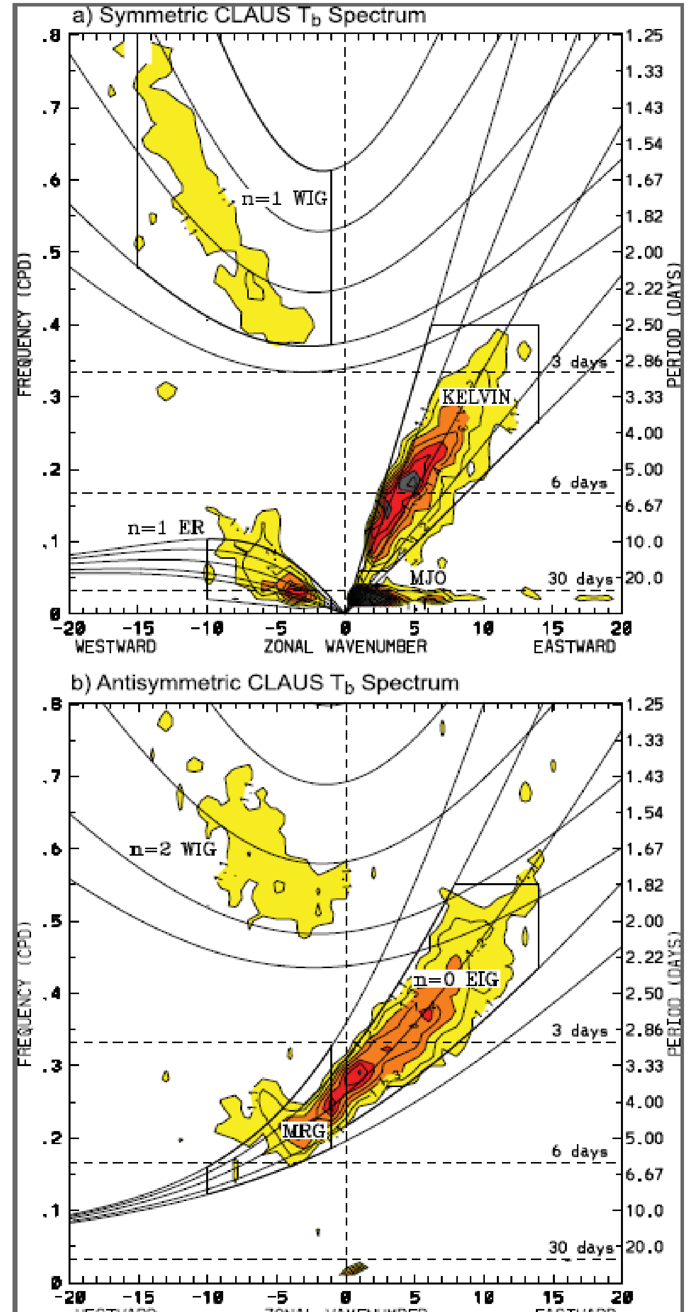


3. CCEWs

Long-term T_b variance maps from Kiladis et al. (2009)



Wave filtering regions



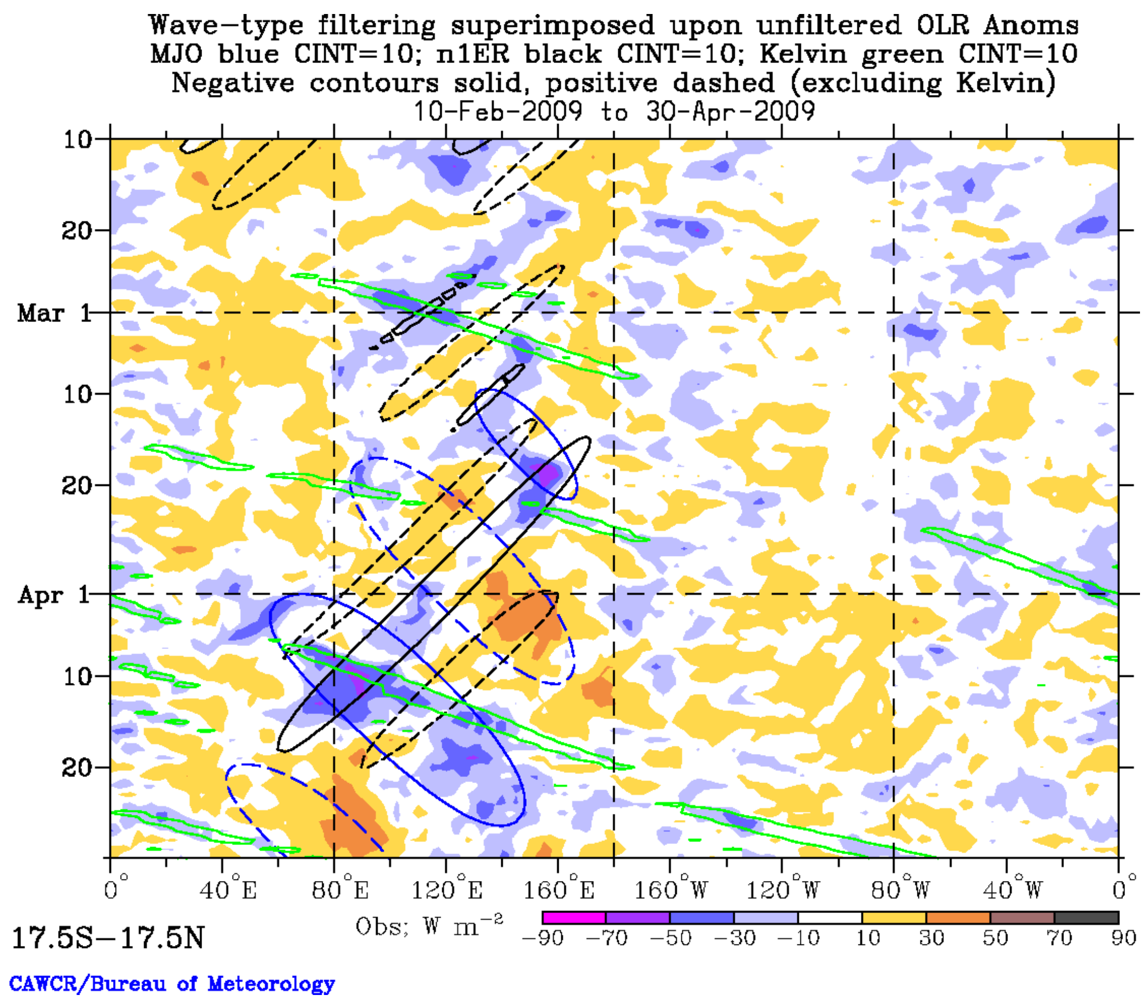
(1) The multiple interacting waves of March-April 2009

Co-existence of MJO, CC Kelvin waves, and CC Equatorial Rossby (ER) waves.

ER wave convection was maximized off the equator (in both hemispheres), whereas Kelvin wave convection was maximized close to the equator.

Sometimes, (e.g. 10th April near 90°E), the interaction appears remarkably linear.

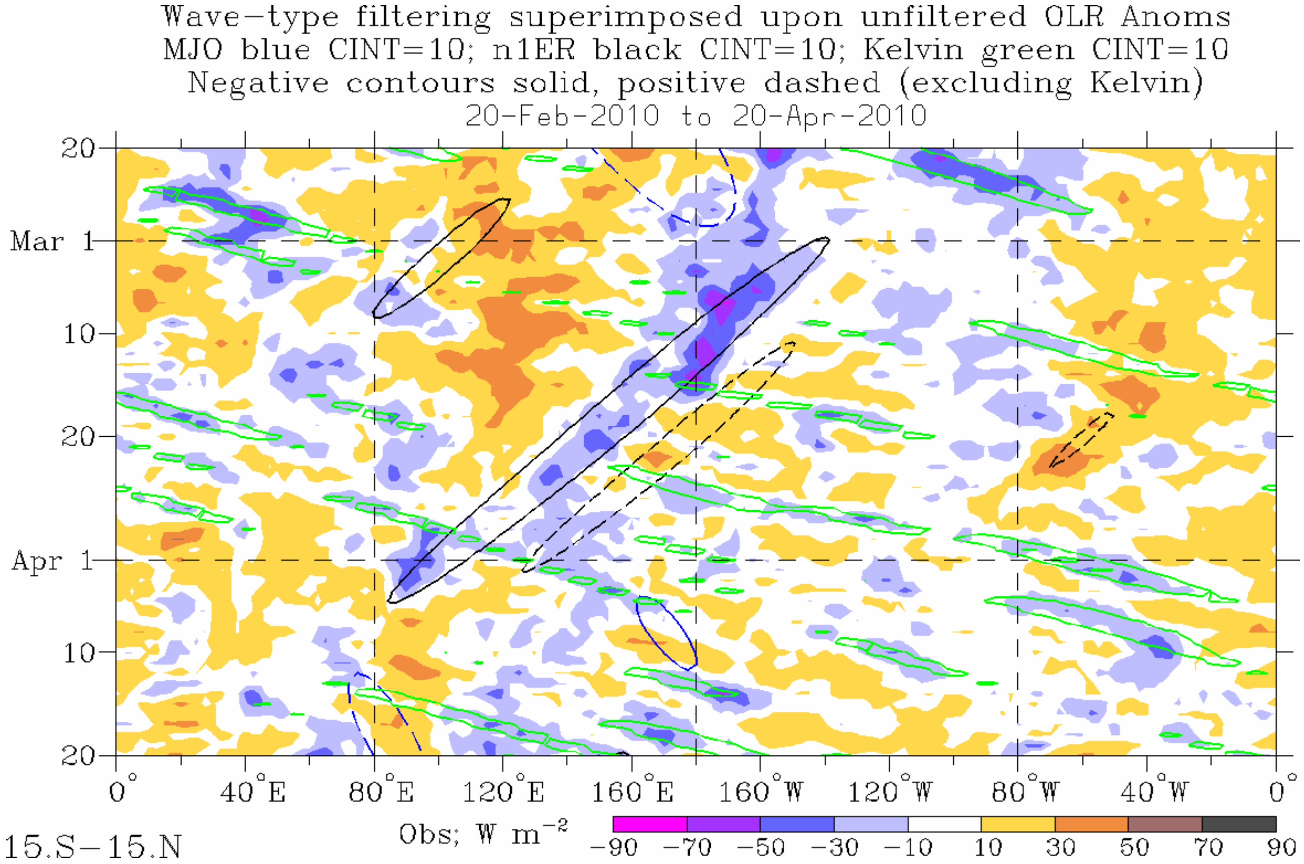
Can a full GCM reproduce this seemingly linear interaction?



(2) ER wave with several imbedded TCs in March 2010

Westward moving convection, mostly symmetric about the equator, had several imbedded TCs: TCs Tomas and Ului in the southern hemisphere and TC Omais (Agaton) in the northern hemisphere.

Prominent CC Kelvin wave activity also occurred during this period.



4. Dynamical model MJO forecasts

There are two important resources for operational MJO forecasts during YOTC:

1. The NOAA-CPC web-page at:

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

(As first developed by the CLIVAR MJO Working Group in cooperation with WGNE, but now guided by the YOTC MJO Task Force)

2. The TIGGE MJO forecasts at:

http://tparc.mri-jma.go.jp/TIGGE/tigge_MJO.html

(Developed by Dr. Mio Matsueda of JAMSTEC, Japan)

1. YOTC MJO Task Force activity (CPC web page)

Multiple operational centres have contributed to this activity to apply a standard diagnostic to model forecasts and display them in real time.

US – NCEP

ECMWF

United Kingdom

Brazil

US – NRL

India

Taiwan

Australia

Japan

Canada – CMC

A description of the activity and methods of forecast verification are provided in Gottschalck et al. (2010).

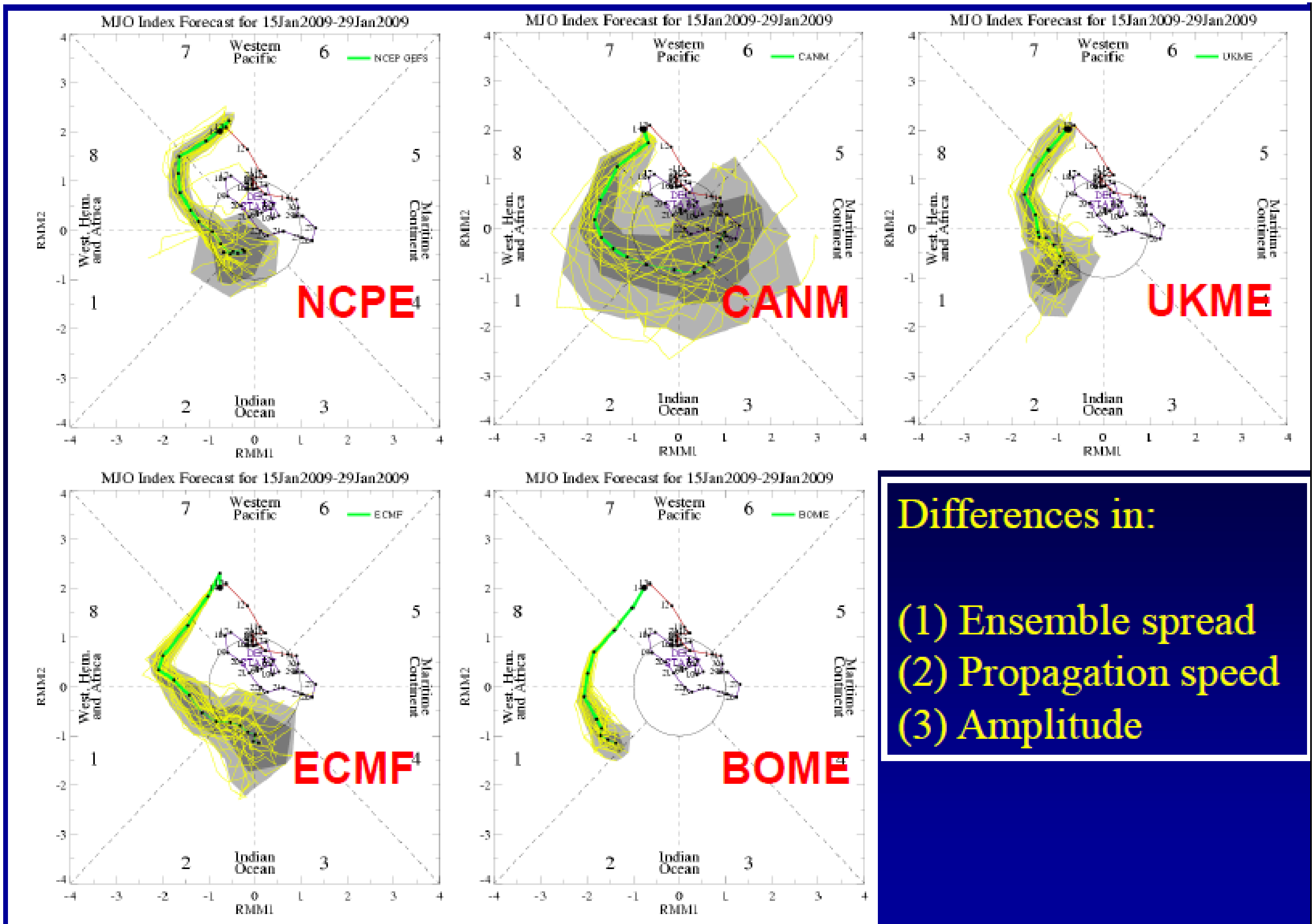
A FRAMEWORK FOR ASSESSING OPERATIONAL MADDEN–JULIAN OSCILLATION FORECASTS

A CLIVAR MJO Working Group Project

BY J. GOTTSCHALCK, M. WHEELER, K. WEICKMANN, F. VITART, N. SAVAGE, H. LIN, H. HENDON, D. WALISER, K. SPERBER, M. NAKAGAWA, C. PRESTRELO, M. FLATAU, AND W. HIGGINS

Multiple operational centers helped develop and apply a diagnostic to track the state of the MJO and skill of real-time numerical MJO forecasts.

Model forecast data is projected onto the EOFs of the combined fields of OLR and 850hPa and 200 hPa zonal winds from observations (Wheeler and Hendon 2004). Here is an example during YOTC MJO case (c).



Evaluating MJO forecasts with Wheeler-Hendon 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)

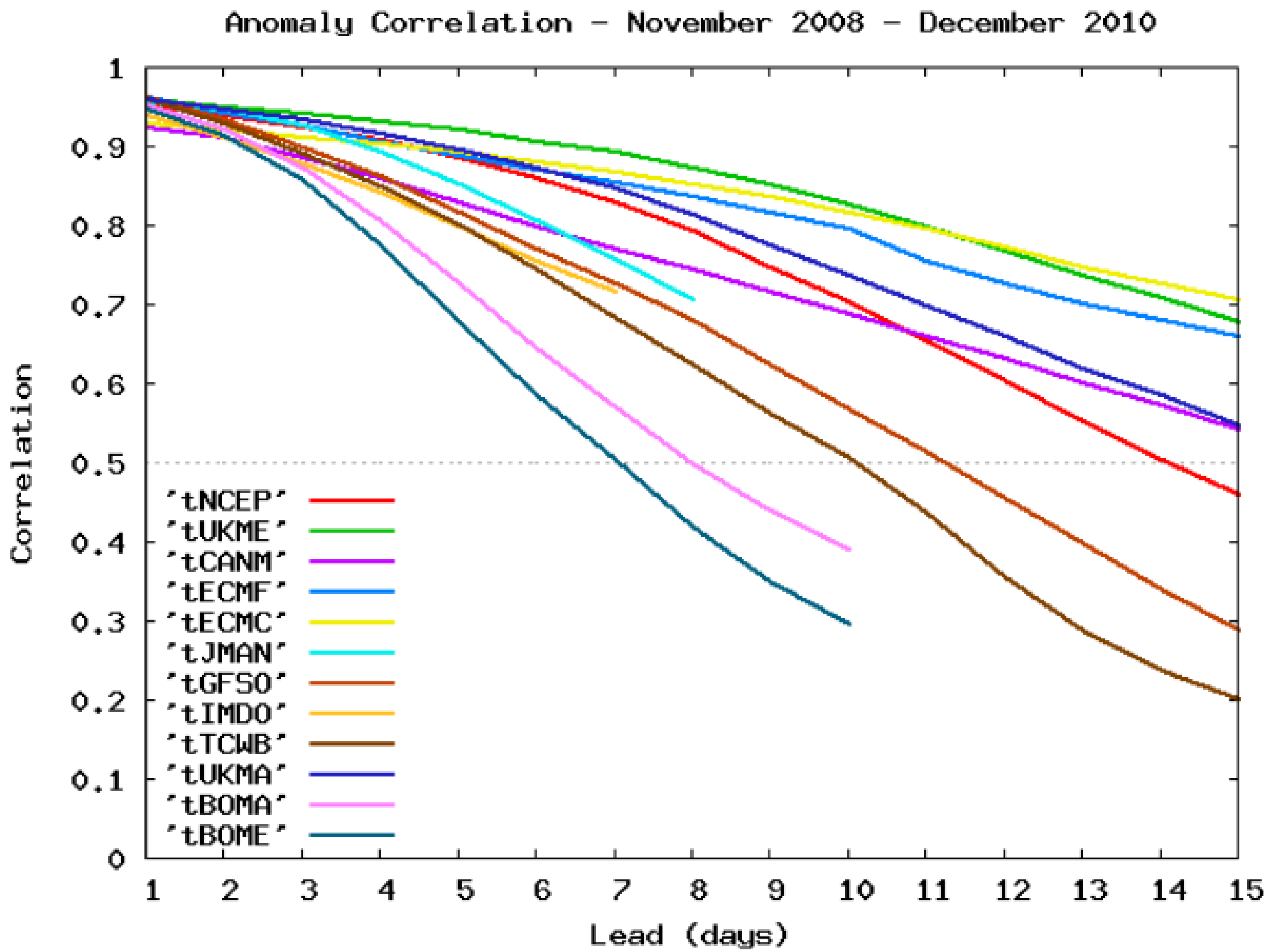
$$COR(\tau) = \frac{\sum_{t=1}^{N}\left[a_1(t)b_1(t,\tau) + a_2(t)b_2(t,\tau)\right]}{\sqrt{\sum_{t=1}^{N}\left[a_1^2(t) + a_2^2(t)\right]}\sqrt{\sum_{t=1}^{N}\left[b_1^2(t,\tau) + b_2^2(t,\tau)\right]}}$$

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

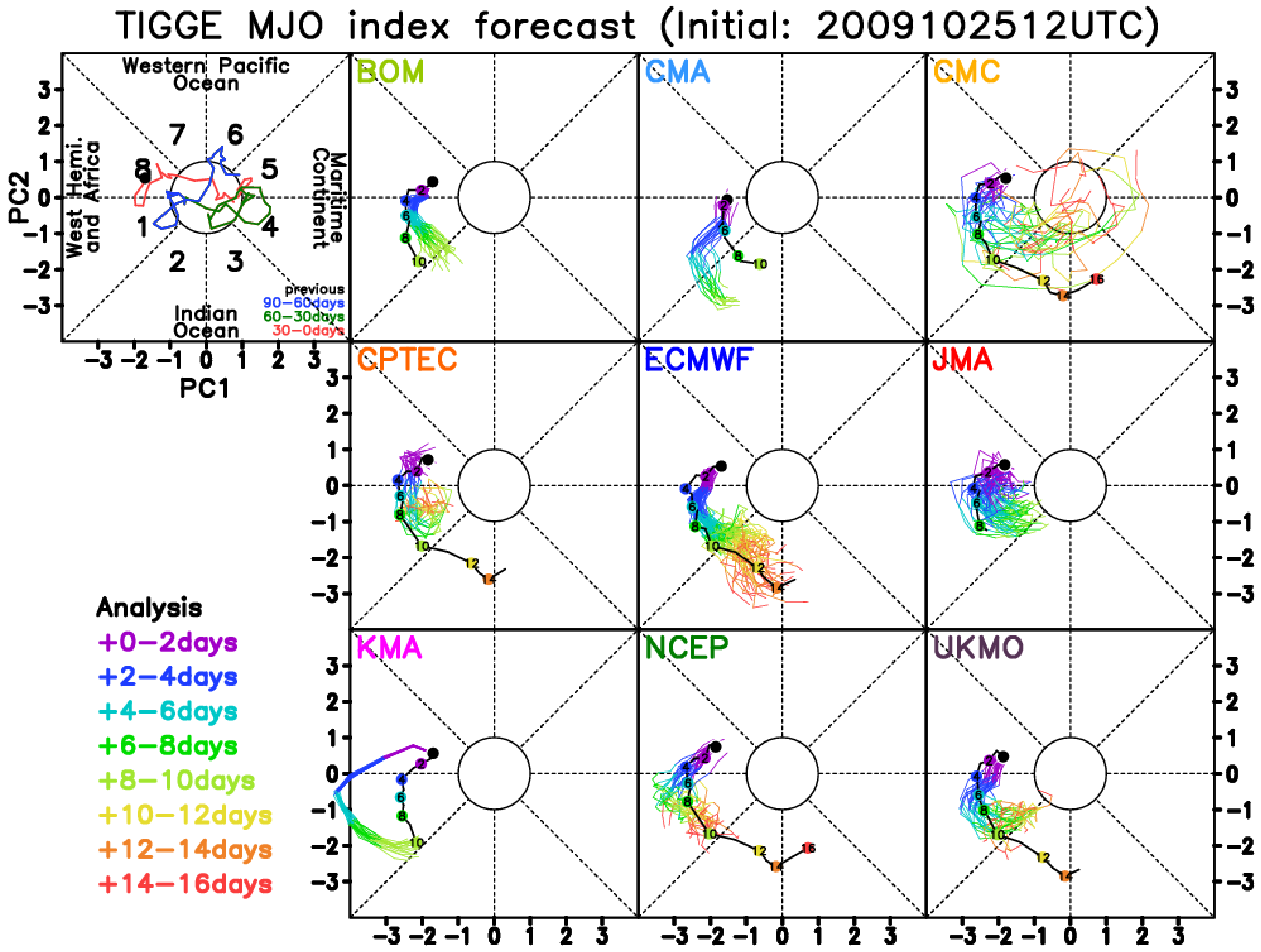
$a_1(t)$ and $a_2(t)$ observed RMM1 and RMM2

$b_1(t,\tau)$ and $b_2(t,\tau)$ are forecast RMM1 and RMM2

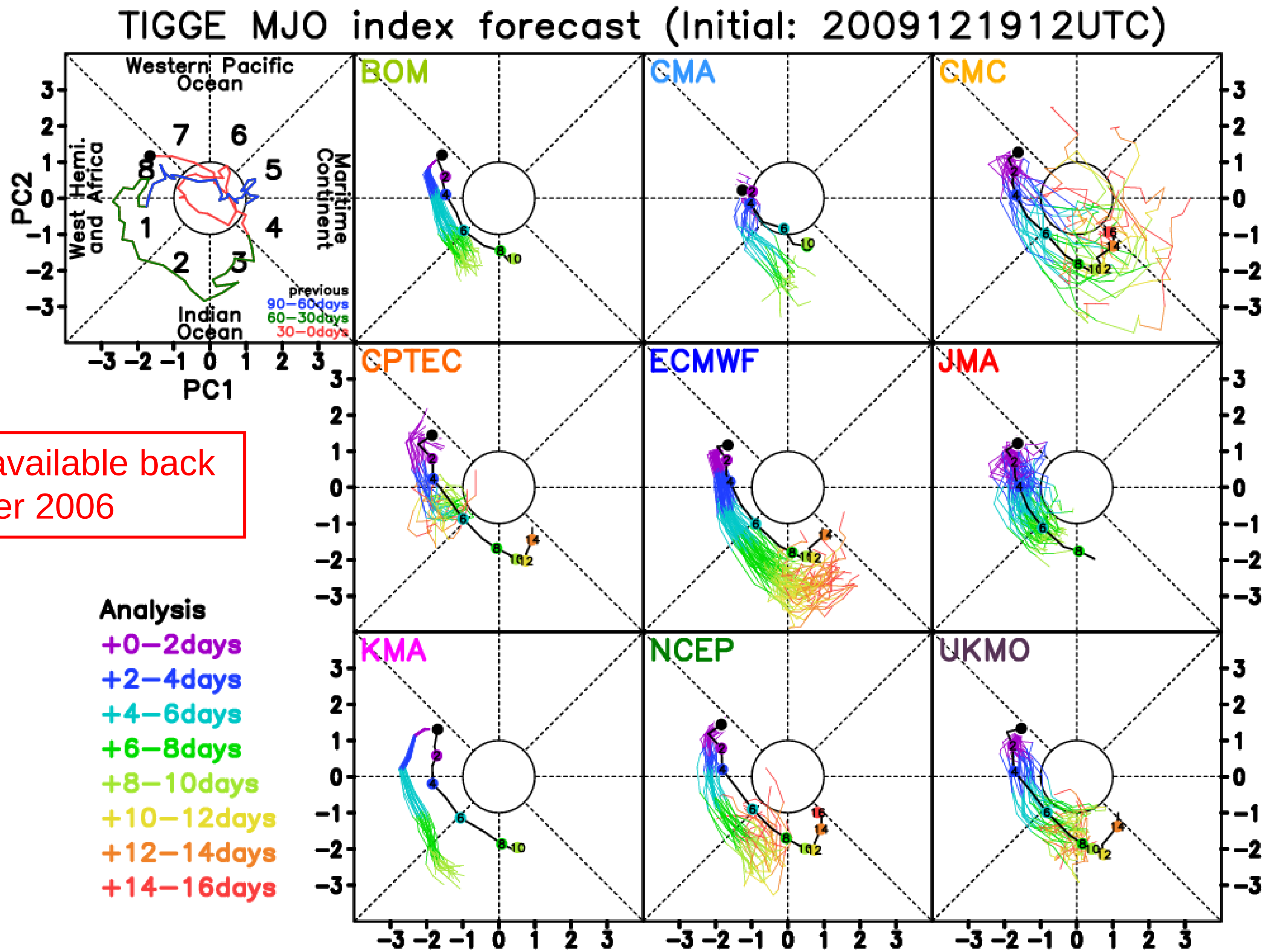
Preliminary Verification



2. TIGGE MJO forecasts: Example during YOTC MJO case (e)



Example during YOTC MJO case (f)



Archive available back to October 2006

5. Summary and Discussion

1. Six identified MJO cases for further observational study and modelling.

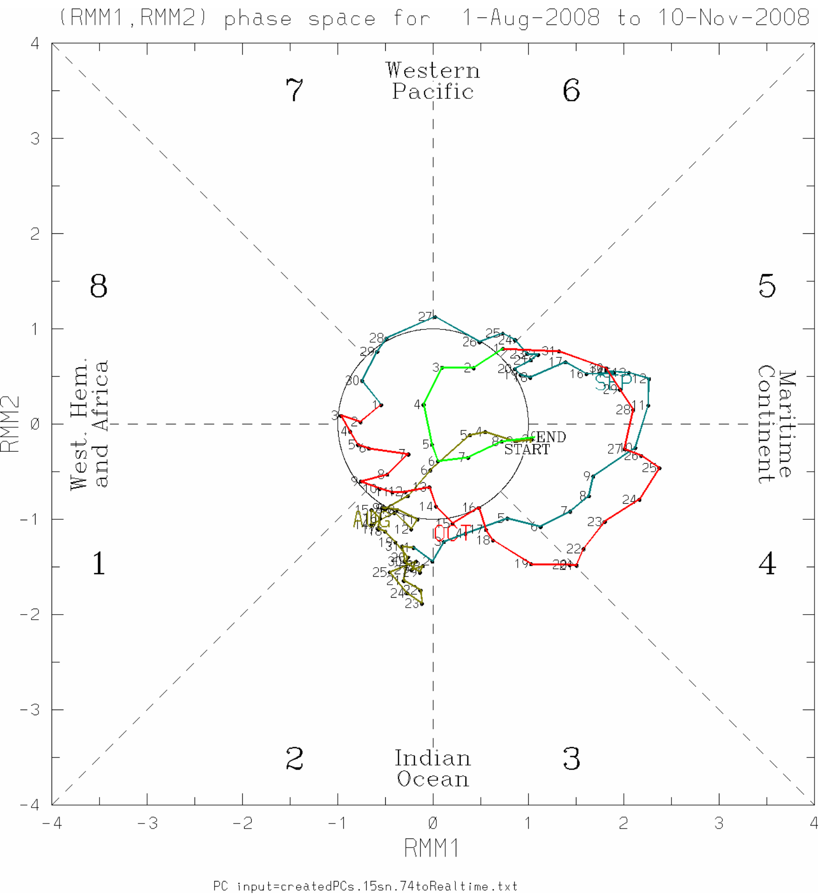
2. Notable periods of weak or no MJO variability as well (which is also important to model and study).

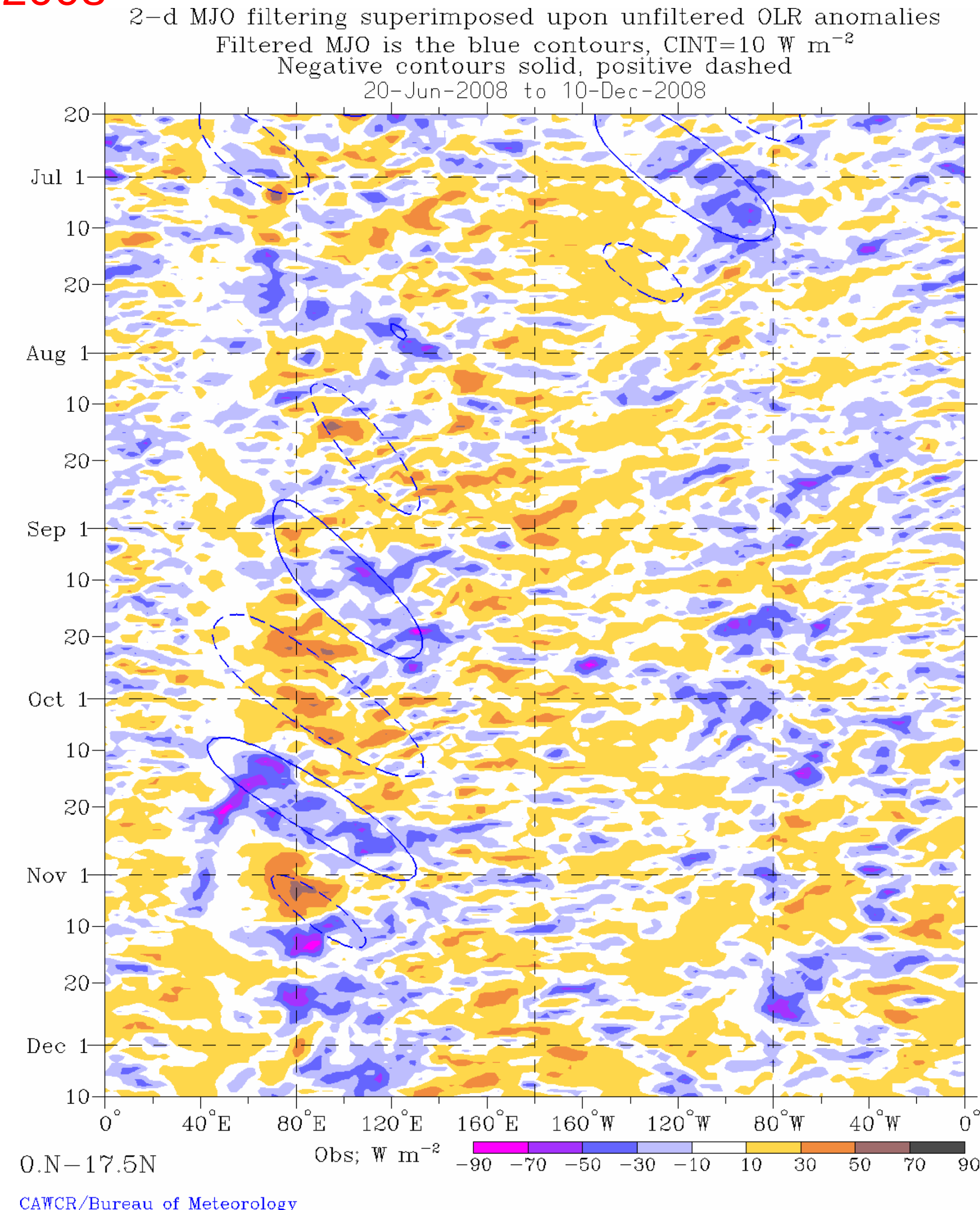
3. Many cases of convectively-coupled Kelvin and Rossby waves. Two example periods that stand out are March 2009 and March 2010.

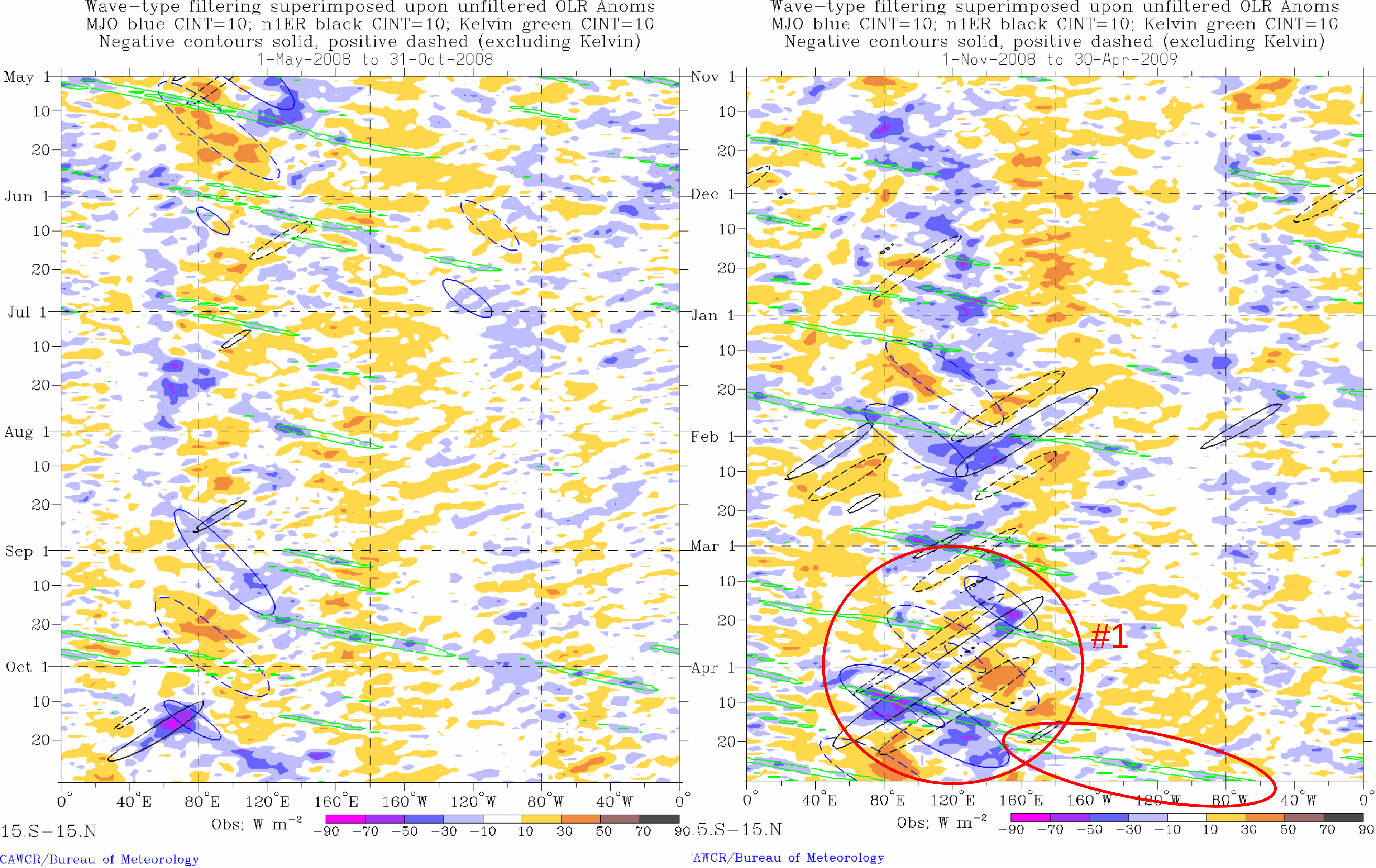
4. Operational dynamical MJO forecasting has been an active area of research and discovery during the YOTC period.

The End

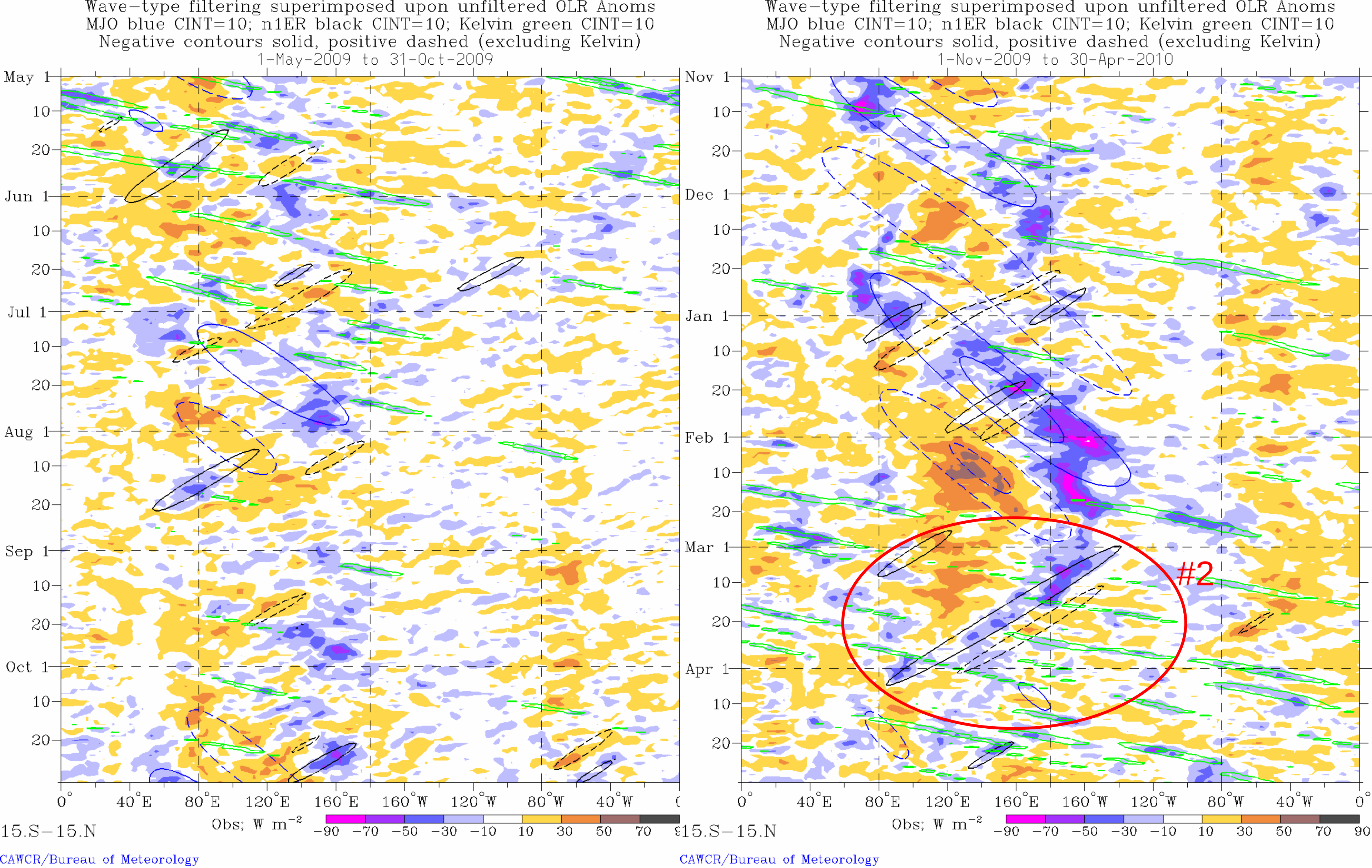
MJO case: (b) August-October 2008



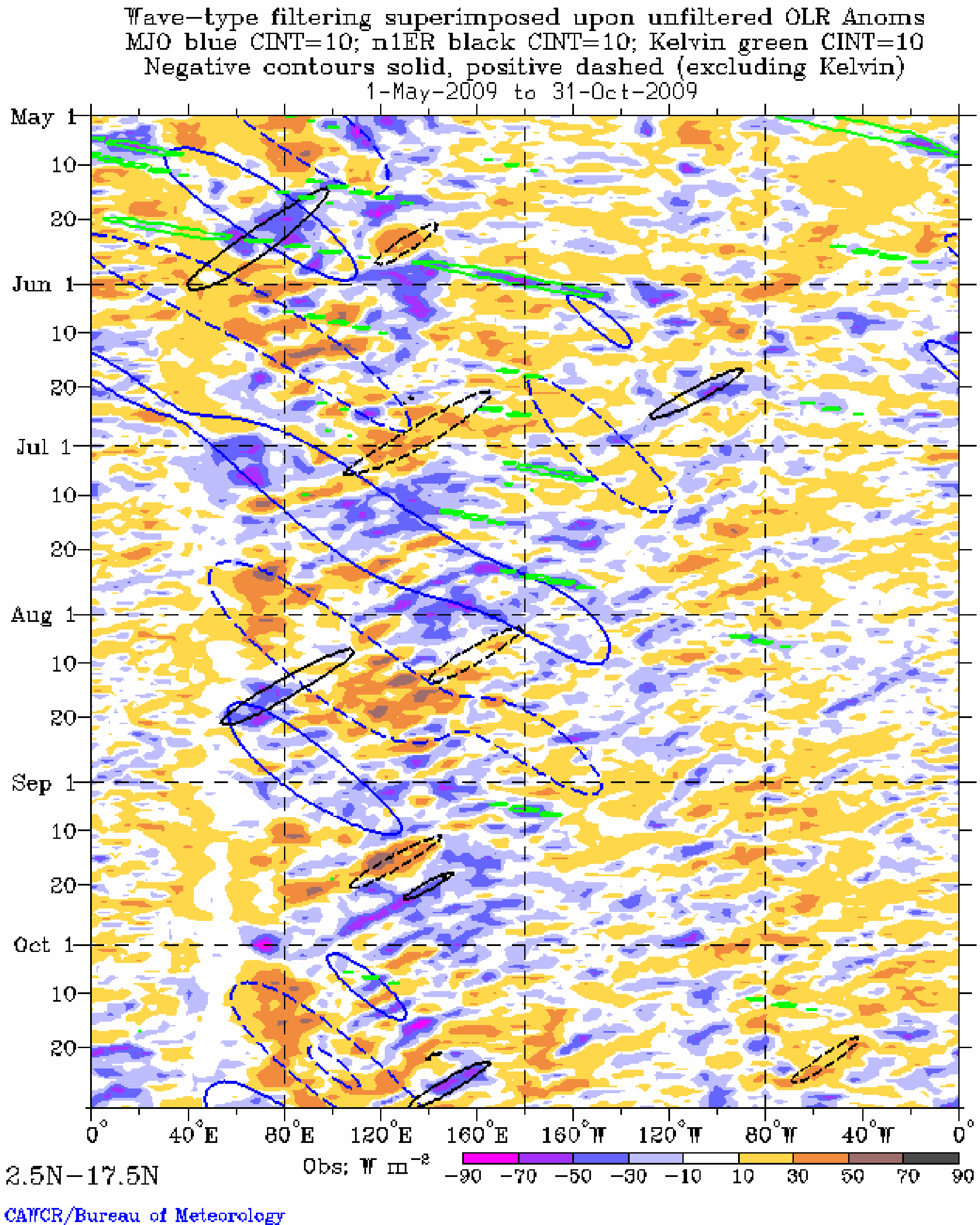




Wave−type filtering superimposed upon unfiltered OLR Anoms
MJO blue CINT=10; n1ER black CINT=10; Kelvin green CINT=10
Negative contours solid, positive dashed (excluding Kelvin)
1-May-2008 to 31-Oct-2008
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
0°
40°E
80°E
120°E
160°E
160°W
120°W
80°W
40°W
Obs; W m−2
−90 −70 −50 −30 −10 10 30 50 70 90
15.S−15.N
CAWCR/Bureau of Meteorology
Wave−type filtering superimposed upon unfiltered OLR Anoms
MJO blue CINT=10; n1ER black CINT=10; Kelvin green CINT=10
Negative contours solid, positive dashed (excluding Kelvin)
1-Nov-2008 to 30-Apr-2009
Nov 1
Dec 1
Jan 1
Feb 1
Mar 1
Apr 1
#1
15.S−15.N
CAWCR/Bureau of Meteorology



SH TC Tomas. Moved westward from 10-15 March (from 170 W to dateline).
SH TC Ului. 10 March at 170E. 21 March at 150E (landfall on Queensland coast).
In NH TC Omais (Agaton) was moving westwards at same time. 22-26 March.


Wave-type filtering superimposed upon unfiltered OLR Anoms
MJO blue CINT=10; n1ER black CINT=10; Kelvin green CINT=10
Negative contours solid, positive dashed (excluding Kelvin)
1-May-2009 to 31-Oct-2009
May 1
10
20
Jun 1
10
20
Jul 1
10
20
Aug 1
10
20
Sep 1
10
20
Oct 1
10
20
0°
40°E
80°E
120°E
160°E
160°W
120°W
80°W
40°W
0°
2.5N-17.5N
Obs; W m⁻²
-90 -70 -50 -30 -10 10 30 50 70 90
CAWCR/Bureau of Meteorology