MJO Simulations/Hindcasts with NICAM

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Monsoon Intraseasonal Variability Modelling Workshop

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APEC Climate Center, Busan, Korea

Group web page is http://nicam.jp

JAMSTEC

EARTH SIMULATOR

KAKUSHIN

Outlines

- **Overview of NICAM**

  Nonhydrostatic ICosahedral Atmospheric Model for Global Cloud-Resolving Simulations

- **Monsoon and ISV simulations with NICAM**

  Seasonal simulation, sensitivity experiments (SST, physics)

  –**2004 boreal summer series** (Oouchi et al. 2009a,b; Noda et al. 2010) → Oouchi

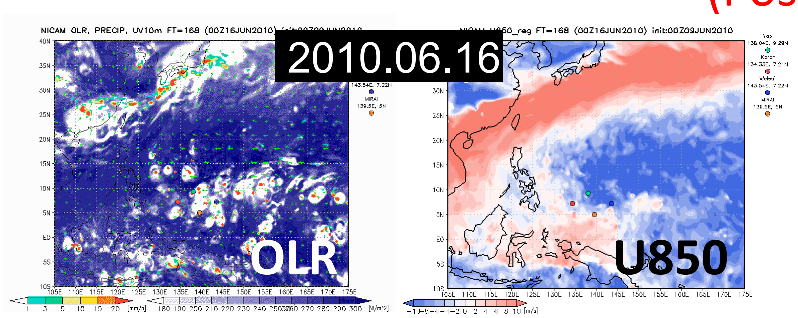
  Collaboration with field observation projects **MISMO** (Poster 6/15)

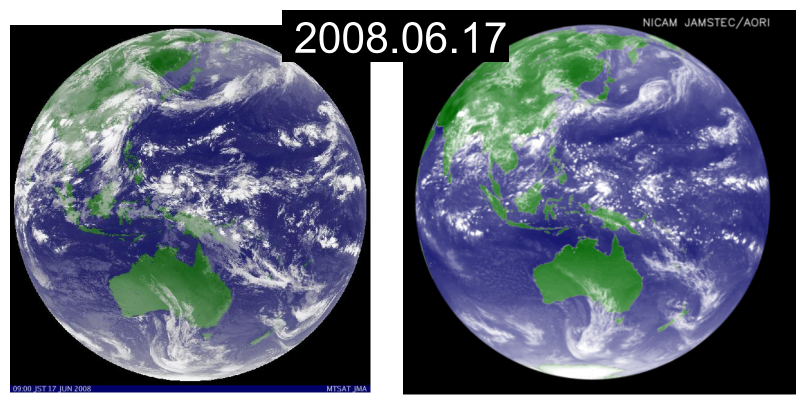
  –**2006 boreal winter series** (Miura et al. 2007, 2009) → Miyakawa (Poster 6/16)

  –...rgis; Taniguchi et al. 201... w !)

  PALAU2010 (15may-20jun) → Oouchi (Poster)

  PALAU2008, YOTC





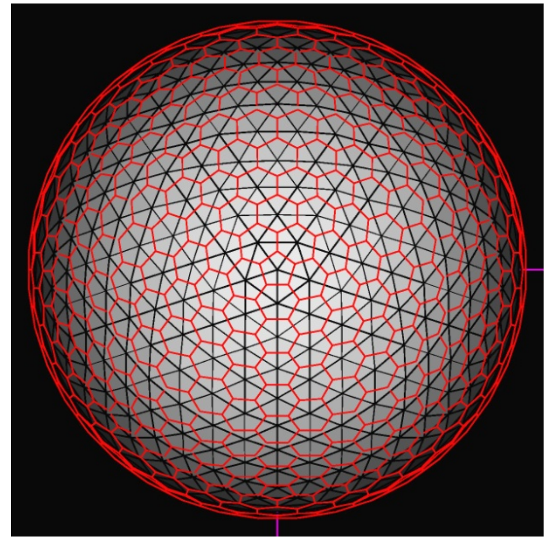
MTSAT-1R, IR

NICAM 3.5km, OLR

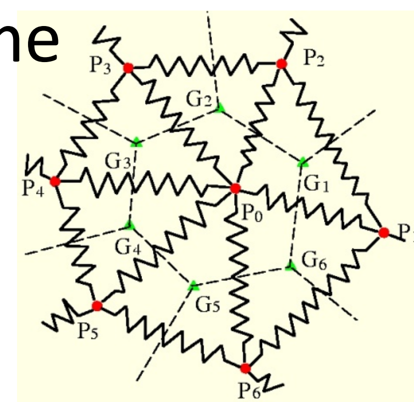
- **Summary and Future plans**

NICAM

- Nonhydrostatic Icosahedarl Atmospheric Model
  - Development since 2000
    - Tomita and Satoh(2005, *Fluid Dyn. Res.*)
    - Satoh et al.(2008, *J. Comp. Phys.*)
  - First global dx=3.5km run in 2004
    - Tomita et al.(2005, *Geophys. Res. Lett.*)



- Icosahedral grid
  - Spring dynamics smoothing
  - Second order accuracy
    - Tomita et al.(2001, *J. Comp. Phys.*), Tomita et al.(2002, *J. Comp. Phys.*)
- Flux-form conservative nonhydrostatic scheme
  - Split-explicit time integration
  - Mass, total energy & momentum conserving
    - Satoh (2002, *Mon. Wea. Rev.*)
    - Satoh (2003, *Mon. Wea. Rev.*)



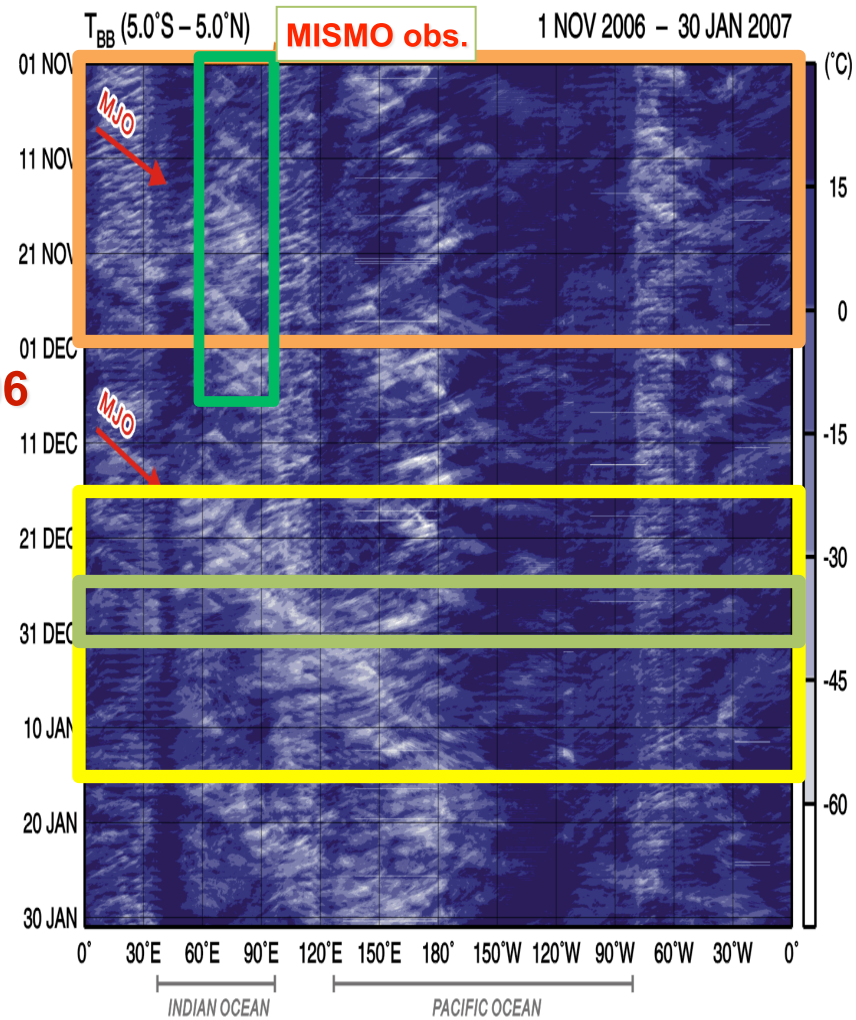
Model description

■ Dynamics	
governing equations	Fully compressible non-hydrostatic system
spatial discretization horizontal grid configuration vertical grid configuration topography	Finite Volume Method Icosahedral grid Lorenz grid Terrain-following coordinate
conservation	Total mass, total energy
temporal scheme	Slow mode － explicit scheme （RK2, RK3） Fast mode － Horizontal Explicit Vertical Implicit scheme
■ Physics	
radiation	MSTRNX / MSTRNX-AR5 (Sekiguchi and Nakajima, 2008)
cloud physics	Grabowski(1998); NSW6(Tomita 2008);NDW6(Seiki 2009)
shallow clouds boundary layer	MY level 2 (Mellor and Yamada 1982; Noda et al. 2010) MYNN level 2.5 or 3 (Nakanishi and Niino 2006)
surface flux	Louis(1979), Uno et al.(1995)
surface processes	SST specified & bucket / slab ocean & MATSIRO

MJO/ISV Simulations with NICAM

2006 boreal Winter MJO hindcasts

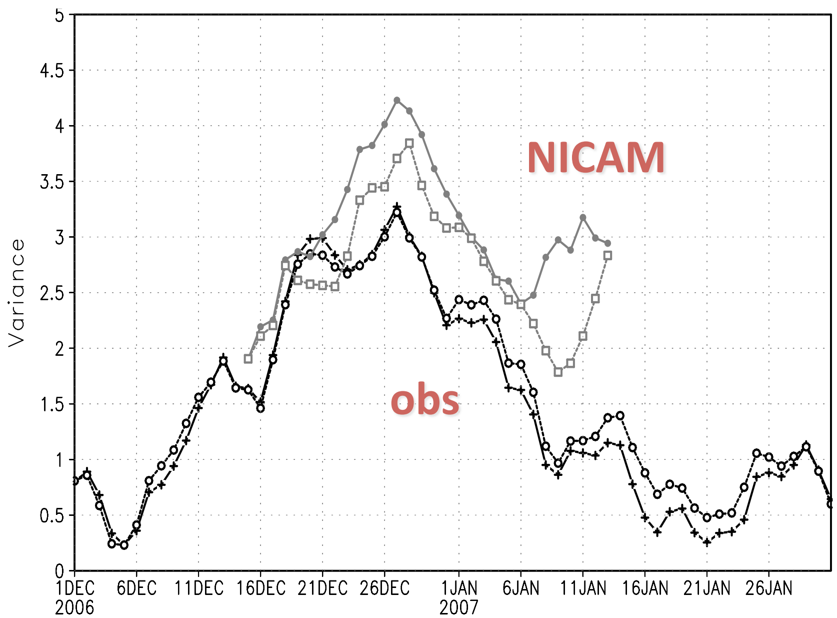
Horizontal grid spacing: 14 km, 7 km, 3.5 km
Vertical domain:
0 m ~ 38,000 m 40-levels (stretching grid)
Integration:
7km, 14km runs: 30 days from 1 Nov 2006
7km, 14km runs: 30 days from 15 Dec 2006
3.5km run: 7 days from 25 Dec 2006
Initial conditions:
Interpolated from NCEP final analysis
(6 hourly, 1.0x1.0 degree grids)
Boundary conditions:
Reynolds SST, Sea ICE (weekly data)
ETOPO-5 topography
Matthews vegetation
UGAMP ozone climatology (for AMPI2)



- EXP. Dec 2006: Miura et al.(2007,Science), Nasuno et al.(2009,JMSJ), Sato et al. (2009, J.Clim)
- Liu et al. (2009, MWR), Fudeyasu et al. (2009, GRL)
- EXP. Nov. 2006 (MISMO): Miura et al. (2009, GRL)

Liu, et al. (2009), Mon. Wea. Rev.

MJO index



Phase diagram

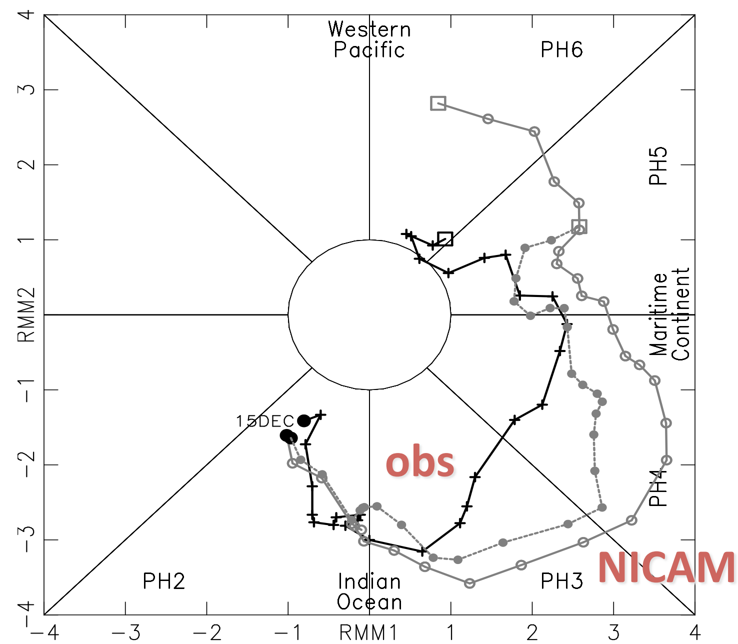
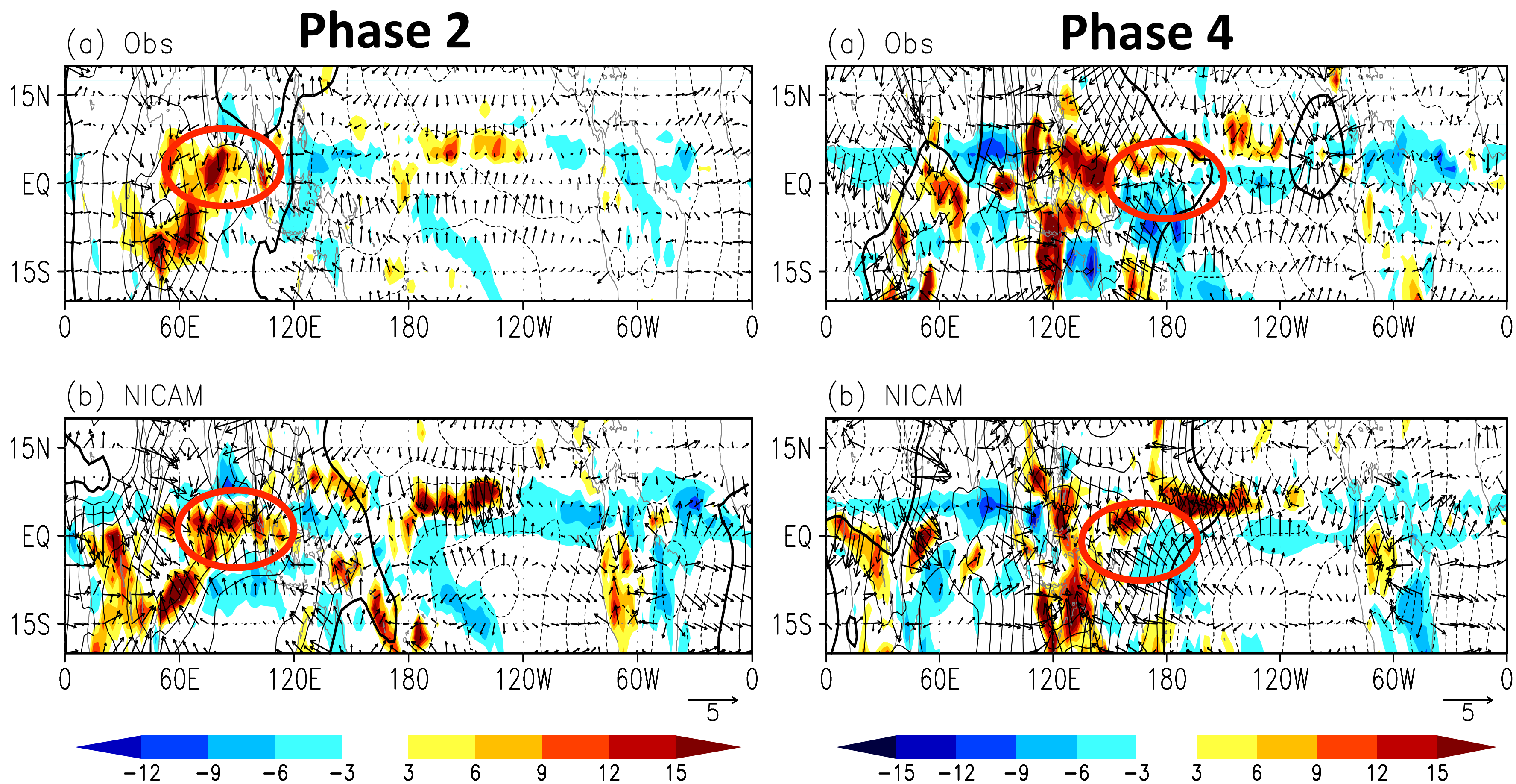


Fig. 3 Evolution of the MJO event in amplitude represented by $(RMM1^2 + RMM2^2)^{1/2}$. The black-solid curve is derived using the anomalous fields described in WH04; others use simple anomalies by excluding the observed climatology for observations (black-dashed), the 14-km NICAM (gray-solid), and the 7-km NICAM (gray-dashed).

Fig. 4 RMM diagram for the MJO event in observations (black-solid), the 14-km NICAM (gray-solid) and the 7-km NICAM (gray-dashed).

Liu, et al. (2009), Mon. Wea. Rev.

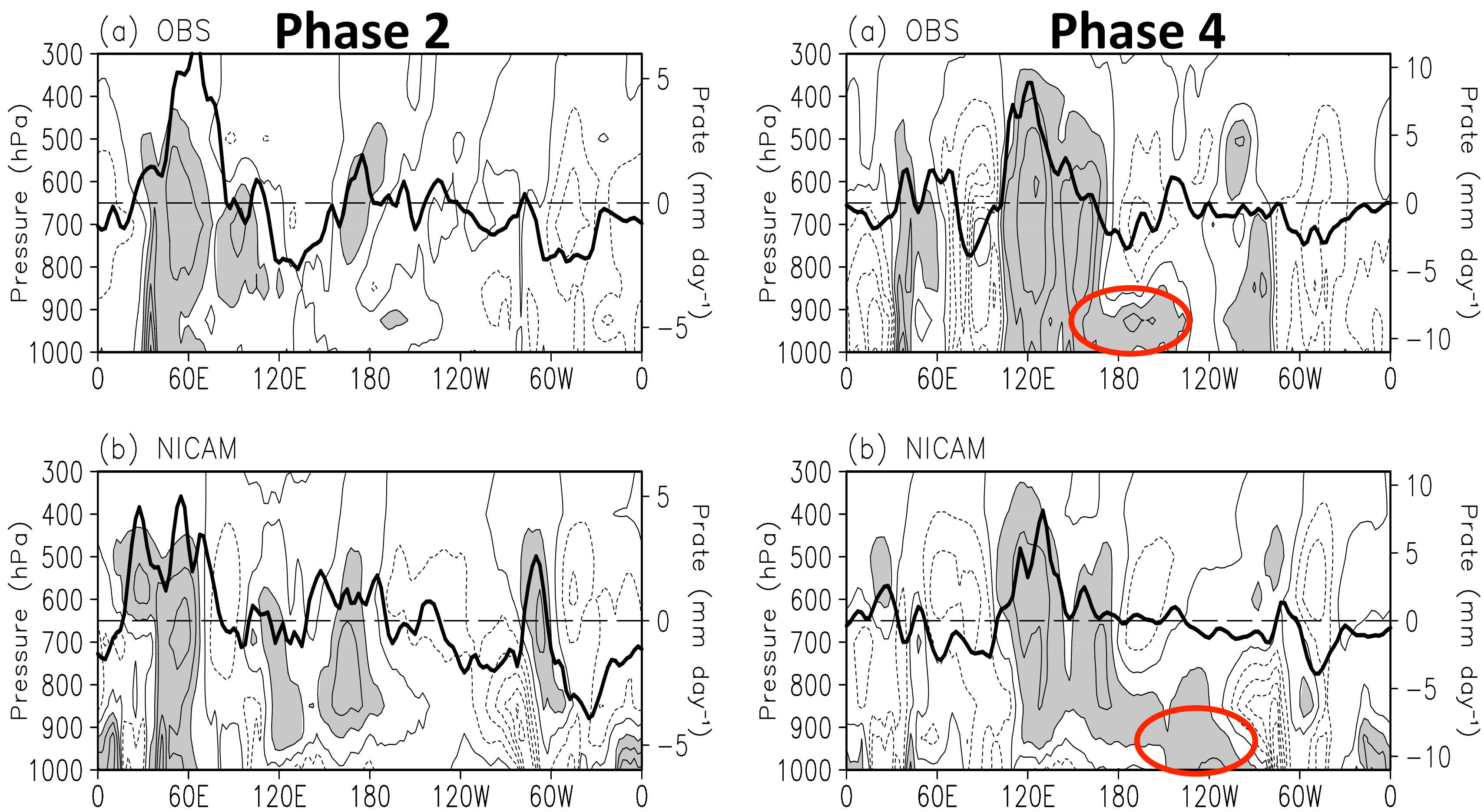


Color: precipitation, contour: divergent wind (925hPa)

Fig. 5 Composited anomalies for Phase 2 of the MJO event in observations (a), and the 7-km NICAM (b). Contours represent the velocity potential (interval is 1×10^6 m^2 s^{-2} with thick-black as 0) at 925 hPa and vectors for the divergent wind at this level. The shading represents the precipitation rate (mm day^{-1}) from the TRMM (a) and NICAM (b).

Liu, et al. (2009), Mon. Wea. Rev.

Vertical structure of Specific Humidity

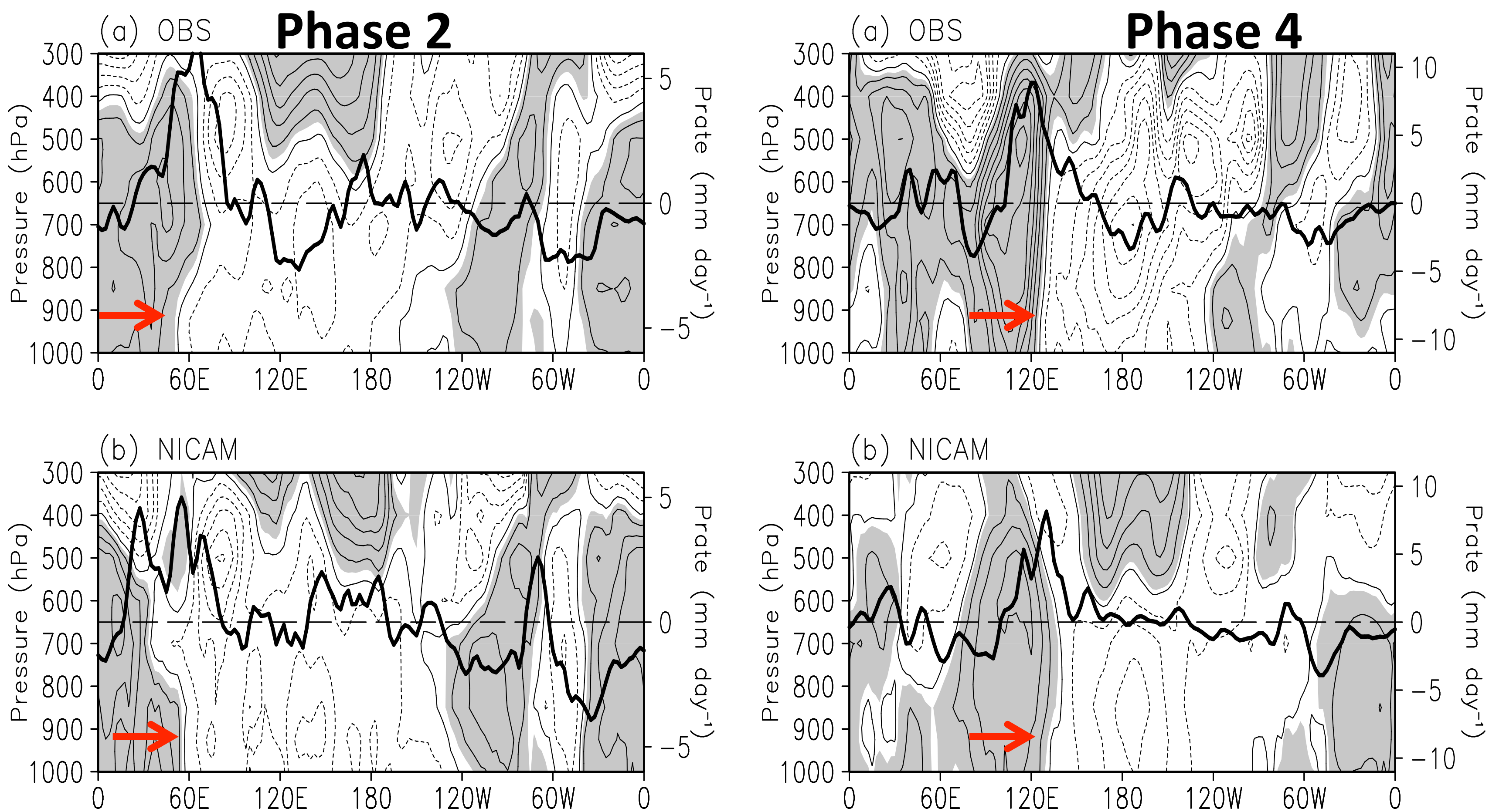


Contour: precipitation

Fig. 6 Same as Fig. 5 except contours represent the specific humidity (interval 0.5 g kg^{-1}) with shaded values greater than and equal to 0. The thick-black curve is for precipitation rate (mm day^{-1}) in TRMM (a) and NICAM (b). All values are along the equator (averaged between 15^{o}S and 15^{o}N).

Liu, et al. (2009), Mon. Wea. Rev.

Vertical structure of zonal wind



Contour: precipitation

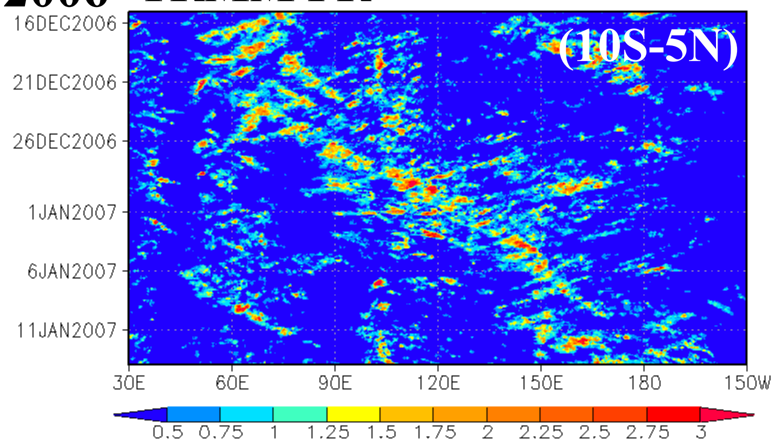
Fig. 7 Same as Fig. 6 except contours represent the zonal wind (interval 0.5 m s^{-1}).

Convective momentum transport (CMT) in MJO

- **Moncrieff (2004), Grabowski and Moncrieff (2001), Houze et al. (2000), Oouchi and Yamasaki (2001), <u>Tung and Yanai (2002)</u>**

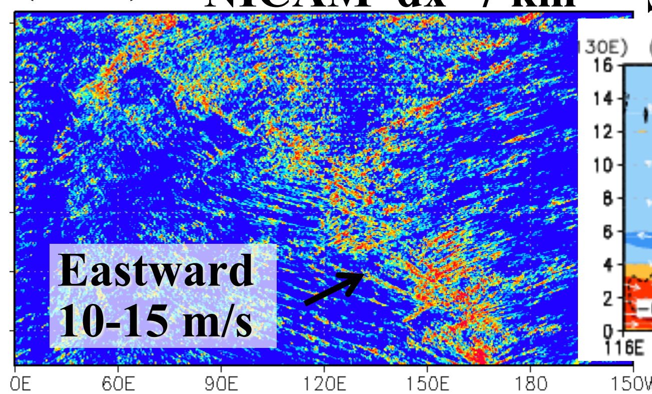
calculation of CMT in a NICAM simulation of an MJO event

2006 TRMM PR

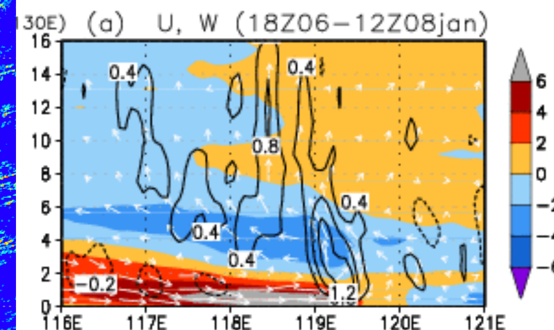


Miura et al. (2007)

NICAM dx=7 km



Squall -type cluster



Nasuno et al. (2009)

→ <u>Miyakawa (poster)</u>

$$\frac{\partial \bar{u}}{\partial t} = -\bar{u}\frac{\partial \bar{u}}{\partial x} - \bar{v}\frac{\partial \bar{u}}{\partial y} - \bar{w}\frac{\partial \bar{u}}{\partial z} - \frac{1}{\bar{\rho}}\overline{\left(\frac{\partial \rho u'u'}{\partial x} + \frac{\partial \rho u'v'}{\partial y} + \frac{\partial \rho u'w'}{\partial z}\right)} - \frac{1}{\bar{\rho}}\frac{\partial \bar{P}}{\partial x} + f\bar{v} + \overline{F_x}$$

1°mean wind — **Subgrid wind** — **"Convective momentum transport"** — **Turbulence etc.**

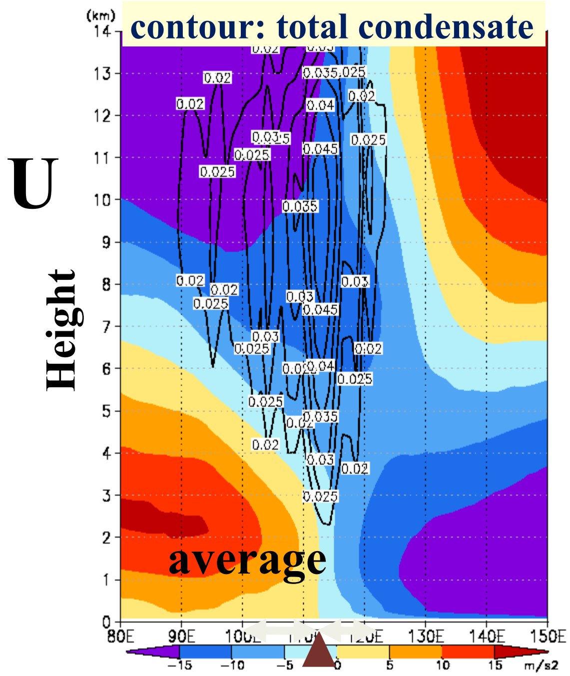
$X = \bar{X} + X'$

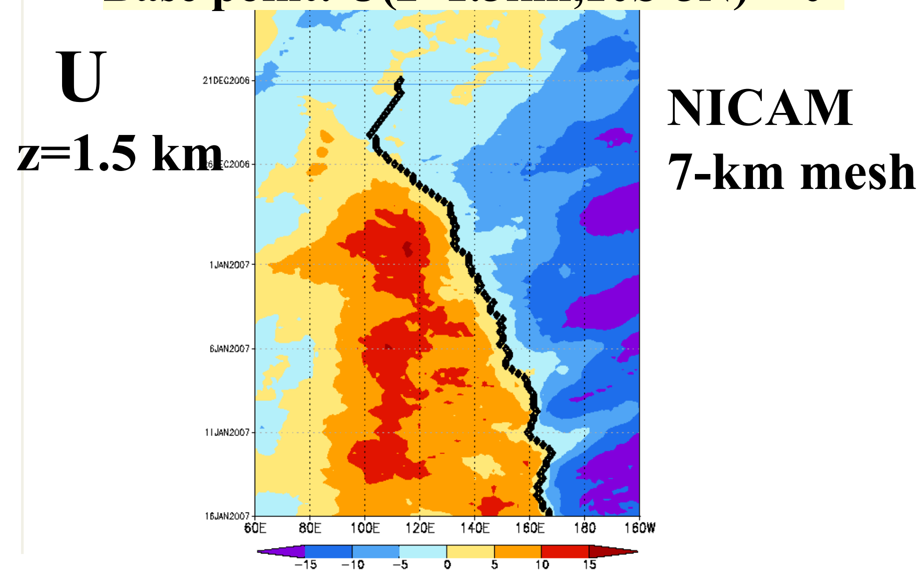
$\bar{X}$: ~1° mean values

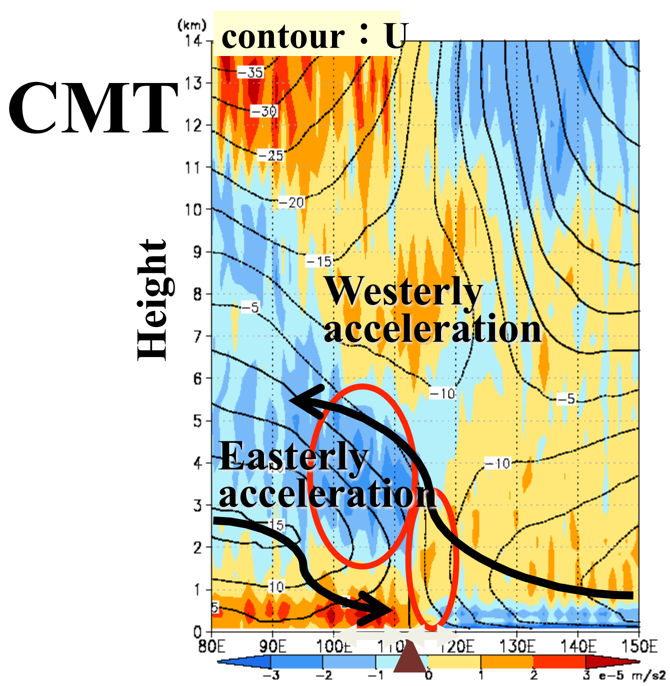
X' : deviations

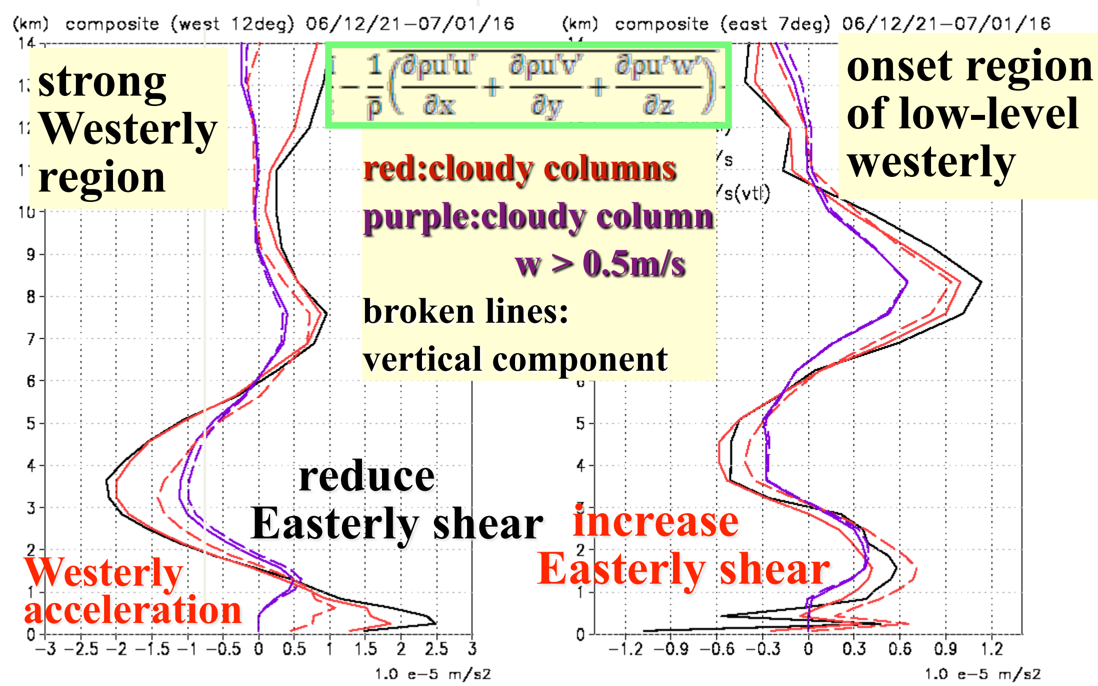
composite of U and CMT(10S-5N)

Base point: U(z=1.5km,10S-5N) = 0

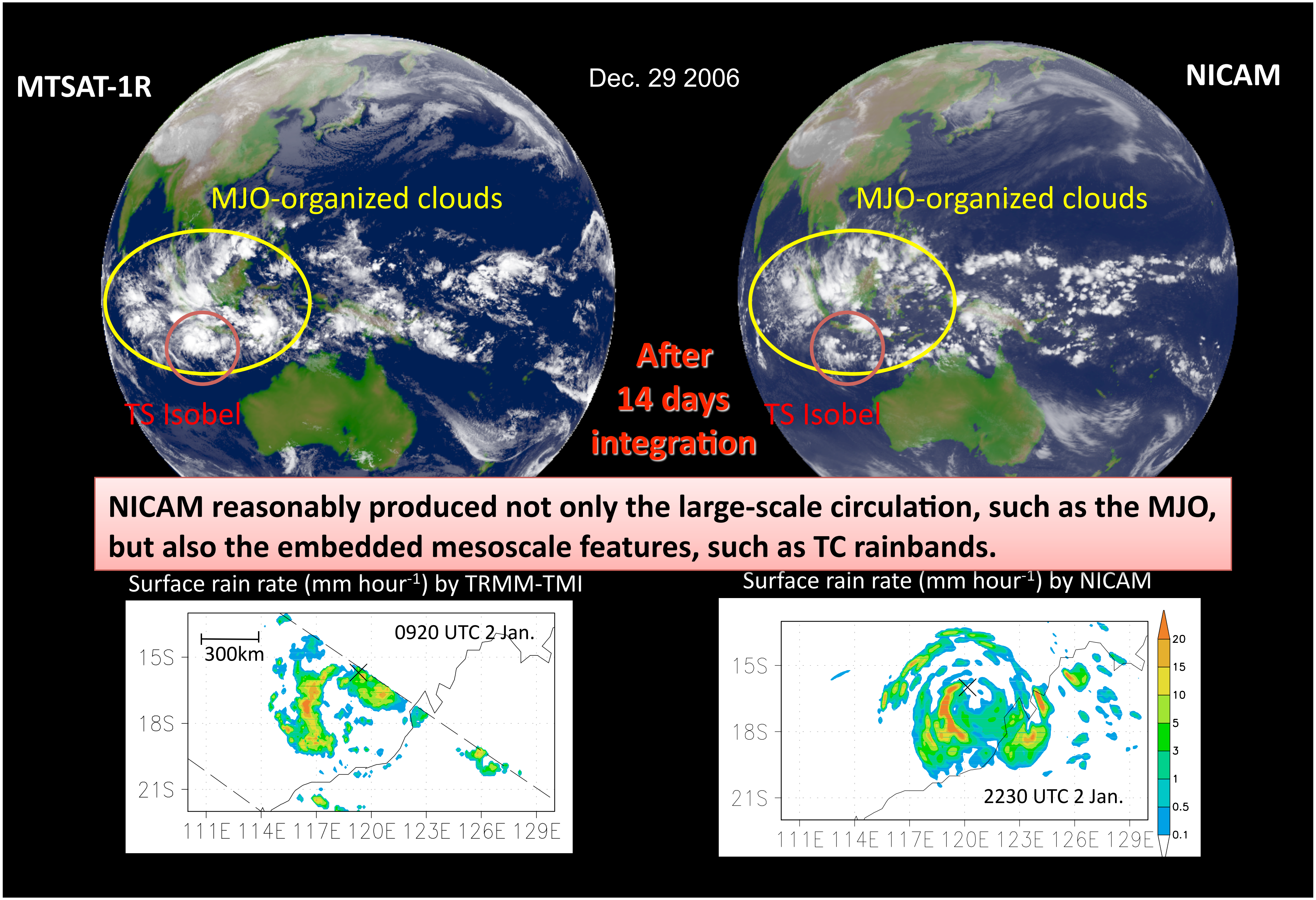






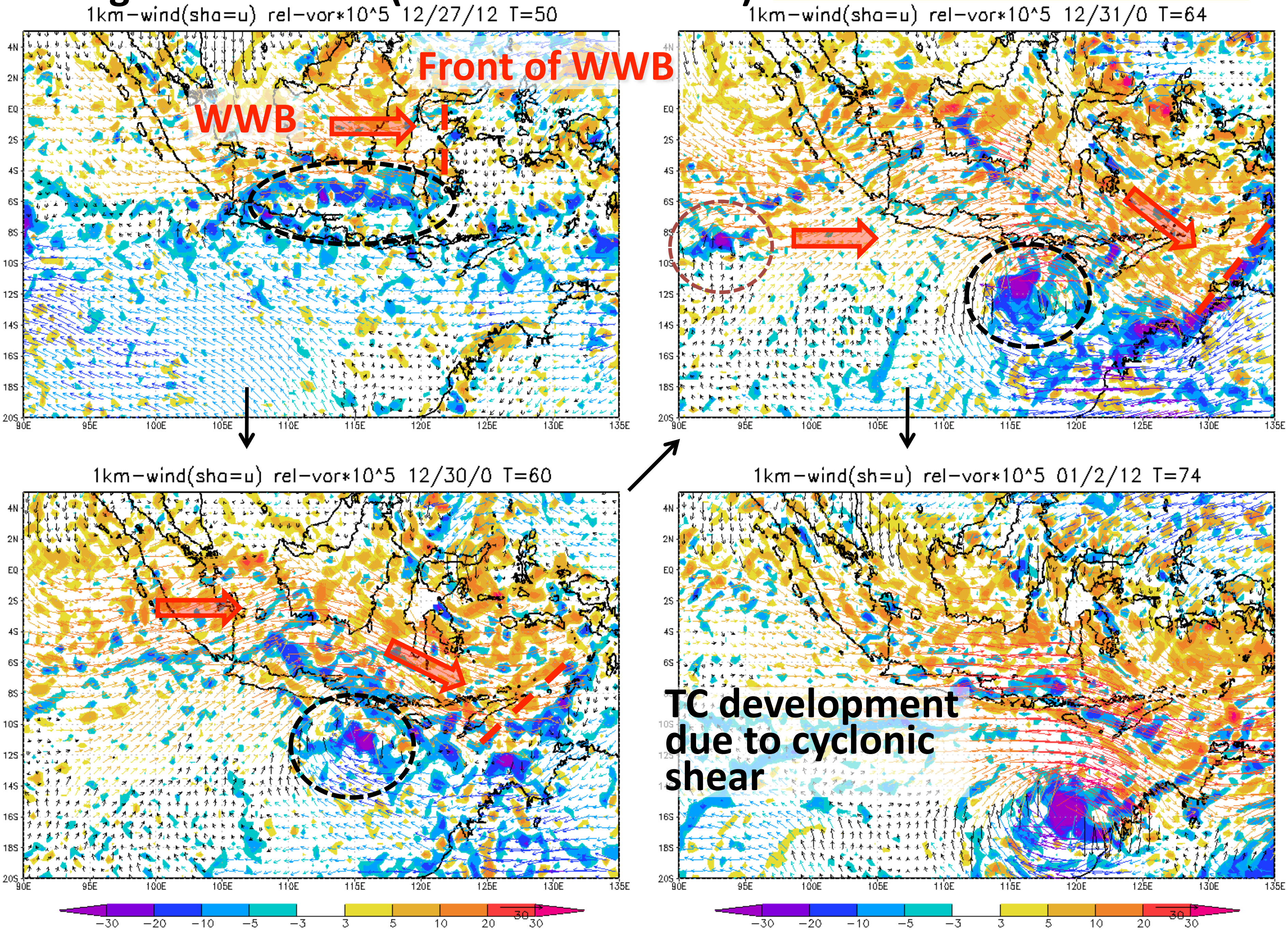


Fudeyasu, H., Wang, Y., Satoh, M., et al. (2008) The global cloud-resolving model NICAM successfully simulated the lifecycles of two real tropical cyclones. Geophys. Res. Lett., 35, L22808.



TC genesis in MJO (NICAM 7-km mesh)

Relative vorticity (z=1km)



TC Nargis ensemble simulation

Taniguchi et al. (2010), JMSJ special edition on the Myanmar Cyclone, in press

http://www.nasa.gov/mission_pages/hurricanes/archives/2008/h2008_nargis.html)

Horizontal mesh size: **14 km**

Vertical mesh size: 0 m ~ 38,000 m

（40 layer, stretching grid ）

Integration: **30-days**

Initial condition:

linear interpolation from **JMA GPV/GSM data** (every 6hr, 0.5x0.5grid)

initial time: **1200UTC, 10, 23, 24, 25, 26, 27, 28, Apr 2008**

(7 control run without any perturbation:

Lagged Average Forecasting (LAF) method, Hoffman and Kalnay, 1993)

without any nudging process (Nargis formed on **27 Apr 2008**)

Boundary condition:

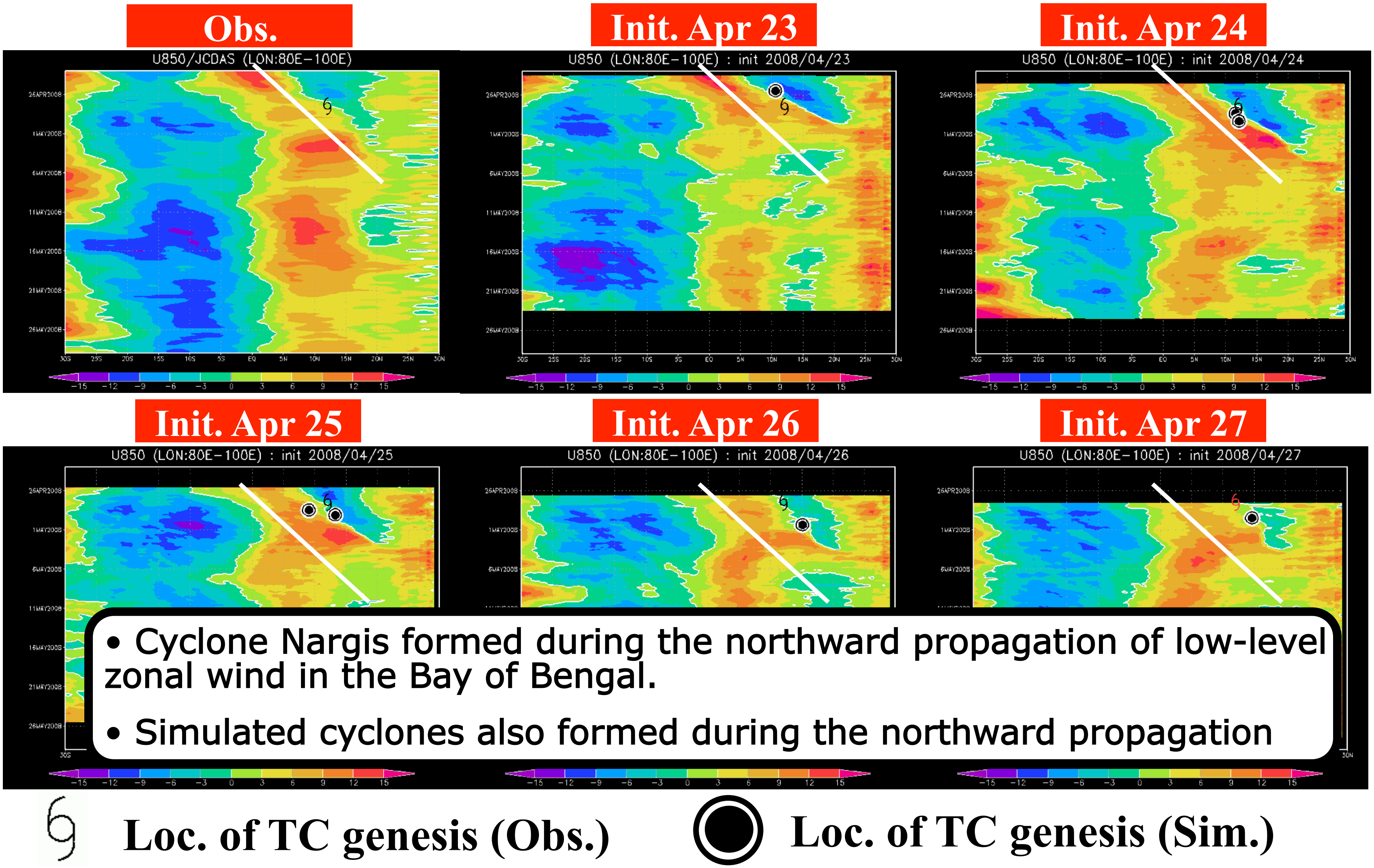
weekly Reynolds-SST , Sea ICE

ETOPO-5 topography, Matthews vegetation

UGAMP ozone climatology (AMIP2)

Taniguchi et al. (2010), J. Meteor. Soc. Japan

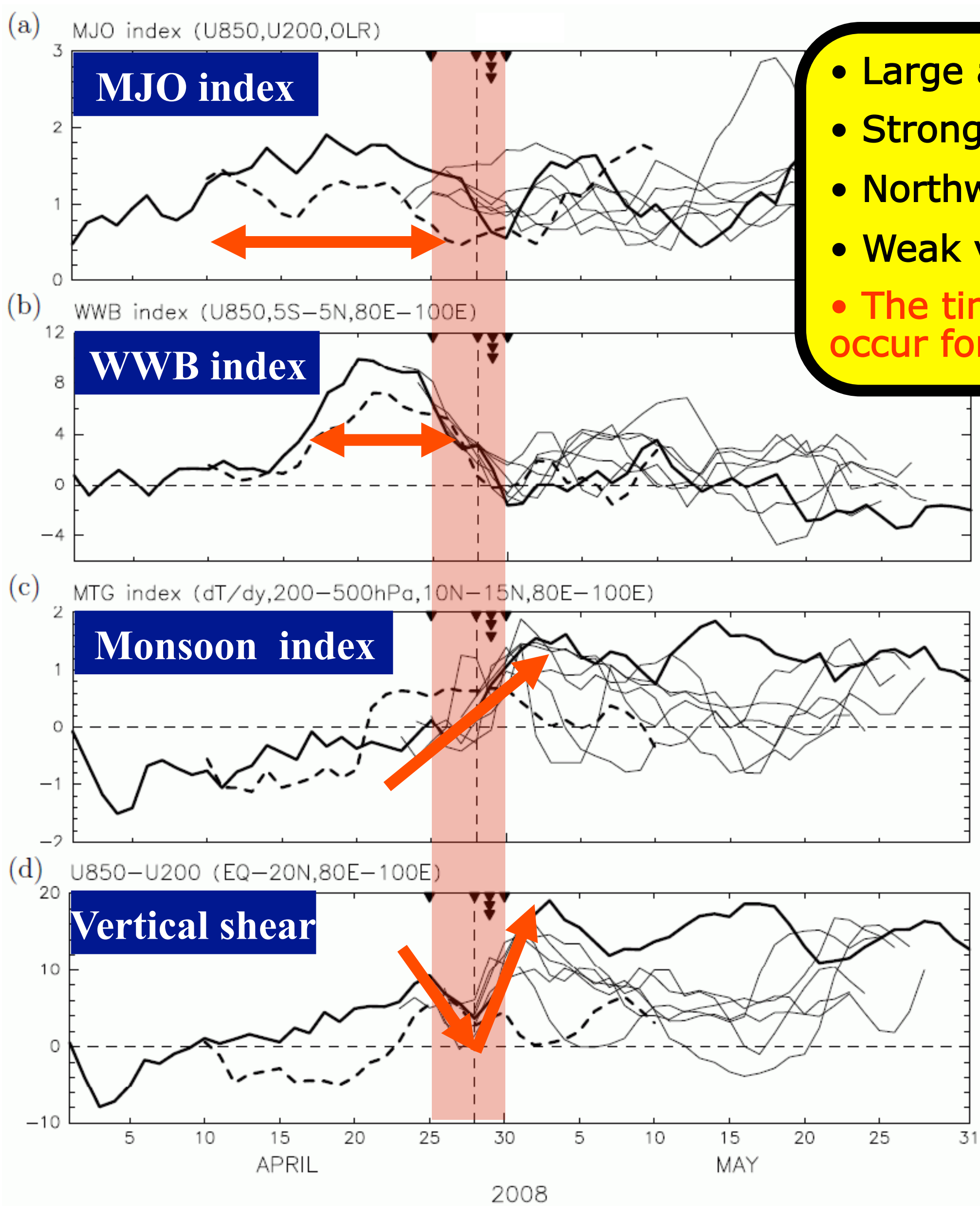
U850 (Averaged: 80E-100E)



- Cyclone Nargis formed during the northward propagation of low-level zonal wind in the Bay of Bengal.
- Simulated cyclones also formed during the northward propagation

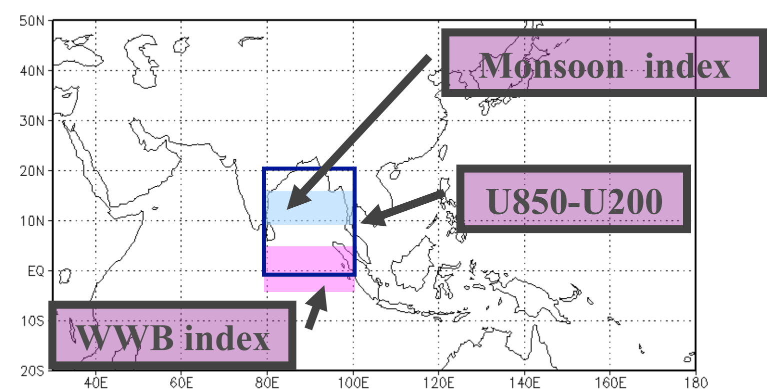
Taniguchi et al. (2010), J. Meteor. Soc. Japan

(a) MJO index, (b) WWB index, (c) MTG index, (d) Vertical shear



- Large amp. before TC genesis (MJO)
- Strong wind in BoB before TC genesis (WWB)
- Northward migration of the area of westerly in BoB
- Weak vertical shear before TC genesis
- The timing of Monsoon onset is earlier or does not occur for the case with initial day of Apr. 10.

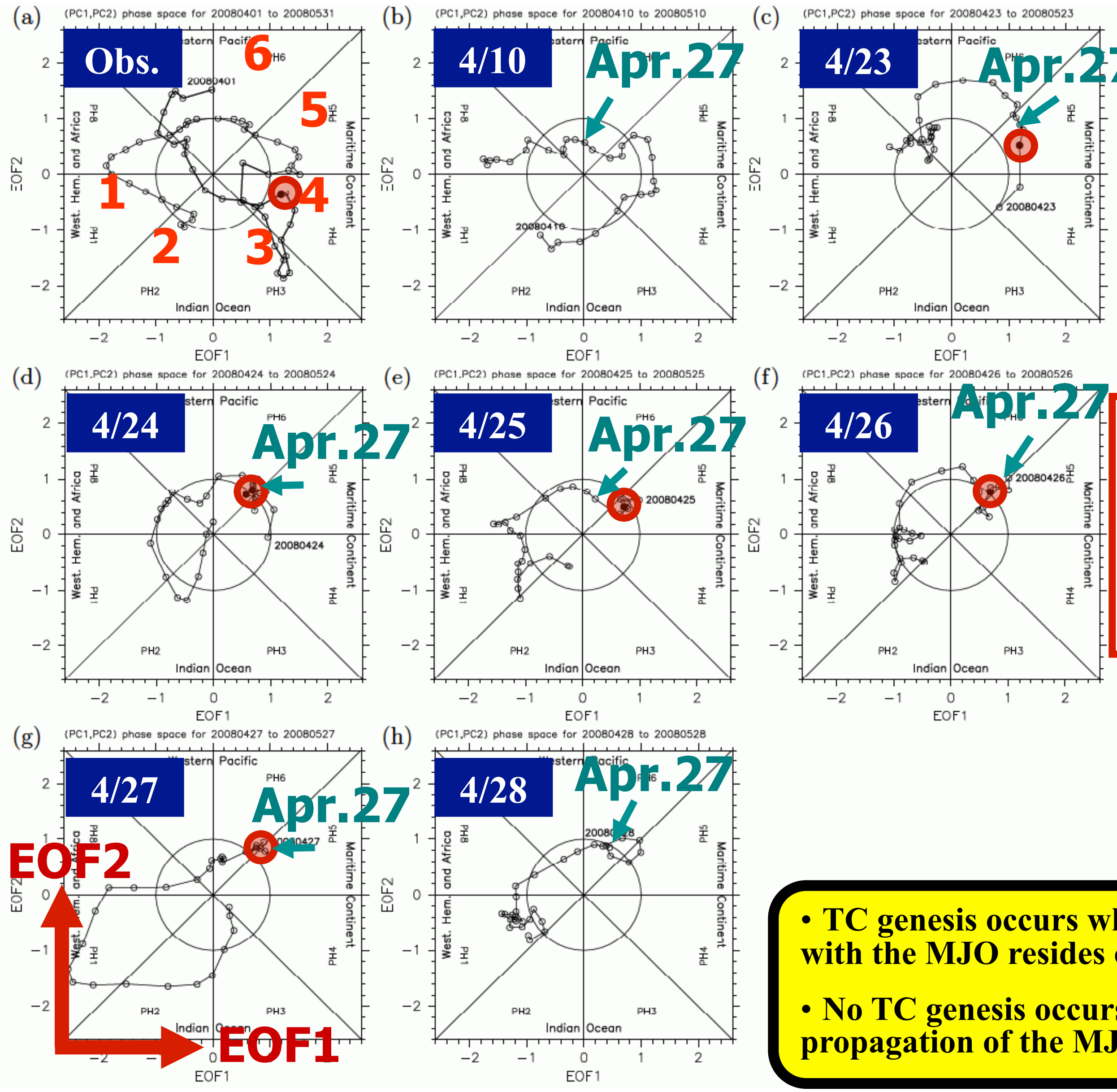
Observed index
Simulated index (4/10)
Simulated index (others)
Simulated TC
period of TC genesis



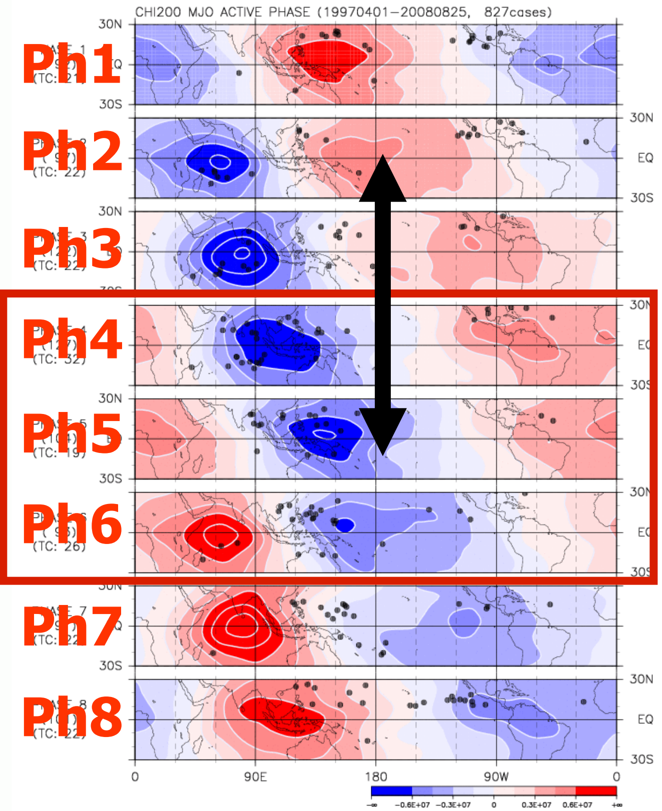
Taniguchi et al. (2010), J. Meteor. Soc. Japan

MJO phase: (a) observed, (b-h) simulated

TC genesis



CHI200 composite on each MJO phase

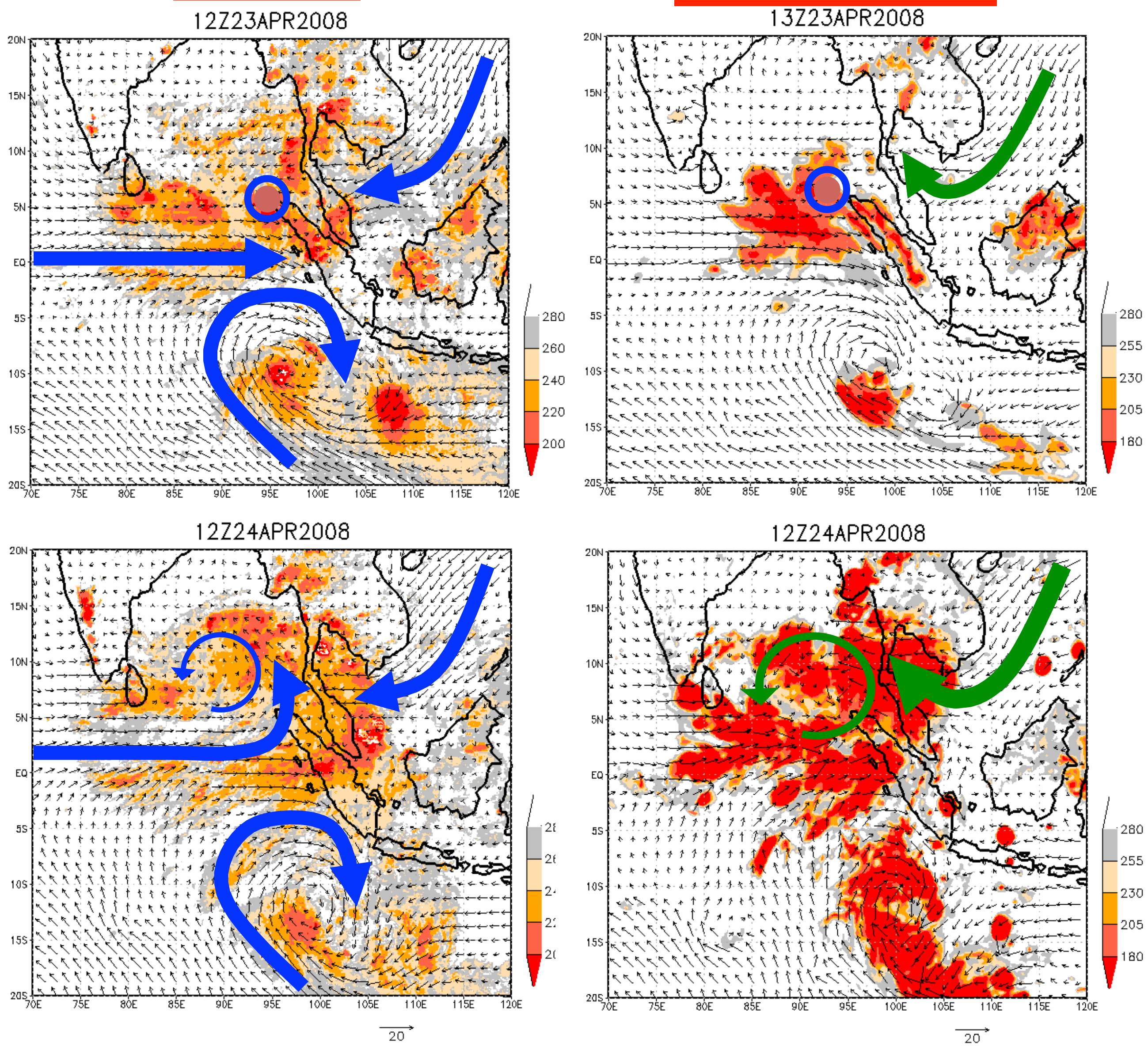


- TC genesis occurs when active convective region associated with the MJO resides over the maritime continent region.
- No TC genesis occurs for the member of which phase propagation of the MJO is not reproduced.

Taniguchi et al. (2010), J. Meteor. Soc. Japan

Incipient disturbances for cyclone Nargis: U10m & OLR (IR)

Obs. | **NICAM : 4/23**

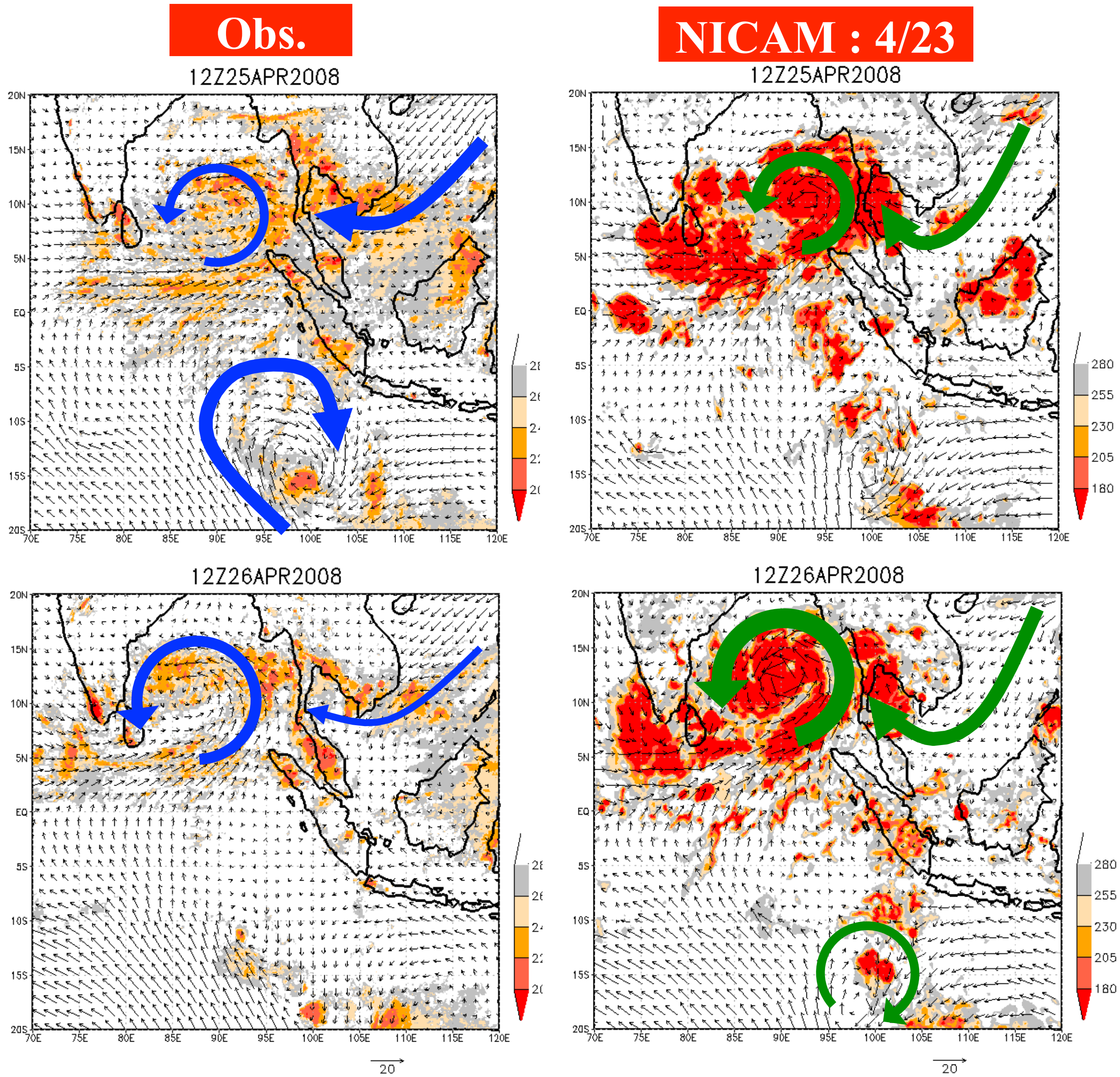


- **WWB**
- **Cyclonic eddy in SIO**
- **Wind from the South China Sea**
- **A weak cyclonic circulation**

- **Northward migration of WWB**
- **Cyclonic eddy in NIO**
- **Wind from the South China Sea**

Taniguchi et al. (2010), J. Meteor. Soc. Japan

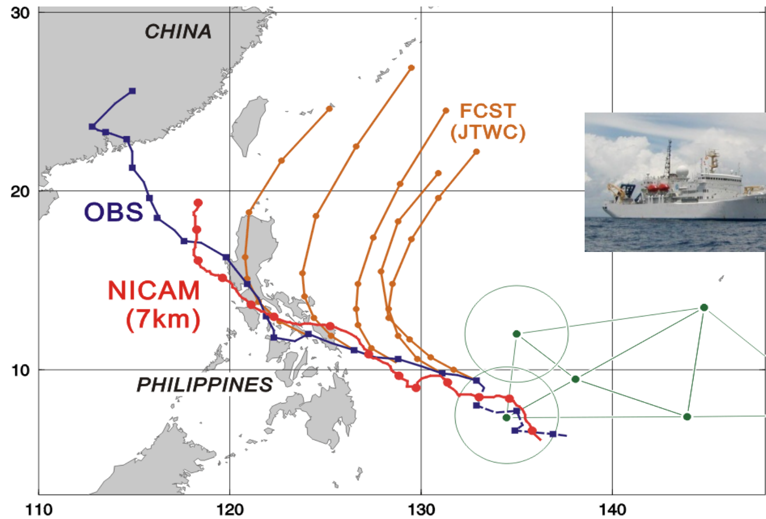
Incipient disturbances for cyclone Nargis



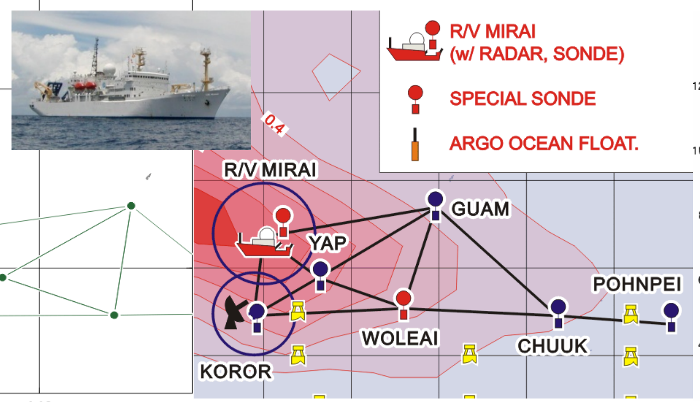
- **Northward migration of Cyclonic eddy in NIO**
- **Wind from the South China Sea**

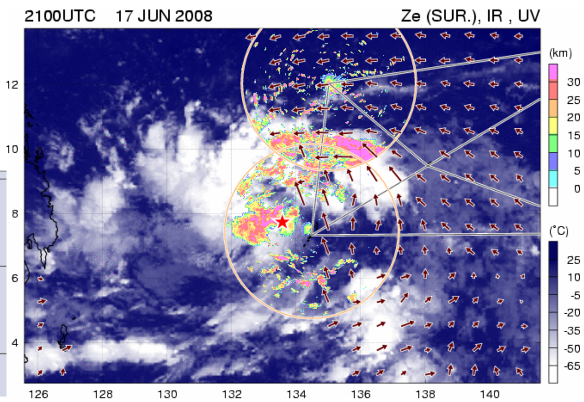
- **Northward migration of Cyclonic eddy in NIO**
- **northward movement of northern vortex and its cyclonic circulation development**

TC Fengshen simulation



PALAU2008 Field Experiment





Horizontal grid spacing: **14 km, 3.5 km**

Vertical domain: 0 m ~ 38,000 m (40-levels)

Integration: **7 days integration just finished**

10 (7) days from 00UTC 15 Jun 2008

Initial conditions:

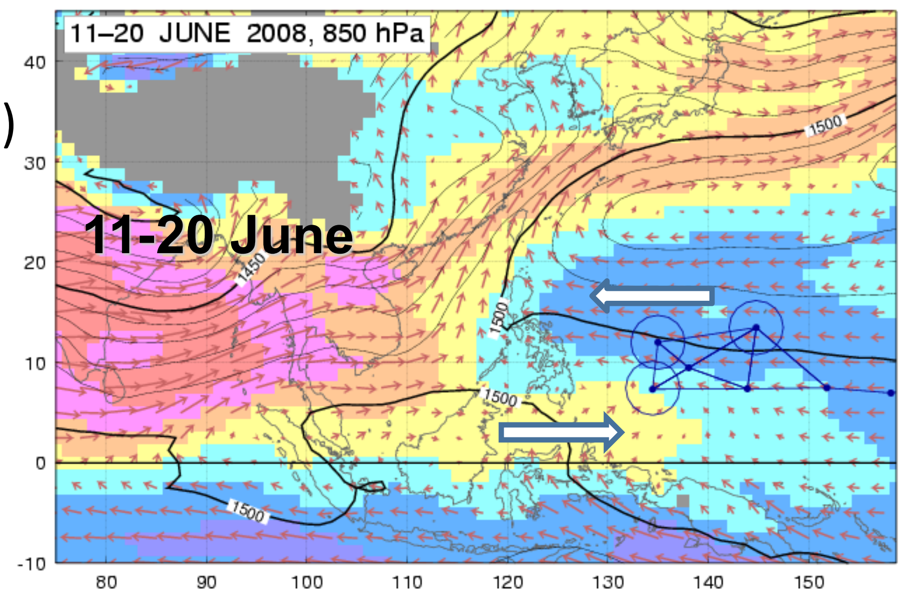
ECMWF YOTC Operational data

NCEP final analysis (land surface, SST)

Boundary conditions:

slab ocean (nudging to Reynolds weekly SST)

--- Fengshen formed on **17 Jun 2008**



Onset of Western Pacific Monsoon & Weak MJO → equatorial westerly

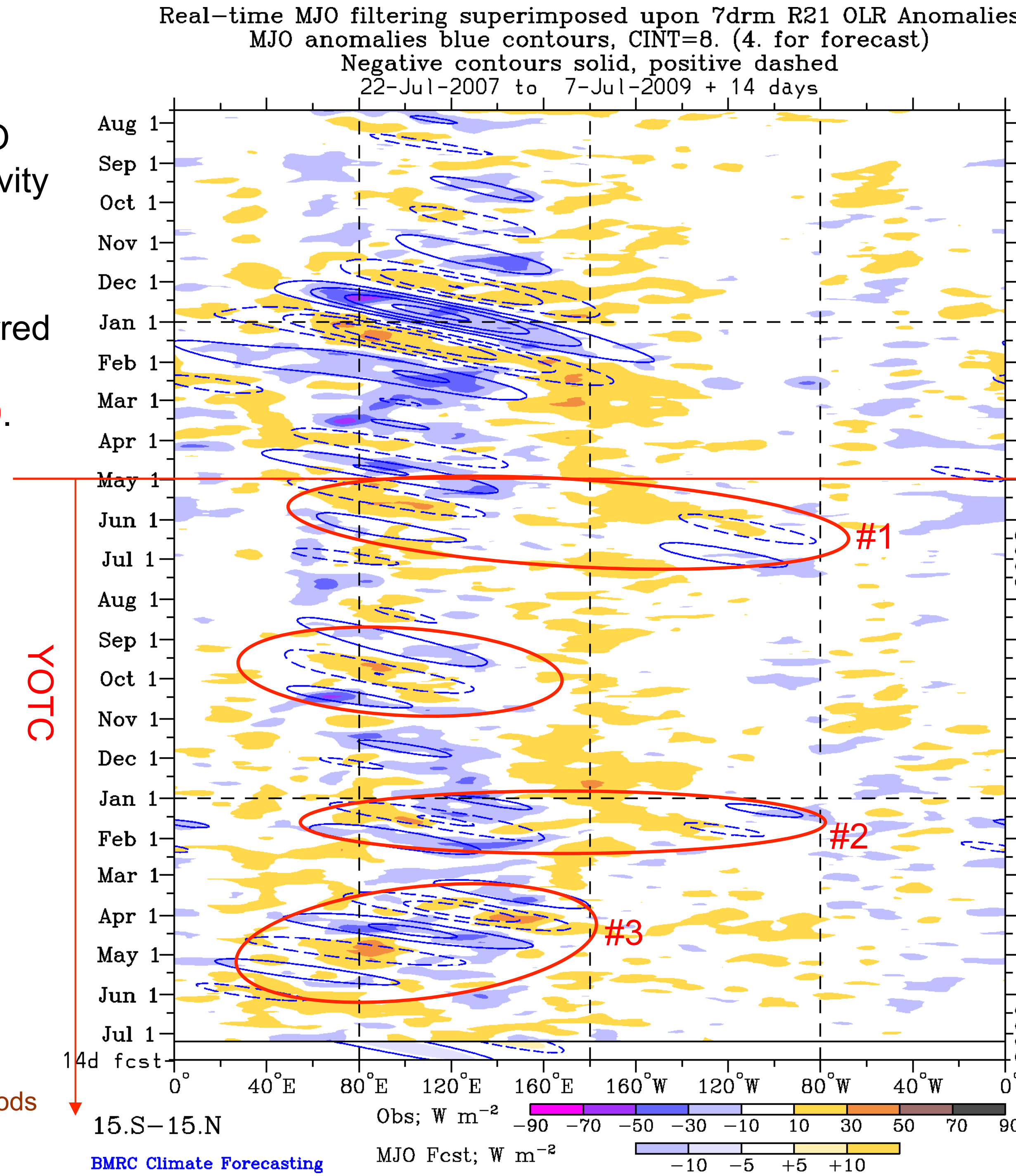
2. MJO activity

Compared to the very strong MJO activity of DJF 2007/08, MJO activity during YOTC has been weaker.

Nevertheless, important and interesting MJO activity still occurred in May-Jun 2008, Sept-Oct 2008, Jan-Feb 2009, and Mar-Jun 2009.

So far, the MJO activity centred on **April 2009** has been the strongest (using multiple measures).

Note also the tendency for suppressed convection near and to the east of the date line during much of the YOTC period (i.e. weak La Nina).

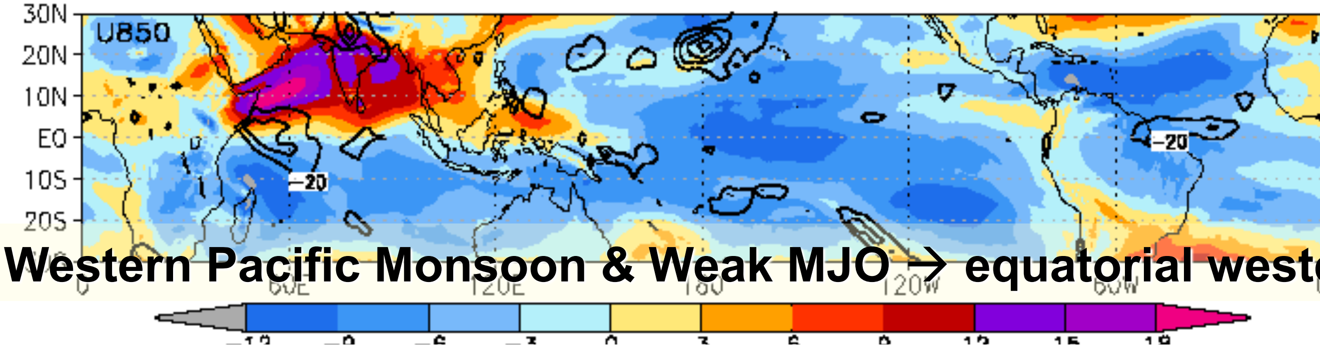


"MJO" defined in this plot through filtering of OLR anomalies for eastward waves 1-5, periods 30-96 days (Wheeler and Weickmann 2001)

U850

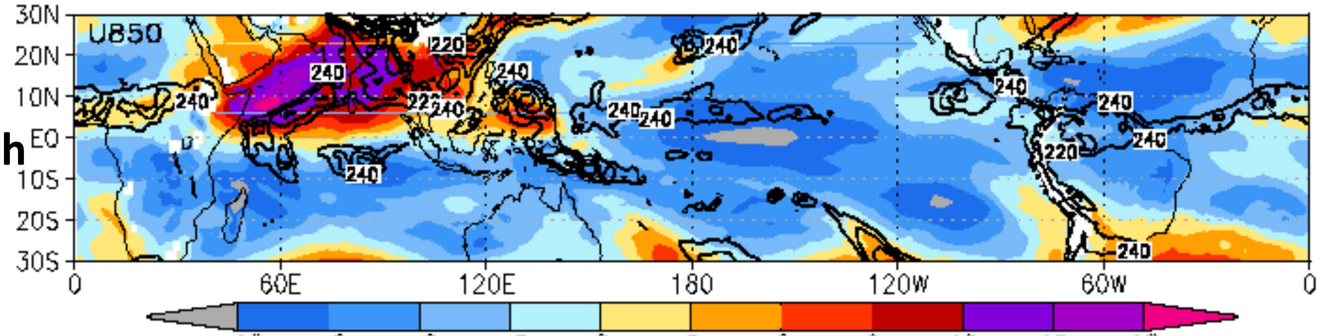
15-21 June 2008

ECMWF YOTC

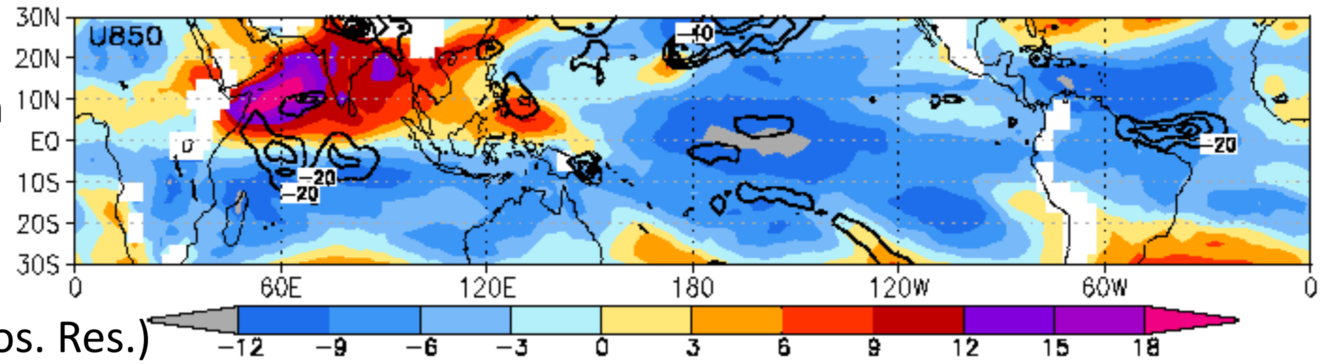


Onset of Western Pacific Monsoon & Weak MJO → equatorial westerly

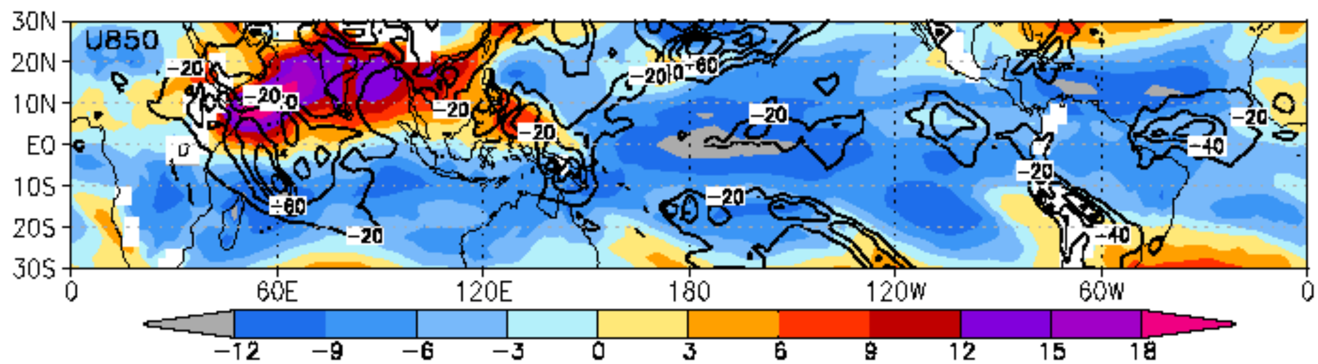
NICAM 3.5 km mesh



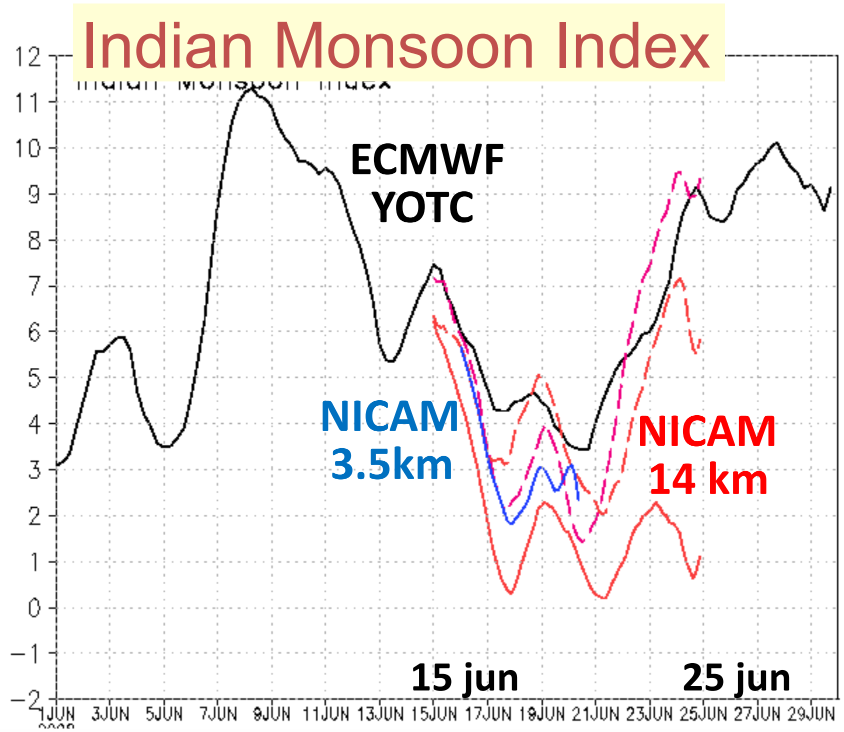
NICAM 14km mesh (MY2) Revised by Noda et al. (2010, Atmos. Res.)

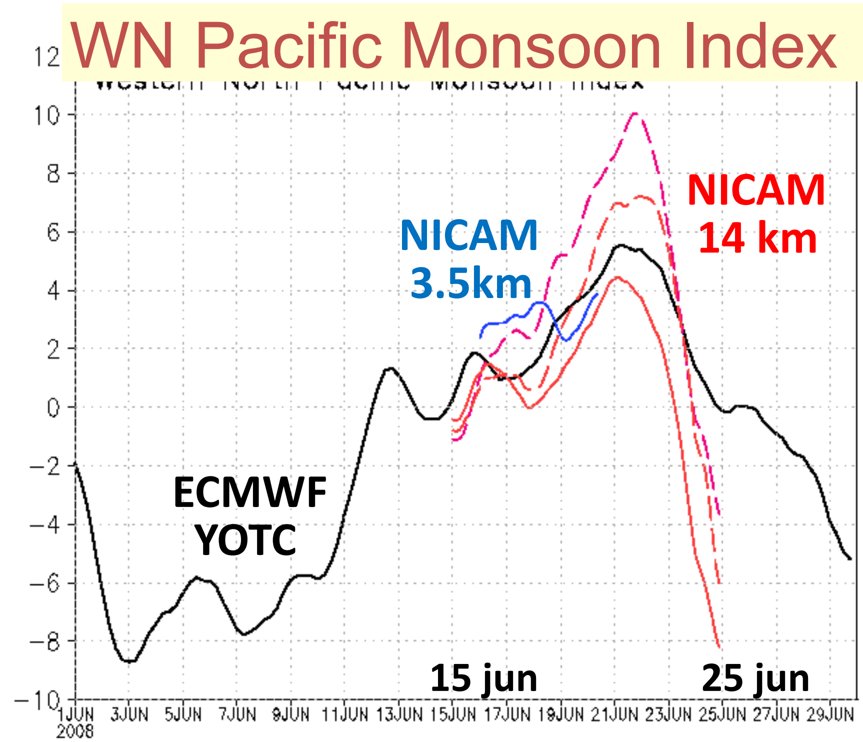


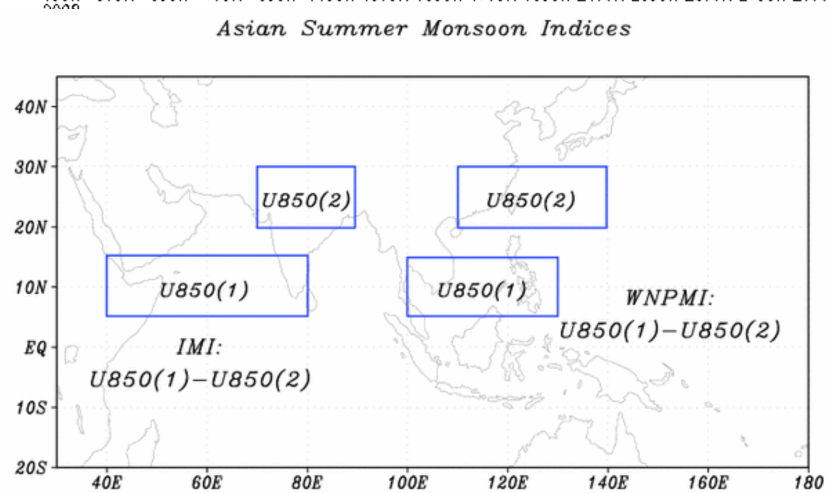
NICAM 14km mesh (MYNN2.5) not tuned



Monsoon indices (Jun 2008)

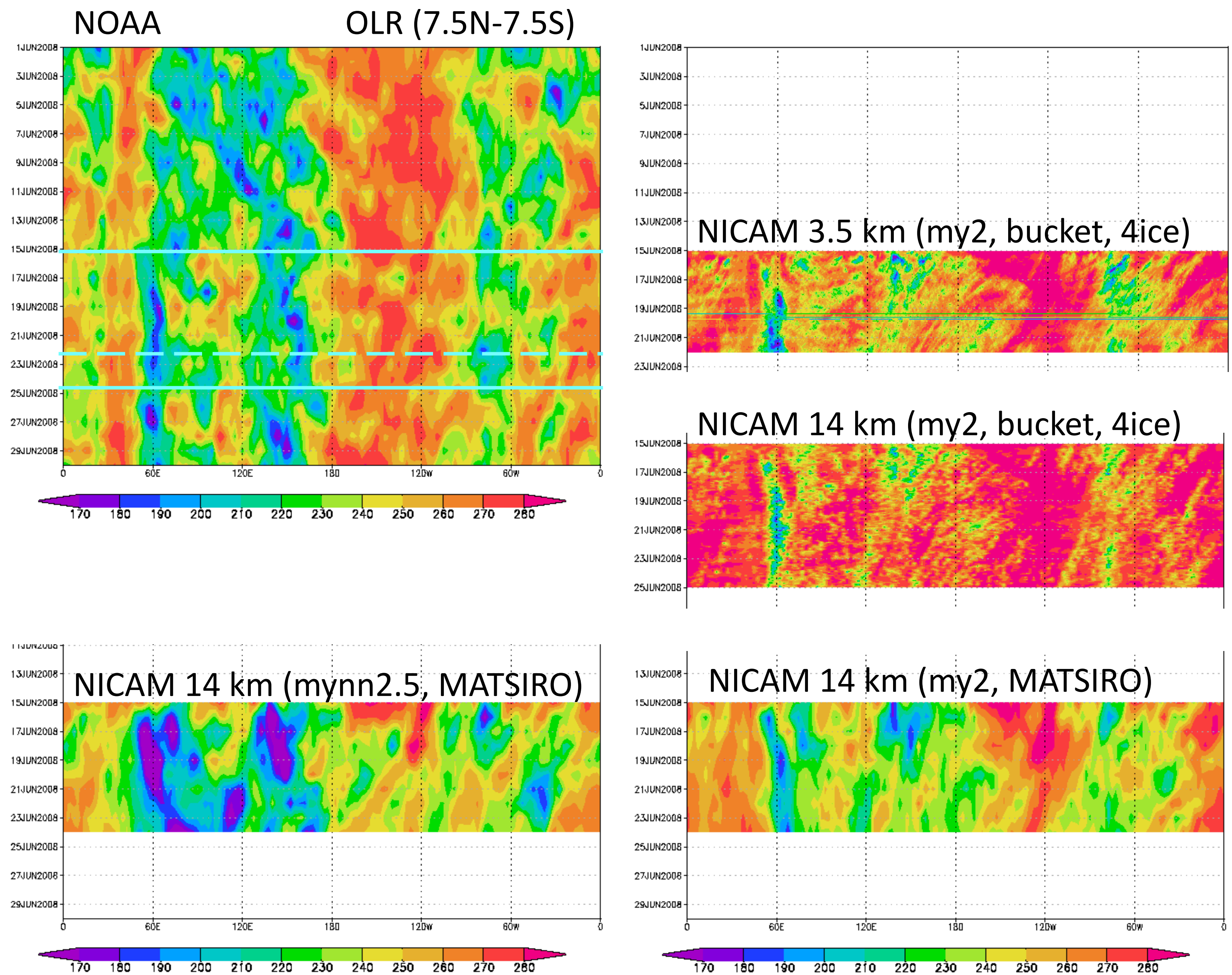


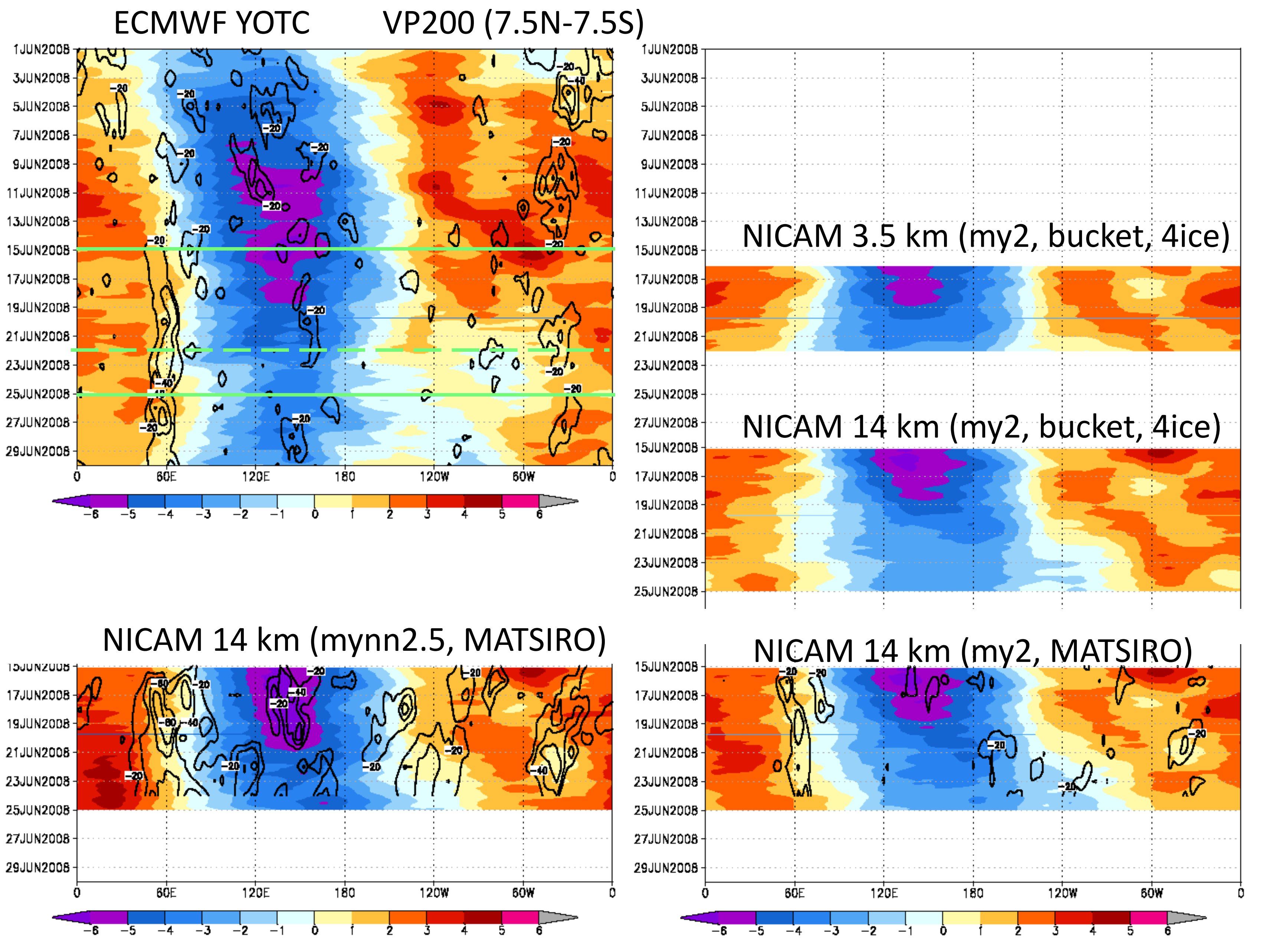




IM Index = U850(40E-80E,5N-15N)
-U850(70E-90E,20N-30N)

WNPM Index = U850(100E-130E,5N-15N)
-U850(110E-140E,20N-30N)


NOAA
OLR (7.5N-7.5S)
NICAM 3.5 km (my2, bucket, 4ice)
NICAM 14 km (my2, bucket, 4ice)
NICAM 14 km (mynn2.5, MATSIRO)
NICAM 14 km (my2, MATSIRO)
1JUN2008 3JUN2008 5JUN2008 7JUN2008 9JUN2008 11JUN2008 13JUN2008 15JUN2008 17JUN2008 19JUN2008 21JUN2008 23JUN2008 25JUN2008 27JUN2008 29JUN2008
0 60E 120E 180 120W 60W 0
170 180 190 200 210 220 230 240 250 260 270 280

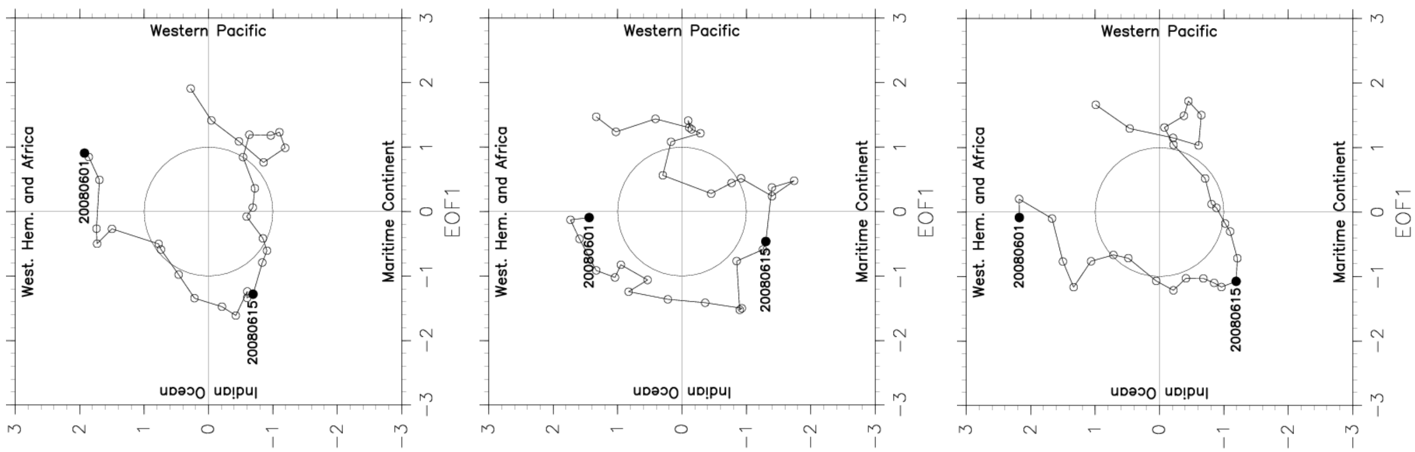

ECMWF YOTC
VP200 (7.5N-7.5S)
NICAM 3.5 km (my2, bucket, 4ice)
NICAM 14 km (my2, bucket, 4ice)
NICAM 14 km (mynn2.5, MATSIRO)
NICAM 14 km (my2, MATSIRO)
1JUN2008
3JUN2008
5JUN2008
7JUN2008
9JUN2008
11JUN2008
13JUN2008
15JUN2008
17JUN2008
19JUN2008
21JUN2008
23JUN2008
25JUN2008
27JUN2008
29JUN2008
0
60E
120E
180
120W
60W
−6 −5 −4 −3 −2 −1 0 1 2 3 4 5 6

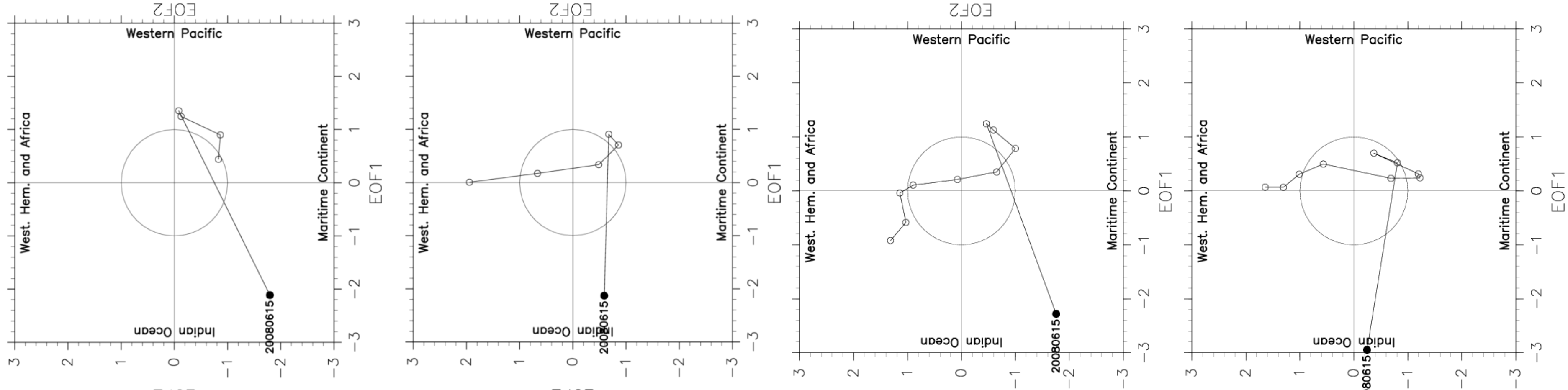
Reproducibility of MJO phase (VP200) in NICAM 2008/06

Taniguchi et al. (2010)

Reanalysis

ECMWF YOTC | JCDAS | NCEP





3.5km_MY2 | 14km_MY2 | 14km_MY2_MAT | 14km_MYNN2.5_MAT

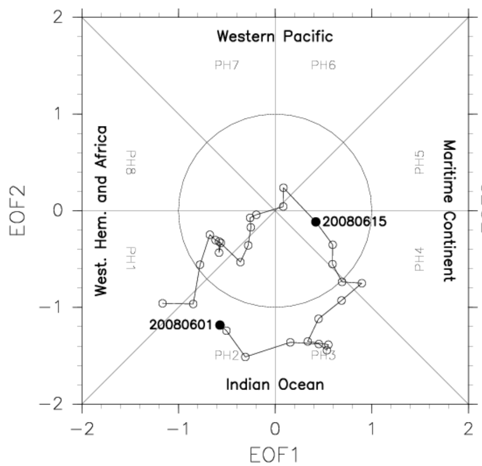
NICAM

Reproducibility of MJO phase (U850,U200, OLR) in NICAM (Jun 2008)

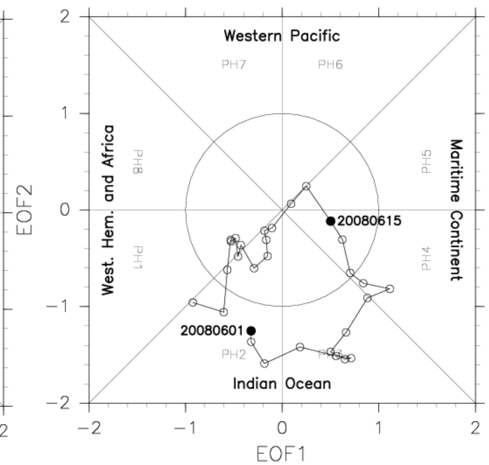
Wheeler and Hendon (2004)

Reanalysis

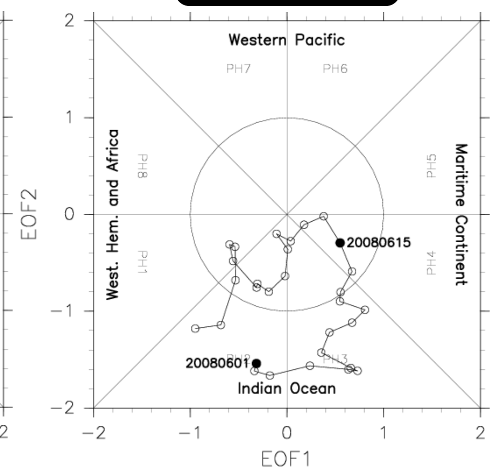
ECMWF YOTC

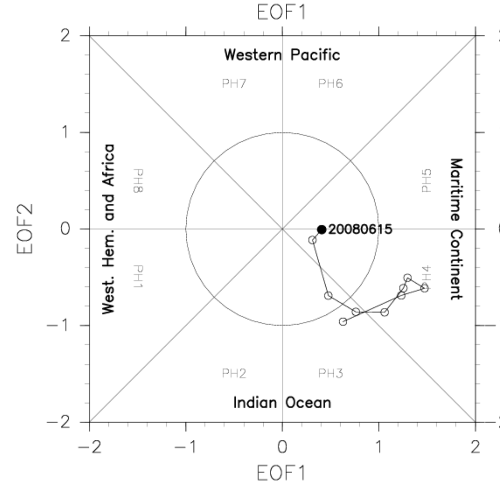


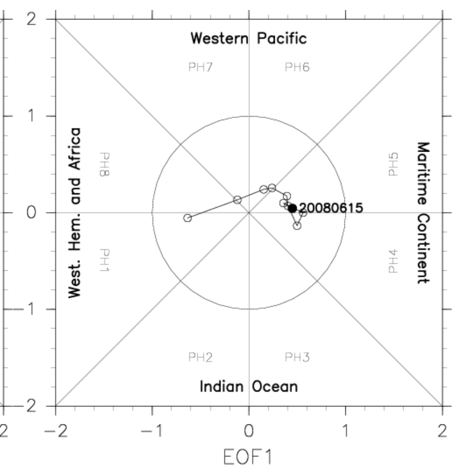
JCDAS



NCEP



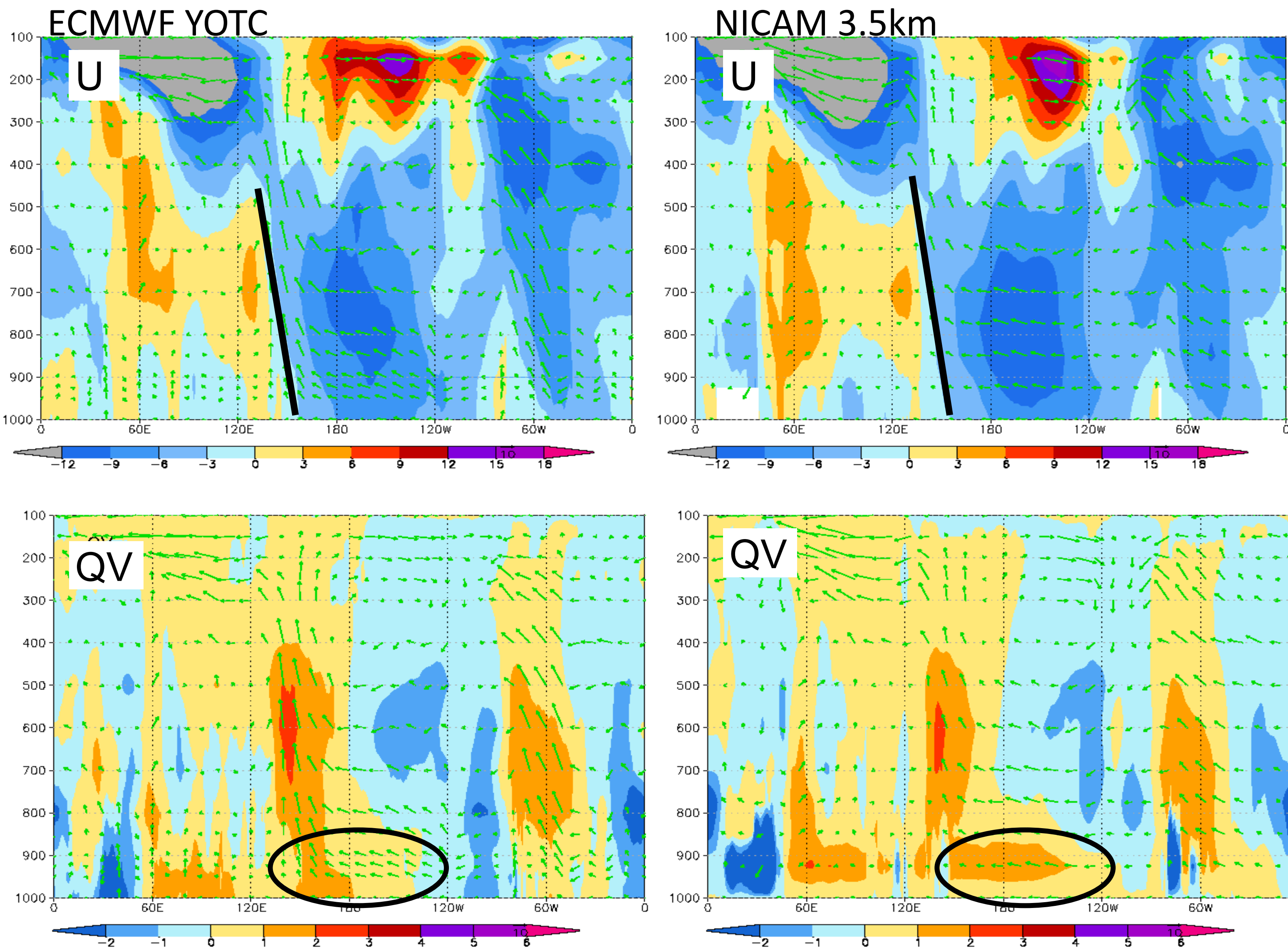




3.5km_MY2 **14km_MY2** **14km_MY2_MAT** **14km_MYNN2.5_MAT**

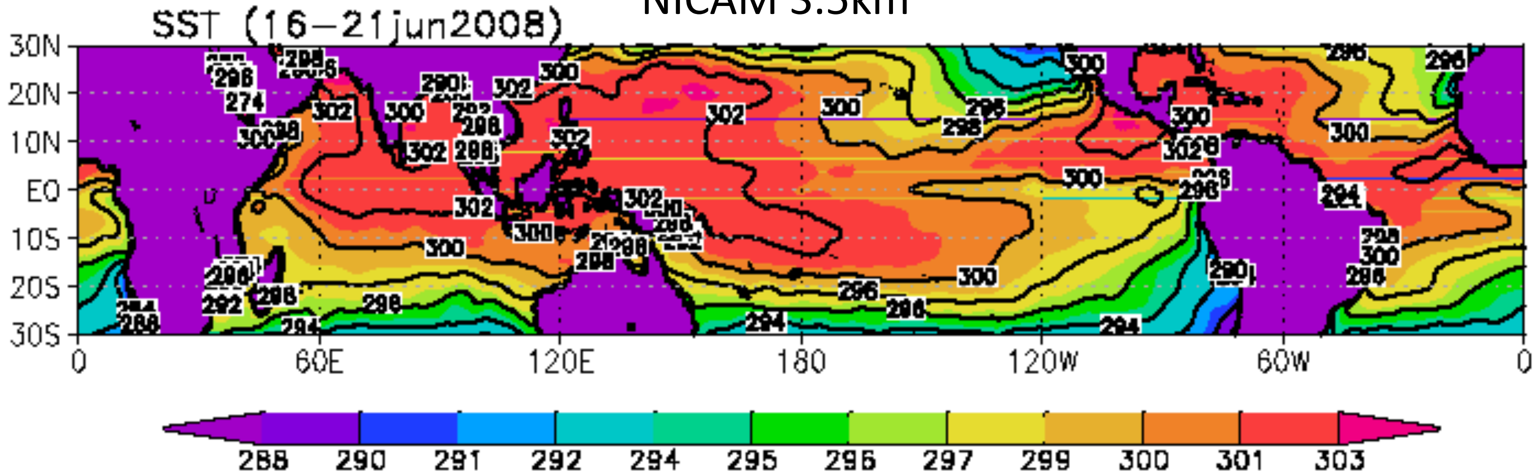
NICAM

Vertical structure (7.5N-7.5S) 16-20 Jun 2008) MJO phase 6-7

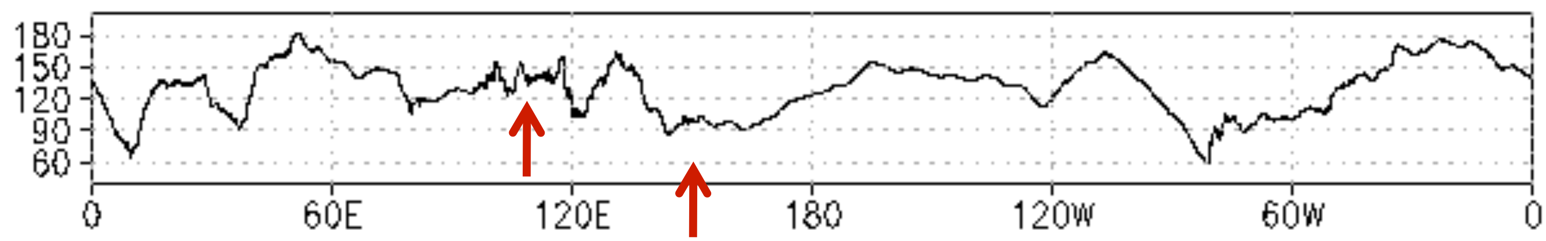


Surface flux (7.5N-7.5S)   16-20 Jun 2008 MJO phase 6-7

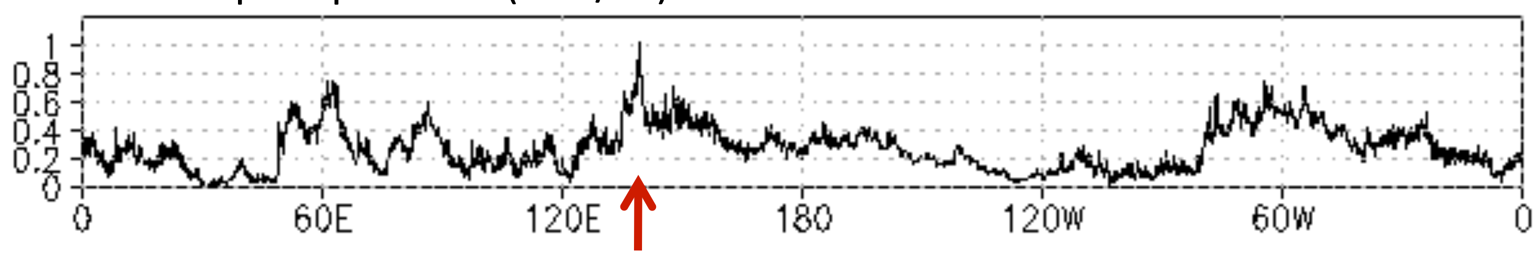
NICAM 3.5km



Surface latent heat flux   16-20 Jun2008 7.5N-7.5S



Surface precipitation (mm/hr)   16-20 Jun2008 7.5N-7.5S



Consistent with Kim et al. (2009) Fig.9 ?

Summary & Future plan

- NICAM simulations suggest potential ability of GCRM in study of multi-scale mechanisms associated with monsoon and ISV (e.g., TC genesis, convectively coupled waves; latent heating, moisture transport, CMT and air-sea interactions in ISV)
- MJO index using VP200 is useful for GCRM simulations (OLR is sensitive to model physics).
- Strategy to better simulate of Monsoon and ISV:

1. Sensitivity study of model physics (e.g., cloud microphysics, turbulence, slab ocean, land)
2. Collaboration with field observation projects and validation using satellite data are underway.

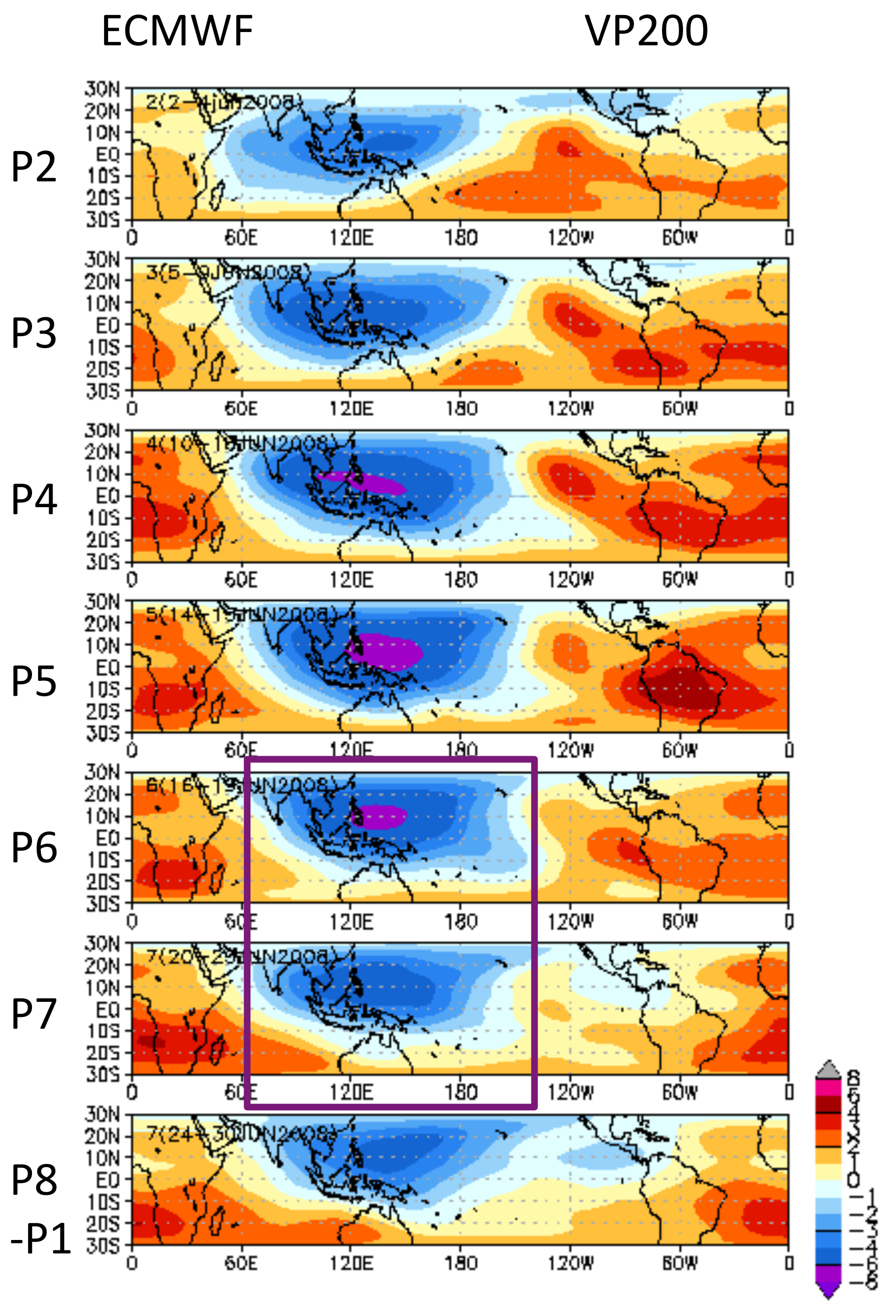
- Extension of integration period (~ 1 year) and ensemble simulations (1~3 month) using 7, 14 km mesh are planned.

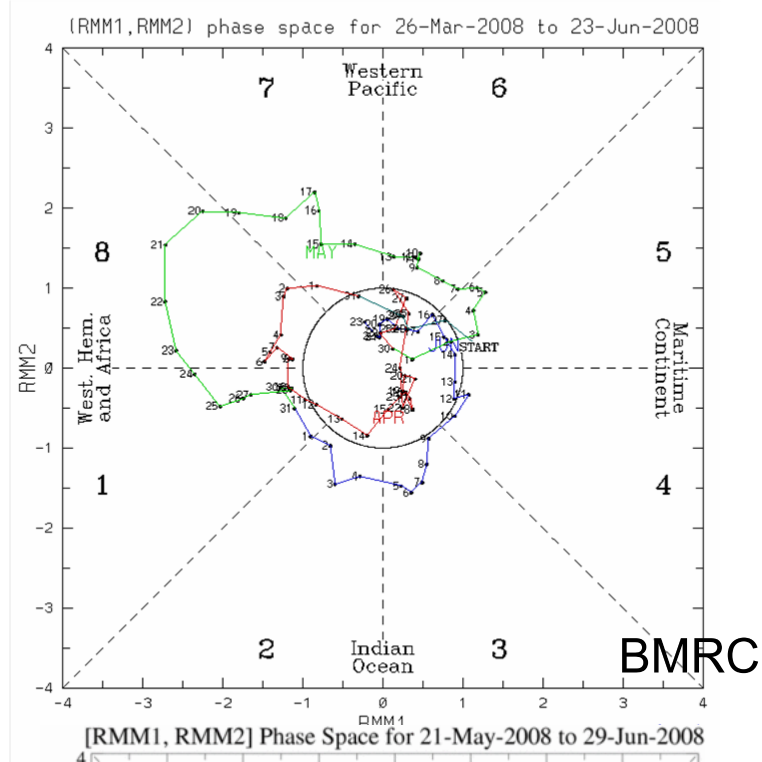
→ MJO diagnostics by CLIVAR MJO WG is applicable.

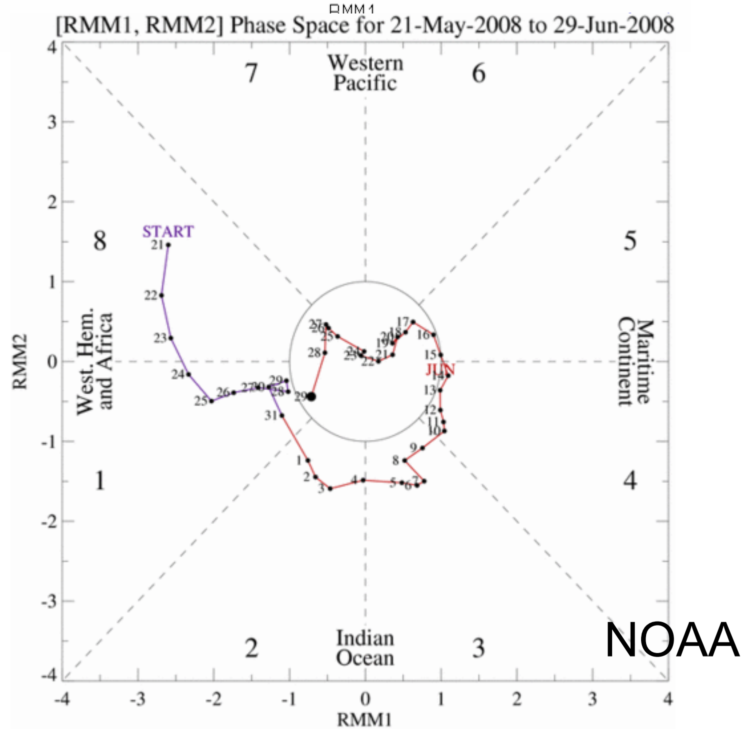
Acknowledgement

- This research was supported by the Core Research for Evolutional Science and Technology program of the Japan Science and Technology Agency, and by the Innovative Program of Climate Change Projection for the 21th century (KAKUSHIN) project "Global Cloud Resolving Model Simulations toward More Accurate and Sophisticated Climate Prediction of Cloud/precipitation Systems" funded by Ministry of Education, Culture, Sports, Science and Technology (MEXT).
- ECMWF YOTC operational data was used to initialize and validate the simulation using NICAM (Jun 2008 case).

appendix


ECMWF
VP200
P2
P3
P4
P5
P6
P7
P8
-P1
2(2–4JUN2008)
3(5–9JUN2008)
4(10–13JUN2008)
5(14–15JUN2008)
6(16–19JUN2008)
7(20–23JUN2008)
7(24–30JUN2008)

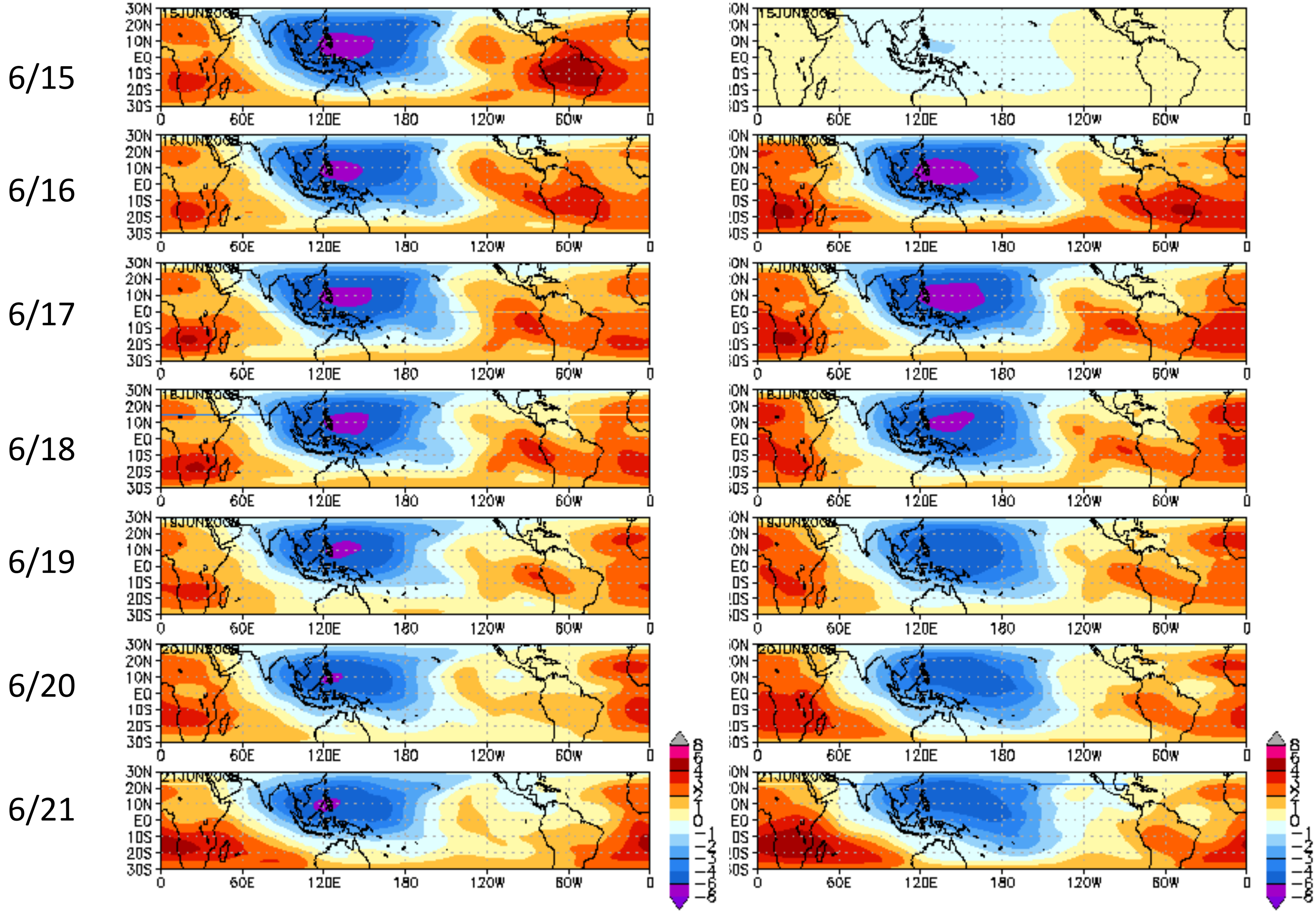

(RMM1,RMM2) phase space for 26-Mar-2008 to 23-Jun-2008
Western Pacific
West. Hem. and Africa
Maritime Continent
Indian Ocean
RMM1
RMM2
START
MAY
JUN
APR
BMRC


[RMM1, RMM2] Phase Space for 21-May-2008 to 29-Jun-2008
Western Pacific
West. Hem. and Africa
Maritime Continent
Indian Ocean
RMM1
RMM2
START
JUN
NOAA

ECMWF

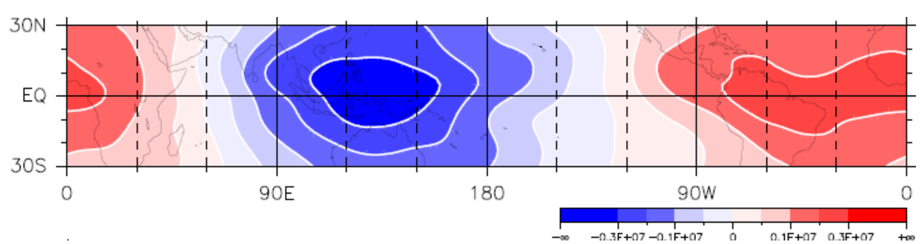
VP200

NICAM 14 km my2 MATSIRO

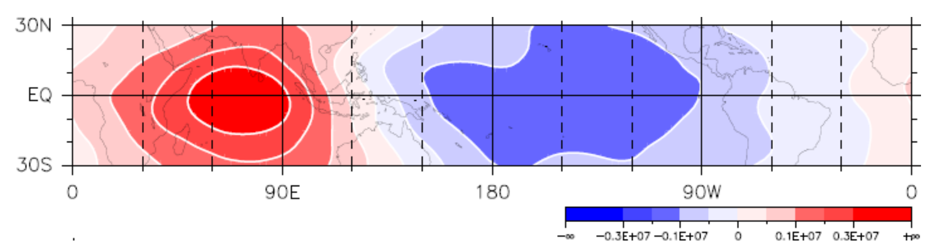


MJO index by CHI200 (Matthews, 2000; Taniguchi et al., 2008)

- **It is based on a pair of empirical orthogonal functions of velocity potential anomaly at 200 hPa (CHI200) data.**
- **Methodology**
  1. **Creating daily data of CHI200 (1xdaily) from intended data**
  2. **Creating low-pass filtered (60-day) daily climatology data of JRA-25 data from 1979-2007**
  3. **Preparing anomaly data of intended daily data (1.) from climatology data (2.).**
  4. **Creating band-pass filtered (30-90 day) anomaly data (3.)**
  5. **Calculate EOF modes of band-pass filtered data (4.)**



JRA-25(1979-2007), EOF1 (40.5%)

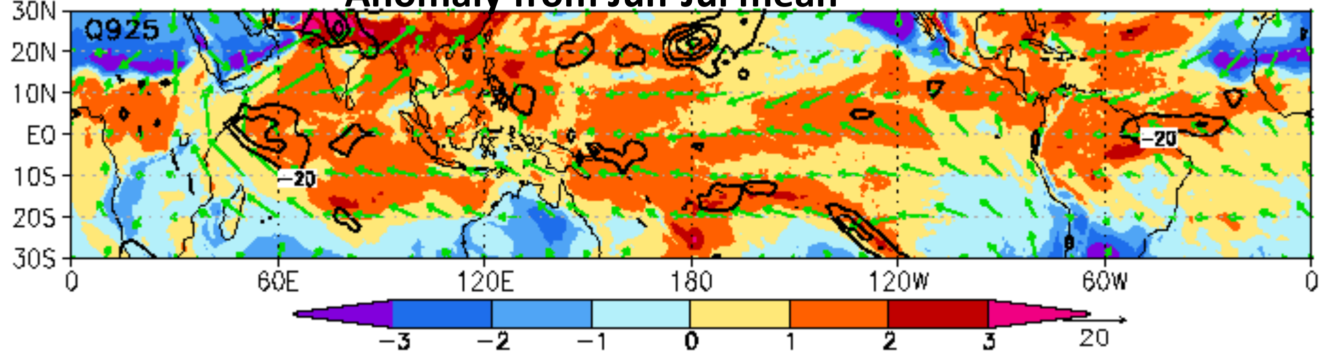


JRA-25(1979-2007), EOF2 (34.0%)

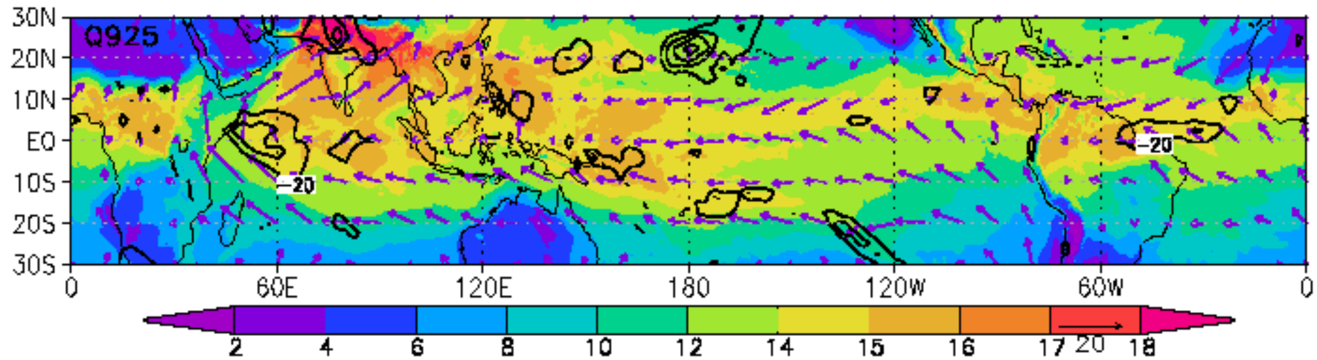
Moisture (925hPa) 16-20 Jun 2008 MJO phase 6-7

Anomaly from Jun-Jul mean

ECMWF YOTC



ECMWF YOTC



NICAM 3.5 km mesh