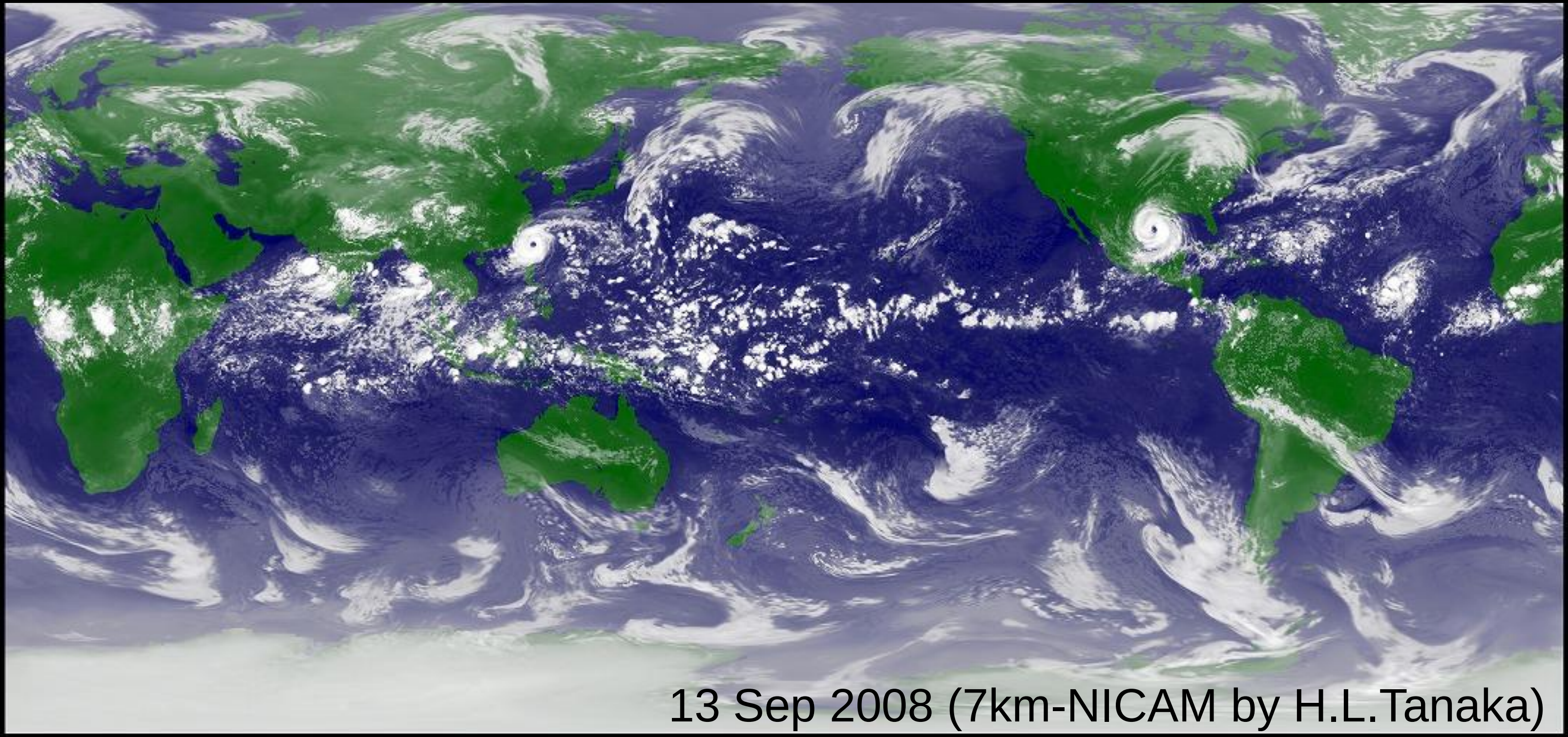
Global Cloud-system Resolving Modeling

Masaki Satoh

Tomoe Nasuno, Hiroyuki Yamada, Tempei Hashino

Tomoki Miyakawa and Yukari Takayabu (AORI/JAMSTEC)



13 Sep 2008 (7km-NICAM by H.L.Tanaka)

YOTC International Science Symposium & 8th AMY International Workshop, 16-19 May, 2011, Beijing, China

http://yotc-amy-2011.csp.escience.cn/

Group web page http://nicam.jp

Journal of the Meteorological Society of Japan (JMSJ)

JMSJ is an international English journal of the Meteorological Society of Japan. JMSJ publishes original research articles relating to meteorology. The articles are se... ted carefully by a thorough ... ew based on the latest sci...

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JMSJ, Since 1882

Vol. 88, No. 3 (2010) Special Edition on the Myanmar Cyclone
by Masaki Satoh, edit.
Vol. 89A (2011) Special Issue on MAHASRI
by Jun Matsumoto, edit.

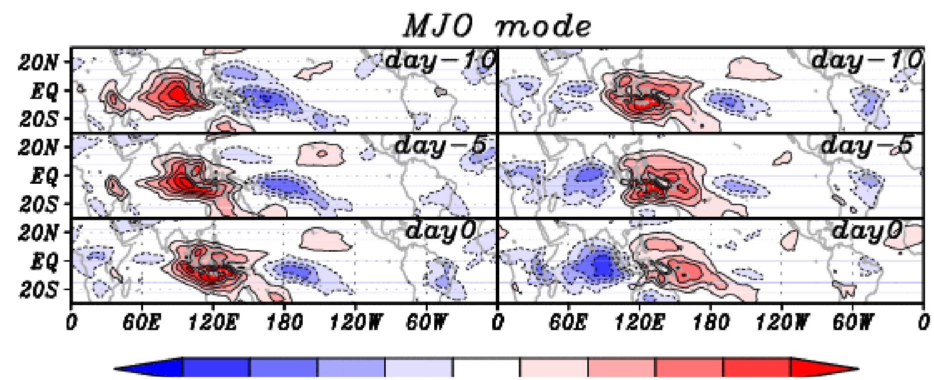
...//www.jstage.jst.go.jp/browse/jmsj
...ubmit papers and browse archives (*free access!*)

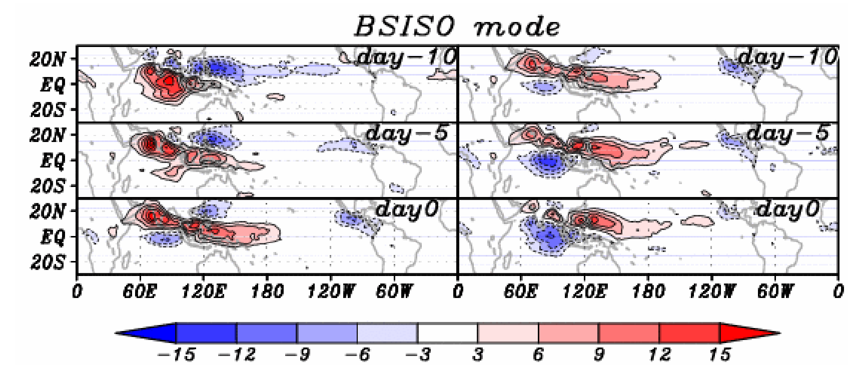
Bimodal ISO index

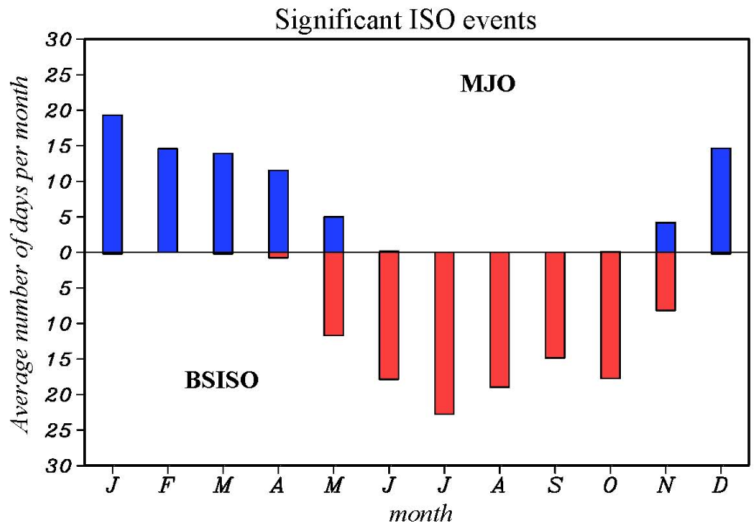
from historical data analysis to real time monitoring

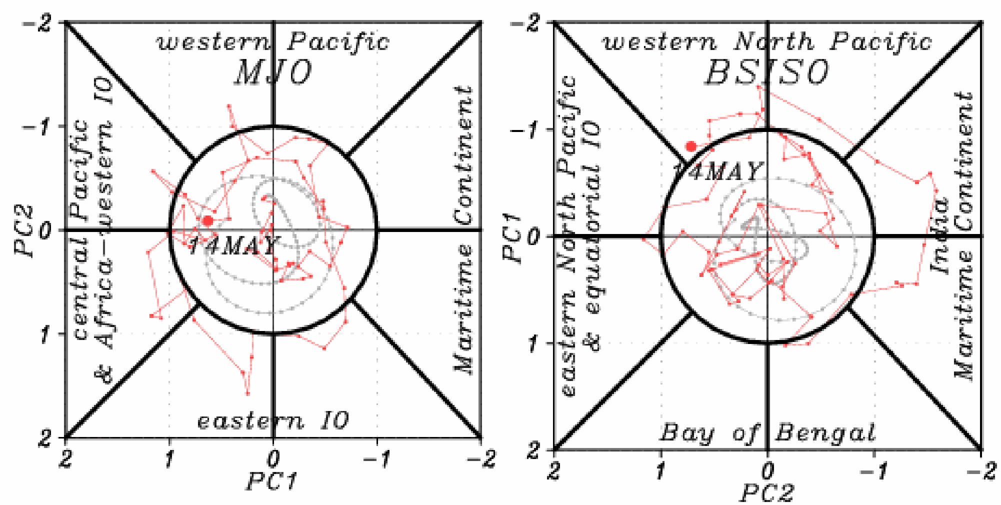
Kazu Kikuchi (IPRC, Hawaii)

http://iprc.soest.hawaii.edu/~kazuyosh/









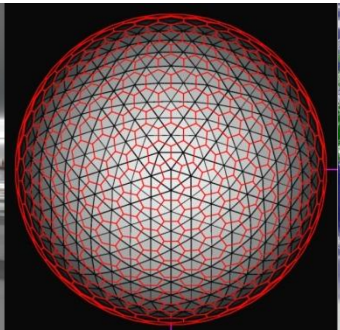
Kikuchi and Wang (2010,JMSJ); Kikuchi et al.(2011,Clim. Dyn.)

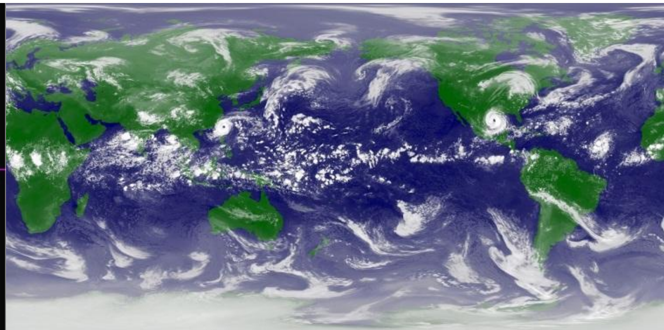
Contents

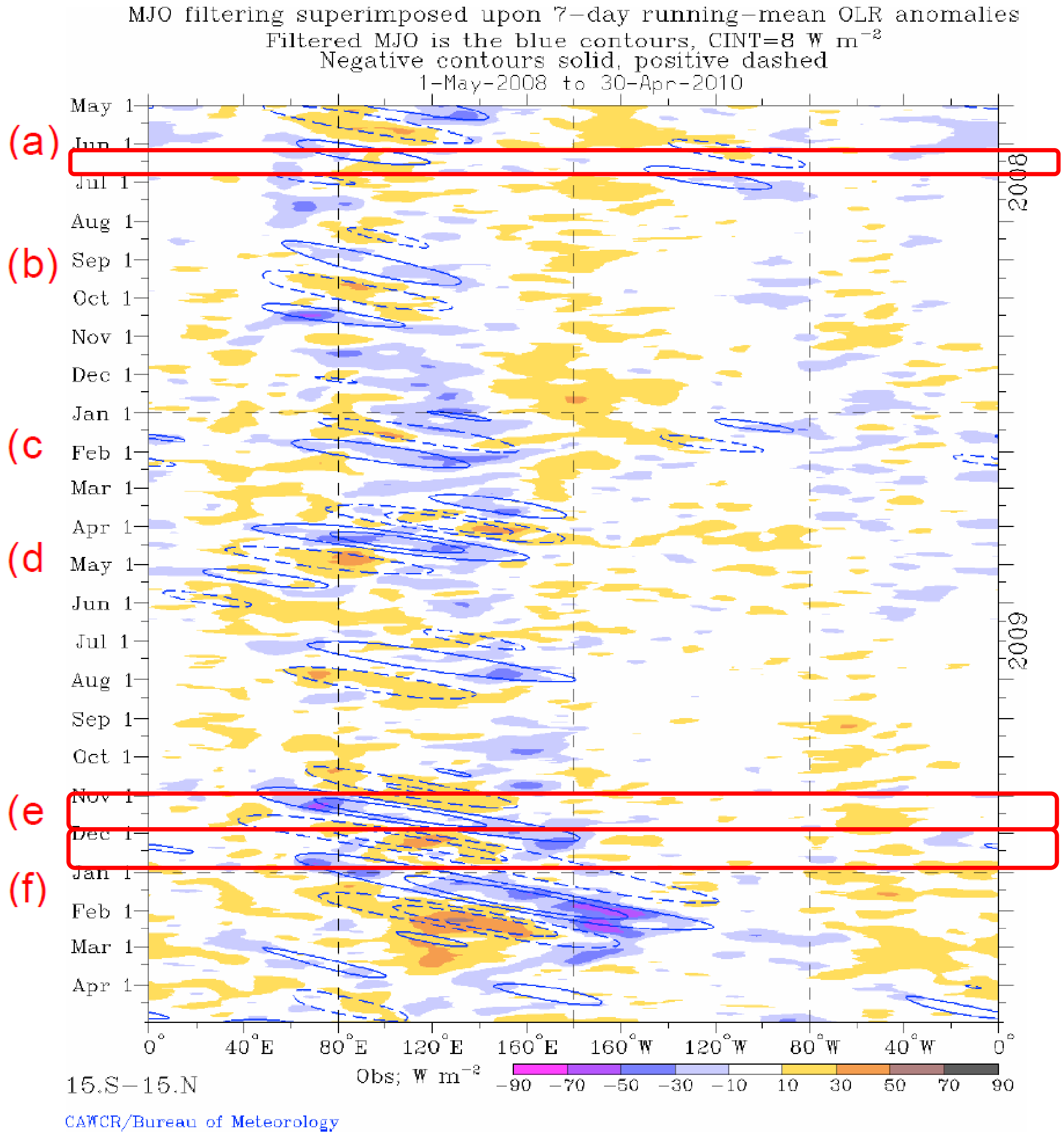
- **3.5km mesh NICAM simulation for TC Fengshen (June 2008) YOTC #1**
  - **Tomoe Nasuno, Hiroyuki Yamda (poster)**
- **Cloud properties and evaluation**
  - **J-Simulator by T. Hashino and the EarthCARE team**
- **MJO simulation: Convective Momentum transport**
  - **Miyakawa et al. (poster)**
- **Preliminary Result for YOTC #5 & #6**

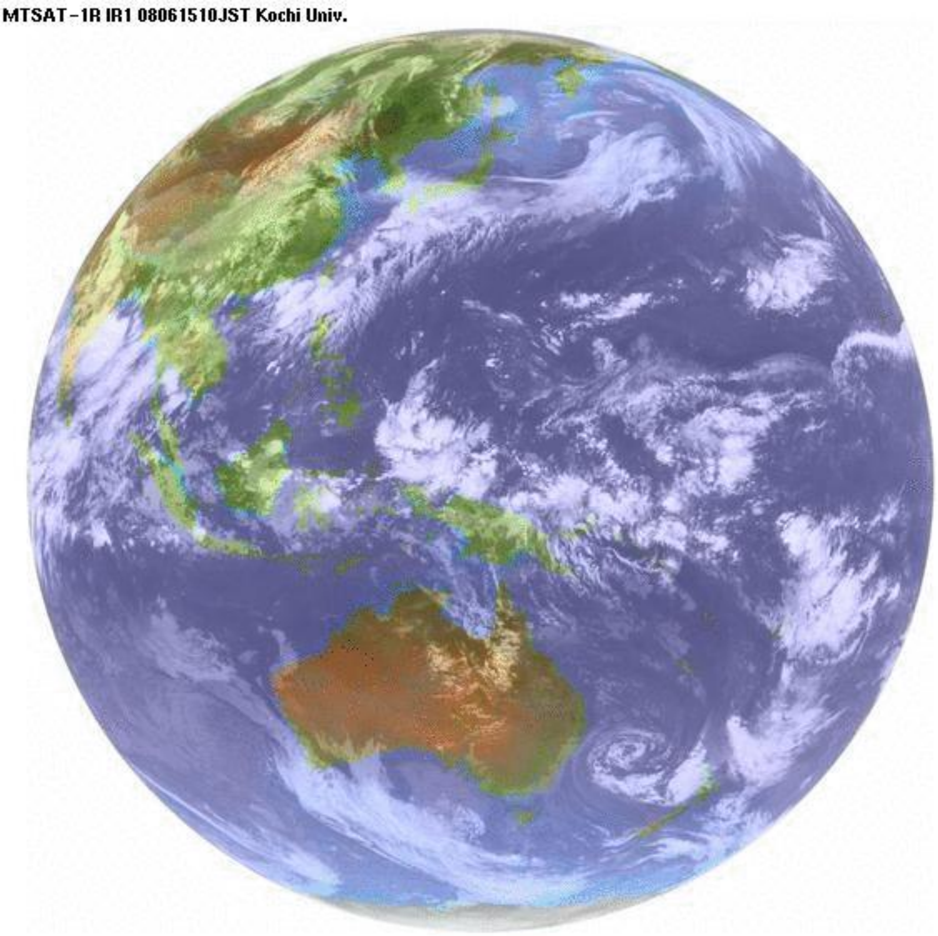
Global Cloud-Resolving Modeling

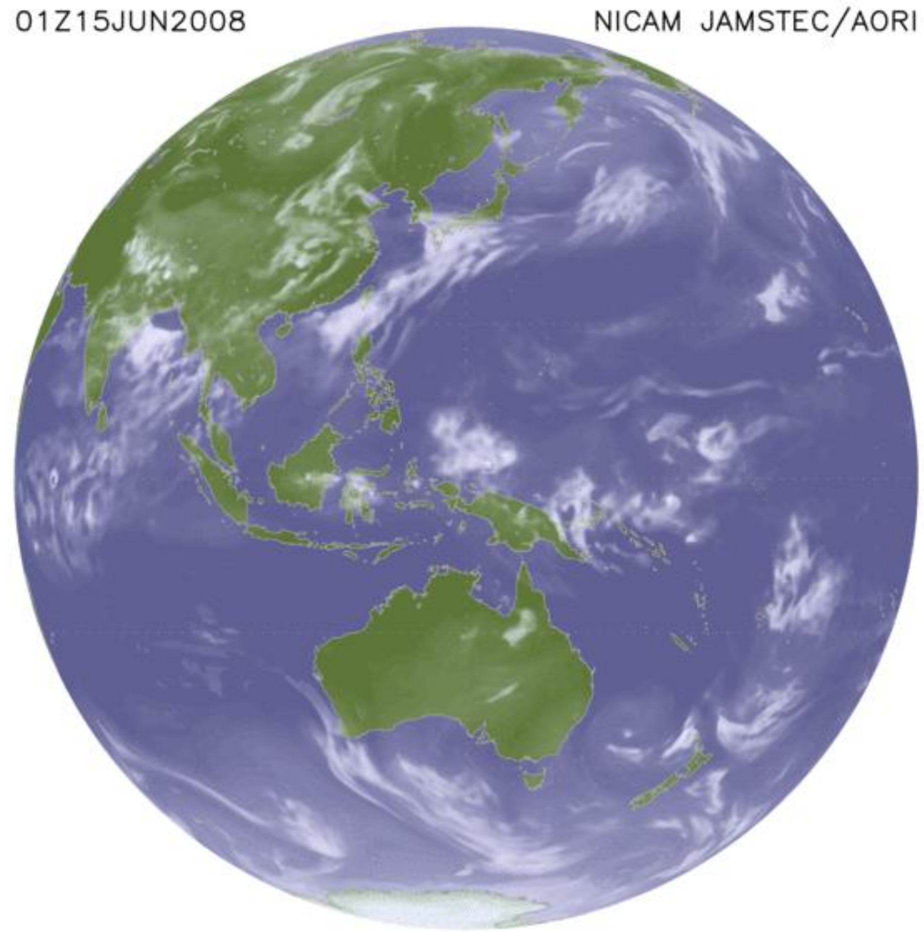
- NICAM: Nonhydrostatic Icosahedal Atmospheric Model
  - -Development since 2000
    - Tomita and Satoh(2005, *Fluid Dyn. Res.*), Satoh et al.(2008, *J. Comp. Phys.*)
  - -First global dx=3.5km run in 2004 using the Earth Simulator (JAMSTEC)
    - Tomita et al.(2005, *Geophys. Res. Lett.*), Miura et al.(2007, Science)
  - -Toward higher resolution global simulation
    - dx=1.7km, 880m, 440m using K-computer (10PF; Kobe,Riken,2012)
- International collaboration
  - –Athena project (2009-10): COLA, NICS, ECMWF, JAMSTEC, Univ. of Tokyo
  - –G8 ICOMEX (2011-): Germany, UK, France, US, Japan






MJO filtering superimposed upon 7-day running-mean OLR anomalies
Filtered MJO is the blue contours, CINT=8 W m^{-2}
Negative contours solid, positive dashed
1-May-2008 to 30-Apr-2010
(a)
(b)
(c)
(d)
(e)
(f)
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Nov 1
Dec 1
Jan 1
Feb 1
Mar 1
Apr 1
2008
2009
0°
40°E
80°E
120°E
160°E
160°W
120°W
80°W
40°W
15.S-15.N
Obs; W m^{-2}
-90 -70 -50 -30 -10 10 30 50 70 90
CAWCR/Bureau of Meteorology





NICAM 3.5km-mesh experiment for YOTC: July 15-25, 2008

Nasuno et al. (2011)

Validation of cloud microphysical statistics simulated by a global cloud-resolving model with active satellite measurements

Tempei Hashino[1], Masaki Satoh[1], Yuichiro Hagihara[2], Takuji Kubota[3], Toshihisa Matsui[4], Tomoe Nasuno[5], and Hajime Okamoto[2]

Email: hashino@aori.u-tokyo.ac.jp

(2011, to be submitted)

[1]Atmosphere and Ocean Research Institute, The University of Tokyo

[2] Research Institute for Applied Mechanics, Kyushu University

[3]Japan Agency for Marine-earth Science and Technology

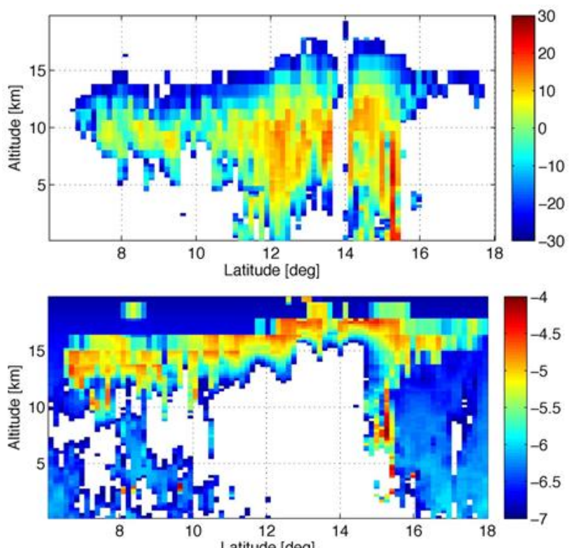
[4]NASA Goddard Space Flight Center

[5]Japan Agency for Marine-earth Science and Technology

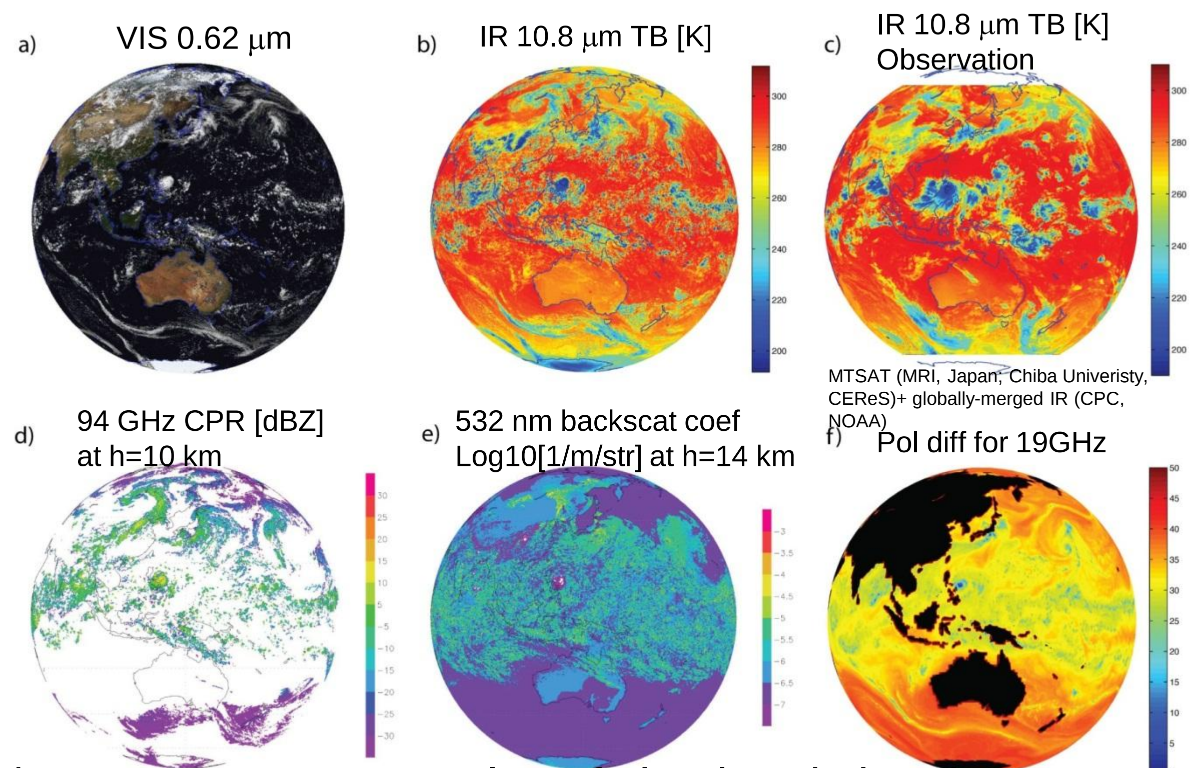
J-simulator (Joint Simulator for Satellite Sensors)

by T. Hashino and the EarthCARE team

- Simulate EarthCARE (2014) observations from CRM outputs.
- Built on Satellite Data Simulator Unit (SDSU)
  Masunaga et al. (2010, BAMS)
- Extension at NASA/Goddard: Goddard-SDSU
  courtesy of T. Matsui & NASA GPM team



Cross section through the TC at longitude 127E



Examples of simulated signals

Joint Simulator for Satellite Sensors
J-Simulator

http://www22.atwiki.jp/j-simulator/

Data set

CloudSAT-CALIPSO merged data set provided by H. Okamoto group

NICAM simulation dataset (Nasuno et al. 2011)

- horizontal grid spacing: 3.5 km; 40 vertical levels (0~3.8km)
- cloud microphysical parameterization: NSW6 (Tomita 2002)

↓ J-simulator

Simulated CloudSAT & CALIPSO merged data set

Data period

2008 June (1 month) for observations

2008 June 17th 00Z ~ 25th 00Z for NICAM

Apply Cloud Mask schemes developed by Hagihara et al. (2010) to extract signals from cloud & precipitating particles.

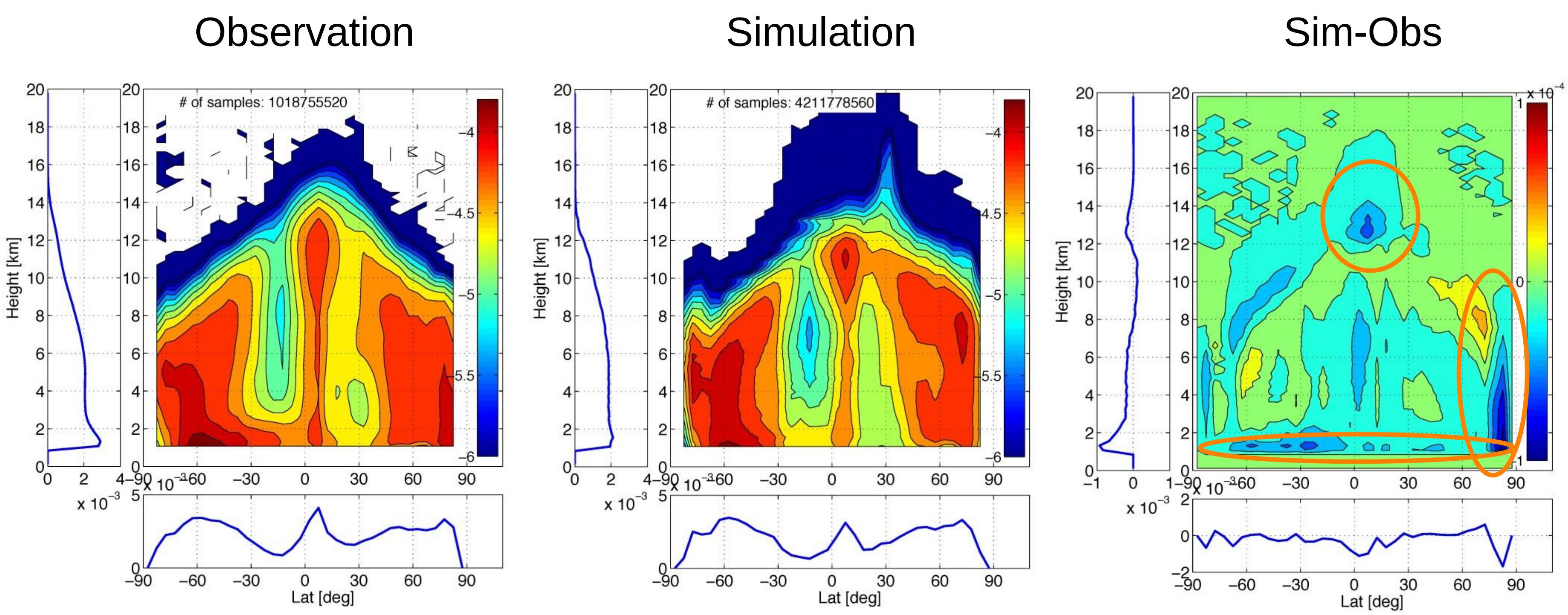
Radar mask (RO); cloud & precipitating particles.

Lidar mask (LO); cloud particles.

Radar and Lidar mask (RAL); cloud particles

Radar or Lidar mask (ROL); all particles

Latitudinal distribution of cloud occurrence defined with RO mask

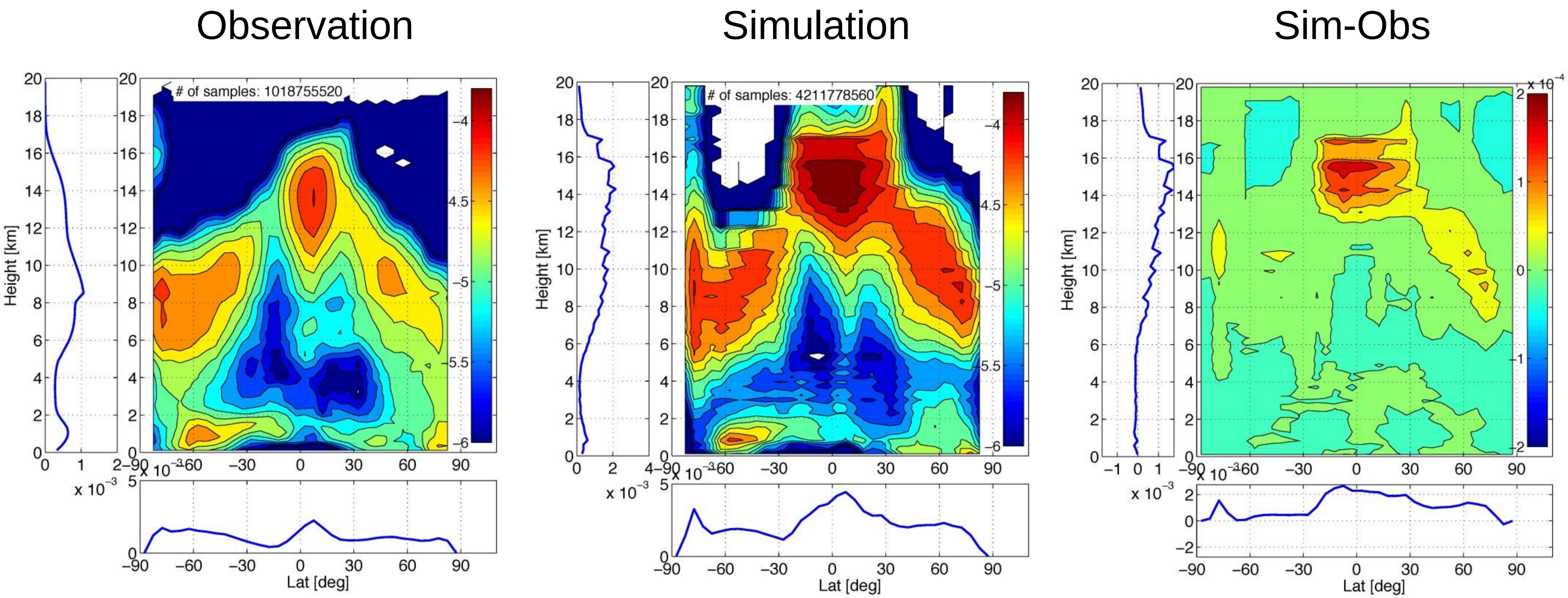


The marginal distributions of the cloud occurrences seen by CPR show a good agreement.

The cloud occurrence for NICAM is less than the obs in above 12 km in -15 < θ < 35º, which suggests that the cloud top defined by RO mask in NICAM is lower.

Relative error < 60% (except for the upper level in tropics)

Latitudinal distribution of cloud occurrence defined with LO mask



According to the marginal distributions, NICAM has more occurrences above 10 km, which contributes to the overestimation of occurrence over all the latitudes.

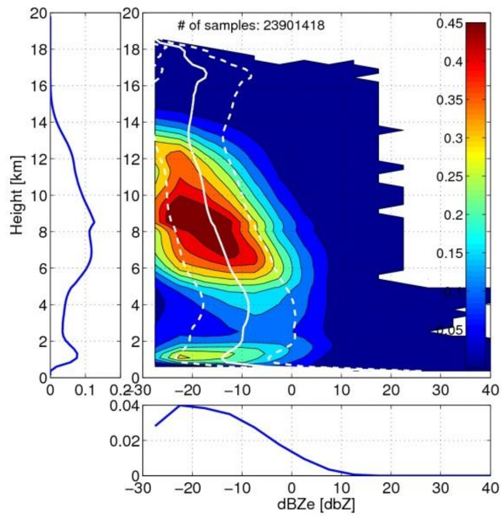
NICAM actually has more occurrences of clouds above 12 km in -30 < θ < 30º, and also the occurrences are higher in the other latitude in NICAM.

Consistent with IR comparison.

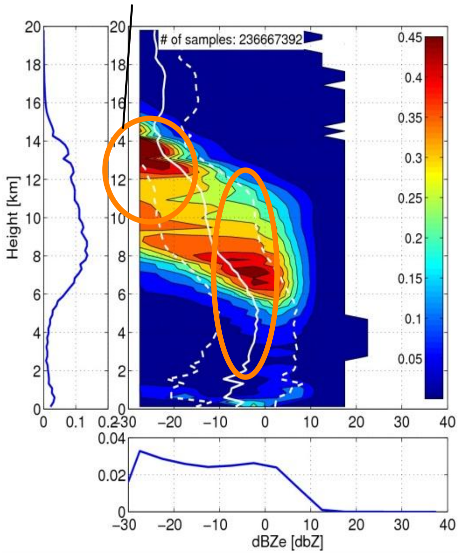
The low level cloud (less than 2 km) occurrences are comparable between them.

Global CFAD: Apply Cloud Mask schemes developed by Hagihara et al. (2010) to extract signals from cloud & precipitating particles

CloudSAT; 94 GHz Radar Ref



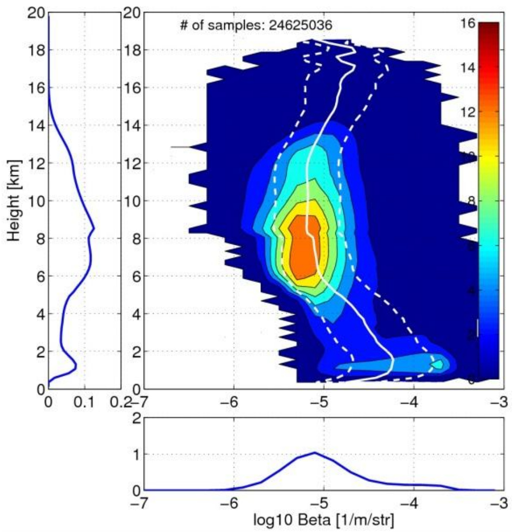
NICAM; 94 GHz Radar Ref



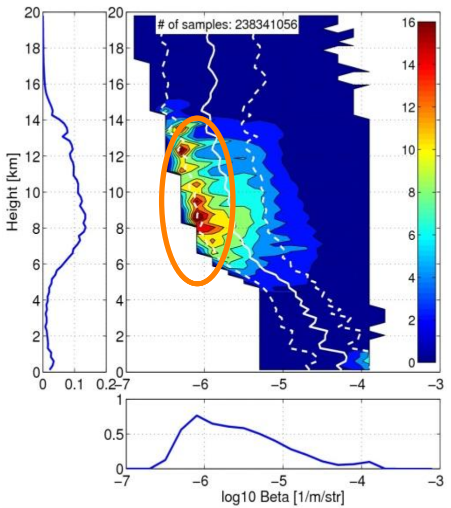
Ice particles, probably snow, tend to be large in NICAM.

More occurrence of high clouds.
Low level clouds are less frequent in NICAM?

CALIPSO; 532 nm Backscattering coef



NICAM; 532 nm Backscattering coef

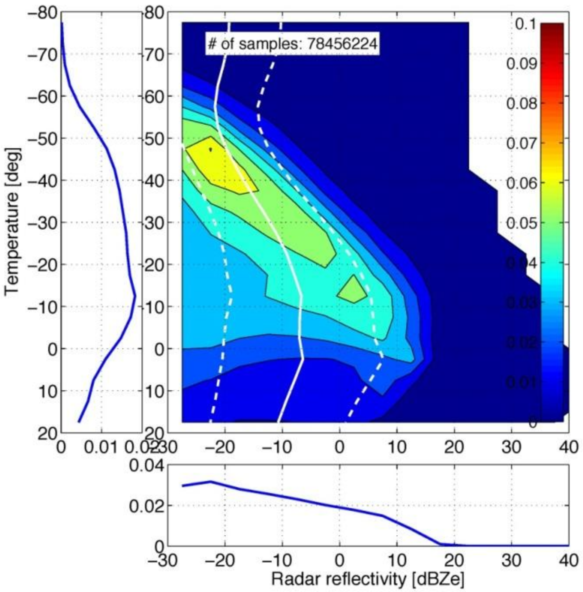


High frequency at small backscattering coefficient due to possibly large snow particles or small IWC.

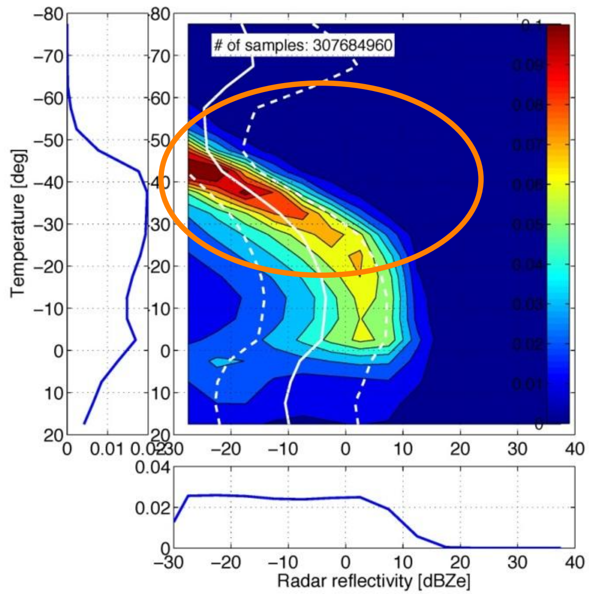
Global CFED

CFED: Contoured Frequency by tEmperature diagram

CloudSAT; 94 GHz Radar Ref



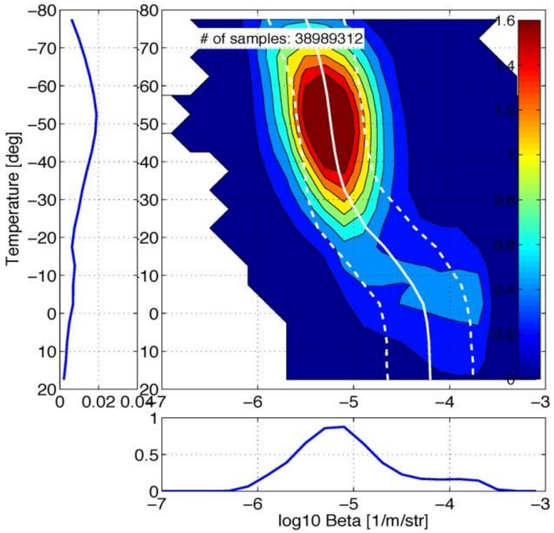
NICAM; 94 GHz Radar Ref



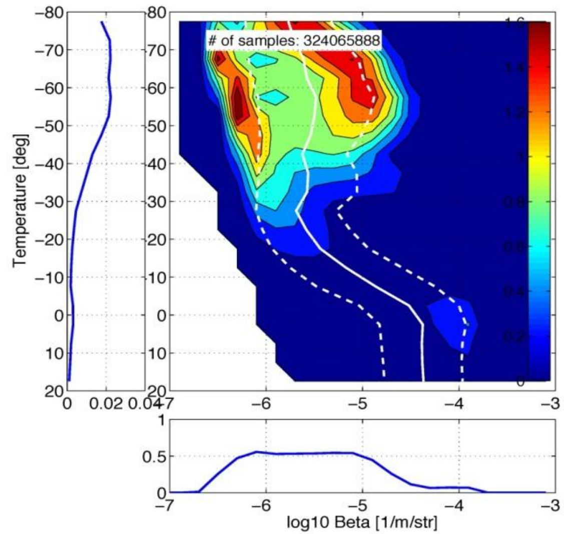
The marginal distribution over the temperature indicates the occurrence of in-cloud reflectivity in NICAM has two modes: one at just above the freezing point and another at ~-40°C.

Simulated reflectivity is more concentrated.

CALIPSO; 532 nm Backscattering coef



NICAM; 532 nm Backscattering coef



The joint frequency of in-cloud $\beta532$ in NICAM has distinct two modes: around -6.2 and -5.2 above ~-40°C level.

Summary of the J-simulator evaluation

- The cloud occurrence
  - Radar mask: underestimated at upper levels in the tropics, in the northern high-latitude and for BL clouds
  - Lidar mask: significantly overestimated at upper levels
- Generally larger reflectivity below -30C level.
- There is a separation of signals in Lidar backscat coef associated with cloud ice and snow, which causes a large difference in occurrence of upper level clouds defined by RAL mask.
- NICAM tends to simulate larger R_{eff} and smaller IWC than the observation.
- More occurrences of deep clouds with high cloud tops, less occurrences of middle and shallow clouds.
- Tends to be more convective for clouds with high and low tops.
- Slightly more clear profiles, less cloud profiles, more precipitation profiles.
- Cloud1 and drizzle profiles should be improved since they have the large # of samples.

Global cloud-system resolving simulation of typhoon Fengshen (2008): comparison with ECMWF YOTC operational analysis data

Tomoe Nasuno, Hiroyuki Yamada, Wataru Yanase,
Akira T. Noda, and Masaki Satoh
Email: nasuno@jamstec.go.jp

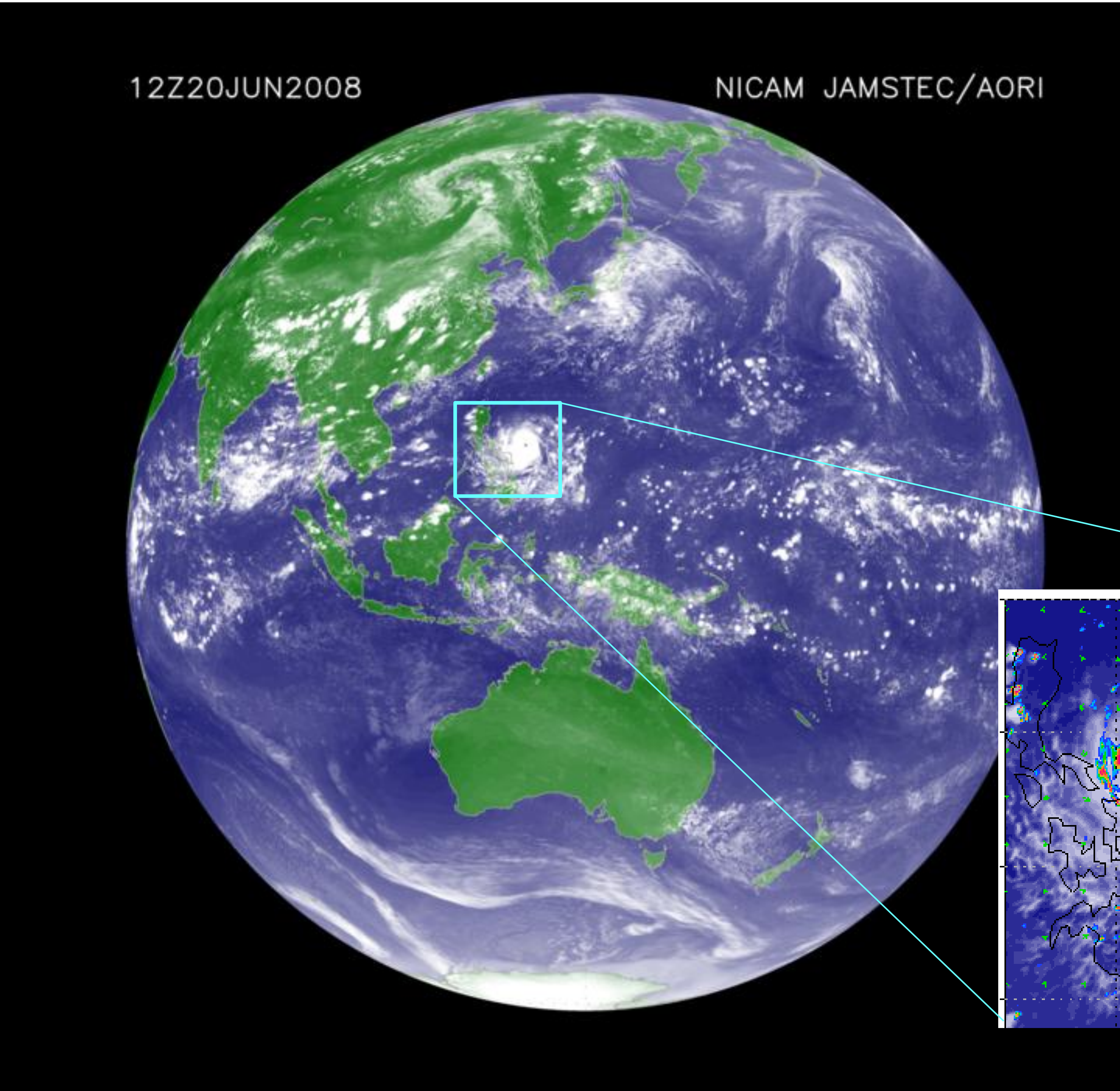
Genesis of Typhoon Fengshen (2008) from an uptilted synoptic-scale disturbance: PALAU field experiment and global cloud-resolving simulation

Hiroyuki Yamada, Tomoe Nasuno, Wataru Yanase,
Ryuichi Shirooka, and Masaki Satoh
Email: yamada@jamstec.go.jp

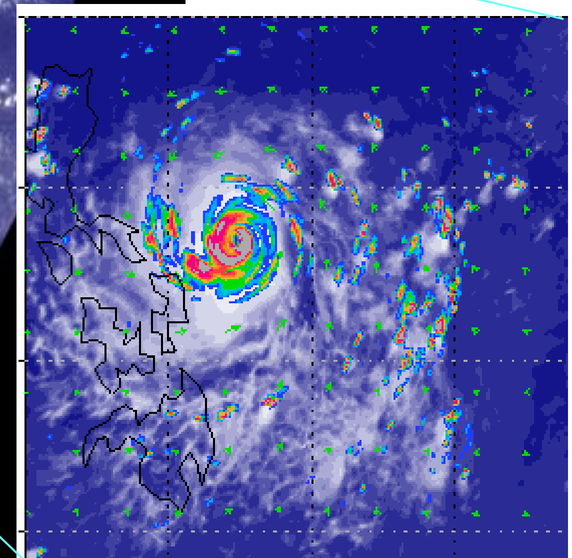
(2011, to be submitted)

See also poster presentations

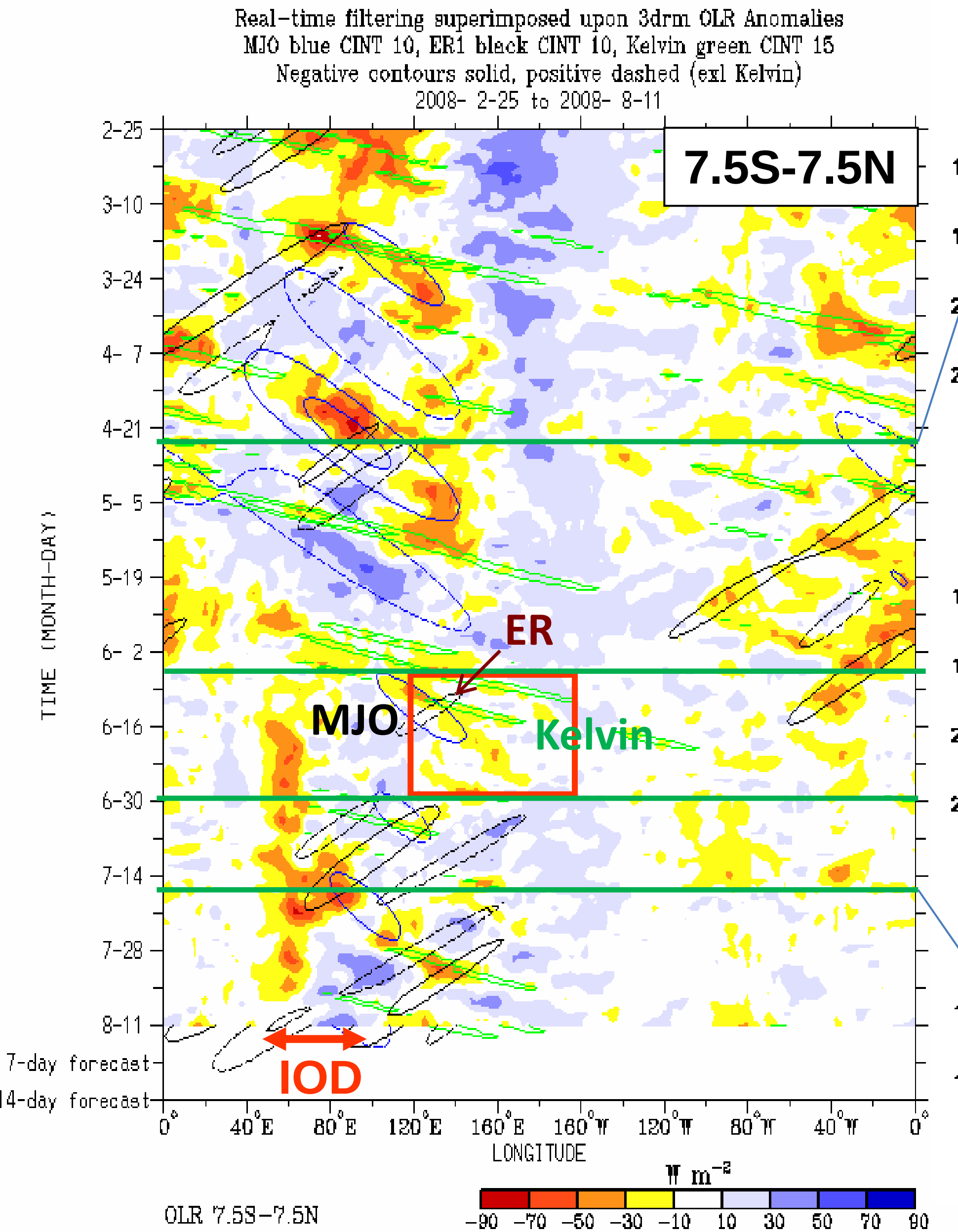
NICAM 3.5 km mesh
2008/06/20 12UTC

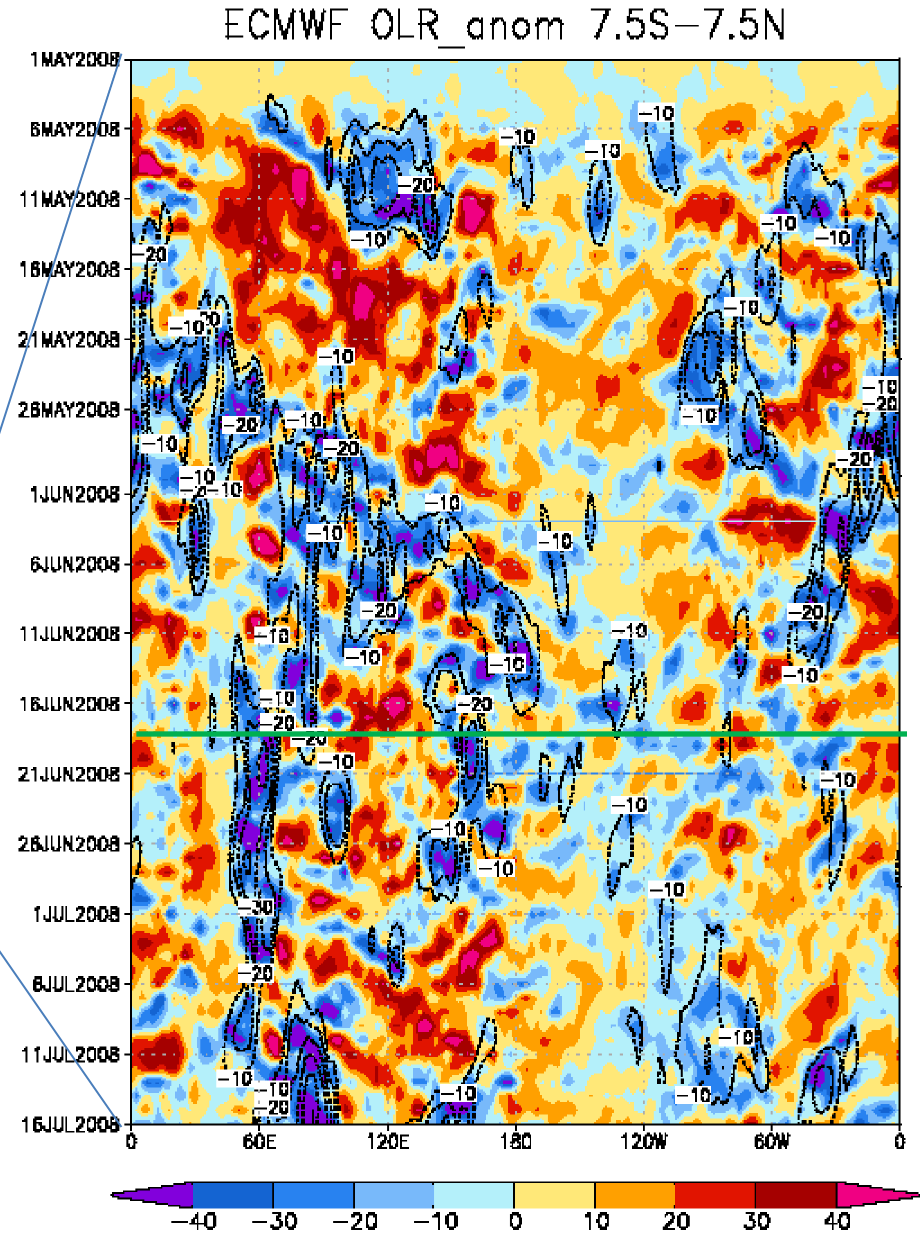


TC Fengshen



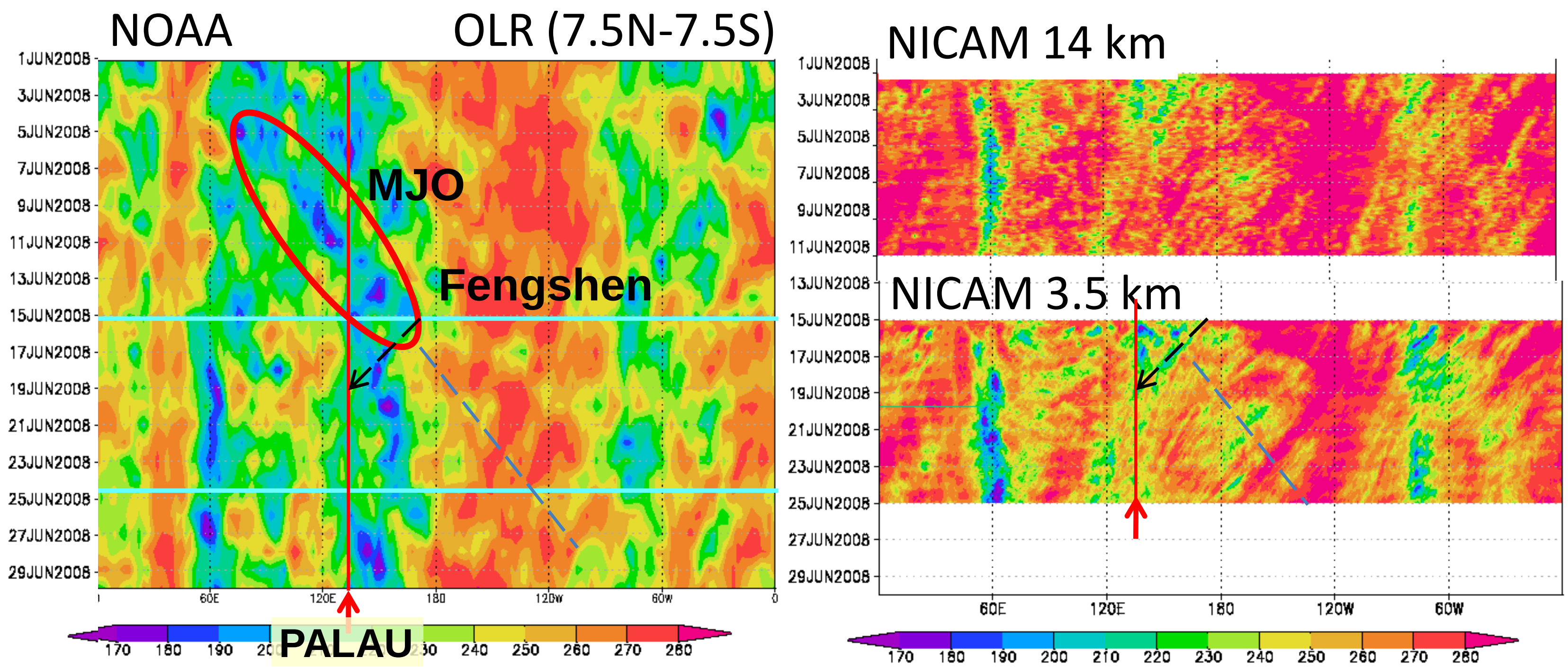
CAWCR OLR 解析





http://cawcr.gov.au/bmrc/clfor/cfstaff/matw/maproom/OLR_modes/h.6.ALL.N.html

Global cloud-resolving simulation of YOTC period #1



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

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

Integration: **10 days from 00UTC 15 Jun 2008**

Initial conditions: **ECMWF YOTC Operational data**

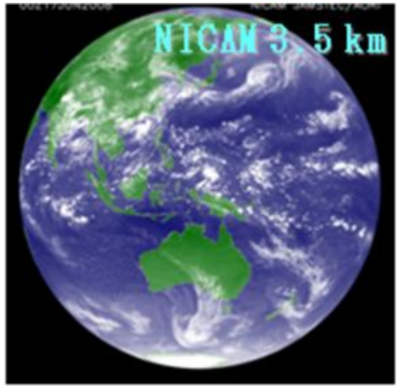
NCEP final analysis (land surface, SST)

Boundary conditions: **slab ocean** (nudging to Reynolds weekly SST)

- Fengshen formed on **17 Jun 2008** （ **PALAU2008 Field campaign** ）

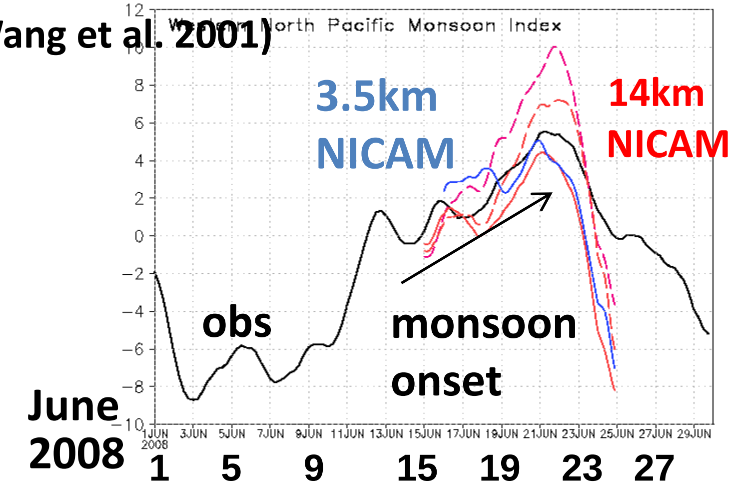
Global cloud-resolving simulation of YOTC period #1

06/17/2008 00UTC



North western Pacific Monsoon Index

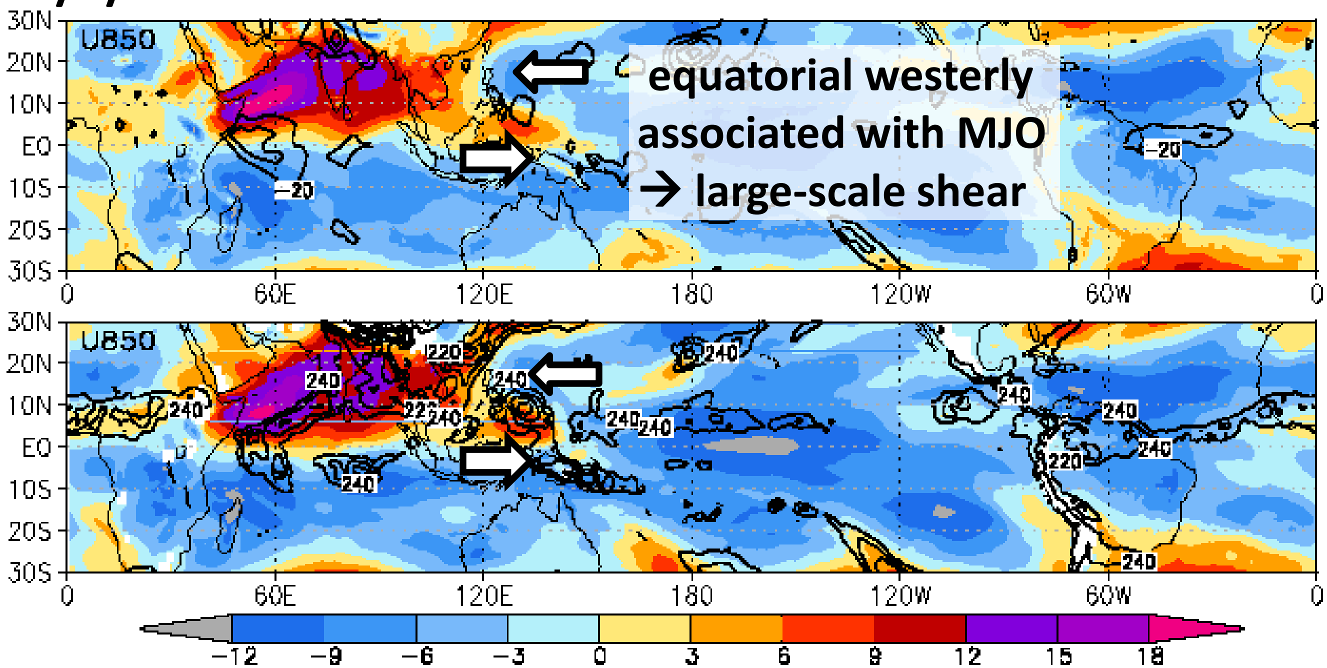
(Wang et al. 2001)



2008/6/15-21 zonal wind 850hPa

ECMWF YOTC analysis

3.5km NICAM

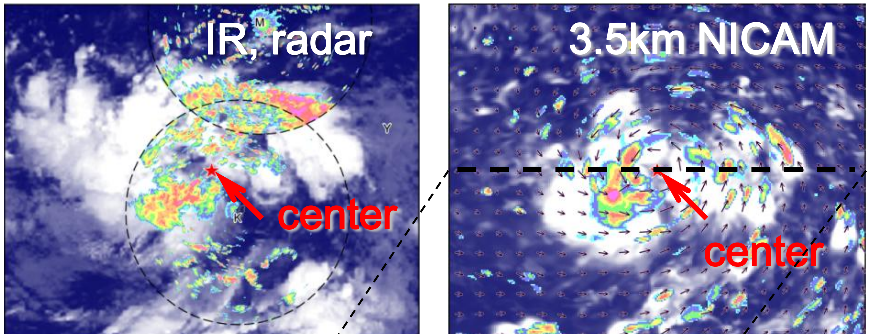


Large-scale condition is successfully reproduced

Global cloud-resolving simulation of YOTC period #1

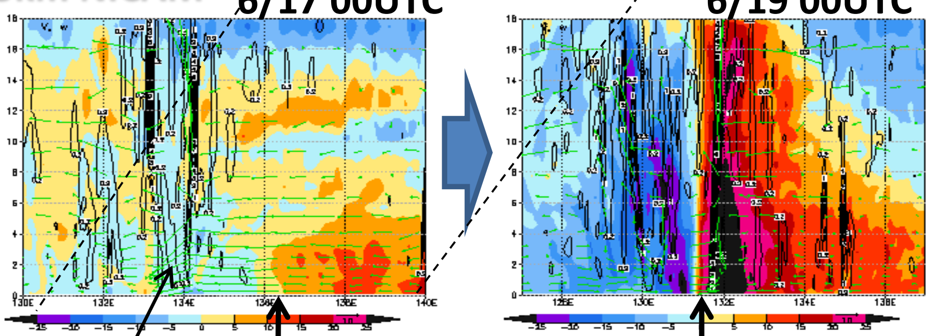
Genesis process of Typhoon Fengshen

06/17/2008 00UTC



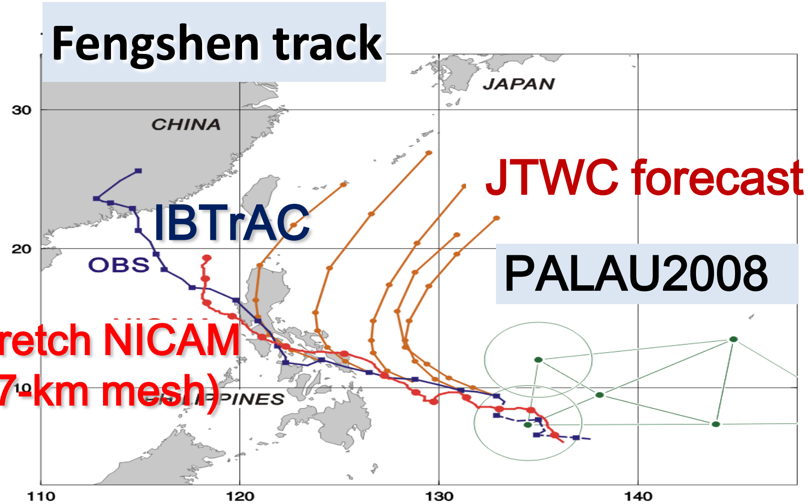
Initial vortex of typhoon Fengshen
Cloud distribution is asymmetric

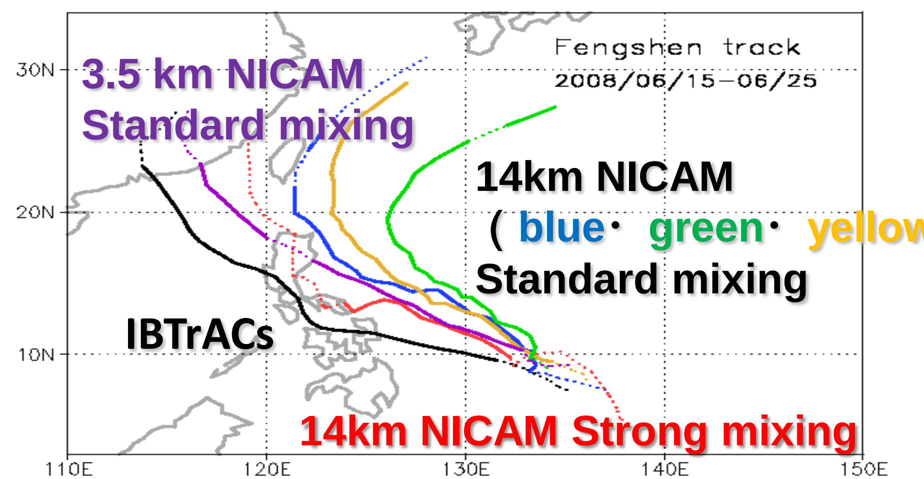
3.5km NICAM **6/17 00UTC** **6/19 00UTC**



condensate center — center

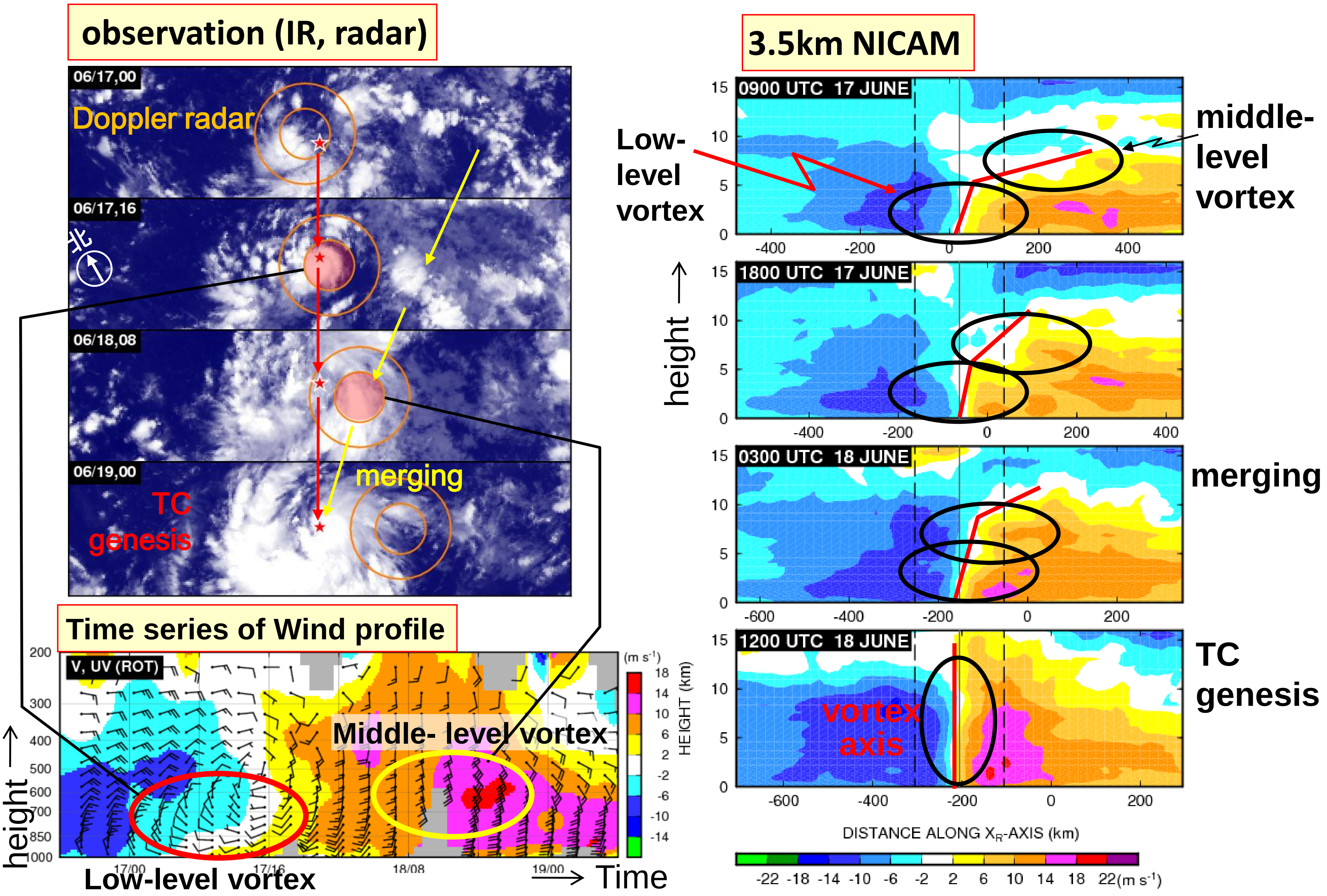
Deepening of axisymmetric structure Is realistically simulated

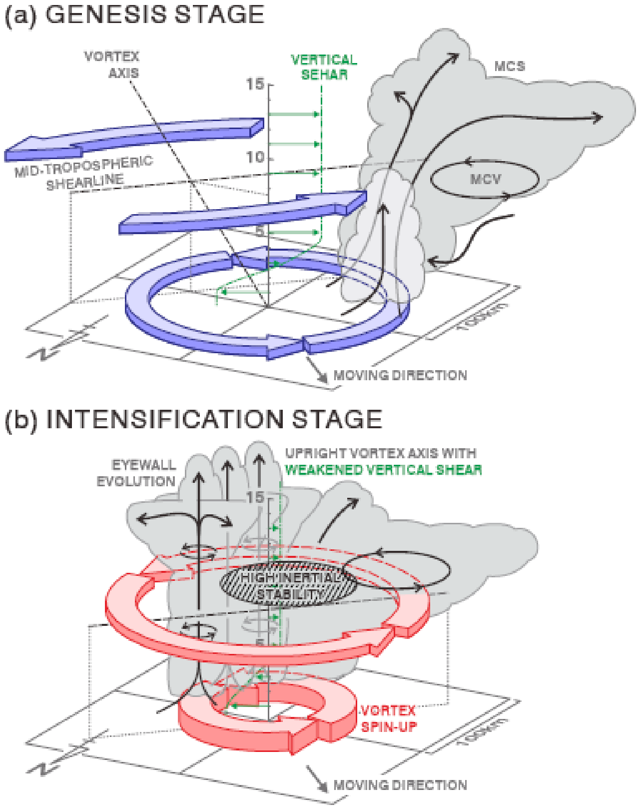


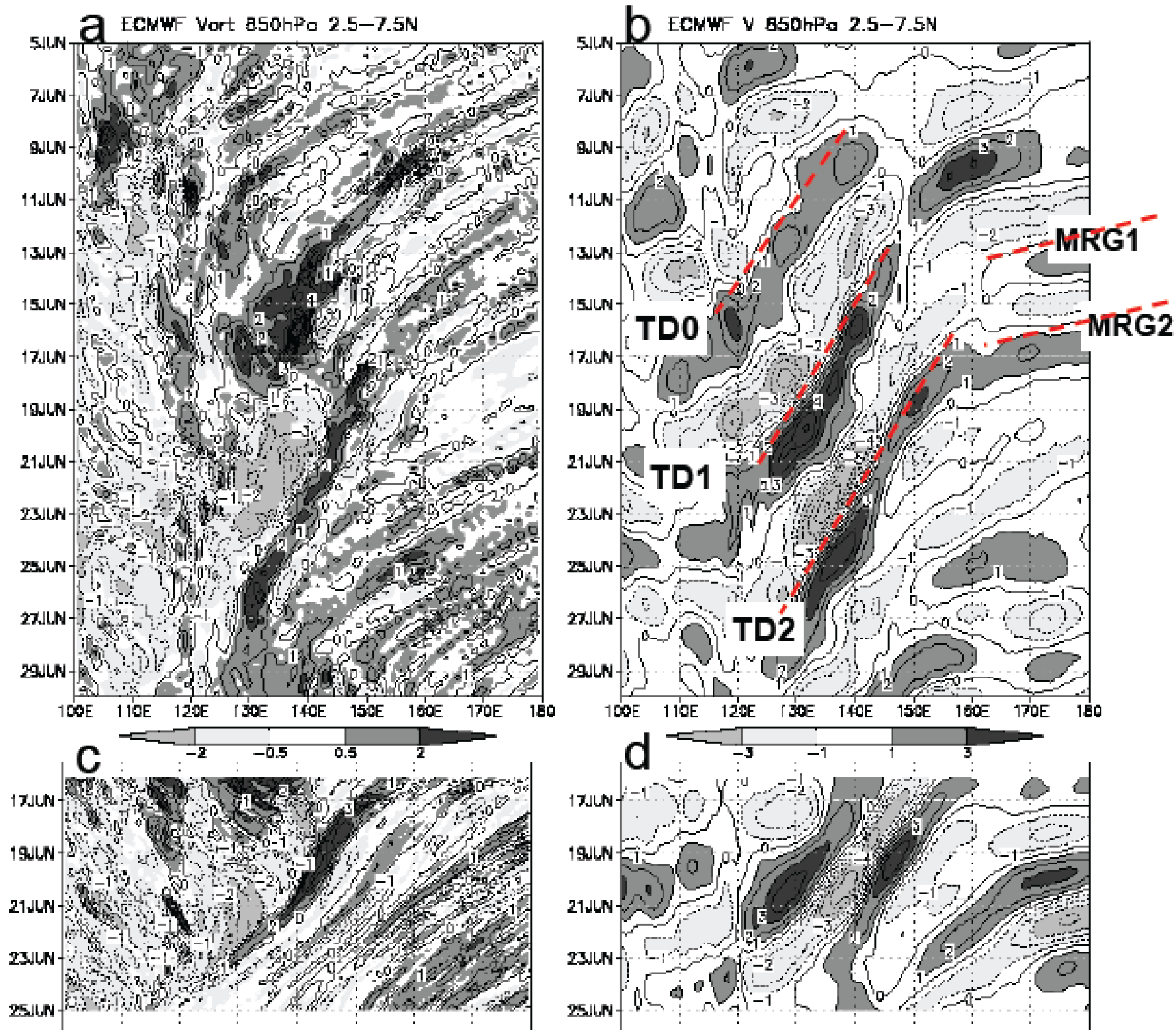


Fengshen track is better simulated by 3.5 km NICAM than 14 km runs.

Genesis process of Typhoon Fengshen: mesoscale analysis



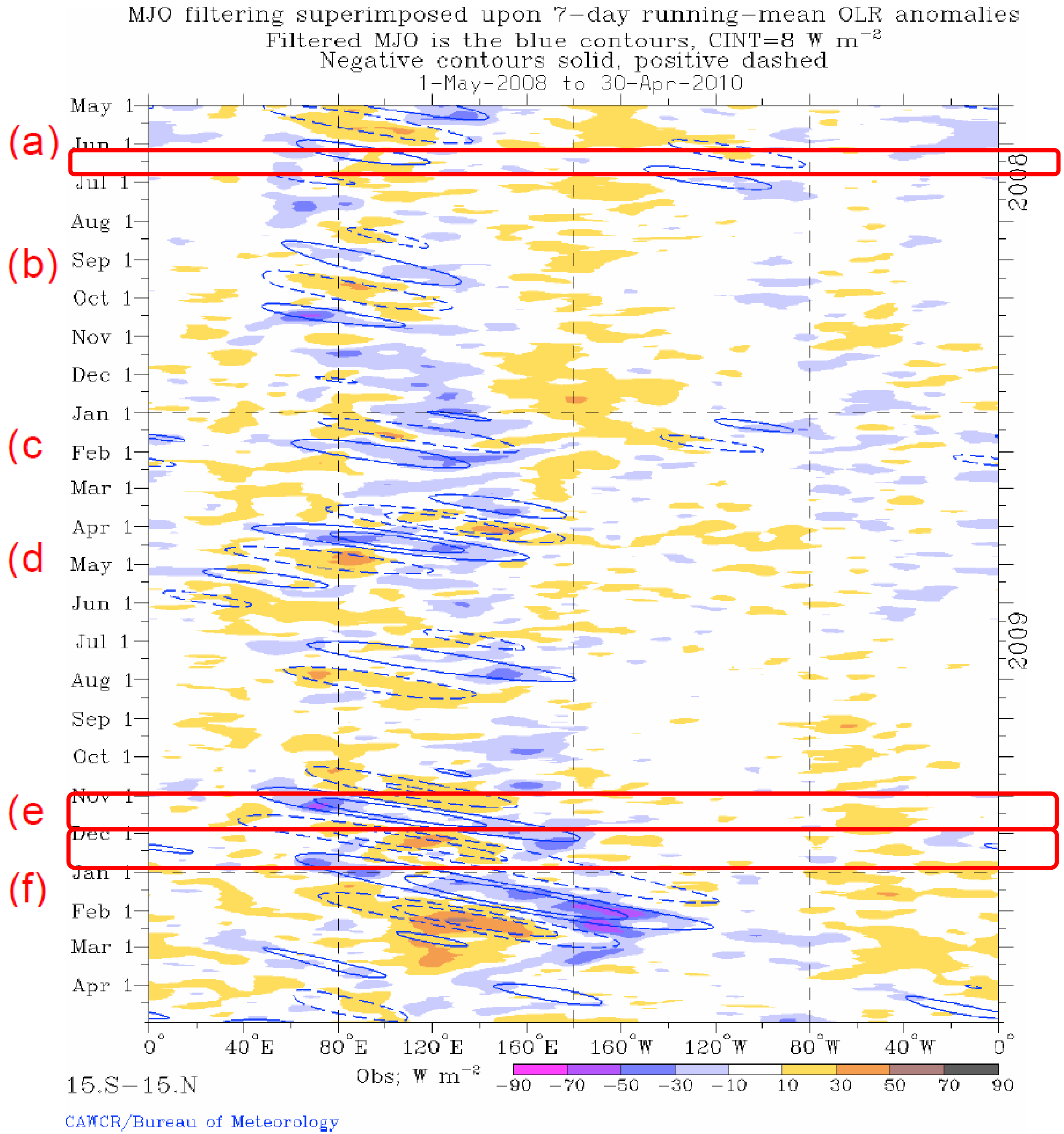




TC genesis and intensification occurs with coupling of multiple waves and vorticities under the (MJO modulated) preferable environmental condition.

Summary of the Fengshen simulation

- The sea-level pressure began to decrease when a cloud system on a slow-moving low-level vortex merged with another cloud system with faster propagating speed.
- Synoptic scale: The latter system was embedded in a westward-propagating disturbance with cyclonic circulation particularly in the middle troposphere. The vertical structure of the disturbance was initially tilted eastward with height, while it became upright before merging with the pre-Fengshen low-level vortex. This upward tilting was taken place in a large-scale off-equatorial convergence zone associated with a MJO.
- Mesoscale: The superposition of this uptilted cyclonic disturbance on the low-level vortex caused an environment with reduced vertical shear so that mesoscale convective systems maintain within the vortex. The pressure fall was led by sustained adiabatic heating due to organized convection.
- The tropical cyclogenesis was associated with westward-propagating synoptic disturbance, such as a MRG wave and/or a TD-type disturbance. This suggests an importance of reproducing convectively-coupled disturbances for better simulation of a tropical cyclogenesis in the tropical western Pacific.



MJO filtering superimposed upon 7-day running-mean OLR anomalies
Filtered MJO is the blue contours, CINT=8 W m^{-2}
Negative contours solid, positive dashed
1-May-2008 to 30-Apr-2010
(a)
(b)
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May 1
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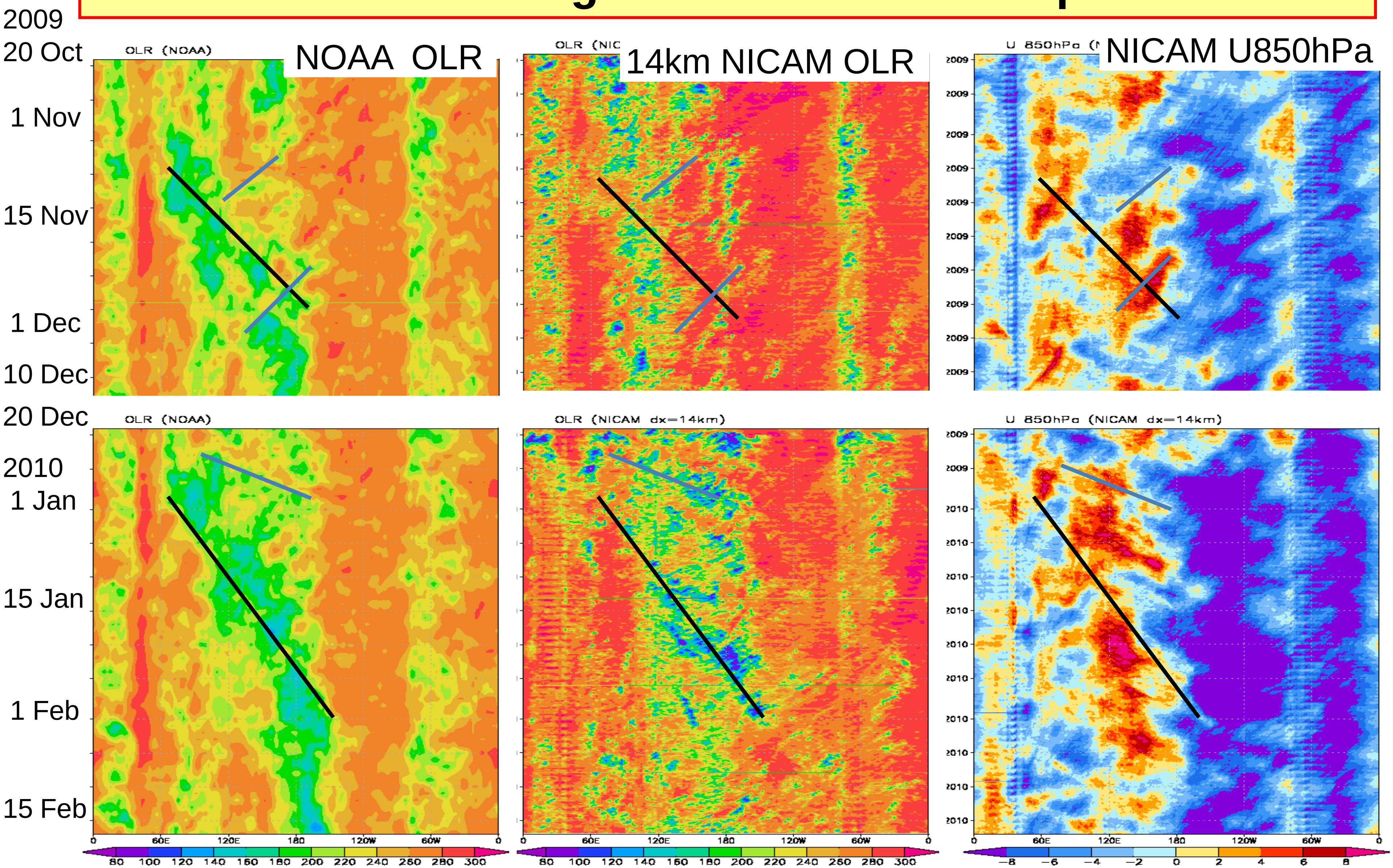
Oct 1
Nov 1
Dec 1
Jan 1
Feb 1
Mar 1
Apr 1
2008
2009
0°
40°E
80°E
120°E
160°E
160°W
120°W
80°W
40°W
15.S-15.N
Obs; W m^{-2}
-90 -70 -50 -30 -10 10 30 50 70 90
CAWCR/Bureau of Meteorology

Global cloud-resolving simulation of YOTC period #5 & 6



First one month is relatively good. OLR is sensitive to cloud microphysics in NICAM.

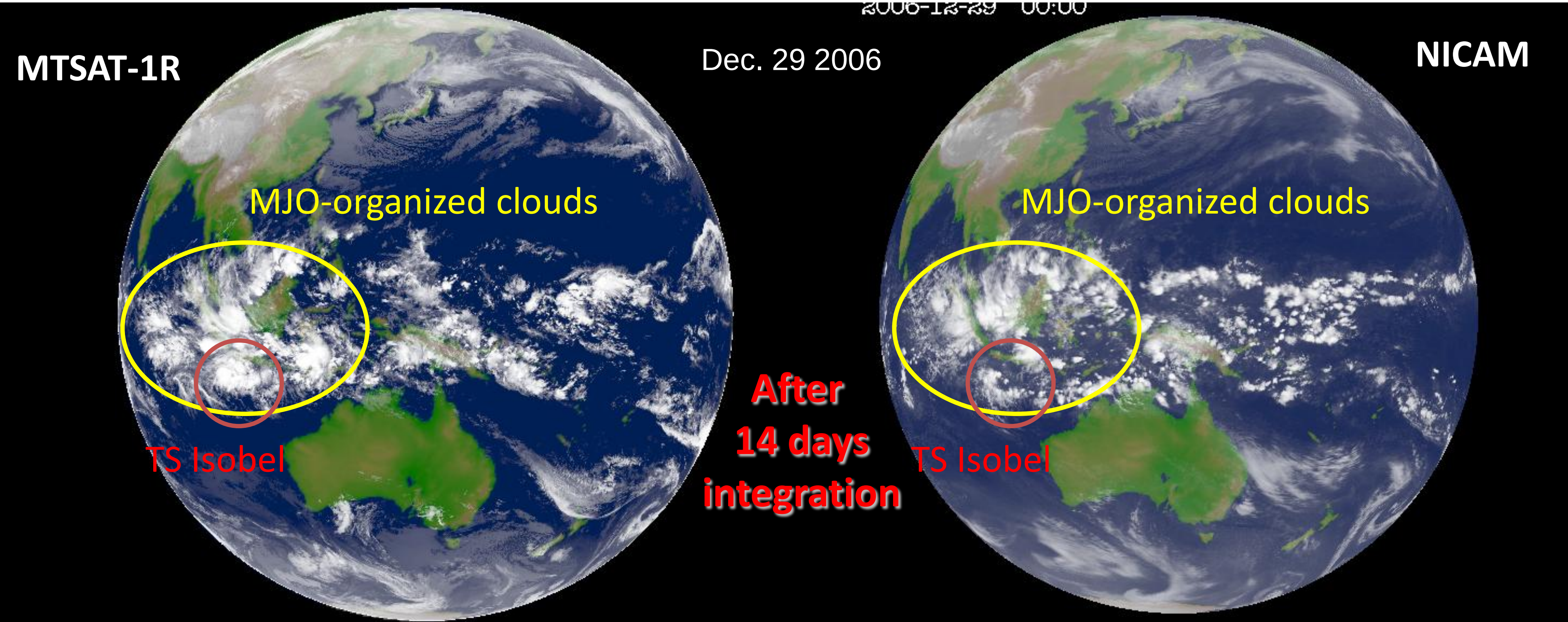
Convective momentum transport by rainbands within a Madden-Julian oscillation in a global nonhydrostatic model with explicit deep convective processes
Part I: Methodology and general results

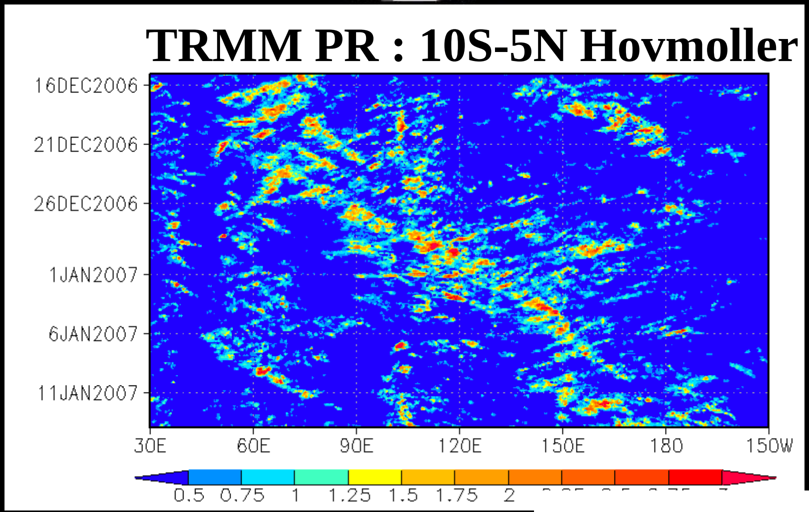
Tomoki Miyakawa, Yukari N. Takayabu, Tomoe Nasuno
Hiroaki Miura, Masaki Satoh, Mitchell W. Moncrieff

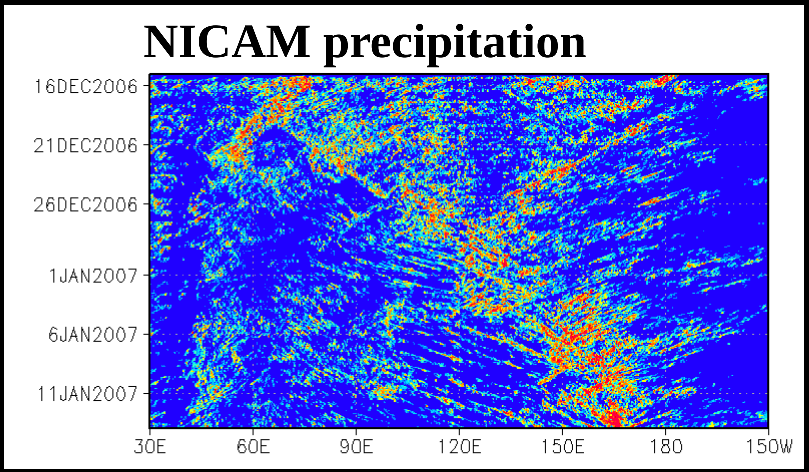
(2011, submitted to J.Atmos.Sci.)

See also poster presentations

2006 boreal Winter MJO simulation





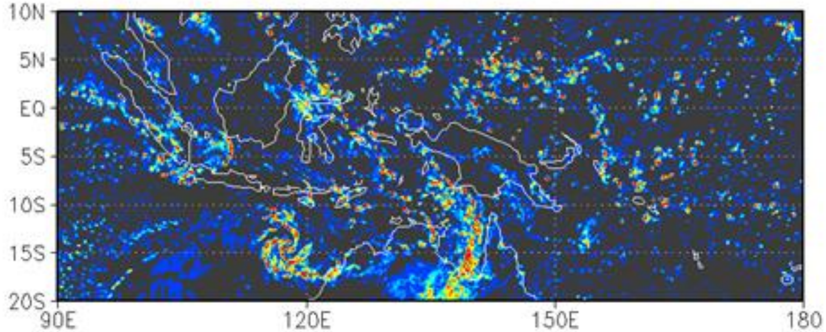


NICAM dx=7km , 15 Dec 2006-15 Jan 2007, Miura et al.(2007)

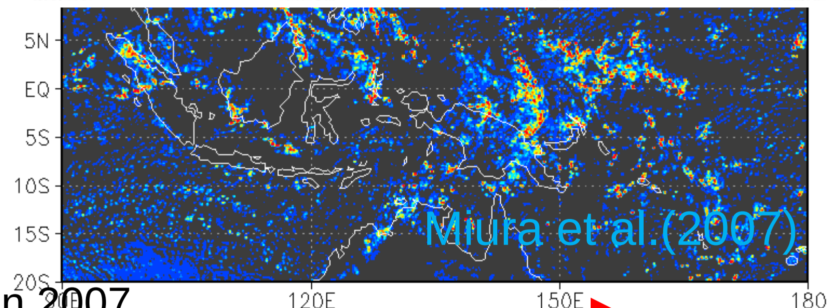
Rainband structures

NICAM

2Jan 2007

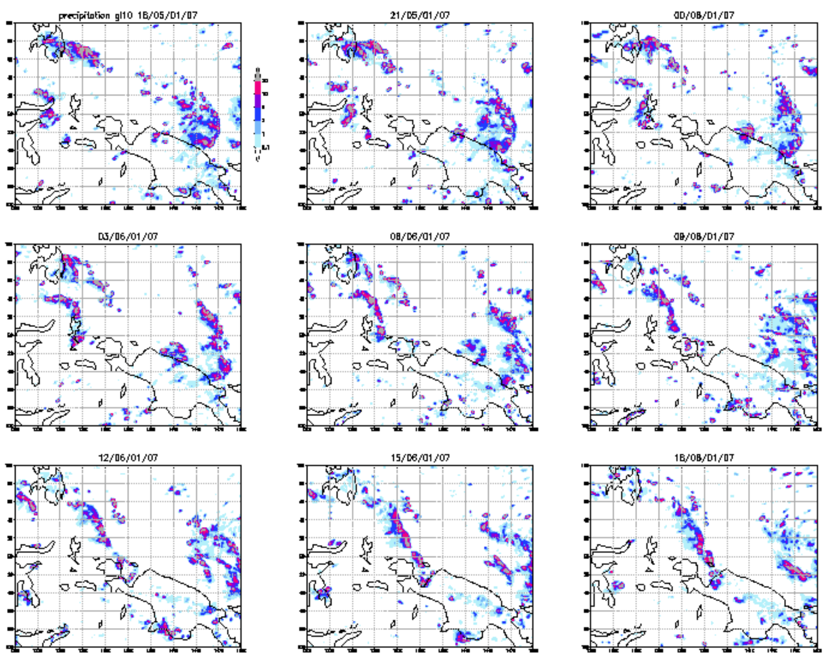


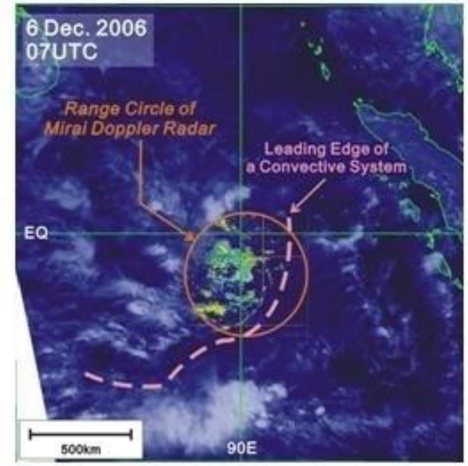
6 Jan 2007

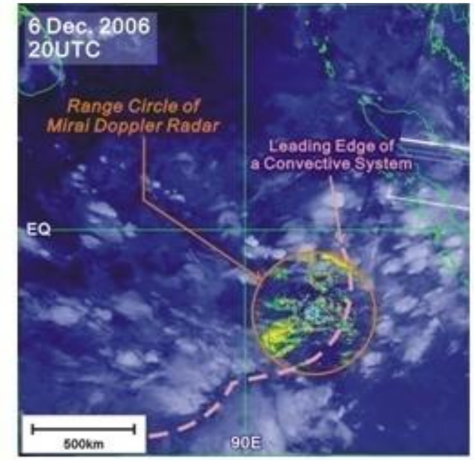


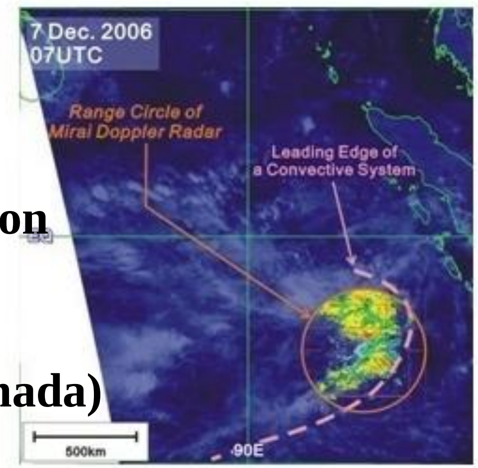
Miura et al.(2007)

18Z 5 Jan 2007





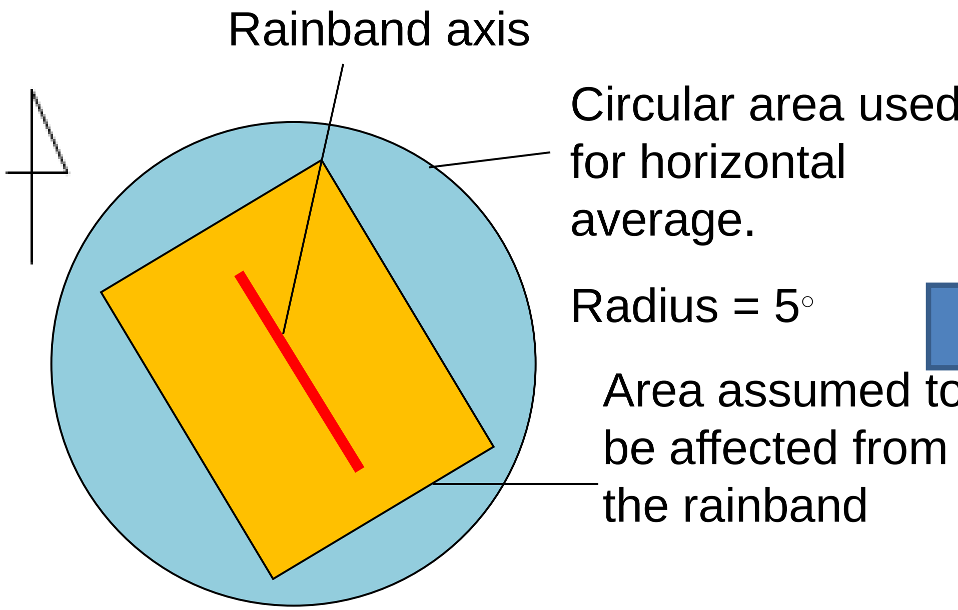


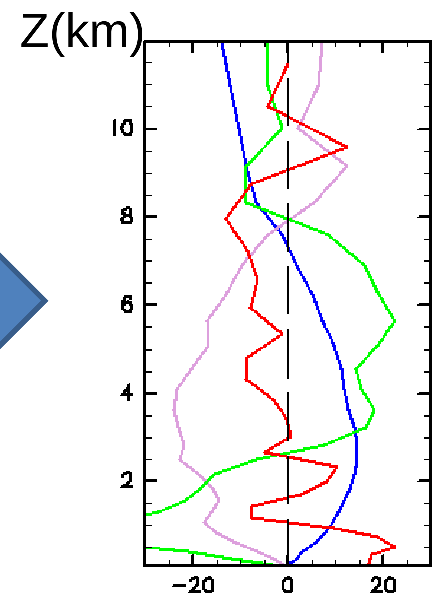


MIRAI observation
Nov 2006
Indian Ocean
(Courtesy of H.Yamada)

Threshold used for rainband detection

(Size of continuous area where precipitation≧0.3mm/h) ≧ 500km^2





Examples of various vertical profiles calculated for a rainband

blue : $\overline{u}$

purple : $(\overline{u'w'})$

red : $-\frac{1}{\overline{\rho}}\frac{\partial \overline{\rho}\,\overline{u'w'}}{\partial z}$

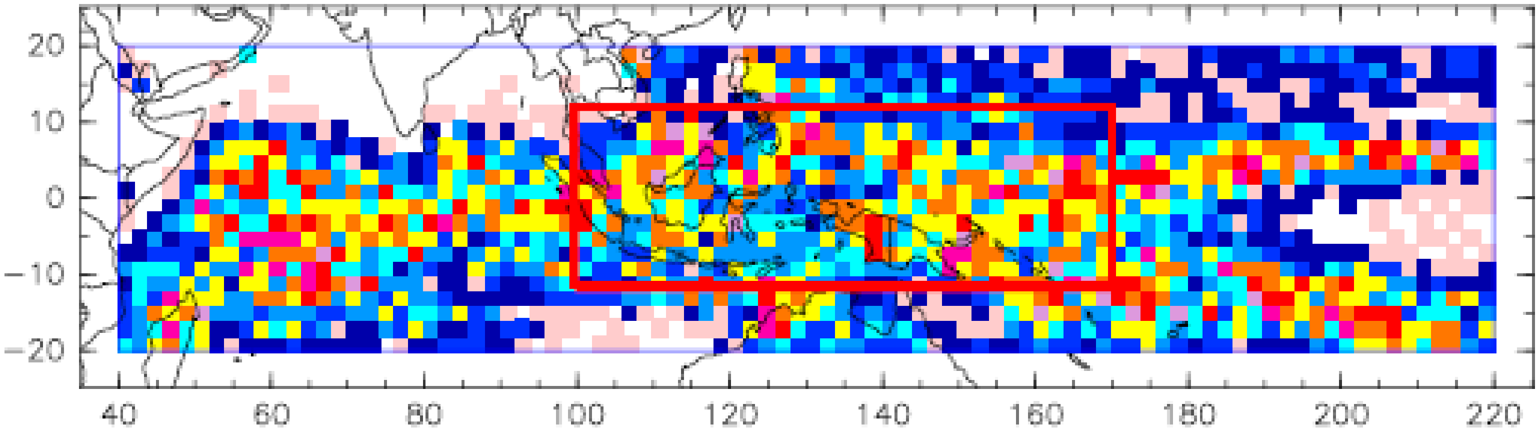
green : $-\overline{u'w'}\frac{\partial \overline{u}}{\partial z}$

Contribution from the orange rectangular area to this term (upscale acceleration on $\overline{u}$) is considered as the CMT effect of this rainband.

PDF of detected rain bands TMI v s NICAM

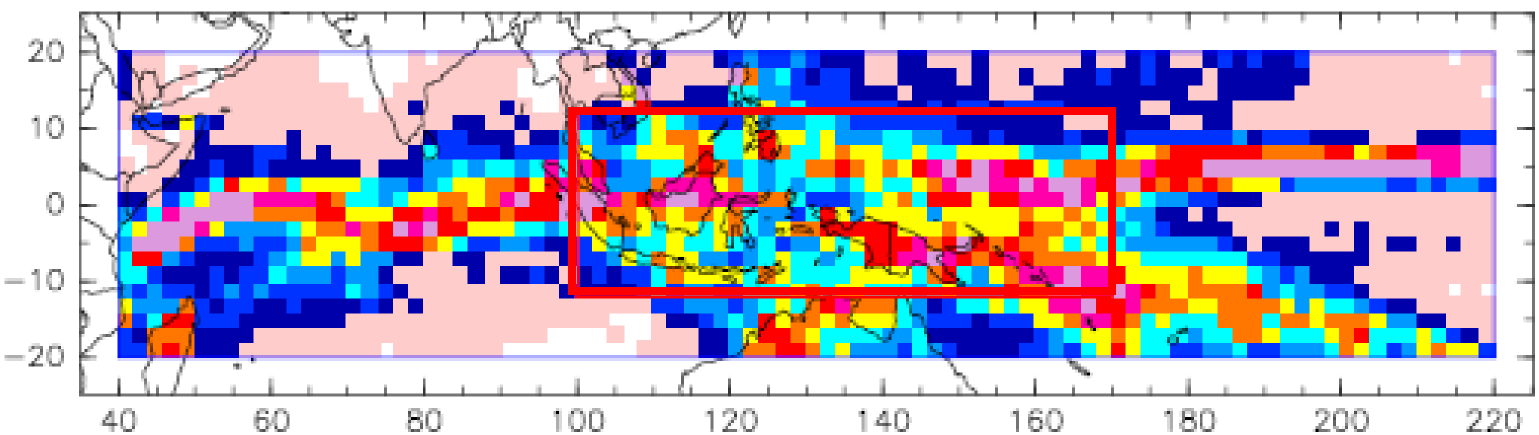
TRMM TMI

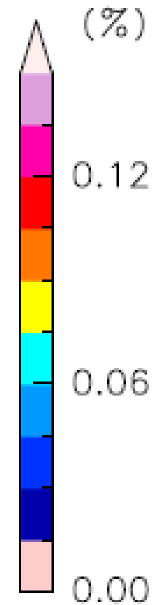
~14,000cases



NICAM

~160,000cases

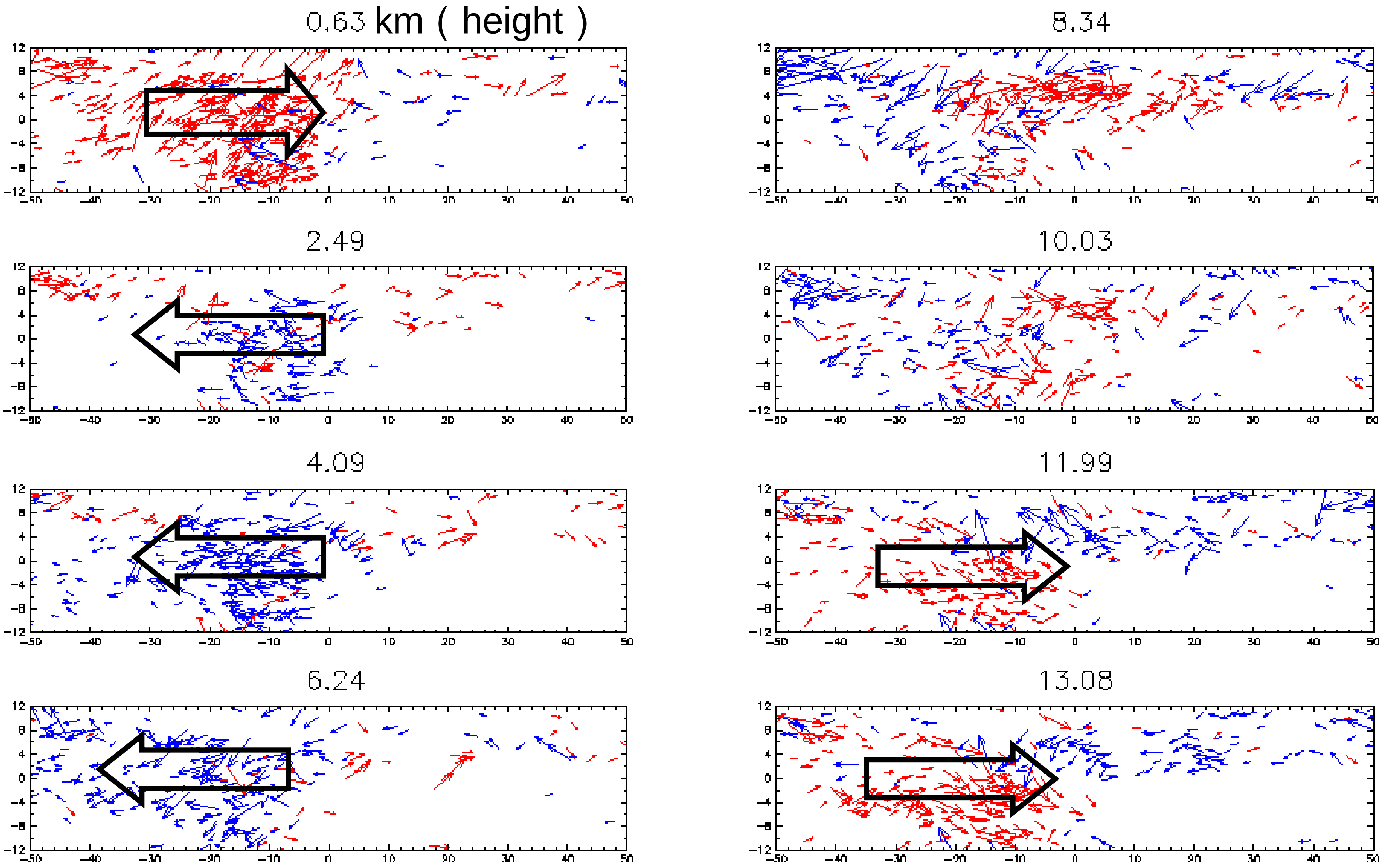




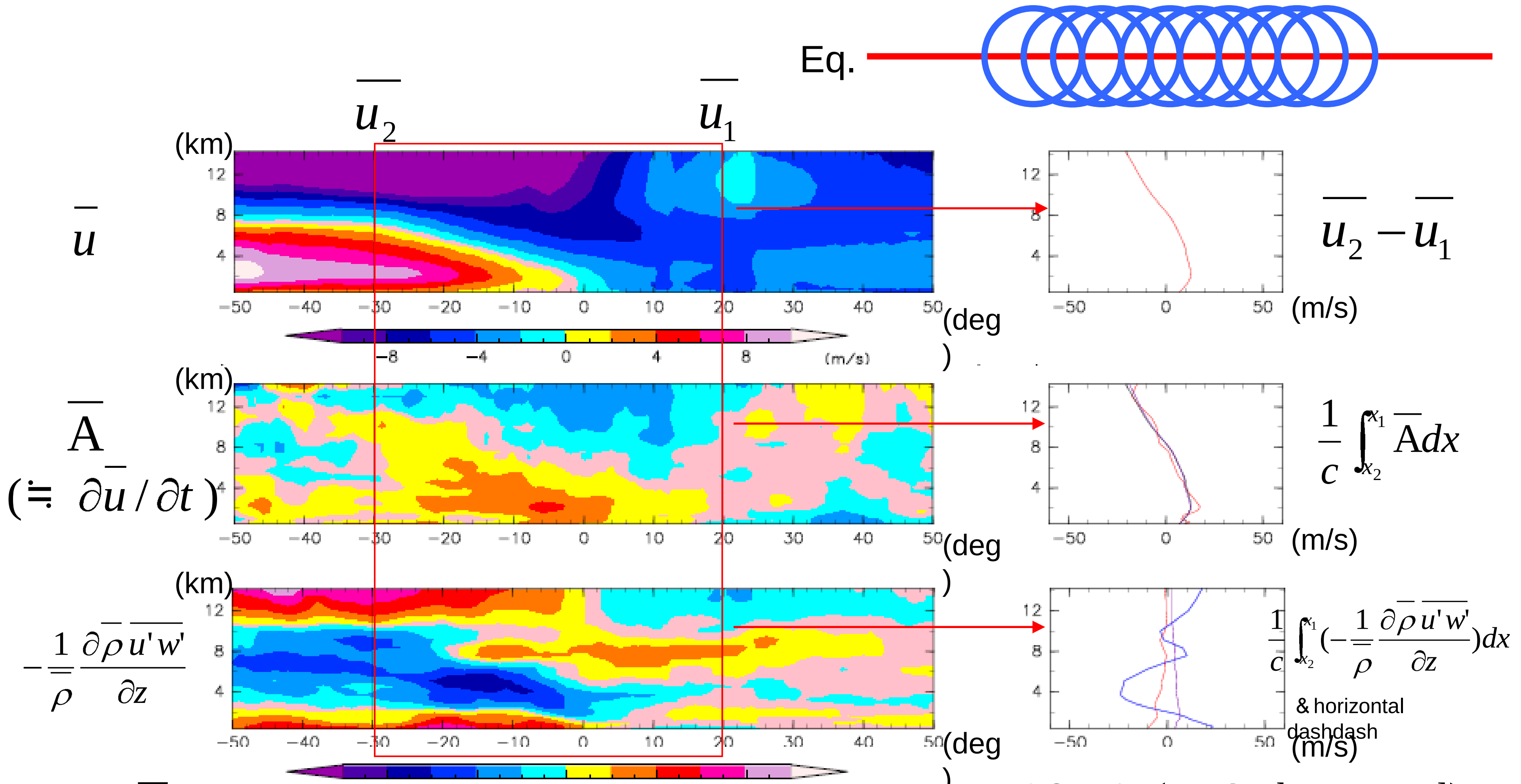
a. MJO relative horizontal maps of CMT vectors

Vectors : acceleration due to CMT on $\bar{u}$, $\bar{v}$

red / blue : positive / negative zonal component



b. Quantitative evaluation of the impact of CMT on $\overline{u}$

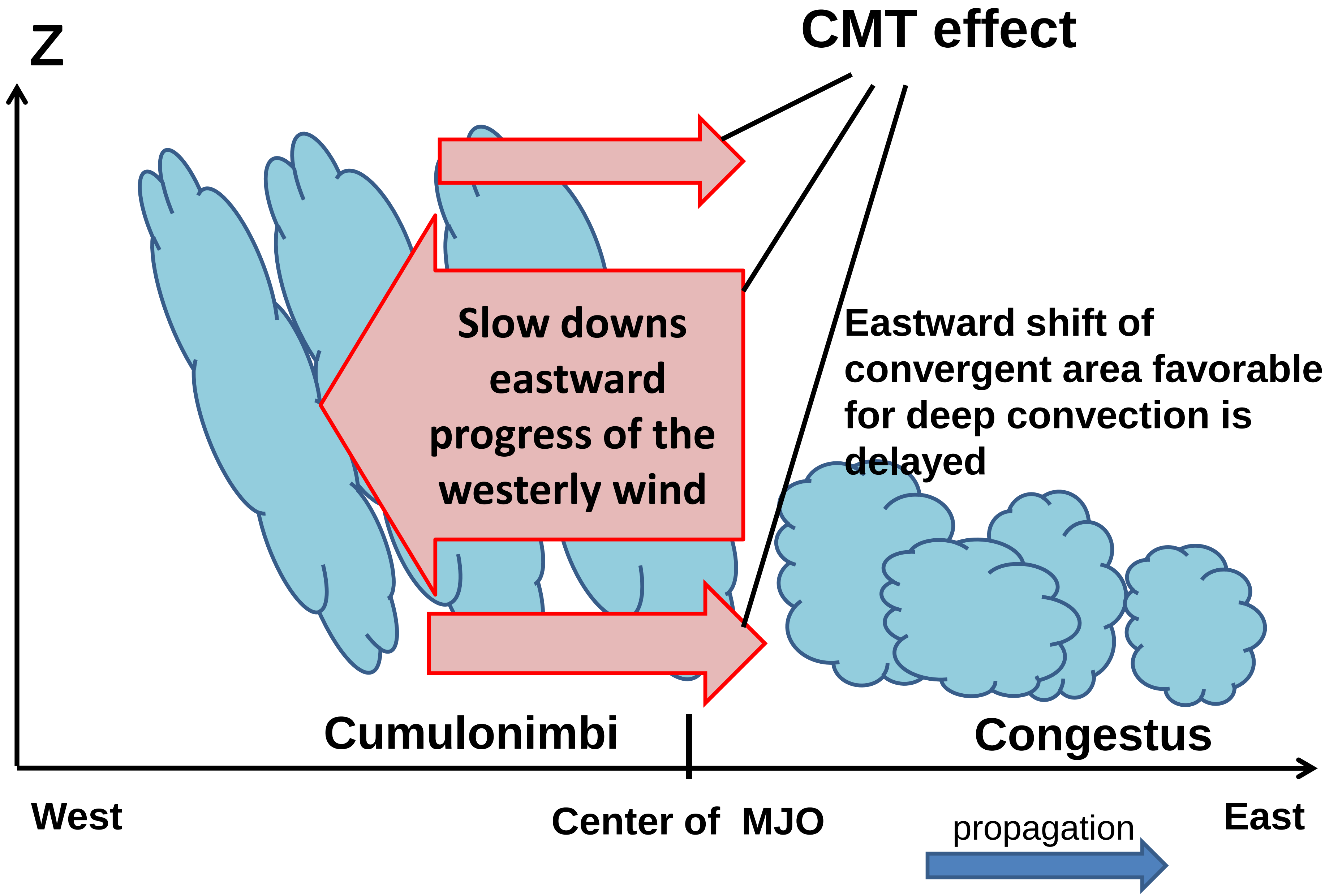


$c = 4.8\, m/s$ (MJO phase speed)

$\overline{\mathrm{A}}$

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

The role of CMT



Summary

Global cloud-resolving modeling approach

- 3.5km NICAM data can be used as a pseudo nature of meso-scale cloud systems
- First-ever analysis of convective momentum transports of an MJO event

•Clouds properties

- Evaluation using satellite simulators
- Clarify biases in different regions and different types of clouds over the global domain
- Next step: tuning, improving, and developing microphysics schemes

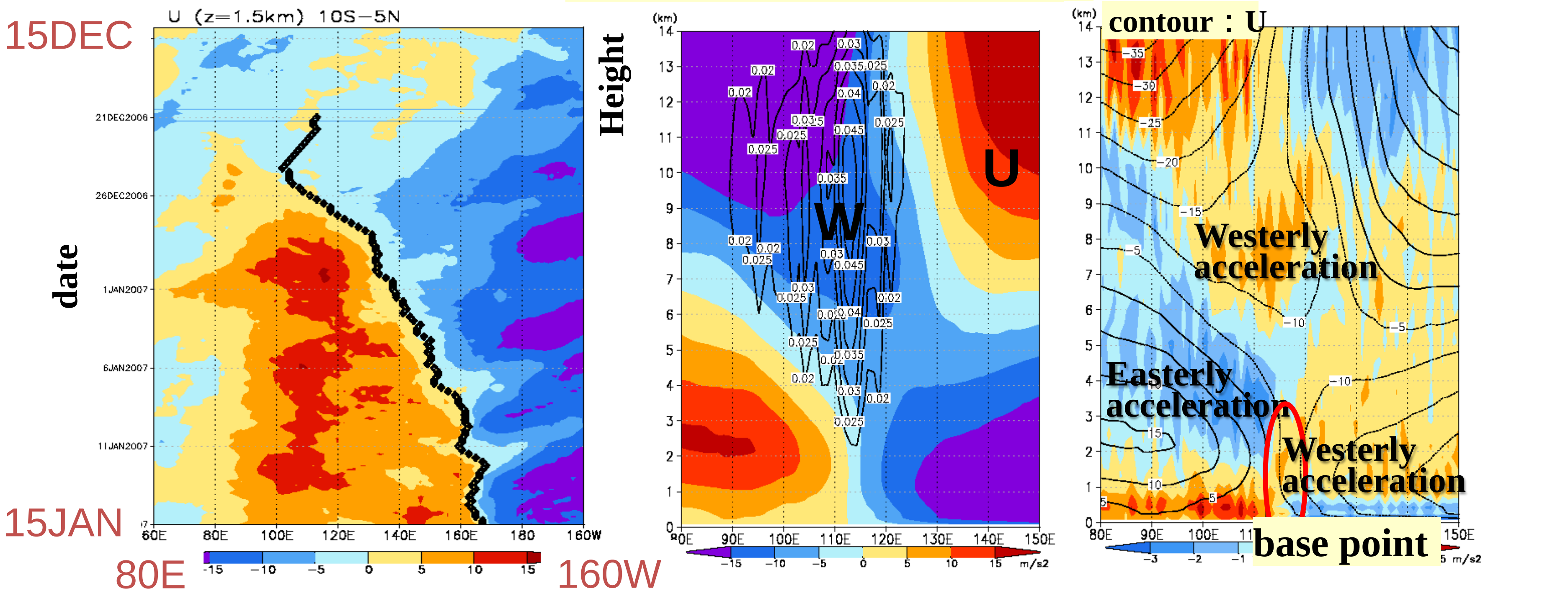
•ISV/MJO, Equatorial waves & Tropical cyclones

- Cyclogenesis of Fengshen, comparison with the field observation
- Roles of multiple waves and vorticities
- Remote effects of ISV/MJO and waves on TC-genesis

Convective momentum transport (CMT) in MJO

Nasuno et al. (2009)
→ Miyakawa (poster)

composite(10S-5N)



Roles of CMT in the MJO events during TOGA COARE IOP (Tung and Yanai 2002)

1. **As westerly initiated in the lower troposphere, CMT is typically upgradient and may maintain middle level easterly shear.**
2. **At the later stage with strong low to middle level westerlies, CMT is mostly downgradient and reduces the middle level zonal wind shear.**