Recent Progresses of the NICAM research

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and
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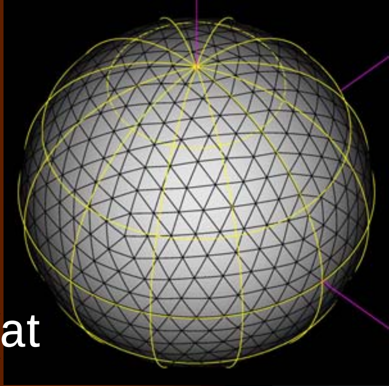
In Principio


Icosahedral grid

- Recent NICAM researches
  - Short-term integration (~ few tens days) using 3.5km mesh (at most)
    - Predictability and improvement of individual events as a reference
      - (e.g., hindcast of typhoon courses, MJOs, …)
  - Long-term integration (~ several months) using 7km and 14km meshes
    - Monsoon circulation, statistical behavior of TCs, …)

- Ongoing works
  - Statistical studies
    - Sensitivity of Physics-Updated exp.
      - (14-km & 7-km meshes)
    - Global warming exp.
      - Warmed SST scenario and CO2*2 of AR4 (14-km mesh)
  - Eventual studies
    - Filliping cyclone Fengshen on June 2008
      - Stretched-grid (max 7km-mesh) and homogeneous-grid 3.5km-mesh NICAMs
    - Ensemble experiment for Myanmar cyclone Nargis on May 2008
  - etc…

Talk

- Target
  - Diurnal variations of precipi. and clouds
    - Current performance
    - Resolution dependencies in 7-km mesh and 14-km mesh models
- Motivation
  - 14-km mesh model is a useful tool to examine basic performance
    - A little sensitivity of gross behavior of clouds, and tropical disturbances such as MJO propagation, precipi. and TCs (Miura et al. 2005; 2007)
    - can be done with much lower cpu time and storage sizes
      - 34 nodexhours for one-day integration on ES2
  - Then, what are practical advantages of using higher resolution?
    - Do we have notable differences in shorter-time scale disturbances?
      - e.g., diurnal variations
    - Why do the differences occur?

Experimental Design

Initialization	NCEP Global analysis on 00Z Jun 1, 2004
Atmos. Nudging	Not used (optionally available)
Bottom boundary	Bucket model and NOAA Weekly Reynolds SST
Horizontal resolution	14km & 7km (2 experiments)
Vertical resolution	80m～2.9km (Stretched)
Cloud	Cloud microphysics (Grabowski et al. 1998) (Predicting cloud condensates and then diagnosing them into liquid and ice phases)
Cumulus Convection parameterization	Not used (Now implementing a parameterization of meso-scale convection systems for 14-km mesh)
Turbulence	Improved version of Mellor-Yamada Level 2 with subgrid-scale condensation (Nakanishi & Niino 2006; Noda et al. (Atmos. Sci. in press)) ※ partial cloudiness not considered
Surface turbulent flux	Bulk parameterization by Louis (1979)
Radiation	MSTRNX
Integration period	June 1st～August 31st (for 7-km mesh) June 1st～November 7th (for 14-km mesh) (but focused only in JJA)
Aerosol process	Not used (optionally available)

Surface Precipi. ~Global distribution~

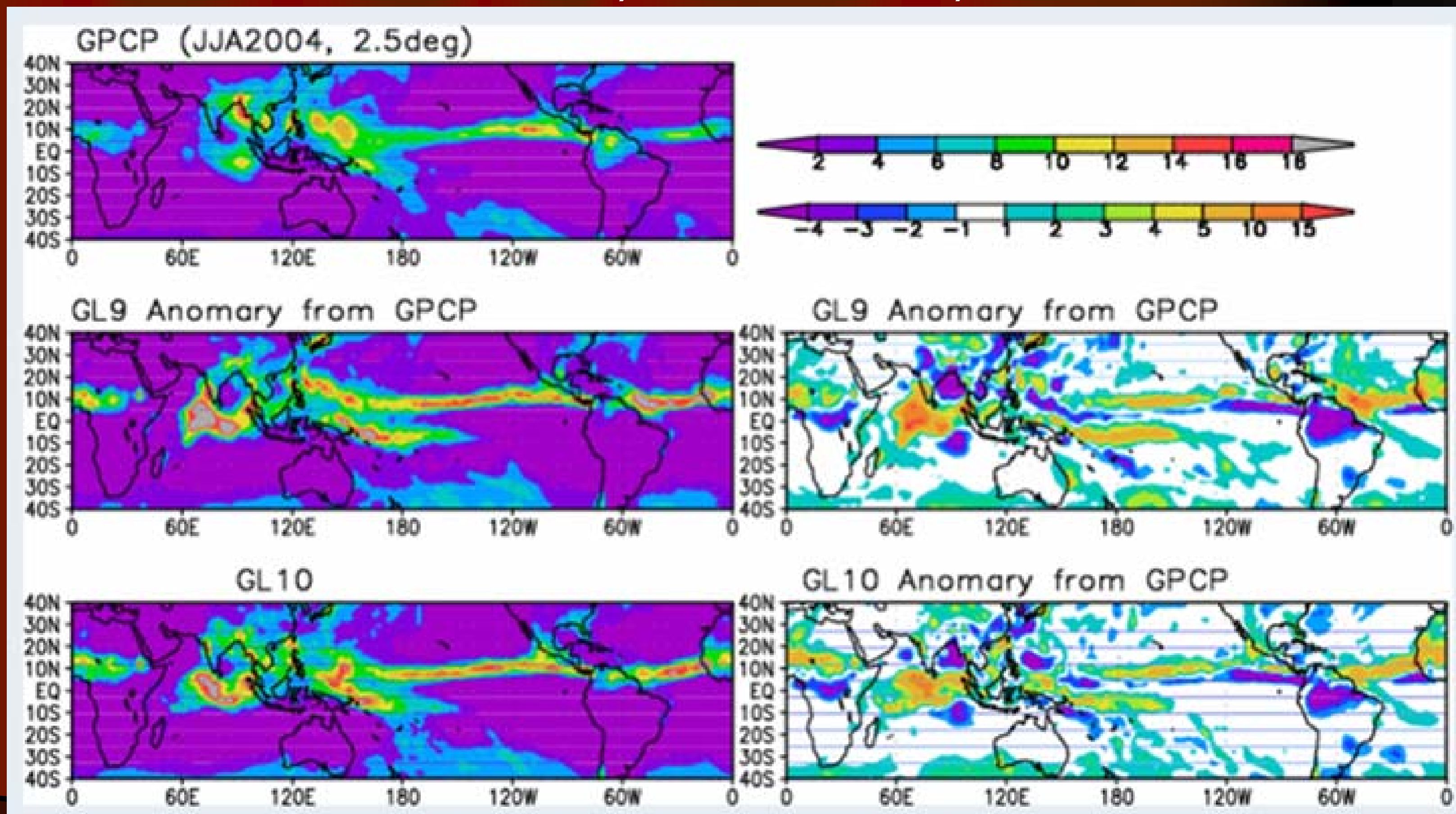
JJA204
compared in 2.5deg

Spatial distributions reasonably simulated
Though,
overestimated over Indian ocean, ITCZ, African continent
underestimated over India, Eastsouth Asia, Latin America

GPCP

14km

7km



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Diurnal Variations of Precipi.

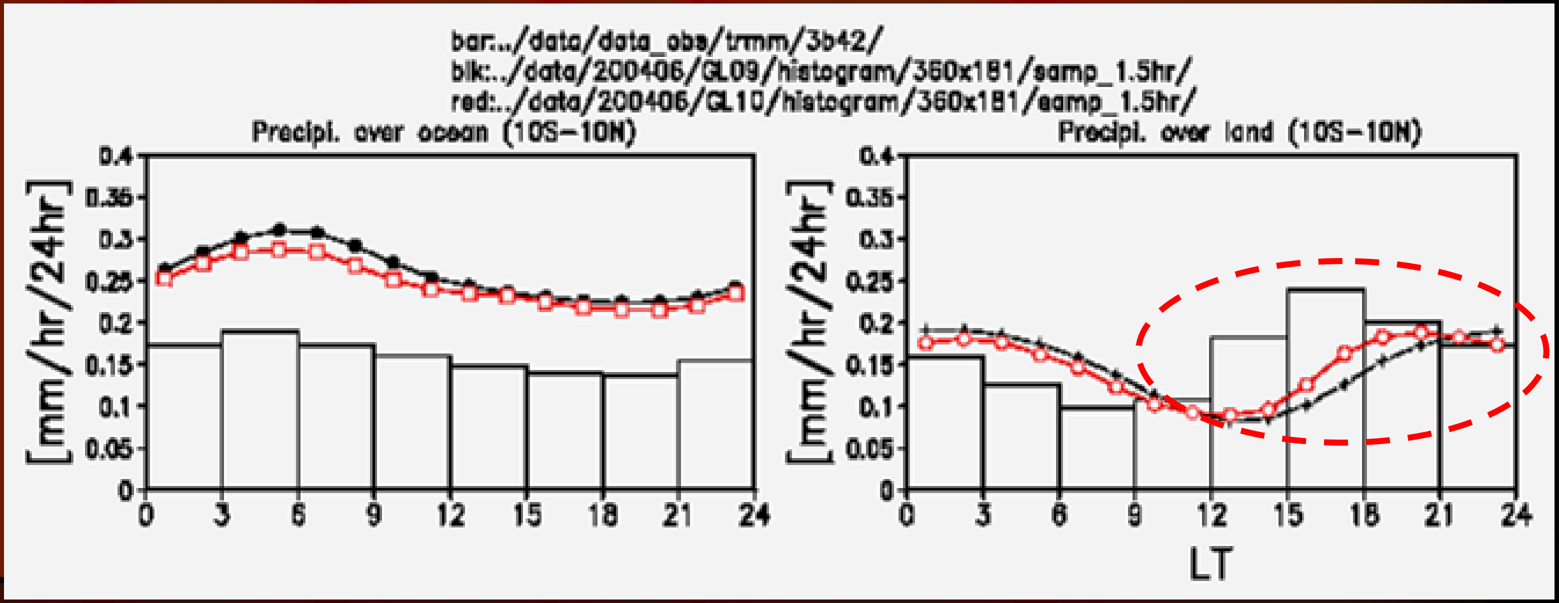
Bars：TRMM 3B42 (3hourly)
Black: 14-km mesh (1.5hourly)
Red : 7-km mesh (1.5hourly)

over ocean
diurnal variations reasonable in both 7km and 14km

over land
7km more accurate than 14km
improves the precipi. delay at around 3hours

10N-10S

over Ocean **over Land**



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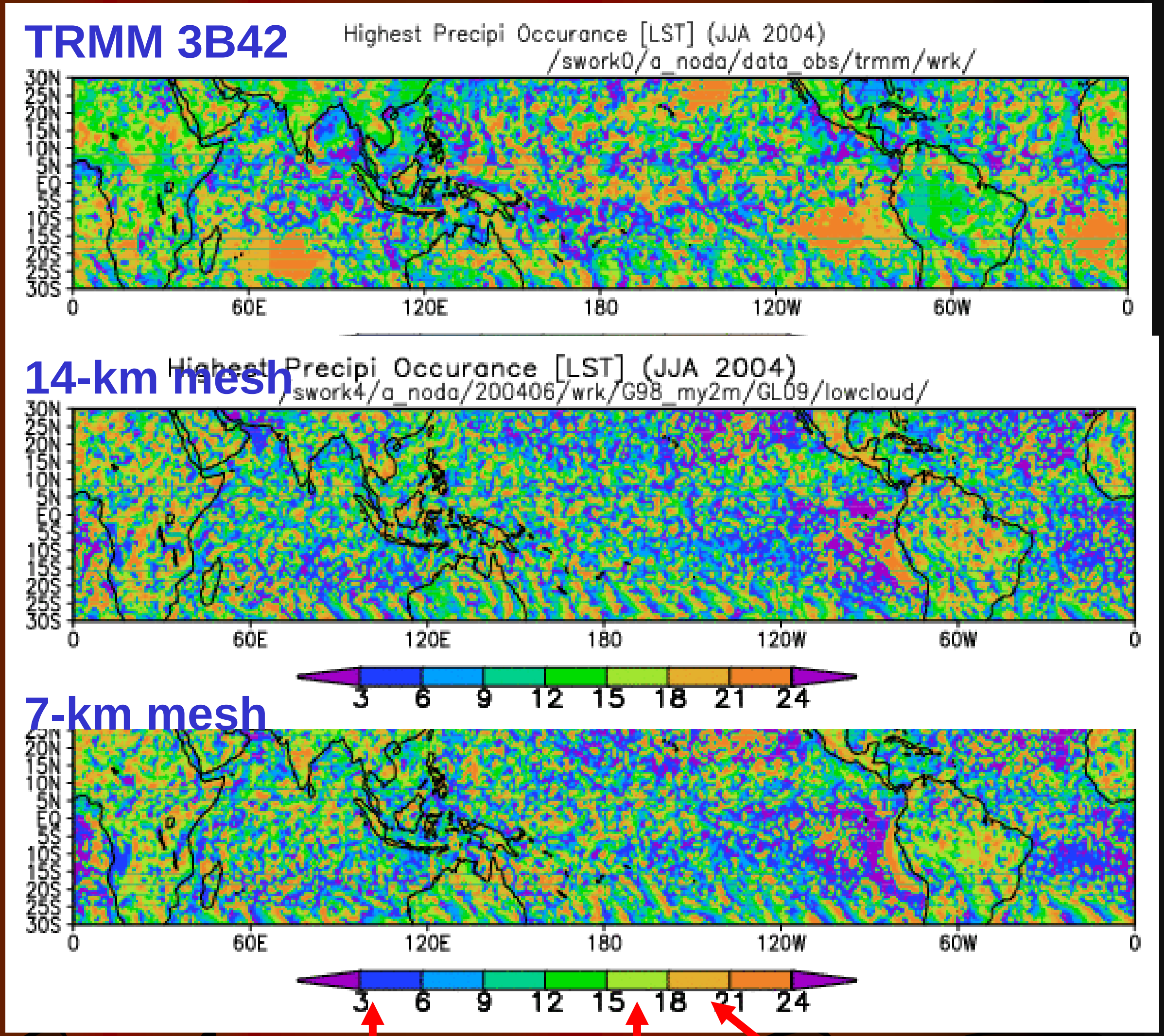
Diurnal cycle
～Max Precipi. Occurrence in Local Time～

Delay over land appears to be a general issue in continental regions rather than in local regions (e.g., maritime continent, costal regions)



Max precipi.: Ocean Land（TRMM) （NICAM)

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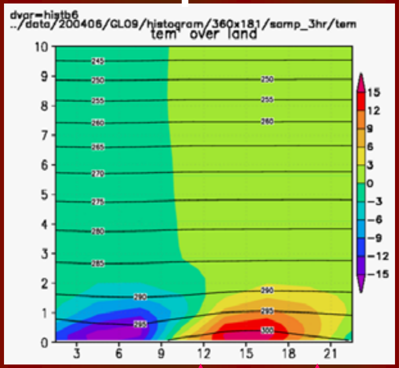
Robust mechanisms controlling diurnal precipi. variations in both resolutions

Lines: diurnal variations at each altitude
Colors: anomaly from altitude-mean

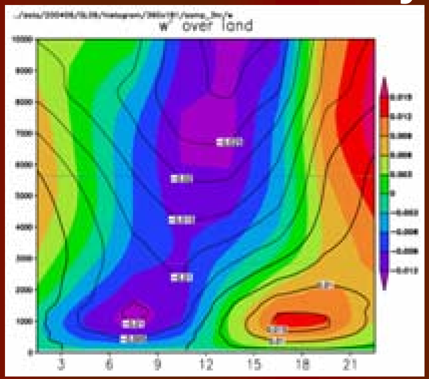
over land 0-10kmASL

over land
Mostly controlled by the processes in the lower-level

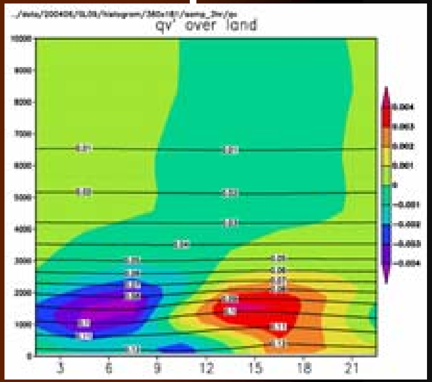
Temperature



Vertical velocity



Vapor

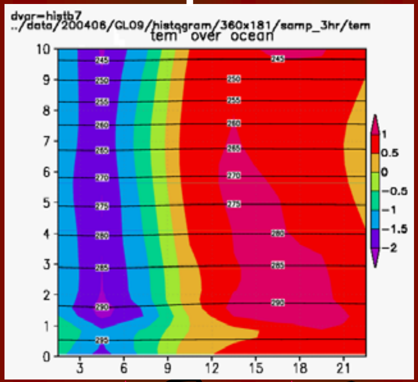


Min **Max precipi. time**

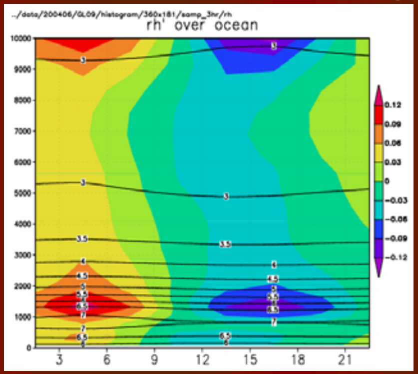
over ocean

over ocean
Mostly controlled by temperature changes (radiative heating/cooling)

Temperature



Relative Humidity



Max **Min precipi. time**

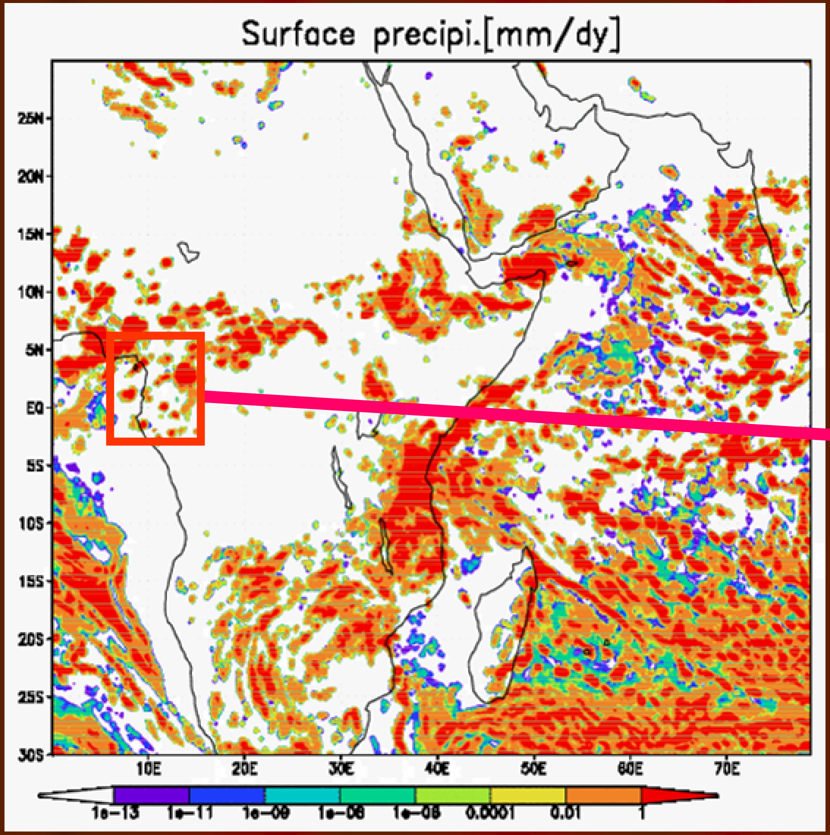
Diurnal variations
of
precipi. cells and updrafts

Definition

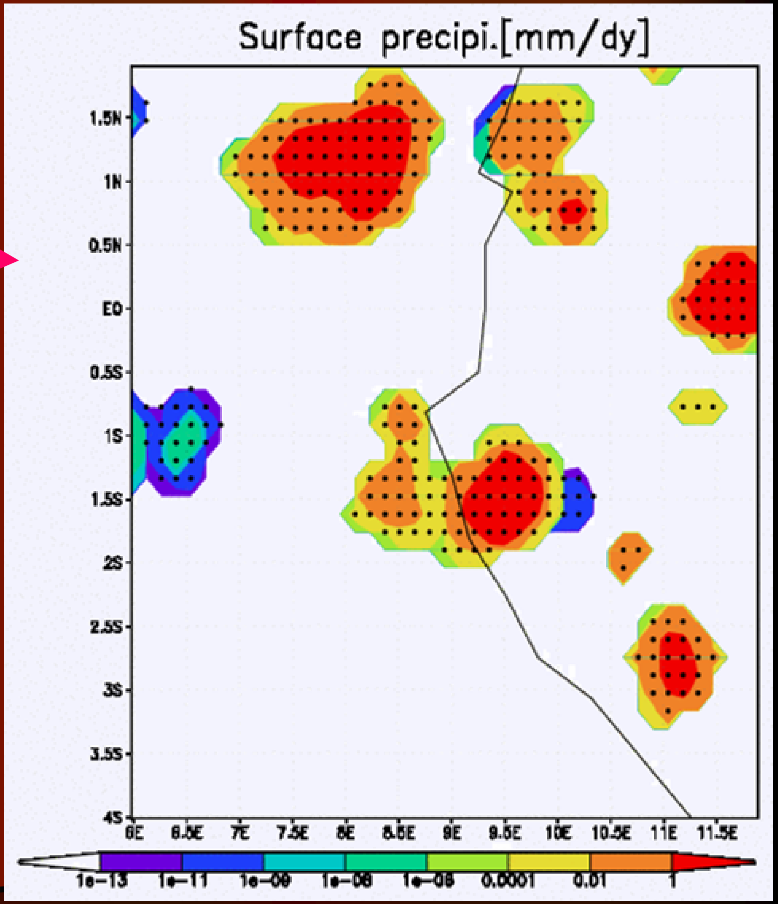
- Cell size
  - count grid numbers that have more than 2 spatially-continuous grids
    - not count one-grid precipitation to omit numerical noises
  - convert to equivalent radius of circle（e.g., 2 grids of 14-km mesh: $S=(14\text{km})^2)*2=392\text{km}^2 \rightarrow r=11\text{km}$
    - note that min cell size is conveniently less than the actual grid size (e.g., r<14km)

- Size of precipi. cell
  - spatially-continuous grids where surface precipi. >0.5mm/hr
- Size of precipitating updraft
  - spatially-continuous grids accompanying both rain water and updraft
    - not consider non-precipitating convections to avoid counting updraft motions by dry gravity waves
- Cloud mass flux
  - M=(air density)*A*<w>
    - A: area of precipitating updraft, <w>：mean updraft in the area

Example of Cell Detection Algorithm



The detection algorithm identified 10 precipi. cells (hatched), e.g., in the box



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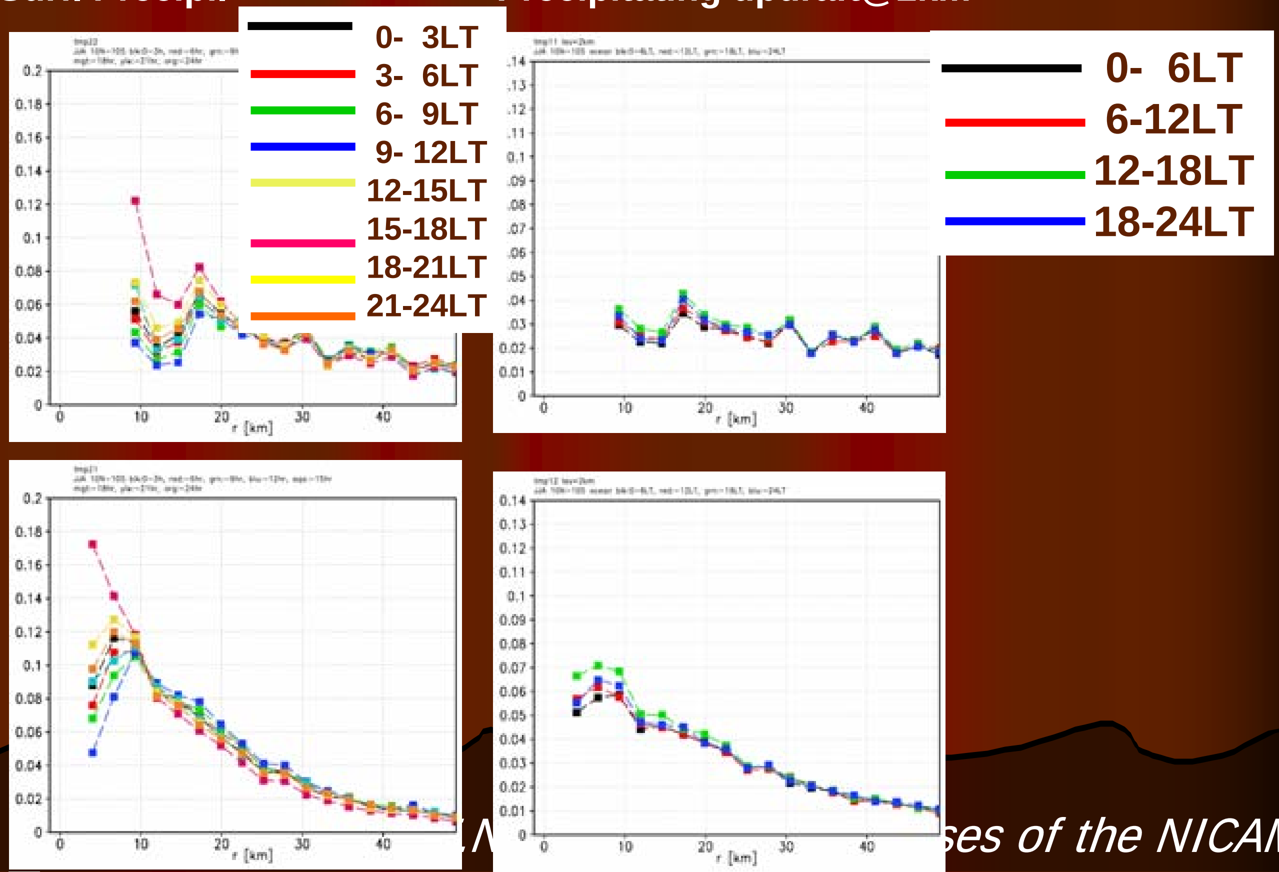
Diurnal Cycles of PDFs ~over land~

More active diurnal cycles of precipi. in 7km especially for small-scale cells
Smaller cells in 7km remarkably develop after noon, contributing to mass vertical transport and improving the precipi. delay

Cell size of : Surf. Precipi. **Precipitating updraft@2km**

14-km mesh

7-km mesh



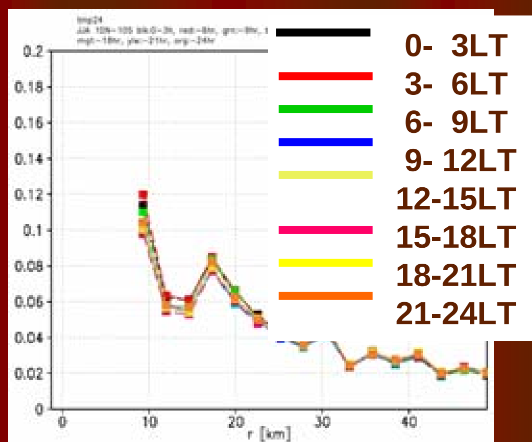
ses of the NICAM research

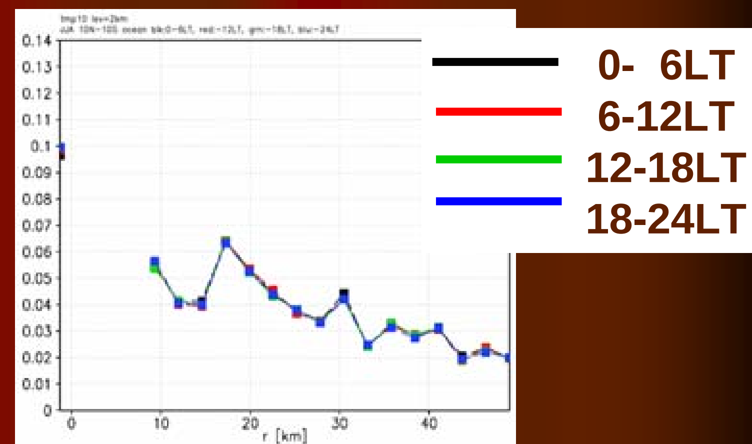
Diurnal Cycles of PDFs ~over ocean~

Much less diurnal variations than over land
More continuous cell distributions in 7-km mesh

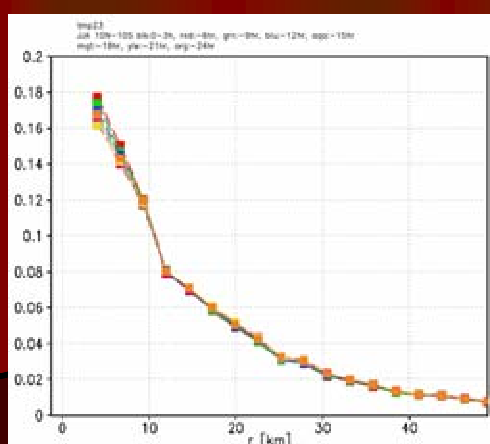
Cell size of : Surf. Precipi. **Precipitating updraft@2km**

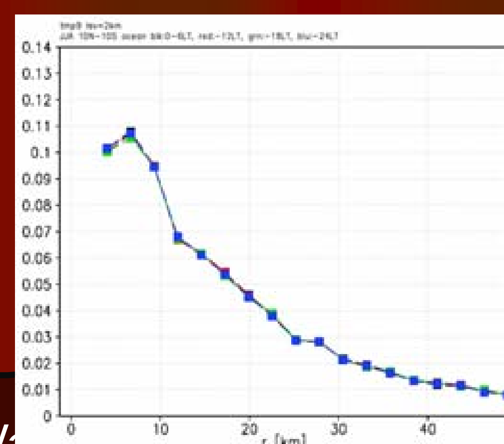
14-km mesh





7-km mesh



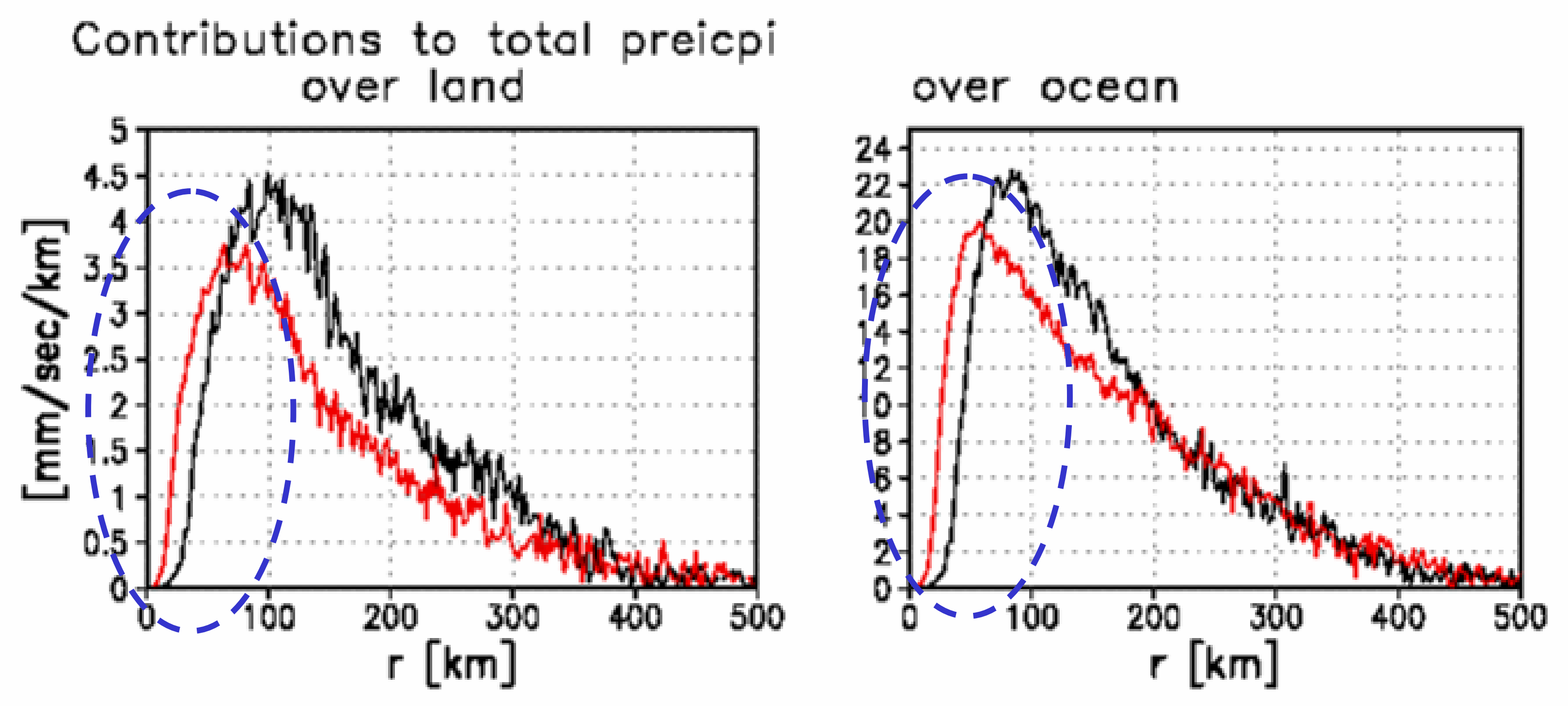


Size dependencies contributing to the total precipi.

10N~10S

Black: 14-km mesh
Red: 7-km mesh

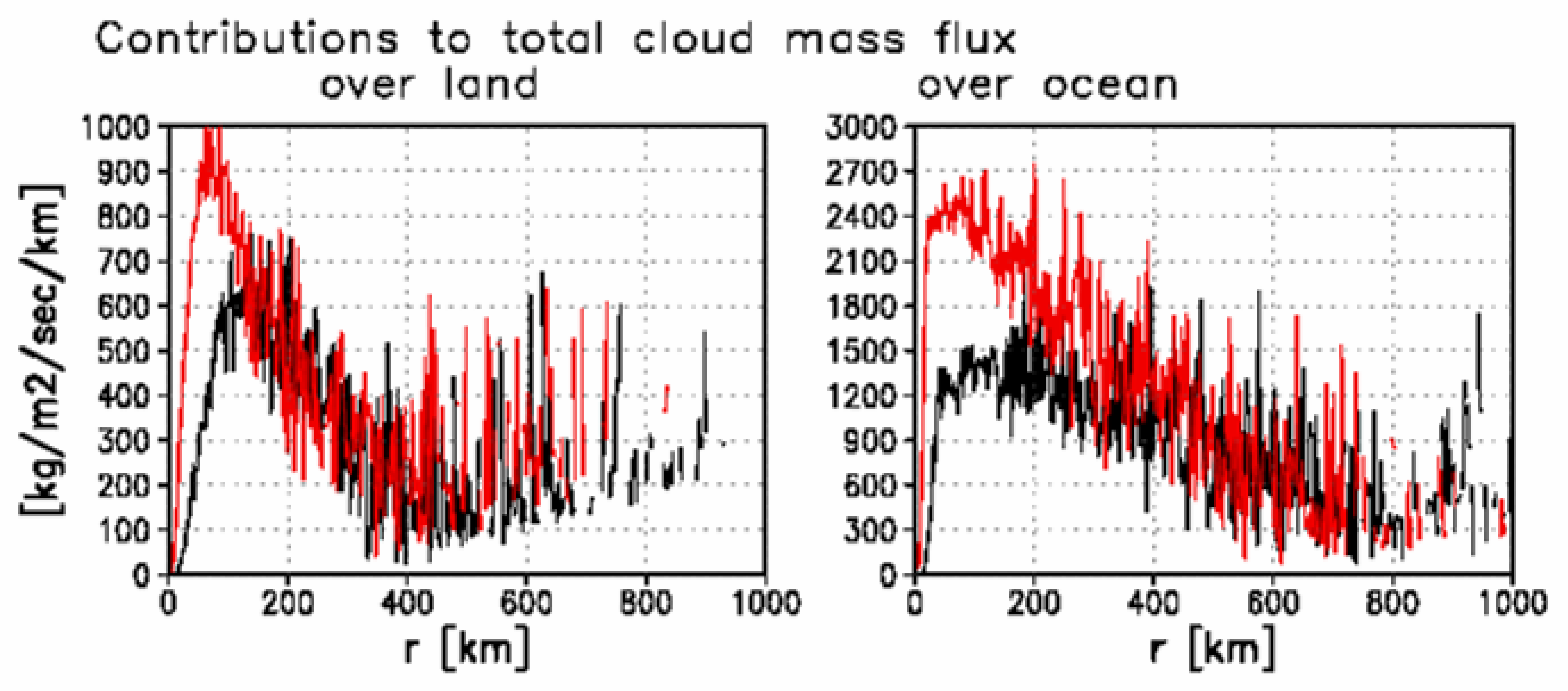
For 7km, small-scale precipi. cells contribute much more to the total precipi. in both land and ocean



Size dependencies contributing to the total cloud mass flux (z=2km)

10N~10S

Black: 14-km mesh
Red: 7-km mesh



Diurnal and Semi-diurnal variations

* Not discuss higher frequency components (wave number>2) as their physical interpretations are not obvious

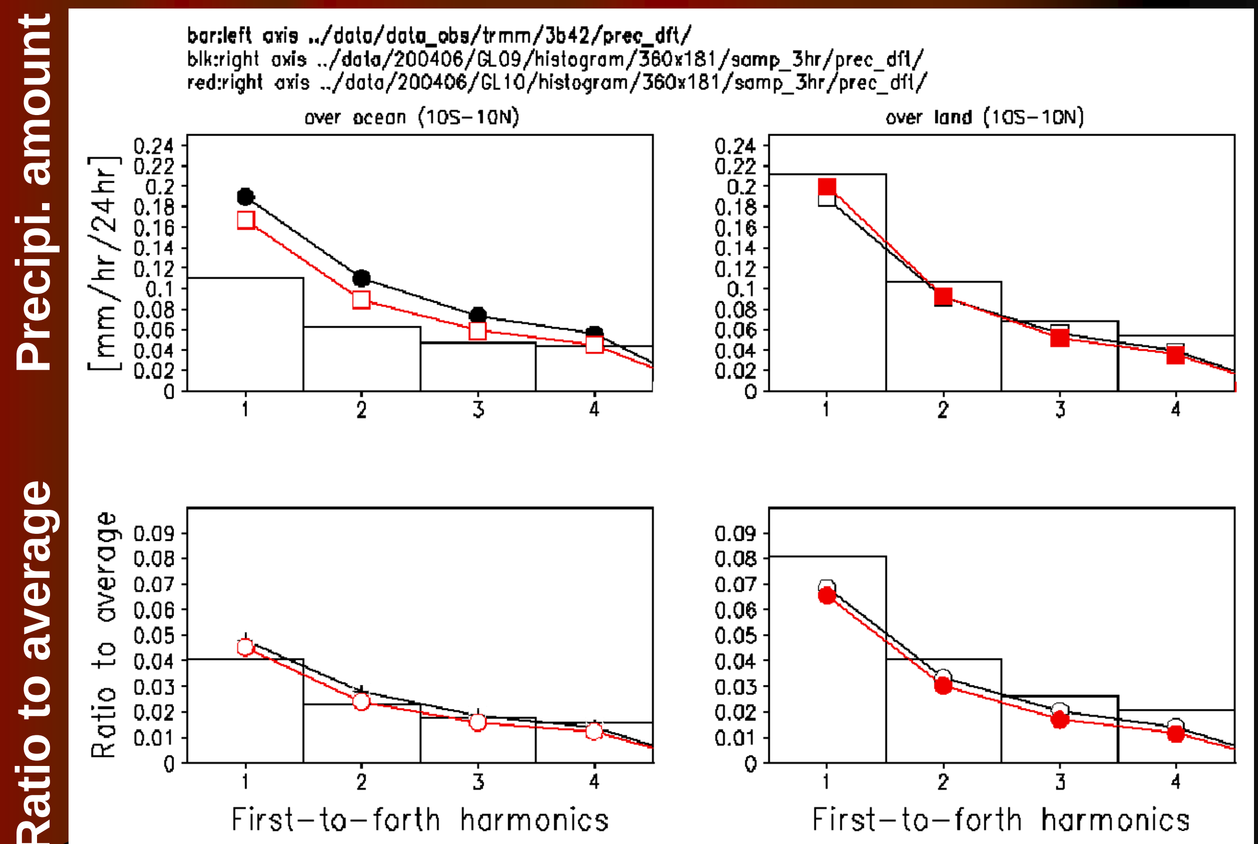
Contributions of harmonics (1)

Bar: TRMM 3B42
Black: 14-km mesh
Red: 7-km mesh

※Relative magnitude of anomaly components (~O(10-1)[mm/dy]) are relatively small against averages (~O(1)[mm/dy])

For ocean absolute values overestimated but relative contributions of each harmonics agree with TRMM obs.
(i.e., relative amplitudes of each harmonics reasonable)

over ocean **over land**



Contributions of harmonics (2)

※Relative magnitude of anomaly components (~O(10-1)[mm/dy]) are relatively small against averages (~O(1)[mm/dy])

Bar: TRMM 3B42
Black: 14-km mesh
Red: 7-km mesh

For ocean
No significant differences in 7km and 14km
1st component mostly explains the total

For land
Precipi. in 1st component of 7km develops earlier (~1-3hrs)
Stronger contrast of amplitude in 2nd component of 7km
Both components contribute to improving the precipi. delay

2nd components for both ocean and land follow semidiurnal variations in surface pressure (thermal tide)

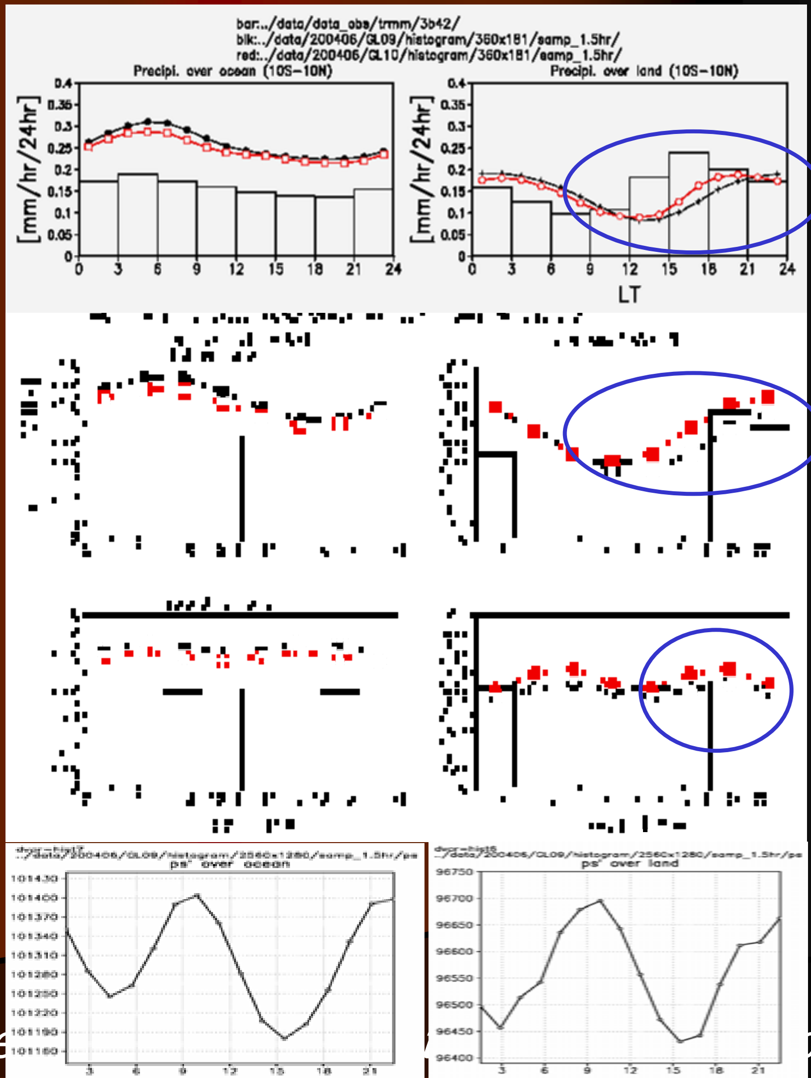
over ocean **over land**

all components

1st

2nd

Surface pressure



Diurnal variations of Clouds

Definition

- Categorized by subtraction of equivalent brightness temperatures at ground (Tbbs) from those at cloud top (Tbb) (based on Minnis and Harrison 1984)
    - High cloud: Tbbs-Tbb<39K
    - Mid cloud：13K<Tbb-Tbbs<250K
    - Low cloud: Tbb>13K

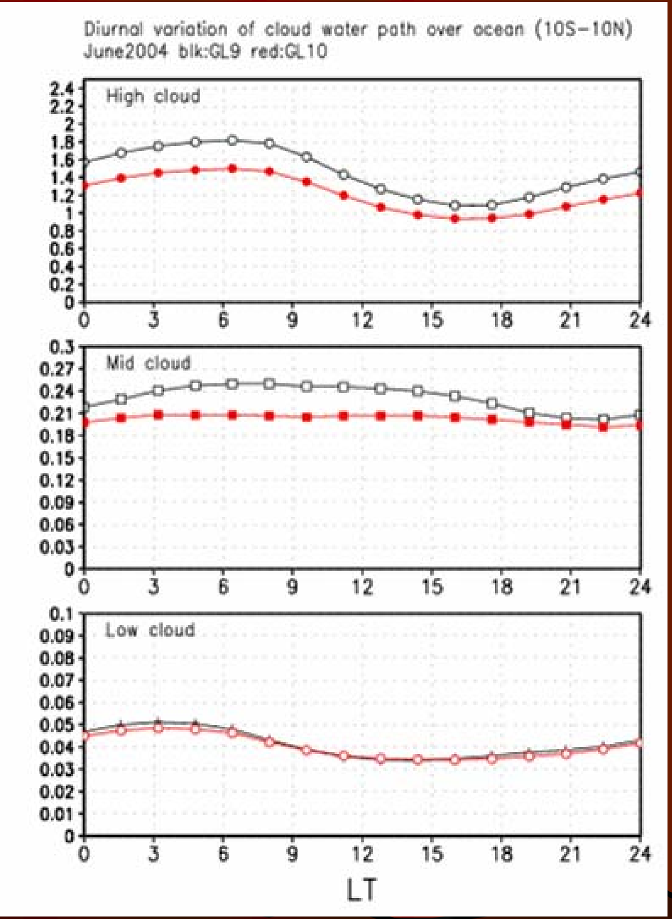
Diurnal variations of liquid+ice water path

Black: 14-km mesh
Red: 7-km mesh

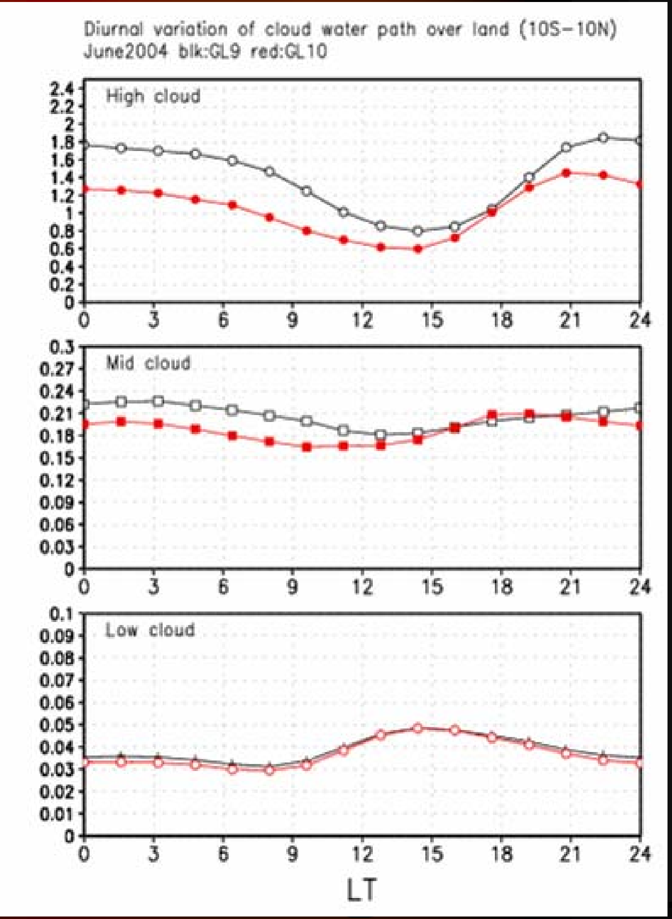
According to the improvement of the delay of precipi. time, high and mid clouds develop earlier than in 14-km mesh

Few notable resolution dependency in low clouds for both ocean and land

over ocean



over land



Diurnal cycle of low cloud

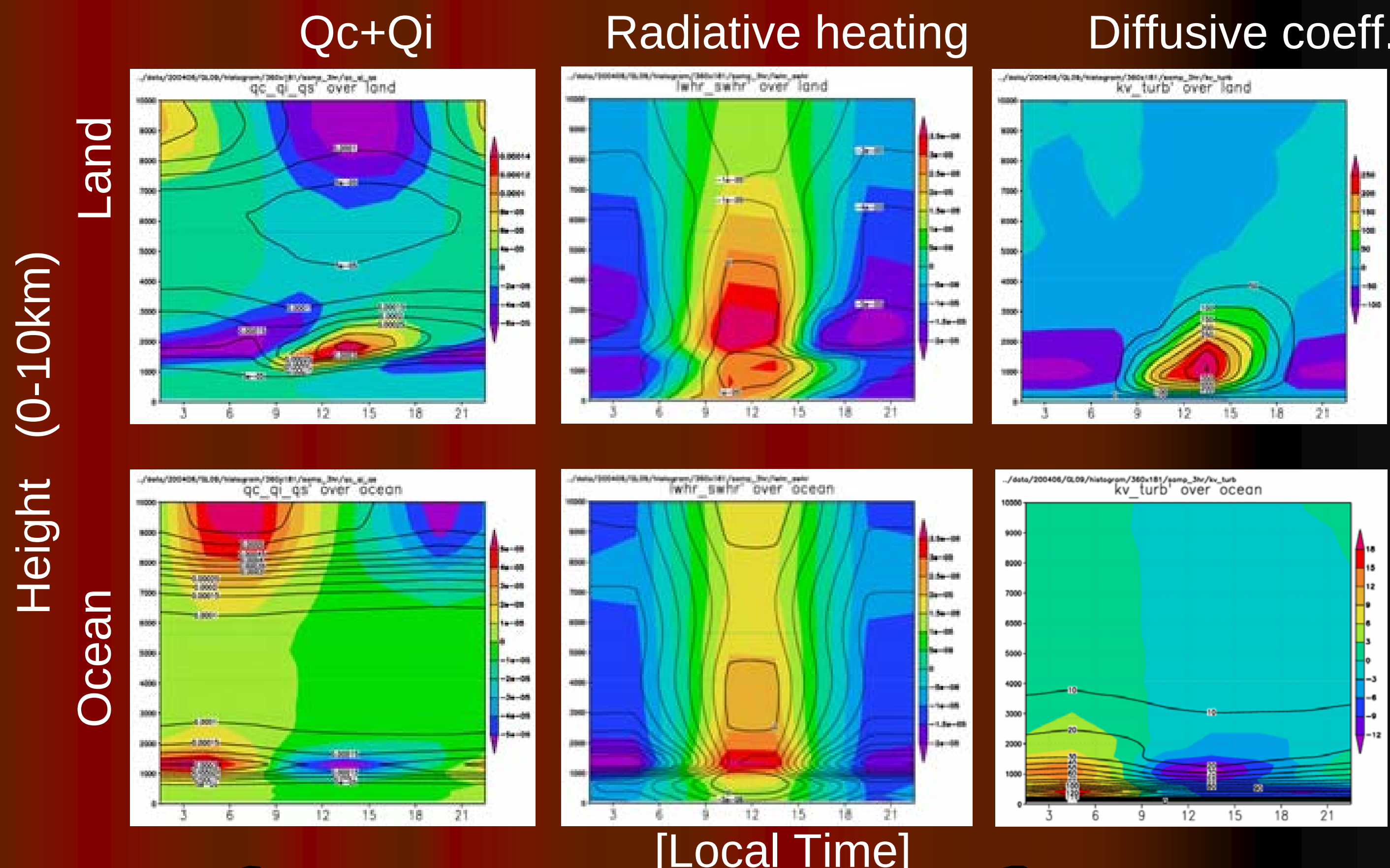
Color: Anomaly from mean at each altitude

For land
Diffusive coeff. in PBL grows from morning to evening
PBL depth and Low cloud develops
Low cloud mostly controlled by subgrid turbulence model

For ocean
Mostly controlled by temperature changes (radiative heating/cooling)

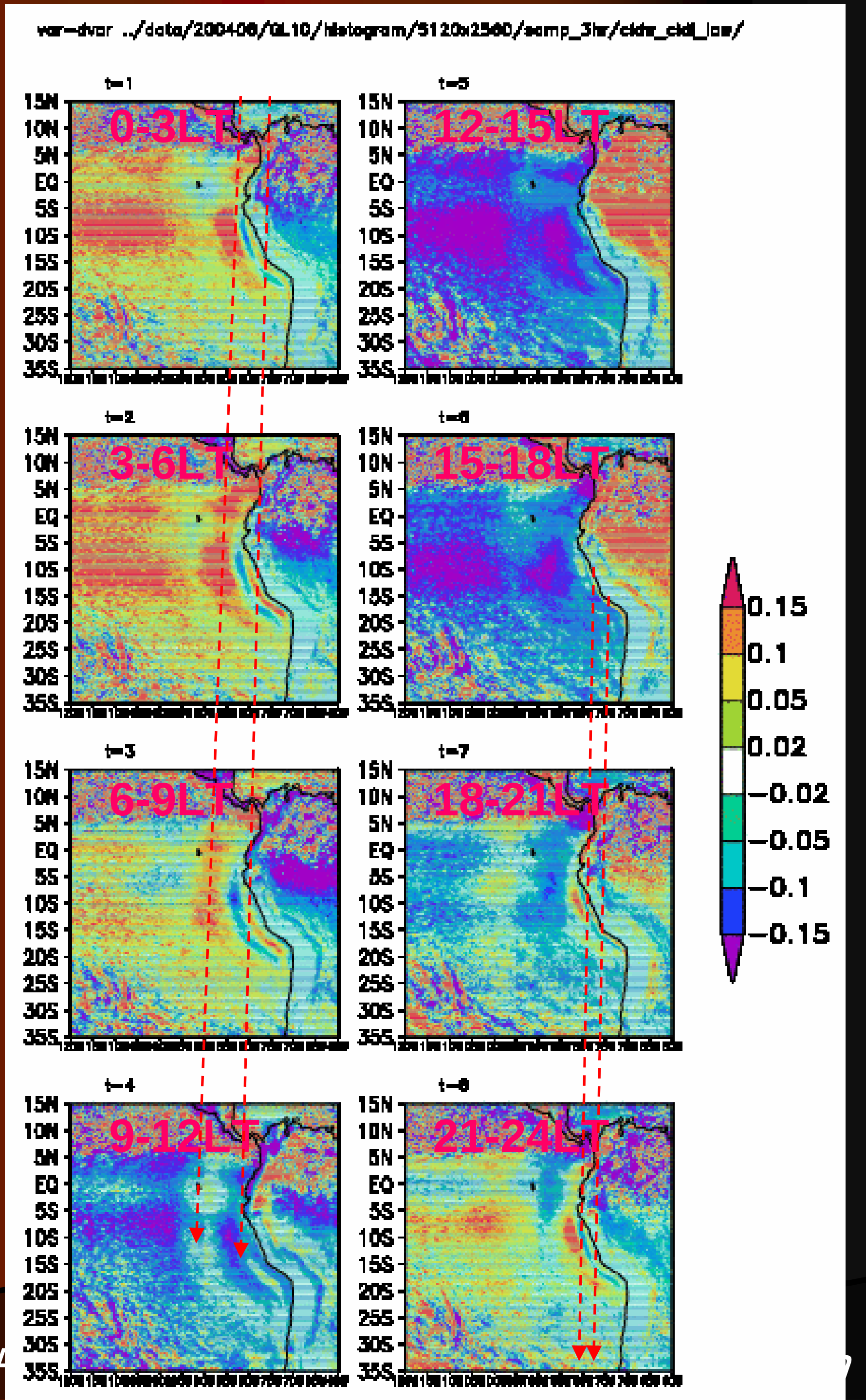
Primary mechanisms controlling low clouds over ocean and land appears to be somewhat different (subgrid process and radiation)

Both mechanisms have less dependency with horizontal resolution



Example of localized diurnal characteristics

7km-mesh
JJA2004



Low clouds (anomaly from day-mean coud water path)

Westward propagating low clouds from late afternoon to morning as in Garreaud and Munoz (2004)

Phase speed of about 1 deg/hr having at least 2 ridges

Recent Major Update of Physical Processes

Latest Physics

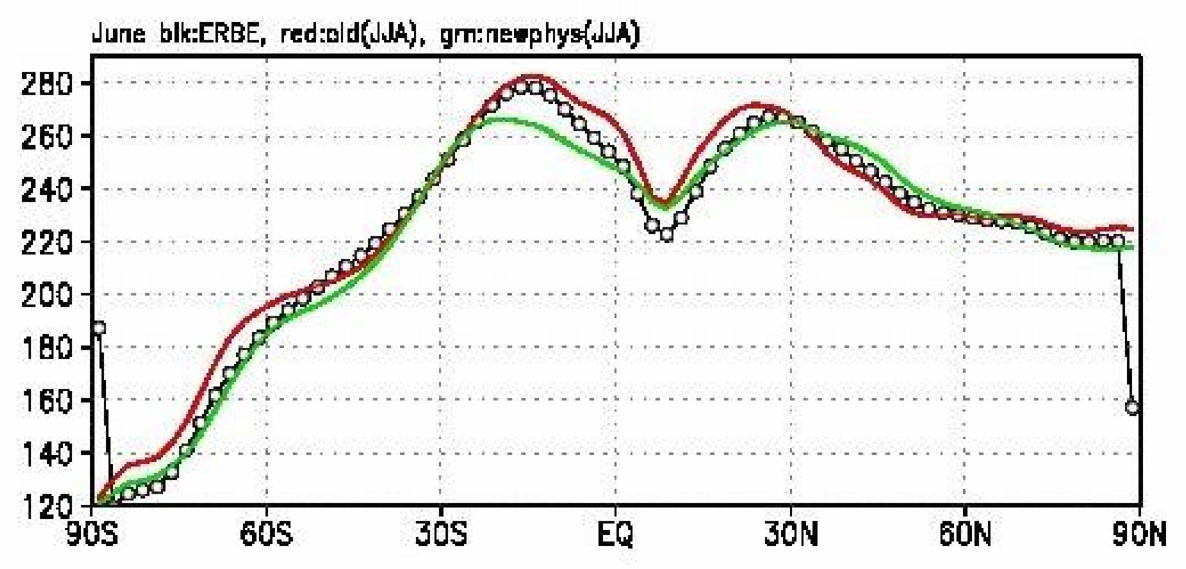
Initialization	NCEP Global analysis on 00Z Jun 1, 2004
Atmos. Nudging	Not used (optionally available)
Bottom boundary	Bucket model and NOAA Weekly Reynolds SSTSST→MATSIRO (Detailed vegetation+Tank model) and one-layer mixed ocean model with e-folding time of 5 days (nudged to the Reynolds SST)
Horizontal resolution	14km
Vertical resolution	80m〜2.9km (Stretched)
Cloud	Cloud microphysics (Grabowski et al. 1998) → NSW6 (6-category with 1-moment scheme; Tomita 2008)
Cumulus Convection parameterization	Not used (Now implementing a parameterization of meso-scale convection systems for 14-km mesh)
Turbulence	Improved version of Mellor-Yamada Level 2 with subgrid-scale condensation (Nakanishi & Niino 2006; Noda et al. (Atmos. Sci. in press)) ※ partial cloudiness not considered
Surface turbulent flux	Bulk parameterization by Louis (1979)
Radiation	MSTRNX
Integration period	June 1st〜November 7th (for 14-km mesh) (but focused only in JJA)
Aerosol process	Not used (optionally available)

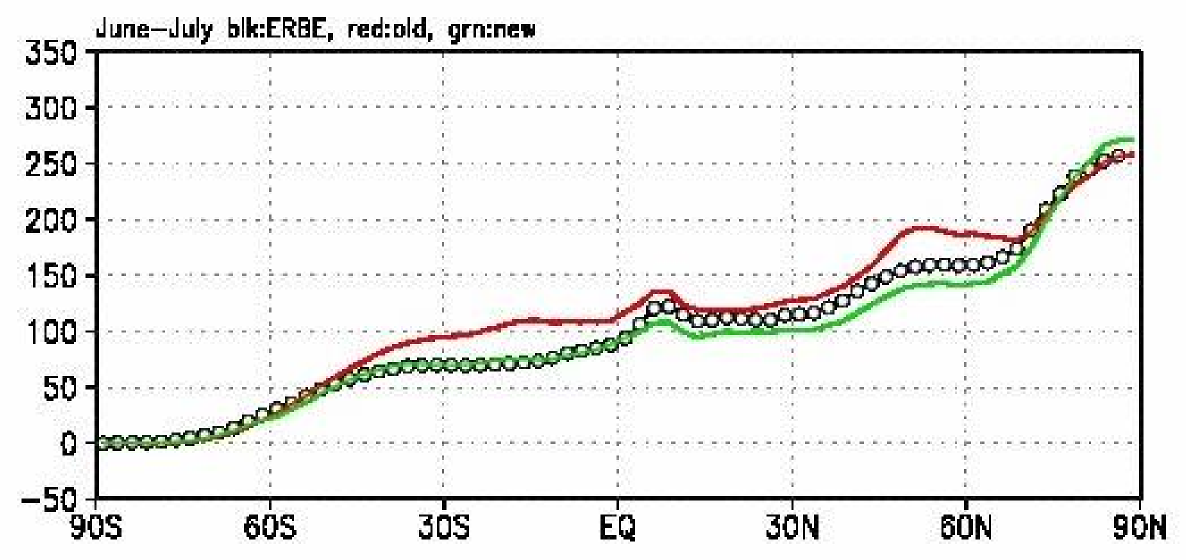
Radiation budget

Black: ERBE
Red: Previous
Green: New phys.

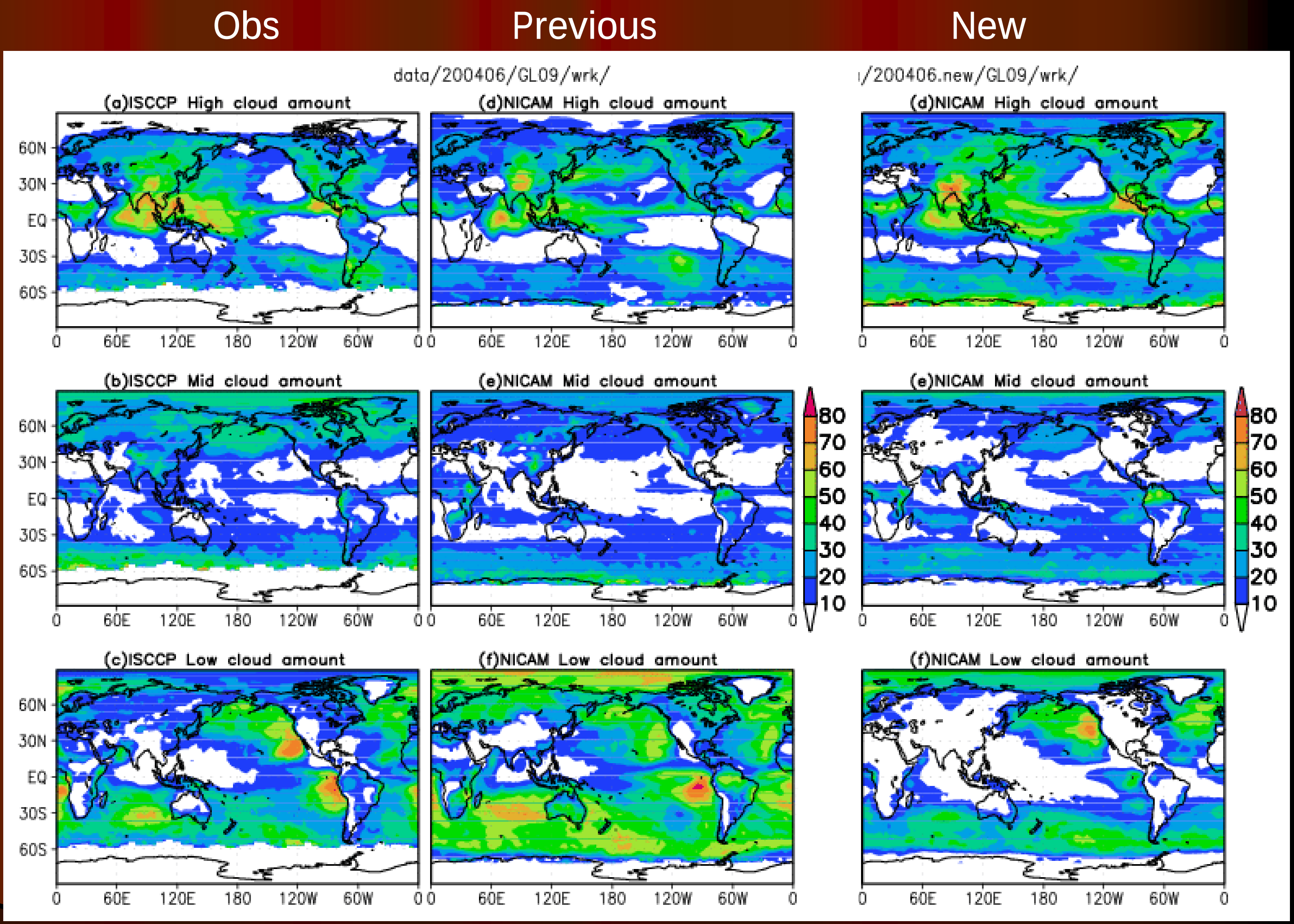
OLR
南半球中高緯度や北半球亜熱帯の改善(西太平洋の負バイアスの軽減に対応)
南半球熱帯で負バイアス(上層雲の過剰化に対応)

OSR
南半球の過大が全体的に改善(下層雲の減少に対応)
北半球のバイアスは同程度だが符号が正から負に変化(上層雲の増大よりも下層雲が減少した方が効いている？)





ISCCP cloud category



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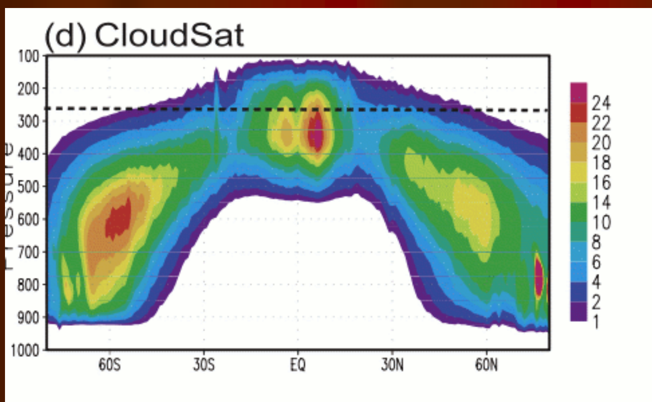
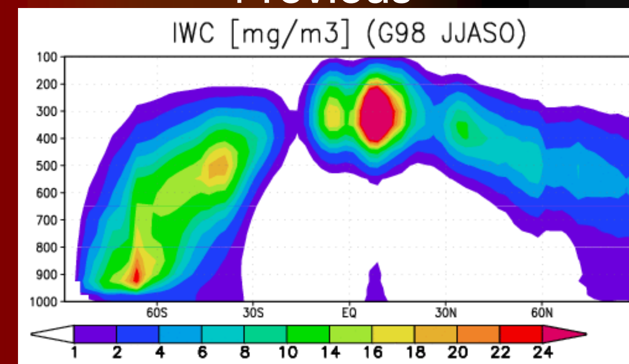
IWC distributions

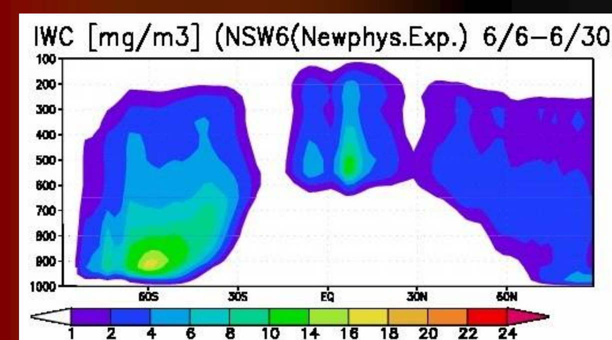
Waliser et al. 2009

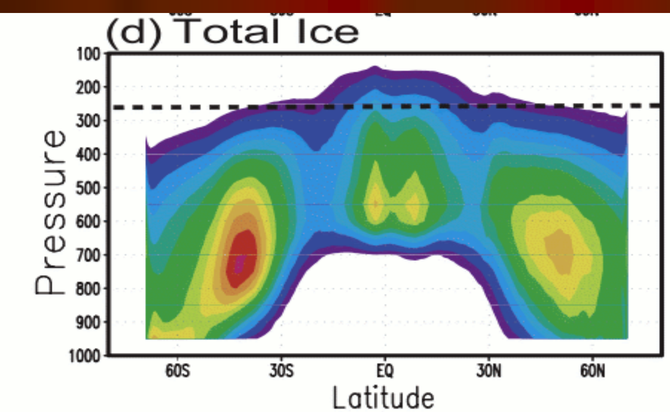


Previous

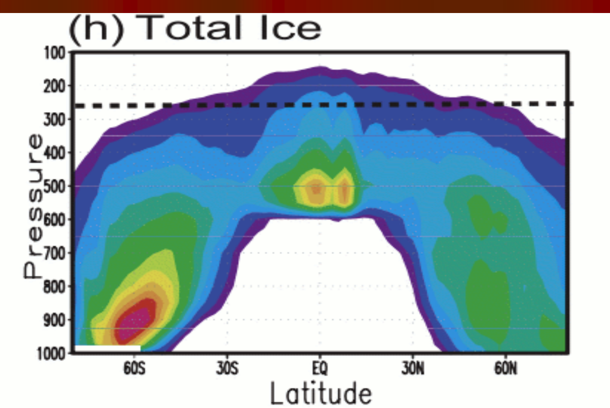


New





RAVE



fvMMF

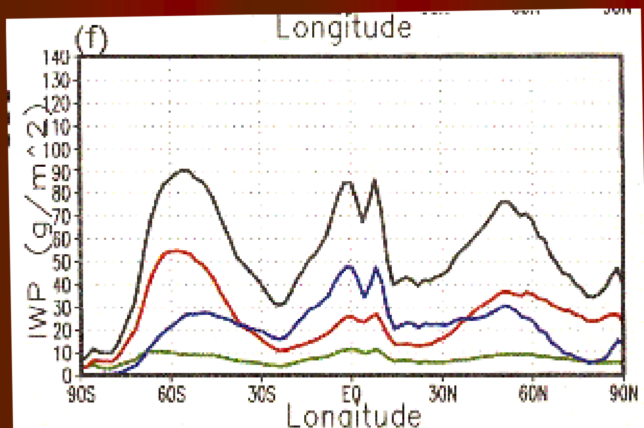
NICAM

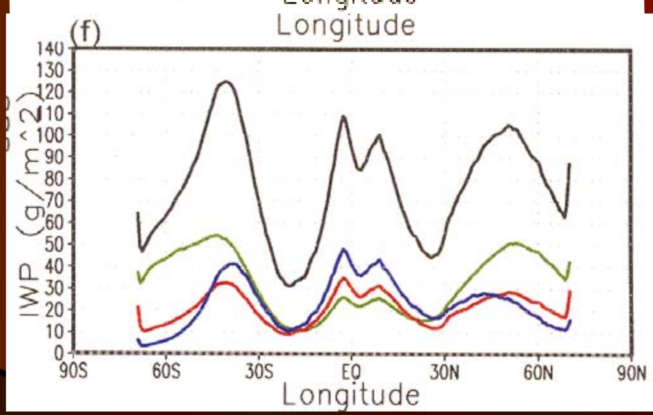
Zonal-mean IWP

Black : total
Green: cloud ice
Red: snow
Blue: graupel

Diffecult to know how IWP distribution should be, though
Becomes closer to the current CRM experiments

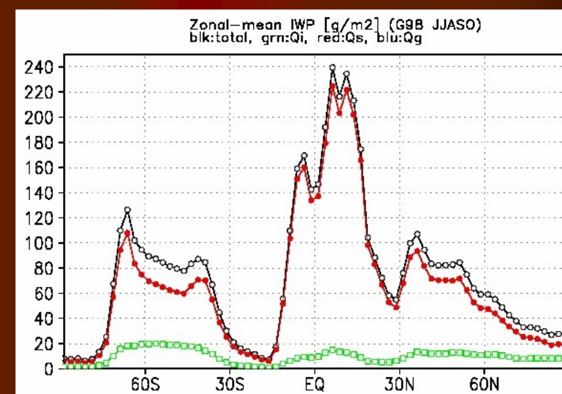
RAVE & fvMMF



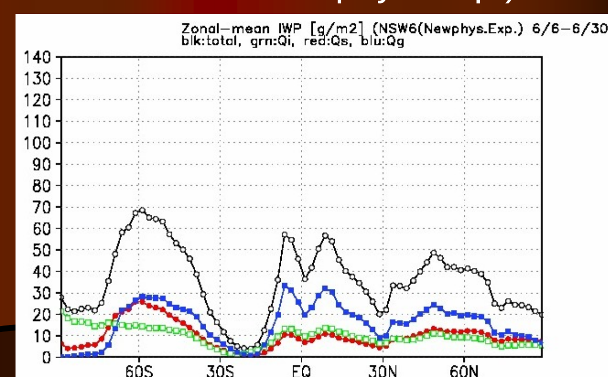


NICAM（Old exp.）

140g/m2→



NICAM（New phys. exp.）



Waliser et al. 2009

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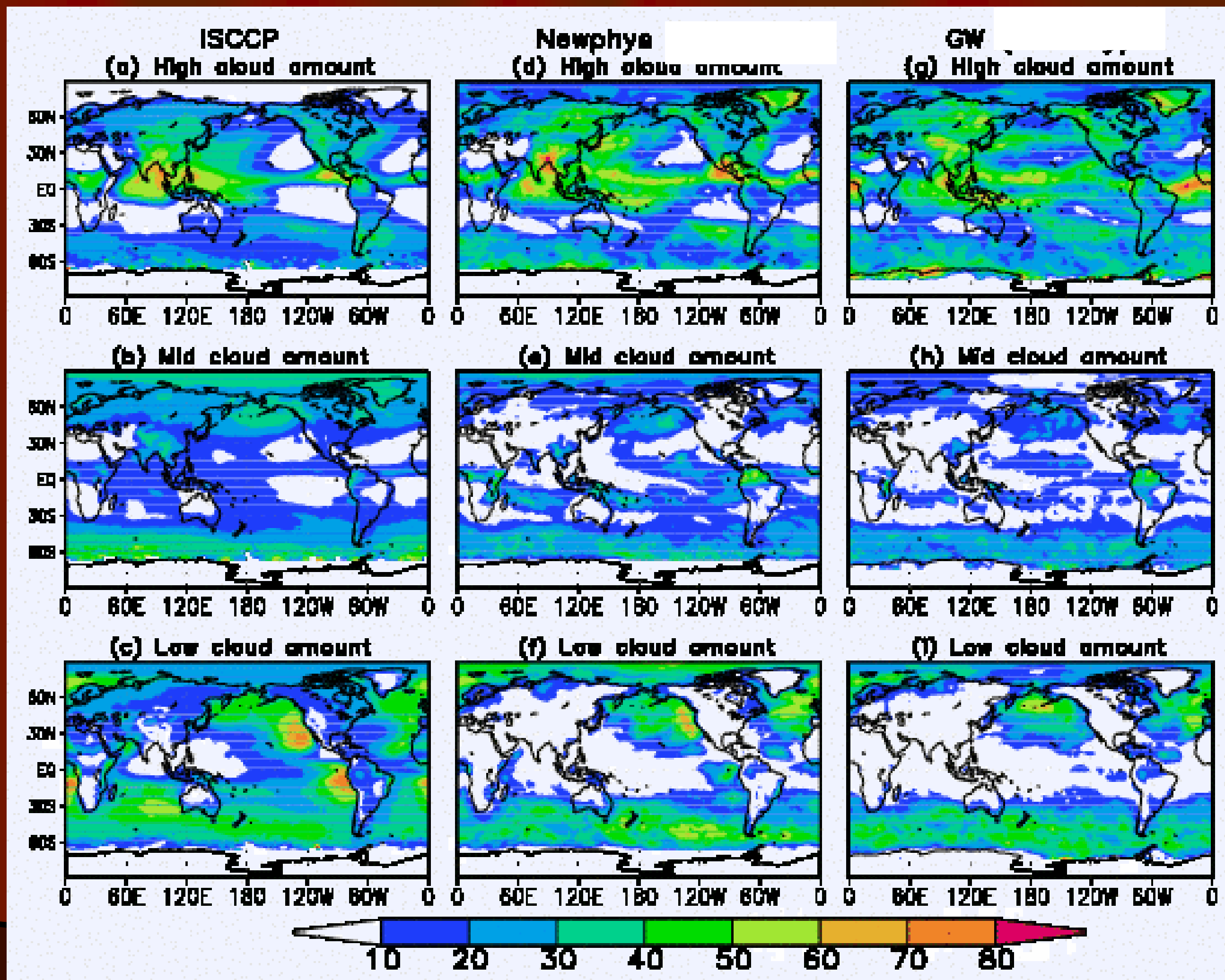
Global warming experiment

+2K SST, CO_2*2, Sea ice concentration (with diagnostic ice depth) by the model ensemble of the IPCC AR4

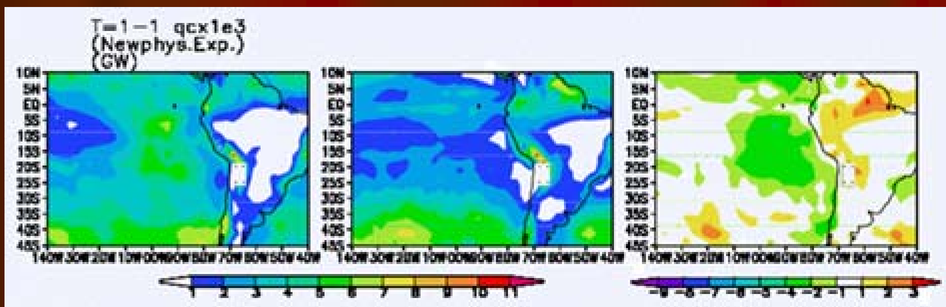
ISCCP Cloud amounts ~June~

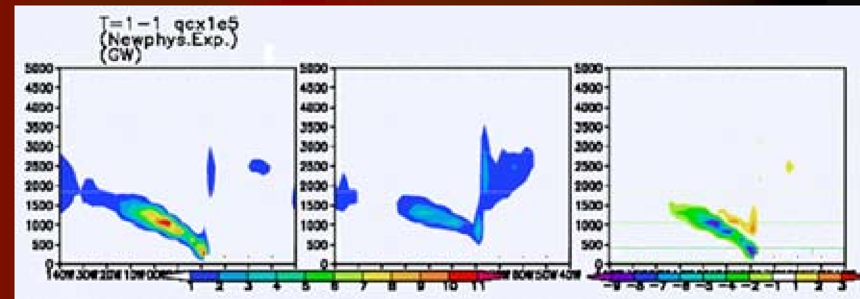
Remarkable reduction of subtropical low clouds, and increase of high clouds



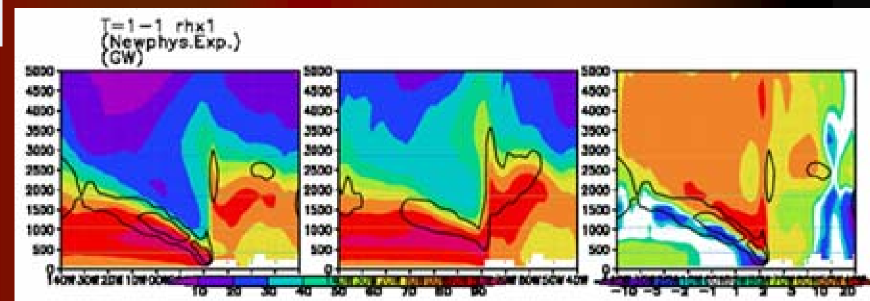
Sensitivity to Peruvian stratocumulus

CTL GW GW-CTL





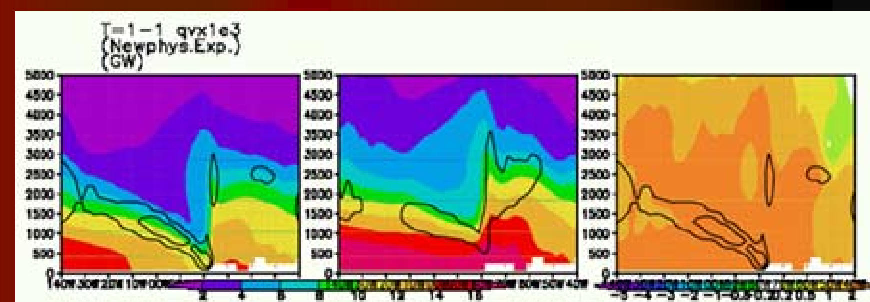
RH



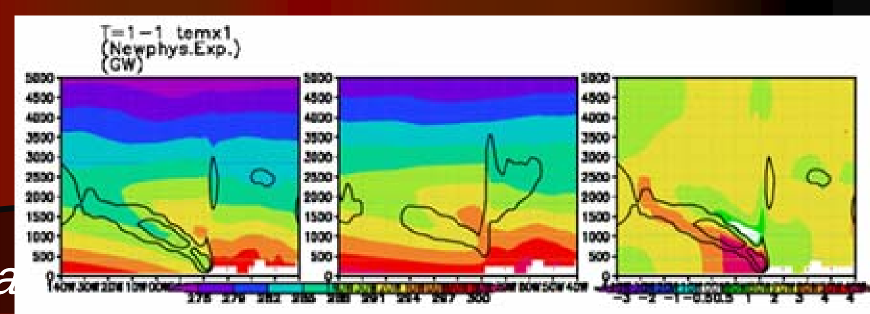
GW exp.
Deeper PBL depth

Both vapor and temperature increase.
Though, more temperature gain due to higher SST leads to less RH in PBL, reducing west coastal clouds

Vapor



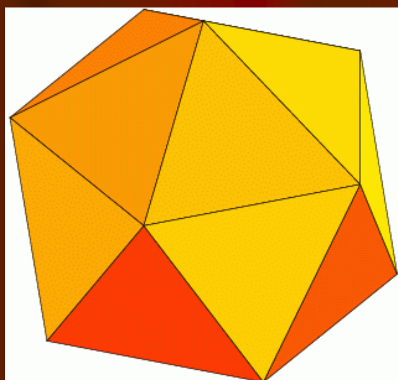
Temp.



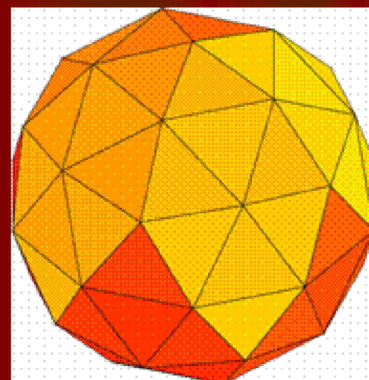
Philippine Typhoon Fensheng by Stretched-NICAM (by W.Yanase)

Non-hydrostatic ICosahedral Atmospheric Model (NICAM)

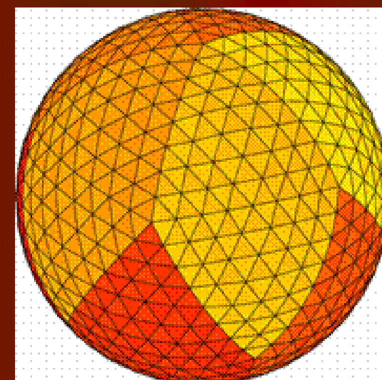
Icosahedra



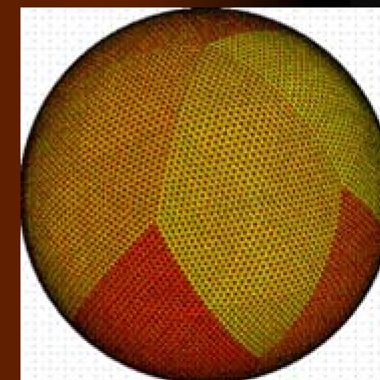
glevel-1



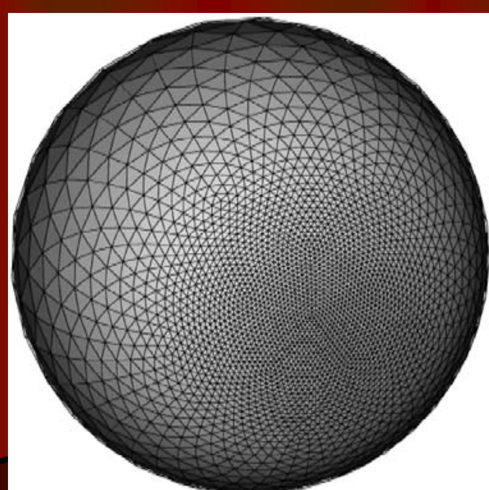
glevel-3



glevel-5



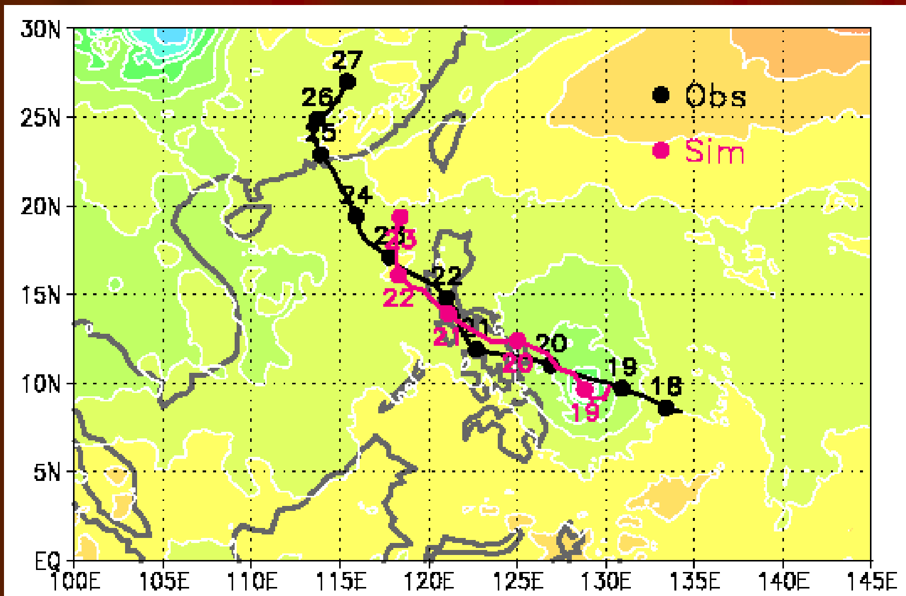
Stretched grid



Model setting

- NICAM
  - ストレッチ格子の間隔：台風付近で7km
  - 雲微物理：NSW6 (水蒸気・雲水・雲氷・雨・雪・あられ)
  - 積雲スキーム：なし
- 初期条件
  - JMA・NCEPの解析データ（水平風・気温・水蒸気）
  - 台風発生(6月19日00UTC)より前の初期値を色々試す
    ➔ 15日00UTCのNCEP初期値がベストケース(今回発表)
- 境界条件
  - Reynolds 海面水温 の週データを内挿して与える

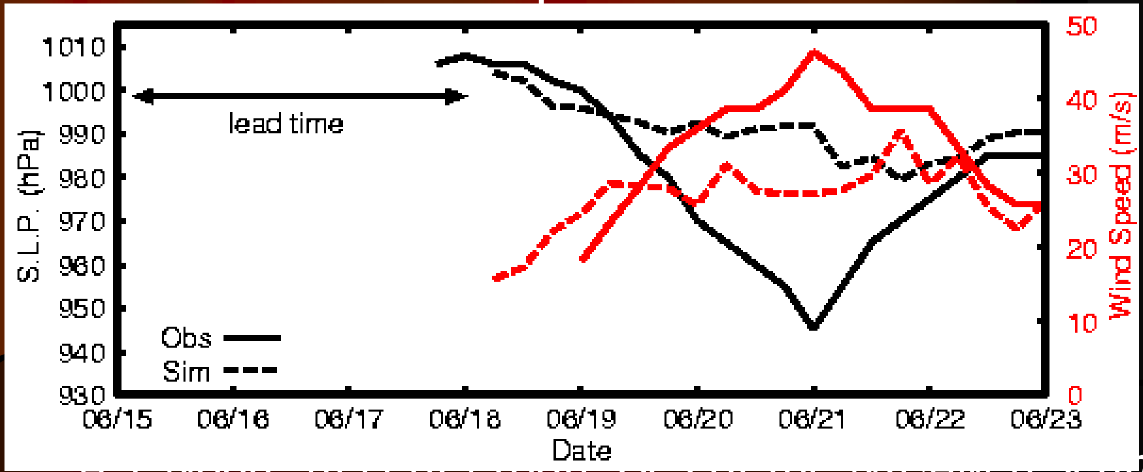
Case of Typhoon Fensheng



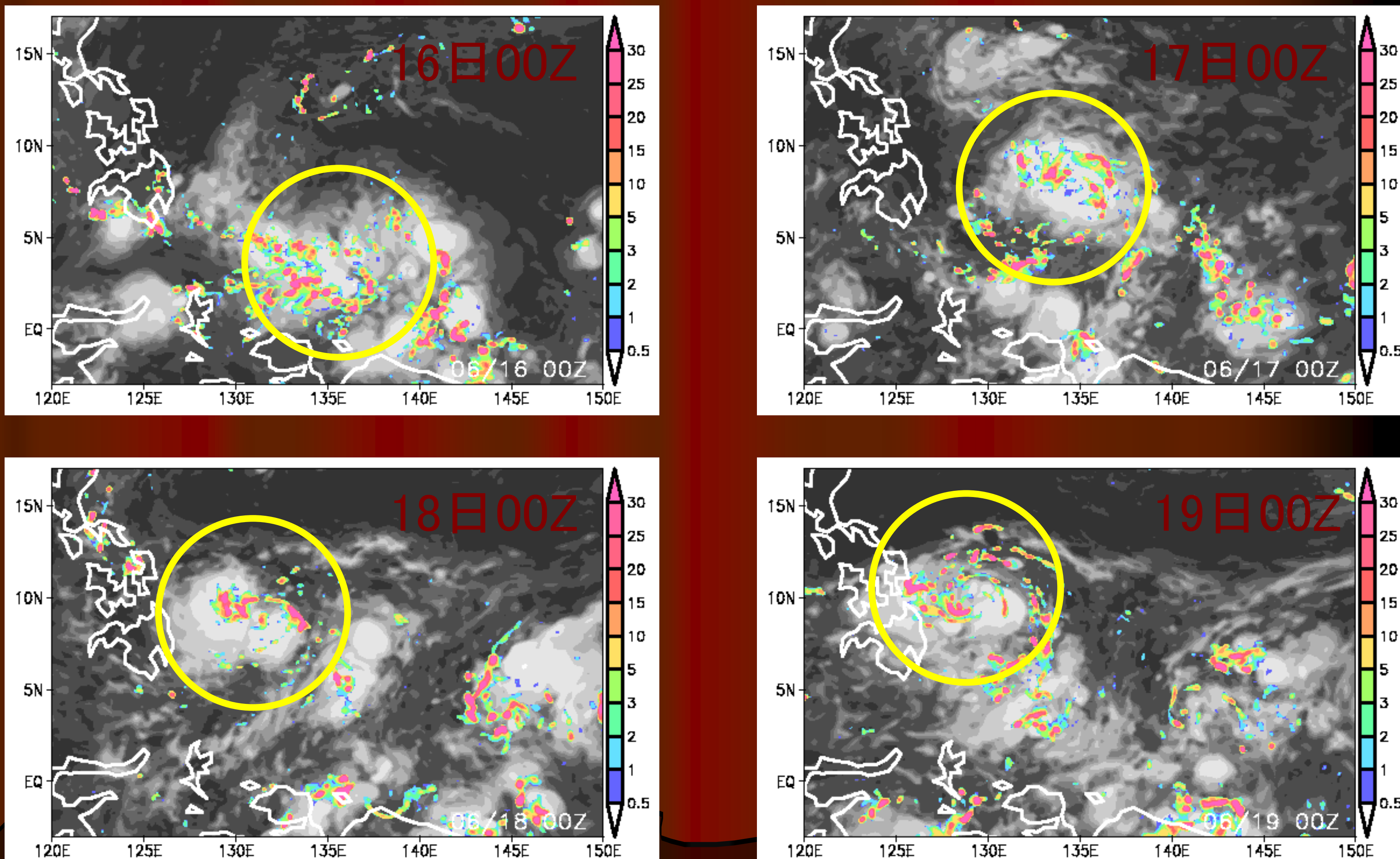
Initiation, location and course agree well with obs.

Course

Pressure depress. and max. wind



Organization of modeled meso-scale convections
Clouds(gray) and Precipi.(color)



Ensemble experiment of the Typhoon Nargis (by H.Taniguchi)

Experimental Setup of Apr. / May 2008

Initial condition:

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

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

(7 control run without any perturbation:

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

without any nudging process (Nargis formed at 0600UTC, Apr 28, 2008)

Boundary condition:

weekly Reynolds-SST , Sea ICE

ETOPO-5 topography, Matthews vegetation

UGAMP ozone climatology (AMIP2)

Horizontal mesh size: 14 km (DX14)

Tracks

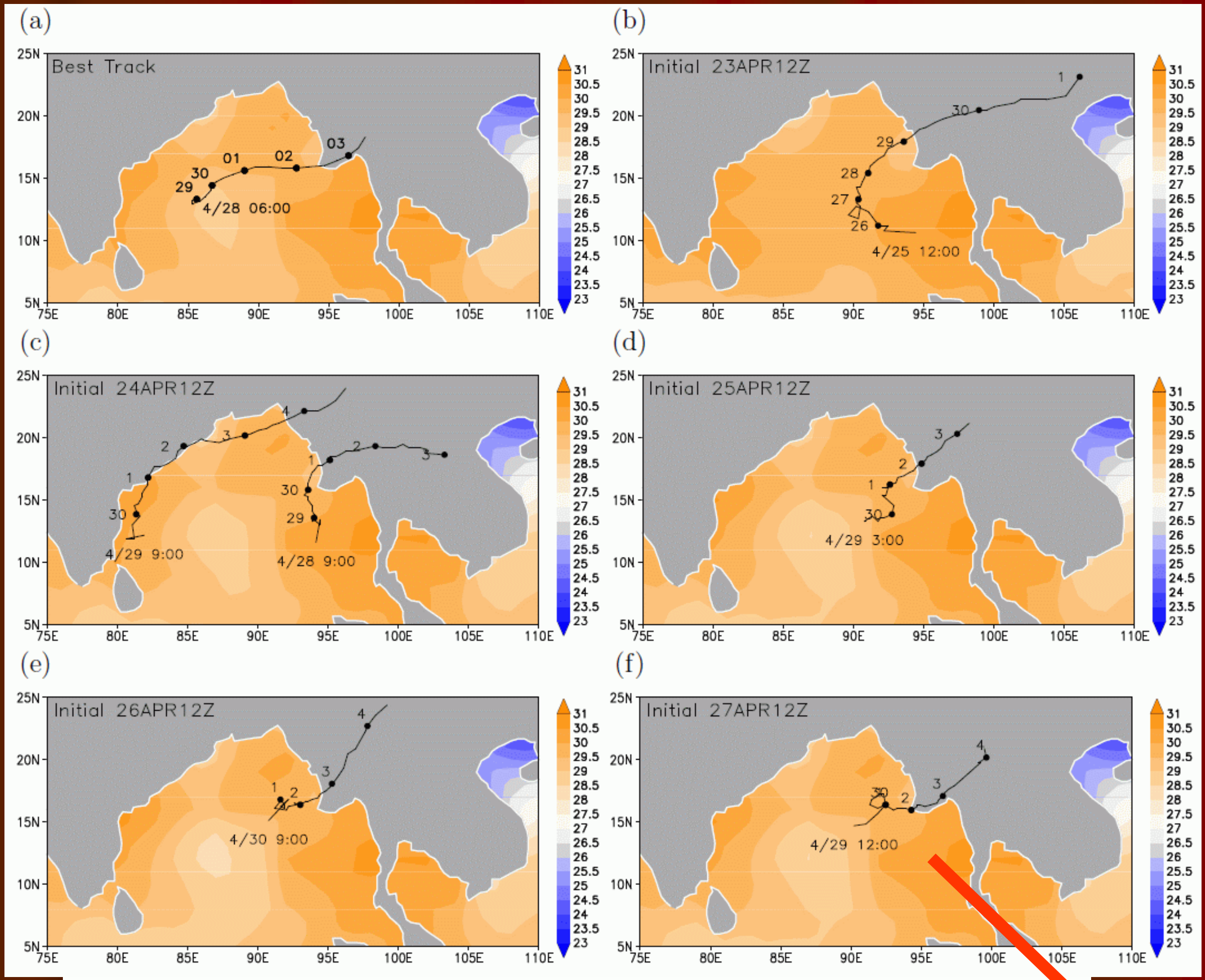


Figure 7: (a) Best track of cyclone Nargis (line) started from TC formed day in April 28, 2008 obtained by JTWC data center. (b-f) Tracks of simulated cyclones (lines). Each shading shows observed weekly-averaged Reynolds-SST (K) at the genesis day of observed cyclone Nargis (a) and the simulated cyclones (b-f). Solid circles with digits number show the day and position of each cyclone. Panels of (b) to (f) show the results of simulations with initial days, 23, 24, 25, 26, and 27 April, 2008. In our simulation, there exists no cyclone which is formed in the bay of Bengal for the initial day of 10 and 28 April 2008 (not shown).

- **Successfully simulated cyclogenesis except for Apr 10 and 28 initial day cases.**
- **Cyclogenesis occurs in the higher SST area.**
- **There exists a large SST gradient in the South China sea and BoB.**

Color shading shows SST during the week including cyclogenesis

Temporal evolution of observed fields

4/1

5/31

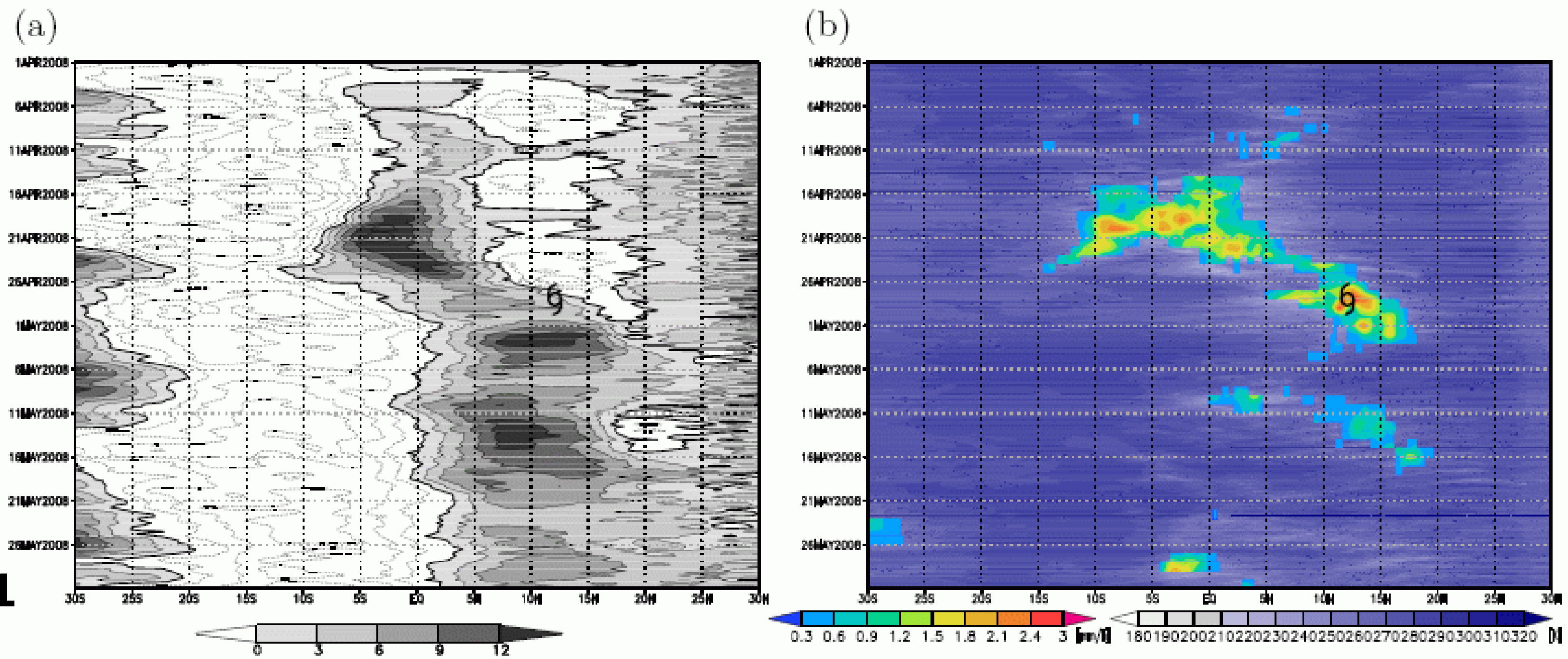


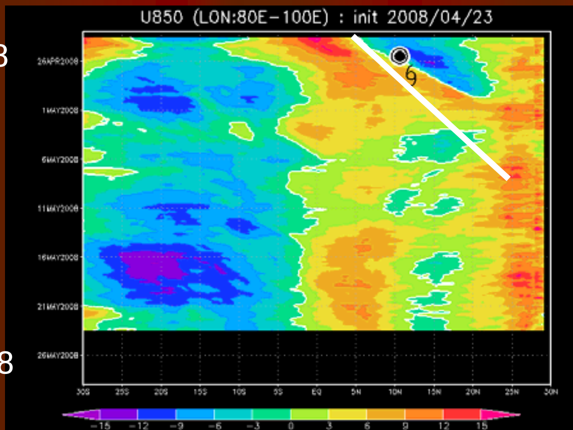
Figure 8: Temporal evolution of observed (re-analysis) field of zonally-averaged zonal wind (m/s) at 850-hPa (JMA/JCDAS) over 80°E–100°E (a), blended zonally-averaged infrared (IR) brightness temperature (NCEP/CPC 4 km Global IR datasets) by white to navy colors shades (K) over 80°E–100°E and zonally-averaged surface precipitation rate (mm/h) (Global Rainfall Map by JAXA/EORC GSMaP Near Real-Time System, Ver.1.0) by rainbow color shades for the value of grater than 0.3 (mm/h) over 80°E–100°E (b) during the period of 1 April to 31 May 2008. An weather symbol in each figure shows the position and day of cyclone Nargis genesis.

U850 (80E-100E)   Initial DAY 23-28

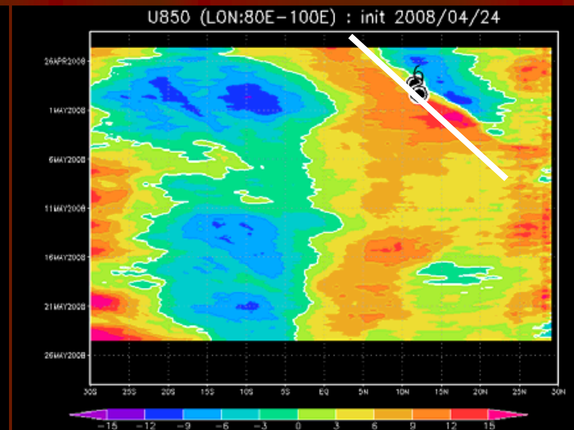
26APR2008

26MAY2008

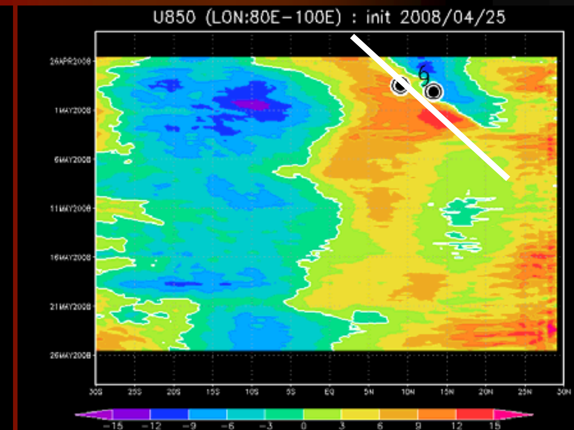
2008/04/23



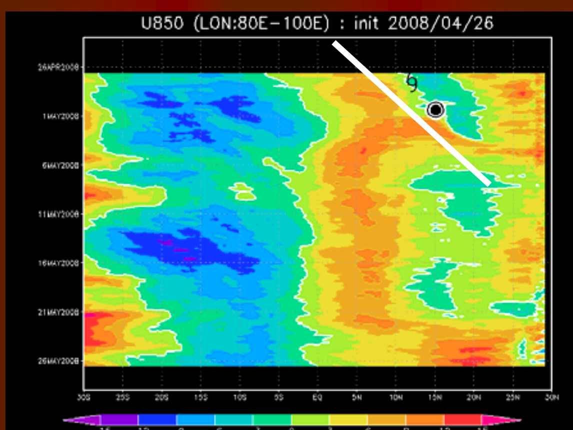
2008/04/24



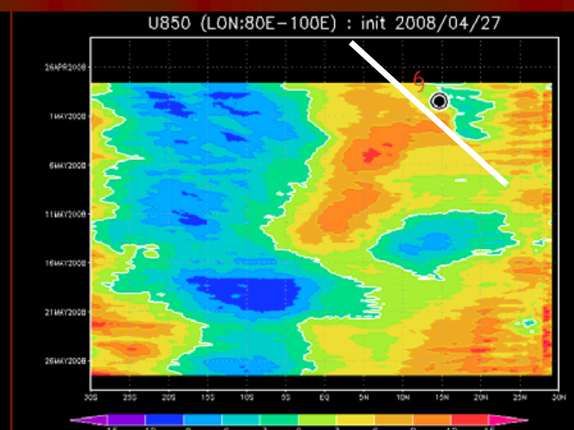
2008/04/25



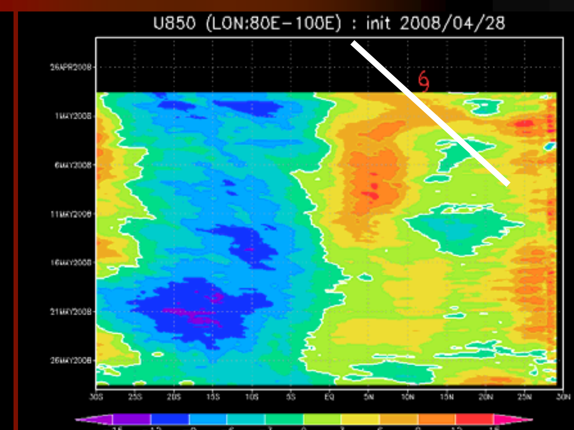
2008/04/26



2008/04/27



2008/04/28

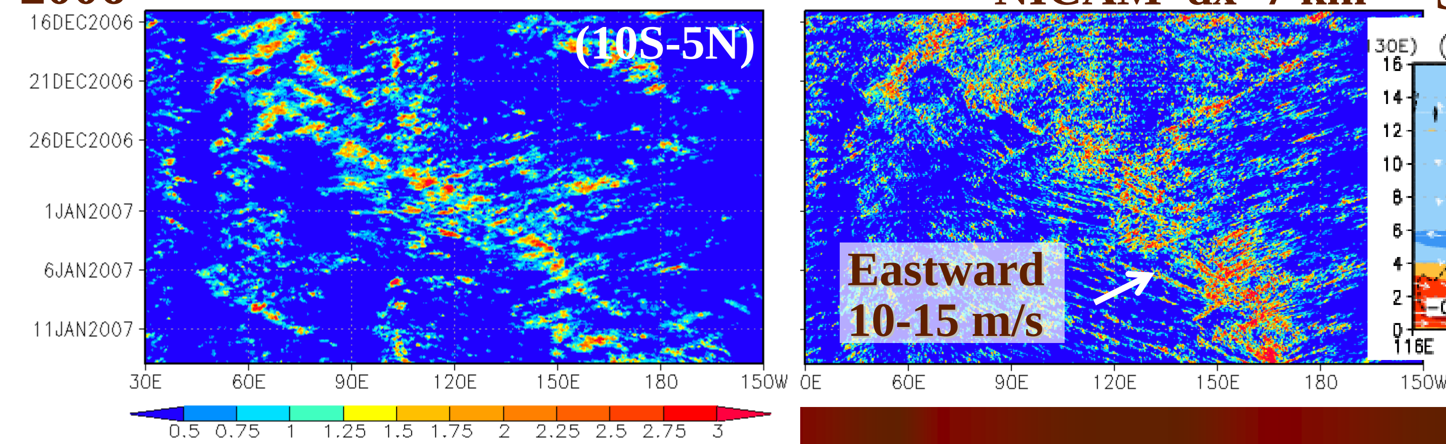


Longitude

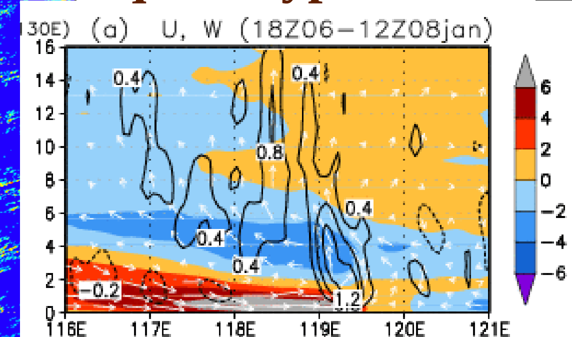
Convective Momentum Transport in the Dec 2006 MJO (by T.Nasuno)

NICAM simulation of an MJO event Dec. 2006

2006 TRMM PR **Miura et al. (2007)** **NICAM dx=7 km**



Squall -type cluster



Nasuno et al. (2009)
Miyakawa（CCSR）

➢ Convective momentum transport (CMT)

Moncrieff (1981, 1997, 2004), Grabowski and Moncrieff (2001),

LeMone et al. (1983, 1984), Houze et al. (2000), <u>Tung and Yanai (2002)</u>

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

1. **As westerly iniated 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 moistly downgradient and reduces the middle level zonal wind shear.**

momentum transport” etc.

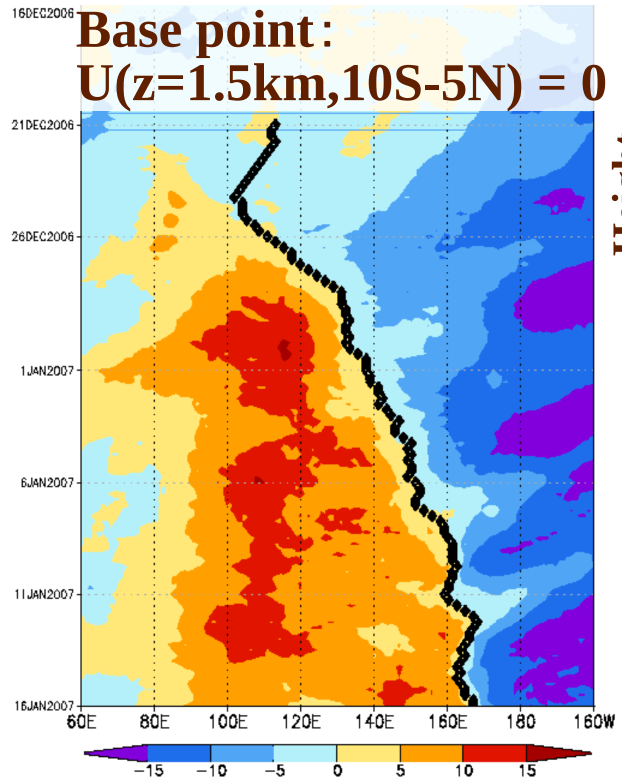
$X = \overline{X} + X'$

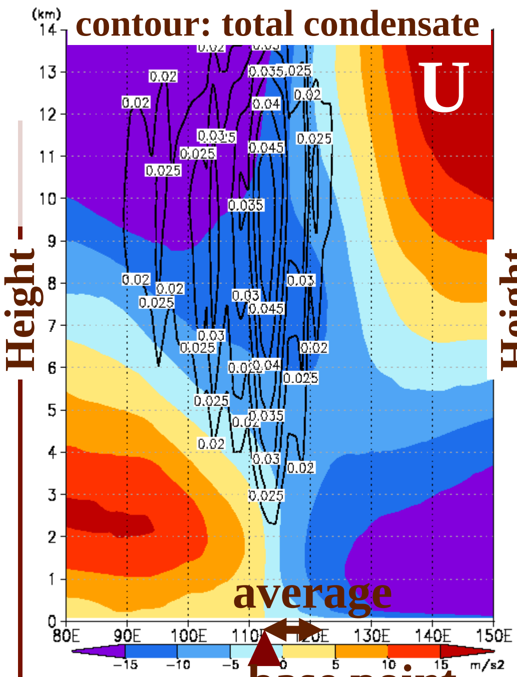
$\overline{X}$: ~1° mean values

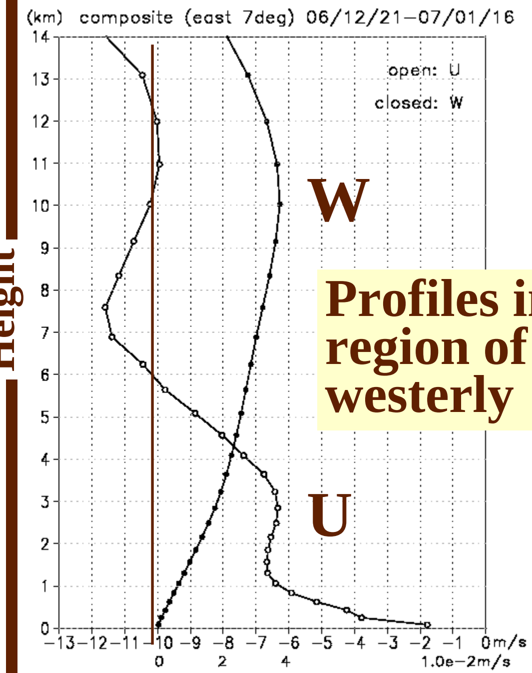
X' : deviations

Purpose: Investigate roles of CMT on a MJO event by explicit calculation of convection using NICAM.

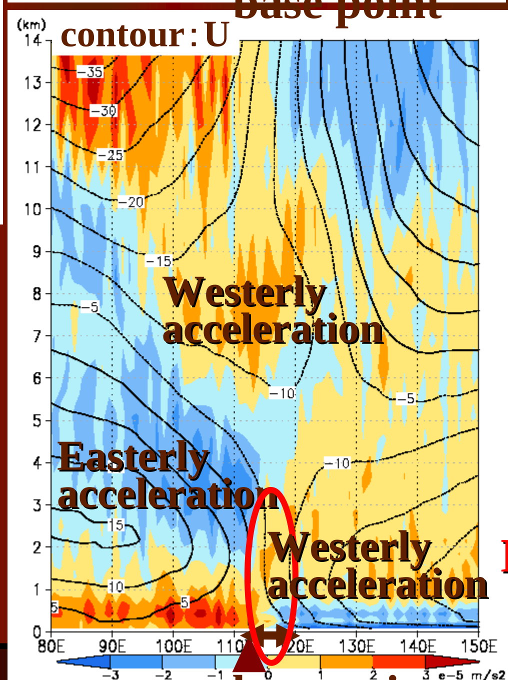
composite(10S-5N)

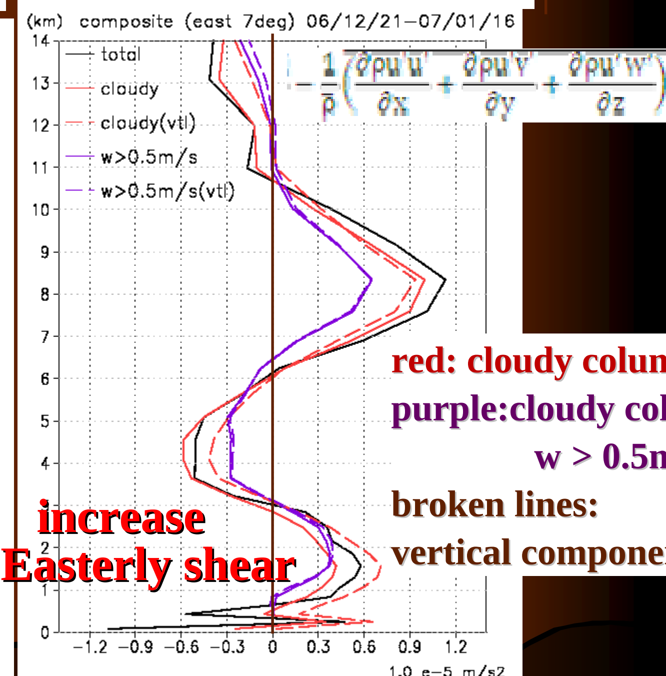






Profiles in the onset region of low-level westerly

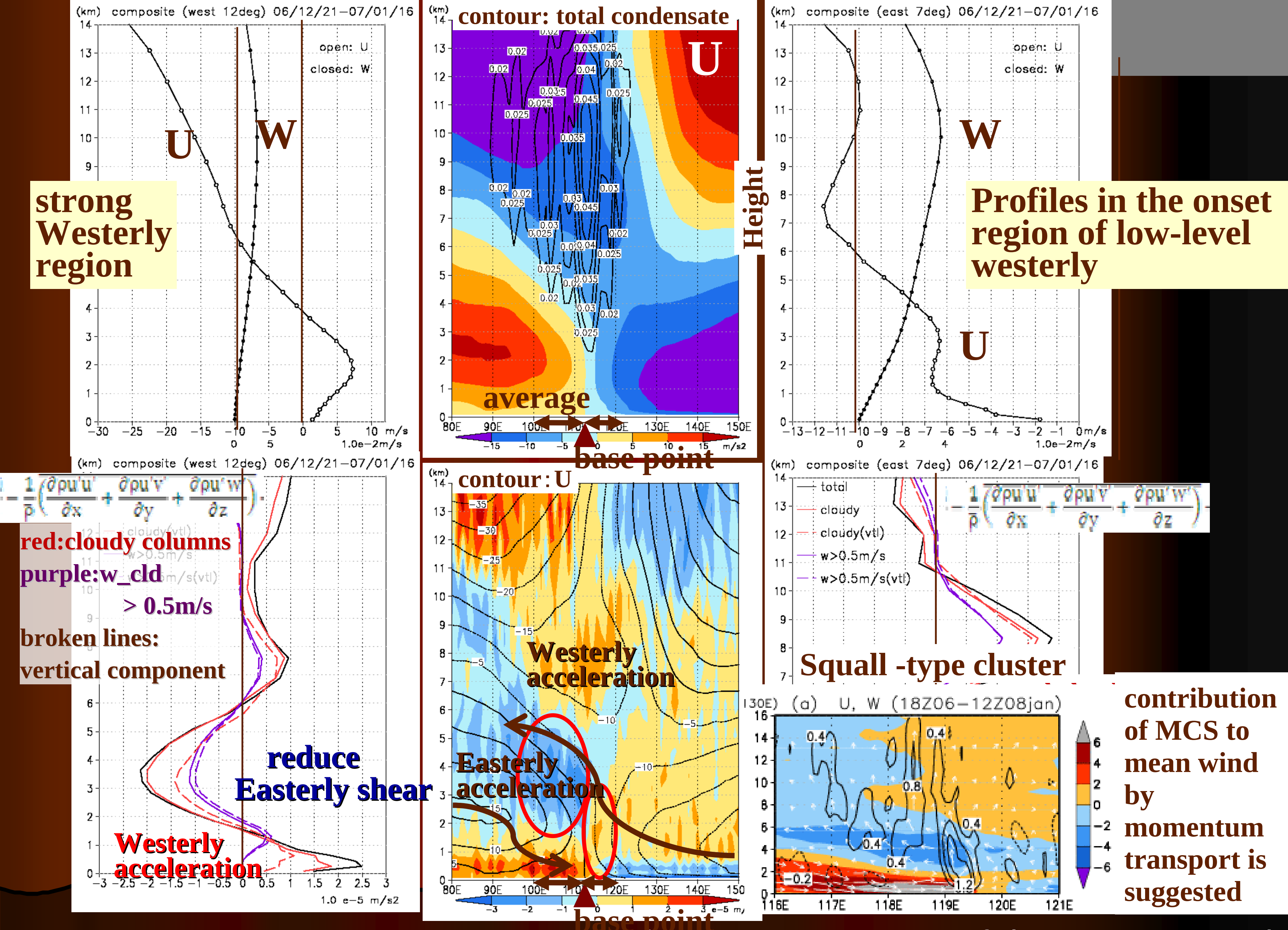




red: cloudy columns

purple: cloudy column w > 0.5m/s

broken lines: vertical component


composite (west 12deg) 06/12/21–07/01/16
open: U
closed: W
U
W
strong Westerly region
contour: total condensate
U
Height
average
base point
composite (east 7deg) 06/12/21–07/01/16
W
U
Profiles in the onset region of low-level westerly
$-\frac{1}{\bar{\rho}}\left(\frac{\partial \rho u'u'}{\partial x}+\frac{\partial \rho u'v'}{\partial y}+\frac{\partial \rho u'w'}{\partial z}\right)$
red:cloudy columns
purple:w_cld
> 0.5m/s
broken lines:
vertical component
reduce
Easterly shear
Westerly acceleration
contour: U
Westerly acceleration
Easterly acceleration
base point
total
cloudy
cloudy(vtl)
w>0.5m/s
w>0.5m/s(vtl)
Squall -type cluster
(a) U, W (18Z06–12Z08jan)
contribution of MCS to mean wind by momentum transport is suggested

Summary

- Resolution dependency (7-km and 14-km) in diurnal variations of global-scale precipi. and clouds
  - Importance of vertical heat transport by diurnally-variating small-scale (~O(10km)) precipi. cells
  - Global-scale precipi.
    - For land, more accurate in 7-km mesh than in 14-km mesh
      - due to more active diurnal cycles of, especially, small scale precipi. cells
    - For ocean, in contrast few differences among the two resolutions
      - as mostly controlled by diurnal temperature (i.e., relative humidity) changes due to radiative process (having less resolution dependency)
  - Global-scale cloud condensates
    - High and mid clouds start to develope earlier (1-3hrs) in the 7km-mesh model
      - corresponding to the earlier development of precipi.
    - Few resolution dependencies in low clouds
      - as mostly controlled by subgrid turbulent process for land, and radiative process for ocean

- Ongoing works
  - statistical studies
    - Sensitivity of Physics-Updated exp.
      - (14-km & 7-km meshes)
    - Global warming exp. (14km-mesh)
      - Warmed SST + CO2*2 scenario of AR4
  - Eventual studies
    - TC Fensheng on June 2008
      - (Stretched-grid together with the 3.5km homogeneous-grid NICAMs)
    - Ensemble experiment for TC Nargis on May 2008
  - etc… (to be appeared)