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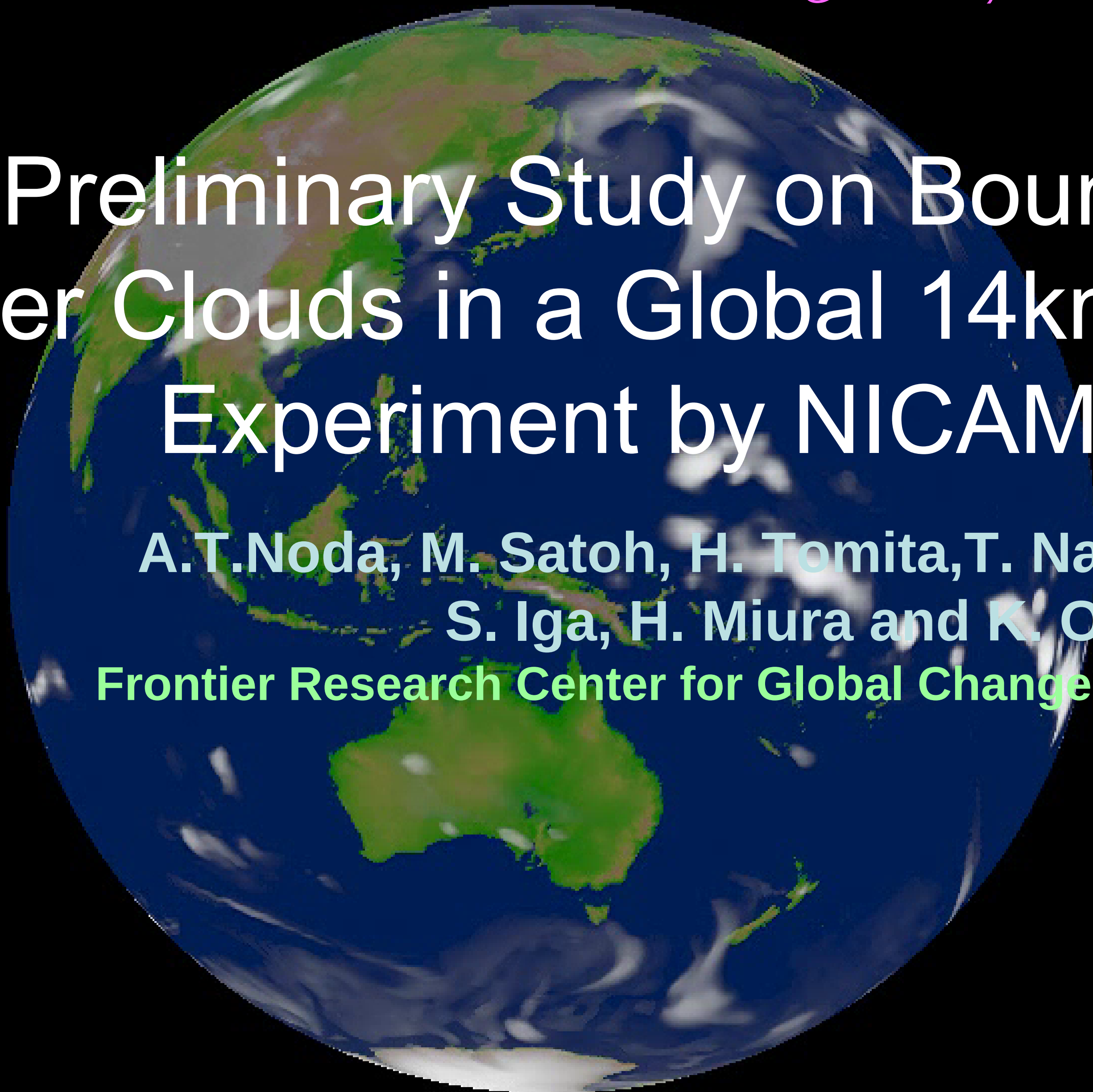
A Preliminary Study on Boundary-Layer Clouds in a Global 14km-mesh Experiment by NICAM

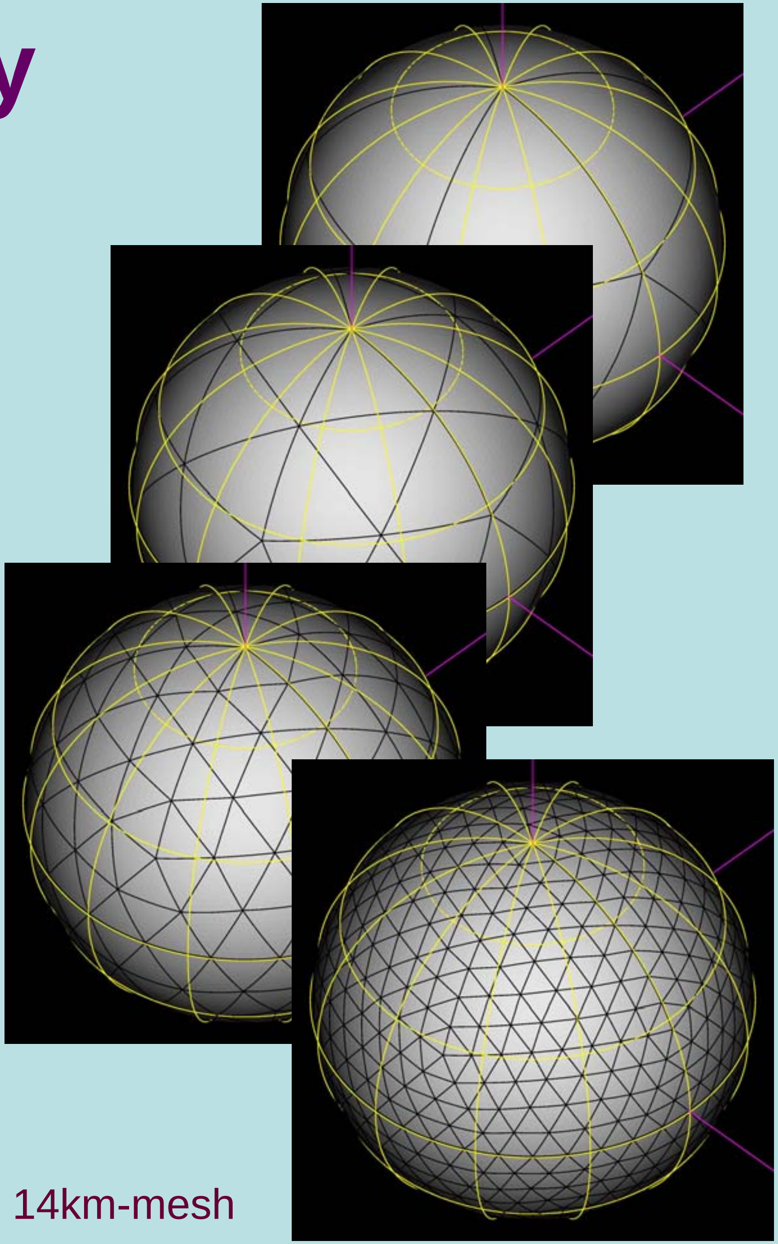
A.T.Noda, M. Satoh, H. Tomita,T. Nasuno, S. Iga, H. Miura and K. Oouchi
Frontier Research Center for Global Change, Japan



※OLR of 3.5km-mesh simulation by NICAM

History

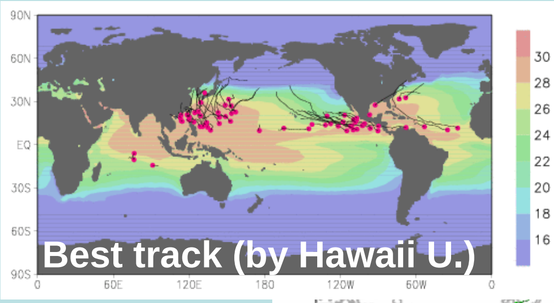
- Aqua planet experiment (+2K SST Exp.)
  - Convectively-coupled Kelvin waves
  - Change of general circulation and radiative budget as a global CRM/Deep convection-resolving model
- Perpetual July experiment (+2K SST Exp.)
  - Climatology of tropical cyclones
  - Change of general circulation and radiative budget as a global CRM/Deep convection-resolving model
- Typhoon on Apr 2004
  - Movement and development of depression and fine-structure
- MJO event on Dec 2006
  - Development process, dynamic structure, predictability
- …

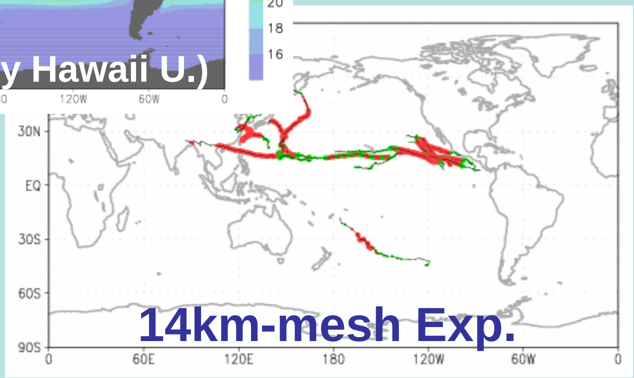


※Each simulation done by 3.5km, 7km and 14km-mesh

Series of NICAM experiments

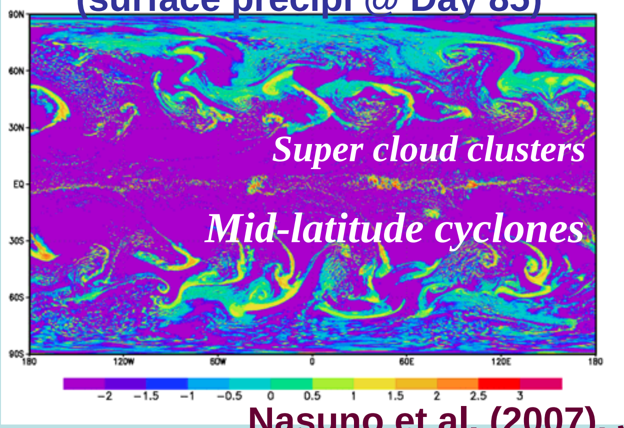
Tropical cyclones in Perpetual July Exp.





3.5km-mesh Aqua Planet Exp.

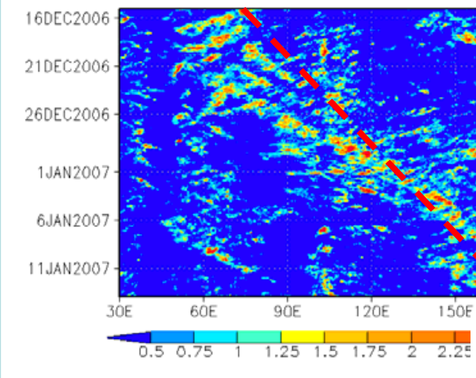
(surface precipi @ Day 85)



Nasuno et al. (2007), *JAS*

2006/12 MJO Exp.

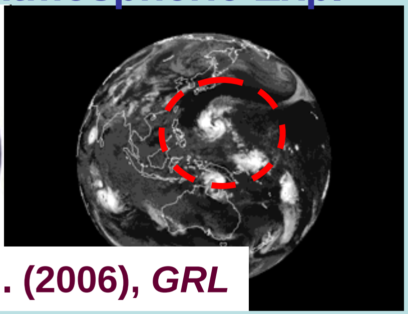
(Hovmellor-diagram of surface precipi.)



Miura et al., *Science* (accepted)

NCEP 7km-mesh NICAM

2004/04 Real Atmospheric Exp.



Miura et al. (2006), *GRL*

GSM 3.5km-mesh NICAM

Objective of new experiment

- Specific interest
  - Validation of intra-seasonal change in NICAM
    - BL cloud
    - Monsoon circulation
    - Tropical cyclone
- In this talk
  - In the first stage of
    - Basic structure of general circulation
    - BL cloud

Experimental Design

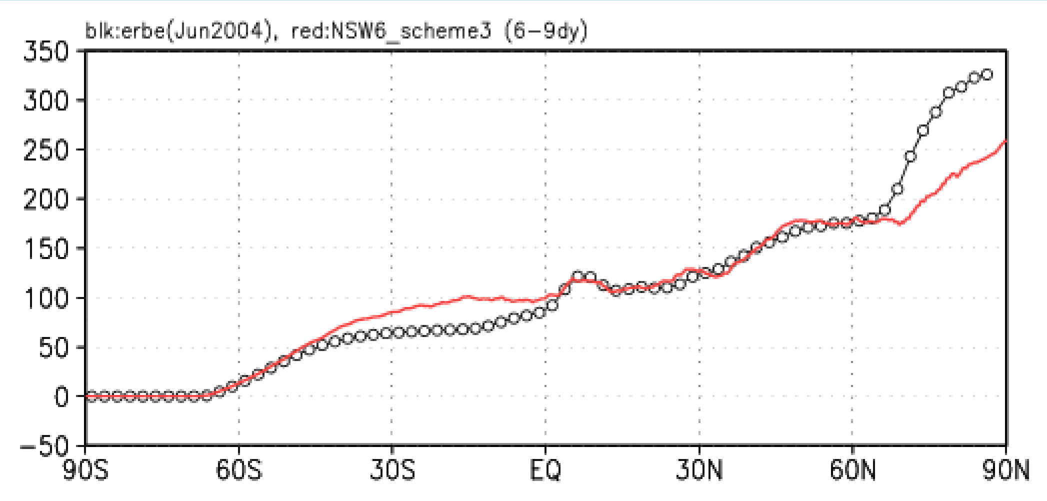
※About 11 hrs for 10-day experiment on the Earth Simulator (80nodes * 8prosessors)

Initialization	NCEP Global analysis on 00Z Jun 01, 2004
Nudging	None
Bottom boundary	Bucket model and Weekly Reynolds SST
Horizontal resolution	14km (in this talk) & 7km
Vertical resolution	Stretched grid (80m ~ 2.9km)
Cloud	Cloud microphysics ~~by Grabowski (1998)~~ by NSW6 (Lin-type 3-ice-class 1-moment scheme; Tomita 2007)
Turbulence	Improved version of Mellor-Yamada Level 2 with subgrid-scale condensation (Nakanishi & Niino 2004; Mellor and Yamada 1982) ※Not producing a partial cloud yet
Surface turbulent flux	Bulk parameterization by Louis (1979)
Radiation	MSTRNX (Nakajima et al. 2001; Sekiguchi 2004)
Integration period	2004/6/1 ~ 6/10 (at present) (planning a 3-month integration)

Movie (OLR)

General Circulation

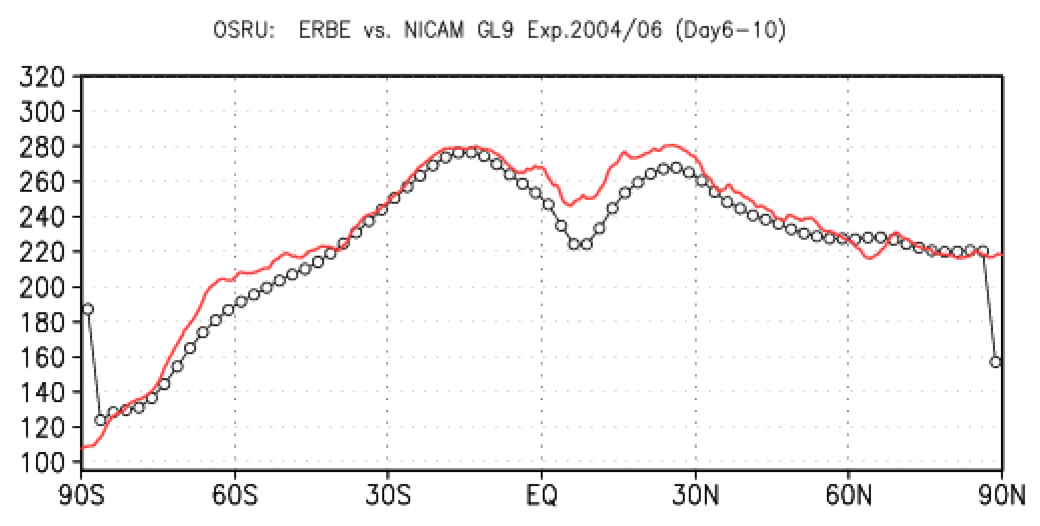
Radiation Budget
~ ERBE vs. NICAM ~



OSR

High OSR may come from high cloud amount accompanying baroclinic instability waves

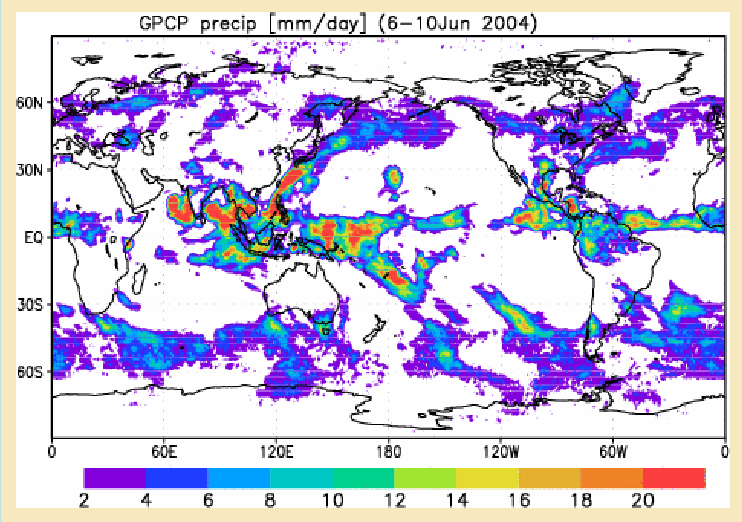
OLR



ERBE

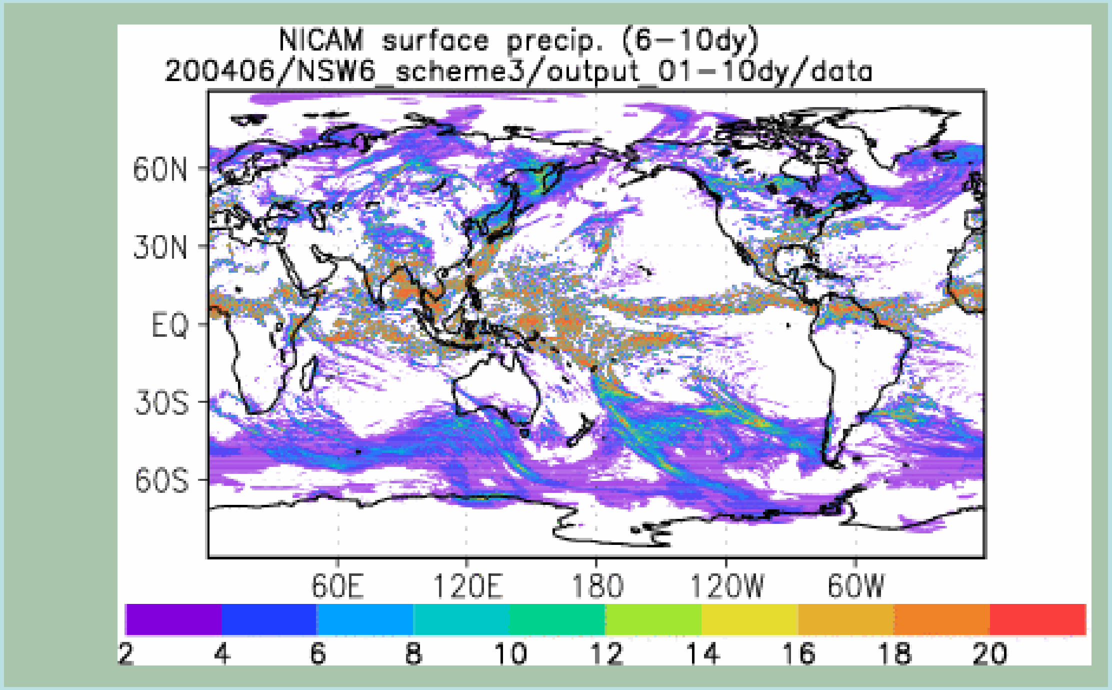
NICAM (6~10 June 2004)

Surface precipitation
~ GPCP vs. NICAM ~

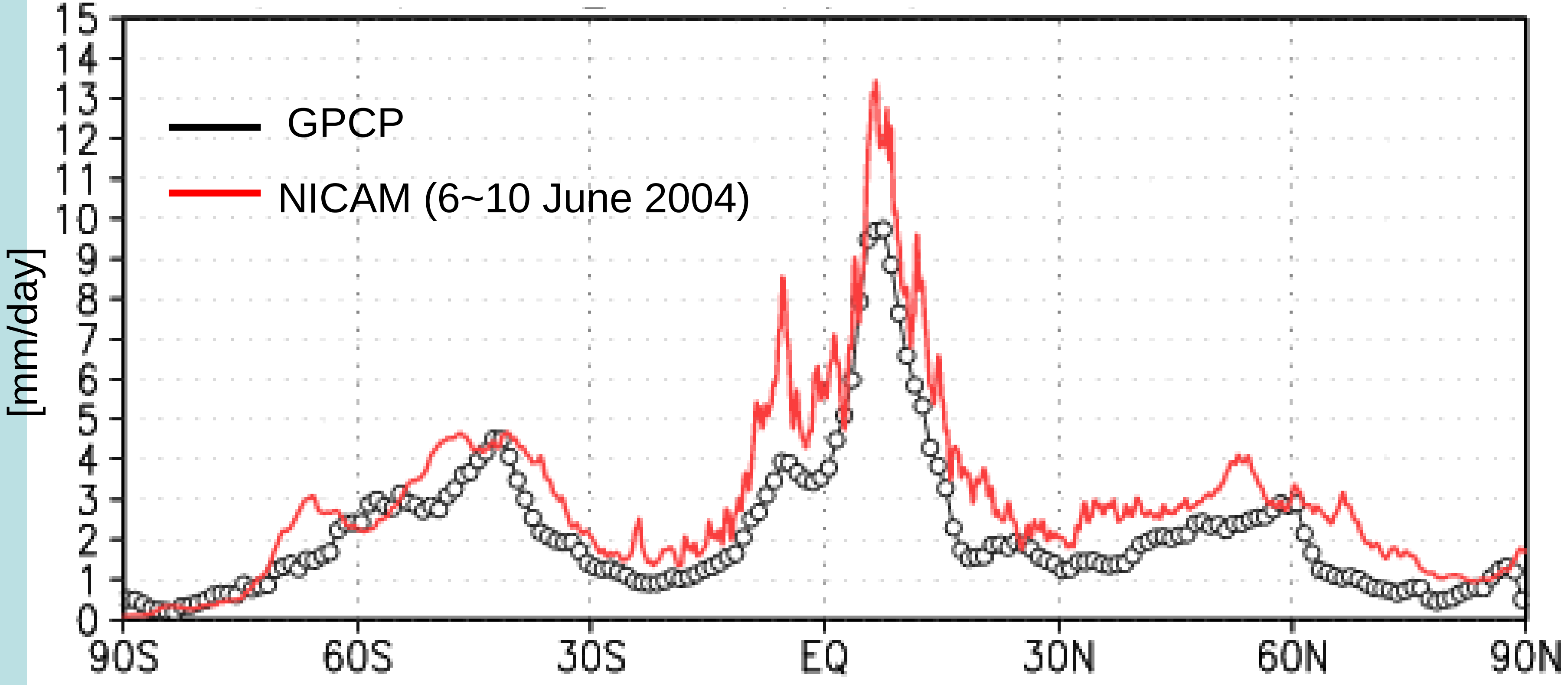


GPCP (June 2004)

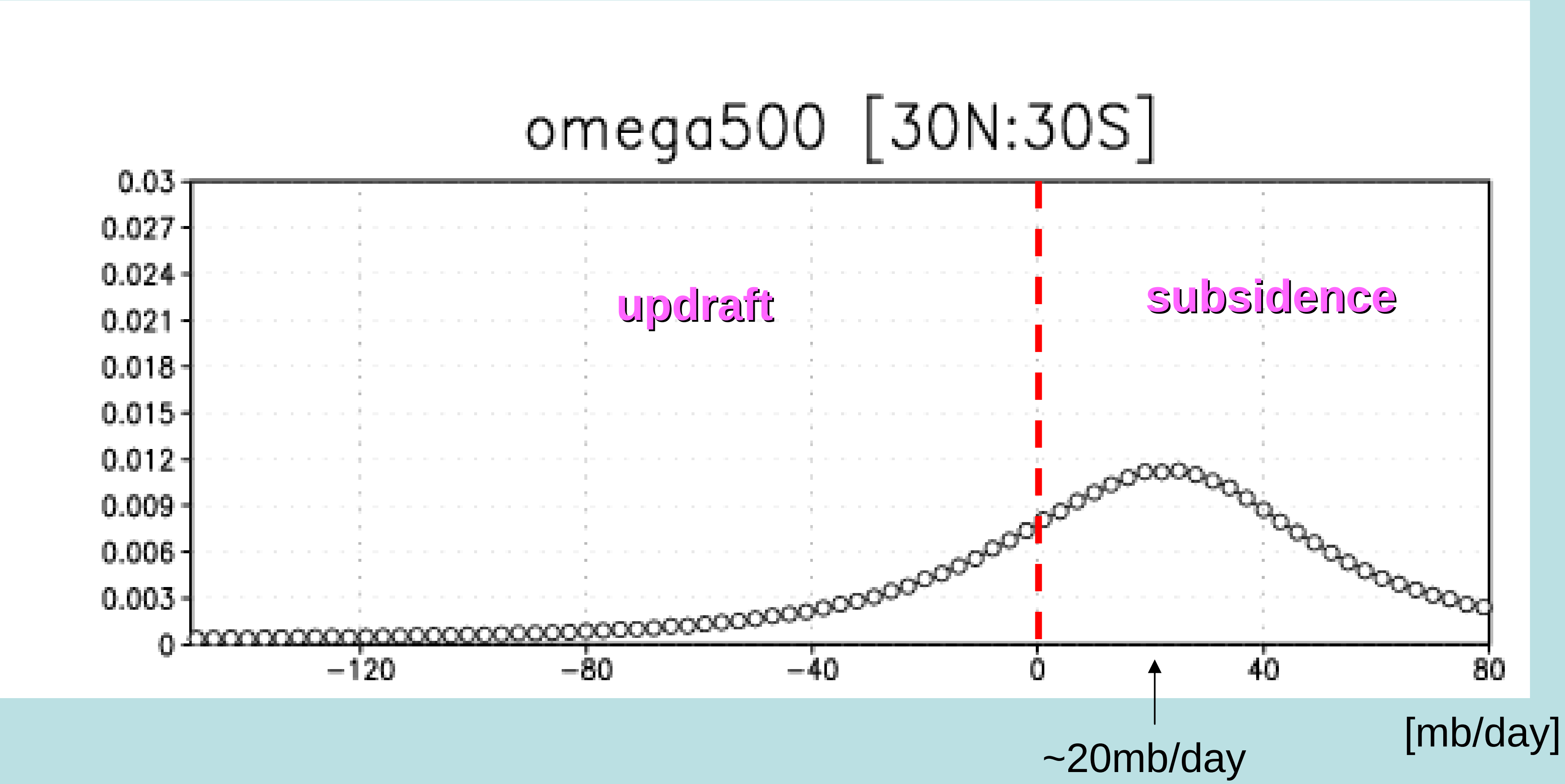
Spatial distribution looks nice
But, somewhat strong especially in tropics



Surface Precipitation
NICAM vs. GPCP

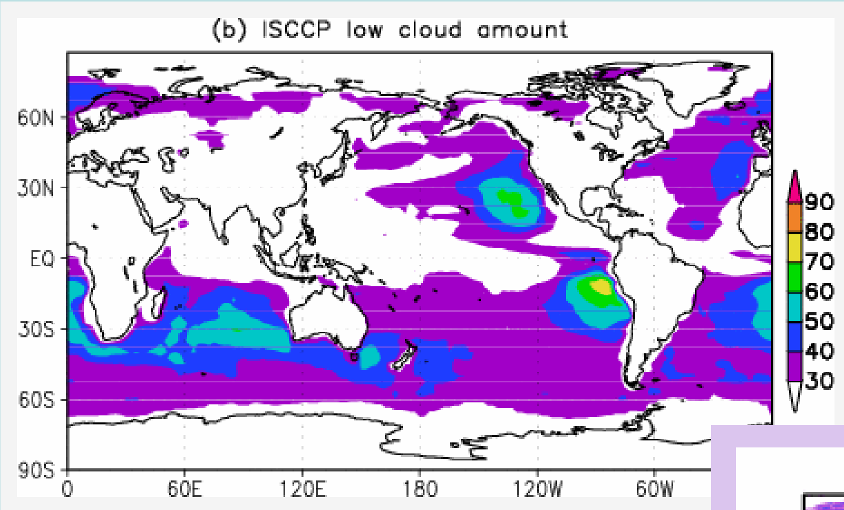


PDF of Vertical velocity (ω@500hPa) over subtropics and tropics



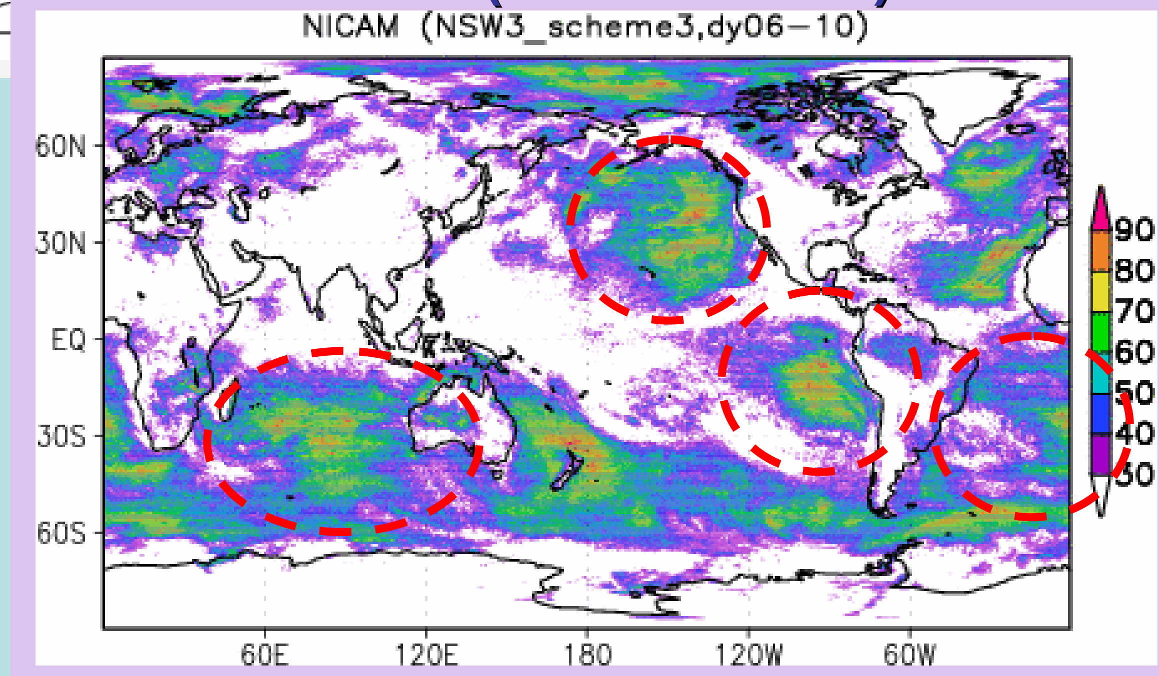
BL clouds

BL clouds over Glove



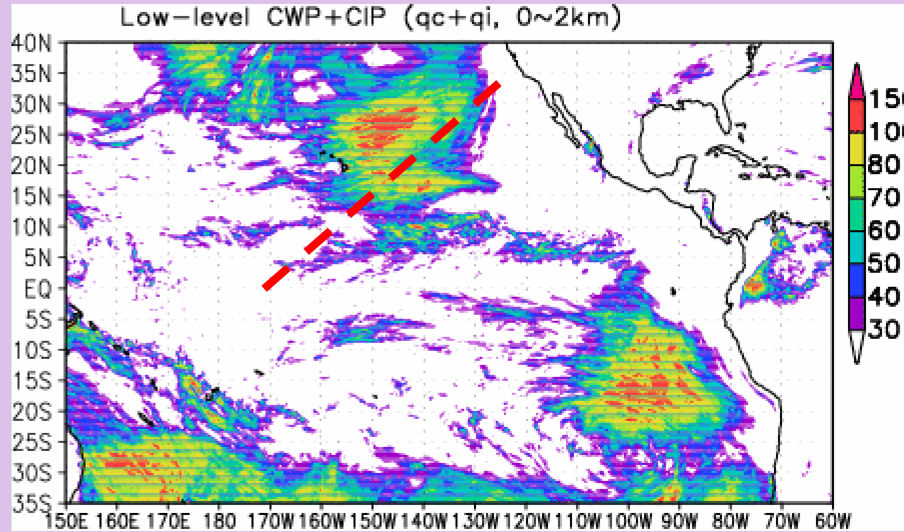
Climatology on June
(ISCCP Obs.)

ISCCP simulator in NICAM
(6～10 June 2004)

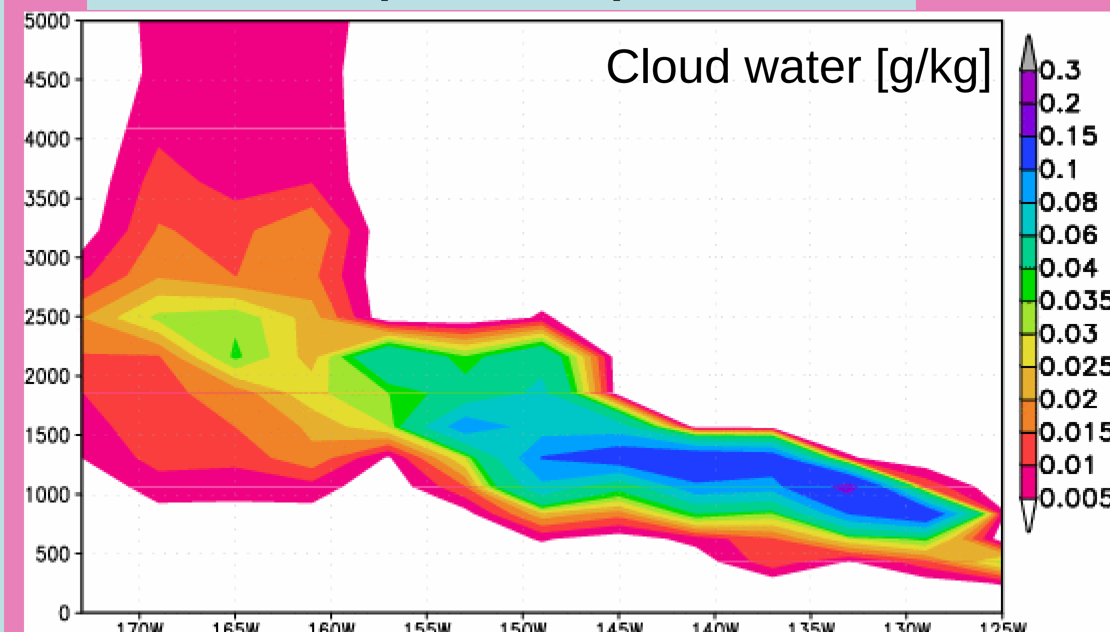


GPCI cross-section

※GPCI: GCSS Pacific Cross section Intercomparison

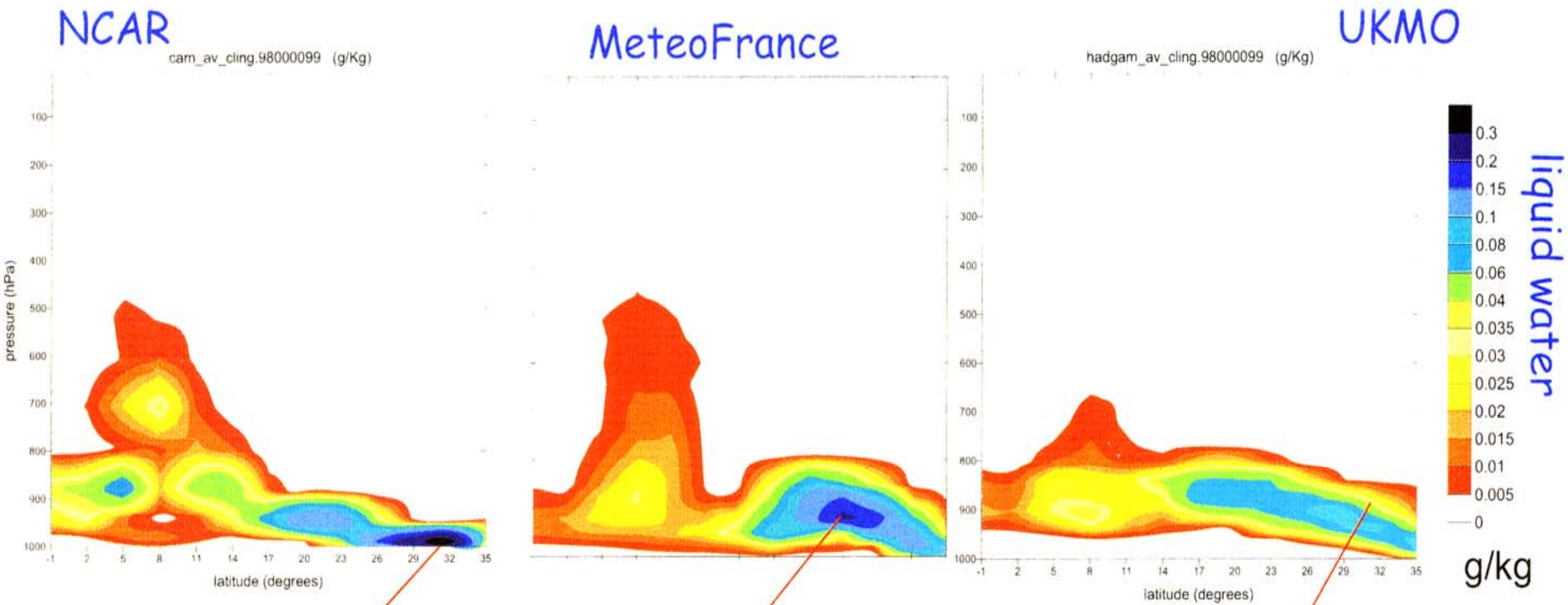


Spatial development of PBL cloud from subtropics to tropics



averaged over 6~10 June 2004

Mean GPCI liquid water crossection - JJA98



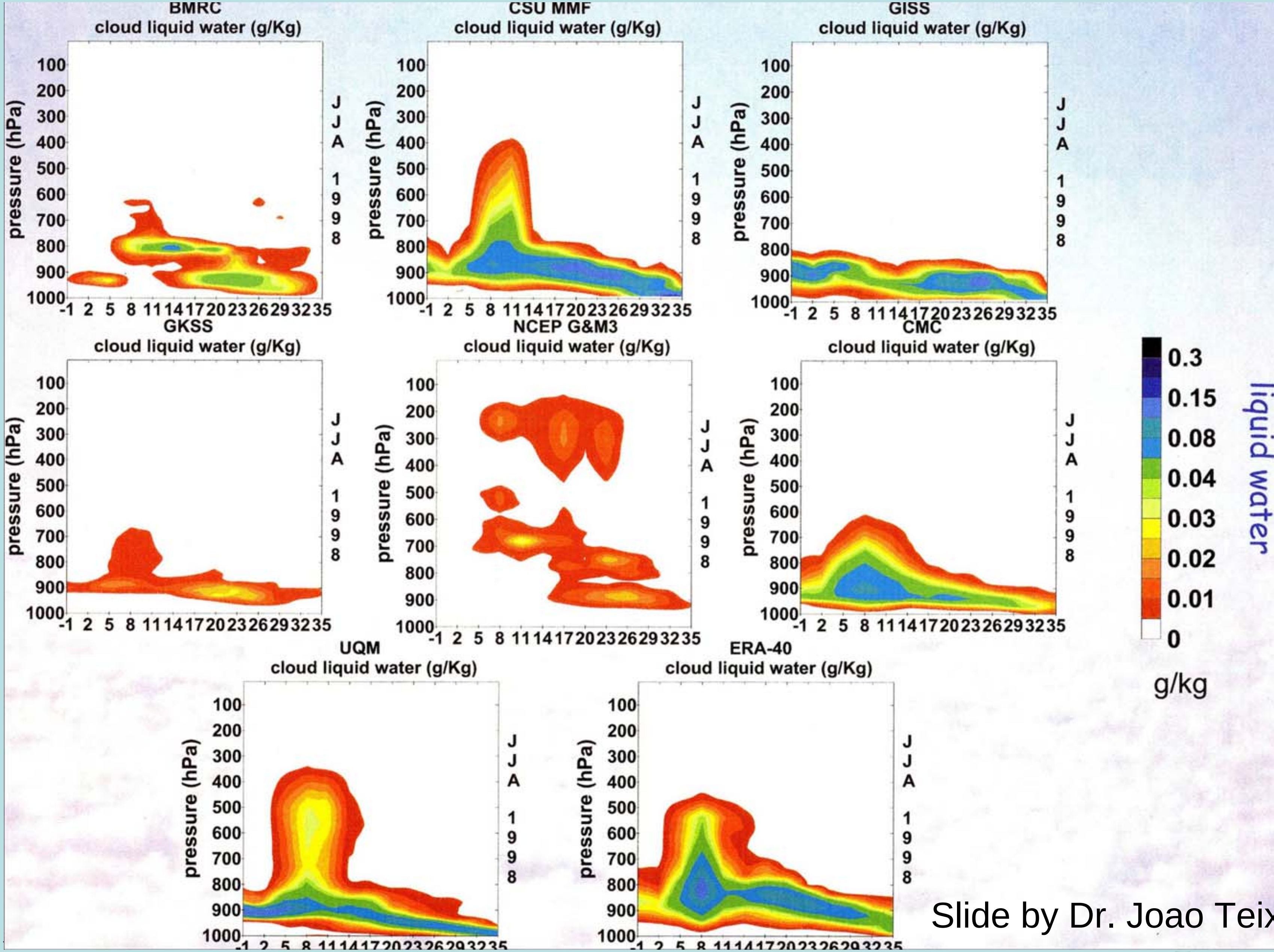
Too shallow -> fog

Is this too much liquid water?

How deep should the PBL be..?

We need observations of cloud and boundary layer (PBL) parameters: PBL height, liquid water,..

Slide by Dr. Joao Teixeira



Slide by Dr. Joao Teixeira

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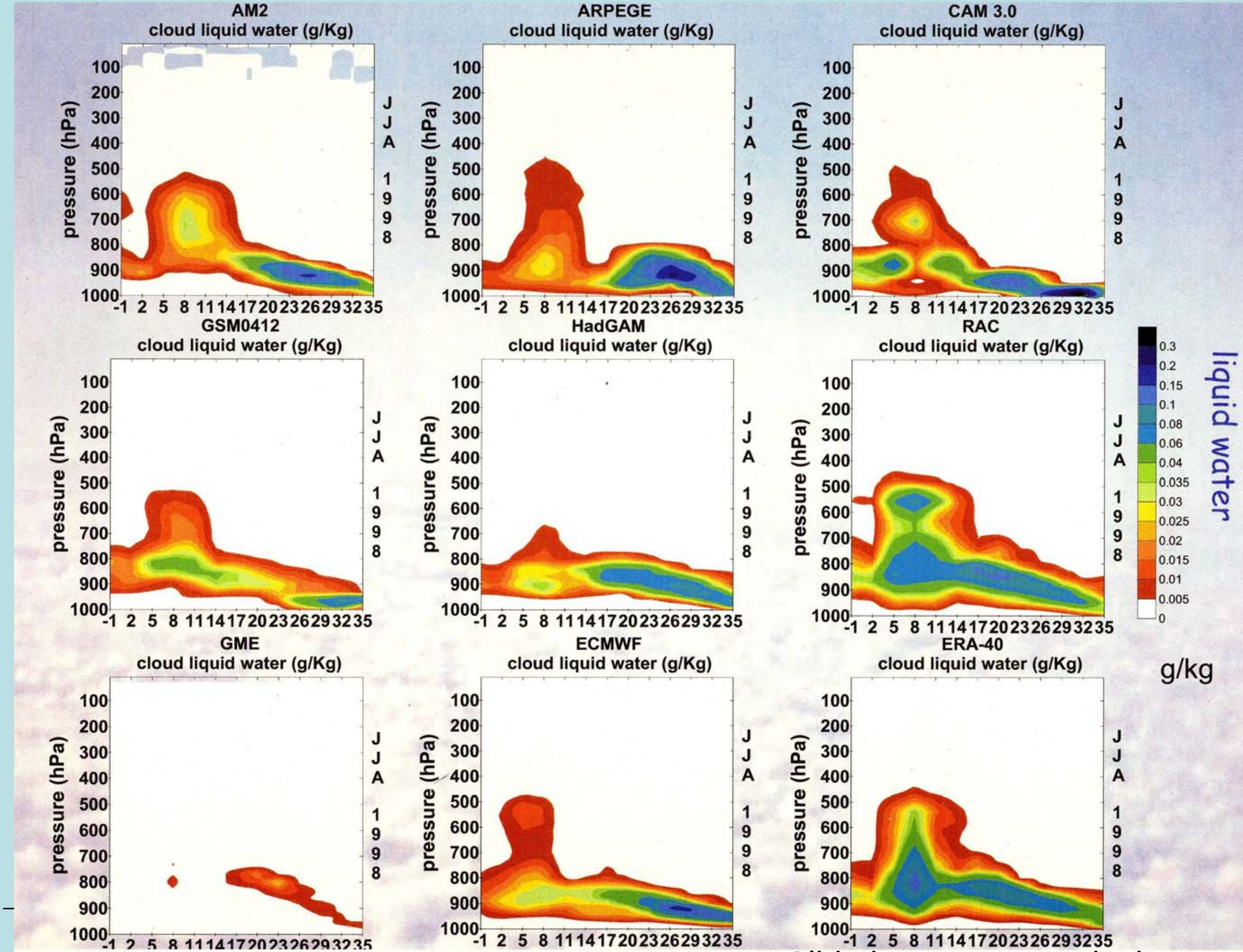
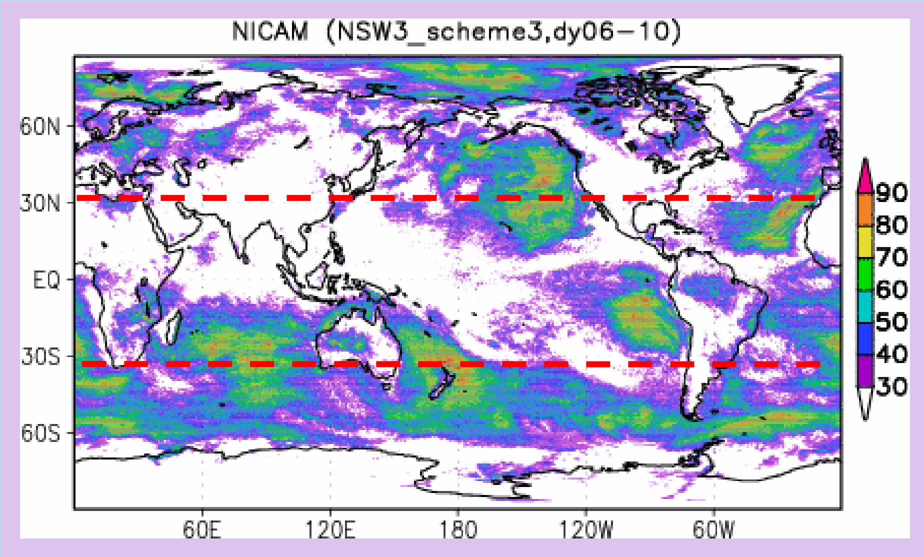


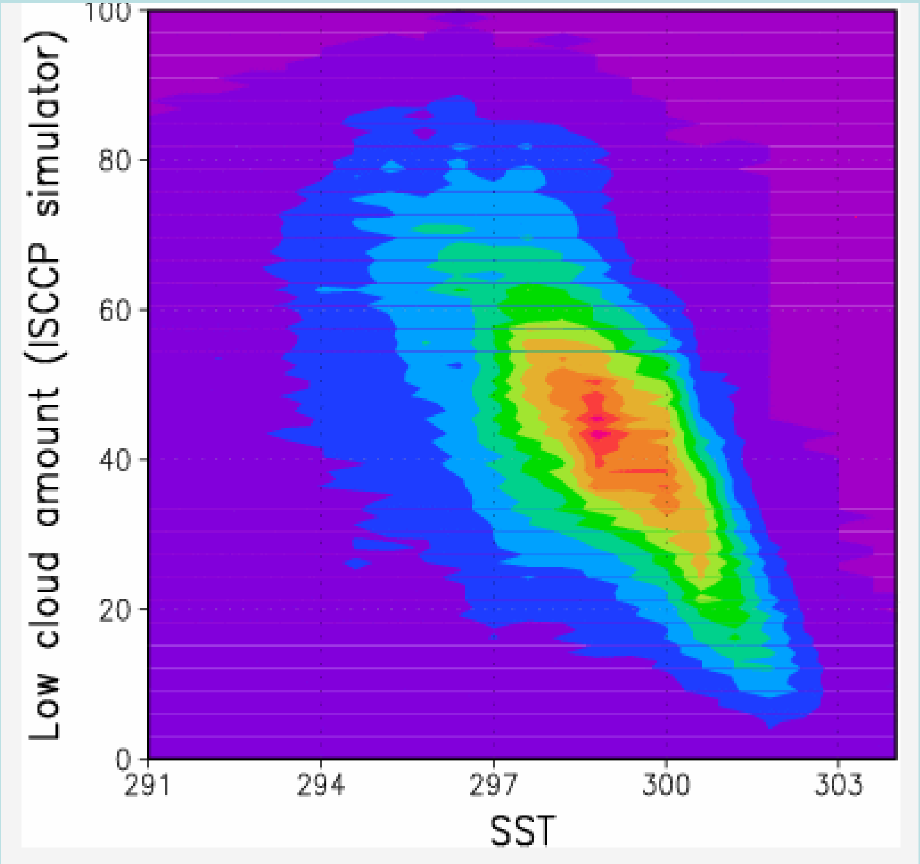
Slide by Dr. Joao Teixeira

Joint-PDF
SST vs. Low-cloud amount

30N ~ 30S

※14km-resolution





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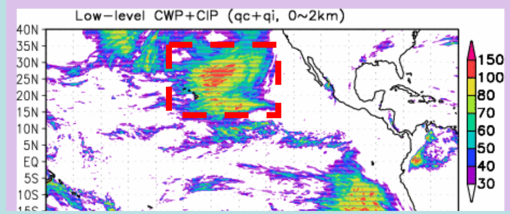
Diurnal variation

~ Stratocumulus off the coast of California ~



24hrs

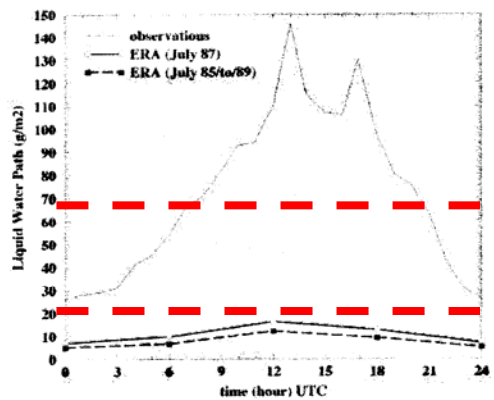
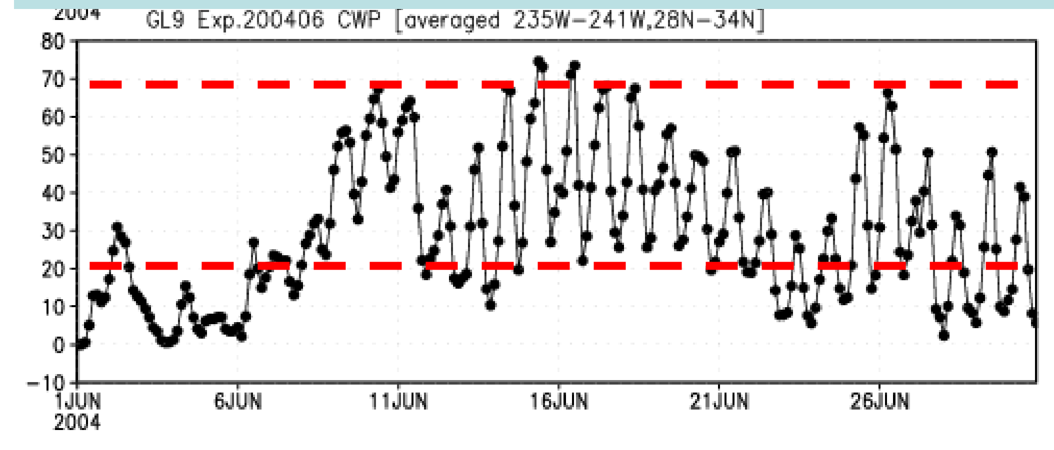


Figure 4.8: Mean diurnal variation of liquid water path: FIRE I observations from 1 to 19 July 1987 (thin line), July 1987 of ERA (thick full line) and July 1985/86/87/88/89 of ERA (dashed line) Duynkerke and Teixeira (2001).

Duynkerke and Teixeira (2001)

6/1 ~ 6/30 (30 days)



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Summery and Future

Summery

- Trying to examine an intra-seasonal change and climate of NICAM as a 14km-mesh (7km-mesh) global model
- BL cloud, which is essentially important for earth's climatology, in NICAM during the first 10 days looks nice so far
  - e.g., off the coast of California, Peru, Guinea, South-East of the Atlantic Ocean, South of Indian Ocean
  - Spatial development in the subtropics along the GPCI cross section
  - but, maybe too much along the mid-latitude

Future

- Improvement of physics (w.r.t BL process)
  - Treatment of the subgrid-scale condensation by BL clouds
  - Time-dependent turbulent closure for high-resolution models (7km, 3.5km-mesh models)
- Climatology and mechanism in NICAM (w.r.t. interaction in large- and fine-scale disturbances)
  - Diurnal variation of BL clouds
  - Role of large-scale circulations on BL clouds
  - Relation of BL processes to tropical cyclones and monsoon circulation
- Sensitivity experiments
  - What is a key to reproduce the BL cloud?
  - Dependency on resolution (particular interest in influence of the vertical grid space of BL)

- トラックの解析は最近手法を変えましたので、そちらをお送り致します。
  現実と同じz=10mの風速が17m/sというしきい値を用いるようにしました。
  ただし微小擾乱や基本場の風を除くため、軸対象成分の風速を用いています。

  図の見方
  ・ 丸印は6時間ごとの位置
  ・ 大きな丸は風速17m/s以上
  ・ 赤色は2K以上の暖気核を中層に持つもの; 緑はそれ以外

  熱帯低気圧の定義
  ・ 風速17m/sと暖気核の条件を2日以上持続
  ・ 30度より低緯度に発生したもの

  添付ファイル
  ・ 全ての低気圧のトラック
  ・ 熱帯低気圧のみのトラック

  他に必要な図がありましたら遠慮なく言って下さい。
  非静力学WSの時よりは解析が進んでいますので、
  最新版の図をお送りできます。(来週の札幌で発表)

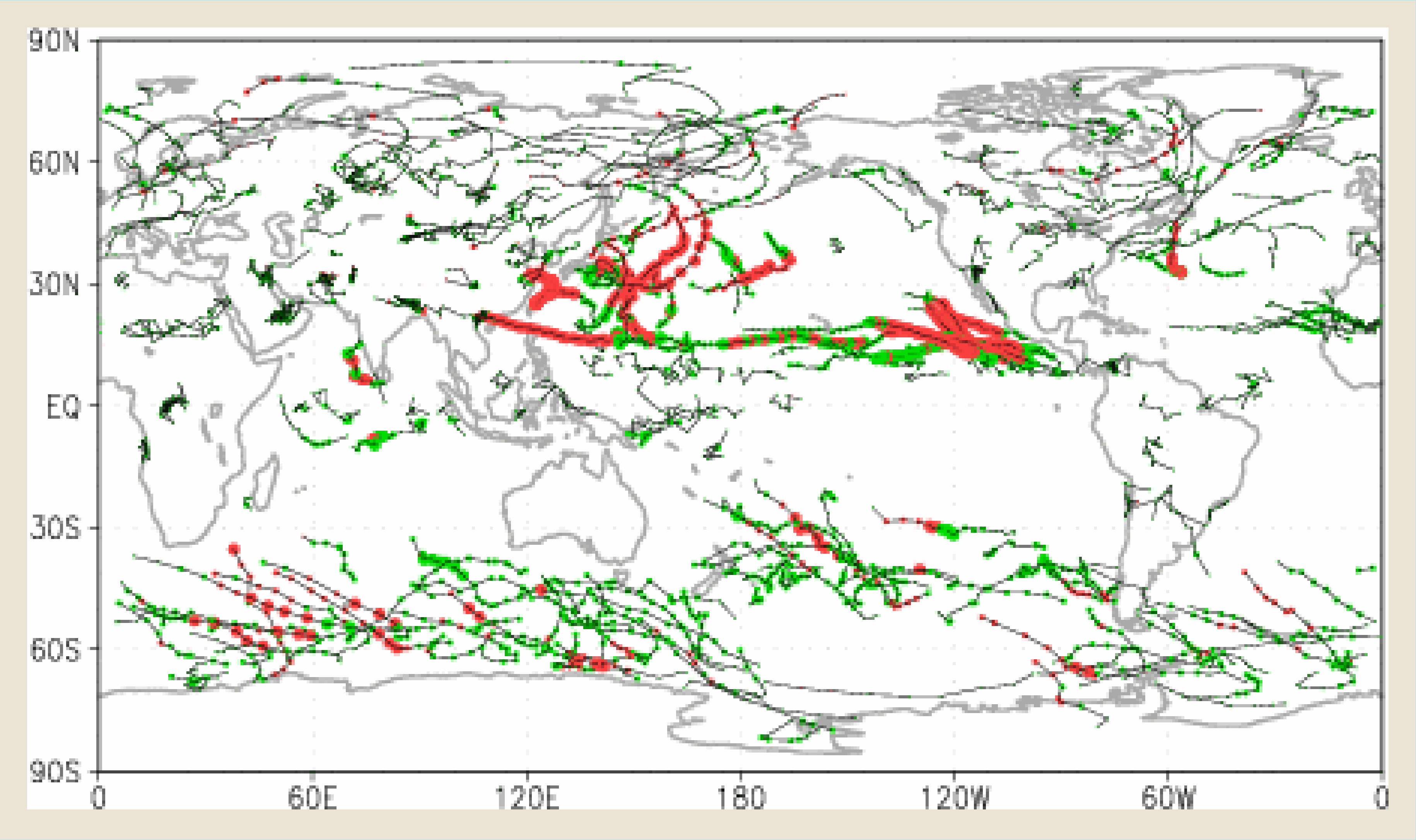
  1996-2000年の7月(150日分)の現実の分布を参考に送ります。
  北太平洋の西部と東部の発生分布が再現されていることがわかります。
  細かいことを言いますと、西部ではフィリピン東の発生が少ないです。

  発生数はNICAMの方が30日分ですので、1/5であれば良いわけですが、
  やや多めに再現しているように見られます。

  ベストトラックはハワイ大学のデータを使用
  色はSSTです。

MJO

- 12/15計算開始、12/20位にインド洋沖で発生
  - それ以前の擾乱の起源は不明
  - 12/16~12/21の強い降水は台風
- SST勾配（インド洋東部、西部）と水蒸気移流が効いている
  - 西側でSSTが高いと低気圧偏差となり東から高湿度空気の移流が強化され、対流が発達
- 中澤さんの積雲スケールの西進は見られない
  - 衛星、TRMMは上空の風に流されたアンビルからの降水を見ている？
  - 西進する必然性は無い？
- ～5m/s
- 12/15~12/30位の対流が弱めの頃にはケルビン波の速度の伝播が卓越
- 内部の積雲スケールの擾乱は10m/s
- 高解像度のメリットは冷気流に伴う下層収束で雲が立つなど、ローカルに見れば現実的な相互作用が起こる
  - 従来パラでは下層で暖湿であるだけで熱を解放
  - 大規模スケールでは？



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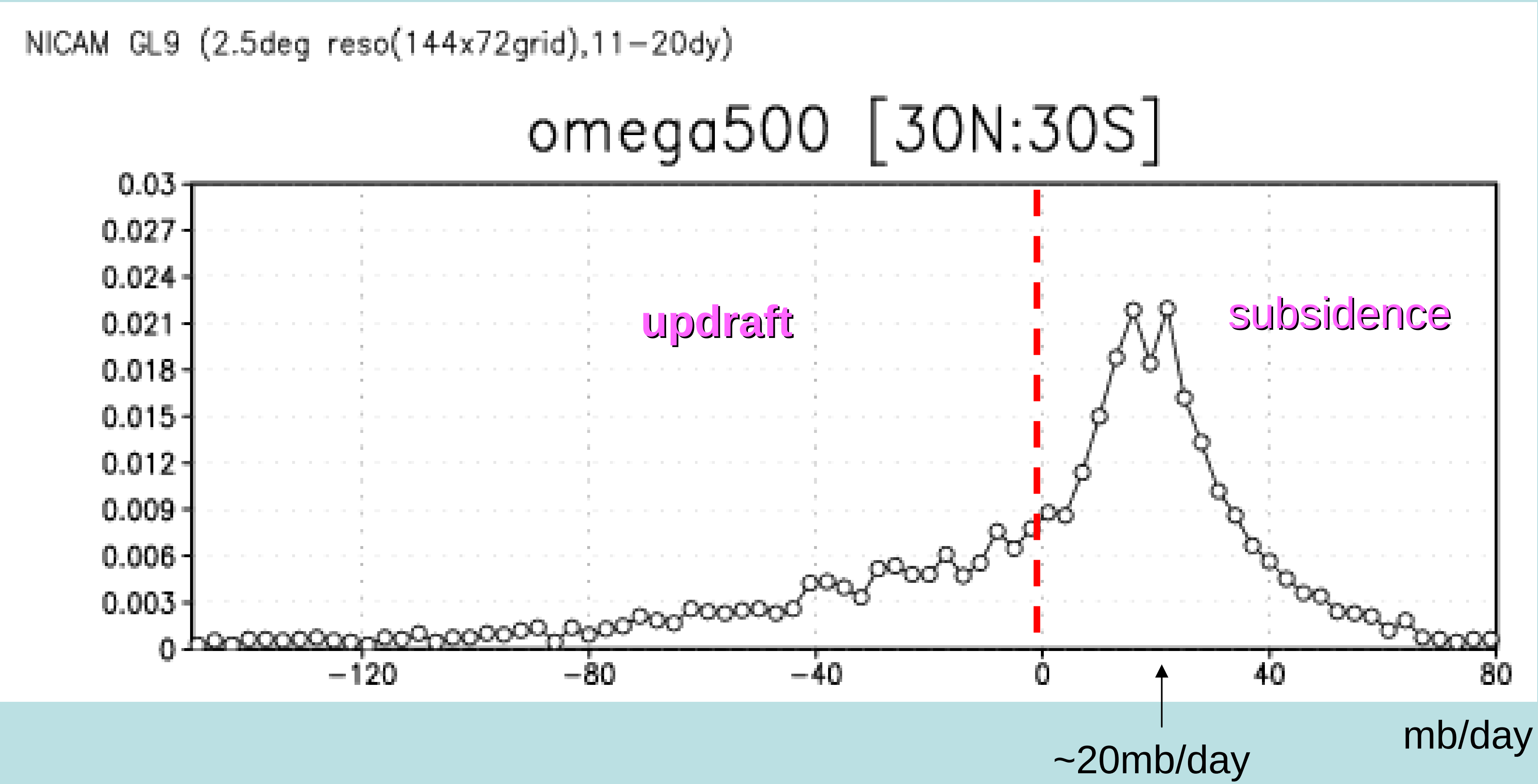
PDF of Vertical velocity over subtropics and tropics



改良版M-Yスキーム

- 改良点
  - 安定度を考慮した乱流長さスケール
  - 気圧相関項の浮力効果を考慮
  - クロージャー定数の改訂

$$\frac{1}{L}=\frac{1}{L_s}+\frac{1}{L_T}$$

$$L_s=\kappa z$$

$$L_T=0.1\frac{\int_0^\infty qzdz}{\int_0^\infty qdz}$$

→

$$\frac{1}{L}=\frac{1}{L_s}+\frac{1}{L_T}+\frac{1}{L_B}$$

$$L_s=\begin{cases} kz/3.7 & 1\le\varsigma \\ kz(1+2.7\varsigma)^{-1} & 0\le\varsigma<1 \\ kz(1-100\varsigma)^{0.2} & \varsigma<0 \end{cases}$$

$$L_T=0.23\frac{\int_0^\infty qzdz}{\int_0^\infty qdz}$$

$$L_B=\begin{cases} q/N & \partial\Theta_V/\partial z>0,\ \varsigma\ge 0 \\ \left[1+5(q_c/L_T N)^{1/2}q/N\right] & \partial\Theta_V/\partial z>0,\ \varsigma<0 \\ \infty & \partial\Theta_V/\partial z\le 0 \end{cases}$$

q（=√2×TKE）は乱流速度スケール
qc (=g/Θ<wθ>_s L_T)^0.3) は対流速度スケール

Nakanishi & Niino (2004)