Joint Simulator for Satellite Sensors
J-Simulator

Atmosphere and Ocean Research Institute
The University of Tokyo

Joint-Simulator利用ワークショップ
2013年1月21日、東京大学本郷小柴ホール

Joint-Simulatorの概要とNICAMへの利用

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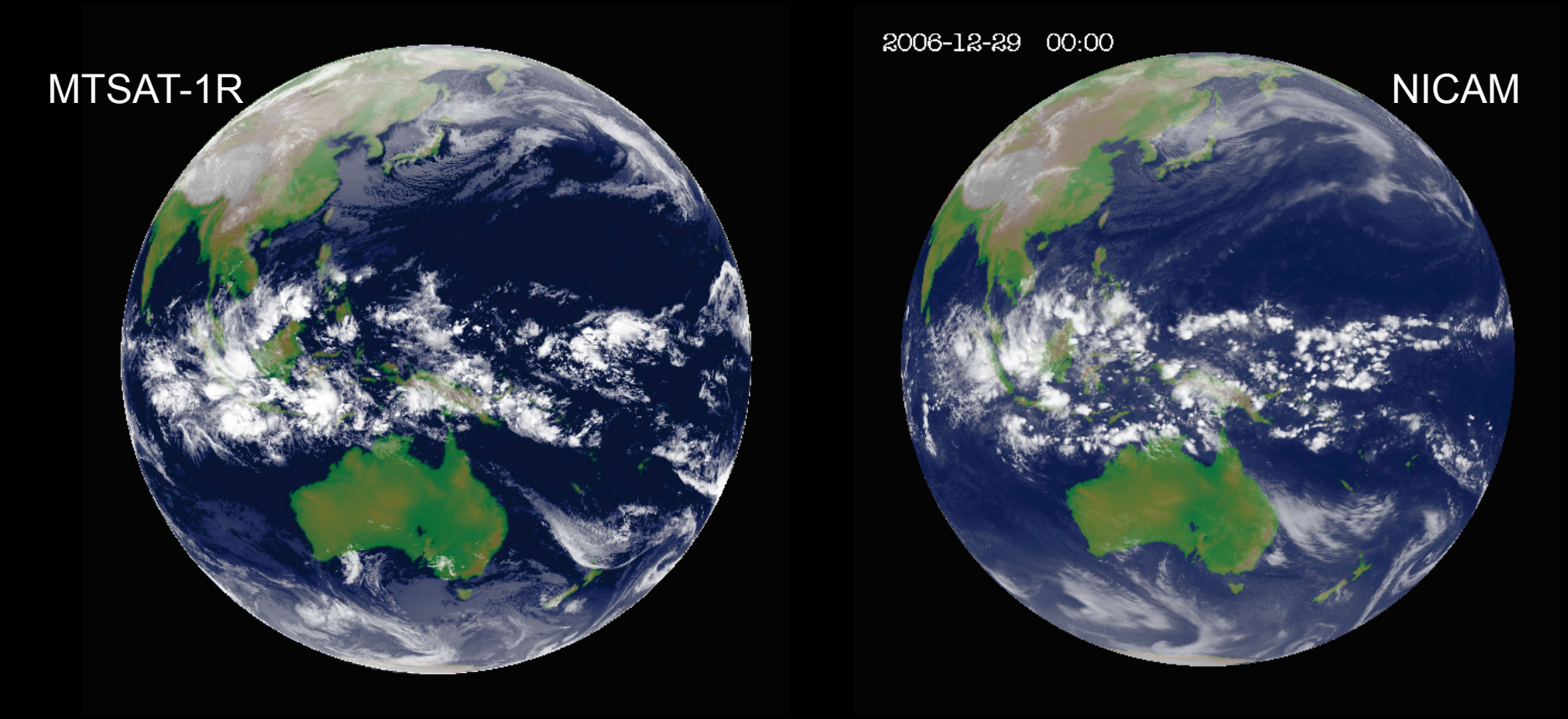
内容

- 衛星シミュレータとは
- Joint-Simulator 概要
- NICAMの雲評価例
- 今後の予定

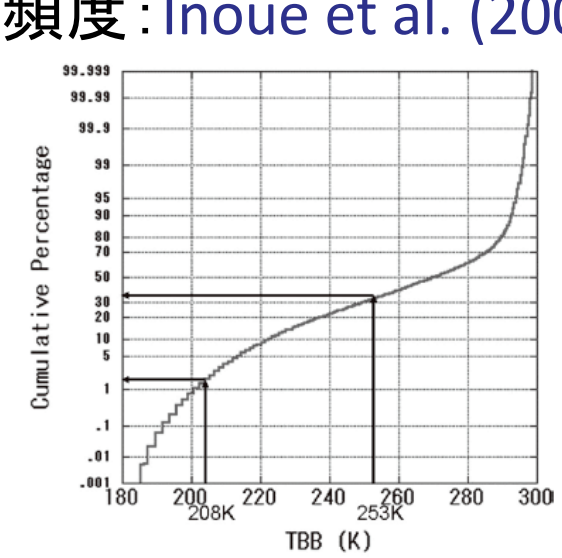
3.5km-mesh NICAM simulation

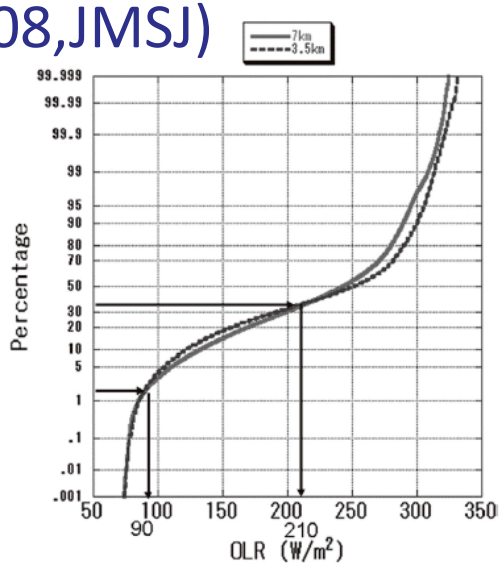


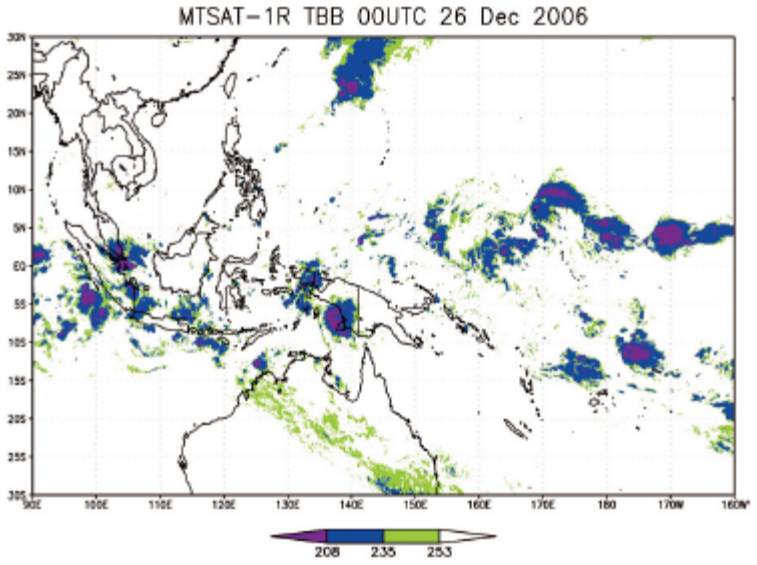
Miura et al. (2007,Science)

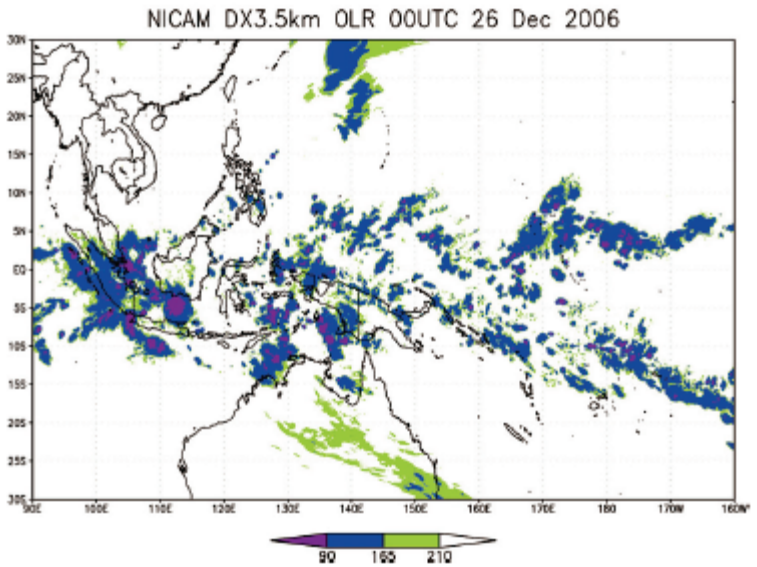
OLR とTBB との対応

- OLR = TBB^4: Very simple method
- 対応する頻度 : Inoue et al. (2008,JMSJ)





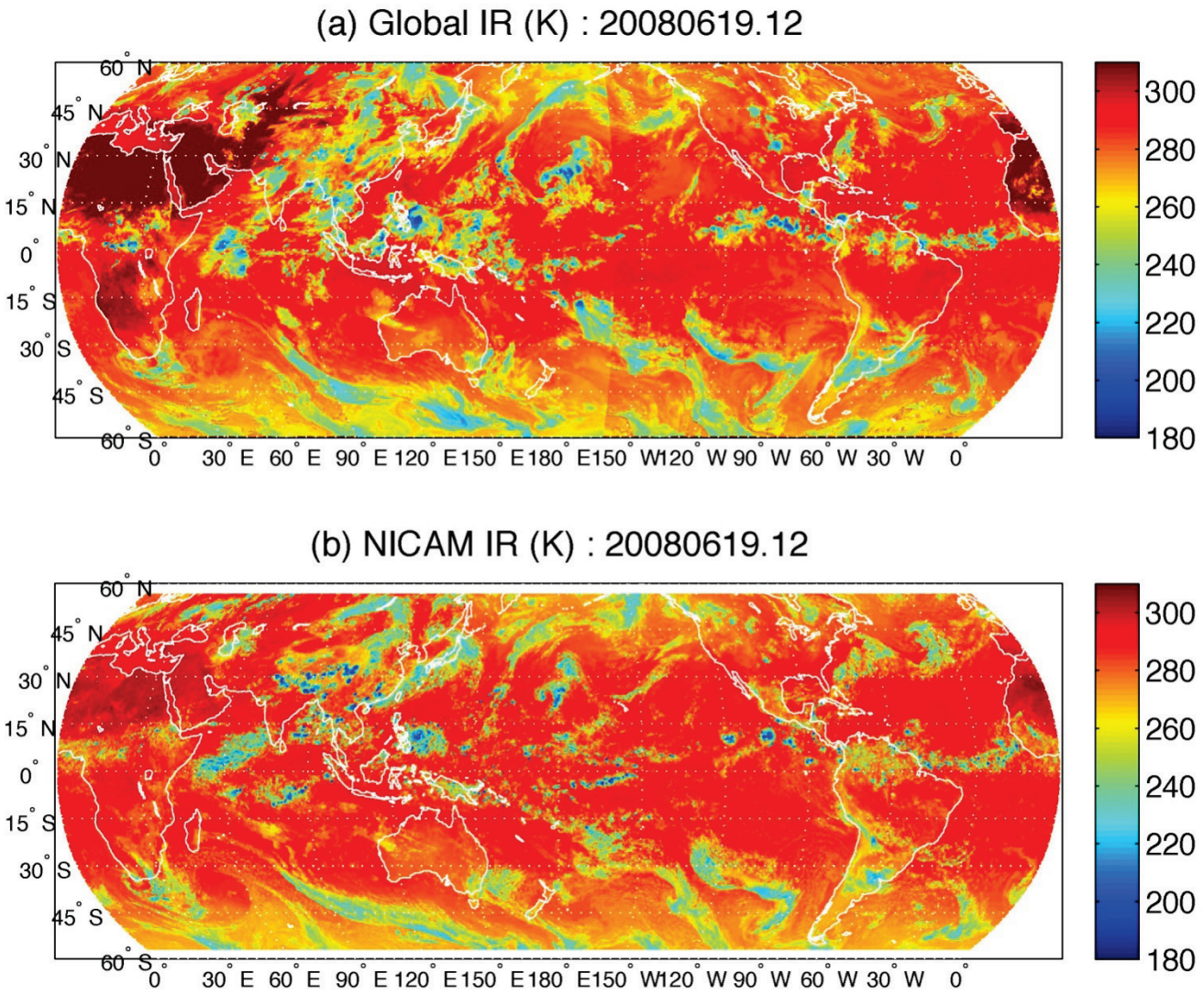




IR (10.8 μm) brightness temperature Joint-Simulator の適用例

(a) MTSAT (MRI, Japan; Chiba Univeristy, CEReS)+ globally-merged IR (CPC, NOAA)

(b) RSTAR
[Nakajima and Tanaka 1988]
[Sekiguchi and Nakajima 2008]



Realistic horizontal distribution of clouds are simulated.

- The horizontal distribution of clouds is well simulated, especially in southern hemisphere.
- The marine warm clouds off the coast of Peru, Australia, and Madagascar are also simulated well.

- The cloud organization appears different: simulation has less spread of detrainment in the tropics.
- The $T_{b,\,sim}$ of convective clouds tends to be smaller than the $T_{b,\,obs}$ over Himalaya and in the east.

衛星シミュレータとは?

Masunaga et al. (2010), BAMS

The increasing variety of satellite sensors has greatly expanded the applicability of satellite data, particularly when different sensors are combined to exploit the information content beyond the capability of an individual sensor.

A need for multi-sensor satellite simulator with self-consistency and targeted for meteorological application.

Satellite Data Simulator Unit

Evaluation of aerosol-cloud models

The uncertainty can be studied easily with the forward approach.

Algorithm development

Retrieval schemes, data assimilation, OSSE.

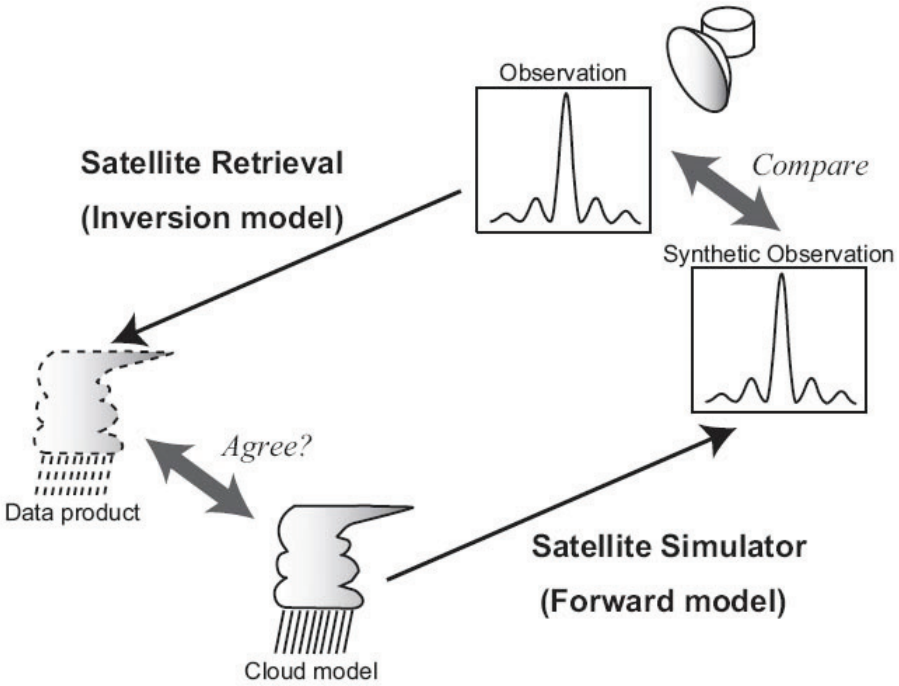


Fig4. Masunaga et al. (2010)

衛星シミュレータ

- ISCCP simulator: Klein and Jacob (1999)
  - *International Satellite Cloud Climatology Project*
- COSP: for CMIP5 (Bodas-Salcedo, 2011,BAMS)
  - *the CFMIP Observations Simulator Package*
- RTTOV: Operational Centers
  - *Radiative Transfer for TOVS (top operational vertical sounding)*
- SDSU: Masunaga et al.(2010,BAMS)
  - *Satellite Data Simulator Unit*
- Goddard-SDSU: T. Matsui
- Joint-Simulator: Hashino et al.(2013,JGR,in revision)
- ECSIM: European version版のECARE simulator
- Simulator portal: https://sites.google.com/site/satellitesimulators/

Joint Simulator for Satellite Sensors
J-Simulator

Joint-simulator (Joint Simulator for Satellite Sensors)

- Simulate EarthCARE observations from Cloud Resolving Model (CRM) outputs.
- Built on Satellite Data Simulator Unit (SDSU) (Masunaga et al. 2010, BAMS), specifically NASA Goddard-SDSU (NASA-open source http://opensource.gsfc.nasa.gov/projects/G-SDSU/index.php)
- Target: validation and improvement of aerosol-cloud microphysical schemes in cloud resolving models
  - Has an universal interface that can be applied for various cloud microphysical outputs
    - For Global CRMs as well as regional CRMs.

      e.g., NICAM, WRF, GCE, etc.
  - Provide diagnosis tools and data set

EarthCARE Active SEnsor Simulator (EASE)

Okamoto et al., 2007, 2008 JGR, Nishizawa et al., 2008 JGR

J-simulator available by requests; see http://www22.atwiki.jp/j-simulator/

Summary: Joint-Simulator development

Various 1D plane-parallel simulators available

- Visible and infrared imagers
  - ✓ RSTAR (Nakajima & Tanaka 1986, 1988)
- Microwave radiometers and sounders
  - ✓ Kummerrow (1993)
- Radars
  - ✓ EASE (Okamoto et al. 2007, 2008; Nishizawa et al. 2008)
  - ✓ Masunaga & Kummerow (2005)
- Lidars
  - ✓ EASE
  - ✓ Matsui et al (2009)
- Broadband radiometers
  - ✓MSTRN X (sekiguchi & Nakajima 2008)

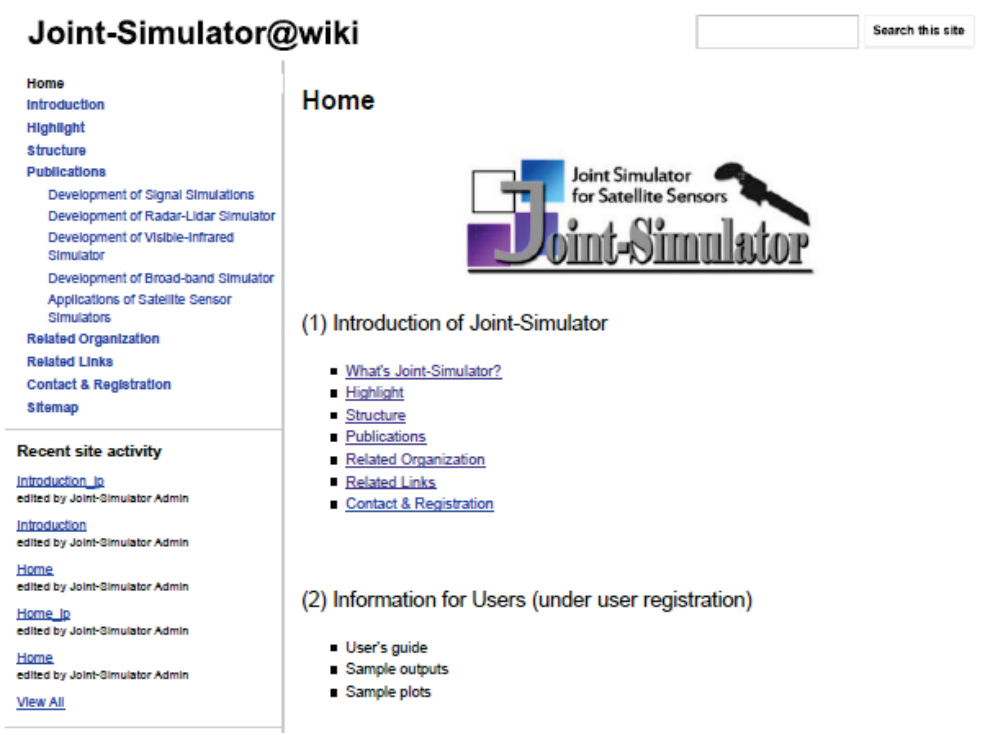
← Single scattering library for non-spherical particles is available for EASE.

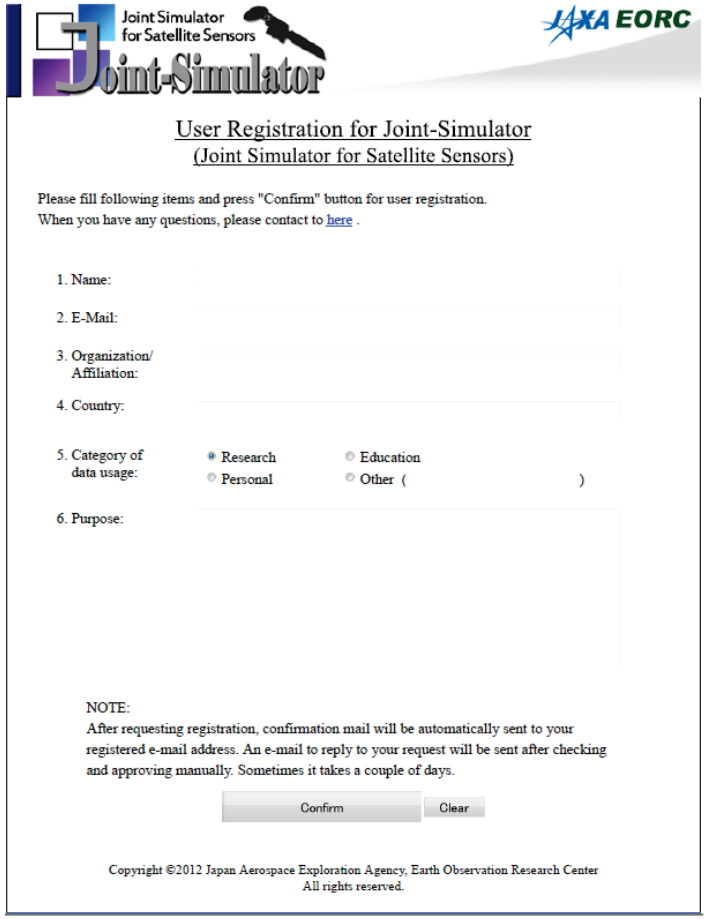
Universal interface for CRMs and cloud microphysical schemes has been developed.

- Input data format is netCDF.
- applied to NICAM, NICAM-SPRINTARS, JMA-NHM+ACBM, WRF-CHEM
- Particle size distribution, mass-dimensional relationship, and fall velocity are easily specified with a namelist.
- Parallel-computation is available.

Joint-simulator wiki

- Joint-simulator is available by requests
- https://sites.google.com/site/jointsimulator/





Joint-simulator development/validation

JAXA/EORC

J-simulator model evaluation
Satellite data processing (RESTEC)

Present data set

A-train
MODIS (spectrum)
CERES (Broadband)
CloudSat
CALIPSO

TRMM
TMI
PR

AMSR
MODIS

Geo
IR
VIS

Future missions' data set

E-CARE

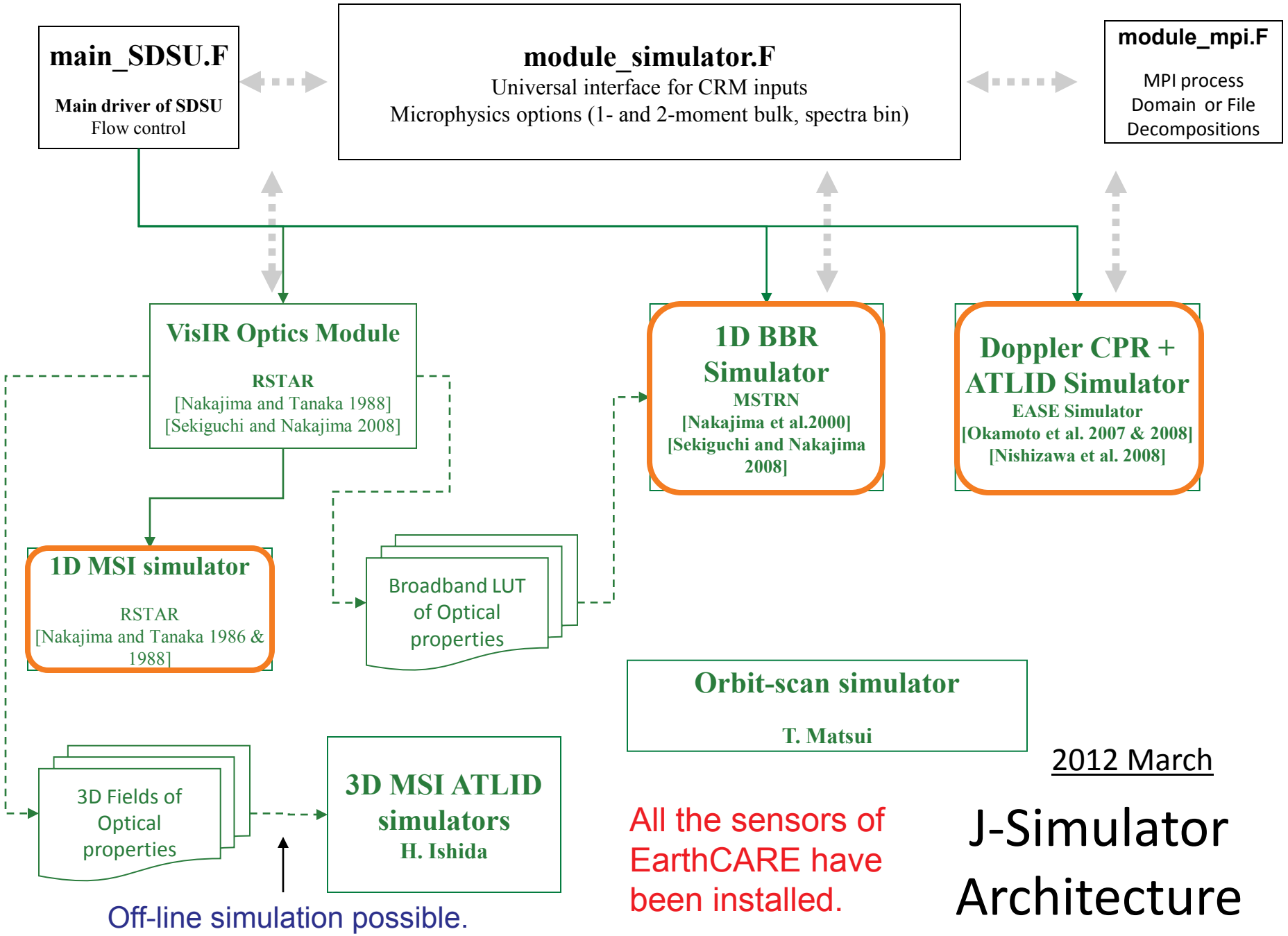
GPM

GCOM-W/C

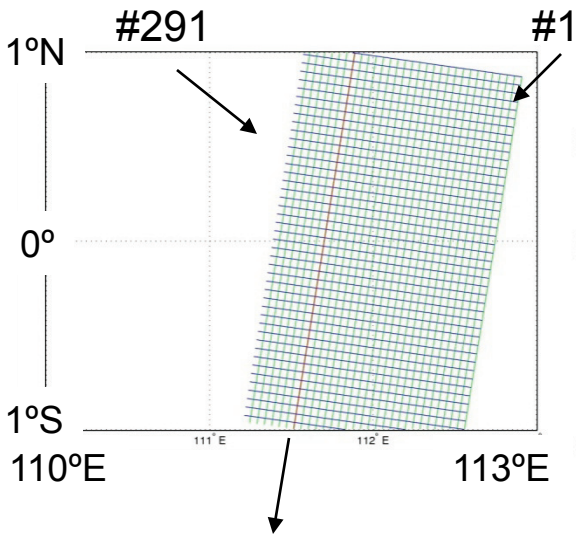
E-CARE project

Joint-simulator devlopment/integration

Integration of forward models
I/O modules
Generalized interface
PSD/Ice scattering libraries
Orbital simulators
Parallelization
Diagnosis output modules

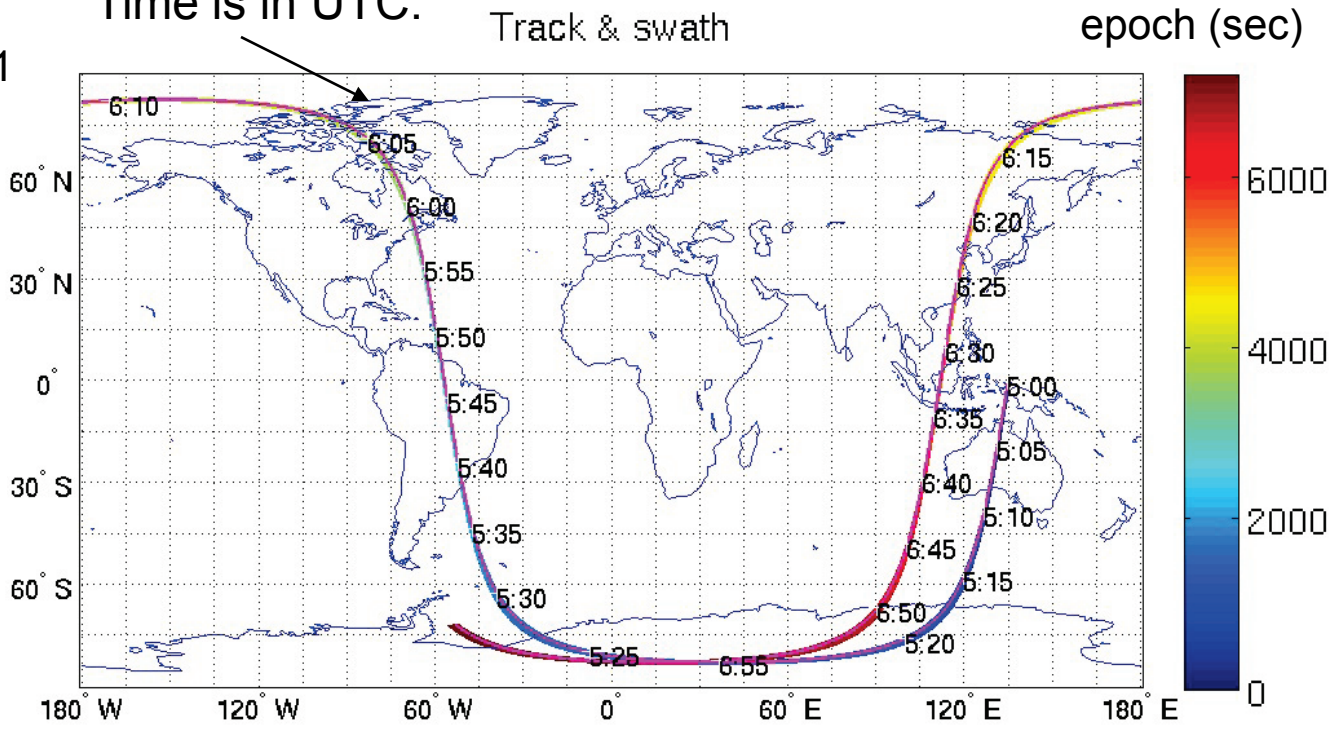

main_SDSU.F
Main driver of SDSU
Flow control
module_simulator.F
Universal interface for CRM inputs
Microphysics options (1- and 2-moment bulk, spectra bin)
module_mpi.F
MPI process
Domain or File
Decompositions
VisIR Optics Module
RSTAR
[Nakajima and Tanaka 1988]
[Sekiguchi and Nakajima 2008]
1D BBR Simulator
MSTRN
[Nakajima et al.2000]
[Sekiguchi and Nakajima 2008]
Doppler CPR + ATLID Simulator
EASE Simulator
[Okamoto et al. 2007 & 2008]
[Nishizawa et al. 2008]
1D MSI simulator
RSTAR
[Nakajima and Tanaka 1986 & 1988]
Broadband LUT of Optical properties
Orbit-scan simulator
T. Matsui
3D Fields of Optical properties
3D MSI ATLID simulators
H. Ishida
Off-line simulation possible.
All the sensors of EarthCARE have been installed.
2012 March
J-Simulator Architecture

Orbit-scan simulator

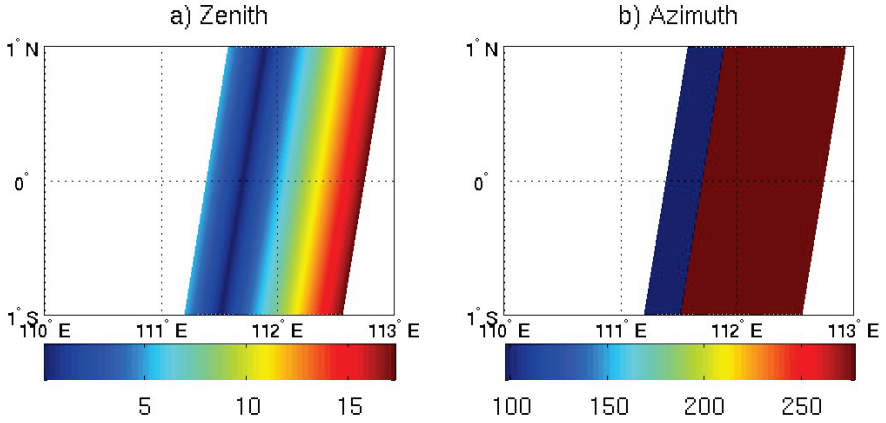


Direction of satellite

Time is in UTC.



Satellite

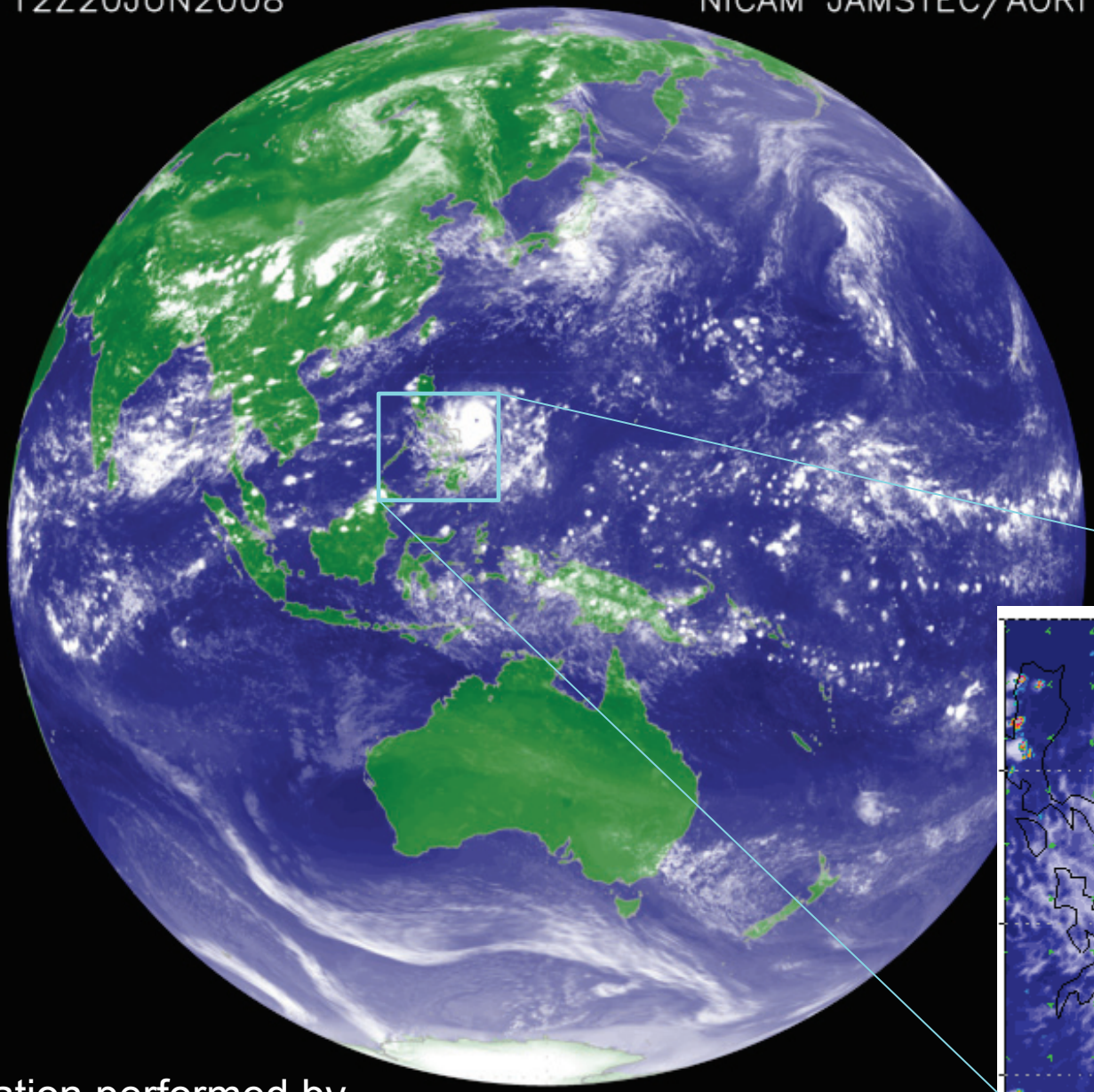


Orbit-scan simulator was provided by Dr. Toshi. Matsui@NASA.

A push-broom cross scan was installed for MSI.

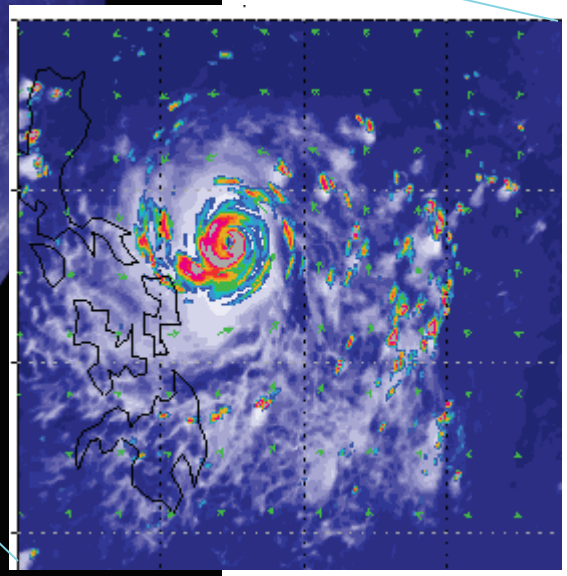
Can be used for scene generation

NICAM 雲評価例



3.5 km mesh
NICAM
12UTC 20 June 2008

TC Fengshen

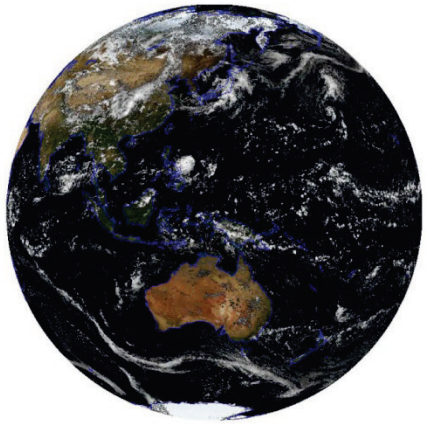


Simulation performed by
T. Nasuno, H. Yamada, W. Yanase, A. T. Noda, and M. Satoh (2011)

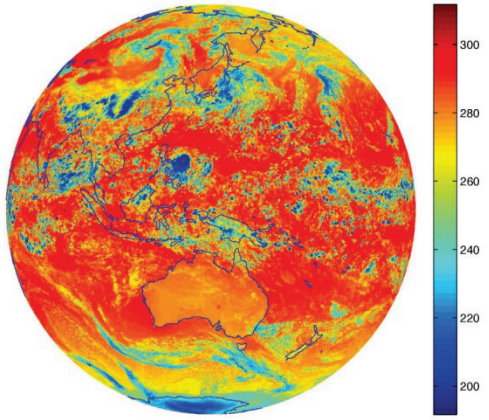
Examples of simulated signals

Background: Blue Marble: Next Generation, NASA

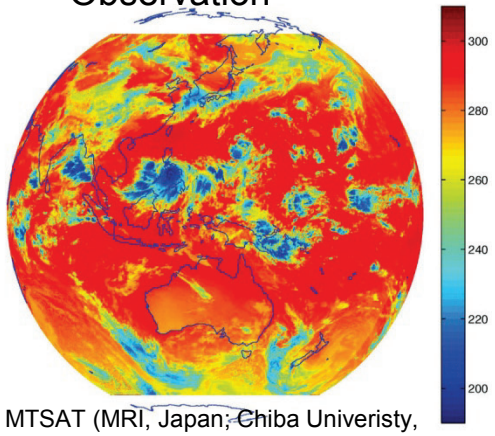
a) VIS 0.62 μm



b) IR 10.8 μm TB [K]

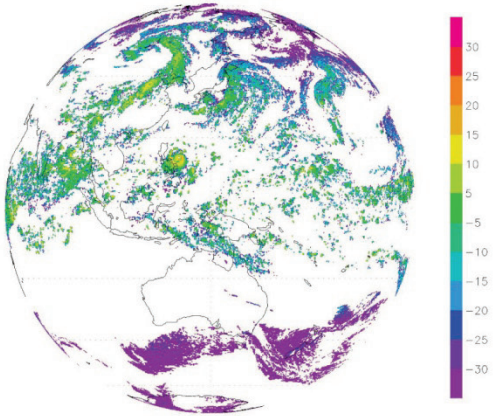


c) IR 10.8 μm TB [K] Observation

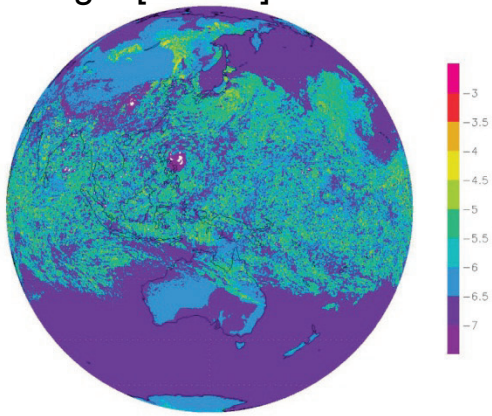


MTSAT (MRI, Japan; Chiba Univeristy, CEReS)+ globally-merged IR (CPC, NOAA)

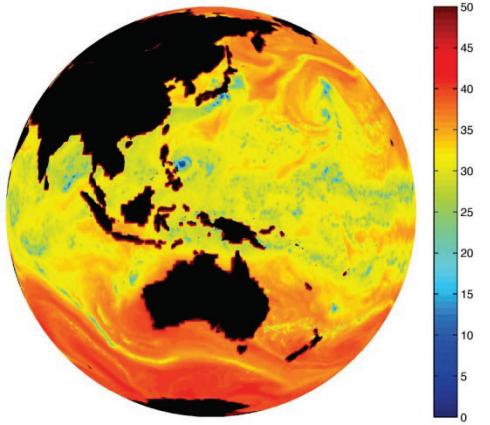
d) 94 GHz CPR [dBZ] at h=10 km



e) 532 nm backscat coef Log10[1/m/str] at h=14 km



f) Pol diff for 19GHz



Data set for CloudSat/CALIPSO validation

Observation：CloudSAT-CALIPSO merged data set（Hagihara et al. 2010）

NICAM global simulation：2008 TC Fengshen (Nasuno et al. 2009)

- horizontal grid spacing: 3.5 km; # of vertical grids: 40 (0~3.8km)
- cloud microphysical parameterization: NSW6 (Tomita 2002)
  - ✓ 1 moment scheme, 6 categories (vapor, cloud, rain, cloud ice, snow, graupel)

↓ Forward calculation by a satellite simulator

Simulation：CloudSAT & CALIPSO merged data set

Time period

Observation：2008 June

Simulation：2008 June 17th 00Z ~ 25th 00Z

Four cloud masks

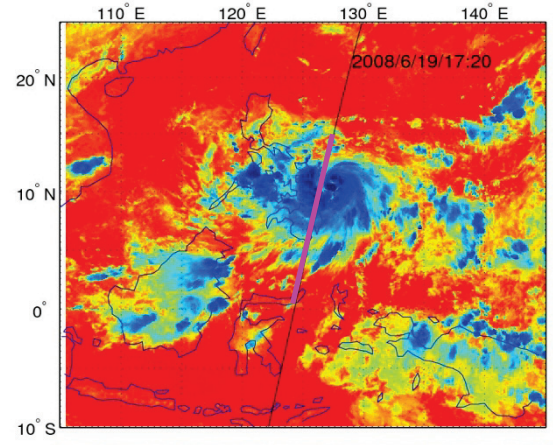
Radar mask (C1); cloud & precipitating particles.
Lidar mask (C2); cloud particles.
Radar and Lidar mask (C3); cloud particles
Radar or Lidar mask (C4); all particles

CloudSAT and CALIPSO data are adjusted to have the same spatial resolutions and grids（240m for vertical, 1.1km for horizontal).

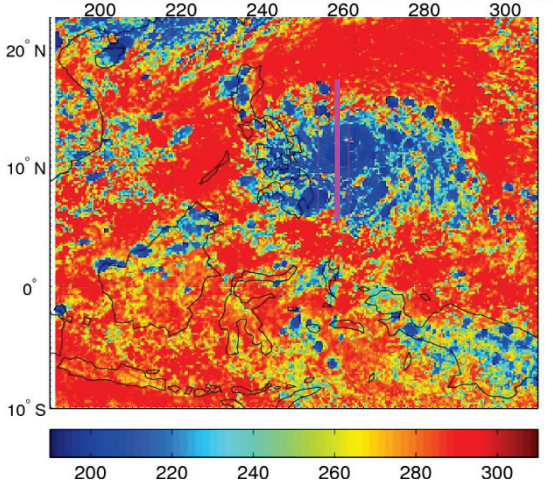
Example 1: Tropical Cyclone

MTSAT IR T_b (10.8 μm)

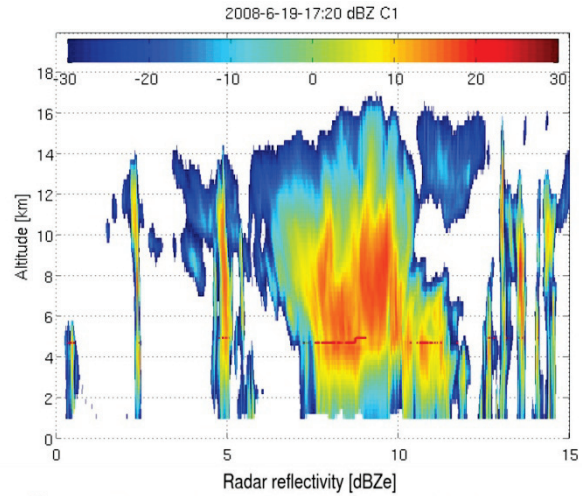
Obs.

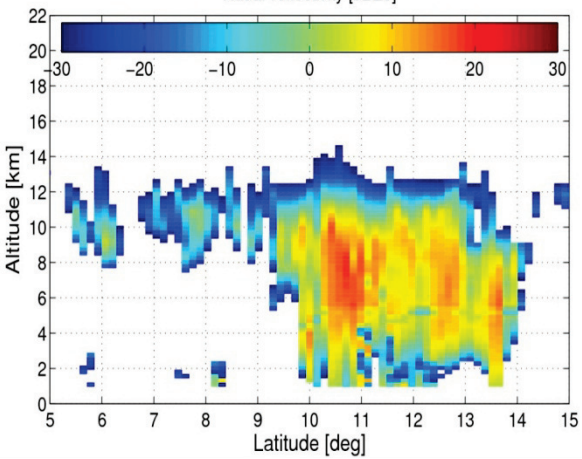


NICAM

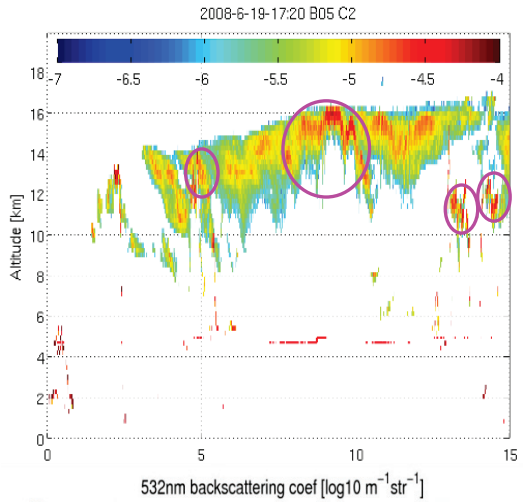


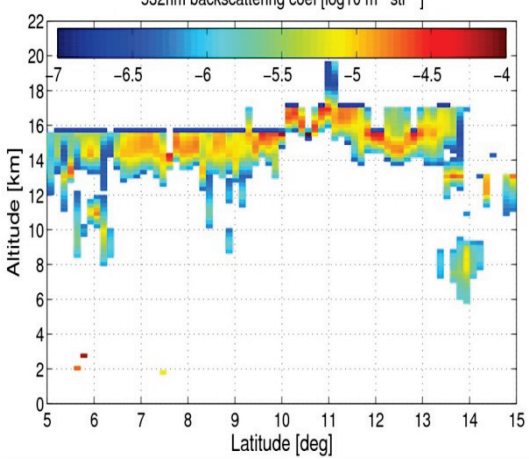
CloudSAT 94 GHz





CALIPSO 532 nm





OBS:

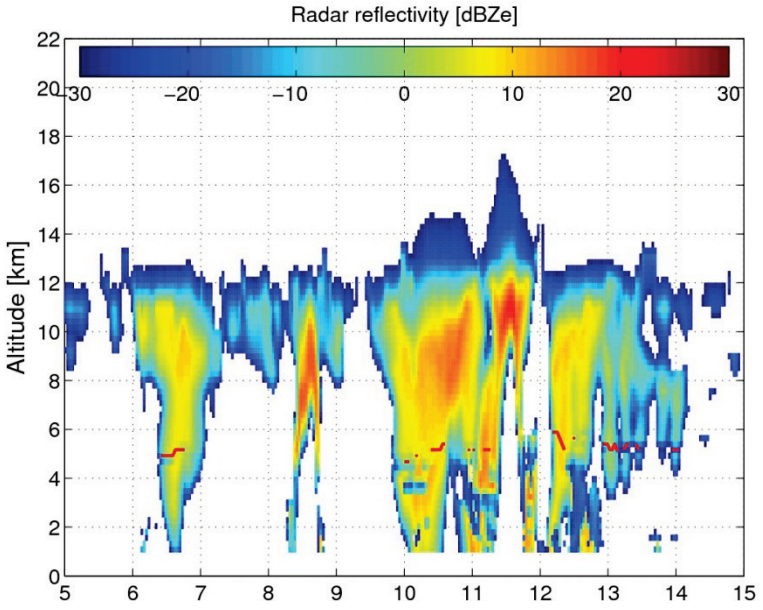
- Bright band exists.
- High β_{532} above convective cores.
- Overlap regions of C1 and C2 mask exist.

NICAM:

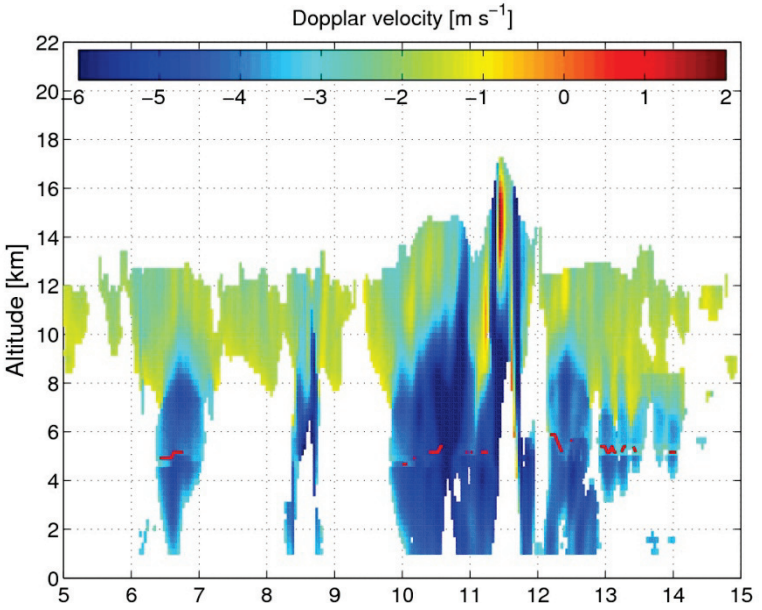
- Bright band exists.
- Low cloud top for C1, but high for C2.
- Few overlap regions of C1 and C2 mask exist.

Example; Tropical Cyclone; Simulation

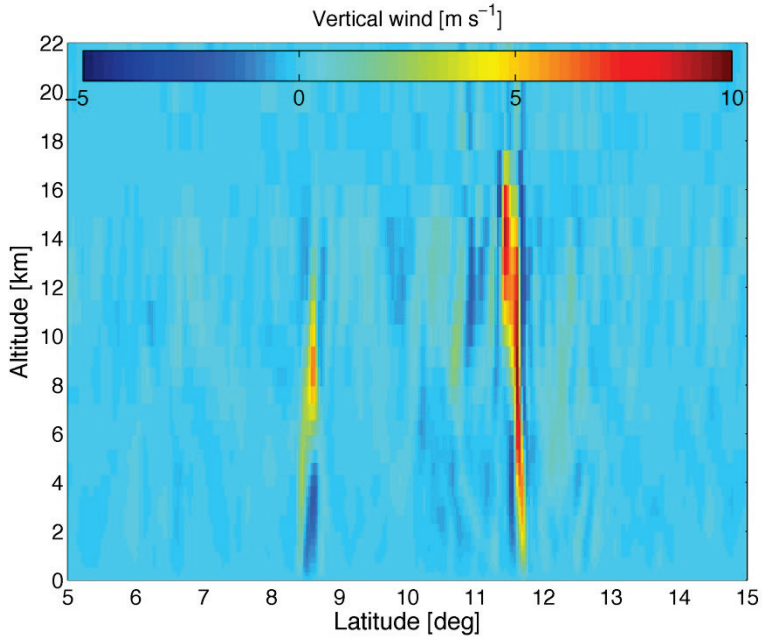
CloudSAT 94 GHz



Doppler velocity



Vertical wind



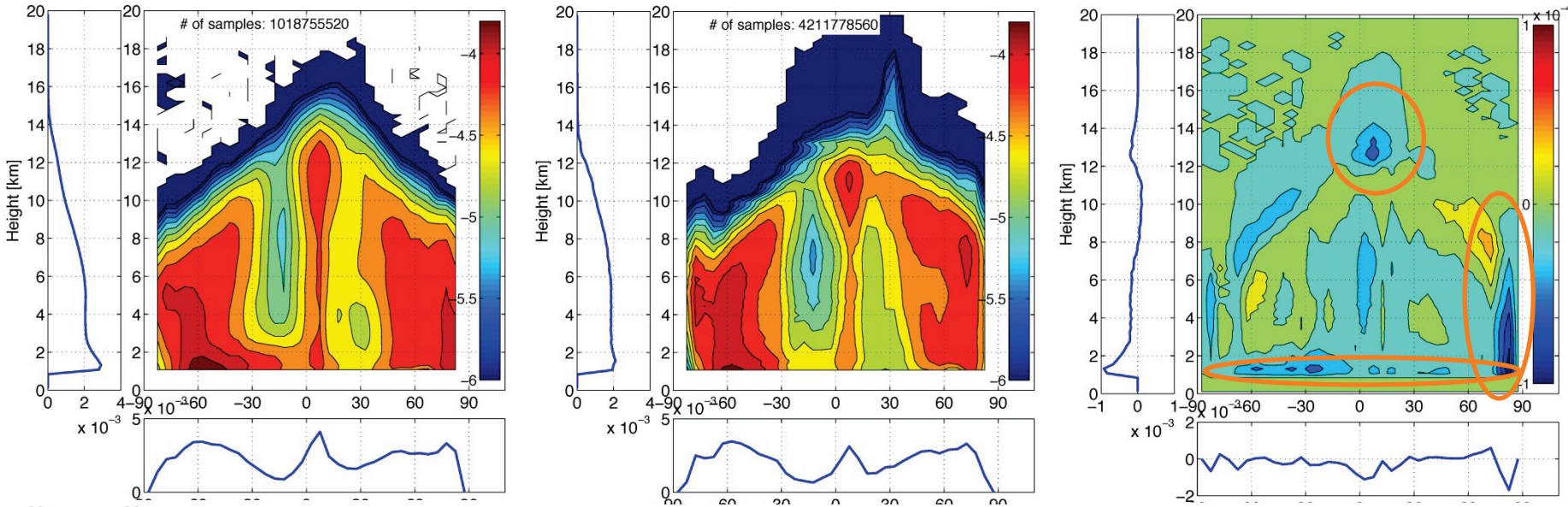
The relation of bright band and vertical motion suggests that the identification of stratiform vs convective profiles is possible (at least for simulation).

- Scattering of snow flakes and graupel
- Melting process in BWP

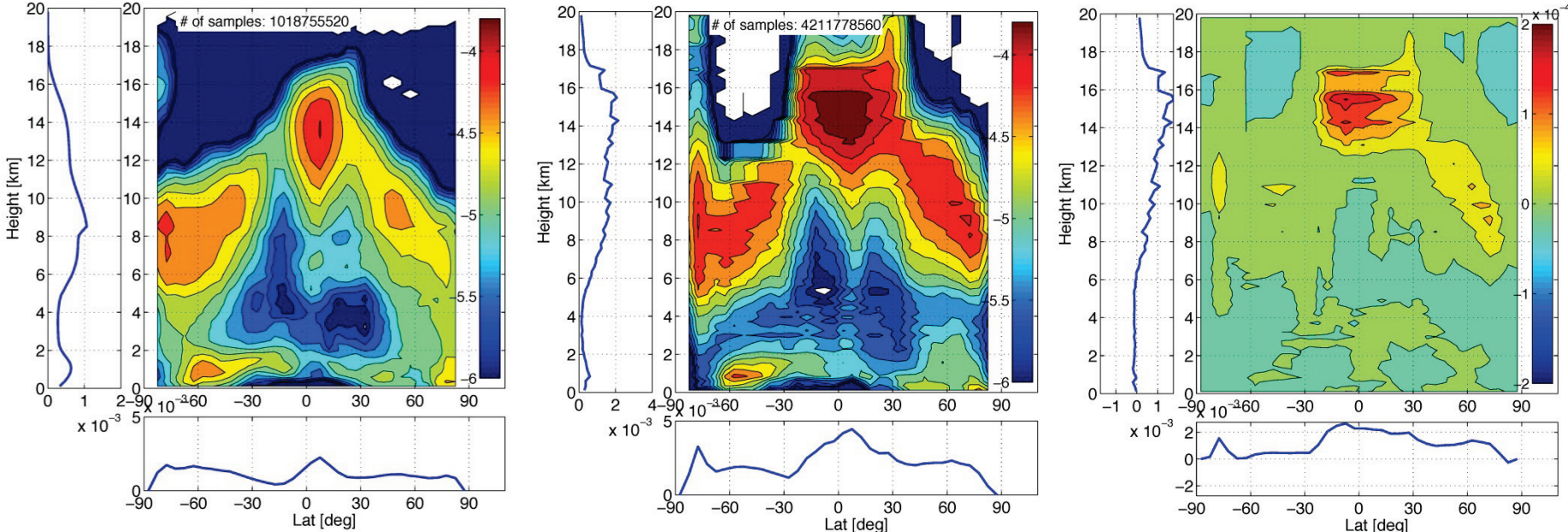
Latitudinal distribution of cloud occurrences

Observation | Simulation | Sim-Obs

Radar



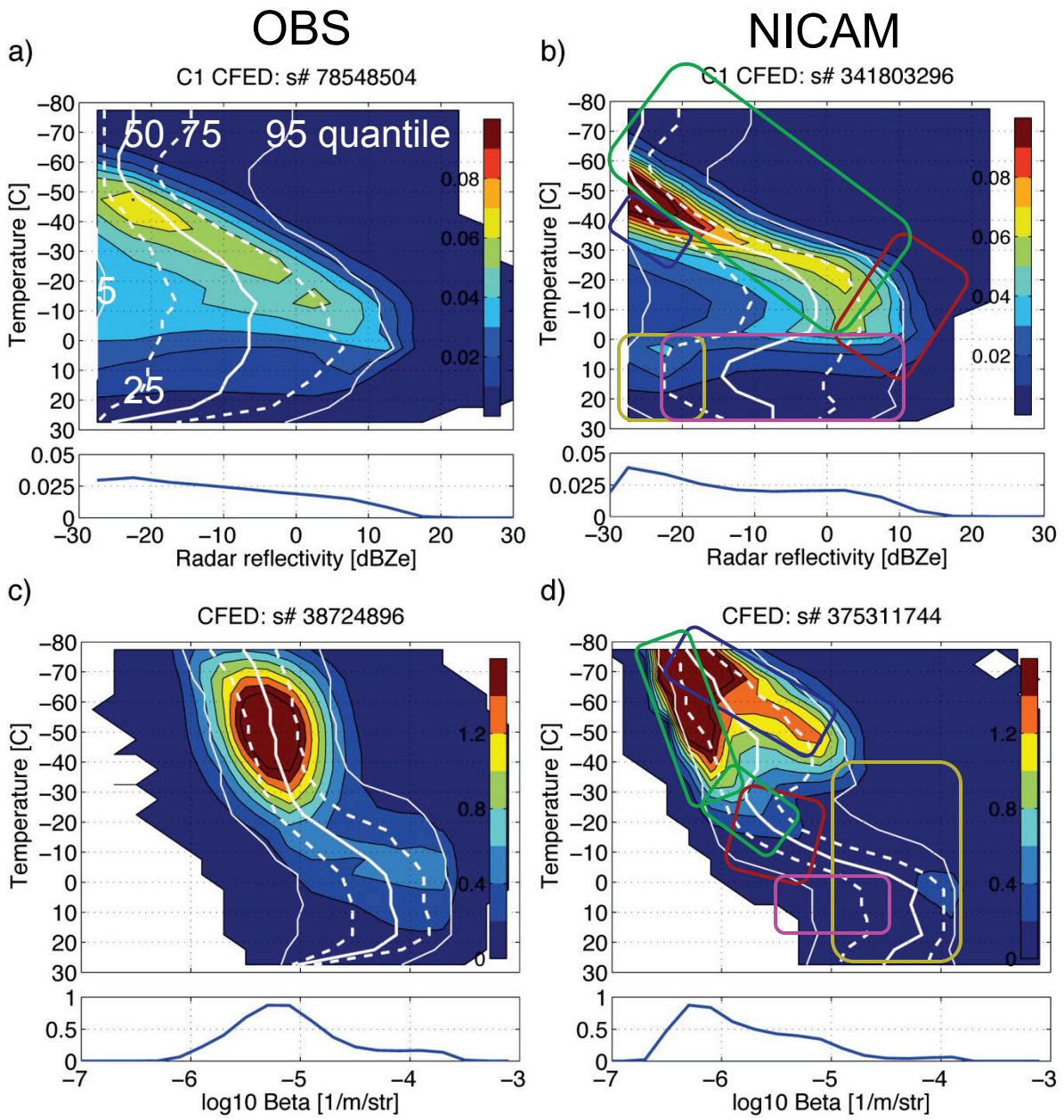
Lidar



Global Contoured Frequency by tEmperature Diagram (CFED)

CloudSAT 94GHz radar

CALIPSO 532nm Lidar



OBS

- one single dominant mode for a given T at T < -10C (z as vertical axis does not show it)

NICAM

- High occurrences of small dBZe especially at -60<T< -30° C.
- Overestimates the occurrence of 0 < dBZe' < 10 dB.
- The 95th quantile smaller at T < -40 ° C and -20 < T < 10 ° C.
- The 50th quantile larger at -35 < T < 0 ° C.

- Two modes exist for log10(β_{532}) at T < -40° C level.
- the 75th and 95th quantiles underestimated for liquid

Contribution of each hydrometeor category

Cloud ice
Cloud droplets
Snow
Rain
Graupel

Contoured Frequency by tEmperature Conditioned on Radar Diagram (CFERD)

Okamoto et al. (2003)

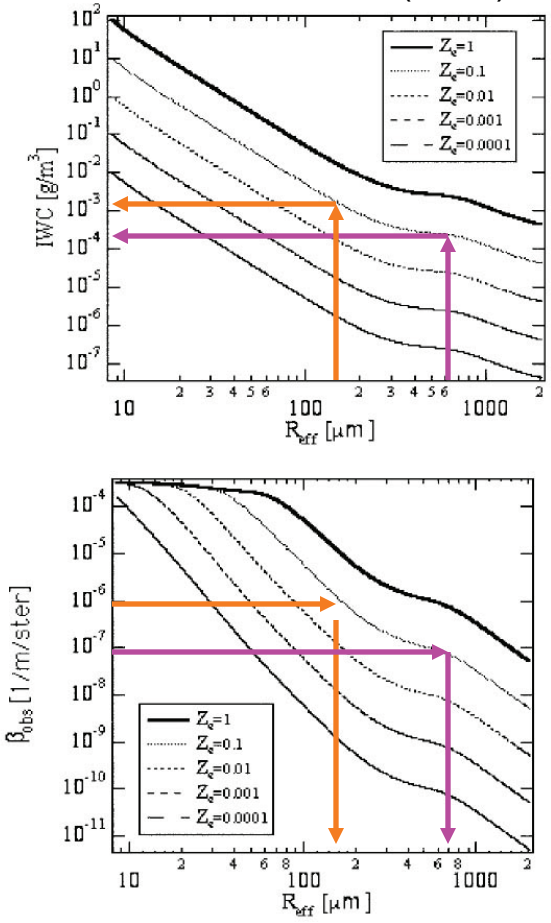


Figure 4. (a) Relationship between IWC and r_{eff} for a given $Z_{e,obs}$. A single cloud layer with geometrical thickness of 96 m is considered, and there is no cloud layer below this one. (b) Relationship between β_{obs} and r_{eff} for a given $Z_{e,obs}$. For a given $Z_{e,obs}$, IWC is estimated for each r_{eff}. Then β_{obs} is estimated for each set of r_{eff} and IWC.

Aim: obtain the relative information on size and IWC.

If Z_e are the same among two grid boxes, smaller β means larger $R_{eff,m}$ and smaller IWC

Assumption

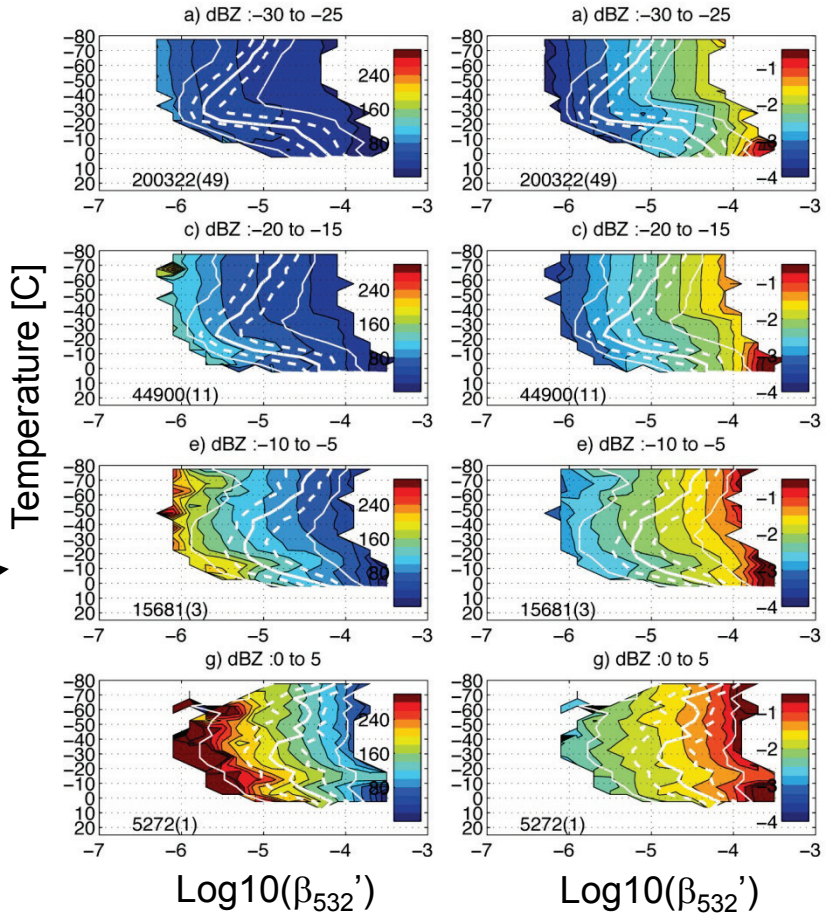
Both the observation and simulation follow a similar β - $R_{eff,m}$ and IWC - $R_{eff,m}$ relationship for a given Z_e.

- $R_{m,eff}$ and IWC are Okamoto et al. (2010)'s lidar-radar retrievals.
- The diagnosis usually valid for a range of T

Effective radius in terms of Mass-equivalent radius

Mean $R_{m,eff}$ [μm]

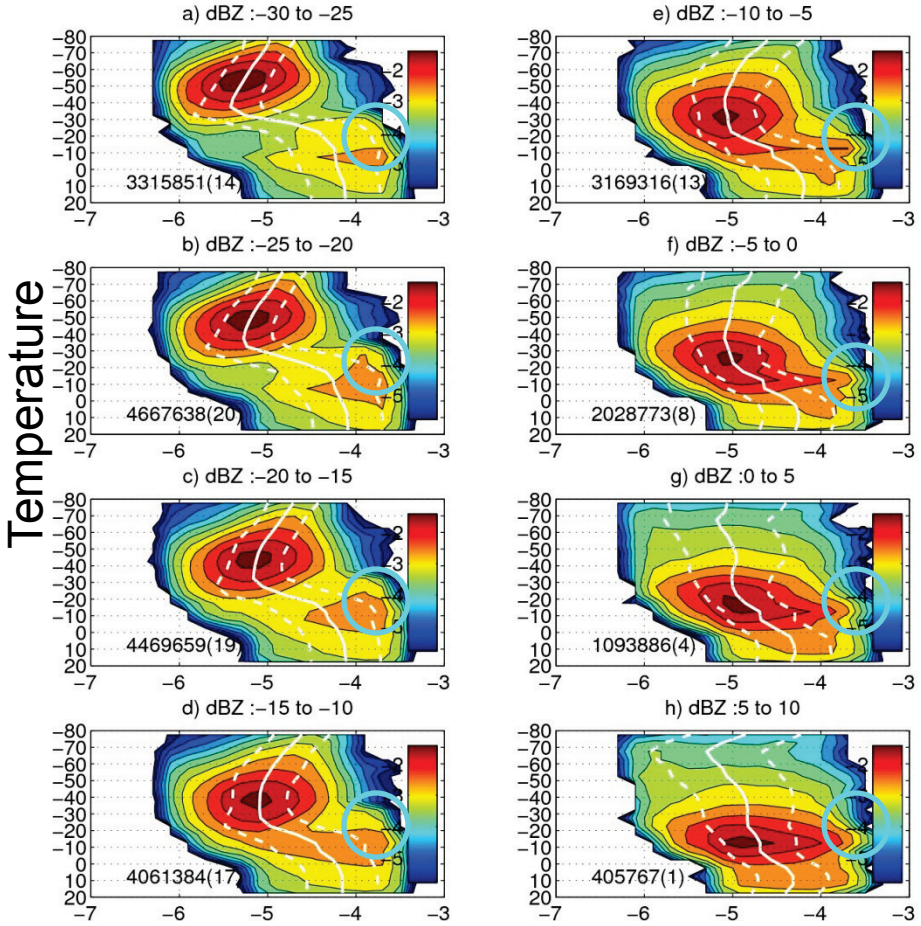
Mean IWC [log10(g/cm^3)]



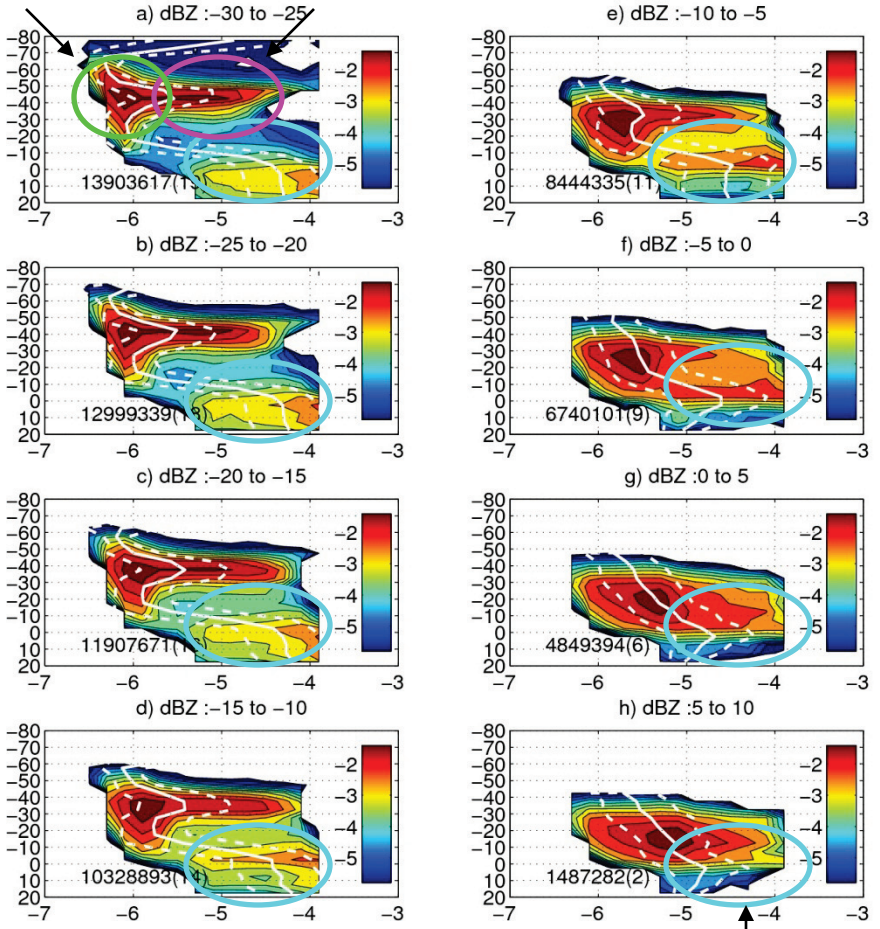
Global BETTER

beta-temperature radar conditioned diagram

Lidar backsct coef: Observation



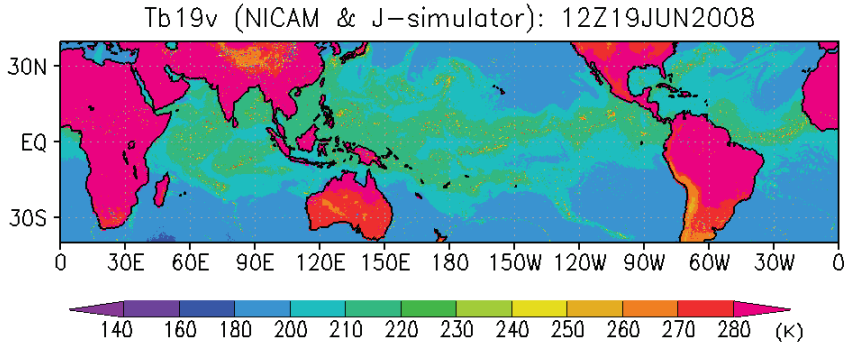
Lidar backsct coef: Simulation

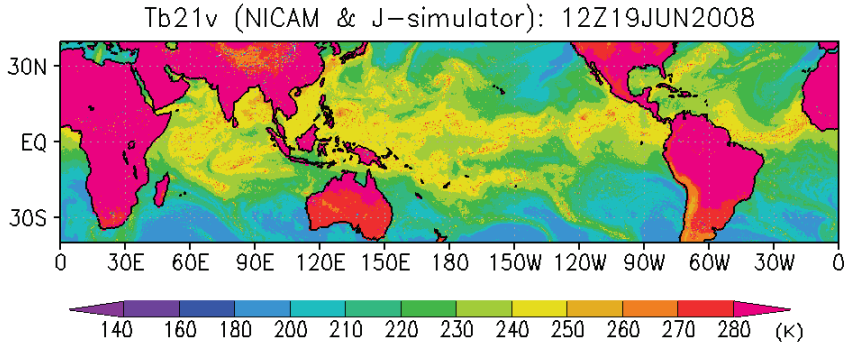


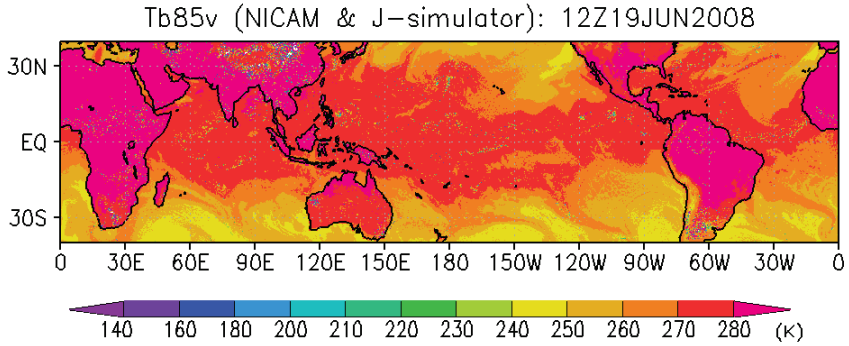
On average NICAM have larger R_{eff} & smaller WC than obs（cloud droplets & snow）

NICAMとTRMM/TMIとの比較

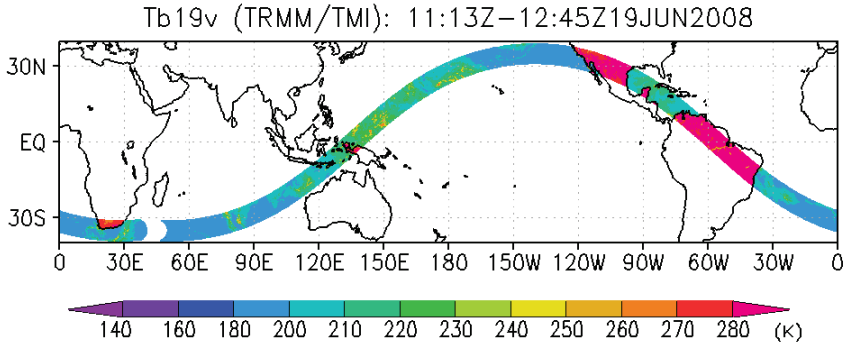
Joint-SimulatorによりNICAMから計算した輝度温度

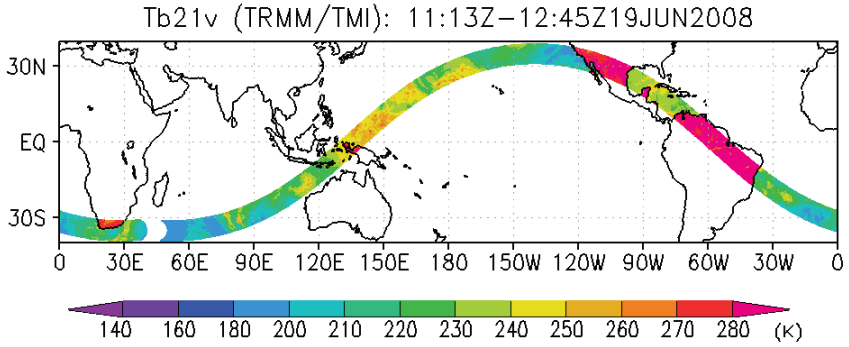


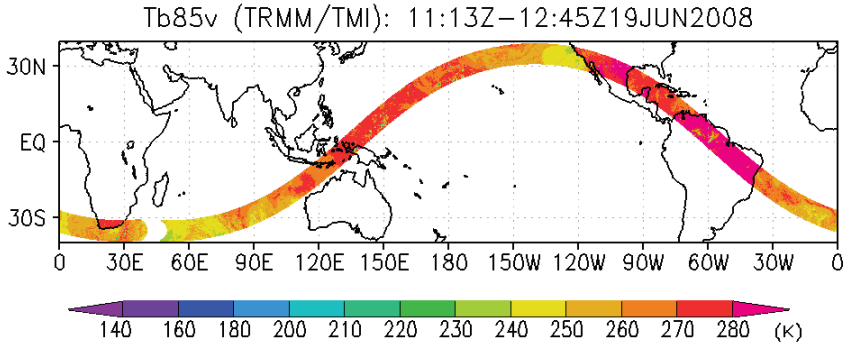




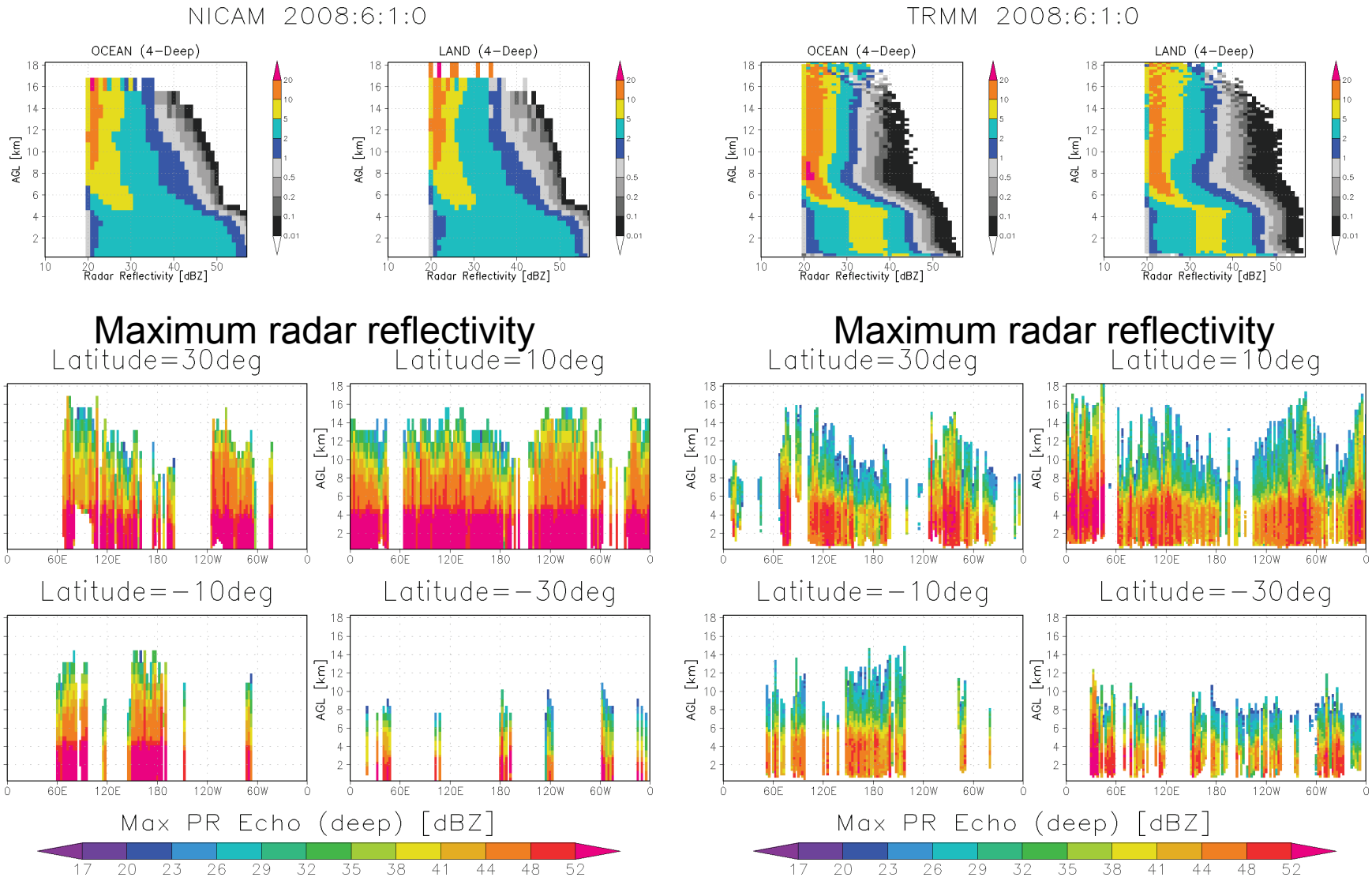
TRMM/TMI観測の輝度温度



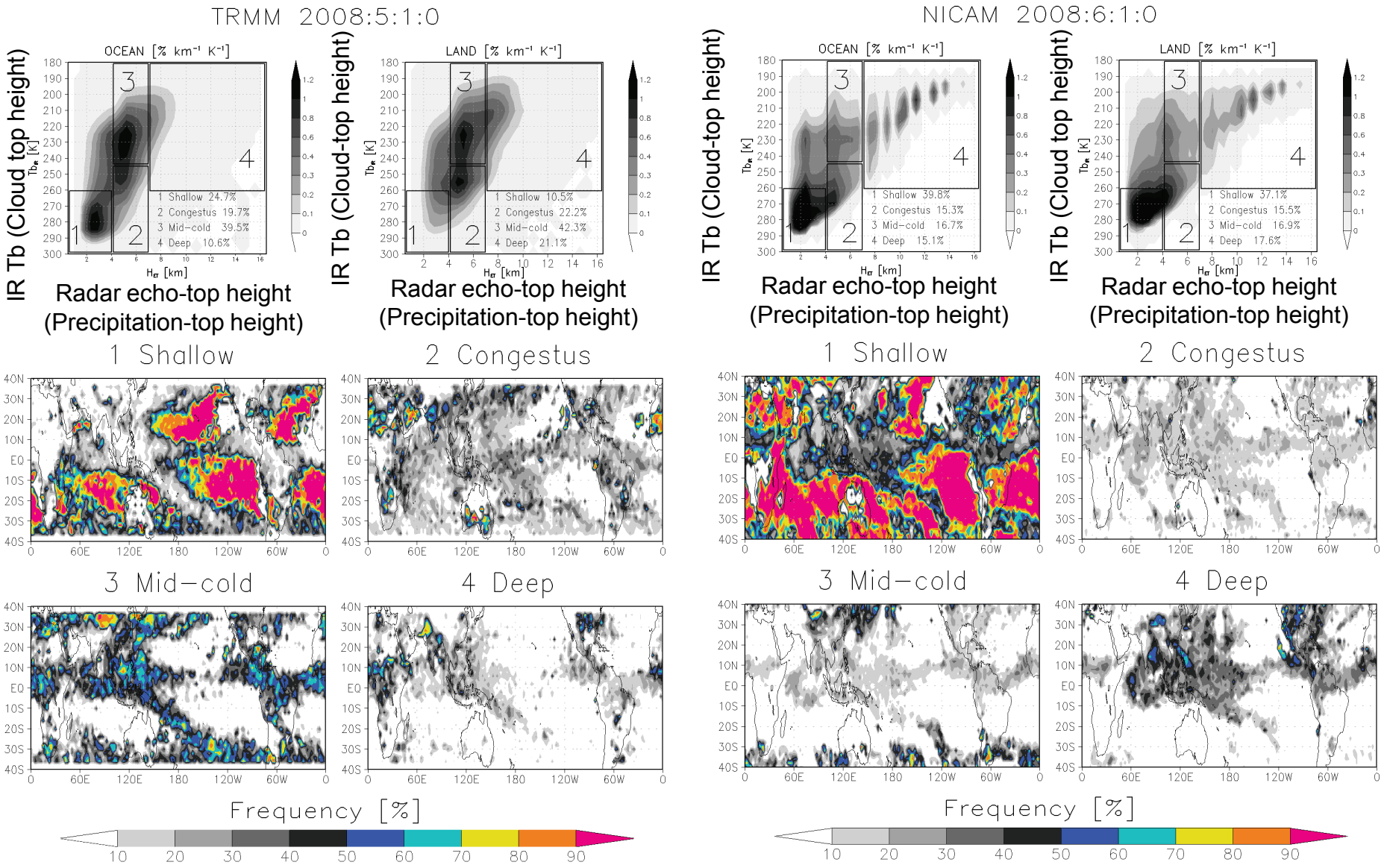




CFAD (Deep) : NICAM vs TRMM



雲頂と降雨レーダー(PR)頂ダイアグラム



TRMM観測データ

NICAMデータ

Comparison of 1D and 3D RTM (Preliminary results)

High resolution simulation of marine stratocumulus
- provided by Mr. Y. Sato (Prof. Nakajima group)
- horizontal resolution: 500x500m

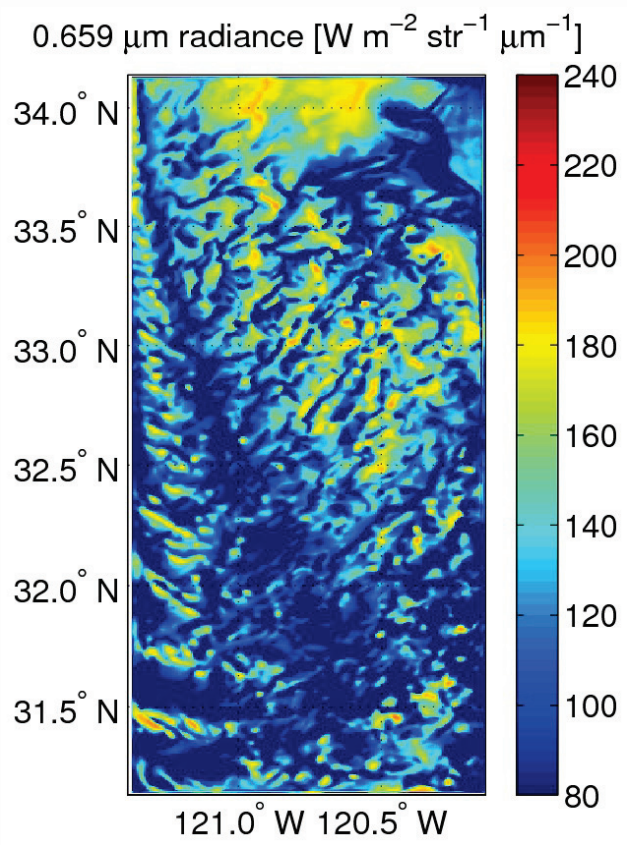
Can be useful for retrieval algorithm development

Experiment design

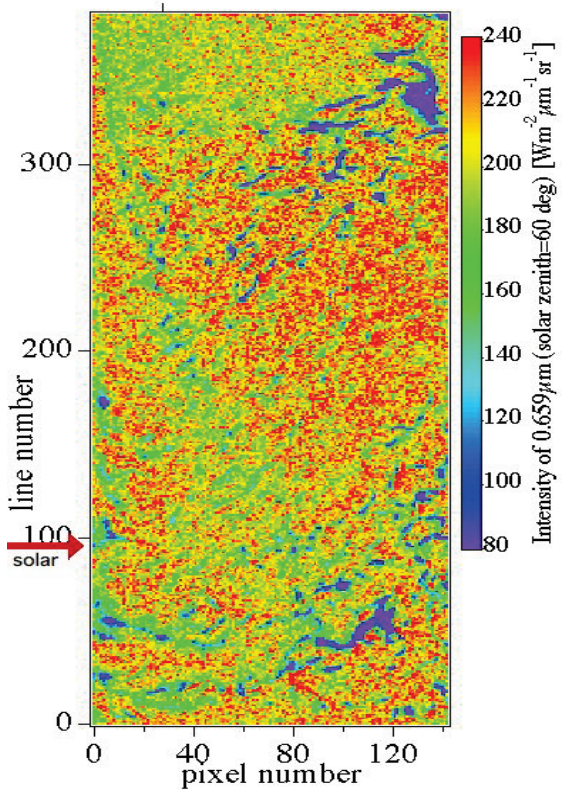
- solar zenith angle: 60°
- viewing zenith angle: 14.3°
- difference between solar azimuth angle and viewing azimuth angle:0°
- no surface reflection (RSTAR not changed yet)

RSTAR: lower radiance between clouds.

1D RTM: RSTAR6b



3D RTM: MCARaTS (Dr. Ishida)



今後の予定

- Joint-simulator 今後の開発
  - 非球形table
  - Diagnosis or retrieval
    cf. MODIS Re (by. T.Nakajima)
  - Aerosol Interface
  - 3D transfer
- 検証用データ
  - Hagiwara data, T3EF
  - EORCで整備
- モデル対応
  - NICAM
  - WRF: 標準diagnosis としてproposal
  - NHM, CReSSへも対応予定
  - GCMへも対応: MIROC,MRI,GMS..

Summary

- Joint-simulator は EarthCARE　向けに開発中
  - Joint-Simulator は SDSU を内包する
    - 並列処理
    - Generalized interface
    - Lidar: EASE
- 比較データ
  - CloudSat/CALIPSO: Hagiwara data comparison
  - TRMMT3EF: Matsui's data
  - EORC で比較データアーカイブ中
- 雲解像モデルに対応
  - NICAM
  - WRF
  - NHM, CReSSにも対応予定
- GCMへも対応予定
- Aerosol interface
- 3D transfer

References

for NICAM cloud evaluation by satellite simulators

Joint-Simulator

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ISCCP simulator

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