



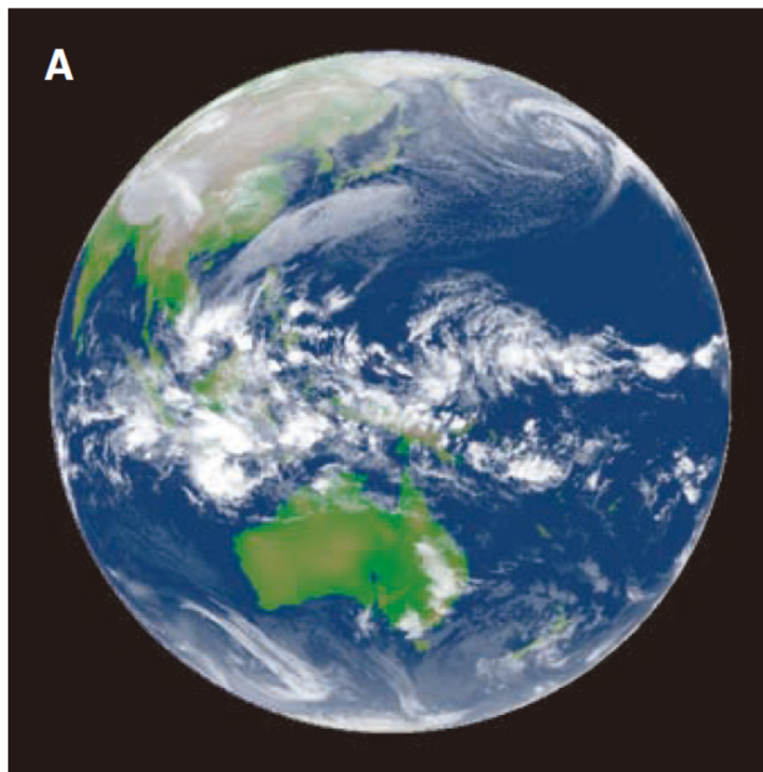
衛星データシミュレータが拓く衛星大気観測の新活用

増永 浩彦

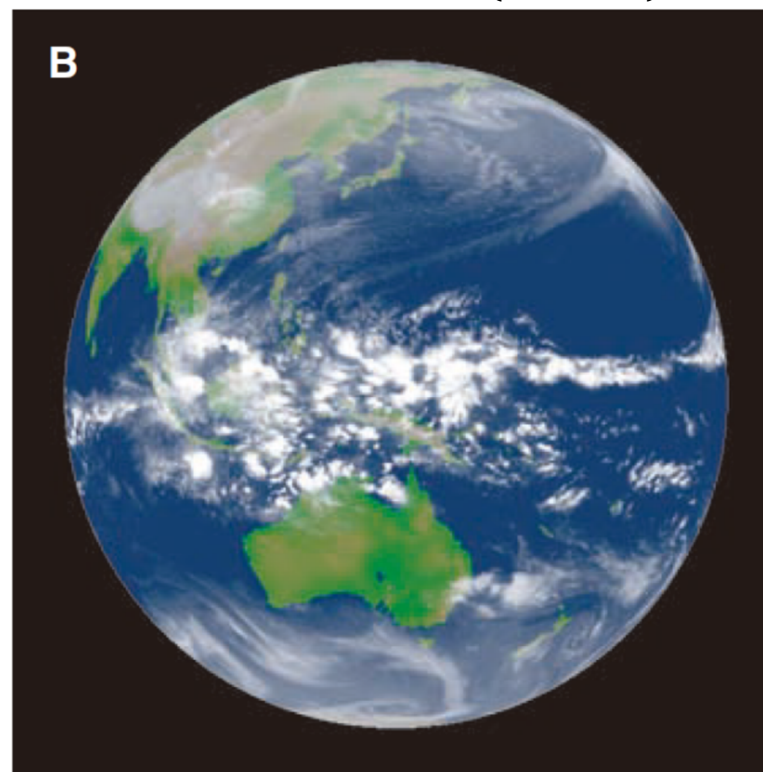
名古屋大学 宇宙地球環境研究所

現実の地球（左）と数値モデルによる仮想地球（右）

衛星観測 (MTSAT)



全球雲解像モデル (NICAM)

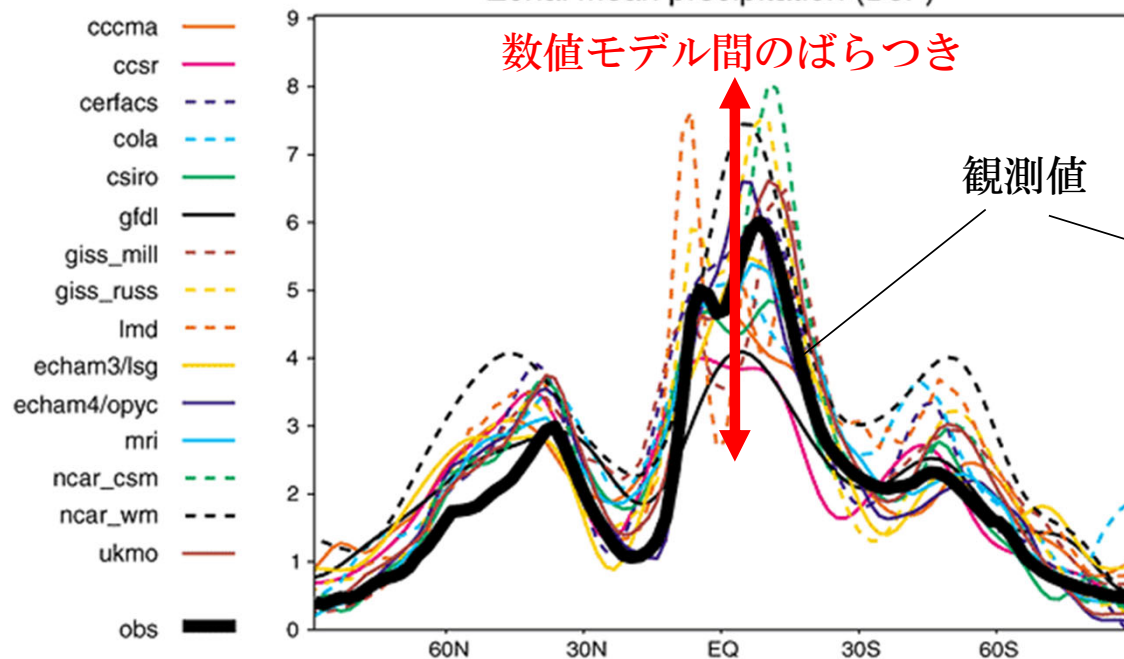


Miura et al., *Science* (2007)

数値モデルの検証：ある事例

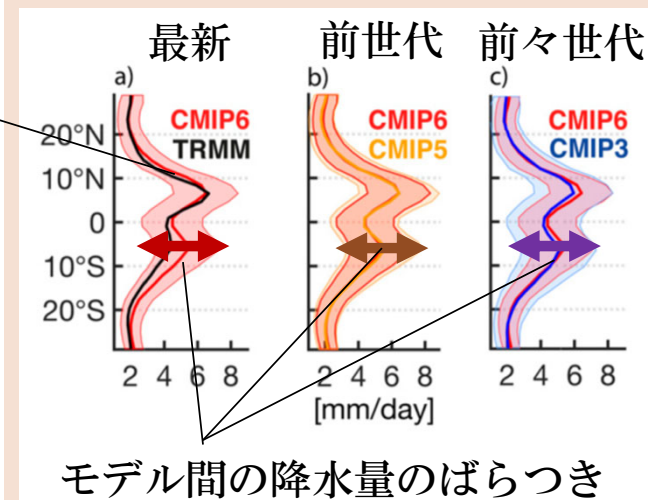
降水量（12月-2月緯度平均）

Zonal mean precipitation (DJF)



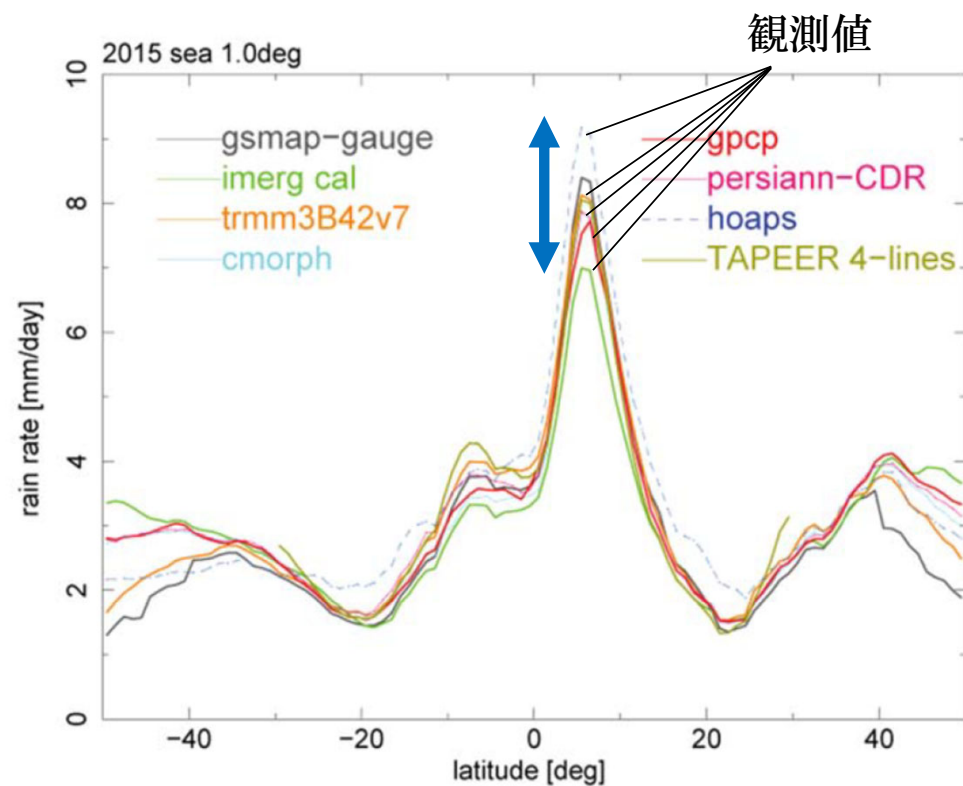
IPCC 第三次報告書（2001）

全球気候モデルの降水量再現性は、現在に至るまで抜本的には改善していない。



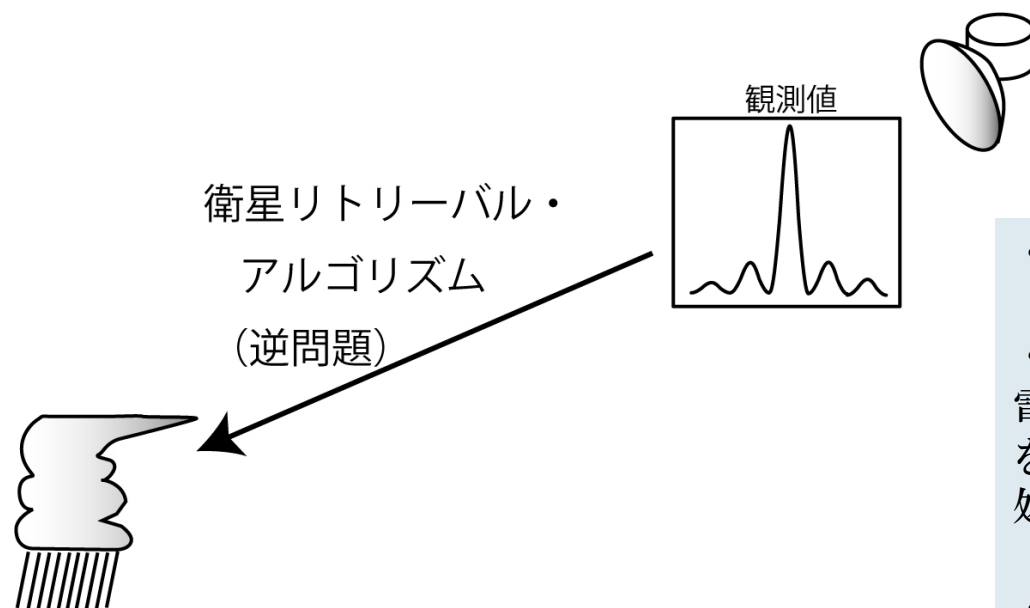
Fiedler et al., *Mon. Wea. Rev.* (2020)

観測値は「真値」か？



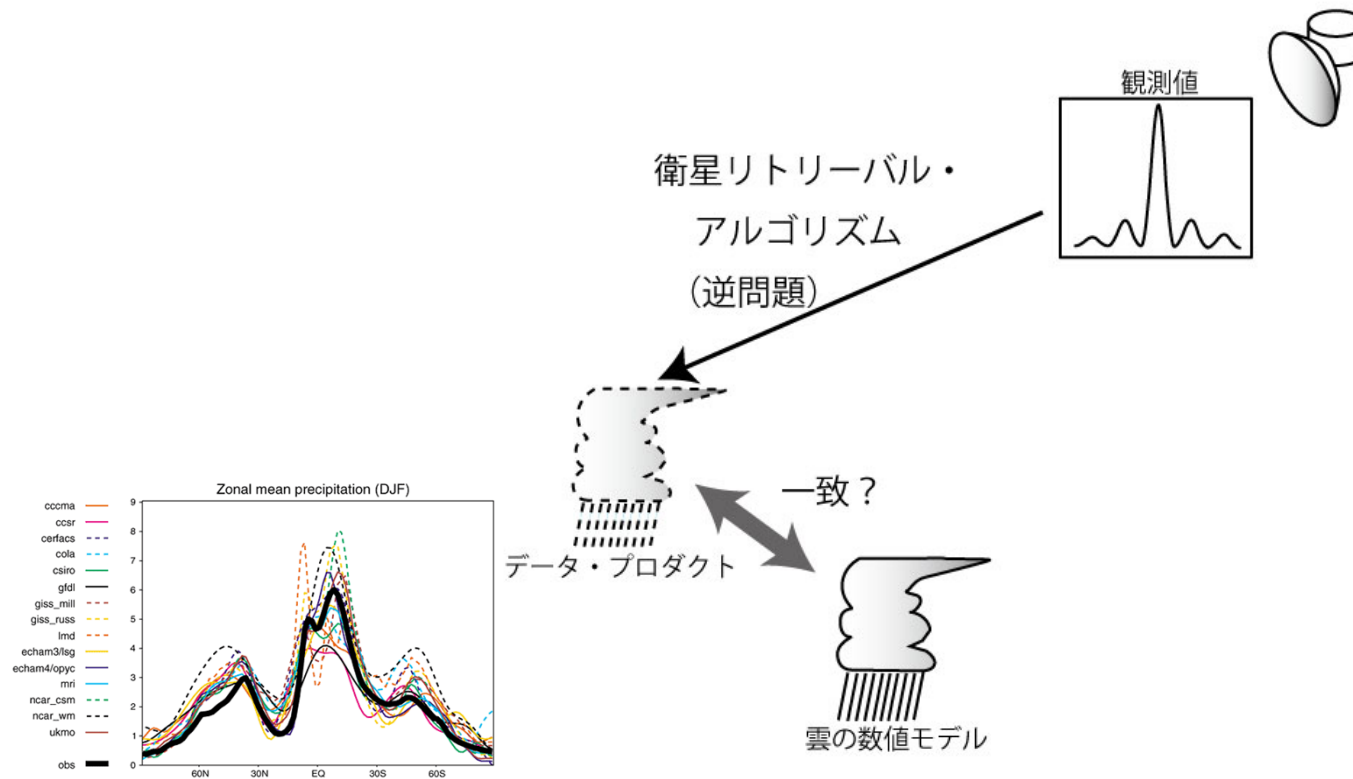
Masunaga et al., *Env. Res. Lett.* (2019)

なぜ観測値が「真値」から外れるのか？

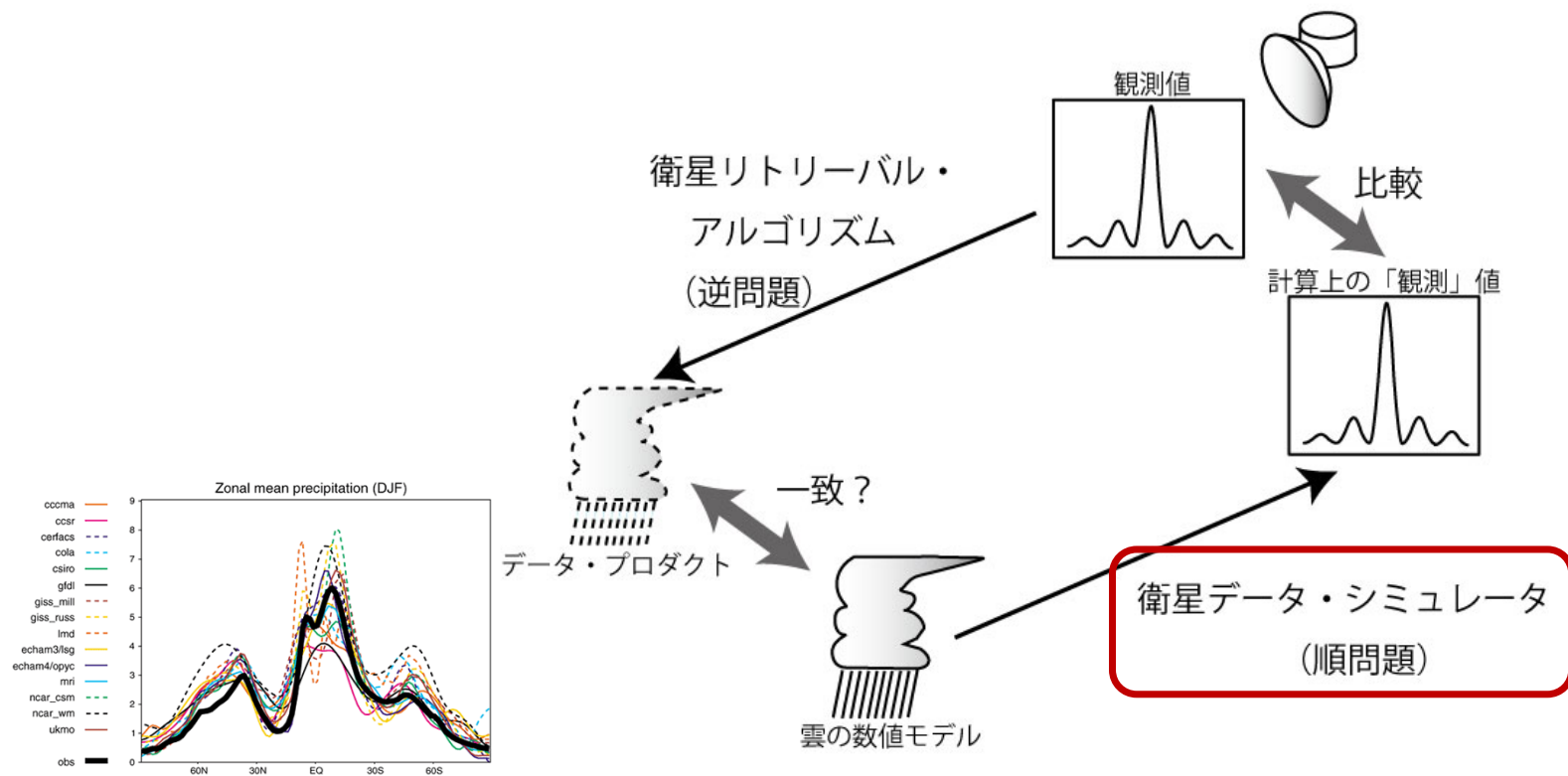


- 衛星は電磁波の信号を計測する。
- 気象パラメータ（降水量など）は、電磁波の信号をもとに放射伝達問題を逆に解いて推定する（このデータ処理をリトリバルと呼ぶ）。
- 逆問題は解の一意性が保証されず、多くの仮定を要する。この仮定が降水量推定値の精度を左右する。

逆問題と順問題



逆問題と順問題



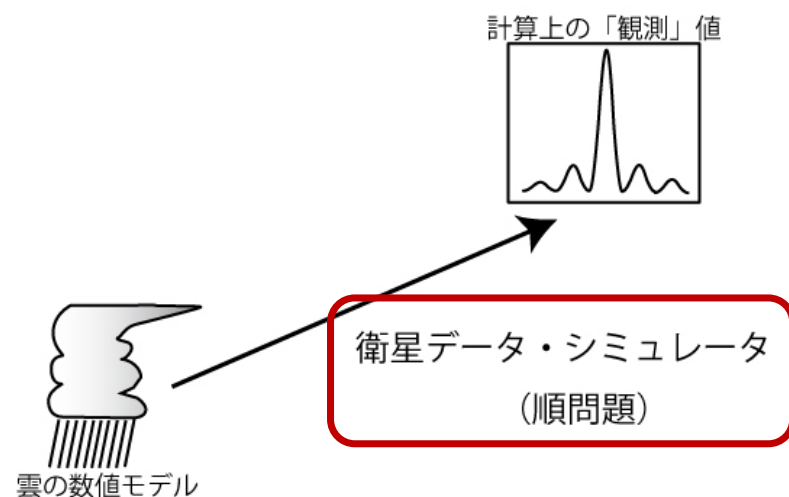
衛星データシミュレータ

衛星データシミュレータ

疑似自然データ（数値モデル等）に放射伝達計算を適用し、仮想的な衛星観測値を算出するソフトウェア

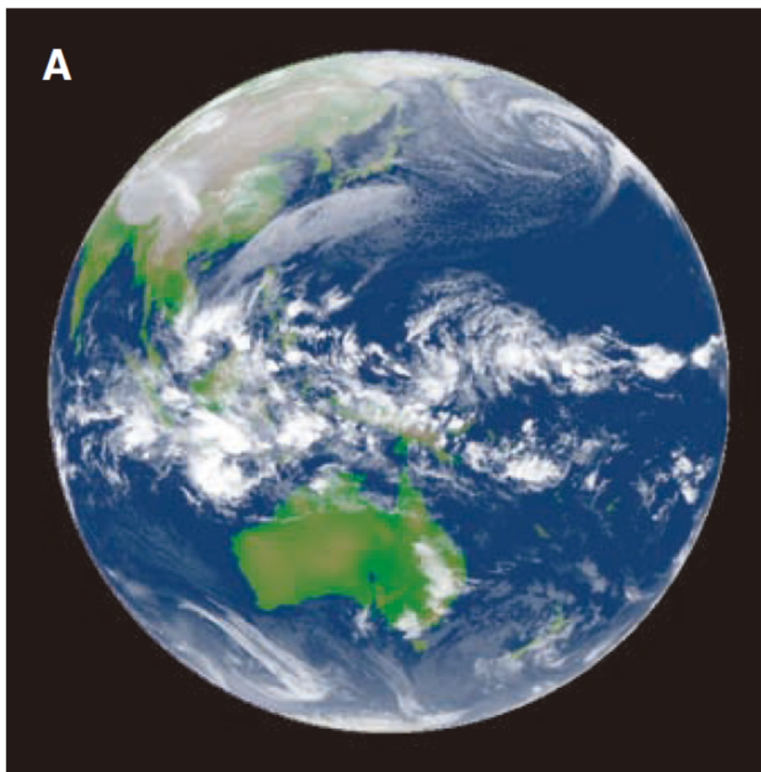
主な用途

- 数値モデル性能検証
- 将来衛星ミッションのリトリバルアルゴリズム開発
- 数値気象予報（データ同化技術）

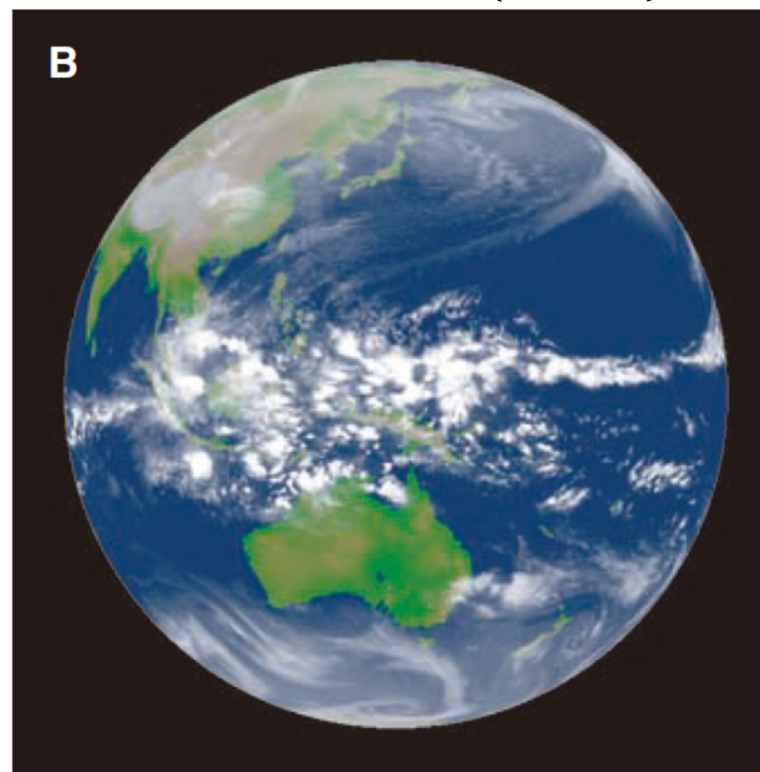


衛星データシミュレータ応用例：数値モデル検証

衛星観測 (MTSAT)



全球雲解像モデル (NICAM)

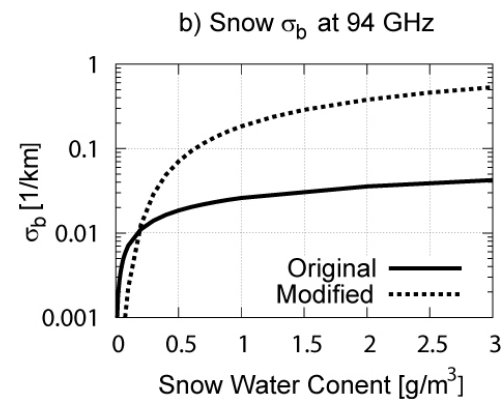
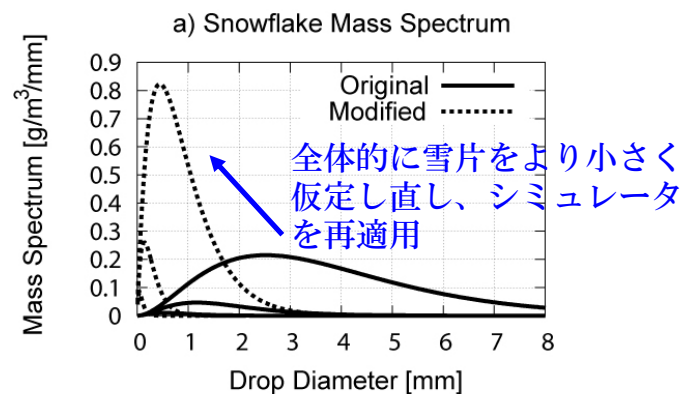
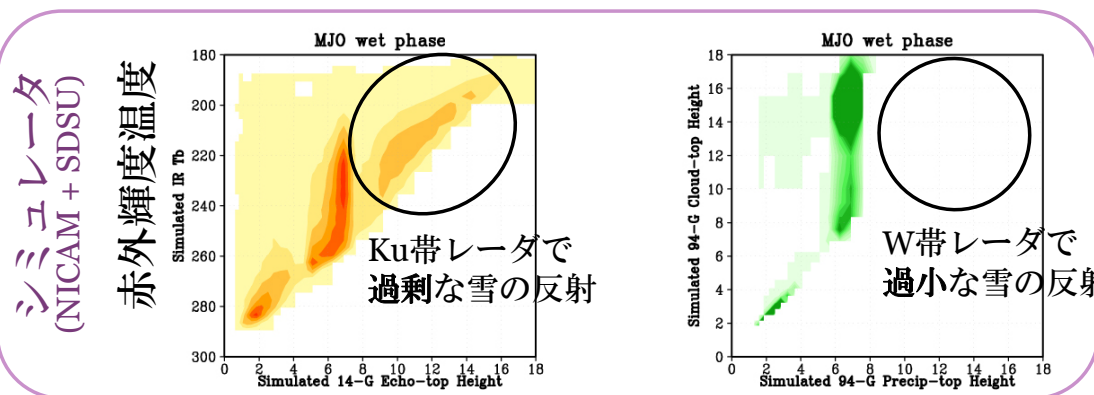
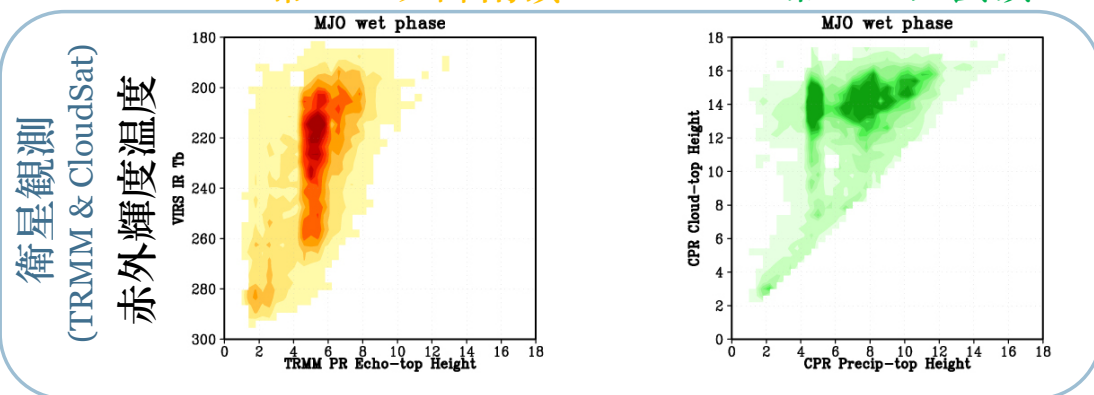


Miura et al., *Science* (2007)

衛星データシミュレータ応用例：数値モデル検証

Ku帯レーダ降雨頂

W帯レーダ雲頂

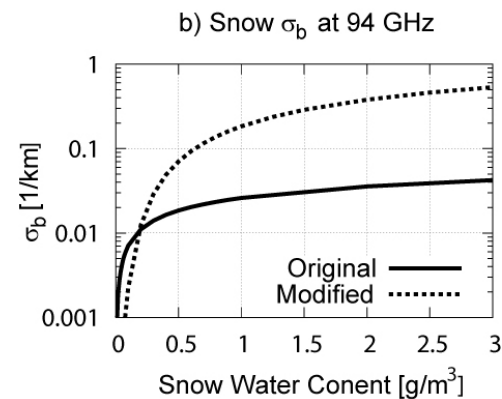
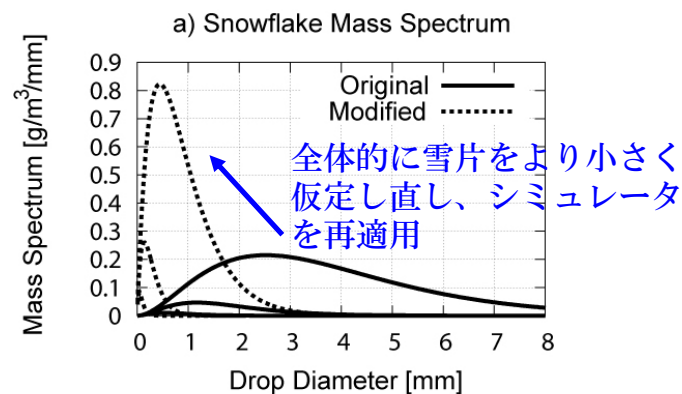
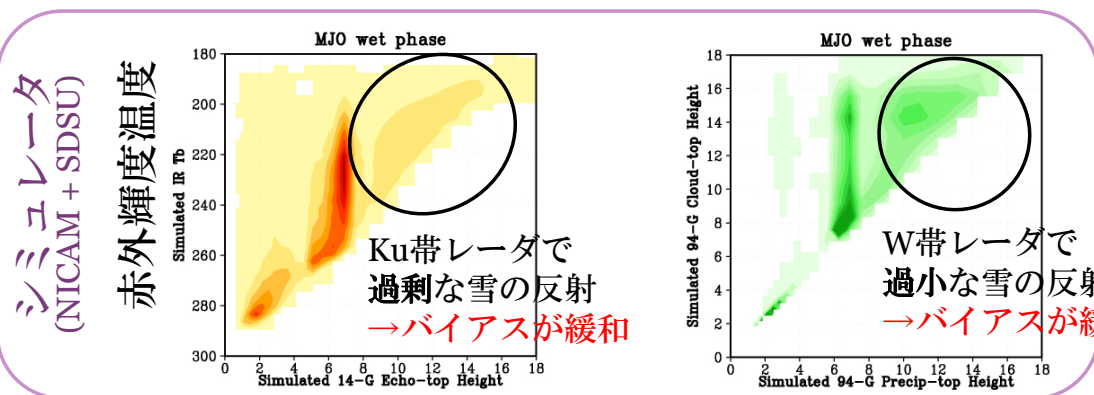
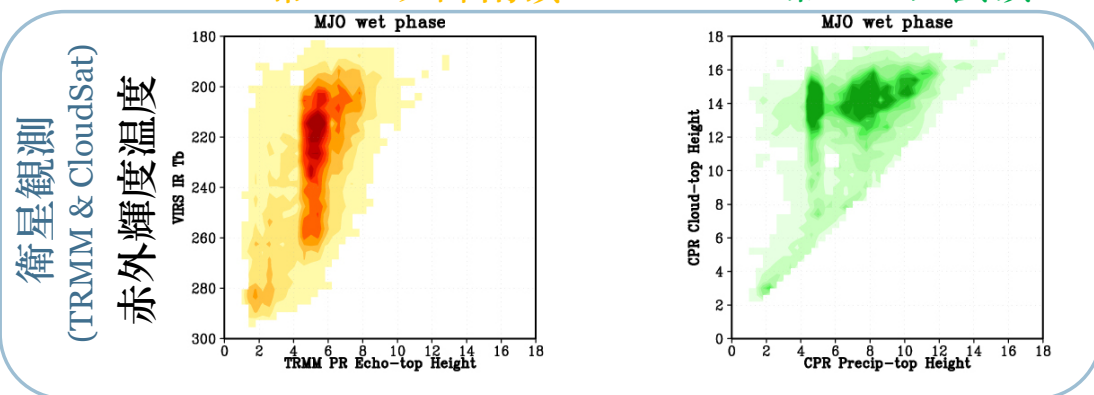


Masunaga et al., *J. Geophys. Res.* (2008)

衛星データシミュレータ応用例：数値モデル検証

Ku帯レーダ降雨頂

W帯レーダ雲頂



Masunaga et al., *J. Geophys. Res.* (2008)

代表的な衛星データシミュレータ

COSP, SDSU, Goddard SDSU, Joint Simulator, RTTOV, CRTM, ...

About COSP

The CFMIP Observation Simulator Package (COSP) takes the models representation of the atmosphere and simulates the retrievals for several passive (ISCCP, MISR and MODIS) and active (CloudSat (radar) and CALIPSO (lidar)) sensors.

An overview of COSP is provided in the [COSP1 BAMS paper](#).

COSP Version 2 (COSP2) is a major reorganization and modernization of the previous generation of COSP. For a detailed description, see the [COSP2 GMD paper](#).

The simulator developed by **Satellite Data Simulator Unit (SDSU)**

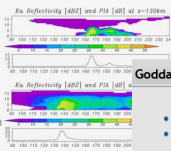
SDSU ver. 2.1.4 is now available (released on June 27, 2019).

Met Offr. Overview

- LLNL (L)
- LMD/IP
- CSU (C)
- UW (U)
- CU/CIRI

Condi

The code is in the direct



Goddard Satellite Data Simulator Unit (G-SDSU)

- Project Home Page
- Software

G-SDSU core modules enables users to insert their own set of satellite observable signals (radiance or backscatter) collected by corresponding satellite level-1 measurement.

Goddard Satellite Data Simulator Unit (G-SDSU)

G-SDSU core modules including various input/output (IO) and MPI module handle fast, scalable process to drive 1d

These goals are listed below.

Project Goals

The G-SDSU is being developed to support NASA's high-resolution atmospheric modeling system. For example, such virtual satellite mission will be coupled with high-resolution atmospheric modeling system. For example, such virtual satellite mission will be coupled with high-resolution atmospheric modeling system. For example, such virtual satellite mission will be coupled with high-resolution atmospheric modeling system.

Functional Goals

The functional goals of G-SDSU core module include reading various atmospheric model simulations developed by various atmospheric modeling systems. SDSU core module will permit the coupling of various future-satellite simulators by multiple collaborating organizations.

Evolvability Goals

The software is intended to be scalable and evolvable. It is expected that users from academia and from industry will use the software and that they will contribute to future releases.

Usability Goals

The software is intended to be used by meteorologists and other science experts. It is not intended for general use.



Joint-Simulator Home



Introduction of Joint-Simulator

- What's Joint-Simulator?
- Highlight
- Structure
- Publications
- Related Organization
- Related Links
- Contact & Registration

Download of Joint-Simulator software

The Joint-Simulator software (source code) is available for registration.

To compile the source code of the Joint-Simulator software, please refer to the following page.

(For Japanese)

Community Radiative Transfer Model (CRTM)

The CRTM is composed of four important modules for gaseous transmittance, surface emission and reflection, cloud and aerosol absorption and scattering, and a solver for a radiative transfer. The CRTM was designed to meet users' needs. Many options are available for users to choose from: input surface emissivity; select a subset of channels for a given sensor; inclusion of scattering calculations; computation of upwelling radiance at aircraft altitudes; computation of aerosol optical depth only; and threading of the CRTM.

Figure 1 (below) shows the interface diagram for users (public interface) and internal modules for developers contained in the lower dashed box. The CRTM forward model is used to simulate the satellite-measured radiance, which can be used to verify measurement accuracy, uncertainty, and long-term stability. The k-matrix module is used to compute Jacobian values (i.e., radiance derivative to geophysical parameters), which is used for the inversion processing in retrieval and radiance assimilation. Using tangent-linear and adjoint modules is equivalent to using the k-matrix module, and is also applied to some application in radiance assimilation.

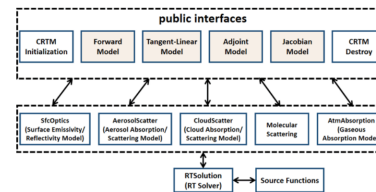


Figure 1. CRTM Public Interfaces



Introduction

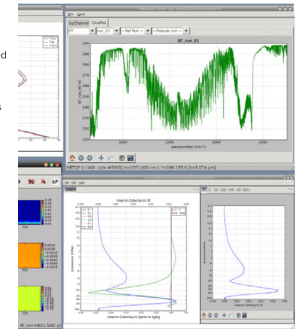
Current version: v13.2 (December 2022)

RTTOV (Radiative Transfer for TOVS) is a very fast radiative transfer model for passive visible, infrared and microwave downward-viewing satellite radiometers, spectrometers and interferometers. It is a FORTRAN 90 code for simulating satellite radiances, designed to be incorporated within user applications. The following paper gives an overview of the model and should be used when citing RTTOV:

Saunders, R., Hoeking, J., Turner, E., Rayet, P., Ruedle, D., Brunel, P., Vidot, J., Roquet, P., Matricardi, M., Geer, A., Bormann, N., and Lupu, C., 2018: An update on the RTTOV fast radiative transfer model (currently at version 12), Geosci. Model Dev., 11, 2717-2737. <https://doi.org/10.5194/gmd-11-2717-2018>

Given an atmospheric profile of temperature, water vapour and, optionally, trace gases, aerosols and hydrometeors, together with surface and atmospheric radiances in each of the channels of the sensor being

cal depths due to gas absorption which is described in the RTTOV v13 Science and gives the Jacobian matrix which describes the change in radiance for a change in ship about a given atmospheric state. For a brief mathematical overview of



衛星データシミュレータに期待される役割

- ・既存のLevel 2/3プロダクトの枠を超え、Level 1データ活用のポテンシャルを発掘
- ・数値モデルの出力（降水量など）に留まらず、モデル内部に埋め込まれた物理過程（雲微物理など）の検証へ（プロセス指向研究）
- ・複数の装置・衛星を組み合わせた解析で、さらに豊かな情報量を抽出できる可能性

