Cloud-Radiation-Precipitation Modeling and Assimilation

An IDS for Improving NWP and Climate Modeling

Arthur Y. Hou

NASA Goddard Space Flight Center

Co-Investigators and Collaborators:

J. Bacmeister/*GSFC*
M.-D. Chou/*GSFC*
L. Donner/*GFDL*
M. King/*GSFC*
W. Lau/*GSFC*
S.-J. Lin/*GFDL*
X. Lin/*UMBC*
P. Norris/*UMBC*
W. Olson/*UMBC*
S. Platnick/*GSFC*
P. Rasch/*NCAR*
Y. Sud/*GSFC*
W.-K. Tao/*GSFC*

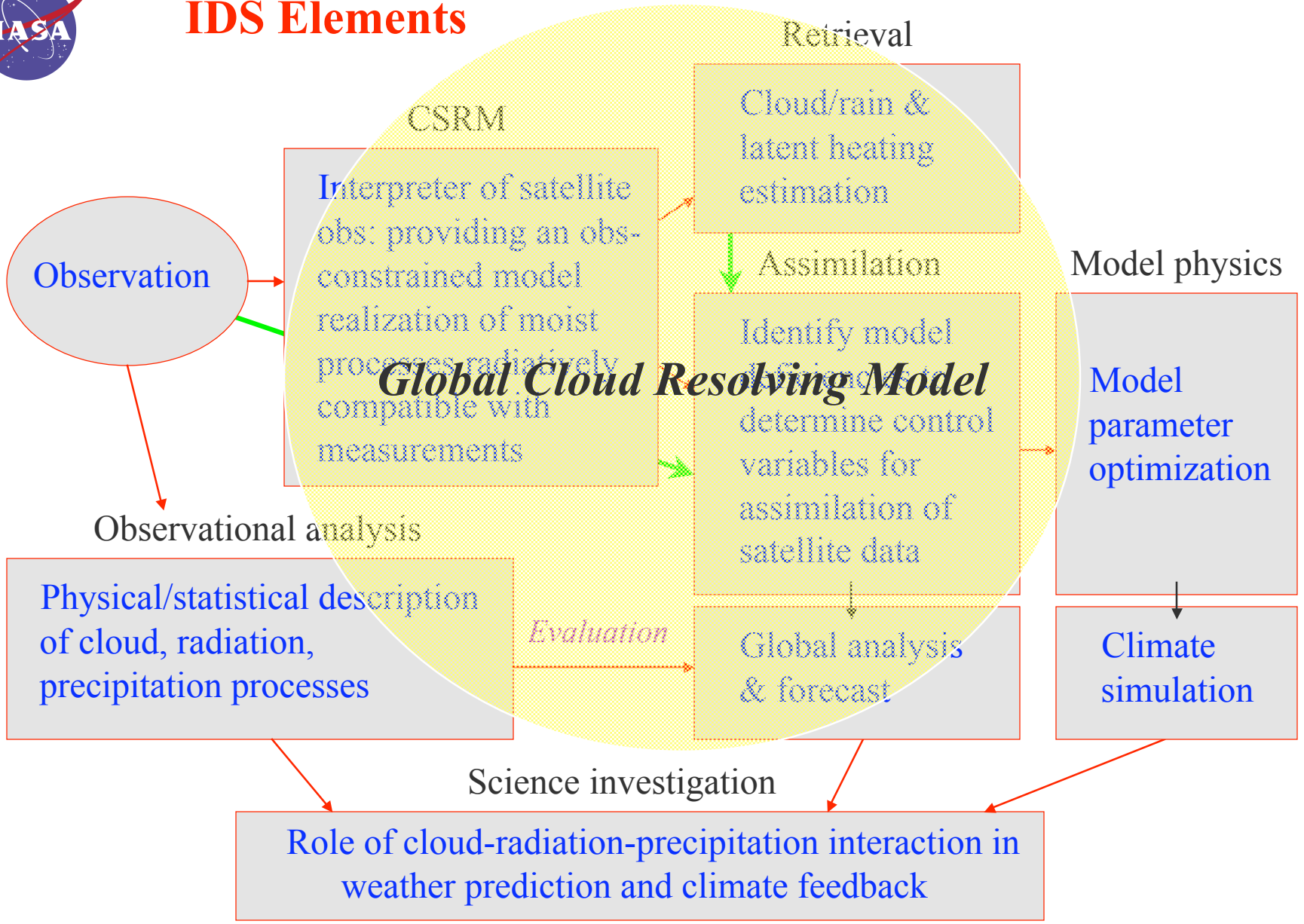
NSF STC Workshop, December 15, 2003, Silver Spring, Maryland

IDS Aim and Strategy

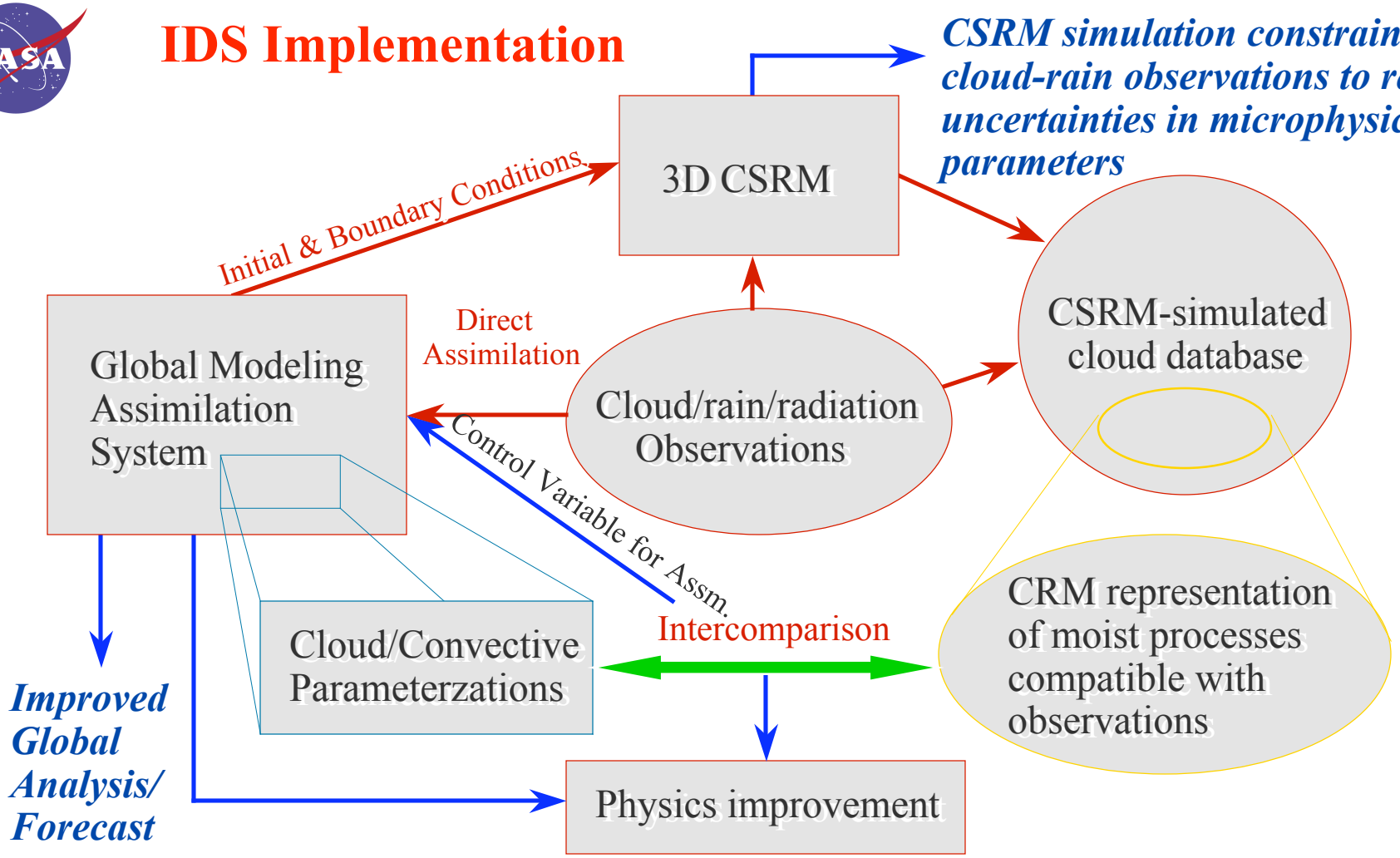
A CSRM-centric strategy to bridge satellite measurements and global models:

Use 3D CSRM to transfer information from cloud-radiation-precipitation measurements at satellite-pixel scales to global modeling & forecast systems

IDS Elements



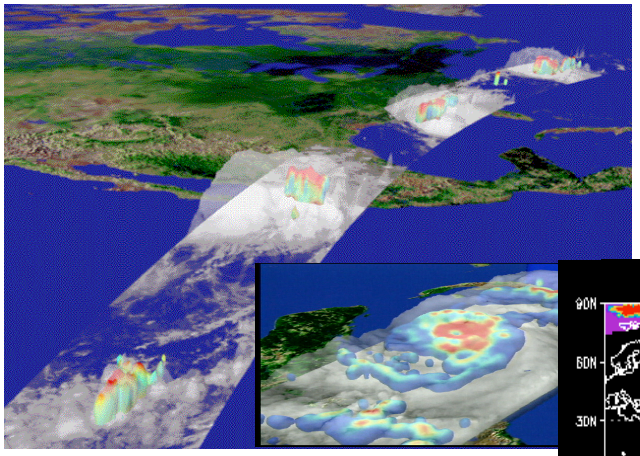
IDS Implementation



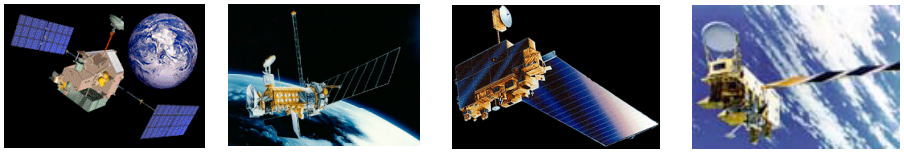
The IDS components operate as an offline global cloud-resolving model (without CSRM-feedback) to explore new pathways to using satellite data to improve model physics and develop effective assimilation methods for global forecast systems

IDS Building Blocks: Satellite Observations

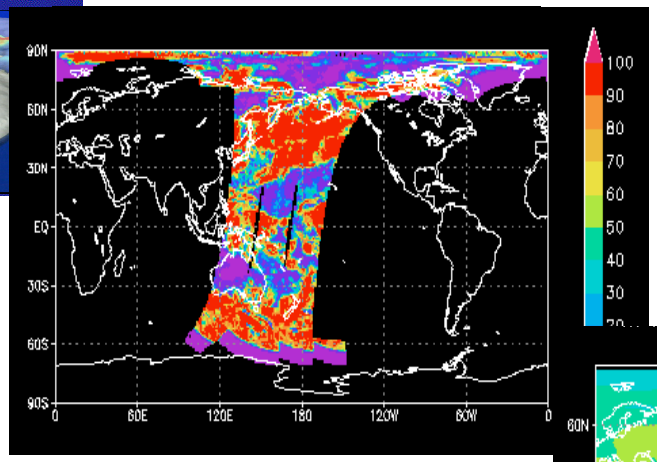
Precipitation from active/passive microwave sensors:
TRMM, SSM/I, AMSR, *GPM*



Tropical Storm Howard, Hurricane Isis, Hurricane Earl and Hurricane Danielle on Sept. 2, 1998

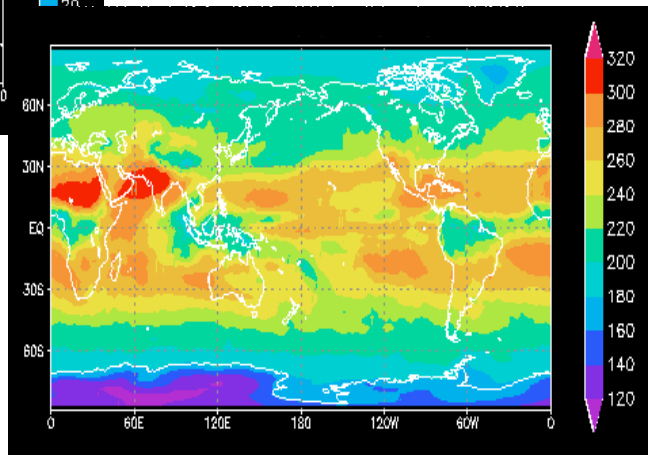


Cloud information MODIS,
CloudSat, A-Train, EarthCARE



MODIS (Terra) Total Cloud Fraction (day-time) retrieval based on optical properties (00 UTC May 5, 2001)

CERES TOA
radiation measurement

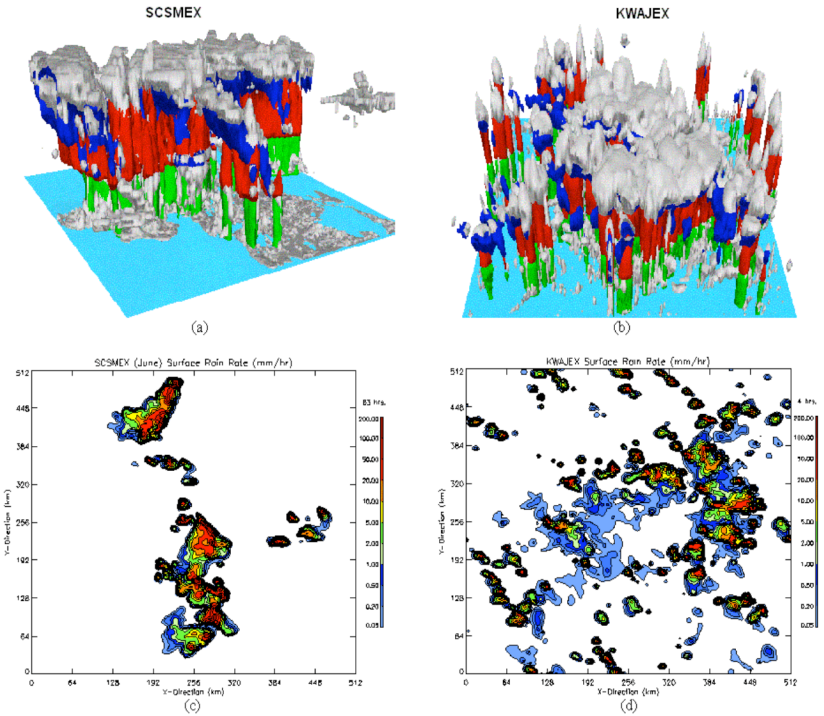


CERES ES4 All-Sky OLR (W m^{-2}) April 2000

IDS Building Blocks: CRM, Global GCM & DAS

Cloud System Resolving Model:

Goddard Cumulus Ensemble model

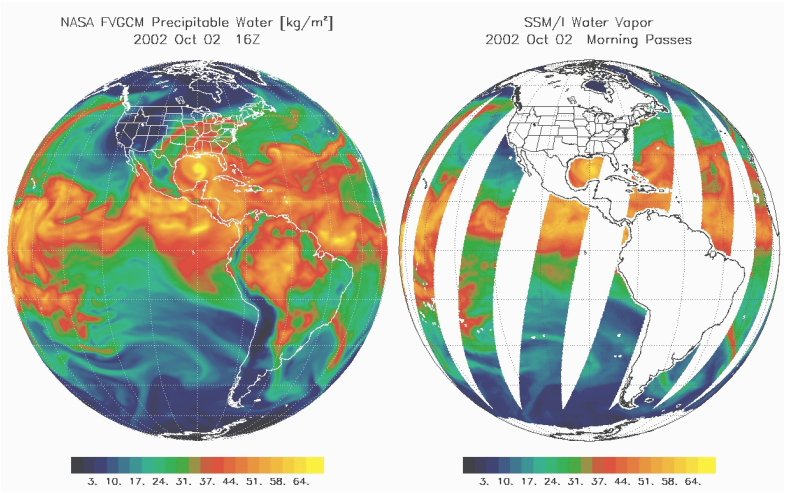


3D GCE model-simulated cloud hydrometeor mixing ratios for SCSMEX and KWAJEX. Top: White for cloud water/ice, blue for snow, green for rain water, and red for graupel. Bottom: Surface rain rate in mm h^{-1} resembling radar observations

Global Modeling & Data Assimilation:

- NASA finite-volume dynamic core
- Cloud/precipitation schemes:

  McRAS, NCAR, GFDL, CSU



Left: 88-hour fv-GCM forecast of the total precipitable water. Right:Composite of SSM/I estimates.

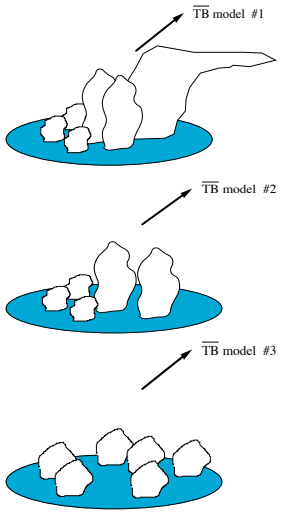
Both GCE and fv-GCM & DAS use the latest Goddard CLIRAD radiative transfer code to model cloud-radiation interactions allowing direct comparison of results

IDS Building Blocks: CRM-based Physical Retrievals

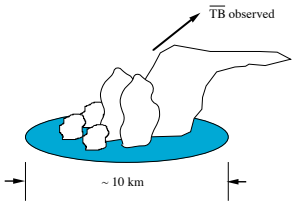
A Bayesian technique to estimate rain from MW T_b

$$E[R]=\sum_k R_k \frac{\exp\left\{-0.5\left(\mathbf{TB_M}(R_k)-\mathbf{TB_O}\right)^T \mathbf{O_{TB}}^{-1}\left(\mathbf{TB_M}(R_k)-\mathbf{TB_O}\right)+C\right\}}{\hat{N}}$$

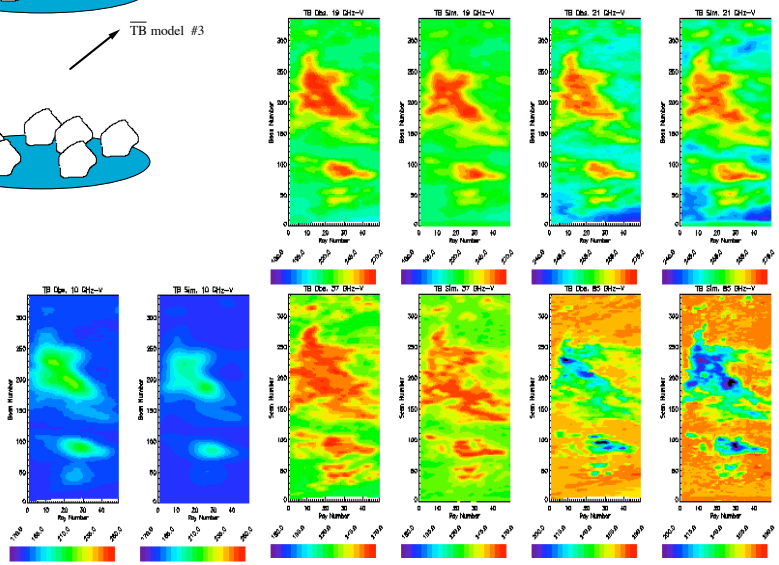
Modeled T_b



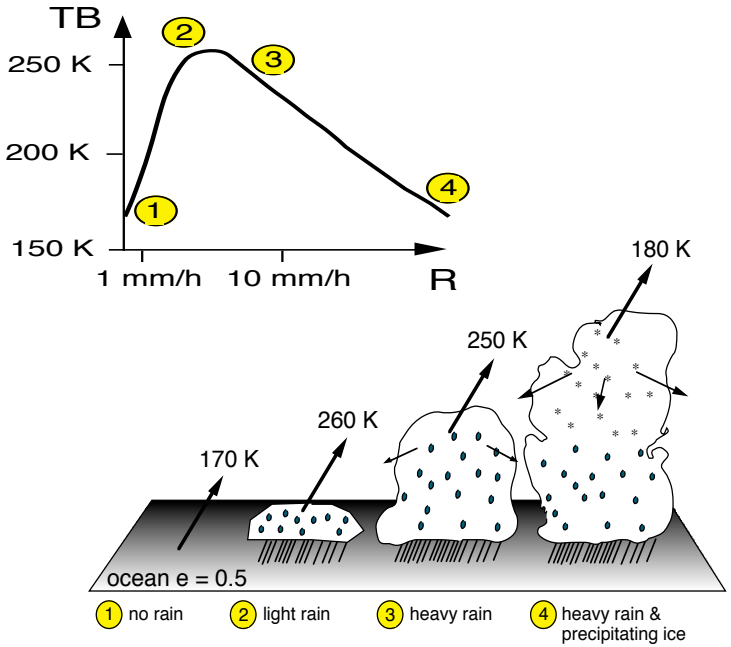
Observed T_b



Simulated vs. TMI observed T_b



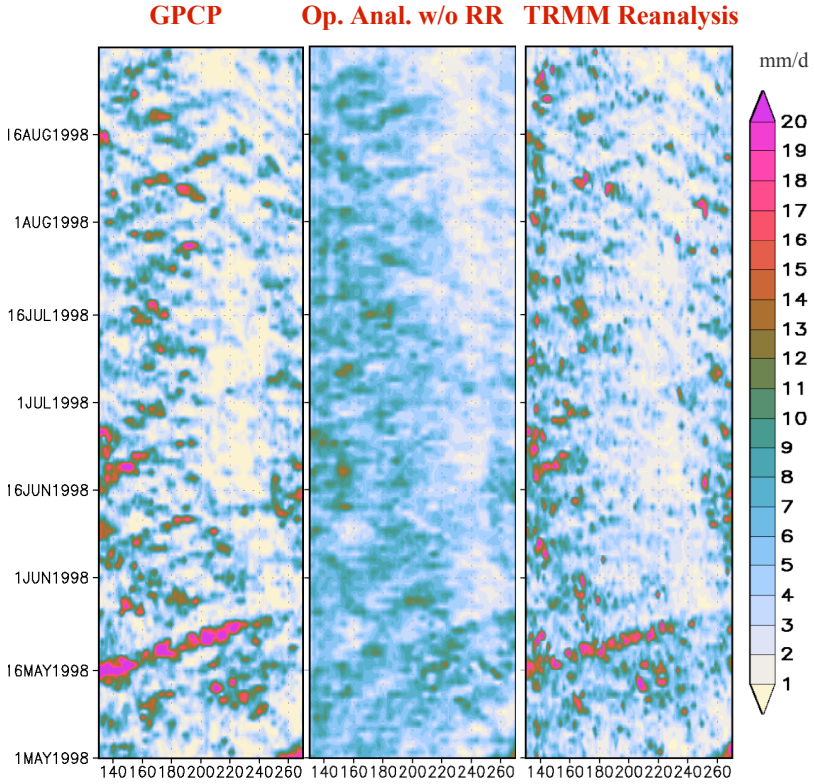
Microwave radiance at 37 GHz



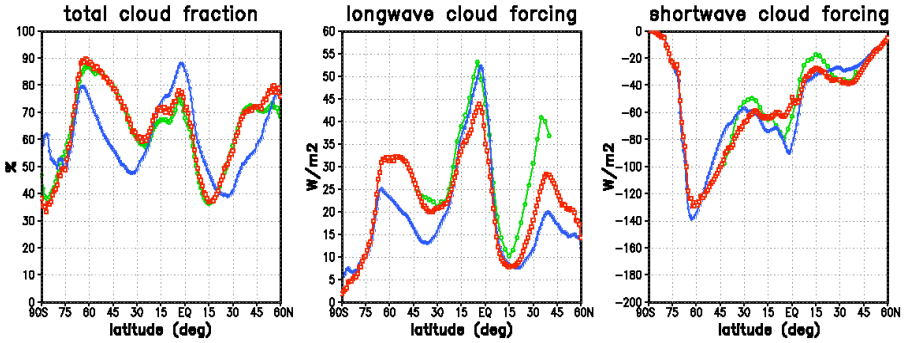
Providing an observation-constrained CRM realization of moist processes that are radiatively consistent with satellite measurements

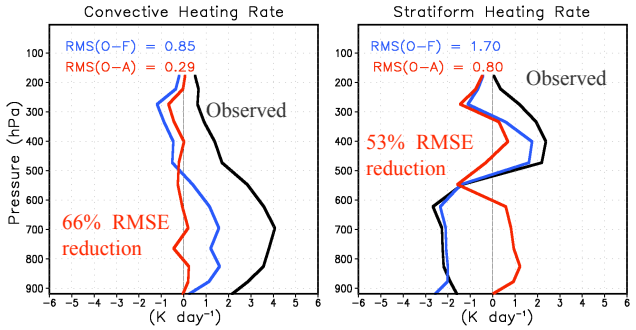
IDS Building Blocks: Precipitation& Cloud Assimilation

Impact of rainfall assimilation on MJO Signal in Precipitation (10°N-10°S)



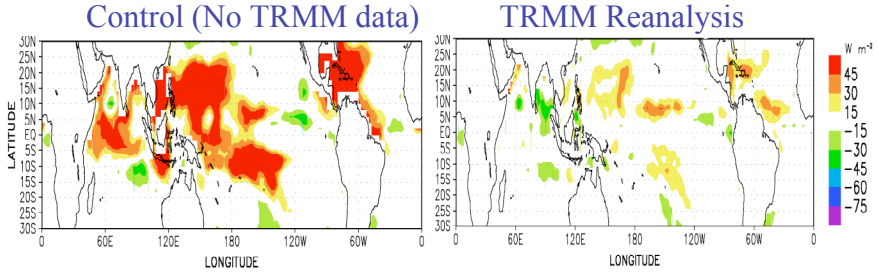
Assimilation of ISCCP cloud fraction through parameter optimization improves TOA radiation in GEOS analysis



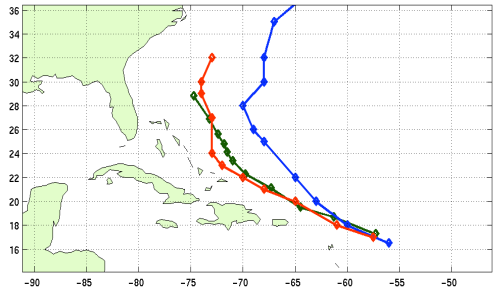


Assimilation of TRMM latent-heating using moist-physics parameters as control variable

IR Cloud Forcing TRMM re-analysis Minus CERES (Jan 1998)



Improved 5-day Hurricane Bonnie track forecast



Blue: Control (No cloud or rain data)

Red: With cloud or rain data

Green: Verification

Forecast issued from 12UTC 8/20/1998

Challenges and Expected Results

- Bayesian retrievals of rain/latent heating information using an improved CSRM-simulated cloud database for observed meteorological conditions
- Providing an observation-constrained CRM benchmark of moist processes consistent with satellite measurements for evaluating global model physics and identifying control variables for assimilation of cloud/rain observations
- Observational analyses of cloud-radiation-rain processes to assess global model physics and uncertainties in microphysics in CRMs to guide model improvements
- Developing effective methods for assimilating cloud and precipitation information from satellite sensors in global forecast systems to improve atmospheric analyses and forecasts
- Exploring new pathways to optimize physics schemes in global models through parameter estimation within the *data assimilation cycle* to improve model physics
- Identifying critical parameters in microphysical representations (e.g. cloud-rain partition) that dominate climate feedback processes to improve climate modeling and prediction