An Observationally-Based Evaluation of Clouds and Radiation in Global Climate Numerical Models Using Contemporary Satellite Data

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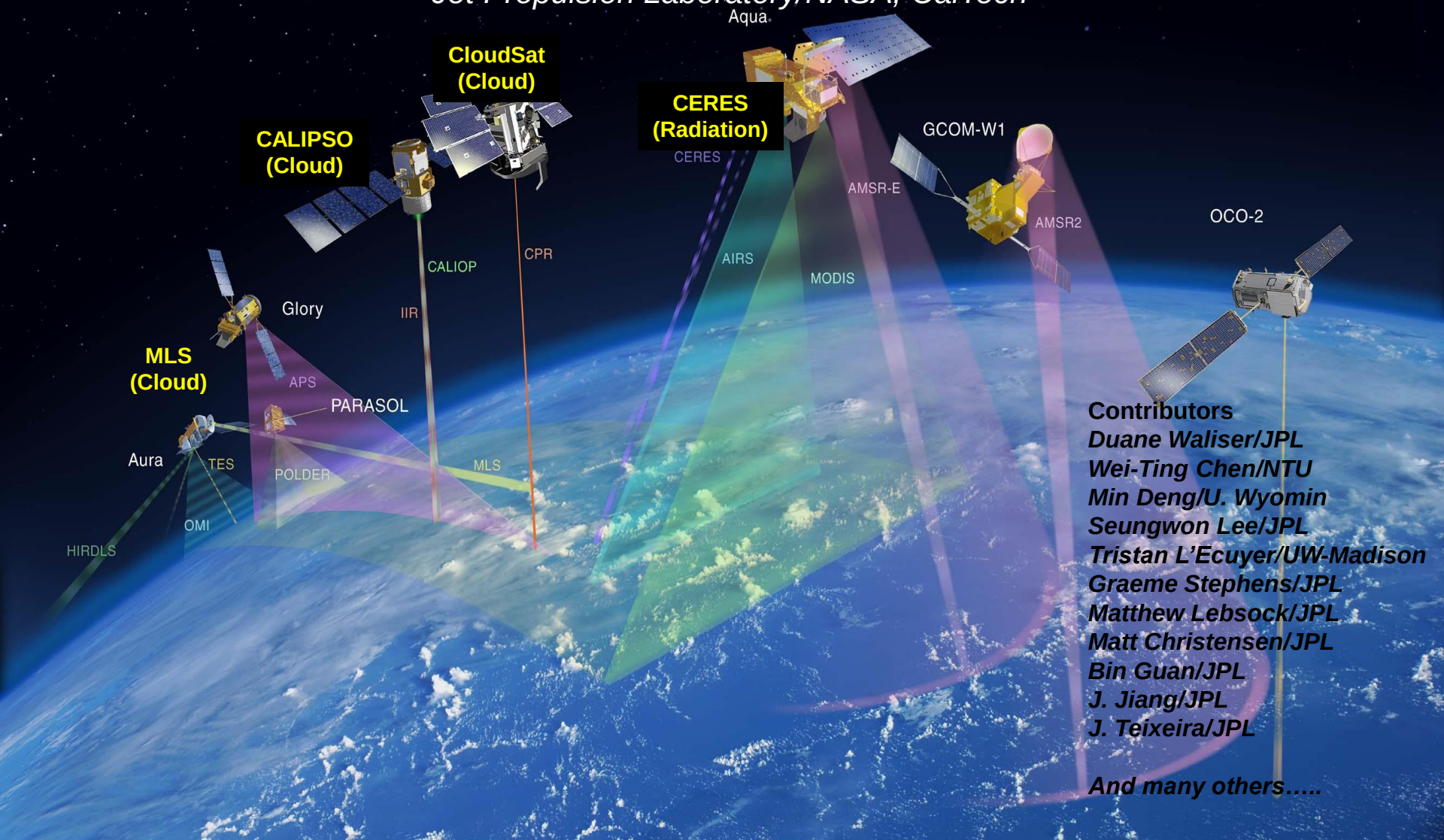

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And many others…..

Cloud Water Measurement From Satellites using Passive Techniques

Passive Techniques such as those used in the CERES/MODIS, ISCCP, MODIS, and NOAA/MW products can provide Total ice water path (IWP) estimates - challenging in multi-layer, mixed and thick clouds.

MLS - a limb sounder - can probe the upper troposphere to estimate IWC (but not Total IWP)

Satellite data usingactive techniques from CloudSat/CALIPSO provide an opportunity for validating and constraining vertical cloud hydrometeors profiles for models

CloudSat/CALIPSO

Uncertainties & Applications of the Retrived Cloudsat/CALIPSO "Cloud Ice and Liquid"

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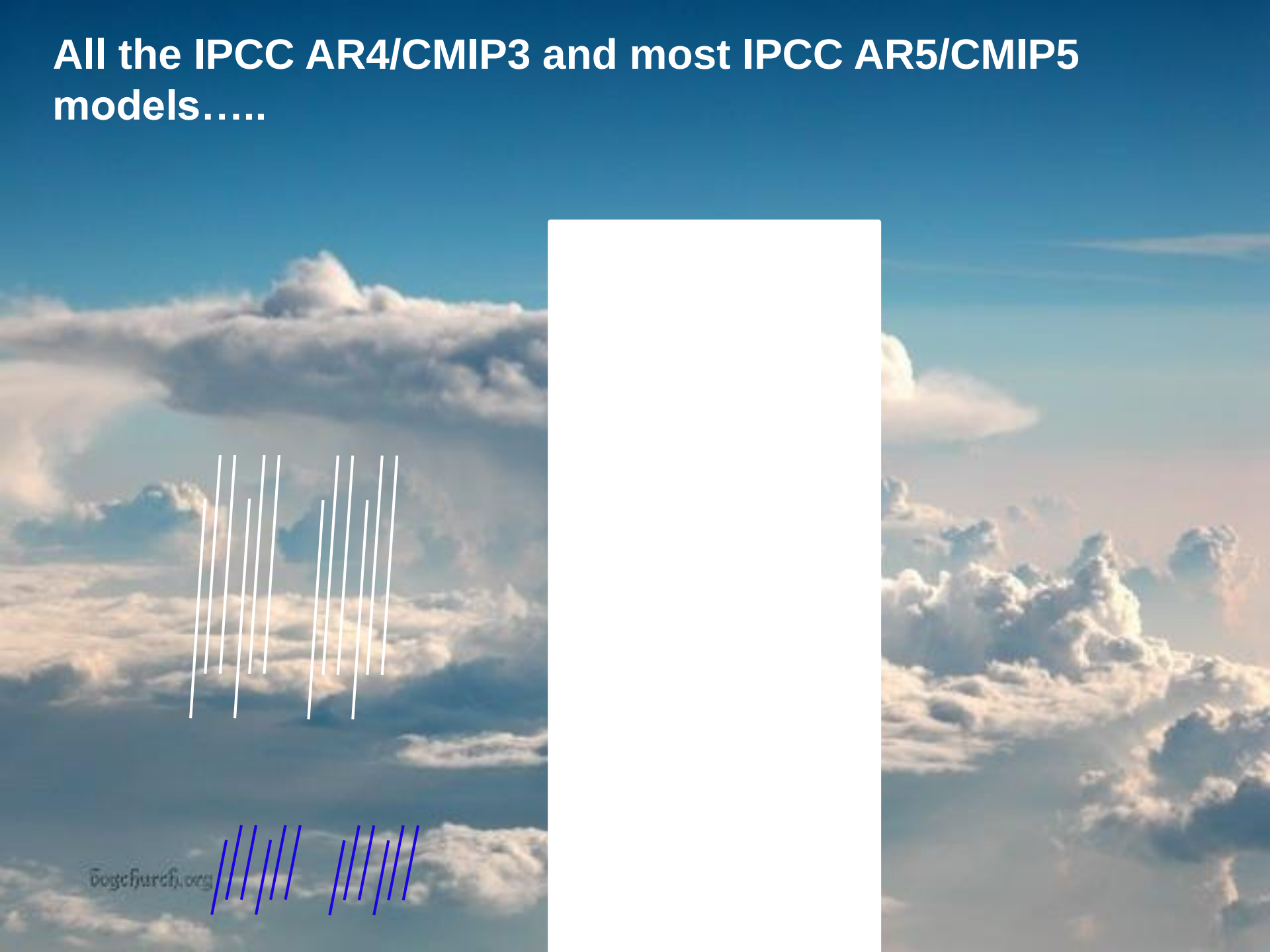
All the IPCC AR4/CMIP3 and most IPCC AR5/CMIP5 models…..



All the IPCC AR4/CMIP3 and most IPCC AR5/CMIP5 models…..

- **Assuming deep cumulus clouds fraction is very small, and rain/snow fall down onto the surface**
- **Assuming big drop of falling snow scatters very little radiation compared to the same mass in tiny little droplets**
- **These assumptions to date haven't been too bad with coarser resolution (e.g., 4 latitude by 5 Longitude).**

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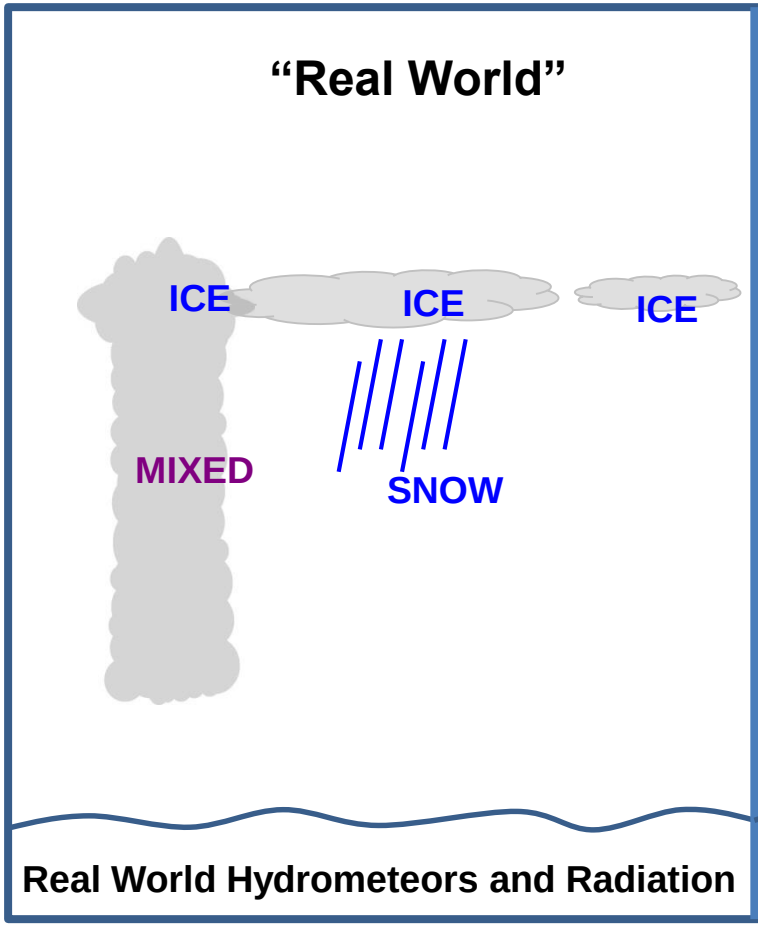
Representation of Ice Water Content (IWC) for Radiation Calculation in GCMs



- **Few GCMs such as NASS-GISS model, NCAR-CAM5, GFDL-AM3 and CSIRO etc include *diagnostic* falling snow and/or convective ice (or snow) in their models**

(Li et al., 2012)

Available CloudSat/CALISO IWC Products:

1. **2CWC** - CloudSat Radar Only (Standard CloudSat product)

2. **DARDAR** - CloudSat Radar +CALIPSO Lidar combined products (Delanoe et al., 2010)].

3. **2CICE** - CloudSat Radar +CALIPSO Lidar combined products (Deng, 2011)

These data are sensitive to "falling" and "floating cloud" particles

For a meaningful model-data comparison

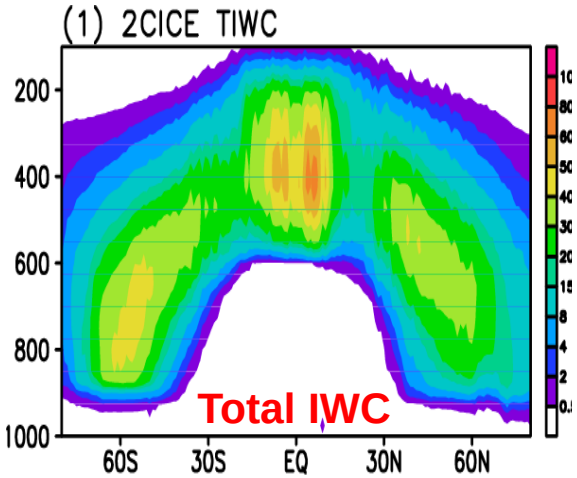
Discriminate observed "cloud only" IWC data
or
Include large ice particle in a GCM
or
Cloud simulator is another good choice

(Li, J.-L. F., D. E. Waliser, S. Lee, Guan, T. Kubar, G. Stephens, H-Y Ma, (2012a): An Observational Evaluation of Cloud Ice Water in CMIP3 and CMIP5 GCMs and Contemporary Analyses, J. Geophys. Res., doi:10.1029/2012JD017640.)

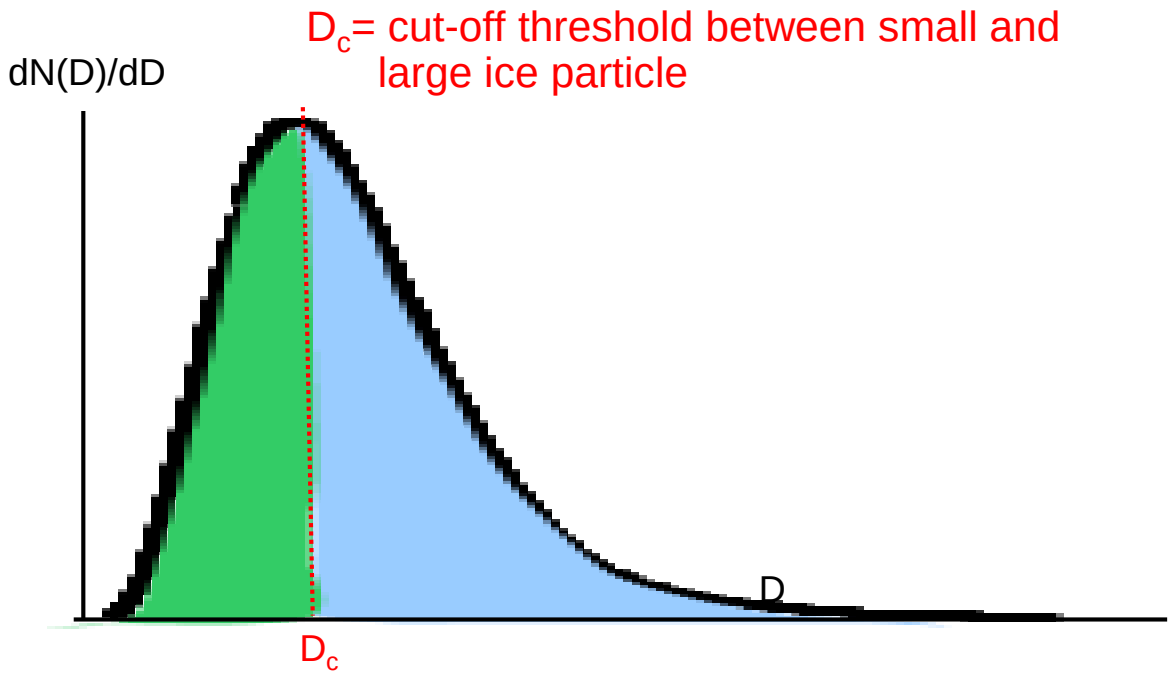
Discrimination of Observed Cloud Ice Water Content

Methods to estimate observed cloud ice water content (CIWC) and cloud liquid water content (CLWC) from CloudSat and/or Calipso:

FLAG method - filter out cloud hydrometers using flags with convective & precipitation cases to get ballpark estimates of CIWC & CLWC



PSD method - Using CloudSat Specified PSD information
Separate Cloud only ice (CIWC) and Precipitating Ice ("large") in CloudSat Total IWC



$IWC_{<Dc}$ = "Small" Ice Mass (cloud ice)

$IWC_{>Dc}$ = "Large" Ice Mass (precipitating ice)

(Chen et al., 2011)

Observed Ice Water Content (IWC) for Model-Data Evaluation

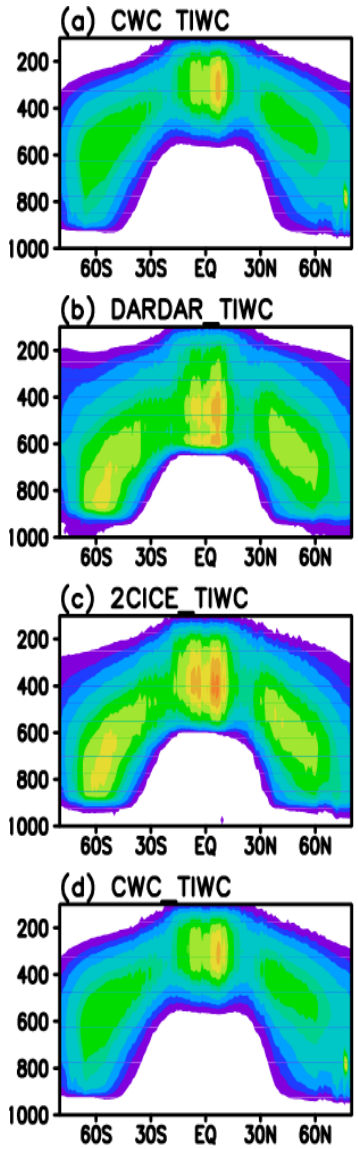
Total IWC

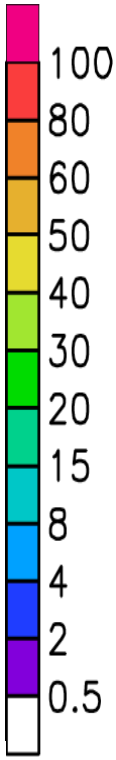
CWC
FLAG

DARDAR
FLAG

2CICE
FLAG

CWC
PSD

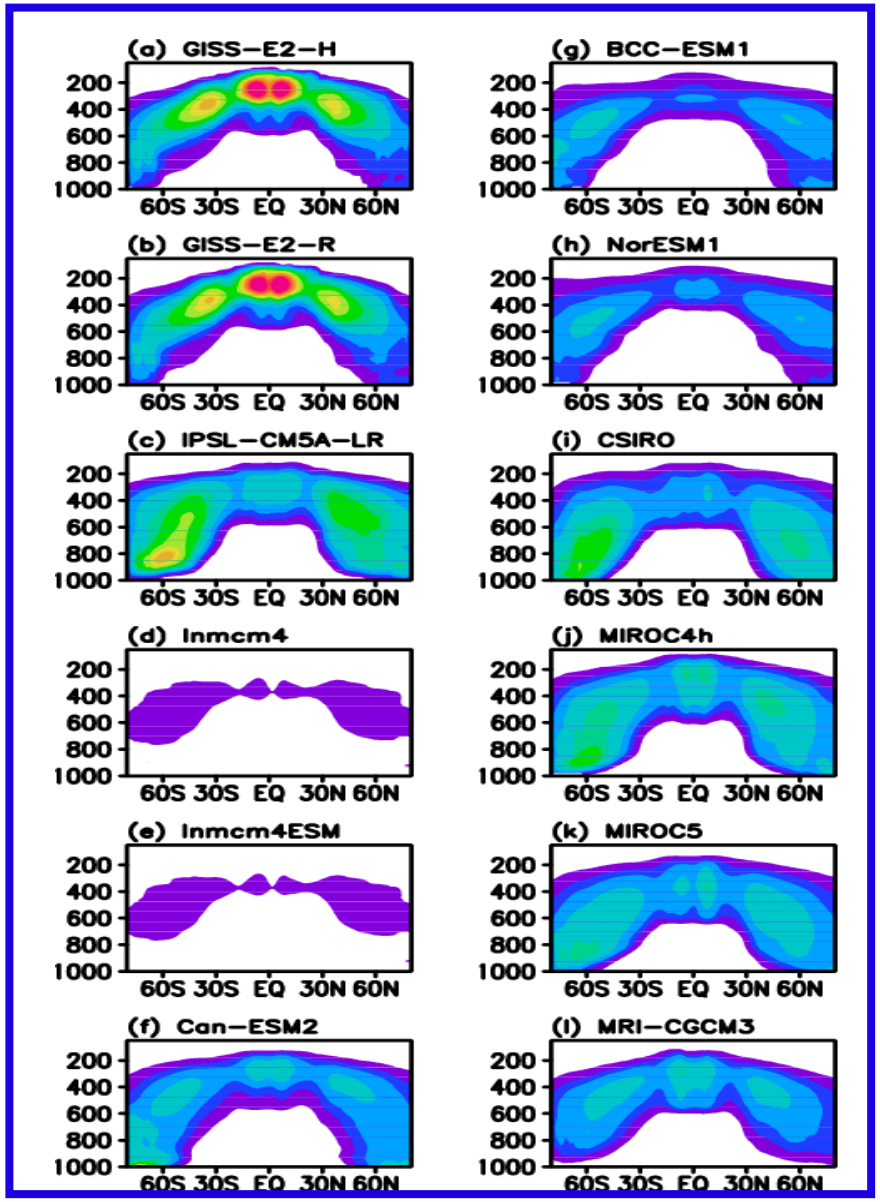


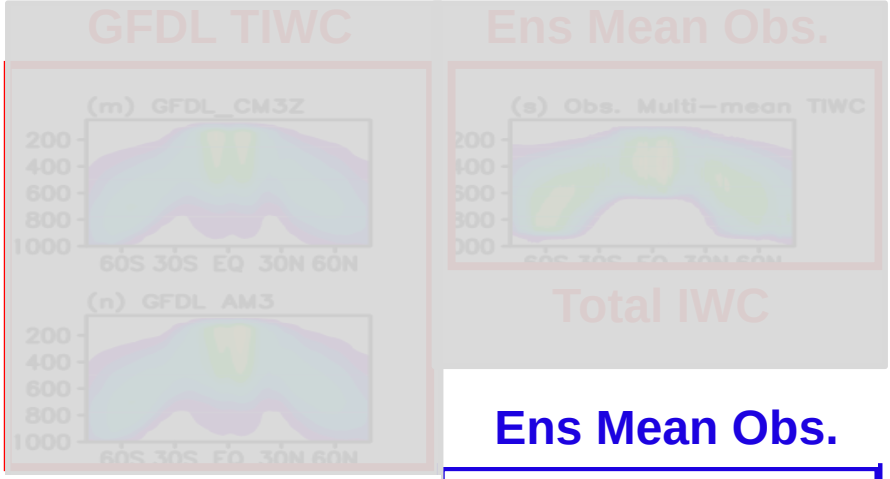


(Li et al., 2012)

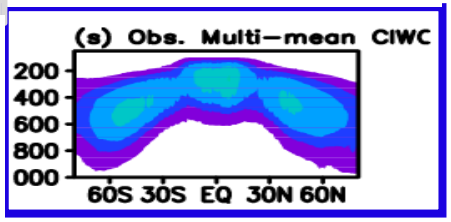
IPCC CMIP5 Model Uncertainties: “Cloud Ice Water Content- CIWC”

CMIP5 – Cloud only IWC

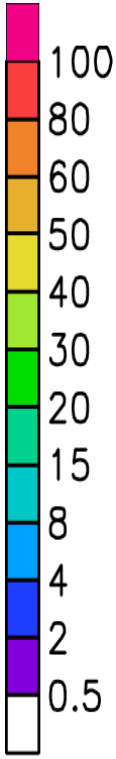




Ens Mean Obs.

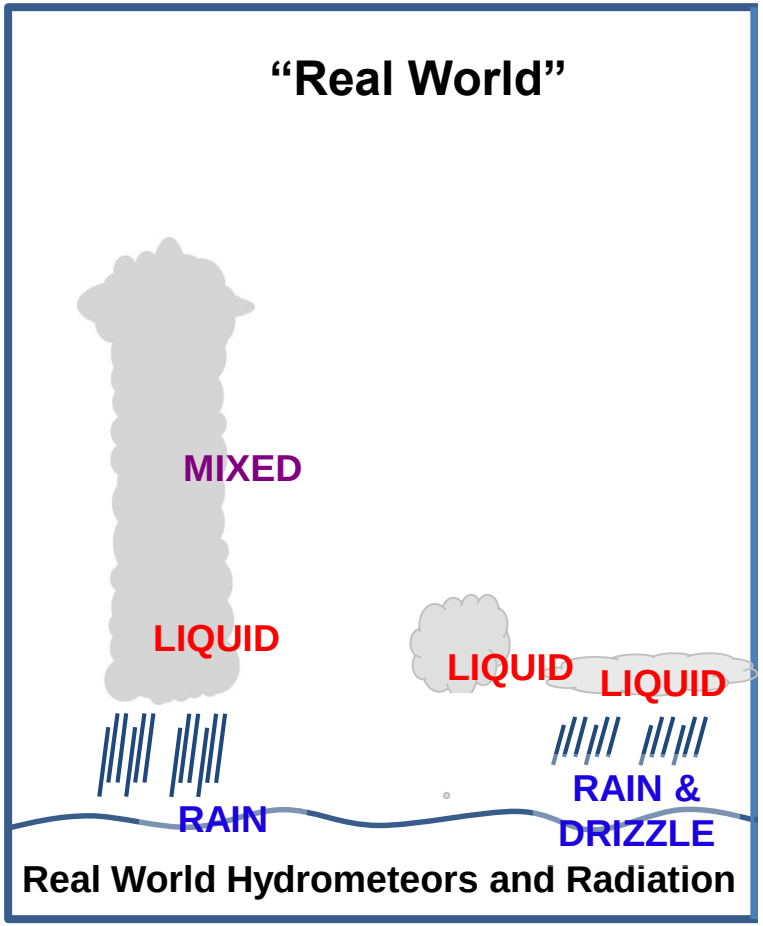


Cloud Only IWC



(mg kg^{-1})

Representation of Liquid Water Content (LWC) for Radiation Calculation in GCMs



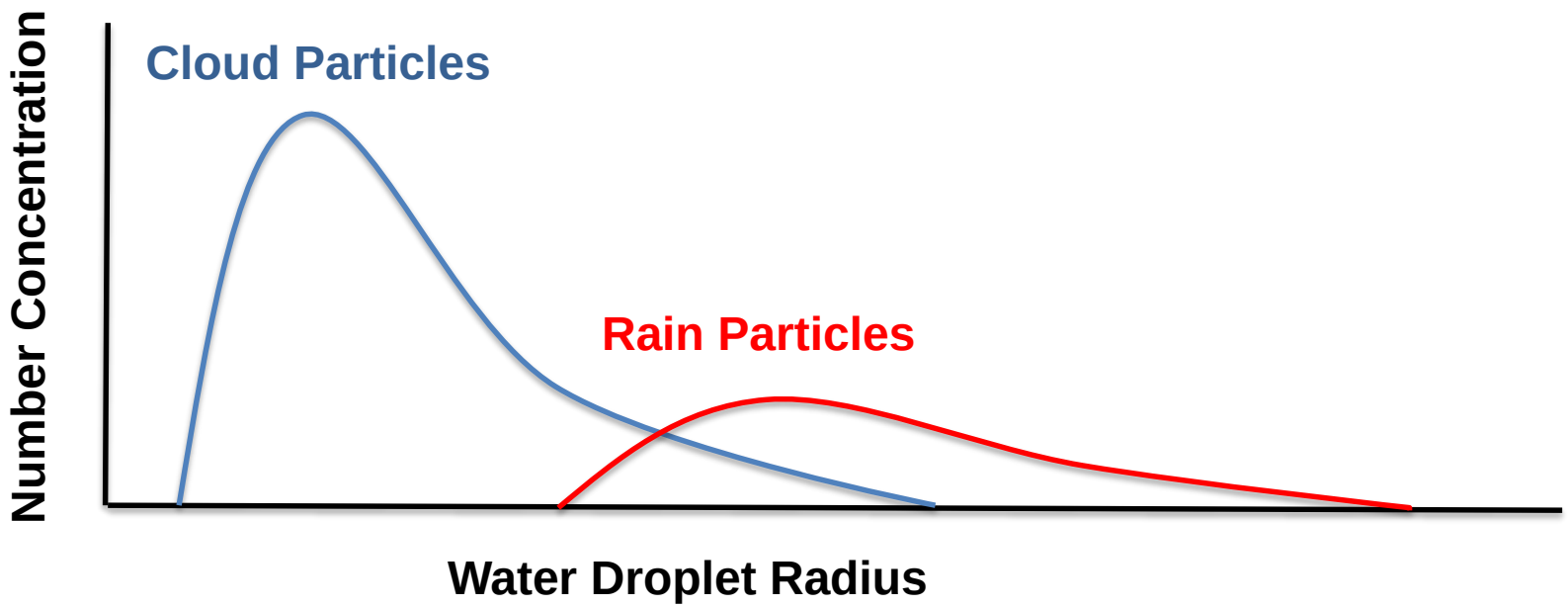
(Li et al., 2013, under revision)

CloudSat LWC/LWP Retrieval: Major Uncertainties & Caveats

- **Failure of LWC retrieval below about 800 meters (~950-900 hPa) above the surface due to surface clutter.**

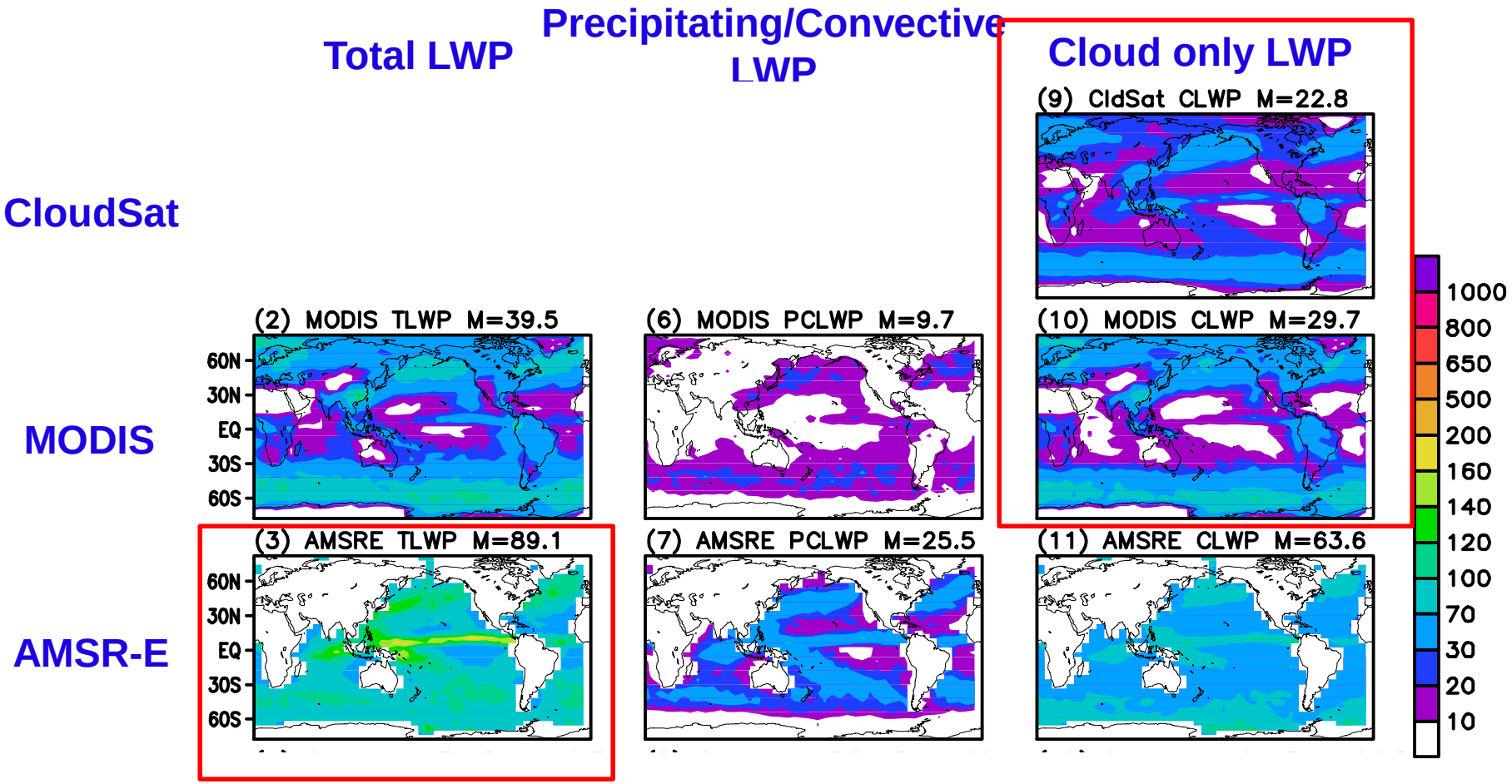
- **But the standard CloudSat retrieval assumes the entire PSD follows one functional PSD.**

- **BUT, CloudSat radar is more sensitive to large-size particles, and the water droplet particle size distribution (PSD) for cloud particles (small-size) is different from the PSD for rain particles (large-size).**

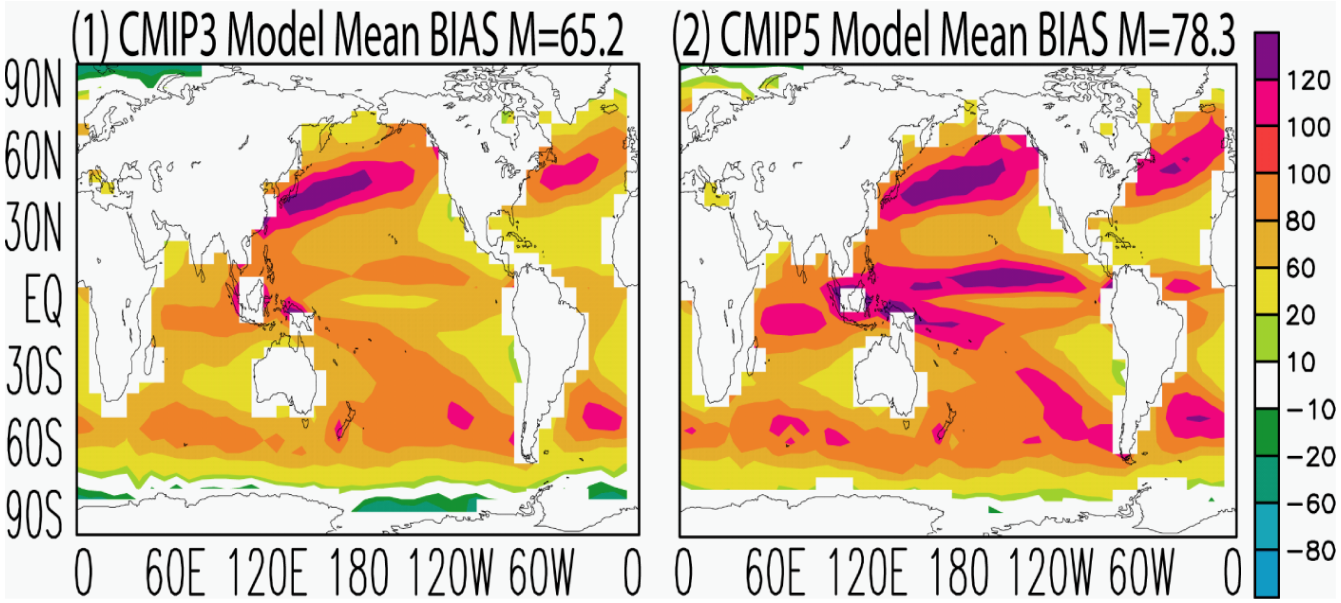


Extimate Liquid Water Content (LWC) Data

(g m^{-2})



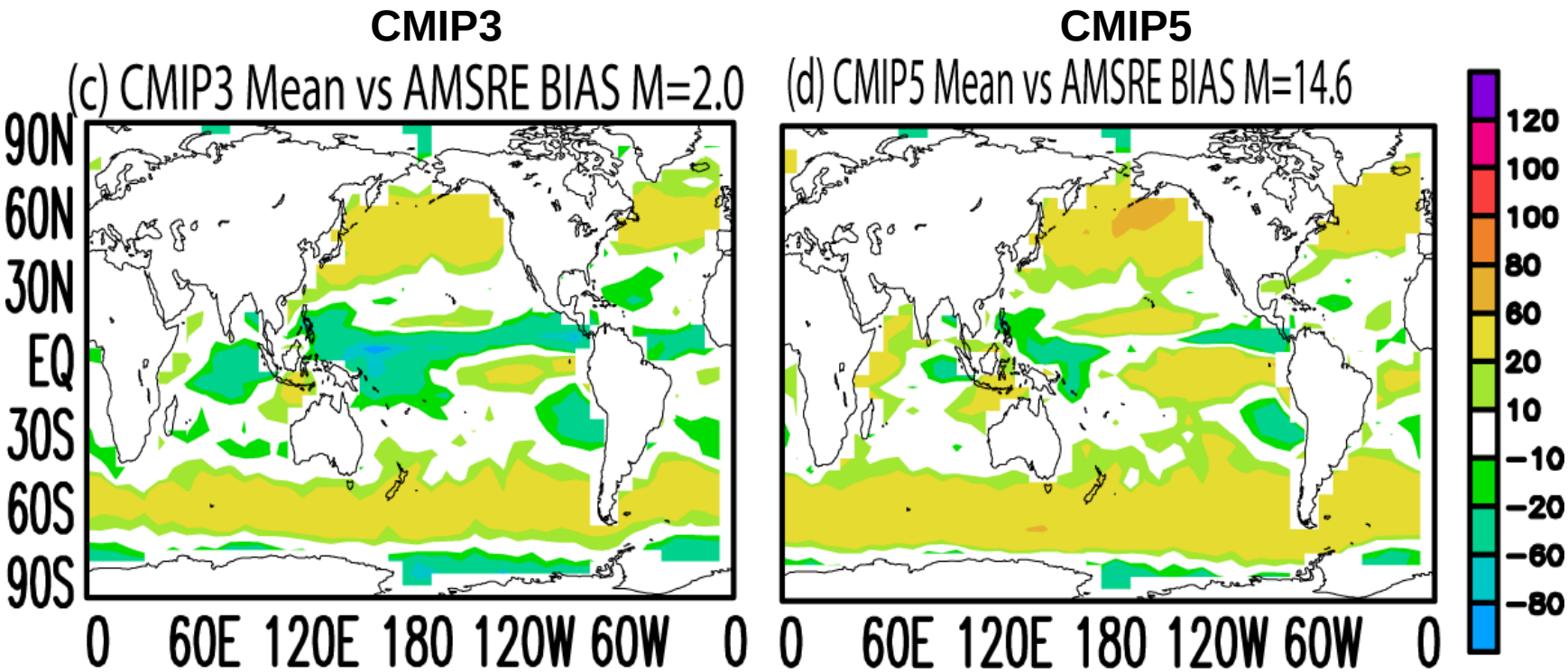
CMIP3/CMIP5 CWLP Mean Bias vs CloudSat+MODIS-based "Cloud only" LWP



No improvement from CMIP3 to CMIP5 for CLWP estimation.

Most models significantly overestimate CLWP.

Bias of CMIP Ensemble Mean CLWP vs AMSRE-"Total LWP"



The ensemble CMIP3 and CMIP5 LWP have similar biases relative to ensemble mean AMSR-E LWP

Underestimate "total" LWP over heavy rainfall regions

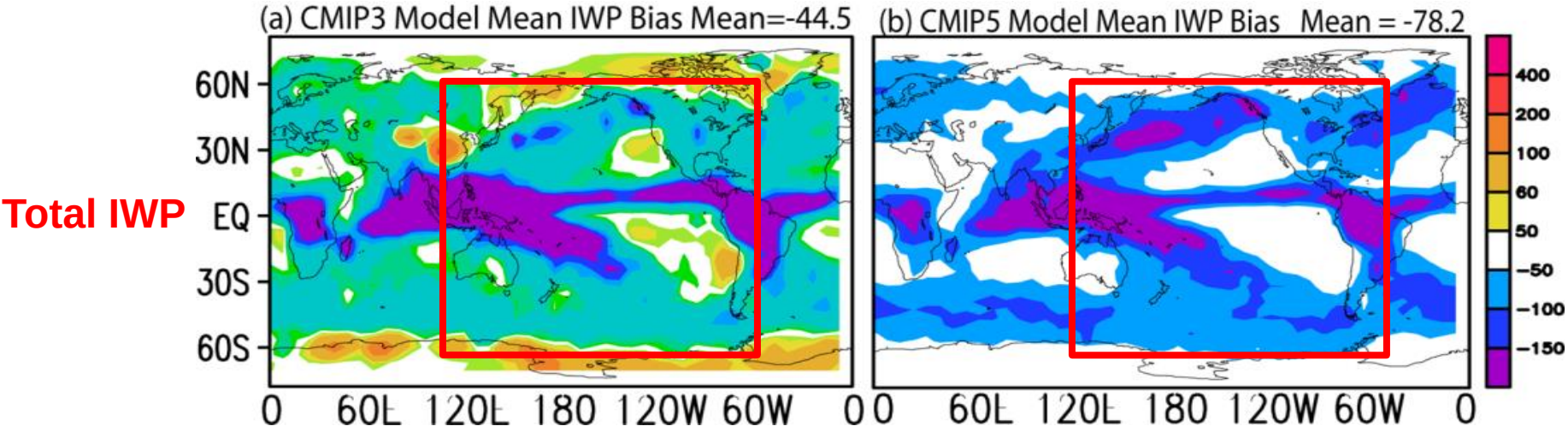
LWC/LWP Major Retrieval Uncertainties and Caveats

It is imperative to consider the issues presented here to properly utilize the CloudSat (LWC/LWP) and other passive LWP data (MODIS, AMSR-E) for model comparison and validation.

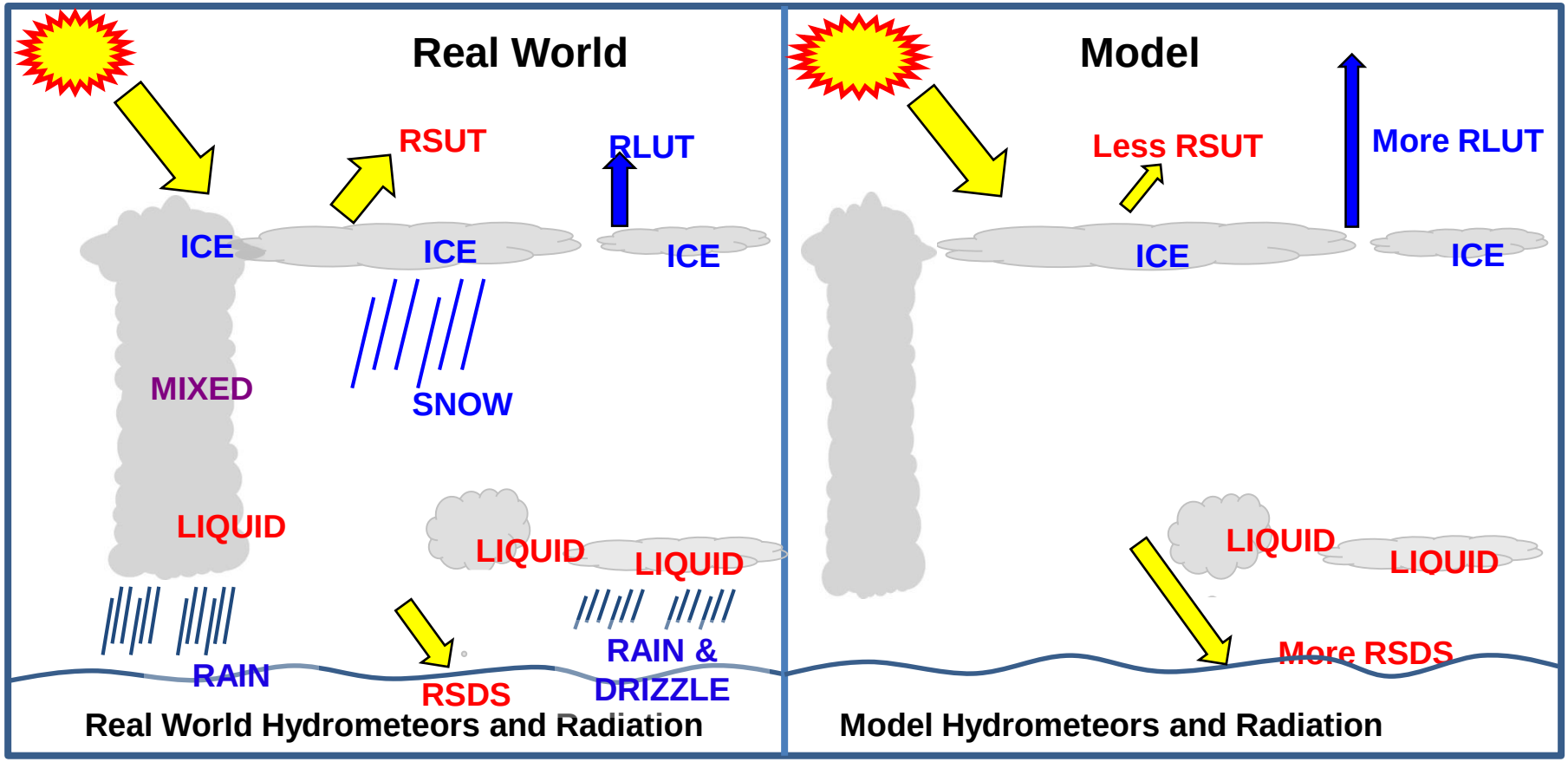
Use these retrieved LWC and/or LWP for model evaluation cautiously…..

Bias of CMIP Ensemble Mean Cloud Only IWP vs Obs. *Total CloudSat* IWP

CMIP3 **CMIP5**



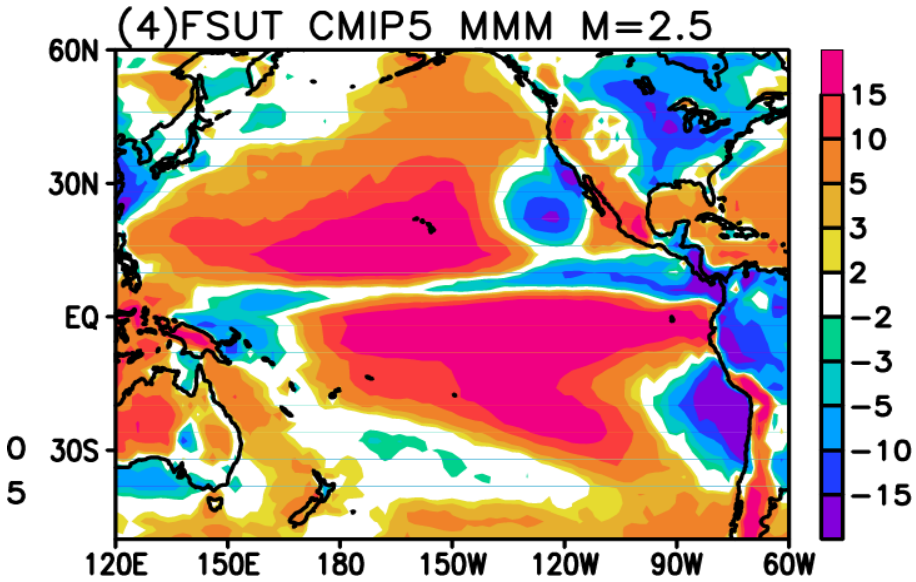
Representation of Cloud Water Content (CWC) for Radiation Calculation in GCMs



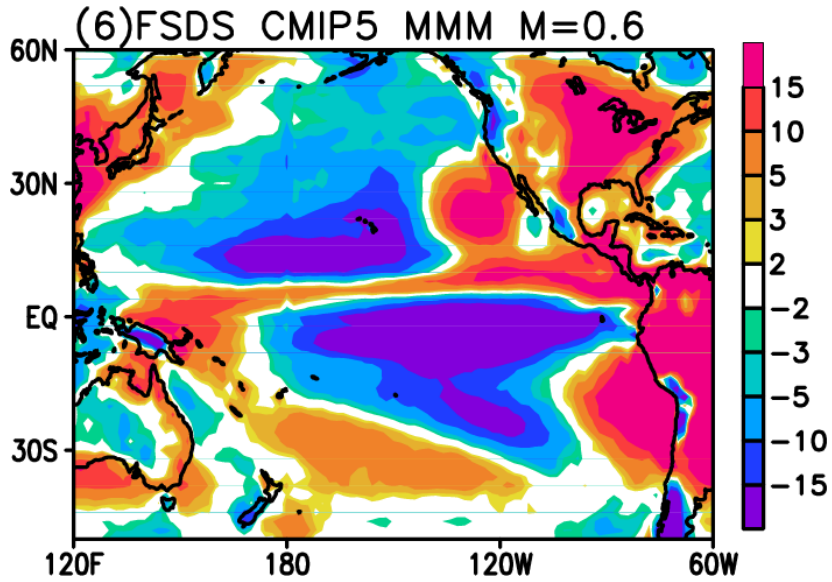
Bias of CMIP5 Ensemble Mean Radiation vs. Water Vapor - Total PW

(CMIP5 Model fluxes) – (CERES Fluxes)

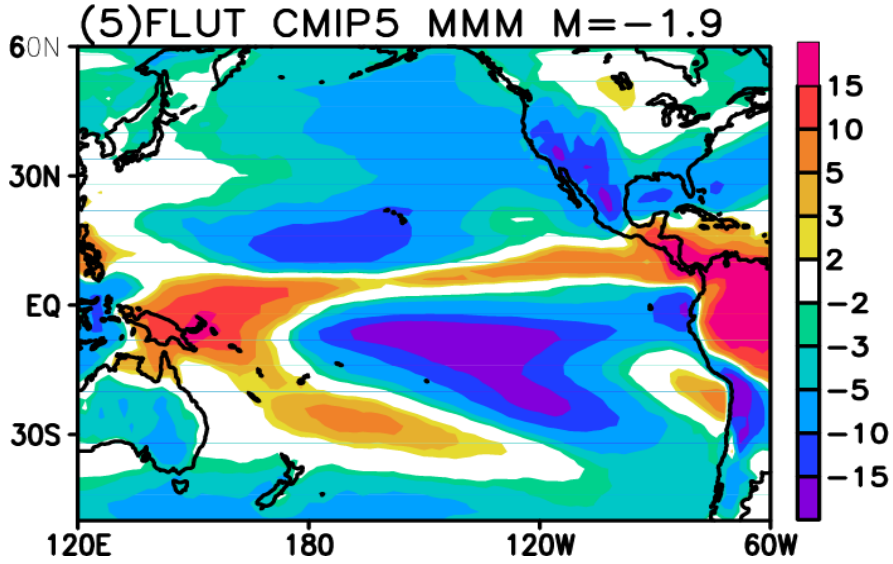
Reflected Shortwave at TOA



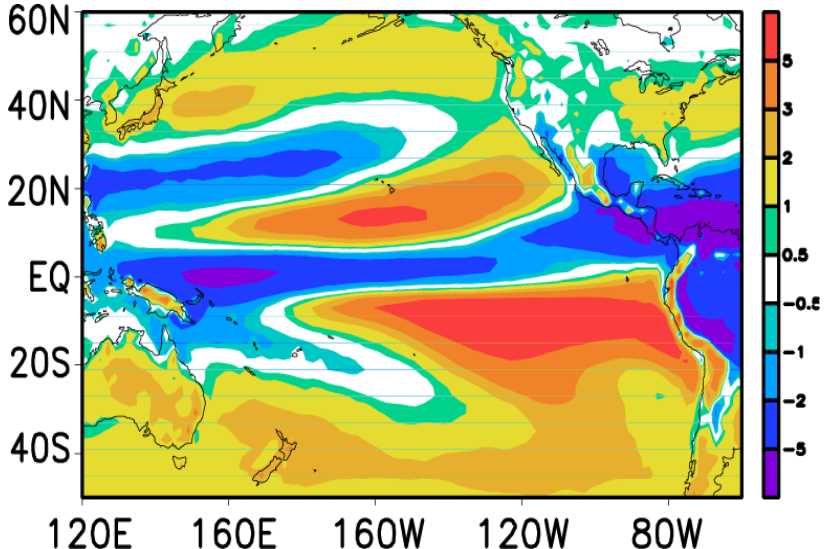
Downward Shortwave at SFC



Outgoing Longwave at TOA



CMIP5 Total Precipitable Water (mm)



Result Highlights

•Caution must be taken into account when making model-data comparisons related to cloud ice/liquid water content and their radiative fields if precipitating/convective core cloud hydrometeors are not represented in the models (Known as conventional GCM including *All CMIP3 & most CMIP5*).

•With filtering out convective clouds and precipitating cases from the observations, we can get a *first order* estimate of ice/liquid in clouds for conventional GCM use *(albeit this has shortcomings)*

•Regional excessive OLR and net surface shortwave fluxes are evident over convective active regions against CERES data, consistent with what was suggested in Waliser et. al. (2011) & Li et al. (2013a;b) that such a bias might be caused by not treating the interaction of precipitation and/or convective core and with radiation in the models.

The impacts of Cloud-Radiation Bias on Circulations, Water Vapor Simulations in CMIP5 and NCAR CESM Sensitivity Experiments

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Jet Propulsion Laboratory/NASA, CalTech

Friday: A53I. Cloud, Convection, Radiation, Water and Energy Cycles II

2:25 PM - 2:40 PM @3010 (Moscone West)

A53I-04. The impacts of Cloud-Radiation Bias on Circulations and Water Vapor Simulations in CMIP5 and NCAR CESM Sensitivity Experiments

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