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Validating Post-CMIP5 Model Improvements in Clouds and Water Vapor using Satellite Observations

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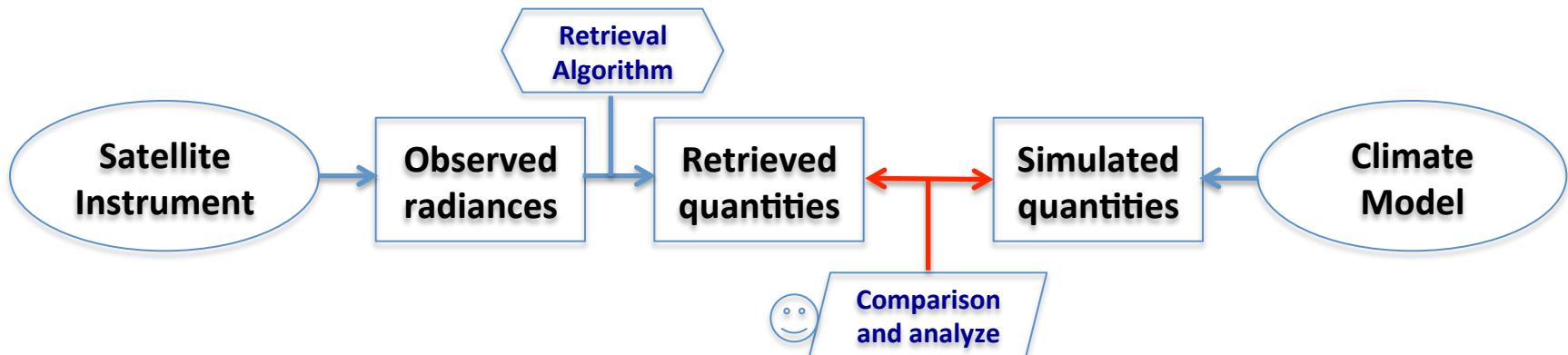
Masahiro Watanabe
Model for Interdisciplinary Research On Climate (MIROC), University of Tokyo, Chiba, Japan

CFMIP – Meeting on Cloud Processes and Cloud Feedbacks, Pacific Grove, CA

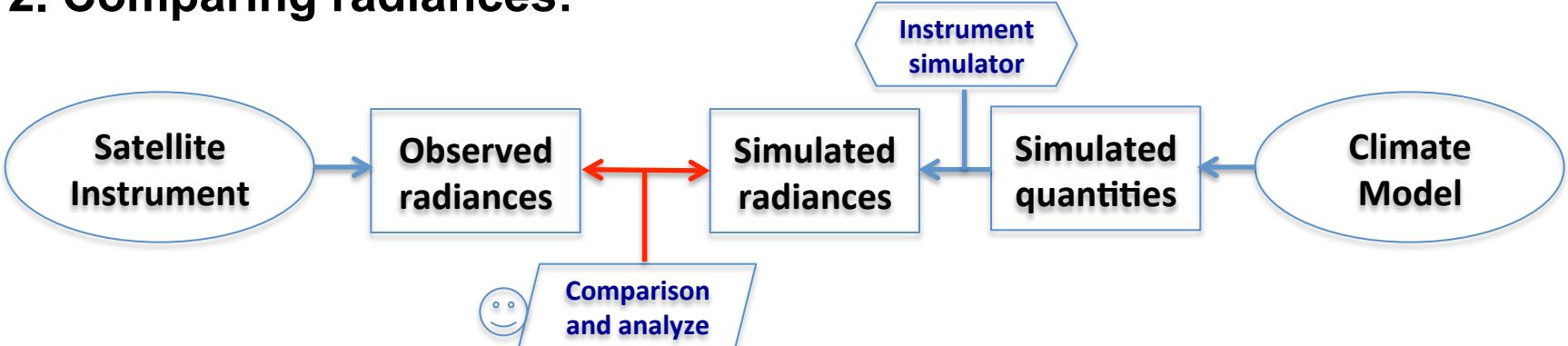


Two model-observation comparison approaches

1. Comparing physical quantities:



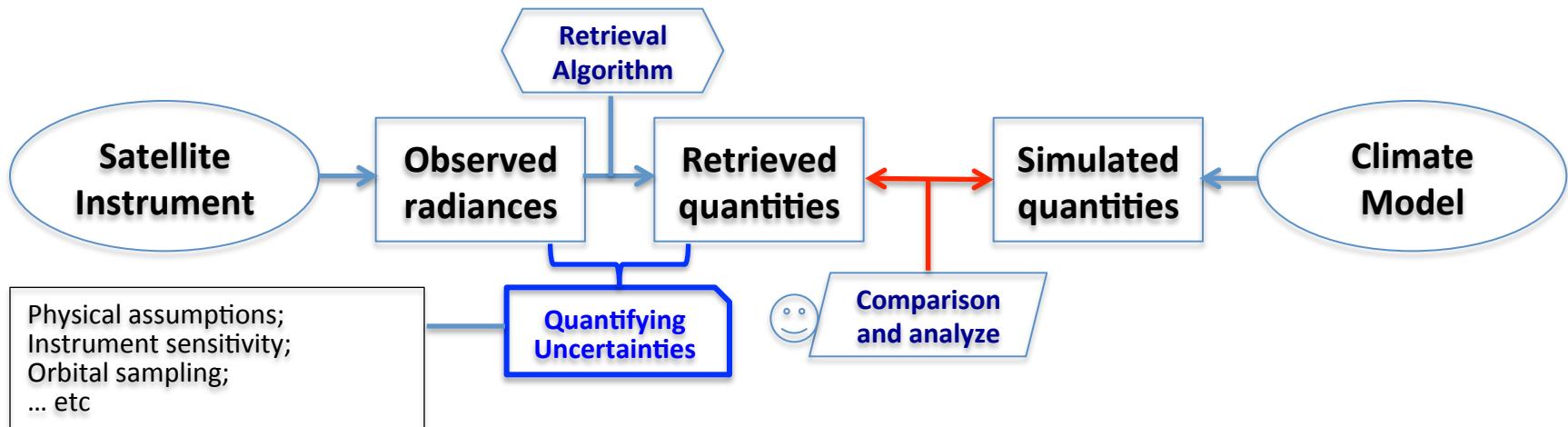
2. Comparing radiances:



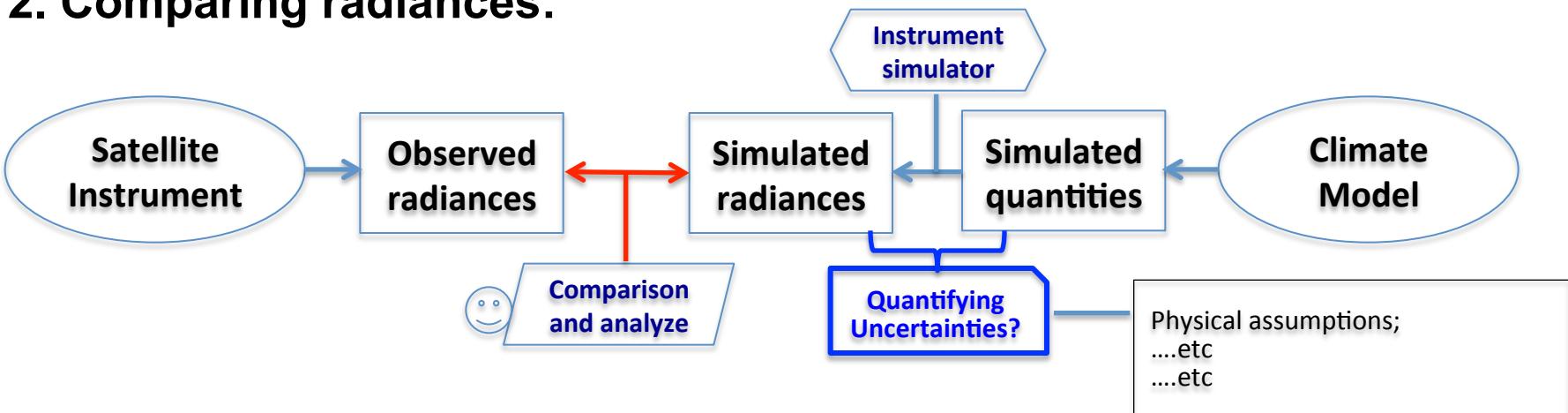


Two model-observation comparison approaches

1. Comparing physical quantities:



2. Comparing radiances:



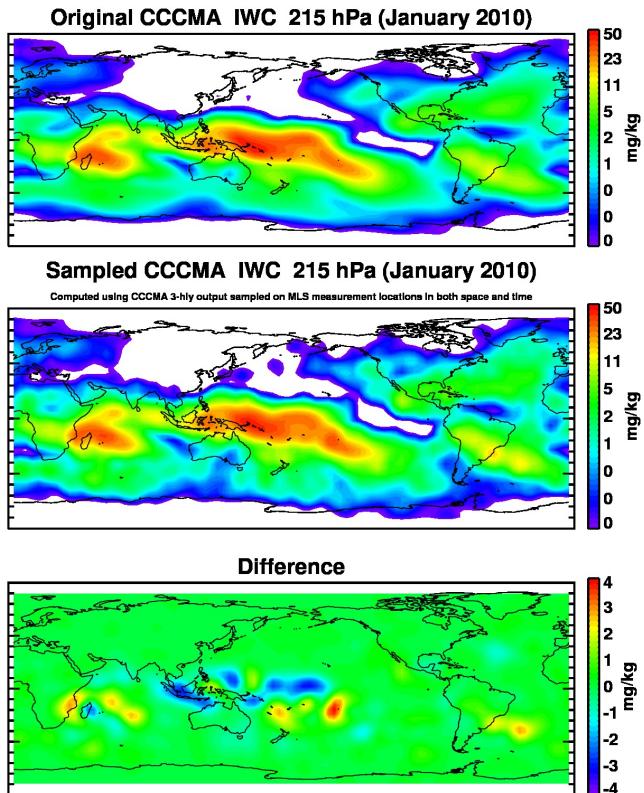


Uncertainties of model-observation comparisons

1. Sampling error: (in retrievals and some simulators)

Uncertainties due to:

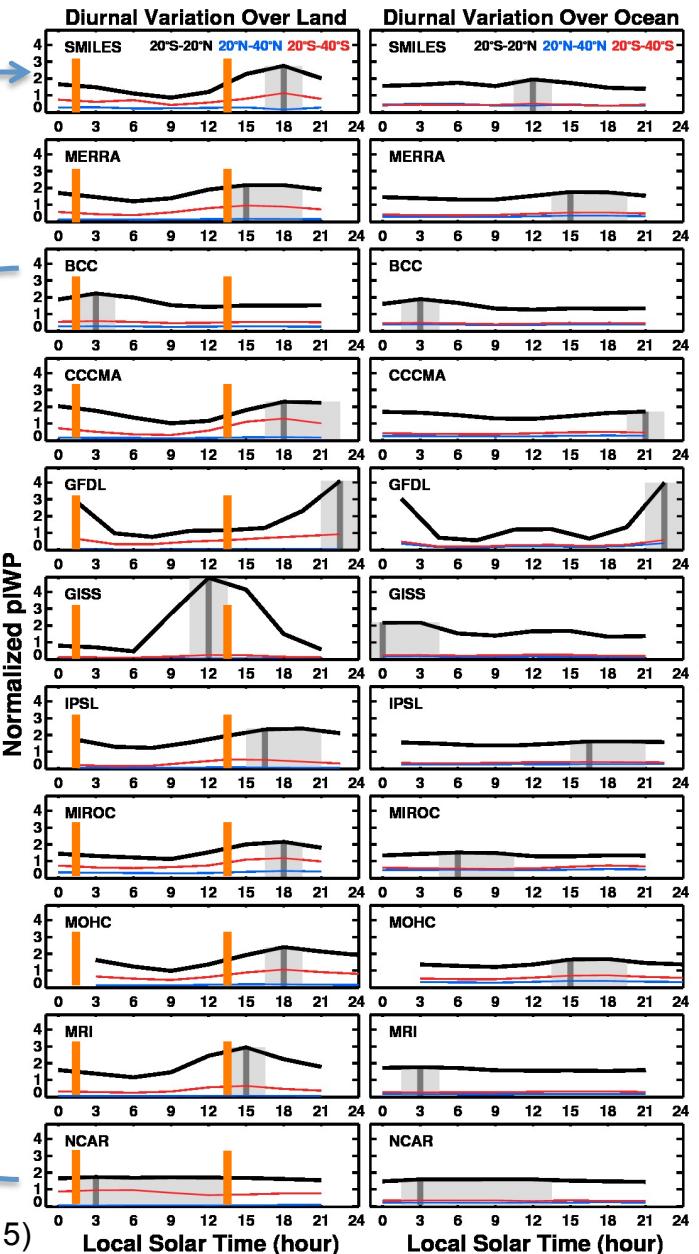
- instrument pointing errors/viewing-angles (e.g. Gong & Wu 2013),
- sampling patterns (e.g. Wu et al. 2006),
- orbit/temporal sampling frequency/diurnal cycles, Jiang et al. 2015)
- Guan et al. (2013) estimated such errors are up to ~30%.



SMILES

Climate Models

Jiang et al. (2015)





2. Instrument sensitivity: (in retrievals)

Combined (active and passive) instruments/techniques provide better cloud retrievals and thus instrument-combined products have been developed, e.g.

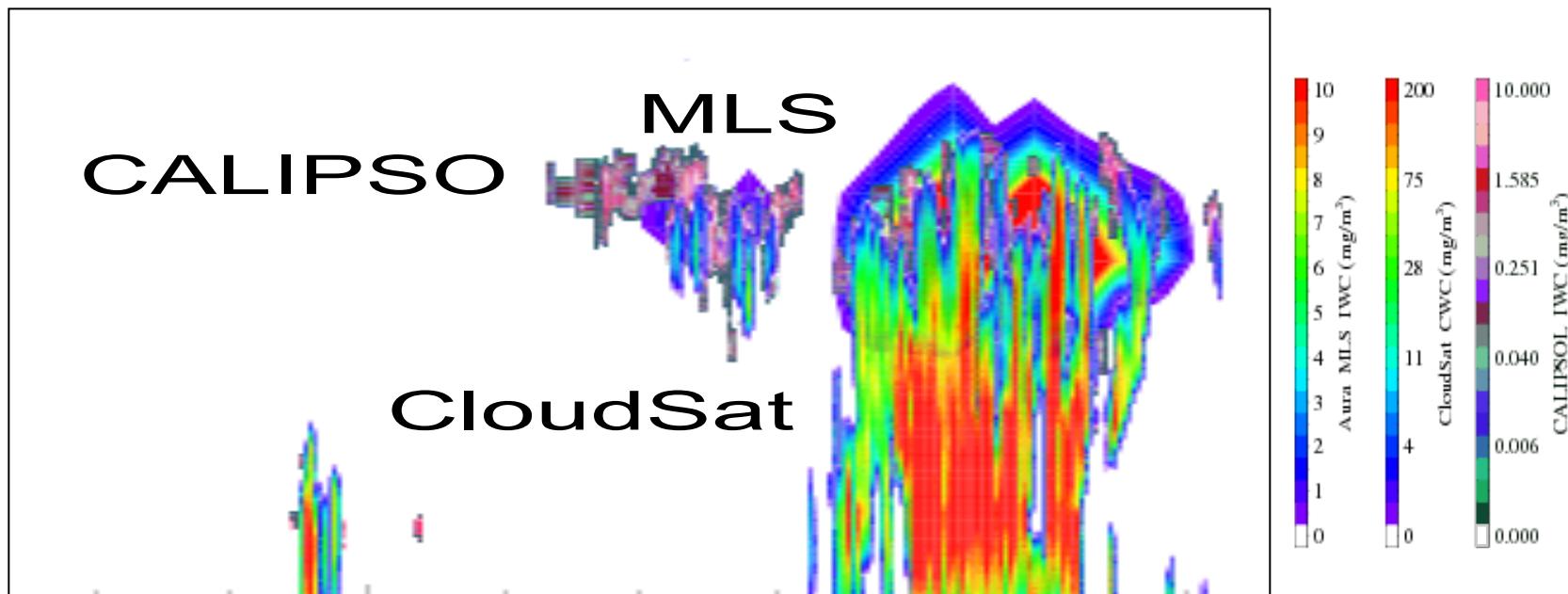
CloudSat/CALIPSO, Mace et al. (2009)

CloudSat/CALIPSO/Visible, Austin and Stephensl (2009)

HIRDLS/CALIPSO, Massie (2012)

HIRDLS/MLS, Massie and Jiang (2013)

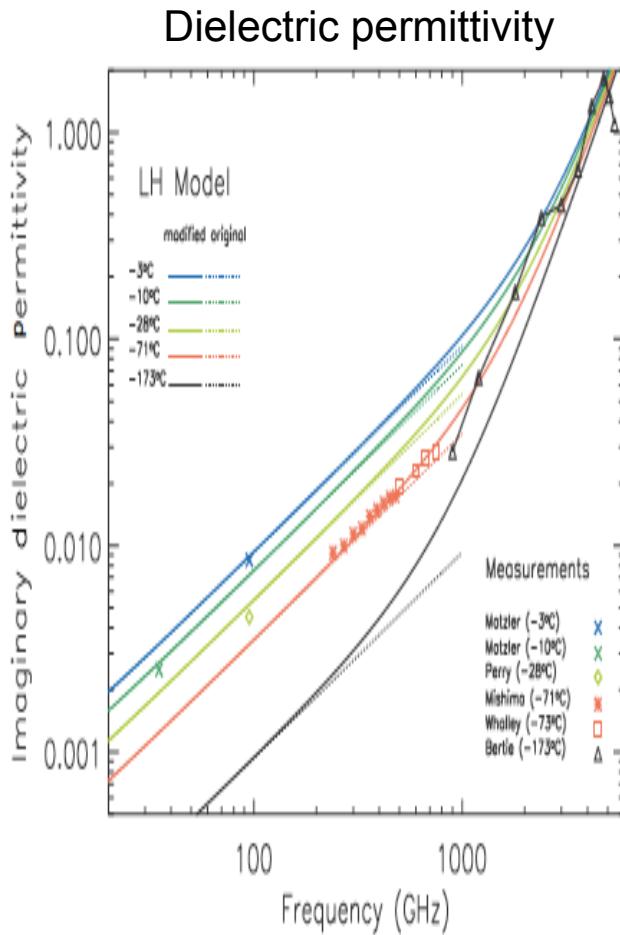
MLS/CALIPSO, Wu et al. (2014), Gong and Wu (2014)



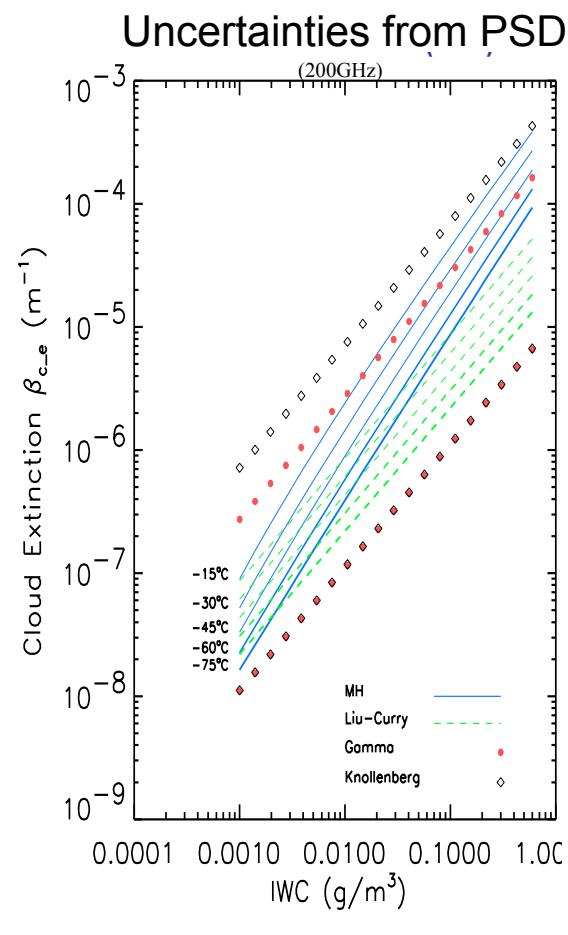


Uncertainties of satellite cloud retrievals

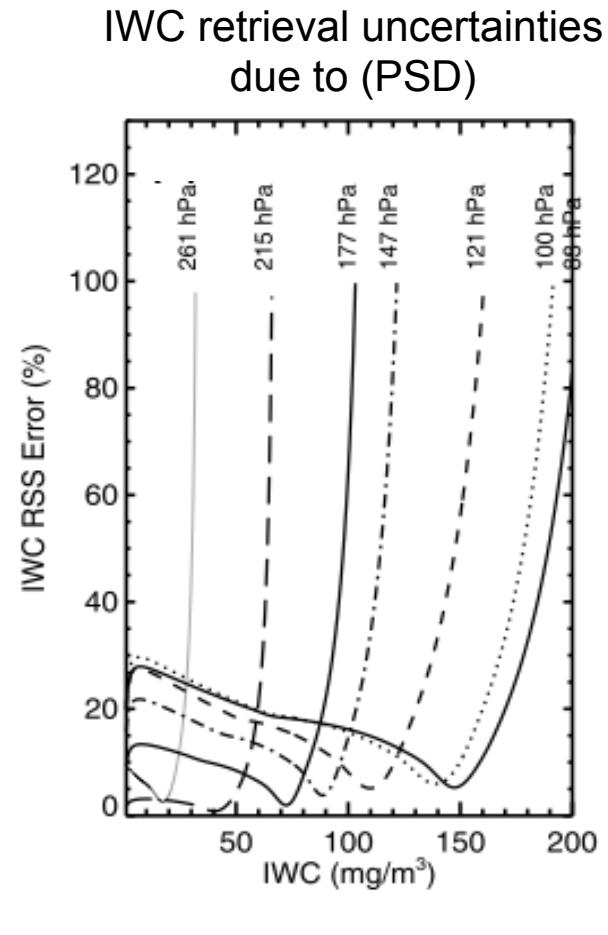
3 Uncertainties from physical assumptions: (in all retrieval and simulators)



Jiang and Wu (2004)



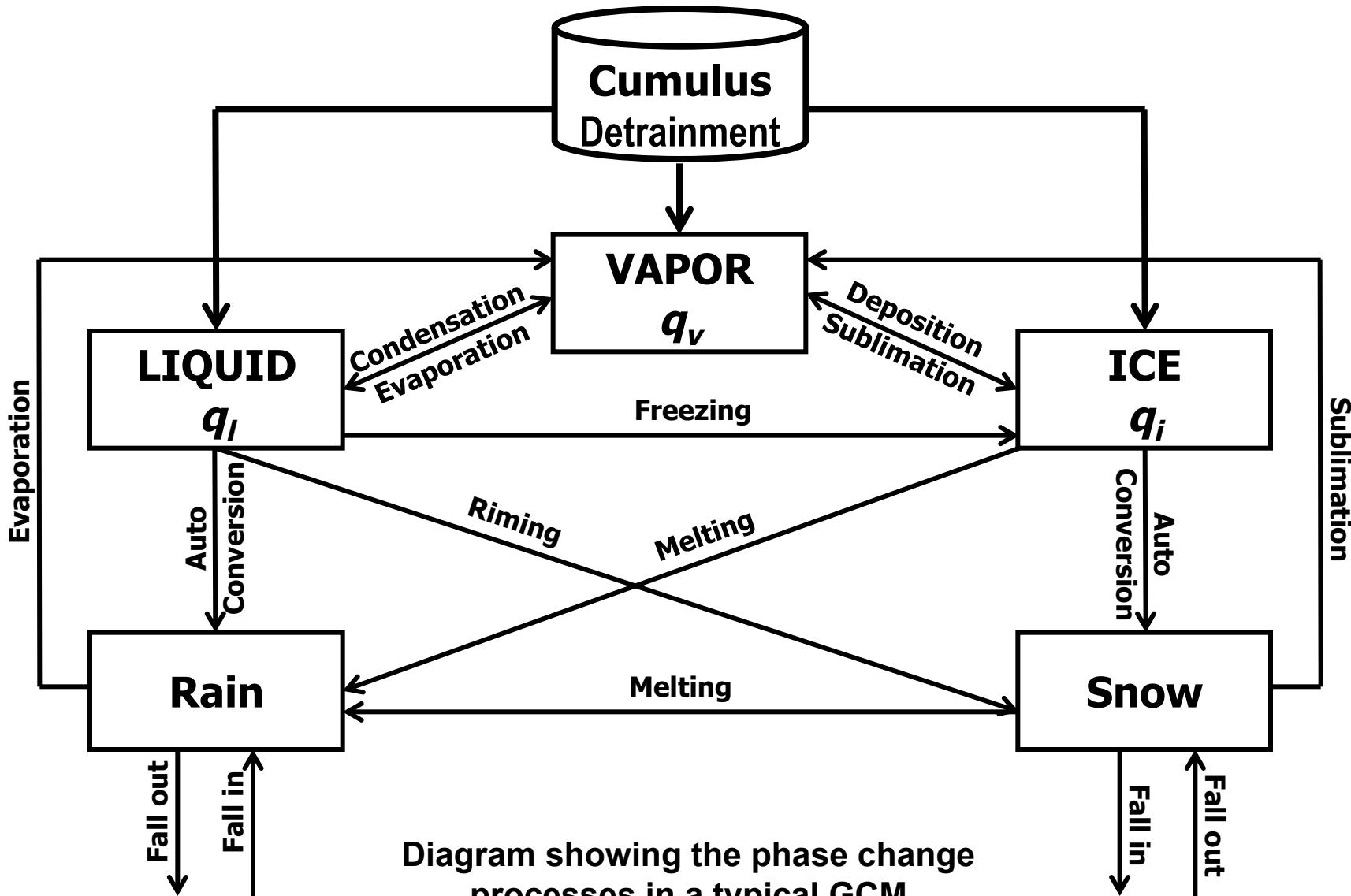
Wu and Jiang (2004)



Wu et al. (2008)



Three phases of water in GCMs

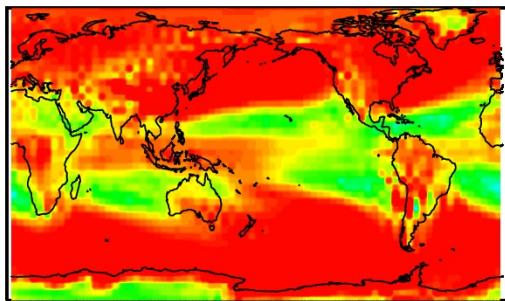




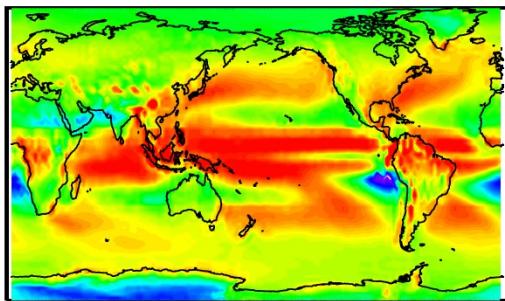
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Improvement in clouds may effect the quality of water vapor simulation

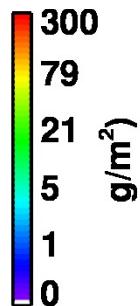
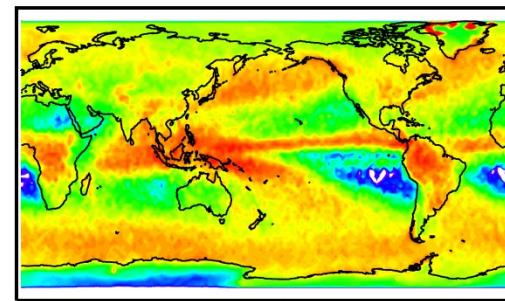
GISS e-r IWP (AR4)



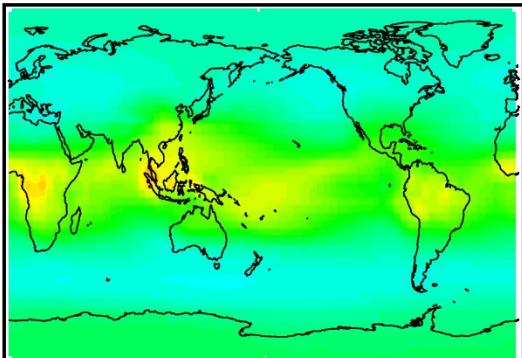
GISS e2-r IWP (AR5)



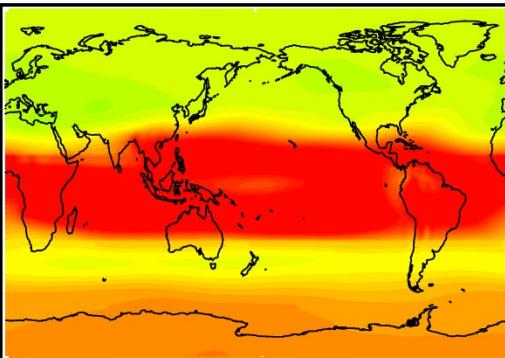
IWP CloudSat/CALIPSO



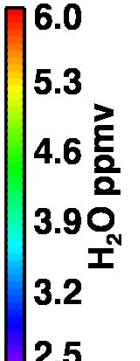
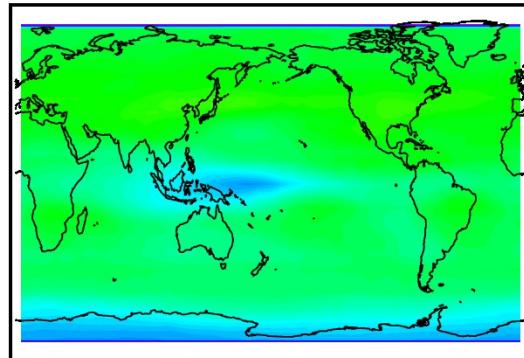
GISS e-r 100hPa (AR4)



GISS e2-r 100hPa (AR5)



100hPa (MLS)



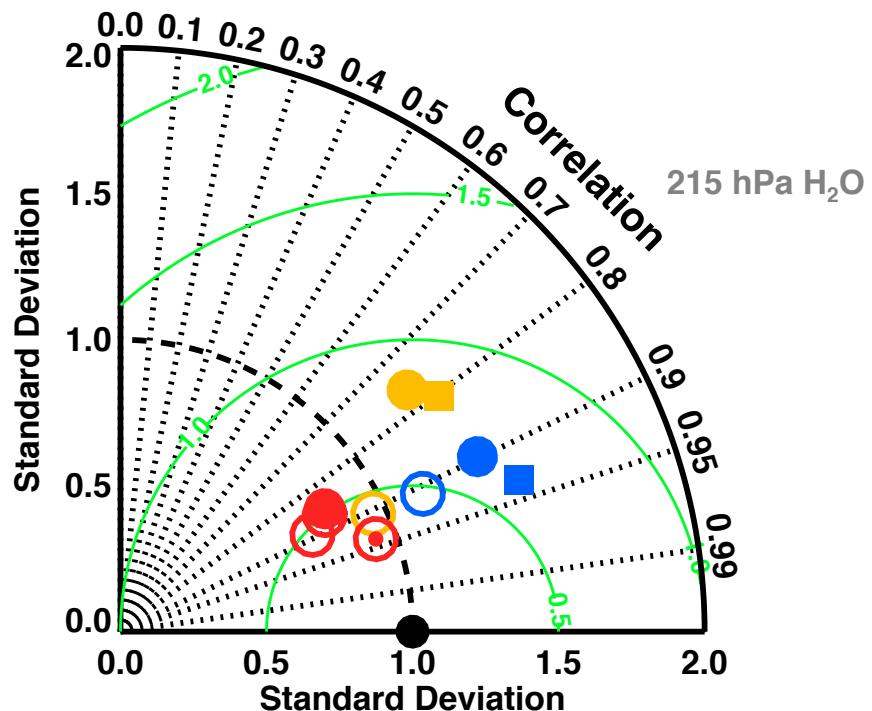
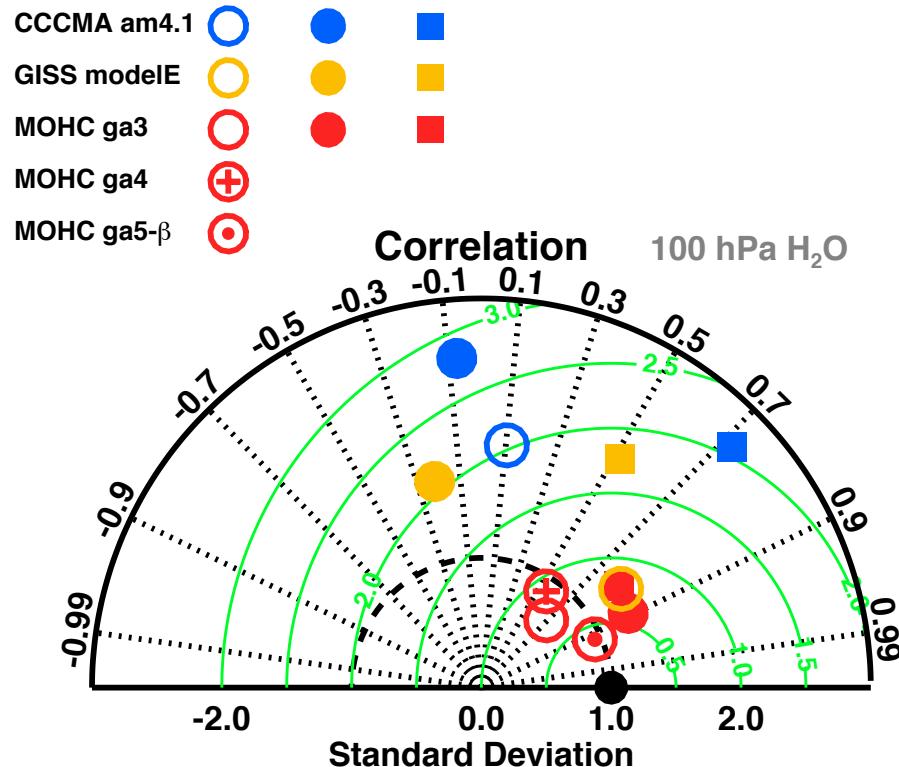


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Post-CMIP5 improvements in upper tropospheric water vapor simulations

● Aura MLS Observation

post-CMIP5 CMIP5 CMIP3

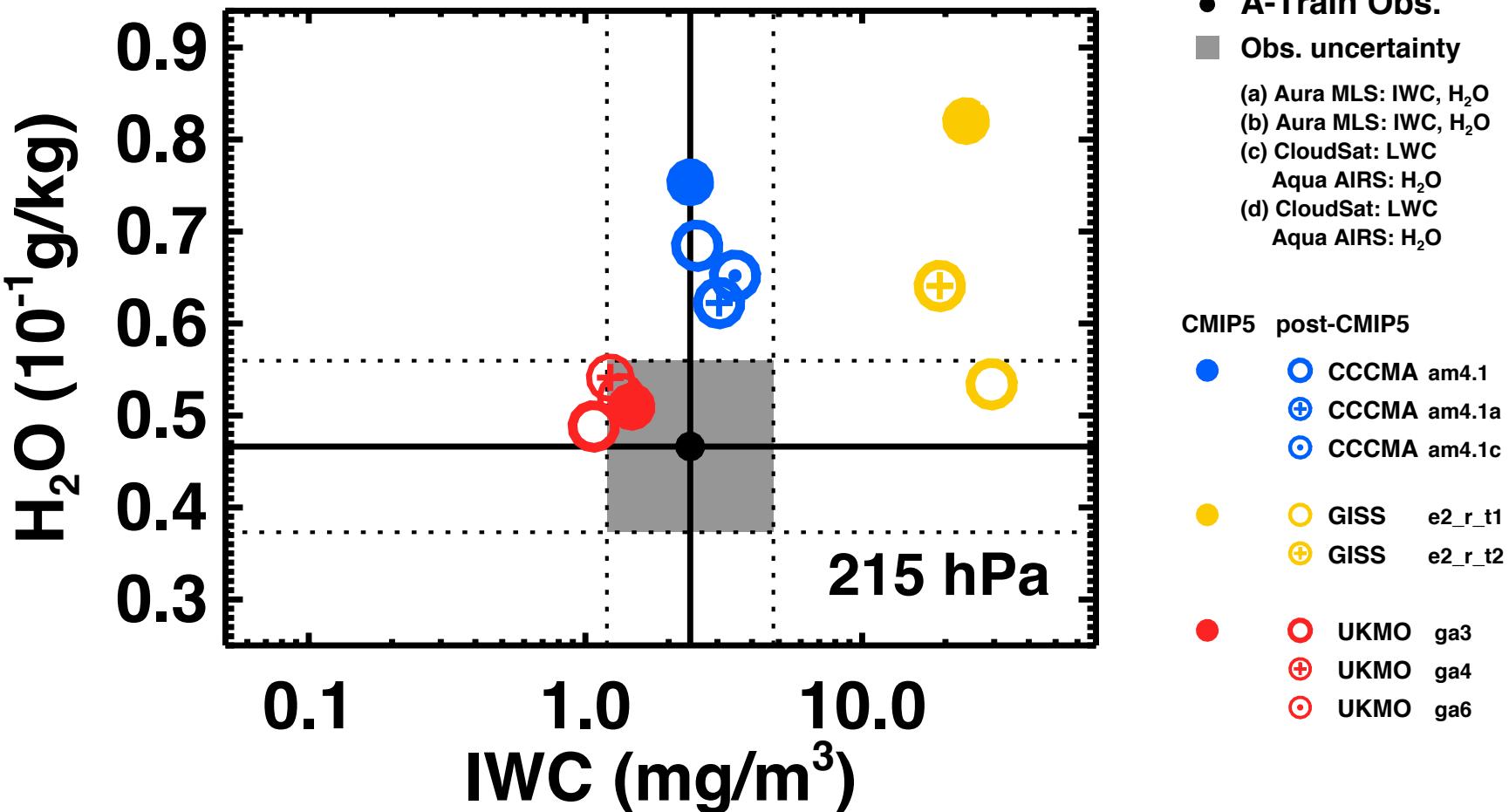




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Combined cloud and water vapor metrics

Post-CMIP5 model evaluation and improvement



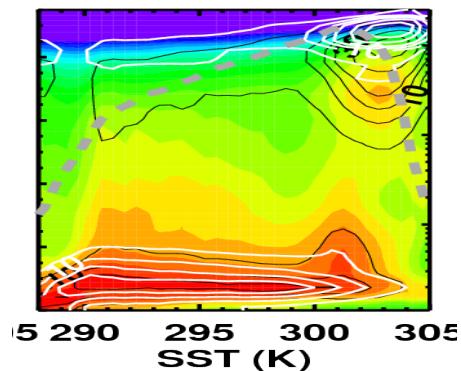


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Post-CMIP5 improvements in clouds simulations

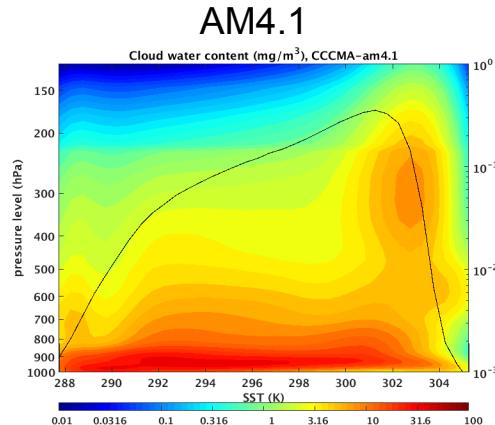
CMIP5 (Su et al. 2013)

AM4

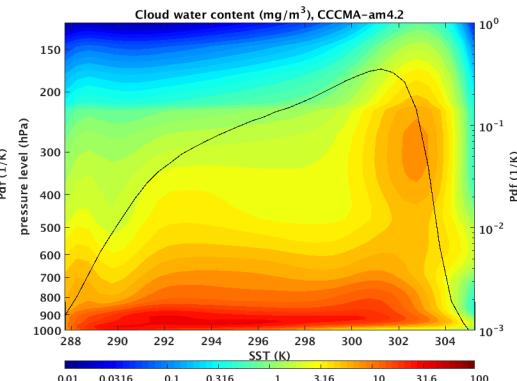


CCCMA

post-CMIP5

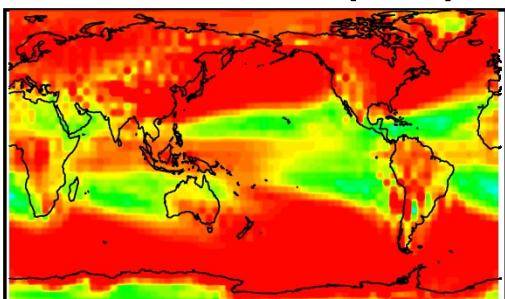


AM4.2



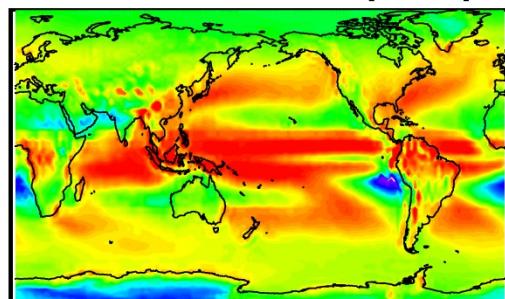
CMIP3

GISS e-r IWP (AR4)



CMIP5 (Jiang et al. 2012)

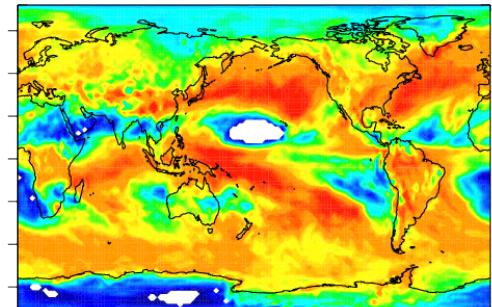
GISS e2-r IWP (AR5)

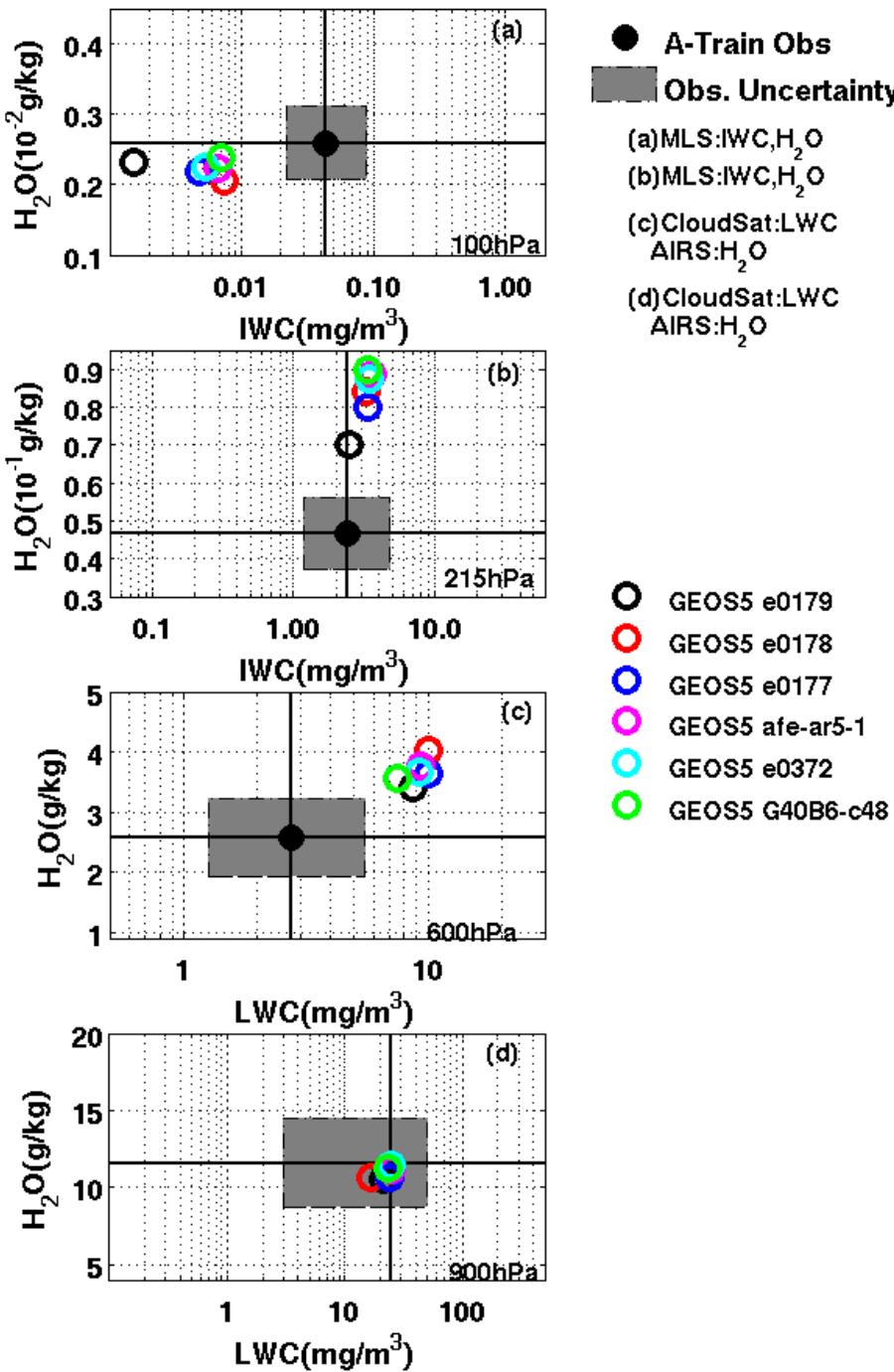


GISS

post-CMIP5

New Microphysics





Tracking the changes for the GEOS5-AGCM development

e0179: a version of the GEOS5 AGCM that was used in the MERRA Data Assimilation System.

e0178: identical to e0179 except the rate of re-evaporation of precipitation (liquid & ice) was increased by a factor of 2.

e0177: added to e0178 a change in the specified vertical profile of the width of PDF for subgrid scale water (vapor +condensate). Near the surface this change resulted in a decrease in the PDF width, and above the boundary layer the new PDF is wider.

afe-ar5-1: added to e0177 changes in the turbulence parameterization, which included an increase in near-surface turbulent diffusion, and replace the turbulent surface layer parameterization stability functions with ones that increase the fluxes under stable and cold conditions.

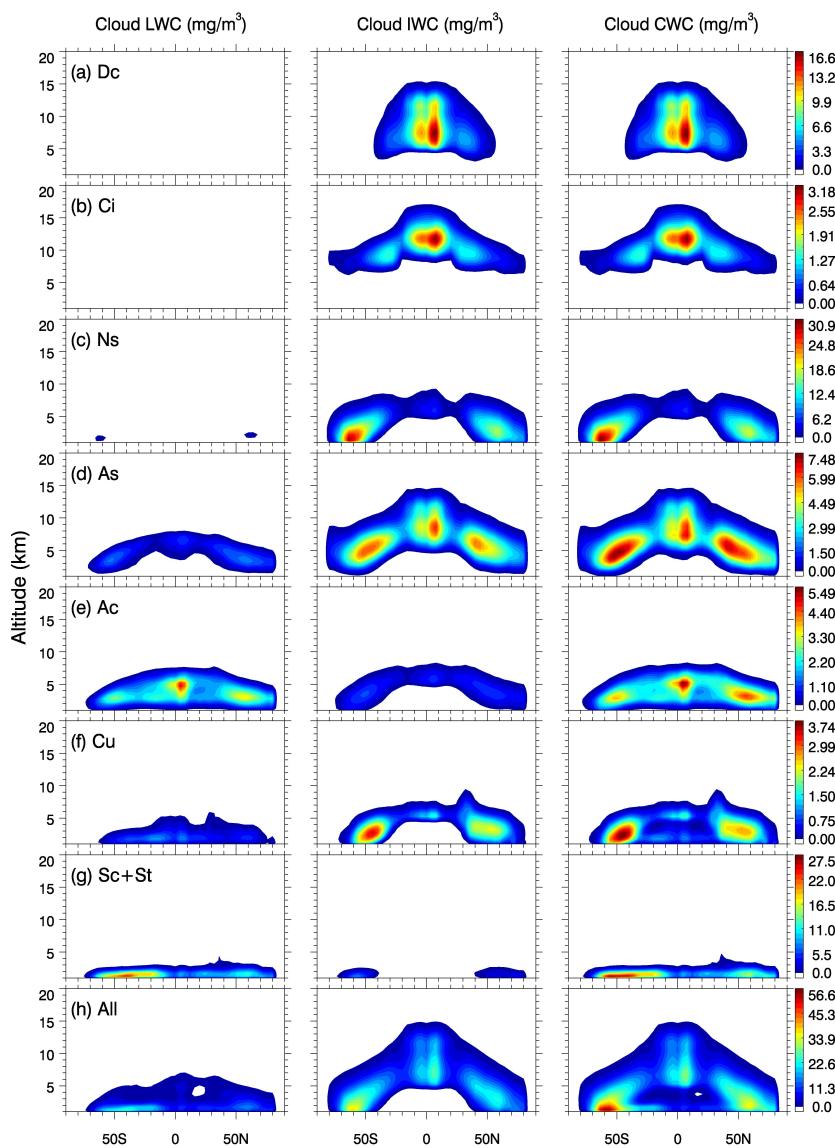
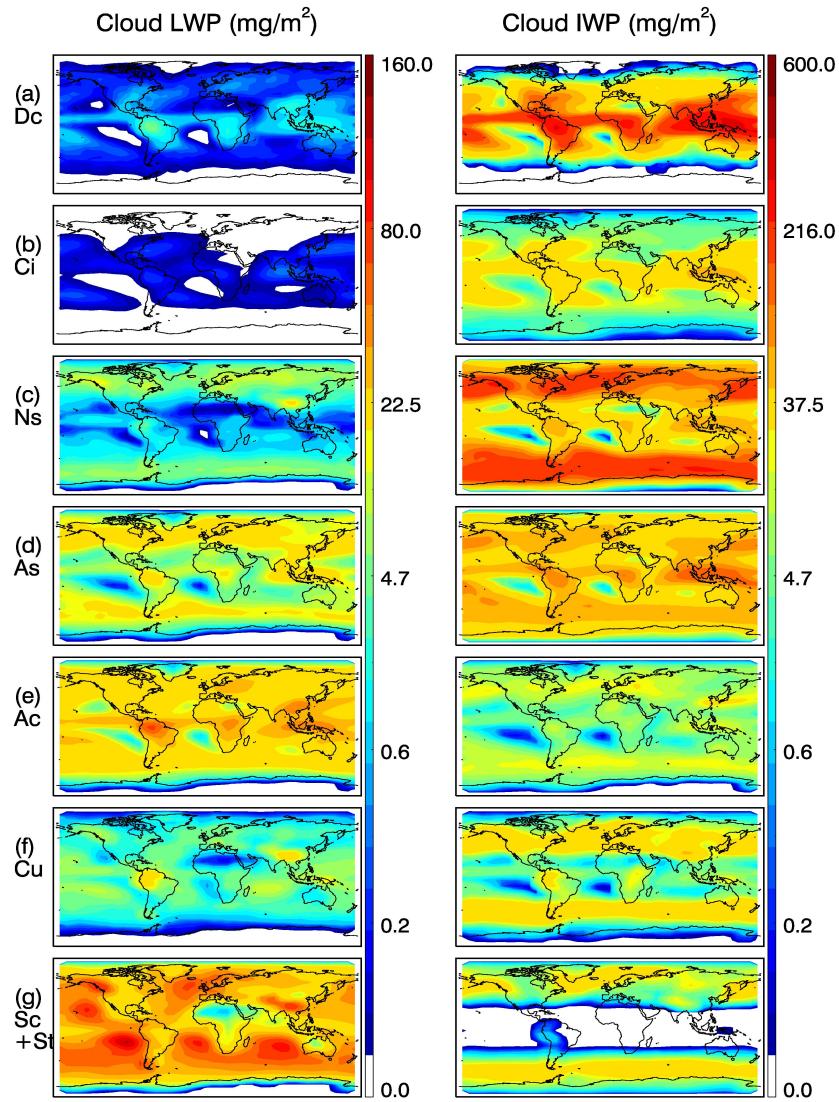
e0372: added to afe-ar5-1 a change in ocean surface roughness parameterization. The roughness was increased in the medium (>5 m/sec) wind speed range based on new observations, and was decreased in the high wind speed range (>25 m/sec) based on theoretical arguments and laboratory results.

G40B6-c48 added to e0372 changes in the cryosphere parameterizations. A new glacier model was added which includes snow layers on top of the glacier, and the sea ice albedo was modified to include a seasonal cycle. This is essentially the version of the GEOS-5 AGCM that was used as part of the MERRA2 Data Assimilation System.



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New CloudSat/CALIPSO cloud type classification



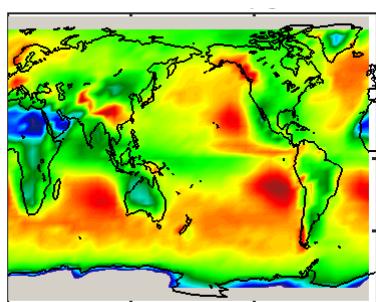


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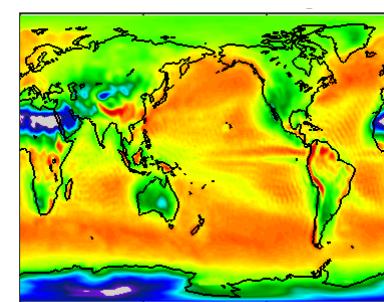
Stratiform Clouds: observed versus simulated

Stratiform Clouds

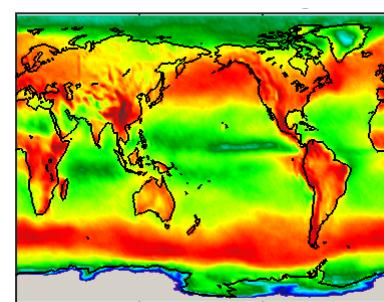
CloudSat/CALIPSO



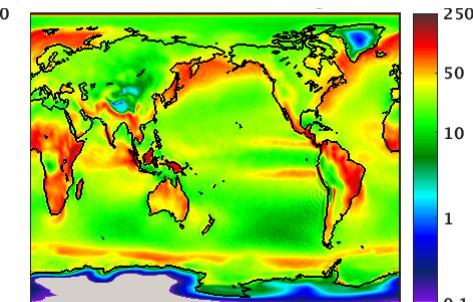
MIROC



GISS



BCC

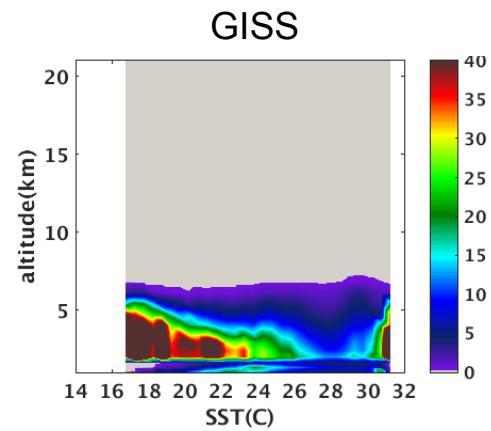
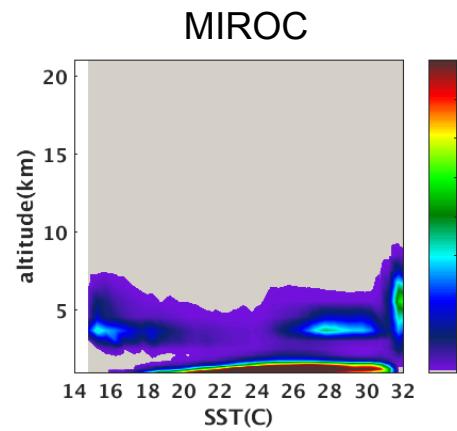
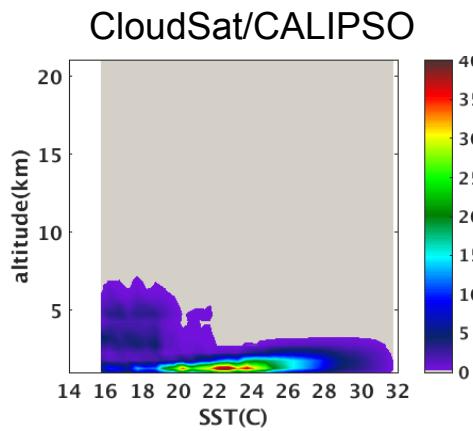
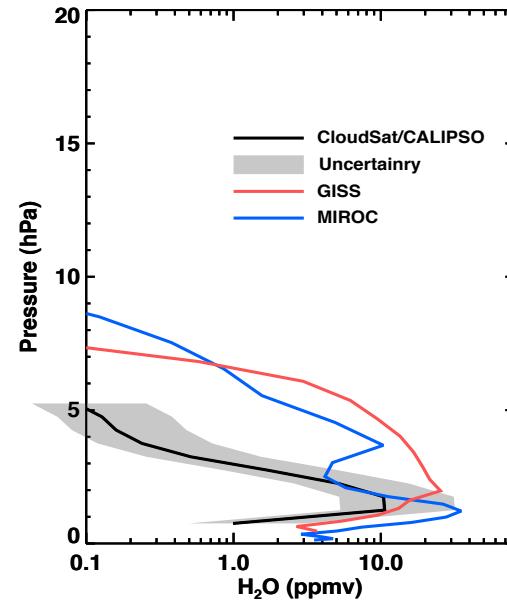
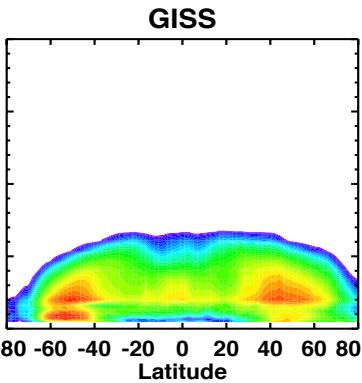
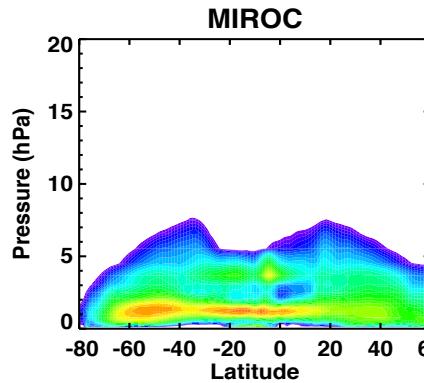
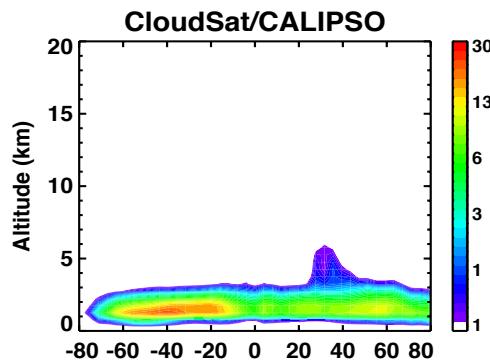


LWP (g/m²)



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Stratiform Clouds: observed versus simulated





Summary

- There are two different approaches for climate model evaluations using satellite observations: (1) using satellite retrieval; (2) using satellite simulator.
 - Uncertainties must be defined and quantified with both approaches and in any model evaluations.
 - Especially, uncertainties of using satellite simulator are needs to be studied.
- Model evaluation and improvement effort, especially for cloud simulations, should not focus on a single variable (e.g. cloud water content), but other related fields as well (e.g. water vapor mixing ratio).
- Satellite observational metrics are used in recent post-CMIP5 model performance validations and improvements in simulating clouds and water vapor.
 - Preliminary analysis shows the new MERRA2 has slight improvement in clouds but biases in upper tropospheric moisture are getting worse.
 - Ongoing/future work: New CloudSat/CALIPSO cloud type classification could be used in validating different types of clouds simulated by global models.