

An assessment of the impacts of Ice Cloud Vertical Heterogeneity (ICVH) on global ice cloud records from passive satellite retrievals

Chenxi Wang, Steven Platnick, Thomas Fauchez, Kerry Meyer

(GSFC),

Zhibo Zhang (UMBC),

Hironobu Iwabuchi (Tohoku University),

Brian Kahn (JPL)

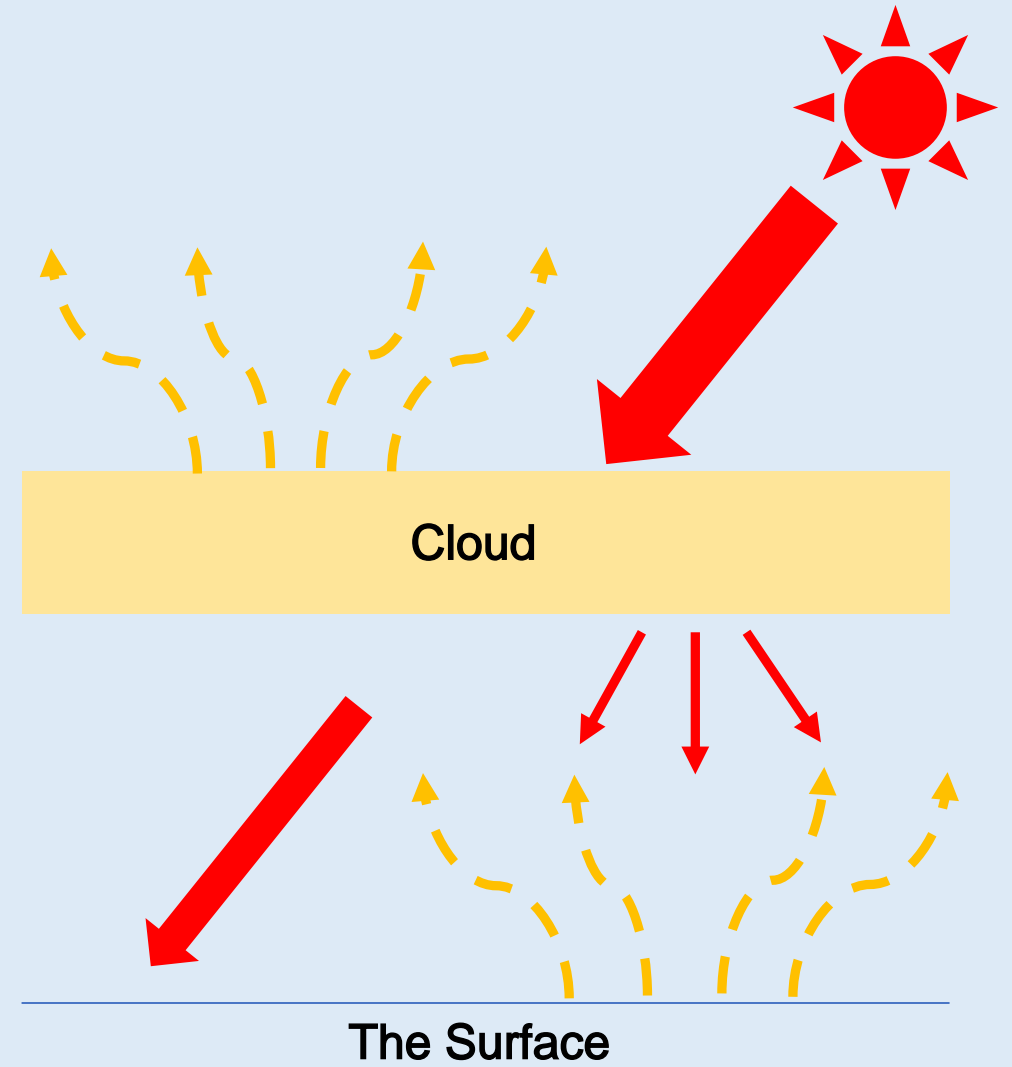
Oct 29th ~ Nov. 2^d, 2018
ICWG-2 Workshop

Motivation

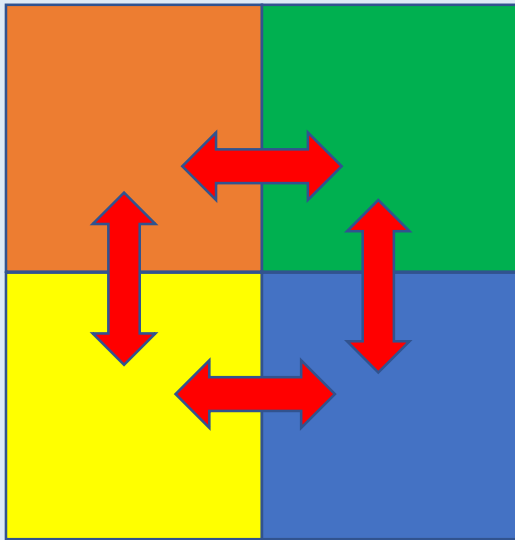
Observed clouds



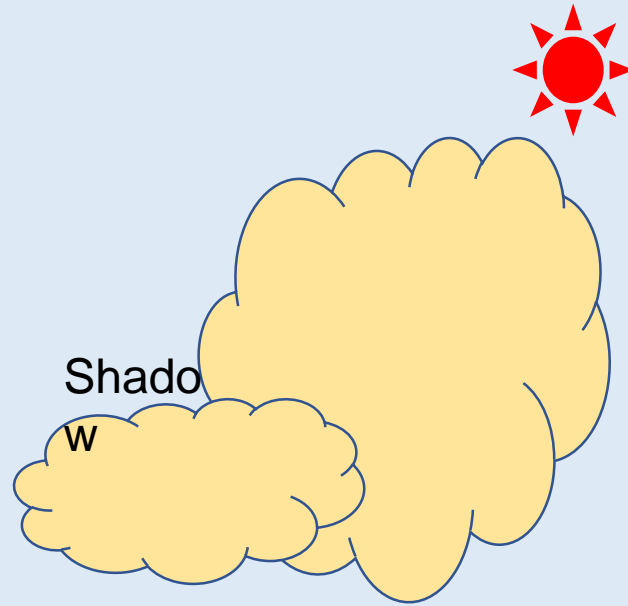
Cloud in 1-D plane-parallel model



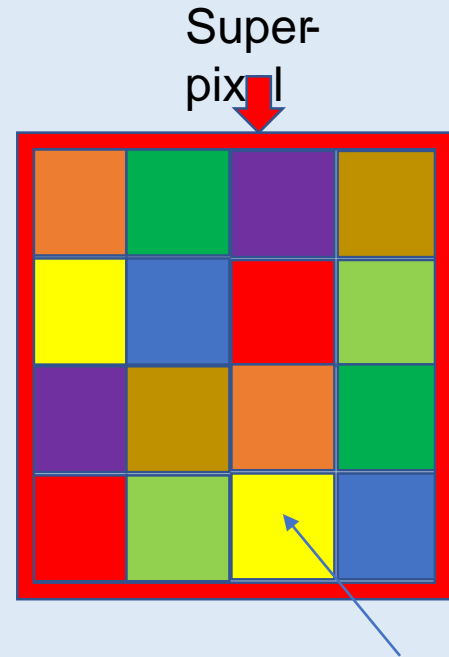
Things missing from 4D models



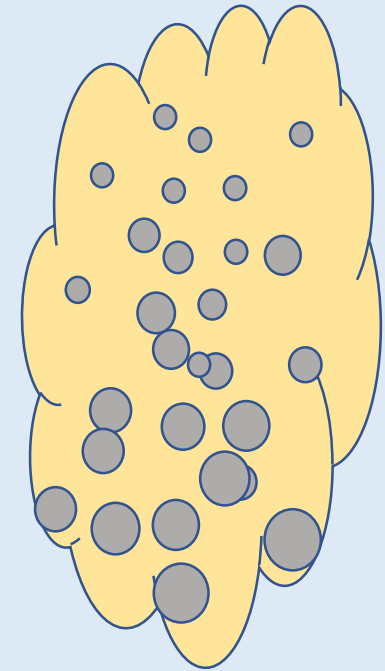
A. Radiation transfer from a cloudy pixel to contiguous pixels



B. Irregular shape

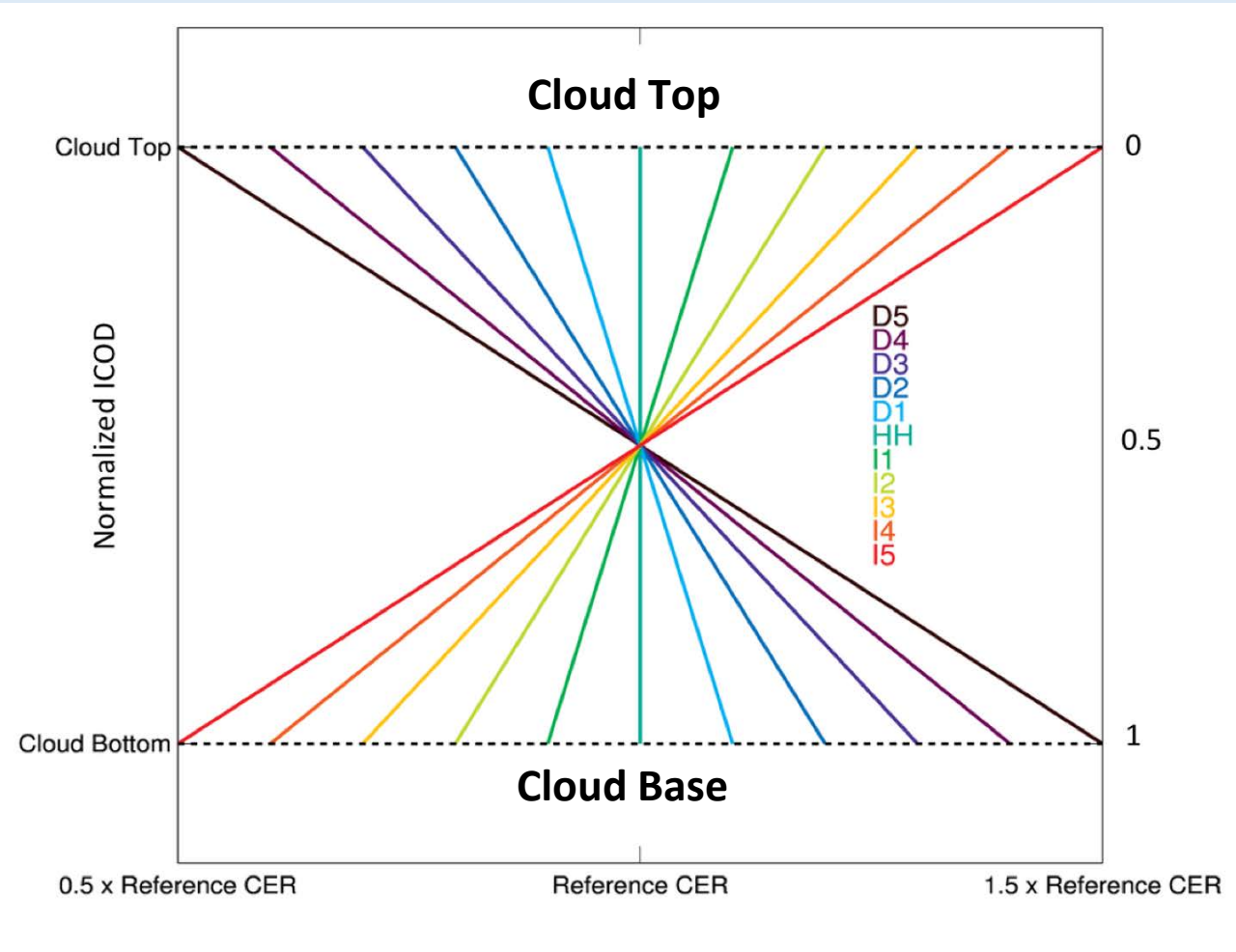


C. Subpixel variability



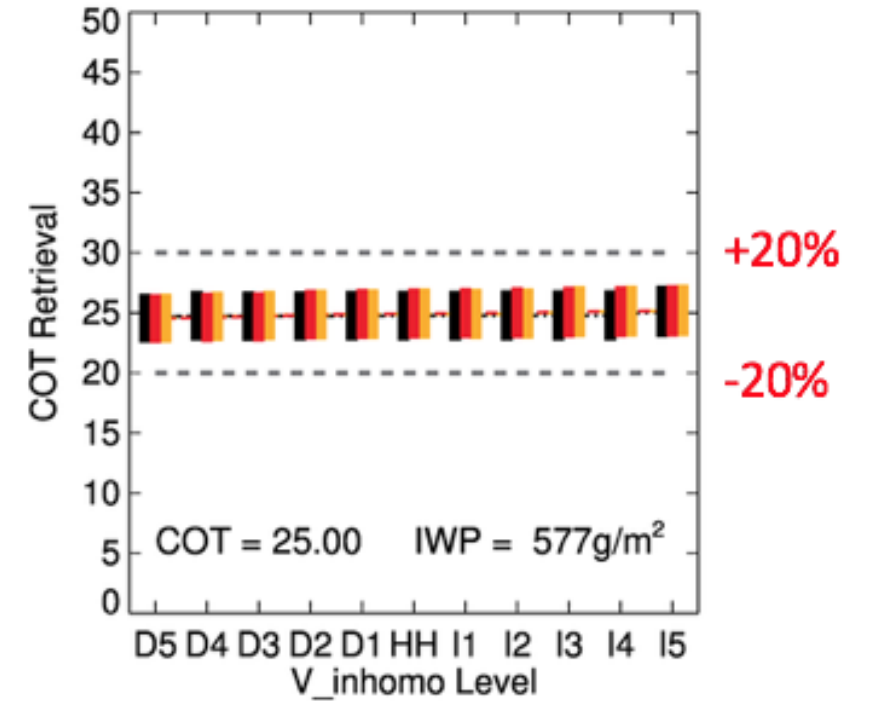
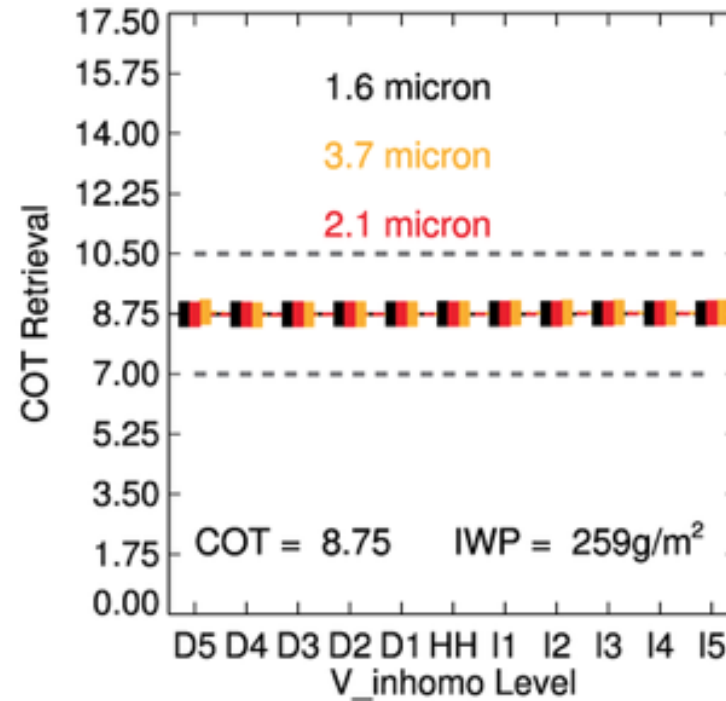
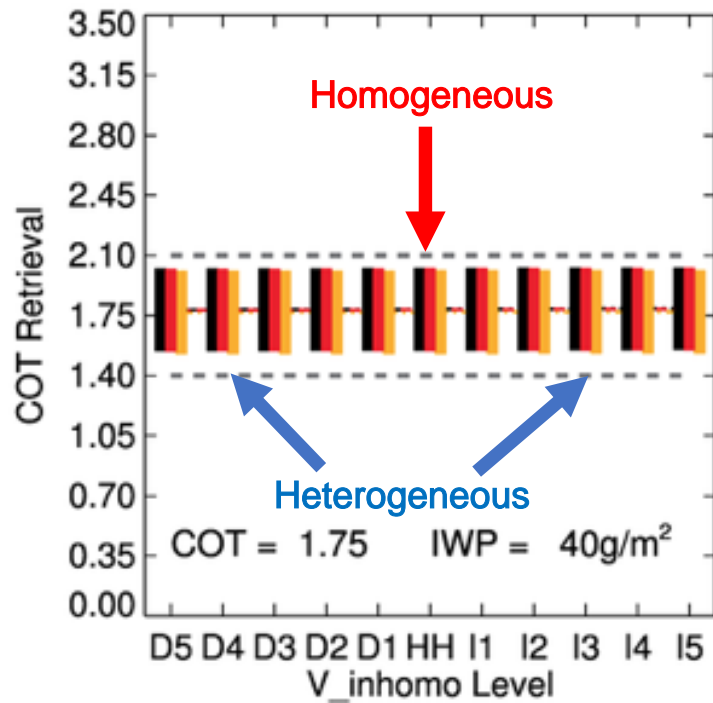
D. Particle microphysical properties varies vertically

ICVH Impacts (Pixellevel)



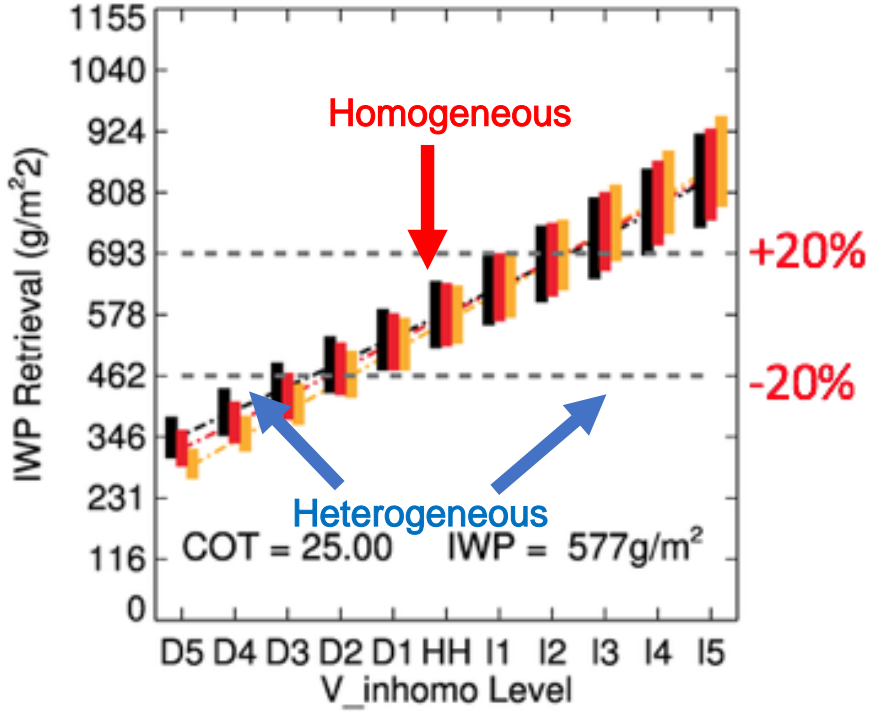
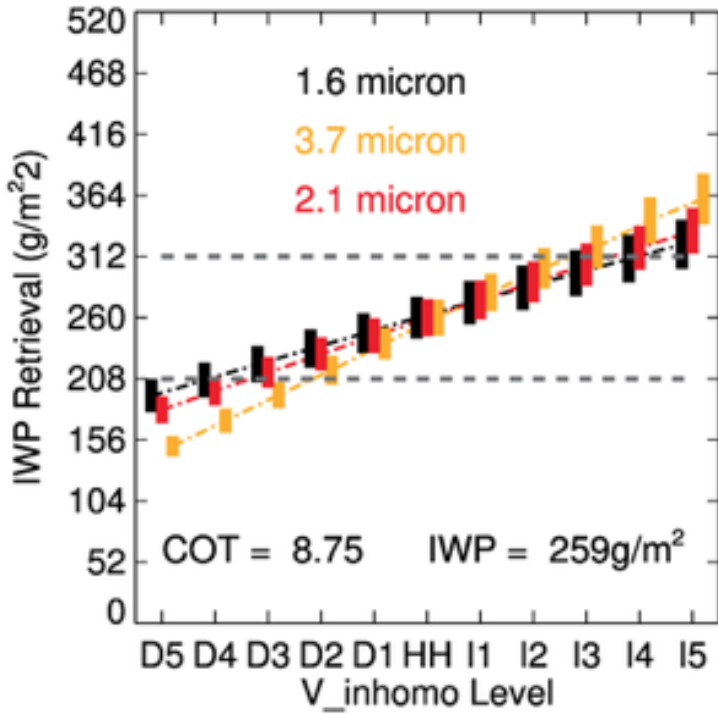
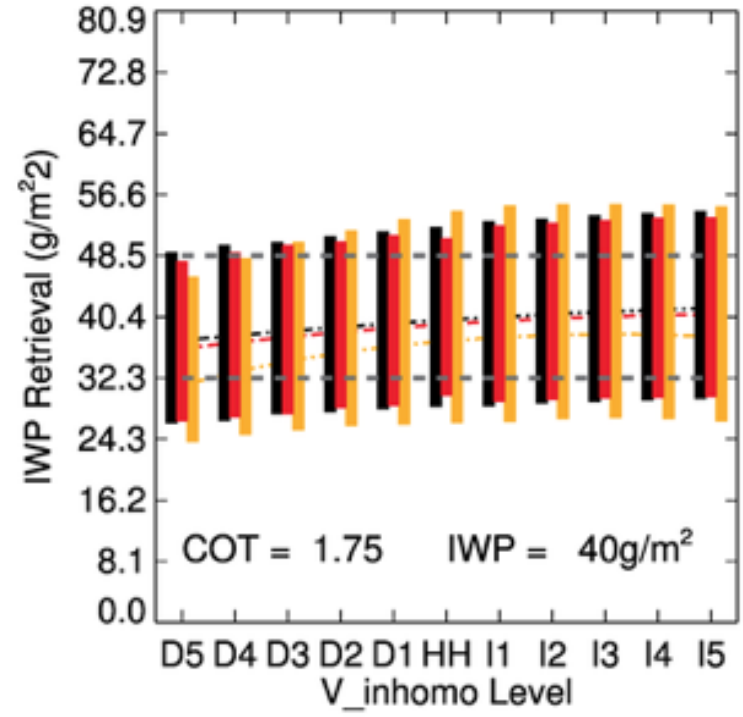
- Eleven idealized **C**loud **E**ffective **R**adius (**CER**) profiles
- Simulation: “observation” → DISORT (inhomogeneous clouds)
- Retrieval: → MODIS-like “bi-spectral” retrievals (homogeneous clouds):
 - $2.1 + 0.86 \mu\text{m}$
 - $1.6 + 0.86 \mu\text{m}$
 - $3.7 + 0.86 \mu\text{m}$
- **C**loud **O**ptical **T**hickness (**COT**) and **I**ce **W**ater **P**ath (**IWP**) will be tested.
- MODIS Collection 6 ice model
- Uncertainty from different sources are considered

ICVH Impacts (Pixellevel COT)



Little Impact on COT (~ 1%)

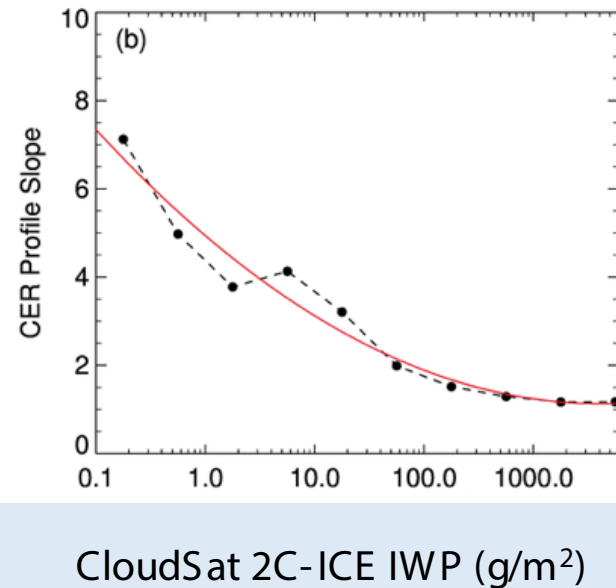
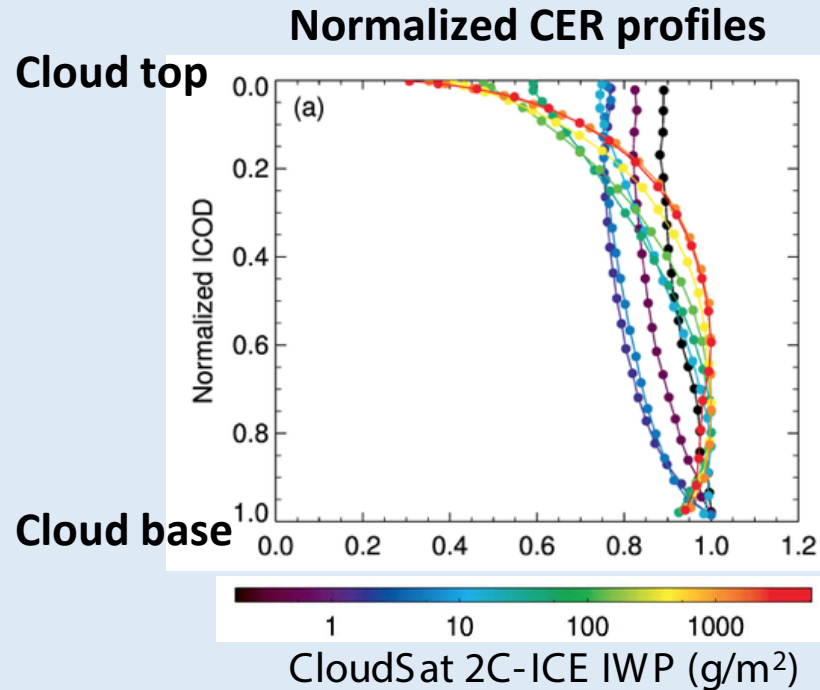
ICVH Impacts (Pixellevel IWP)



Large Impact on IWP (up to 50%)

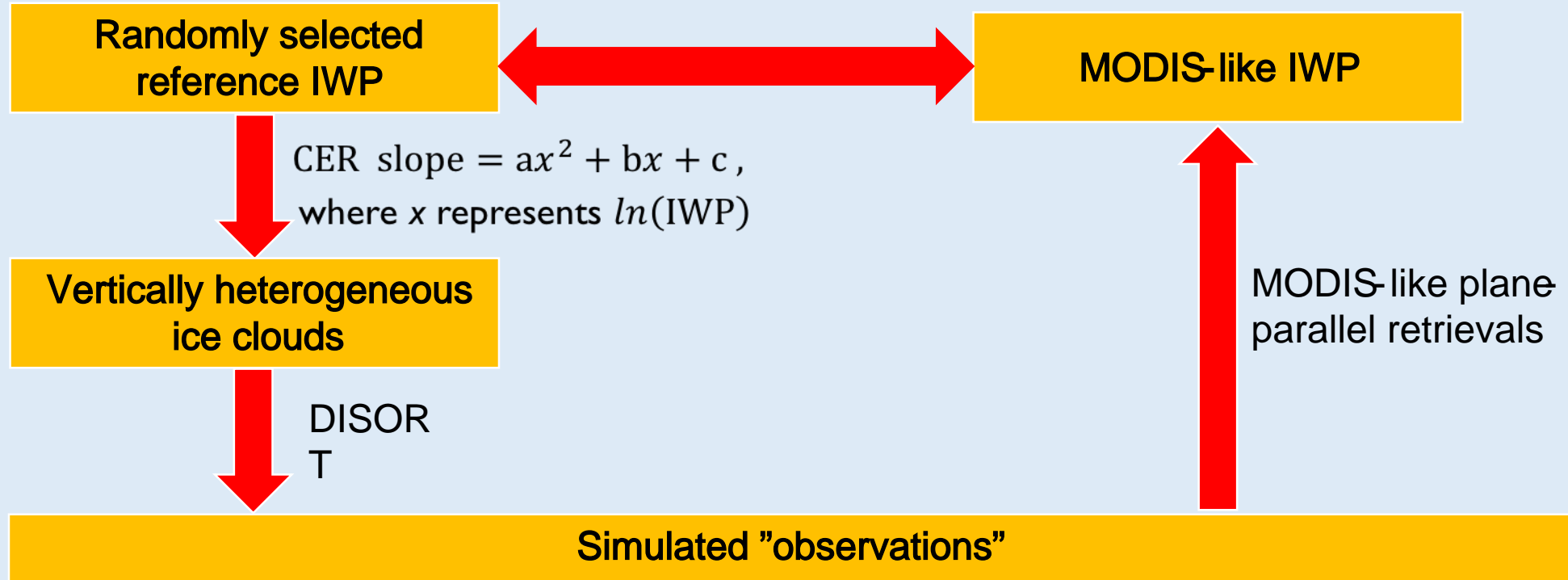
ICVH impacts on monthly-mean ice cloud records

- One year global ice cloud profiles (2007) from CALIPSO/CloudSat-2ICE (*Deng et al., 2015*)

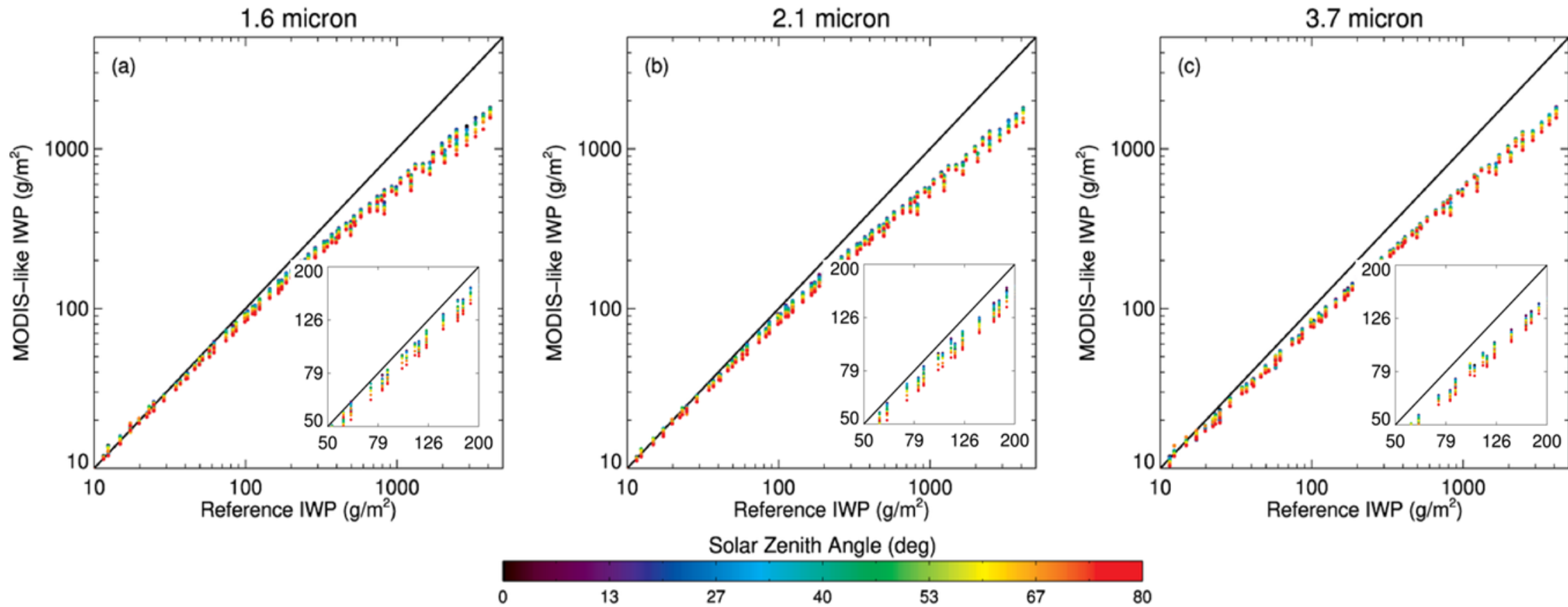


CER slope = $ax^2 + bx + c$,
where x represents $\ln(\text{IWP})$

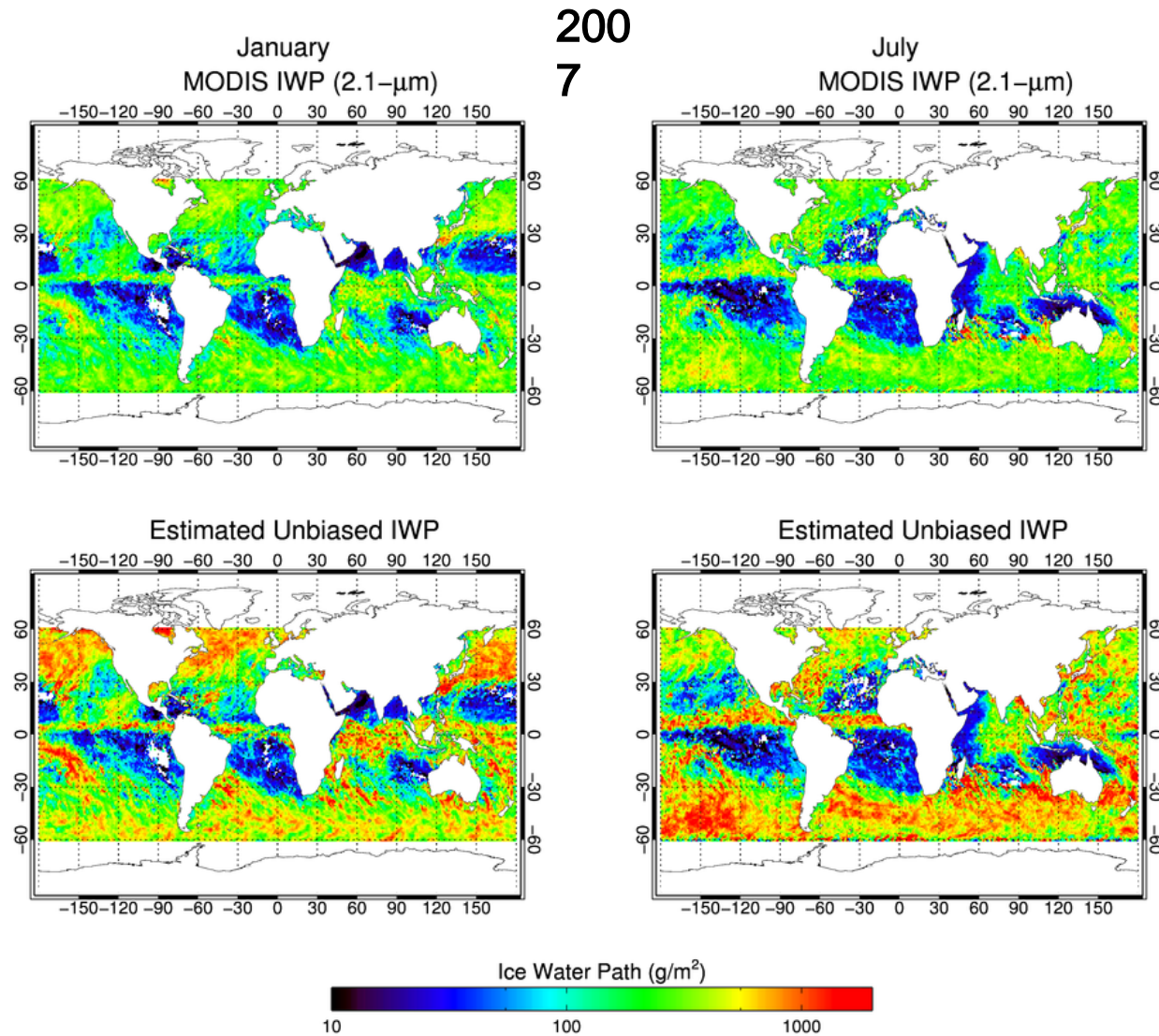
Estimate IWP biases caused by the ICVH



Estimate IWP biases caused by the ICVH



Estimate MODIS L3 IWP biases caused by the ICVH

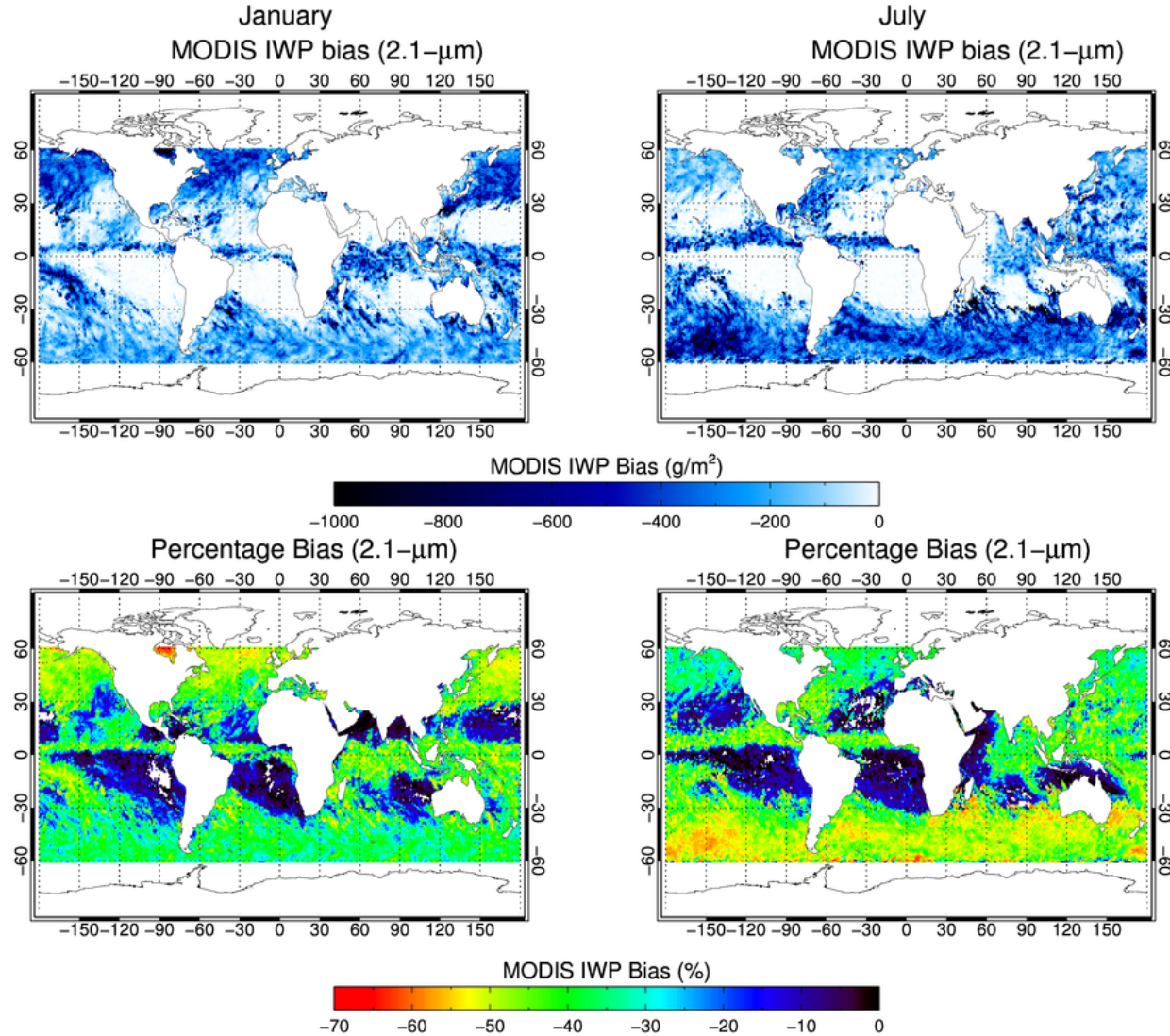


$$\overline{\text{IWP}}_{\text{MODIS}} = \frac{\sum_i \sum_j \text{IWP}_{\text{MODIS}}(\text{COT}_i, \text{CER}_j) \times f(i, j)}{\sum_i \sum_j f(i, j)}$$

$$\overline{\text{IWP}}_{\text{ref}} = \frac{\sum_i \sum_j \text{IWP}_{\text{ref}}(\text{COT}_i, \text{CER}_j) \times f(i, j)}{\sum_i \sum_j f(i, j)}$$

Large Impacts on Level-3 IWP

Estimate MODIS L3 IWP biases caused by the ICVH



$$\overline{\text{IWP}}_{\text{MODIS}} - \overline{\text{IWP}}_{\text{ref}}$$

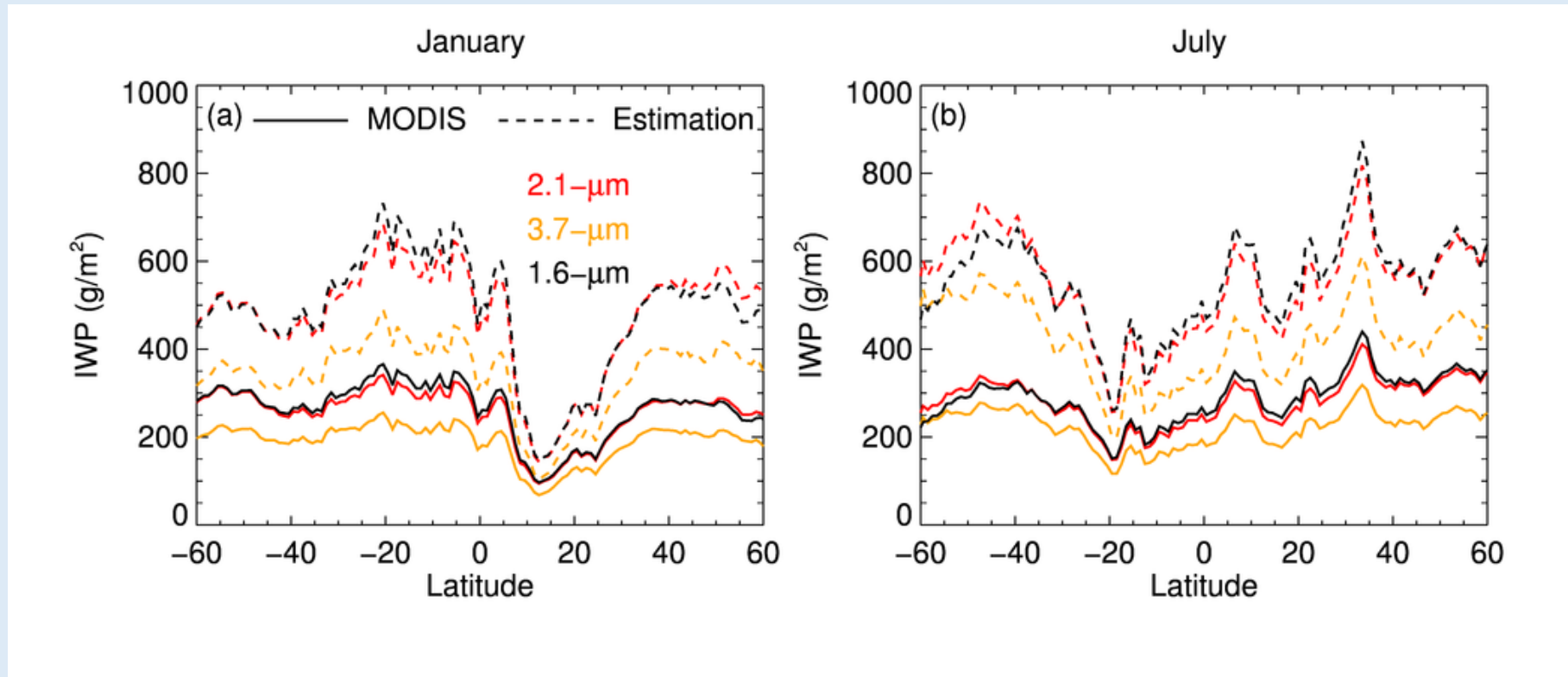
Up to -1000
 g/m^2

$$\frac{(\overline{\text{IWP}}_{\text{MODIS}} - \overline{\text{IWP}}_{\text{ref}})}{\overline{\text{IWP}}_{\text{ref}}}$$

Up to -
50%

Large Impacts on Level-3 IWP

Estimate MODIS L3 IWP biases caused by the ICVH



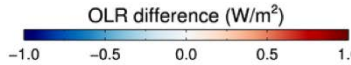
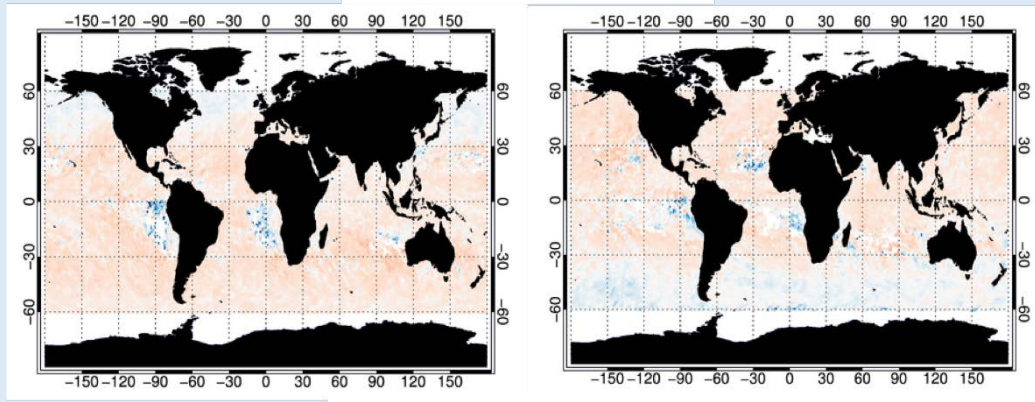
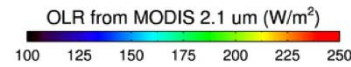
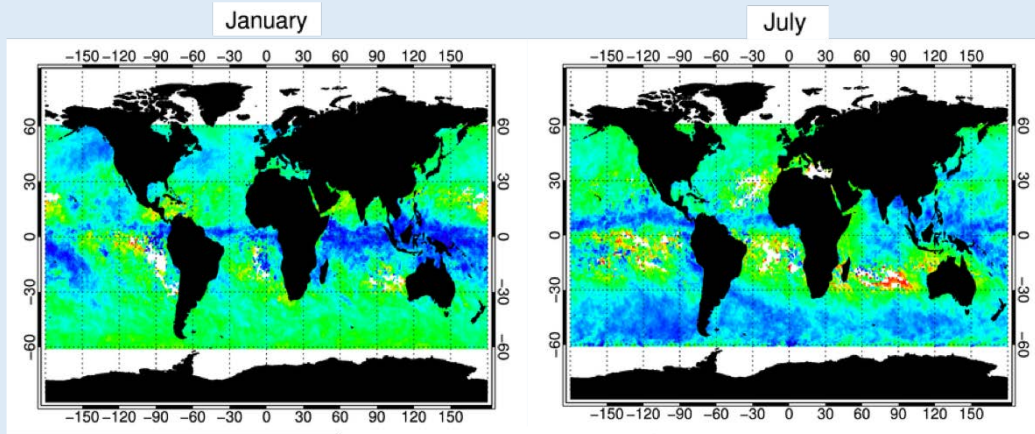
ICVH is not the only reason for the 3.7 μ m and 2.1 (1.6) μ m retrieval differences.

- Mixed phase cloud?
- Thermal emission from 3.7 μ m?
- Imperfect CER profiles?
- Multi-layer clouds?

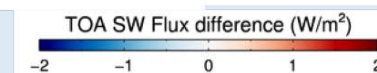
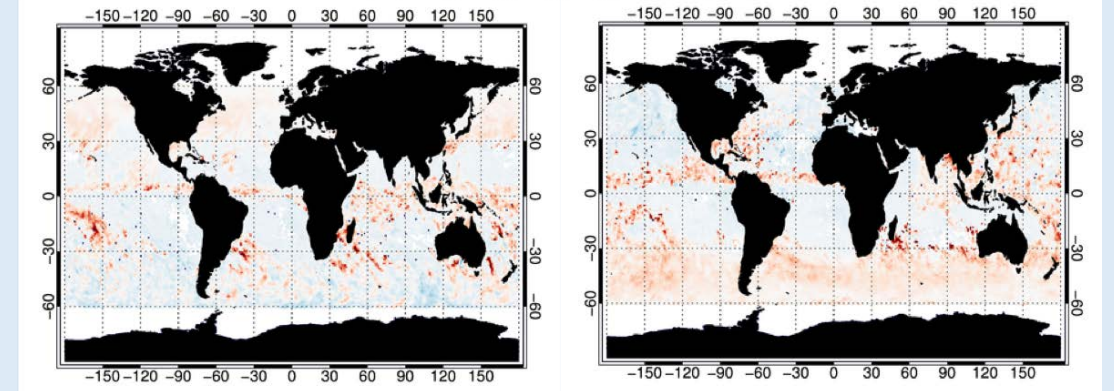
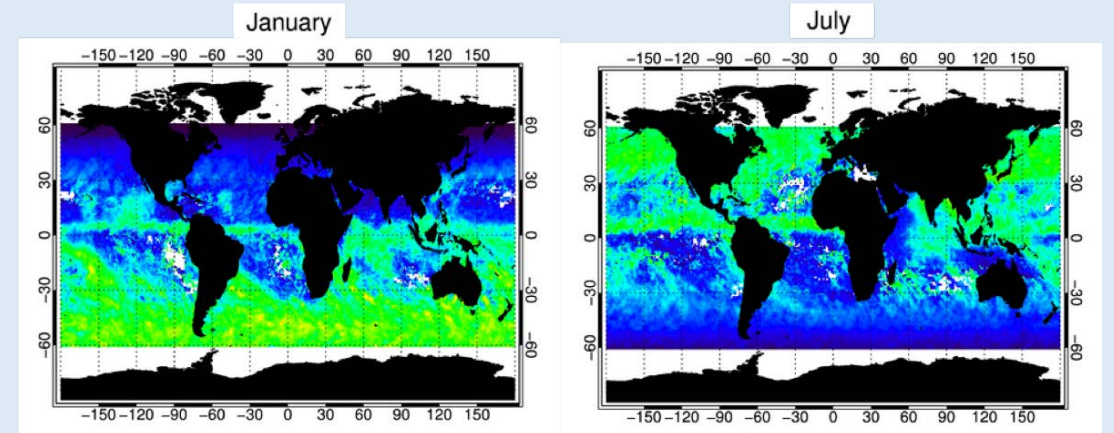
Estimate flux biases using MODIS L3 IWP

$$\overline{\text{OLR}} = \frac{\sum_i \sum_j \text{OLR}(\overline{\text{CTH}}, \text{COT}_i, \text{CER}_j) \times f(i,j)}{\sum_i \sum_j f(i,j)}$$

$$\overline{\text{RSR}} = \int \frac{\sum_i \sum_j \text{RSR}(\overline{\text{CTH}}, \text{COT}_i, \text{CER}_j, \theta_0(t, \varphi)) \times f(i,j)}{\sum_i \sum_j f(i,j)} dt$$



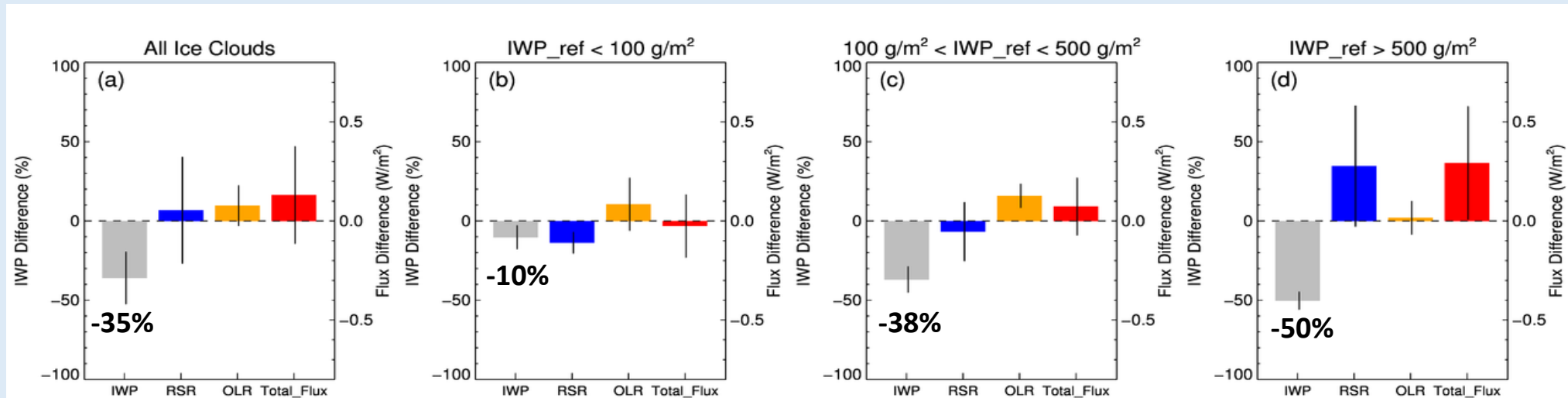
Outgoing LW Radiation



TOA Outgoing SW Flux

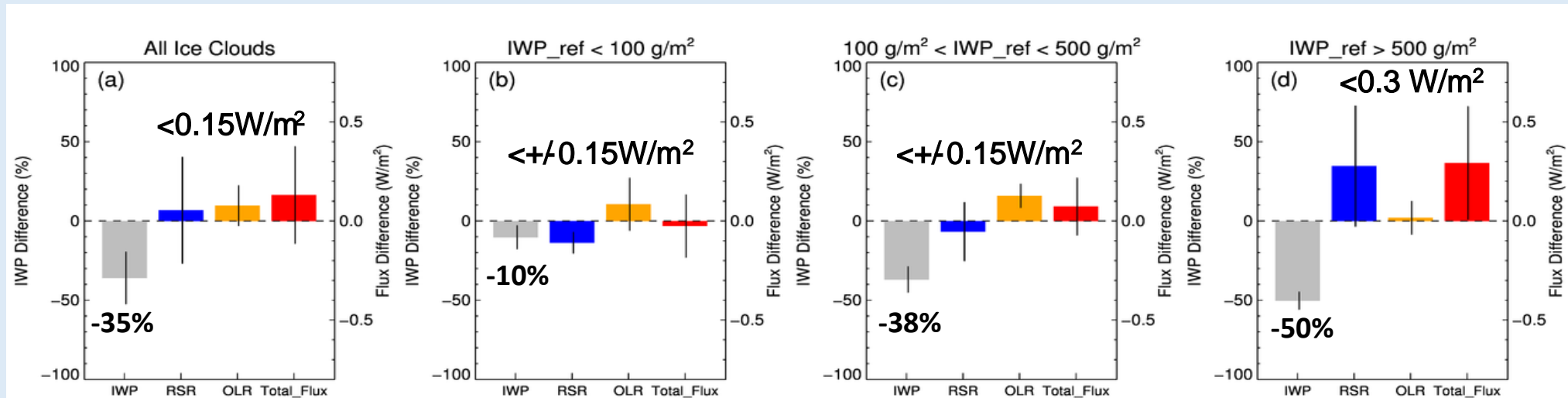
Take home messages

- ICVH could lead to relatively large IWP bias.
 - (MODIS-like IWPs are biased low because the prevailing CER profiles show large particles are closed to cloud bottom)
- ICVH leads to little COT and flux biases.
 - use the same ice microphysical model in both retrieval and flux calculation.
 - MODIS will have pixellevel flux product available.
- More details and interesting discussions and analyses are included in our recent manuscript.
 - (Wang et al., 2018 JGR, under review)



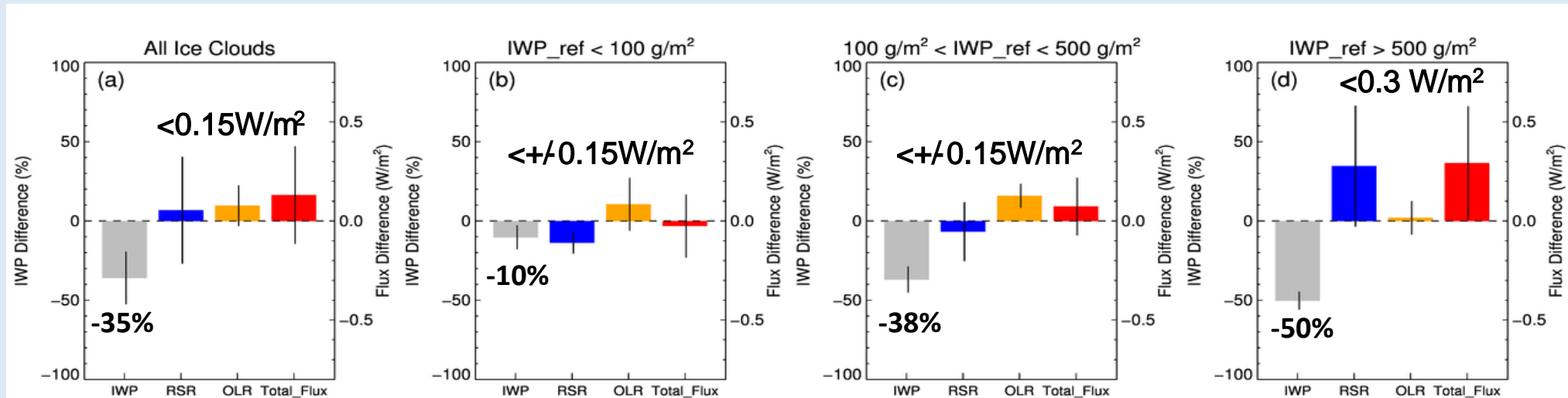
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Extra

