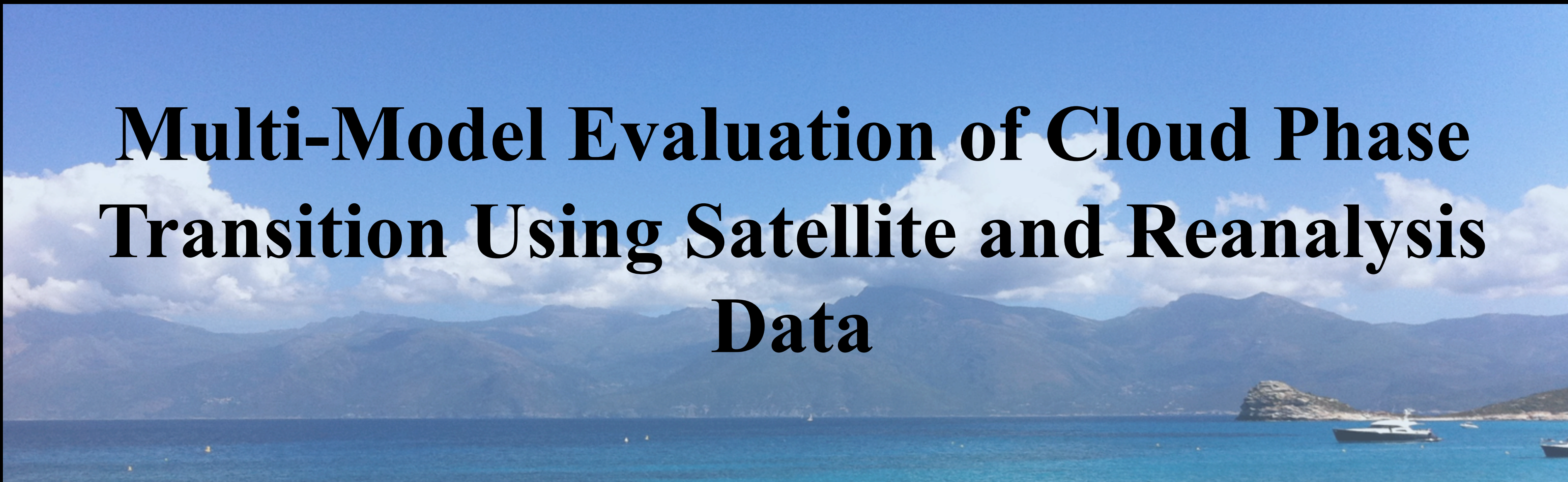
CFMIP Monterey 06/09/2015



Multi-Model Evaluation of Cloud Phase Transition Using Satellite and Reanalysis Data

Grégory Cesana

Jet Propulsion Laboratory, Pasadena, California

Contributors: D. Waliser, X. Jiang, J-F Li, H. Chepfer, J. Cole, P-L. Ma, R. Roehrig

***Cesana**, Waliser, Jiang & Li: Multi-Model Evaluation of Cloud Phase Transition using Satellite and Reanalysis data, 2015, JGR DOI:* 10.1002/2014JD022932

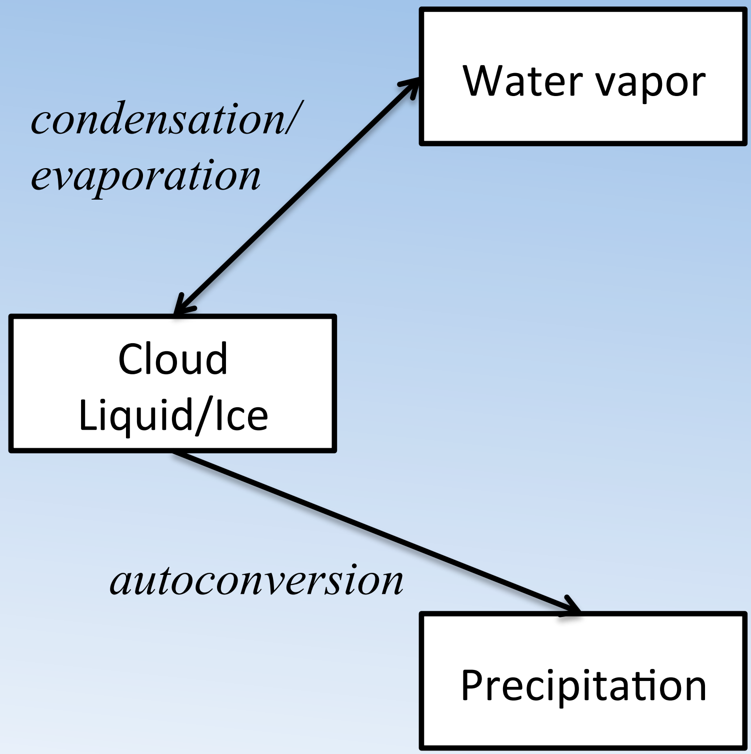
Why does the Cloud Phase matter?

- Different radiative properties (e.g. Twomey, 1977)
- Cloud lifetime
- Precipitation
- In GCMs, clouds, climate sensitivity & radiation are sensitive to the treatment of the cloud phase (e.g. Li & LeTreut 1992, Forbes and Ahlgrimm 2014).

Cloud Phase in GCMs

T-Dependent

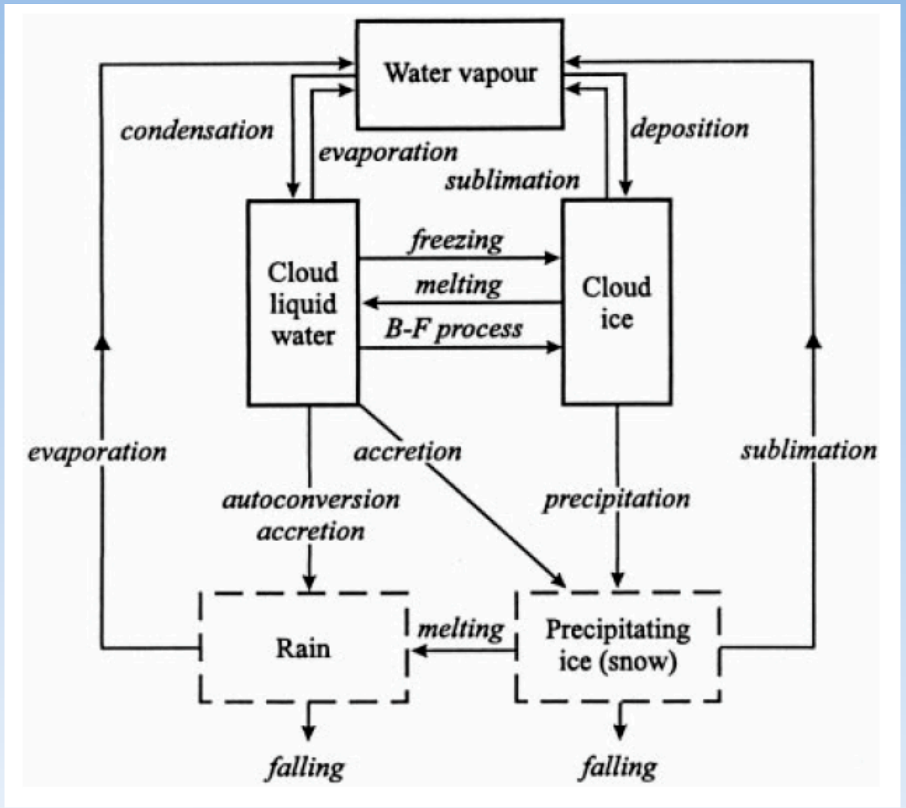
Diagnose and split as a function of the T



e.g. Tiedtke, 1993

Complex Microphysics

Prognose using more complex processes



e.g. Rotstayn et al., 2000

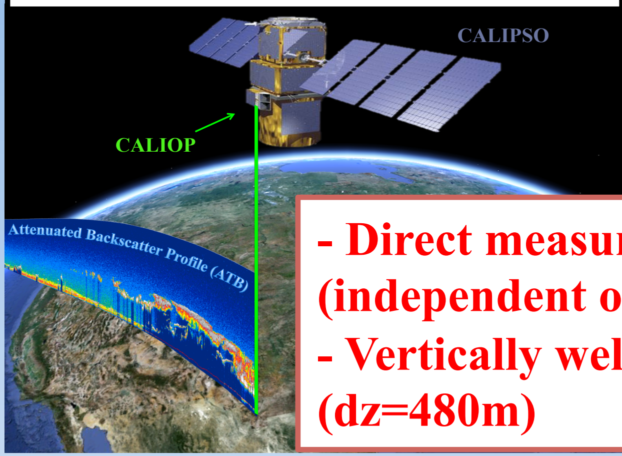
Goals of the study

- Develop a method to compare obs and models
- Evaluate the cloud phase representation in the models
- Evaluate T-dependent vs. complex microphysics for cloud phase representation

Cloud Phase Evaluation:

Obs vs. Model

Obs: CALIPSO

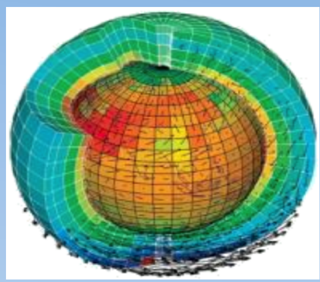


- Direct measurement (independent of T)
- Vertically well-resolved (dz=480m)

CALIPSO-GOCCP

Ice & Liq Cloud Frequency

Models (16)



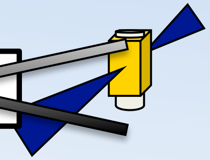
GASS-YOTC: 10 GCMs

CMIP5: 6 GCMs

Ice & Liq Water Content

NOT CONSISTENT

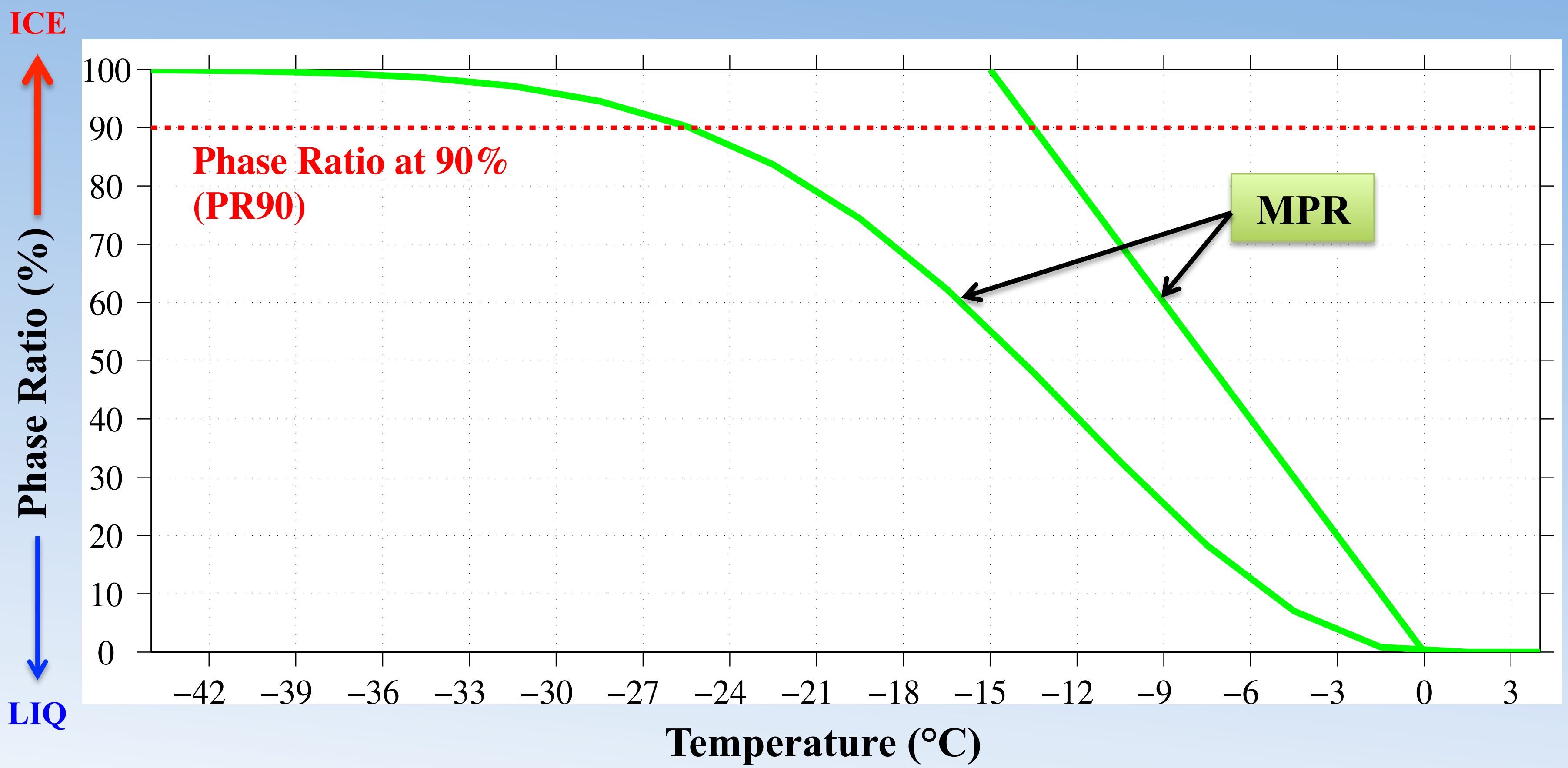
~~Lidar Simulator~~



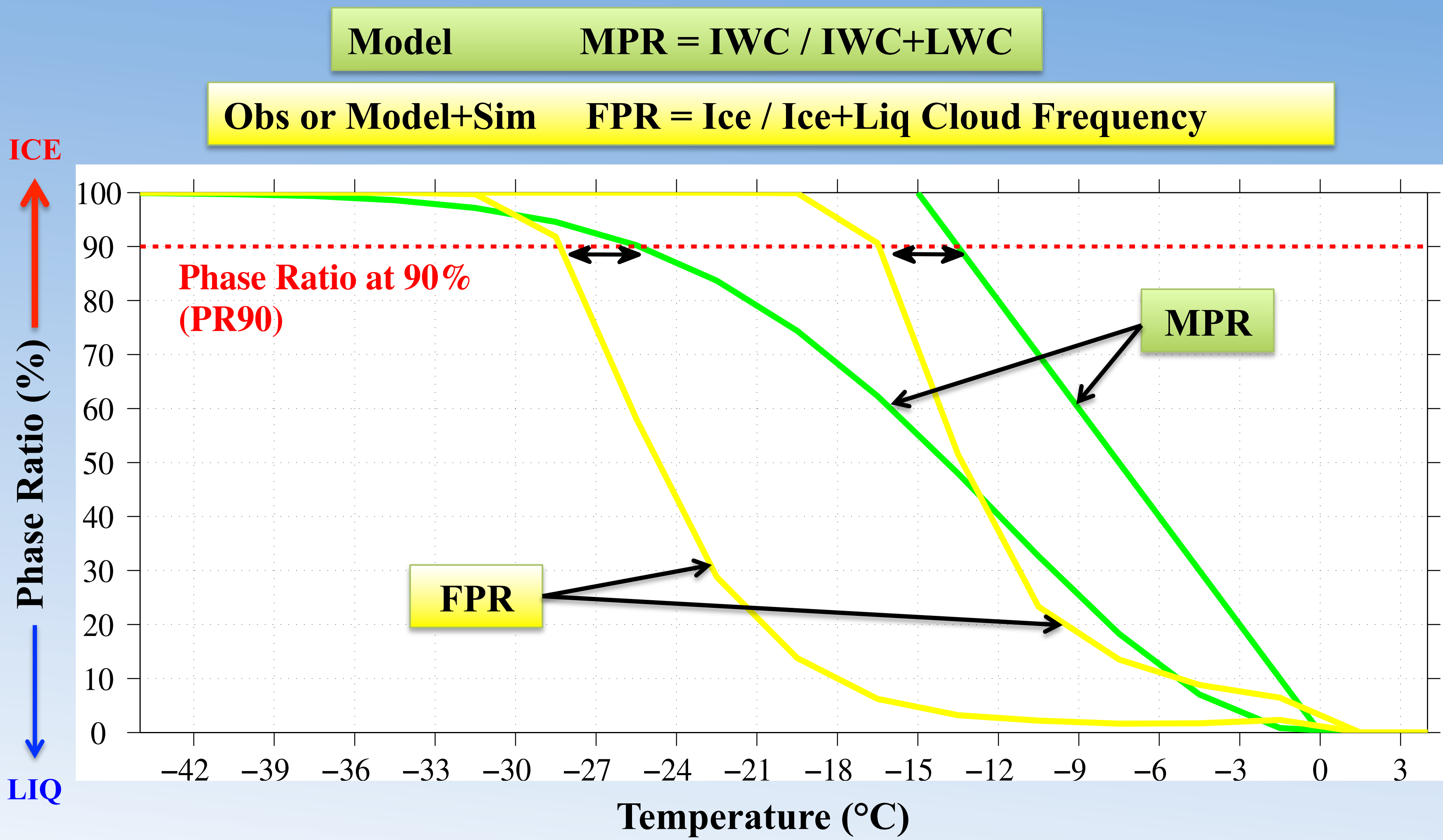
Since no lidar simulator is used in this part of the study, we developed another method to evaluate the models in a consistent way.

Method: Phase Ratio at 90% (PR90)

Model MPR = IWC / IWC+LWC



Method: Phase Ratio at 90% (PR90)



At 90%, Mass Phase Ratio (Model) ≈ Frequency Phase Ratio (Obs)
➔ PR90 allows a consistent evaluation of the models <u>while no simulator is used</u>.

Results

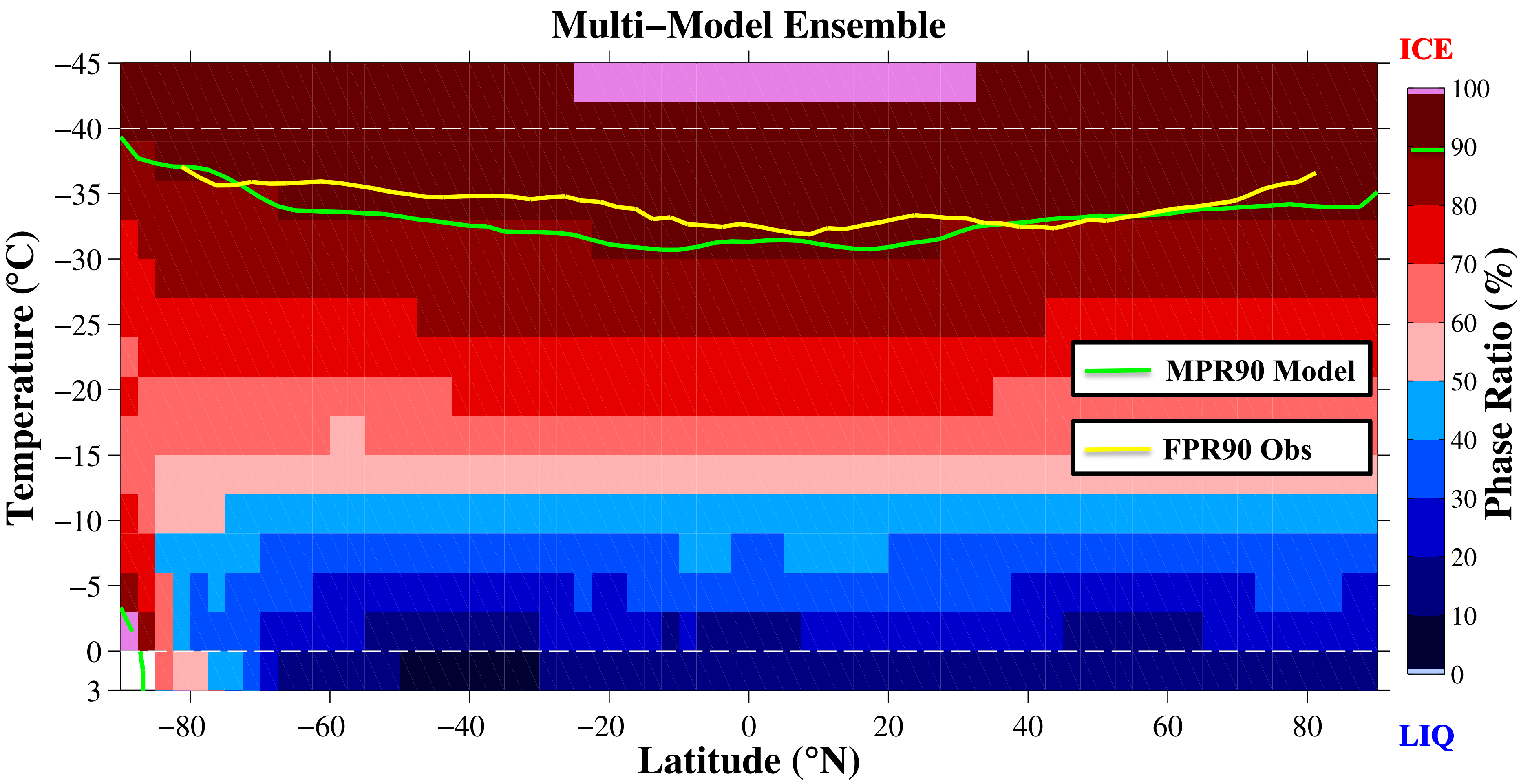
16 Models (GASS-YOTC & CMIP5)

- 2.5x2.5 and 40 temperature levels
- Daily frequency
- Annual Mean
- AMIP-like

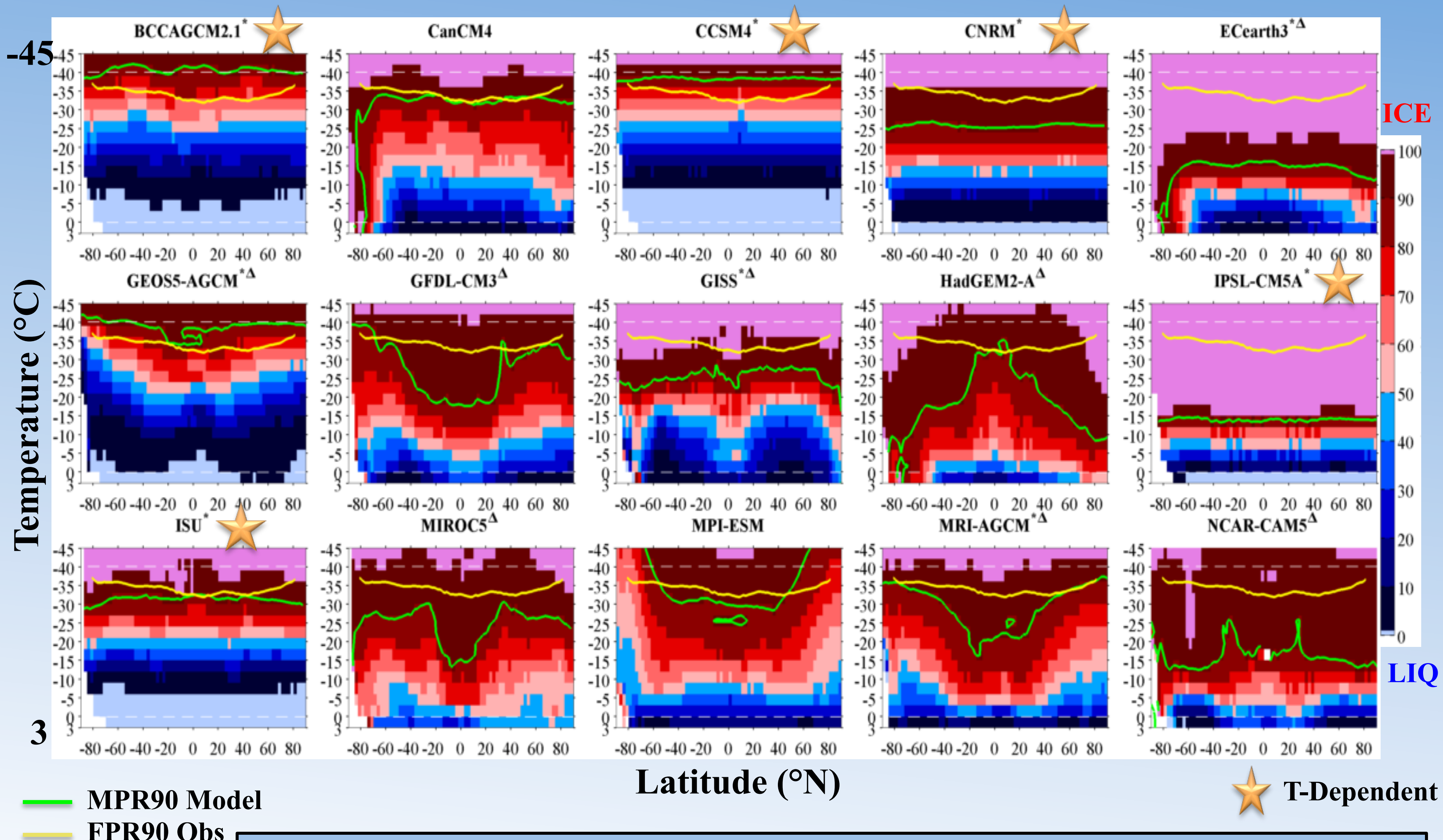
Obs

- 2.5x2.5 and 40 temperature levels
- Daily frequency (Nighttime only)
- Annual mean (7years)

Zonal mean of the Mass Phase Ratio



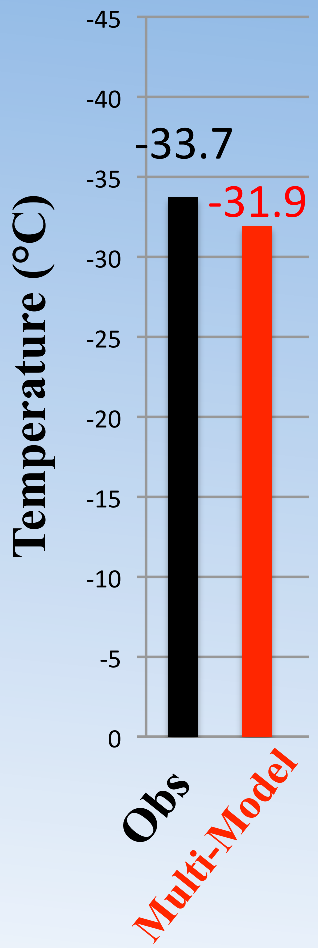
Zonal mean of the Mass Phase Ratio



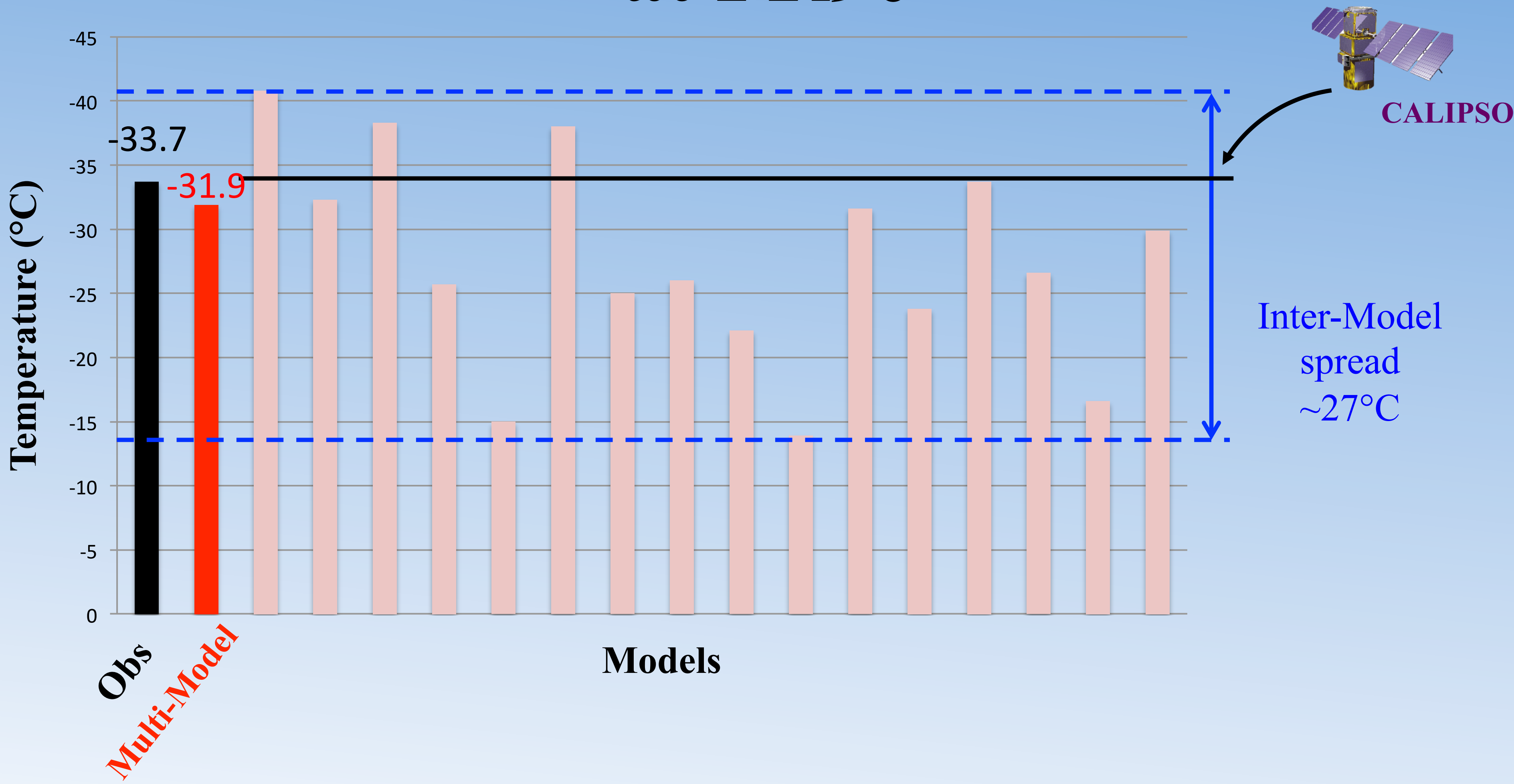
➔Large diversity in the model's behavior.

➔Few models are able to reproduce the observed zonal variations at PR90.

Global Average of the Temperature at PR90



Global Average of the Temperature at PR90



➔ **Inter-Model spread very large**
➔ **In 13/16 models, the temperature at PR90 is too warm compared to Obs.**

Conclusions

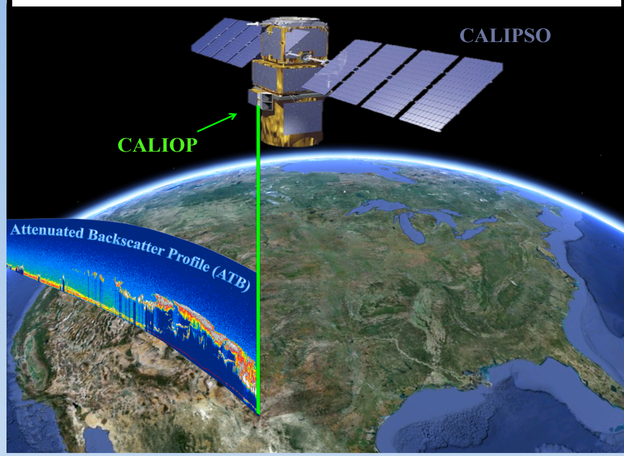
Using the Phase Ratio at 90% in both CALIPSO-GOCCP observations (FPR90) and 16 GCMs (MPR90), we showed that:

- *Very few models are able to reproduce the observed zonal variations of the cloud phase at PR90.*
- *Transition from mixed-phase to ice clouds occurs at too warm temperature in most models (13/16).*
- *Apart from observations, models demonstrate a wide variation in Mass Phase Ratio across all latitudes/temperatures.*

Cloud Phase Evaluation:

Obs vs. Model

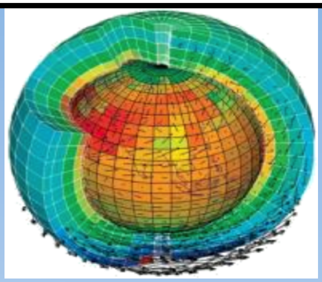
Obs: CALIPSO



CALIPSO-GOCCP

FPR: Ice & Liq
Cloud Frequency

Models



CMIP5: 4 GCMs

MPR: Ice & Liq
Warer Content

Lidar Simulator

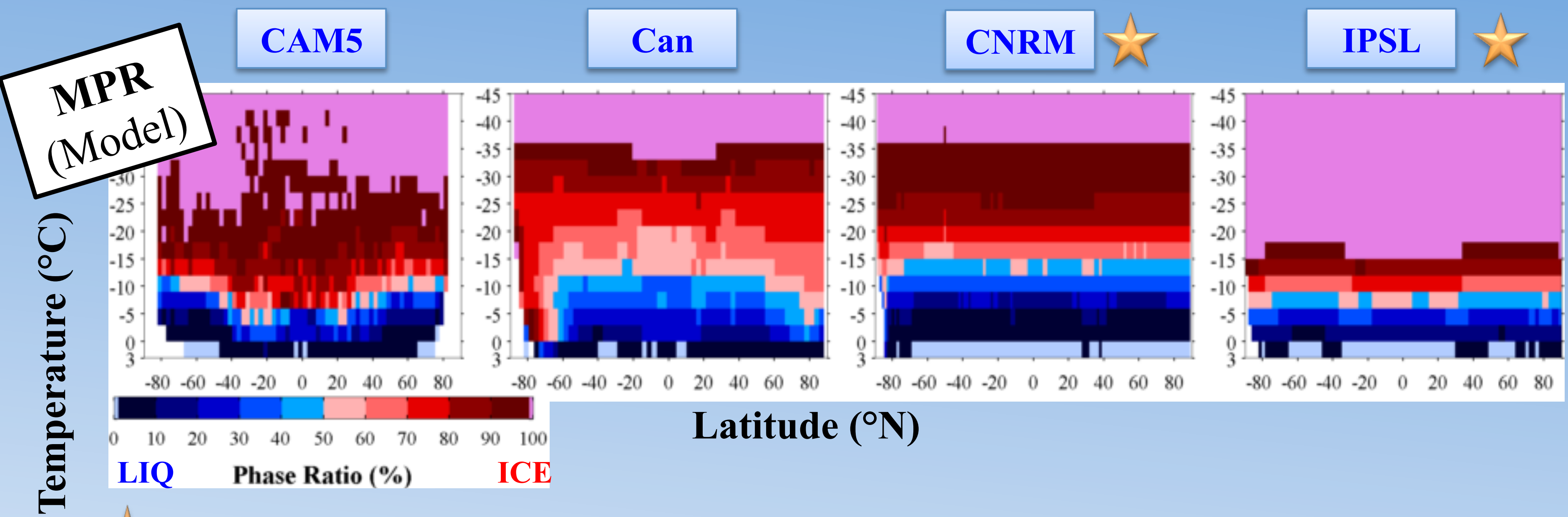
FPR: Ice & Liq
Cloud Frequency

OK at 90%

CONSISTENT

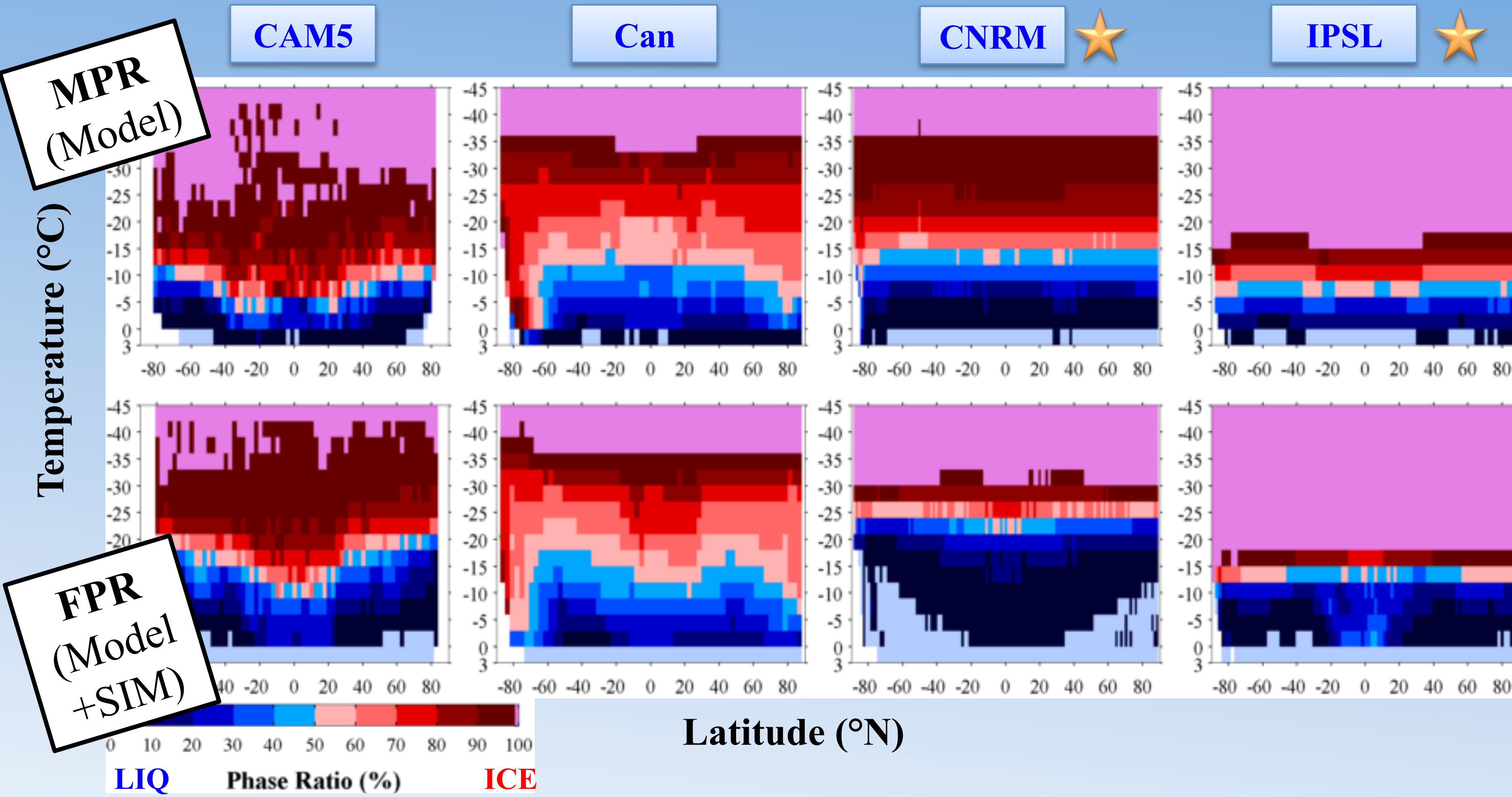
- Using the simulator allows a consistent evaluation of the cloud phase at every temperature and for every height level (not only at PR90)

Zonal mean of the Phase Ratio



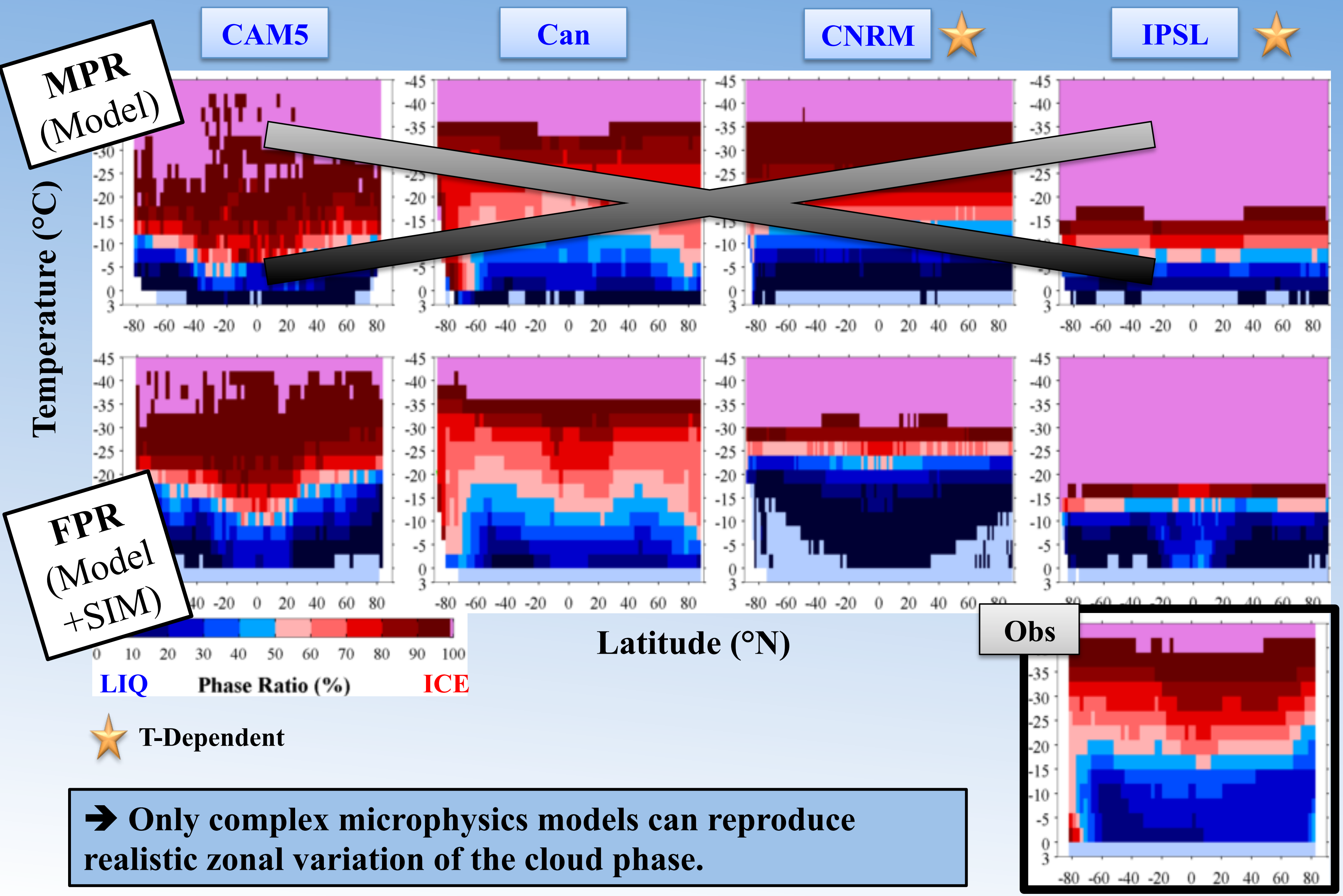
T-Dependent

Zonal Mean of the Phase Ratio (SIM)



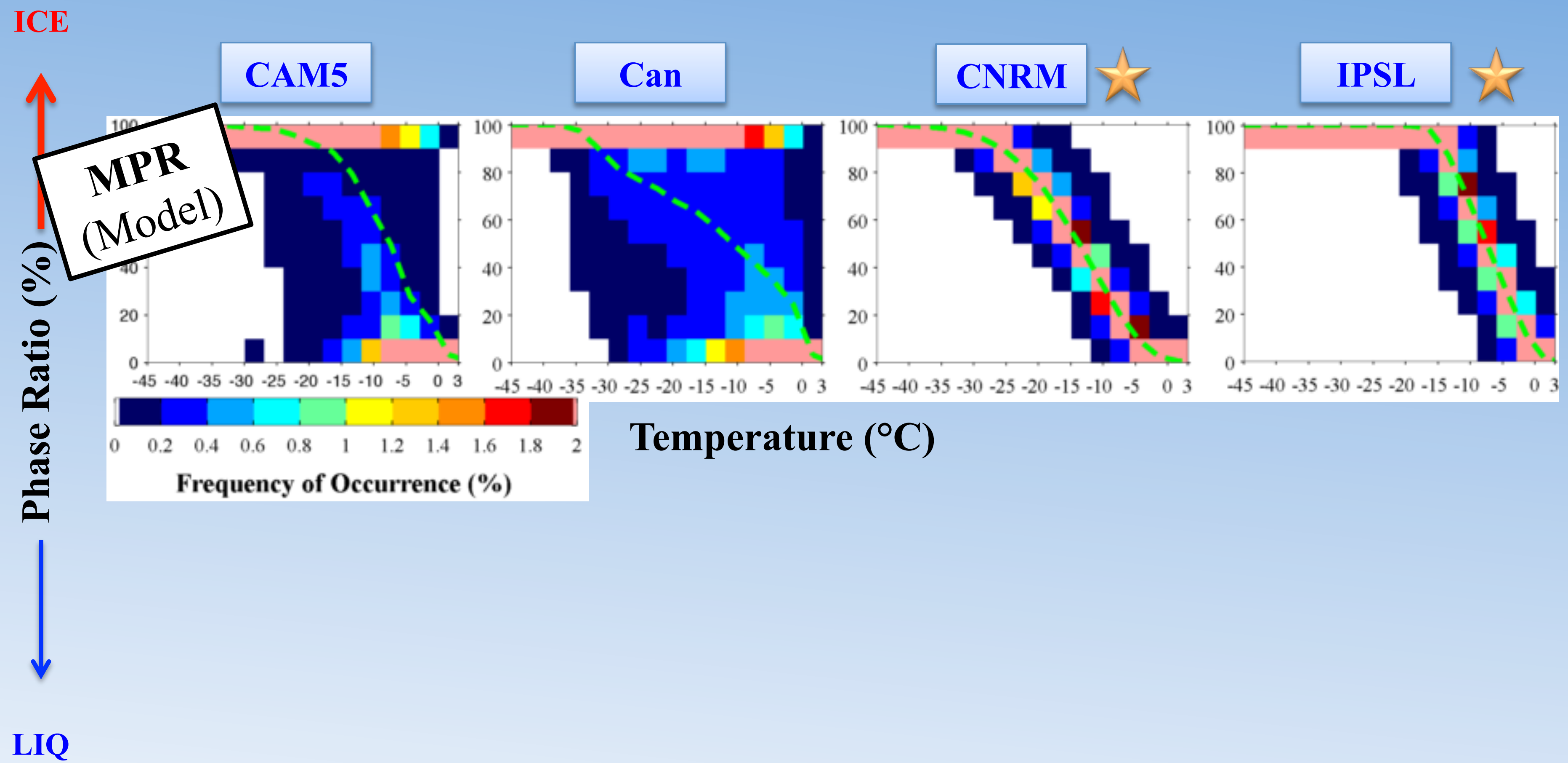
T-Dependent

Zonal Mean of the Phase Ratio (SIM)

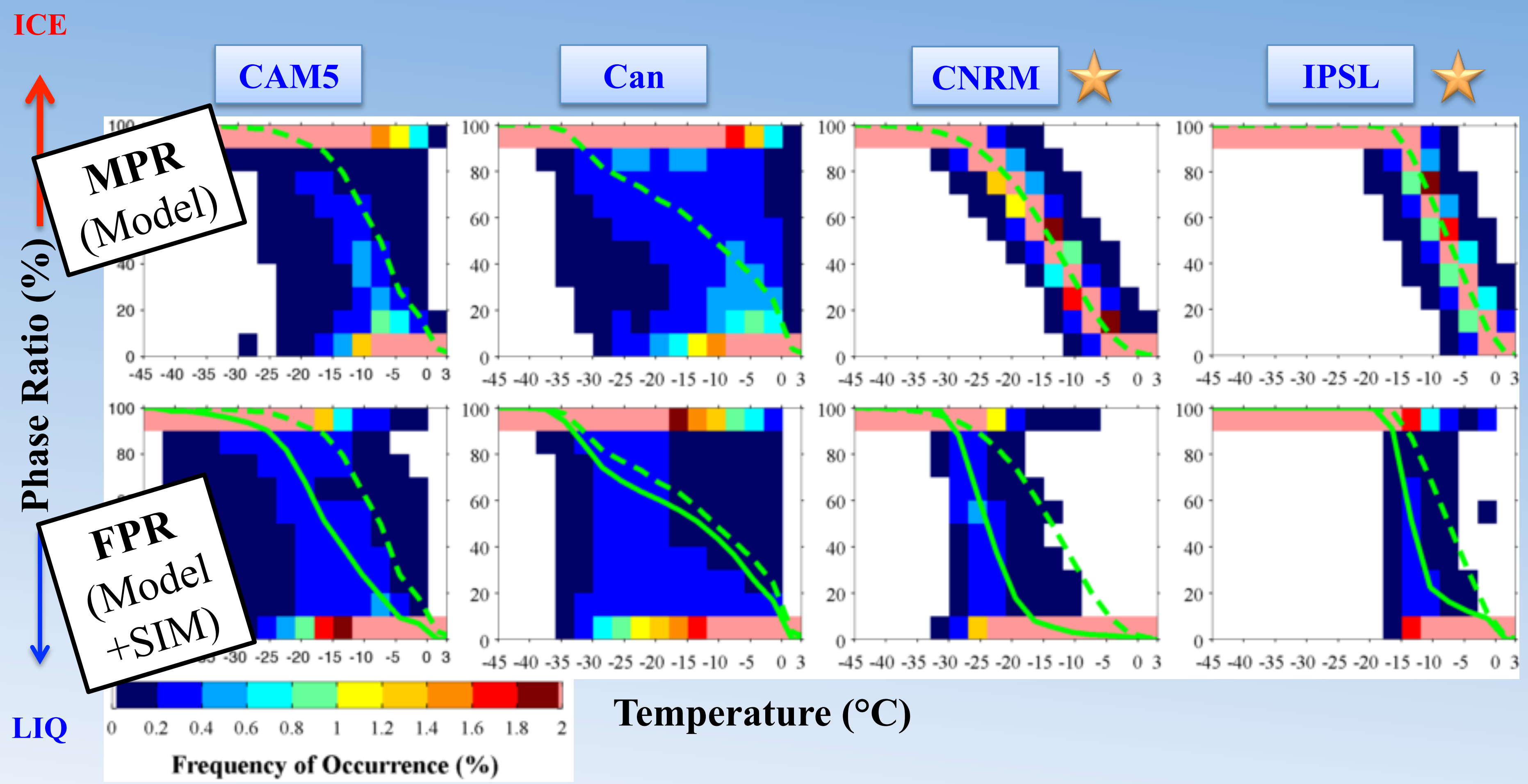


➔ **Only complex microphysics models can reproduce realistic zonal variation of the cloud phase.**

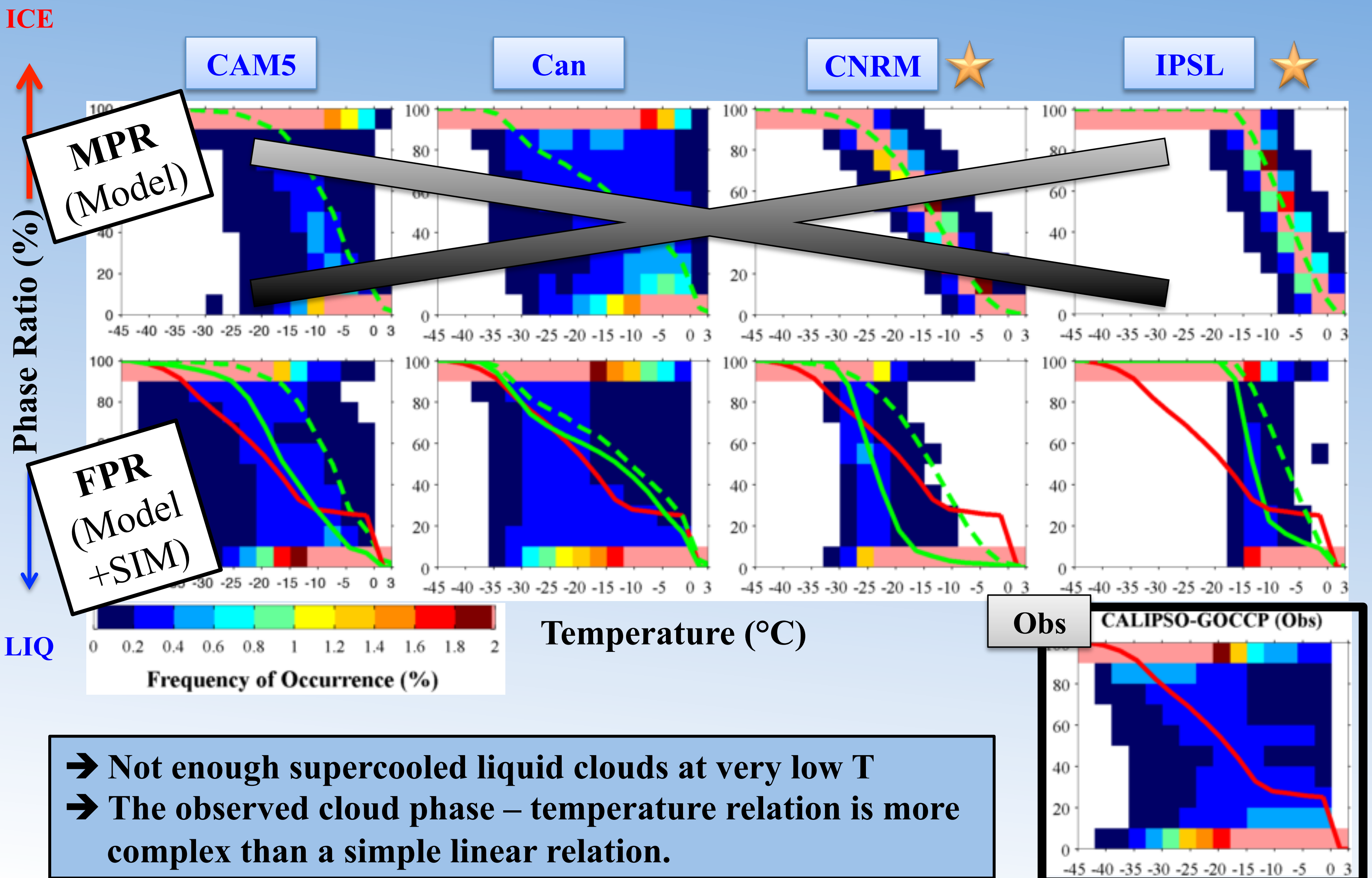
Temperature / Phase + Simulator



Temperature / Phase + Simulator



Temperature / Phase + Simulator



➔ Not enough supercooled liquid clouds at very low T

➔ The observed cloud phase – temperature relation is more complex than a simple linear relation.

Summary

Using CALIPSO-GOCCP observations, we assessed the cloud phase representation in several GCMs (GASS-YOTC and CMIP5).

- **Without simulator**, we can still evaluate some aspects of the cloud phase using the phase ratio at 90% method:

- *The zonal variations of the cloud phase (barely reproduced by few models)*
- *The transition temperature (height) from mixed-phase to ice clouds (too warm in 13/16 models)*

- **With the simulator,** we can fully evaluate the cloud phase at every temperature and height level:

- *T-dependent cloud phase partitioning is not realistic*
- *Not enough supercooled liquid clouds at temperature colder than -30°C*

Overall, complex microphysics cloud schemes are needed to better reproduce observations.