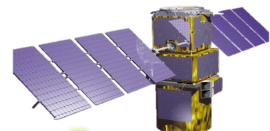


# **Characterizing And Understanding Systematic Biases In The Vertical Structure Of Clouds In CMIP5/CFMIP2 Models**

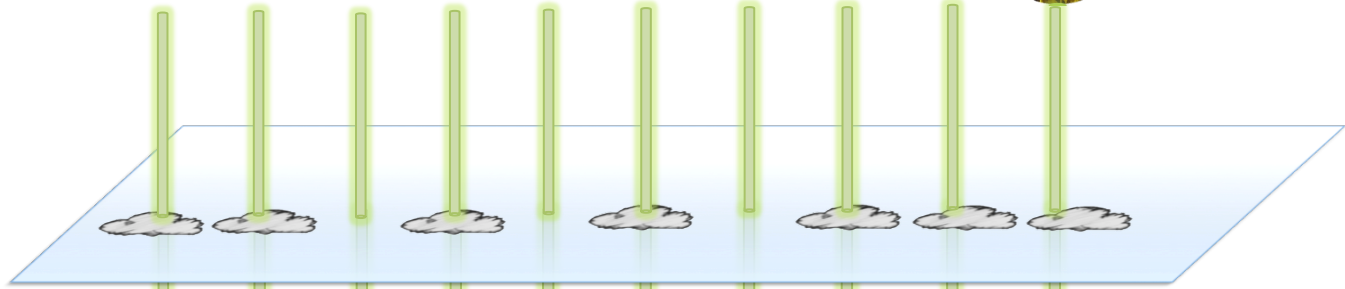
G. Cesana<sup>1</sup>, D. E. Waliser<sup>1</sup> ....

Part is already submitted to GRL

# Definition of the Cloud Frequency/Fraction (CALIPSO-GOCCP)



Layer:  
Low  
mid  
high  
tot



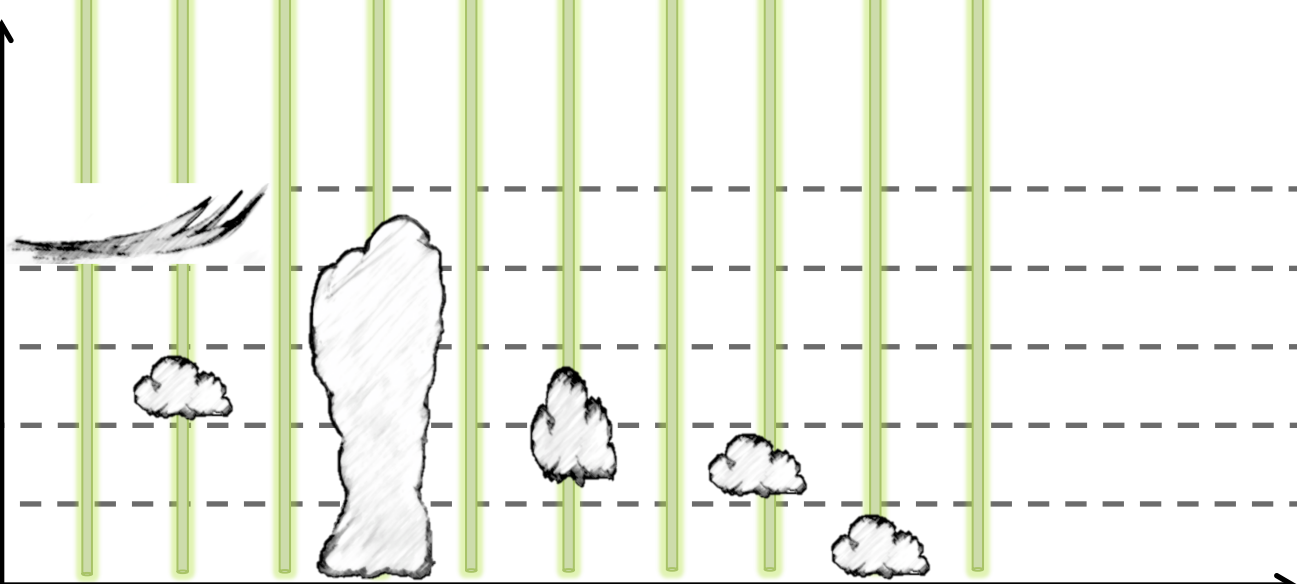
**Layered Cloud Frequency**

70%

Height

Layer:  
Low  
mid  
high  
tot

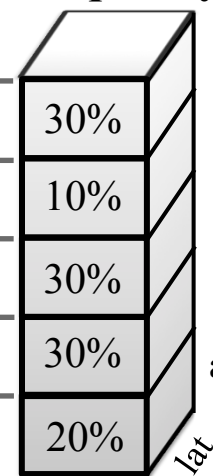
Level  
480m



Lidar profiles along track

x,y

**Level Cloud Frequency**



30%

10%

30%

30%

20%

alt

lon

# Tools

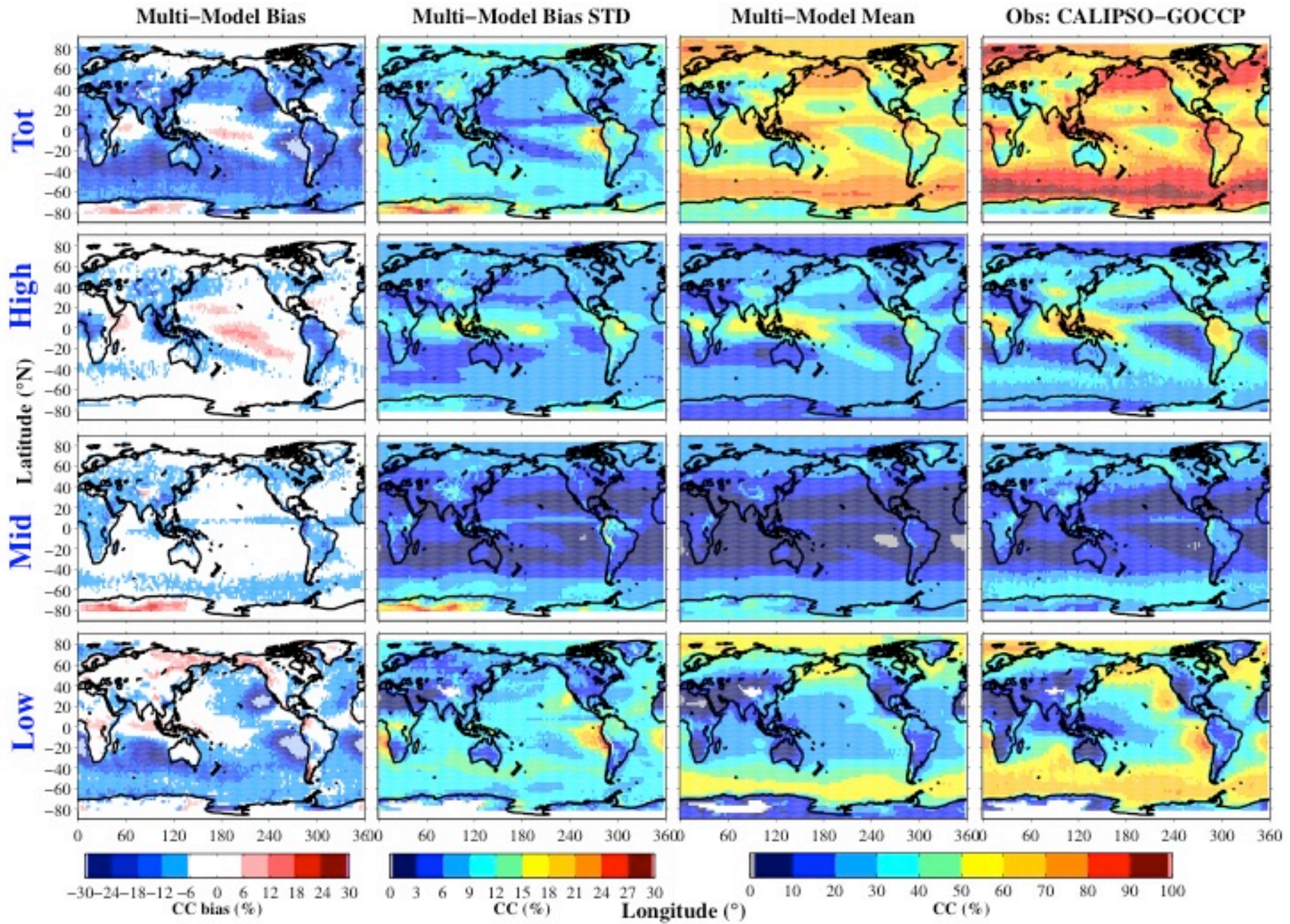
## Models:

- **12 CMIP5/CFMIP2 models** + Simulator
- Interpolated onto 2.5x2.5x40L grid
- 20-years average based on daily files

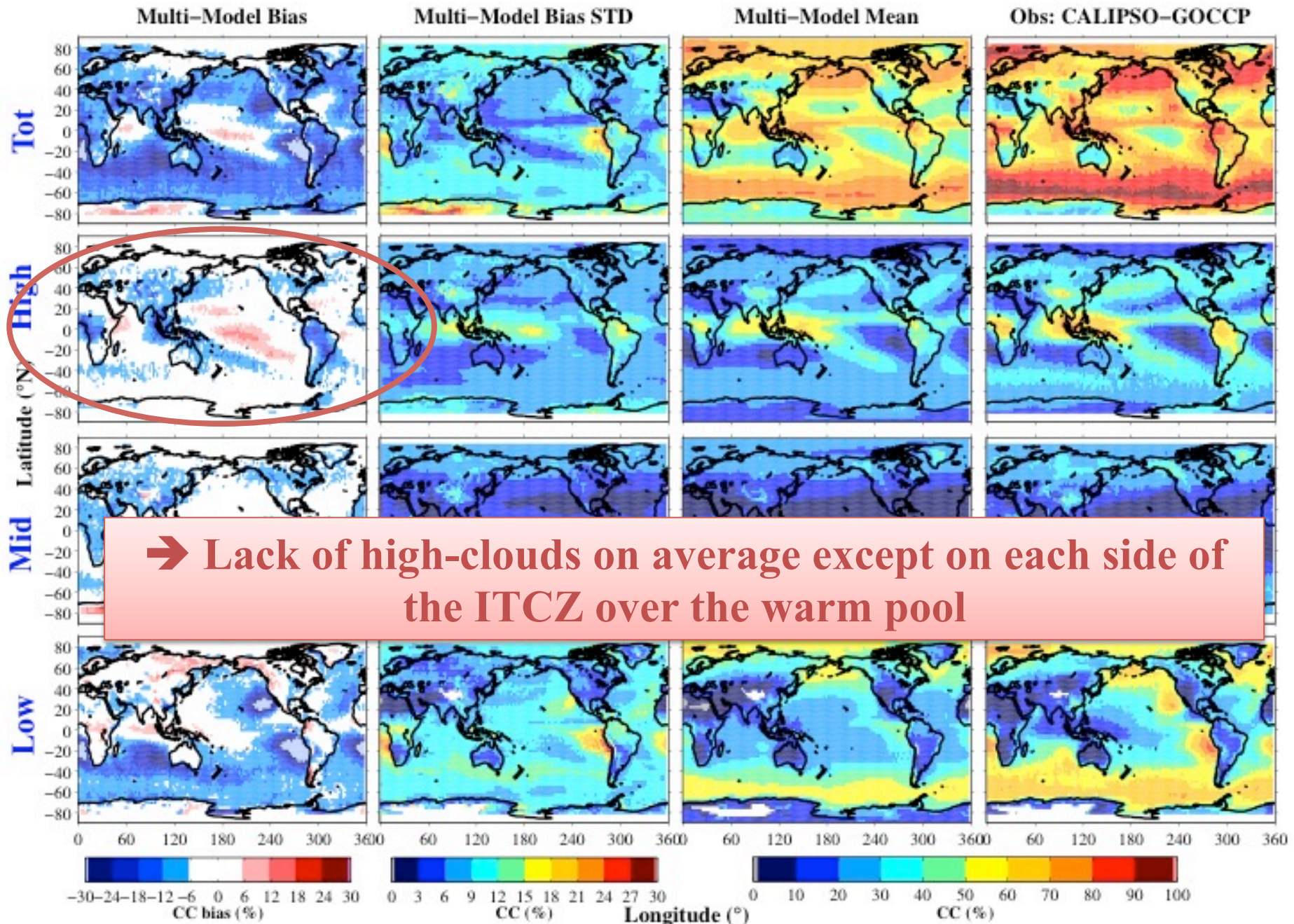
## Obs:

- **CALIPSO-GOCCP**
- 2.5x2.5x40L grid
- 9-years average based on daily files day +night
- ERAi daily files during the same period for RH and  $\omega_{500}$

# 1.A Layered Cloud Frequency: Maps



# 1.A Layered Cloud Frequency: Maps



# 1.B Layered Cloud Frequency: Scores

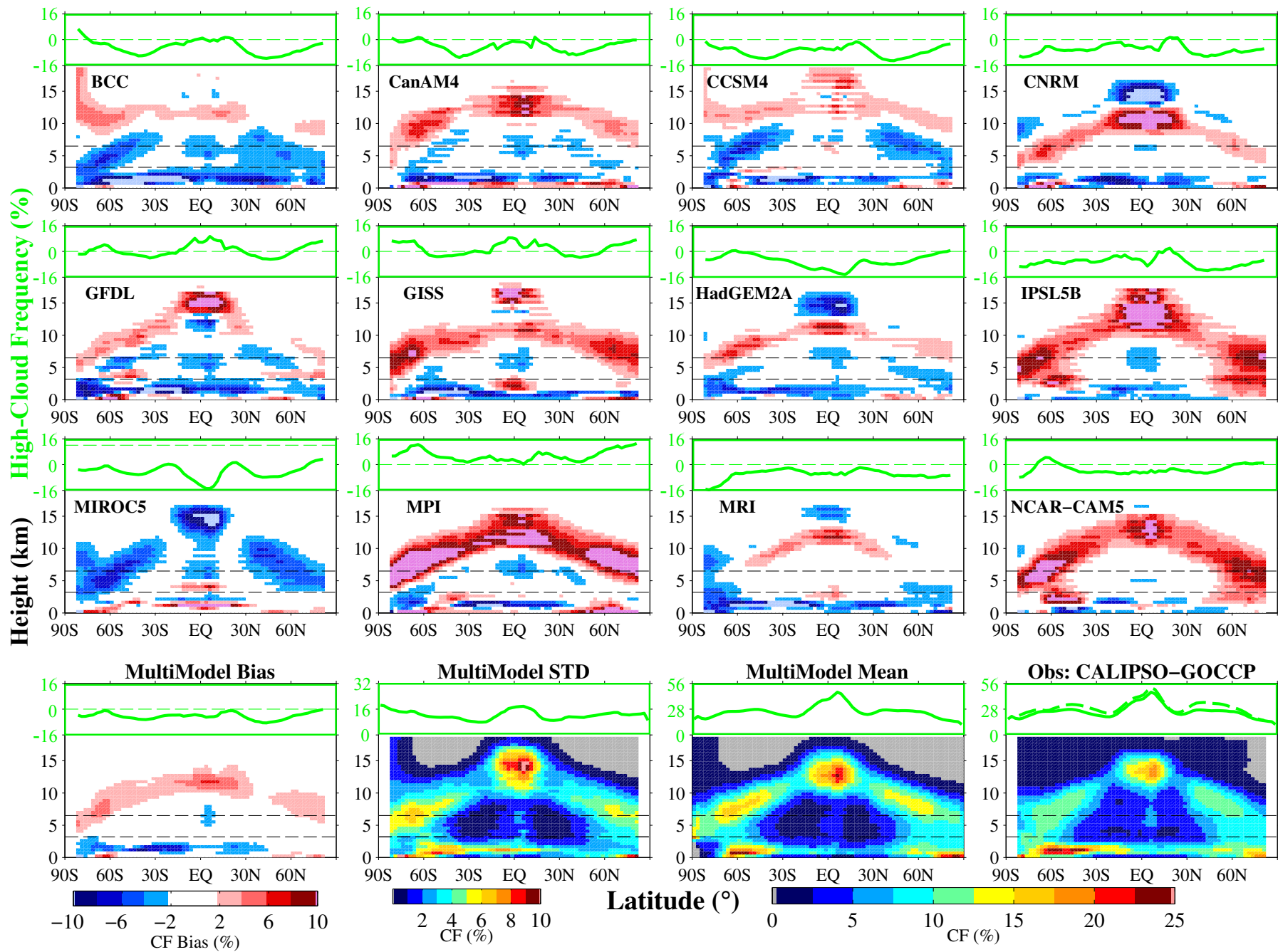
Positive bias

Negative bias

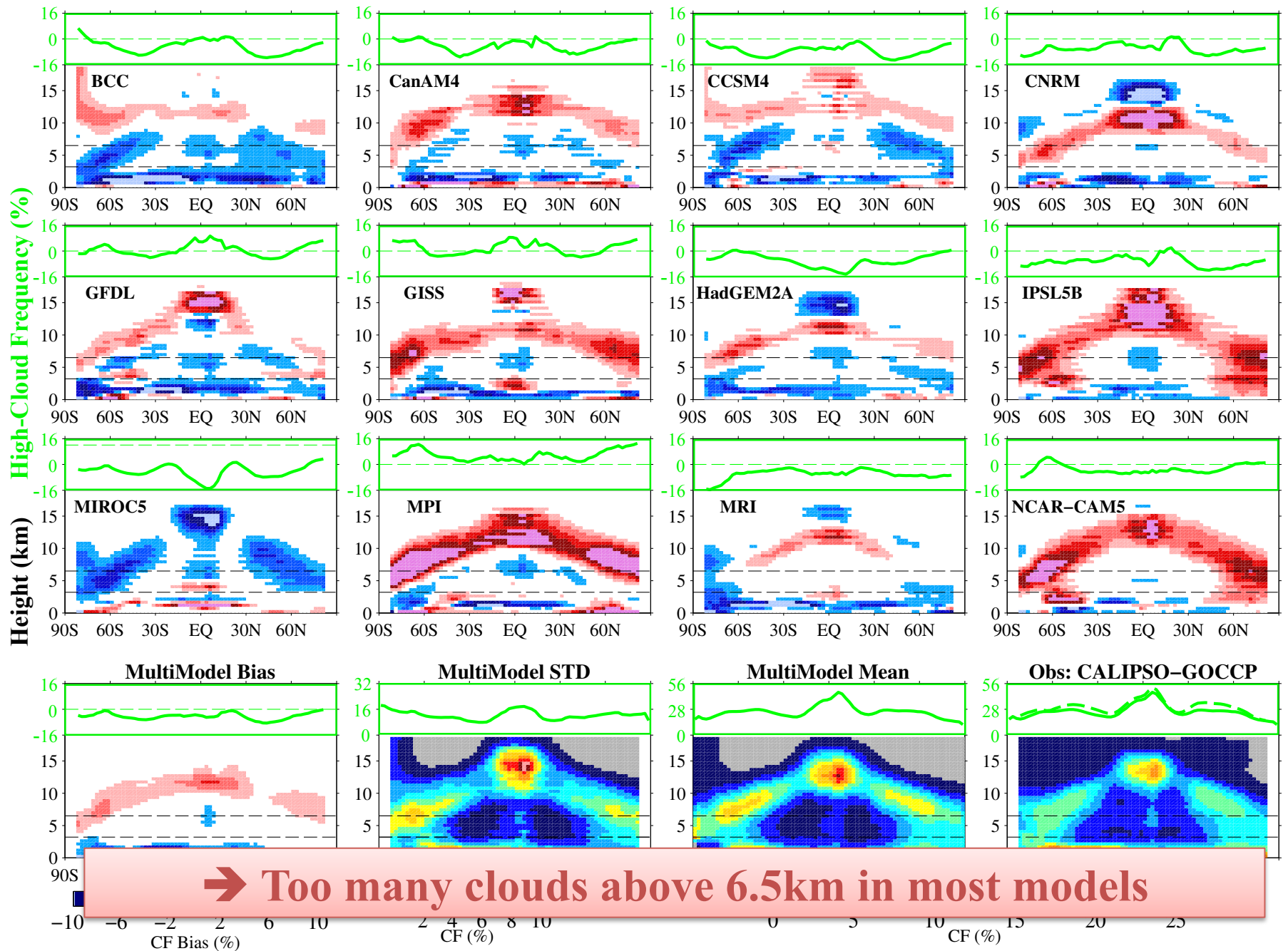
all	Low			Mid			High			Total		
Model	tot	oc	land	tot	oc	land	tot	oc	land	tot	oc	land
'NCAR-CAM5'	-5	-4.8	-0.3	-2.2	-0.7	-1.5	-3.5	-2	-1.5	-9.8	-7	-2.8
'GISS'	-8.3	-9.6	1.3	-2.8	-2.5	-0.3	1.4	1.7	-0.3	-9.5	-9.5	0
'CanCM4'	-3.4	-3.7	0.4	-6.7	-4.7	-2.1	-4.6	-1.8	-2.8	-7	-4.6	-2.4
'MPI-ESM'	-6.8	-5.9	-1	-5.3	-4.2	-1.1	4.7	3.7	1	-5.5	-4.7	-0.8
'MRI-AGCM'	-14.7	-12.5	-2.2	-4.6	-2.1	-2.5	-5.3	-2.8	-2.5	-16.8	-12.3	-4.5
'CNRM'	-12.7	-10.5	-2.2	-3.2	-0.9	-2.3	-5.5	-2.6	-2.8	-16.8	-11.7	-5.1
'MIROC5'	2.7	2.6	0.1	-7.5	-4.6	-2.8	-17.1	-11.4	-5.6	-12.7	-7.4	-5.3
BCCAGCM2.1'	-13.5	-12.8	-0.7	-11.6	-7.4	-4.2	-4.7	-2.2	-2.4	-19.3	-15	-4.3
'GFDL'	-5	-5.5	0.5	-2.4	-1.6	-0.9	0.7	1.3	-0.6	-3.8	-3.3	-0.5
'IPSL-CM5B'	-11.1	-9	-2.1	-7.4	-4.6	-2.8	-6	-2.6	-3.4	-14.3	-9.3	-5
'HadGEM2-A'	-10.8	-9.1	-1.8	-5.5	-3.2	-2.3	-7	-3.9	-3.1	-14.3	-10	-4.3
'EC-EARTH'	-15.5	-13.9	-1.7	-8.9	-5.4	-3.5	-7.4	-4.7	-2.7	-21.2	-16.2	-5
<b>MultiModel</b>	<b>-9</b>	<b>-8.1</b>	<b>-0.8</b>	<b>-5.7</b>	<b>-3.5</b>	<b>-2.2</b>	<b>-4.5</b>	<b>-2.3</b>	<b>-2.2</b>	<b>-12.6</b>	<b>-9.3</b>	<b>-3.3</b>
<b>Obs</b>	<b>37.7</b>	<b>31.4</b>	<b>6.3</b>	<b>18.2</b>	<b>11.4</b>	<b>6.8</b>	<b>32.1</b>	<b>22.2</b>	<b>9.9</b>	<b>67.3</b>	<b>50.4</b>	<b>16.9</b>

→ High-clouds biased low over land as well as ocean on average

# 2.A Zonal Mean Cloud Profiles



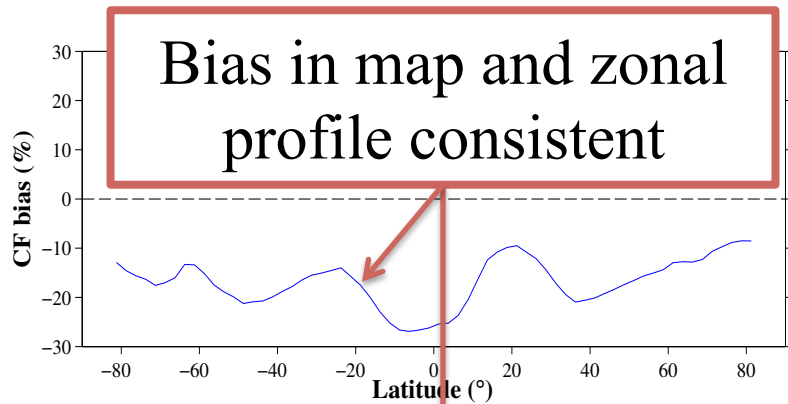
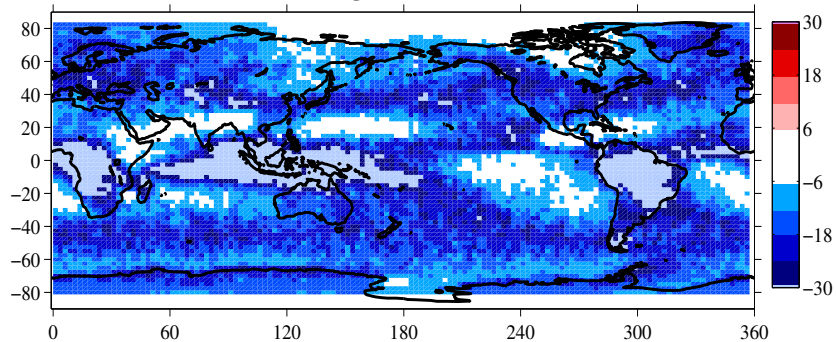
# 2.A Zonal Mean Cloud Profiles



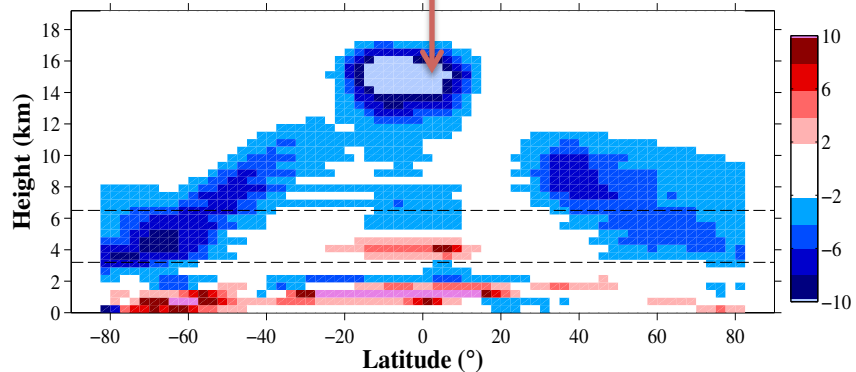
# High-CF vs. Level CF bias

MIROC5

a. High-Cloud Bias

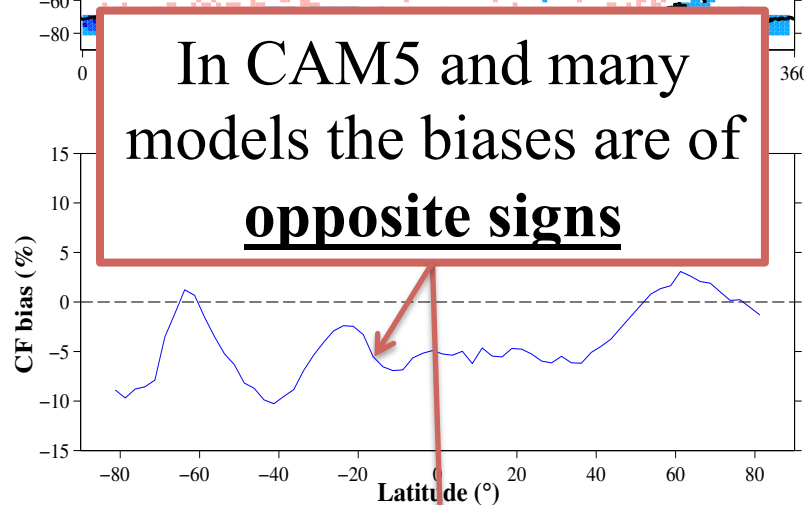
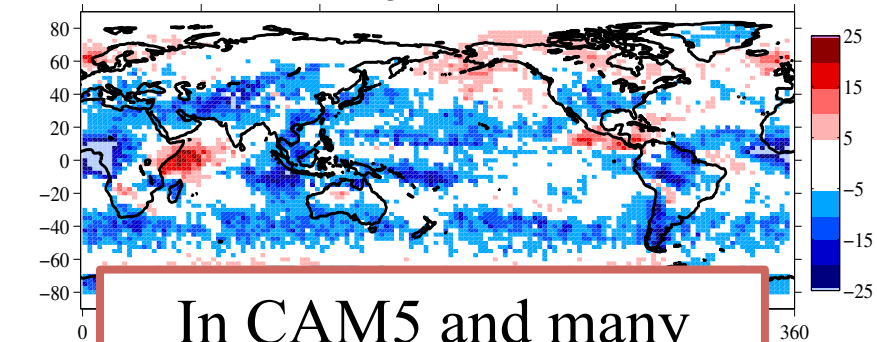


c. Zonal Profile Bias

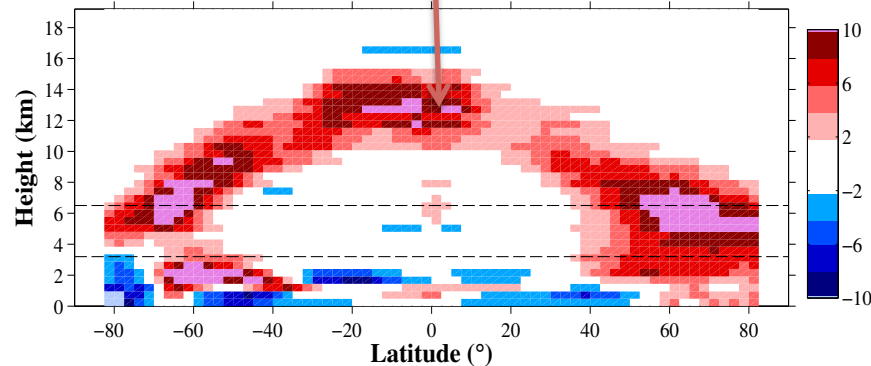


NCAR-CAM5

a. High-Cloud Bias

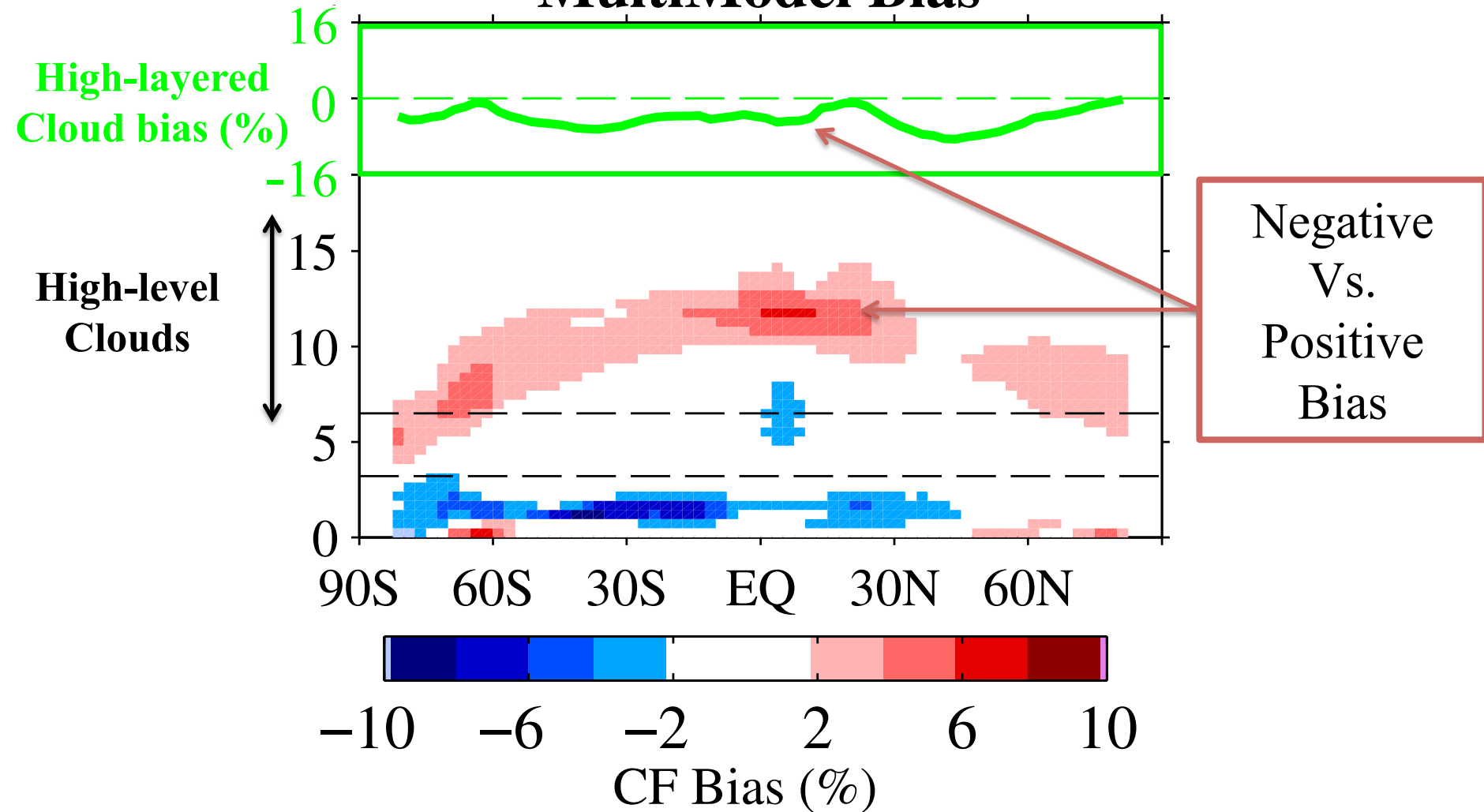


c. zonal Profile Bias



# High-CF vs. Level CF bias

## MultiModel Bias



→ Too few high-clouds in the zonal mean (green upper plot) while too many clouds above 6.5km in the zonal mean profile

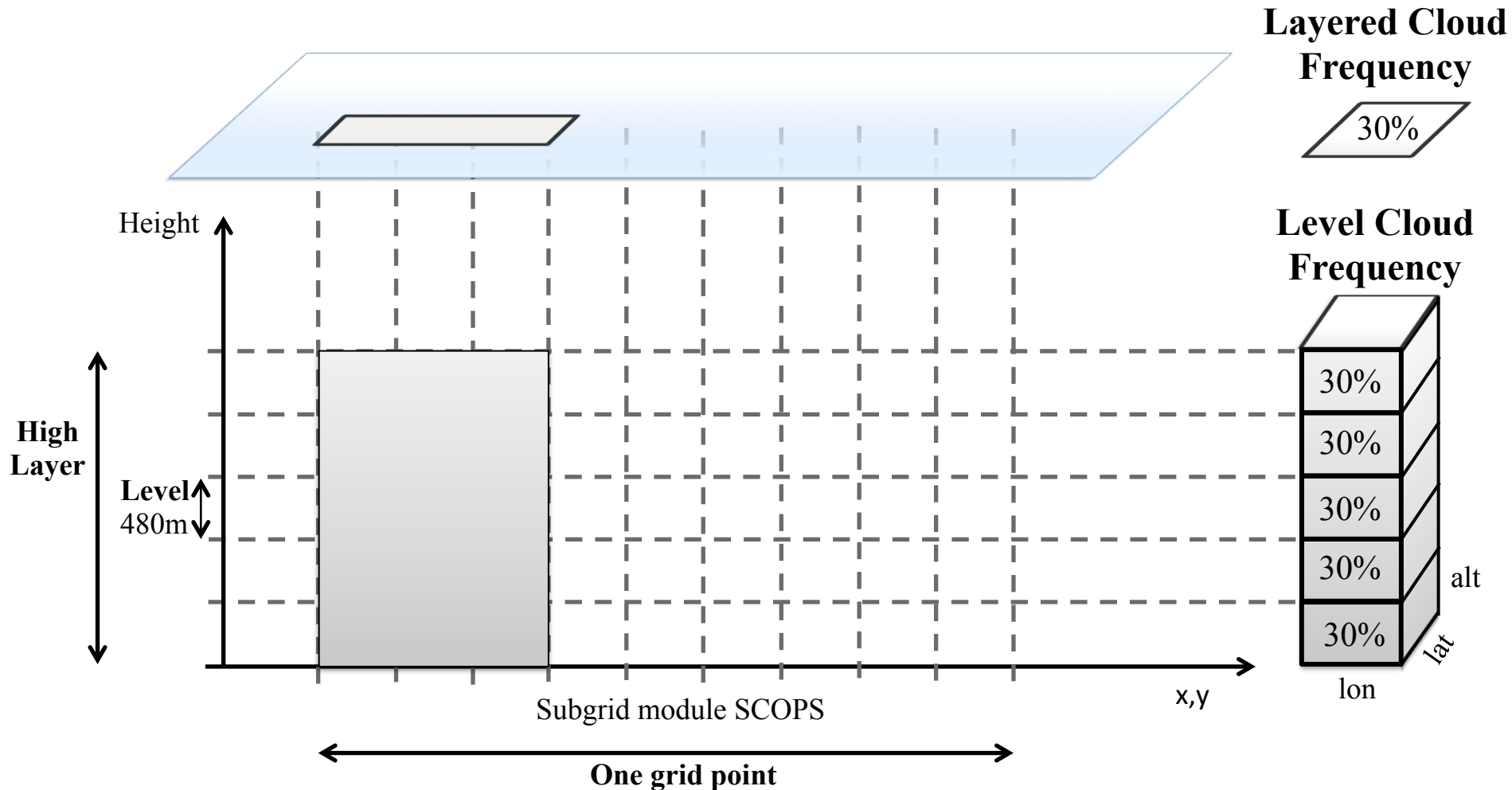
# Overlap in COSP: max/random (most models)

## Input of the model:

CF= 30% at every level of the gridbox in the high layer +  
max/random overlap

## Output of COSP:

CF  $\leq$  30% at every level of the gridbox in the high layer  
CF high= 30%



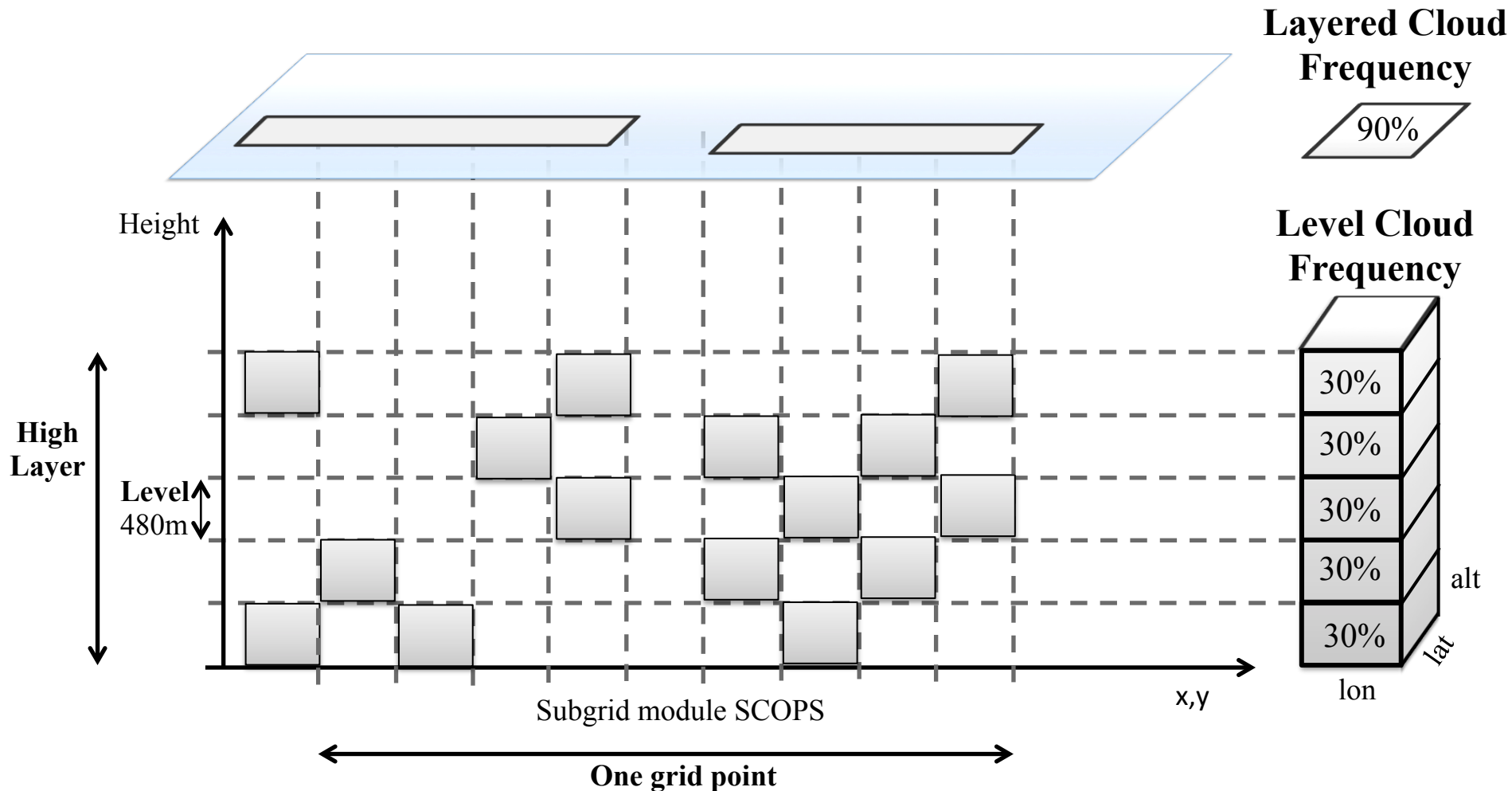
# Overlap in COSP: random

## Input of the model:

CF= 30% at every level of the gridbox in the high layer +  
random overlap

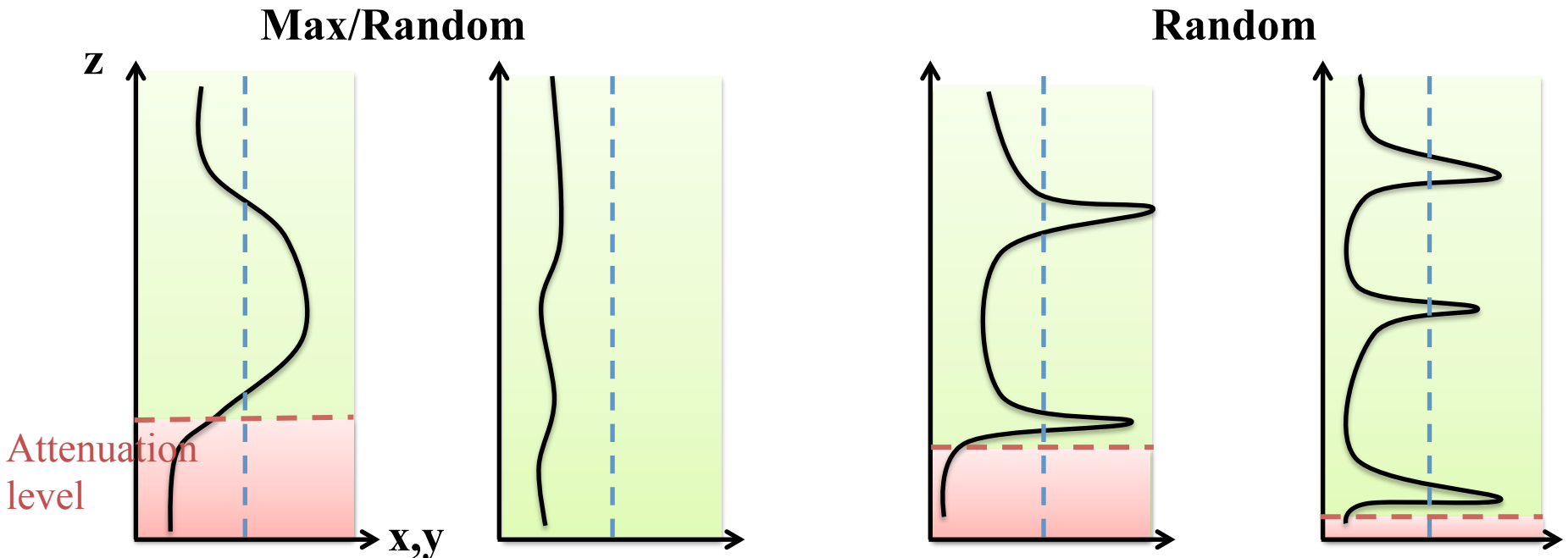
## Output of COSP:

CF  $\leq$  30% at every level of the gridbox in the high layer  
CF high= 90%



# Changing the overlap assumption in COSP

*may also change the 3D profiles*



- 1) Thick cloud → Signal attenuated and blind for the lowest levels
- 2) More weight for the clear sky in the lowest levels

- 1) Sparse clouds → Less attenuation
- 2) More cloudy detection in the lowest levels

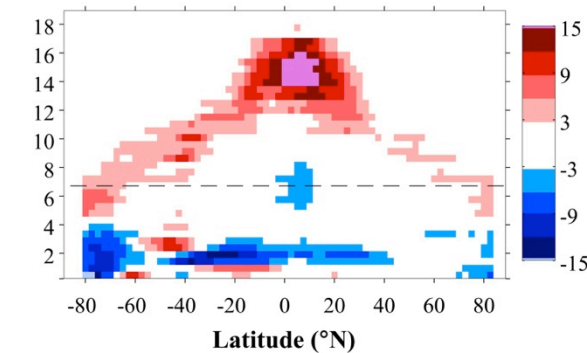
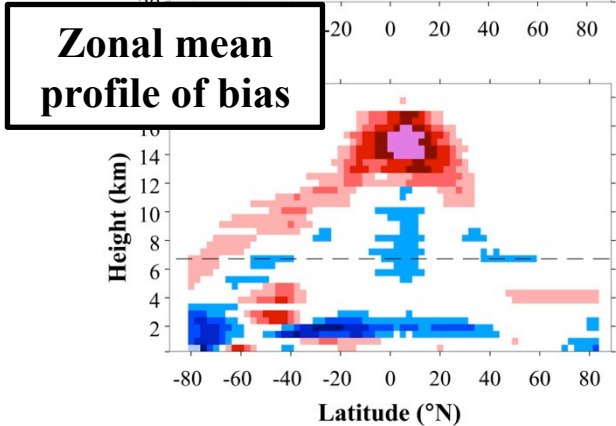
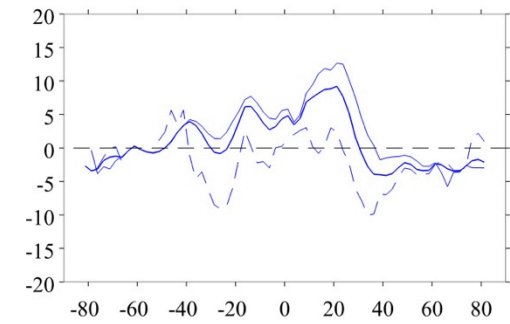
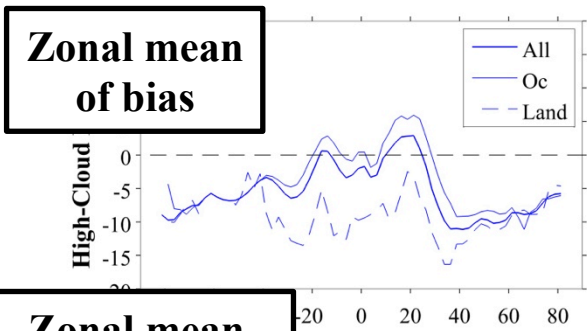
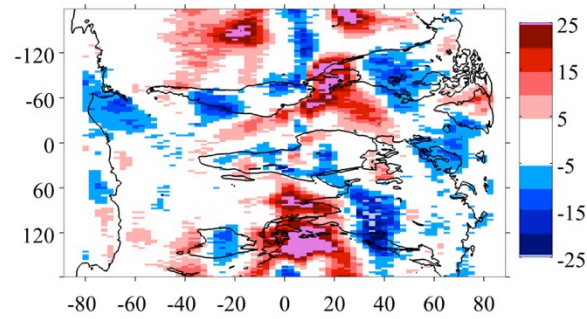
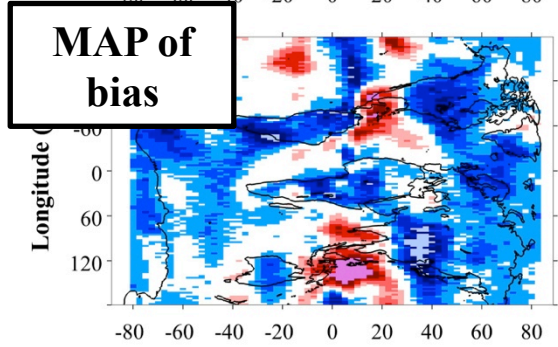
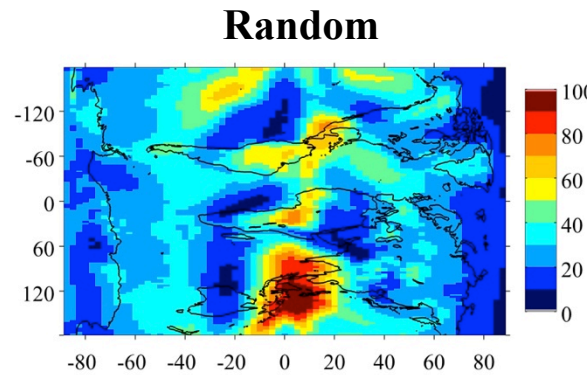
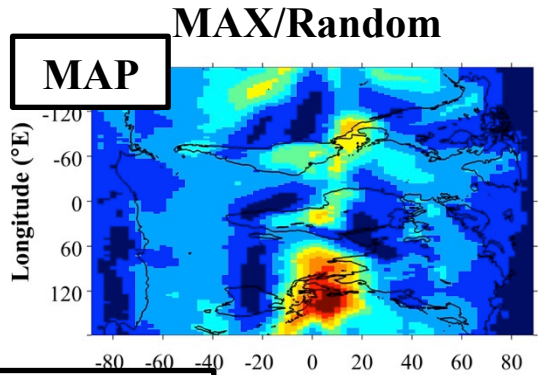
→ Using random not only increase the high-layered cloud frequency but also the high-level cloud frequency

# Changing the overlap assumption in COSP for the IPSL model

*Based on one-year AMIP simulation*

→ Larger positive bias in the convective areas

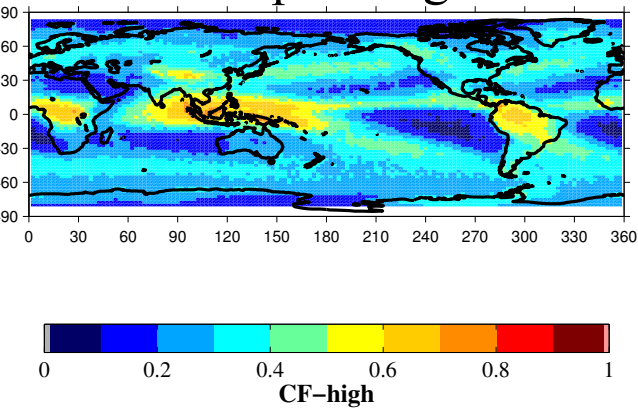
→ However, the biases are in better agreement



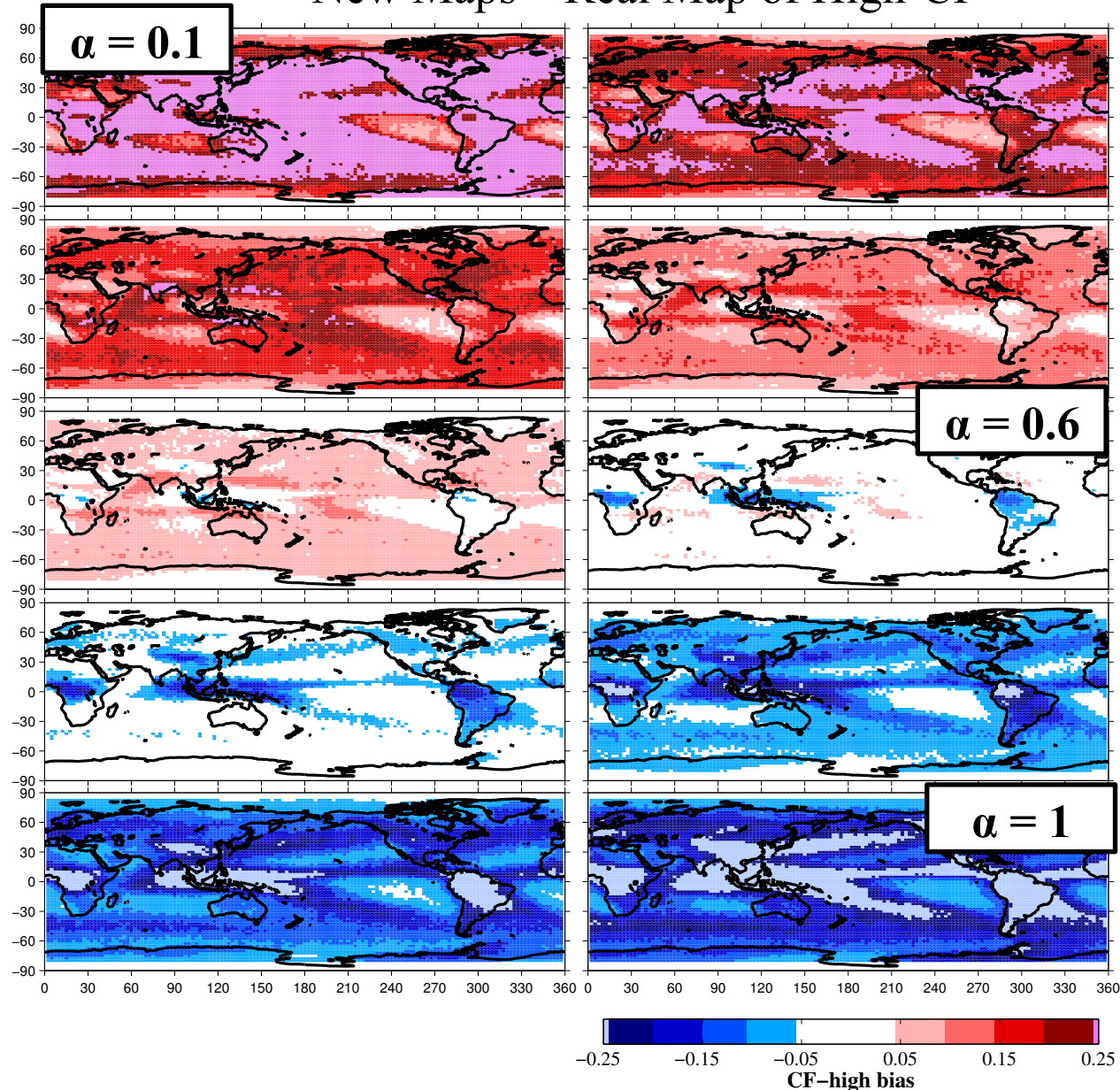
**Using CALIPSO-GOCCP To  
Guess A Better Overlap  
Assumption**

# Overlap assumption based on 3D Cloud Fraction

## Real Map of High-CF



## New Maps – Real Map of High-CF



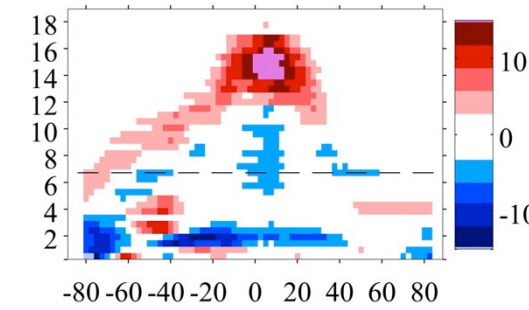
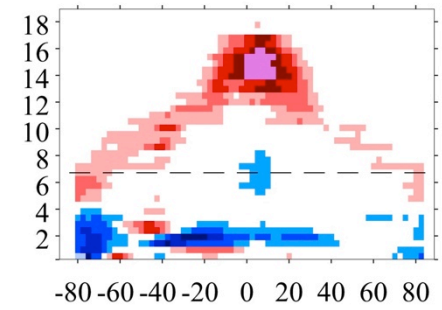
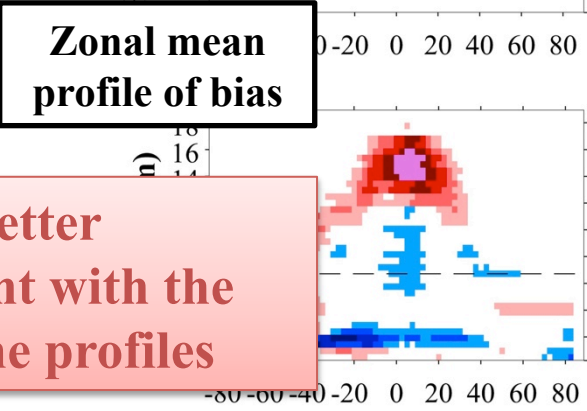
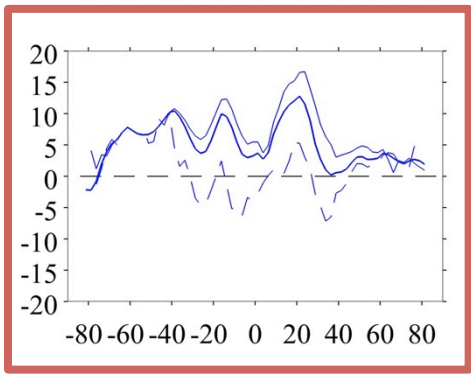
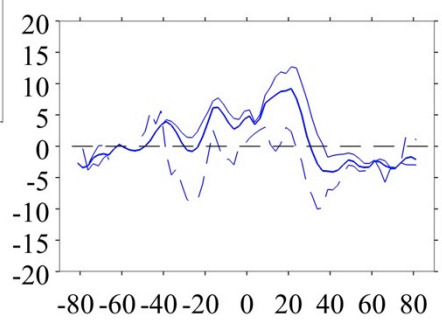
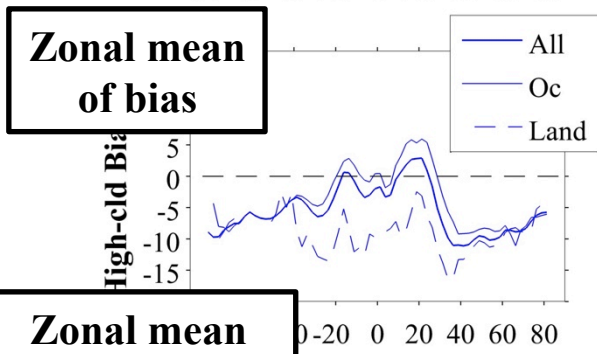
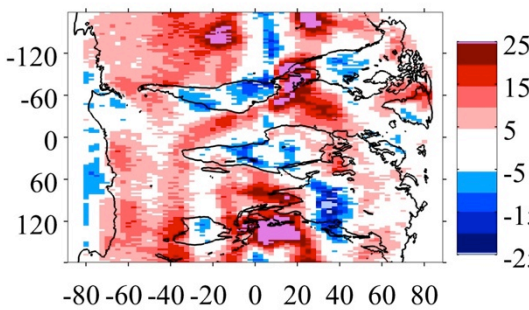
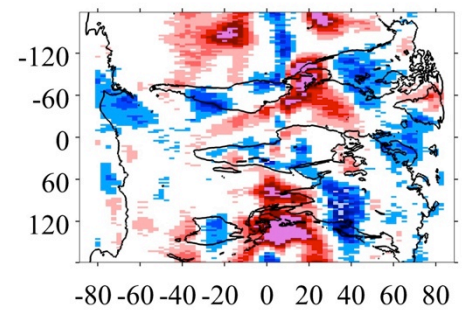
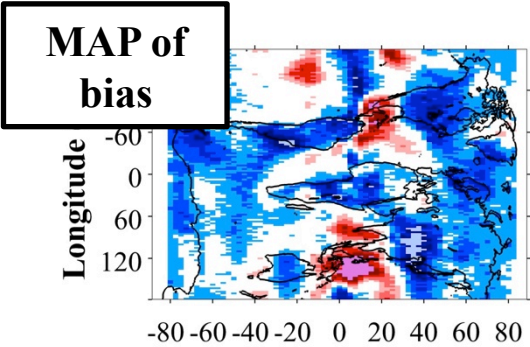
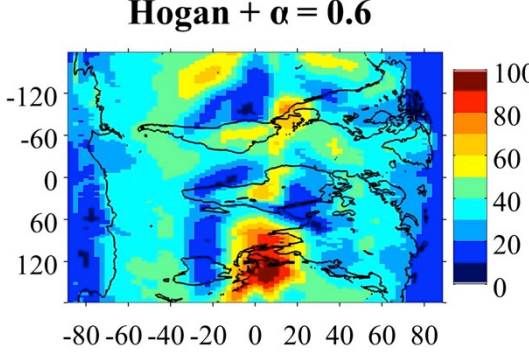
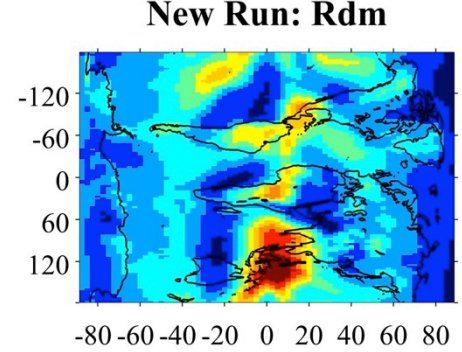
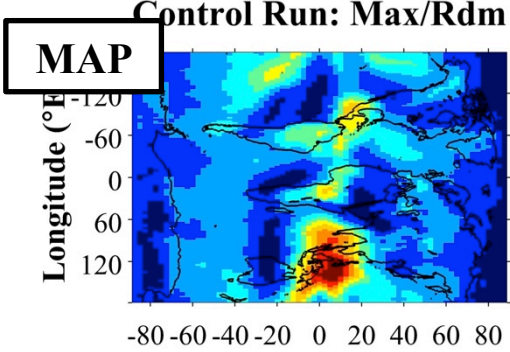
We computed High-layered cloud fraction maps using the overlap assumption of Hogan et al. (2000) on the daily 3D\_CloudFraction files for different values of  $\alpha$ :

$$CF = \alpha C_{max} + (1-\alpha)C_{rand}$$

→  $\alpha = 0.6$  is the best value to match the real map of High-CF

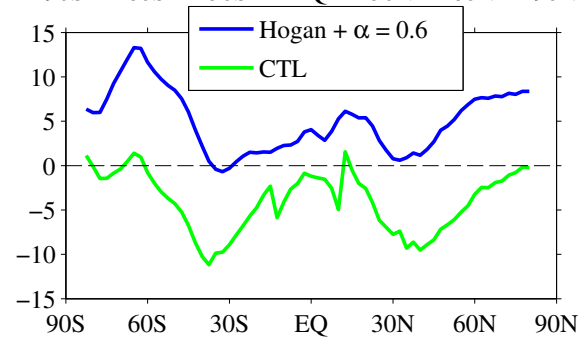
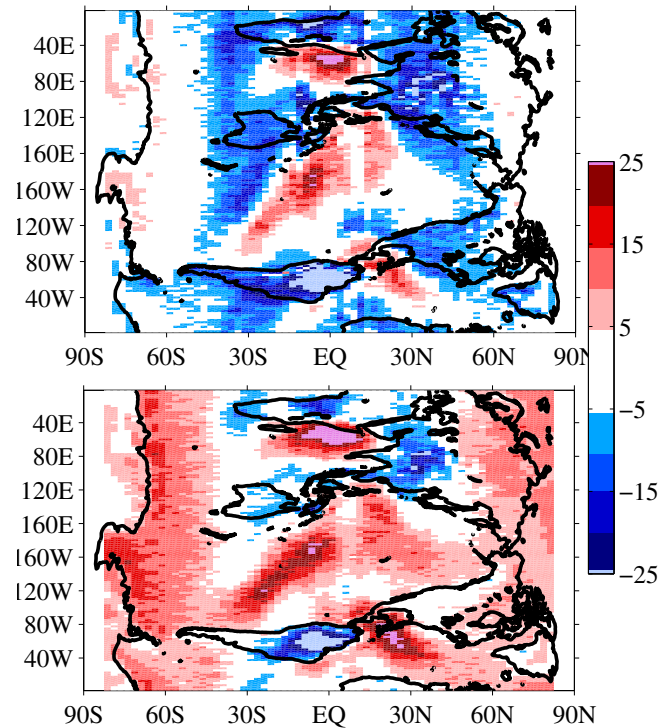
**Now Using This New Overlap  
Assumption In The Models**

# IPSL model

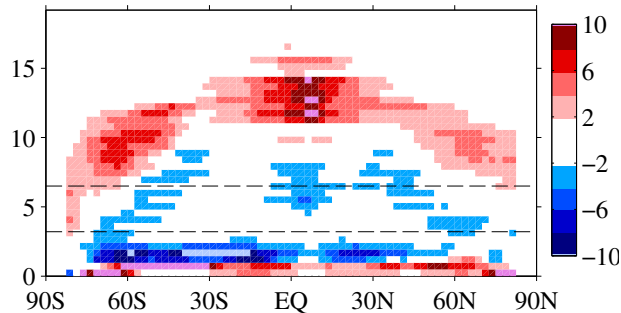


→ Bias in better agreement with the bias in the profiles

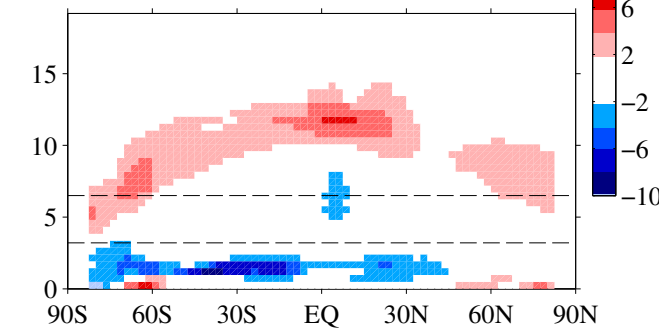
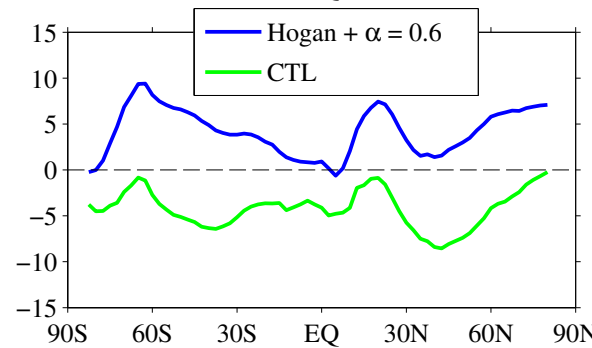
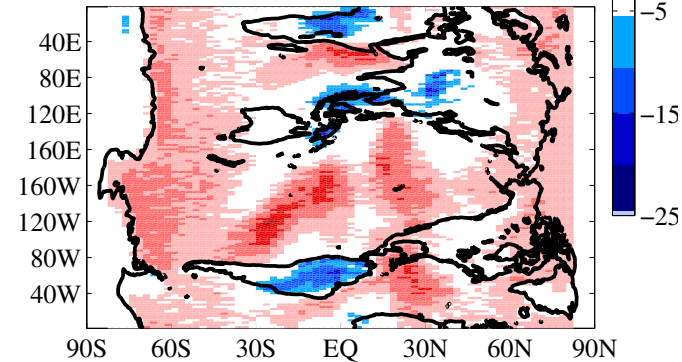
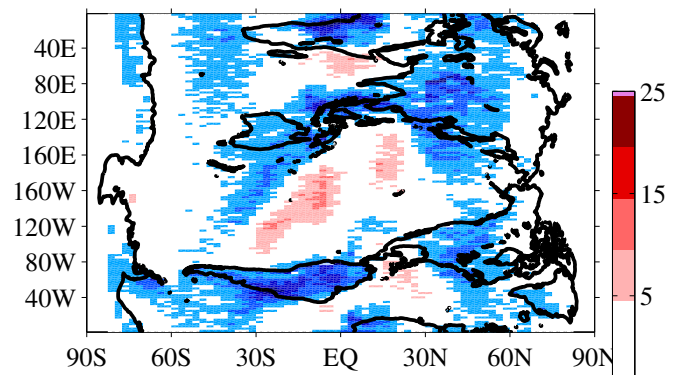
# CanAM4 model



→ Again, bias (blue line) in better agreement with the bias in the profiles

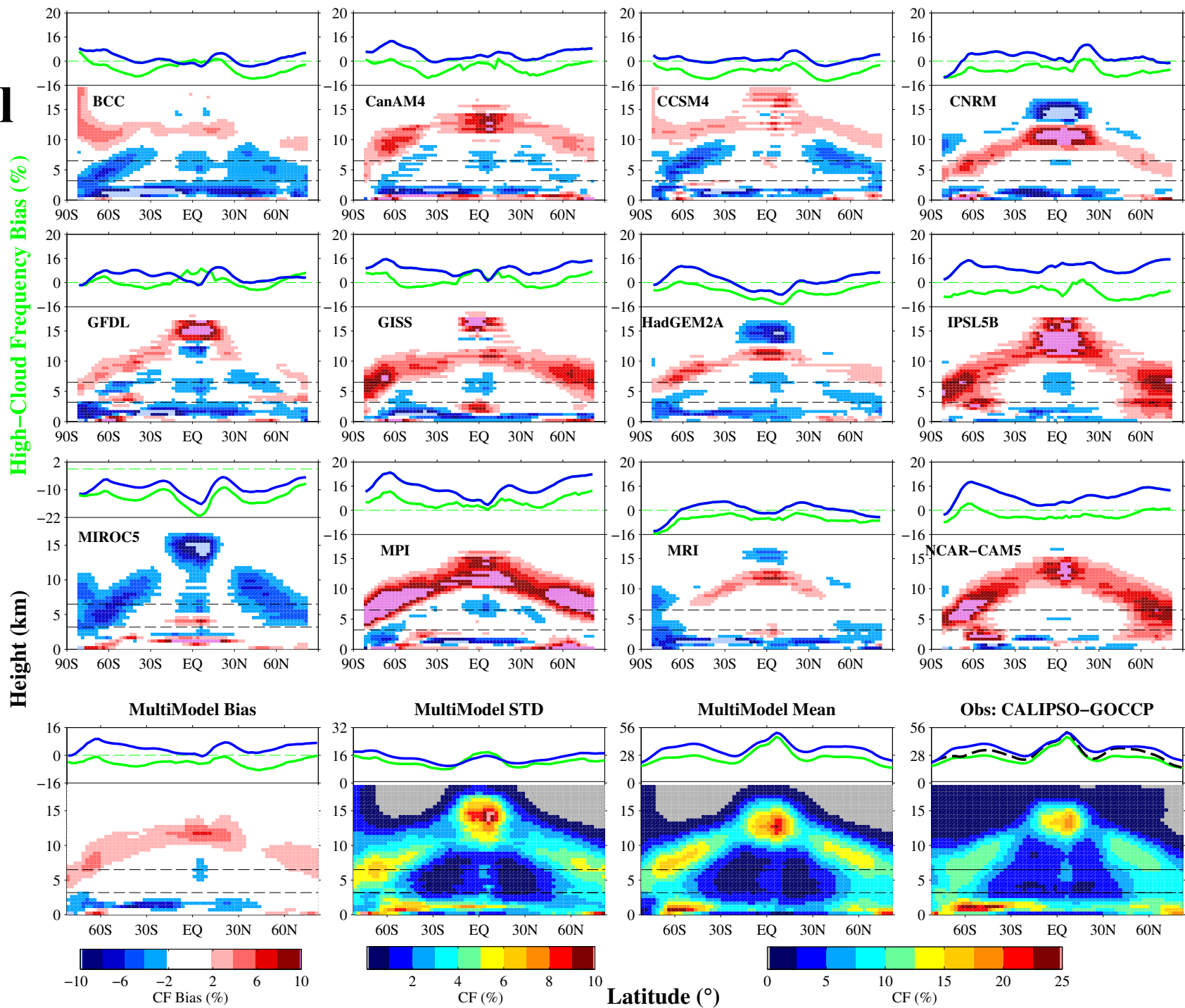


# Multi-model



→ Again, bias (blue line) in better agreement with the bias in the profiles

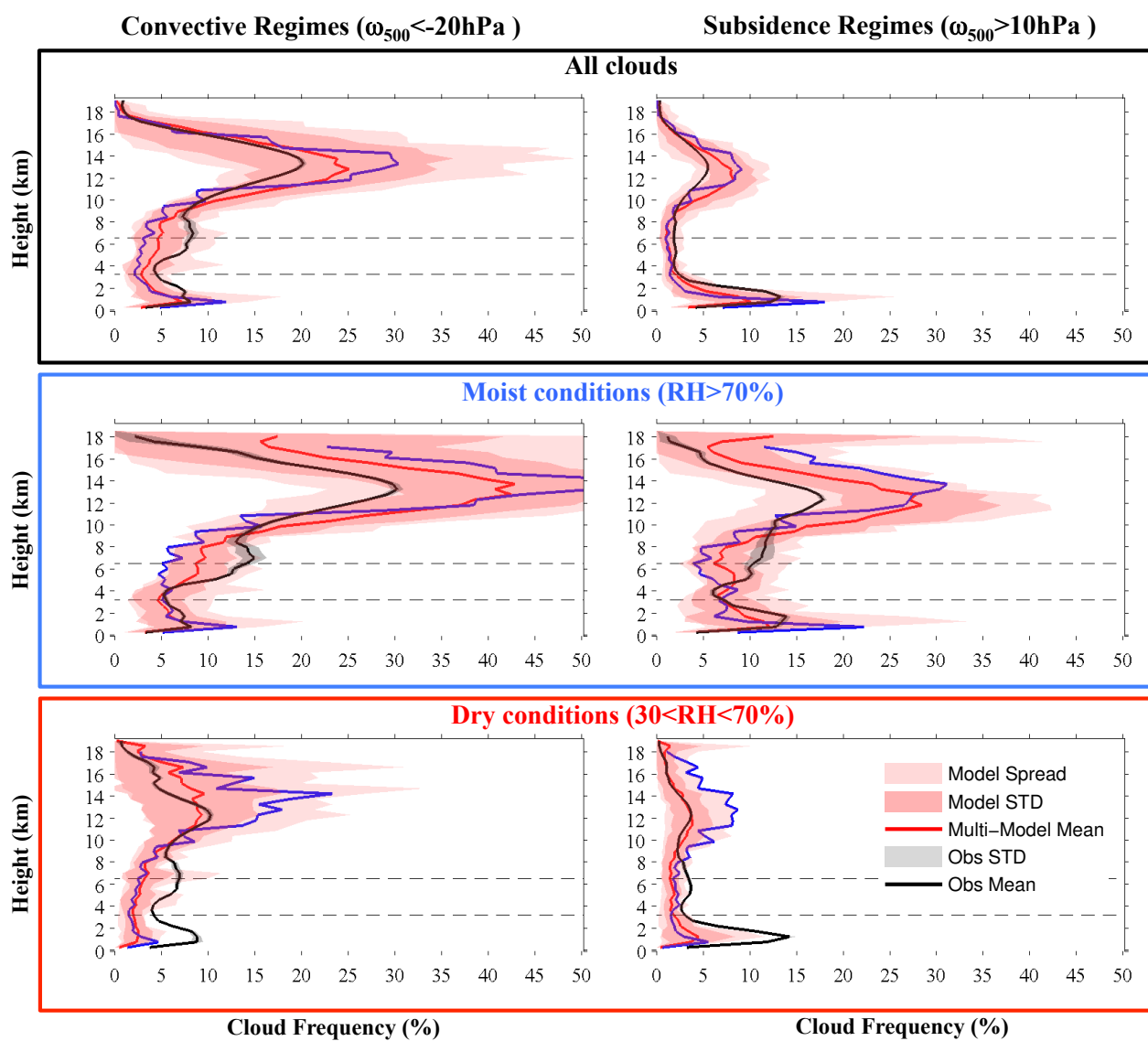
# Each Model



**Too few low-clouds in dry  
environments**

**&**

**Too many high-clouds in moist  
environments**



**Figure 3:** Annual mean of level-cloud frequency in the tropics ( $30^{\circ}\text{S}$  to  $30^{\circ}\text{N}$ ), simulated by the models for convective regimes ( $\omega_{500} < -20\text{hPa}$ ; left column) and subsidence regimes ( $\omega_{500} > 10\text{hPa}$ ; right column) for all clouds (first row), low RH clouds (second row) and high RH (third row). The red and black lines represent the multi-model and the observations (CALIPSO-GOCCP and ERAi for  $\omega_{500}$  and RH) means, respectively. The pink, light pink and grey shadings represent the models' STD, models' spread and the observations' STD (over nine years). This figure was plotted using one year of simulation (see text S2 for more information about the method).