Improved diagnostics for high cloud assessment in the LMDZ climate model

Marine Bonazzola, Sofia Protopapadaki, Claudia Stubenrauch
LMD, Paris

Introduction: High clouds cover about 30% of the globe and have important effects on climate. Hence they should be properly represented in general circulation models.

In the LMDZ AGCM some parameters controlling high cloudiness (e.g. precipitation efficiency in the upper troposphere, ice crystals speed sedimentation) are not fully constrained by the radiative budget.

Our aim: Better constrain high cloud parameters in the LMDZ AGCM by considering the life cycle of simulated high clouds, its dependency on parameters, and by comparing this life style to AIRS and IASI satellite observations.

Method for comparing model and satellite data:

- AIRS has a 13.5x13.5 km horizontal resolution and observes at 1:30AM and 1:30PM local time (IASI: at 9:30AM and 9:30PM LT). Detects only the highest cloud if its optical depth is greater than 0.05.

- LMDZ outputs are available every 3 hrs, cloud cover is given on each of the 79 vertical levels. Horizontal resolution: 2.5 deg x 1.25 deg.

Cloud properties retrieved from AIRS and IASI (*Stubenrauch et al. 1999):* LMD_CIRS (Cloud Retrieval from IR Sounders)
cld cover, Pcld, Tcld, cld emiss, IWP etc.

A model to satellite approach *(Hendricks et al, 2010)*

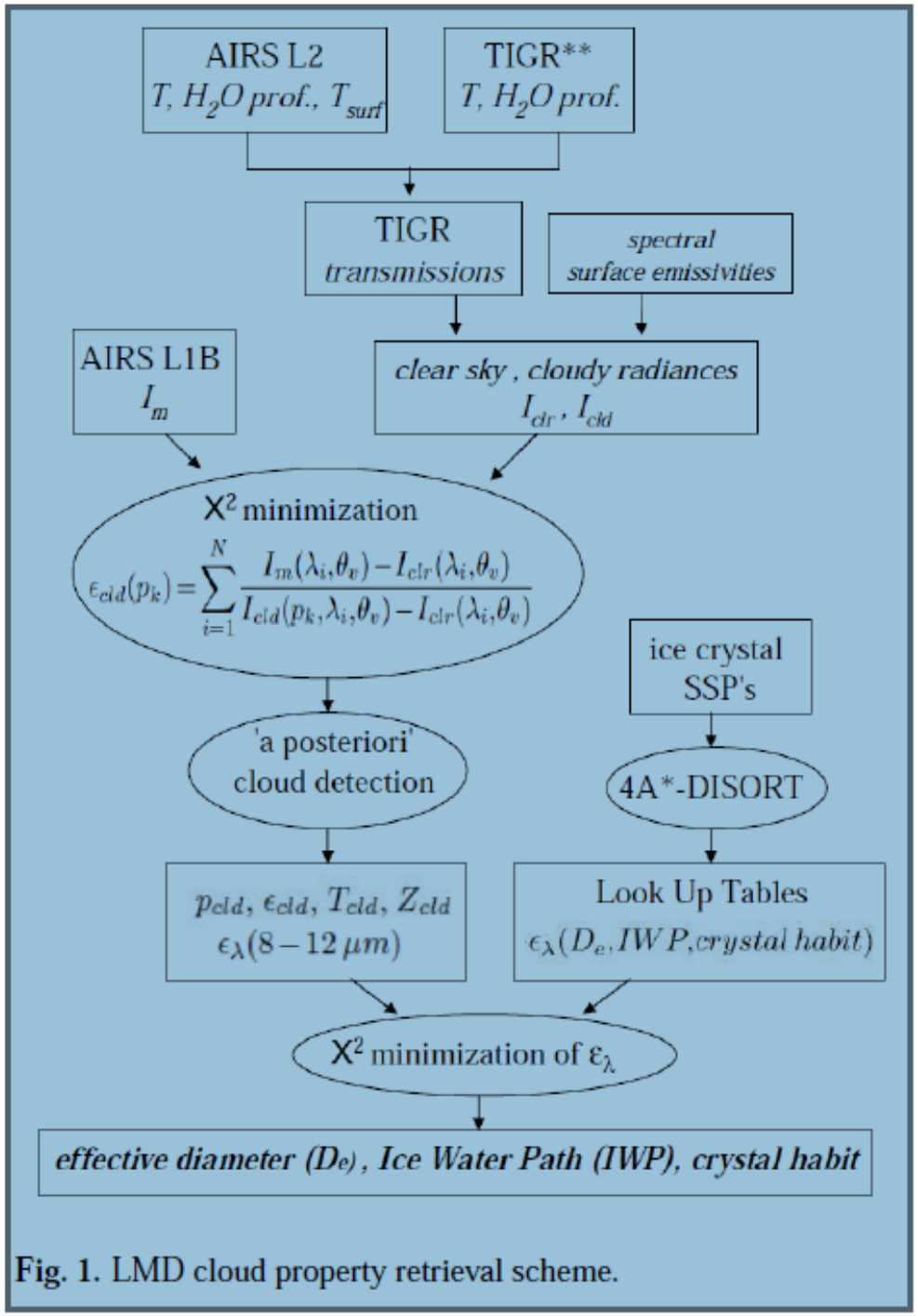

Fig. 1. LMD cloud property retrieval scheme.

Cloud properties retrieval developed at LMD.
LMD_CIRS (Cloud Retrieval from IR Sounders)
(Stubenrauch et al. 1999)

- Uses 8 AIRS radiances between 11 and 13 microns.
Detects the presence of a cloud, determines Pcld, Tcld, Zcld, Ecld.

-Methodology of crystal habit retrieval based on the difference between spectral emissivities between 8 and 12 microns.

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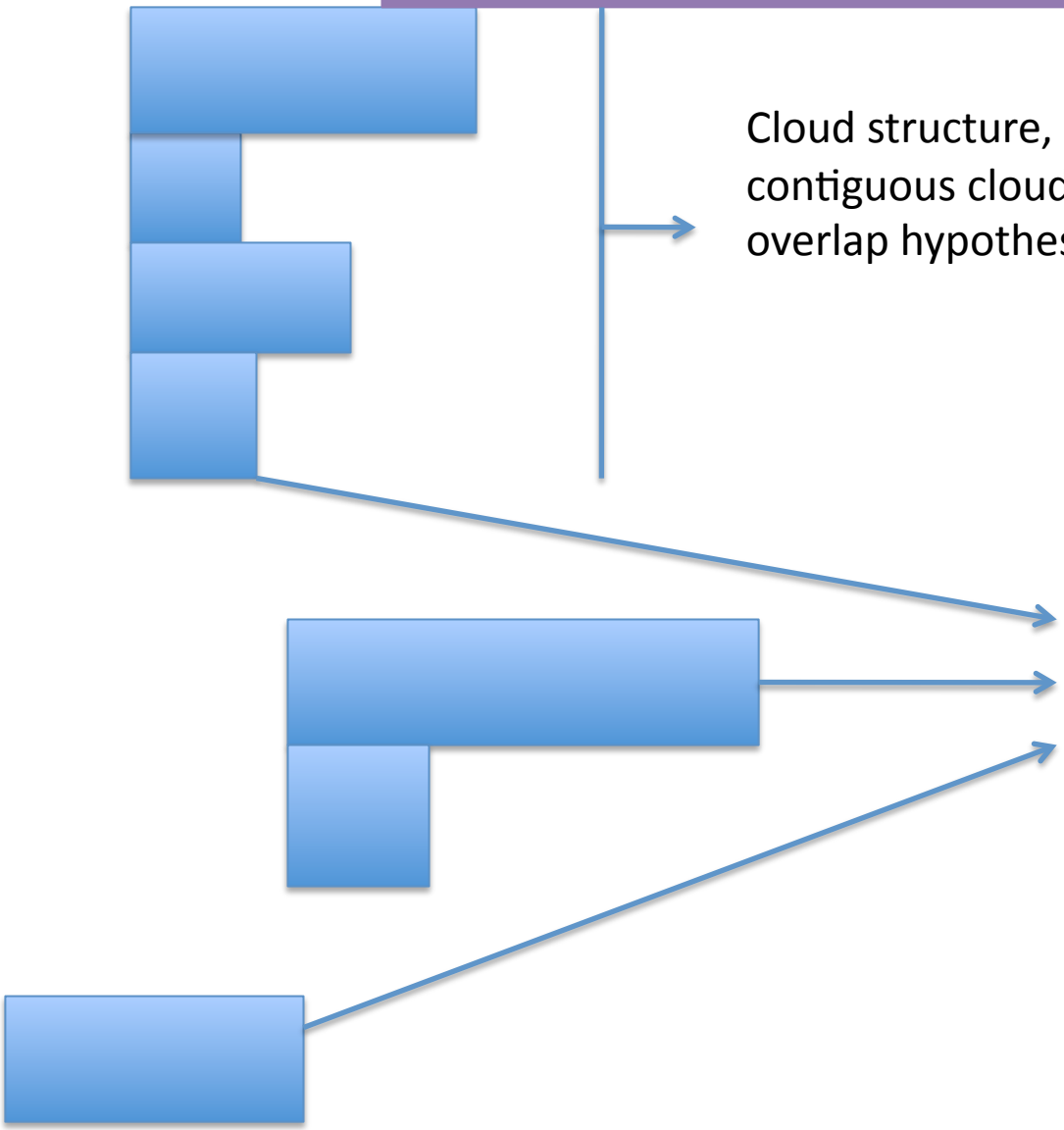
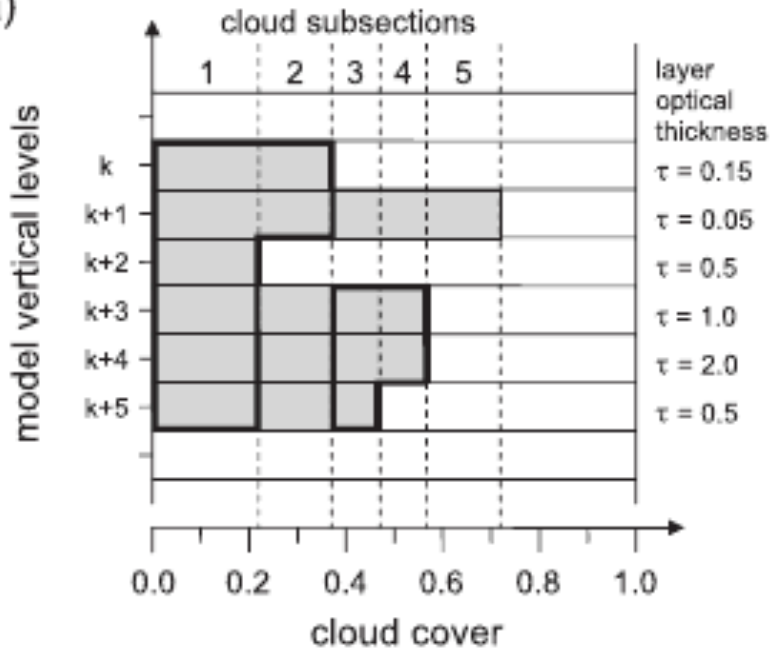
Model to satellite approach *(Hendricks et al. 2010)*: Hypotheses on cloud vertical structure in LMDZ



Cloud structure, with vertically contiguous cloud layers: Maximum overlap hypothesis

Random overlap hypothesis for distinct cloud structures

a)



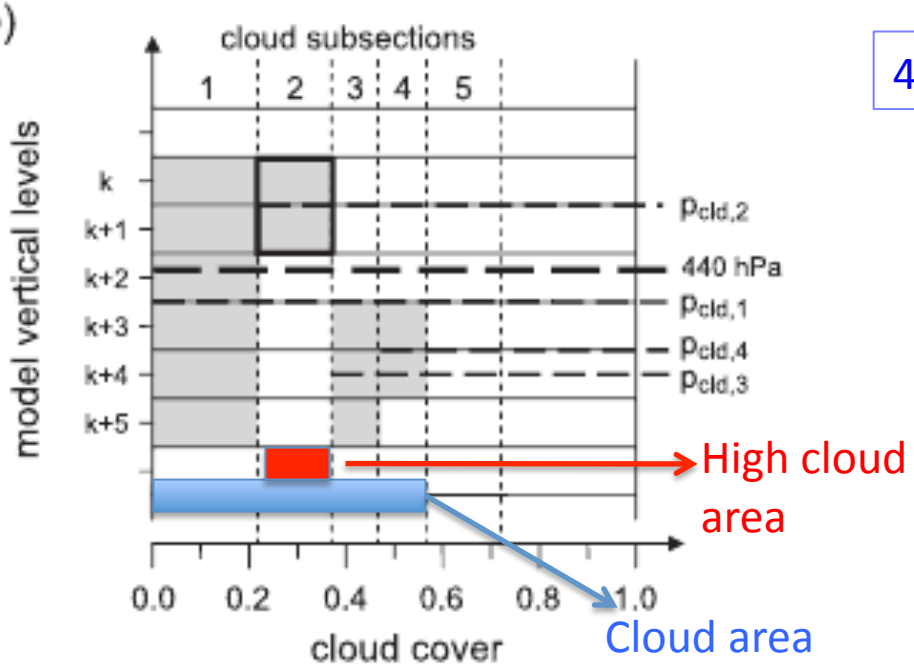
Each cloud structure is divided in sub-sections. In each sub-section optical depths are summed up.

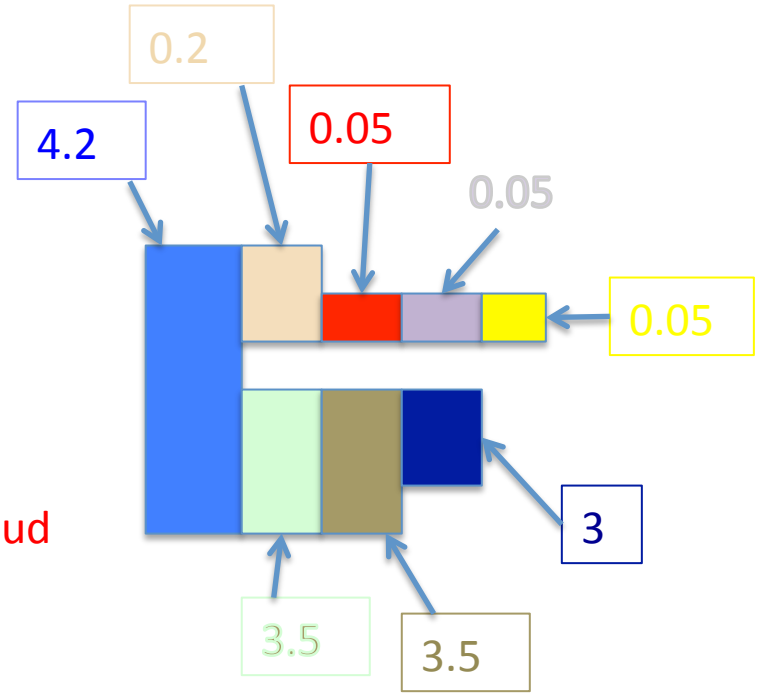
Cloud is detected if $\sum_i \tau_i > 0.05$

Clouds located below detected clouds are not detected.

The cloud is "high" if $p_{cld} - p_{tropo} < 250Pa.$

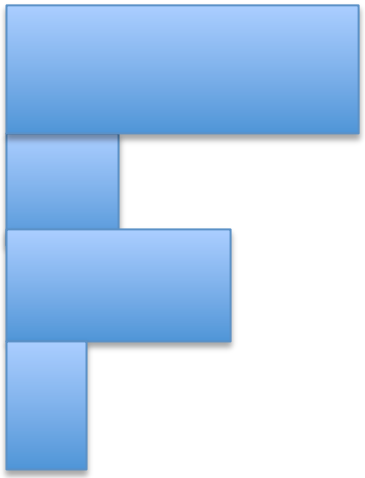
b)





Average on the LMDZ mesh of cloud structure quantities:

Cloud structure, with vertically contiguous cloud layers: Maximum overlap hypothesis



- Total area
- High cloud area
- Cb area (with cld emiss>0.85)
- Anvil area (with 0.25 < cld emiss< 0.85)
- Thin Cirrus area (with emiss< 0.25)

For each type of clouds:

- Cloud pressure
- Cloud temperature
- Emissivity
- Ice water path
- Geometrical depth *etc.*

Random overlap hypothesis for distinct cloud structures

$$\overline{A} = 1 - \prod_{j} (1 - A_j)$$

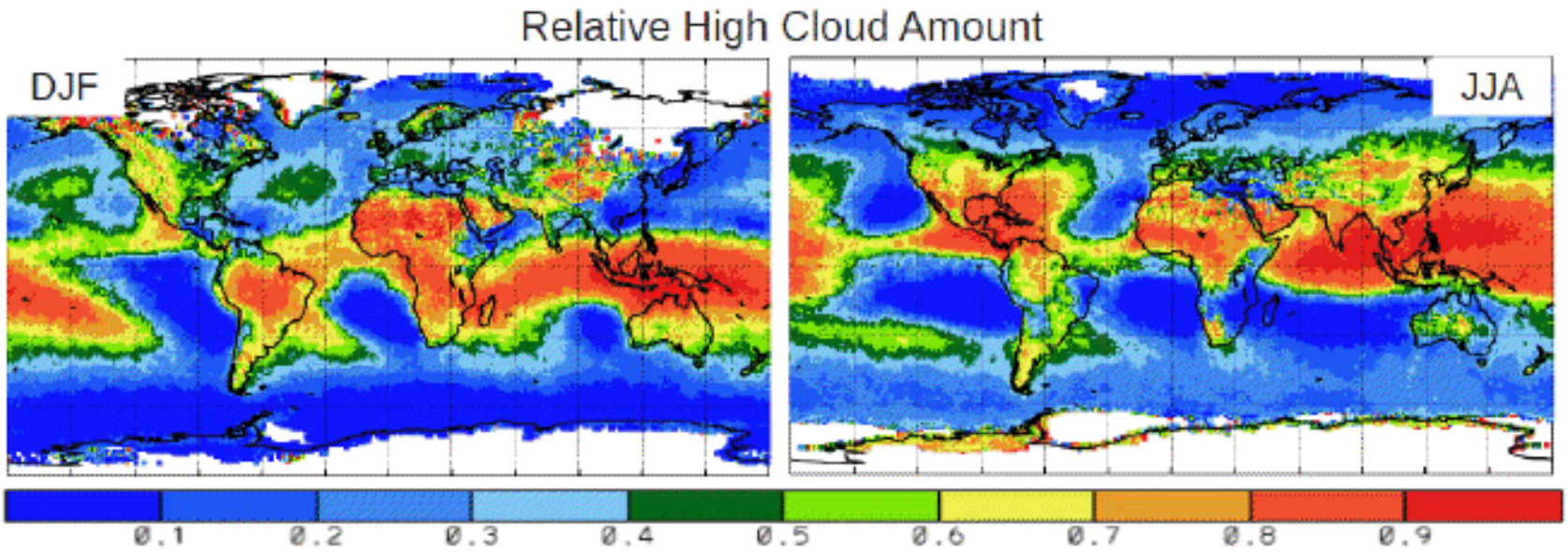
$$\overline{A_{hc}} = A_{hc1} + \sum_{j=2}^{N} \left[A_{hcj} \times \prod_{i=1}^{j-1} (1 - A_i) \right]$$

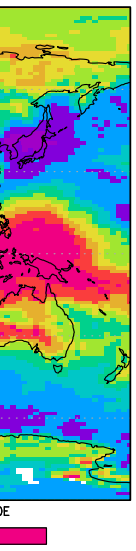
$$\overline{X_{hc}} = \frac{1}{\overline{A_{hc}}} \left[A_{hc1} X_1 + \sum_{j=2}^{N} (A_{hcj} X_j \times \prod_{i=1}^{j-1} (1 - A_i) \right]$$

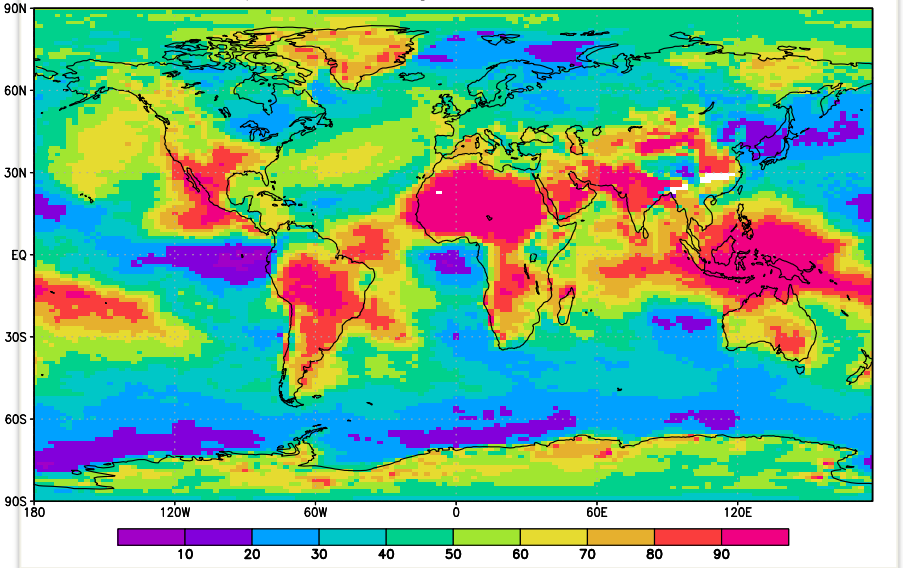
Percentage of high clouds over total cloudiness

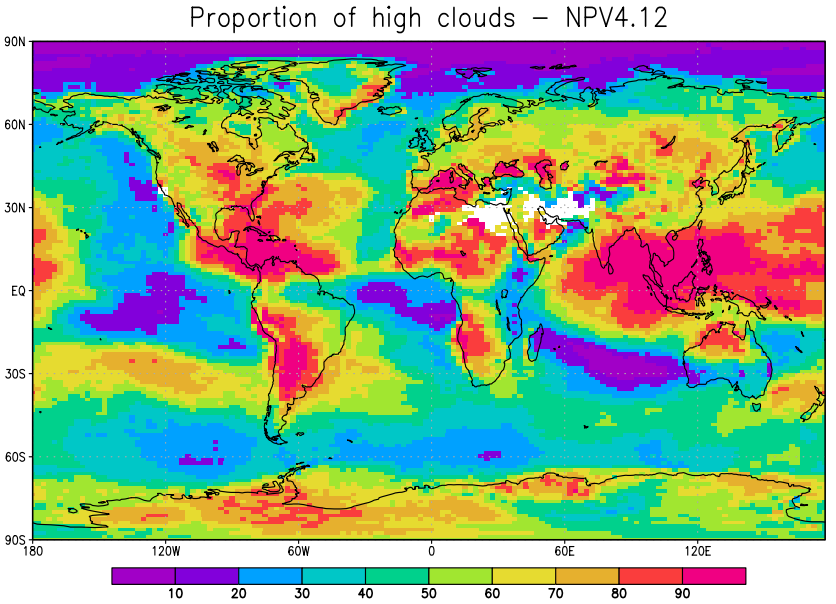
Winter	Tropics	NH midlat	SH midlat
NPV4_12	63%	43%	31%
Guignard et al.	62%	31%	14%

Summer	Tropics	NH midlat	SH midlat
NPV4_12	59%	55%	36%
Guignard et al.	58%	32%	28%


Relative High Cloud Amount
DJF
JJA
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9




Proportion of high clouds – NPV4.12
90N
60N
30N
EQ
30S
60S
90S
180
120W
60W
0
60E
120E
10
20
30
40
50
60
70
80
90


Proportion of high clouds – NPV4.12
90N
60N
30N
EQ
30S
60S
90S
180
120W
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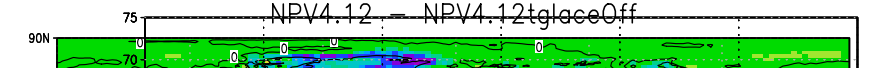
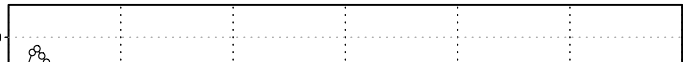
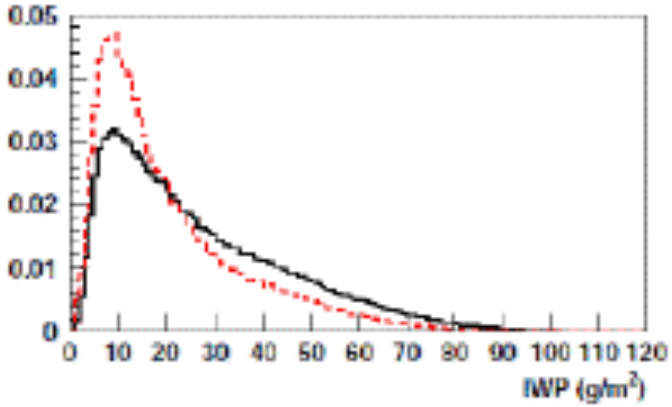
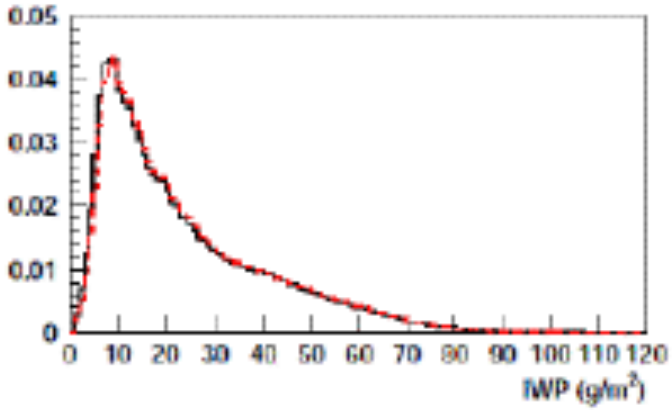
0
60E
120E
10
20
30
40
50
60
70
80
90

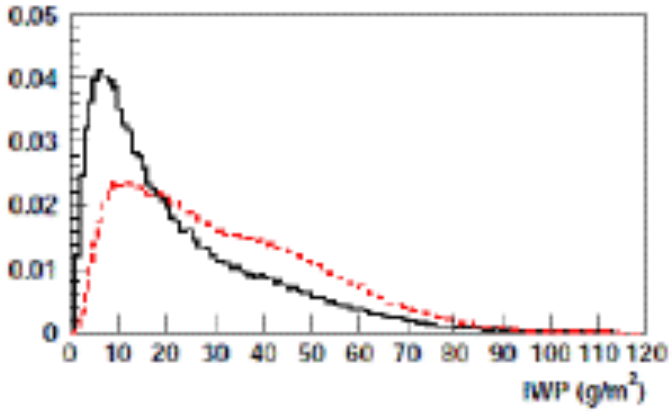

NPV4.12 – NPV4.12tglaceOff
75
90N
70


80

IWP median values for high “anvil” clouds



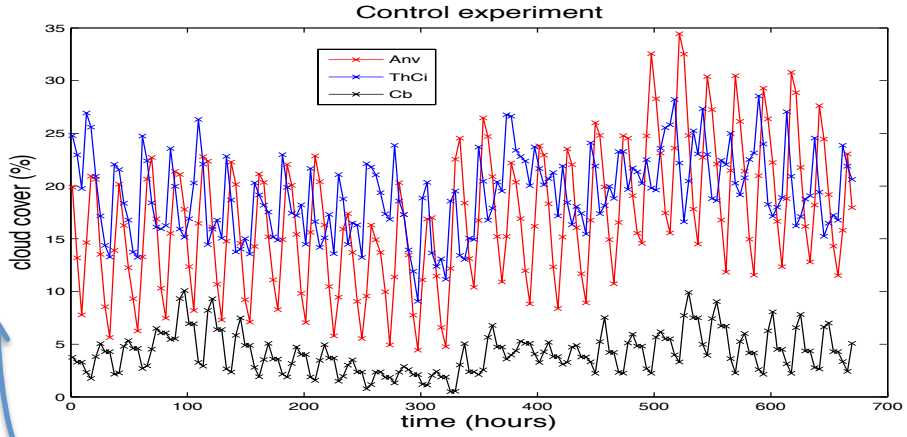


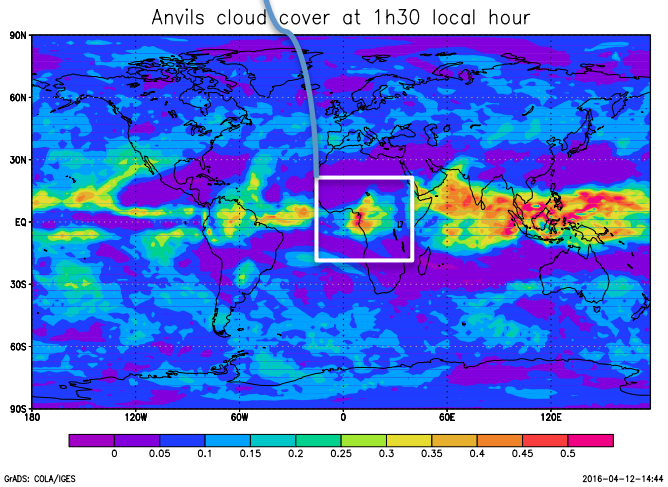


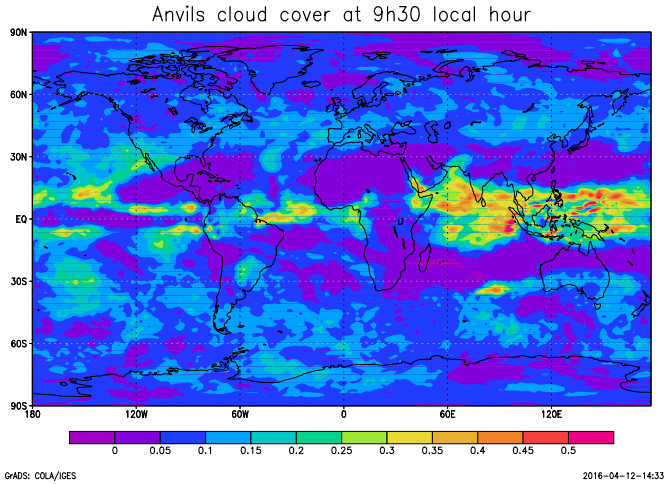
Winter	Tropics	NH	SH
NPV4_12	19	24	27
Guignard et al.	19	25	18

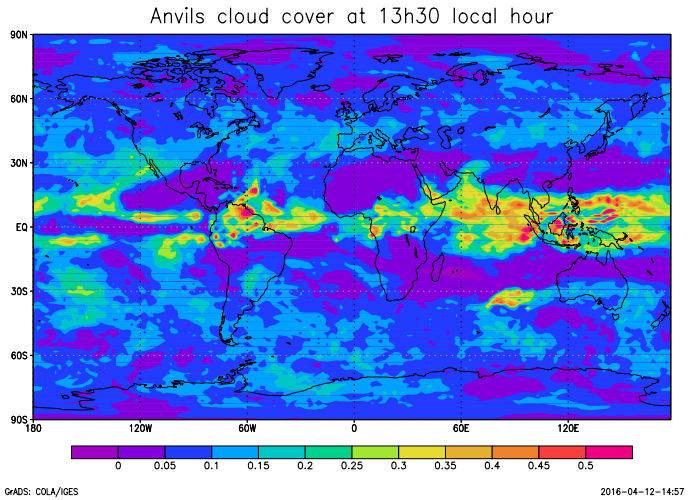
Summer	Tropics	NH	SH
NPV4_12	18	23	24
Guignard et al.	20	17	30

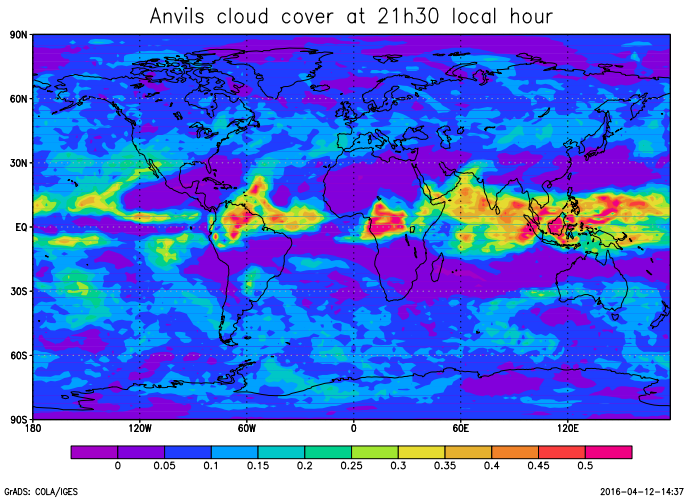
The diurnal cycle of high clouds in LMDZ

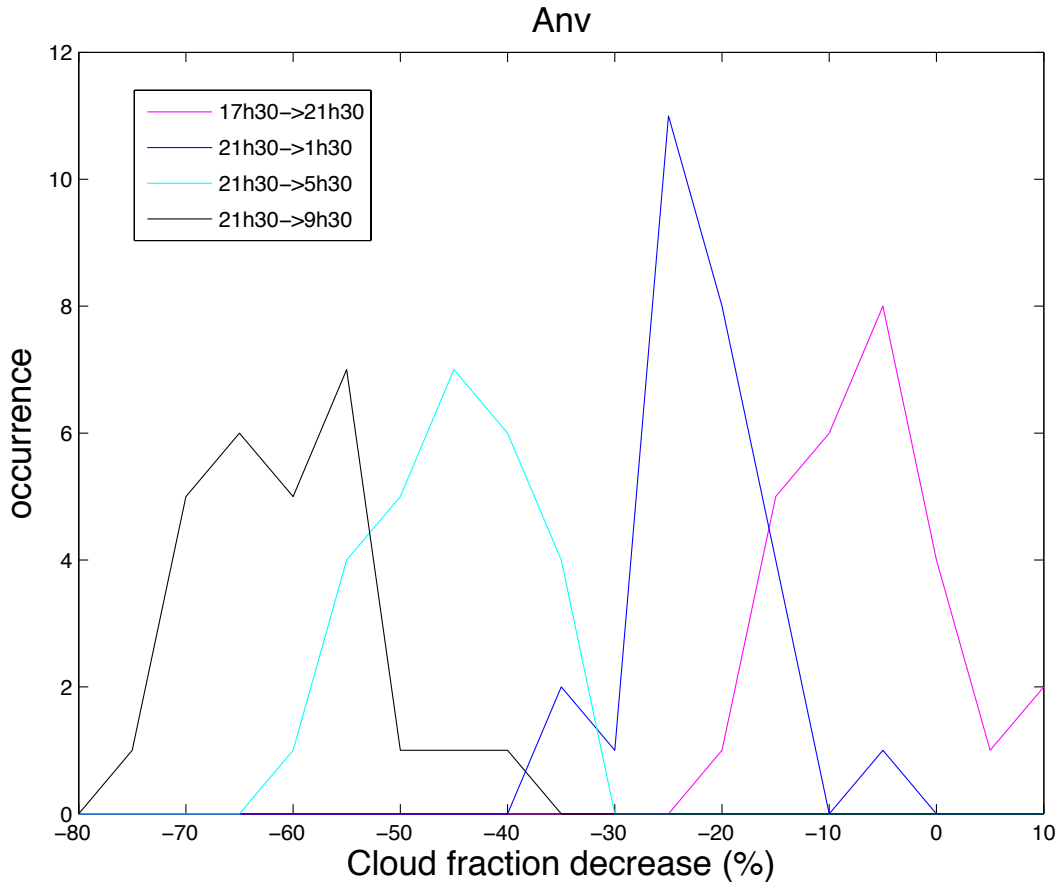












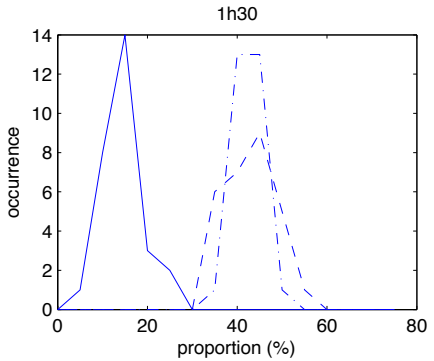
Relative decrease of anvil cover from 21h30:

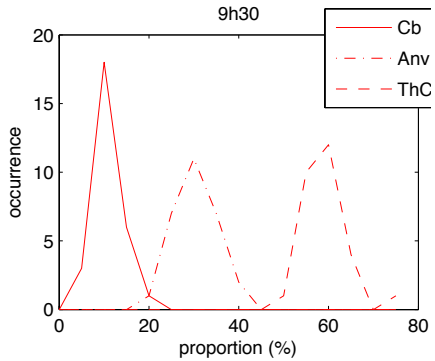
25% from 21h30 to 1h30

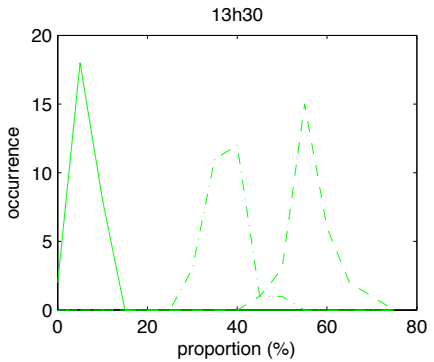
60% from 21h30 to 9h30.

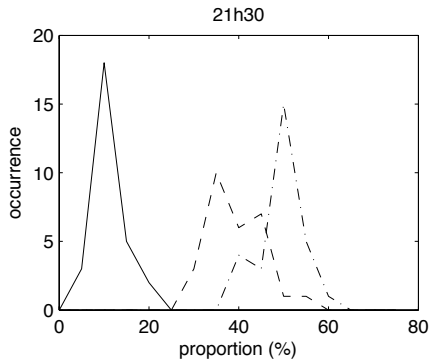
Percentage of Cb, anvils and Thin Cirrus over high clouds in AIRS, IASI and LMDZ (African box)

LMDZ control experiment

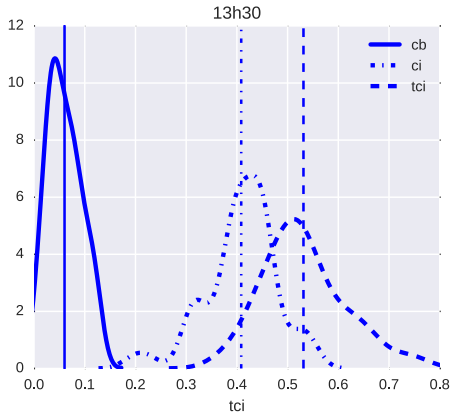


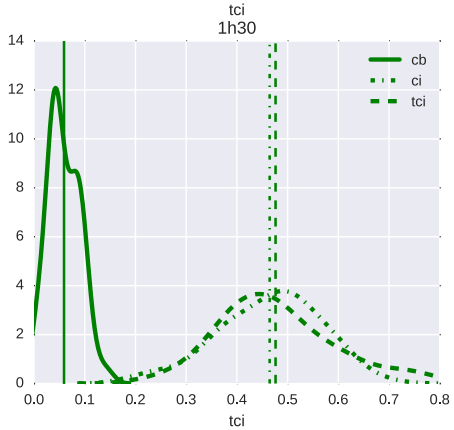




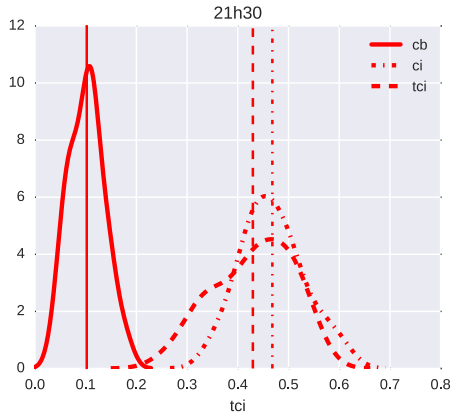


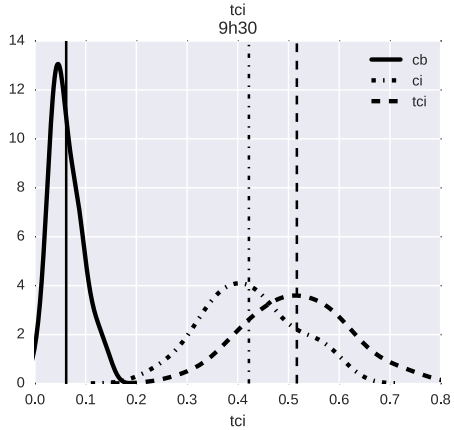
AIRS





IASI



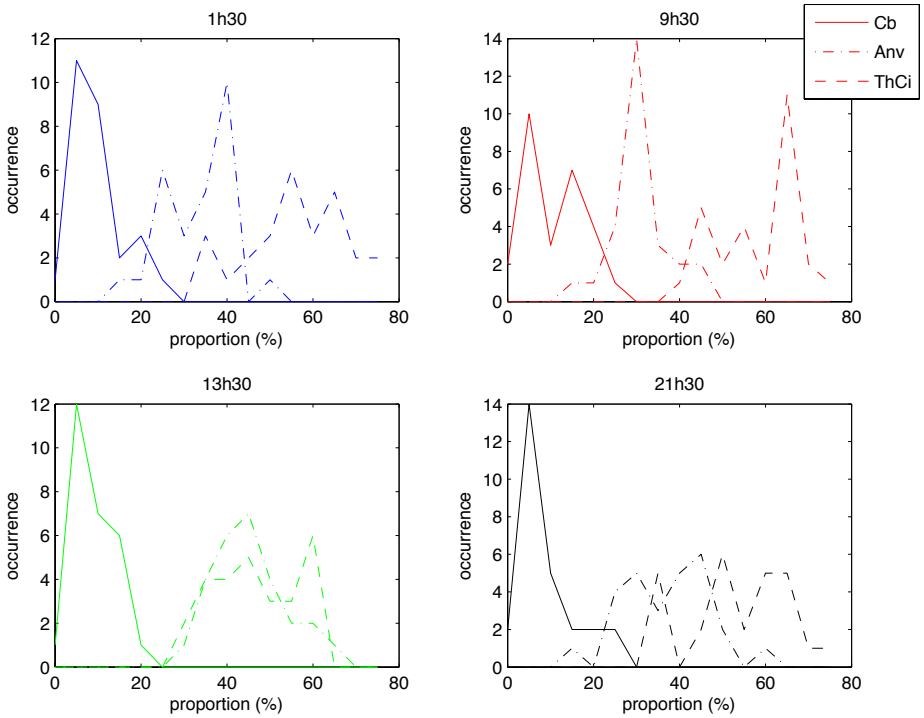


ThCi have the highest cover at 9h30 LT and 13h30.

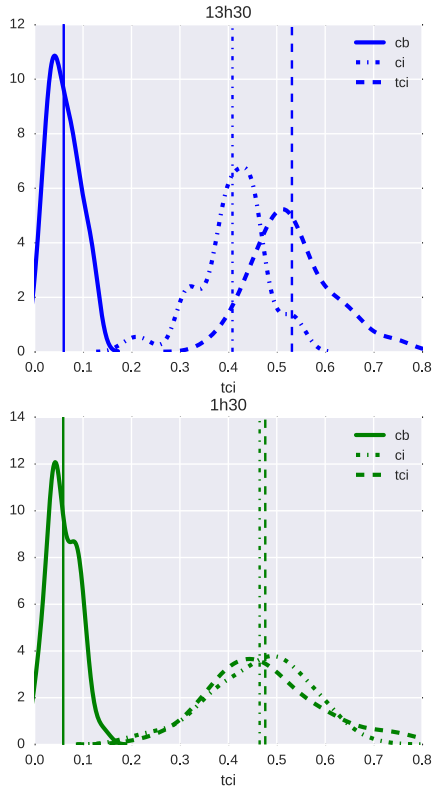
Anvils have the highest cover at 21h30 LT.

ThCi and anvils cover are equivalent at 1h30.

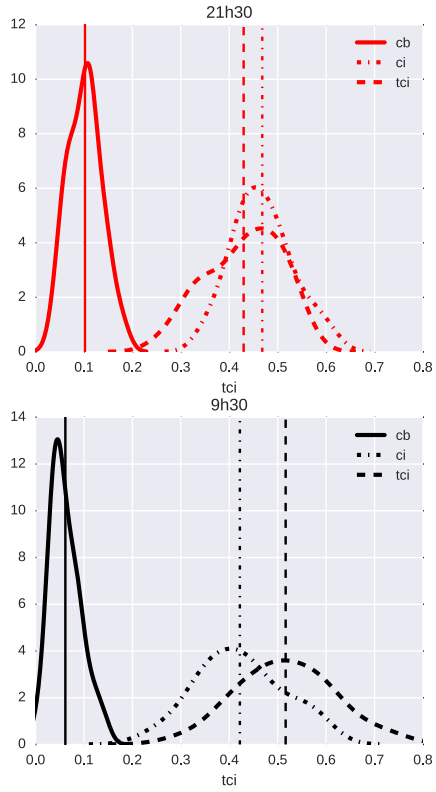
Increasing precipitation efficiency in the upper troposphere in LMDZ



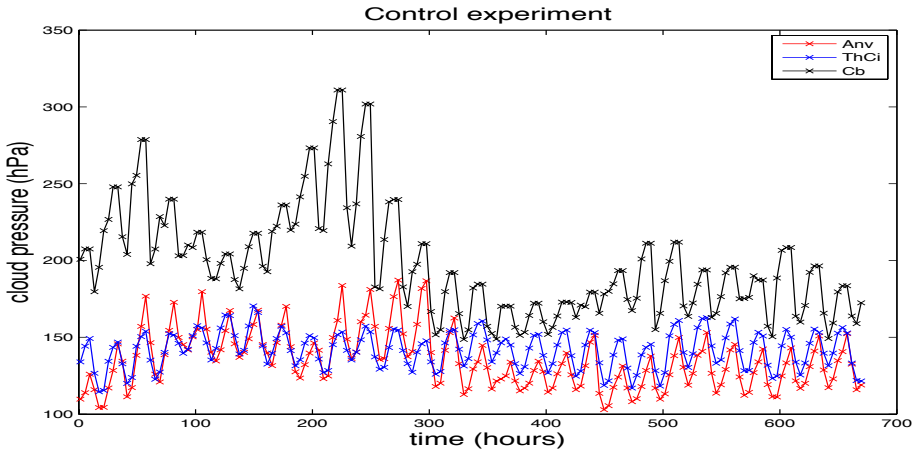
AIRS

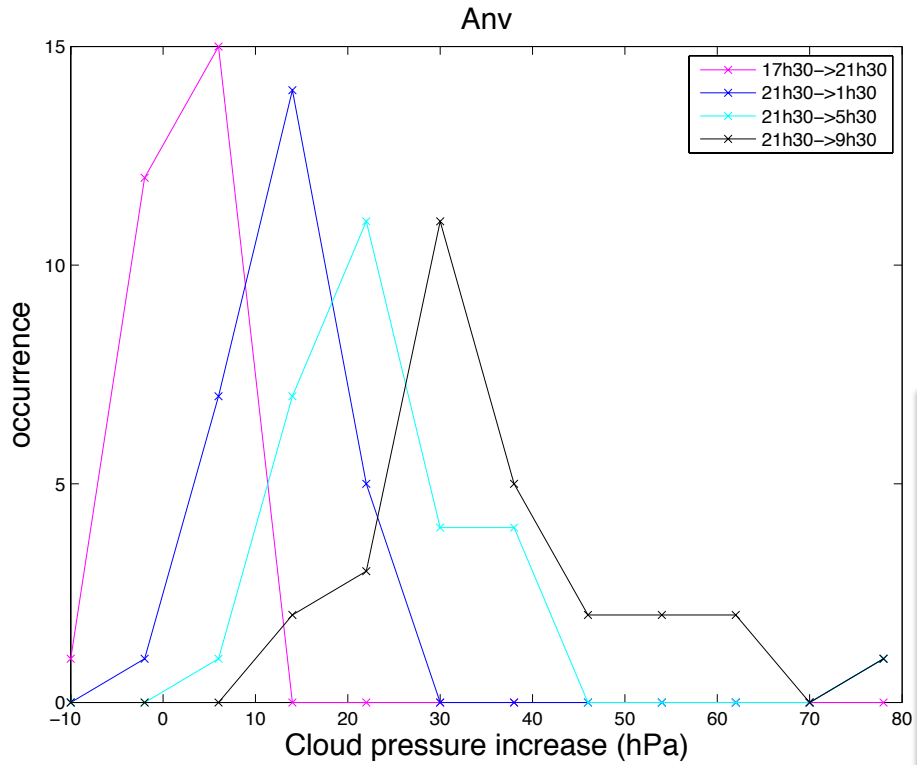


IASI



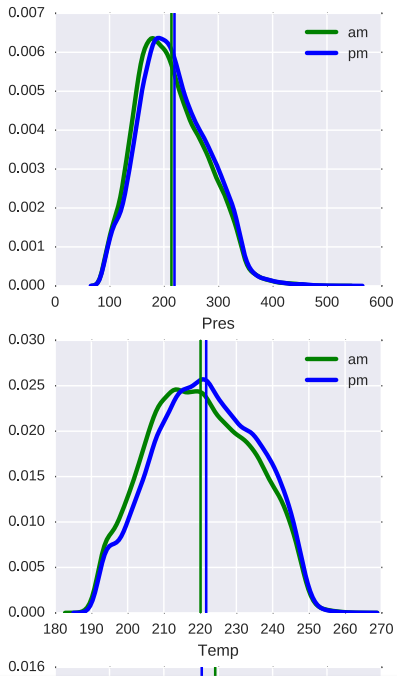
The distributions are sensitive to the epmax parameter.



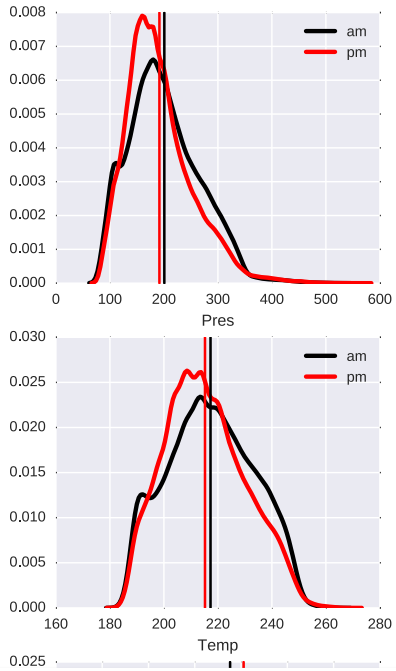


Diurnal cycle of Anvils top pressures

AIRS



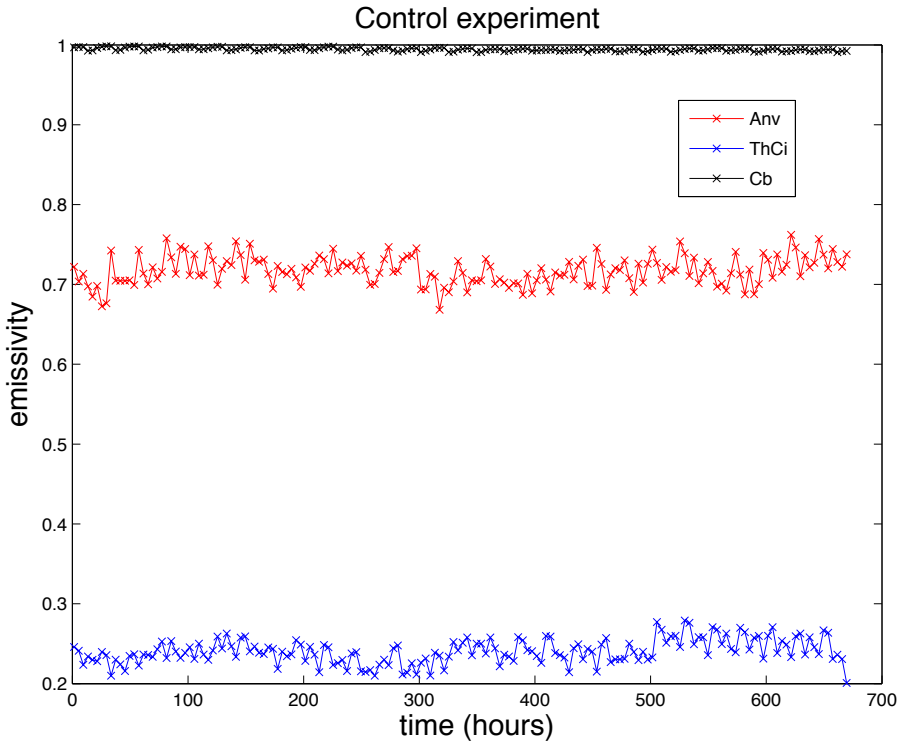
IASI

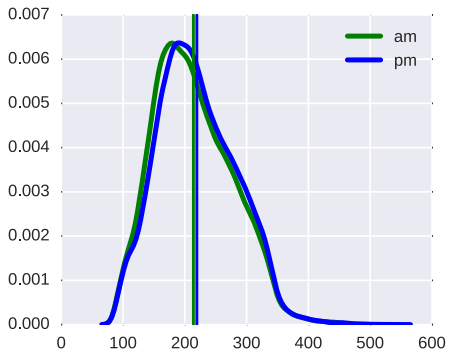


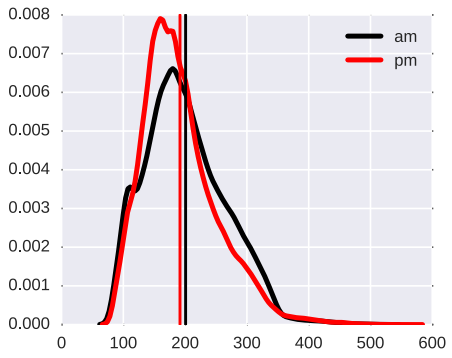
Cloud top pressure is lower in late afternoon, higher in the morning

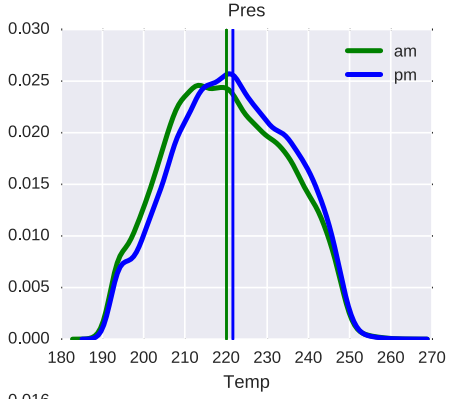
Sensitive to fallv parameter?

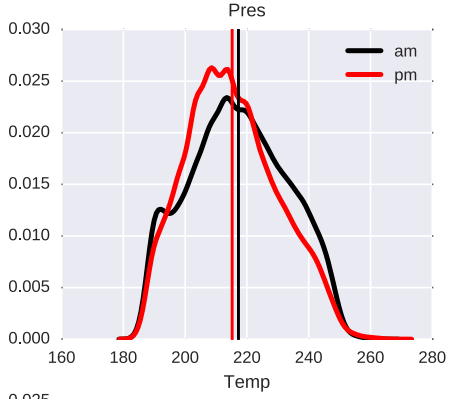
Diurnal cycle of Anvils emissivities

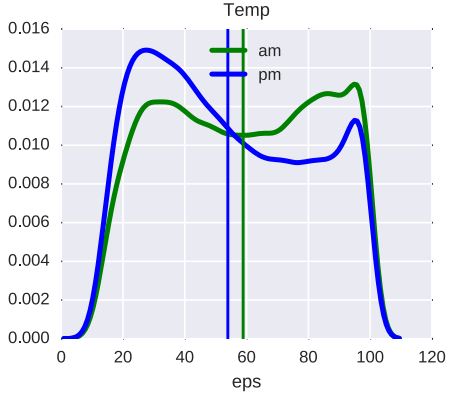


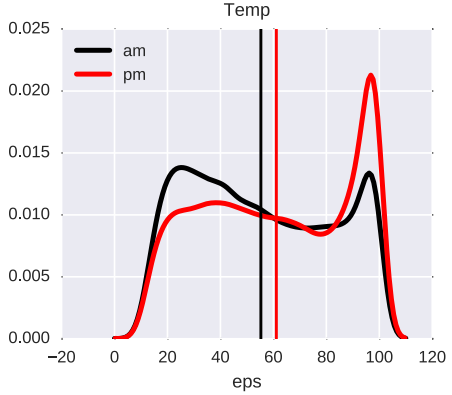






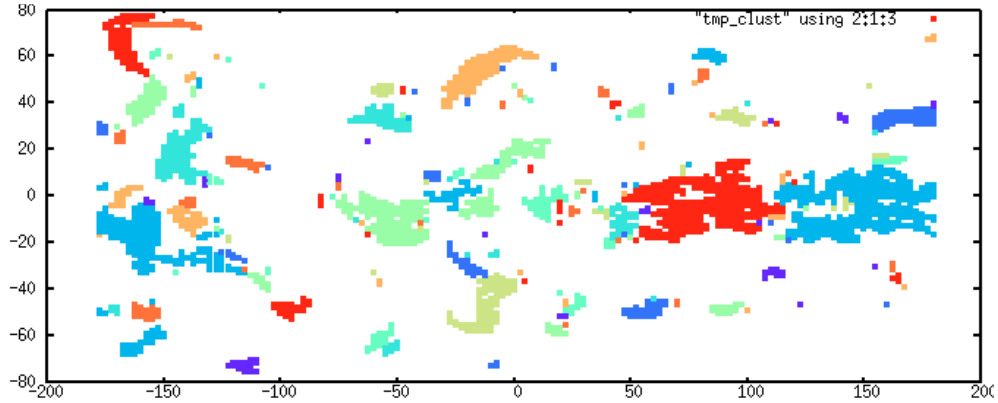




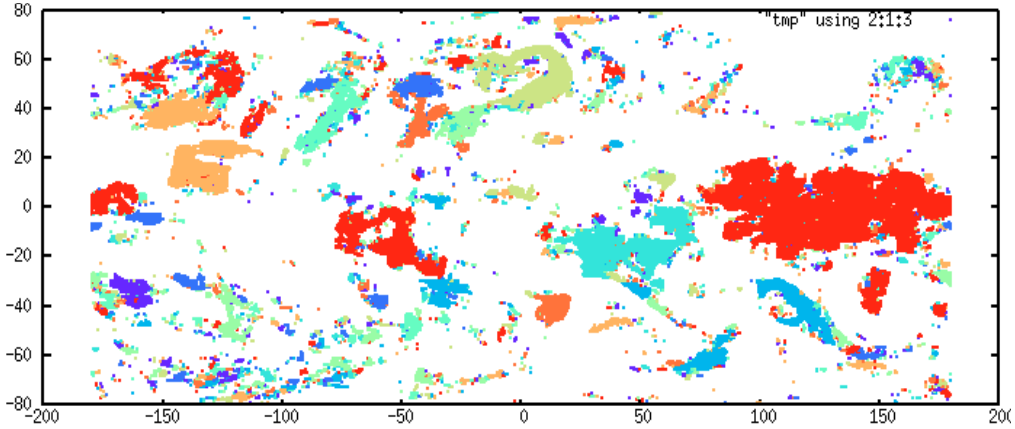


Cloud clusters

Model : grids of 2.5 x 1.26 degrees



Data : grids of 0.5 x 0.5 degrees



* Compute cloud clusters at the LMDZ horizontal resolution with new thesholds?
* Perform simulations at higher resolution?

Conclusions: Comparing the diurnal cycle and the life time of anvils in GCM ouputs with AIRS and IASI data can constrain upper tropospheric GCM parameters.

-The proportion of Anvils vs Thin cirrus is sensitive to the precipitation efficiency in LMDZ .

- We expect the Pcld diurnal cycle to be sensitive to the sedimentation speed of ice crystals.

- Cloud clusters statistics might also be sensitive to the GCM parameters.