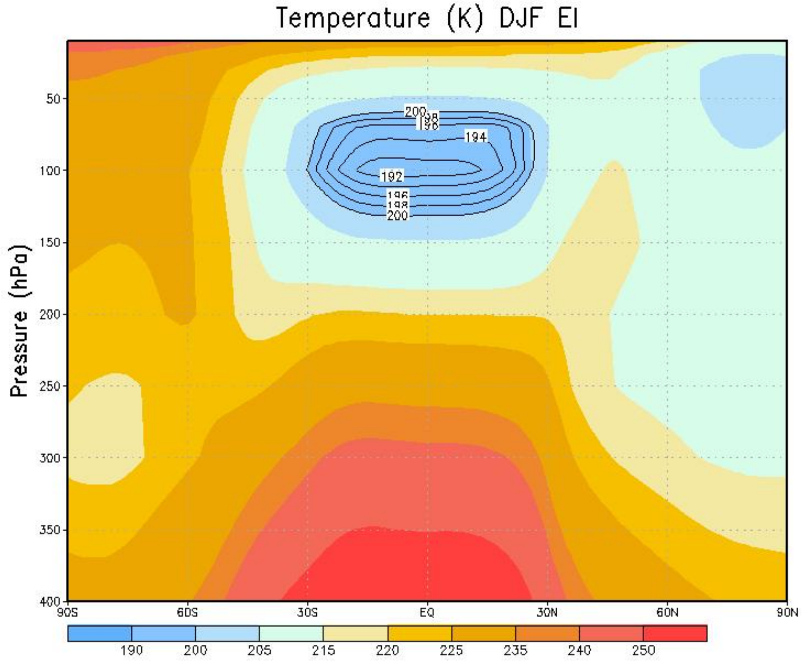
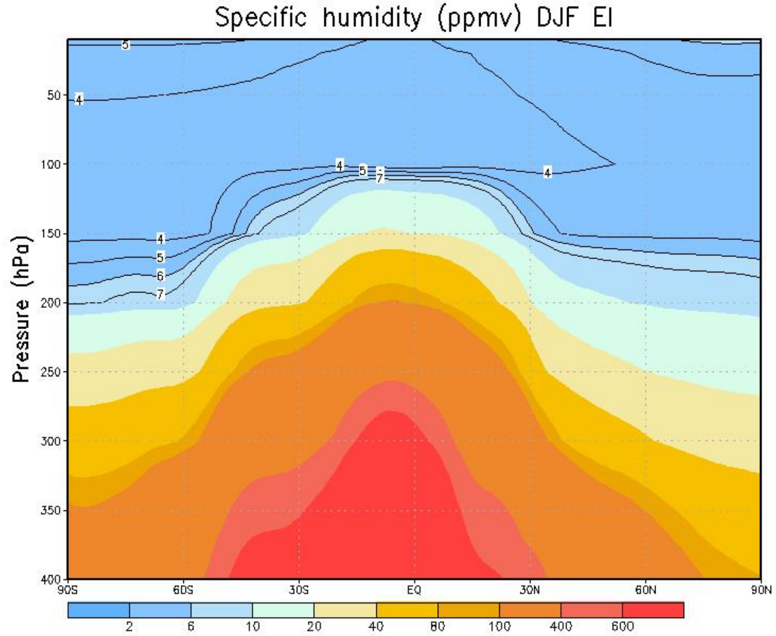
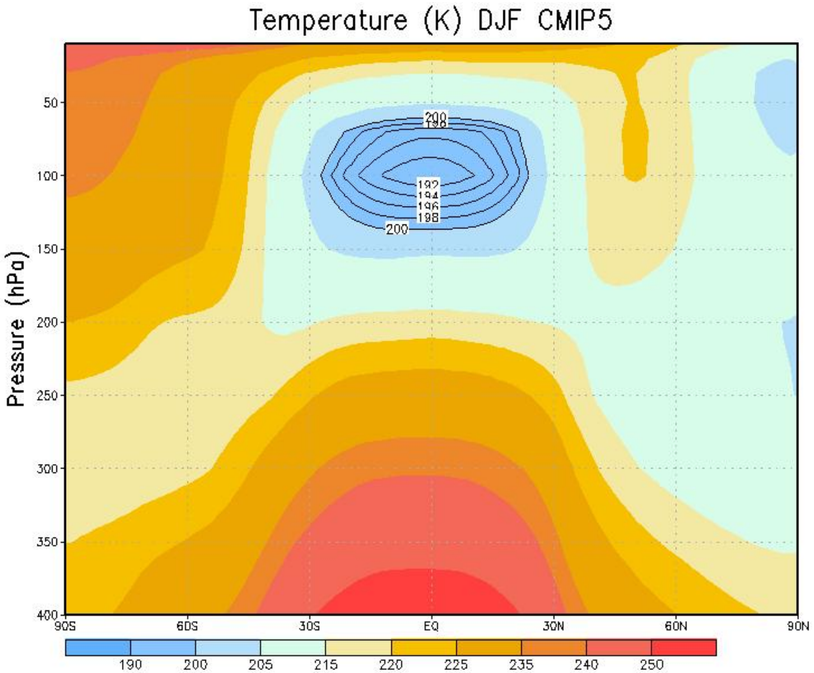
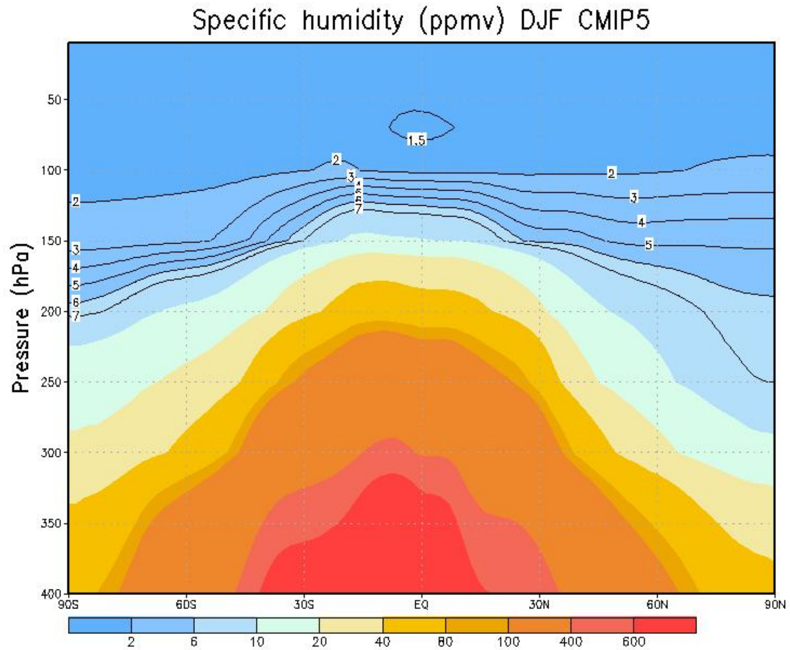
Validation of LMDZ CMIP5 simulations: Comparison with EI reanalyses

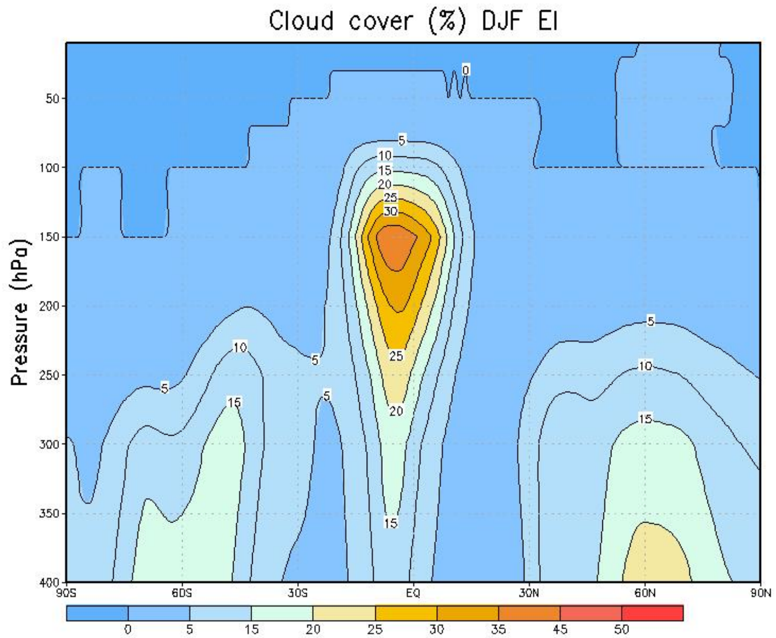


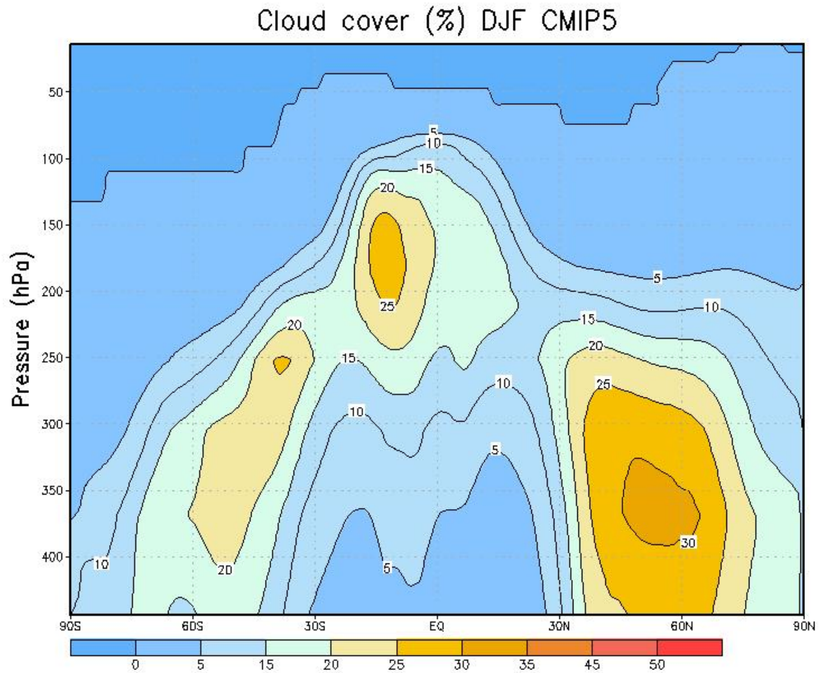






Validation of LMDZ CMIP5 simulations: Comparison with EI reanalyses





Methode de comparaison
Proprietes nuageuses LMDZ – Donnees AIRS

Differentes resolutions horizontale et verticale:

- Donnees AIRS: 40 km x 40 km x 50 hPa
- Sorties LMDZ: 3.75 deg. (lon) x 1.9 deg. (lat)
  Niveaux verticaux a la tropopause:
  304 hPa; 252 hPa; 212 hPa; 181 hPa; 155 hPa; 131 hPa; 110 hPa; 91 hPa.

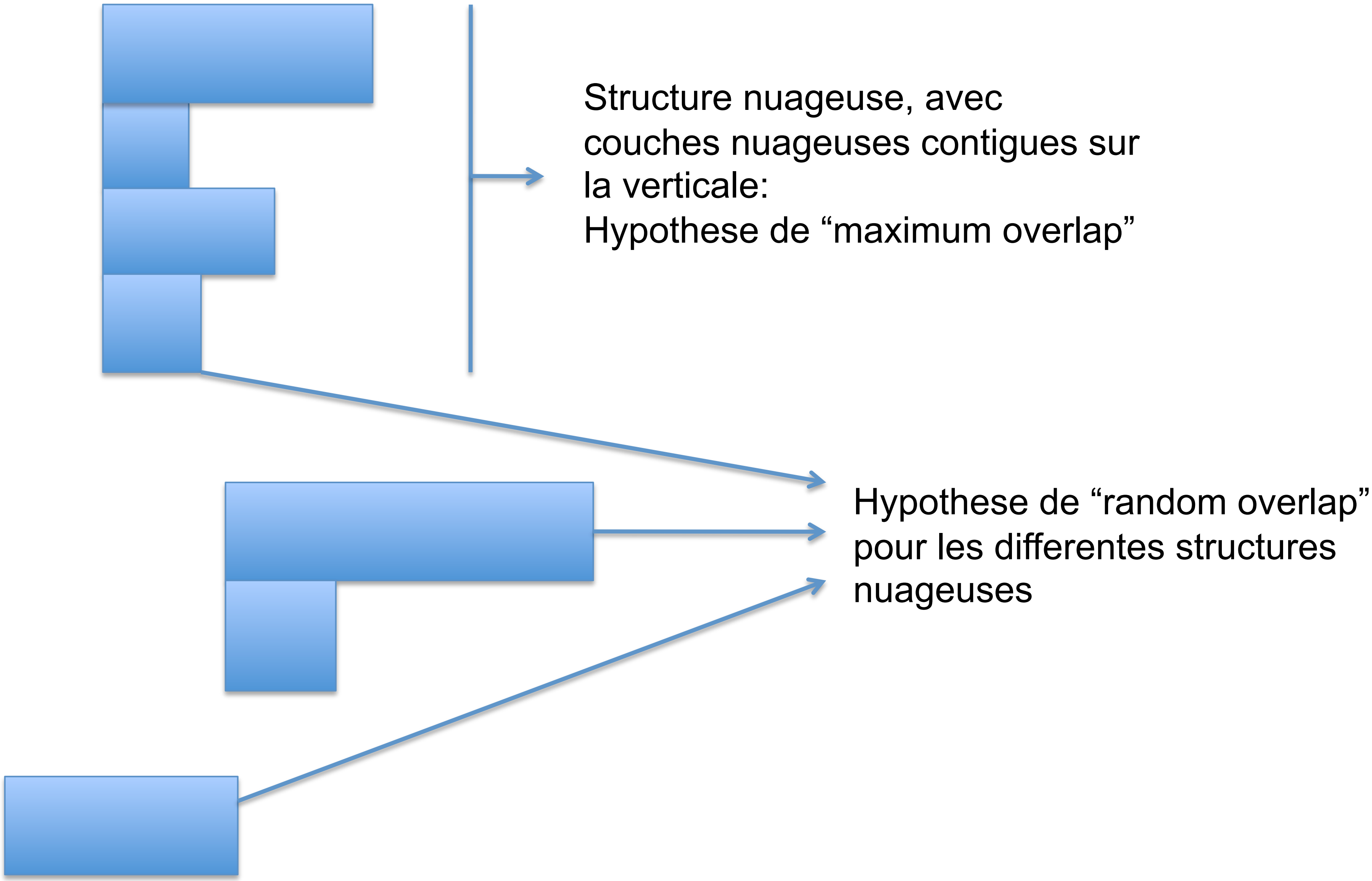
Differente resolution temporelle:

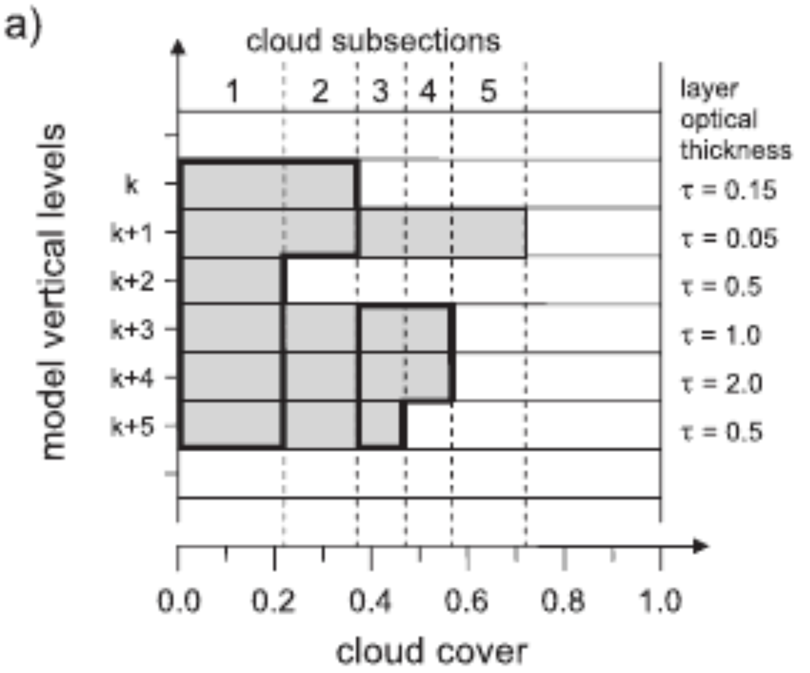
AIRS observe des champs instantanes a 1h30 et 13h30.

AIRS: pas d'information sur la distribution verticale des couches nuageuses

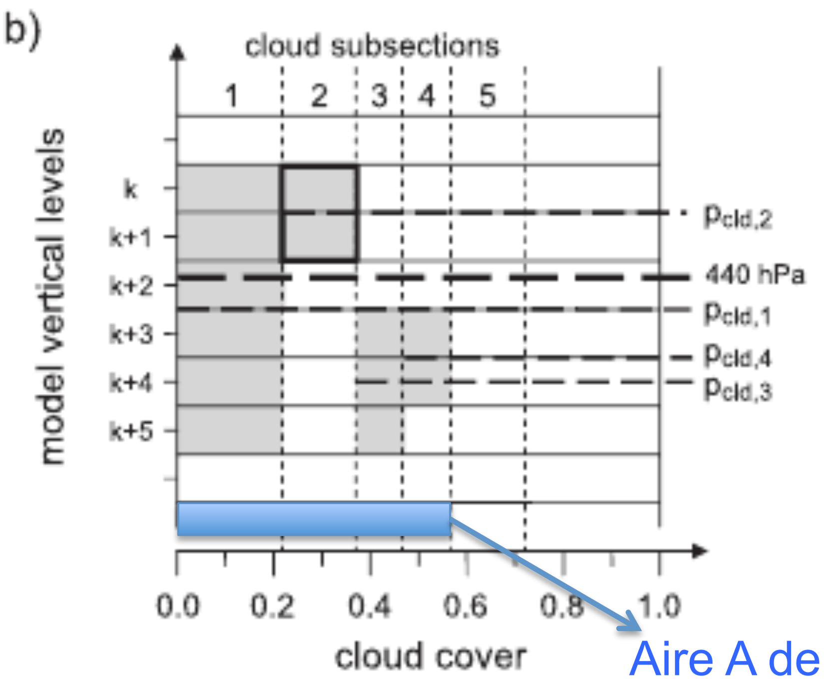
- Ne detecte pas les nuages dont l'epaisseur optique est inferieure a 0.05
- Detecte seulement le nuage le plus haut si son epaisseur optique est superieure a 0.05

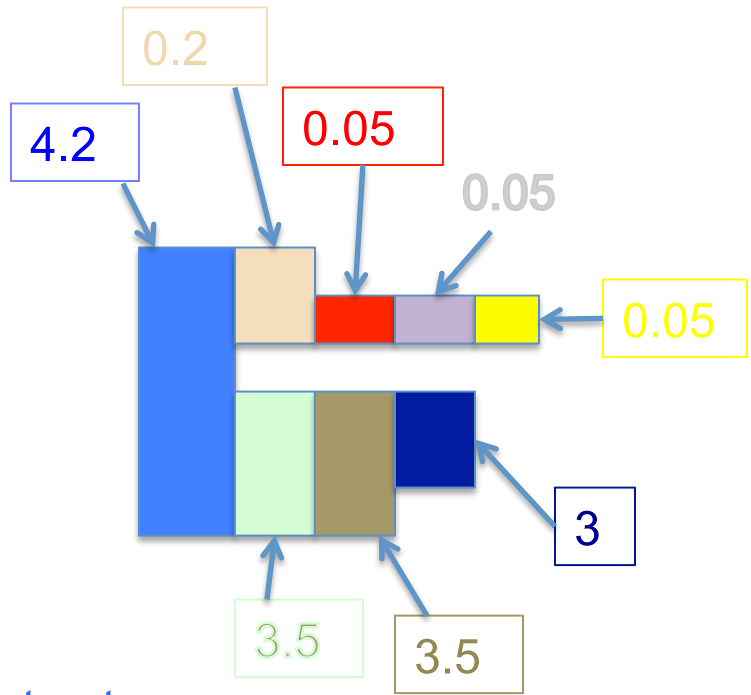
Colonne atmospherique de LMDZ



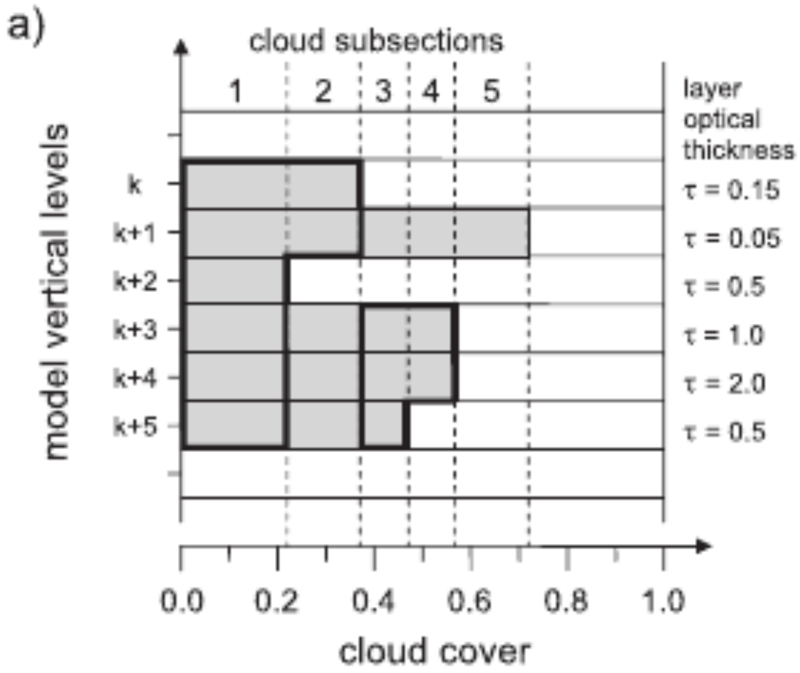


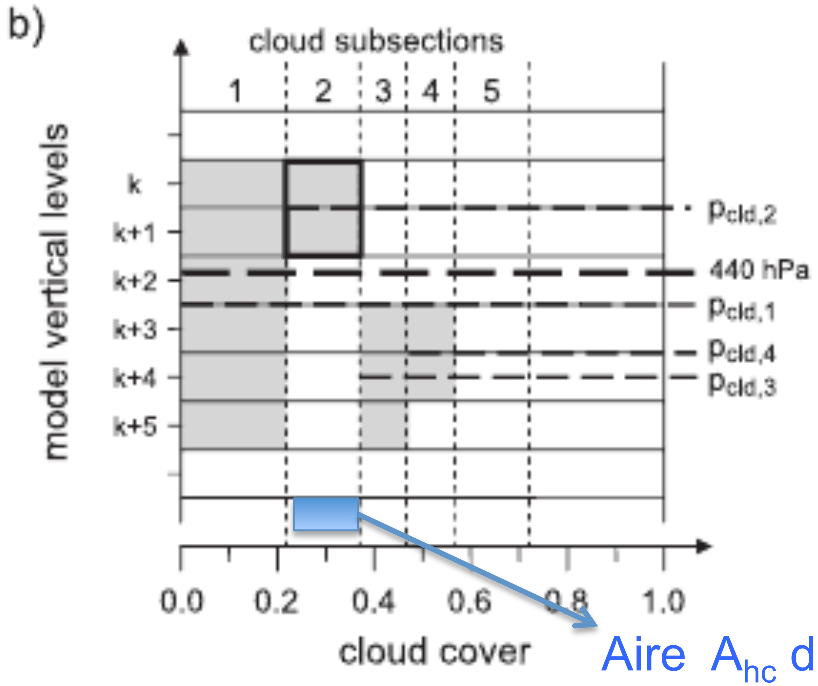
Chaque structure nuageuse est divisee en sous-sections (definies par les aires respectives des couches nuageuses).
Dans chaque sous-section on somme les epaisseurs optiques des couches contigues.
Le nuage est dit detectable si $\sum_i \tau_i > 0.05$
Les nuages places sous les nuages detectes ne sont pas detectes.





Aire A de la structure nuageuse





Aire A_{hc} des nuages hauts de la structure nuageuse

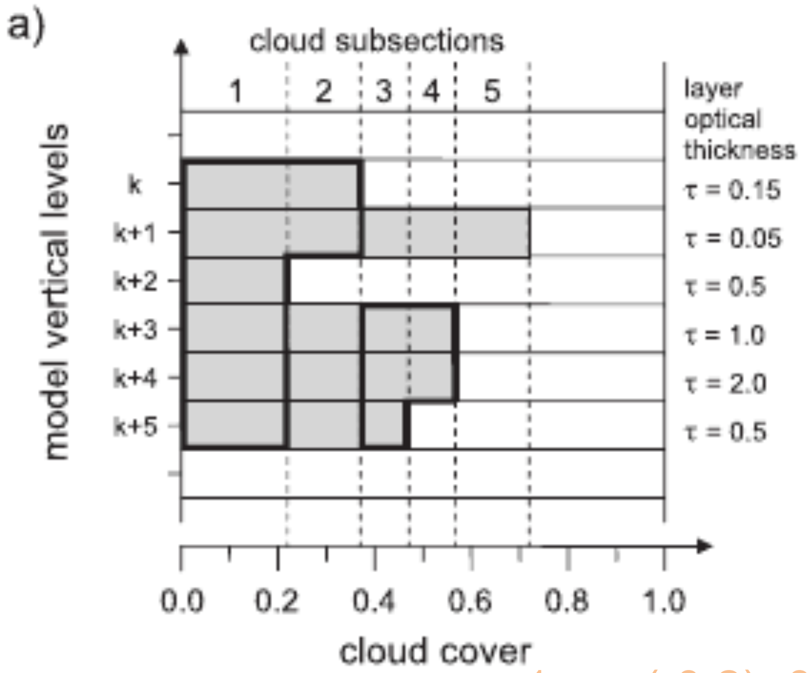
Definition des nuages hauts

On calcule p_{cld} dans chaque sous-section.

C'est le milieu entre le sommet du nuage et l'atltitude ou l'epaisseur optique du nuage est egale a 3.

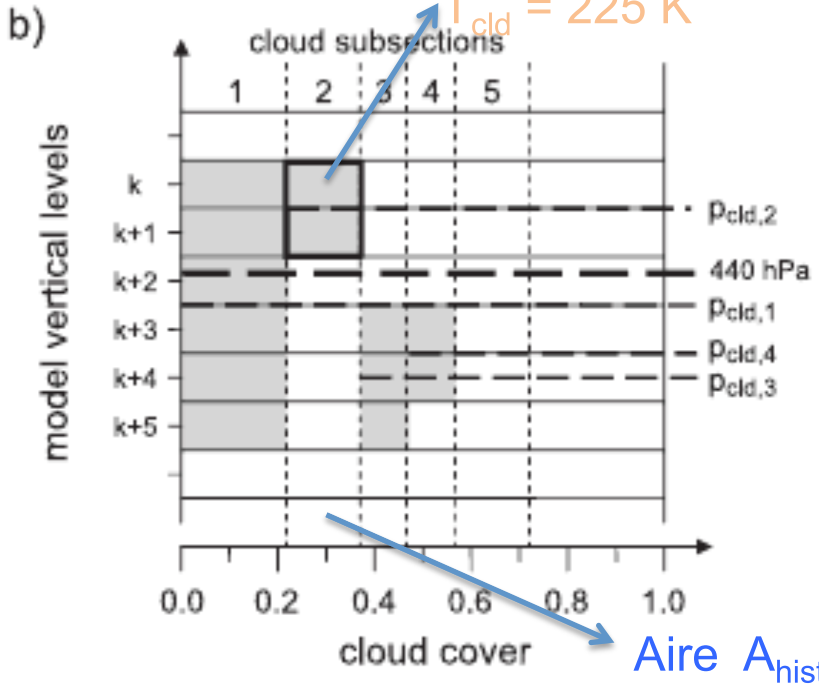
Si le nuage n'est pas suffisamment epais, on prend le sommet du nuage.

Le nuage est dit "haut" si $p_{cld} < 440 Pa.$



$e = 1-exp(-0.2)=0.18$

$T_{cld} = 225$ K



Aire A_{hist} des nuages hauts de glace et ST. $A_{hist} = 0$

Definition des nuages hauts, de glace et semi-transparents

On calcule p_{cld} dans chaque sous-section.

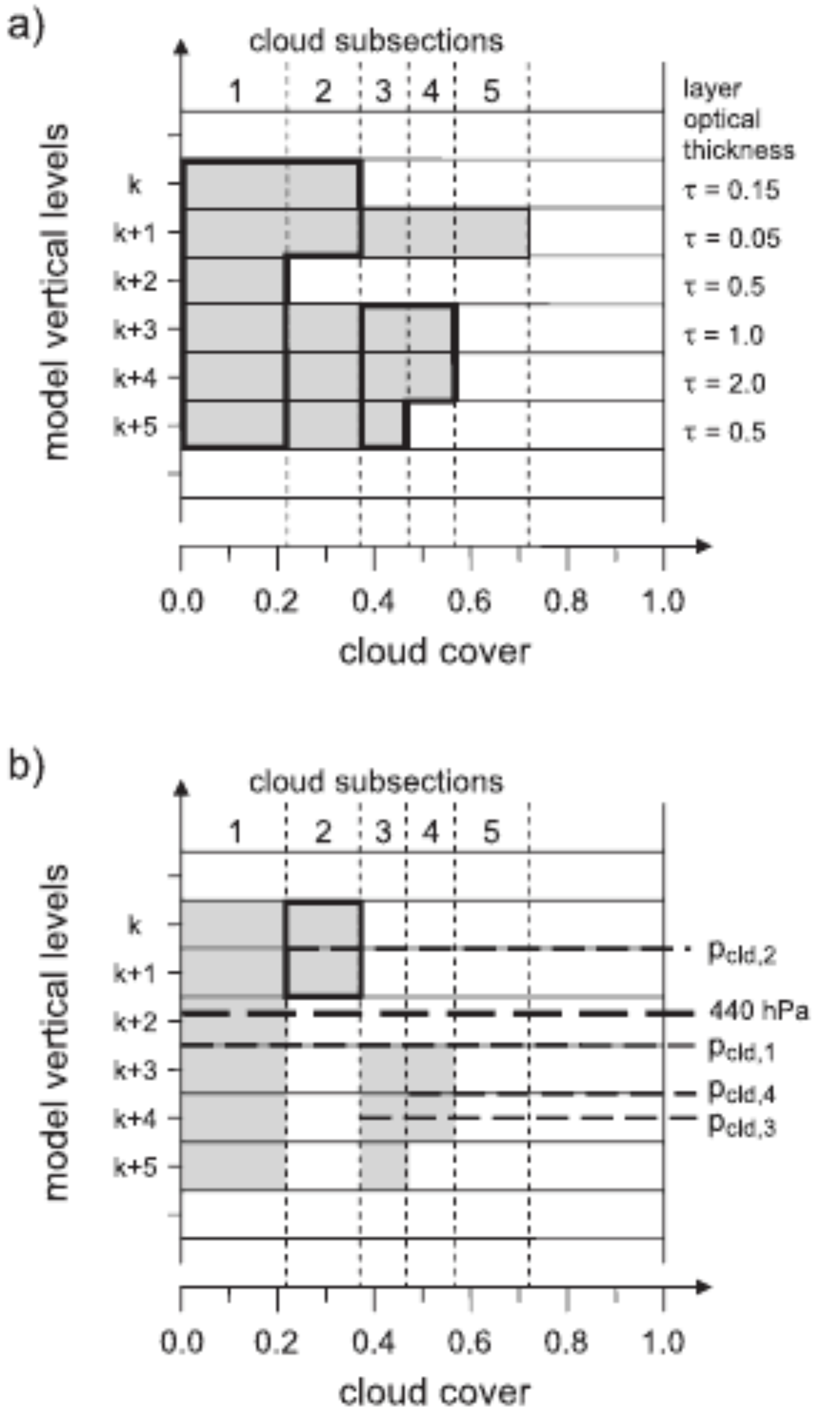
On calcule T_{cld} dans chaque sous-section.

On calcule l'emissivite *e* dans chaque sous-section:

$$e = 1-exp(-\mathcal{T})$$

Un nuage est dit haut, de glace et semi-transparent lorsque:

- $P_{cld} < 440$ hPa
- $T_{cld} < 230$ K
- $0.2 < e < 0.85$



Variables definies pour chaque structure nuageuse:

- L'aire *A* de la structure nuageuse
- L'aire *Ahc* des nuages hauts
- L'aire *Ahist* des nuages hauts, de glace et semi-transparents

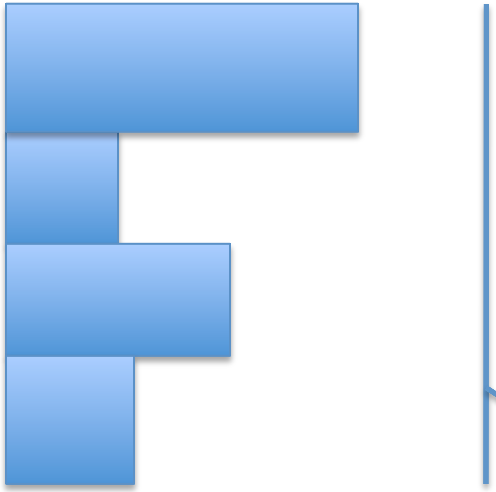
- La pression P_{cld}
- La temperature T_{cld}

- L'emissivite $e = 1-exp(-\tau)$

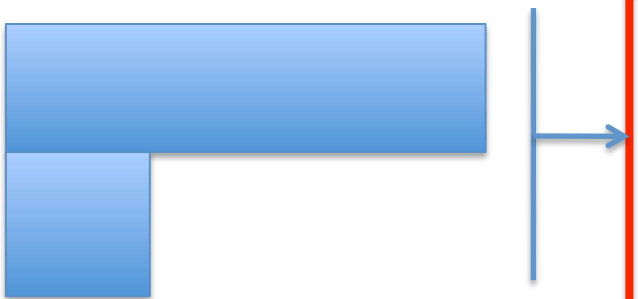
- Ice water path $IWP = \sum_i IWC_i \times \Delta z_i$

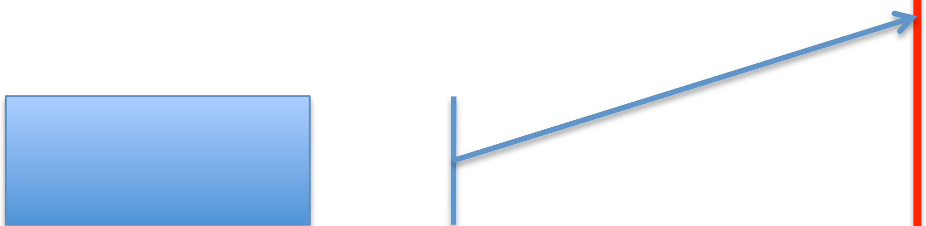
On moyenne sur la structure nuageuse en ponderant les variables definies dans chaque sous-section par l'aire de la sous-section.

Moyenne des variables sur la maille de LMDZ



- L'aire *A* de la structure nuageuse
- L'aire *Ahc* des nuages hauts
- L'aire *Ahist* des nuages hauts, de glace et semi-transparents
- La pression P_{cld}
- La temperature T_{cld}
- L'emissivite *e* = *1-exp(-*τ*)*
- Ice water path $IWP = \sum_i IWC_i \times \Delta z_i$





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

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

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

Sensitivity to microphysical processes

$$wv_{strato} = (1 - f_{tropo}).wv_{[CH_4]} + f_{tropo}.\underbrace{[wv(T_{TTL}) + wv_{con} + wv_{ov} + wv_{\mu\varphi}]}_{wv_{tropo}}$$

→

1. Sensitbilite a la temperature du changement de phase glace/eau liquide
2. Sensibilite a la sursaturation
3. Overshoots

Couverture de nuages hauts

Winter	Tropics	NH	SH
NPV4_03	41%	24%	19%
NPV4_12	42%	26%	21%
NPV4_12tglaceOff	42	24	19
Guignard et al.	42%	22%	14%

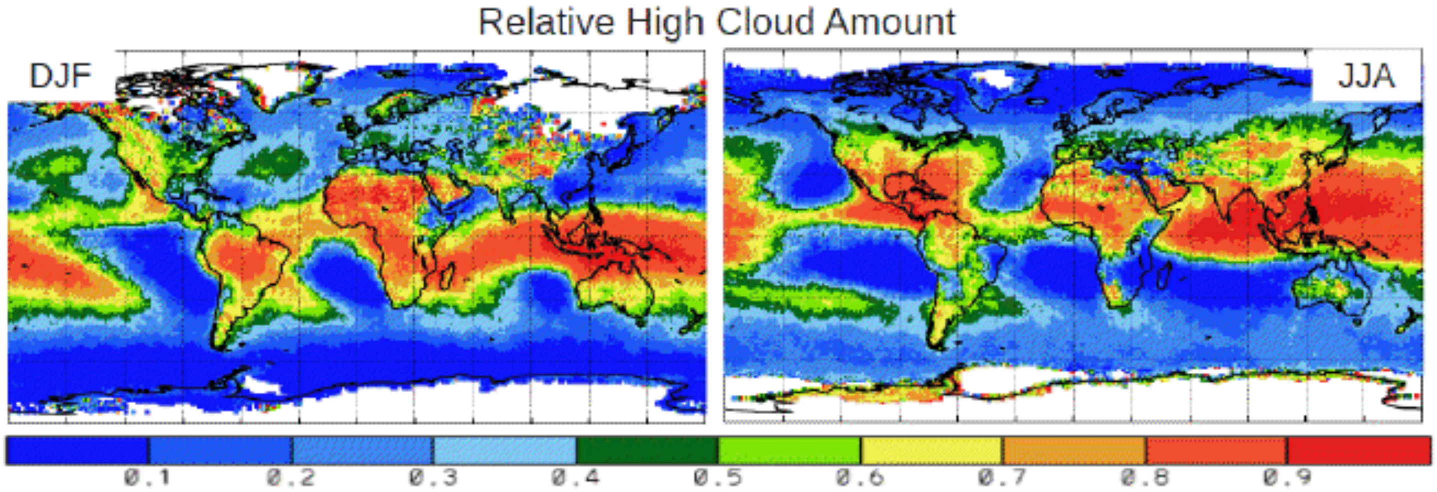
Summer	Tropics	NH	SH
NPV4_03	37%	20%	27%
NPV4_12	39%	23%	27%
NPV4_12tglaceOff	39%	23%	26%
Guignard et al.	39%	26%	23%

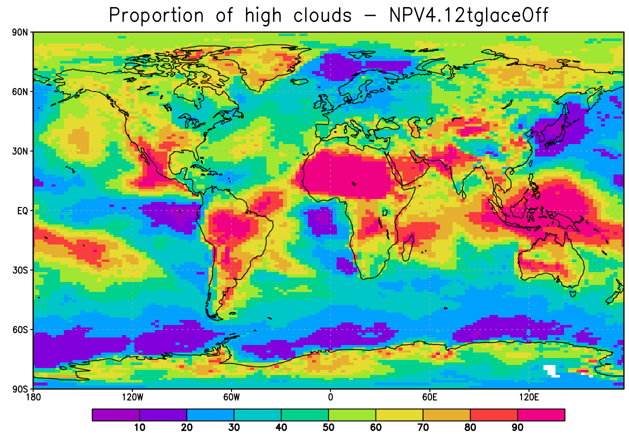
Proportion de nuages hauts

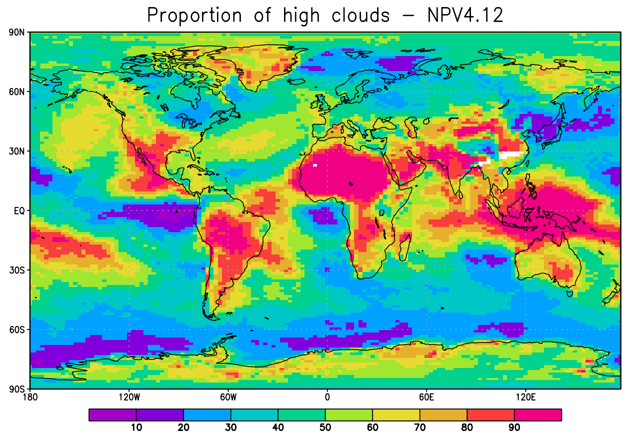
Winter	Tropics	NH	SH
NPV4_03	59%	44%	28%
NPV4_12	63%	43%	31%
NPV4_12tglaceOff	63%	44%	28%
Guignard et al.	62%	31%	14%

Summer	Tropics	NH	SH
NPV4_03	55%	50%	36%
NPV4_12	59%	55%	36%
NPV4_12tglaceOff	58%	52%	35%
Guignard et al.	58%	32%	28%

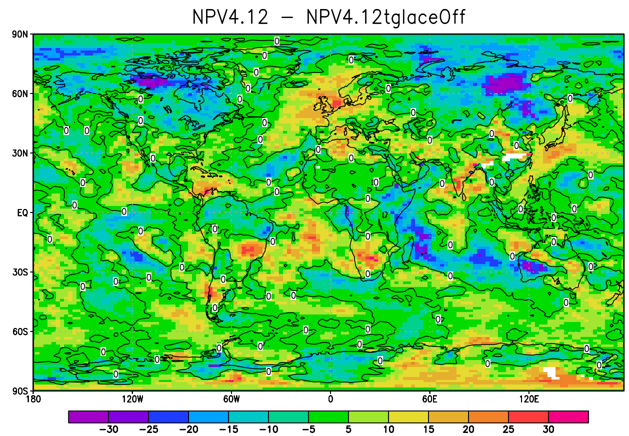
Trop de nuages hauts aux moyennes latitudes

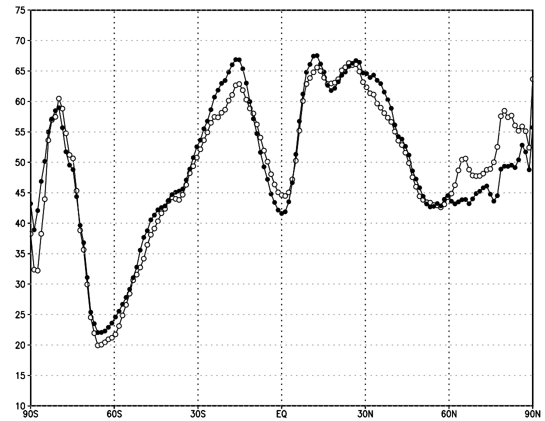

Relative High Cloud Amount
DJF
JJA
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9


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

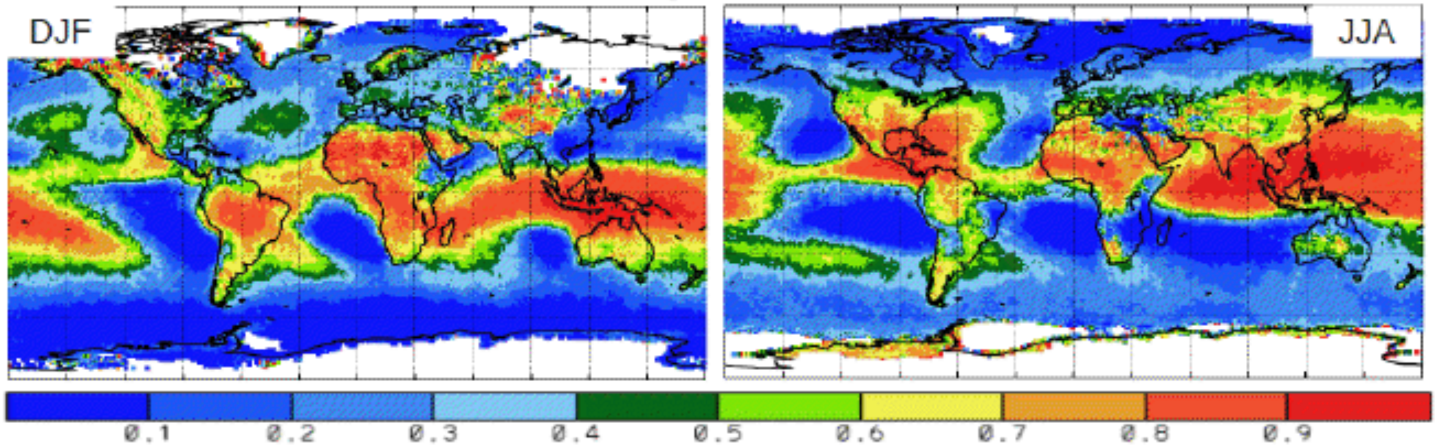

Proportion of high clouds – NPV4.12
90N 60N 30N EQ 30S 60S 90S
180 120W 60W 0 60E 120E
10 20 30 40 50 60 70 80 90

DJF


NPV4.12 – NPV4.12tglaceOff
90N 60N 30N EQ 30S 60S 90S
180 120W 60W 0 60E 120E
−30 −25 −20 −15 −10 −5 5 10 15 20 25 30

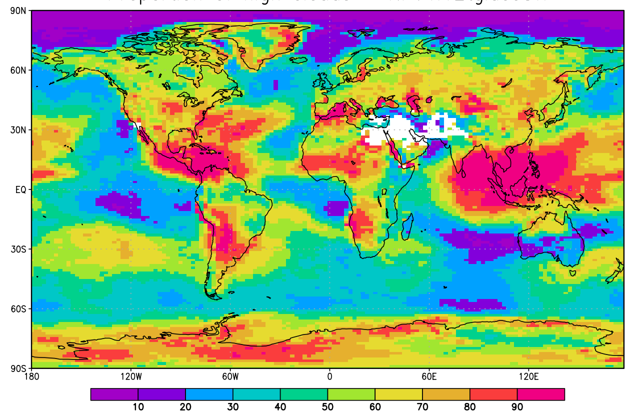

75 70 65 60 55 50 45 40 35 30 25 20 15 10
90S 60S 30S EQ 30N 60N 90N

Relative High Cloud Amount

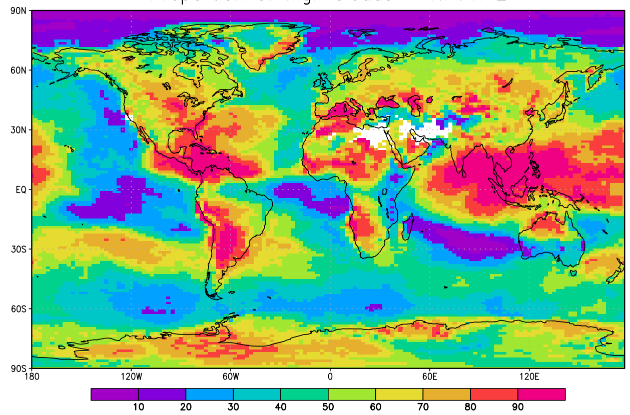


JJA

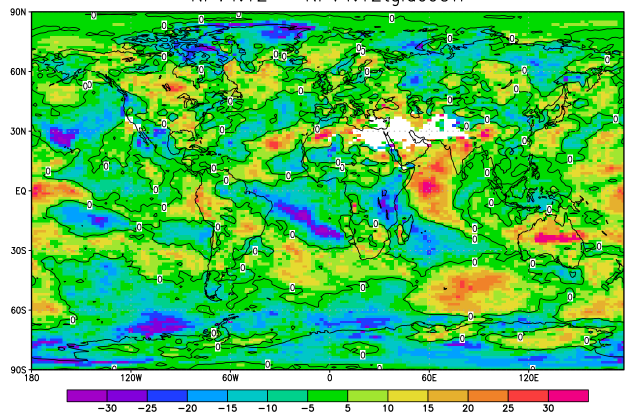
Proportion of high clouds – NPV4.12tglaceOff

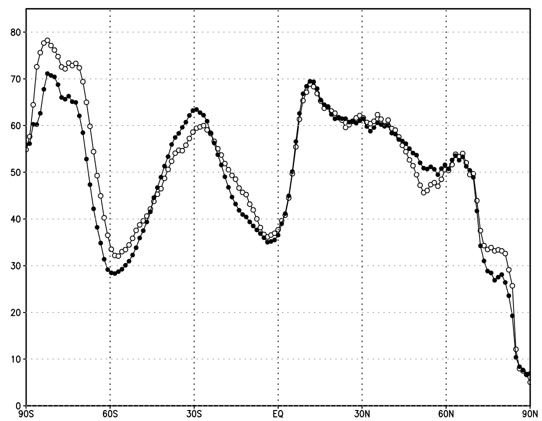


Proportion of high clouds – NPV4.12



NPV4.12 – NPV4.12tglaceOff





Couverture de nuages hauts de glace et semi-transparents

Winter	Tropics	NH	SH
NPV4_03	14	12	8
NPV4_12	16	11	8
NPV4_12tglaceOff	15	11	8
Guignard et al.	12	11	1

Summer	Tropics	NH	SH
NPV4_03	13	9	13
NPV4_12	14	9	12
NPV4_12tglaceOff	15	9	12
Guignard et al.	10	4	10

Proportion de nuages hauts de glace et semi-transparents

Winter	Tropics	NH	SH
NPV4_03	21	23	12
NPV4_12	23	19	12
NPV4_12tglaceOff	23	22%	12
Guignard et al.	18%	15%	1%

Summer	Tropics	NH	SH
NPV4_03	20%	22%	18%
NPV4_12	21%	23%	16%
NPV4_12tglaceOff	21	23	17
Guignard et al.	15%	4%	12%

Trop de nuages hauts de glace et ST aux moyennes latitudes

Epaisseur des nuages hauts de glace et semi-transparents

Winter	Tropics	NH	SH
NPV4_03	2980	3410	2810
NPV4_12	2910	2920	2540
NPV4_12tglaceOff	2930	3190	2620
Guignard et al.	4900	5500	5000

Summer	Tropics	NH	SH
NPV4_03	2940	2560	3260
NPV4_12	2870	2310	2950
NPV4_12tglaceOff	2940	2320	2980
Guignard et al.	4500	3800	5900

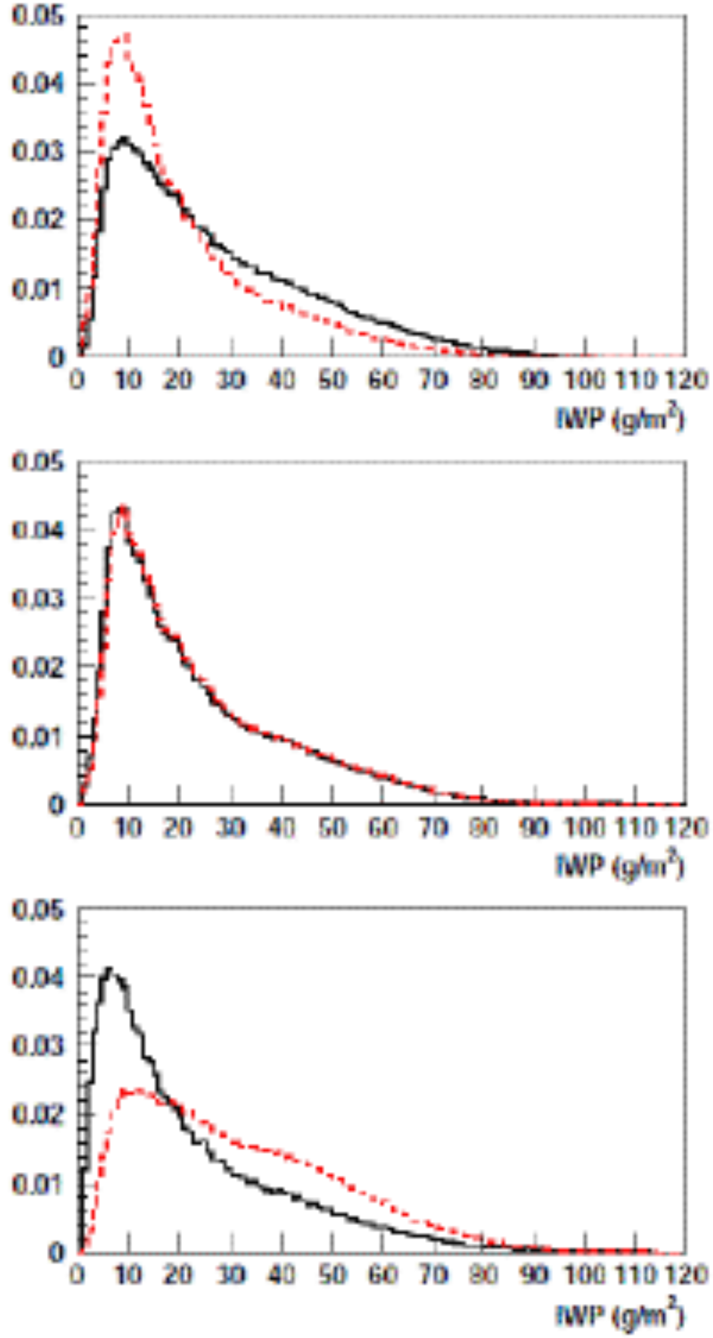
Dans NPV4_12 diminution de l'epaisseur des nuages.
Nuages trop fins

Rayon des cristaux de glace dans les nuages hauts de glace semi-transparents

Winter	Tropics	NH	SH
NPV4_03	28	29	28
NPV4_12	27	29	28
NPV4_12tglaceOff	28	29	29
Guignard et al.	25	27	23

Summer	Tropics	NH	SH
NPV4_03	28	31	28
NPV4_12	28	31	28
NPV4_12tglaceOff	28	32	28
Guignard et al.	27	27	27

IWP des nuages de glace hauts et ST

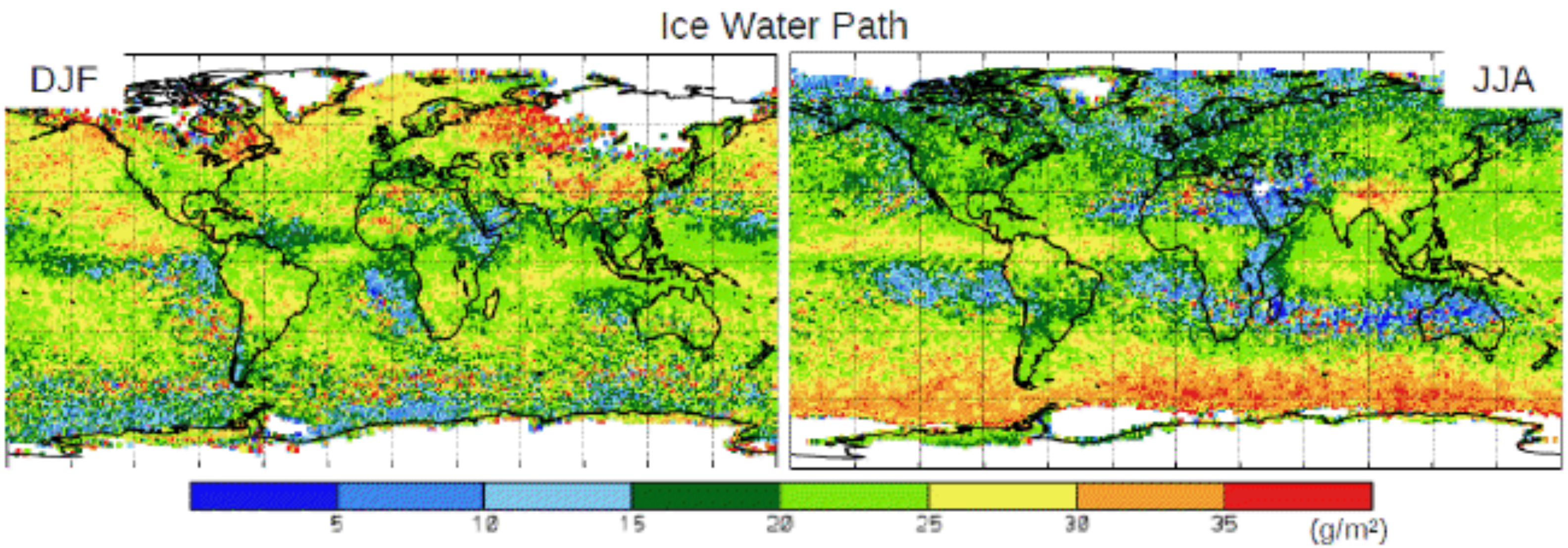


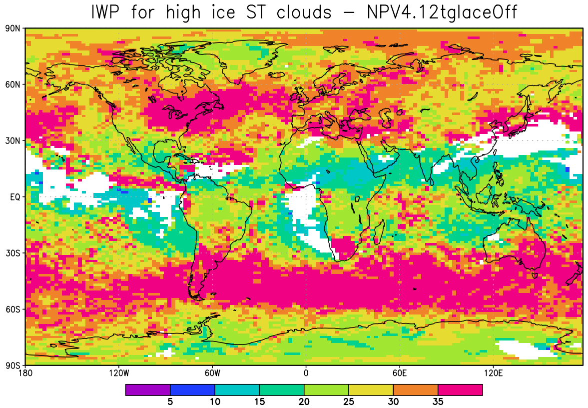
Mediane des IWP pour les nuages hauts de glace et semi-transparents

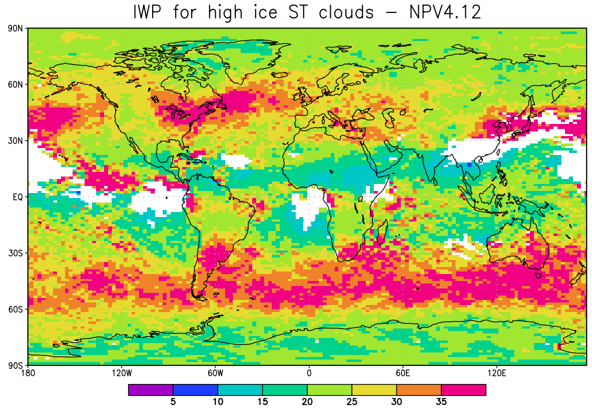
Winter	Tropics	NH	SH
NPV4_03	19	26	30
NPV4_12	19	24	27
NPV4_12tglaceOff	19	26	29
Guignard et al.	19	25	18

Summer	Tropics	NH	SH
NPV4_03	18	26	26
NPV4_12	18	23	24
NPV4_12tglaceOff	18	24	26
Guignard et al.	20	17	30

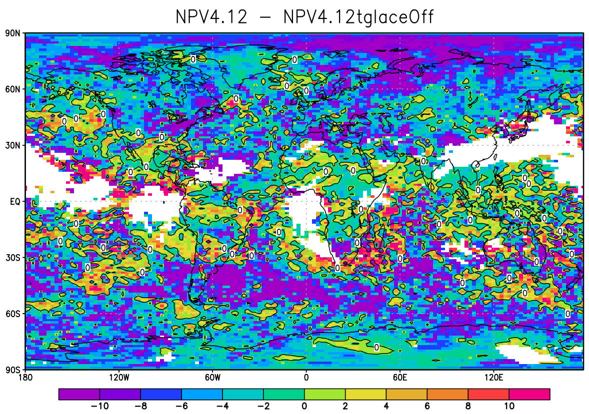
Dans NPV4_12 legere diminution de IWP aux moyennes latitudes

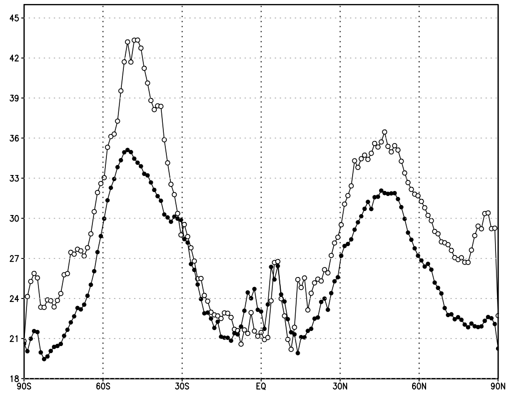

Ice Water Path
DJF
JJA
5
10
15
20
25
30
35
(g/m²)


IWP for high ice ST clouds – NPV4.12tglaceOff
90N
60N
30N
EQ
30S
60S
90S
180
120W
60W
0
60E
120E
5
10
15
20
25
30
35

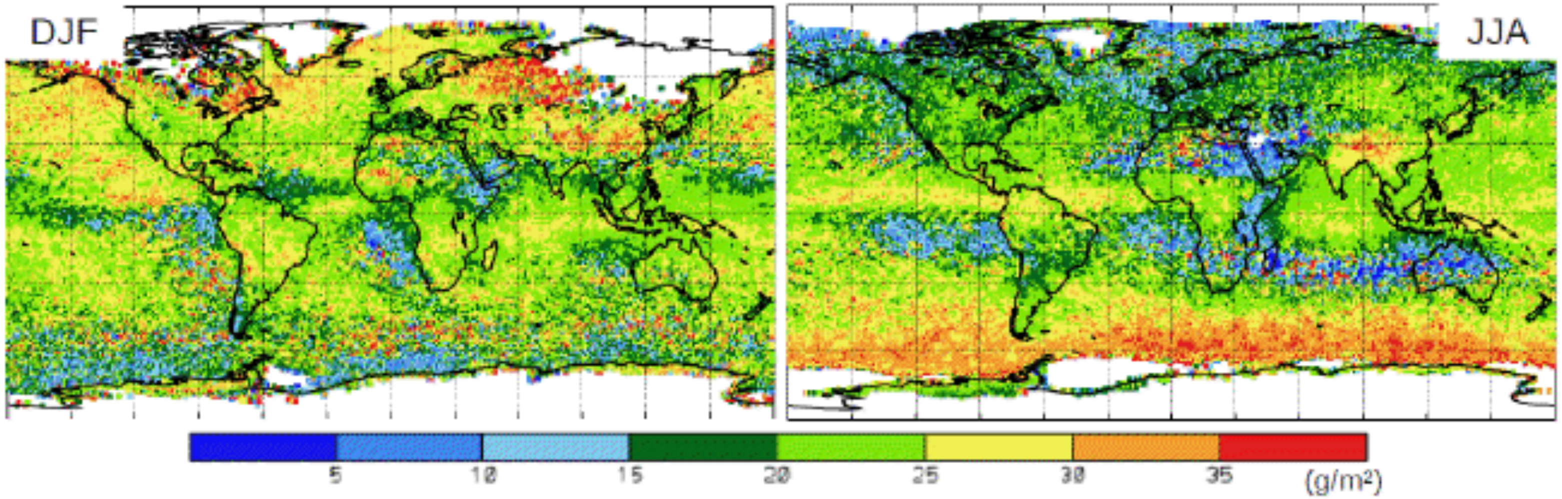

IWP for high ice ST clouds – NPV4.12
90N
60N
30N
EQ
30S
60S
90S
180
120W
60W
0
60E
120E
5
10
15
20
25
30
35

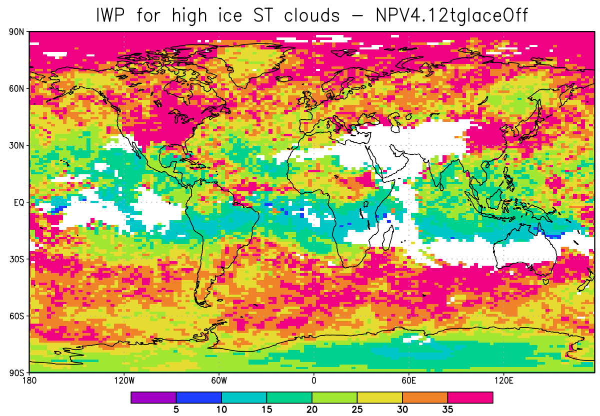
DJF

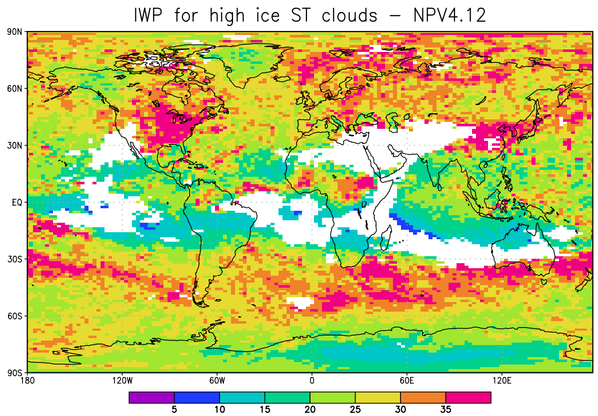

NPV4.12 – NPV4.12tglaceOff
90N
60N
30N
EQ
30S
60S
90S
180
120W
60W
0
60E
120E
-10
-8
-6
-4
-2
0
2
4
6
8
10


45
42
39
36
33
30
27
24
21
18
90S
60S
30S
EQ
30N
60N
90N

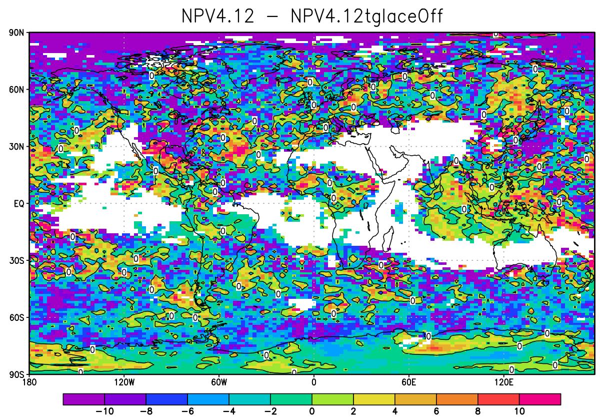
Ice Water Path

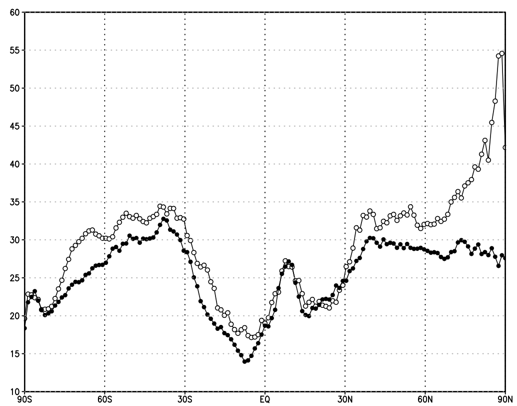




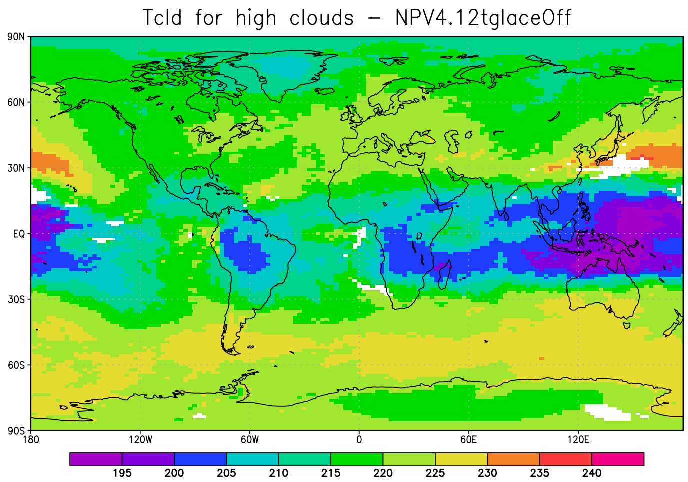


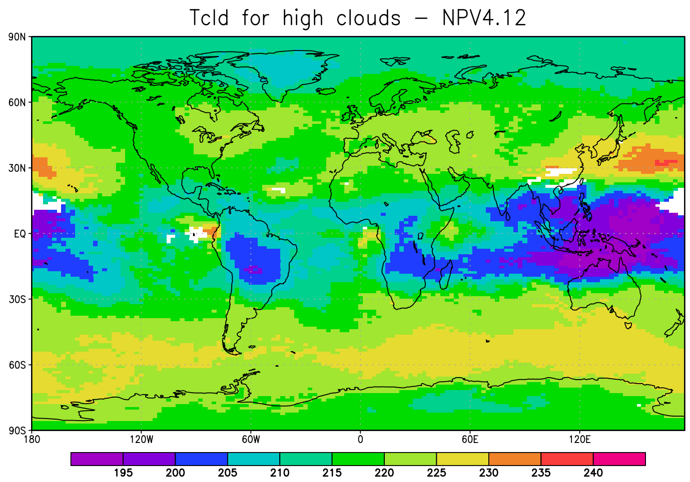
JJA

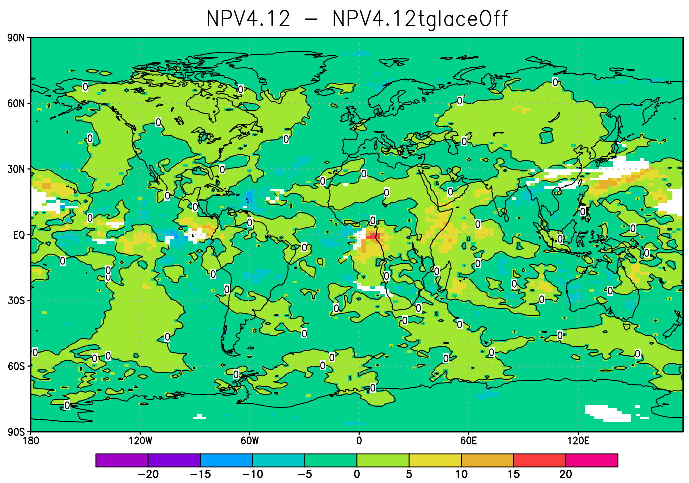


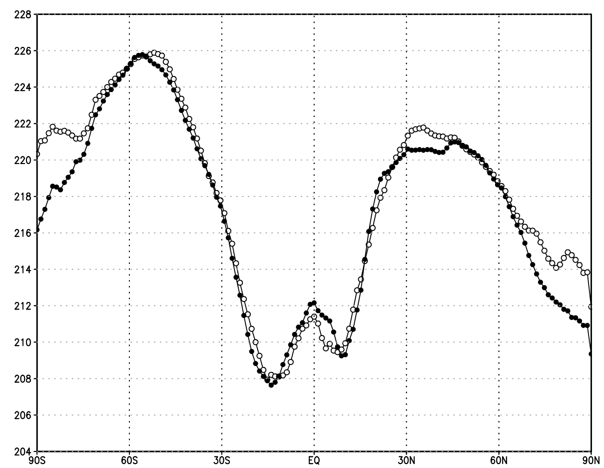


Tcld high clouds DJF

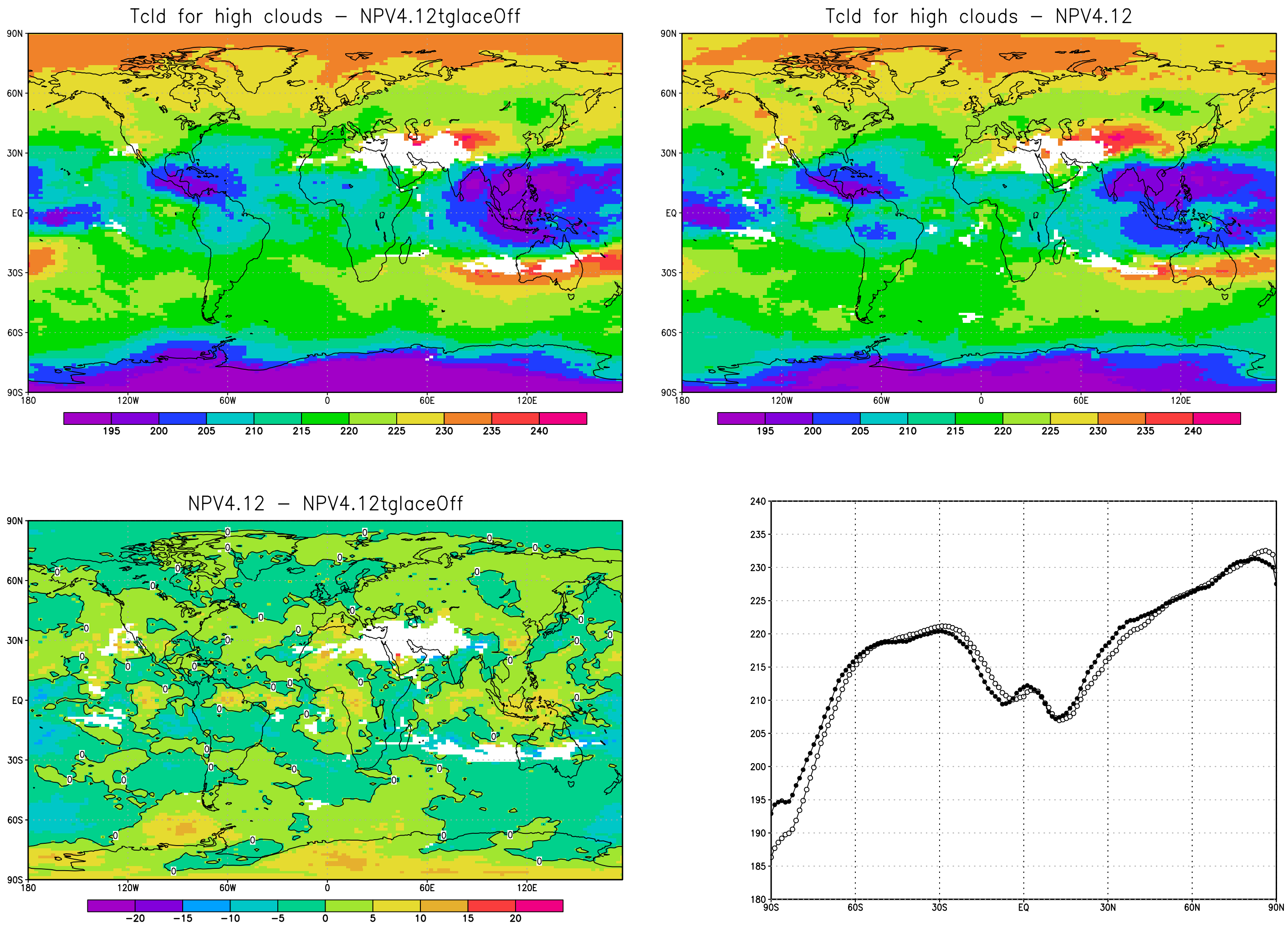








Tcld high clouds JJA



Sensitivity to microphysical processes

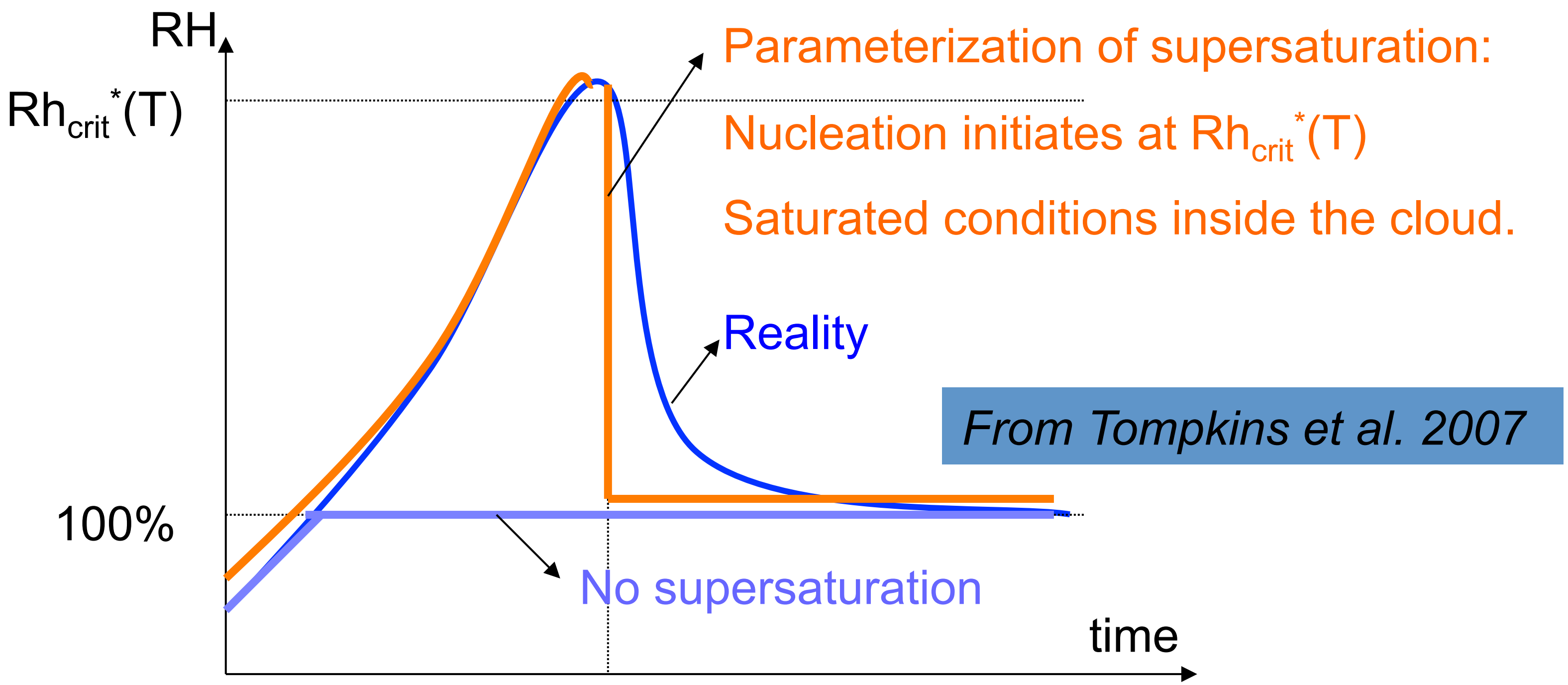
$$wv_{strato} = (1 - f_{tropo}).wv_{[CH_4]} + f_{tropo}.\underbrace{[wv(T_{TTL}) + wv_{con} + wv_{ov} + wv_{\mu\varphi}]}_{wv_{tropo}}$$

1. Sensitbilite a la temperature du changement de phase glace/eau liquide
2. Sensibilite a la sursaturation
3. Overshoots

Parameterization of supersaturation in LMDZ

Ice nucleation process can be homogeneous and heterogeneous.

We consider only the homogeneous process.



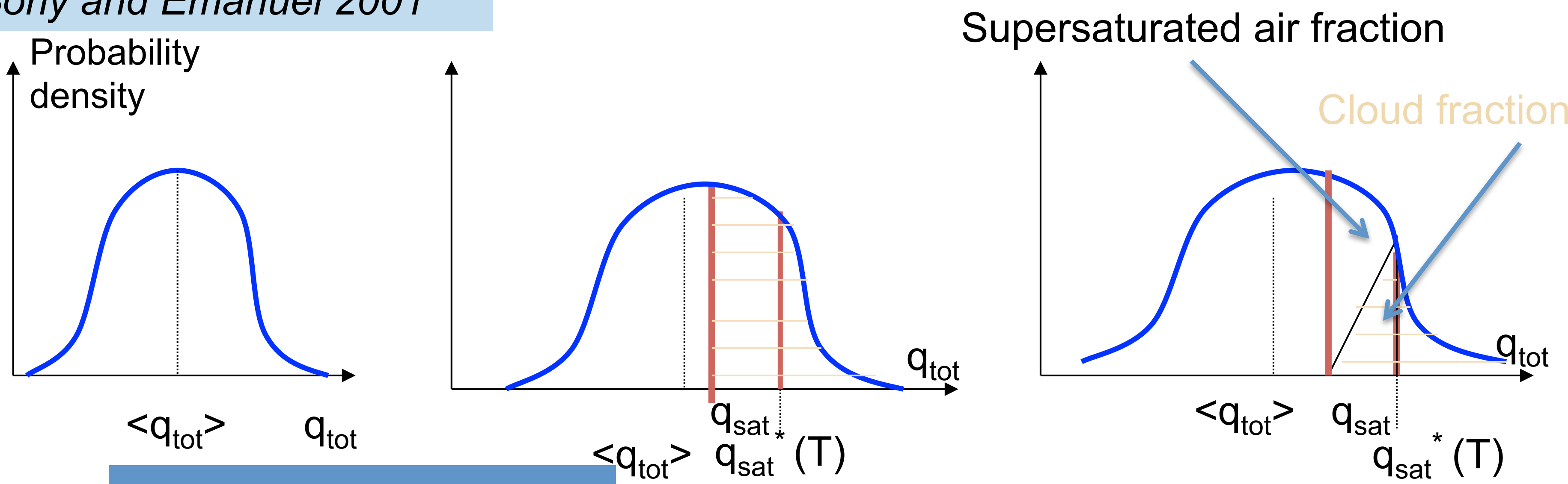
$Rh_{crit}^{*}(T)$ as in *Kaercher and Lohmann (2002):*

T = 235 K 45% supersaturation

T = 190 K 67% supersaturation

Parameterization of supersaturation in LMDZ

Bony and Emanuel 2001



Without supersaturation

With supersaturation

Cloud fraction:

$$f = \int_{q_{sat}}^{\infty} P(q_{tot})\,dq_{tot}$$

Amount of total water in cloud:

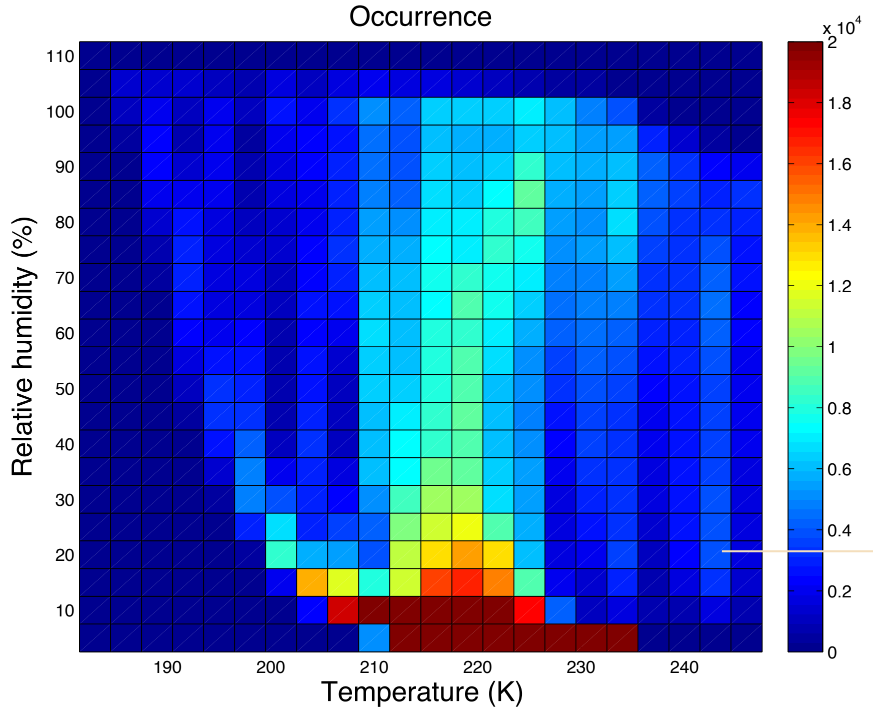
$$q_{cloud} = \frac{1}{f} \int_{q_{sat}}^{\infty} q_{tot} P(q_{tot})\,dq_{tot}$$

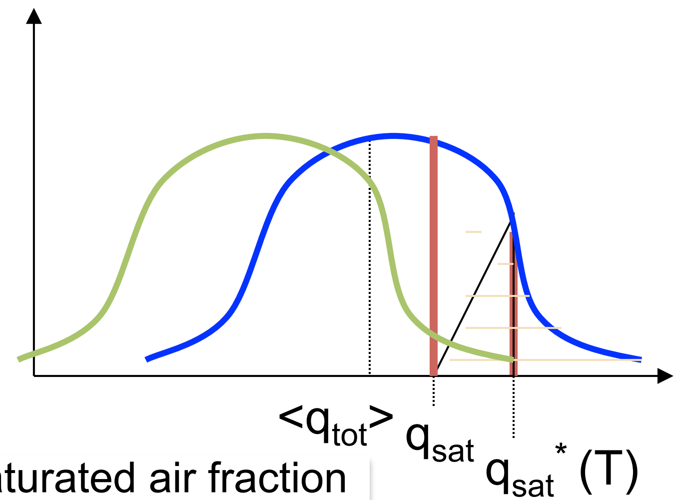
Amount of condensed water in the grid box:

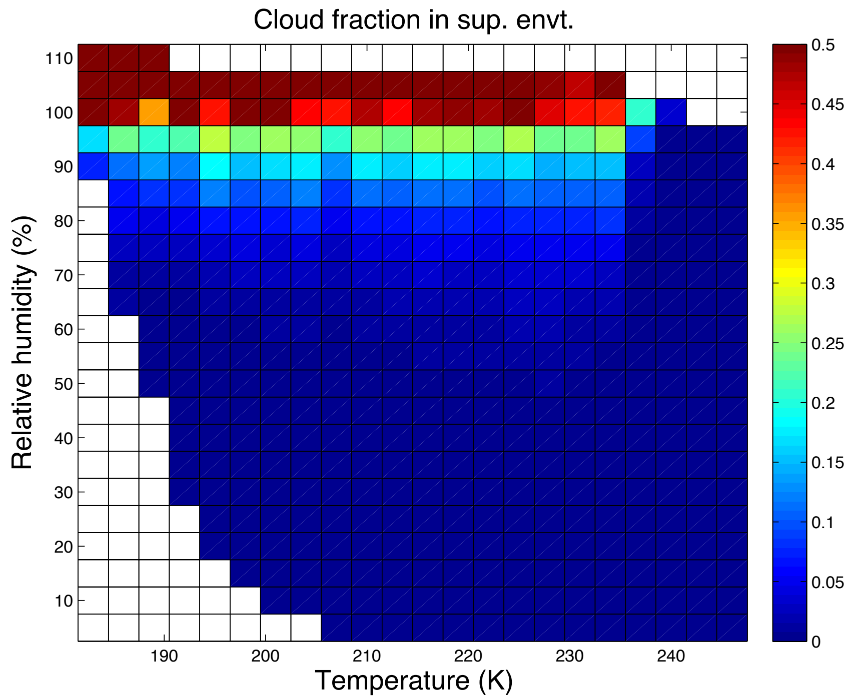
$$q_{cond} = f.(q_{cloud} - q_{sat})$$

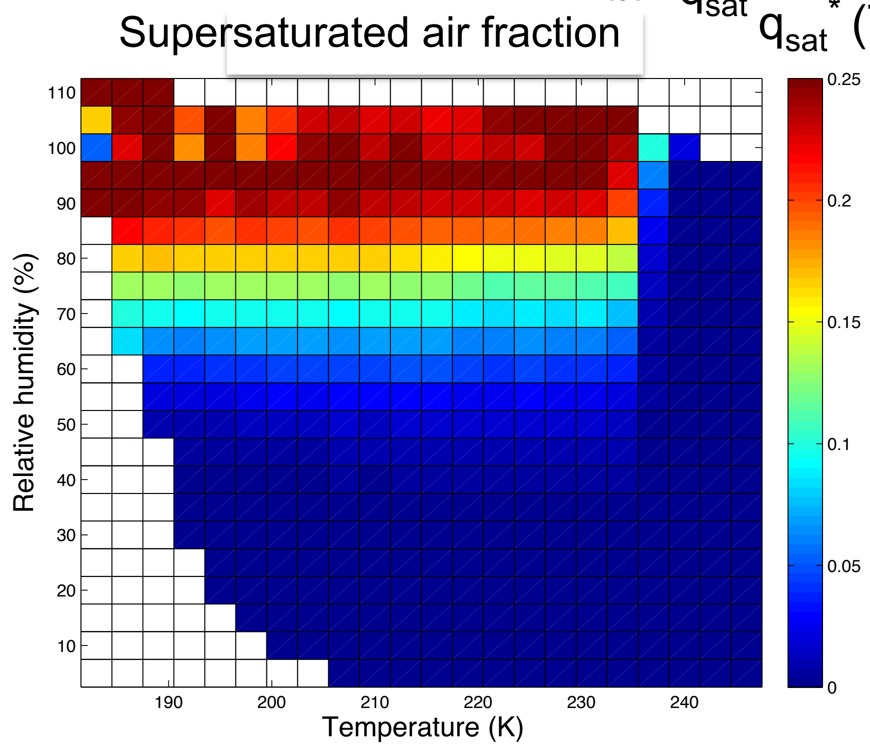
$q_{tot} > q_{sat}$ possible in clear sky

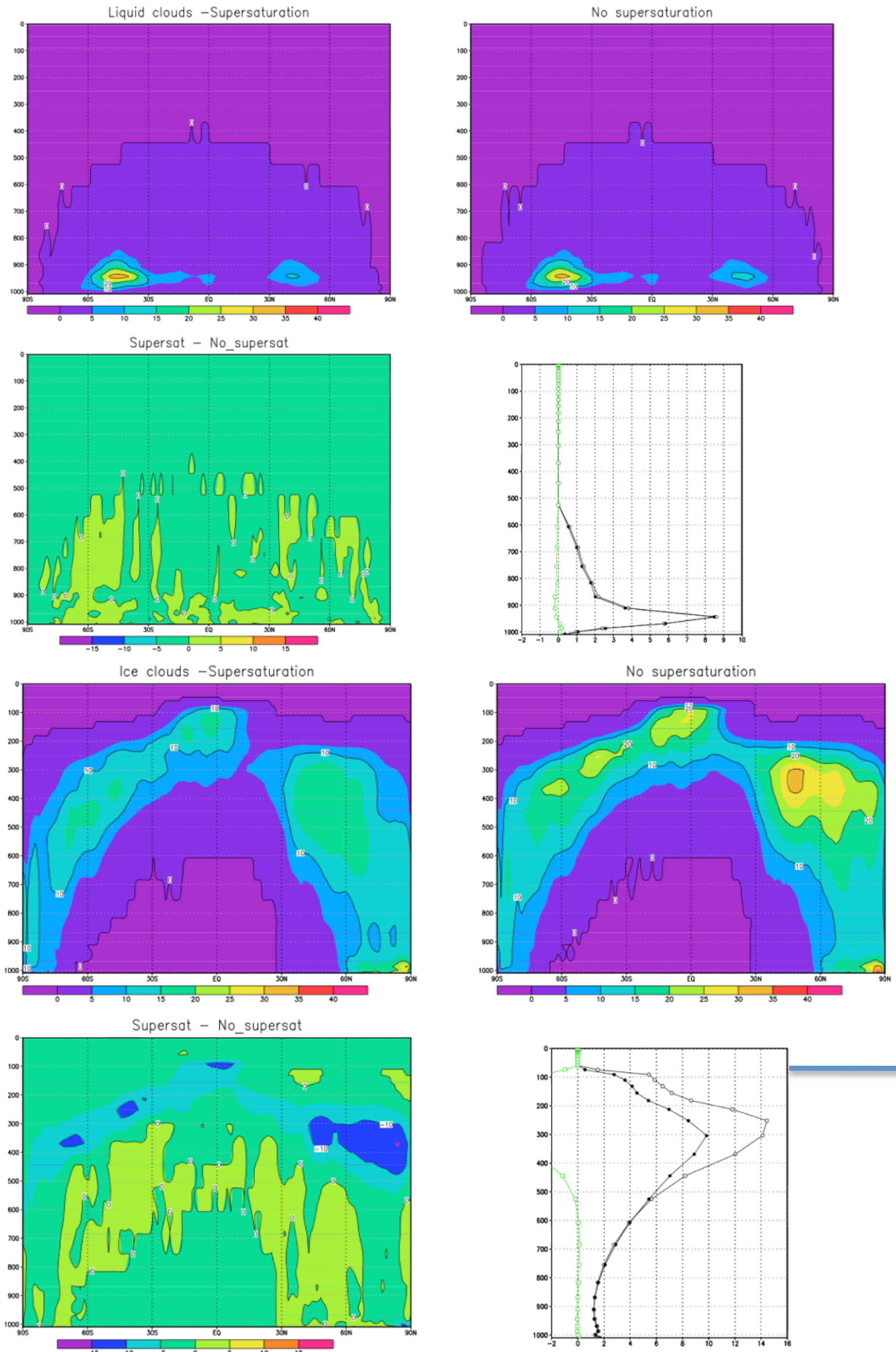
Diagnostics for supersaturation scheme

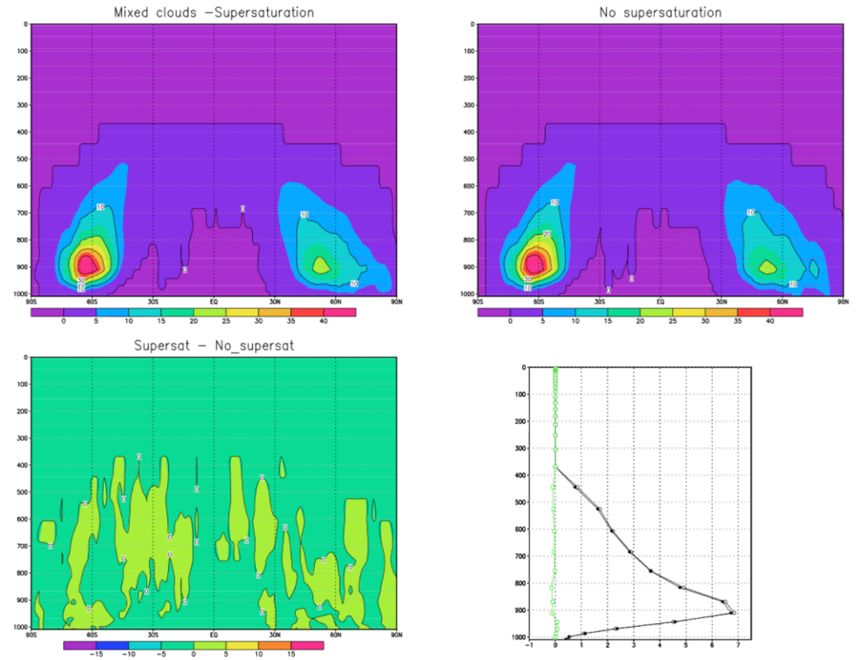






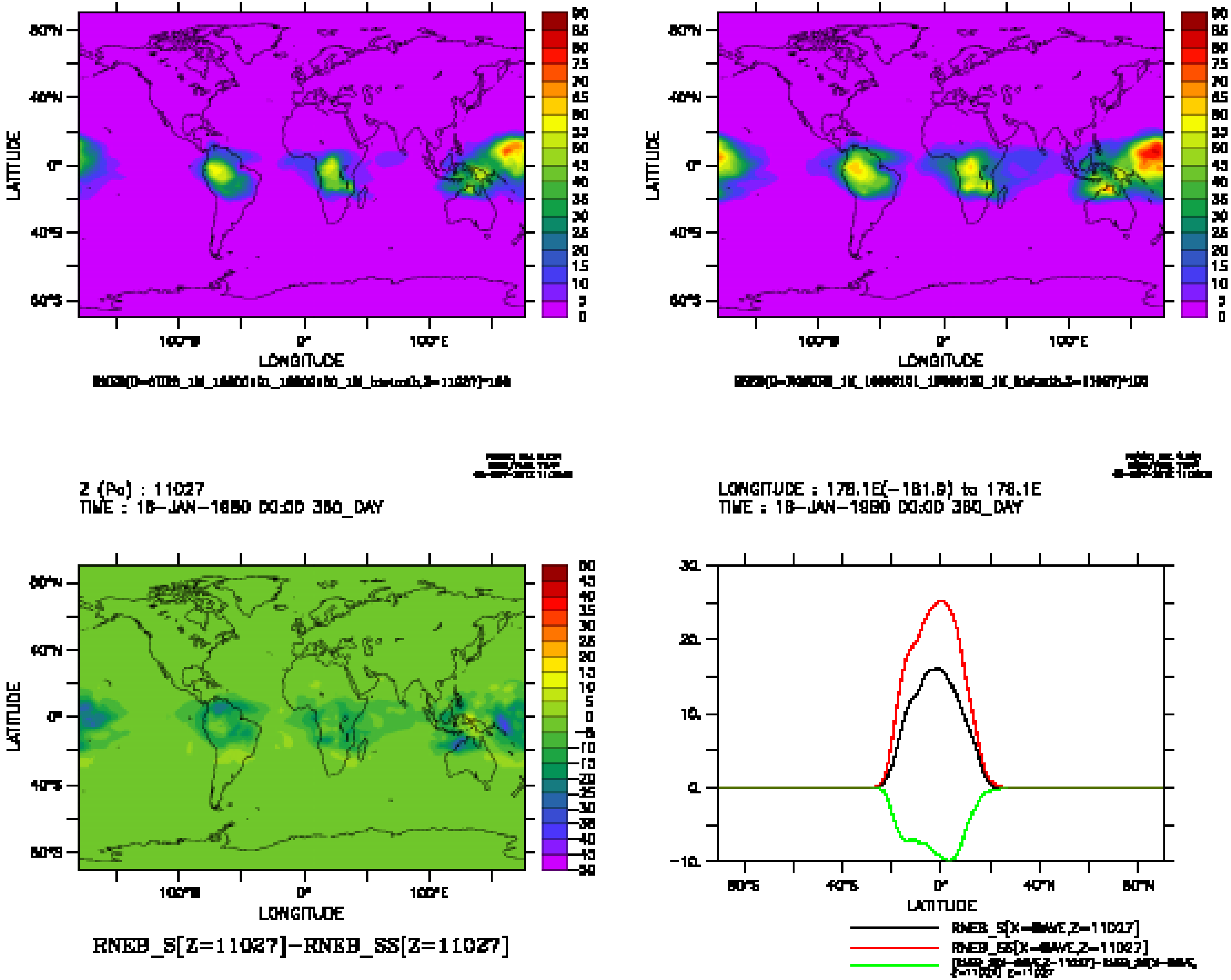




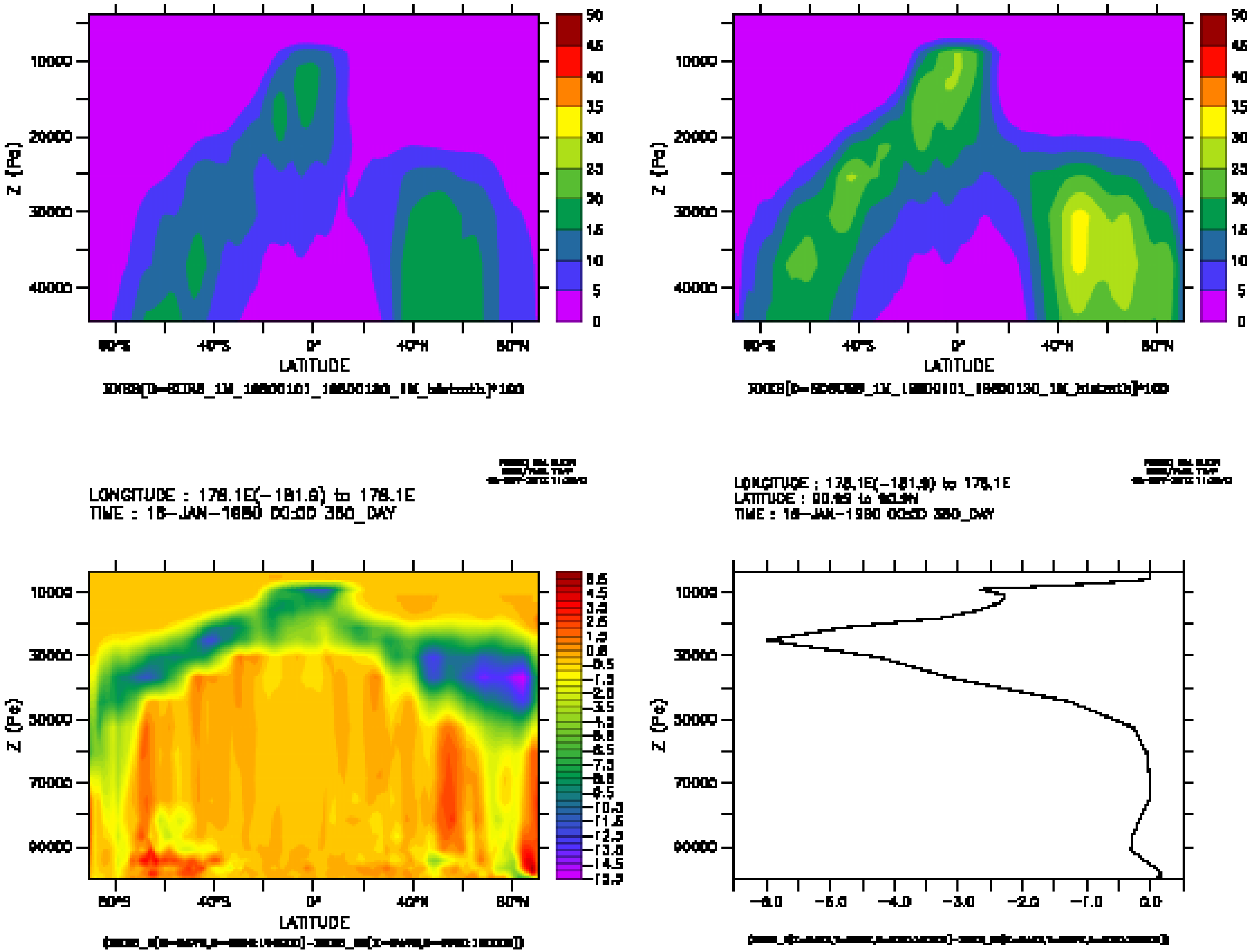


The supersaturation scheme only affects ice clouds.

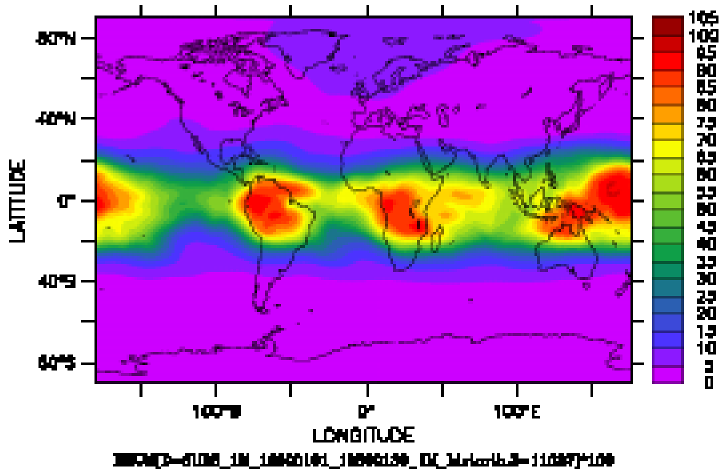
Effect of the supersaturation scheme on the cloud cover at 110 hPa

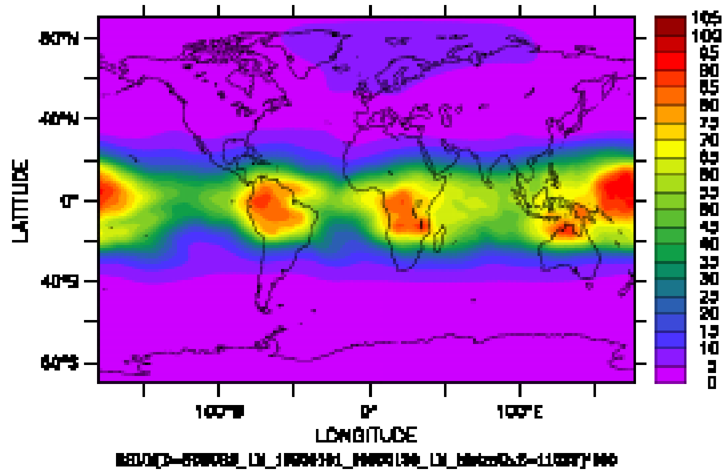


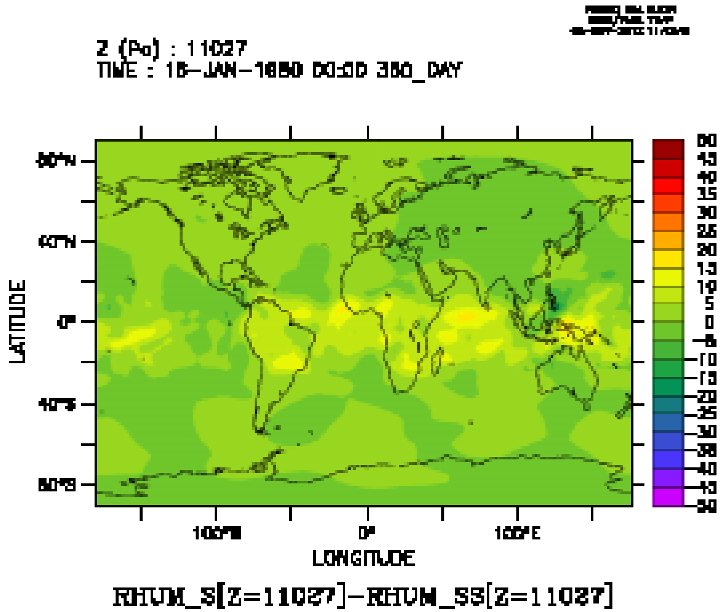
Effect of the supersaturation scheme on the vertical profiles of cloud cover

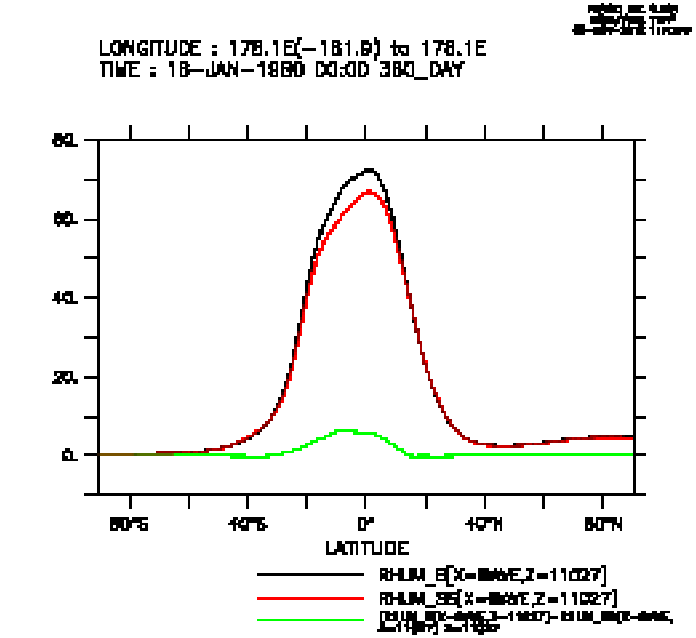


Effect of the supersaturation scheme on the relative humidity at 110 hPa

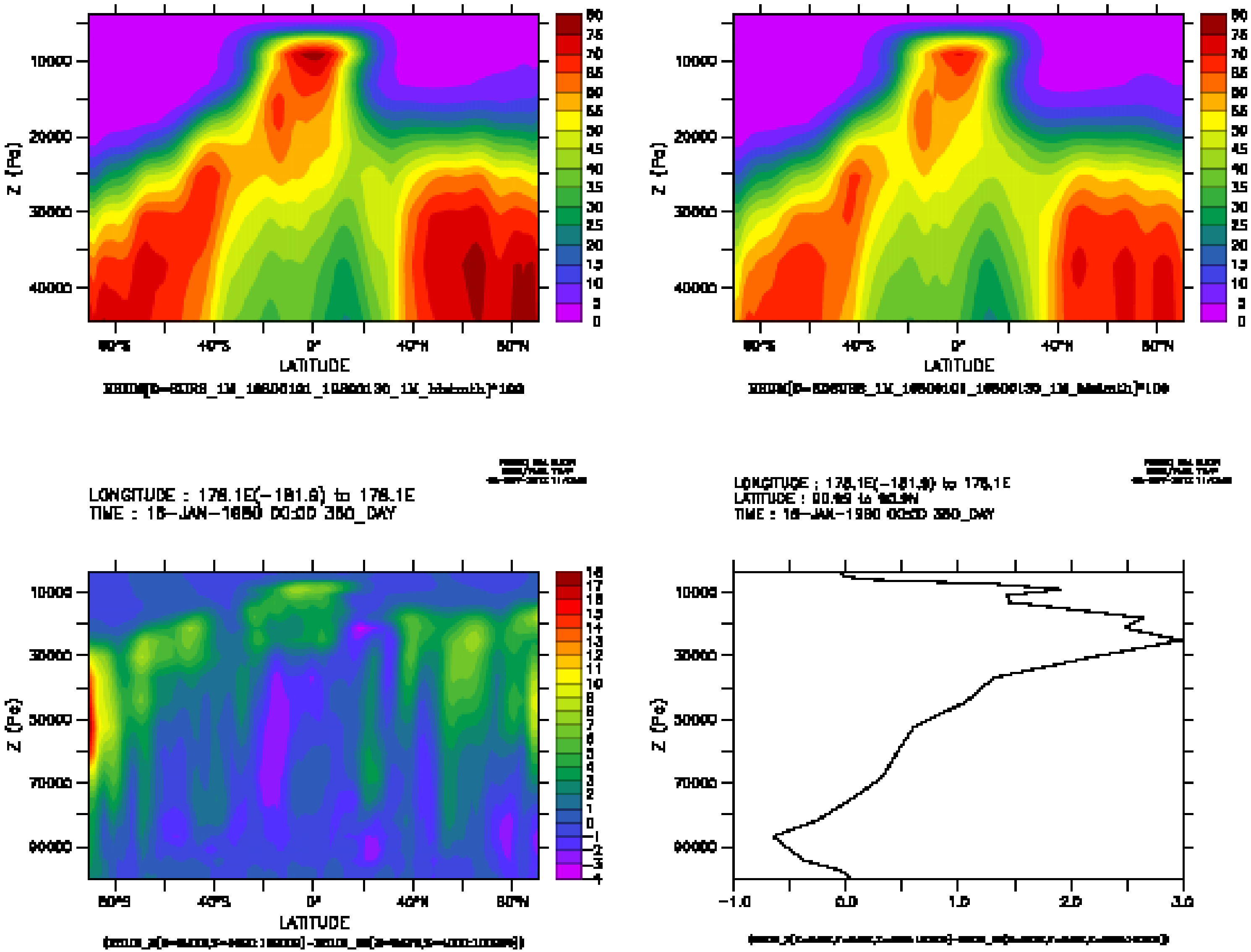








Effect of the supersaturation scheme on the vertical profiles of relative humidity

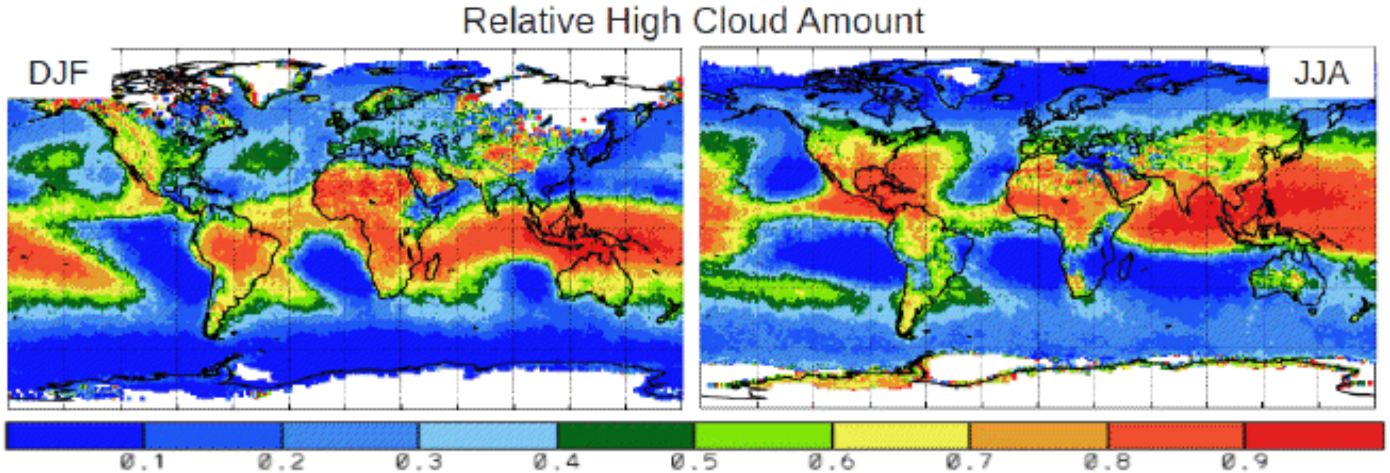


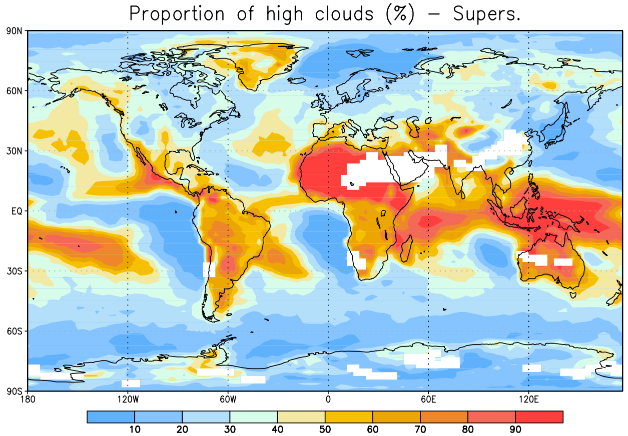
Proportion de nuages hauts

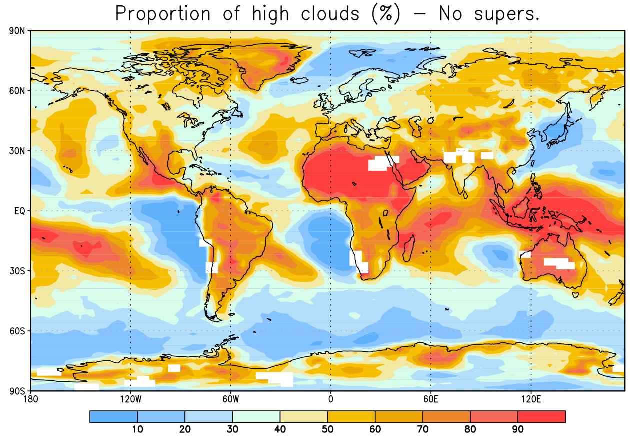
Winter	Tropics	NH	SH
No supersaturation NP	59%	43%	27%
Supersaturation NP	55%	31%	23%
No supersaturation OP	69%	57%	34%
Supersaturation OP	65%	44%	28%
Guignard et al.	62%	31%	14%

Summer	Tropics	NH	SH
No supersaturation NP	55%	44%	36%
Supersaturation NP	49%	37%	26%
No supersaturation OP	66%	43%	44%
Supersaturation OP	59%	37%	35%
Guignard et al.	58%	32%	28%

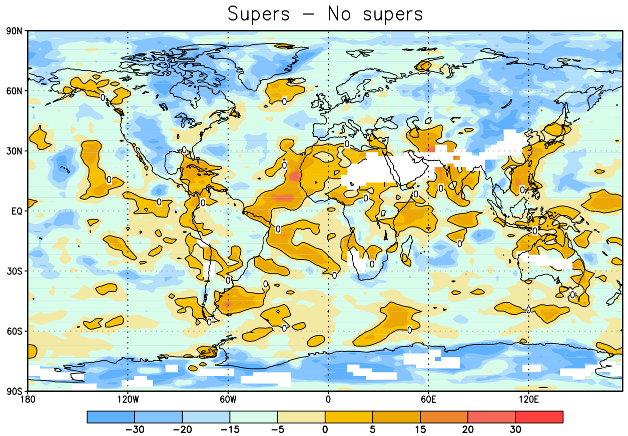
Nouvelle physique et ancienne physique: trop grande proportion de nuages hauts aux moyennes latitudes, corrige par la sursaturation
Dans les Tropiques, plus faible proportion de nuages hauts dans la nouvelle physique que dans l'ancienne

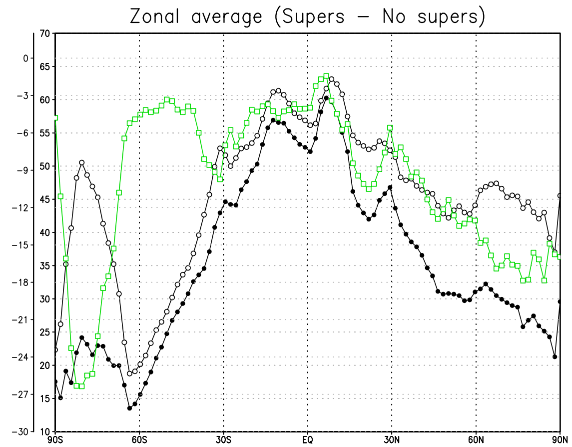


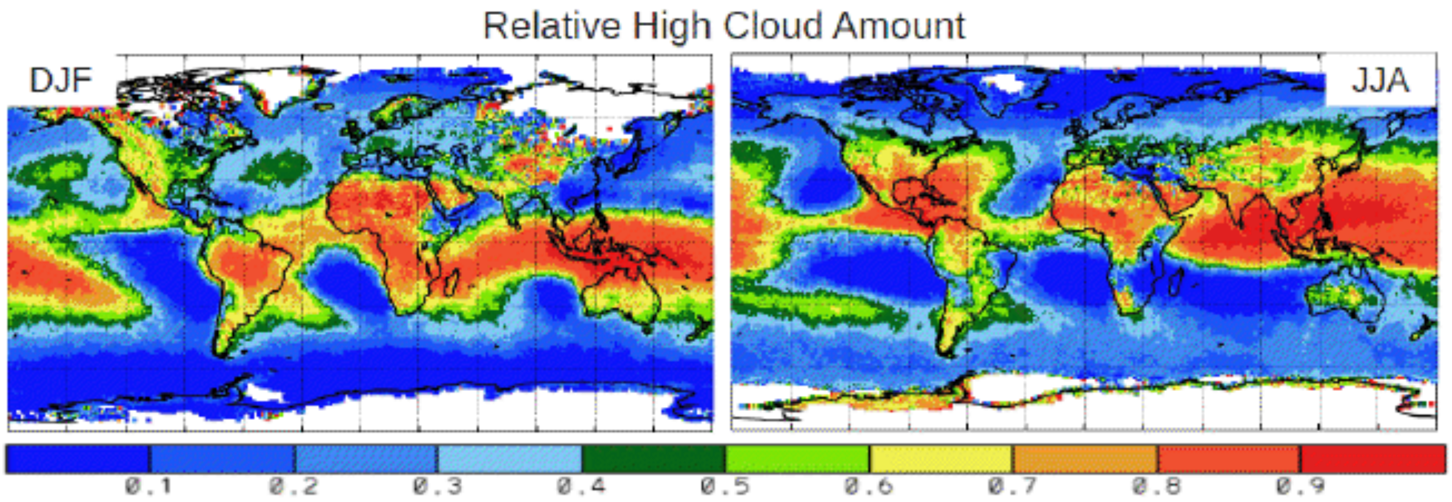


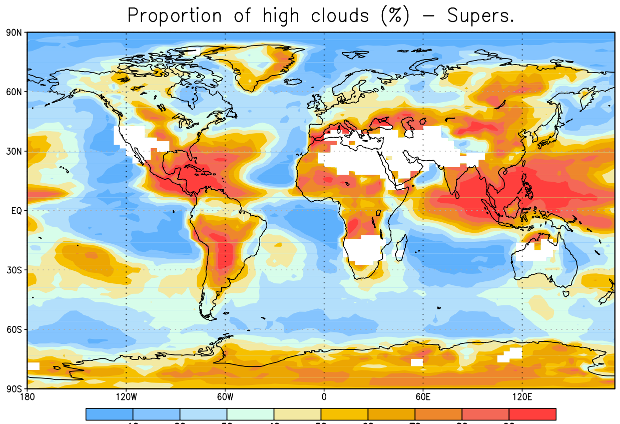


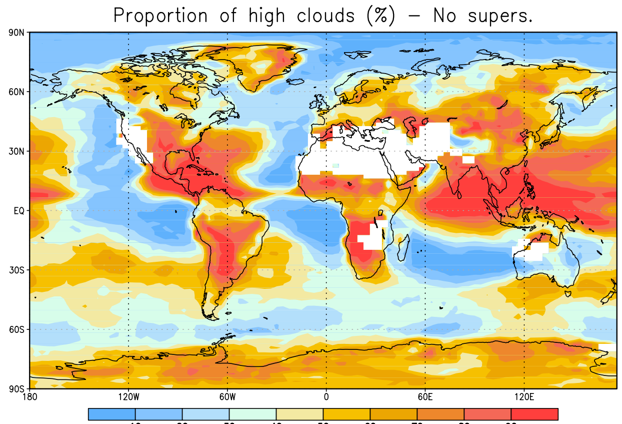
Nouvelle physique Hiver



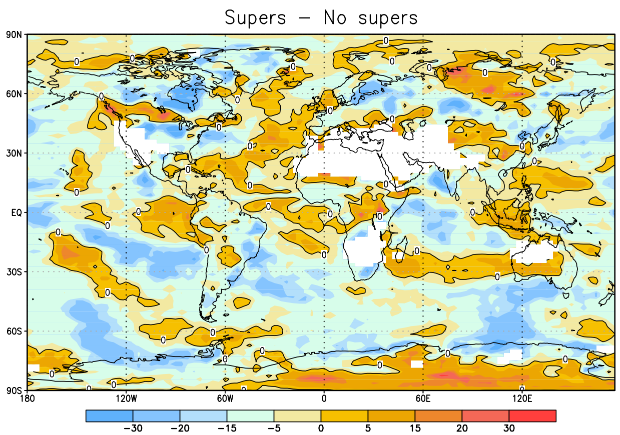


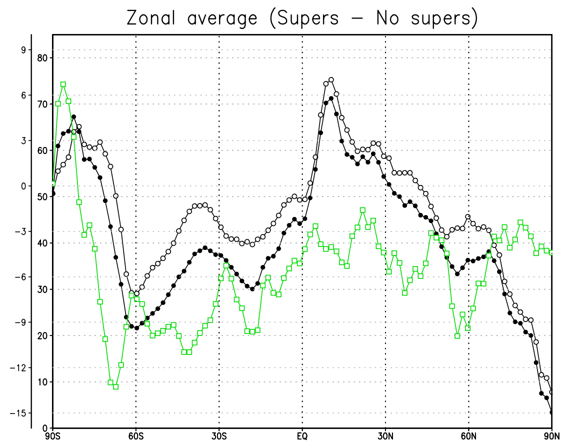






Nouvelle physique Ete





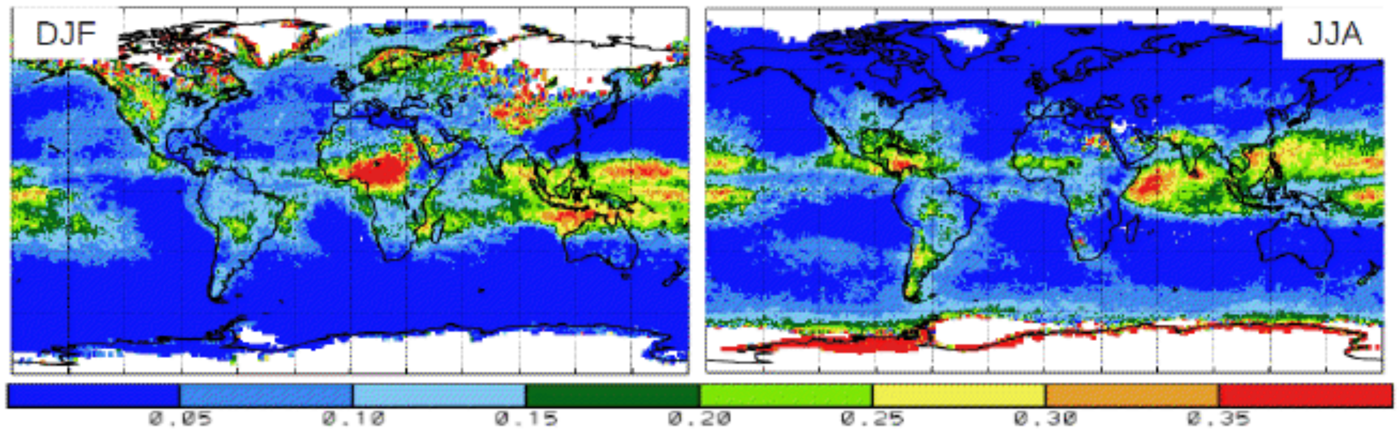
Proportion de nuages hauts de glace et semi-transparents

Winter	Tropics	NH	SH
No supersaturation NP	23%	17%	7%
Supersaturation NP	18%	10%	2%
No supersaturation OP	24%	18%	8%
Supersaturation OP	24%	10%	2%
Guignard et al.	18%	15%	1%

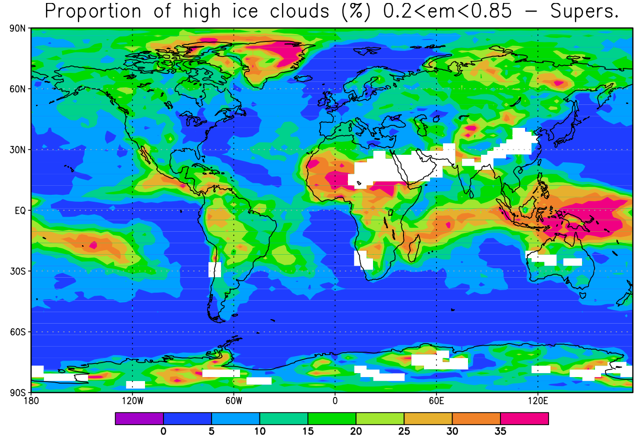
Summer	Tropics	NH	SH
No supersaturation NP	22%	14%	12%
Supersaturation NP	17%	6%	7%
No supersaturation OP	24%	12%	11%
Supersaturation OP	24%	4%	6%
Guignard et al.	15%	4%	12%

Avec la sursaturation, diminution des nuages hauts de glace ST, en accord avec les donnees AIRS

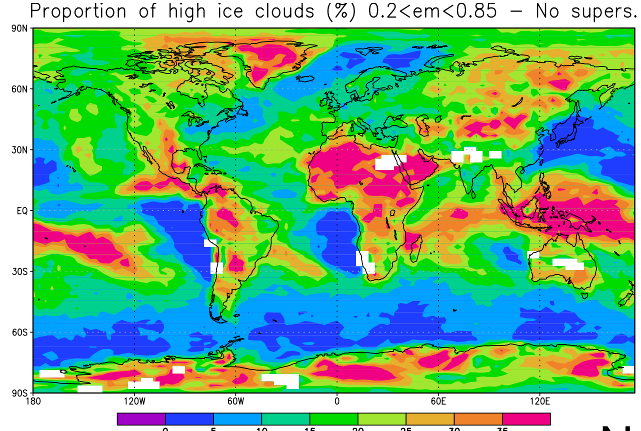
Relative Semi-Transparent High Ice Cloud Amount



Proportion of high ice clouds (%) 0.2<em<0.85 – Supers.

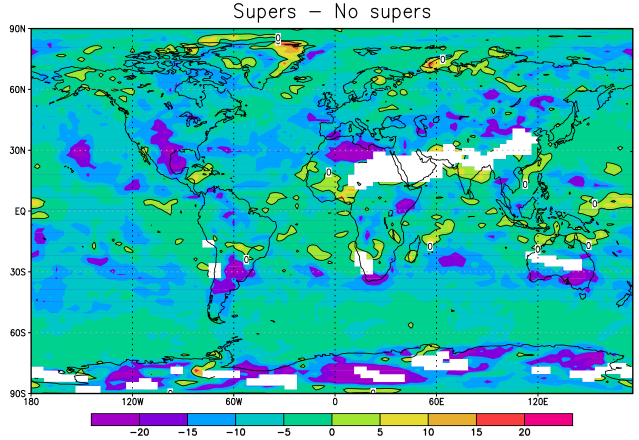


Proportion of high ice clouds (%) 0.2<em<0.85 – No supers.

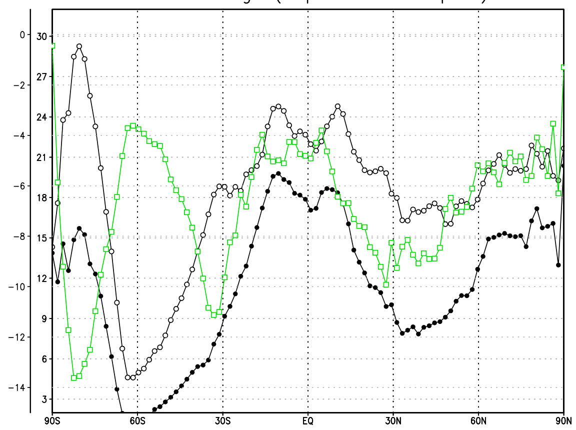


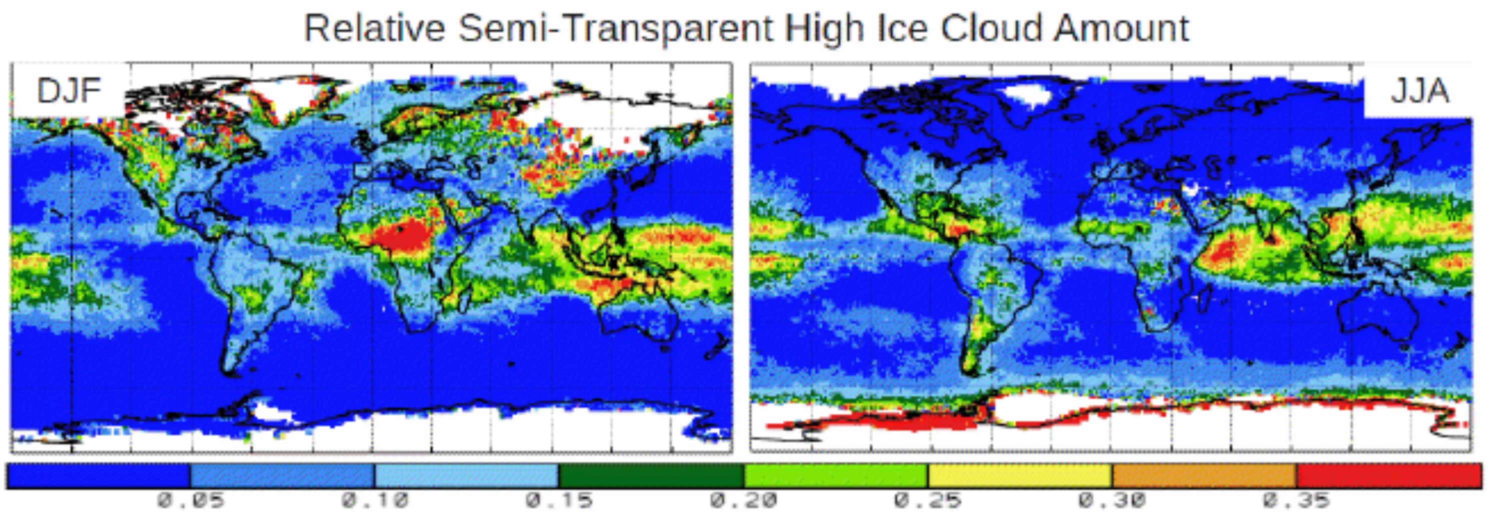
Nouvelle physique Hiver

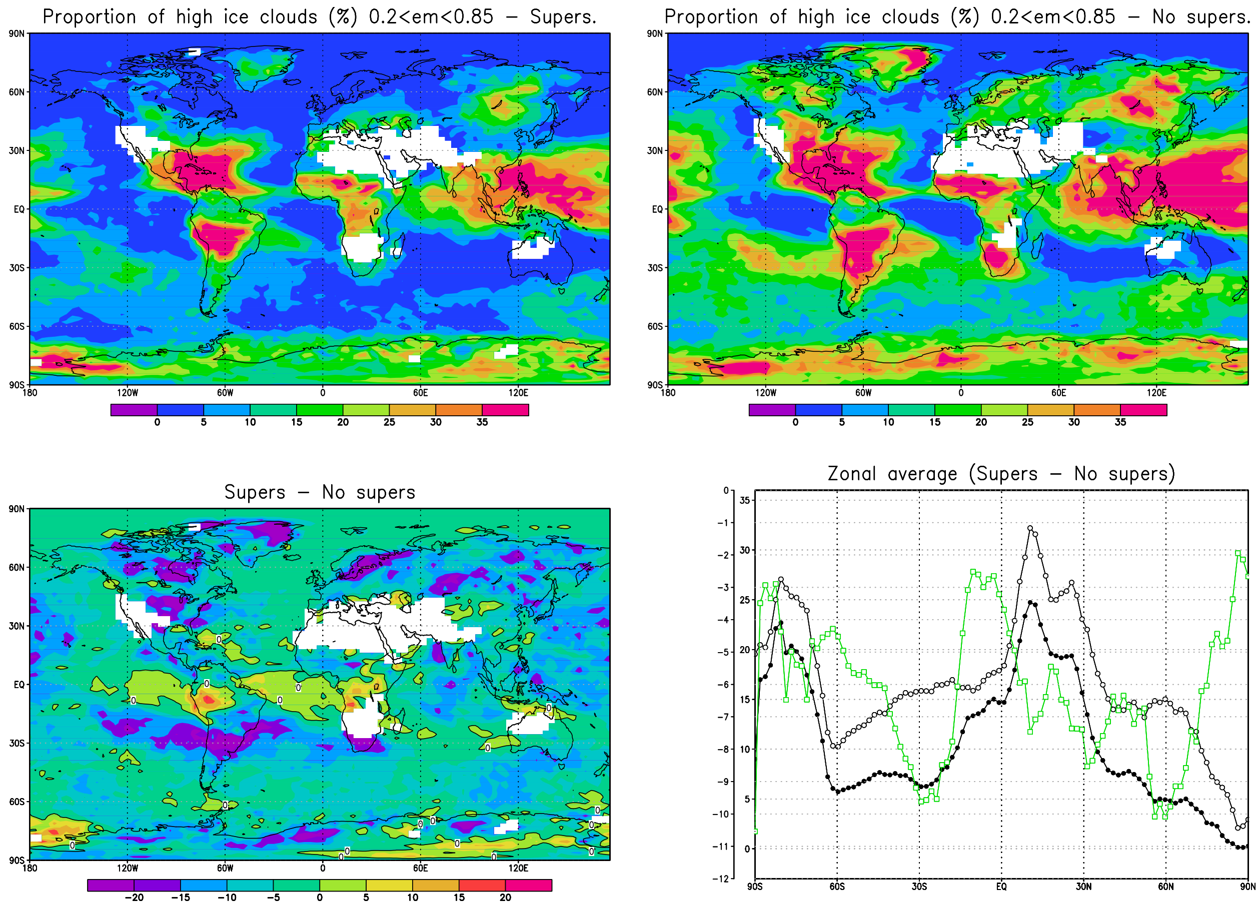
Supers – No supers



Zonal average (Supers – No supers)

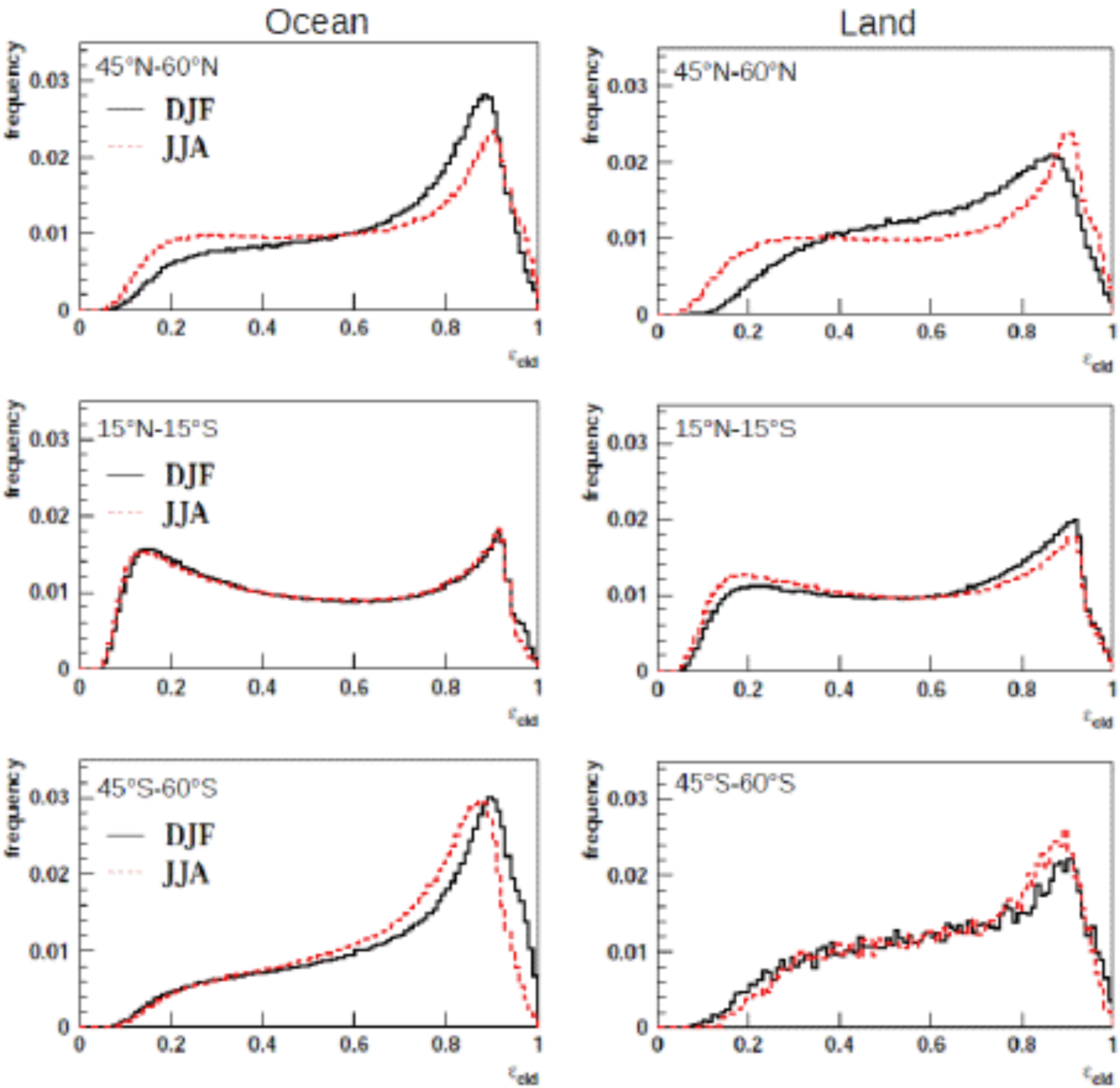




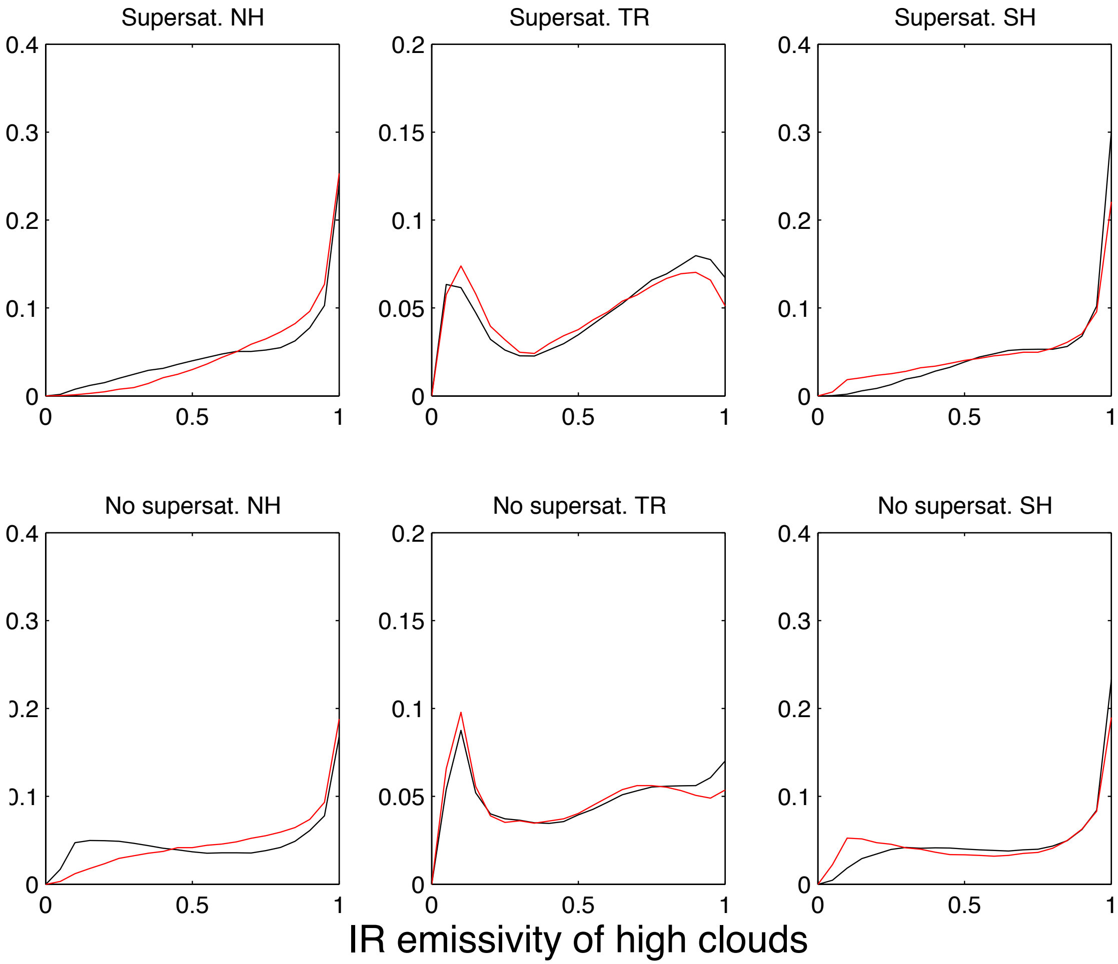


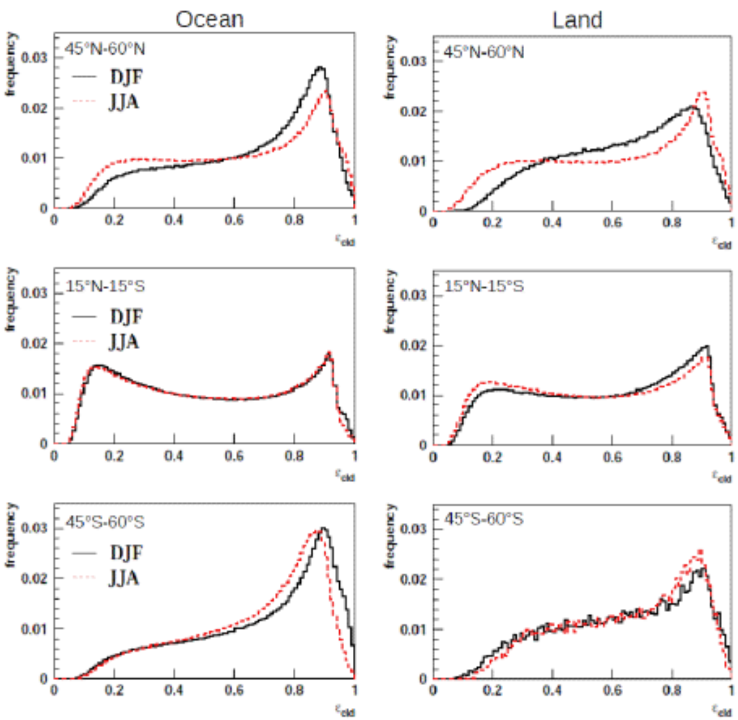
Nouvelle physique Ete

Cloud emissivities in LMDZ and AIRS data



Nouvelle physique





Epaisseur des nuages hauts de glace et semi-transparents

Winter	Tropics	NH	SH
No supersaturation NP	4101	3597	2776
Supersaturation NP	3289	2221	1869
No supersaturation OP	3667	2558	2043
Supersaturation OP	2943	1896	1593
Guignard et al.	4900	5500	5000

Summer	Tropics	NH	SH
No supersaturation NP	4023	2527	3318
Supersaturation NP	3004	1776	2445
No supersaturation OP	3488	2055	2532
Supersaturation OP	2678	1583	2044
Guignard et al.	4500	3800	5900

Dans la nouvelle physique, augmentation de l'epaisseur geometrique des nuages en accord avec les observations
La sursaturation affine les nuages: pas en accord avec les obs.

Sensitivity to microphysical processes

$$wv_{strato} = (1 - f_{tropo}).wv_{[CH_4]} + f_{tropo}.\underbrace{[wv(T_{TTL}) + wv_{con} + wv_{ov} + wv_{\mu\varphi}]}_{wv_{tropo}}$$

1. Sensitbilite a la temperature du changement de phase glace/eau liquide
2. Sensibilite a la sursaturation
3. Overshoots

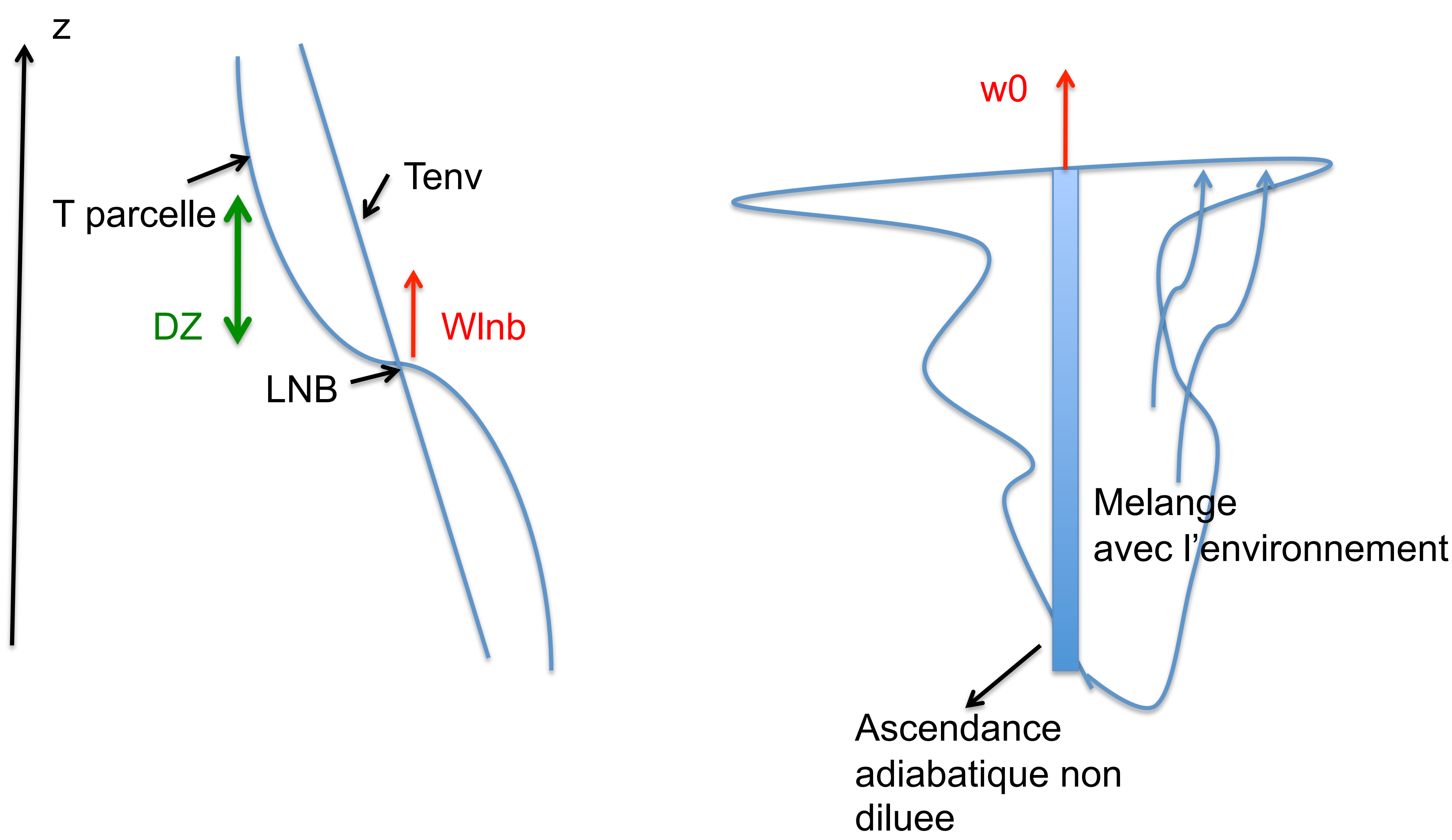
Liu and Zipser, JGR, 2005:

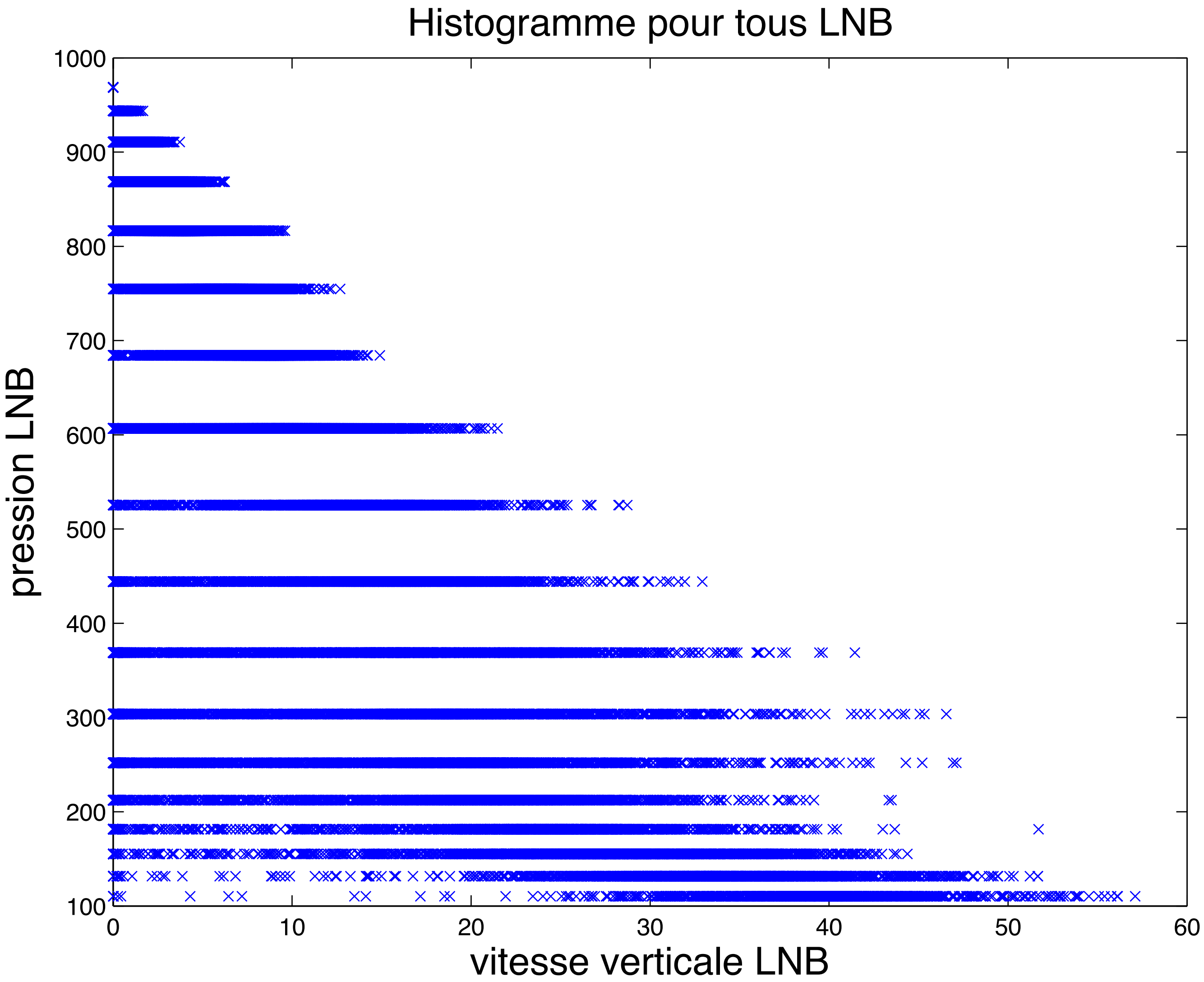
Tropical deep convection with overshooting tops is identified by defining 5 different reference heights using a 5-year TRMM database.

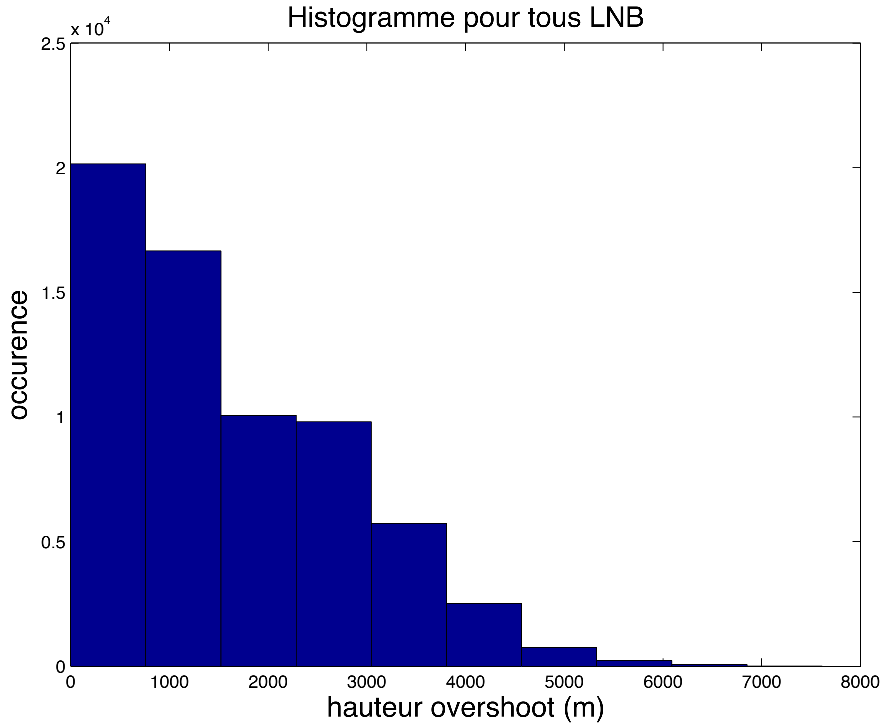
Population percentage: 0.54%
Mean overshooting distance (km): 1.14
Mean overshooting area (km2): 288 -> diametre de 19 km

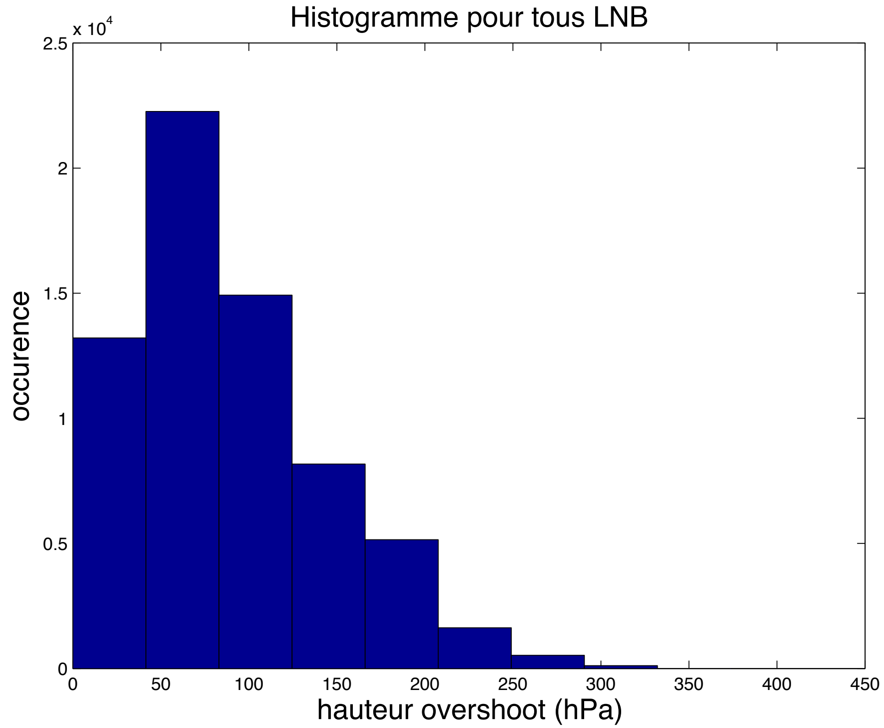
Overshooting mainly in the Tropics over continents.

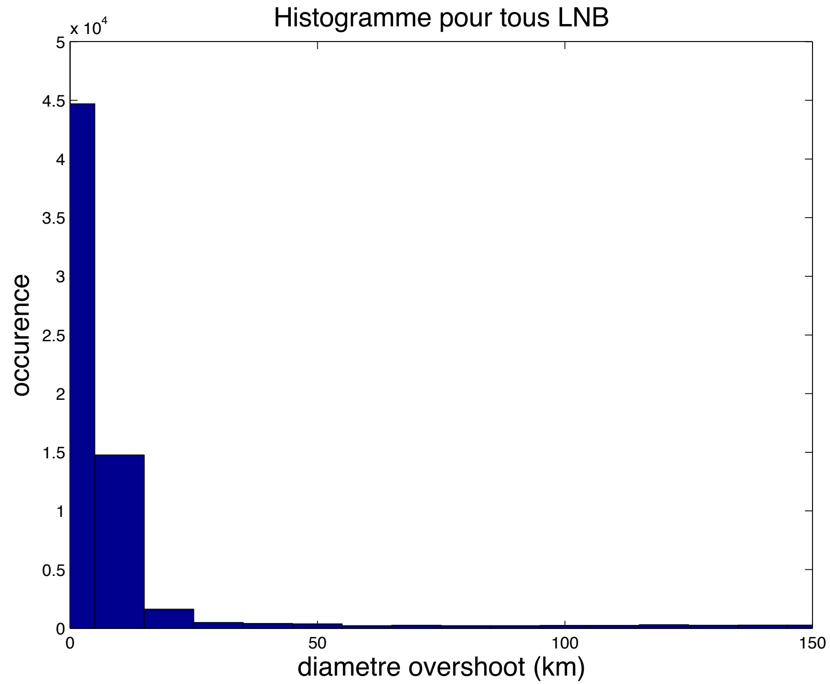
Schema de convection d'Emanuel

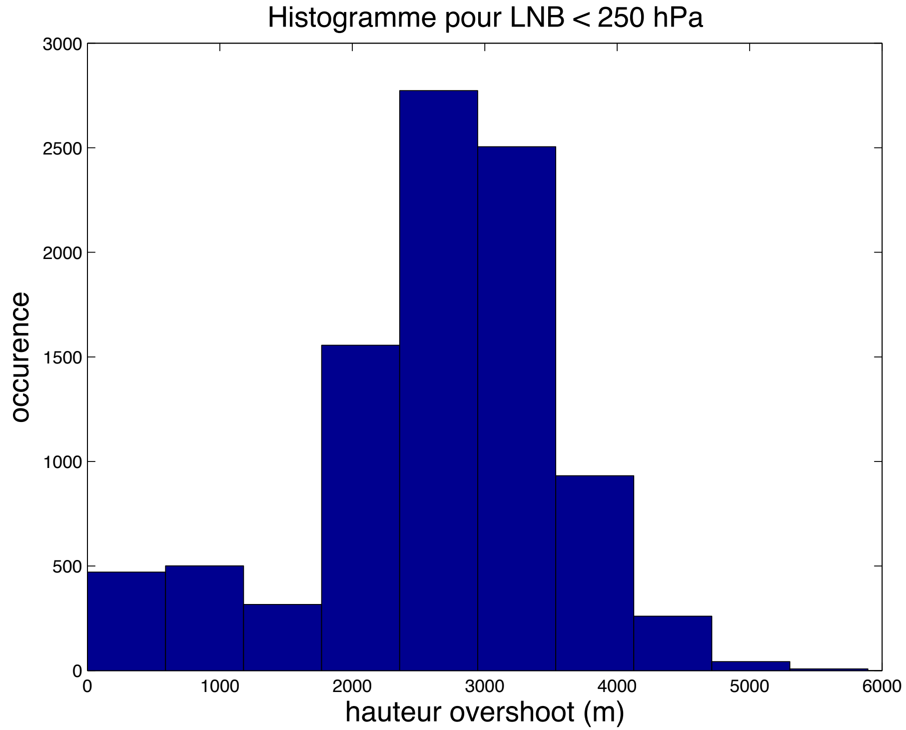


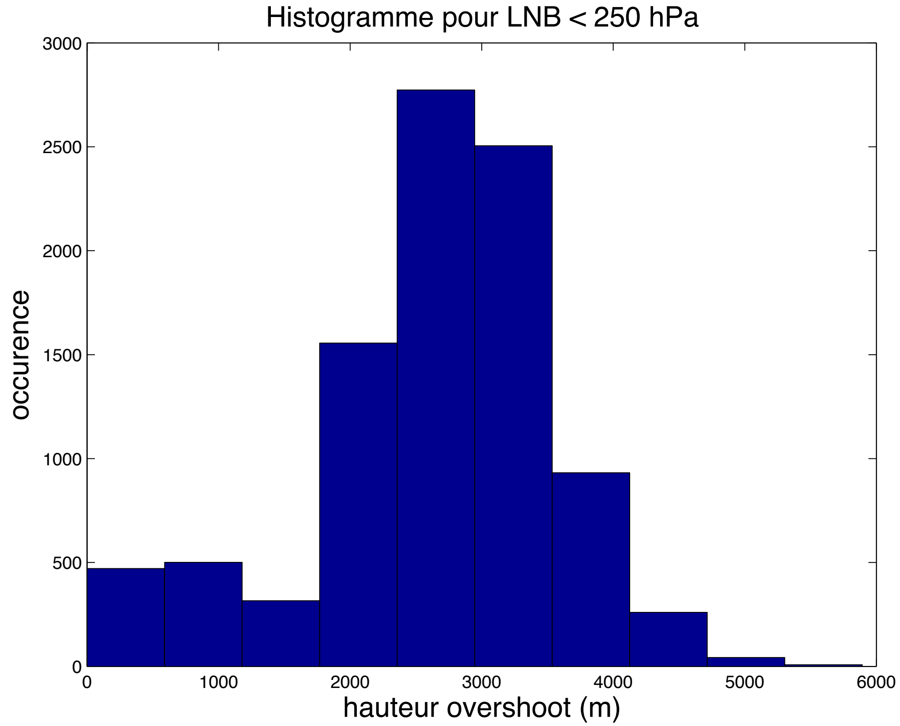

Histogramme pour tous LNB
pression LNB
vitesse verticale LNB
1000
900
800
700
600
500
400
300
200
100
0
10
20
30
40
50
60

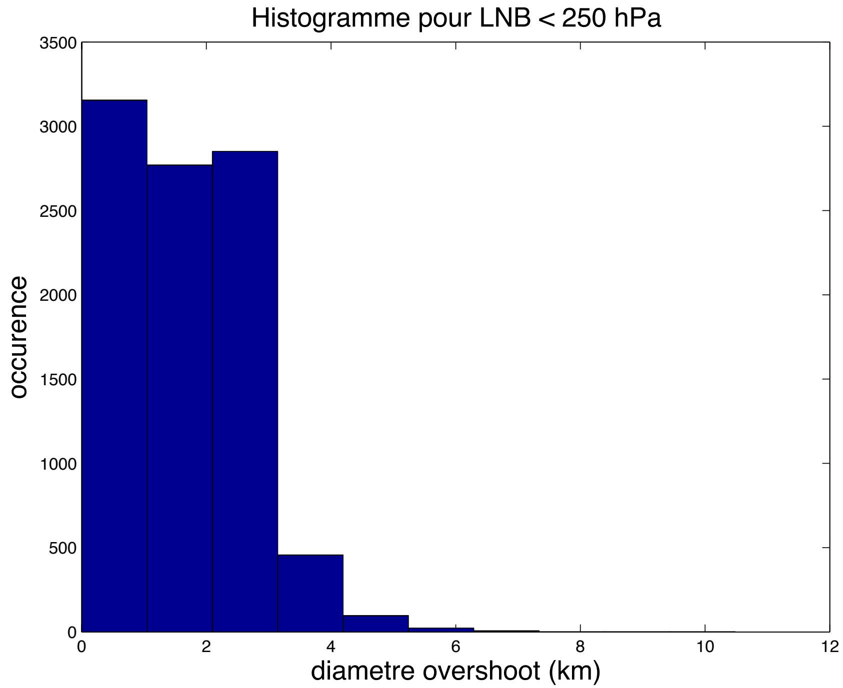

Histogramme pour tous LNB
x 10^4
occurence
hauteur overshoot (m)
0 1000 2000 3000 4000 5000 6000 7000 8000
0 0.5 1 1.5 2 2.5

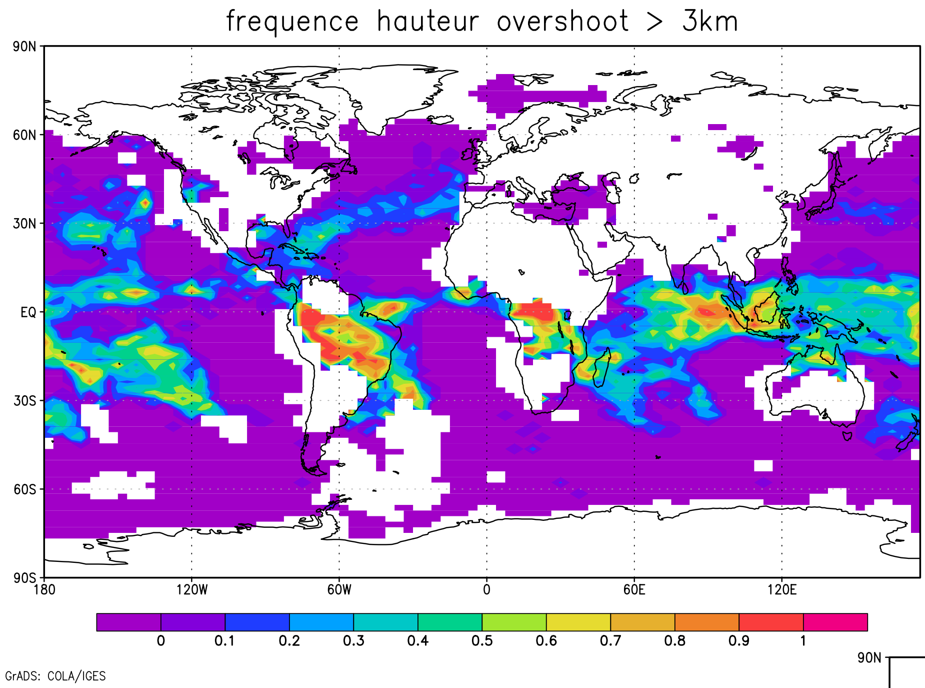

Histogramme pour tous LNB
x 10^4
occurence
hauteur overshoot (hPa)
0 50 100 150 200 250 300 350 400 450
0 0.5 1 1.5 2 2.5

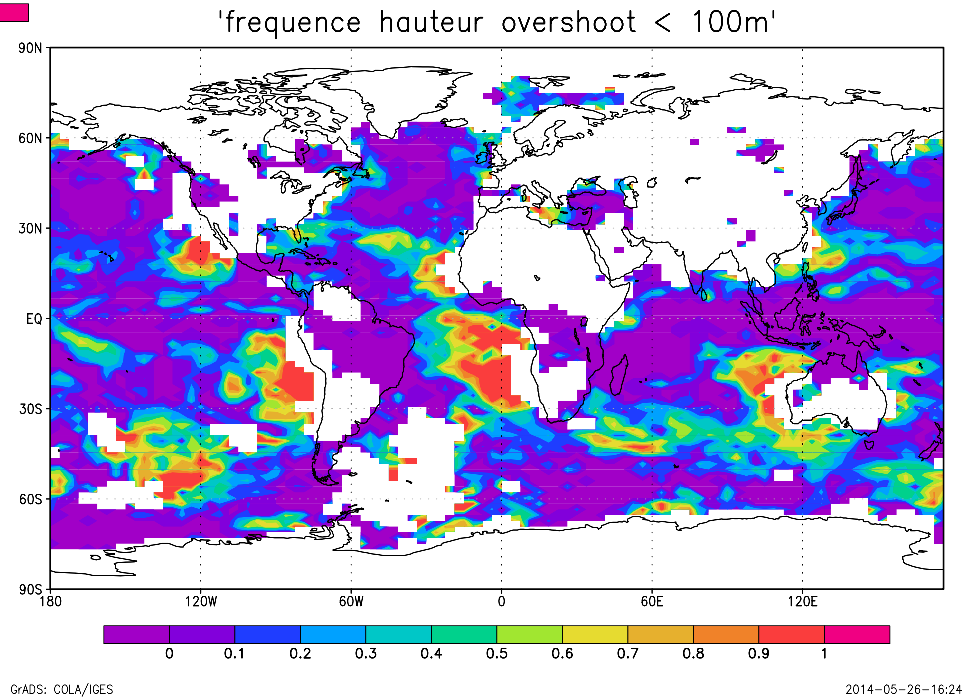

Histogramme pour tous LNB
x 10^4
occurence
diametre overshoot (km)
0 50 100 150
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5


Histogramme pour LNB < 250 hPa
occurence
hauteur overshoot (m)
0
500
1000
1500
2000
2500
3000
0
1000
2000
3000
4000
5000
6000


Histogramme pour LNB < 250 hPa
occurence
hauteur overshoot (m)
0
500
1000
1500
2000
2500
3000
0
1000
2000
3000
4000
5000
6000


Histogramme pour LNB < 250 hPa
occurence
diametre overshoot (km)
0
500
1000
1500
2000
2500
3000
3500
0
2
4
6
8
10
12


frequence hauteur overshoot > 3km
90N
60N
30N
EQ
30S
60S
90S
180
120W
60W
0
60E
120E
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
GrADS: COLA/IGES


'frequence hauteur overshoot < 100m'
90N
60N
30N
EQ
30S
60S
90S
180
120W
60W
0
60E
120E
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
GrADS: COLA/IGES
2014-05-26-16:24

Conclusions

- Reasonable tropo-stratospheric transport in LMDZ
- The air parcels penetrate at the bottom of the TTL in regions of deep convection
- Presence of horizontal transport in the LMDZ TTL.
- 0.6 K cold bias of Lagrangian temperature minima, and a 0.2 ppmv dry bias of the amount of water vapour at the entry of the TTL.
- Phase temperature change slightly decreases IWP in midlatitudes, high cloud cover is too large in midlatitudes.
- Supersaturation increases the TTL water vapour of 0.2 ppmv, increases relative humidity of 10 % (consistent with *Tompkins et al. 2007*), reduces cloud fraction in midlatitudes.