

# High clouds in the LMDz climate model: overview & future development

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# High clouds in the LMDz climate model

(1) Formed by large-scale advection and deep convection (anvils) ; in this latter case they

depend on the detrainment of water vapor and maximum **precipitation efficiency**  $\epsilon_{\max}$

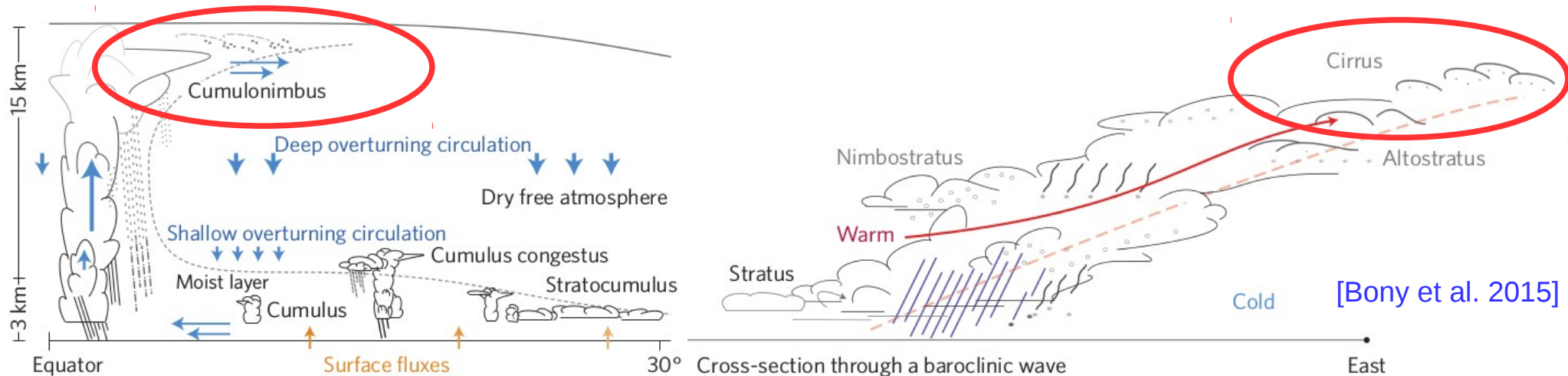
[Emanuel & Živković-Rothman 1999 ; Bony & Emanuel 2001; Rio et al. 2012 ; Grandpeix & Lafore 2010]

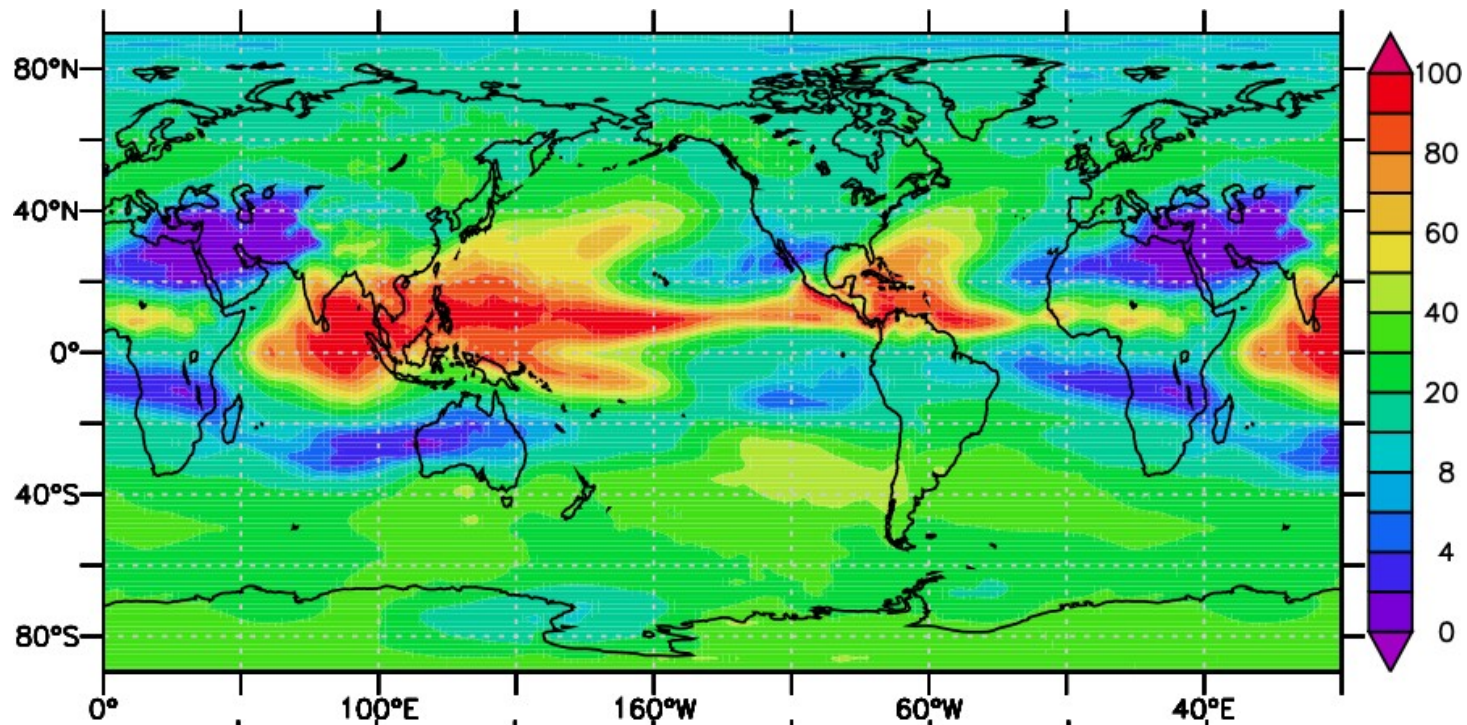
(2) **Phase** based on temperature using  $x_{\text{liq}} = \left( \frac{T - T_{\text{ice}}}{T_0 - T_{\text{ice}}} \right)^{n_x}$

(3) Precipitation mass flux  $(\rho w_{iw} q_{iw})$  computed using **ice particle fall velocity**

$w_{iw} = \gamma_{iw} w_0$  with  $w_0 = 3.29(\rho q_{iw})^{0.16}$  and  $\gamma_{iw}$  a tuning coefficient

[Zender and Kiehl, 1997 ; Heymsfield and Donner, 1990]

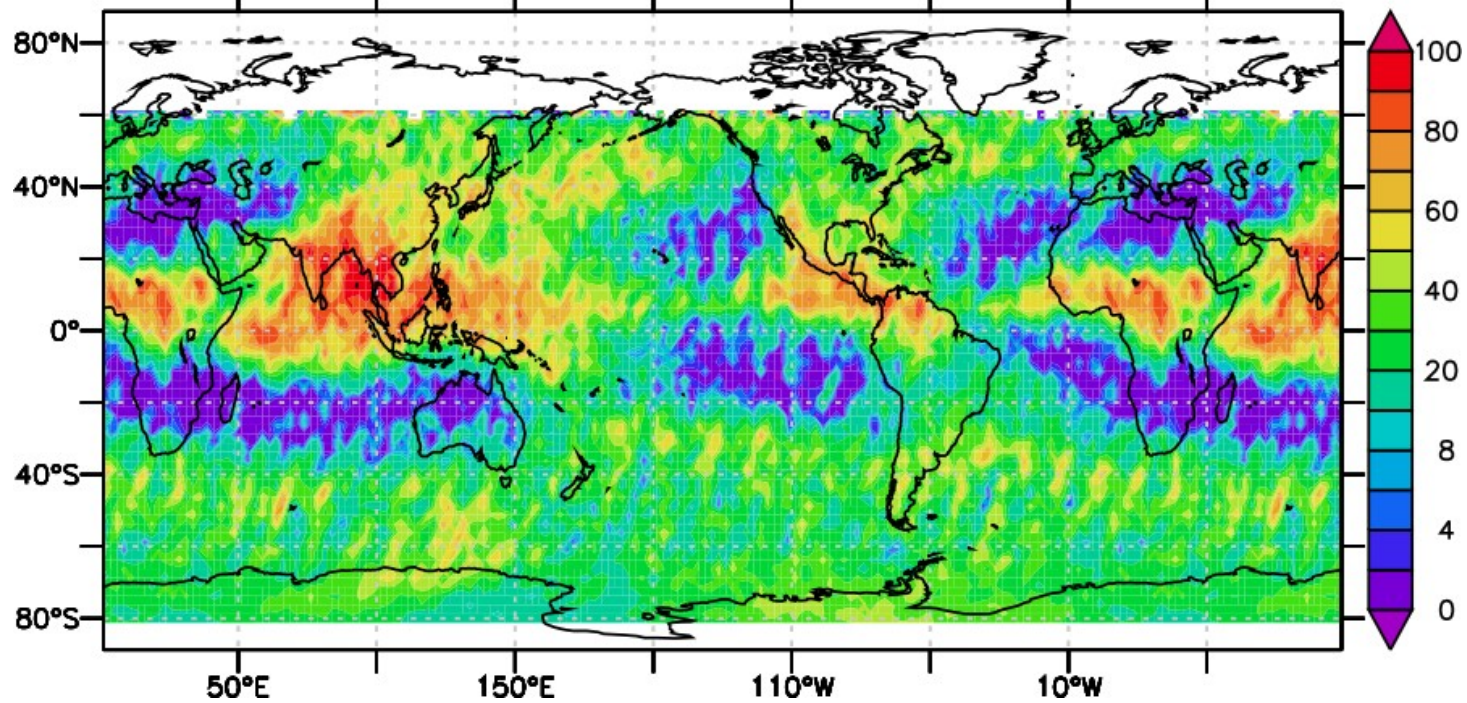




**Cloud fraction of  
high clouds  
( $p < 440\text{hPa}$ )**

**LMDz**

(latest  
development  
version)

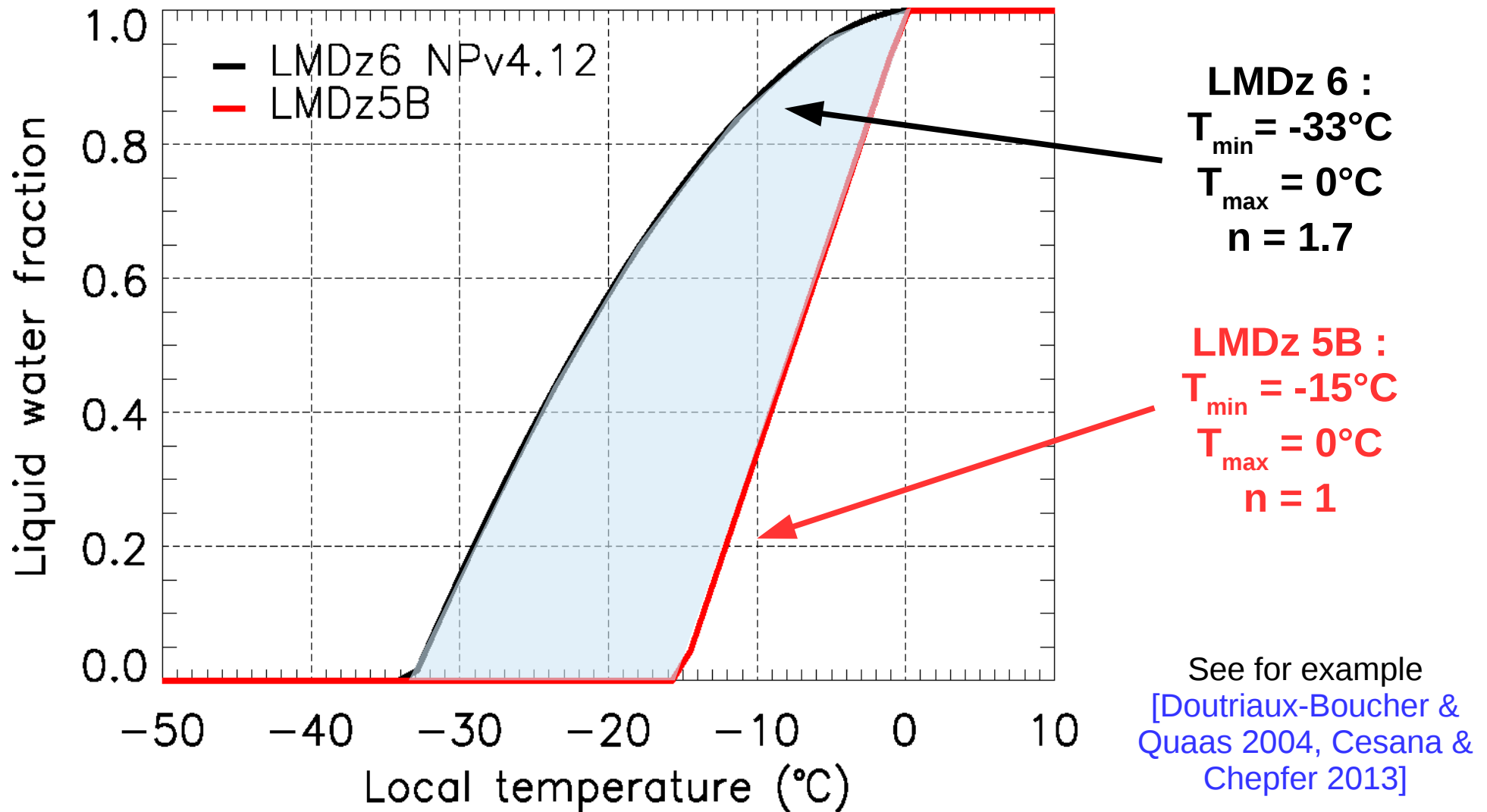


**CALIPSO**

Monthly average  
for July 1982-1989



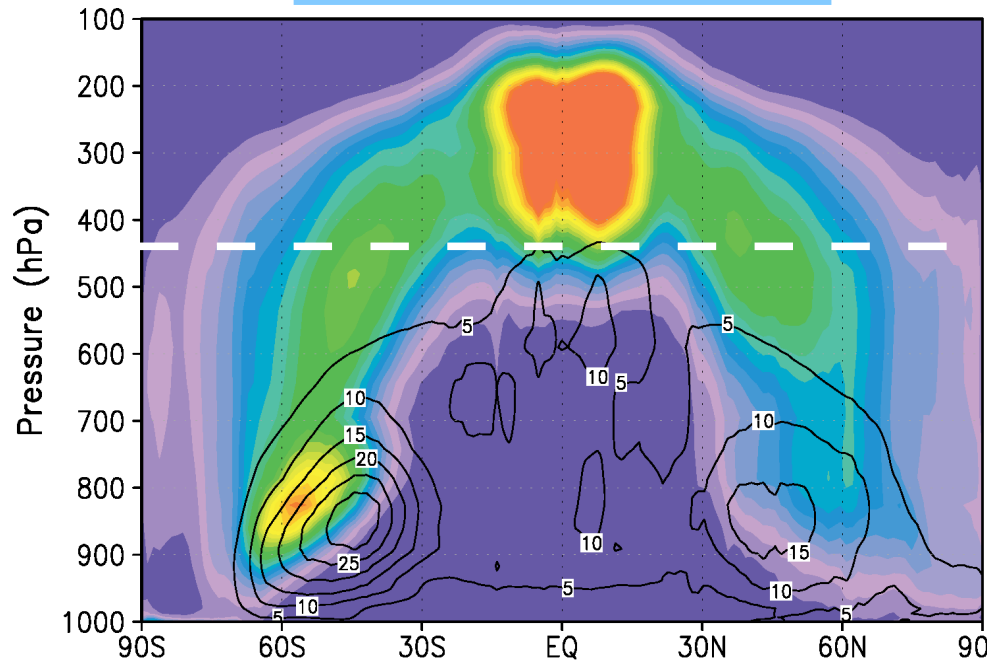
# Parameterization of cloud phase



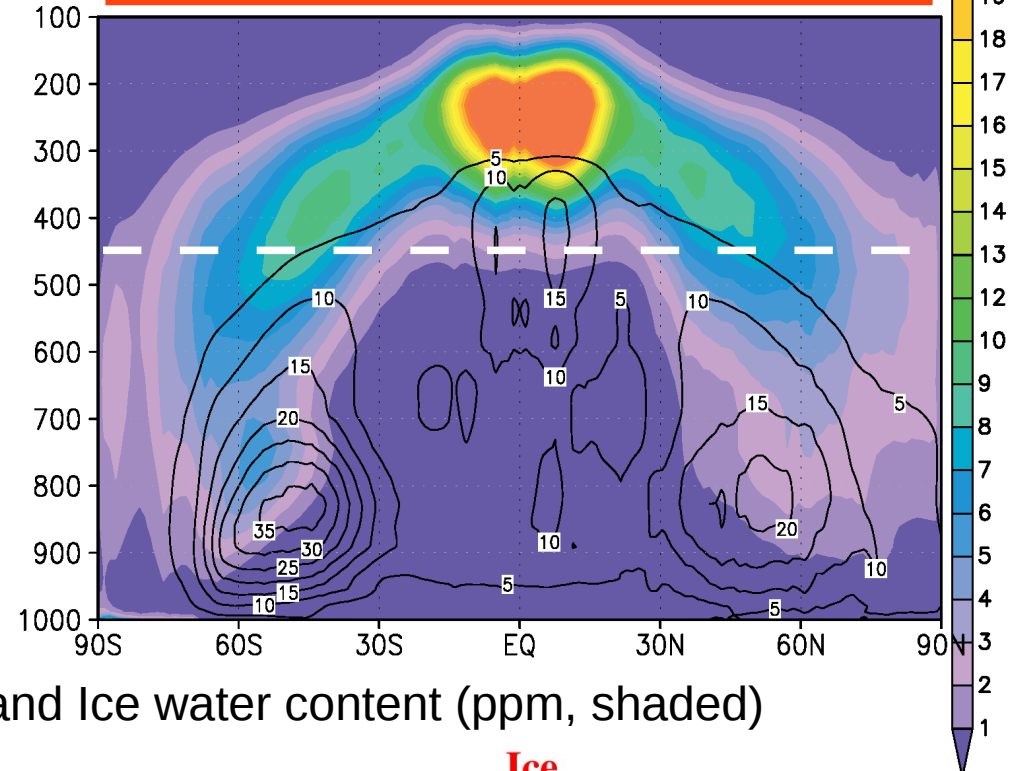
$$\text{Cloud liquid fraction} = \left( \frac{T - T_{\min}}{T_{\max} - T_{\min}} \right)^n, \text{ for } T_{\min} \leq T \leq T_{\max}$$

# Impact on phase distribution

More ice crystals

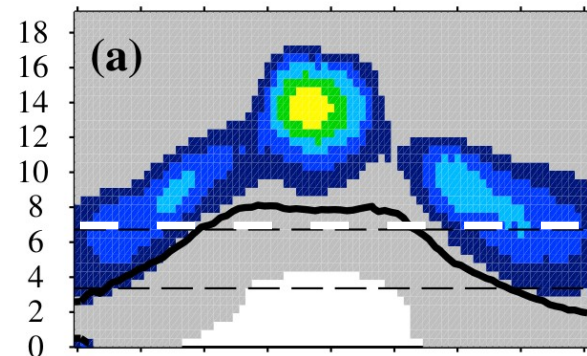


More supercooled droplets



Liquid water content (ppm, contours) and Ice water content (ppm, shaded)

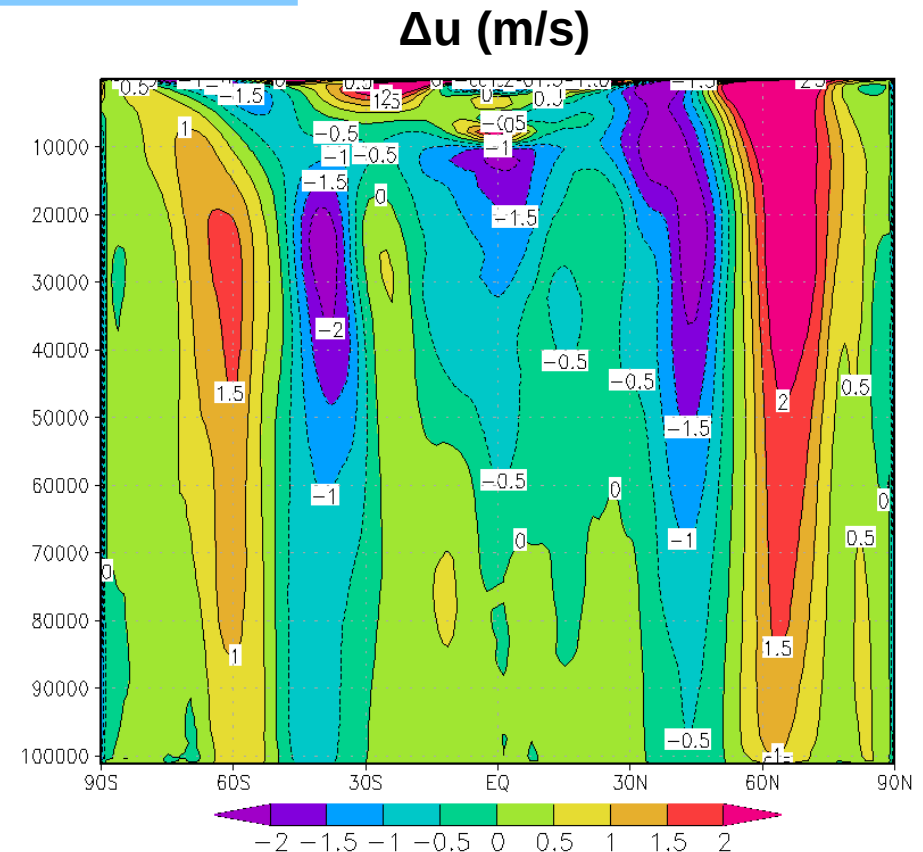
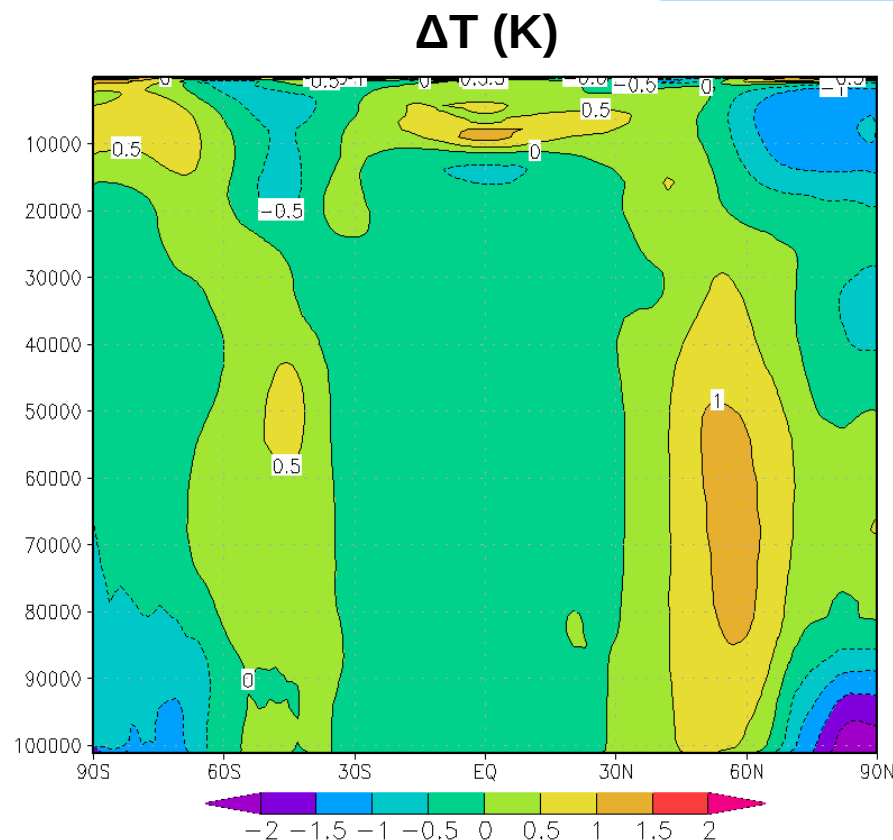
**Ice**



CALIPSO-GOCCP  
[Cesana & Chepfer, 2013]

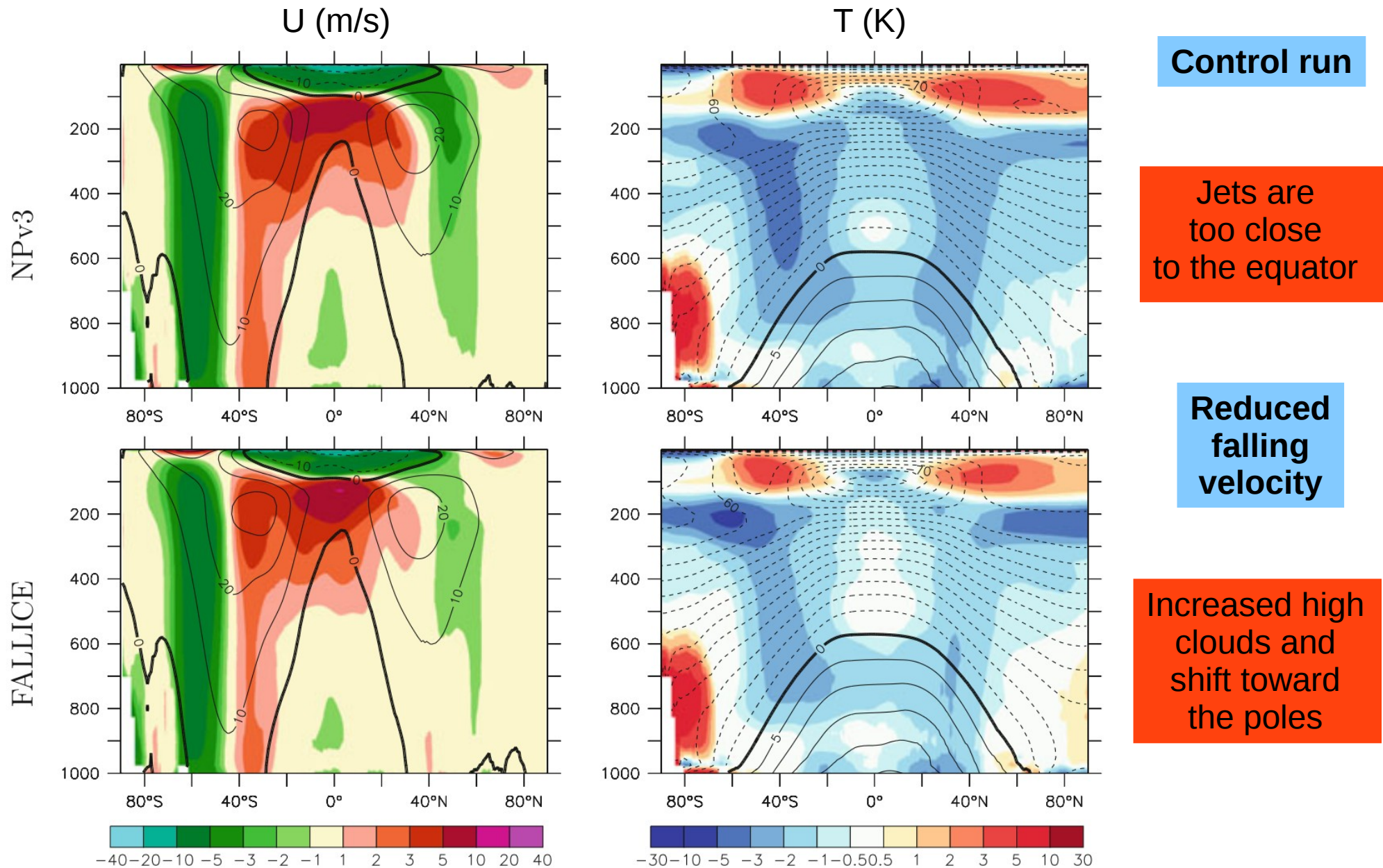
# Impact of cloud phase on thermal structure

More ice crystals



Ice clouds were heating the mid-latitudes  
and moving the jets toward the poles

# Sensitivity to $\gamma_{iw}$ , the ice particle falling velocity



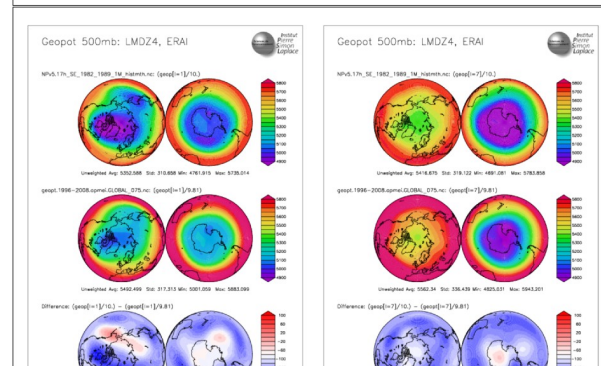
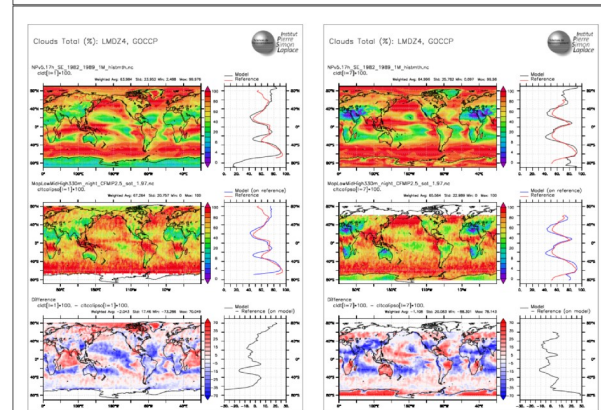
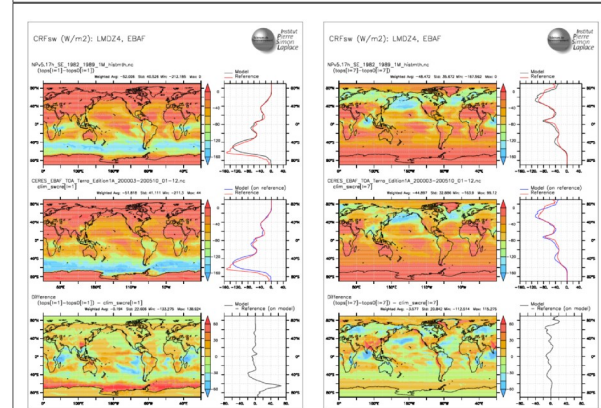
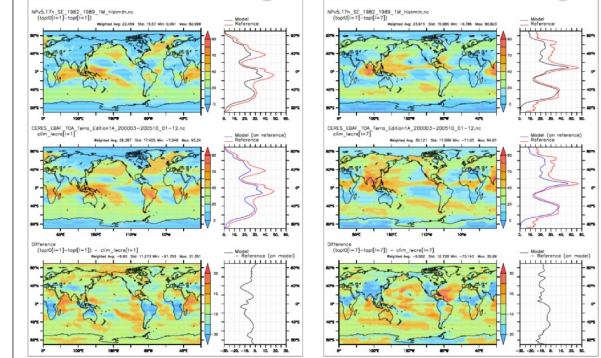
Model results (contours) and biases compared to ERA-interim

[Hourdin et al, 2013]



# New diagnostics

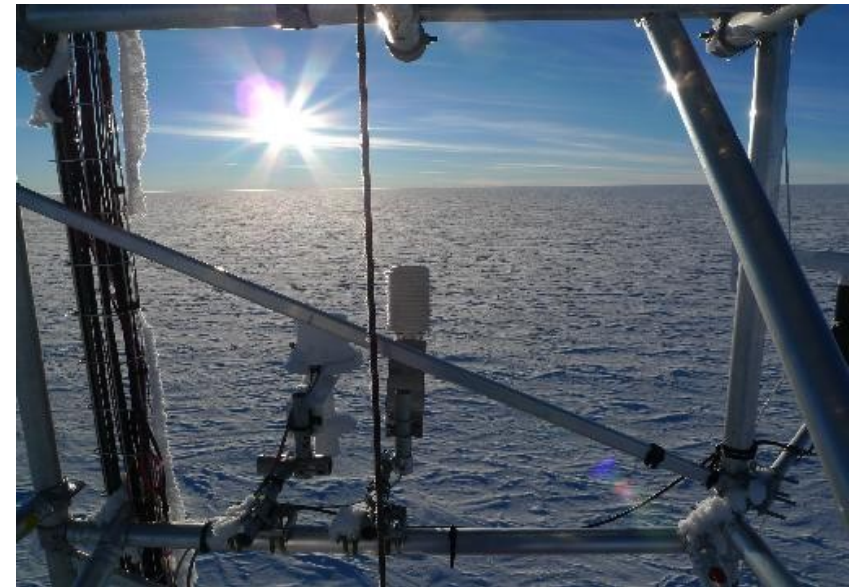
- **High sensitivity** of the whole dynamics to the amount and properties of high clouds
- Work is underway to develop **new diagnostics** for model development and tuning :
  - **AIRS** data (see talk by M. Bonazzola)
  - **CALIPSO-CloudSat** (phase, vertical structure, heating rates, cloud lifetime...) [[Cesana & Chepfer 2013](#), [Konsta et al. 2011](#),...]
  - ...





# Ongoing and future developments

- **Measurement and parameterization of supersaturation** (starting in polar regions, e.g. Antarctica)
- Beginning of a PhD project on **high cloud subgrid-scale inhomogeneity** (Jean Jouhaud)
- Improvement of **ice particle sizes** and parameterization of **solid precipitation**



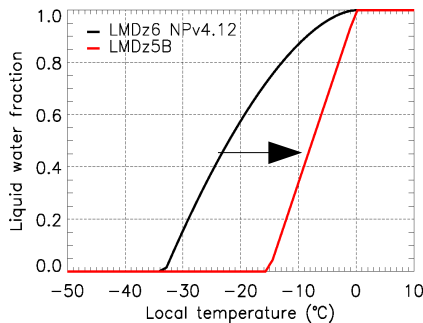
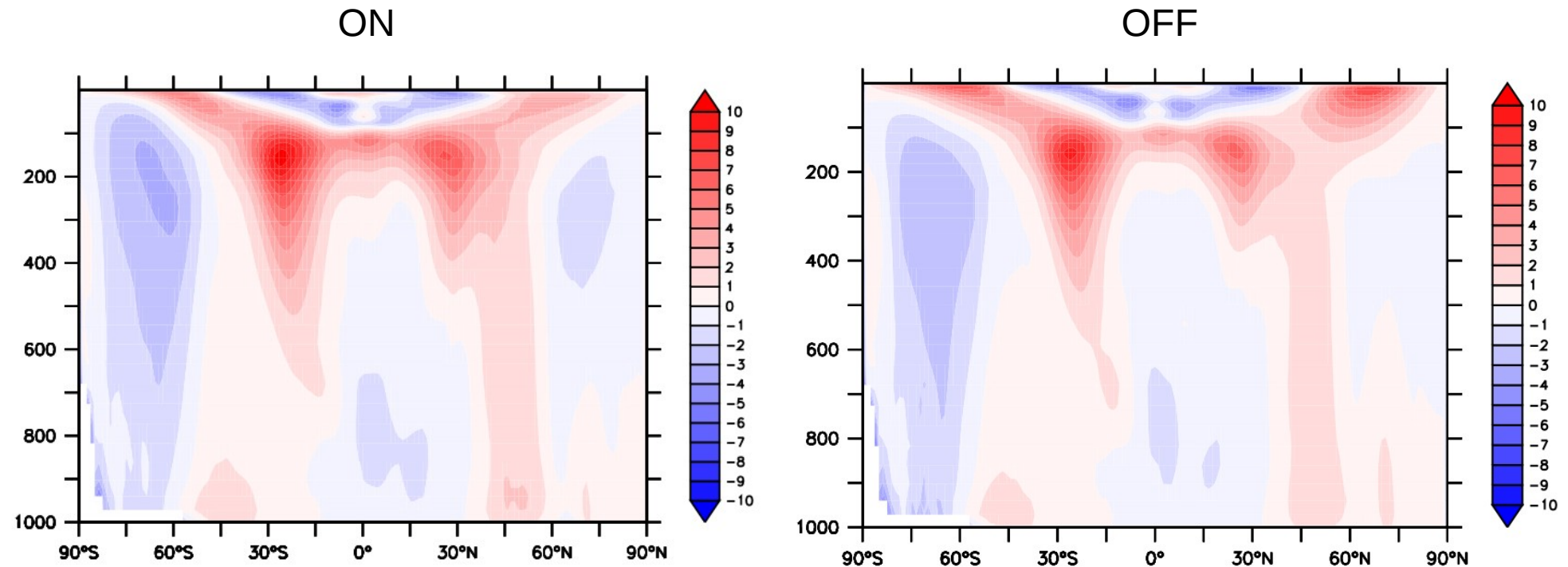
Dome C, Antarctica  
view from the mast (E. Brun)

Backup slides

# Cas de la version NPv5.17c

## Sensibilité Tglace (avec thermo glace)

Biais vent zonal en moyenne annuelle sur 3 ans (1981-1983)

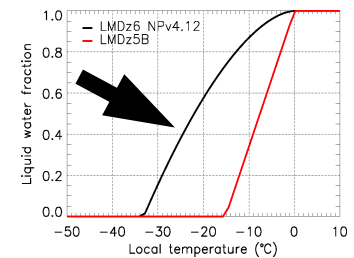
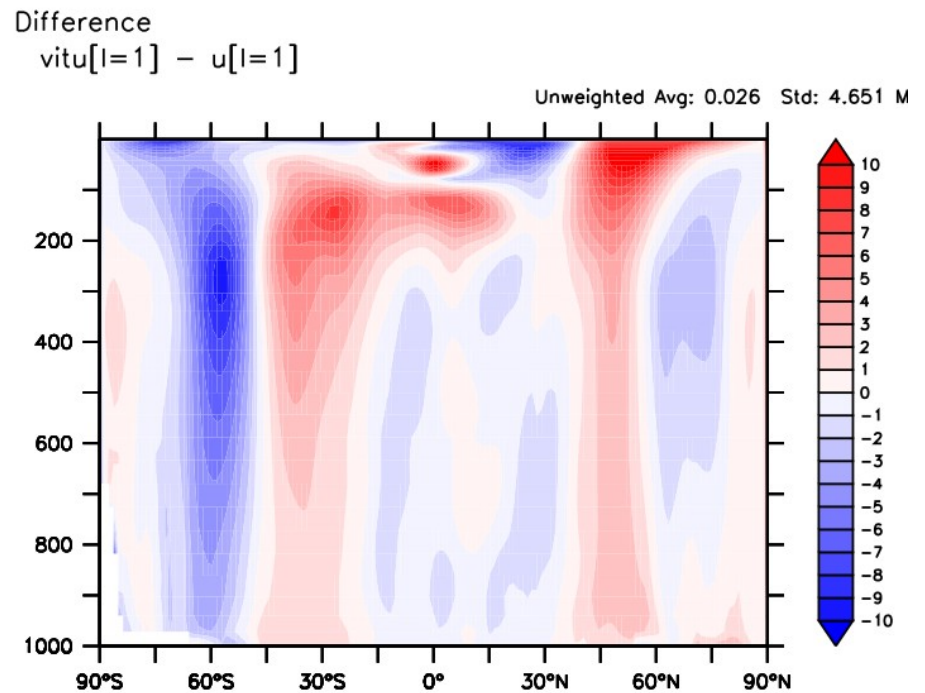
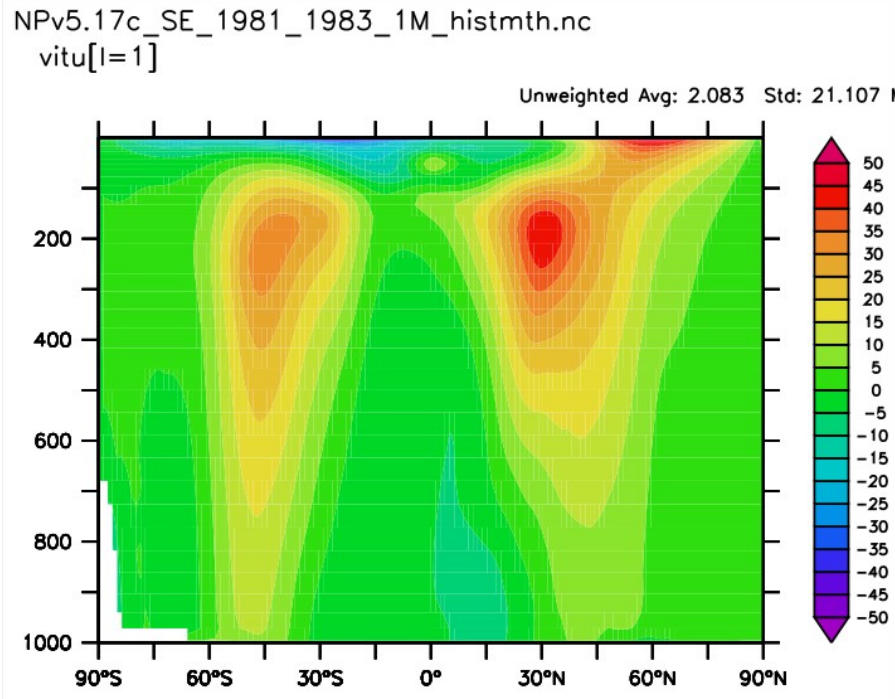


En moyenne annuelle, si on augmente la quantité de glace dans les nuages hauts, on déplace les jets vers les pôles (cohérent, on chauffe les moyennes latitudes, next slide)



# Biais saisonniers (Tglace ON)

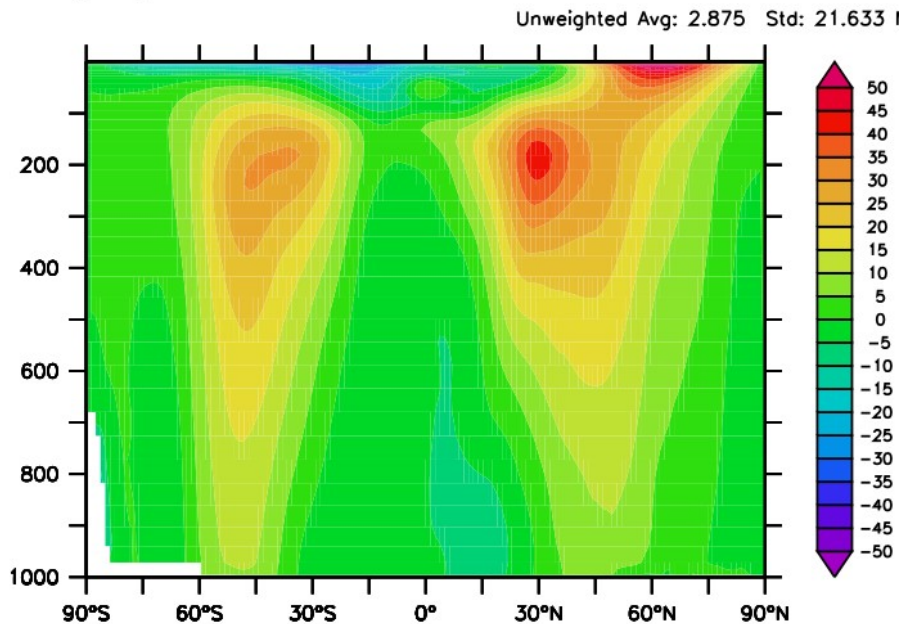
Janvier



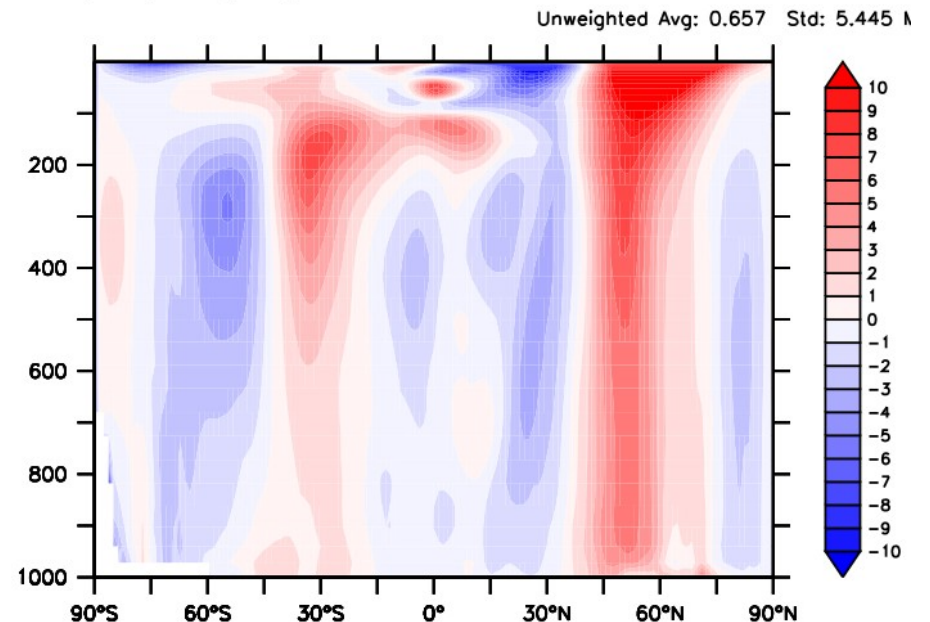
# Biais saisonniers (Tglace OFF)

Janvier

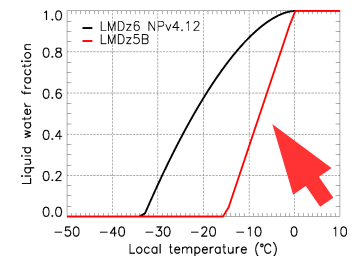
NPv5.17cTGlance01\_SE\_1981\_1983\_1M\_histmt.nc  
vitu[l=1]



Difference  
vitu[l=1] - u[l=1]

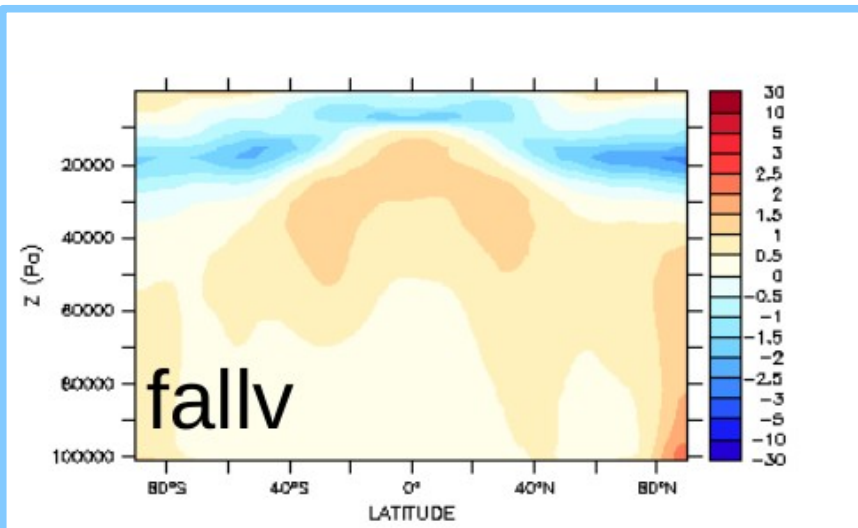


L'ajout de glace **dégrade** la position du jet dans  
l'hémisphère **d'hiver** ;  
L'ajout de glace **améliore** la position du jet dans  
l'hémisphère **d'été** ;



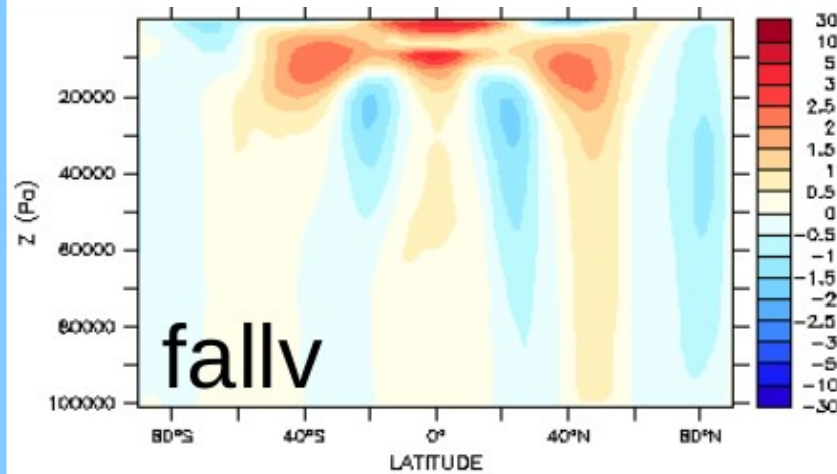
# Tuning et position des jets

T (K)



T (K) FALLICE

U (m/s)



U (m/s) FALLICE

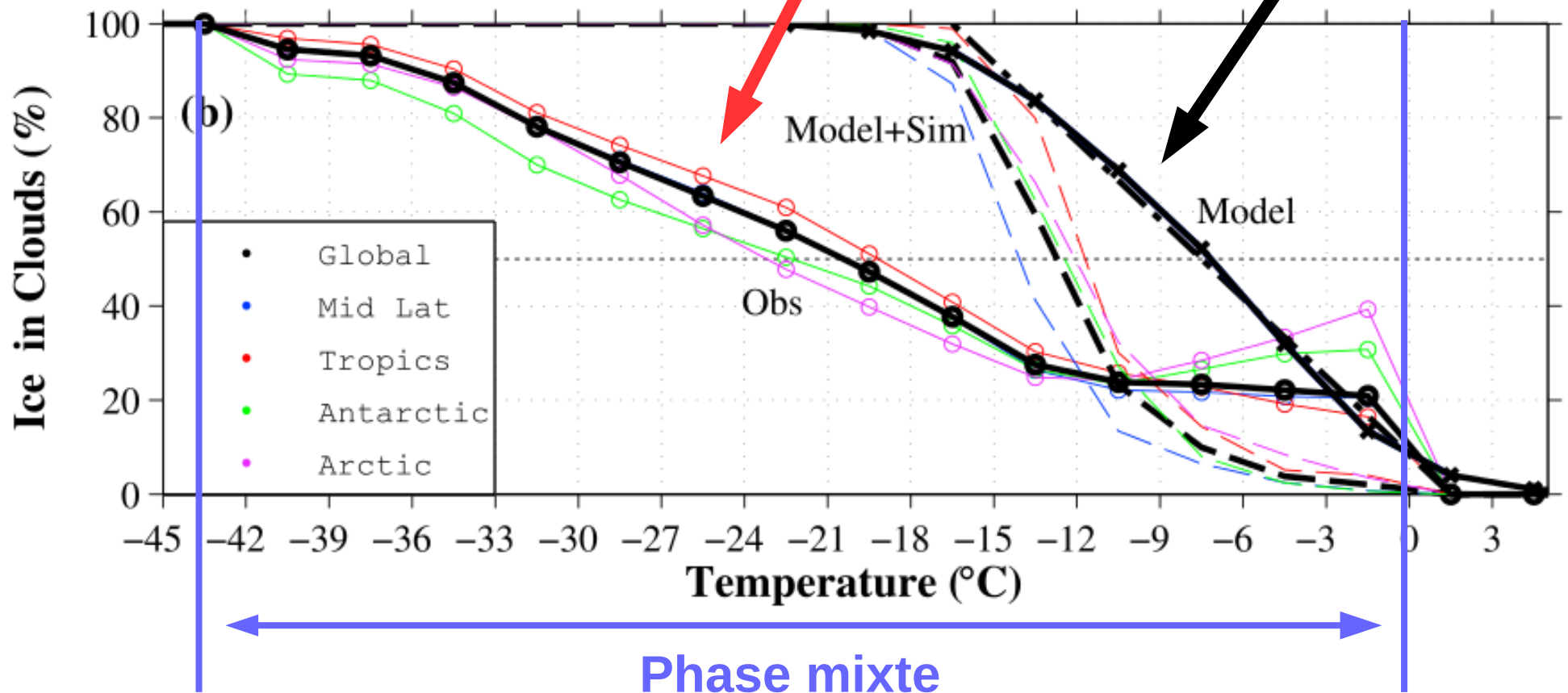


# Nuages en phase mixte

- Cristaux de glace et gouttelettes d'eau liquide en surfusion à des températures négatives

**Observations**

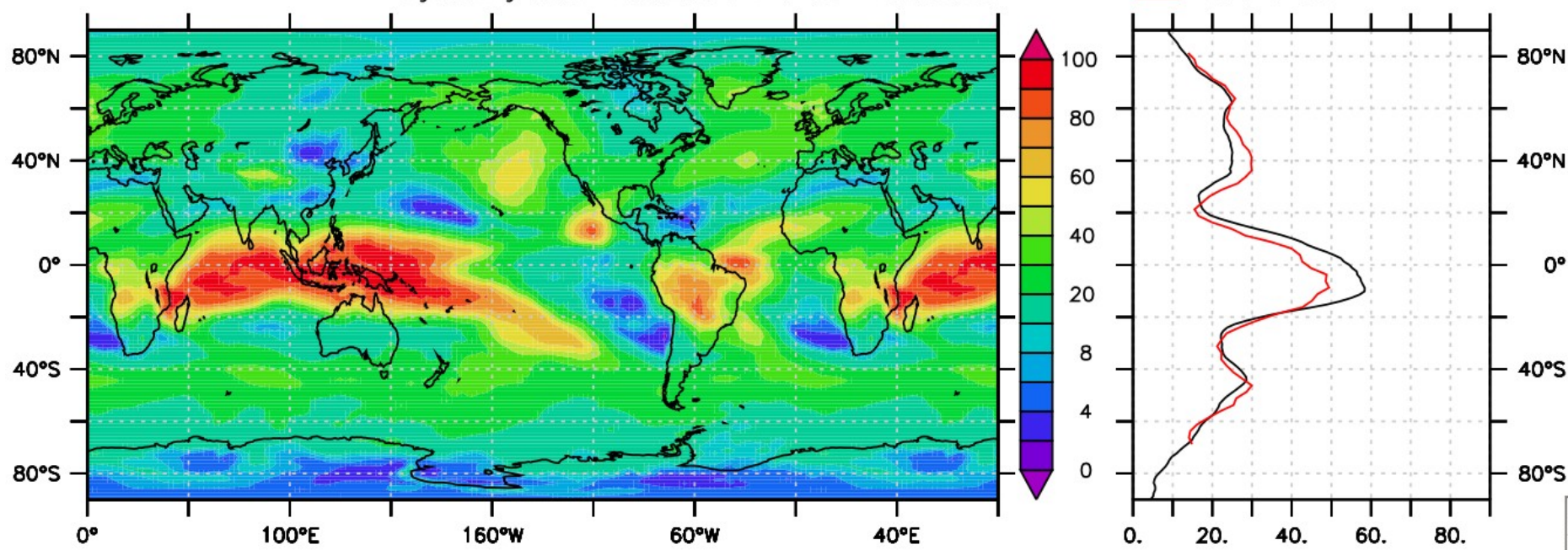
**LMDz 5B**



# High clouds – TGlance ON

NPv5.17c\_SE\_1981\_1983\_1M\_histmtth.nc  
cldh[I=1]\*100.

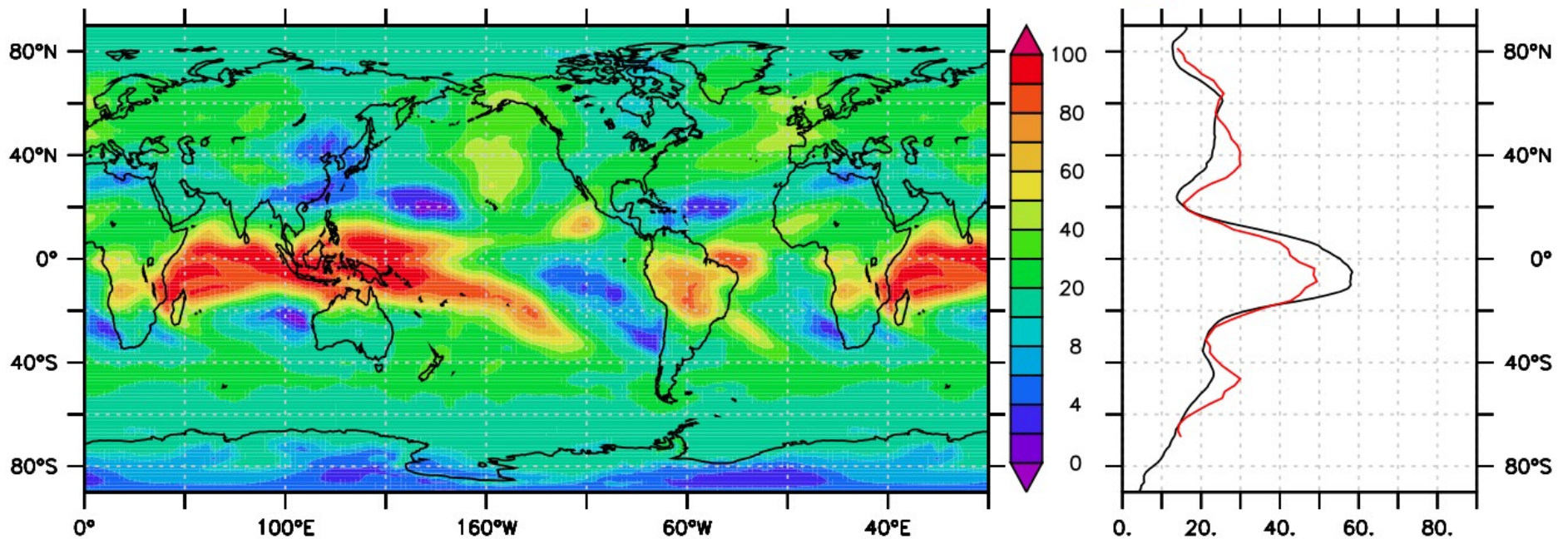
Weighted Avg: 29.831 Std: 22.045 Min: 1.564 Max: 99.938



# High clouds – TGlance OFF

NPv5.17cTGlance01\_SE\_1981\_1983\_1M\_histmtm.nc  
cldh[l=1]\*100.

Weighted Avg: 28.487 Std: 22.469 Min: 1.259 Max: 99.985

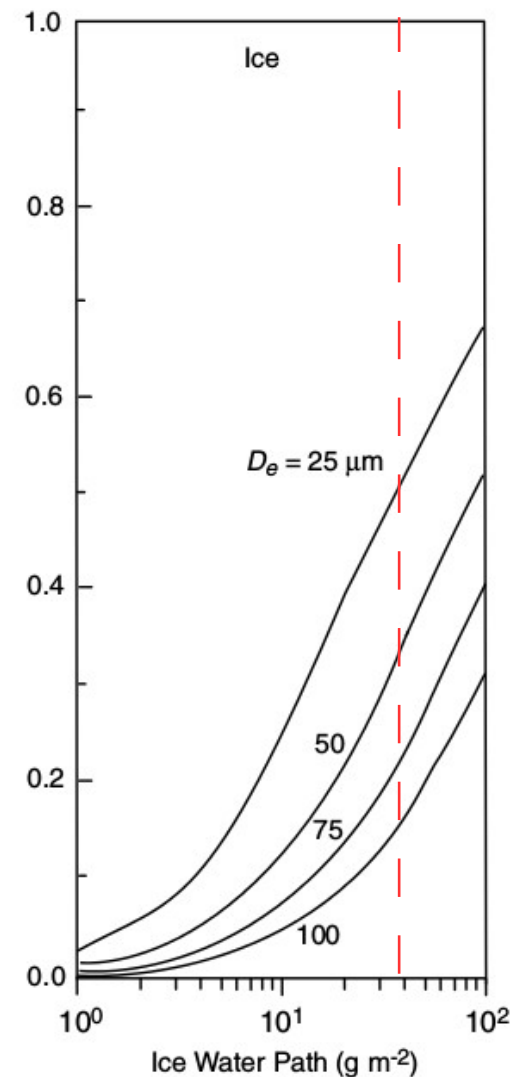
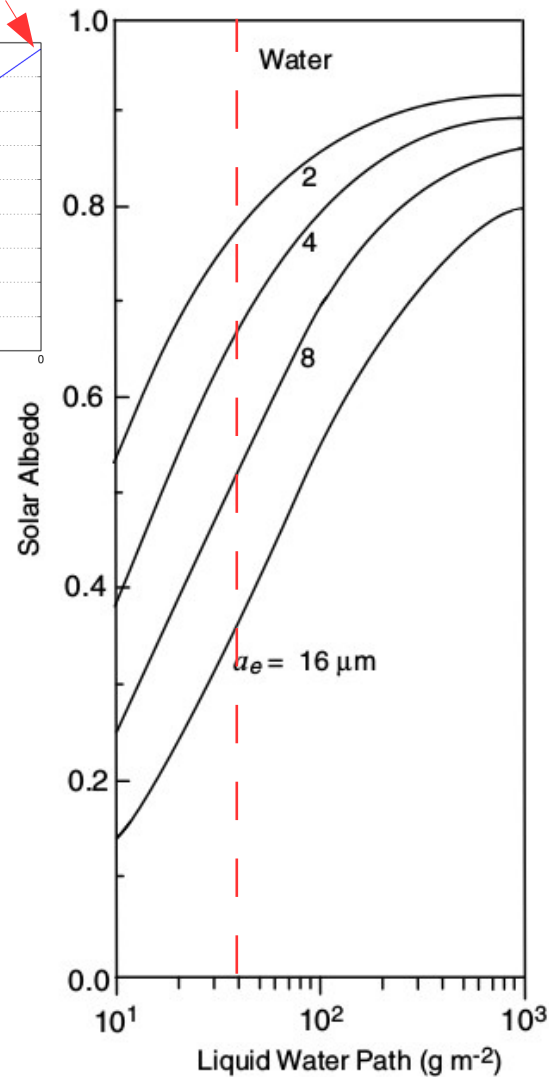
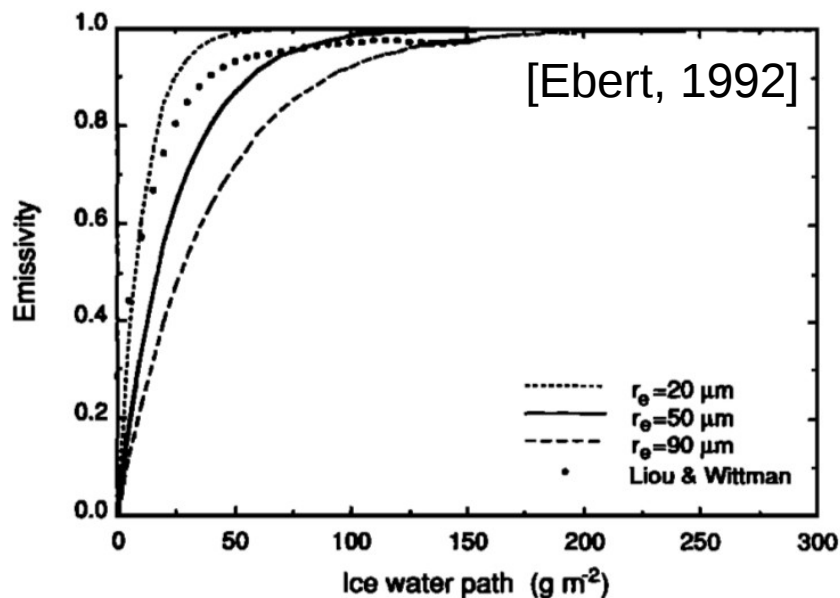
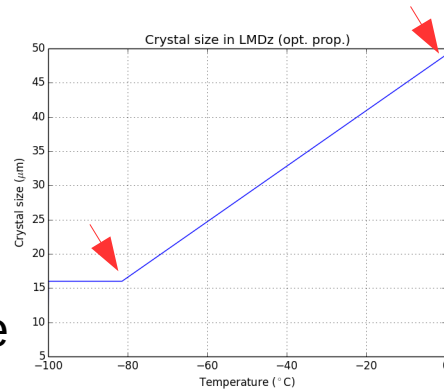


Pourtant, meilleurs nuages hauts avec Tglance ON  
→ pourquoi améliorer les nuages hauts dégrade le jet ?



# Propriétés radiatives des nuages

- Nuages liquides : si LWC augmente, réflexion domine et forçage négatif
- Nuages de glace : si IWC augmente, forçage sensible à la taille des cristaux



[Liou 2002]

# Résumé stratégie tuning

cldtau :	Cloud water auto-conversion time constant, $\tau_{convers}$
cldlc :	In-cloud water threshold for autoconversion, $clw$
epmax :	maximum precipitation efficiency for deep convection, $ep_{max}$
fallv :	Factor on ice particles fall velocity, $\gamma_{iw}$
ratqshaut :	relative width of subgrid-scale water distribution above 300 hPa, $\xi_{300}$
rei_min/max :	Ice crystals min. and max. effective radius, $(er_{iw,min}, er_{iw,max})$

Valeurs  
typiques  
(NPv3)

1,800 s  
0.6 g/kg  
0.997  
0.67  
0.25  
(20, 61.29)  $\mu\text{m}$

[Hourdin et al, 2013]

Stratégie adoptée jusqu'à présent :

1. Ajuster les nuages hauts pour un bon bilan radiatif avec **fallv**, **epmax**, **ratqshaut**
2. Corriger la quantité de nuages bas : **cldlc**, **cldtau**
3. Récemment : modifier **rei\_min/max** pour changer relation opacité/iwc

1.
  - Augmenter fallv :
    - Diminue transport de l'eau vers les hautes latitudes
    - Diminue les **nuages hauts** (partout)
  - Augmenter epmax :
    - Diminue le déentraînement
    - Diminue les **nuages hauts** (régions convectives)
  - Augmenter ratqs :
    - Eloigne de la saturation
    - Diminue les **nuages hauts**

2.
  - Augmenter cldlc :
    - Augmente les **nuages bas**
  - Augmenter cldtau :
    - Augmente les **nuages bas**
3.
  - Augmenter rei\_min :
    - Diminue l'épaisseur optique des **nuages hauts** (et l'albédo)
    - Diminue l'émissivité des **nuages hauts**

# La phase mixte dans les GCMs

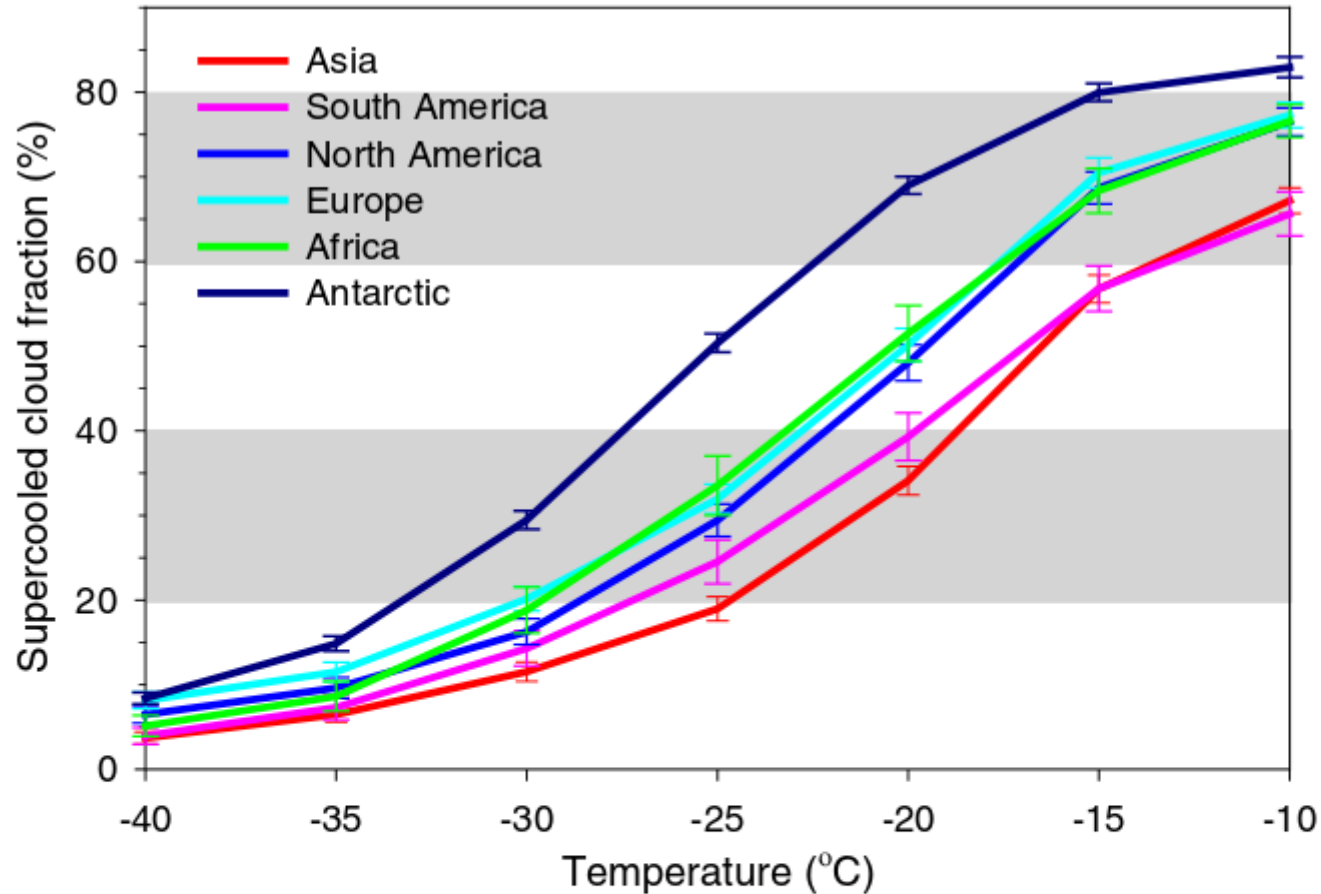
**Table 1.** Cloud Phase Partitioning Schemes by Temperature in Various Climate Models<sup>c</sup>

GCM	Type	$T_{\min}, ^\circ\text{C}$	$T_{\max}, ^\circ\text{C}$	$n$	Reference
C20	a	-20	0	1	This study
C40	a	-40	0	1	This study
SNU	a	-15	0	1	<i>Lee et al. [2001]</i>
S90	a	-15	0	2	<i>Smith [1990]</i>
<b>LMD</b>	<b>a</b>	<b>-15</b>	<b>0</b>	<b>6</b>	<b><i>Doutriaux-Boucher and Quaas [2004]</i></b>
ERA40	a	-23	0	2	<i>Weidle and Wernli [2008]</i>
MIROC low	a	-15	0		<i>Le Treut and Li [1991]</i>
MIROC high	a	-25	-5		<i>Le Treut and Li [1991]</i>
UIUC	a	-30	0		<i>Sundqvist [1988]</i>
CAM3	a	-40	-10	1	<i>Collins et al. [2004]</i>
CAM5	a	-35	-5	1	<i>Song et al. [2012]</i>
GISS, Land	b	-40	-10	2	<i>Del Genio et al. [1996]</i>
GISS, Ocean	b	-40	-4	2	<i>Del Genio et al. [1996]</i>

$$^a \text{Cloud liquid fraction} = \left( \frac{T - T_{\min}}{T_{\max} - T_{\min}} \right)^n, \text{ for } T_{\min} \leq T \leq T_{\max}$$

[Choi et al., 2014]

	$T_{\min}$	$n$
<b>POLDER</b> (Doutriaux-Boucher & Quaas, 2004)	<b>-33°C</b>	<b>1.7</b>
CALIPSO (Cesana & Chepfer 2013, Choi et al. 2010)	-40°C	~1

**B**

**Fig. 1.** (A) Annual mean (June 2006–May 2007) SCF at  $-20^{\circ}\text{C}$  isotherm. The fraction is lowest over the Asian continents and South America, but highest over the Southern Hemisphere high latitudes. (B) Annual mean supercooled cloud fraction with respect to temperature over the selected regions in (A): Asia, South America, North America, Europe, Africa, and the Antarctic. The error bar corresponds to a standard error of  $\pm 3$ .





**EARTH**



**MARS**