Analysis of the mechanisms controlling tropical low cloud feedback in the IPSL-CMIP5a model

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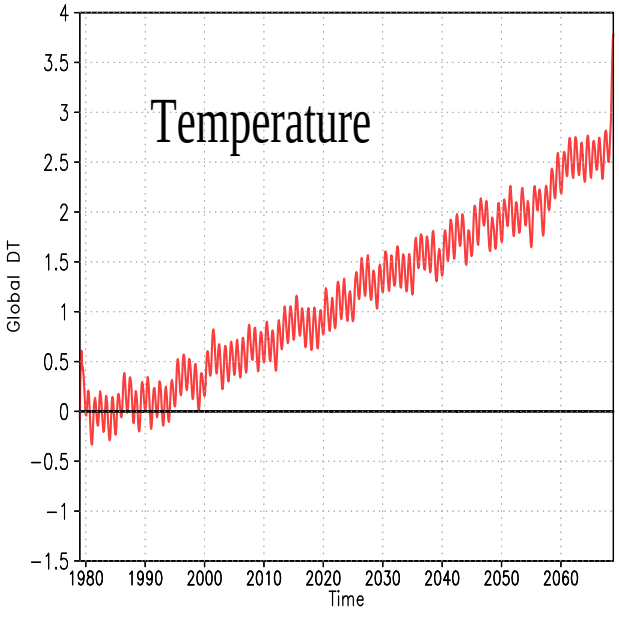
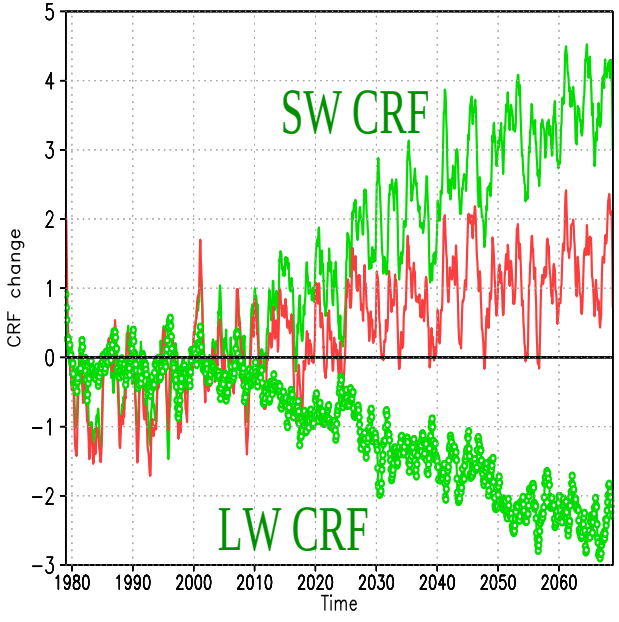
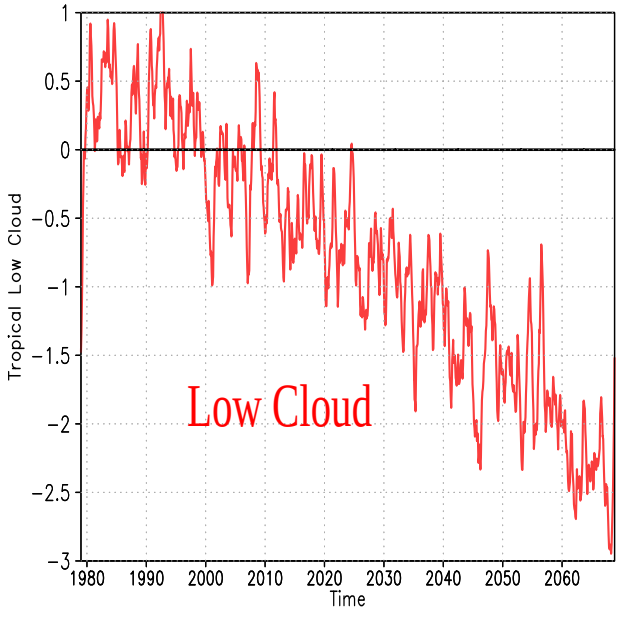
IPSL-CM5a Model

IPSLCM5a : +1pct CO_2 / year

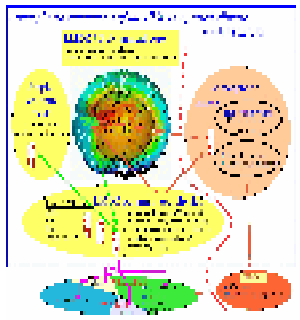




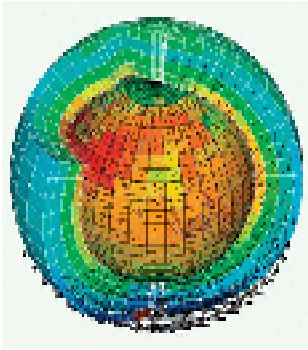


- CO_2 doubling : +3K of surface temperature increase (High sensitivity model)
- Cloud Radiative Forcing : ΔCRF SW gives the sign of ΔCRF Net (less négative)
- Positive feedback link to the tropical low cloud decrease → Difficulty to understand the mechanisms involved in a coupled model

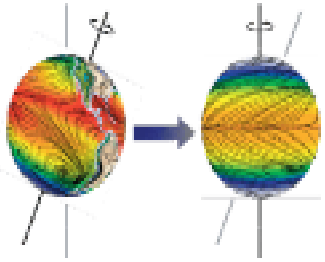
Model Hierarchy



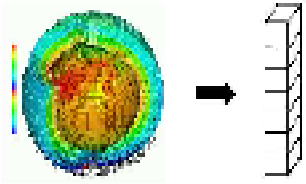
ESM : IPSLCM5a



AGCM : LMDZ



Aquaplanet : LMDZ

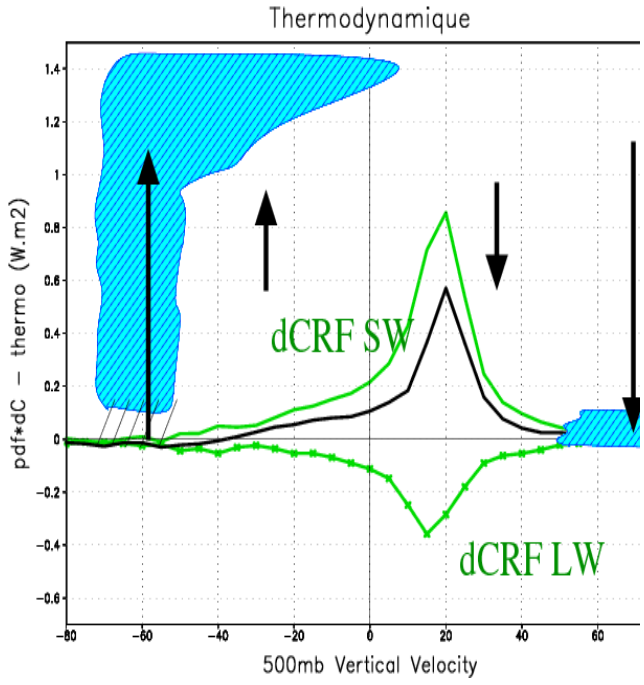


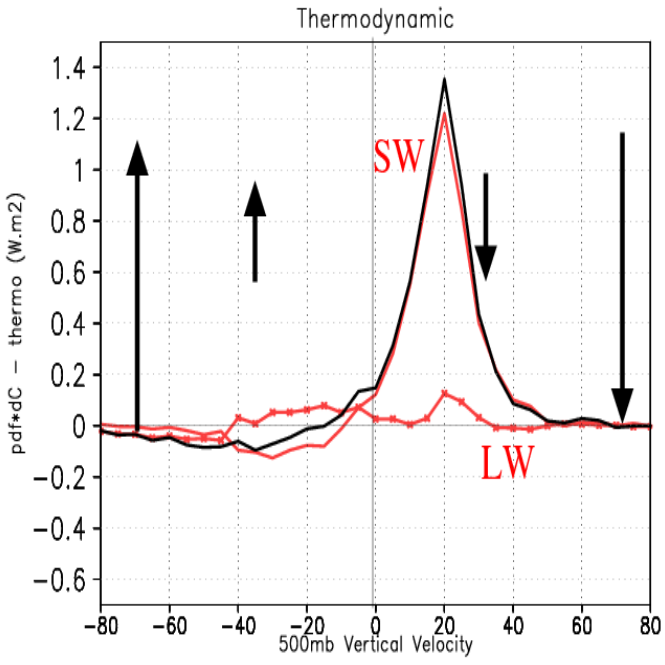
SCM : LMDZ

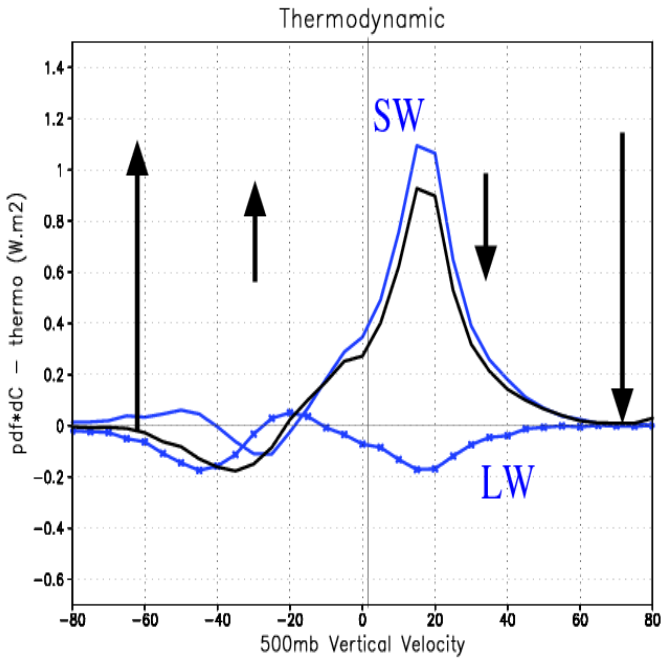
- Simplication of IPSLCM5a model
- Atmospheric Models : AMIP and Aquaplanet
- Simplification of radiative forcing : $+1\%\ CO_2/\text{year} \rightarrow +4K$ et $4X\,CO_2$
- Single Column Model (SCM) : Ability to understand physical mechanisms

- Is the positive cloud feedback reproduce in all GCM configurations ?

Model Hierarchy

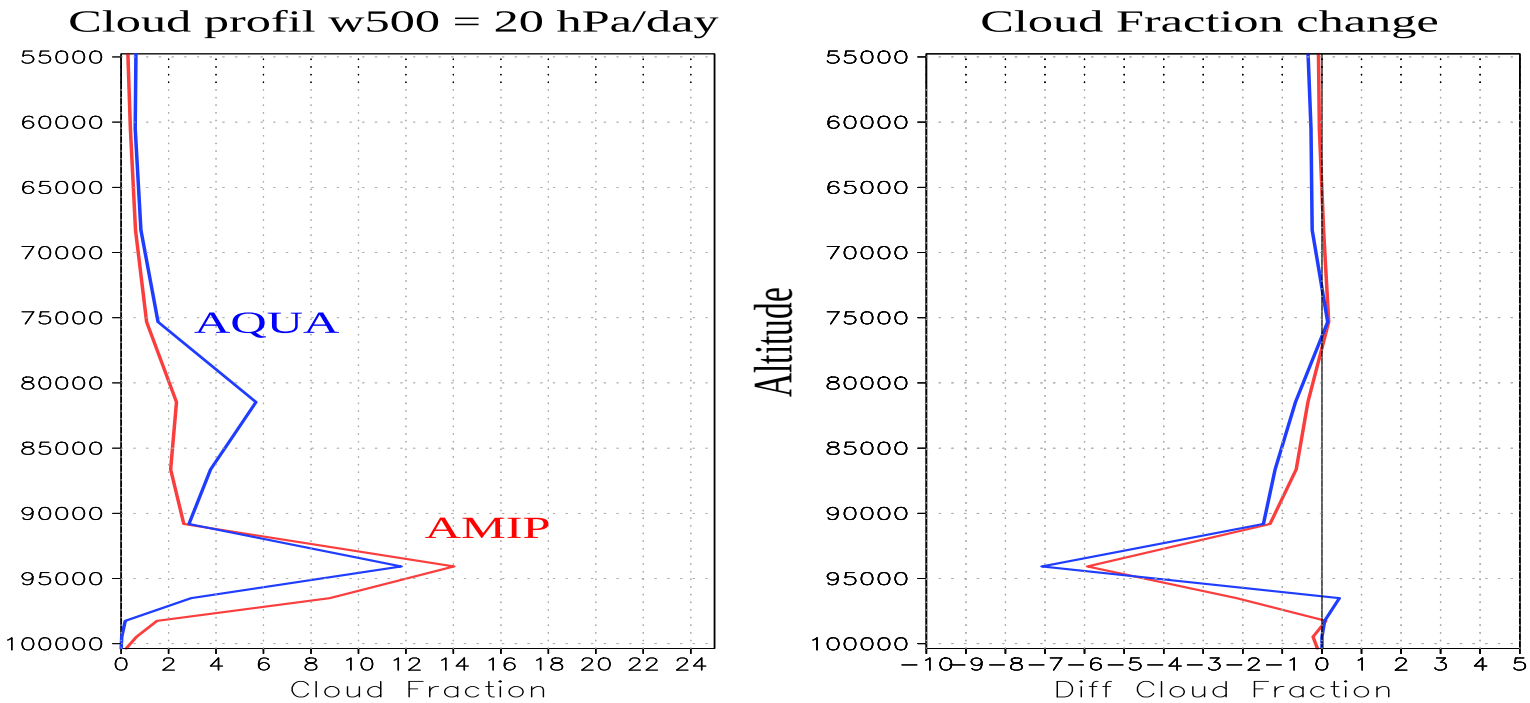






- Hierarchy : IPSLCM5a, LMDZ AMIP et AQUA
- Same response between coupled models and atmospheric models (idealized atmospheric circulations using w_{500})
- Tropical ΔCRF controlled by ΔSWCRF in weak subsidence areas (w_{500}=0-30hPa/day)
- What controls the SW CRF increase on this area ?

Zoom on weak subsidence area

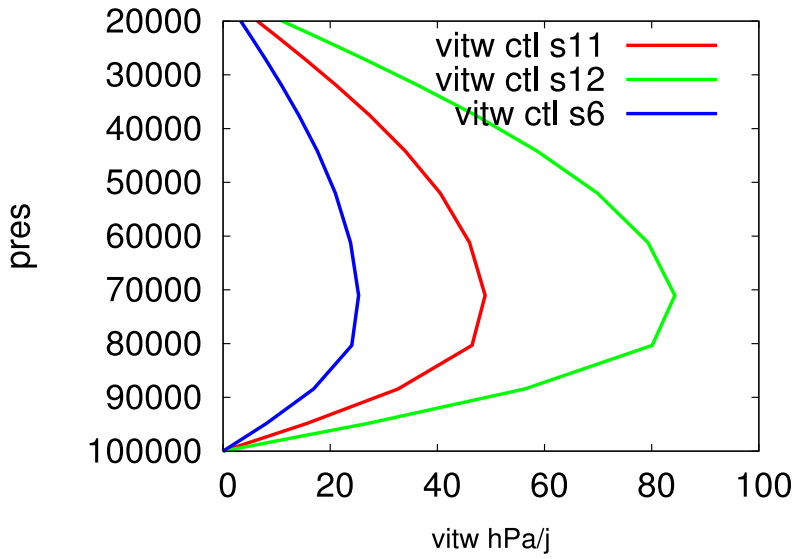


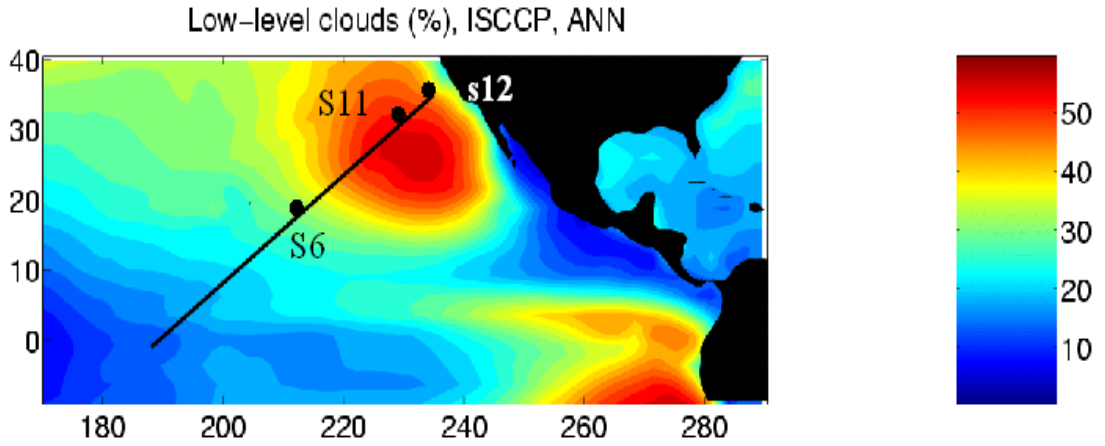
- Cloud profil on a weak subsidence area (w_{500}=20hPa/day)
- Decrease of cloud fraction in the 950mb layer
- Justify the positive cloud feedback of IPSLCM5a model (due to the high geographical weight)
- Need to reproduce the 3D behaviour in a SCM.

Using a Single Column Model

CGILS Intercomparaison :

Similar experiments SCM/LES/CRM.



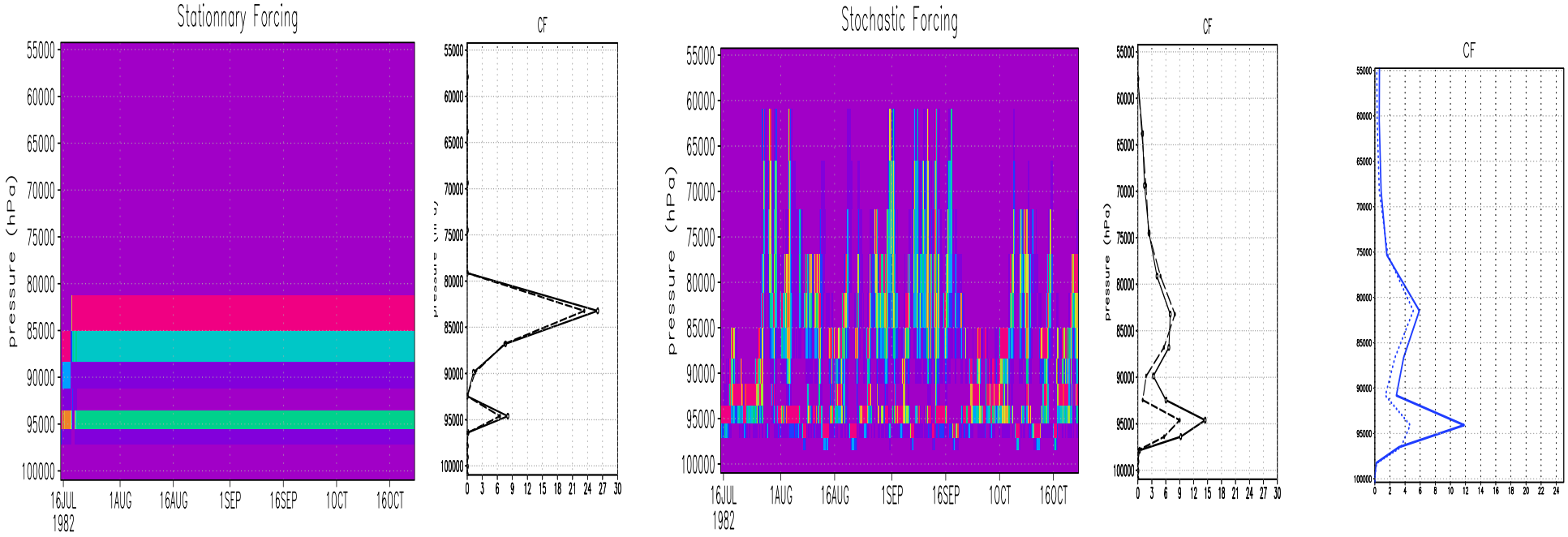


$$(\frac{\partial \phi}{\partial t}) = (\frac{\partial \phi}{\partial t})_{phy} + (\vec{V}.\vec{\nabla}\phi)_{LS} - \omega \frac{\partial \phi}{\partial P}$$

- Study of only one case : a weak subsidence (s6) corresponding to Shallow Cumulus. Idealized experiments of present and future climates
- Are CGILS experiments a good framework to understand the IPSL/GCM cloud feedback ?

Using a Single Column Model

s6 CGILS case ———————— s6 ω-stochastic (σ=σ_{GCM}) —— **3D**

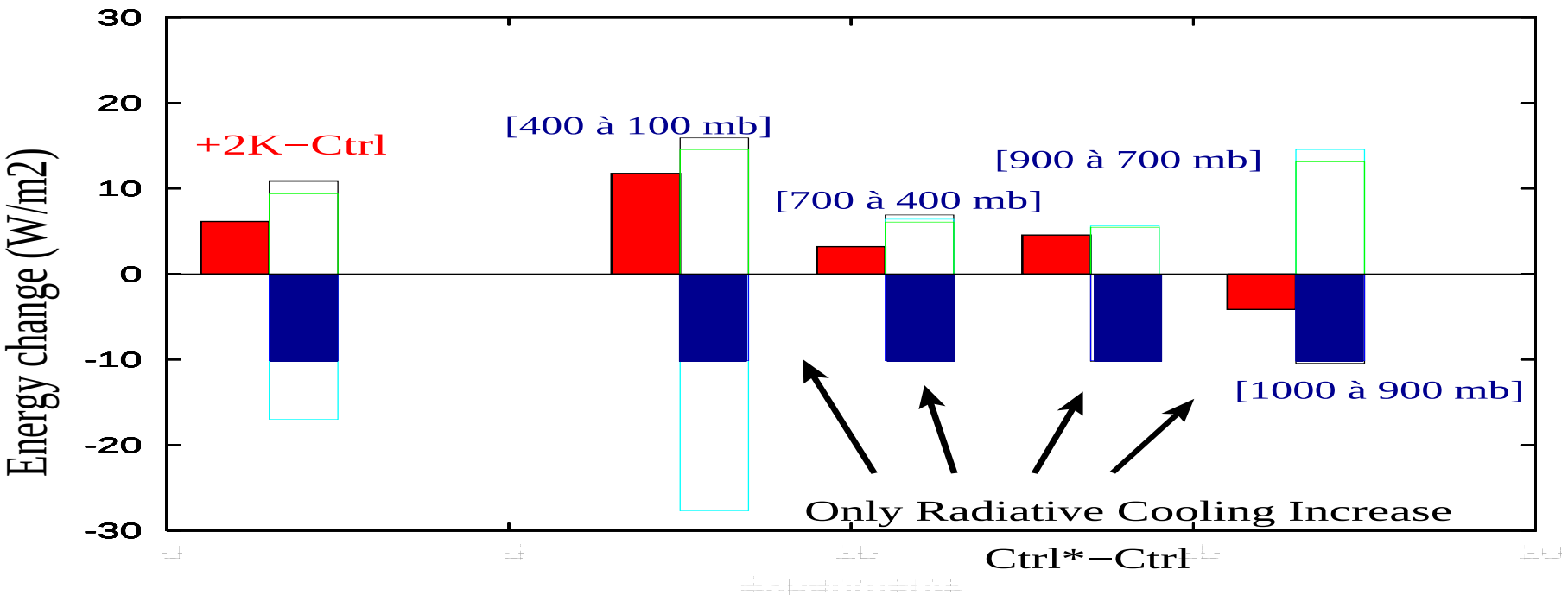


- SCM able to reproduce cloud profil in both present and future climat only by adding of a variation on vertical velocity
- Stochastic forcing allows a alternance of strong convective and subsidence states (characteristics of weak subsidence case).
- CGILS s6 case can help analyse GCM cloud feedback ?

Cloud Feedback analysis (1D)

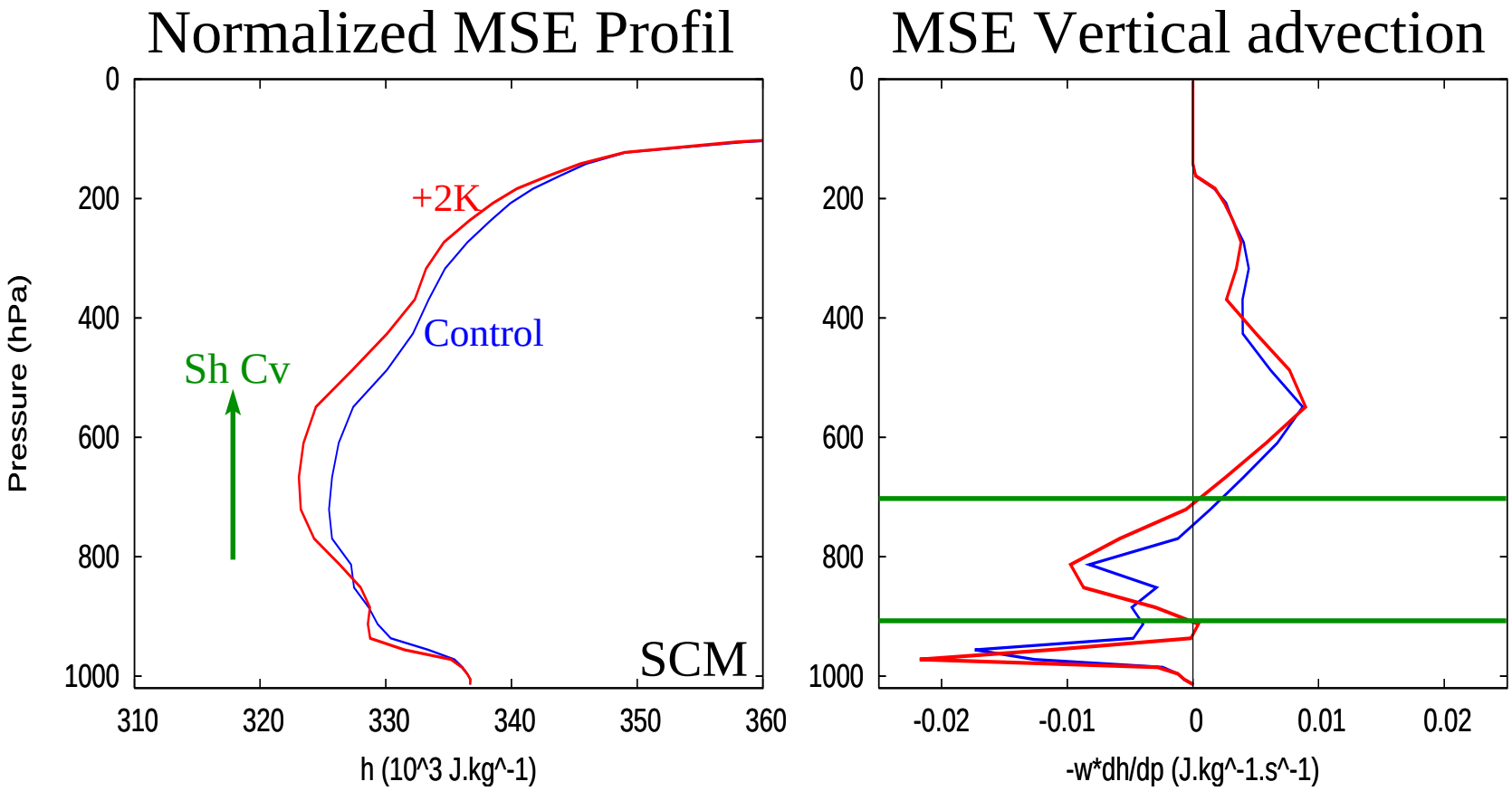
Why $\Delta CRF > 0$? : Decompostion of the Moist Static Energy (MSE) budget integrated over the entire atmosphere

$$\Delta CRF = -(\Delta CSRadCooling + \Delta(LH + SH) + \Delta(-\omega \frac{\partial MSE}{\partial P}) + \Delta(\vec{V}.\vec{\nabla} MSE)_{LS})$$



- Radiative Cooling applied on the upper troposphere : Higher impact on MSE vertical advection

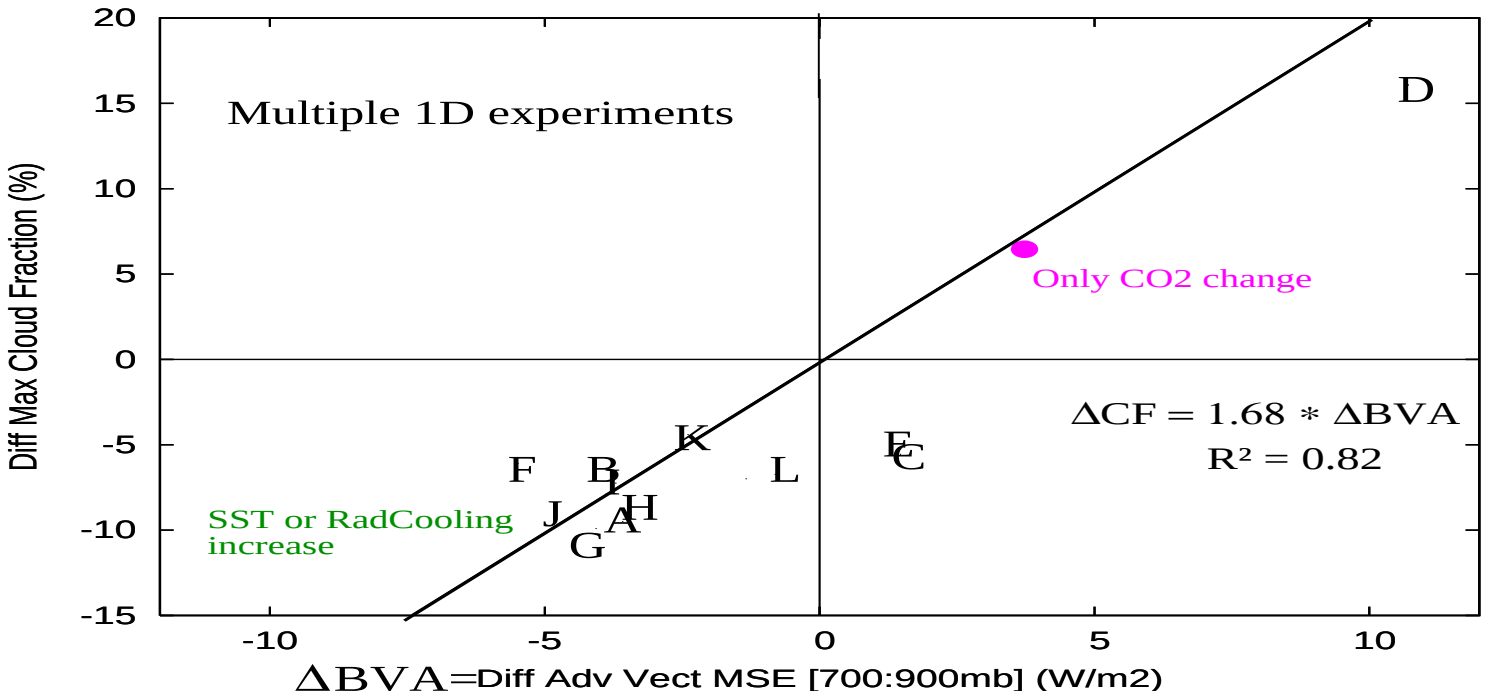
Cloud Feedback analysis (1D)



- Enhanced Shallow convection : Minimum of MSE higher and weaker (compared to the MSE value on surface)
- Major change in the Upper Cloud layer $\rightarrow$ Indice of Boundary layer Vertical Advection (BVA $= \int_{700mb}^{900mb} -\omega \frac{\partial MSE}{\partial P} \delta P$))
  ΔBVA Vs cloud fraction change ?

Cloud Feedback analysis (1D)

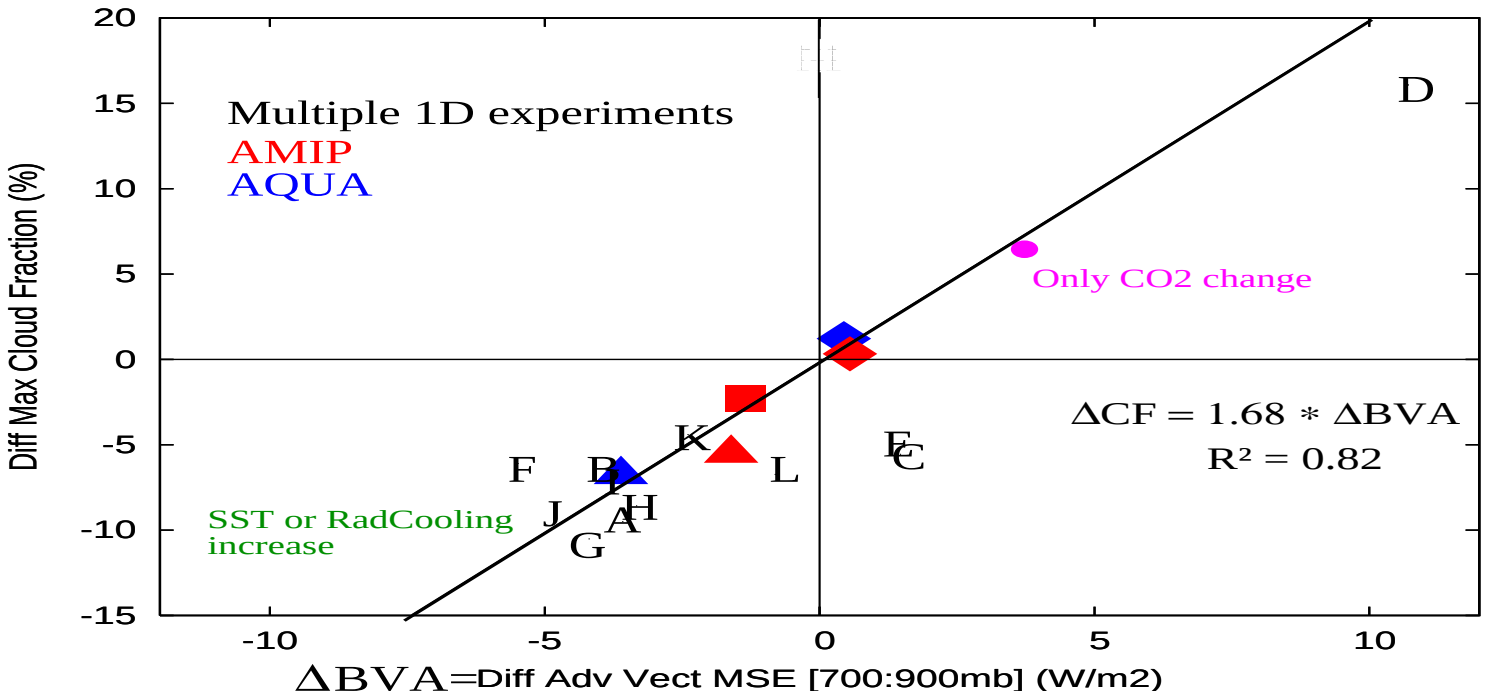
Linear Relation between the 950mb cloud layer change and ΔBVA whatever the forcing applied.



- Cloud fraction ↘ when Boundary Layer Inversion ↗
- Linear relation between low cloud change and vertical gradient of RH and T change above the cloud layer.

Cloud Feedback analysis (3D)

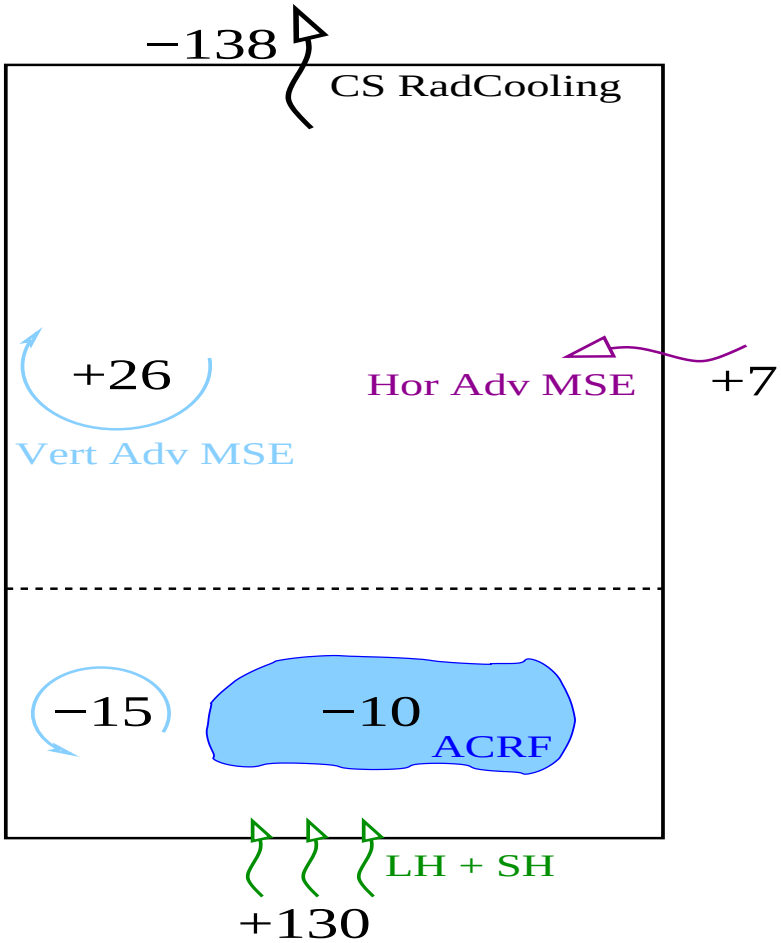
Linear Relation between the 950mb cloud layer change and ΔBVA whatever the forcing applied.



- Addition of 3D w_{20} change
- 3D points on the 1D linear relation : Justify the mechanism between inversion and BL cloud fraction change.

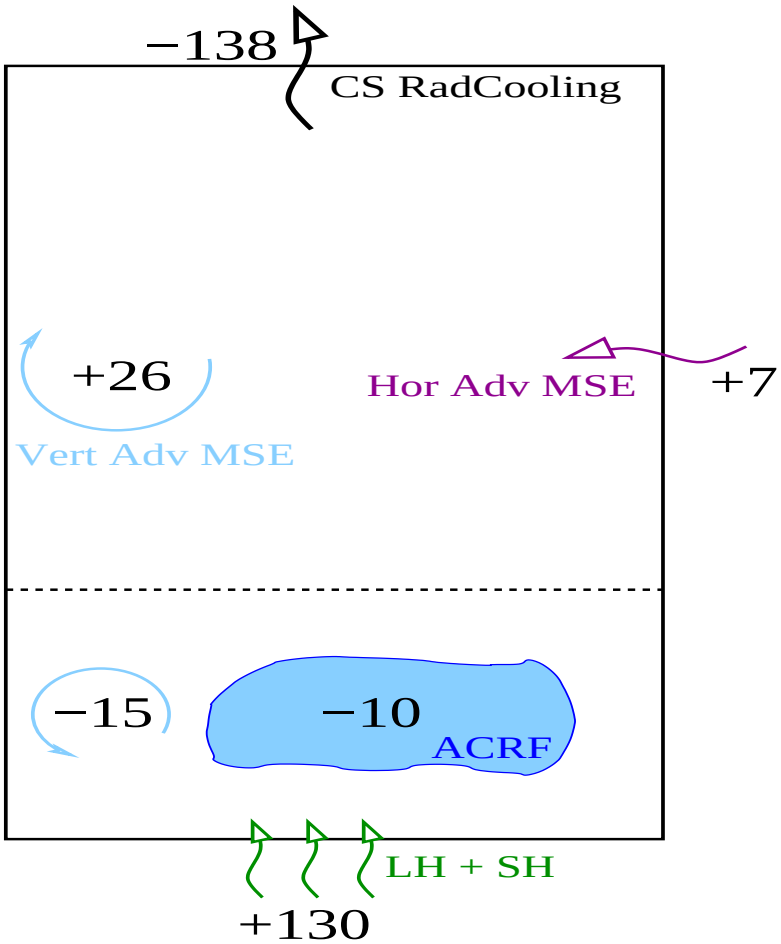
To summarized

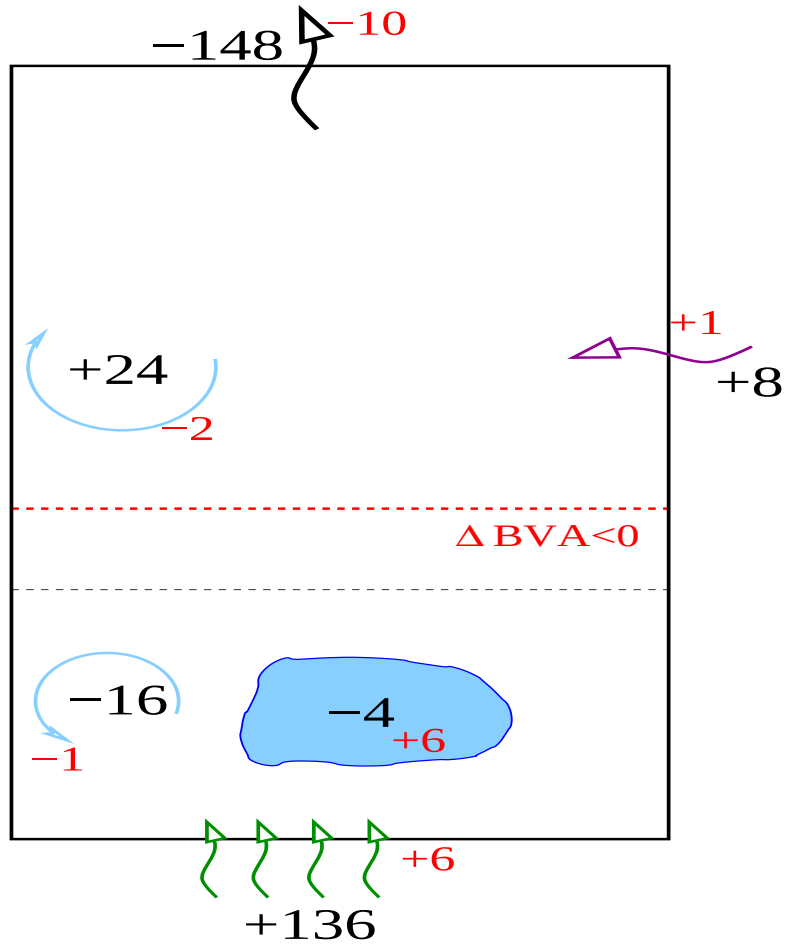
A typical weak subsidence column of IPSL model (W/m^2)



To summarized

A typical weak subsidence column of IPSL model : +2K experiment (W/m^2)





Conclusions

- Positive cloud feedback controlled by the 950mb cloud fraction decrease
- Single Column Model able to reproduce 3D cloud profil both in the present and future climate (need to apply stochastic forcing on ω for CGILS case)
- Higher effect of radiative cooling on the upper troposphere
- Strong link between low cloud change and vertical advection of MSE integrated above the cloud layer : Increase of Boundary Layer height.
- Perspectives : Creation of a index which allow to link both the seasonnal/inter-annual variability and the cloud feedback in LMDZ ? and in CMIP5 models ?

Thank You