1DVAR assimilation experiments with cloud affected AIRS radiances

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Introduction

Motivation

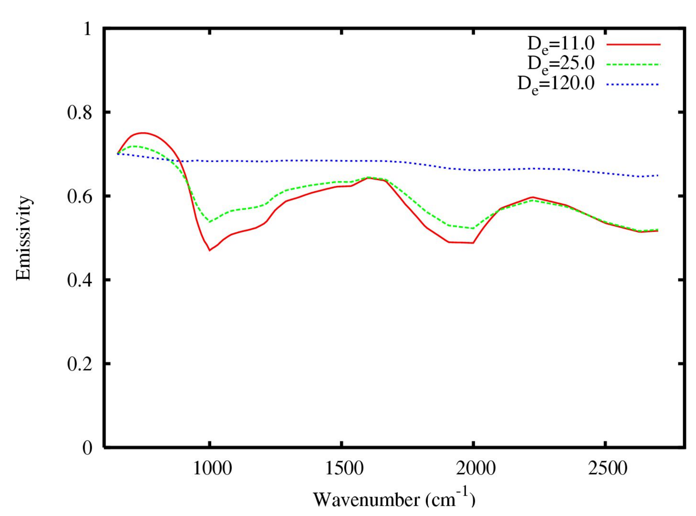
From hyperspectral infrared observations, retrieve temperature and humidity profiles down to the cloud top, and possibly below broken clouds.

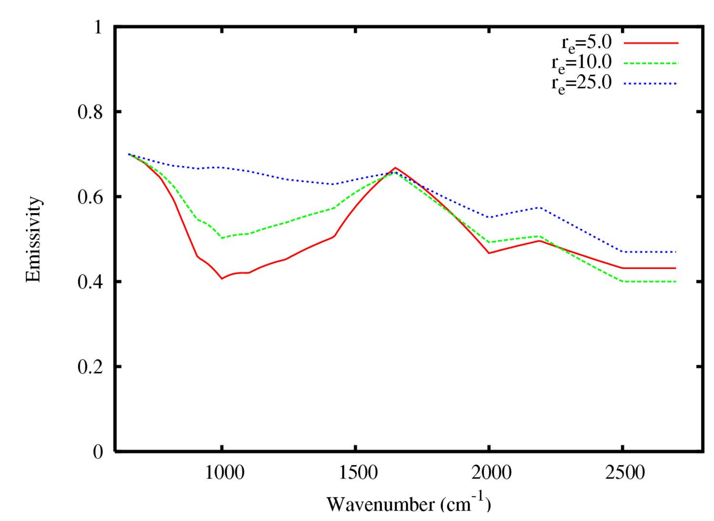
Data

A subset of 100 AIRS channels is used along with collocated and coincident 6-h forecasts.

Sensitivity to the particle size parameters r_e and D_e

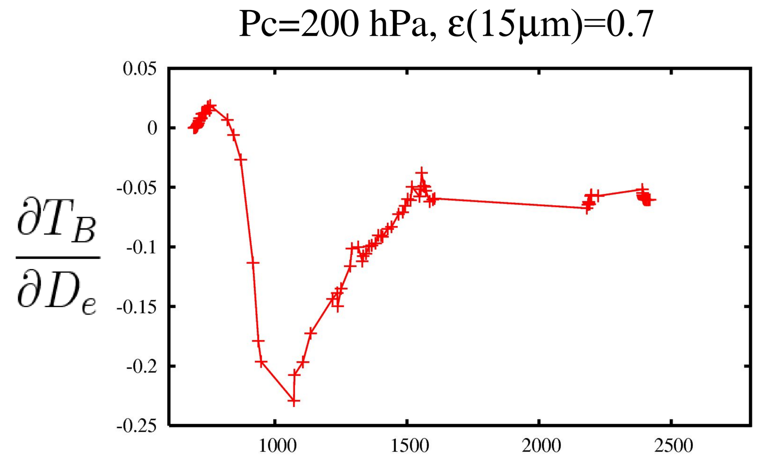
CO_2 slicing provides us with a good estimate of cloud top pressure and 15 µm emissivity. Nevertheless some uncertainty remains on the emissivity at other wavelength due to the lack of reliable knowledge on the size parameters.





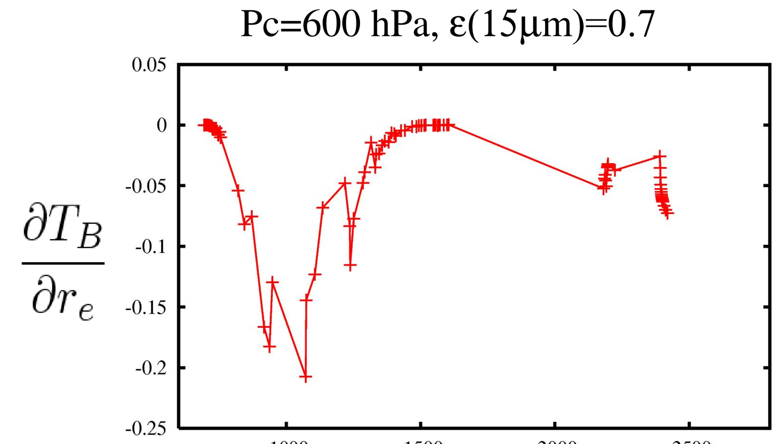
Pure ice case

Pc=200 hPa, ε(15µm)=0.7



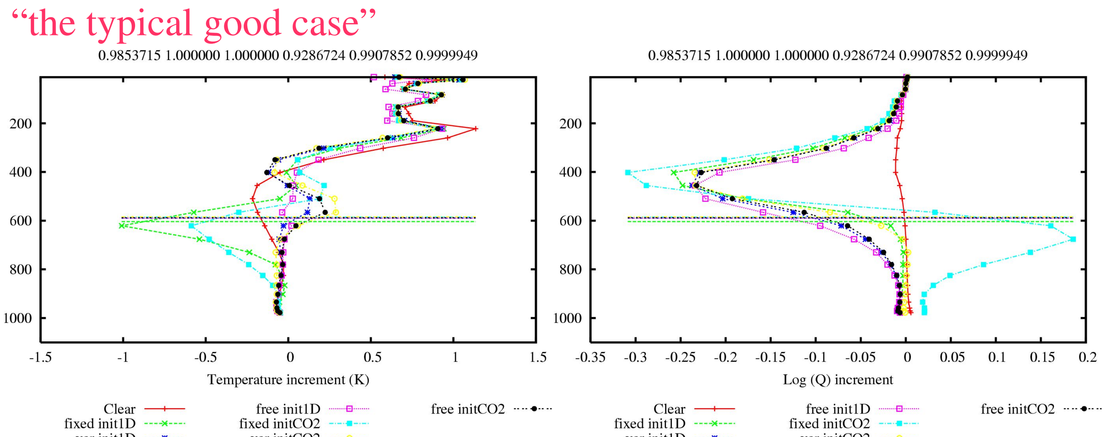
Liquid water case

Pc=600 hPa, ε(15µm)=0.7

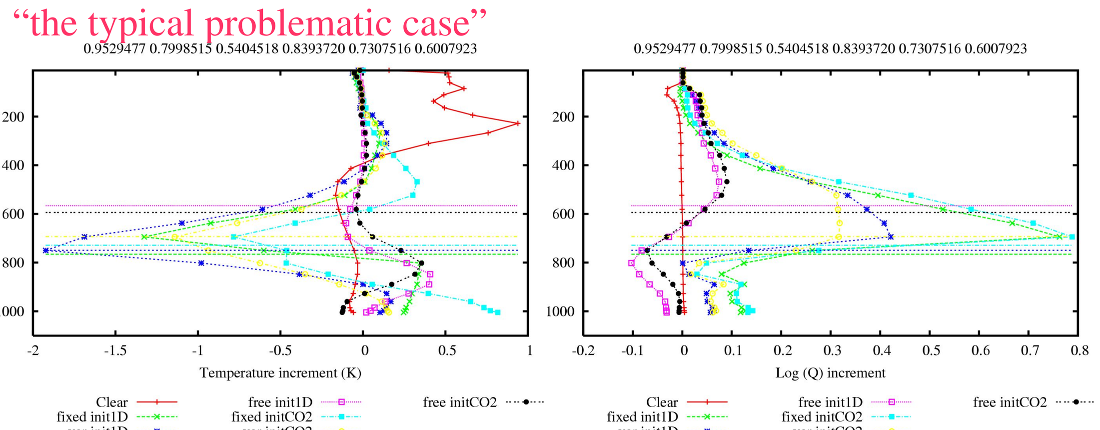


1D-var experiments with real data

"the typical good case"



"the typical problematic case"



- Temperature and log(Q) profile increments for 2 situations.
- Red curve : assimilates "clear" channels unaffected by clouds.
- Green curve : assimilation of all channels
- Other curves : assimilation of all 100 selected AIRS channels with variable or fixed cloud parameters resulting from CO_2 slicing or variational refinement.
- The horizontal lines represent the cloud top level.

The systematic analysis of these 1D var experiments allows us to draw some conclusions :

- it seems dangerous to use fixed cloud parameters in the 1D var process because excessive increment in humidity and temperature may result
- best (more reasonable) results are obtained with free or very weakly constrained cloud parameters
- some weird situations still occurs from time to time (as the "typical problematic case" shown above). We are still looking for a simple criterion to exclude these situations from the real 3D/4D var analysis. A pre-assimilation 1D var is may be a good (but computationaly expensive) solution
- a validation of the temperature and water vapour increments obtained in cloudy situations is still missing. Validation against spatially collocated and coincident radiosondes was attempted without conclusive results

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Cloud radiative modelling

Single layer effective cloud : $I_{cld}(\nu) = N\epsilon(\nu) I_{ovc}(\nu, P_c) + (1 - N\epsilon(\nu)) I_{clr}(\nu)$

The clear sky radiance $I_{clr}(\nu)$ and the overcast radiance $I_{ovc}(\nu)$ are provided by RTTOV in its latest version (8.5)

$N\epsilon(\nu)$ is provided by a cloud emissivity model which :

- Approximately accounts for scattering following Chu et al. (1999)
- Mixed phase clouds are accounted for using liquid water fraction f_w according to Rockel et al. (1991)
- Use parameterized optical properties of liquid water according to Lindner and Li (2000) using a variable effective radius r_e
- Use parameterized optical properties of ice (hexagonal columns) according to Baran et al. (2004) using a variable effective diameter D_e
- Provides a parameterization of the full infrared cloud emissivity spectrum using only four parameters : the cloud temperature T_c, the effective cloud depth δ, the effective radius r_e and the effective diameter D_e. All these parameters are wavelength-independent.

$$N\epsilon(\nu) = 1 - \exp\left[-k_{cld}(\nu)\delta\right]$$

with $\delta = \sec\theta \Delta P g_*^{-1} CWC$ (cloud effective depth) and $k_{cld}(\nu) = k_{ext}(\nu)\left[(1-\omega(\nu)) + b(\nu)\omega(\nu)\right].$

with $b = \frac{1}{2}\int_0^1 d\mu \int_{-1}^0 \bar{P}(\mu,\mu')d\mu'$. (backscattered fraction) related to the assimetry factor g $b(g) = \frac{1-g}{2g}\left[\frac{2}{\pi}(1+g)K(g^2) - 1\right]$

(Henyey-Greenstein phase function)

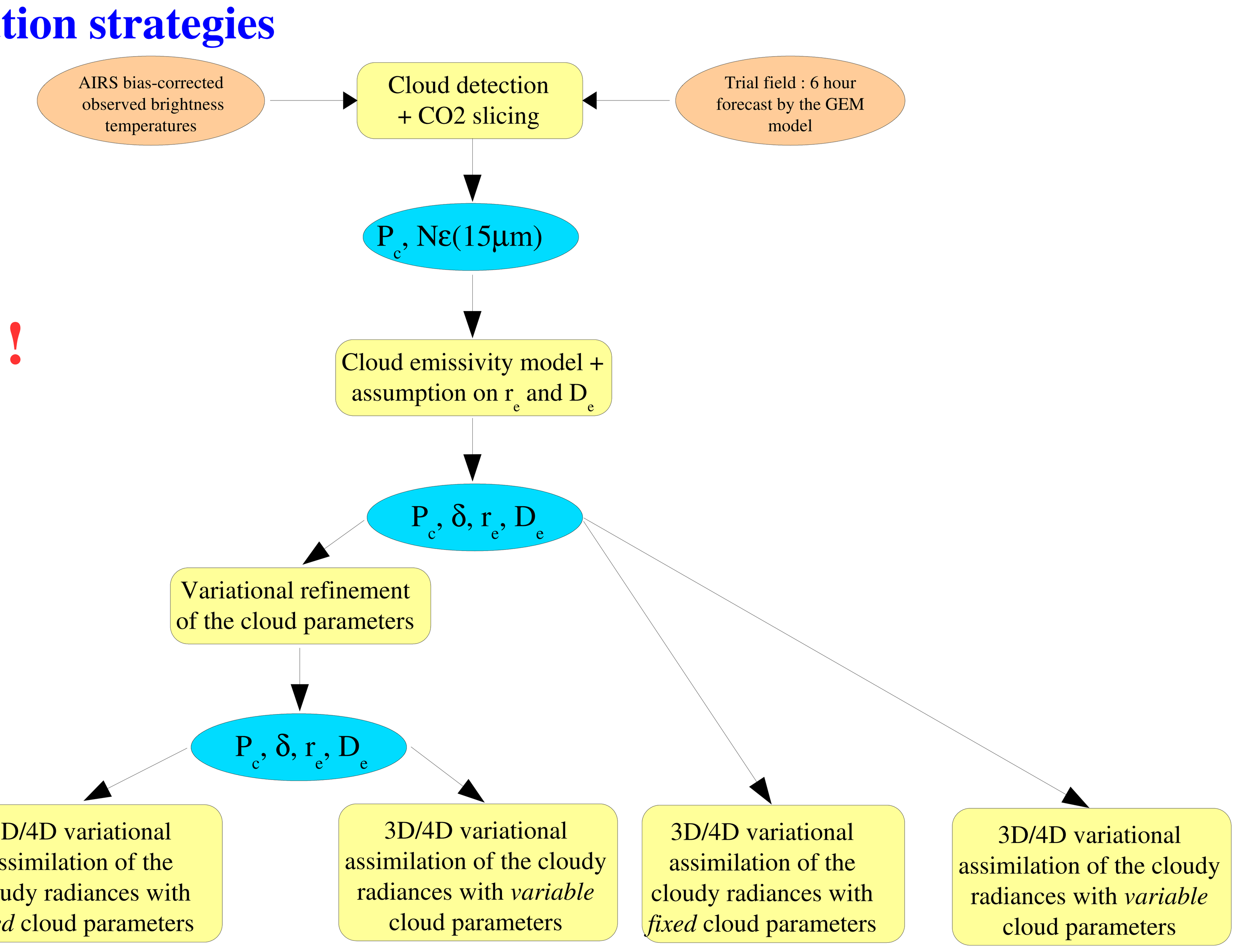
water fraction is given by $f_w = \begin{cases} 0.0059 + 0.9941\exp\left[-0.003102(T_c - 273.16)^2\right]; & T_c < 273.16 \\ 1.0; & T_c > 273.16 \end{cases}$

ice and water optical properties are combined as follow

$$k_{ext} = f_w k^w_{ext} + (1-f_w)k^i_{ext} \qquad \omega = \frac{f_w k^w_{ext}\omega^w + (1-f_w)k^i_{ext}\omega^i}{f_w k^w_{ext} + (1-f_w)k^i_{ext}} \qquad g = \frac{f_w k^w_{ext}\omega^w g^w + (1-f_w)k^i_{ext}\omega^i g^i}{f_w k^w_{ext}\omega^w + (1-f_w)k^i_{ext}\omega^i}$$

Possible cloudy radiances assimilation strategies

At least four possible schemes !



Conclusion, perspectives

- A realistic cloud emissivity model was set up in order to describe the whole infrared cloud emissivity spectrum with only 4 cloud parameters
- The inclusion of the size parameters r_e and D_e as variable parameters appears to be required for the assimilation of some channels (8µm-12µm window region in particular)
- 1D-Var assimilation experiments of cloudy AIRS radiances were performed in various configurations
- Elimination of problematic cases requires additionnal study
- 3D/4D variationnal experiments with variable cloud parameters are planned