

1D variational assimilation of cloudy radiances from hyperspectral infrared sounders

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Introduction

Motivation

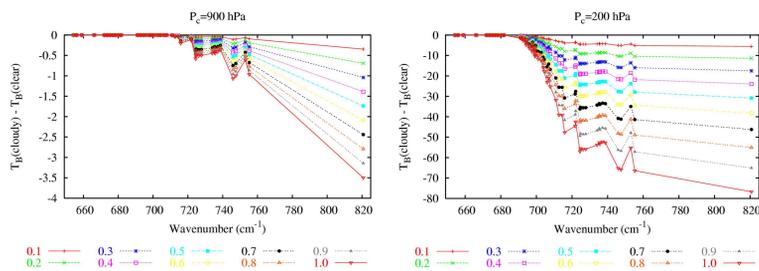
From hyperspectral infrared observations, retrieve temperature and humidity profiles down to the cloud top, and possibly below broken clouds.

Approach

Develop first a robust methodology to retrieve the effective cloud top and emissivity (with spectral variation). With these two parameters fixed, proceed to cloudy radiance assimilation.

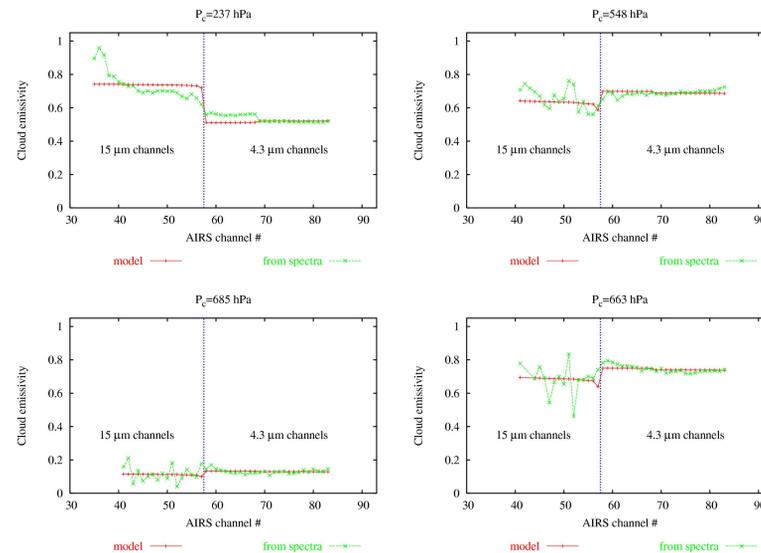
Single layer cloud model

$$I_{cloudy}(\nu) = N\epsilon(\nu)I_{overcast}(\nu) + (1 - N\epsilon(\nu))I_{clear}(\nu)$$



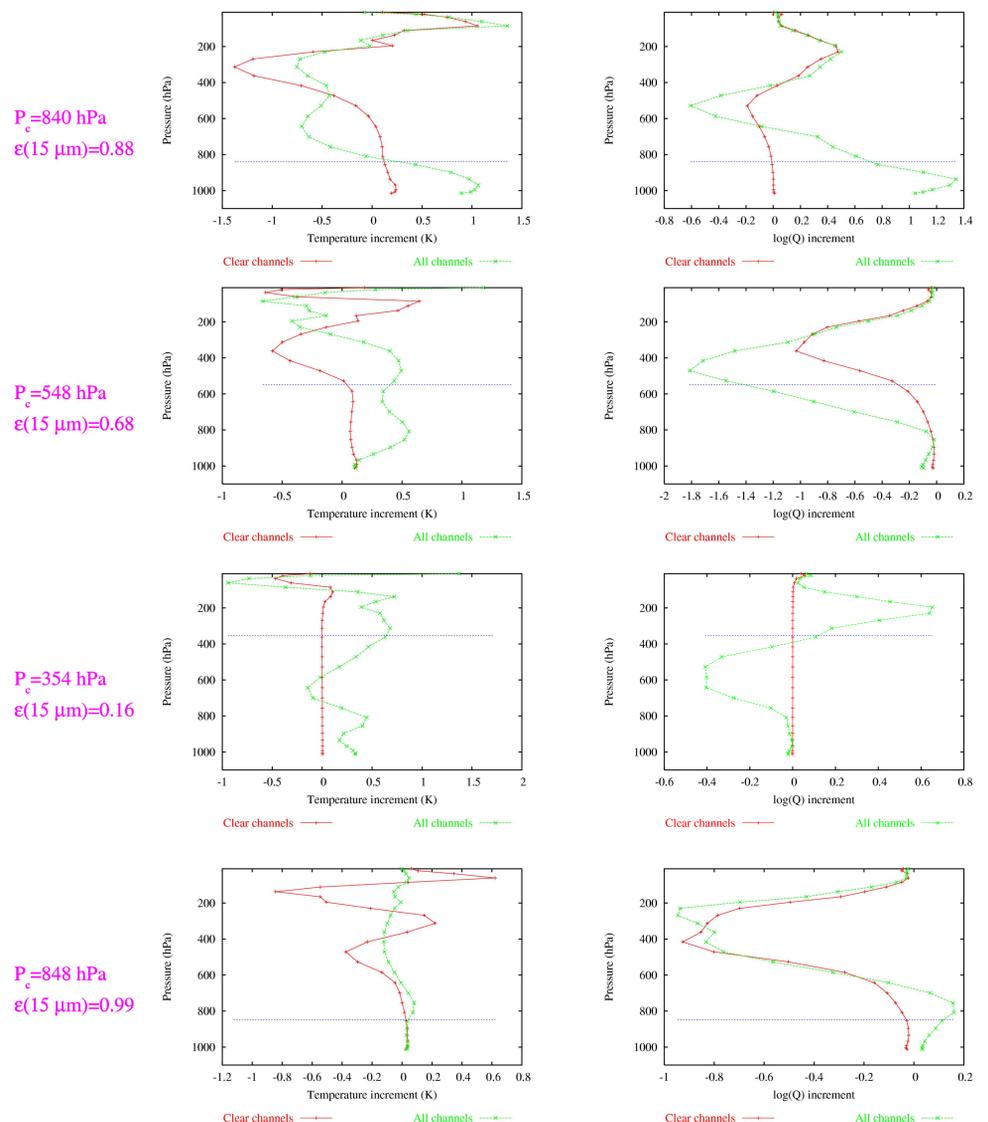
Validation of cloud emissivity retrievals

Examples taken from real AIRS observations: comparison between the multi-spectral emissivity retrieval and that obtained from individual channels using $N\epsilon(\nu) = \frac{I_{obs}(\nu) - I_{clear}(\nu)}{I_{clear}(\nu) - I_{overcast}(\nu)}$



1D-var experiments with real AIRS cloudy radiances

- Temperature and log(Q) profile increments for 4 typical situations.
- Red curve : assimilates "clear" channels unaffected by clouds.
- Green curve : assimilates all 123 selected AIRS channels.
- Blue line represents the cloud top level.



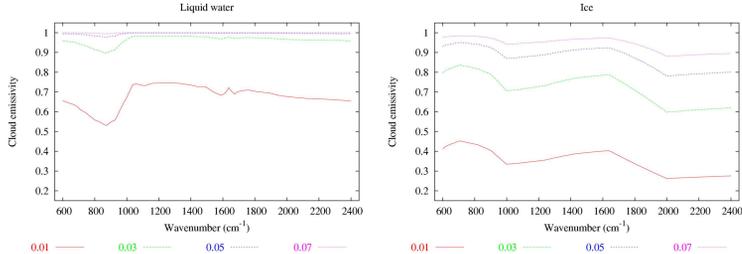
Cloud emissivity model

$$N\epsilon(\nu) = 1 - \exp[-\sec\theta\Delta P g^{-1} CWC(k_w(\nu)f_w + k_i(\nu)(1 - f_w))]$$

- $k_w(\nu)$ liquid water absorption coefficient according to Hu et al. (1993) using an effective radius of 10 μm
- $k_i(\nu)$ ice absorption coefficient according to Ebert et al. (1992) using an effective radius of 25 μm
- Liquid water fraction according to Rockel et al. (1991)

$$f_w = \begin{cases} 0.0059 + 0.9941 \exp[-0.003102(T - 273.16)^2] & T < 273.16 \\ 1.0 & \text{else} \end{cases}$$

Cloud emissivity spectra according to the used model for different values of the effective cloud depth $\delta = \frac{CWC \sec\theta\Delta P}{g}$



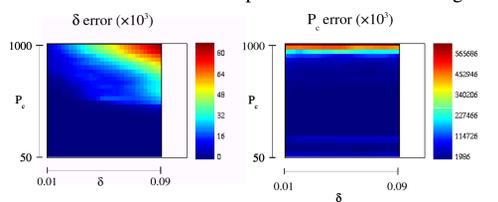
Retrieval of cloud height and optical thickness

By minimization of the following cost function :

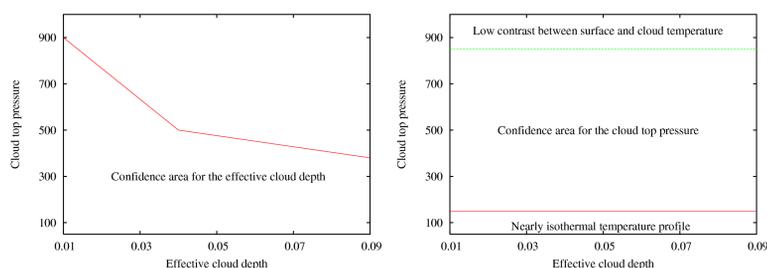
$$J_{cloud}(P_c, CWC) = \sum_{i=1}^n \left[\frac{T_{Bobs}^i - T_{Bcalc}^i(P_c, CWC)}{\sigma_i} \right]^2$$

Uses most channels except those within the 6.7 μm water vapor band.
Numerically more robust than CO_2 slicing technique.

RMS error of the determination of cloud parameters estimated using Monte-Carlo experiments :



Confidence area of the retrieved cloud parameters :



Conclusion, perspectives

- A robust estimation of cloud top and cloud emissivity is obtained, including the effect of cloud phase.
- Conditions for valid estimates of these two parameters are defined.
- 1Dvar assimilations with real data performs as expected.
- Next step is assimilation tests in 3D-var system.