CENTRE NATIONAL D'ÉTUDES SPATIALES

Near surface profiles over land. Influence of emissivity and Temperature inversion

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With contributions from PF Coheur, L. Lavanant, A. Klonecki. Many thanks for useful discussions

Outline

1. Assessment on poor quality of profiles near the surface
2. Physics
3. Effective temperature determination or correction due to emissivity
4. Temperature inversion. Occurrence. Models capability to know it
5. Error introduced by error Teff- Tair
6. Some propositions to overcome this issue

Accuracy of profiles for various regimes

TWP

SGP

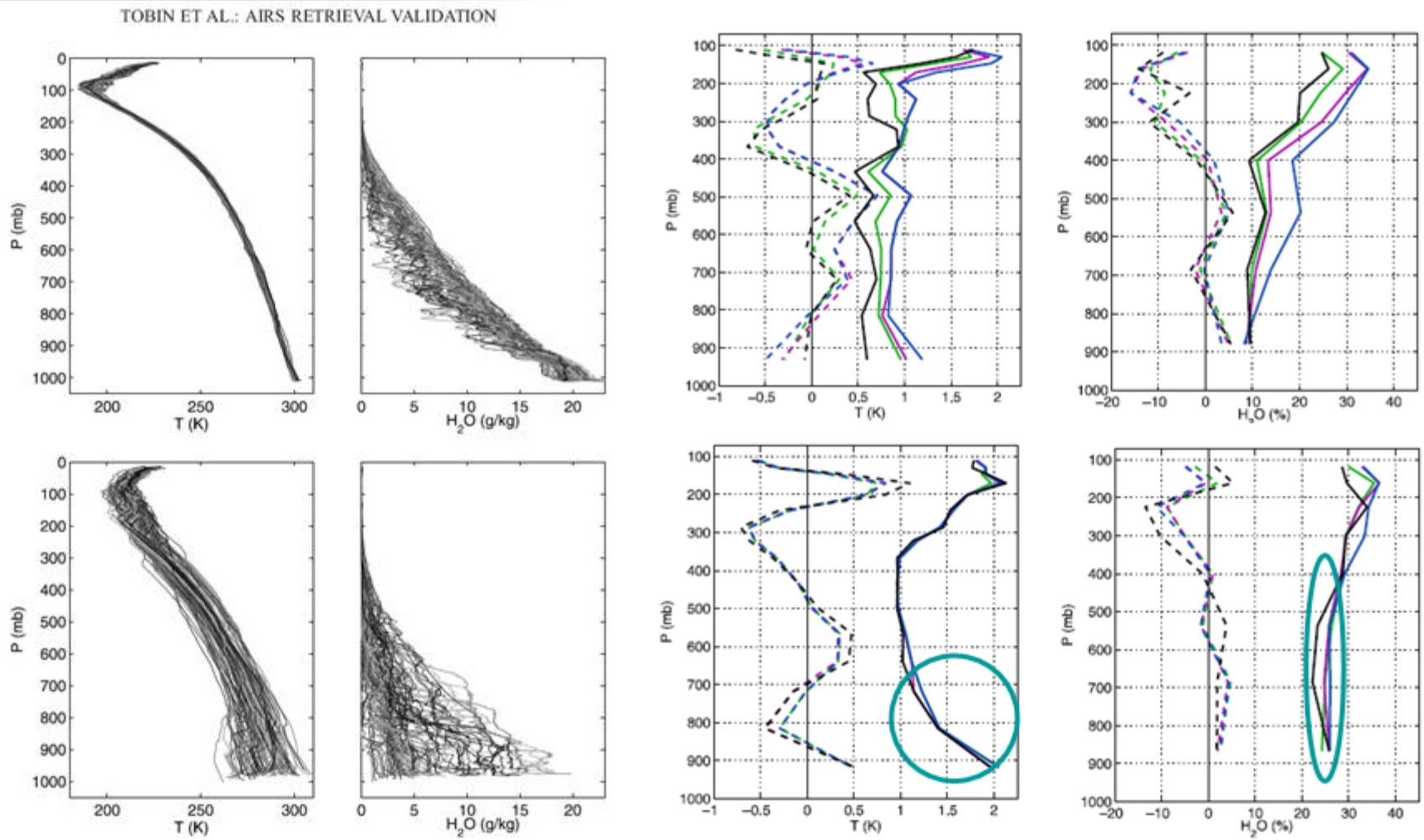
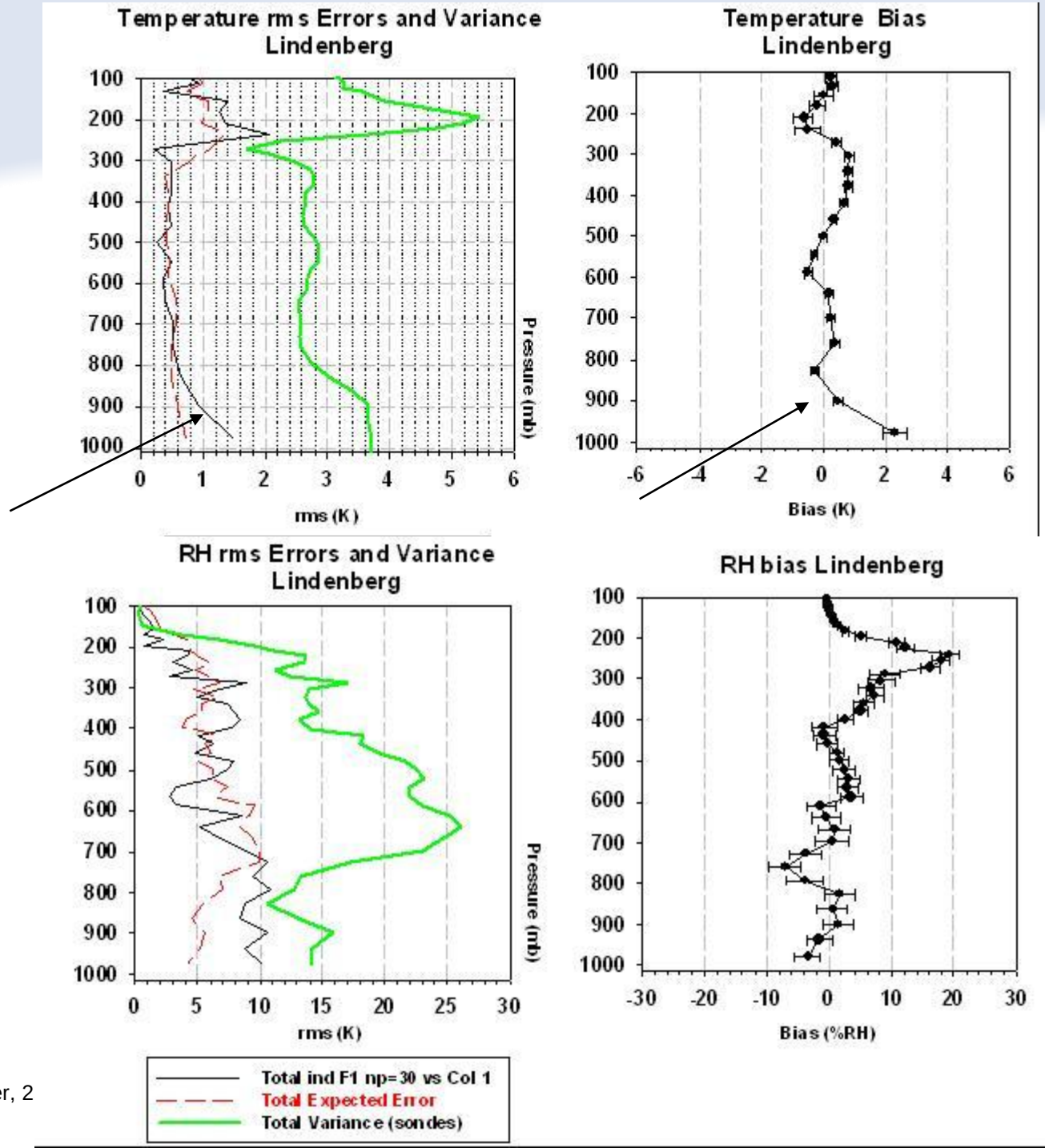


Figure 6. Sample temperature and water vapor profiles at the (top) TWP and (bottom) SGP sites.


Temperature rms Errors and Variance
Lindenberg
Pressure (mb)
rms (K)
Temperature Bias
Lindenberg
Bias (K)
RH rms Errors and Variance
Lindenberg
Pressure (mb)
rms (K)
RH bias Lindenberg
Bias (%RH)
Total ind F1 np=30 vs Col 1
Total Expected Error
Total Variance (sondes)

Soundings over land

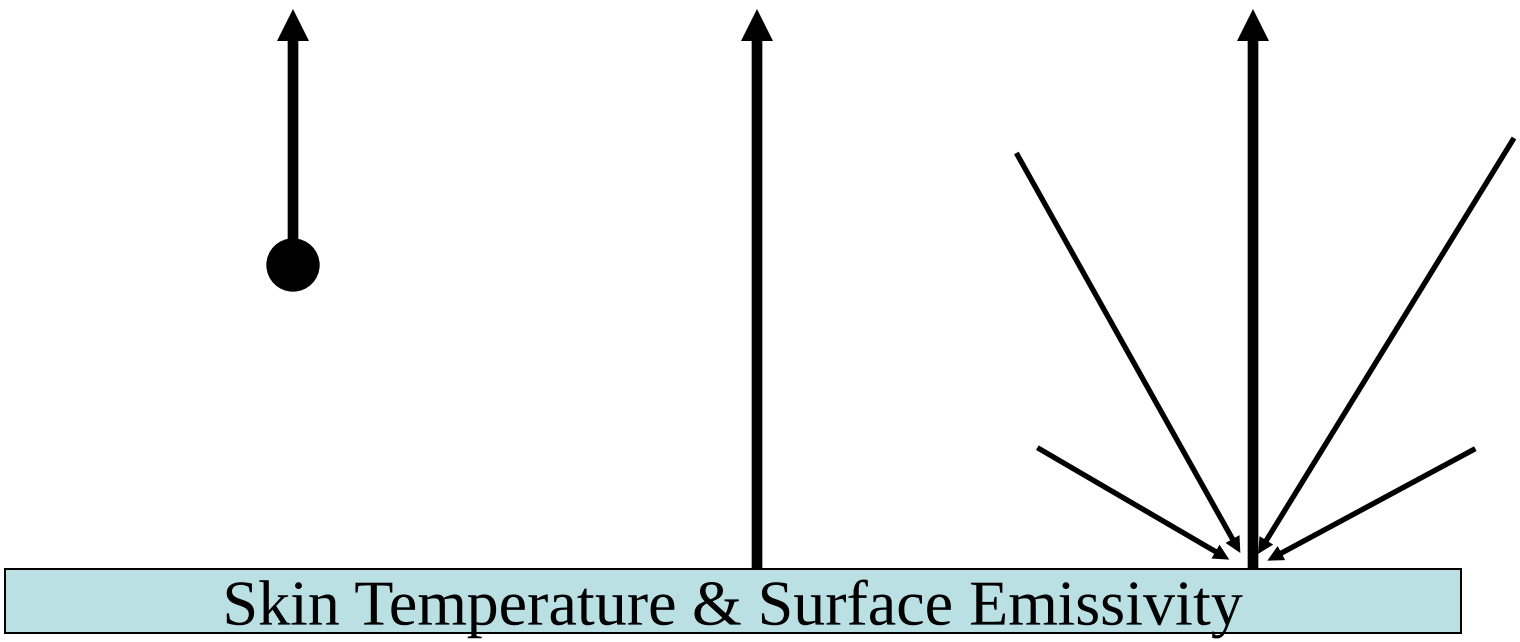
- Lower accuracy of temperature beyond 800 hPa
- Fine structures not retrieved neither for Temperature nor for Humidity
- Specially in desert or polar regions

The reasons for coarse estimate near the surface

- Surface emissivity
- Temperature inversion
- Difference between air temperature at maximum of total absorption (T1) and the effective surface temperature T*
- Many others…

Infrared Radiative Transfer Equation
(lambertian surface)

$$N_\nu^{\uparrow} = \underbrace{\int B_\nu(T(P))d\tau_\nu}_{N_\nu^{atm\uparrow}} + \underbrace{\tau_\nu^{tot} \cdot e_\nu \cdot B_\nu(T_S)}_{\text{Surface Emission}} + \underbrace{\tau_\nu^{tot} \cdot (1-e_\nu) \cdot \overline{N}_\nu^{\downarrow}}_{\text{Surface Reflection}}$$



$$N_\nu^{atm\uparrow} = \int B_\nu(T(p))\partial\tau_\nu = (1-\tau_\nu^{tot})B_\nu(T_1)$$

$$\overline{N}_\nu^{atm\downarrow} = \int B_\nu(T(p))\partial\tau_\nu^{\downarrow}(\beta_{diff}) = (1-\tau_\nu^{tot}(\beta_{diff}))B_\nu(T_2) \qquad \beta_{diff} \approx 55°$$

$$B_\nu(T_\nu^*) = e_\nu B_\nu(T_s) + \rho_\nu \overline{N}_\nu^{atm\downarrow} = B_\nu(T_s) - \rho_\nu\left[B_\nu(T_s) - (1-\tau_\nu^{tot}(\beta_{diff}))B_\nu(T_2)\right]$$

$$N_\nu^{\uparrow} = \int B_\nu(T(P))d\tau_\nu + \tau_\nu^{tot}\cdot e_\nu \cdot B_\nu(T_S) + \tau_\nu^{tot}\cdot(1-e_\nu)\cdot\overline{N}_\nu^{atm\downarrow}$$

$$= B_\nu(T_\nu^*)\tau_\nu^{tot} + (1-\tau_\nu^{tot})B_\nu(T_1)$$

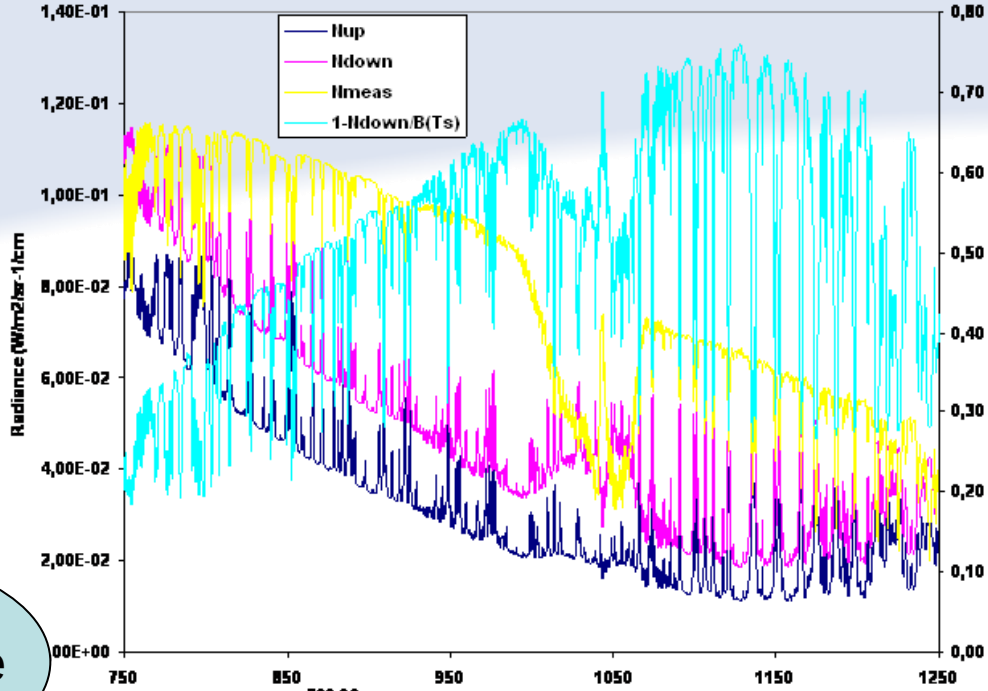
$$= B_\nu(T_1) + \tau_\nu^{tot}(B_\nu(T_\nu^*) - B_\nu(T_1))$$

$$N_\nu^{atm\uparrow}$$

and

$$\overline{N}_\nu^{atm\downarrow}$$

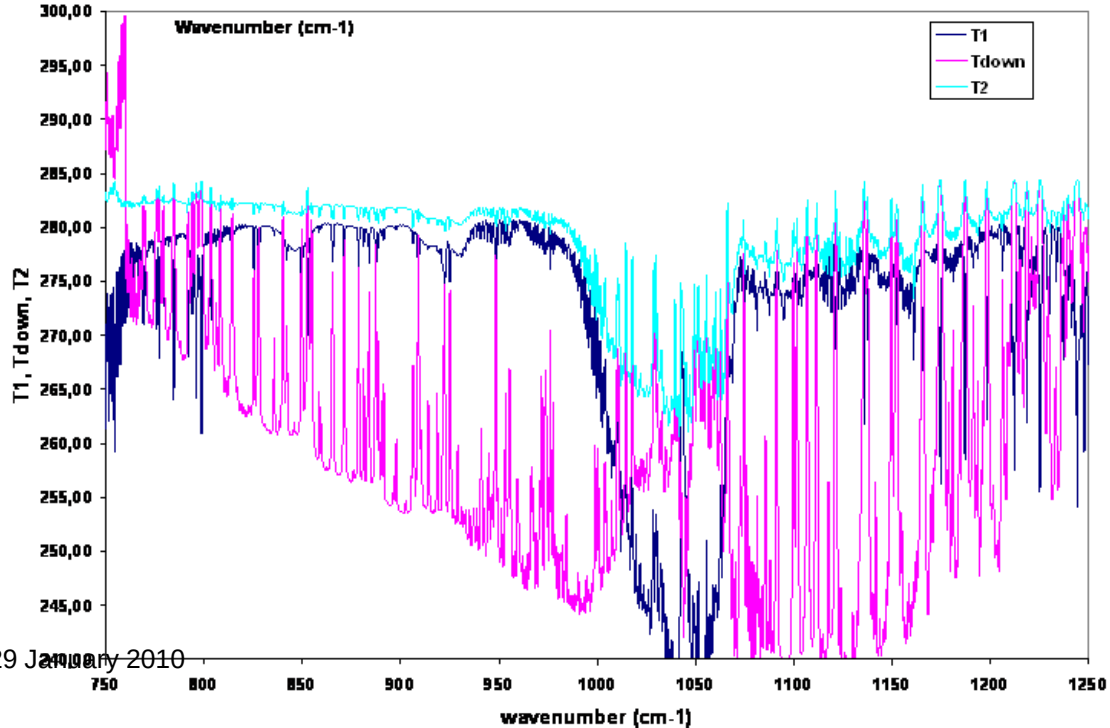
Not negligible



T_1 and T_2 vs wavenumber in the window 750-1250 cm-1

Can be easily computed as

T2 =T1+2 K in atmospheric windows



Summary (1)

- **Assume surface is a blackbody, the error on Ts is such**

$$\frac{\Delta B(T_s)}{B(T_s)} = -\frac{\Delta\varepsilon}{\varepsilon}\left(1-\frac{\overline{N\downarrow}}{B(Ts)}\right)$$

Non blackbody atmospheric ratio : κ

Inferred from τ

- **Impact or error of emissivity on Ts :**
  - **Higher for small wavenumber**
  - **Higher for high temperature**
  - **Higher for low emissivities**

In 800 to 1200 cm^{-1} window Typically 1K for 2% in windows and 0.3K in lines

ν/ε	0,98		0,95		0,92		0,87		0,82		0,7	
	300	280	300	280	300	280	300	280	300	280	300	280
800,00	0,80	0,70	0,82	0,72	0,85	0,74	0,90	0,78	0,95	0,83	1,12	0,97
1000,00	0,64	0,56	0,66	0,57	0,68	0,59	0,72	0,63	0,76	0,66	0,89	0,78
1200,00	0,53	0,46	0,55	0,48	0,57	0,49	0,60	0,52	0,64	0,55	0,75	0,65
2000,00	0,32	0,28	0,33	0,29	0,34	0,30	0,36	0,31	0,38	0,33	0,45	0,39
2200,00	0,29	0,25	0,30	0,26	0,31	0,27	0,33	0,28	0,35	0,30	0,41	0,35
2600,00	0,25	0,21	0,25	0,22	0,26	0,23	0,28	0,24	0,29	0,26	0,34	0,30

Above 2000 0.3 to 0.4 K For 2%

Impact of downward flux reflectance leads to a factor κ of typically 0.75 (windows) to 0.2(lines).

Summary (2) : retrieval of surface temperature Ts or T* kowing emissivity

- **Accurate estimate of Land surface temperature to better than 1K using 800-1200 cm-1 window once emissivity is determined and atmospheric profiles are known or with approximate multispectral methods**

- **Uncertainty on Ts much lower above 2500 cm-1 (impact of $\Delta\varepsilon/\varepsilon$)**

- **For retrieval of trace gases or aerosols worthwile to estimate T***
  - **Can be done with a priori profile and a diffusive factor of 55°, knowing a priori emissivity.(Accuracy of this assumption?)**
  - **A simpler estimate T*=Ts (1– $\rho(\nu).\psi(\nu)$ (1-κ)) where $\kappa = \gamma\ \tau_\nu$**

    where τ_ν from a priori profile

Summary (3)

- **Alternative methods to get products accounting for emissivity without computing T*:**
  - **Based upon known value of emissivity, retrieval method accounting for emissivity (e.g. neural networks). Full re-processing**
  - **Compute radiance $I_{\nu(\varepsilon=1)}$ from I_ν knowing ε and apply algorithms for blackbodies**

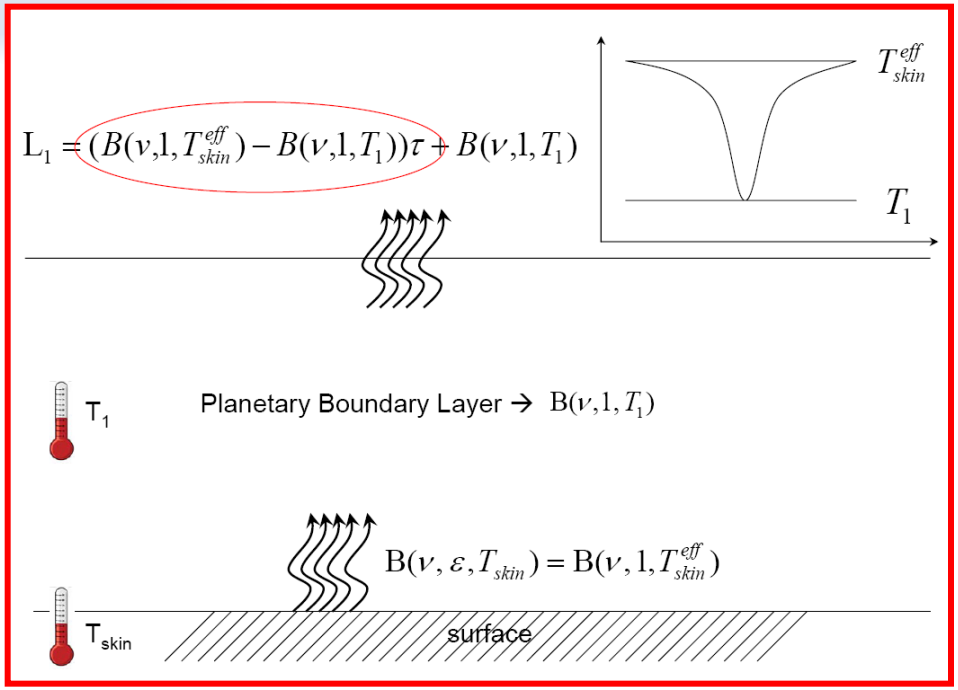
$$I_\nu^{BB} = I_\nu + (1-\varepsilon_\nu) B_\nu(T_s)\left[1 - \frac{\overline{N}_\nu^{atm\downarrow}}{B_\nu(T_s)}\right]\tau_\nu^{tot}$$

  - **Correct product of the effect of emissivity** $U(\varepsilon)=F(U(\varepsilon=1;\varepsilon;\theta;\tau)$

Impact of inversion T*-T1 on profiles

Tropospheric sources

Dependence upon *thermal contrast*



$$\Delta T = T^* - T1$$

T_1 is such as

$$B(\upsilon,l,T_1) = \frac{1}{1-\tau}\int B(\upsilon,l,T(z))\frac{\partial\tau}{\partial z}dz$$

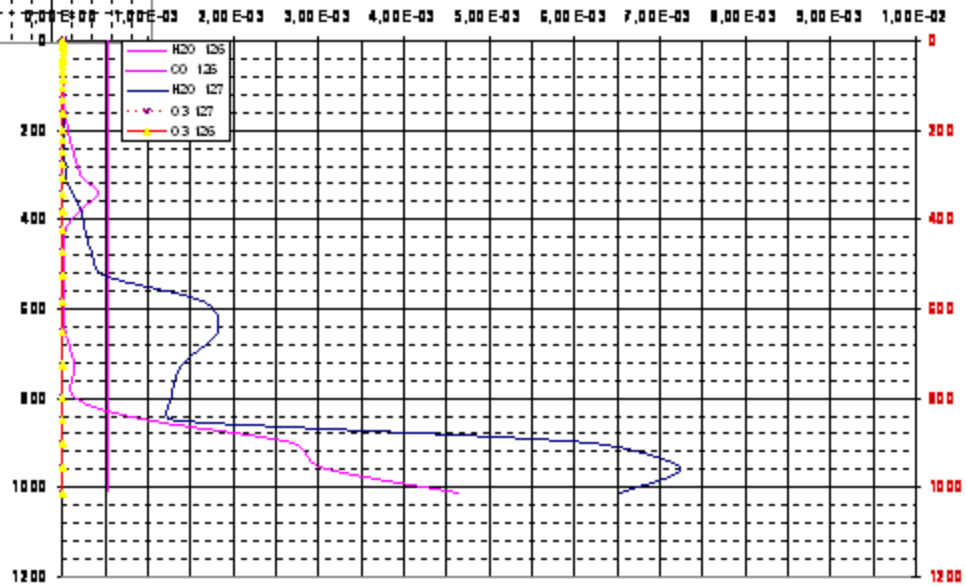
$T_1 = T_{skin}^{effective}$ → no spectral information from the first layer

$T_1 < T_{skin}^{effective}$ → Absorption from the first layer (usual case during daytime)

$T_1 > T_{skin}^{effective}$ → Emission from the first layer (temperature inversion; night-time mainly)

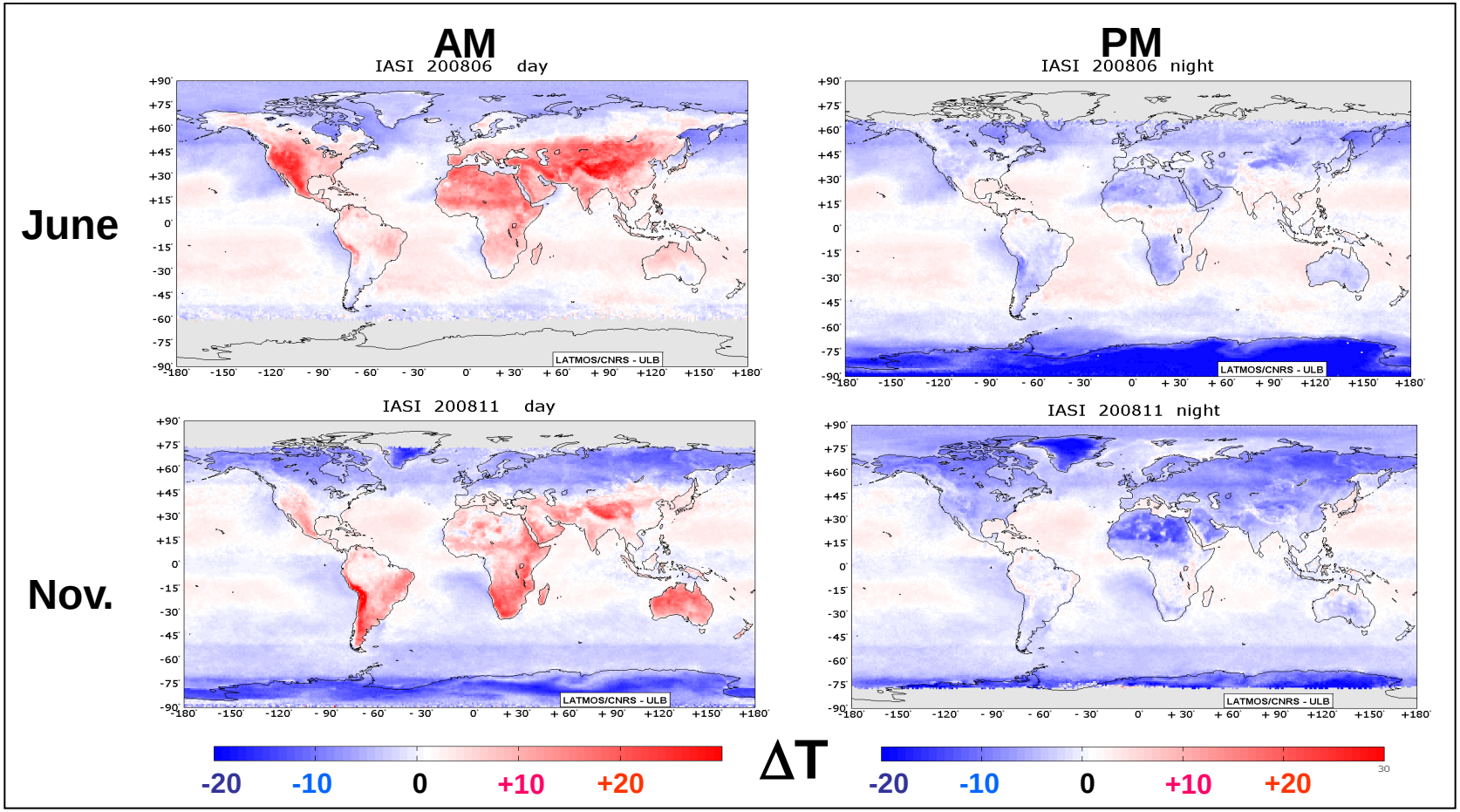
From P.F Coheur, 2009

Study case



Distribution of values (Ts-T1)

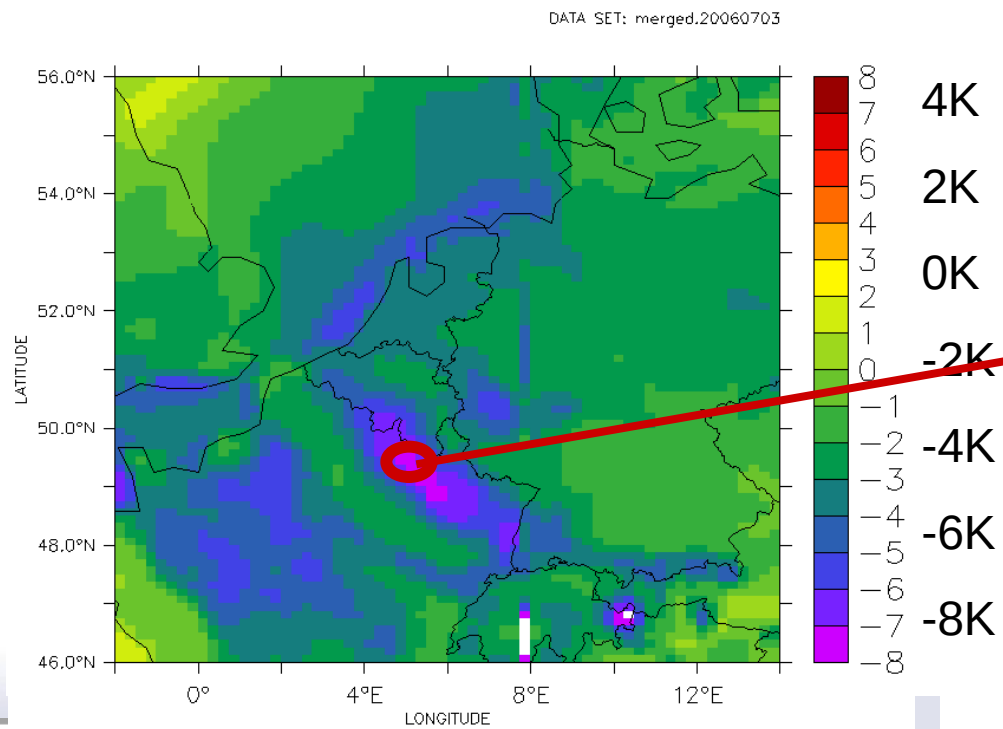
Strong negative values over desert And polar regions, but also at night over continents



How good are Ts and T1 from IASI-L2?
How good are the models?

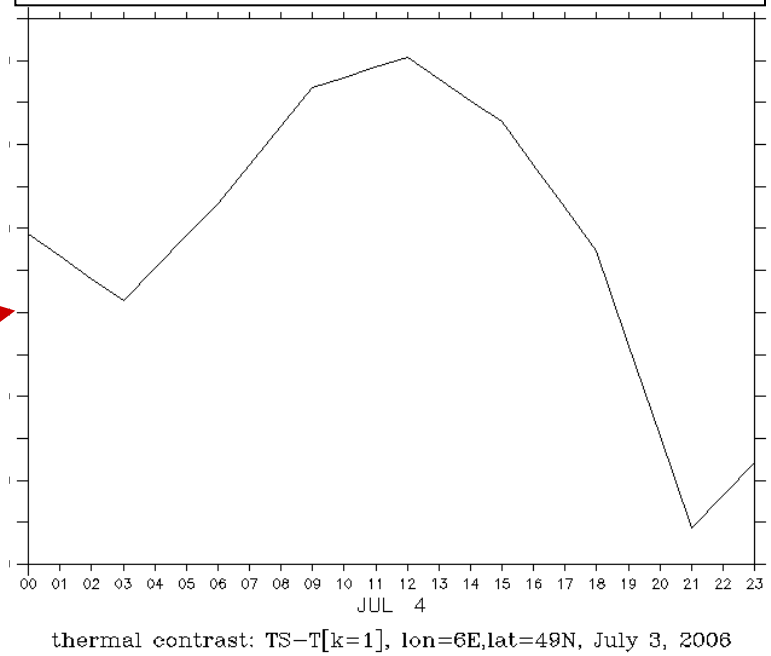
Approach 2: Temperature contrast in the model between surface and first atmospheric level

$T_{surf}-T_{L1}$ (K), 22H



$T_{surf}-T_{L1}$, lon=6E, lat=49N

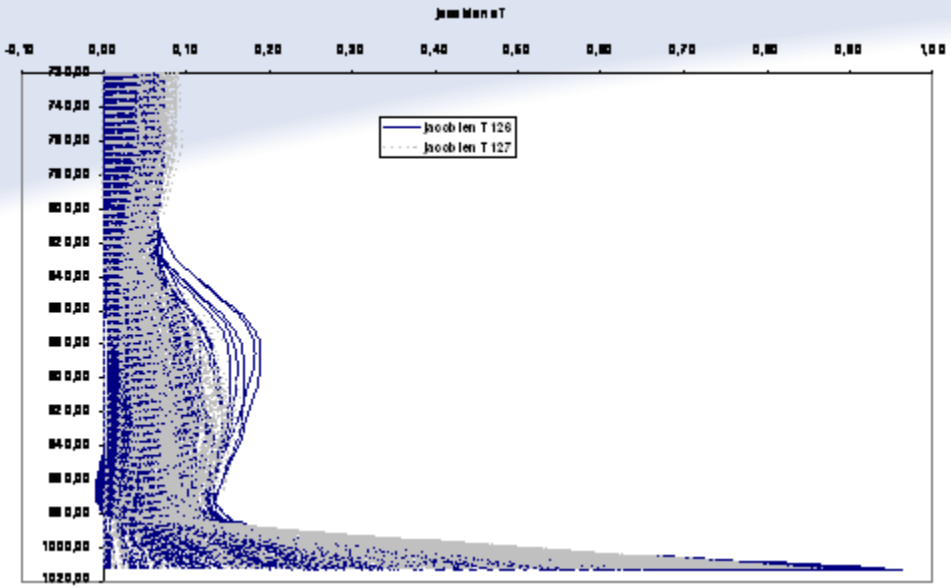
Diurnal cycle for the selected grid

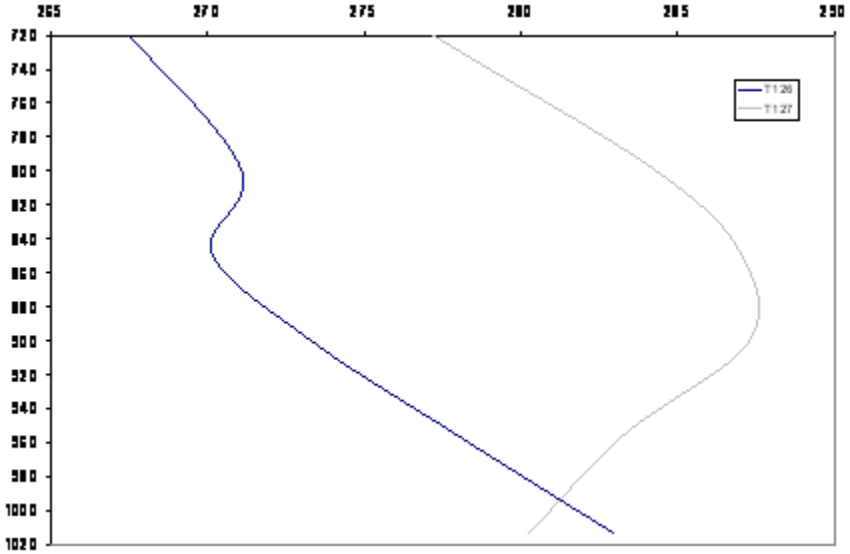


Noveltis

cnes

How does it impact the inversion?





Only slight differences in jacobians :

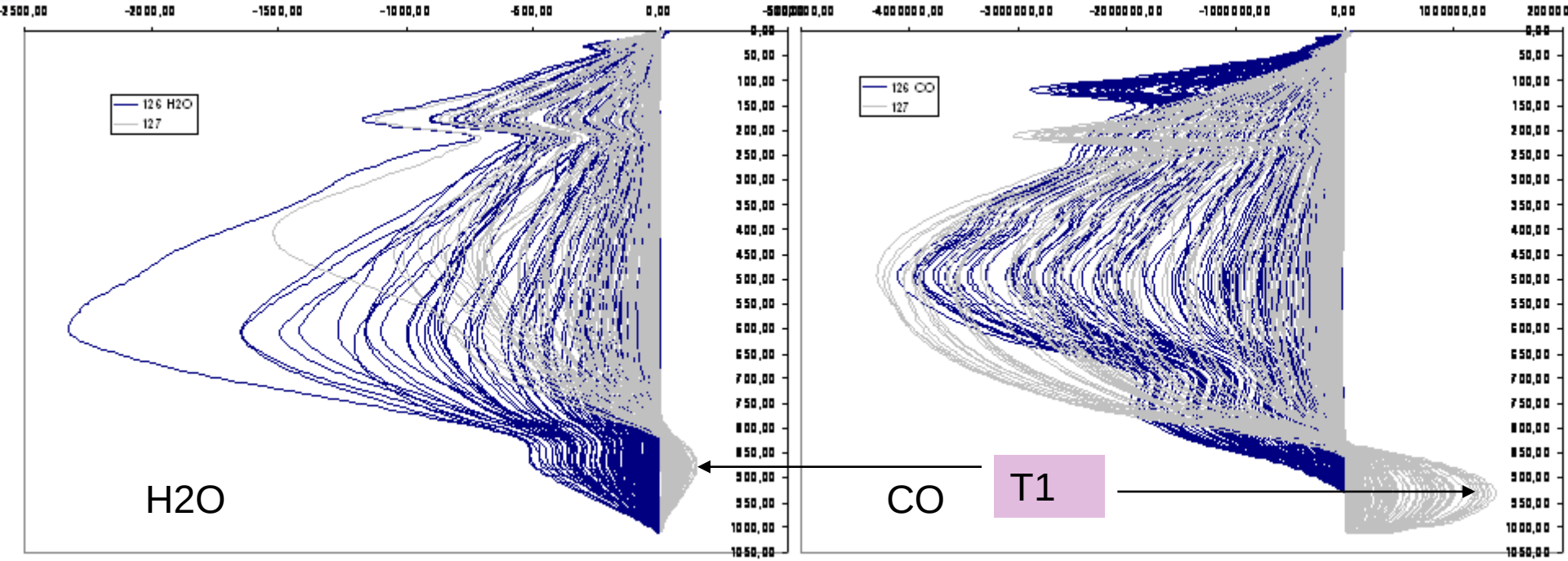
•126 higher than 127 at max of inversion

•127 higher just above inversion in 126.

Using jacobians from 126 will minimize the increment to background profile => may miss the inversion.

Nevertheless the choice of background profile is decisive

Jacobians in q and CO



Jacobians of humidity and CO for atmosphere 126 and 127

Using a priori Temperature profile with no inversion 126 will generate wrong estimate of columns or profile of air components like H_2O or CO

Summary

- If temperature inversion is missed ($T^* - T_1$), compensation on τ or T_1.

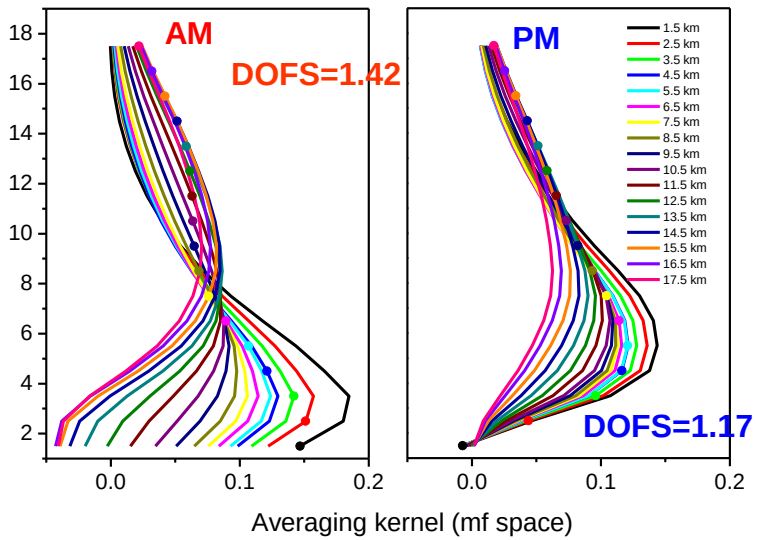
⇒In CO2 band, τ known, if T* overestimated will force T1 to small. Inversion could not be detected

⇒In H2O or CO bands if T*- T1 of the bad sign, underestimate or no possible retrieval of CO or H2O

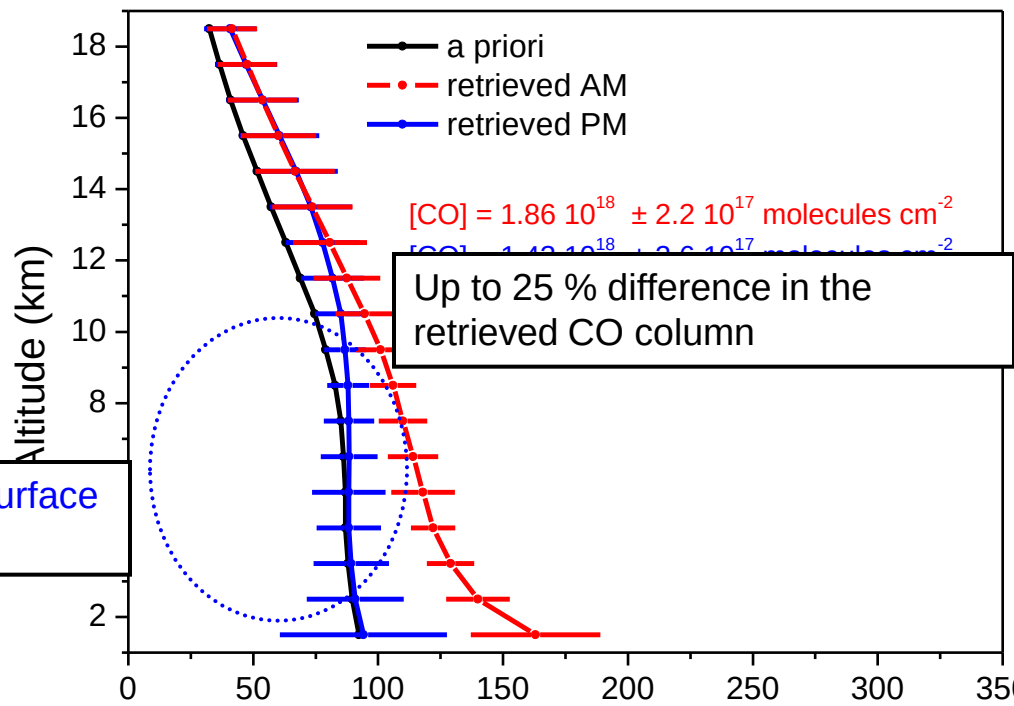
Tropospheric sources

Dependence upon *thermal contrast*

Teheran as test case



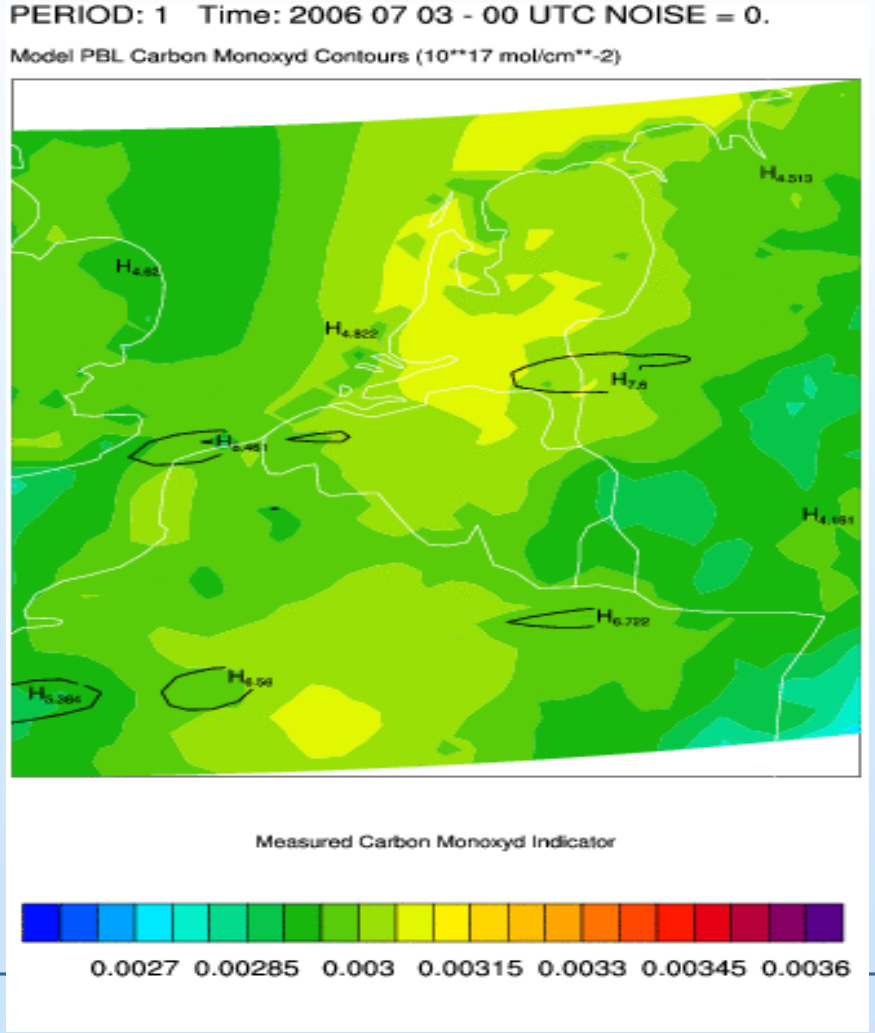
CO retrievals



Up to 25 % difference in the retrieved CO column

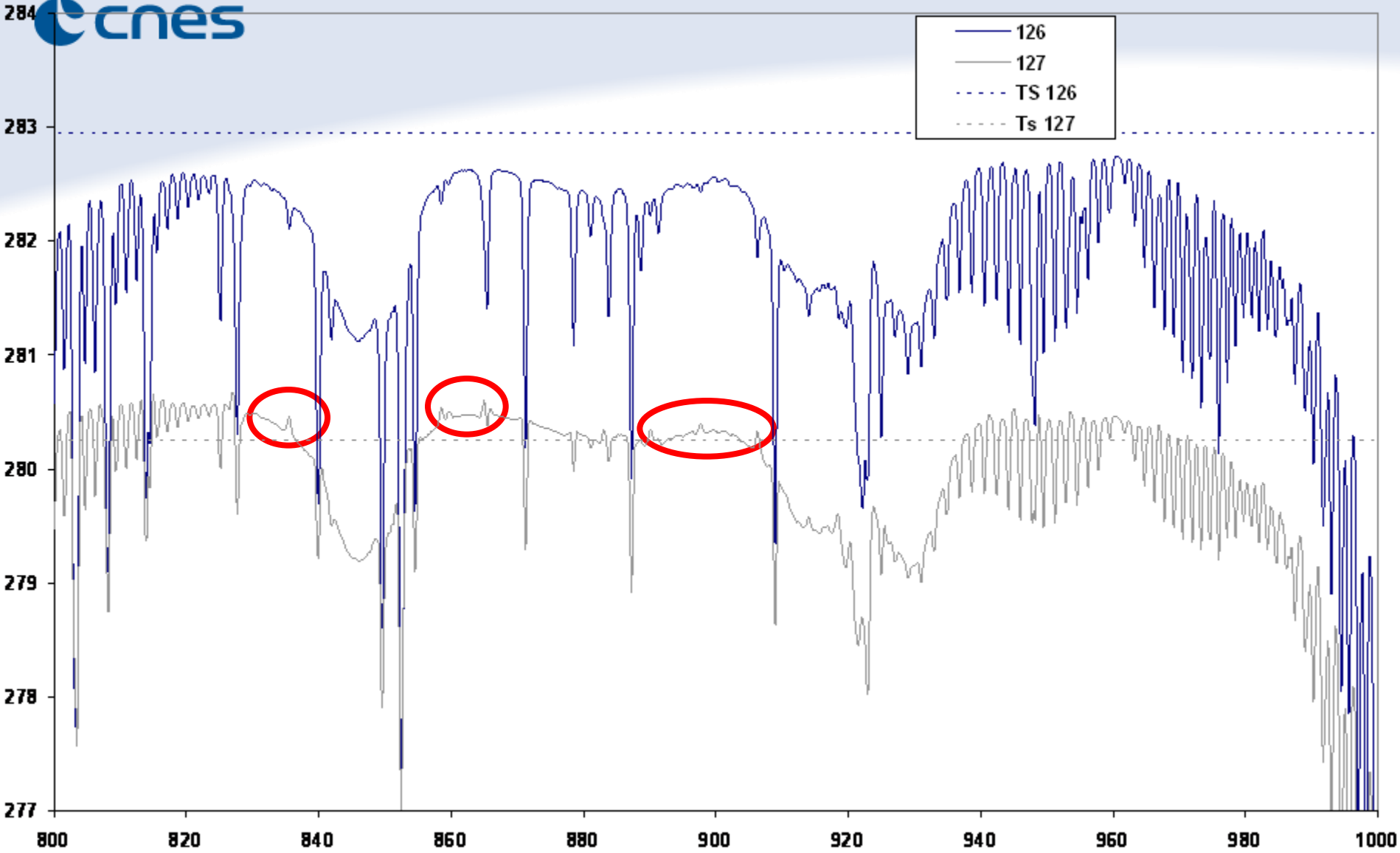
Vanishing sensitivity at the surface due to low thermal contrast

Animation, I_{co}, PERIOD 1



Necessity to have a good estimate of T* -T1

- **For T* see above**
- **For T1:**
  - **Use of spectra features**
    - In the CO_2 band
    - In minor absorption band
  - **Assume slow variations of abundant absorbing gas like CO**



Some filtering techniques would allow to detect and quantify spectra anomalies:

Detect inversion using weak CO2 lines (861to864 -865). With T* deduce the inversion level and amplitude

Conclusions

- Profiles in the lowest troposphere over continental areas (specially where few observations available) should desserve more attention.
- Retrieval of temperature inversion could be possible using information on chemical species dynamics or signal processing on the features of spectra
- In any case retrieval of emissivity is necessary to improve the products near the surface
- Some simple techniques (still to be tested) could permit to easily reprocess the data to correct the level 2 for emissivity.
- Assimilating spectra for all variables (atmosphere + chemistry + surface) could be a solution to get better near surface profiles over land (to be studied).