Retrieval of temperature from atmospheric Infrared spectra

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Overview

IR spectra observed in the mid infrared are routinely used to infer abundance of trace gases from the ground in the NDACC and TCCON [De Maziere et al., 2018, Wunch et al., 2011] . IR spectra recorded in this networks may also be used to retrieve information about temperature. For this the temperature dependence of the intensity relationship of the rotational CO_2 bands is used. CO_2 is used because it is (a) uniformly distributed in the stratosphere, (b) not very variable and (c) high precision measurements of the column from the TCCON network exist.
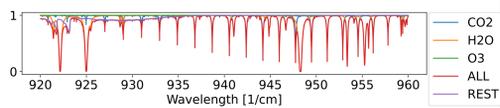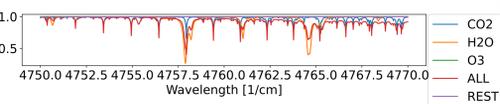

Figure 1: Window 1 920-960 cm^{-1}

Figure 2: Window 3 4750-4770 cm^{-1}

After inspecting the MID-IR wavelength range, two bands were identified:

920 - 960 cm^{-1} MCT detector range (Figure 1)

4750 - 4770 cm^{-1} INSB and InGaAs detector range (Figure 2)

which

1. contain almost no interfering lines
2. contain complete branches of the rotational part of the vibrational transition
3. contain no strong Q branch (large error due to line mixing).

High resolution of IR spectra were used to infer temperature in (not complete)

[Olsen et al., 2016] method to use for measurements on mars, but checked against earth atmosphere. From the 10 bands only one is really usable, because the other ones have H_2O interference or are very weak and not really visible from ground.

[Wang et al., 2004] used MIPS to derive temperature in the TIE and compared against GPS. Also from space in limb.

[Riese et al., 1999] Space shuttle instrument CHRISTA

Retrieval of temperature

The retrieval of the temperature is performed using the same routines which are used for the retrieval of the trace gases. However, after the modification of the temperature profile, the ray tracing and calculation of the corrections have to be repeated. The code is written in a way to ensure, only the necessary calculation are repeated to save computing time. For the temperature retrieval the Thicken Phillips regularization with smoothness (L1) constraint is used (examples in figure 3
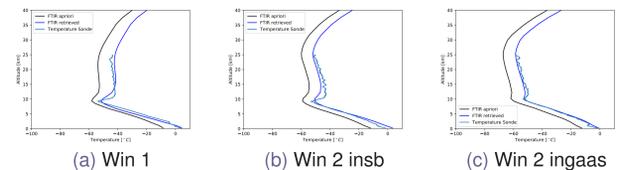

(a) Win 1   (b) Win 2 insb   (c) Win 2 ingaas

Figure 3: Examples of retrievals

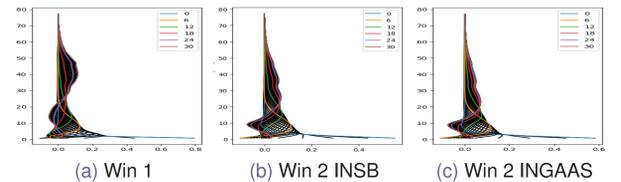(a) Win 1   (b) Win 2 INSB   (c) Win 2 INGAAS

Figure 4: Averaging kernels for retrieval setups

Comparison to temperature measurements by radiosonde

The performance of the temperature retrieval was tested in Ny Ålesund, Spitsbergen. The retrieval was setup with the temperature a priori profiles, x_A, taken from NCEP and NECP -10 K. The retrieved temperature profiles, $\hat{x}$, were compared to radiosondes which were started up to three hours before the measurement.

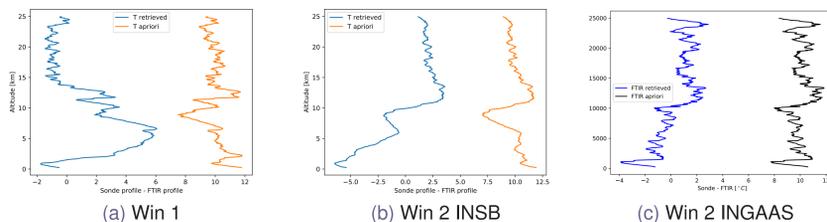(a) Win 1   (b) Win 2 INSB   (c) Win 2 INGAAS

Figure 5: One year of T profile measurements by sonde and FTIR. The sonde profiles are not smoothed.

Figure 5 shows the mean comparison with sonde profiles for one year (2019). Shown are the graphs:

$$\hat{x} - x_{\text{Sonde}} \quad \text{and} \quad x_A - x_{\text{Sonde}} \tag{1}$$

All three retrieval retrieval setups perform similar, in the sense, that the difference to the a priori is lowered considerably. Differences are related to the information content of the retrievals as show by the AVK's in Figure 4. The information content for the retrievals are DOFS=3 for the retrieval in Win 1, 2.5 for the retrieval in Win 2 (INSB) to 1.5 in Win 2(INGAAS). The difference in the latter two is due to the different resolution.

Summary

► Ground based FTIR radiometry can be used to retrieve temperature profiles with 1 to 3 degrees of freedom

► Comparison with radiosonde shows good results of the retrieval, even if the a priori is wrong by 10 K.

► Discrepancies near the surface may be caused by line shape modeling deficiencies.

Outlook

► Check of T retrieval setups for tropical regions (high water vapor interference).

► Test of line mixing and line shape parameters.

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