

# TOVS TRANSMITTANCES: IS THERE AN OPTIMUM SPECTROSCOPIC DATA SET?

D. Spänkuch and W. Döhler

Meteorological Service of the GDR  
Potsdam, German Democratic Republic

## 1. INTRODUCTION

Physical retrieval methods require in contrast to simple regression methods explicitly the knowledge of atmospheric transmittances. Inaccuracies in these transmittances enhance retrieval errors. This fact is demonstrated in Figure 1 taken from Spänkuch et al. (1981 a,b) where the bias in temperature retrieval is shown for some reference cases. The full line represents the bias using the most appropriate atmospheric transmittances calculated line-by-line on the basis of in situ measurements. The dashed line represents the bias caused by not taking into account the effect of trace gases. Figure 1 is the result of comparisons of retrievals of interferometric data in the the 15  $\mu$ m region (Spänkuch 1980) with colocated radiosonde measurements for cloudless cases in midlatitudes. The use of the most appropriate transmittance reduces the retrieval error in altitude regions with weighting function peaks (troposphere with the exception of the tropopause region, lower stratosphere).

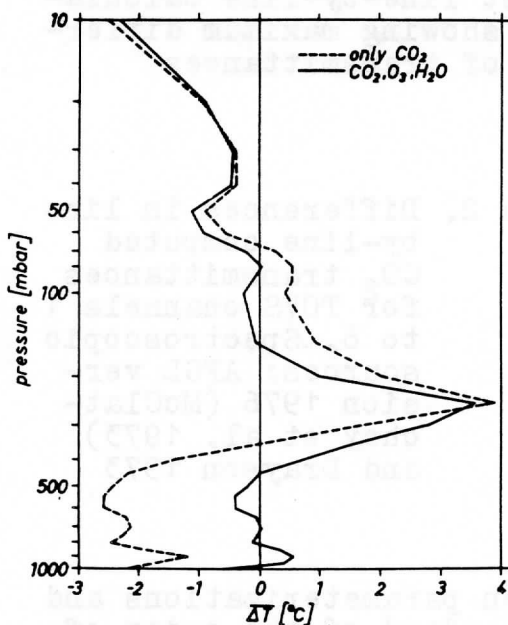


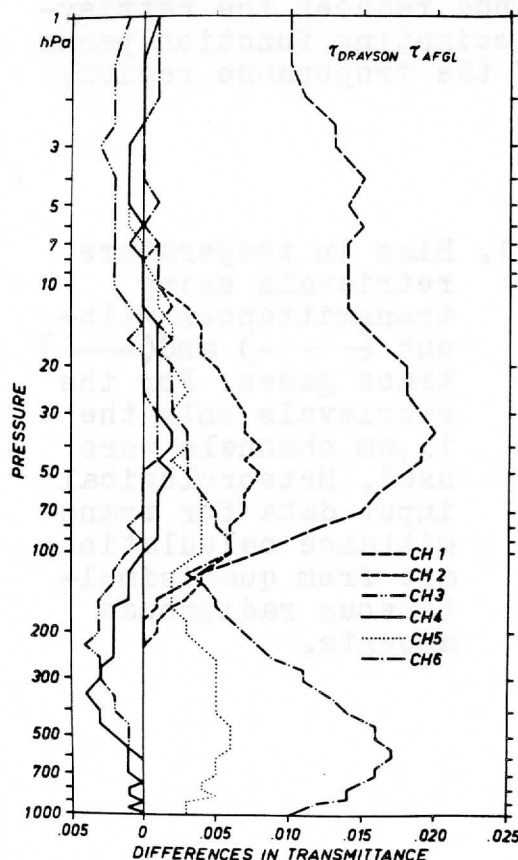
Figure 1. Bias in temperature retrievals using transmittances without (---) and (—) trace gases. For the retrievals only the 15  $\mu$ m channels were used. Meteorological input data for transmittance calculations are from quasisimultaneous radiosonde ascents.

Errors in atmospheric transmittances are of systematic and random nature and cause, therefore, systematic and random retrieval errors. The transmittance error sources are two-fold (Kondratyev and Timofeyev 1978). One source is an incorrect radiative transfer model due to incorrect spectroscopic line parameters (line intensity, line shape, half width, temperature dependence and so on) as well as numerical deficiencies (use of approximations, handling of line wings and far lines, and others). The second error source is the incorrect knowledge of that physical parameters responsible for atmospheric emission (concentration of atmospheric gases and aerosols, temperature, clouds). Errors caused by the first source are mainly systematic errors and can be minimized by special experimental and theoretical investigations. The second source produces mainly random errors and is the limiting factor for the accuracy of atmospheric transmittances.

This paper is a contribution to the first source of errors in atmospheric transmittances.

## 2. TOVS TRANSMITTANCES

The operational use of TOVS data requires a computationally fast and accurate transmittance model (McMillin and Fleming 1976, Weinreb et al. 1981). Such a model can



not rely on line-by-line calculations but has to be highly parameterized. The accuracy of this and other parameterizations was checked against line-by-line calculations showing maximum differences of transmittances

Figure 2. Differences in line by-line computed  $\text{CO}_2$  transmittances for TOVS channels 1 to 6. Spectroscopic sources: AFGL version 1976 (McClatchey et al. 1973) and Drayson 1973

between parameterizations and the standard of the order of .001 (McMillin et al. 1980).  $\Delta \tau$  of line-by-line calcula-

tions using two different spectroscopic data sources are shown in Figure 2 for the 15  $\mu\text{m}$  temperature retrieval channels. Maximum  $\Delta\tau$  are considerably larger between the two 'standards' than between the parameterization and one 'standard' and are especially large for TOVS channels 1 (668.5  $\text{cm}^{-1}$ ) and 6 (733.2  $\text{cm}^{-1}$ ). That is to say, the uncertainty of the 'standard' is significantly higher than the capability of parameterizations to approximate the standard! Details of the line-by-line calculations based on line data of Drayson (1973) and McClatchey et al. (1973) are given by Spänkuch et al. (1984) and do not consider trace gases. We emphasize once again, that the differences are only caused by the first error source as the same atmospheric input data (midlatitude summer standard atmosphere with zero nadir angle) were used. There is no significant change of  $\Delta\tau$  with nadir angle. Central wave-number  $\nu_0$  and half-width  $\Delta\nu$  of the TOVS channels assumed are given in Table 1 and are only added for completeness.

Table 1: Assumed  $\nu_0$  and  $\Delta\nu$  for TOVS channels

CH	$\nu_0$ ( $\text{cm}^{-1}$ )	$\Delta\nu$ ( $\text{cm}^{-1}$ )
1	668.50	4.0
2	680.00	14.0
3	691.56	12.0
4	703.00	20.0
5	716.00	20.0
6	733.20	16.0

### 3. COMPARISON OF MEASURED AND COMPUTED TRANSMITTANCES FOR HOMOGENEOUS CONDITIONS

To improve the accuracy of the 'standard' means to solve the problem of the most appropriate line data. Spectroscopic line data are not accurate in the proper sense of the word due to the semiempiric character of line absorption theory and the necessary tuning to experimental data. Hence, this problem can only be solved by comparing computed transmittances with measured ones at wellknown conditions. The comparison for homogeneous conditions is the first necessary step. Without going into detail we present in Figure 3 the averaged systematic differences between measured ( $\tau^{\text{exp}}$ ) and calculated  $\text{CO}_2$  transmittances ( $\tau^{\text{calc}}$ )

$$\overline{\Delta\tau} = \frac{1}{N} \sum_{i=1}^N (\tau^{\text{exp}} - \tau^{\text{calc}})$$

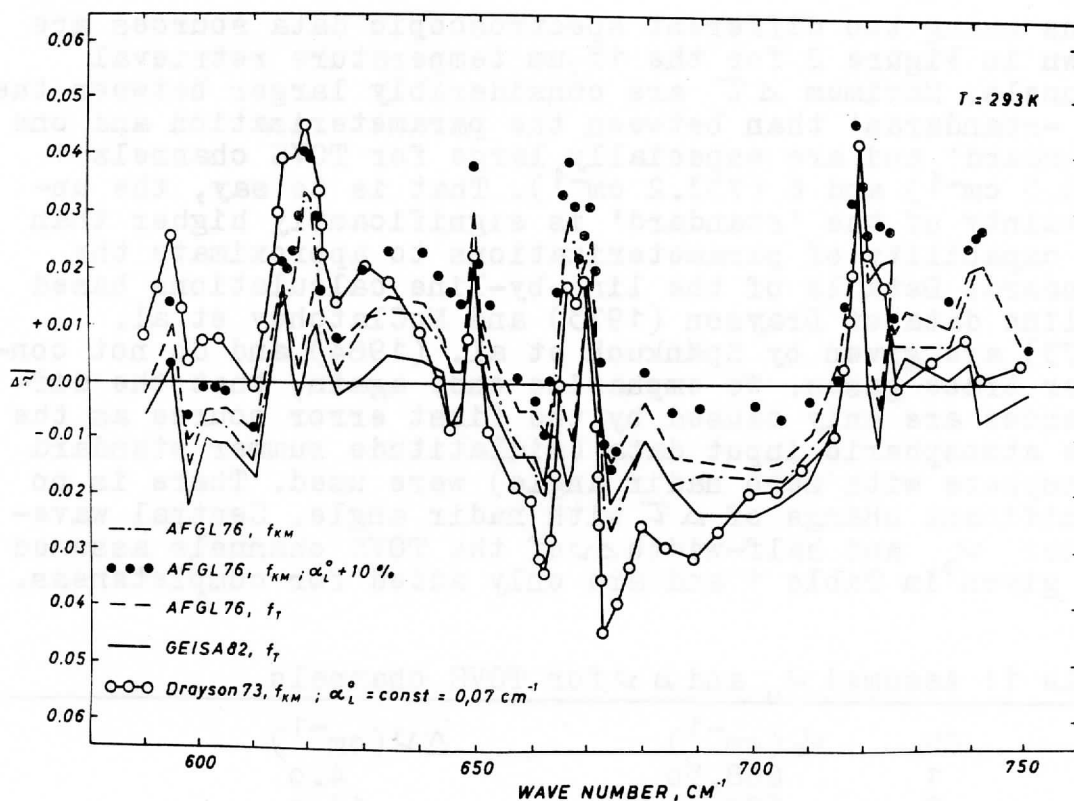


Figure 3. Averaged differences between line-by-line computed ( $\tau^{\text{calc}}$ ) and experimental ( $\tau^{\text{exp}}$ )  $\text{CO}_2$  transmittances for homogeneous conditions (see Döhler and Spänkuch 1985).  $T = 293 \text{ K}$   
 Spectroscopic sources: AFGL version 1976 (McClatchey et al. 1973), GEISA 1982 (Chedin et al. 1982) and Drayson 1973.  $f_{KM}$  and  $f_T$  = line shape after Kunde and Maguire (1974) and Dokuchaev et al. (1982), the latter one includes the effect of line interference;  $\alpha_L^0$  - Lorentzian half-width.

versus wavenumber from  $590 \text{ cm}^{-1}$  to  $750 \text{ cm}^{-1}$  with  $N = 8$  number of experimental homogeneous conditions for  $T = 293 \text{ K}$ . Theoretical transmittances were calculated for a variety of input data including different line sources (AFGL 1976, GEISA 1982, Drayson 1973), line shapes  $f$  and half-widths  $\alpha_L$ . Details are given in Döhler and Spänkuch (1985). Comparisons made for stratospheric temperatures ( $T = 213 \text{ K}$ ), too, give similar results and demonstrate that the temperature dependence of spectroscopic data is well reflected. TOVS channel 1 to 6 lie on the right half of Figure 3. Note that the differences of Figure 2 are reflected by the differences between the curves of Figure 3 (different spectroscopic sources) but not by the difference against the measured values. Figure 3 demonstrates that empirical adjustments (e.g. the enhancement of half-width by 10% for

AFGL version 1976) can considerably reduce the discrepancy of theoretical against experimental transmittances in some spectral intervals (670 - 715  $\text{cm}^{-1}$ ). There are, on the other hand, spectral intervals (e.g. around the band center 668  $\text{cm}^{-1}$ ) where only the inclusion of additional physical effects (line interference, considered in  $f_m$ ) is able to reduce this discrepancy to an acceptable degree. For other regions the spectroscopic data have to be corrected. This is the case for the 10001 - 01101 band intensity which is too large by about 10% (Clough 1984).

#### 4. CONCLUSIONS

(i) Differences in line-by-line computed atmospheric transmittances using different spectroscopic input data are considerably larger as differences between modern parameterizations of transmittances and line-by-line computations.

(ii) Improvements in spectroscopic line parameters can be done on the basis of comparisons between calculated and measured atmospheric transmittances for well-defined conditions.

(iii) Those improvements include corrections in line data by empirical adjustment as well as the consideration of additional physical processes.

(iv) The question for an optimum spectroscopic data set of the presently available sets can at present not definitely be answered. The most appropriate spectroscopic data source for one spectral interval is not necessarily the most appropriate one for another interval (see Figure 3).

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**Cooperative Institute for Meteorological Satellite Studies  
Space Science and Engineering Center  
University of Wisconsin  
1225 West Dayton Street  
Madison, Wisconsin 53706  
(608) 262-0544**

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