Development of new fast radiative transfer coefficients for microwave sensors using AMSUTRAN

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1. What is AMSUTRAN ?

AMSUTRAN is a line-by-line transmittance model operating in the microwave spectrum (from 1 – 1000 GHz). It is designed principally to provide accurate surface to space transmittance profiles for use as training data for fast radiative transfer coefficients for RTTOV.

The gaseous absorption calculated by AMSUTRAN takes in to account the following molecular species: water vapour, oxygen, ozone and the nitrogen continuum

Calculations are made over a set of diverse atmospheric profiles – e.g. the 83 profile set shown in Figure 1. The resulting variation in surface to space transmittance & optical depths across the microwave spectrum are shown in Figure 2.

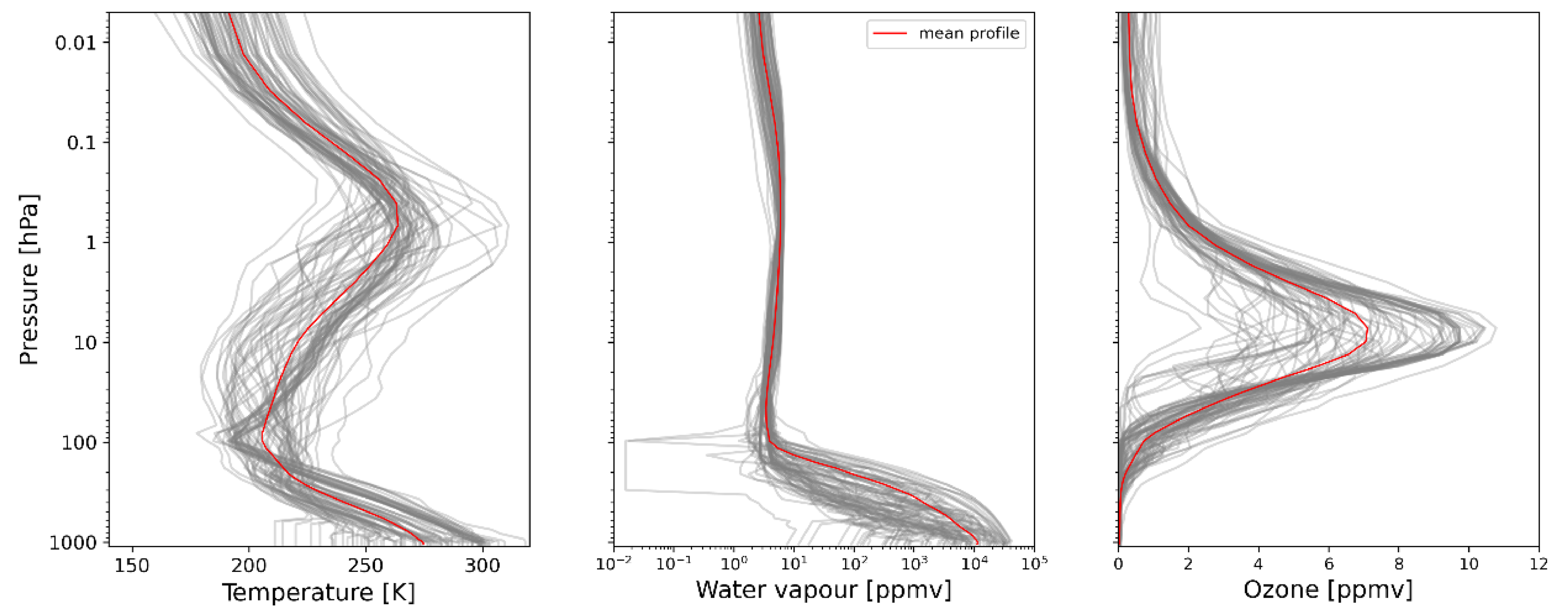

Figure 1. Set of atmospheric profiles used in AMSUTRAN standard calculations.

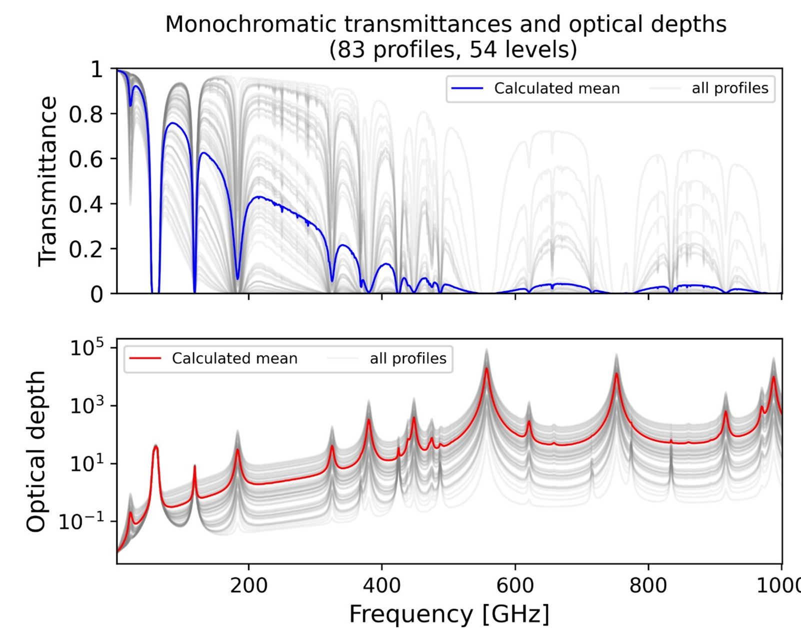

Figure 2. AMSUTRAN calculated surface to space transmittance and optical depths as a function of frequency

2. Spectroscopy Updates

The details of spectroscopic datasets used in a standard AMSUTRAN run for water vapour and ozone are shown in Table 1 (left hand columns – referred to as Spectroscopy 2019). Over the next few years there are new operational instruments such as the Ice Cloud Imager (ICI) that use sub-mm channels (frequencies greater than 200 GHz). Several studies have noted (e.g. Turner et al. 2019) that v2019 spectroscopy does not contain enough lines beyond 300 GHz to accurately represent these new channels. Updated spectroscopic datasets were obtained to improve the modelling beyond 300 GHz. The sources are shown in Table 1 and referred to as Spectroscopy 2023. Note that the treatment of the mixed gases (Oxygen and Nitrogen) are unchanged.

As expected, the impact of the change to spectroscopy v2023 makes only small differences for frequencies less than 200 GHz (up to 1K), but large impacts in the sub-mm range (in excess of 10 K for certain frequencies). This is shown in Figure 3 by test runs across the mw spectrum out to 670 GHz using the different databases. The arrows denote the frequencies at which the largest changes are found when integrated over channel passbands on a selection of new and existing sensors. The magnitude of these changes are shown in Table 3, including the ICI instrument.

Gas	Spectroscopy v2019 OLD		Spectroscopy v2023 NEW	
	No. of lines	Source	No. of lines	Source
Ozone	35 < 300 GHz	HITRAN 2000	1242	HITRAN 2020
Water Vapour	30	MPM89*	366	AER 3.8
Water Vapour continuum	N/A	MPM89	N/A	MT-CKD v4.2

Table 1 The sources of the spectroscopic databases for ozone and water vapour lines and the continuum model for water vapour. * denotes modifications to air broadening parameters for the 22 and 183 GHz (see Turner et al, 2019 for further details)

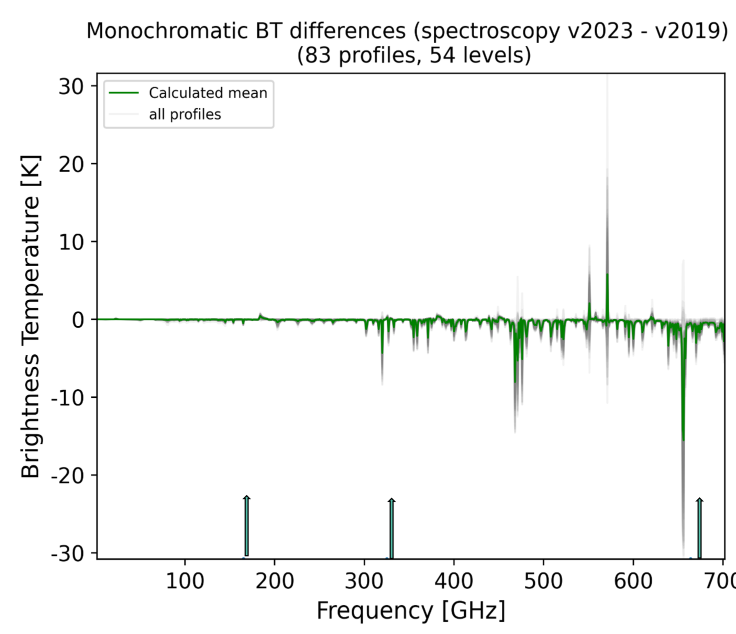

Figure 3. TOA brightness temperature difference between AMSUTRAN runs using spectroscopy v2023 and v2019

Inst.	Band (GHz) & channel	Impact (K)
ATMS	183.31; ch 22	+0.21
AWS	325.15; ch 19	-0.55
ICI	664.0; ch 12,13	-1.79
MWI	165.5 ; ch 21	-0.11
MWHS2	183.31; ch 11	+0.21

Table 3. The largest impact of the spectroscopy change on selected instruments

3. Tests of spectroscopy v2023 in IFS and MetOffice global NWP systems

RTTOV fast coefficients were generated for **all** existing microwave instruments based on updated training data provided by AMSUTRAN with the spectroscopy v2023. These coefficients were then tested independently in NWP trials at the Met Office and ECMWF(IFS)

The trial periods and configurations were as follows:

ECMWF (IFS): summer 2022/winter 2023 configuration:IFS-CY49R1 using RTTOV 13

Met Office: June 2021-August 2021 configuration: OS45 using RTTOV 12.3

Figures 4 and 5 show the change in fit (standard deviation) of the observation – background for two MW sensors (GMI and AMSUA respectively). It can be seen for GMI that the fits of the observations against the updated RTTOV coefficients have generally improved in both ECMWF and Met Office models. Both centres show improvement to channel 12 and 13 operating in the 183 GHz band for instance. In the case of AMSUA the change is more mixed, with ECMWF fits improving for the low frequency channels 1 & 2 but seeing some degradation in the 50 GHz band (e.g channel 8 in both Met Office and ECMWF experiments). Overall forecast impact of the change is considered neutral. In Figure 6 results from the Met Office NWP experiment, show a mix of small benefits and degradations to forecast fields.

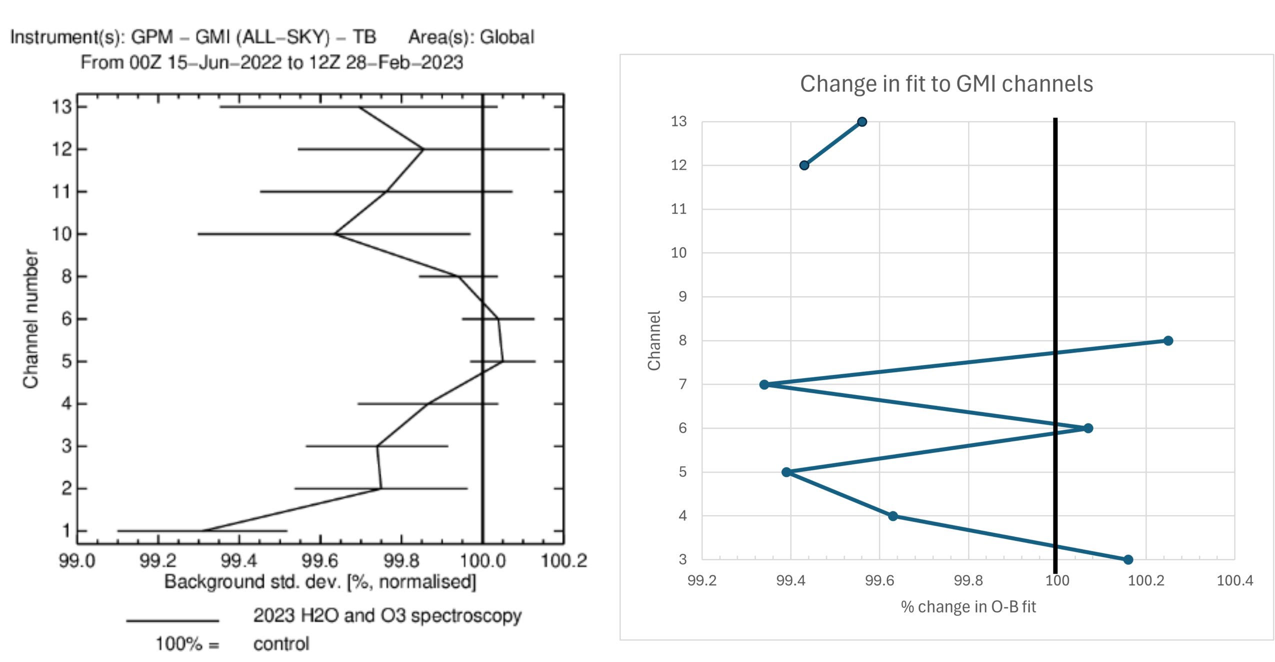

Figure 4. Change in O-B difference (std deviation) of **GMI** channels due to the new spectroscopy. *Left panel:* ECMWF, *Right panel:* Met Office

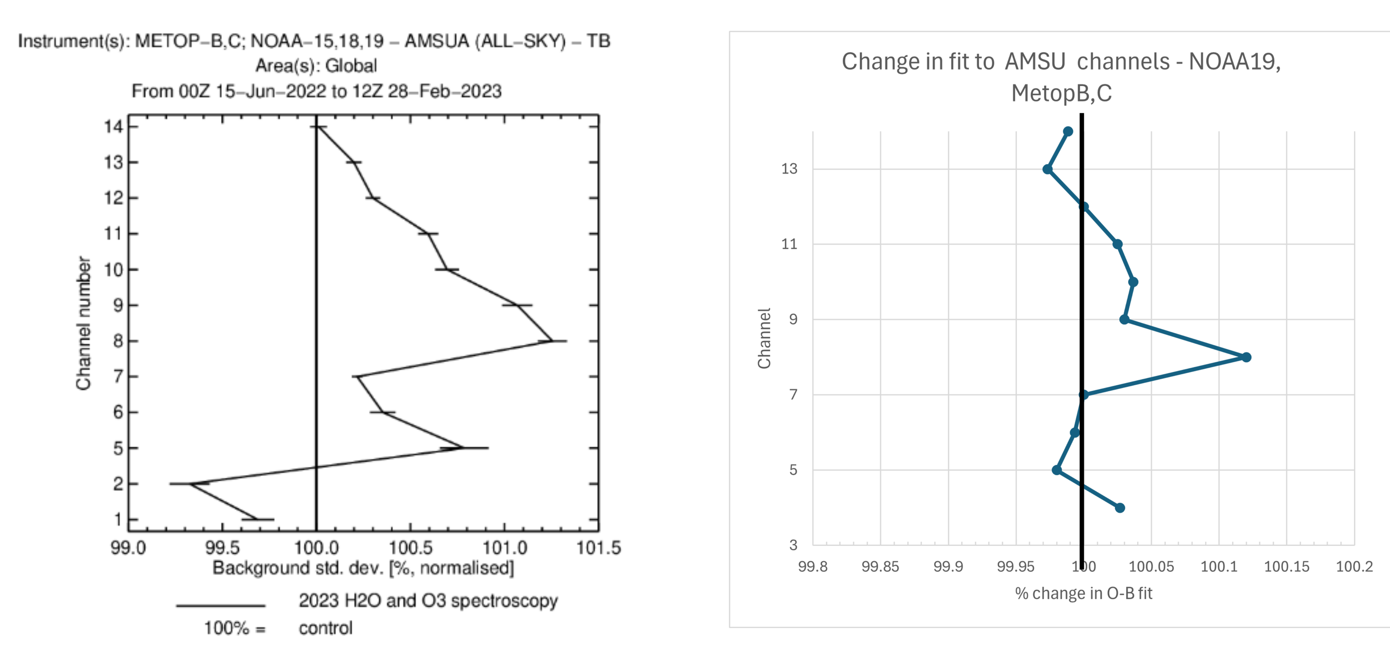

Figure 5. Change in O-B difference (std deviation) of **AMSUA** channels due to the new spectroscopy. *Left panel:* ECMWF, *Right panel:* Met Office

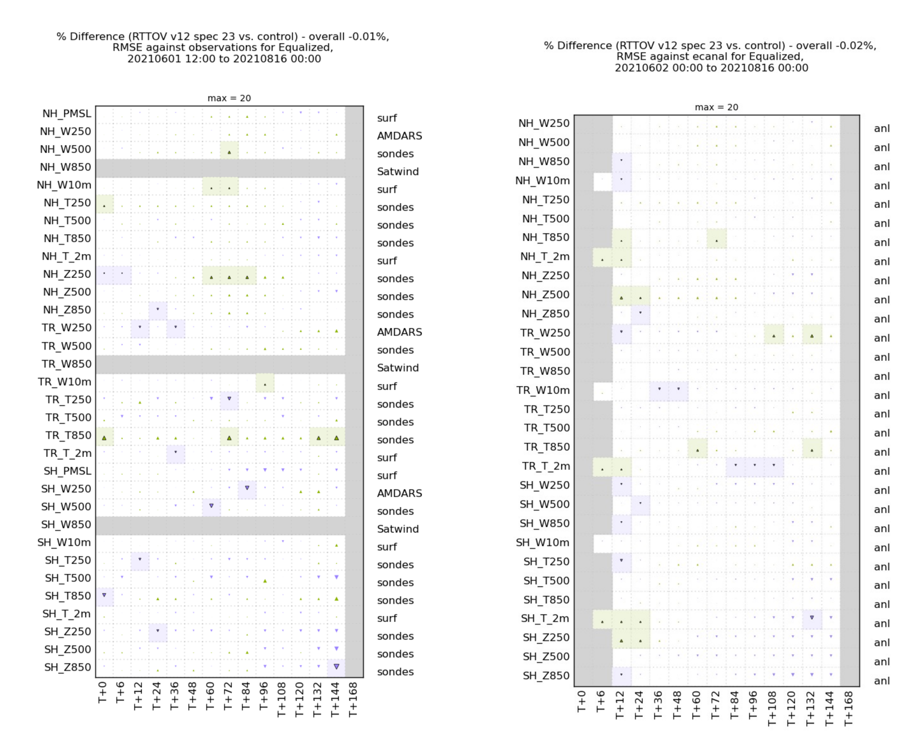

Figure 6. Met Office forecast scorecards due to the new spectroscopy. *Left panel:* verified against observations, *Right panel:* verified against ECMWF

Conclusions and Next Steps

- ❑ RTTOV fast coefficients have been produced from AMSUTRAN calculations using an updated spectroscopy dataset (v2023). This improves the treatment of ozone and water vapour, in readiness for new instruments containing sub-mm channels.
- ❑ Tests of the new fast coefficients on existing instruments show some sensitivity to fit of observations against NWP fields in two global models. Overall, the forecast impact is considered neutral for use in existing instruments.
- ❑ You can obtain these updated coefficients from the NWP SAF website at *https://nwp-saf.eumetsat.int*
- ❑ We intend to extend the tests of updates to spectroscopy. For example, to include new line parameters for the Oxygen band.

References and Further Information

The AER dataset: Cady-Pereira, K., Alvarado, M., Mlawer, E., Iacono, M., Delamere, J., & Pernak, R. (2020). AER Line File Parameters (v3.8.2) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.7853414

For more details on the HITRAN database see I. E. Gordon, L. S. Rothman, R. J. Hargreaves, R. Hashemi, E. V. Karlovets, F. M. Skinner, *et al.*, "The HITRAN2020 molecular spectroscopic database", *J. Quant. Spectrosc. Radiat. Transfer* **277**, 107949 (2022).

Turner, E., Rayer, P., and Saunders, R. (2019) AMSUTRAN: A microwave transmittance code for satellite remote sensing. Journal of Quantitative Spectroscopy and Radiative Transfer, 227 p117-129.

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