Met Office

Quantification of line-by-line parameter errors in the 183.31 GHz water vapour line

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NWP SAF Numerical Weather Prediction
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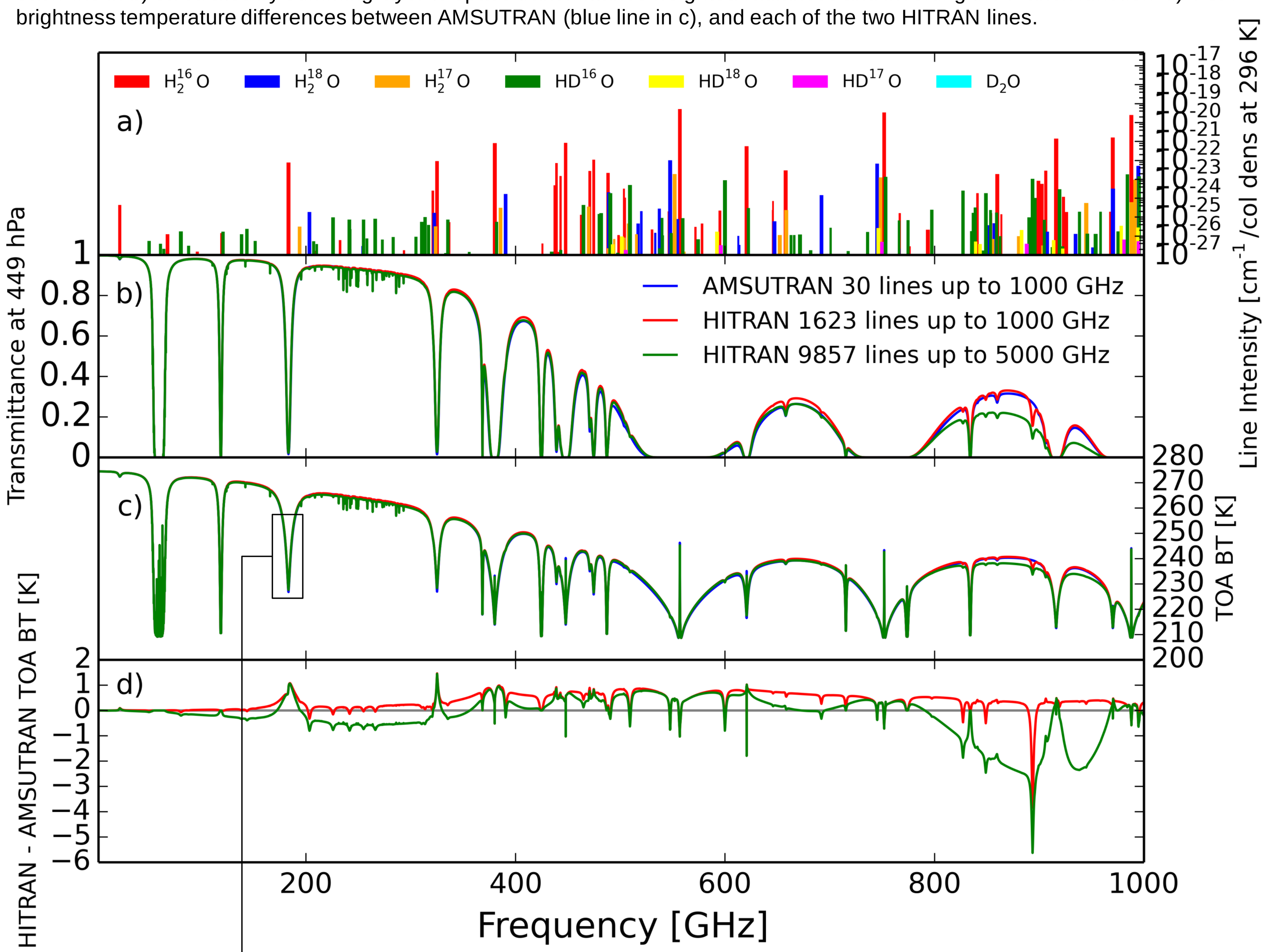
Abstract

The rotational transition of water vapour at 183.31 GHz is one of the most heavily utilised spectroscopic lines measured by current and future satellite instruments such as SAPHIR, MHS, ATMS, SSMIS and ICI. The passbands of channels centred at this frequency typically span a wide frequency range (e.g. 24 GHz for SAPHIR channel 6) in order to profile tropospheric humidity. However, equivalent radiative transfer simulations of these satellite observations show errors that increase further away from the line centre. The Met Office microwave line-by-line model AMSUTRAN is used to investigate the sensitivity to the 183.31 line's spectroscopic parameters by replacing the existing configuration with those from the latest HITRAN database, along with their associated range of uncertainties. The effect on top of atmosphere brightness temperatures are shown monochromatically and for satellite channels centred on the line. Channel differences can reach up to 1 K and the uncertainties surrounding HITRAN parameters can add up to ±1 K around this. Differences decrease in channels further from the line centre but uncertainties can remain high.

Figure 1. a) Positions and intensities (at 296 K) of HITRAN 2016 lines for 7 isotopes of water vapour. Line half widths are to scale. b) Level to space transmittances at 449 hPa calculated using AMSUTRAN's standard configuration of 30 H_2O lines[a] (blue), all available HITRAN H_2O lines up to 1000 GHz (red) and up to 5000 GHz (green). c) Top of atmosphere brightness temperatures for each line in b) calculated by summing layer to space transmittance weighted radiances and inverting the Planck function. d) TOA brightness temperature differences between AMSUTRAN (blue line in c), and each of the two HITRAN lines.



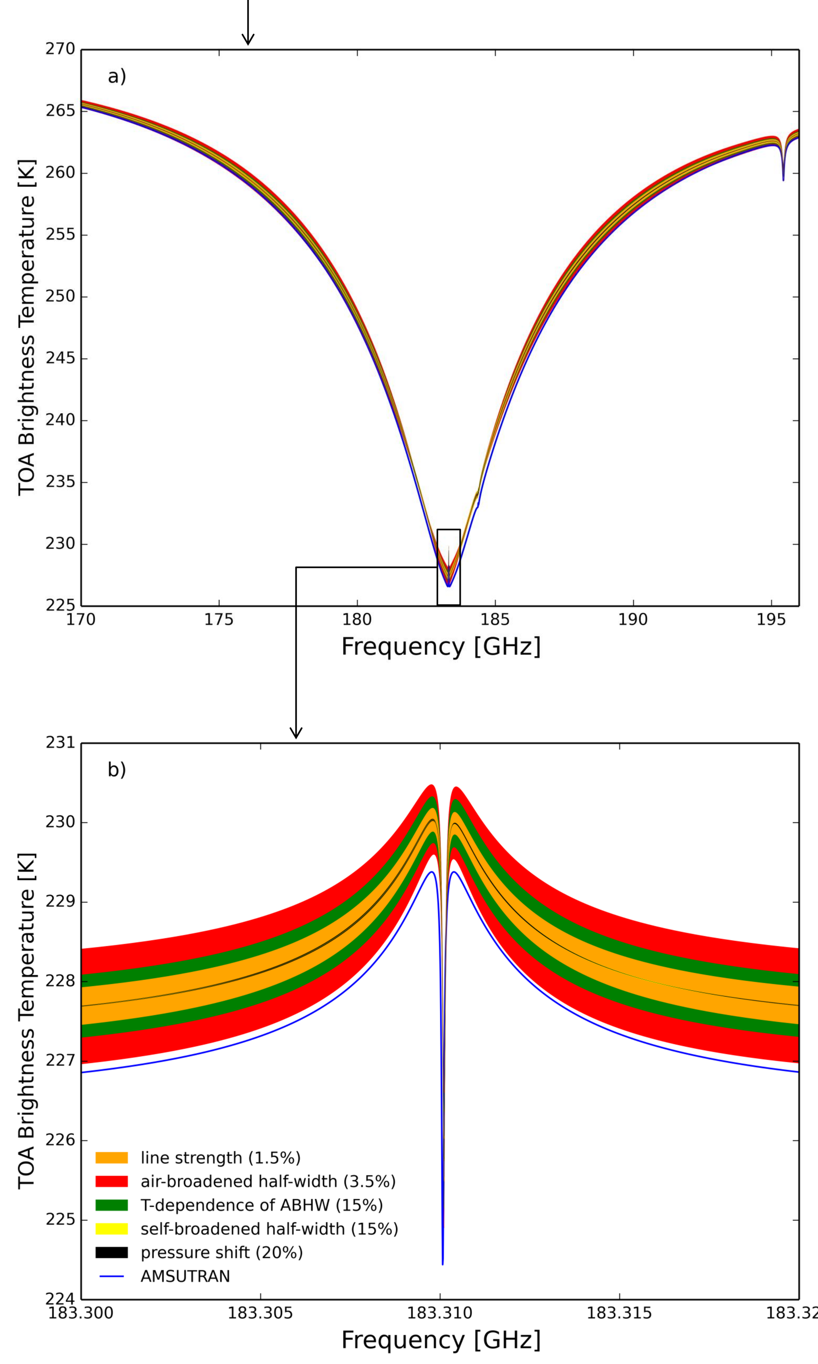


Figure 2. a) and b) Enhanced views of the 183.31 GHz line in Figure 1c (HITRAN 1623 water vapour lines up to 1000 GHz and AMSUTRAN 30 lines only), with cumulative uncertainties in each of the HITRAN line parameters listed in Table 1. added either side of the line. Note the uncertainty in the central frequency is not included and the uncertainty of the T-dependence of the self-broadened half-width is negligible.

Conclusions

- Moving to HITRAN 2016 line parameters will alter TOA brightness temperatures by up to 1 K between 150 – 800 GHz
- Larger differences are seen around line centres, beyond 800 GHz, and throughout the spectrum when more lines > 1000 GHz are included
- The difference at the peak of the 183.31 GHz line is 1.25 K
- The range of uncertainties in the HITRAN lines reaches up to 1.5 K but still do not encompass the results from the existing AMSUTRAN configuration
- Differences in satellite channels decrease further away from the line centre but uncertainties do not necessarily, in contrast to what is often observed in measurements
- For comparison, errors in RTTOV generated BT's are < 0.05 K with respect to the averaged line-by-line BT's used in this study.

Table 1. Spectroscopic parameters used to calculate 183.31 GHz line absorption. Intensities and half widths are calculated at a temperature of 296 K. HITRAN uncertainties are those quoted in the line record.

Spectroscopic Parameter	AMSUTRAN	HITRAN 2016	HITRAN 2016 Uncertainty (±%)
ν_{ij} (central frequency) [GHz]	183.310074[a]	183.310107[b]	0.005
S_{ij} (line intensity) [kHz/kPa]	2.39[a]	2.35[c]	1.5
γ_{air} (air-broadened half-width [ABHW]) [MHz/kPa]	29.49[d]	29.35[e]	3.5
n_{air} (T-dependence of ABHW)	0.77[e]	0.76[e]	15
γ_{self} (self-broadened half-width [SBHW]) [MHz/kPa]	156.48[a]	153.56[f]	15
n_{self} (T-dependence of SBHW)	0.85[a]	0.76[g]	15
δ (frequency pressure shift) [GHz/kPa]	0[a]	-0.000796[e]	20

AMSUTRAN: Transmittance model for monochromatic or satellite instrument simulations

Line Parameters (+ continuum)

$$\alpha(\nu,T,p)[dB/km] = 0.1820\nu \sum_{i}^{nlines} S_i F_i(\nu)$$

Monochromatic Transmittance

$$T = 10^{\frac{\sum_{z}^{TOA}\alpha(\nu)dz}{10}}$$

Channel Averaged Transmittance

$$T = \sum_{\nu} 10^{\frac{\sum_{z}^{TOA}\alpha(\nu)dz}{10}} \Big/ num\_\nu$$

RTTOV Coefficients

$$T = \sum_{i}^{num\_p} c_i^{gas} p_i^{gas}$$

TOA Brightness Temperature

$$BT(r,z) = \sum_{z}^{TOA} T_z r_z$$

Figure 3. Atmospheric profile used for all simulations

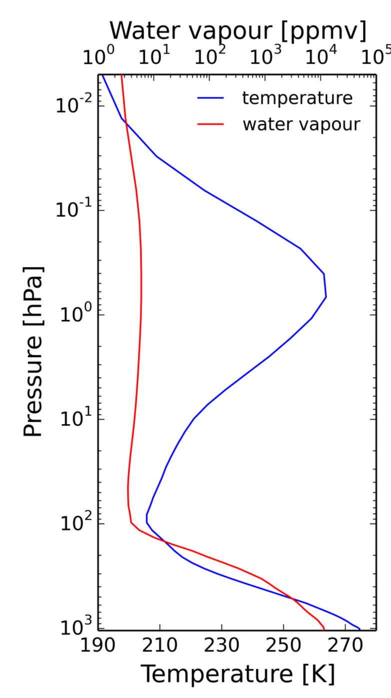
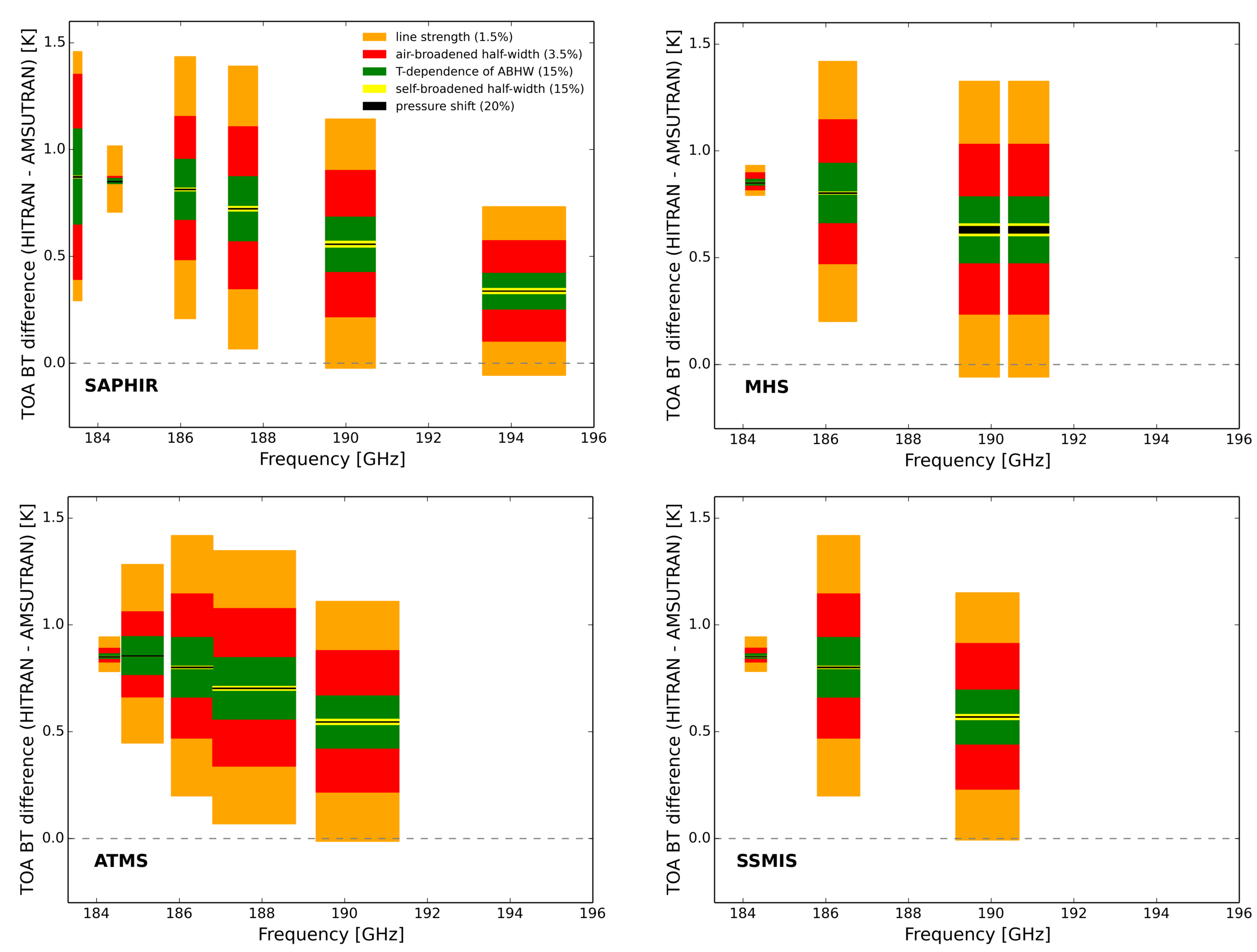


Table 2. Model specifications applied to both sets of line inputs.

Specifications	
Lineshape	Van Vleck Weisskopf
Cut off	None
Continuum	Liebe 1989[a]
Atmospheric Profile	54 levels from 1050-0.005 hPa[h] (shown in Figure 3.)
Viewing angle	0°

Figure 4. Brightness temperature differences between HITRAN and AMSUTRAN water vapour line spectroscopy for satellite channels centred on 183.31 GHz. BT's are generated straight from channel averaged transmittances without going through the RTTOV pathway. Differences are represented in the passbands on one side of the 183 line. The difference between using the complete set of values in Table 1. is the centre (black line) of each channel block and the cumulative uncertainty due to each of the parameters (apart from ν_{ij} and n_{self}) is shown around it.



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[d] The same source as [e], however the value is from the complex implemeation of the Robert-Bonamy theory instead of the results from comparisons with ground—based measurements
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