Sensitivity of microwave downwelling brightness temperatures to spectroscopic parameter uncertainty

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RATIONALE

Atmospheric brightness temperatures (T_B) are simulated through radiative transfer calculations, which rely on spectroscopic parameters (b) for modelling the atmospheric absorption.

The uncertainty affecting the spectroscopic parameters b contribute to the uncertainty on the simulated T_B and on the derived atmospheric retrievals.

APPROACH

The following approach is used to investigate the impact of spectroscopic parameter uncertainties on simulated T_B and retrievals:

1. **Review spectroscopic parameter uncertainty**
2. **Sensitivity study – small perturbation analysis**
3. **Uncertainty propagation**
4. **Retrieval impact quantification**

2 Sensitivity study – small perturbation analysis

Sensitivity study – small perturbation analysis for identifying the spectroscopic parameters b with significant impact. Each parameter has been perturbed individually considering six different climatologic conditions.

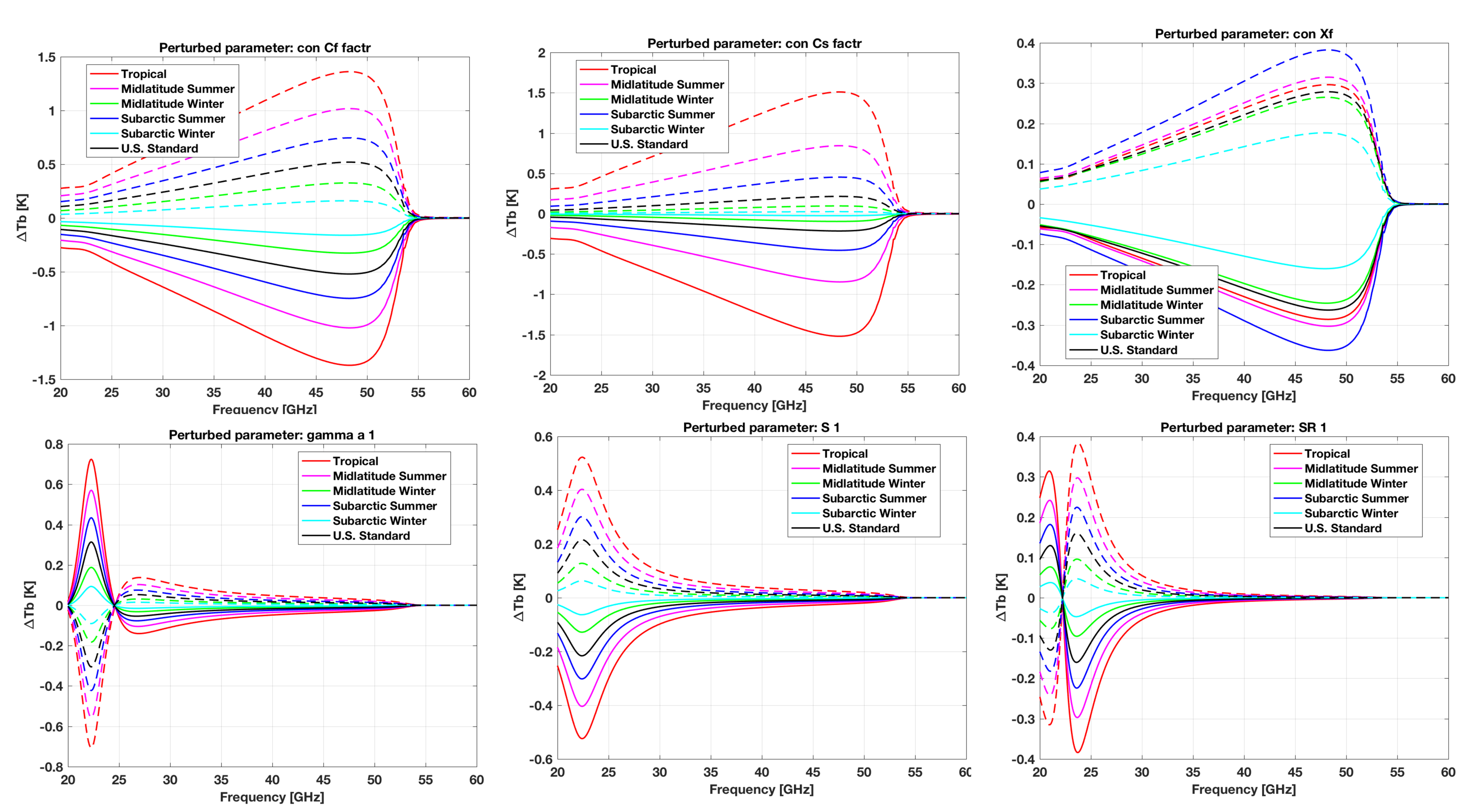

Figure 1: T_B deviations obtained perturbing water vapor spectroscopic parameters for 6 climatological atmospheric conditions (color-coded). Solid lines correspond to negative perturbation (value - uncertainty), dashed lines to positive perturbation (value + uncertainty). The 6 spectroscopic parameters with higher impact (i.e. > 0.1 K) are shown, which correspond to the 6 highlighted in red in the water vapor tables.

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SUMMARY and FUTURE WORK

The approach to investigate the impact of spectroscopic parameter uncertainties on simulated downwelling T_B and the derived atmospheric retrievals is presented. The characterization of the full parameter uncertainty covariance matrix needs to be completed.

The analysis may be extended to higher frequencies and upwelling T_B in future work.

PRELIMINARY RESULTS

1 Review spectroscopic parameter uncertainty

Here we focus on downwelling T_B in the 20-60 GHz range, where absorption comes mainly from oxygen and water.

Parameters with uncertainty impacting T_B for more than 0.1 K are highlighted in red.

Oxygen

Par [units]	Meaning	Value	Uncertainty	Reference
X [unitless]	Temperature dependence of broadening coefficient for O_2 lines	0.80	0.05	Tretyakov et al., 2005
w2a [unitless]	Water-to-air broadening ratio	1.20	0.05	Koshelev et al. 2015
ν_0 [kHz]	Line frequency	Table 1	Table 1	Tretyakov et al., 2005
S [Hz/cm²]	Line strength	HITRAN, 2012	1%	
B_e [unitless]	Temperature-exponent for strength	HITRAN, 2012	<1%	
γ_i [MHz/mb]	Pressure-broadening parameter	Table 5	Table 1 + calculations	Tretyakov et al., 2005
WB300	Non-resonant pressure broadening width	0.56	15%	
Y300	Mixing coefficients	a5 + a6	To be computed	Tretyakov et al., 2005
V	Mixing coefficients temperature dependence	a6	To be computed	Tretyakov et al., 2005

Water vapor

Parameter [units]	Meaning	Value @22GHz	Uncertainty @22GHz	Value @183GHz	Uncertainty @183GHz	Reference
ν_0 [kHz]	Line frequency	22235079.85	0.05	183310087	1	Tretyakov, 2016
γ_a [MHz/mb]	Air-broadening parameter	2.6882	0.0390	2.9447	0.0150	Koshelev et al. 2018
γ_w [MHz/mb]	Water-broadening parameter	13.2813	0.0338	14.7762	0.3750	Koshelev et al. 2018
n_a [unitless]	Temperature-exponent of air-broadening	0.70	0.05	0.74	0.03	Tretyakov, 2016
n_w [unitless]	Temperature-exponent of water-broadening	1.20	0.05	0.78	0.08	Tretyakov, 2016
S [Hz/cm²]	Line strength	$1.3161e^{-14}$	$1.2891e^{-16}$	$2.3222e^{-12}$	$2.3084e^{-14}$	Tretyakov, 2016
SR [unitless]	Shift to width ratio	-0.0089	0.0106	-0.0245	0.0026	Koshelev et al. 2018

Parameter [units]	Meaning	Value	Uncert.	Reference
Cf [km⁻¹ mb⁻² GHz⁻²]	Foreign-broadened water vapor continuum coefficient	$5.43e^{-10}$	$5.56e^{-11}$	Rosenkranz 1998; Turner et al., 2009
Cs [km⁻¹ mb⁻² GHz⁻²]	Self-broadened water vapor continuum coefficient	$1.8e^{-8}$	$3.245e^{-9}$	Rosenkranz 1998; Turner et al., 2009
Xf [unitless]	Foreign-broadened temperature dependence coefficient	3.0	0.6	Tretyakov, 2016
Xs [unitless]	Self-broadened temperature dependence coefficient	7.5	0.6	Tretyakov, 2016

3 Uncertainty propagation

$$S_{y_b} = K_b * S_b * K_b^T$$

- S_{y_b}: Simulated measurement uncertainty covariance matrix due to b
- K_b: Jacobian of the measurement with respect to spectroscopic parameters. Values are estimated with brute force from the sensitivity analysis.
- S_b: Uncertainty covariance matrix of spectroscopic parameters b. Diagonal terms are the squared parameter uncertainties. Off-diagonal terms will be estimated from parameter definitions and measurement conditions.

4 Retrieval impact quantification

Retrieval impact quantification – the retrieval uncertainty covariance matrix due to spectroscopic parameter uncertainty is:

$$P = (D_y K_b) S_b (D_y K_b)^T$$

Contribution function matrix, i.e. the Jacobian of the inverse model with respect to the measurement

$$D_y = \partial I(y)/\partial y = (K_x^T S_\epsilon^{-1} K_x + S_a^{-1})^{-1} K_x^T S_\epsilon^{-1}$$