

# EFFECTS OF ATMOSPHERIC TURBULENCE IN RADIATIVE TRANSFER MODELLING

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## Introduction

A “Joint workshop on uncertainties at 183 GHz” (Brogniez, English and Mahfouf, 2015) was celebrated to discuss biases observed between measurements at 183 GHz and calculations using different Radiative Transfer Models (RTM) and using either radiosondes or short range forecasts from Numerical Weather Prediction (NWP) systems. The results were reflected in a paper published one year later (Brogniez et al. 2016). The findings are well summarised in a figure from this paper, which is reproduced here in Figure 1.

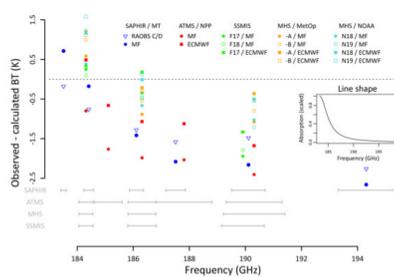


Fig. 1: Mean observed BT minus calculated BT

Microwave absorption measurements made between mountain tops (Kursinski et al. 2012; Kursinski et al. 2016) also show a similar behaviour (Brogniez et al. 2016). These measurements are useful because they can be made in a very controlled manner and can give meaningful results. Figure 3 illustrates these measurements.

Radiosonde and satellite sounding data have been shown to be consistent with each other (Calbet et al. 2017). Current efforts to collocate these datasets when looking for consistency are increasingly showing that turbulence is an important ingredient when comparing these datasets (Calbet and Peinado-Galan, 2016). Figure 2 illustrates this phenomena showing the structure functions of temperature and water vapour obtained solely from radiosonde data. Differences in the plots are taken between the measurements from two sondes launched one hour apart at the same pressure level. To have meaningful statistics, differences from all pressure levels within the troposphere are plotted in the figure. These functions clearly show the 2/3 law from Kolmogorov's theory of turbulence.

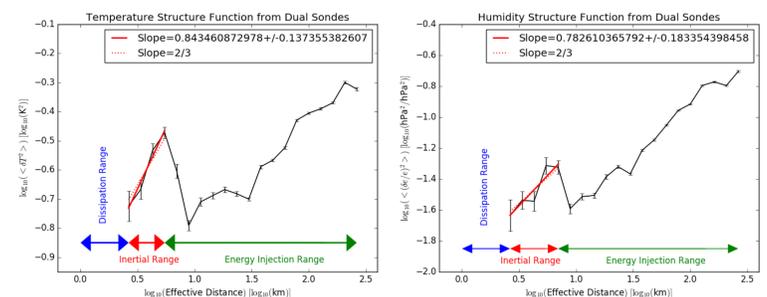


Fig. 2: Temperature and relative partial water vapour pressure structure functions

## Can Turbulence have significant effects in RTM calculations?

It is well known that radiative transfer is an extremely non-linear process, whereas the sum of two different temperature and water vapour profiles do NOT necessarily generate radiances at the top of the atmosphere that are the sum of each individual radiance component. The question then arises, will the turbulence effects affect significantly the calculated radiances at the top of the atmosphere? To answer this question we model the radiances using a turbulent, instead of a still, medium and compare with actual measurements.

## Simulations

Turbulence is simulated in the radiative process by feeding into an RTM a profile of temperature and water vapour that follows the turbulent structure observed in radiosondes. Turbulence is modelled by following a random Gaussian field which is correlated in the horizontal only, following the 2/3 structure functions (Fig. 2). There is no vertical correlation of turbulent component of the temperature and water vapour fields. The microwave radiative transfer model used is AM version 9.2 (Paine 2017). This is a fast microwave RTM which has been proven accurate in previous experiments (Kursinski et al. 2012; Kursinski et al. 2016).

## Results for Mountain Top observations

For mountain top observations described in Kursinski et al. (2016) preliminary results of the simulations are shown in Figure 3. The simulations including turbulence seem to model the wings of the absorption lines better. Further work has to be carried out in both the RTM simulations with turbulence and in the processing of the microwave measurement data to reach firmer conclusions.

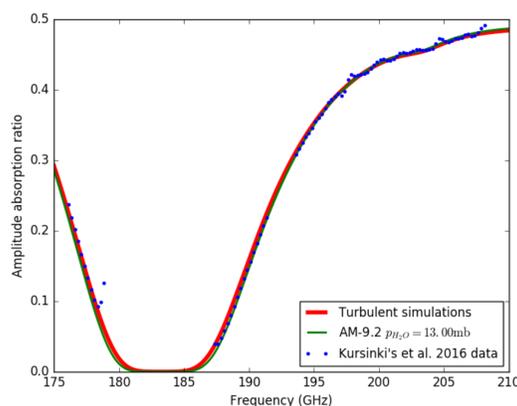


Fig. 3: Simulations of amplitude absorption ratios with turbulence (red solid line) and without turbulence (green solid line) compared with the measurement data (blue dots) from Kursinski's et al (2016).

## Results for Satellite observations

Results from these simulations for satellite based observations are shown in Figure 4.

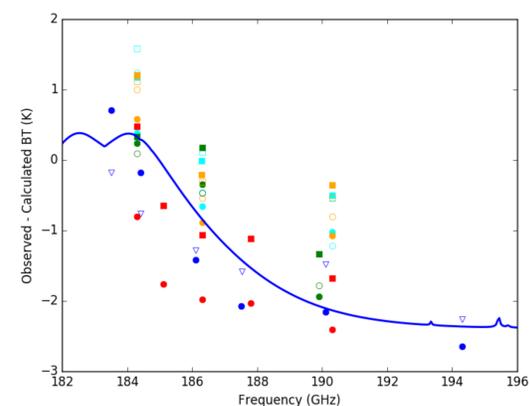


Fig. 4: Simulations of mean observed BT minus calculated BT (solid blue line), superimposed to the experimental data of Fig 1.

## Conclusions

Turbulence seems to be a critical effect in radiative transfer and, if this is confirmed, should probably be included into RTMs.

## Bibliography

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