Improving Water Vapor Absorption in Microwave Radiative Transfer Models

Research Highlight

Water vapor absorbs radiation across the electromagnetic spectrum, and to properly model the climate, models must accurately compute this absorption. However, the spectral shape of the water vapor absorption line is not well known, and the currently used line shapes (e.g., Lorentz line shape) have deficiencies especially at frequencies away from line center. Thus, to improve the modeling of water vapor absorption in the atmosphere, most detailed line-by-line radiative transfer models separate the total contribution of water vapor absorption into local absorption line contributions (i.e., contributions within 25 cm-1 of absorption line centers) and "continuum" effects (i.e., the contributions from the far-wings of the lines beyond 25 cm-1 of line centers). However, it is difficult to perform laboratory studies of the strength of the water vapor continuum absorption in different spectral bands, making it critical to obtain atmospheric measurements of this important model component.

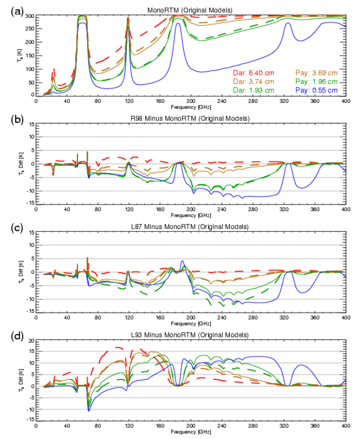

Figure 1: The top panel shows downwelling microwave brightness temperature calculations from the original version of the MonoRTM for six different atmospheres. The bottom three panels show the spectral differences between the MonoRTM and the original Liebe87, Liebe93, and Rosenkranz98 models for these six profiles. Payerne profiles are shown with solid lines, while Darwin data are denoted with dashed lines.

Turner et al. (2009) used measurements from two newly developed microwave radiometers that measure the downwelling emission from the atmosphere at 150 GHz (5 cm-1) to evaluate the accuracy of the water vapor continuum absorption parameterization in four frequently used radiative transfer models (Liebe87, Liebe93, Rosenkranz98, and MonoRTM). These radiometers were deployed in the Black Forest of southwestern Germany as part of the ARM-sponsored Convective and Orographic Precipitation Study in 2007. The study first confirmed that the two radiometers agreed well with each other, even though each of the radiometers was calibrated independently of the other using similar approaches. The team then demonstrated that the four models disagreed with the observations to various degrees. By analyzing the residuals as a function of precipitable water vapor (PWV), the study was able to distinguish between the contributions for the so-called "self-broadened" and "foreign-broadened" components of the water vapor continuum, and thus consistent modifications were made to all four models to bring them into agreement with the observations. While the modifications were based upon observations at 150 GHz (5 cm-1), the ramifications extend beyond that frequency. The water vapor continuum absorption changes slowly with frequency, and thus these modifications result in better agreement with the observations at 31 GHz. In addition, the modified models demonstrated improved consistency with each other. This point is demonstrated in Figures 1 and 2, wherein six different atmospheres were used to provide examples over a range of PWV conditions (0.55 to 6.4 cm). In these figures, the solid lines are from a mid-latitude site (Payerne, Switzerland), while the dashed lines are from a tropical site (Darwin, Australia). Note that the two wetter cases from the mid-latitude site have similar PWV with the two drier tropical profiles, thereby allowing the differences in the temperature dependence between the models to be elucidated. In particular, note how the spread between the models in the spectral regions between absorption lines (e.g., 90 GHz) was greatly reduced when the modified models were compared (comparing Fig. 1 to Fig. 2).

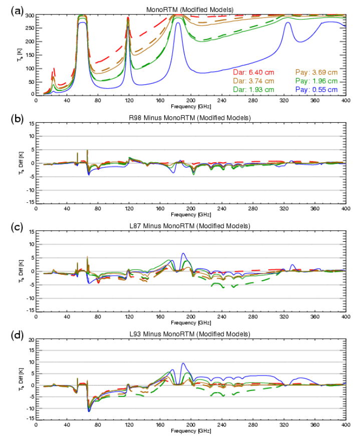

Figure 2: Similar to figure 1, except using the models that have been modified as a result of this work. The agreement between the models across the spectrum has been greatly improved.

These improved microwave absorption models will result in significantly better retrievals of PWV, cloud liquid water path, and surface emissivity, all of which are important applications of microwave remote sensing. In addition, this work provides a solid anchor point for improving the parameterization of the far-infrared (50 – 600 cm-1) water vapor continuum absorption, as this spectral band is opaque at most surface locations yet plays a critical role in the radiative transfer in the middle and upper troposphere.

Reference(s)

Turner DD, MP Cadeddu, U Loehnert, S Crewell, and A Vogelmann. 2009. "Modifications to the water vapor continuum in the microwave suggested by ground-based 150 GHz observations." IEEE Transactions on Geoscience and Remote Sensing, 47(10), 3326-3337.

Contributors

David D. Turner, *University of Wisconsin-Madison*; Ulrich Loehnert, *University of Cologne, Institute for Geophysics and Meteorol*; Maria P. Cadeddu, *Argonne National Laboratory*; Susanne Crewell, *University of Cologne*; Andrew M. Vogelmann, *Brookhaven National Laboratory*

Working Group(s)

Radiative Processes