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A neural network for real-time retrievals of low amounts of PWV and LWP in the Arctic from millimeter-wave ground-based observations

M. Cadeddu (1), D.D. Turner (2), and J.C. Liljegren ()

(1) Argonne National Laboratory, Argonne, IL USA(mcadeddu@anl.gov), (2) University of Wisconsin-Madison, Madison, WI USA (dturner@ssec.wisc.edu)

We present a Neural Network (NN) algorithm for real-time retrievals of low amounts of precipitable water vapor and liquid water path from measurements collected by a new 183.3-GHz G-Band Vapor Radiometer (GVR) operating at the Atmospheric Radiation Measurement (ARM) Program Climate Research Facility (ACRF) in Barrow, Alaska. The instrument has been operating since 2005 and is the first ground-based instrument continuously operating in Alaska in this frequency range. Its high sensitivity to very low amounts of PWV and LWP provides an advantage over traditional instruments operating in the 20-to-30-GHz spectral region. On the other hand, the non-linear response of the GVR channels to PWV, together with the rapid saturation of channels near the line center, introduces new challenges in the development of real-time retrievals.

An innovative part of the work deals with the development of a methodology to compute individual error bars associated with the NN output and with the detailed discussion of the output error. Through the error analysis it is possible to isolate several components contributing to the overall retrieval errors and to analyze the dependence of the errors on the inputs. The proposed methodology to compute individual error bars is general and can be applied to similar networks.

The network outputs and associated errors are then compared with results from a physical retrieval and with results from the ARM two-channel Microwave Radiometer (MWR) statistical retrieval. It is shown that the use of GVR measurements and neural network algorithm significantly improves the accuracy of the retrievals of low amounts of precipitable water vapor (PWV < 5 mm) and liquid water path (LWP < 100 g/m$\hat{2}$). Specifically, integrated water vapor amounts between 1 and 5 mm can be retrieved with 5% accuracy. The evaluation of LWP retrievals is conducted by computing longwave downwelling surface fluxes (corresponding to the retrieved LWP) and comparing the simulations with observations. The comparison shows that downwelling surface fluxes residuals obtained from GVR retrievals are generally in within the uncertainty of the longwave radiative flux measurements themselves ($\pm$ 4 W/m2).