A neural network for PWV and LWP retrievals from Arctic millimeter-wave observations

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MOTIVATION

The G-Band Water Vapor Radiometer (GVR) can be used to improve retrievals of low amounts of precipitable water vapor (PWV < 10 mm) and low amounts of liquid water (LWP < 100 g/m^2). The dependence of the brightness temperatures from the PWV, shown in Fig. 1, requires the use of a non-linear algorithm. A neural network provides the means to explore the non-linear regime of the measurements and to investigate the physical boundaries of operability of the instrument.

Advantages:
1) Explore the non-linear regime of the measurements for investigating the performance of the PWV and LWP retrieval when the PWV amount is higher than a few mm.
2) Once trained, the retrieval does not require vertical profiles of temperature and humidity as input. This advantage makes computations significantly faster.
3) Provides real time retrievals of PWV and LWP from GVR for all seasons.

Disadvantages:
1) Statistical techniques are not as constrained as a physical retrieval.
2) Need development of a methodology to treat network output errors.

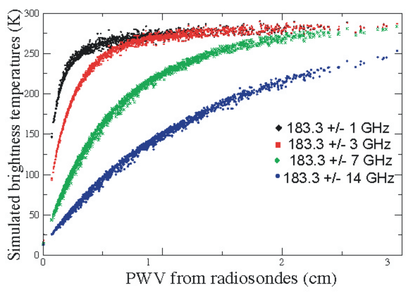

Fig. 1. Dependence of brightness temperatures on PWV.

NEURAL NETWORK TRAINING

The neural network was trained with seasonal datasets to minimize the RMS Error during very dry conditions, when the sensitivity of the instrument is higher. Figures 2 and 3 show the training sets used for PWV and LWP retrievals.

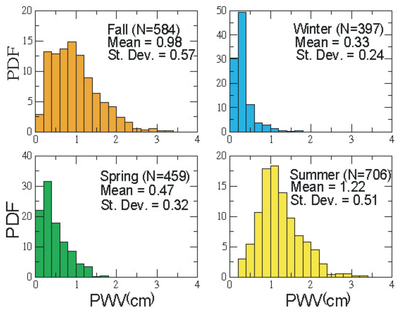

Fig. 2. PWV distributions in the training dataset.

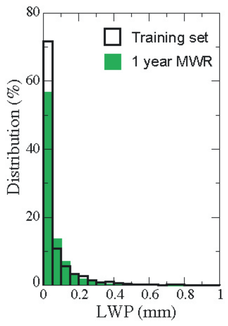

Fig. 3. LWP distributions in the training dataset and for one year of MWR data.

COMPUTATION OF OUTPUT ERRORS

Three error components of the network output were treated independently:
1) Target noise: Computed with an auxiliary network trained on the residuals.
2) Network architecture error: Computed by evaluating the Hessian of the network.
3) Instrument noise: Computed by evaluating the Jacobian of the outputs.

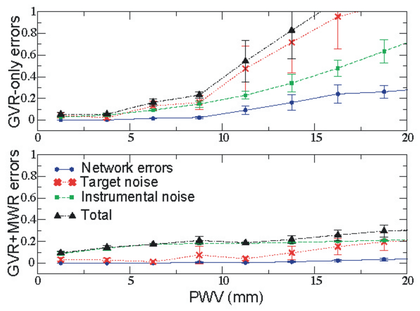

Fig. 4. Contribution of individual error components to the total PWV retrieval error (mm). When the GVR only is used (top panel) the largest contribution comes from the target noise. When the GVR is combined with the MWR (bottom panel), the contribution from the MWR noise is the most important source of error.

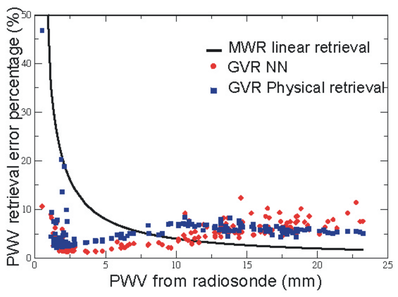

Fig. 5. Dependence of retrieval errors from the PWV amount. When the PWV is less than 1 cm the GVR NN retrievals of PWV have smaller errors compared to the MWR only retrievals.

EXAMPLES OF RESULTS

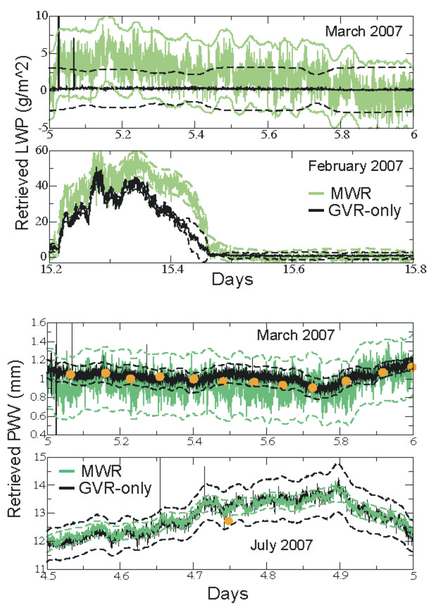

Fig. 6. LWP retrieved from GVR measurements (black line) and from MWR measurements (green line). Dashed lines indicate +/-1 standard deviation. In the top panel is a clear-sky day. In the bottom panel is a case of a thin cloud.

Fig. 7. PWV retrieved from GVR measurements (black line) and from MWR measurements (green line). Orange circles are radiosondes. In the top panel is a dry case in early spring. In the bottom panel is a case in summer.

LWP VALIDATION

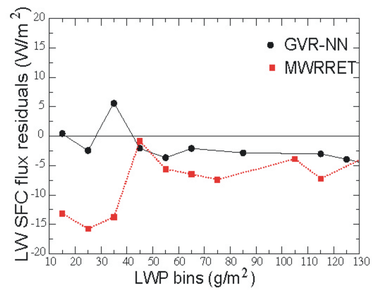

Fig. 8. Radiative transfer computations show that longwave downwelling surface fluxes, computed using GVR-retrieved LWP (black circles), are closer to the measured fluxes than those computed using MWR-retrieved LWP (red squares).

What can we conclude from the NN results?

Range of instrument operability:

The analysis of NN retrievals and associated errors show that the instrument can produce good PWV and LWP retrievals when the PWV amount is less than 1 cm. Between 1 and 1.5 cm the uncertainty in the retrievals increases.

PWV retrieval uncertainty is 5% between about 2 and 10 mm and about 10% when the PWV is higher than 1 cm.

LWP retrievals have a significantly improved clear-sky bias (mean of ~2.4 g/m^2) and a retrieval error varying from 1 to about 10 g/m^2 when the PWV amount is between 1 and 10 mm.

What is coming next ?

Real time PWV and LWP retrievals from the GVR:

This study has been submitted to TGARS. After publication, real-time retrievals from GVR measurements will be available from the ARM Archives.

MP183 (GVRP):

A new microwave radiometer operating in the same frequency range as the GVR will be deployed at the NSA in March. The instrument has 15 tunable channels in the range of 173 to 183.3 GHz.

Based on the NN results the MP183 will be sent to support Vocals operation next fall. The water vapor conditions are expected not to exceed 1.5 cm and the MP183 will provide measurements auxiliary to the 2 channel MWR.

The MP183 will be deployed in support of RHUBIC II in 2009

References:

Cadeddu, M.P., Turner, D. D., Liljegren J. C., "A neural network for real-time retrievals of PWV and LWP from Arctic millimeter-wave ground-based observations," submitted to *IEEE Trans. Geosci. Remote Sensing*, 2008.

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