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New multi-station and multi-decadal trend data on precipitable water. Recipe to match FTIR retrievals from NDACC long-time records to radio sondes within 1 mm accuracy/precision

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We present an original optimum strategy for retrieval of precipitable water from routine ground-based mid-infrared FTS measurements performed at a number globally distributed stations within the NDACC network. The strategy utilizes FTIR retrievals which are set in a way to match standard radio sonde operations. Thereby, an unprecedented accuracy and precision for measurements of precipitable water can be demonstrated: the correlation between Zugspitze FTIR water vapor columns from a 3 months measurement campaign with total columns derived from coincident radio sondes shows a regression coefficient of R = 0.988, a bias of 0.05 mm, a standard deviation of 0.28 mm, an intercept of 0.01 mm, and a slope of 1.01. This appears to be even better than what can be achieved with state-of-the-art micro wave techniques, see e.g., Morland et al. (2006, Fig. 9 therein). Our approach is based upon a careful selection of spectral micro windows, comprising a set of both weak and strong water vapor absorption lines between 839.4 – 840.6 cm-1, 849.0 – 850.2 cm-1, and 852.0 – 853.1 cm-1, which is not contaminated by interfering absorptions of any other trace gases. From existing spectroscopic line lists, a careful selection of the best available parameter set was performed, leading to nearly perfect spectral fits without significant forward model parameter errors.

To set up the FTIR water vapor profile inversion, a set of FTIR measurements and coincident radio sondes has been utilized. To eliminate/minimize mismatch in time and space, the Tobin best estimate of the state of the atmosphere principle has been applied to the radio sondes. This concept uses pairs of radio sondes launched with a 1-hour separation, and derives the gradient from the two radio sonde measurements, in order to construct a virtual PTU profile for a certain time and location. Coincident FTIR measurements of water vapor columns (two hour mean values) have then been matched to the water columns obtained by integrating the best-estimate radio sonde profiles. This match was achieved via investigating the quality of the correlation plots between the columns derived from the radio sondes and the FTIR retrievals, and iteratively tuning the regularization strength of the FTIR retrieval. The FTIR regularization matrix is based on a Tikhonov operator which allows for empirical tuning of the regularization strength via one parameter. The figures of merit for the iterative tuning have been the slope, the intercept, and the regression coefficient of the correlation. By this way an optimum retrieval setting could be found, guaranteeing a response of the FTIR retrievals to true water vapor changes, which is matched to the radio sonde operation.

As first examples for utilizing this approach to derive long-term trends of precipitable water from NDACC type long-term FTIR measurements, we present trends from two time series. I.e., one retrieved from continuous FTIR measurements at the NDACC Primary Station Zugspitze, Germany (47.42 °N, 10.98 °E, 2964 m a.s.l.), which covers the time span 1995-2009, and one from the International Scientific Station of the Jungfraujoch (ISSJ, 46.5°N, 8.0°E, 3580m a.s.l., Swiss Alps), covering the time span 1984 – 2009. A detailed trend analysis of both series via the bootstrap method will be presented.

In ongoing work we apply this optimum retrieval approach to historical long-time measurement series of

further selected FTIR stations of the NDACC network. Thereby we will obtain unprecedented new climate data via long term trends of precipitable water at a set of globally distributed locations.

Reference

Morland, J., Deuber, B., Feist, D. G., Martin, L., Nyeki, S., Kämpfer, N., Mätzler, C., Jeannet, P., and Vuilleumier, L.: The STARTWAVE atmospheric water database, Atmos. Chem. Phys., 6, 2039-2056, 2006.