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Introducing VESPA-22: a ground-based microwave spectrometer for measuring middle atmospheric water vapour at polar latitudes

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We present the latest updates on the project VESPA-22 (water Vapour Emission Spectrometer for Polar Atmospheres at 22 GHz), a ground-based microwave instrument developed for long-term observations of water vapour in the polar stratosphere and mesosphere (SMWV).

The short- and long-term change in water vapour concentration from the lower stratosphere to the mesosphere is one of the main areas of interest for atmospheric composition studies in the current decade. In fact, SMWV influences the temperature of the stratosphere by radiative processes, the concentration of several chemical species (also through the production of OH) and the formation of aerosols. Recent studies showed that in the last 30 years mid-latitude SMWV has been changing for mechanisms not yet fully understood. Model studies indicate that these changes could have had a significant impact (25-30%) on the tropospheric radiative forcing and surface temperature trends observed since 1980. Moreover, at polar regions, changes in SMWV strongly affect the formation rate of polar stratospheric clouds, both directly (how much is available for uptake on PSC particles) and indirectly (impact on stratospheric temperature). This is especially critical in the Arctic stratosphere where temperatures are not as cold they are over Antarctica and, for the purpose of denitrification and ozone depletion processes, an increase in SMWV of 1 ppmv is modelled to be equivalent to a 1 K decrease in temperature.

In the past decade, satellite-based instruments have provided accurate and global measurements of SMWV, but a similar coverage is not expected in this decade. Conversely, the ground-based microwave spectrometers currently active provide both the long time series necessary for decadal scale monitoring and the high time resolution (a few hours) needed to understand fast dynamical processes. Today, none of these sustained SMWV measurements are being carried out at polar regions.

Our observation technique is based on the inversion of the water vapour emission line centred at 22.235 GHz detected by an uncooled low-noise heterodyne receiver and acquired by a FFT digital spectrometer with a 1 GHz bandwidth. VESPA-22 is designed to observe diurnal changes in the mesosphere by inversion of high resolution spectra (61 kHz) integrated over 12 hours, and to observe faster processes in the lower stratosphere with a reduced resolution (610 kHz) every hour. To obtain the needed signal-to-noise ratio (SNR) with a high time resolution we adopt a balanced beam-switching configuration with a chopper mirror that allows an effective integration time of 40%. The need for a long-term stable reference at a remote polar station led us to employ both the calibrated noise injection technique every 20-30 minutes and a hot-cold calibration with liquid nitrogen on a monthly basis.

We present laboratory tests on the two calibration procedures, comparing the corresponding receiver noise temperature measurements. We show initial spectral observations obtained with VESPA-22 and discuss potential future improvements to the system which should improve the spectral baseline. Preliminary retrievals of water vapour vertical profiles are also presented together with estimates on the minimum observing time needed to achieve the desired SNR at polar sites.