First measurements of the new 22 GHz water vapor spectrometer VESPA-22 obtained during the SVAAP campaign at Thule, Greenland

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Abstract

Water vapor has a large impact on the Earth radiative budget, affecting both infrared and shortwave radiation. In the Arctic region, the importance of water vapor is enhanced by the so called Artic Amplification effect [Serreze and Francis, 2006], a positive feedback that links the quantity of water vapor in the troposphere, the presence of clouds, the ice coverage, and the surface temperature. Additionally, about 10% of the surface warming measured during the last two decades can be ascribed to stratospheric water vapor [Solomon et al., 2010]. The characterization of middle atmospheric water vapor profiles is also important to understand many chemical processes that occur in the Polar middle atmosphere, as water vapor is involved in the ozone chemistry.

In order to identify and quantify the contribution of water vapor to the changes that are occurring in the Arctic, long-term measurements of tropospheric and stratospheric water vapor are necessary. With this purpose, during the SVAAP measurements campaign funded by the Italian PNRA (see the contribution by Meloni et al. to the ARCA conference) and in synergy with the ARCA project, a new 22 GHz spectrometer (the water Vapor Emission Spectrometer for Polar Atmospheres at 22 GHz, VESPA-22 [Bertagnolio et al., 2012]) was installed at Thule Air Base (76.5° N, 68.8° W), Greenland. VESPA-22 has been set-up for continuous unattended measurements. Since the early 90's Thule Air Base has been hosting a NDACC (Network for the Detection of Atmospheric Composition Change) atmospheric observatory where instruments belonging to Italian (http://www.thuleatmos-it.it/), Danish and US research institutes and universities are installed to monitor the Arctic atmosphere and radiation budget.

The SVAAP campaign took place in July 2016 and was mainly aimed at studying the role of water vapor and clouds in the radiation budget at the surface, which is also an important objective of the ARCA project. During the campaign we launched 23 radiosondes, carried out measurements of various atmospheric parameters (see contribution by Meloni et al.), and VESPA-22 operated side by side with the HATPRO microwave radiometer [Rose et al., 2006]. The campaign was characterized by ten days of fair weather followed by ten days of more unstable and cloudy conditions.

VESPA-22 (figure 1) collects the microwave radiation emitted by the H_2O rotational transition at 22.235 GHz with a spectral resolution of 31 kHz and a bandwidth of 500 MHz (figure 2). Using the relation between the emission line width and the atmospheric pressure, VESPA-22 spectral measurements can be inverted to obtain water vapor profiles from about 30 km up to 70 km with a vertical resolution of about 7 km and a temporal resolution of 1-2 profiles a day, depending on weather conditions (figure 3).

The instrument can also retrieve the precipitable water vapor (PWV) by measuring the sky opacity τ_z with a temporal resolution of a few minutes and using the formula:

$$\mathrm{PWV} = a\tau_z + b\tau_z T_{atm} + c \quad (1)$$

[Deuber et al., 2005] where T_{atm} is the mean tropospheric emission temperature calculated using radiosounding data, while a, b, and c are three site dependent coefficients. Equation 1 does not take

into account the contribution of clouds liquid water content to the τ_z measured and therefore VESPA-22 can estimate PWV only during cloud-free conditions. The coefficients a, b, and c are obtained during the initial cloud-free calibrating period by matching the PWV values measured by HATPRO and VESPA-22. The result of the fit is shown in table 1.
The τ_z values measured by VESPA-22 have also been compared with the τ_z values computed by the atmospheric simulation software ARTS [Eriksson et al., 2011] initialized with the radiosounding profiles of atmospheric relative humidity, temperature and pressure. In figure 4 we show the values of τ_z measured by VESPA-22 during the campaign using different techniques and the ARTS simulated τ_z. The measured τ_z values show an agreement within 15% of the simulated ones during the days characterized by lower optical depth (cloud-free conditions).
The poster presentation will show the retrieved water vapor vertical profiles from VESPA-22 spectral measurements as well as a comparison of VESPA-22 with AURA/MLS [Waters et al. 2006] profiles. The data collected by VESPA-22 will also be analyzed in synergy with all the measurements carried out during the SVAAP campaign in order to study the relation between water vapor concentration, temperature, irradiance at the surface, and cloud cover.

Figure 1: *VESPA-22 installed at the NDACC atmospheric observatory at Thule Air Base.*

coefficient	values
a	190 ± 15
b	-0.31 ± 0.06
c	-0.52 ± 0.03
R^2	0.96

Table 1: *The values of equation 1 coefficients and R^2 obtained fitting the PWV measured by HATPRO versus the τ_z measured by VESPA-22 and the T_{atm} from radiosounding profiles.*

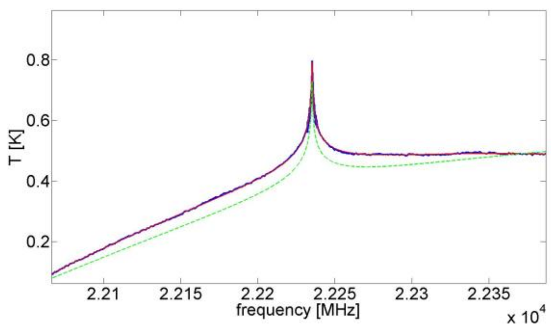

Figure 2: *A spectrum measured on July 17 with 10 hours of integration (blue) compared with the fit-spectrum obtained from the retrieved profile shown in Figure 3(red) and with the apriori spectrum used in the inversion algorithm (green).*

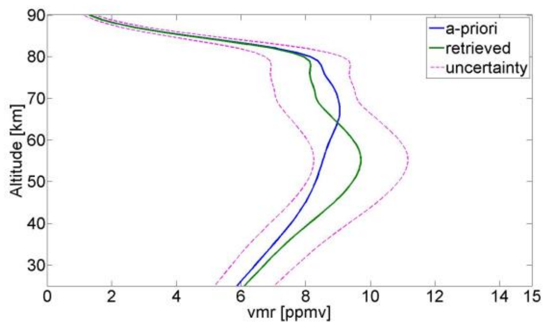

Figure 3: *The water vapor vertical profile obtained from the inversion of the spectrum shown in Figure 2 (blue) with its uncertainty (magenta) and the apriori profile (green).*

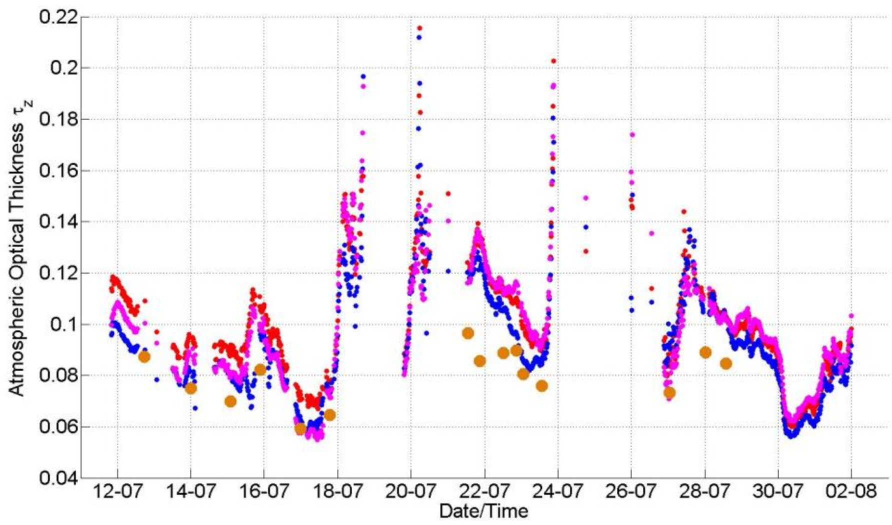

Figure 4: *The optical depth measured by VESPA-22 using different techniques (red, blue and purple dots) compared with the optical depth calculated from radiosoundings using ARTS (orange dots)*

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