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Stratospheric processes as measured by collocated Lidar, airglow, radiometer and infrasound measurements

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Abstract

To better initialize weather forecasting systems, a key challenge is to understand stratosphere-resolving climate models. Systematic multi-year comparisons between Lidar soundings at several stations part of the international Network for the Detection of Atmospheric Composition Changes (NDACC) and ECMWF models were performed. Below 50 km altitude, they highlight differences as large as ~20°K, more specifically during stratospheric warming events. At some sites, comparisons with collocated infrasound measurements provide additional useful integrated information about the structure of the stratospheric waveguide. We investigate possible correlation between unexpected infrasound propagation paths and unresolved atmospheric perturbations in the stratosphere. Such collocated observations from different complementary sounding techniques offer a unique opportunity to provide detailed information on upper atmospheric processes from seasonal to daily scales and study their interaction with the mean circulation.

ARISE measurement campaign

Middle-atmospheric temperature measurements

The ARISE project aims to design a novel infrastructure integrating different atmospheric observation networks to accurately recover the vertical structure of the wind and temperature from the ground to the mesosphere. This network includes Lidar and mesospheric airglow observations, complemented by continuous ground-based wind and infrasound measurements. Collocating such measurements helps to better describe the interaction between atmospheric layers from the ground to the mesosphere and the influence of large scale waves on the atmospheric dynamics.

In order to evaluate the ECMWF model (http://www.ecmwf.int/), we have systematically compared Lidar measurements at several stations part of the international Network for the Detection of Atmospheric Composition Change (NDACC, (http://www.ndsc.ncep.noaa.gov/) and the vertical structure of the ECMWF temperature model. The measurement of stratospheric and mesospheric temperature using Rayleigh Lidar technique was initiated 30 years ago at Haute-Provence Observatory, France. Monochromatic laser pulses are sent vertically into the atmosphere and a temporal analysis of the backscattered light provides information about the vertical structure and composition of the atmosphere. The temperature profile is deduced from the density profile. Figure 1 compares differences between the ECMWF temperature model and Lidar measurements between 2003 to 2009. This comparison highlights significant errors which increase with altitude. Errors may be as large as 40°K in the mesopause.

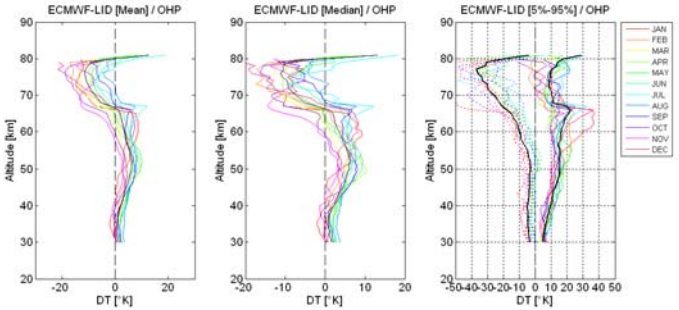


Figure 1 – Differences between ECMWF temperature model and Lidar measurements at Haute-Provence Observatory versus altitude. Left: median of the differences. Right: error distribution (5%-95%).

Figure 2 compares the vertical structure of the ECMWF model and Lidar measurements at the Haute-Provence Observatory site during the 2012-2013 winter experiment campaign.. These comparisons highlight significant errors more specifically in January 2013, during Sudden Stratospheric Events event (SSW).

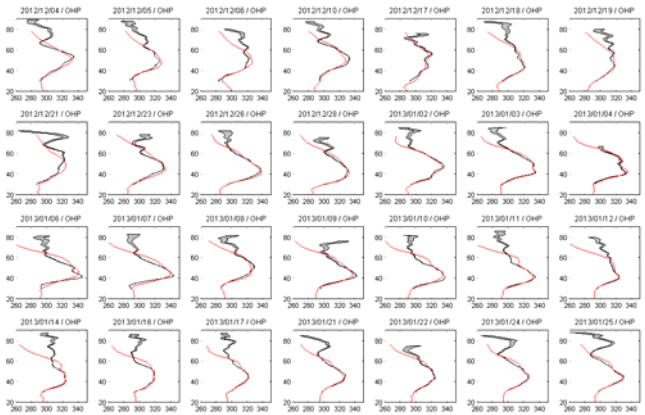


Figure 2 – Detailed comparisons between ECMWF temperature model and Lidar measurements at Haute-Provence Observatory site in winter. Values are in °K. Red: ECMWF. Gray: Lidar sounding with error bars.

Middle-atmospheric wind profile measurements

At Haute-Provence Observatory, additional ground-based sounding technique for measuring the vertical structure of the wind fields was deployed by R. Rüfenacht (Institute of Applied Physics, University of Bern, Switzerland). This system is a microwave Doppler-spectro-radiometer specifically designed for the measurement of middle atmospheric horizontal wind by observing ozone emission. Figure 3 shows significant errors in the wind model. Compared with ECMWF, between 40-50 km altitude, differences reach 12 m/s and 58 m/s for 50 and 95 percentiles, respectively.

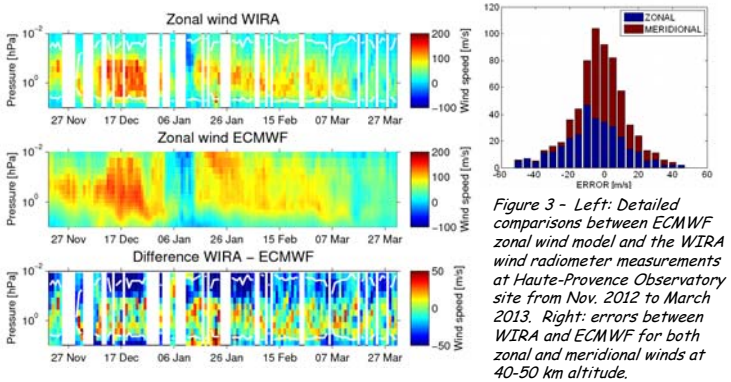


Figure 3 – Left: Detailed comparisons between ECMWF zonal wind model and the WIRA wind radiometer measurements at Haute-Provence Observatory site from Nov. 2012 to March 2013. Right: errors between WIRA and ECMWF for both zonal and meridional winds at 40-50 km altitude.

Collocated ground-based infrasound measurements

Including collocated infrasound measurements provide additional useful directional and integrated information about the structure of the stratospheric waveguide. Figure 4 is an example of synthetic view presenting on the same time basis the temporal evolution of Lidar measurements and ECMWF model. The number of infrasound signals is superimposed to the ECMWF effective sound speed ratio (defined as the ratio between the sum of the along-path wind and temperature at 30-60 km altitude and the sound speed at the ground level). Below 0,5 Hz, most infrasound signals originate from ocean swells in the North Atlantic region. As expected, since most long-range propagating signals travel in the stratospheric waveguide, improved detection capability occurs downwind. Deviations from this trend are either related to short time-scale variability of the atmosphere (e.g., large-scale planetary waves, stratospheric warming effects), or can be explained by changes in the nature of the source.

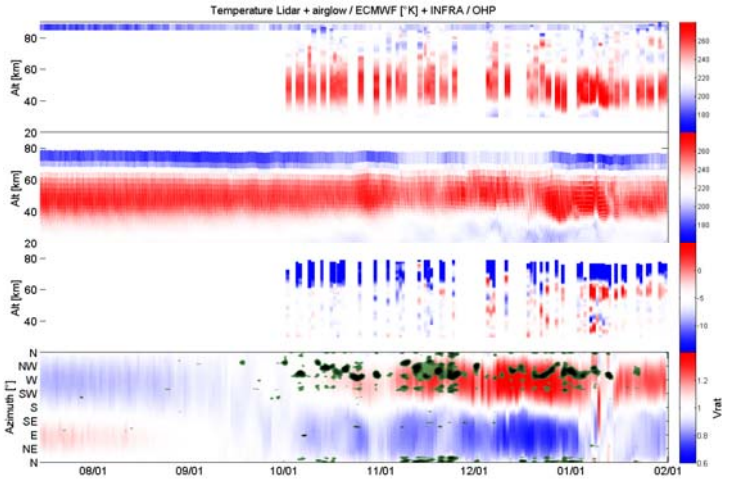


Figure 4 – Multi-technology synthetic view at Haute-Provence Observatory. From top to bottom: Lidar measurements, ECMWF temperature model, difference between Lidar and ECMWF, logarithm of the number of microbarom detections superimposed to the effective sound-speed ratio (ECMWF).

Conclusion

- ❑ Detailed comparisons between collocated wind and temperature measurements in the middle atmosphere indicate significant errors in the ECMWF model.
- ❑ Infrasound measurements provide additional integrated constraints on upper atmospheric processes (e.g. large-scale planetary waves, stratospheric warming effects).
- ❑ Combined with range-dependent propagation modeling, analyzing infrasound waveform parameters could highlight propagation anomalies in relation to unresolved atmospheric structure

➔ Including other techniques (wind profile and airglow measurements) would help to better constrain atmospheric specifications at stratospheric and mesospheric altitudes and understand atmospheric coupling processes and their influence on weather and climate (Atmospheric dynamics Research InfraStructure in Europe, http://arise-project.eu).

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