Comprehensive Analysis of Antarctic Ozone Hole Dynamics Using Day-Night IASI Infrared Observations

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ABSTRACT

The Antarctic ozone hole is a recurring phenomenon which typically forms on late August and dissipates by late November or early December. Due to climate change and the resulting stratospheric cooling, the ozone hole is expected to deepen, exhibiting low O_3 mixing ratios. Indeed, 2021 and 2023 recorded some of the most extensive and deep ozone holes.

In this work we discuss the spring onset of the Antarctic ozone hole using infrared observations from the IASI sounder based on a recently developed all-sky forward model (σ-IASI/F2N) for computing spectral radiances in the range of 100 to 2760 cm^{-1}. The code originally developed for I ASI observations, in the framework of Italian Space Agency Projects (FORUM-SCIENZA and FIT-FORUM), has been extended in the Far Infrared to cope with the 9th ESA Earth Explorer Mission, the Far-infrared Outgoing Radiation Understanding and Monitoring (FORUM).

To enhance our understanding of this phenomenon, we developed an all-sky retrieval tool that inverts the entire IASI spectrum to estimate a set of thermodynamic and geophysical parameters, including ozone and nitric acid, which are crucial for analyzing the Antarctic ozone hole. Unlike VIS/UV sensors, IASI provides day-night coverage over the inner part of Antarctica during the critical period for O_3 hole formation. Our scheme also identifies and fits ice polar stratospheric clouds.

We retrieved maps of atmospheric ozone, nitric acid, temperature, and lower stratosphere height for July, September, and October of 2021 and 2023. These results were compared with data from TROPOMI (TROPOspheric Monitoring Instrument) and OMI (Ozone Monitoring Instrument), showing an overall excellent agreement. The comparison of simultaneously retrieved O_3 and HNO_3 indicates that the onset of the ozone hole is linked to significant denitrification in the Antarctic stratosphere. In 2023, our findings revealed that ozone depletion episodes occurred as early as July. Although preliminary, our analysis highlights the importance of assimilating all-sky infrared radiances—day, night, clear, or cloudy—to provide a comprehensive picture of the Southern Hemisphere spring ozone depletion over Antarctica.

The study also aims at identifying the potential contributions of the EE9-FORUM mission. FORUM will observe in the spectral range between 100 to 1600 cm^{-1}, encompassing the ν_1 and ν_3 ozone bands, similar to IASI.