EGU23-11977, updated on 26 Apr 2024
https://doi.org/10.5194/egusphere-egu23-11977
EGU General Assembly 2023

Using a machine learning and stochastics-founded model to provide near real-time stratospheric polar vortex diagnostics based on high-latitude infrasound data

Mari Eggen[1,2], Alise Danielle Midtfjord[1], Ekaterina Vorobeva[2,3], Fred Espen Benth[1], Patrick Hupe[4], Quentin Brissaud[2], Yvan Orsolini[5], Alexis Le Pichon[6], Constantino Listowski[6], and Sven Peter Näsholm[2,7]
[1]Department of Mathematics, University of Oslo, Oslo, Norway
[2]NORSAR, Kjeller, Norway
[3]Department of Physics, Norwegian University of Science and Technology, Trondheim, Norway
[4]BGR, B4.3, Hannover, Germany
[5]Norwegian Institute for Air Research, Kjeller, Norway
[6]CEA/DAM/DIF, Arpajon, France
[7]Department of Informatics, University of Oslo, Oslo, Norway

Acoustic waves below the frequency limit of human hearing - infrasound - can travel for thousands of kilometres in the atmosphere. The global propagation signature of infrasound is highly sensitive to the wind structure of the stratosphere.

This work exploits processed continuous data from three high-latitude infrasound stations to characterize an aspect of the stratospheric polar vortex. Concretely, a mapping is developed which takes the infrasound data from these three stations as input and outputs an estimate of the polar cap zonal mean wind averaged over 60-90 degrees in latitude at the 1 hPa pressure level. This stratospheric diagnostic information is relevant to, for example, sudden stratospheric warming assessment and sub-seasonal prediction.

The considered acoustic data is within a low-frequency regime globally dominated by so-called microbarom infrasound, which is continuously radiated into the atmosphere due to nonlinear interaction between counter-propagating ocean surface waves.

We trained a stochastics-based machine learning model (delay-SDE-net) to map between a time series of five years (2014-2018) of processed infrasound data and the ERA5 (reanalysis-based) daily average polar cap wind at 1 hPa for the same period. The ERA5 data was hence treated as ground-truth. In the prediction, the delay-SDE-net utilizes time-lagged inputs and their dependencies, as well as the day of the year to account for seasonal differences. In the validation phase, the input was the 2019 and 2020 infrasound time series, and the model inference results in an estimate of the daily average polar cap wind time-series. This result was then compared to the ERA5 representation of the stratospheric diagnostic time-series for the same period.

The applied machine learning model is based on stochastics and allows for an interpretable approach to estimate the aleatoric and epistemic prediction uncertainties. It is found that the mapping, which is only informed of the trained model, the day of year, and the infrasound data from three stations, generates a 1 hPa polar cap average wind estimate with a prediction error standard deviation of around 10 m/s compared to ERA5.

Focus should be put on the winter months because this is when the coupling between the stratosphere and the troposphere can mostly influence the surface conditions and provide additional prediction skill, in particular during strong and weak stratospheric polar vortex regimes. The infrasound data is available in real-time, and we discuss how the developed approach can be extended to provide near real-time stratospheric polar vortex diagnostics.