Using Artificial Intelligence (AI) for aerosol data reanalysis

Anthropogenic aerosols cause a forcing of climate change that is potentially comparable in magnitude but opposite in sign to greenhouse gases. In contrast to the climate effect of greenhouse gases, which is understood relatively well, the negative forcing (cooling effect) caused by aerosols represents the largest reported uncertainty in the most recent assessment of the Intergovernmental Panel on Climate Change (IPCC). This uncertainty severely hampers future predictions of climate change. Strong aerosol cooling in the past and present would imply that future global warming may proceed at, or even, above the upper extreme of the range projected by the IPCC. Aerosols are also known to strongly affect air quality, especially in regions with high industrial activity and large amounts of traffic, or in regions that are influenced by biomass burning. Exposure to particulate matter air pollution has major adverse human health impacts, including asthma attacks, heart and lung diseases, and premature mortality.

Satellite measurements are essential to understand and quantify the effect of aerosols on climate and air quality. The daily coverage of aerosol satellite measurements depends on the instrument and orbit characteristics and also on cloud coverage, because aerosol measurements can only be obtained in cloud free regions and on average ~70% of the globe is covered by clouds. One way to solve this problem is by applying data assimilation methods which combine global atmospheric transport models with satellite measurements to provide daily global information on aerosol properties. However, data assimilation has a high computational cost because of the complexity of atmospheric transport models, in particular for high resolution global models.

In this project, it will be investigated how AI can be used for aerosol data reanalysis. The goal is to train a neural network that provides global aerosol properties when aerosol properties sampled by a satellite are given as an input together with other information such as wind fields, relative humidity, and known locations of aerosol sources. To train the neural network, model simulations by a global atmospheric transport model will be used. First, measurements of the most widely used aerosol property, the Aerosol Optical Depth (AOD) will be used. Neural network models will be designed and trained to provide global AOD fields from the input of incomplete AOD measurements, model simulation results and meteorological input. Alternatively or as a second step, the research can be extended to other aerosol properties such as the Single Scattering Albedo (SSA) and the aerosol size. In the first phase of the projects simulated observations will be used to investigate what input and what architecture is most suited for our goal. Such an approach allows easy evaluation and verification of the implemented deep neural network models. When time permits, it is possible to extend this to real satellite measurements.

The research will be carried out at SRON-Netherlands Institute for Space Research (that is located in Leiden from September 2021 onwards). The project will be very important for the SPEXone satellite instrument that has been developed under lead of SRON and will fly on the NASA Phytoplankton, Aerosol, Cloud & ocean Ecosystem (PACE) mission, to be launched in 2023.

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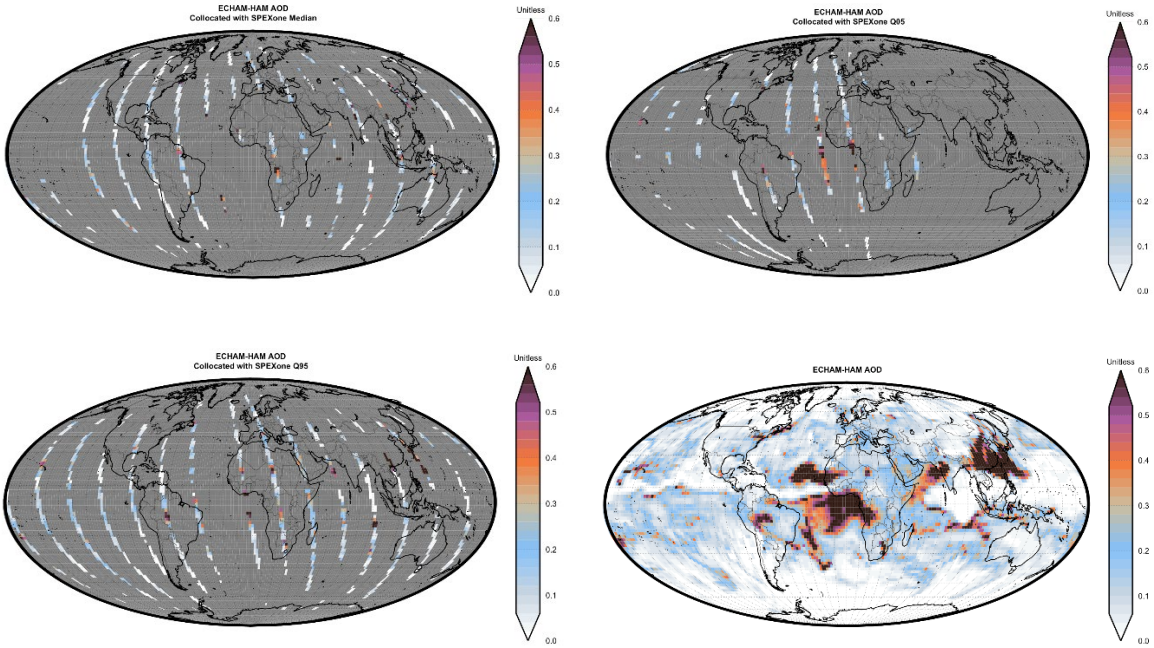

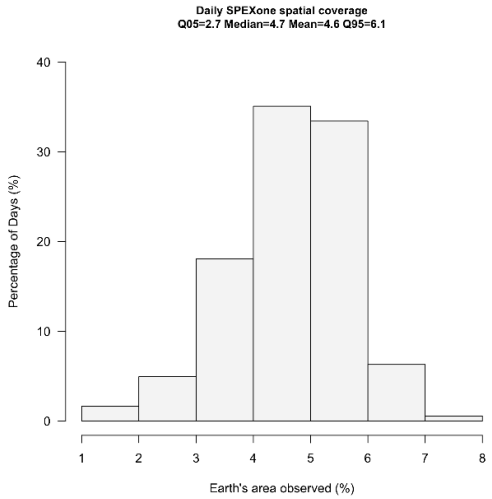

Illustration SPEXone spatial coverage for different days. a. Median: A typical day, where SPEXone observations cover 4.7% of the planet ; b. Q05: For a worst case scenario, where SPEXone obserrvations cover 2.7% of the planet; c. Q95: For a well observed day, where SPEXone observations cover 6.1% of the planet; d. Full model AOD (with a resolution 1.875x1.875 degrees); e. Statistics where obtained by analyzing SPEXone mask data for a year.

(PS. SPEXone is a concept satellite instrument that will measure the characteristics of aerosols in the earth's atmosphere with unparalleled accuracy for the purpose of climate and air quality research. SPEXone is developed by a consortium consisting of SRON and Airbus Defence and Space NL, with support from TNO. This initiative contributes to NASA PACE (Plankton, Aerosol, Cloud, Ocean Ecosystem) mission)