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Dust Aerosol Detection, Monitoring and Forecasting

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Software

- Review
- Repository
- Archive

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Summary

The training course on 'Dust Aerosol Detection, Monitoring and Forecasting' is a Python-based training that provides a hands-on introduction to satellite-, ground- and model-based data used for dust monitoring and forecasting. The course is organised in three main chapters: (i) observations (satellite- and ground-based), (ii) forecast models and a (iii) practical case study. It features twelve different datasets derived from satellites, ground-based measurement networks and forecast models. The course material is developed in the form of well-described and modular Jupyter notebooks. In total, the course consists of 17 notebooks; 12 data workflows and five practical exercise notebooks.

The training course is available as a JupyterBook. In addition, an executable version of each notebook can be accessed via a dedicated JupyterLab training platform, which has the required programming environment and data already preinstalled. Furthermore, the training course is also available via a GitLab repository.

The training material has been developed by the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and the Barcelona Supercomputing Centre (BCS-CNS), in collaboration with Copernicus and ACTRIS, the Aerosol, Clouds and Trace Gases Research Infrastructure.

Statement of Need

Sand and dust storms are common meteorological hazards in arid and semi-arid regions and are mostly caused by thunderstorms that increase wind speed over a wide area. They mainly occur in the arid regions of Northern Africa, the Arabian Peninsula, Central Asia and China (World Meteorological Organization, 2022a). However, dust minerals can also be transported over great distances, impacting not only areas where they originate but also communities far from the source areas (United Nations Convention to Combat Desertification, 2022). Every year, around 2,000 million tons of dust enters the atmosphere and particles affect climate, weather, atmospheric chemistry and ecosystems. It is projected that sand and dust storms will increase in number and intensity as a result of climate change and environmental degradation (Barcelona Supercomputing Center, 2022; World Meteorological Organisation, 2021).

Sand and dust storms represent a serious hazard with multisectorial effects at local, regional and global scales. Short term hazards associated with sand and dust storms include crop damage, livestock mortality, infrastructure damage, interruption of transport and air and traffic accidents. Long term effects include chronic health problems, soil erosion, reduced soil quality, soil pollution through the deposition of pollutants and the disruption of global climate regulation services (United Nations Convention to Combat Desertification, 2022).

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Hence, monitoring, forecasting and early warning systems for airborne dust are crucial to evaluate impacts and to better guide preparedness, adaptation and mitigation policies. Advances in satellite and ground-based observations and computer modelling have greatly enhanced the ability to issue early warnings in recent years (World Meteorological Organisation, 2021). However, several leading global organisations such as the UN Coalition to Combat Sand and Dust Storms and the World Meteorological Organisation (WMO) have identified the need for stronger efforts to facilitate information exchange, for training and capacity-building and for advocacy and awareness raising (United Nations Environment Management Group, 2018; World Meteorological Organisation, 2022b).

In order to facilitate raising awareness and training data users in existing data products to monitor and forecast sand and dust storms, the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and the WMO Global Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS), in collaboration with Copernicus and the Aerosol, Clouds and Trace Gases Research Infrastructures (ACTRIS), developed a modular training course on 'Dust Aerosol Detection, Monitoring and Forecasting'. The training course aims to provide a practical introduction and overview of different data products for dust monitoring and forecasting and is of interest for dust service providers, researchers and data users alike.

Learning Objectives and How to Access

The overall learning objective of the course is to give an introduction and overview of data that can be used and applied for dust monitoring and forecasting. After completing the course, data users will be able to:

- find, access and download satellite-, model-based and ground-based data products for dust monitoring and forecasting,
- use relevant Python packages to load, process and visualise these data, and
- assess advantages and limitations of each data product.

The entry point of the course is a Jupyterbook, which guides data users step-by-step through different thematic chapters. Each chapter consists of an introduction, e.g. an introduction to Remote Sensing observations with satellites, as well as practical data workflows. The practical data workflows are self-contained Jupyter notebooks which provide an introduction to a specific dataset and help data users to find, access, analyse and visualise the dataset. At the beginning, each of these notebooks provide a general introduction to the dataset combined with informational boxes about 'basic facts' and information on 'how to access the data'.

In addition to being a page in the Jupyter Book, the practical data workflows are further hosted on a dedicated JupyterLab-based training platform. Here, the notebooks are available as an executable version, together with the required Python libraries and data. First time data users are required to register for an account. Registration is free. Once registered, each executable notebook can be opened via a direct link from the Jupyter Book, at the top of each practical data workflow.

Finally, the Jupyter notebooks are also hosted and can be accessed via a dedicated GitLab repository, which allows data users to replicate the content and programming environment locally. The repository contains detailed instructions on how to reproduce the setup on a local machine.

Course Content

The course is organised in three main chapters: (i) observations (satellite- and ground-based), (ii) forecast models and a (iii) practical case study. The first two chapters provide an overview and introduction to different types of data available for dust monitoring and forecasting and serve as a basis for the third chapter. The third chapter consists of guided exercises, where data users perform an analysis of a real-world dust event with a problem-based learning approach.

Observations

This chapter provides an overview of nine different observation data and is again subdivided in two distinct sections: (i) Remote Sensing observations from satellites and (ii) Ground-based observations with remote and in-situ sensors.

Remote sensing observations from satellites

This chapter introduces data users to the principles of remote sensing with satellites and puts a specific focus on how dust and the amount of aerosols in the atmosphere can be retrieved from satellites. Six datasets from different satellite missions are introduced, covering three different processing levels, from Level 1 to Level 3. Level 1 data are the observed top-of-atmosphere radiances measured by satellites, Level 2 data are retrieved geophysical products and Level 3 are geo-referenced gridded data, where multiple measurements are averaged or accumulated over a grid cell.

The following data are featured:

- Level 1 data from two satellite instruments: (i) the SEVIRI instrument onboard the Meteosat Second Generation satellites operated by EUMETSAT and (ii) the MODIS instrument onboard the Terra and Aqua satellites operated by the National Aeronautical Space Agency (NASA).
- Three Level 2 aerosol data products: (i) the Sentinel-5P TROPOMI Aerosol Index product as part of Copernicus, (ii) the MODIS Aerosol product and (iii) the Polar Multi-Sensor Aerosol Optical Properties (PMAp) product.
- One Level 3 data product: the Absorbing Aerosol Index Level 3 product from the GOME-2 instrument onboard the three satellites Metop-A, -B and -C.

Ground-based observations with remote and in-situ sensors

This chapter features three datasets:

- AErosol RObotic NETwork (AERONET) Aerosol Optical Depth data,
- Vertical lidar backscatter profiles from the European Aerosol Research Lidar Network (EARLINET), and
- Air Quality measurements from the European Environment Agency (EEA).

Model forecasts

This chapter provides an introduction to dust forecast models and features three model forecast products from two different forecasting models:

- CAMS Global atmospheric composition forecasts
- CAMS European Air Quality forecasts and analyses, and
- SDS-WAS regional dust forecasts.

The first two products are retrieved from the model operated by the Copernicus Atmosphere Monitoring Service (CAMS). The SDS-WAS regional dust forecasts are retrieved from the NMMB/MONARCH model, which was developed by the Barcelona Supercomputing Center (BSC-CNS), in collaboration with NOAA's National Center for Environmental Prediction (NCEP), NASA's Goddard Institute for Space Studies and the International Research Institute for Climate Society (IRI).

Practical case study

This chapter gives data users a chance to reflect on the learned content and to practically work with the data. In five exercises, data users will be guided step-by-steph through the analysis of a real dust event that took place over the Canary Islands in February 2020.

As a prerequisite, this chapter requires that data users go through the data chapters in which the featured observation and model forecast data were introduced before.

Teaching Experience

The training material on 'Dust Aerosol Detection, Monitoring and Forecasting' has been used for training events since autumn 2021. The course is designed to equally accommodate self-paced learning and instructor-led training sessions. So far, the material has been used in two instructor-led week-long training schools and for several shorter webinars about dust monitoring and forecasting. So far, around 500 training participants have been reached. The overall feedback to the training is very positive. The training participants have shared feedback that they appreciate the well-documented notebooks and the practical case study in particular.

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