

Report on the outcomes of a Virtual Mobility¹

Action number: CA21119

Grantee name: Stavros-Andreas Logothetis

Virtual Mobility Details

Title: Long-term dust aerosol optical depth variability over the Eastern Mediterranean: Trends and driving mechanisms

¹ This report is submitted by the grantee to the Action MC for approval and for claiming payment of the awarded grant. The Grant Awarding Coordinator coordinates the evaluation of this report on behalf of the Action MC and instructs the Grant Holder Manager to verify the grant documents compliance and proceed with the payment.

Description of the work carried out during the VM

During the Virtual Mobility (VM), the grantee conducted a comprehensive investigation of the long-term variability of dust optical depth (DOD) over the Eastern Mediterranean, Eastern Sahara, and Middle East during 2001–2025. The work was implemented through regular virtual collaboration and scientific exchanges with researchers from the Research Centre for Atmospheric Physics and Climatology of the Academy of Athens and the Physikalisch-Meteorologisches Observatorium Davos/World Radiation Center. The virtual meetings focused on the methodological framework, interpretation of the results, preparation of figures, and development of the resulting scientific manuscript.

The first work package (**WP1**) focused on constructing and analysing an updated DOD record based on the Modis Dust AeroSol (MIDAS) dataset. MIDAS products derived from MODIS Aqua and Terra observations were merged to improve data availability and provide a continuous 25-year record. Annual, seasonal, and regional DOD trends were subsequently calculated over the study domain. In addition to full-period trends, the sensitivity of the results to the starting year and duration of the analysed period was examined to identify non-stationary behaviour and temporal shifts in regional dust activity.

The second work package (**WP2**) investigated the mechanisms controlling DOD variability. Meteorological variables from ERA5, precipitation from GPM IMERG, land-surface indicators, and MERRA-2 dust-emission estimates were processed and harmonized on a common spatial and temporal grid. Stepwise multiple linear regression models were developed separately for the Mediterranean Sea, Eastern Sahara, and Middle East. Predictor multicollinearity was assessed using the variance inflation factor, while the Lindeman–Merenda–Gold method was applied to quantify the relative contribution of each retained predictor to the explained DOD variance.

The third work package (**WP3**) examined connections between DOD, its regional drivers, and large-scale climate variability. Monthly and annual climate indices, including the AO, NAO, PDO, ENSO, and DMI, were compared with regional DOD anomalies, meteorological variables, land-surface conditions, and dust emissions using time-series and correlation analyses.

The work followed the original working plan without major deviations. However, several methodological refinements were introduced, including the merged Aqua–Terra MIDAS record, the use of robust trend-detection methods accounting for serial correlation due to the addition of the predictors trend analysis, and a

Description of the VM main achievements and planned follow-up activities

The VM successfully achieved its principal scientific objectives and produced an integrated assessment of DOD variability and its controlling mechanisms over the Eastern Mediterranean, Eastern Sahara, and Middle East during 2001–2025. The study combined an updated satellite-based DOD record with meteorological reanalysis, satellite precipitation, land-surface indicators, dust-emission estimates, and large-scale climate indices.

A major achievement was the identification of distinct regional patterns in recent dust evolution. Robust decreases in DOD were detected over the Mediterranean Sea and Eastern Sahara, particularly for long records beginning in the early 2000s. Mean DOD over the Mediterranean Sea decreased from approximately 0.095 during 2001–2008 to 0.075 during 2009–2025, while Eastern Saharan DOD decreased from approximately 0.21 during 2001–2013 to 0.18 during 2014–2025. In contrast, the Middle East exhibited a clear temporal regime shift, with enhanced dust loading during 2008–2012 followed by generally reduced dust conditions after 2013.

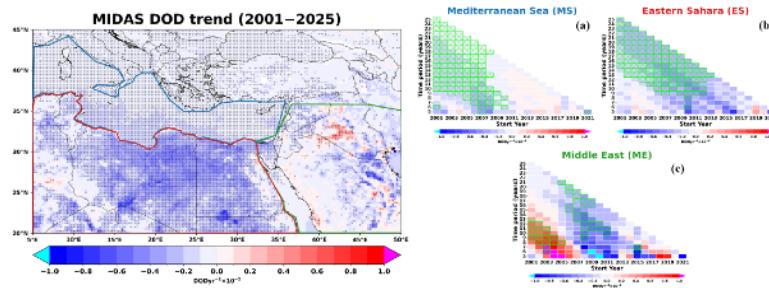


Figure 1. Spatial and time-window variability of MIDAS DOD trends over the Mediterranean Sea, Eastern Sahara, and Middle East during 2001–2025.

The multiple linear regression models explained a substantial fraction of monthly DOD variability, with R^2 values of 0.72, 0.79, and 0.86 for the Mediterranean Sea, Middle East, and Eastern Sahara, respectively. Mediterranean DOD variability was primarily associated with Saharan dust-source activity and lower-tropospheric transport. Eastern Saharan variability was mainly controlled by winds, atmospheric moisture, and source emissions, whereas Middle Eastern variability reflected interactions between meteorological conditions, regional emissions, and land-surface dryness.

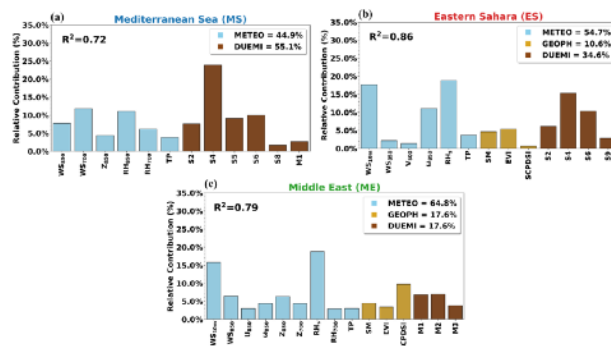


Figure 2. Relative contributions of meteorological, geophysical, and dust-emission predictors to regional DOD variability over the Mediterranean Sea, Eastern Sahara, and Middle East, estimated using stepwise MLR and LMG variance decomposition.

The climate-index analysis indicated that large-scale circulation patterns generally influence DOD indirectly by modulating winds, geopotential height, humidity, precipitation, drought conditions, vegetation, and dust-source activity. The results therefore demonstrate that recent dust variability cannot be attributed to a single driver but emerges from region-specific interactions among atmospheric circulation, surface conditions, and source activity.

