Hellenic Foundation for Research & Innovation

Description of the funded research project

2nd Call for H.F.R.I. Research Projects to Support Post-Doctoral Researchers

Title of the research project:

Mineralogy of Dust Emissions and impacts on Environment and Health

Principal Investigator: Stavros Solomos

Reader-friendly title: MegDETH

Scientific Area: Meteorology and atmospheric sciences

Institution and Country: Greece

Host Institution: Academy of Athens

Budget: 189,715.00

Duration: 36 months

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Research Project Synopsis

Mineral dust is a major modulator for environmental processes with impacts on radiative transfer, clouds, ocean fertilization and human health. All aforementioned impacts are affected by particle composition which in turn is a function of the soil mineralogy at the source regions. Absence of this information from relevant studies results in limited accuracy of future climate projections and dust impacts on weather, biogeochemistry and health. Our hypothesis is that dust mineralogy plays a more important role in nature than currently acknowledged and including this parameter in modeling studies could dramatically change the future projections related to weather and climate forcing of dust. Upon this hypothesis we propose to develop novel processing chains and techniques for deriving mineralogical information directly from satellite hyperspectral and multispectral sensors and integrate this information in atmospheric models.

In MegDETH we will: (i) Derive a mineralogical map of Saharan dust sources by applying advanced pattern recognition algorithms on hyperspectral (Hyperion-EO1) and multi-spectral (Sentinel-2, Sentinel-3) satellite sensors; (ii) implement this information in atmospheric-dust models; (iii) Quantify the impacts of dust minerals on radiative transfer, cloud formation, ocean fertilization and human health using updated model simulations that will take into account the mineralogical composition of dust. The relative contribution of different minerals to the various environmental processes will be discussed using comparisons with detailed dust measurements (e.g. Antikythera PANGEA station and ASKOS campaign at the Atlantic Ocean). This will be the first time for a holistic and quantified assessment of these taking into account all dust characteristics (amounts, size, composition, optical properties) and will establish a new era for dust activities in atmospheric research.

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Project originality

Desert mineralogy is a missing and understudied component in dust-related atmospheric studies (Mahowald et al., 2011). Limitations towards integrating and successfully simulating the particle mineralogy include the lack of detailed initial and boundary conditions in the models for the mineralogical composition and the amount of dust uplift at sources. Until now, existing models assume that the dust mineralogical composition is related to the soil type, as this is provided by a global atlas (e.g., Claquin et al., 1999; Nickovic et al., 2013; Scanza et al., 2015). This relation is based upon massive extrapolation due to limited sampling of soil mineralogy (especially over desert areas) and neglects mineral variations between regions of identical soil type. Moreover, the existing databases include measurements based on wet sedimentation ("wet sieving") techniques that disturb the soil samples, breaking the aggregates that are found in the original, undispersed soil that is subject to wind erosion. Beyond the limitations related to the soil mineralogy, the models are also biased on simulating the amount of airborne dust particles. This is due to the absence of initial and boundary conditions since most models rely on a warm-start approach (Solomos et al., 2017), i.e. the initial conditions for dust are taken from the results of a previous forecast cycle, implying the propagation of numerical errors and deviation of model solutions. Additional uncertainties are introduced from the inability of weather models operating at mesoscale or coarser resolutions (e.g. climate models) to describe certain local scale and boundary layer dust production mechanisms such as Low Level Jets (LLJ) (Schepanski et al., 2015) and convectively driven haboobs (Solomos et al., 2012, 2017). So far, various assimilation techniques of DOD are only available in GCMs using data from polar orbit satellite sensors such as MODIS (e.g. ECMWF, UK Met Office Unified Model).

Expected results & Research Project Impact

MegDETH will make game-changing contribution in several scientific disciplines, such as:

- **Produce, for the first time, pattern-recognition algorithms able to estimate soil mineral composition from multi-spectral observations. Continuous measurements of the surface composition at areas bordering the dust sources will monitor the evolution of desertification and the anthropogenic effects on new dust sources and the associated future climate scenarios.**
- **Incoming solar radiation depends directly on the chemical composition and load of desert aerosols. Therefore, the modelling tools developed in the framework of this research will allow the accurate estimates of solar-energy potential at the Mediterranean region, better planning of solar-energy investment and will contribute towards improving the energy security of Europe.**
- **Improve forecasting weather and climate: Desert dust is the major source of ice nuclei that are involved in cloud formation. Better prediction of hail and rain as well as a better prediction of the wet depositions of dust minerals will have direct impacts in the agricultural sector.**
- **Several minerals contained in desert dust, like iron (Fe) and phosphorus (P), are important nutrients for marine ecosystems. In oligotrophic regions, like the Mediterranean Sea, airborne dust can be the major contributor of such nutrients, modulating all aspects of the marine ecosystem. The outcomes of the proposed research will affect planning of many aspects of economic activity related to marine environment (blue economy) like the fishing industry, aquacultures, and tourism.**
- **The minerology of these particles, particularly their iron concentration directly affects lung disease and carcinogenesis. Moreover, meningitis out-brakes in the Sahel region are strongly correlated with dust episodes even though the exact mechanism and the role of minerology is not fully understood. Accurate forecasts of mineral dust composition can help understand and quantify the impact of dust aerosols in health and assist the designing of more effective air-quality policies in national and European level.**

The importance of this funding

Receiving this HFRI Grant is of paramount importance for me at the current stage of my career. I have already worked as Postdoctoral Researcher at the University of Athens and at the National Observatory of Athens and since 2020 I am Associate Researcher at the Academy of Athens. At this point, HFRI gives me a unique opportunity to establish my research group, expand my activities in my area of expertise and consolidate my status in the scientific community at Greek and European level. This project brings added expertise and opens new directions for scientific research in the fields of atmospheric modeling and remote sensing synergies, at the cutting-edge topics of climate change and aerosol–atmosphere feedbacks. MegDETH will support the training of new scientists, in this demanding and challenging scientific field and assist them to initialize high-level careers, also upgrading the human resources capacity at country level.

COMMUNICATION

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