SHORT TERM SCIENTIFIC MISSION (STSM) SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: CA16202, International Network to Encourage the Use of Monitoring and Forecasting Dust Products
STSM title: The 4th Short Term Scientific Mission (STSM) Call
STSM start and end date: 20/11/2019 to 15/03/2020
Grantee Name: Yalda Fatahi

PURPOSE OF THE STSM

The STSM was carried out at Finnish Meteorological Institute in Helsinki, Finland. During this mission, under the supervision of Dr. Mikhail Sofiev, satellite-derived aerosol products, such as Aerosol Optical Depth AOD and soil moisture were related to the surface soil properties to determine the role of dynamic and static environmental factors on dust outbreaks.
The goal of the current study was to find the best way to modeling the relation between AOD and soil moisture. To answer this question, correlation analysis was performed between the time series of these variables. In order to account for the differences in the land cover categories, climate conditions, and spatial and temporal variability of AOD, the analysis has been done in 17 regions of interest over Asia, Europe, and Africa over a long time period from 2002 till 2019.
More specifically, this STSM was aimed to get practical skills on:

- Improve knowledge and practical expertise in remote sensing technology and available products
- Satellite imagery access and analysis in Python programming language
- Acquaintance with construction and application of atmospheric model **SILAM**

CONTRIBUTION TO THE ACTION AGENDA

The STSM aims were built around two main objectives of COST Action CA16202, in particular, **identify and exploit dust monitoring observations (from both ground-based and satellite platforms) and forecast products best suited to be transferred to the needs of end-users**. This study concentrated on the satellite AOD variations and land surface parameters such as soil moisture and land cover and analyzed the relationship between those. These parameters are keys output products and input variables, respectively, for every dust forecasting model. Better understanding of their relations therefore facilitates the model improvement and service development.

The STSM was also aimed at the capacity building, training and education. The Grantee has undergone an extensive training in one of the European dust forecasting laboratories and familiarized herself with a variety of available satellite and model products and services.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

Figure 1, shows target regions selected from Asia, Africa, and Europe.

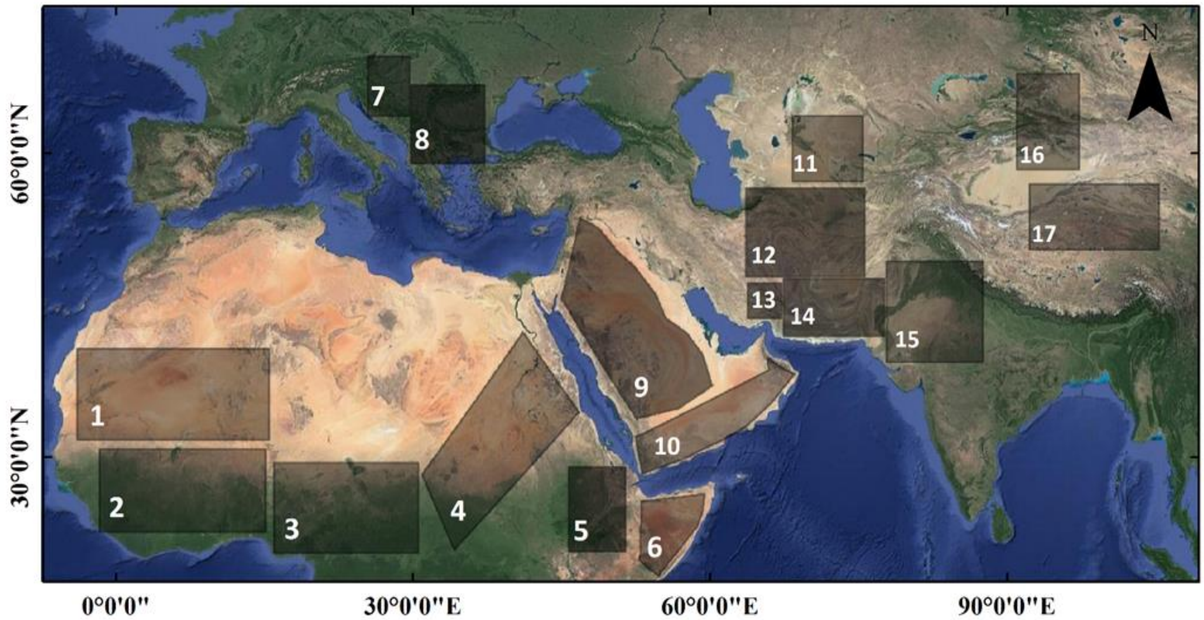

Figure. 1 Selected regions to study variations of AOD and SM over 17 years (2003-2020)

The AOD variations were considered in the context of the International Geosphere-Biosphere Program classification (IGBP) land cover classification.
To initially identify the dust clouds, the visual interpretations of satellite aerosol products were performed with a help of https://worldview.earthdata.nasa.gov/. After this identification, MODIS deep blue (DB) AOD values were downloaded to monitor the aerosols status. In the next step, soil moisture (SM) content was considered at the same time and place. The daily values of DB and SM have been extracted from MODIS and GLDAS data sets respectively for a period of 17 years from 2002 to 2019. The International Geosphere-Biosphere Program classification was utilized to the considered land cover types. To reduce the volume of these satellite-based observations and accelerate the process, about-70 pixels were randomly selected for each 17 chosen areas.

Through the data preprocessing step, missing values due to clouds, cloud shadows, and also over the bright surfaces were removed from the original data. After cleaning, the AOD values were matched temporality with SM. The relationship between these variables was established via Pearson correlation analysis. The point values of ‘r’ were interpolated with the Arc Map 10.1 software to visualize the results as a correlation map.

In the second part of this research, to strengthen the analysis, land cover as another surface parameter matched with SM and AOD time series. After applying the same pre-processing on land cover data set, the multinomial logistic regression model was used to verify the following hypotheses:

- Null hypothesis (H0): there is no significant correlation between the variables
- Alternative hypothesis (H1): there is an association between variables

All steps to implement the classification and evaluation were performed using available libraries in python 3.8.

DESCRIPTION OF THE MAIN RESULTS

Different distribution patterns of AOD even under the same humidity conditions showed that aerosols recorded by MODIS was originated from various sources including desert dust, sea salt, biomass burning (especially in summer), and anthropogenic activities.

Figure 2 presents the results obtained from Pearson correlation analysis performed to evaluate the relationship between soil moisture and AOD at each site. As seen from the picture, a positive correlation was found primarily in Africa (sites 1, 4 and 5) but even there the sites 3, 12, and 13 showed negative correlation. There was.no significant correlation between the variables in substantial parts of the 17 selected regions. It is apparent from this correlation map that the observed relationship between selected variables does not support the idea that aerosol loading is always directly affected by surface humidity.

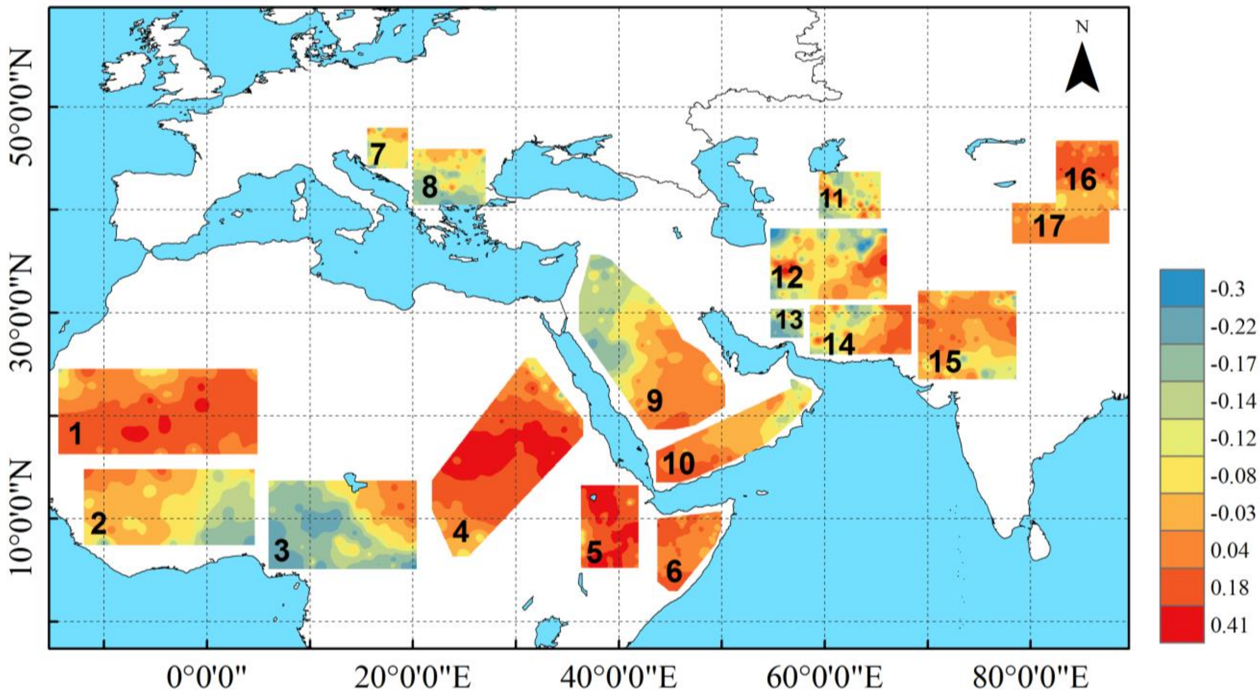

Figure 2. Correlation map between MODIS deep blue AOD and GLDAS soil moisture using historical data of 17 years (2002– 2019)

Table 1, summarizes multinomial regression results. From this table, although correlation coefficient (r) in some cases with p-values <0.05 is statistically significant, these values do not indicate a strong relationship. Furthermore, extremely low values of coefficient of determination ($R^2 < 0.03$), shows there is no association between variables and model is

not able to accurately predict the values of response (AOD) from predictor variables (e.g. soil moisture).
Among the possible explanations for this unexpected finding, three main reasons deserve attention. Firstly, dust outbreaks require not only dry soil but strong winds. Secondly, the contribution from other sources of aerosols can have their impact in some of the regions, Thirdly, the non-local nature of the AOD should be accounted for: despite the regions were selected covering large areas, it is plausible to expect substantial contribution from the sources outside the regions to the aerosol load inside.

Table 1. Statistical descriptions of multinomial logistic regression

No. of Box	r	R^2	RMSE
1	0.02	0	0.2
2	-0.01	0	0.19
3	-0.12	0.01	0.18
4	0.07	0.01	0.15
5	0.12	0.01	0.13
6	0.11	0.01	0.14
7	-0.11	0.01	0.13
8	-0.14	0.02	0.13
9	-0.17	0.03	0.18
10	-0.05	0	0.21
11	-0.09	0.01	0.1
12	-0.11	0.01	0.12
13	-0.18	0.03	0.12
14	-0.06	0	0.18
15	-0.15	0.02	0.21
16	-0.02	0	0.22
17	-0.12	0.01	0.16

FUTURE COLLABORATIONS (if applicable)

To improve the results and better review the work process, with the consent of the host institution, the mission is extended for another 5 months. At this opportunity, which is provided to me with the help of the host institute, I have time to answer the questions that have arisen during this period under the supervision of this experienced team. The aim is to understand the reasons for disproval of initially reasonably0looking hypothesis and prepare an article using the findings obtained during this course. The first draft of this review has been started.

ACKNOWLEDGMENTS

I would like to express my gratitude to COST, my host and home institutes for arranging and organizing this visit. Their purport and willingness to share experiences were invaluable to the success of the STSM. A special thanks to Dr. Ari Karppinen, head of Modelling group of Atmospheric Composition Department and Dr. Mikhail Sofiev, deputy of Atmospheric Composition Modelling group for their full support, training and supervising me during the

visit. The skills I learned in this STSM have certainly enriched my knowledge and experience and will be very useful for my future studies and researches.