AEROSOL TYPING AND CHARACTERIZATION DURING PRE-TECT CAMPAIGN OVER FINOKALIA, CRETE

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Abstract Aerosol typing schemes based on the intensive properties derived from a multiwavelength Raman lidar are used for the characterization of the aerosol load over Crete. The dataset used was acquired during the Pre-TECT campaign, which was organized by the National Observatory of Athens (NOA) in the framework of the ACTRIS (Aerosol, Clouds and Trace Gases Research Infrastructure). Pre-TECT experiment took place from 1st to 30th of April 2017 at the Greek atmospheric observatory of Finokalia of the University of Crete and acquired multispectral observations of the aerosol properties above the area in high temporal and vertical resolution. The typing results are evaluated against detailed layer-characterization using auxiliary available measurements (from lidar, photometer, in-situ and satellite data) and model simulations (from backward trajectories and models specialized in dust, smoke and sea-salt transport). Aim of this work is to evaluate the performance of the new typing scheme and to provide a detailed aerosol characterization over Crete during the campaign, and the results of this work will be used in future studies of aerosol-cloud interactions in the eastern Mediteranean.

1 Introduction

Aerosol abundance and composition is on the spotlight of the scientific interest. Aerosols affect the surface radiation, the formation and evolution of clouds and can be harmful for human health. In order to assess aerosol impacts, the identification of their source and composition is an important tool for both the characterization of events and the alerting of hazardous atmospheric situations, as well as for estimating their radiative impacts. Lidar measurements provide vertical profiling of aerosol properties with high temporal and spatial resolution, hence their multiwavelength retrieved properties are. The parameters derived with multiwavelength lidars are useful for aerosol characterization. In the last years, two aerosol typing schemes (NATALI, Mahalanobis-based algorithm) have been developed within EARLINET (European Aerosol Research Lidar NETwork) utilizing lidar observations with the purpose of providing the predominant aerosol type in observed layers (Nicolae et al., 2018; Papagiannopoulos et al., 2018), making use of the available aerosol-type-sensitive intensive properties (e.g., Ångström Exponent, backscatter-related Ångström Exponent, lidar ratios, ratio of lidar ratios) and providing the main aerosol components as a function of height. In this work we present a new lidar-based typing algorithm developed within AUTH (Aristotle University of Thessaloniki) and we are using the new scheme to identify the predominant aerosol types observed above Creta during spring 2017, and in particular, during the period of the Pre-TECT experiment. Pre-TECT (http://pre-tect.space.noa.gr/about/) aim to advance the desert dust microphysical characterization from ground-based remote sensing, by employing sophisticated inversion techniques, capable of retrieving aerosol microphysics. The campaign and the D-TECT ERC project (http://d-tect.space.noa.gr/) was clustered with the A-LIFE field in the framework of the A-LIFE ERC project (https://www.a-life.at/) and the A-LIFE ERC project (https://www.a-life.at/) that was implemented during the same period in the Mediterranean region.

2 Data and Methodology

The lidar measurements processed in this study were collected above Finokalia station (35º 20'N, 25º 40'E) in the northern coast of Crete. Finokalia station is a background station, representative of a broader area in the eastern Mediteranean, as the nearest largest urban centre (Heraklion; 150.000 inhabitants) is 47km away. The station is mainly affected by natural sources and mixtures of maritime aerosols with transported-elevated layers (Hamill et al., 2016).

In this work, we are using the lidar measurements collected from 1st to 30th of April 2017 during the Pre-TECT experiment. During the campaign, the NOA Polly^{XT} lidar (Engelmann et al., 2016) performed measurements on a 24h basis, along with a wide range of other remote sensing observations and in situ measurements. The PollyXT lidar measurements are used in this work for the classification. We analyse the lidar data to derive the level 2 optical and geometrical products using the SCC algorithm (reference) and the PollyNET algorithm (Baars et al., 2016).

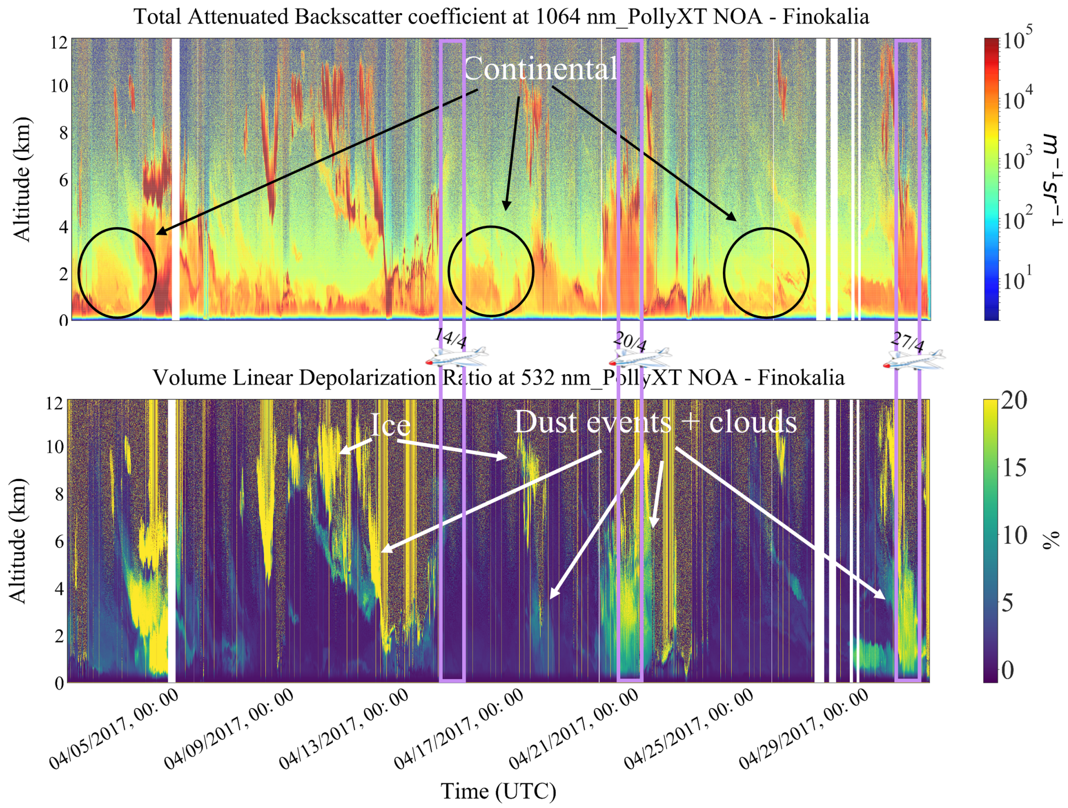

Fig. 1. The Pre-Tect lidar observations of the range corrected signal at 1064nm (above) and the volume depolarization ratio at 532nm (below). Highlighted are the time periods of the FALCON flights above the

station.

In Synergy with the A-LIFE project, three coordinated flights were performed above Finokalia station by the FA20 research aircraft of of the German Aerospace Center (DLR), equipped with an extended in-situ aerosol payload, a wind lidar and meteorological sensors. The aircraft in-situ instrumentation is capable to provide information on the aerosol size distribution and composition.

The new typing scheme developed at AUTH (Aristotle University of Thessaloniki), which provides the main aerosol components as a function of height, is applied on the Pre-TECT lidar measurements. The AUTH typing scheme is based on the Mahalanobis distance (Mahalanobis, 1936) and the classification of each aerosol layer is made by calculating the distance of each point from predefined reference classes and by attributing each point to a specific class based on the minimum distance. The aforementioned algorithms require lidar data with 3β + 2α + (1d) configuration (3 backscatter and 2 extinction coefficient profiles and particle depolarization profiles).

3 Results and discussion

In the following, we present the case of 20/4/2017. For the characterization of the examined aerosol layers at Finokalia station the atmospheric dispersion FLEXPART-WRF model was used in backward mode for the computation of source-receptor relationships (Brioude, et al., 2013). The dispersion model is coupled offline with the WRF-ARW atmospheric model. The backward FLEXPART runs are performed for 3-day periods and we assume a release of 40000 tracer particles from each layer that was observed at specific heights over Finokalia station. We created emission sensitivity maps with the information on the areas the tracer particles detected at heights between 0-1km in the past 3-days, along with the information of the time that the tracer particles spend there. (Figure 2a). Ancillary data are further used for the characterization of the air masses observed, i.e. analytical 5-day hysplit back-trajectories (Figure 2b) and dust, sea salt and smoke transport model forecasts (not shown here). For this case study, the air masses are characterized by the transportation of Saharan dust from northern Africa in altitudes ~2.7 km, the transport of continental aerosols in altitudes ~1.7km and the transport of marine particles from the Mediterranean Sea in latitudes ~0.5 km above the station (Figure 2b). The FLEXPART-WRF output shows that the dust-prone area of northern Africa (Morocco and northern Algeria) are most likely the sources of the dust layer (Figure 2a).

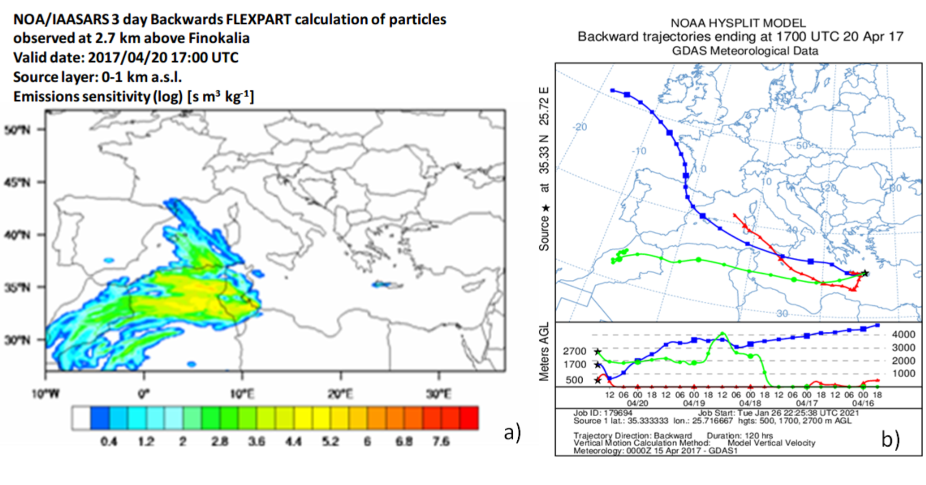

Fig. 2. (a) FLEXPART-WRF Source–Receptor Relationships [(log)(sm^3kg^{-1})] ***for the air masses arriving at Finokalia at 2.7 km, with sources between 0-1km above ground level, and (b) Hysplit back-trajectories for the***

air masses arriving at Finokalia at 0.5, 1.7 and 2.7km, on 20 April 2017 at 17:00 UTC.

In Figure 3, the intensive and extensive properties and of the layers observed with the lidar are presented along with the typing results of the AUTH algorithm. Vertical profiles of the aerosol optical properties are presented: Backscatter coefficient at 355, 532 and 1064 nm, extinction coefficient at 355 and 532 nm, lidar ratio and Ångström exponents. The algorithm identifies 2 layers. The 1st layer (1.5-1.9km) is characterized as a polluted continental layer, while the 2nd layer (2.3-3.4km) demonstrates optical properties representative of dust particles, with lidar ratio values of 60 sr and and Ångström exponent close to zero. Both layers are classified correctly from the algorithm taking into consideration the meteorological tools of Figure 3. At the same day, in-situ samples were collected with the DLR aircraft above Finokalia site, at 3.1 km above sea level, between 12:22 to 12:35 UTC. The samples were analysed in coarse and accumulation mode and show dominance of dust particles in both modes, with an ~30% contribution of organic matter and sulfate in the accumulation mode (source: A-CARE ESA report).

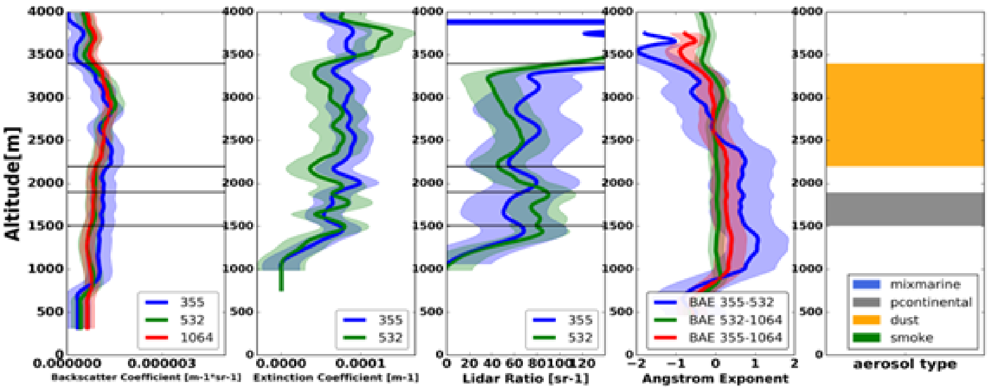

Fig. 3. PollyXT optical products and aerosol typing from the AUTH classification algorithm on 20 April 2017 at 17:00 – 18:00 UTC.

An overview of the aerosol and cloud air masses observed during PRE-TECT, analyzed in terms of aerosol typing is shown in Figure 4. During the experiment, multiple dust events were observed above the station in altitudes up to 8 km, with clouds formed on top of them. Additionally, continental aerosols were observed in altitudes up to 3 km. Marine layers were also identified. Falcon collected aerosol profiles above the station 3 days, and 2 of the samples were under dust presence. The results of the classification are presented in Figure 4. We see that the majority of the detected layers are classified as clean continental aerosols (with percentages up to 30%), along with marine particles (occurrence ratio of 28%). Dust layers are also observed during the campaign (with percentages above 10%). Pure dust particles, but also Dust polluted particles (dust + smoke and/or dust + polluted continental) and mixed dust particles (dust + marine) are assigned. Moreover, a number of layers (with percentages up to 30%) are not assigned to any cluster due to the threshold criteria applied in the typing procedure (related to higher uncertainties).

Although the algorithms succeed in correctly classifying a lot of cases, their classification fail in humidify aerosol layers which are erroneously categorize as marine dominated (Tsekeri et al., 2017). Future work is dedicated to calculate the water vapor mixing ratio and the relative humidity conditions inside the detected aerosol layers and check the applicability of the typing algorithms for different relative humidity conditions.

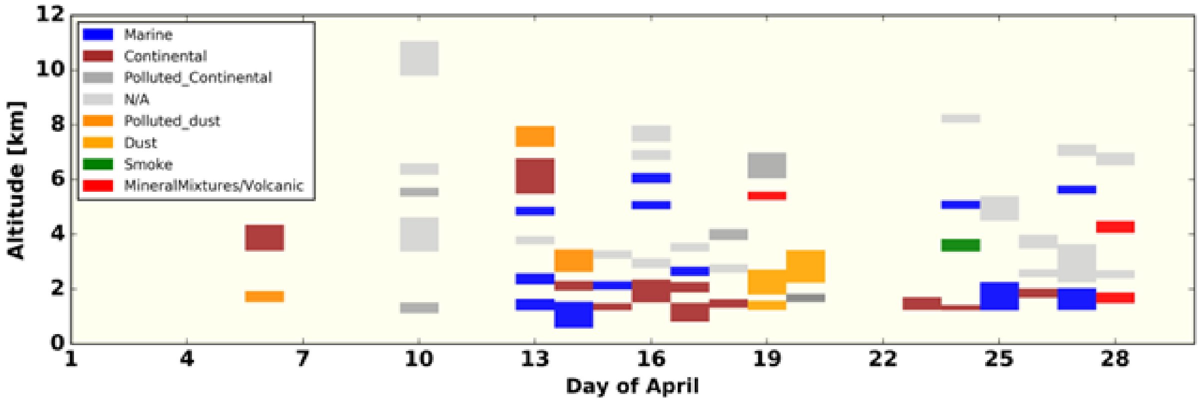

Fig. 4. The Pre-Tect NATALI - based aerosol typing form the nighttime measurements.

4 Conclusions

Different typing schemes are used to provide the aerosol characterization of the layers over Finokalia during the Pre-TECT experiment. During that period, clean continental particles (with percentages up to 30%) and marine particles seem to dominate in the region. Saharan dust outbreaks were also observed, not only as pure aerosol layers, but also with mixtures with other particles. Some aerosol layers are misclassified, and are characterised as marine-dominated in altitude where marine is not expected. Same misclassification is observed in dusty layers with high water vapor concentrations. Future analysis of the aerosol layers above Crete during Pre-TECT based on a high resolution mode of the AUTH typing scheme and results from the other two aforementioned EARLINET typing schemes are going to be tested in order to investigate the overall algorithm performance and consistency. The performance of the classification schemes will be evaluated with the collocated aircraft measurements. Going one step further, the applicability of the typing algorithms in different water vapor mixing ratios and relative humidity conditions within the aerosol layers is going to be further investigated. The Pre-TECT air mass characterizations will be used in future studies of aerosol-cloud interactions. The new typing scheme will be used in the future for aerosol typing of the multy-annual datasets of several lidar stations (eg. AUTH, Finokalia, PANGEA) in order to better characterize the seasonal evolution of the elevated aerosol masses above Greece. Additionally, the new algorithm will be used for the evaluation of the aerosol typing of the upcoming EARTHCARE spaceborne lidar of ESA.

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References

Basart, S., Pérez, C., Nickovic, S., Cuevas, E., and Baldasano, J.: Development and evaluation of the BSC-DREAM8b dust regional model over Northern Africa, the Mediterranean and the Middle East, Tellus B, 64, 18539, https://doi.org/10.3402/tellusb.v64i0.18539, 2012b.

Brioude, J., Arnold, D., Stohl, A., Cassiani, M., Morton, D., Seibert, P., Angevine, W., Evan, S., Dingwell, A., Fast, J. D., Easter, R. C., Pisso, I., Burkhart, J., and Wotawa, G.: The Lagrangian particle dispersion model FLEXPART-WRF version 3.1, Geosci. Model Dev., 6, 1889–1904, https://doi.org/10.5194/gmd-6-1889-2013, 2013.

Engelmann, Ronny & Kanitz, Thomas & Baars, Holger & Heese, Birgit & Althausen, Dietrich & Fahrwald, A. & Wandinger, Ulla & Komppula, Mika & Stachlewska, I. & Amiridis, Vassilis & Marinou, Eleni & Mattis, Ina & Linné, Holger & Ansmann, Albert., The automated multiwavelength Raman polarization and water-vapor lidar PollyXT: The neXT generation. Atmospheric Measurement Techniques. 9. 1767-1784. 10.5194/amt-9-1767-2016.

Groot Zwaaftink, C. D., Henne, S., Thompson, R. L., Dlugokencky, E. J., Machida, T., Paris, J.-D., Sasakawa, M., Segers, A., Sweeney, C., and Stohl, A.: Three-dimensional methane distribution simulated with FLEXPART 8-CTM-1.1 constrained with observation data, Geosci. Model Dev., 11, 4469-4487, https://doi.org/10.5194/gmd-11-4469-2018, 2018.

Hamill, P., Giordano, M., Ward, C., Giles, D., and Holbein, B.: An AERONET-based aerosol classification using the Mahalanobis distance, Atmos. Environ., 140, 213–233, https://doi.org/10.1016/j.atmosenv.2016.06.002, 2016.

Mahalanobis, P. C.,: On the generalized distance in statistics. Proceedings of the National Institute of Science of India, 12, 49–55, 1936.

Nicolae D., Vasilescu J., Talianu C., Binietoglou I., Nicolae V., Andrei S., and Antonescu B., A Neural Network Aerosol Typing Algorithm Based on Lidar Data, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2018-492, 2018.

Papagiannopoulos, N., Mona, L., Amodeo, A., D'Amico, G., Gumà Claramunt, P., Pappalardo, G., Alados-Arboledas, L., Guerrero-Rascado, J. L., Amiridis, V., Kokkalis, P., Apituley, A., Baars, H., Schwarz, A., Wandinger, U., Binietoglou, I., Nicolae, D., Bortoli, D., Comerón, A., Rodríguez-Gómez, A., Sicard, M., Papayannis, A., and Wiegner, M.: An automatic observation-based aerosol typing method for EARLINET, Atmos. Chem. Phys., 18, 15879-15901, https://doi.org/10.5194/acp-18-15879-2018, 2018.

Papagiannopoulos, N., Mona, L., Alados-Arboledas, L., Amiridis, V., Baars, H., Binietoglou, I., Bortoli, D., D'Amico, G., Giunta, A., Guerrero-Rascado, J. L., Schwarz, A., Pereira, S., Spinelli, N., Wandinger, U., Wang, X., and Pappalardo, G.: CALIPSO climatological products: evaluation and suggestions from EARLINET, Atmos. Chem. Phys., 16, 2341–2357, https://doi.org/10.5194/acp-16-2341-2016, 2016.

Tsekeri, A., et al.: Profiling aerosol optical, microphysical and hygroscopic properties in ambient conditions by combining in situ and remote sensing, Atmos. Meas. Tech., 10, 83–107, https://doi.org/10.5194/amt-10-83-2017, 2017.

Voudouri, K. A., Siomos, N., Michailidis, K., Papagiannopoulos, N., Mona, L., Cornacchia, C., Nicolae, D., and Balis, D.: Comparison of two automated aerosol typing methods and their application to an EARLINET station, Atmos. Chem. Phys., 19, 10961–10980, https://doi.org/10.5194/acp-19-10961-2019, 2019.