Synergy of Unmanned Aerial Vehicles and Ground-based remote sensing for spaceborne lidar calibration and validation

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Abstract: The Cyprus Institute has acquired expertise during the ASKOS campaign, for the Cal/Val of Aeolus, through the deployment of our UAVs in Cabo Verde, equipped with aerosol and cloud instruments (optical particle counters, backscatter sonde, and impactors for dust sample collection). The UAVs reached altitudes up to ~5,000 m above sea level, and measured the height-resolved particle size-distribution and the mineralogy of airborne dust, and were co-located with ground-based remote sensing activities. These observational platforms will also be deployed for the Cal/Val of EarthCARE, expected to be launched this year, together with our ground-based lidar, sunphotometers and ceilometers. In this presentation, I will present these efforts, discuss the strategic location of Cyprus for aerosol studies, and highlight the great potential coming from the collaboration with the nearby remote sensing facilities of the ERATOSTHENES centre of excellence.

1. Introduction

The Cyprus Institute's Climate and Atmosphere Research Centre (CARE-C) develops, adapts and optimises novel unmanned aerial vehicles (UAVs) and sensors for dedicated atmospheric campaigns, in order to document and contrast long-range transported pollution and dust aerosols [1]. These facilities are a mobile exploratory platform of ACTRIS and they represent a valuable validation infrastructure for spaceborne lidar validation. In addition to the UAVs, CARE-C operates the Cyprus Atmospheric Observatory (CAO), providing long-term in-situ and remote sensing observations over the island, which is another valuable validation infrastructure, and also part of ACTRIS [2].

A large amount of development has occurred in the last few years around the launch of two spaceborne lidar missions by the European Space Agency (ESA). Aeolus, active from 2018 to 2023, was the first satellite capable of observing winds from the surface to the stratosphere, and has led to significant progress in atmospheric dynamics research and operational weather forecasting. EarthCARE, expected to be launched in May 2024, aims to significantly improve our understanding of how clouds and aerosols affect the Earth's radiative budget, with observations at unprecedented levels of accuracy.

Here, I will present efforts at the Cyprus Institute, in deploying its observational facilities to contribute to the calibration and validation of both satellites using both ground-based remote sensing and UAV-borne in-situ methodologies. Fig. 1 illustrates operations during the ASKOS campaign for Aeolus cal/val).

Figure 1. UAV operations during the ASKOS campaign.

2. Aeolus Cal/Val (ASKOS campaign)

During June 2022, the Unmanned Systems Research Laboratory (USRL) of the Cyprus Institute took part in the ESA-ASKOS experiment in Mindelo, Cabo Verde, and operated several Unmanned Aerial Vehicles (UAVs), fitted with a number of unique in-situ aerosol instruments able to profile the Saharan Air Layer between the surface and altitudes up to 5,300 m ASL [3]. The ATMO-ACCESS TransNational Access (TNA) project "Diurnal vAriation of the vertically resolved siZe distribution in the Saharan Air Layer" (DAZSAL) was also conducted at the same time. The campaign aimed to validate the Aeolus L2A product in the presence of dust and marine aerosols, estimate the influence on Aeolus products of non-spherical particles, evaluate the impact of particle orientation, and study the diurnal cycle of the dust size-distribution at high altitudes.

The instruments deployed on-board the UAVs permitted evaluation of the vertically-resolved particle size-distribution between 0.1 and 40 μm diameter (fig. 2), investigation of the particle orientation, and complementing observations of ground-based remote sensing set out by the National Observatory of Athens (NOA) and the Leibniz Institute for Tropospheric Research (TROPOS). Moreover, high-altitude dust samples were collected on impactors, for further analysis by Scanning Electron Microscopy (Fig. 3). The weather was a determining factor for both the ground-based remote sensing operations and the UAV operations and the UAV operation, and airport traffic was another constraint that needed to be accounted for.

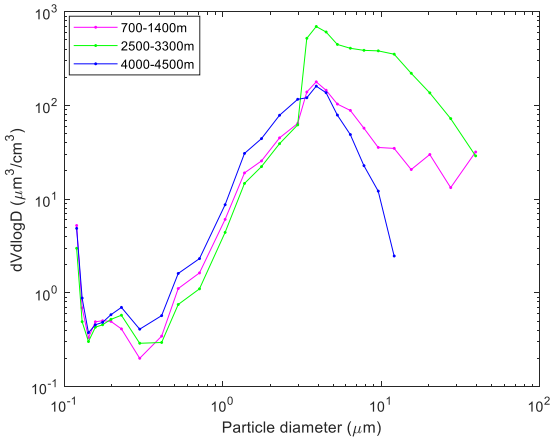

Figure 2. Volume size-distribution of dust particles in different atmospheric layers in the free troposphere, on 24 June 2022, during ASKOS.

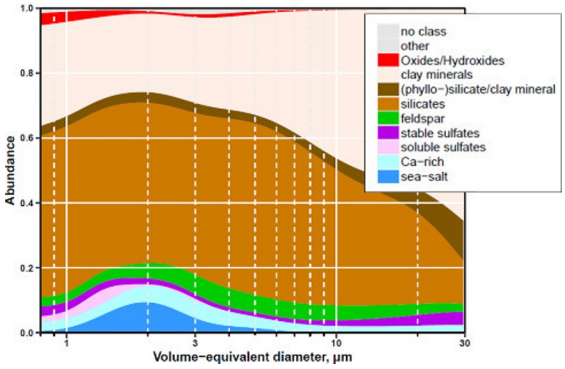

Figure 3. Mineralogical analysis for the dust sample collected on 24 June 2022 at the altitude 3,100–4,800 m ASL, during ASKOS.

3. EarthCARE Cal/Val plans

The UAV observations can be complemented through the CAO infrastructure (Fig. 4), mentioned in the introduction and which provides long-term in-situ and remote sensing observations over the island (lidar, ceilometers, sunphotometers and radiative flux station). Moreover, a great potential for the exploitation of synergies is available through the collaboration and memorandum of understanding with the nearby ERATOSTHENES centre of excellence, home of another national facility, the Cyprus Atmospheric Remote Sensing Observatory (CARO).

In this presentation, I will discuss the potential and complementarity of these three infrastructures for the Cal/Val of EarthCARE,

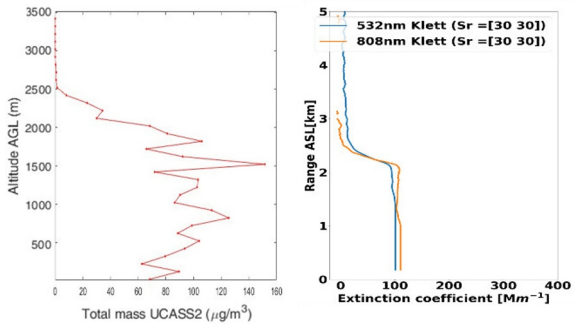

Figure 4. UAV-derived aerosol concentration profile (left) and ground-based lidar-derived aerosol extinction coefficient (right) in Cyprus, 25 October 2023.

the existing plans, the room for further development, the funding opportunities, and the challenges [4].

4. Further developments

The synergy of remote sensing and airborne in-situ observations has a strong potential and at the Cyprus Institute we plan to further exploit it for the exploration of atmospheric dust, pollution and the physics of cloud systems. Moreover, Cyprus being in a region affected by several emission sources, at the crossroad of several transport pathways, it has a strategic location for aerosol studies, and in particular mineral dust. Some initial thoughts and plans will be shared during the conference.

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