1. General information

Project acronym ACEMED

Project title Evaluation of CALIPSO's aerosol classification scheme over Eastern Mediterranean

Type Scientific project

Scientific theme The proposal aims at the evaluation of CALIPSO's algorithm for aerosol type classification using airborne and ground-based measurements over Eastern Mediterranean

Main scientific field and Specific discipline Earth Sciences & Environment / Global change & Climate observation

Participants undertaking research

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<th>Name + link to id card</th>
<th>Research status</th>
<th>Email</th>
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Identification and classification of aerosol types is important, since different aerosol types have different effects on climate, visibility and health. The space-borne lidar CALIOP on-board the CALIPSO satellite (Winker et al., 2007), provides information on layer-stratified types of aerosol that can be detected with this instrument. The CALIPSO Vertical Feature Mask (VFM) product (Vaughan et al. 2004), classifies aerosols and clouds based on their optical properties. With the scene-classification algorithm, the atmospheric features are classified as either clouds or aerosols and then the clouds and aerosols are separated into different subclasses (Omar et al., 2009). They confirm that CALIPSO algorithms are able to discriminate between clouds and aerosols and detect the cloud top and base altitudes reliably. However, no previous work has been focused explicitly on the evaluation of the quality of CALIPSO's aerosol type classification scheme.

Scientific problems being addressed by the experiments to be performed. Brief summary of the experiments

The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO), a joint U.S. (NASA) and French (CNES) satellite mission, is the first active sensor being in operation during the last four years, providing new insight into the role that clouds and aerosols play in regulating Earth's weather, climate, and air quality (Winker et al., 2007, 2009). CALIPO's observations provide, for the first time, the vertical structure of aerosol distributions globally, along with aerosol type estimations, which however have not yet been evaluated. The identification of aerosol types is important, since different aerosol types have different effects on climate, visibility and health. We propose to evaluate CALIPSO's aerosol-type classification schemes over Greece, using high quality airborne aerosol measurements along with ground-based lidar, sunphotometric and in-situ observations. Aerosol backscatter and depolarization vertical profiles, size distributions, scattering coefficients, aerosol absorption and SSA airborne measurements will be used for the characterization of elevated aerosol layers. During the campaign, intensive ground-based measurements will be performed in Athens, Thessaloniki and Finokalia stations. These measurements will be used to classify the particular characteristics of diverse and mixed aerosol types and compare them with CALIPO's aerosol-type classification scheme.

The validation study will add to the efforts taken for aerosol characterization within the framework of the "Aerosols, Clouds and Trace gases Research InfraStructure network - ACTRIS" project. The results will also be valuable for the simulation studies currently performed at the European Space Agency (ESA) in anticipation of future lidar satellite missions (e.g. ADM-AEOLUS, EarthCARE, A-SCOPE).

Aircraft BAe146 - FAAM

Why this aircraft best suits the experiments? Proposed alternative aircraft The FAAM - BAe146 aircraft is equipped with most of the relevant instrumentation needed to fulfill the scientific objectives of ACEMED. The choice of FAAM BAE-146 is based on its large payload that allows airborne lidar measurements and complimentary radiation and in situ particulate pollution monitoring. Furthermore, the Aerosol Mass Spectrometer (AMS) will provide us with useful time-resolved information on the aging of aerosol particles in the atmosphere, which is considered of particular importance for aerosol characterization. The acquisition of the aerosol vertical structure and the size, concentration, absorption and chemical composition of the aerosol particles over Greece, will enable us to characterize the aerosol type and compare it with CALIPSO's retrievals.

2. Description of the experiments

Scientific objectives / Proposed work / Anticipated output Identification and classification of aerosol types is important, since different aerosol types have different effects on climate, visibility and health. The space-borne lidar CALIOP on-board the CALIPSO satellite (Winker et al. 2007), provides information on layer-stratified types of aerosol that can be detected with this instrument. The CALIPSO Vertical Feature Mask (VFM) product (Vaughan et al. 2004), classifies aerosols and clouds based on their optical properties. With the scene-classification algorithm, the atmospheric features are classified as either clouds or aerosols, and then the clouds and aerosols are separated into different subclasses (Omar et al., 2009). The classification of features as clouds or aerosols by CALIOP has been previously validated, for example, by Kim et al. (2008) and Liu et al. (2009). They confirm that CALIPSO algorithms are able to discriminate between clouds and aerosols and detect the cloud top and base altitudes reliably. However, no previous work has been focused explicitly on the evaluation of the quality of CALIPSO’s aerosol type classification scheme. In the aforementioned studies, misclassifications of CALIPO VFM product have been reported. Among these misclassifications, the most prevalent were those associated with dust and smoke particles, over or close to the source regions (Liu et al., 2009). Moreover, the similarity of the optical properties of polluted continental and smoke aerosols, poses a challenge for CALIPSO’s classification algorithm and is one of the limitations of the subtyping scheme (Omar et al., 2009).

In the framework of ACEMED campaign, we propose to evaluate CALIPSO’s aerosol-type classification schemes (Level 2, Version 3.01 products), using high quality airborne aerosol measurements along with ground-based lidar, sunphotometric and in-situ observations. The region selected to apply our study is the Eastern Mediterranean, recognized by the IPCC as one of the “hot” spots globally concerning climate change, since there, almost all aerosol types and related processes are met (e.g. Lelieveld et al., 2002). Specifically, Greece is year round...
affected by dust storms from desert or semi-arid areas in Africa, smoke from biomass burning, maritime aerosols, biogenic emissions and anthropogenic aerosols, the later produced either locally or transported mainly from continental Europe. It is, therefore, incontestable that such a complex mixture of different aerosol types, in a particularly variable environment, provides a setting of a unique natural laboratory for studying aerosol classification schemes.

Special focus, within ACEMED will be put on the role of the absorbing aerosols in Eastern Mediterranean, which have a negative surface radiative forcing and large positive atmospheric forcing values, nearly identical to the highly absorbing south Asian haze observed over the Arabian Sea (Markowicz et al., 2002; Leilieveld et al., 2003; Sciare et al., 2003; Sciare et al., 2008). The effect of these fires on the aerosol budget over Greece is poorly assessed and based on ground-based measurements in Thessaloniki and Finokalia (Sciare et al., 2008; Amiridis et al., 2009). The contribution of these light absorbing particles is particularly important during the summer period when most of air masses over the Eastern Mediterranean originate from the Balkans, Turkey and Central/Eastern Europe (Vrekoussis et al., 2005; Bryant et al., 2005; Kabadzis et al., 2007; Sciare et al., 2008; Amiridis et al., 2009). During this period, extensive forest fires from Southern Europe are significantly contributing to large-scale aerosol emissions in the Mediterranean environment (Balis et al., 2003; Kabadzis et al., 2007; Amiridis et al., 2009, Sciare et al., 2008). The biomass burning regions contributing to the absorbing aerosol background over Greece are extended across Russia in the latitudinal belt between 45°N – 55°N, as well as in Eastern Europe (Baltic countries, Western Russia, Belarus, and the Ukraine). The highest frequency of agricultural fires occurs during summer, as depicted in Figure 1.

In addition, the impact of dust in regional aerosol loads has been extensively studied during major Saharan dust outbreaks, and its role on radiative forcing has been depicted (Balis et al., 2004; Gerasopoulos et al., 2007; Kalivitis et al., 2007; Amiridis et al., 2009). Even though the maximum influence is encountered in spring, many studies highlight the presence of elevated dust layers over Greece during summer (e.g. Papayannis et al., 2009). Summer is also the season during which local processes of anthropogenic aerosol production are favored and transport from continental Europe is encountered due to the dominance of Northerly winds called Etesians.

The challenge for the CALIPSO classification algorithm scheme, is to discriminate these diverse aerosol types, present in the Mediterranean environment, either as separated layers or external mixtures. The performance of CALIPSO will be evaluated within ACEMED in order to estimate the adequacy of these products for long-term climatological studies.

In order to achieve the aim of ACEMED, aircraft lidar measurements of the vertical structure and in-situ aerosol measurements will be performed during under-flights of CALIOP overpasses. Aerosol backscatter and depolarization vertical profiles, size distributions, scattering coefficients, aerosol absorption and SSA airborne measurements will be used for the characterization of elevated aerosol layers. Additional intensive ground-based measurements will be performed in Athens, Thessaloniki and Finokalia, including:

- Multi-wavelength lidar measurements
- Columnar sunphotometric measurements
- Surface aerosol properties monitoring (optical, chemical, physical properties)
- Aerosol characterization will be established by ground-based active and passive remote sensing techniques. These measurements will be used to invert optical data into microphysical particle properties and to develop a high-sophisticated aerosol-type classification scheme. Direct surface measurements will be used for the speciation of particle samples and aerosols will be chemically classified by the predominant species (e.g., sulfates, black carbon, organic carbon, etc.).

Overall, CALIPSO's aerosol classification schemes will be evaluated in elevated layers and surface against the detailed aircraft and ground-based retrievals.

BENEFITS - OUTPUTS

The validation study will add to the efforts taken for aerosol characterization using in-situ and remote sensing methods within the framework of the "Aerosols, Clouds and Trace gases Research Infrastructure network" (ACTRIS) project. The results will also be valuable for the simulation studies currently performed at the European Space Agency (ESA) in anticipation of future lidar satellite missions (e.g. ADM-AEOLUS, EarthCARE, A-SCOPE). Finally, the feasibility of long term aerosol studies will be assessed after the evaluation of CALIPSO's aerosol classification schemes.

The results from the proposed experiments will be published in remote sensing and atmospheric chemistry/physics related scientific journals (e.g. Atmospheric Chemistry and Physics, Journal of Geophysical Research, Atmospheric Environment, Atmospheric Measurements and Techniques etc.). It is expected that several publications on aerosol characterization and satellite validation will be the outcome of this study.

REFERENCES

Amiridis, V., S. Balis, E. Giannakaki, A. Stohl, S. Kazadzis, M. E. Koukouli, and P. Zanis, Optical characteristics of biomass burning aerosols over Southeastern Europe determined from UV-Raman lidar measurements, Atmospheric Chemistry and Physics, 9, 2431-2440, 2009
Kim, S.-W., S. Berthier, J.-C. Rault, P. Chazette, F. Dulac, and S.-C. Yoon, Validation of aerosol and cloud layer structures from the spaceborne lidar CALIOP using a ground-based lidar in Seoul, Korea, Atmos. Chem. Phys., 8, 3705–3720, 2008

Weather conditions (e.g. clouds, atmospheric stability, wind speed and direction, weather…) Since the campaign is concentrated on aerosol characterization, cloud-free conditions are required during aircraft’s CALIPSO under-flights.

Time constraints (time of the day, pass(es) of satellites, weekends, season…) Periods during mid and late summer are preferable to include smoke aerosol background and possible Saharan dust advection over Greece.

The proposed project is clustered with the AEGEAN_GAME2 EUFAR project. The preferred time window of the campaign is similar (01/09/2011 – 10/09/2011). ACEMED is an aerosol campaign focused on satellite validation and aerosol characterization, thus having completely different measurable objectives from AEGEAN_GAME2 which is concentrated on the study of physical and chemical processes of polluted air masses over the Aegean Sea for model evaluation.

Location(s) and reason for that choice

The aircraft will under-fly CALIPSO overpasses over Greece focusing also above the ground-based stations of Athens, Thessaloniki and Finokalia. CALIPSO overpasses to be followed are presented in Figure 2 along with the corresponding date and time information. 2 flights are requested, one during daytime and one during nighttime, either on 2nd or 9th of September 2011.

Number of flights / flight hours and flight patterns

The aircraft will under-fly CALIPSO overpasses over Greece. The overpasses that are closer to the ground-based stations are selected for this project, so the synergy between airborne and ground-based observations for satellite validation will be feasible. The maximum information will be used for aerosol characterization and evaluation of CALIPO’s retrievals. In Figure 2, CALIPO overpasses for September of 2011 are presented.

In total, a minimum of 10 flight hours are requested that correspond to approximately 2 aircraft missions. The aircraft is proposed to take off from Thessaloniki’s or Chania’s (near Finokalia station) airport (see Figure 2), measuring between 1-4 km. The flights should be performed during both daytime and nighttime. Two days are proposed for the flights, either the 2nd or 9th of September 2011.

Other constraints or requirements

None

3. Key measurements required to achieve science aims

Parameter / measurement required

A combination of remote sensing and in-situ aerosol measurements with FAAM aircraft will be required for aerosol characterization over Greece.

Active remote sensing measurements will include aerosol attenuated backscatter and depolarization ratio profiles from the NON-CORE Mini-Lidar Leosphere ALS450. Backscatter profiles will be used to evaluate CALIPSO’s vertical structures. Depolarization profiles will be used for dust discrimination over Greece.

In-situ measurements will include: number size distributions from the Passive Cavity Aerosol Spectrometer Probe (PMS-PCASP, 0.1–3 μm radius), scattering coefficient at 450, 550 and 700 nm from the integrating nephelometer (TSI 3563), absorption coefficient at 567 nm from the Particle Soot Absorption Photometer (PSAP-FAAM) and total sub-micron number concentration from the Condensation Particle Counter (TSI 3025A Ultra Fine CPC). Aerosol composition and mass distribution of volatile and semi-volatile components of aerosols as a function of particle size (50 – 500nm) will be additionally measured using the Aerosol Mass Spectrometer (AMS) of FAAM. The combination of the collected in-situ aerosol measurements will serve for the characterization and classification of aerosols during flights, in respect to their sources. Filter samples will be collected and analyzed to provide mass loadings of sulphates, nitrates, ammonium and organic mass. The Black carbon content (using the PSAP instrument) is important to assess aerosol absorption characteristics especially in case of smoke plumes.

Basic meteorological instrumentation of FAAM - BAe146 (temperature, wind, humidity and turbulence sensors) is additionally needed together with solar and terrestrial radiative flux measurements to provide the atmospheric state. Finally, concentration measurements of background pollutants such as O₃ and CO are needed as tracers for air mass characterization in relation to the source (transport, mixing). Measurements of NOₓ will contribute to the identification of the photochemical efficiency and the origin of the air masses (fresh emissions, aged, transported). The sampling and analysis of NMHC (WAS) is important for tracing the origin of organic species (anthropogenic, natural) but also for estimating the reactivity of the organic mixture at different locations.

If applicable, specify TA instrument required

None

Instruments to be provided by hosting aircraft operator (basic instrumentation owned by the aircraft operator described on EUFAR website only) Assuming that the basic instrumentation of FAAM (as this is presented in EUFAR site) will be available, the following instruments are additionally required:

- FAAM NON-CORE Mini-Lidar Leosphere ALS450
- AMS (Aerosol Mass Spectrometer)
Instruments to be provided by scientific group (Have already been flown. On which aircraft? Do the instruments have their own data acquisition system?) None

Instrument operators onboard (in addition to those provided by the aircraft operator). If so, how many? 3

If applicable, plans for simultaneous field work plans / ground equipment to be used The institutes and universities participating in ACEMED will provide the following recourses and observations from the satellite and ground-based sector:

NATIONAL OBSERVATORY OF ATHENS (NOA):
NOA will be responsible for satellite data processing of CALIPSO products (Level 2, Version 3.01) during the campaign and the evaluation study in relation with the aircraft and ground-based retrievals. Considering the ground-based observations, NOA will provide sunphotometric measurements (CIMEL, UV-MFR) and the corresponding aerosol microphysical retrievals from the AERONET's Atmospheric Remote Sensing Station (ARSS) of Athens. Additional retrievals of aerosol absorption will be provided in the UV by the application of methodologies based on radiative transfer calculations in synergy with surface irradiance measurements. In-situ surface aerosol measurements will be provided over Athens. Specifically, 1-min aerosol scattering coefficients at 530 nm measured with a single-wavelength portable integrating nephelometer (M903, Radiance Research, Seattle, USA), will be averaged in 5-min time intervals. Aerosol absorption coefficients will be additionally provided using a PSAP photometer at 470, 522 and 660 nm. Filters will be also collected for full chemical composition characterization.

NATIONAL TECHNICAL UNIVERSITY OF ATHENS (NTUA):
NTUA will provide aerosol vertical distributions over Athens by elastic and Raman lidar techniques. Additionally, NTUA will provide vertical profiles of microphysical aerosol properties by the application of advanced inversion techniques on multi-wavelength lidar optical data.

ARISTOTLE UNIVERSITY OF THESSALONIKI (AUTH):
AUTH will provide aerosol vertical distributions over Thessaloniki by elastic and Raman lidar techniques. Additionally, AUTH will provide vertical profiles of microphysical aerosol properties by the application of advanced inversion techniques on multi-wavelength lidar optical data. Finally, the sunphotometric measurements and inversion microphysical retrievals from Thessaloniki’s AERONET station will be provided.

UNIVERSITY OF CRETE (UoC):
UoC will provide in-situ surface physicochemical aerosol characterization, trace gases measurements and sunphotometric aerosol measurements (CIMEL):
Ground level measurements of gaseous pollutants (O3, NOx, and CO), various aerosol particle parameters (PM10 mass, mass and number size distributions, optical properties, chemical composition measurements), as well as meteorological parameters (temperature, relative humidity, wind speed and direction) will be performed at the monitoring station of University of Crete located at Finokalia, Crete (http://finokalia.chemistry.uoc.gr/). Concentrations of O3, CO and NOx will be monitored with commercial gas analyzers (Thermoelectron). Size distribution measurements of aerosol particles will be measured with a Scanning Mobility Particles Sizer and a 11-stages cascade impactor, whereas the scattering and absorption coefficients of the aerosol particles will be determined by commercial Nephelometer (Radiance research) and aethalometer (PSAP). Additionally, high resolution aerosol chemical composition measurements using PILS (for the main ions and cations) and EC/OC using a sunset instrument will be performed during the flight dates.

4. Data processing and analysis

Methodology for handling the data and analysis of output (airborne data acquisition, ground-truthing / observations, data processing and interpretation) Aircraft operators will perform the airborne measurements. For the non-core instruments, the instruments’ operators will be responsible. The PIs of the ground-based stations involved will ensure instrument operation and aerosol retrievals. NOA will be responsible for satellite (CALIPSO) data processing. Additionally, NOA will ensure the collection and archiving of the data from aircraft, satellite and ground-based segments.

Ground-based lidars and sunphotometers that will be used in the campaign are routinely calibrated within the framework of EARLINET and AERONET networks. In-situ instrumentation is also routinely calibrated by the operators also in framework of EUSAAR. The calibration of nephelometers is based on the instrument filling with a gas of different scattering coefficient than the ambient air, as well as the adjustment of zero and span constants for the appropriate scattering values. Ambient air is filtered through a 0.45µm filter and the produced particle free air is used as a zero reference scatterer, purging the entire nephelometer column. Afterwards the column is filled with the upscale gas scatterer (CO2), for the span adjustment. Special care is given to the ‘wall scattering’ value, as is an indicator for the maintenance procedures (cleaning or realignment of optics) performance. The PSAPs are calibrated by inter-laboratory field measurements and comparison of the absorption coefficient with the corresponding coefficient of the same or similar techniques instruments.

Resources available to support the project beyond the flying/data acquisition period (funding, cooperation with other projects, manpower for analysis of results and preparation of user report, availability of laboratory facilities …) The PI will be actively participating in the field campaign contributing in flight planning, and post-flight analysis. He, along with the PIs of the ground-based stations in Greece will ensure the operation of the instruments during the campaign and the corresponding data analysis. 3 professors, 4 senior researchers, 3 Post-Doc, 1 PhD and 2 MSc students will form the post-possessing data analysis team. They will be responsible for aircraft, satellite and ground-based data analysis. The participating personnel is composed by experienced tenured research staff and project-funded students. The ACEMED campaign is scientifically related with the ACTRIS (Aerosols, Clouds and Trace gases Research InfraStructure network) EU project, starting at 1st of April 2011. It is anticipated that the campaign results will contribute to ACTRIS efforts “to develop new integration tools to fully exploit the use of multiple atmospheric techniques in particular for the calibration/validation/integration of satellite sensors and for the improvement of the parameterizations used in global and regional-scale climate and air quality models”. The campaign will be followed by experienced researchers acting as consultants. These are Dr. Gelsomina Pappalardo (coordinator of ACTRIS) and Dr. Detlef Mueller. Dr. Mueller has kindly provided algorithms for aerosol microphysical retrievals from remote sensing data.

5. Planning

Starting date: 24-08-2011
Ending date: 09-09-2011

Preferred and acceptable dates (season / time windows) 01/09/2011 – 10/09/2011
6. Other useful comments

Training benefit of the project (e.g. spread potential of airborne research to a wide scientific community; training of research students in experimental planning, methodology, data analysis and applications, etc) Most of the participants have experience on airborne campaigns gained within the framework of several projects (e.g. MINOS, 2001 - http://luna.tau.ac.il/~peter/MEIDEX/Reports/Minos/minos.htm; SCOUT-O3, 2006 - http://www.ozone-sec.ch.cam.ac.uk/scout_o3/field_campaigns/uv_campaign/index.html; THERMOPOLIS, 2009 - http://www.esa.int/esaCP/SEMVNMH7KYF_index_0.html). The proposed work provides excellent training opportunities to new students and postdoctoral researchers involved. They will gain experience in the planning and execution of a major aircraft experiment and the understanding of aircraft observation techniques. Through this experiment, all the members involved will gain expertise on aerosol monitoring with in-situ and remote sensing methods. In addition, three group members from NOA, NTUA and AUTH wish to participate in the flights preparation and if possible in the flights.

If possible, 3 scientific reviewers that EUFAR may contact Lucas Alabos Arboledas
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Sources of funding of the project and of related projects (If clustering with existing projects supported either by national or other EC funding, how the project add additional or complementary aims to the already funded experiments) Most of the team members are funded by the participating Institutes/Universities, thus they will support this project merely for scientific reasons.

Scientific training provided by lead scientist to other EUFAR sponsored scientists within the fields of the proposed experiments and analysis Yes

Number of students 3

Number of days recommended 2

Knowledge about EUFAR opportunities from From your colleagues

Related documents
You may need to login to the EUFAR Back Office to see all the documents.

- Project ACEMED: Figure 1
- Project ACEMED: Map of general area - CALIPSO overpasses

7. Reporting

Campaign dates: From 29-08-2011 to 09-09-2011

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<th>Name</th>
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Confirmation of the user access (list of flights, number of flight hours) / Evaluation of the service provided by the operator: mark (1-Unsatisfactory, 2-Insufficient, 3-Satisfactory, 4-Good, 5-Excellent) and comments
B638 ACEMED Flight 1, duration: 4hrs. Evaluation = 5 (Excellent) B644 ACEMED Flight 2 duration:3hrs 15mins. Evaluation = 5 (Excellent)
Excellent management and excellent coordination from FAAM's operators. The flights were organized in detail during the pre-campaign meetings. Both flights followed exactly the schedule. Scientific aims are anticipated to be fulfilled. This is evident also by a first inspection of the data by ACEMED’s team. The instruments were operated continuously and only few failures have been recorded which however did not affect the scientific value of the campaign data. Data and exact flight patterns were available each next flight day. We have been impressed by the organization of the instrument operators. It was evident that the crew was fully aware of the scientific goals of the project and tried to do their best to schedule the flights and corresponding instrumentation according to campaign's needs.

Quality of data and associated service
High quality data in general. Some problems during first ACEMED flight regarding the operation of the Nephelometer (in flight data suspect, potential instrument fault) and NOx (not operating). Excellent cooperation during the campaign (and after the end of it) with the Instrument Scientists and Data Specialists.

Main achievements / Further plans for analysis
At this stage, the flight-data have to be interpreted by ACEMED’s researchers. Overall, the data seem very promising. A first validation study of CALIPSO has been established for the 9th of September. The results will be presented in the COMECAP conference and ACTRIS EARLINET General Assembly. This report will be updated and the related presentations/publications will be uploaded.

Difficulties encountered
Difficulties encountered on flight planning due to track restrictions from the Civil Aviation Authority. ACEMED's flights were adjusted accordingly, and CALIPSO's satellite under-flights were successfully performed.

Publications linked to the project

Website of the project