The CALIGOLA Mission: An overview of the present status and the forthcoming steps

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Abstract: The Cloud and Aerosol Lidar for Global Scale Observations of the Ocean-Land-Atmosphere System (CALIGOLA) is an advanced multi-purpose space lidar mission with a focus on observations of the atmosphere and oceans and aimed at characterizing the Ocean-Earth-Atmosphere system and mutual interactions within it. This mission has been conceived by the Italian Space Agency (ASI) with the aim to provide the international atmospheric and ocean science communities with an unprecedented dataset of geophysical parameters, with the ultimate purpose of generating increasing scientific knowledge in the areas of atmospheric, aquatic, terrestrial, cryospheric and hydrological sciences. ASI is partnering with NASA on this exciting new space lidar mission. The mission is planned to be launched in the time frame 2030-2031, with an expected lifetime of 3-5 years, thus allowing data collection over a time period presently not covered by other space lidar missions. CALIGOLA is baselined to fly in an orbit compatible with other NASA missions seeking to advance an understanding of aerosols, clouds and convection for possible formation flight during a portion of CALIGOLA's duration.

1. Introduction

The Italian space industry, and specifically Leonardo S.p.A., has gained unique skills at the international level in the development of space-qualified power laser sources for lidar Earth observation applications (Aeolus, EarthCARE). Moreover, the Italian space industry has a consolidated experience in the development of sensors and optical devices to be exploited in the design and development of space lidar telescopes and receivers and lidar thermo-mechanical structures. The Italian Space Agency (ASI) intends to benefit from this base of expertise to design and develop CALIGOLA. Exploiting the three Nd:YAG laser emissions at 354.7, 532 and 1064 nm and the elastic (Rayleigh-Mie), depolarized and Raman lidar echoes from the atmosphere, the oceans and the Earth surface, CALIGOLA will carry out unprecedented observations of the Earth system and the mutual interactions among its components (atmosphere, oceans and the terrestrial surface) [1].

2. The space mission in a glance

CALIGOLA will perform profile measurements of a number of targeted atmospheric variables. Among others, the particle backscatter coefficient and depolarization ratio at 354.7, 532 and 1064 nm and the particle extinction coefficient at 354.7 nm from aerosols and clouds. These measurements allow for aerosol typing and determination of aerosol size and microphysical properties. Furthermore, measurements of the elastic and depolarized backscattered echoes from the sea surface and the underlying layers will be exploited to characterize the optical properties of suspended particulate matter in terms of oceanic particulate backscattering coefficient, while diffuse attenuation for downwelling irradiance at 1-2 wavelengths will be determined from the H_2O roto-vibrational Raman signals. These measurements will allow for the characterization of depth-resolved phytoplankton seasonal and inter-annual dynamics, with the aim to improve our present understanding of the role of phytoplankton in marine biogeochemistry, in the global carbon cycle and of the response of marine ecosystems to climate variability [2-4]. Fluorescent scattering measurements at 450 and/or 685 nm will be exploited to increase skill in aerosol typing, to characterize dissolved organic matter stocks in the ocean (450 nm), and to assess ocean primary production and the health and stress status of marine and land plants (685 nm). CALIGOLA will also allow for accurate measurements of the small-scale variability of the earth's surface elevation, primarily associated with variations in ice and snow, terrain, and vegetation canopy height, as well as snow depth and snow water equivalent measurements.

The exploitation of sub-systems already developed at the national level for space applications, with a high technology rediness level, in combination with the expertise developed at NASA on advanced detection and sampling systems based on the strong heritage from the CALIOP mission [5], should permit the design and develop this ambitious space lidar mission in a relatively short time (hopefully 6-7 years), ultimately leading to a mission with high scientific impact and timeliness.

The space mission CALIGOLA is explicitly included in the recent ASI Three-Year Activity Plan (2021-2023), with a phase A study focusing on the technological feasibility of the major sub-systems carried out by Leonardo S.p.A. over the last 18 months. Scientific studies in support of the mission were started by the University of Basilicata in 2021 and are presently carried out by a scientific group including approx. 20 scientists, primarily from Italy and US, with representatives from the atmospheric and ocean science communities. In December 2023, the ASI Board of Directors officially approved the funding of CALIGOLA phase B1 activities. In September 2023, NASA-LARC initiated a pre-formulation study to assess the feasibility of a possible contribution to the CALIGOLA mission based on the development of the receiver detection chain and data down link capabilities. At the end of the pre-formulation study (September 2024), NASA will decide whether to proceed with cooperation on the mission.

This conference contribution aims at providing an overview of the different mission scientific objectives, with a primary focus on atmospheric and ocean sciences, and a preliminary assessment of the mission observational requirements in terms of observable quantities, their vertical/horizontal resolution and their degree of precision (RMS)/accuracy (bias) needed to address the identified mission scientific goals. The contribution also aims to illustrate the technical and technological solutions identified in the design of the space lidar system during the pre-feasibility and feasibility studies.

Expected system performance in a variety of environmental conditions can be assessed based on the application of a space lidar simulator [6-8], which is currently underway.

3. References

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