

## Cloud studies for the FORUM mission

### Research Project

The research project is developed in the frame of the Far-infrared-Outgoing-Radiation Understanding and Monitoring (FORUM) mission. FORUM was selected by ESA as the 9<sup>th</sup> Earth Explorer satellite mission and is currently in the Phase-B studies (2020-22). FORUM, whose launch is scheduled in 2026, will measure the Earth's top-of-atmosphere emission spectrum from 100 to 1600  $\text{cm}^{-1}$  (nominal resolution of 0.3  $\text{cm}^{-1}$ ), thus filling the observational gap across the so-called far-infrared (100-667  $\text{cm}^{-1}$ ) where the exiting radiance is highly sensible to upper tropospheric water vapor and cirrus clouds.

The Physics and Astronomy Dep. of the University of Bologna was part of the FORUM proposer committee and deeply involved in the FORUM Phase-A and Phase-B1 activities. The current scientific goals involve ice clouds studies. The focus of the studies is on the characterization of clouds radiative properties, the implementation and application of cloud and aerosols identification/classification algorithms and cloud properties retrieval techniques exploiting the far infrared information content.

It is co-responsibility of the Physics and Astronomy Dep. of the University of Bologna (in collaboration with DEIMOS Space and CNR) to contribute in the scene definition and generation and in the development of the retrieval products of an End-to-end simulator for the FORUM mission (project E2EFORUM). The End-to-end is a tool which simulates the end-to-end performance of a mission, i.e. from the observed (earth/atmosphere) scene or phenomena to the retrieved parameters. E2E simulators are used during the satellite mission preparation to support activities such as performance consolidation on mission level, quantification of trade-offs impact on the mission product, early preparation of user community for mission exploitation.

Within the FORUM preparatory activities, the Physics and Astronomy Dep. of the University of Bologna will also participate to the analysis of field campaigns interferometric data in the mid and far infrared part of the spectrum that are programmed by the ESA before the satellite launch. The first field campaign is scheduled to occur in spring 2021. In particular, the goals pursued by the data analysis are: the characterization of the radiance signal in presence of cirrus clouds, the application of machine learning algorithm to upwelling/downwelling high spectral resolution data in the infrared for the cloud identification and classification and the assessment of the geophysical retrieved cloud properties.

### Activity Plan

The activities are related with the developments of the End-2-End-FORUM Simulator and the analysis of field campaigns data collected by FORUM prototype sensors. The candidate will work in a UNIX environment and will be able to implement software codes in Python, MATLAB, C and Fortran programming languages.

The main tasks are related to:

#### E2EFORUM project

Algorithm specification and justification. The physical and mathematical backgrounds are collected in the ATBD module. The activity will require the production of documentation containing:

- Description of the physical problem and of the available algorithms or methods and applicability.
- Detailed description of the physics and of the numerical implementation when innovative methods or algorithms are accounted for. Short description and detailed references of the physics and of the numerical implementation of methodologies derived from literature.
- Estimation of the effect of possible parameterizations and/or physical and mathematical simplification

Input scenes definition and generation and Scene Generator for FORUM end-to-end simulator

- Selection of key geophysical parameters of the atmosphere and surface definition of input scenes.
- Definition of a reference database for climate model atmospheric profiles, emissivity and clouds parameters.

- Implementation of software tools for the Scenes configuration. In case of non-homogeneous scenes, multiple runs of the RT code is required to produce the observed radiance and the functionality will be implemented.

- Definition of cloud properties (by use of external routines) from single scattering single particle ice crystal databases or from water and ice index of refraction in case of water or mixed phases (Mie solution).

#### Level 1 and 2 products generation

- set up and implementation of multiple algorithms for: land mask, cloud mask and cloud/aerosols classifications, evaluation of level of heterogeneity of the scene, generation of cloud properties first guess for inversion methods, application of retrievals and assessment of the derived products

#### Field campaigns data analysis

Data quality checks, studies for the characterization of the radiance signal in presence of ice clouds, application of machine learning algorithm to identify clear and cloudy spectra and classify cloud and aerosol layers, will be implemented in order to ingest FORUM prototype sensors data in multiple observational conditions and geometry.