High Spatio-Temporal Resolution Land Surface Temperature Mission – a Copernicus candidate mission in support of agricultural monitoring

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ABSTRACT

Evolution in the Copernicus Space Component (CSC) is foreseen in the mid-2020s to meet priority Copernicus user needs not addressed by the existing infrastructure, and/or to reinforce services by monitoring capability in the thematic domains of CO_2, polar, and agriculture/forestry. This evolution will be synergetic with the enhanced continuity of services for the next generation of CSC.

The "High Spatio-Temporal Resolution Land Surface Temperature Monitoring (LSTM) Mission", identified as one of the CSC Expansion High Priority Candidate Missions (HPCM), currently undergoes an ESA preparatory phase (phase A/B1) study to establish mission feasibility.

The LSTM mission shall provide enhanced measurements of land surface temperature with a focus responding to user requirements related to agricultural monitoring.

***Index Terms*—** Agricultural monitoring, land surface temperature, evapotranspiration, Copernicus.

1. INTRODUCTION

Earth surface thermal variations occur at various time and space scales in relation to both natural and human-induced processes. These variations are connected to the surface energy and water balance and their interaction with the surface-atmosphere boundary layer. Thermal observations are therefore critical to address a range of applications and scientific objectives, and closely complement observations of other environmental variables. Those applications include products for agriculture and associated water resources management, precision farming and crop yield forecasting. Earth observation (EO) monitoring products based on thermal observations are therefore considered important for policy making including amongst others the UN Sustainable Development Goals (e.g. SDG 6.4), the UN Convention for Combating Desertification and Land Degradation, the UN Water Strategy, the EU Common Agriculture Policy, the EU Policy Framework on Food Security, the EU Water Framework Directive and the EU 2030 agenda for Sustainable Development.

Specifically, monitoring of high resolution thermal signatures allows e.g. assessment of crop water status and overall water stress, support to irrigation management and optimisation of scarce water resources for crop production, and further allows to derive essential soil parameters that cannot be retrieved in the VNIR/SWIR spectral range. This would support the implementation of resilient agricultural practices, maintaining ecosystems and progressively improving land, soil and water quality, and thus leading to sustainable agriculture. In this context, high-resolution thermal images, as a basis for evapotranspiration retrieval, will directly reveal water conservation practices or the need thereof. Unauthorised water abstractions can be detected by comparing evapotranspiration maps with volumetric water rights.

Surface temperature derived from thermal infrared (TIR) observations is already being obtained from spaceborne TIR sensors e.g. MODIS, Sentinel-3 and Landsat however, at spatio-temporal resolutions insufficient for many applications and services including agriculture at European field scales making the case for future TIR satellite missions addressing global water and food security issues (Fisher et al., 2017).

2. MISSION OBJECTIVES

High spatio-temporal Resolution Thermal Infrared observations are considered fundamental to sustainable management natural resources in the context of water and food security of a global society. Operational land surface temperature (LST) measurements and derived evapotranspiration (ET) are key variables in understanding and responding to climate variability, managing water resources for agricultural production, predicting droughts but also addressing land degradation, natural hazards, coastal and inland water management as well as urban heat island issues.

The existing Copernicus space infrastructure, in particular Sentinel-1 and Sentinel-2, already provides useful information for agricultural applications. Although Sentinel-3 already provides global LST measurements, the limited 1km spatial resolution does not capture the field-scale variability required for irrigation, crop growth modelling and reporting on crop water productivity. In view of the foreseen evolution in Copernicus, additional high-level observation requirements have been assessed and discussed at the EC Copernicus Agriculture and Forestry User Requirement Workshop in 2016, revealing the lack of European spaceborne capability for providing high spatio-temporal resolution Thermal Infrared (TIR) observations[1]. Therefore, a dedicated LSTM mission is foreseen in the frame of the Copernicus evolution with the overall objective:

To complement Sentinel observation capabilities with high spatio-temporal resolution Thermal Infrared observations over land and coastal regions in support of agriculture management services, and possibly a range of additional services.

The LSTM mission would deploy one or more satellites equipped with TIR instruments optimised to support agriculture management services with the specific mission objectives below. Based on the European and international policies the mission objectives are specified as:

- Primary objective: to support monitoring evapotranspiration (ET) rate at European field scale by capturing the variability of Land Surface Temperature (LST) (and hence ET) enabling more robust estimates of field-scale water productivity.
- Secondary objective: to support mapping and monitoring the soil composition (mineralogy and organic matter) and its dynamics through emissivity estimates.
- Complementary objective: to support a range of additional services benefitting from TIR observations (e.g. coastal zone management, High-Temperature Events (HTE), urban heat islands).

The primary objective requires observations of LST and emissivity (essential for derivation of LST) while the secondary objective can be satisfied with just the estimates of emissivity (Bastiaanssen and Harshadeep, 2005; Bastiaanssen et al., 2008; Sobrino et al. 2016). The additional services that could be included in the complementary objective in most cases also require observations of both LST and emissivity.

3. HIGH-LEVEL MISSION REQUIREMENTS

In response to the priority user needs, the initial Mission Requirements Document (MRD) for the space component has been developed by an international Mission Expert Group (MEG) under European Space Agency (ESA) leadership. The MRD serves as a starting point for the preparatory phase study, by conveying the EU policy framework, the user needs, the objectives and the observation requirements for each candidate mission. The objective of the LSTM MEG was to advise ESA on the definition of requirements for a future operational space component to meet user needs in the context of a Copernicus mission contributing to Agriculture Monitoring and potentially additional domains.

At the beginning of 2018 an ESA Mission Advisory Group (MAG) was selected and established as part of an open call. The MAG will follow and provide advice to ESA throughout the Phase A/B1 preparatory phase activities, and in particular for the consolidation of mission requirements.

4. FEASIBILITY STUDY PHASE

Upon identification of the LSTM mission as a high priority candidate, and with the MRD prepared by the MEG, a number of ESA Phase A/B1 preparatory activities have been planned. Based on a competitive ESA industrial tender, two parallel competitive system level studies have now been kicked off with European industrial consortia, each of which will be conducted over the course of 2018 and early 2019.

[1] Agriculture & Forestry Applications User Requirements Workshop Report (2016): http://workshop.copernicus.eu/sites/default/files/content/attachments/form-WfbHTJJLH6suSlxf09G4p6pXsUAIEArRc76DBmZ3lDA/agri_forestry_ws_final_report.pdf

The objective of the system level activities and accompanying support studies and campaigns is to establish the feasibility of each of the two respective mission concepts, with the goal to arrive at a consolidated mission design by mid-2019. At the end of 2019 a decision on the content of the Copernicus Expansion and selected missions is anticipated amongst ESA member states at a Council meeting at Ministerial level.

5. CONCLUSIONS

Based on user requirements collected by the European Commission the "High Spatio-Temporal Resolution Land Surface Temperature Monitoring (LSTM) Mission" has been identified as one of the CSC Expansion High Priority Candidate Missions (HPCM). Over the course of the next year, the prospective LSTM Sentinel mission will be studied in further detail, starting in spring 2018. The mission requirements consolidation is expected to be an on-going process, supported by the MAG, industrial and scientific studies and campaign activities in 2018-19. A consolidated Copernicus Expansion plan and decision on which HPCM candidates proceed to full implementation is expected at the end of 2019. The CSC is co-funded by the EU and ESA with complementary roles. Proper funding through programme subscriptions by ESA Member States and by the EU within its next Multiannual Financial Framework is a requisite for a successful implementation of the CSC evolution scenario including CSC expansion missions

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