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REVIEW

The Space Weather and Ultraviolet Solar Variability (SWUSV) Microsatellite Mission

Luc Damé *, and The SWUSV Team (Mustapha Meftah, Alain Hauchecorne, Philippe Keckhut, Alain Sarkissian, Marion Marchand, Abdenour Irbah, Éric Quémerais, Slimane Bekki, Thomas Foujols, Matthieu Kretzschmar, Gaël Cessateur, Alexander Shapiro, Werner Schmutz, Sergey Kuzin, Vladimir Slemzin, Alexander Urnov, Sergey Bogachev, José Merayo, Peter Brauer, Kanaris Tsinganos, Antonis Paschalis, Ayman Mahrous, Safinaz Khaled, Ahmed Ghitas, Besheir Marzouk, Amal Zaki, Ahmed A. Hady, Rangaiah Kariyappa)

Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS), Institut Pierre-Simon Laplace (IPSL), CNRS, Université Versailles Saint-Quentin (UVSQ), 11 Boulevard d'Alembert, 78280 Guyancourt, France

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Abstract We present the ambitions of the SWUSV (*Space Weather and Ultraviolet Solar Variability*) Microsatellite Mission that encompasses three major scientific objectives: (1) Space Weather including the prediction and detection of major eruptions and coronal mass ejections (Lyman-Alpha and Herzberg continuum imaging); (2) solar forcing on the climate through radiation and their interactions with the local stratosphere (UV spectral irradiance from 180 to 400 nm by bands of 20 nm, plus Lyman-Alpha and the CN bandhead); (3) simultaneous radiative budget of the Earth, UV to IR, with an accuracy better than 1% in differential. The paper briefly outlines the mission and describes the five proposed instruments of the model payload: SUAVE (*Solar Ultraviolet Advanced Variability Experiment*), an optimized telescope for FUV (Lyman-Alpha) and MUV (200–220 nm Herzberg continuum) imaging (sources of variability); UPR (*Ultraviolet Passband Radiometers*), with 64 UV filter radiometers; a vector magnetometer; thermal plasma measurements and Langmuir probes; and a total and spectral solar irradiance and Earth radiative budget ensemble

* Corresponding author. Tel.: +33 1 80285119; fax: +33 1 80285200.
E-mail address: luc.dame@latmos.ipsl.fr.

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(SERB, *Solar irradiance & Earth Radiative Budget*). SWUSV is proposed as a small mission to CNES and to ESA for a possible flight as early as 2017–2018.

Introduction

The proposed microsatellite mission SWUSV (*Space Weather and Ultraviolet Solar Variability*) is two-fold since addressing solar-terrestrial relations and in particular Space Weather with the very early detection of major flares and CMEs through Lyman-Alpha imaging, and the solar UV variability influence on the climate, through a complete coverage of the UV from 180 to 400 nm, Lyman-Alpha and the CN bandhead, but also the modeling of stratospheric circulation and atmospheric chemistry of the middle atmosphere. It also includes a simultaneous local radiative budget, so that simultaneous measurements allow to properly capture the correct amplitudes of local variations and sudden stratospheric warnings (SSWs).

Modern technological infrastructures on the ground and in Space are vulnerable to the effects of natural hazards. Of increasing concern are extreme Space Weather events, such as geomagnetic storms and coronal mass ejections (CMEs), that can have serious impacts on ground- or Space-based infrastructures such as electrical power grids, telecommunications, navigation, transport or even banking. In terms of power-grid assets, damage to high voltage transformers is a likely outcome leading, through cascading effects, to power outages that could ripple to impact other services reliant on electrical power like disruption of communication, transport, distribution of potable water, lack of refrigeration, loss of food and medication, etc. [1]. A superstorm like the one that happened in 1859 (and known as the ''Carrington event'')—largest with measurements—would seriously impact activities on Earth. However, forecasting a solar storm is a challenge and present techniques are unlikely to deliver actionable advice. To mitigate the risk, early precursor indicators of major solar events with geoeffectiveness are required.

SWUSV aims at observing space environment, and more specifically the onset of Interplanetary Coronal Mass Ejections, ICMEs, that is, the most important since with a potential impact on Earth. They manifest themselves in extreme ultraviolet and in X-rays, but their early detection (often linked to a filament or prominence disappearance, or to a newly emerging bipolar region) is best carried in the far ultraviolet (FUV), that is, in Lyman-Alpha (121 nm). With these resolved solar disk observations and the appropriate modeling (noticeably differences between Lyman-Alpha and H-Alpha), we expect to be able to better forecast and predict large flares and CMEs and their incoming potential (geoeffectiveness) destructive force.

Solar ultraviolet irradiance below 350 nm is the primary source of energy for the Earth's atmosphere. The basic thermal structure of the atmosphere results from the absorption of solar radiation via photodissociation and photoionization of neutral species. An understanding of solar UV radiation input is also essential for studying atmospheric chemistry. For example, solar far UV (FUV) radiation (100–200 nm) photodissociates molecular oxygen in the stratosphere and mesosphere, leading to the creation of ozone. On the other hand, the solar middle UV (MUV) radiation (200–310 nm) is the primary loss mechanism for ozone through photodissociation in the stratosphere. The balance of these two processes, along with a series of complex ozone chemical reactions, creates the ozone layer with its peak density in the stratosphere.

The FUV is the only wavelength band with energy absorbed in the high atmosphere (stratosphere), in the ozone (Herzberg continuum, 200–220 nm) and oxygen bands, and its high variability is most probably at the origin of a climate influence (UV affects stratospheric dynamics and temperatures, altering interplanetary waves and weather patterns both poleward and downward to the lower stratosphere and tropopause regions). Recent measurements at the time of the recent solar minimum [2] suggest that variations in the UV may be larger than previously assumed what implies a very different response in both stratospheric ozone and temperature.

With SWUSV, we expect to have observations in the FUV to UV range to understand how solar UV radiation directly influences stratospheric temperatures, and how the dynamical response to this heating extends and de-multiply the solar influence. A simultaneous Earth radiative budget allows to feed properly, without phase delay, the atmospheric models. With the lost of SORCE expected in the next years, the UV observations proposed are essential. SWUSV gives us the unique opportunity to develop measurements and analysis tools to apprehend the influence of UV variability on climate.

Space Weather awareness and solar UV forcing on climate are strong themes, relevant to the Solar-Terrestrial extended community, and measurements/observations to support them are lacking. SWUSV is intending to get them quickly.

The SWUSV Microsatellite Mission investigation was first proposed as a French–Egyptian mission for a study in 2010 in response to the Joint Research Call of the SDTF/IRD [3], and the proposal was renewed in 2011 [4]. It was then deeply enhanced and proposed in 2012 in response to the ESA Call for a Small Mission opportunity for a launch in 2017 [5]. It is also proposed to CNES [6] and considered for its future—prospective—programs [7]. SWUSV builds on the success of two previous space missions, PICARD and PROBA-2, and proposes to use the same platform as the microsatellite PICARD, MYRIADE, on a similar orbit and with comparable pointing system. The launch is compatible with a Vega launcher in piggy-back with 2 satellites given the small size of the microsatellite ($<$ 900 mm width and $<$ 1 m height) what should help maintain reasonable the launching costs. Likewise, the instruments will be developed from repeating units of qualified flight instruments (TRL 8–9) from the PICARD and PROBA-2 missions, while significant evolutions (in particular of imaging telescope to the far ultraviolet) are supported by a CNES Research & Technology (R&T) program.

In this paper, we present in ''*Scientific objectives*'' the two major science objectives of SWUSV: Space Weather early warnings of major events and solar ultraviolet variability influence on climate. In ''*Mission profile and spacecraft*'', we present the SWUSV mission profile and in ''*SWUSV model payload*''