Open Call for Ideas for
New data products, tools and services for Swarm

Template

Send completed template(s) to Swarm_DISC_CallForIdeas@space.dtu.dk.

- Proposer(s): Ewa Slominska (OBSEE), Dorota Przepiorka-Skup (CBK PAN), Marek Strumik (CBK PAN), Jan Slominska (CBK PAN)
- Institution(s):OBSEE, CBK PAN
- Point of contact: Ewa Slominska, eslominska@icloud.com, +48604690124

In order to facilitate 'cross pollination' between ideas and research groups, the Proposer(s) declare in submitting this idea, that the Swarm DISC may publish the name(s) of the proposer(s) and the title of the idea. Please indicate below (select Yes or No) whether DISC can also publish the entire content of the submitted idea:

Publish the entire content (Yes/~~No~~)

Product/Tool/Service Idea

SULi Index - **S**warm-based **U**LF **Li**ghtning index for identification of magnetic field fluctuations triggered by TLEs.

Product/Tool/Service Description (2 pages maximum)

- ***Description of proposed product/tool/service***

The idea is focused on the development of the SULi index product. It has been shown that TLEs (Transient Luminous Events), mostly Sprites and Gigantic Jets, occasionally can be detected by the Swarm VFM magnetometers [1], as isolated spikes characterised by amplitudes from 0.2-1.5 nT, which clearly stand out from the background noise. The goal is to provide a Level-2 data product, which allows Swarm users to identify origin of small scale fluctuations of the Earth's magnetic field possibly triggered by intense lightning activity. In particular SULi index is aimed at identification of signatures of a special class of strong lightning discharges, so called TLEs, occurring in the mesosphere between the top of thunderclouds and the lower ionosphere.

- ***Description of current state of the art and level of maturity of proposed algorithm***

The SULi index relies on the approach of event flagging in the Swarm 50 Hz magnetometer time series, which are generated on a daily basis. Algorithms and software for production of the SULi index is fully written in Python and can be employed for production of SULi index as a daily product, allowing for discrimination between lightning and non-lightning sources of magnetic field perturbations along the Swarm orbit.

Three types of cases are identified and following flags are defined:

Flag = 10 - defines perturbations triggered by lightning event with no additional changes in electron density (fluctuations in electron density below 5% with respect to the background level)

Flag = 0 - spikes in magnetic residuals are accompanied by prominent changes in electron density, event related to occurrence of plasma bubbles, not linked with lightning

Flag = 5 - shape and duration of fluctuations similar to those typical for lightning events, but auxiliary data sources do not confirm occurrence of thunderstorm activity in the proximity of the satellite orbit.

Following main steps are recognised in the processing chain:

- computation of the scalar field from the VFM 50Hz data, and removal of the Earth's main field, performed over 10 seconds time-spans;
- detrending electron density along the orbit;
- synchronisation of magnetic field residuals, electron density fluctuations with auxiliary data from the World Wide Lightning Location Network (WWLLN) allowing for recognition of regions with intensified lighting activity in the close proximity of the satellite track (within the geographic distance $d \lesssim 5°$to the satellite positions projected on the Earth surface).
- screening the magnetic strength residuals for predefined signatures describing events of explosive nature (the derivative of a Gaussian function, time scales between 0.1 and 0.5 s).
- characterisation of the event based on the fit-quality parameters and spectral properties;
- classification of the event with respect to criteria defined for three flags.
- organising a time series of defined flags separately for ascending and descending passes.

- ***Data input needs and output and frequency of delivery, strategy for delivery***

Production of the SULi index utilises Swarm L1 operational products: VFM 50 Hz data, EFI_LP 1 Hz data, auxiliary low-resolution data from the World Wide Lightning Location Network (WWLLN) provided with 1-hour cadence.
SULi index is envisaged as a daily product in the CDF format, produced on a daily basis. Available database of auxiliary data allows for delivery of dataset covering time-period from January 2018 till present. The CDF format of the SULi index allows for quick integration with existing Swarm Environments for data analysis, such as ViRES or Swarm-PAL.
Data can be provided directly to DISC servers or available from the CBK servers.

- ***Scientific/application benefits, complementarity with other relevant ESA and non-ESA activities including opportunities for new scientific activities based on implementation of the proposed product / service***

From the perspective of existing L2 Swarm products dedicated to lightning activity, SULi index could be used as a supplement to the existing Swarm_whistler product, expanding scientific analysis from ELF range to lower frequencies. Unlike Whistler products, it is not limited only to time periods, when the satellite operates in the Burst mode.

- ***Expected User Community***

Lightning can be considered as one of the most common examples of natural hazard phenomena, but it is also reported that it accompanies simultaneously other types of natural catastrophic events, such as seismic activity (earthquake lights (EQL)) or volcanic eruptions (volcano lightning). The SULi index product could be beneficial for the scientific community focused on detection of various types of signatures related to natural hazard phenomena. Proper understanding of small-scale magnetic field fluctuations is an essential step for an effective and accurate characteristics of anomalies related to so-called Lithosphere-Atmosphere-Ionosphere Interactions, and its application to the highly challenging problem of the seismic precursors.

References:

[1] ESA stories:
https://www.esa.int/Applications/Observing_the_Earth/FutureEO/Swarm/The_curious_incident_of_Swarm_and_sprites_in_the_night-time