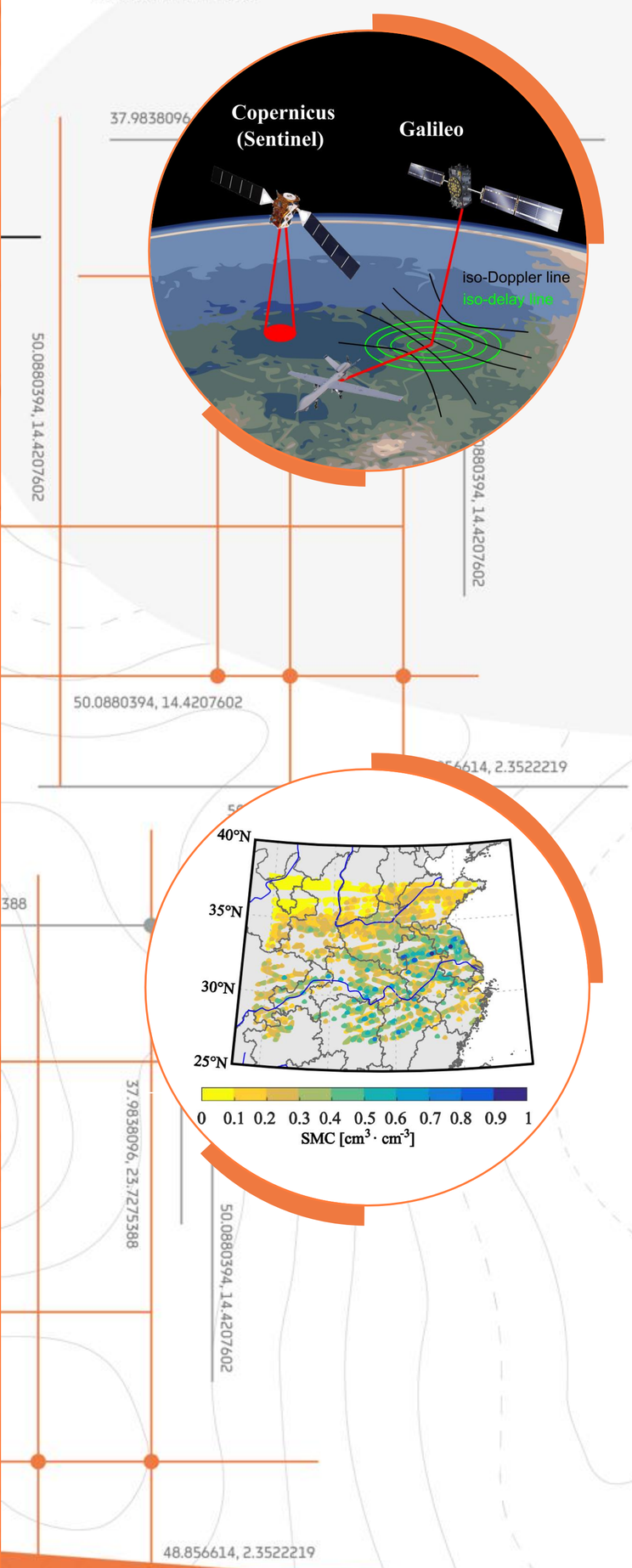
Monitoring land surface properties with Galileo Reflectometry

Area of Interest

- Monitoring land surface dynamics is crucial for plant growth and crop yield, as well as for flood/drought, freeze/thaw, and erosion prediction (see figure on the left). For instance, soil moisture is a key parameter for planning and managing irrigation strategies, while it simultaneously regulates energy and water exchange between the land and the atmosphere, and other hydrological and climate processes.
- Therefore, monitoring and predicting land surface dynamics is very important for social and economic human activity. The impact of disasters and crises on agriculture and food security need to be mitigated through models that can predict the future state of the land held. Some clear examples are droughts and floods, which can significantly reduce crop production by amount of about 10%.
- Land surface dynamics can be estimated locally from a wide variety of direct methods and techniques. However, these traditional methods are expensive and cumbersome over large areas, whereas microwave measurements from unmanned aerial vehicles (UAV) and satellites have shown numerous advantages, including revisiting time, global coverage, low cost, all-weather measurements, and near real-time data availability.
- Galileo Reflectometry (Galileo-R) is an innovative Earth observation technology using the signal of opportunity for terrestrial remote sensing, which employs the Earth's surface bouncing of signal transmitted from Galileo satellites to remotely sense geophysical parameters of interface for Earth observation, such as soil moisture, freezing and thawing, forest biomass, inland water and wetlands, etc.
- In this scheme, crop yield forecast and monitoring is important for various purposes, such as national food security, near real-time information for optimum management, and also for import/export planning. Therefore, monitoring land surface properties with Galileo-R can help to estimate and forecast crop yield and monitor hydrological cycle.



Approaching the Problem

- The proposed surveying solution integrates Galileo-R receiver's onboard drones, airplanes, or satellites for monitoring land surface properties, including soil moisture and freeze/thaw. The resulting reflectivity products will be validated and/or combined with Copernicus products (e.g., Sentinel data). For instance, the reflectivity data from a Galileo-R receiver will be combined with Copernicus' vegetation optical depth (VOD) and bare soil roughness (BSR) products to estimate soil moisture content. Finally, Galileo-R soil moisture estimates will be validated with Copernicus' products.
- A Galileo-R system holds the same geometrical configuration properties of a bi-static radar, where the scattered signal is sampled over the illuminated zone in delay and frequency, creating the so-called Delay Doppler Map (see figure on the left). This is the basic product containing physical information of a surface, including reflectivity, which allows the assessment of soil dielectric properties and estimation of several land surface parameters.
- In the Galileo microwave band (L-band), the complex permittivity is very sensitive to the change of liquid water in the near-surface soil (5-10 cm depth to the topsoil). As the temperature decreases, most of the liquid water in the soil undergoes a phase change and it converts into solid ice, thus leading to an abrupt decrease in the complex permittivity of the soil. Therefore, surface freeze/thaw state monitoring is based on the differences of complex permittivity between liquid water and other natural substances. In a similar way, the converted Fresnel linear reflectivity coefficients from Galileo-R reflectivity estimates can be employed to derive soil moisture.
- Compared with the traditional monostatic remote sensing, a Galileo-R platform just need to carry a delay/Doppler receiver. These receivers have numerous advantages, including low cost, low mass, and low power consumption. This greatly reduces the costs with respect to traditional techniques, and eases the installation of Galileo-R receivers in any kind of platform (drones, airplanes, satellites, etc.). Low cost unmanned aerial platforms and services for biomass mapping have been developed before (https://www.coregalproject.com/), but solutions to estimate parameters such as soil moisture and freeze/thaw have not been developed/implemented yet. Besides, new multi-constellation / multi-frequency receivers can potentially increase the data coverage and revisiting time.

Conclusions and Next Steps

- This project aims to employ Galileo signals for terrestrial remote sensing such as soil moisture and freeze/thaw parameters, and validate and/or combine the resulting output with Copernicus products.
- First results for soil moisture and freeze/thaw retrieval using Navstar Global Positioning System (GPS) receivers onboard the Cyclone Global Navigation Satellite System (CYGNSS) satellites have been already published in peer-reviewed academic journals. In our previous work, the reflectivity data from CYGNSS was successfully combined with VOD and BSR measurements from NASA's Soil Moisture Active Passive (SMAP) mission to retrieve soil moisture content (SMC) estimates, and the results were validated with SMAP SMC products. Figure on the left shows SMC on 1 April 2019 [Calabia et al., 2020, doi:10.3390/rs12010122].
- The first part of the project will be the installation of a Galileo-R sensor onboard an unmanned aerial vehicle, being an ideal solution for planning and managing irrigation strategies. This low cost application will open the possibility to upgrade to multi-constellation / multi-frequency receivers, and to install a similar receiver in a CubeSat mission. This will be an efficient solution to cover larger regions, ideal for climate change and many other applications. The use of Galileo-R can potentially increase the data coverage and revisiting time that the present techniques offer for terrestrial remote sensing in the microwave domain.
- This project is planned to be supported/funded by several private and public entities, including, e.g., National Natural Science Fund (standard grants and young scientist grants), as well as similar programs from local governments; R&D grants for teams formed by researchers from industry, academia and labs (National Key R&D Programs and similar programs at the local level); and international cooperation and co-funding schemes, i.e. ad hoc programs supporting joint projects between European and Chinese partners (both at the national and the local level).

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