Exploration of Spaceborne Coherent GNSS Reflectometry for High Resolution Hydrological and Ice Observation

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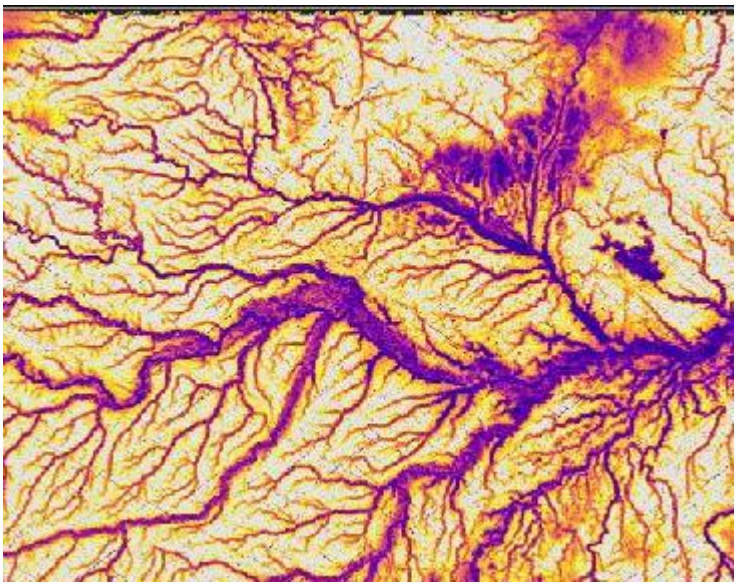
Soil moisture is an Essential Climate Variable (ECV) closely associated with hydrology, weather, agriculture and climate change, and that has potential for improved measurement from space, and operational flood alerts could benefit from faster availability of such remotely sensed measurements.

GNSS Reflectometry has been demonstrated as a new Earth Observation technique with much potential. Surrey's GNSS-Reflectometry instrument has been used on TechDemoSat-1 and the NASA CYGNSS constellation to measure ocean winds, and reflections are also retrieved over land and ice. SSTL is continuing its work with an experiment on the 17 kg DoT-1 satellite, and leads a consortium in the ESA Scout HydroGNSS mission concept.



[GNSS reflections over Amazon basin from NASA CYGNSS using Surrey's GNSS-Reflectometry receiver (Clara Chew, UCAR)]

GNSS Reflections retrieved over the Amazon show the unique property of highlighting rivers underneath the rain forest canopy. The resolution of GNSS reflections is assumed to be around 25 km over the ocean, but when there is a flat surface, the reflections become coherent, and the resolution approaches the Fresnel zone of ~500 metres. These properties make GNSS-R a potential tool for assessing soil moisture and flooding under canopies. The improved resolution could help map over-banking – a source of methane poorly modelled in Earth System Models. High resolution could also allow GNSS-R to map ice edges with greater accuracy than currently used radiometers. Coherent reflectometry could also increase resolution of freeze / thaw monitoring over permafrost, and open the door for altimetry using GNSS, and for target detection of objects with very reflective flat surfaces.

The processing scheme currently used on the instruments assumes that signals are not coherent, but are incoherent, and crucial information such as carrier phase is not being collected. This PhD studentship

will investigate alternative processing schemes for collecting coherent signals from GPS and the wider bandwidth Galileo signals. Raw data collected by TechDemoSat-1 can be used to test new signal processing schemes, and there is the potential for involvement and implementation of algorithms on the DoT-1 and HydroGNSS satellite missions. Some of the challenges include: open loop capture of coherent signals, radiometric correction of measurements, allowing for noise, and calibration and validation of measurements against in-situ or other sources of data, in collaboration with other scientists, as well as practical implementation in an embedded signal processing instrument that can be operated in orbit.

A further application is the consideration how GNSS-R coherent data could be fused with other existing sensors, e.g. SAR and optical payloads that might be carried on the same satellite. Biomass may be recoverable using the combination of GNSS-R off the forest floor, and radar measurements off the top of the canopy.

Training opportunities:
The studentship will have access to the University of Surrey's space course lectures and materials. As a CASE studentship, the student will spend significant time embedded within Surrey Satellite Technology Ltd (SSTL) exploring the use of reflectometry data collected from the UK TDS-1 satellite and close involvement in subsequent satellite missions. The student will have access and make use of SSTL's laboratories and GNSS facilities.

Student profile:
The candidate must have a strong aptitude and preferably experience with signal processing theory and practice. Detailed knowledge of at least one of Earth Observation Radar, GNSS signals, FPGAs, C-programming will be essential. The student should hold a good first degree or Master's level degree in electronic engineering, spacecraft engineering or a physical science.

Funding particulars:
This is a CASE (Collaborative Awards in Science and Engineering) studentship with financial top-up from SSTL.

References: (optional)
TDS-1 publication list at: http://merrbys.co.uk/resources/publications
Unwin et al., "Spaceborne GNSS-Reflectometry TechDemoSat-1: Early Mission Operations and Exploitation", 10.1109/JSTARS.2016.2603846. [2016 GRSS J-STARS Prize Paper]
Use of TDS-1 GNSS-R to measure freeze/thaw https://ieeexplore.ieee.org/document/9103273
NASA JPL's TDS-1 use https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016GL068189