Subject: Study the effects of the angular sampling, noise and spatial heterogeneity in the retrieval of surface moisture (SM) and optical thickness (VOD) obtained by inversion of the radiative transfer forward model used by the data processing algorithms of the SMOS space Earth observation mission.

Graduate internship: master 2, engineering school final year.

Skills/profile: applied mathematics, science computing in Matlab, ability to analyse and synthesis, autonomy, writing skills, knowledge of space remote sensing would be a must.

Duration: 6 months

Location: CESBIO laboratory, Paul Sabatier University, Toulouse https://www.cesbio.cnrs.fr.

Remuneration: ~585euros/month

Start date: ideally end 2022, possible up to the first quarter of 2023.

Keywords: non-linear model, inverse problem, SMOS, Matlab

SMOS, for Soil Moisture and Ocean Salinity, is a space mission for earth observation launched in 2009. SMOS is specifically designed to observe the surface soil moisture and the ocean salinity. To this end, the satellite SMOS measures the natural microwave emission from the Earth's surface using an interferometric L-band (1.4 GHz) radiometer providing unprecedented, multi-angular and fully polarised brightness temperature measurements (TB) (Fig. 1) that are totally new to Earth observation from space.

SMOS observation (TB) represents an area of about 43km on average that can cover highly variable surface conditions of soil moisture, vegetation, texture (clay, sand), surface temperatures, ... Emitted brightness temperatures, magnitudes and polarization incidences angle shapes, are function of these surface conditions resulting in strong spatial heterogeneity of local brightness temperatures (tb) emission. A TB observed by SMOS can be considered as a weighted integral measurement; the integral of the spatial distribution of local emissions (dtb) weighted by the normalised directional gains (G) of the instrument antennas: $TB=\langle dtb \rangle_G$

The algorithms of the operational processing chain of SMOS measurements were developed at CESBIO. These algorithms allow, by inversion of a non-linear radiative transfer forward model, to retrieve the surface soil moisture (SM) as well as the optical thickness of the vegetation (VOD) from the measured brightness temperature profiles (Fig. 1).

The objective of the internship is to study the following three effects and to characterise their impact on the quality of the retrieved (SM and VOD) as well as their validation by using direct modelling - inverse modelling simulations (Fig. 2):

- Incidence angles sampling (Fig. 1) and non-uniqueness of the inverse solution: distribution of incidence angle of the TBs, number of TBs, radiometric noise, SMOS-specific observation geometry and their impact on the error budget (by Monte-Carlo type approach)
- Spatial heterogeneity and non-linearity effects on the inversion: $F(\langle dp \rangle_G)$ vs. $\langle F(dp) \rangle_G$. What are the impacts if the TB are modeled such as: i) $F(\langle dp \rangle_G)$ the TB model of the averages of the surface conditions (actual choice for SMOS algorithm) vs. ii) $\langle F(dp) \rangle_G$ the average of the modeled TB obtained from the spatially distributed surface conditions (more realistic)
- Spatial heterogeneity and resolution effects: local magnitude (e.g. a field measurement) vs. integrated magnitude (observed SMOS surface of ~43 km diameter).

How: in collaboration with the SMOS team at CESBIO, the trainee will have to define the adequate simulation scenarios of direct => inverse modelling type. He/she will have to: i) implement these scenarios in Matlab by becoming familiar with the existing direct and inverse modelling codes, ii) adapt them to the needs of the study, iii) organise the results and analyse them in order to present his/her conclusions at the end of the internship.

More about SMOS mission: https://labo.obs-mip.fr/smos-blog

Internship supervisors

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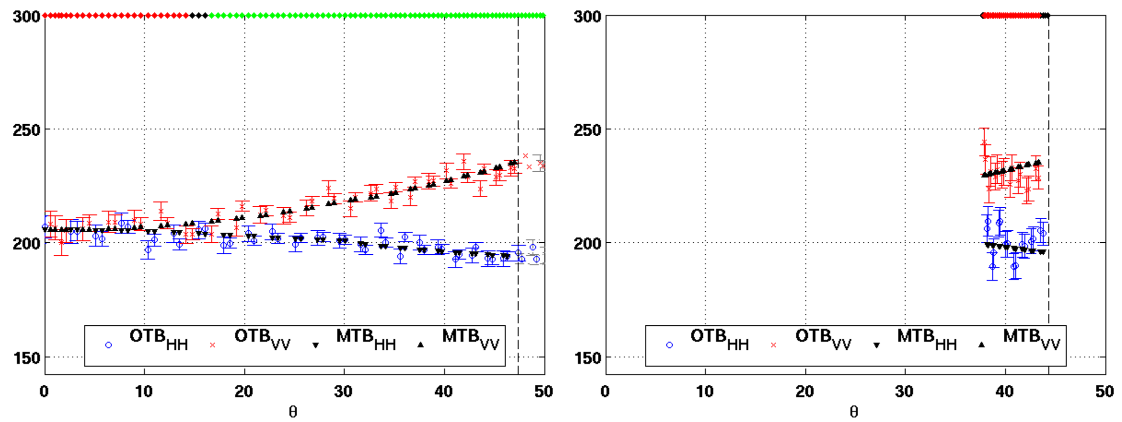

Figure 1 : brightness temperature [K] profile observed by SMOS (colours), inverse modelling (black) as function of the geometry (incidence angles θ) and the variability of the angular sampling and noise (error bars) for the same observed location but under different geometry, satellite sub-track (left), field of view border (right)

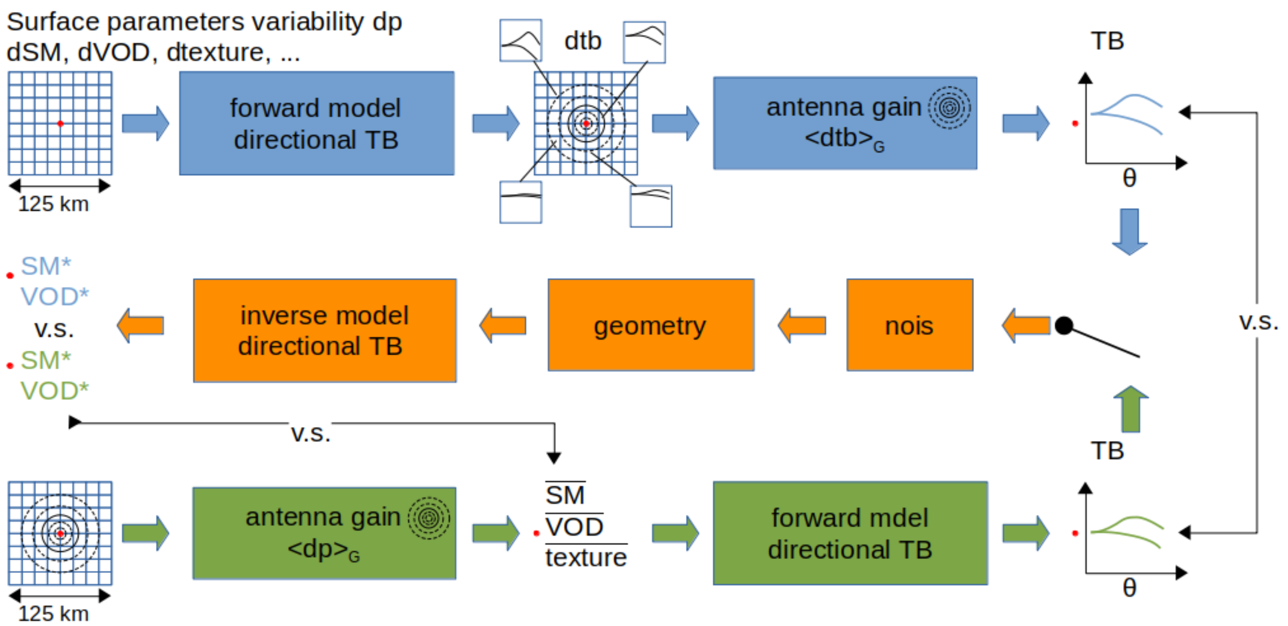

Figure 2 : conceptual overview of the modelling simulation : forward (here two types blue and green) : geophysical parameter (dSM, dVOD, dtexture) to brightness temperatures TB injected to an inverse schema : brightness temperature, perturbed (added noise angular sampling decimation, ...) toward retrieved geophysical parameters (SM,VOD*).*