# SMOSHiLat - Microwave L-band emission from organic-rich soils in the northern cold climate zone in the framework of the SMOS mission

Simone Bircher, Jean-Pierre Wigneron, François Demontoux, Mike Scwhank, François Jonard, Stephen Razafindratsima, Valery Mironov, Philippe Richaume, Arnaud Mialon, Lutz Weihermüller, et al.

# SMOSHiLat - Microwave L-band emission from organic-rich soils in the northern cold climate zone in the framework of the SMOS mission

*Simone Bircher*[1], Jean-Pierre Wigneron[2], François Demontoux[3], Mike Schwank[4], François Jonard[5], Stephen Razafindratsima[3], Valery L. Mironov[6], Philippe Richaume[1], Arnaud Mialon[1], Lutz Weihermüller[5], Kimmo Rautiainen[7], Jouni Pulliainen[7], Mie Andreasen[8], Karsten Høgh Jensen[8], Yann H. Kerr[1]*

1. Centre d'Etudes Spatiales de la Biosphère, Toulouse, France
2. Division Ecologie fonctionelle et Physique de l'Environnement, Institut National de la Recherche Agronomique, Bordeaux-Aquitaine, France
3. Laboratoire de l'Intégration du Matériau au Système, Bordeaux University, Bordeaux, France
4. Swiss Federal Institute for Forest, Snow and Landscape Research, Birmensdorf, Switzerland
5. Institute of Bio- and Geosciences Agrosphere (IBG-3), Forschungszentrum Jülich GmbH, Germany
6. Kirensky Institute of Physics, Siberian Branch of the Russian Academy of Science, Krasnoyarsk, Russia
7. Finnish Meteorological Institute, Helsinki, Finland
8. Department of Geosciences and Natural Resource Management, University of Copenhagen, Denmark

* Corresponding author: simone.bircher@cesbio.cnes.fr

Organic-rich soils are typical for the circumpolar northern cold climate zone (boreal zone/tundra). Due to above-average rising temperatures in the higher northern latitudes, a large amount of these important carbon sinks might be released, possibly causing a significant positive feedback on global warming. Thus, there is a strong need to monitor hydrologic processes in these regions.

The ESA's Soil Moisture and Ocean Salinity (SMOS) [1] mission carries the first space-borne passive L-band microwave (1.4 GHz) radiometer on board. It acquires global brightness temperatures (TB) from which surface soil moisture is retrieved, taking advantage of the very large difference between the dielectric constant (also known as relative permittivity) of dry soil and liquid water at this frequency. The retrieval algorithm is based on the L-band Microwave Emission of the Biosphere (L-MEB) model [2][3] which uses tuning parameters derived from study sites in dry and warm temperate climate zones.

In order to improve our understanding of L-band emission of organic soil surface layers and thus, supporting the quality of SMOS data in the northern cold climate zone the SMOSHiLat project has been evoked in the framework of ESA's Changing Earth Science Network. It aims at creating a database including L-band TBs and dielectric constant values of soils, mainly from two northern study sites in Sodankylä, Finland (Finnish Meteorological Institue, FMI), and Gludsted, Denmark (Hydrologic OBsErvatory, HOBE). L-band dielectric constants are quantified by modeling from calibrated soil moisture measurements input to a dielectric mixing model, as well as direct measurements from collected samples using two complementary approaches, namely

wave-guide (e.g. [4]) and resonant cavity techniques (e.g. [5]). Using these estimates, L-band TBs are modeled by means of physically-based radiative transfer modeling to supplement the tower-based radiometer observations from both study sites. In case of the Danish site, organic-rich soil from a heathland was transported to the TERENO test site Selhausen of the Forschungszentrum Jülich GmbH in Germany for observations of L-band radiative properties under highly controlled conditions [6]. Based on this database the L-MEB model is adapted for organic-rich soils encountered in northern regions. In a second step it will be tested in the SMOS soil moisture prototype retrieval algorithm in view of its implementation in the operational retrieval scheme. An overview of the approach is illustrated in Fig. 1.

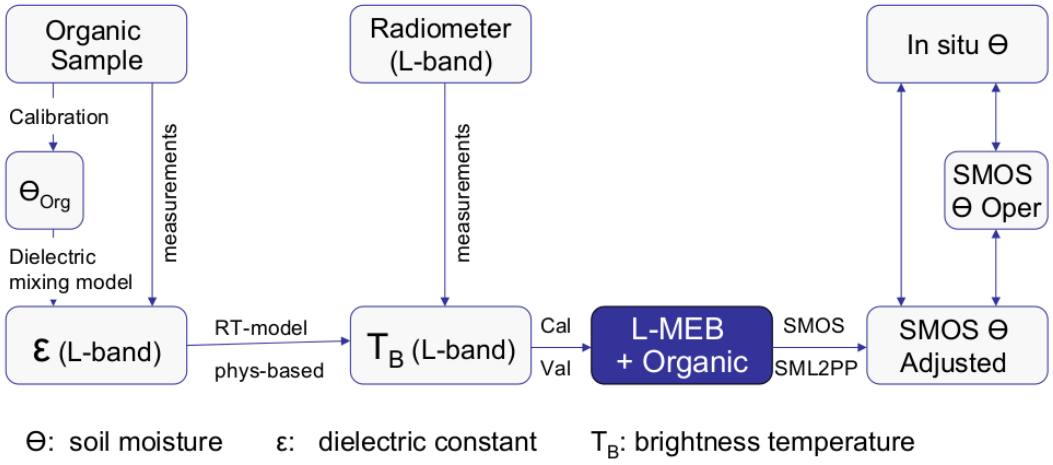


Figure 1: Illustration of the approach of the SMOSHiLat project

Examples of dielectric constant and TB data collected at the FMI Sodankylä test site are depicted in Figures 2 and 3, respectively. Figure 2 illustrates direct measurements of the L-band dielectric constant of the organic soil horizon, carried out at the Laboratoire de l'Intégration du Matériau au Système (IMS) in Bordeaux, France, using two complementary approaches. L-band dielectric constants estimated for an average mineral soil by [7] are plotted along.

Figure 3 illustrates the tower-based radiometer observations (ELBARA, [8]) acquired in a boreal forest clearing at FMI's Arctic Research Center between fall 2009 and 2012 together with observations of essential soil state variables (soil moisture and soil temperature).

In this communication, the established dielectric constant and brightness temperature database will be presented. Furthermore, first simulations of an adapted L-MEB model for organic-rich soils and corresponding SMOS soil moisture processor runs will be shown and discussed.

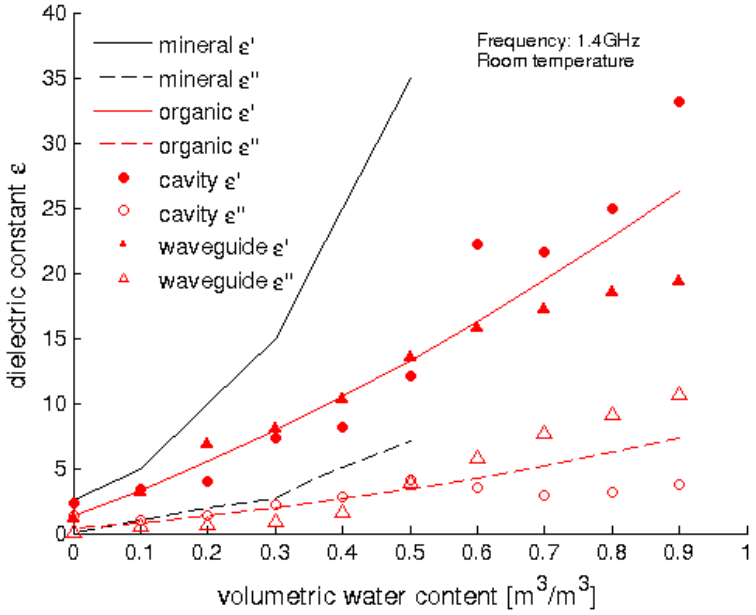


Figure 2: L-band dielectric constants (real/imaginary parts, ε'/ε'') fitted through preliminary wave-guide and cavity measurements of the organic surface layer from the FMI Sodankylä test site, Finland. For comparison, estimated values for an average mineral soil by [7] are also given (black line).

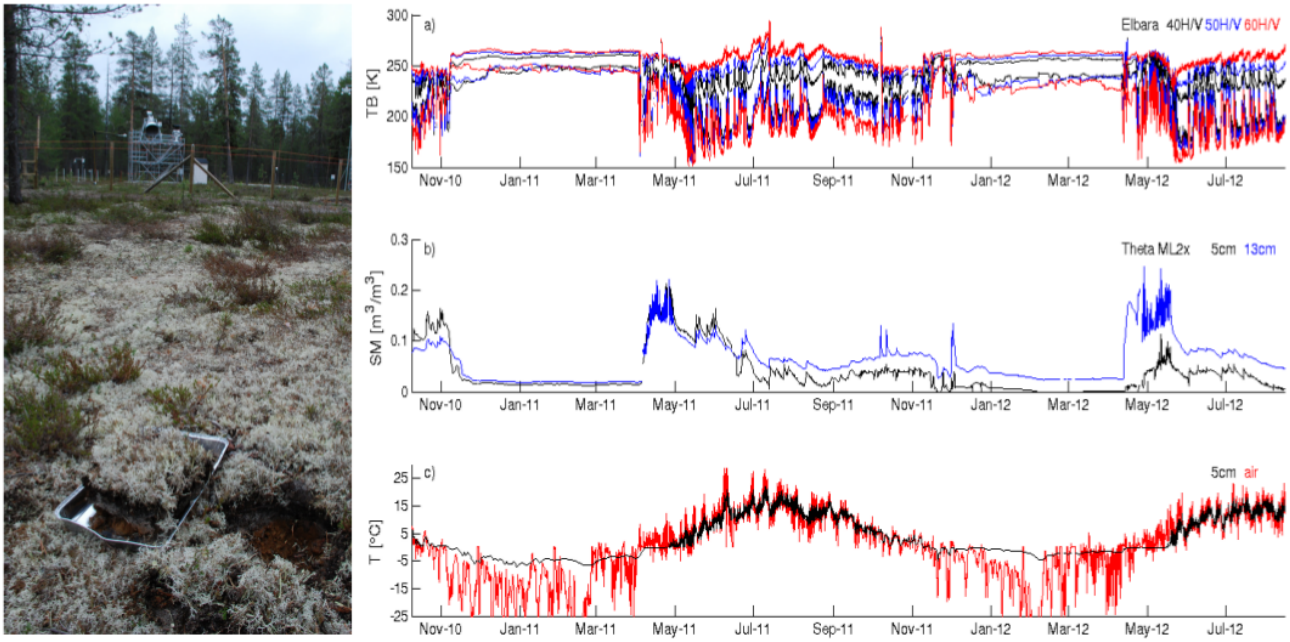


Figure 3: Elbara radiometer site at the FMI Arctic Research Center in Sodankylä, Finland (left), and time series from the FMI Sodankylä test site, Finland: a) L-band passive microwave radiometer (Elbara) TB observations at 40, 50, and 60° incidence angles, horizontal (H) and vertical (V) polarization, b) corresponding ThetaProbe ML2x in situ soil moisture at 5 and 13 cm depth, and c) 5cm-soil and air temperatures.

## References

[1] Y. Kerr, P. Waldteufel, J.-P. Wigneron, J.-M. Martinuzzi, J. Font, and M. Berger, “Soil moisture retrieval from space: The Soil Moisture and Ocean Salinity (SMOS) mission“, IEEE Transactions on Geoscience and Remote Sensing, vol. 39(8), pp. 1729-1735, 2001.

[2] J.-P. Wigneron, Y. Kerr, P. Waldteufel, K. Saleh, Escorihuela, M.-J., P. Richaume, P. Ferrazoli, P. de Rosnay, R. Gurney, J.-C. Calvet, J. Grant, M. Guglielmetti, B. Hornbuckle, C. Maetzler, T. Pellarin, and M. Schank, “L-band microwave emission of the biosphere (L-MEB) model: Description and calibration against experimental data sets over crop fields”, Remote Sensing of Environment, vol. 107, pp. 639-655, 2007.

[3] Y. H. Kerr, P. Waldteufel, P. Richaume, J.-P. Wigneron, P. Ferrazzoli, A. Mahmoodi, A. Al Bitar, F. Cabot., C. Gruhier, S. Enache Juglea, D. Leroux, A. Mialon, and S. Delwart, “SMOS Soil Moisture Retrieval Algorithm”, IEEE Transactions on Geoscience and Remote Sensing, vol. 50(5), pp. 1384-1403, 2012.

[4] W. B. Weir, “Automatic measurement of complex dielectric constant and permeability at microwave frequencies”, Proceedings of the IEEE, vol. 62(1), pp. 33-36, 1974.

[5] L. Erdogan and C. Akyel, “Dielectric properties of oil sands at 2.45 GHz with TE1,0,11 mode determined by a rectangular cavity resonator”, Journal of Microwave Power and Electromagnetic Energy, vol. 45(1), pp. 15-23, 2011.

[6] F. Jonard, L. Weihermüller, M. Schwank, K. Z. Jadoon, H. Vereecken, and S. Lambot, “Estimation of the hydraulic properties of a sand using ground-based passive and active microwave remote sensing”, IEEE Transactions on Geoscience and Remote Sensing, under review.

[7] M. Hallikainen, F. Ulaby, M. Dobson, M. El-Rayes, and W. Li-Kun, “Microwave dielectric behavior of wet soil – part 1: Empirical models and experimental observations”, IEEE Transactions on Geoscience and Remote Sensing, vol. 23(1), pp. 25-34, 1985.

[8] M. Schwank, A. Wiesmann, C. Werner, C. Maetzler, D. Weber, A. Murk, I. Völksch, and U. Wegmüller,“Ellbara II, an L-band radiometer system for soil moisture research“, Sensors, vol. 10 (1), pp. 584–612, 2010.