Evaluation of vegetation effect on the retrieval of snow parameters from backscattering measurements: a contribution to CoReH2O mission

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1. INTRODUCTION

The COld REgions Hydrology High-resolution Observatory (CoReH2O) is one of the three satellite missions selected for scientific and technical feasibility studies (Phase-A) within the Earth Explorer Programme of the European Space Agency (ESA) [1]. The principal aim of the CoReH2O mission is the spatially detailed frequently measurement of snow and ice in order to advance the knowledge and prediction of the water cycle in cold regions and to improve the representation of the cryosphere in climate models. The proposed sensor is a dual frequency SAR, operating at Ku-band (17.2 GHz) and X-band (9.6 GHz), VV and VH polarizations, with a swath width of about 100 km. The principal products obtained from the mission will be the estimations of the extent, the water equivalent (SWE) and melting state of the seasonal snow cover and the snow accumulation on glaciers. At present, several projects are taking place in order to consolidate the interactions of Ku- and X-band radar backscatter with snow and ice by means of theoretical/semi-empirical model and experimental data. Also methods for the retrieval of physical snow properties are under improvement. In order to estimate SWE from the backscattering measurements, it is necessary to separate the signal of the snow volume from the contribution of the background target (e.g. soil features like roughness and steepness, vegetation cover, etc.) and also to account for effects of grain size on scattering. The presence of vegetation has a significant impact on the propagation of the radar signal at X-and Ku-band, depending on its structure, biomass, water content and cover fraction. The attenuation of the signal coming from snow cover will be quite different, ranging between the extremes of low, dormant vegetation and dense coniferous forest. Indeed, for herbaceous vegetation or short vegetation (such as alpine grass, tundra, etc.) the influence on the backscattering signal seems not to be significant. Moreover, the effect of vegetation is comparable to other effects such as the soil roughness, soil moisture or presence of rocks ([2]-[4]). On the other hand, the influence of forest strongly depends on forest density and fractional cover: in the case of a sparse forest or a high percentage of non-forested area in the pixel (as in the case of low-resolution sensors), the effects of snow dominates the radar signal, but for dense forest (even in case of a moderate biomass), the vegetation signal strongly covers the signal from snow and, consequently, compromises the sensitivity to snow parameters ([5],[6]). The aim of this paper is to investigate the impact of vegetation on the retrieval of snow parameters from backscattering measurements at the X- and Ku-bands. An electromagnetic model able to simulating scattering from a vegetated snow-covered terrain was then developed and implemented. Lastly, a sensitivity analysis to vegetation parameters was conducted on sparse vegetation and coniferous forest.

2. THE SNOW-VEGETATION MODEL

The first part of the work was devoted to identify the most representative types of vegetation for the upper part of the boreal hemisphere (i.e. for the zones with latitude greater than 40°). For this purpose data on global vegetation types and density, available from international projects (e.g. ECOCLIMAP; CORINE of the European Commission, and GLOBCOVER of ESA) has been used. In particular the new GLOBCOVER data base of ESA, comprising more than 20 land cover classes at 300 m spatial resolution, is a very interesting option for supporting SWE retrievals. It was found that the most common forest stands are composed by coniferous trees like spruce and larch. In particular, among the possible trees, we selected the black spruce (Picea mariana) and the Norway spruce (Picea abies) for modeling simulations. The geometrical characteristics of these two kinds of trees were available in literature; moreover in order to better assess the characteristics of the Norway spruce a dedicated campaign was carried out on the Italian Alps at the end of 2009. Among the possible models a MIMICS-like model, which was originally developed at IFAC ([7],[8]) for the simulation of agricultural crops, and then modified for forest vegetation and tested during the Phase 0 of the CoReH2O project [6],[9] was selected. The main advantages of this model are that it can be combined with the snow model that was developed and tested within the CoReH2O activities and which was used to investigate on sensitivities to snow parameters at X and Ku band. The limit of this method is that the multiple scattering effects are neglected.

Because of the lack of contemporaneous acquisitions of SAR and ground data (of both snow and vegetation) the validation at Ku- and X-band of the complete model (snow+vegetation) so far has been unfeasible. Nevertheless the model was validated at C-band by using the data set presented in recent papers. We expect that the planned activities in (a) NoSREx campaign, northern Finland and (b) Churchill campaign in Canada during the winter of 2009-2010 will provide valuable new data sets at both X- and Ku-band. Also concurrent space-borne observations with TerraSAR-X, Cosmo SkyMed X-band SAR and Ku-band QuikScat scatterometer will be collected in the campaigns enabling satellite data analysis and testing of algorithms.

The sensitivity analysis to vegetation parameters was conducted on coniferous forest. For these crop types the backscattering coefficient was simulated at the CoReH2O configuration: frequencies 9.6 and 17.2 GHz, polarization VV and HV, incidence angle between 30 and 40 degrees. The ground under the vegetation was assumed to be covered with dry snow having a SWE value between 20 and 600 mm. The simulations were conducted for two to three different grain sizes and two different soil roughness. Preliminary results showed that in the case of low biomass or low fractional cover (i.e. vegetation biomass lower than 110 m3/ha and fractional cover lower than 25%) the snow backscatter dominates the radar signal. With increasing density or fractional cover the effects of vegetation increase and consequently the sensitivity to SWE decreases at both X- and Ku-band. Other investigation will be performed in the next months.

For practical application we produced, by using the above mentioned databases, a vegetation cover maps in order to flag out all of those areas over which the snow parameters retrieval is not possible or is severely affected by the presence of dense forest. Methodology to include this information in the retrieval algorithm of *CoReH2O* will be proposed.

4. REFERENCES

[1] European Space Agency (2008) Candidate Earth Explorer Core Missions – Reports for Assessment, ESA SP-1313(3), Mission Science Division, ESA-ESTEC, Noordwijk, The Netherlands, ISSN 0379-6566, 104pp, available at http://www.congrex.nl/09c01/

[2] Floricioiu D. and H. Rott,: Seasonal and short-term variability of multifrequency, polarimetric radar backscatter of alpine terrain from SIR-C/X-SAR and AIRSAR **data.** IEEE Trans. *Geosc. Rem. Sens*., Vol.39, Issue 12, 2634 –2648. 2001

[3] Nghiem SV, Tsai WY. 2001. Global snow cover monitoring with spaceborne Ku-band scatterometer. *IEEE Transactions on Geoscience and Remote Sensing* **39**: 2118-2134

[4] Cline D. *et al*. 2004. Ku-band radar response to terrestrial snow properties. *EOS Trans. AGU*, 85(47).

[5] Hallikainen, M.; Makynen, M.; Pullainen, J.; Vanska, T.;Radar backscatter from boreal forest in winter**,**Geoscience and Remote Sensing, 1997. IGARSS '97. 'Volume 2, 3-8 Aug. 1997 Page(s):803 - 805 vol.2 ,1997

[6] Nagler, T., H. Rott, G. Macelloni, S. Pettinato, E. Santi, J. Pulliainen, C. Haas, C. Duguay. 2008: Retrieval of physical snow properties from SAR observations at Ku- andX-band frequencies. Final Report. ESTEC contract 20756/56/07/NL/CB.

[7] Ulaby F.T., K. Sarabandi, K. McDonald, M. Whitt, and M.C. Dobson, "Michigan microwave canopy scattering model", *Int. J. Remote Sensing*, Vol.11, pp. 1223-1253, 1990.

[8] Macelloni G., S. Paloscia, P. Pampaloni, F. Marliani, and M. Gai, "The Relationship between the Backscattering Coefficient and the Biomass of Narrow and Broad Laf crops", *IEEE Transactions on Geoscience and Remote Sensing*, GRS-39, No. 4, pp. 873-884, April 2001.

[9] Macelloni, G.; Pettinato, S.; Santi, E.; Rott, H.; Cline, D.; Rebhan, H.;Impact of Vegetation in the Retrieval of Snow Parameters from Backscattering Measurements at the X- and Ku-bands; Geoscience and Remote Sensing Symposium, 2008. IGARSS 2008. IEEE International; Volume 3, 7-11 July 2008 Page(s):III - 218 - III - 221