Comparison of Real and Simulated Surface Clutter from the EarthCARE Cloud Profiling Radar (CPR) over Land

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Introduction

- Work: simulation of the clutter signal from EarthCARE CPR, using the approach outlined in [1]: ray tracing, using a very high resolution DEM (30 m) and realistic surface backscatter model based on a terrain classification map.
- Results: comparison of clutter profiles obtained from the simulations and the ones taken from the L1b products of EarthCARE, analysis of deviations in the flat Doppler profiles over land with respect to the case over ocean.
- Two main aims: 1) enhance Doppler calibration including land surfaces (without pronounced orography and surface inhomogeneities) and 2) better characterisation of ground clutter reflectivity profile for ground clutter removal purposes.

Methodology

The radar reflectivity Z and Doppler v_D profiles can be computed as [2]:

$$Z(r) \propto \sum_{i,j} \frac{\sigma_0(\psi_{ij}) G_n^2(\mathbf{u}_{ij}^{LoS}) \left| u(t - 2r_{ij}/c) \right|^2}{r_{ij}^4} dS_{ij} \quad (1)$$

$$v_D(r) \propto \sum_{i,j} \frac{v_{SC}(ij) \sigma_0(\psi_{ij}) G_n^2(\mathbf{u}_{ij}^{LoS}) \left| u(t - 2r_{ij}/c) \right|^2}{r_{ij}^4} dS_{ij} \quad (2)$$

where:

1. for line-of sight unit vectors $\mathbf{u}_{ij}^{LoS}$, pixel normal $\mathbf{u}_{ij}^{n}$, and incidence angle ψ_{ij} see Fig. 1.
2. G_n is the relative antenna gain: a gaussian antenna pattern has been used.
3. σ_0 is the normalised radar cross section (NRCS), computed based on LUTs for different terrain classes [3].
4. $v_{SC}(ij) = \mathbf{u}_{ij} \cdot \mathbf{v}_{SC}$ is the projection of the satellite velocity along the line-of-sight.

Geometrical quantities are computed using the DEM, in combination with the satellite position and velocity in ECEF frame from the L1b data. Real Doppler and reflectivity signals are generated according to the method proposed by [4], adding noise and a receiver response model with the EarthCARE PTR.

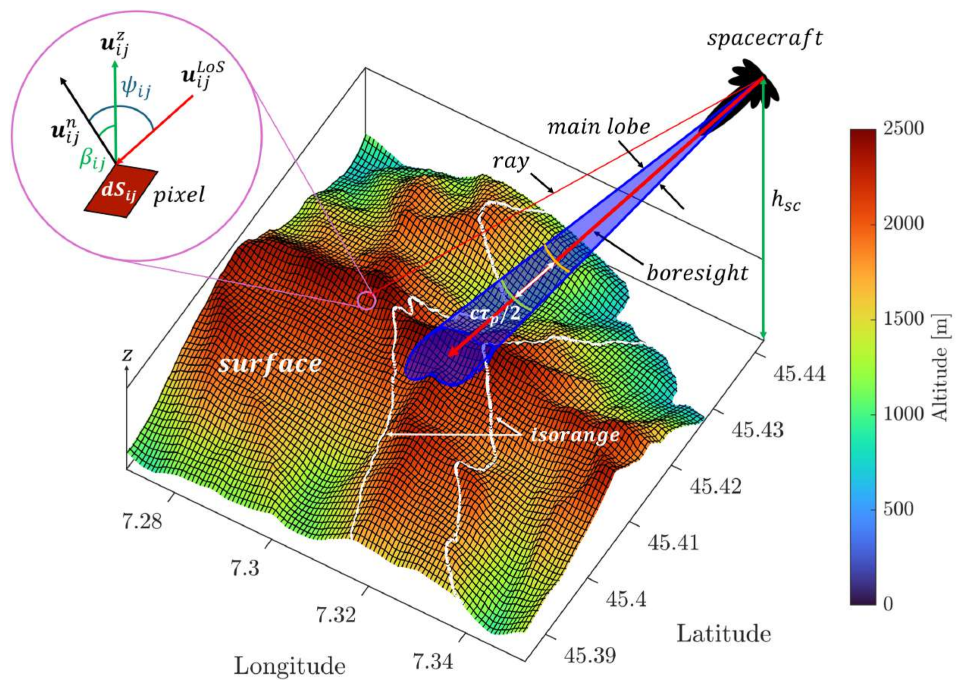

Figure 1: Representation of the geometry of the radar observations over an orographic scene (a slant case is shown as example. Details of the quantities involved in the computations are included.

Results

- Interpolated position and velocity of EarthCARE from L1b data is obtained for a pass over the Piedmont region in northwest Italy
- Each echo is simulated and integrated over roughly 500 metres.
- The simulation shows a capability of reproducing the real measurements, with some differences.
- Simulated reflectivity profiles have lower power than measured: a renormalization was performed to the maximum of the EC profiles.
- Measured Doppler profiles seem to have lower internal variability compared to the simulation.

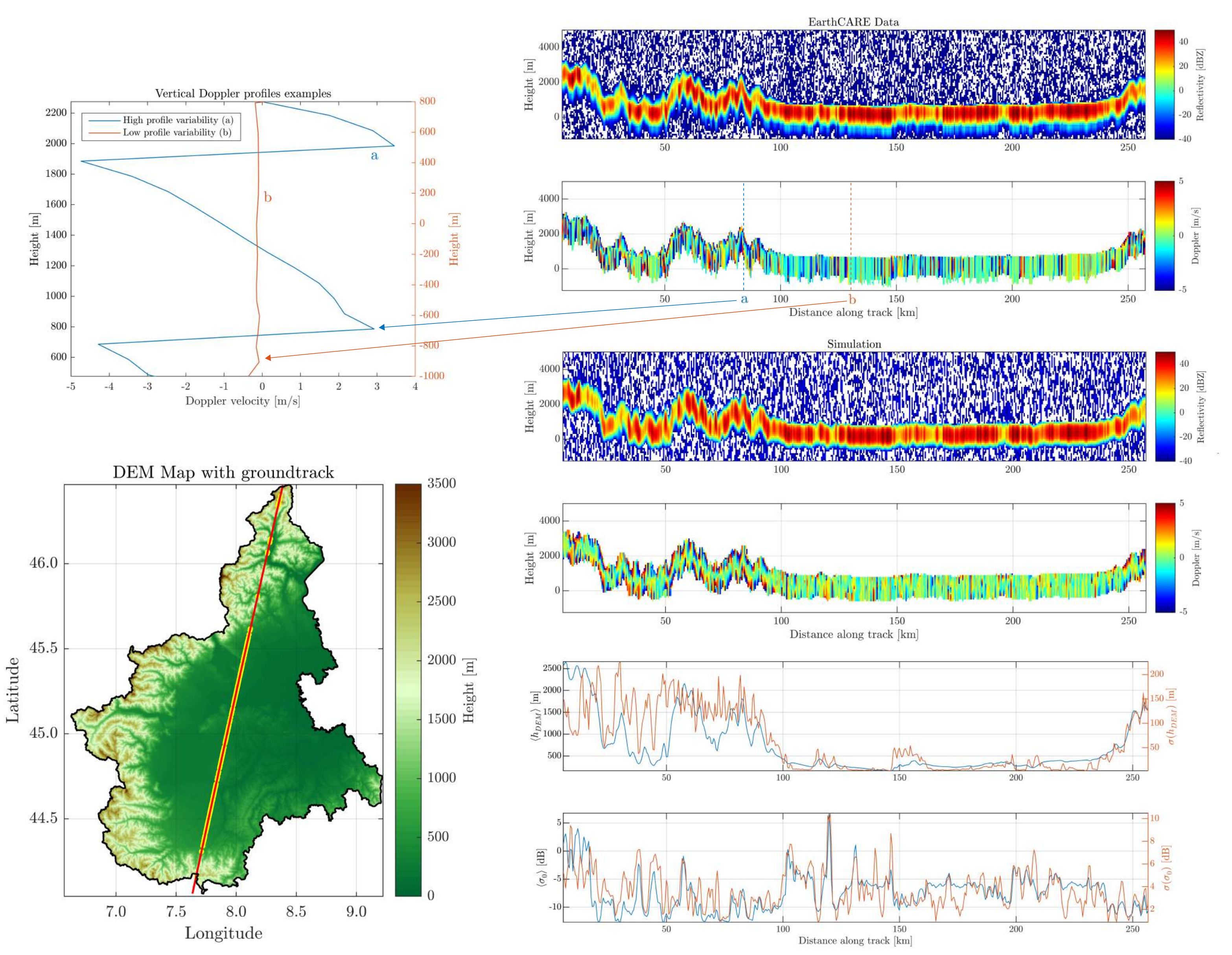

Figure 2: Ground clutter profiles: from EarthCARE data (top two right panels) and simulated results (middle two right panels). The bottom two right panels show DEM elevation and NRCS mean and std. dev. values computed for each data point over the ~500 m integration window. In the top left panels, examples of Doppler vertical profiles with high and low internal variability (at 82 km and 126 km, points a and b). The groundtrack of the overpass is shown in the bottom left panel.

- To address the enhancement of Doppler calibration via antenna mispointing characterization, a comparison with the profiles over ocean has been carried out.
- Distribution of the standard deviations inside each Doppler profile for the simulated scan and over ocean in clear sky are shown in Fig. 3.
- It's possible to filter data to to identify profiles over land that show variability similar to the one over water.
- Percentages of profiles over the mean value of internal Doppler std. dev. over ocean are included: a larger fraction of profiles over land have higher internal variability.
- Filtered points over land are highlighted in yellow in the bottom left panel of Fig. 2: these correlate well with regions with lower orographic and NRCS variability (bottom right panels).
- Additionally, in the bottom panel of Fig 3, a trend can be seen, where higher internal Doppler std. dev. of each profile correlates with higher orographic variability.

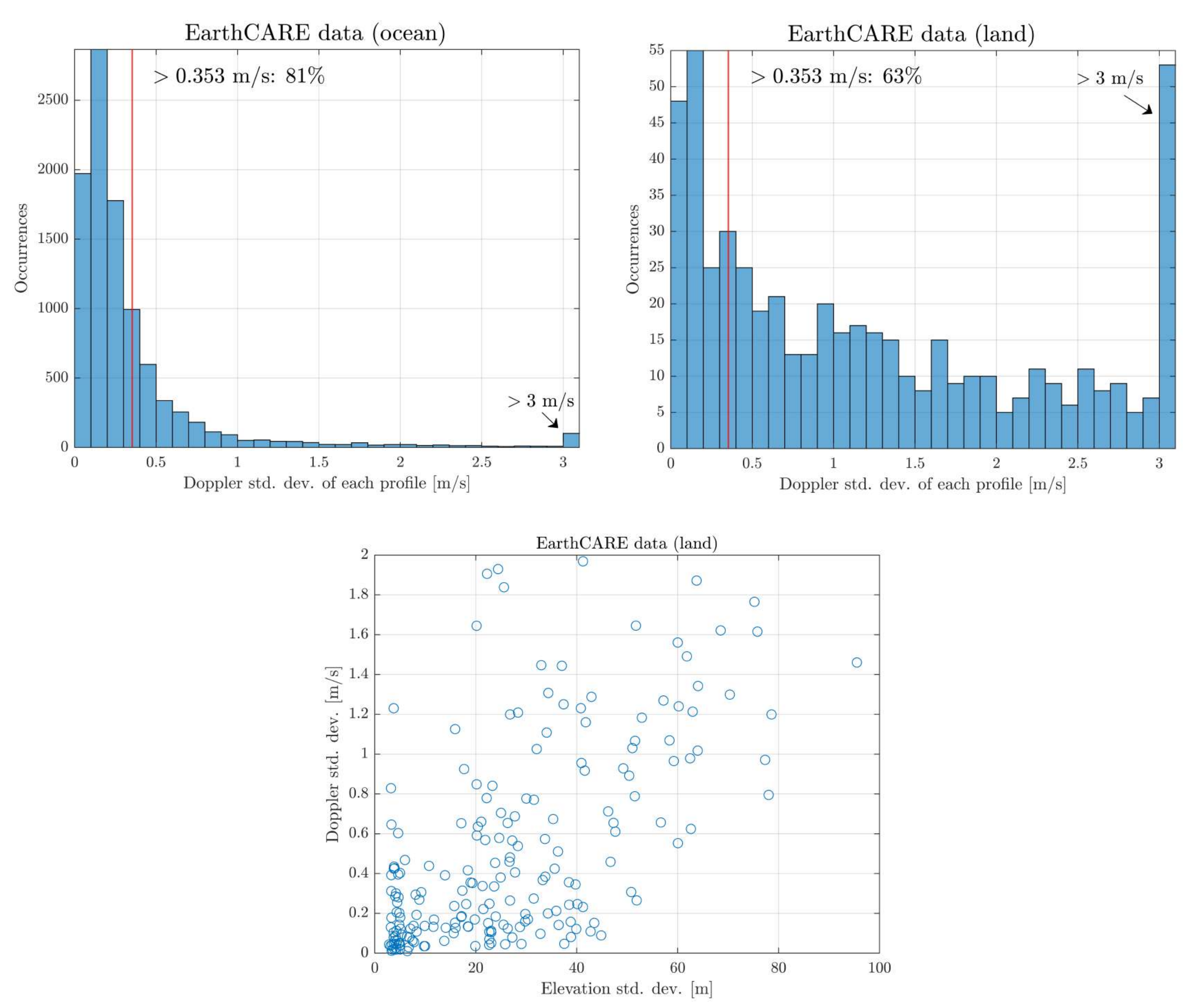

Figure 3: Top panels: distribution of standard deviations inside each profiles for land (data from the selected overpass case study) and ocean using EarthCARE L1b data. Red lines represent the mean value of the standard deviation for the selected samples over ocean. Bottom panel: scatter plot of internal Doppler std. dev. vs orographic variability.

Conclusions

- We can successfully simulated the ground clutter profiles within an acceptable degree of realism.
- The NRCS LUTs need improvements to better reproduce the actual measurements: in general, the σ_0 values seem to be underestimated.
- We have identified std. dev. inside the profiles as a parameter to select good calibration points.
- This has to be established with larger amounts of data and comparison with the reference antenna pointing characterization LUT obtained from statistical data over ocean and snow-covered land.

References

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