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High-resolution mapping and modelling of surface albedo in Norwegian boreal forests: from remotely sensed data to predictions

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Surface albedo, a key parameter of the Earth's climate system, has high variability in space, time, and land cover and its parameterization is among the most important variables in climate models. The lack of extensive estimates for model improvement is one of the main limitations for accurately quantifying the influence of surface albedo changes on the planetary radiation balance. We use multi-year satellite retrievals of MODIS surface albedo (MCD43A3), high resolution land cover maps, and meteorological records to characterize albedo variations in Norway across latitude, seasons, land cover type, and topography. We then use this dataset to elaborate semi-empirical models to predict albedo values as a function of tree species, age, volume and climate variables like temperature and snow water equivalents (SWE). Given the complexity of the dataset and model formulation, we apply an innovative non-linear programming approach simultaneously coupled with linear un-mixing.

The MODIS albedo products are at a resolution of about 500 m and 8 days. The land cover maps provide vegetation structure information on relative abundance of tree species, age, and biomass volumes at 16 m resolution (for both deciduous and coniferous species). Daily observations of meteorological information on air temperature and SWE are produced at 1 km resolution from interpolation of meteorological weather stations in Norway. These datasets have different resolution and projection, and are harmonized by identifying, for each MODIS pixel, the intersecting land cover polygons and the percentage area of the MODIS pixel represented by each land cover type. We then filter the subplots according to the following criteria: i) at least 96% of the total pixel area is covered by a single land cover class (either forest or cropland); ii) if forest area, at least 98% of the forest area is covered by spruce, deciduous or pine. Forested pixels are then categorized as spruce, deciduous, or pine dominant if the fraction of the respective tree species is greater than 75%.

Results show averages of albedo estimates for forests and cropland depicting spatial (along a latitudinal gradient) and temporal (daily, monthly, and seasonal) variations across Norway. As the case study region is a country with heterogeneous topography, we also study the sensitivity of the albedo estimates to the slope and aspect of the terrain.

The mathematical programming approach uses a variety of functional forms, constraints and variables, leading to many different model outputs. There are several models with relatively high performances, allowing for a flexibility in the model selection, with different model variants suitable for different situations. This approach produces albedo predictions at the same resolution of the land cover dataset (16 m, notably higher than the MODIS estimates), can incorporate changes in climate conditions, and is robust to cross-validation between different locations.

By integrating satellite measurements and high-resolution vegetation maps, we can thus produce semi-empirical models that can predict albedo values for boreal forests using a variety of input variables representing climate and/or vegetation structure. Further research can explore the possible advantages of its implementation in land surface schemes over existing approaches.