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Evaluating precipitation in a regional climate model using ground-based radar measurements in Dronning Maud Land, East Antarctica

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Occasional very intense snowfall events over Dronning Maud Land (DML) region in East Antarctica, contributed significantly to the entire Antarctic ice sheet surface mass balance (SMB) during the last years. The meteorological-cloud-precipitation observatory running at the Princess Elisabeth station (PE) in the DML escarpment zone since 2009 (HYDRANT/AEROCLOUD projects), provides unique opportunity to estimate contribution of precipitation to the local snow accumulation and new data for evaluating precipitation in climate models. Our previous work using PE measurements showed that occasional intense precipitation events determine the total local yearly SMB and account for its large interannual variability. Here we use radar measurements to evaluate precipitation in a regional climate model with a special focus on intense precipitation events together with the large-scale atmospheric dynamics responsible for these events. The coupled snow-atmosphere regional climate model MAR (Modèle Atmosphérique Régional) is used to simulate climate and SMB in DML at 5-km horizontal resolution during 2012 using initial and boundary conditions from the European Centre for Medium-range Weather Forecasts (ECMWF) Interim re-analysis atmospheric and oceanic fields. Two evaluation approaches are used: observations-to-model and model-to-observations. In the first approach, snowfall rate (S) is derived from the MRR (vertically profiling 24-GHz precipitation radar) effective reflectivity factor (Ze) at 400 m agl using various Ze-S relationships for dry snow. The uncertainty in Ze-S relationships is constrained using snow particle size distribution from Snow Video Imager - Precipitation Imaging Package (SVI/PIP) and information about particle shapes. For the second approach we apply the Passive and Active Microwave radiative TRAnsfer model (PAMTRA), which allows direct comparison of the radar-measured and climate model-based vertical profiles of the radar Ze and Doppler velocity. In MAR, the mass and terminal velocity of snow particles are defined as for the graupel-like snowflakes of hexagonal type, determining single scattering properties for snow hydrometeors used as input (along with cloud particle properties and atmospheric parameters) into PAMTRA.

MAR simulates well the timing of major synoptic-scale precipitation events, while overestimating snowfall rate during the intense precipitation events beyond the Ze-S relationship uncertainty. This bias is also evident in significantly longer tail of the frequency distribution towards high values for MAR synthetic Ze near the surface compared to PE radar. This bias can be related to the differences both in the amount and type of snowflakes reaching the surface. The most intense precipitation event contributing almost 50% to the local yearly SMB occurred on 6 November 2012 and was associated with an atmospheric river. MAR model produced more than twice as much precipitation compared to PE radar measurements on this event. Reasons for this high bias are investigated by looking at the moisture transports, cloud properties (ice/liquid occurrence and cloud vertical structure), and precipitation formation efficiency especially related to the mixed-phase clouds (the Bergeron-Findeisen process).