Accumulation over the Greenland Ice Sheet as Represented in Reanalysis Data

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Mass changes of the Greenland Ice Sheet (GrIS) have potential impact on the global sea level and the ocean thermohaline circulation, and therefore play an important role on the future climate. The GrIS is maintained by the mass balance (MB) between the net accumulation from precipitation/evaporation, and ablation from runoff/ice discharge. To quantify the MB becomes a key to understand to what extent that the GrIS can influence the future climate. Previous studies concluded that accumulation, which is the main source of input to the GrIS, has a significant impact on the surface MB, particularly in the high-elevation or dry-snow region. It also revealed that in a doubled carbon-dioxide concentration scenario (2×CO2), the enhanced accumulation even dominates the surface MB of the GrIS, since the ablation in this scenario does not compensate for the increased accumulation. In the upper accumulation area of the GrIS, the vertical stratigraphy of snow and ice makes it possible to obtain direct estimates of accumulation from ice cores and snow pits. In the lower zones, however, accumulation is not possible to observe, as the mass is partially lost. For these coastal zones, the accumulation is defined as solid precipitation minus evaporation. In Greenland, we mostly collect direct precipitation measurements at the synoptic stations of the Danish Meteorological Institute (DMI) based on gauge observations. These data are sparse, limited to coastal areas, and have their own uncertainties associated with precipitation catch. Measurements of evaporation from the surface of the ice sheet are rare, and in Greenland, there are only four experiments that lasted more than a month. As a result, adequate modeling of precipitation and evaporation is necessary.

Observations are the key resource in producing reanalyses, however, observations are temporally or spatially limited in Greenland. How well the reanalysis data represent the accumulation of the GrIS has led to interest in the intercomparison and validation of output from different reanalysis data. Here we provide a primary evaluation of the annual precipitation, evaporation and accumulation of the GrIS as depicted in reanalysis products from ECMWF, NCEP/NCAR, and NCEP/DOE over the common period of 1989-2001. These reanalysis datasets are called ERA-40, ERA-interim, NCEP1 and NCEP2 respectively. The original ERA-40 data have T159 (≈125 km) resolution, and ERA-interim data have T255 (≈80 km) resolution. However, these datasets are available online in a 2.5º × 2.5º (for ERA-40) and 1.5º × 1.5º (for ERA-interim) regular latitude-longitude grid, respectively. Both NCEP-1 and NCEP-2 data use T62 (≈210 km) resolution. Comparisons are made with in situ measurements obtained from the DMI synoptic stations, the Program for Arctic Regional Climate Assessment (PARCA) ice cores drilled in 1997/1998, and an annual accumulation map based on observations both from synoptic stations and ice cores.
The results tell us that the ERA-40 and ERA-interim have better spatial distributions of precipitation than NCEP-1 and NCEP-2, particularly in their depiction of the moderate precipitation (more than 400 mm yr^{-1}) region along the western flank of Greenland. Evaporation from ERA-40 and ERA-interim has more a reasonable spatial distribution than

that from NCEP-1 and NCEP-2. Accumulation calculated from ERA-interim shows the closest spatial distribution to the observed accumulation. The mean annual precipitation averaged over the whole GrIS from ERA-interim (363 mm w.e.a^{-1}) and mean annual accumulation (319 mm w.e.a^{-1}) are very close to the observations. Concerning temporal variability, ERA-interim showed the best correlation with observed precipitation at five synoptic stations and the best correlation with observed accumulation at nine ice core sites. However, it still overestimates precipitation over the GrIS, especially along the coastal region and also showed the possible systematic errors in the accumulation estimations.

Overall, our work gives useful information about the reliability of the reanalysis data in Greenland area. To different extents, both ERA-interim and NCEP-2 are improvements over ERA-40 and NCEP-1, respectively. In addition, this initial validation suggests that further improvements to reanalysis models are needed.

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