Use of Twentieth Century Reanalysis data in the construction of a new Greenland Ice Sheet surface mass balance record 1870-2009

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Our new 1870-2009 Greenland Ice Sheet (GrIS) surface mass balance (SMB) annual time series was constructed from a combination of Twentieth Century Reanalysis (C20thR) (1870-2008) (Compo et al. 2006 and submitted) and European Centre for Medium Range Weather Forecasts (ECMWF) (Uppala et al. 2005) (1958-2009) meteorological (re)analysis. Surface air temperature, precipitation and surface latent heat flux from both (re)analysis were bilinearly interpolated to a 5x5-km polar stereographic grid (Janssens & Huybrechts 2000, Ekholm 1996). Empirically-derived ice-sheet surface lapse rates were used to correct C20thR and ECMWF modelled surface air temperatures, following the method described in Hanna et al. (2005), and resulting modelled mean summer temperatures were generally within 0.5-1 degC of observed Danish Meteorological Institute (DMI) and Greenland Climate Network (GC-Net) station values. Precipitation output from both C20thR and ECMWF were calibrated against the Bales et al. (2009) kriged precipitation map based on the latest and most comprehensive compilation of ice-core snow accumulation and DMI coastal precipitation data, the latter corrected for wind-catch loss (Bales et al. 2009), to remove spatial biases in the (re)analysis precipitation fields. Modelled snow accumulation time series from both C20thR (1870-2008) and ECMWF (1958-2008) showed statistically significant agreement with long-term annual snow accumulation series from ice cores (Glueck et al. unpublished MS and McConnell et al. unpublished data), in an update to Hanna et al. (2006). C20thR evaporation was unrealistically large, so a rescaling factor with ECMWF mean evaporation was determined for the period of overlap and applied to the pre-1958 period. C20thR precipitation and runoff variability, suppressed by the inherently lower spatial resolution of the C20thR (2x2o) compared with ECMWF (re)analysis (1.125x1.125o), was also rescaled to match that of ECMWF for the 1958-2008 overlap period, to produce a statistically coherent and self-consistent time series. It is assumed that the ECMWF analysis is superior to the C20thR for the common period because of the relative lack of in situ data, mainly restricted to coastal stations around

Greenland, assimilated into both (re)analyses, and the inclusion of some satellite/upper air data in the ECMWF, whereas the C20thR uses solely surface pressure observations and sea-surface-temperature/sea-ice boundary conditions from HadISST1 (Compo et al. 2006): hence we use ECMWF as the default analysis for 1958-2009, and also the C20thR is currently lacking 2009. However, the C20thR shows significant skill in replicating whole-Greenland climate for the pre-1958 period. Our new hybrid SMB series is a significant advance on the 1866-2005 GrIS SMB time series of Wake et al. (2009), who necessarily used only spatio-temporal correlation information from coastal weather stations and ice cores, rather than much more spatially extensive and coherent meteorological (re)analysis data, as a basis for modelling SMB across the ice sheet for the pre-1958 period, as the C20thR has only recently become available (mid-2010 for the whole of Version 2) as a new climatological tool for cryospheric modelling. Uncertainties of modelled SMB are estimated to be 10% for accumulation and 25% for runoff, giving a combined uncertainty of 27%.