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An assessment of historical Antarctic precipitation and temperature trend using CMIP5 models and reanalysis datasets

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ABSTRACT

The study of Antarctic precipitation has attracted a lot of attention recently. The reliability of climate models in simulating Antarctic precipitation, however, is still debatable. This work assess the precipitation and surface air temperature (SAT) of Antarctica (90 °S to 60 °S) using 49 Coupled Model Intercomparison Project phase 5 (CMIP5) global climate models and the European Centre for Medium-range Weather Forecasts "Interim" reanalysis (ERA-Interim); the National Centers for Environmental Prediction Climate Forecast System Reanalysis (CFSR); the Japan Meteorological Agency 55-year Reanalysis (JRA-55); and the Modern Era Retrospective-analysis for Research and Applications (MERRA) datasets for 1979–2005 (27 years). For precipitation, the time series show that the MERRA and JRA-55 have significantly increased from 1979 to 2005, while the ERA-Int and CFSR have insignificant changes. The reanalyses also have low correlation with one another (generally less than +0.69). 37 CMIP5 models show increasing trend, 18 of which are significant. The resulting CMIP5 MMM also has a significant increasing trend of 0.29 ± 0.06 mm year^{-1}. For SAT, the reanalyses show insignificant changes and have high correlation with one another, while the CMIP5 MMM shows a significant increasing trend. Nonetheless, the variability of precipitation and SAT of MMM could affect the significance of its trend. One of the many reasons for the large differences of precipitation is the CMIP5 models' resolution.

1. Introduction

Antarctic precipitation is an important parameter in the discussion of Antarctic surface mass balance (SMB). Precipitation in the Antarctic is greatly influenced by atmospheric dynamic and the interaction with topography (Bromwich, 1988). Snow accumulation in Antarctica is also affected by poleward transient moisture transport associated with cyclone activities (Oshima and Yamazaki, 2004; Peixoto and Oort, 1992; Peixóto and Oort, 1983). Moreover, several studies indicated that "atmospheric river", the intense moisture flux with narrow and filament forms, dominates annual snow accumulations in some regions of the Antarctic (Gorodetskaya et al., 2014; Welker et al., 2014). Rain occasionally falls at coastal regions especially on the western side of the Antarctic Peninsula such as the Adelaide Island (King and Turner, 2007). The Antarctic SMB is maintained by accumulation of precipitation, blowing snow and ice loss due to melting, evaporation and calving of ice along the coast. This balance of snow accumulation and melting will subsequently affect global sea level and oceanic conditions.

The SMB is defined as follow:

$$\text{SMB} = \text{precipitation} - \text{run-off} - \text{evaporation} + \text{blowing snow}.$$

The current method of data collection relies on measurement with limited temporal basis, with distances between measurements exceeding 1300 km (Knuth et al., 2010). This makes instrumental-based measurement of precipitation in Antarctic highly unreliable (Genthon et al., 2003). A non-quantitative method had been developed to measure snowfall by sensing the fluctuation in surface emissivity (Bindschadler et al., 2005). Quantitative Antarctic precipitation detection, on the other hand, had been developed following the installation of the cloud profiling radar (CPR) onboard the CloudSat satellite (Liu, 2008; Stephens et al., 2008). The recent CloudSat products had been incorporated in a study to produce a model-independent, multi-year climatology of Antarctic precipitation north of 82°S (Palerme et al., 2014). However, the CloudSat product started only in 2008 and could not be used to compare with CMIP5 nor the ERA-Interim (ERA-Int) for the historical study starting from 1979. Nicolas and Bromwich (2011) used monthly mean precipitation from the Global Precipitation Climatology Project Version 2 (GPCP) to study the precipitation changes in

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