Abstract

Over Antarctica, short-lived extremes in wind, precipitation, and near-surface temperature influence surface mass balance by affecting snow accumulation, snow redistribution, meltwater production, and ice-shelf stability. This thesis uses a combination of in-situ observations, reanalysis, and outputs from regional climate model (RCM) and global climate model (GCM) simulations to address key four knowledge gaps in Antarctic weather extremes, especially concerning the physical mechanisms driving low-level jets (LLJs), extreme precipitation events (EPEs), and compound warm–wet extremes (CWWEs).

Firstly, this thesis shows that LLJs over the Amundsen Sea Embayment (ASE) region of West Antarctica occur in about half of the radiosonde profiles, are mostly directed offshore, and are reasonably represented by the RCM. These LLJs are mainly produced when katabatic winds are strengthened by synoptic forcing associated with a low-pressure system over the Bellingshausen Sea, and they extend across the ASE ice shelves and adjacent ocean. Secondly, the first four leading circulation modes explain 93.7% of EPE days at two coastal stations in the ASE, with a coupled Amundsen Sea Low and blocking-high pattern to the east as the dominant driver, accounting for 44.75% of EPE days. El-Nino Southern Oscillation-related variability, enhanced atmospheric river (AR) activity, and the Southern Annular Mode contribute 22.16%, 21.1%, and 12%, respectively. Thirdly, significant positive changes in total and extreme precipitation are identified across six Antarctic drainage basins, and detection and attribution analysis using GCM large ensemble simulations shows that combined anthropogenic and natural forcings are responsible for these changes, with greenhouse gases and stratospheric ozone depletion emerging as important external drivers. Fourthly, CWWEs are shown to occur on one or two occasions each summer over West Antarctic ice shelves and are driven by a low-high pressure couplet and ARs, which support warm and moist air transport toward the ice shelves. Future simulations show that the precipitation and near-surface temperature thresholds for CWWEs increase markedly in the future, with the thresholds for temperature often exceeding the melting point by the late 21st century, indicating greater potential for surface melting and rainfall over these ice shelves.