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Climatology, variability and change in polar planetary boundary layers

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The planetary boundary layer (PBL) controls important climate processes, including surface energy and moisture fluxes, cloud formation, and ozone chemistry. In polar regions, the PBL frequently exhibits surface-based inversions (SBI), which influence these processes by inhibiting vertical mixing and de-coupling the surface from the free troposphere. However, because of differences in the spatial and temporal scales of interest in PBL meteorology and climate science, the intersection of these two sub-disciplines of atmospheric science has not been fully explored. Climatological polar PBL and SBI properties have not been fully characterized, nor have climate model simulations been compared comprehensively to observations. Using radiosonde and ERA-Interim reanalysis data, and simulations by two climate models (NCAR-CAM3 and GFDL-AM3), we explore the climatology, variability and trends in SBIs in the Arctic and Antarctic over the past two decades (1990-2009). Building on previous studies, we examine three SBI characteristics - frequency of occurrence, depth (from the surface to the inversion top), and intensity (temperature difference over the SBI depth) - and relationships among them. In both polar regions, SBIs are more frequent, deeper, and stronger in winter and autumn than in summer and spring. In the Arctic, these tendencies increase from the Norwegian Sea eastward toward the East Siberian Sea, associated both with (seasonal and diurnal) variations in solar elevation angle at the standard radiosonde observation times and with differences between continental and maritime climates. The two climate models and one reanalysis dataset show similar seasonal patterns and spatial distributions of SBI properties as the radiosonde observations, but with biases in their magnitudes that differ among the models and that are smaller in winter and autumn than in spring and summer. The three SBI characteristics exhibit generally positive seasonal, spatial, and (more weakly) interannual correlations, and negative correlations with surface temperature. Trends in polar SBI characteristics are difficult to assess, because changes in radiosonde data processing methods (from manual data recording, to early automated methods, to current computer-based methods) have led to increases in the vertical resolution of atmospheric profiles. Derived SBI depth and intensity, and to a lesser extent frequency, time series show artificial discontinuities associated with these data processing changes. We present estimates of SBI trends at the few Arctic stations with homogeneous records for the periods 1990-2009 and 2000-2009, during which remarkable trends in surface temperature and sea ice have been widely reported.