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Analysis of anomalously low surface air temperature in the Northern Hemisphere during the winter of 2009/2010

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Using NCEP/NCAR reanalysis data, the anomalously low surface air temperature (SAT) and the corresponding atmospheric circulation anomalies in the Northern Hemisphere (NH) during the winter (DJF) of 2009/2010 are analysed. Surface air temperature anomalies (SATA) were zonally distributed with a "positive-negative-positive" pattern from the tropical to the polar region which was characterized by positive SATA in both low and high latitudes, and negative SATA in middle latitudes. The coldest SATA were located in Eurasia and eastern USA, and in some regions the SATA exceeded -4^{o}C. Compared with the average of last 15 years, the SAT in middle latitudes decreased almost 1^{o}C, and in Eurasia the SAT even decreased 8^{o}C. The anomalous feathers of the horizontal circulation indicated that, both the sea level pressure (SLP) and the geopotential height fields exhibited positive anomalies in high latitudes and negative anomalies in lower latitudes, associated with anticyclonic circulation anomalies in the polar region and cyclonic circulation anomalies in the subtropical region. The horizontal circulation anomalies were characterized by an equivalent barotropic structure in the vertical direction. The anomalous feathers of zonal mean meridional circulation indicated that, the Ferrel Cell was weaker, consisting of an anomalous ascending motion in middle latitudes and an anomalous descending motion in higher latitudes. Meanwhile, the tropospheric air was colder than normal in middle latitudes but warmer in higher latitudes, associated with a stronger jet in the subtropics and a weaker jet in the polar region. Composite and correlation analysises between the Northern Hemisphere Annular Mode (NAM) and the SATA indicate that, during the positive (negative) phase of NAM, warm (cold) anomalies exit in middle latitudes, and the correlation is most significant in Eurasia and eastern USA with nearly 2^{o}C warming (cooling) in some regions. Analysis of the air temperature equation shows that meridional temperature advection anomalies caused by the anomalous meridional wind plays an important role in the variation of the local temperature, and its distribution resembled the SATA pattern closely in 2009/2010 winter. With composite and correlation analysises, the mechanism for the relationship between the NAM and the SATA is investigated. During the positive phase of the NAM, the Ferrel Cell is anomalously stronger than normal and the air mass between the polar and lower regions exchanges. Therefore, positive SLP anomalies exit in the middle latitudes and negative anomalies lie in the higher latitudes, which forces southerly surface wind anomalies in the subtropical region. As a result, the meridional temperature advection is enhanced, which results in the warmer SAT in middle latitudes. The situation is opposite during the negative phase of the NAM. The above-mentioned physical mechanism reveals that the SAT in the NH middle latitudes is almost modulated by the NAM as a natural variability.