The anomalous atmospheric circulations in the 2009/2010 winter caused extreme weather events globe-wide. The winter was timed after the prolonged 2007-2009 11yr solar cycle minimum, when was in the negative phase of the current 88yr solar cycle. Whether the anomalous winter and the peculiar solar minimum just happened coincidentally, or whether there were physical and dynamical relationship between them, is the focus of the present work based on data analysis using NCEP/NCAR Reanalysis data. Results show that the anomalous winter atmospheric circulations in the 2009/2010 winter were greatly influenced by the solar cycle minimum. Two fundamental influence paths from solar activity to atmospheric wave activity are presented. First, the solar minimum could enhance the mid-lat meridional temperature gradient (or baroclinicity) and, therefore, prefer the longer waves to develop over shorter ones. Second, the solar minimum could enhance the land-ocean contrast in wintertime and, therefore, the topographic waves. When the mid-lat baroclinicity is enhanced to a degree that wavenumber 1-3 traveling waves are amplified, the large-amplitude topographic waves may resonate. Such a process may lead to stronger troposphere-stratosphere interaction. Intensive stratospheric sudden warming events and the tropospheric blocking situations were observed during the winter, with vigorous meridional exchange of heat, energy and moisture. These physical and dynamical processes largely explain the influence of the 2007-2009 solar minimum on the extreme weather events in the 2009/2010 winter. The coexisting El Nino Modoki in the central tropical Pacific provides abundant moisture, causing several record-breaking snowfall events in North America, Europe and Northeast Asia.