Supplementary Material

The HiRAM underestimation could be accounted for due to the role of ENSO-induced stratospheric polar vortex variation (weakening or strengthening) following strong or weak ENSO (El Nino and La Nina) events and associated NAO-like pattern. The stratospheric polar vortex and associated NAO-like response are underestimated in HiRAM, like other global models, and therefore the associated temperature (i.e., cooling) response following El Nino in the arctic region is also underestimated in HiRAM compared to CFSR. As polar vortex changes originates in stratosphere that moves to surface through tropospheric–stratospheric interactions. These polar vortex changes (strengthening or weakening) following ENSO events effects polar jets that in turn produce strong changes in the mid-latitude and polar regions. HiRAM have lower model top (that covers lower stratosphere only, model top reaches 10 hPa) compared to CFSR (that covers entire stratosphere, model top reaches 0.1 hPa), which could be one of the reason that the HiRAM underestimates weakening (i.e., breakdown) or strengthening of polar vortex and associated NAO-like response following strong and weak ENSO forcing. Following supplementary Figure S1 shows the Geopotential Height anomaly following two strong ENSO events (i.e., composited for winter 1982-83 and winter 1991-92). HiRAM underestimation is clearly seen. Supplementary Figure S2 shows the SLP and Geopotential Height anomalies at 850 mb, which are also underestimated in HiRAM response compared to NCEP reanalysis. These Figures enhance our understanding regarding HiRAM underestimation following ENSO forcing as HiRAM model shows weaker response to ENSO induced polar vortex and associated NAO-like pattern (Figure S1, Figure S2). Hatching shows the statistically significant areas with at least 95% confidence level evaluated using Student t-test. We have added relevant text at Page 7, lines 25-37 and Page 8, lines 1-3.

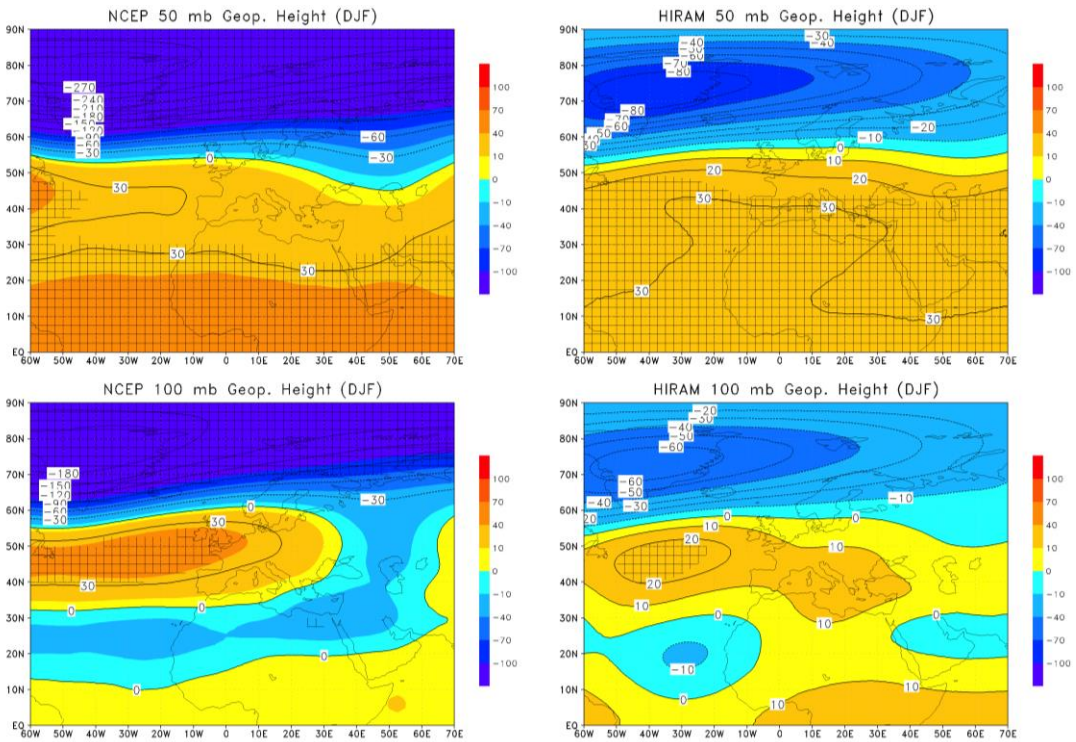

Figure S1: Geopotential Height anomaly at 50 mb and 100 mb that covers lower stratosphere, following two strong ENSO events (i.e., composited anomaly for winter 1982/1983 and winter 1991/1992). Left panel is from NCEP reanalysis and right panel is produced from HiRAM simulation. Anomalies are calculated with respect to the seasonal winter climatology, calculated for the 30-year period 1979–2008 but excluding the winter period of two ENSO events (i.e., winter 1982/1983 and winter 1991/1992). Hatching shows the statistically significant areas with at least 95% confidence level.

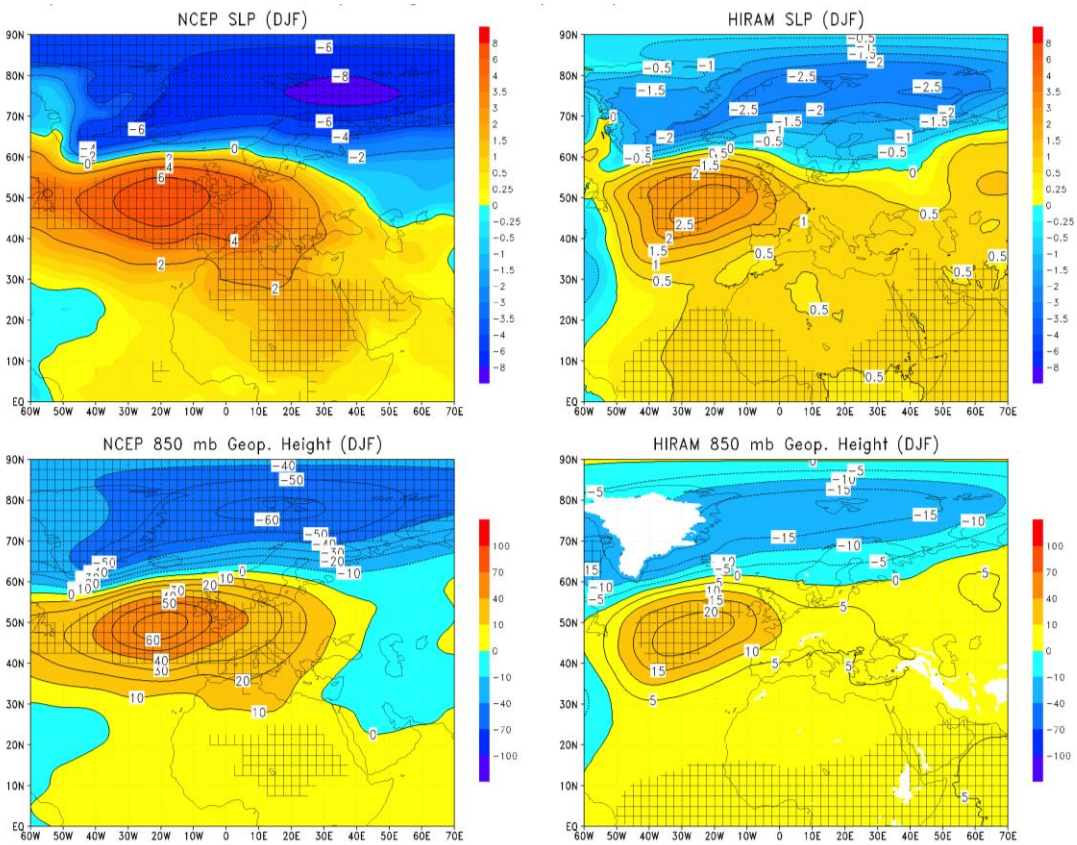

Figure S2: SLP and 850mb Geopotential Height anomaly, following two strong ENSO events (i.e., composited for winter (DJF) period of 1982/1983 and 1991/1992 ENSO events). Left panel is produced using NCEP reanalysis and right panel is produced from HiRAM simulation. Anomalies are calculated with respect to the seasonal winter climatology, calculated for the 30-year period (1979–2008) but excluding the winter period of two ENSO events (i.e., winter 1982/83 and winter 1991/1992). Hatching shows the statistically significant areas with at least 95% confidence level.