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Upper tropospheric and lower stratospheric ENSO signal derived from GPS radio occultation temperature

B. Scherllin-Pirscher (1,2,3), C. Deser (2), S.-P. Ho (3), C. Chou (4), W. Randel (2), and Y.-W. Kuo (3)

(1) Wegener Center for Climate and Global Change (WEGC) and Institute for Geophysics, Astrophysics, and Meteorology (IGAM), University of Graz, Graz, Austria (barbara.pirscher@uni-graz.at), (2) National Center for Atmospheric Research, Boulder, Colorado, USA, (3) University Corporation for Atmospheric Research, Boulder, Colorado, USA, (4) Research Center for Environmental Changes, Academia Sinica, Taipei, Taiwan

We use radio occultation (RO) temperature data from CHAMP, GRACE, and Formosat-3/COSMIC (F3C) to detect the El Niño-Southern Oscillation (ENSO) signal in the troposphere and lower stratosphere. Merging data of all satellites, we calculate monthly mean climatologies with a horizontal resolution of 5° latitude and 5° longitude and a vertical spacing of 100 m from the surface up to 20 km. A sufficient number of profiles (>40000 profiles per month) is available since August 2006, when F3C measurements became available.

The investigation of temperature anomalies (anomalies are obtained from subtracting the mean annual cycle) in the equatorial region up to 16 km yields a natural split into zonal-mean and eddy (deviations from the zonal-mean) ENSO components. EOF1 is dominated by the zonally-symmetric component where positive sea-surface temperature anomalies come along with warm tropospheric temperatures. It explains almost 70 % of total variance. The corresponding PC1 is highly correlated with the Nino 3.4 index (correlation equals 0.85 at a lag of 3 months). EOF2, which is dominated by the eddy ENSO signal, explains more than 7 % of total variance. PC2 is almost perfectly correlated with the Nino 3.4 index (correlation equals 0.95 at a lag of 0 months). Due to these findings we separate data into zonal-mean and eddy temperature fields and apply PCA and multiple linear regression analysis separately to both fields.

Taking advantage of the high vertical resolution of RO data, we show that the node of the positive and negative zonal-mean ENSO signal occurs around the tropopause. Relative to the surface ENSO signal, the atmospheric zonal-mean signal is lagged by 3 months. At low latitudes equatorwards of about 30°, the eddy ENSO signal is characterized by an east-west dipole centered slightly westward to the date line. The vertical node to a reversed east-west dipole occurs at approximately 14.5 km altitude, which is well below the tropopause. At tropospheric mid latitudes, the eddy ENSO signal is out-of-phase with the low latitude signal. The vertical transition of positive/negative ENSO responses occurs at approximately 11 km in the southern hemisphere, slightly lower in the northern hemisphere. These coherent signals are evidence that atmospheric zonal-mean and eddy ENSO responses are modulated through different physical mechanisms.