Rapid Desiccation of the Stratosphere in 2016: Connection to an Anomalous Change in the QBO

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The quasi-periodic cycle of alternating westerly and easterly zonal winds in the tropical stratosphere, better known as the quasi-biennial oscillation (QBO), alters the stratospheric distributions of water vapor, ozone and other trace gases. The switch between QBO phases manifests itself as changes in tropical upwelling and the temperature of the tropical stratosphere. These inter-annual QBO changes have occurred in a fairly repeatable way since records began in 1953, with one exception: the 2015/2016 cycle. At the end of 2015, easterly winds had begun their expected downward propagation in the tropics, reaching 15 hPa by early 2016. However, in January 2016 this normal progression was curtailed by an anomalous upward displacement of the existing westerlies between 15 and ~30 hPa, and easterly winds suddenly appeared at ~30 hPa. These "early" easterlies continued their downward propagation during 2016, cooling the tropical tropopause and dramatically decreasing water vapor in the tropical lower stratosphere.

Annual and inter-annual variations in tropical lower stratospheric water vapor are generally attributed to the seasonal and QBO-induced cycles of tropical tropopause temperatures, respectively (see Figure 1). Extremes in these variations occur when the annual and inter-annual cycles of tropical coldpoint temperatures are constructively superimposed. In 2016 the cooling of the tropical tropopause by "early" QBO easterlies was augmented by the normal seasonal cooling during the latter half of the year. Tropical tropopause temperatures dropped 2.5°C during 2016 and tropical lower stratospheric water vapor mixing ratios fell 1.9 ppmv, 40% of the average December mixing ratio at 83 hPa. The strongest dry tropical anomalies, spanning the Indian Ocean from Africa to Indonesia, may have been intensified by enhanced convection driven by La Niña conditions. By December 2016 the desiccated tropical air had been transported poleward and upward, drying the subtropical lower stratosphere and advecting a dry layer to higher altitudes.

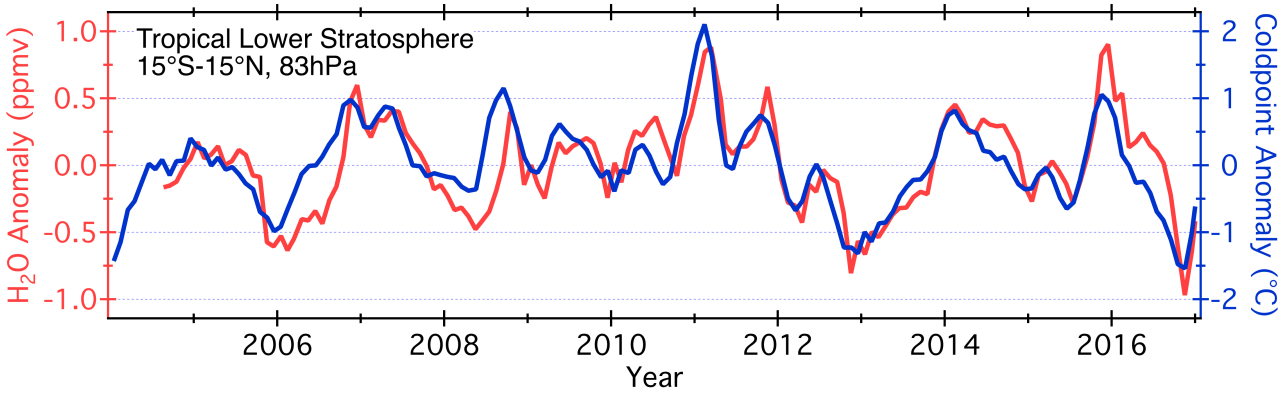

Figure 1. Water vapor anomalies in the tropical lower stratosphere are based on monthly zonal averages of Aura Microwave Limb Sounder retrievals (red). Tropical coldpoint temperature anomalies, based on the MERRA2 reanalysis (blue), slightly precede and correspond well with the water vapor anomalies. There were rapid and large declines in both anomalies during 2016.