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Stratospheric Response to 11-Year Solar Forcing: Evidence for Coupling to the Troposphere-Ocean Response

Lon Hood and Boris Soukharev
Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona, USA (lon@lpl.arizona.edu)

Observational studies of stratospheric ozone and temperature records obtained since the onset of continuous global satellite measurements in late 1978 indicate the existence of statistically significant responses to 11-year solar UV forcing at tropical and subtropical latitudes. In addition to an upper stratospheric response that is attributable to direct photochemical and radiative forcing, a significant variation is also observed in the lower stratosphere that appears to be dynamical in origin and is much less well understood. Here, we present evidence that the observed lower stratospheric response at low to middle latitudes is produced at least in part by a modulation of the Brewer-Dobson circulation that is in turn forced primarily by an associated response of the troposphere-ocean system.

To characterize the troposphere-ocean response, a multiple regression (MR) statistical analysis is applied to Hadley Center sea surface temperature and sea level pressure data over the 1979-2009 time period. SST and SLP solar regression coefficients are determined as a function of phase lag relative to the solar cycle by shifting the time series at one-year increments. For this time period, it is found that the NH winter (DJF) SST anomalies exhibit a La Niña-like solar response beginning 3 to 4 years prior to solar maxima, transitioning to an El Niño-like response at and several years after solar maxima. MR analysis of NCEP reanalysis daily meridional eddy heat flux data near 20 hPa over the 1979-2009 period yields evidence for a corresponding decadal variation of extratropical wave forcing that peaks several years after solar maxima when the troposphere-ocean response is El Niño-like. The increased wave forcing following solar maxima accelerates the Brewer-Dobson circulation, which increases the upwelling rate in the tropics and midlatitude summer hemisphere. The increase in upwelling rate produces negative ozone tendencies in the lower stratosphere. Conversely, during the years leading up to solar maxima when the troposphere-ocean response is La Niña-like, a decrease in upwelling rate occurs and produces positive ozone tendencies. Analytic models suggest that the observed decadal variation of wave forcing is sufficient to explain most of the observed solar cycle variation of lower stratospheric ozone. The observed lower stratospheric temperature response is likely to be partly dynamical in origin and partly a consequence of increased radiative heating associated with the ozone response.