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SPARC SOLARIS & HEPPA intercomparison activities: Possible feedbacks of the Pacific climate response to 11-year solar forcing on lower stratospheric ozone at tropical and subtropical latitudes

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Continuous global satellite measurements beginning in late 1978 exhibit a decadal variation of total column ozone and temperature at tropical and subtropical latitudes that is approximately in phase with the solar cycle. Analyses of ozone profile and temperature records show that the solar cycle response in the tropics consists of a maximum in the upper stratosphere - apparently a direct photochemical and radiative response to UV forcing - and a second maximum in the lower stratosphere. The lower stratospheric maximum has a primarily dynamical origin and is mainly responsible for the decadal column ozone variation. Most current mechanisms for explaining a solar cycle variation in the lower stratosphere involve "downward control" from the upper stratosphere. However, it is also possible that "feedbacks from below" are a major contributing cause if there is a significant 11-year variation of the troposphere-ocean system. To investigate the existence of a troposphere-ocean response, a multiple linear regression (MLR) statistical analysis is applied to Hadley Center sea surface temperature (SST) and sea level pressure (SLP) data over the 1880-2009 period. To minimize possible aliasing from ENSO, a lagged ENSO term is included in the statistical model. In addition, the reproducibility of the SST and SLP solar regression coefficients is tested by carrying out separate regression analyses for different time periods (e.g., 1880-1945 and 1946-2009). In agreement with previous authors, results indicate a statistically significant and repeatable surface climate response to 11-year solar forcing in the North Pacific region during winter. Specifically, a broad positive SLP response anomaly is obtained during years near and approaching solar maxima in the North Pacific centered south of the Gulf of Alaska with an amplitude of 2 to 4 hPa on average during boreal winter. This positive anomaly has the effect of weakening the Aleutian low and shifting it slightly westward. An associated SST response is also obtained, characterized by positive and negative anomalies in the North Pacific. Next, we investigate whether the observed Pacific climate response can produce a change in tropical upwelling rates, which would modify ozone concentrations in the lower stratosphere. One indication that this hypothesis is true is that the observed positive SLP response near solar maxima occurs in the same region where a positive change in the NiÒa 3.4 ENSO index produces a pronounced negative SLP response. It is well established that an increase in N3.4 during an El Niño produces an increase in wave forcing, an acceleration of the Brewer-Dobson circulation (BDC), and negative ozone tendencies in the tropical lower stratosphere. The observed positive SLP response anomaly is therefore consistent with a La NiÒa-like response to solar forcing, which would produce reduced tropical upwelling rates and ozone increases approaching solar maxima. To test this hypothesis further, we consider lower stratospheric meridional eddy heat flux (v'T') calculated from daily NCEP/NCAR reanalysis data over the 1979-2009 period. The eddy heat flux is a close proxy for the extratropical planetary wave flux, which is known empirically to be a good indicator of the strength of the BDC. Correlative studies show that SLP in the region south of the Gulf of Alaska correlates negatively with zonally averaged extratropical heat flux at 20 hPa. Moreover, a decadal variation of 35-month running averages of extratropical v'T' is observed with troughs occurring near and approaching solar maxima and peaks occurring several years before solar minima. Analytic models suggest that this decadal variation of wave forcing and associated changes in the BDC contribute substantially to the observed solar cycle variation of lower stratospheric ozone.