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Control of UTLS ozone by the seasonal variation of equivalent length: Present and future climate

John Gille†; Svetlana Karol; Douglas Kinnison; Rolando Garcia; Bruno Nardi; Valery Yudin
† Univ. of Colorado/NCAR, USA
Leading author: Gille@ucar.edu

Ozone in the upper troposphere/lower stratosphere (UTLS, alternatively designated the upper tropical troposphere and lowermost stratosphere) is very important for Earth's radiative balance. It is therefore important to ensure that we understand the processes that maintain its distribution, and how they may change in future climate scenarios. Isentropic exchange between the troposphere and lowermost stratosphere is possible in principle, but is limited by potential vorticity gradients. The High Resolution Dynamics Limb Sounder (HIRDLS) on NASA's Aura spacecraft has recently made near-global measurements of ozone with 1 km vertical resolution. These have been used with meteorological analyses to evaluate the Equivalent Length (EqL) on potential temperature surfaces as a function of equivalent latitude in the UTLS region. (In this approach, large scale stirring of a quantity distorts and lengthens its contours, across which small-scale mixing can take place. The greater the EqL, the more rapid the mixing, and vice versa.) Baroclinic waves drive the sub-tropical jets (STJ), and create regions of low EqL, and thus strong barriers to mixing between stratosphere and troposphere in winter, but these become much weaker in summer. Ozone descending at high latitudes due to the Brewer-Dobson circulation builds up in winter, when mixing is inhibited, creating large differences between high and low latitudes. In summer the weak barrier allows ozone to mix rapidly to low latitudes. One result is that the slope of ozone mixing ratio vs equivalent latitude on potential temperature surfaces is much steeper in winter than in summer. This leads to an out-of-phase relationship between the winter maximum at high latitudes, and a summer maximum at low latitudes, as observed. Simulations suggest that projected climate change will strengthen the STJ, resulting in even stronger barriers in winter, and possibly continuing into the summer, so that high latitude ozone builds up, mixing very slowly to low latitudes. This will lead to larger ozone mixing ratios at high latitudes and lower values in the tropics. To accommodate this, the balances between chemical and dynamical processes in both places will need to change. We present preliminary results of testing these ideas by analyzing climate simulations made with the NCAR Whole Atmosphere Community Climate Model (WACCM).