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# Long-term changes and variability in a transient simulation with a CCM

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A transient simulation with the interactively coupled chemistry-climate model (CCM) E39/C has been carried out which covers the 60-year period between 1960 and 2020. Forcing of natural and anthropogenic origin is prescribed where the characteristics are sufficiently well known and the typical timescales are slow compared to synoptic timescale so that the simulated atmospheric chemistry and climate evolves under a 'slowly' varying external forcing. Based on observations and predictions of a coupled atmosphere ocean model, sea surface temperature (SST) and ice cover, with regard to a monthly mean basis, are prescribed. The increase of well-mixed greenhouse gas and chloroflurocarbon concentrations, as well as nitrogen oxide emissions is taken into account. The 11-year solar cycle is considered in the calculation of heating rates and photolysis of chemical species. The three major volcanic eruptions during that time (Agung, 1963; El Chichon, 1982; Pinatubo, 1991) are considered. The quasi-biennial oscillation (QBO) is forced by linear relaxation, also known as nudging, of the equatorial zonal wind in the lower stratosphere towards observed zonal wind profiles. Beyond a reasonable reproduction of mean parameters and long-term variability characteristics there are many apparent features of episodic similarities between simulation and observation. For example, in mid-latitudes of the Southern Hemisphere ozone anomalies, especially in 1985, 1989, 1991/92, and 1996, resemble the corresponding observations. In the Northern Hemisphere, the first half of the 1990s is dynamically quiet, no stratospheric warming is found for a period of at least 6 years. As observed, volcanic eruptions strongly influence dynamics and chemistry, though only for few years. Obviously, planetary wave activity is strongly driven by the prescribed SST and modulated by the QBO. The solar cycle also effects the modulation of dynamics and chemistry of the lower stratosphere. Preliminary evidence of realistic cause and effect relationships strongly suggest that detailed process-oriented studies

will be a worthwhile endeavor.