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# Long-term changes and variability in a transient simulation with a chemistry-climate model employing realistic forcing

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Abstract. A transient simulation with the interactively coupled chemistry-climate model (CCM) E39/C has been carried out which covers the 40-year period between 1960 and 1999. 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 evolve under a "slowly" varying external forcing. Based on observations, sea surface temperature (SST) and ice cover are prescribed. The increase of greenhouse gas and chlorofluorocarbon concentrations, as well as nitrogen oxide emissions are 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: In the years 1986 and 1988 the Antarctic ozone holes are smaller than in the other years of that decade. In mid-latitudes of the Southern Hemisphere ozone anomalies resemble the corresponding observations, especially in 1985, 1989, 1991/1992, and 1996. In the Northern Hemisphere, the episode between the late 1980s and the first half of the 1990s is dynamically quiet, in particular, no stratospheric warming is found between 1988 and 1993. 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. Preliminary evidence of realistic cause and effect relationships strongly suggests that detailed process-oriented studies will be a worthwhile endeavour.

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