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Use of the HadGEM2 climate-chemistry model to investigate interannual variability in methane sources

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The global mean atmospheric concentration of methane (CH_4) has more than doubled during the industrial era [1] and now constitutes ≈20% of the anthropogenic climate forcing by greenhouse gases [2]. The globally-averaged CH_4 growth rate, derived from surface measurements, has fallen significantly from a high of 16 ppb yr^{-1} in the late 1970s/early 1980s and was close to zero between 1999 and 2006 [1]. This overall period of declining or low growth was however interspersed with years of positive growth-rate anomalies (e.g., in 1991-1992, 1998-1999 and 2002-2003). Since 2007, renewed growth has been evident [1, 3], with the largest increases observed over polar northern latitudes and the Southern Hemisphere in 2007 and in the tropics in 2008. The observed inter-annual variability in atmospheric methane concentrations and the associated changes in growth rates have variously been attributed to changes in different methane sources and sinks [1, 4].

In this paper, we report results from runs of the HadGEM2 climate-chemistry model [5] using year- and month-specific emission datasets. The HadGEM2 model includes the comprehensive atmospheric chemistry and aerosol package, the UK Chemistry Aerosol community model (UKCA, http://www.ukca.ac.uk/wiki/index.php). The Standard Tropospheric Chemistry scheme was selected for this work. This chemistry scheme simulates the O_x, HO_x and NO_x chemical cycles and the oxidation of CO, methane, ethane and propane.

Year- and month-specific emission datasets were generated for the period from 1997 to 2009 for the emitted species in the chemistry scheme (CH_4, CO, NO_x, HCHO, C_2H_6, C_3H_8, CH_3CHO, CH_3CHOCH_3). The approach adopted varied depending on the source sector:

- **Anthropogenic**: The emissions from anthropogenic sources were based on decadal-averaged emission inventories compiled by [6] for the Coupled Carbon Cycle Climate Model Intercomparison Project (C4MIP). These were then used to derive year-specific emission datasets by scaling the emission totals for the different years and source sectors using sector and species-specific scaling factors based on the annual trends given in various EDGAR time series: (a) version 4.2 for all species (except NMVOCs) and version 4.1 for NMVOCs; (b) v3.2. This approach was also applied to the emissions from aviation (only for oxides of nitrogen) and international shipping.
- **Biomass burning**: Month-specific emission inventories are available from the Global Fire Emissions Database (GFED, v3.1) for the years 1997 to 2009 [7]. The emissions were rescaled to give the same decadal mean as used in the Hadley Centre's earlier HadGEM2 runs (25 Tg CH_4 per annum).
- **Other**: Sources such as termites and hydrates for methane were taken from the GEIA website and the dataset of Fung et al. [8]. The datasets contain a single annual cycle, which was assumed to apply for all years.

For CH_4, there are also emissions from wetlands. These were either based on the dataset of Fung et al. [8] or derived from the JULES (Joint UK Land Earth Simulator) land surface model [9, 10]. The standard version of JULES uses a simple methane wetland emission parameterization, developed and tested by [11] for use at large spatial scales.

The surface concentrations from the different model runs have been compared to surface atmospheric CH_4 measurements. In addition, growth rates have been derived. These comparisons will be reported and used to assess the contribution of different methane sources to the interannual variations in the methane growth rate.

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