ECHAM-HAMMOZ echam6.3.0-ham2.3-moz1.0:
Brief description and reference publications

Model release page:

https://redmine.hammoz.ethz.ch/projects/hammoz/wiki/Echam630-ham23-moz10

General overview of the model

The ECHAM-HAMMOZ model version **echam6.3.0-ham2.3-moz1.0** is based on the **ECHAM6** global climate model (Stevens et al., 2013) and the sub-model for tropospheric aerosols **HAM** (Stier et al., 2005; Zhang et al., 2012, Kokkola et al., 2008; Bergman et al., 2012) and the sub-model for trace gas chemistry **MOZ** (Schultz et al., in preparation).

The **HAM sub-model** predicts the evolution of sulfate (SU), black carbon (BC), particulate organic matter (POM), sea salt (SS), and mineral dust (DU) with the size distribution of this aerosol population being described by seven log-normal modes with prescribed variance as in the **M7 aerosol module** (Vignati et al., 2004; Stier at al., 2005; Zhang et al., 2012). The prognostic variables are the particle number concentration of each mode, as well as the mass concentration of each compound present in that mode. As an alternate to M7, HAM also includes the **aerosol microphysics module SALSA** which uses the sectional approach for representing the aerosol size distribution. SALSA includes all chemical components of HAM but also includes the volatility basis set (VBS) approach for secondary organic aerosol (Kühn et al., in preparation).

The **MOZ sub-model** describes the trace-gas chemistry of ozone and related species for the troposphere and stratosphere. The Jülich Atmospheric Mechanism (**JAM002**) contains 258 species, and 617 reactions, 125 of which are photolysis reactions. The mechanism is a blend of the stratospheric chemistry from WACCM (Kinnison et al., 2007) and the tropospheric chemistry from MOZART 4 (Emmons et al., 2012) with additions from MPI Chemistry in Mainz and Forschungszentrum, Jülich. These changes include: extended isoprene mechanism including recent discoveries, explicit degradation of benzene, toluene, and lumped xylenes, explicit initial oxidation step of 5 individual terpene species, and various minor updates to gas-phase and heterogeneous reactions. Heterogeneous reactions in the stratosphere are treated according to Kinnison et al., 2007. Tropospheric heterogeneous chemistry is described in Stadtler et al, in preparation. Gas-phase mixing ratios of ozone, CH_4, CO_2, O_3, N_2O and CFCs from MOZ are used in the radiative transfer equations of ECHAM by default. Water vapor arising from the stratospheric oxidation of methane is also returned back to ECHAM.

Alternatively, the MOZ sub-model can run with a simplified chemical mechanism, the GEOMAR Atmospheric Mechanism (**GAM001**). The mechanism is based on the chemical mechanism used in ECHAM5-HAMMONIA (Schmidt et al., 2006) with minor adjustments for HAMMOZ. The GAM001 mechanism focuses on the stratospheric and mesospheric chemistry, and uses a simplified tropospheric chemistry compared to the Juelich Atmospheric Mechanism. GAM001 uses 48 compounds, 46 photolyses, and in total 174 reactions. It is not part of the default distribution of HAMMOZ (explanations on how to build and use it can be found in https://redmine.hammoz.ethz.ch/projects/hammoz/wiki/How_to_build_GAM).

Emissions

- Prescribed emissions:
    - A detailed description of prescribed emission fields for use in HAMMOZ are available under:
      https://redmine.hammoz.ethz.ch/projects/hammoz/wiki/3_V0002.
    - The prescribed emissions for aerosols and aerosol precursors include anthropogenic and biomass burning emissions.

- Online computation of aerosol and aerosol precursors:
    - Emissions of sea salt are computed interactively following Long et al. (2011) taking into account temperature dependence according to Sofiev et al (2011) (recommended for using HAM-M7), or alternatively following Guelle et al. (2001) and Stier et al. (2005)
    - Dust emissions are computed interactivity following Stier et al. (2004) based on Tegen et al. 2002) with updated Asian soil properties as described in Cheng et al. (2008) . For Saharan dust sources a satellite-based source mask is implemented (Heinold et al., 2016). Regional tuning factors are included to calibrate dust emissions from the main dust source regions.
    - Natural emissions of dimethyl sulfide (DMS) from the marine biosphere are calculated online following Kloster et al. (2006).
    - Biogenic emissions of several short-lived VOC, NOx, etc. are calculated with an implementation of the MEGAN2.1 model (Guenther et al., 2012; Henrot et al., 2017)
    - SOA emissions are prescribed according to AEROCOM as described in Dentener et al. (2006) (http://themasites.pbl.nl/en/themasites/edgar/index.html)
    - SALSA uses the MEGAN model for SOA precursor emissions
- Emission vertical resolution (see annex 1)
- Aerosol emission size ranges for the M7 aerosol microphysics scheme (see annex 2)

Oxidant fields

- Oxidant fields (OH, O_3, NO_3, NO_2, H_2O_2) are a multi-year average taken from the MACC system (Flemming et al., 2009) as described in Inness et al., 2012. Note that these are not used when HAM and MOZ are run jointly, but instead the oxidant concentrations are then calculated by the MOZ module.

- A detailed description of the oxidant field data can be found at https://redmine.hammoz.ethz.ch/projects/hammoz/wiki/3_V0002

Aerosol- and cloud-related schemes

- The sulfur chemistry module is based on sulfur cycle model described in Feichter et al. (1996).

- Below-cloud scavenging by rain and snow follows Croft et al. (2009).

- In-cloud scavenging (nucleation and impaction) follows Croft et al. (2010).

- Aerosol water uptake scheme follows the Kappa-Koehler theory based approach following Petters and Kreidenweis (2007) as described in Zhang et al. (2012).

- The nucleation scheme follows Kazil and Lovejoy (2007) as described in Kazil et al. (2010)

- Organic nucleation scheme based on Kulmala et al. (2006) is included.

- Cloud microphysics are described with a 2-moment scheme described in Lohmann et al., (2007) and Lohmann and Hoose (2009). A 1-moment scheme is also available (Lohmann and Roeckner, 1996).

- The stratiform cloud scheme consists of prognostic equations for the water phases (vapor, liquid, solid), bulk cloud microphysics (see above), and an empirical cloud cover scheme (Sundqvist et al., 1989).

- Aerosol activation in warm clouds follows Abdul-Razzak and Ghan (2000) and is described in Stier (2016). An aerosol activation scheme following Lin and Leaitch (1997) is also available.

- Ice crystal cirrus scheme is based on Kärcher and Lohmann (2002) and described in Lohmann et al. (2008).

- Autoconversion of cloud droplets to rain follows Khairoutdinov and Kogan (2000).

- Immersion and contact freezing follows Lohmann and Diehl (2006).

- *[Optional]* Orographic cirrus cloud scheme by Joos et al. (2010).

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Annex 1: Emission vertical resolution

Biomass burning emission vertical resolution

2D fire emissions are injected both within and above the PBL with the following percentages:

- 75 % within the PBL (equally distributed in all levels within the PBL)

- 17 % in the first level above the PBL

- 8 % in the second level above the PBL

In case the PBL depth is higher than 4km, then the 2D fire emissions are only injected within the PBL (equally distributed in all levels within the PBL).

The references paper for this parameterization is to be found in Val Martin M. et al, 2010.

Anthropogenic emission vertical resolution

Emissions from ships an energy sector are injected in the 2nd lowest model height.

Annex 2: M7 Aerosol emission size ranges

M7 modes:

Nucleation Mode (r < 0.005 μm), soluble (NS)

Aitken Mode (0.005 μm < r < 0.05 μm), soluble (KS) and insoluble (KI)

Accumulation Mode (0.05 μm < r < 0.5 μm), soluble (AS) and insoluble (AI)

Coarse Mode (r > 0.5 μm), soluble (CS) and insoluble (CI)

Distribution by sectors:

AGRICULTURAL WASTE BURNING, DOMESTIC, FOREST FIRE, GRASS FIRE,

BC --> KI

OC --> 0.35*KI, 0.65*KS

SO4 --> 0.5*KS, 0.5*AS

AIRCRAFT

BC --> KI

BIOGENIC (when prescribed SOA are used)

OC --> 0.35*KI, 0.65*KS

ENERGY, SHIPS

BC --> KI

OC --> KI

SO4 --> 0.5*AS, 0.5*CS

INDUSTRIAL, TRANSPORT, WASTE

BC --> KI

OC --> KI

SO4 (2.5% SO2) --> 0.5*KS, 0.5*AS

VOLCANIC

SO4 (2.5% SO2) --> 0.5*KS, 0.5*AS

DUST

DU --> AI, CI (distributed accordingly to the dust scheme)

SEASALT

SS --> AS, CS (distributed accordingly to the seasalt scheme)