# HTAP2 MODEL DESCRIPTION

# The GFDL AM3 Global Chemistry-Climate Model

## 1. General Information

**#Model Short Name.**
GFDL AM3

**#Model Full Name.**
The GFDL AM3 global chemistry-climate model

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**#A Brief Description of the Model and its Characteristics**
GFDL AM3 is a global chemistry-climate model with interactive stratosphere-troposphere chemistry and dynamics. For HTAP2 experiments, the model is nudged to reanalysis winds.

**#Citations to Further Model Documentation**
Lin M.Y., L.W. Horowitz, S. J. Oltmans, A. M. Fiore, Songmiao Fan: *Tropospheric ozone trends at Manna Loa Observatory tied to decadal climate variability*, **Nature Geoscience, 7**, 136–143 (2014a) | doi:10.1038/ngeo2066

Lin, M.Y. *et al. Transport of Asian ozone pollution into surface air over the western United States in spring*. **J. Geophys. Res., 117**, D00V07 (2012)

Donner, L. J. *et al. The Dynamical Core, Physical Parameterizations, and Basic Simulation Characteristics of the Atmospheric Component AM3 of the GFDL Global Coupled Model CM3*. **Journal of Climate 24**, 3484-3519 (2011)

## 2. Spatial and Temporal Properties

**#Coordinate System and Projection.**
The GFDL AM3 model applies the cubed-sphere grid coordinate system: the model's horizontal resolution is denoted as Cn, where n is an integer number indicating total number of cells (finite volumes) along each edge of the cube. For HTAP2, we apply C90 (where the size of the grid cell varies from ~87 km at the 6 corners of the cubed sphere to ~123 km near the center of each face) horizontal resolution. The model output is

regridded to ~1x1 degree resolution for regional model boundary conditions and analysis with observations.

**#Vertical Structure.**
The model includes 48 vertical layers, ranging in thickness from ~70 m near the Earth's surface to 1-1.5 km near the tropopause and 2-3 km in much of the stratosphere. The model top is 0.01 hPa. **The following formula should be applied when vertically interpolating AM3 data for regional boundary conditions.**

- hybrid coefficients pk and bk (provided in netCDF file: atmos*.static.nc)
- surface pressure (provided in netCDF file: in atmos*.ps.nc)
- sample codes for computing pressure at layer center

```
# nlev: number of vertical levels
# p_i(nlev+1): pressure at layer face    [Pa]
# p_m(nlat,nlat,nlev): pressure at layer center [Pa]
# psfc: surface pressure

hybi( nlev+1 ) = bk( nlev+1 )
hyai( nlev+1 ) = pk( nlev+1 )

DO j=1,nlat
   DO i=1,nlon
      p_i(:)    = hybi(:)*psfc(i,j)+hyai(:)
      DO k=1,nlev
         pdel = abs( ( hyai(k+1) + psfc(i,j)*hybi(k+1)) - (hyai(k) + psfc(i,j)*hybi(k) ) )
         p_m(i,j,k) = pdel/( log(p_i(k+1)) - log(p_i(k)) )
      END DO
   END DO
END DO
```

## 3. Chemistry and Radiative Transfer

The GFDL AM3 model include fully coupled stratosphere-troposphere chemistry and dynamics [Donner et al., 2011; Lin et al., 2012b]. The tropospheric chemistry is based on a modified version of the chemical scheme in Horowitz et al [2003, 2007] as described by Naik et al [2013]. The stratospheric chemistry, based on *Austin and Wilson* [2010, 2013], includes the full range of gas phase reactions covering the $HO_x$, $NO_x$, $ClO_x$, and $BrO_x$ catalytic cycles and heterogeneous reactions on sulfate aerosols (liquid ternary $H_2SO_4$-$HNO_3$-$H_2O$ solution) and polar stratospheric clouds.

The influence from major volcanic eruptions is imposed through the specification of monthly time series of zonal mean, multi-wavelength aerosol extinction as a function of altitude and latitude based on satellite measurements [?; Lin et al., 2014b].

**# Photolysis rate**: Fast-J and update

## 4. Land Cover and Orography

*See Donner et al.* [2011]

## 5. Emissions.

**#List emitted species for anthropogenic and fire emissions in AM3.**

Gas species: SO2, NO, NH3, formaldehyde, isoprene, terpenes, acetone
ethane (C2H6), ethene (C2H4), propane (C3H8)
C3H6 ( = propene+other_alkenes_and_alkynes*1.33)
C4H10 (=butanes+pentanes*1.25+hexanes_and_higher_alkanes*1.5)
C2H5OH = alcohols *0.8
CH3OH = alcohols*0.2

Aerosol species: BC, OC

**#Anthropogenic emissions.**

EDGAR-HTAP2:
http://edgar.jrc.ec.europa.eu/htap_v2/index.php?SECURE=123
Date of last download: Dec 20, 2013

**#VOC speciation for energy, transport, industry, and residential sectors**

EDGAR-HTAP2:
ftp://ftp.aero.jussieu.fr/outgoing/aude/HTAPv2/VOC_emissions_files/tar_files/
Date of last download: Feb 15, 2014

**#VOC speciation for shipping emissions**

This is not provided by HTAP2. The speciation ratios from the ACCMIP emission inventory are used to scale HTAP2 total NMVOC emissions for international shipping.

**#Vertical distribution of aircraft emissions.**

Emissions from EDGAR-HTAP2 are regridded to 0.5x0.5 degrees, and then distributed vertically to 25 levels based on the ratio of (total)/(assigned emissions at each altitude) for each grid from the ACCMIP inventory available at the same 0.5 grid resolution (Lamarque et al., 2010). The spatial distribution of HTAP2 aircraft emissions is slightly different from that in ACCMIP. Where the emissions are zero in ACCMIP but nonzero in HTAP2, the vertical ratio at a nonzero, nearest grid in ACCMIP is used for scaling HTAP2 emissions. This procedure is performed for NOx, SO2, CO, BC, and OC emissions. Other species from aircraft emissions are assumed to be very small and are thus not considered in the model.

**#Fire emissions.**

Daily biomass burning emissions for 2007–2010 are adopted from *Wiedinmyer et al.* [2011] (FINN v1, 1 × 1 $km^2$) and emitted in the model surface layer.
Date of last download: Jan 10, 2014.

**#Biogenic emissions.**
Isoprene emissions from vegetation are calculated online based on the Model of Emissions of Gases and Aerosols in Nature (MEGAN v2.1) [*Guenther et al.*, 2006], as implemented in *Emmons et al.* [2010] with modifications described by *Rasmussen et al.* [2011]. Other natural emissions are included as in the standard AM3 simulation.

## 6. Meteorology.

*See also Lin et al [2012a]. Below is a brief summary:*

All AM3 HTAP2 simulations are forced with observed SSTs, but horizontal winds are nudged to those from the NCEP Global Forecasting System (GFS) at T85 horizontal resolution (approximately 1.4° × 1.4°, 64 sigma levels, archived 3 hourly) [*Kanamitsu et al.*, 1991]. We apply a pressure-dependent nudging technique (e.g., relaxing with a time scale of 6 hours in the surface level, ~60 hours by 100 hPa, and ~600 hours by 10 hPa). No nudging is implemented above ~10 hPa since the GFS model top (~0.32 hPa) is lower than that of AM3 (~0.01 hPa). Our goal is to preserve the large-scale features of the observed airflow in the troposphere while allowing AM3 to simulate atmospheric circulation in the stratosphere. The weakening nudging strength in the UT/LS minimizes the impacts of noise introduced via nudging.

## 7. AM3 Chemical Boundary Conditions for Regional Models

**#Selected relatively long-lived chemical species:**
Ozone, CO, PAN, SO2, NO2, ethane, propane, acetone, black carbon, organic carbon, dust, sulfate, nitrate, and PM2.5.

The three VOC species (ethane, propane, acetone) are selected to represent relatively long-lived species, following the guidelines from MICS-Asia Phase II. This set of chemical boundary species has also been applied for CMAQ and WRF-Chem modeling during HTAP Phase I and it works well (see Lin et al., 2009; Lin et al., 2010). Regional models can use their default fixed boundary conditions for other short-lived species.

**#Temporal frequency:**
3 hourly instantaneous fields

**#Interface Package:**
Meiyun is working on developing the AM3-to-CMAQ and AM3-to-WRF/Chem processing packages. Contact Meiyun.Lin@noaa.gov if you are interested in using AM3 data.

**#Importance notice!!**
Regional models need to have sufficiently high vertical resolution in the UT/LS region (near the tropopause), at least equivalent to that in AM3. The coarse vertical resolution in the upper

troposphere might not resolve the tropopause. When realistic O3 profiles derived from global models or ozonesondes are provided at the model boundaries, O3 in the stratosphere will be quickly dispersed throughout the very thick regional model layer that straddles the tropopause, resulting in an artificial downward transport of $O_3$ into the upper troposphere and further to the surface. See Lin et al. (2009) for further discussion.

## 8. AM3 HTAP2 Simulations.

**#Time Periods**:
2008-2010, initialized at January 1, 2007

**#Scenarios:**
BASE: Base emissions, methane=1798 ppb
CH4INC: Base emissions, methane=2121 ppb
GLOALL: 20% decrease of all anthropogenic emissions globally
NAMALL: 20% decrease of all anthropogenic emissions in HTAP2 Tier1 domain for North America
EASALL: 20% decrease of all anthropogenic emissions in HTAP2 Tier1 domain for East Asia
EURALL: 20% decrease of all anthropogenic emissions in HTAP2 Tier1 domain for Europe
*Methane in GLOALL, NAMALL, EASALL, EURALL are as in BASE.

Possibly FIRE perturbation

## 9. Model Evaluation

To be updated for HTAP2 simulations
See Lin et al. (2012a), Lin et al (2012b) and Lin et al. (2014a) for previous model evaluation

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