MEGAN and WRF-CHEM

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Emissions for Chemical Transport Models

- Point
- Area
- Mobile
  - On-road
  - Off-road
- Fire
- Biogenic
Biogenic Emissions Modeling: MEGAN

**MEGAN:**
Model of Emissions of Gases and Aerosols from Nature
- Guenther et. al., *Atmospheric Chemistry and Physics*, 2006
  - Other papers forthcoming
- 134 emitted chemical species
  - Isoprene
  - Monoterpenes
  - Oxygenated compounds
  - Sesquiterpenes
  - Nitrogen oxide
- 1 km² resolution
- Input files available at: [http://cdp.ucar.edu](http://cdp.ucar.edu)

Online version of MEGAN in WRF-CHEM currently *same* as offline version 2.04
MEGAN Framework: Calculation of emissions

\[ EM = \varepsilon \cdot \gamma_{CE} \cdot \gamma_{age} \cdot \gamma_{SM} \cdot \rho \]

\[ \gamma_{CE} = \gamma_{LAI} \cdot \gamma_{P} \cdot \gamma_{T} \]

EM: Emission (µg m\(^{-2}\) hr\(^{-1}\))
ε: Emission Factor (µg m\(^{-2}\) hr\(^{-1}\))
\( \gamma_{CE} \): Canopy Factor
\( \gamma_{age} \): Leaf Age Factor
\( \gamma_{SM} \): Soil Moisture Factor
ρ: Loss and Production within plant canopy
\( \gamma_{LAI} \): Leaf Area Index Factor
\( \gamma_{P} \): PPFD Emission Activity Factor (light-dependence)
\( \gamma_{T} \): Temperature Response Factor

(Guenther et al., 2006)
Current MEGAN Code in WRF-CHEM

\[ EM = \varepsilon \cdot \gamma_{CE} \cdot \gamma_{age} \cdot \gamma_{SM} \cdot \rho \]

\[ \gamma_{CE} = \gamma_{LAI} \cdot \gamma_{P} \cdot \gamma_{T} \]

- The algorithm and data for \( \gamma_{SM} \) and \( \rho \) are not yet ready. They are assigned to 1.0.

- The light dependent factor is only applied to fractions of emission factors based on biological function of plants.

- Only maps of isoprene emission factors are used
  - All other species are assigned an emission factor by PFT

- No explicit canopy model
  - Xuemei Wang has implemented canopy model in one version.
MEGAN Framework: Canopy Factor calculations

**For isoprene:**
Follow equation 14 of Guenther et al. (2006):

\[
\gamma_T = \frac{E_{OPT} \cdot C_{T2} \cdot \exp(C_{T1} \cdot x)}{(C_{T2} - C_{T1}) \cdot (1 - \exp(C_{T2} \cdot x))}
\]

Where

\[
x = \frac{[(1/T_{opt}) - (1/T_{hr})]}{0.00831}
\]

\[
E_{OPT} = 1.75 \cdot \exp(0.08 \cdot (T_{daily} - 297))
\]

\[
T_{opt} = 313 + (0.6 \cdot (T_{daily} - 297))
\]

\[T_{hr} = \text{hourly air temperature (K)}\]

\[T_{daily} = \text{daily average air temperature (K) representative of model simulation period}\]

\[C_{T1} = 80\]

\[C_{T2} = 200\]

**For Monoterpenes:**
From Guenther et al., 1995

\[
\gamma_T = \exp[\beta \cdot (T - T_S)]
\]
MEGAN Framework: Canopy Factor calculations

\( \gamma_p = \) the dependence of emissions on light
This is based on equations 11-13 of Guenther et al. (2006).

Where:

\( \gamma_p = 0 \) when \( a \leq 0, a \geq 180 \)

\[ \gamma_p = \sin(a) \left[ 2.46 \times 0.9 \times \phi^3 \times \left(1 + 0.0005 \times (P_{daily} - 400)\right) \right] \]

when

\( 0 < a < 180 \)

Where

\( \phi = \) above canopy PPFD transmission (non-dimensional)
\( P_{daily} = \) daily average above canopy PPFD (\( \mu \text{mol m}^{-2} \text{ s}^{-1} \))
\( a = \) solar angle (degree)

\[ \phi = \frac{P_{ac}}{\sin(a) \times P_{toa}} \]

where

\( P_{ac} = \) above canopy PPFD (\( \mu \text{mol m}^{-2} \text{ s}^{-1} \))
\( P_{toa} = \) PPFD at the top of atmosphere (\( \mu \text{mol m}^{-2} \text{ s}^{-1} \))

\[ P_{ac} = DSW \times \left(4.66 \frac{\mu \text{mol}}{m^2 \text{s}}\right) \times 0.5 \]

\[ P_{toa} = 3000 + 99 \times \cos[2 \times 3.14 - (DOY - 10) / 365] \]

where DOY = day of year
Emission Factors for Isoprene

Fig. 5. Monthly normalized isoprene emission rates estimated with MEGAN for 2003. Rates are normalized by the emission estimated for standard LAI (=5 m² m⁻²) and leaf age (80% mature leaves). These normalized rates illustrate the variations associated with changes in only LAI and leaf age; i.e. all other model drivers are held constant.
MEGAN Input file
Includes isoprene emission factors, LAI, plant functional type fractions, and climatological temperature and solar radiation for each model grid cell
Preprocessed prior to WRF-chem simulation

Process 1:
Calculation of Gamma Values
Read into WRF-chem simulation

Temp @ 2m
Downward Solar Radiation
Read in from model

Process 2:
Calculation of explicit emissions

Process 3:
Speciation of Emissions to pre-determined Mechanism:
Current Options include:
CBMZ, SAPRC99, SAPRCII, RADM2, RACM

Return emissions to model
Table 1: Input parameters for MEGANv2.0, including class of compound (1-20), base emission factors (mg m\(^{-2}\) hr\(^{-1}\)) for broadleaf trees (EF\(_{BT}\)), Needleleaf Trees (EF\(_{NT}\)), Shrubs (EF\(_{SHR}\)), and Crops/Grasses (EF\(_{CG}\)). \(\beta\) is the dimensionless parameter used to calculate \(\gamma_1\) for compounds other than isoprene. The light dependent fraction (LDF) is the fraction of the total emissions that should have a light dependency assigned.

<table>
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<tr>
<th>ClassName</th>
<th>Class ID</th>
<th>EF(_{BT})</th>
<th>EF(_{NT})</th>
<th>EF(_{SHR})</th>
<th>EF(_{CG})</th>
<th>(\beta)</th>
<th>Leaf Age Case</th>
<th>LDF</th>
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<td></td>
<td></td>
<td></td>
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<td>5</td>
<td>1</td>
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<td>5</td>
<td>100</td>
<td>8</td>
<td>0.1</td>
<td>0.09</td>
<td>5</td>
<td>1</td>
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<tr>
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<td>20</td>
<td>75</td>
<td>22</td>
<td>0.3</td>
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<td>45</td>
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<td>50</td>
<td>0.7</td>
<td>0.09</td>
<td>2</td>
<td>0.1</td>
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<td>limonene</td>
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<td>45</td>
<td>100</td>
<td>52</td>
<td>0.7</td>
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<td>85</td>
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<td>8</td>
<td>90</td>
<td>300</td>
<td>100</td>
<td>1.5</td>
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<td>450</td>
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<td>100</td>
<td>100</td>
<td>0.11</td>
<td>1</td>
<td>0</td>
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<td>120</td>
<td>120</td>
<td>120</td>
<td>0.13</td>
<td>1</td>
<td>0</td>
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<td>formic acid, formaldehyde, acetic acid</td>
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<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>0.09</td>
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<td>0</td>
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<td>300</td>
<td>300</td>
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<td>0.75</td>
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<td>nitrogen gases: NO, NH3, N2O</td>
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<td>41</td>
<td>200</td>
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<td>0</td>
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<td>other monoterpenes</td>
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<td>other sesquiterpenes</td>
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<td>1.83</td>
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<td>969.2</td>
<td>969.2</td>
<td>969.2</td>
<td>0.09</td>
<td>1</td>
<td>0.75</td>
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</tbody>
</table>

Values can be edited in module_data_megan.F
MEGAN INPUT FILE

• MEGAN input file needs to be preprocessed before model simulation
  – Can either use geographic processing software or preprocessor available at http://www.acd.ucar.edu/wrf-chem/download.shtml
• File must include:
  – Model Grid information
  – Normalized Isoprene Emission factor*
    • From NCAR Community Data Portal (EF21.zip)
    • Values from downloaded grid converted from ug/m2/hr to mole/km2/hr
  – Monthly LAI
    • From NCAR Community Data Portal
  – Plant Functional Type (PFT)
    • From NCAR Community Data Portal
  – Average monthly temperature and downward solar radiation

• Currently only uses grid-specific isoprene emission factors
• User may edit variables in module_data_megan2.F
Monthly Temperature and Solar Radiation

- Princeton University
  - Princeton Global Forcings
  - Jan-1948 - Dec-2000
    https://dss.ucar.edu/datazone/dsszone/ds314.0/#monthly

- NCEP NARR (NCEP North American Regional Reanalysis)
  http://www.cdc.noaa.gov/cdc/data.narr.html

- Temperature and Solar Radiation data:
  http://www.cdc.noaa.gov/PublicData/tables/monthly.html

- For Downward Solar Radiation:
  http://gswp2.tkl.iis.u-tokyo.ac.jp/gswp2/free/ddc.html
MEGAN vs. BEIS3.11

BEIS

OUTPUT FROM WRF V2.2 MODEL

DATA SET: beis_avg_avg

MEGAN

OUTPUT FROM WRF V2.2 MODEL

DATA SET: mgn_avg_avg

EBIO_ISO*68.11

EBIO_ISO*68.11
BEIS 3.0

Isoprene Emission

Max = 4358 g/km²-hr
Total average emission = 7417 tons hr⁻¹

MEGAN

Isoprene Emission

Max = 10542 g/km²-hr
Total average emission = 12145 tons hr⁻¹
Limited support available from:

Christine Wiedinmyer  
christin@ucar.edu

Tiffany Duhl  
duhl@ucar.edu

Thank you!
Preparing MEGAN Input file

- MEGAN file is space-delimited
- File contains:
  - Grid information (i,j)
  - Isoprene Emission Factor for each grid cell
  - PFT percentage (broadleaf trees, needleleaf trees, shrubs, herbaceous)
  - Monthly LAI
  - Monthly air temperature
  - Monthly downward solar radiation
Preparing MEGAN input file using ArcGIS software:

- Download raster files from http://cdp.ucar.edu
- Create polygon file of model domain/grid
  - Include i,j cell numbers
- Perform *zonal statistics* on rasters from cdp
  - Use mean value of isoprene EF, PFTs, monthly LAI
- Find monthly-averaged air temperature and downward solar radiation
  - Interpret mean of each grid cell for each month
- Combine all information into one file
- Format for input to model
EF

- level access

You may either download a file by clicking on it (hyperlink in the first column, if available), or add files to your Data Cart to prepare a multi-files request.

1-3 of 3 datafiles

start from file #:0 +1 and display 20 files per page (max:100) (NEW: optional filename match: )

My Data Cart: Add selected files to Data Cart | Empty Data Cart | Go to Data Cart.

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<th>Type</th>
<th>Size</th>
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NEW: Select All Files: NCAR DISK Deselect All Files

1-3 of 3 datafiles

User: christin | CDP Home | Help Page | Contact Us | My Data Cart | My Data Requests | Privacy Policy | Terms of Use

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Preparing MEGAN input file

Fields of file:
COL, ROW, EF_ISO2, LAI1, LAI2, LAI3, LAI4, LAI5, LAI6_1, LAI7_1, LAI8, LAI9, LAI10, LAI11, LAI12, pft_bt, pft_nt, pft_shr, pft_gc, T1, T2, T3, T4, T5, T6, T7, T8, T9, T10, T11, T12, DSW1, DSW2, DSW3, DSW4, DSW5, DSW6, DSW7, DSW8, DSW9, DSW10, DSW11, DSW12

Format:
'(2(I5," "),41(E11.2E2," "))'