

# MEGAN and WRF-CHEM

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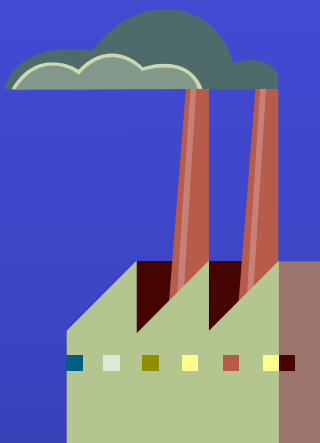
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# Emissions for Chemical Transport Models

- 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 km<sup>2</sup> resolution
    - Input files available at: <http://cdp.ucar.edu>

Online version of MEGAN in WRF-CHEM currently same as offline version 2.04

# MEGAN Framework:

## Calculation of emissions

$$EM = \varepsilon \bullet \gamma_{CE} \bullet \gamma_{age} \bullet \gamma_{SM} \bullet \rho$$

$$\gamma_{CE} = \gamma_{LAI} \bullet \gamma_P \bullet \gamma_T$$

EM: Emission ( $\mu\text{g m}^{-2} \text{hr}^{-1}$ )

$\varepsilon$ : Emission Factor ( $\mu\text{g m}^{-2} \text{hr}^{-1}$ )

$\gamma_{CE}$ : Canopy Factor

$\gamma_{age}$ : Leaf Age Factor

$\gamma_{SM}$ : Soil Moisture Factor

$\rho$ : 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

$$EM = \varepsilon \bullet \gamma_{CE} \bullet \gamma_{age} \bullet \gamma_{SM} \bullet \rho$$


$$\gamma_{CE} = \gamma_{LAI} \bullet \gamma_P \bullet \gamma_T$$

- 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):

$$\gamma_T = \frac{E_{OPT} * C_{T2} * \exp(C_{T1} * x)}{(C_{T2} - C_{T1} * (1 - \exp(C_{T2} * x)))}$$

Where

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

$$E_{OPT} = 1.75 * (\exp(0.08 * (T_{daily} - 297)))$$

$$T_{opt} = 313 + (0.6 * (T_{daily} - 297))$$

$T_{hr}$  = hourly air temperature (K)

$T_{daily}$  = 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:

$$\gamma_p = 0 \text{ when } a \leq 0, a \geq 180$$

and

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

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)

$$\phi = \frac{P_{ac}}{\sin(a) * P_{toa}}$$

where

$P_{ac}$  = above canopy PPFD ( $\mu\text{mol m}^{-2} \text{s}^{-1}$ )

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

$$P_{ac} = DSW * (4.66 \frac{\mu\text{mol}}{\text{m}^2 \text{s}}) * 0.5$$

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

where DOY = day of year

# MEGAN Framework: Canopy Factor calculations

$\gamma_{LAI}$  = the dependence of the emissions on Leaf Area Index.

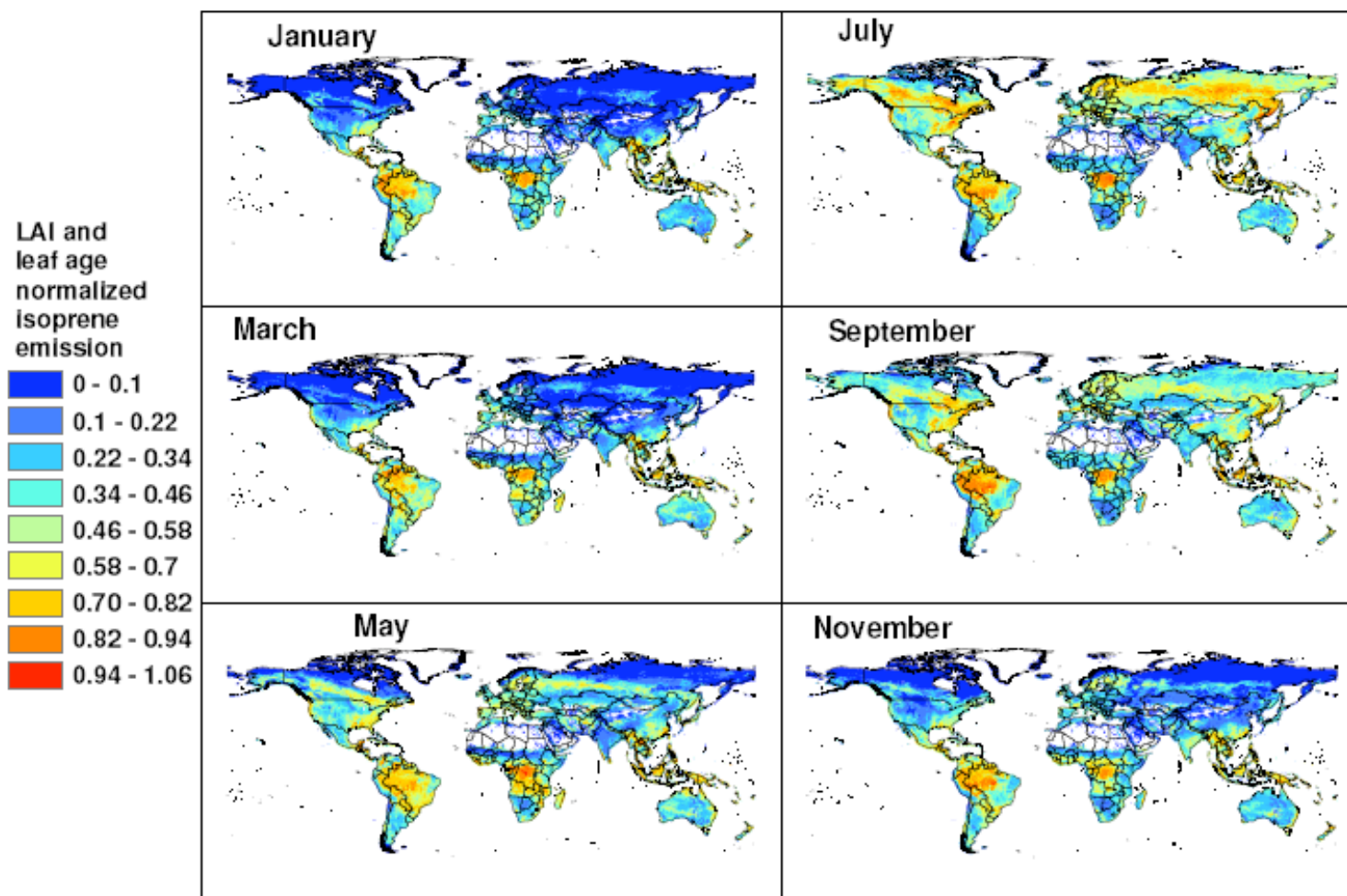
$$\gamma_{LAI} = 0.49 * LAI_c / [(1 + 0.2 * LAI_c^2)^{0.5}]$$

*Where:*

LAI<sub>c</sub> = leaf area index of the current month  
(or the month that is being simulated)



# 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 ( $=5 \text{ m}^2 \text{ m}^{-2}$ ) 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.

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

ClassName	Class ID	$\text{EF}_{\text{BT}}$	$\text{EF}_{\text{NT}}$	$\text{EF}_{\text{SHR}}$	$\text{EF}_{\text{CG}}$	$\beta$	Leaf Age Case	LDF
Isoprene	1	13000	2000	11000	400	0.09	5	1
MBO	2	5	100	8	0.1	0.09	5	1
Myrcene	3	20	75	22	0.3	0.09	2	0.05
Sabinene	4	45	70	50	0.7	0.09	2	0.1
limonene	5	45	100	52	0.7	0.09	2	0.05
carene <3->	6	18	160	25	0.3	0.09	2	0.05
ocimene <trans beta>	7	90	60	85	1	0.09	2	0.8
pinene <beta->	8	90	300	100	1.5	0.09	2	0.1
pinene <alpha->	9	180	450	200	2	0.09	2	0.1
farnescene <alpha->	10	60	30	50	0.9	0.15	3	0.8
caryophyllene <beta->	11	60	75	65	1.2	0.15	3	0.8
Methanol	12	400	400	400	400	0.09	4	0
Acetone	13	100	100	100	100	0.11	1	0
Acetaldehyde and ethanol	14	120	120	120	120	0.13	1	0
formic acid, formaldehyde, acetic acid	15	70	70	70	70	0.09	1	0
methane	16	300	300	300	300	0.05	1	0.75
nitrogen gases: NO, NH3, N2O	17	5	5	41	200	0.07	1	0
other monoterpenes	18	87.2	180.4	108.2	4.81	0.09	2	0.1
other sesquiterpenes	19	107.7	125.4	104.4	1.83	0.15	3	0.8
other VC	20	969.2	969.2	969.2	969.2	0.09	1	0.75

Values can be edited in module\_data\_megan.F

## MEGAN Input file

Includes emission factors, LAI, plant functional type fractions, and climatological temperature and solar radiation for each model grid cell

Preprocessed prior to WRF-chem simulation\*

Read into  
WRF-chem  
simulation

Temp @ 2m  
Downward Solar Radiation

Read in from model

Process 1:  
Calculation of Gamma Values

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

# MEGAN INPUT FILE

- MEGAN input file needs to be preprocessed before model simulation
  - Documentation being developed
  - Currently requires geographic processing software
- File must include:
  - Model Grid information
  - Normalized Isoprene Emission factor\*
    - From NCAR Community Data Portal
    - Values from downloaded grid converted from g/km2/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

- NCEP NARR (NCEP North American Regional Reanalysis)

<http://www.cdc.noaa.gov/cdc/data.narr.html>

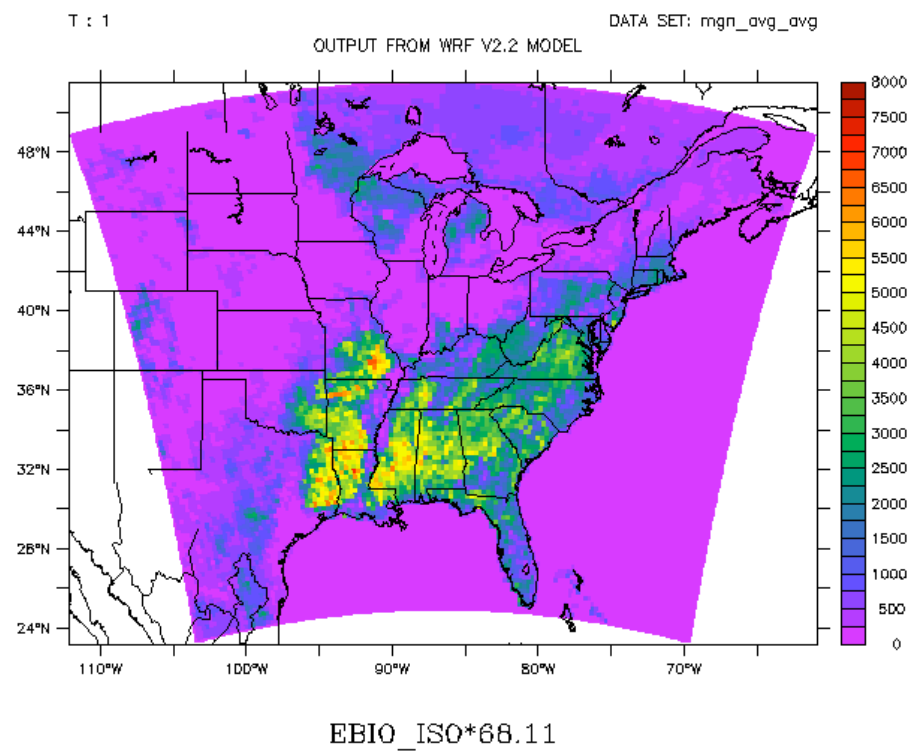
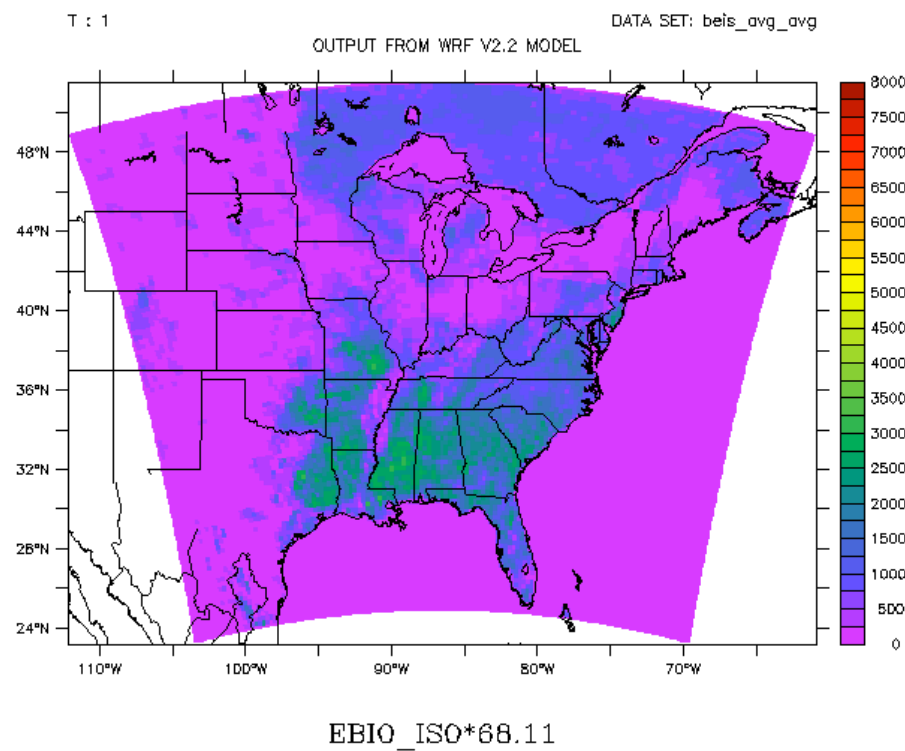
- Temperature and Solar Radiation data:

<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

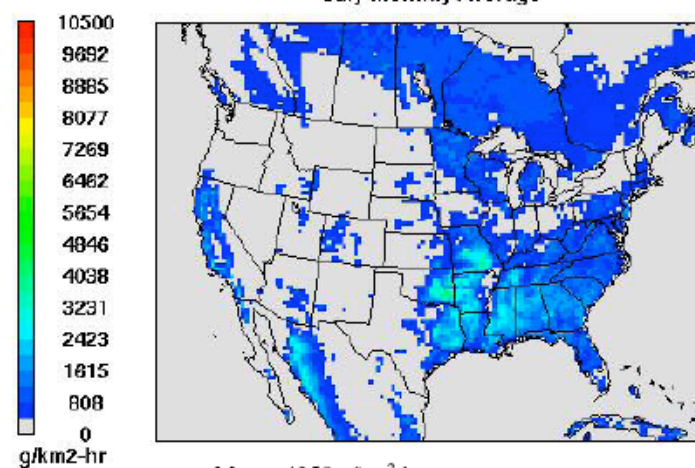


BEIS 3.0

MEGAN

### Isoprene Emission

BEIS3.0 (ISOPRENE mass)  
July Monthly Average

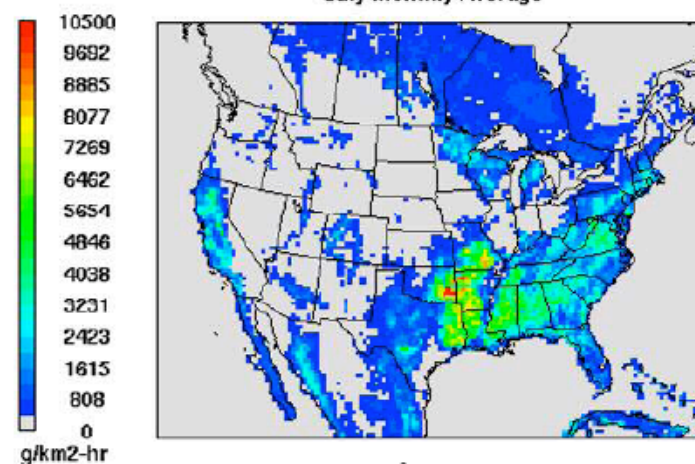


Max = 4358 g/km<sup>2</sup>-hr

Total average emission = 7417 tons hr<sup>-1</sup>

### Isoprene Emission

MEGANv2.02 EF-S06 (ISOPRENE mass)  
July Monthly Average



Max = 10542 g/km<sup>2</sup>-hr

Total average emission = 12145 tons hr<sup>-1</sup>

## Still Working on MEGAN implementation

- Input processing and documentation
- Evaluation of code/output
- WRF-Chem v3 – being validated

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\*Limited support available





# 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

Right now, methods use 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

actions Hierarchy: [MEGAN \(Model of Emissions of Gases and Aerosols from Nature\)](#) > [MEGAN Version 2.0](#) > [Input](#) > [ESRI\\_GRID\\_30sec](#) >



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 #:  +1 and display  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](#) .


File	Metadata	Format	Type	Size	Add to Data Cart	OPeNDAP
<a href="#">EF.zip</a>				180783419	<input type="checkbox"/> NCAR DISK	
<a href="#">ef21.zip</a>				726388093	<input type="checkbox"/> NCAR DISK	
<a href="#">efmt21.zip</a>				1039497882	<input type="checkbox"/> NCAR DISK	

NEW: Select All Files: ☐ NCAR DISK ☐ Deselect All Files

1-3 of 3 datafiles

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NCAR Community Data Portal, sponsored by 

# 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,T  
8,T9,T10,T11,T12,DSW1,DSW2,DSW3,DSW4,DSW5,DSW6,DSW7,D  
SW8,DSW9,DSW10,DSW11,DSW12

Format:

```
'(2(I5," "),41(E11.2E2," "))'
```