Biogenic and Fire Emissions in WRF-Chem Or… MEGAN and FINN

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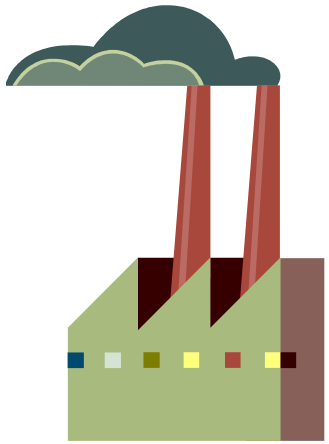
Emissions for Chemical Transport Models

- Point
- Area
- Mobile
  - On-road
  - Off-road
- Biogenic
- Fire



Biogenic Emissions Modeling: MEGAN

- **MEGAN**:
  Model of Emissions of Gases and Aerosols from Nature
  - Guenther et. al., *Atmospheric Chemistry and Physics*, 2006
    - Version 2.1 is in preparation
  - 134 emitted chemical species
    - Isoprene
    - Monoterpenes
    - Oxygenated compounds
    - Sesquiterpenes
    - Nitrogen oxide
  - 1 km^2 resolution
  - Input files available at:

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

MEGAN Framework: Calculation of emissions

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

$$\gamma_{CE} = \gamma_{LAI} \bullet \gamma_{P} \bullet \gamma_{T}$$

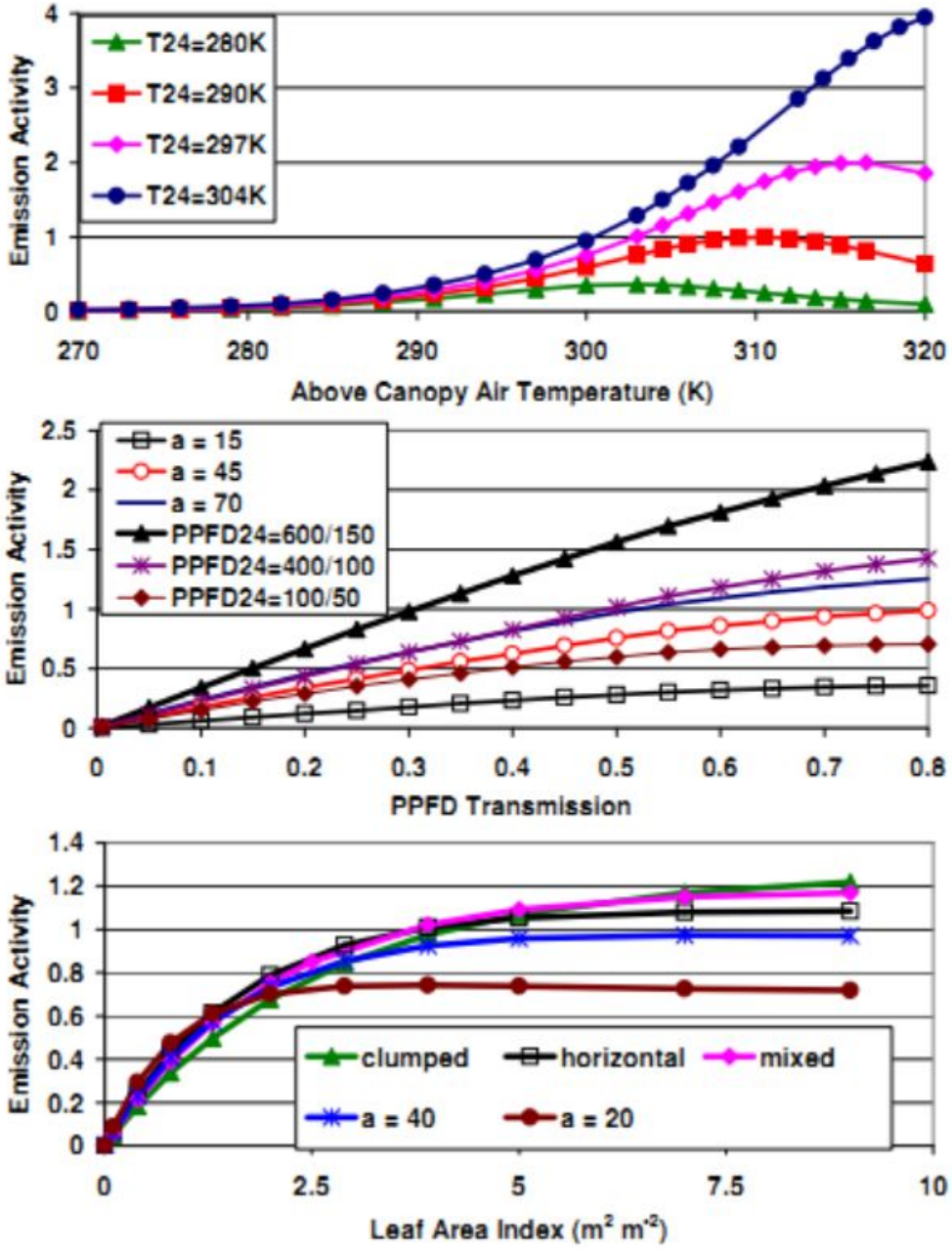
EM: Emission ($\mu g\ m^{-2}\ hr^{-1}$)
ε: Emission Factor ($\mu g\ m^{-2}\ hr^{-1}$)
γ_{CE}: Canopy Factor
γ_{age}: Leaf Age Factor
γ_{SM} : Soil Moisture Factor
ρ: Loss and Production within plant canopy
γ_{LAI} : Leaf Area Index Factor
γ_{P} : PPFD Emission Activity Factor (light-dependence)
γ_{T}: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

Current MEGAN Code in WRF-CHEM

$$EM = \varepsilon \bullet \gamma_{CE} \bullet \gamma_{age} \bullet \cancel{\gamma_{SM}}^{1} \bullet \cancel{\rho}^{1}$$

$$\gamma_{CE} = \gamma_{LAI} \bullet \gamma_{P} \bullet \gamma_{T}$$

- The algorithm and data for γSM and ρ 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



Guenther et al., 2006, *ACP*

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

$$\gamma_T = \exp\left[\beta \bullet \left(T - T_s\right)\right]$$

MEGAN Framework: Canopy Factor calculations

γ_P = the dependence of emissions on light

This is based on equations 11-13 of Guenther et al. (2006).

Where:

$\gamma_P = 0$ when $a \le 0, a \ge 180$

and

$$\gamma_P = \sin(a) * \left[2.46 * 0.9 * \phi^3 * \left(1 + 0.0005 * (P_{daily} - 400)\right)\right.$$

when

$0 < a < 180$

Where ϕ = above canopy PPFD transmission (non-dimensional)

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

a = solar angle (degree)

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

where

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

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

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

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

where DOY = day of year

Emission Factors for Isoprene

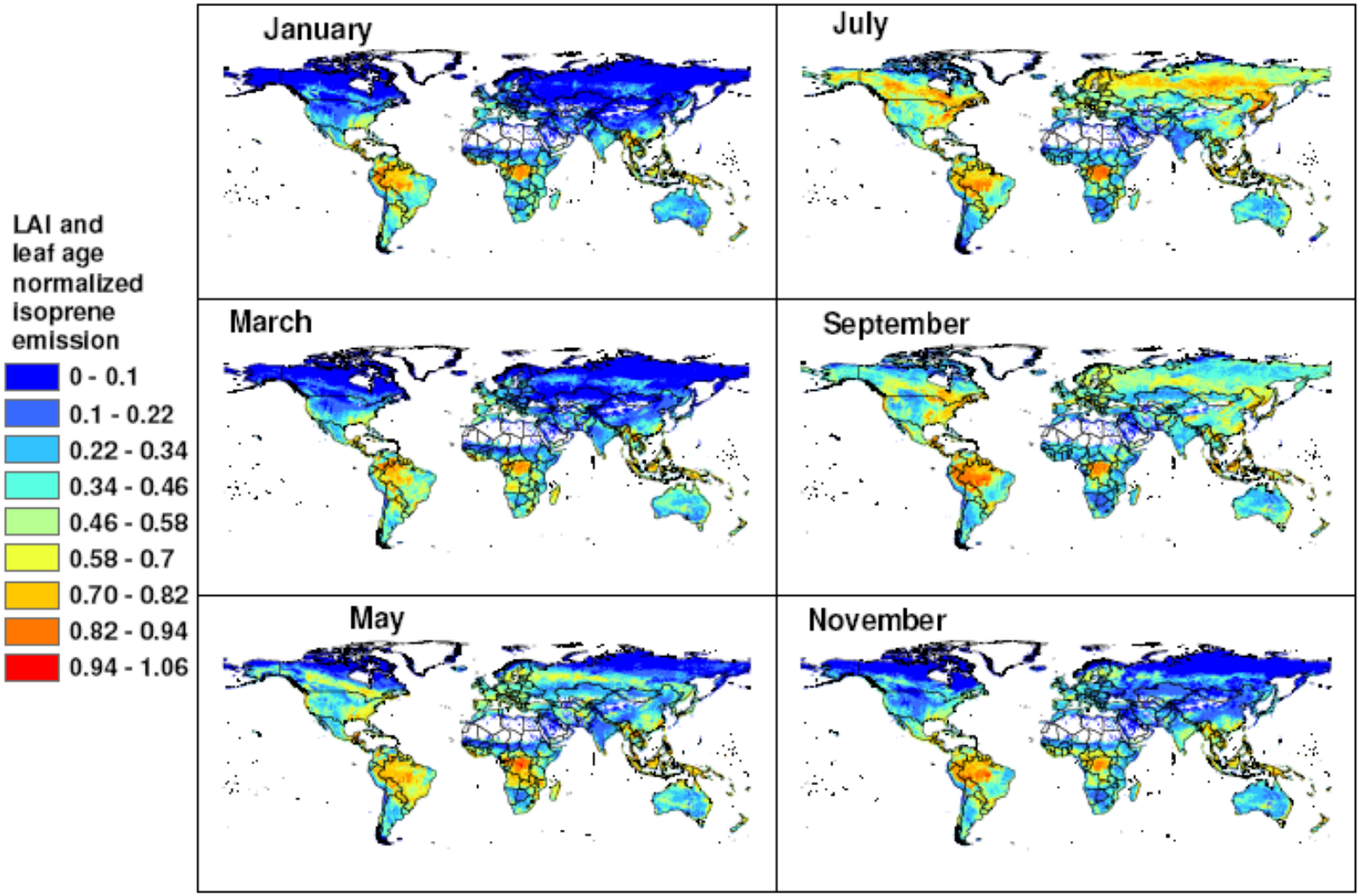


Fig. 5. Monthly normalized isoprene emission rates estimated with MEGAN for 2003. Rates are normalized by the emission estimated for standard LAI (=5 m^2 m^{-2}) and leaf age (80% mature leaves). These normalized rates illustrate the variations associated with changes in only LAI and leaf age; i.e. all other model drivers are held constant.

PREPROCESSOR: bio_emiss

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*

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

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}), Needleaf Trees (EF_{NT}), Shrubs (EF_{SHR}), and Crops/Grasses (EF_{CG}). β is the dimensionless parameter used to calculate γ_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	EF_{BT}	EF_{NT}	EF_{SHR}	EF_{GC}	β	Leaf Age Case	LDF
Isoprene	1					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

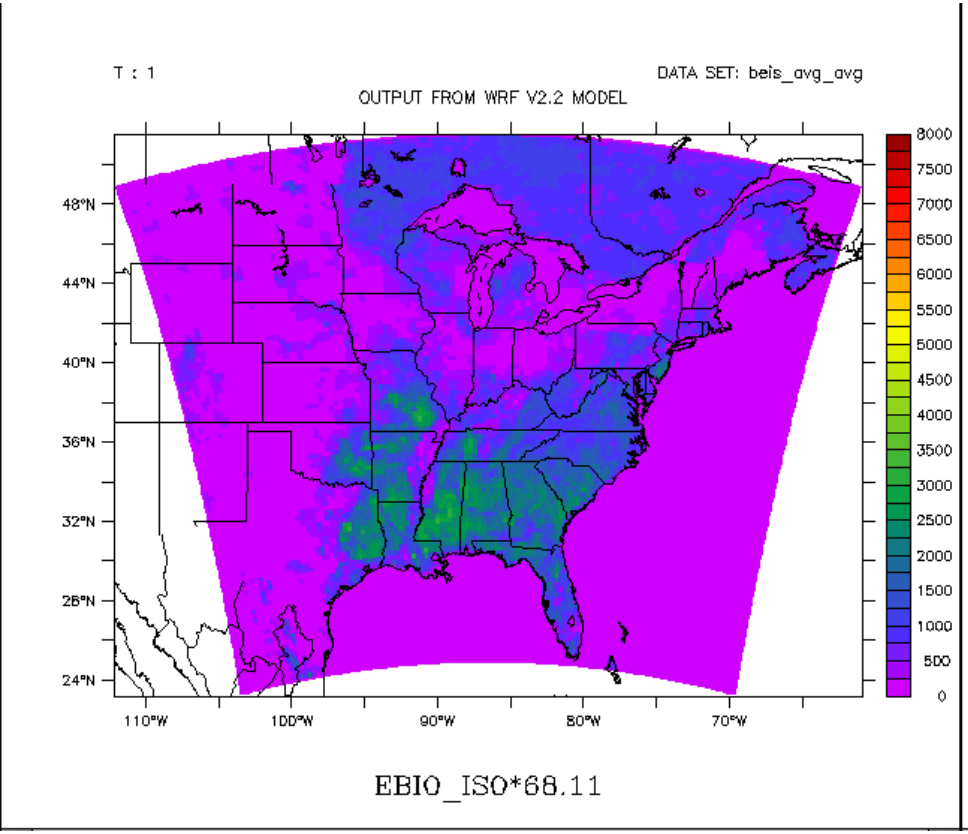
Values can be edited in module_data_megan.F

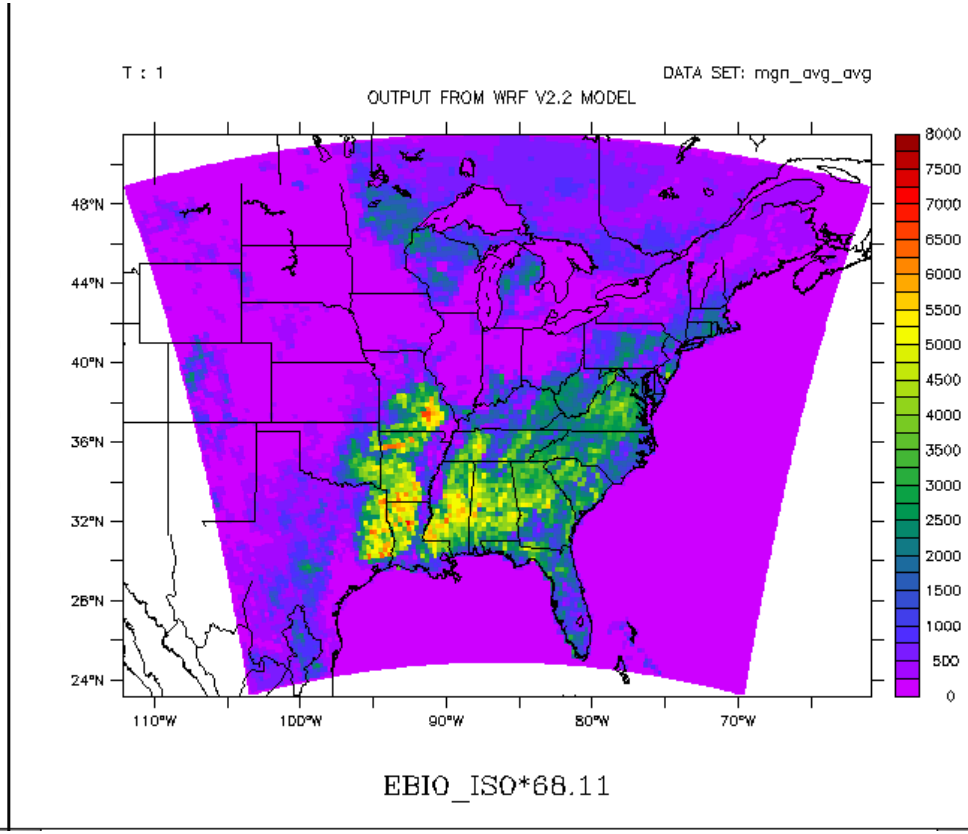
MEGAN INPUT FILE

Use the Bio_emis preprocessor:
http://www.acd.ucar.edu/wrf-chem/

- Currently only uses grid-specific isoprene emission factors
- User may edit variables in **module_data_megan2.F**

MEGAN vs. BEIS3.11





Emissions From Fires

Fire Emissions: **Fire INventory from NCAR (FINN)**

Daily fire emissions calculated with FINNv1

Wiedinmyer et al., *Geoscientific Model Development*, 2011, http://www.geosci-model-dev.net/4/625/2011/gmd-4-625-2011.html

- Daily global fire emissions
  - GHG, CO, NOx, VOCs, SO2, NH3, Particulate Matter
- Spatial resolution ~ 1km^2
- Available for hindsight and forecast model applications

Fire Emissions: **Fire INventory from NCAR (FINN)**

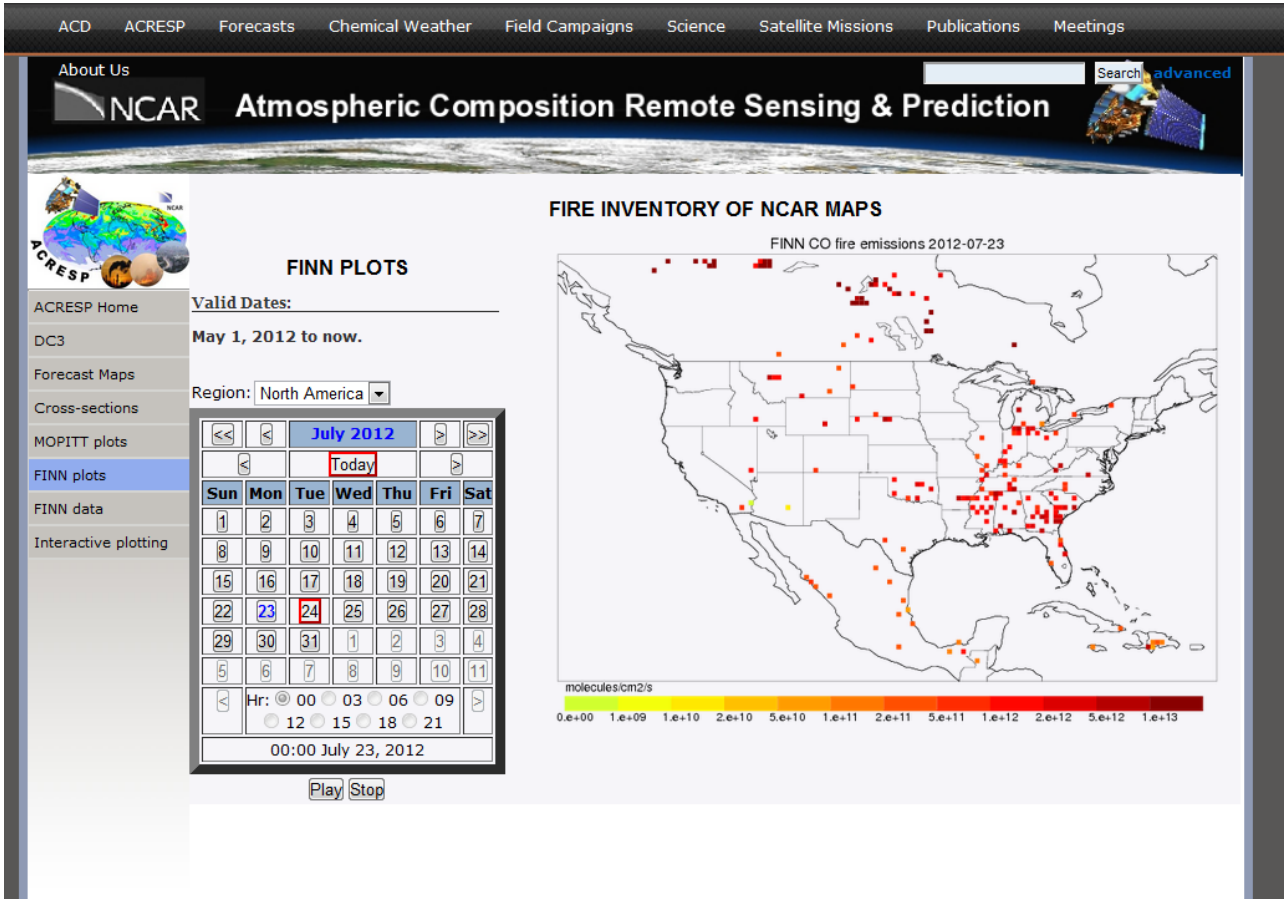
Daily global emissions available from 01 January 2002 – 30 June 2012

http://bai.acd.ucar.edu/Data/fire/

Also available at:

http://web3.acd.ucar.edu/acresp/dc3/finn.shtml

http://web3.acd.ucar.edu/acresp/dc3/finn-data.shtml



Modeling Fire Emissions

$$Emissions_i = f(A(x,t), B(x,t), E_{f_i})$$

A(x,t): Area burned

B(x): Biomass burned (biomass burned/area)

- type of vegetation (ecology)
- fuel characteristics:
  - amounts of woody biomass, leaf biomass, litter, ...
- fuel condition
  - moisture content

E_{fi}: Emission factor (mass emission$_i$ /biomass burned)

- fuel characteristics
- fuel condition

Model Drivers:

MODIS Rapid Response fire detections

MODIS Vegetation Continuous Fields and Land Cover Type

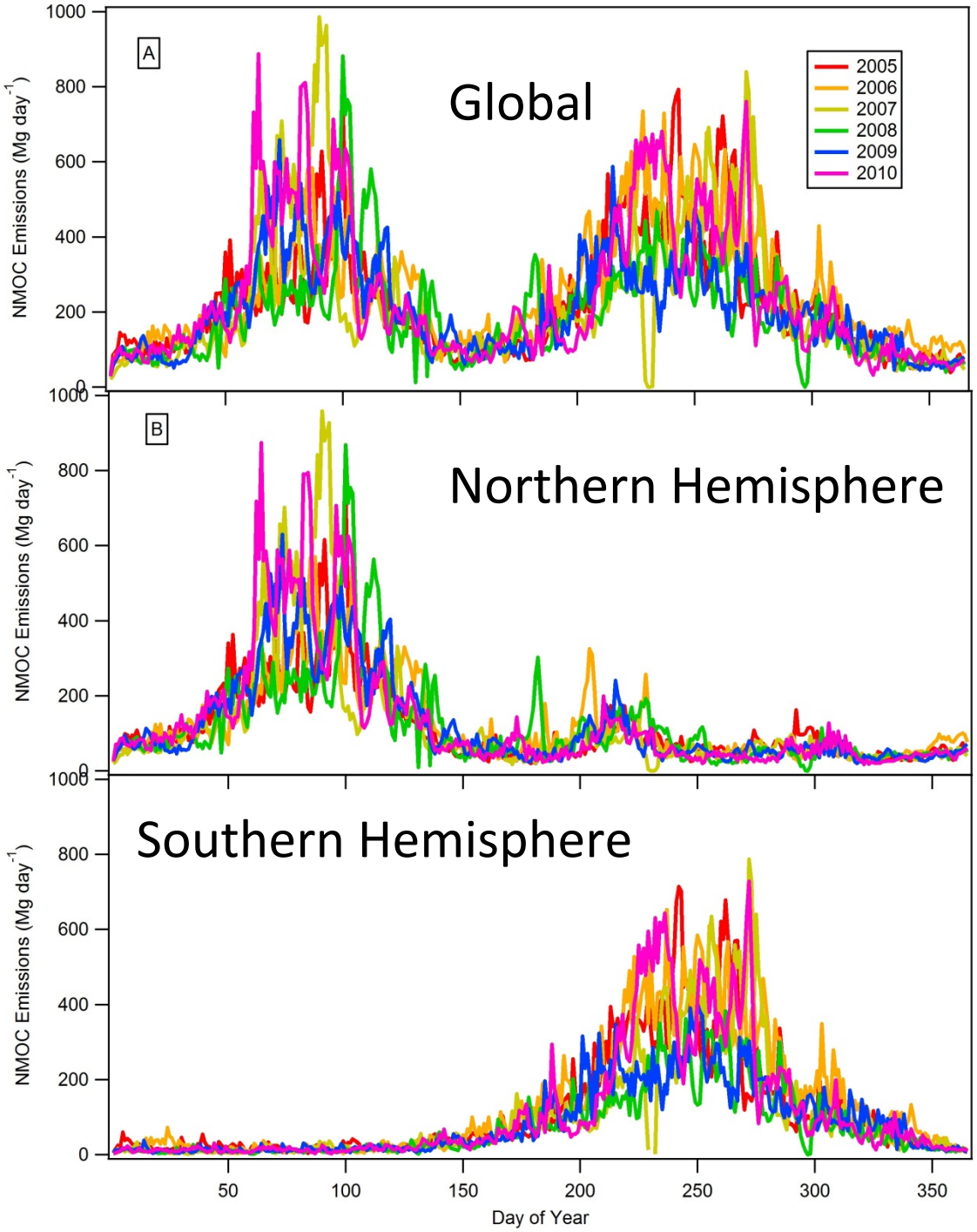
Emission factors from Akagi et al., *ACP,* 2011.

Speciation of VOCs provided for MOZART-4, SAPRC99, GEOS-Chem

Plume rise option available- *but requires additional inputs*

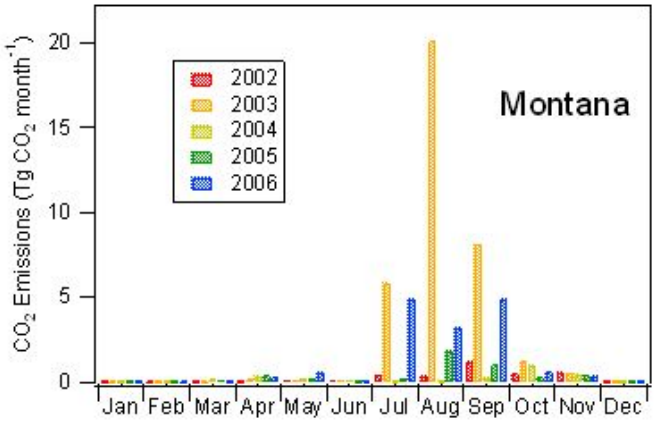
Global Daily Emission

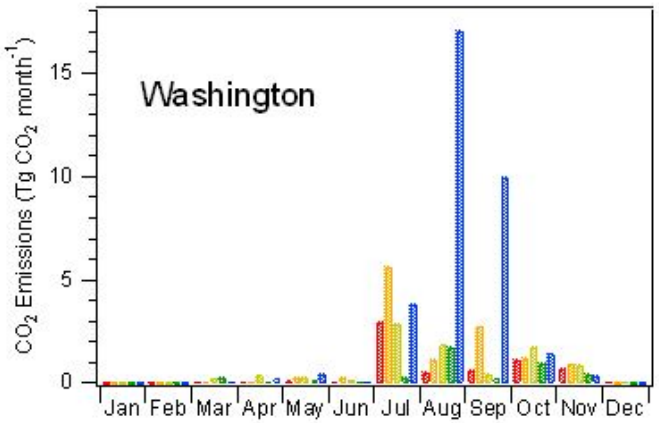
Emissions highly variable
- Daily
- Season
- Spatial

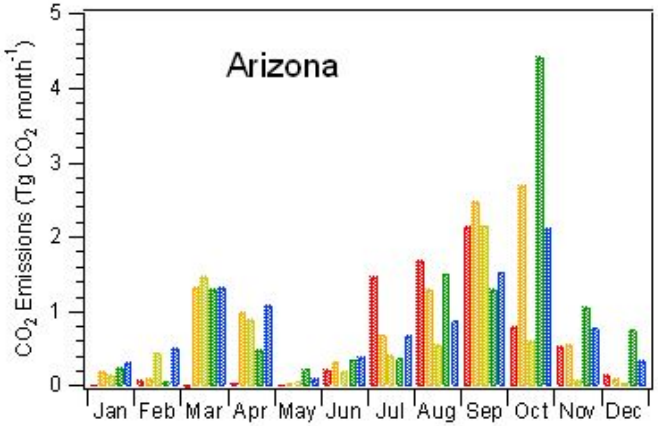


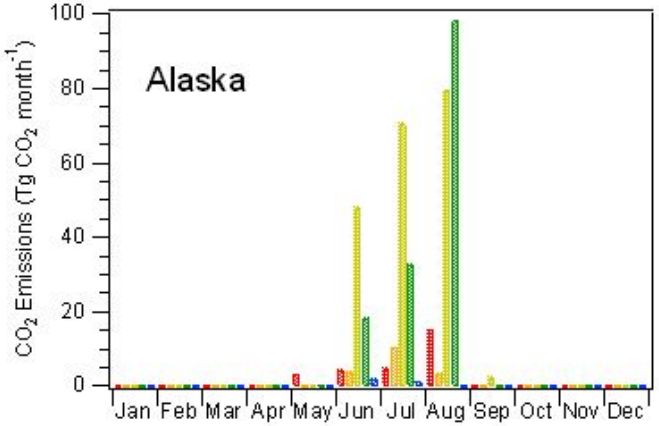
Wiedinmyer et al., *GMD*, 2011

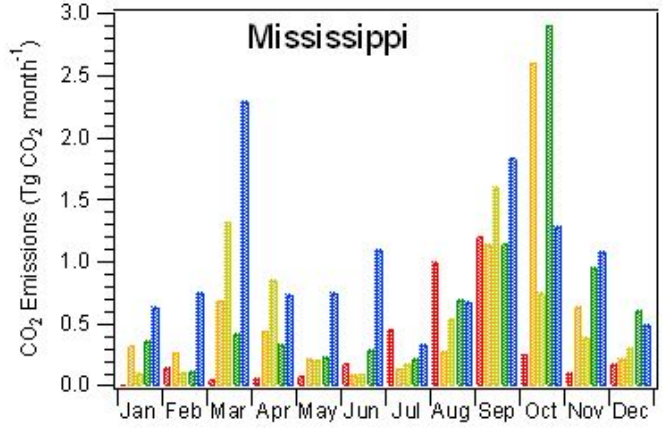
Fire Emissions Variability:
-Spatial
-Temporal

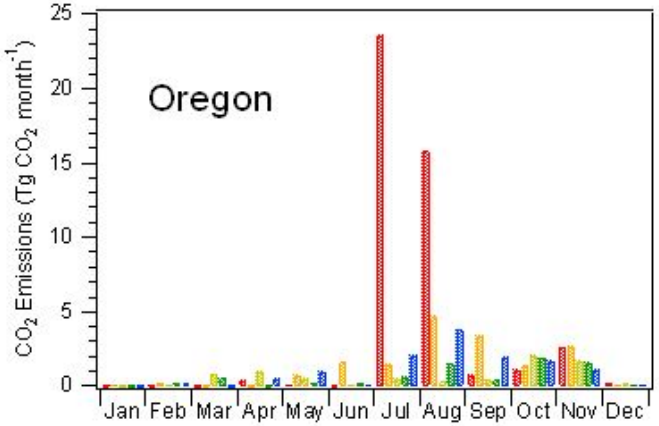










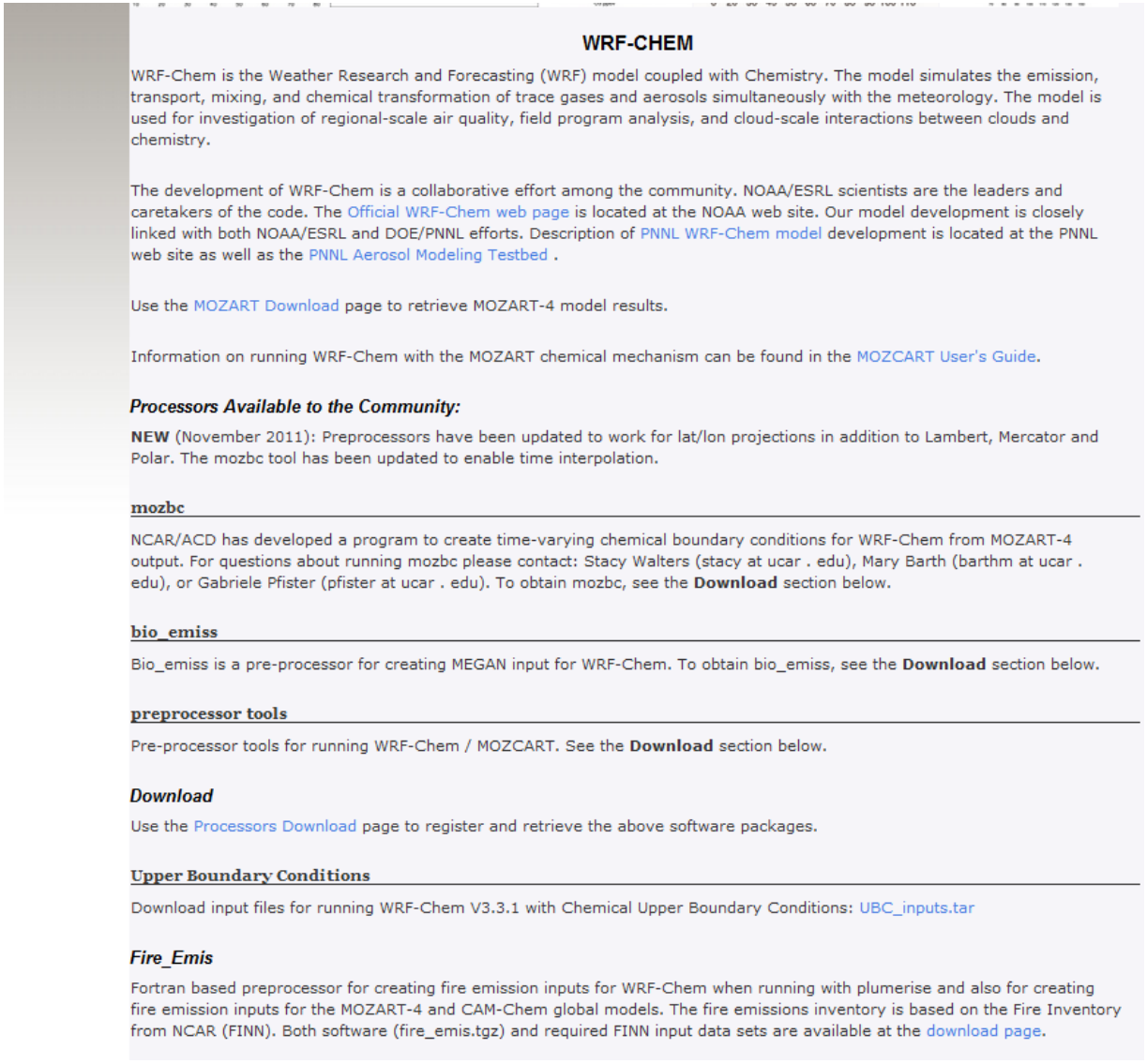


Wiedinmyer and Neff,
Carbon Balance and Management,
2007

Preprocessors Available!!!

http://www.acd.ucar.edu/wrf-chem/

- Bio_emiss
- Fire_emis



WRF-CHEM

WRF-Chem is the Weather Research and Forecasting (WRF) model coupled with Chemistry. The model simulates the emission, transport, mixing, and chemical transformation of trace gases and aerosols simultaneously with the meteorology. The model is used for investigation of regional-scale air quality, field program analysis, and cloud-scale interactions between clouds and chemistry.

The development of WRF-Chem is a collaborative effort among the community. NOAA/ESRL scientists are the leaders and caretakers of the code. The Official WRF-Chem web page is located at the NOAA web site. Our model development is closely linked with both NOAA/ESRL and DOE/PNNL efforts. Description of PNNL WRF-Chem model development is located at the PNNL web site as well as the PNNL Aerosol Modeling Testbed .

Use the MOZART Download page to retrieve MOZART-4 model results.

Information on running WRF-Chem with the MOZART chemical mechanism can be found in the MOZCART User's Guide.

Processors Available to the Community:

NEW (November 2011): Preprocessors have been updated to work for lat/lon projections in addition to Lambert, Mercator and Polar. The mozbc tool has been updated to enable time interpolation.

mozbc

NCAR/ACD has developed a program to create time-varying chemical boundary conditions for WRF-Chem from MOZART-4 output. For questions about running mozbc please contact: Stacy Walters (stacy at ucar . edu), Mary Barth (barthm at ucar . edu), or Gabriele Pfister (pfister at ucar . edu). To obtain mozbc, see the **Download** section below.

bio_emiss

Bio_emiss is a pre-processor for creating MEGAN input for WRF-Chem. To obtain bio_emiss, see the **Download** section below.

preprocessor tools

Pre-processor tools for running WRF-Chem / MOZCART. See the **Download** section below.

Download

Use the Processors Download page to register and retrieve the above software packages.

Upper Boundary Conditions

Download input files for running WRF-Chem V3.3.1 with Chemical Upper Boundary Conditions: UBC_inputs.tar

Fire_Emis

Fortran based preprocessor for creating fire emission inputs for WRF-Chem when running with plumerise and also for creating fire emission inputs for the MOZART-4 and CAM-Chem global models. The fire emissions inventory is based on the Fire Inventory from NCAR (FINN). Both software (fire_emis.tgz) and required FINN input data sets are available at the download page.

Thank you!

Christine Wiedinmyer
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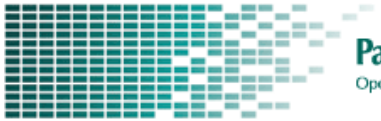
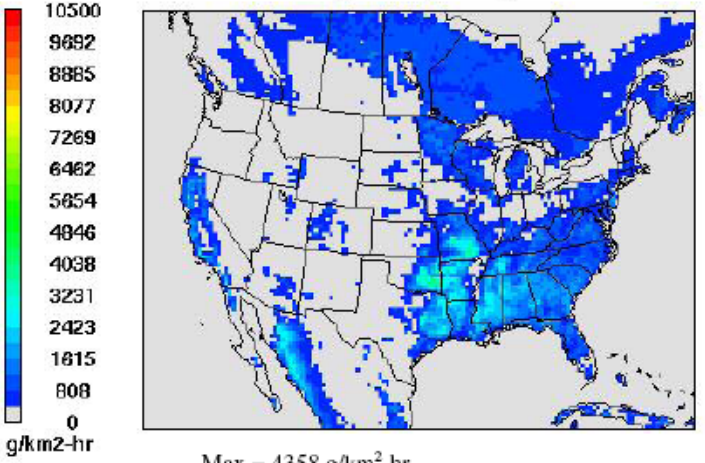


Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

BEIS 3.0

Isoprene Emission

BEIS3.0 (ISOPRENE mass)
July Monthly Average



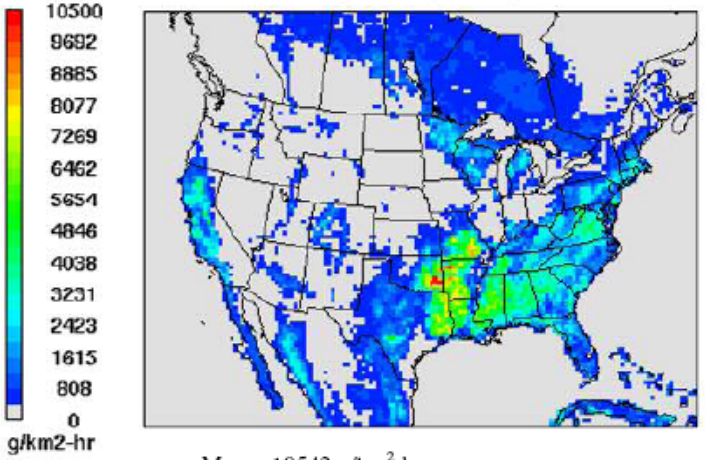
Max = 4358 g/km^2-hr

Total average emission = 7417 tons hr^{-1}

MEGAN

Isoprene Emission

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



Max = 10542 g/km^2-hr

Total average emission = 12145 tons hr^{-1}