MEGAN and WRF-CHEM

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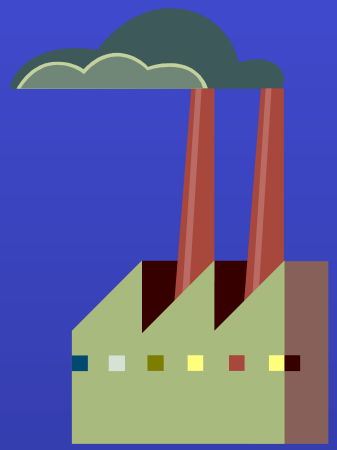
Emissions for Chemical Transport Models

- 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 km^2 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 ($\mu g\ m^{-2}\ hr^{-1}$)
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

(Guenther et al., 2006)

Current MEGAN Code in WRF-CHEM

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

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

- The algorithm and data for γSM and ρ are not yet ready. They are assigned to 1.0
- **T**he 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

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

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

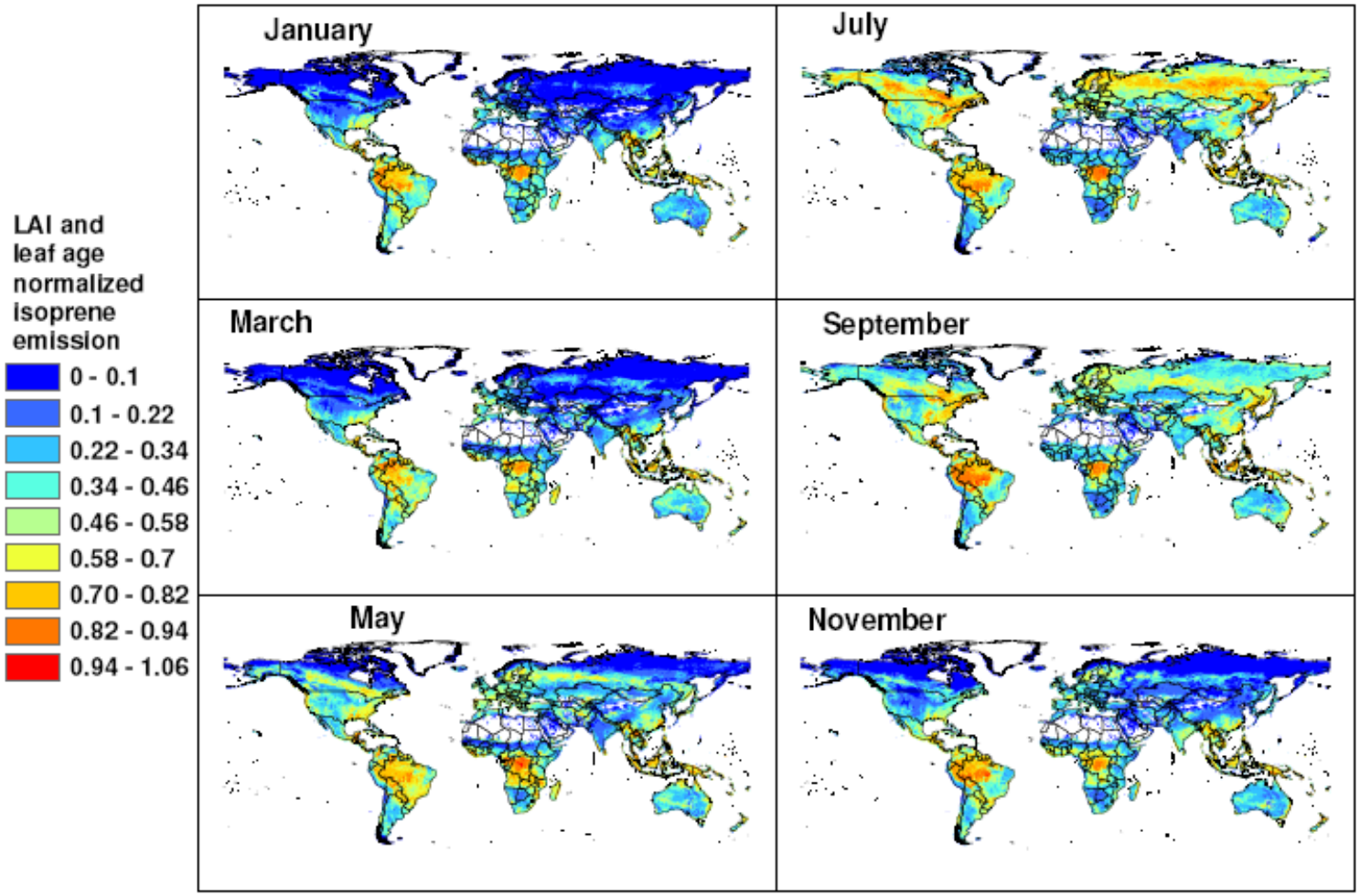


Fig. 5. Monthly normalized isoprene emission rates estimated with MEGAN for 2003. Rates are normalized by the emission estimated for standard LAI (=5 $m^2 m^{-2}$) and leaf age (80% mature leaves). These normalized rates illustrate the variations associated with changes in only LAI and leaf age; i.e.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

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*

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

- 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:

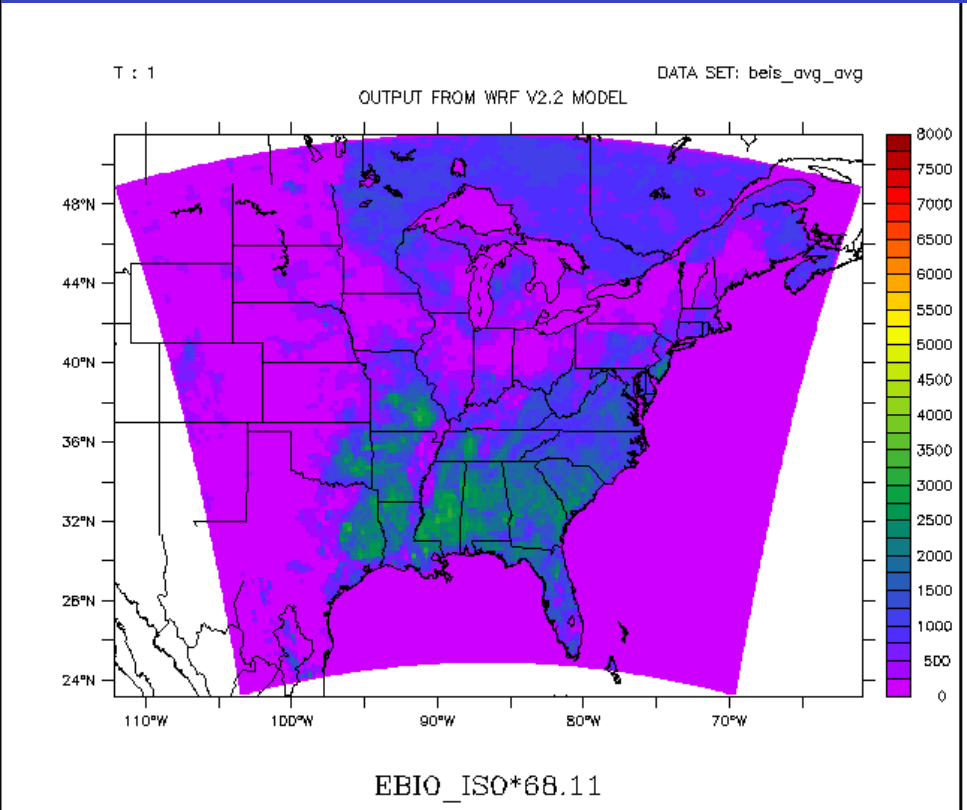
http://www.cdc.noaa.gov/PublicData/tables/monthly.html

- For Downward Solar Radiation:

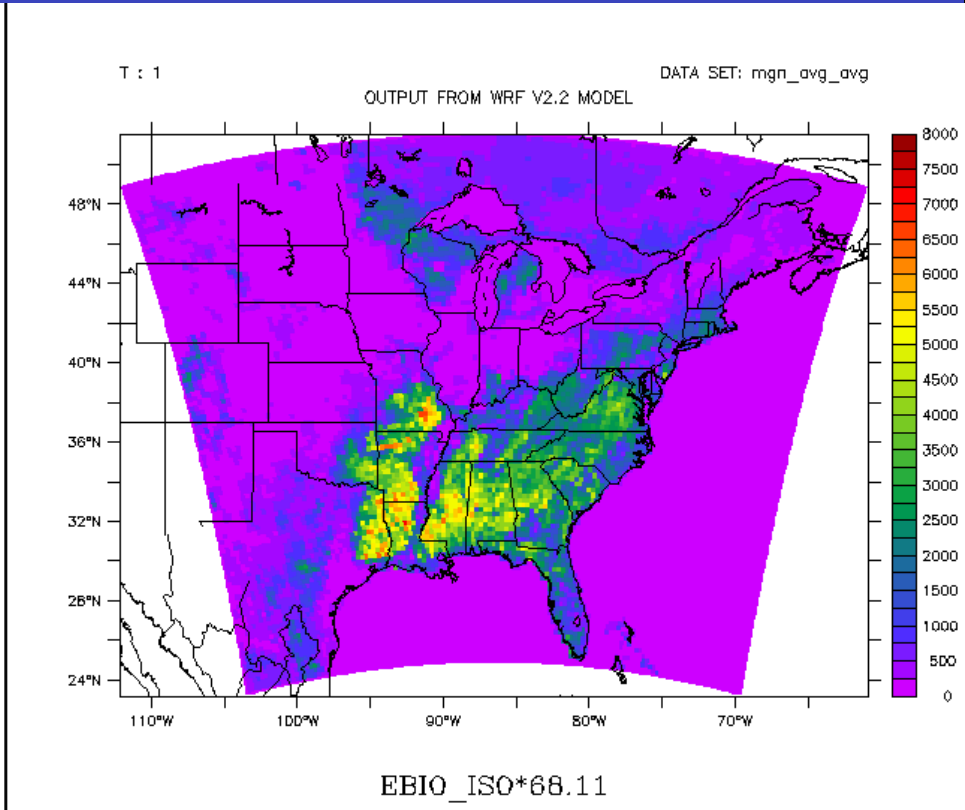
http://gswp2.tkl.iis.u-tokyo.ac.jp/gswp2/free/ddc.html

MEGAN vs. BEIS3.11

BEIS

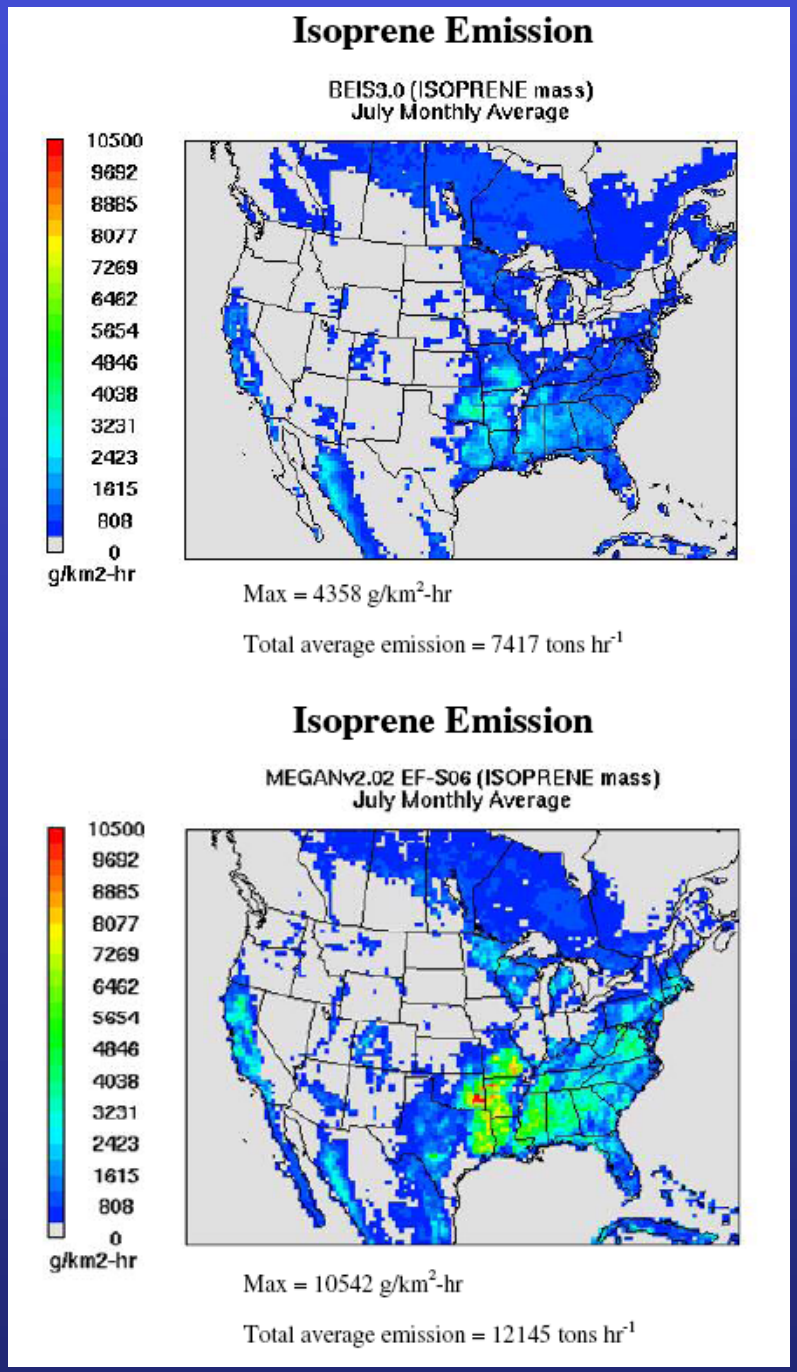


MEGAN



BEIS 3.0

MEGAN



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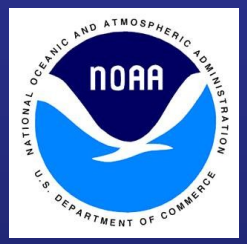
Thank you!

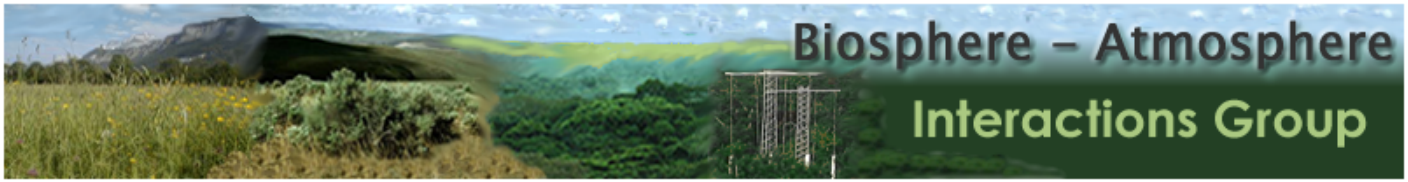


Preparing MEGAN Input file

- 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:) go

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
EF.zip				180783419	NCAR DISK	
ef21.zip				726388093	NCAR DISK	
efmt21.zip				1039497882	NCAR DISK	

NEW: Select All Files: NCAR DISK Deselect All Files

1-3 of 3 datafiles

NCAR Community Data Portal, sponsored by National Science Foundation

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," "))'