Integration of the Model of Emissions of Gases and Aerosols from Nature (MEGAN) into the CMAQ Modeling System

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United States Environmental Protection Agency
Office of Research and Development
National Exposure Research Laboratory | Atmospheric Modeling and Analysis Division|

Why using MEGAN in CMAQ?

1. Biogenic Emissions are important to both Ozone and PM
2. MEGAN represents the latest science in the estimation of biogenic VOCs
3. MEGAN is being used by other modeling groups especially global modeling
4. MEGAN can be used on both global, regional, and local scales

Topics to be Discussed

1. **Brief introduction to *MEGAN and BEIS***
   - **Biogenic Emissions Inventory System (BEIS v3.14)**
   - **Model of Emissions of Gases and Aerosols from Nature (MEGAN v2.04)**
2. **Spatial differences between two models for an annual simulation**
3. **Temporal differences between the two models**
4. **Future Work**

Details about BEIS3.14

- Based on BELD3 vegetation database (limited to North America)
- Emission factors derived for USGS land use types, crops, and specific tree types
- Soil NO algorithm is a function of temperature, rainfall, and growing season (Yienger and Levy, 1995)
- Simple canopy model for light adjustment
- Summer/Winter factors based on freeze dates

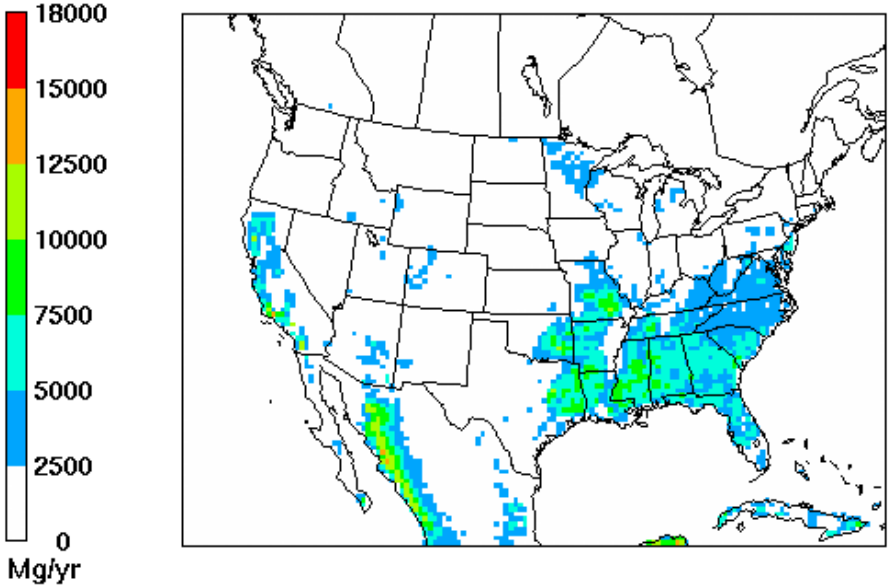
Details about MEGANv2.04

- Gridded emission factors based on global datasets for 11 chemical compounds.
- Emission factors for all other compounds divided into only 4 functional plant types (broadleaf, needles, shrubs, etc)
- NO emission estimates are a function of temperature only
- Simple parameterization of canopy light attenuation in Version 2.04; Version 2.10 will have an explicit canopy model
- Monthly gridded leaf area indices (LAIs) used for seasonal variation

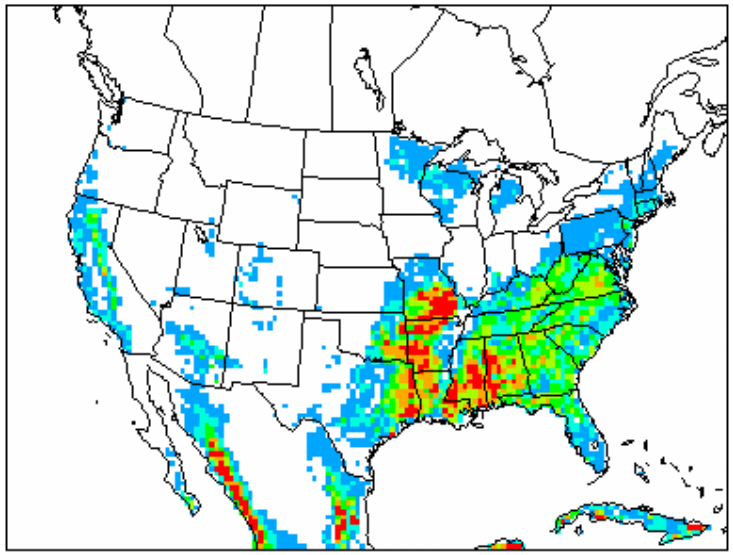
Guenther, A., T. Karl, et al. (2006). "Estimates of global terrestrial isoprene emissions using MEGAN (Model of Emissions of Gases and Aerosols from Nature)." Atmos. Chem. Phys. 6(11): 3181-3210.

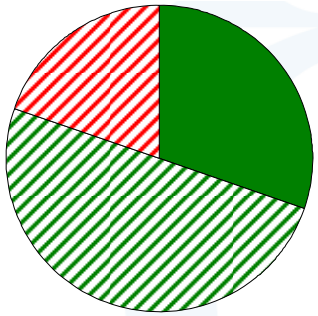
Isoprene Emissions Estimated for 2003

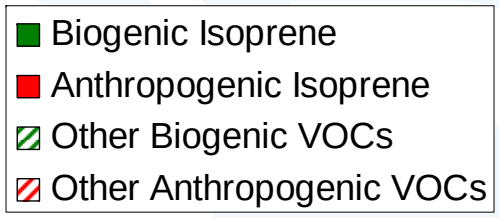
BEIS

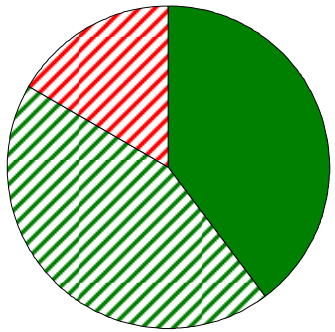


MEGAN

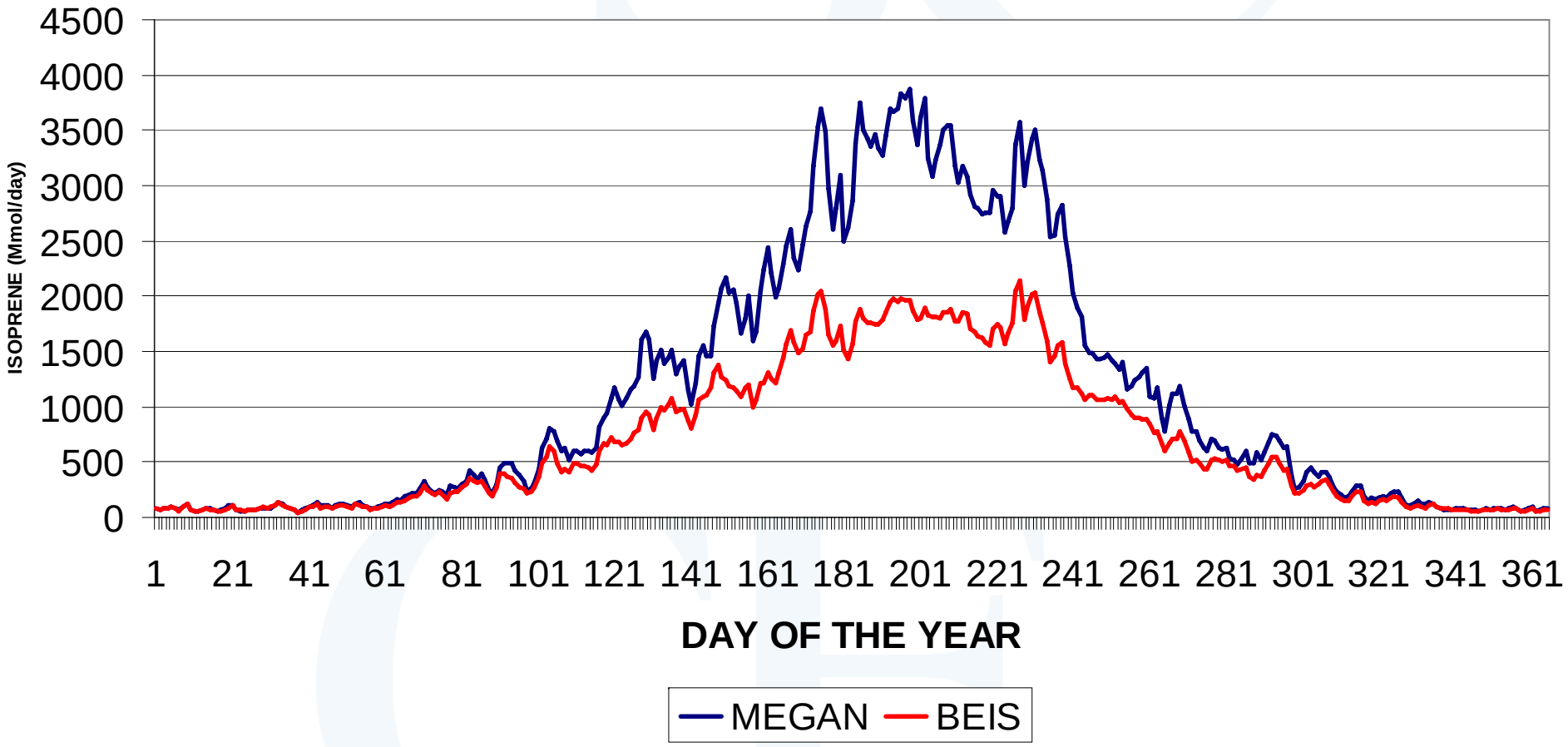








Isoprene 36km daily domain totals 2003



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Now that we've established that estimates from MEGAN and BEIS are quite different, can we ascertain the algorithmic reasons why they are different?

Isoprene emission calculation

- BEIS

$$Emission = \varepsilon_l \gamma_T \gamma_P$$

- MEGAN

$$Emission = \varepsilon_c \gamma_{LAI} \gamma_P \gamma_T \gamma_{SM} \gamma_{age}$$

Comparison of normalized fluxes

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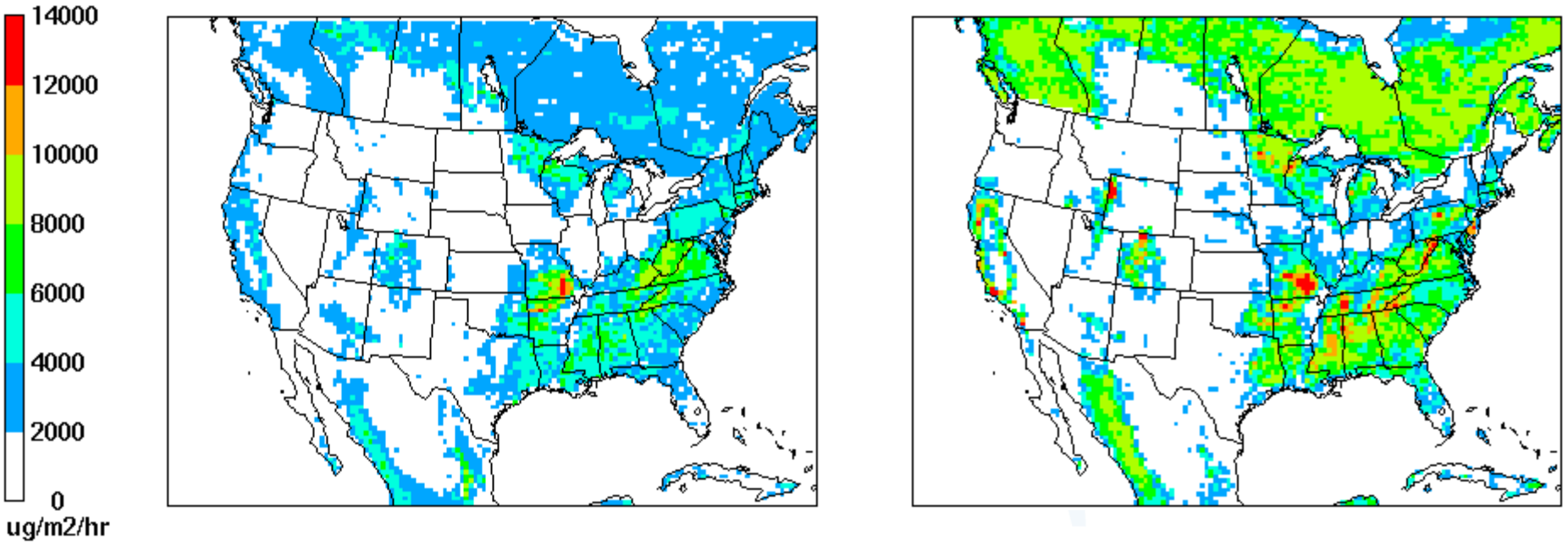
Normalized Emissions MEGAN

Normalized Emissions BEIS



MEGAN's normalized fluxes are actually lower than BEIS (by ~38%) because they represent "shaded" canopy-level fluxes rather than leaf-level fluxes

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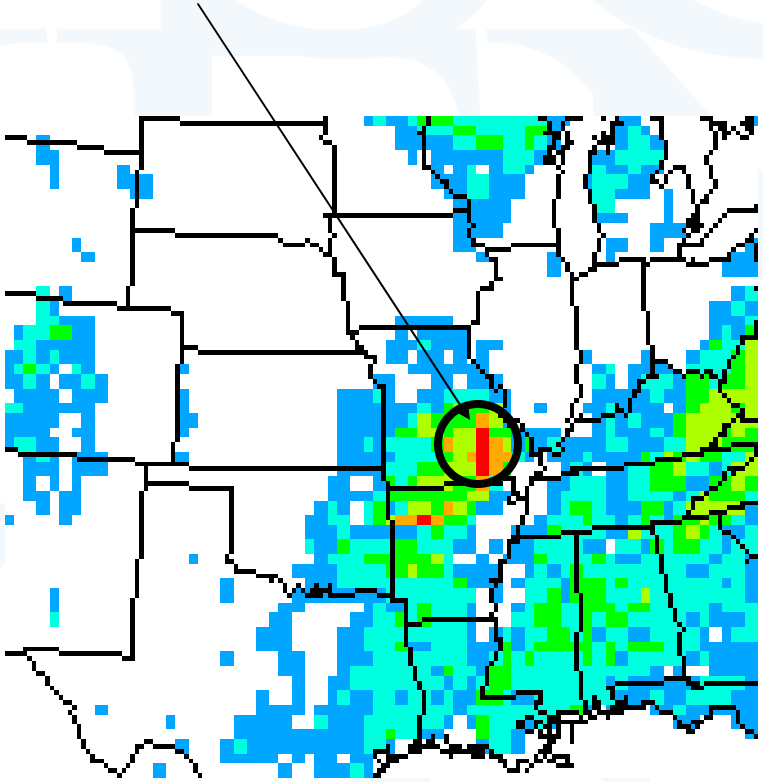
To further probe model differences, let's zoom into a grid cell in Missouri on August 1, 2003



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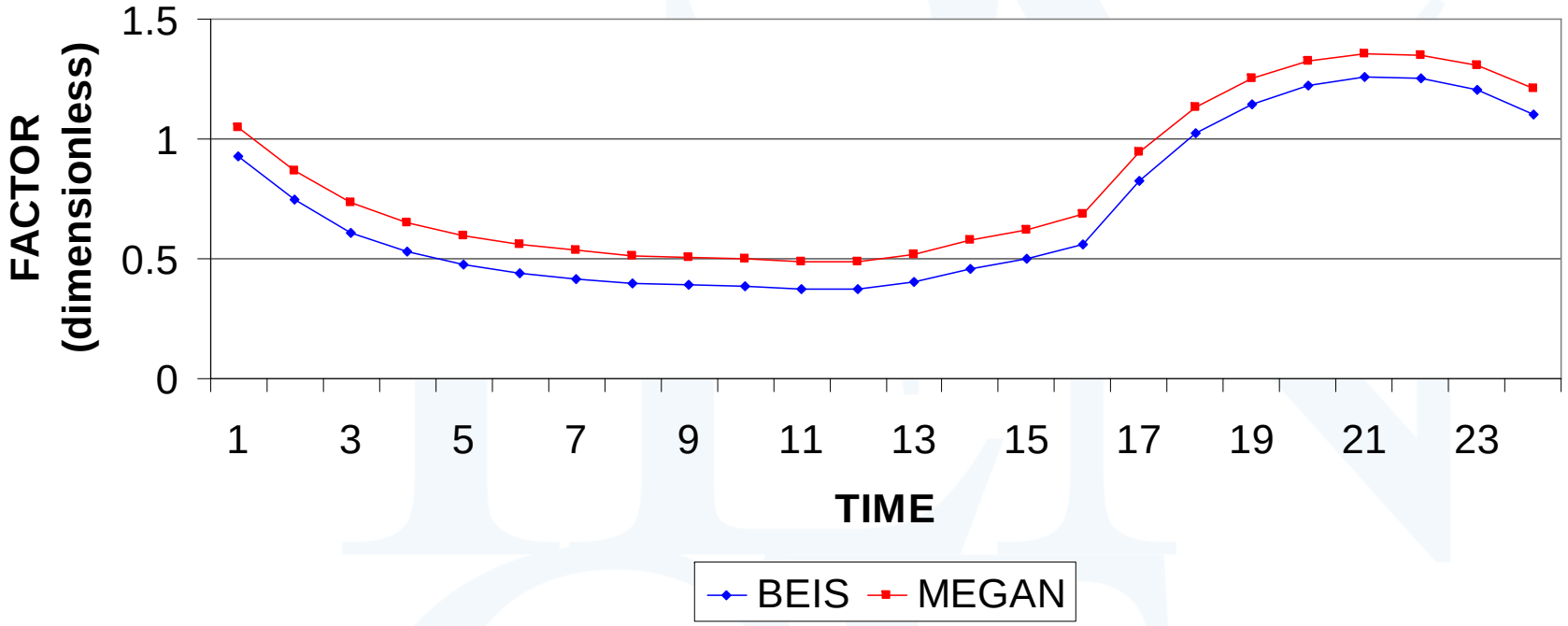
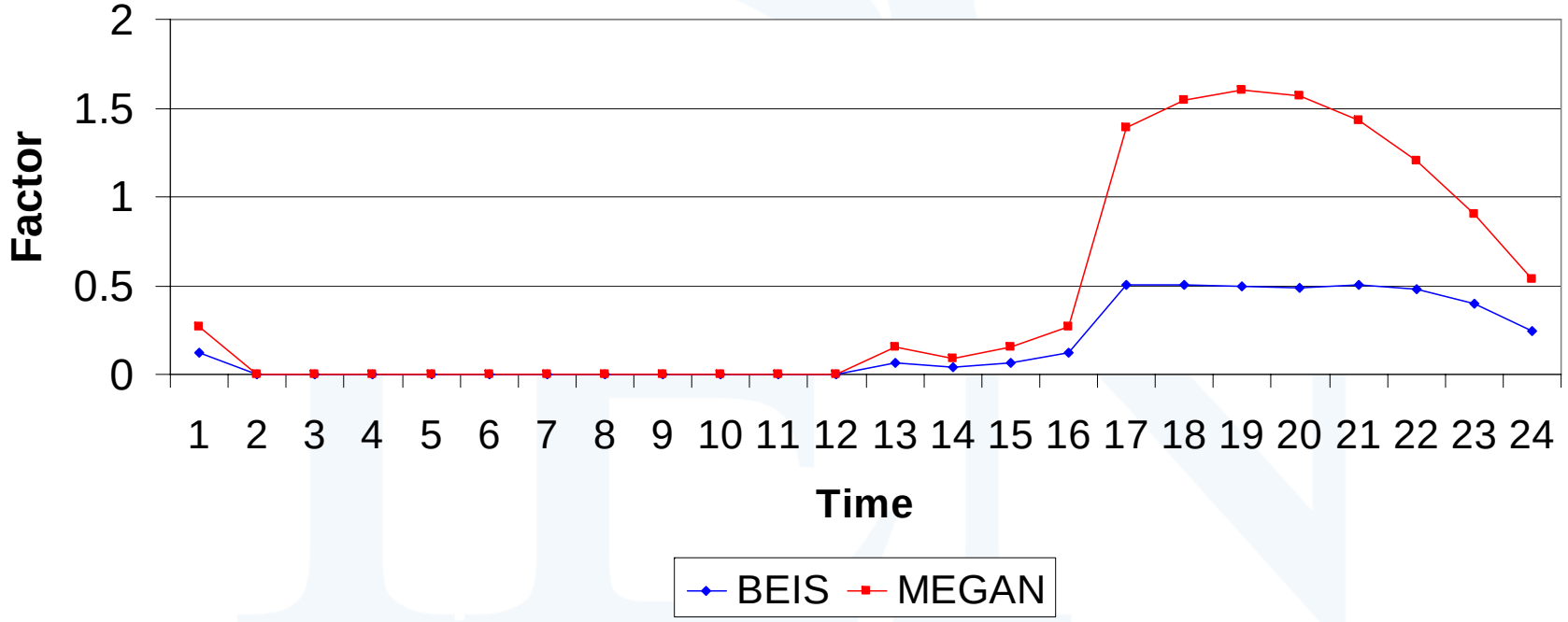
Temperature Correction Factor



MEGAN's temperature correction factor is 15% higher than the BEIS factor. (8/1/2003)

Light Correction Factor



MEGAN's light correction factor is as much as 2x higher than the BEIS factor…Why?

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Other Megan Factors (at grid cell on this day)

$$\gamma_{LAI} = 0.958$$

$$\gamma_{SM} = 1$$

$$\gamma_{age} = 1.11$$

These other factors (not used in BEIS) increase emission estimates in MEGAN by only ~10%.

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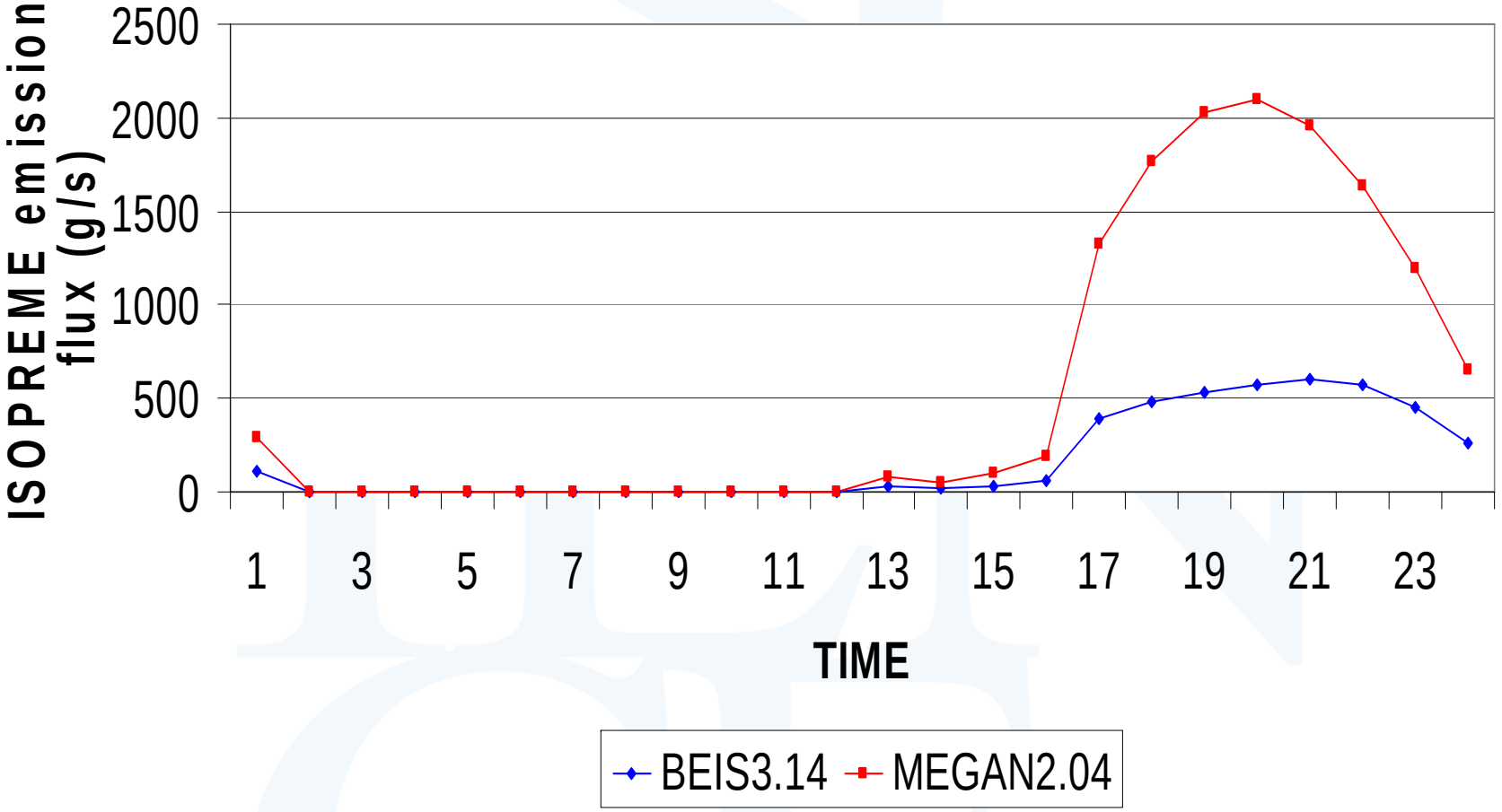
BEIS vs MEGAN



Overall, hourly emissions at this grid cell are as much as 3x higher with MEGAN than BEIS.

Probing MEGAN's light adjustment factor

$$\gamma_P = \sin(a)[2.46(1+0.0005\times(P_{daily}-400))\phi - 0.9\phi^2]$$

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

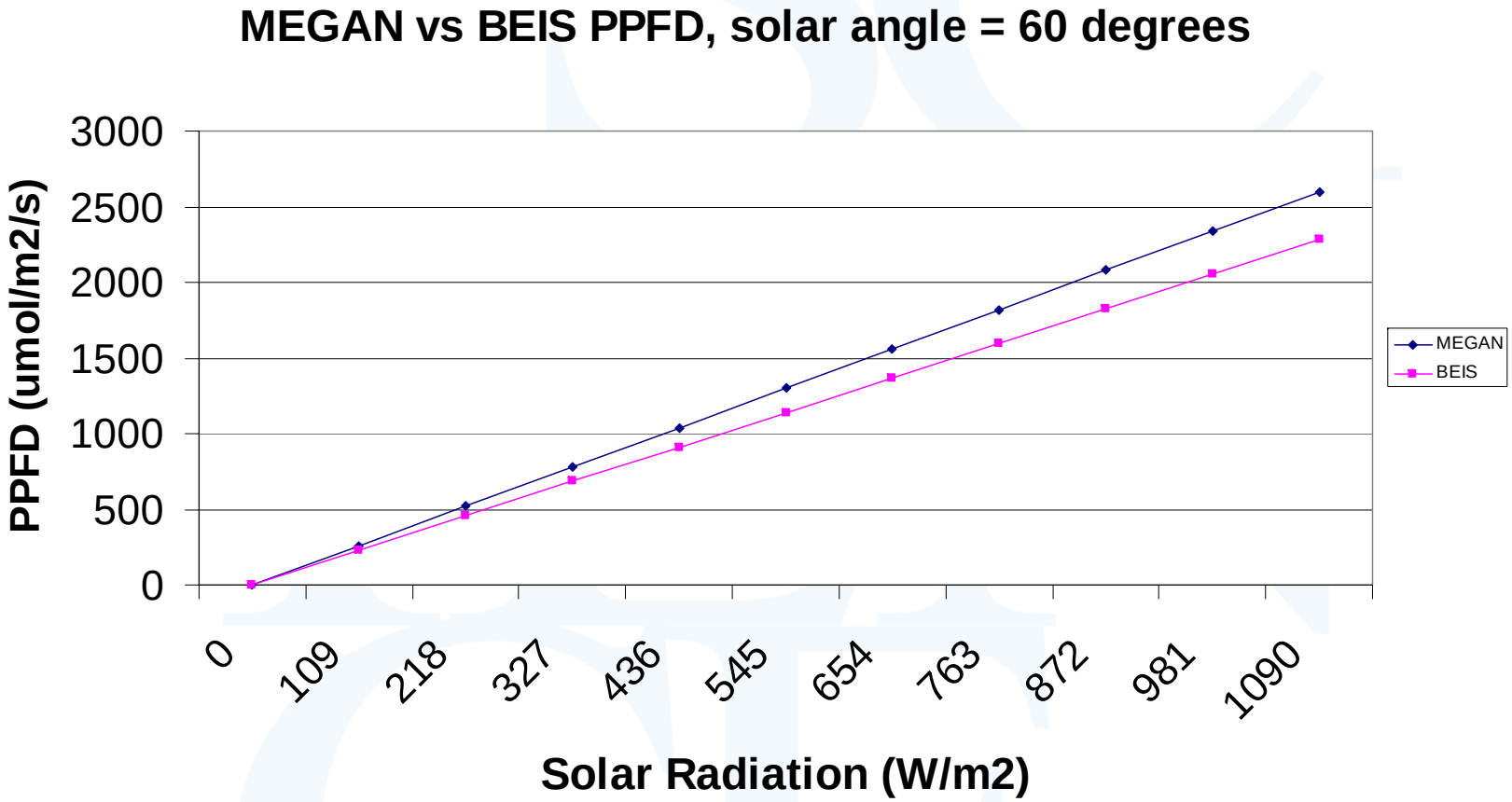
$$P_{toa} = 3000+99*\cos(2\cdot\pi\cdot(DOY-10)/365))$$

a=solar angle, P_{ac}=above canopy PPFD, P_{daily}=average daily above canopy PPFD,P_{toa} =PPFD at top of atmosphere

BEIS light Factor

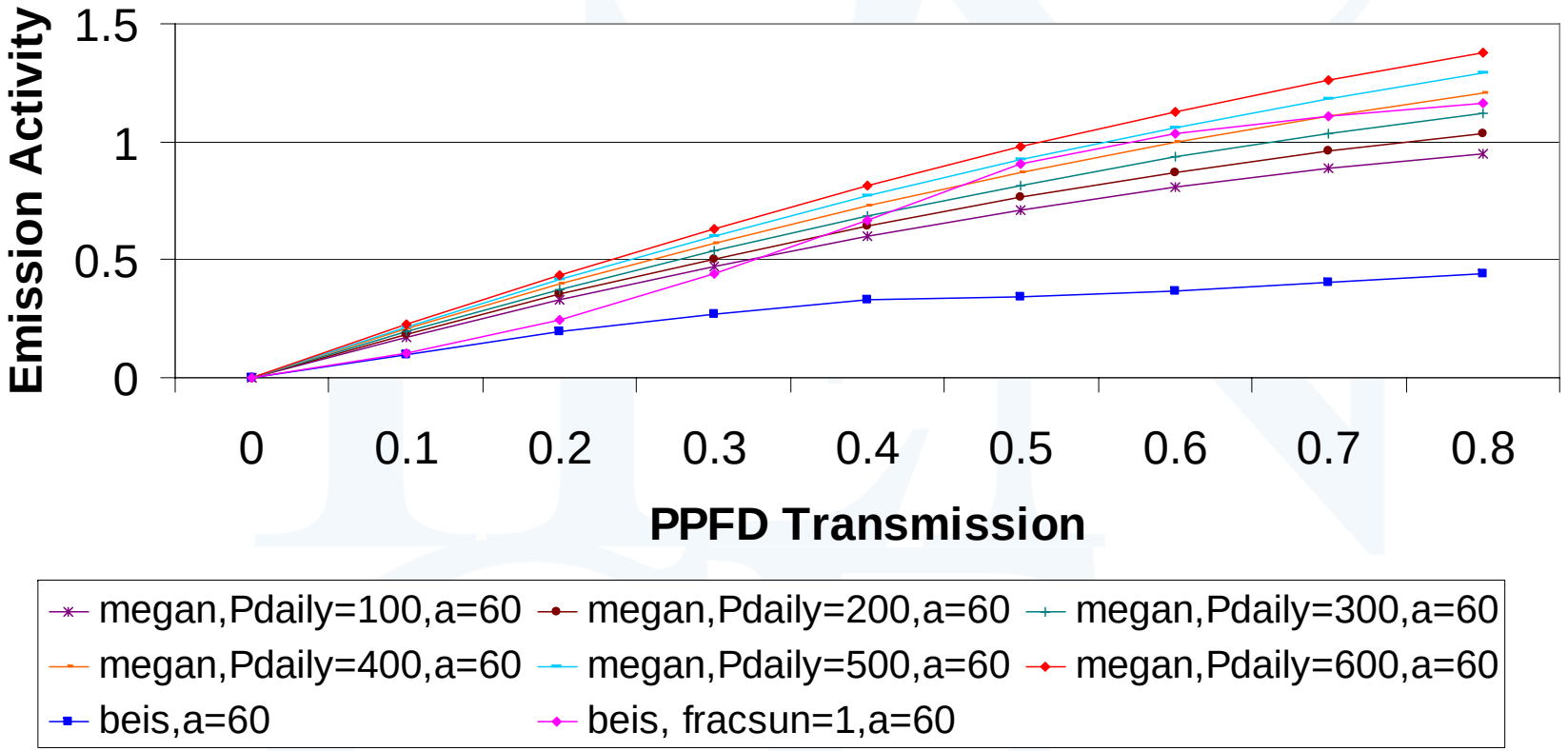
$$\gamma_P = f_{sun} \frac{\alpha C_L PAR_{sun}}{\sqrt{1+\alpha^2 PAR^2_{sun}}} + f_{shade} \frac{\alpha C_L PAR_{shade}}{\sqrt{1+\alpha^2 PAR^2_{shade}}}$$

Photosynthetic Photon Flux Density (PAR) is estimated from total solar radiation



PPFD is 14% higher in MEGAN than BEIS; PPFD directly impacts light correction coefficient.

MEGAN vs BEIS radiation response



PPFD Transmission = fraction of radiation that reaches canopy

BEIS has lower response to solar radiation because

- Photosynthetic Photon Flux Density (PPFD) is lower in BEIS than MEGAN
- The Campbell and Norman (1998) solar radiation algorithm in BEIS accounts for shaded and sunlit leaves
  - For LAI=5/solar angle=60°, 80% shaded and 20% sunlit
  - Underestimates solar fraction because of different leaf thickness ignored for sunlight vs shaded leaves

Summary

- MEGAN2.04 estimates higher isoprene than BEIS3.14 primarily because of differences in how the light adjustment factor is treated
  - Different estimate of PPFD
  - Sunlight vs shaded leaves
- Other factors in MEGAN that increase isoprene
  - Temperature adjustment factor
  - Leaf age factor
- MEGAN's lower "canopy-level" emission flux does not offset its higher light correction factor vs BEIS.

Future Work

- Compare CMAQ results for BEIS3.14 and MEGAN2.04 for 3 week period in 2003
- Incorporate MEGAN into CMAQ as an option compared to BEIS
- MEGANv2.10 is expected by the end of the year (will include updated canopy model)
- Eventually may replace BEIS with MEGAN
- Understand how canopy fluxes are derived in MEGAN
- Disclaimer: Although this work was reviewed by EPA and approved for publication, it may not necessarily reflect official Agency policy