Biogenic Emissions Modeling

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Biogenic VOC

- Biogenic VOC comprise approximately 75-80% of the North American annual 2005 VOC emission inventory
- Biogenic emissions largely a function of plant type, leaf area index, temperature, and solar radiation (PAR)
- Biogenic emissions for regional and global scale photochemical models are typically developed from either MEGAN or BEIS
  - Biogenics Emission Inventory System **(**BEIS**)**
    - Currently developed by US EPA
  - Model of Emissions of Gases and Aerosols from Nature **(**MEGAN**)**
    - Currently developed by PNNL

Part I: Ozarks

- July 1998 OZarks Isoprene Experiment (OZIE) field study designed for evaluation of biogenic models; ozone focused
- Compare MEGAN and BEIS isoprene and other biogenic VOC estimates to surface and upper air OZIE field study measurements
- Evaluate sensitivity of CMAQ predictions when using alternative biogenic emissions models for
  - Primary gas phase: isoprene
  - Secondary species: O_3, formaldehyde
- Alternative source of solar radiation; what impact does this variable have on MEGAN and BEIS estimates? How well does WRF capture solar radiation?

Ozarks Isoprene Experiment: July 1998

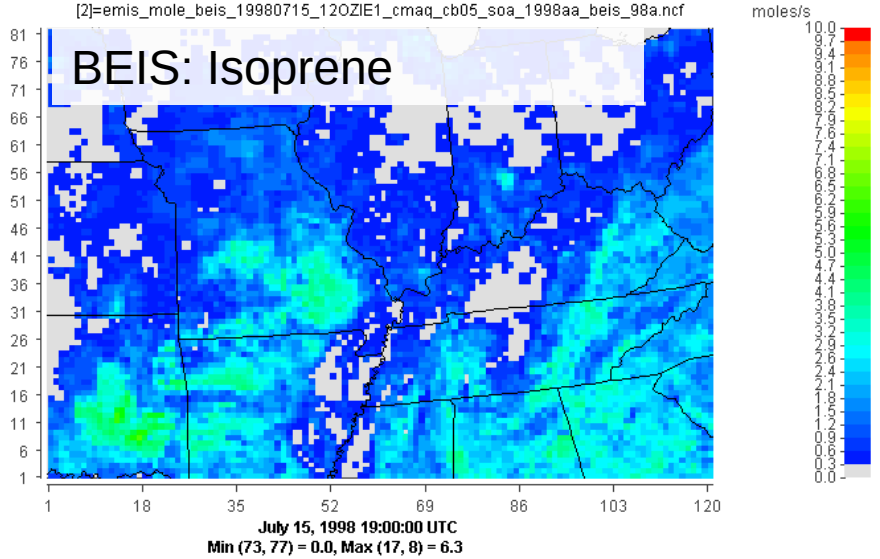
Model Background

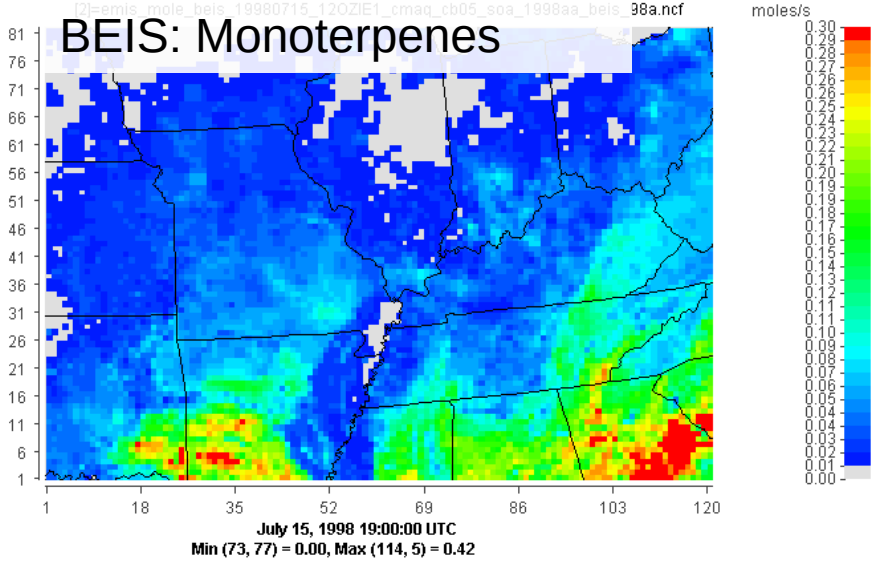
- Modeled June 15-July 31, 1998 episode
- CMAQ v4.7.1 (CB05 chemistry) and WRF v3.1 meteorology
- 2001 v2 based anthropogenic emissions

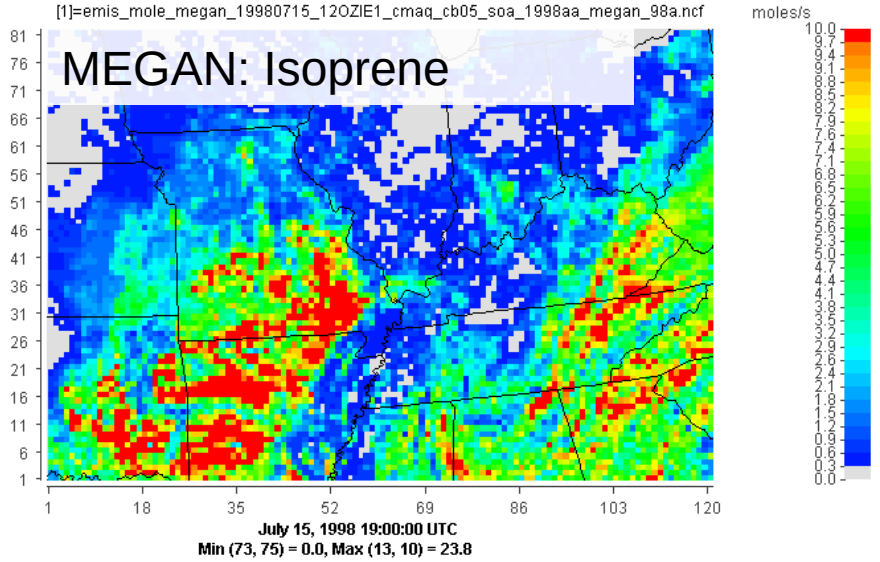
- BEIS v3.14 and MEGAN v2.04
  - WRF 2 m temperature and WRF shortwave downward radiation (98a)
  - WRF 2 m temperature and satellite estimated photosynthetically activated radiation (98b)

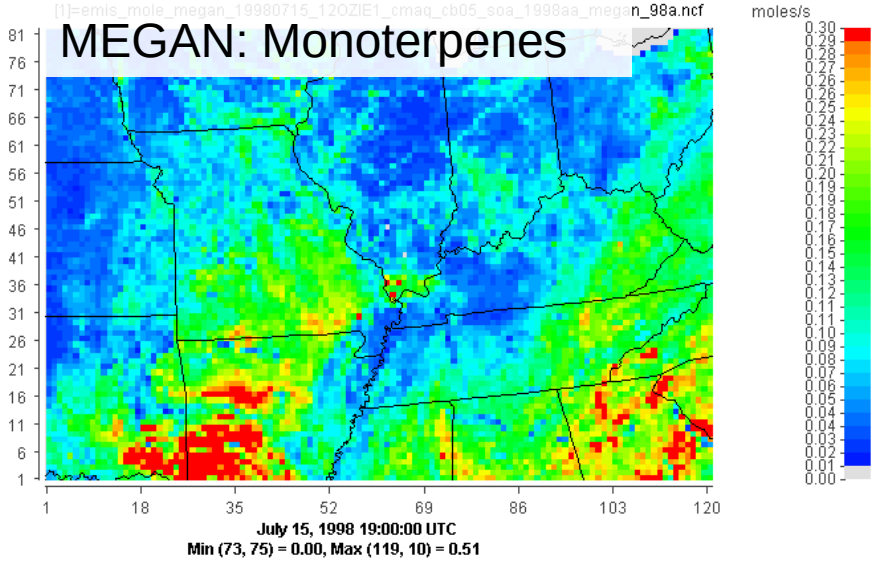
- Photosynthetically activated radiation (PAR) is the visible light fraction of shortwave downward radiation
- Satellite based estimates of PAR are available
  - http://www.atmos.umd.edu/~srb/gcip/cgi-bin/historic.cgi
  - Satellite PAR resolution 0.5 x 0.5 degrees and covers the continental United States
  - Missing hours and days replaced by hourly monthly average satellite estimates

Isoprene & Monoterpene Emissions

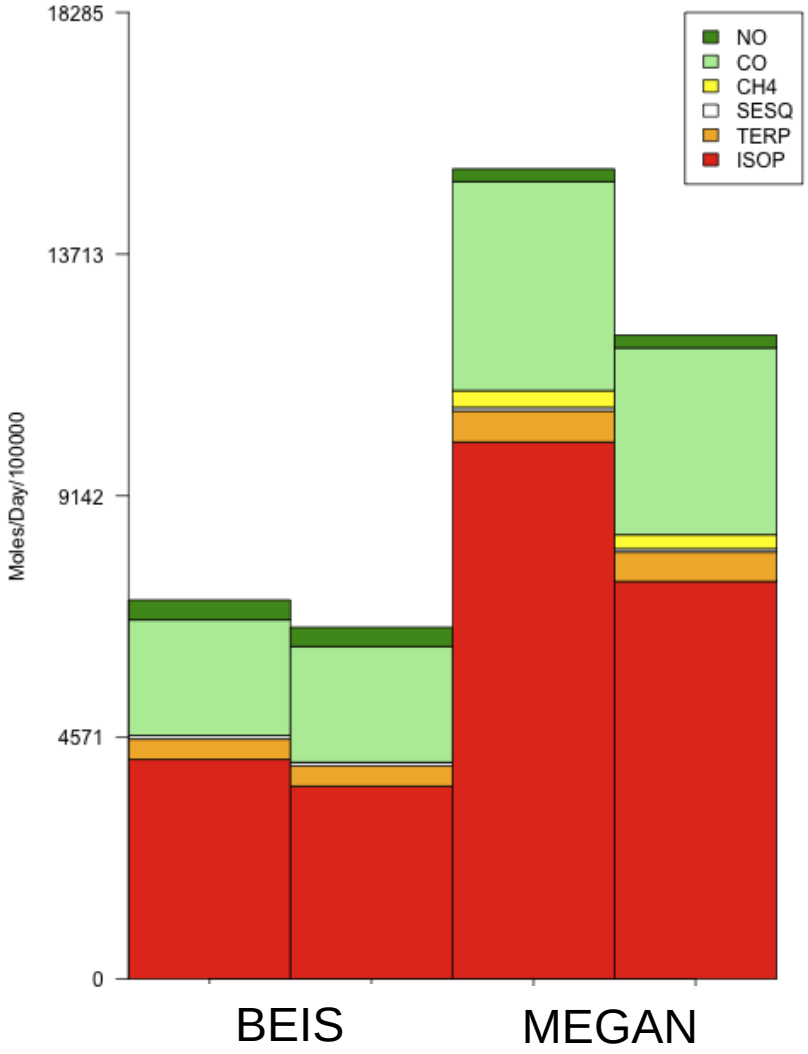


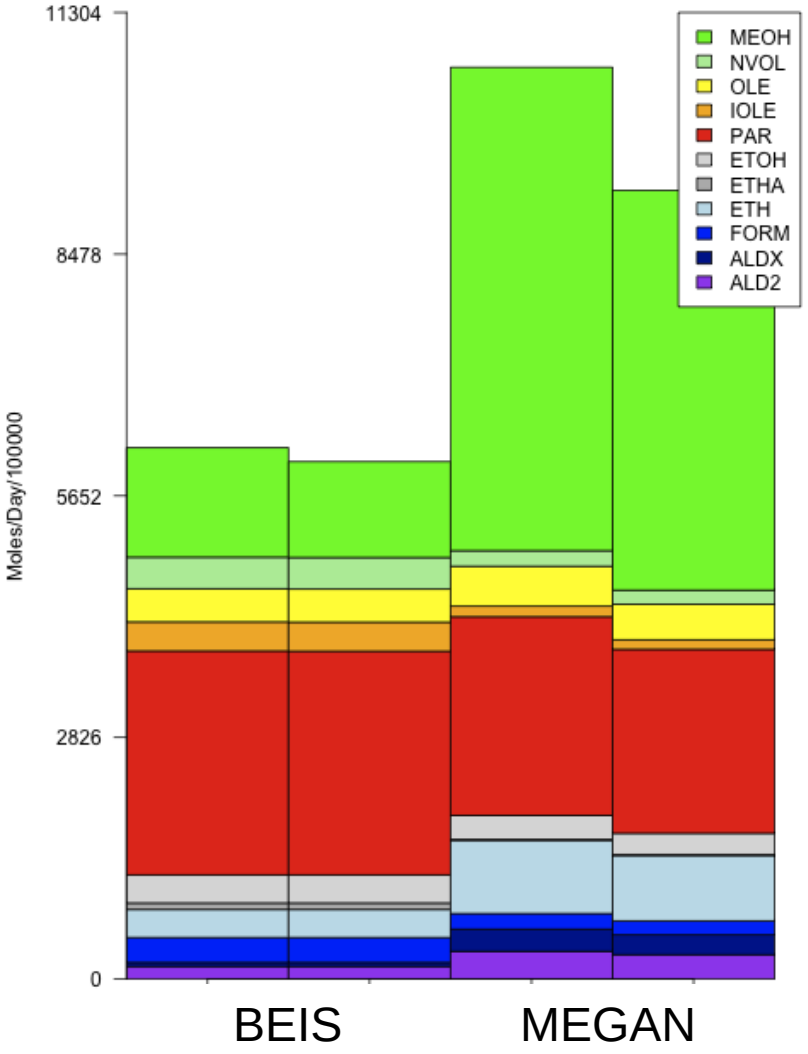






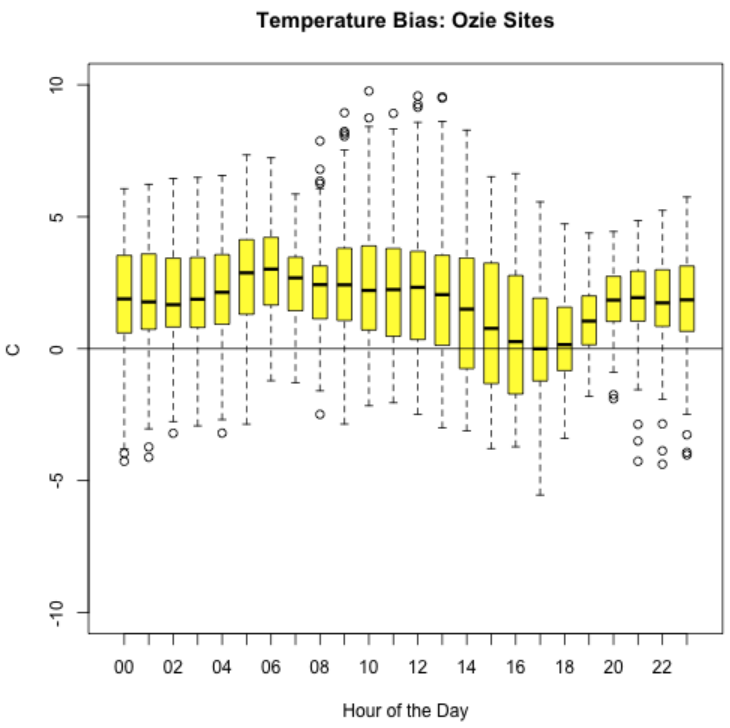
Monthly domain (12OZIE1) total emissions

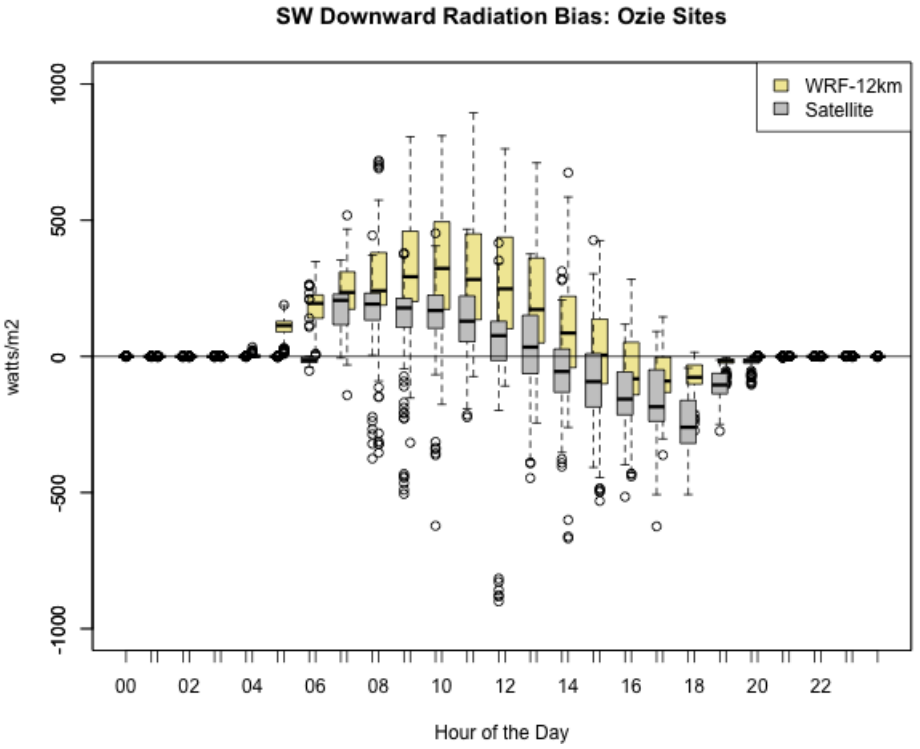




Temperature & PAR at OZIE Sites

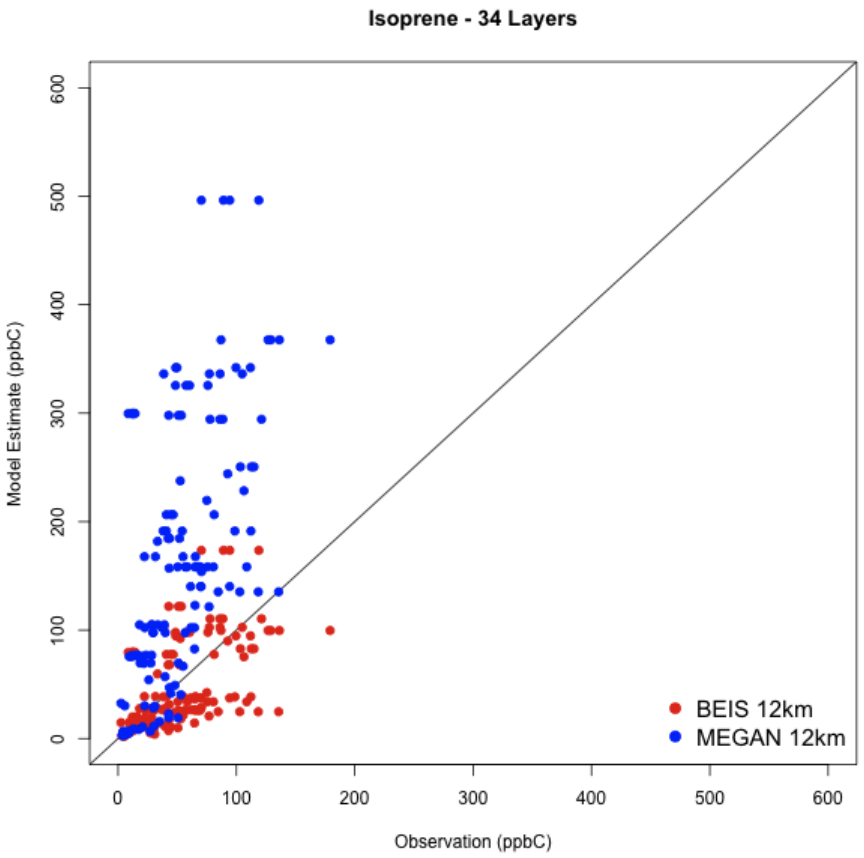
- Temperature and PAR drive biogenic model estimates
- General warm bias over all hours & days
- Morning and early afternoon PAR overestimated
- Satellite PAR estimates compare better to ground observations

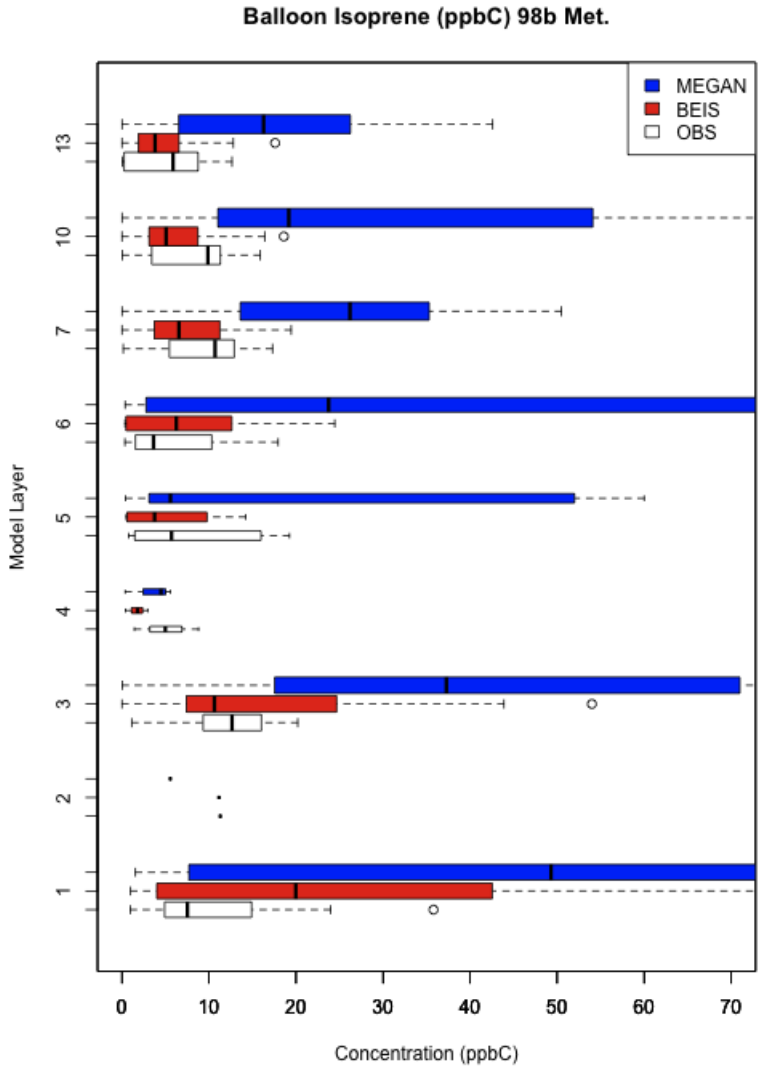




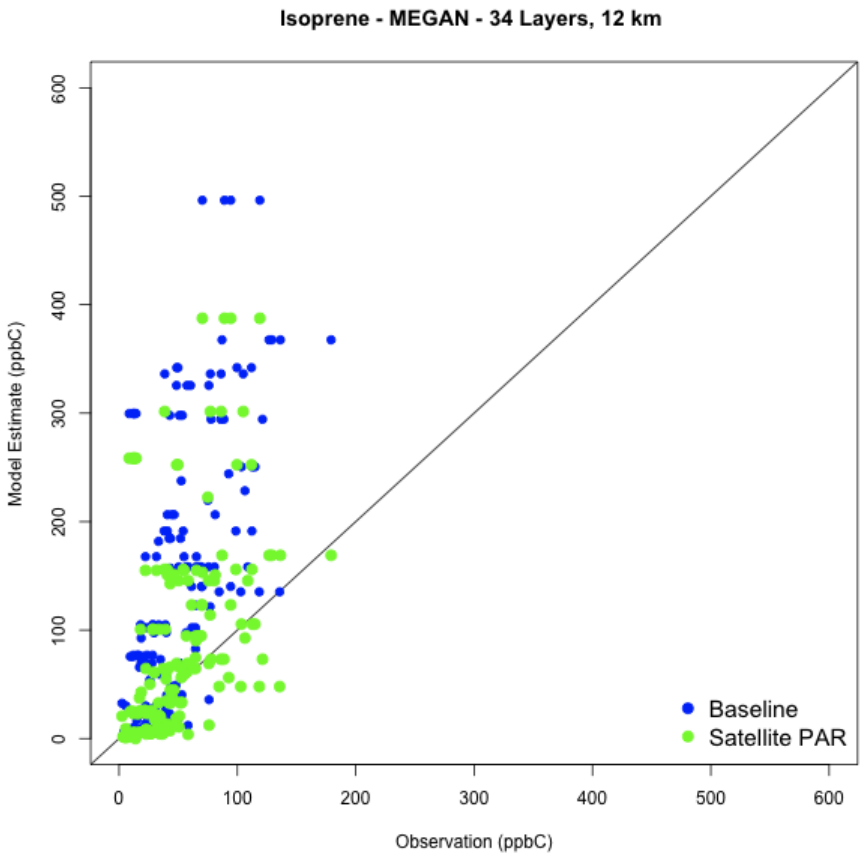
Isoprene Performance

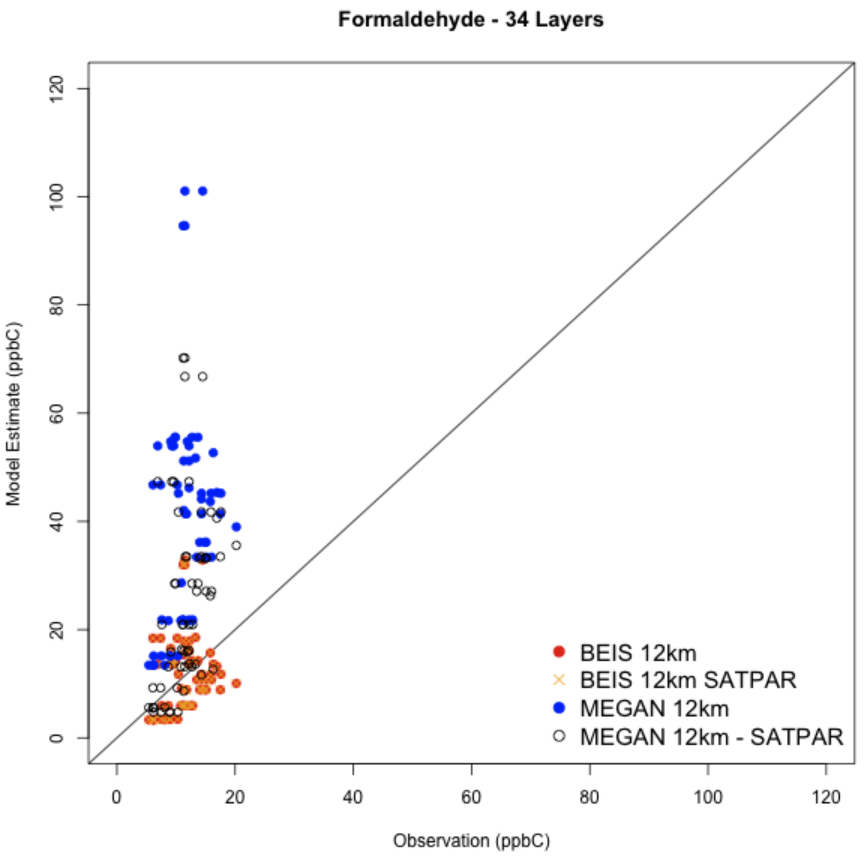
Surface (left) and Balloon (right)





PAR Impact on MEGAN Isoprene (left) & Secondary Impacts on Formaldehyde (right)





Conclusions from OZIE project

- MEGAN isoprene, monoterpenes, and sesquiterpenes much more photosensitive than BEIS
- Error in temperature and PAR important in characterization of biogenic emissions; too much PAR = too much isoprene in MEGAN
- CMAQ/MEGAN tends to estimate higher concentrations of isoprene and monoterpenes than CMAQ/BEIS
- Similar regional O_3 estimates may be due to BEIS having higher emissions of reactive OVOC

- OZIE field study provided little information about PM2.5 precursors such as monoterpenes and sesquiterpenes, radicals, or important chemical intermediate species (methacrolein and MVK)
- Need more robust observation datasets: spatially & temporally

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ARTICLE

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Photochemical Modeling of the Ozark Isoprene Volcano: MEGAN, BEIS, and Their Impacts on Air Quality Predictions

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Supporting Information

ABSTRACT: Biogenic volatile organic compounds (BVOCs) contribute substantially to atmospheric carbon, exerting influence on air quality and climate. Two widely used models, the Model of Emissions of Gases and Aerosols from Nature (MEGAN) and the Biogenic Emission Inventory System (BEIS) are employed to generate emissions for application in the CMAQ air quality model. Predictions of isoprene, monoterpenes, ozone, formaldehyde, and secondary organic carbon (SOC) are compared to surface and aloft measurements made during an intensive study in the Ozarks, a large isoprene emitting region. MEGAN and BEIS predict spatially similar emissions but magnitudes differ. The total VOC reactivity of the emissions, as developed for the CB05 gas-phase chemical mechanism, is a factor of 2 different between the models. Isoprene estimates by CMAQ-MEGAN are higher and more variable than surface and aloft measurements, whereas CMAQ-BEIS predictions are lower. CMAQ ozone predictions are similar and compare well with measurements using either MEGAN or BEIS. However, CMAQ-MEGAN overpredicts formaldehyde. CMAQ-BEIS SOC predictions are lower than observational estimates for every sample. CMAQ-MEGAN underpredicts SOC ~80% of the time, despite overprediction of precursor VOCs. CMAQ-MEGAN isoprene predictions improve when prognostically predicted solar radiation is replaced with the GEWEX satellite product. CMAQ-BEIS does not exhibit similar photosensitivity.

Part II: California

- California has a very unique spatial pattern of high emitting vegetation
  - Leverage multiple field campaigns that together form a unique opportunity to evaluation biogenic emissions models
  - BEARPEX 2009 (Blodgett Forest), CARES/CALNEX 2010 (northern California component)

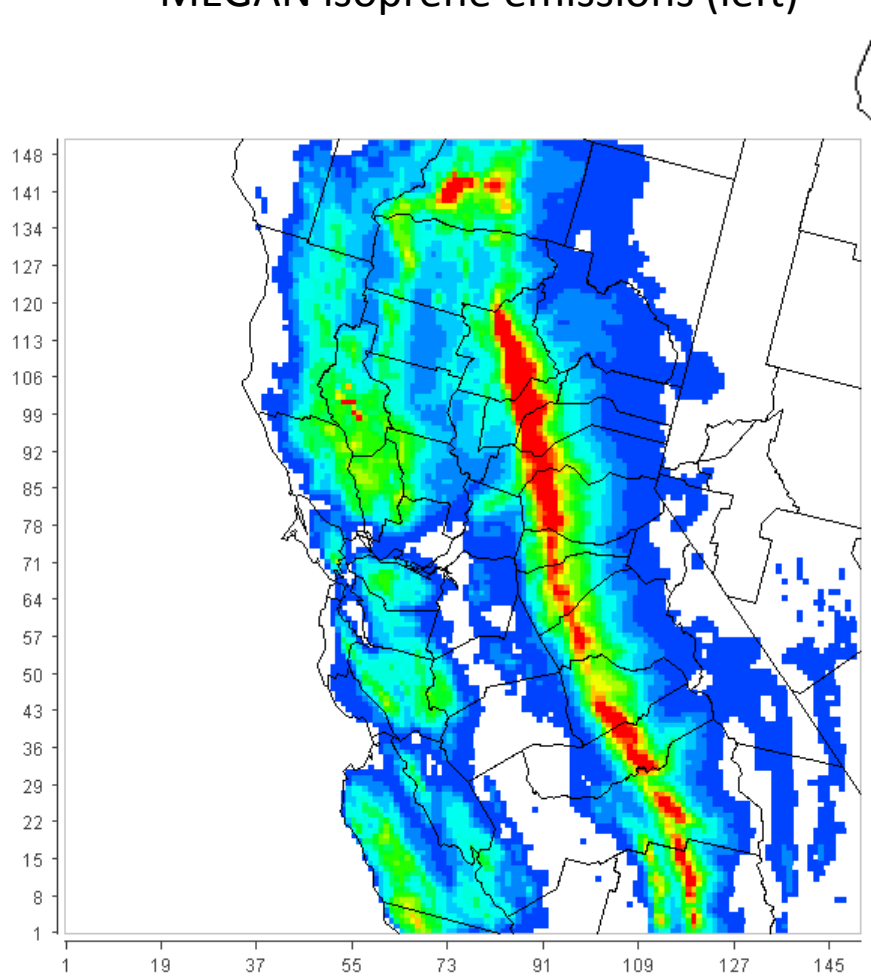
- Compare MEGAN and BEIS isoprene and other biogenic VOC estimates to surface and aircraft field study measurements

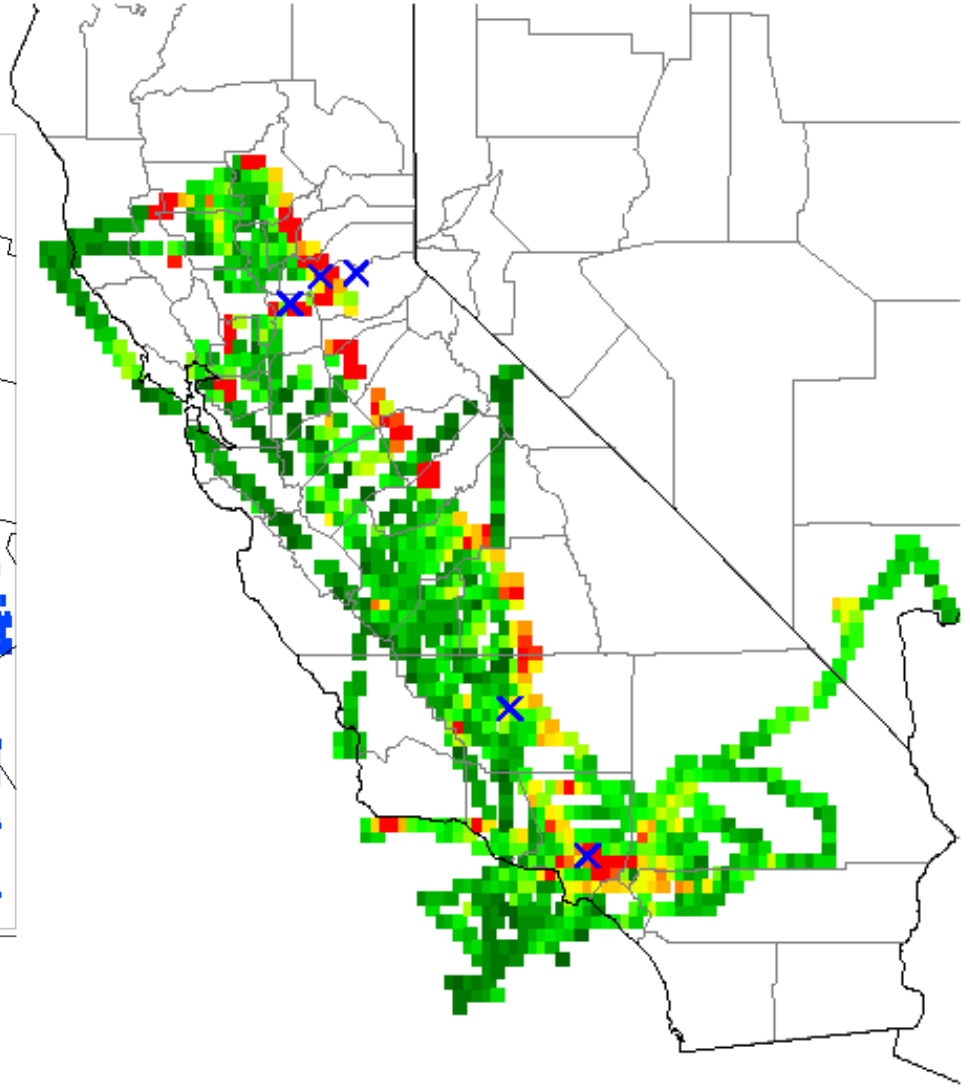
- Evaluate sensitivity of CMAQ predictions when using alternative biogenic emissions models for
  - Primary gas phase: isoprene, **monoterpenes, sesquiterpenes**
  - Radical species: **OH and HO2**
  - Secondary species: O_3, **methacrolein, methyl-vinyl ketones, PM2.5 OM**

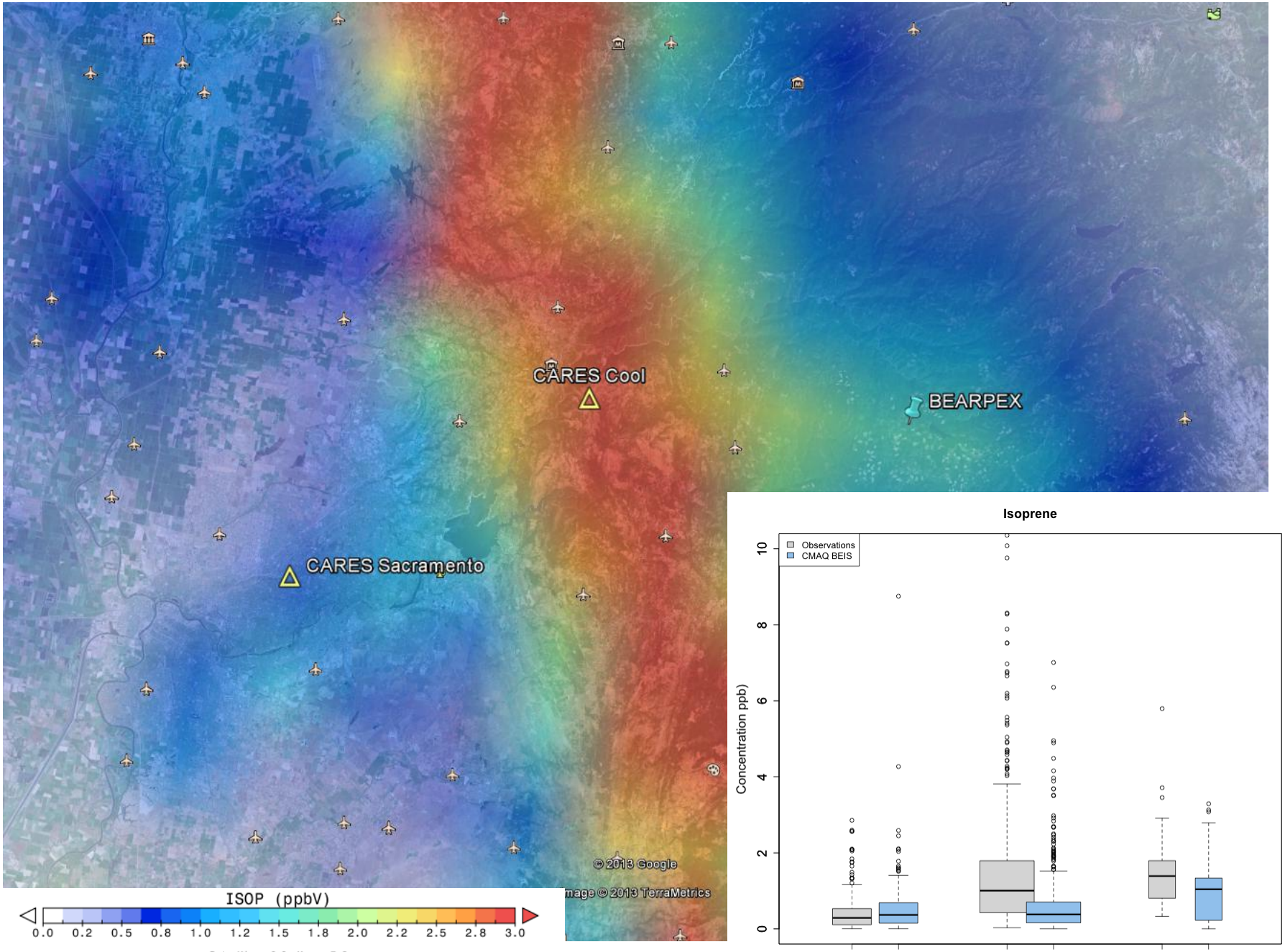
- While not evaluated, extensive heat flux, soil moisture, and soil temperature measurements are available

Unique spatial pattern of isoprene emissions in California

- Isoprene aircraft measurement composite from all CALNEX flights (right)
- MEGAN isoprene emissions (left)





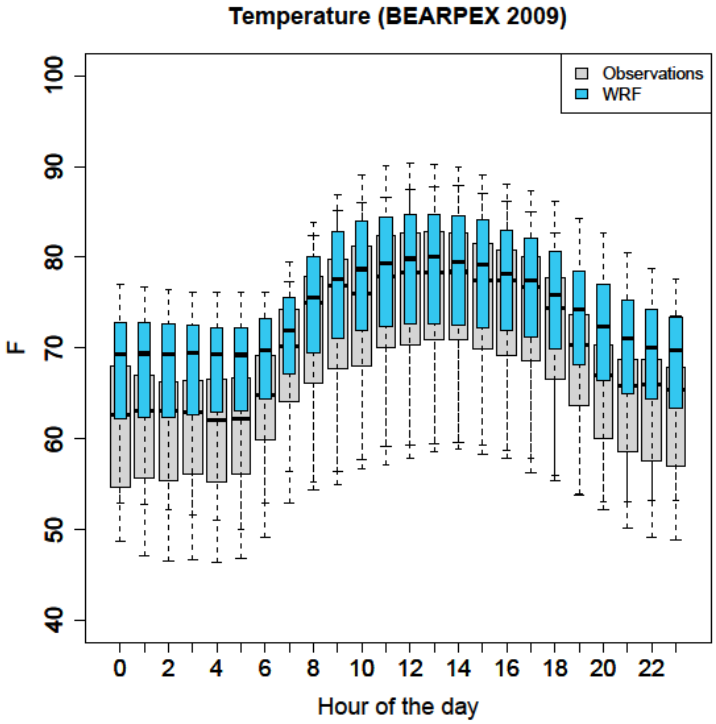

CARES Cool
BEARPEX
CARES Sacramento
© 2013 Google
Image © 2013 TerraMetrics
ISOP (ppbV)
0.0 0.2 0.5 0.8 1.0 1.2 1.5 1.8 2.0 2.2 2.5 2.8 3.0
Data Min = 0.0, Max = 7.8

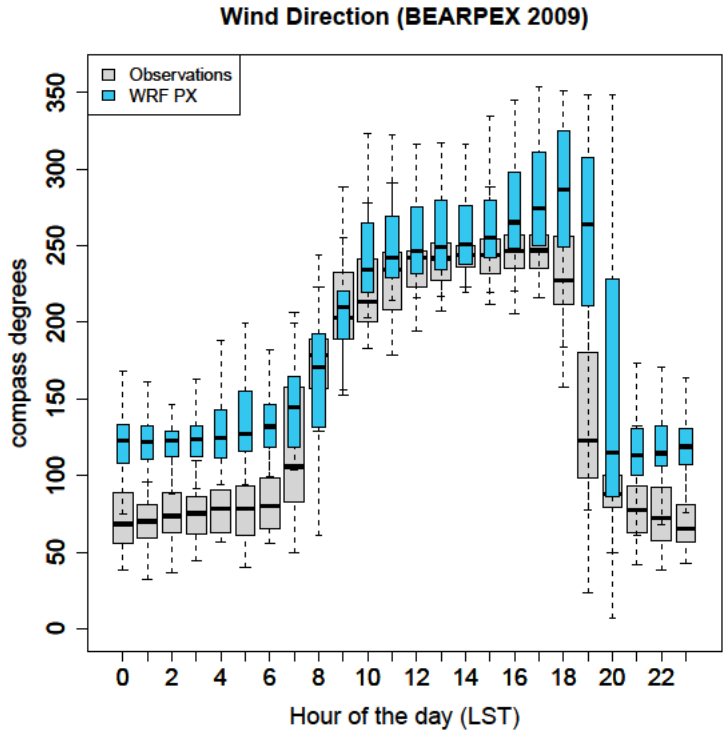
Isoprene
Observations
CMAQ BEIS
Concentration ppb)
0
2
4
6
8
10
Sacramento
Cool
Blodget

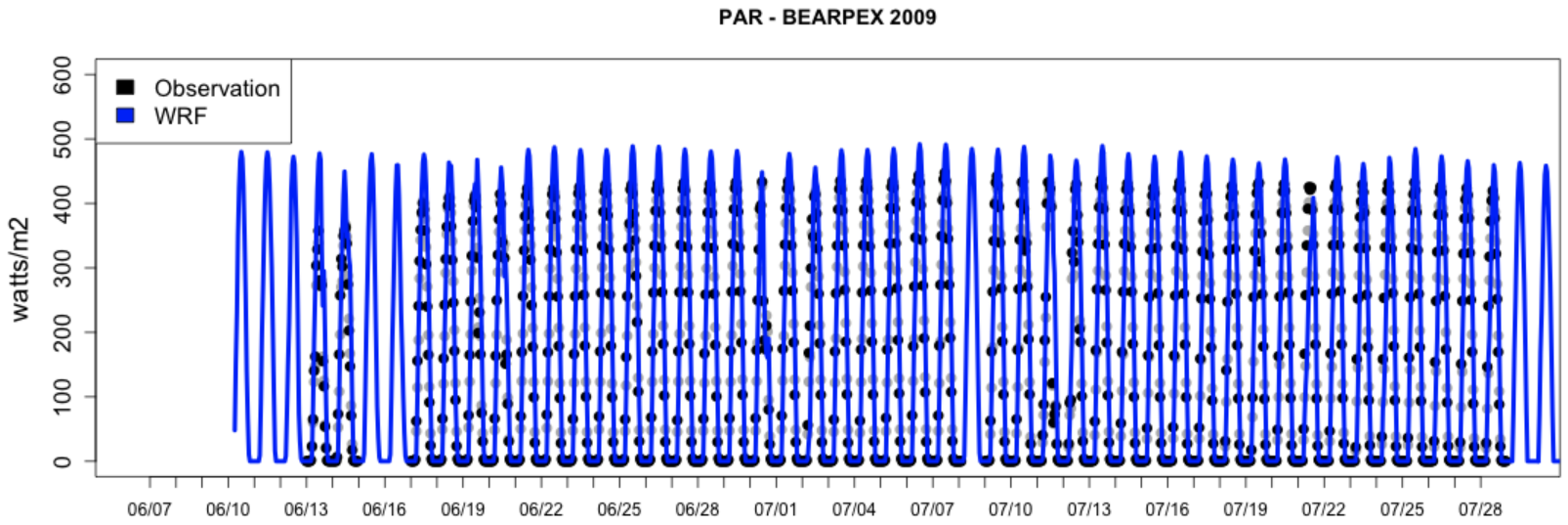
Model Background

- Modeling period: June 5 to July 30, 2009 (BEARPEX)
- 4 km grid resolution; 34 vertical layers (layer 1 height ~39 m)
- WRF v3.3
- CMAQ v5.0.1 (SAPRC07TB)

- **Biogenics: MEGAN v2.10 and BEIS 3.14**
- Anthropogenic emissions based on NEI 2008 v2; EGUs based on 2009 CEM data; mobile emissions interpolated between 2007 and 2011 CARB submission
- Initial and boundary concentrations from a coarser 2009 CMAQ simulation

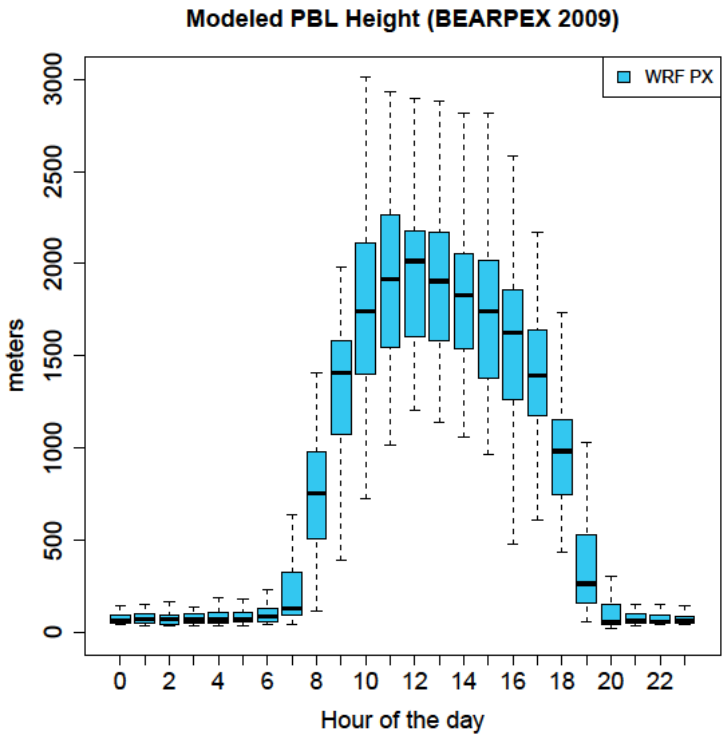

Temperature (BEARPEX 2009)
Observations
WRF
F
Hour of the day

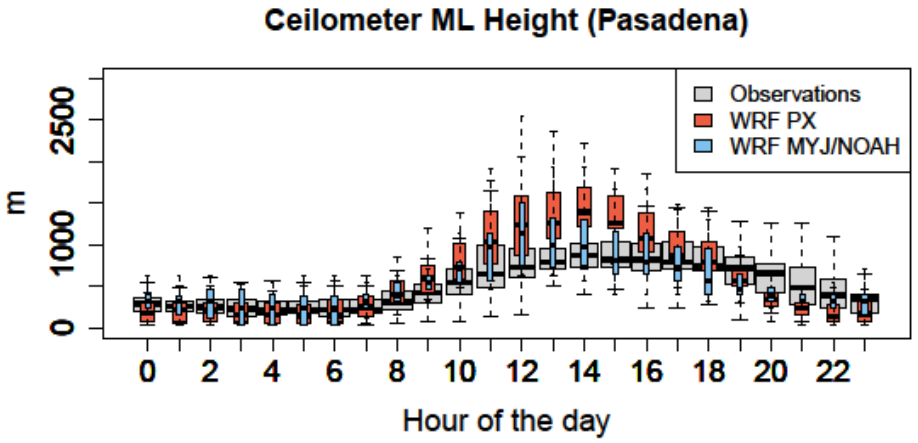

Wind Direction (BEARPEX 2009)
Observations
WRF PX
compass degrees
Hour of the day (LST)

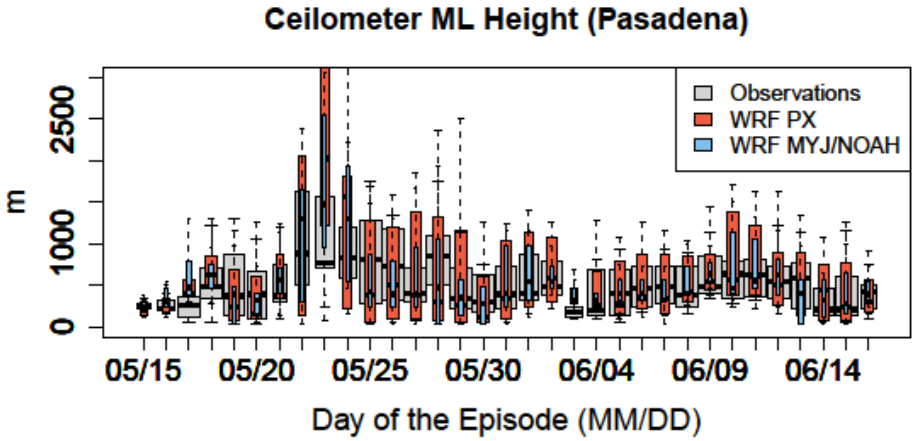

PAR - BEARPEX 2009
Observation
WRF
watts/m2

Mixing Layer Height

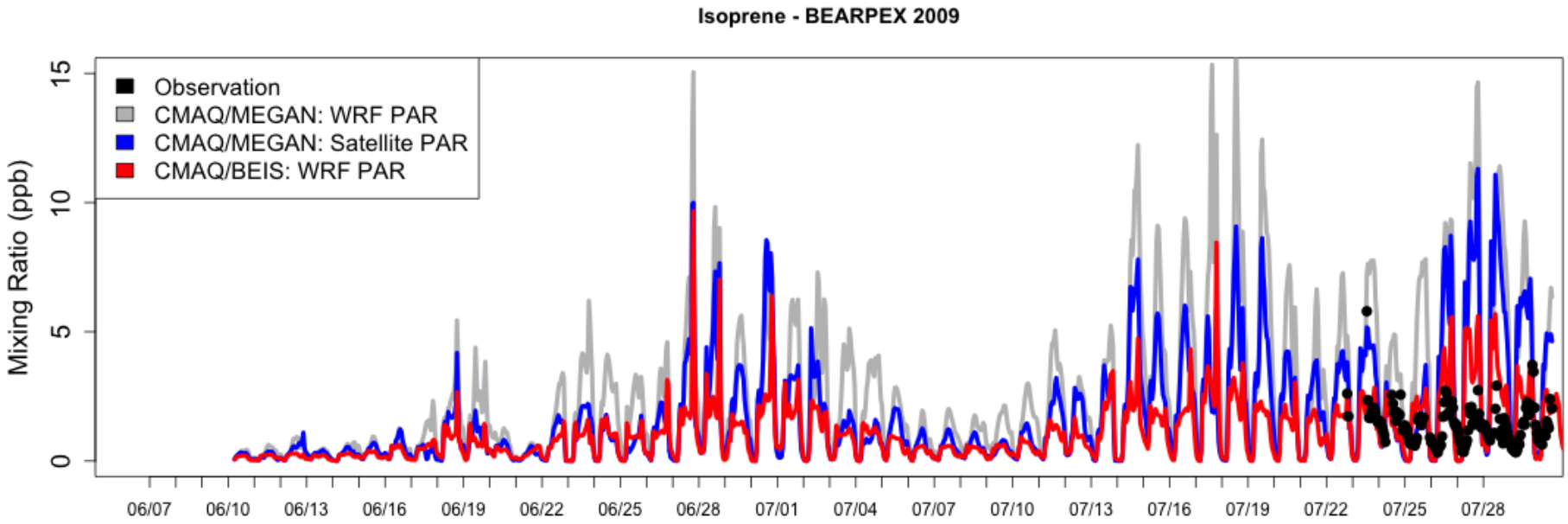
(no site-specific measurements; Pasadena at right)

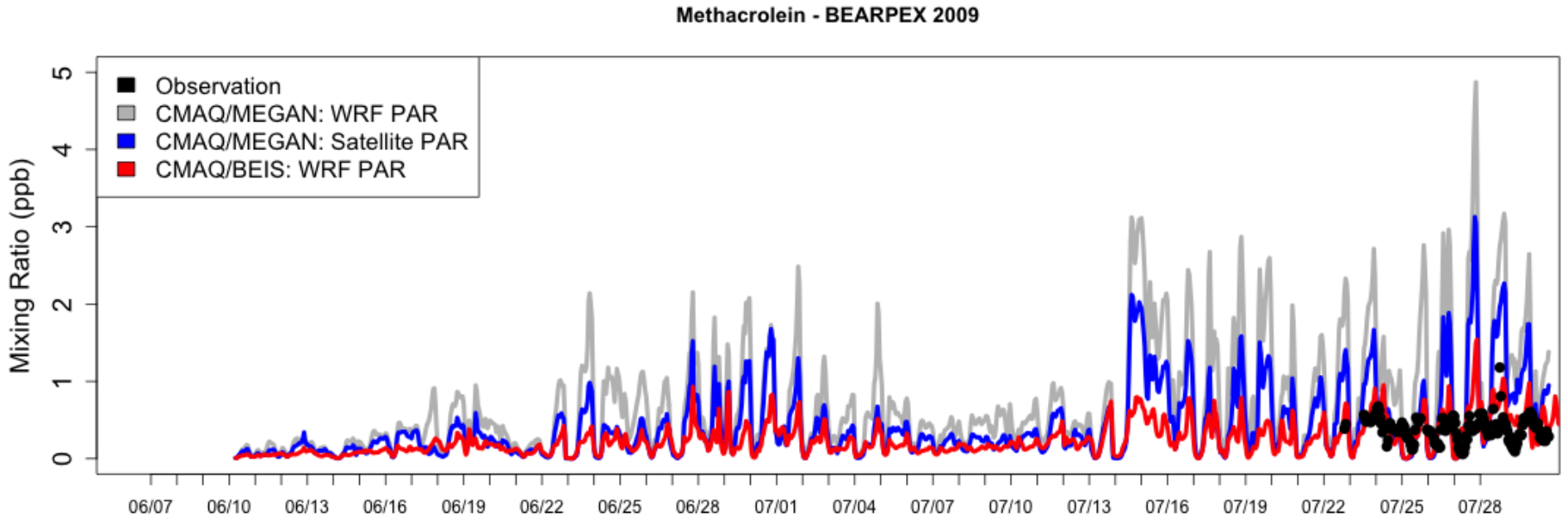


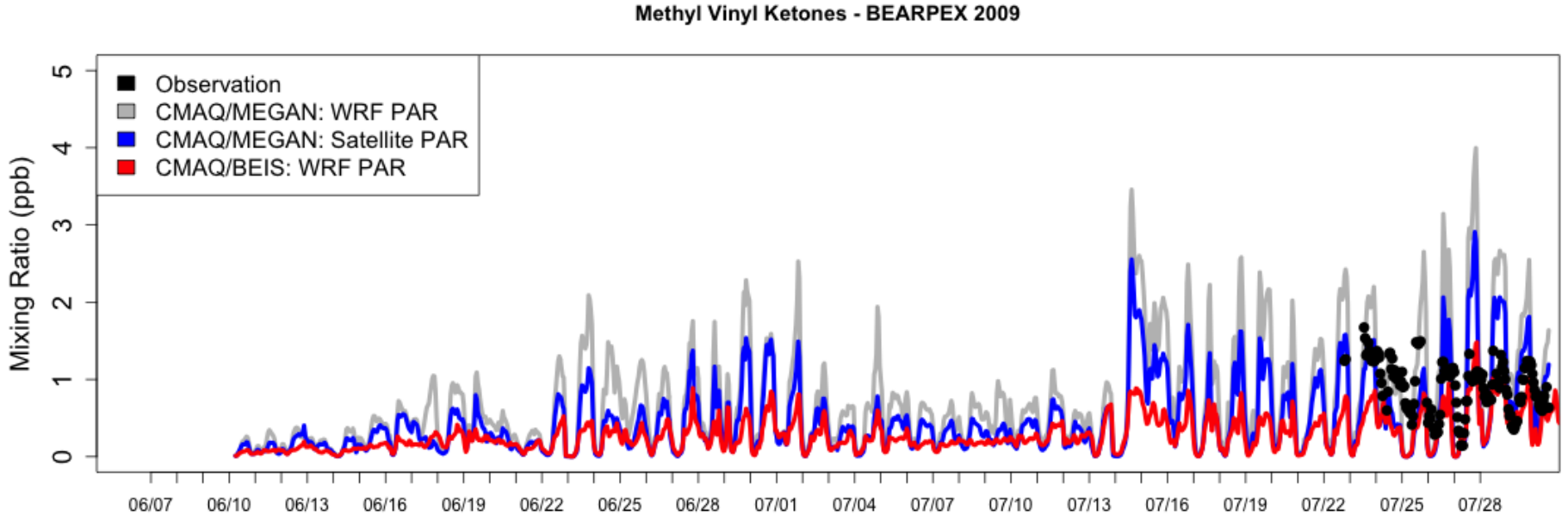


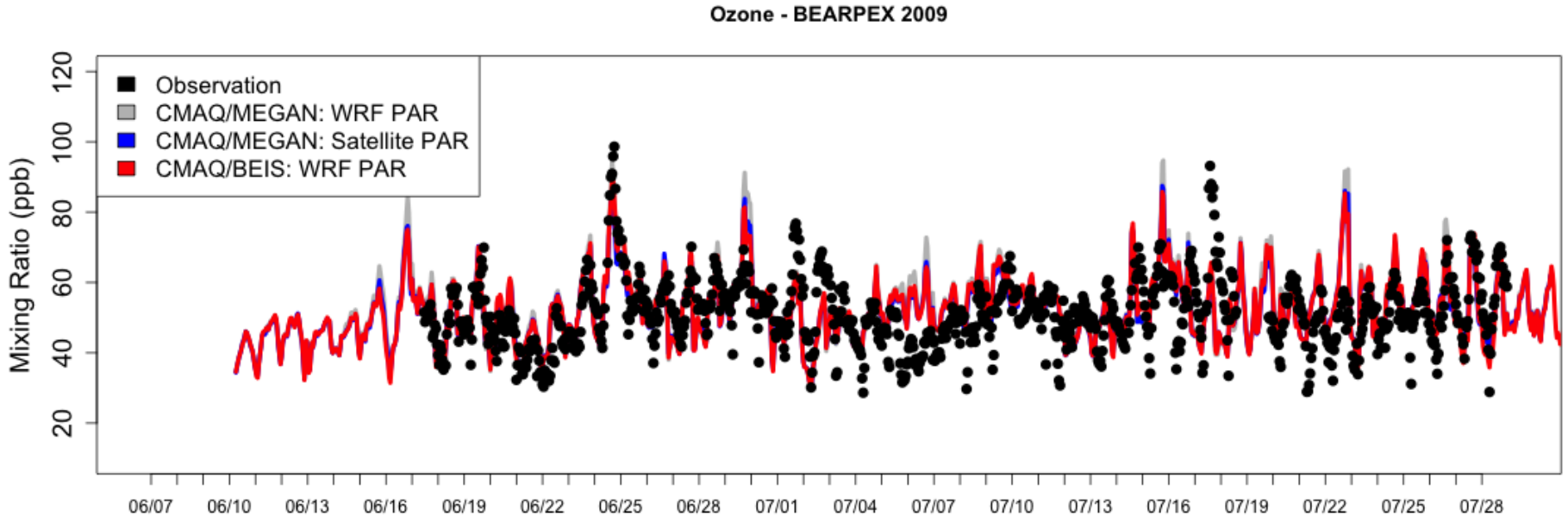


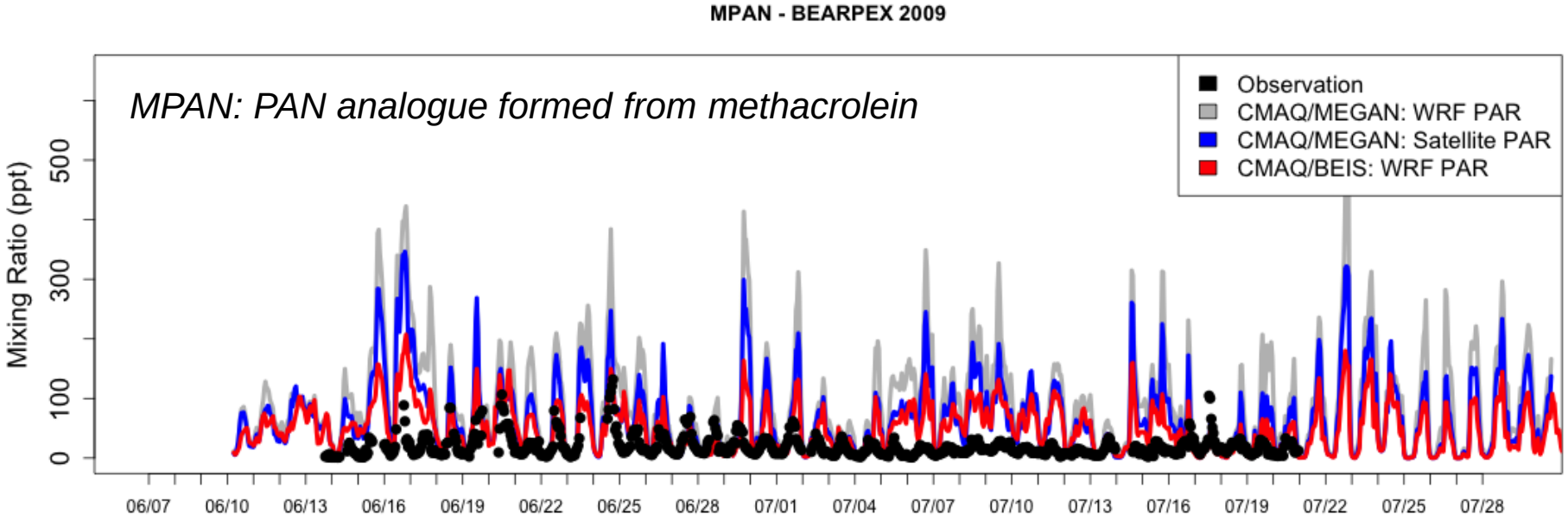
Model Comparison

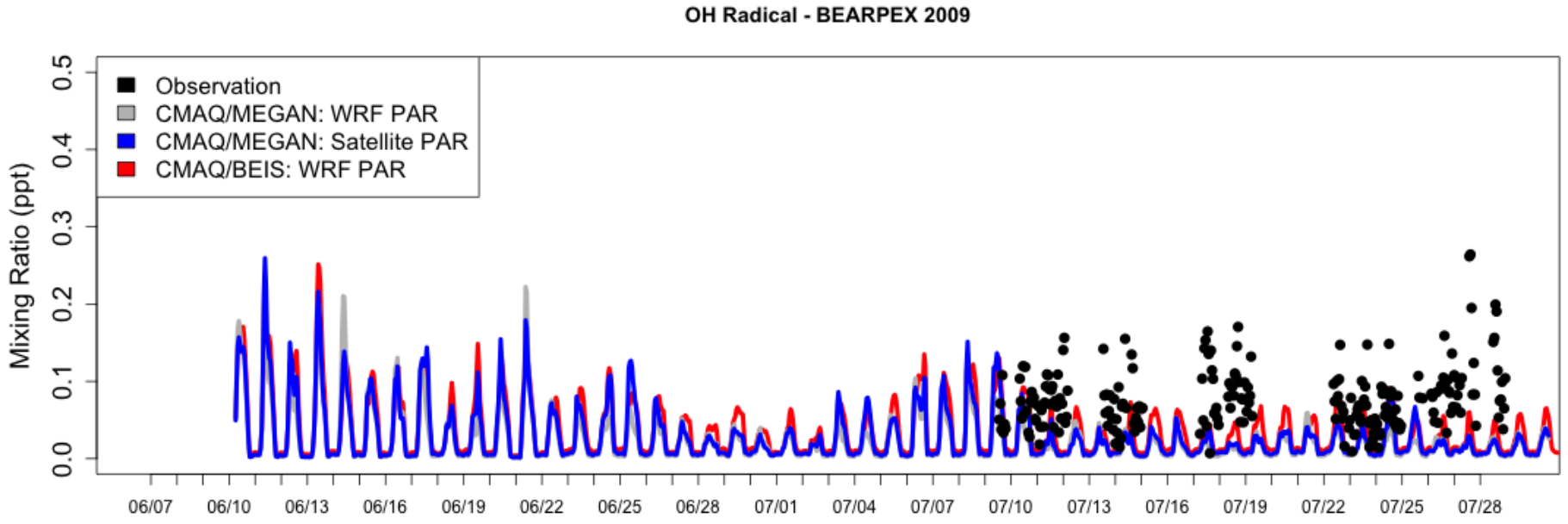


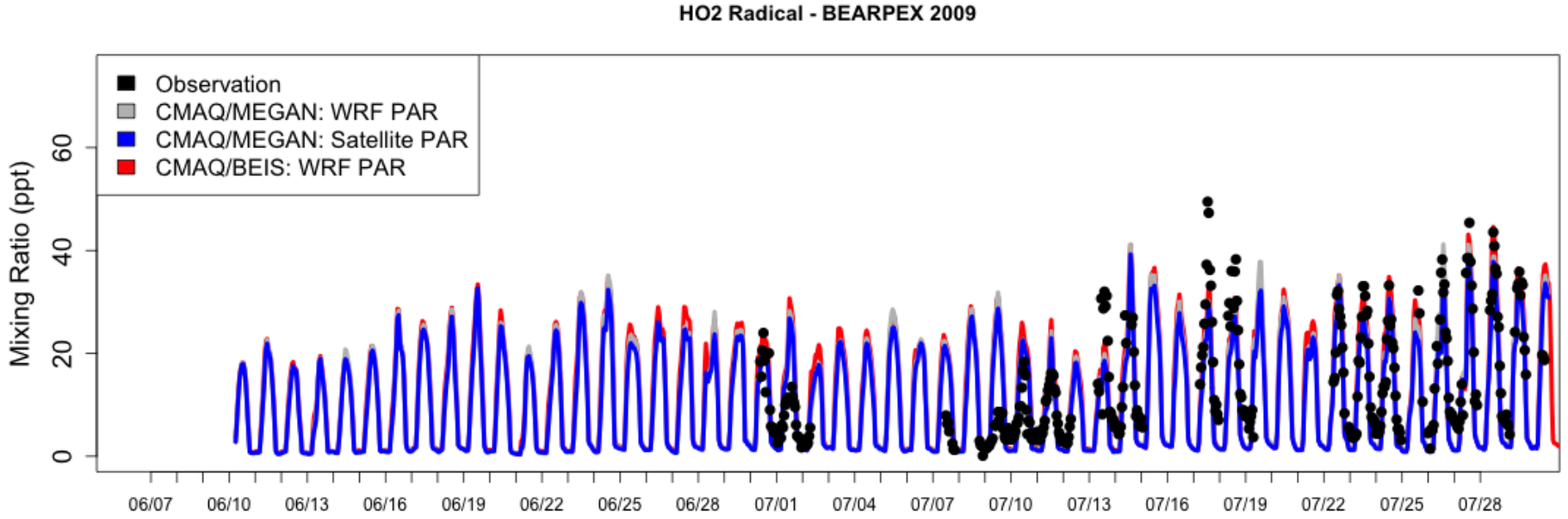

Methacrolein - BEARPEX 2009
Observation
CMAQ/MEGAN: WRF PAR
CMAQ/MEGAN: Satellite PAR
CMAQ/BEIS: WRF PAR
Mixing Ratio (ppb)
0
1
2
3
4
5
06/07
06/10
06/13
06/16
06/19
06/22
06/25
06/28
07/01
07/04
07/07
07/10
07/13
07/16
07/19
07/22
07/25
07/28

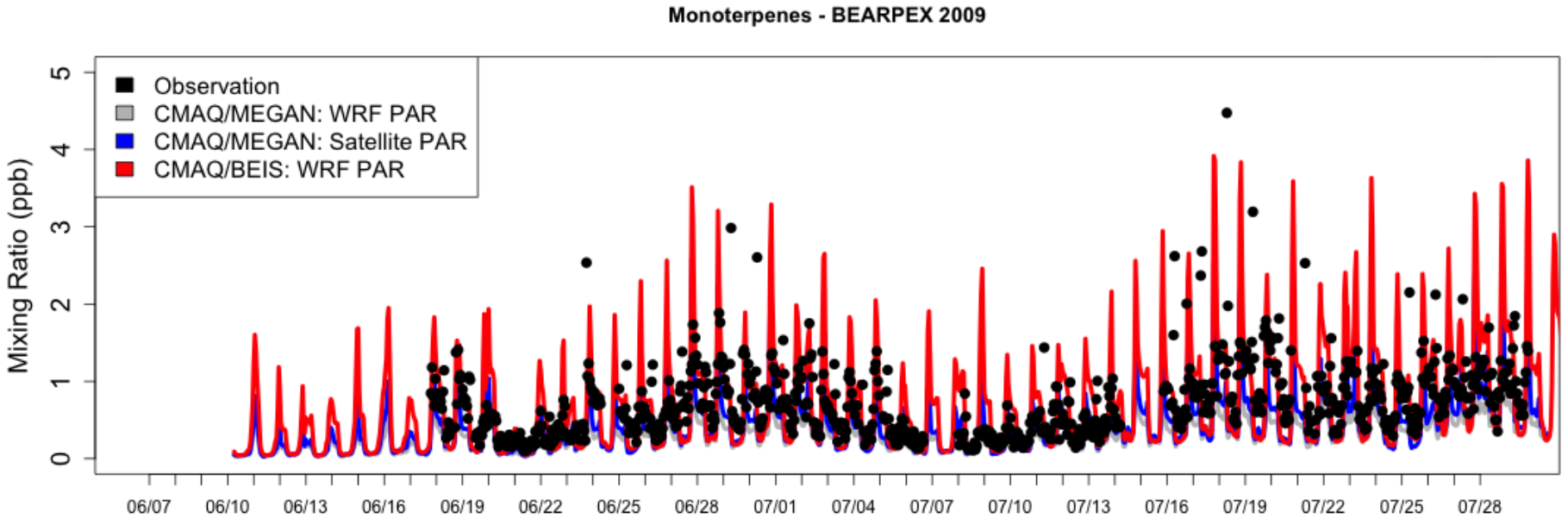

Methyl Vinyl Ketones - BEARPEX 2009
Observation
CMAQ/MEGAN: WRF PAR
CMAQ/MEGAN: Satellite PAR
CMAQ/BEIS: WRF PAR
Mixing Ratio (ppb)
0
1
2
3
4
5
06/07
06/10
06/13
06/16
06/19
06/22
06/25
06/28
07/01
07/04
07/07
07/10
07/13
07/16
07/19
07/22
07/25
07/28


Ozone - BEARPEX 2009
Observation
CMAQ/MEGAN: WRF PAR
CMAQ/MEGAN: Satellite PAR
CMAQ/BEIS: WRF PAR
Mixing Ratio (ppb)
20
40
60
80
100
120
06/07
06/10
06/13
06/16
06/19
06/22
06/25
06/28
07/01
07/04
07/07
07/10
07/13
07/16
07/19
07/22
07/25
07/28


MPAN - BEARPEX 2009
MPAN: PAN analogue formed from methacrolein
Observation
CMAQ/MEGAN: WRF PAR
CMAQ/MEGAN: Satellite PAR
CMAQ/BEIS: WRF PAR
Mixing Ratio (ppt)
0
100
300
500
06/07
06/10
06/13
06/16
06/19
06/22
06/25
06/28
07/01
07/04
07/07
07/10
07/13
07/16
07/19
07/22
07/25
07/28


OH Radical - BEARPEX 2009
Observation
CMAQ/MEGAN: WRF PAR
CMAQ/MEGAN: Satellite PAR
CMAQ/BEIS: WRF PAR
Mixing Ratio (ppt)
0.0
0.1
0.2
0.3
0.4
0.5
06/07
06/10
06/13
06/16
06/19
06/22
06/25
06/28
07/01
07/04
07/07
07/10
07/13
07/16
07/19
07/22
07/25
07/28


HO2 Radical - BEARPEX 2009
Observation
CMAQ/MEGAN: WRF PAR
CMAQ/MEGAN: Satellite PAR
CMAQ/BEIS: WRF PAR
Mixing Ratio (ppt)
0
20
40
60
06/07
06/10
06/13
06/16
06/19
06/22
06/25
06/28
07/01
07/04
07/07
07/10
07/13
07/16
07/19
07/22
07/25
07/28


Monoterpenes - BEARPEX 2009
Observation
CMAQ/MEGAN: WRF PAR
CMAQ/MEGAN: Satellite PAR
CMAQ/BEIS: WRF PAR
Mixing Ratio (ppb)
0
1
2
3
4
5
06/07
06/10
06/13
06/16
06/19
06/22
06/25
06/28
07/01
07/04
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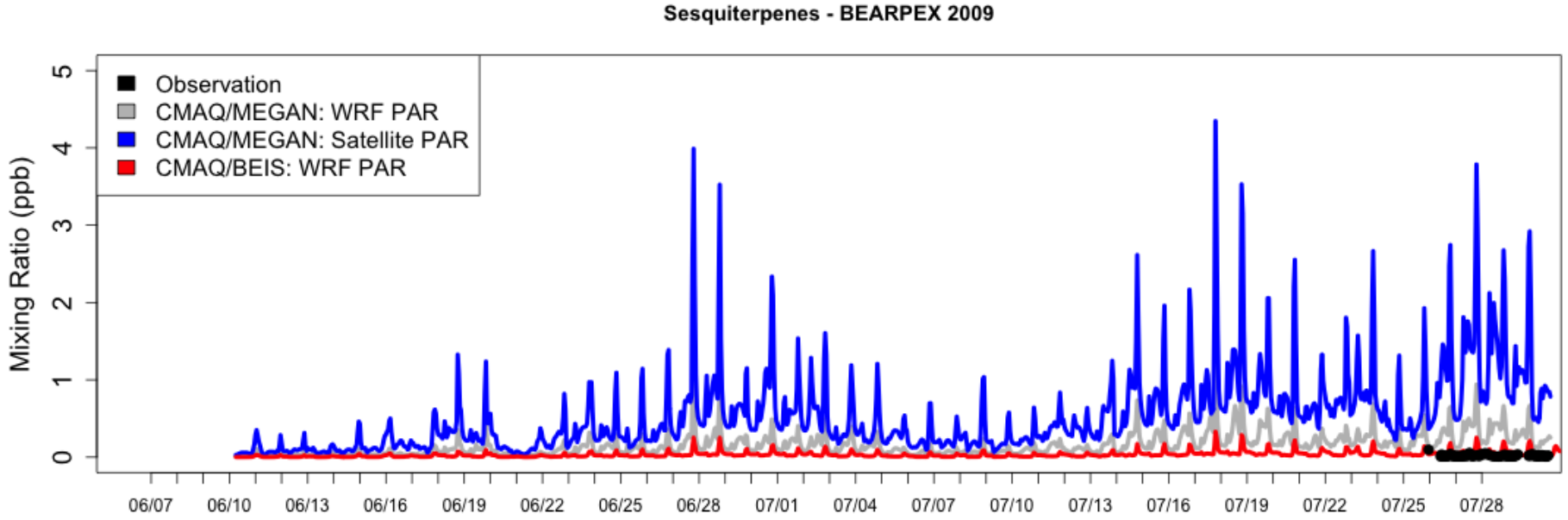
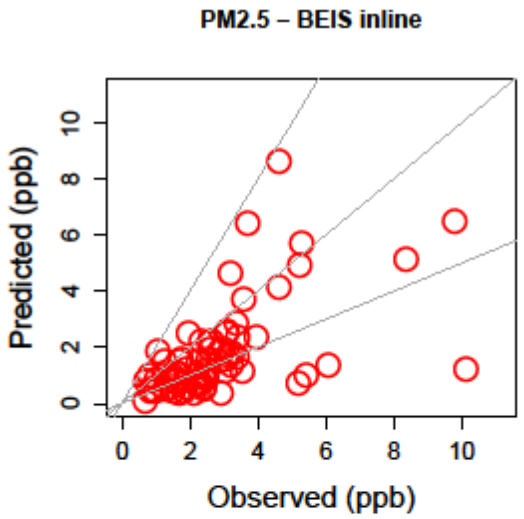
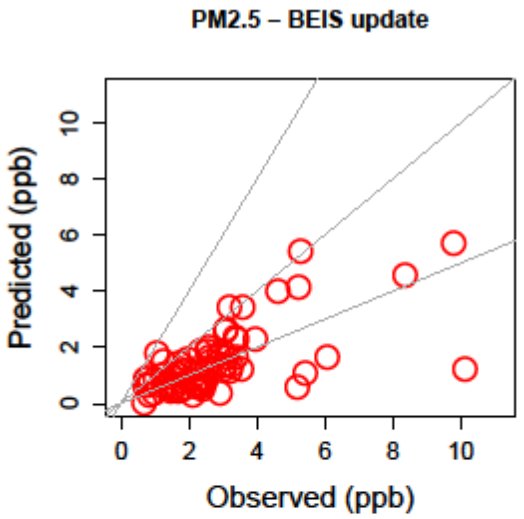
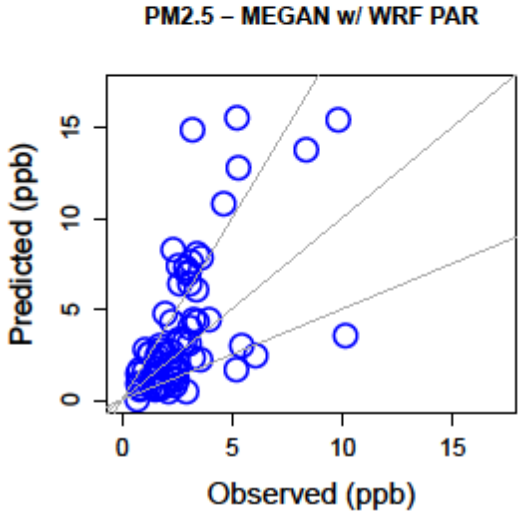
07/13
07/16
07/19
07/22
07/25
07/28

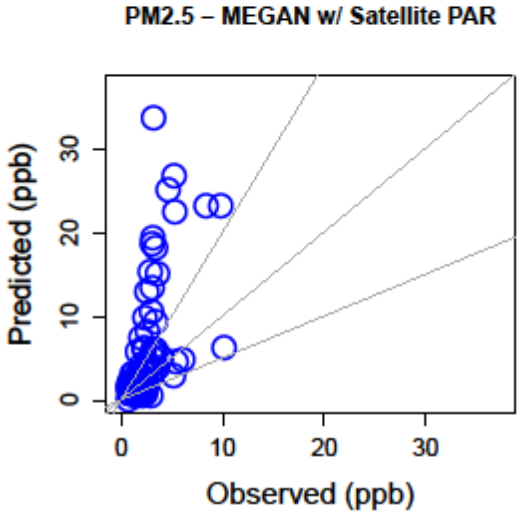

Sesquiterpenes - BEARPEX 2009
Observation
CMAQ/MEGAN: WRF PAR
CMAQ/MEGAN: Satellite PAR
CMAQ/BEIS: WRF PAR
Mixing Ratio (ppb)
0
1
2
3
4
5
06/07
06/10
06/13
06/16
06/19
06/22
06/25
06/28
07/01
07/04
07/07
07/10
07/13
07/16
07/19
07/22
07/25
07/28

PM2.5 Organic Carbon Mass (BEARPEX)









Part III: Future Direction

- Use the BEARPEX/CALNEX/ CARES field data to support model developments to BEIS and underlying landuse data
- Evaluate BEIS and MEGAN using newer field studies that have a more robust set of measurements
  - CABERNET 2011 for California
  - SOAS 2013 for the central and southeast U.S.
- Extend evaluation work to vegetation characterization data
- More focus on PM2.5 impacts

New BEIS Development

- Updating canopy parameterization
  - explicit estimates of leaf temperature & PAR
- Updating landuse and vegetation information
  - BELD updated with landuse data from MODIS, 2006 NLCD, and 2006 USDA census of agriculture land coverage
  - vegetation data from 2002-2013 USDA Forest Inventory Analysis (FIA) interpolated to NLCD land cover types
- Updating vegetation emission factors based on updated literature

Acknowledgements

- Allan Beidler, James Beidler, Charles Chang, and Chris Allen (CSC) for BEIS, MEGAN, and SMOKE emissions modeling
- Chris Misenis (US EPA) and Lara Reynolds (CSC) for WRF application
- Marc Houyoux, Rich Mason, Alexis Zubrow, Alison Eyth (US EPA OAQPS)
- Christine Wiedenmyer (NCAR) and Mike Koerber for OZIE observation data
- Rob Gilliam, George Pouliot and Tom Pierce (US EPA ORD)
- BEARPEX and OZIE field study participants