

Overview of our current knowledge on  
organic aerosol modeling and  
comparison with measurements: an  
AEROCOM multi-model approach

**Kostas Tsigaridis, Maria Kanakidou, Nikos Daskalakis  
and the AEROCOM team**

# 2009

- CAM-Oslo Alf Kirkevåg
- GISS MATRIX\* Susanne Bauer
- GISS modelE\* Kostas Tsigaridis, Dorothy Koch
- GLOMAP\*\* Graham Mann
- SPRINTARS Toshi Takemura
- TM<sub>3</sub> Kostas Tsigaridis, Maria Kanakidou
- TM<sub>4</sub>-ECPL\* Nikos Daskalakis, Maria Kanakidou
- Measurements Lynn Russell and many others

\* Preliminary results

\*\* Results not analyzed yet

# 2010

- AEROCOM modelers

- Alf Kirkevåg (CAM-Oslo)
- Angela Benedetti (ECMWF)
- Kirstie Pringle, Jos Lelieveld (EMAC)
- Gabriele Curci (GEOS-Chem)
- Shantanu Jathar, Peter Adams (GISS II' UBS)
- Graham Mann (GLOMAP)
- Thomas Diehl (GOCART)
- Toshi Takemura (SPRINTARS)
- Maria Kanakidou, Lazaros Perakis, Kostas Tsigaridis (TM<sub>3</sub>)
- Maria Kanakidou, Stelios Myriokefalitakis, Nikos Daskalakis (TM<sub>4</sub>-ECPL)
- Dorothy Koch, Surabi Menon, Kostas Tsigaridis (GISS modelE, GISS modelE + MATRIX)

- Measurements

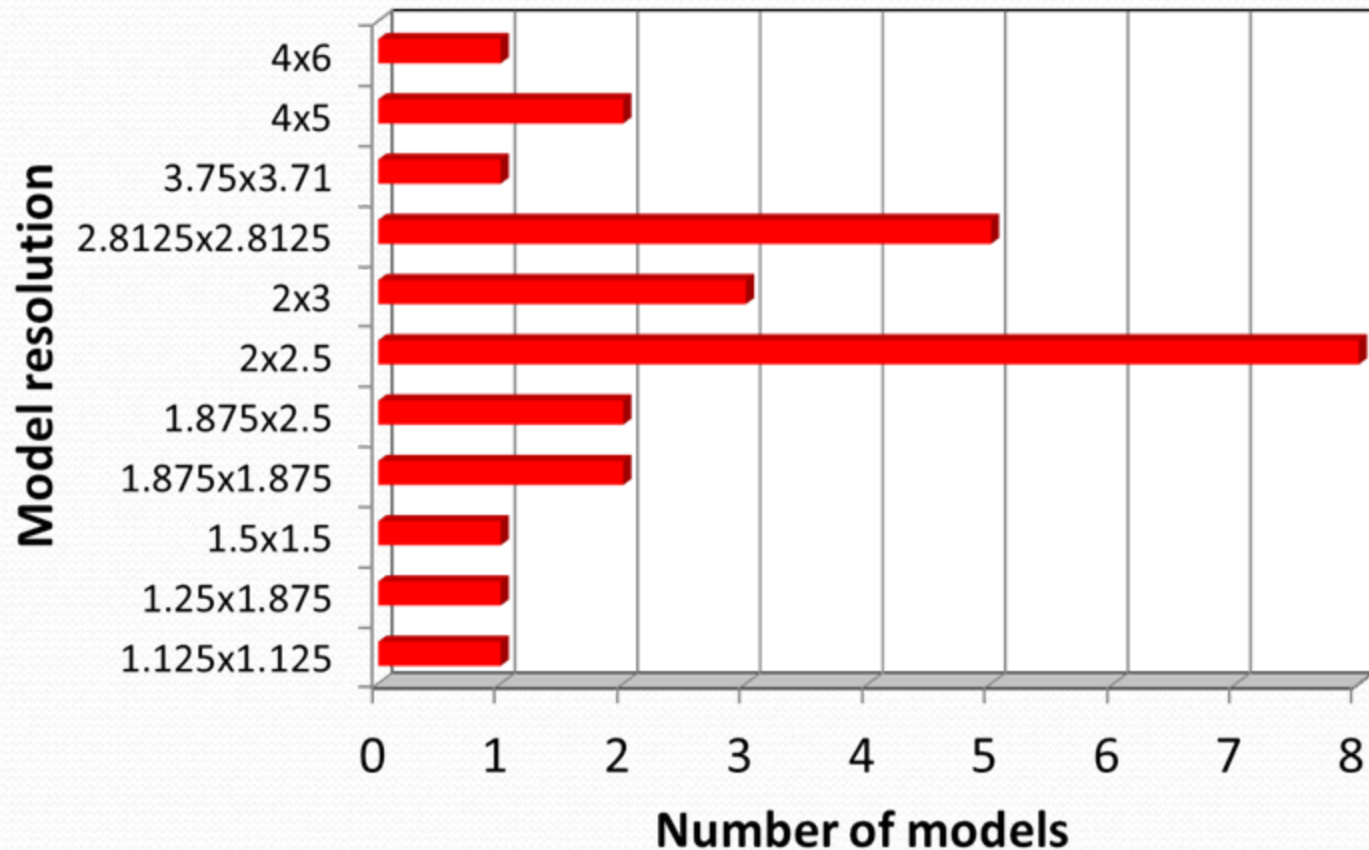
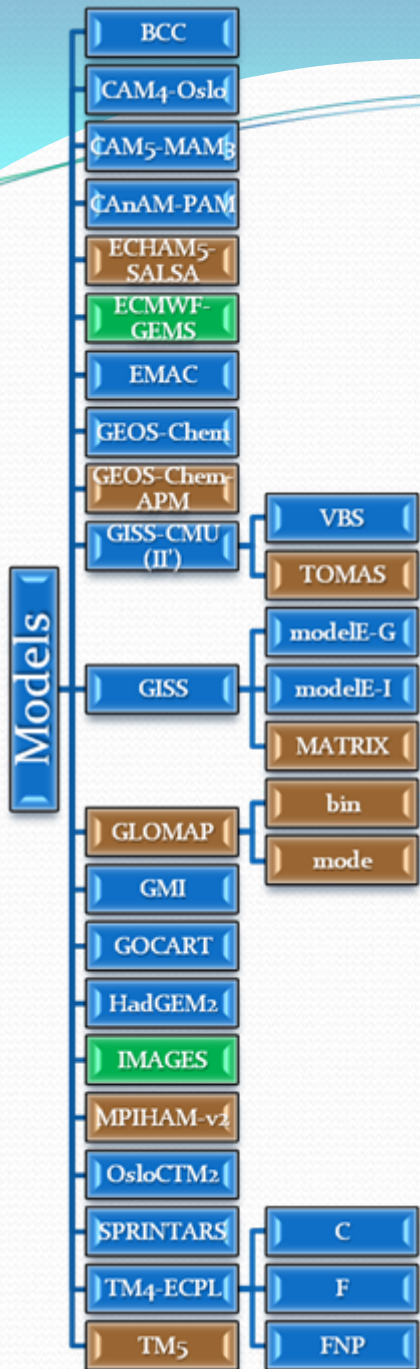
- Lynn Russell, Ranjit Bahadur
- Jose-Luis Jimenez, Qi Zhang, Sally Ng
- Jean Sciare
- Nikos Mihalopoulos



# 2011

K. Tsigaridis<sup>1,2,\*</sup>, M. Kanakidou<sup>3</sup>, N. Daskalakis<sup>3</sup>, P. J. Adams<sup>4,5</sup>, P. Artaxo<sup>6</sup>, R. Bahadur<sup>7</sup>, S. E. Bauer<sup>1,2</sup>, N. Bellouin<sup>8</sup>, A. Benedetti<sup>9</sup>, T. Bergman<sup>10</sup>, T. K. Berntsen<sup>11,12</sup>, H. Bian<sup>13</sup>, K. Carslaw<sup>14</sup>, M. Chin<sup>15</sup>, G. Curci<sup>16</sup>, T. Diehl<sup>15,17</sup>, R. Easter<sup>18</sup>, S. Ghan<sup>18</sup>, S. L. Gong<sup>19</sup>, C. R. Hoyle<sup>20</sup>, T. Iversen<sup>21</sup>, S. Jathar<sup>4</sup>, J.-L. Jimenez<sup>22</sup>, J. W. Kaiser<sup>9</sup>, A. Kirkevåg<sup>21</sup>, D. Koch<sup>1,2,23</sup>, H. Kokkola<sup>10</sup>, Y. H. Lee<sup>4,24</sup>, X. Liu<sup>18</sup>, G. Luo<sup>25</sup>, G. Mann<sup>26</sup>, N. Mihalopoulos<sup>3</sup>, J.-J. Morcrette<sup>9</sup>, J.-F. Müller<sup>27</sup>, G. Myhre<sup>12</sup>, S. Myriokefalitakis<sup>3</sup>, S. Ng<sup>28</sup>, D. O'Donnell<sup>29,30</sup>, K. J. Pringle<sup>31,32</sup>, L. M. Russell<sup>7</sup>, J. Sciare<sup>33</sup>, Ø. Seland<sup>21</sup>, R. B. Skeie<sup>12</sup>, J. Stavrakou<sup>27</sup>, S. Steenrod<sup>17</sup>, A. Strunk<sup>34</sup>, T. Takemura<sup>35</sup>, H. Tost<sup>36</sup>, T. van Noije<sup>34</sup>, K. von Salzen<sup>37</sup>, D. Spracklen<sup>14</sup>, F. Yu<sup>25</sup>, Z. Wang<sup>38</sup>, Z. Wang<sup>39</sup>, D. M. Westervelt<sup>4</sup>, R. Zaveri<sup>18</sup>, H. Zhang<sup>38</sup>, K. Zhang<sup>29,40</sup>, Q. Zhang<sup>41</sup>, X. Zhang<sup>39</sup>

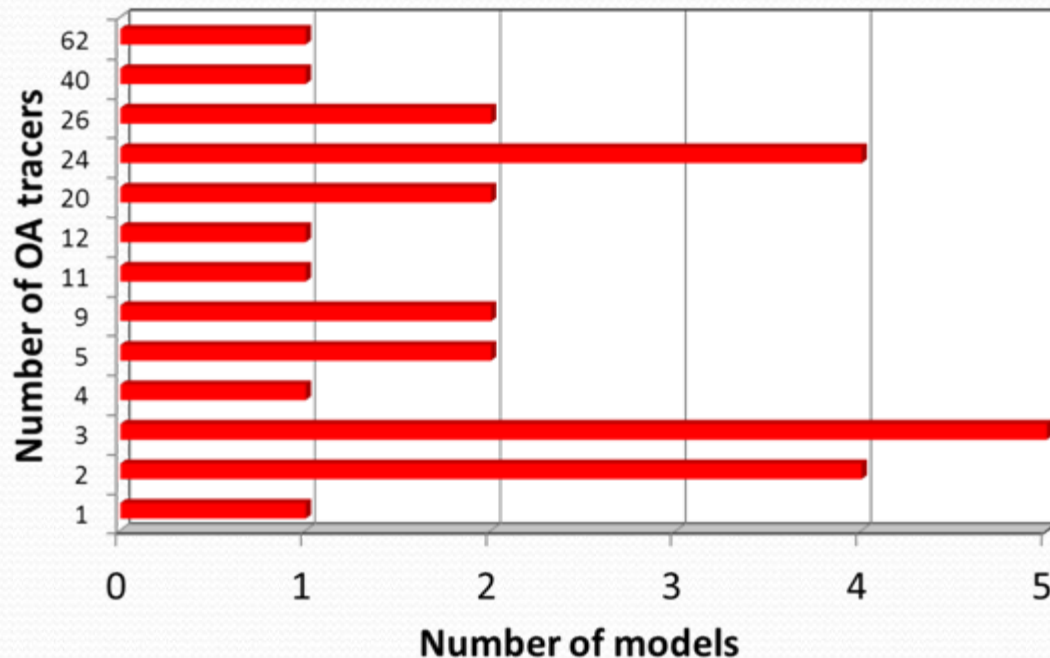
# Total number of models: 27



2 more models are expected: IMPACT (3 versions) and INCA

# Facts





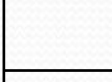
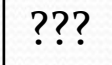
- Year(s) simulated: **Mostly 2006**, but not always with 2006 emissions and/or meteorology.
- Focus on **surface concentrations**, at least for now.
- **Emissions** vary greatly. This is not necessarily bad.
- **OM/OC** is **1.4** for most models, but not all.





# What does 2006 mean?

- 1 BCC
- 2 CAM4-Oslo
- 3 CAM5-MAM3
- 4 CcnAM-PAM
- 5 ECHAM5-SALSA
- 6 ECMWF-GEMS
- 7 EMAC
- 8 GEOS-Chem
- 9 GEOS-Chem-APM
- 10 GISS-CMU-VBS
- 11 GISS-MATRIX
- 12 GISS-modelE-G
- 13 GISS-modelE-I
- 14 GISS-TOMAS
- 15 GLOMAPbin
- 16 GLOMAPmode
- 17 GMI
- 18 GOCART
- 19 HadGEM2
- 20 IMAGES
- 21 MPIHAM-v2
- 22 OsloCTM2
- 23 SPRINTARS
- 24 TM4-ECPL-C
- 25 TM4-ECPL-F
- 26 TM4-ECPL-FNP
- 27 TM5

	Year other than 2006
	Year other than 2006, calculated online
	Year 2006, calculated online
	Year 2006
	Not available
	Uncertain

# What does 2006 mean?

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Meteo	Yellow	Light Green	Yellow	???	???	Green	???	Green	Green	Yellow	Light Green	Light Green	Light Green	Light Green
FF, BF	Red	Green	Red	???	???	Red	Red	Red	Red	Red	Red	Green	Green	Green
BB	Red	Green	Red	Green	Red	Green	Red	Green	Green	Red	Green	Green	Green	Green
mPOC	White	Light Green	White	White	White	White	White	White	White	White	White	Yellow	Yellow	White
trSOC	White	Red	White	Red	Red	Red	Red	White	White	White	Red	White	White	Red
Isop	White	White	Red	White	White	White	White	Light Green	Light Green	Red	White	Light Green	Light Green	White
Terp	White	White	Red	White	White	White	White	Light Green	Light Green	Red	Red	Red	Red	White
Arom	White	White	Red	White	White	White	White	White	Red	Red	Red	White	White	White
Other	White	White	Red	White	White	White	White	White	Light Green	Red	Red	White	White	White

	15	16	17	18	19	20	21	22	23	24	25	26	27
Meteo	Green	Green	Green	White	White	Green	Green	Green	White	Green	Red	Green	Green
FF, BF	Red	Red	Red	???	???	Red	Green	Red	Red	Green	Red	Green	Green
BB	Red	Red	Red	Green	???	Red	Green	Red	Red	Green	Red	Green	Green
mPOC	White	White	White	White	White	White	White	White	White	Green	Yellow	Green	White
trSOC	Red	Red	Red	Red	White	White	White	White	Red	White	White	White	Red
Isop	White	White	White	White	White	Light Green	???	Red	White	Red	Red	Red	White
Terp	White	White	White	White	???	Red	???	Red	White	Red	Red	Red	White
Arom	White	White	White	White	White	Red	Red	Red	White	Green	Red	Green	White
Other	White	White	White	White	White	White	White	White	White	Green	Red	Green	White



# Primary Organic Matter (POM)

- All models have **fossil fuel, biofuel and biomass burning** terrestrial sources (tPOM). GISS-CMU-VBS assumes **semivolatile tPOM**. CAM4-Oslo, GISS-modelE and TM4-ECPL also include **marine POM** (mPOM).
  - **Fossil fuel and biofuel**: Bond et al. (2004; 2007); Diehl et al. (2008); Lamarque et al. (2010); Dentener et al. (2006); Park et al., 2003; CIRCE.
  - **Biomass burning**: GFED (v1; v2; v3); Diehl et al. (2008); Dentener et al. (2006); Lamarque et al. (2010).
  - **Marine sources**: CAM4-Oslo, GISS-modelE, TM4-ECPL.

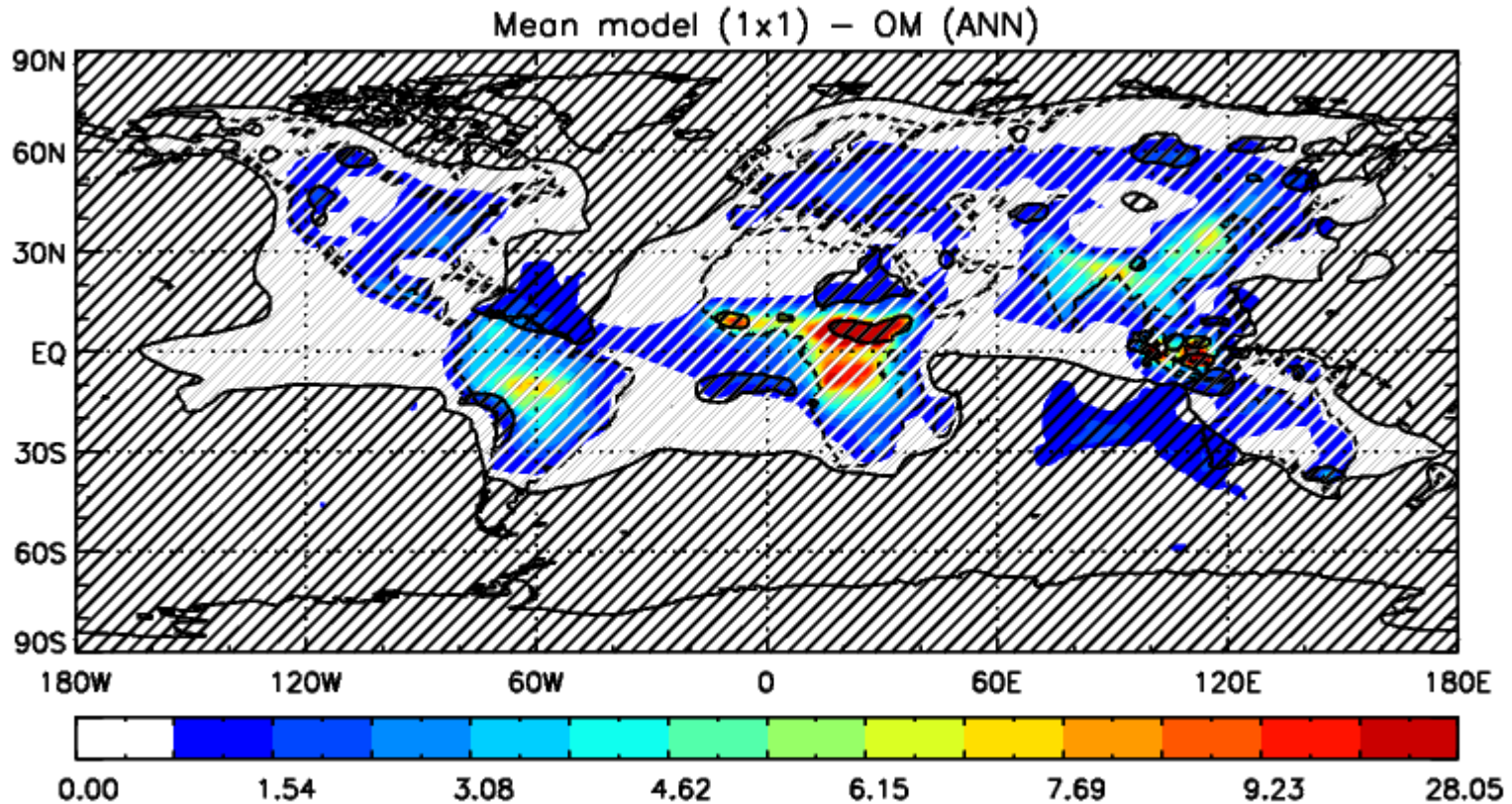
# Secondary Organic Matter (SOM)

Almost all models have some SOM representation:

- **None**: 1 model (BCC).
- **trSOM**: 26 models
  - **Non-volatile**: 13 models; SOM is included in tPOM.
    - **A yield from terpenes emissions** (CAM4-Oslo, CanAM-PAM, ECHAM5-SALSA, ECMWF-GEMS, EMAC, GISS-MATRIX, GMI, GOCART, SPRINTARS, TM5)
    - **A yield from terpenes oxidation** (GISS-TOMAS, 2 GLOMAP versions)
  - **Semi-volatile**: 13 models; “traditional” SOM, trSOM.
    - **A yield from terpenes emissions** (CAM5-MAM3)
    - **Fixed 3D monthly climatology** (HadGEM2, climatology from STOCHEM)
    - **2-product model** (GEOS-Chem, GEOS-Chem-APM, 2 GISS-modelE versions, IMAGES, MPIHAM-v2, OsloCTM2, 3 TM4-ECPL versions)
    - **Volatility-basis set** (GISS-CMU-VBS)
- **ntrSOM (Glyoxal, from cloud and aerosol water chemistry)**: 4 models (IMAGES, 3 TM4-ECPL versions)
- **MSA (from DMS oxidation)**: 9 models (CAM4-Oslo, GEOS-Chem-APM, 2 GISS-modelE versions, 3 TM4-ECPL versions, TM5)

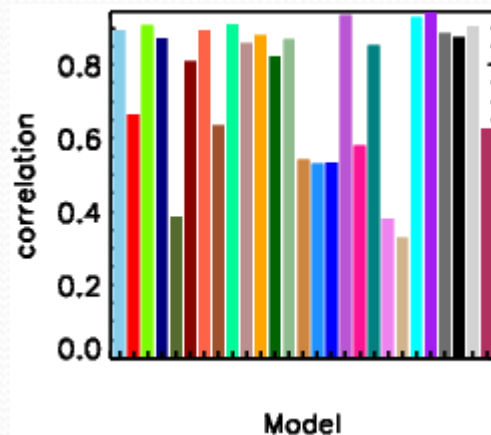
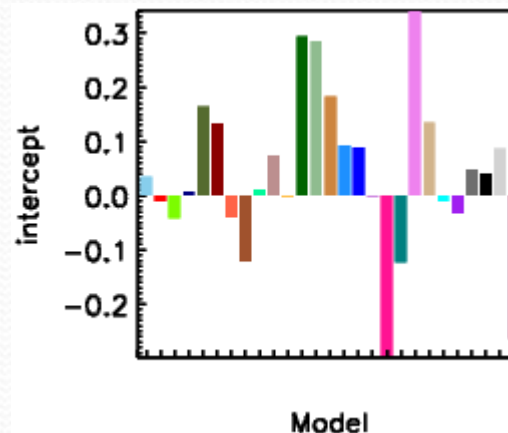
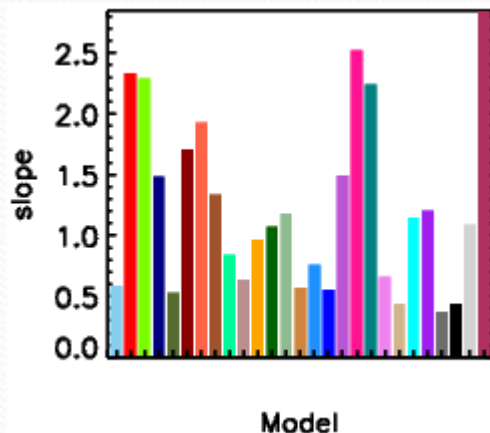


# Mean model surface distribution





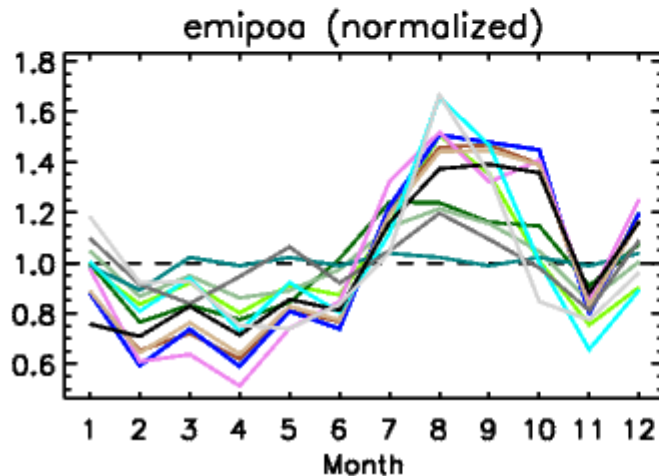
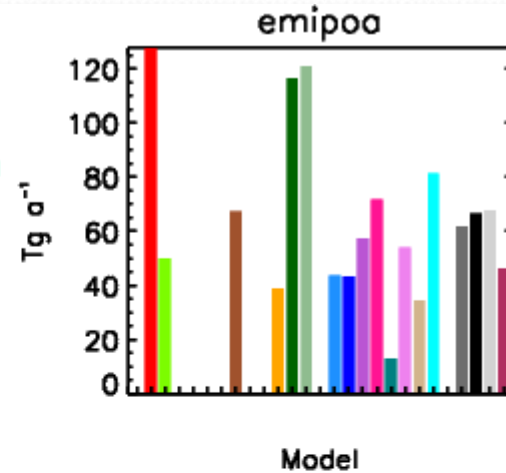
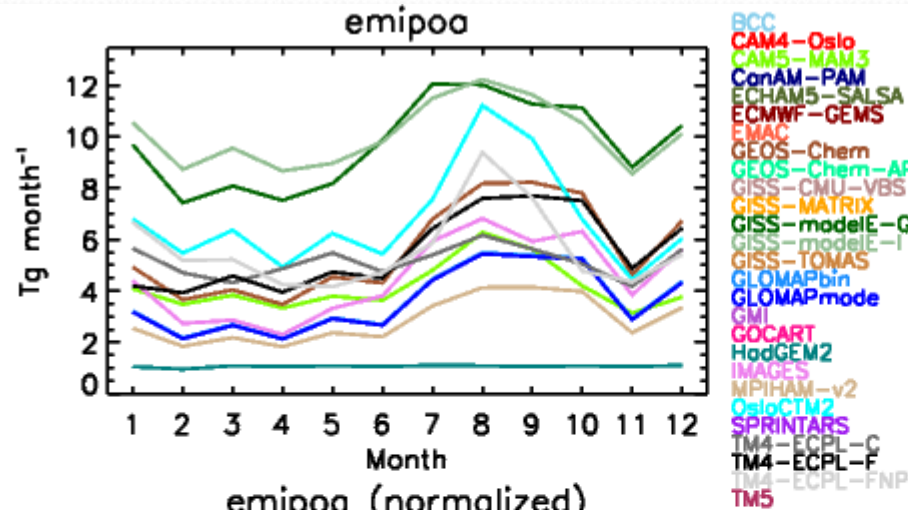
# Median vs. individual models (1x1 grid)



- BCC
- CAM4-Oslo
- CAM5-MAM3
- CanAM-PAM
- ECHAM5-SALSA
- ECMWF-GEMS
- EMAC
- GEOS-Chem
- GEOS-Chem-APM
- GISS-CMU-VBS
- GISS-MATRIX
- GISS-modelE-G
- GISS-modelE-I
- GISS-TOMAS
- GLOMAPbin
- GLOMAPmode
- GMI
- GOCART
- HadGEM2
- IMAGES
- MPIHAM-v2
- OsloCTM2
- SPRINTARS
- TM4-ECPL-C
- TM4-ECPL-F
- TM4-ECPL-FNP
- TM5

# Global budgets

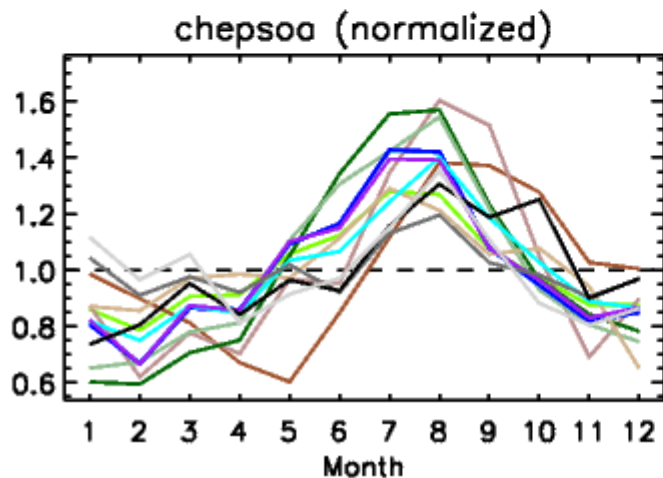
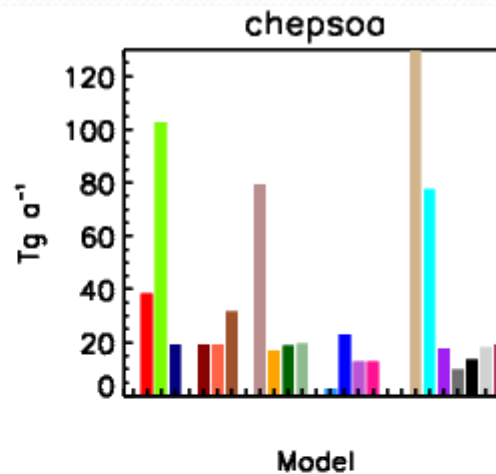
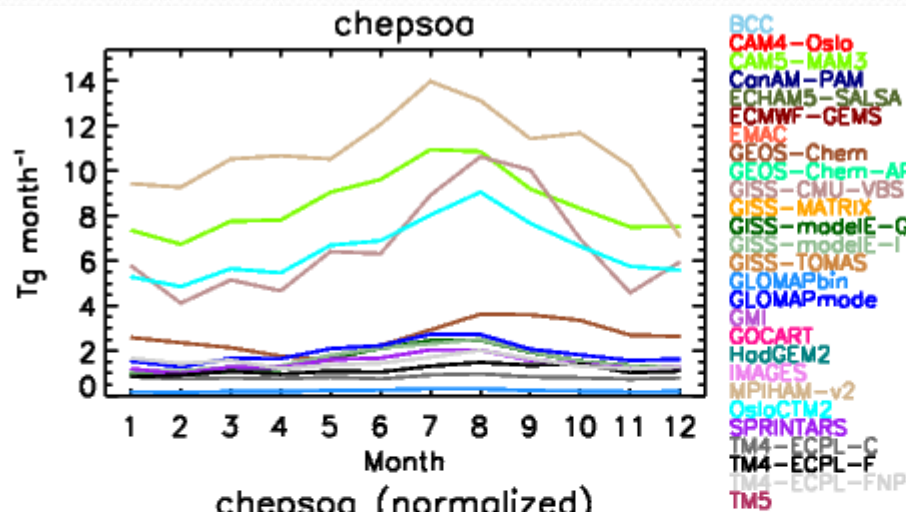
# Primary Organic Matter (POM)



Textor et al. (2006) mean:  
 $96.6 \text{ Tg a}^{-1} \pm 26\%$   
 (includes  $19.1 \text{ Tg a}^{-1}$  non-volatile SOM)



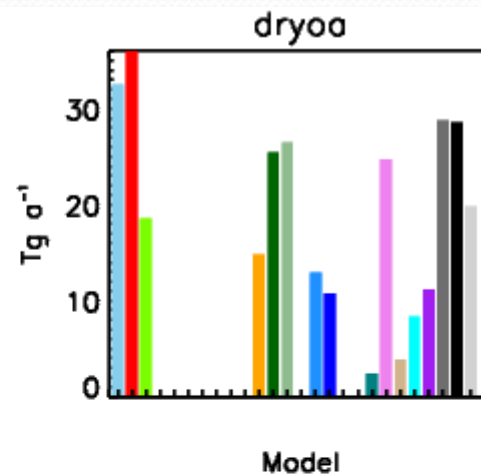
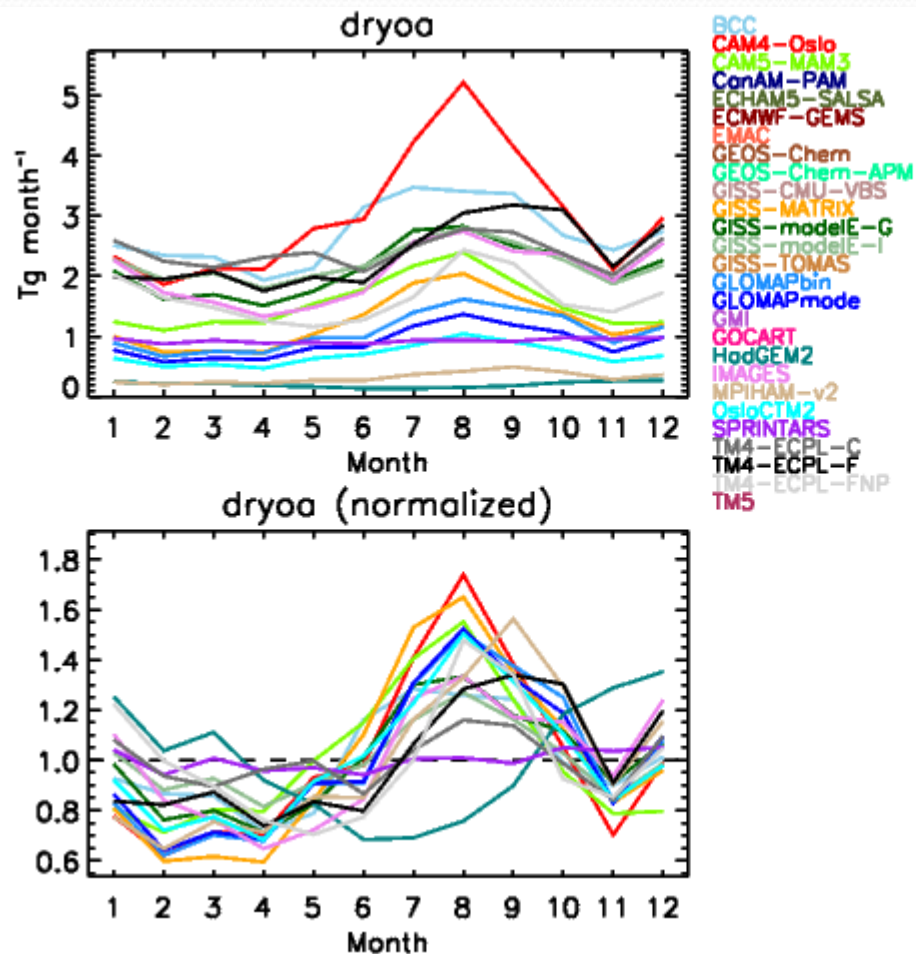
# Secondary Organic Matter (SOM)



## Possible precursors

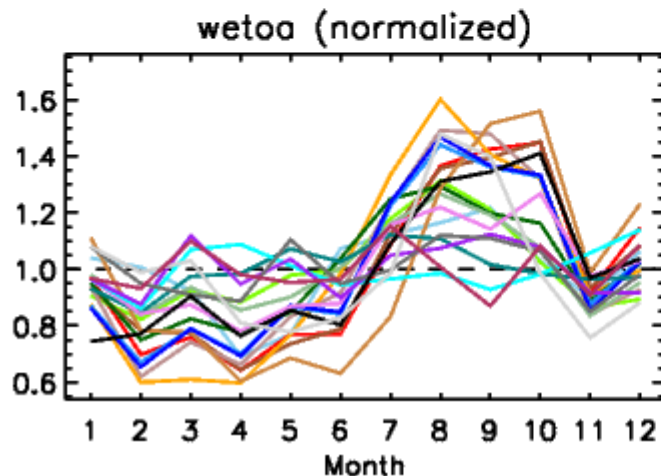
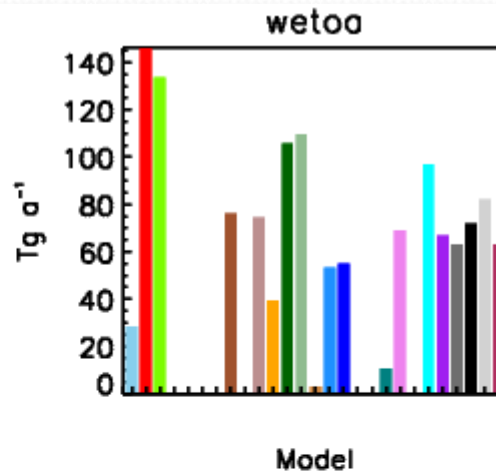
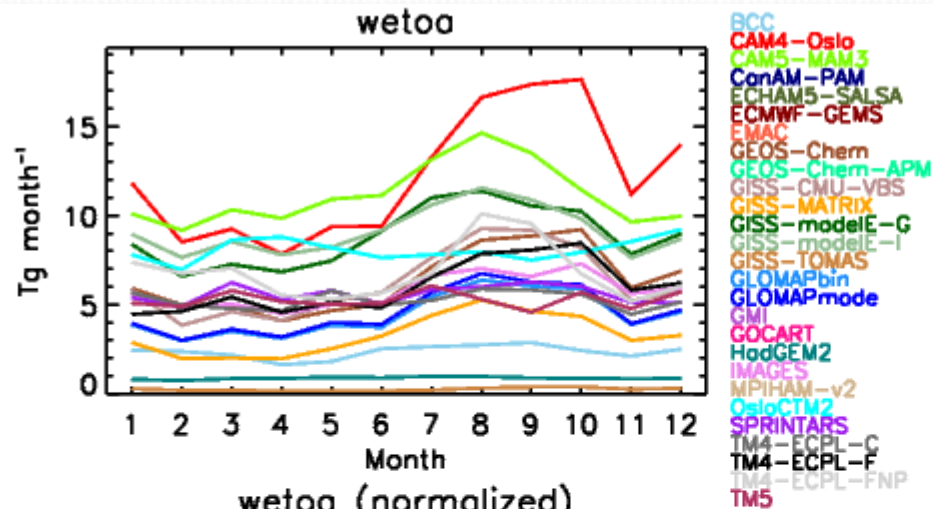
- Isoprene, monoterpenes
- Higher terpenes
- Aromatics
- Higher alkanes, alkenes

# Dry deposition



Textor et al. (2006) mean:  
 $18.6Tg\ a^{-1} \pm 49\%$

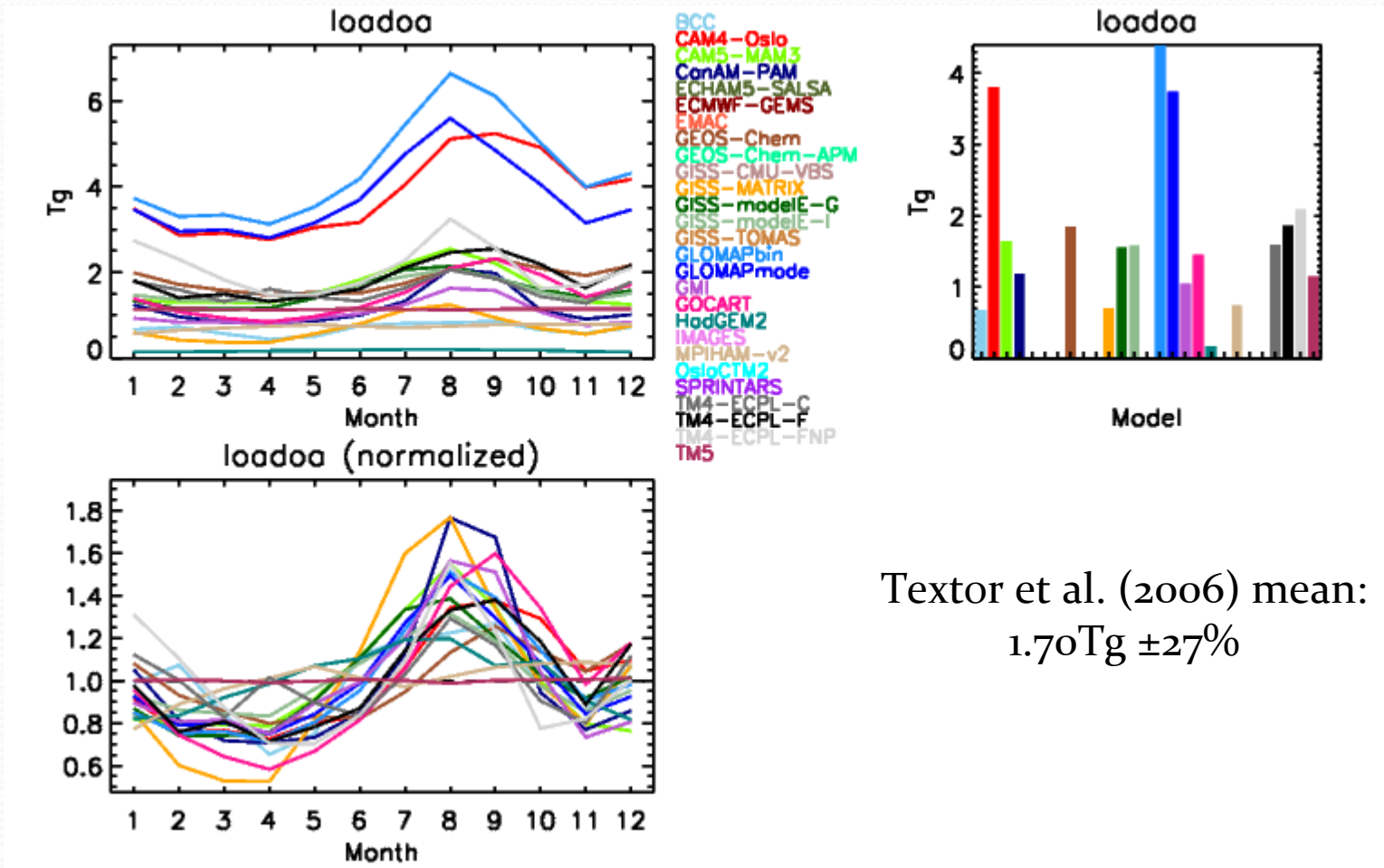
# Wet deposition



Textor et al. (2006) mean:  
 $86.9 \text{ Tg a}^{-1} \pm 32\%$

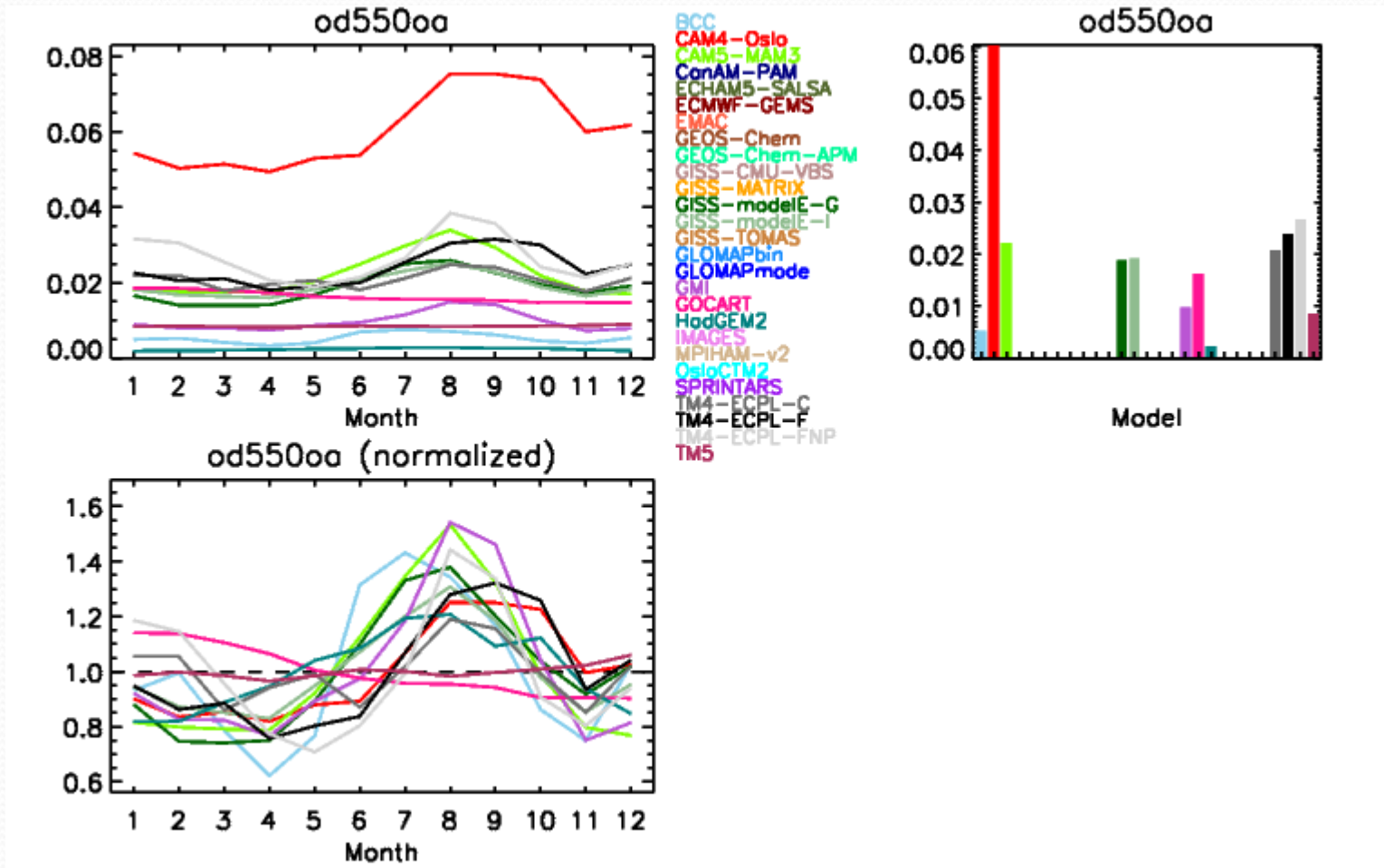


# Burden

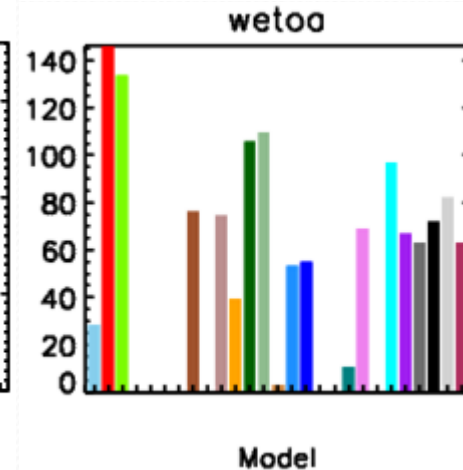
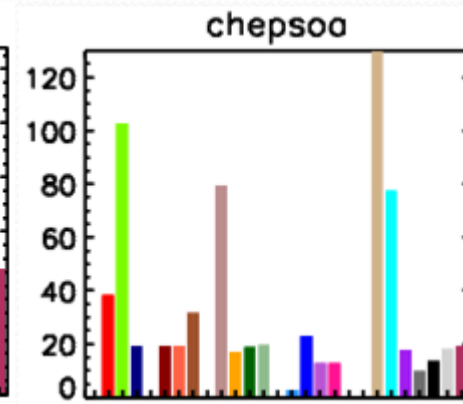
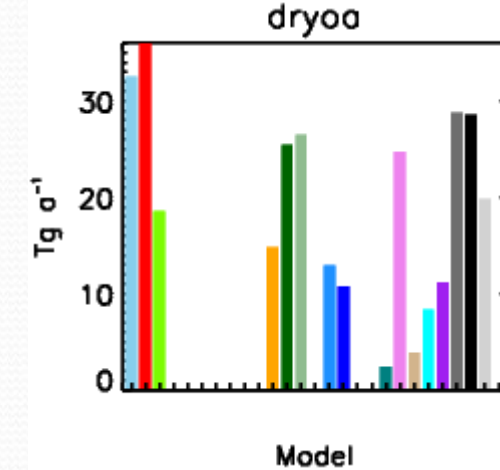
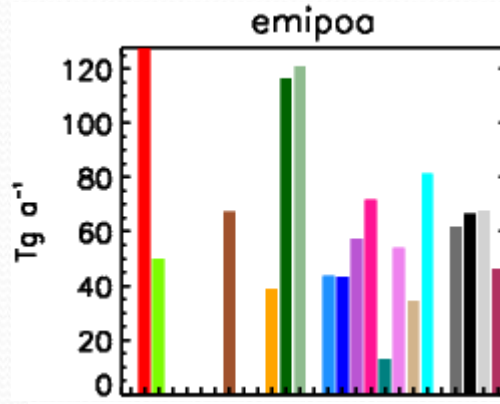
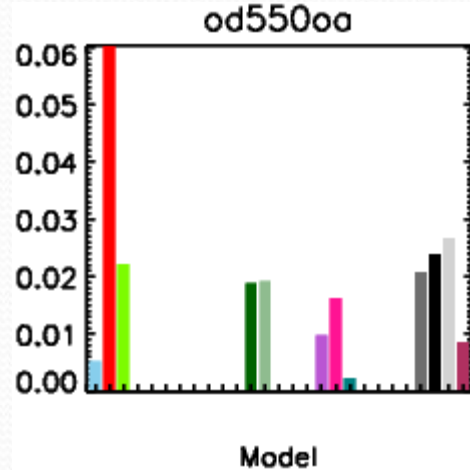
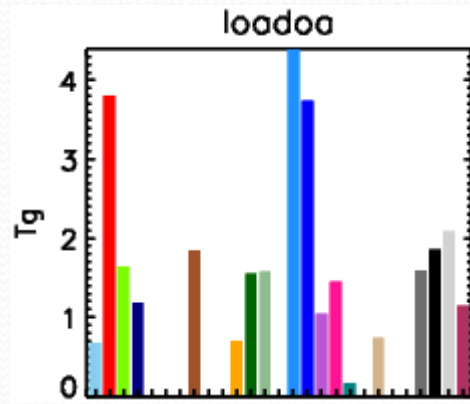


Textor et al. (2006) mean:  
 $1.70Tg \pm 27\%$

# Aerosol Optical Depth (AOD) 550nm



# OA life cycle



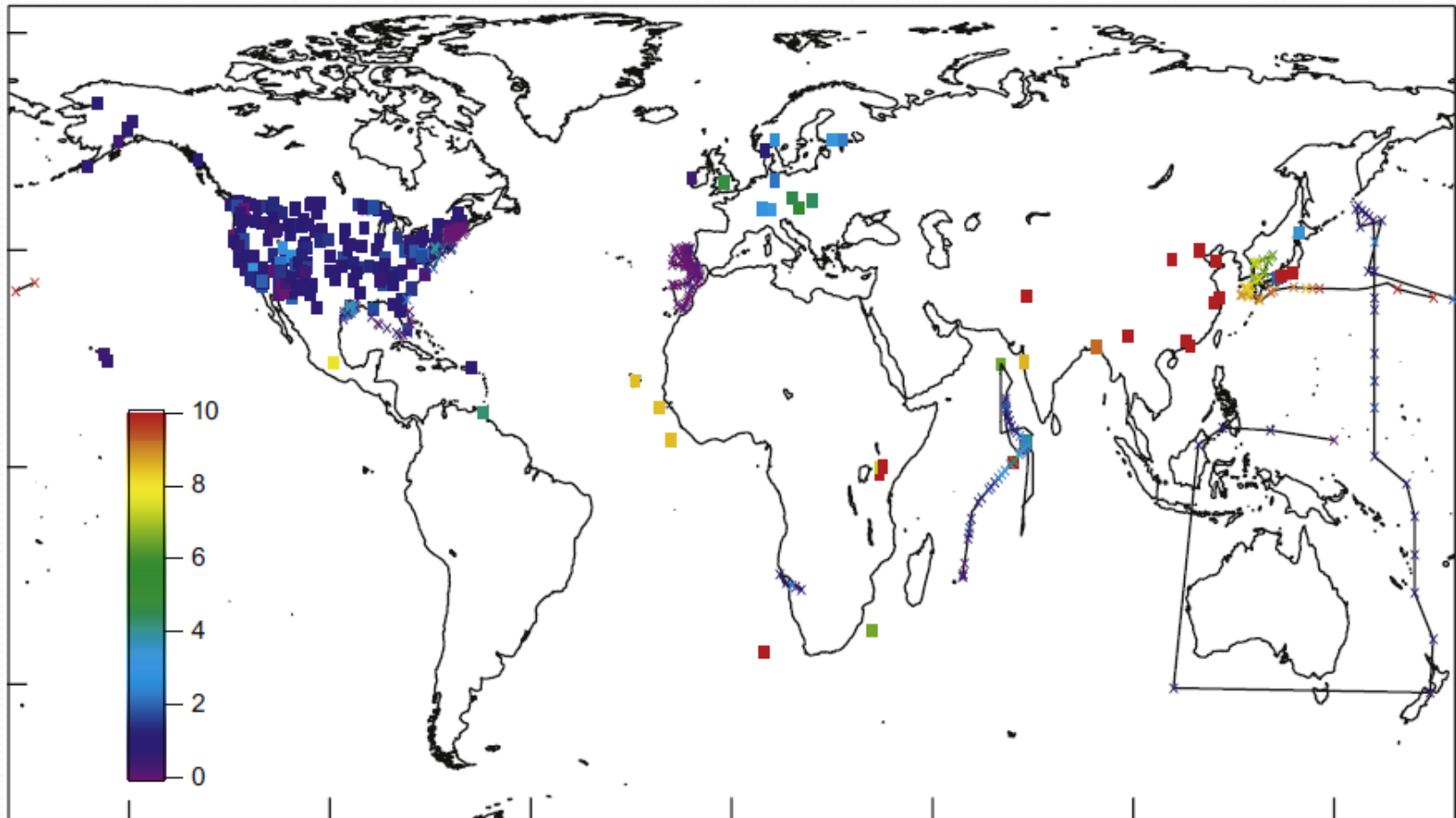
- BCC
- CAM4-Oslo
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- EMAC
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- GISS-MATRIX
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- TM4-ECPL-F
- TM4-ECPL-FNP
- TM5



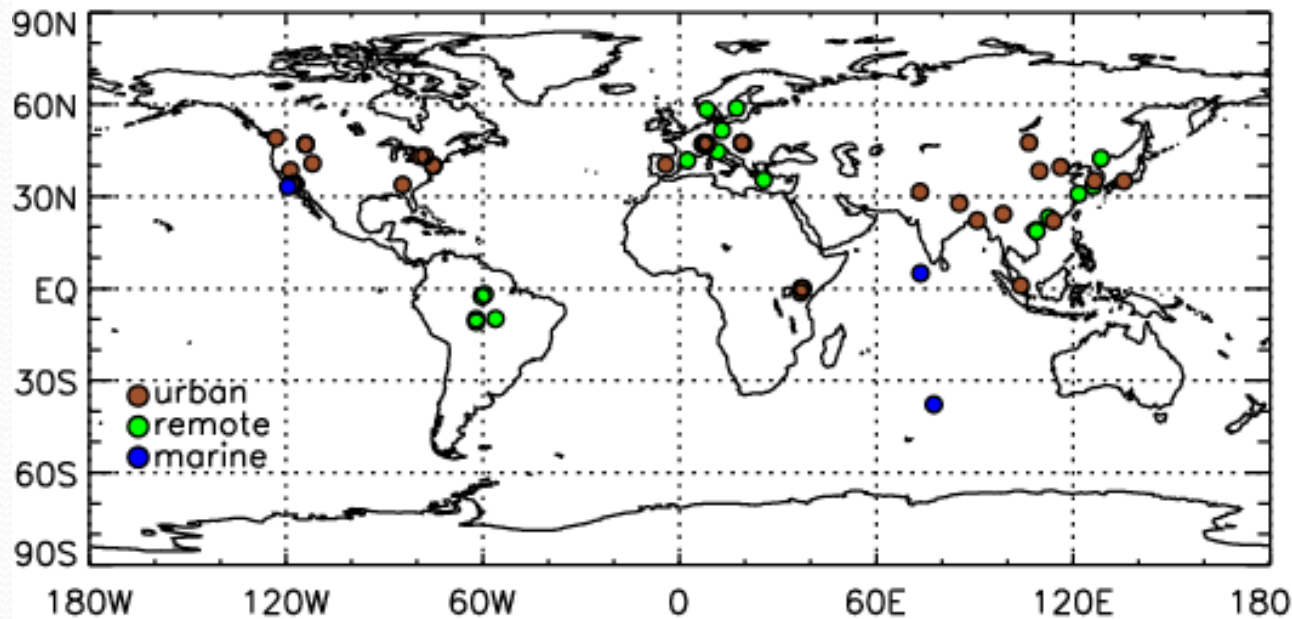
# Comparison with measurements (gridded)

# Organic Carbon (OC) – PM<sub>2.5</sub>

Bahadur et al., 2009



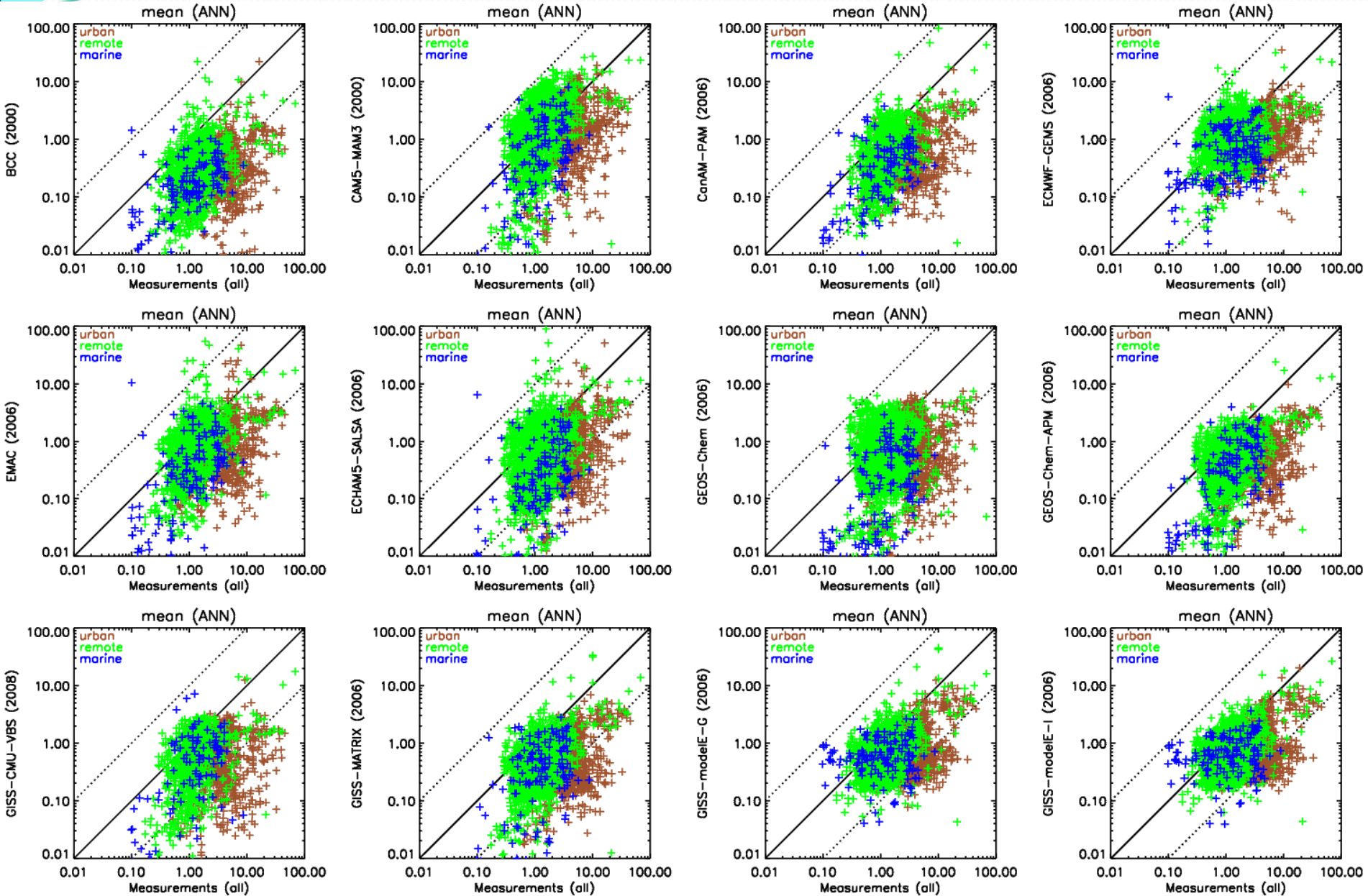
# Organic Carbon (OC)



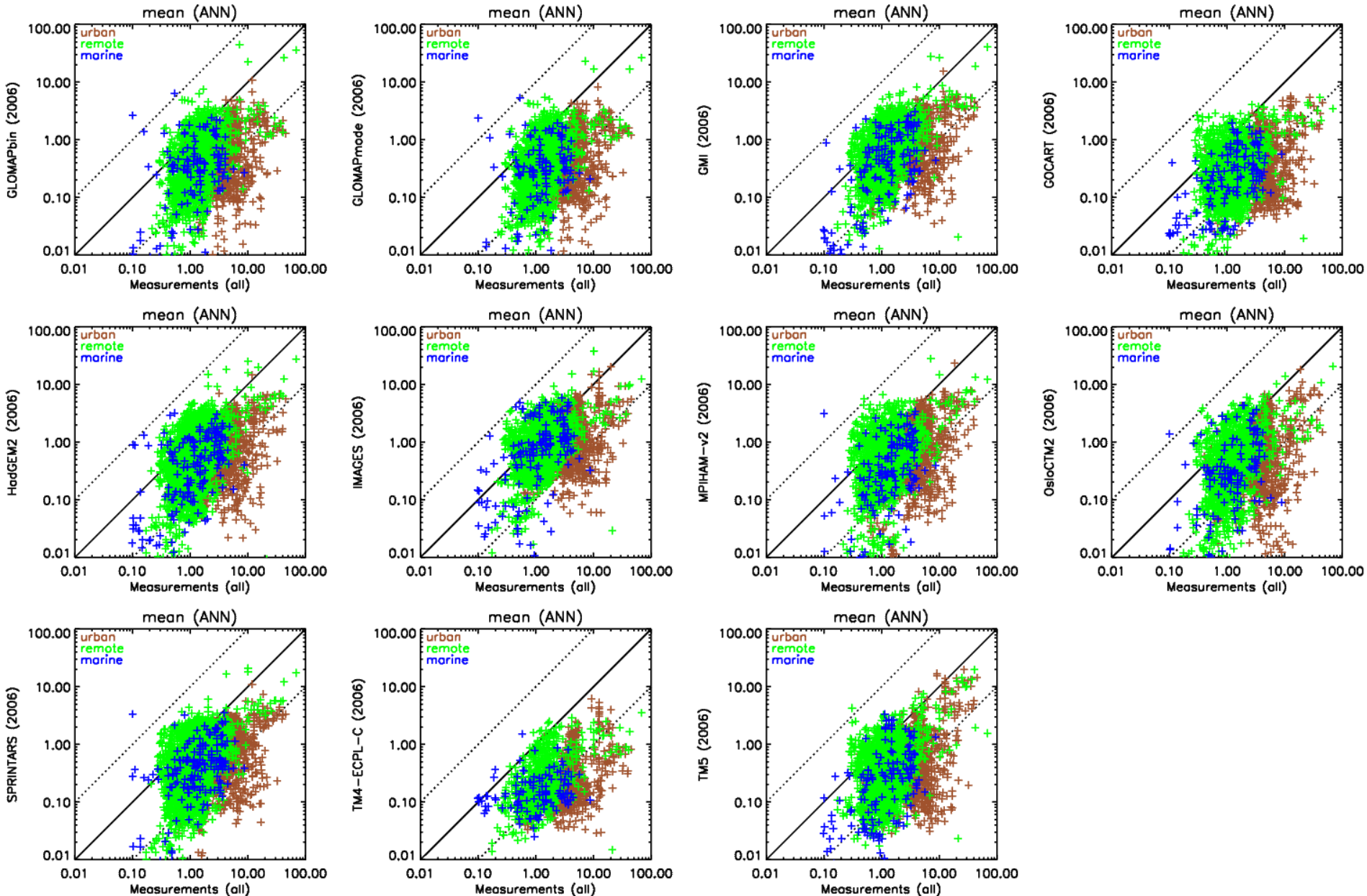
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Ward et al., 2004  
Koulouri et al., 2008  
Li et al., 2009  
He et al., 2004  
Salma et al., 2004  
Graham et al., 2003  
Sciare et al., 2009  
Fuzzi et al., 2007  
Gatari and Boman, 2002  
Smith et al., 1996  
Zappoli et al., 1999  
Chow et al., 1994  
Hueglin et al., 2005  
Kim et al., 2005  
Ho et al., 2004  
Fan et al., 2004  
Eatough et al., 2001; 2003  
Long et al., 2003  
Sawant et al., 2004  
Kim et al., 2000  
Jeong et al., 2004  
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Balasubramanian et al., 2003  
Xu et al., 2004  
Krivacsy et al., 2001  
Shakya et al., 2010



# Comparison with OC measurements

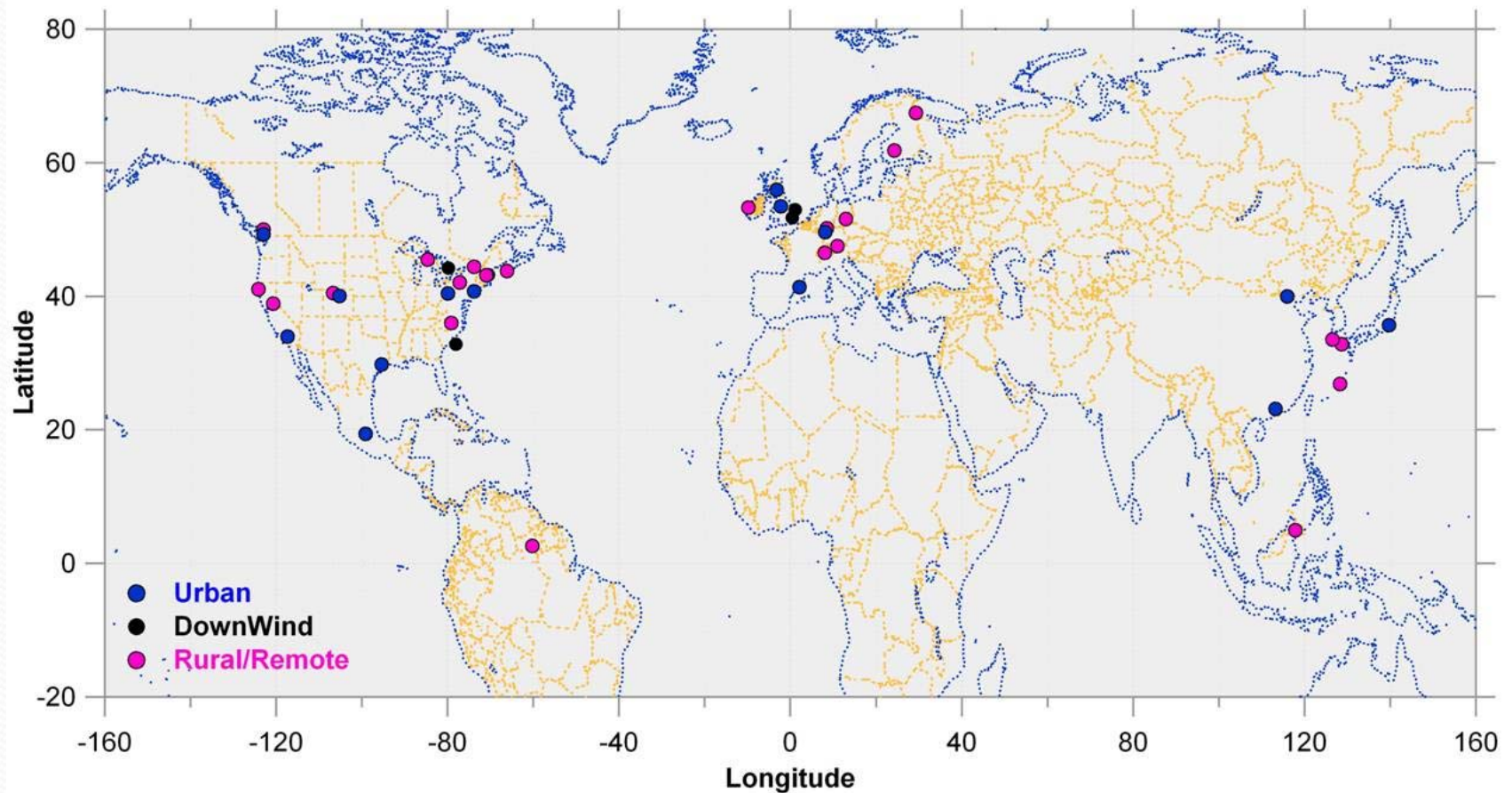


# Comparison with OC measurements



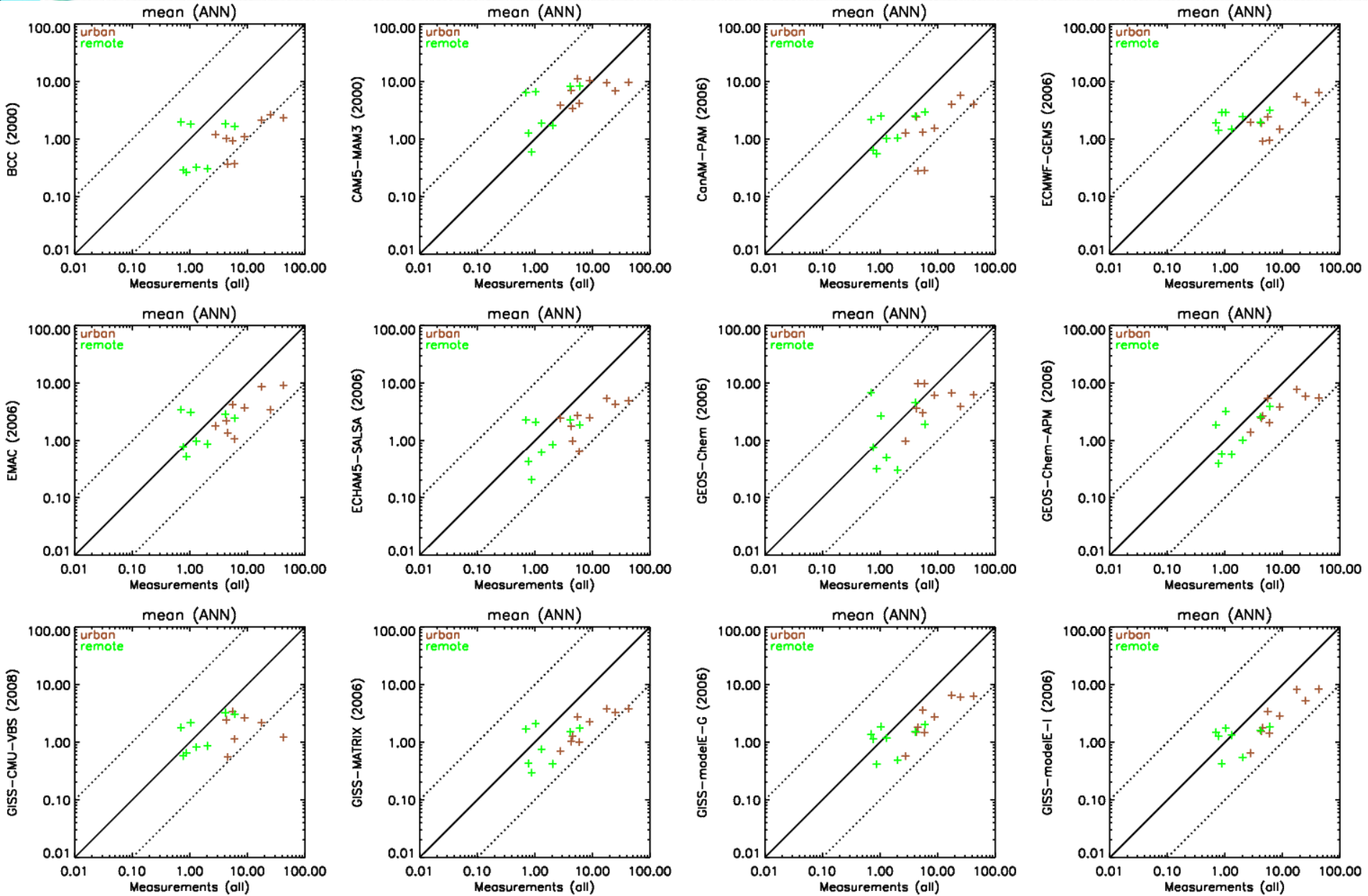


# Organic Matter (OM) – PM<sub>1</sub>

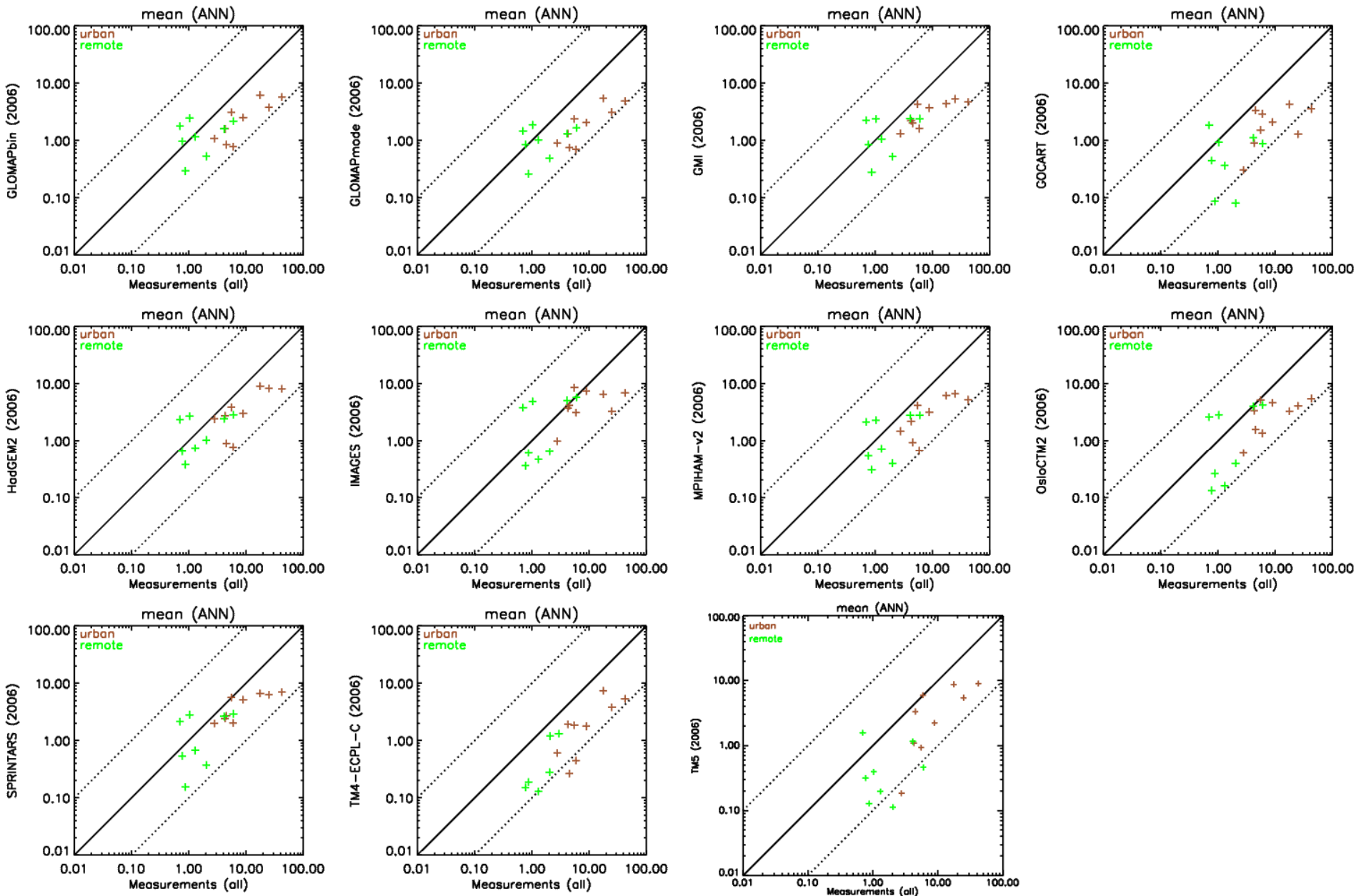




# Comparison with OM measurements



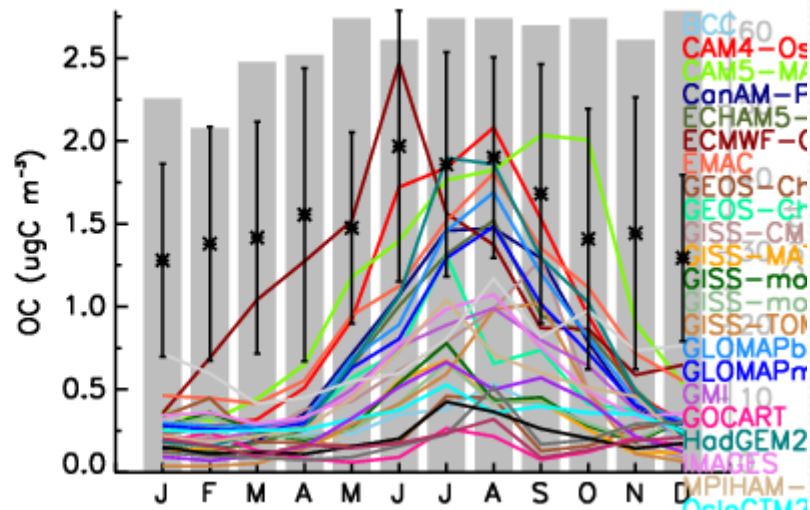
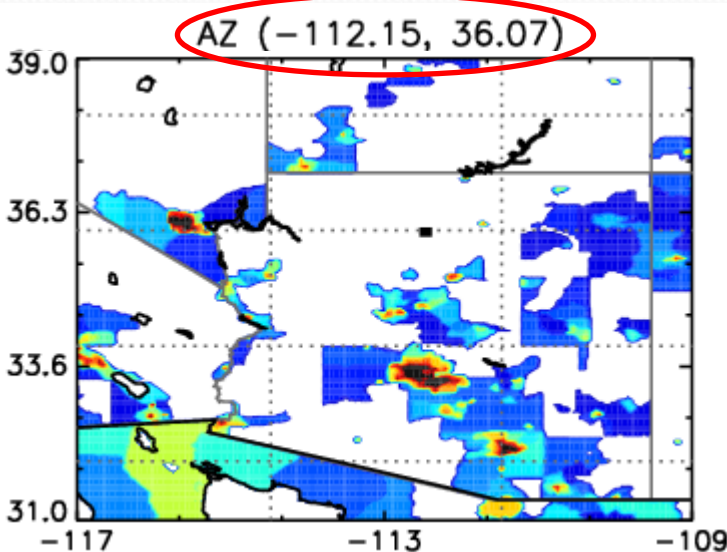
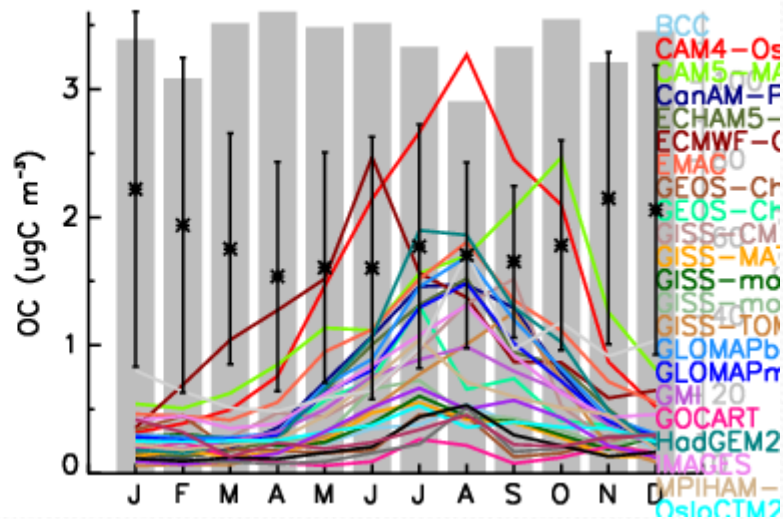
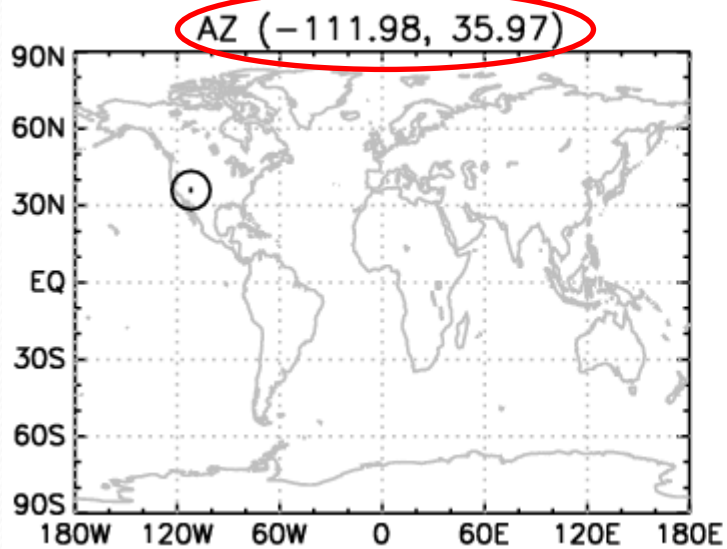
# Comparison with OM measurements



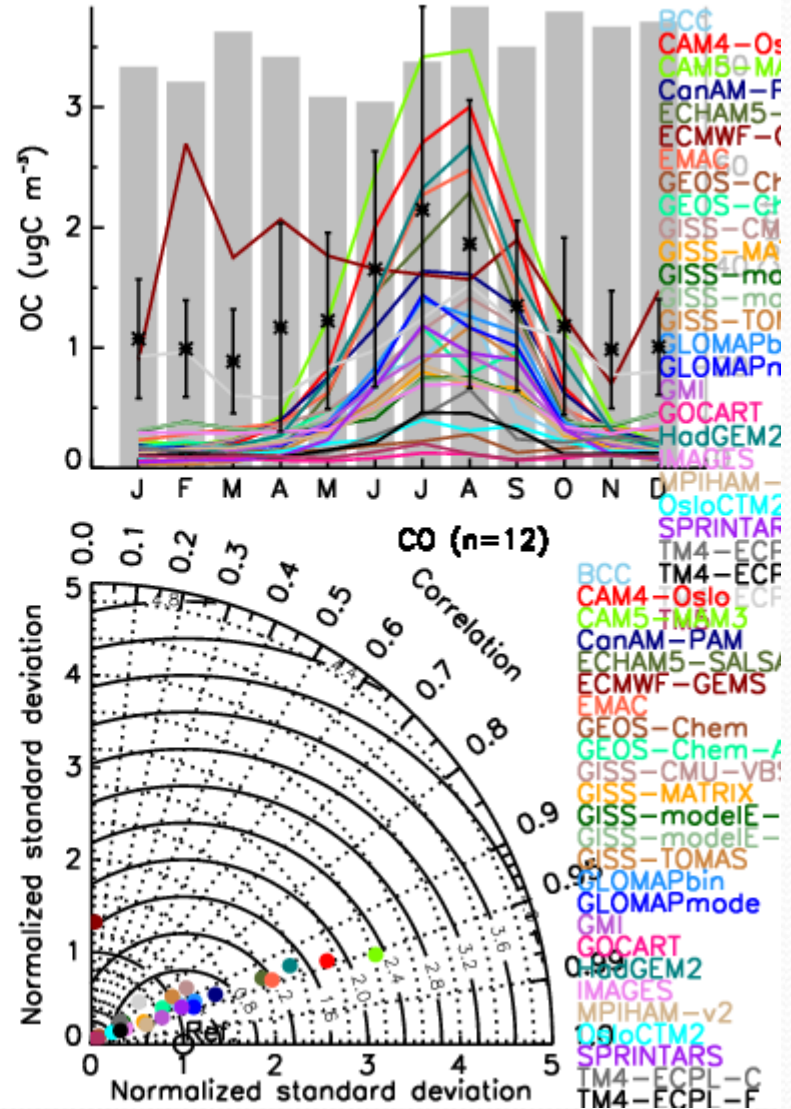
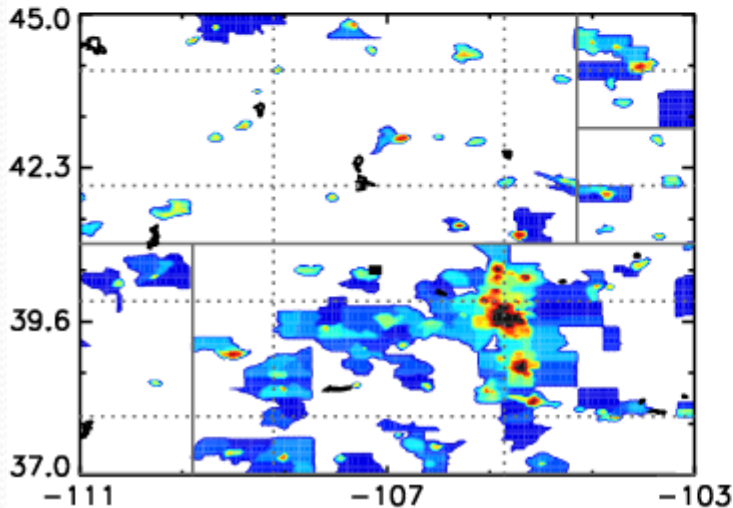
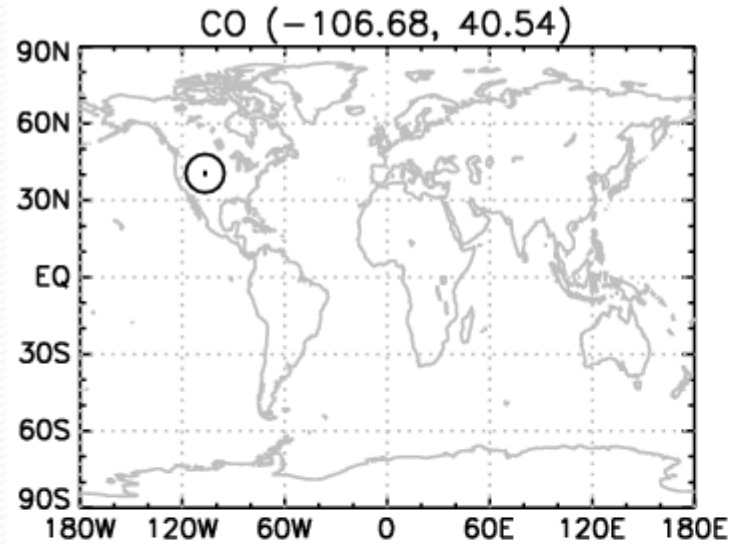
# Comparison with measurements (stations)



# Seasonality

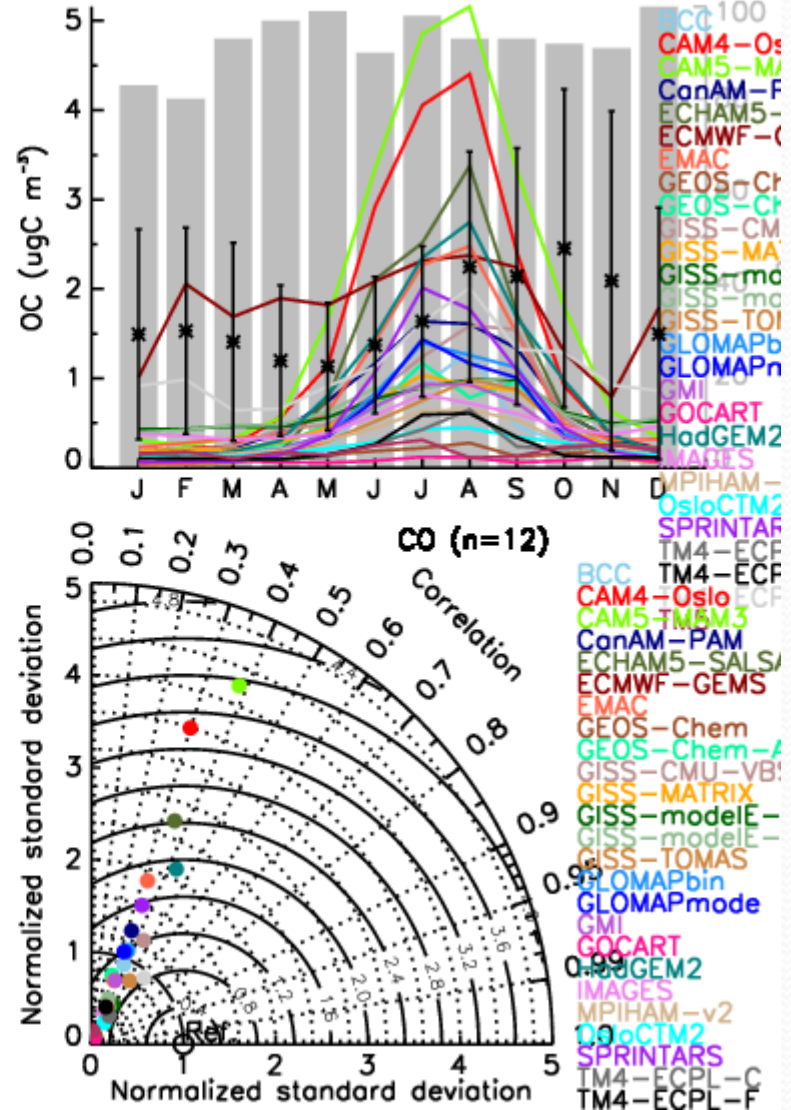
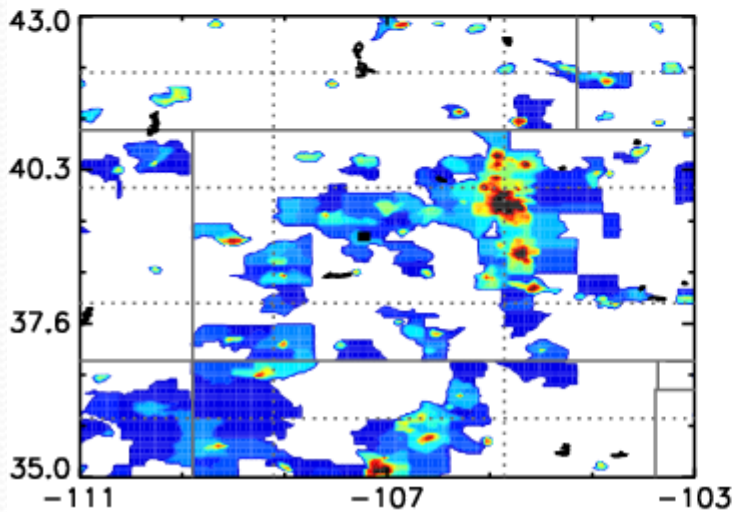
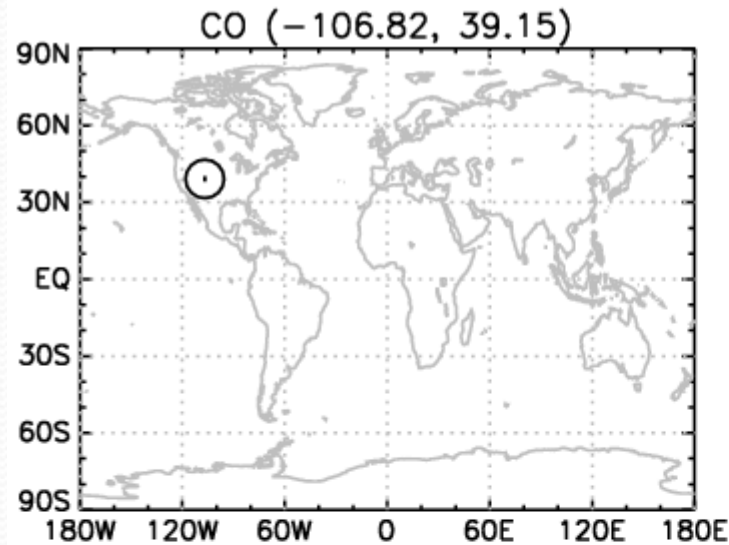


# Almost identical correlations



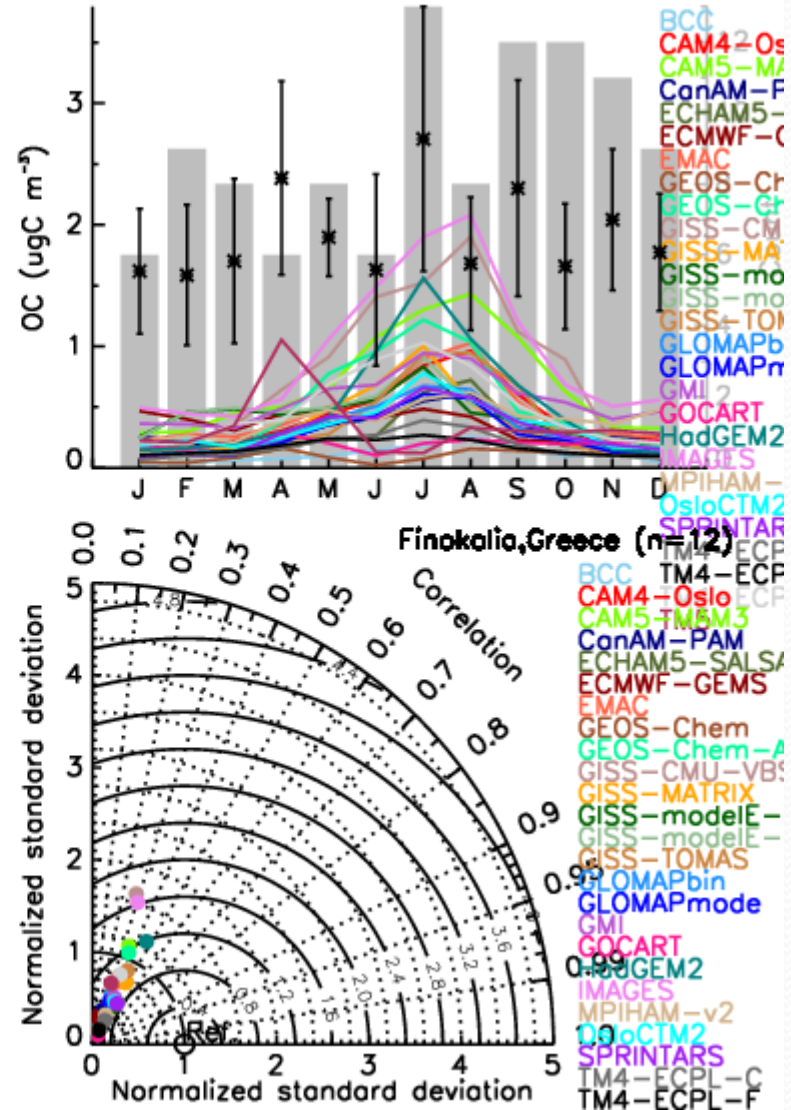
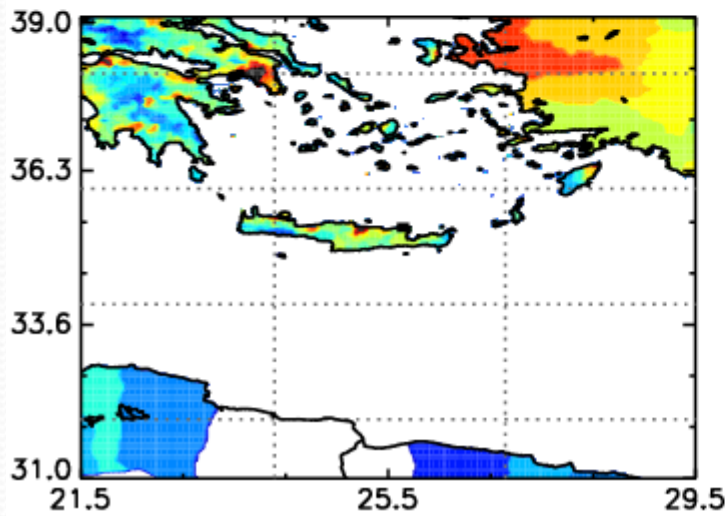
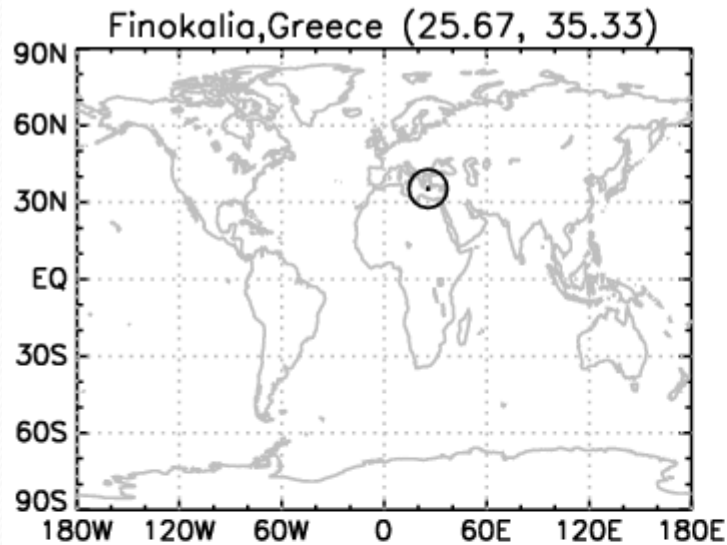


# Almost identical correlations

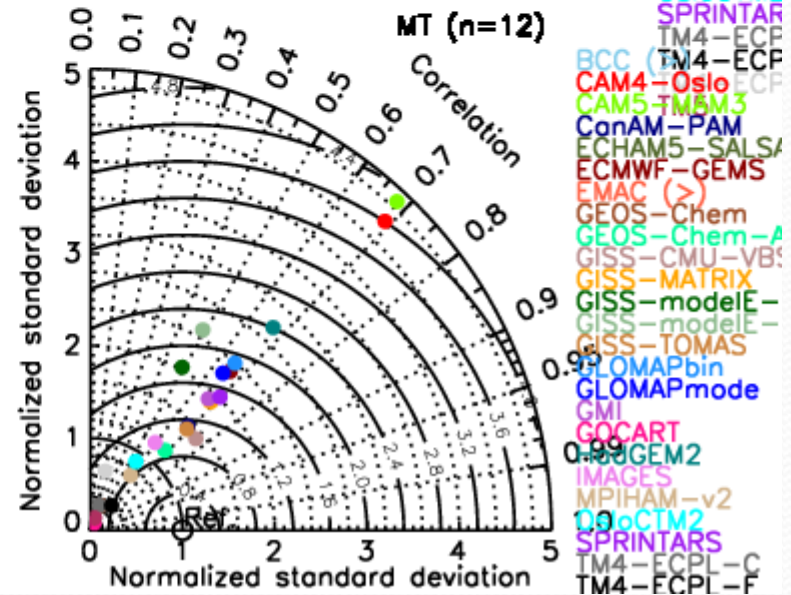
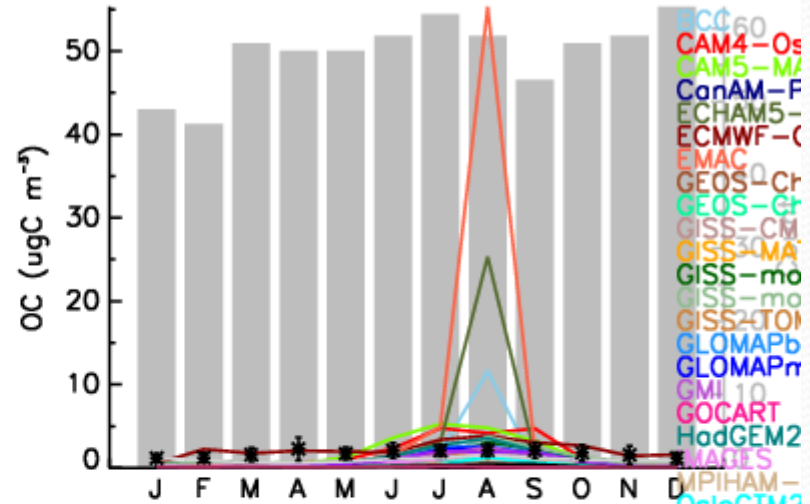
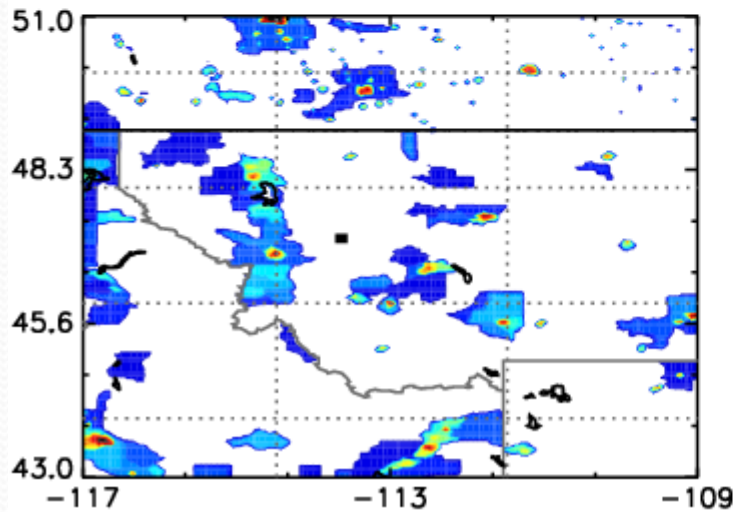
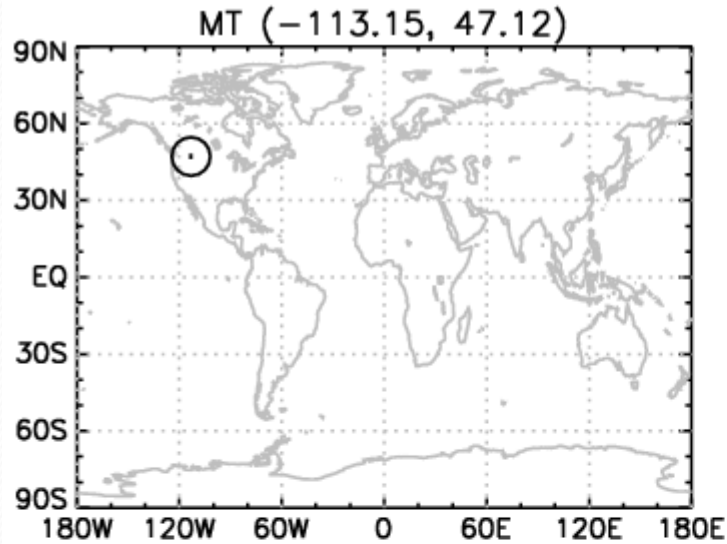




# Finokalia

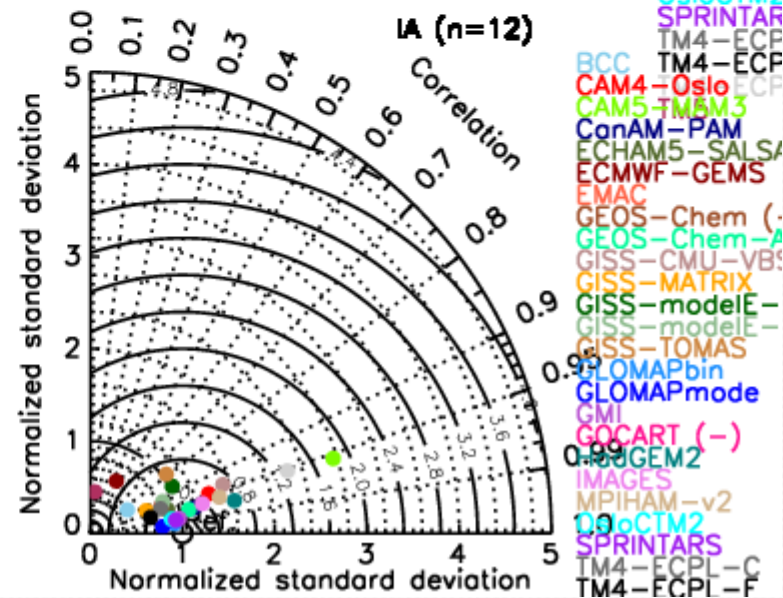
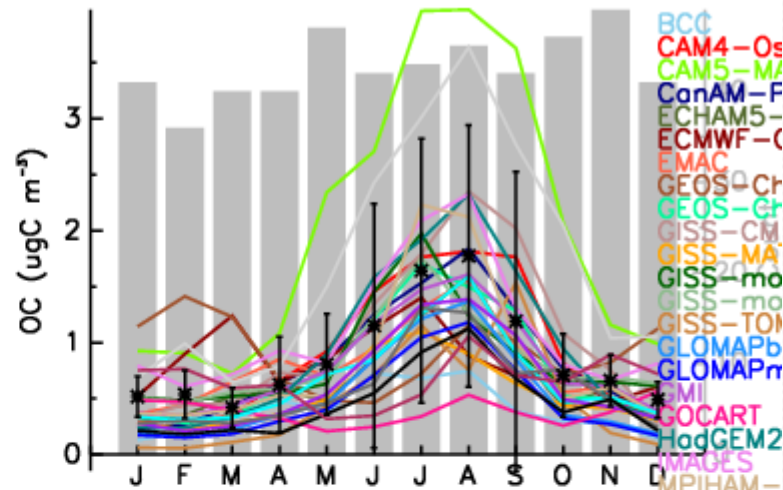
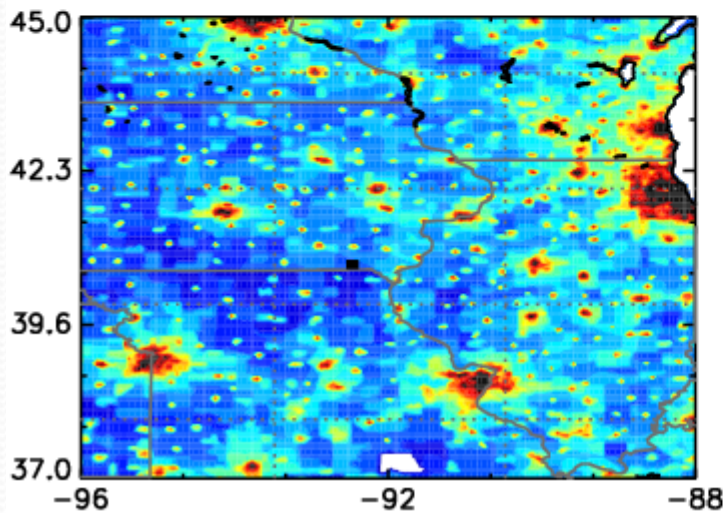
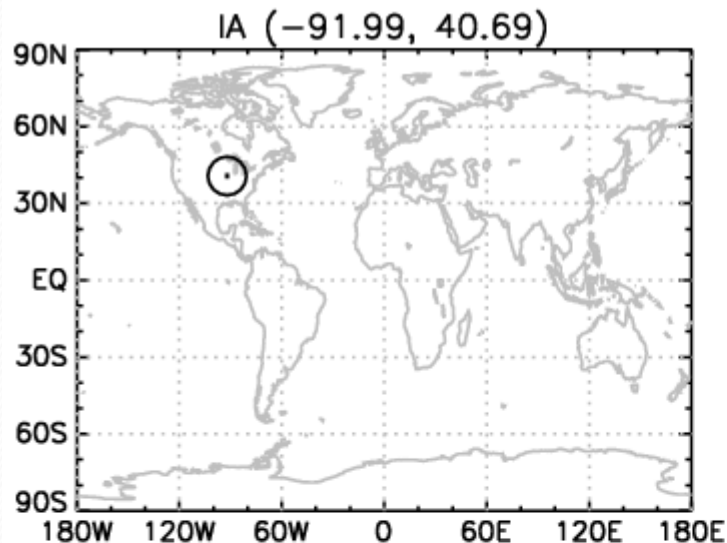


# Huge peaks





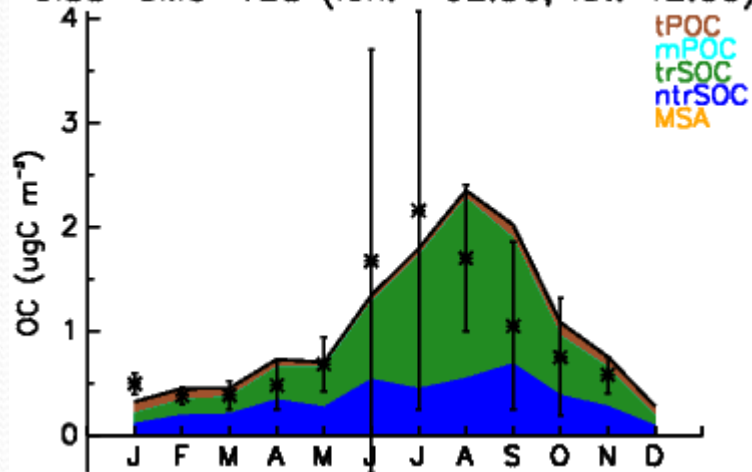
# Nice performance



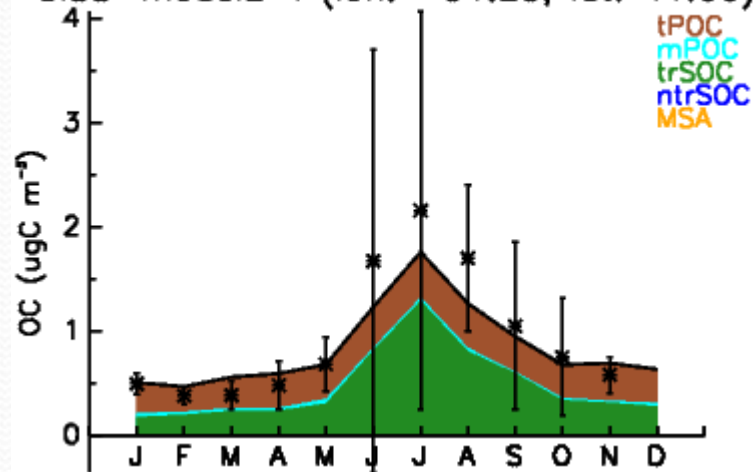


# Nice performance

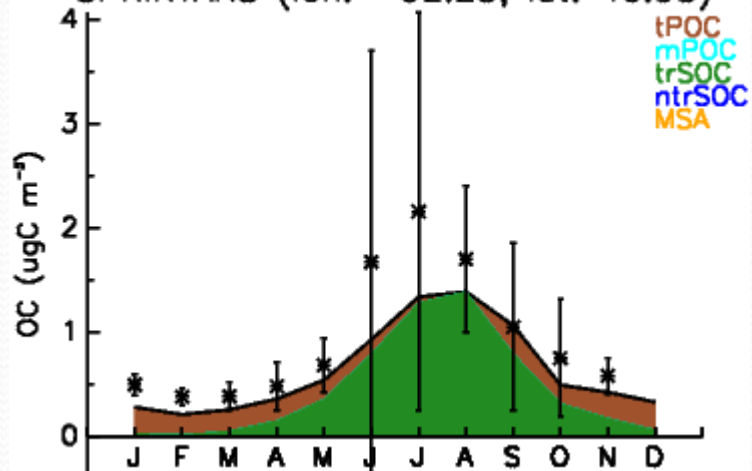
GISS-CMU-VBS (lon: -92.50, lat: 42.00)



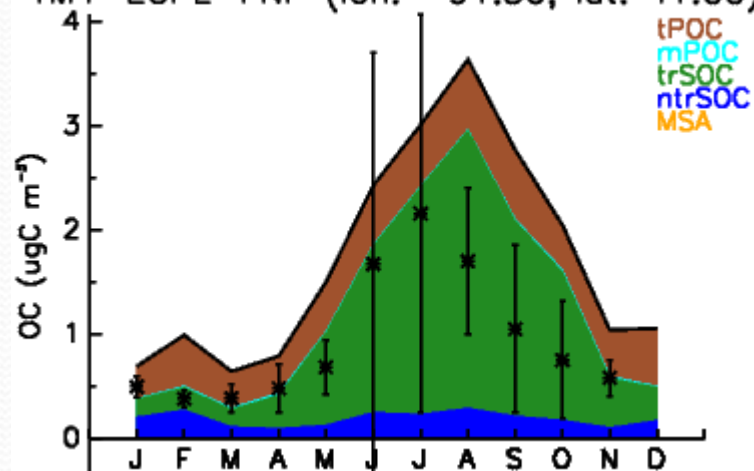
GISS-modelE-I (lon: -91.25, lat: 41.00)



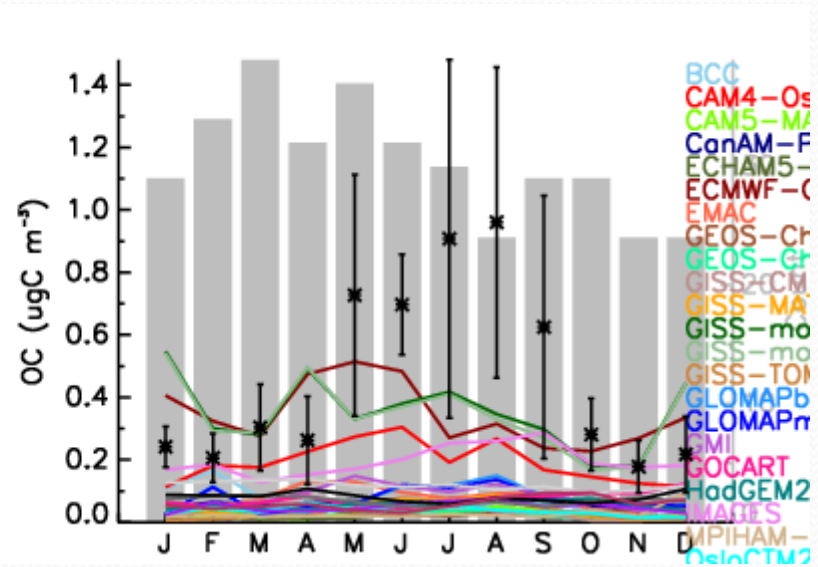
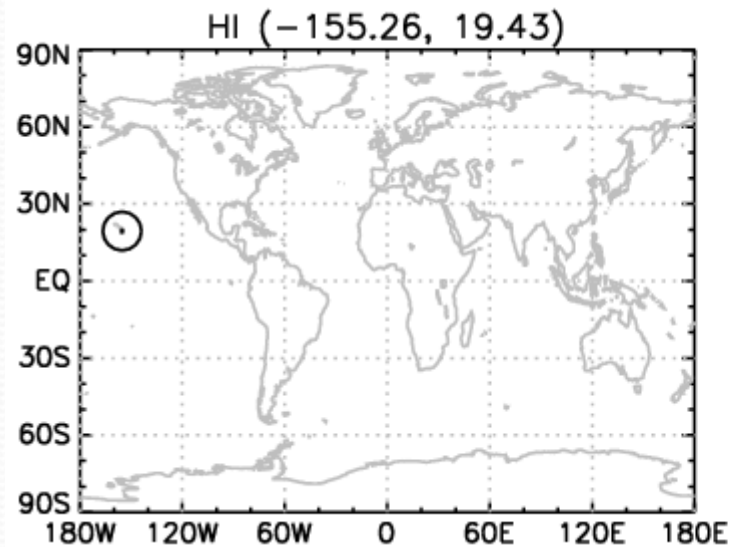
SPRINTARS (lon: -92.25, lat: 40.93)



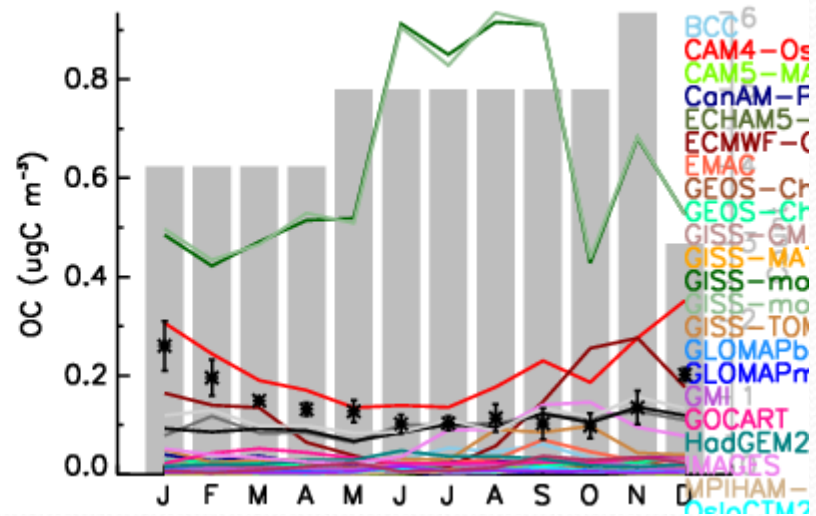
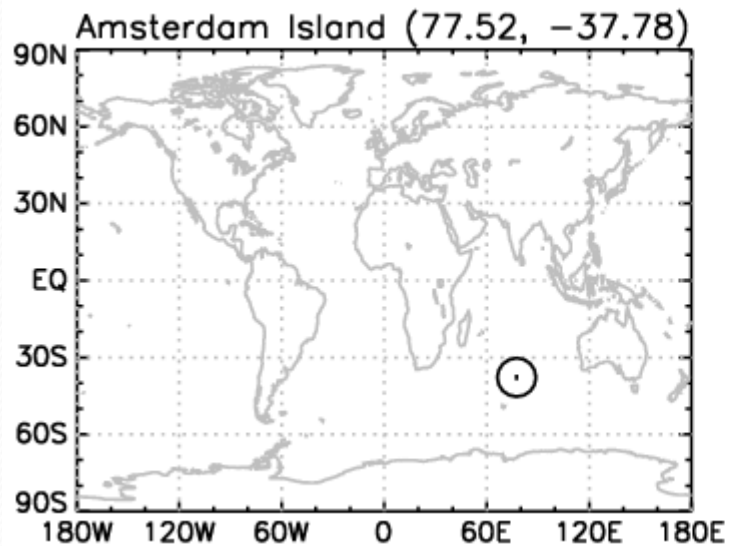
TM4-ECPL-FNP (lon: -91.50, lat: 41.00)



# Hawaii

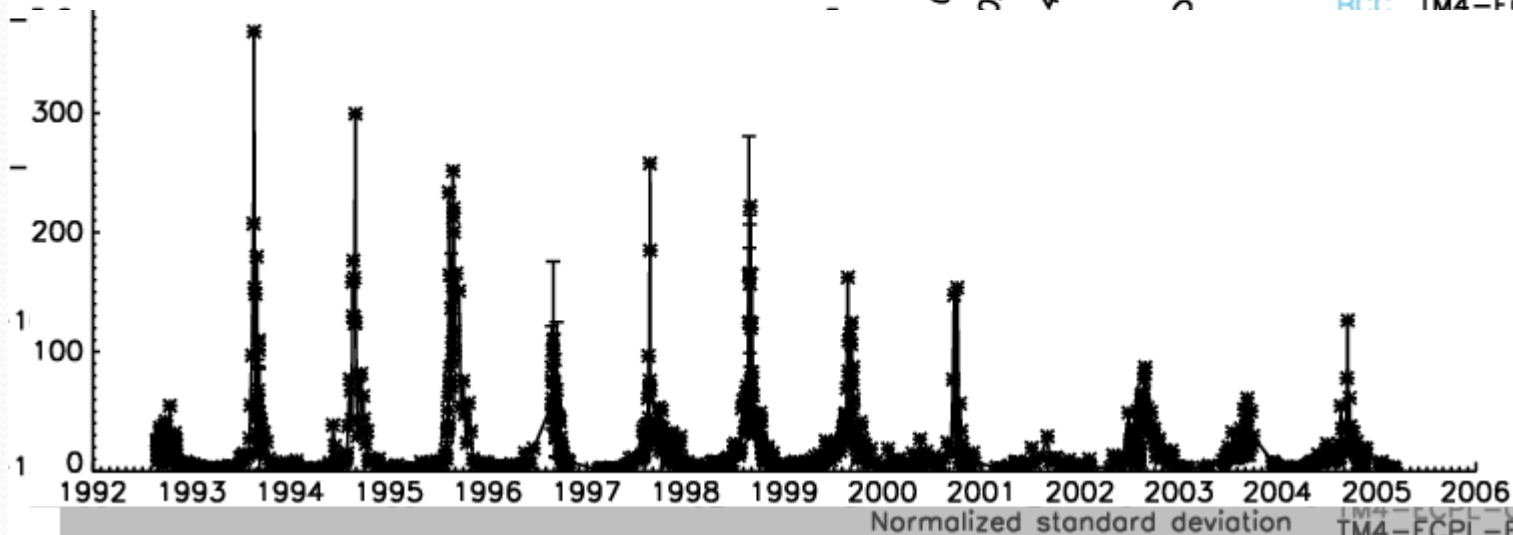
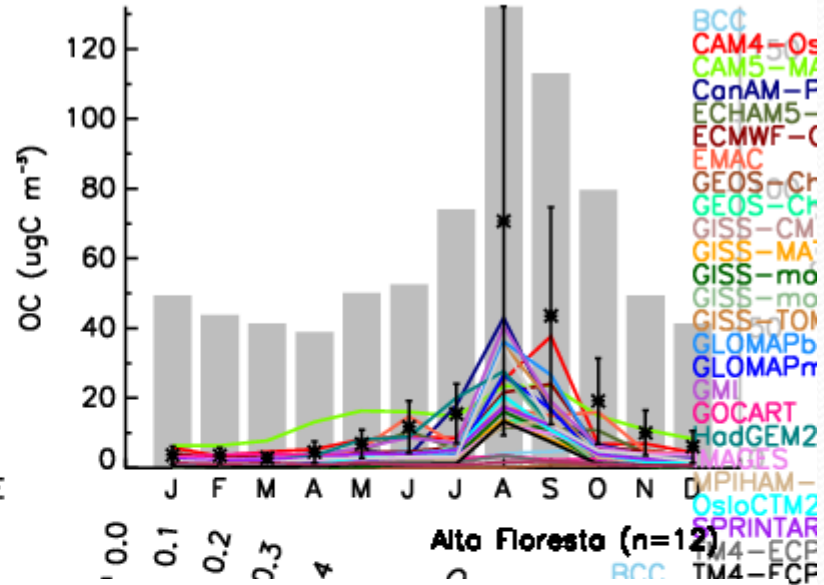
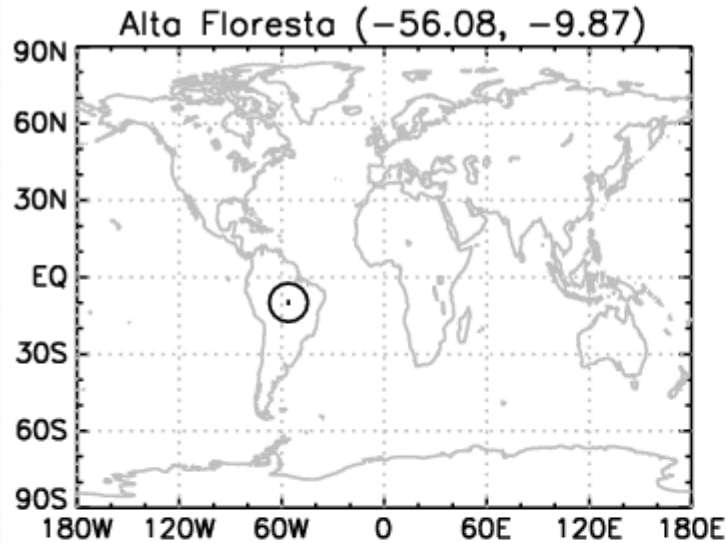


# Amsterdam Island

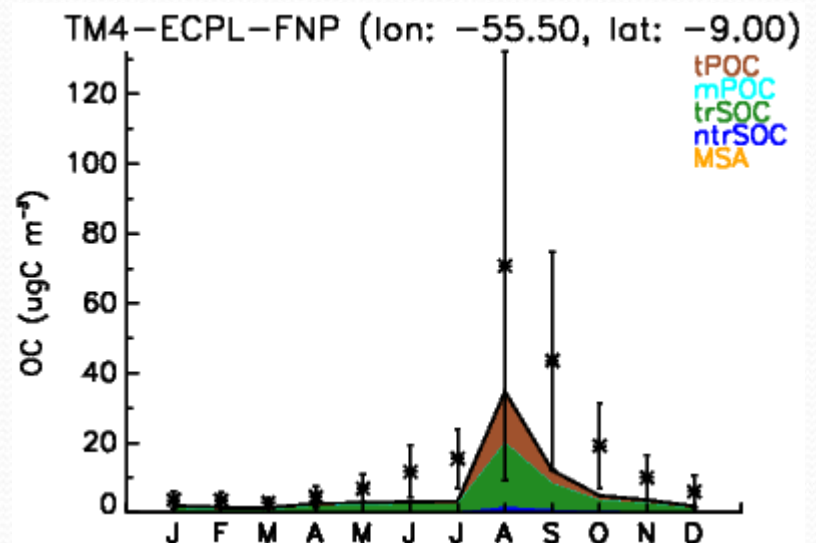
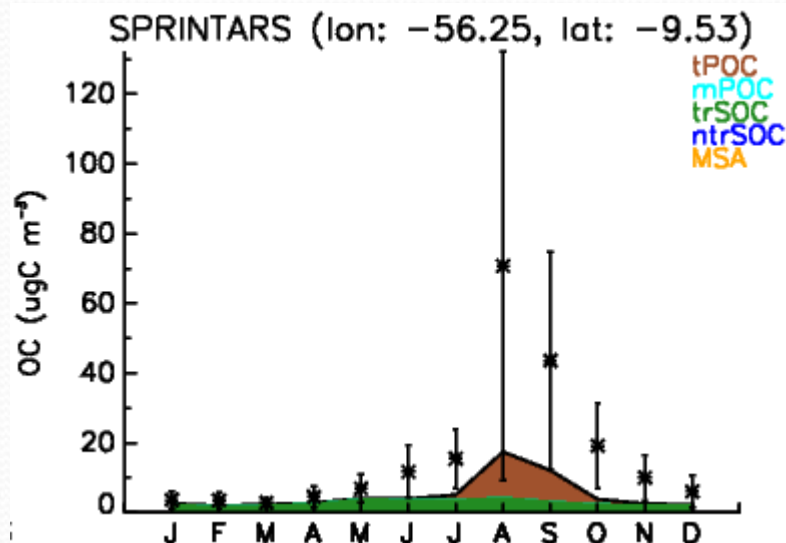
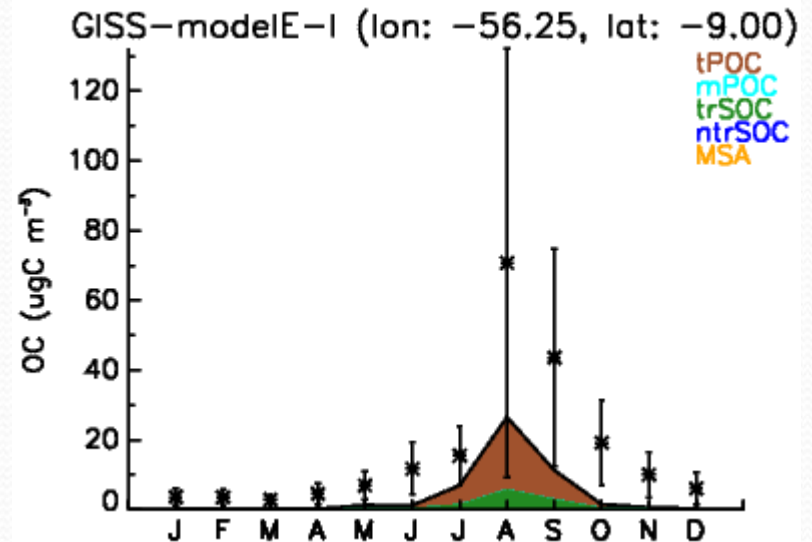
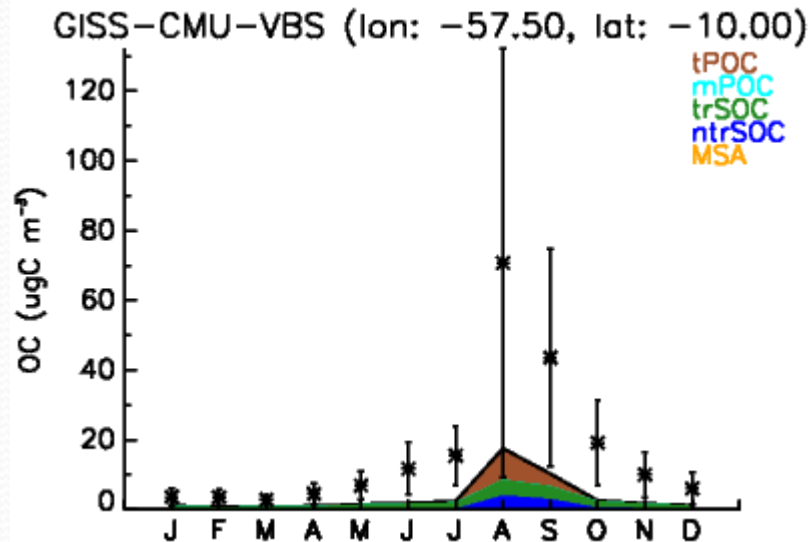




# Alta Floresta, Brazil



# Alta Floresta, Brazil



# Concluding remarks

- Large model **diversity**.
- In general models **underestimate** measurements, especially during **winter**.
- **Remote stations** are better captured compared to urban and marine ones.
  
- A condensed (and updated?) version of this presentation is scheduled for **IAMA (Davis) and AGU (SF) this December**.
- A paper is under preparation. At least two others are planned.