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Evaluation of NCAR aerosol assimilation using AEROCOM

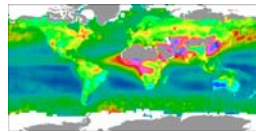
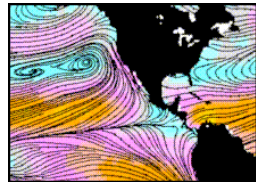
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Boulder, Colorado*



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Role of MATCH in SARB



Chemical Transport Model

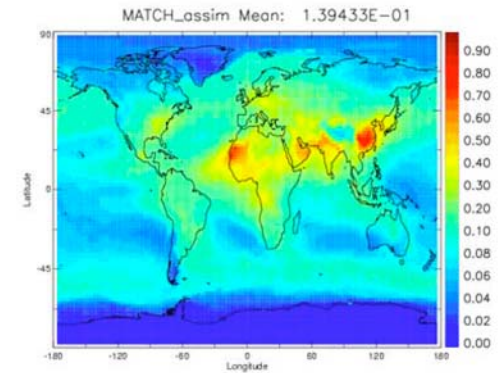
Aerosol mixing ratio q_i

Aerosol Optical Models

Optical depth τ_i , asymmetry g_i , ssa ω_i

Fu/Liou Radiative Transfer Code

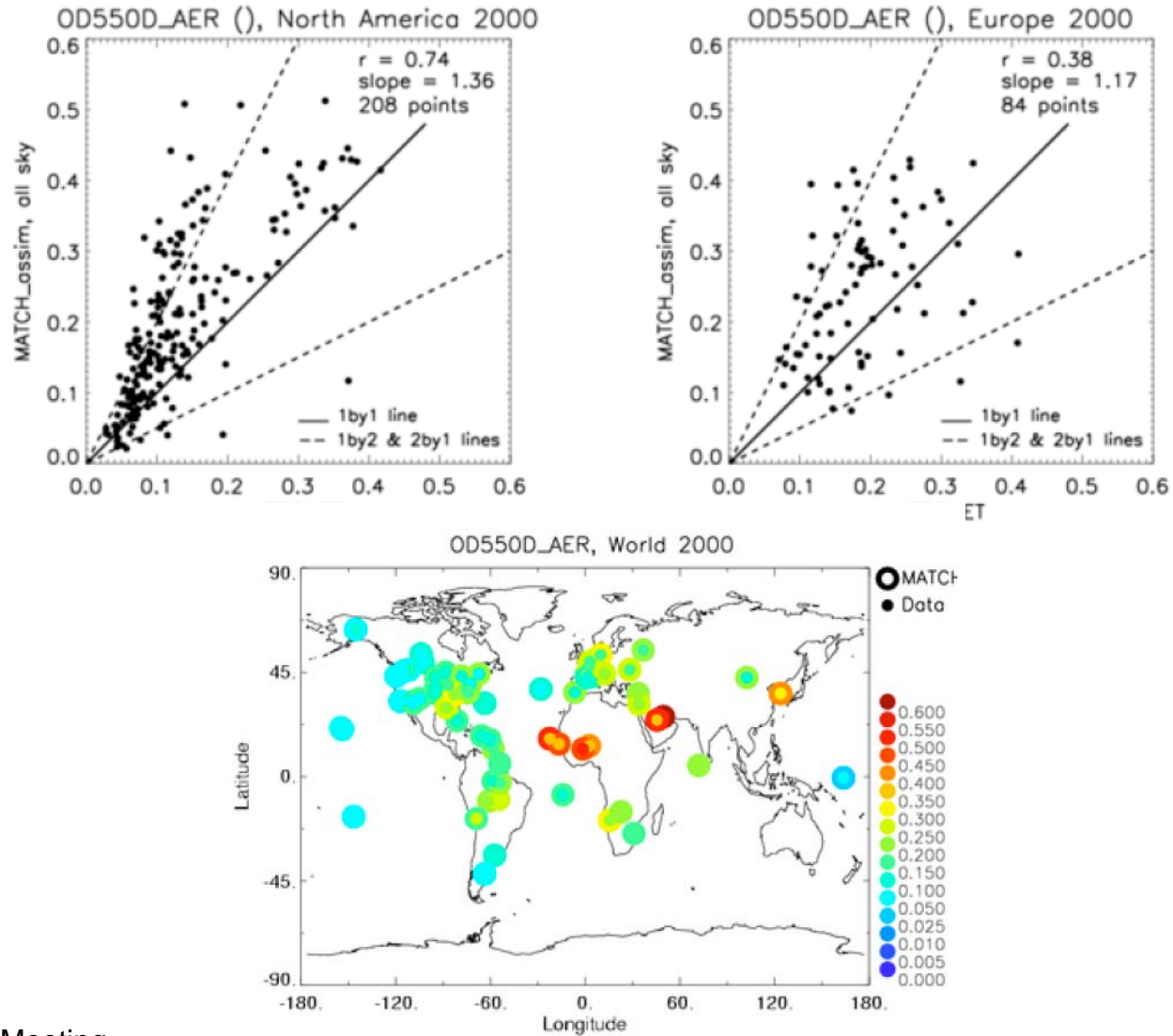
Surface/Atmosphere Radiation Budget





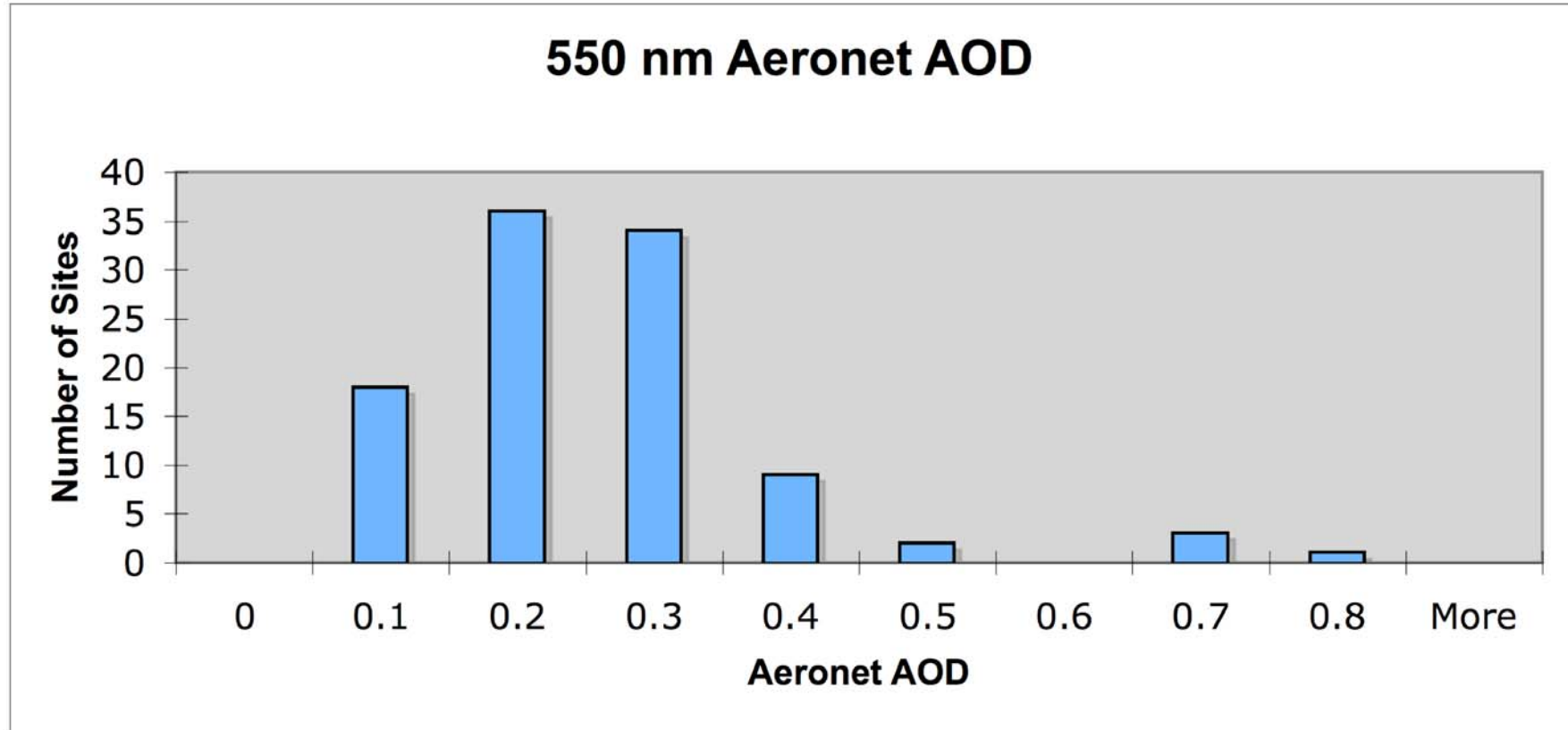
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Evaluation of MATCH using AEROCOM (Aeronet 550 nm AOD)





Aeronet AOD for Sites with 4-year Records



- Number of Sites = 103
- Mean AOD = 0.21
- Stdev AOD = 0.13

Model Mean-Square Error (MSE)

Define

M = Model time series of daily-mean AOD

A = AERONET time series of daily-mean AOD

$\langle M \rangle$ = Time-mean model AOD

$\langle A \rangle$ = Time-mean AERONET AOD

Then mean square error is

$$\begin{aligned} MSE &= \langle (M - A)^2 \rangle \\ &= \langle [(M - \langle M \rangle) - (A - \langle A \rangle) + (\langle M \rangle - \langle A \rangle)]^2 \rangle \\ &= \langle (M - \langle M \rangle)^2 \rangle + \langle (A - \langle A \rangle)^2 \rangle - 2 \langle (M - \langle M \rangle)(A - \langle A \rangle) \rangle + (\langle M \rangle - \langle A \rangle)^2 \\ &= \text{Var}(M) + \text{Var}(A) - 2 \text{Cov}(M, A) + (\langle M \rangle - \langle A \rangle)^2 \\ RMSE &= \sqrt{MSE} \end{aligned}$$

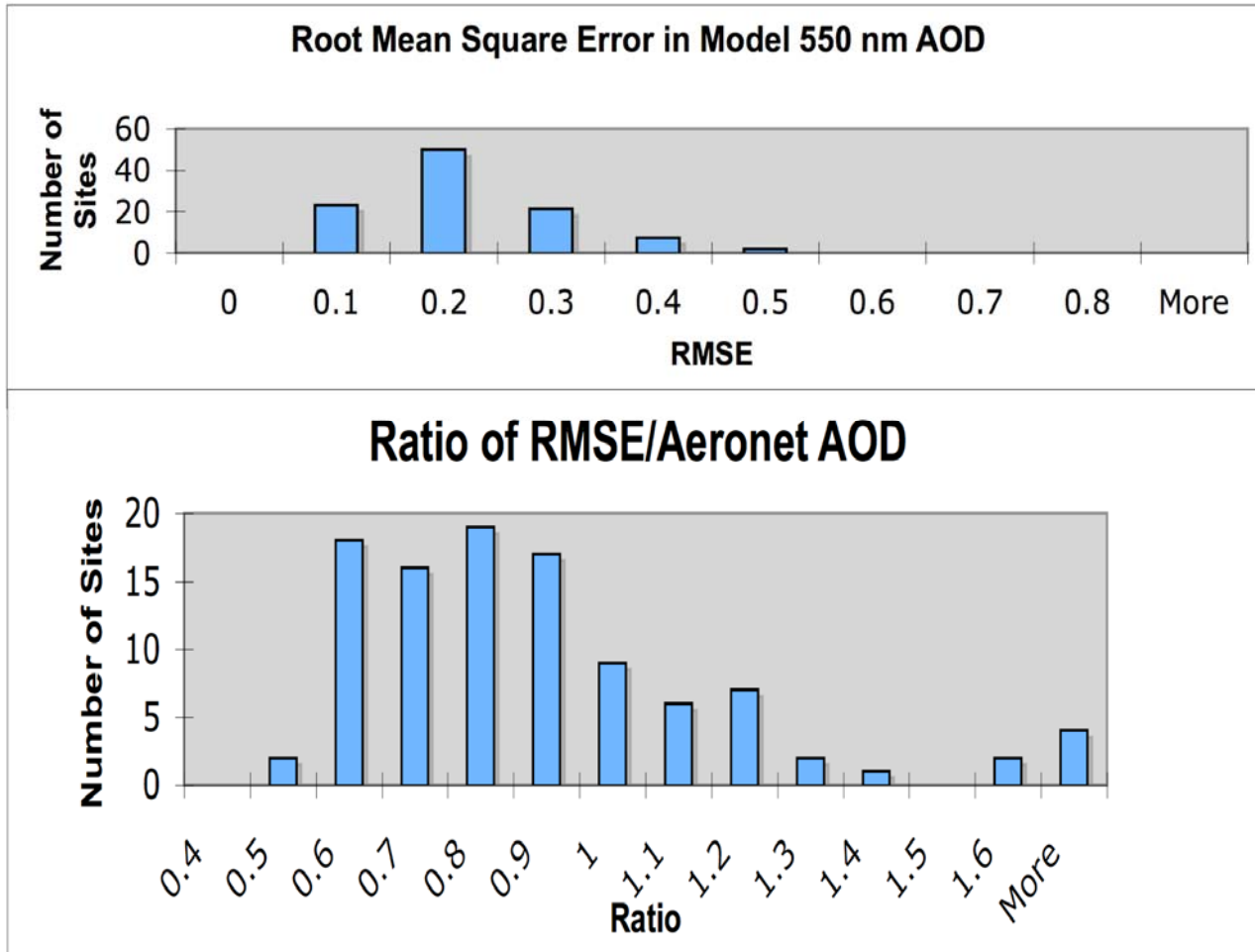
Symbols are

$\text{Var}(M)$ = Variance in model time series

$\text{Var}(A)$ = Variance in AERONET time series

$\text{Cov}(M, A)$ = Covariance in model and AERONET time series

RMSE in Daily-mean Model AOD



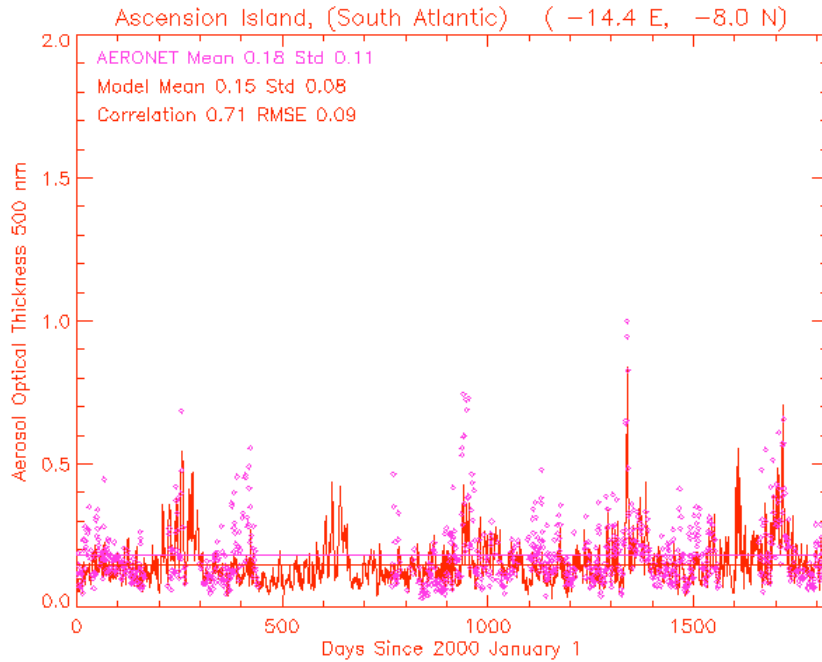
- Mean RMSE = 0.17
- Stdev RMSE = 0.09

- Median Ratio = 0.79
- Minimum Ratio = 0.43
- Maximum Ratio = 4.22

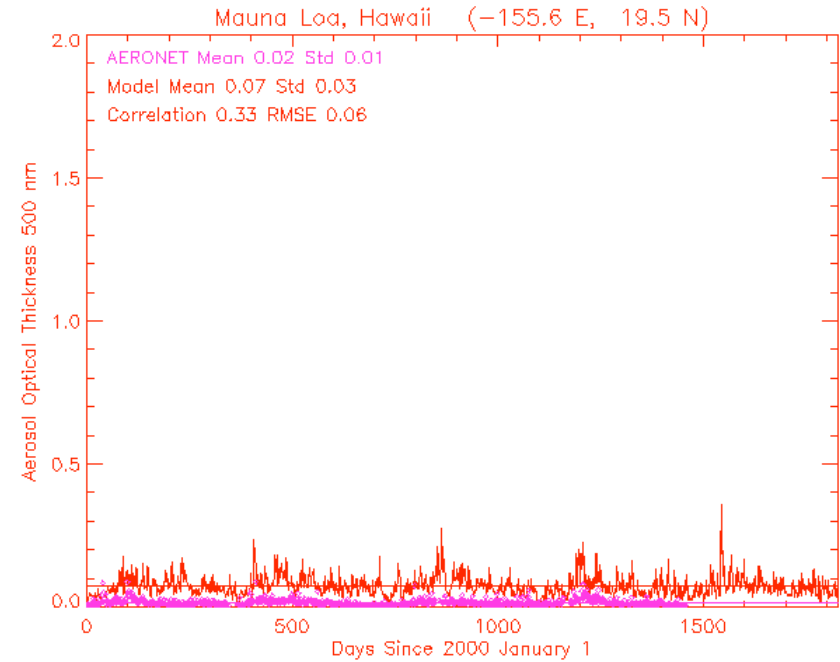


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Examples: Small & Large RMSE / Aeronet AOD



RMSE / Aeronet AOD = 0.48



RMSE / Aeronet AOD = 4.21



Decomposition of Mean-Square Error

Since least-squares correlation coefficient is

$$r = \frac{\text{Cov}(M, A)}{\sqrt{\text{Var}(M)}\sqrt{\text{Var}(A)}}$$

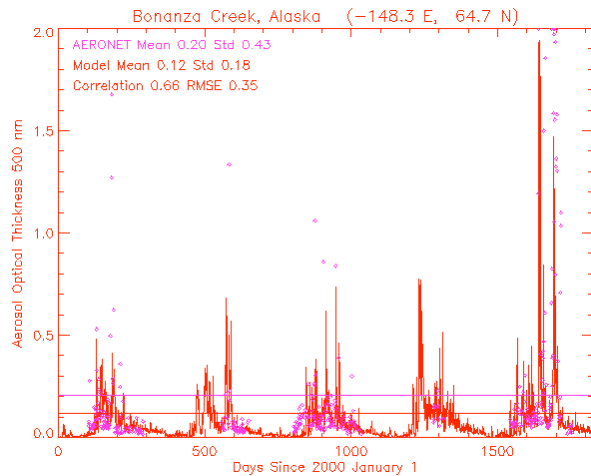
Therefore the **MSE** can be written in the form

$$\begin{aligned} \text{MSE} &= \text{Var}(M) + \text{Var}(A) - 2 \text{Cov}(M, A) + (\langle M \rangle - \langle A \rangle)^2 \\ &= \text{Var}(M) + \text{Var}(A) - 2 \boxed{r} \sqrt{\text{Var}(M)} \sqrt{\text{Var}(A)} + (\langle M \rangle - \langle A \rangle)^2 \\ &= \text{Var}(M) + \text{Var}(A) - 2 \boxed{(r - 1 + 1)} \sqrt{\text{Var}(M)} \sqrt{\text{Var}(A)} + (\langle M \rangle - \langle A \rangle)^2 \\ &= \left(\text{Var}(M) + \text{Var}(A) - 2 \sqrt{\text{Var}(M)} \sqrt{\text{Var}(A)} \right) \\ &\quad - 2(r - 1) \sqrt{\text{Var}(M)} \sqrt{\text{Var}(A)} + (\langle M \rangle - \langle A \rangle)^2 \\ &= \underbrace{\left(\sqrt{\text{Var}(M)} - \sqrt{\text{Var}(A)} \right)^2}_{\text{Variance}} + \underbrace{2(1 - r) \sqrt{\text{Var}(M)} \sqrt{\text{Var}(A)}}_{\text{Correlation}} + \underbrace{(\langle M \rangle - \langle A \rangle)^2}_{\text{Mean}} \end{aligned}$$

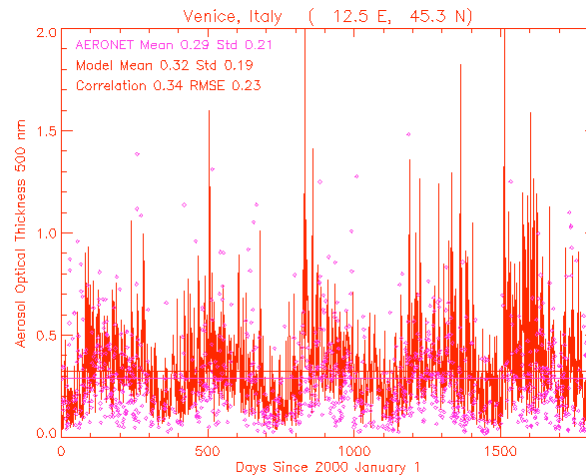
Decomposition of Mean-Square Error

Therefore the mean-square error is a sum of 3 terms:

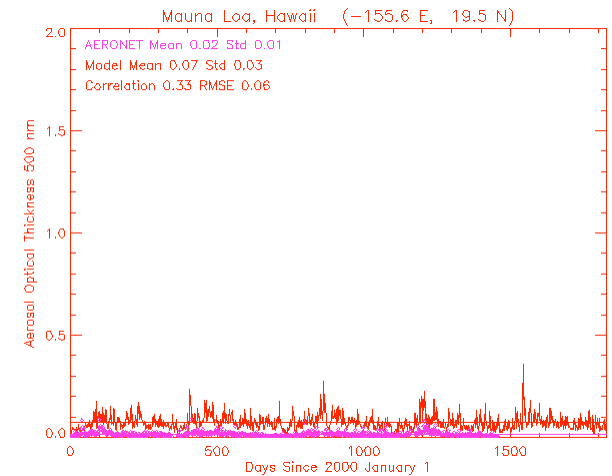
$$MSE = MSE(\text{variance}) + MSE(\text{correlation}) + MSE(\text{mean})$$



MSE(var)/MSE=0.51



MSE(cov)/MSE=0.98

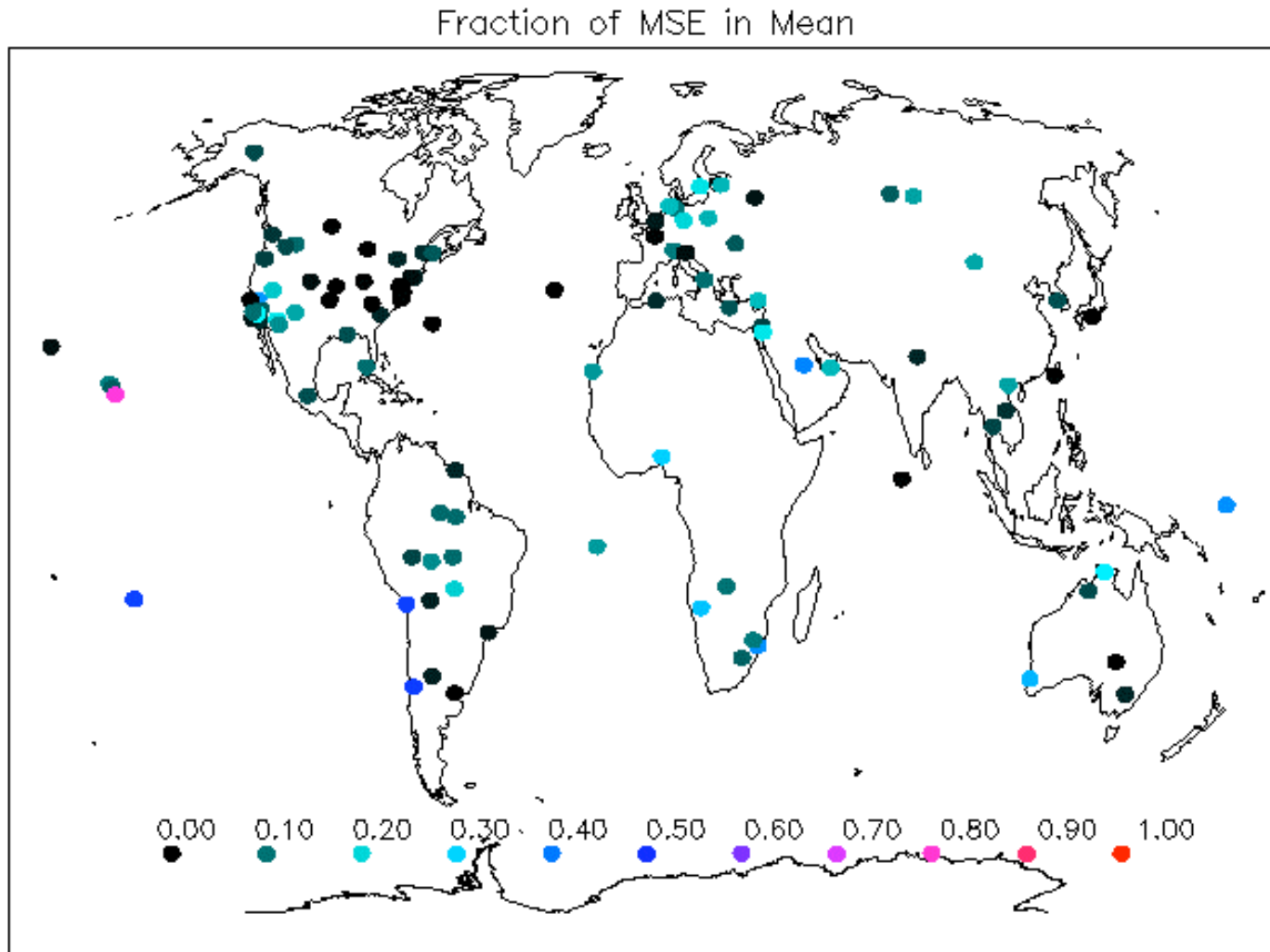


MSE(mean)/MSE=0.79



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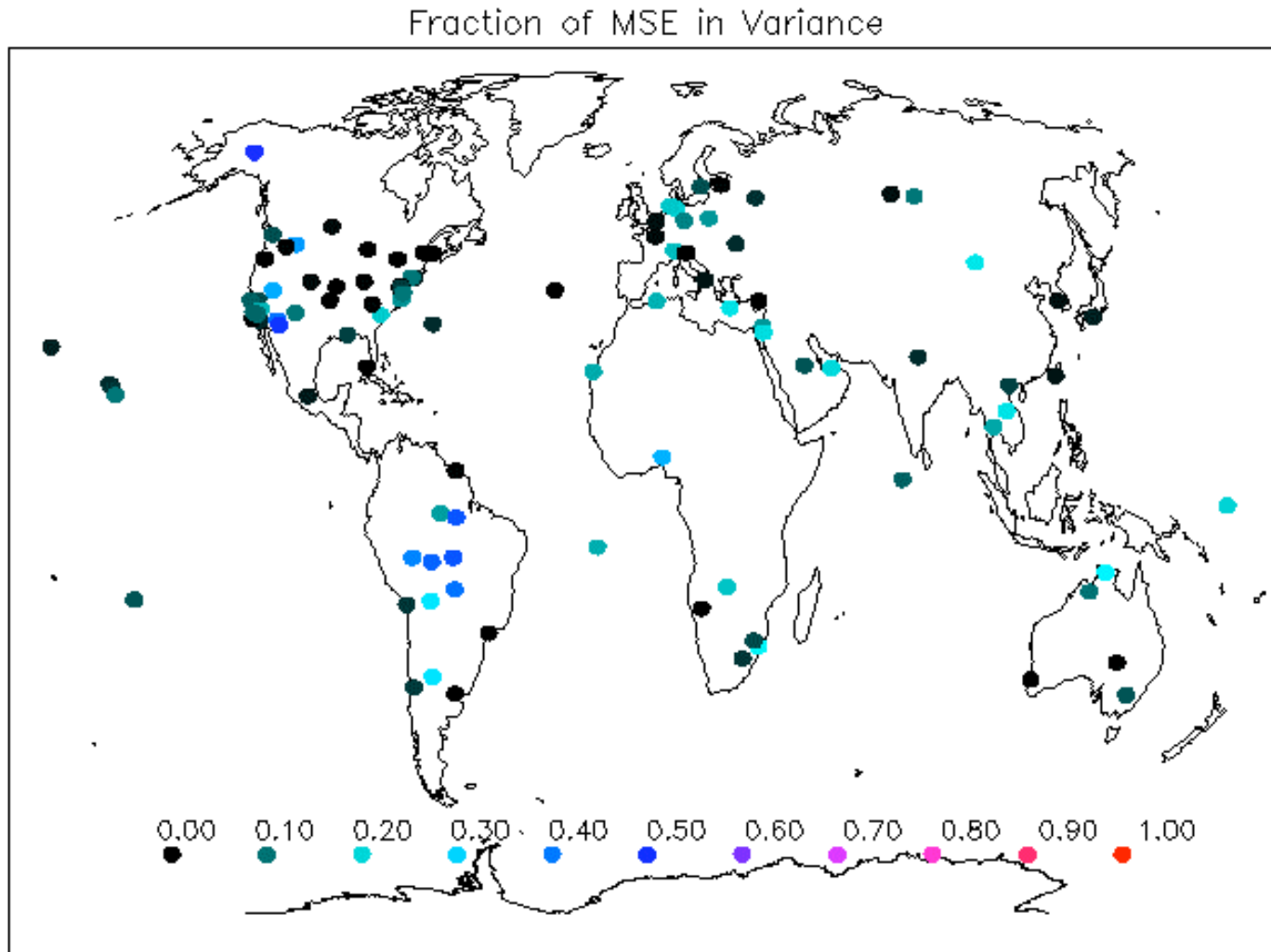
Fractional Contribution of Errors in AOD Mean





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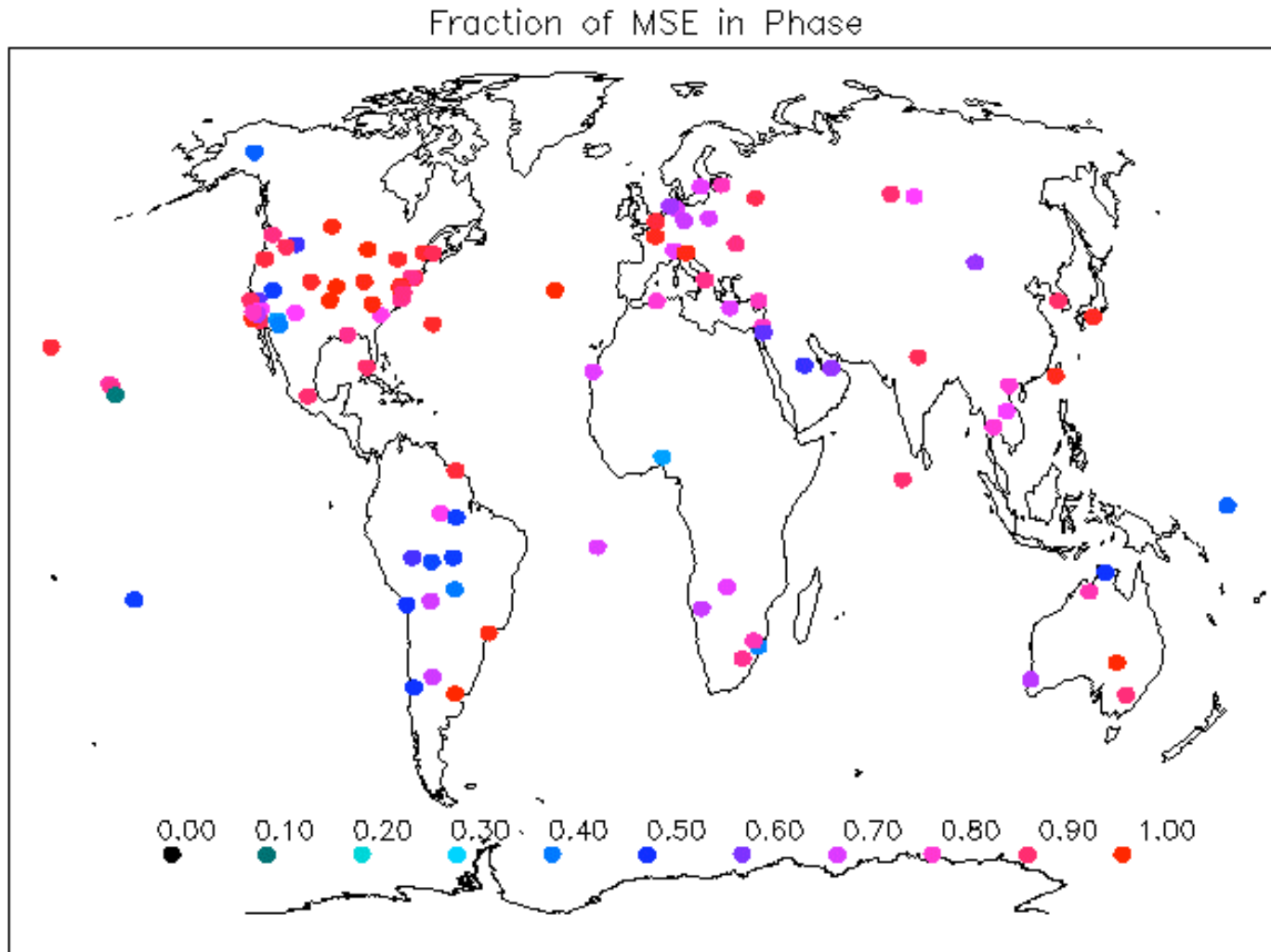
Fractional Contribution of Errors in AOD Variance





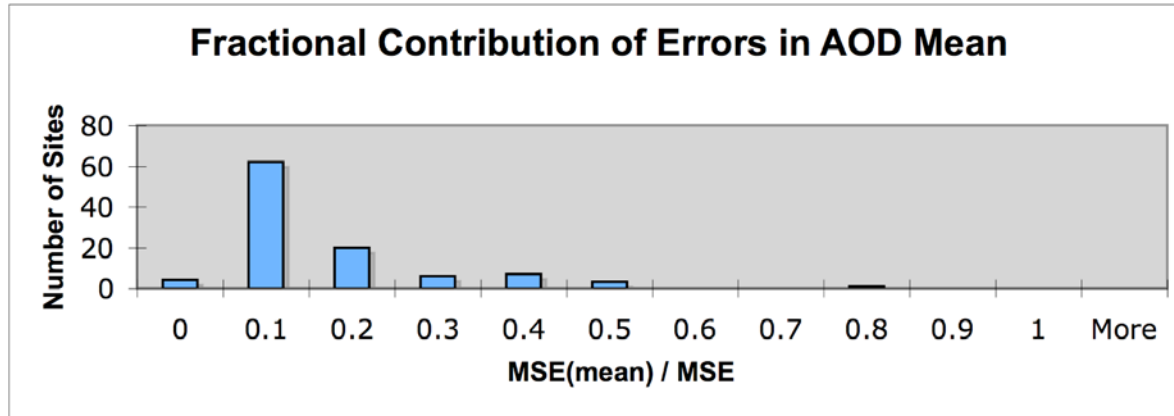
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Fractional Contributions of Errors in AOD Correlation

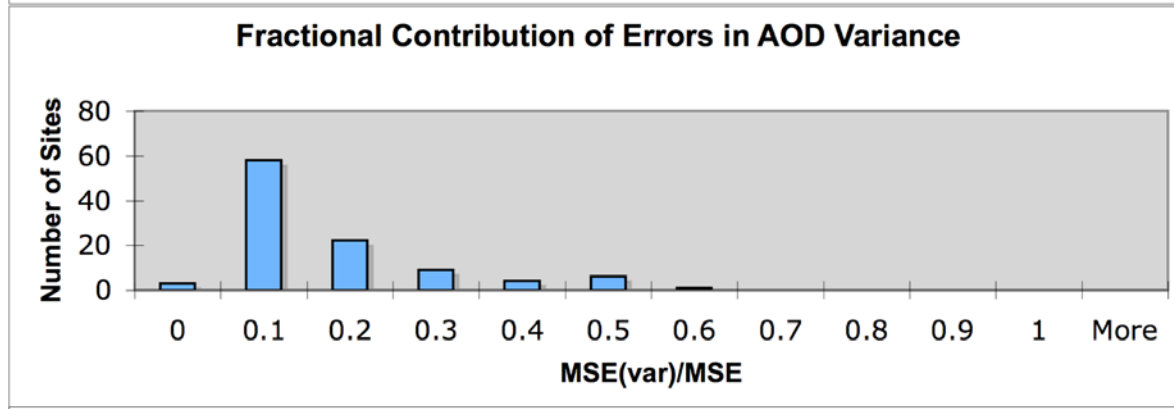




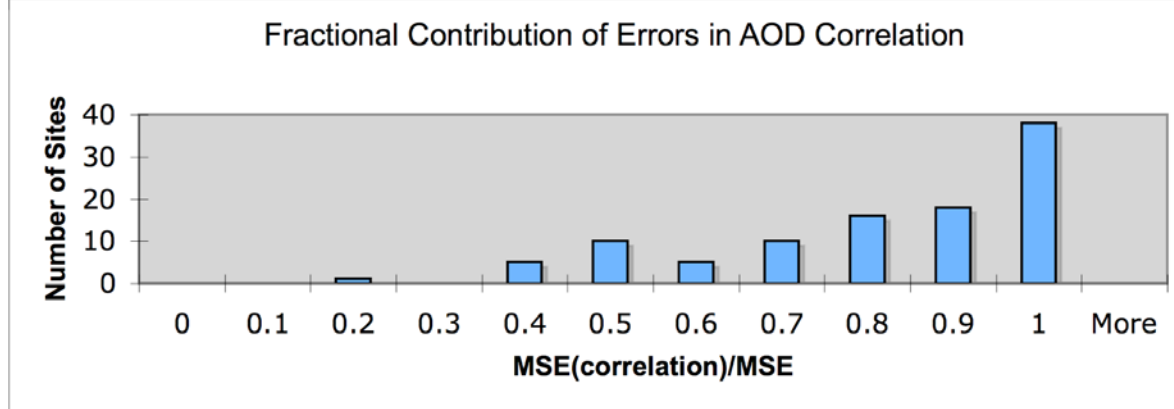
Contributions to Mean Square Error



- Median Ratio = 0.07
- Minimum Ratio = 0.00
- Maximum Ratio = 0.79

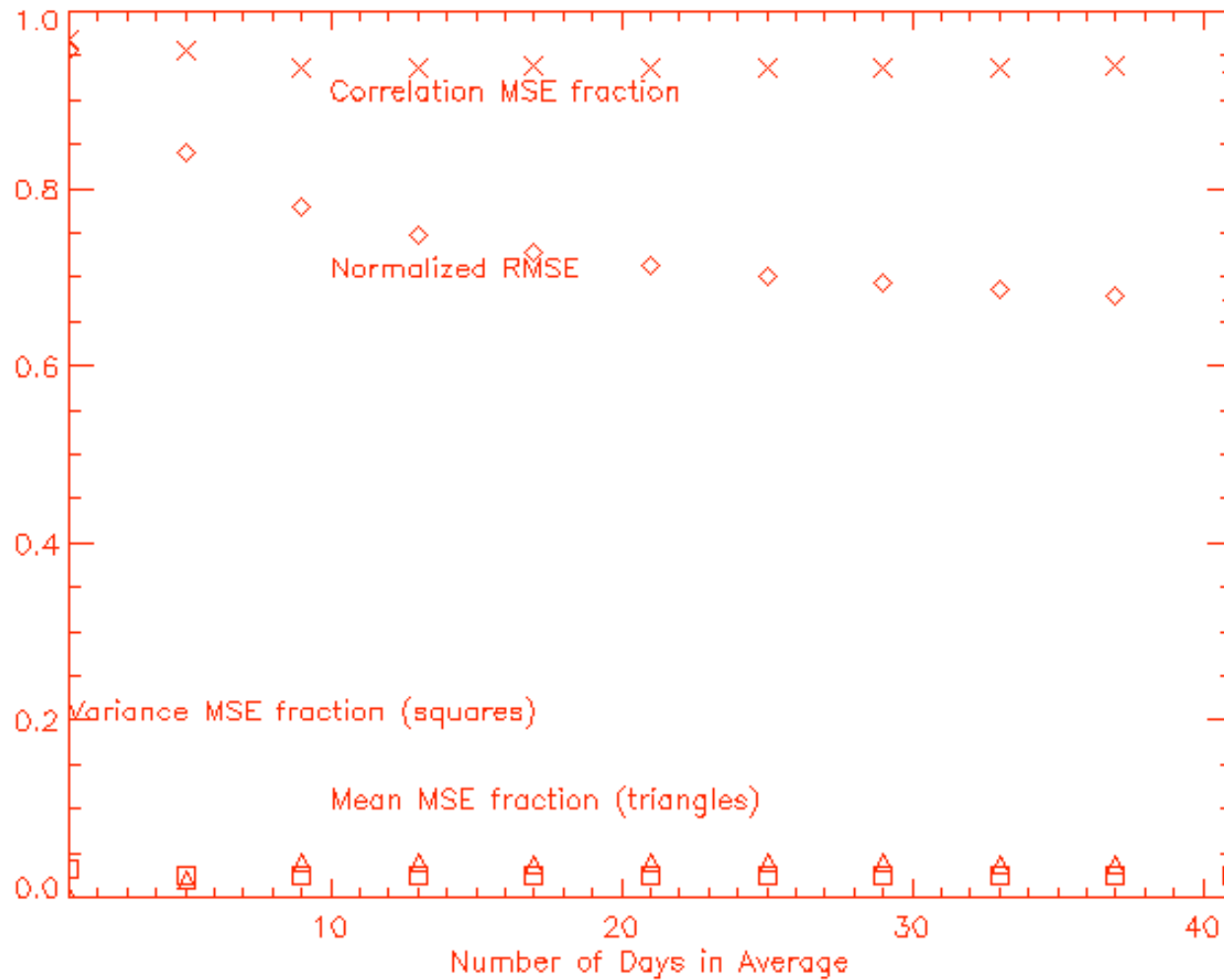


- Median Ratio = 0.07
- Minimum Ratio = 0.00
- Maximum Ratio = 0.51



- Median Ratio = 0.83
- Minimum Ratio = 0.11
- Maximum Ratio = 0.99

Fractions vs. Averaging Time Period

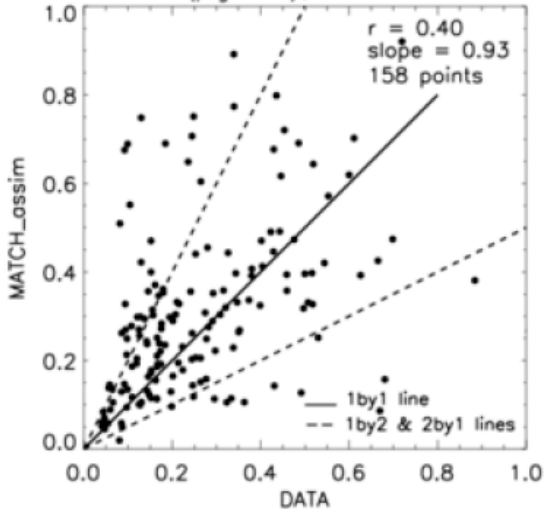




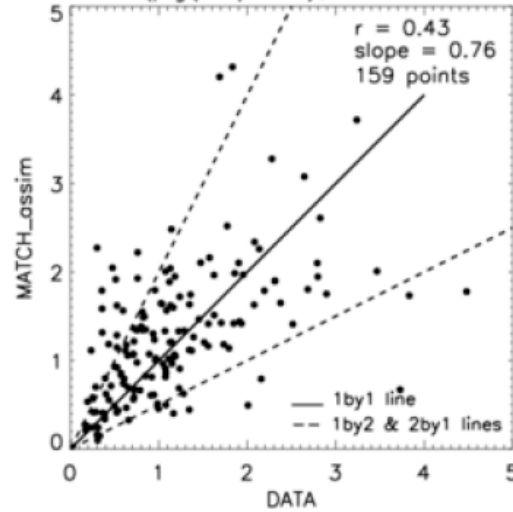
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Surface Concentration by Species: N. America

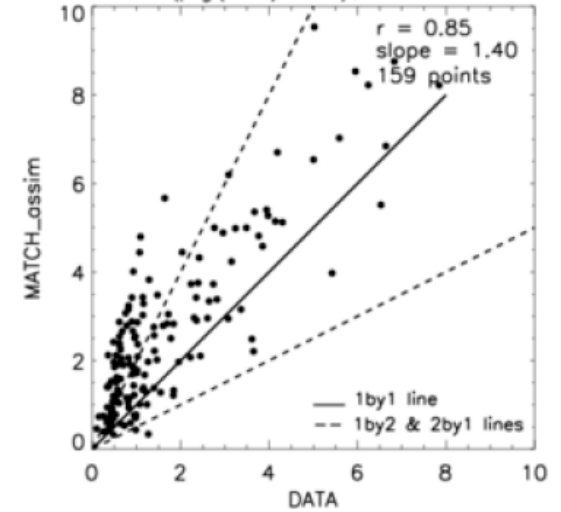
CONC3D_BC ($\mu\text{g}\cdot\text{m}^{-3}$), North America 2000



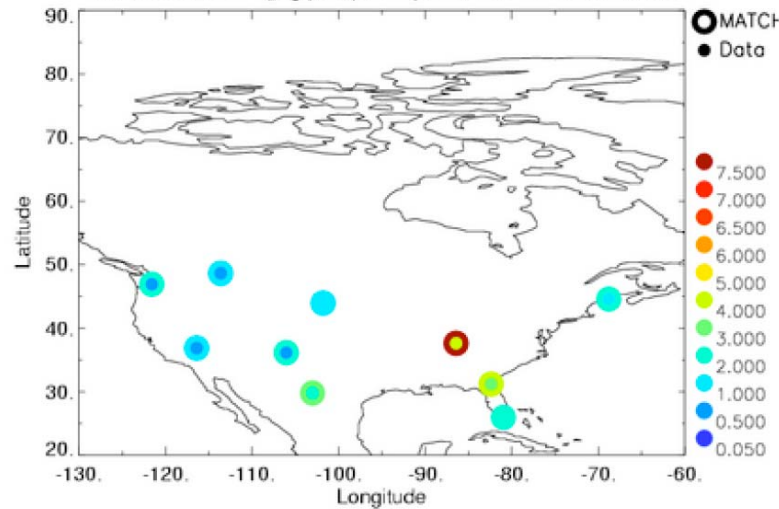
CONC3D_OC ($\mu\text{g}(\text{OC})\cdot\text{m}^{-3}$), North America 2000



CONC3D_SO4 ($\mu\text{g}(\text{SO}_4)\cdot\text{m}^{-3}$), North America 2000



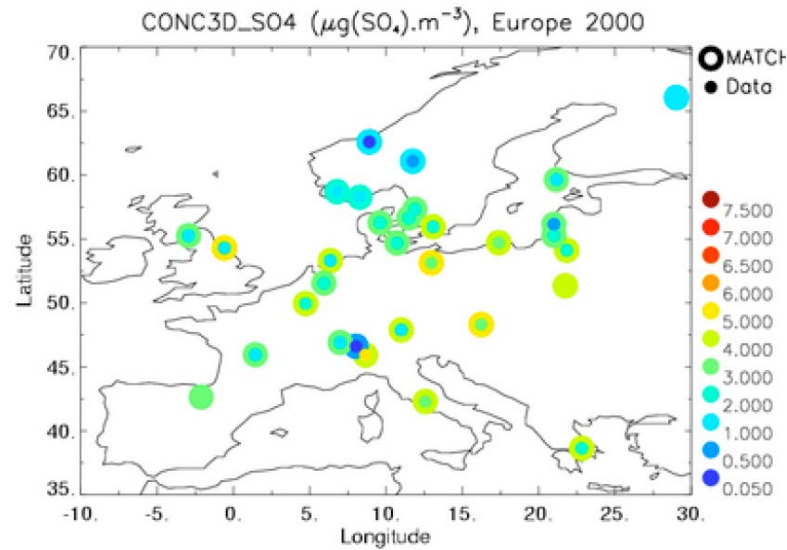
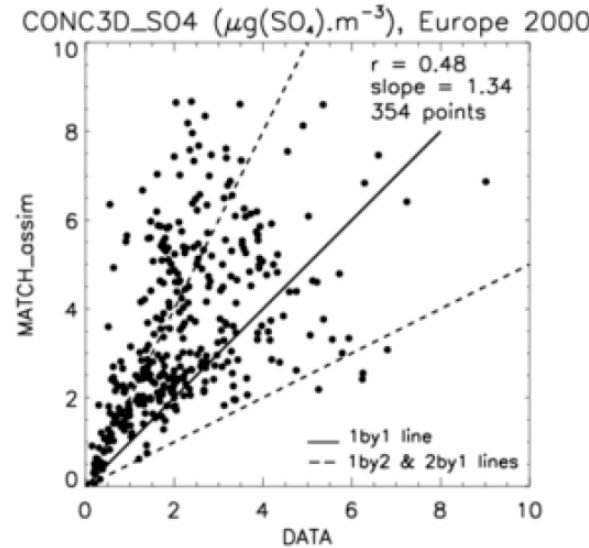
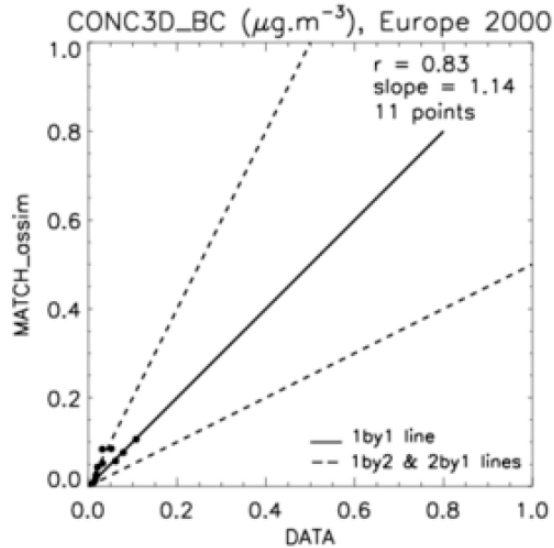
SCONCD_SO4 ($\mu\text{g}(\text{SO}_4)\cdot\text{m}^{-3}$), North America 2000





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Surface Concentration by Species: Europe





Conclusions

- In a global mean sense, MATCH and Aeronet AODs are in reasonable agreement:
 - *Model* = 0.217 ± 0.24
 - *Aeronet* = 0.218 ± 0.20
- However, the RMSEs on daily timescales are large:
 - *Correlation* = 0.57
 - *Global mean RMSE* = 0.17 ± 0.09
- These errors are dominated by correlation/phase errors:
 - *MSE(mean)/MSE* = 0.07
 - *MSE(var)/MSE* = 0.07
 - *MSE(cov)/MSE* = 0.83
- Puzzle: Why don't phase errors decrease with averaging interval?
 - *Lifetime of tropospheric aerosols is ~ 1 week.*
 - *Transport timescales in upper troposphere is ~ 1 week.*