

Aerosol transport analysis across global models

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HTAP team and modellers
AEROCOM modellers

Acknowledgement: LSCE, CEA, CNRS, EU, CNES, NASA



**Task Force on Hemispheric
Transport of Air Pollution**

AC&C - HTAP Workshop, Washington June, 2008

Status
of HTAP aerosol paper?

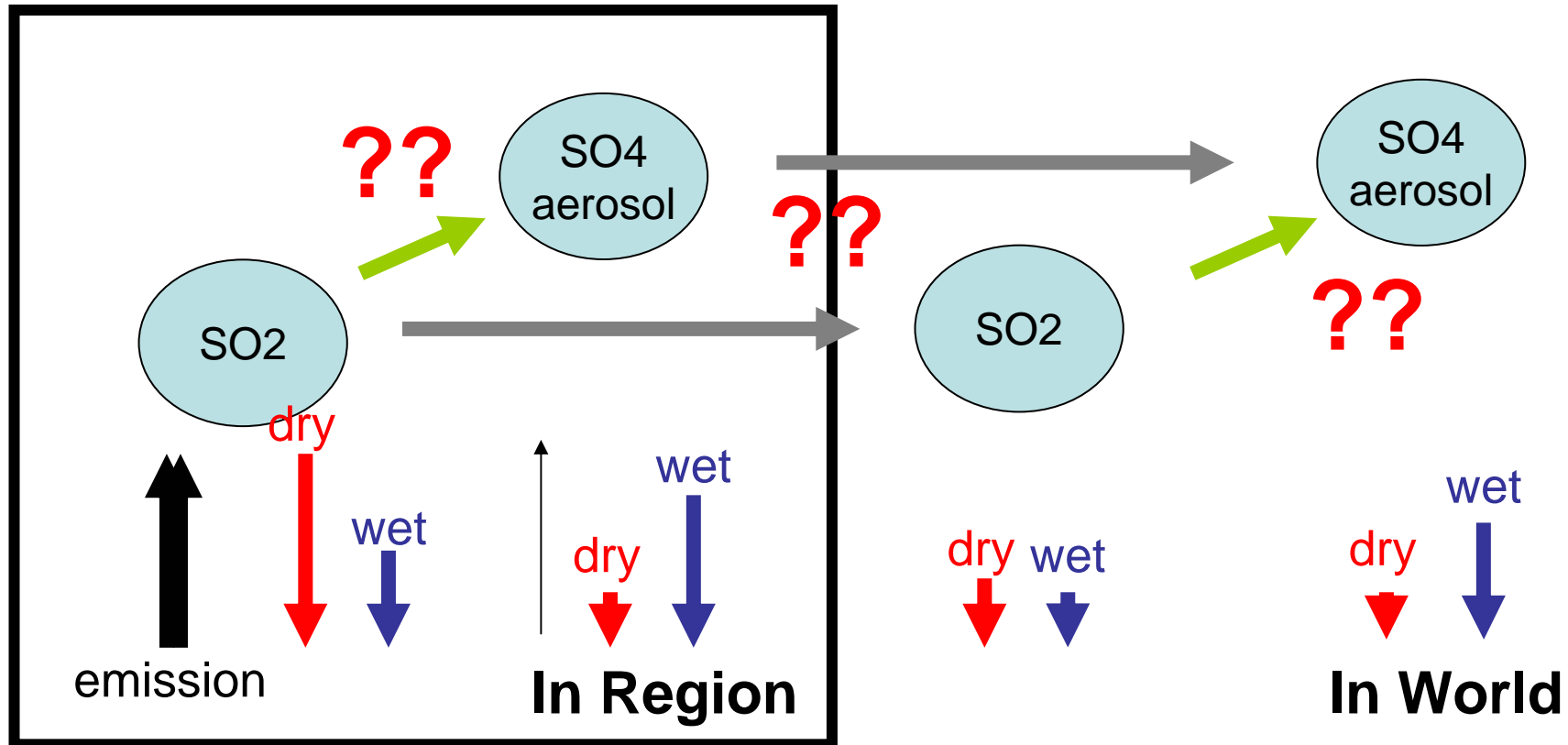
--- Slightly DELAYED ---



HTAP Aerosol simulations from 17 models

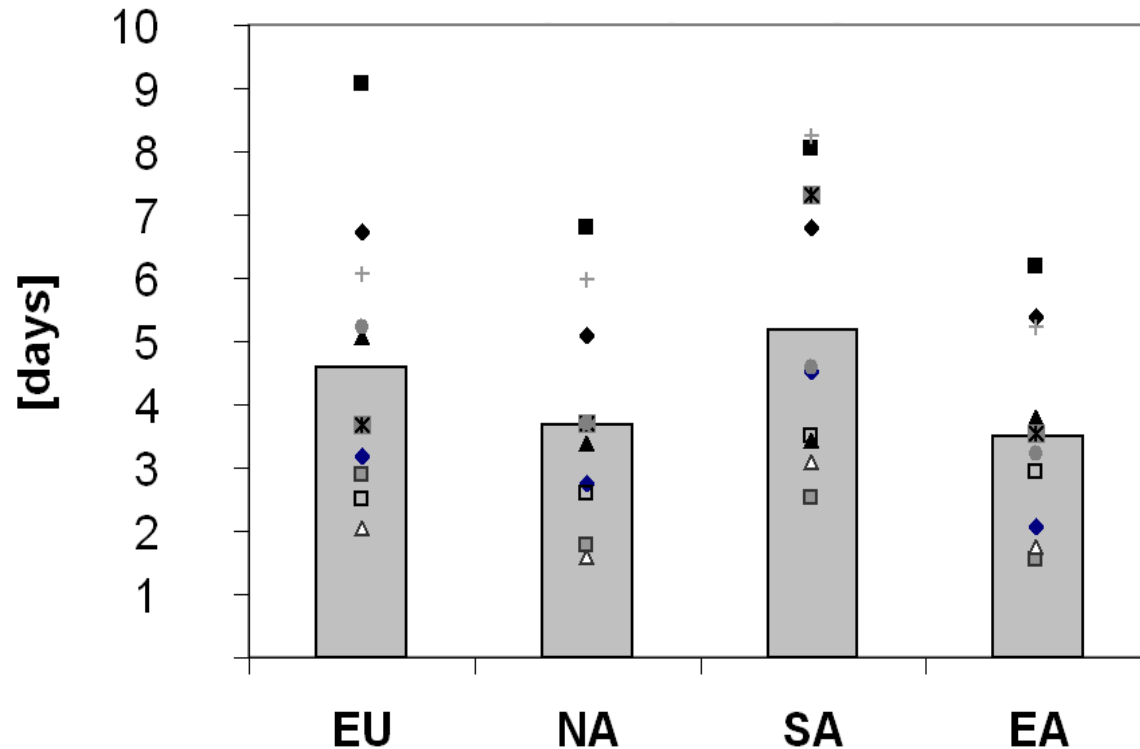
| Model/version | Institute |
|----------------------------|---|
| CAMCHEM-3311m13 | National Center for Atmospheric Research, Boulder, CO, USA. |
| ECHAM5-HAMMOZ | LMCA, EPFL, Lausanne, Switzerland |
| EMEP-rv26 | Norwegian Meteorological Institute Oslo, Norway. |
| GEMAQ-EC | Environment Canada, Canada |
| GEOSChem-v07 | Harvard University, Cambridge, USA |
| GISS-PUCCINI-modelA | NASA GISS Goddard Institute for Space Studies, New York, USA |
| GISS-PUCCINI-modelE | NASA GISS Goddard Institute for Space Studies, New York, USA. |
| GMI-v02a | NASA GSFC (Goddard Space Flight Center), Greenbelt, MD, USA. |
| GOCART | NASA, USA |
| INCA-v2MS | IPSL, Paris, France |
| LLNL-IMPACT-T5a | Lawrence Livermore National Laboratory, Livermore, CA, USA. |
| MOZARTGFDL-v2 | Geophysical Fluid Dynamics Laboratory, Princeton, NJ, USA |
| OsloCTM2 | Oslo University, Norway. |
| SPRINTARS-v356 | RIAM, Kyushu University, Japan |
| STOCHEM-v02 | Hadley Centre, Met Office, UK |
| TM5-JRC-cy2-ipcc-v1 | European Commission, Joint Research Center, Italy |
| ULAQ | University of L'Aquila, Italy |

Average Sulphur Budget derived from HTAP model simulations SR1 + SR6



| | | | | | | | | |
|---------------------------------------|-----------|-----------|----------|-----------|----------|----------|----------|-----------|
| 100 | 35 | 10 | 3 | 25 | 4 | 2 | 1 | 18 |
| Sulphur Flux contributions [%] | | | | | | | | |

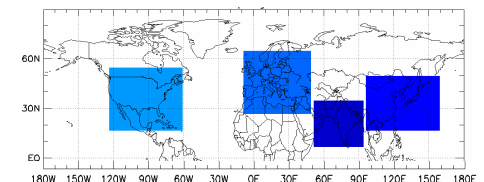
Regional Residence time τ of anthropogenic sulfur



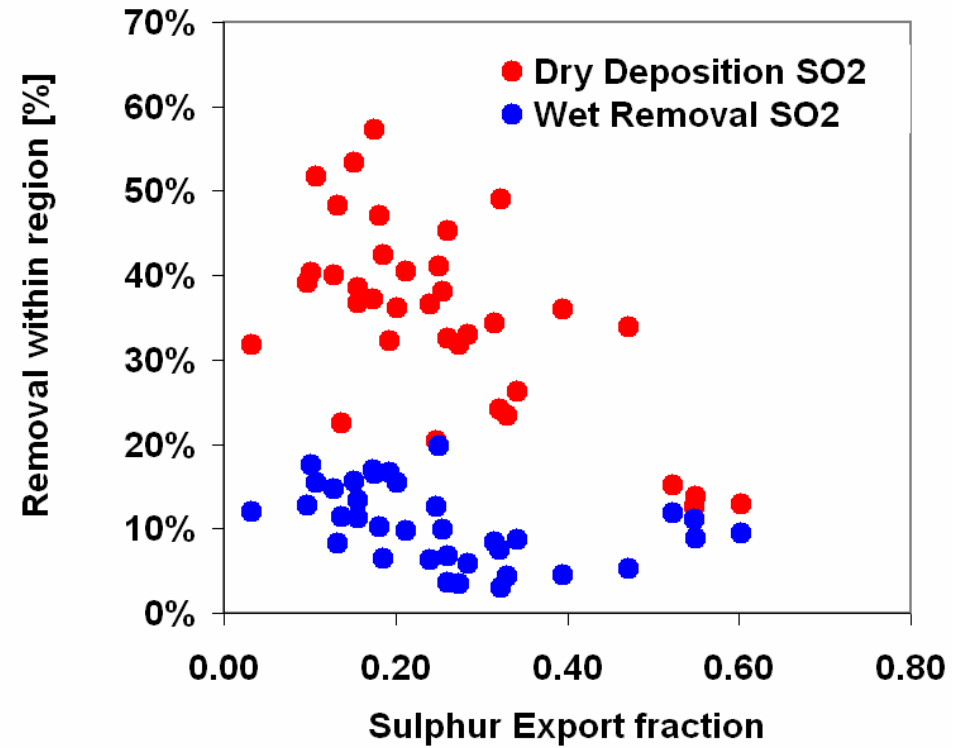
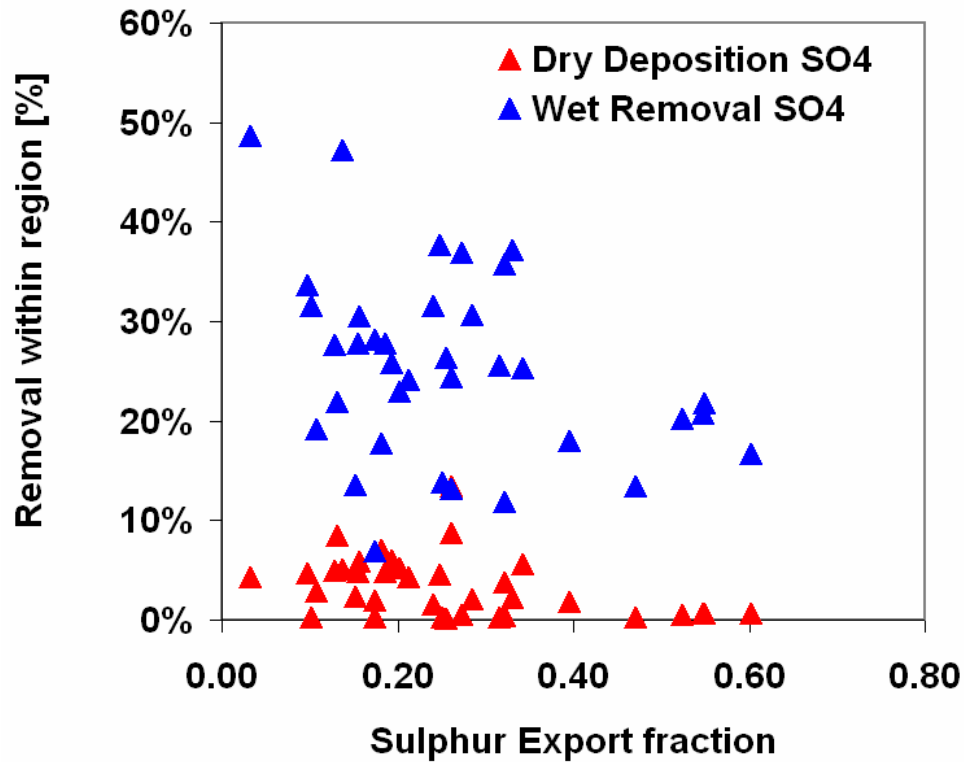
Residence time τ
= Δ load / Δ deposition flux

from Response
to 20% perturbation
of anthropogenic emissions
in HTAP simulations

- Large differences in τ (factor 4)
- Role of different processes??

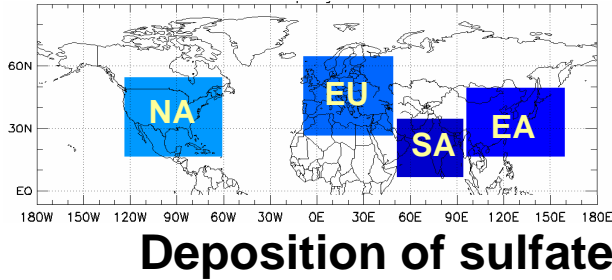


Split of removal within source region according to process --- against export

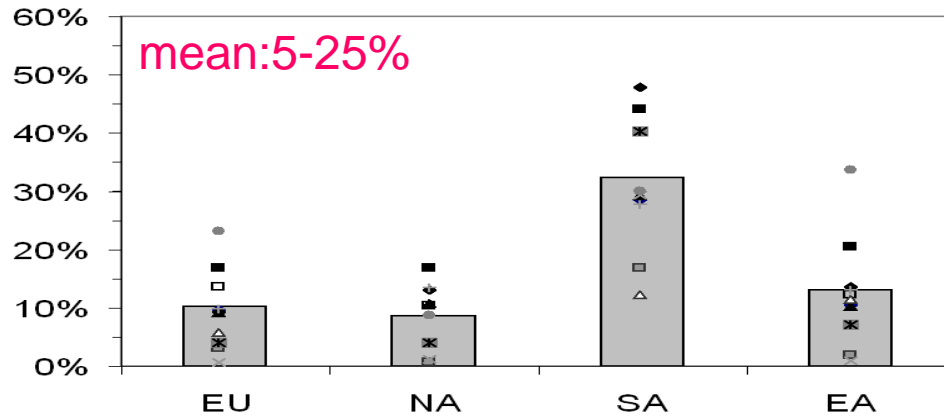


All regions and models

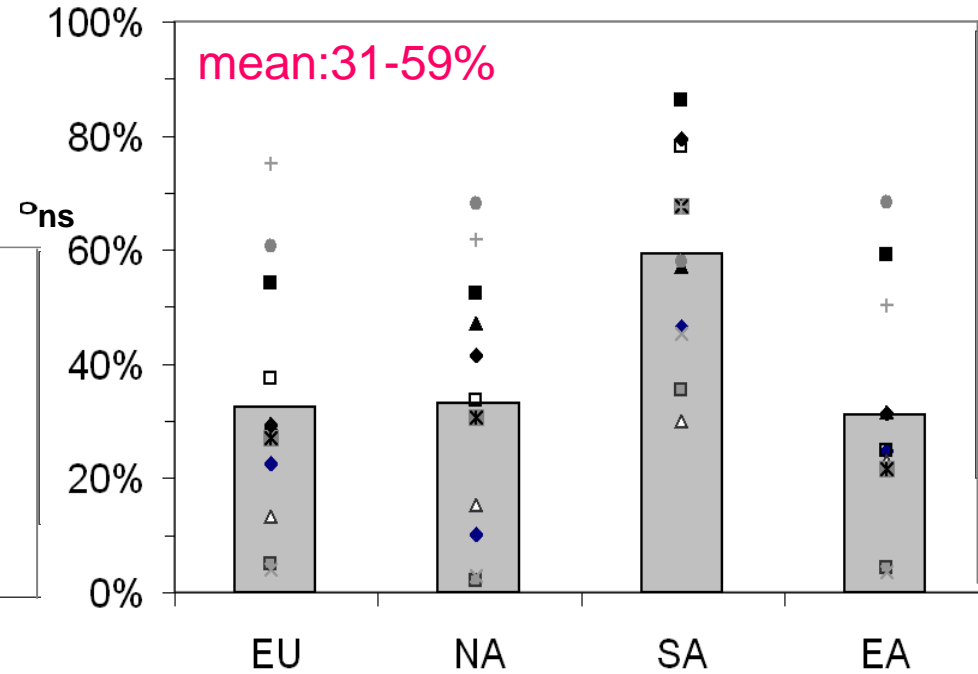
Import into target regions as compared to domestic contribution



Deposition of sulfate



Column load of sulfate



Can we evaluate the long range transport simulations?

Credibility of model results?

HTAP Model diagnostics

SR1 with sulphur

CAMCHEM3311M13
CAMCHEM3514
ECHAM5HAMMOZV21
EMEPRV26
GEOSCHEMV07
GISSPUCCINIMODELE
GMIV02A
GOCARTV4P2
HADGEM2AV01
INCAV2MS
LLNLIMPACTT5A
MOZARTGFDLV2
SPRINTARSV356
STOCHADAM3V01
STOCHEMV02
TM5JRCCY2IPCCV1

ULAQV02
CHASERV03
GISSPUCCINIMODELA

SR1+SR6 with AOD

CAMCHEM3311M13
CAMCHEM3514
ECHAM5HAMMOZV21
GEMAQEC
GMIV02A
GOCARTV4P2
HADGEM2AV01
INCA
INCA
LLNLIMPACTT5A
SPRINTARSV356
ULAQV02

Model Evaluation Methodology applied

Collection of observational data on AeroCom datasever
Eg EMEP sulfate deposition 2001 / Aeronet AOD 2000+2001

Daily obs and model data averaged
to corresponding monthly means

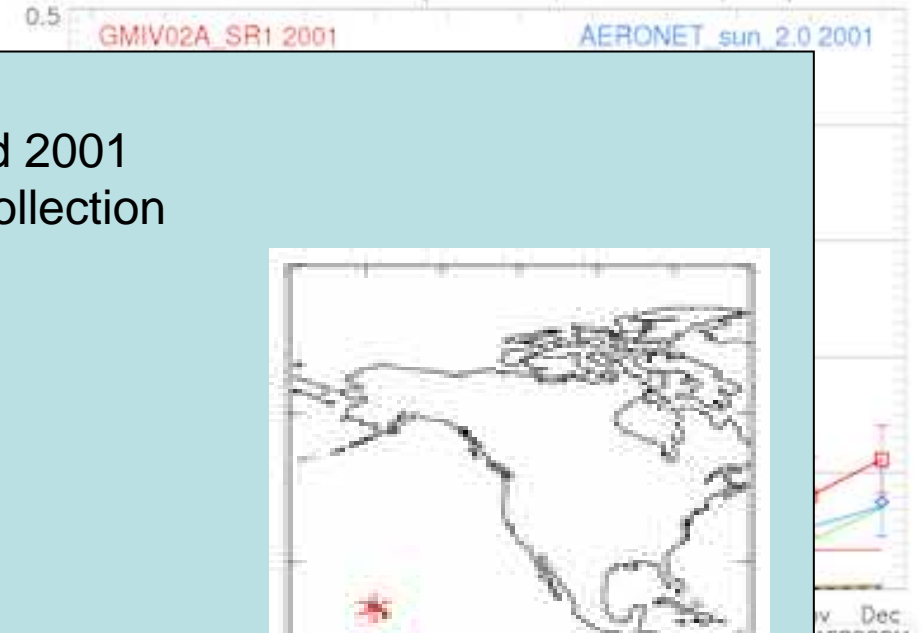
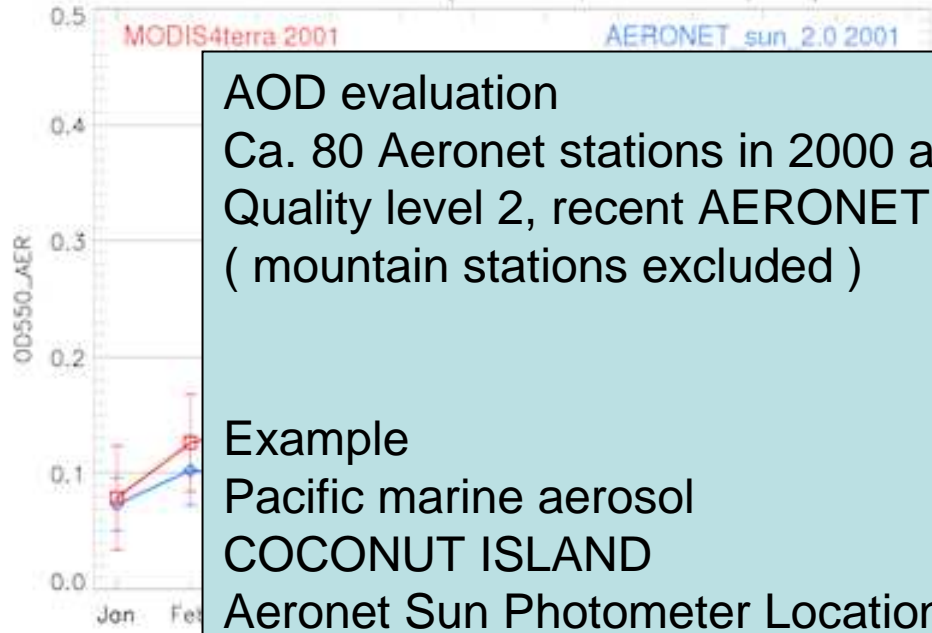
Eventual filtering per region, station subsets

Time series , maps, score tables, scatterplots, Taylor plots

Image catalogues stored behind AeroCom web interface

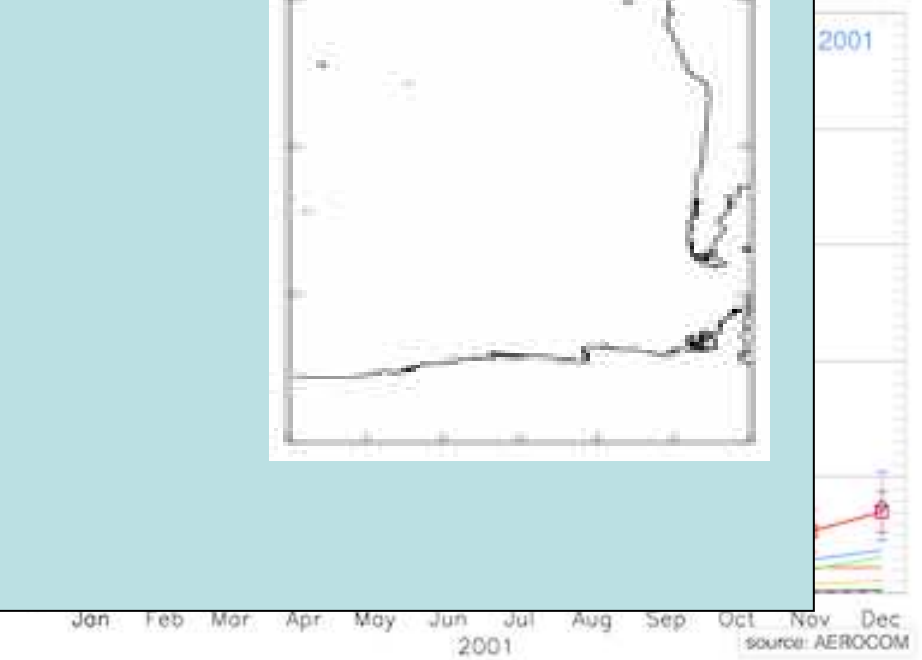
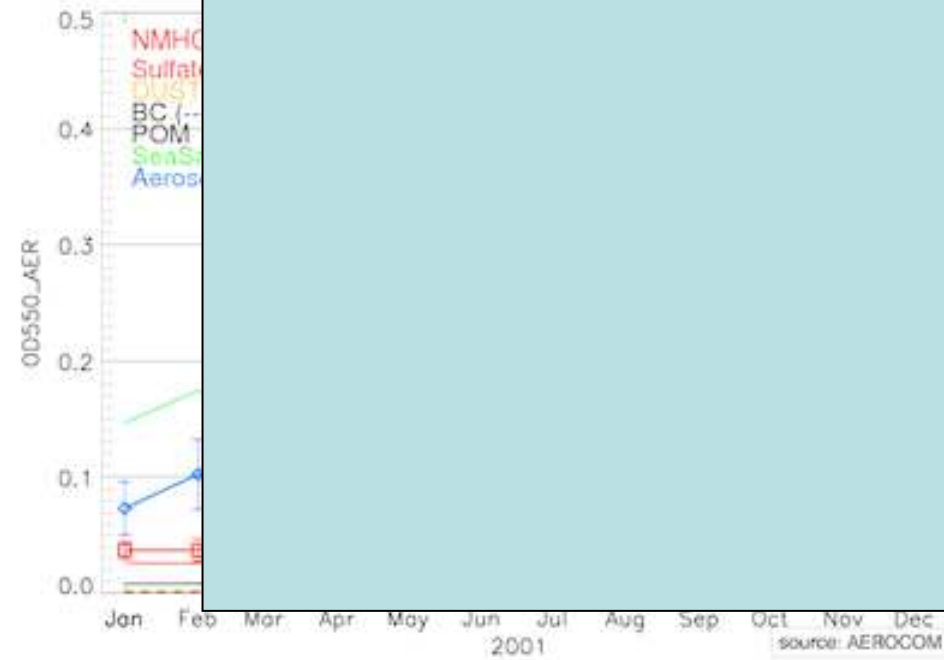
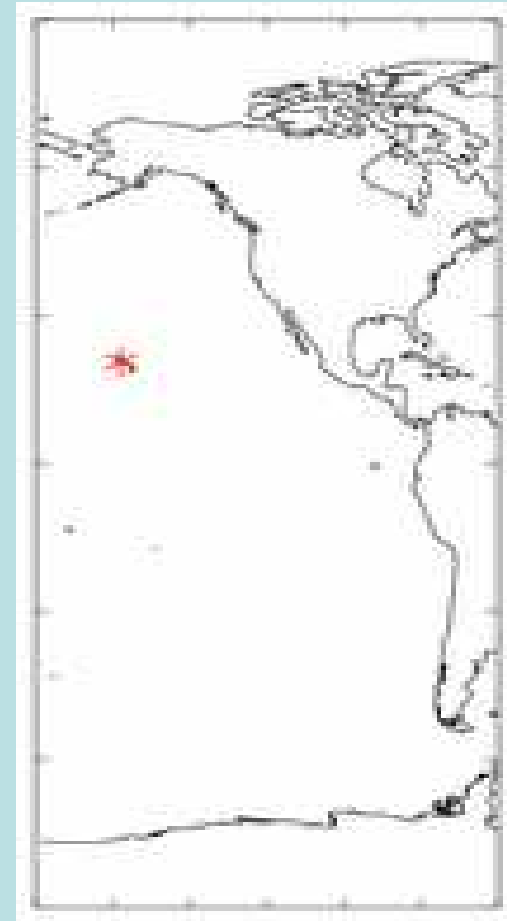
CoconutIsland (21.43N ; 157.79W ; 0m)

CoconutIsland (21.43N ; 157.79W ; 0m)

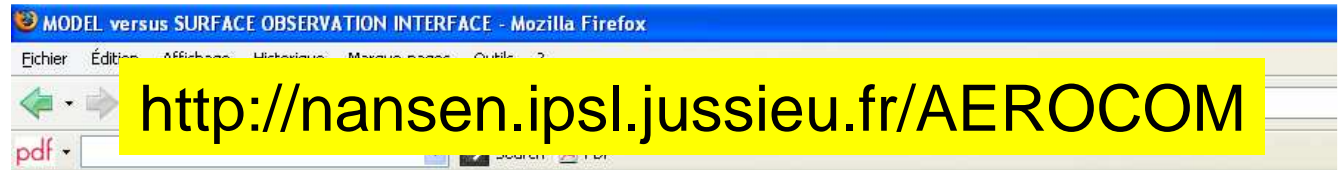


AOD evaluation
 Ca. 80 Aeronet stations in 2000 and 2001
 Quality level 2, recent AERONET collection
 (mountain stations excluded)

Example
 Pacific marine aerosol
 COCONUT ISLAND
 Aeronet Sun Photometer Location



Introduction into AeroCom Zoo



SURFOBS Interface!!

Project Selection
HTAP (S models)
HTAP (AOD+S)

Type of diagnostic

Score tables

Filter/Region/Station

Subset stations

- AEROCOM PRELIMINARY RESULTS - MODEL versus SURFACE OBSERVATIONS

UPDATE - Synchron Scroll - # of frames -> 4 Images - links -> presently on dataipsl surfobs interface

Subsetting to Model Group / Project : HTAP-S - Subsetting Observation type : ALL DATA

| Graph | Model/Data | Species | Parameter |
|----------|--------------|----------|-----------|
| SCORE | EMEPRV26_SR1 | SO4 | WET |
| AllSites | an2001 | mALLYEAR | |

EMEPRV26_SR1 2001 EMEP 2001
only Stations below 400m
of valid observations: 780
OBS mean 0.436
MODEL mean 0.842
Spearman Rank Correlation 0.423
Pearson Correlation Coefficient 0.348
Spatial yearly mean Corr Coeff 0.688
Seasonal Anomaly Corr Coeff 0.894
RMS error 0.944
Slope fit forced through zero 0.492
Regression coefficient, Slope 0.448
Regression constant, Offset: 0.059
STDDEV(Model)/STDDEV(Data): 0.776
Score (mean relative bias) 145%
Taylor Score 0.666

Barcarrola (38.48N ; 6.92W ; 393m)

image created 07.06.2008

| Graph | Model/Data | Species | Parameter |
|------------|----------------|----------|-----------|
| SERIES | GOCARTV4P2_SR1 | SO4 | WET |
| Barcarrola | an2001 | mALLYEAR | |

Barcarrola (38.48N ; 6.92W ; 393m)

image created 07.06.2008

| Graph | Model/Data | Species | Parameter |
|------------|--------------------|----------|-----------|
| SERIES | TMSJRCY2IPCCV1_SR1 | SO4 | WET |
| Barcarrola | an2001 | mALLYEAR | |

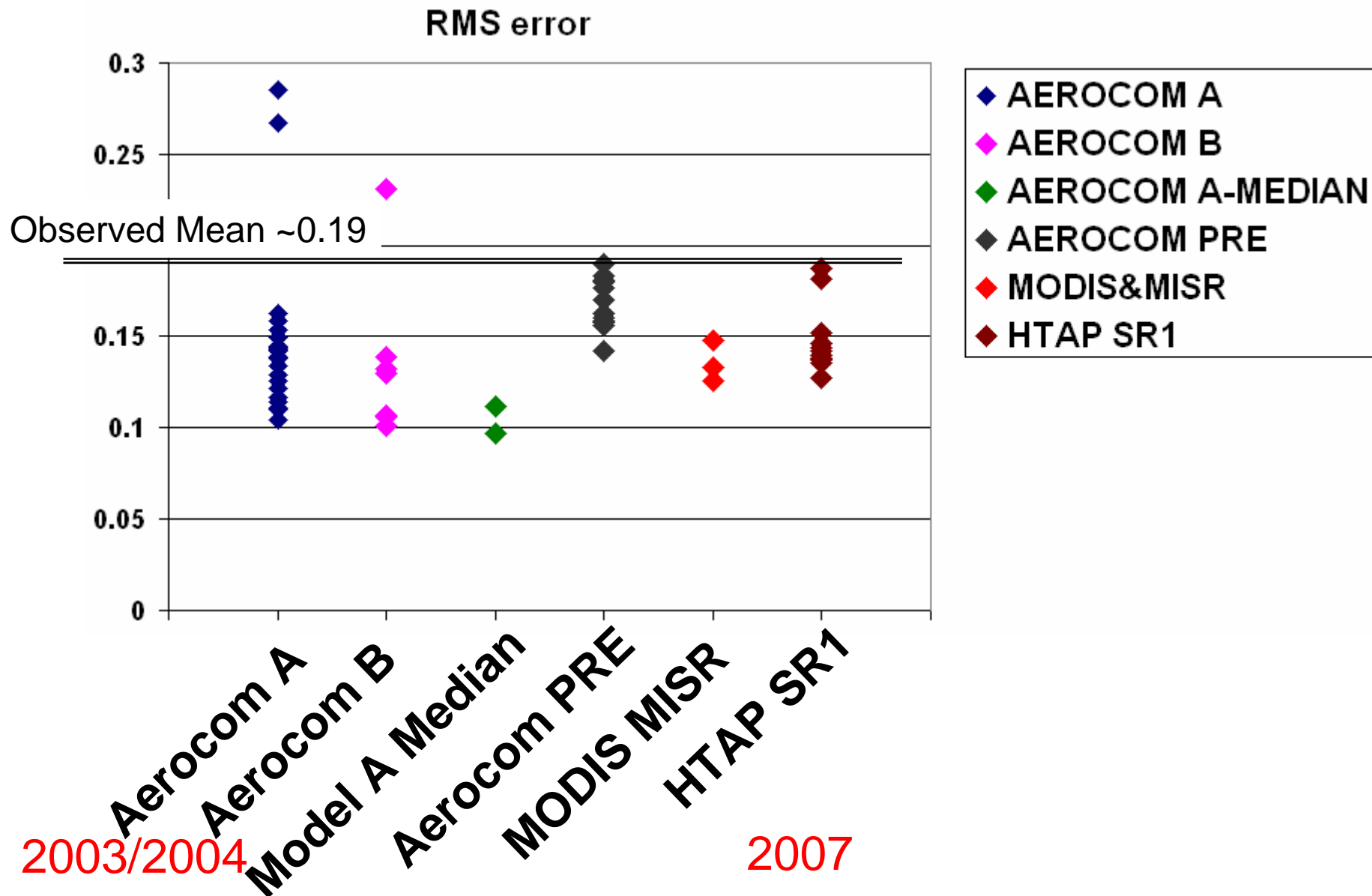
Barcarrola (38.48N ; 6.92W ; 393m)

image created 07.06.2008

HTAP results public???

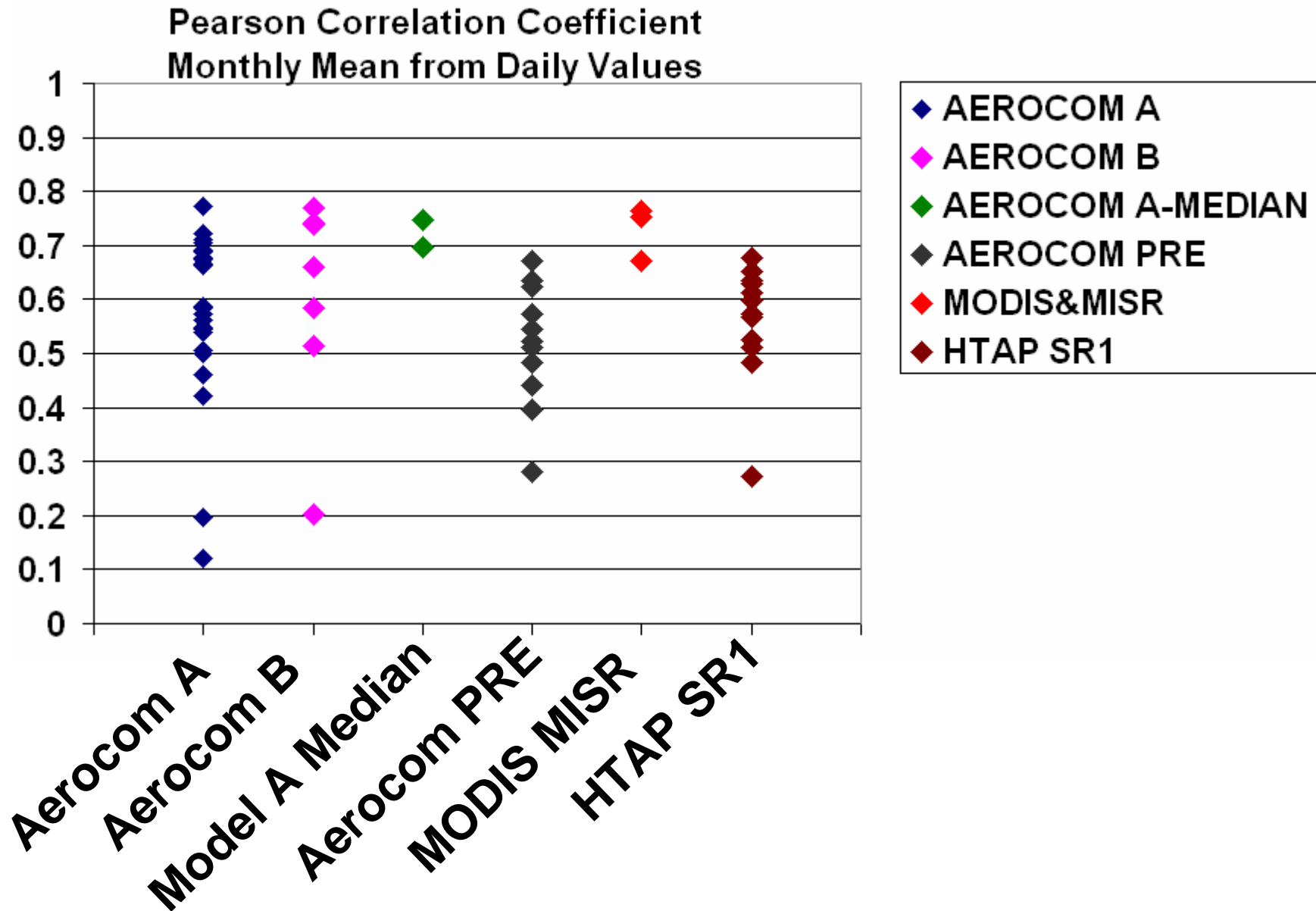
Aerosol Optical Depth

Models compared to Aeronet (2001 # 721 / 2000 # 606)



Aerosol Optical Depth

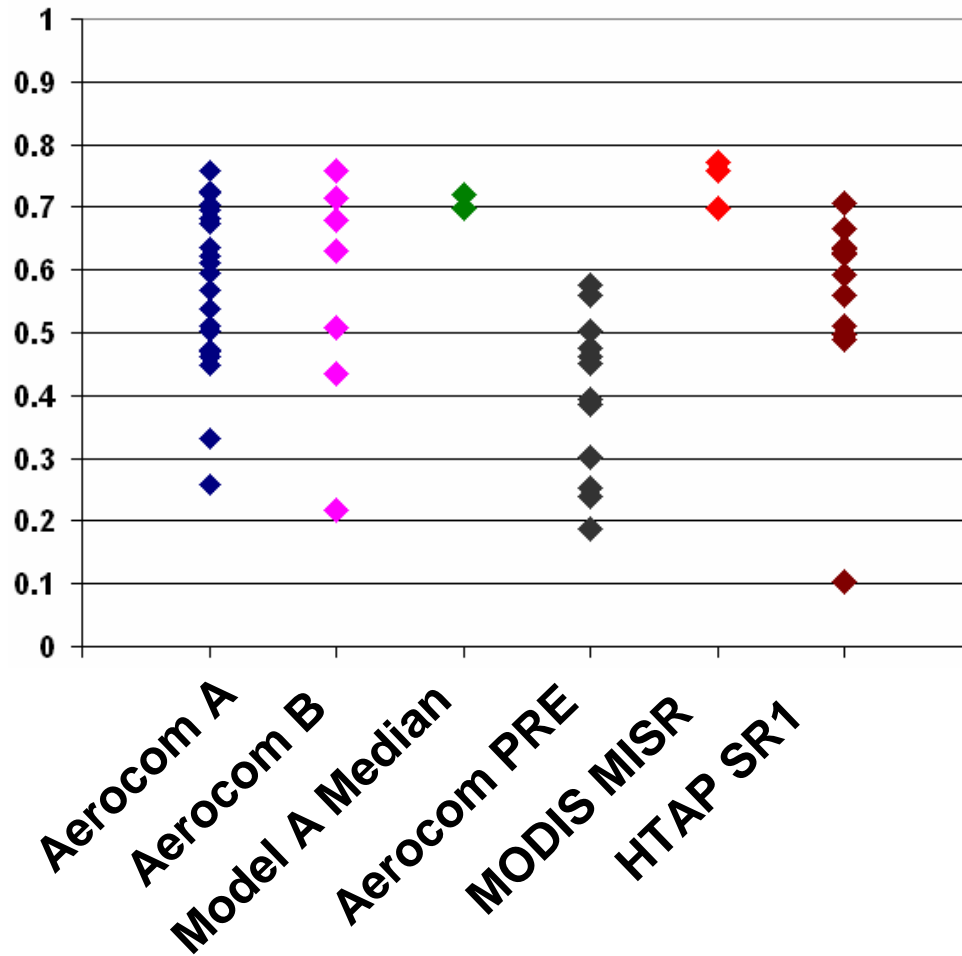
Models compared to Aeronet (2001 # 721 / 2000 # 606)



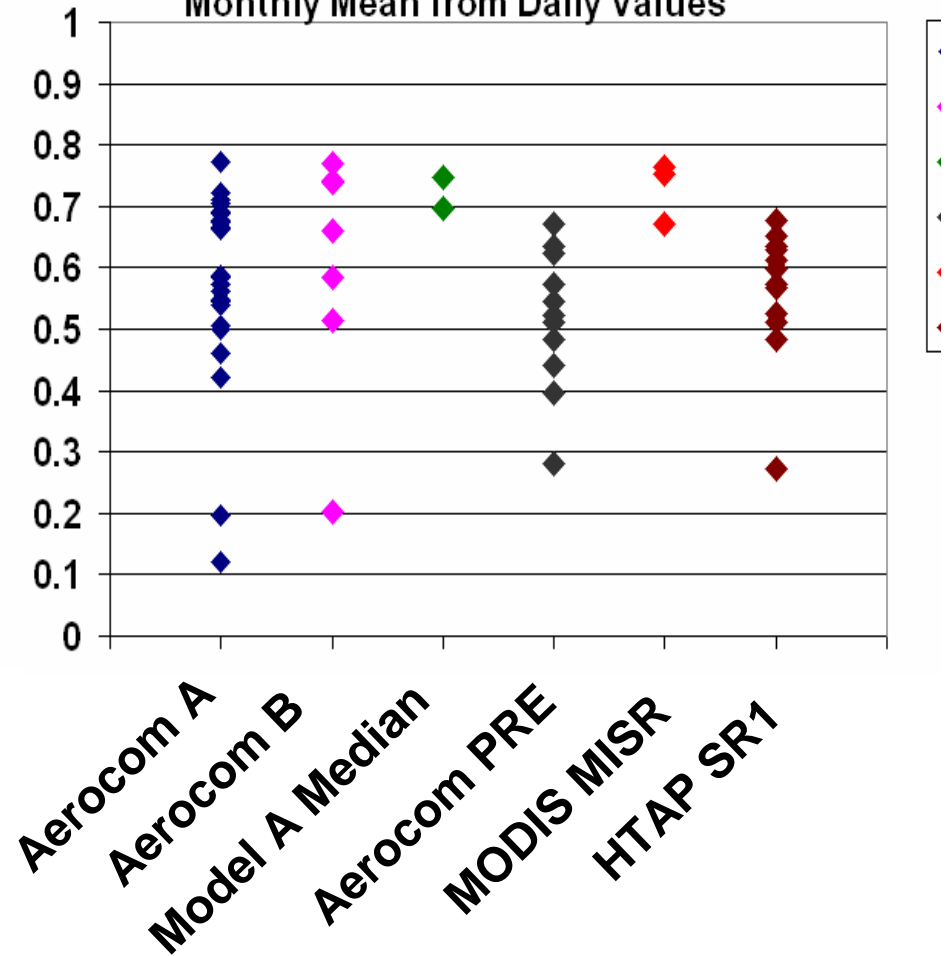
Models compared to Aeronet

Rank correlation vs Pearson ??

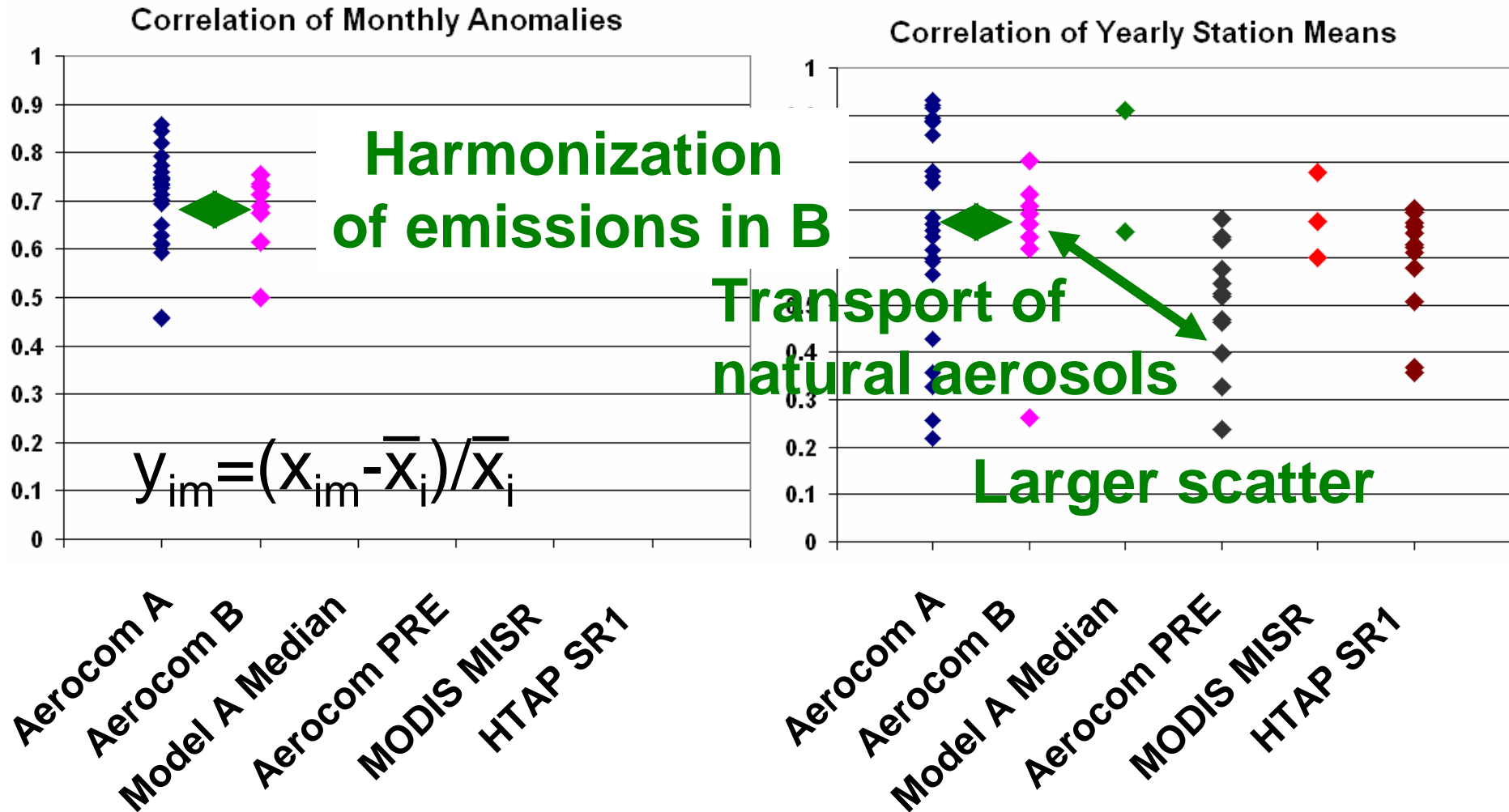
Rank Correlation of Monthly Station Means



Pearson Correlation Coefficient
Monthly Mean from Daily Values



Aerosol Optical Depth Decomposition of Correlation



Transport & Removal Events
Emission Seasonality

Emission spatial distribution
Average transport

Mean of Scores across models

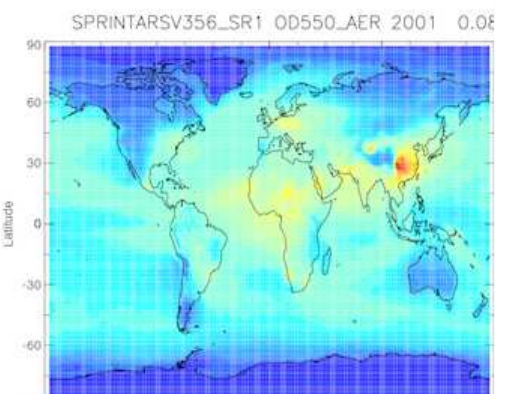
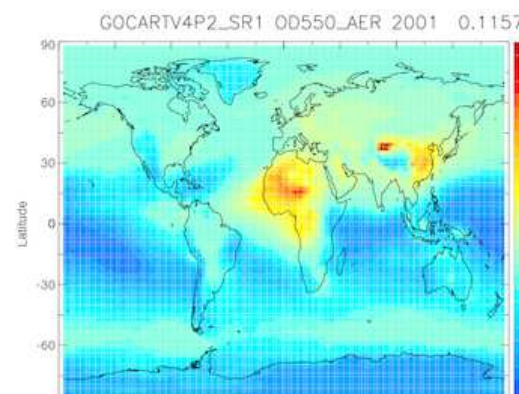
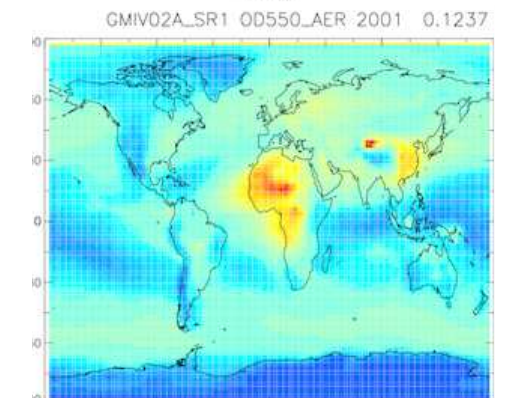
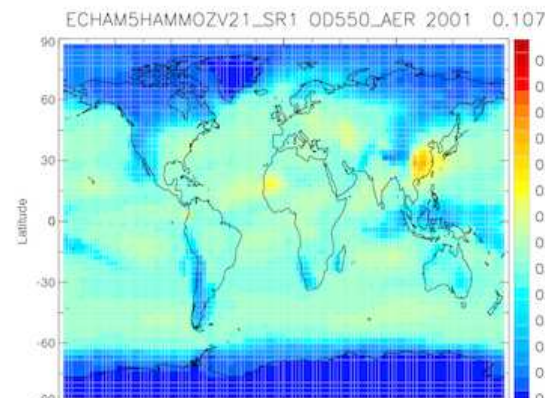
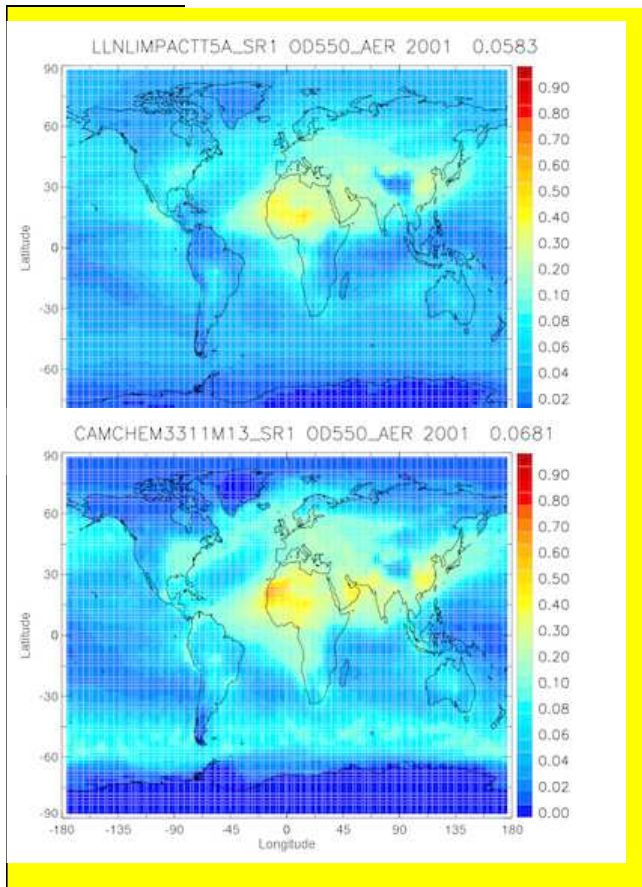
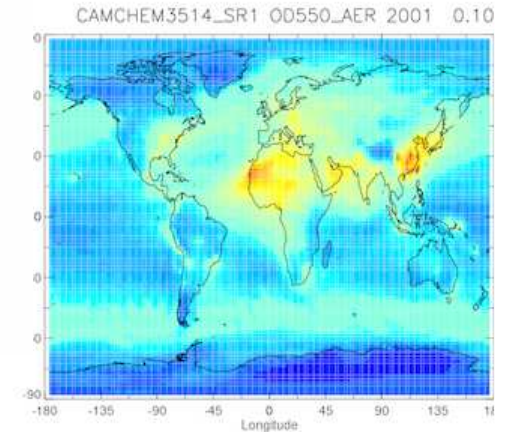
Models compared to Aeronet AOD

| | 80 stations 2000+2001 Aerocom A | 36 stations 1/2 stations 2000 Aerocom A | 2000 Aerocom B | 2000 Aerocom A MEDIAN | 1750vs2000 Aerocom PRE | 2000+2001 ODIS&MISF SAT | 2001 HTAP SR1 |
|--------------------------------------|--|---|----------------------|-----------------------------|------------------------------|-------------------------------|---------------------|
| # of valid observations: | 653 | 286 | 593 | 606 | 669 | 629 | 721 |
| MODEL/SAT mean | 0.190 | 0.172 | 0.157 | 0.168 | 0.090 | 0.261 | 0.157 |
| OBS mean | 0.192 | 0.179 | 0.188 | 0.188 | 0.193 | 0.199 | 0.197 |
| RMS error | 0.145 | 0.127 | 0.135 | 0.097 | 0.168 | 0.136 | 0.148 |
| Mean relative bias per month | 49% | 48% | 48% | 33% | 62% | 48% | 49% |
| STDDEV(Model)/STDDEV(Aeronet): | 1.04 | 1.08 | 0.91 | 0.77 | 0.69 | 1.08 | 0.84 |
| Correlation of Monthly station means | 0.57 | 0.57 | 0.62 | 0.55 | 0.51 | 0.73 | 0.56 |
| Spearman Rank Correlation monthly | 0.57 | 0.60 | 0.58 | 0.60 | 0.40 | 0.74 | 0.55 |
| Correlation of Yearly station means | 0.67 | 0.58 | 0.64 | 0.61 | 0.50 | 0.68 | 0.59 |
| Corrleation of monthly anomalies | 0.70 | 0.74 | 0.68 | 0.67 | 0.67 | 0.75 | 0.70 |
| Taylor Score | 0.80 | 0.78 | 0.79 | 0.86 | 0.66 | 0.90 | 0.76 |

Natural Aerosols | Versus Total AOD
Robustness of scores? Of Median Model
 Minimum Quality for anthropogenic aerosol simulation

What if we remove North American derived AOD?? Does correlation over Europe deteriorate??

| | Global | | European Stations Only | |
|-----------------|--------|---|------------------------|--------------------|
| | SR1 | | SR6NA | |
| CAMCHEM3311M13 | 0.63 | > | 0.62 | 0.38 = 0.38 |
| CAMCHEM3514 | 0.51 | > | 0.49 | 0.44 > 0.43 |
| ECHAM5HAMMOZV21 | 0.48 | > | 0.43 | 0.51 > 0.48 |
| GMIV02A | 0.57 | < | 0.59 | 0.58 > 0.56 |
| GOCARTV4P2 | 0.60 | = | 0.60 | 0.56 > 0.53 |
| LLNLIMPACTT5A | 0.64 | > | 0.61 | 0.63 = 0.63 |
| SPRINTARSV356 | 0.65 | > | 0.64 | 0.60 < 0.63 |



Wet deposition of Sulfate Analysis

- AEROCOM PRELIMINARY RESULTS - MODEL versus SURFACE OBSERVATIONS

UPDATE - Synchron Scroll - # of frames -> 4 Images - links -> presently on dataipl surfobs interface

Subsetting to Model Group / Project : -> HTAP-S - Subsetting Observation type: -> ALL DATA

Graph Model/Data Species Parameter
 SCORE EMEPRV26_SR1 SO4 WET
 AllSites an2001 mALLYEAR

```

EMEPRV26_SR1 2001 EMEP 2001
only Stations below 400m
# of valid observations: 780
OBS mean 0.436
MODEL mean 0.842
Spearman Rank Correlation 0.423
Pearson Correlation Coefficient 0.348
Spatial yearly mean Corr Coeff 0.688
Seasonal Anomaly Corr Coeff 0.894
RMS error 0.944
Slope fit forced through zero 0.492
Regression coefficient, Slope 0.448
Regression Constant, Offset: 0.059
STDDEV(Model)/STDDEV(Data): 0.776
Score (mean relative bias) 145%
Taylor Score 0.666
  
```

image created 07.06.2008

Graph Model/Data Species Parameter
 SERIES EMEPRV26_SR1 SO4 WET
 Barcarrola an2001 mALLYEAR

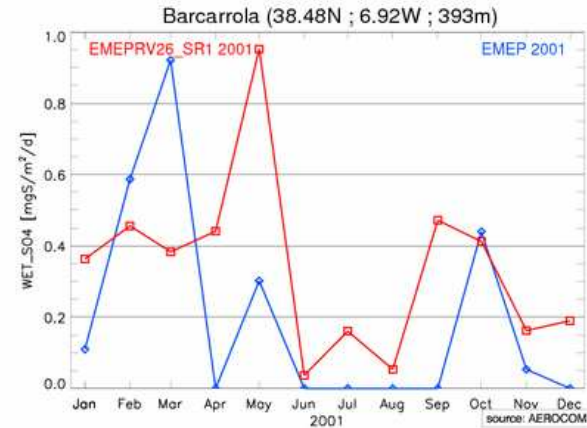


image created 07.06.2008

Graph Model/Data Species Parameter
 SERIES GOCARTV4P2_SR1 SO4 WET
 Barcarrola an2001 mALLYEAR

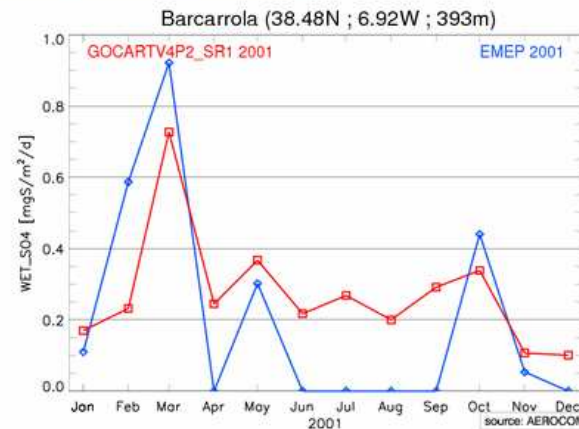


image created 07.06.2008

Graph Model/Data Species Parameter
 SERIES TM5JRCCY2IPCCV1_SR1 SO4 WET
 Barcarrola an2001 mALLYEAR

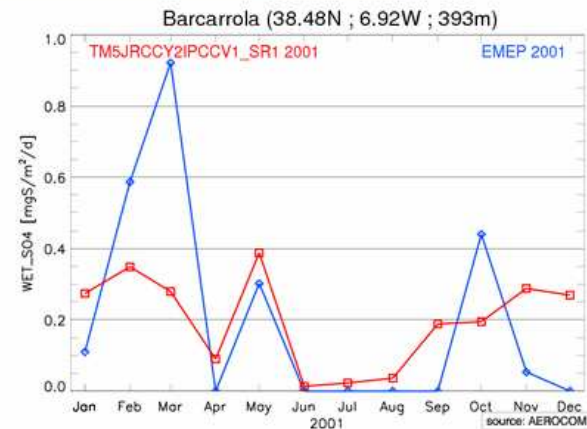
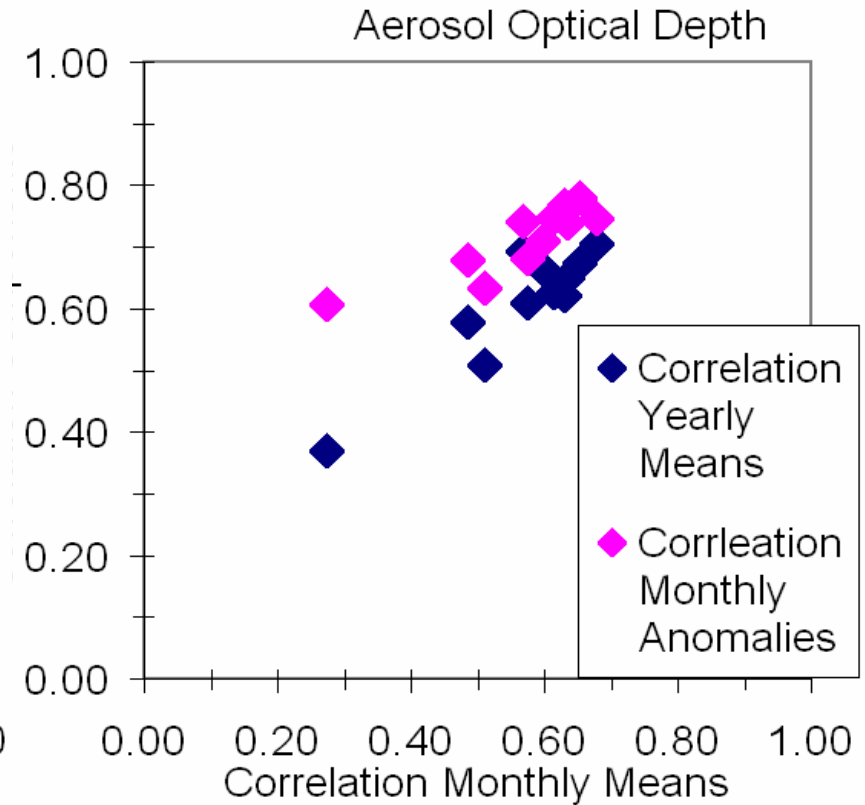
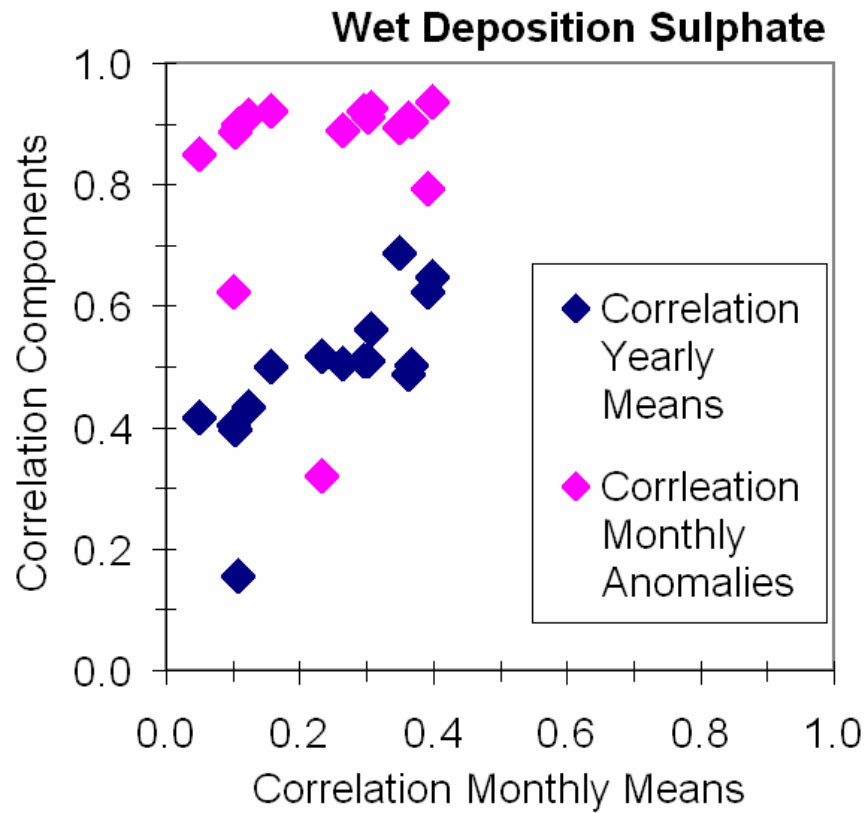


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Decomposition of Correlation

Comparison WET-SO4 and OD550_AER



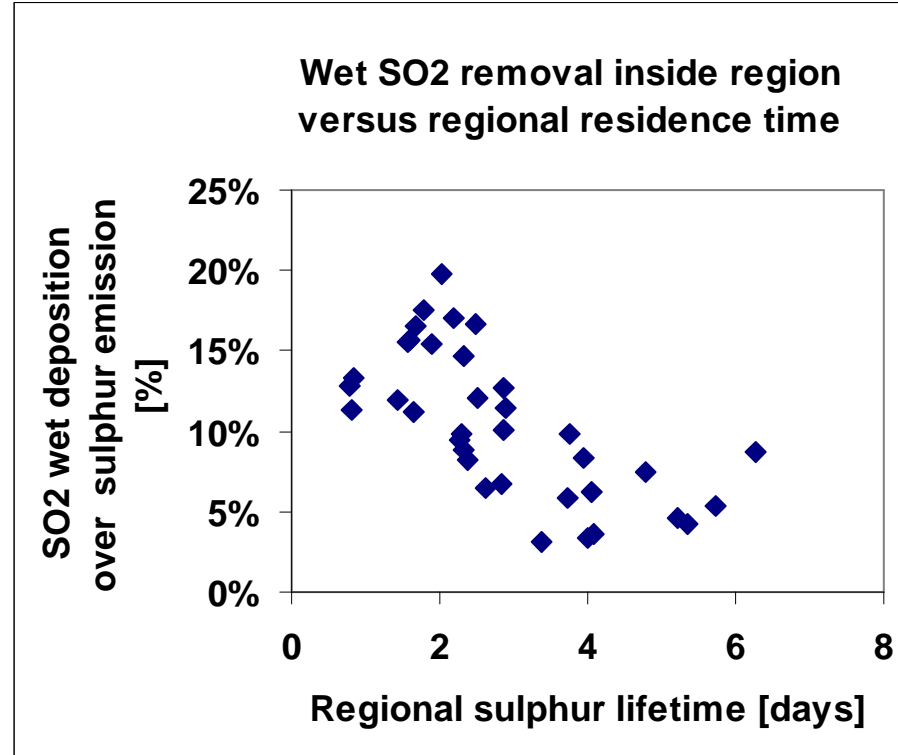
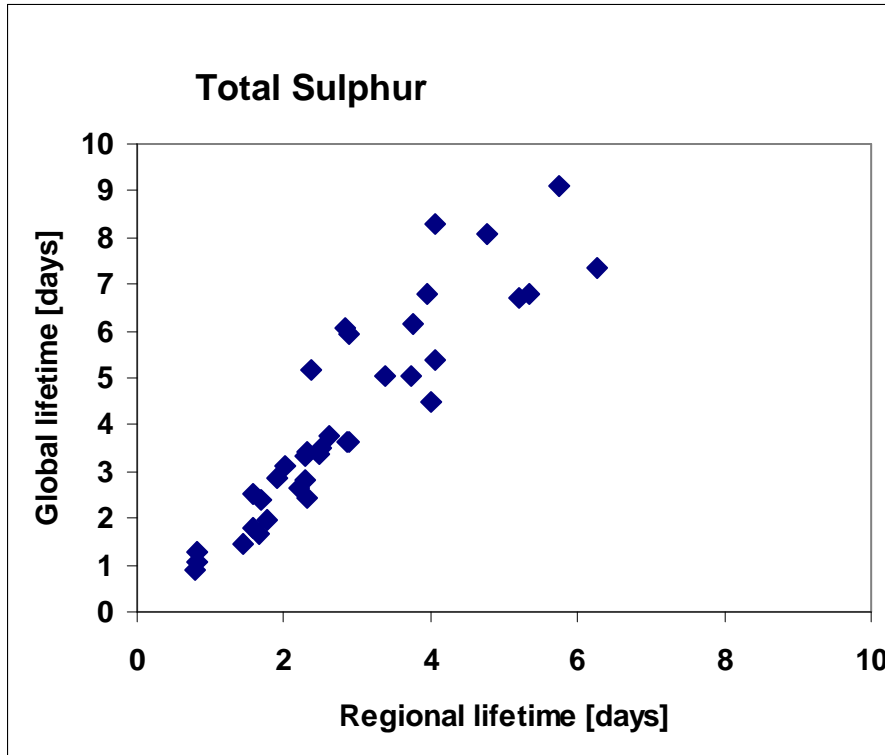
What if we remove North American derived SO₄??

Does correlation over Europe deteriorate??

| | EUROPE WET_SO4 2001 | | GLOBAL OD550_AER 2001 |
|--------------------------------------|---------------------------|-----------------------|-----------------------------|
| | HTAP SR1 | (No America) SR6NA | HTAP SR1 |
| # of valid observations: | 780 | 780 | 721 |
| MODEL mean | 0.68 | 0.64 | 0.16 |
| OBS mean | 0.44 | 0.44 | 0.20 |
| RMS error | 1.15 | 1.14 | 0.15 |
| Mean relative bias per month | 164% | 159% | 49% |
| STDDEV(Model)/STDDEV(Aeronet): | 0.869 | 0.858 | 0.84 |
| Correlation of Monthly station means | 0.244 | 0.246 | 0.56 |
| Spearman Rank Correlation monthly | 0.334 | 0.337 | 0.55 |
| Correlation of Yearly station means | 0.491 | 0.497 | 0.59 |
| Correlation of monthly anomalies | 0.844 | 0.845 | 0.70 |
| Taylor Score | 0.444 | 0.434 | 0.76 |

Is Wet Removal of SO₂ a valid diagnostic ??

Should it be added to wet deposition of SO₄ ??



Does correlation improve if we add wet deposition of SO₂ and SO₄ ??

| | EUROPE WET_SO4 2001 HTAP SR1 | EUROPE WET_SO4+SO2 2001 HTAP SR1 |
|--------------------------------------|--|--|
| # of valid observations: | 780 | 780 |
| MODEL mean | 0.68 | 1.14 |
| OBS mean | 0.44 | 0.44 |
| RMS error | 1.15 | 1.43 |
| Mean relative bias per month | 164% | 225% |
| STDDEV(Model)/STDDEV(Aeronet): | 0.869 | 1.202 |
| Correlation of Monthly station means | 0.244 | 0.246 |
| Spearman Rank Correlation monthly | 0.334 | 0.348 |
| Correlation of Yearly station means | 0.491 | 0.492 |
| Corrleation of monthly anomalies | 0.844 | 0.754 |
| Taylor Score | 0.444 | 0.493 |

Conclusions

North American Influence on European aerosol likely to be seen in AOD rather than wet deposition – as suggested already by import sensitivities

Explanatory power of American AOD and SO₄ wet deposition for variability of observations in Europe is small. Significance?

Mean annual spatial distribution more difficult than monthly anomalies for both AOD and WET SO₄

Model credibility?

Multimodel median still a good benchmark

HTAP models (2007) slightly worse than AeroCom (2003).

How to achieve modeling progress without efforts devoted to joint evaluation and model discussion?

Outlook

HTAP aerosol paper draft for summer

How to test long range transport of models by observations?

Further development of AeroCom tools to include more data (worldwide deposition, PM, other satellites, surface conc. etc) (see AeroCom talk Wednesday)

Standard benchmark tools (idl) which can reproduce standard analysis, against, multimodel background, by inclusion of fixed observational datasets