**Aerosol systematic variability – observations and simulations**

**Abstract**

Systematic variability

Only NOAA sites

**1. Introduction, Background and Literature Review**

* Motivation for why to compare aerosol models and measurements
* Why systematic variabilty

The primary objective of AeroCom is to improve modeling of aerosols and thus improve predictions of the aerosol-related climate effects. Because, ultimately, the climate effects of aerosol particles are caused by their optical properties

* How well do models simulate the overall relationships among aerosol optical properties

**2. Methods**

2.1 Description of in-situ aerosol optical property data

The data used in this study consists of surface in-situ aerosol light scattering coefficients and aerosol light absorption coefficients. The measurements are typically made following GAW protocols (REFERENCE) meaning the measurements are made at controlled humidity (usually RH<40%) and have appropriate instrumental corrections applied as described below. Figure 1 is a map of the surface in-situ sites used in this study. Table S1 in supplemental materials provides more information about the surface sites used in this study.

The Level 2, hourly-averaged QA/QC’d data were downloaded from EBAS (need proper name, citation) and underwent further review and interaction with the data providers as previous efforts involving multi-site analyses have shown external data review to be extremely helpful (Asmi et al., 201X; Collaud Coen et al 201X; Andrews et al., 20XX). The hourly data are averaged to coarser time resolutions for comparison with less temporally resolved model output.

The light scattering measurements are made by integrating nephelometers (either TSI model#3563 or various models of the Ecotech nephelometer). The TSI nephelometer is a spectral instrument (450, 550 and 700 nm) allowing the calculation of wavelength dependence of scattering. Most sites with Ecotech nephelometers also submitted spectral scattering (450, 525 and 635 nm) although some sites operated single wavelength Ecotech instruments. TSI nephelometer data were corrected for known instrument non-idealities (truncation, light source) using the Anderson and Ogren (1998) method. Ecotech nephelometer data were corrected using Mueller et al. (XXXX).

The light absorption measurements are made using a variety of filter-based instruments including the Multi-Angle Absorption Photometer (MAAP, Thermo, Inc.); the Particle Soot Absorption Photometer (PSAP, Radiance Research) and the Continuous Light Absorption Photometer (CLAP, NOAA’s extended sampling time version of the PSAP). The MAAP and original PSAP are single wavelength instruments providing light absorption at 635 nm and 550 nm, respectively. The CLAP and newer versions of the PSAP are multi-wavelength instruments (PSAP: 467, 530 and 660 nm; CLAP: 467, 528 and 652 nm). The PSAP and CLAP are corrected for scattering artifacts, etc. (e.g., Bond et al., 1999, Virkkula et al., XXXX;XXXX, Ogren et al., 2010). Aethalometer data were not used as, as yet, EBAS does not have an approved Level 2 data format for reporting corrected, QA/QC’d aerosol absorption from aethalmeter measurements.

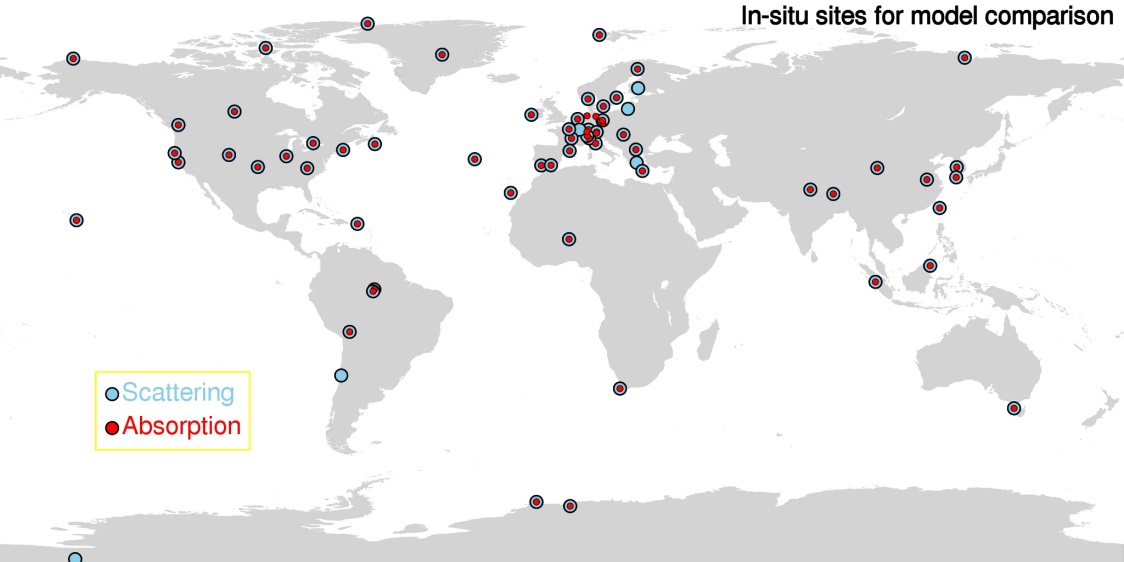
From the available measurements of aerosol light absorption and scattering additional parameters can be calculated. Here we will focus on three(?):the aerosol single scattering albedo (SSA), the scattering Angstrom exponent (scattering AE (SAE)) and the absorbing Angstrom exponent (absorbing AE (AAE)) and fine mode fraction (FMF)?

(1) AE = log(1/2)/log(2/1)

and

(2) SSA = sp,i/(sp,i + ap,i)

where  is the aerosol light scattering (subscript ‘sp’ (or absorption (subscript ‘ap’) at wavelength i (i) and size range ‘fine’ (i.e., diameter< 1um) or total (all aerosol). SAE is a parameterization of aerosol size. Larger SAE values (SAE ~2) indicate that there is more scattering contribution from sub-micrometer particles while smaller SAE values (SAE<1.5) indicate larger particles (>1 m) have a greater contribution to the observed light scattering (reference). AAE has been used as an indicator of particle composition/type (reference). The SSA provides information on the contribution of aerosol absorption to aerosol extinction. Values of SSA close to unity represent a primarily scattering aerosol (little to no absorption) while decreasing values of SSA indicate relatively more absorption is contributing to extinction. The single scattering albedo of black carbon is approximately 0.3 (reference). FMF is another indicator of particles size and has been shown to be strongly correlated with SAE (e.g., Delene and Ogren, 2002)



**Figure 1.** Map of sites with in-situ aerosol scattering and absorption. Need to update with actual sites used (pretty much just noaa network).

2.2 Description of AeroCom models used (grid size, temporal res, variables, etc)

Model output was requested from the AeroCom community of aerosol modelers for the INSITU experiment. The specific output requested was blah blah. Table 1 provides a list of the models which provided output either for this Phase III AeroCom data call or had previously provided relevant data for an AeroCom Phase II data request.

**Table 1.** Description of models used in analysis

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Model name**  Gridbox size  Output Year | **Citation(s)** | **MET** | **Mixing** | **Something**  **Else**  **Chemistry?** |
| **TM5**  3.0° x 2.0°  2010 | Van Noije et al., 2014 | Offline (ERA-Interim) | Internal mixing within modes |  |
| **GEOS-Chem**  2.4° x 2.0°  2010 | Bey et al. (2001) | offline chemistry-transport model  (GEOS-5) | External mixing |  |
| **CAM5**  2.4° x 1.9°  2010 | Liu et al. (2012)  Ghan et al. (2012) | horizontal winds nudged towards ERA-Interim reanalysis | Internal mixing by volume |  |
| **ECHAM6-SALSA**  1.8° x 1.9°  2010 | Bergman et al. 2012.  Laakso et al., 2016 | Nudged towards ERA-Interim reanalysis data | Internal mixing by volume |  |
| **GEOS5-Globase**  1.25° x 1°  2010 | Chin et al., 2002, 2014  Colarco et al. 2010 | runs in “re-play” mode; MERRA met analysis | External mixing |  |
| **GEOS5-MERRAero**  0.6° x 0.5°  2010 | Buchard et al 2015, 2016 | Driven by meteorology from the MERRA-1 reanalysis | External mixing |  |
| **Oslo models (Oslo CAM5 and OsloCTM) can be added too I think** | **(need to check wavelengths provided for them)** |  |  |  |

2.3 Merging of model and measurement-

* Picked closest model gridpoint (same as Eckhardt et al., 2015)
* Adjusting measurements to ambient TP (since not all models provide T&P) use neph P and model T? (use same model T for all adjustments from highest res (space/time model) for which it’s available. (currently just assuming an annual T).

**3. Results**

* + 1. *Systematic variability*

*Intro:* systematic variability may provide information about how well the model is simulating aerosol processing, sources, transport, etc. need a stronger statement here….what nick S said in beijing about intensive vs intensive systematic variability plots allow for ??

Discuss figure 2 and figure 3

**4. Discussion**

**5. Conclusions**

**6. References**

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Andrews mountain paper XXXX

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IPCC, XXXX

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Mueller, Ecotech neph trunc paper

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Petzold map paper?

Samset et al., 2014 (BC);

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Virkkula PSAP papers (original and correction)

**Model papers in table 1 – need to sort and complete references**

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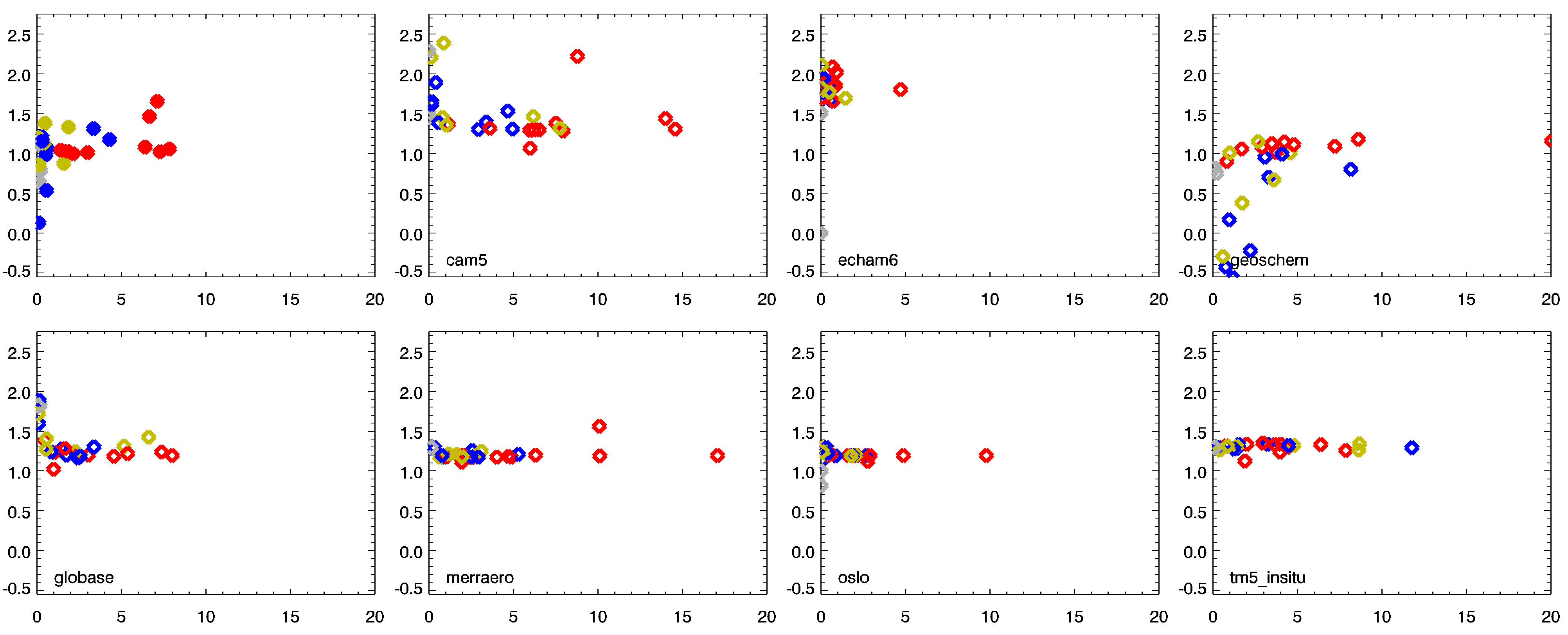
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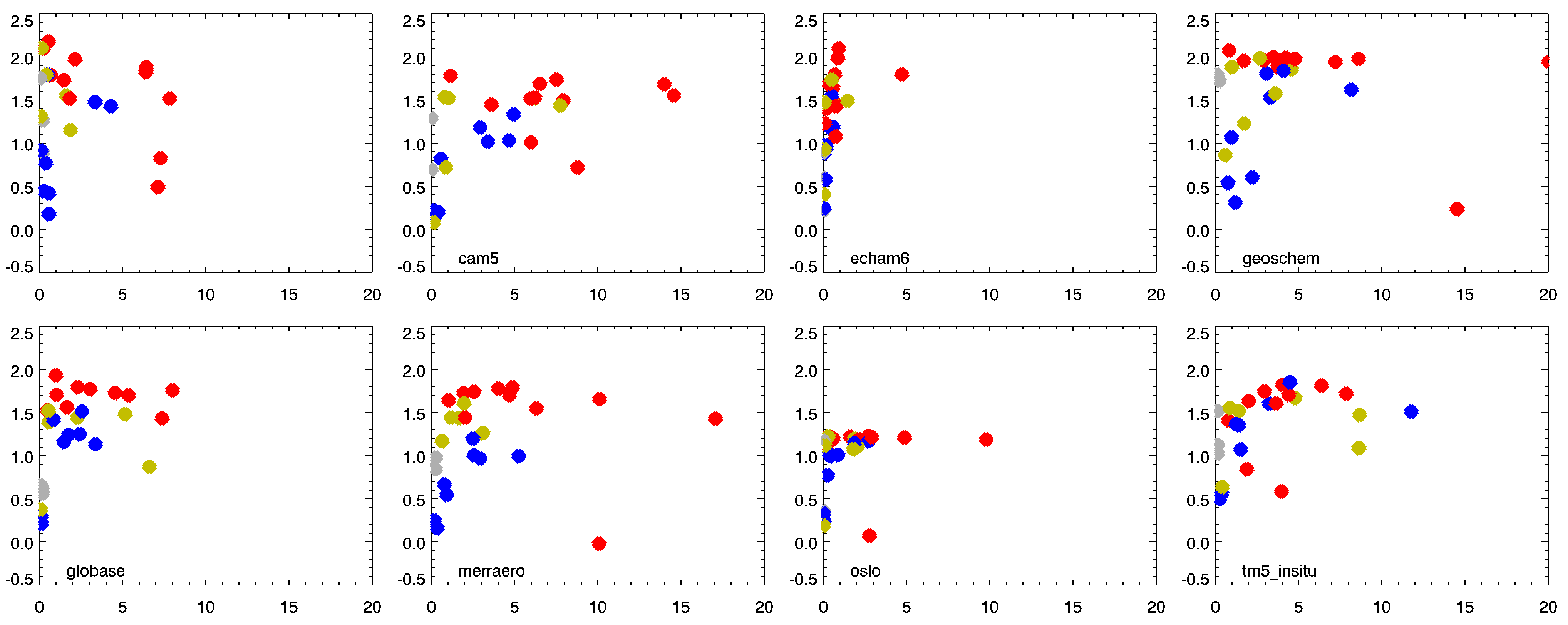
**Figure 2** Annual median values of single scattering albedo (at 550 nm) vs scattering Angstrom exponent (440/550nm wavelength pair – check!)

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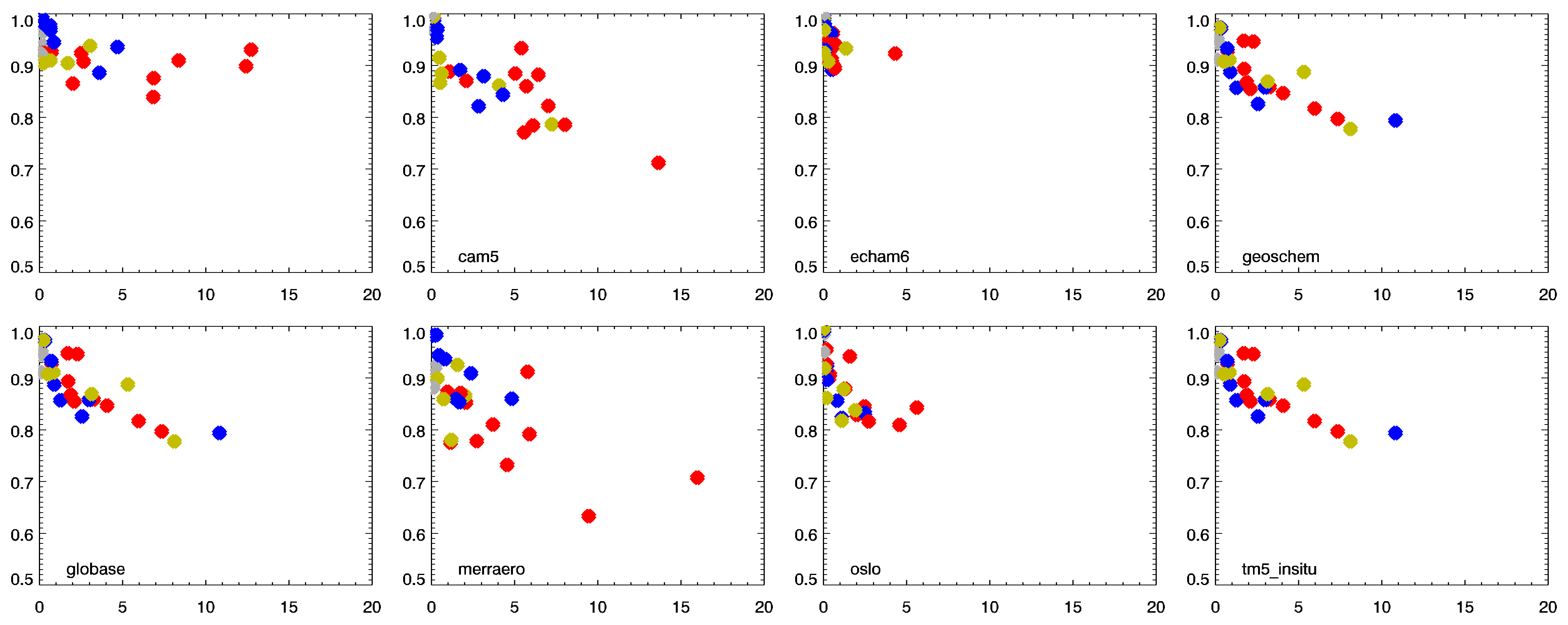
**Figure 3** Annual median values of absorption Angstrom exponent vs scattering Angstrom exponent (440/550nm wavelength pair for both variables– check!)



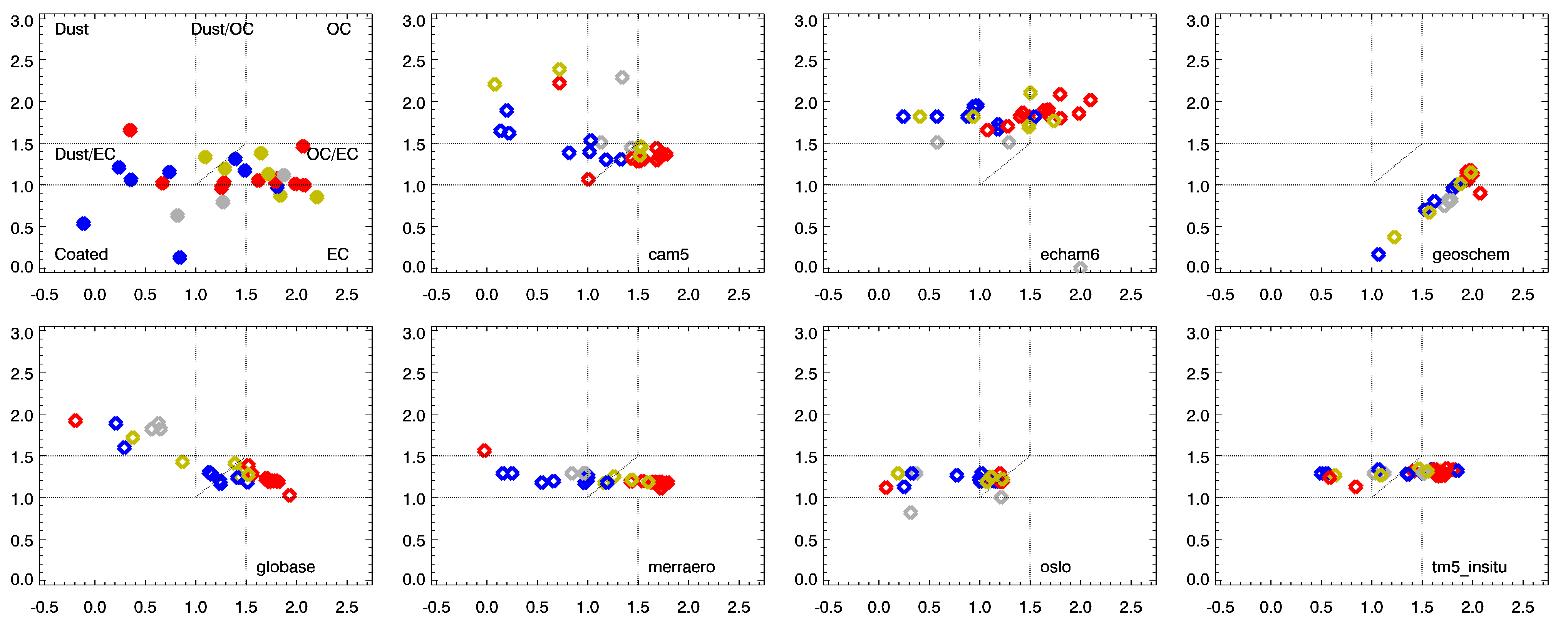
Abs vs AAE



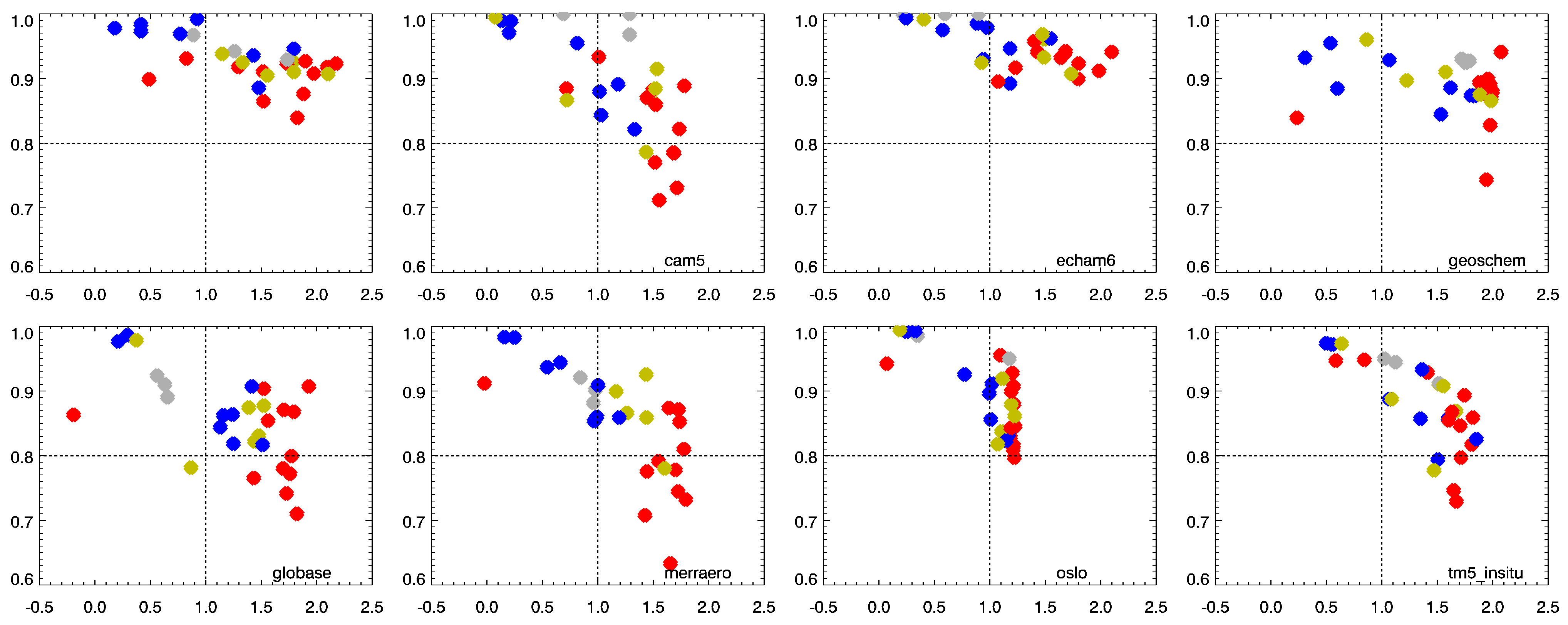
Abs vs SAE



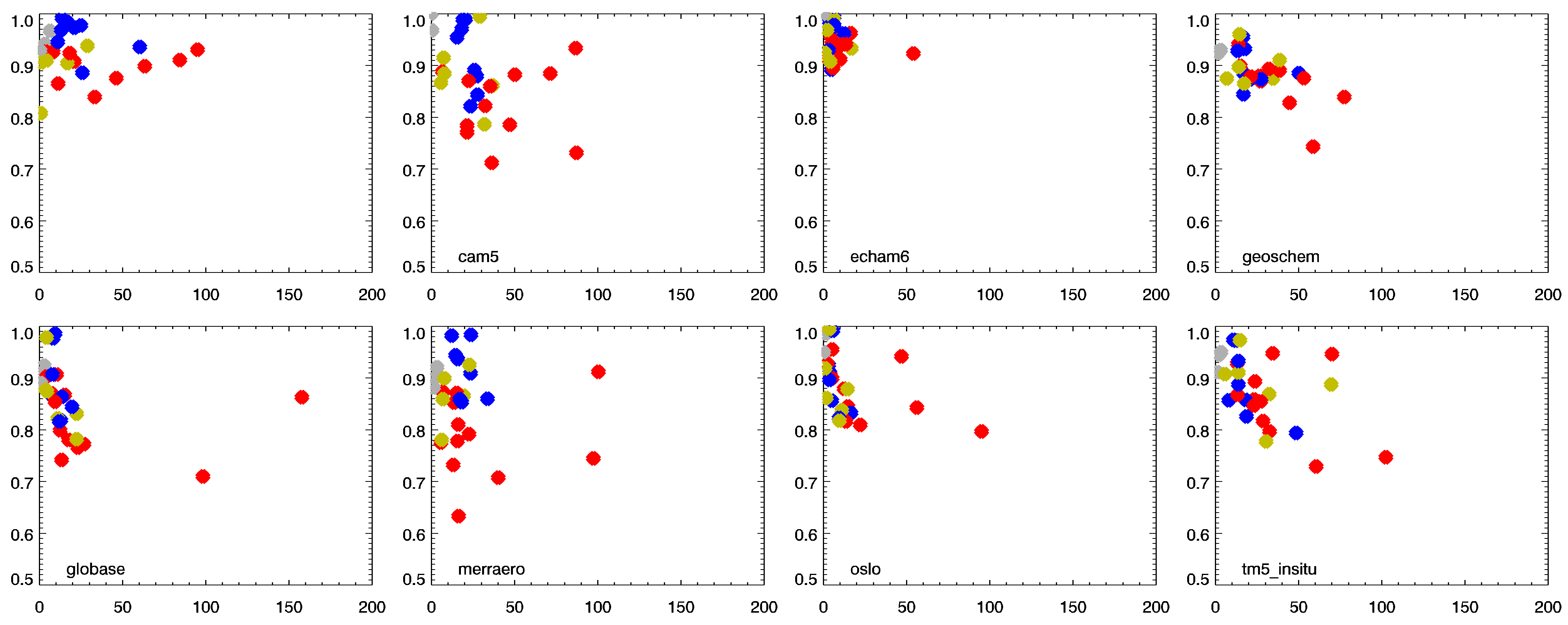
Abs vs SSA



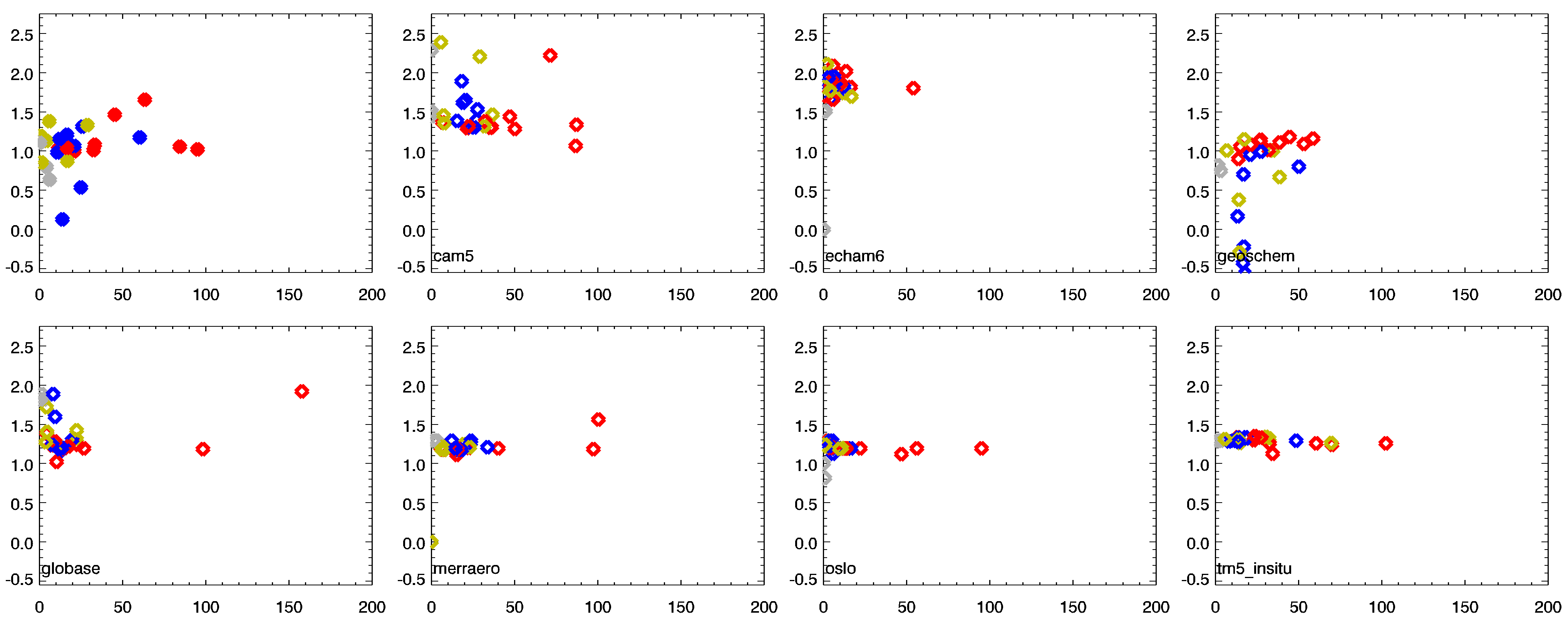
SAE vs AAE



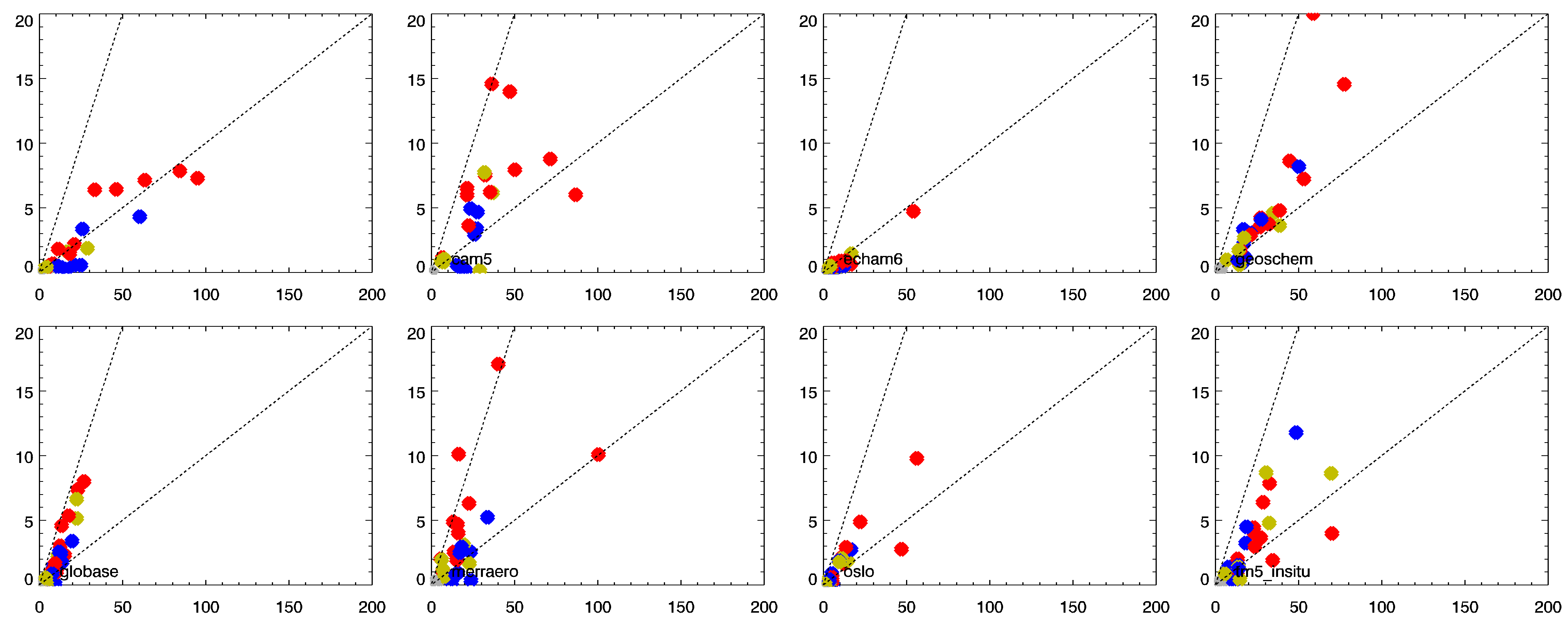
SAE vs ssa



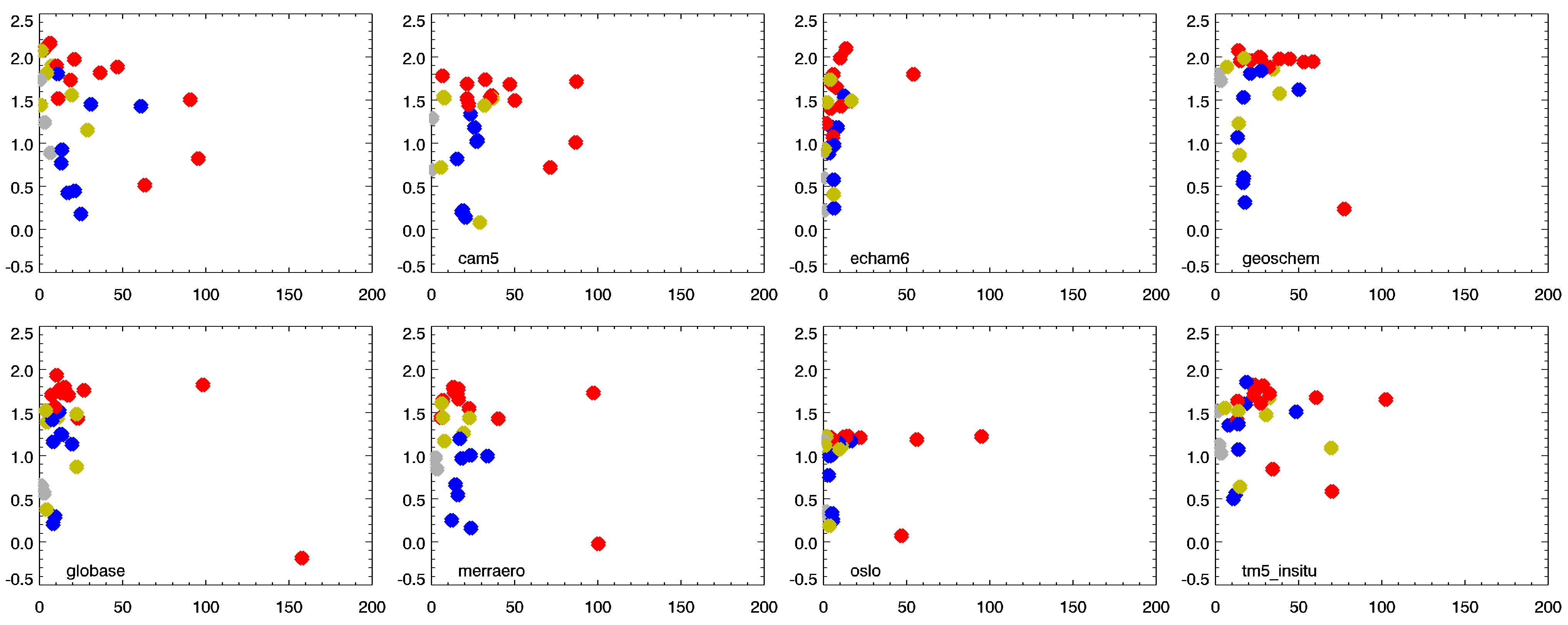
Scat vs SSA



Scat vs AAE



Scat vs abs



Scat vs SAE

**Appendix - Supplementary Materials**

**Table S1.** List of sites used in this study

|  |  |  |
| --- | --- | --- |
| **Station ID**  **Station name**  **‘Type’** | **Country**  **Lat Long Elev** | **Instruments (dates)** |
| ALT  Alert  ‘Polar’ | Canada | TSI neph  PSAP-3w  CLAP-3w |
| AMY  Anmyeon-do  ‘coastal’ | South Korea | TSI neph  PSAP-3w  CLAP-3w |
| ANB  Annaberg-Buchholz  ‘continental’ | Germany |  |
| APP  Appalachian State  ‘continental’ | USA | TSI neph  PSAP-3w  CLAP-3w |
| APT  Aspvreten  ‘continental’ | Sweden |  |
| ARN  El Arenosillo  ‘coastal’ | Spain | TSI neph  CLAP-3w |
| BEO  BEO-Moussala  ‘mountain’ | Bulgaria | TSI neph  CLAP-3w |
| BIR  Birkenes  ‘continental’ | Norway |  |
| BKT  Bukit Kototabang  ‘continental’ | Indonesia |  |
| BND  Bondville  ‘continental’ | USA | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| BRW  Barrow  ‘polar’ | USA | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| BSL  Bosel  ‘continental’ | Germany |  |
| CES  Cabauw  ‘coastal’ | The Netherlands |  |
| CGO  Cape Grim  ‘coastal’ | Australia |  |
| CHC  Chacaltaya  ‘mountain’ | Bolivia |  |
| CMN  Monte Cimone  ‘mountain’ | Italy |  |
| CPR  Cape San Juan  ‘coastal’ | USA (Puerto Rico) | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| CPT  Cape Point  ‘coastal’ | South Africa | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| DEM  Demokritos  ‘continental’ | Greece |  |
| DMV  Danum Valley  ‘continental’ | Malaysia |  |
| EGB  Egbert  ‘continental’ | Canada | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| ETL  East Trout Lake  ‘continental’ | Canada | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| FIK  Finokalia  ‘coastal’ | Greece |  |
| FKB  Hesselbach  ‘continental’ | Germany | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| GSN  Gosan  ‘coastal’ | South Korea | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| GRW  Graciosa  ‘coastal’ | Portugal (Azores) | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| HFE  Shouxian  ‘continental’ | China | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| HPB  Hohenpeissenberg  ‘continental’ | Germany |  |
| HYY  Hyytiala  ‘continental’ | Finland |  |
| IPR  Ispra  ‘continental’ | Italy |  |
| IZA  Izana  ‘mountain’ | Spain (Tenerife) | TSI neph  MAAP |
| JFJ  Jungfraujoch  ‘mountain’ | Switzerland | TSI neph  MAAP |
| KPS  K-puszta  ‘continental’ | Hungary | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| LEI  Leipzig  ‘continental’ | Germany |  |
| LEW  Leipzig-West  ‘continental’ | Germany |  |
| LLN  Mt. Lulin  ‘mountain’ | Taiwan | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| MAN  Manacapuro  ‘continental’ | Brazil | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| MAO  Manaus  ‘continental’ | Brazil |  |
| MHD  Mace Head  ‘coastal’ | Ireland | TSI neph |
| MLO  Mauna Loa  ‘mountain’ | USA | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| MPZ  Melpitz  ‘continental’ | Germany |  |
| MSA  Montsec | Spain |  |
| MSY  Montseny | Spain |  |
| NIM  Niamey  ‘continental’ | Niger | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| NMY  Neumayer  ‘polar’ | Antarctica (Germany) |  |
| OPE  Obs. Perenne de L’Environ.  ‘continental’ | France |  |
| PAL  Pallas  ‘polar’ | Finland |  |
| PGH  Nainital  ‘continental’ | India | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| PLA  Preila  ‘continental’ | Lituania |  |
| PUY  Puy de Dome  ‘mountain’ | France |  |
| PVC  Cape Cod  ‘coastal’ | USA | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| PYE  Point Reyes  ‘coastal’ | USA | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| RSL  Resolute  ‘polar’ | Canada | TSI neph  CLAP-3w |
| SGP  Southern Great Plains  ‘continental’ | USA | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| SIR  SIRTA  ‘continental’ | France |  |
| SPL  Storm Peak  ‘mountain’ | USA | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| SPO  South Pole  ‘polar’ | USA (Antarctica) | TSI neph |
| SSL  Schauinsland  ‘continental’ | Germany |  |
| SUM  Summit  ‘polar’ | Greenland | TSI neph  CLAP-3w |
| THD  Trinidad Head  ‘coastal’ | USA | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| TIK  Tiksi  ‘polar’ | Russia | TSI neph  MAAP |
| TRL  Trollhaugen  ‘polar’ | Norway (Antarctica) |  |
| TRS  Troll  ‘polar’ | Norway (Antarctica |  |
| VAV  Vavihill  ‘continental’ | Sweden |  |
| WAL  Waldhof  ‘continental’ | Germany |  |
| WHI  Mt Whistler  ‘mountain’ | Canada | TSI neph  PSAP-1w  PSAP-3w  CLAP-3w |
| WLG  Mt Waliguan  ‘mountain’ | China | TSI neph  PSAP-1w  PSAP-3w |
| WSA  Sable Island  ‘coastal’ | Canada | TSI neph  PSAP-1w |
| ZEP  Zeppelin  ‘polar’ | Norway |  |
| ZSF  Zugspitze  ‘mountain’ | Germany | TSI neph  MAAP |

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**Figure S1** Modelled annual median **(mean?)** aerosol scattering coefficient at 550 nm (No MerrAero, as only data at site locations was provided). Need to rearrange so models in same order as Figure 3b.

**Figure S2** Modelled annual median **(mean?)** aerosol absorption coefficient at 550 nm (No MerrAero, as only data at site locations was provided). Need to rearrange so models in same order as Figure 4b

**Figure S3** Modelled annual median **(mean?)** aerosol single scattering albedo at 550 nm (No MerrAero, as only data at site locations was provided). Need to rearrange so models in same order as Figure 3b.

**Figure S4** Modelled annual median **(mean?)** aerosol scattering Ångström exponent for 440/550(?) nm wavelength pair. (No MerrAero, as only data at site locations was provided). Need to rearrange so models in same order as Figure 3b.