# MULTI-DECADAL VARIATIONS OF AEROSOLS FROM MULTI-MODEL HINDCAST EXPERIMENTS AND MULTI-SATELLITE OBSERVATIONS

Mian Chin Report at AeroCom workshop, September 2012

# AeroCom II hindcast model experiments

- Motivation: Understand the relationship between the change of emission, change of aerosol distributions, and change of surface radiation or aerosol forcing
- Simulation period: 1980-200x
- Emissions (Diehl et al., 2012):
  - A2-MAP (anthropogenic, biomass burning, volcanic)
  - A2-ACCMIP (anthropogenic and biomass burning)
  - Dust and sea salt emissions calculated by each model
  - ECHAM5-HAMMOZ, GISS-modelE, and GISS-MATRIX do not consider volcanic emissions

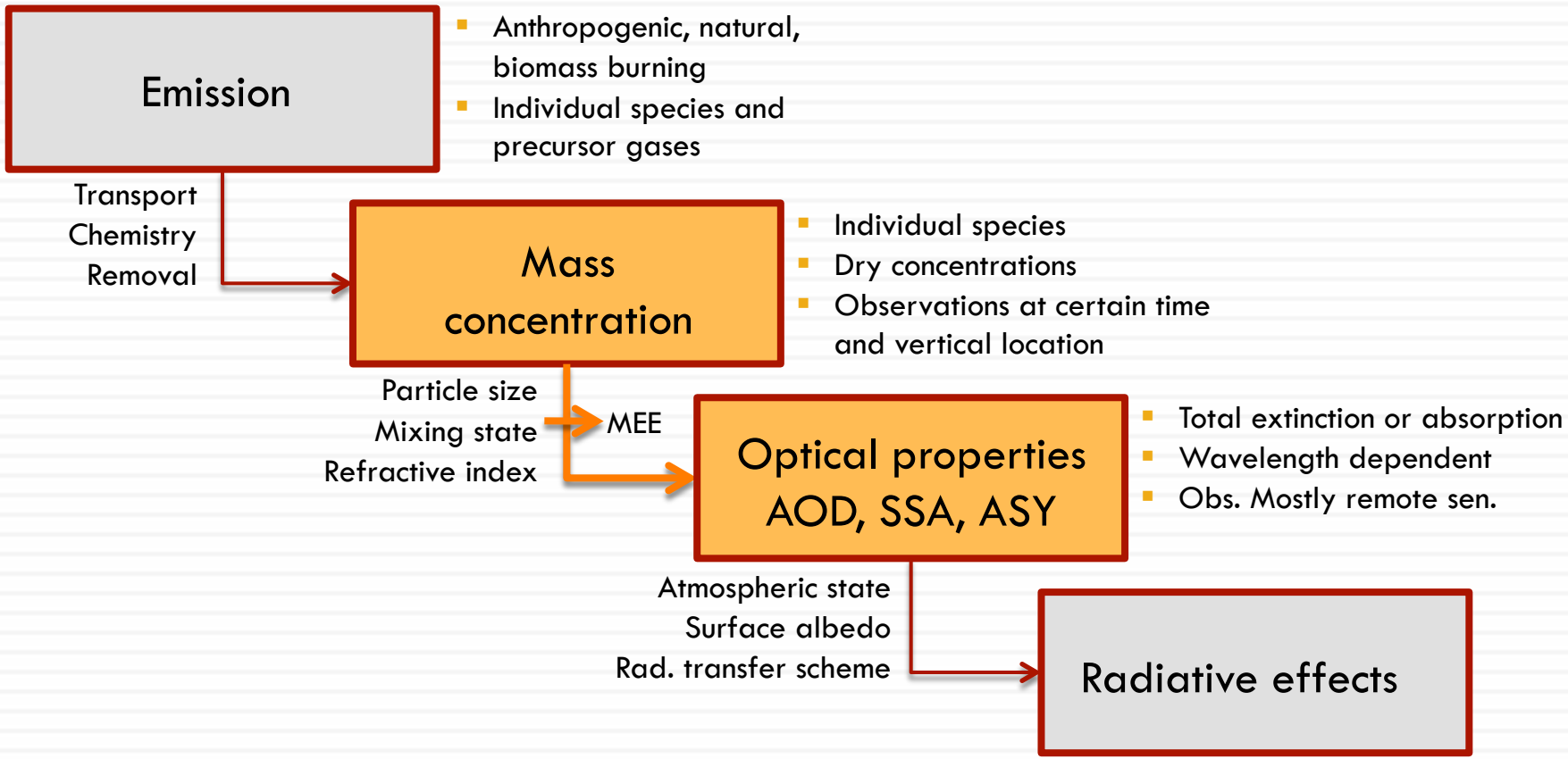
| Model | Abbr. | Emission | Period |
|---|---|---|---|
| ECHAM5-HAMMOZ.A2.HCA-0 | ECH-0 | A2-MAP | 1980-2005 |
| GISS-modelE.A2.HCA-IPCC | GIE-i | A2-ACCMIP | 1980-2008 |
| GISS-MATRIX.A2.HCA-IPCC | GIM-i | A2-ACCMIP | 1980-2008 |
| GOCART-v4.A2.HCA-0 | GO2-0 | A2-MAP | 1980-2007 |
| HadGEM2-ES.A2.HCA-0 | HAD-0 | A2-MAP | 1980-2006 |
| SPRINTARS-v384.A2.HCA-0 | SPR-0 | A2-MAP | 1980-2008 |
| SPRINTARS-v384.A2.HCA-IPCC | SPR-i | A2-ACCMIP | 1980-2008 |

# Satellite data

- Global long-term observations are only available from satellite observations
- Early sensors (AVHRR, TOMS) suffer from retrievable information or coverage
- Modern sensors has much better coverage and accuracy but time series is not long enough (12 to 14 years) for addressing climate-relevant trends

| Satellite data | Abbr. | Spatial Coverage | Period used |
|---|---|---|---|
| AVHRR – NOAA retrieval | AVH-n | Ocean | 1981-2004 |
| AVHRR – GACP retrieval | AVH-g | Ocean | 1981-2006 |
| SeaWiFS | SeaW | Land + ocean | 1997-2008 |
| MISR | MISR | Land + ocean | 2000-2008 |
| MODIS-Terra (including DB) | MOD-t | Land + ocean | 2000-2008 |
| MODIS-Aqua (including DB) | MOD-a | Land + ocean | 2002-2008 |

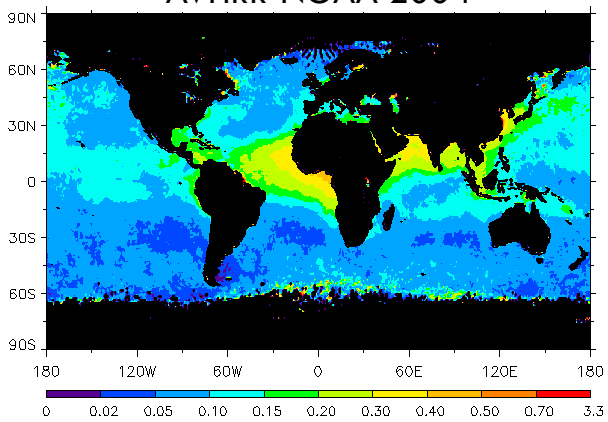
# From emission to radiative effects of aerosols – what does a model do



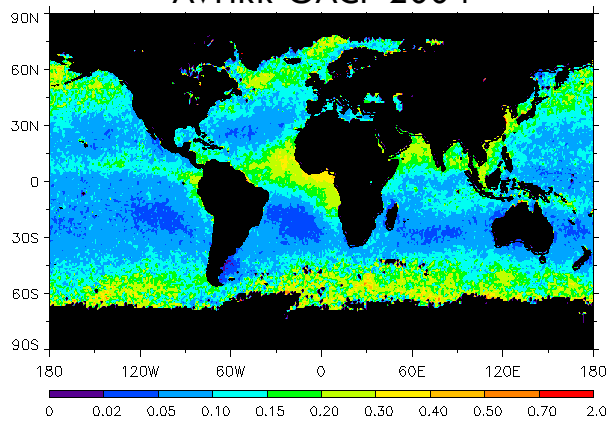

Direct verification in general is performed by comparisons of observed mass concentrations and AOD, but it is difficult to evaluate convoluted processes leading to the resulting concentration and AOD

# 2004 Annual avg AOD - satellite

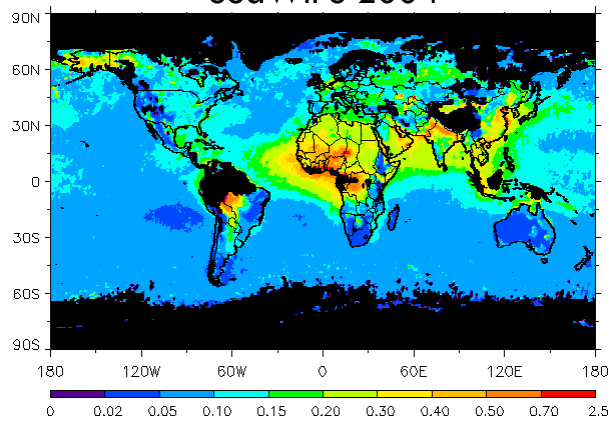
AVHRR-NOAA 2004



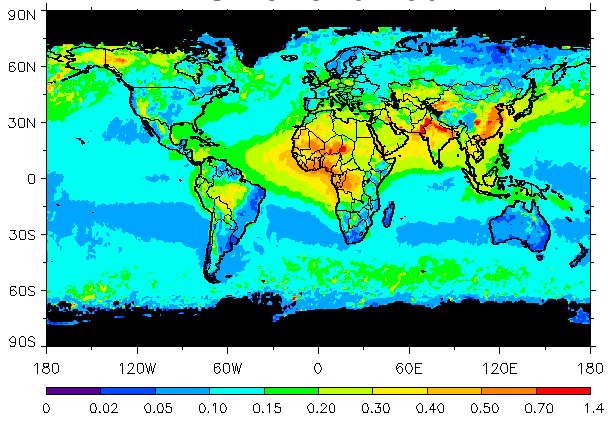

AVHRR-GACP 2004



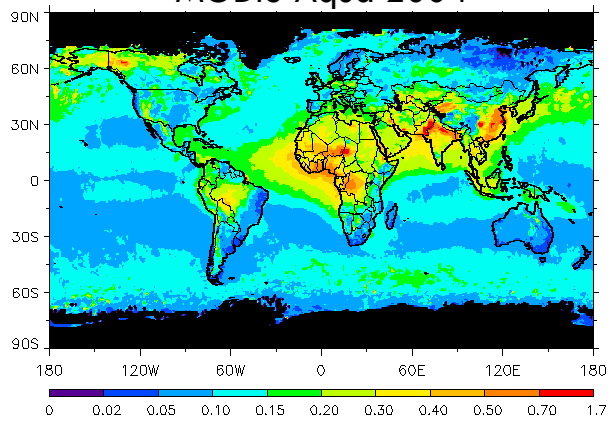

SeaWiFS 2004



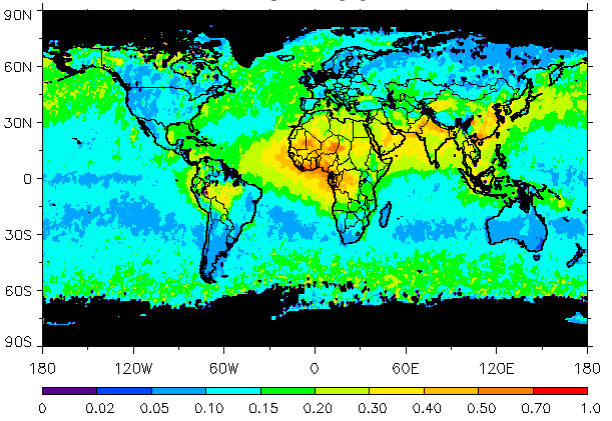

MODIS-Terra 2004




MODIS-Aqua 2004



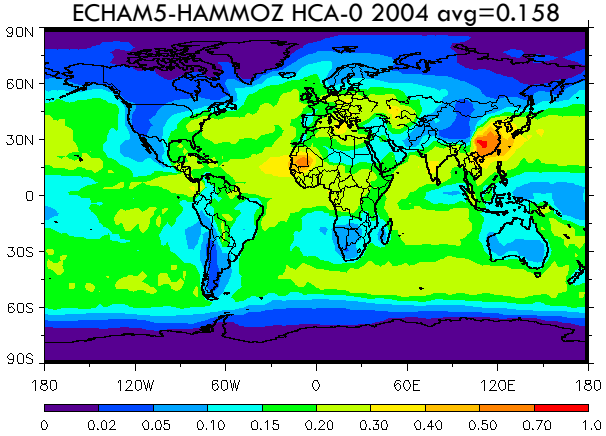

MISR 2004



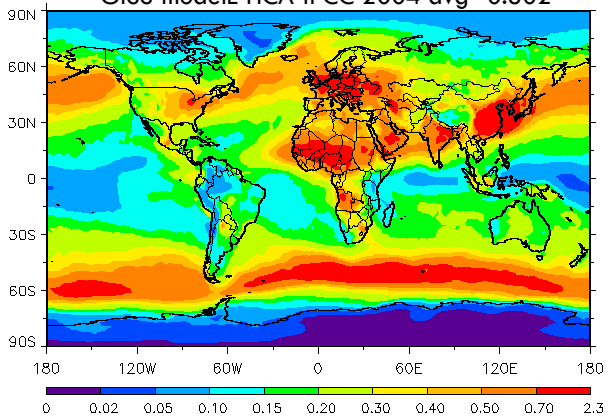
# 2004 Annual avg all sky AOD - model

- GISS-modelE has excessive AOD over the ocean – mostly sea salt
- GOCART has the highest AOD in the polar regions

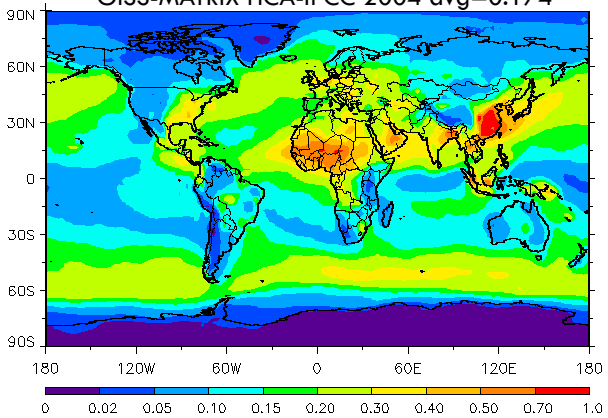
ECHAM5-HAMMOZ HCA-0 2004 avg=0.158



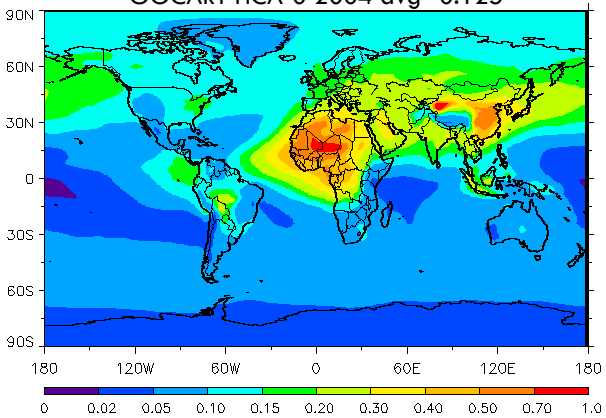

GISS-modelE HCA-IPCC 2004 avg=0.302



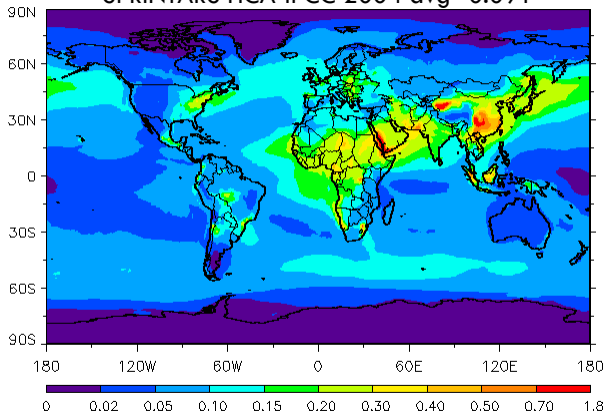

GISS-MATRIX HCA-IPCC 2004 avg=0.174



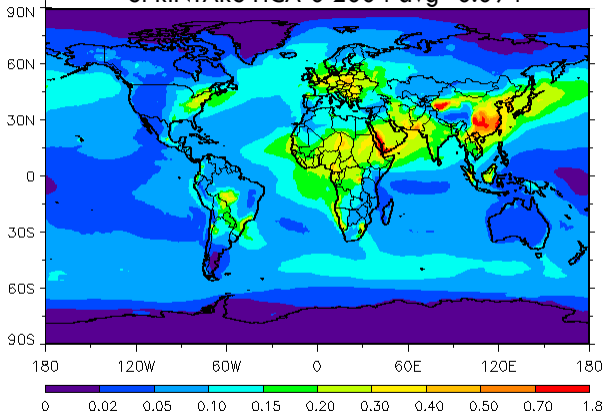

GOCART HCA-0 2004 avg=0.125



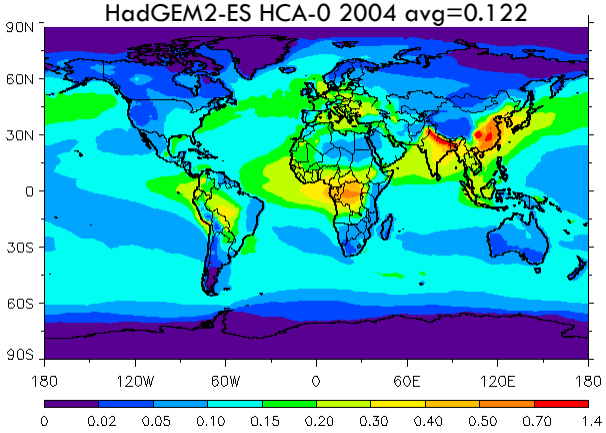

SPRINTARS HCA-IPCC 2004 avg=0.091




SPRINTARS HCA-0 2004 avg=0.094



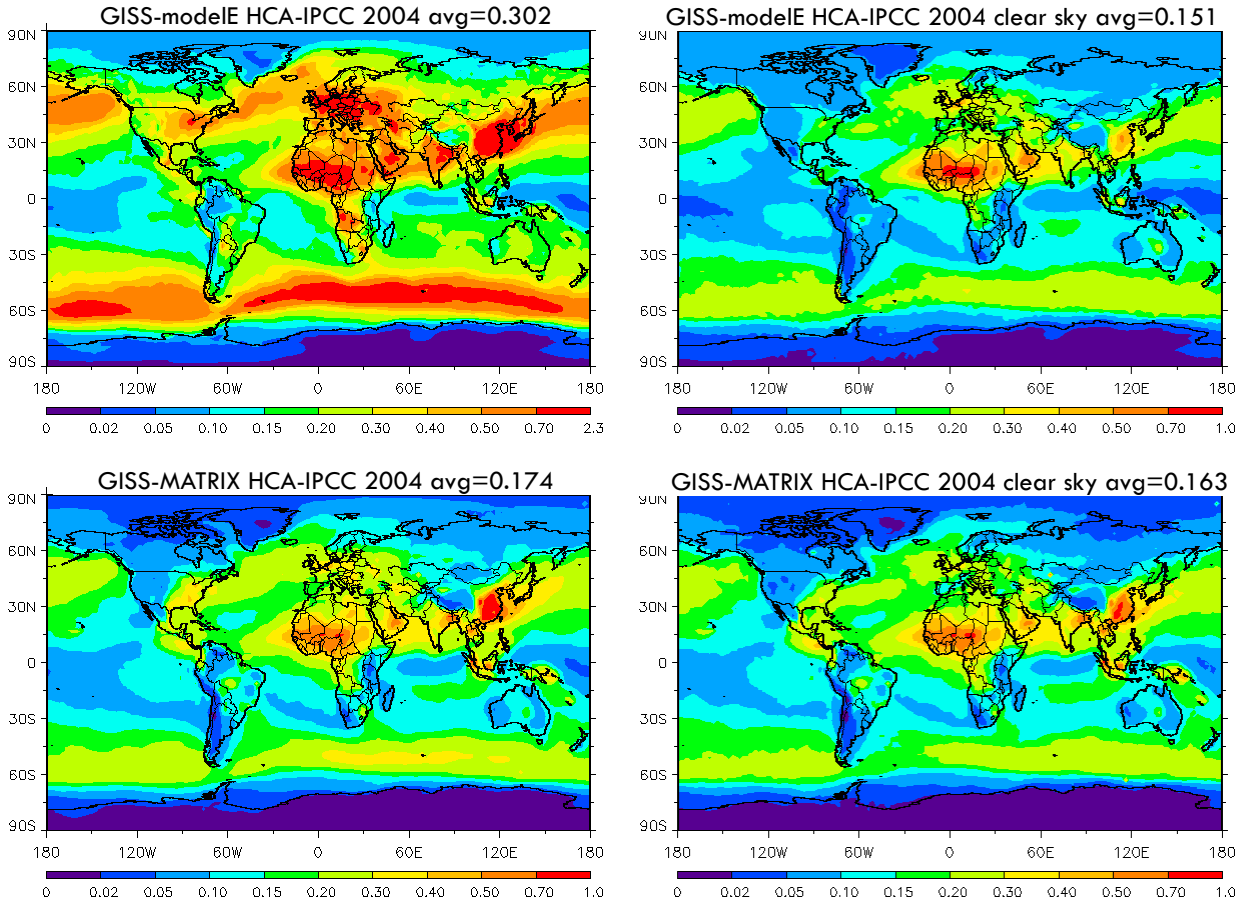

HadGEM2-ES HCA-0 2004 avg=0.122



# 2004 Annual avg AOD – all sky vs clear sky in two GISS models

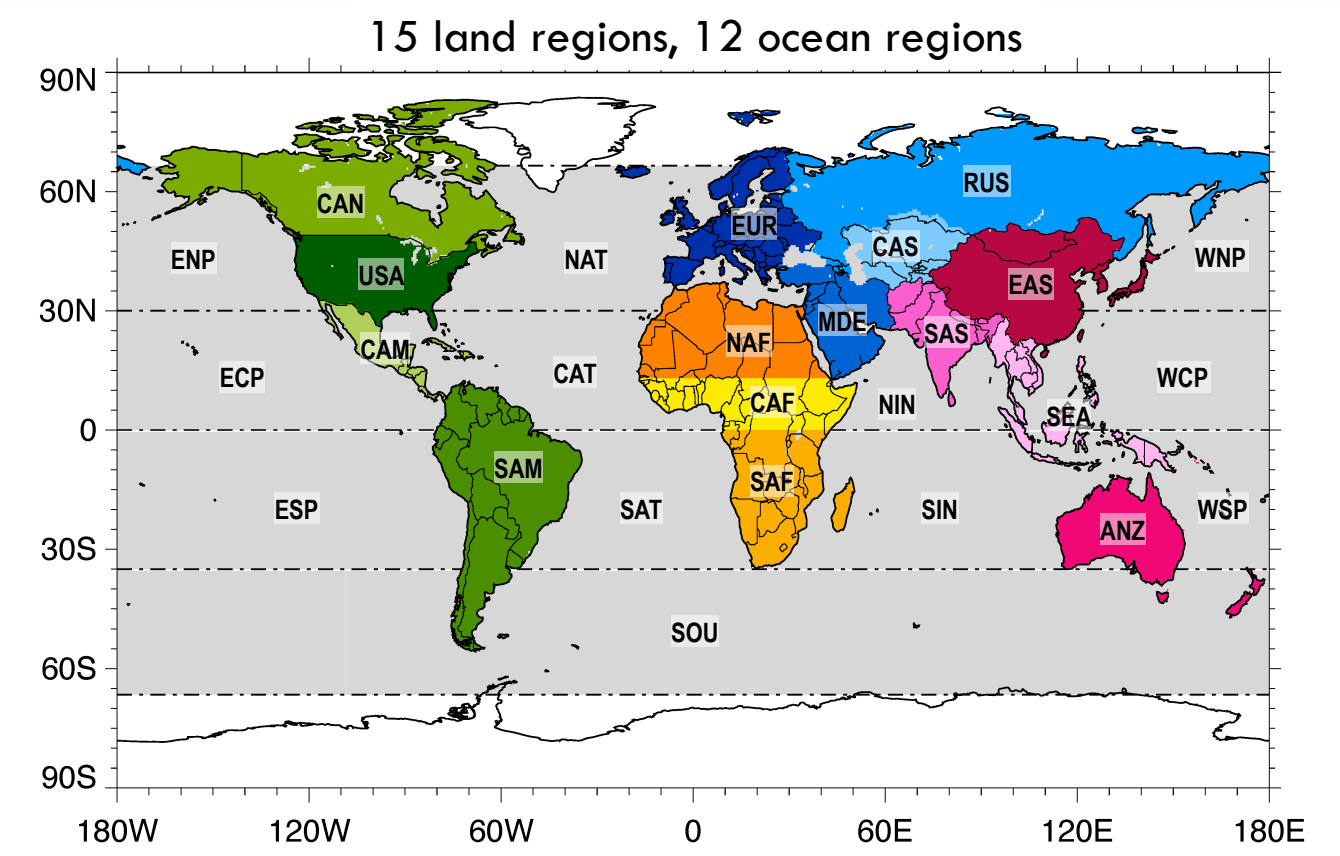
All sky

Clear sky



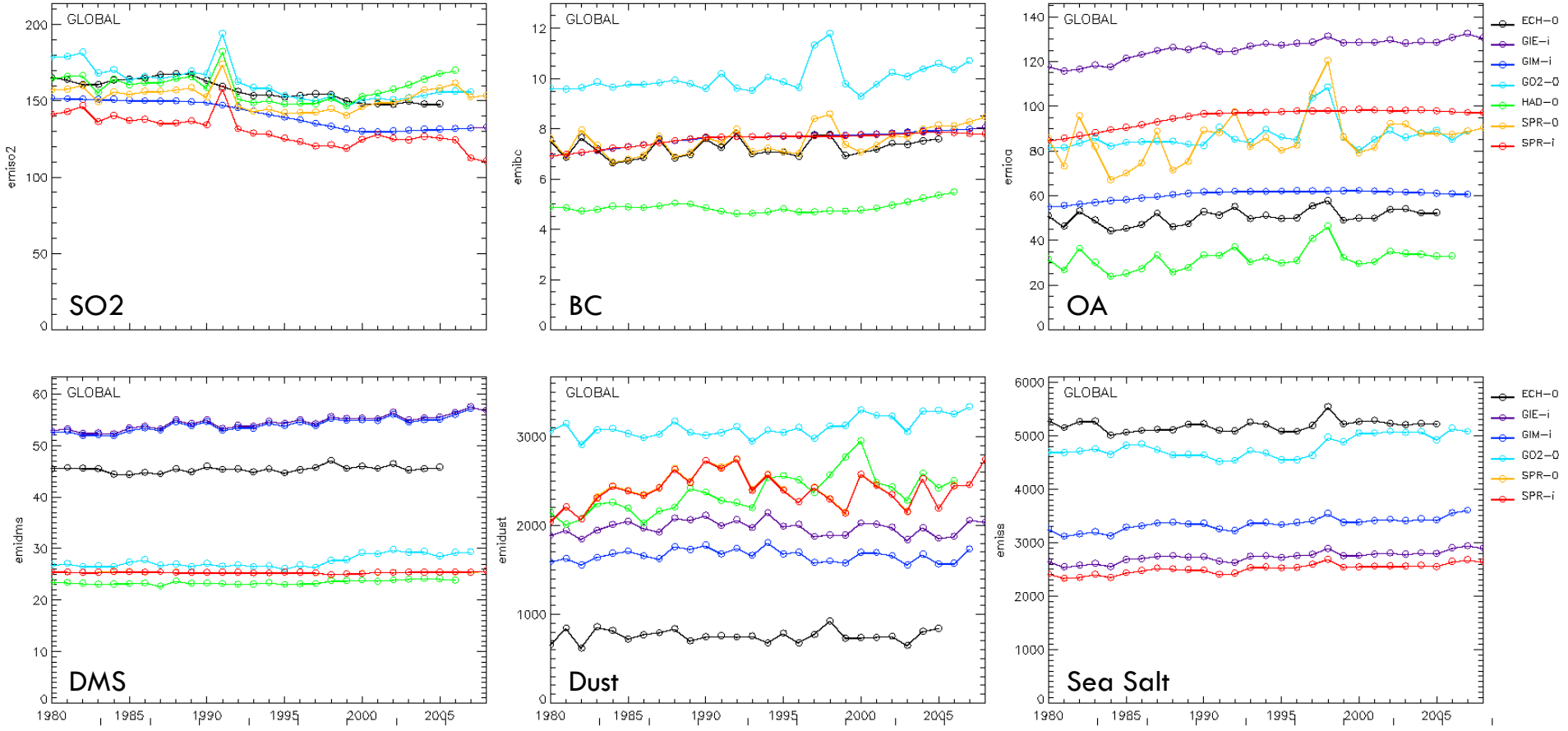

How can we verify AOD under all sky condition???

# Regional AOD trends – model and satellite



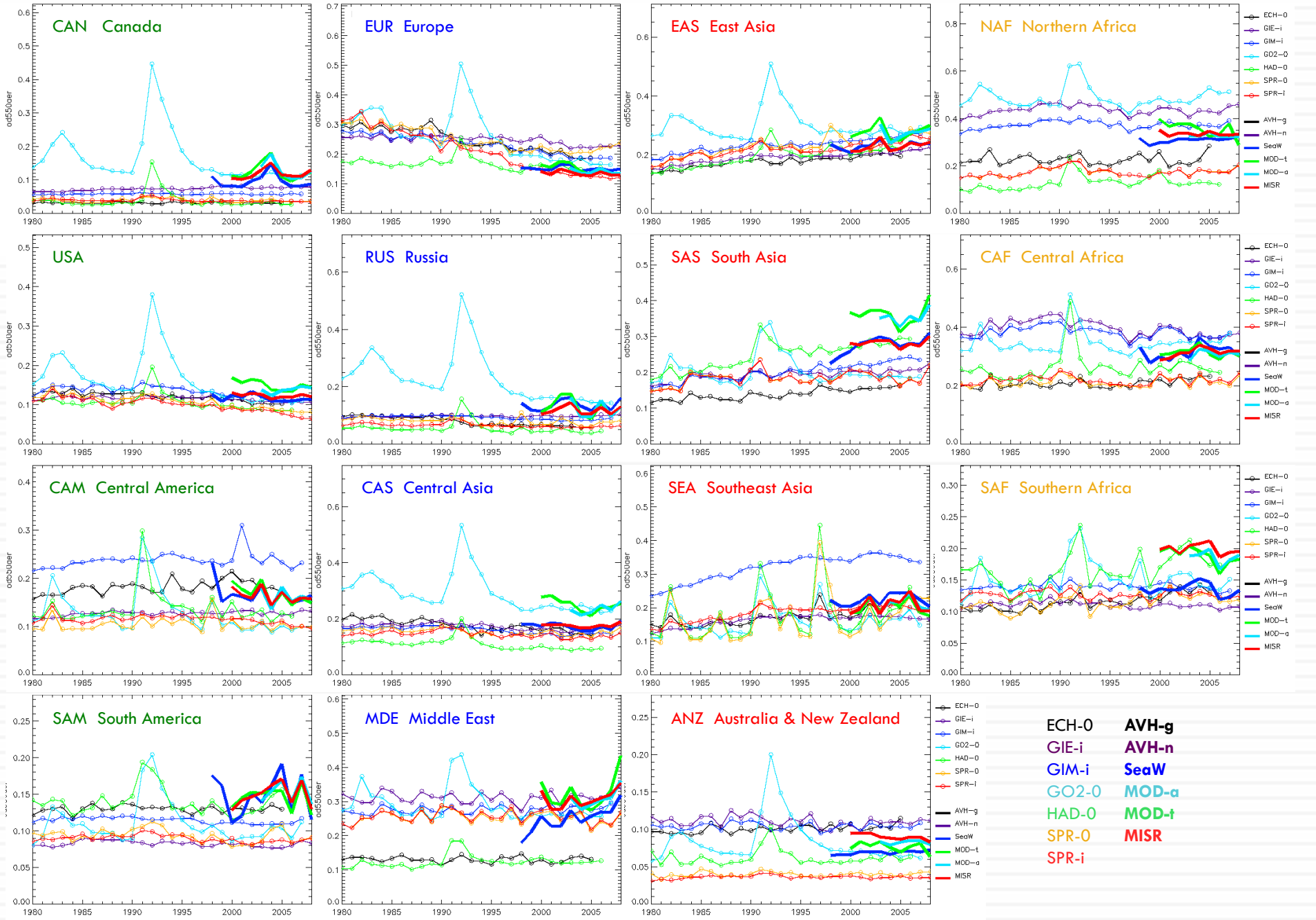

- Caveats:
  - Comparison of monthly or annual average from independent datasets - No spatial or temporal match
  - Satellite data are clear-sky, 1-2 times/day composite, but models are all-sky (except GISS models), averaged over diurnal simulations

# Differences in global annual emissions

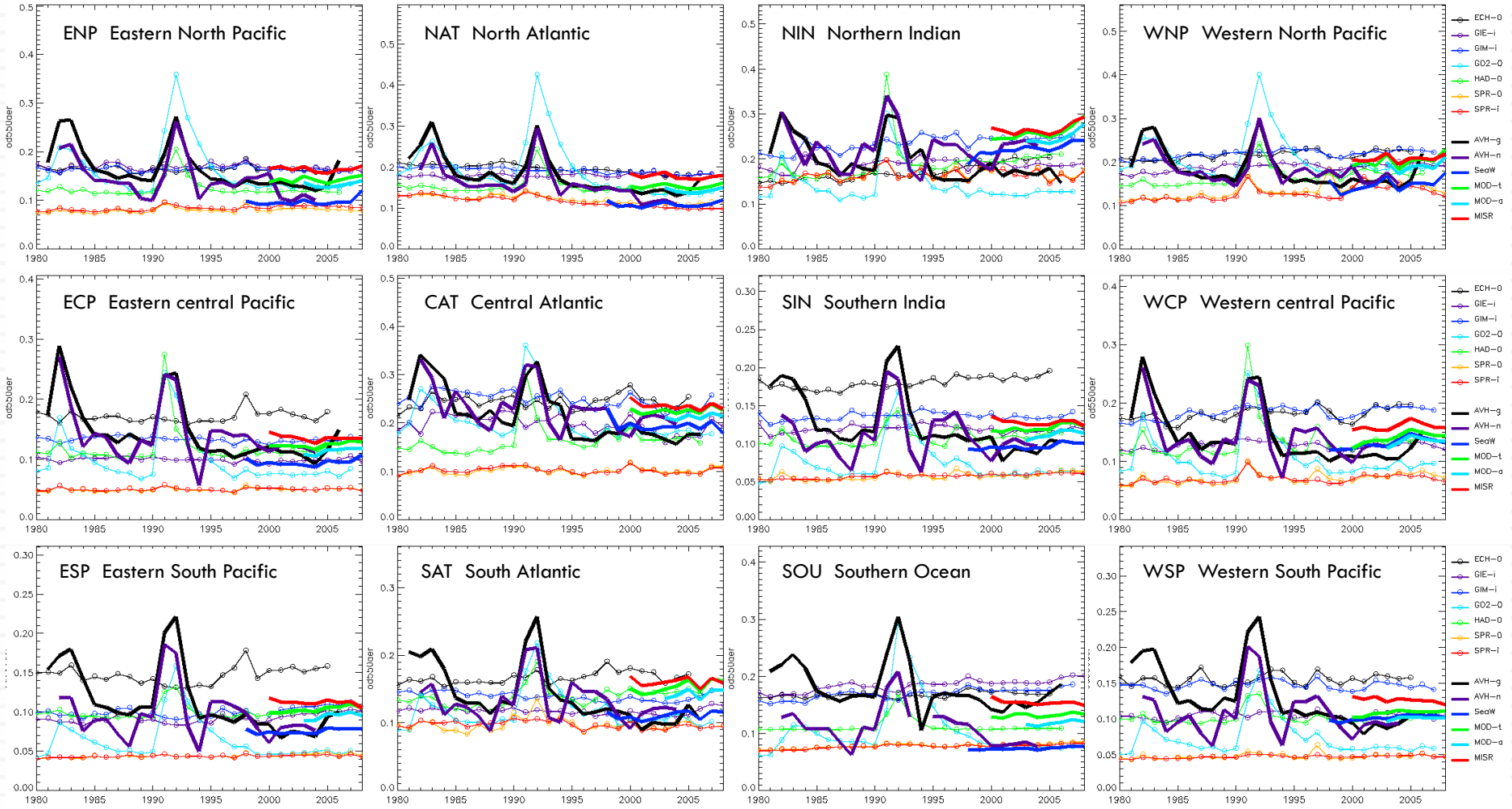



ECH-0 GIE-i GIM-i GO2-0 HAD-0 SPR-0 SPR-i

# Regional AOD trends over 15 land regions



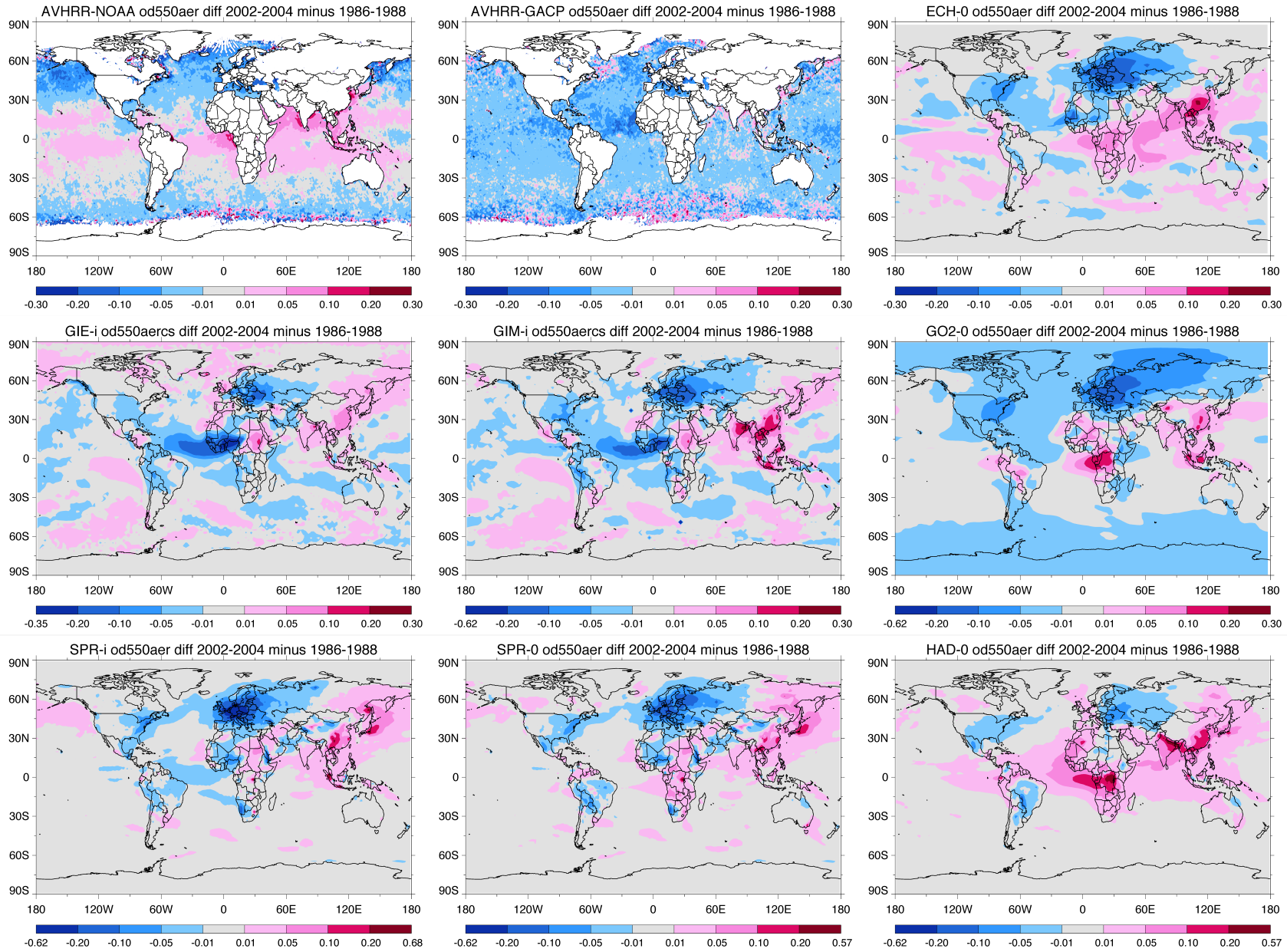
# Regional AOD trends over 12 ocean regions



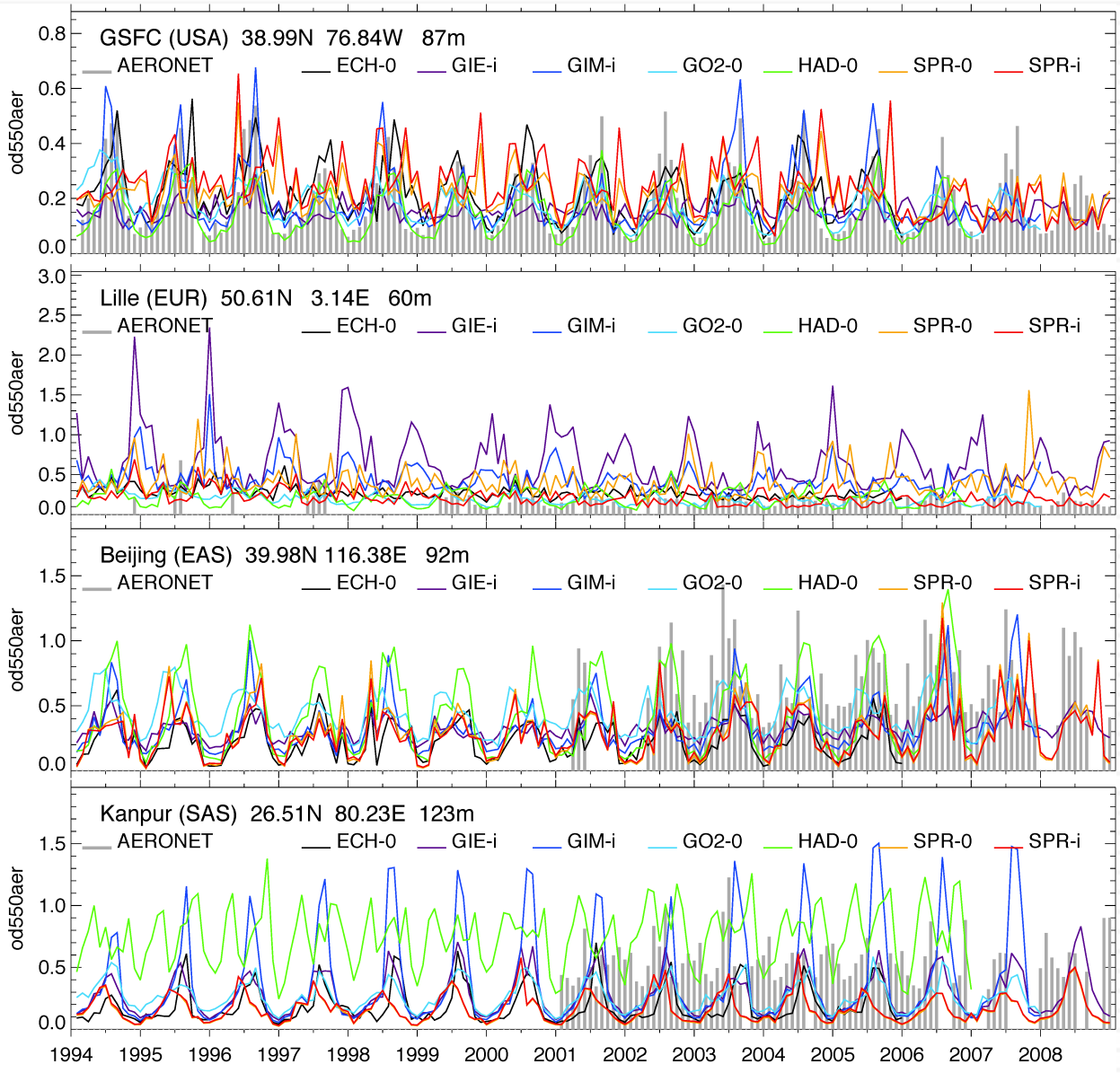

- Model regional avg AOD differences are mostly about 0.1 in periods without large volcanic eruptions
- Spread among satellites is much smaller (within 0.05)

ECH-0 **AVH-g**
GIE-i **AVH-n**
GIM-i **SeaW**
GO2-0 **MOD-a**
HAD-0 **MOD-t**
SPR-0 **MISR**
SPR-i

# “Trends” – Differences between (2002-2004) and (1986-1988)



# Comparisons with AERONET – Land sites



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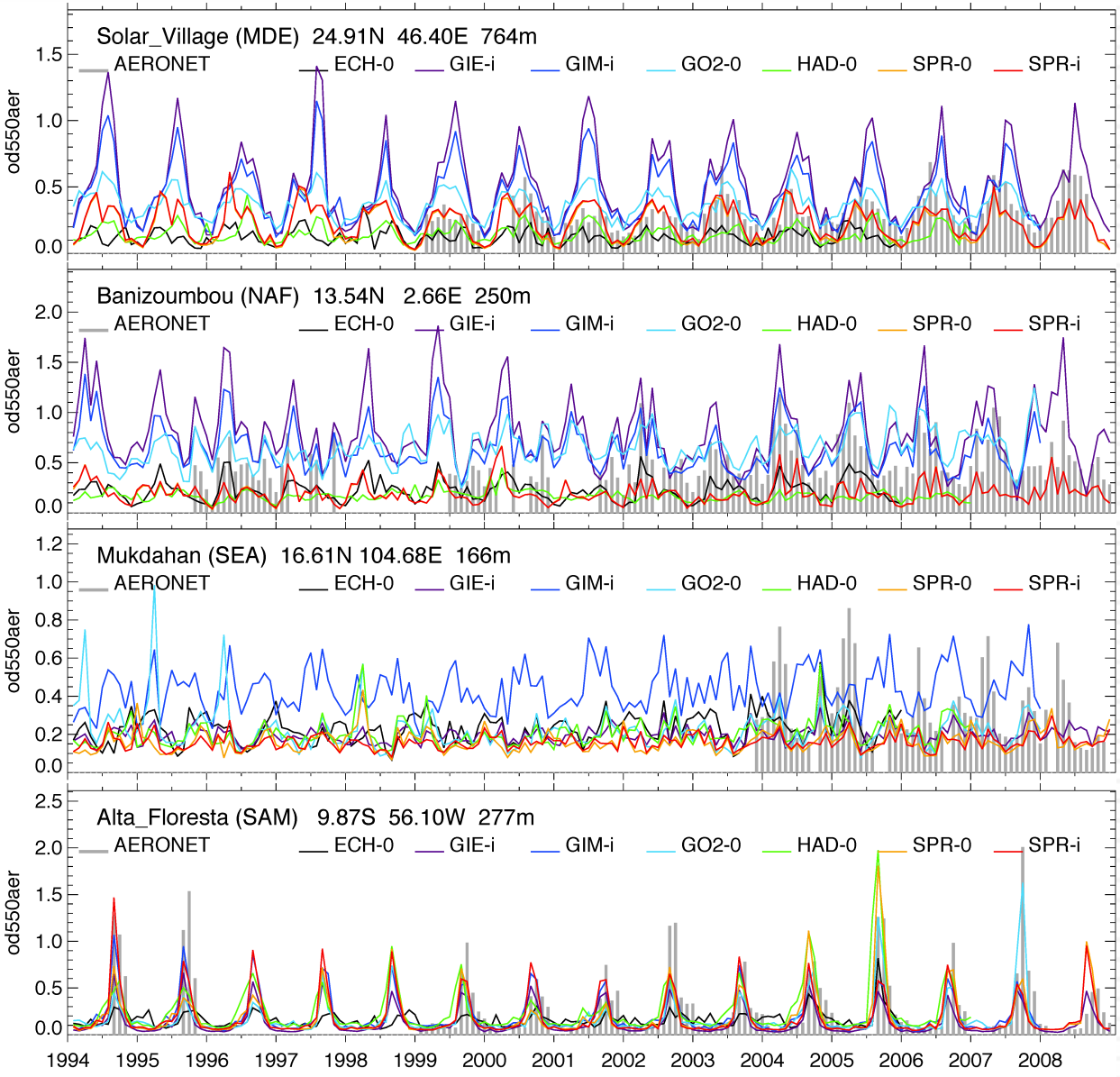
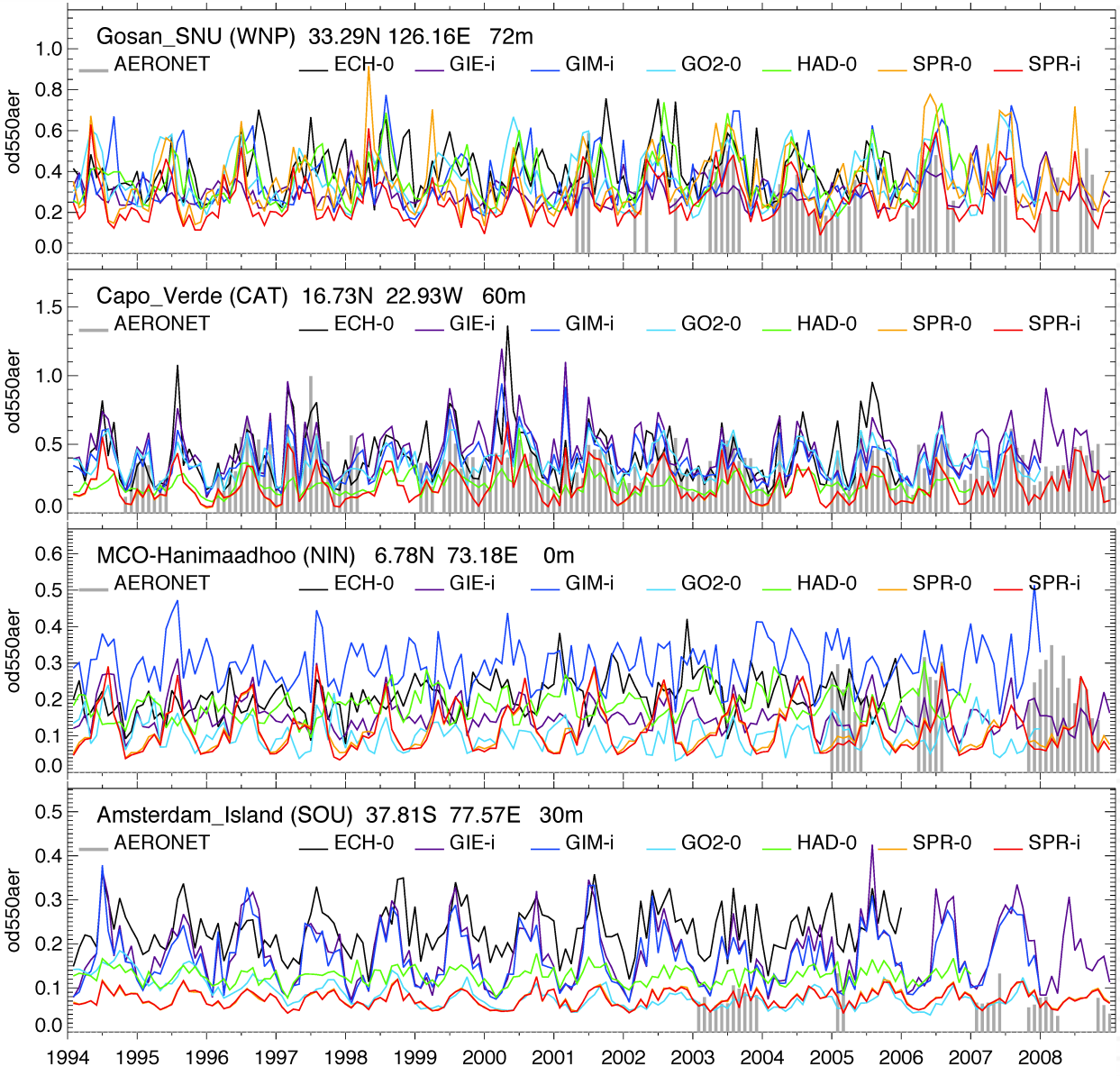
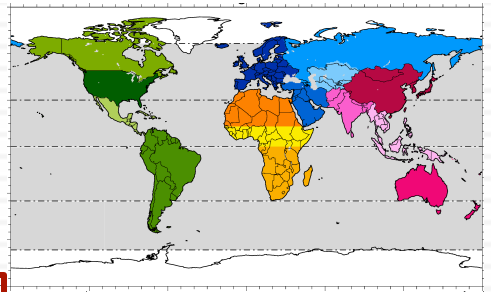


# Comparisons with AERONET – Island sites



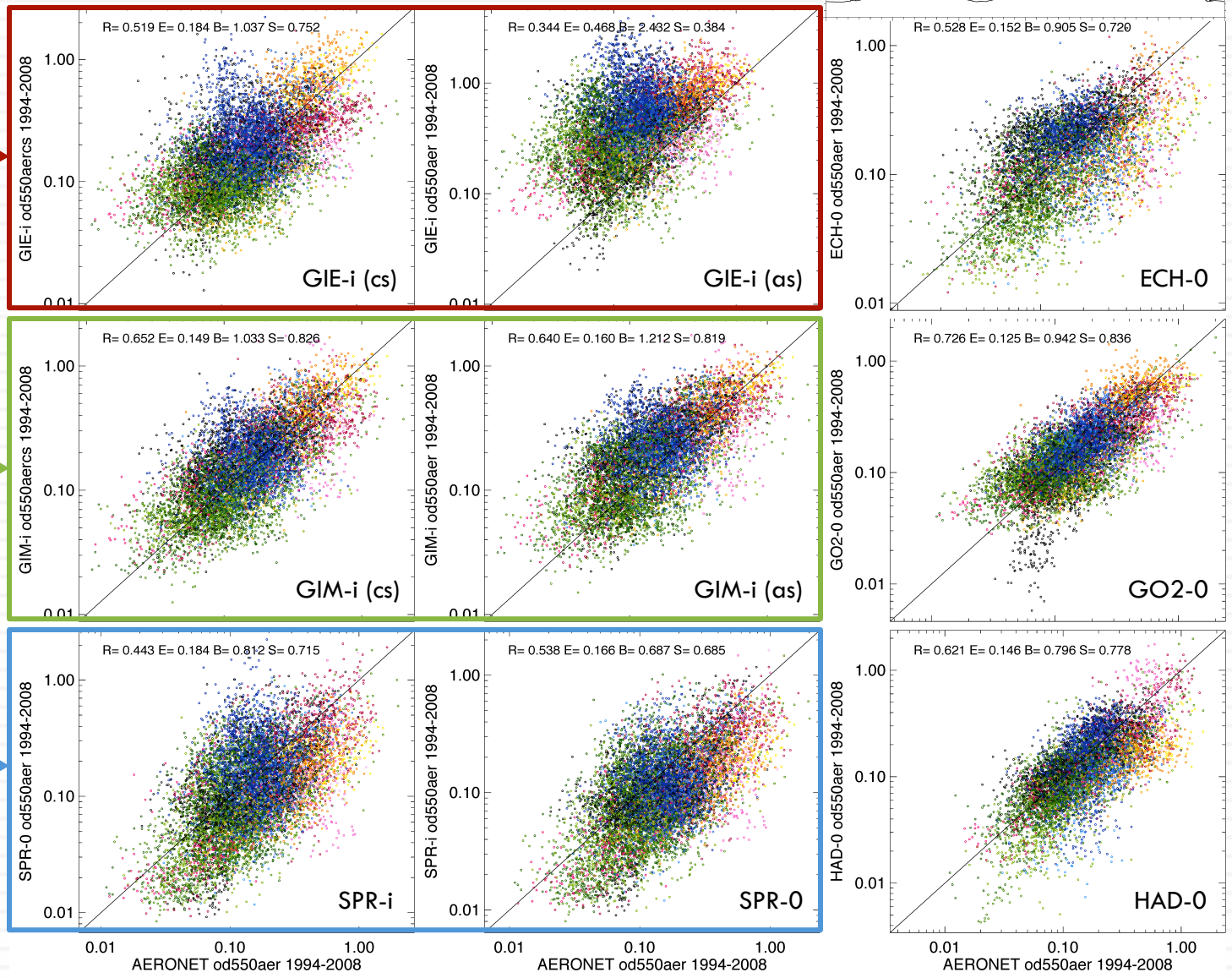
# Scatter plot of monthly AOD: model vs. AERONET at all sites (>200), 1994-2008



Clear sky vs. all sky AOD

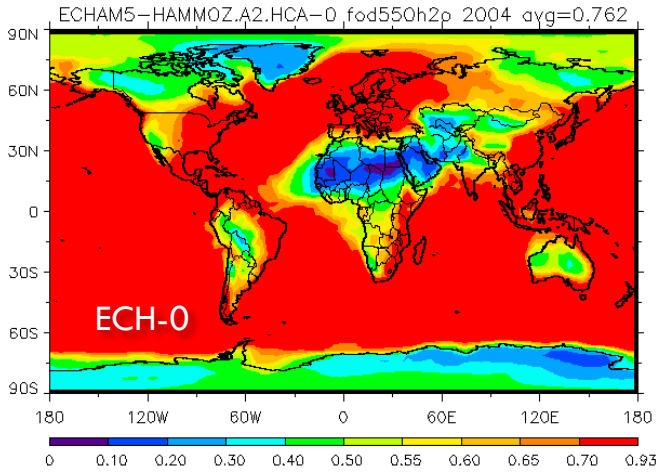
Clear sky vs. all sky AOD

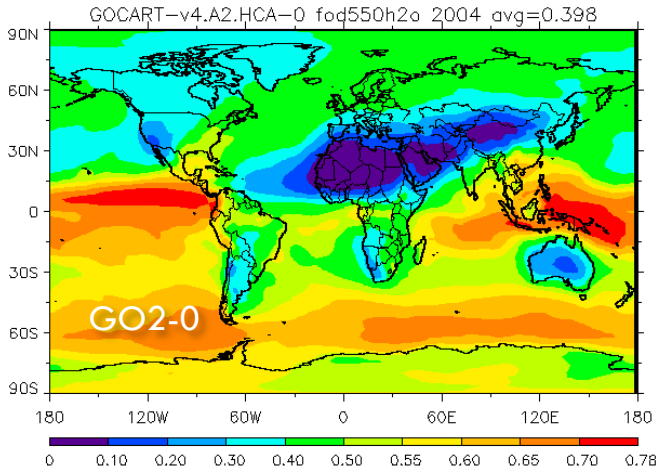
ACCMIP emission vs MAP emission

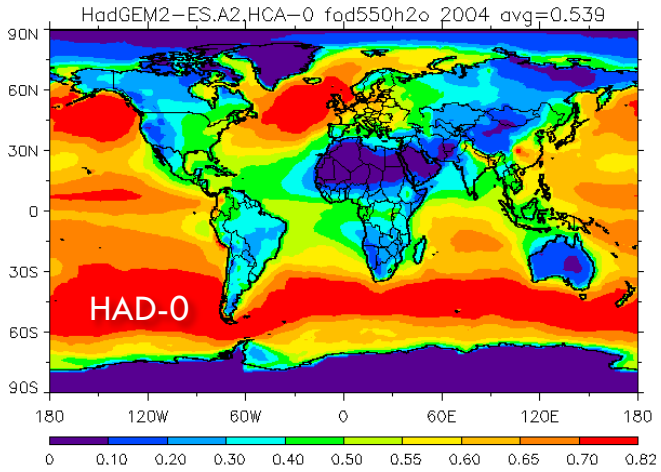


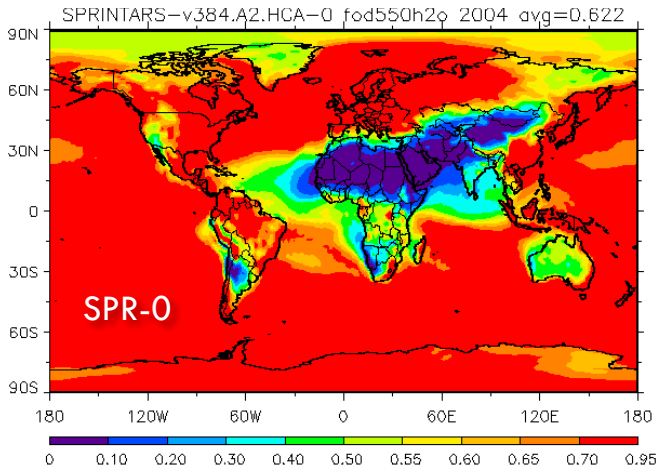
# Differences in fraction of H2O AOD (2004)

- ECHAM5 has the highest fraction of H2O OD (global annual avg=76%) and GOCART has the lowest (40%)
- Over the most of ocean area and some part of land area, ECHAM5 and SPRINTARS contains 70-95% of H2O fraction as AOD



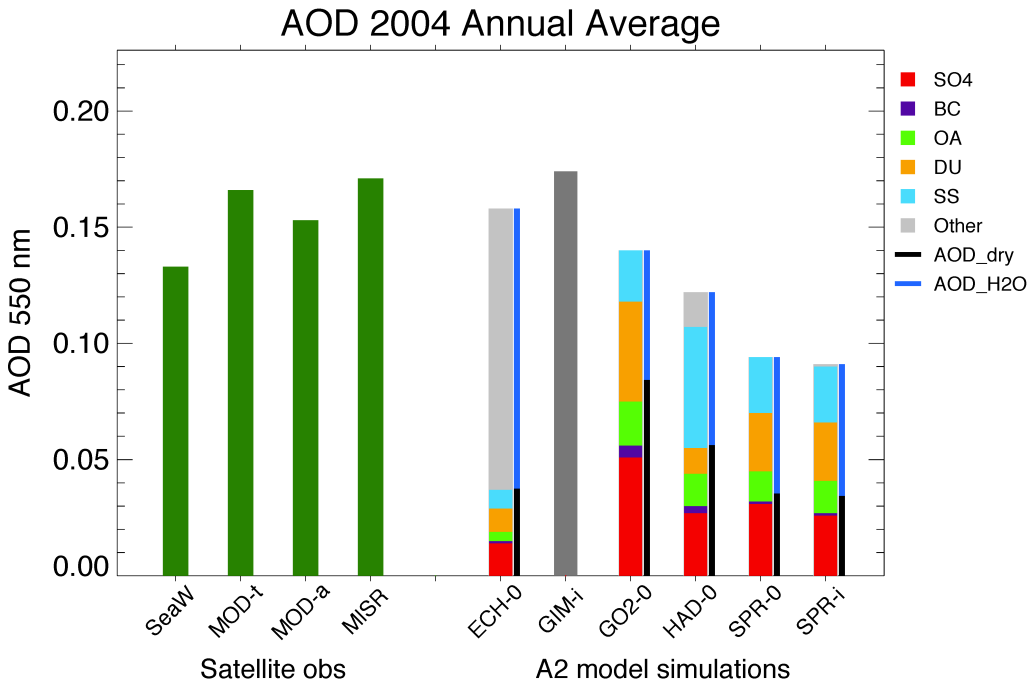



# Comparisons of global annual average AOD

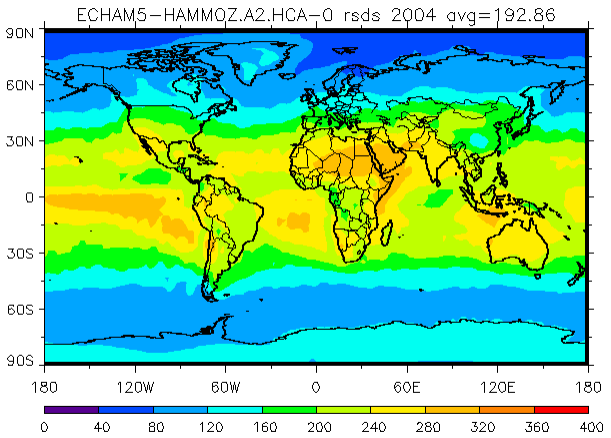
- There are spatial and temporal coverage differences
- The AOD agrees within 70% among the models but the differences in aerosol composition and hygroscopic growth are larger.
- Satellite (and AERONET) AOD data do not provide sufficient constraints on model diversity and processes

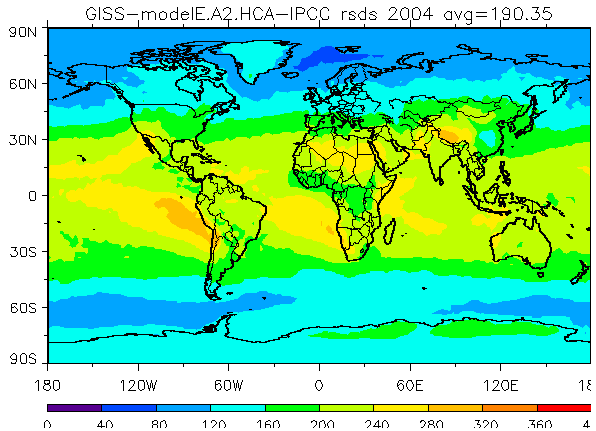


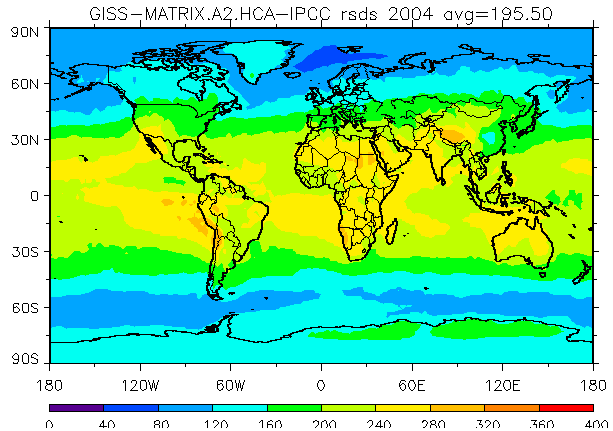

Note: (1) ECH-0 aerosol components are dry AOD
(2) GIM-0 does not have components separated
(3) "Other" includes nitrates and SOA that is not in OA; for ECH-0 it is mostly H2O

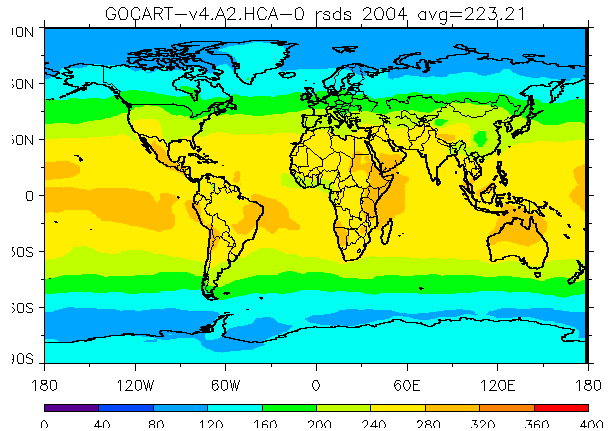
# 2004 Annual avg rsds (shortwave downward rad flux at sufrace, all sky) (W $m^{-2}$)

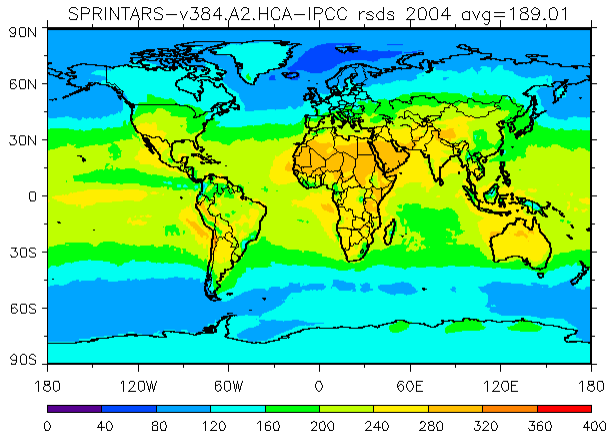
- GOCART all sky rsds is about 30 W $m^{-2}$ higher than the others, most likely due to the cloud fields

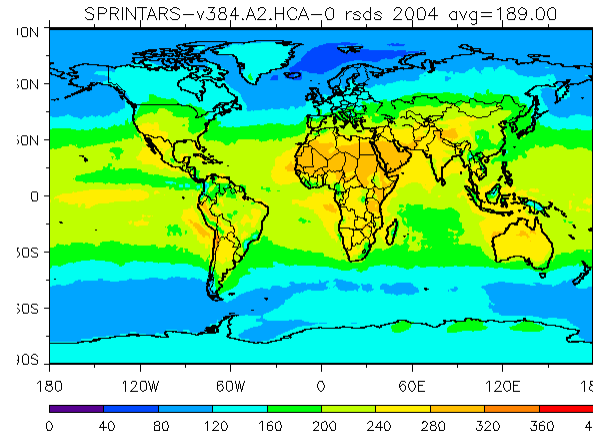


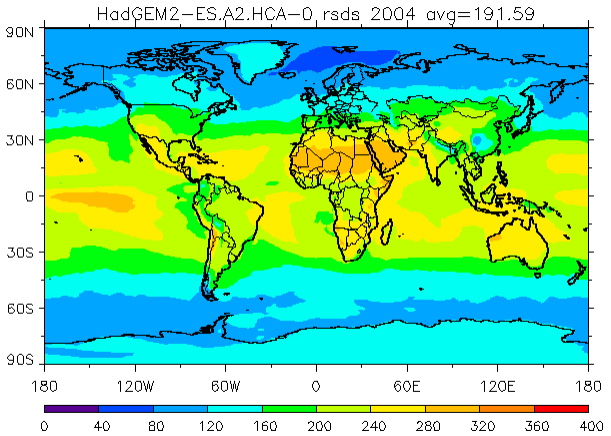



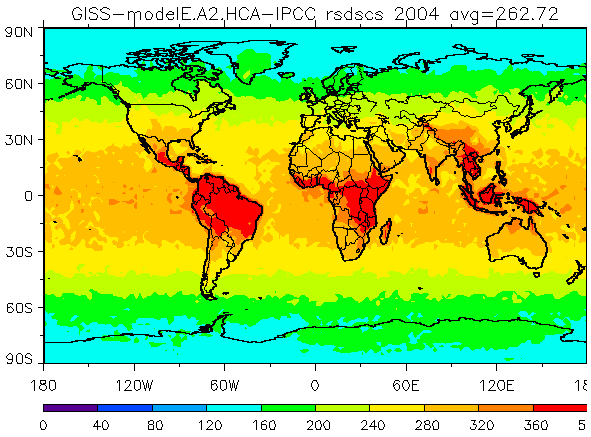



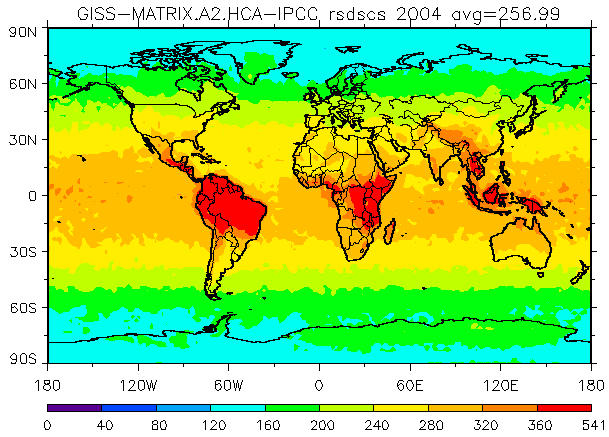



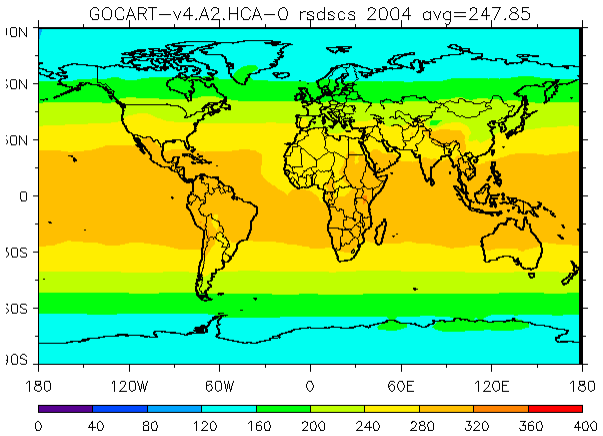
# 2004 Annual avg rsdscs (shortwave downward rad flux at surfrace, clear sky) (W $m^{-2}$)

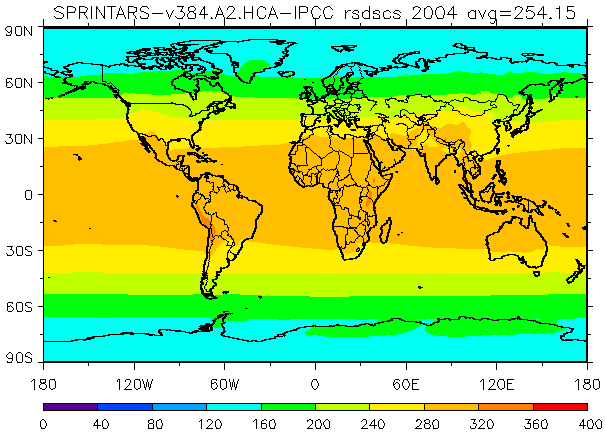
- GISS models have very high numbers over some tropical land areas, which could be higher than TOA. This is because the clear sky rad flux was sampled between clouds, not calculated at cloud-free conditions (instantaneous ensemble, not 24-hour avg)
- Other models are more consistent with each other

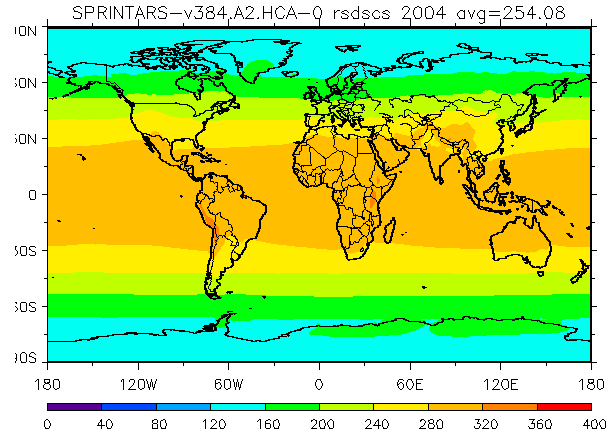
ECH-0 does not have rsdscs saved

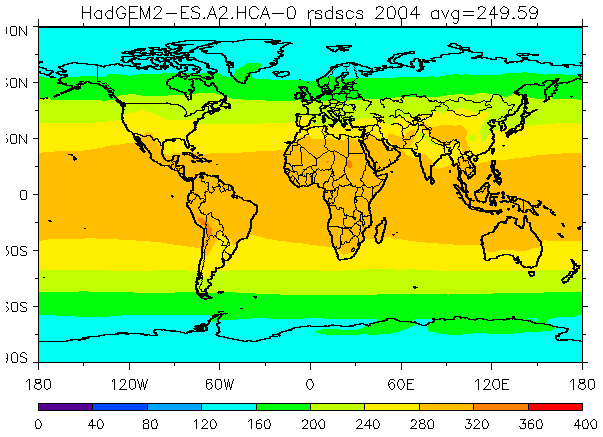


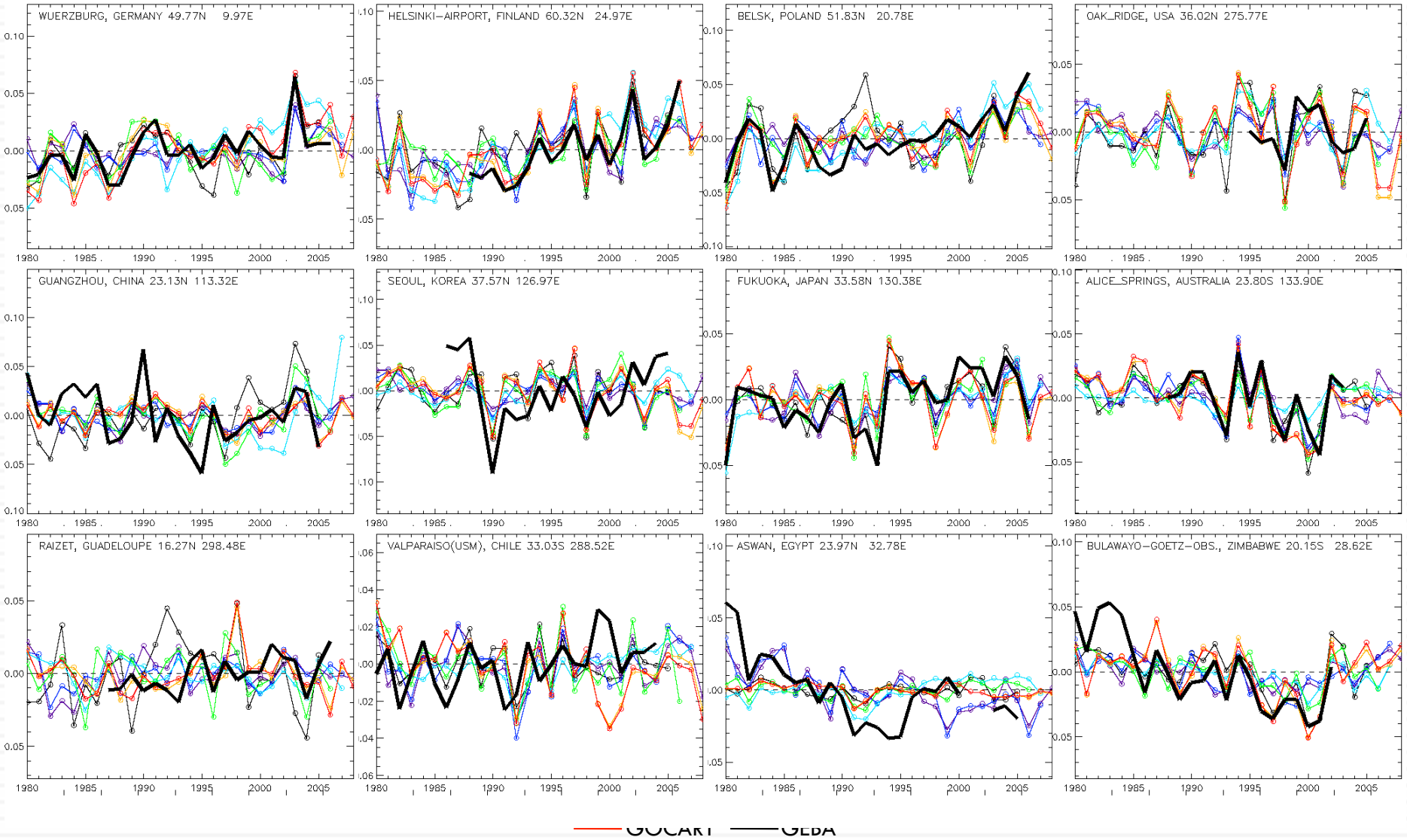



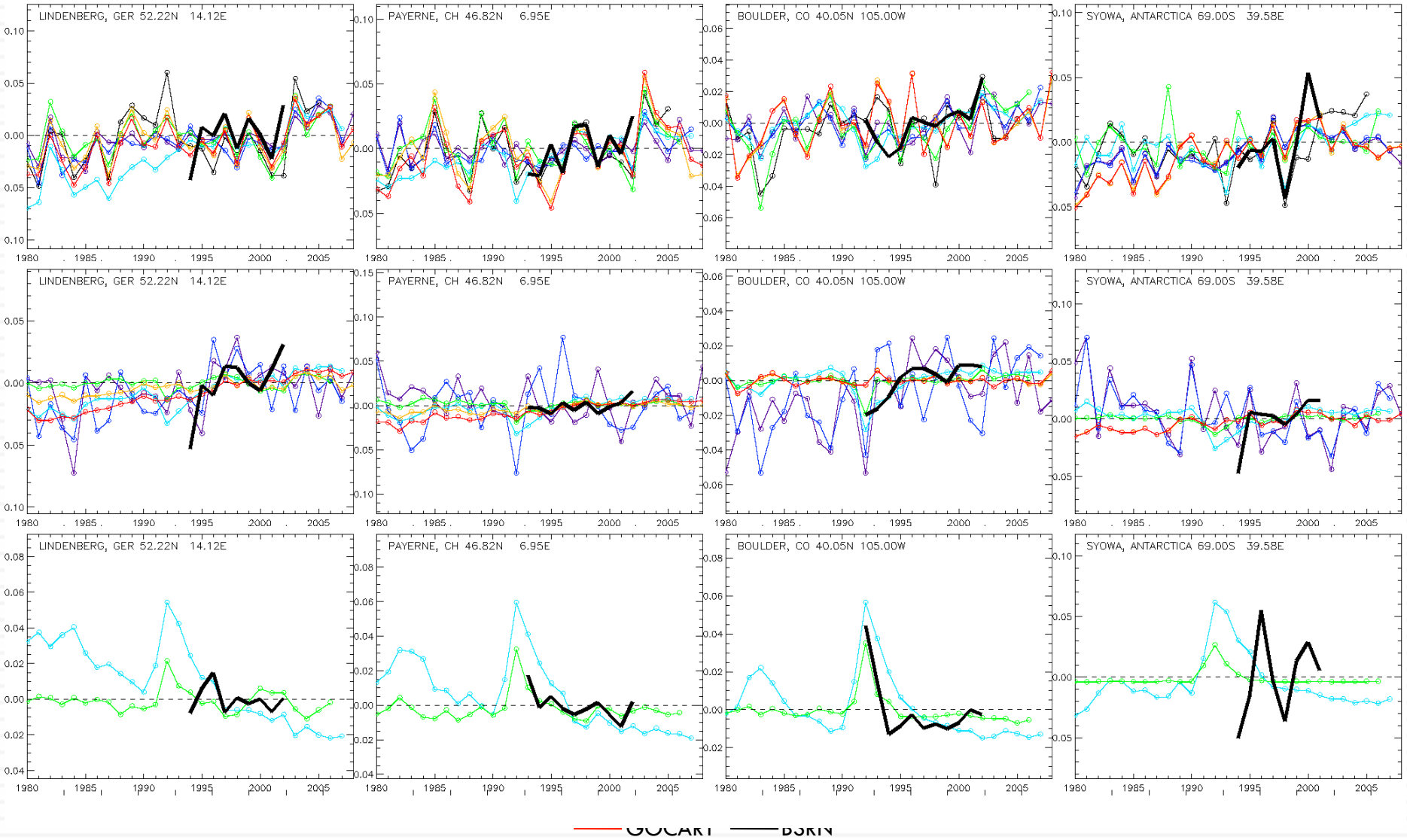
# Comparisons with surface measurements of shortwave downward radiation

- Three networks:
  - GEBA: all sky total radiation, monthly avg
  - BSRN: all sky and clear sky radiation, total, direct, diffuse, daily
  - CMA: all sky and clear sky radiation, total, direct, diffuse, daily
  - Satellite-based data from ISCCP and SRB are not used for trend study, because they are "tuned" to get the radiation right but not the trends, thus not appropriate for our study
- However the model output are monthly average, thus hindering the possibility of comparisons in clear sky conditions due to the sampling of clear sky (not appropriate to use the monthly average clear sky), and most model does not have diffuse or direct radiation fields submitted
- Therefore, the comparisons between model and observations are performed as follows:
  - Using all sky total downward radiation at the surface (rsds), monthly average fields and averaged to annual mean for trends
  - Normalized to TOA flux (rsds/rsdt) to get rid of the uneven measurement availability through the seasons
  - Trends are shown as annual average deviation from the multi-year means (i.e. anomaly) to minimize the differences in model/observed cloud and radiation fields

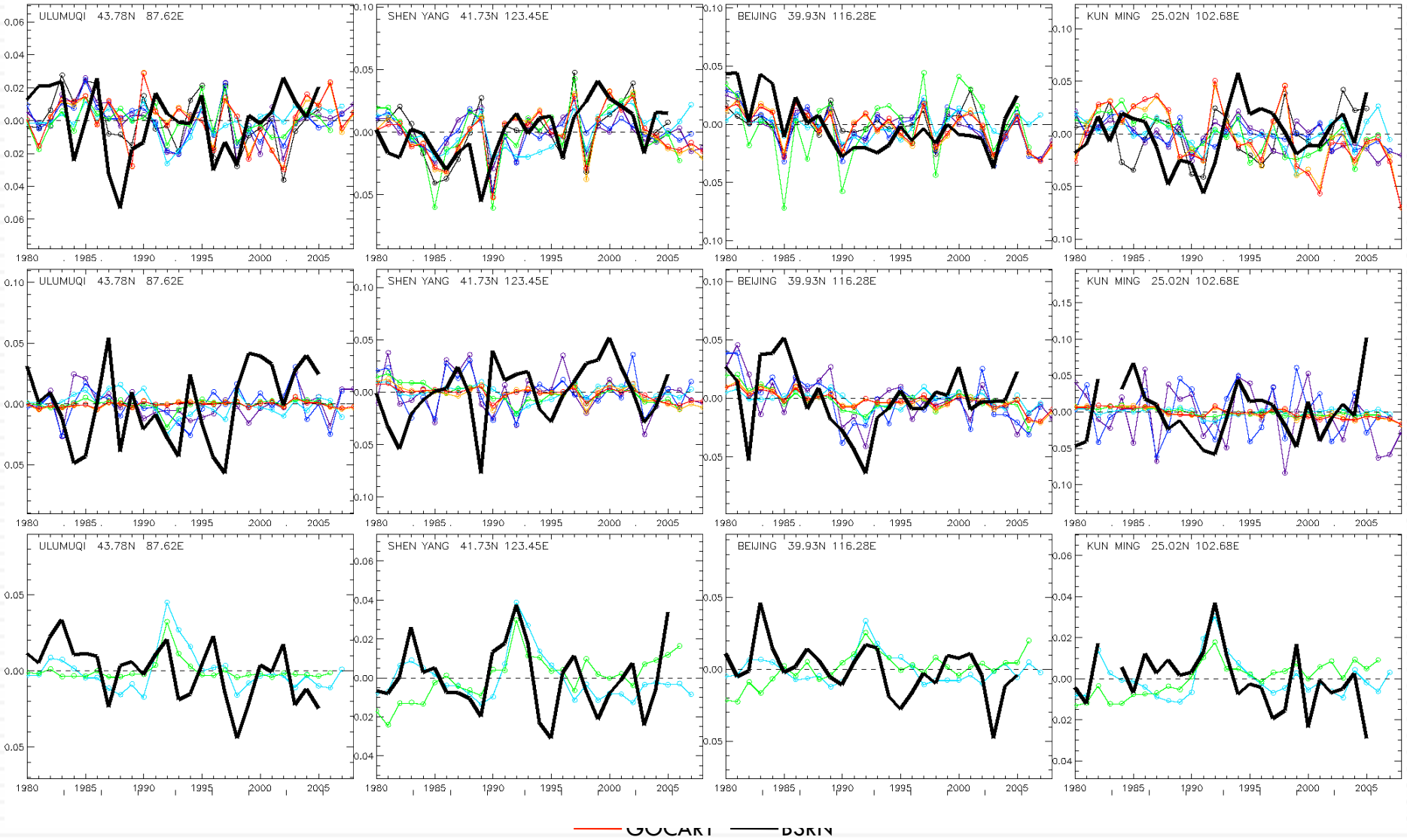
# Comparisons of anomaly of surface/toa SW downward radiation with GEBA (all-sky total)



# Comparisons of anomaly of surface/toa SW downward radiation with BSRN (all-sky total, clear-sky total, clear-sky diffuse)



# Comparisons of anomaly of surface/toa SW downward radiation with CMA (all-sky total, clear-sky total, clear-sky diffuse)



# Thoughts

- "All models are wrong, but some are useful. The practical questions is how wrong they have to be to not be useful."
  – George Box
- How should we assess/verify all-sky AOD and water fraction of AOD
- What is the correct way to compare with satellite data
- How can we reconcile between surface aerosol species concentrations, column AOD, and vertical shape
- Does global average AOD mean anything
- Need rsdscs and rsdscsdif to assess aerosol effects on surface dimming/brightening

# What should we do next?