Multi-decadal variations of atmospheric aerosols and their effects on surface radiation trends

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Introduction

- Long-term observations of surface downward solar radiation have shown a wide-spread trends from dimming to brightening in the past 50+ years over Europe, North America, China (e.g., Wild et al. 2005; Qian et al., 2006)

- Various explanations have been given, with special attention given to aerosols since the anthropogenic emission trends of aerosol and precursor gases mirror the change of surface radiation (Streets et al., 2006, 2008)

- However, the link of the changes of anthropogenic emission and surface radiation is not straightforward because of the complex atmospheric processes especially the interactions of aerosol and clouds

- This work attempts to investigate the aerosol trends in the modern era (1980 to present) and assess the role of aerosol effects on surface radiation using satellite data, ground-based observations, and a global model

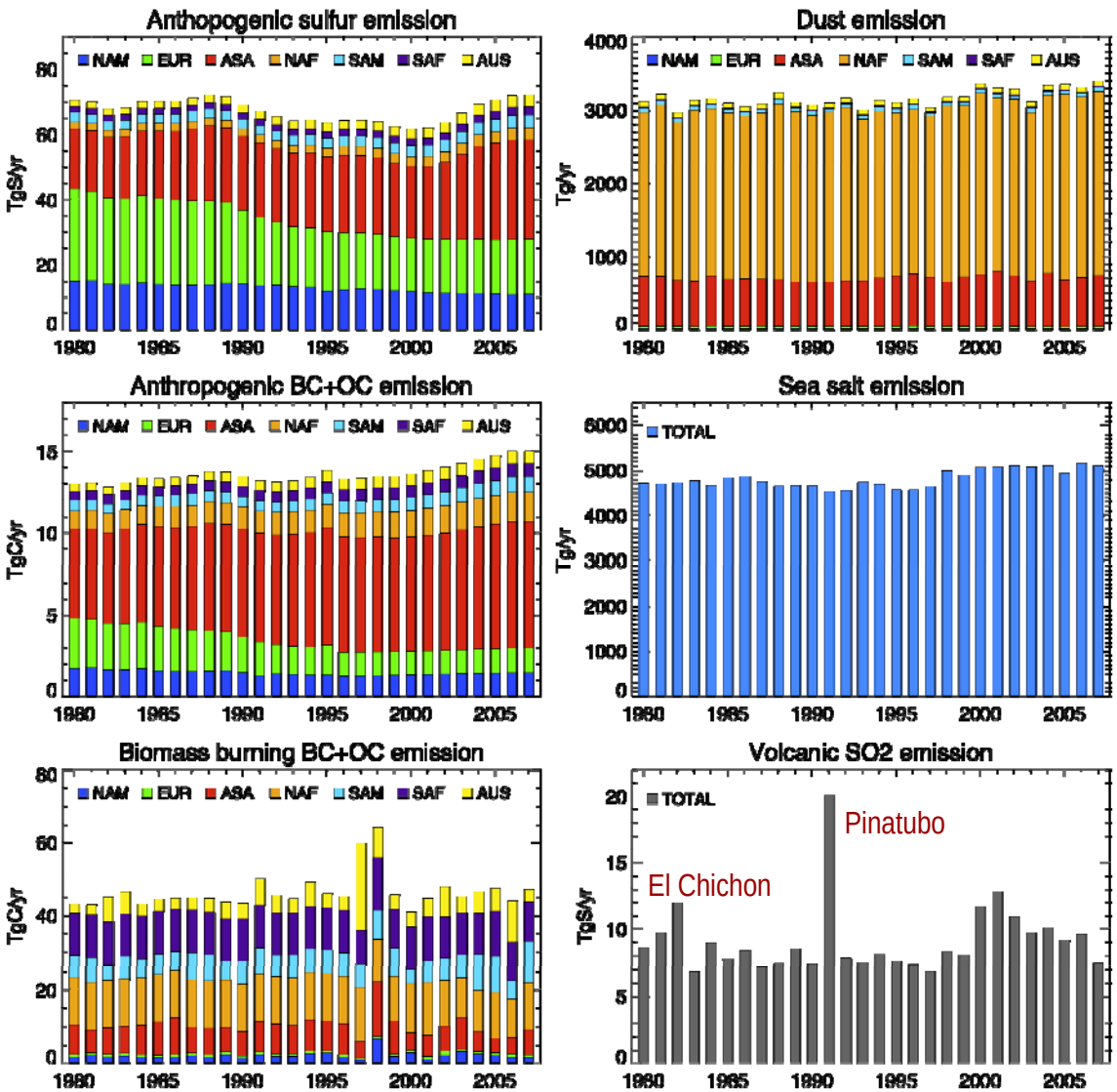
Model and observations

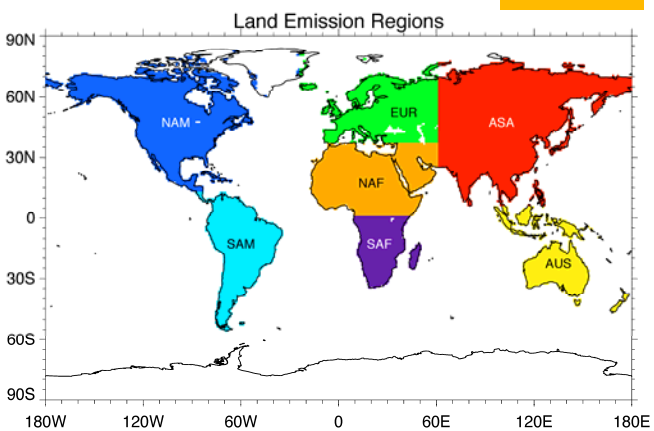
- Model: GOCART – global aerosol chemistry and transport model using the assimilated meteorology from GEOS-DAS, with sulfate, dust, BC, POM, and sea salt simulated
- Satellite observations: AOD from AVHRR (two different retrievals from NOAA and GISS), MODIS, and MISR
  - Limitations: MODIS and MISR only available since 2000
  - AVHRR only covers ocean
- Surface radiation data: Global Energy Balance Archive (GEBA) network (annual average, total SW downward total flux, all sky), Baseline Surface Radiation Network (BSRC, daily, total/diffuse/direct), and China Meteorological Administration (CMA, daily, total/diffuse/direct)

Today's talk:

- Showing multi-decadal variations of AOD from 1980 to 2007 from GOCART simulations and satellite data on global and regional scales
- Comparing model simulated short-wave radiative flux at the surface with the CMA data (preliminary results)
- Discussing the possible role of aerosols on the multi-decadal variation of surface radiation change – your feedback is appreciated!

Anthropogenic and natural emissions of aerosols and precursors – 1980 to 2007

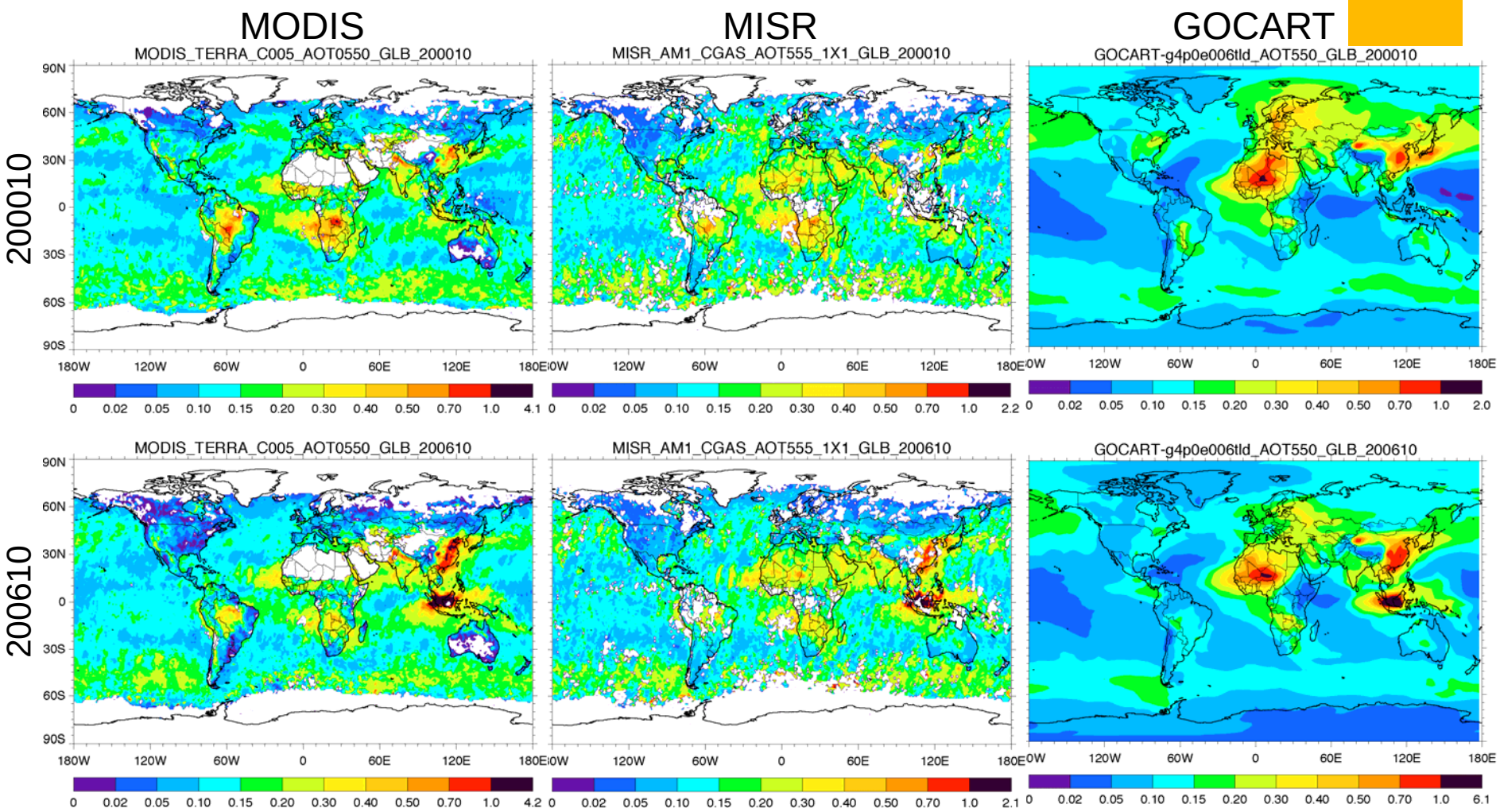




Anthropogenic emissions:
- North America and Europe – decreased
- Asia and other regions – increased

Biomass burning and natural emission:
- Varying from year to year (and place to place)

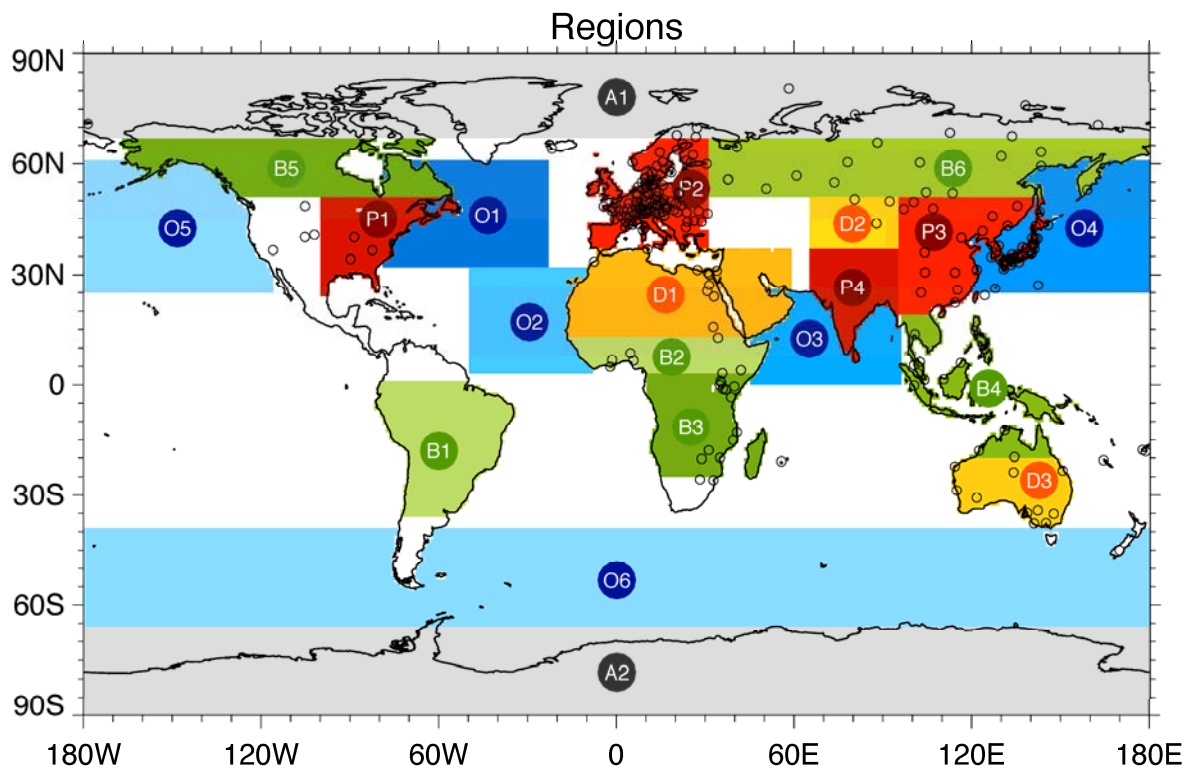
Global distribution of AOD



Comparisons between 200010 and 200610:

- Pollution regions: N. America & Europe decreased, Asia increased
- Biomass burning: Large fire in Indonesia in Oct 2006

Global and regional aerosol trends – comparisons of AOD between model and satellite data



21 regions:

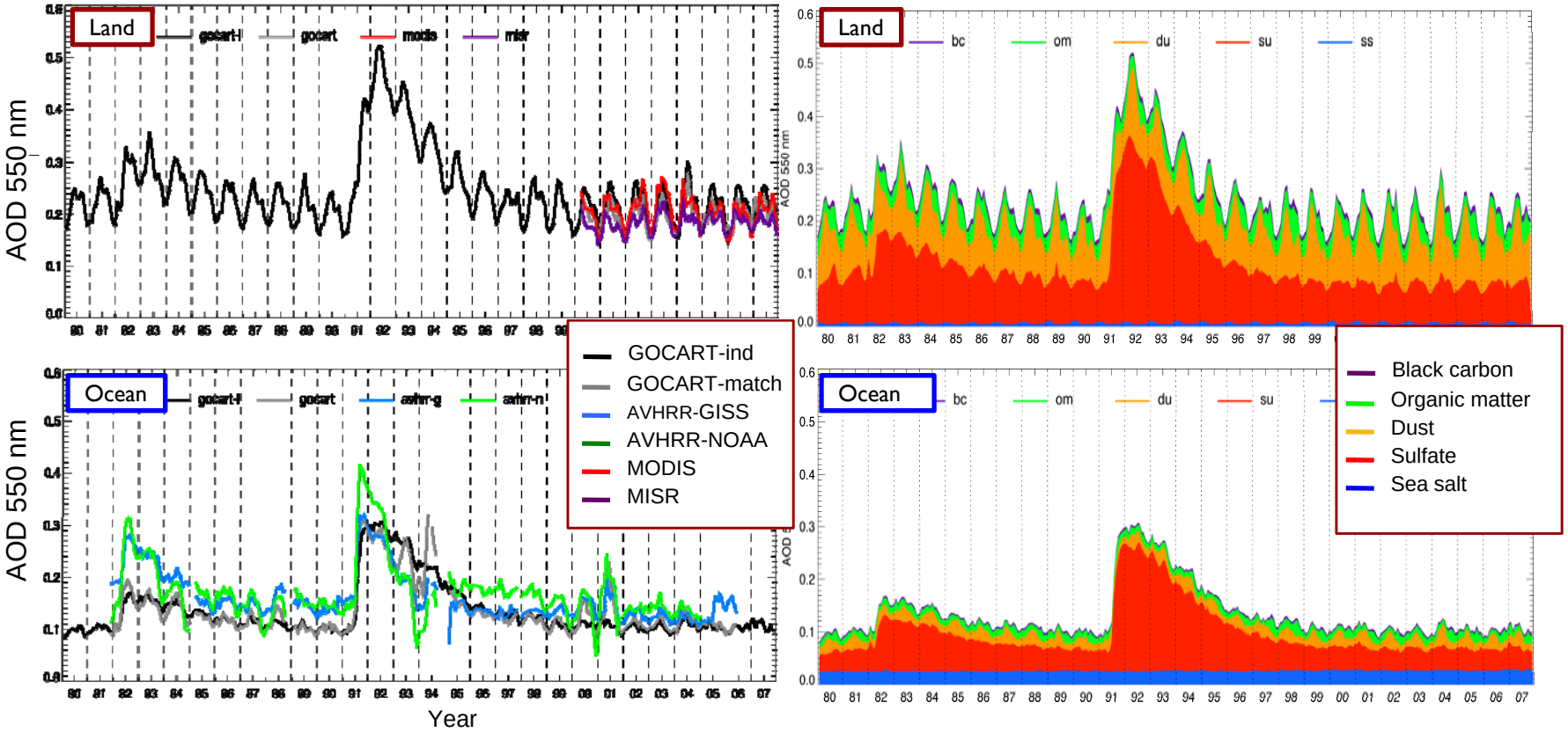
- 4 pollution (P)
- 6 Biomass burning (B)
- 3 Dust/mixed (D)
- 6 Oceanic (O)
- 2 polar (A)

Open circles are locations of 260 GEBA surface radiation sites

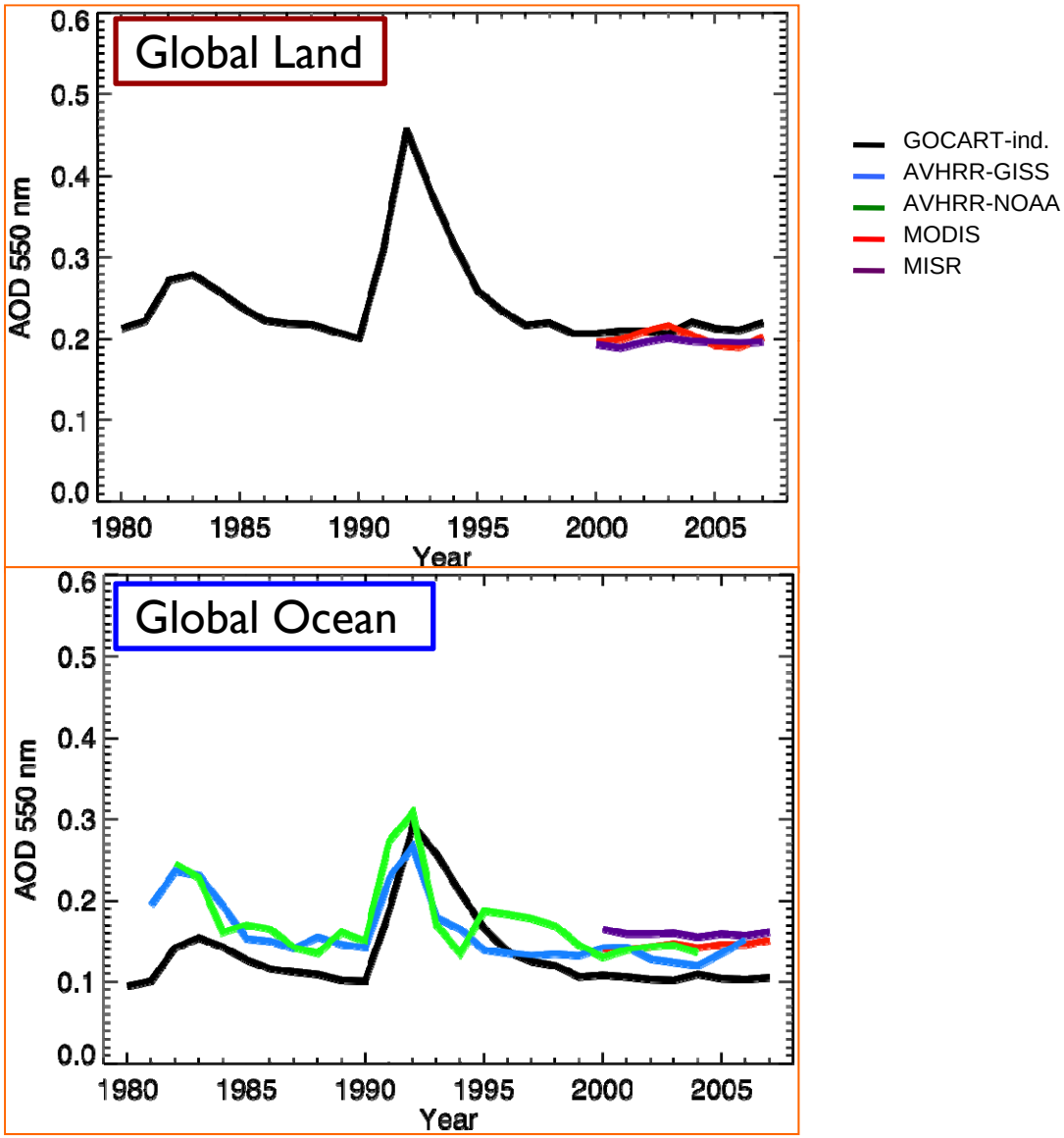
Multi-year variations of AOD – Global land and ocean

Comparisons of monthly mean AOD from co-located satellite data and model

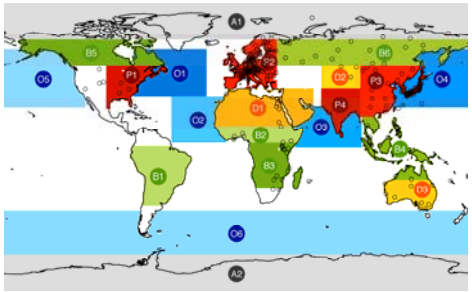
GOCART aerosol composition

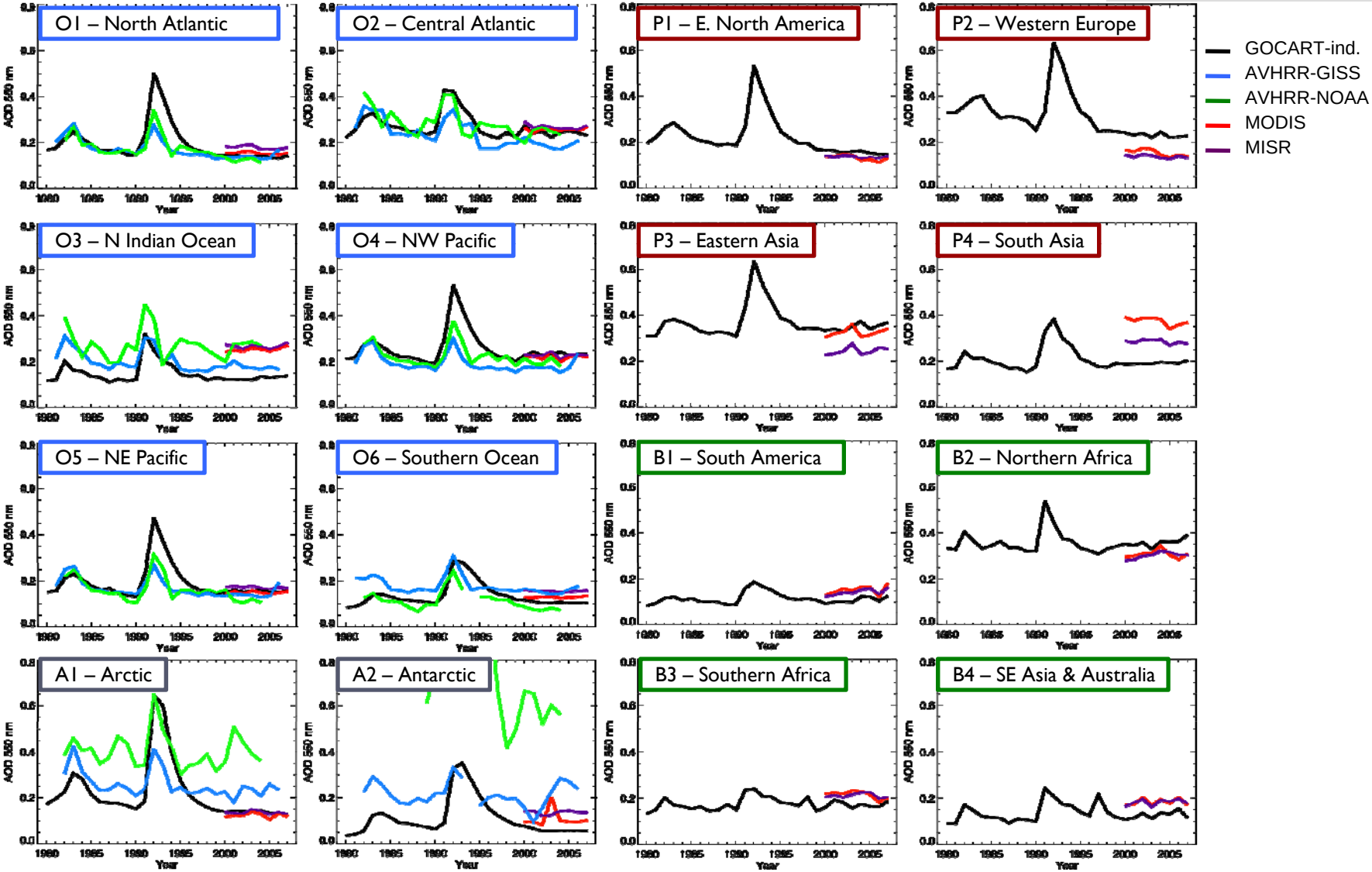


Multi-year variations of AOD – Global land and ocean annual average

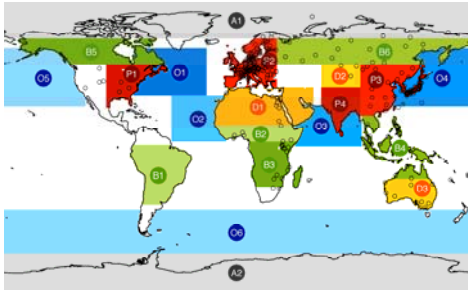


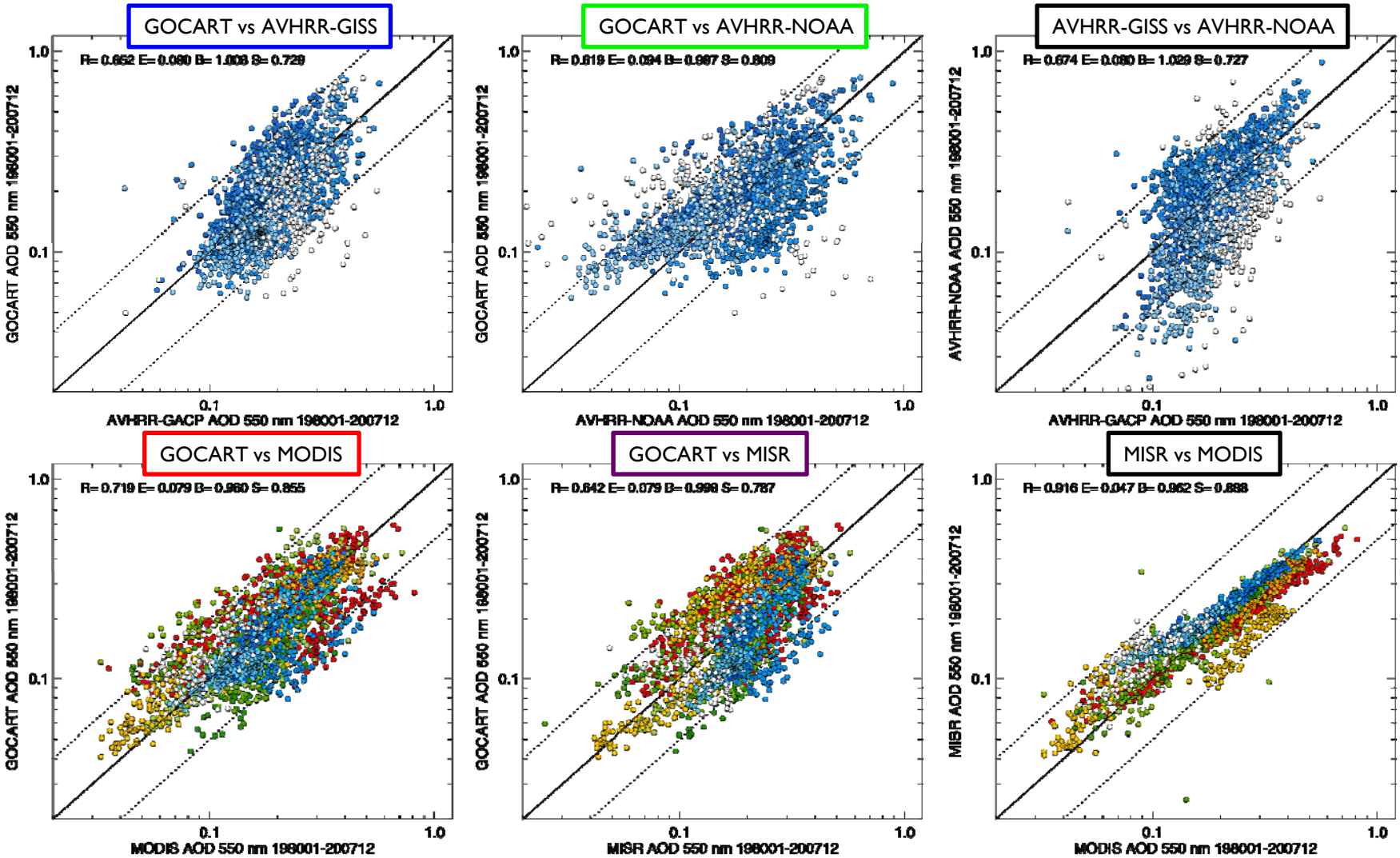
Multi-year variations of AOD – Regional





Overall comparisons of AOD (monthly avg, 198001-200712)

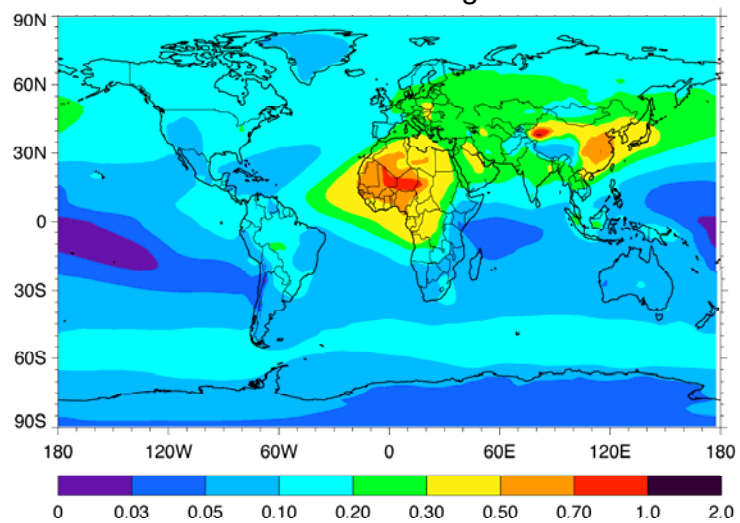




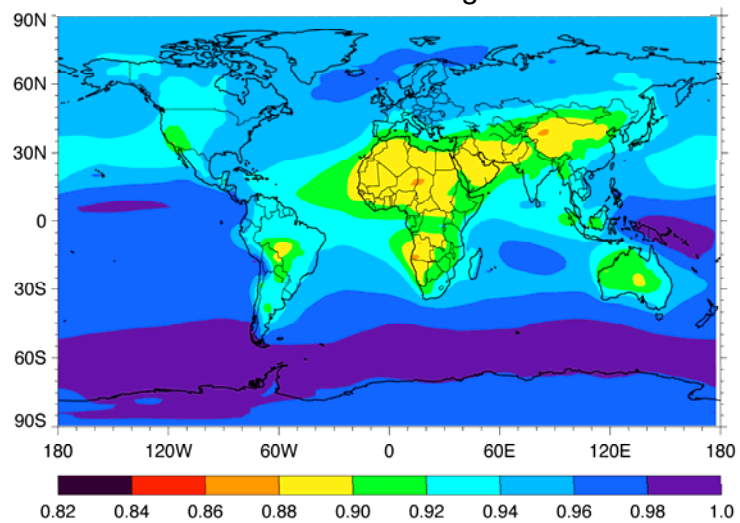
Calculation of surface radiation

- Modeled AOD, single scattering albedo, and asymmetry factor interfaces with the Goddard radiative transfer model
- Climatological CO_2 and ozone from the Goddard models using the same meteorological data as GOCART, and clouds and water vapor from the GEOS-DAS
- We us the all-sky SW downward flux at the surface for comparison with GEBA, BSRN, and CMA data

GOCART 2000-2007 average AOD 550 nm

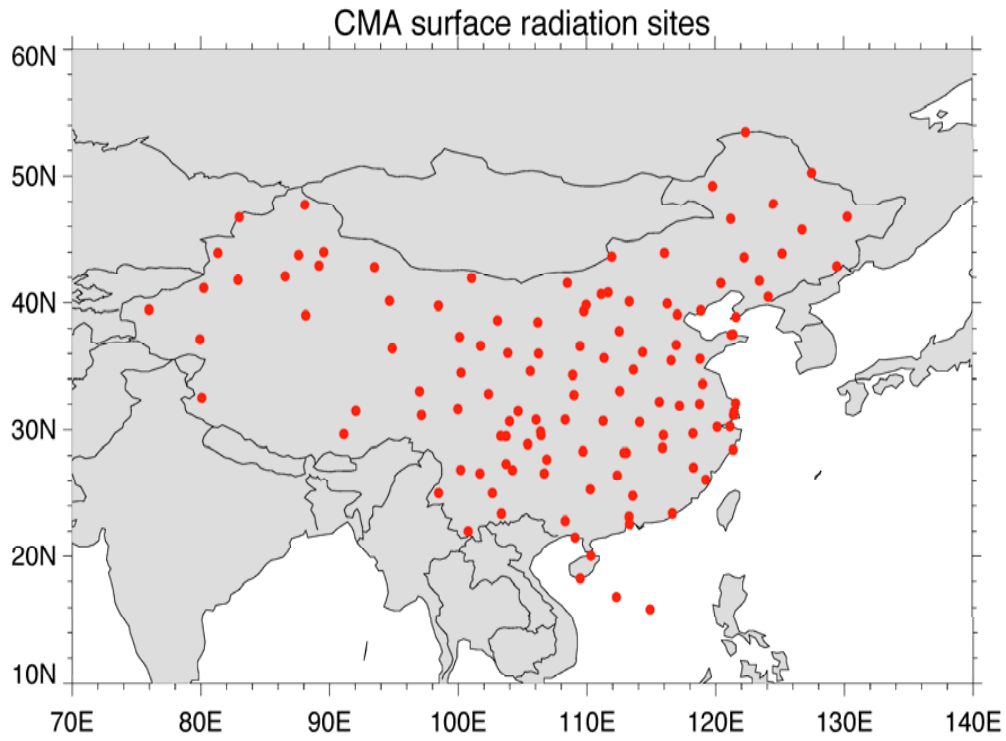


GOCART 2000-2007 average SSA 550 nm

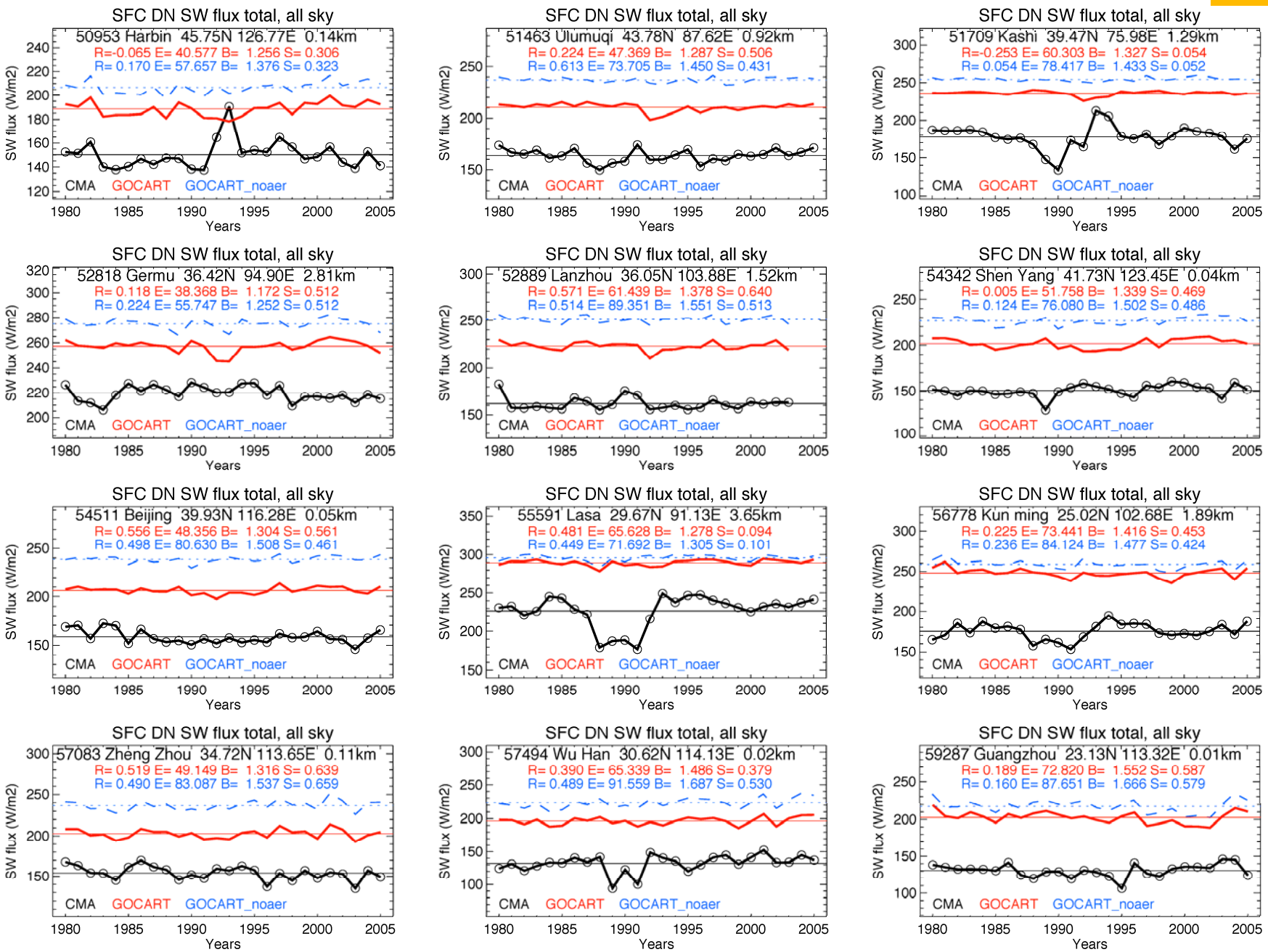


Comparison with surface radiation data from China Meteorological Administration (CMA) sites

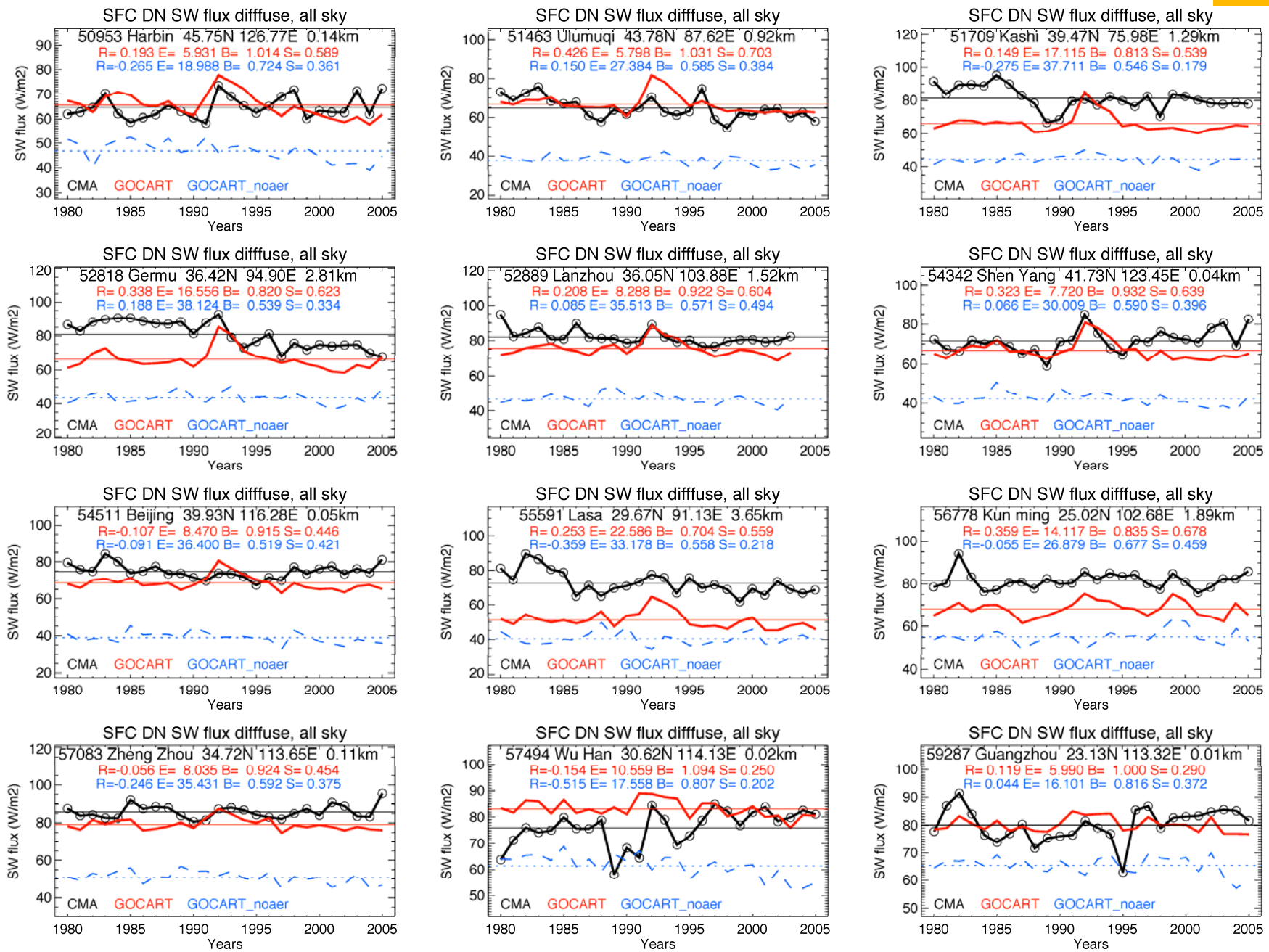
- 122 sites measuring daily total downward SW flux during 1980-2005 timeframe
- Only 13 of them have separate measurements of total, diffuse, and direct radiative flux data continuously from 1980 to 2005
- We mask "clear sky" with observed cloud fraction less than 10%



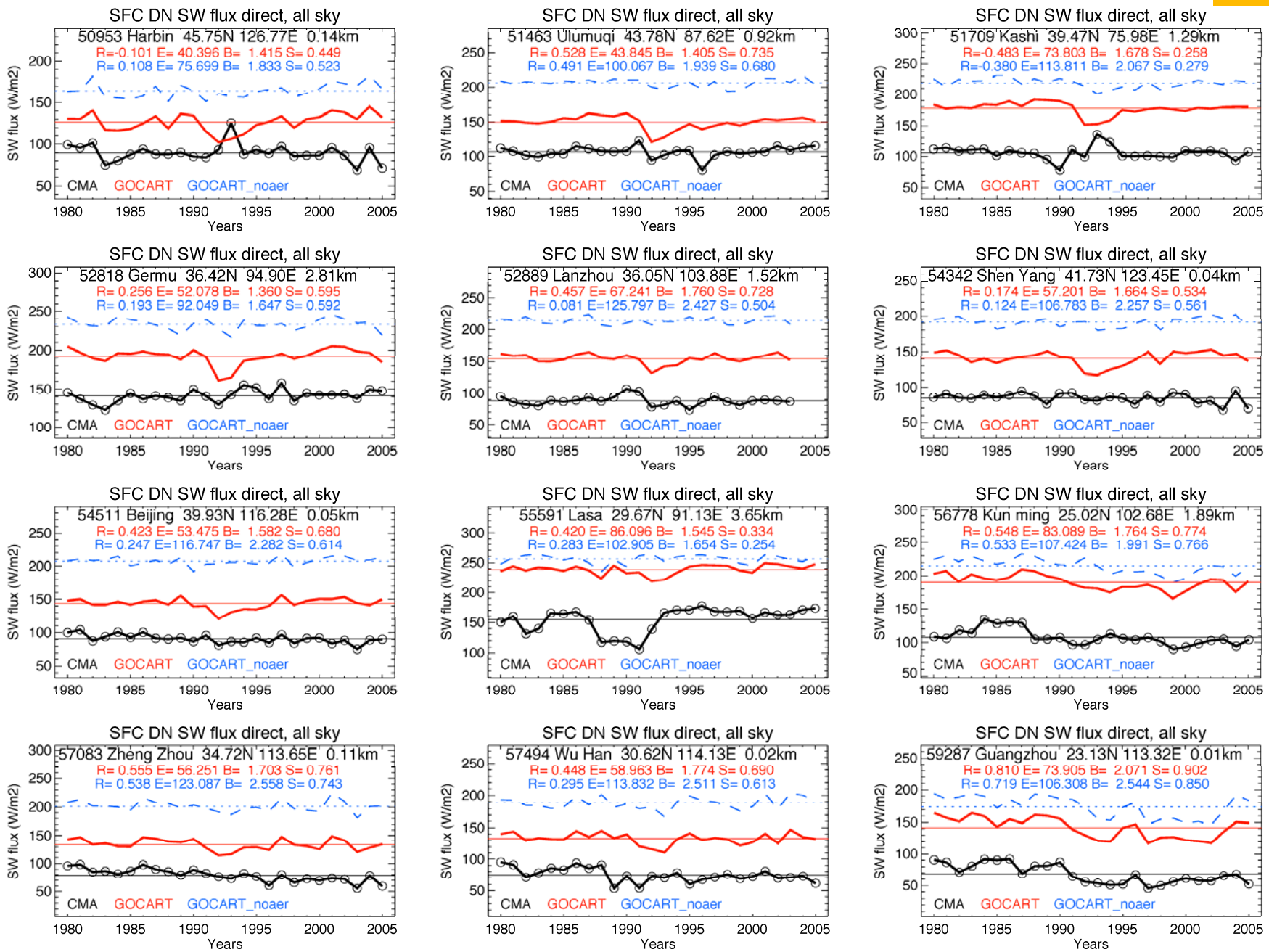
Total SW downward flux, all sky – model 40-60 W/m^2 higher



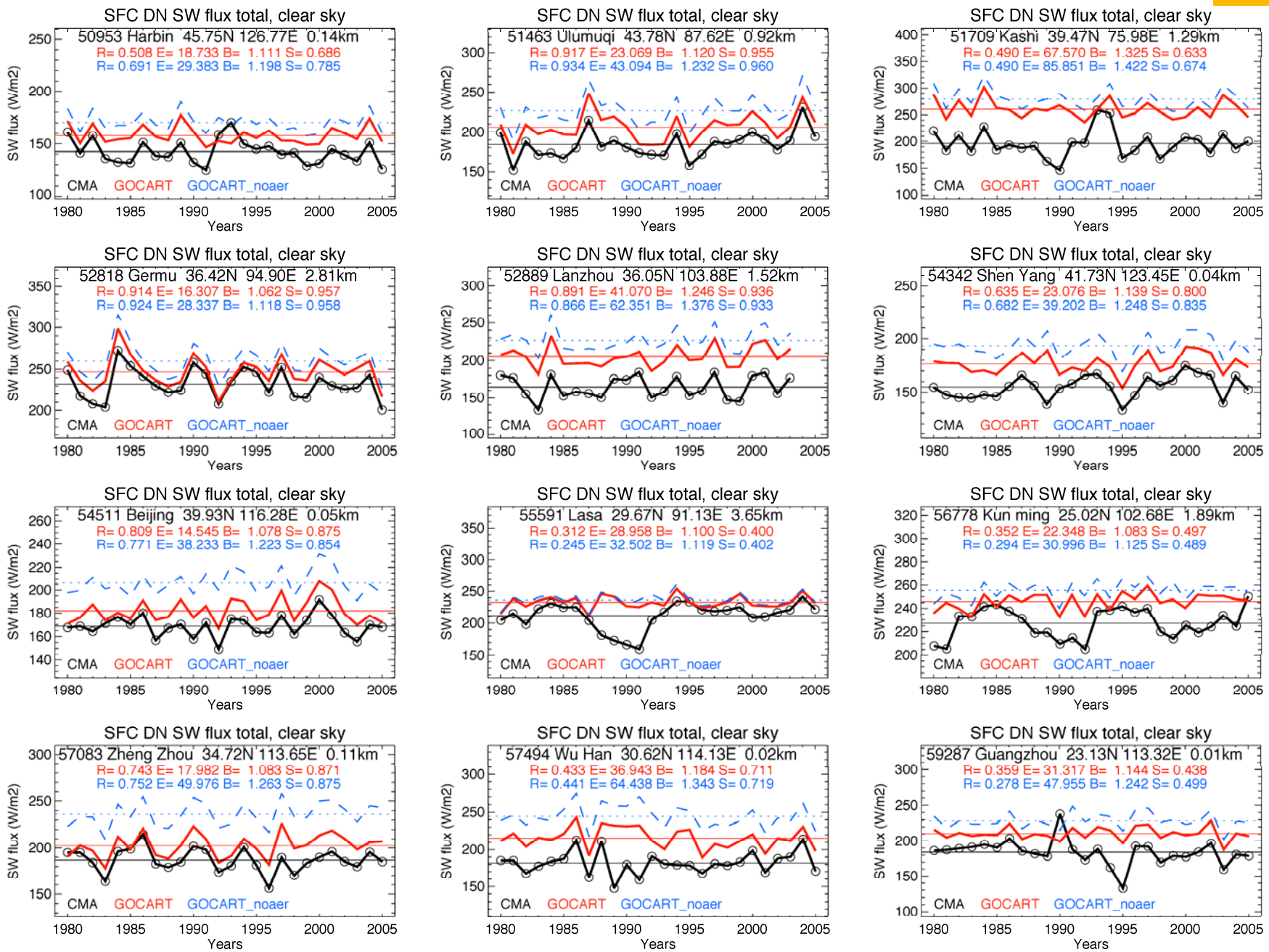
Diffuse SW downward flux, all sky – model 0-20 W/m^2 lower



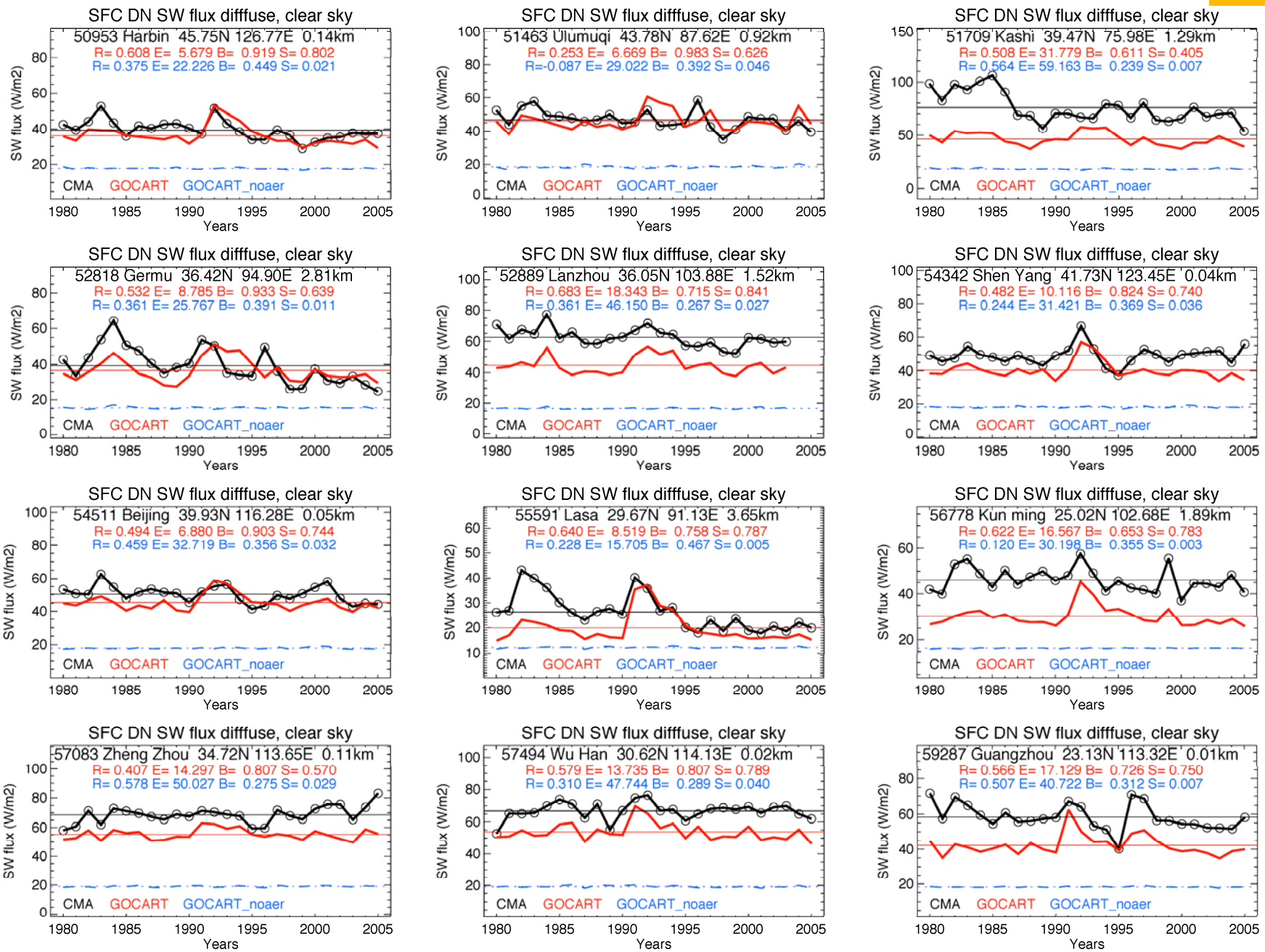
Direct SW downward flux, all sky – model 50-90 W/m^2 higher



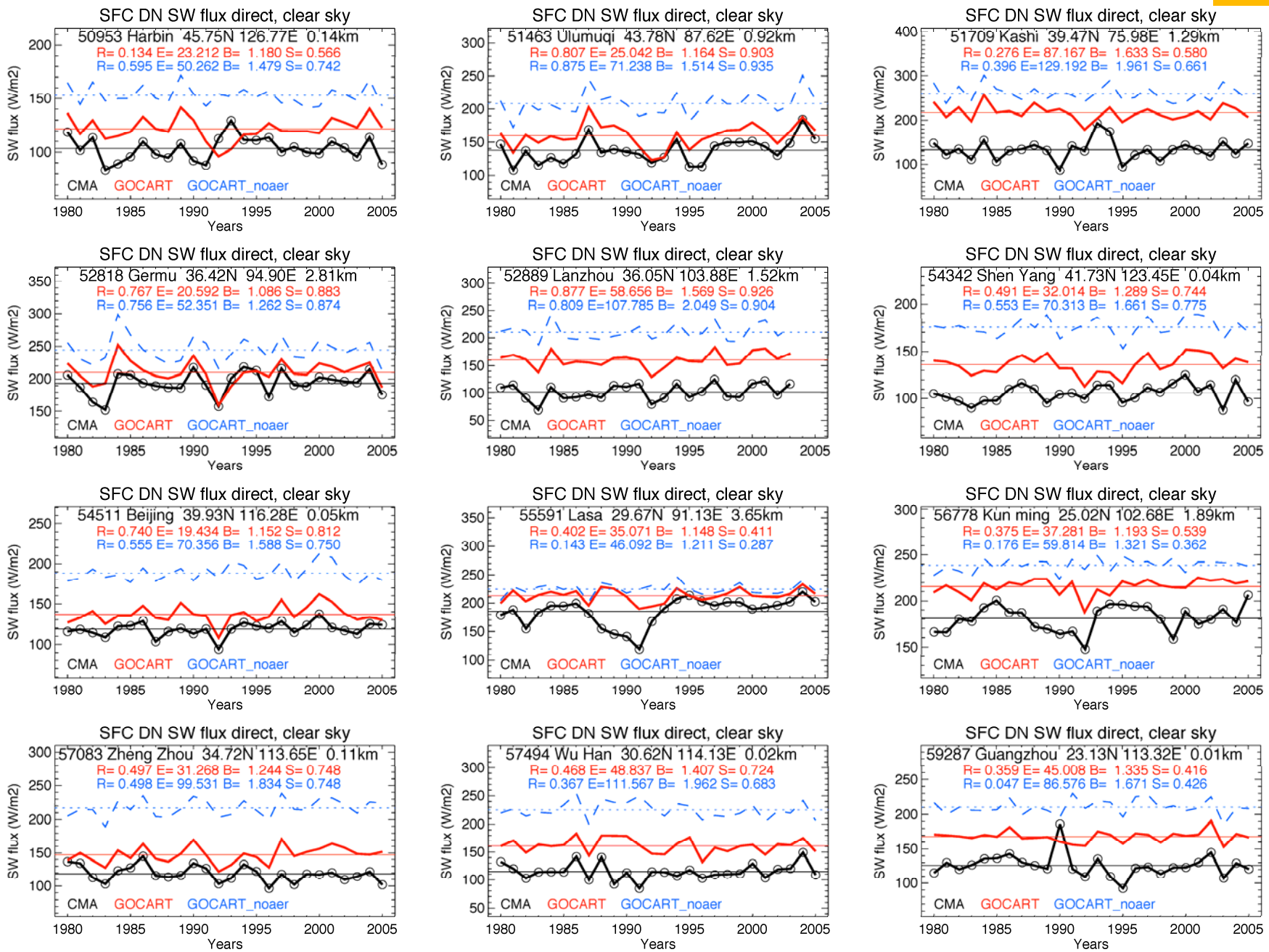
Total SW downward flux, clear sky – model 10-50 W/m^2 higher



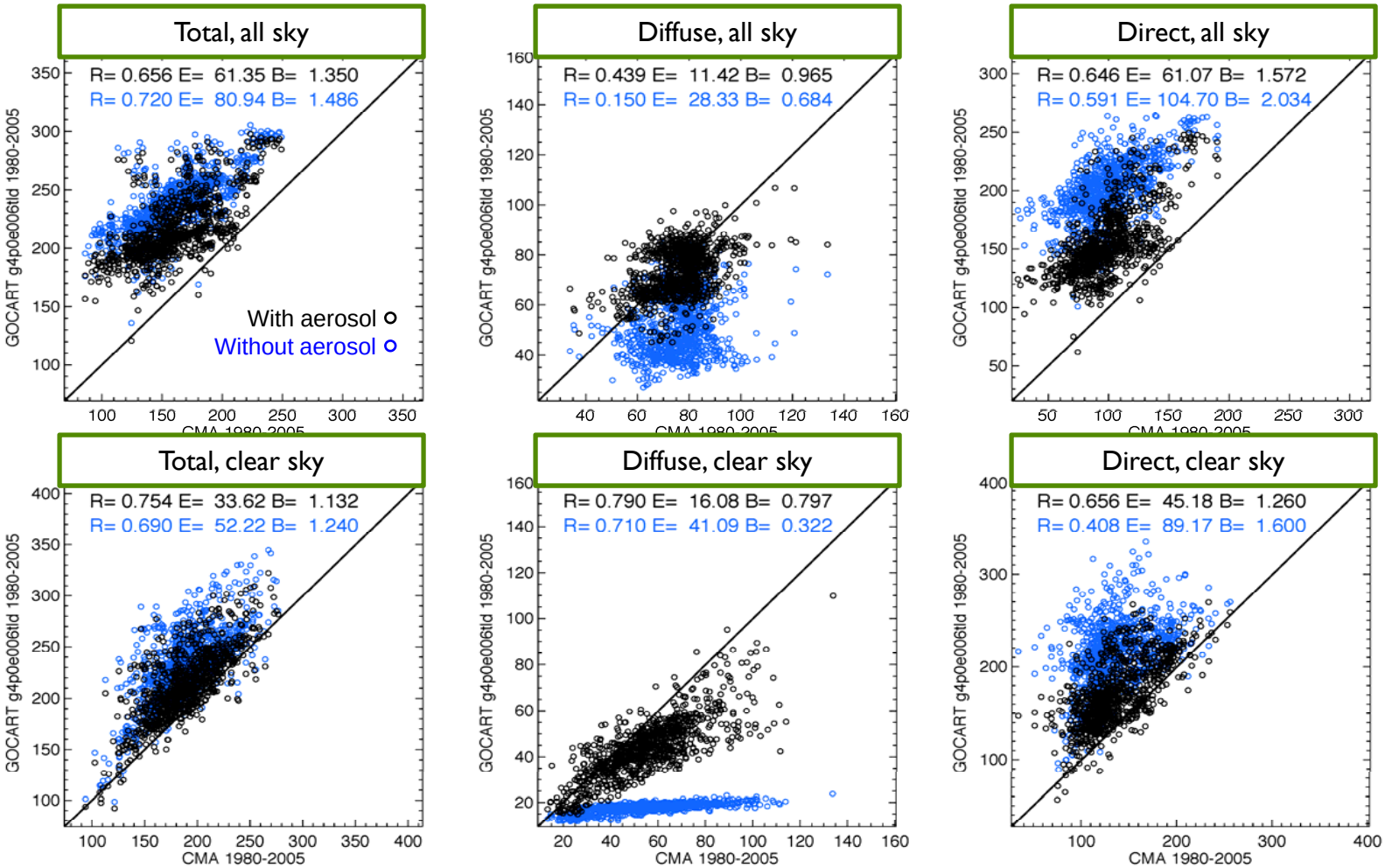
Diffuse SW downward flux, clear sky – model 0-25 W/m^2 lower



Direct SW downward flux, clear sky – model 20-50 W/m^2 higher



Over all comparison…



Remarks

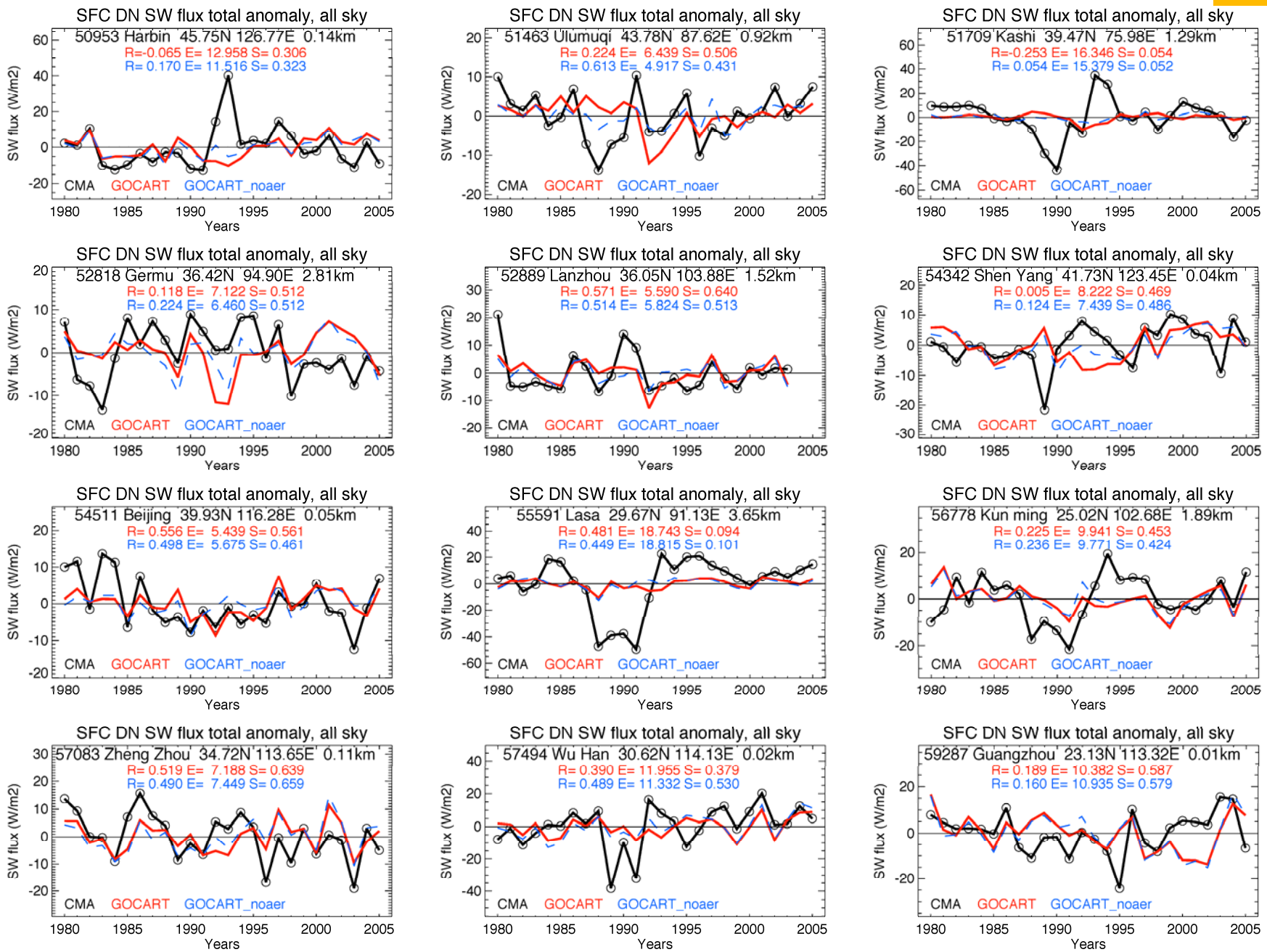
- With seasonal and interannual variation of anthropogenic, biomass burning, and natural emissions, the model simulated global distributions of AOD and its multi-decadal variations agree with different satellite observations within a factor of 2
- Comparison with surface downward radiation data over China shows
  - Total SW downward flux at surface is too high from the model, especially under all-sky condition
  - This overestimate is mainly due to the overestimate of direct radiation
- Aerosol attenuates the direct radiation but amplifies the diffuse radiation
- However it is difficult to deduce a general, clear "trend" of surface radiation over Asia despite clear increasing trends of anthropogenic emissions of aerosols and precursors

Next steps

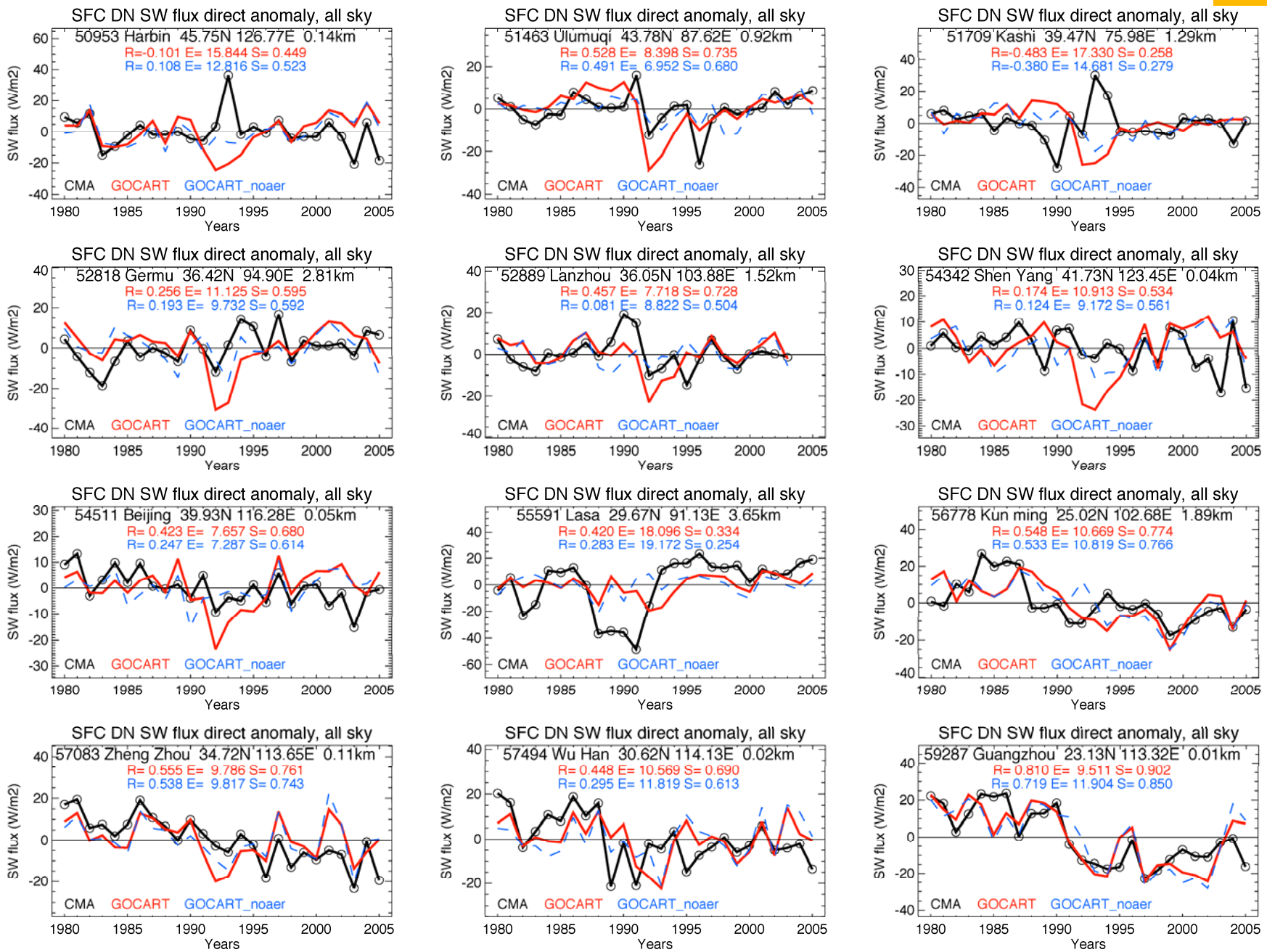
- Quality screening of CMA data
- Comparisons with BSRN data (28 stations in different world geographic locations) and GEBA data (many stations mostly in Europe, but only total all sky data)
- Understanding the model bias
- Examination of the relationships between emission, AOD, and radiation

Backup slides

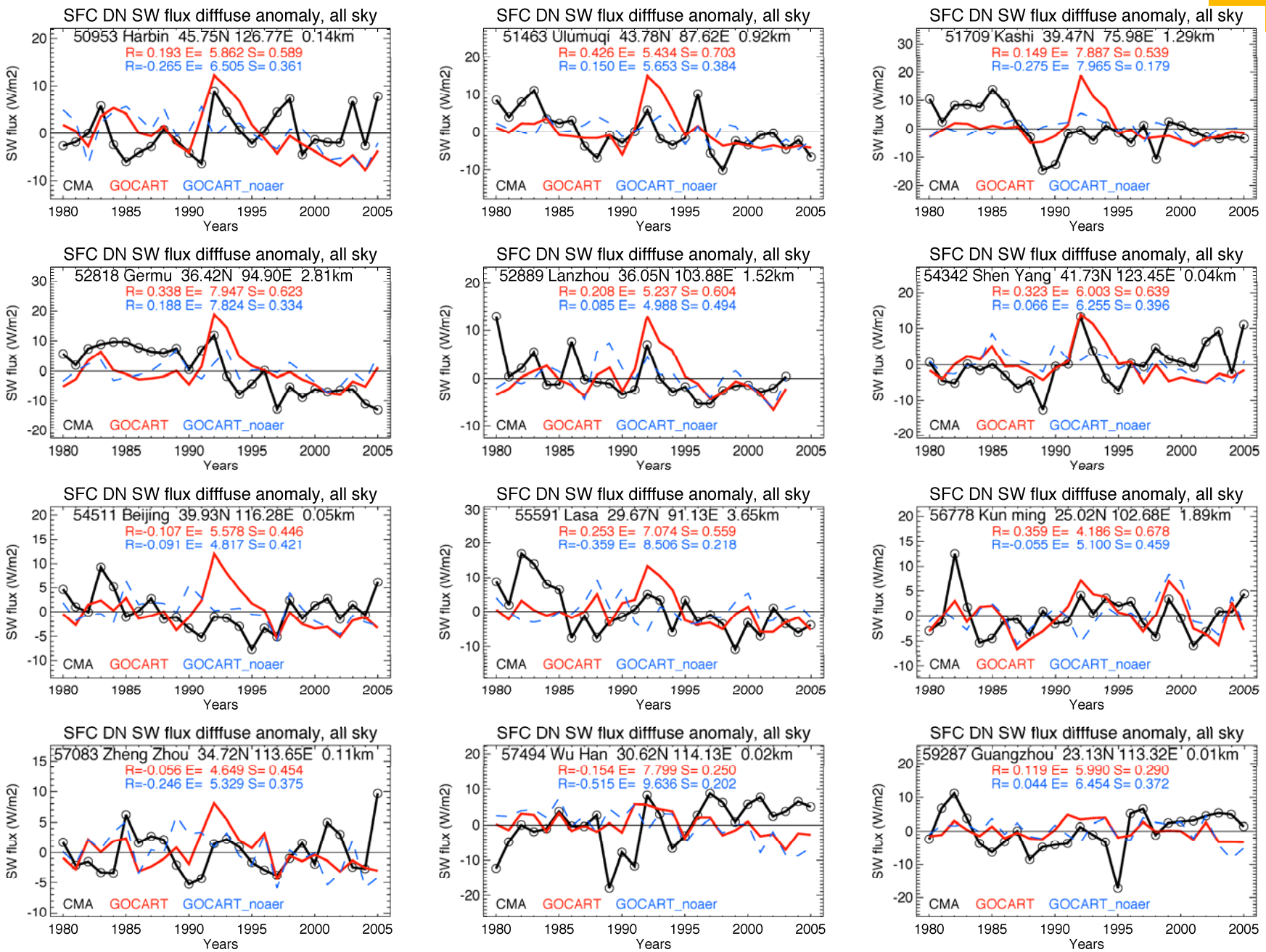
Anomaly of total SW downward flux, all sky



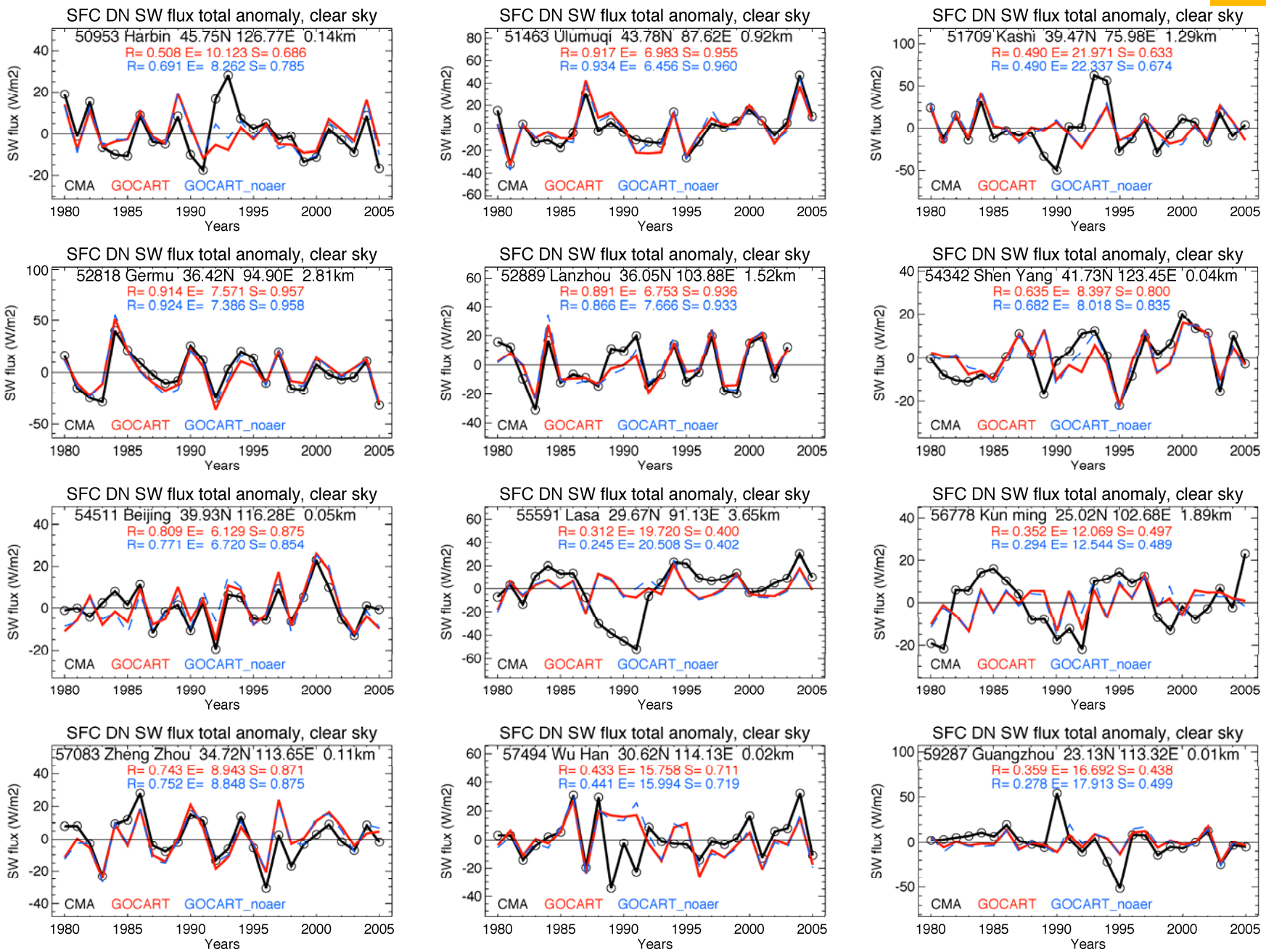
Anomaly of direct SW downward flux, all sky



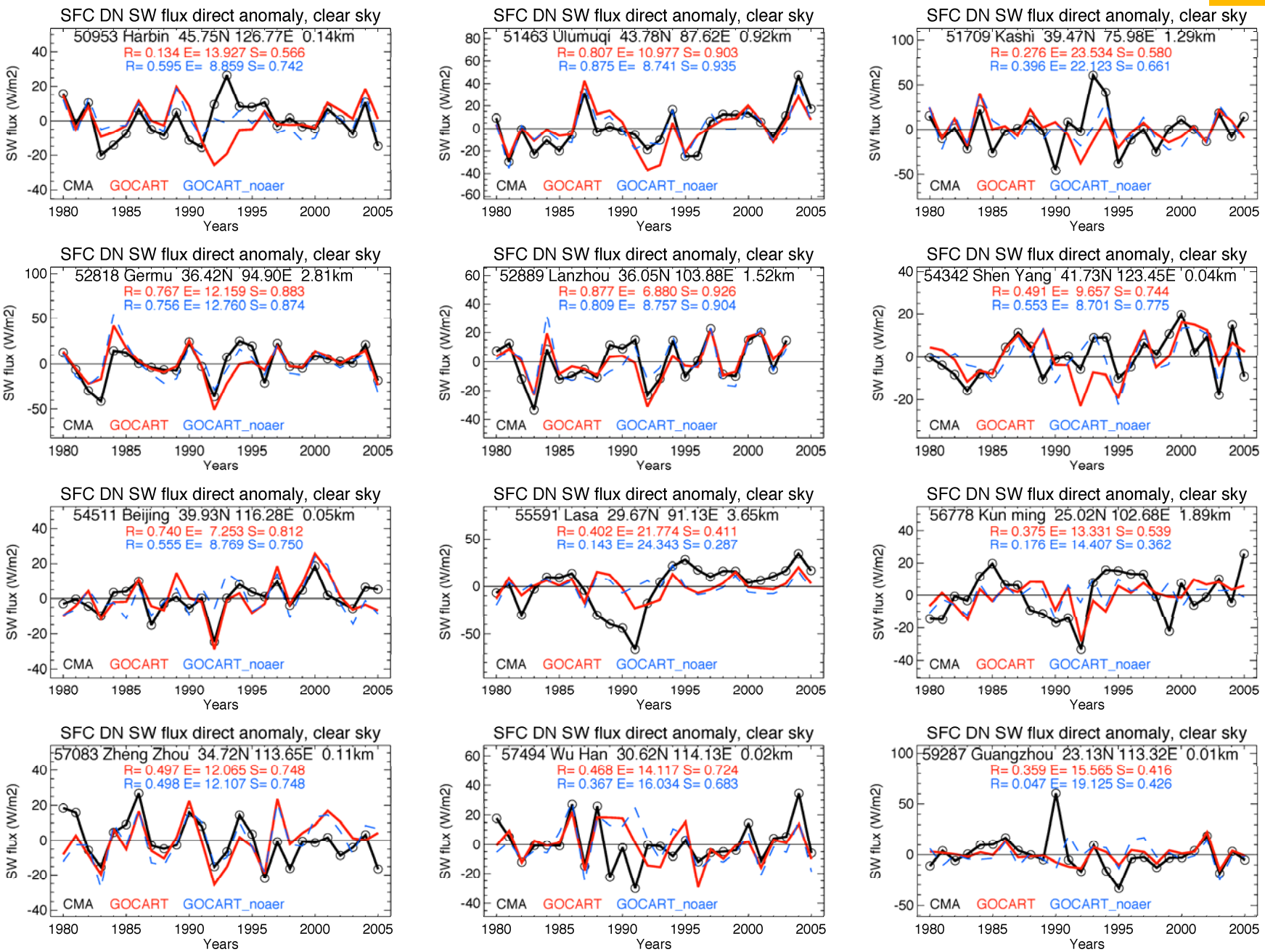
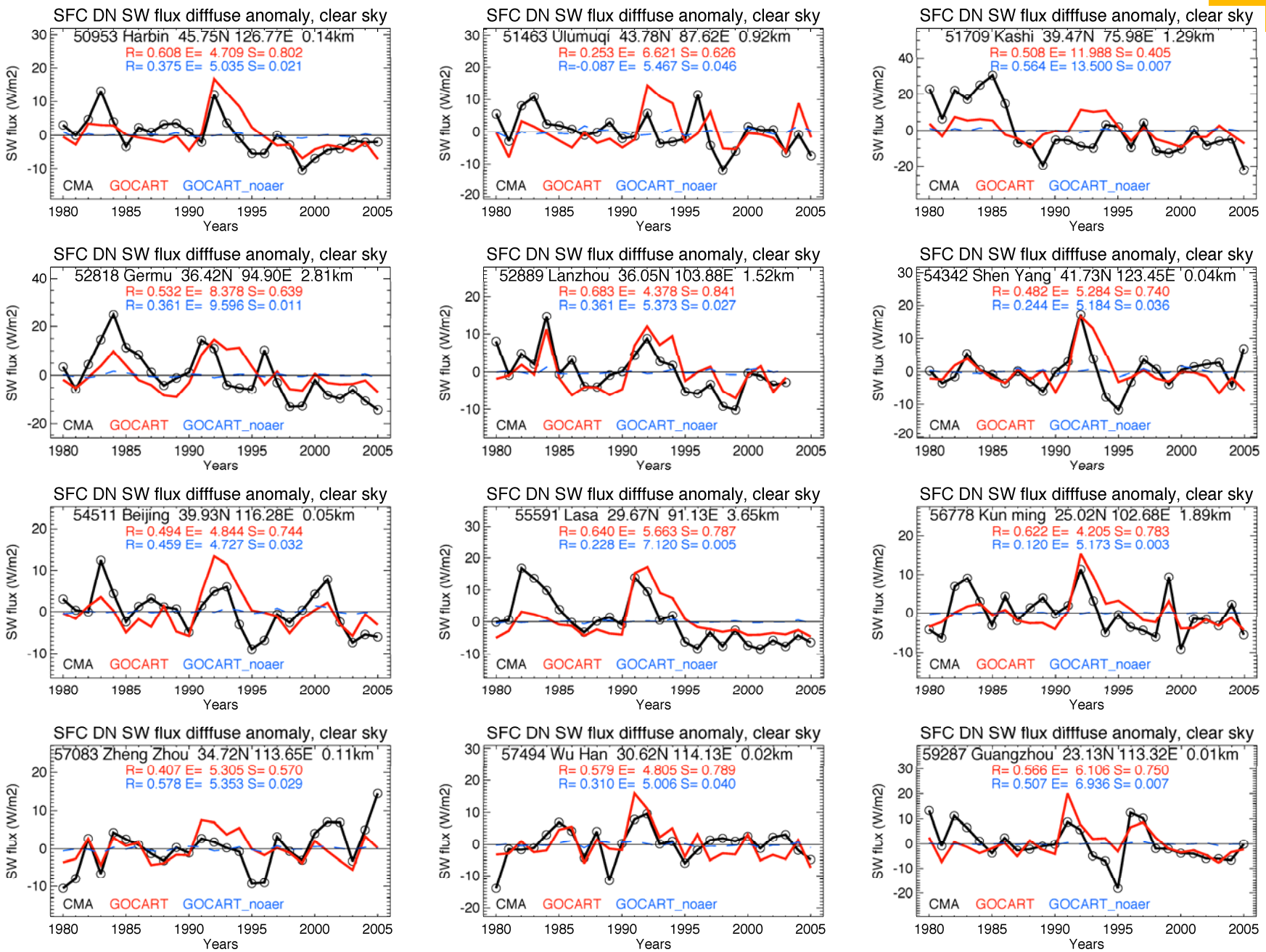
Anomaly of diffuse SW downward flux, all sky



Anomaly of total SW downward flux, clear sky



Anomaly of direct SW downward flux, clear sky



Anomaly of diffuse SW downward flux, clear sky