Surface radiative flux diagnostics based on surface radiation data

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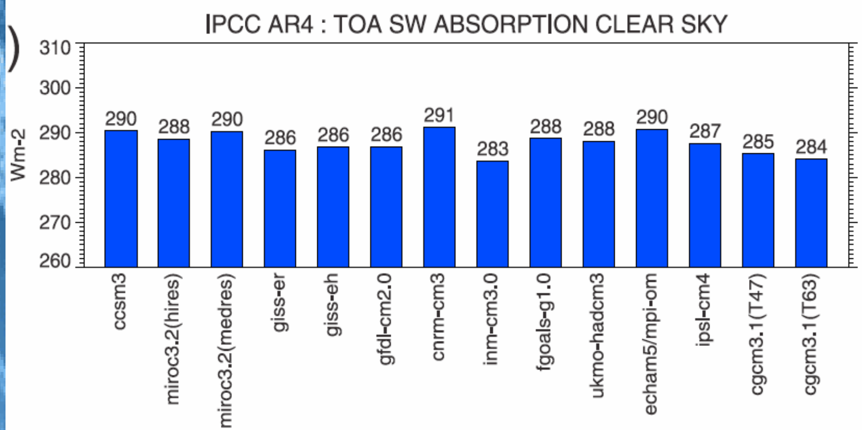
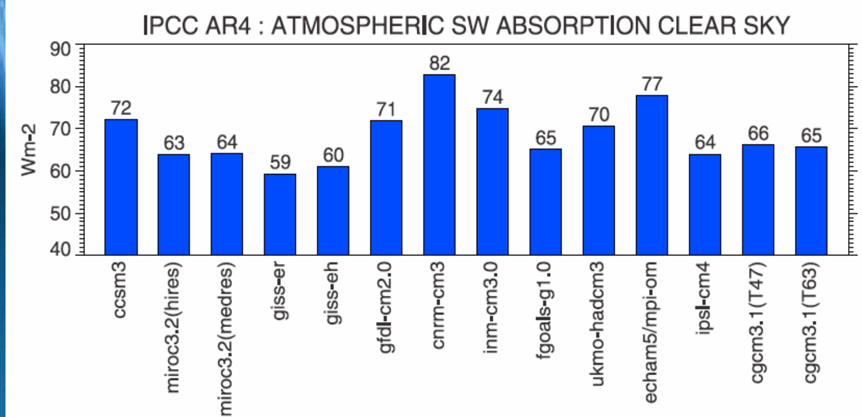
Clear sky solar radiation budgets in IPCC AR4 GCMs

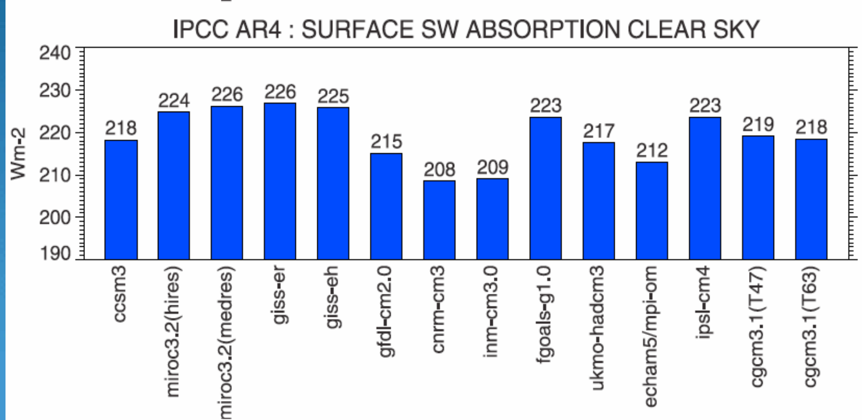


Absorbed SW clear sky
top of atmosphere (global mean)
Range of models: 8 Wm^{-2}
Standard deviation: 2.4 Wm^{-2}

Wild et al. 2006, J. Geophys. Res.



Absorbed SW clear sky
in the atmosphere (global mean)
Range of models: 24 Wm^{-2}
Standard deviation: 6.7 Wm^{-2}



Absorbed SW clear sky
at the surface (global mean)
Range of models: 18 Wm^{-2}
Standard deviation: 6.2 Wm^{-2}

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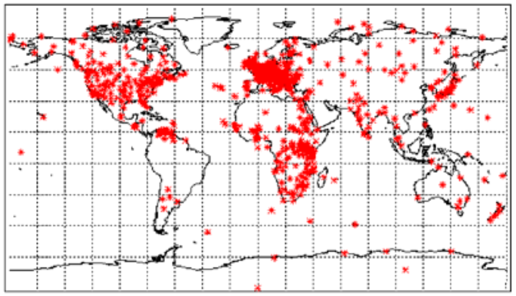
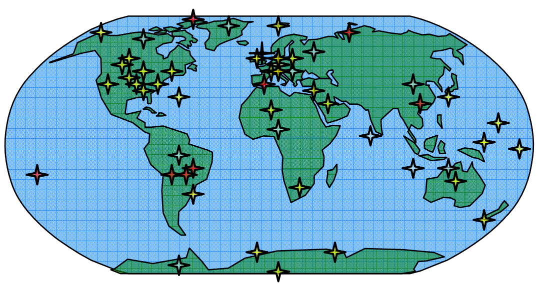
Reducing the uncertainty: the worldwide surface radiation networks



Ohmura, Gilgen, Wild 1989

GEBA
Global Energy Balance Archive

- Worldwide measurements of energy fluxes at the surface (2500 sites)
- Solar radiation data since 1960s
- Monthly mean values



Ohmura et al. 1998

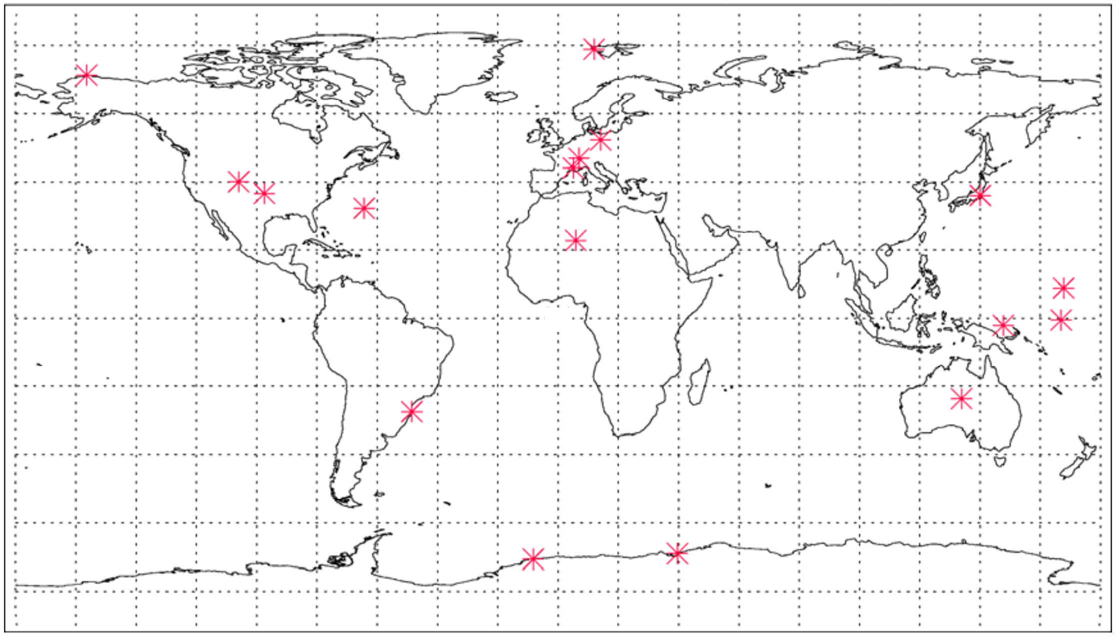
BSRN
Baseline Surface Radiation Network

- Highest measurement quality at selected sites worldwide (currently 38 anchor sites)
- Starting in 1992
- Minute Values
- Ancillary data for radiation interpretation

SW clear sky climatologies at BSRN sites

- **Evaluation of the IPCC AR4 GCM clear sky SW fluxes with newly obtained observed clear sky climatologies**
- **Clear sky climatologies constructed from BSRN data using Long and Ackermann (2000) clear sky detection algorithm based on 1 minute data.**

BSRN sites with surface SW clear-sky climatologies



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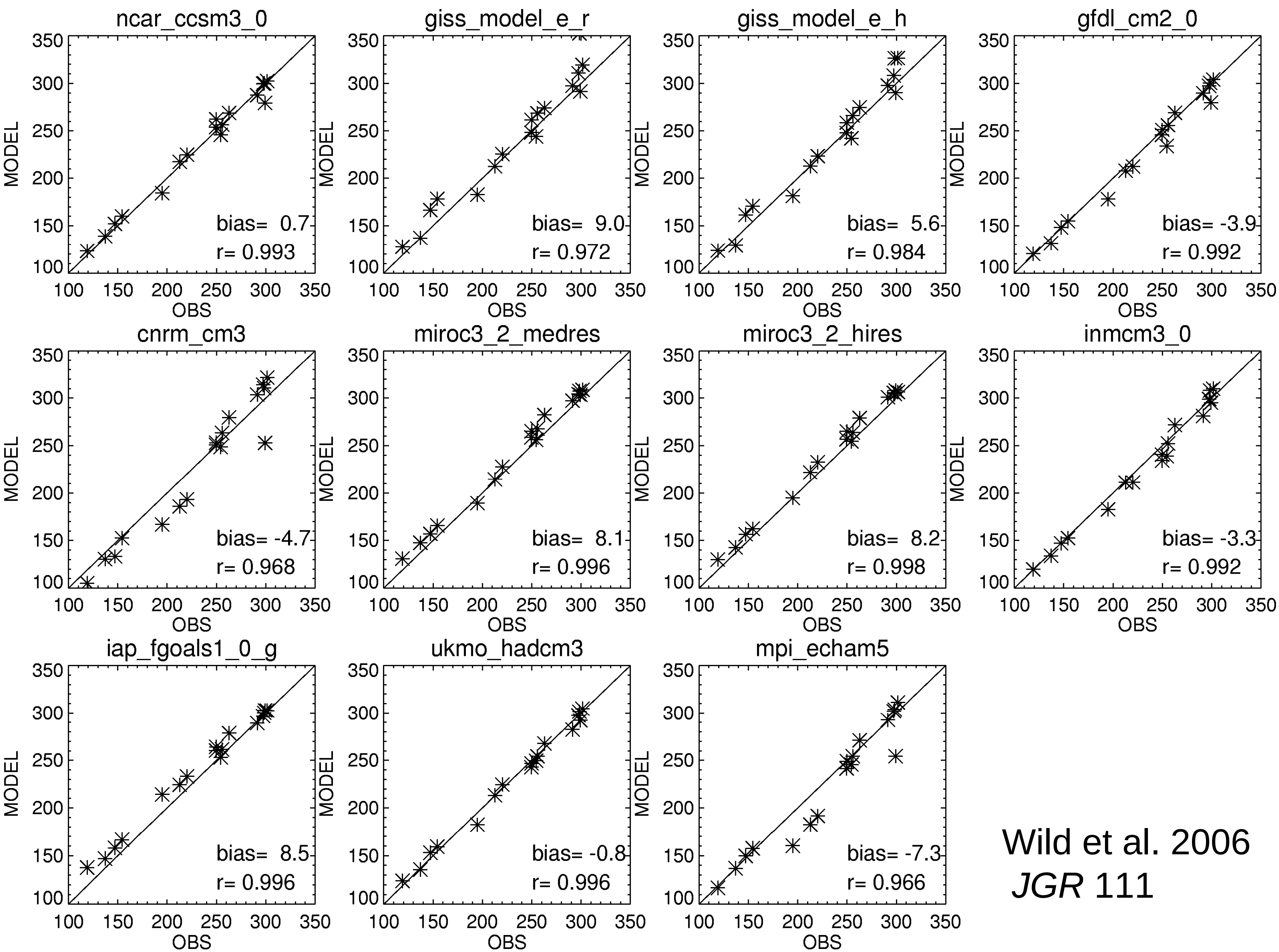
SWD clear sky: IPCC AR4 Models versus BSRN



Wild et al. 2006
JGR 111

Clear sky fluxes in GCMs with/withouth aerosol

Wild et al. 2006 JGR

Annaul cycles of $SWD_{clearsky}$

BSRN obs. in black

Hadley Centre GCMs:

HadAM2:
- **no aerosol (dashed line)**

HadAM3:
- **no aerosol (dotted line)**
- **with aerosol (solid line)**

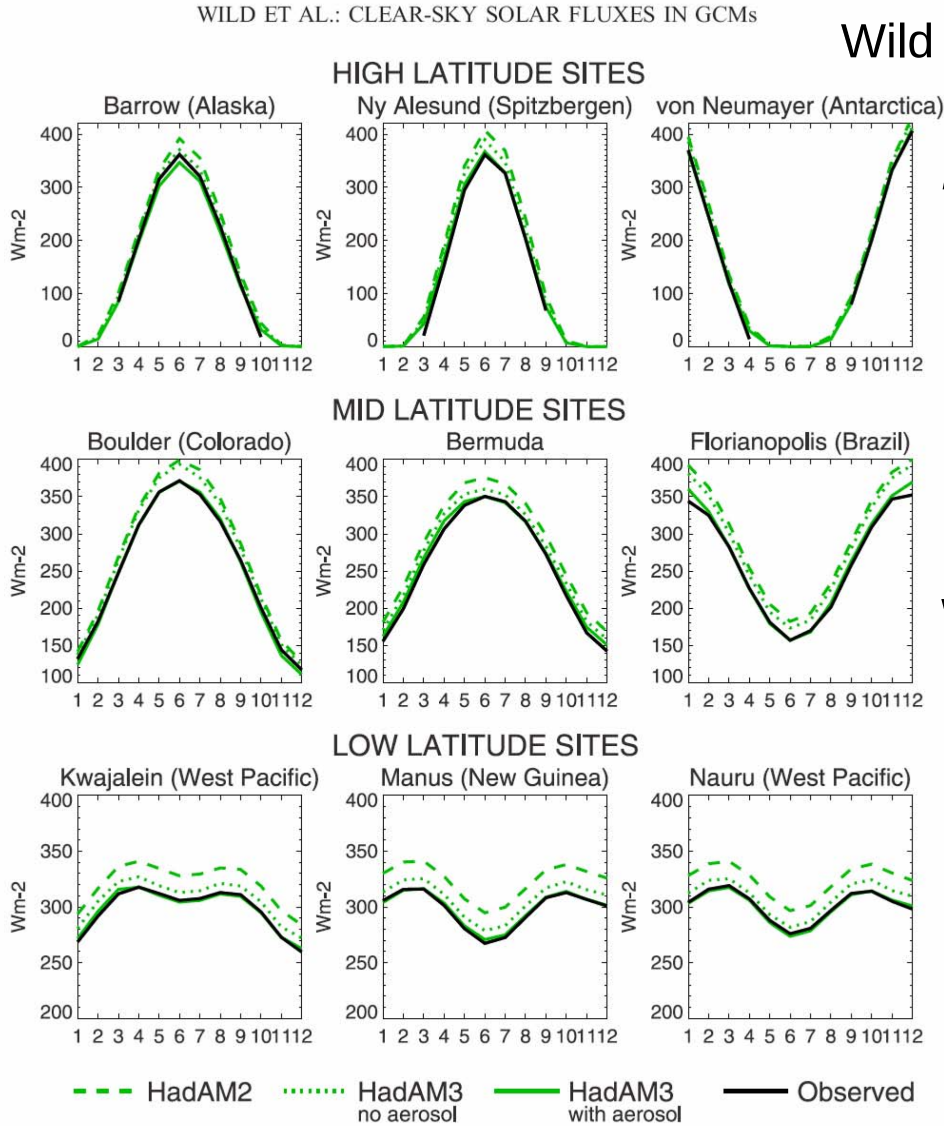


Figure 7. Mean annual cycle of clear-sky insolation at the surface as observed at selected BSRN sites and calculated in the Hadley Centre for Climate Prediction and Research model versions HadAM2 (participating in AMIP I), HadAM3 without aerosols and HadAM3 with aerosols (participating in AMIP II and IPCC AR4) Units are Wm^{-2}.

Mean biases:

HadAM3 no aerosol +14 Wm^{-2}

HadAM3 with aerosol +0.4 Wm^{-2}

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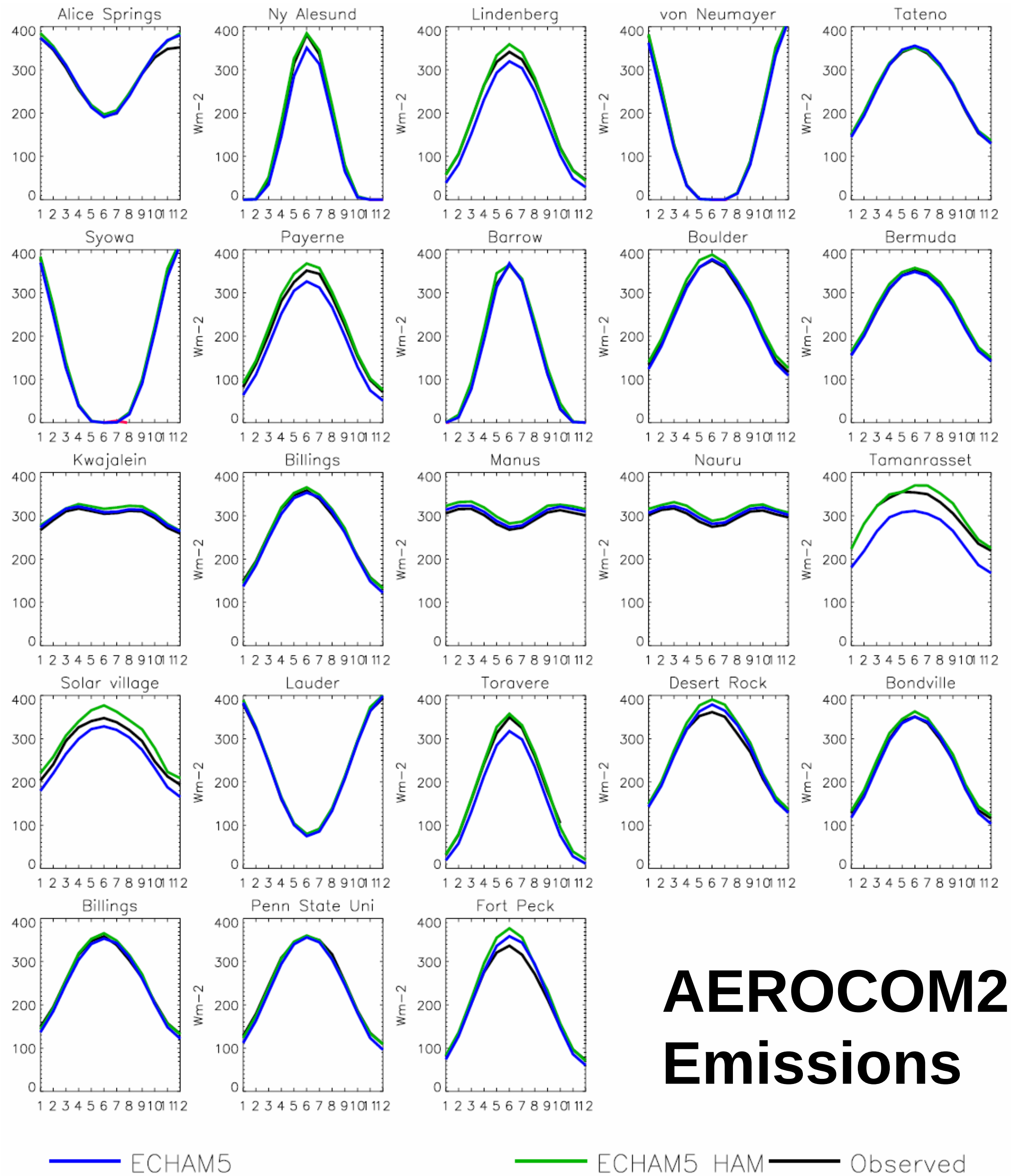
ECHAM5-HAM nudged version year 2000

SWD
Clear Sky



ECHAM5-HAM
ECHAM5
BSRN Obs.

Model data courtesy of Philip Stier

AEROCOM2000 Emissions

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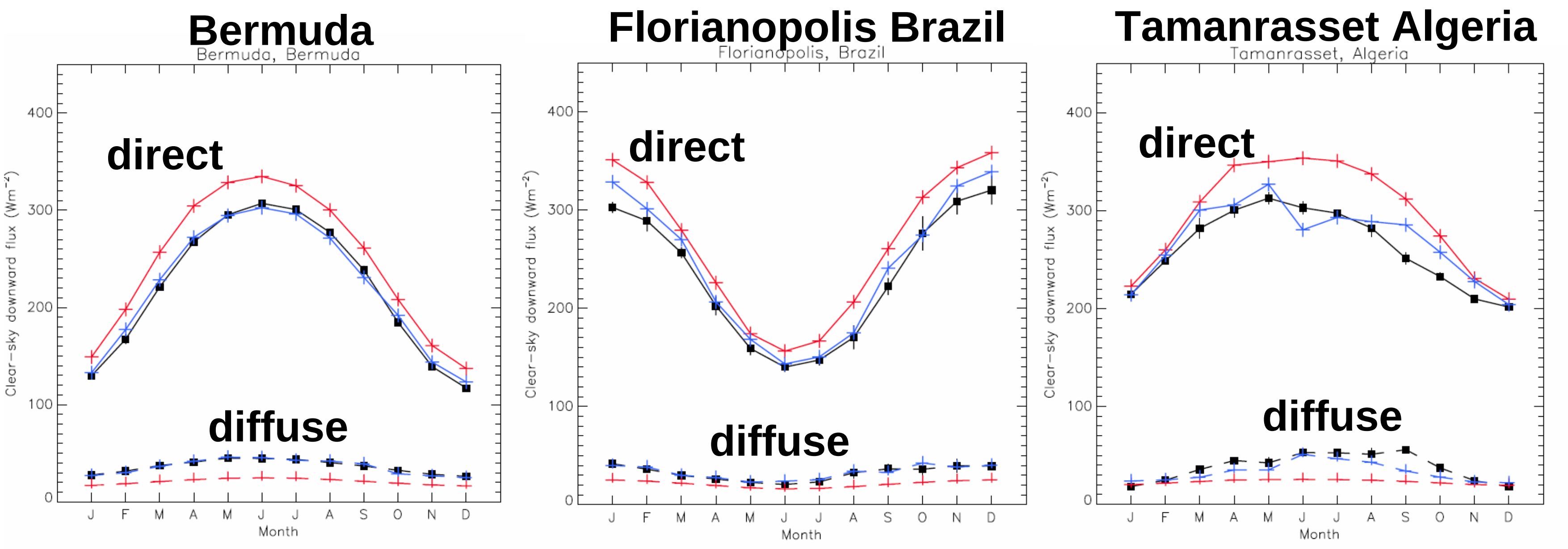
Evaluation of surface SW diffuse/direct radiation

Analysis by N. Bellouin UKMO



BSRN observations

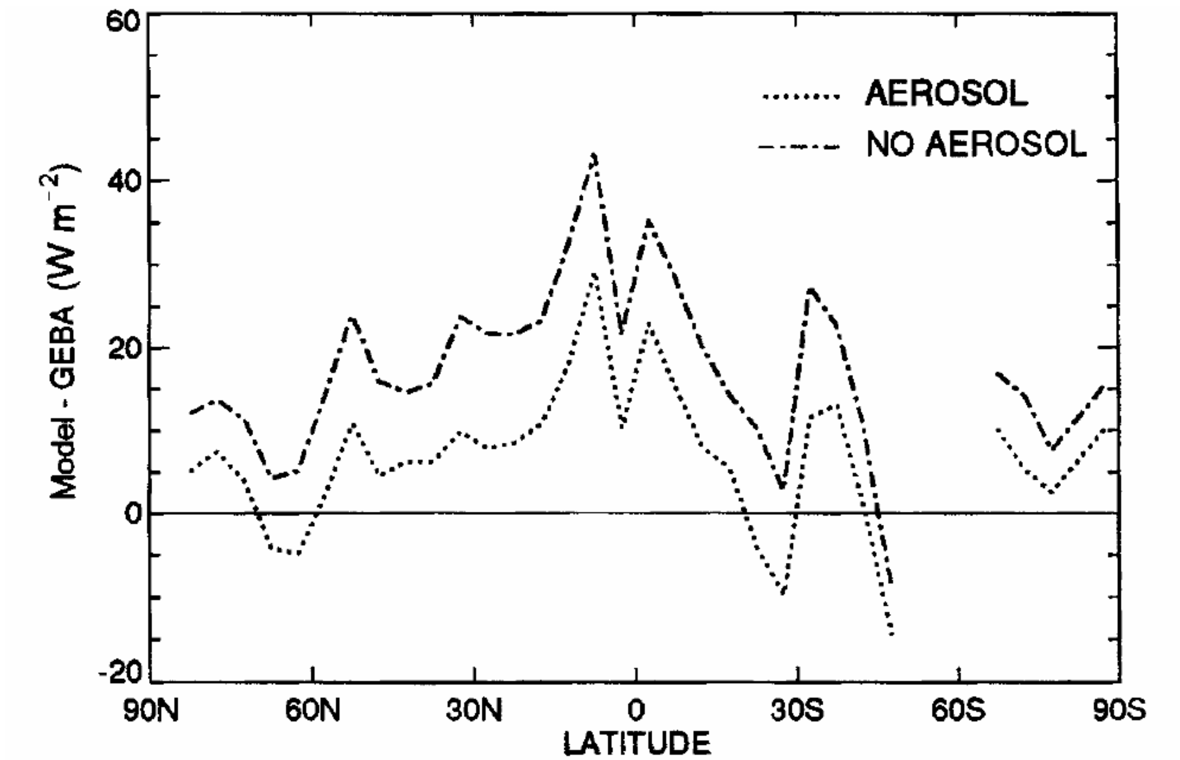
HadGEM GCM, withouth aerosol radiative effects

HadGEM GCM, with aerosol radiative effects

All sky fluxes in GCMs with/withouth aerosol

Surface insolation biases as function of latitude

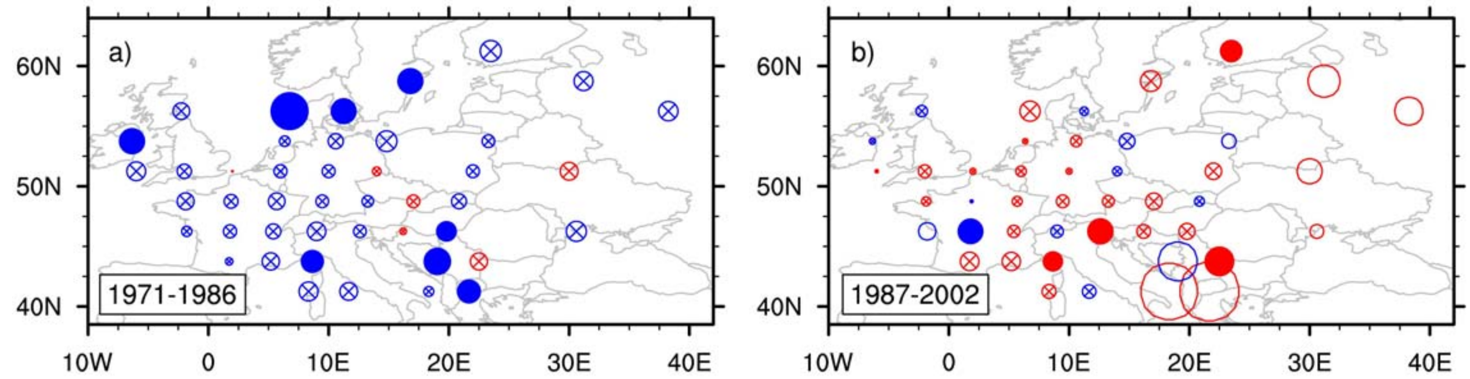
Compared to 760 sites from GEBA



Cusack, Slingo, Edwards, Wild 1998 Q.J.R. Meteorol. Soc.

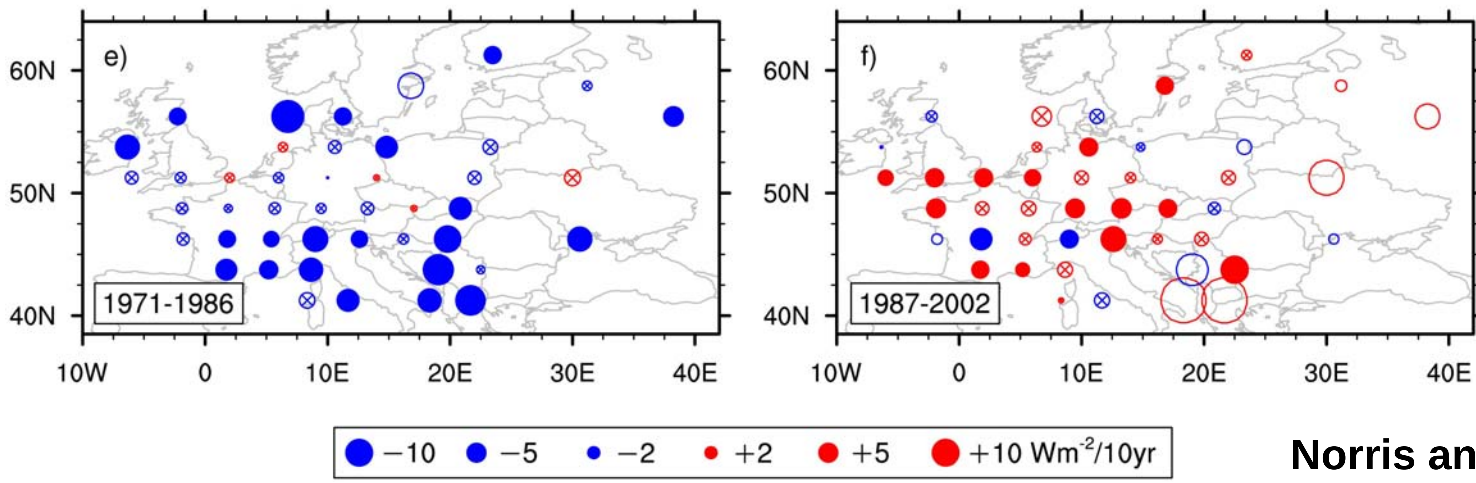
Effects of cloud amount on dimming/brightening in Europe

Original surface SW radiation trends in GEBA (all sky)



1971-1986 **1987-2002**

Trends after removing effects form cloud cover changes



Norris and Wild 2007, JGR

Dimming and brightening trends remain after removal of effects of changing cloud covers

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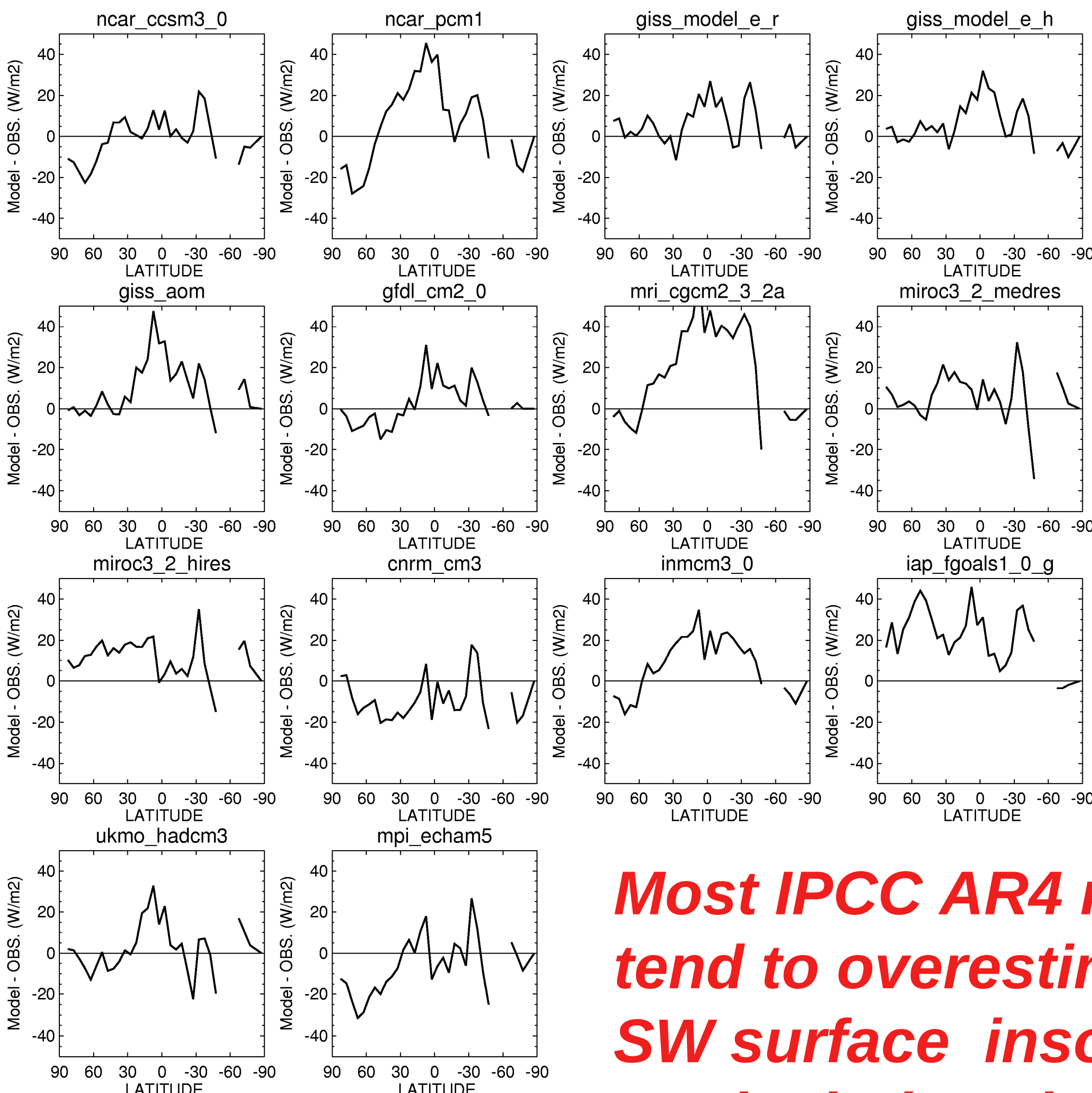
Doward solar radiation at the surface:

IPCC AR4 model biases as function of latitude

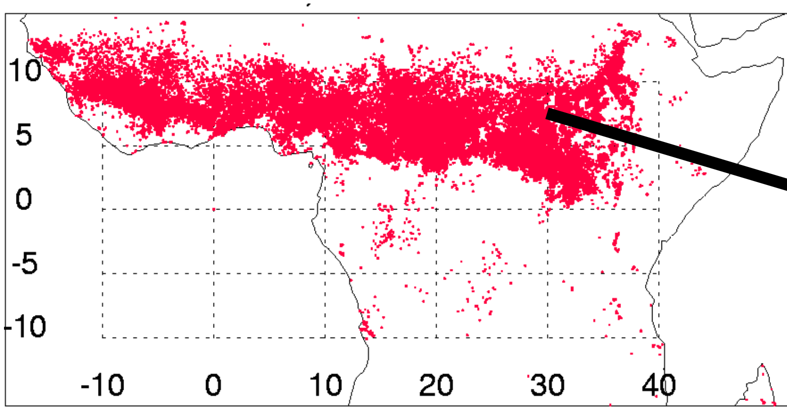


Most IPCC AR4 models tend to overestimate SW surface insolation particularly at low latitudes

Biomass burning in Equatorial Africa

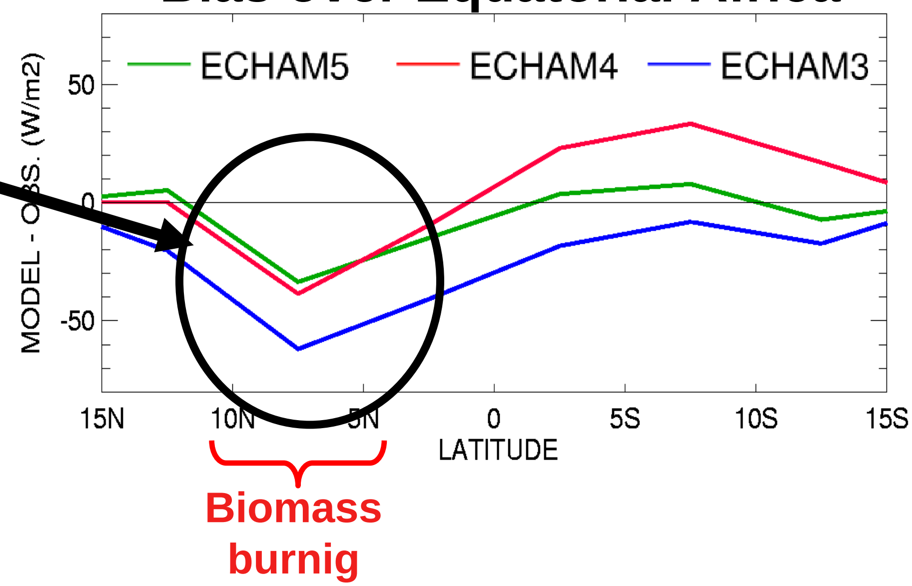
- Problems in areas with large seasonal aerosol loadings: Example: Equatorial Africa, strong biomass burning in dry season
- Estimates for atmospheric SW column absorption from combined surface (GEBA) and satellite (ERBE) measurements.

Fires counts over Africa January



Wild 1999, J. Geophys. Res.
Wild and Roeckner 2006 J. Climate

Atmospheric SW Absorption: Bias over Equatorial Africa



Large atmospheric absorption biases remain in areas with high loadings of absorbing aerosol

Wild and Roeckner 2006 J. Climate 2005
Wild JGR 1999

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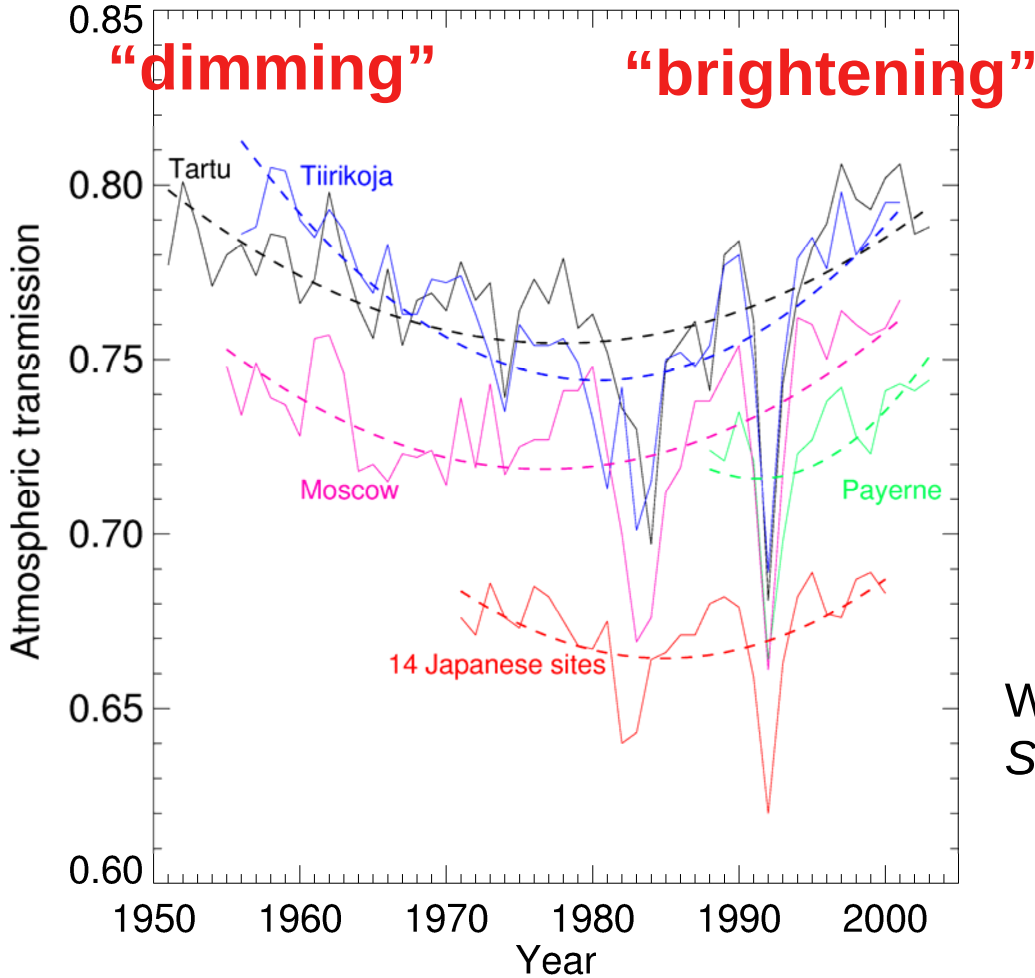
Main message Part I

Adequate treatment of aerosol in climate models is a prerequisite for realistic simulation of surface solar radiation

Not fulfilled in many IPCC AR4 models

Temporal changes in surface SW fluxes

Changes in atmospheric transmission 1950-2000

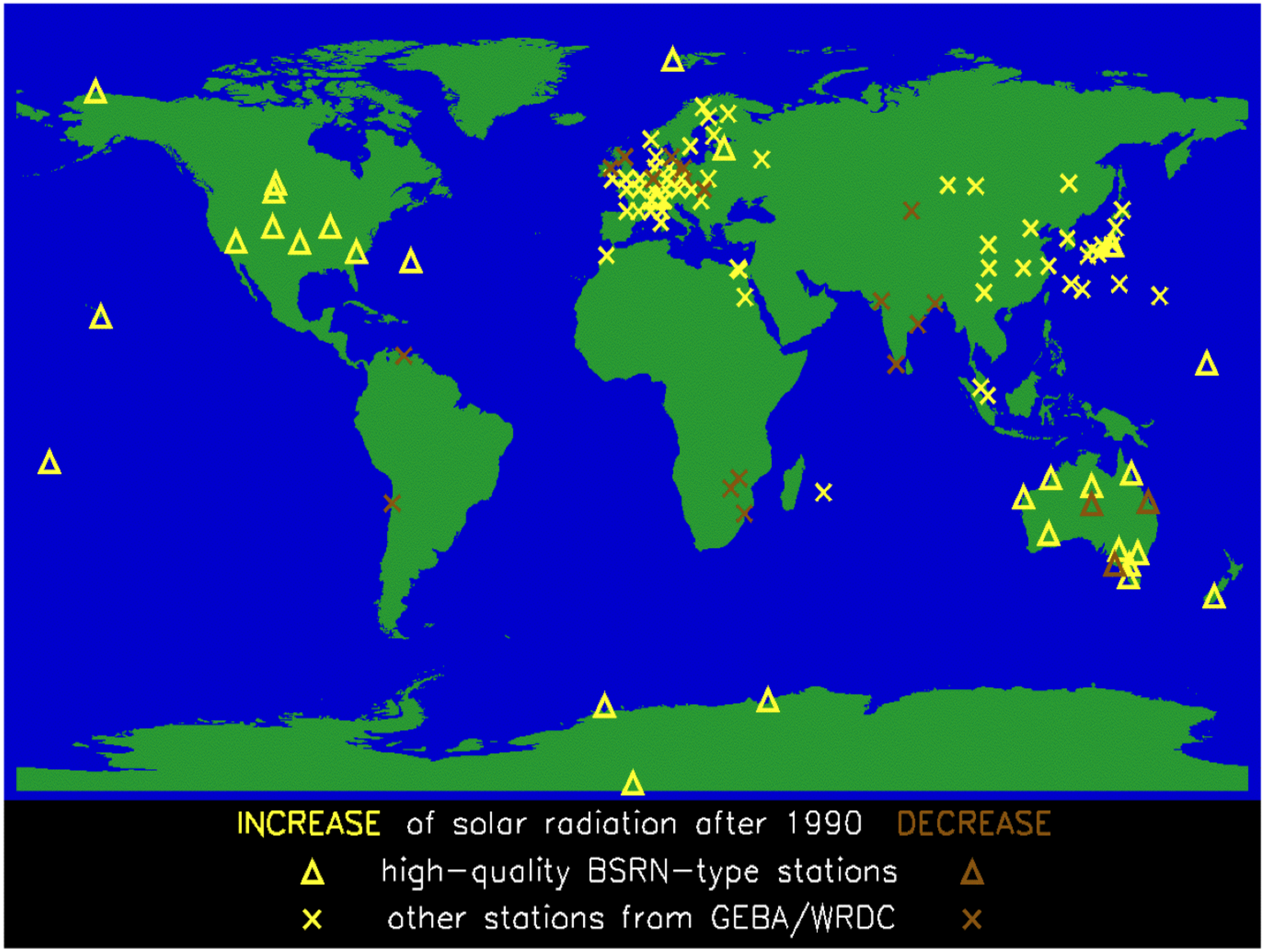


Wild et al. 2005
Science 308

Decadal variations in atmospheric transmittance

Changes in surface solar radiation after 1990

Observed at BSRN and GEBA sites since 1990



Wild et al., 2005, *Science* 308

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Changes in surface solar radiation at BSRN sites

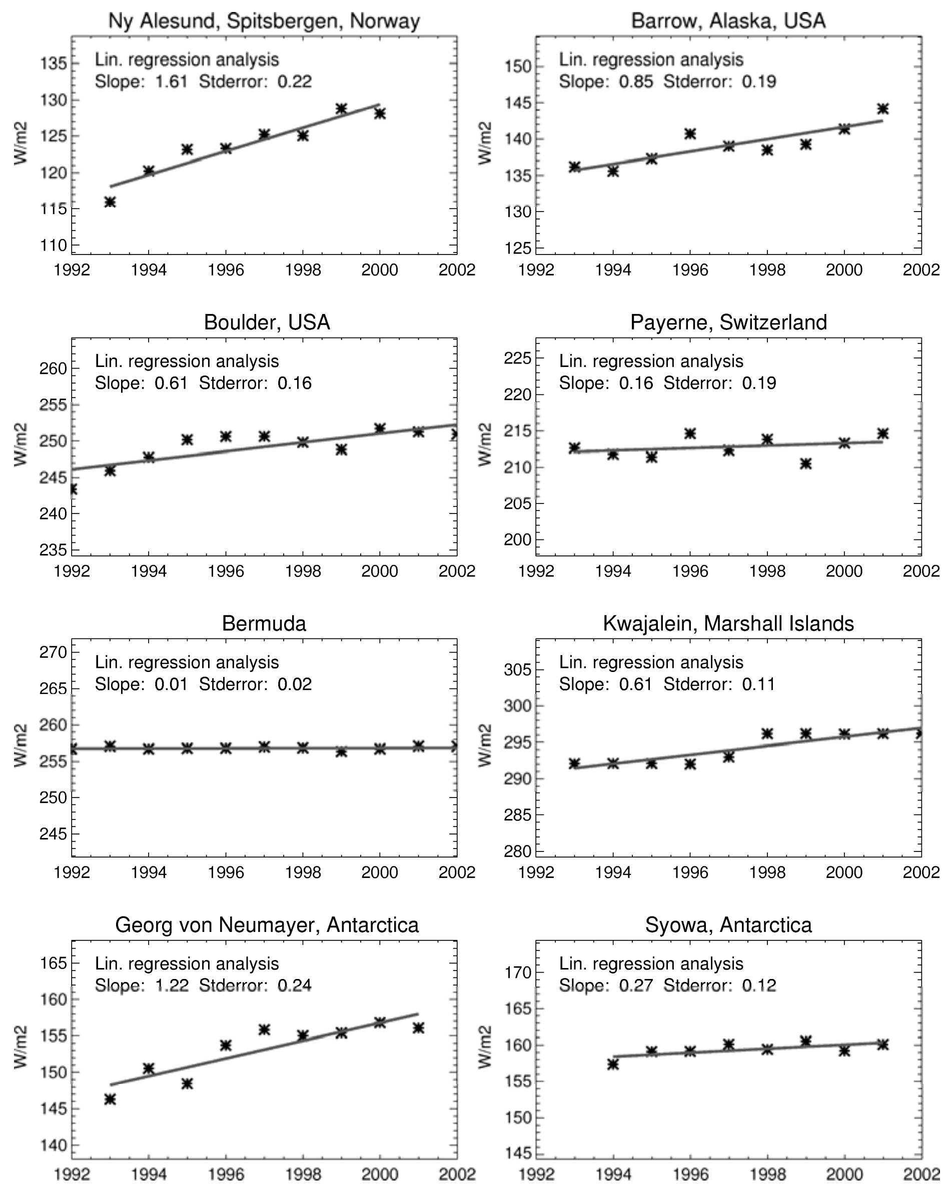
Wild et al., 2005, *Science* 308

Clear sky

1992- 2002

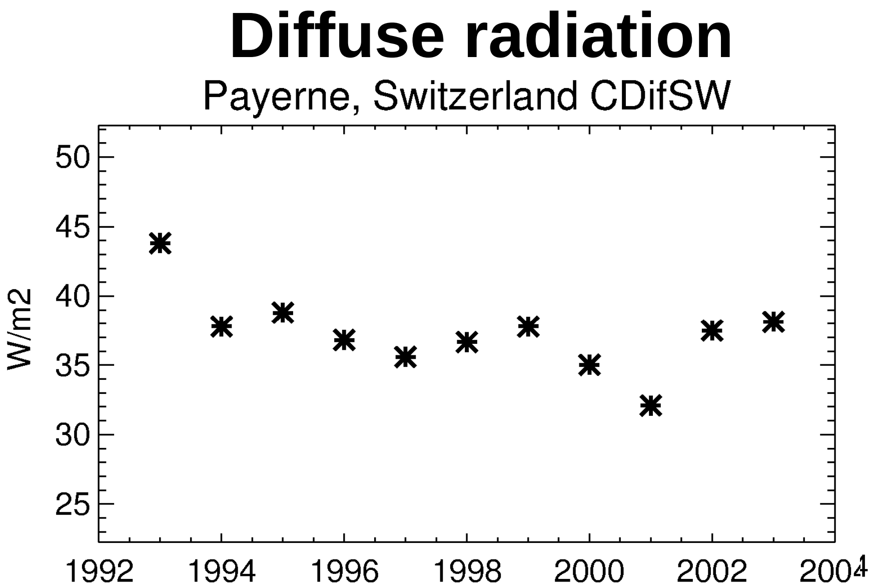
Clear sky detection Algorithm:
Long + Ackermann (2002)

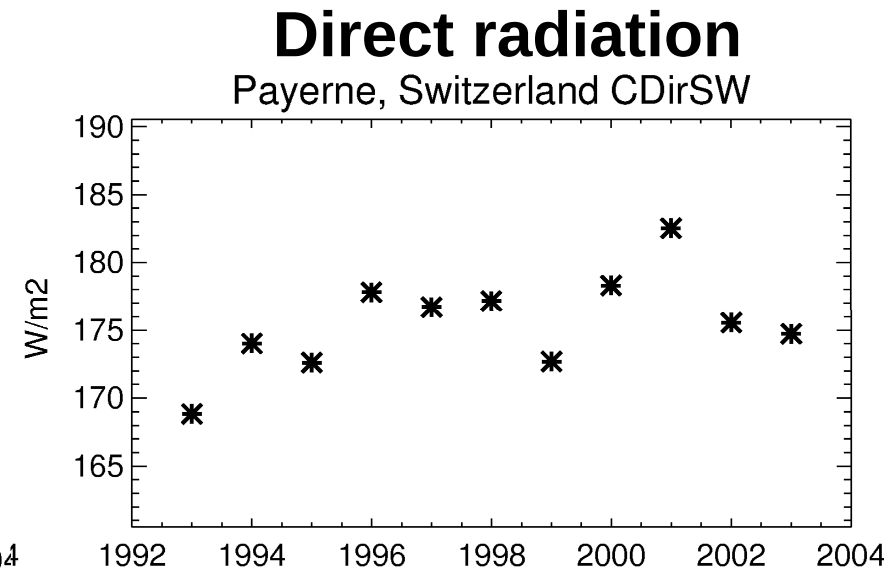
Increase of clear sky SW fluxes at all sites



Diffuse and direct radiation timeseries

Changes in diffuse and direct surface SW radiation





BSRN Station Payerne Switzerland, 1992-2003

Update in SWD clearsky changes at BSRN/Surfrad sites

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Joint analysis with Chuck Long

Mean change at 19 sites: 0.47 Wm^{-2} / year

18 sites increase (14 significant)

1 site decrease (0 significant)

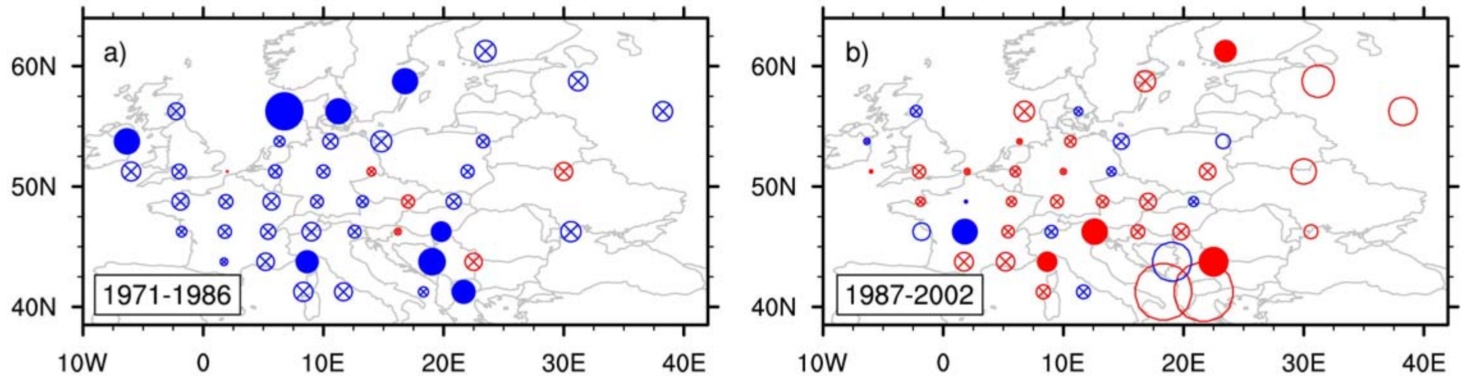
Mid and high lat. sites stronger increase than low lat. sites

Station Name	No. Years	Ob period	Change in Wm-2
Ny Alesund	11	1993-2003	0.86 (+/- 0.21)
Barrow	10	1993-2002	0.85 (+/- 0.22)
Boulder	12	1992-2003	0.63 (+/- 0.13)
Payerne	11	1993-2003	0.10 (+/- 0.13)
Bermuda	12	1992-2003	0.12 (+/- 0.13)
Kwajalein	11	1993-2003	0.59 (+/- 0.11)
G v. Neumayer	12	1993-2004	0.83 (+/- 0.16)
Syowa	9	1994-2002	0.13 (+/- 0.11)
Table Mountain CO	9	1996-2004	0.60 (+/- 0.21)
Bondville	10	1995-2004	0.55 (+/- 0.29)
Desert Rock	7	1998-2004	0.90 (+/- 0.75)
Fort Peck	9	1996-2004	0.54 (+/- 0.51)
Goodwin Creek	10	1995-2004	0.47 (+/- 0.41)
Manus	8	1997-2004	-0.02 (+/- 0.03)
Nauru	6	1999-2004	0.02 (+/- 0.01)
Rock Springs	6	1999-2004	0.38 (+/- 0.26)
South.Great Plain	9	1996-2004	0.43 (+/- 0.24)
South Pole	12	1992-2004	0.62 (+/- 0.14)
Lindenberg	8	1995-2002	0.27(+/- 0.36)

From dimming to brightening: Europe

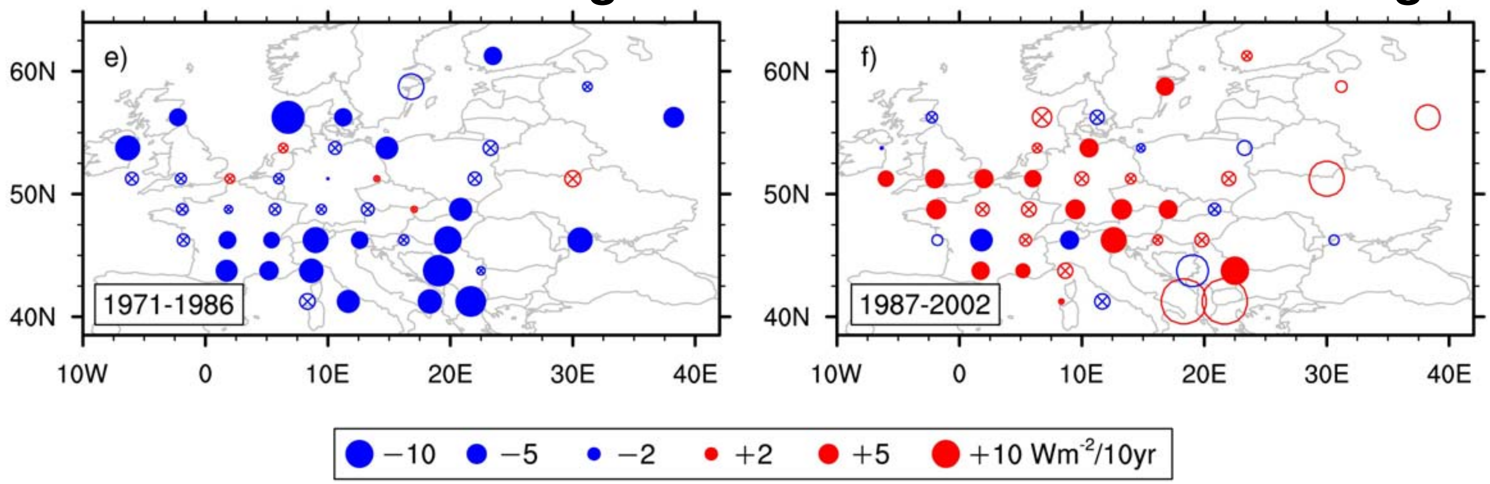
Norris and Wild 2007, JGR

Original trends in GEBA (all sky)



1971-1986 **1987-2002**

Trends after removing effects form cloud cover changes



Dimming and brightening trends remain after removal of effects of changing cloud covers

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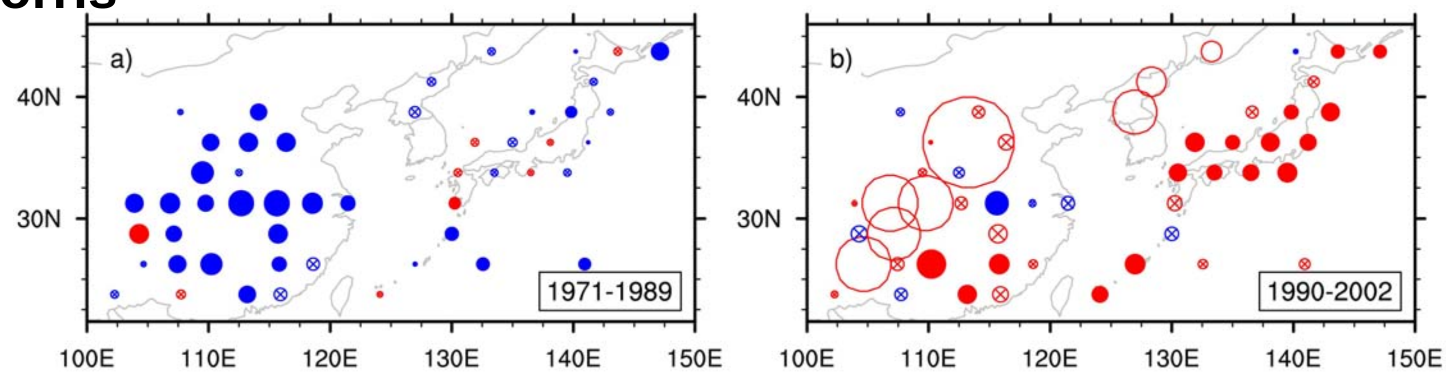
From dimming to brightening: Asia

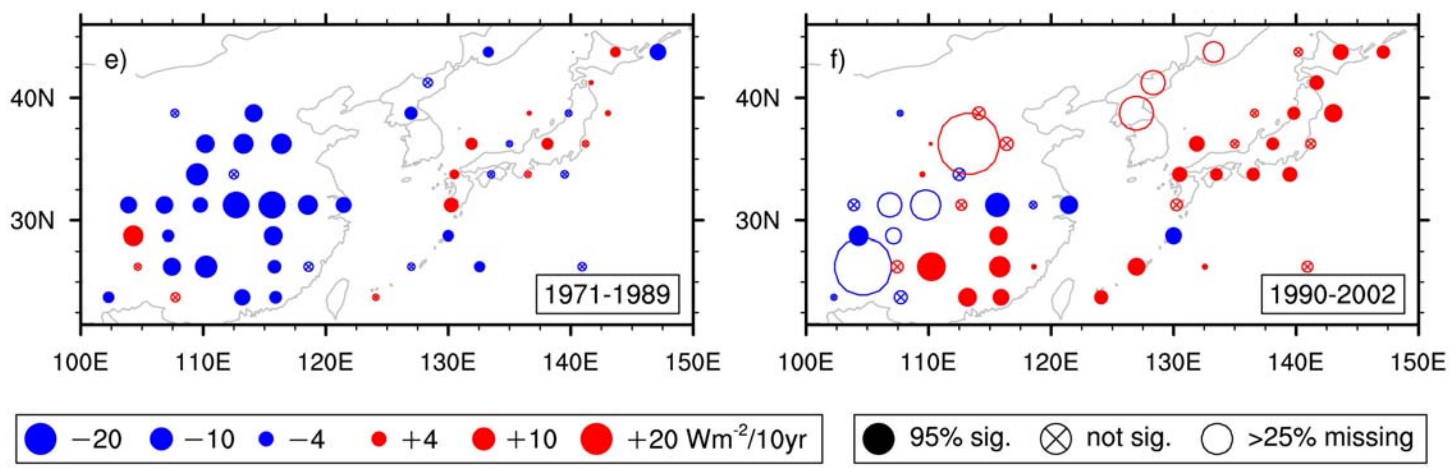
Work with Joel Norris

Surface SW radiation trends in GEBA (all sky)



1971-1989 **1990-2002**

Trends after removing effects form cloud cover changes



Dimming and brightening trends remain after removal of effects of changing cloud covers

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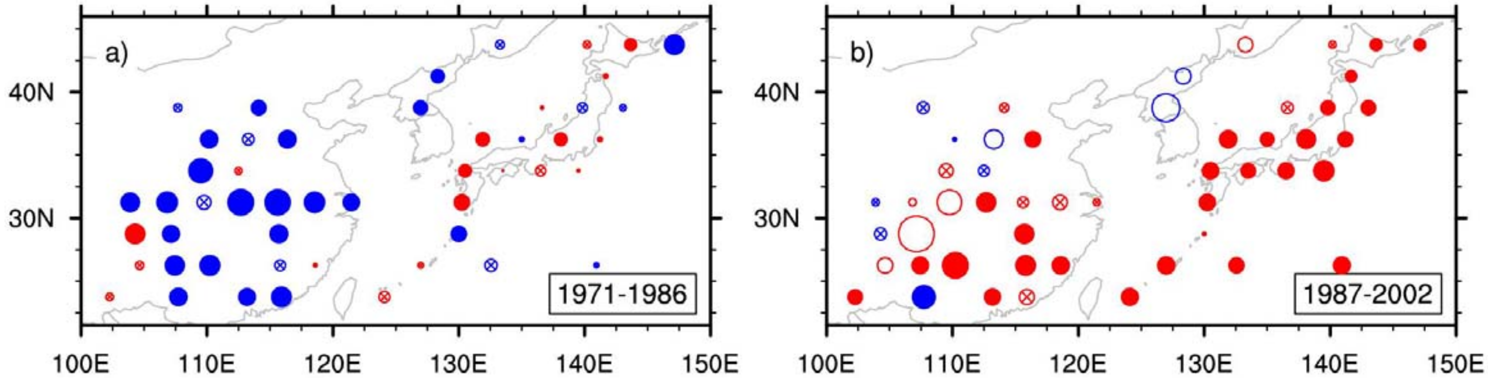
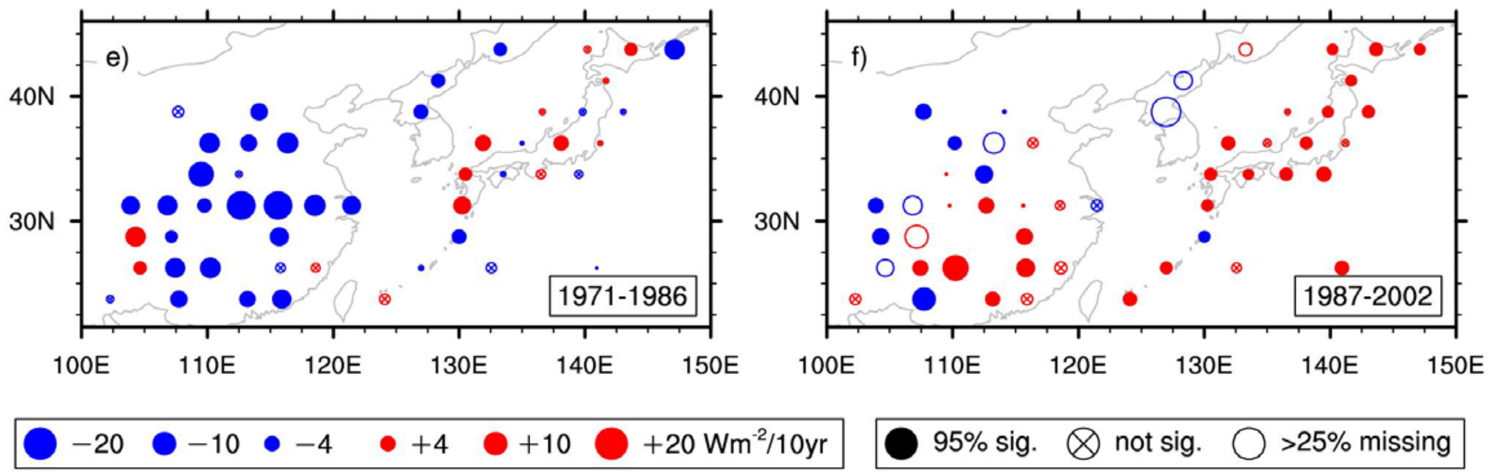
From dimming to brightening: Asia

Original trends in GEBA (all sky)



1971-1986 **1987-2002**

Trends after removing effects form cloud cover changes



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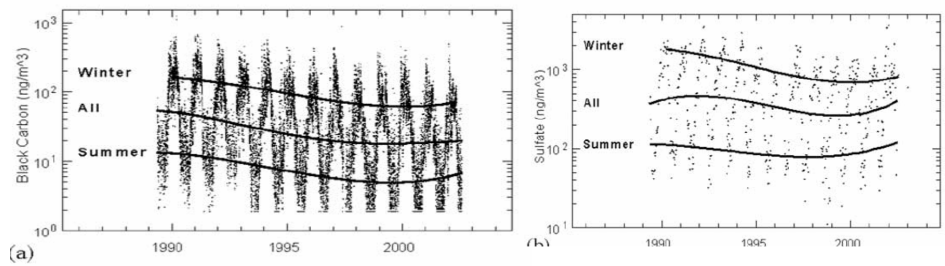
Aerosol contribution to dimming/brightening

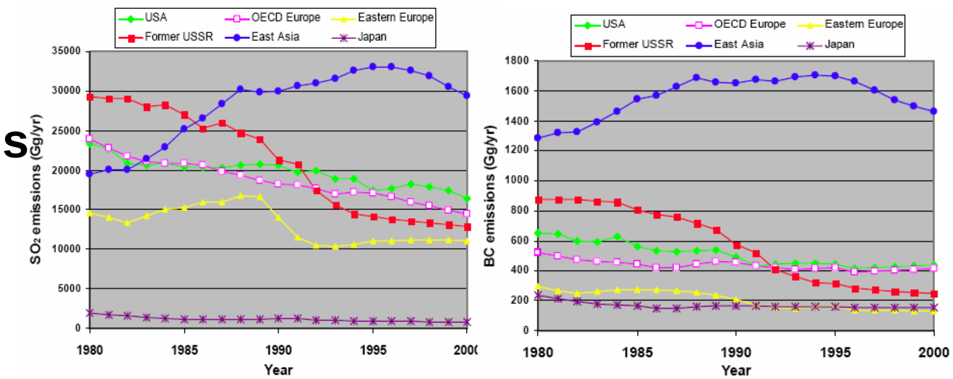
Direct measurements

(Canadian arctic)
BC decrease 1989-2002: 60%
Sulfate decrease 1989-2002: 29%
(Sharma et al. 2004)



Emission histories

Reduction of SO_2 and BC emissions in industrialized regions 1980-2000
(Streets et al. 2006)



Satellite estimates

Decrease of AOD over oceans 1990- 2005
(Mishchenko et al. 2007)

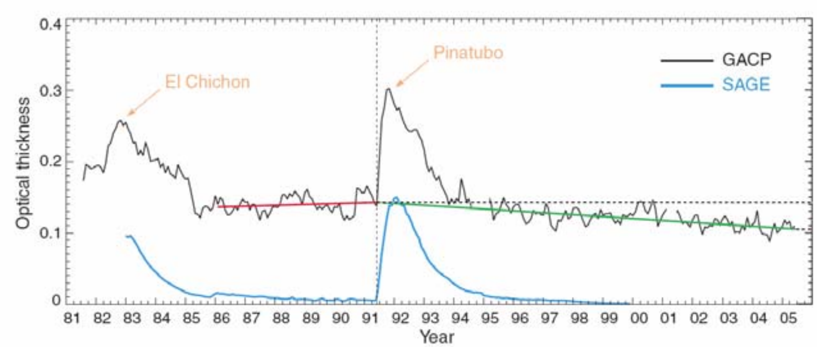


Fig. 1. GACP record of the globally averaged column AOT over the oceans and SAGE record of the globally averaged stratospheric AOT.

Measurement uncertainty: single measurement

Kurzwellig:

- Pyranometer:
  2% (Ohmura and Gilgen 1993)
  4 Wm^{-2} bei guter Wartung der Instrumente (Konzelmann und Ohmura 1995)

Langwellig:

- Pyrgeometer: +/- 2 Wm^{-2} (R. Phillipona, Pers. Mitteilung)
- Pyrradiometer:
  Belüftet, mit Schattenscheibe: +/- 10 Wm^{-2}

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BSRN Measurement Accuracy Target

- **Direct SW radiation: 1% or 2 Wm-2 (normal incidence pyrheliometer)**
- **Diffuse radiation: 4 % or 5 Wm-2 (ventilated pyranometer)**
- **Global Radiation 2% or 5 Wm-2 (ventilated pyranometer)**
- **Reflected SW radiation: 5% (ventilated pyranometer)**
- **Downwelling longwave radiation +/ - 2 Wm-2 (pyrgeometer)**

Fehleranalyse Globalstrahlung (SW down)

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Representativität eines einzelnen Jahresmittelwertes für mittlere Klimatiologie einer 2.5° Gitterbox:

Mittlerer Fehler: 7 %

zusammengesetzt aus:

- Zufälliger Messfehler (2%)

- Vernachlässigung Trends (3%)

- Vernachlässigung interanuelle Variabilität (4%)

- Subgrid Variabiltät (5%)

GCM Analysen:

- **zufällige Messfehler, Trend, interannuelle Variabilität: minimiert, da nur langjährige Messreihen**
- **Subgrid Variabilität reduziert bei T106 (1.1°) Analysen**

Mittlerer Fehler der Obswerte in GCM Vergleichen << 7 %

Identification of clear sky periods

Long and Ackerman (2002), JGR 105 (D12), 15609-15626

- Based on 1 minute data of downwelling total and diffuse shortwave irradiance
- 4 tests applied:

A) **Normalized total shortwave magnitude test** Normalized with solar zenit angle, nominal range of values for clear sky

B) **Maximum diffuse shortwave test**
clear sky diffuse irradiance below a certain threshold

C) **Change in magnitude with time test**
compares temporal change in total irradiance, small for clear periods compared to cloudy periods over short timescales

D) **Normalized diffuse ratio vatiability test**
diffuse divided by total irradiance,smooth timeseries for clear skies, variability below threshold