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ETH

AEROCOM meeting, Ocober 9, 2017, Helsinki

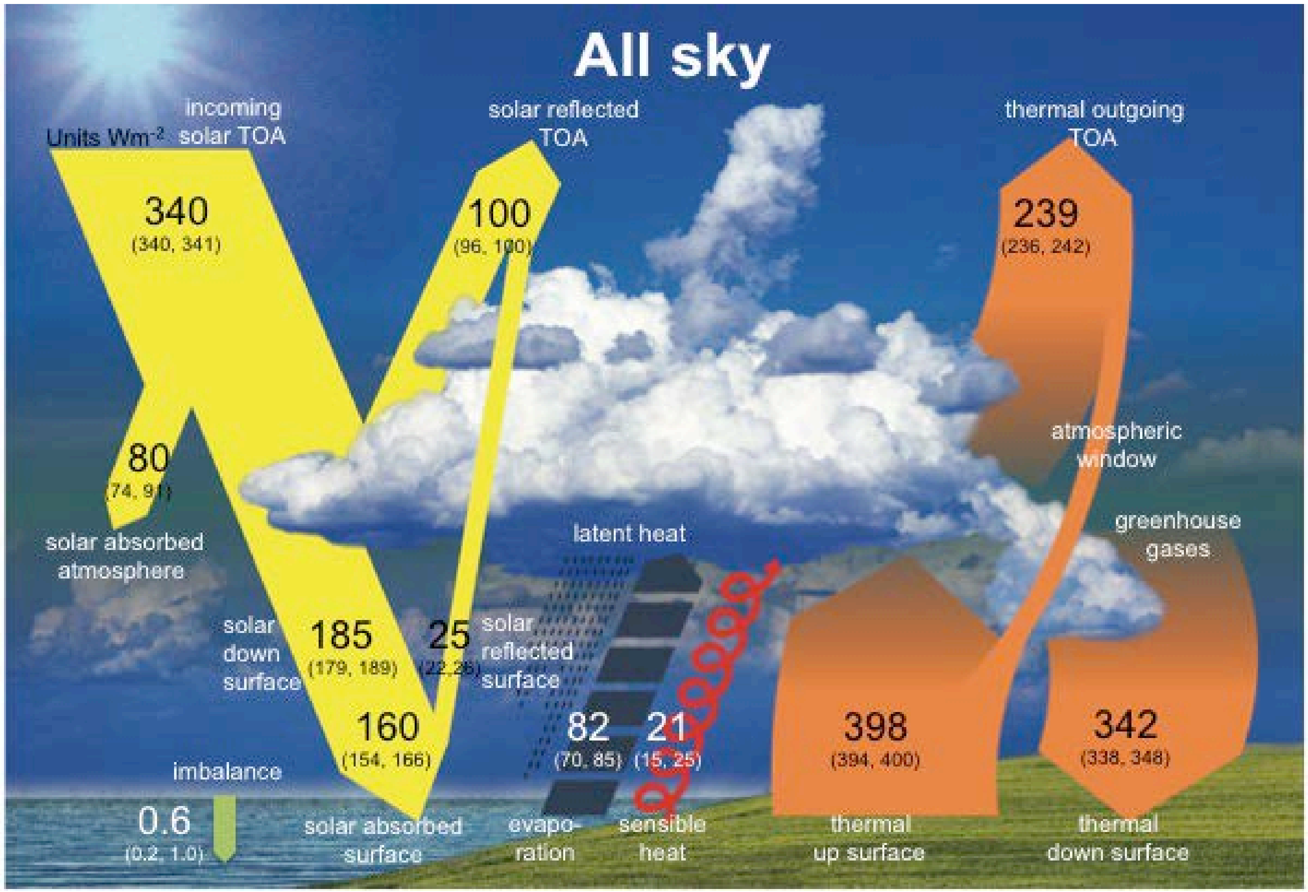
Assessment of clear sky solar radiative fluxes in climate models using surface observations

Martin Wild

ETH Zurich, Switzerland

Acknowlegements to Maria Hakuba, Doris Folini, Veronica Manara, Chuck Long, Arturo Sanchez Lorenzo, Alejandro Sanchez Romero , Pierre Nabat

Earth Radiation Budget



Units Wm^{-2}

IPCC AR5 Fig. 2.11 / Wild et al. 2013 Climate Dynamics

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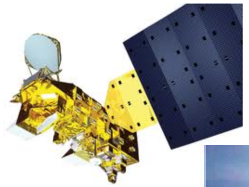
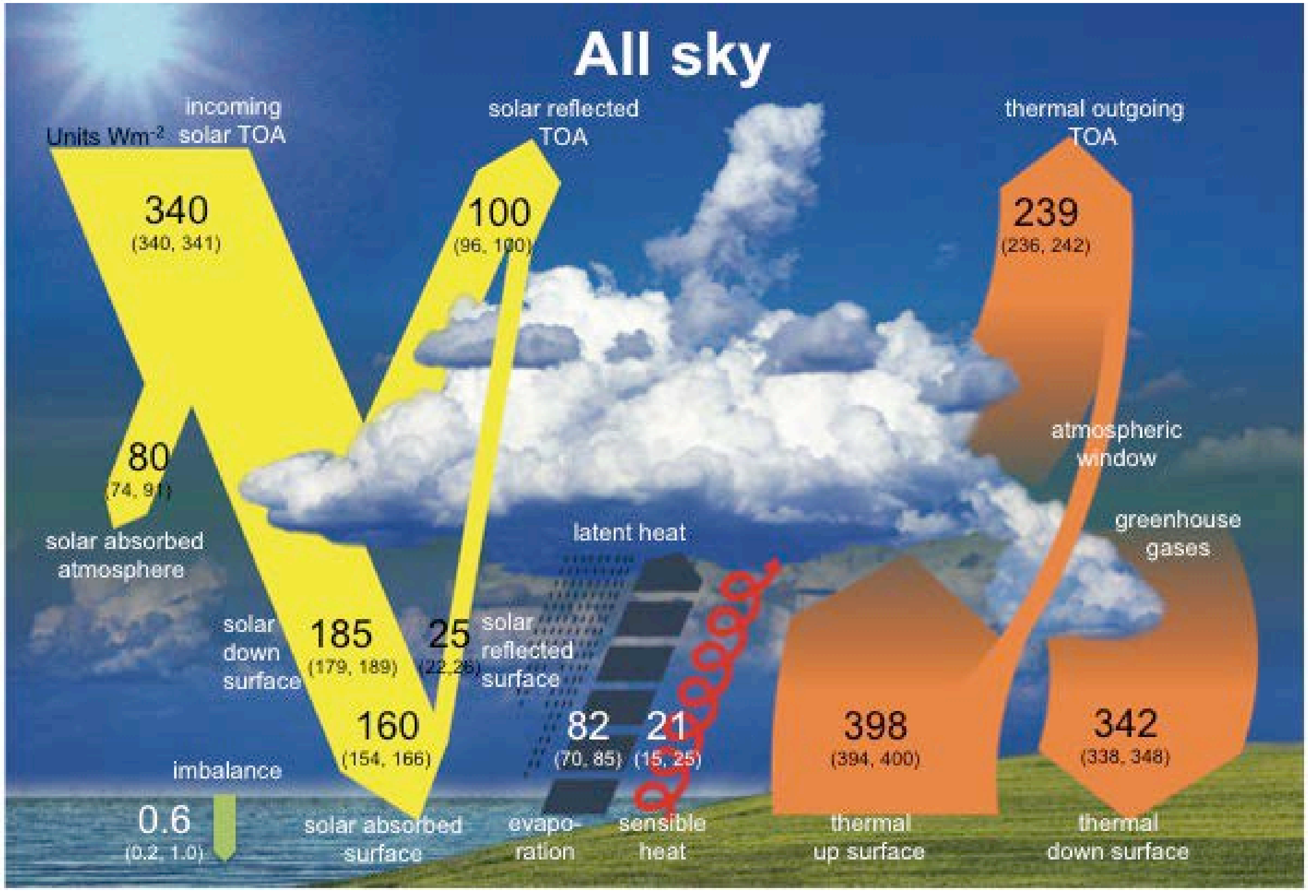
Earth Radiation Budget



TOA fluxes from CERES satellite data

Units Wm^{-2}



IPCC AR5 Fig. 2.11 / Wild et al. 2013 Climate Dynamics

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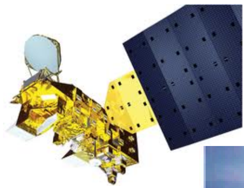
Earth Radiation Budget



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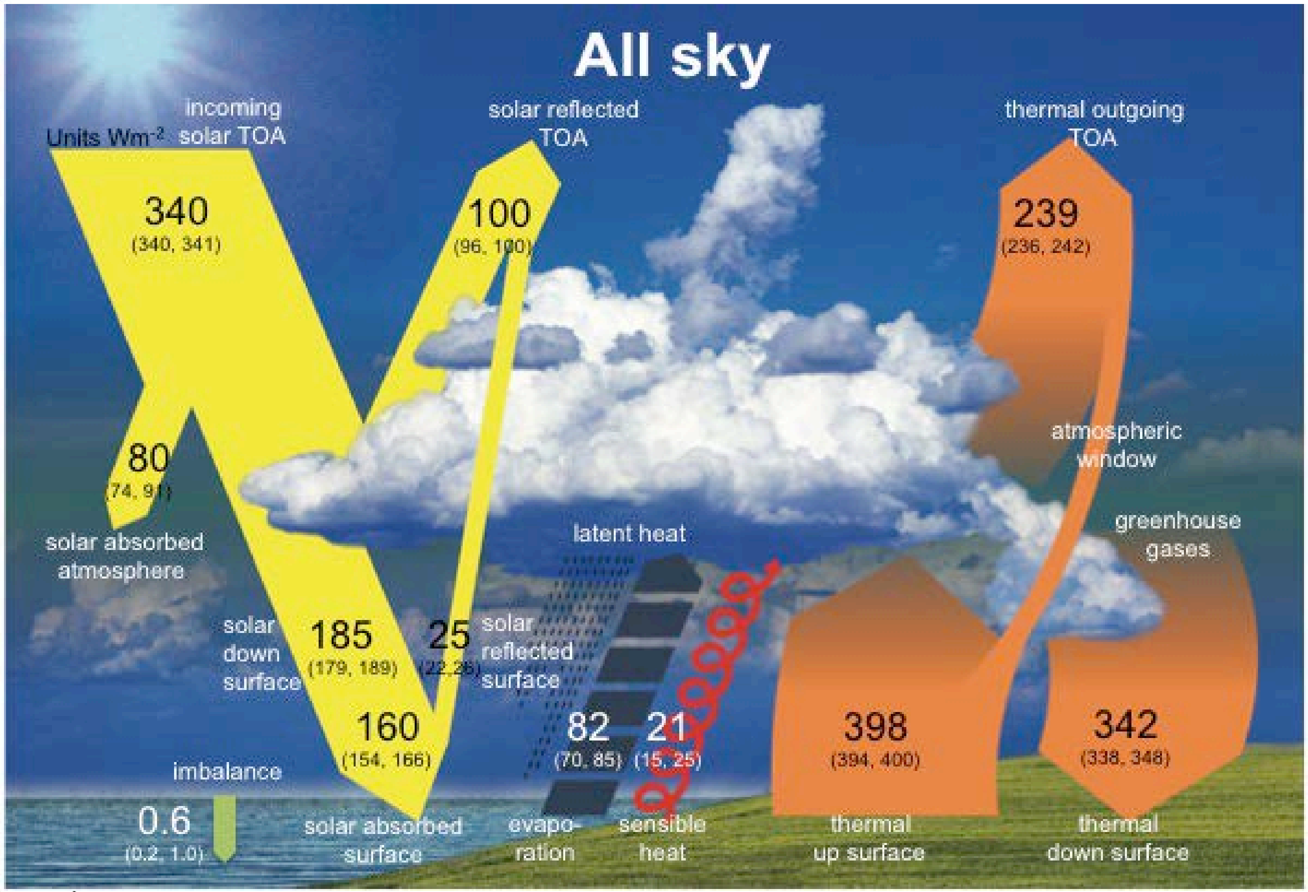
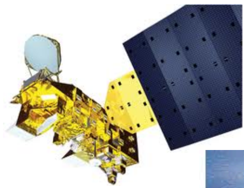


Surface fluxes from surface station observations

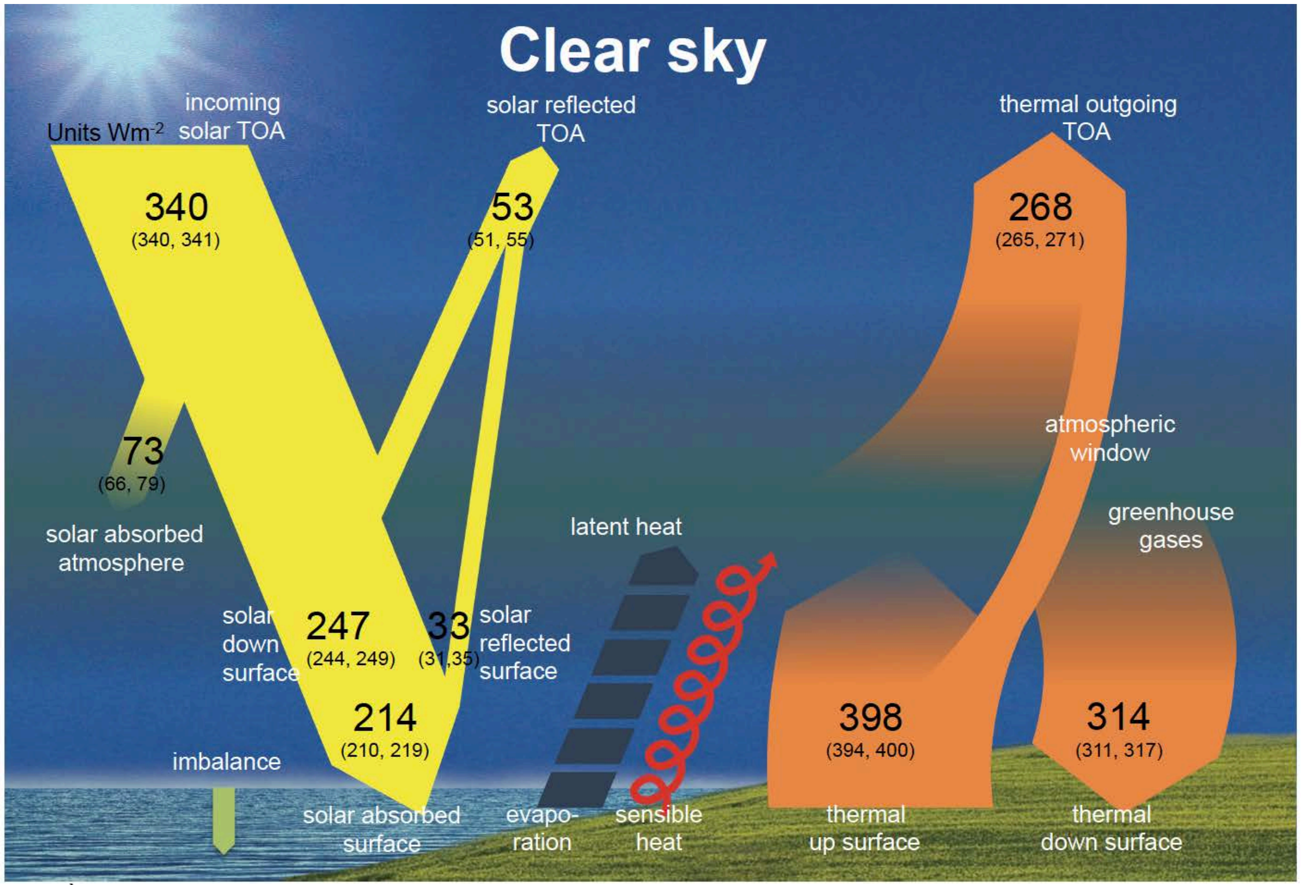
IPCC AR5 Fig. 2.11 / Wild et al. 2013 Climate Dynamics

Earth Radiation Budget



TOA fluxes from CERES satellite data

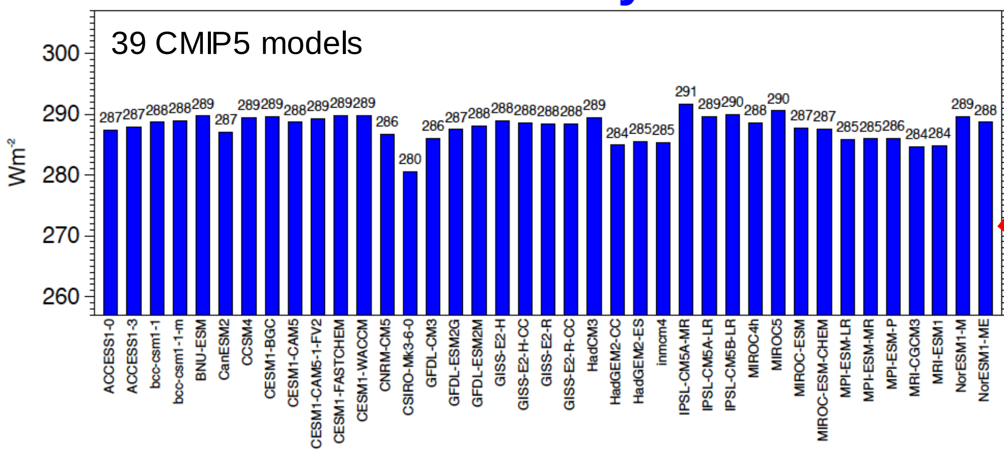
Units Wm^{-2}



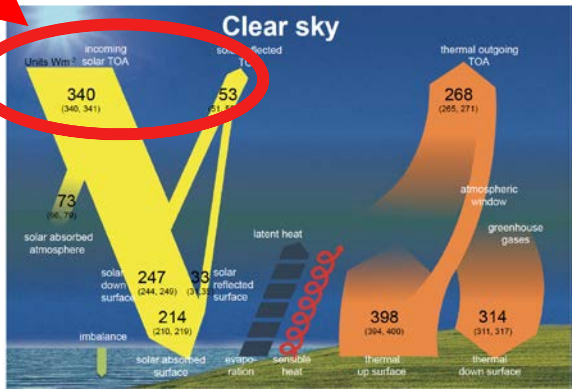
Surface fluxes from surface station observations

Global mean shortwave clear sky budgets in CMIP5 GCMs

TOA absorbed shortwave clear sky



Multimodel mean: 288 Wm^{-2}
Range of models: 11 Wm^{-2}
Standard deviation: 2.1 Wm^{-2}
CERES Observed: 287 Wm^{-2}



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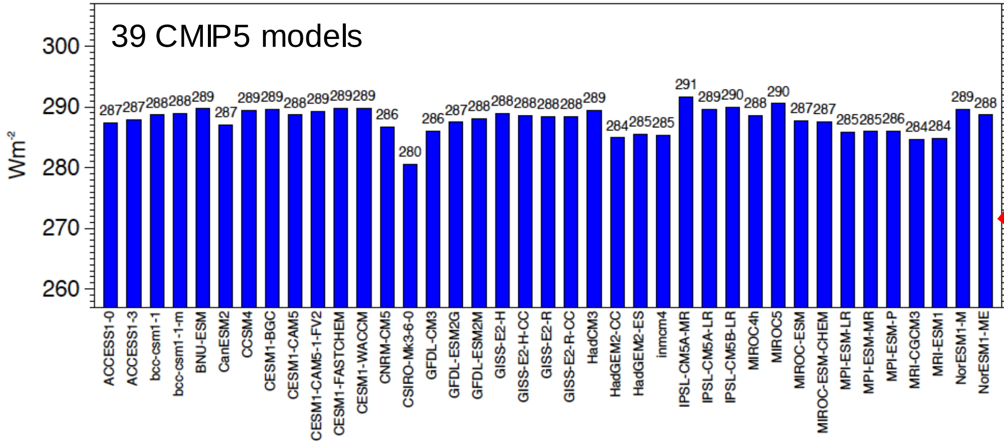

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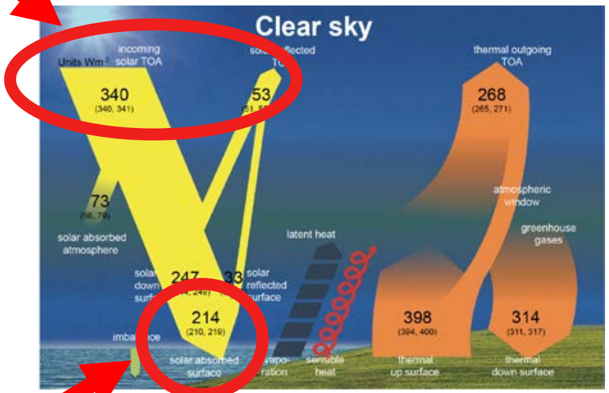
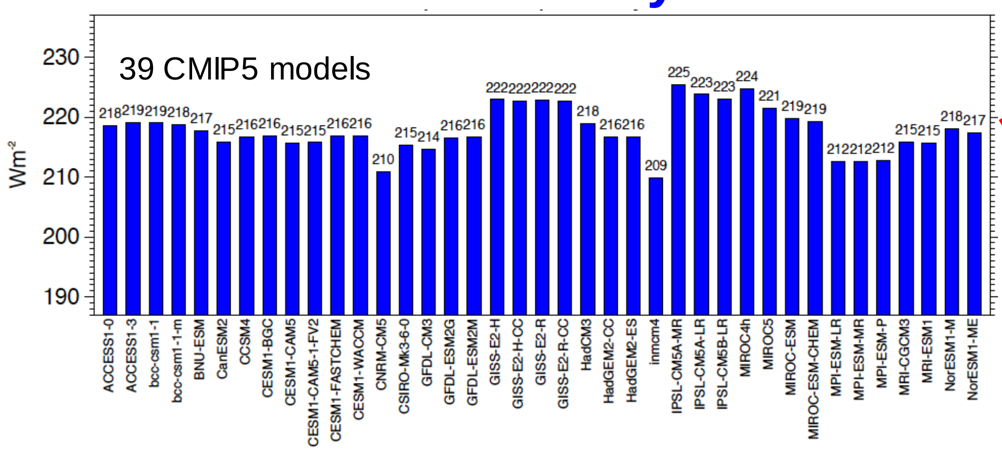


Surface absorbed shortwave clear sky



Multimodel mean: 218 Wm^{-2}
Range of models: 16 Wm^{-2}
Standard deviation: 3.7 Wm^{-2}

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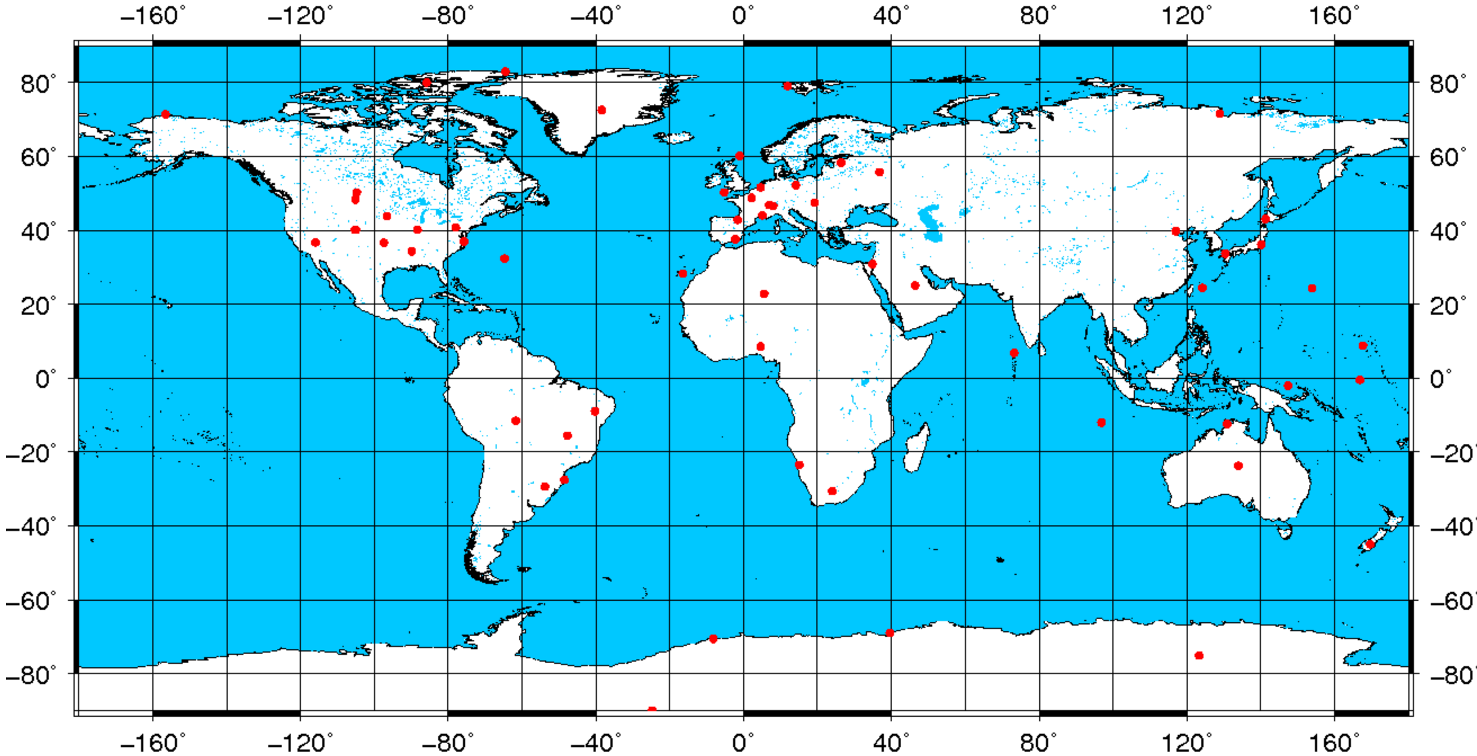
Constraints from surface observations

BSRN Baseline Surface Radiation Network

- WCRP initiative, starting in 1992
- Highest measurement quality at selected sites worldwide (currently more than 50 anchor sites)
- Minute values
- Ancillary data for radiation interpretation



54 Stations covering a latitude range from 80˚ N to 90˚ S and various climate regimes

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Estimating clear-sky climatologies at BSRN sites

Clear sky estimates making use of the high temporal resolution of the BSRN records (minute data)

SW clear sky detection algorithm

Long and Ackerman (2002) JGR

Takes into account magnitude and temporal variability of diffuse and total downward solar radiation

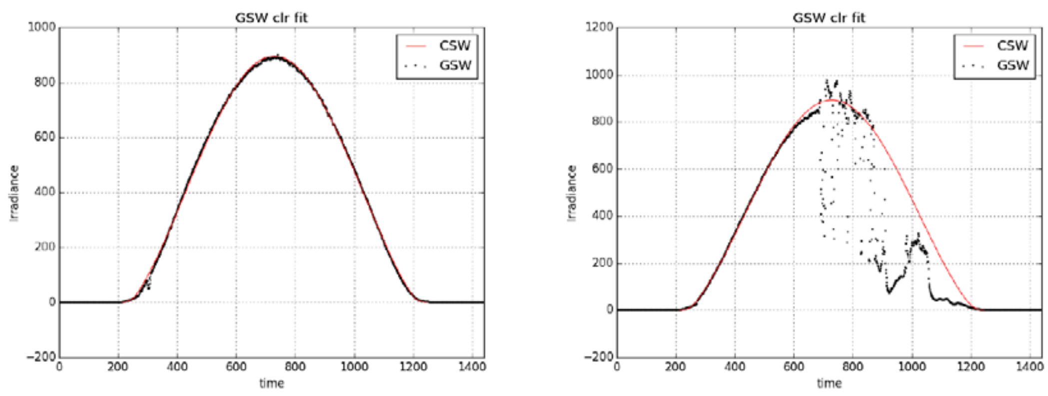
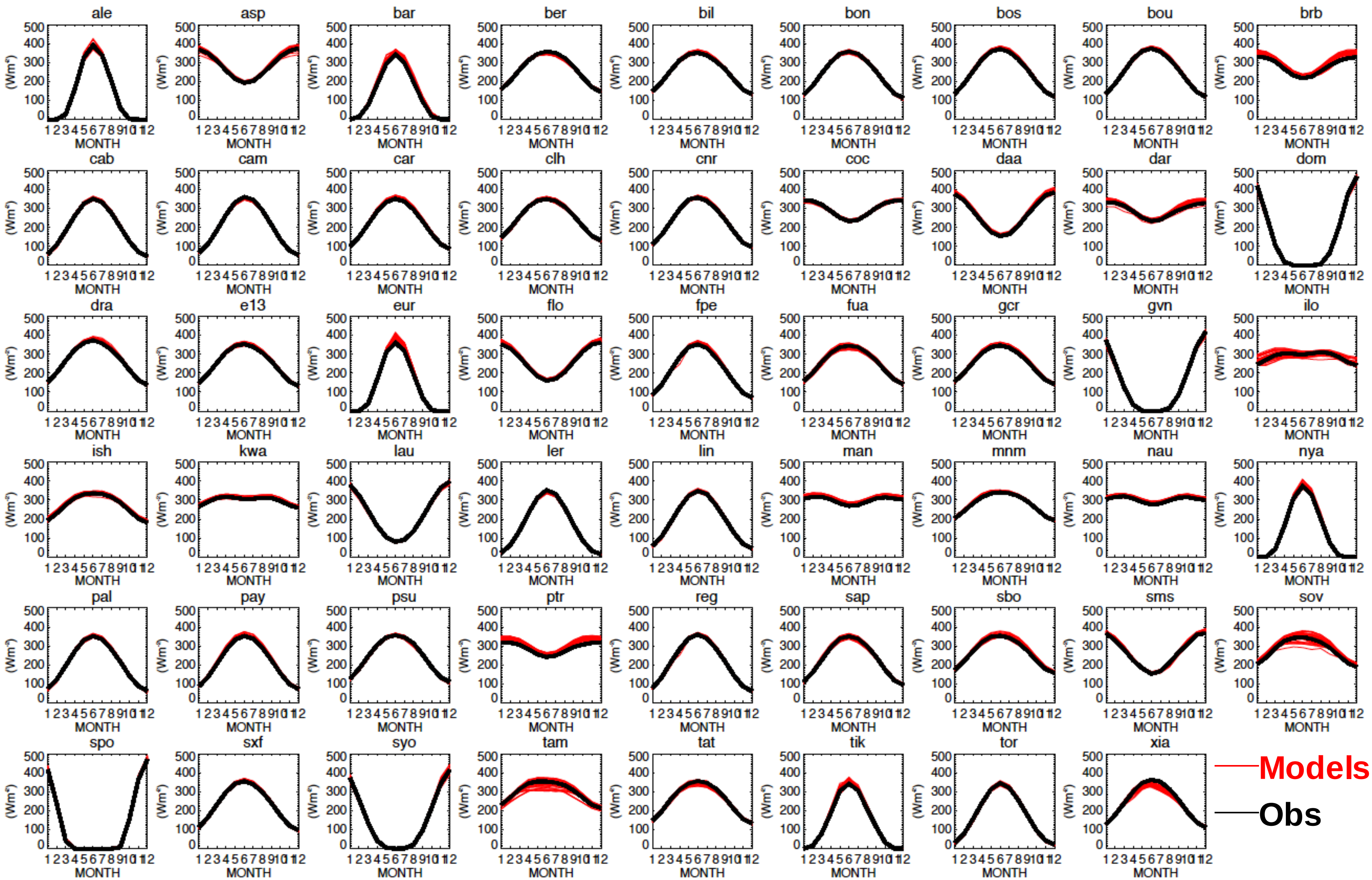


Figure 3: Diurnal cycles of downwelling total (global) SW (black) and clear-sky fits (red) at Lindenberg on 5th of May 2006 (left) and 6th of May (right).

Algorithm implemented at ETH Zurich by Maria Hakuba with support from Chuck Long

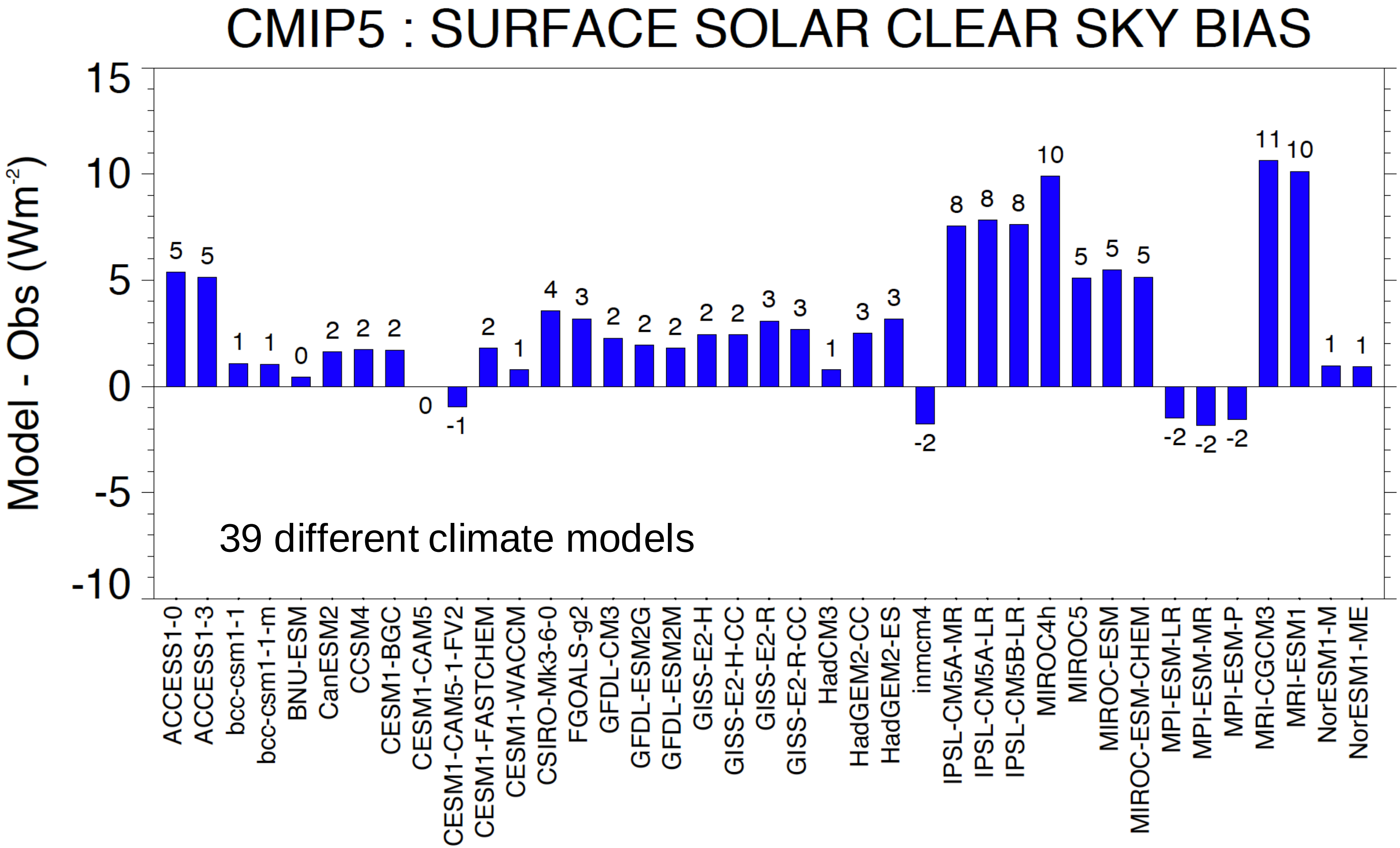
Mean climatologies of clear sky solar radiation

SW down clear sky evaluation



39 CMIP5 models at 53 BSRN sites

SW down clear sky evaluation



Individual CMIP5 model biases averaged over 53 BSRN sites

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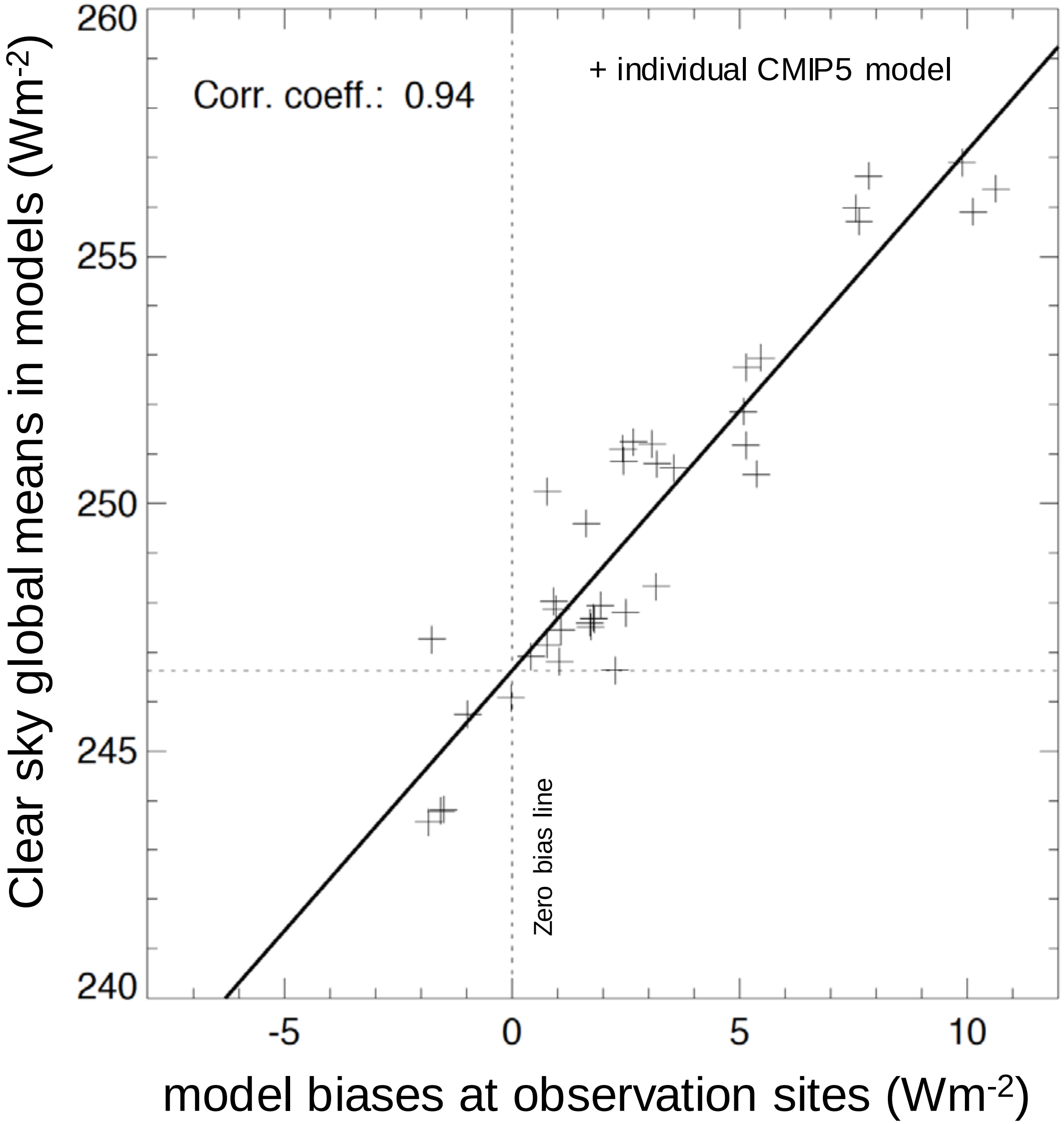
Best estimates for global mean clear sky fluxes

Surface SW down clear sky

GCM global means versus their biases averaged over BSRN sites



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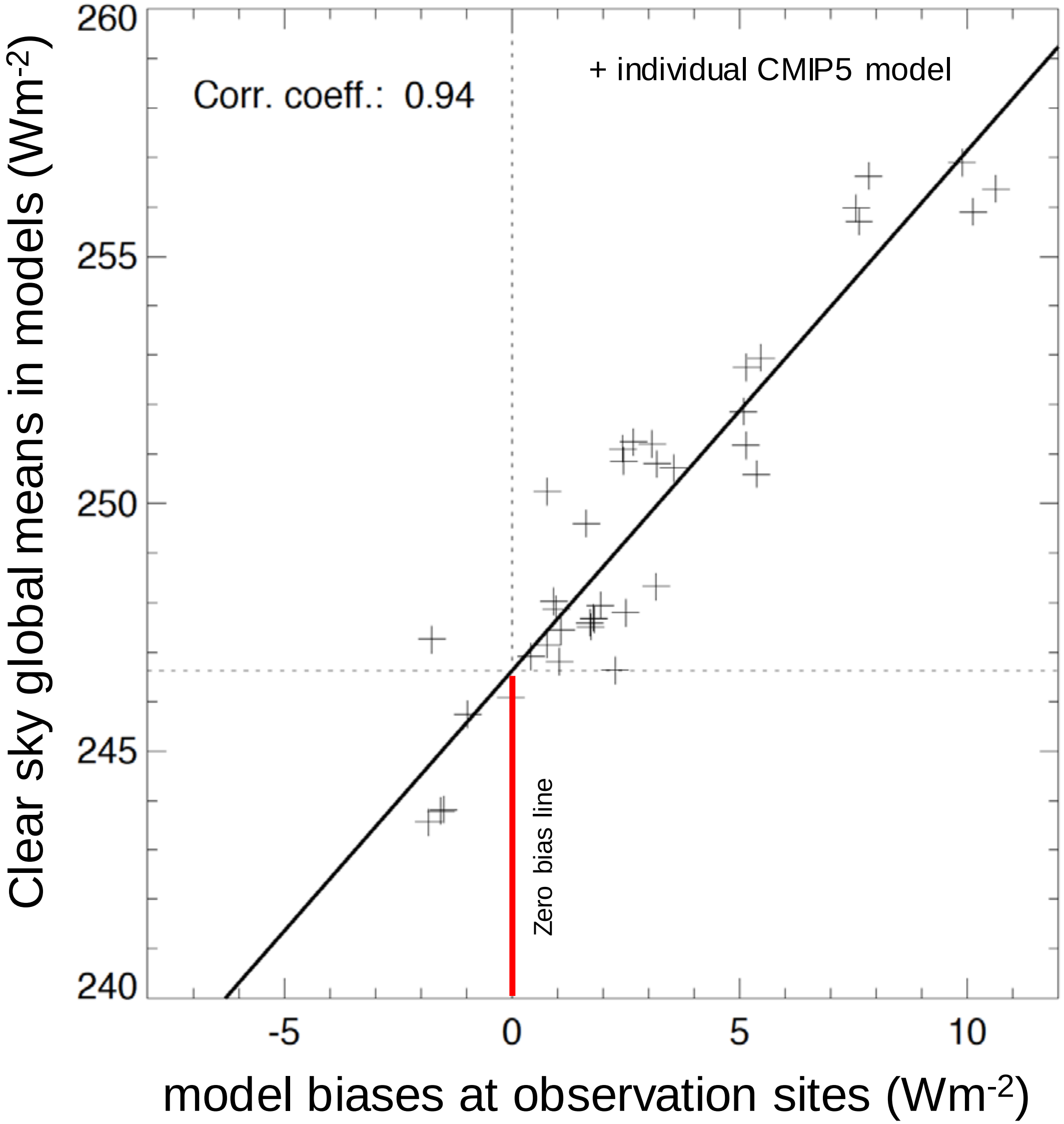

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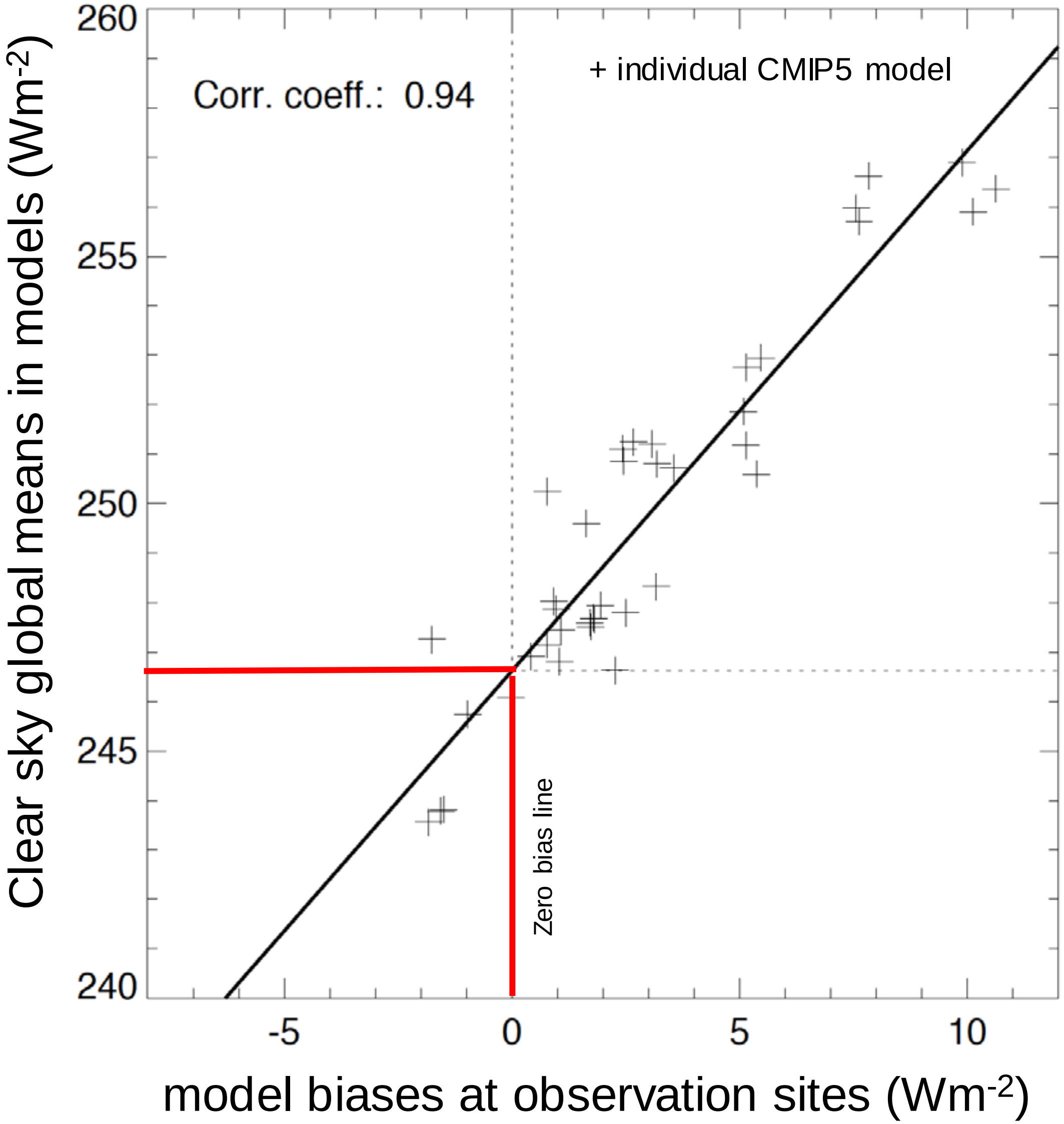
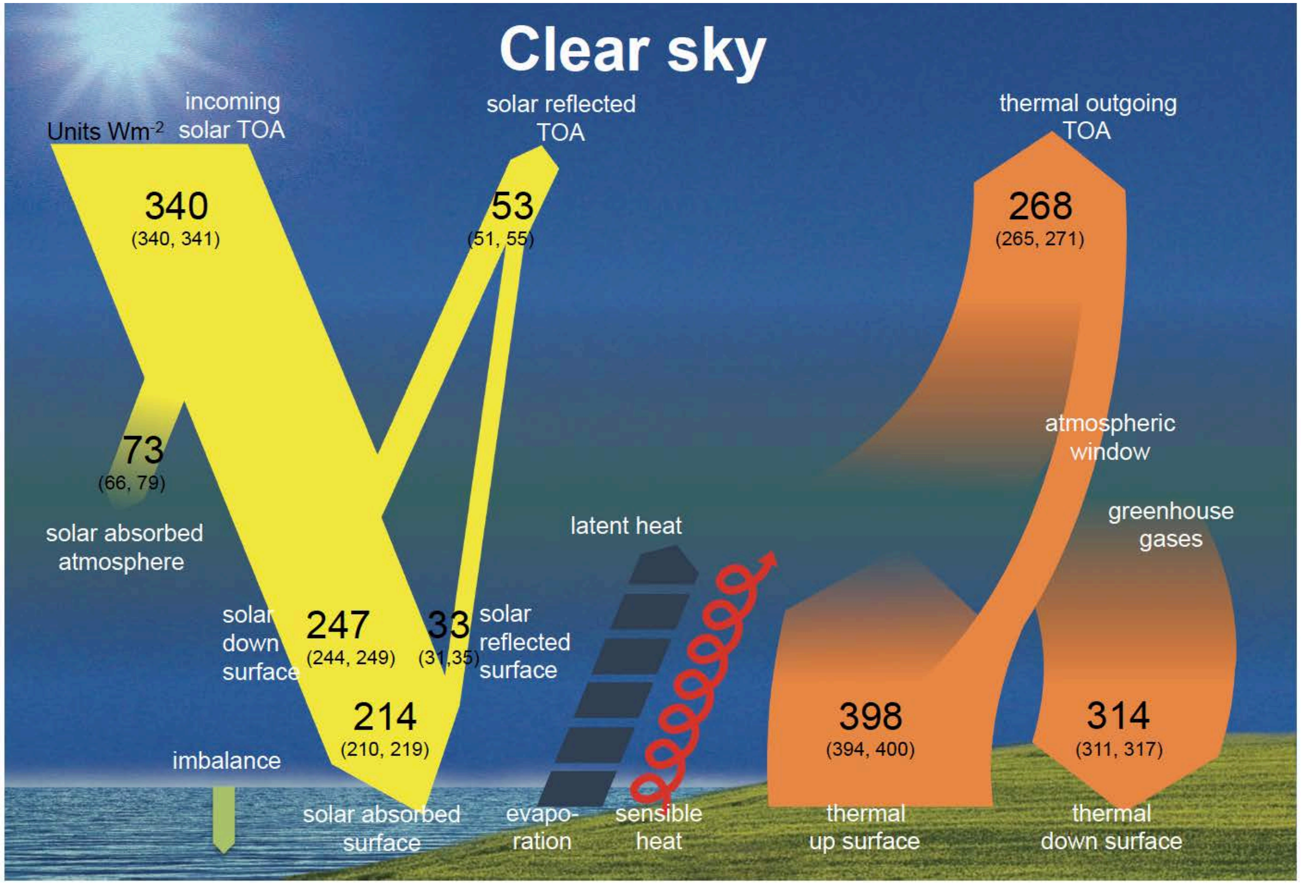


Best estimate surface SW down Clear sky:
247 Wm^{-2}

Earth Radiation Budget without clouds



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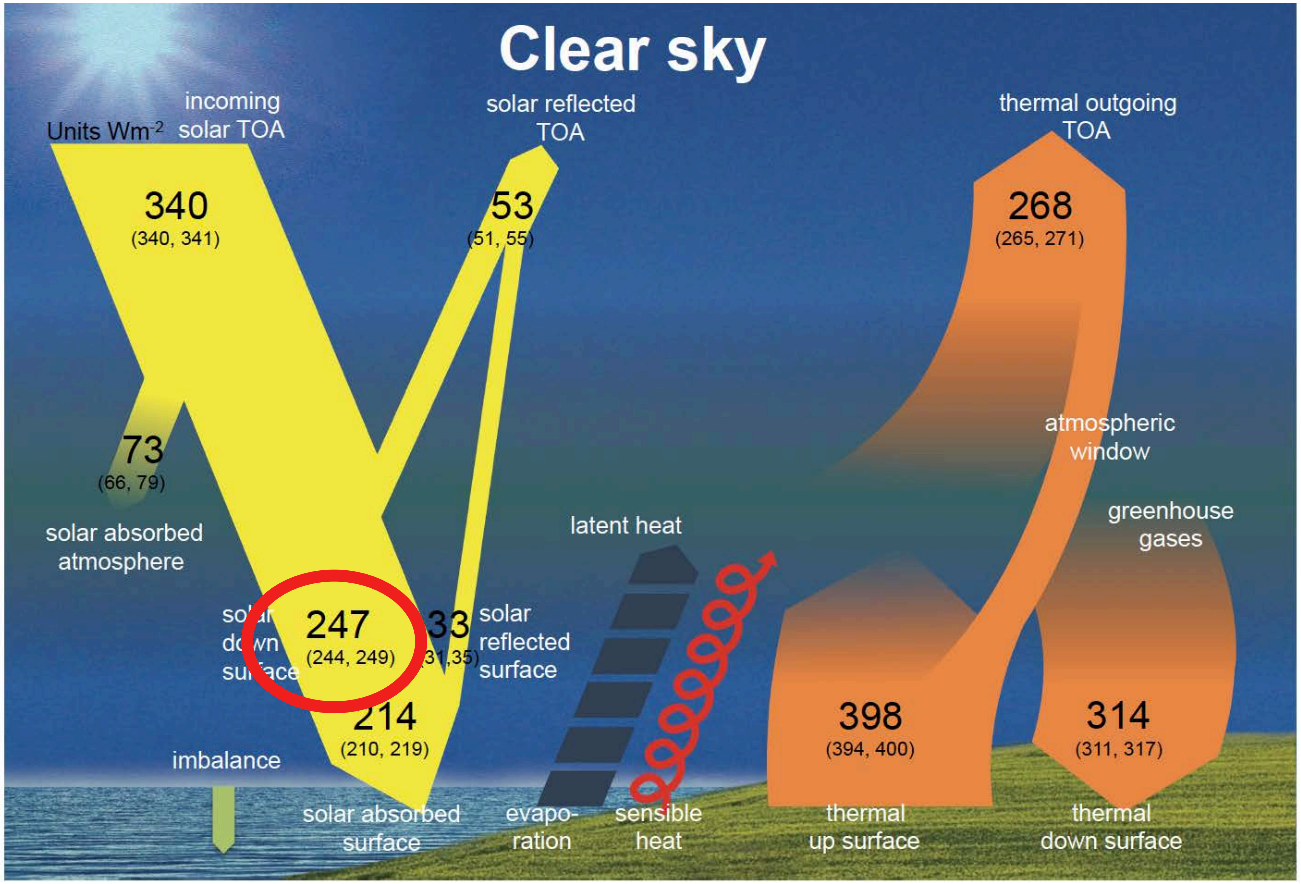

Global mean surface downward solar clear sky fluxes

BSRN observations + CMIP5

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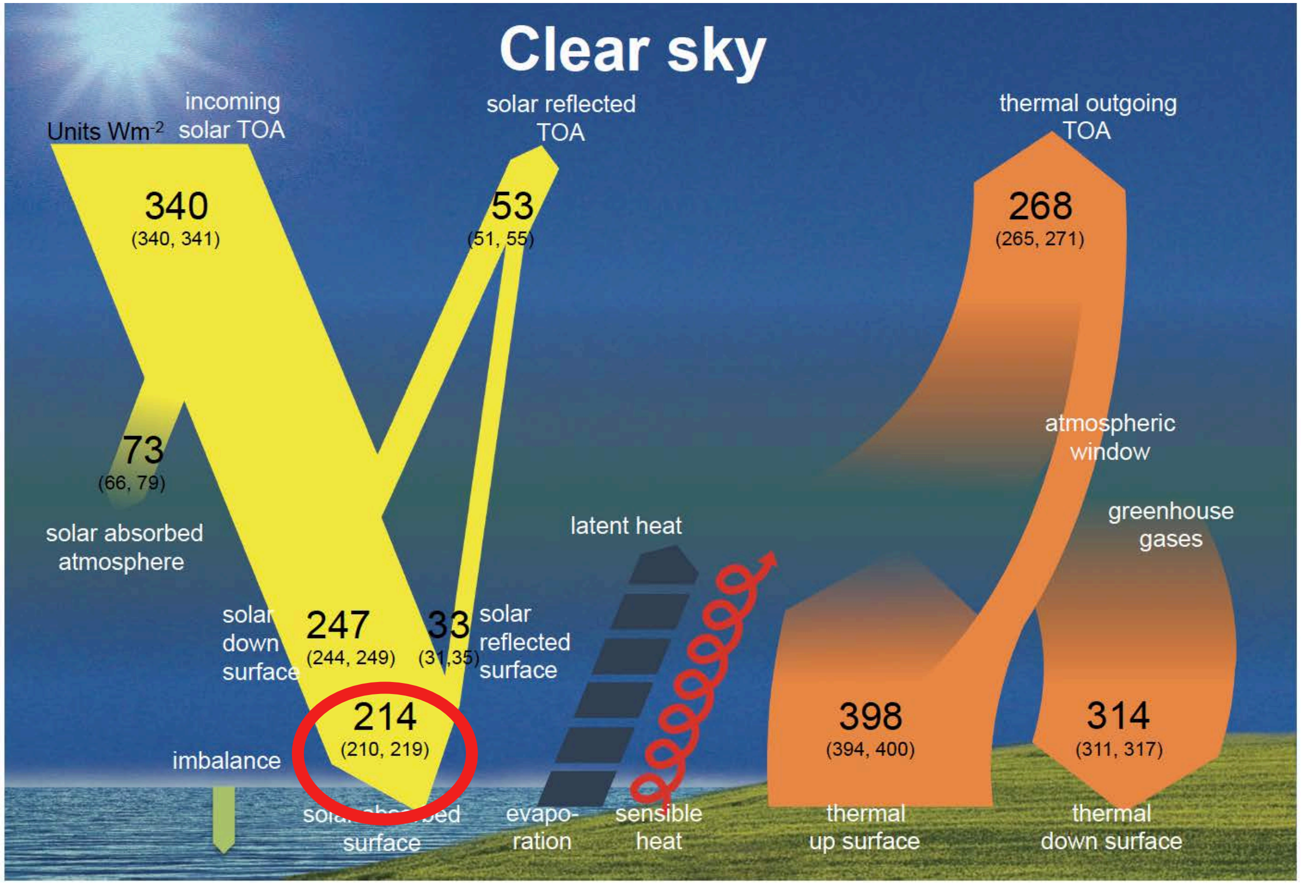
Earth Radiation Budget without clouds



Additional surface albedo estimate (0.13) to derive surface clear sky absorbed SW of 214 Wm^{-2}

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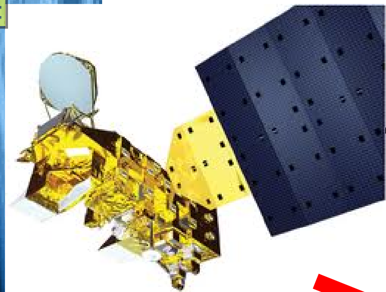
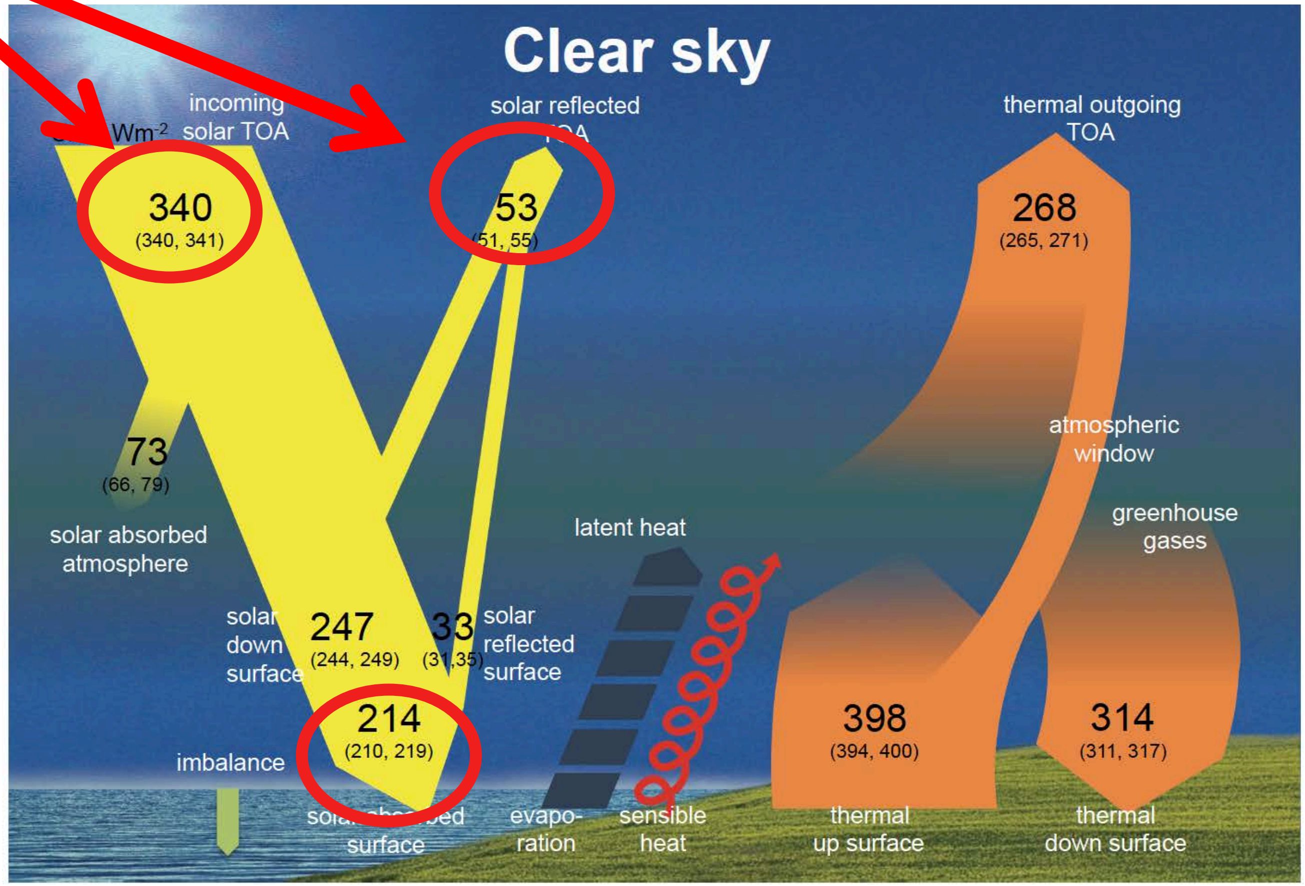
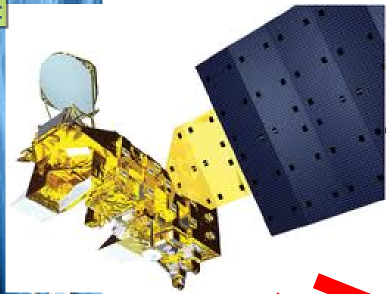


Earth Radiation Budget without clouds

Clear sky TOA fluxes from CERES EBAF

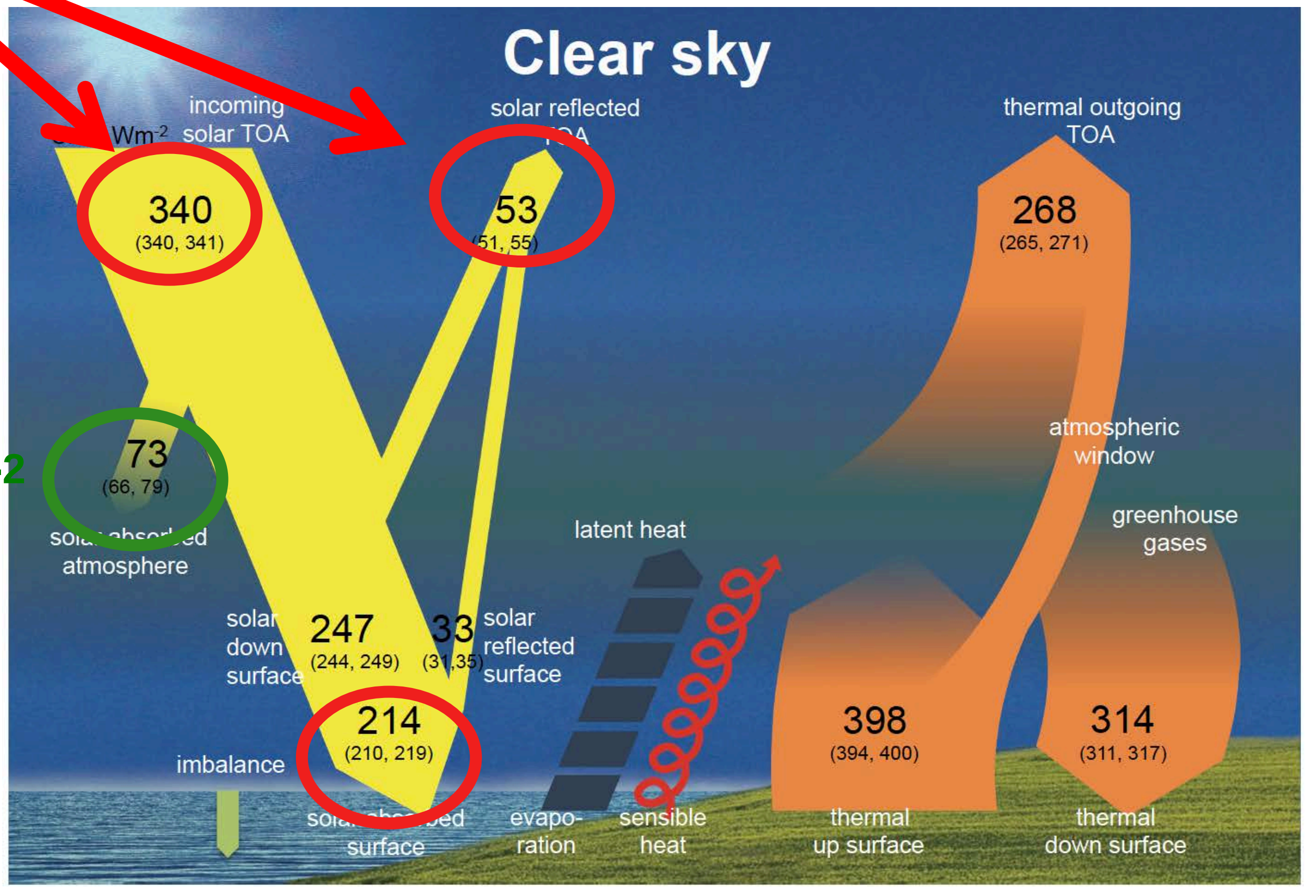




Earth Radiation Budget without clouds

Clear sky TOA fluxes from CERES EBAF

73 Wm^{-2}



Combining SW clear sky TOA and surface absorption to obtain atmospheric clear sky SW absorption

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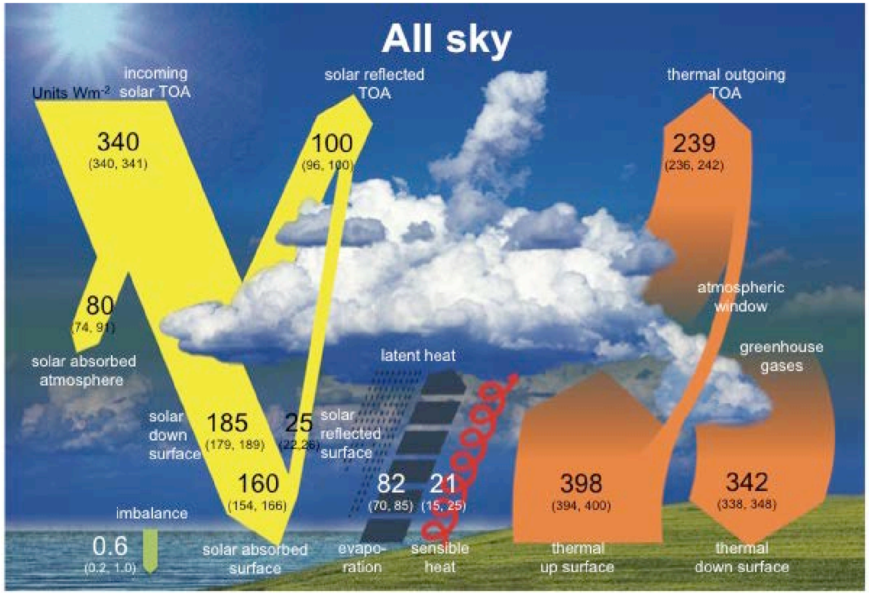
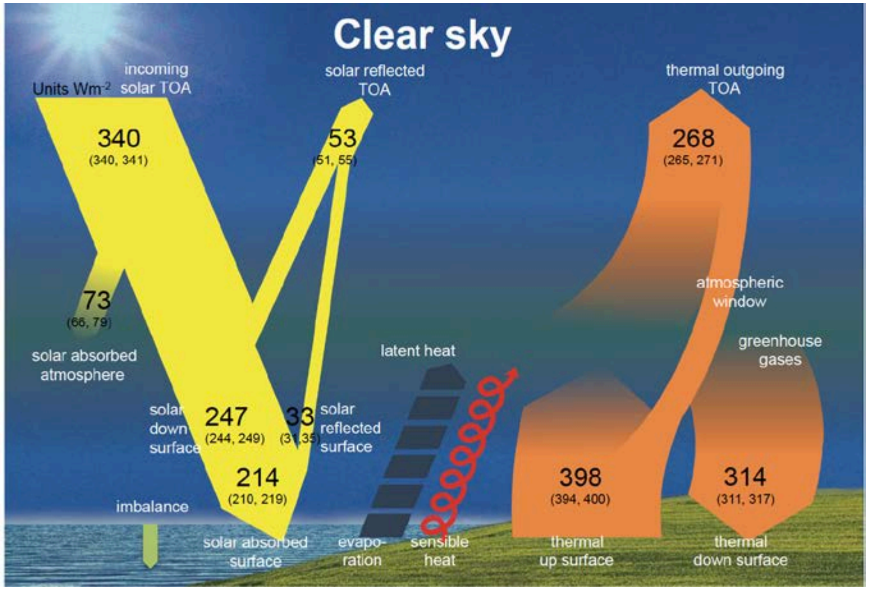
Global mean Cloud Radiative Effect (CRE)

All sky

Clear sky



Wild et al 2015 Clim. Dyn.



Present study

Units Wm^{-2}	SW CRE	LW CRE	Net CRE
TOA	-47	29	-18
Atmosphere	7	1	8
Surface	-54	28	-26
Surface CMIP5	-53	25	-28

Temporal changes in clear sky solar radiation

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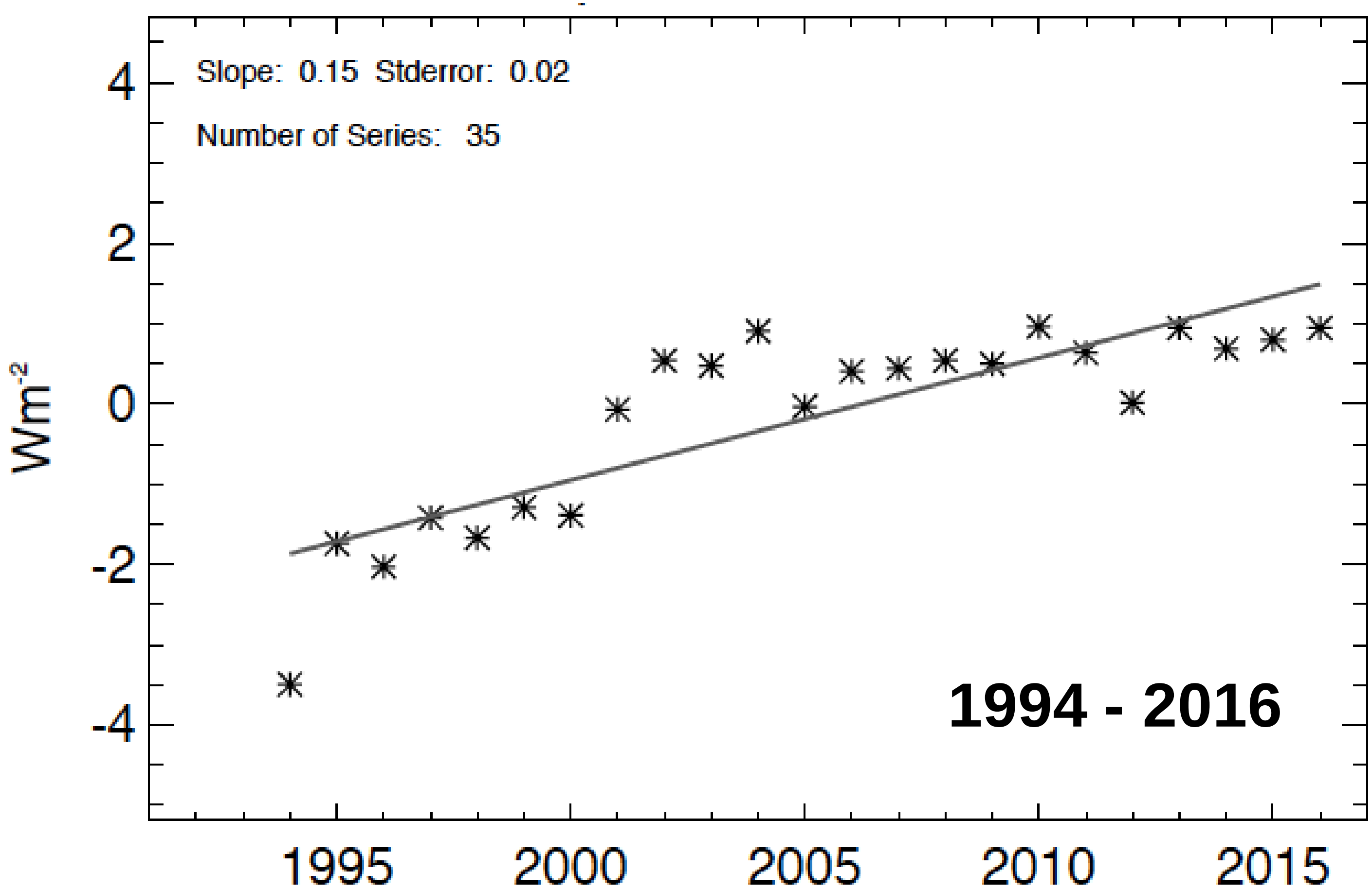
Composite solar clear sky BSRN time series

Clear-sky surface solar radiation composite series



Composite from 35 longest BSRN records

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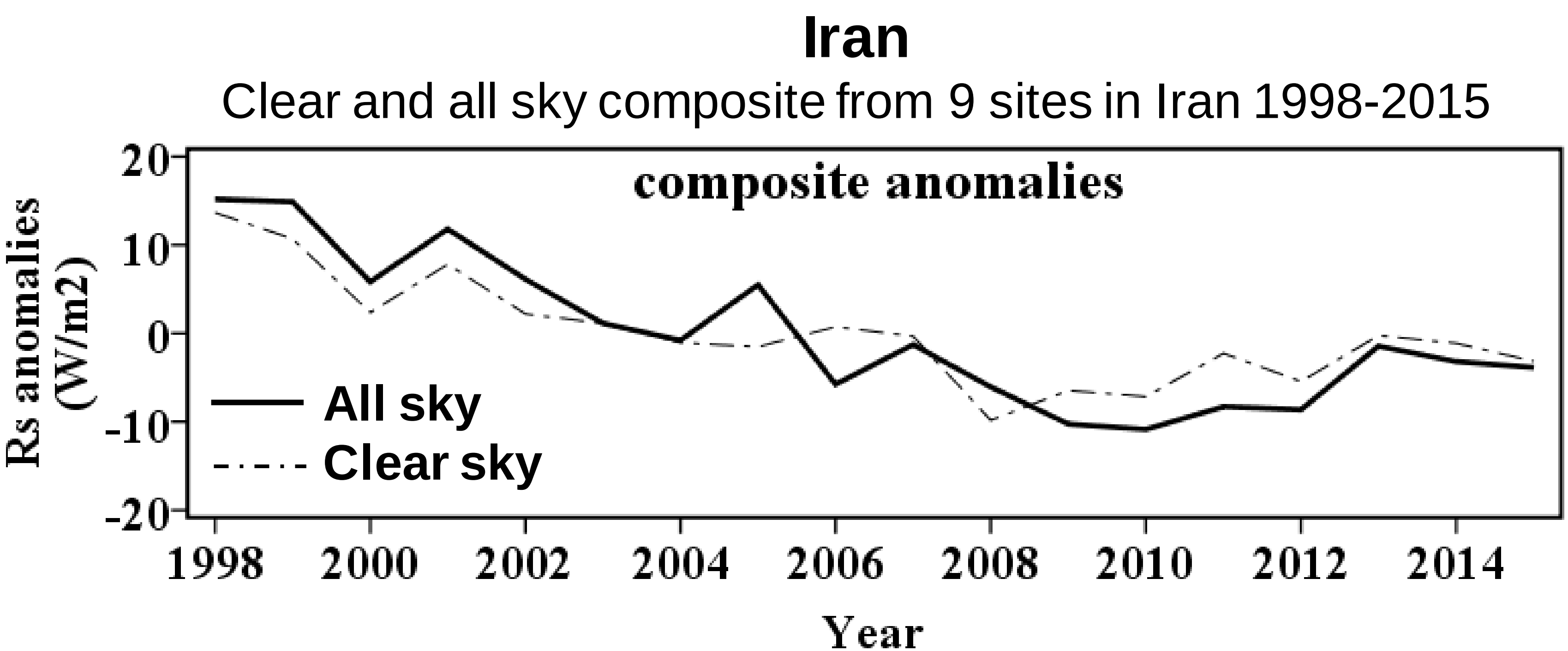
Clear sky trends in non-BSRN records



- Based on daily radiation data
- clear sky identification using daily synop cloud information

Jahani, Dinpashoh, Wild 2017

Jahani B., Dinpashoh Y., Wild, M. 2017: Dimming in Iran since the 2000s and the potential underlying causes. *Int. J. Climatol.*

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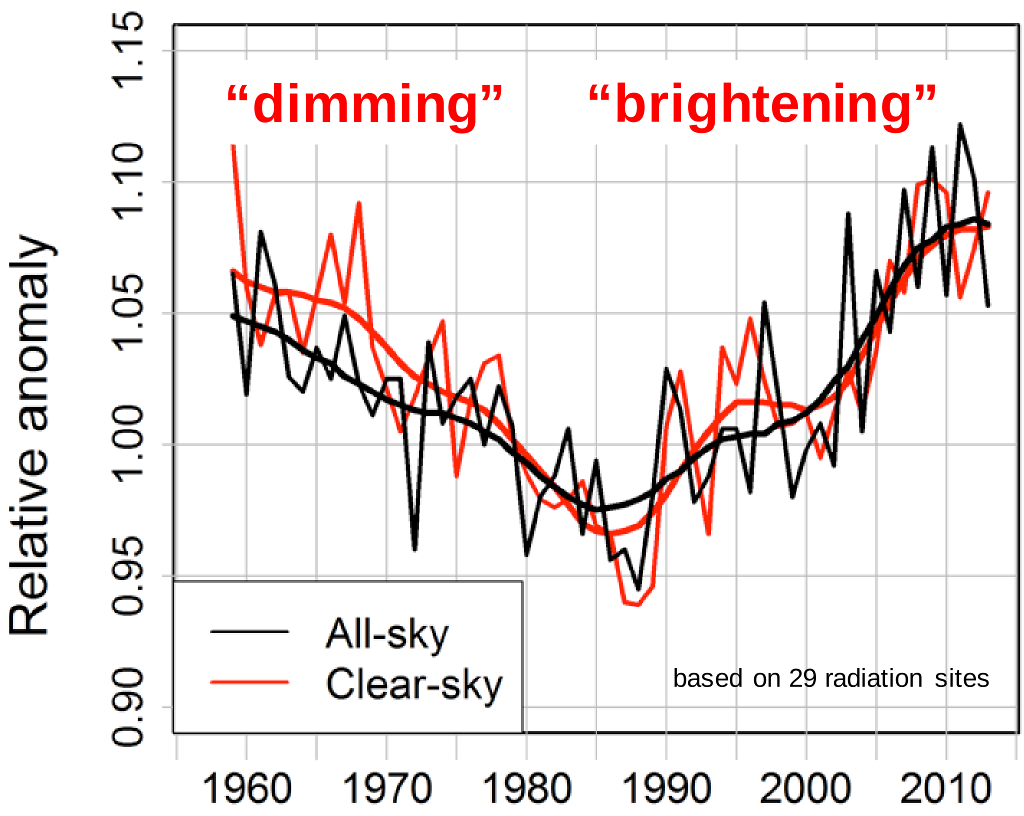
Changes in clear sky radiation further back in time

Surface solar radiation in Italy 1959-2013



Similar variations under clear and all sky conditions

Manara et al. 2016, ACP

Daily data: Clear sky detection using synop cloud information

Manara, V., Brunetti, M., Celozzi, A., Maugeri, M., Sanchez-Lorenzo, A., and Wild, M., 2016: Detection of dimming/brightening in Italy from homogenized all-sky and clear-sky surface solar radiation records and underlying causes (1959–2013), *Atmos. Chem. Phys.*,**16,** 11145-11161,

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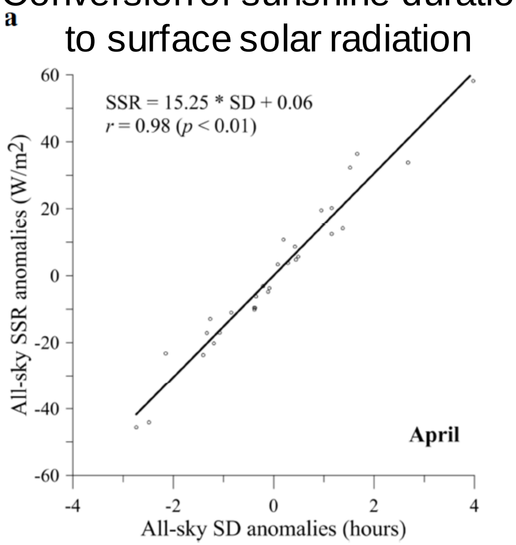
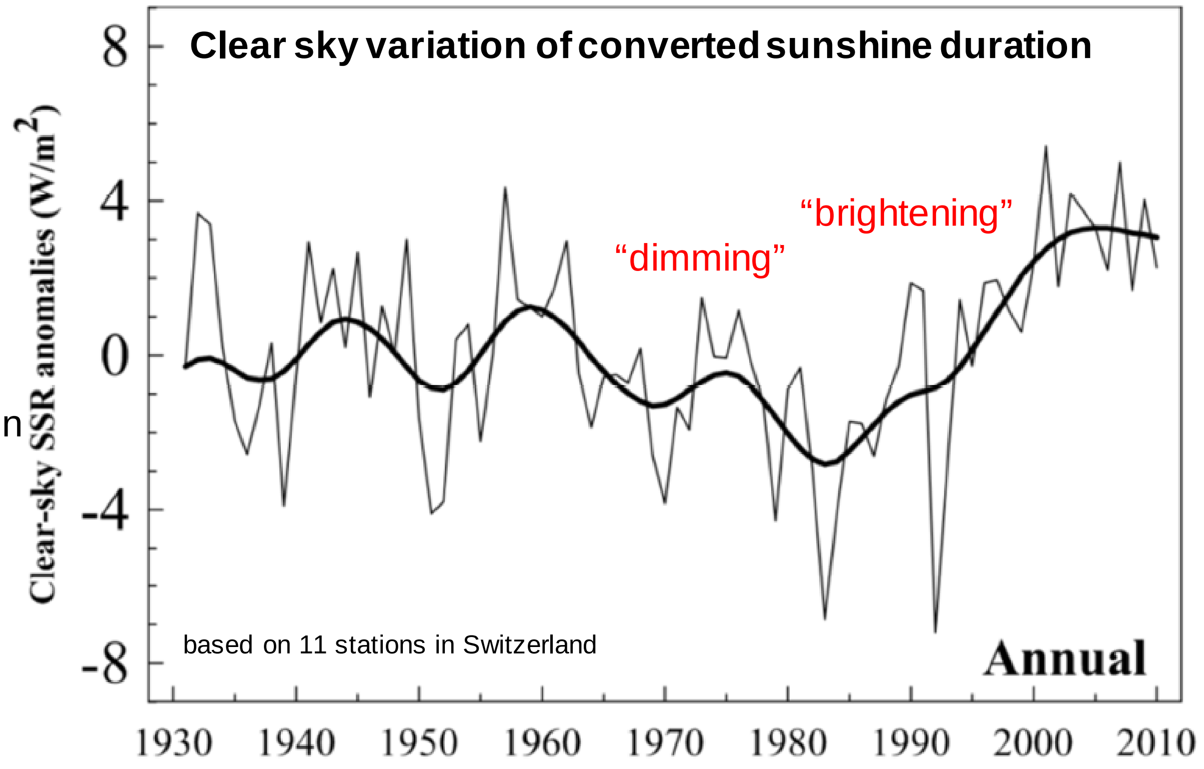
Changes in clear sky radiation further back in time

Clear sky surface solar radiation in Switzerland back to 1930s inferred from Sunshine Duration records

Conversion of sunshine duration to surface solar radiation





Sanchez-Lorenzo and Wild 2012, ACP

Sanchez-Lorenzo, A., and Wild, M., 2012: Decadal variations in estimated surface solar radiation over Switzerland since the late 19th century, *Atmos. Chem. Phys.*, **12**, 8635–8644,

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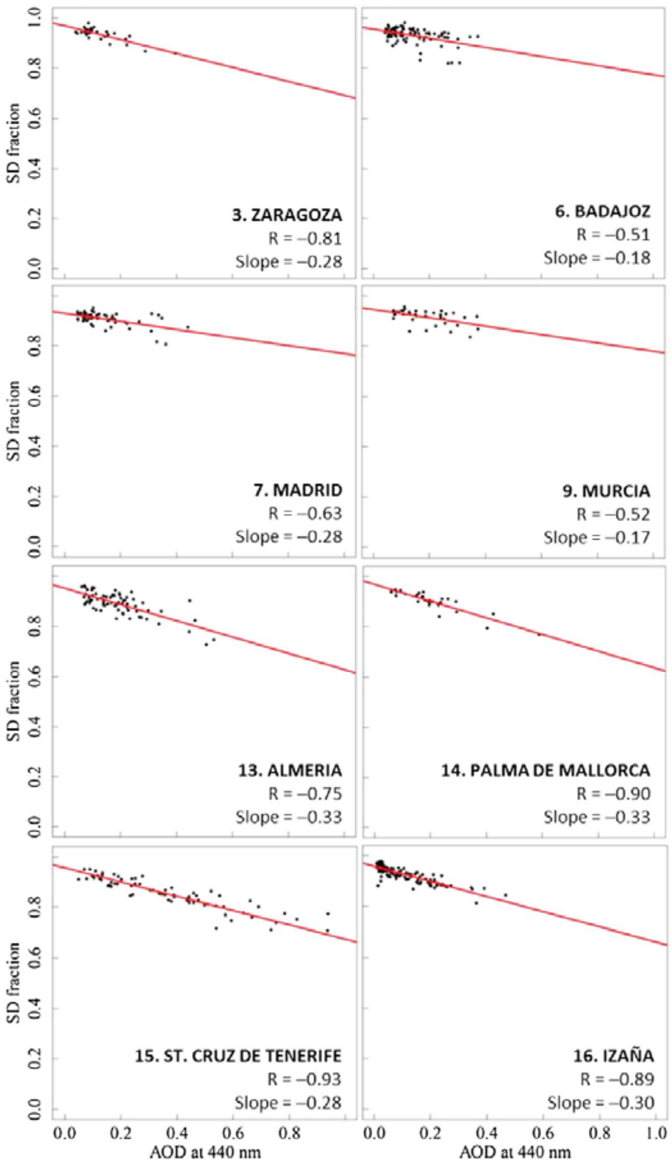
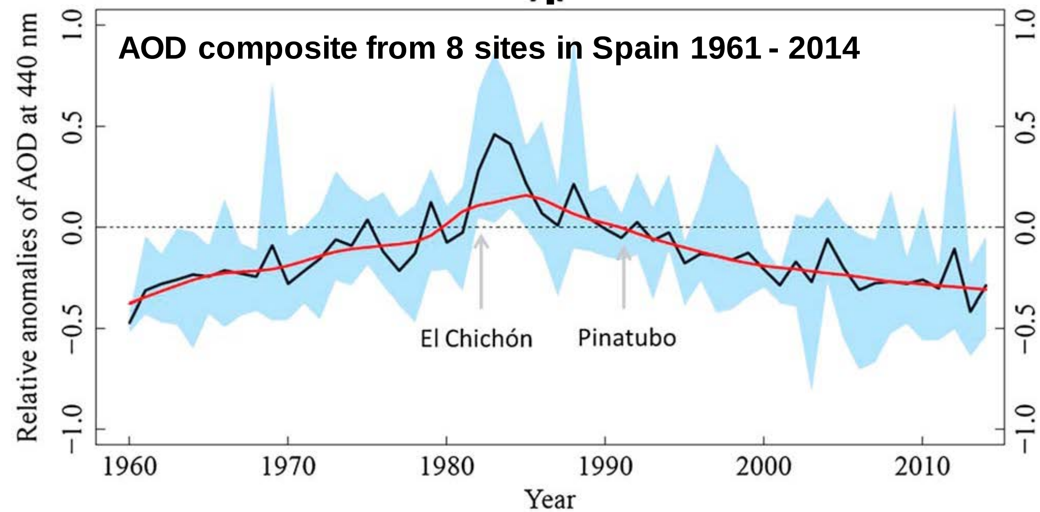
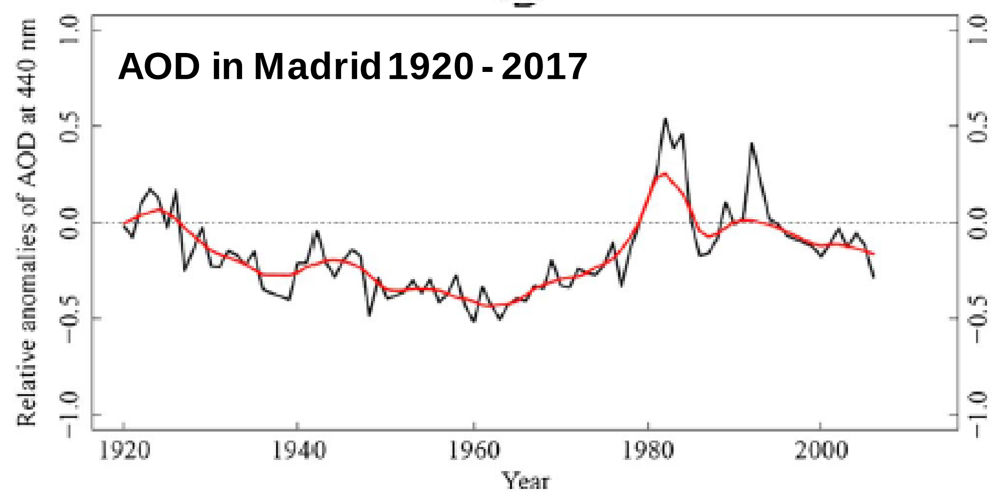
Reconstruction of AOD from Sunshine duration

Correlation between clear sky Sunshine Duration and AOD at 8 Aeronet sites in Spain



Reconstruction of AOD from SD in Spain





Sanchez-Romero et al. 2016

Sanchez-Romero, A., A. Sanchez-Lorenzo, J. A. González, and J. Calbó (2016), Reconstruction of long-term aerosol optical depth series with sunshine duration records, *Geophys. Res. Lett.*, **43,** 1296–1305,

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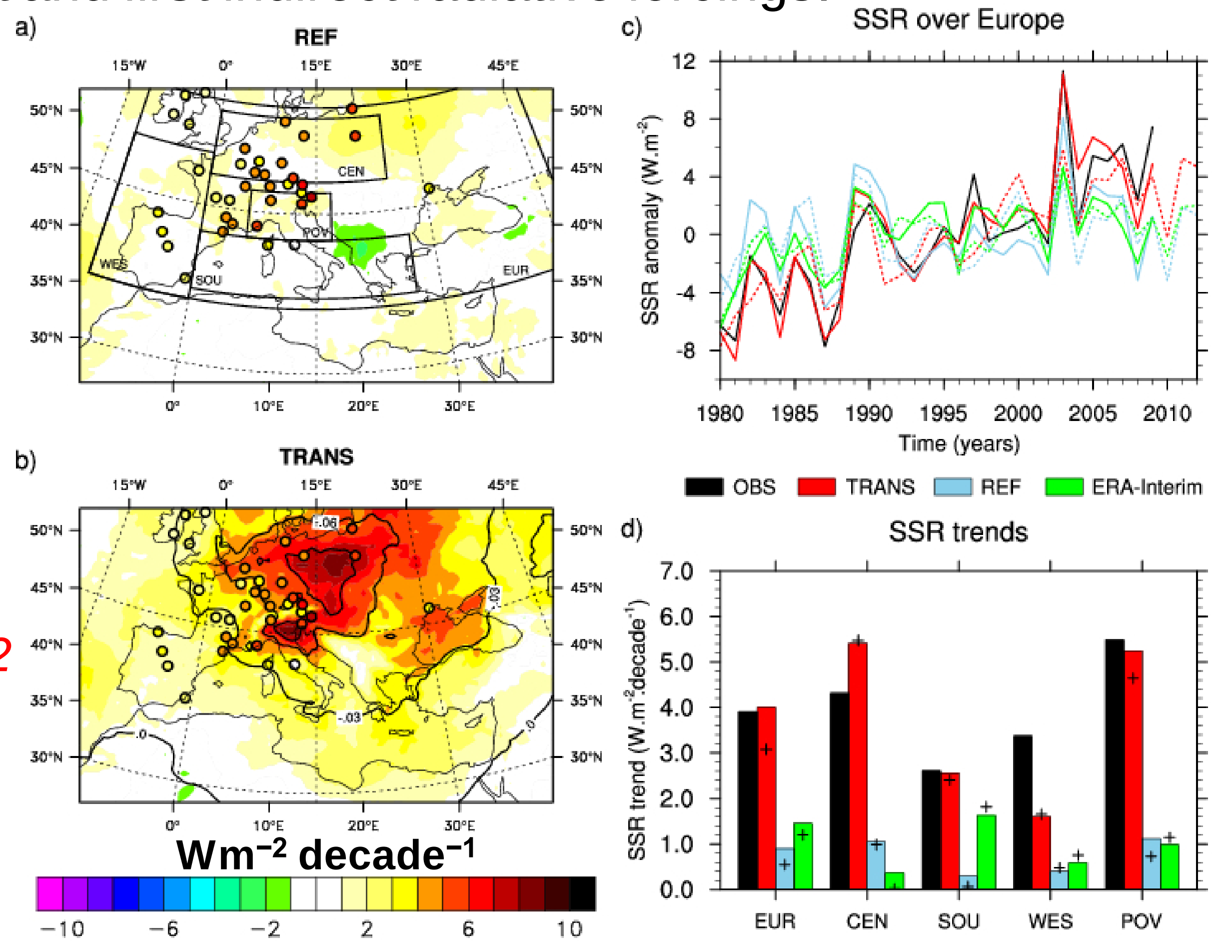
Brightening in a regional climate model

- fully coupled Regional Climate System Model CNRM-RCSM4, driven by the ERA-Interim, with/without time-varying aerosols
- includes aerosols through monthly AOD climatologies and simulates direct, semi-direct and first indirect radiative forcings.

Brightening over Europe (1980 - 2012) realistically captured

- *Aerosol changes explain 81% of the brightening 1980-2012*
- *mostly through direct aerosol effect*
- *Improves simulated warming over Europe*



Nabat, P., S. Somot, M. Mallet, A. Sanchez-Lorenzo, M. Wild (2014), Contribution of anthropogenic sulfate aerosols to the changing Euro-Mediterranean climate since 1980, *GRL* **41**

Nabat et al., 2014 GRL

Conclusions

- Clear sky surface solar radiation flux climatologies inferred from high accuracy Baseline Surface Radiation Network (BSRN) minute data
- So far used for assessment of the CMIP5 clear sky fluxes and the estimation of the energy balance under cloud free condition, as well as cloud radiative effects, both globally and at BSRN sites
- Clear sky fluxes maybe of use for diagnosing AeroCom simulations
- BSRN clear sky solar records show an overall increase in radiation since the1990s with a recent leveling off
- Daily surface solar radiation data from non-BSRN stations allow the estimation of clear sky variations ("dimming/brightening") further back in time and with a higher spatial coverage
- Also sunshine duration data may be of use to estimate variations of clear sky surface solar radiation and AOD on multidecadal timescales

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Identification of clear sky periods

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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

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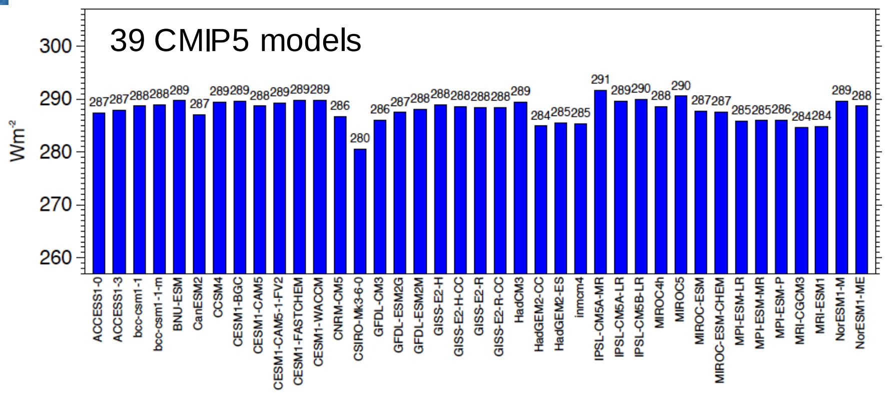
Global mean SW clearsky radiation budgets in CMIP5



Absorbed SW clear sky top of atmosphere

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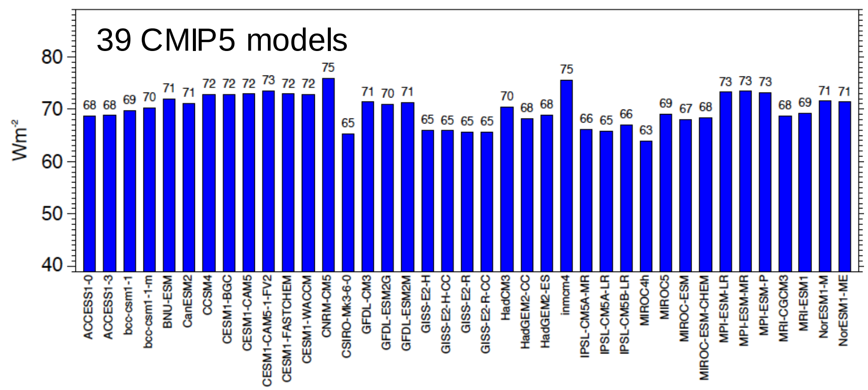
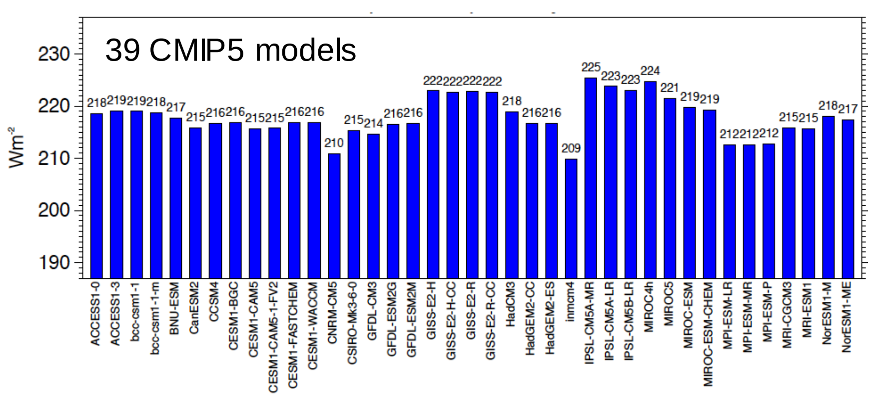
Standard deviation: 2.1 Wm^{-2}
CERES Reference: 287 Wm^{-2}



Absorbed SW clear sky in the atmosphere

Multimodel mean: 70 Wm^{-2}
Range of models: 12 Wm^{-2}
Standard deviation: 3.0 Wm^{-2}



Absorbed SW clear sky at the surface

Multimodel mean: 218 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)

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%)

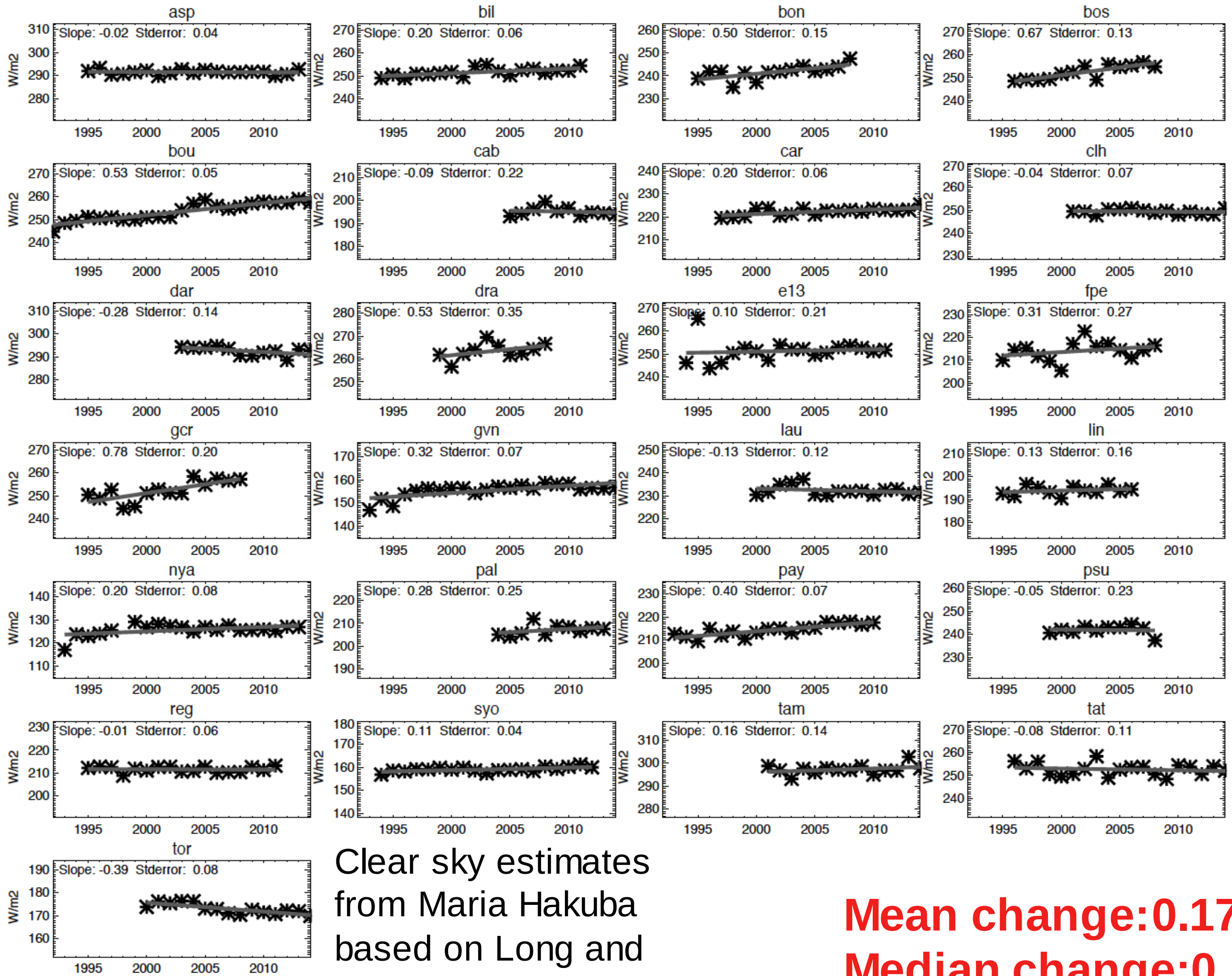
GCM Analysen:

- **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 %

SW down update to 2014: clear sky

25 stations (min.10 years), 388 years totally, 16(14) pos, 9(3) neg. slopes



Clear sky estimates from Maria Hakuba based on Long and Ackermann (2000)

Mean change: 0.17 $Wm^{-2}y^{-1}$
Median change: 0.16 $Wm^{-2}y^{-1}$

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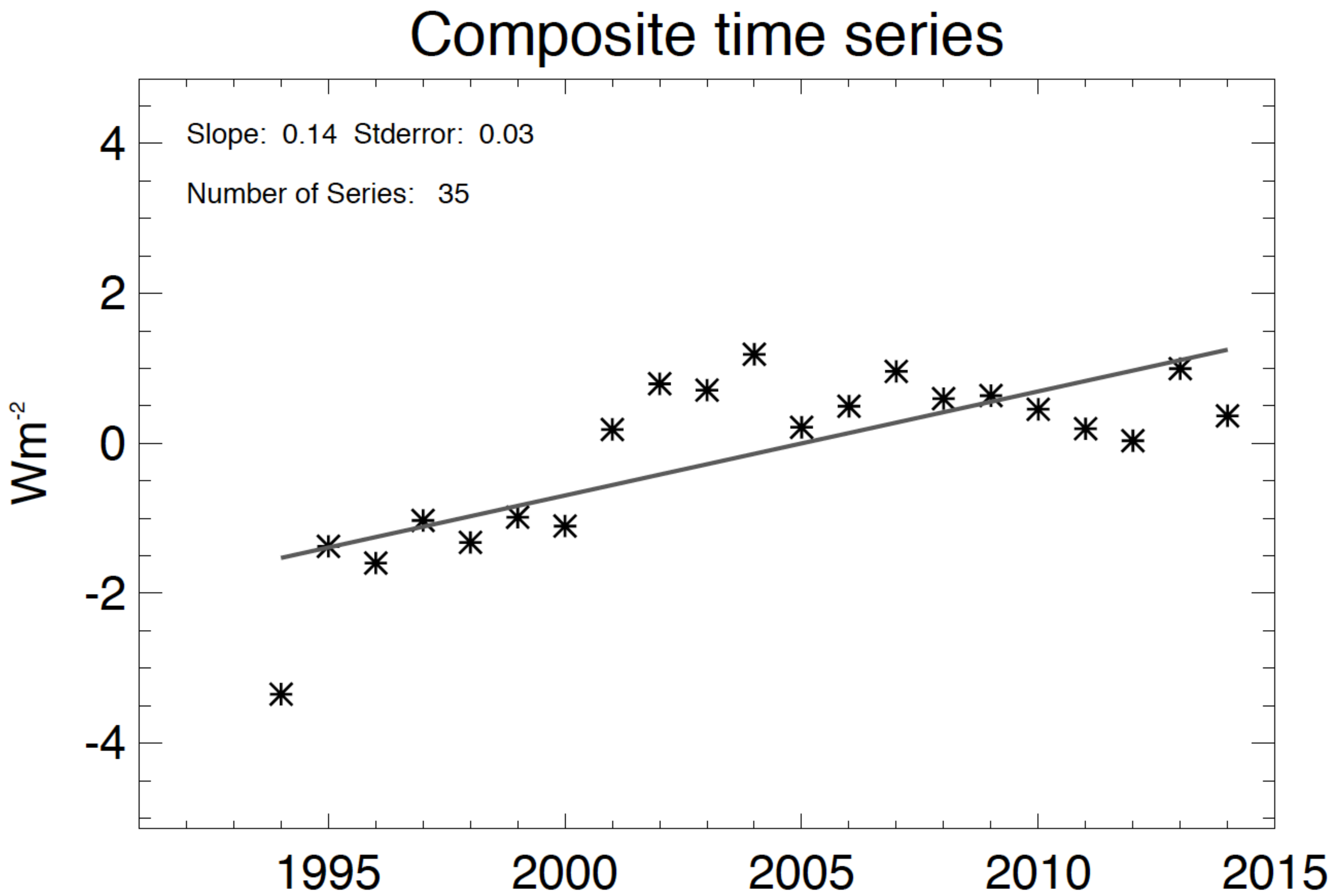
Composite solar clear sky BSRN time series



Composite from 35 longest BSRN records

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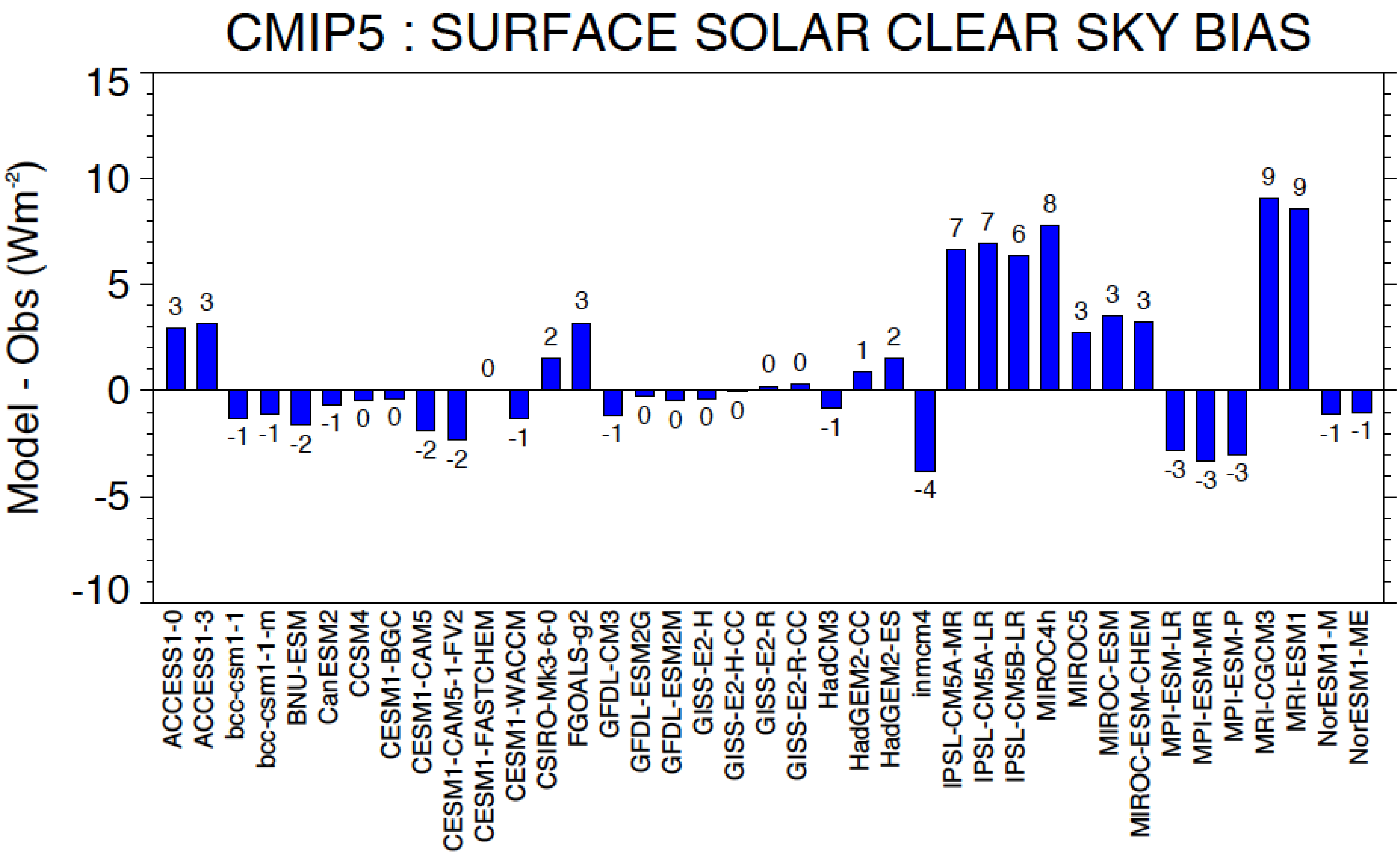
SW down clear sky evaluation



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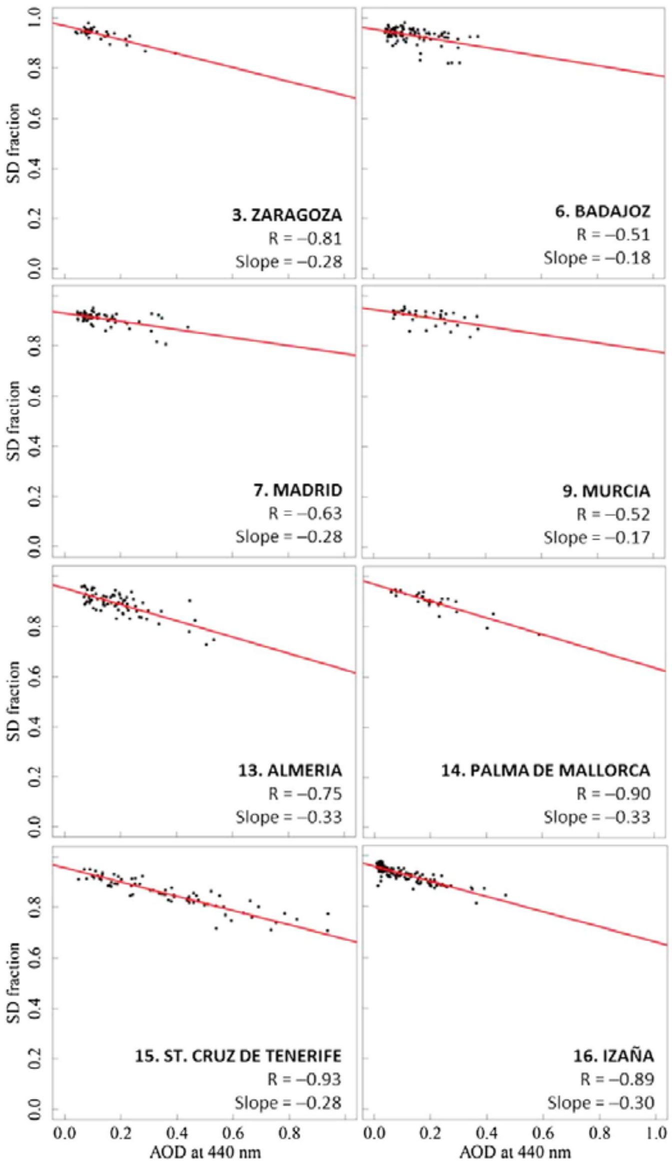

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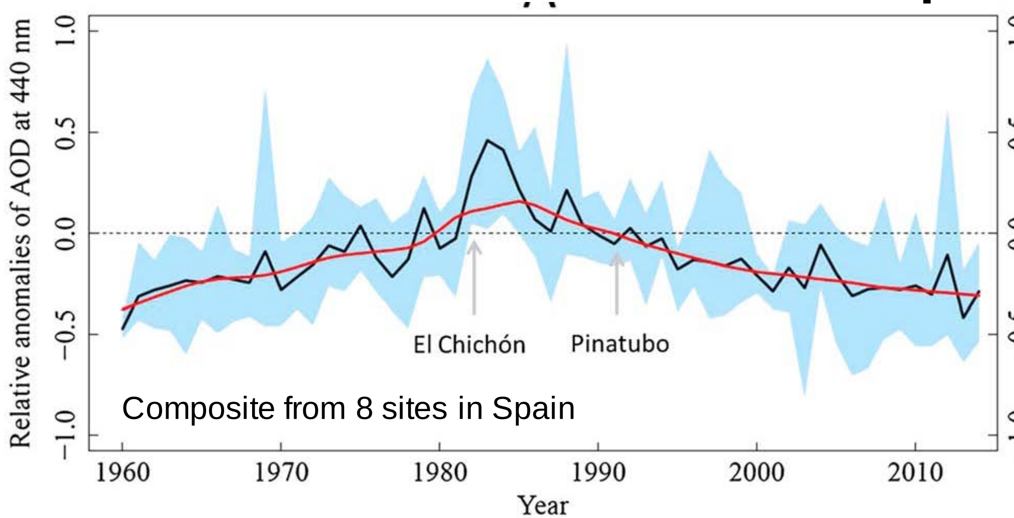

Sanchez-Romero et al. 2016

Sanchez-Romero, A., A. Sanchez-Lorenzo, J. A. González, and J. Calbó (2016), Reconstruction of long-term aerosol optical depth series with sunshine duration records, *Geophys. Res. Lett.*, **43,** 1296–1305,

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Conclusions

- Clear sky surface solar radiation fluxes inferred from high accuracy Baseline Surface Radiation Network (BSRN) minute data.
- Combined with CMIP5 models, has been used for the estimation of the global energy balance under cloud free condition, as well as the global cloud radiative effects
- BSRN stations show an overall increase in clear sky surface solar radiation since the1990s with a recent leveling off.
- Daily surface solar radiation data from non-BSRN data allow the estimation of clear sky variations further back in time
- Also sunshine duration data may be of use to estimate variations of clear sky surface solar radiation and AOD on multidecadal timescales

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