A Meteosat-based Climate Data Record of the Surface Solar Irradiance: Description and Evaluation

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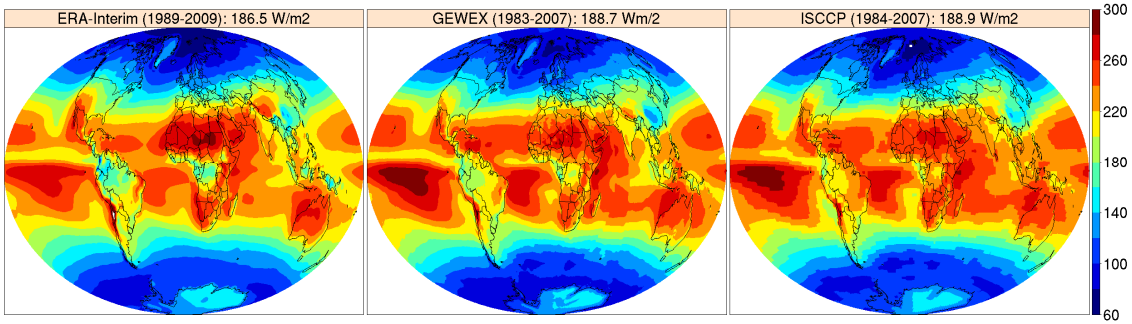
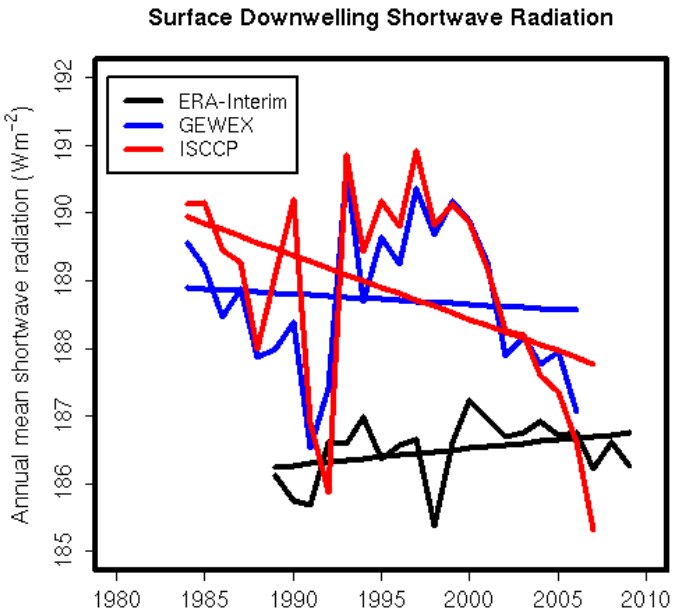
Motivation

- Surface Solar Irradiance highly relevant:
  - Climate Monitoring and Climate Analysis
  - Solar Energy
- Available data sets agree well on the mean
- differ substantially in the temporal evolution
- Rather coarse spatial resolution of the available data sets





The CM SAF approach

- Retrieve surface solar irradiance (SIS) from the geostationary Meteosat satellites (1982 – today)
- Apply a well-established method:

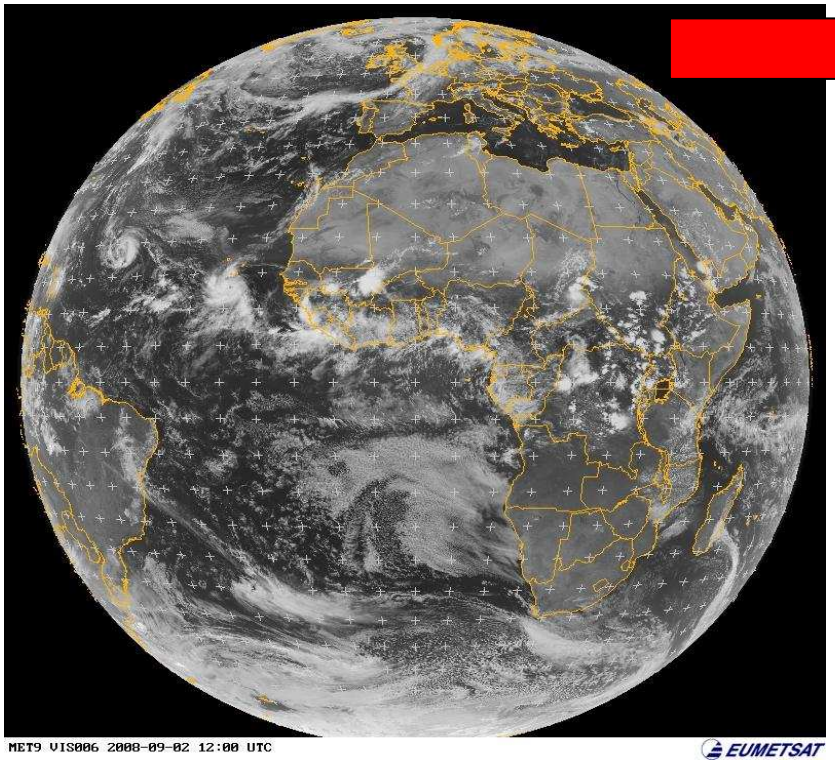
  Heliosat (Cano et al.,1986, Hammer et al., 2003)
- Provide the data with high temporal and spatial resolution, free and easy accessable to the User
- Validate the data with BSRN surface station data
- Evaluate the data with alternative data sets

The Heliosat method

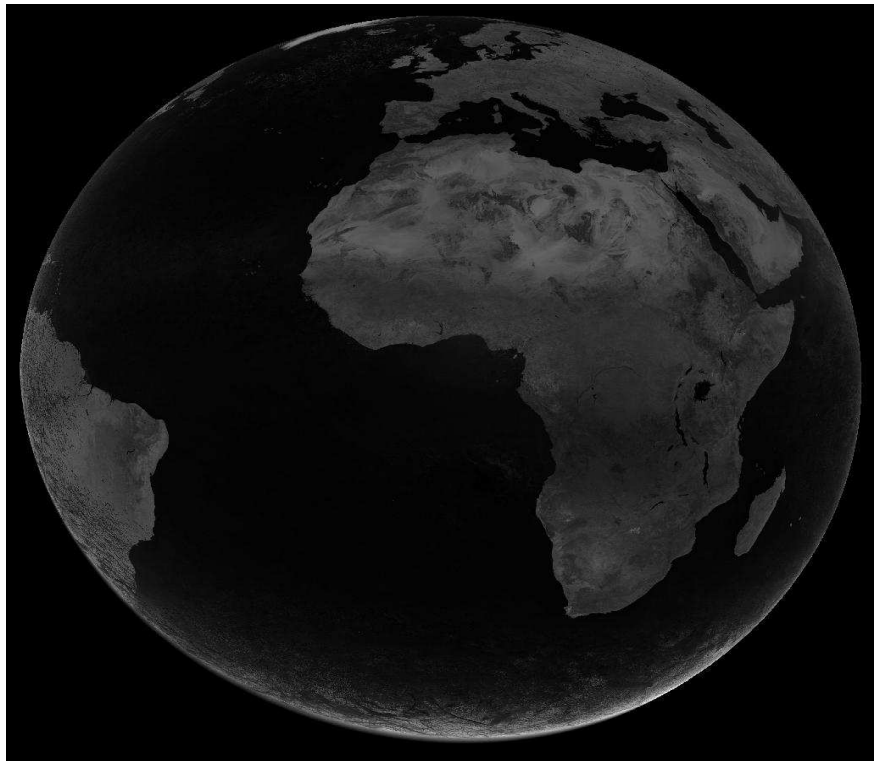
1. The surface clear-sky radiation can be accurately calculated (information on the water vapor and aerosol is required)
2. For each satellite pixel and time slot the minimum reflectance of each months represents clear sky conditions (i.e., effect of Rayleigh scattering + surface albedo on the reflectance)
3. The cloud optical depth is related to the cloud-reflected solar radiation (= brightness of the visible satellite channel)
4. The degradation of sensor sensitivity can be monitored by bright targets (maximum reflectance)

The Heliosat method

Reflectivity, 12 UTC, 2 Sept 2008

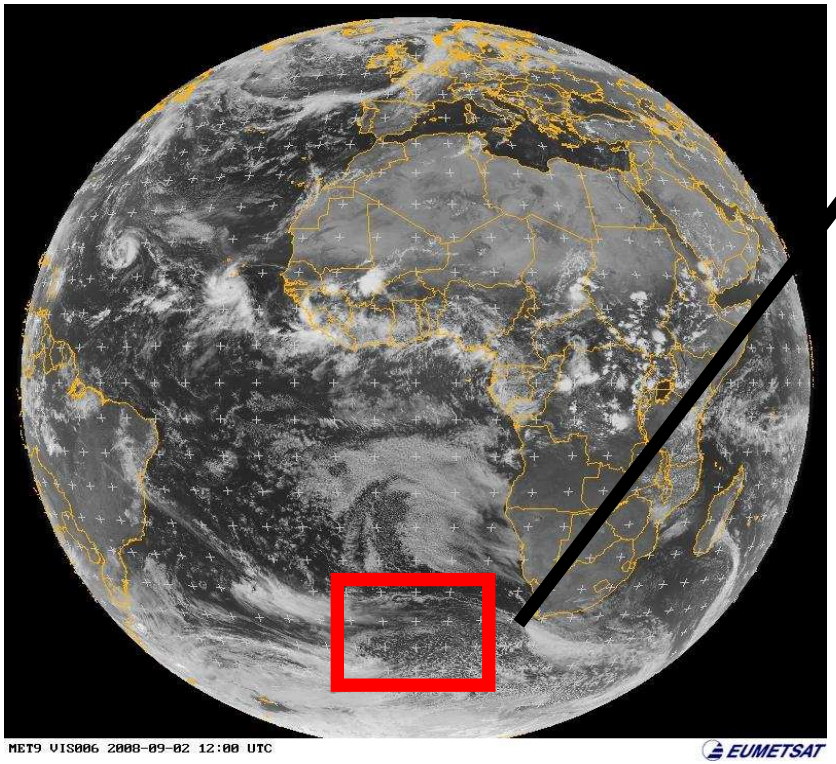


Min. Reflectivity, R_{min}, 12 UTC, Sept 2008



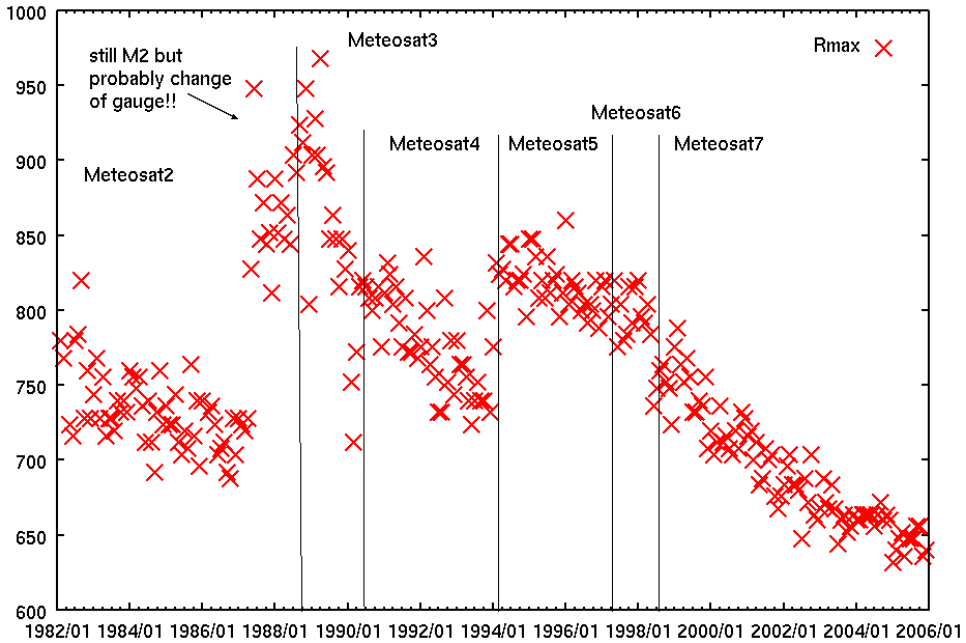
The Heliosat method

Reflectivity, 12 UTC, 2 Sept 2008



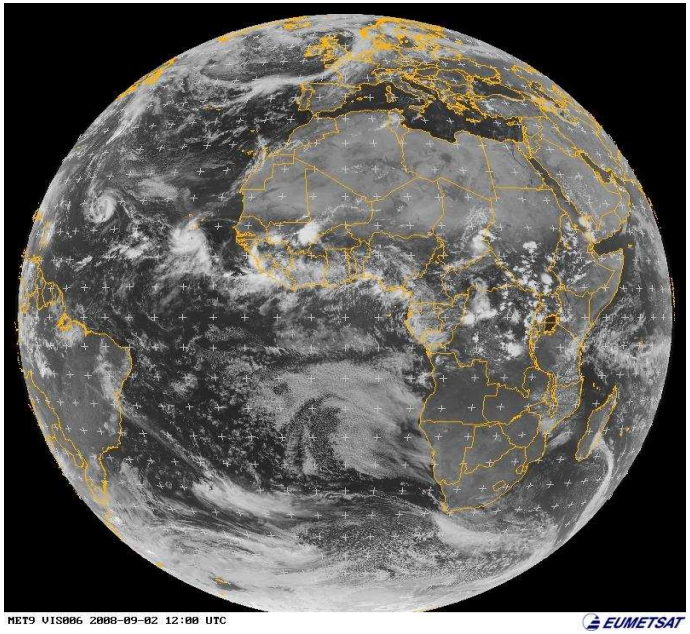
Max. reflectance, R_{max}:
95 % percentile of counts during one month in the reference region

Temporal evolution of R_{max}

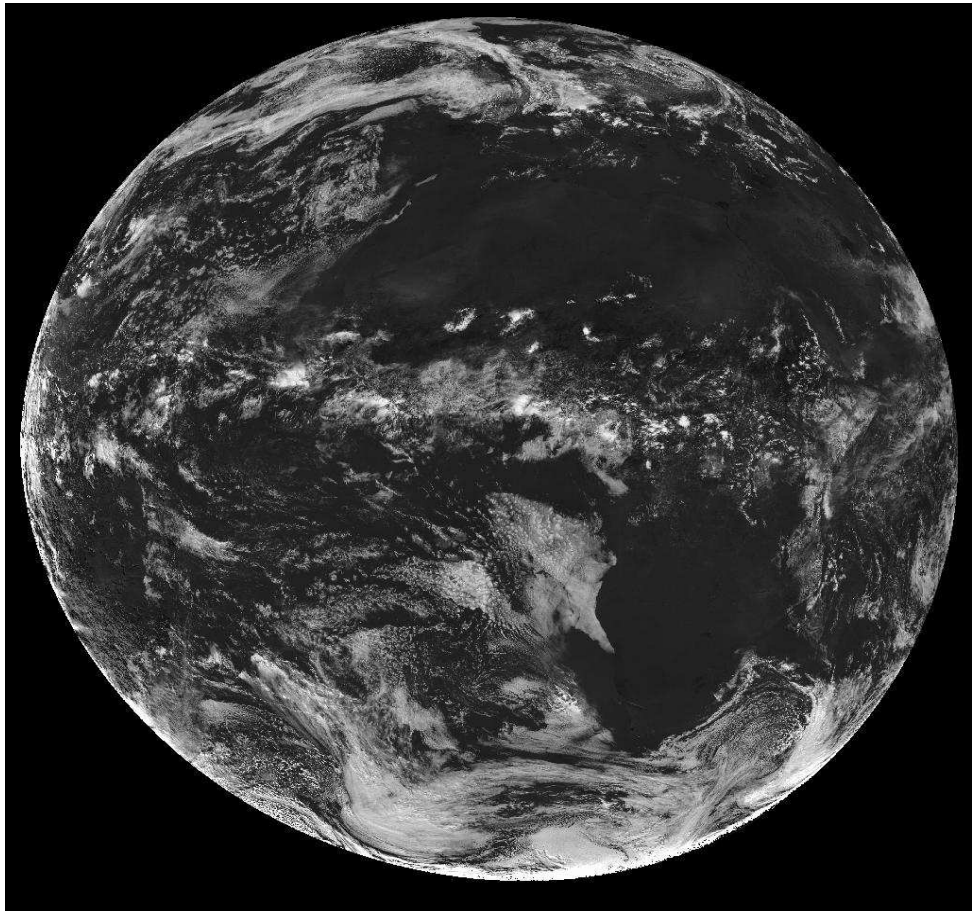


The definition of the Cloud Index n:

$$n = \frac{R - R_{min}}{R_{max} - R_{min}}$$

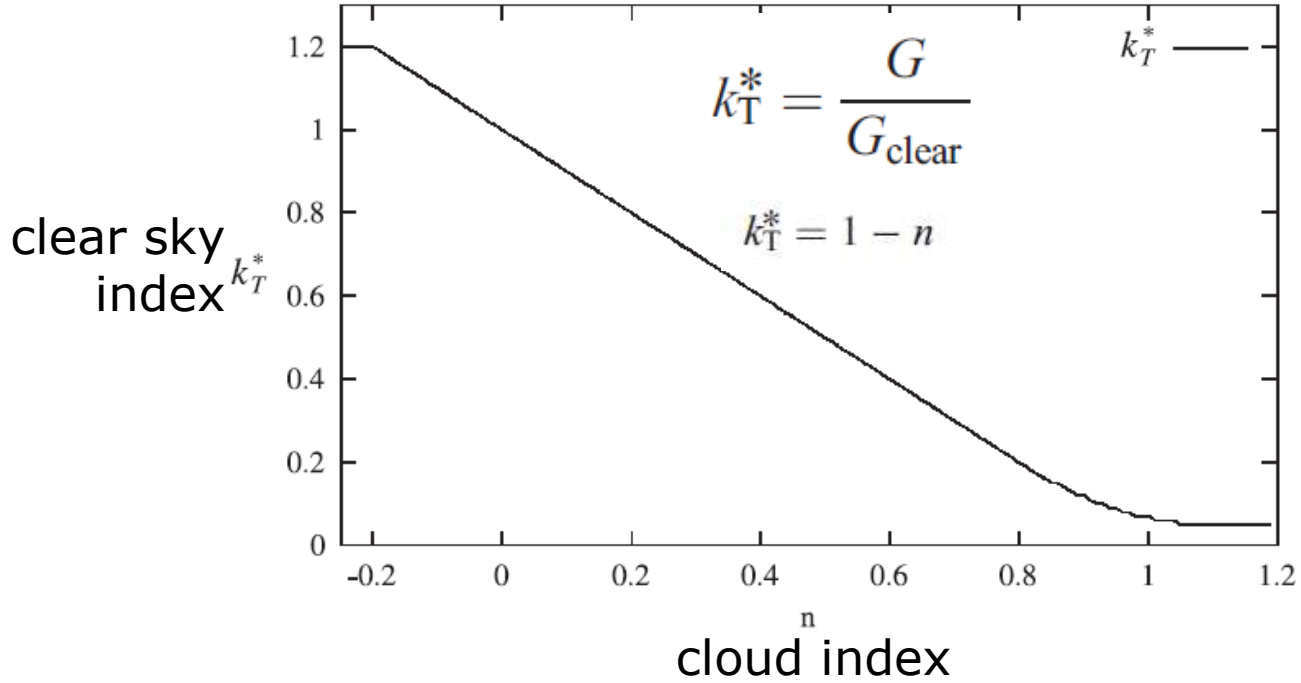


Cloud Index, 11 UTC, 1 July 2005



The Heliosat method

- The cloud index, n, is related to the clear sky index, k.
- The clear sky index, k, is the ratio between the all-sky surface irradiance, G, and the clear sky surface irradiance, G_{clear}



The Heliosat method

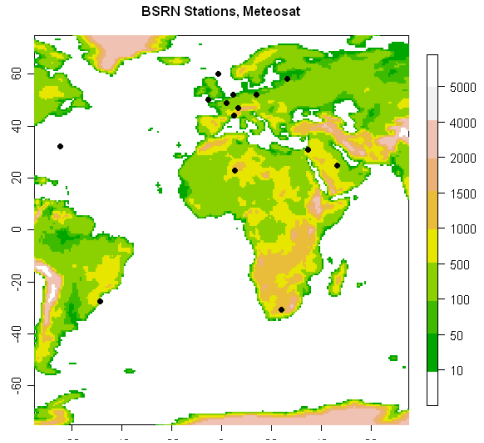
$$G = k * G_{clear}$$

- G_{clear} can be calculated by radiation transfer calculations using the fast and accurate clear sky model ***gnu-MAGIC*** *(Mesoscale Atmospheric Global Irradiance Code, Mueller et al., 2009,* http://sourceforge.net/projects/gnu-magic/)

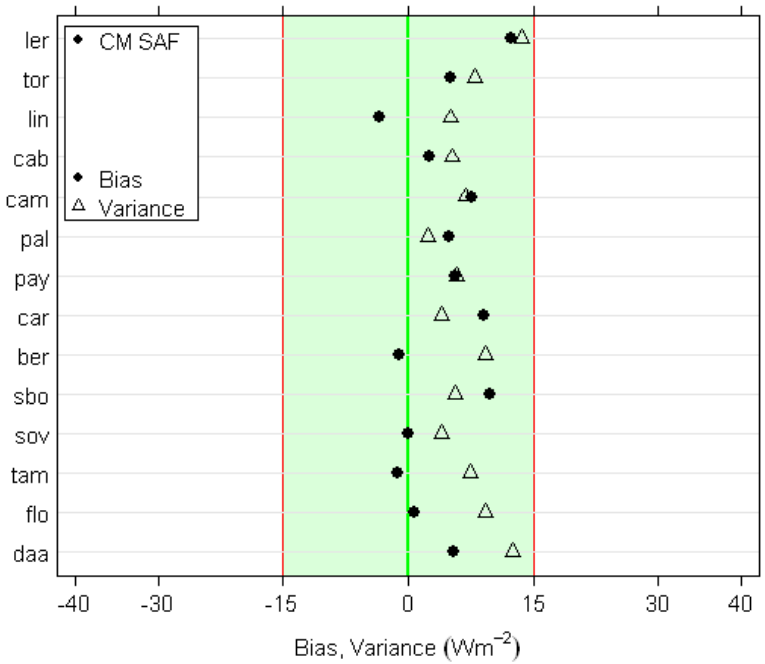
- Assumptions on the water vapor column and aerosol content and type are required for the clear sky calculations (H_2O: ERA-40, ERA-Interim; aerosol: GADS-OPAC)

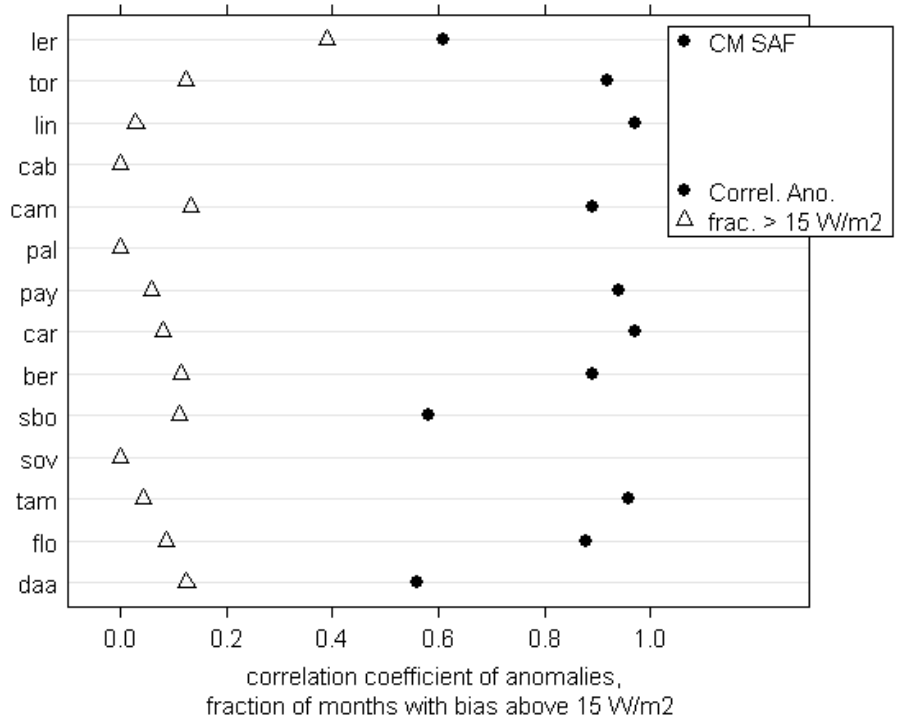
- Global radiation is retrieved for each satellite pixel / time slot
- Average and interpolate to hourly / daily / monthly means on a 0.03^{o}-regular lon-lat-grid.

Validation



- **Monthly mean** SIS from 14 BSRN stations within the Meteosat disk
- **Measures**: Bias, Variance, Correlation Coefficient of Anomalies, Fraction of months with bias above 15 Wm^{-2}





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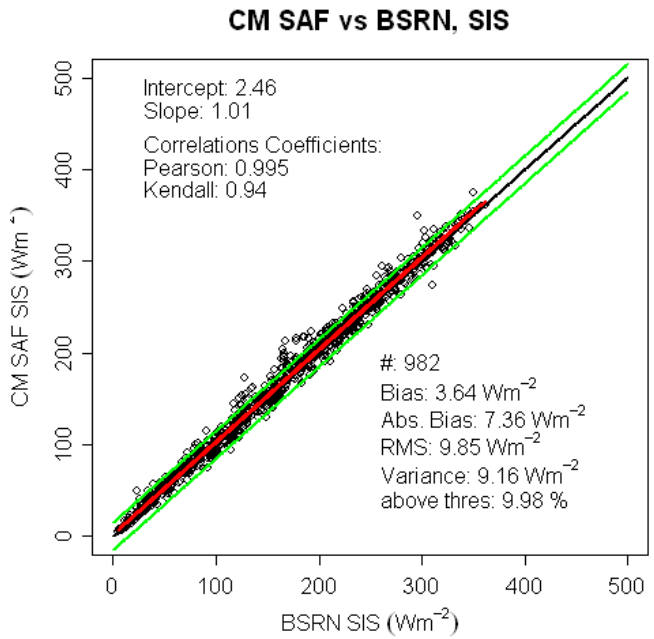
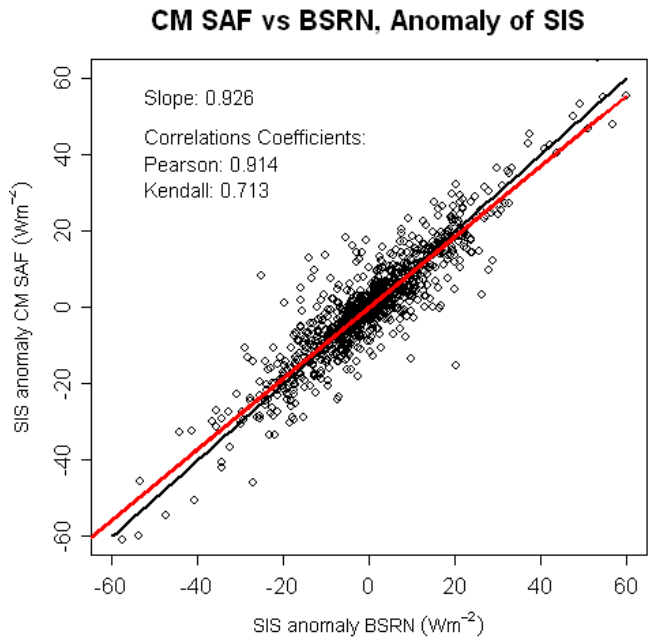
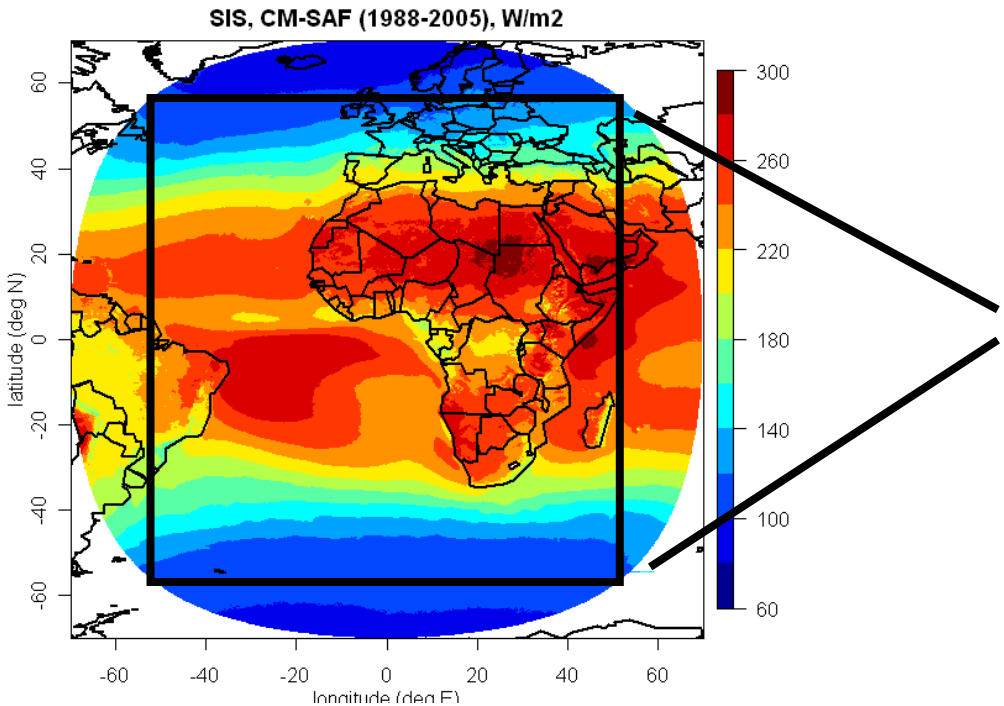
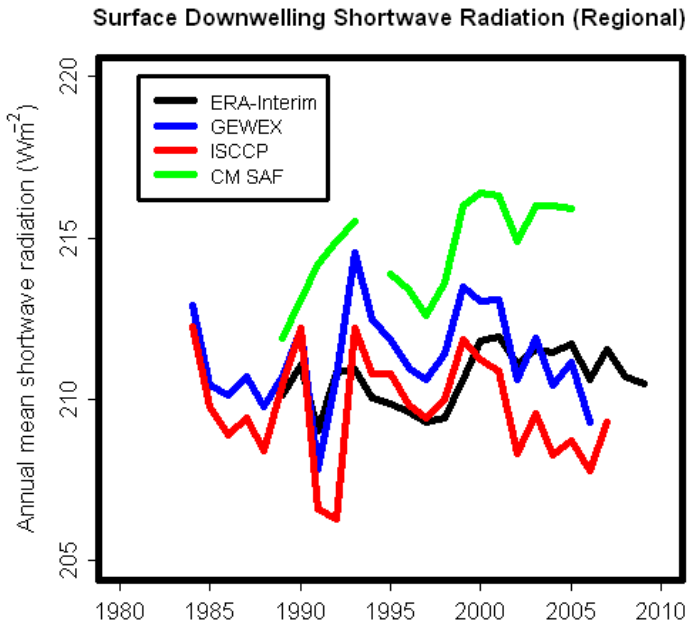


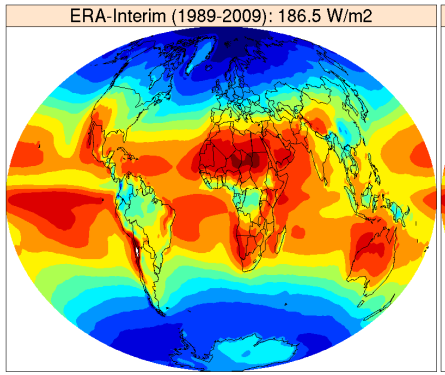


Data set	Analyzed Months	Bias (Wm^{-2})	Abs. Bias (Wm^{-2})	Variance (Wm^{-2})	Corr. Ano.	Frac. Months > 15 Wm^{-2},%
CM SAF	982	3.6	7.4	9.2	0.91	10.0

Evaluation



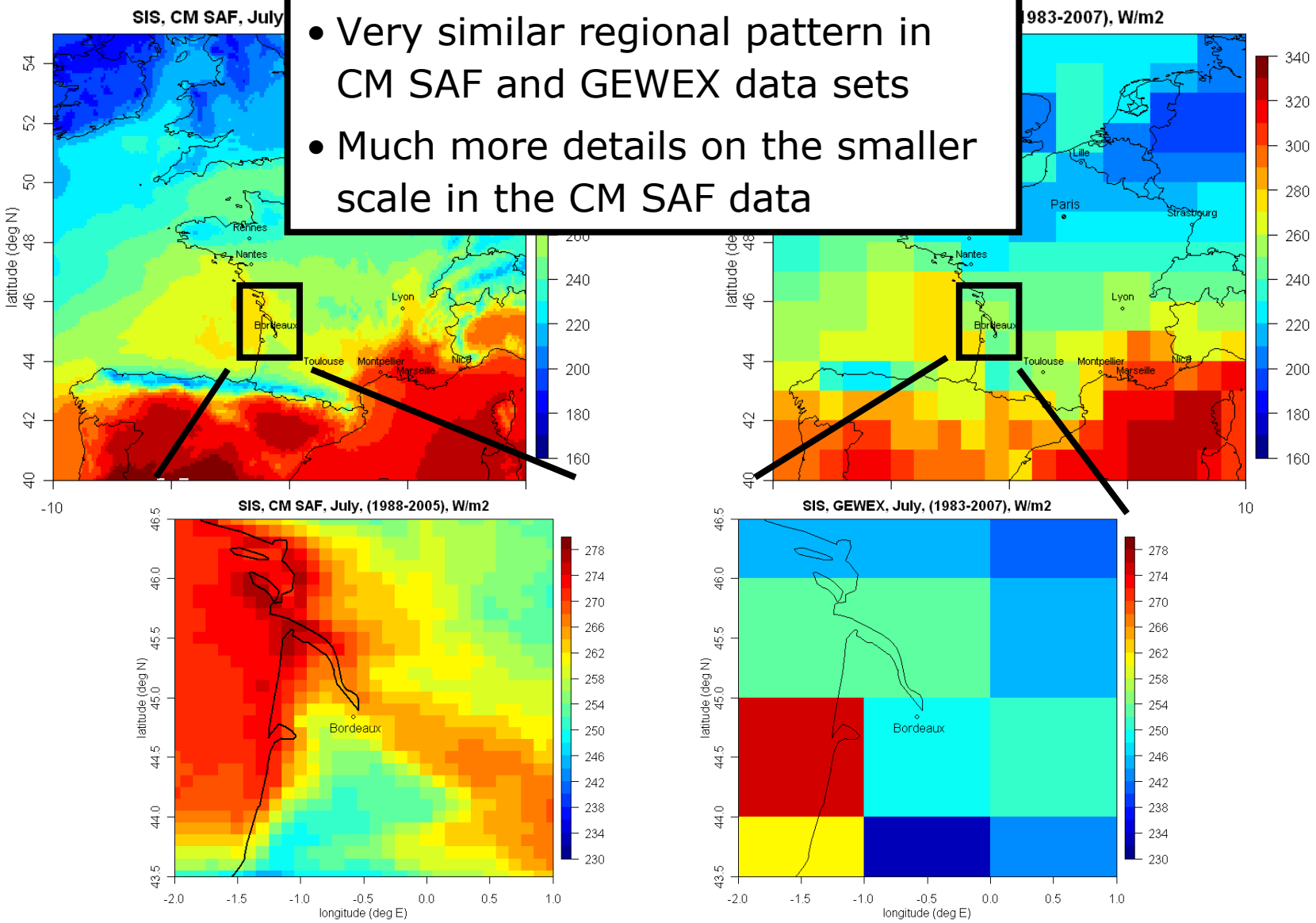




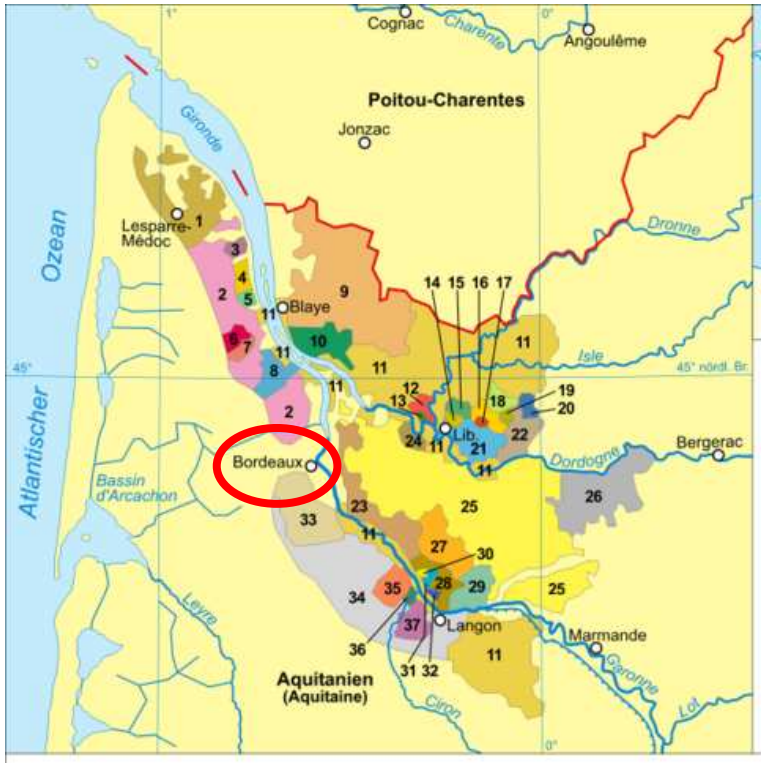
- CM SAF data about 2-3 Wm^{-2} higher than alternative data sets
- Temporal evolution of CM SAF consistent with alternative data sets, exception 1991 (Pinatubo??)

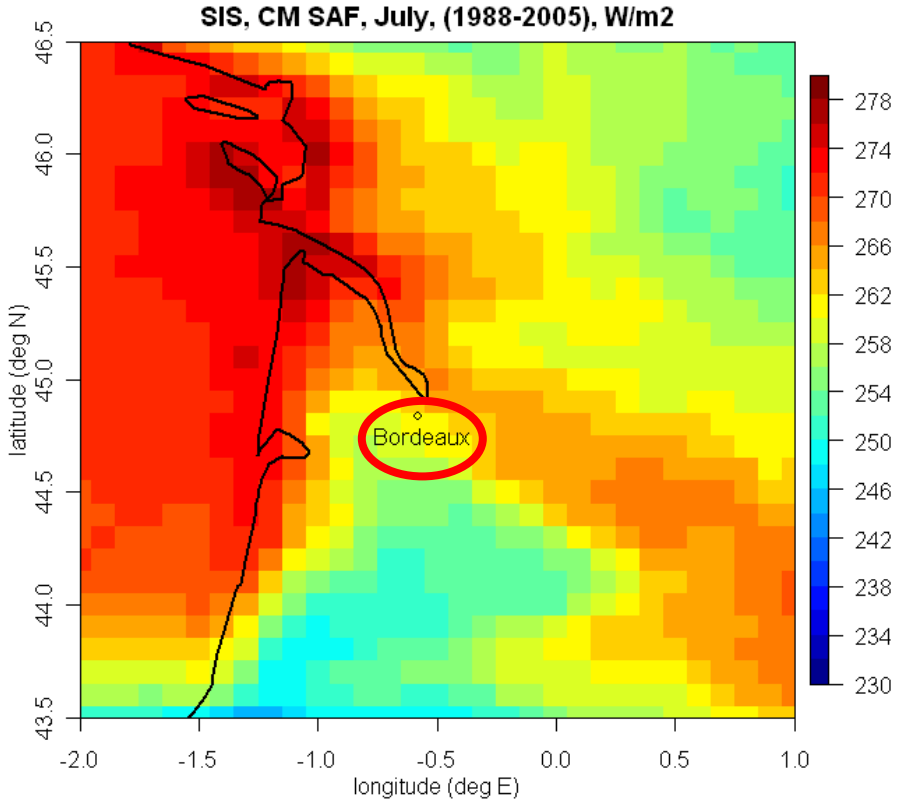
Regional Pattern

- Very similar regional pattern in CM SAF and GEWEX data sets
- Much more details on the smaller scale in the CM SAF data



Solar Irradiance in the Bordeaux Wine Regions





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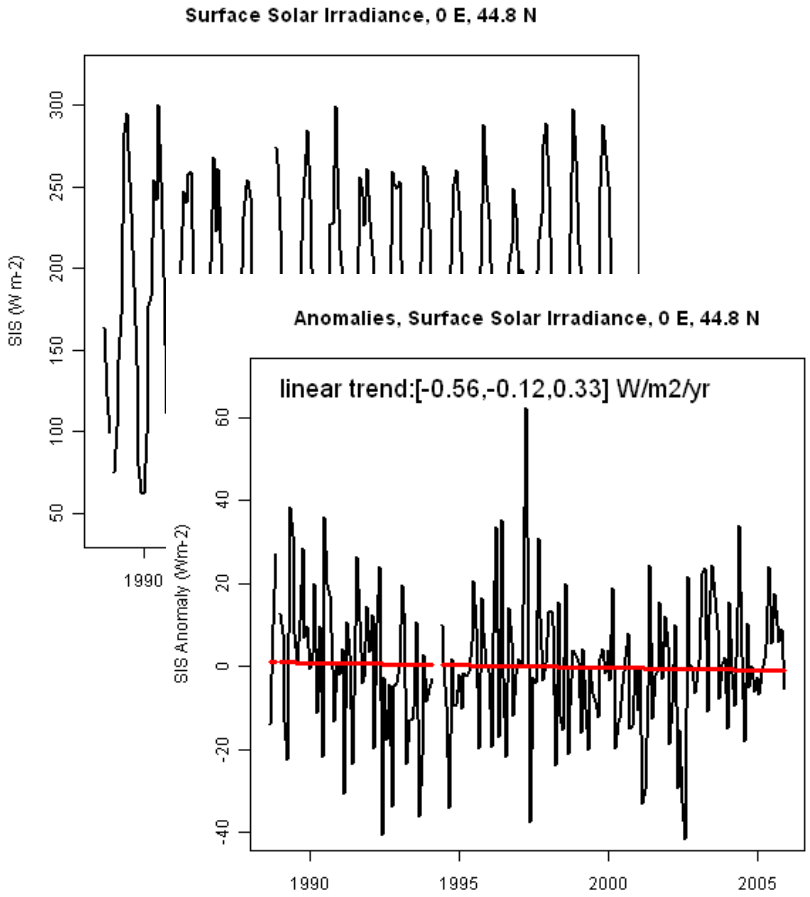
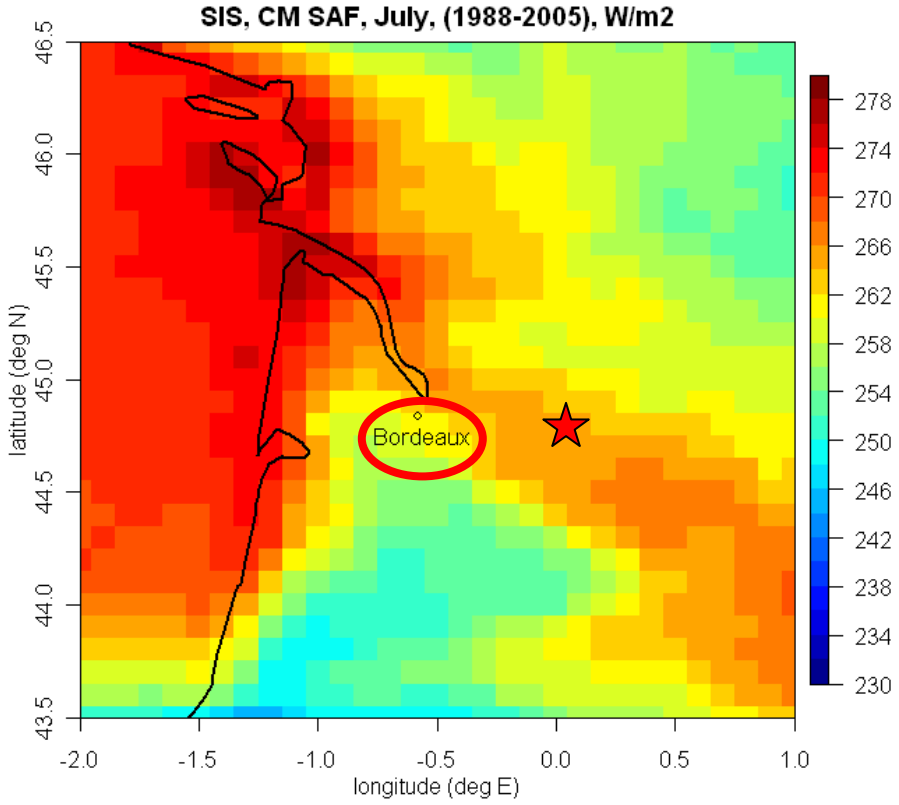


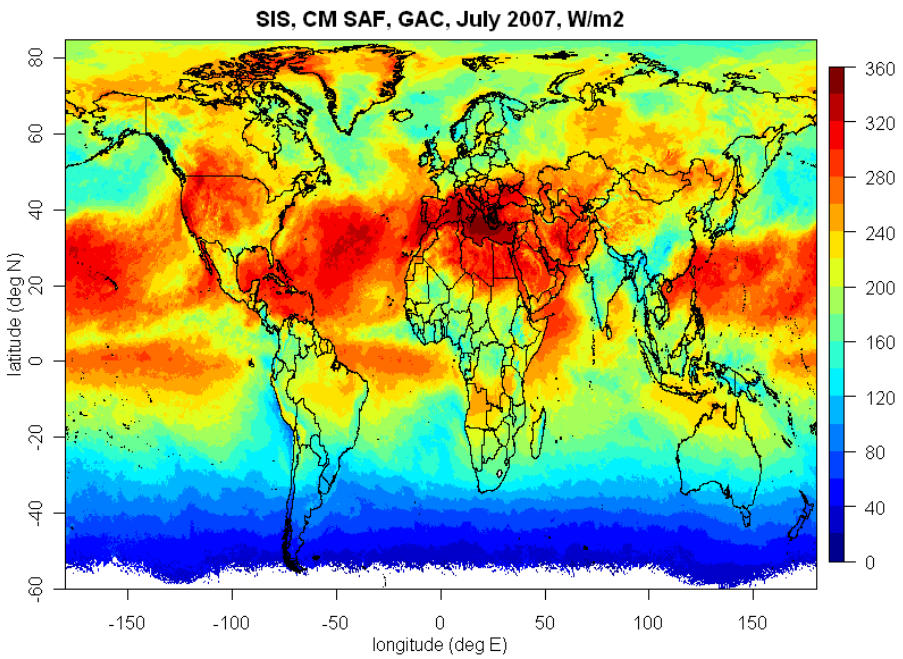


Specifications

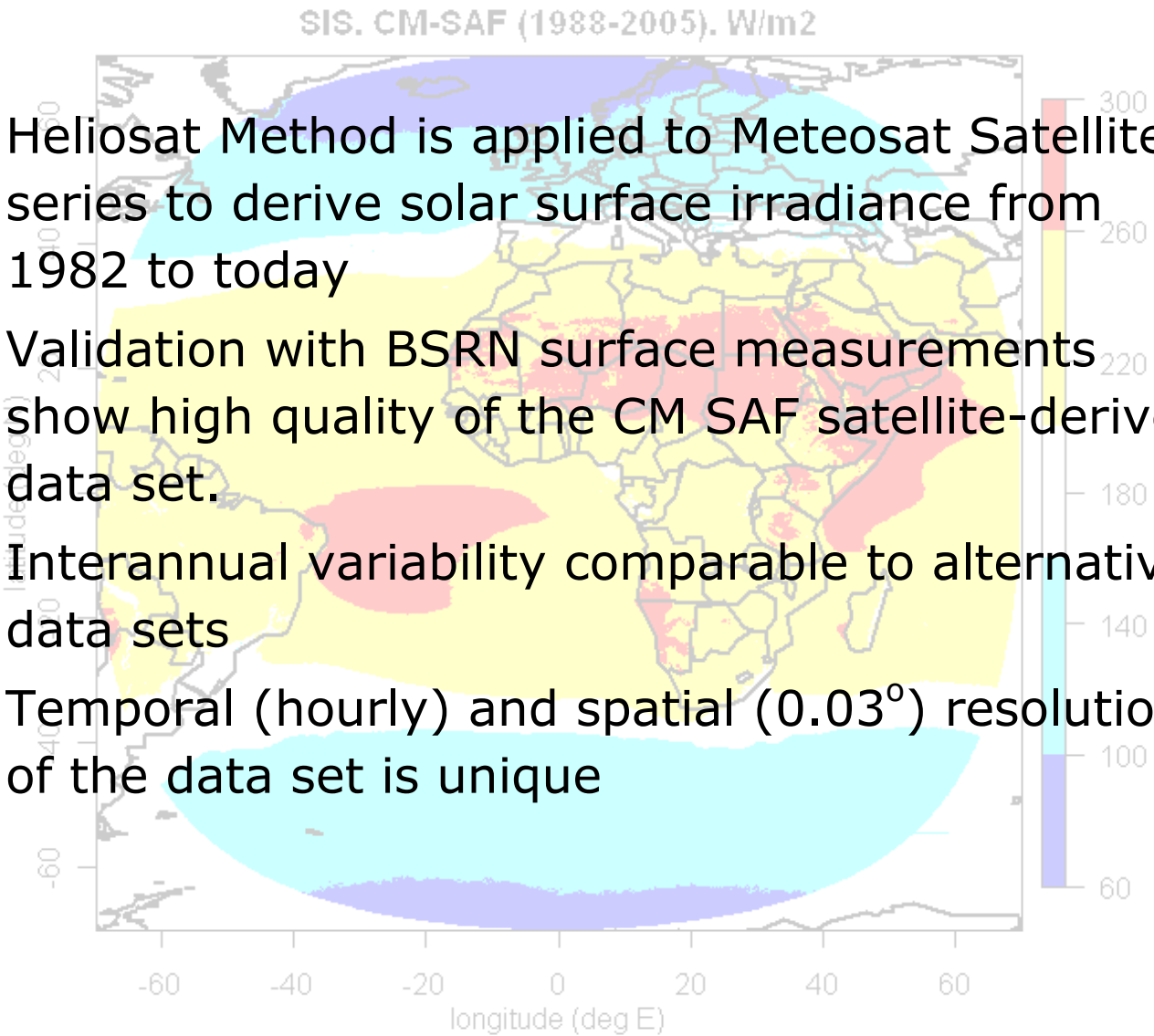
- Official release is scheduled for Fall/Winter 2010
- Data set includes
  - solar irradiance (SIS)
  - direct solar irradiance (SID)
  - cloud index (CAL)
- Available from 1982 to 2005 based on Meteosat Satellites
- Temporal resolution:
  hourly, daily, monthly means
- Spatial resolution:
  0.03^{o}-regular lon-lat grid
- Data Format: netcdf
- Data Policy:
  data freely available without restrictions; only registration on the CM SAF Website required (www.cmsaf.eu)

Outlook

- Further validation / evaluation by CM SAF and Users
- Improve the data set based on ongoing validation / evaluation (e.g., aerosol information)
- Continuous releases of improved data sets every 2 to 5 years
- Derive a global data set for solar surface irradiance based on AVHRR GAC

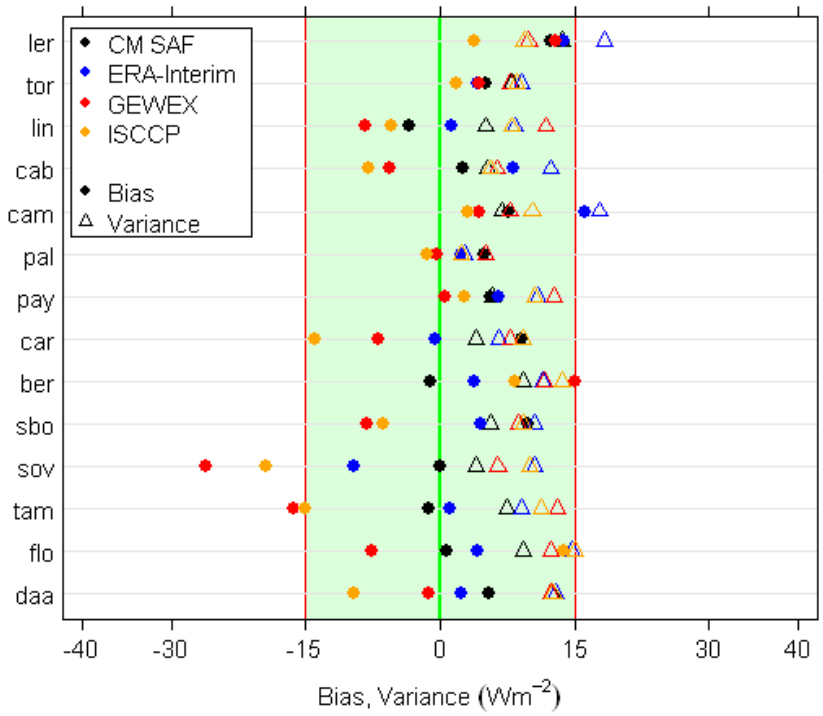


Summary



- Heliosat Method is applied to Meteosat Satellite series to derive solar surface irradiance from 1982 to today
- Validation with BSRN surface measurements show high quality of the CM SAF satellite-derived data set.
- Interannual variability comparable to alternative data sets
- Temporal (hourly) and spatial (0.03°) resolution of the data set is unique

Validation


ler
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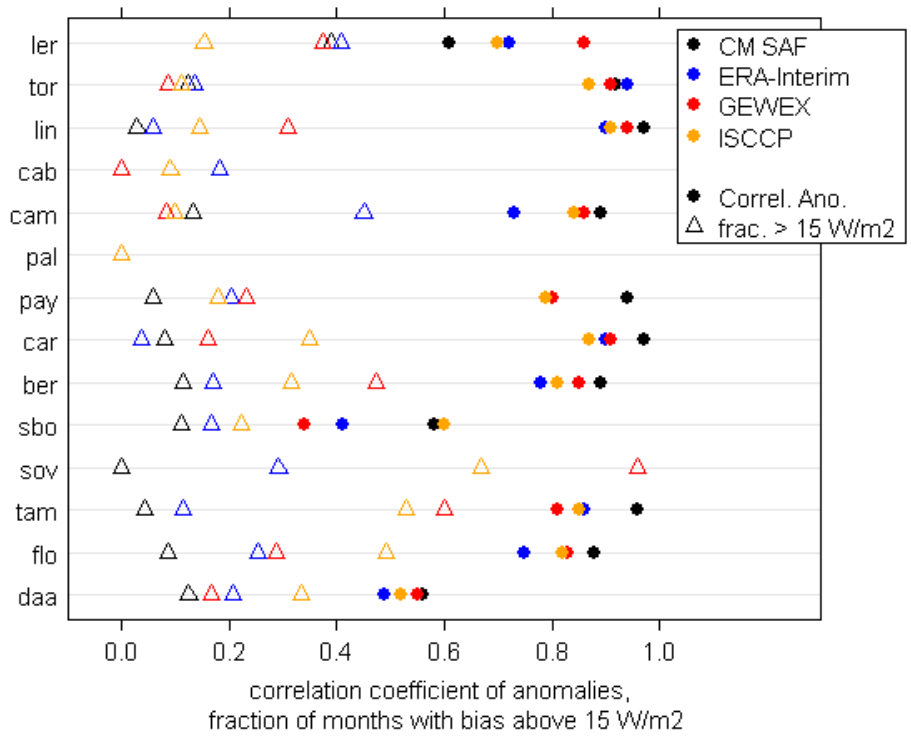
daa
CM SAF
ERA-Interim
GEWEX
ISCCP
Bias
Variance
-40
-30
-15
0
15
30
40
Bias, Variance (Wm^{-2})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tor
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car
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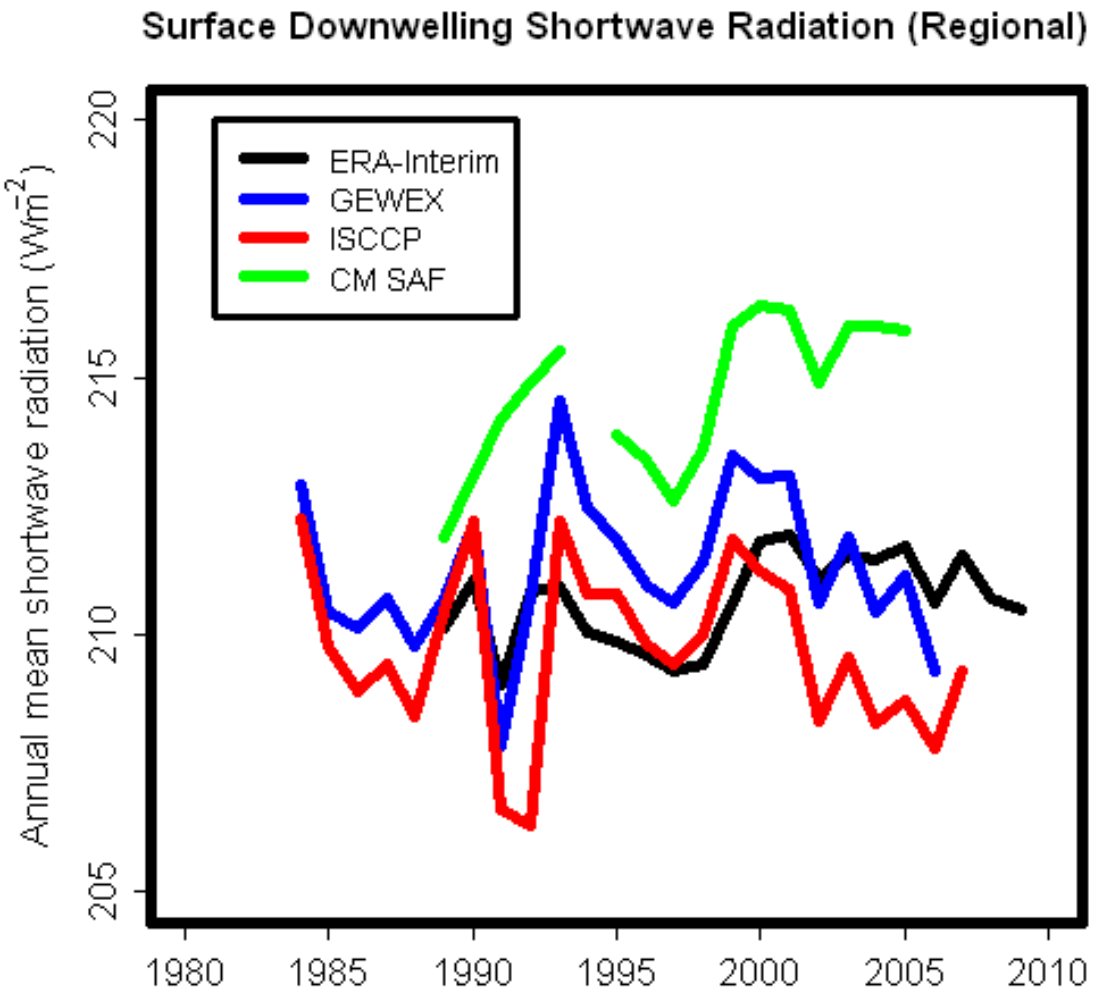
sbo
sov
tam
flo
daa
CM SAF
ERA-Interim
GEWEX
ISCCP
Correl. Ano.
frac. > 15 W/m2
0.0
0.2
0.4
0.6
0.8
1.0
correlation coefficient of anomalies,
fraction of months with bias above 15 W/m2

Evaluation


Surface Downwelling Shortwave Radiation (Regional)
Annual mean shortwave radiation (Wm^{-2})
205
210
215
220
1980
1985
1990
1995
2000
2005
2010
ERA-Interim
GEWEX
ISCCP
CM SAF

Evaluation, ERA Interim