Stability of satellite based climate data records (CDRs) retrieved by CM SAF

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Satellite-Based Climate Monitoring, DWD

9th seminar for homogenization and quality control in climatological databases and 4th conference on spatial interpolation techniques in climatology and meteorology (Budapest, 10.04.2017)

Overview

Stability of satellite based climate data records (CDRs) retrieved by CM SAF

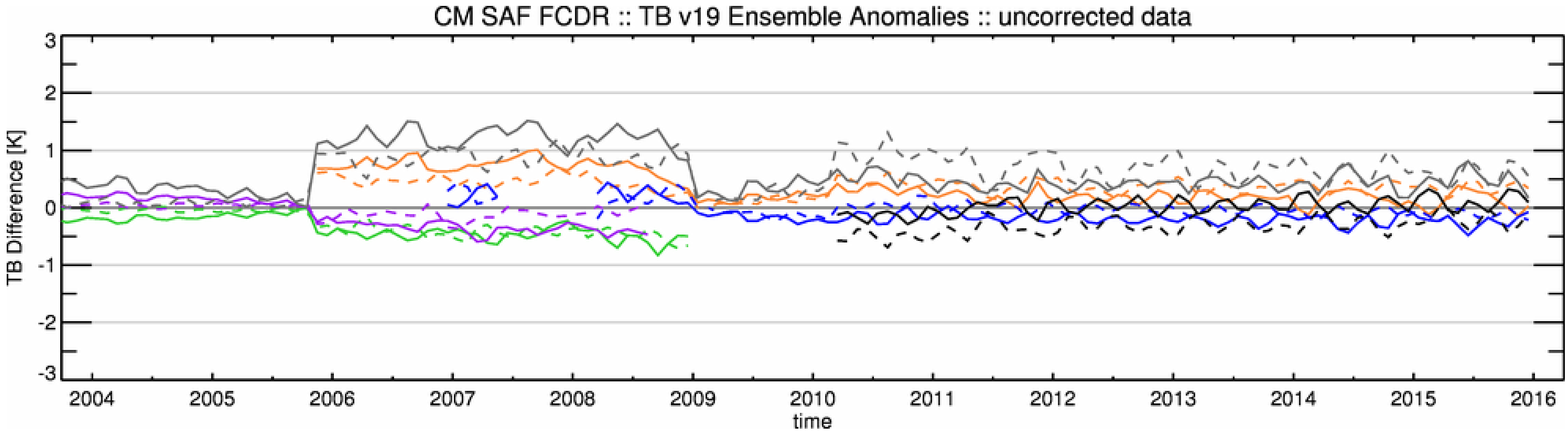
- Satellite based products:
  - Fundamental Climate Data Record (FCDR)
  - Thematic Climate Data Records (**TCDRs**)
    - HOAPS-4.0 products (evaporation, precipitation,…)
    - HOAPS uncertainty estimates
    - Decadal stability of HOAPS-4.0 products
    - Decadal stability of CLARA-A2 cloud fractional cover
    - Trends in SARAH-2 surface irradiance
- Summary

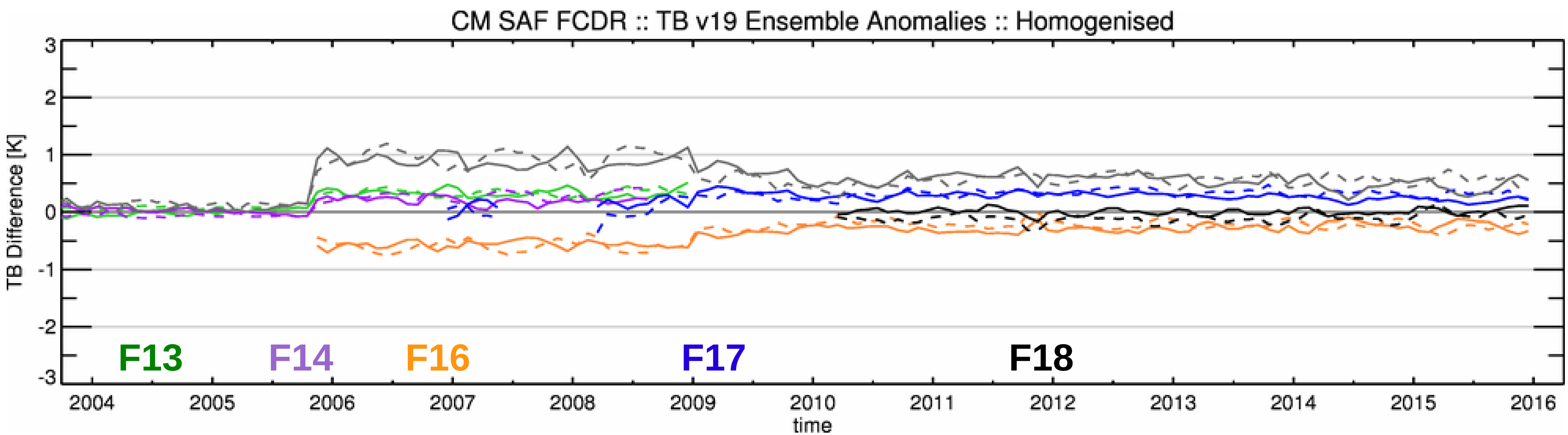
CM SAF FCDR Features

- The Fundamental Climate Data Record (FCDR) contains Brightness Temperatures .
- Covered time period 1979 – 2015.
  - SMMR 1979 – 1987 (Nimbus 7)
  - SSM/I 1987 – 2008 (F08,F10,F11,F13,F14,F15)
  - SSMIS 2006 – 2015 (F16, F17, F18)
- Completely reprocessed data record, starting from measured counts (SSM/I,SSMIS).
- New Earth scene geolocation based on smoothed daily TLEs (SSM/I, SSMIS).
- Data processing accounts for identified instrument issues:
  - Moonlight-intrusions, Sunlight-intrusions, Along-scan non-uniformity, Reflector emissivity.
- Includes uncertainty estimates.
- Earth incidence angle normalization offsets (SSM/I, SSMIS).
- Scene dependent inter-sensor calibration to F11 via transfer targets F13 and F16 for SSMIS and ERA-20C for SMMR.

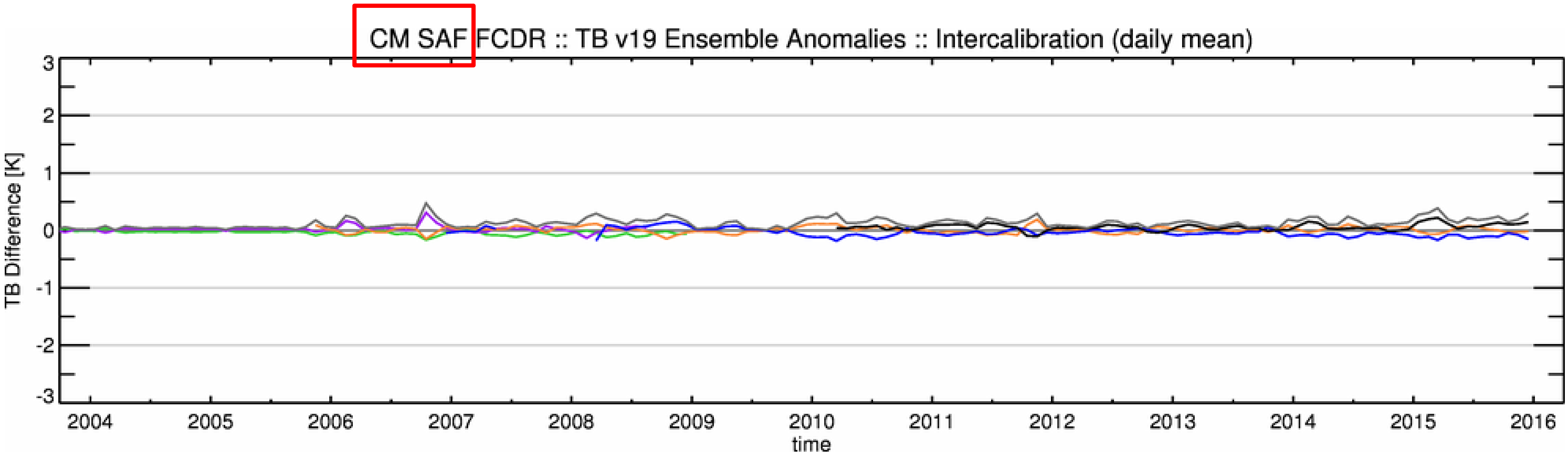
- Available at http://www.cmsaf.eu/wui, doi: 10.5676/EUM_SAF_CM/FCDR_MWI/V003

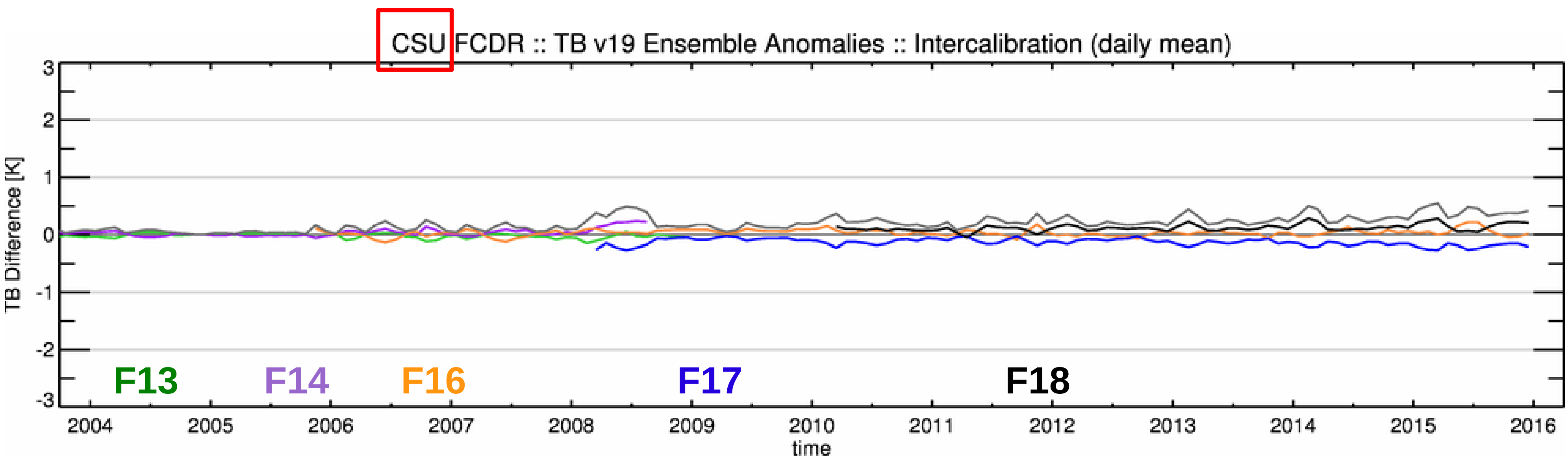
Evaluation TB v19 Normalization





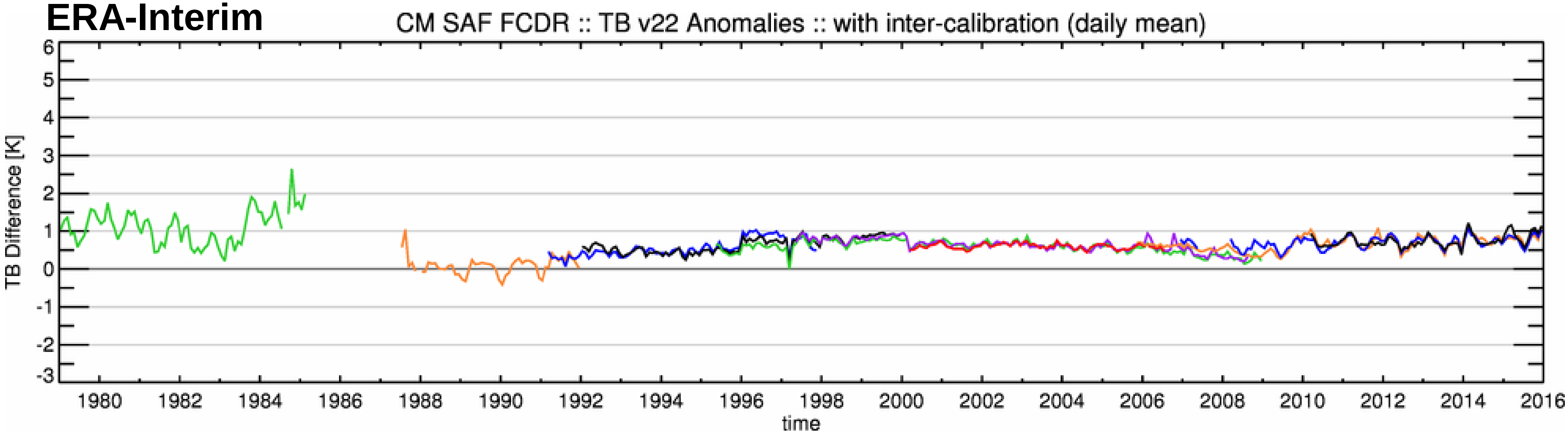
Evaluation TB v19 Intercalibration



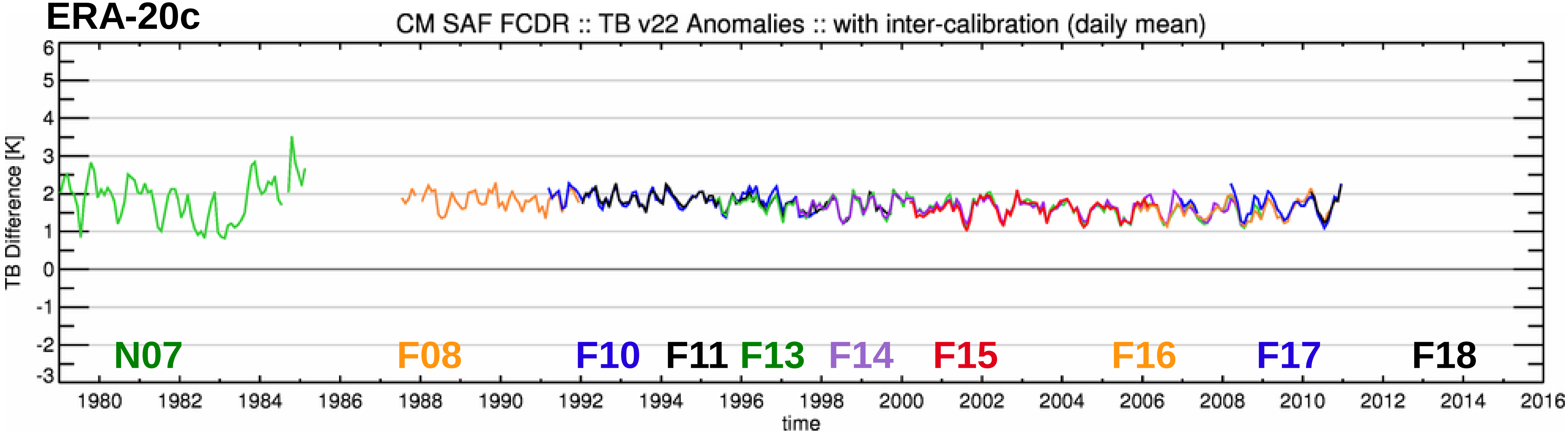


Evaluation FCDR using reanalysis data

ERA-Interim



ERA-20c



Stability monitoring Rainforest (v19 – h19)

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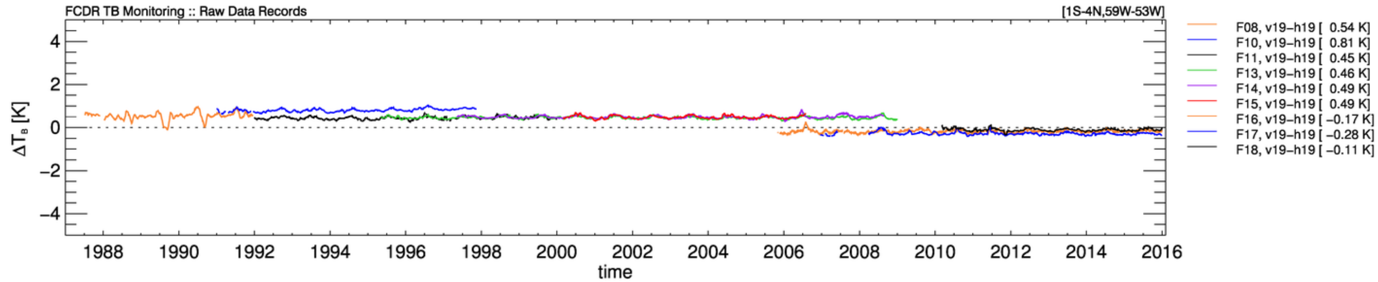
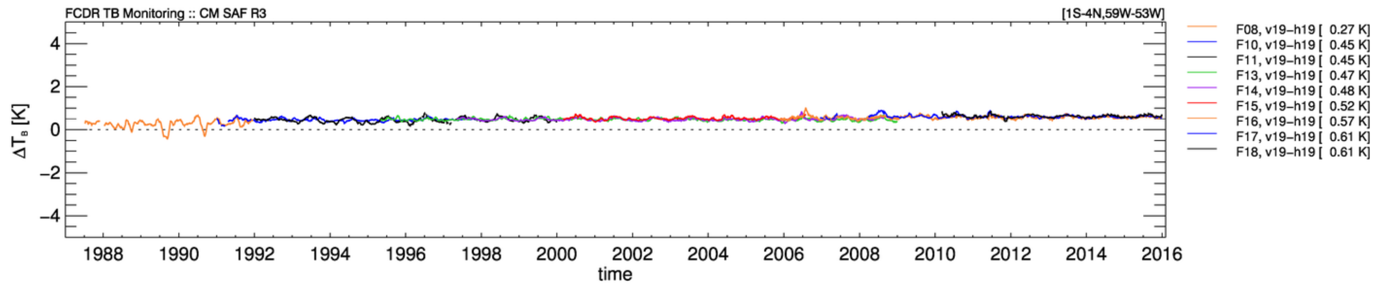
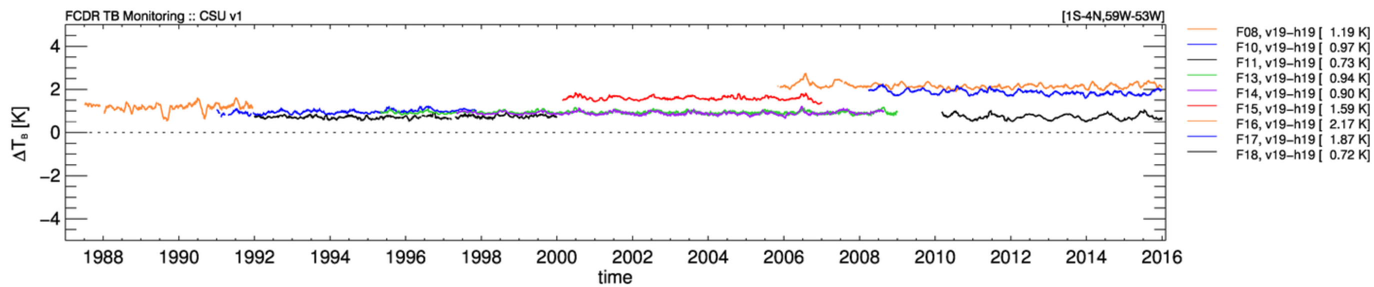
Deutscher Wetterdienst
Wetter und Klima aus einer Hand



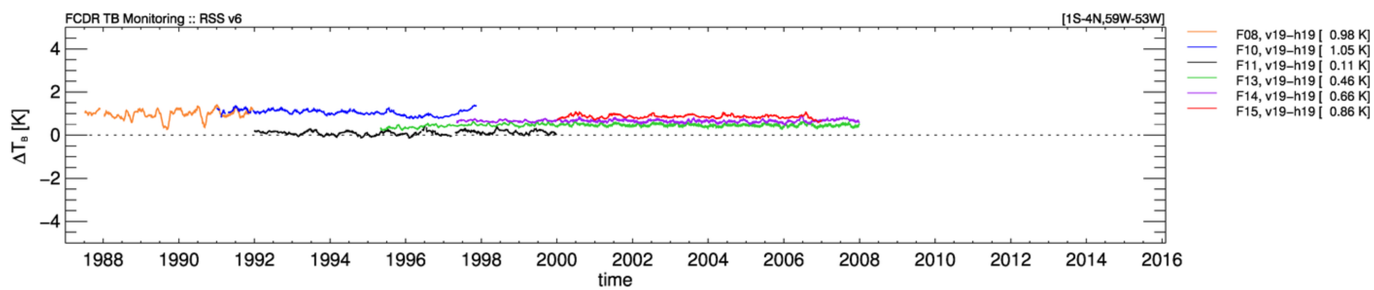
CM SAF



CSU

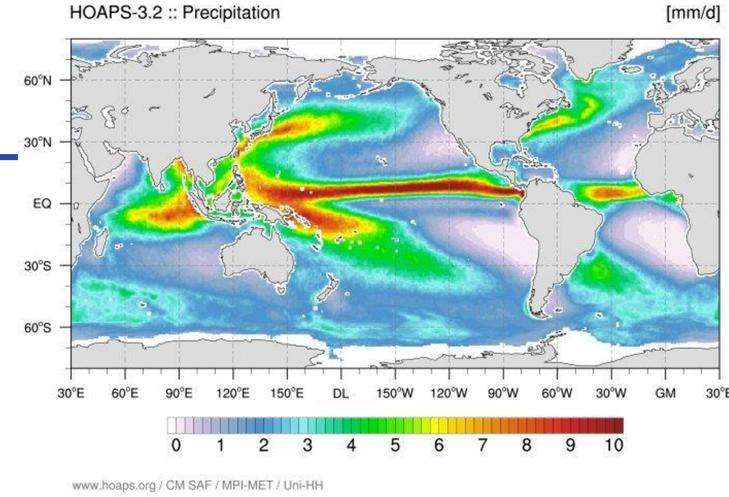


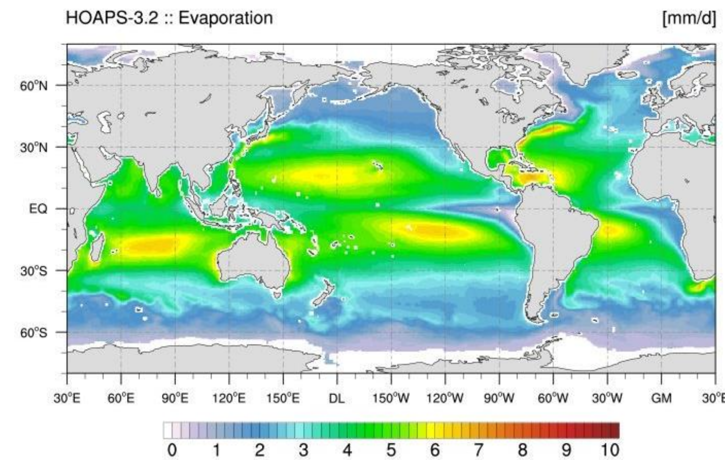
REMSS

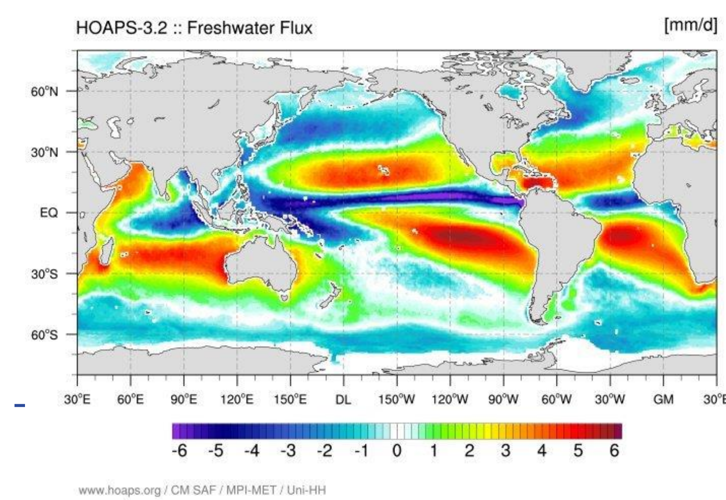


HOAPS products

- The Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite (HOAPS) was developed at UHH/MPI-M and successfully transferred to CM SAF.
- doi: 10.5676/EUM_SAF_CM/HOAPS/V002, available at http://www.cmsaf.eu/wui.
- Global ice-free ocean in 0.5°,
- Monthly averages, 6-hourly composites,
- July 1987 – Dec 2014.
- Based on the passive Instruments SSM/I and SSMIS measuring MW radiation coming from the earth on-board the polar orbiting DMSP satellites.
- Eight products:
  - Integrated water vapour (1D-Var),
  - Near surface humidity (Bentamy et al., 2003),
  - Near surface wind speed (1D-Var),
  - Precipitation (Andersson et al., 2010),
  - Latent heat flux (Fairall et al., 1996, 2003),
  - Evaporation (Fairall et al., 1996, 2003),
  - Freshwater flux (E-P),
  - SST (auxiliary, basis: OI SST)

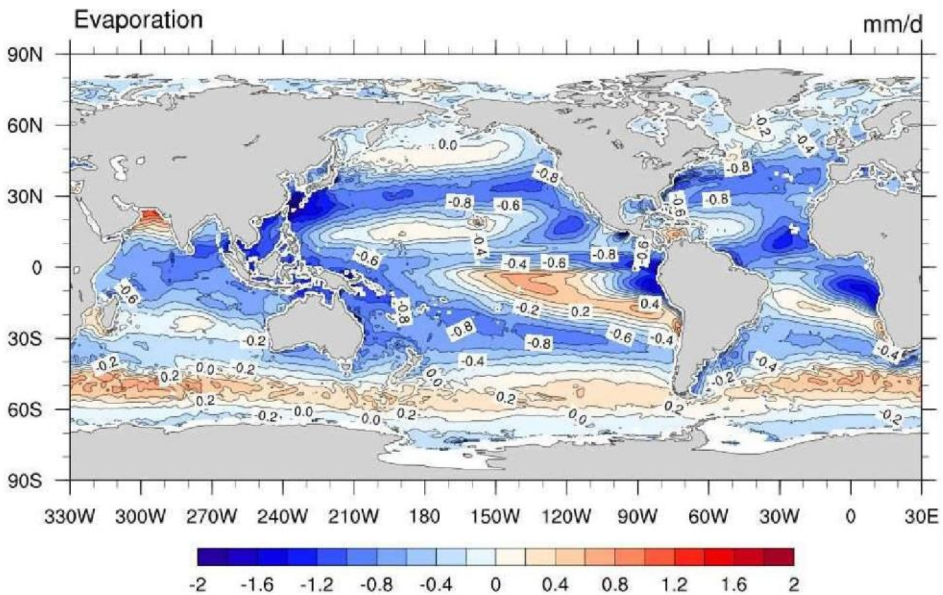




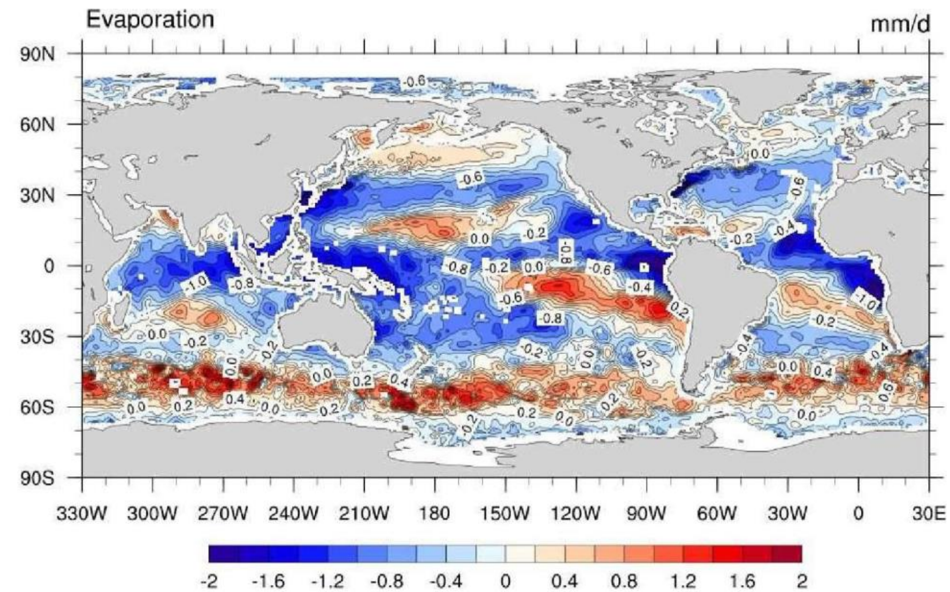


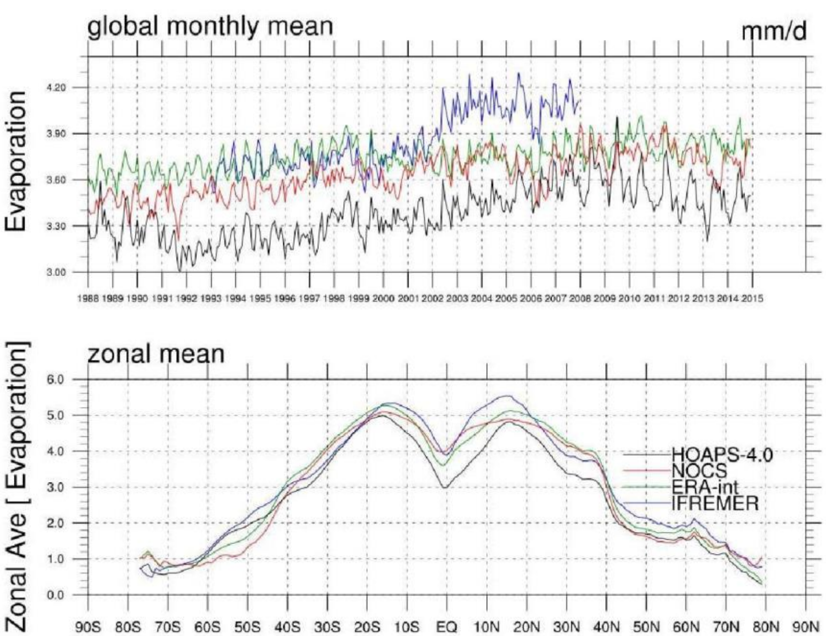
Validation Example (evaporation)

HOAPS-4.0 minus ERA-Interim: evap 1988-2014

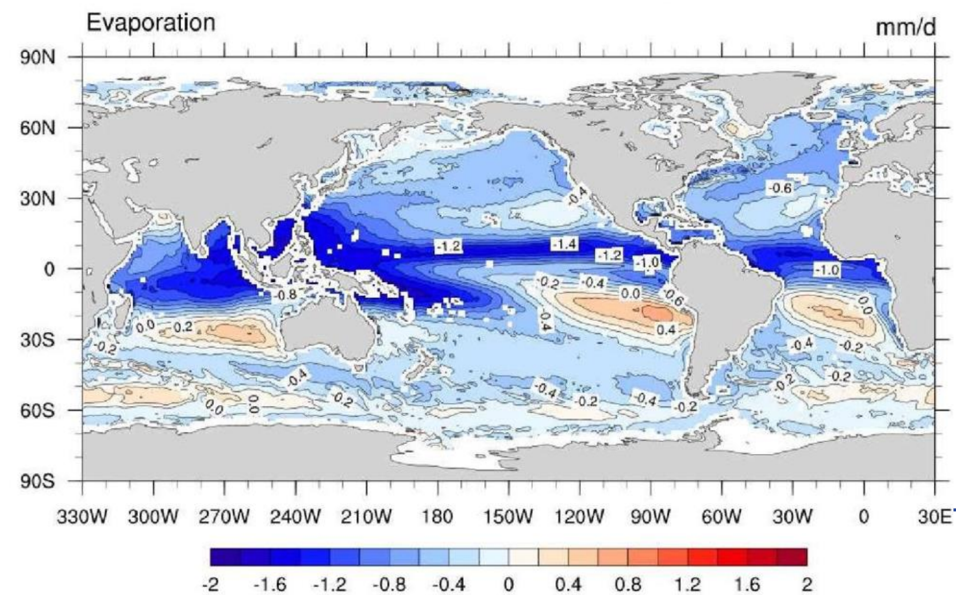


HOAPS-4.0 minus NOCS: evap 1988-2014





HOAPS-4.0 minus IFREMER: evap 1993-2007



Multiple triple collocation
to estimate retrieval uncertainty

Why care?

Adequate knowledge of underlying error characteristics is indispensable
→ prerequisite for the satellite's data application in scientific studies

Which error sources need to be considered?

1) Error associated with the underlying model (E_M)
2) Error associated with noise (E_N)

How perform error decomposition?

Comparison to in-situ ground truth data (“single-double-collocation”)
→ this introduces three further error sources, namely:

3) Error associated with the collocation criteria Δx & Δt (E_C)
4) Error of representativeness (“point-to-area collocation”) (E_R)
5) Error of in-situ measurement itself (E_{ins})

Conventional double collocation doesn't allow for deriving all unknowns!

Idea: Performance of Double-Triple-Collocation

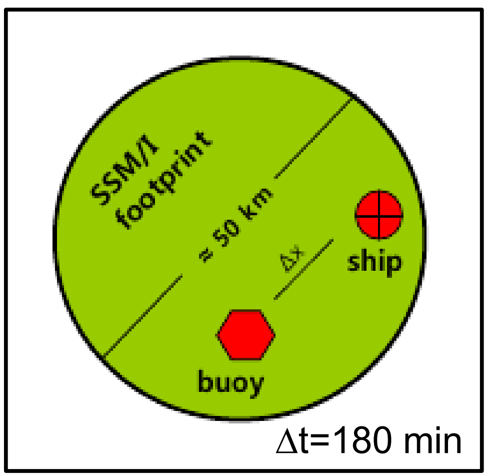
Concept and Prerequisites

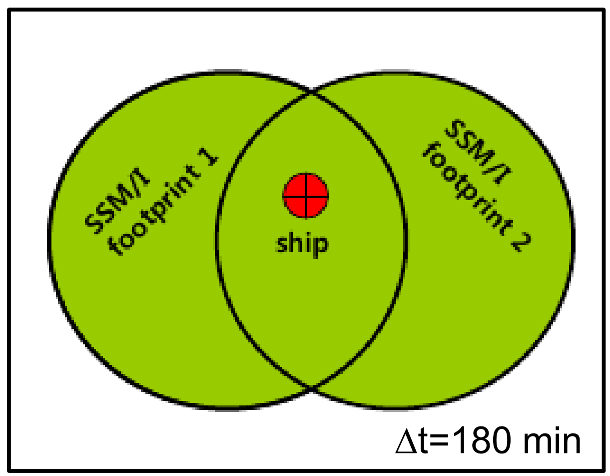
- Triple collocation (TC) technique was first realized by *Stoffelen* (1998) in the field of wind speed error analysis and has been widely accepted since.
- Apply three independent data sources (→ corr($\varepsilon_{i,}\varepsilon_j$) = 0!)
  → **1)** satellites; **2)** ships; **3)** buoys
- Minimize the in-situ errors as best as possible
  → apply only 'selected ships' (according to *WMO47 report*)
- Here, apply TC twice (→ **unique approach, Kinzel et al., 2016**):

TC *Version 1*:

1x SSM/I
1x ship
1x buoy

Σ 3x independent





TC *Version 2*:

2x SSM/I
1x ship

Σ 2x independent

Results (Level 2)

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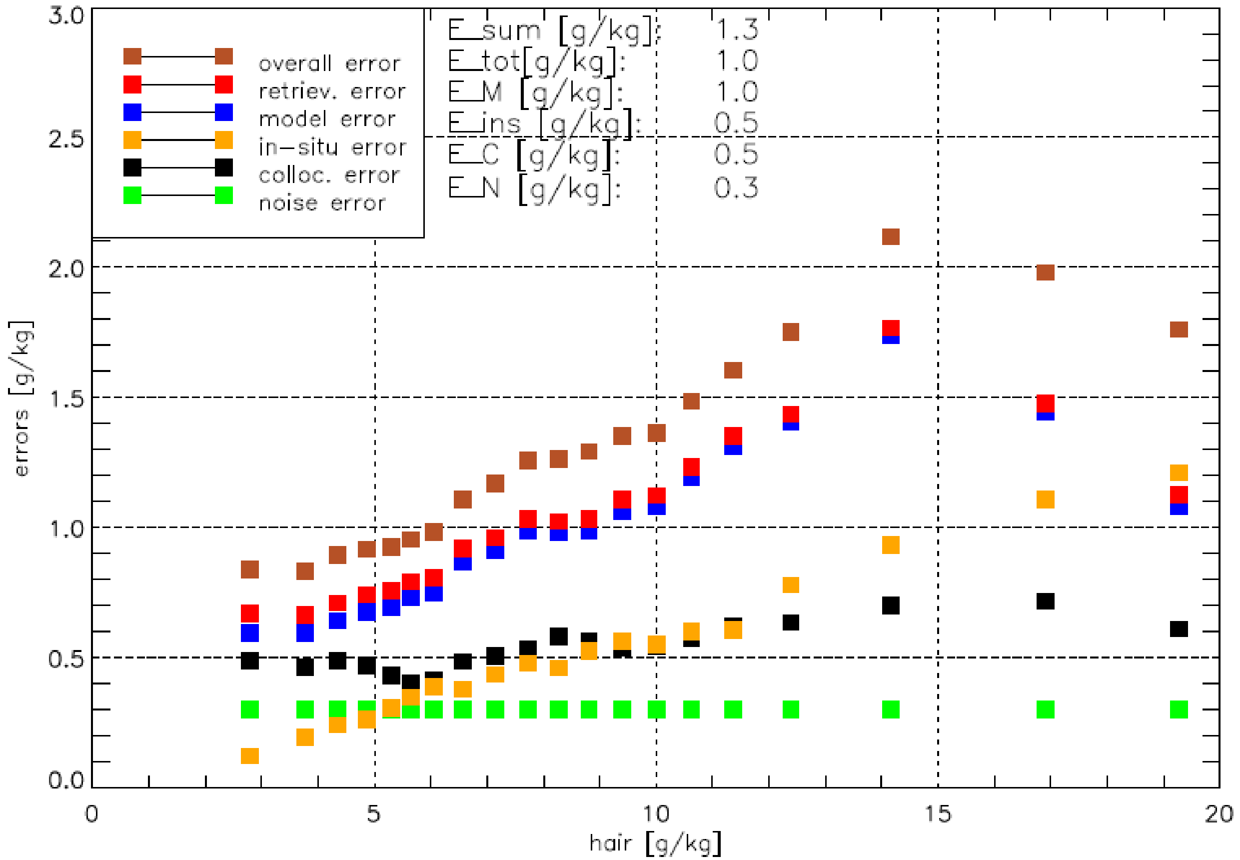
Wetter und Klima aus einer Hand



Near surface specific humidity

Kinzel et al. (2016), also in Löw et al. (2017), in prep.

- In-situ and collocation uncertainty could be separated from total uncertainty.
- Thus, retrieval error can be estimated:
  - “Average Level 2 retrieval uncertainty”
  - Retrieval error not at all constant.

HOAPS bias and standard uncertainty characterization

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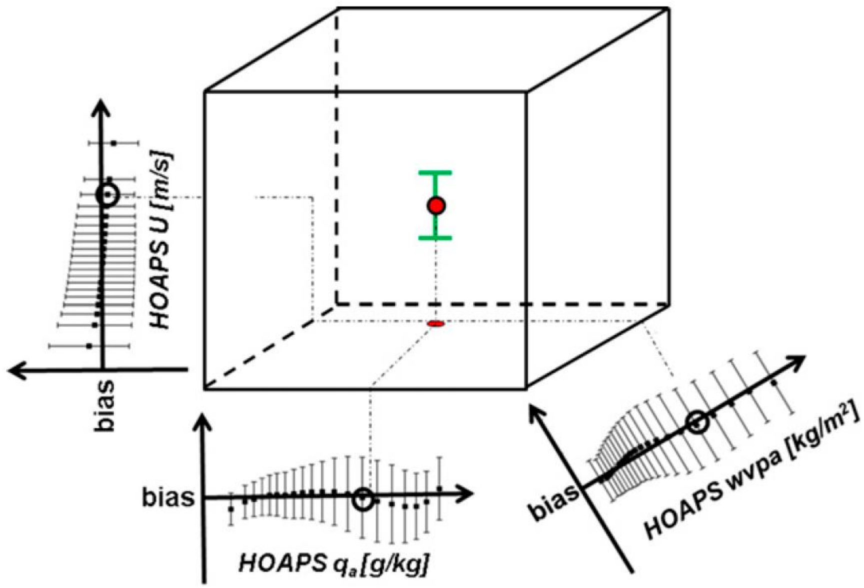
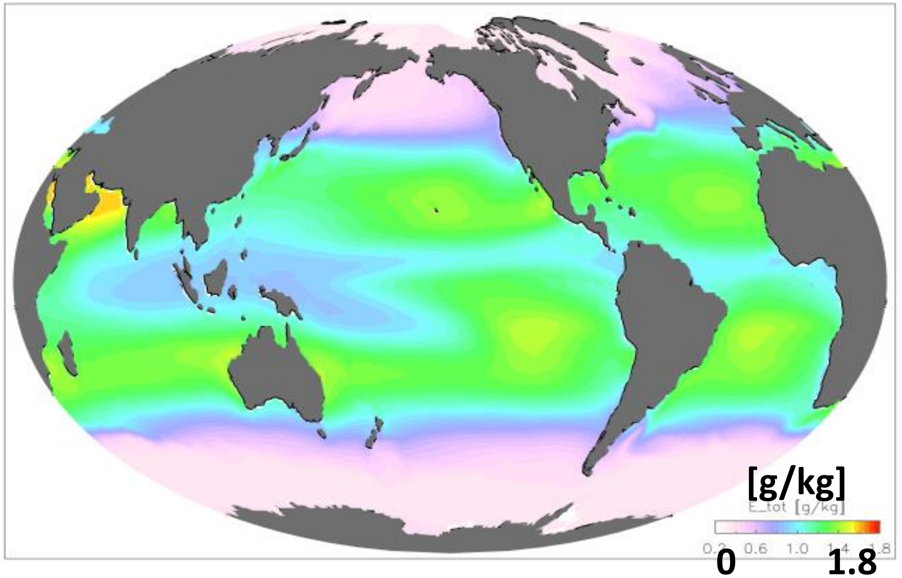
Multi-dimensional bias analysis



MTC

E_{tot} of HOAPS q_a



Kinzel et al. (2016)

Approach: Δq [HOAPS-insitu] depend on *atm. state* → assign each instantaneous bias to a unique bin!

Contains in-situ and collocation contributions

→ remove them using **MTC** (Kinzel et al. 2016)!

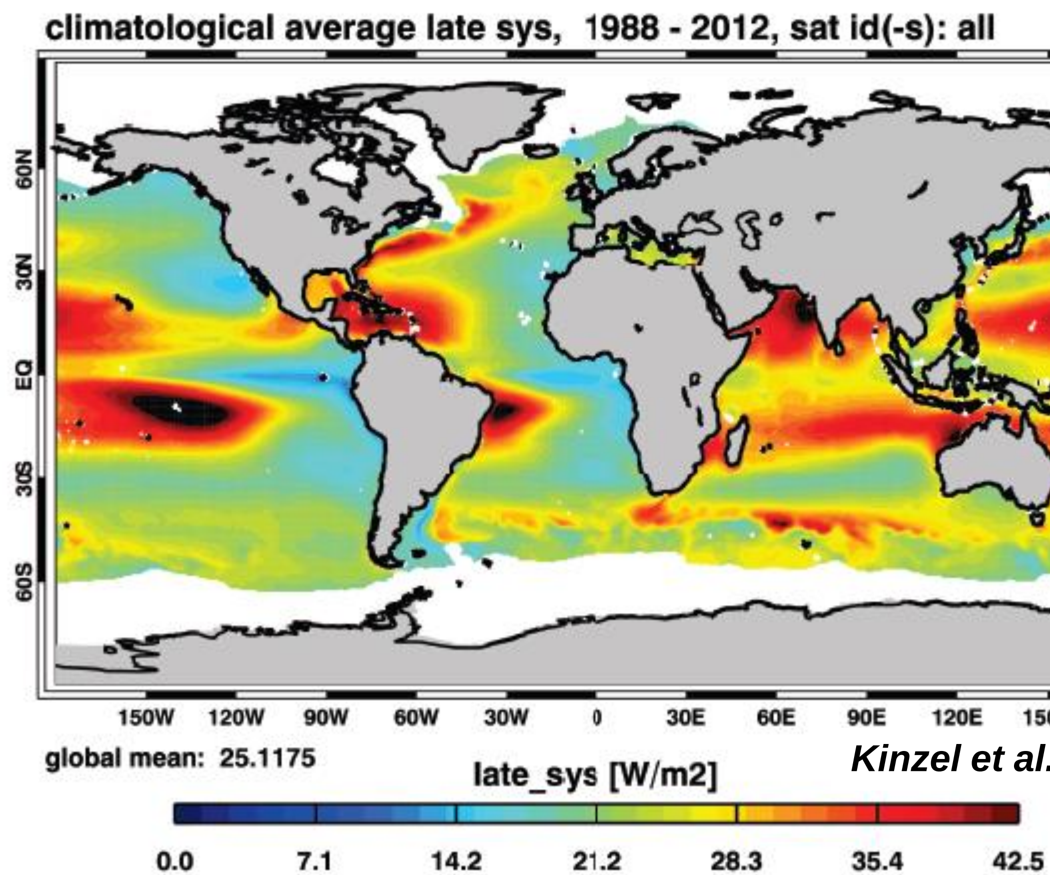
→ remaining: random retrieval error $\mathbf{E_{tot}}$

- HOAPS q_a E_{tot} largest in (sub-) tropics
- Minima over extra-tropics and Pacific Warm Pool region

Error decomposition via MTC allows for uncertainty characterization of HOAPS.

Results (Level 3)

- Consider bias (see above), standard uncertainty for the retrieval (scaled with N) and sampling uncertainty (after Tomita and Kubota, 2011).
- Consider error propagation for LHF.



Kinzel et al. (2017), in prep.

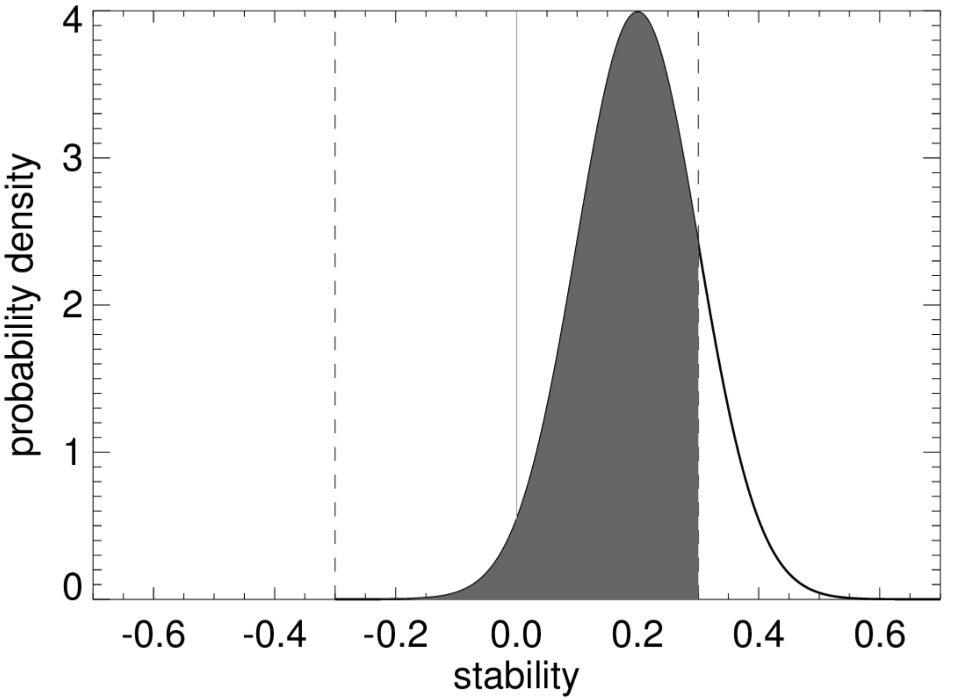
- Dominant source: bias, mainly bias in near surface specific humidity.

Method to calculate stability in HOAPS-4.0:

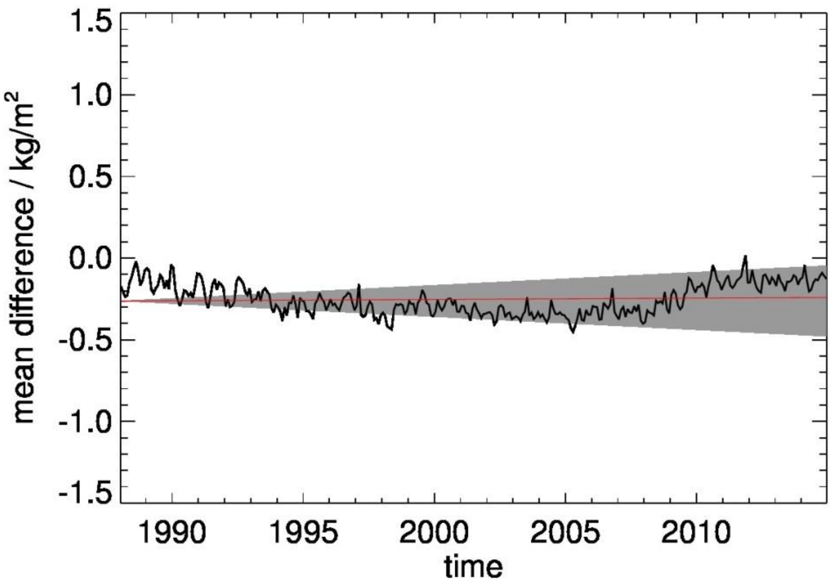
The probability, that the stability is smaller than a requirement is computed by integrating the Gaussian noise distribution using the 1-sigma noise level from the linear regression analysis within limits defined by the requirement. It gives the coverage probability of the stability being within the requirement. Based on this the p-value can be computed. The null hypothesis is that the stability is outside the requirement and the alternative hypothesis is that the stability is smaller than the requirement. The null hypothesis needs to be rejected if the coverage probability >95% (or $p<0.05$).

Details on figure:

stability=0.2 ± 0.1 and requirement=0.3 → $p=0.16$



Stability



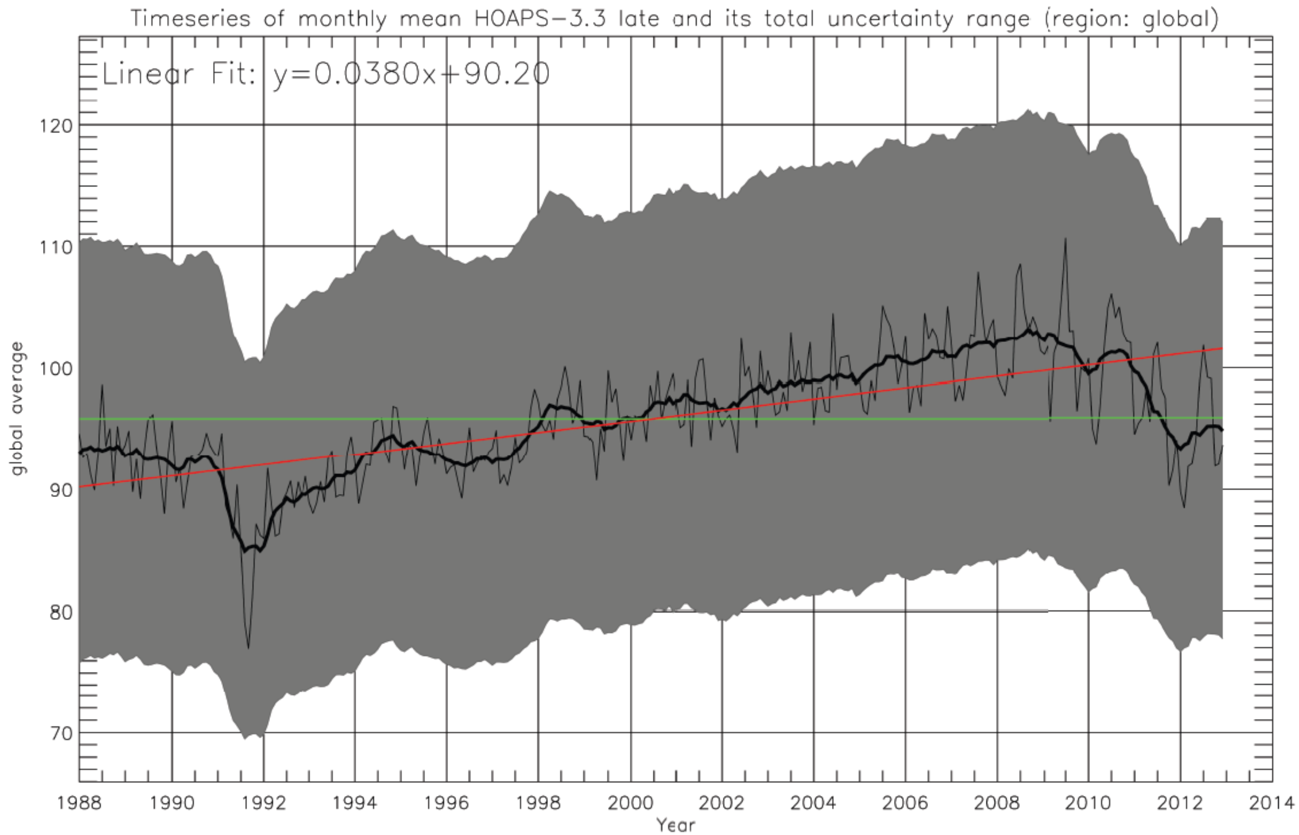
Parameter	Decadal stability Target	Decadal stability Optimal	Decadal stability HOAPS-4.0
Near surface humidity CM-12901	0.10 g/kg (100%)	0.04 g/kg (99.9%)	0.02 ± 0.007 g/kg
Near surface wind speed CM-12911	0.12 m/s (98.3%)	0.03 m/s (0.0%)	-0.09 ± 0.012 m/s
Evaporation CM-12801	0.14 mm/d (100%)	0. 0043 mm/d (2.8%)	-0.02 ± 0.010 mm/d
Latent heat flux CM-12811	3.9 W/m² (100%)	0.12 W/m² (3.0%)	-0.64 ± 0.300 W/m²
Precipitation CM-12611	0.02 mm/d (74.4%)	0.004 mm/d (10.8%)	0.01 ± 0.0090 mm/d
Freshwater flux CM-12821	0.14 mm/d (96.3%)	0.005 mm/d (0.0%)	-0.09 ± 0.028 mm/d
Vertically integrated water vapour CM-12701	0.20 kg/m² (100%)	0.08 kg/m² (100%)	0.00 ± 0.008 kg/m²

Mean difference between TCWV from HOAPS-4 and REMSS. Red: stability, grey: optimum requirement (0.08 kg/m²/decade). Developed during DRR2.7, taken from Löw et al. (2017), in preparation.

Results from the decadal stability analysis of global monthly mean anomalies (numbers are per decade). The values in brackets give the probability that the stability is smaller than the requirement (given here: target and optimal).

But…

- Time series of globally averaged LHF in W/m^2.
- Red: trend from linear regression, green: long-term average.
- Grey shaded: standard uncertainty.

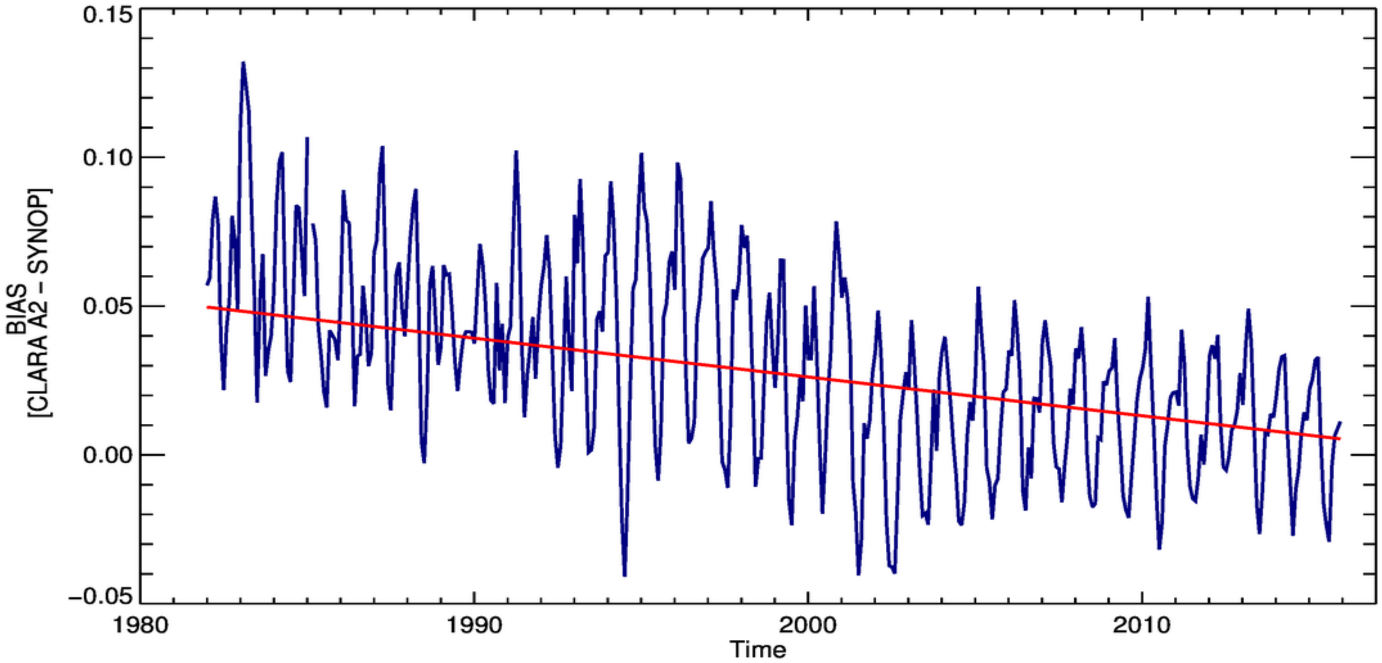


Kinzel et al. (2017), in prep.

- Classical linear regression: significant trend!

Decadal Stability of CLARA-A2

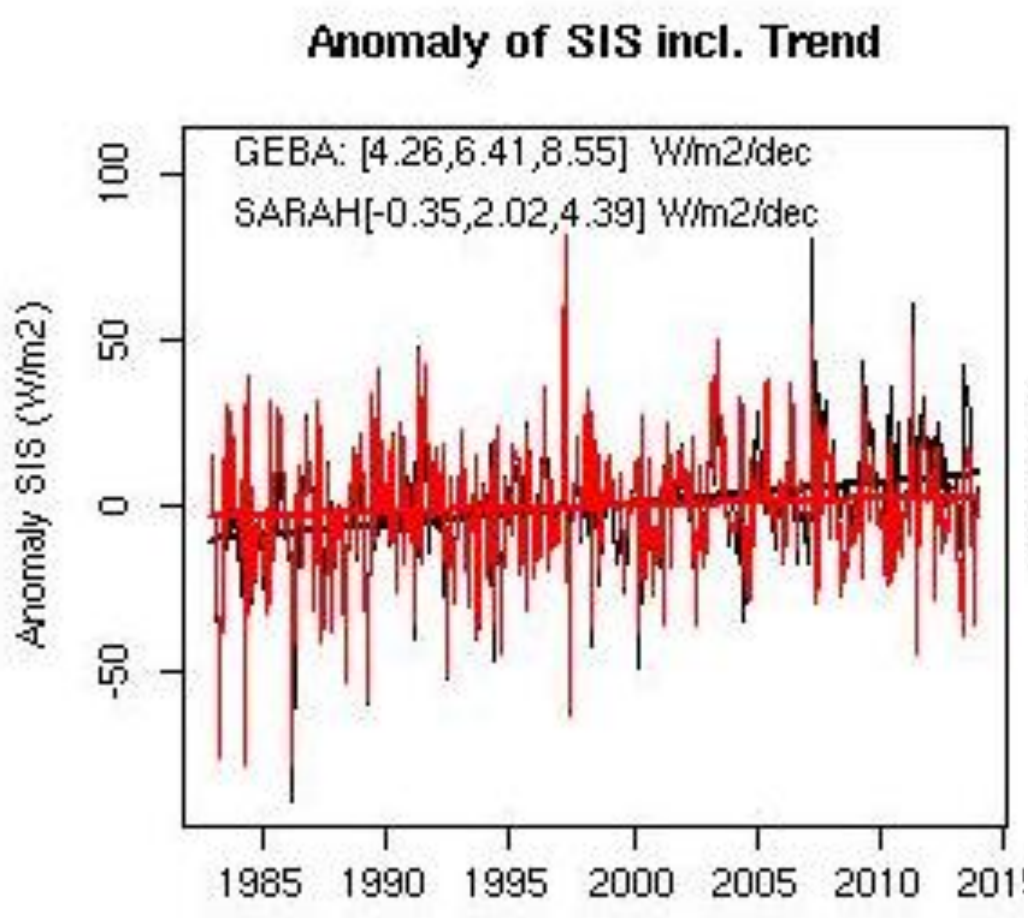
- CLARA-A2 (CM SAF cLoud, Albedo and surface RAdiation dataset from AVHRR data - Edition 2) has been released in March 2017 and comprises the time period from 1982-2015.

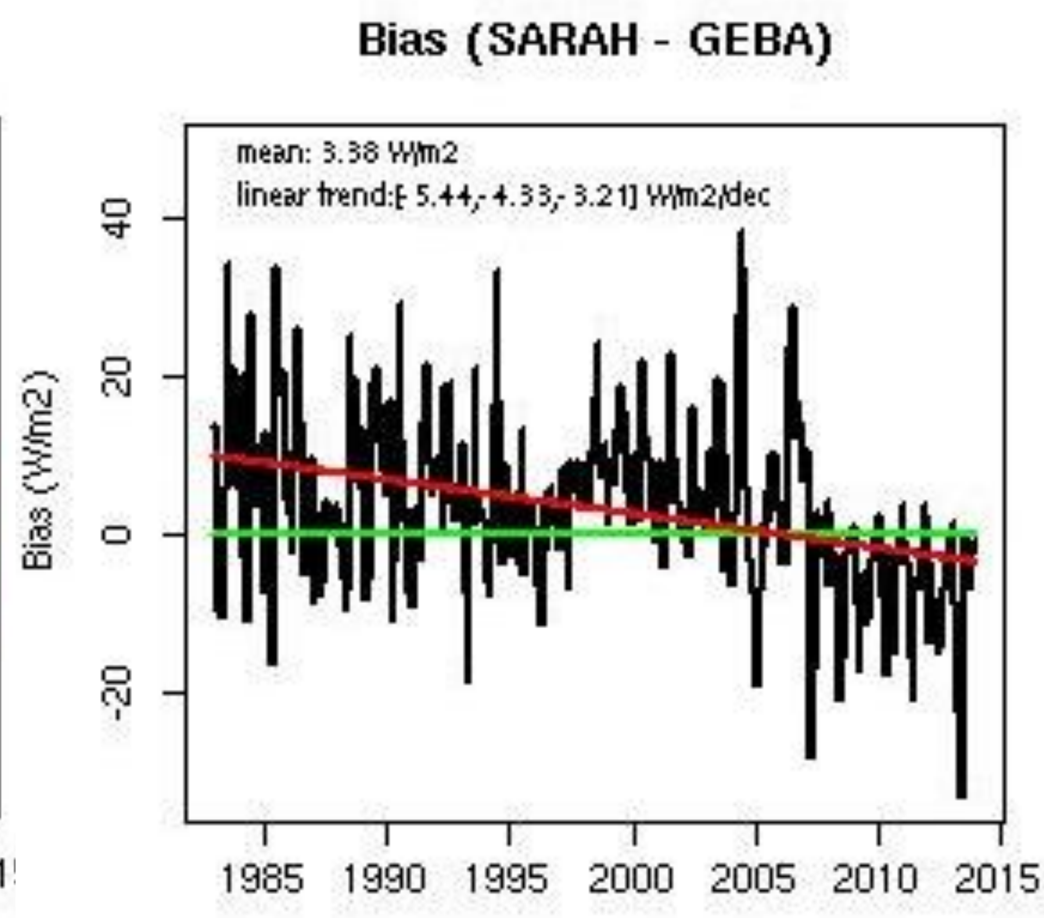


- Temporal variation of the bias between the monthly mean cloud fractional cover and the SYNOP monthly mean data record for a subset of stations containing only stations, that are available for at least 95 % of the entire time series.
- The number of AVHRRs increases with time → strong impact on representation of diurnal cycle.
- The calculated linear fit (red line) has a decreasing trend of 1.3 % per decade.
- The bias time series stabilises after 2001, when the number of simultaneously available satellites gets higher (four or higher).

CM SAF Climate Monitoring — Deutscher Wetterdienst, Wetter und Klima aus einer Hand

Locarno (Swiss)

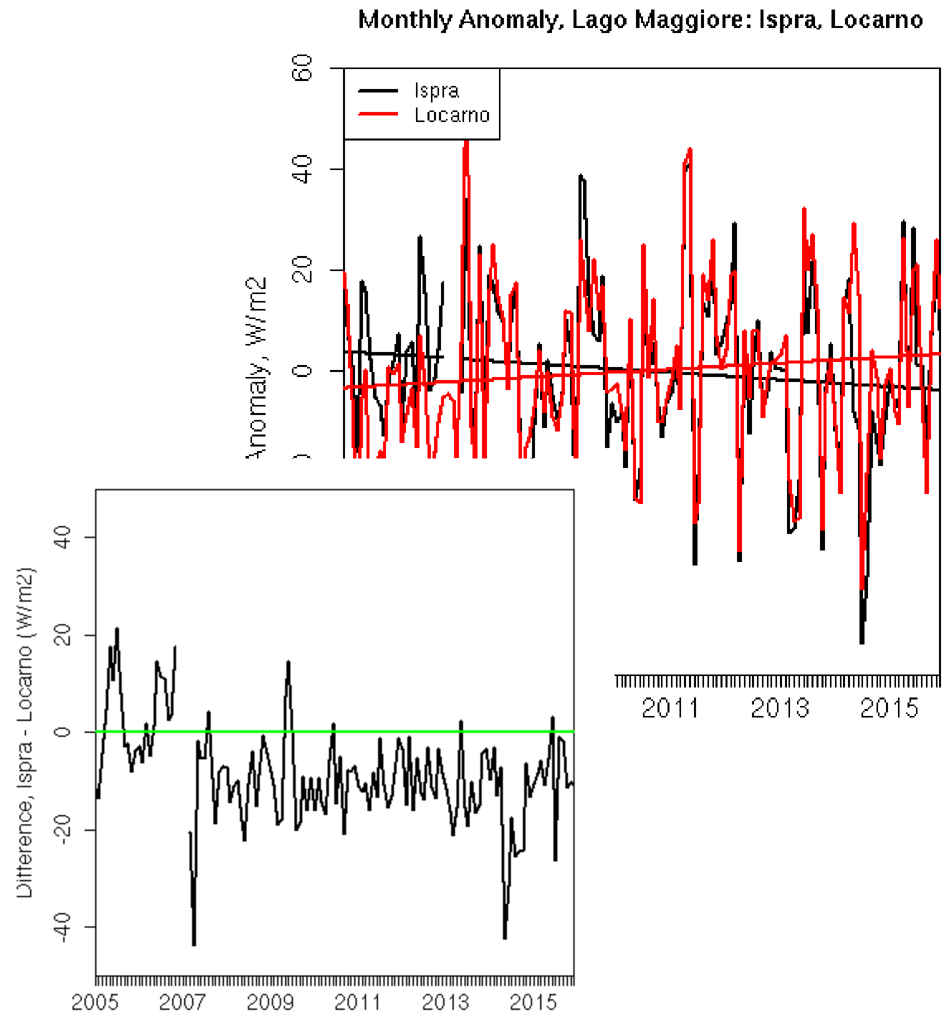




Satellite vs Station data

SARAH vs Locarno and Ispra

- Exceptional positive trends in 2000s, in particular in the South (Lago Maggiore)
- Comparison with measurements from JRC / Ispra showed diverging trends
- "Jump" in the bias between these time series in / around 2007
- Installation of new surface radiation network at MeteoSwiss between 2005 and 2008; Locarno: March 2006
- Parallel measurements (old / new system) show seasonal dependence of difference (max. > 10 %)
- MeteoSwiss currently working on homogenizing the data!



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Satellite vs Station data

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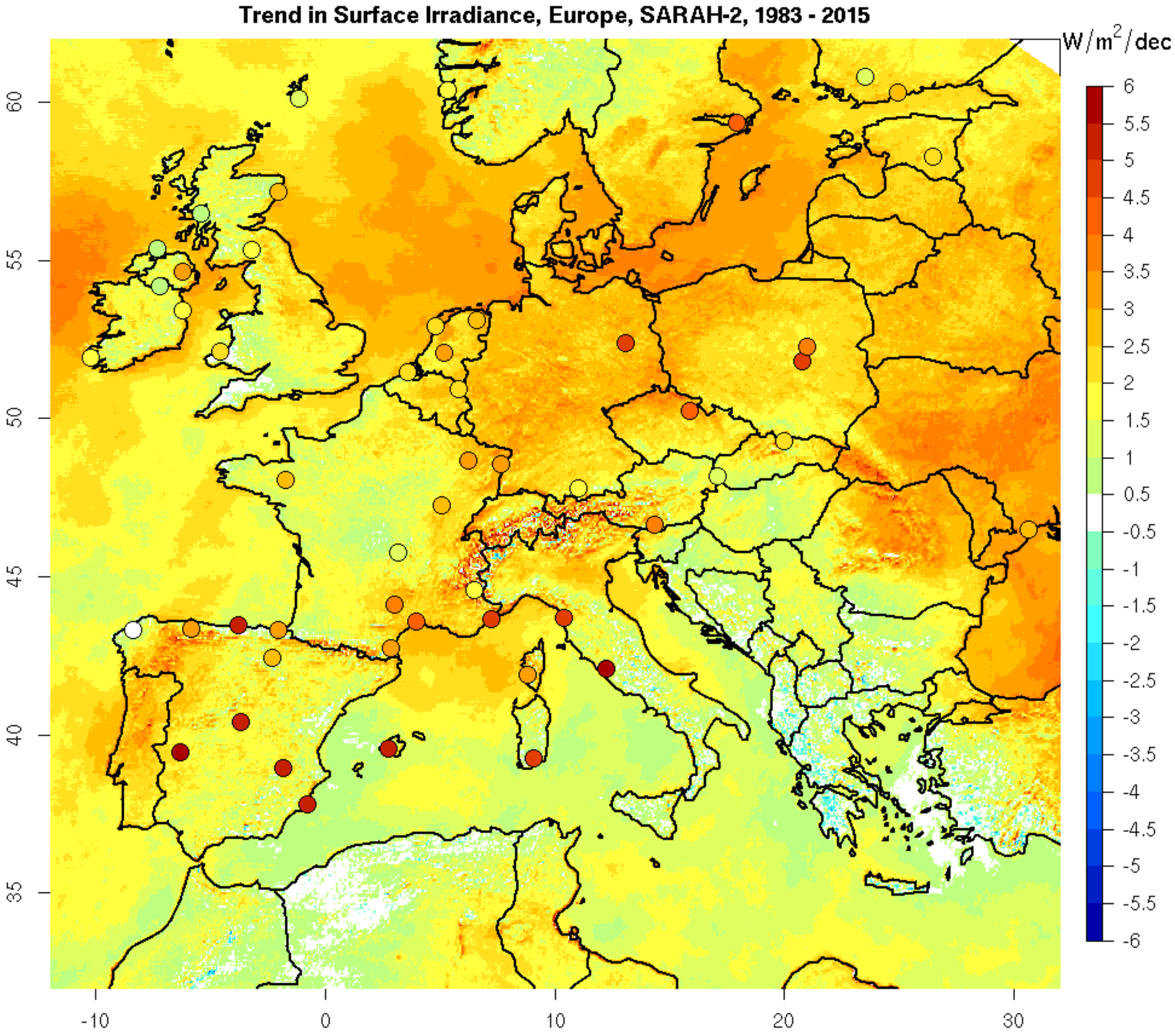
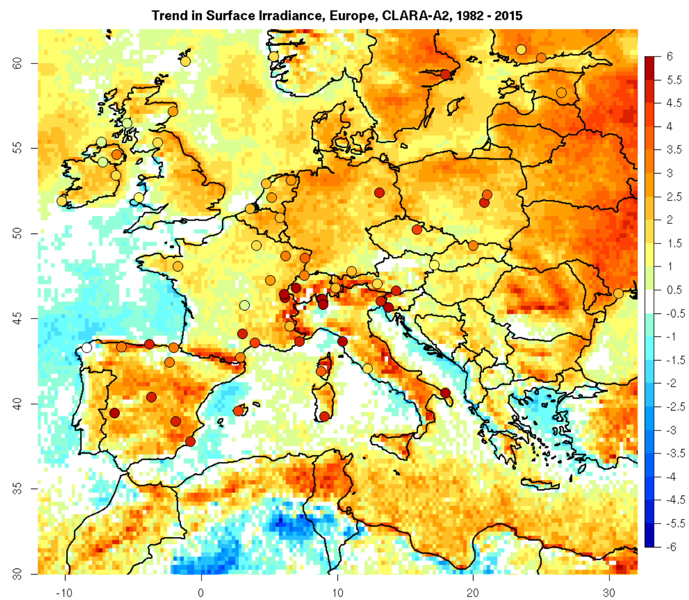
SARAH

Trends 1983 - 2015



CLARA

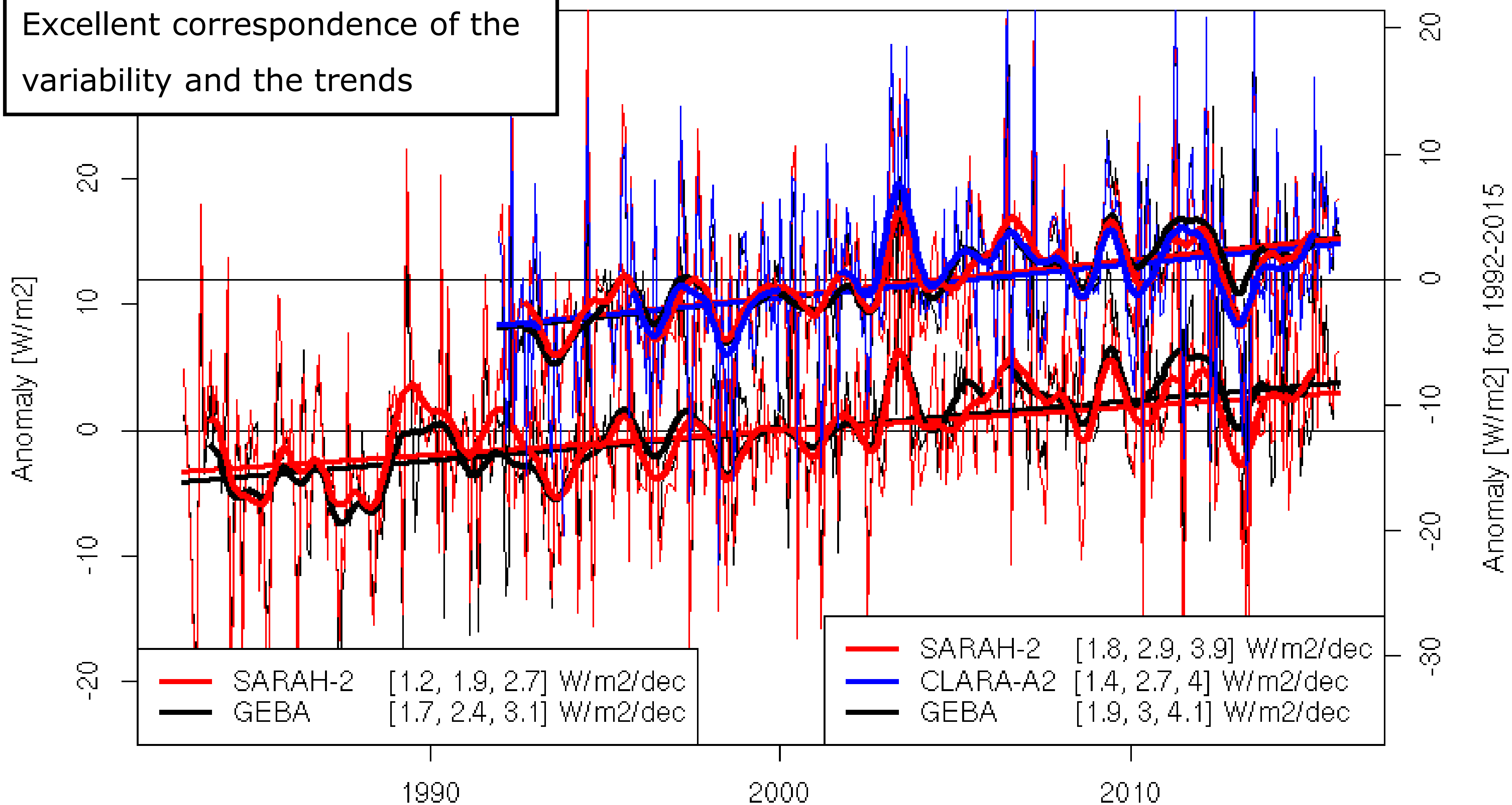
Trends 1992 - 2015



Satellite vs Station data

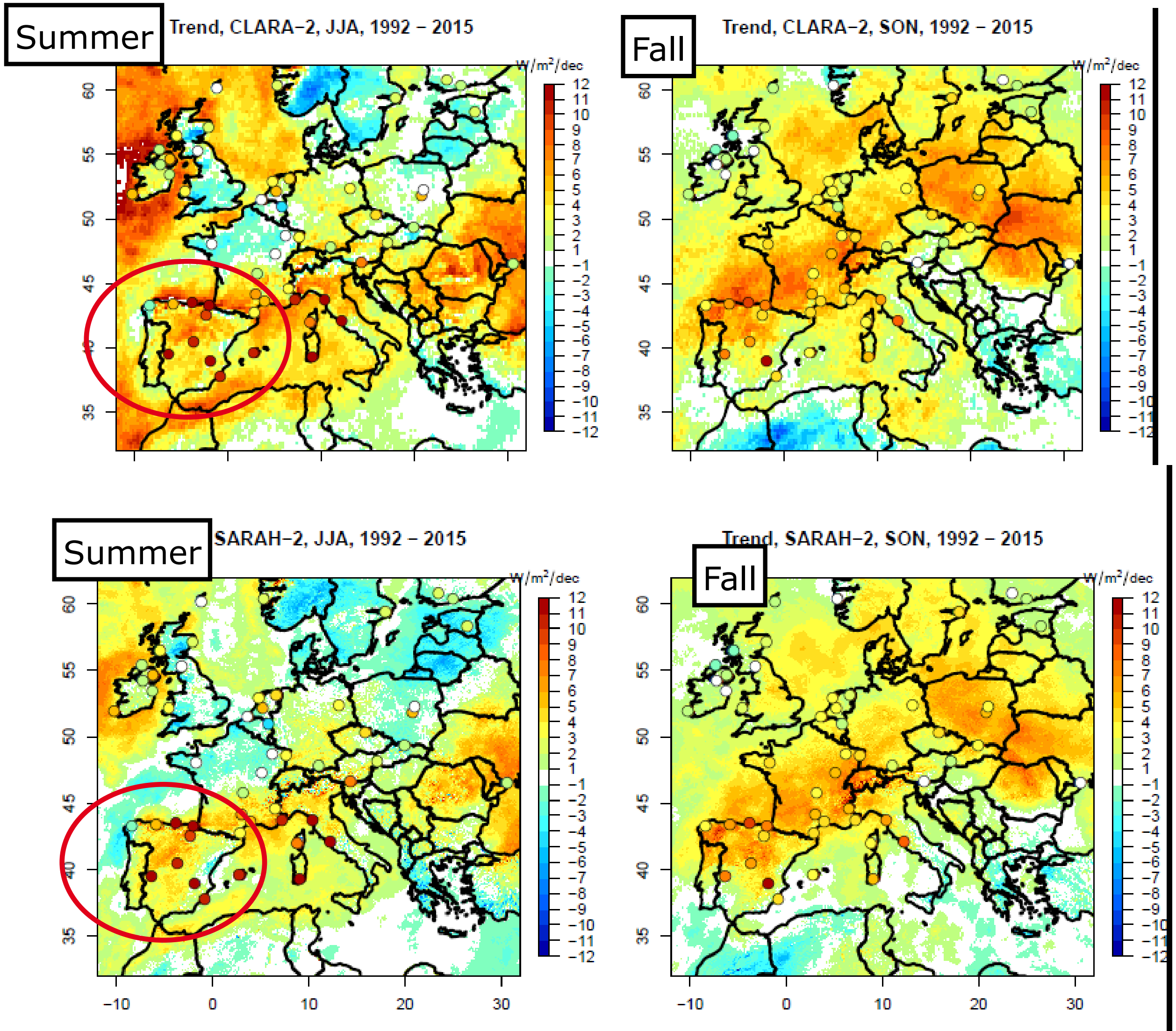
Anomaly Time Series (1983-2015), SARAH-2 and stations

Excellent correspondence of the variability and the trends



Satellite vs Station data

Seasonal trends (1992 -2015) based on CMSAF SARAH and CLARA

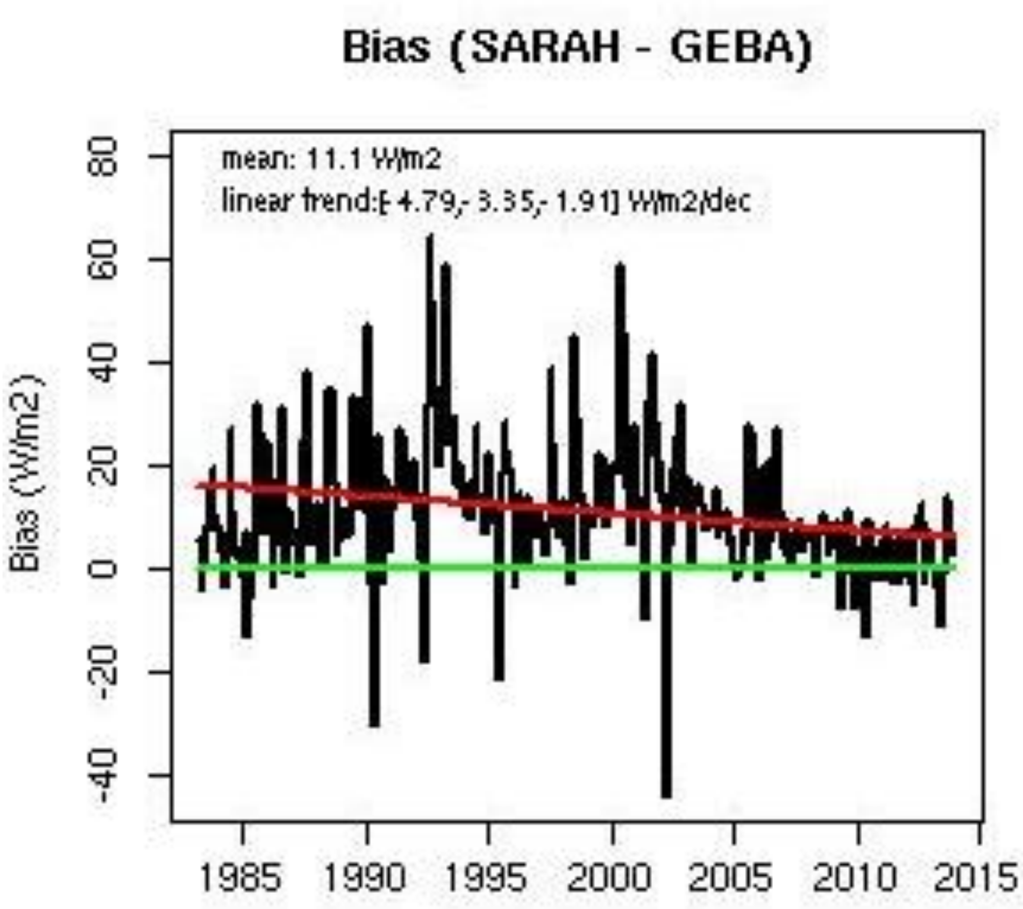


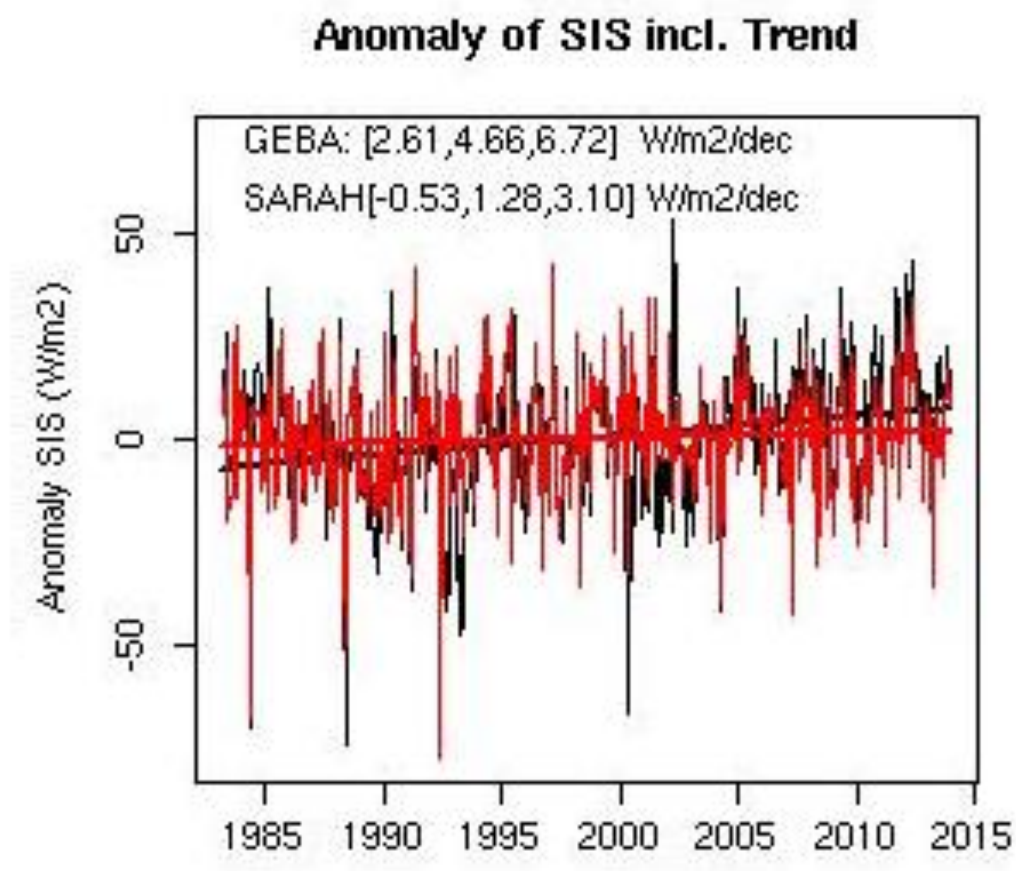
CLARA

- Remarkable agreement between spatial pattern of trends from CLARA and SARAH

SARAH

Albacete (Spain)

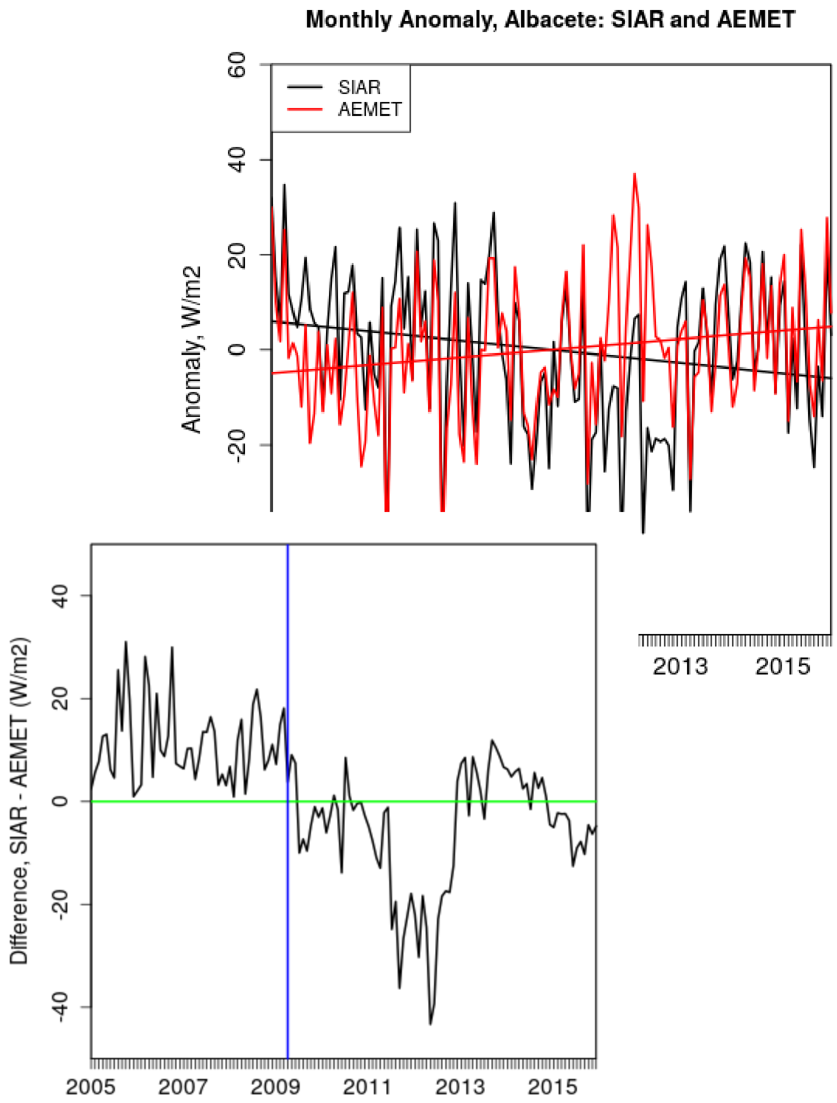




Satellite vs Station data

SARAH-2 vs Albacete

- Exceptional positive trends in 2000s, in particular in the South during Summer
- Comparison with measurements from SIAR network shows diverging trends, e.g., Albacete
- “Jump” in the bias between the data records in / around 2009
- Huge difference in 2012 likely due to SIAR network
- Modernization of surface radiation network at AEMET between 2005 and 2010; Albacete: April 2009 (new pyranometer: CM11 to CM21)
- No parallel measurements available.
- Undefined impact of modernized surface radiation network on data homogeneity



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Deutscher Wetterdienst
Wetter und Klima aus einer Hand

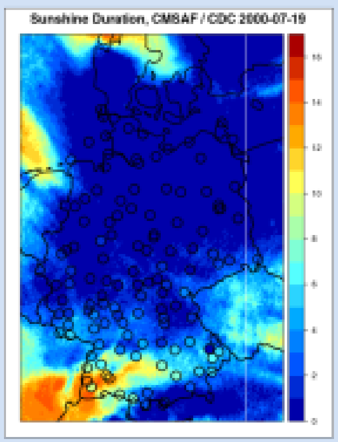
Gridded sunshine duration climate data record for Germany based on combined satellite and in situ observations

Jakub P. Walawender, Steffen Kothe, Jörg Trentmann, Uwe Pfeifroth, Roswitha Cremer

Introduction

Surface measurements offer high quality data for selected locations, whereas satellite observations provide spatially continuous information. Geostatistical methods enable to combine both types of data to generate high resolution gridded climate datasets.

In this study regression kriging was used to produce gridded daily sunshine duration climate data record for Germany on the basis of available CM SAF SARAH v2.0 SDU data record and in situ sunshine duration measurements.



Input datasets:

Daily sums of sunshine duration:

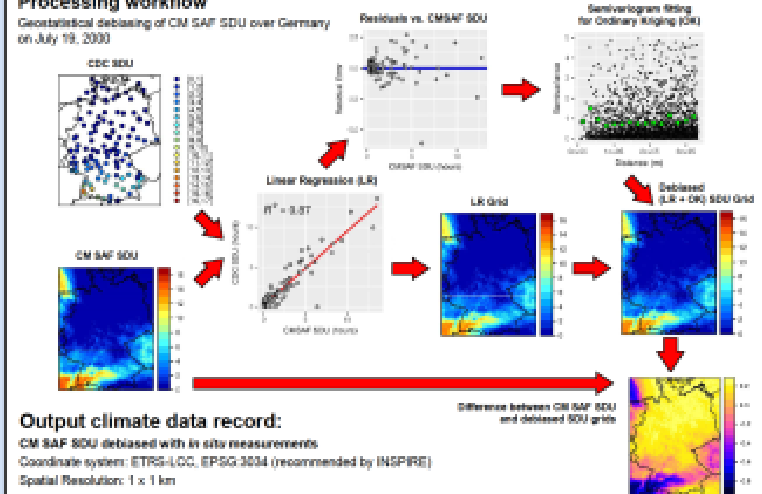
- **Satellite data record** – CM SAF SARAH v2.0 SDU (**CM SAF SDU**) → SDU = DNI ≥ 120 W/m², spatial resolution: 0.05° x 0.05°
- **Ground measurement data record** from DWD archive (**CDC SDU**) → **121 stations** with less than 10% missing daily values over the whole period.

Spatial and temporal extent:

Study area: Germany
Study period: 1983 – 2015 (33 years)

Methods and outcomes

Processing workflow



Output climate data record:

CM SAF SDU debiased with in situ measurements
Coordinate system: ETRS-LCC, EPSG:3034 (recommended by INSPIRE)
Spatial Resolution: 1 x 1 km

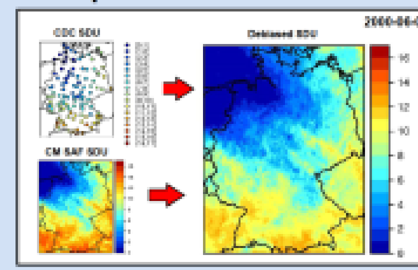
Methods

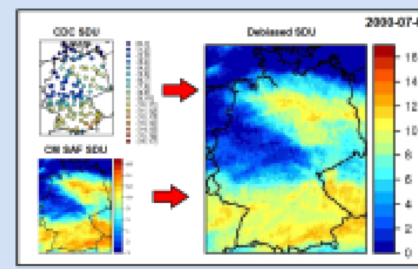
- Exploratory spatial data analysis (ESDA)
- Multiple linear regression
- Kriging of regression residuals
- Accuracy assessment (cross-validation)
- Comparative analysis of the input and output gridded datasets
- Climatological analysis of sunshine duration over Germany

Outcomes

- R tool incl. Instructions
- Gridded (1x1 km) sunshine duration dataset for Germany
- Summary statistics for each daily grid
- Information on the spatial distribution and temporal variability of the SDU over Germany in the period 1983 – 2015

Examples





Summary

- **Satellite climate data records** are useful as explanatory variables for spatial interpolation of *in situ* measurements
- **Ground measurements** can also be used to debias satellite products
- **Regression kriging** is one of the spatial prediction methods for merging multiple datasets from various sources (e.g. satellite data and *in situ* measurements)
- **CM SAF SDU** slightly overestimates sunshine duration

EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF), www.cmsaf.eu
Contact person: Jakub P. Walawender (CM SAF Visiting Scientist), e-mail: jakub.walawender@dwd.de

Summary

- High quality long term TCDRs such as HOAPS, CLARA, SARAH among others are generated from satellite data by CM SAF (http://www.cmsaf.eu)
- HOAPS:
  - Single source for Evaporation, Precipitation, and E-P.
  - Use of CM SAF FCDR.
  - Sound uncertainty estimates available for four parameters after Kinzel et al. (2016) and Kinzel et al. (2017, in preparation).
  - Decadal stability achieves target or even optimal requirements for HOAPS-4.0 products.

- Independent reference data sets are required to access the stability of CDRs.

- Need for more reliable long term surface measurements, especially parallel measurements.

Thank you for your attention!

Stability of HOAPS-4.0 products