The EUMETSAT Network of Satellite Application Facilities

CM SAF
Climate Monitoring

EUMETSAT's CM-SAF
- Status and outlook -

Rainer Hollmann
Deutscher Wetterdienst (DWD)
With contributions from the full CM SAF team

http://www.cmsaf.eu

EUMETSAT | Deutscher Wetterdienst Wetter und Klima aus einer Hand | DWD | KNMI | RMI | SMHI | Schweizerische Eidgenossenschaft Confédération suisse Confederazione Svizzera Confederaziun svizra | Met Office

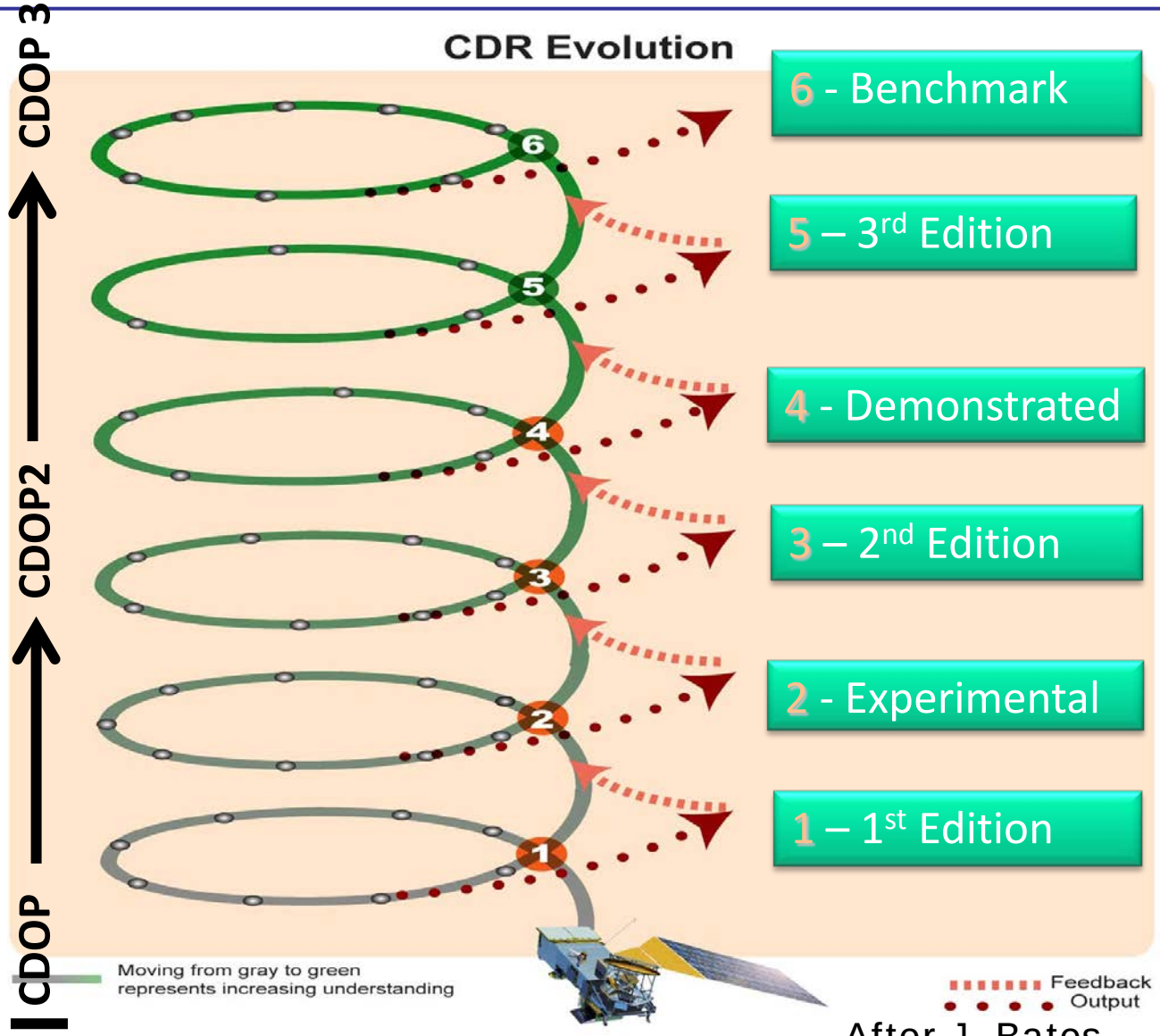
Content

- EUMETSAT's CM SAF and its vision
- achievement in the generation of CDR's
- upcoming CDR's in CDOP2
- Application of our data sets in science and for services
- User support, training activities and outreach
- Research activities
- International relations
- Summary & Conclusion

Vision

- **CM SAF** is continuing to develop capabilities for a sustained generation and provision of Climate Data Records (CDR's) derived from operational meteorological satellites.

CM SAF: sustained generation of CDR‘s



After J. Bates

Vision

- **CM SAF** is continuing to develop capabilities for a sustained generation and provision of Climate Data Records (CDR's) derived from operational meteorological satellites.

- **CM SAF** generates and provides of long-term climate data sets based on FCDR's

- **CM SAF** makes the resulting data sets suitable for the analysis of climate variability and potentially the detection of climate trends.

- **CM SAF** works in close collaboration with the EUMETSAT CF and liaises with the international research community

- **Thematically,** the focus is on ECVs associated with the global energy and water cycle.

CM SAF's Targeted User Communities

- **Global and regional climate trends and variability analysis**
  - high quality Climate Data Records (CDR) are expected e.g. for climate studies in contribution to IPCC.
  - Thematic Climate Data Records (TCDR) from CM SAF will provide consistent information on Essential Climate Variables (ECV) related to the global energy and water cycle supporting closure studies

- **Support to global and regional climate modelling**
  - use of Climate Data Records for model evaluations, feedback studies, and uncertainty studies
  - these datasets needed at high(er) temporal and spatial resolutions
  - most recent satellite instrument, only cover short time periods.

- **Operational climate monitoring and infrastructure planning**
  - long term Climate Data Records (of ECVs) AND near real time operational products required
  - Consistent climate datasets and according near real time operational products needed (identical algorithm and auxilliary data)

CM SAF CDR Product portfolio

Sensor, Satellite resp.	Parameter	Release	Period	Coverage
Fundamental **C**limate **D**ata **R**ecord (FCDR)				
SSM/I, SSMIS	Microwave Radiances	**2012** 2014 (16)	**1987 – 2008** 1987 – 2012 (14)	global
Climate Data Record (CDR)				
SEVIRI	Cloud parameters, surface rad., aerosol optical depth ECV A04, A06, A09, T22	**2013** 2015	**2004 – 2011** 2004 – 2014	Europe & Africa
GERB/SEVIRI	Top of atmosphere radiative fluxes ECV A06	**2013** 2015	**2004 – 2011** 2004 – 2014	Europe & Africa
MVIRI/SEVIRI	Cloud parameters, surface radiation parameters, land surface temp., FTH ECV A04, A06, A03	**2011** 2014 2016	**1983 – 2005** 1983 – 2012 1983 – 2015	Europe & Africa
MVIRI/SEVIRI/GERB	Top of atmosphere radiative fluxes ECV A06	2015	1982 – 2014	Europe & Africa
AVHRR GAC	Cloud parameters, surface radiation parameters, incl. albedo ECV A04, A06, T22	**2012** 2015	**1982 – 2009** 1982 – 2014	global
TOVS/ATOVS	(high) cloud amount and top ECV A04	2016	1984 – 2009	global
ATOVS	Water vapour and Temperature profile ECV A03	2013	**1998 – 2008**	global
SSM/I, SSMIS	HOAPS (precip, evap, hum., wind, …) ECV A01, A03, A05	**2011** 2015 (17)	**1987 – 2008** 1987 – 2012 (14)	global ice free ocean

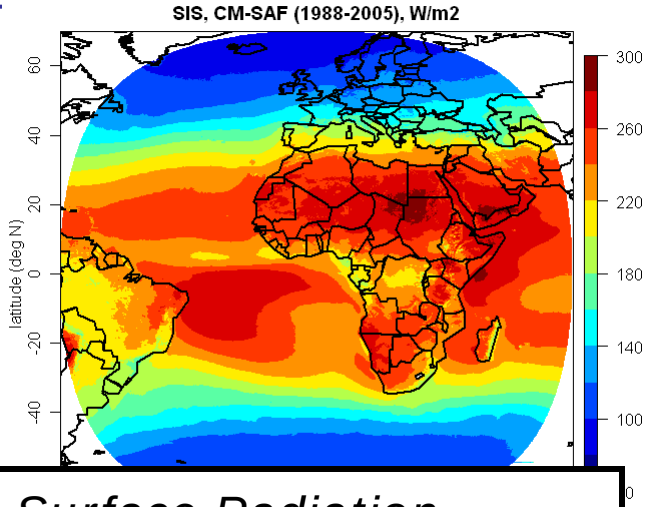
CM SAF CDR Achievements

Sensor, Satellite resp.	Parameter	Release date	Period	Coverage
Fundamental **C**limate **D**ata **R**ecord (FCDR)				
SSM/I, SSMIS	**Microwave Radiances**	2012	1987 – 2008	global
Climate Data Record (CDR)				
SEVIRI	**Cloud parameters, aerosol optical depth**	2012	2004 – 2009	Europe & Africa
GERB/SEVIRI	**Top of atmosphere radiative fluxes**	2012	2004 – 2009	Europe & Africa
MVIRI/SEVIRI	**Cloud parameters, surface radiation parameters, land surface temp., FTH**	2011	1983 – 2005	Europe & Africa
AVHRR GAC	**Cloud parameters, surface radiation parameters, incl. albedo**	2012	1982 – 2009	global
SSM/I, SSMIS	**HOAPS 3.2 (precip, evap, hum., wind, …)**	2011	1987 – 2008	global ice free ocean
ATOVS	**Water vapour and Temperature profile**	2013	1998 – 2008	global

All CDR‘s are accessible via DOI Numbers

CM SAF Data Sets: Meteosat

Meteosat Surface Radiation



First Generation (Posselt et al., 2012)

- 1983 – 2005; 0.03 deg; Meteosat Full Disk, monthly/daily/hourly
- 6 different MVIRI satellite instruments (of the same type) used!

+

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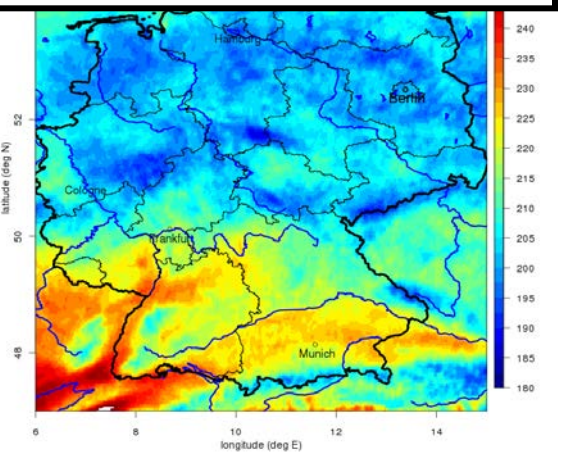
Meteosat Surface Radiation

- 1983 to 2010!
- 8 different satellite instruments

2nd Generation (Posselt et al., 2013)

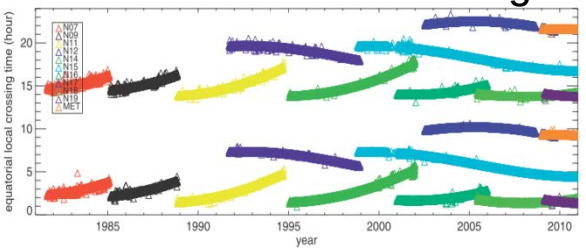
- 2004 – 2010; 0.03 deg; Meteosat Full Disk, monthly/daily
- 2 different SEVIRI satellite instruments (of the same type) used!



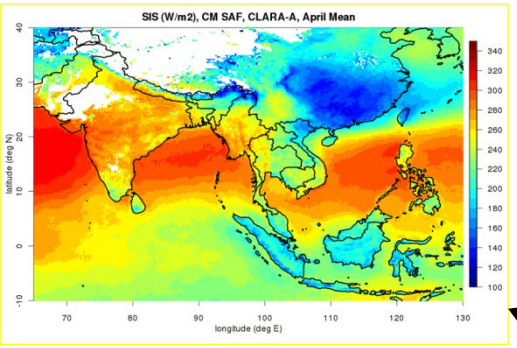
CM SAF Data Sets: CLARA

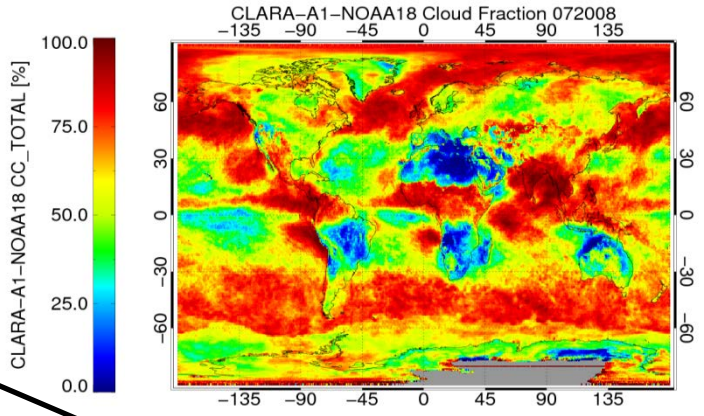
- CM SAF Clouds, Albedo, Radiation (Karlsson et al., 2013)
- 1982 – 2009; 0.25 deg; global coverage, monthly/daily
- Netcdf; polar regions: EASE-grid

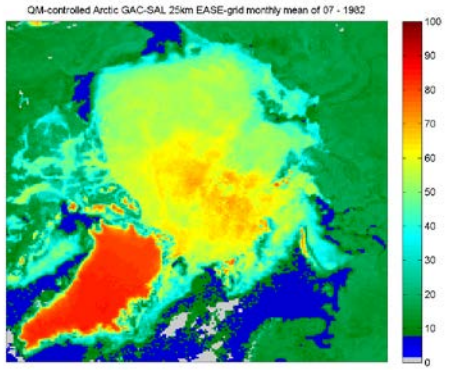
Satellite Coverage



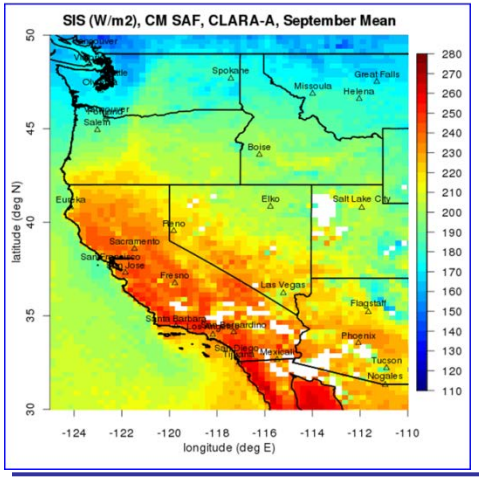
Central Asia

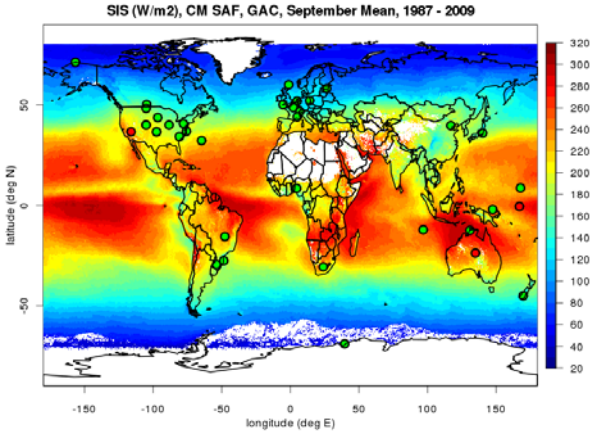


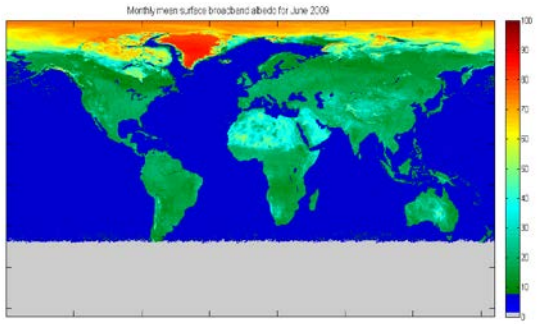




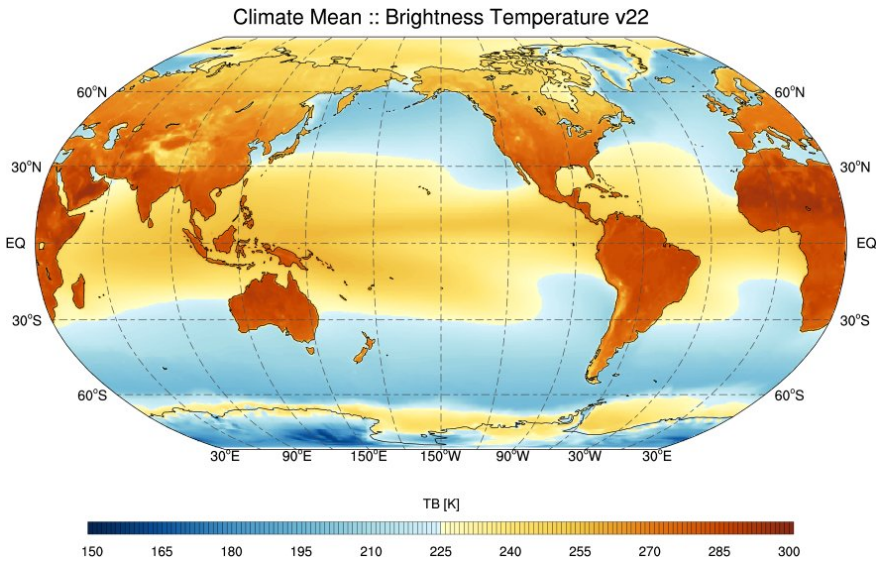
Western US

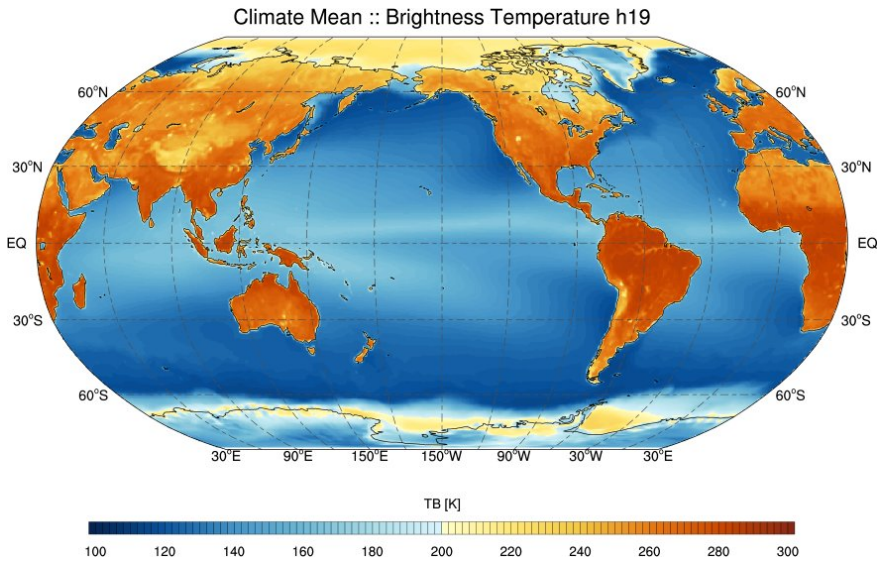






CM SAF FCDR of SSM/I Brightness Temperatures





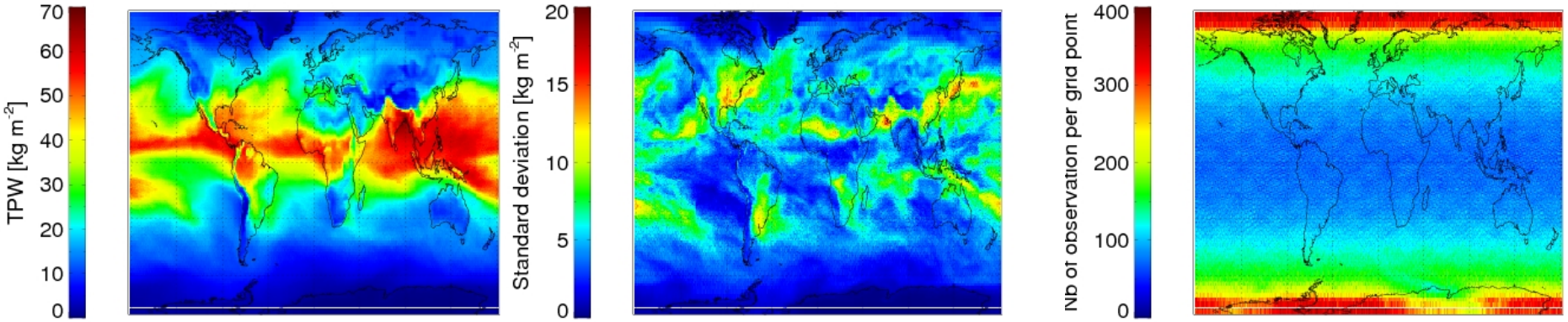
DOI: 10.5676/EUM_SAF_CM/FCDR_SSMI/V001

- **July 1987 – December 2008.**
- Calibration with smoothed cold and hot load readings
- geo-location based on smoothed TLEs.
- Data processing accounts for known issues:
  - Moonlight-intrusions,
  - Sunlight-intrusions,
  - Along-scan non-uniformity.

- 85 GHz Brightness temperatures averaged to 37 GHz antenna pattern.
- Synthetic 85 GHz data over ocean for F08.
- Earth incidence angle normalization
- Non-linearity calibration coefficient.
- Scene dependent inter-calibration to

Will be used in next ERA!

CM SAF TCDR of Water vapour and Temperature



- DOI: 10.5676/EUM_SAF_CM/WVT_ATOVS/V001

- Time period: 1999 – 2011, 90 km × 90 km, NetCDF, CF and metadata Convention v1.5, Monthly and daily products

- Global humidity and temperature products:
  - HTW: total precipitable water vapour
  - HLW: layered precipitable water vapour and temperature in 5 layers
  - HSH: Specific humidity and temperature at 6 levels

- Derived from the ATOVS instruments (AMSU-A, -B, MHS, HIRS) flying onboard the NOAA and Metop polar orbiting satellites

CM SAF TCDR of Free tropospheric humidity (FTH)

DOI: 10.5676/EUM_SAF_CM/FTH_METEOSAT/V001

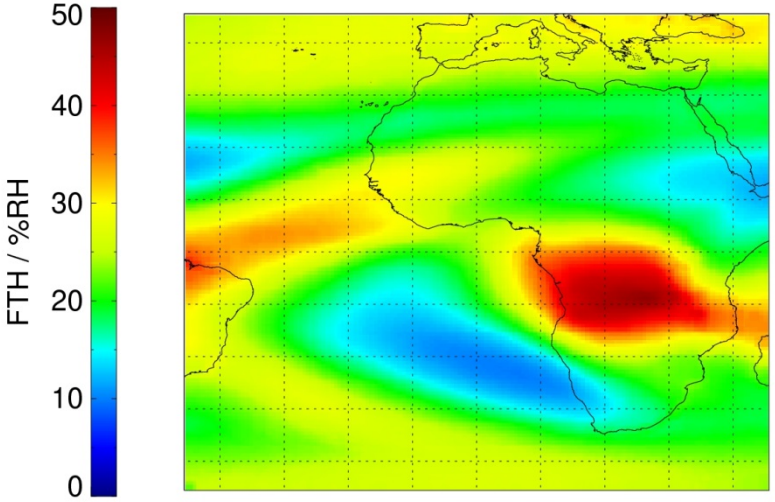
Instruments used: MVIRI + SEVIRI: METEOSAT 2-5, 7-9.

July 1983 – December 2009, Tropical Africa/Atlantic: 45°N/S/E/W in 0.625° spatial resolution, 3 hourlies, monthly averages.

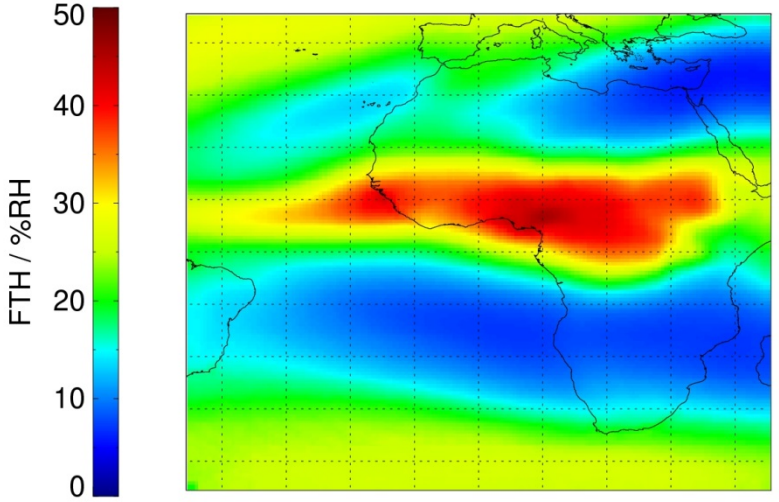
Input: ISCCP radiances, SEVIRI radiances from DWD archive, ERA-Interim, ISCCP cloud mask and cloud top pressure.

Retrieval after (Roca et al., 2009), homogenisation after Picon et al. (2003), inter-calibration after Breon et al. (2000).

DJF



JJA

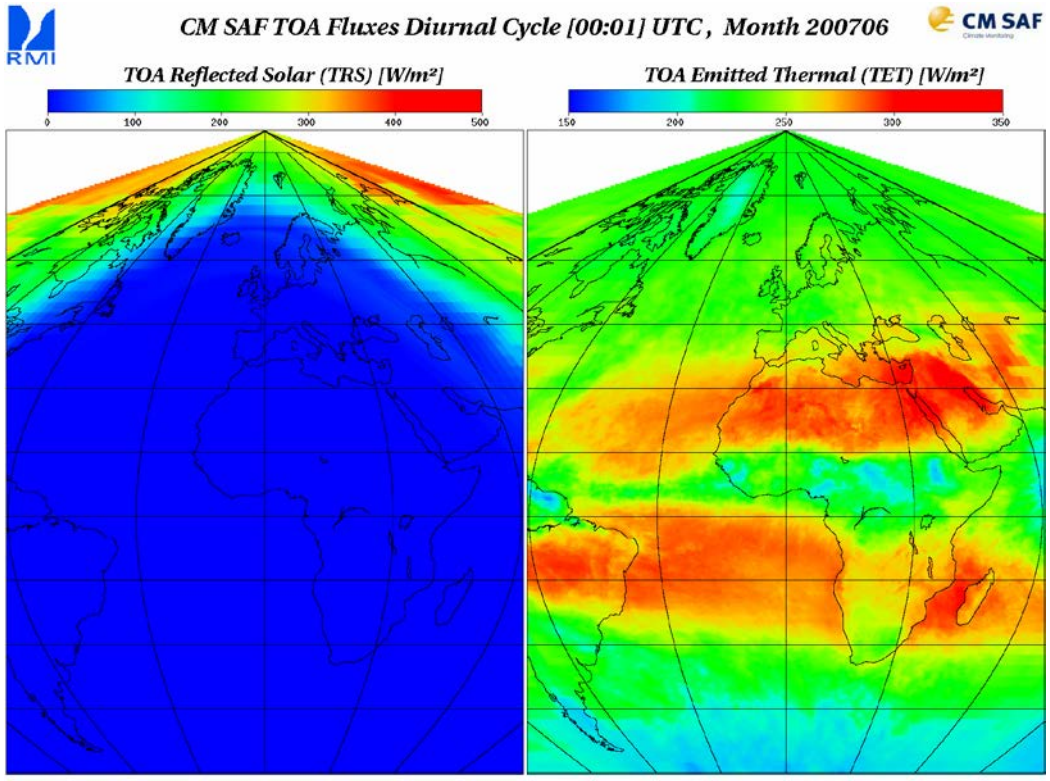


CM SAF TCDR of TOA Radiation

DOI: 10.5676/EUM_SAF_CM/TOA_GERB/V001

Instruments used: GERB: METEOSAT 8 & 9

February 2004 – January 2011, Meteosat Field of view in 45km x 45km spatial resolution, hourlies, daily and monthly averages.



Monthly mean diurnal cycle of TOA radiation (June 2007)

CM SAF CDR - Upcoming data sets

Sensor, Satellite resp.	Parameter	Release date	Period	Coverage
Fundamental **C**limate **D**ata **R**ecord (FCDR)				
SSM/I, SSMIS	Microwave Radiances	2014 2016	1987 – 2012 1987 – 2014	global
Climate Data Record (CDR)				
SEVIRI	Cloud parameters, aerosol optical depth	2015	2004 – 2014	Europe & Africa
GERB/SEVIRI	Top of atmosphere radiative fluxes	2015	2004 – 2014	Europe & Africa
MVIRI/SEVIRI	Cloud parameters, surface radiation parameters, land surface temp., FTH	2014 2016	1983 – 2012 1983 – 2015	Europe & Africa
MVIRI/SEVIRI/GERB	Top of atmosphere radiative fluxes	2015	1982 – 2014	Europe & Africa
AVHRR GAC	Cloud parameters, surface radiation parameters, incl. albedo	2015	1982 – 2013	global
TOVS/ATOVS	(high) cloud amount and top	2016	1984 – 2009	global
SSM/I, SSMIS	HOAPS (precip, evap, hum., wind, …)	2015	1987 – 2012	global ice free ocean

The EUMETSAT Network of Satellite Application Facilities

CM SAF Climate Monitoring

Example: Meteosat + SEVIRI data set

Sensor, Satellite resp.	Parameter	Release date	Period	Coverage
Fundamental **C**limate **D**ata **R**ecord (FCDR)				
SSM/I, SSMIS	Microwave Radiances	2014 2016	1987 – 2012 1987 – 2014	global
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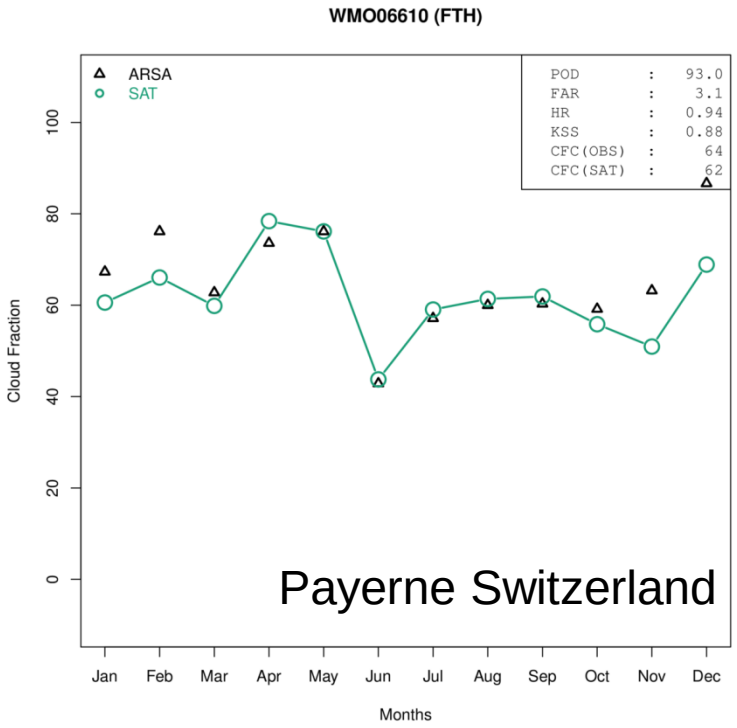
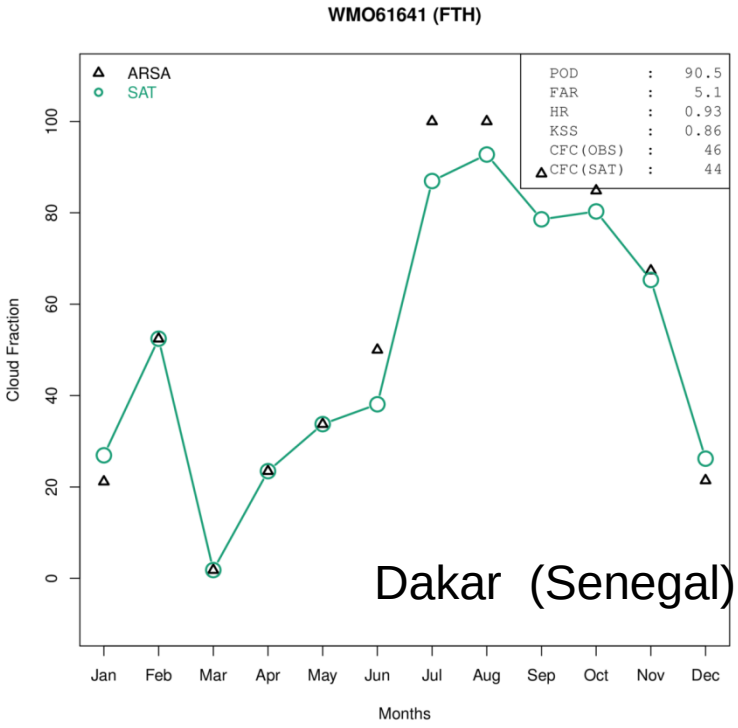
AVHRR GAC	Cloud parameters, surface radiation parameters, incl. albedo	2015	1982 – 2013	global
TOVS/ATOVS	(high) cloud amount and top	2016	1984 – 2009	global
SSM/I, SSMIS	HOAPS (precip, evap, hum., wind, …)	2015	1987 – 2012	global ice free ocean

Meteosat Climatological Cloud Fraction



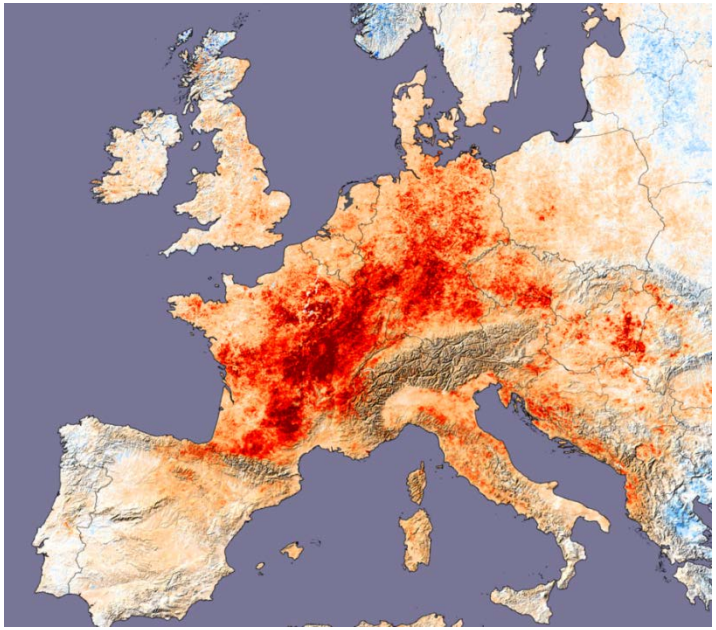


Application areas:

- FTH (CM SAF downstream TCDR)
- Meteosat Albedo and Clear Sky Radiance (EUM CF)
- Drought Monitoring and Land Surface Applications

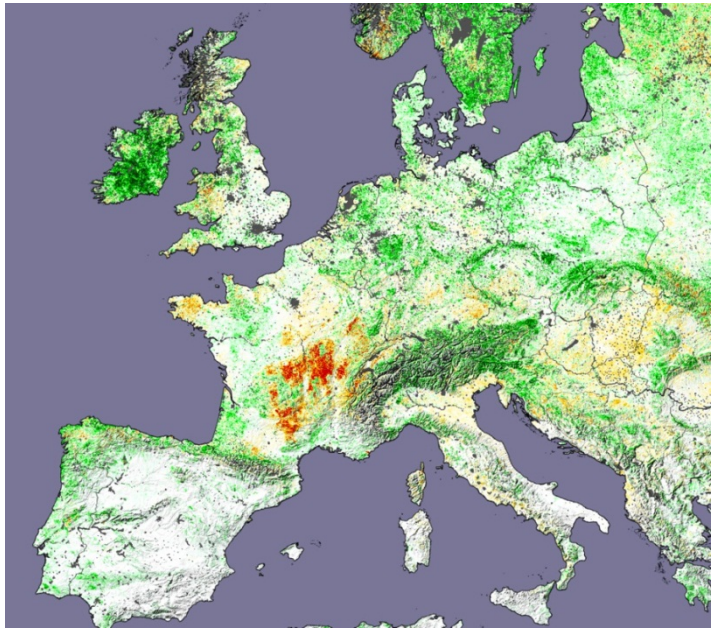
Example: Meteosat + SEVIRI data set, Land Surface Temperature

Linking Heat Waves and Biosphere Anomalies:
- satellite-based analyses offer an highly integral view of the response of our biosphere to climate variation and change.



Land Surface Temperature Anomaly

-10 -5 0 5 10



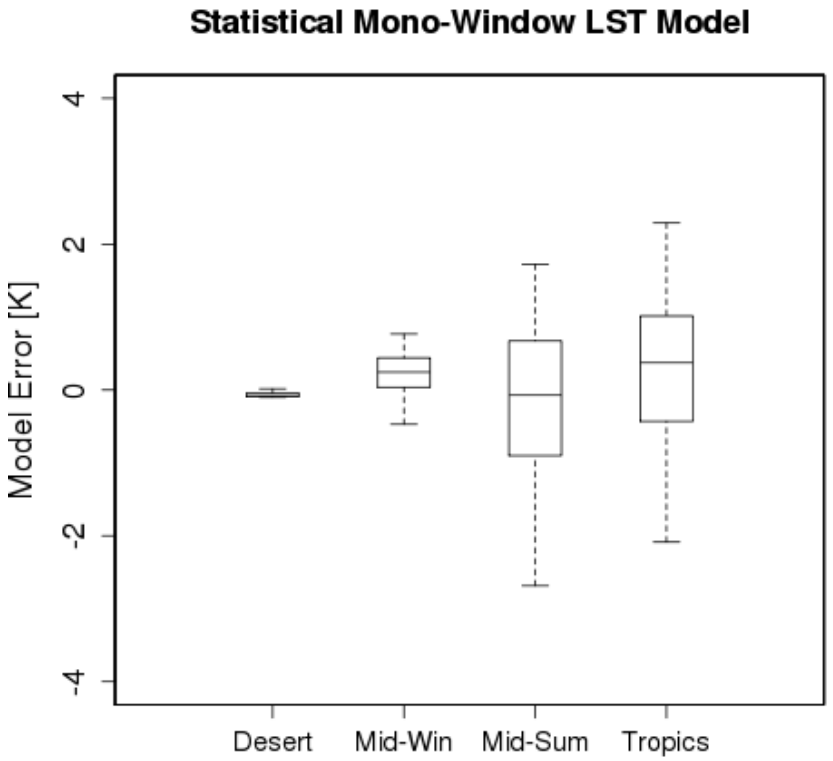
Leaf Area Index Anomaly

-2 -1 0 1 2

MODIS/TERRA satellite data from July & August 2003 versus 2000-2007

Stöckli et al. (2004) in Allen&Lord (2004) Nature, 432: 551-552

Land Surface Temperature



Challenge Meteosat First Generation

Only one thermal channel:

Modern Split-Window approaches

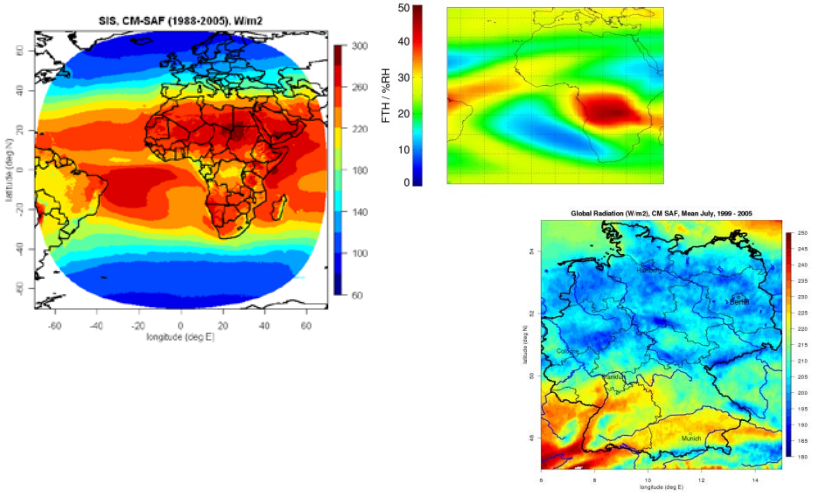
have to be abandoned !

Near Future

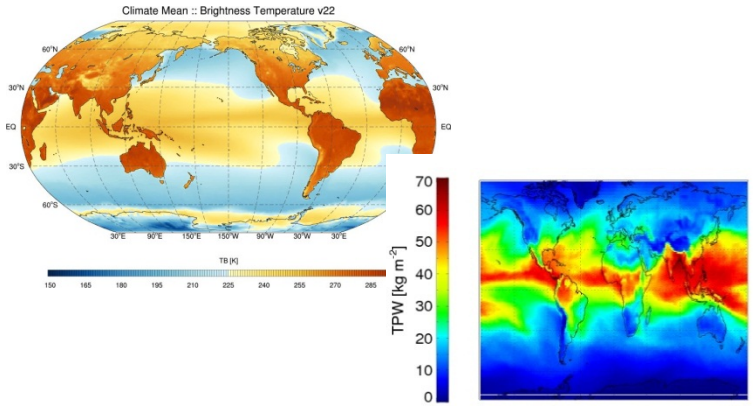
Investigation of physical mono-window LST models

Significant model errors for moist atmospheres!

Application of CM SAF data sets in science and for climate services



CM SAF data sets



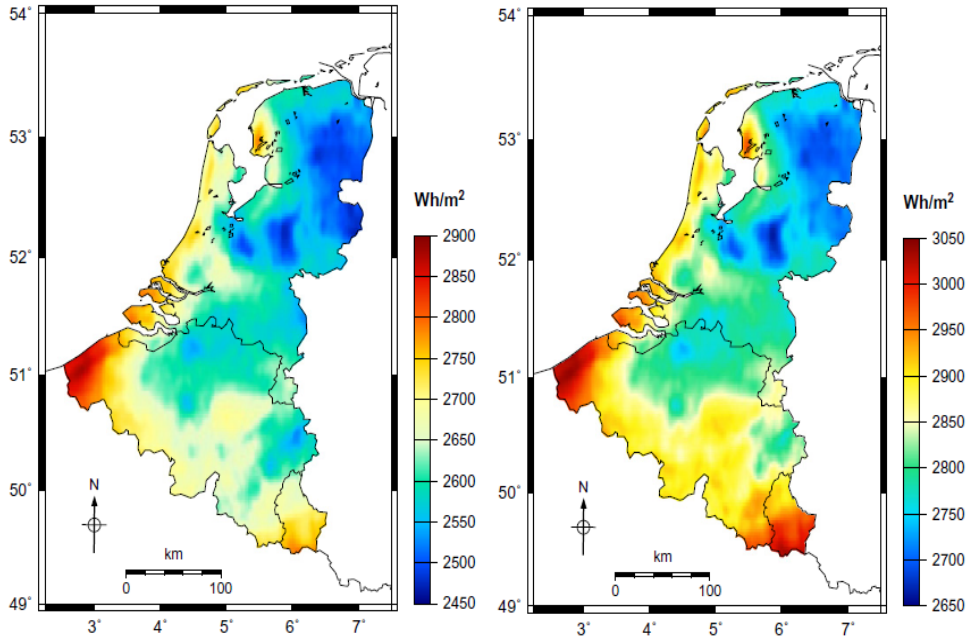
- Solar Energy
- Regional Climate Monitoring
- Arctic Sea Ice
- CMIP5 evaluation
- Trend assessments
- Climate model evaluation
- NWP model evaluation
- Climate Analysis

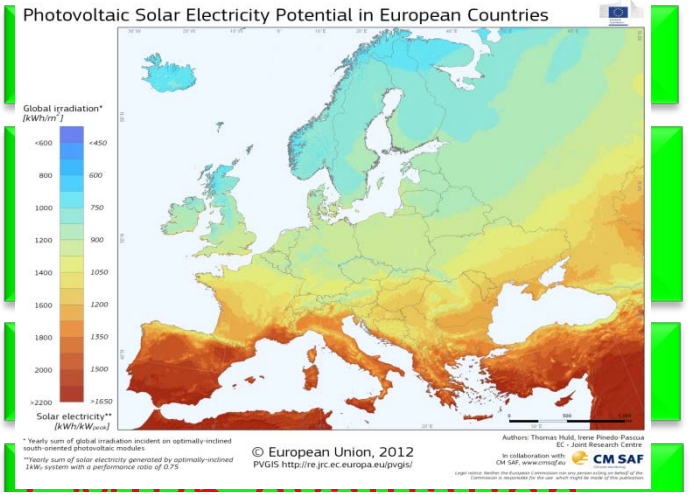
Solar resource assessment in the Benelux by merging Meteosat-derived climate data and ground measurements

Michel Journée [a,*], Richard Müller [b], Cédric Bertrand [a]

[a] Royal Meteorological Institute of Belgium (RMI), Brussels, Belgium
[b] Deutscher Wetterdienst (DWD), Offenbach, Germany

Solar Energy 86 (2012) 3561–3574





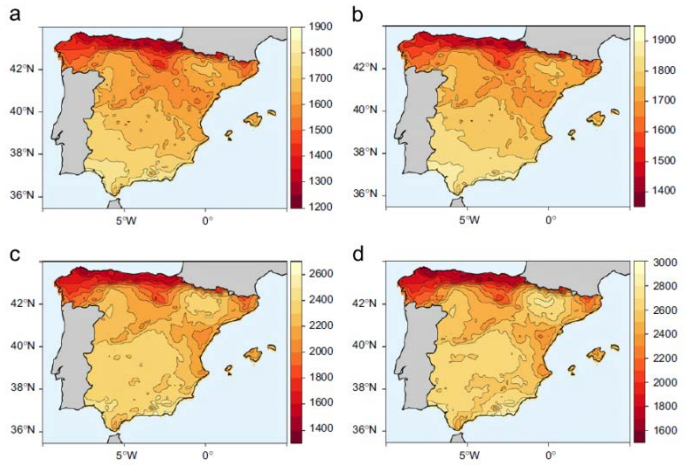


Fig. 9. Global solar irradiation estimated with KED using CM SAF as external drift. (a) G0. (b) Fixed. (c) NS Horiz. (d) Two.

Comparative assessment of global irradiation from a satellite estimate model (CM SAF) and on-ground measurements (SIAR): A Spanish case study

F. Antonanzas-Torres [a,*], F. Cañizares [b], O. Perpiñán [c,d]

[a] EDMANS Group, University of La Rioja, Logroño, Spain
[b] SOLUTE Ingenieros. Avda. Cerro del Águila 3, 28703 San Sebastián de los Reyes, Spain
[c] Electrical Engineering Department, EUIT-UPM, Ronda de Valencia 3, 28012 Madrid, Spain
[d] Instituto de Energía Solar, Ciudad Universitaria s/n, Madrid, Spain

Renewable and Sustainable Energy Reviews 21 (2013) 248–261

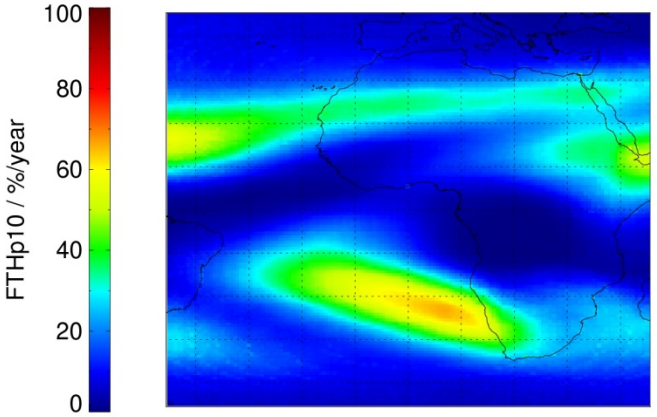
alysis

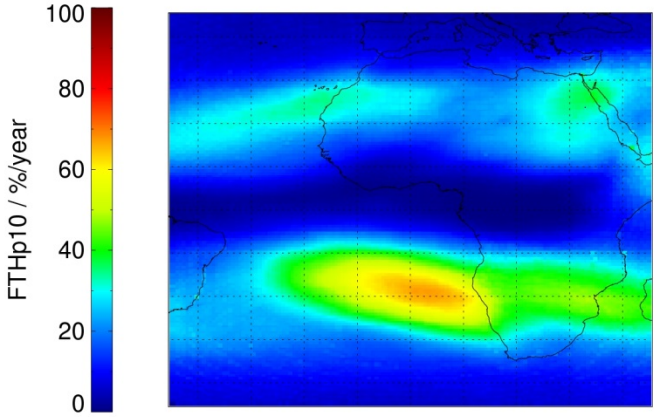
FTH: Application / Analysis

Solar Energy

- FTHp10: Frequency of occurrence of FTH<10%

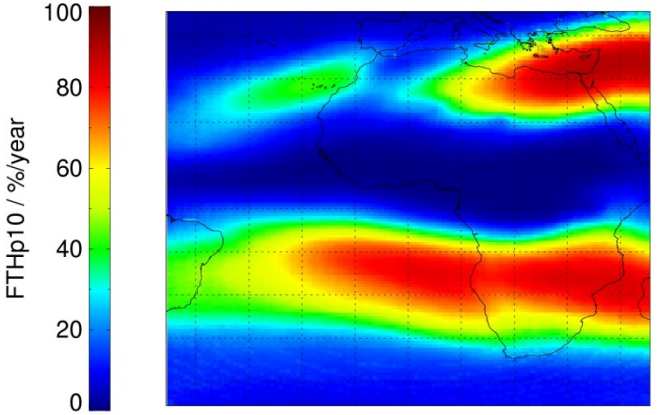
DJF

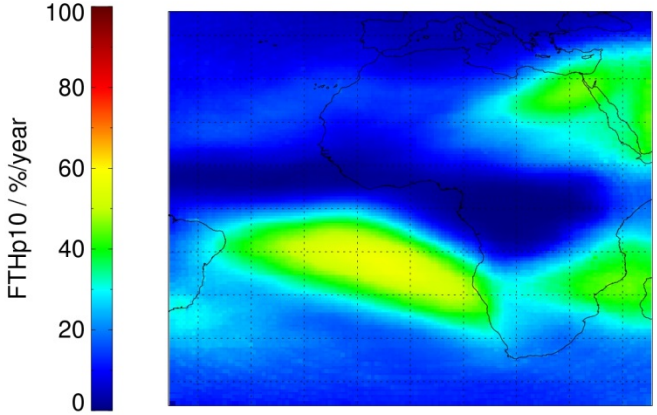




MAM

JJA





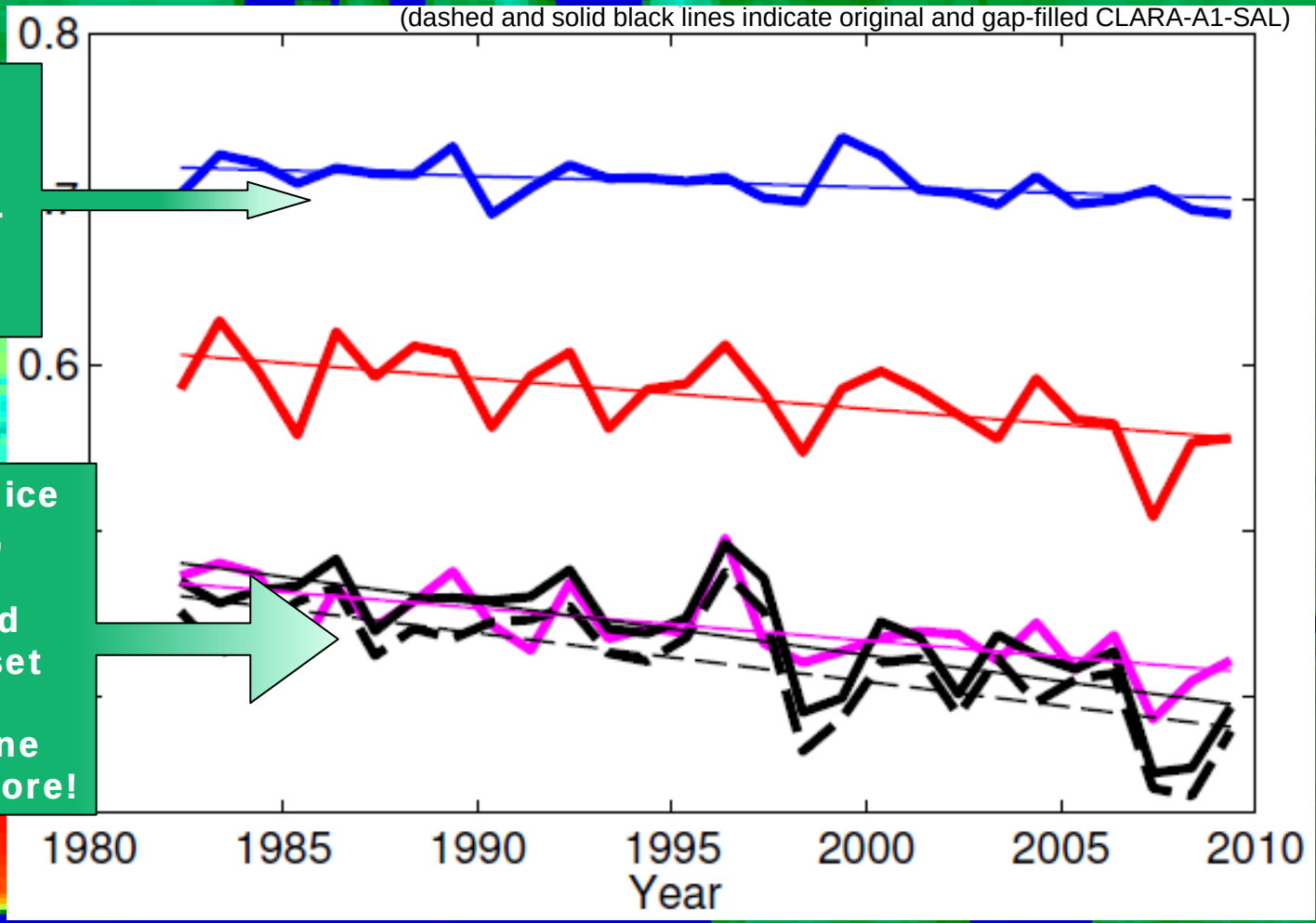
SON

Trends in the albedo (DHR) of remaining Arctic sea ice

(dashed and solid black lines indicate original and gap-filled CLARA-A1-SAL)

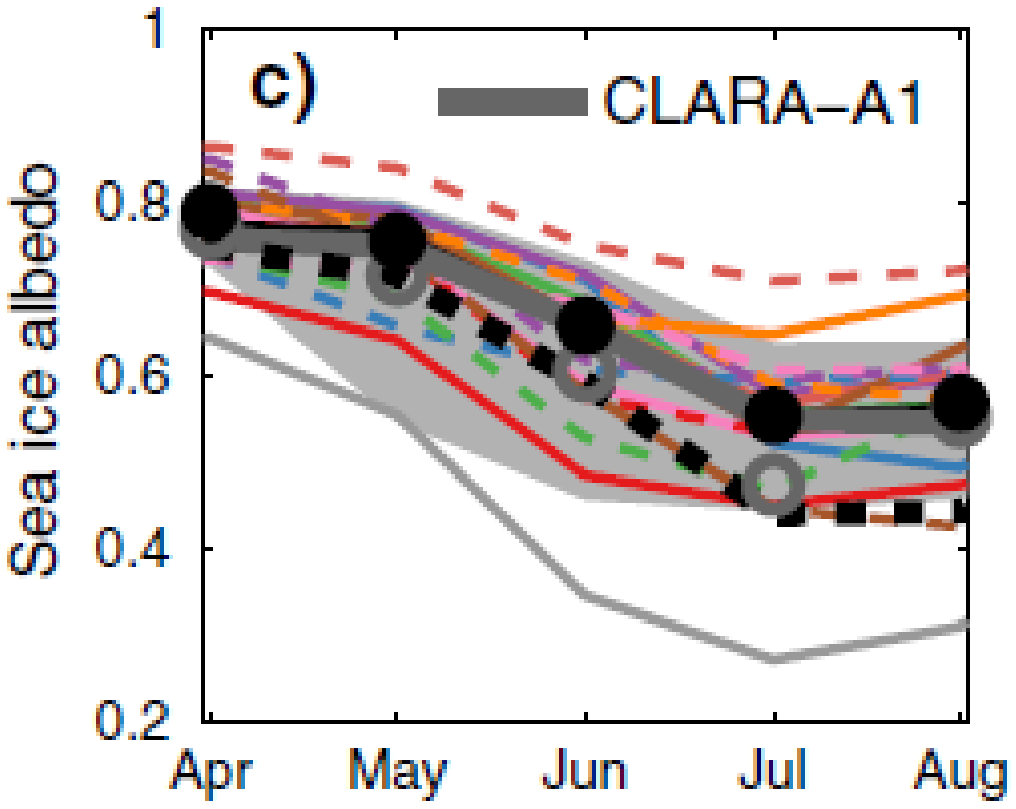
Sea ice / snow cover albedo resets during the cold winter period → no trend!

Late-summer sea ice albedo decreases, possibly with accelerating speed through the dataset → the remaining August sea ice zone is darker than before!



Riihelä, A., Manninen, T., and Laine, V., 2013: Observed changes in the albedo of the Arctic sea-ice zone for the period 1982–2009, Nature Climate Change, doi:10.1038/nclimate1963

Supporting climate model development: Comparing CLARA-A1-SAL with CMIP5 sea ice albedo parameterizations



CMIP5 ensemble mean of sea ice albedo agrees with CLARA-A1-SAL, but individual models have a wide range of variability

Karlsson, J., and G. Svensson (2013), Consequences of poor representation of Arctic sea-ice albedo and cloud-radiation interactions in the CMIP5 model ensemble, *Geophys. Res. Lett.*, *40*, doi:10.1002/grl.50768.

Satellite Energy

Regional Climate Monitoring

Arctic Sea Ice

CMIP5 evaluation

Trend assessments

Climate model evaluation

NWP model evaluation

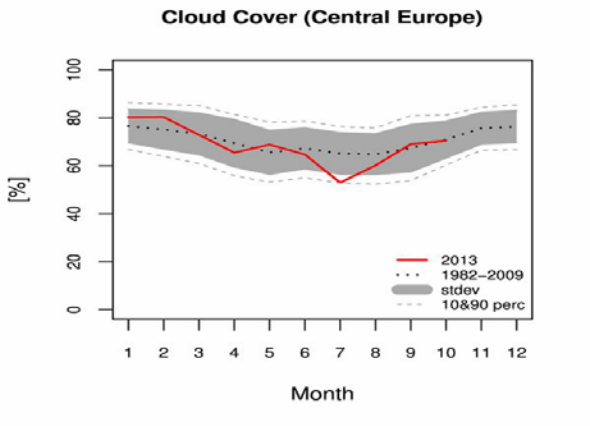
Reanalysis

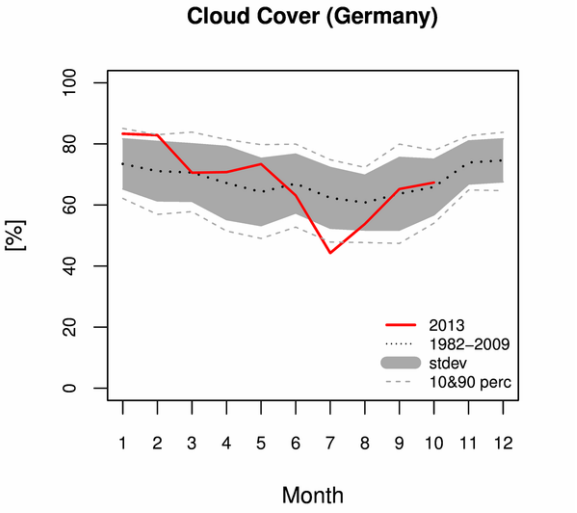
Use of CM SAF Data in climate monitoring activities

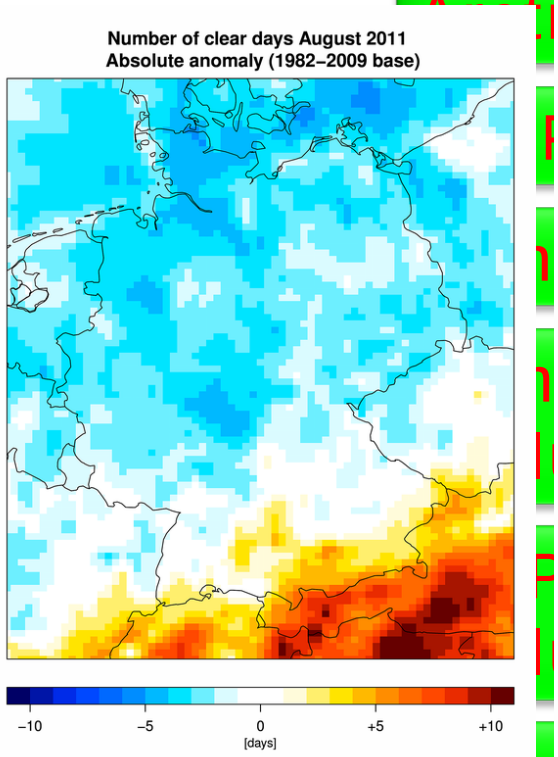
Solar Energy

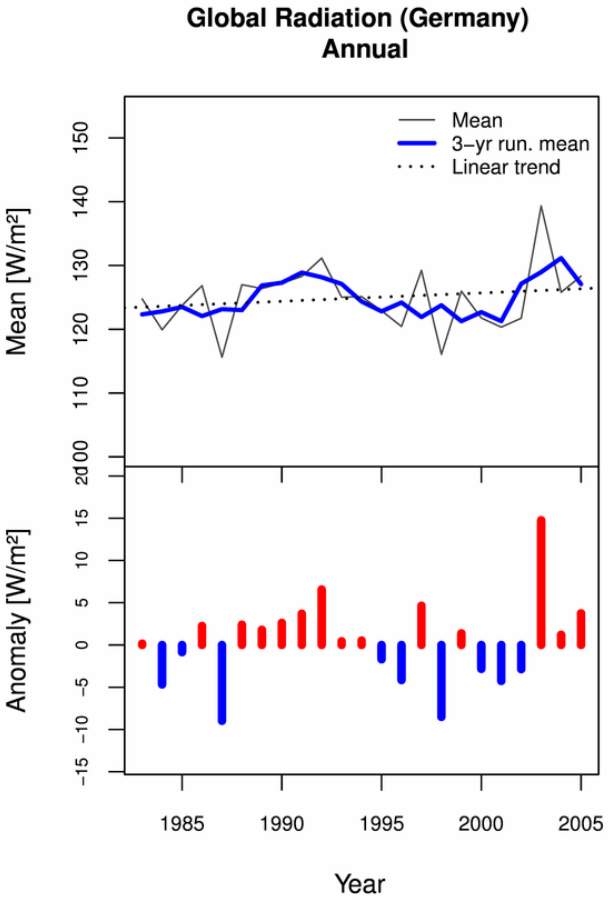
Regional Climate Mon

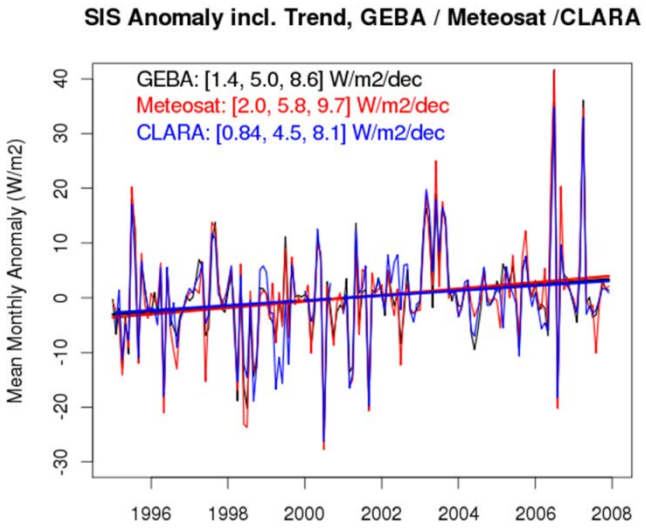
Climate Analysis

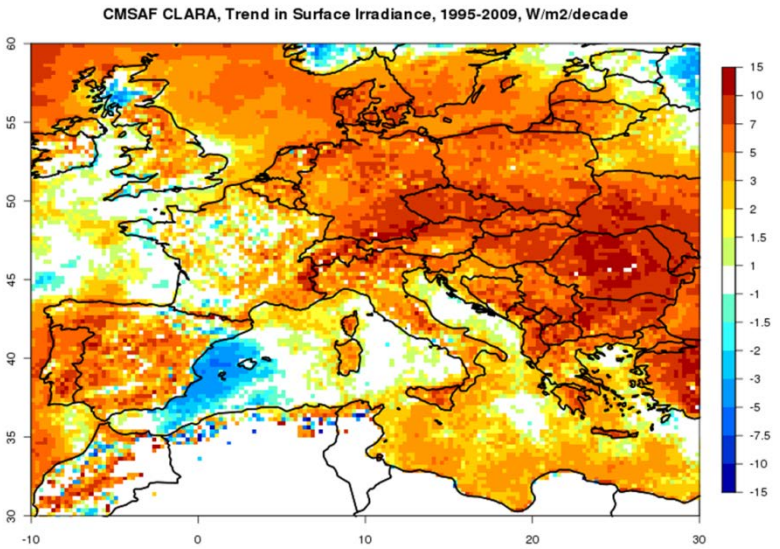












- **The CM SAF Solar Surface radiation data set are homogeneous after 1994.**
- **The spatial distribution of the trends derived from the Meteosat and the CLARA data set is comparable**
- **Brightening in Europe (1994 to 2010) likely not caused by changes in aerosol.**

Climate model evaluation

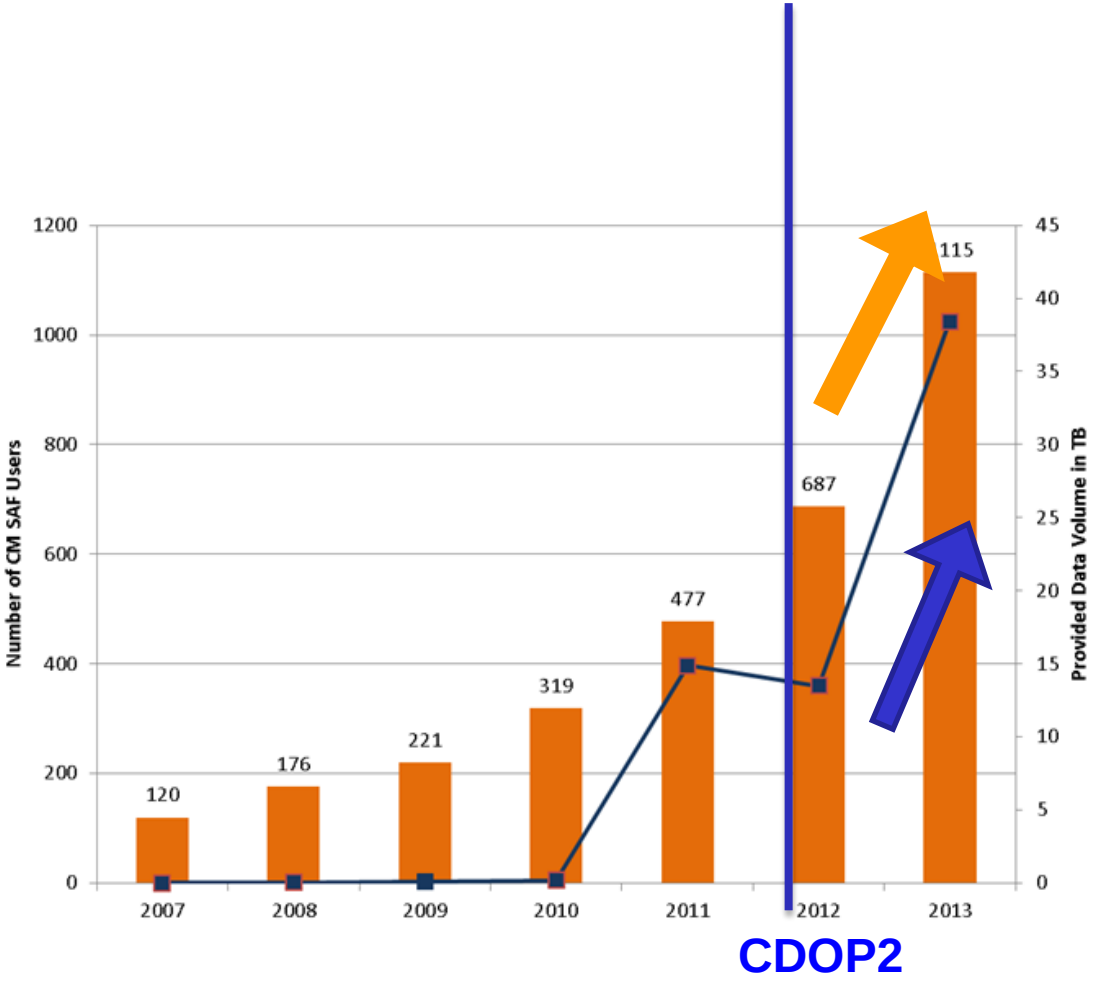
NWP model evaluation

Climate Analysis

Sanchez-Lorenzo et al. 2013

User support, training activities and outreach

- **User statistics**



With public release and availability of CDR's from CM SAF:

Strong increase in Users

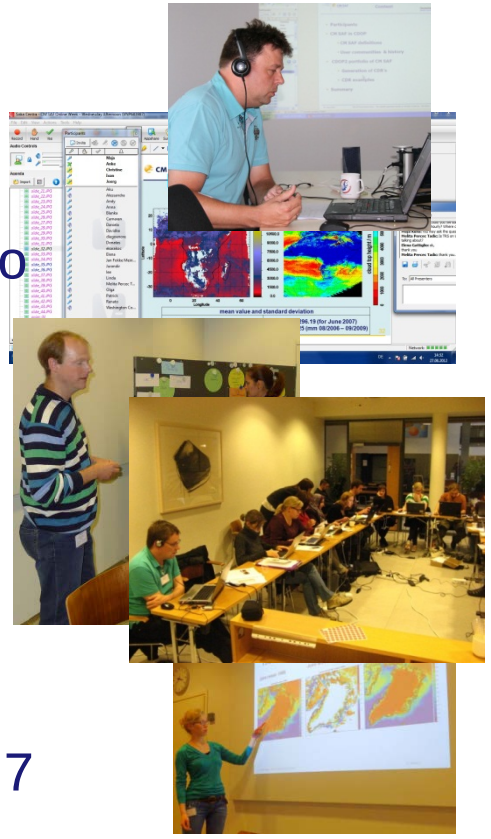
Strong increase in data volume provided

User support, training activities and outreach

Aim of CM SAF training activities is

- **to improve** the **visibility** of its products
- **to provide** more **background information** and **practical assistance** to its users.

Since 2006 annual workshops have been conducted, which nowadays have been developed to **blended learning courses**, combining an online phase and a classroom phase. ~200 participants

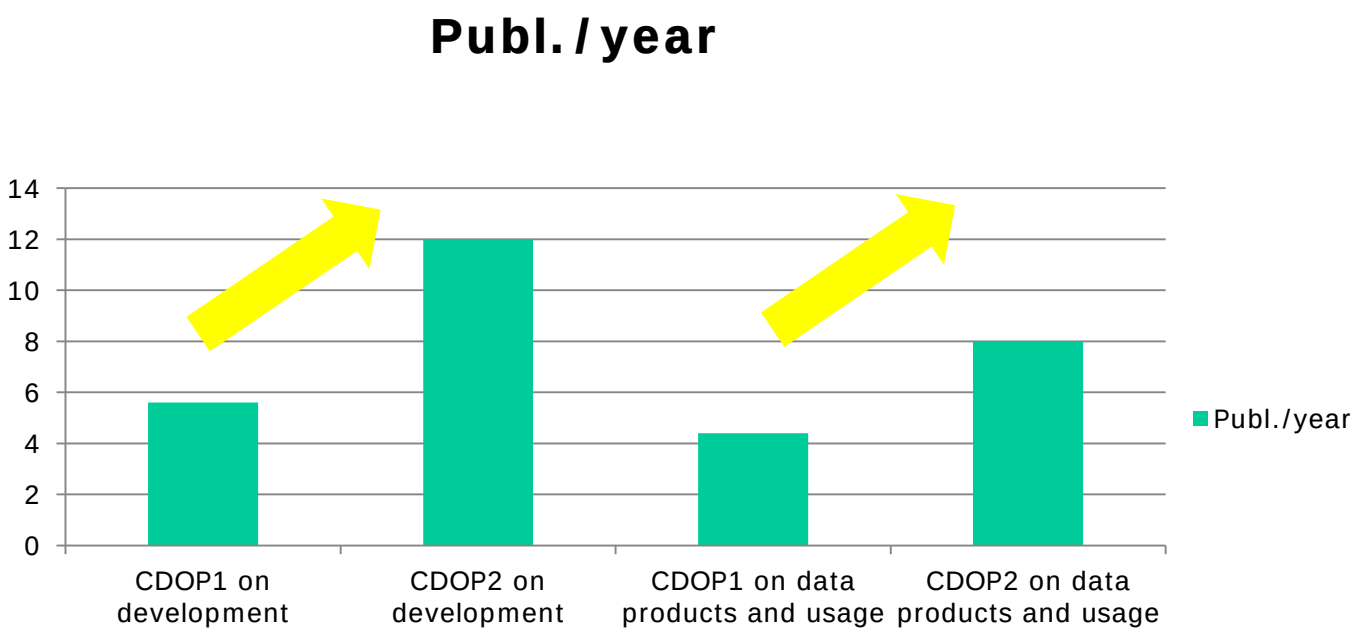


To intensify the dialogue with and among CM SAF users a community site:

http://training.eumetsat.int/enrol/index.php?id=147

User support, training activities and outreach

Outreach: Number of scientific publications



Strong increase visible… earning the fruit‘s

B. Dürr, M. Schröder, R. Stöckli, and R. Posselt, 2013: HelioFTH: Combining cloud index principles and aggregated rating for cloud masking using infrared observations from geostationary satellites. *Atmos. Meas. Tech.*, **6**, 1883-1901, www.atmos-meas-tech.net/6/1883/2013/ doi:10.5194/amt-6-1883-2013.

Bumke, K., Fennig, K., Strehz, A., Mecking, R. and Schröder, M. (2012) HOAPS precipitation validation with ship-borne rain gauge measurements over the Baltic Sea, *Tellus A*, **64**, DOI 10.3402/tellusa.v64i0.18486.

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Laine V., Manninen T., Riihelä, A., 2014: High temporal resolution estimations of the Arctic sea ice albedo during the melting and refreezing periods of the years 2003-2011, Remote Sensing of Environment, 140, 604-613, http://dx.doi.org/10.1016/j.rse.2013.10.001.

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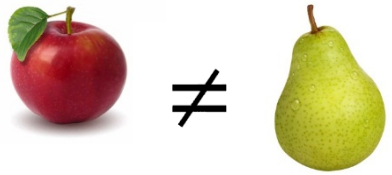
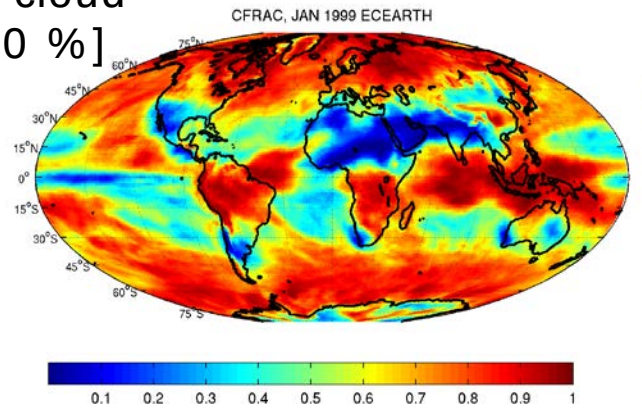
Kottayil, A., S. A. Buehler, V. O. John, L. M. Miloshevich, M. Milz, and G. Holl (2012), On the importance of Vaisala RS92 radiosonde humidity corrections for a better agreement between measured extreme satellite radiances, *J. Atmos. Oceanic Technol.*, **29**, 248–259, doi:10.1175/JTECH-D-11-00080.1

Research activities

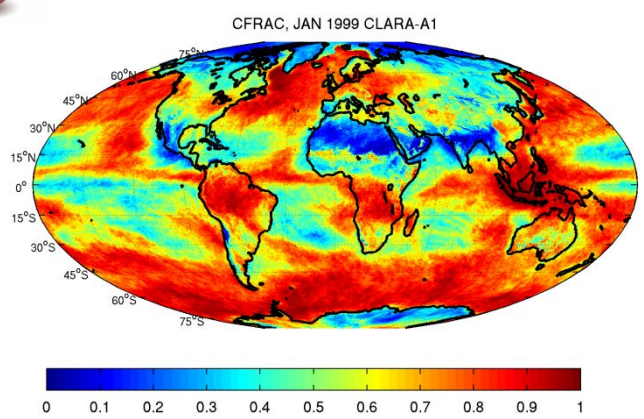
- **Cloud Simulator:** to bridge the gap between usability, coherency and consistency between satellite observations and model output!



EC-EARTH cloud cover [69.0 %]

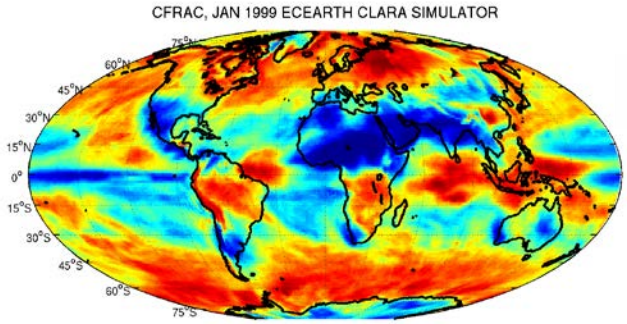


CLARA-A1 [60.9 %]



Class.

With simulator

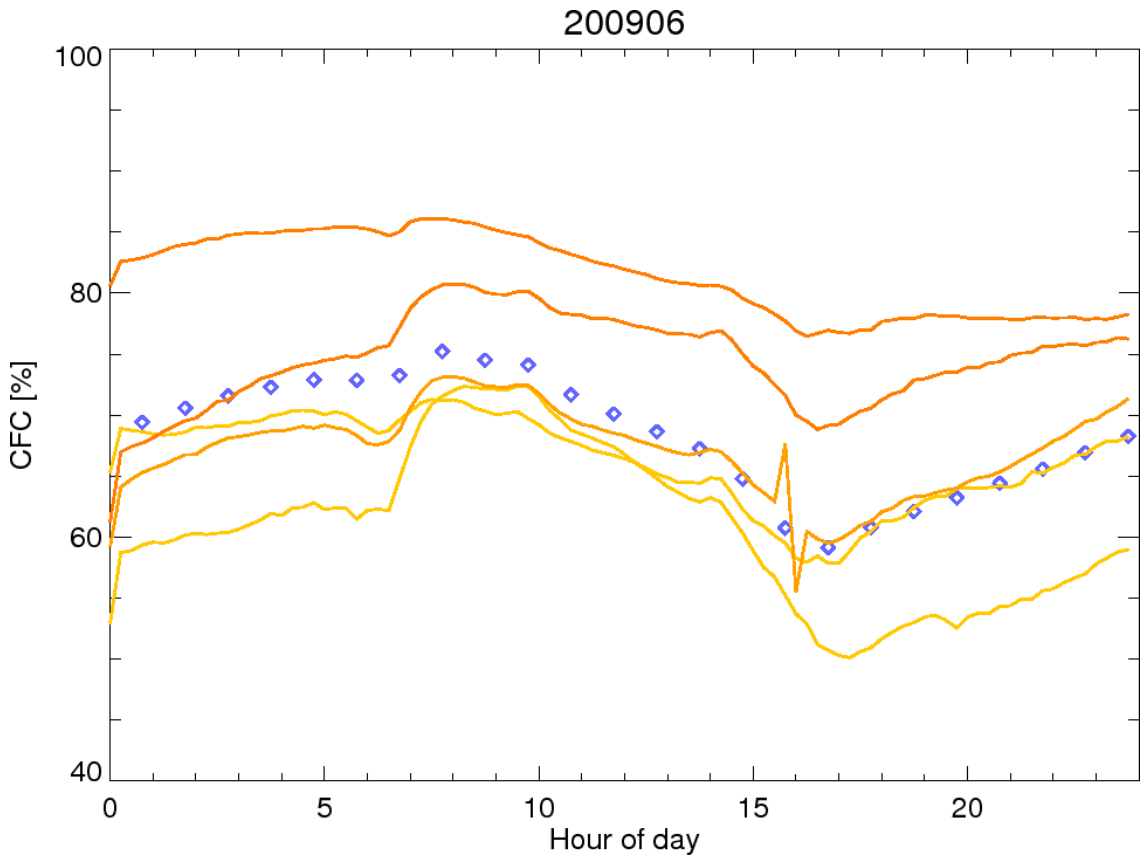


Difference reduced to 2.5 % after applying simulator

International relations

- CM SAF participates in several SCOPE-CM projects (e.g. advancing the FCDR AVHRR)
- CM SAF is closely connected with ESA CCI (Cloud_cci)
- Several EU-projects (e.g. EURO4M, Charme, UERRA)
- CM SAF supports the CORE-climax Project
- CM SAF collaborates with WCRP, CLIVAR, GEWEX in various way
- Several Inter-SAF activities take place (e.g. CPP for PPS, FA on Cloud cover for LSA SAF / OSI SAF

Joint Inter-SAF activity on 15 min cloud mask



Diurnal cycle for cloud fraction off the coast of Namibia and Angola

blue diamonds: monthly mean diurnal cycle of CLAAS (hrly)

colored: 5 individual diurnal cycles of June 2009 (15')

For the OSI SAF and LSA SAF SEVIRI Reproc. Actitvities, CM SAF produces a time-series of SEVIRI cloud mask with 15 minutes temporal resolution and on original SEVIRI pixel size (2004-2012).

To have consistent Climate data sets between LSA, OSI, and CM SAF

International relations

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- Several Inter-SAF activities take place (e.g. CPP for PPS, FA on Cloud cover for LSA SAF / OSI SAF
- **CM SAF is co-leading the GEWEX Water Vapour Assessment**

GEWEX water vapour assessment: G-VAP

- **Overall scope:**
  - **Quantify the state of the art in water vapour products being constructed for climate applications, and by this;**
  - **Support for the selection process of suitable water vapour products by GDAP for its production of globally consistent water and energy cycle products.**

- **Main approach: consistent inter-comparison and comparison to ground-based and in-situ observations, providing comparable evaluation results with focus on troposphere, profiles and stability/variability. No ranking!**

- **Candidate satellite data records (to be evaluated): 36 (23)**
- **Candidate data records (for evaluation): 32**
- **The collection of meta data is done online through data fact sheets DFS. When filled they will be made available at www.gewex-vap.org.**

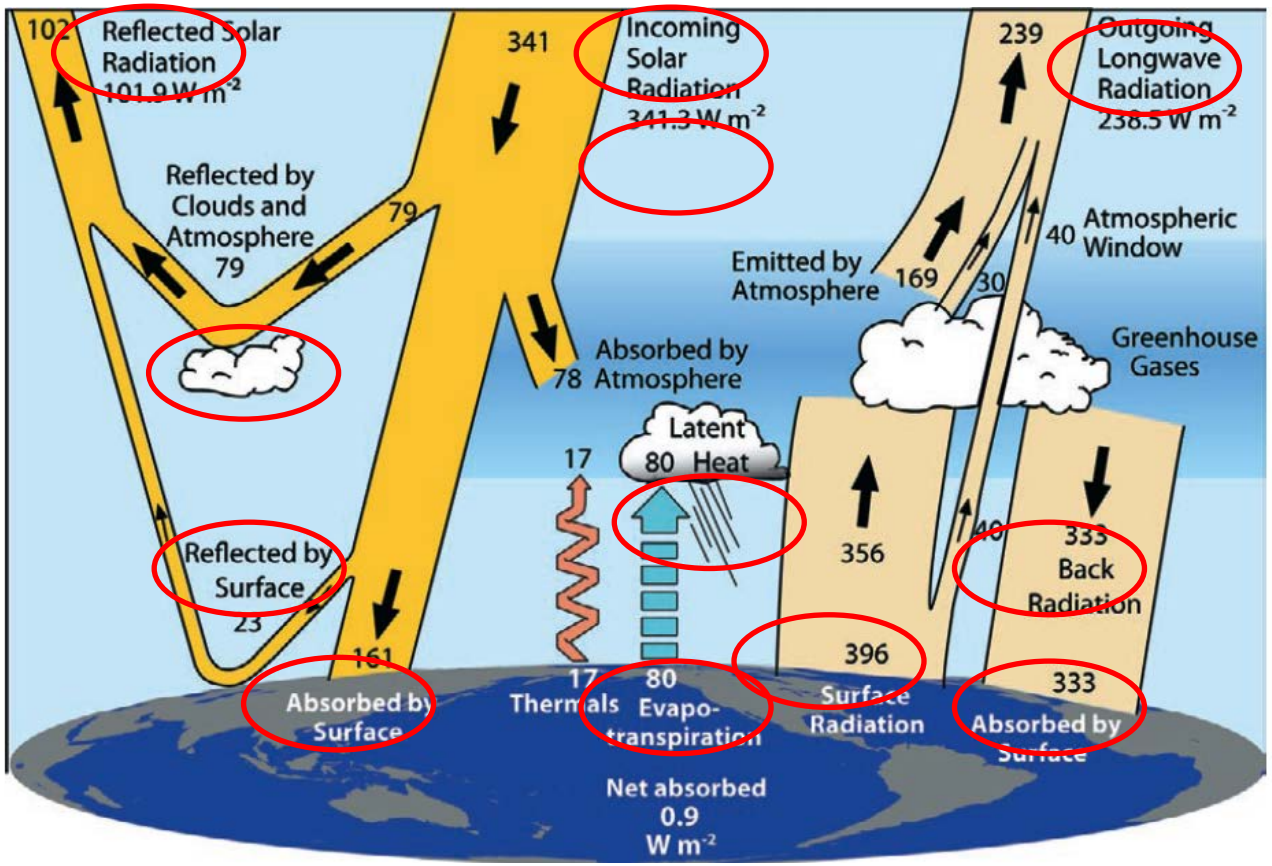
- **Considered ECVs: Total column water vapour (TCWV), upper tropospheric humidity (UTH), tropospheric temperature and water vapour profiles (WV).**

Summary

- **CM SAF** exploits and provides satellite based remote sensing data to derive CDR for ECVs with special emphasis on three target user groups
  - **Global and regional climate trends and variability analysis**
  - **Support to global and regional climate modelling**
  - **Climate service and infrastructure planning**

- **This is achieved through**
  - Application of highest standards and guidelines as lined out by GCOS for the satellite data processing
  - Processing of satellite data within a true international collaboration benefiting from developments at international level and pollinating the partnership with own ideas and standards
  - Intensive validation and improvement of the CM SAF climate data records
  - Taking a major role in data set assessments performed by e.g. WCRP
  - Maintaining and providing an operational and sustained infrastructure that can serve the community

Global Cycle of Water and Energy



Simple concepts have developed to

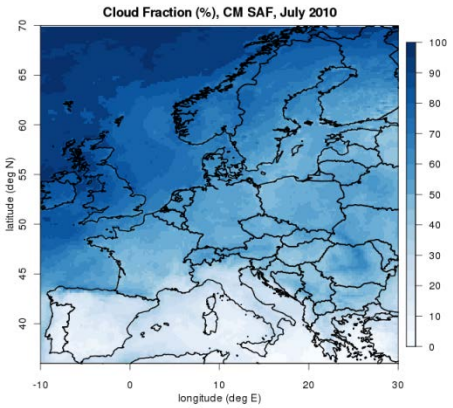
Quantitative estimate based on modelling exercises

CM SAFs Climate data set cover almost all of them and support our understanding of the climate.

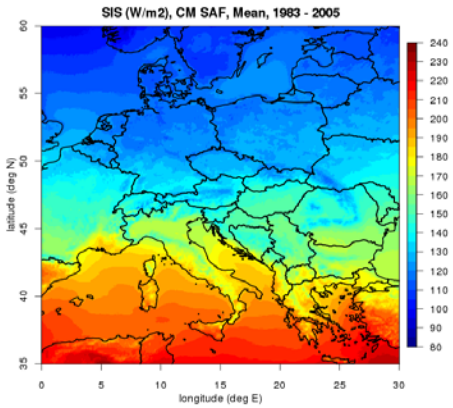
Figure from Trenberth et al. (2009)

Thank you

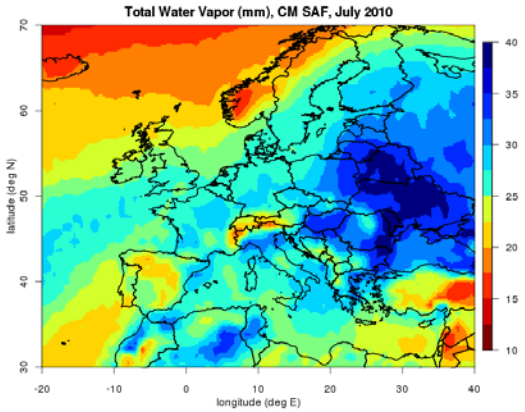
Clouds



Radiation



Water Vapor



- *EUMETSAT Satellite Application Facility on Climate Monitoring* www.cmsaf.eu
- Provides satellite-derived climate data of geophysical variables
- Regional, up to global coverage
- Currently, data available from Jan 1982 to Mar 2013
- Spatial resolution from 0.03° to approx. 1°

- Data freely available in netcdf-format
- User-friendly data access via the Web User Interface: www.cmsaf.eu/wui
- Toolkit (example data + software): www.cmsaf.eu/tools
- CM SAF Community Site available via EUMETSAT: training.eumetsat.int