



Access to satellite-based products

Jędrzej S. Bojanowski

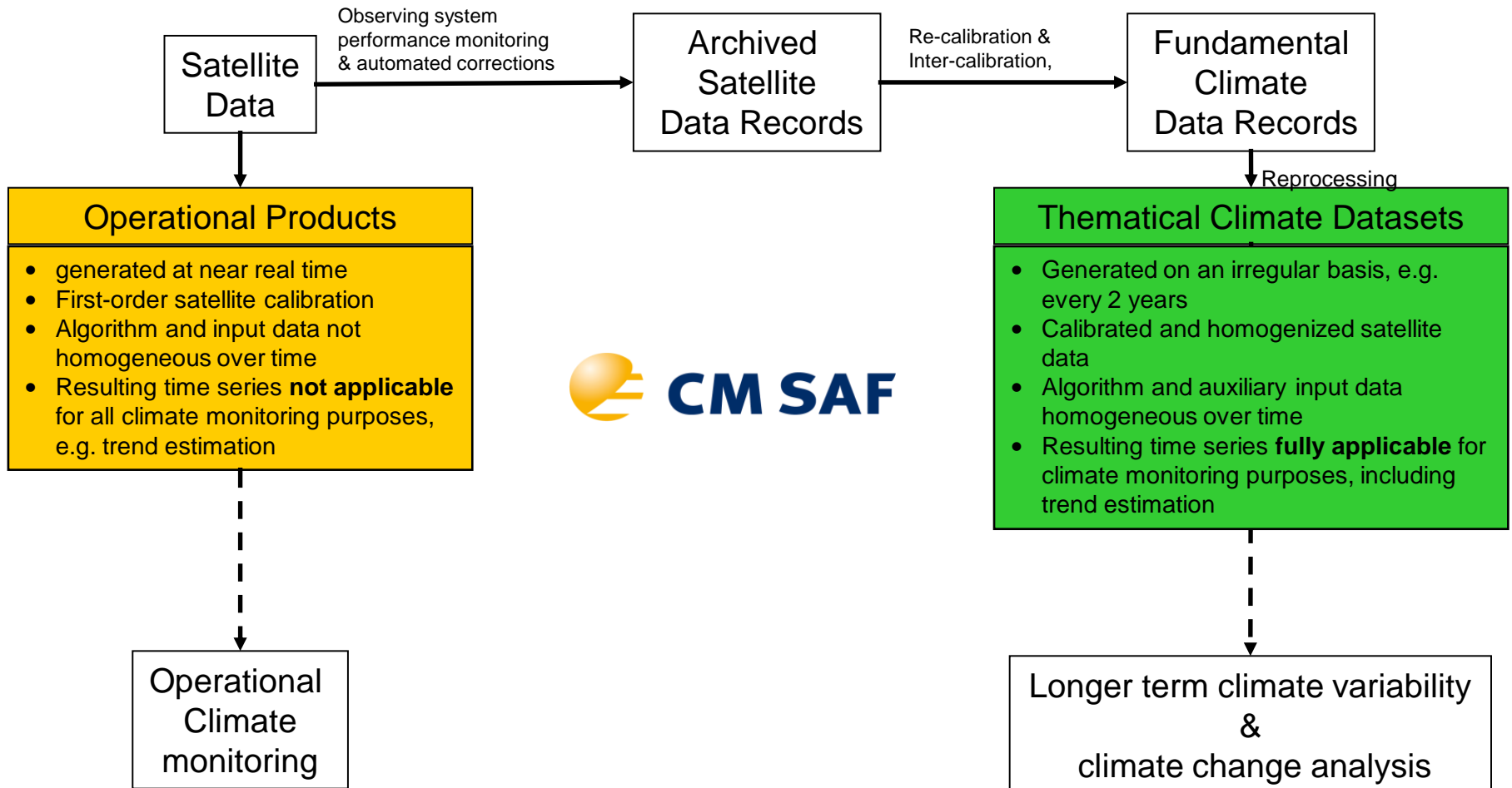
Remote Sensing Centre, Institute of Geodesy and Cartography, Warsaw, Poland



Operational vs climate data

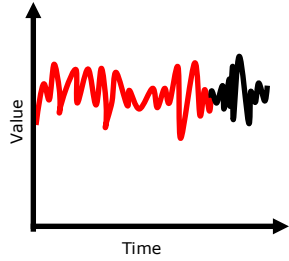
Short and Intermediate Term

Longterm

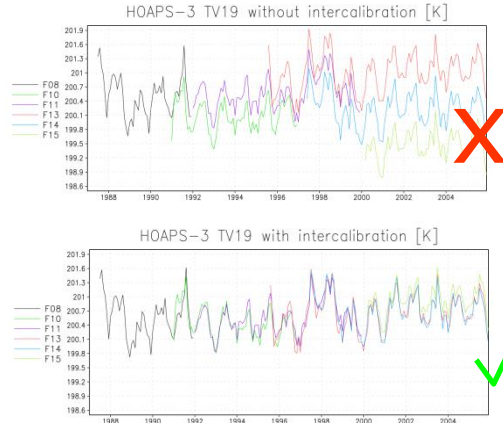




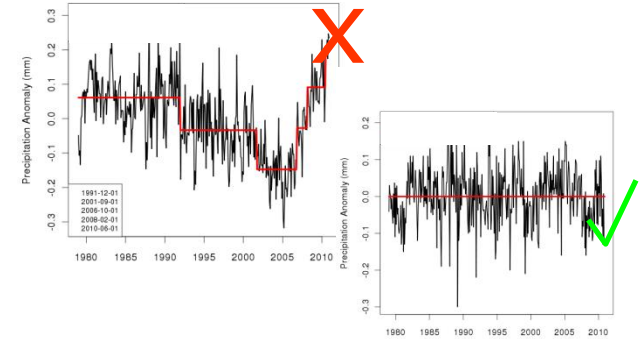
Requirements for climate data



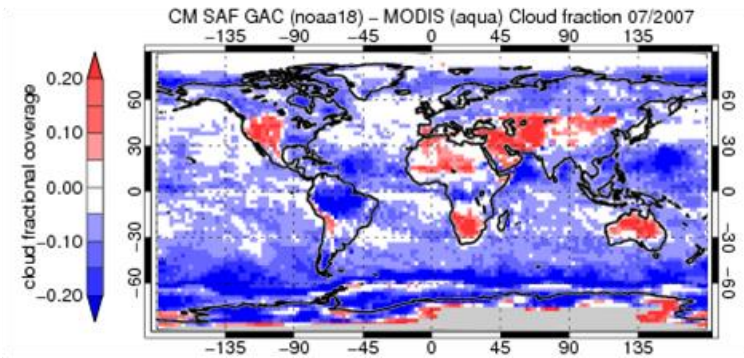
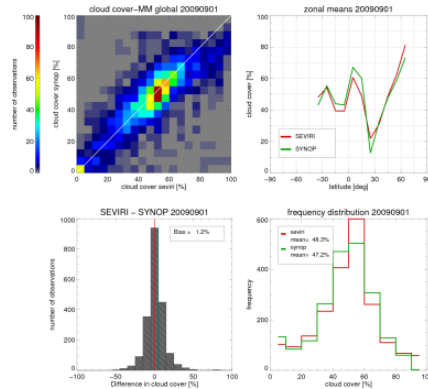
Sufficiently long time series



Calibrated

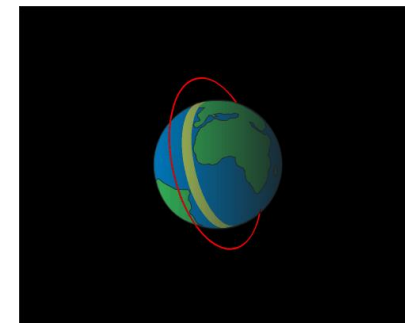


Homogeneous

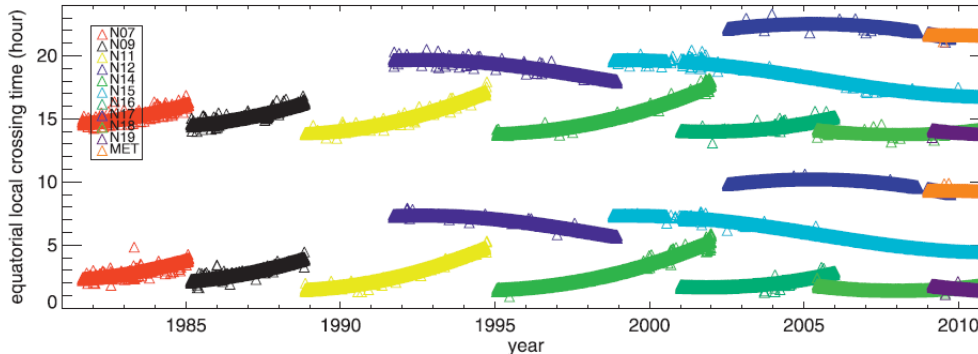


Quality controled

Satellite orbital drift



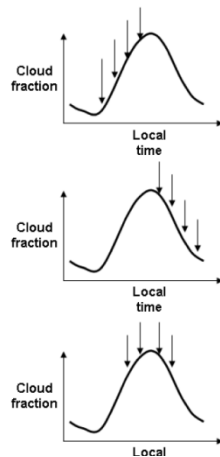
Polar-orbiting



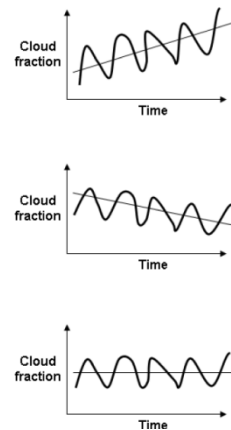
(Foster and Heidinger, 2013)

- Varying number of satellite observations per day
- Varying local time of observations among sensors
- Satellite orbital drift changing local time of image acquisition

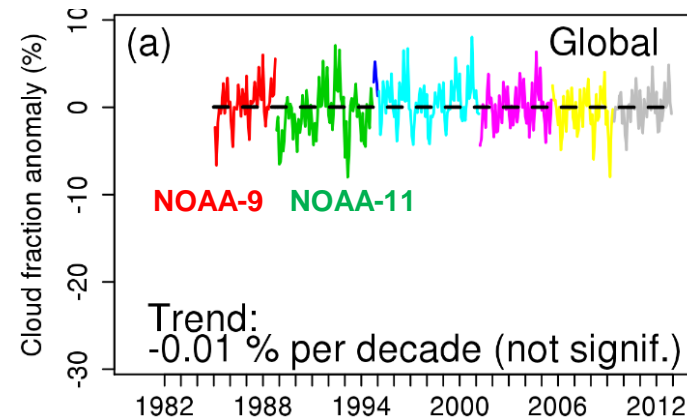
Inconsistent sampling of diurnal cycle of convection



Potential spurious trends in the time-series



(Devasthale et al, 2012)



(Bojanowski et al. 2016)

Requirements for L2/L3 data formats

- handling of various information provided by satellite data, reanalysis or model data
- optimise computing performance
- reduce disk space
- storage of the data in space-time domain
- different data layers
- meta-information, e.g.
 - calibration coefficients
 - geolocation and projection
 - uncertainty
 - gain and offset
 - etc.



HDF: Hierarchical data format
netCDF: network Common Data Form

HDF: Hierarchical Data Format

- general purpose library and file format for storing scientific data
- create and store almost any kind of scientific data structure, e.g. images, arrays of vectors, structured and unstructured grids, etc
- ...can also mix and match different data formats
- efficient storage and computing performance
- created to address the data management needs of high performance, data intensive computing environments, especially on parallel machines

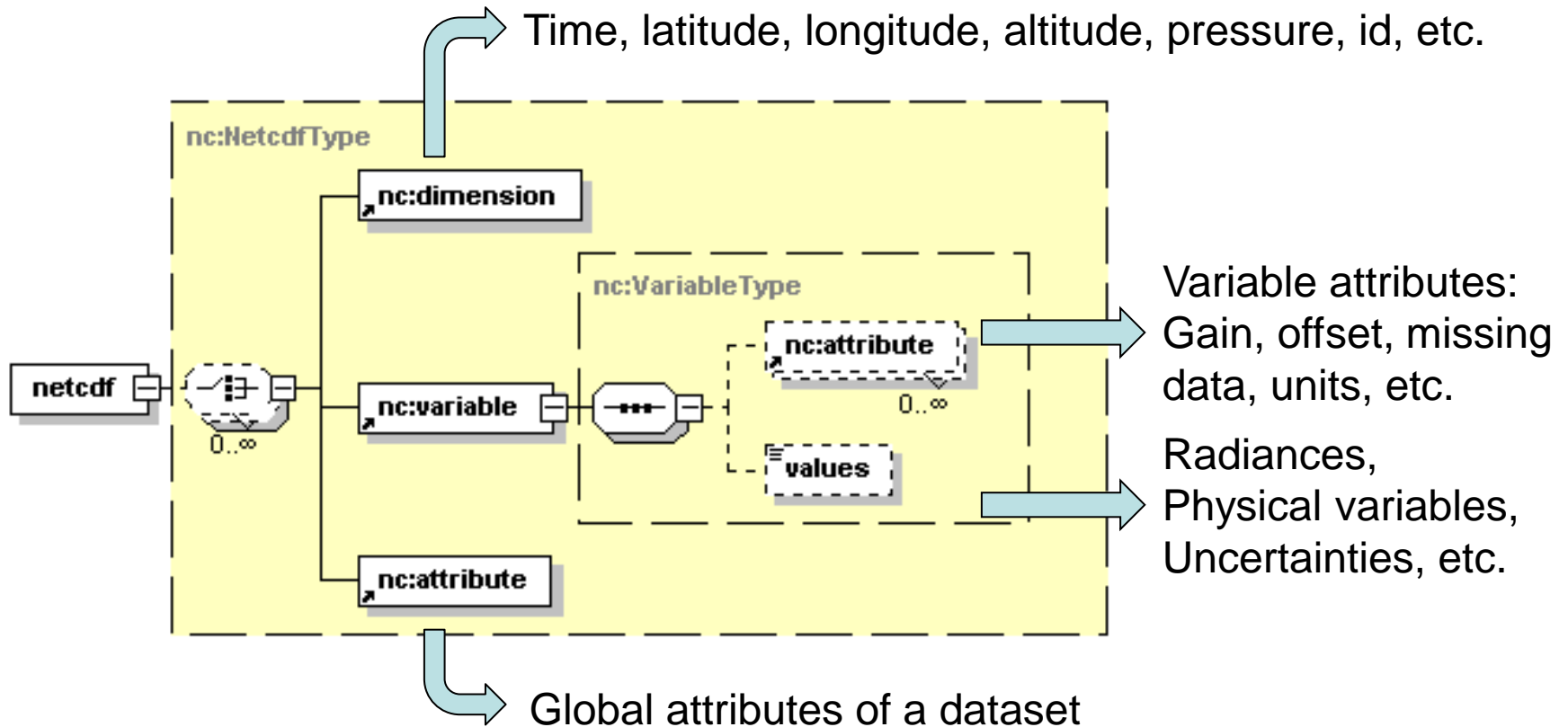
Used by: NASA (e.g. MODIS), NOAA, etc.

netCDF: network Common Data Form

- Information, tools, examples and the netCDF library are available at:
<https://www.unidata.ucar.edu/software/netcdf/>
- Self-Describing: A netCDF file includes information about the data it contains.
- Portable: Win, UNIX, MacOS
- **Direct-access: A small subset of a large dataset may be accessed efficiently, without first reading through all the preceding data.**
- Appendable: Data may be appended to a properly structured netCDF file without copying the dataset or redefining its structure.
- Sharable: One writer and multiple readers may simultaneously access the same netCDF file.

Used by: Reanalysis data of National Centers for Environmental prediction (NCEP) and European Centre for Medium Weather forecast (ERA-Interim), EUMATESAT SAF's, ESA Climate Change Initiative

netCDF: network Common Data Form





Software

ANDX (ARM NetCDF Data eXtract))	HDF (Hierarchical Data Format) interface	ncregrid	Weather and Climate Toolkit (WCT)
ANTS (ARM NetCDF Tool Suite)	HDF-EOS to netCDF converter	nctoolbox (a MATLAB common data model interface)	WebWinds
ARGOS (interActive thRee-dimensional Graphics ObServatory)	HIPHOP (Handy IDL-Program for HDF-Output Plotting)	ncview	xray (Python N-D labelled arrays)
CDAT (Climate Data Analysis Tool)	HOPS (Hyperslab OPERator Suite)	ncvtk	Zebra
CDFconvert (Convert netCDF to RPN and GEMPAK Grids)	iCDF (imports chromatographic netCDF data into MATLAB)	netcdf tools	ArcGIS Pro - Space Time Pattern Mining Toolbox
cdsync (network synchronization of netCDF files)	IDV (Integrated Data Viewer)	netcdf4excel (add-in for MS Excel)	ASA ViewNcDap
CDO (Climate Data Operators)	Ingrid	NetCDF95 alternative Fortran API	Avizo
CIDS Tools	Intel Array Visualizer	Objective-C interface	AVS
CSIRO MATLAB/netCDF interface	IVE (Interactive Visualization Environment)	Octave interface	Barrodale UFI
EPIC	JSON format with the ncdump-json utility	Octave interface (Barth)	DioVISTA/Storm
Excel Use	Java interface	OPeNDAP (formerly DODS)	EnSight
EzGet	Kst (2D plotting tool)	OpenDX (formerly IBM Data Explorer)	Environmental WorkBench
FAN (File Array Notation)	Labview interface	Panoply	ESRI
FERRET	MBDyn (MultiBody Dynamics)	Parallel-NetCDF	FME
FIMEX (File Interpolation, Manipulation, and EXtraction)	Max_diff_nc	Paraview and vtkCSCSNetCDF	HDF Explorer
FWTools (GIS Binary Kit for Windows and Linux)	MeteoExplorer	Perl interfaces	IDL Interface
GDAL (Geospatial Data Abstraction Library)	MeteoInfo	PolyPaint+	InterFormat
GDL (GNU Data Language)	MexEPS (MATLAB interface)	Pomegranate	IRIS Explorer Module
Gfdnavi (Geophysical fluid data navigator)	MEXNC and SNCTOOLS (a MATLAB interface)	Pupynere (PUre PYthon NEtCDF REader)	LeoNetCDF
GMT (Generic Mapping Tools)	Mirone (Windows MATLAB-based display)	PyNGL and PyNIO	Mathematica
Grace	ncBrowse (netCDF File Browser)	Python interfaces	MATLAB
GrADS (Grid Analysis and Display System)	nccmp (netCDF compare)	QGIS (Quantum GIS)	Noesys
Gri	ncdx (netCDF for OpenDX)	R interface	Origin
GXSM - Gnome X Scanning Microscopy project	ncensemble (command line utility to do ensemble statistics)	Ruby interface	PPLUS
	NCL (NCAR Command Language)	Scientific DataSet (SDS) Library	PV-Wave
	NCO (NetCDF Operators)	Apache Spatial Information System (SIS)	Slicer Dicer
		Tcl/Tk interfaces	Surfer
		Tcl-nap (N-dimensional array processor)	vGeo
		Visual Basic and VB.net	VISAGE and Decimate
		VisAD	Voyager



Software (free)

Data visualization:

- Panoply (<https://www.giss.nasa.gov/tools/panoply/>)
- ncview
- hdfview

Data visualization and simple analysis:

- QGIS
- SNAP (<http://step.esa.int/main/toolboxes/snap/>)

Powerfull data handling

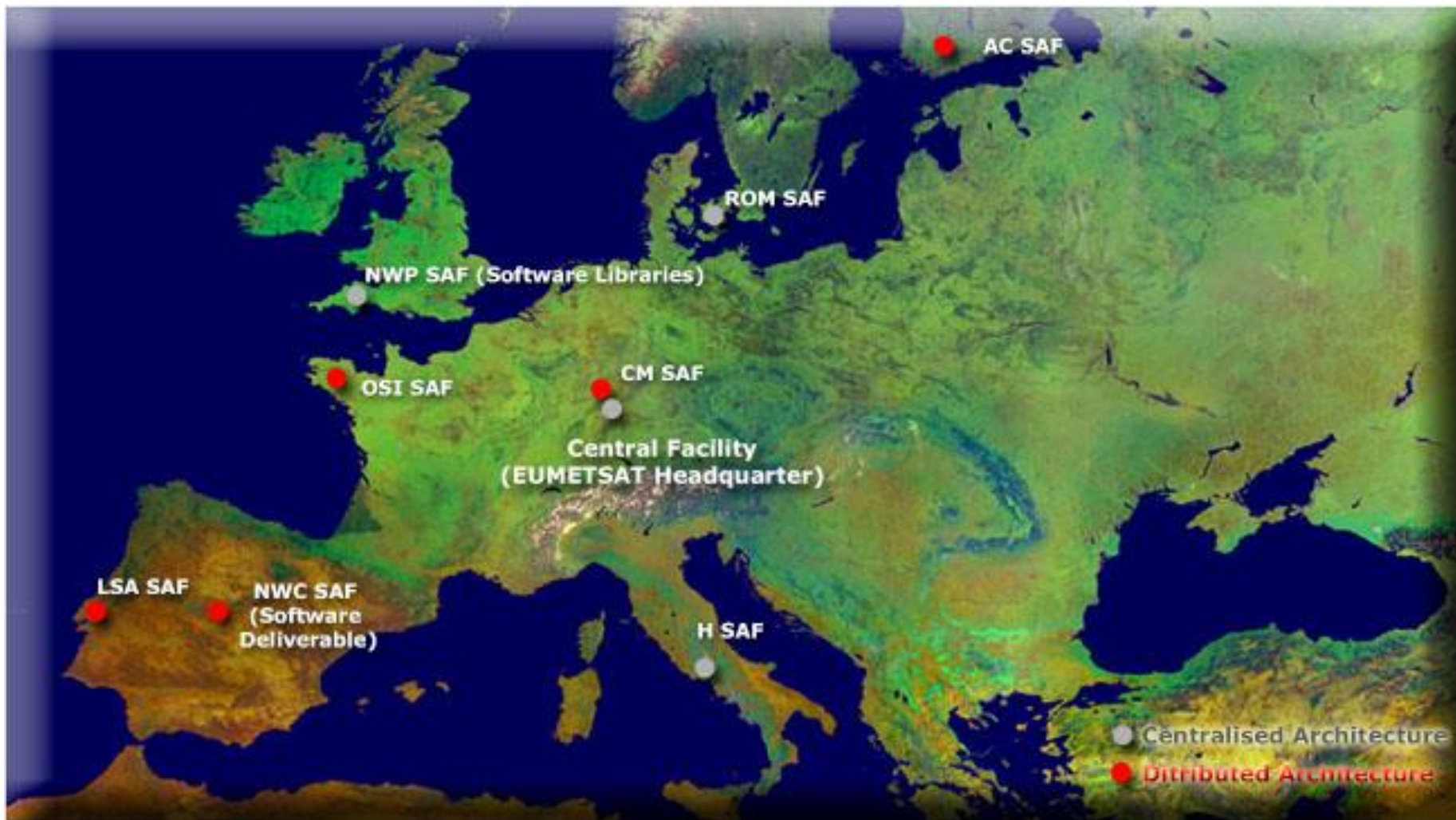
- cdo – Climate Data Operators (<https://code.mpimet.mpg.de/projects/cdo>)
- R
- Python



DATA SOURCES



EUMETSAT Satellite Application Facilities





SAF on Climate Monitoring



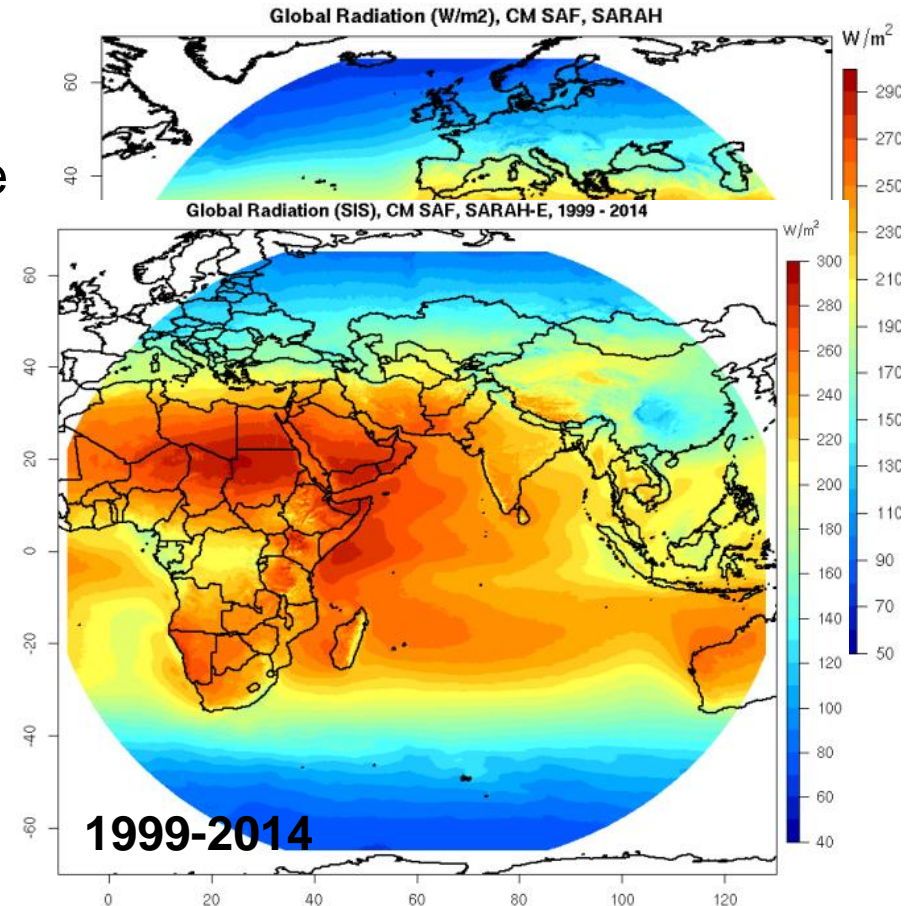
- develop, generates, archives and distributes high-quality satellite-derived products of the energy & water cycle to monitor, understand and adapt to climate variability and climate change
- provides climatologies for Essential Climate Variables (ECV), as required by the Global Climate Observing System implementation plan
- ...based on NOAA/AVHRR, Meteosat (MVIRI, SEVIRI, GERB), ATOVS
- led by: Deutscher Wetterdienst

netCDF format

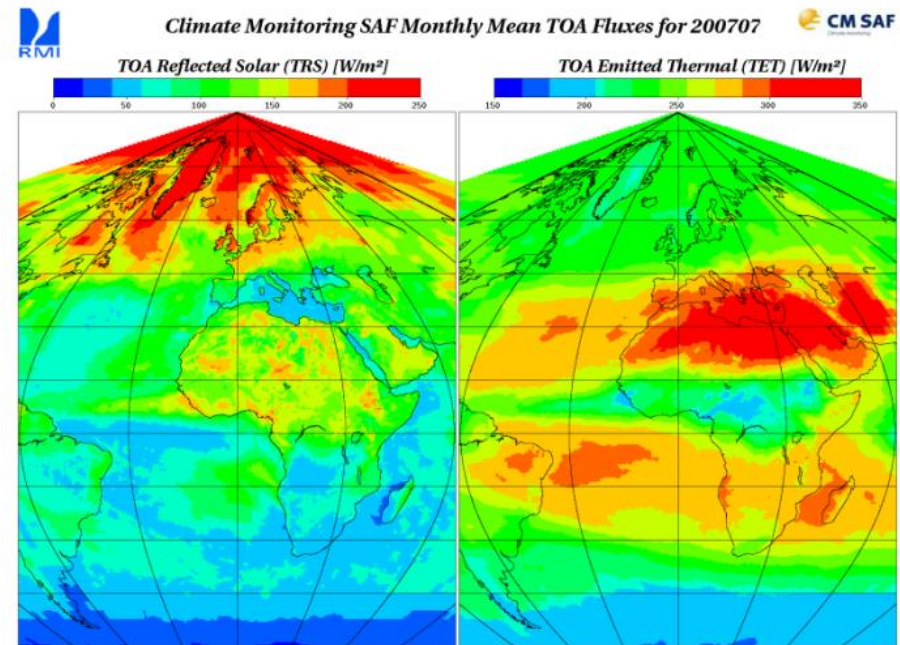
www.cmsaf.eu

The Surface Solar Radiation Data Set - Heliosat

- surface irradiance (SIS) and the effective cloud albedo (CAL)
- derived from Meteosat MVIRI and SEVIRI
- 1983-2013, $0.05^\circ \times 0.05^\circ$
- monthly, daily, and hourly averages



- TOA Reflected Solar, TOA Emitted Thermal
- diurnal cycle of the Earth radiation budget
- derived from Geostationary Earth Radiation Budget (GERB)
- 2004-2011, 45 km x 45 km
- monthly, daily, monthly mean diurnal cycle





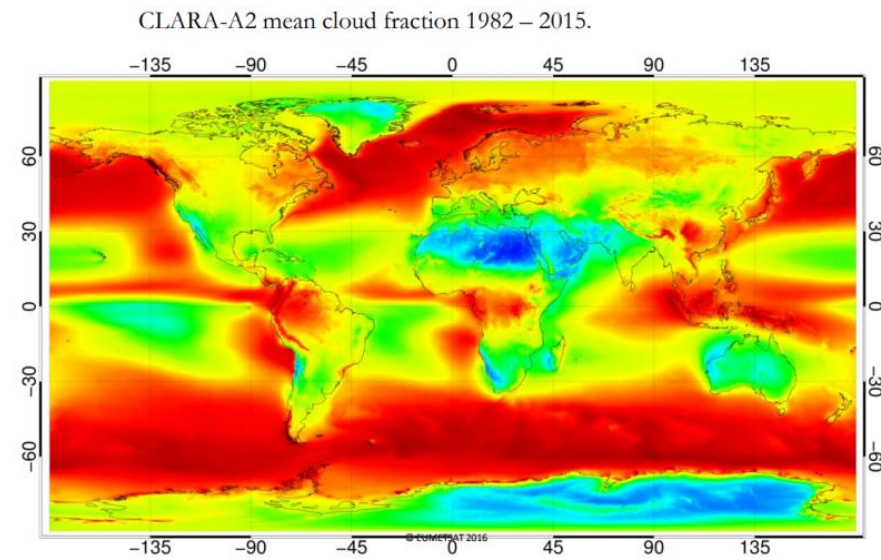
CLARA



cLoud, Albedo & RAdiation dataset

- Fractional Cloud Cover
 - Cloud Top Height, Temp, Pressure
 - Cloud Phase
 - Cloud Optical Thickness
 - Surface Albedo
 - Surface Incoming Shortwave Radiation
 - Surface Outgoing Longwave Radiation
 - Surface Downward Longwave Radiation
-
- derived from AVHRR
 - 1982-2015, 0.25 x 0.25 deg
 - monthly, daily

Szkoła letnia Poland-AOD, Warszawa, 8.07.2017
Jędrzej S. Bojanowski

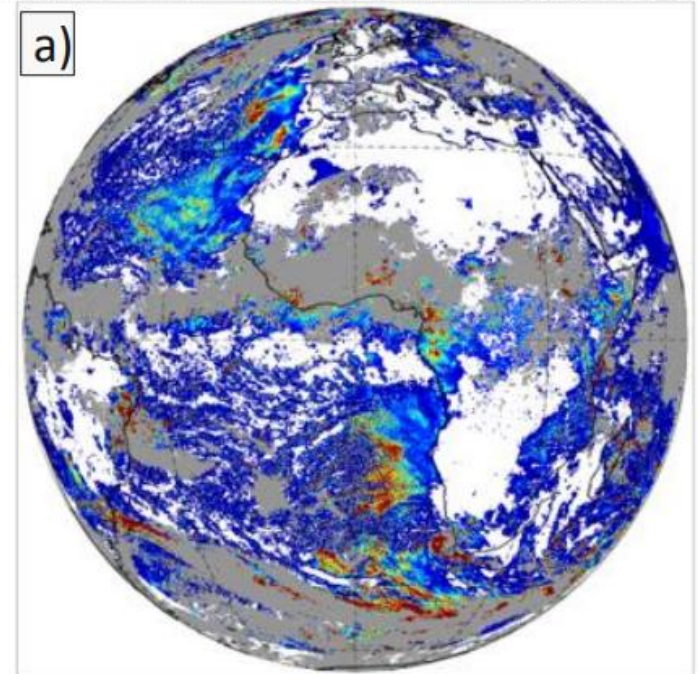


CLoud property dAtAset using SEVIRI

Fractional Cloud Cover
Clout Top Pressure, Height, Temperature
Cloud Phase
Liquid Water Path
Ice Water Path
Joint Cloud property Histogram

- derived from MSG/SEVIRI
- 2004-2015, 0.05 x 0.05 deg
- **15 minutes**, daily and monthly mean,
monthly mean diurnal cycle

CLAAS-2 LWP - Met-9/SEVIRI - 20060715_11





Atmospheric composition



Project aim: radiative transfer calculation methods and other algorithms for creating atmospheric remote sensing data from polar-orbiting satellites Metop-A and Metop-B

Global Ozone Monitoring Experiment (GOME)

- GOME-1 on ERS 1991-2011
- GOME-2 on Metop-A/B/C 2006-2024

2007-2016, 40 x 40 km, global:

- Ozone (O₃) column
- Nitrogen dioxide (NO₂) column (total and tropospheric)
- Bromide monoxide (BrO) column
- Sulphur dioxide (SO₂) column
- Water vapour (H₂O) column
- Formaldehyde (HCHO) column



Ocean and Sea Ice (OSI) SAF



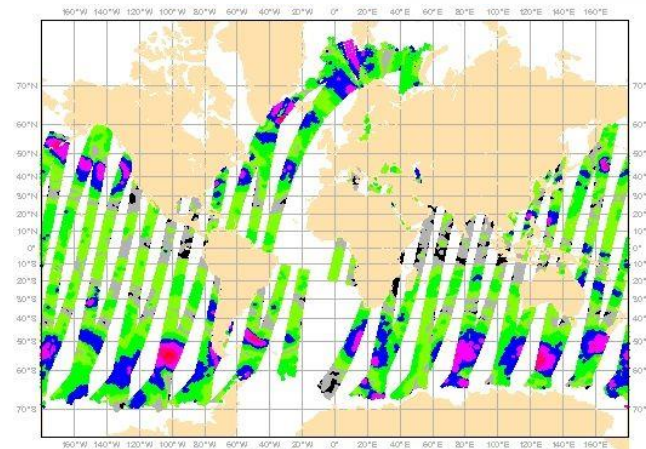
- produces and disseminates products characterising the ocean surface and the energy fluxes across the sea surface
- produces information on the sea ice characteristics (extent, concentration, ...)
- led by: Météo-France
- distributes near real-time products based on NOAA, MSG, Metop, SeaWinds, DMSP and GOES data

netCDF format (mostly)

www.osi-saf.org

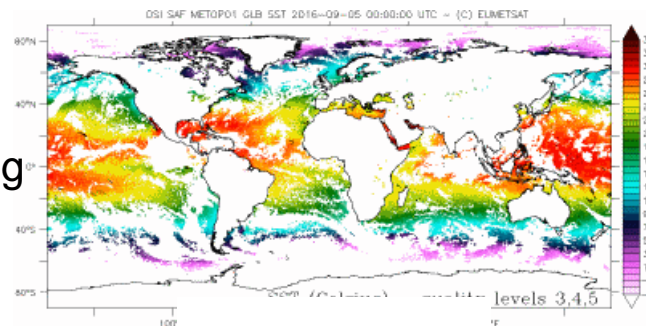
Wind speed and wind direction above the sea surface

- Operational, global, 25 km resolution, 1-5 days, from Metop/ASCAT scatterometer
- Data record 2007-2014
- Data record from QuikScat/SeaWinds, 1999-2009, global, daily, 25 km



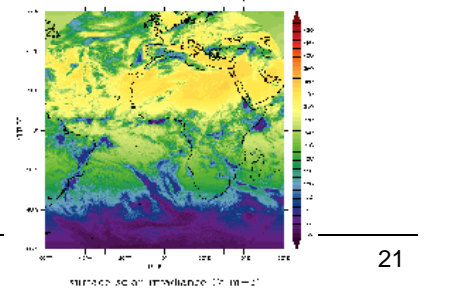
Sea surface temperature

- Operational, global, from NOAA/AVHRR, 2 per day, 0.05 deg
- Operational, Meteosat disk, hourly, 0.05 deg



Downward longwave and shortwave radiation

- Operational from MSG/SEVIRI and GOES/Imager, hourly, 0.05 deg





Aerosols:

- AOD 0.55 μm , 0.67 μm , 0.87 μm
- from ATSR-2 & AATSR
- 1995–2012, global ,10 × 10 km, daily/monthly



Clouds:

- Cloud fraction, cloud physical properties
- from AVHRR, MODIS, (A)ATSR
- 1982-2015, global ,0.05x0.05, daily/monthly



Greenhouse gases:

- column-averaged mole fractions of CO₂ and CH₄
- from ENVISAT/SCIAMACHY and GOSAT/TANSO
- 2002-2015, global ,5x5 deg, daily/monthly



The Atmospheric Science Data Center at NASA Langley Research Center



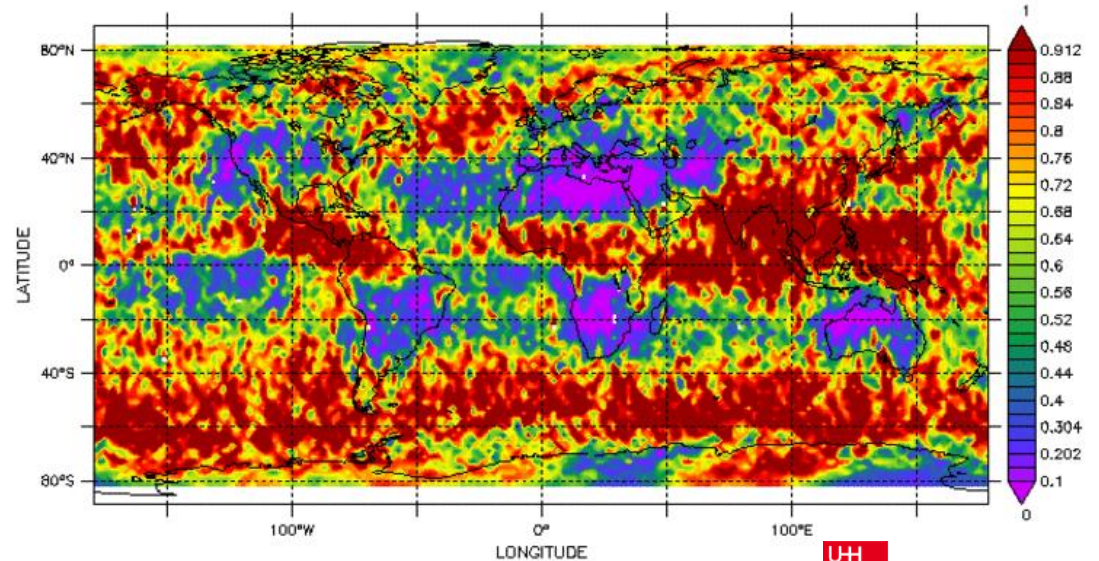
<https://eosweb.larc.nasa.gov/>

CALIPSO: Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations

LAS 7+, ICDC Klimacampus Hamburg 16-Aug-12

TIME : 16-JUL-2006 00:00

DATA SET: CloudSat-Calipso global cloud fraction (total), 2 degree grid resolution



total cloud fraction (fraction)





<http://atmosphere.copernicus.eu>

Aerosol direct radiative forcing	NH ₃	Sea-salt concentration
Aerosol indirect radiative forcing	Nitric acid	Sulfate AOD
Birch pollen	Nitrogen dioxide	Sulfates concentration
Black carbon AOD	Nitrogen monoxide	Sulphur dioxide
Black carbon concentration	Nitrogen oxides	Surface solar irradiation
Carbon dioxide	NMVOOC	Total AOD
Carbon monoxide	NMVOOCs	UV index
Dust AOD	Organic carbon AOD	
Dust concentration	Organic carbon concentration	
Ethane	Ozone	
Fire Radiative Power	PANs	
Formaldehyde	Peroxyacetyl nitrate	
Hydroxyl radical	PM ₁₀	
Isoprene	PM _{2.5}	
Methane	Propane	
N ₂ O	Sea-salt AOD	

Mostly model data



EarthData

<https://earthdata.nasa.gov/>



<https://giovanni.gsfc.nasa.gov/>

▼ Disciplines

- Aerosols (173)
- Atmospheric Chemistry (65)
- Atmospheric Dynamics (345)
- Cryosphere (15)
- Hydrology (967)
- Ocean Biology (44)
- Oceanography (48)
- Water and Energy Cycle (1038)



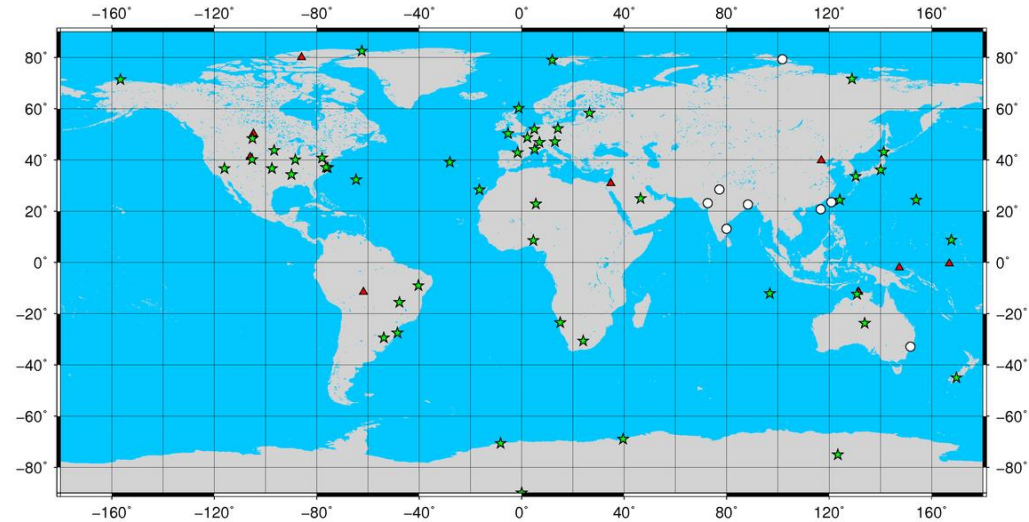
▼ Measurements

- Aerosol Index (3)
- Aerosol Optical Depth (78)
- Albedo (5)
- Angstrom Exponent (16)
- Black Carbon (5)
- CH4 (12)
- CO (17)
- CO2 (2)
- Component Aerosol Optical Depth (5)
- Dust (23)
- Emissivity (1)
- NO2 (2)
- Organic Carbon (4)
- Ozone (23)
- Particulate Matter (39)
- SO2 (4)
- SO4 (4)
- Scattering Angle (4)
- Sea Salt (4)
- Statistics (24)
- Total AOD Climatology Anomaly (6)
- Total Aerosol Optical Depth (49)

Baseline Surface Radiation Network

<http://bsrn.awi.de>

Running, planned, and closed BSRN Stations, May 2017



LR 0100 + LR 0300 (Basic radiation and other radiation measurements)

LR 0300 (Other radiation measurements only, including net and upward fluxes)

LR 0500 (Ultra-violet measurements)

LR 1000 (Meteorological synoptical observations)

LR 1100 (Radiosonde measurements)

LR 1200 (Ozone measurements)

LR 1300 (Expanded measurements), Part I

LR 3010 (Other radiation measurements at 10 m, including upward fluxes)

LR 3030 (Other radiation measurements at 30 m, including upward fluxes)

LR 3300 (Other radiation measurements at 300 m, including upward fluxes)