CM SAF cloud, surface albedo and surface radiation products from AVHRR 1982-2009

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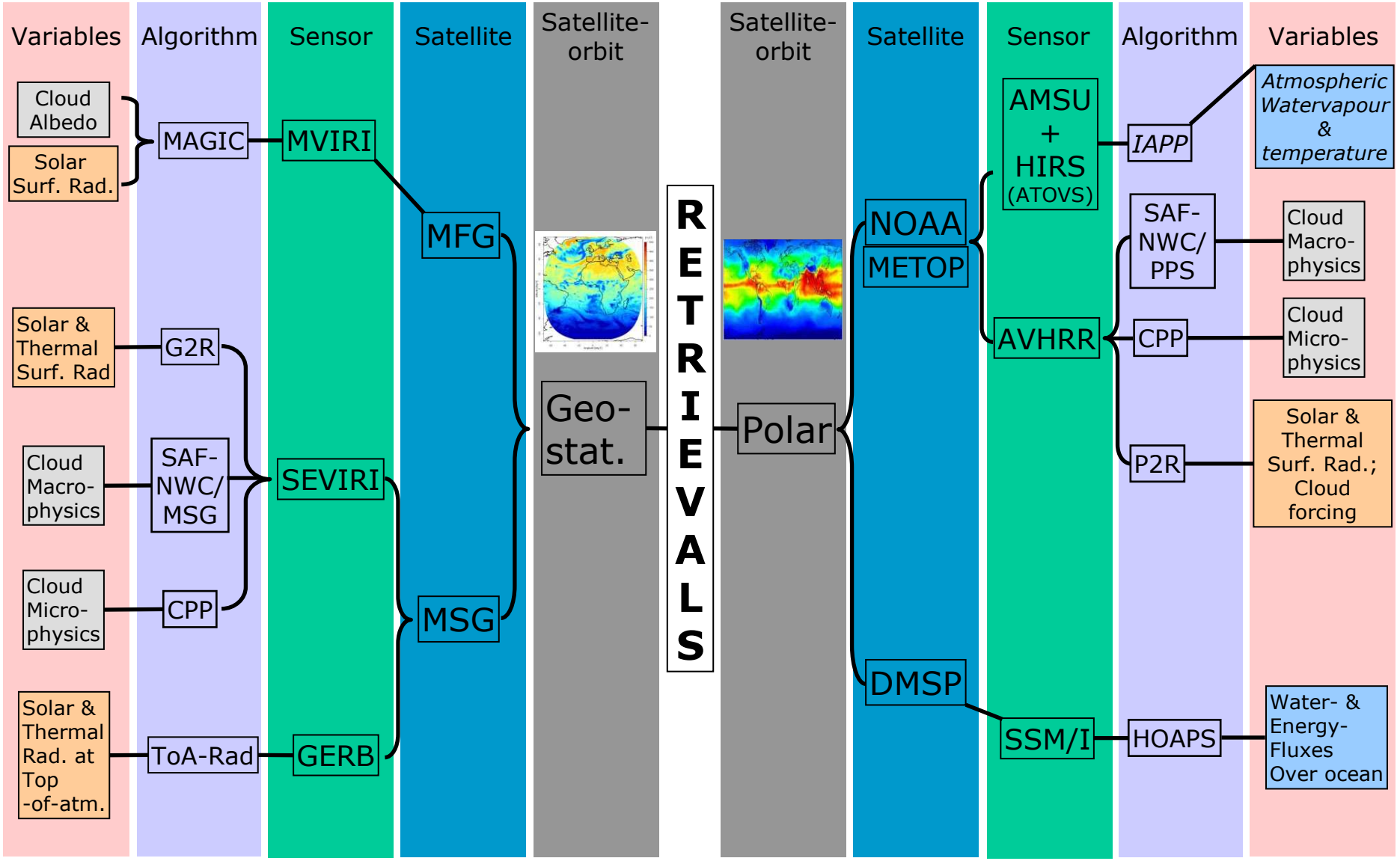
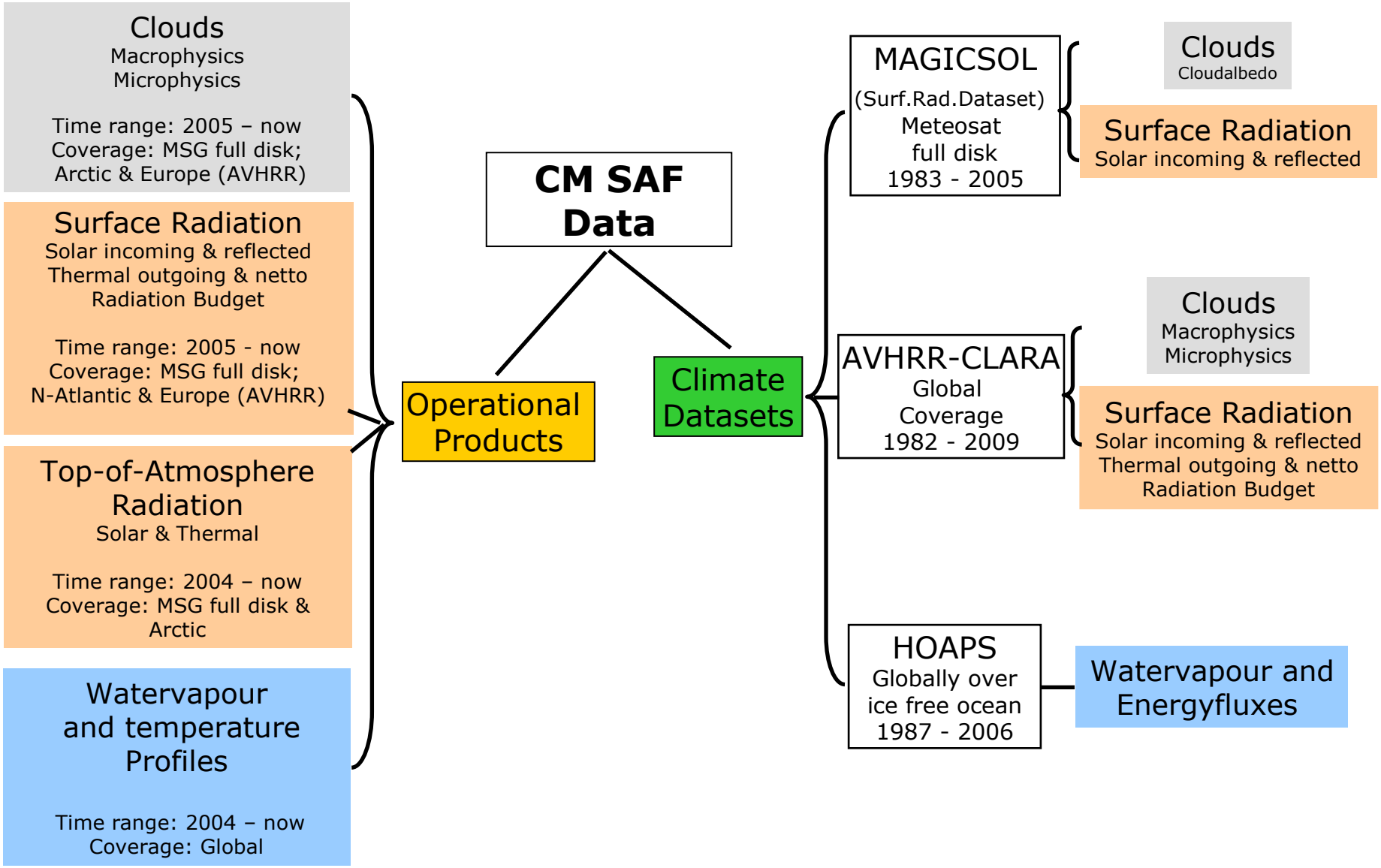
Outline:

- **The historical global AVHRR dataset**
  - sensor, satellites, resolution and radiance calibration
- **Description of CLARA cloud products**
- **Description of CLARA surface albedo products**
- **Description of CLARA surface radiation products**
- **Outlook**

Retrieval Overview

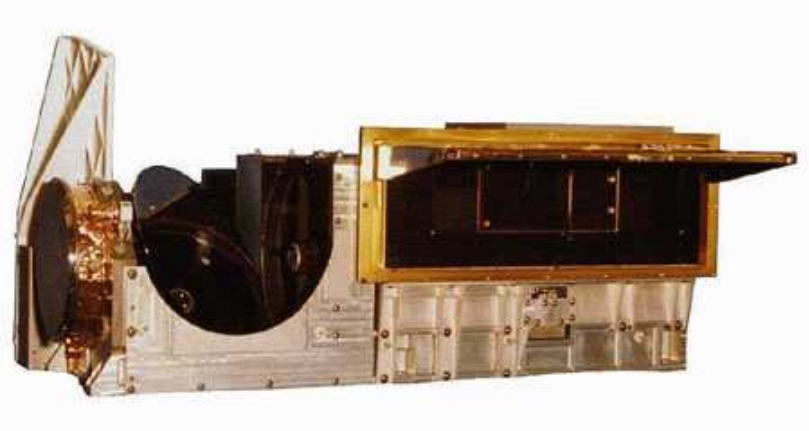


Available operational Products and Datasets



The historical AVHRR data set

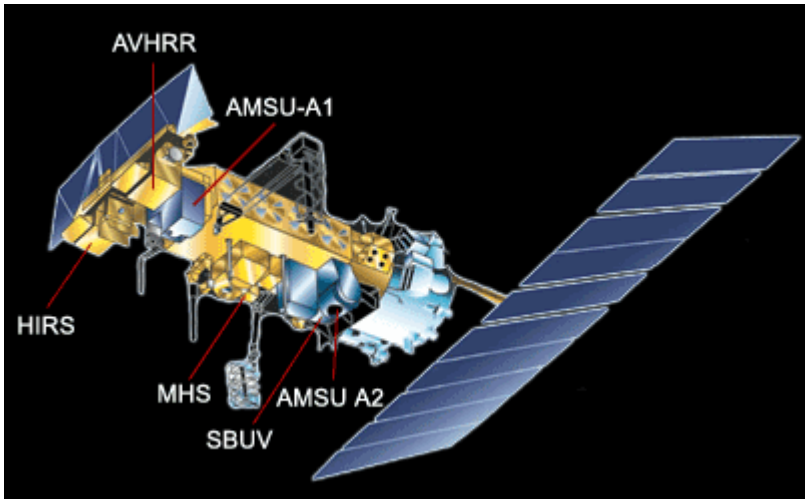
The Advanced Very High Resolution Radiometer – AVHRR



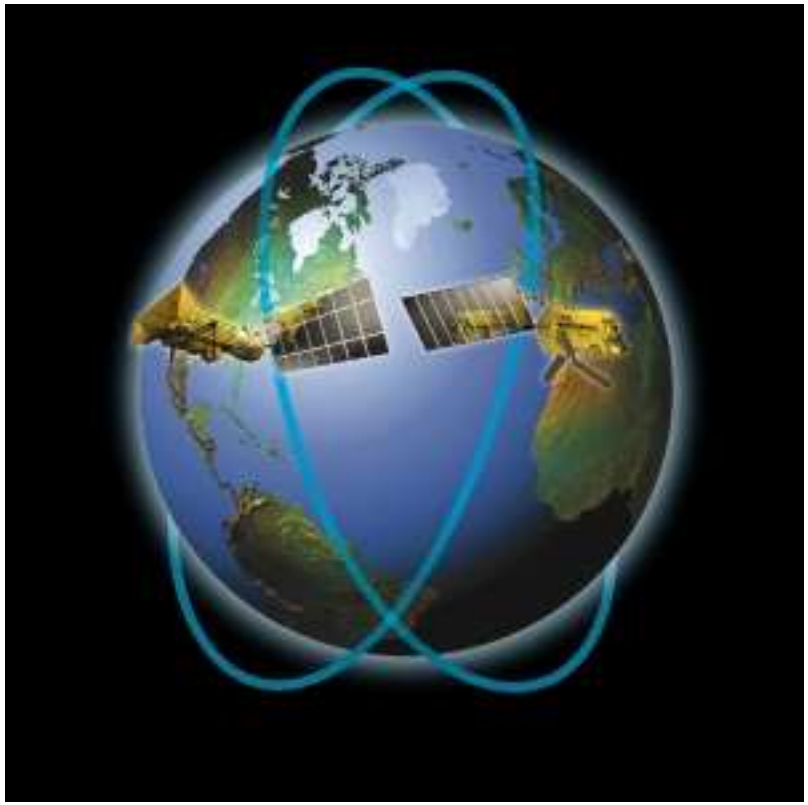
Channel Number	Wavelength (micrometers) AVHRR/1 NOAA-6,8,10	Wavelength (micrometers) AVHRR/2 NOAA-7,9,11,12,14	Wavelength (micrometers) AVHRR/3 NOAA-15,16,17,18 NOAA-19, Metop-A
1	0.58-0.68	0.58-0.68	0.58-0.68
2	0.725-1.10	0.725-1.10	0.725-1.10
3A	-	-	1.58-1.64
3B	3.55-3.93	3.55-3.93	3.55-3.93
4	10.50-11.50	10.50-11.50	10.50-11.50
5	Channel 4 repeated	11.5-12.5	11.5-12.5

The historical AVHRR data set

AVHRR is carried by polar orbiting NOAA and Metop satellites



NOAA satellite and its payload



Orbit configuration of NOAA and Metop satellites

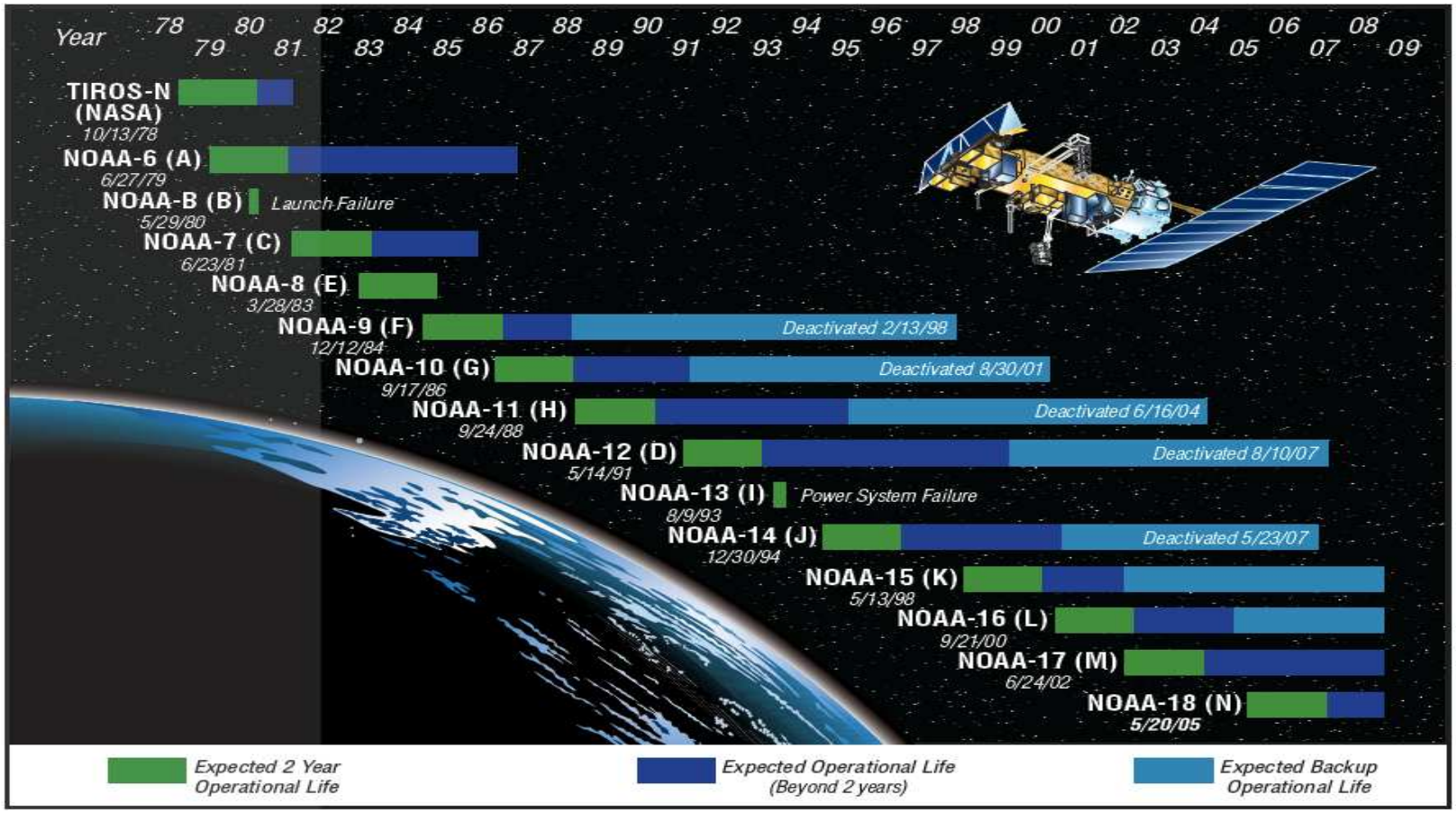
- Operating in sun-synchronous orbits for two orbit constellations 6 hours apart

- NOAA observations at fix local solar times (7:30/17:30 and 13:30/01:30)

- Metop observations at 10:00/22:00

The historical AVHRR data set

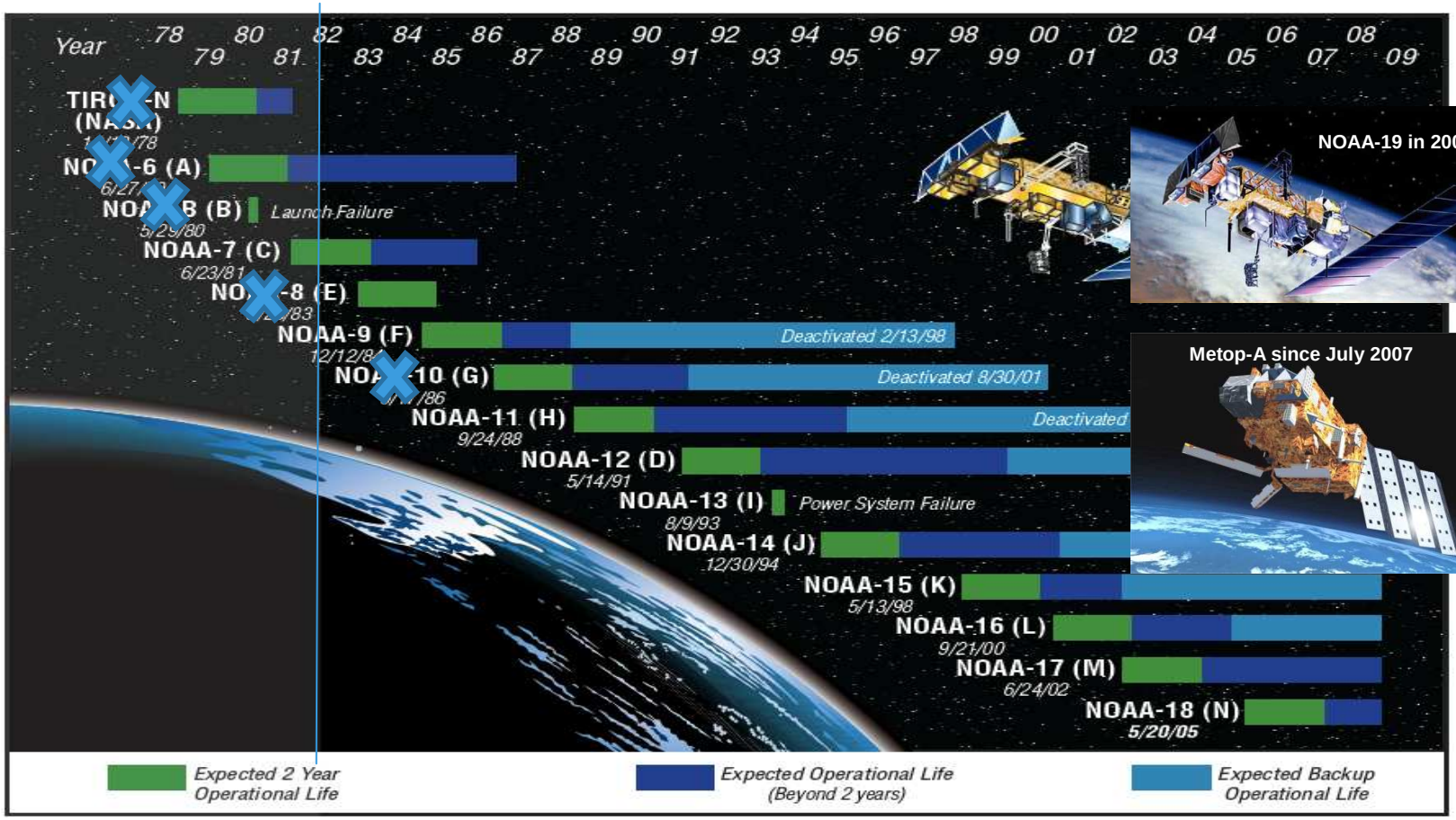
All NOAA satellites used in the CM SAF CLARA dataset 1982-2009



Courtesy of Andrew Heidinger, NOAA

The historical AVHRR data set

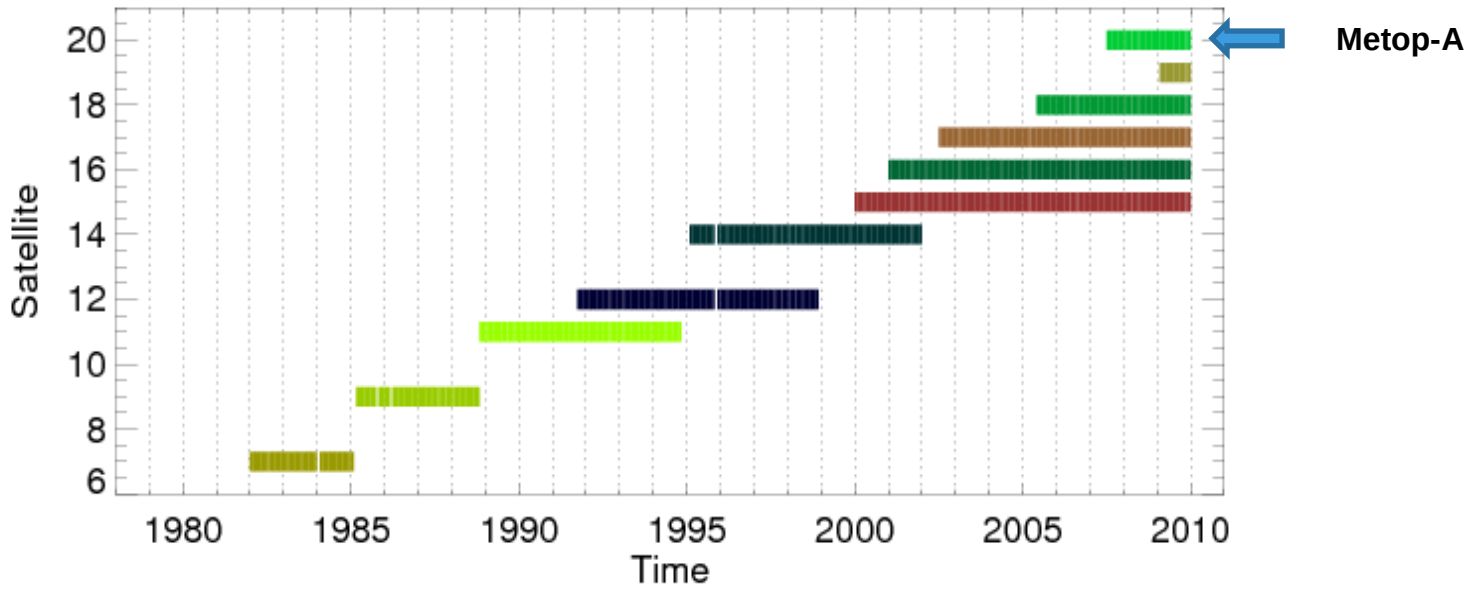
All NOAA satellites used in the CM SAF CLARA dataset 1982-2009



Courtesy of Andrew Heidinger, NOAA

The historical AVHRR data set

All NOAA satellites used in the CM SAF CLARA dataset 1982-2009
- Available time periods for each satellite



Note: Often referred to as the **GAC dataset =** Global Area Coverage AVHRR data provided in a reduced resolution of 4 km

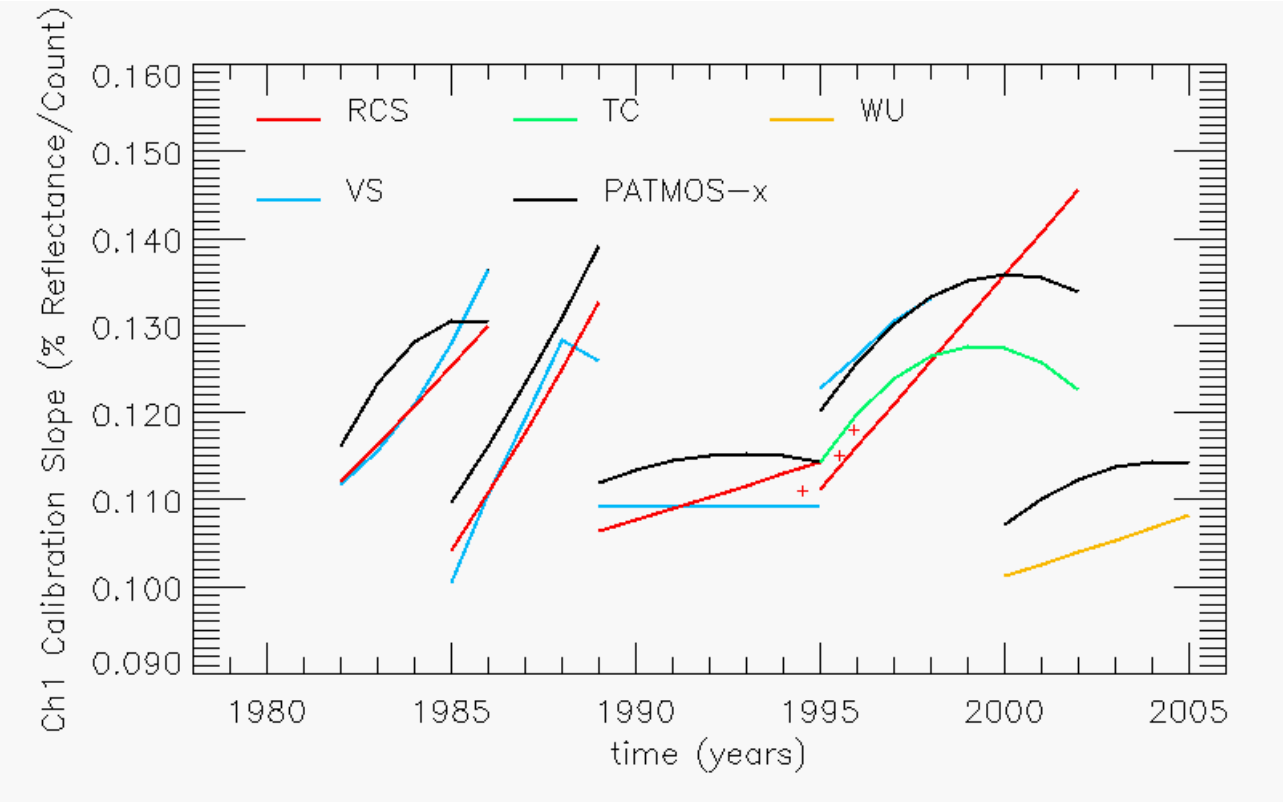
CLARA = CM SAF c**L**ouds, **A**lbedo and **RA**diation dataset

All CLARA products delivered in netCDF format in August 2012

The historical AVHRR data set

Definition of a consistent radiance dataset *(Fundamental Climate Data Record – FCDR)*

CM SAF relies on PATMOS-x FCDR *(Heidinger et al., IJRS, 2010)*



Example of time dependent corrections of calibration constants in AVHRR channel 1 (PATMOS-x black curve) – derived from MODIS and surface site comparisons

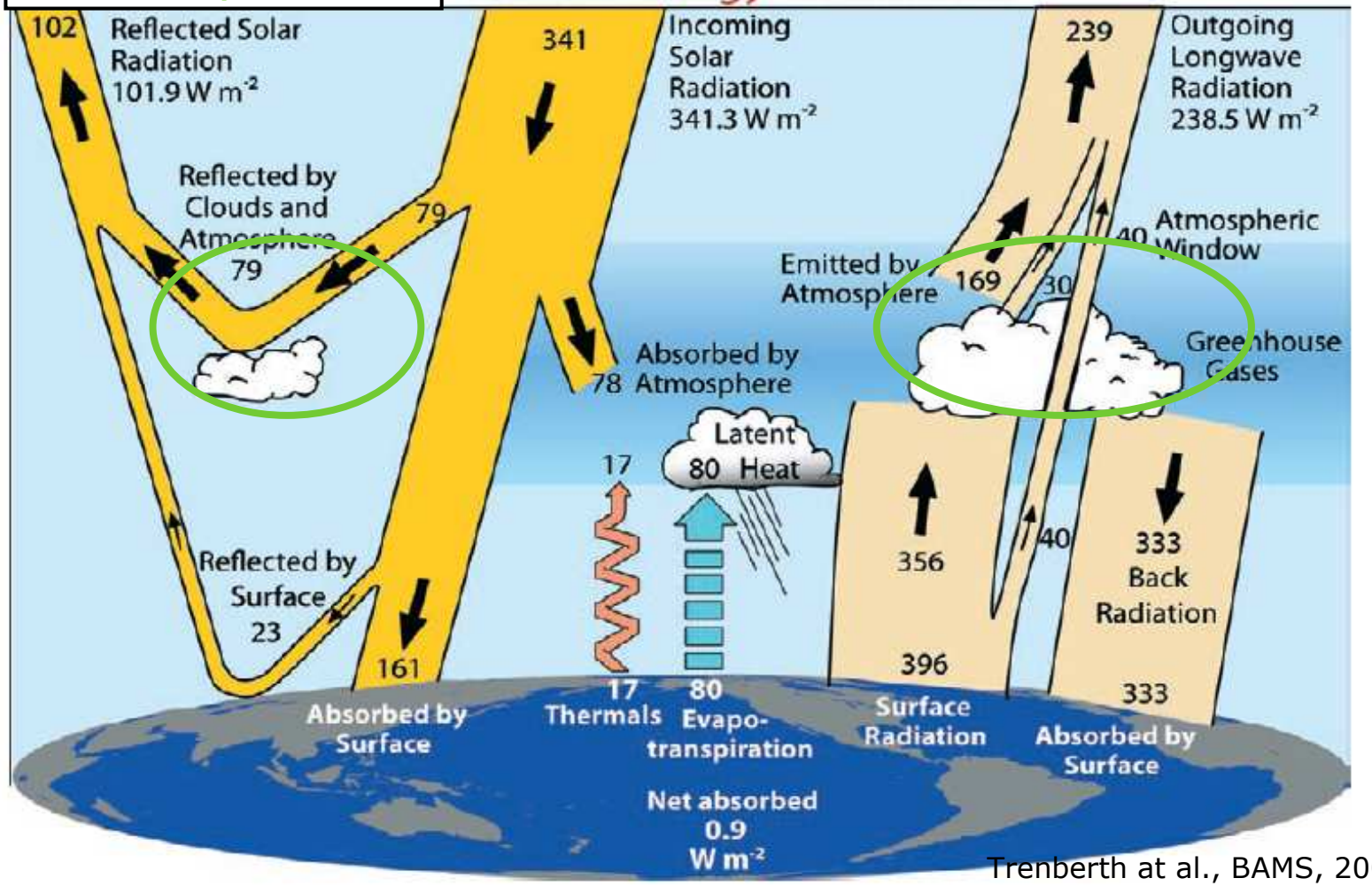
CLARA Cloud products

List of all cloud products:

PRODUCT NAME	PRODUCT CODE	PRODUCT ACRONYM
Fractional Cloud Cover	CM-05	CFC
Cloud Top level	CM-17	CTO
Cloud Optical Thickness	CM-34	COT
Cloud Phase	CM-38	CPH
Liquid Water Path	CM-43	LWP
Ice Water Path	CM-47	IWP
Joint Cloud property histogram	CM-11	JCH

CLARA Cloud products

- Cloud products

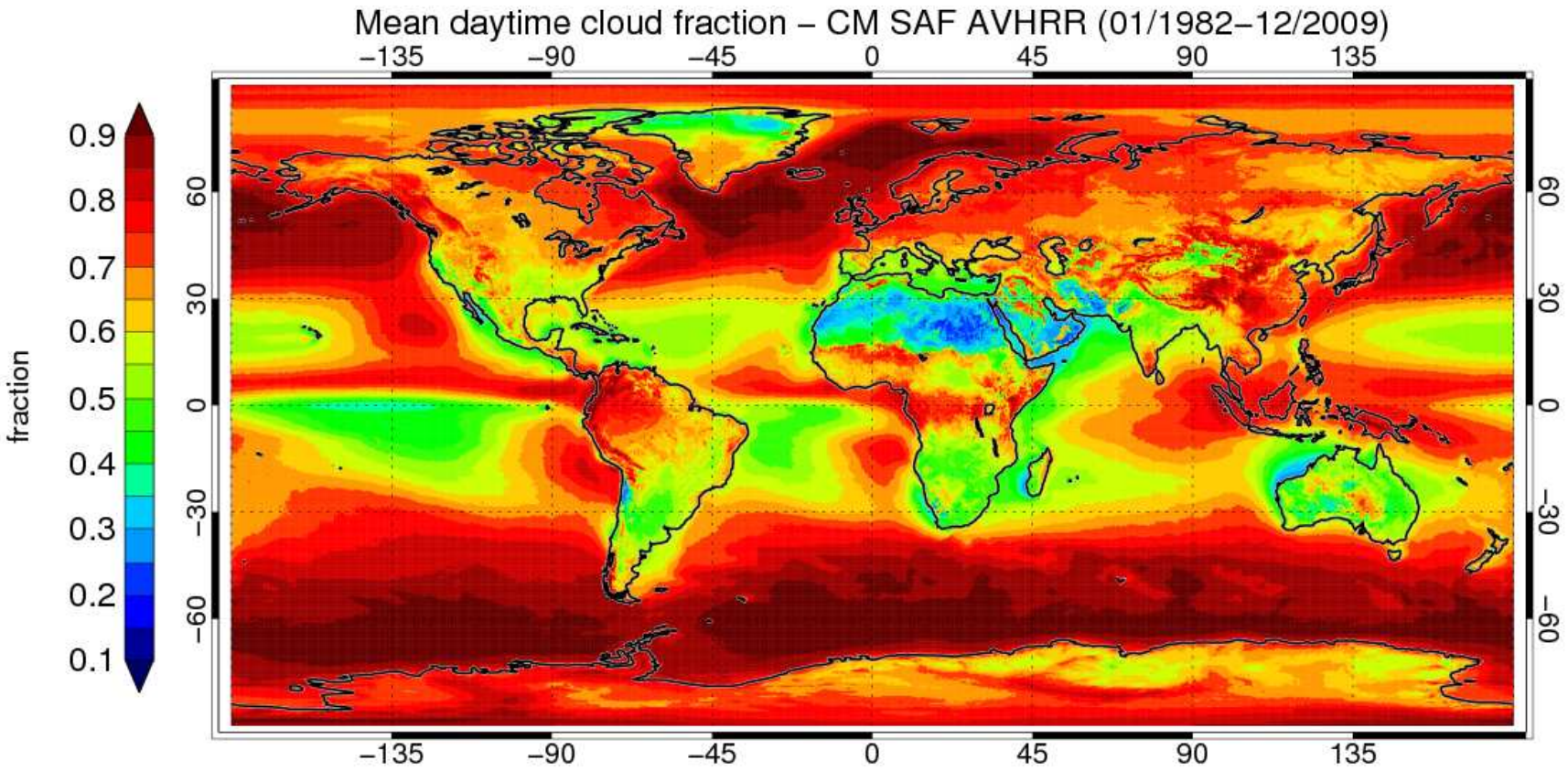


Trenberth at al., BAMS, 2009

CLARA Cloud products

Cloud product composition and options

Spatial grid 1: - Global latitude-longitude grid with 0.25 degree resolution



CLARA Cloud products

Cloud product composition and options

Spatial grid 2: - Two Polar grids with 25 km resolution

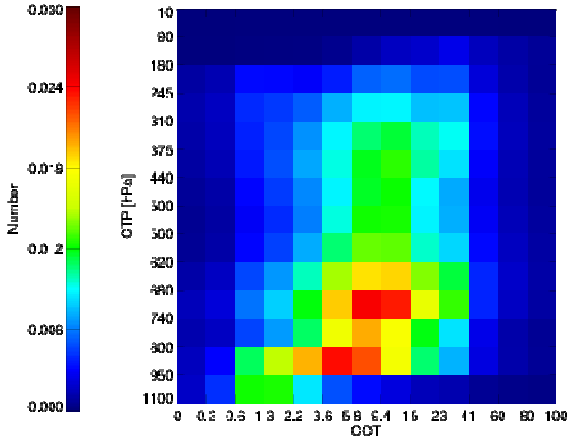
(illustrated later for surface albedo products)

CLARA Cloud products

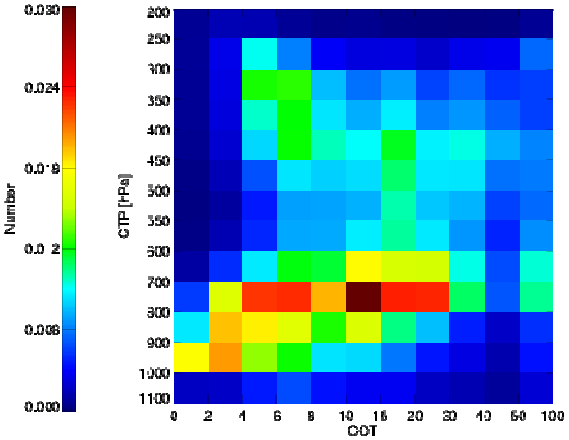
Cloud product composition and options

Spatial grid 3: - Joint histograms defined in 1 degree grid resolution

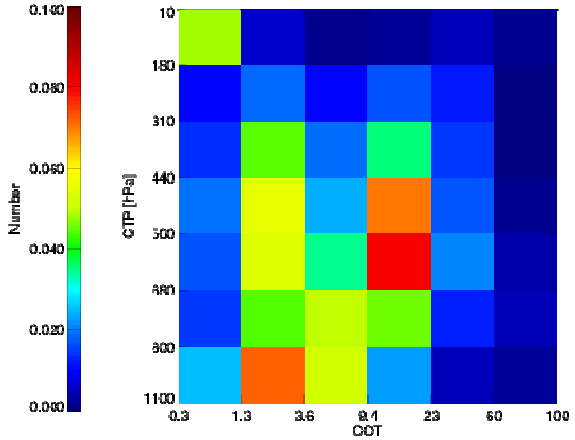
CM SAF



MODIS



ISCCP



Example of JCHs for March 2007 based on all global grid points and for all clouds

- Observe that results can be compiled for user-defined subsets of grid points (regions)!

CLARA Cloud products

Cloud product composition and options

Temporal options:

- Products including all data (all orbits) means that averages have been composed with a latitude-dependent temporal resolution *(normally 4 observations per day at the equator increasing up to 28 observations per day at the pole)*

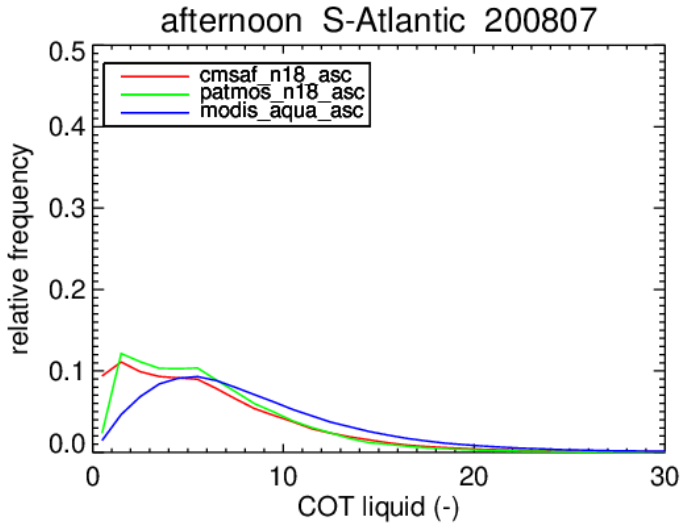
- Sub-setting the dataset is possible, e.g. select results from

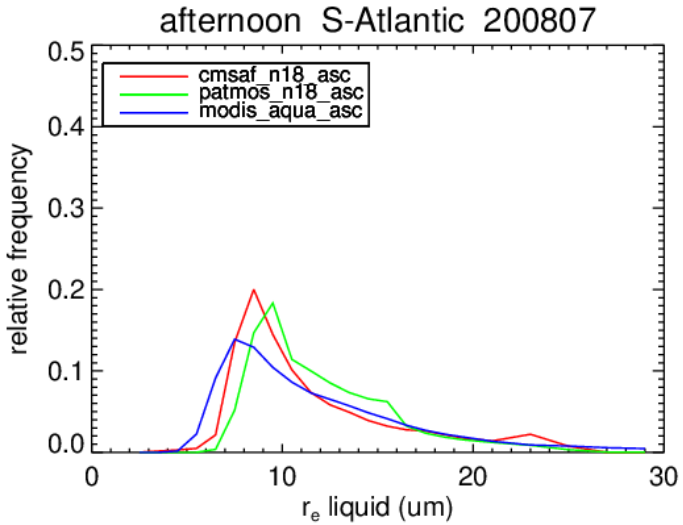
    - Individual satellites
    - Only daytime results (solar zenith angles below 80 degrees)
    - Only night-time results (solar zenith angles above 95 degrees)

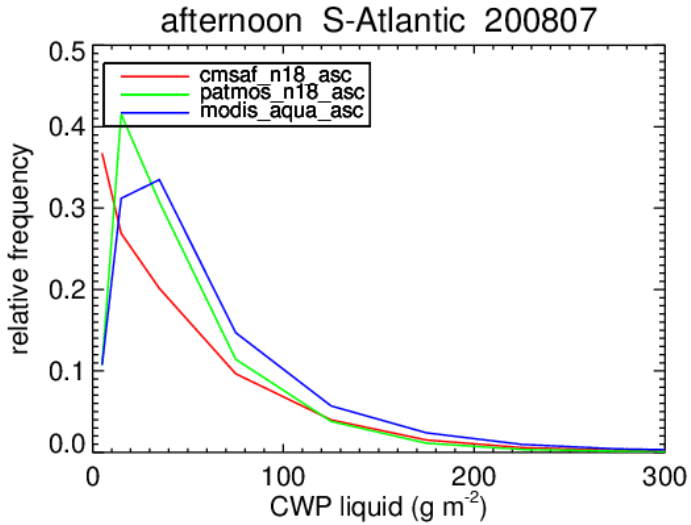
Metadata and auxiliary datasets:

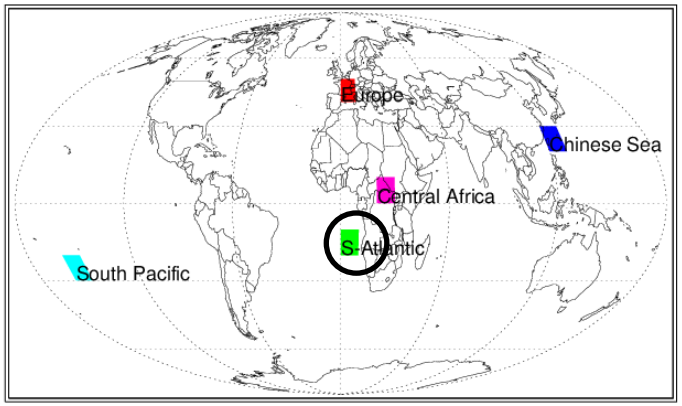
- Products include additional information about e.g. statistical distributions, uncertainties and background information (e.g., topography and land mask)

CLARA evaluation: South Atlantic – liquid water clouds









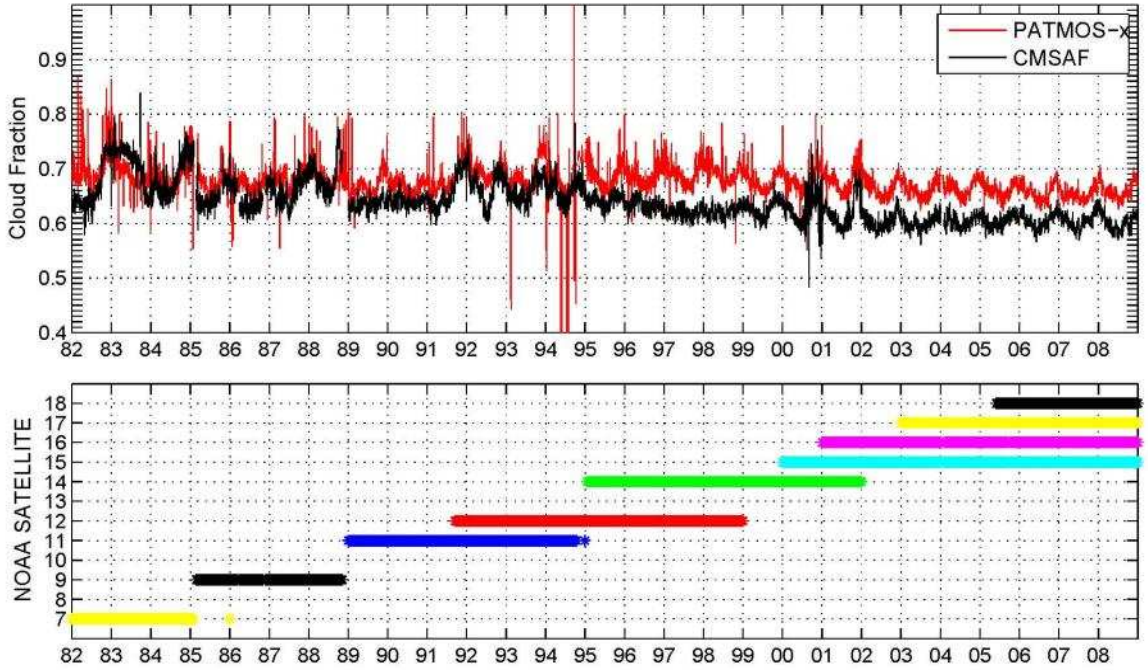
CLARA evaluation: Summary of results

Accuracy requirements are target CM SAF requirements

Product		Accuracy requirement (Mean error or Bias))	Achieved accuracies
Cloud Fractional Cover	(CFC)	10 % (absolute)	3.6 % (SYNOP) -10 % (CALIPSO) -4.1 % (PATMOS-x) -10 % to -20 % (MODIS) 0 % to -12 % (ISCCP)
Cloud Top Height Cloud Top Pressure	(CTH) (CTP)	1200 m 110 hPa	-2661 m (CALIPSO) -20 to 60 hPa (PATMOS-X) -40 to -50 hPa (MODIS) -20 to 60 hPa (ISCCP)
Cloud Optical Thickness	(COT)	15 %	3-20 % (PATMOS-x) -5 % to -10 % (MODIS) 50-60 % (ISCCP)
Cloud Phase	(CPH)	5 % (absolute)	7-15 % (PATMOS-x) 3-20 % (MODIS) 12-15 % (ISCCP)
Liquid Water Path	(LWP)	15 %	+15 % to -26 % (UWisc) 0-30 % (PATMOS-x) 15 % (MODIS) 30-50 % (ISCCP)
Ice Water Path	(IWP)	25 %	0 % to -120 % (PATMOS-x) 0 % to -80 % (MODIS) 30-50 % (ISCCP)
Joint Cloud Histogram	(JCH)	n/a	n/a

Achieved accuracies given for independent datasets (black) and other satellite-based datasets (blue)

CLARA usage: Warning on global trend analysis



Decreasing trend in global cloud fraction mainly a result of changed observation frequency (more observations in the last ten years in morning and evening when cloud detection is more problematic)

- Daytime-only and night-time only results show no trend!

CLARA Cloud products

Strengths:

- Global coverage of seven different cloud properties for the longest time record available from satellites
- Best observational coverage over Polar Regions (high quality observations in the Polar summer)
- Rigorously evaluated products – using both independent and other satellite based datasets
- Best quality found for mid- and high latitudes and over all oceans

Weaknesses

- Latitude-dependent time sampling (two observations per day and satellite at the Equator increasing to 14 at the Poles)
- Some products relying on reflected solar radiation – only daytime!
- Global trend analyses not possible yet
  - Limited coverage in the first part of the period
  - Cloud amounts underestimated over Polar regions in Polar winter
  - Daytime cloud amounts overestimated over subtropical land areas

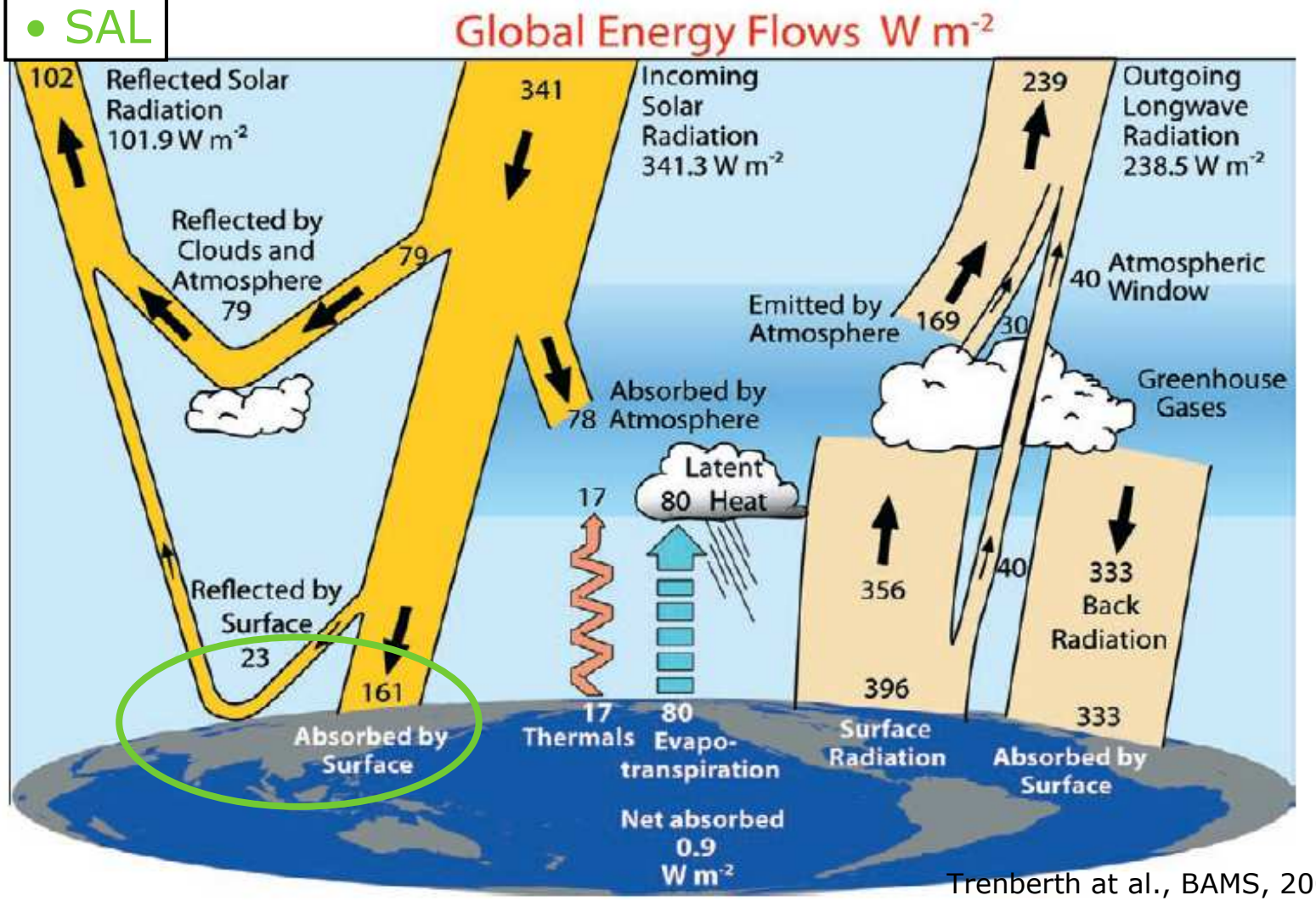
CLARA surface albedo

List of surface albedo products:

PRODUCT NAME	PRODUCT CODE	PRODUCT ACRONYM
Surface albedo	CM-60	SAL

CLARA surface albedo

- SAL

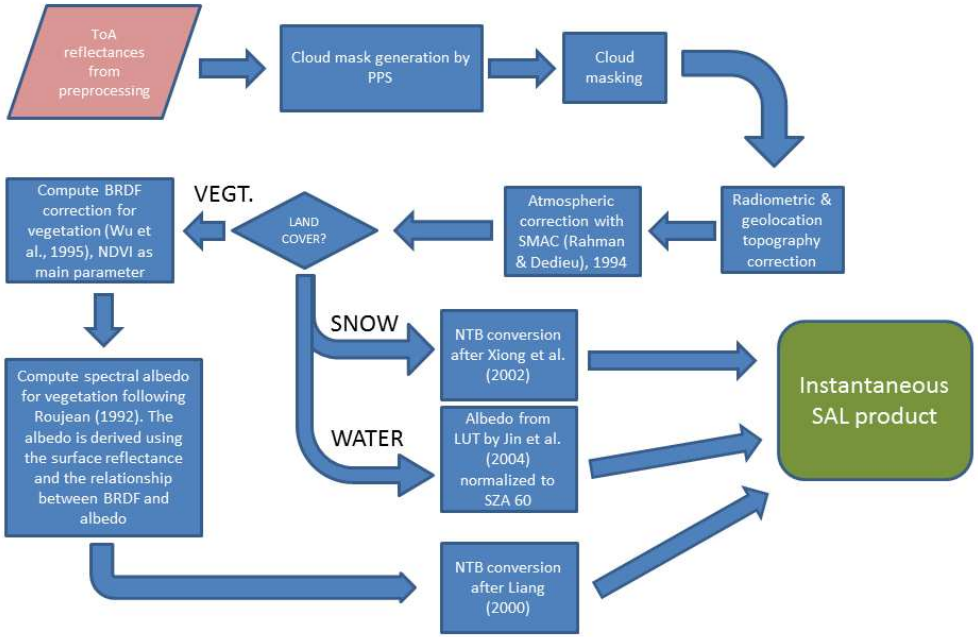


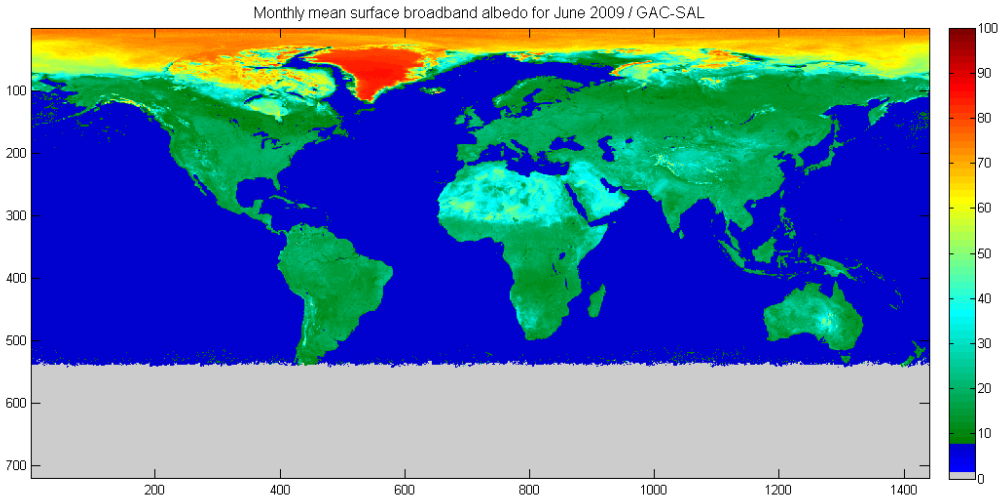
Trenberth at al., BAMS, 2009

CLARA surface albedo

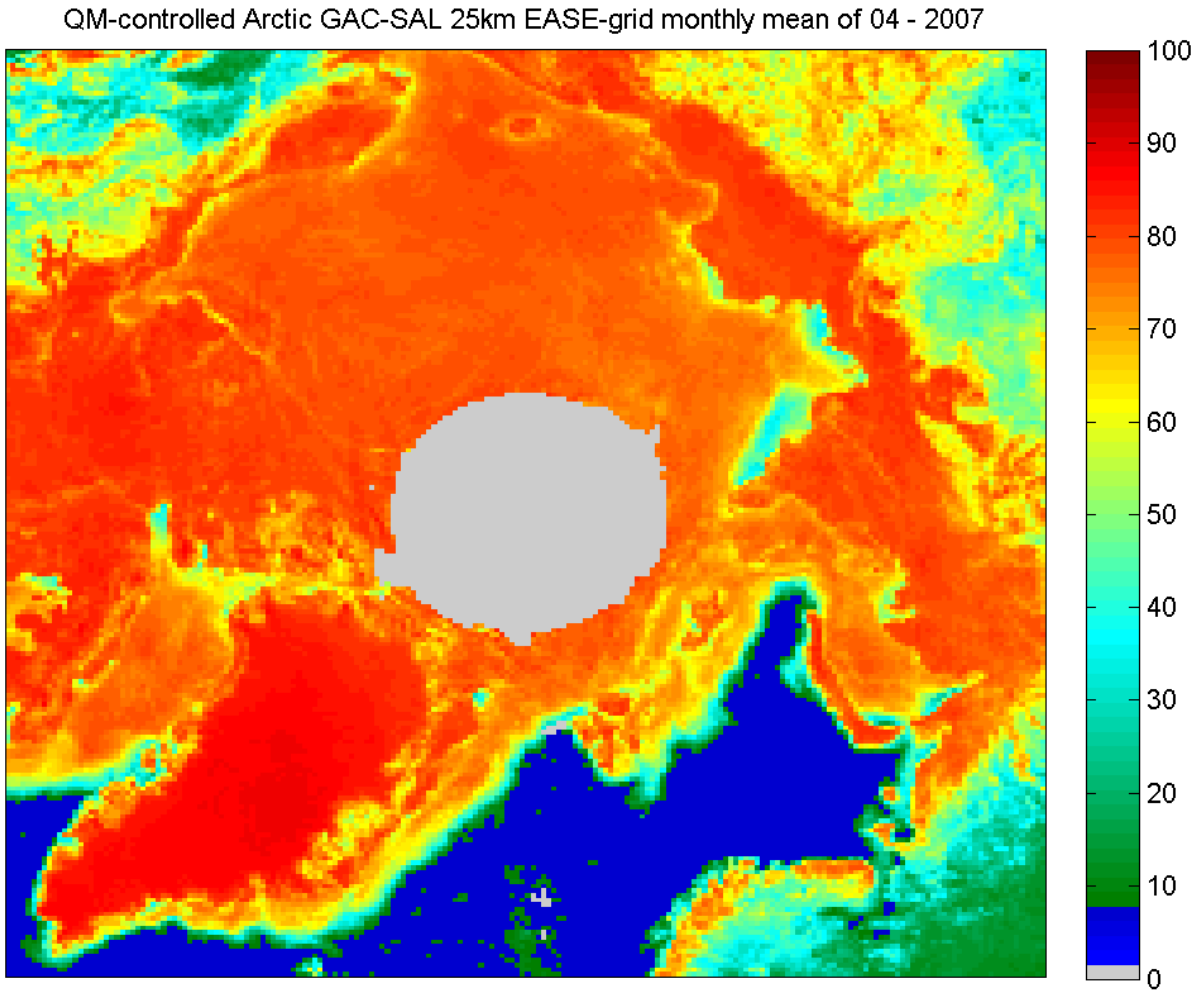
CLARA-SAL

- A shortwave black-sky surface albedo product covering 1982-2009 from AVHRR-GAC
- Monthly and pentad (5-day) means with full global coverage
- Dedicated algorithms for vegetated surfaces, snow/ice, and water
- A radiometric and geolocation correction for topography effects on AVHRR images

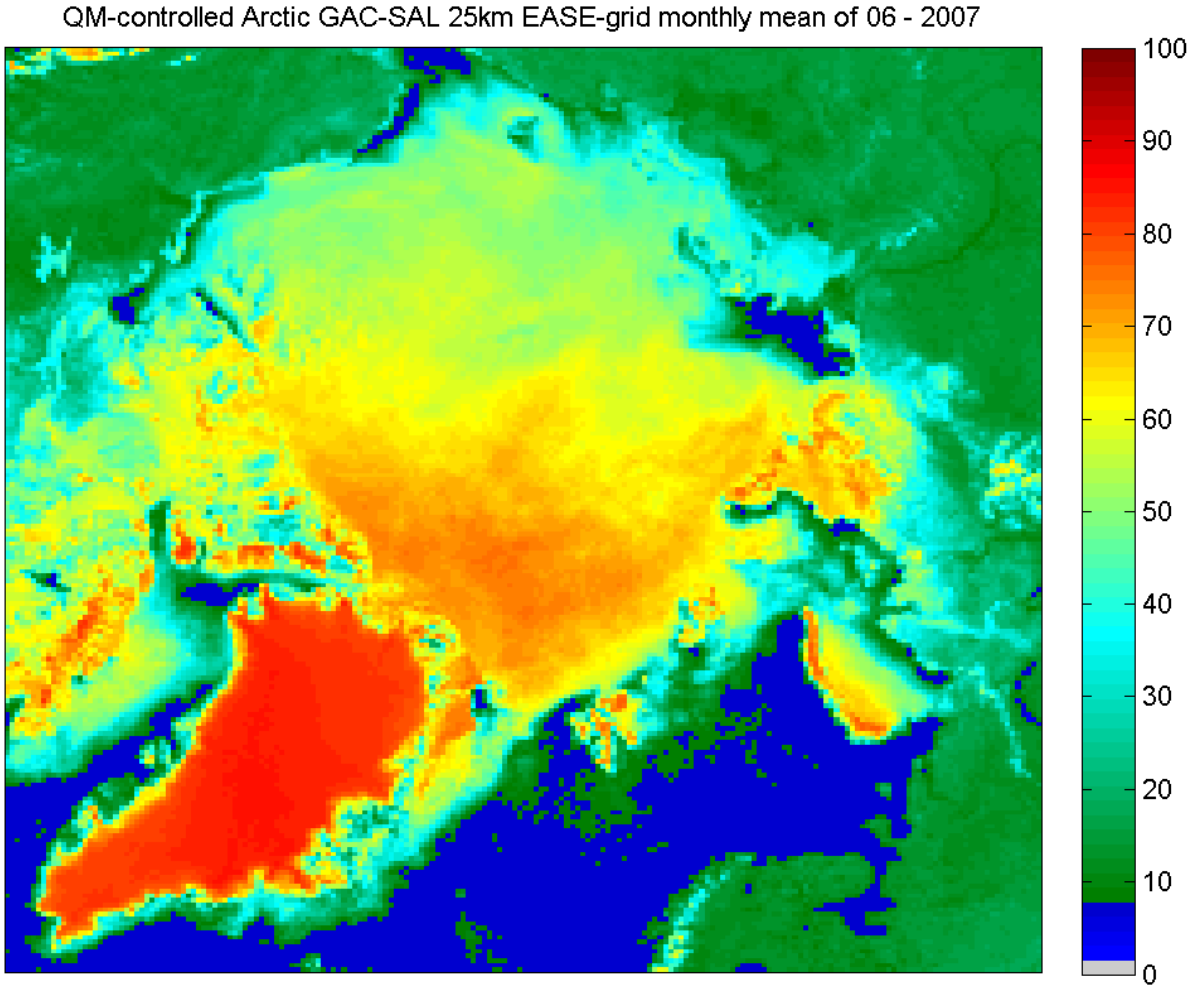




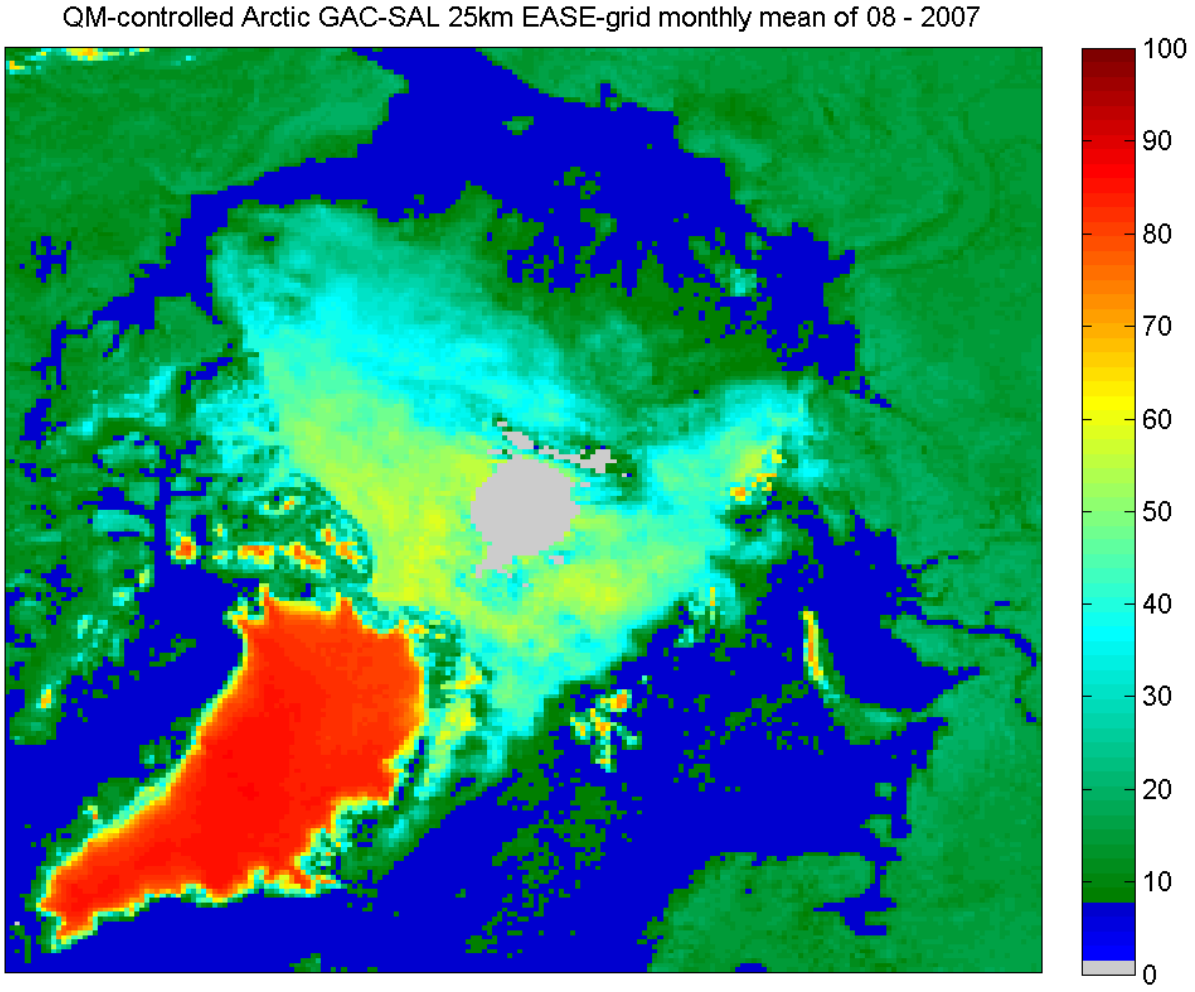
Product example; Arctic albedo April 2007



Product example; Arctic albedo June 2007



Product example; Arctic albedo August 2007



Full animation of 5-day values available for download covering 2007-2009!

CLARA-SAL edition 1 strengths & weaknesses

- Global coverage
- First 28-year record of Arctic (and Antarctic) sea ice albedo
- Based on homogenized AVHRR radiances
- Validation shows 10-15% retrieval accuracy over most natural surfaces

- Retrievals uncertain over regions with high aerosol loading
- Retrievals also uncertain when Sun Zenith Angle is close to 70 degrees

Usage recommendations:
1.Use the SAL supplementary data – number of observations and standard deviation can help find and remove uncertain retrievals from your analysis.
2.Avoid using over Sahara and other regions where AOD content is high and variable.
3.Best validation results found over sea ice and snow – highest value there?

CLARA surface radiation

List of all surface radiation products:

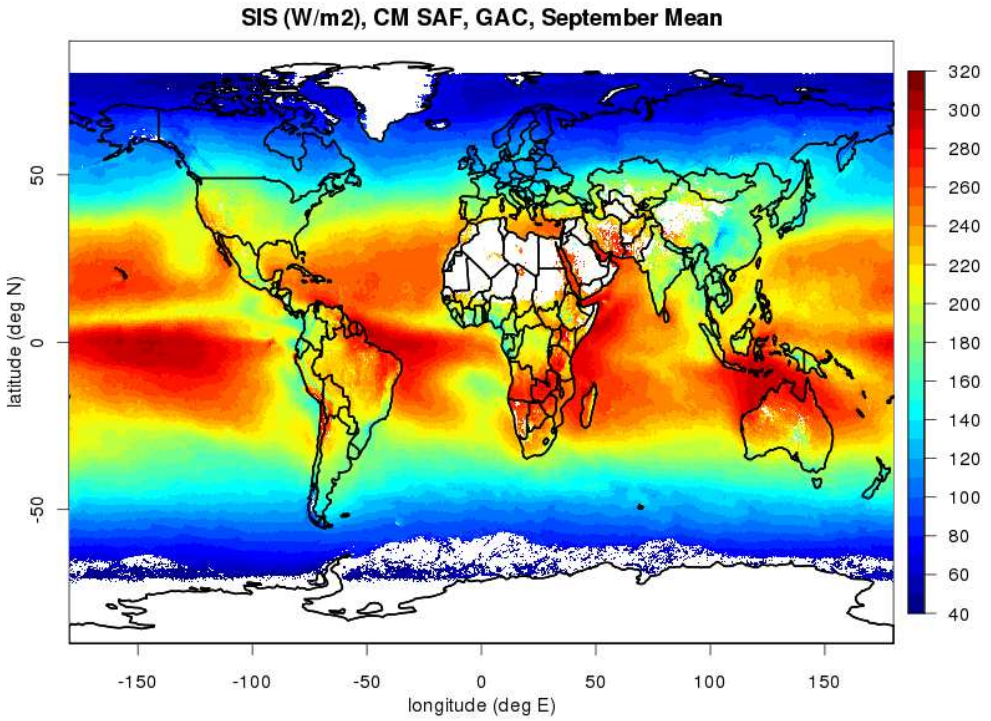
PRODUCT NAME	PRODUCT CODE	PRODUCT ACRONYM
Surface Incoming Shortwave	CM-52	SIS
Surface Net Shortwave	CM-67	SNS
Surface Outgoing Longwave	CM-76	SOL
Surface Downward Longwave	CM-81	SDL
Surface Net Longwave	CM-88	SNL
Surface Radiation Budget	CM-95	SRB
Cloud Radiative Effect Shortwave	CM-100	CFS
Cloud Radiative Effect Longwave	CM-101	CFL

CLARA surface radiation

Polar-Orbiting

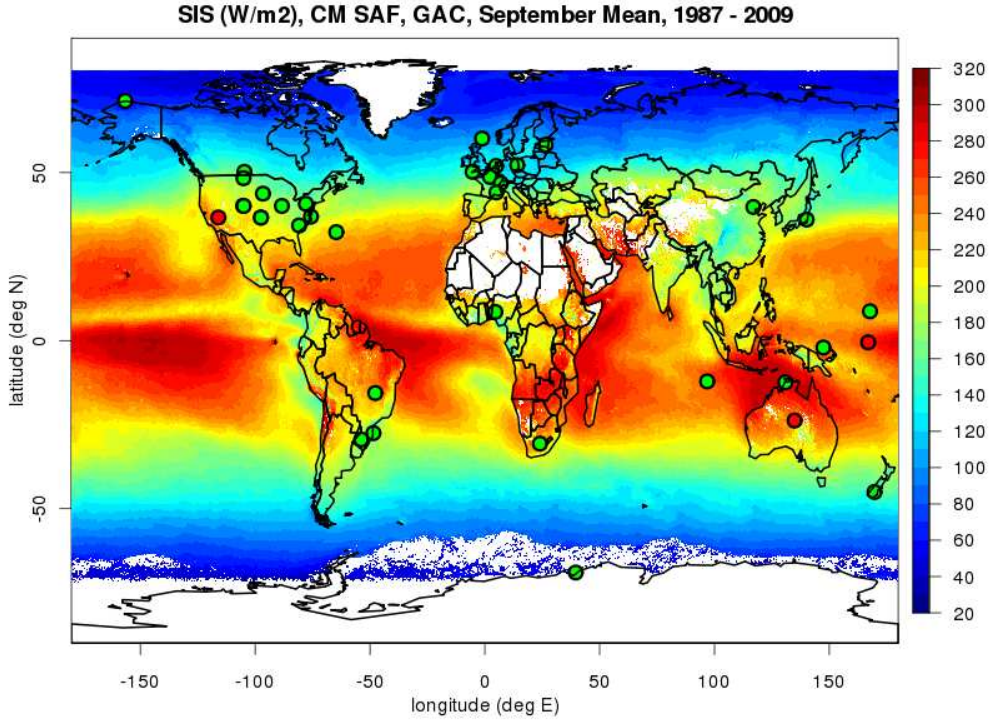
- Based on AVHRR-GAC, using a LUT approach (Mueller et al.,2009)
- Available 1982 to 2009
- 0.25° spatial resolution
- daily, monthly
- Variables:
  - ➢Surface radiation budget

Algorithms to be presented by Rebekka Posselt on Wednesday!



Results using monthly mean Surface Incoming Solar Radiation (SIS)

Validation CLARA - SIS

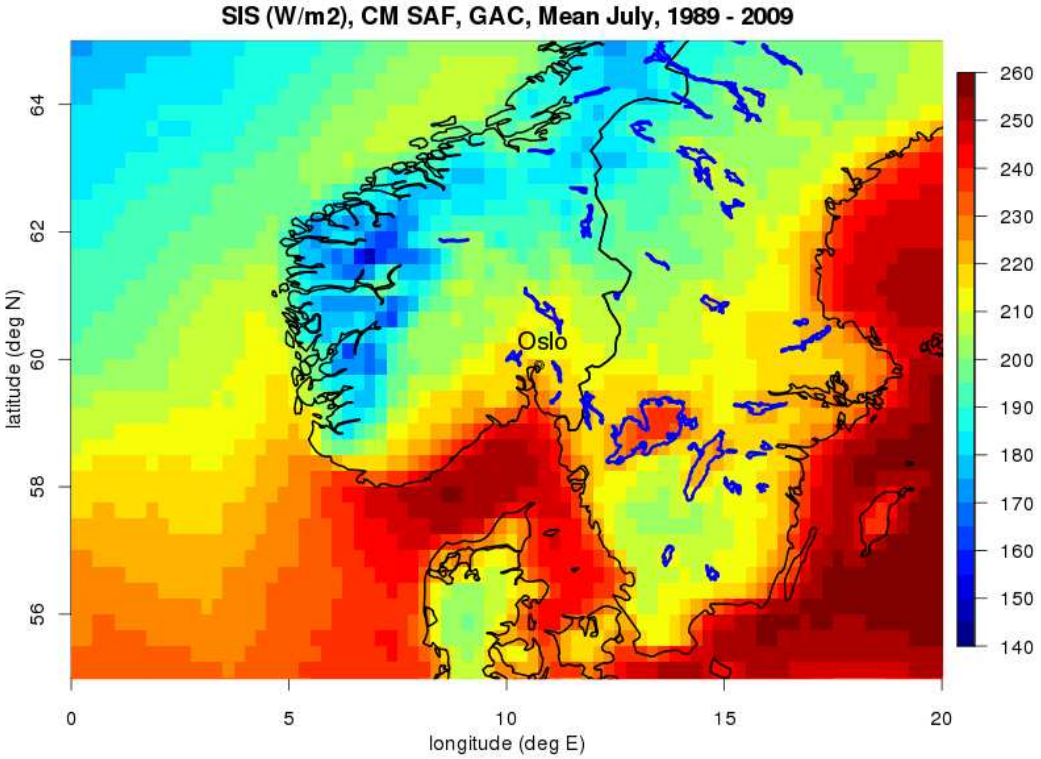


Data set	Analyzed Months	Bias (Wm^{-2})	Abs. Bias (Wm^{-2})	Std. Dev. (Wm^{-2})	Corr. Ano.	Frac. Months $> 15\ Wm^{-2}$,%	Frac. Months $> 20\ Wm^{-2}$,%
CM SAF, GAC	3105	−3.3	10.4	14.4	0.88	23.6	13.7

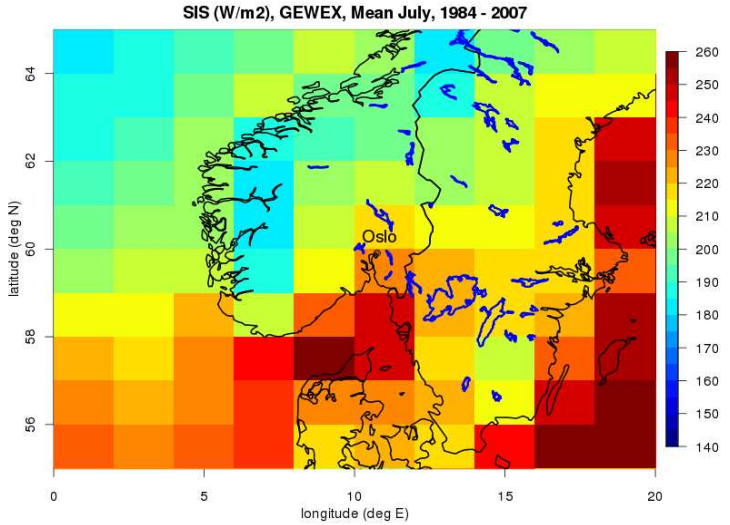
CLARA surface radiation

About applications CLARA - SIS

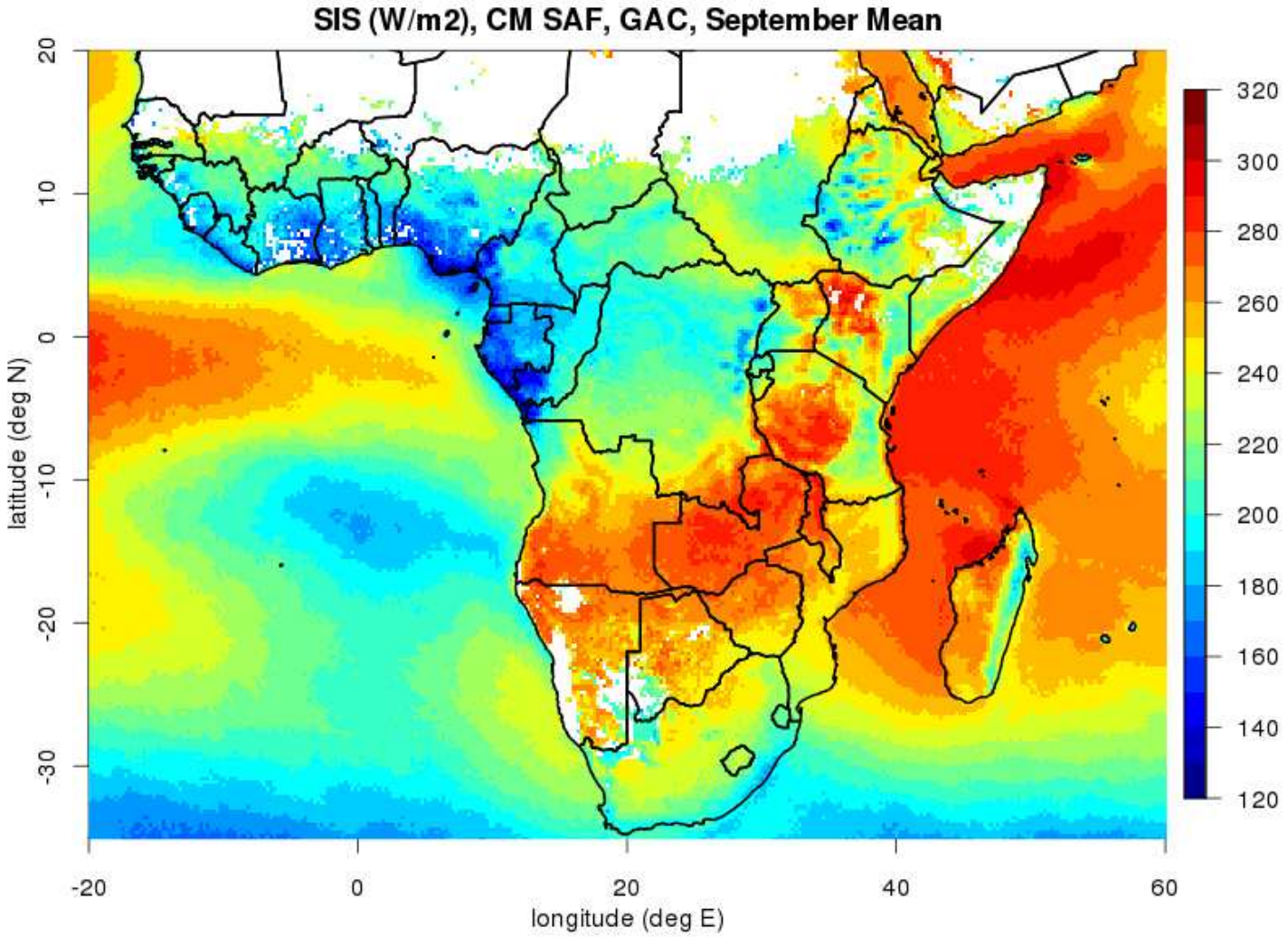
Surface Irradiance, Mean July, CM SAF



- Reduced solar radiation in Western Norway, local effects visible (e.g., Fjords)
- Enhanced radiation over the Baltic Sea and inland lakes.
- GEWEX SRB data misses details due to coarse resolution.

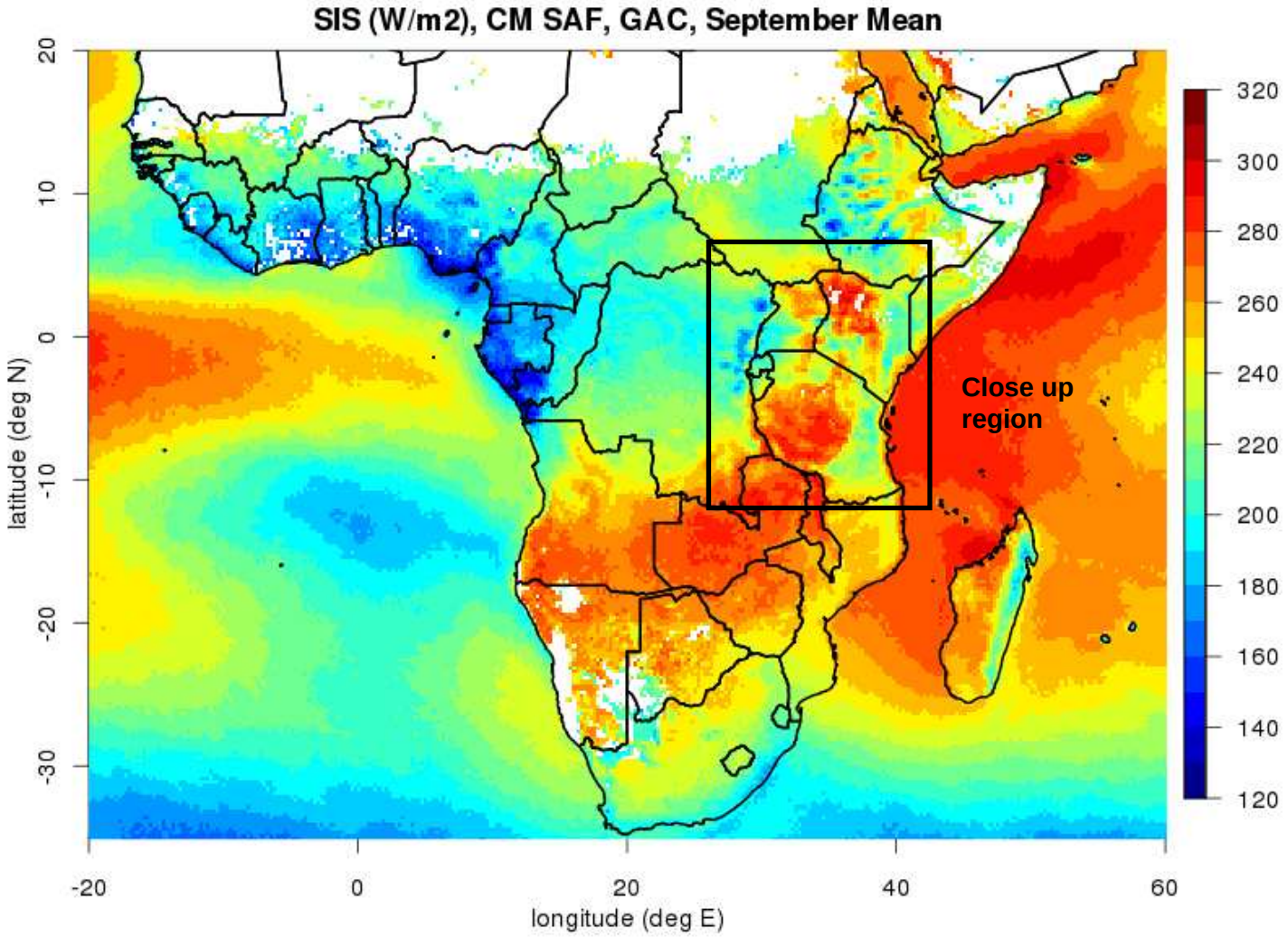


Large-scale results CLARA - SIS

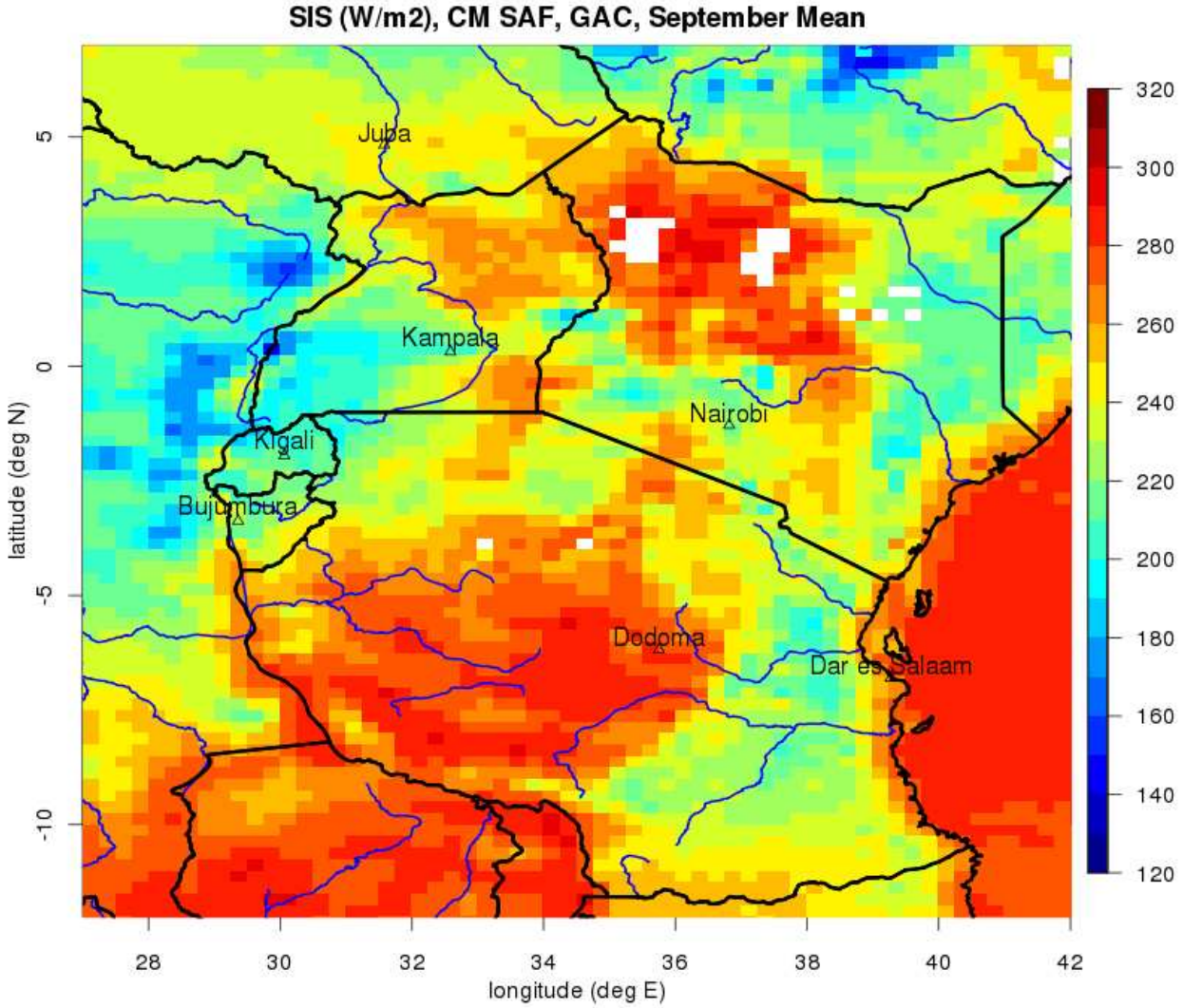


CLARA surface radiation

Large-scale results CLARA - SIS



Local-scale results CLARA - SIS



CLARA surface radiation

Strengths:

- Global coverage at moderate spatial resolution (0.25 deg, alternative global data sets have much lower spatial resolution (1 deg))
- Good quality (accuracy and stability), long time series
- Numerous consistent parameters available (clouds, surface albedo, short- longwave surface radiation)

Weaknesses

- A lot of missing data in surface solar radiation data set -> be careful when calculating spatial and temporal averages!
- Longwave radiation data set relies on ERA-Interim reanalysis data -> could be problematic for model evaluation
- For very local applications, spatial resolution might not be sufficient -> check out the Meteosat surface radiation data set (but only for Europe, Africa, parts of South America available!)

CLARA - Outlook

CLARA Edition 2 (released 2015):

- Regional cloud detection deficiencies solved or mitigated
- Cloud effective radius new official product
- Enhanced product dataset (Level 2 + Level 2b)
- Improved consistency between products
- SAL improvements in atmospheric correction, sea ice identification and use of a more dynamic land cover dataset.
- Improvement of surface radiation products over bright surfaces and improved corrections for the longwave surface radiation products

CLARA Edition 3 (released 2017):

- Extended back to 1978 (AVHRR/1)
- Methods for correcting effects of orbital drift
- Improved error characterization (e.g. probabilistic cloud mask and modelled uncertainties from OE techniques)

The end