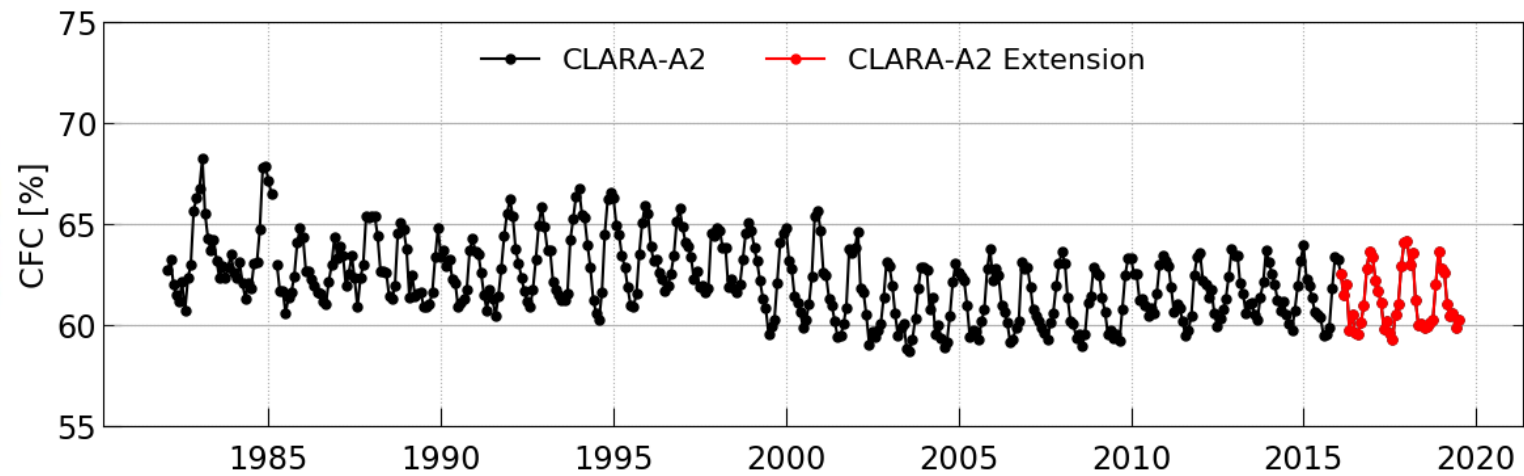
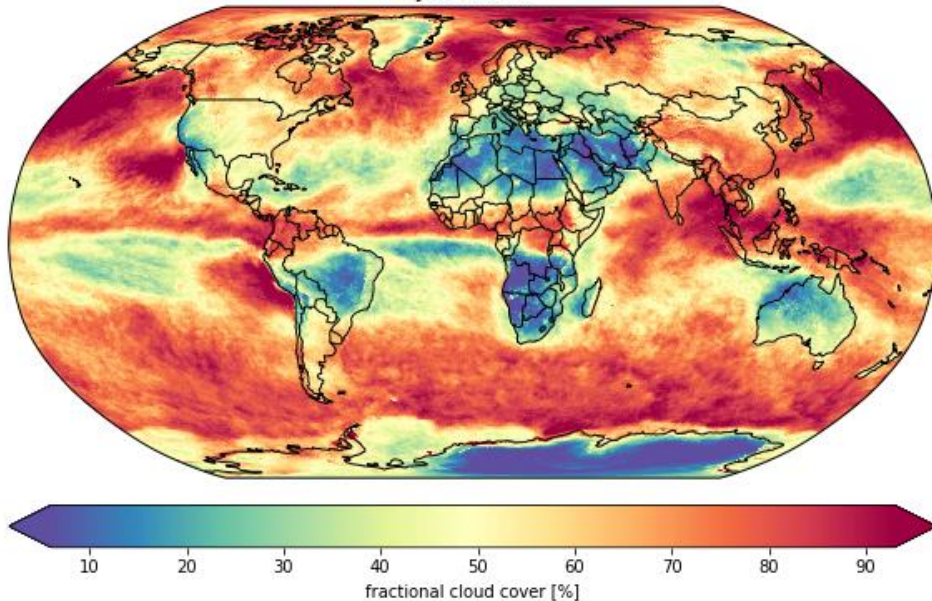


Extending the CM SAF global satellite-based climate data record of cloud properties

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CLARA-A2.1-ALLSAT CFC
June 2019

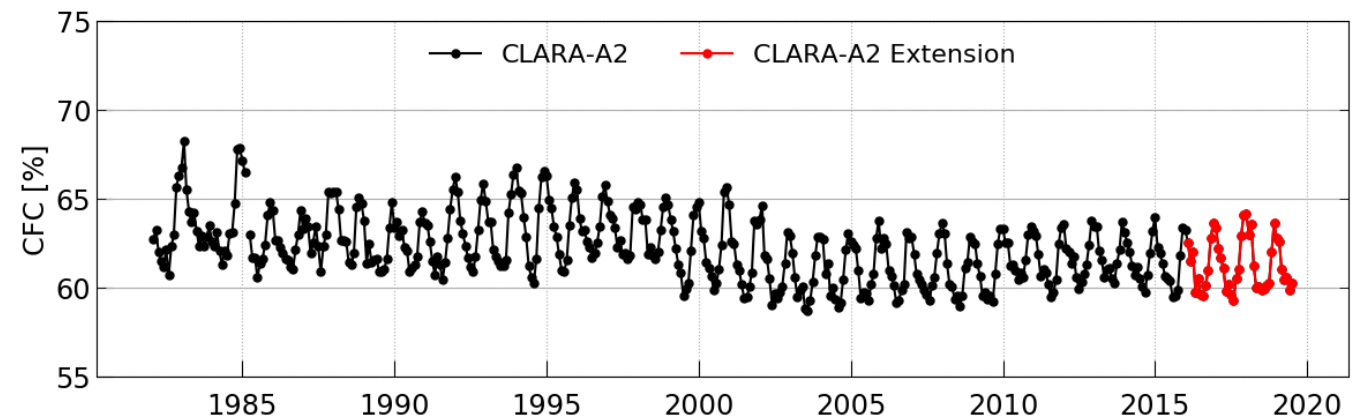


Agenda

- Introduction to CM SAF CLARA record series
- AVHRR GAC data record
- CLARA-A2.1 cloud products and product levels
- Validation of cloud products
 - Strategy
 - Data records for comparison
 - Validation of specific products
 - Fractional Cloud Cover
 - Cloud Top Pressure
 - Cloud Physical Properties: Liquid Water Path, Cloud Optical Thickness, Cloud Effective Radius
 - Decadal stability
 - Summary
- Why should I use CLARA cloud products?

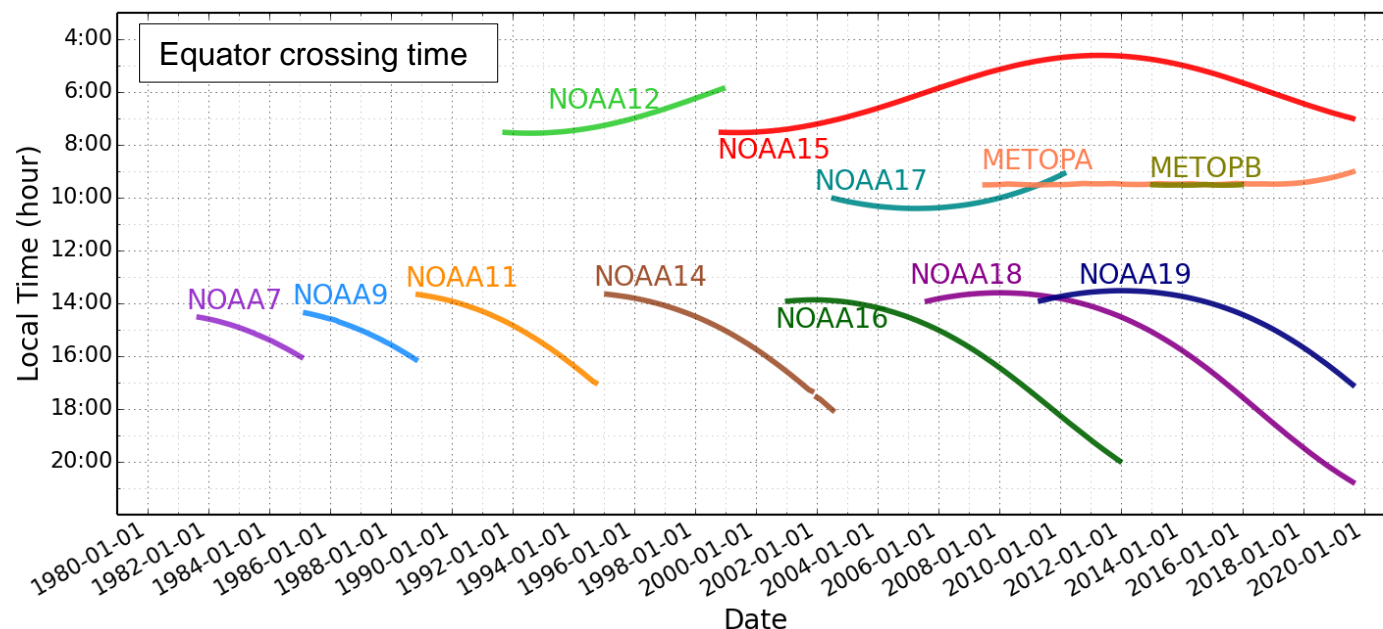
Introduction to the CM SAF CLARA record series

- **CM SAF** (EUMETSAT **S**atellite **A**pplication **F**acility on **C**limate **M**onitoring) generates and provides Climate Data Records (CDR's) derived from operational meteorological satellites
- **CLARA** (CM SAF **C**loud, **A**lbedo and **R**adiation data record – **AVHRR**-based) is based on Advanced Very High Resolution Radiometer observations onboard the NOAA and EUMETSAT MetOp satellites
- CLARA Edition 2.1 (**CLARA-A2.1**)
 - temporally extended version of CLARA-A2 (second release)
 - **extension** includes additional 3.5 years: **Jan 2016 – June 2019**
 - total time coverage: Jan 1982 – June 2019



AVHRR GAC data record

- Advanced Very High Resolution Radiometer Global Area Coverage
- Satellites carrying the AVHRR instrument used in the CLARA-A2.1 data record



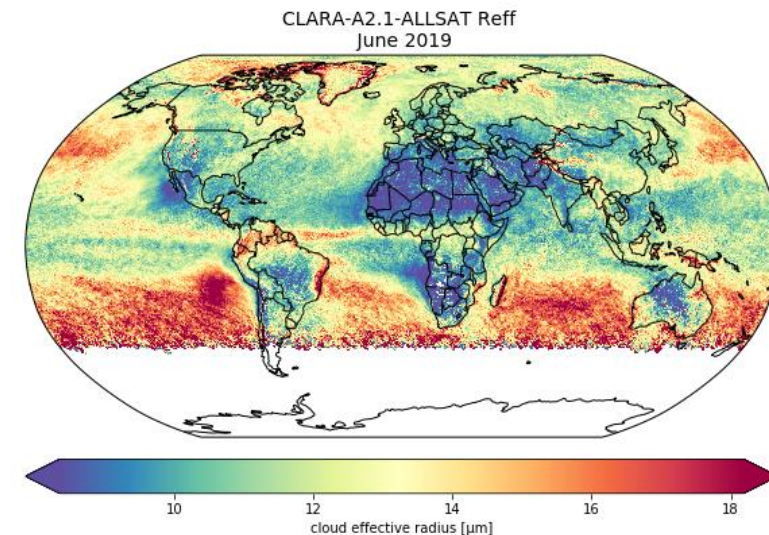
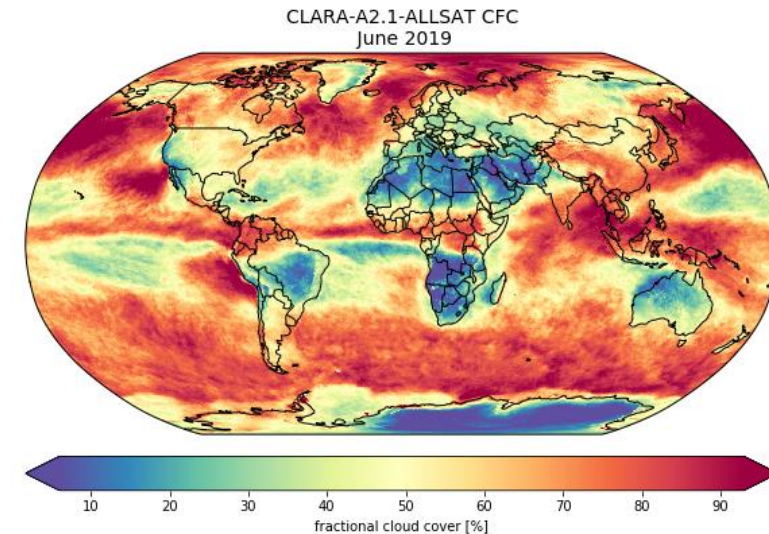
Spectral channels of AVHRR

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

- Metop-B was excluded from the extension (after 2016) due to problems in the re-calibration approach
- No correction of unstable observation times for each satellite

CLARA-A2.1 cloud products

- Fractional Cloud Cover (CFC) →
- Cloud Top level (CTO):
 - Cloud Top Height (CTH)
 - Cloud Top Pressure (CTP)
 - Cloud Top Temperature (CTT)
- Cloud Phase (CPH)
- Joint Cloud property Histogram (JCH)
- Liquid/Ice Water Path (IWP/LWP):
 - cloud optical thickness (COT)
 - cloud water path (IWP/LWP)
 - cloud effective radius (REFF) →



CLARA-A2.1 product levels

Product Level	Level 2b	Level 3
Spatial resolution	0.05°x0.05°	<ul style="list-style-type: none"> • 0.25°x0.25° (global projection) • 25 km x 25km (EASE Grid for polar projection) • 1°x1° (JCH)
Temporal resolution	instantaneous	<ul style="list-style-type: none"> • daily means • monthly means
Product type	global composite	<ul style="list-style-type: none"> • averages • histograms

Validation strategy of CLARA-A2.1 cloud products

- Comparison with well-established data records (e.g., based on CALIOP, MODIS observations)
- Evaluated products: level-2 (instantaneous) and level-3 (monthly mean) data
- Level-3 products should comply with their respective CM SAF's **target requirements**:
 - accuracy
 - precision
 - decadal stability

Product	Accuracy requirement (mean error = bias)	Precision requirement (bias-corrected RMS)	Stability requirement (change per decade)
Cloud Fractional Cover (CFC)	5 % (absolute)	20 % (absolute)	2 % (absolute)
Cloud Top Height (CTH)	800 m	1700 m	200 m
Cloud Top Pressure (CTP)	50 hPa	100 hPa	20 hPa
Cloud Phase (CPH)	10 % (absolute)	20 % (absolute)	2 % (absolute)
Liquid Water Path (LWP)	10 gm ⁻²	20 gm ⁻²	3 gm ⁻²
Ice Water Path (IWP)	20 gm ⁻²	40 gm ⁻²	6 gm ⁻²
Joint Cloud Histogram (JCH)	n/a	n/a	n/a

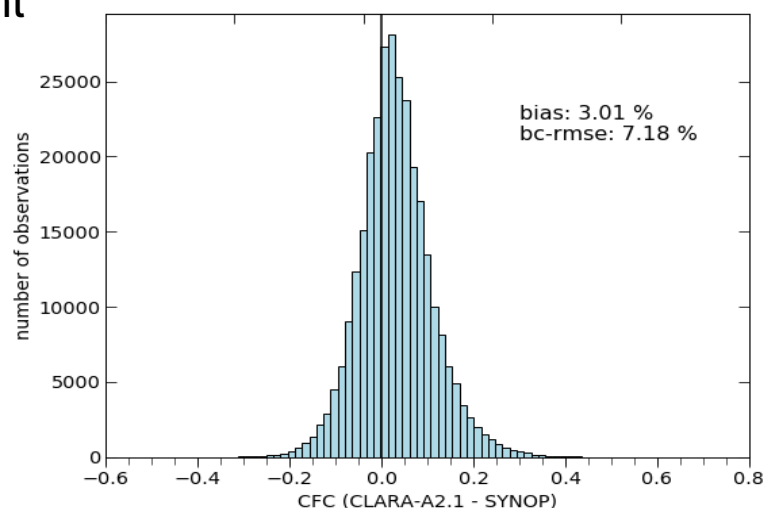
Data Sets for comparison with CLARA-A2.1

- **Independent observations** used for validation
 - manual cloud observations from surface stations (SYNOP)
 - CALIPSO cloud lidar CALIOP
 - space-based lidar+radar DARDAR
 - Microwave-based Multisensor Advanced Climatology of LWP
- **Similar observation data records** used for inter-comparisons
 - NOAA AVHRR Pathfinder Atmospheres – Extended (PATMOS-x)
 - International Satellite Cloud Climatology Project (ISCCP-HGM)
 - Moderate Resolution Imaging Spectroradiometer (MODIS C6.1)
 - Cloud_cci AVHRR-PM data record
- No reference data set fulfils the requirement of complete and homogeneous global and temporal coverage of CLARA-A2.1 (37.5 years) —————> comparison for overlapping time periods
- In this presentation: comparison with data records that are available after 2016! Other comparisons are identical to the validation of CLARA-A2 Cloud Products [[DOI:10.5676/EUM_SAF_CM/CLARA_AVHRR/V002](https://doi.org/10.5676/EUM_SAF_CM/CLARA_AVHRR/V002)]

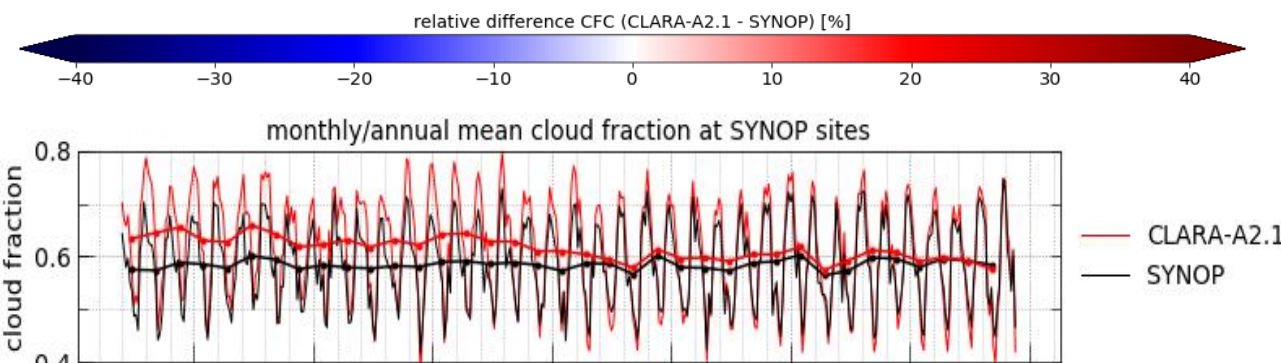
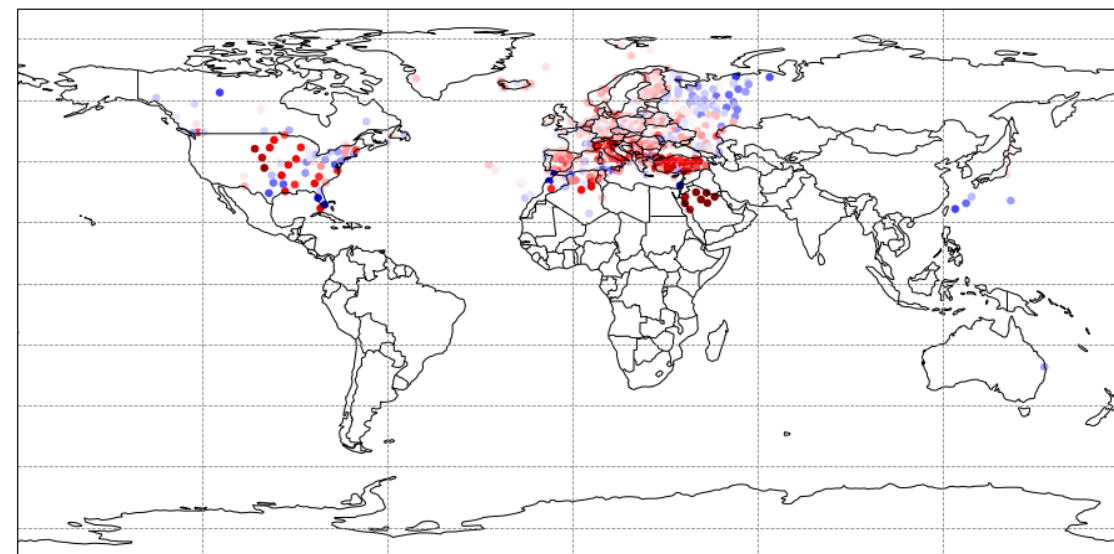
● data sets are available for the extension period after 2016

Validation CFC. SYNOP

- Good agreement: **bias** lies mostly within $\pm 10\%$ cloud amount (~ 1 octa)
- After 2001 the data record shows a **very stable and low bias**, especially for the extension period
- The overall **mean error** remains stable over time and lies at or **within the target accuracy of $\pm 5\%$** cloud amount



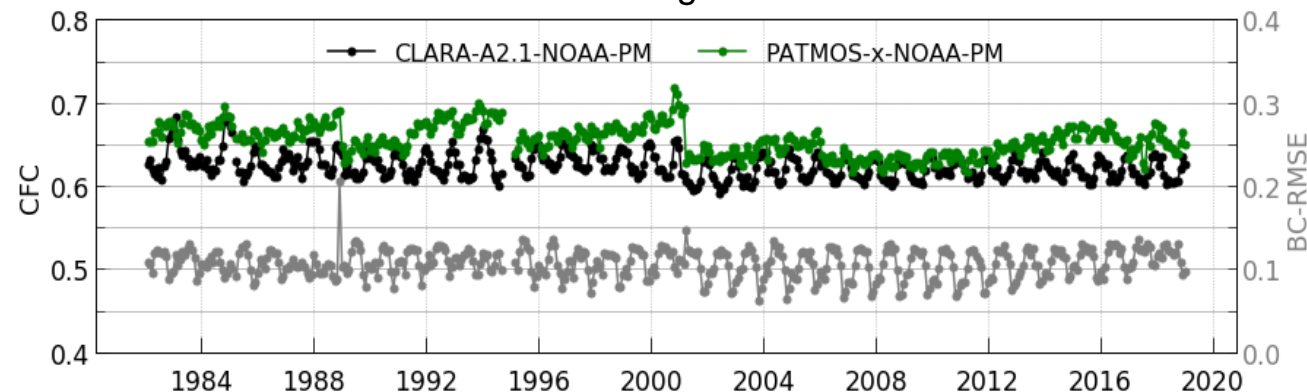
SYNOP sites used for evaluation



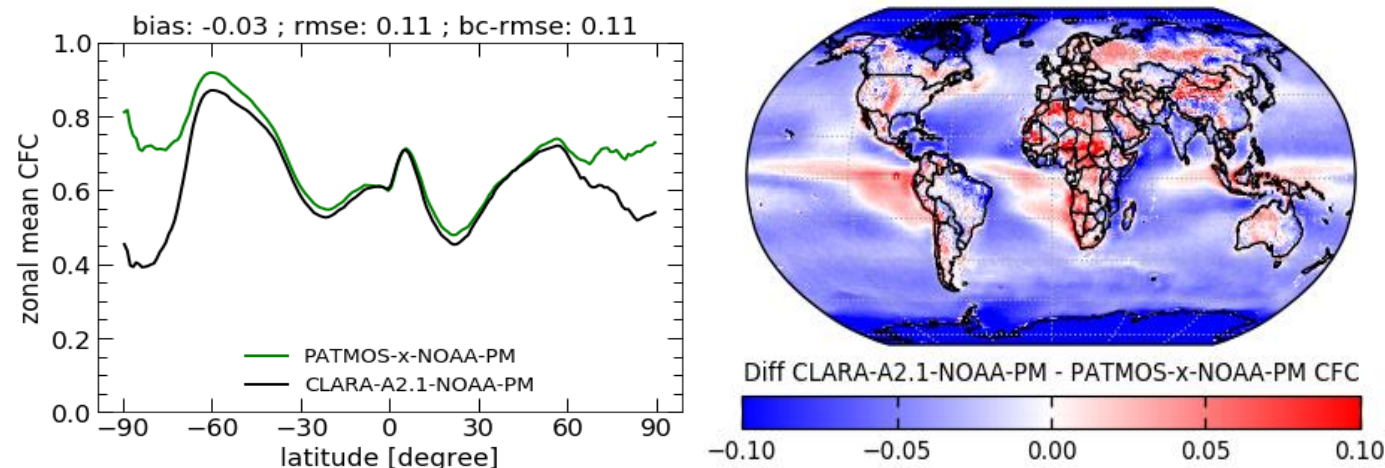
Validation CFC. PATMOS-x 1982-2018

- Periodical increases in CFC coincidence with satellite **orbital drift**. CLARA shows **more stable time series**
- **Low bias** for the global mean, but regionally larger deviations that balance each other
- **Positive deviation** patterns over land, **negative deviations** near the poles
- Target requirement for accuracy are fulfilled, mean bias < 5%

time series of global mean

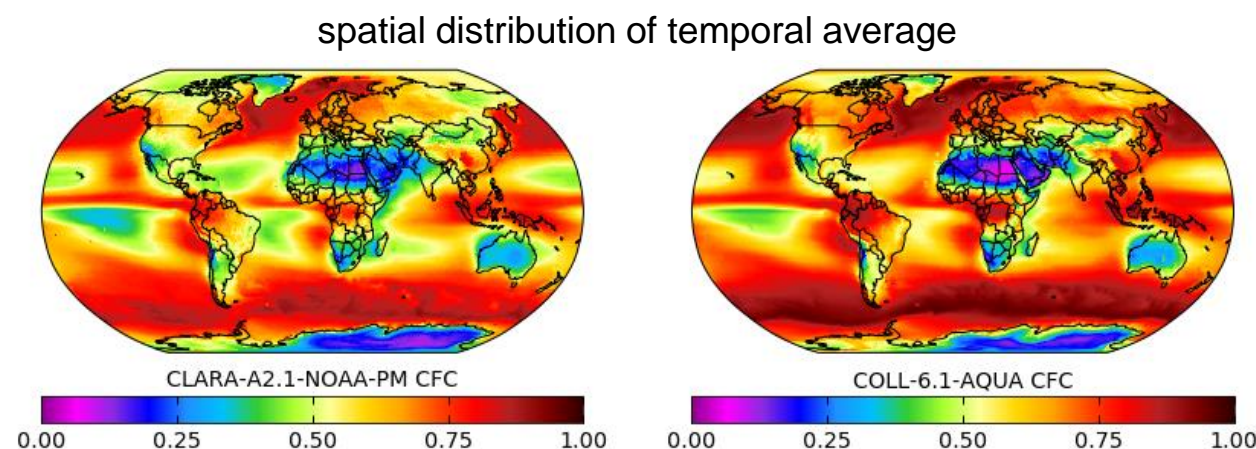
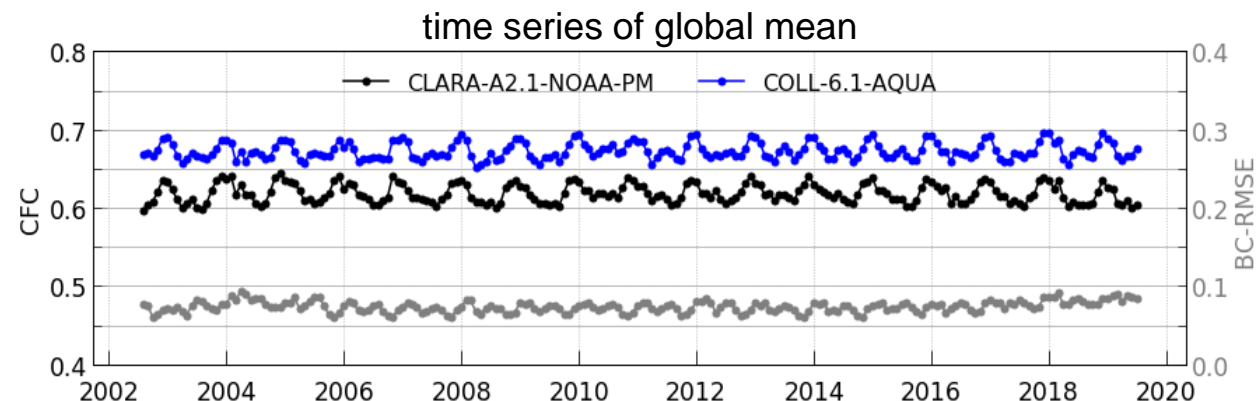


spatial distribution of temporal average



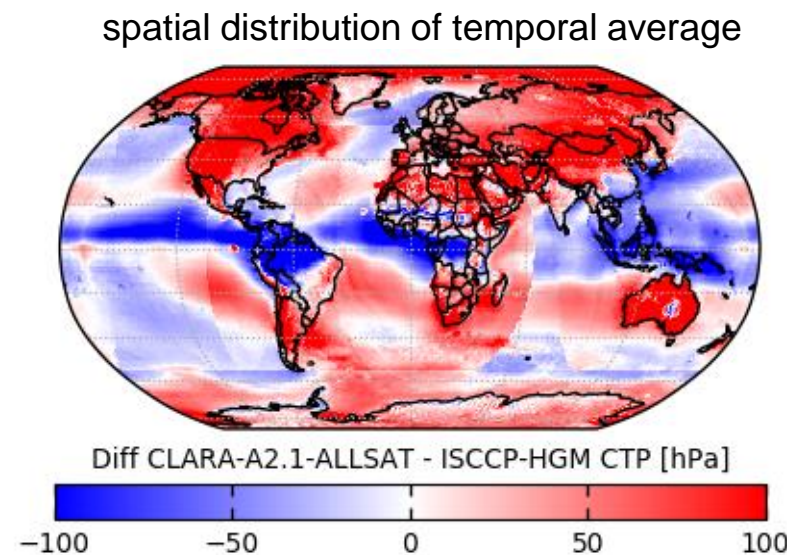
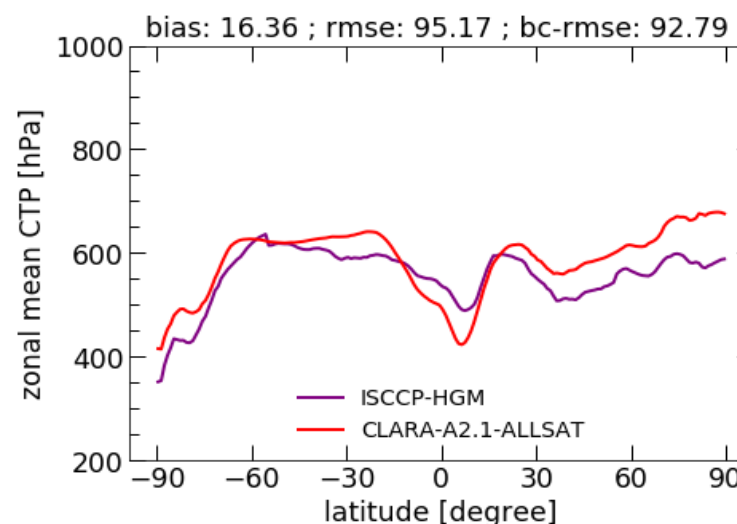
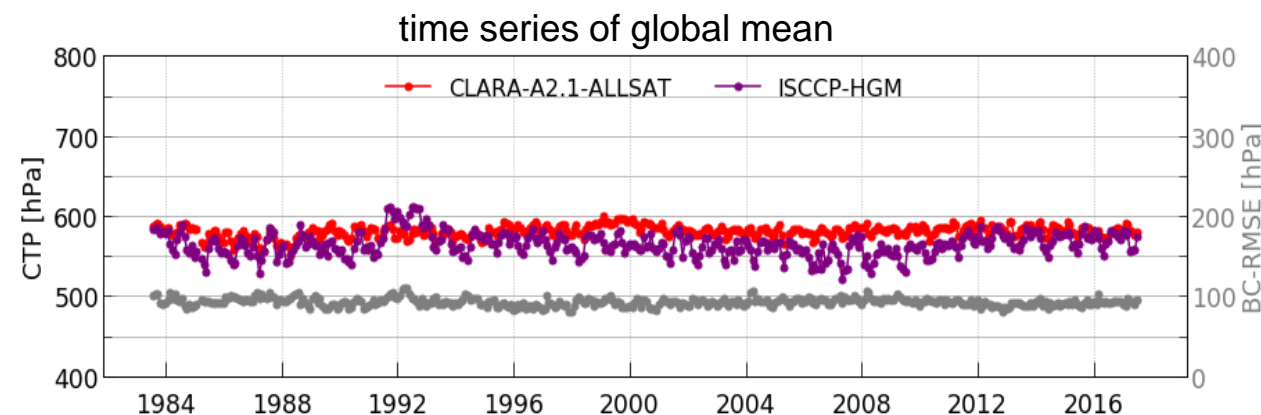
Validation CFC. MODIS-Aqua Collection 6.1 2002-2019

- **Stable negative bias:** MODIS data are supposed to give a better cloud detection capability
- **Small bc-RMSE** indicates a very good agreement with MODIS data
- Target requirements for the bc-RMSE are fulfilled
- **CLARA overestimates** CFC over deserts areas
- The comparison with AQUA and TERRA look similar



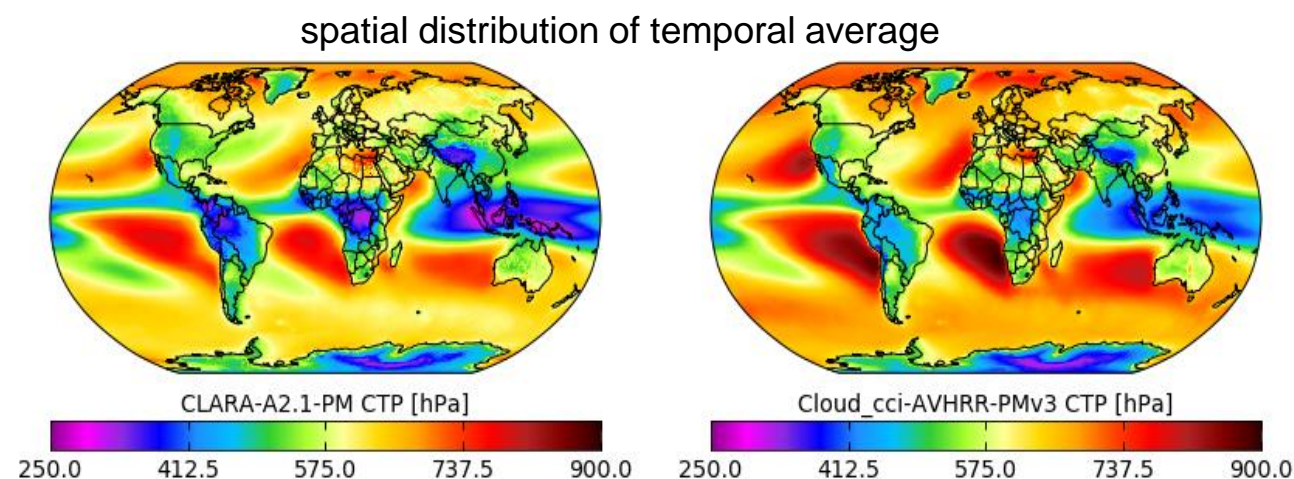
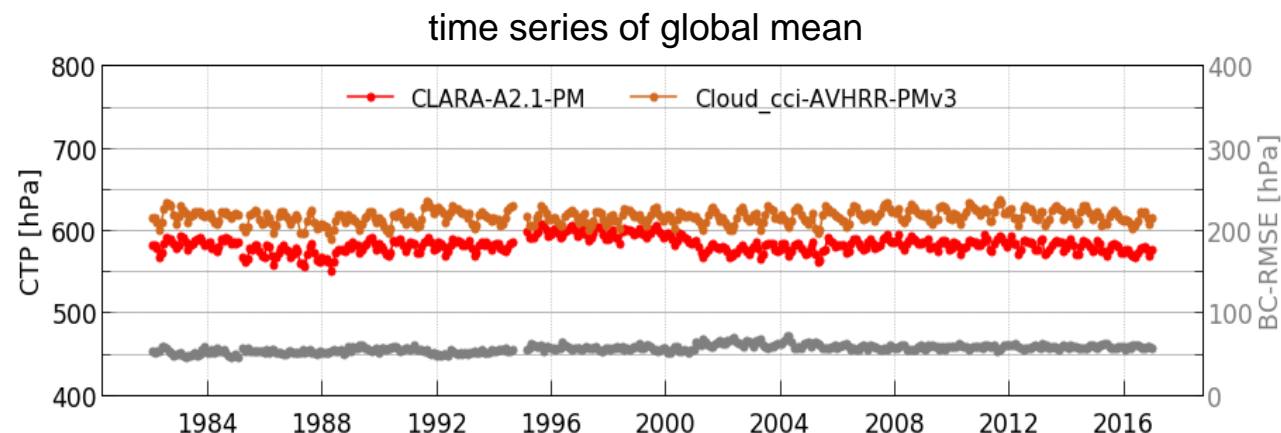
Validation CTP. ISCCP-H 1983-2017

- **Good agreement** between both datasets for the extended period
- **Magnitude** of each data record **deviates** within a region, especially zonally
- **Low mean bias** (16hPa) and **stable bc-RMSE**
- Target requirements are fulfilled
- Discontinuities in the difference plot over oceans complicate the comparison



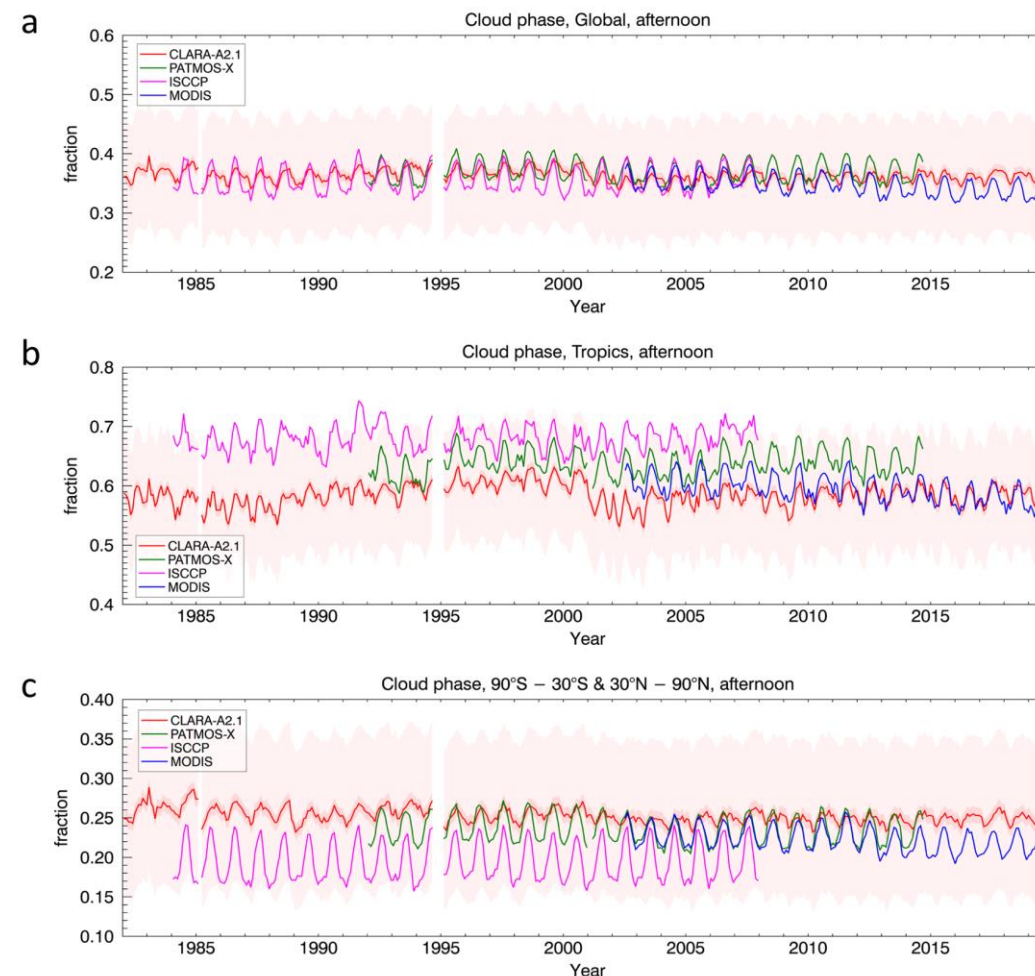
Validation CTP. Cloud_cci AVHRR-PMv3 1982 to 2016

- **New data record** for intercomparison
- Both data sets used the **data from the same instruments**
- CLARA CTP shows **the lowest bc-RMSE** against Cloud_cci-AVHRR-PMv3 compared to other reference datasets
- Stable bias during the extension
- General **underestimation** of CLARA cloud top pressure
- **Larger deviation** over marine stratocumulus regions
- Bc-RMSE is within the optimal requirement of 80 hPa. For bias the target requirement of 50hPa is fulfilled.



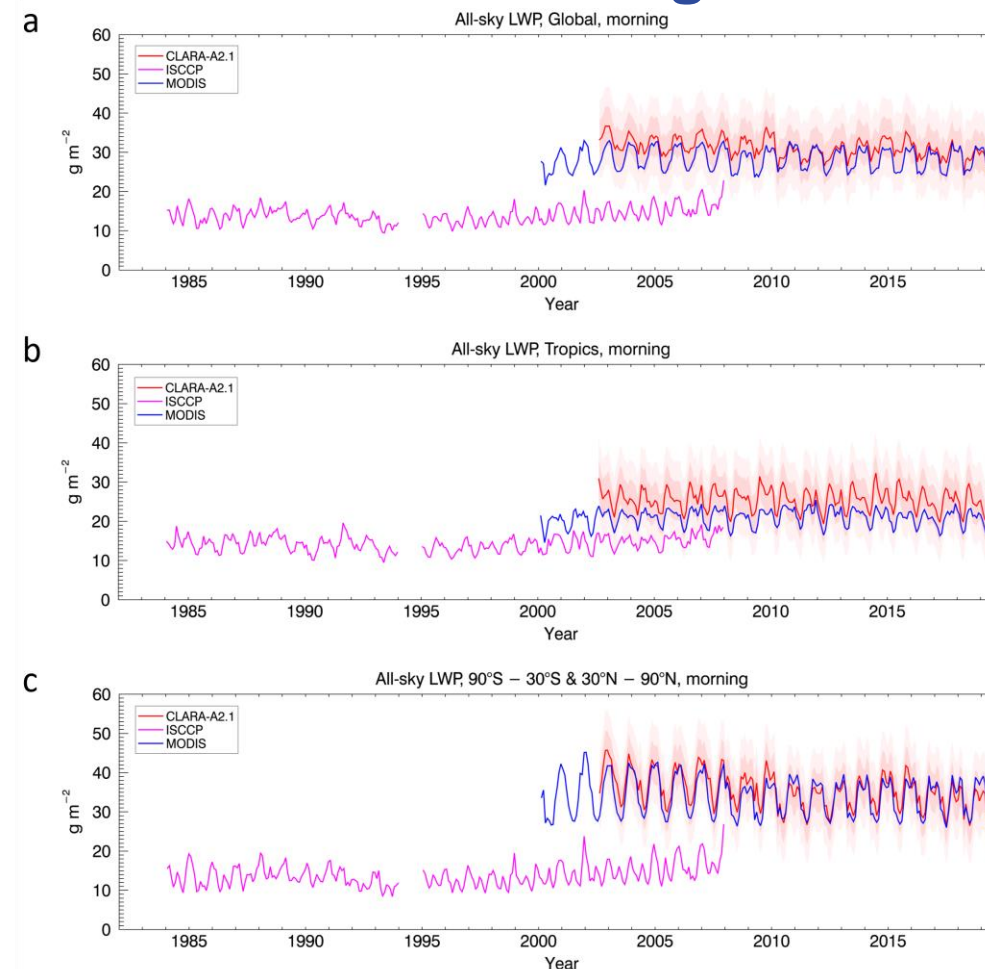
Validation CPH. PATMOS-x, MODIS-Aqua and ISCCP afternoon satellites

- The globally averaged time series analysis of CPH reveals a **very good agreement between** all data sets
- **No discontinuities at the start of the extension** in January 2016
- Corresponding **biases are within the target threshold**, except for the ISCCP CPH estimated over the tropics (b)
- **Discrepancies** in the CPH seasonal cycle appear **outside of the tropics** (c)



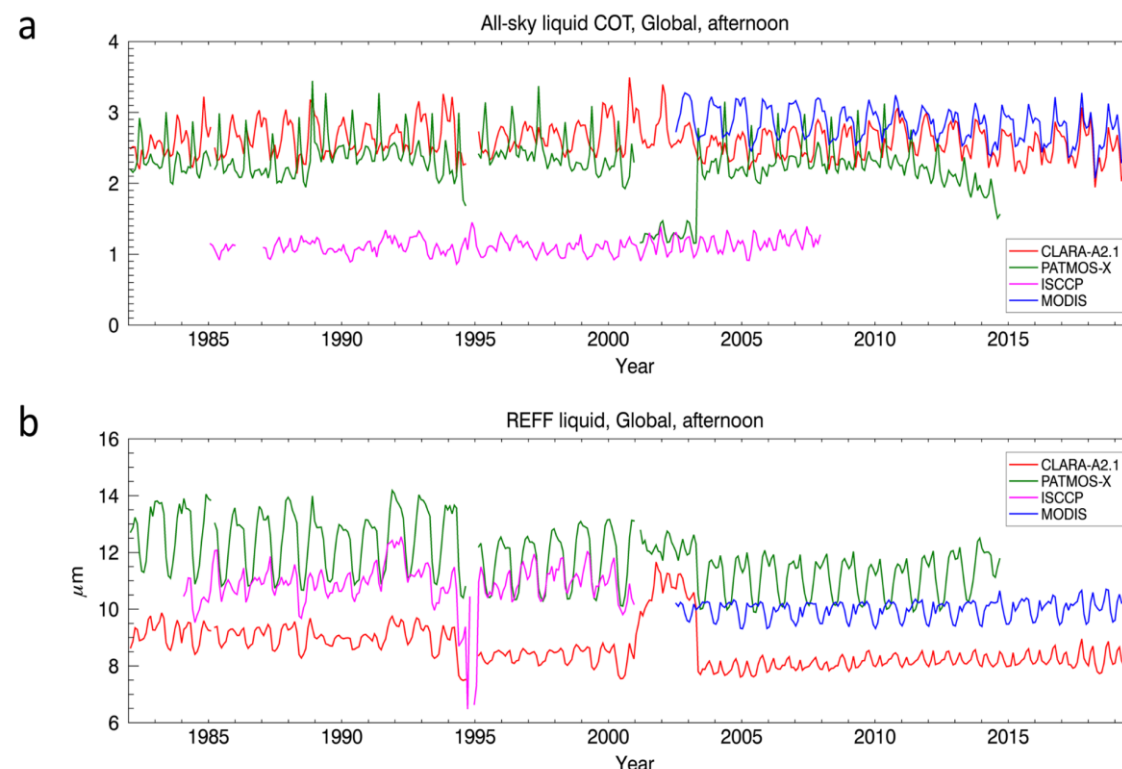
Validation LWP. PATMOS-x, MODIS-Terra and ISCCP morning satellites

- The time series of CLARA global and tropical mean LWP remain **stable over the extended period**
- **Slight decrease in LWP** at the onset of the extension period (January 2016) may be related to adjustments in the calibration coefficients of METOP-A
- **CLARA and MODIS are in very good agreement** in all latitudes



Validation COT/ R_{eff} . PATMOS-x, MODIS-Aqua and ISCCP afternoon satellites

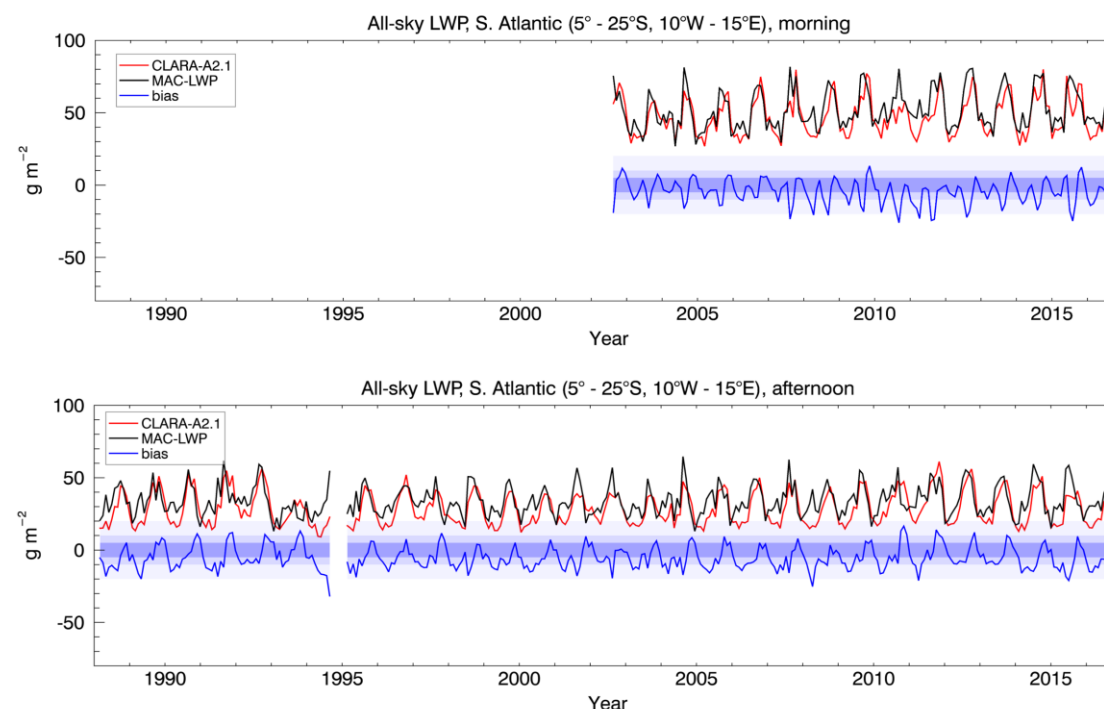
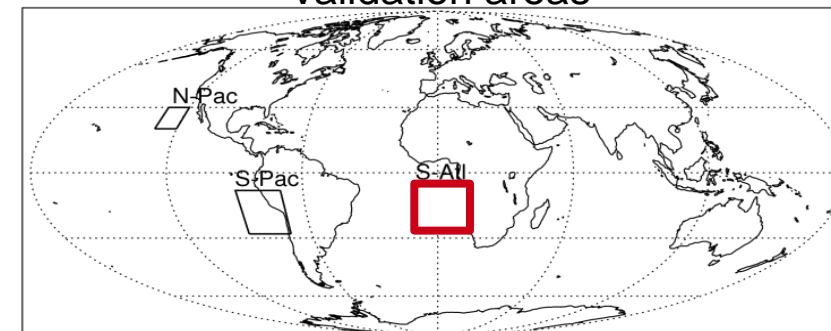
- Liquid COT and R_{eff} are **used for the computation of LWP**
- **COT**
 - similar to LWP
 - **good agreement of CLARA with MODIS**
 - **decline** in CLARA at the end of its time series
- R_{eff}
 - systematically **lower values** in CLARA
 - **increase in 2001-2003** as a result of the different shortwave infrared channel being used.



Validation LWP. MAC-LWP 1988-2016

- **Microwave instruments** measure the LWP at lower altitudes → **stratocumulus** areas for validation
- Data records **correlate well**
- **Bias** fluctuations are **not exceeding the threshold limit** (light blue shading)
- **Morning LWP** is consistently **higher** than in the afternoon: thinning of stratocumulus decks during daytime is well captured

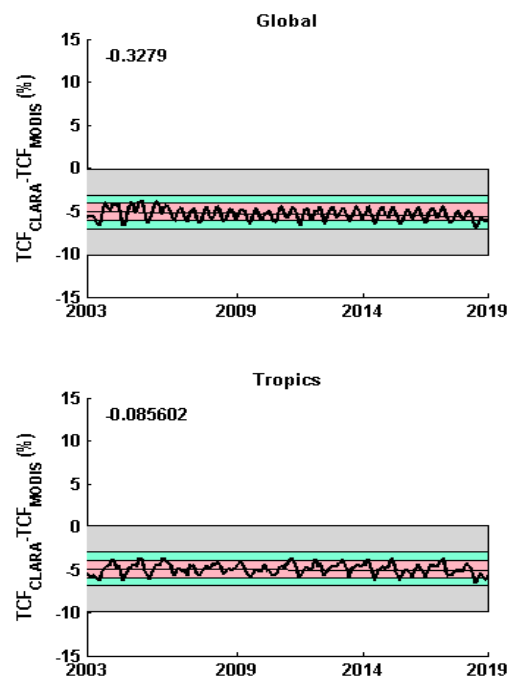
Validation areas



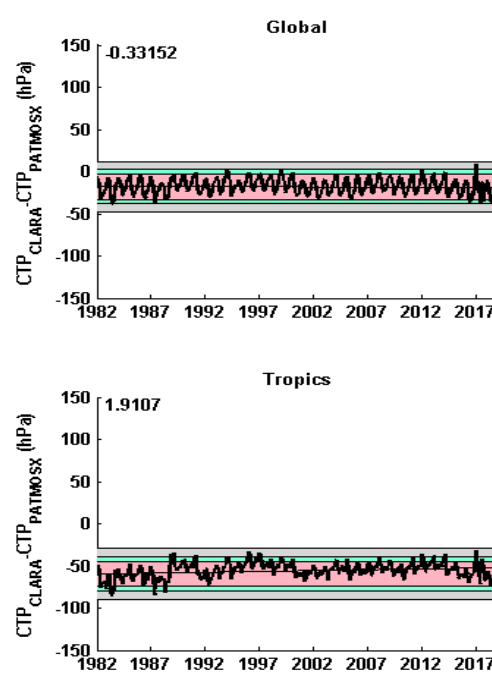
Validation. Decadal stability

- Decadal stability = temporal variation of the bias
- The decadal stability gives information on the stability of the data record, any unnatural trends

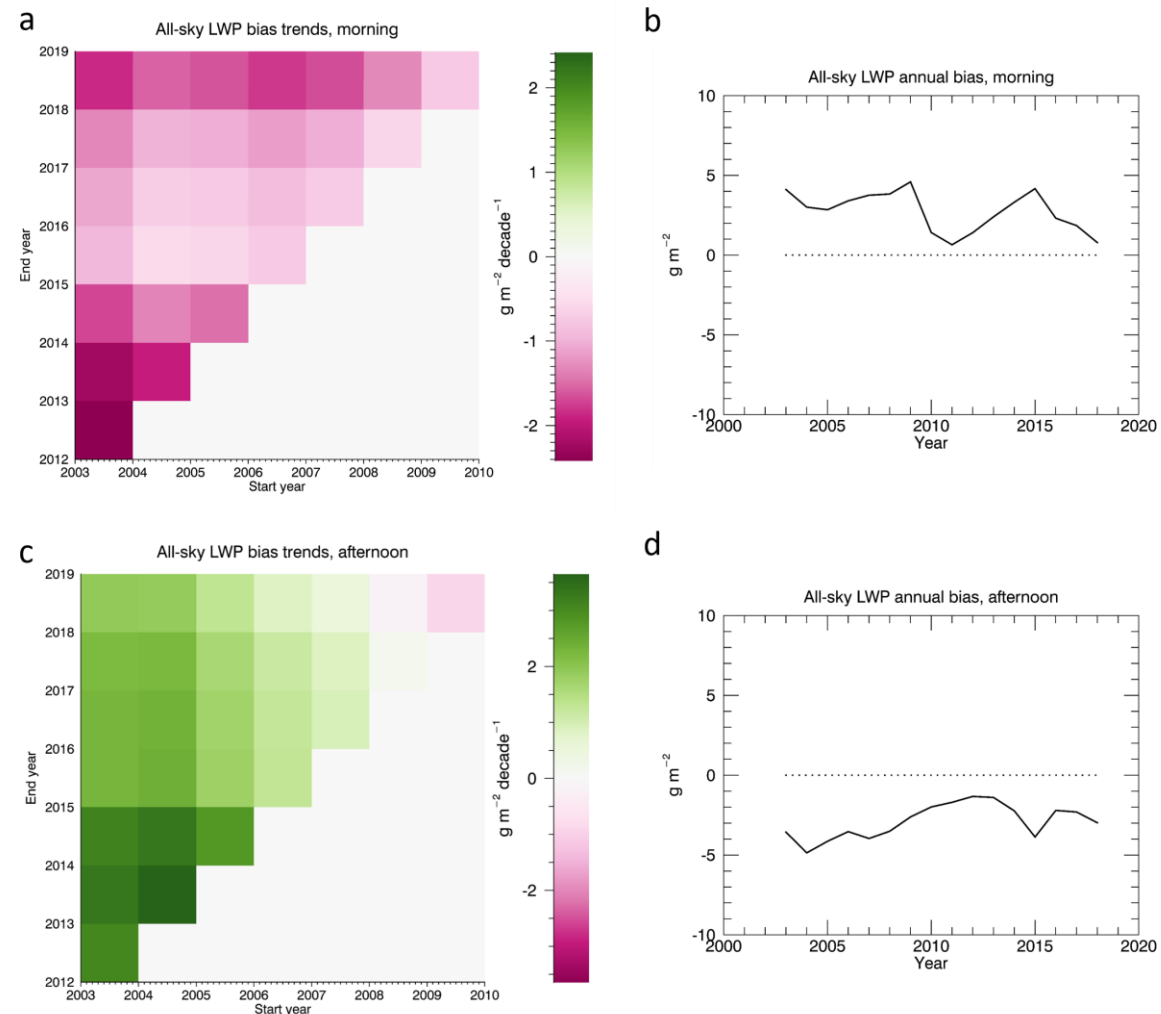
CFC MODIS



CTP PATMOS-x



LWP MODIS



Validation Summary

- An extensive validation of cloud products from the CLARA Edition 2.1
- Comparisons with completely independent observation sources (SYNOP, CALIPSO-CALIOP, SSM/I and AMSR-E) as well as with similar satellite-based data records from passive visible and infrared imagery (MODIS, ISCCP, PATMOS-x, Cloud_cci)
- The time series of CLARA-A2.1 cloud parameters do not show large discontinuities at the start of the extension in January 2016
- CFC, CTP and CTH stay stable over extended part of the data record
- Small decrease in LWP and IWP and an increase in daytime CPH in the afternoon satellite time series during the extended period. These changes are probably related to adjustments in the calibration coefficients and satellites orbital drift.

Why should I use CLARA cloud products?

- There are several satellite-based climate data records available providing similar information. The **value of the CM SAF data record** is:
 - Cf. MODIS: much longer record (37.5 years vs. 16 years)
 - Cf. ISCCP: more homogeneous (no GEO used) and more spectral channels used
 - Cf. PATMOS-x: good to have two similar data records produced with different algorithms to identify strengths /weaknesses of both approaches
 - Cf. CALIPSO, SSM-I, MAC-LWP: different measurement principles, different variables measured, longer time frame
- Cloud products will soon be available in a **near-real-time mode** as CLARA Interim Climate Data Record (ICDR)

Contact

- Getting the data: <https://wui.cmsaf.eu> (soon)
- Contact us: contact.cmsaf@dwd.de

