Cloud CCI: Generation of Optimal Estimation based, Multi Sensor Cloud Property data set.

R. Hollmann[1], M. Stengel, S. Stapelberg, M. Jerg and the Cloud CCI consortium

[1]Deutscher Wetterdienst

ESA‘ Climate Change Initiative (CCI)

- Set up in response to GCOS: 14 different ECV’s from the land, atmospheric and oceanic domain are covered
- provide long-term coherent data sets including uncertainty estimates reaching the GCOS requirements
- Maximize the utilisation of European Earth Observation missions for Climate data sets
- Exploit the synergic capabilities of different European and US Earth observation missions
- Includes aspects of producing a **CDR**: data acquisition, calibration, algorithm development, validation, maintenance and provision of the data to the climate research community
- Establish a science driven system environment

(Hollmann et al. BAMS, 2013)

What's a CDR?

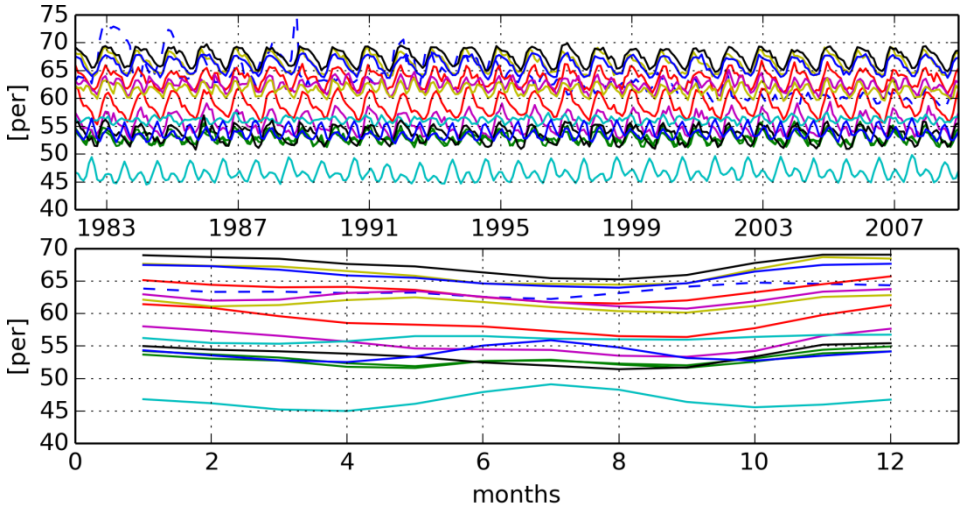
- Climate data record =
  time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change (NRC, 2000)

Transparent	Open accountable in every aspect
Sustainable	Potential for long-term maintenance
Preserved	Secure in perpetuity
Extensible	Forward compatibility in accommodating new data from existing or new instruments
Accessible	Easy obtainable, affordable and understandable
Scientifically defensible	Based on testable hypotheses and methodologies that have been peer reviewed
Continuously assessed/improved	Evaluated on a schedule basis, possibility to incorporate better/improved methods
Reproducible	Producing consistent results within machine rounding errors

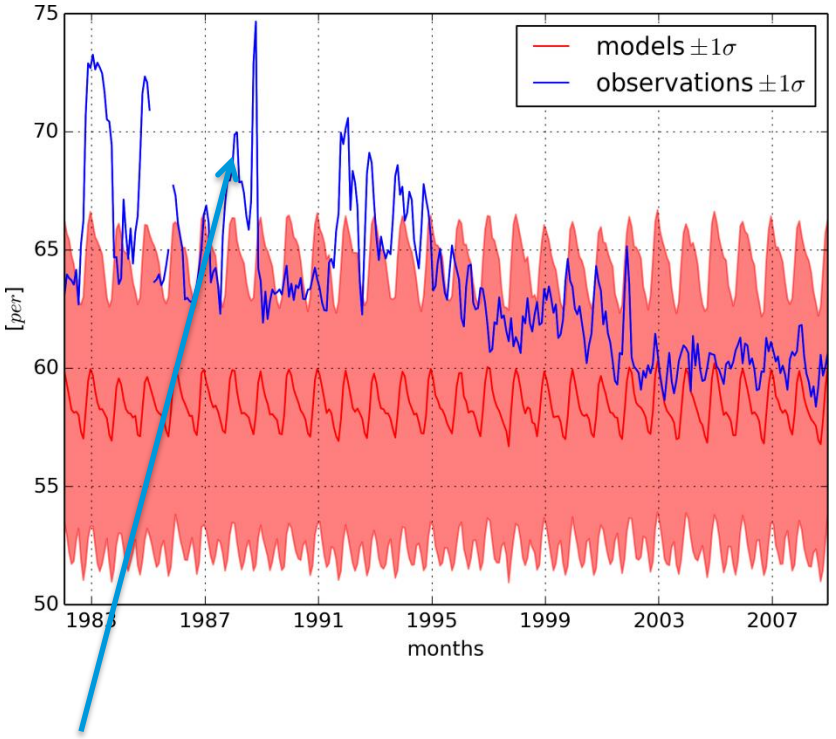
Why still clouds?

Example from CMIP5 Evaluation:

Global mean Cloud Fraction



14 different CMIP5 models
1 Satellite cloud climatology (dashed line)
monthly means vs time (top)
Mean Annual cycle (bottom)



Example Satellite data

Note: preliminary investigation A. Löw, M. Itkin, MPI Hamburg Do not distribute!

Cloud CCI Objectives

Development of inter-calibrated radiance data sets - for ESA and non-ESA instruments in an international collaboration

Development of an Community Optimal Estimation Cloud Retrieval for Climate (CC4CL)

Generation of 2 consistent global prototype data sets for cloud property including uncertainty estimates based on inter-calibrated radiances from:

1) AVHRR, MODIS (AVHRR heritage channels), AATSR
2) Combined AATSR + MERIS measurements ("FAME-C")

CCI PHASE I (2010-2013): first version, 3 year (2007-2009) time series of both data set ("demonstrator")

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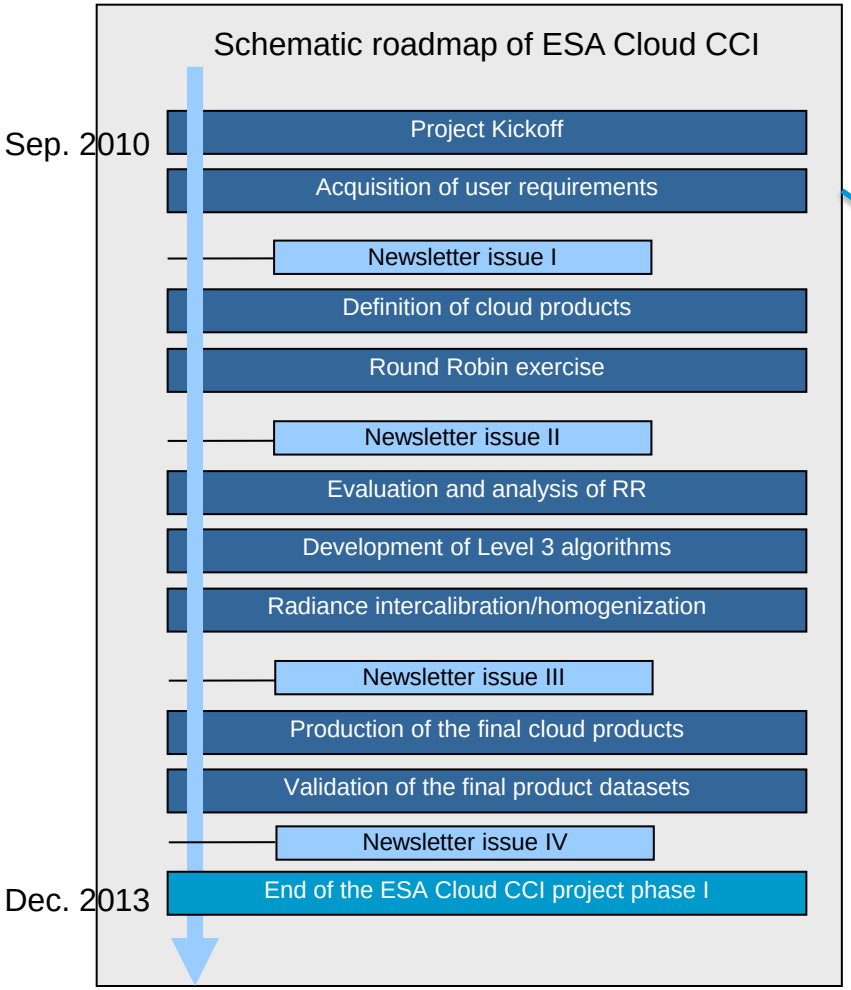
(CCI PHASE II (2014-2016): reprocessing and generating longer time series (1982 to 2012, 2002-2012) FUTURE)

Cloud_cci: the roadmap

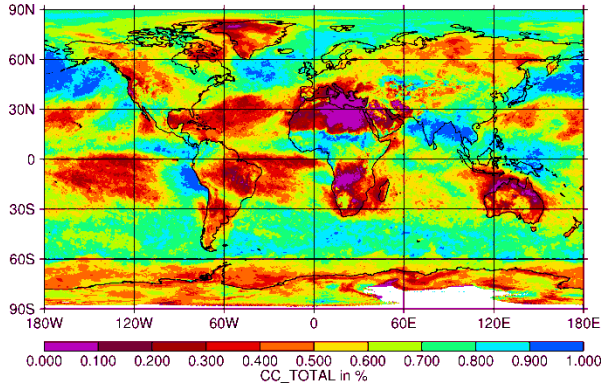


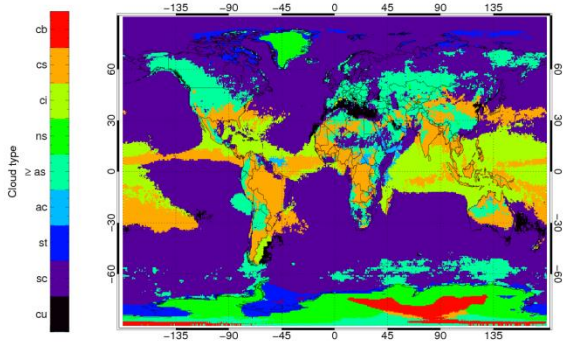
	GCOS requirement
Cloud variable	**Goal, B/T,Thres**
Cloud cover	10, 15, 20%
Cloud top height	0.5, 1, 2 km
Cloud water path	10,20,50 g/m2
Cloud water path (liquid only)	10,15,20 g/m2

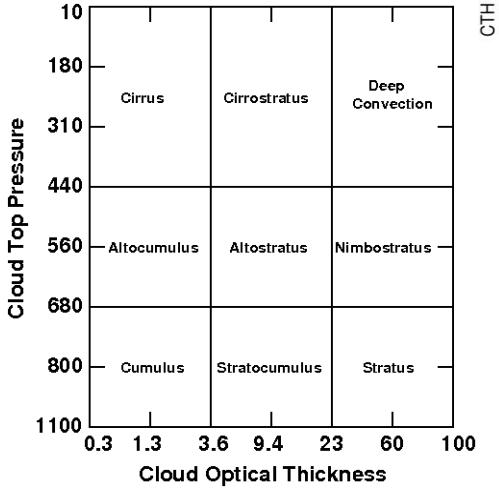
Cloud CCI Products

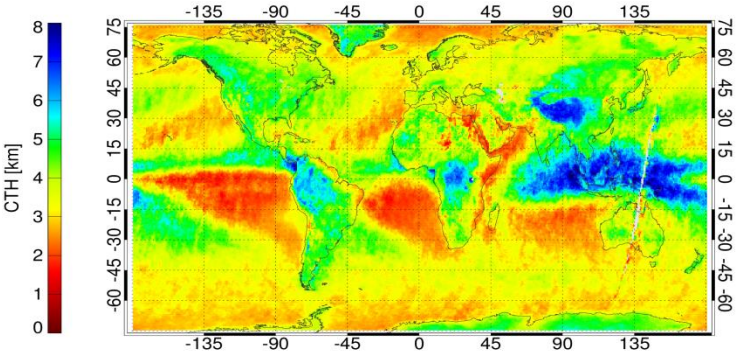
Product suite covers COT, CTP, REF, CPH, CWP, Cma (ECV cloud)

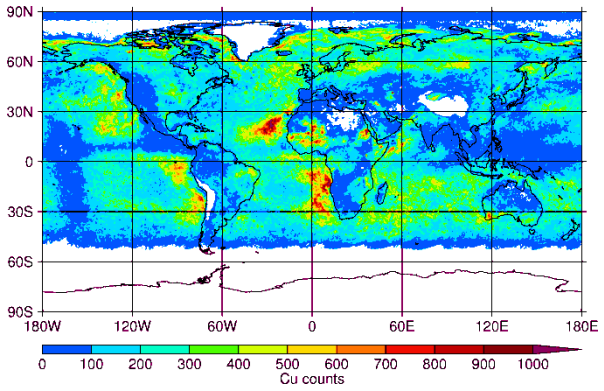
- L2: pixel based results including uncertainty estimates.
- L3U: 0.1 deg. daily L2 composite.
- L3C/S: monthly 0.5 deg. Av., St. Dev.,Median incl. uncert. est., 2D COT-CTP Histograms.



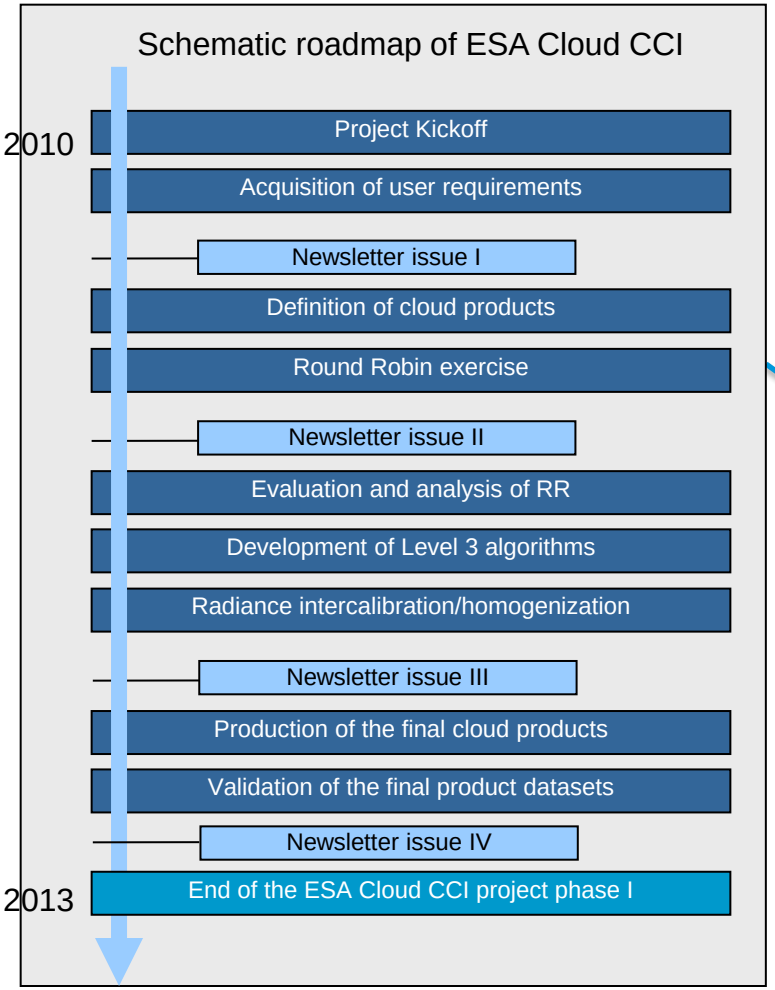


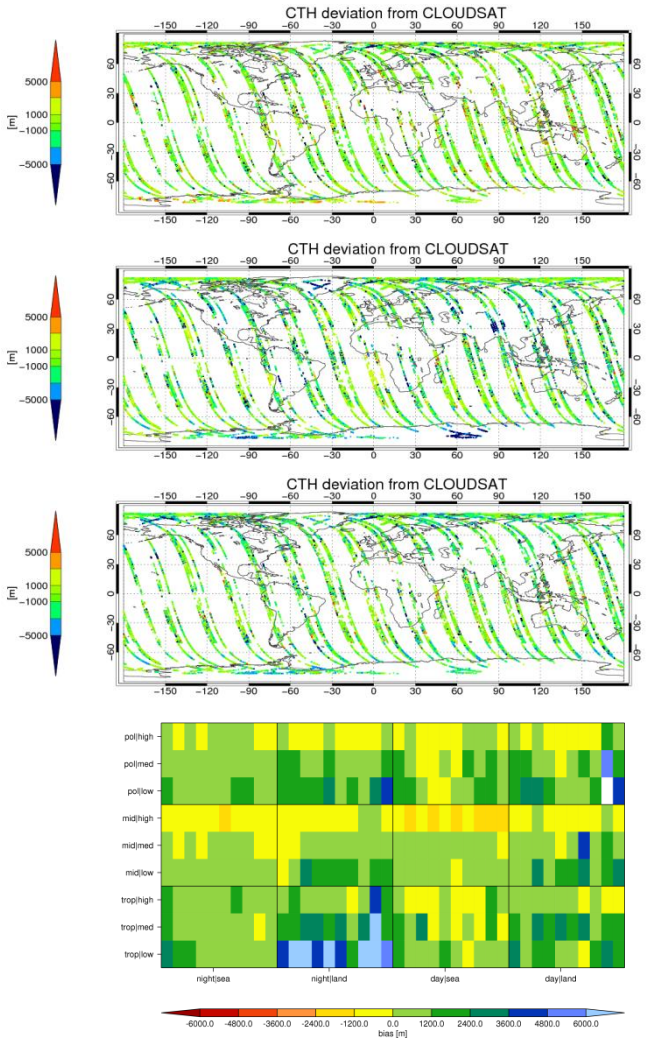






Cloud_cci: the roadmap

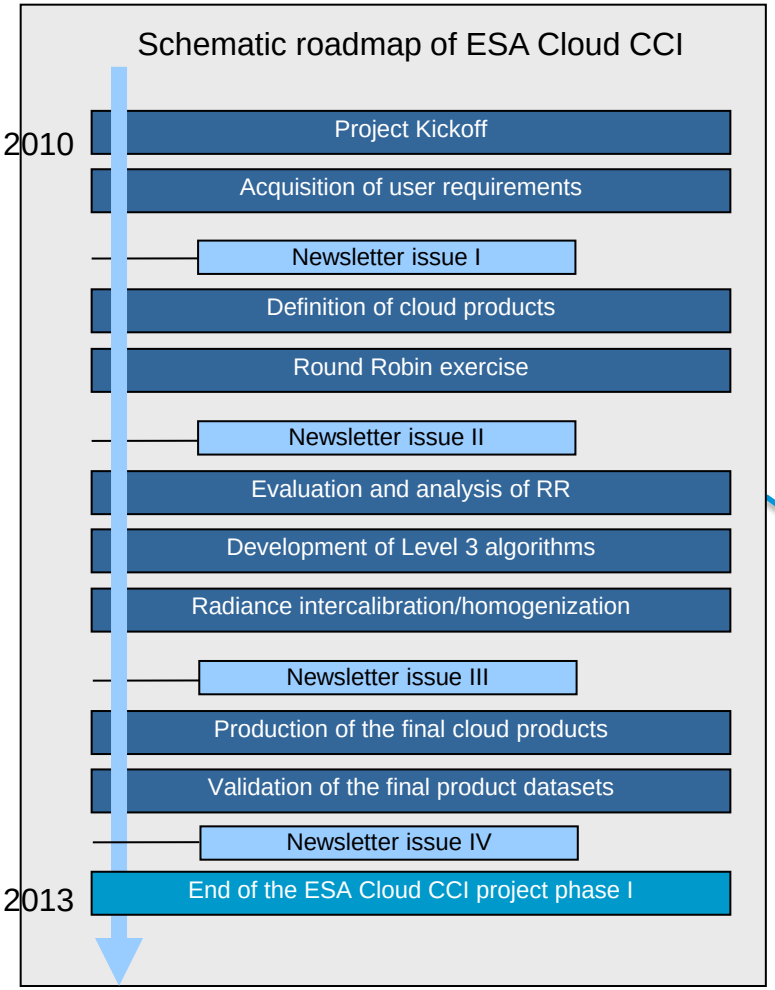


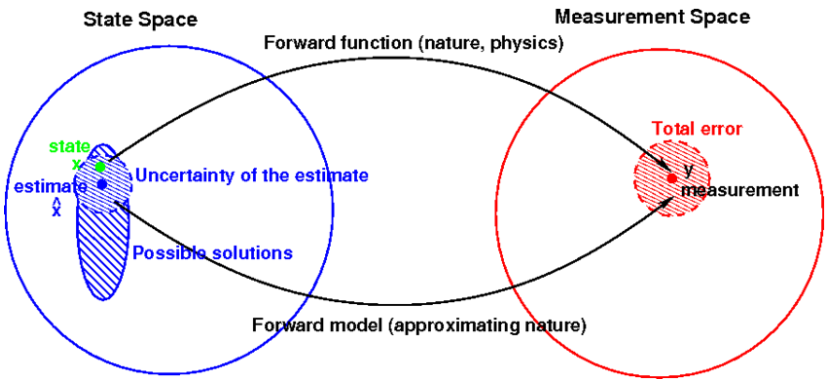


Spatial patters of differences (CTH) for 3 algorithms.

Performance Figure of algorithm

Cloud_cci: the roadmap



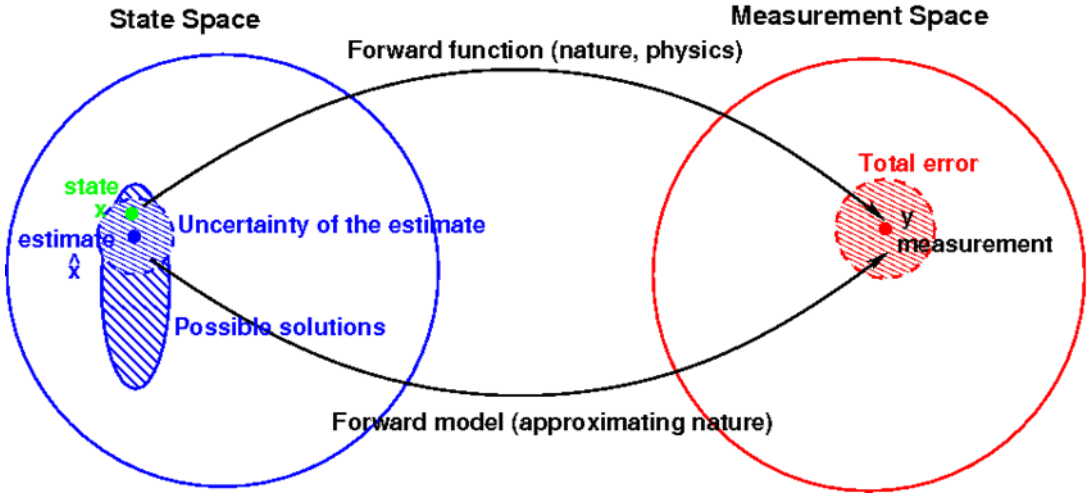


Selection of an OE retrieval (ORAC);
Implementation, adaptation, extension to CC4CL.
Community optimal estimate **C**loud retrieval **4** **CL**imate

OE Community Retrieval (CC4CL)

Main advantages of the community retrieval based on optimal estimation algorithm:

+ Consistency (sensors, channels)
+ Simultaneity (state space parameters)
+ Uncertainty (derived for state space parameters)
+ Flexibility (additional sensors, number of channels)
– High computational costs
– Depend critically on calibration/intercalibration of radiances
? Propagation of level 2 uncertainties to level 3



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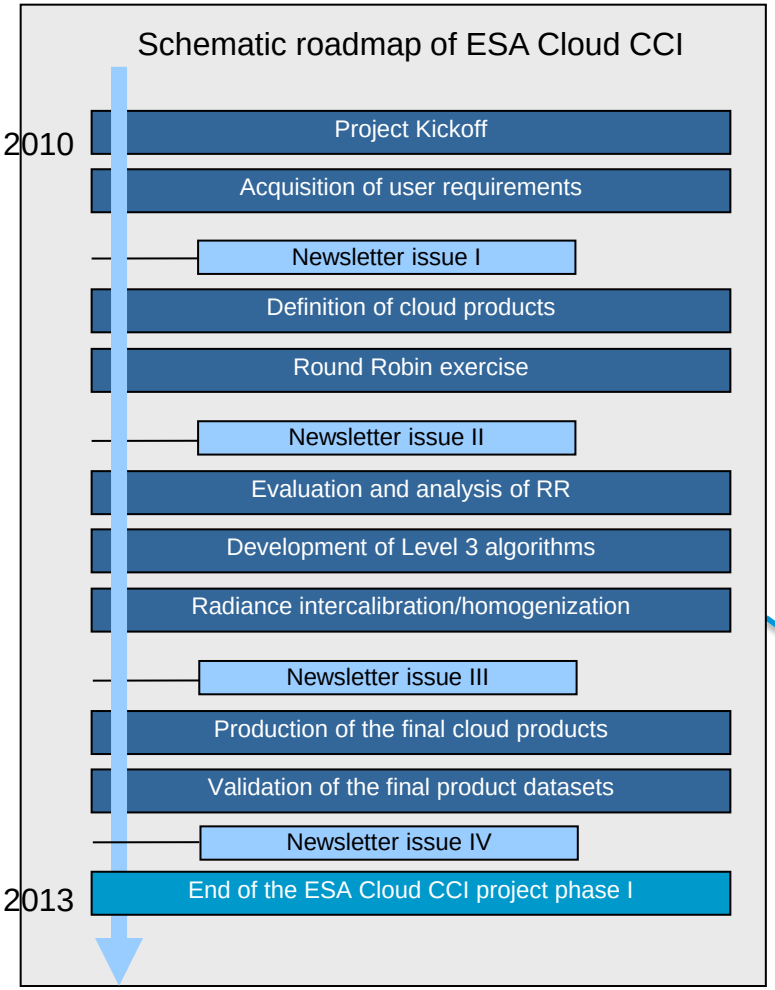
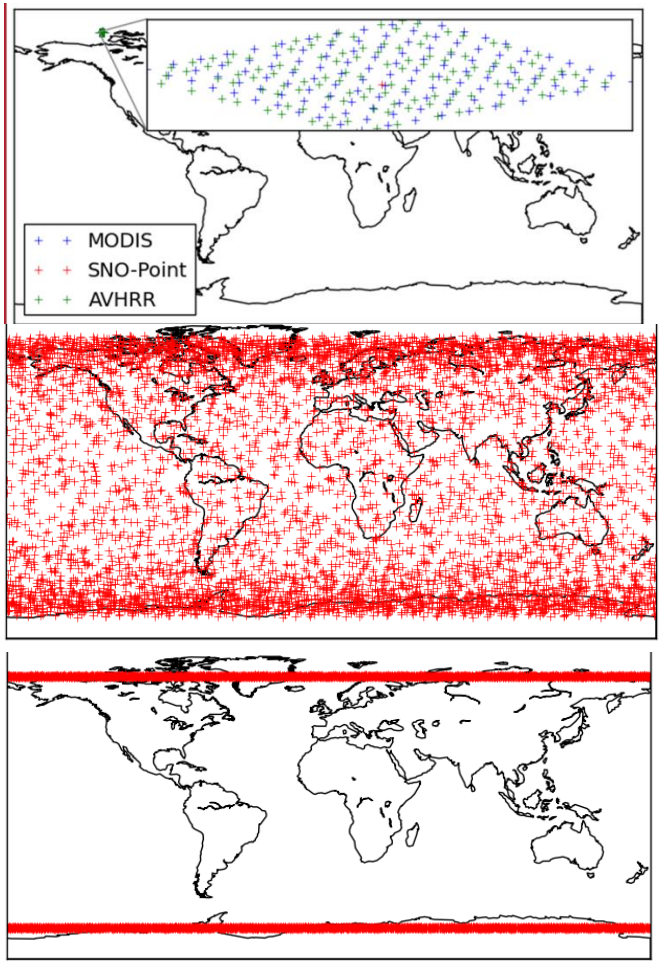
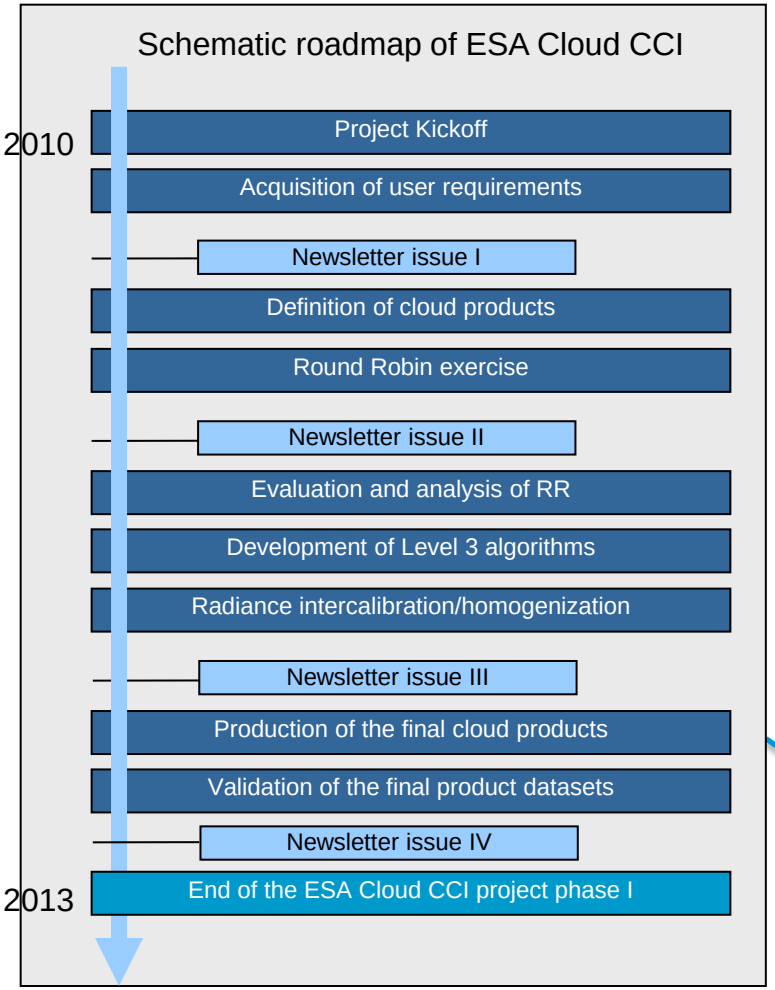
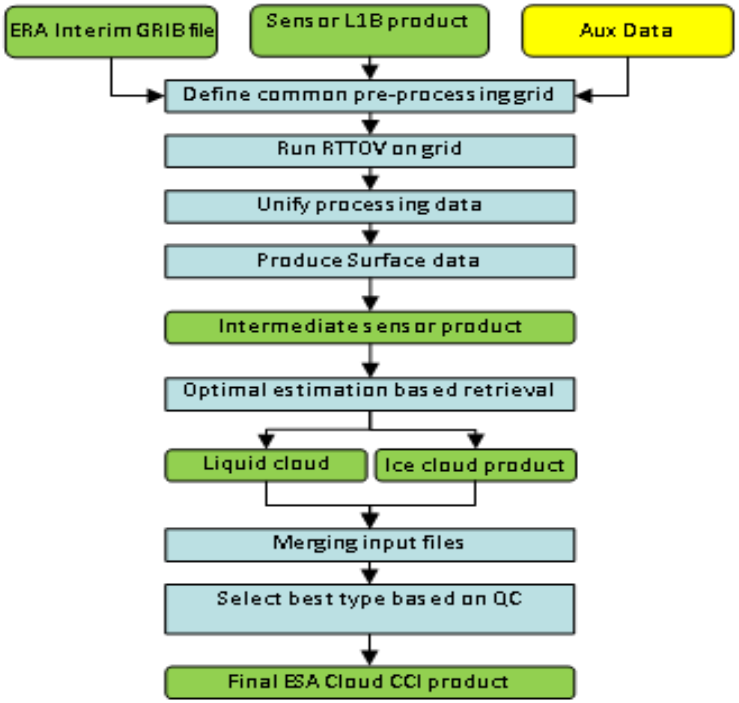




Simulataneous Overpass technique to match Level-1 radiances between AVHRR-MODIS-AATSR-MERIS

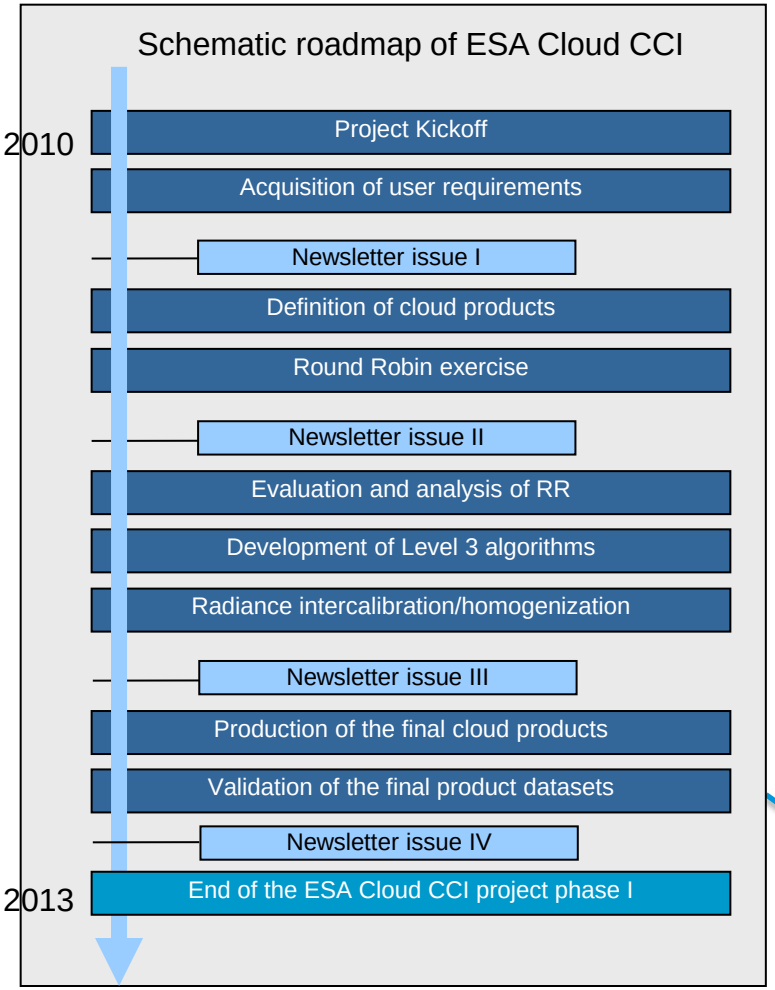
Cloud_cci: the roadmap

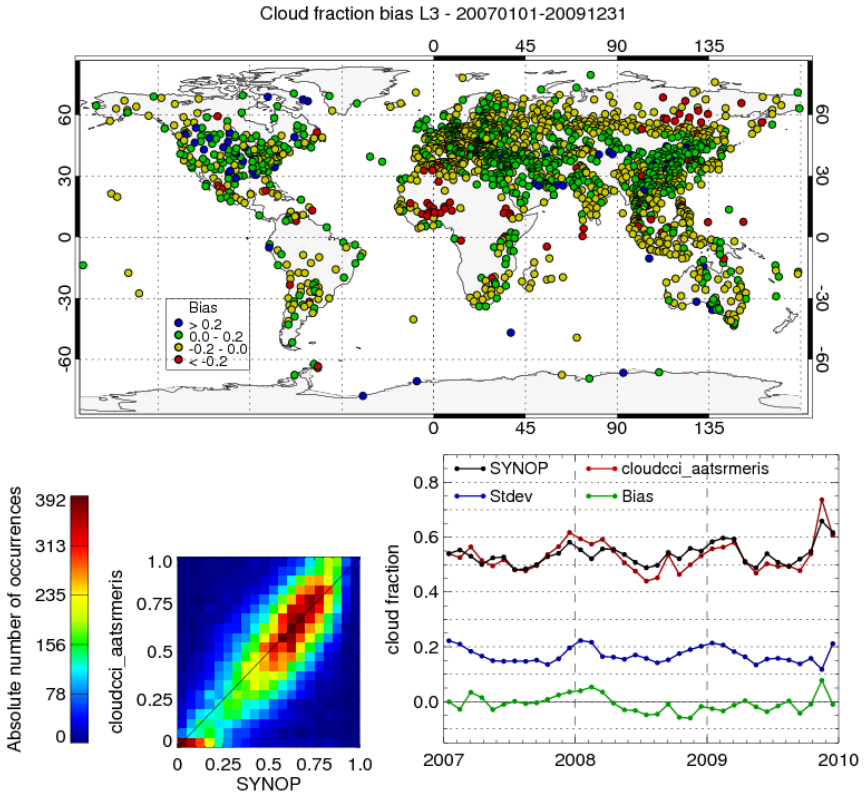




Set-up of end-to-end prototype Production system
Processing of two 3-year data sets (2007-2009)

Cloud_cci: the roadmap





Validation for Cloud Fraction
FAME-c (AATSR/MERIS) - Synop

Comparison studies

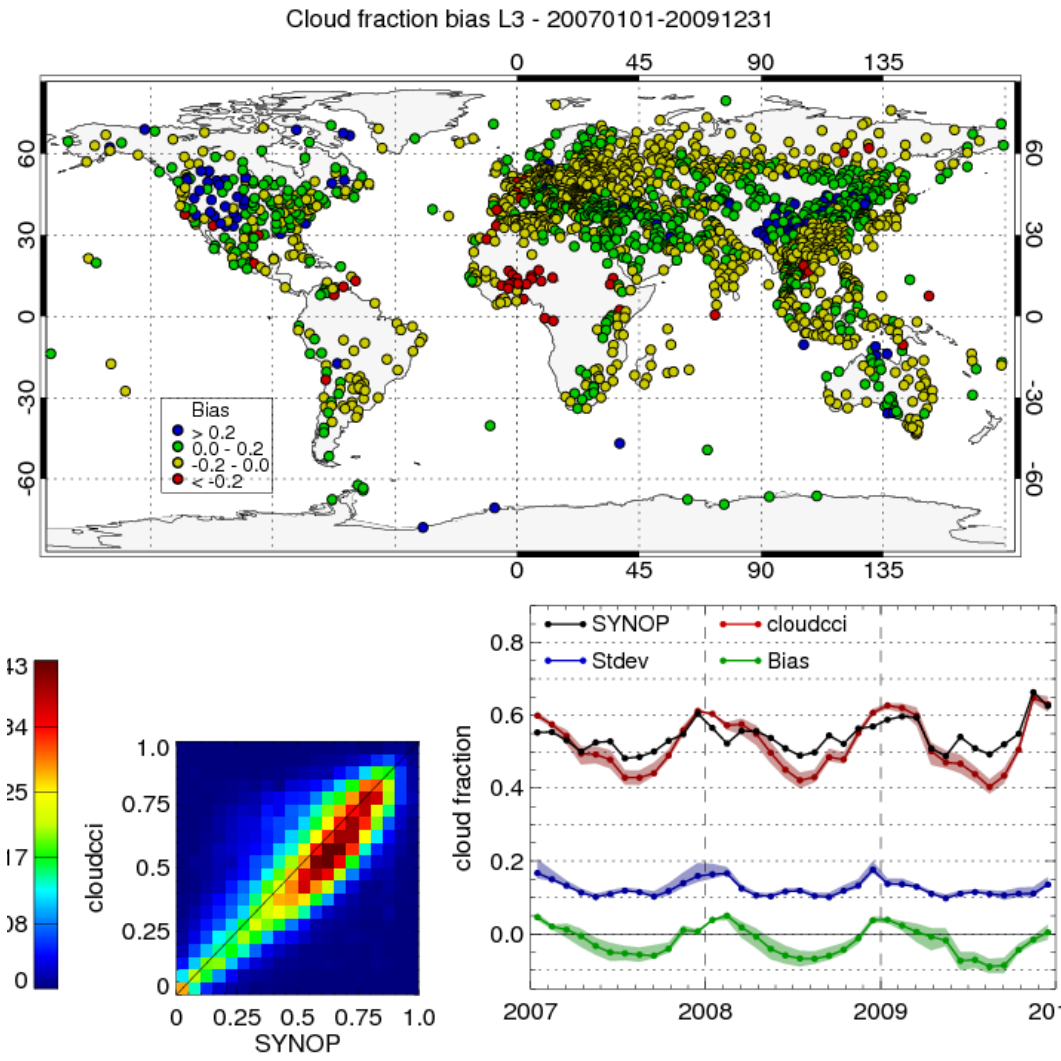
- References:
  - Ground based observations (ARM, Cloudnet, Synoptical Stations)
  - Established Satellite based Climatologies (ISCCP, MODIS Coll5, CM SAF CLARA A1, PATMOS, etc.).

- Following Examples:
  - L3S combined AVHRR product
  - Against Synop stations
  - Time period : 2007-2009
  - Parameter : Cloud Fraction range [0-1]

Validation Cloud fraction: AVHRR

Example for Cloud Fraction
CCI L3S vs SYNOP

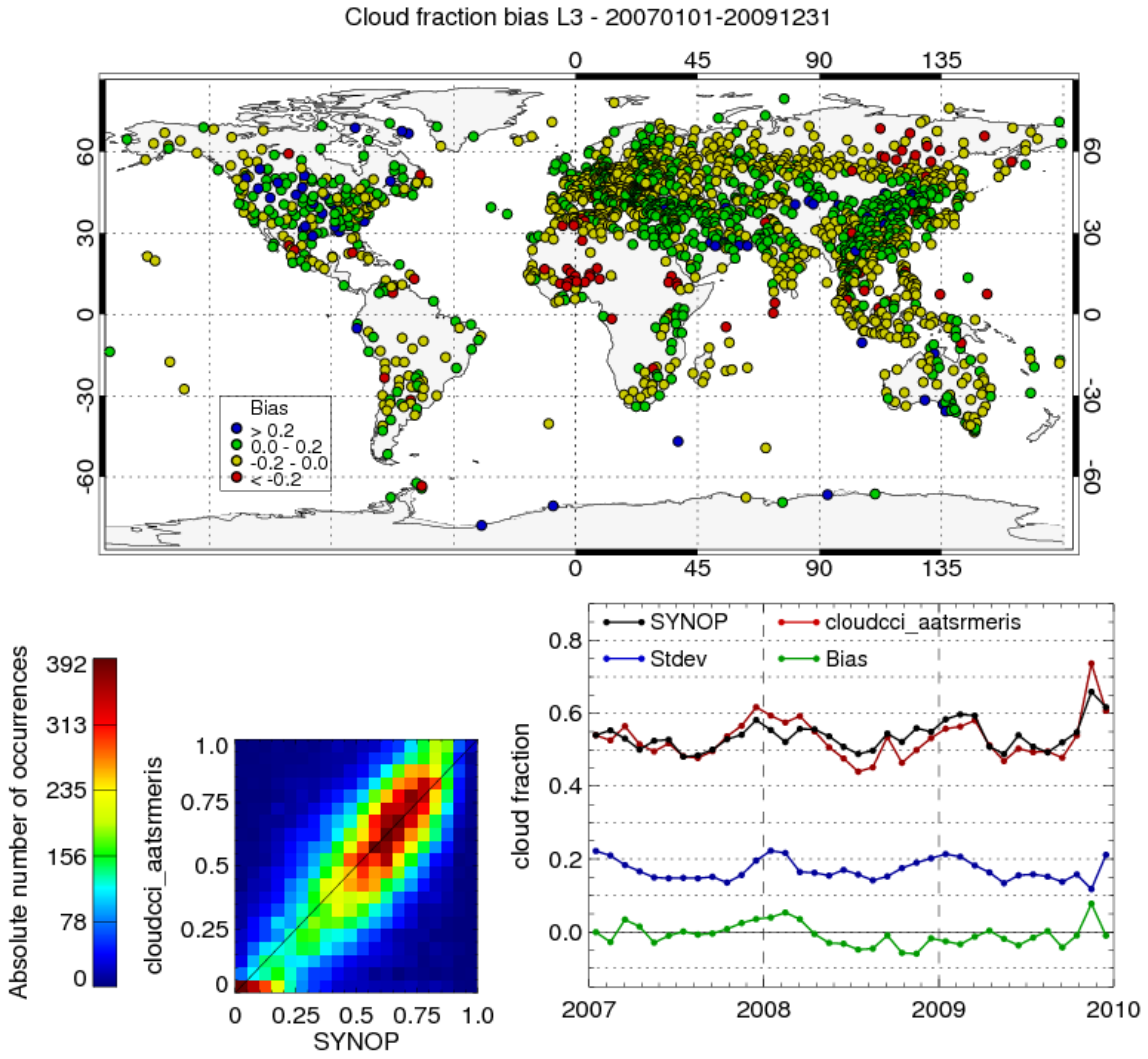
(AVHRR; Noaa-15,16,17,18) - Synop



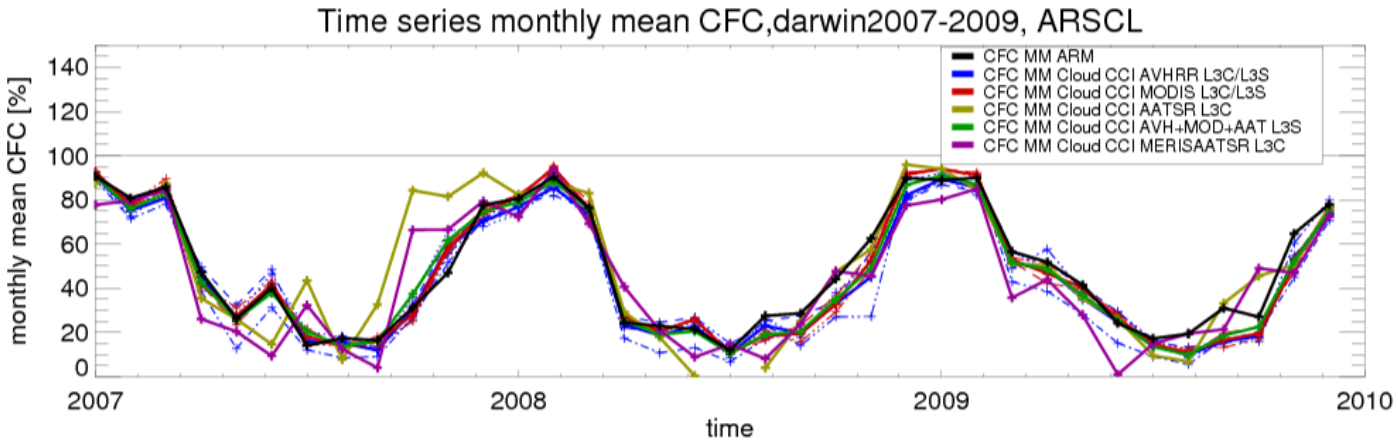
Validation against SYNOP: FAME-C

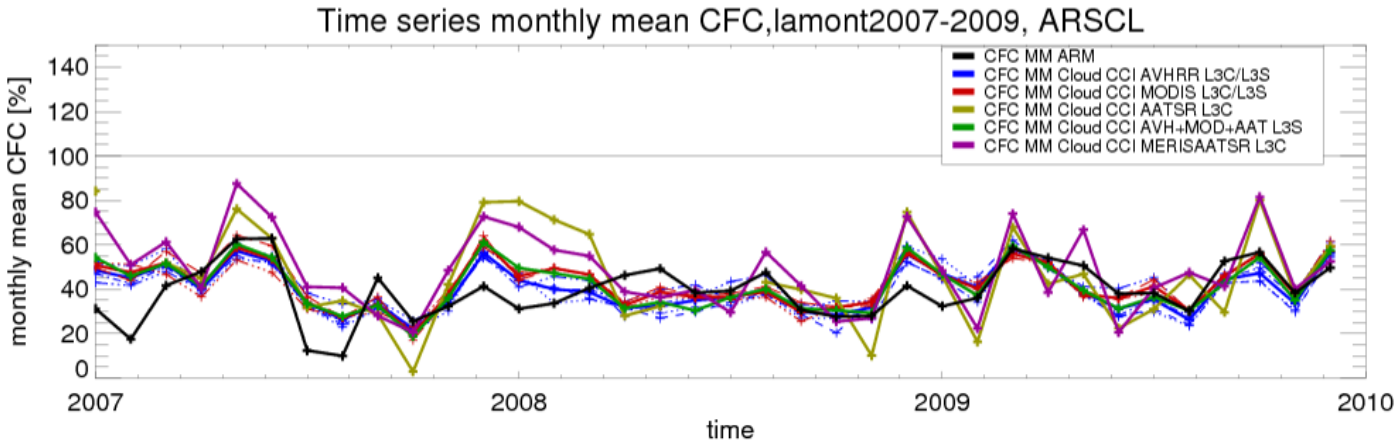
Example for Cloud Fraction FAME-c vs SYNOP

AATSR/MERIS - Synop



Cloud_cci vs ARM



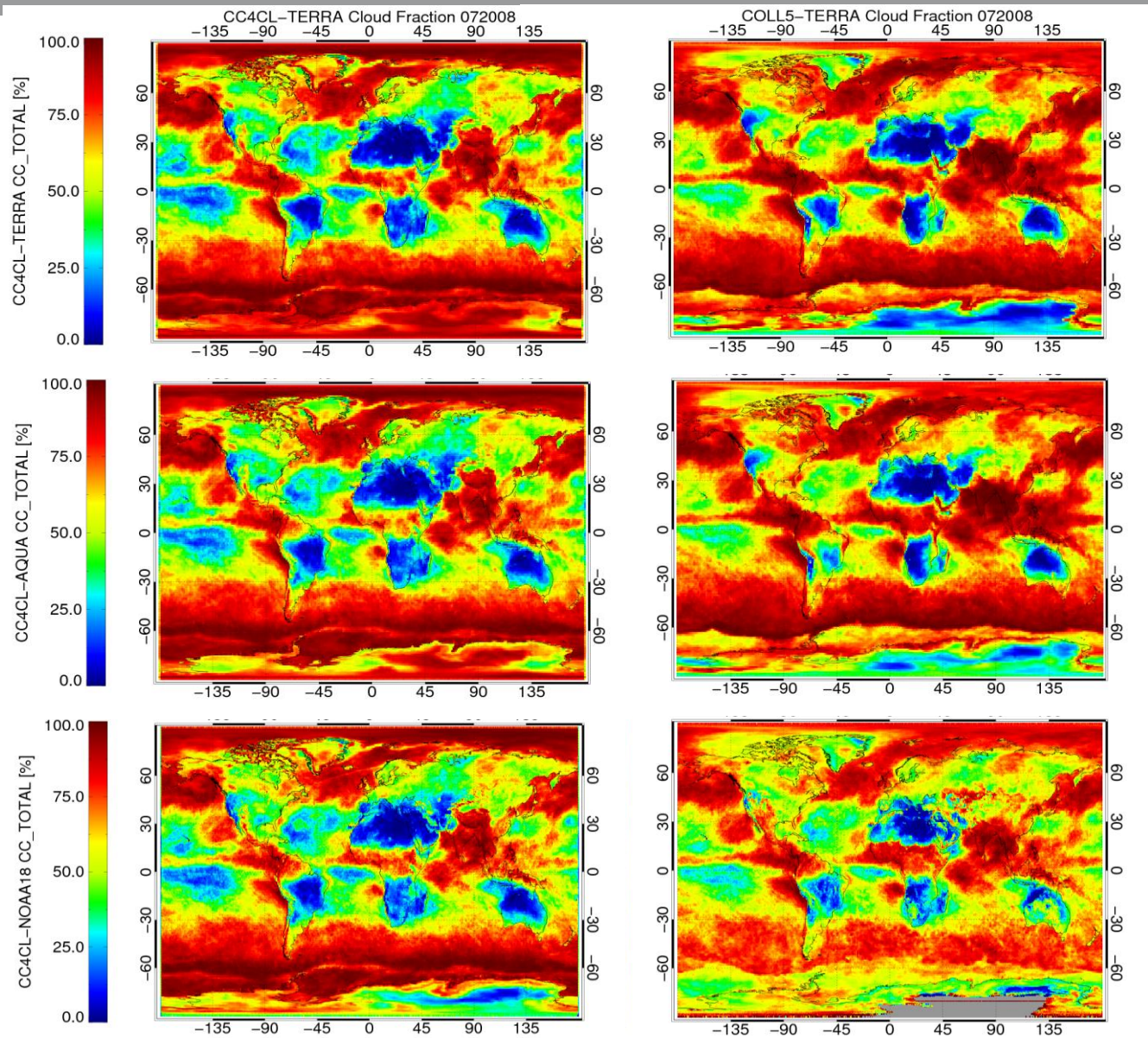


- **Time series of monthly mean cloud fraction observed at ARM site Barrow (upper) and Lamont (lower), compared to several Cloud_cci products.**

M. Stengel, DWD

Monthly mean cloud fraction July 2008

- **CC4CL -Terra**
- **CC4CL -Aqua**
- **CC4CL - NOAA 18**



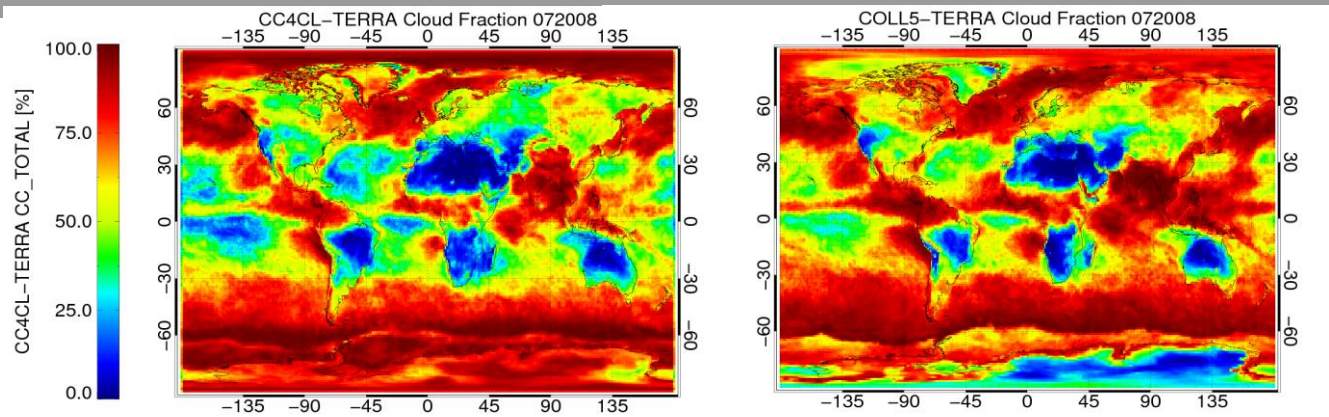
Coll5-Terra

Coll5-Aqua

CLARA-A1-NOAA18

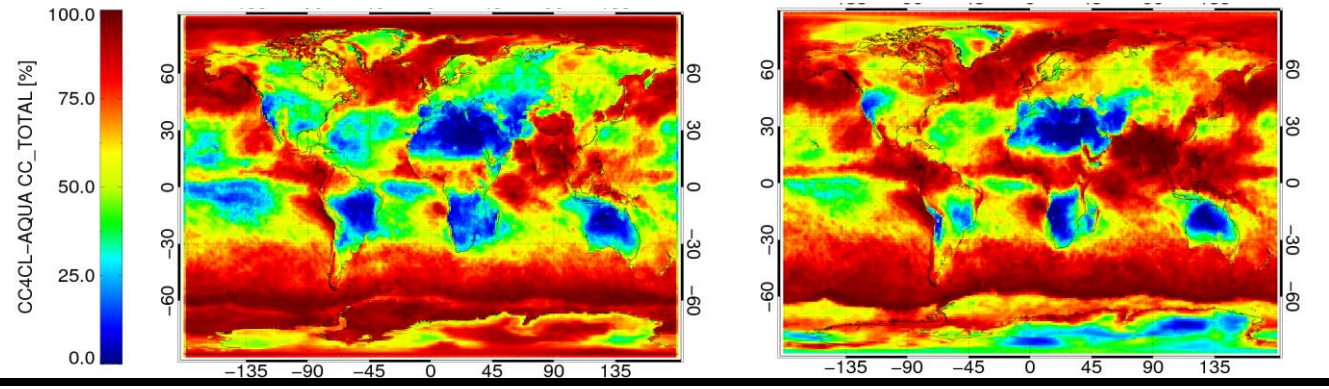
Monthly mean cloud fraction July 2008

- **CC4CL -Terra**



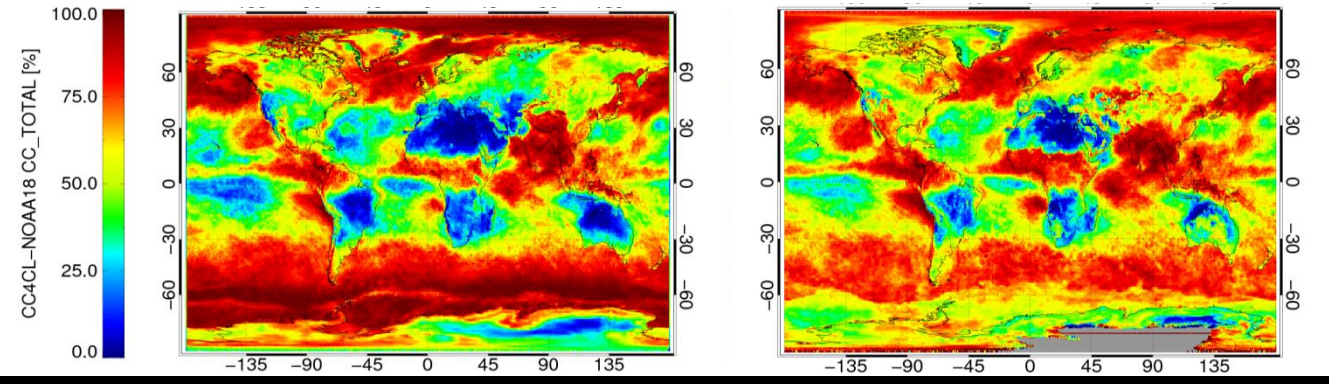
Coll5-Terra

- **CC4CL -Aqua**



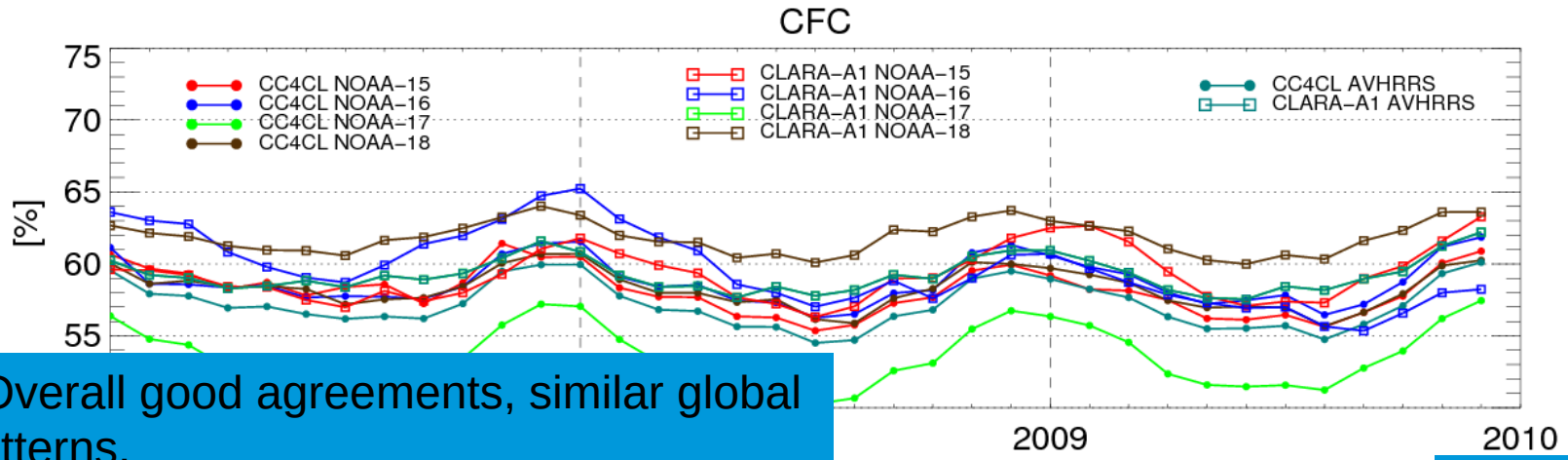
Coll5-Aqua

- **CC4CL - NOAA 18**



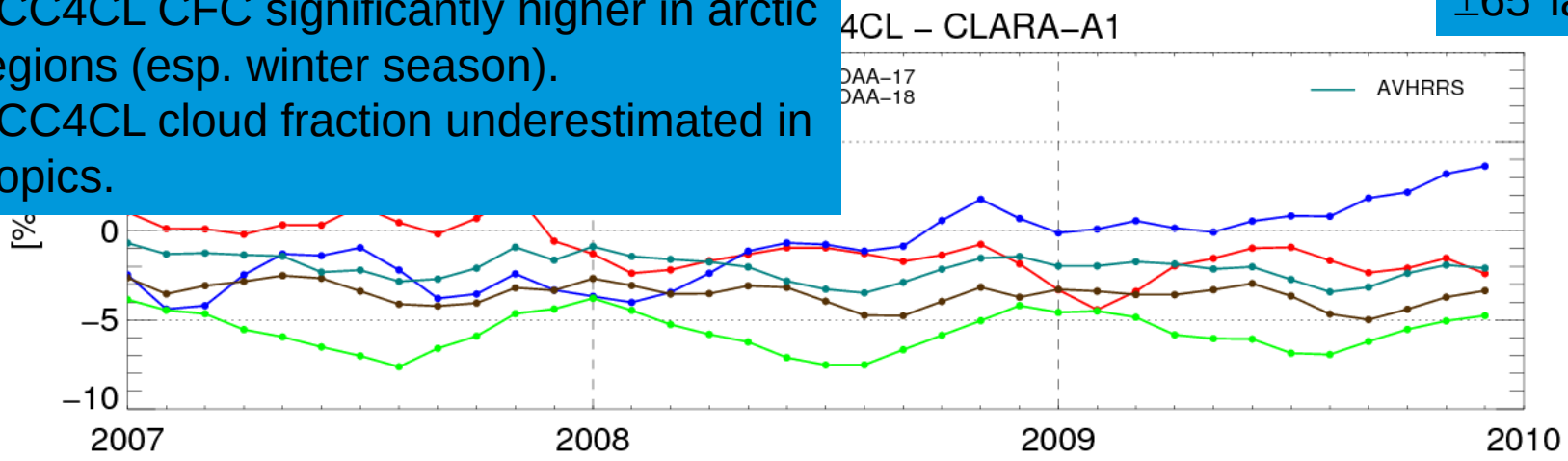
CLARA-A1-NOAA18

CC4CL-AVHRR vs CLARA-A1: cloud fraction



- Overall good agreements, similar global patterns.
- CC4CL CFC significantly higher in arctic regions (esp. winter season).
- CC4CL cloud fraction underestimated in tropics.

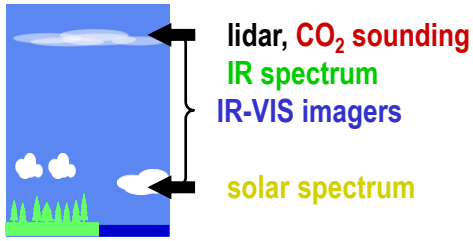
±65°latitude



Cloud cover: validation results vs GCOS

	GCOS requirement	CC4CL			FAME-C
Cloud variable	Goal, B/T,Thres				
		AVHRR	MODIS	AATSR	MERIS/AATSR
Cloud cover	10, 15, 20%	Synop: bias -10 to 5% std 10 to 20%	Synop: bias -5 to 10% std 10 to 20%	Synop: bias -5 to 18% std 15 to 30%	Synop: bias -5 to 5 % std 10 to 20 %
		CLARA-A1: bias -5 to 1% std 10 to 11%			
			MODIS coll5 Terra: bias 9% std 9%		MODIS coll5 Terra: bias -6 to -9% std 13 to 14%
			MODIS coll5 Aqua: bias 8% std 9%		

L3 comparison : global cloud amount

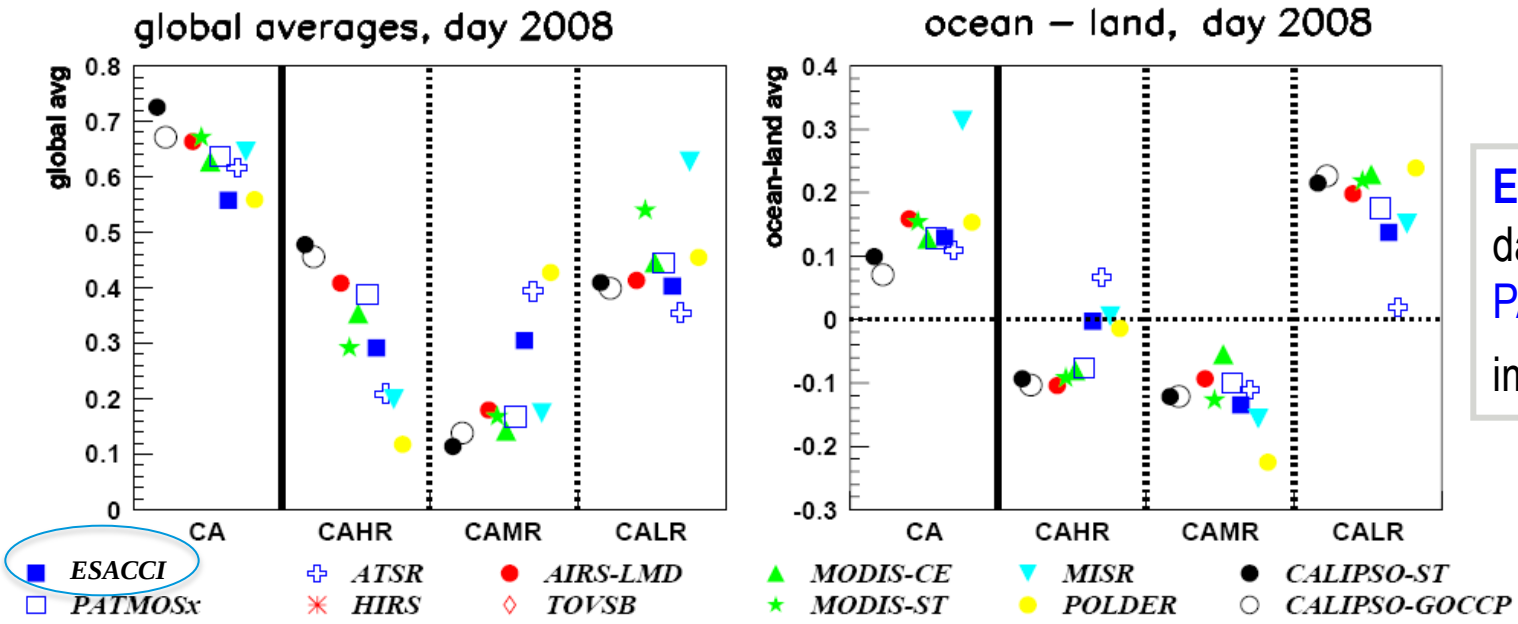


global CA 65-70% (+ 5% subvisible Ci); 40 – 50% of all clouds are high-level clouds

uncertainties & biases depend on cloud scene:

CAHR depends on instrument performance to identify thin Ci
active lidar > IR sounders > VIS-NIR-IR imagers > multi-angle VIS imagers

geographical distributions & seasonal cycles similar



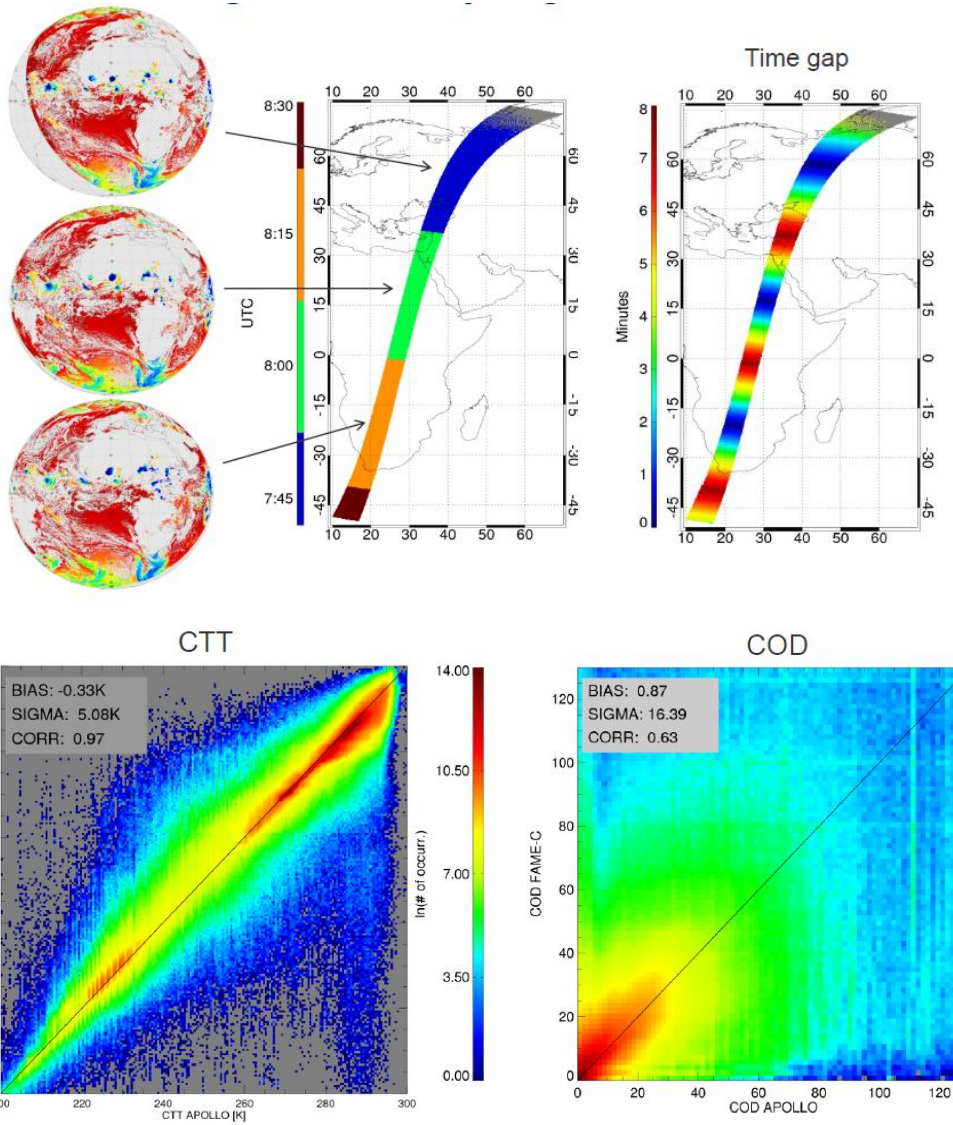
ESACCI using same dataset as PATMOSX: AVHRR imager

global CA underestimated by 0.1; CA larger over ocean by about 0.14, in agreement with other datasets

misidentification of high-level clouds as midlevel clouds (0.1); mostly over land C. Stubenrauch, LMD

L2 Validation FAME-C vs SEVIRI

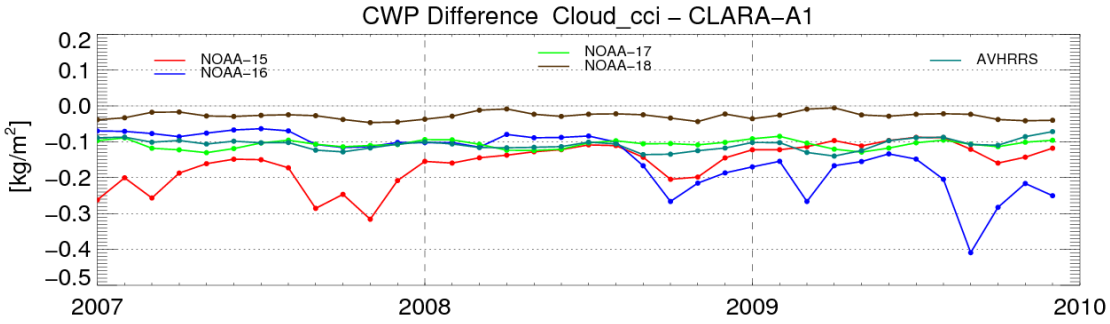
- L2 Comparison with APOLLO-SEVIRI COT and CTT retrievals for 4 days.
- Pixels are matched spatially (nearest neighbour), and temporally to closest 15 minute MSG observations.
- Similar Comparison are performed with the CM SAF CLAAS cloud products.



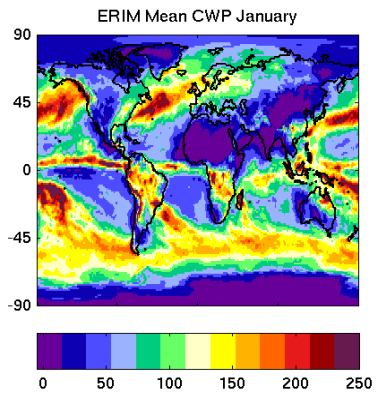
L3 comparison : different instruments

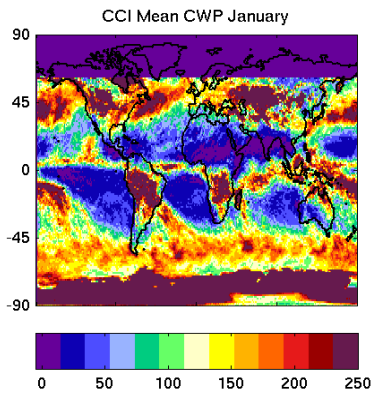
Reference: CLARA-A1 (Karlsson et al. 2013) data set

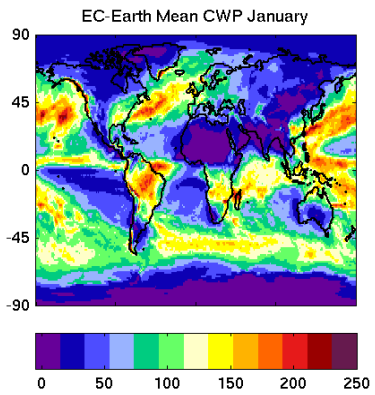
	NOAA-15			NOAA-16		
	CFC	CTP	CWP	CFC	CTP	CWP
Global Bias	0.2 %	7 hPa	-0.16 kg/m²	0.4 %	12 hPa	-0.14 kg/m²
Global BC-RMSE	12 %	54 hPa	0.19 kg/m²	11 %	53 hPa	0.18 kg/m²
	NOAA-17			**NOAA-18**		
	CFC	CTP	CWP	CFC	CTP	CWP
Global Bias	-1.6 %	29 hPa	-0.11 kg/m²	-0.6 %	5 hPa	-0.03 kg/m²
Global BC-RMSE	12 %	49 hPa	0.15 kg/m²	12 %	46 hPa	0.08 kg/m²

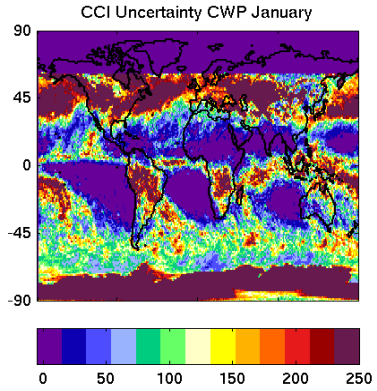


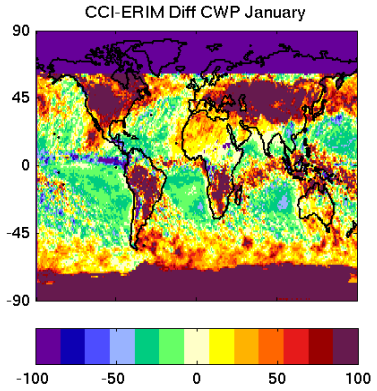
Assessment and Evaluation

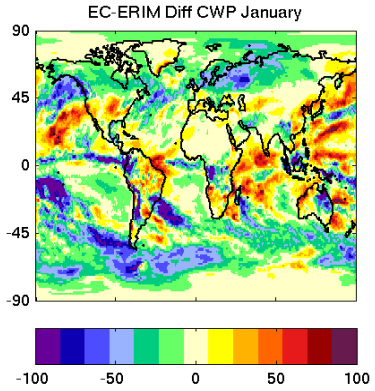












Comparison of Cloud condensate CWP, Jan, 2007-2009, N18: CCI-ERIM-EC-Earth

Initial Evaluation of EC-Earth model:

- Fairly good agreement over ocean
- CCI has very large values over land
- Large CWP Southern Ocean (ERIM possibly too small!)

(U. Willen, Rossby Centre)

Cloud_cci: Achievements

Open Community Algorithm CC4CL

Publications on Round Robin, Algorithms, Inter-calibration, Val/Eval.

Prototype System and Round Robin Algorithm Evaluation Framework

Benefit for user community – Added value of ESA Cloud CCI products:

Spectral consistency of derived parameters, which is achieved by an optimal-estimation approach based on fitting a physically consistent cloud model to satellite observations simultaneously from the visible to the mid-infrared.

Uncertainty characterization, which will be inferred by the application of the optimal estimation approach as physically consistent single pixel uncertainty estimation and further propagated to the final product.

Increased temporal resolution by including multiple polar-orbiting satellite instruments, which also allows for mature cloud property histograms on 0.5° resolution due to high increased sampling rate.

Comprehensive assessment and documentation of the retrieval schemes and the derived cloud property datasets including the exploitation of applicability for evaluation of climate models and reanalyses.

Summary and Outlook

- **ESA Cloud CCI has generated two data sets spanning 2007-2009 exploiting synergistic capabilities of different sensors.**

- **Optimal Estimation technique employed improving homogeneity and stability of time series.**

- **First preliminary validation / evaluation results show**
  - **seasonal cycle is captured well**
  - **Latitudinal agreement ok except poles**
  - **General underestimation of global cloud cover**
  - **Missing high level clouds**

- **Final Data sets publicly available via ftp-server www.esa-cloud-cci.org**
- **Community code of cloud CCI is available: http://proj.badc.rl.uk/orac**

- **For Cloud CCI phase 2 a full (re)-processing is envisaged to create a long-term CDR of cloud properties**

Thank you for your attention

RAL Space

Freie Universität Berlin

Royal Netherlands Meteorological Institute
Ministry of Transport, Public Works and Water Management

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DLR

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Home Affairs FDHA
Federal Office of Meteorology and Climatology
MeteoSwiss

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

DWD

ETH