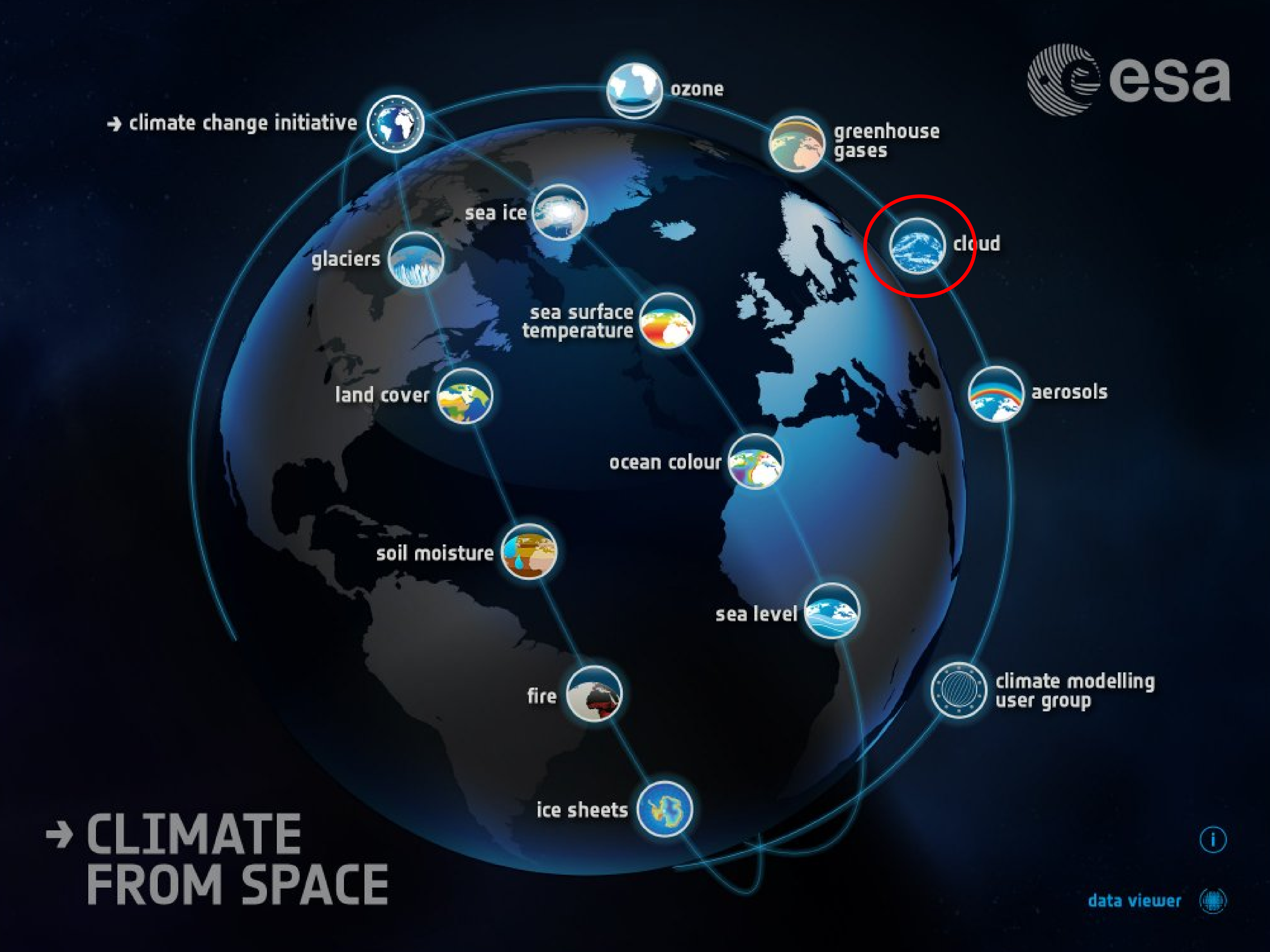
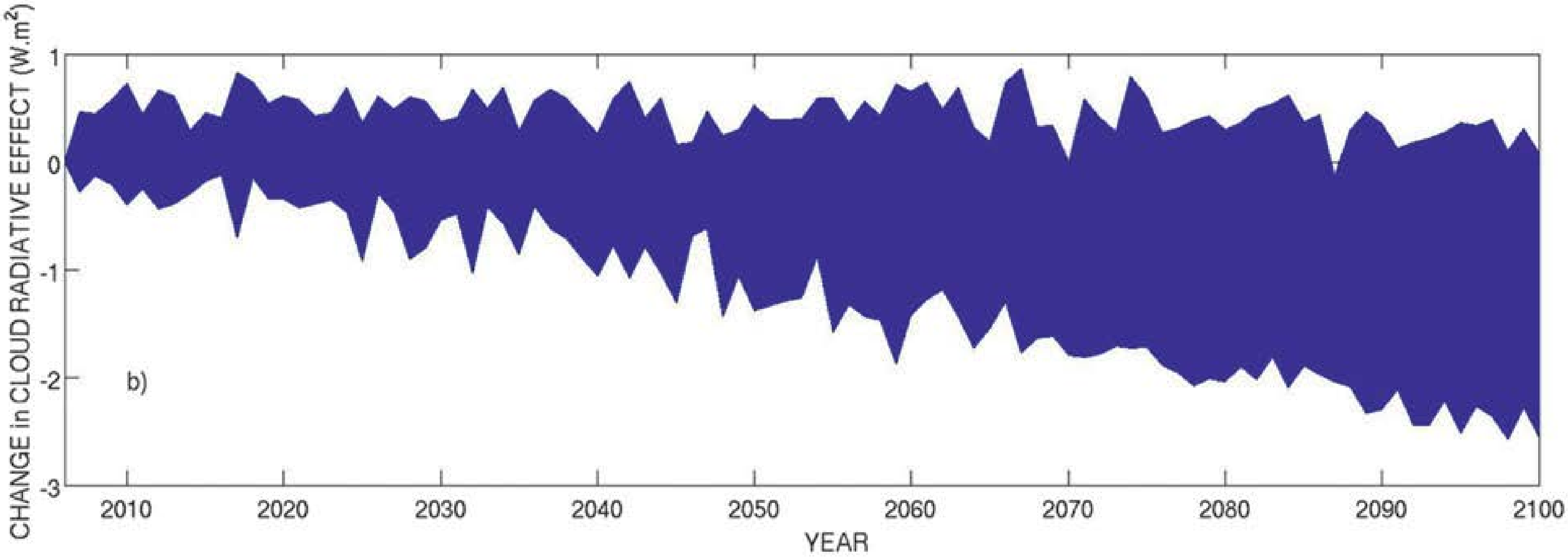
ESA Cloud CCI project

ICWG 2018

Caroline Poulsen, Martin Stengel, Rainer Hollmann, Gareth Thomas, Mathew Christiansen, Simon Proud, Adam Povey, Don Grainger, Oliver Sus, Karl Goran Karlsson and others


esa
climate change initiative
ozone
greenhouse gases
sea ice
cloud
glaciers
sea surface temperature
land cover
aerosols
ocean colour
soil moisture
sea level
climate modelling user group
fire
ice sheets
CLIMATE FROM SPACE
data viewer

Cloud climate uncertainty

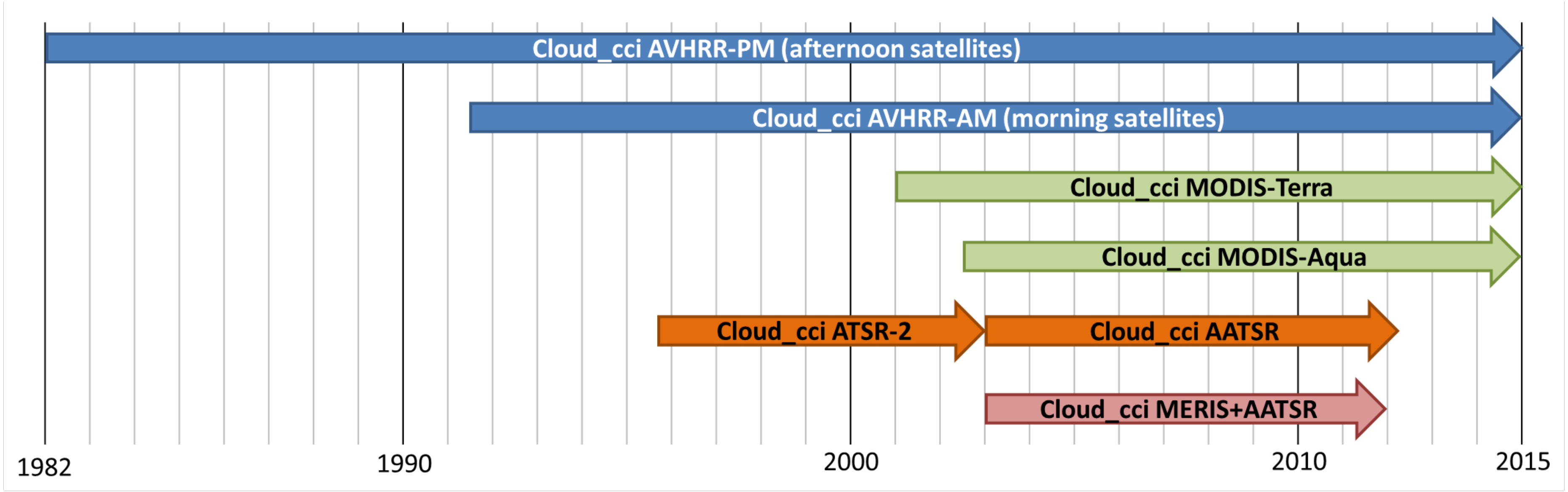


- The range of the change in cloud radiative effects predicted from 2006 to 2100 from eight different models for the same CO2 increase and associated with global temperature rises of between 2.7 and 4.7 K depending on the model.
- large interannual variability.
- Several papers (e.g., Dufresne and Bony 2008) have shown that more than 70% of this intermodel spread on global mean temperature increase is due to uncertainty on cloud feedback.

From Illingworth et al 2014

ESA Cloud_cci objectives

- **Multi-decadal coherent global data sets for GCOS cloud property ECVs including uncertainty estimates based on inter-calibrated radiances**
  - **AVHRR, MODIS, AATSR: CC4CL (Multi-decadal 1982-2016)**
  - **AATSR and MERIS: FAME-C (Decadal data record 2002-2012)**



Cloud_cci v3 datasets

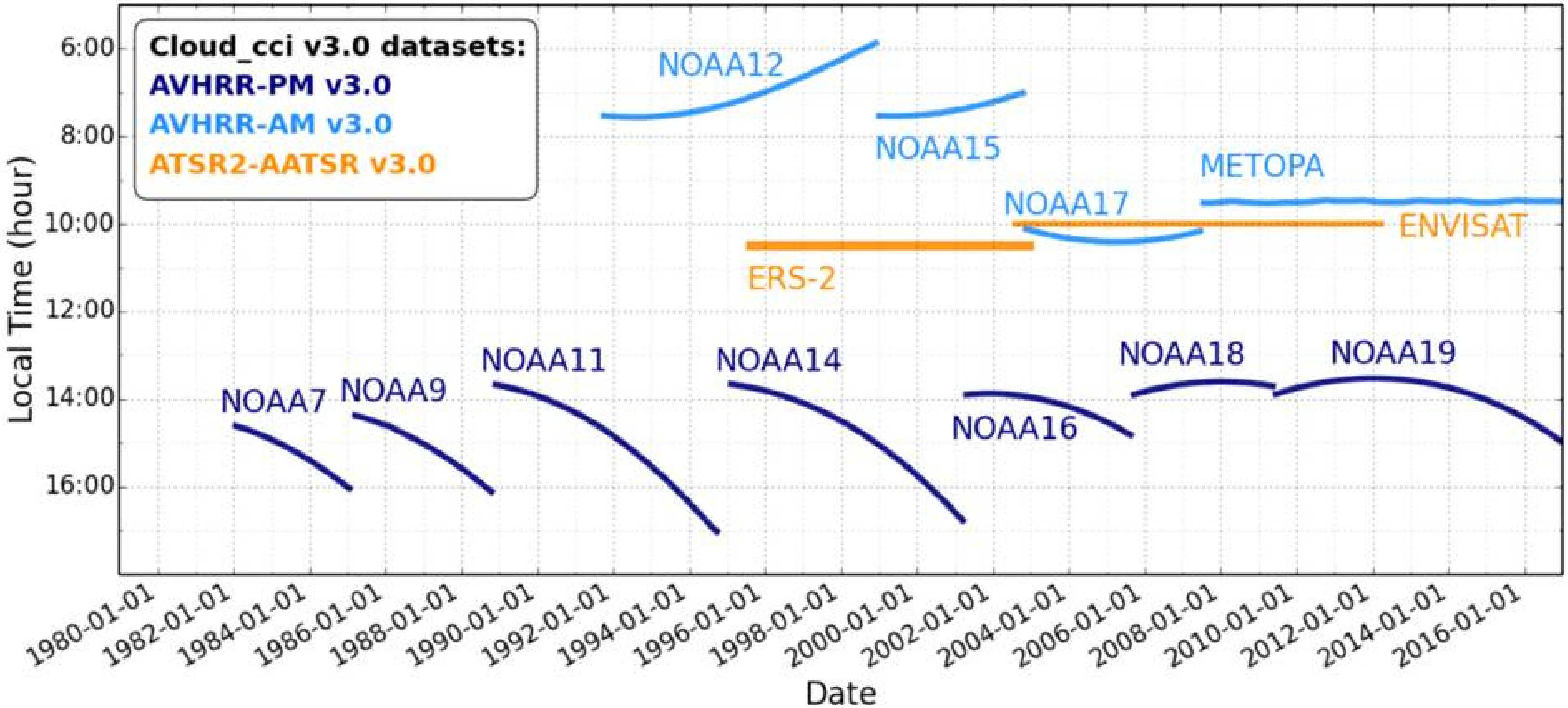


Figure 1-3 *Time periods and local observation times (equator crossing times) of each satellite sensor considered in Cloud_cci. Figure is taken from Stengel et al. (2018b).*

L2 orbit (AATSR/ATSR-2), L3U daily , L3C monthly products
Netcdf-CF compliant
Available from ESA CCI portal

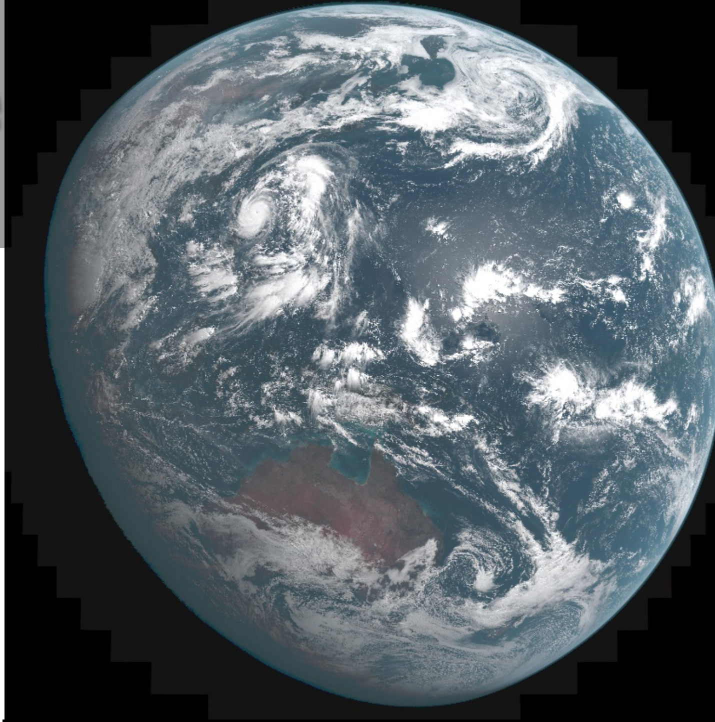
CCI cloud Principles

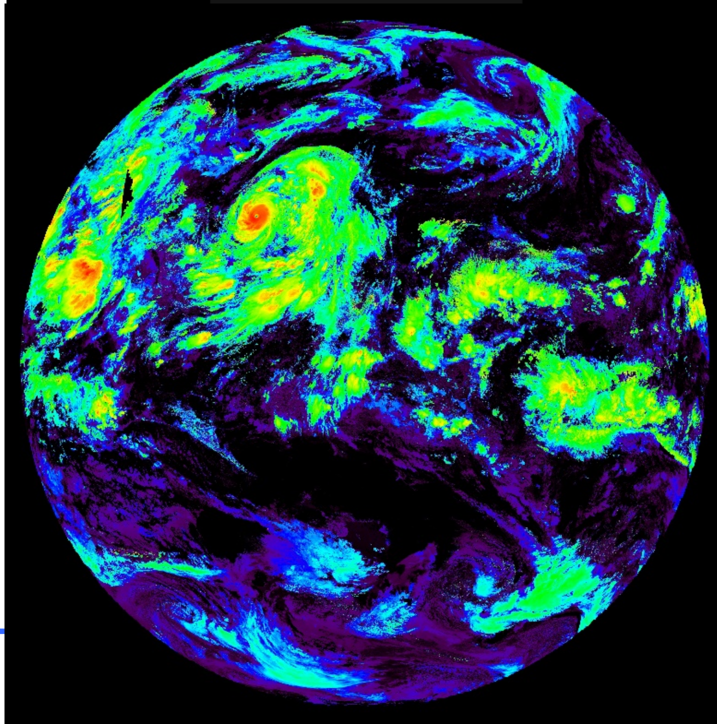
- **Well characterised FCDR**
- **Same algorithm for all instruments**
  - **CC4CL**
    - Neural Net
    - ORAC for optimal estimation (cousin to OCA)
- **Same ‘heritage’ channel selection**
  - **.67, .87, 3.7, 11, 12µm**
- **Consistency with other CCI projects**
  - **ERA Interim, OC CCI, land masks, naming conventions**
- **Uncertainty**
  - **Pixel level**
  - **L3**
- **Comprehensive validation**

McGarragh, G. R. et al., The Community Cloud retrieval for CLimate (CC4CL) – Part 2: The optimal estimation approach, Atmos. Meas. Tech., 11, 3397-3431, https://doi.org/10.5194/amt-11-3397-2018, 2018

Community Code 4 Climate CC4CL

- **Co-developed by:**
  - **DWD, University Oxford and RAL Space**
- **Code:**
  - https://github.com/ORAC-CC/orac
- **Satellites sensors supported:**
  - **ATSR, AATSR SLSTR, AVHRR, MODIS, SEVIRI, AHI/Himawari, ABI/GOES**
- **Currently used by KCL, UKMO, PML, FORUM**



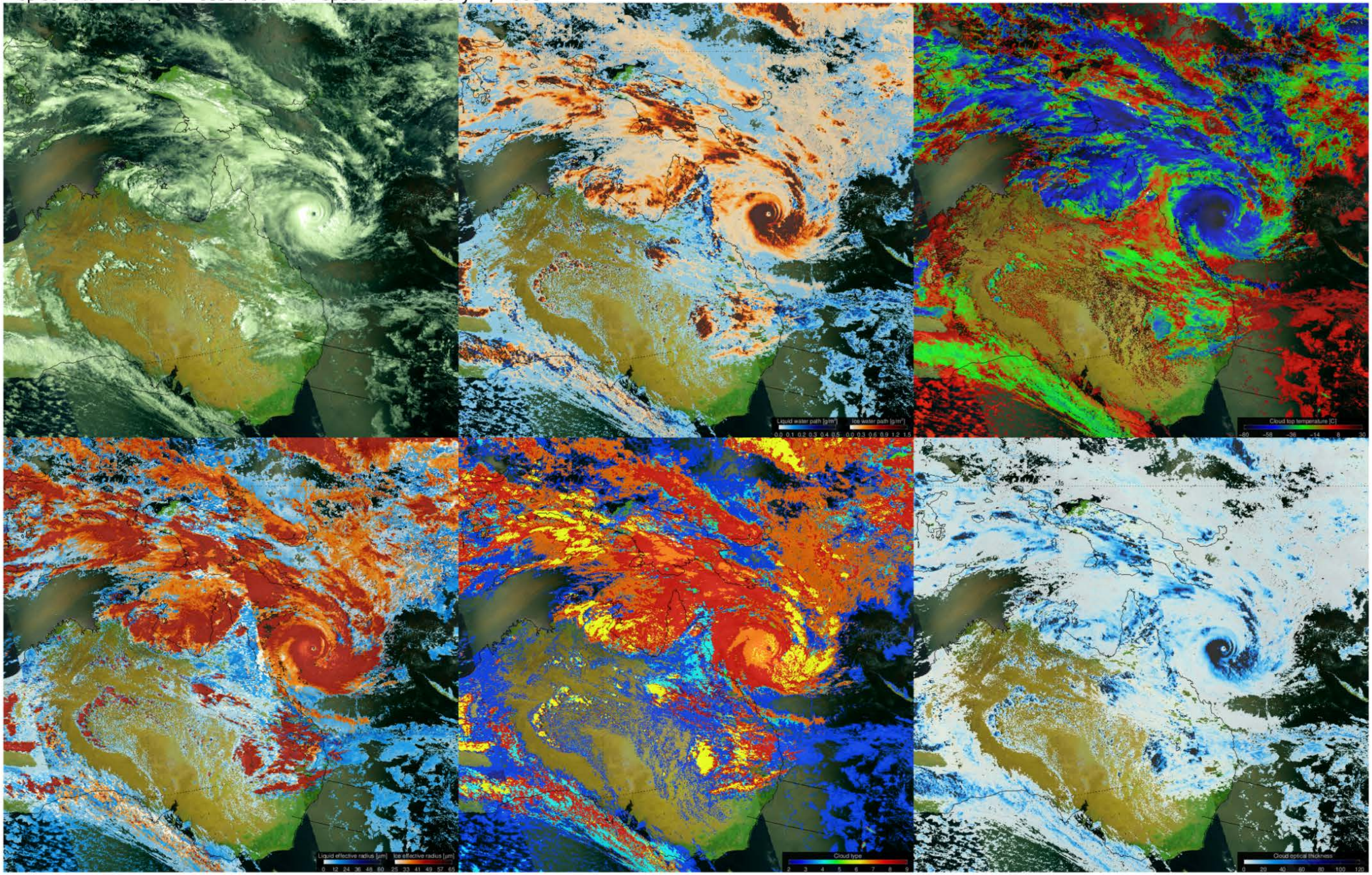


AVHRR 7th Feb

Tropical Storm Oliver – observed from space on February 7, 1993

Liquid and Ice water path

Cloud Top Temperature



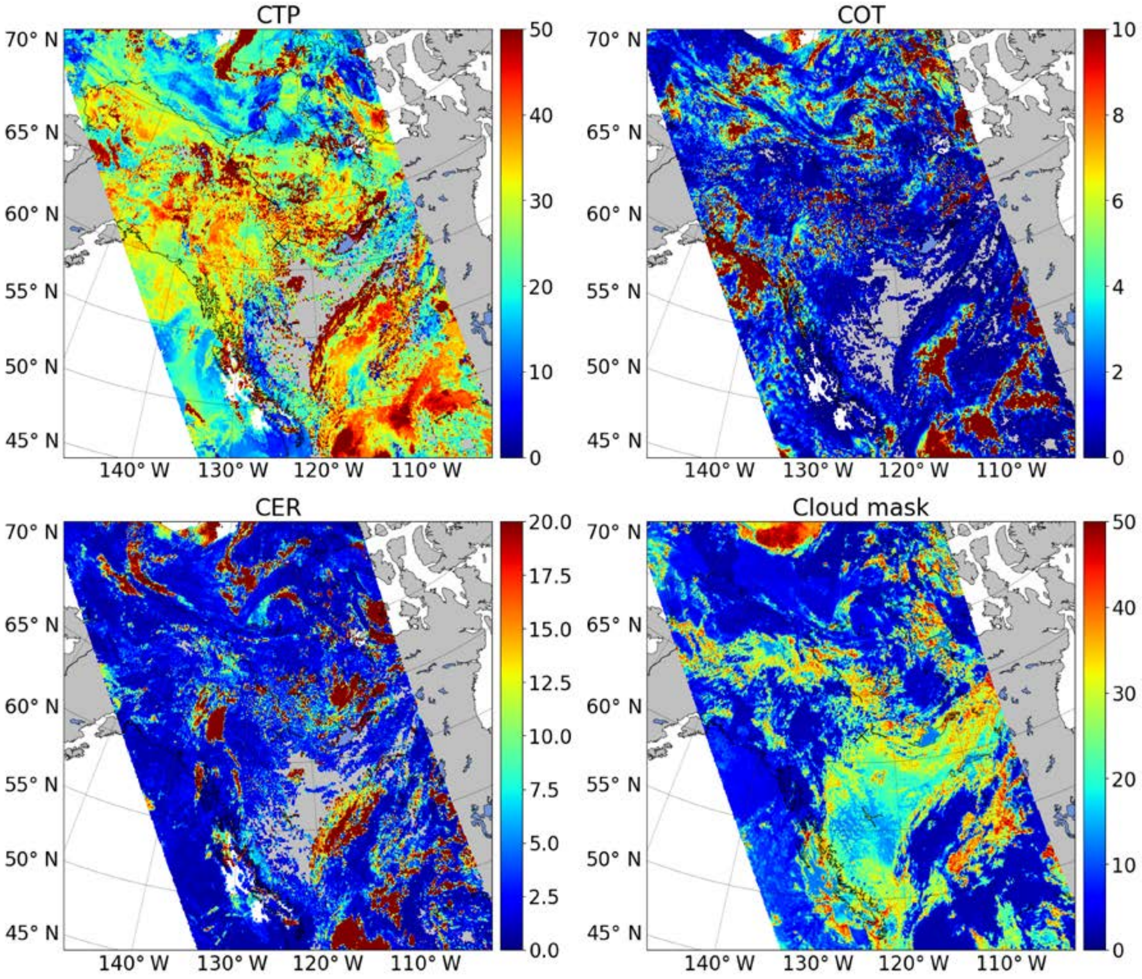
Liquid and Ice effective radius

Cloud type

Cloud optical thickness

Images courtesy Martin Stengel DWD

Uncertainty



7. Absolute uncertainties of MODIS AQUA retrieval data for study area NA2 and CTP [hPa], COT, CER [μm], and Cloud mask [%].

Sources of Uncertainty
Random
- Measurement noise
- Surface reflectance
- Forward model

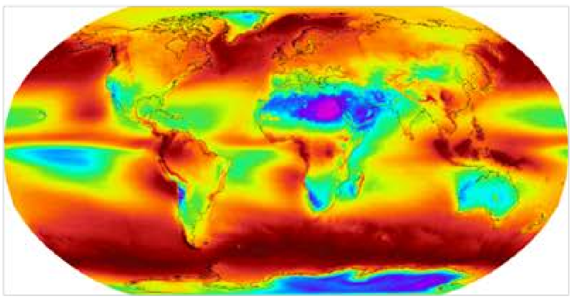
Not considered
Systematic
e.g. single layer cloud assumption

Uncertainty is significant for very thin clouds

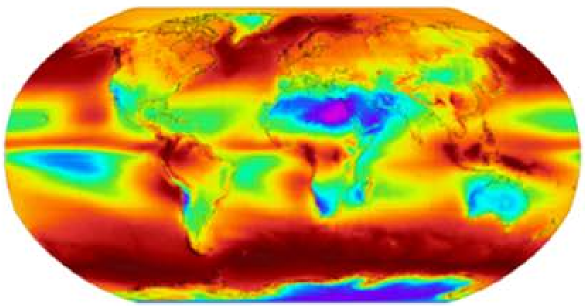
CFC and CPH uncertainty derived from comparison with Calipso

Comparison of Cloud_cci Cloud fraction AVHRR-AM with other datasets

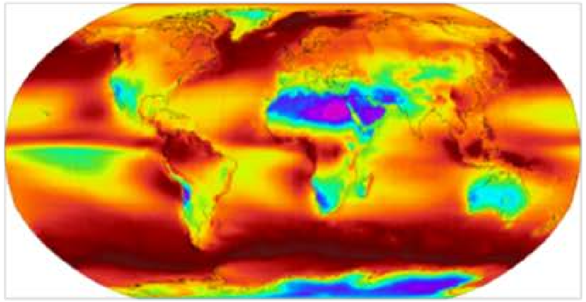
Cloud_cci AVHRR-AM v3.0



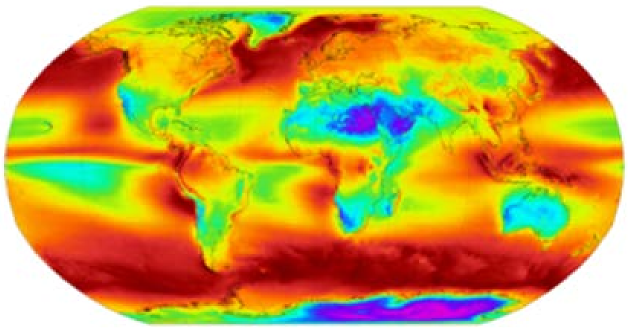
Cloud_cci AVHRR-AM v2.0

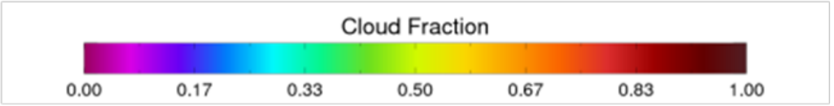


MODIS Collection 6 Terra

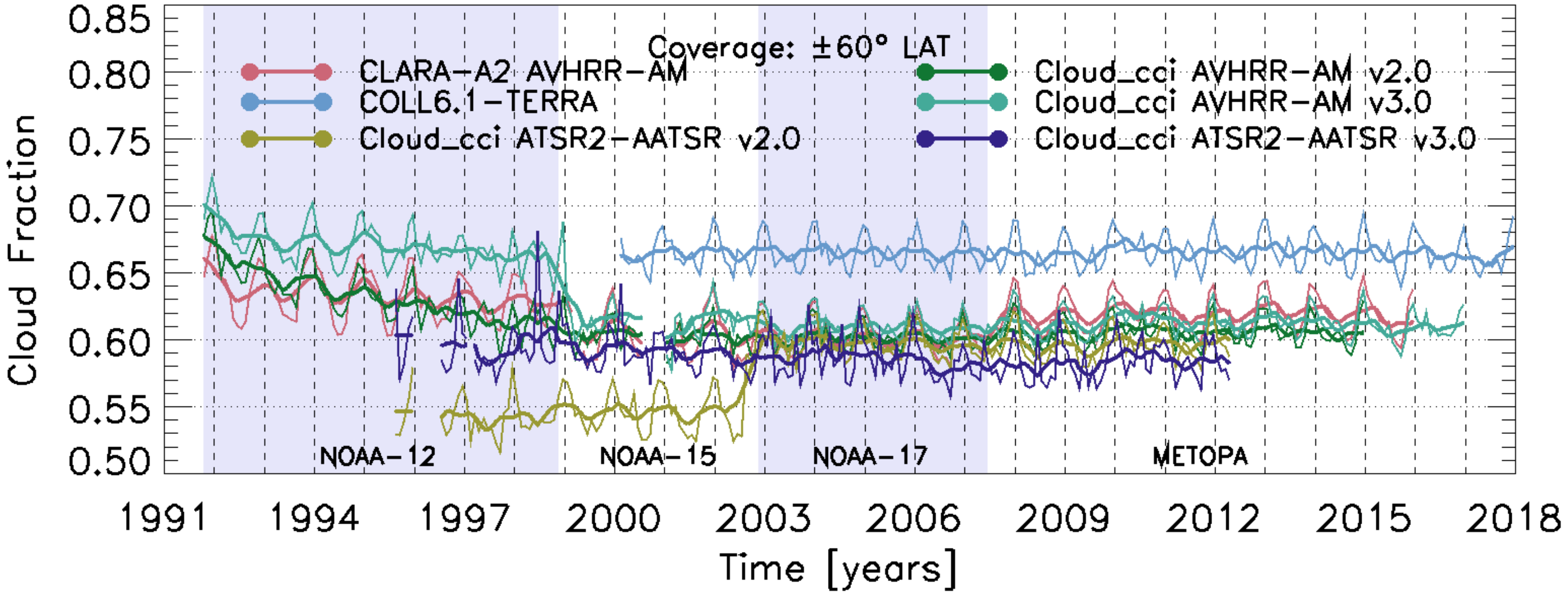


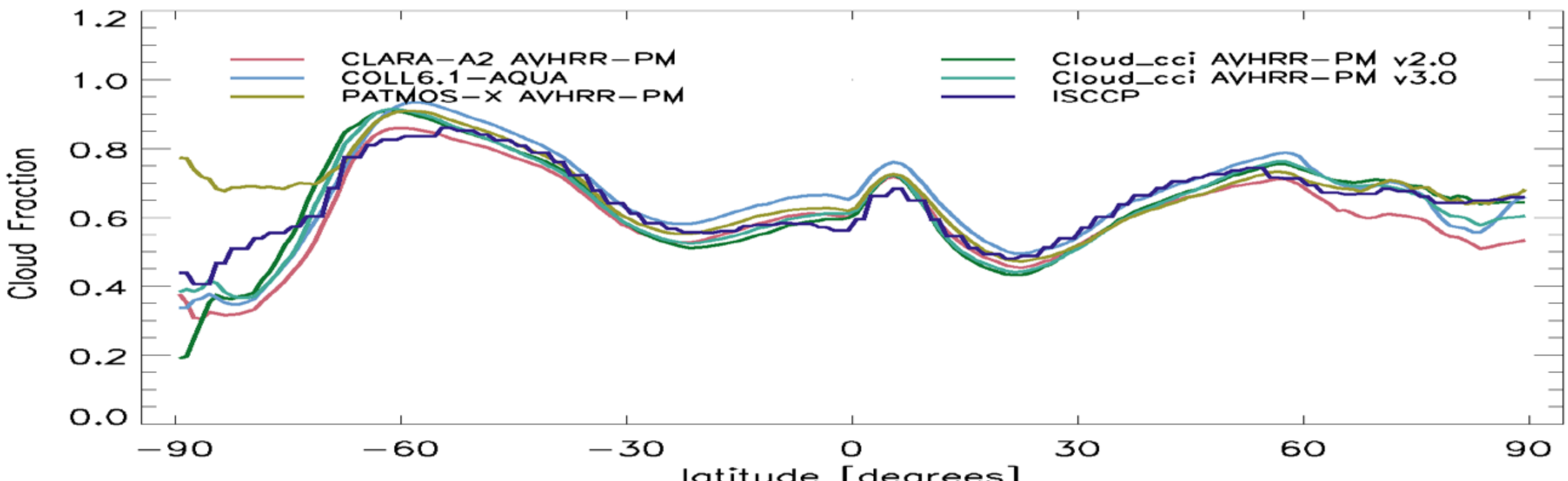
CLARA-A2 AVHRR-AM



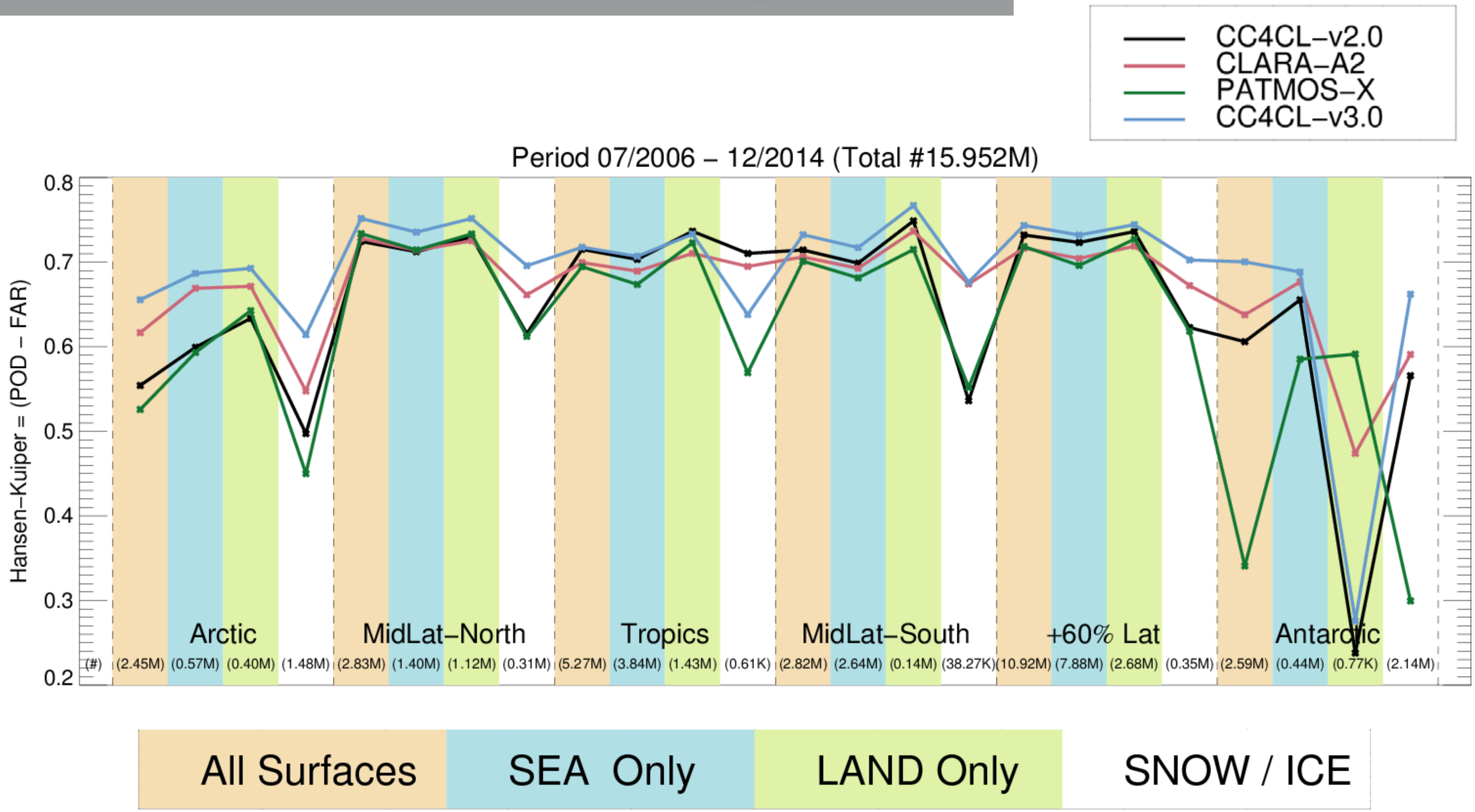


Comparison of Cloud_cci AVHRR-AMv3 and ATSR2-AATSRv3 with other datasests



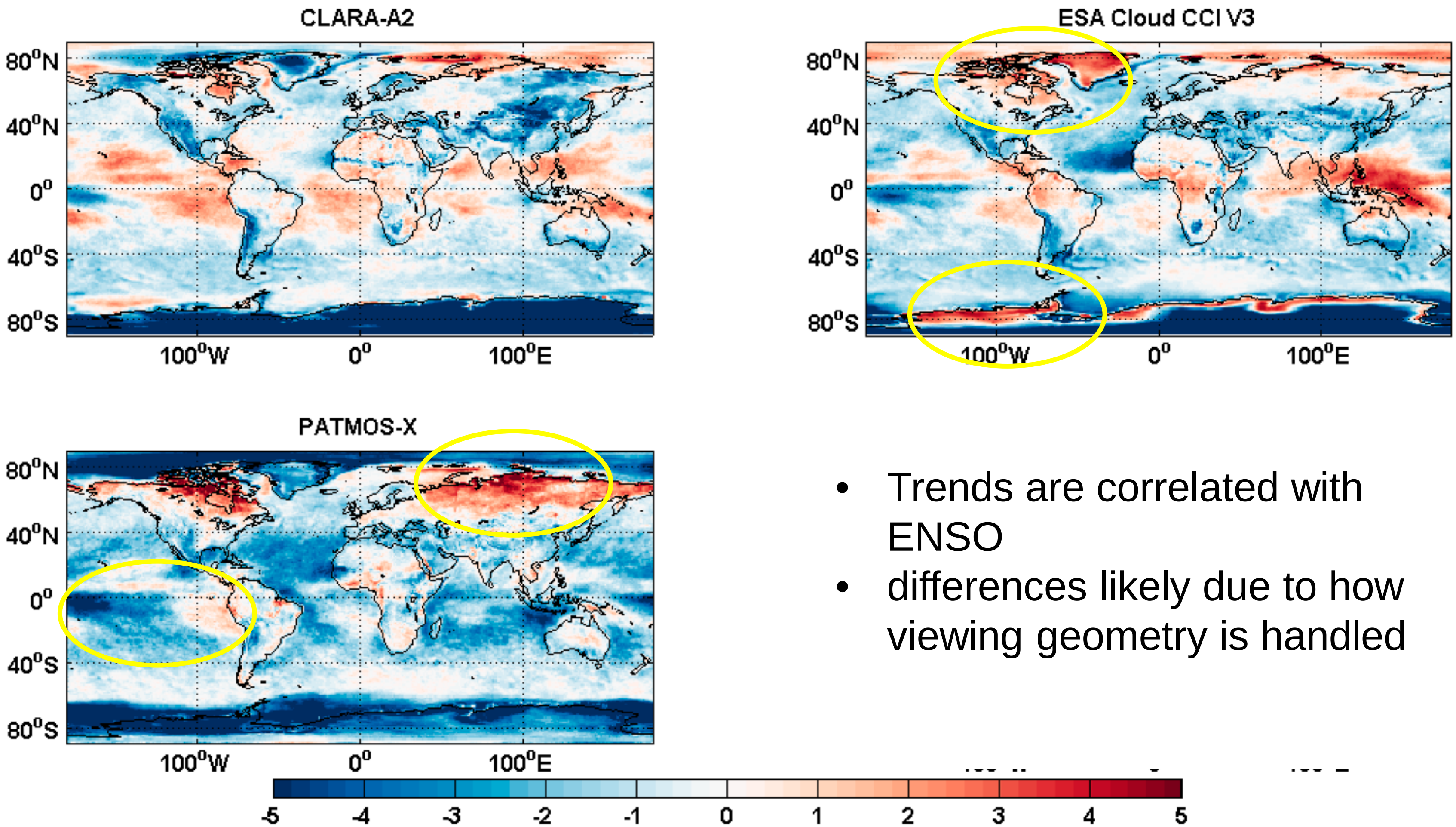


Cloud mask Kuiper Skill of different regions



Comparisons performed for daily products Calipso matches < 3 minutes

Spatial trends in Cloud fraction



- Trends are correlated with ENSO
- differences likely due to how viewing geometry is handled

Figure 4. Spatial distribution of trends in total cloud fraction (% per decade) for the investigated CDRs.

Karlsson and Devasthale Intercomparison and evaluation of 4 longest satellite derived cloud climatologies 2018 RS

Comparison of AVHRR CDRs CTP

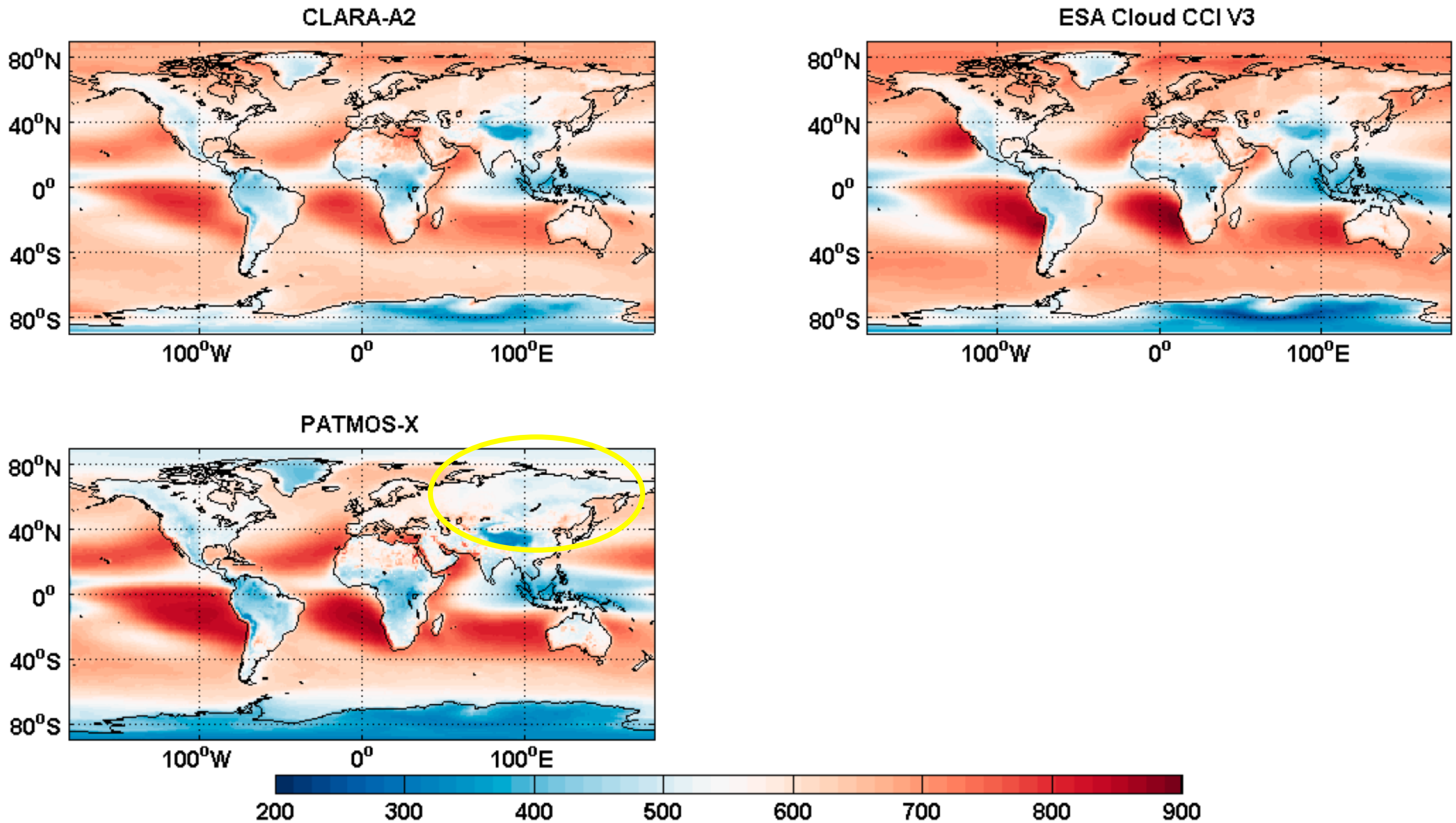


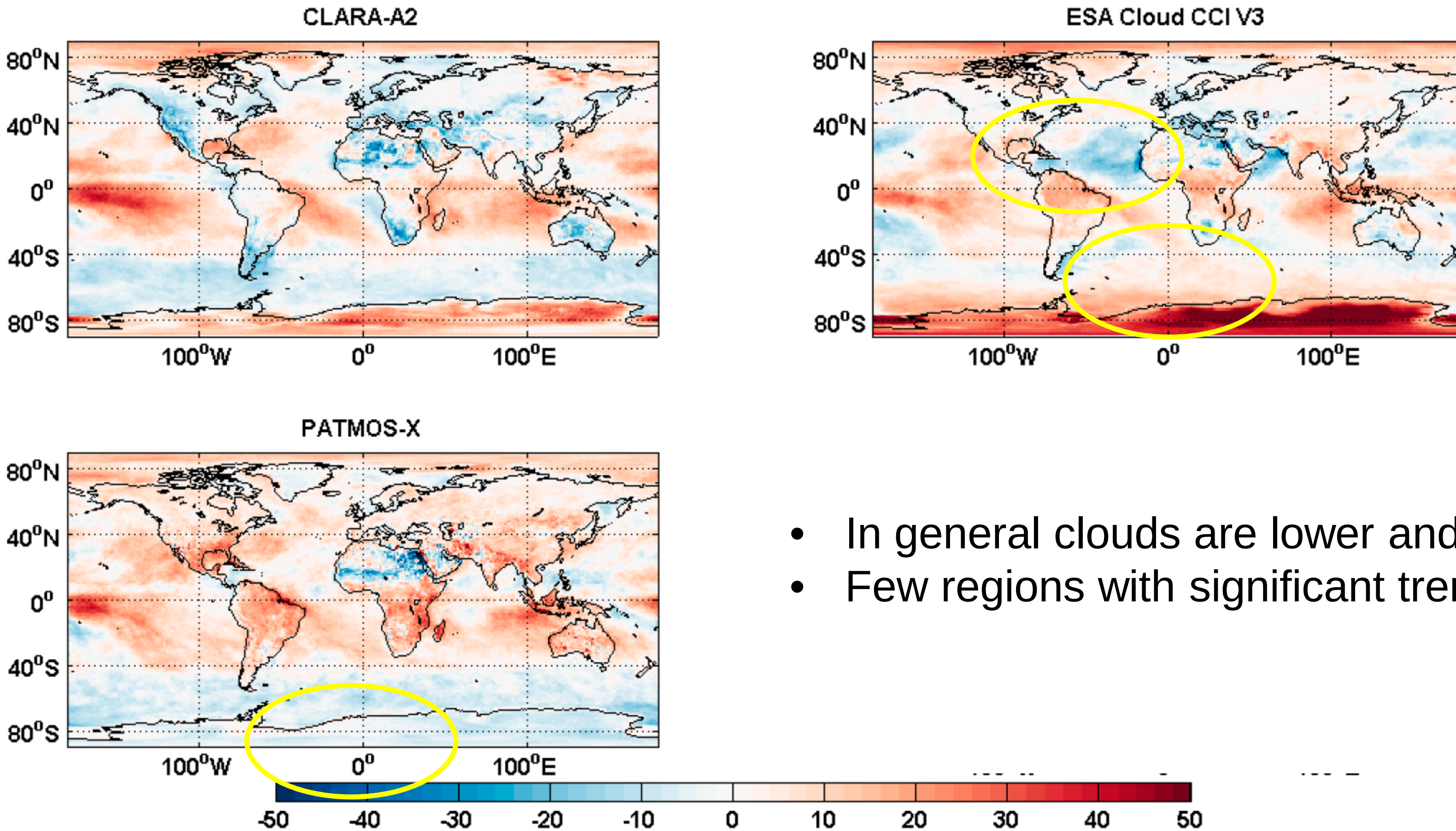
Figure 10. Climatological mean cloud top pressure (hPa) averaged over 26-year period (1984–2009) in four CDRs.

Karlsson and Devasthale Intercomparison and evaluation of 4 longest satellite derived cloud climatologies 2018 RS

CTP validation v2.0 with Calipso

Cloud category	CC4CL^T (AVHRR-PM) Bias (m)	CC4CL (AVHRR-PM) Bias-corrected RMSE (m)	CLARA-A2 Bias (m)	CLARA-A2 Bias-corrected RMSE (m)
All clouds	-1688	3674	-2386	3577
Low-level	222	963	500	1259
Medium-level	-149	1887	-494	1611
High-level	-3005	3918	-4268	3509

Spatial distribution of CTP trends



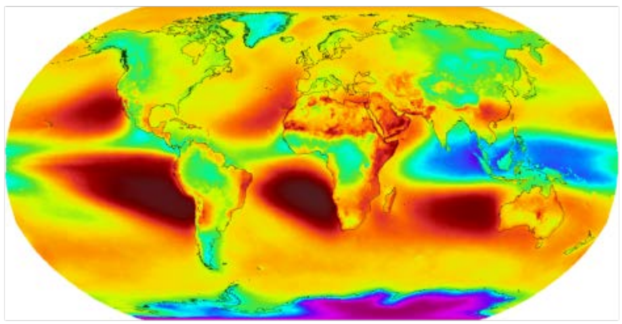
- In general clouds are lower and warmer
- Few regions with significant trends

Figure 13. Spatial distribution of trends in cloud top pressure (hPa per decade) for the investigated CDRs.

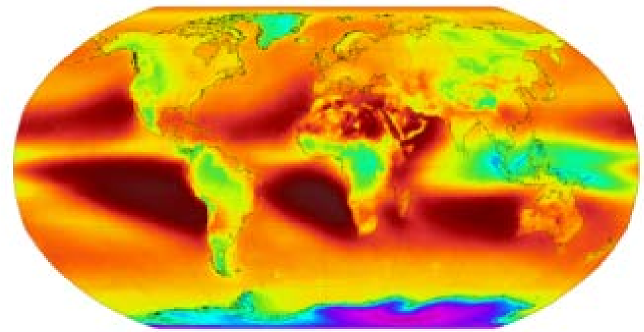
Karlsson and Devasthale Intercomparison and evaluation of 4 longest satellite derived cloud climatologies 2018 RS

Liquid cloud fraction

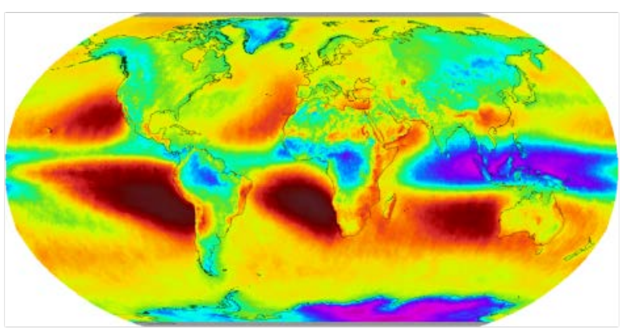
Cloud_cci AVHRR-AM v3.0



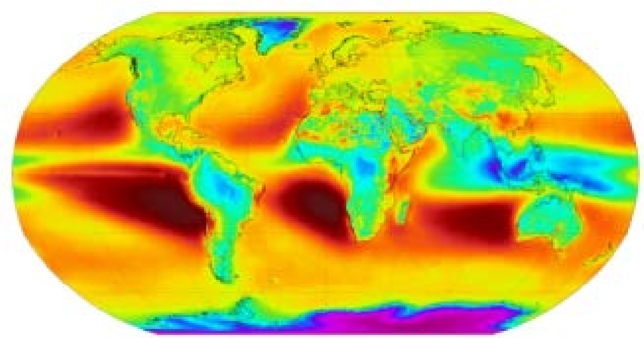
MODIS Collection 6 Terra

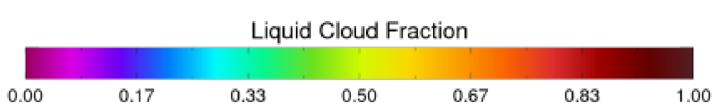


Cloud_cci ATSR2-AATSR v3.0

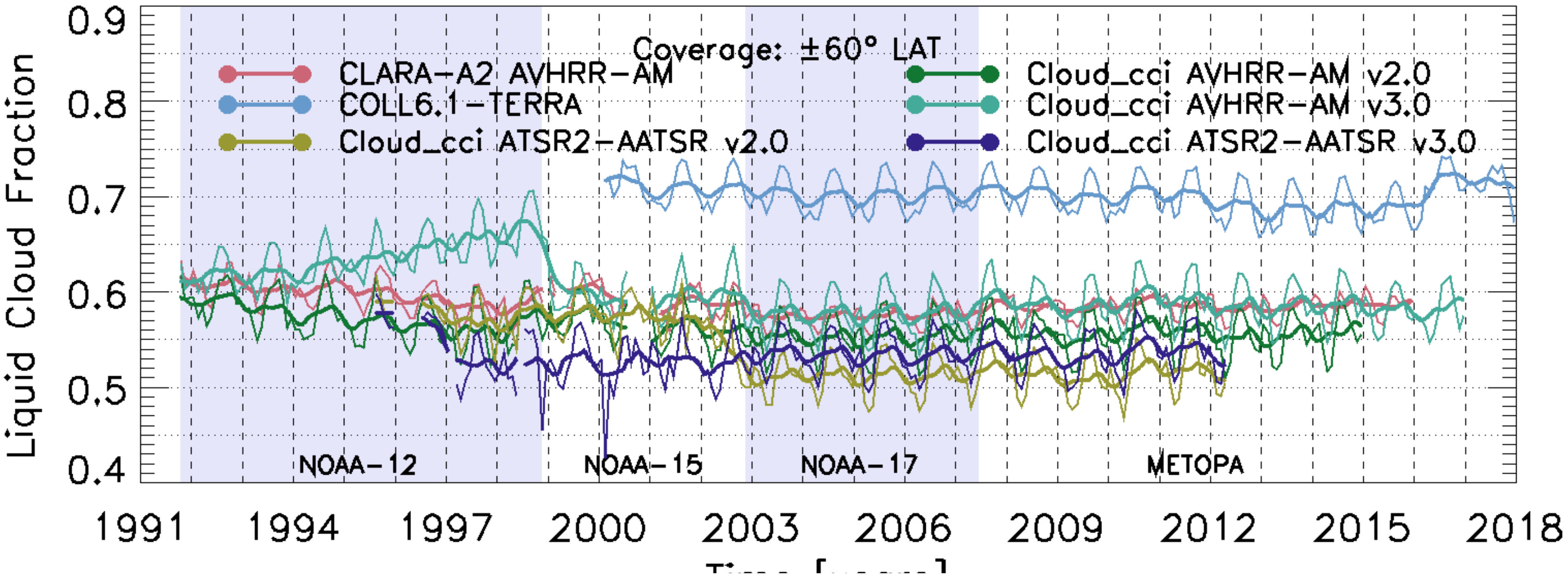


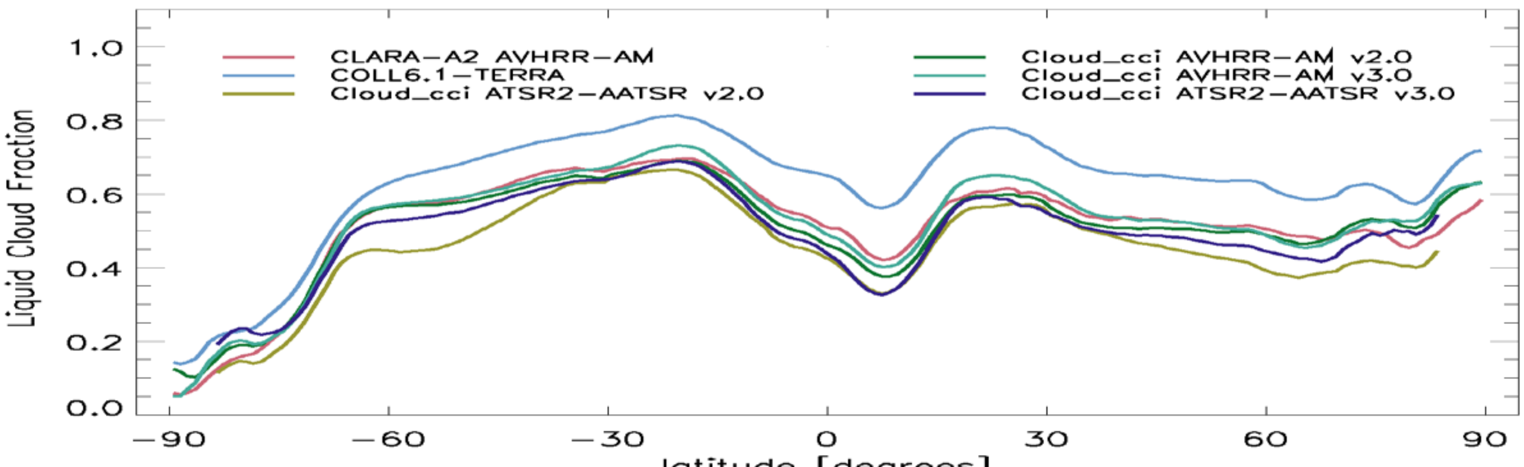
CLARA-A2 AVHRR-AM



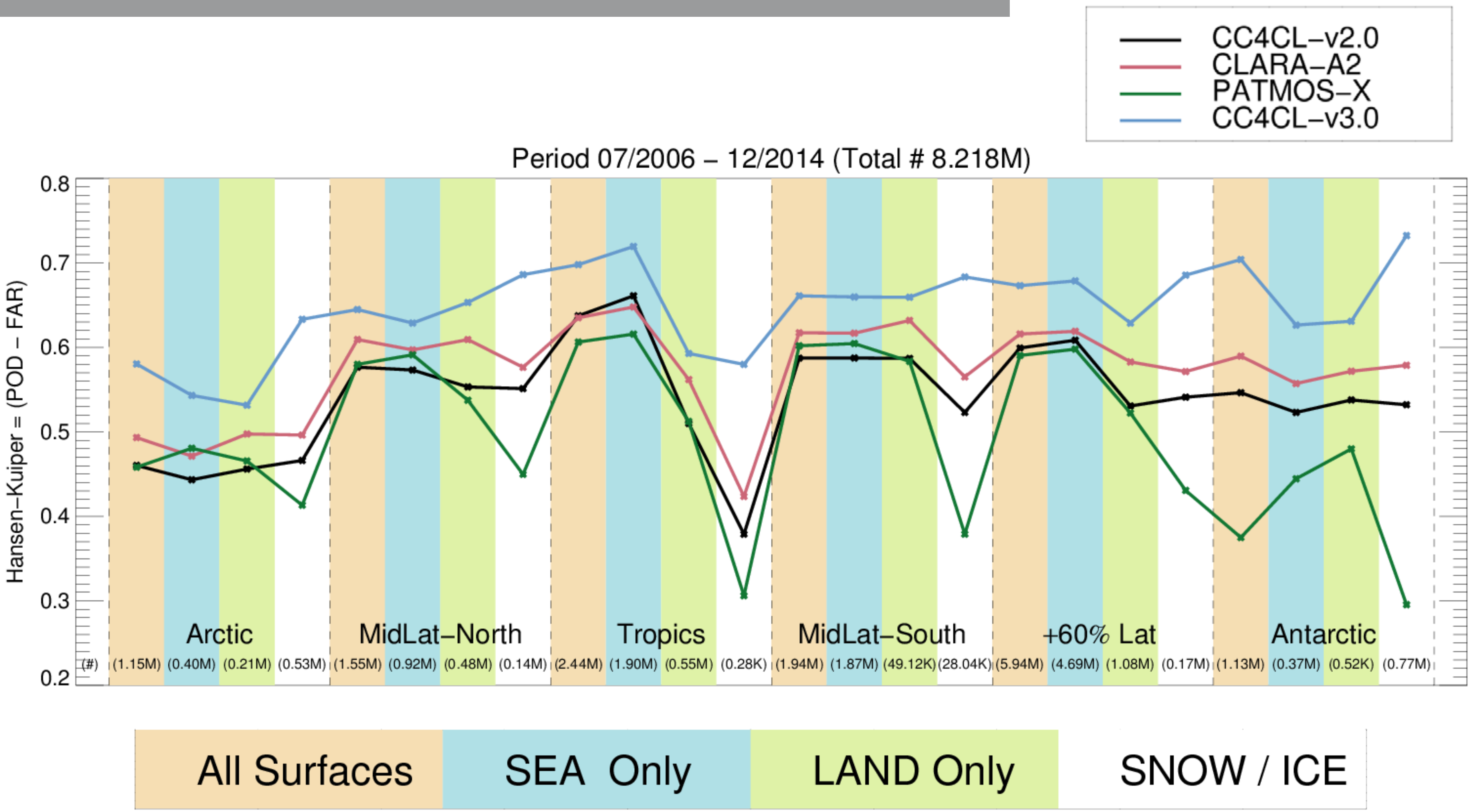


Liquid cloud fraction





Cloud phase Kuiper Skill of different regions

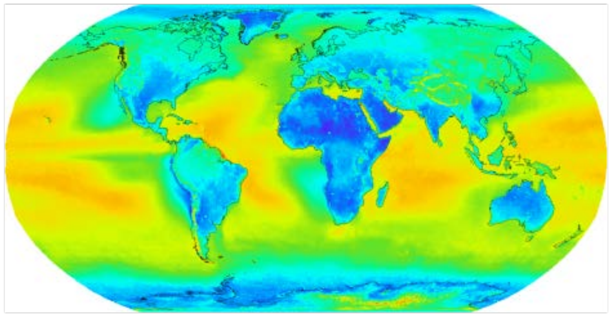


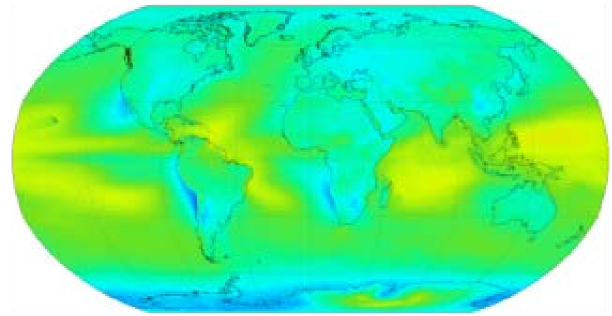
Liquid effective radius

Cloud_cci AVHRR-AM v3.0

MODIS Collection 6 Terra

3.7µm



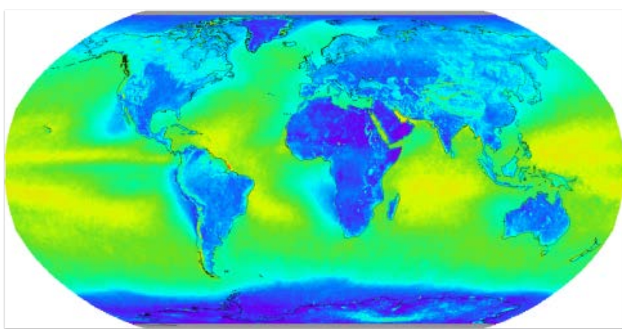


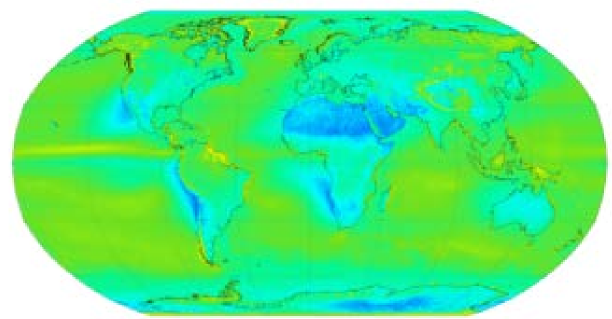
3.7µm

Cloud_cci ATSR2-AATSR v3.0

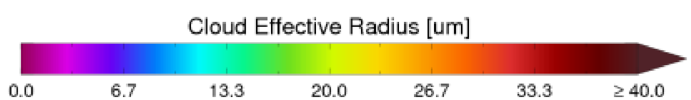
CLARA-A2 AVHRR-AM

1.6µm





3.7µm



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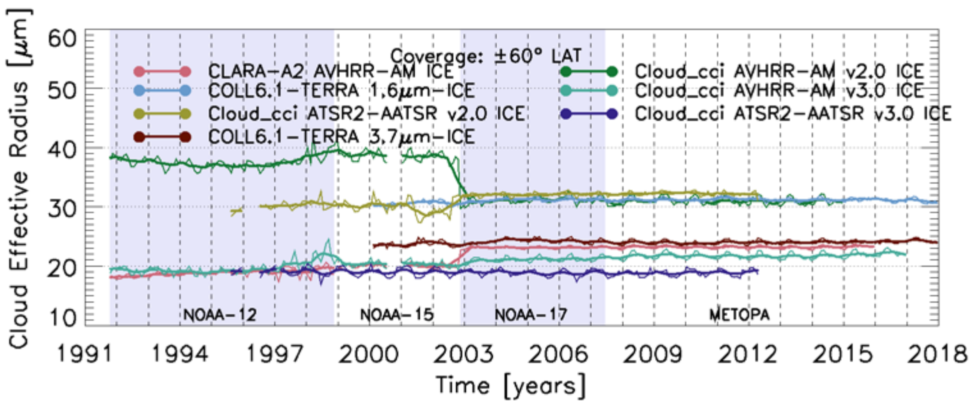
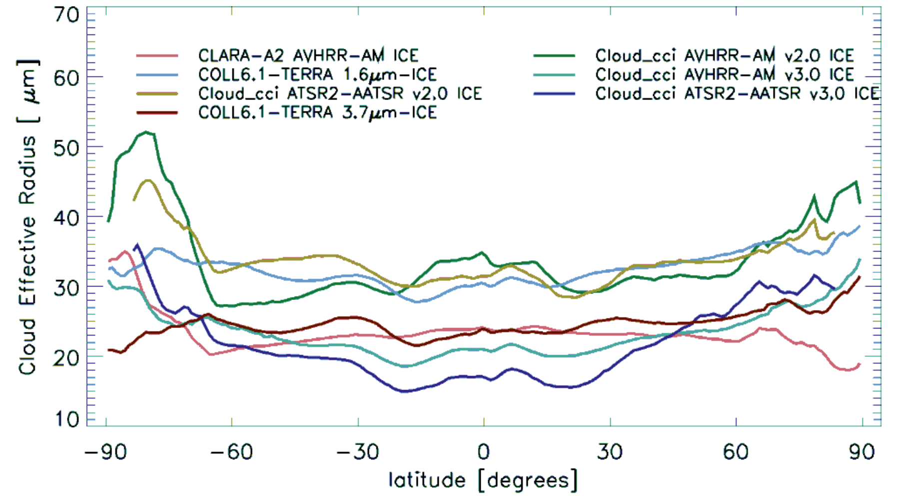
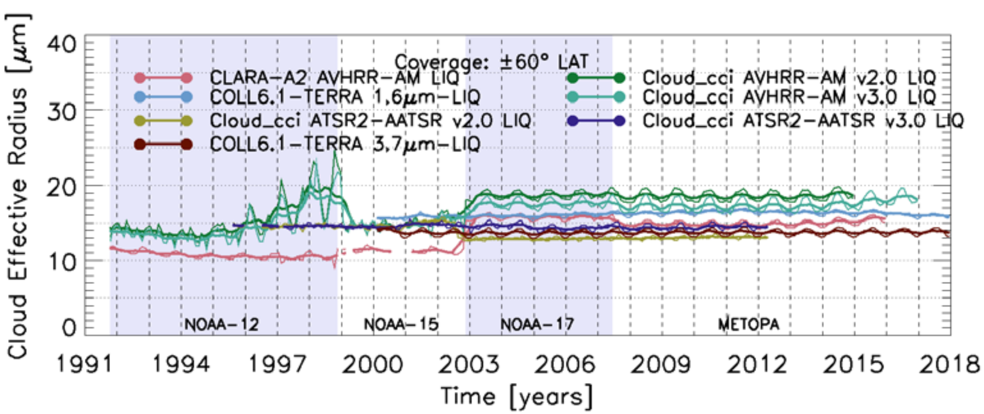
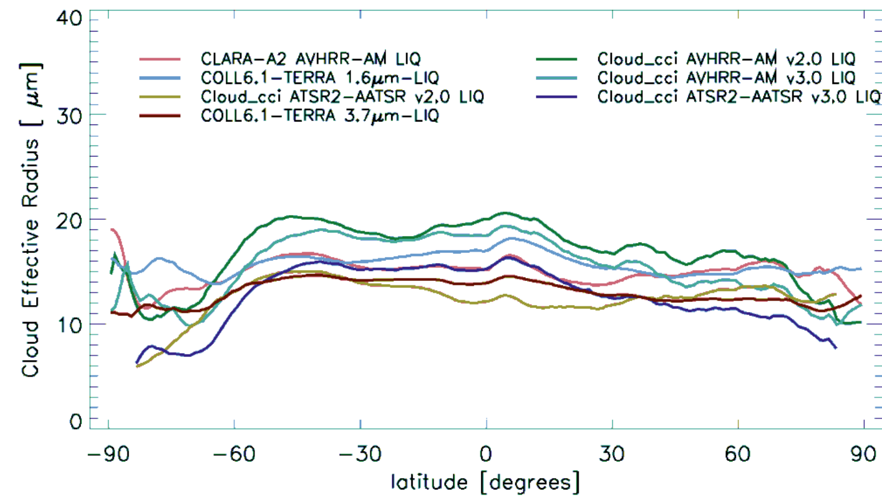
Ice / Liquid effective radius



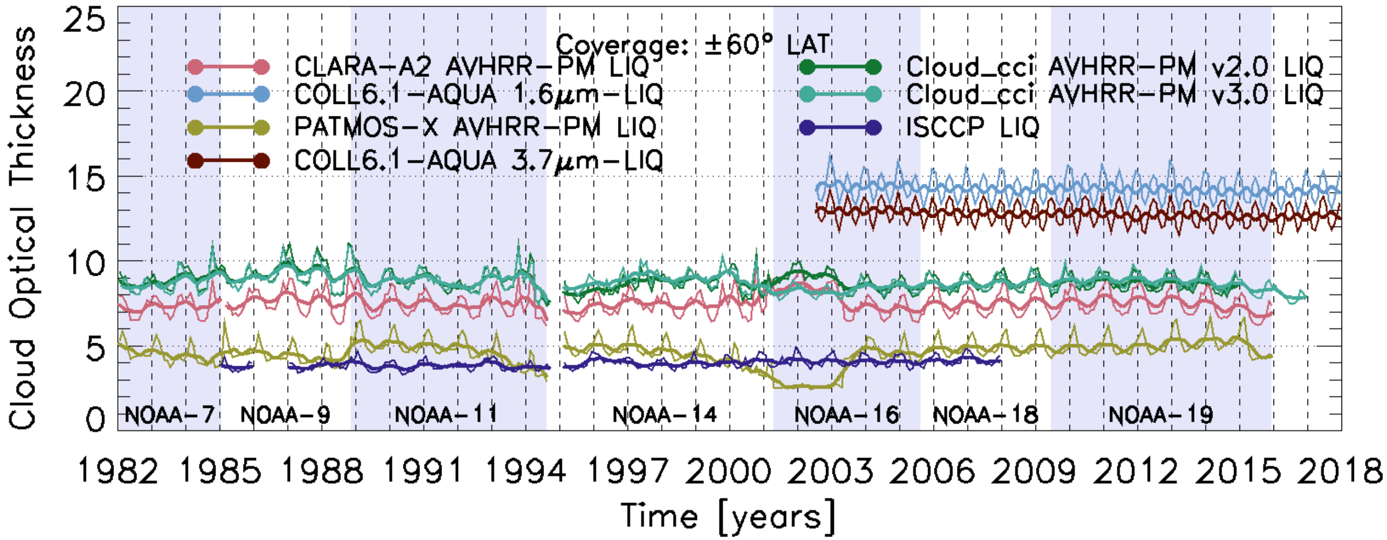


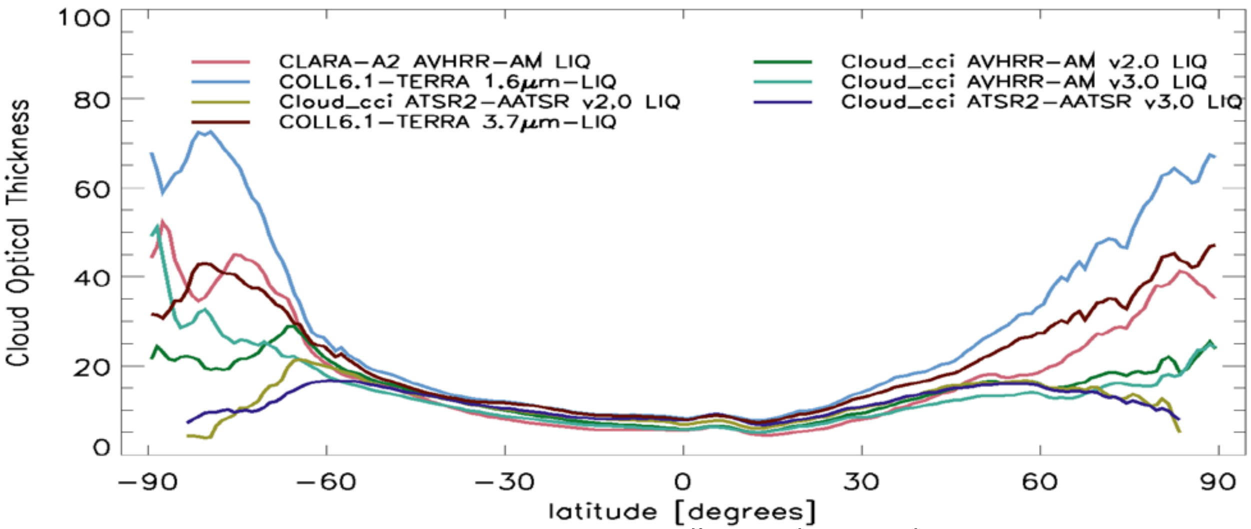




ɔulsen et al.

Liquid optical thickness





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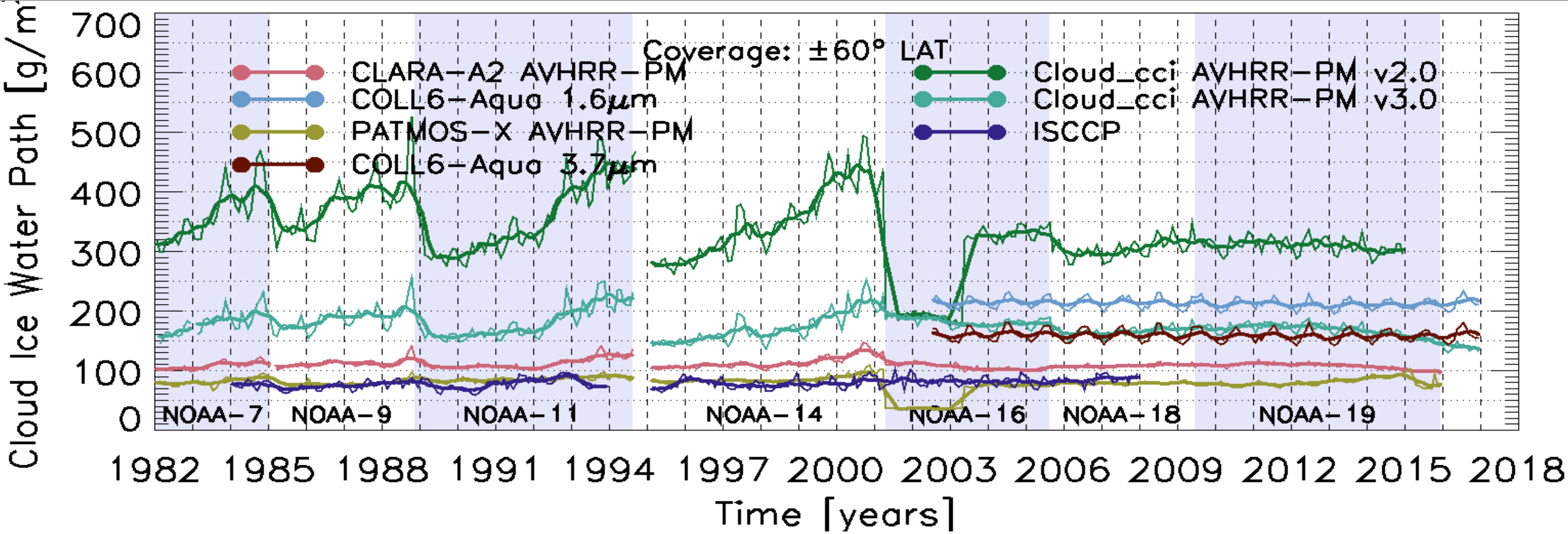
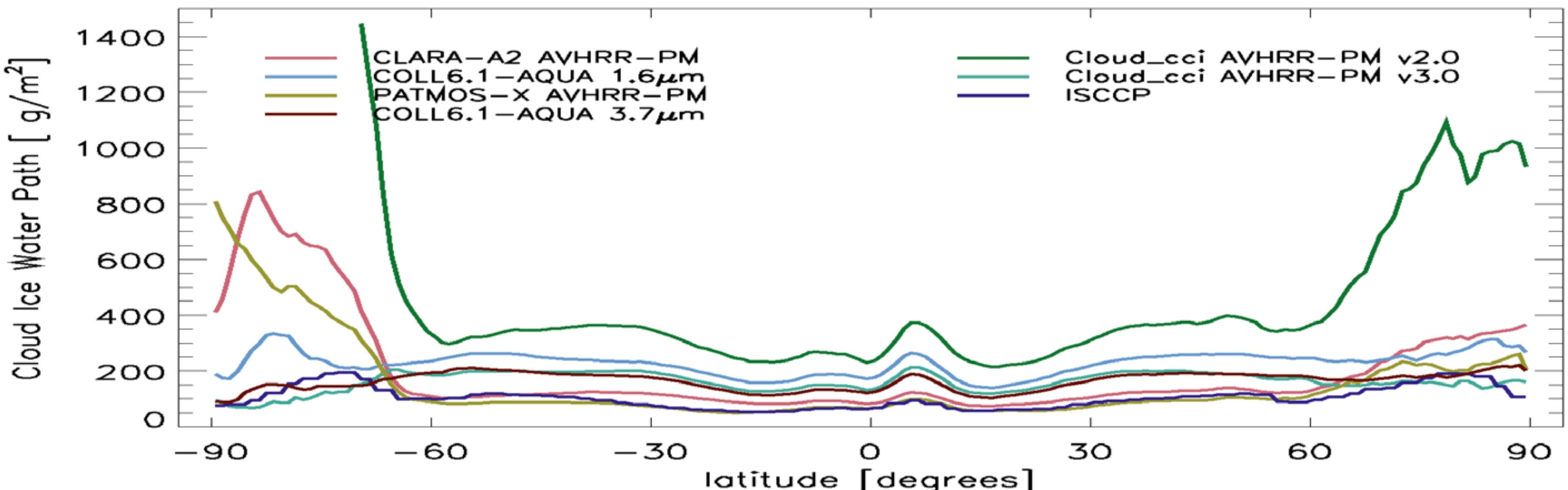
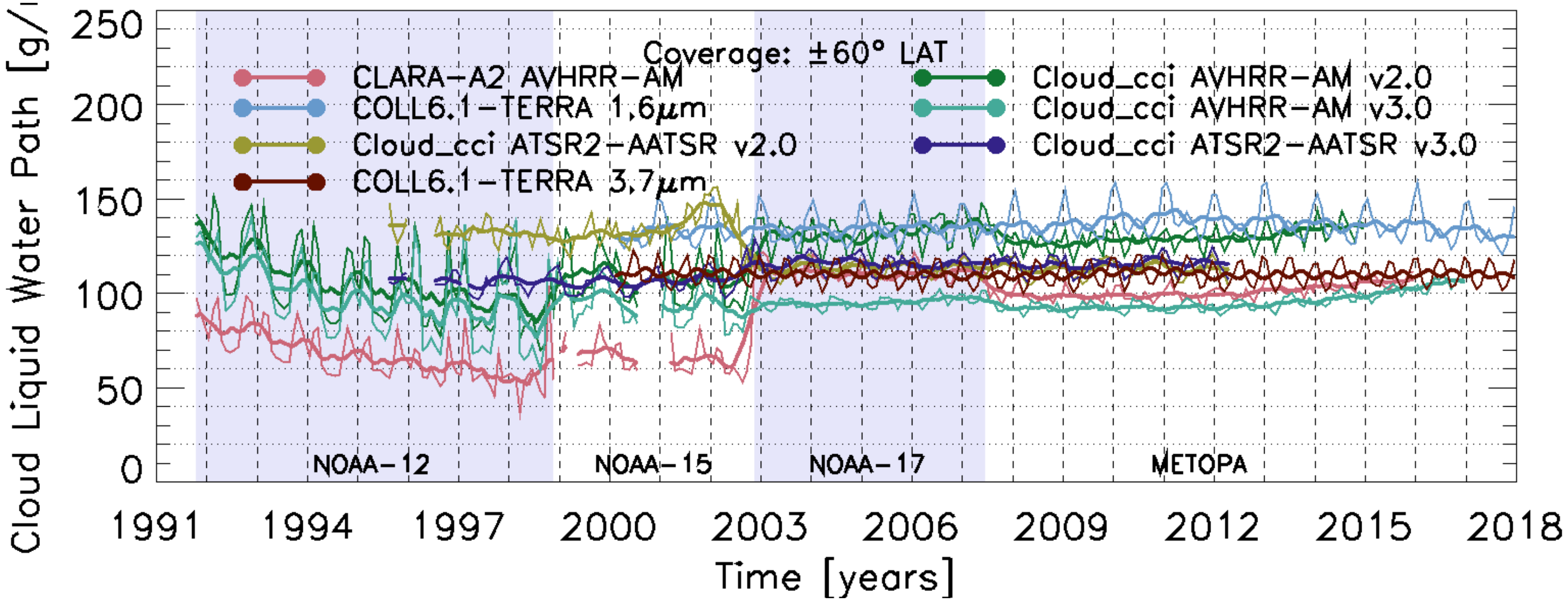
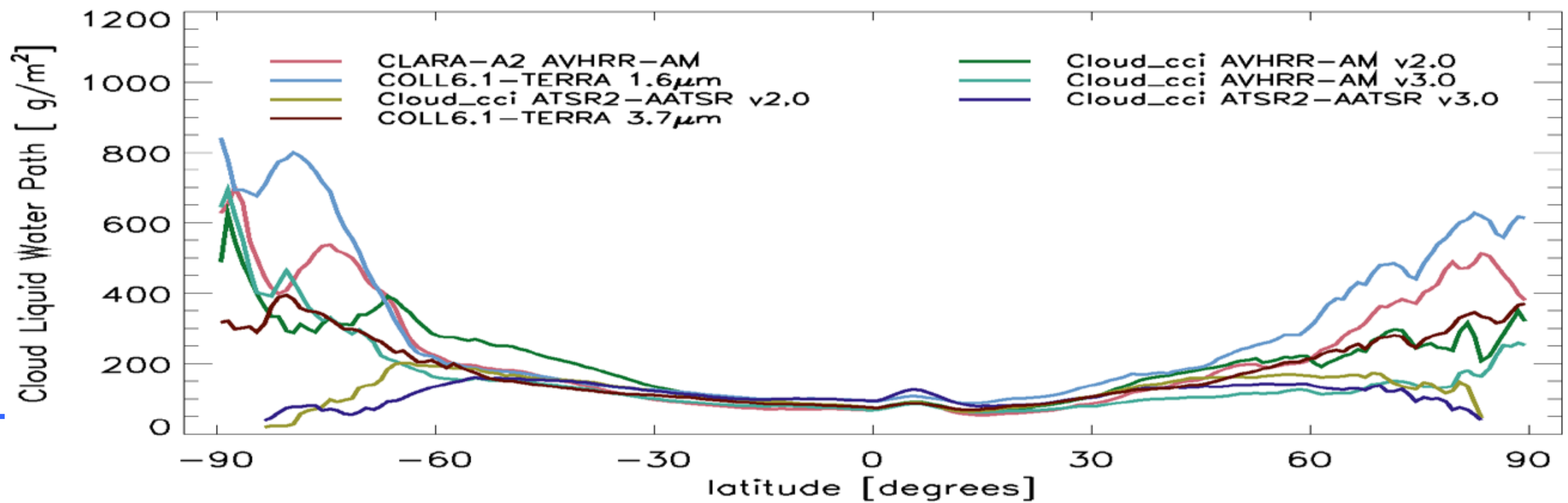
Comparison of Cloud_cci IWP AVHRR-PMv3 with other datasets





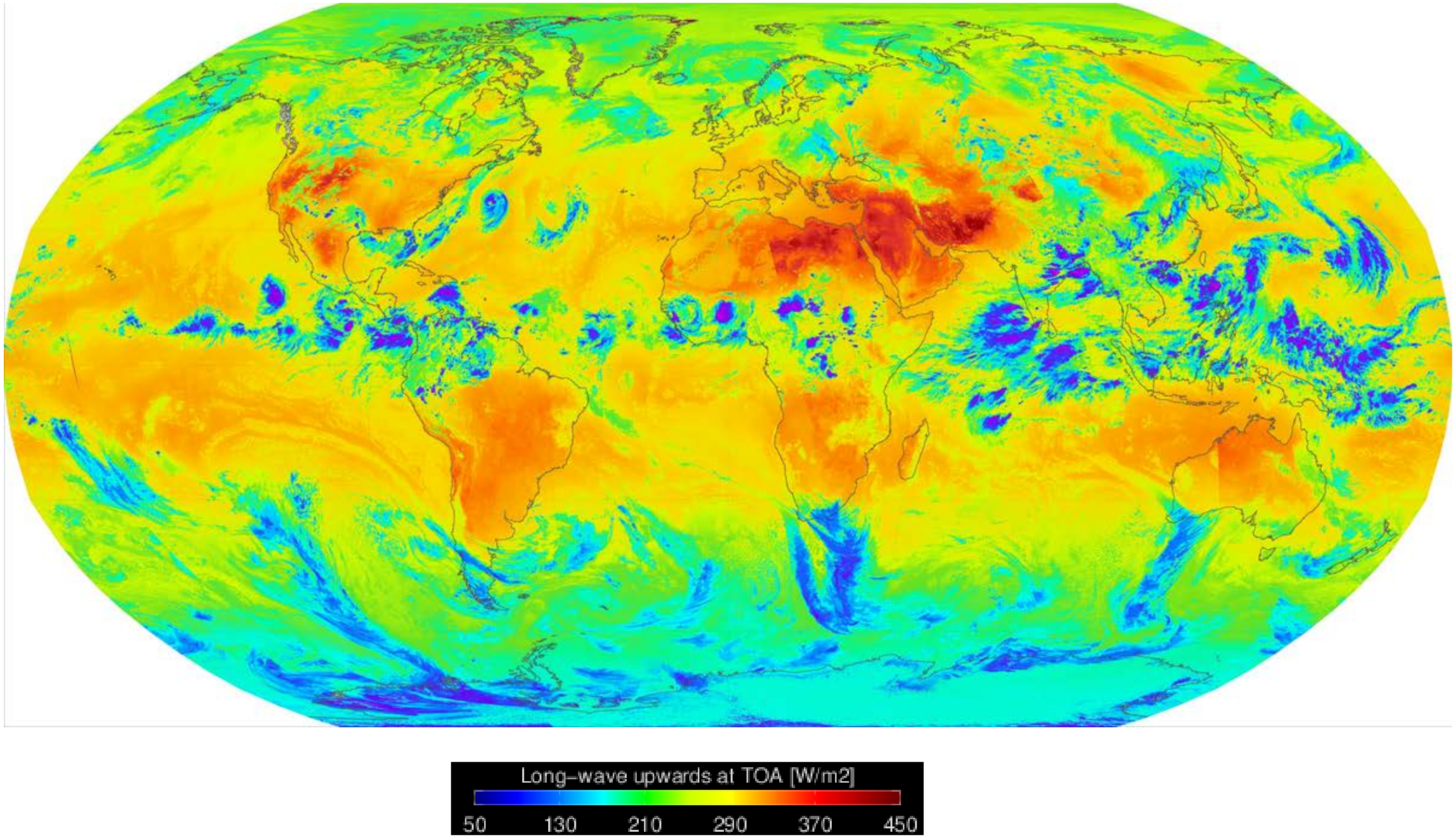
Comparison of Cloud_cci LWP AVHRR-AMv3 with other datasets





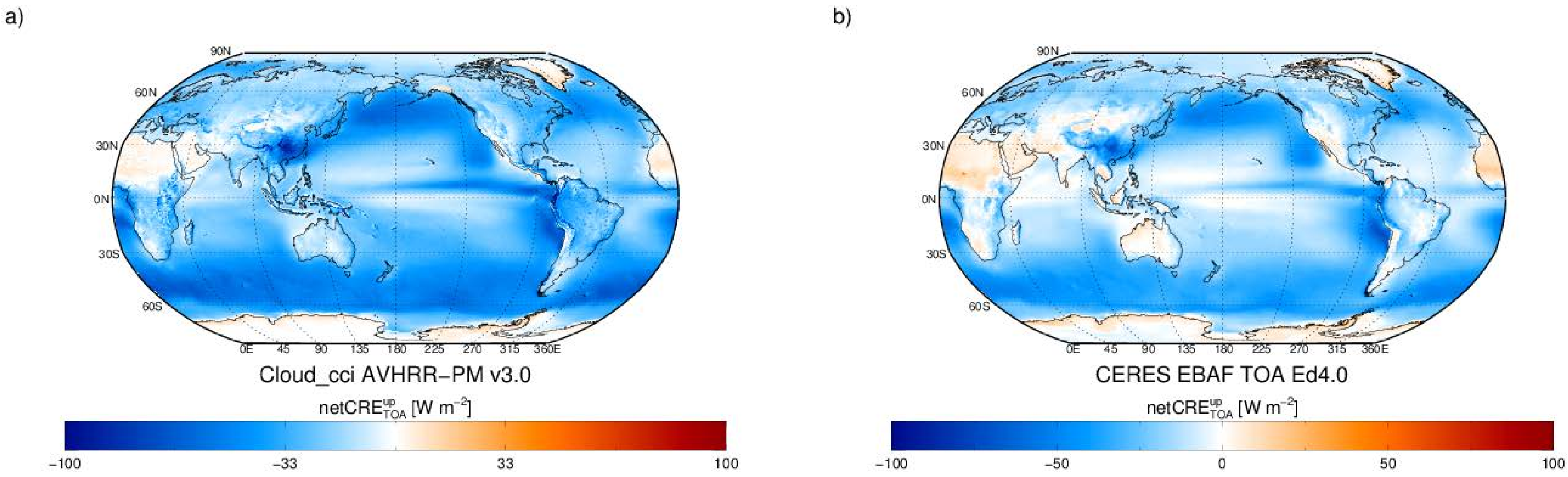
High resolution Cloud Fluxes

TOA LWup all-sky---Long time series



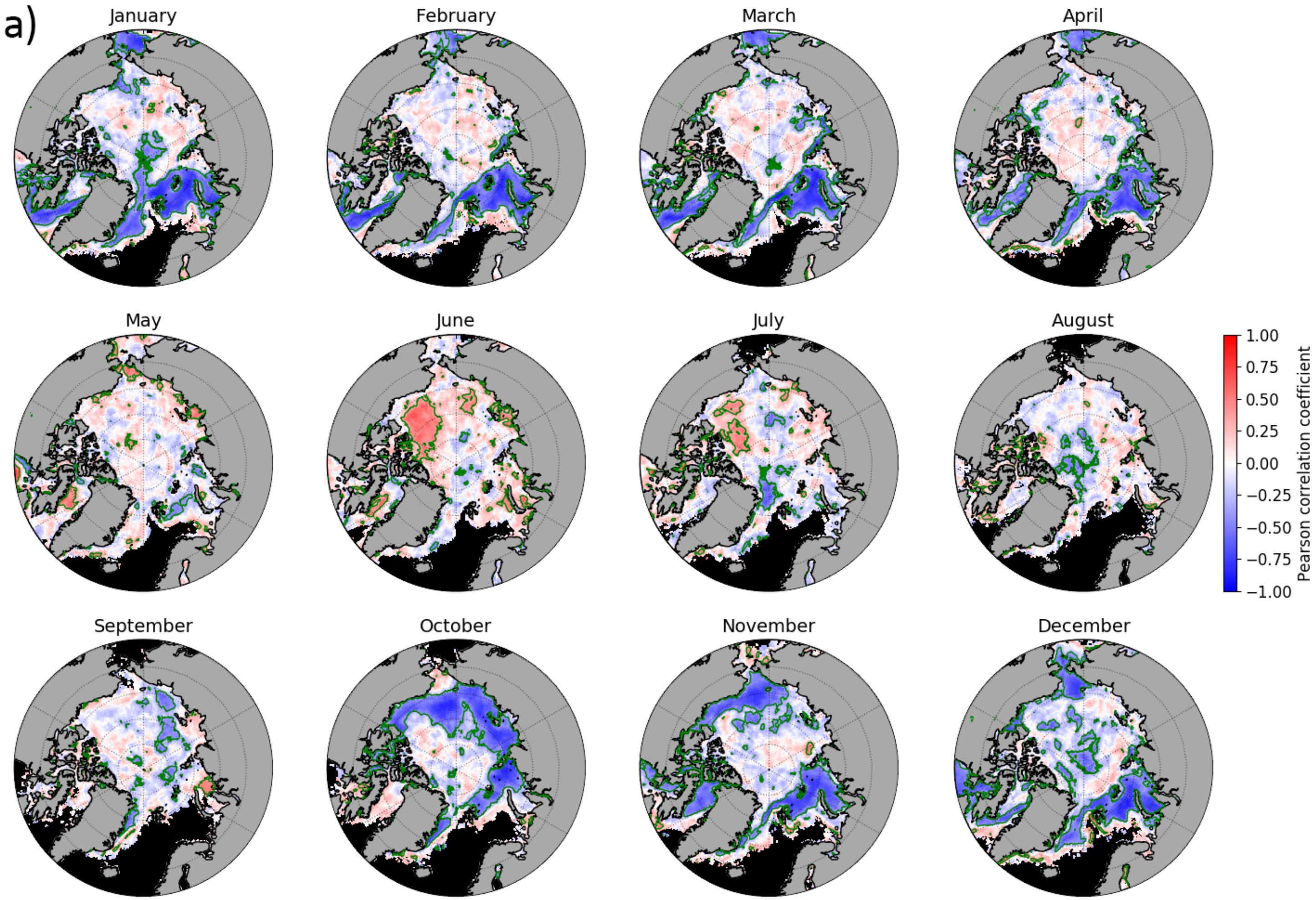
Linking cloud and radiation properties

Cloud radiative effect at TOA (2003-2016)



Very good agreement between Cloud_cci AVHRR-PMv3 and CERES EBAF TOA Ed4.0. cloud radiative effect. Cloud_cci AVHRR-PMv3 covers 1982 to 2016 and includes a large variety of cloud and radiative flux properties at AVHRR GAC spatial resolution (~4km)

Assessing the relationship between artic sea ice and low level clouds (Cloud_cci AVHRR-PMv3)

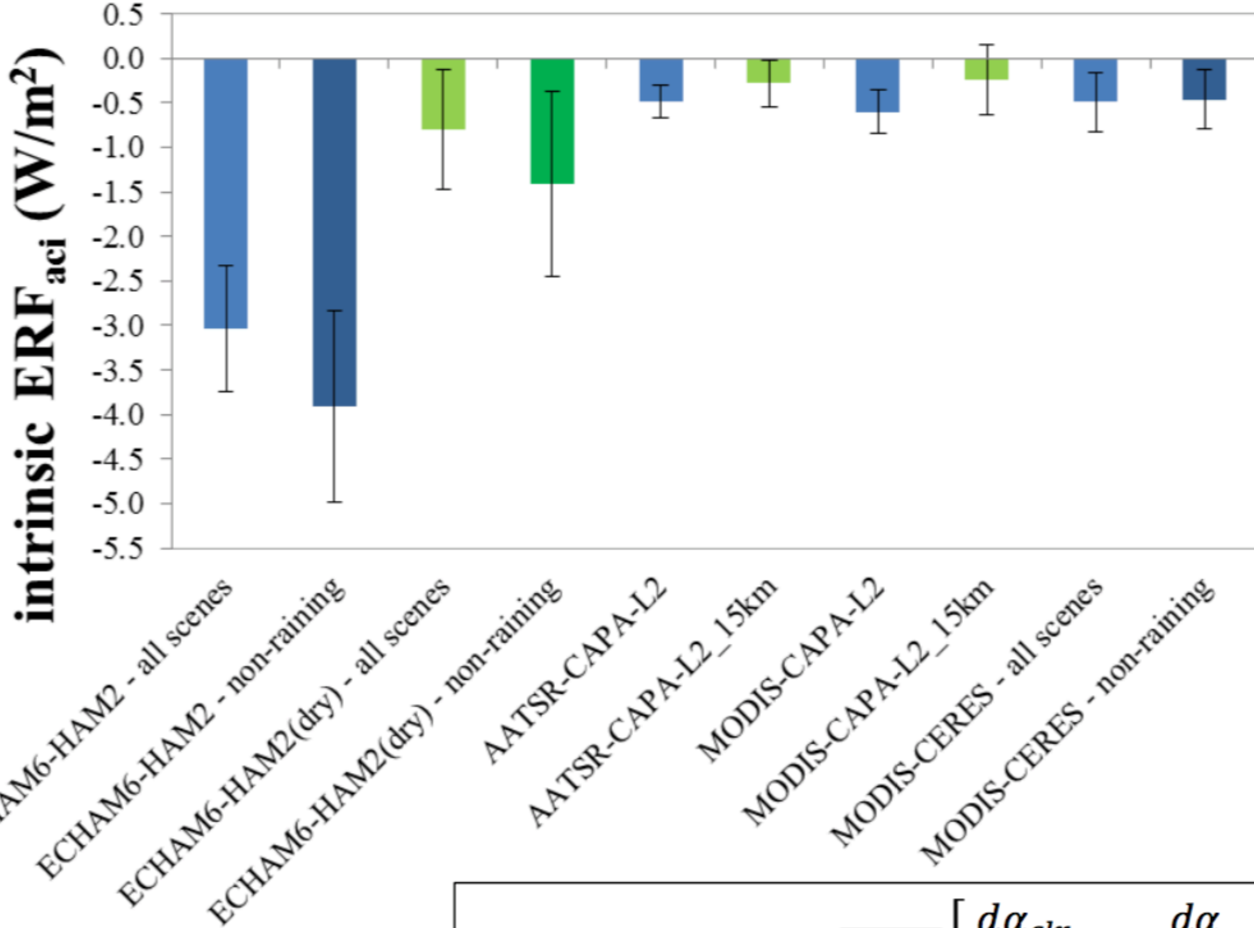


- Artic sea ice decline leads to increased low level cloudiness
- Increased low level cloud, increases downwelling LW Flux at BOA

Figure: Pearson correlation coefficients for low-level cloud fraction with sea ice concentration (1984-2015). Green contour line indicates significance at 95% level of confidence. Grey: Continent; Black: Ocean. Courtesy of Daniel Philipp (DWD).

Effective radiative forcing (ERF_{aci}) of low liquid clouds

(average over global oceans)



$$intrinsic\ ERF_{aci} = \overline{LCC_m}\left[\frac{d\alpha_{clr}}{d\ln AI} - \frac{d\alpha}{d\ln AI}\right]\Delta a_{AI} F_d$$

Neubauer et al. (2017), ACP

Slide from David Neubauer

AATSR-CAPA and MODIS-CAPA data from Christensen et al. (2017), ACP, accepted

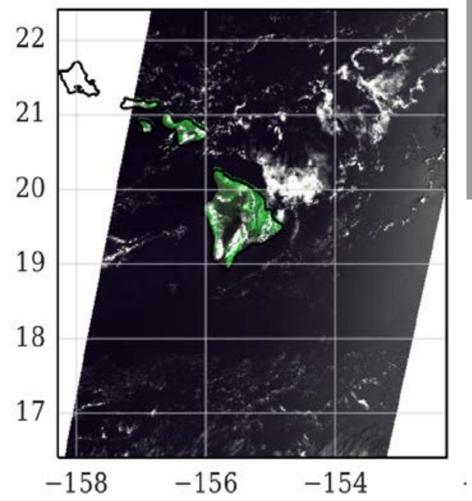
MODIS-CERES data from Chen et al. (2014)

IACETH

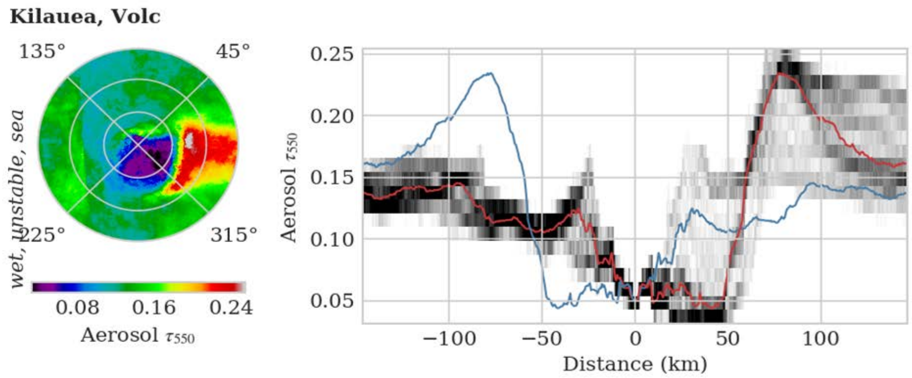
Institute for Atmospheric and Climate Science

The variation of cloud properties with aerosol index *Adam Povey et al.*

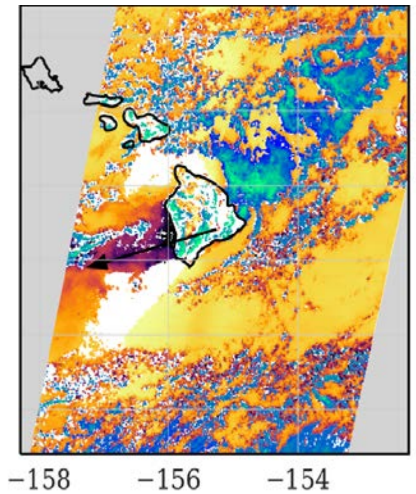
False colour AATSR imagery.

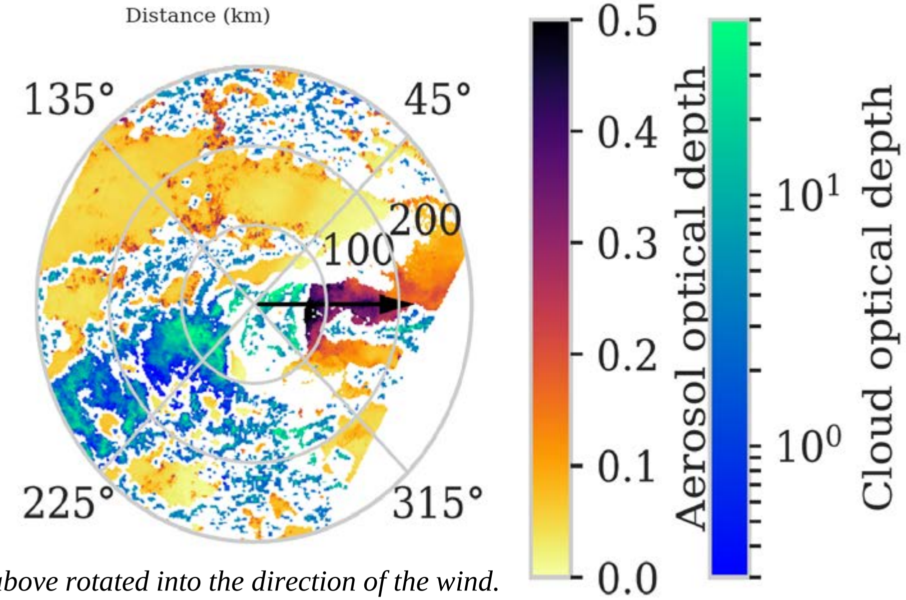


Average aerosol optical depth around Mt. Kilauea



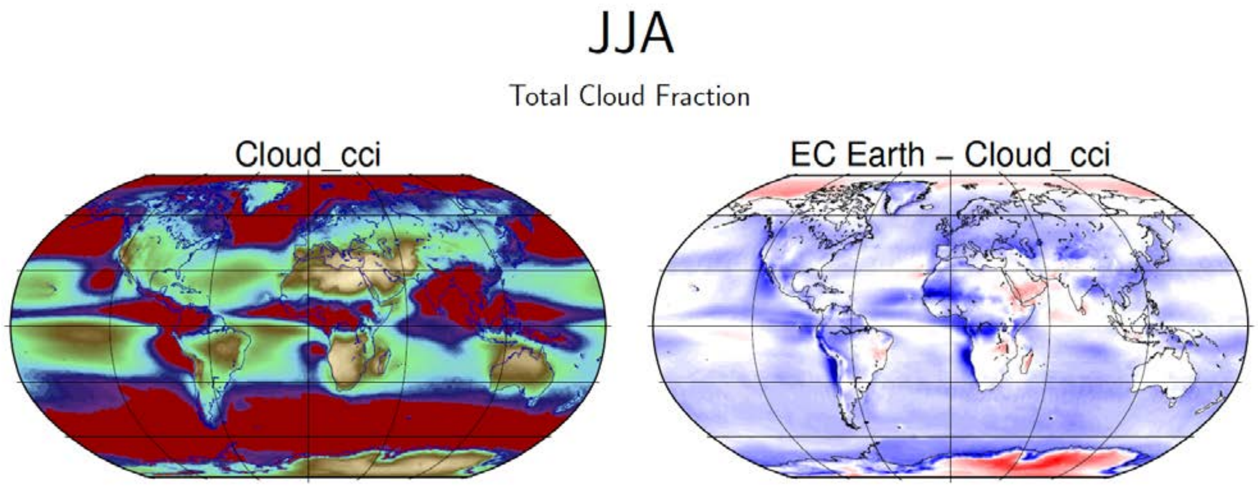
ORAC retrieval of aerosol and cloud.



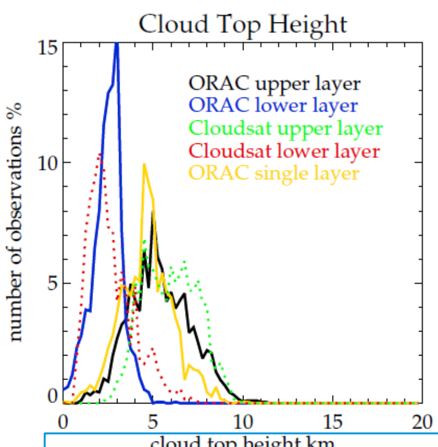


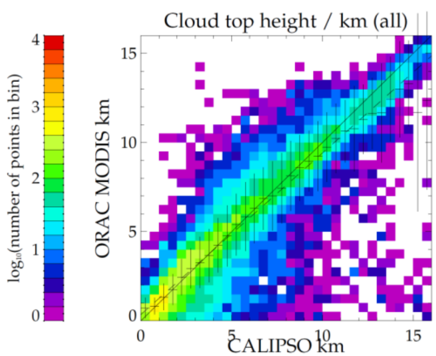
That data above rotated into the direction of the wind.

Additional CCI activities



Simulator
Eliasson et al 2018





Multi-layer cloud algorithm
Demonstration with MODIS

Application to SLSTR

Conclusions I

- **Successes**
  - **Optimal estimation/NN approach**
  - **CDRs cloud properties and fluxes produced from multiple sensors**
  - **Download:http://cci.esa.int/data#ftp**
  - **Science studies, e.g aerosol, cloud sea ice**

Conclusions II

- **Challenges**
  - **Diurnal cycle correction**
  - **Retrievals in twilight**
  - **Cloud detection and retrieval over polar regions**
  - **Consistency between different sensors**
    - Does this really matter?
    - Understand differences in microphysical and derived properties
    - ....phase, calibration, spectral shape, spatial resolution, measurement noise, angular geometry
- **CCI plus**
  - **2019-2021**
  - **Much smaller project**
  - **New R&D focus on SLSTR and SEVIRI**