CLOUD PRODUCTS IN CLARA-A3: AN OVERVIEW

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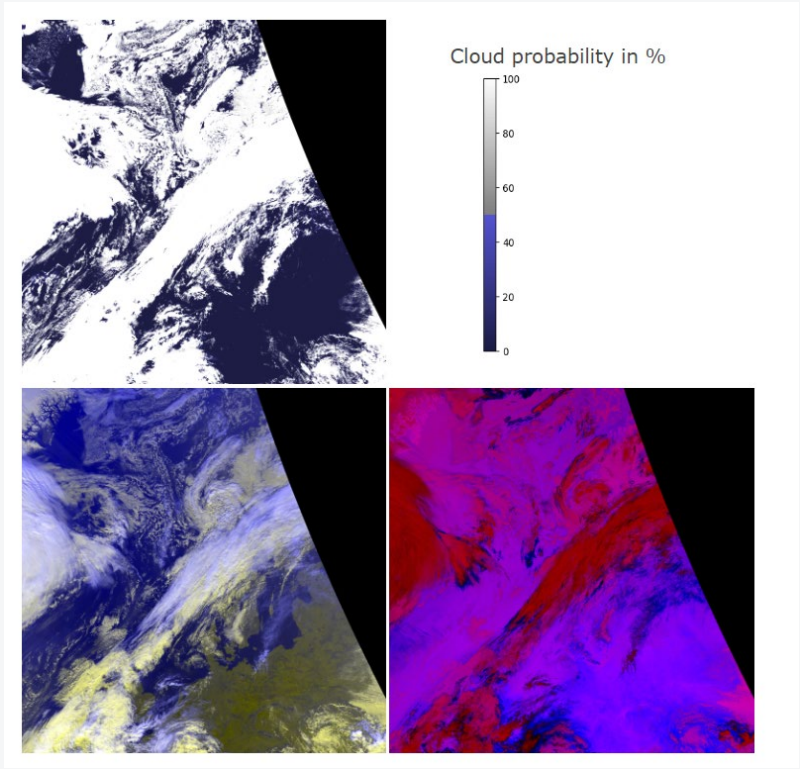
Cloud detection and estimation of fractional cloud cover

5/6-channel **AVHRR** instrument – longest available time series of multispectral data (4+ decades)

Cloud detection: Clouds look different in different spectral channels!

- Clouds are bright in visible channels where the surface is generally dark (except snow)
- Clouds are generally colder than the surface in infrared channels
- Differences between water clouds and ice clouds are utilised in the shortwave infrared channels where also separation from snow is possible
- Cloud signatures are learnt statistically from space-based cloud lidar measurements and used by a statistical classifier

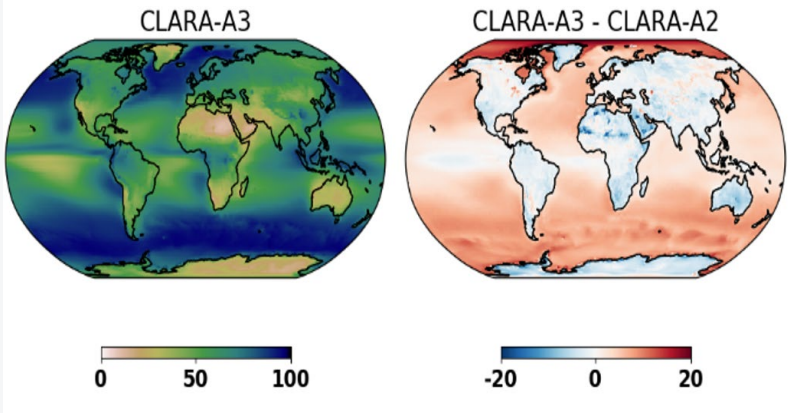
Cloud fraction is computed from the cloud mask (thresholded at 50 % cloud probability) in the CLARA-A3 grid resolution (0.25 degrees).



Example of Cloud probability product and two multispectral images from 16th of September 2023

Cloud detection improvements since CLARA-A2

- New cloud detection method capable of providing uncertainties (probabilities) for the presence of clouds
- Upgraded input data (e.g., ERA5 reanalysis, ice cover and surface emissivities)
- More clouds (+ 3 %) are detected giving an average global cloud fraction of close to 66 %
- More clouds detected over ocean surfaces, especially over mid- to high-latitudes and in particular over the Arctic Ocean.



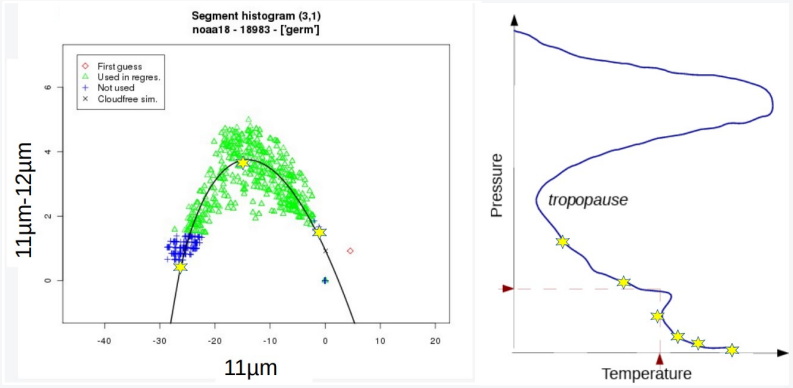
Mean global cloud coverage from CLARA-A3 (left) and difference from CLARA-A2 (right)

Cloud Top Height estimation

Finding the cloud top: Differences in temperature measurements in infrared channels and the variability in the pixel surroundings can be used to estimate cloud top height

- Needs background information on vertical structure in the atmosphere (ERA5 Reanalysis)
- Looks at temperature both at pixel and at pixel surroundings in two infrared channels (11 and 12 microns)
- Neural network trained with height information from space-based cloud lidar measurements

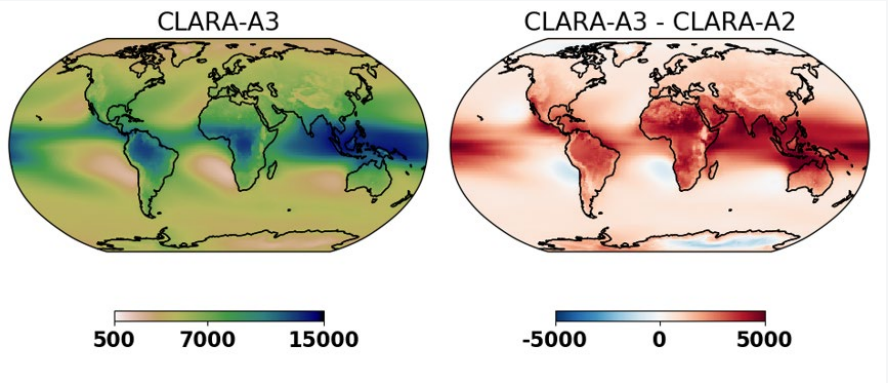
Cloud top temperature first derived and then translated further to cloud top pressure and height



Principles for height determination – neural network with 9 input data (stars): 6 vertical levels (ERA5), pixel temperature, minimum and maximum temperatures in pixel surroundings

Cloud top height improvements since CLARA-A2

- New cloud top height retreival based on machine learning (neural network)
- Method capable of predicting error distribution
- (1 standard deviation)
- Very large improvements for tropical thin cirrus (~ + 3000 meters)
- Some improvements of heights for marine stratocumulus (~ -300 meters)



Mean global cloud top height from CLARA-A3 (left) and difference from CLARA-A2 (right)

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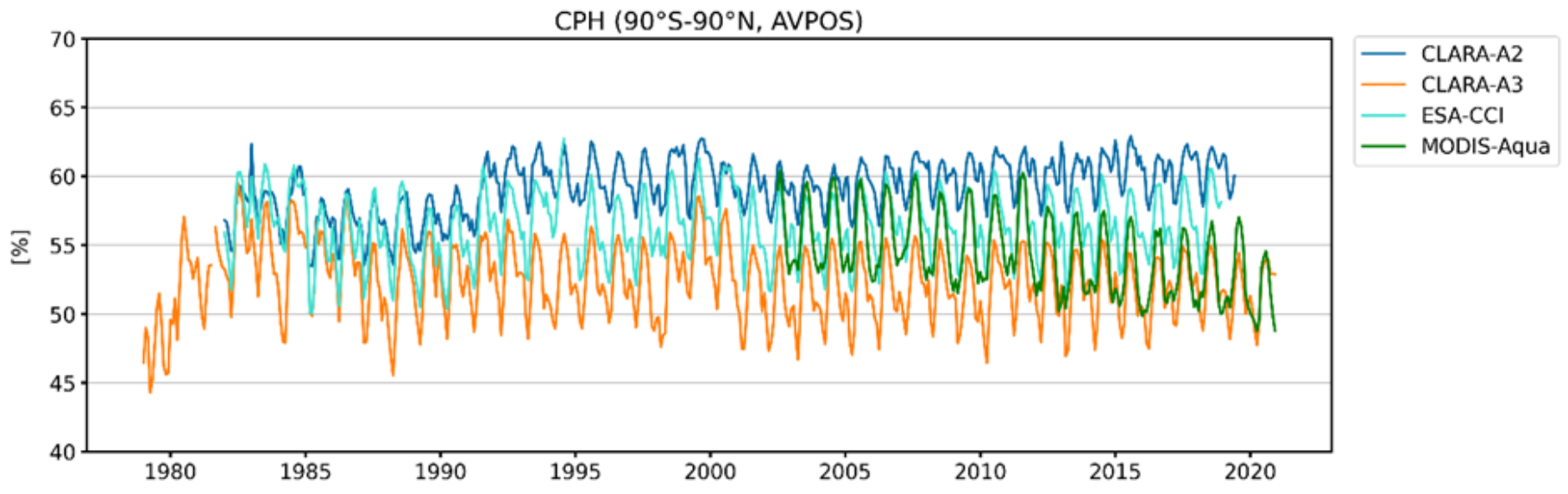
Cloud optical and microphysical properties

- Available parameters
  - CPH: Cloud thermodynamic phase (liquid or ice)
  - COT: Cloud optical thickness
  - CRE: Effective radius of water droplets or ice crystals
  - LWP/IWP: Liquid / ice water path: amount of cloud condensate in vertical column
  - CDNC: Cloud droplet number concentration (liquid water clouds only)
  - CGT: Cloud geometrical thickness (liquid water clouds only)

- Improvements compared to CLARA-A2
  - New radiative transfer calculations with revised representation of cloud particles
  - Improved representation of surface albedo
  - More detailed uncertainty estimates
  - Additional parameters CDNC and CGT
- Keep in mind
  - These products (except cloud phase) are only retrieved during daytime because shortwave channels are required.
  - AVHRR instruments have either channel 3a (1.6 micron) or 3b (3.7 micron) switched on during daytime. Retrievals are performed in both cases but for consistency in aggregated (e.g., monthly mean) products only observations with channel 3b are included.

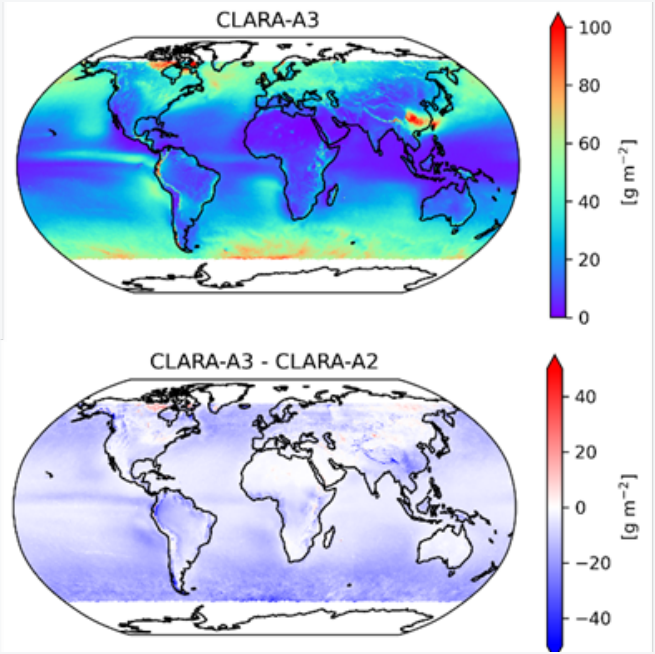
Example: cloud phase

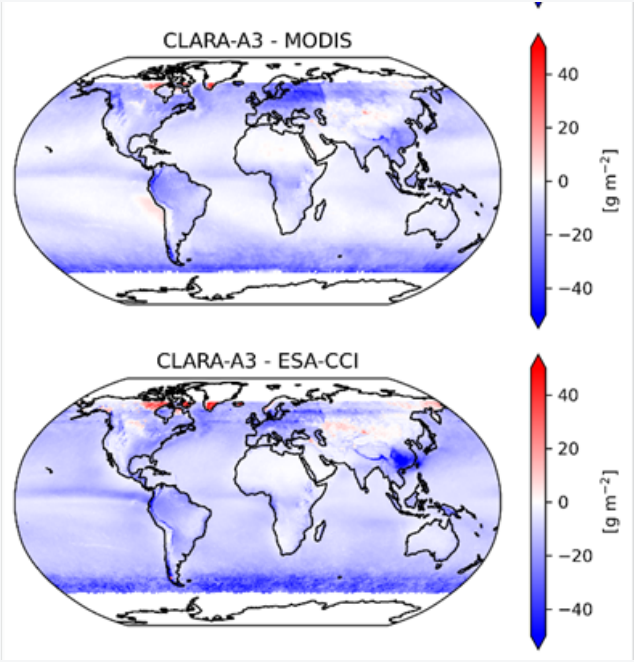
- Overall stable timeseries except first years and around 2000
- Lower liquid cloud fraction than in CLARA-A2 related to larger amount of ice clouds detected and lower corresponding cloud top temperatures



Example: liquid water path

- Overall lower values than other data records, consistent with lower fraction of liquid water clouds

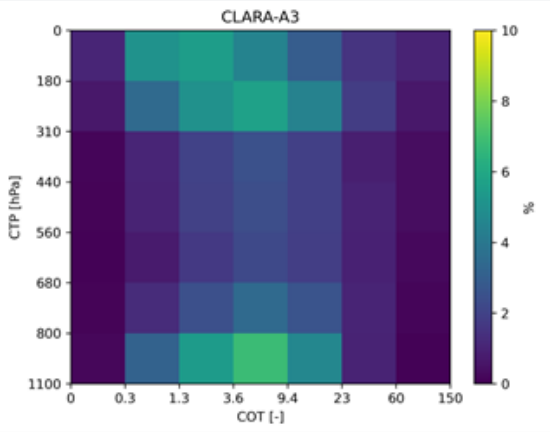




Joint Cloud Histogram

In some applications (for example, evaluation of climate models) it can be valuable to combine several cloud products.

- The Joint Cloud Histogram shows joint information about the cloud phase (water or ice), the height of the cloud and the (optical) thickness of the cloud
- Information is given in a coarse resolution (1 degree grid) to allow for better sampling
- Results should preferably be accumulated over selected regions



Example of joint cloud histogram in the 60°S-60°N latitudinal band for the time period 2003/01 – 2020/12. Both cloud phases are accumulated here.