The CLARA-A1 satellite simulator: Examples using the global climate model EC-Earth

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To facilitate meaningful comparisons of CLARA-A1 cloud properties from passive AVHRR satellite retrievals with GCM simulations, a satellite cloud product dataset simulator was developed. CFMIP identified simulators as an important modeled-cloud analysis tool, as direct comparison of modeled cloud output with satellite observations fails to incorporate assumptions within each respective satellite-derived cloud dataset. This resulted in the development of the COSP framework. This poster displays the capability of the prototype CLARA-A1 cloud product satellite simulator using simulated output from the EC-Earth GCM using prescribed sea-surface temperatures (SA07) from 1982-2009.

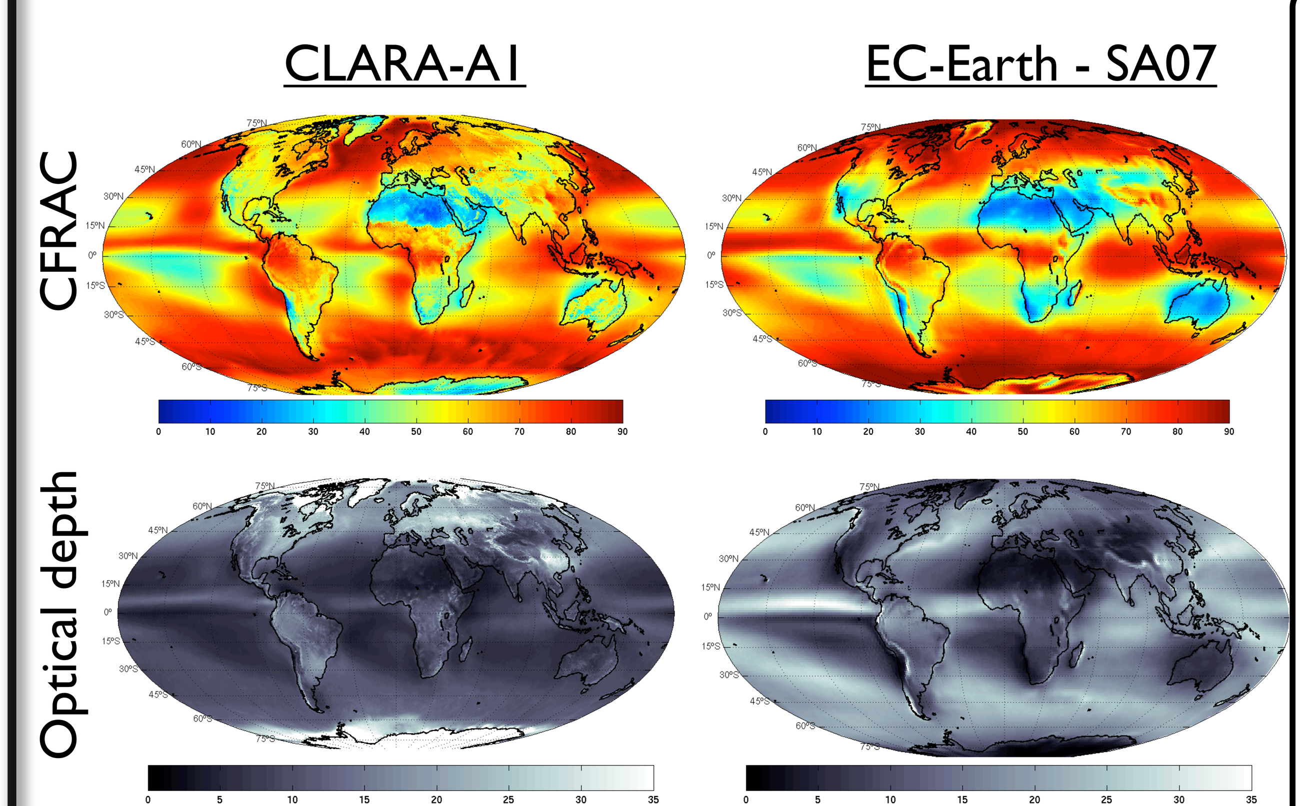
CLARA-A1: CMSAF cLouds, Albedo and RAdiation-AVHRR, 1st reprocessing (Karlsson et al., 2013, ACP)

CFMIP: Cloud Feedback Model Intercomparison Project (cfmip.metoffice.com)

COSP: CFMIP Observation Simulator Package (cfmip.metoffice.com/COSP.html)

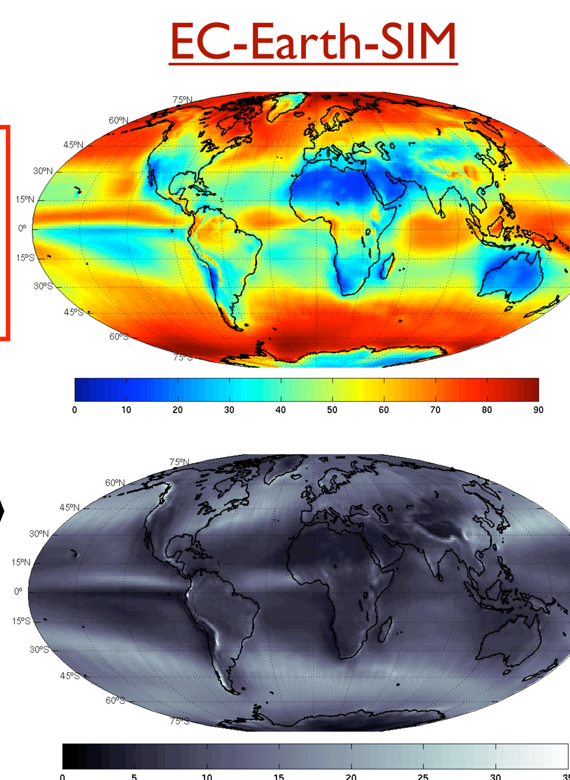
AVHRR: Advanced Very High Resolution Radiometer

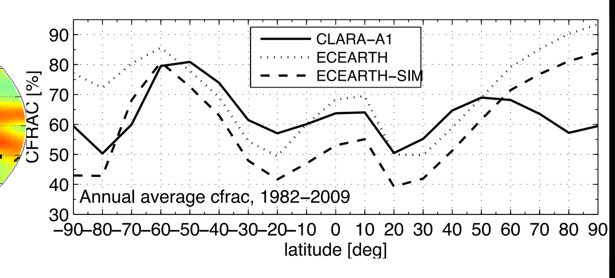
GCM: Global Climate Model

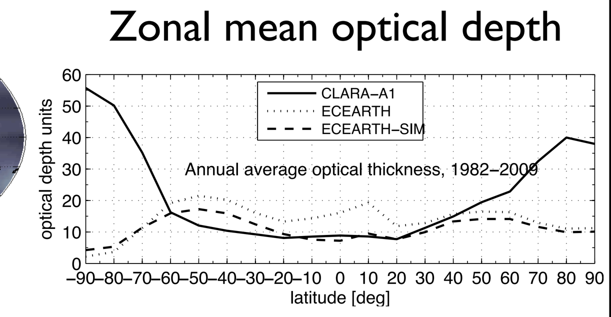


EC-Earth gridbox total cloud fraction (69.6%) geographically coherent with CLARA (63.1%) but important stratocumulus region deficiencies apparent in EC-Earth.
CLARA-A1 has cloud fraction biases over cold ice and snow-covered regions as well as semi-arid hot regions (Karlsson et al., 2013).
Integrated cloud optical depth much larger in EC-Earth than observations.

EC-Earth output run with CLARA-A1 simulator







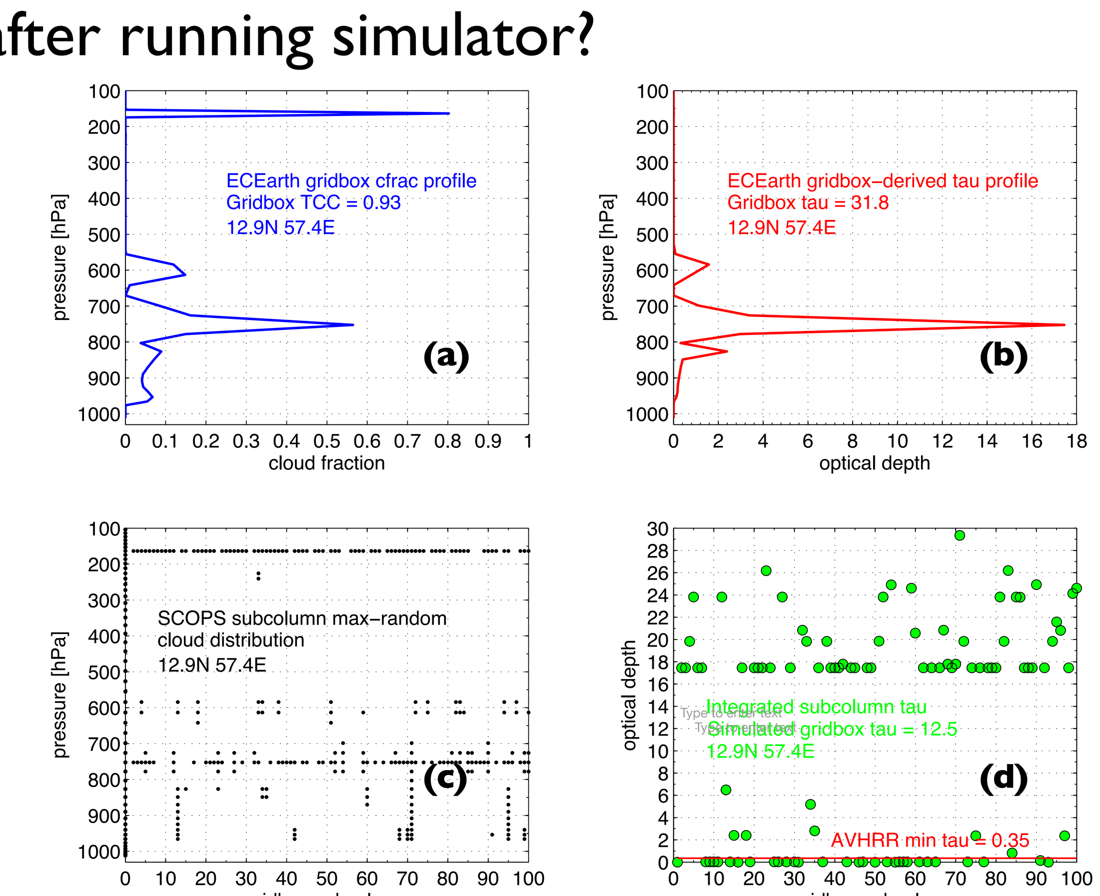
EC-Earth simulated optical depth in better agreement with observations outside of the high latitudes (sea-ice/snow and solar zenith angle restraints complicate microphysical retrievals).
But what causes the reduction in cloud fraction in the simulated GCM output (58.8%) relative to raw model output?

What causes model cloud fraction reduction after running simulator?

SCOPS - Subgrid Cloud Overlap Profile Sampler

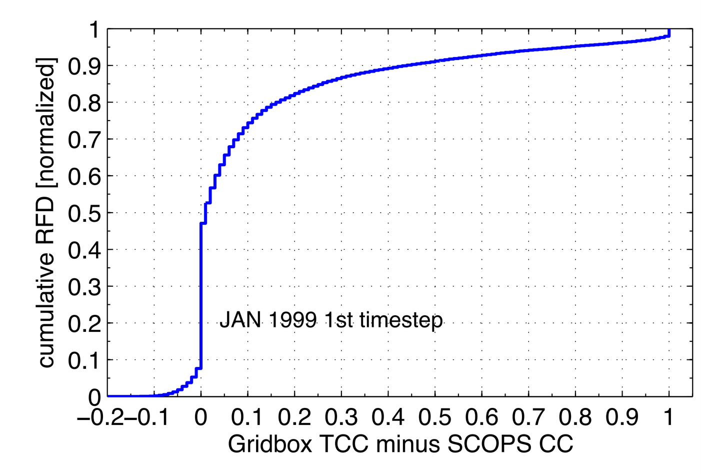
Panels to the right show example profiles of gridbox cloud fraction (a) and optical depth (b); gridbox mean values are given in each panel.

Using the gridbox cloud fraction profile, SCOPS (Klein and Jakob, 1999) distributes n-number of cloud profiles (here 100) pseudo-randomly (c), keeping consistency with model gridbox cloud fraction (a) and using overlap assumptions in the model's radiation code. Each dot in (c) represents a cloudy level in the vertical subcolumn. Each subcolumn vertical level with valid cloud is assigned an optical depth corresponding to the gridbox profile value (b); these are integrated vertically for a subcolumn cloud optical depth (d).

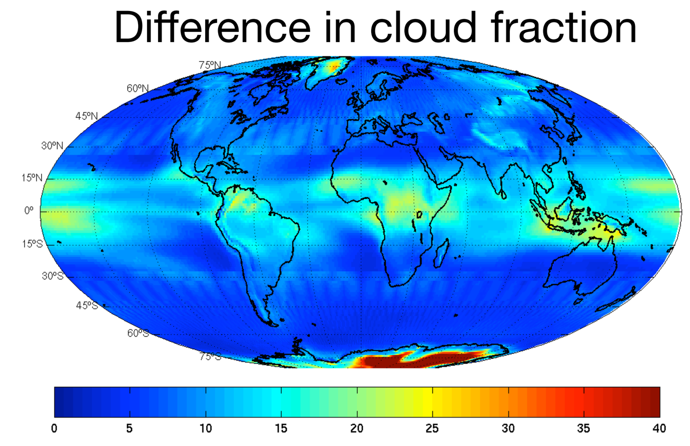


Simulated cloud fraction, and all other cloud properties, are then derived by averaging the distribution of cloudy pixels determined by the subcolumn cloud distribution. The minimum detectable (relative to background) radiation signal from clouds from passive sensors needs to be taken into account by the simulator. For AVHRR this limit is 0.35 (Karlsson and Johansson, 2013). Thus, all cloudy subcolumns with integrated optical depth < 0.35 are essentially clear-sky (d). Resulting simulated cloud fraction for this gridbox is 70%, down from 93% for EC-Earth gridbox cloud fraction!

Model gridbox mean total cloud cover (fraction) minus cloud fraction derived from SCOPS for one model time step for January 1999 (top-right) indicates SCOPS psuedo-random cloud distribution leads to a reduction in cloud fraction between zero and 30%!.

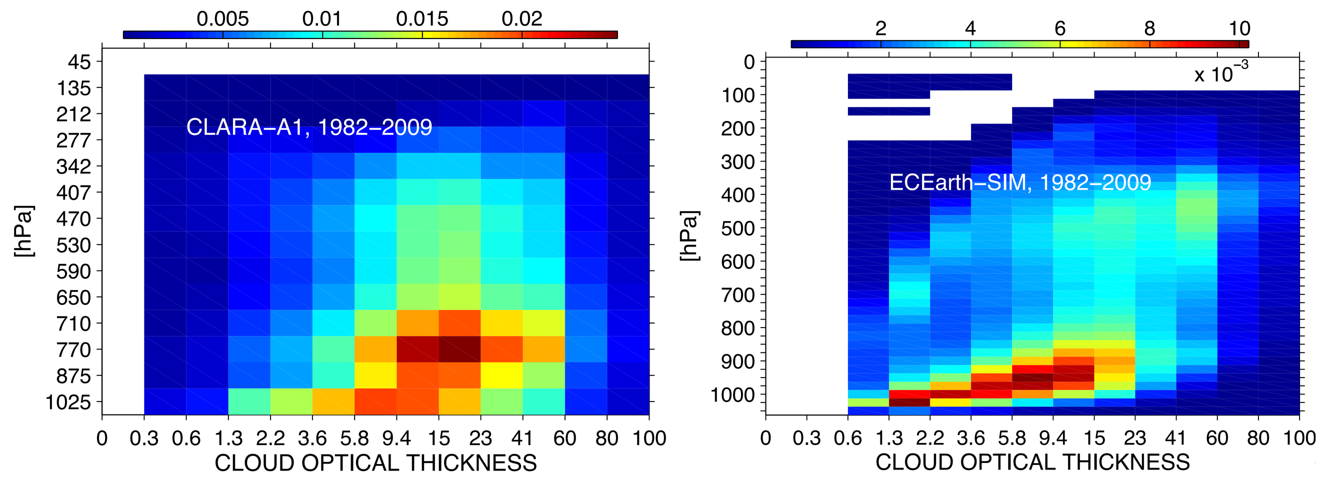


Difference in cloud fraction between EC-Eearth and EC-Earth simulated from 1982-2009 (lower-left). Majority of cloud reduction comes from thin, high clouds in the tropics.



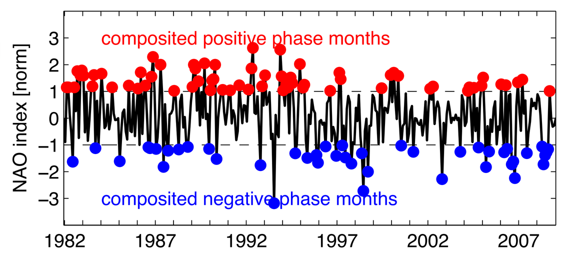
Additional comparisons of CLARA-A1 observations vs. EC-Earth simulations

Pressure-τ histograms



Observational (left) preference for mid-level clouds with modest optical thickness. EC-Earth run with the satellite simulator (right) show increased frequencies of low, optically thinner clouds and high, optically thicker clouds. Here, the observations of cloud top pressure are likely biased by multi-layered clouds.

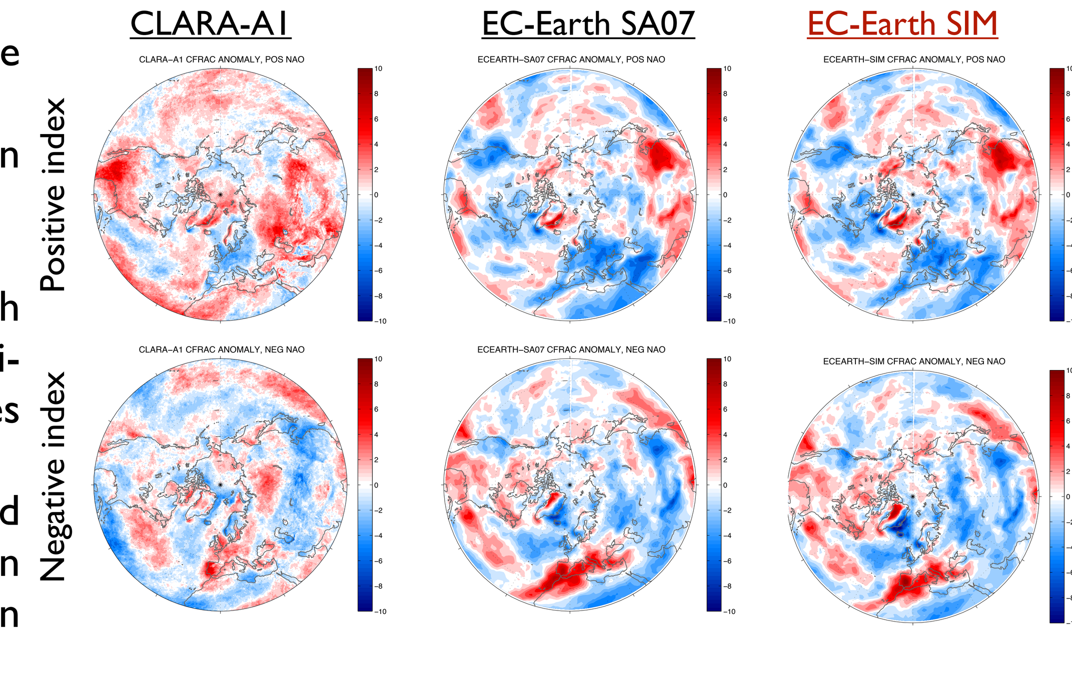
Composited cloud fraction anomalies for positive and negative phases of the North Atlantic Oscillation (NAO)



Observed monthly NAO indices from the Climate Prediction Center (www.cpc.ncep.noaa.gov) (above) with composited +/- months. EC-Earth NAO indices calculated using model SLP differences.

Generally observations capture large-scale behavior of NAO circulation pattern impacts on cloud cover (left-most).

EC-Earth (middle) and EC-Earth simulated (right-most) hemispheric cloud fraction anomalies agree spatially with observed response. EC-Earth simulated anomalies generally larger than EC-Earth - too many optically thin clouds partly masking signal!



Summary

- CLARA-A1 simulator is a necessary tool in order to assess cloud properties in the climate models against the CLARA-A1 observational dataset.
- The treatment of clouds by SCOPS in conjunction with a required minimum integrated cloud optical depth of 0.35, decreases the model cloud fraction by up to 30%, which is more consistent with observations.

Ongoing simulator modifications

- Treat multi-layered and semi-transparent clouds consistent with observations
- Including temporal sampling constraints (local satellite overpass time with model timestep)
- Output LWP/IWP

References

Karlsson and Johansson (2013): On the optimal method for evaluating cloud products from passive imagery using CALIPSO-CALIOP data: examples investigating the CM SAF CLARA-A1 dataset. Atmos. Meas. Tech., 6, 1271-1286.
Karlsson, K.G. and coauthors (2013): CLARA-A1: a cloud, albedo and radiation dataset from 28 yr of global AVHRR data. Atmos. Chem. Phys., 13, 5351-5367.
Klein, S.A. and C. Jakob (1999): Validation and Sensitivities of Frontal Clouds Simulated by the ECMWF Model. Month. Weather Review, 127, 2514-2531.