Evaluation of GEOS total cloud fraction with GLOBE citizen science observations and co-located satellite data

Matthew Starke[1], **Nathan Arnold[2,3]**, Helen Amos[3,4]

[1]NASA Goddard Space Flight Center Intern, [2]Global Modeling and Assimilation Office, Greenbelt, MD, [3]NASA Goddard Space Flight Center, Greenbelt, MD, [4]Science Systems and Applications, Inc., Lanham, MD

GMAO Global Modeling & Assimilation Office

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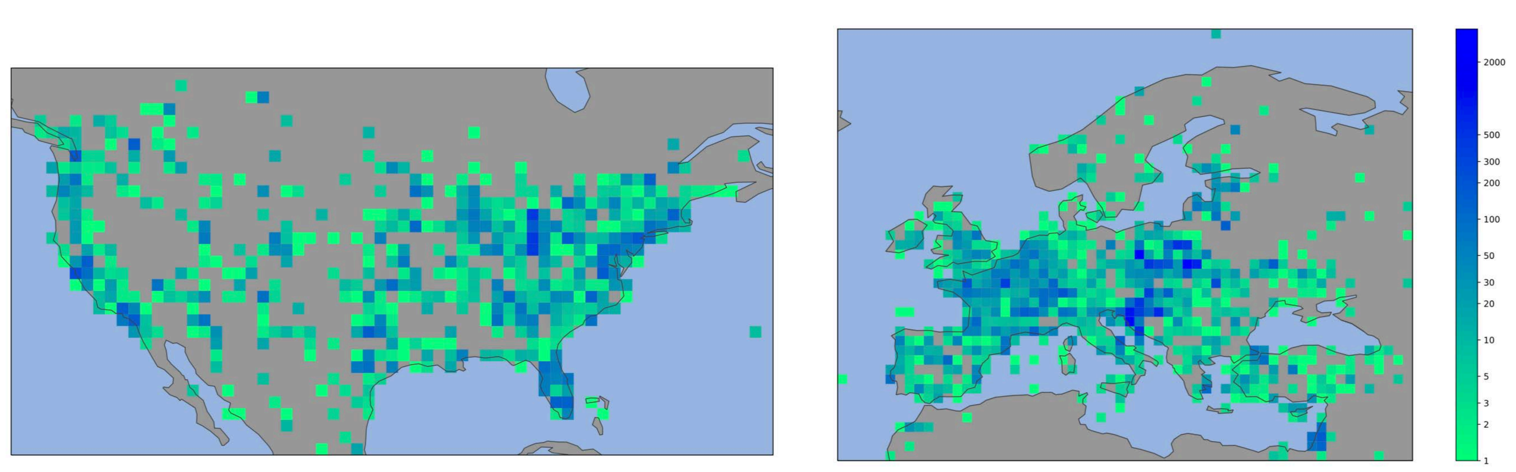
Introduction

Through the Global Learning & Observations to Benefit the Environment (GLOBE) Program, citizen scientists submit observations of cloud fraction online or via smartphone app. Here we use citizen cloud observations over North America and Europe to evaluate simulated cloud fraction from the NASA Global Earth Observing System (GEOS) atmospheric general circulation model (AGCM).

To ensure simulated meteorology is historically consistent, we run "replay" experiments in which the model temperature, humidity and winds are constrained by the MERRA-2 reanalysis. Each experiment uses an alternate form of the probability density function (PDF) describing the sub-grid distribution of total water, which governs the model's stratiform cloud fraction.

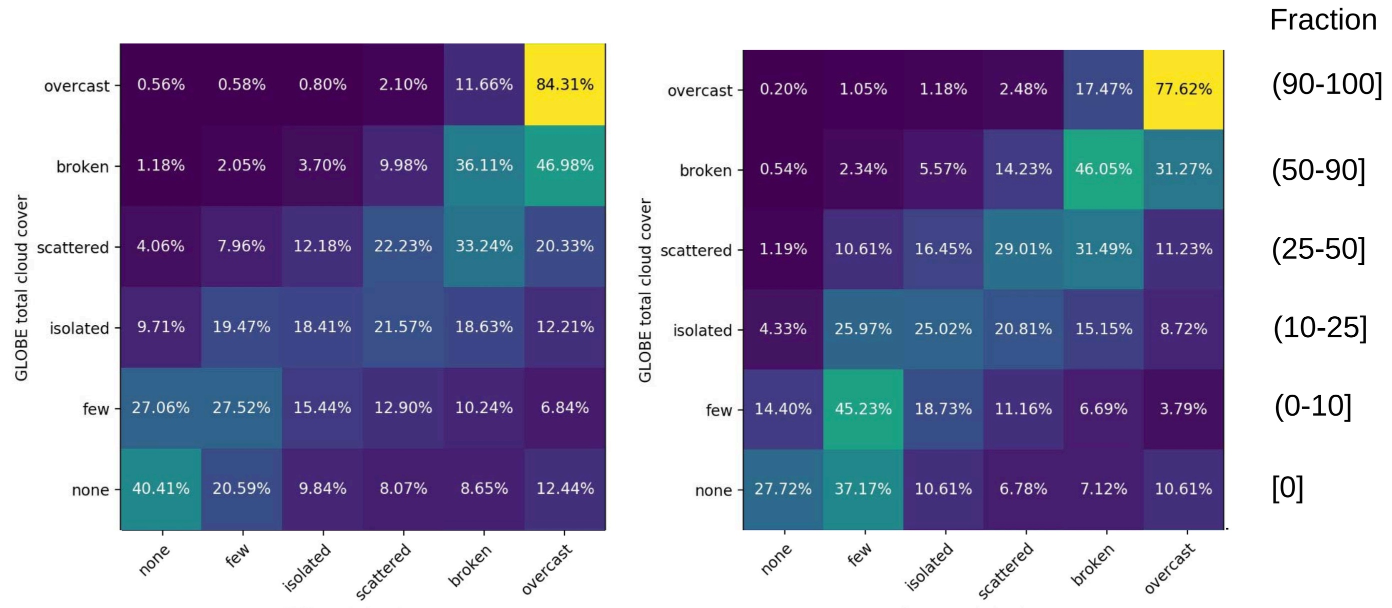
Density of GLOBE observations

We use GLOBE citizen science observations spanning the period March 15 to April 15, 2018, from North America and Europe.



GLOBE cloud fraction vs. MODIS and GEO data

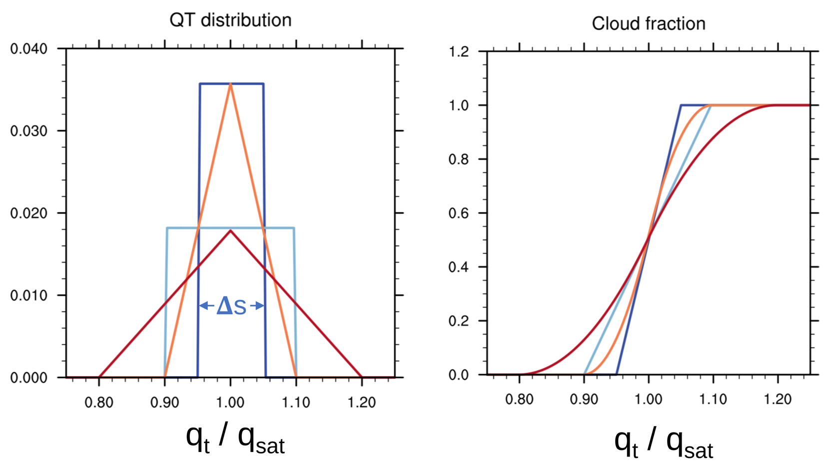
Bivariate histograms matching GLOBE cloud fraction with geostationary satellite estimates (left) and overpasses of Aqua MODIS (right). Normalized row-wise; each row is a histogram conditional on GLOBE cloud cover.

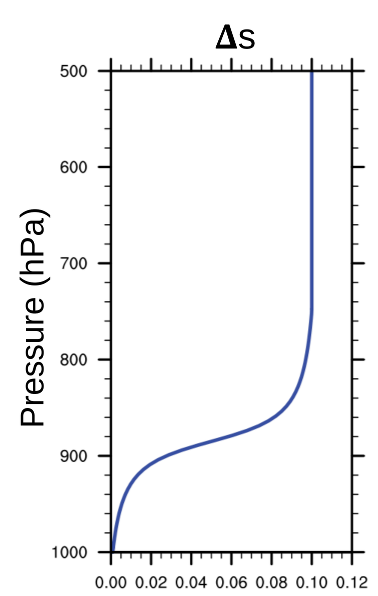


GLOBE observations show little systematic bias relative to the satellite data.

GEOS cloud parameterization and replay procedure

Stratiform cloud fraction is diagnosed using an assumed distribution of sub-grid total water, q_t. The default distribution is uniform with a width Δs that varies with pressure and model resolution. Here we also consider an alternative triangular distribution.





Replay Experiments use a horizontal resolution of ~25 km (C360), with 72 levels.

Schematic of replay procedure shown at right.

Experiments are named based on uniform (Uni) or triangular (Tri) PDF, and width of distribution.

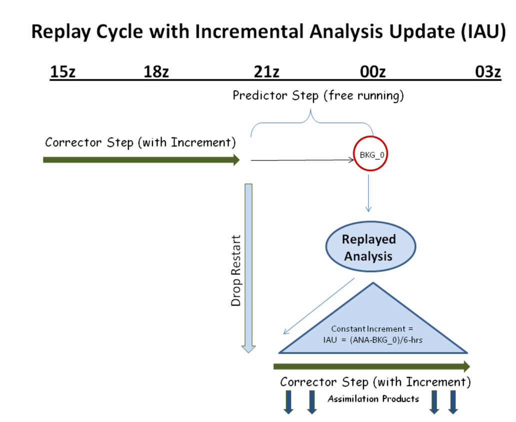


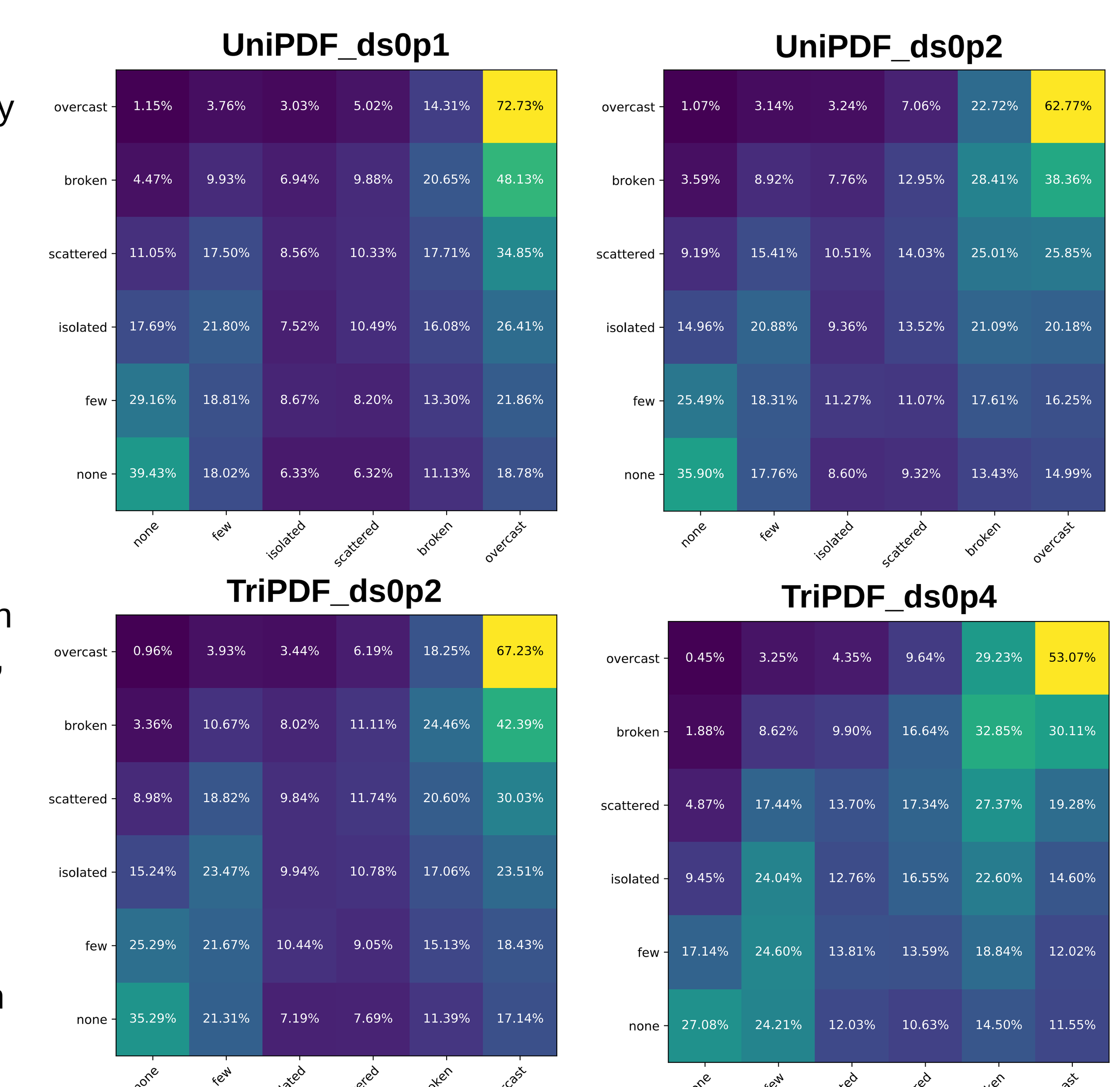
Figure courtesy Larry Takacs

Cloud distributions, GEOS vs. GLOBE observations

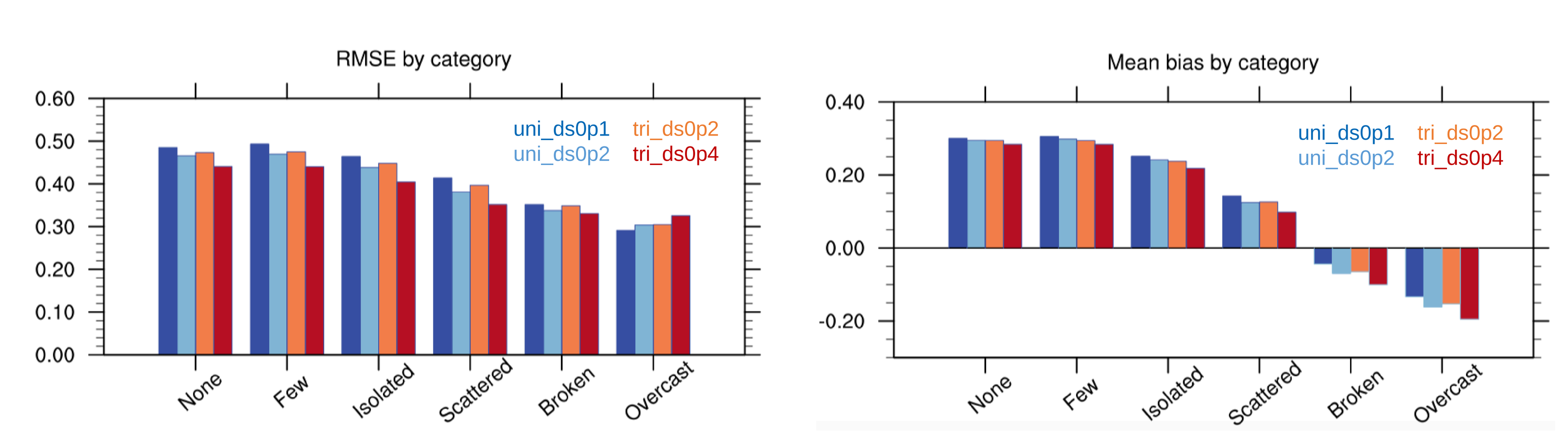
(Right) Histograms of cloud fraction from replay experiments with four options for stratiform cloud PDF.

The default case shows GEOS clouds skew to clear and overcast extremes.

Larger variance (Δs) generally reduces extreme values, but even with 4x the default width, moderate fractions are underestimated.

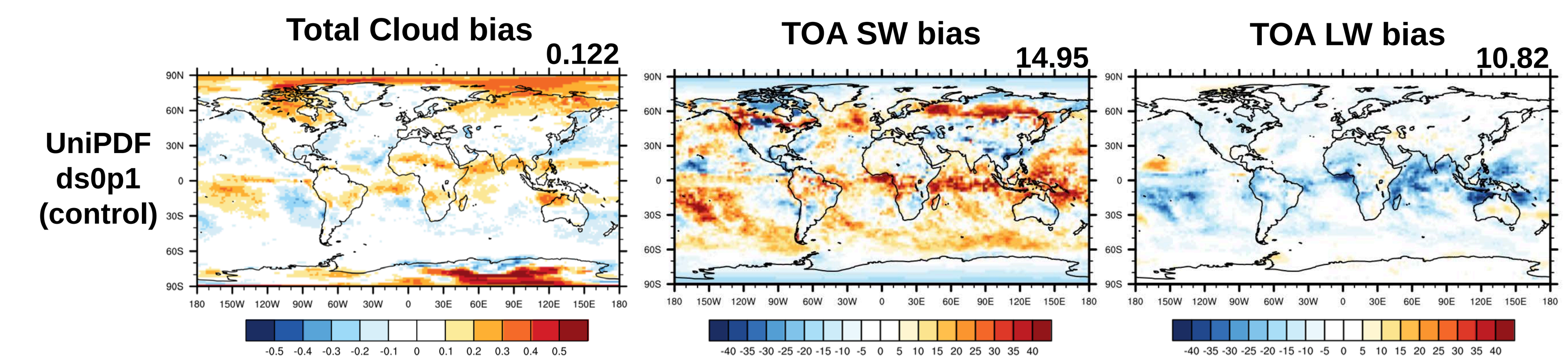


(Below) Root mean squared error and bias within each category show improvements with increased PDF spread, except in Overcast conditions.



Mean cloud fraction and TOA radiation biases

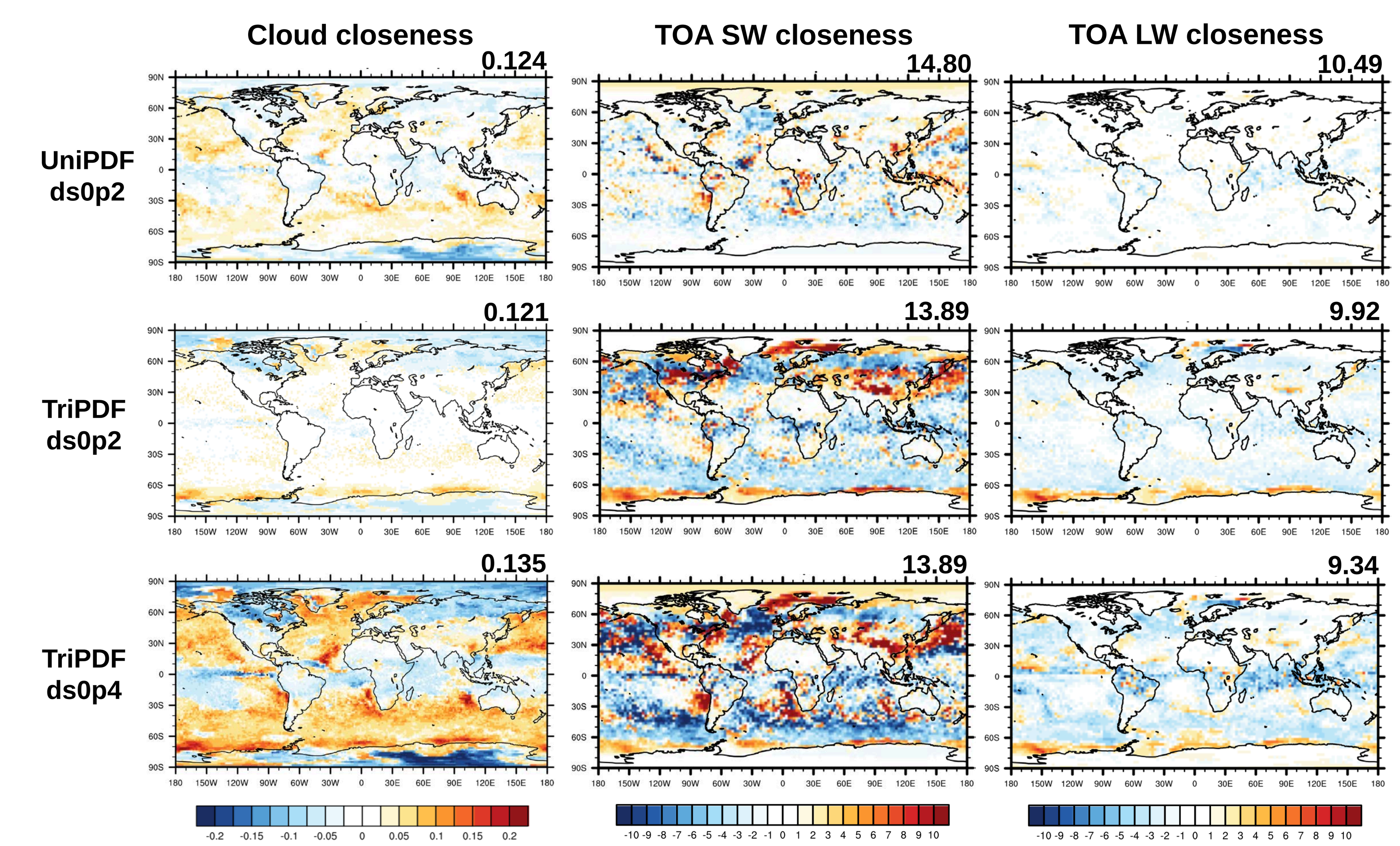
CERES-EBAF4.1 cloud fraction and top-of-atmosphere outgoing radiation are used to evaluate the global impact of PDF changes. RMSE shown in top right corner.



Relative improvement/degradation is measured using closeness to CERES data.

Closeness = $|C_{exp} - obs| - |C_{ctrl} - obs|$

(Blue = better, red = worse)



Conclusions

- GLOBE cloud observations offer dense coverage of CONUS and Europe and appear unbiased relative to MODIS cloud fraction estimates.
- GEOS simulated cloud fraction has a small mean bias but the distribution is skewed toward extreme values (0 and 1).
- Increasing the width of the subgrid total water PDF reduces the extreme bias in the distribution and the cloud fraction RMSE per category. Monthly mean radiation is improved, but mean cloud fraction is degraded over extratropical ocean.
- A triangular PDF reduces mean error relative to uniform PDF for the same distribution width.
- Future work will consider a dynamically diagnosed PDF, and/or a fully prognostic total water variance.

E-mail: nathan.arnold@nasa.gov | *Web:* gmao.gsfc.nasa.gov *and* globe.gov | Download the GLOBE app for iOS and Android and submit your own cloud observations!

National Aeronautics and Space Administration