Object Based Evaluation of MERRA-Simulated Clouds and Radiation For the 1998 El Nino- La Nina Transition

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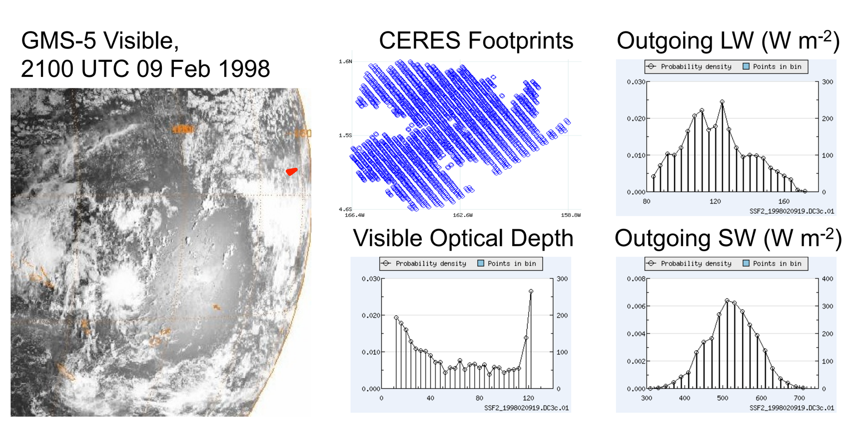
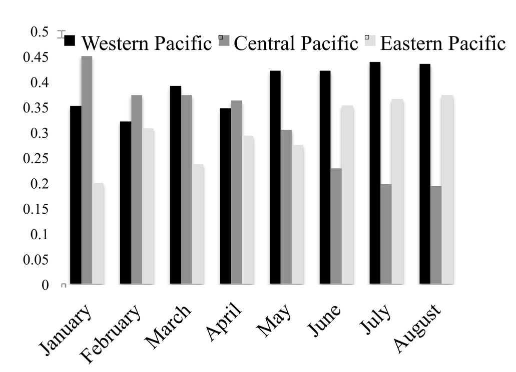
1. INTRODUCTION

Climate models are designed to simulate features on large spatial (hundreds of kilometers) and long time scales (monthly, yearly). While comparison of monthly mean model fields with observations is useful for assessing the gross features of the climate system, evaluation of the physical realism of a climate model requires comparison with instantaneous and fine scale measurements. A baseline test of the robustness of a climate model is the realism of the model output when run in re-analysis mode. The Modern-Era Retrospective Analysis for Research and Application (MERRA) is a reanalysis designed to produce an improved representation of the Earth's hydrologic cycle. We examine the representation of deep convective clouds in MERRA, focusing on the 1998 El Nino – La Nina transition. MERRA analyzed liquid and ice clouds are compared with deep convective cloud objects observed by instruments on the Tropical Rainfall Measuring Mission satellite.

2. CERES CLOUD OBJECT DATA



Deep convective cloud object 1900 UTC 9 February 1998: (a) GMS-5 visible imagery, (b) CERES footprints, PDFs of (c) optical depth, (d) OLR, and (e) OSR.

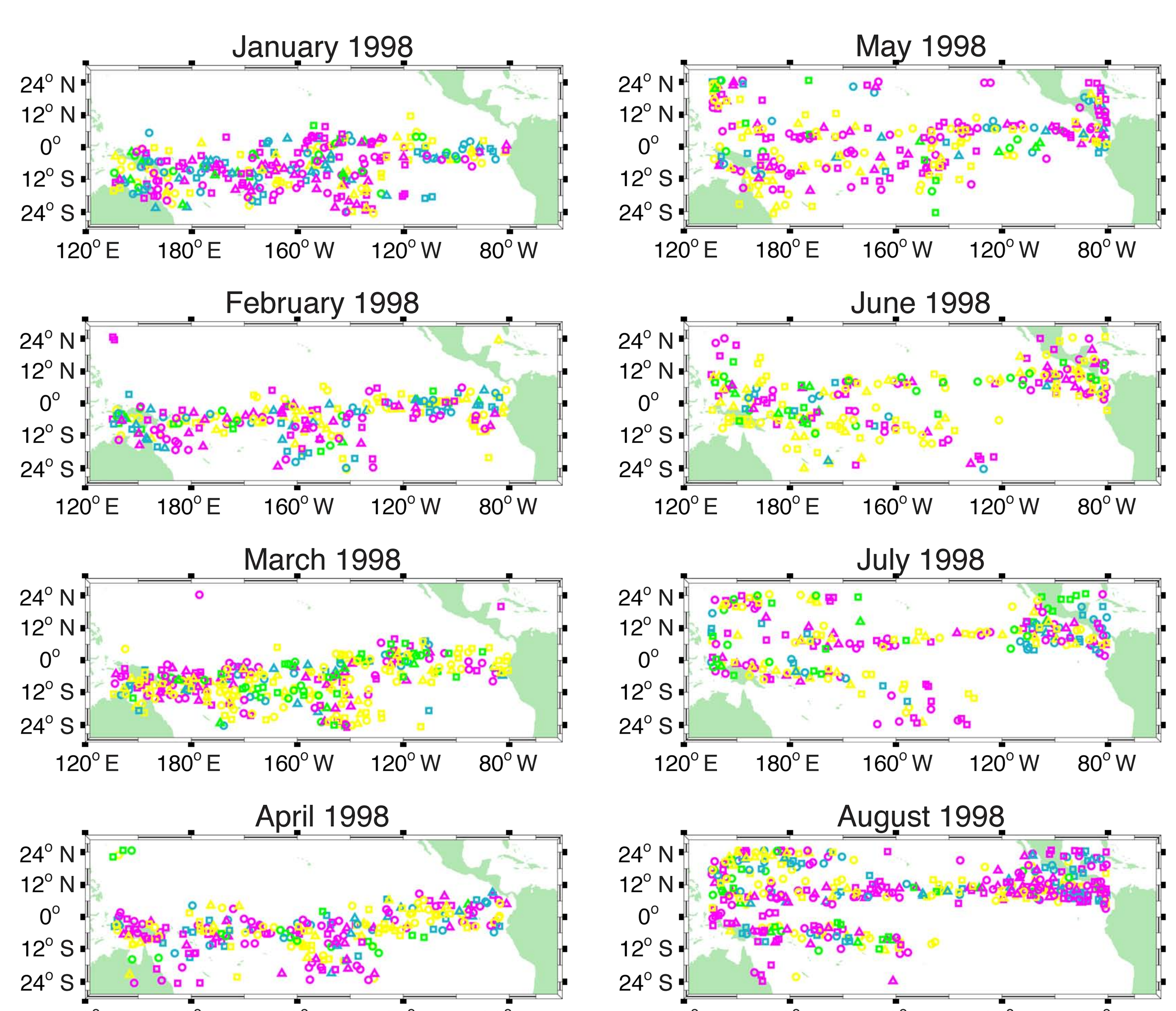


Fraction of deep convective cloud objects in the Western, Eastern, and Central Pacific Ocean January – August 1998.

TRMM-CERES Deep Convective Cloud Objects (Xu 2005):

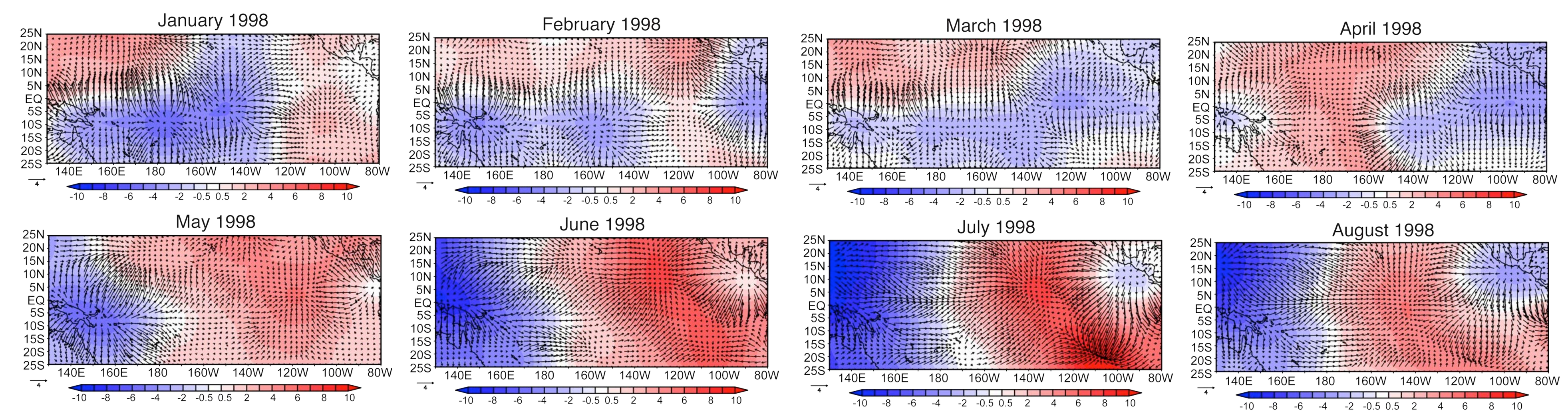
Contiguous regions defined to contain deep convection

- Criteria: optical depth > 10, cloud top height > 10 km, 100% footprint cloud fraction, equivalent diameter > 100 km, 25° S and 25° N latitude
- Objects include PDFs of CERES-derived OLR and OSR, and VIRS retrieved cloud top temperature, pressure, and height; visible optical depth; and liquid and ice water paths



Object locations and sizes for each month in the January – August 1998 time period. Symbols depict the object size, with squares representing objects less than 150 km in diameter, circles objects between 150 and 300 km in diameter, and triangles objects greater than 300 km in diameter. Colors depict the local standard time of occurrence of each object with green representing 0600 – 0900 Local Standard Time (LST), yellow 0900 – 1200 LST, magenta 1200 – 1500 LST, and blue/green 1500 – 1800 LST.

3. MERRA REANALYSIS DATA

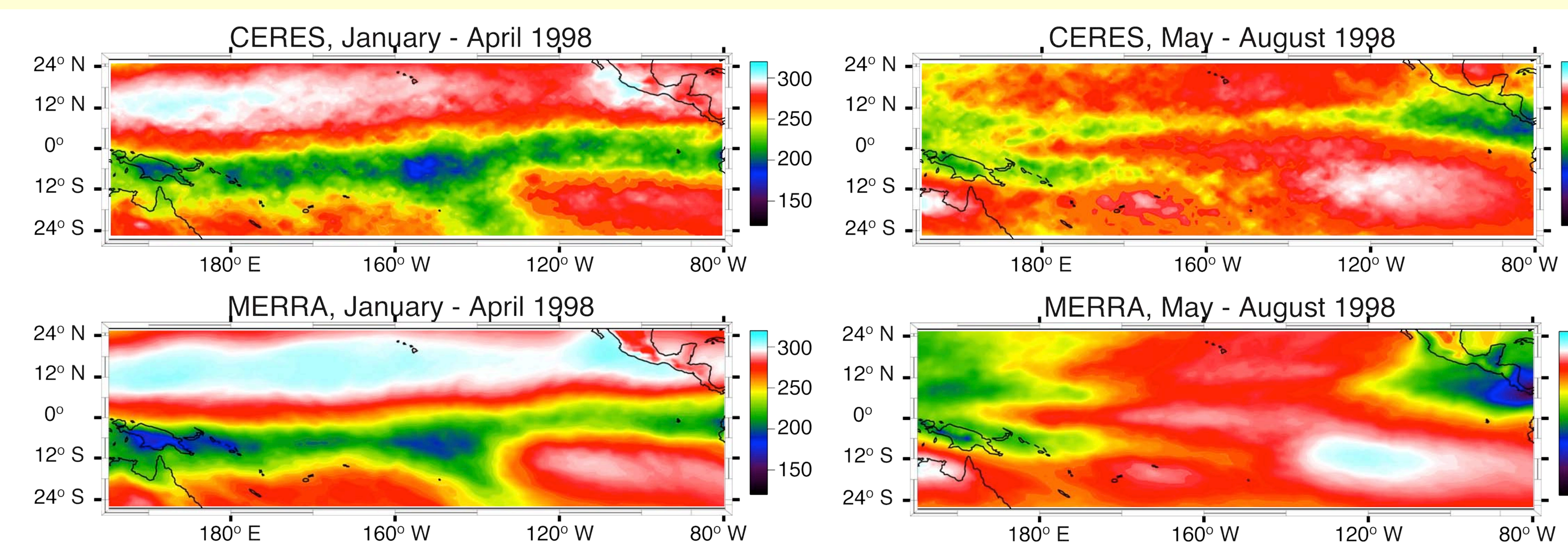


MERRA analyzed monthly mean 250 hPa velocity potential and divergent winds for January- August 1998.

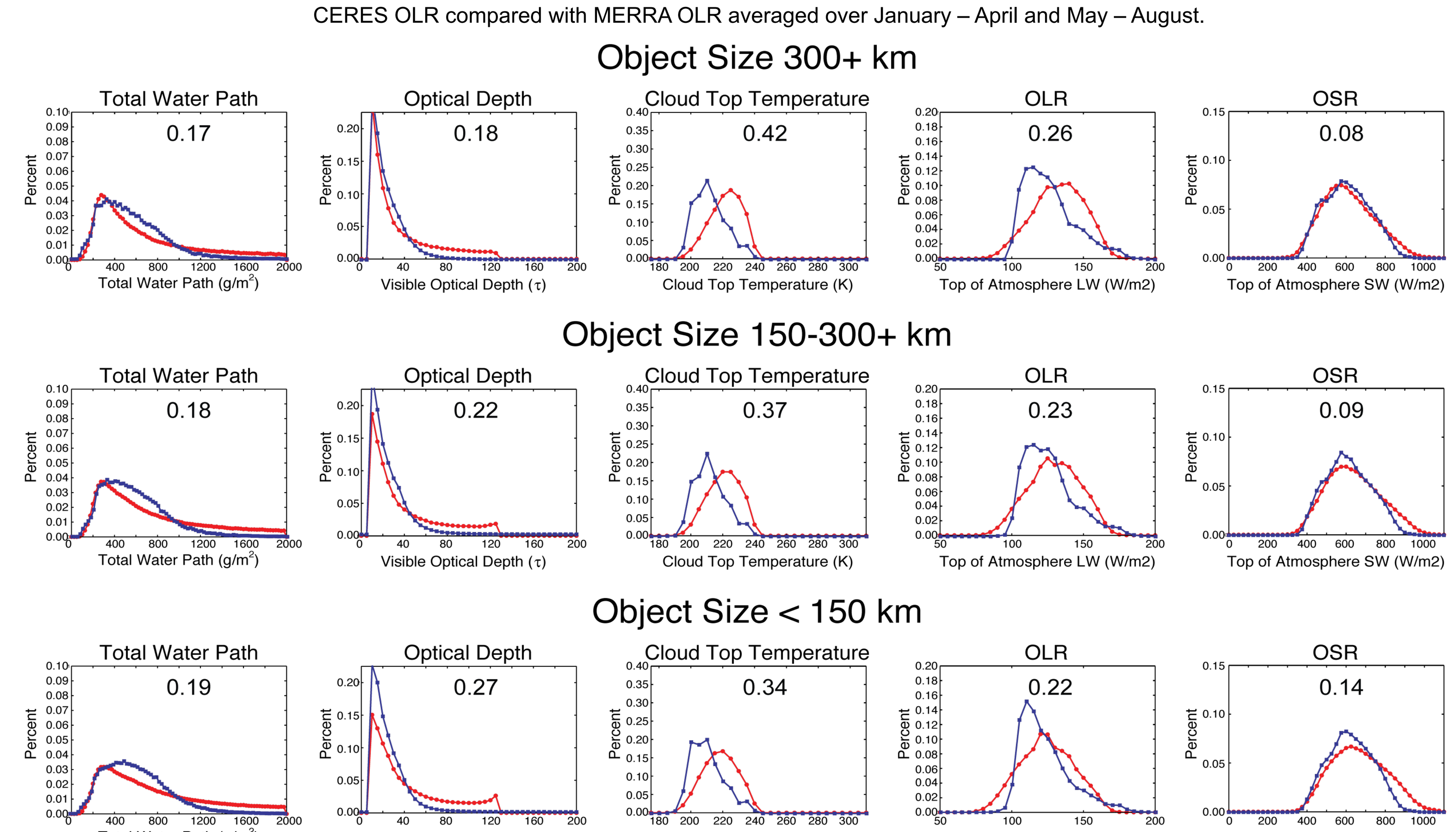
Modern Era Retrospective-analysis for Research and Applications (MERRA) Reanalysis:

- Uses a new version of the Goddard Earth Observing System Data Assimilation System Version 5 (GEOS-5)
- Two data sets used: instantaneous 3 hourly assimilated state variables (basic assimilated fields from IAU corrector) and time averaged 3 hourly cloud variables (upper-air cloud related diagnostics)
- Output variables used in the comparison include large-scale and convective liquid and ice mass mixing ratio, cloud fraction, air temperature, and atmospheric pressure.

4 COMPARISON OF MERRA WITH CERES OLR AND CLOUD OBJECTS



CERES OLR compared with MERRA OLR averaged over January – April and May – August.



Statistics from MERRA simulated objects (blue) and CERES observations (red) for total water path, optical depth, cloud top temperature, outgoing longwave radiative flux, and outgoing shortwave radiative flux. Objects with diameters between 100 – 150 km are shown in the first row, 150 – 300 km in the second row, and greater than 300 km in the third row. The numerical values in each plot correspond to 0.5 * the integrated absolute difference between histograms.

MERRA – Objects Comparison

- Match MERRA grid boxes with cloud object times and locations
- Use COSP (Bodas-Salcedo et al. 2009) subcolumn generator and precip flux to rain/snow mixing ratio conversion to map MERRA grid-scale clouds to CERES footprints
- Cloud condensate is assumed to be distributed evenly among subcolumns and with maximum-random overlap
- Run Fu-Liou radiative transfer model to generate outgoing longwave and shortwave radiative fluxes

5. SENSITIVITY TO ASSUMPTIONS

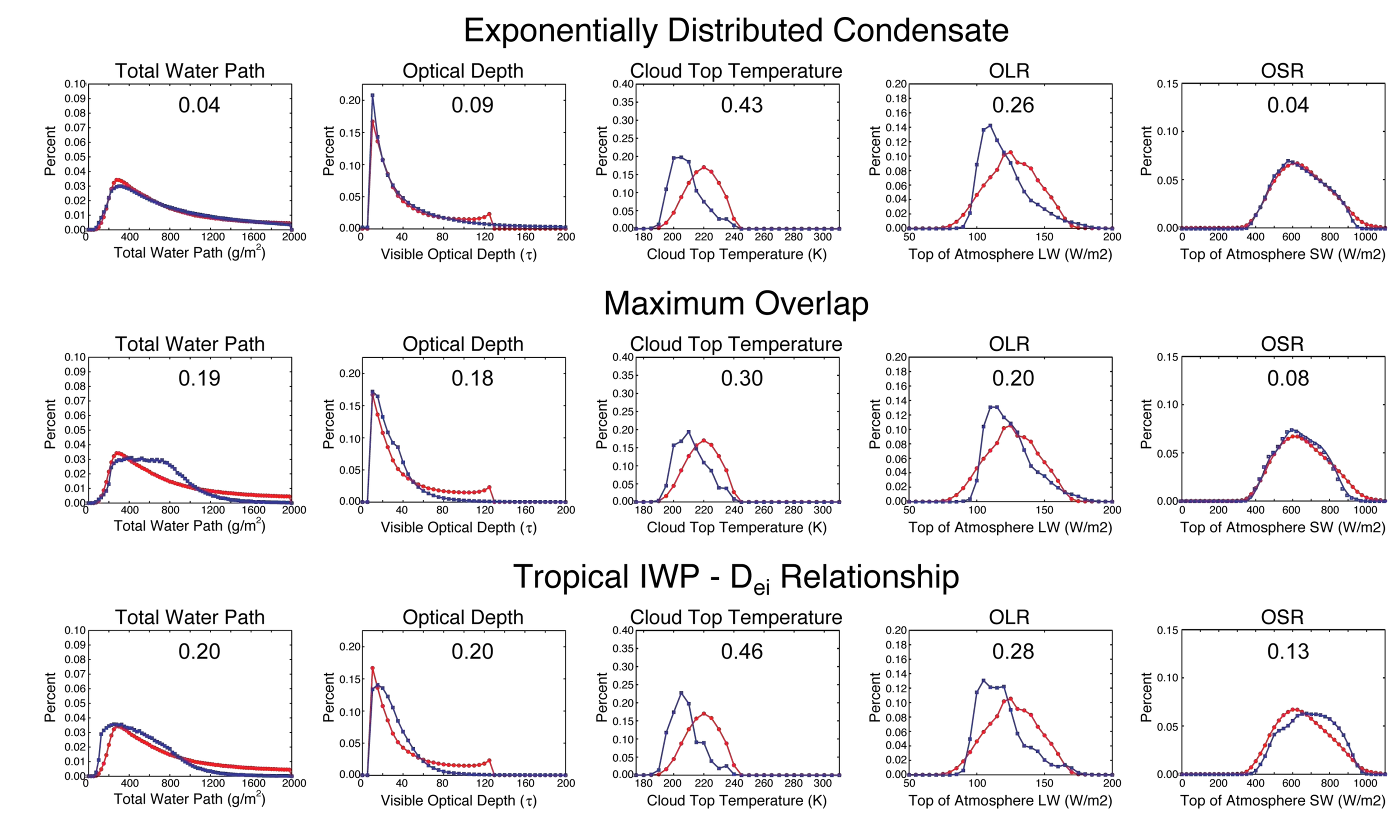
Modifications to Subgrid Cloud and Radiation:

- Assess sensitivity to assumptions used in the comparison
- Weight condensate mass exponentially across subcolumns to emulate the concentration of cloud mass in convective cores. Weights are computed as

$$w(x_i) = \frac{3}{N}\left[\frac{1}{1-\exp\left[-3\left(\frac{N-1}{N}\right)\right]}\right]\exp\left(-\frac{3}{N}x_i\right)$$

where N is the number of cloudy subcolumns

- Replace maximum-random overlap with maximum overlap assumption
- Use a modified IWP – ice effective diameter relationship



MERRA simulated (blue) and CERES observed (red) object PDFs produced using (top row) an assumed exponential distribution of condensate among sub-columns sorted according to cloud depth, (center row) maximum overlap instead of maximum-random, and (bottom row) a modified relationship between IWP and ice effective diameter.

6. CONCLUSIONS

- MERRA contains deep convective cloud for 99.5% of cloud objects.
- Total water path, optical depth, and outgoing shortwave radiation in MERRA match the cloud object observations quite well.
- There appears to be a bias toward higher than observed cloud tops and lower than observed OLR in the MERRA.
- The reanalysis matches observations most closely for the largest class of convective systems with decreased performance for smaller systems.
- Comparisons of simulated total water path, optical depth, and outgoing shortwave radiation (OSR) are found to be highly sensitive to the assumed subgrid distribution of condensate and indicate the need for caution when interpreting model-data comparisons that require disaggregation of grid-scale cloud to satellite pixel scales.

REFERENCES

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ACKNOWLEDGEMENTS

This work was funded through NASA MAP grants NNX08AF77G and NNX09AJ43G. MERRA data was obtained through the Goddard Earth Sciences Data and Information Services (GES-DISC), and cloud object data was obtained from NASA Langley through the NASA Satellite Cloud Object Data website.

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