Terra-CERES Cloud Object Data for Cloud-Climate Process Studies

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1.Introduction

Gridded monthly-mean (Level 3) satellite data are useful for providing validation of climate model simulations. Orbital (Level 2) data contain information for understanding cloud-climate processes and diagnosing deficiencies in physical parameterizations of the model, but are rarely used by climate modelers, due to data volume. This study will provide an overview of an objective analysis procedure that significantly reduces the data volume while preserving cloud-climate process information. This study will also show some statistical results from this "cloud object" data product.

We use Terra-CERES Level 2 (Single scanner footprint, SSF) data to classify distinct cloud objects defined by cloud-system types (deep convection, boundary-layer cumulus, stratocumulus and overcast clouds), sizes, geographic locations, and matched large-scale environments. This analysis method identifies a cloud object as a contiguous region of the Earth with a single dominant cloud-system type. It determines the shape and size of the cloud object from the satellite orbital data and the cloud-system selection criteria (Xu et al. 2005).

The statistical properties of the identified cloud objects are analyzed in terms of probability density functions (PDFs) of a single property or joint PDFs between two properties. This data set matched to concurrent meteorological state data can provide stratifications of cloud objects into subsets according to meteorological state and thus useful constraints on cloud property statistics produced from models. Some examples will be shown in this study.

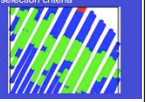
2. Procedure for cloud object analysis

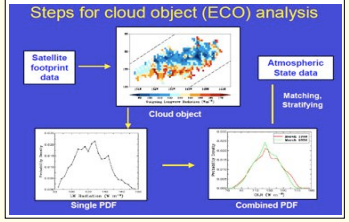
CLOUD OBJECT:

- A contiguous patch of cloudy regions with a single dominant cloud-system type; no mixture of different cloud-system types
- The shape and size of a cloud object is determined by
  - the satellite footprint data
  - the footprint selection criteria
- For example, selection criteria for deep convective cloud objects:
  - Cloud top height z_{top} > 10 km,
  - Cloud optical depth τ > 10, and
  - Footprint cloud fraction: 100%

Extended Cloud Object (ECO):

- Include all cloudy footprints within the minimum/maximum latitudes and longitudes of a cloud object
- May include some footprints satisfying the cloud object selection criteria





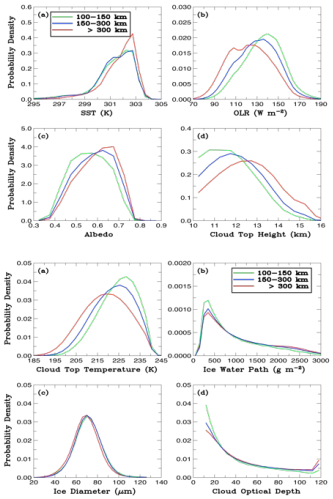
3. Deep convective cloud objects

The criteria for deep convective (DC) cloud objects consist of 1) overcast footprint; 2) cloud top height greater than 10 km, 3) cloud optical depth greater than 10; and 4) within the tropical band between 30 S and 30 N. Results for the first 2-year (March 2000 to February 2002) Terra-CERES period are shown below for the systematic variations with cloud object sizes (3.1) and sea surface temperature anomalies (3.2). The numbers of cloud objects identified from the Pacific Ocean are shown in the table below for different seasons and size categories.

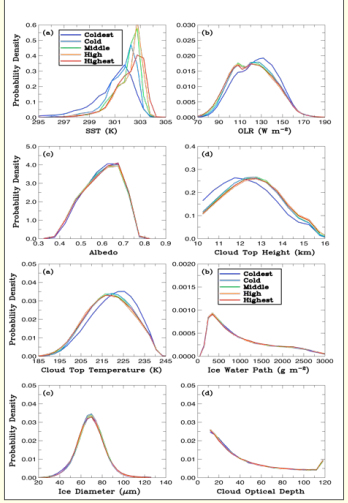
The results show that systematic variations of cloud properties with cloud-object size are pronounced (except ice diameter), but the SST-anomaly dependencies are not for all parameters. An exception is that histograms for the coldest SST anomaly category are slightly different from others.

Size category	Spring (MAM)	Summer (JJA)	Fall (SON)	Winter (DJF)	2-yr total
100-150 km	1307	1005	933	1274	4519
150-300 km	1324	1155	1063	1293	4835
> 300 km	730	604	574	773	2681
Total	3361	2764	2570	3340	12035

3.1 Cloud-object size dependency



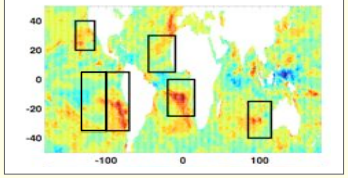
3.2 SST-anomaly dependency



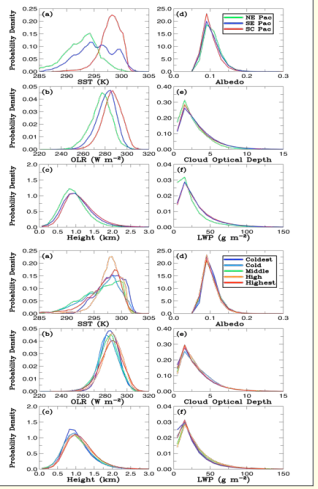
4. Boundary-layer cloud objects

The criteria for boundary-layer cumulus, stratocumulus and overcast cloud objects are 1) cloud top height less than 3 km and 2) footprint cloud fraction in the range of 0.10-0.40 (cumulus), 0.40-0.99 (stratocumulus) and 0.99-1.00 (overcast). In addition, footprints with ice are eliminated. Cloud objects with equivalent diameters greater than 75 km are identified. There are a total of 787,000 cloud objects in the two-year Terra period (March 2000 to February 2002).

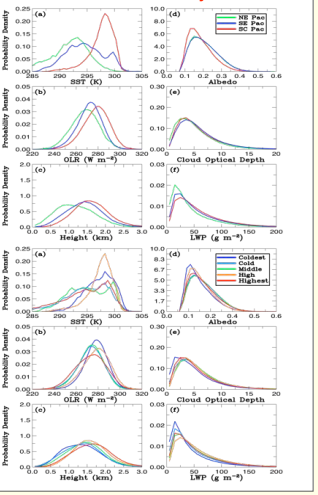
The histograms of cloud properties for three types of boundary-layer cloud objects with sizes of 150-300 km in six regions (boxes in the chart below) are examined (see 4.1, 4.2 and 4.3). These regions are northeastern Pacific, southeastern Pacific, southeast-central (SC) Pacific, northeastern Atlantic, southeastern Atlantic, and southeastern Indian.



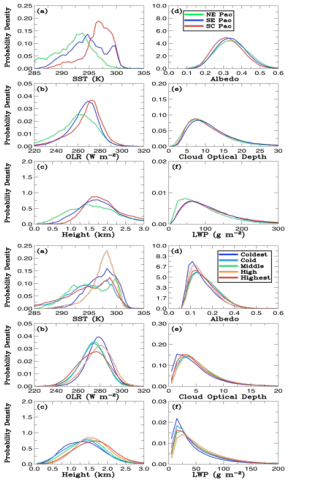
4.1 Cumulus cloud objects



4.2 Stratocumulus cloud objects



4.3 Overcast cloud objects



5. Summary & future work

- There are distinct differences in the histograms of cloud properties between cloud-object types.
- There are various degrees of variability (within a cloud-object type) with cloud-object sizes, SSTAs, and regions, among the cloud properties examined.
- The next step is to subset the cloud objects according to anomalies in thermodynamic and dynamic states (from climatology) to examine the partial derivatives of the variability with SST; the implied cloud feedback strengths.
- The length of data set will be extended to, at least, five years for such cloud feedback estimates.

References

Xu, K.-M., T. Wong, B. A. Wielicki, L. Parker and Z. A. Eitzen, 2005: Statistical analyses of satellite cloud object data from CERES. Part I: Methodology. *J. Climate*, **18,** 2497-2514.

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150-300km size categ.	NE Pac.	SE Pac.	SC Pac.	SE Ind.	SE Atl.	NE Atl.
Cumulus	819	2468	5525	2332	3131	2643
Stratocumulus	1212	3208	4378	3031	2750	2270
Overcast	778	1818	1491	1483	1115	439