Developing a 3D Cloud Properties Dataset for Model Evaluation: Establishing Relationships Between Ground and Satellite Based Measurements

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Introduction

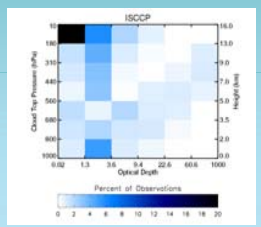
- Vertical profiles of cloud properties and radiative heating rates can be derived at high temporal resolution from ARM ground-based measurements
- These measurements typically represent horizontal scales much smaller than the scales of climate models, making it difficult to compare the two sets of cloud and radiation fields
- Combining ARM ground-based measurements with satellite measurements will allow us to expand the knowledge of vertical structure of cloud properties and heating rates to a larger horizontal scale

Concept

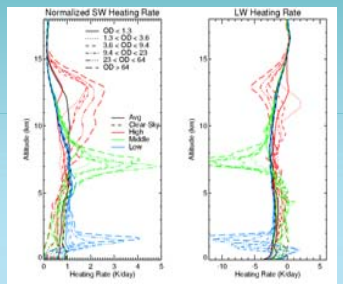
Mather et al (adjacent poster) shows utility of classifying ARM heating rate profiles by cloud height and optical depth. Here we use a slightly different set of classes that correspond to the ISCCP definitions. Using satellite data to say how often these classes occur, does the weighted average of heating rate classes derived from ARM data represent the average heating rate over the larger horizontal area?

ISCCP joint histograms:
- Cover 280km x 280 km area
- Cloud top pressure (7 classes) and total column optical depth (6 classes) → 42 classes
- Percent of observations in each class.

\+ Average ARM heating rate for each ISCCP-defined class. = Average large-scale heating rate?



Example of an ISCCP joint histogram over Manus in March, 2000.

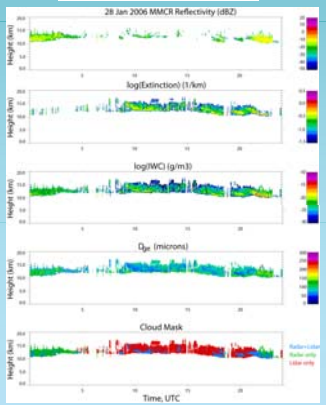


Average ARM heating rates for classification scheme based on cloud top height and total optical depth (ISCCP definitions). Only three of the cloud top classes are shown here for clarity. (Note classes are defined differently from Mather poster.)

Improved Cloud Retrieval

- Our previous work on vertical cloud properties and radiative heating rates used a radar-only cloud retrieval
- As part of the development of the 3D cloud property dataset, we are updating the retrieval to include lidar-detected ice clouds
- The new ice cloud retrieval:
  - Uses Wang and Sassen (2002; JAM, **41**) combined radar-lidar retrieval for regions where both radar and lidar detect cloud
  - Uses tuned regressions as a function of temperature when only one instrument detects the cloud (lidar only – thin or high cirrus; radar only – optically thick clouds)
  - Regressions are defined separately for each cloud system (daily)

Darwin 28 Jan 2006

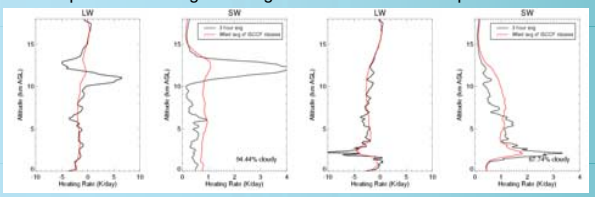


Measurements of MMCR reflectivity and lidar extinction show regions of mismatch where each instrument does not detect cloud

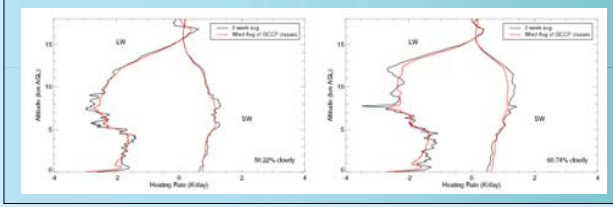
Results of combined lidar/radar retrieval of IWC and D_{ge}. Tuned regressions derived during overlap periods (see cloud mask) provide empirical means for retrieving quantities during non-overlap periods.

Proof of Concept

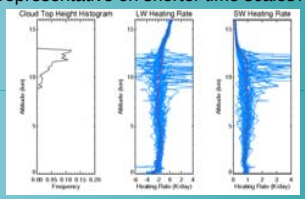
Using ARM heating rates only, examine how weighted average of each class represents average heating rate over various time periods:



(top plots) Average heating rate (black line) over 2 selected 3-hour periods and corresponding weighted average of heating rate (red line) from component ISCCP classes. (bottom plots) Same as above but for selected 2-week periods.



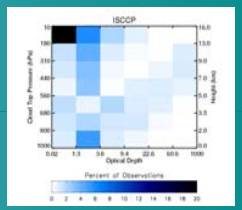
Why is weighted average not representative on shorter time scales?

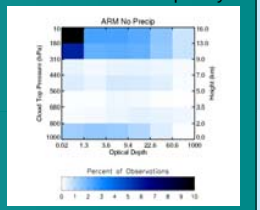


Individual members of class are shown with blue lines and average heating rate of class in red line. The broad cloud top height histogram leads to a broad peak in average HR profile although individual clouds have much sharper peaks.

Cloud top height histogram (left) and SW (middle) and LW (right) heating rates for class with cloud top between 9-13 km and optical depth < 3.6.

Do ISCCP and ARM see the same cloud class frequency?





(left) Total ISCCP histogram and (right) total Manus ARM histogram for March – July 2000 period. ARM cloud frequency is 47% while ISCCP cloud fraction is 69%. ARM detects more frequent high cloud (due in part to ISCCP mis-classification of high over low cloud) and more frequent optically thick cloud.

Summary/Future Work

- Weighted average shows promise; more representative for long-term (2-weeks) than short-term (3-hour) periods
- Classes combine clouds with differing cloud top heights; structure of heating rate is strongly dependent on distance from cloud top/base – explore normalization of heating rate to cloud top height
- Differences between ARM/ISCCP histograms need to be further examined; ISCCP can have difficulty with multi-layer clouds - some mid-layer might really be high cloud over low cloud (Rossow et al. 2005, *J. Clim,* **18)**
- Add additional information on temperature/humidity from ECMWF to classification