Radiative Cloud Forcing Over Darwin
Using Inputs from Multiple Ground-based and Satellite Remote Sensors

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Introduction

- The vertical distribution of radiative heating plays an important role in determining dynamic atmospheric processes. An accurate representation of heating rates in the atmosphere is limited by our ability to describe the thermodynamic state and cloud properties of the atmosphere.
- Observations from multiple remote sensing instruments are required to obtain a comprehensive view of clouds.
- Using observations from the A-train satellite constellation allows for a near-global set of radiative heating profiles.
- Comparisons to radiative heating rate profiles derived from ARM observations provide insight into the advantages and disadvantages present in each data set and provide guidance on how such data sets might be improved.

Cloud forcing

ARM: solid line, CCCM: dashed line

Ice water content and effective diameter

CCCM: IWC is much larger below about 16 km.
This difference is larger during the daytime (not shown).

Diurnal extinction

Both datasets show that clouds are optically thinner at night.
CCCM extinction biased low relative to ARM at night.

Potential impact on CF

Test case: cloud from surface to 15 km (precipitating), focusing on the cloud top region.
- Using CWC-RO alone smooths/reduces peak in SW CF by around 15 K day⁻¹. Also increases the LW cooling at cloud top.
- Note: CloudSat FLXHR product does not show the large heating seen in the CCCM product (not shown).
- Using MODIS Dₐ with CALIPSO β reduces peak in SW CF by around 8 K day⁻¹.

Comparison Method

- Comparison from July 2006 through June 2010. Only periods when all instruments (MMCR/ MPL/ CALIPSO/ CloudSat) are producing quality data are used.
- CCCM data taken from a 5° x 5° domain.
- Focus our comparison on radiative cloud forcing:
  \[ CF = Q_{radiative} - Q_{cloud} \]
- In this comparison we use the full set of ARM data with the daytime solar zenith angle fixed at the mean value from the CCCM data.
- Limiting ARM data to within 2 hours of A-train overpasses produces statistically identical heating rate profiles to this fixed solar zenith angle data.

Why is daytime CCCM CF so much larger?

Relationship between extinction, IWC and effective diameter (Fu, JCLIM, 1996):

\[ \beta = \frac{4(e)^{3/2} IWC}{\Delta \rho} \]

Protal et al. (JTecha, 2010) showed that CloudSat CWC-RO product tends to underestimate \( \beta \) above 11 km.

In the CCCM dataset, when both CALIPSO and CloudSat detect a cloud:
- Use CALIPSO β (\( \geq \) CloudSat β) and CloudSat Dₐ (large positive bias) \( \rightarrow \) large IWC and a large CF
- Daytime (nighttime) CALIPSO + CloudSat IWC 69% (24%) larger than CWC-RO.
- This will effect the mean profiles of CF more for:
  - Optically thick clouds which have large CF already (both ARM and CCCM datasets show that clouds are optically thicker during the day).
  - In addition, optically thick clouds attenuate CALIPSO which means these enhanced IWCs will occur near cloud top only, which is already the most radiatively active region of the cloud.

Conclusions

- Using CALIPSO extinction with CloudSat size to infer IWC may produce inaccurate profiles of CF.
- Reprocessing of the CCCM dataset may definitively show if this is the case.
- We also performed this analysis for Nauru which shows similar results.

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