Thermodynamics and Cloud Radiative Effect from the First Year of GoAmazon

Allie Marquardt Collow
Mark Miller and Lynne Trabachino

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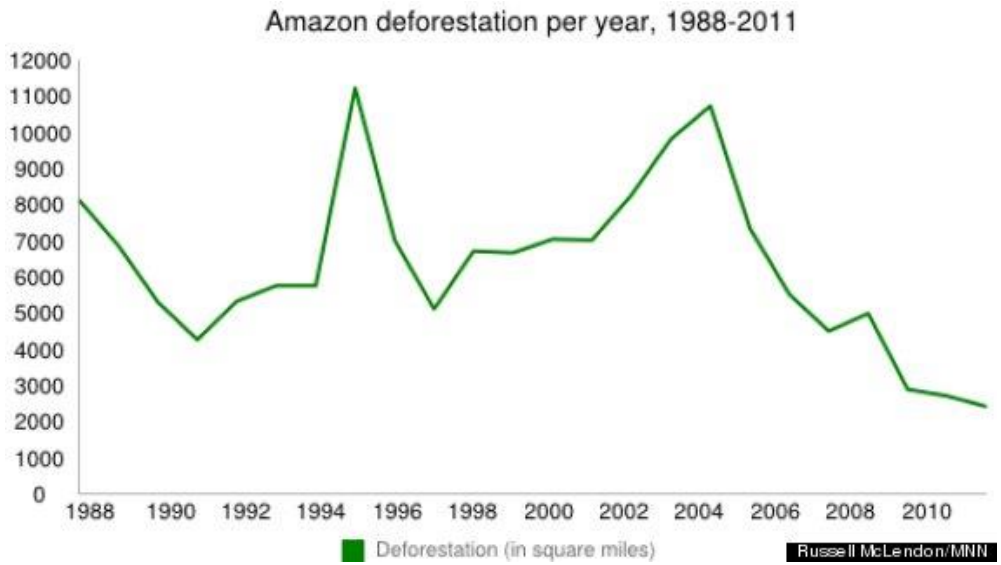
RUTGERS USRA NASA

Motivation



Deforestation in the Amazon can:

- Alter precipitation rates (Chue et al., 1994, Cauduro Dias de Paiva and Clarke, 1995, D'Almeida et al, 2007)
- Decrease the albedo (Giambelluca et al., 1997)
- Decrease the world's oxygen (Fernside, 1985)
- Impact LW budget (CO_2)

- Scientific interest in the 80s and 90s however there has been a gap in observations despite land surface changes
- Dry/Wet Seasons lead to varying cloud conditions → great for radiation studies

Goals

- Assess seasonal changes in thermodynamics and how these changes impact the radiation budget
  - Relationship between LCL and cloud fraction
  - Column radiative flux divergence (RFD) and cloud radiative effect (CRE)

- Evaluate the height of the LCL and regional radiation budget in context of the Modern Era Retrospective Analysis for Research and Applications – Version 2 (MERRA-2)

Outline

- Background
  - MERRA-2, CERES
  - Climate in the Amazon
- Results from GoAmazon 2014
  - Thermodynamic structure
  - Relationship between LCL, CAPE, cloud fraction, and precipitation
  - Influence of land surface on LCL height
  - Radiation budget and Cloud Radiative Effect (CRE)

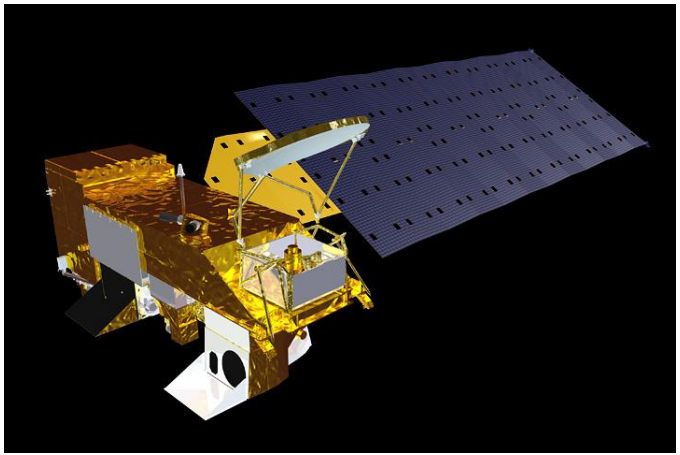
MERRA-2

- Developed by NASA GSFC's Global Modeling and Assimilation Office
- Data available every hour at a spatial resolution of 0.625° longitude x 0.5° latitude
- Incorporates numerous satellite observations that are not used in MERRA
- Reduces trends and jumps from changes in observing systems seen in MERRA
- Aerosols are assimilated (first and only reanalysis product to do so)
- Tight constraint on the water budget

Now Available at GES DISC!

Clouds and the Earth's Radiant Energy System (CERES)

- Near polar orbit on Terra and Aqua
- Data available 2 times every day (one nighttime, one daytime)
- 20 km resolution



Aqua.nasa.gov

Annual Precipitation in the Amazon Rainforest of Brazil

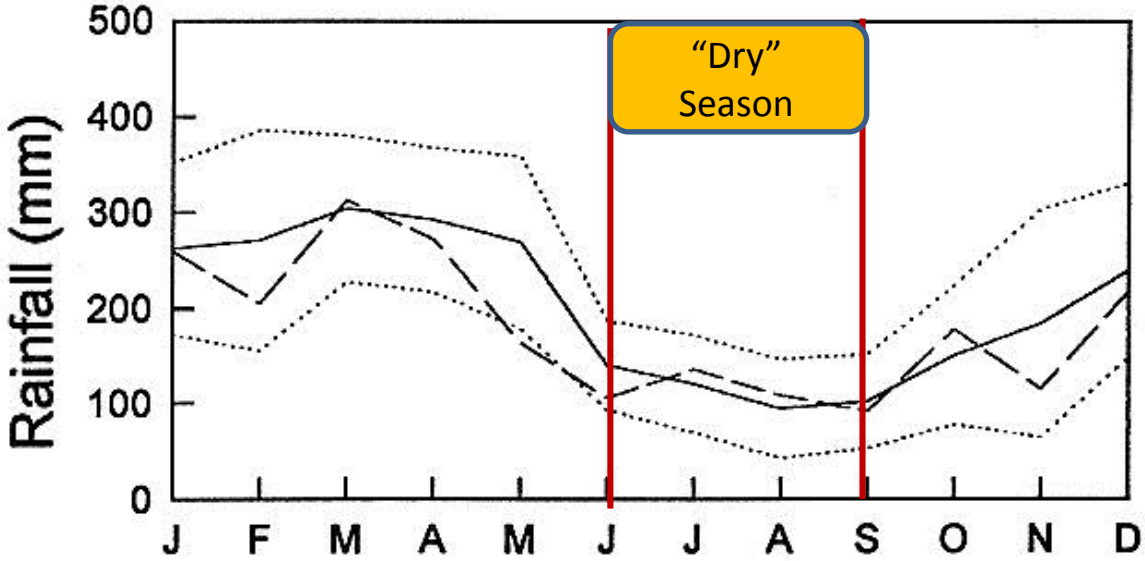
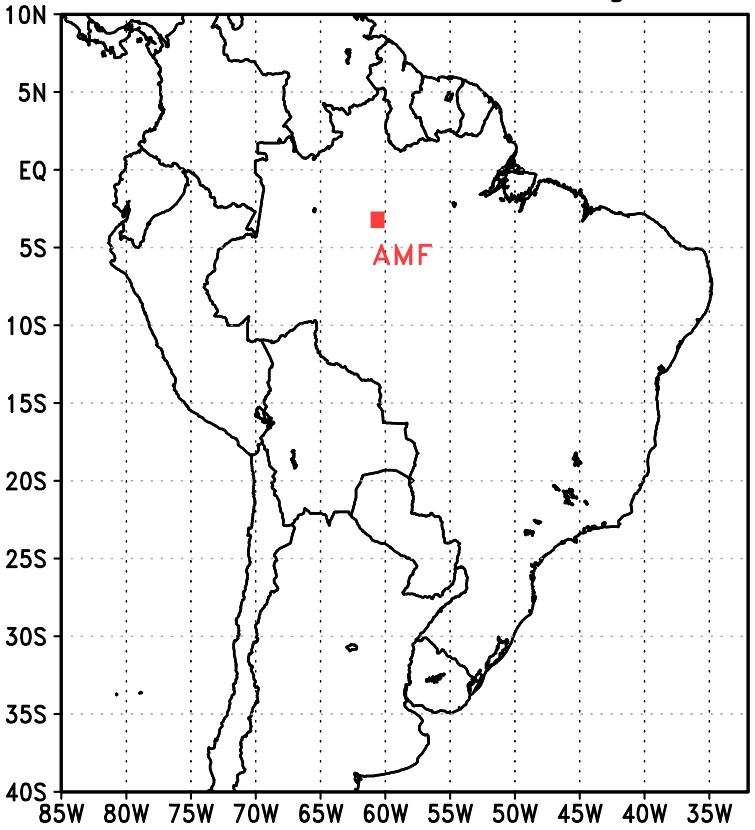
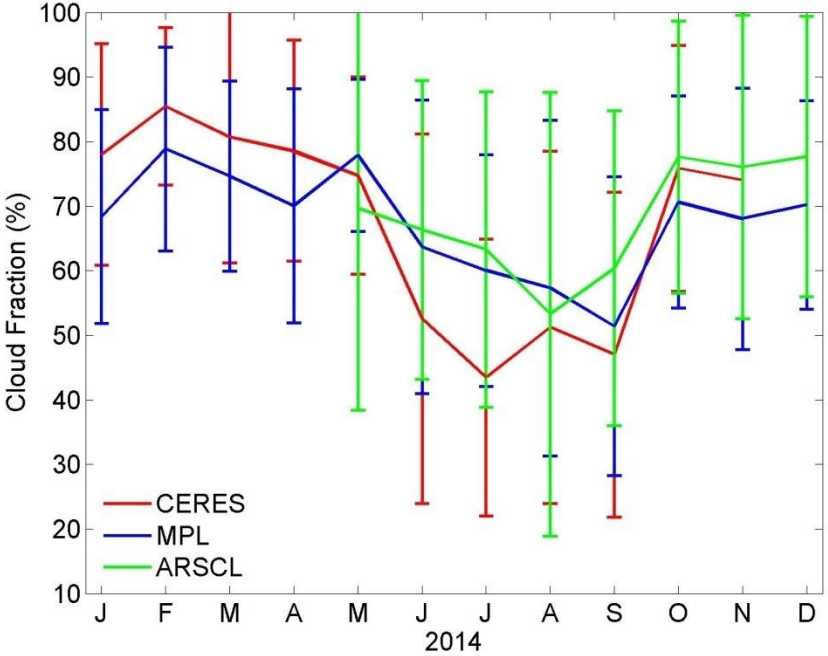


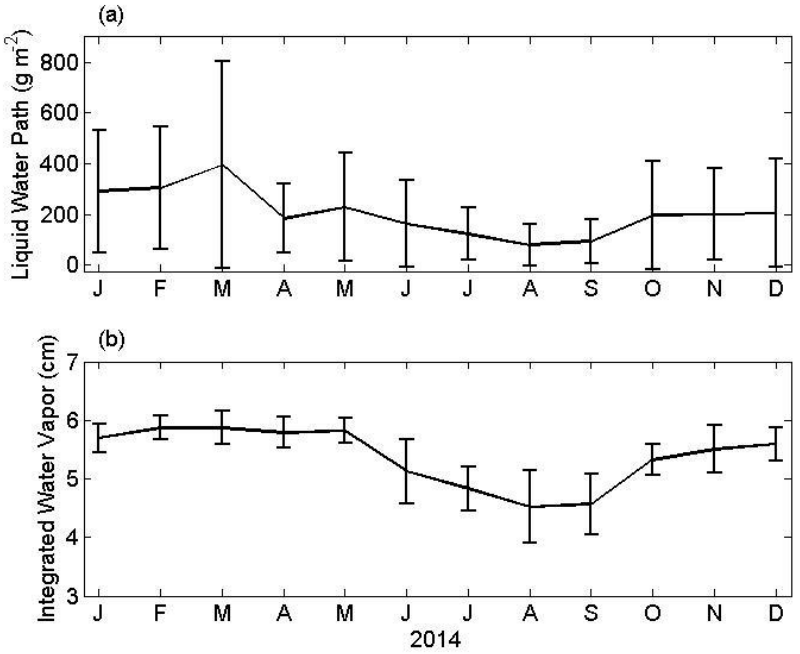
Fig. 1. Mean long-term rainfall (solid line) compared with the mean for the years covered by the ABRACOS data (dashed line). The dotted lines are plotted at plus and minus one standard deviation from the long-term mean. (Culf et al., 1998)

Results: Thermodynamics



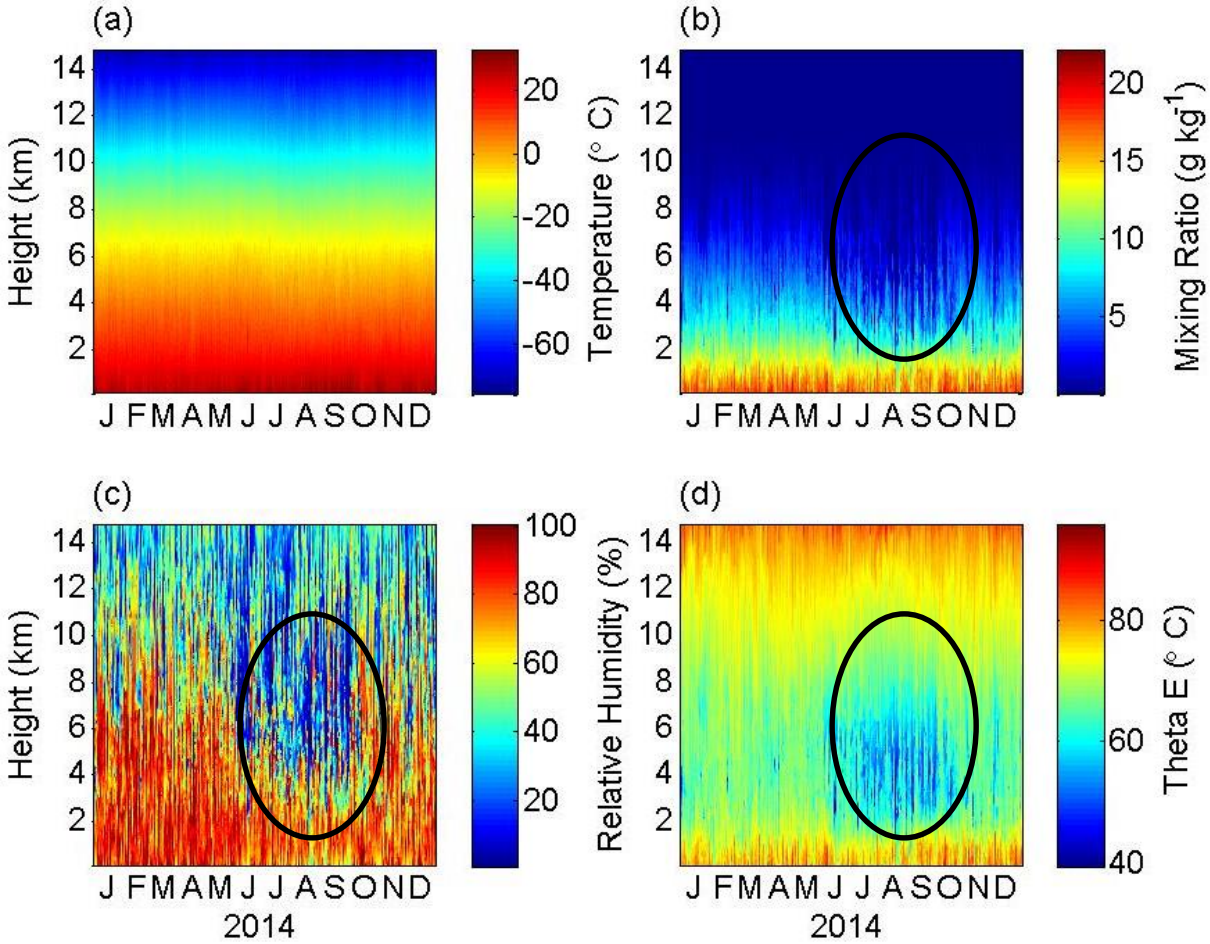
Observations from the ARM Mobile Facility



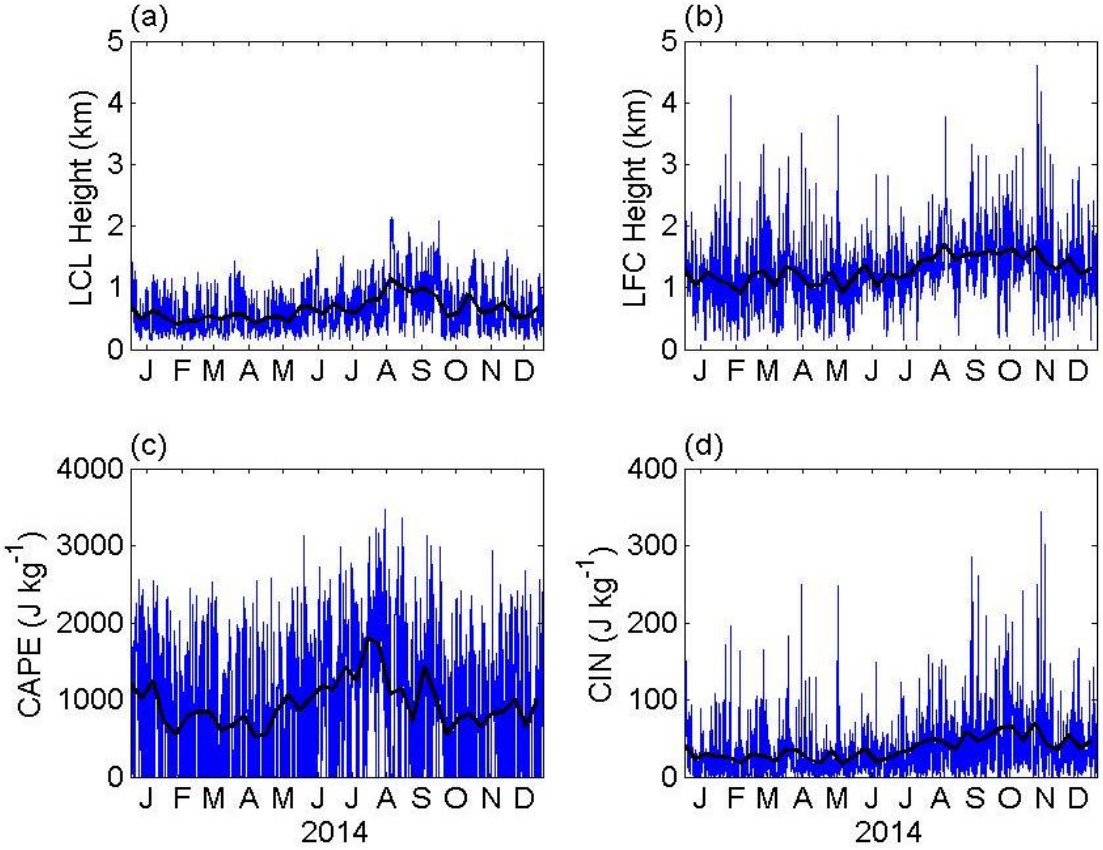


Error bars denote +/- one standard deviation

Thermodynamic Profile Time Series from 6-hourly Radiosonde Launches

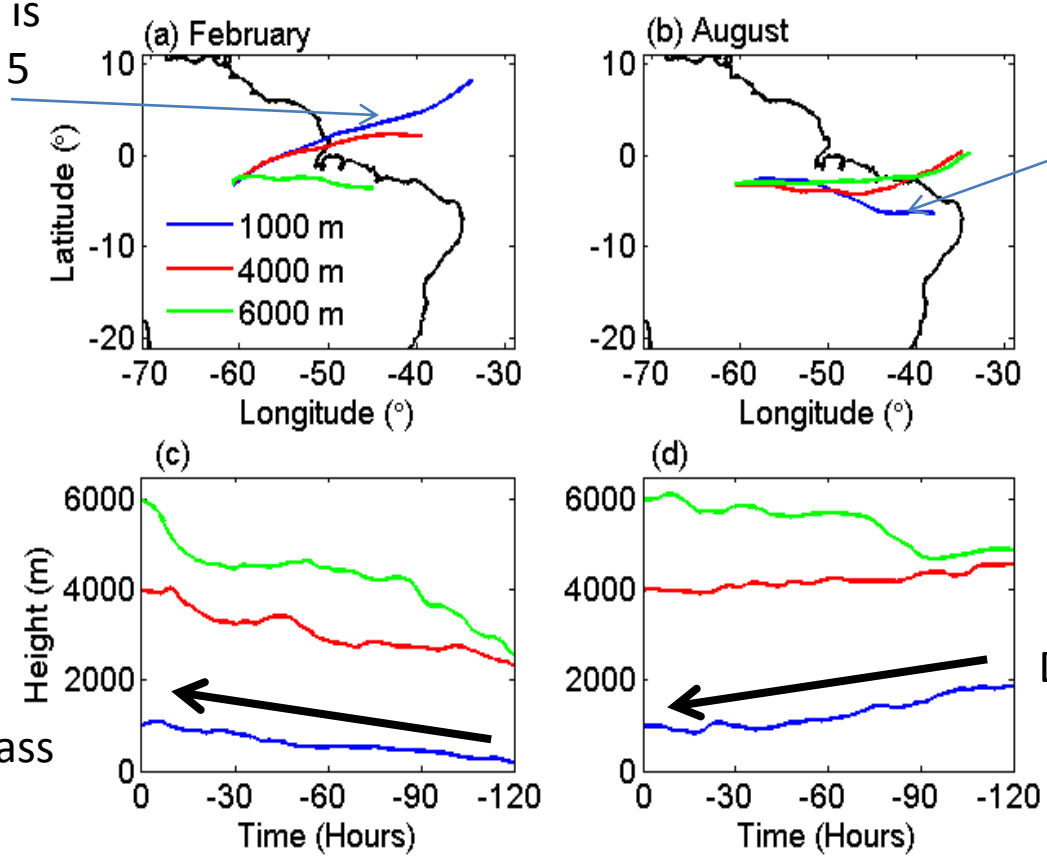


Thermodynamic Time Series from 6-hourly Radiosonde Launches



Back Trajectories from HYSPLIT

1000 m airmass is over the ocean 5 days prior

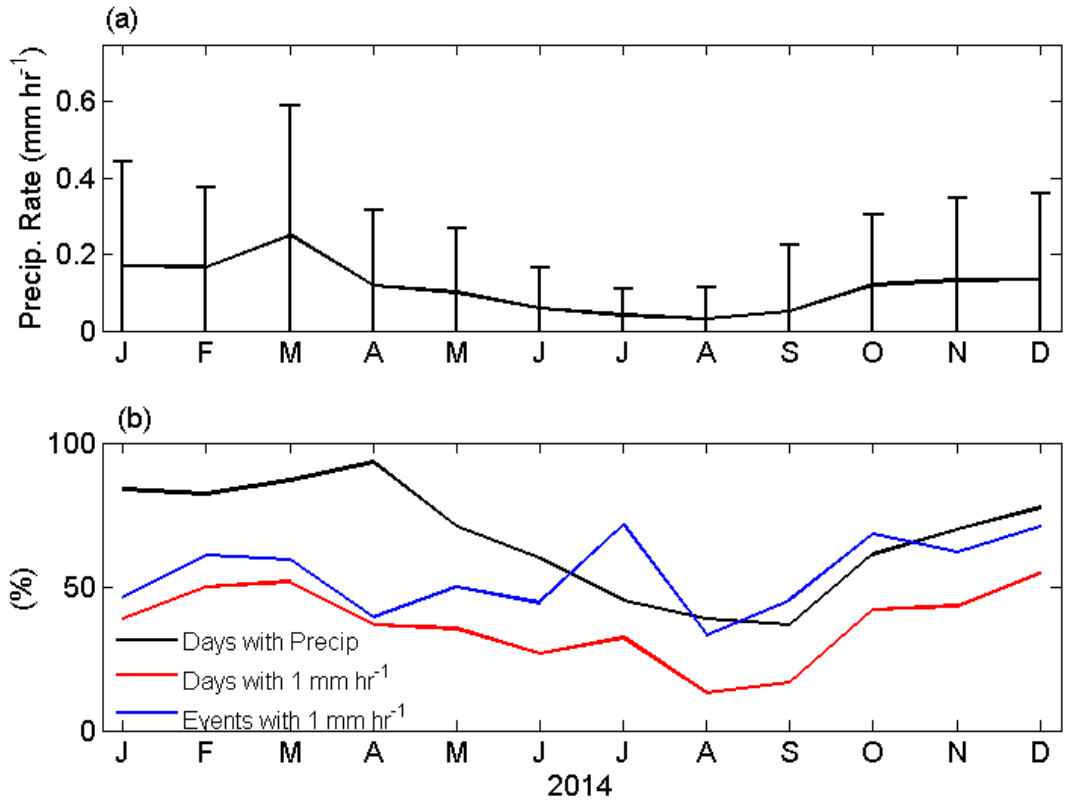


1000 m airmass is over land 5 days prior

Ascending Air mass

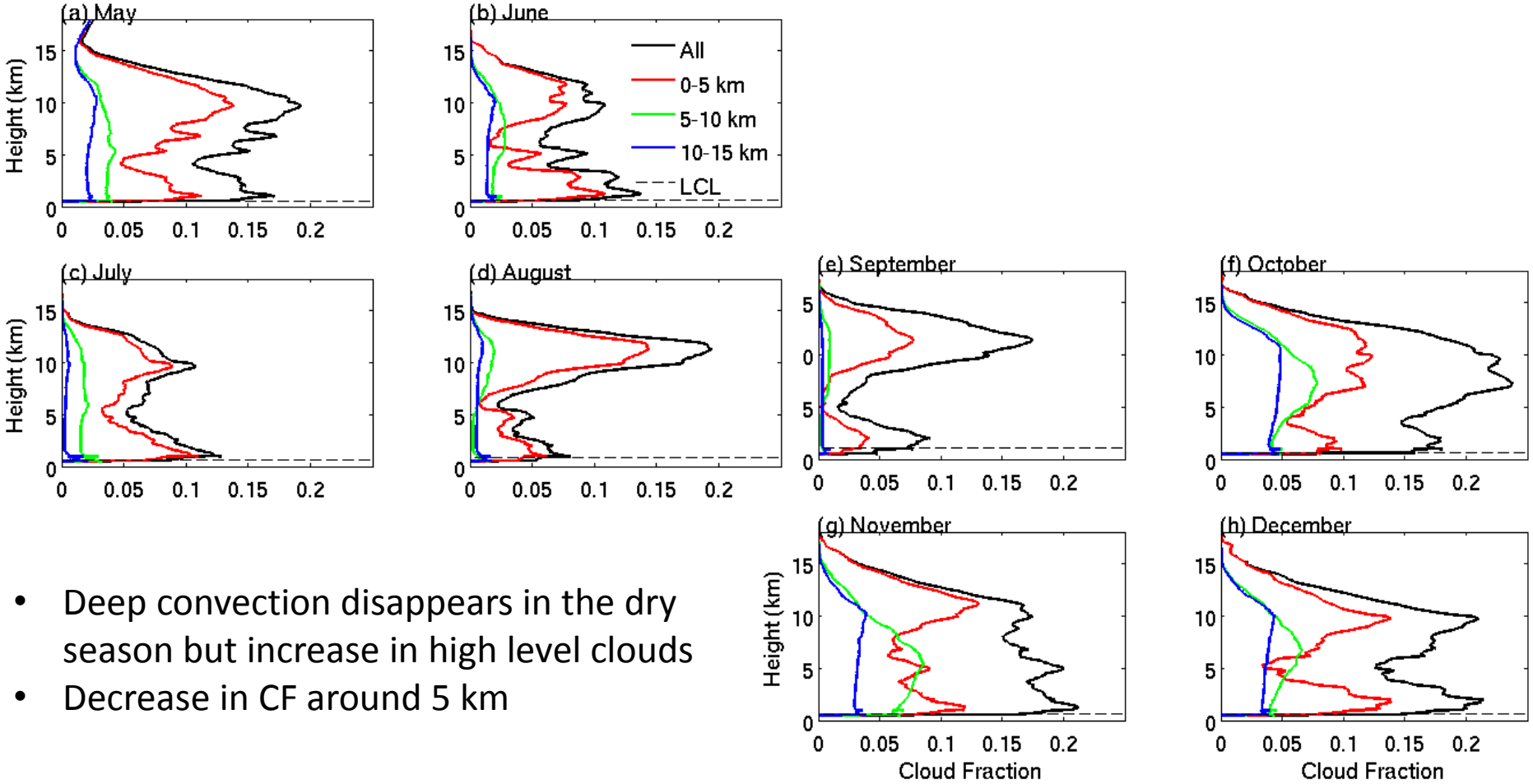
Descending Air mass

Precipitation in the Amazon



- Rains nearly every day in the wet season
- Dry season has fewer days with rain but a larger percent of days with rain have more intense precipitation
- Literature suggests dry season is more convective (Culf et al, 1998, Machado et al., 2004)
- Although convection is common, Amazonia sees fewer intense storms than other tropical land regions

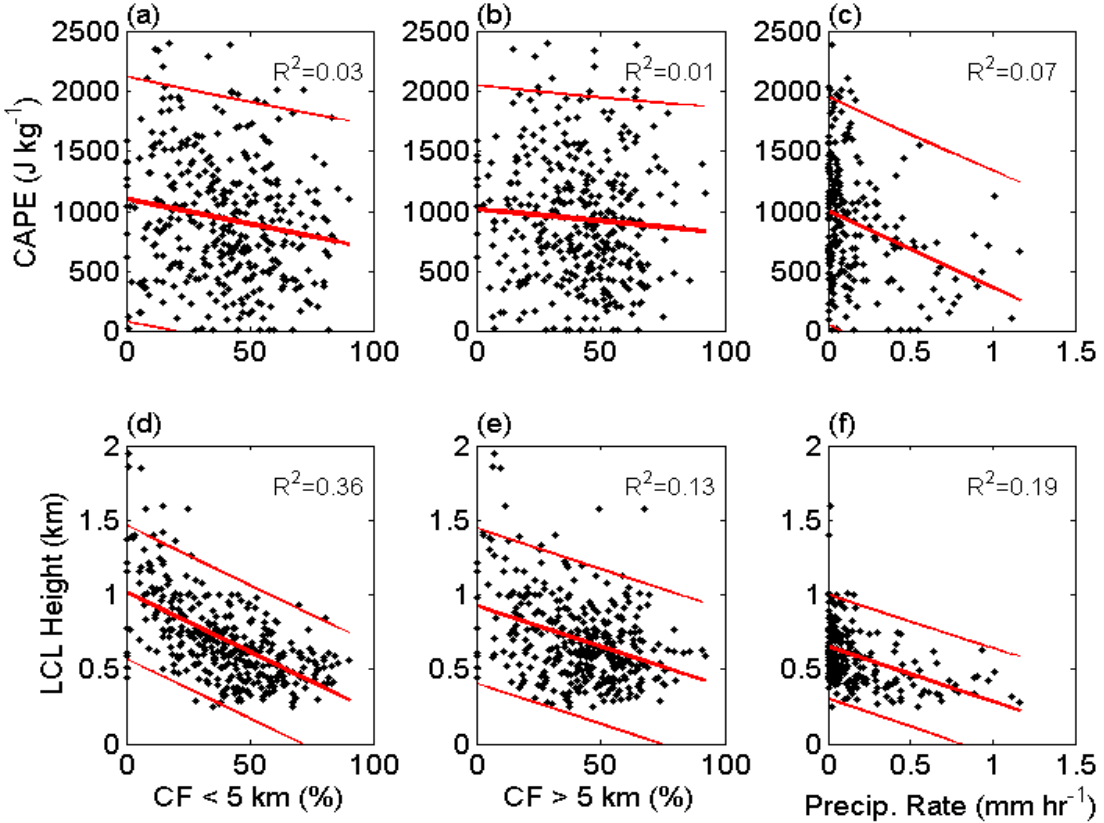
Vertical Profile of Clouds



- Deep convection disappears in the dry season but increase in high level clouds
- Decrease in CF around 5 km

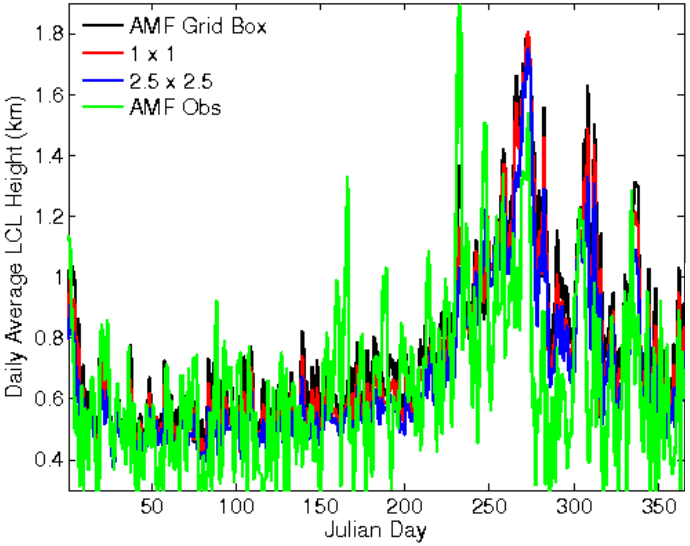
CAPE and LCL vs Cloud Fraction and Precipitation

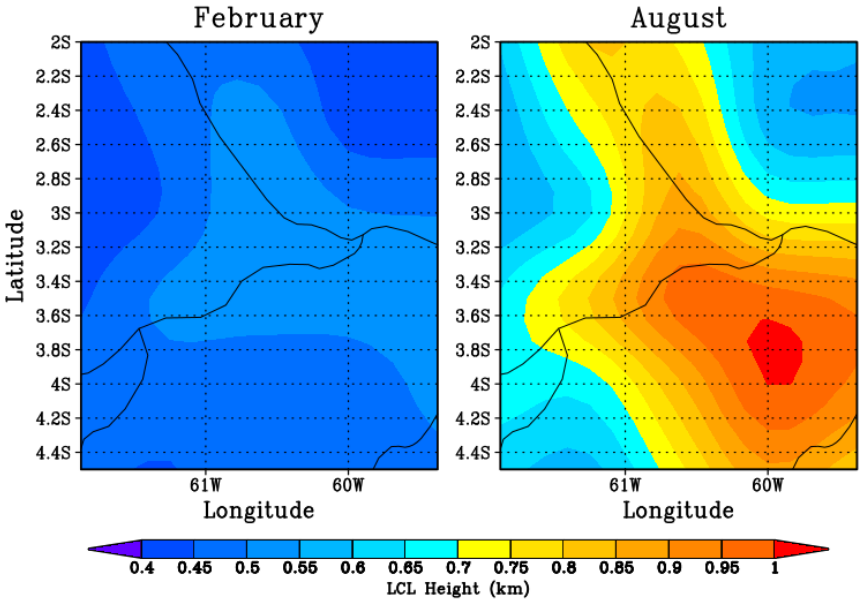
Weak/no relationship to CAPE: in agreement with other studies in the tropics

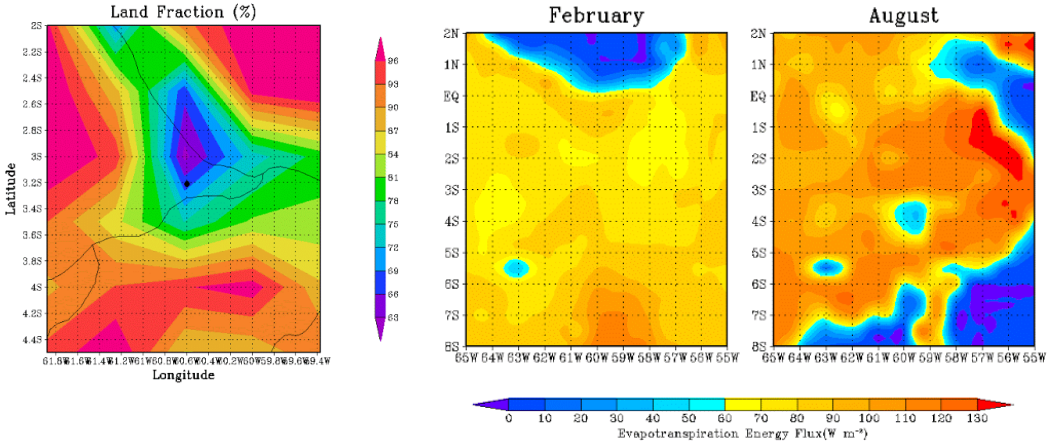


- Thick red line = line of best fit
- Thin red lines = 95% confidence interval

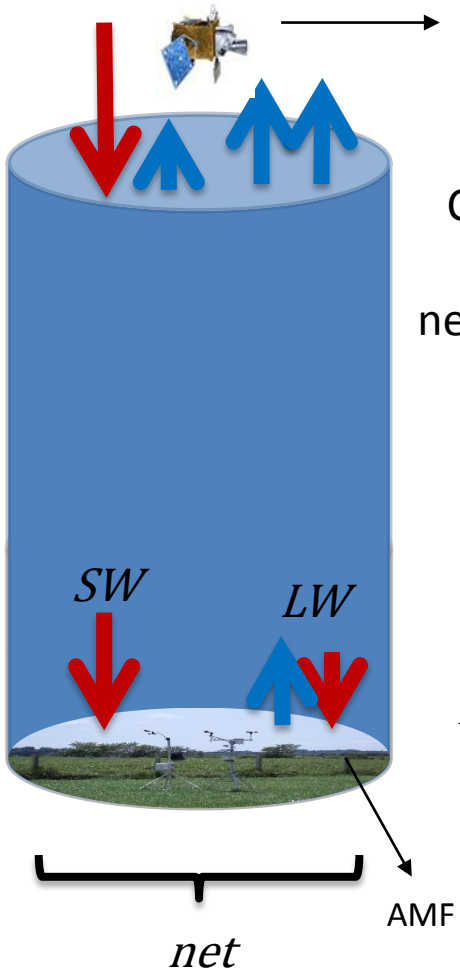
A Closer Look at LCL Height with MERRA-2







Results: Radiation Budget and Cloud Radiative Effect from GoAmazon 2014



Cross Atmosphere Radiative Flux Divergence (RFD) =
net radiation into column - net radiation out of column

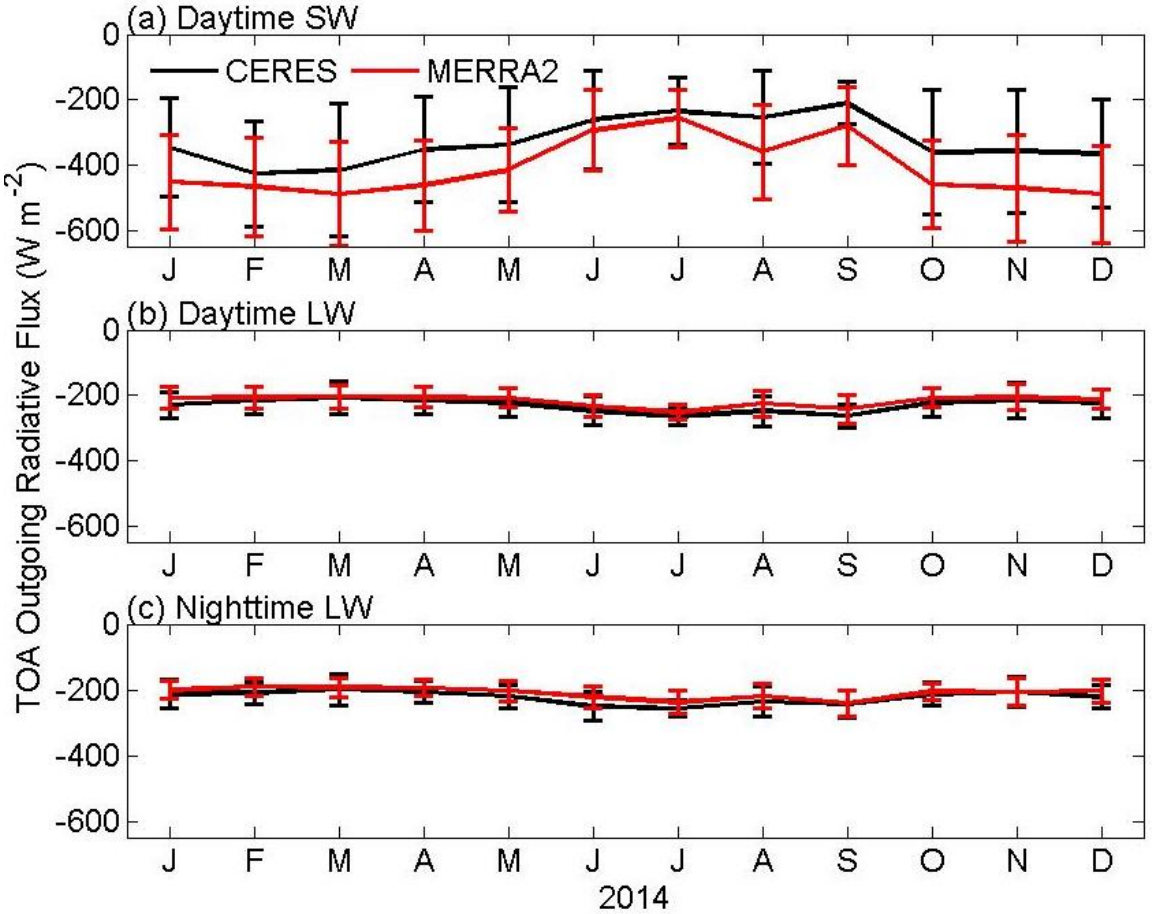
- positive values imply radiative heating
- negative values imply radiative cooling

$$RFD_{SW} = I_o - SWU_{TOA} + SWU_{surface} - SWD_{surface} \quad (1)$$

$$RFD_{LW} = LWU_{surface} - LWD_{surface} - LWU_{TOA} \quad (2)$$

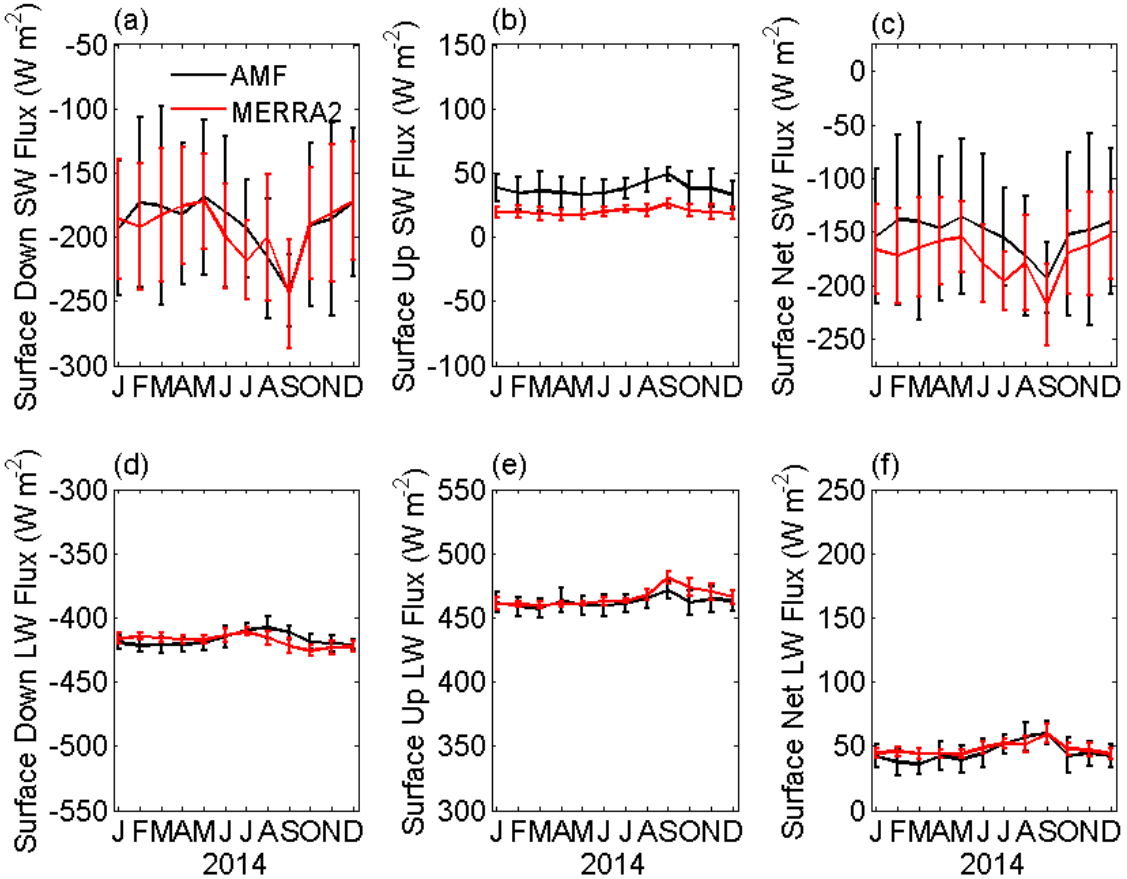
$$RFD_{Net} = RFD_{SW} + RFD_{LW} \quad (3)$$

TOA Radiative Fluxes from CERES and MERRA-2



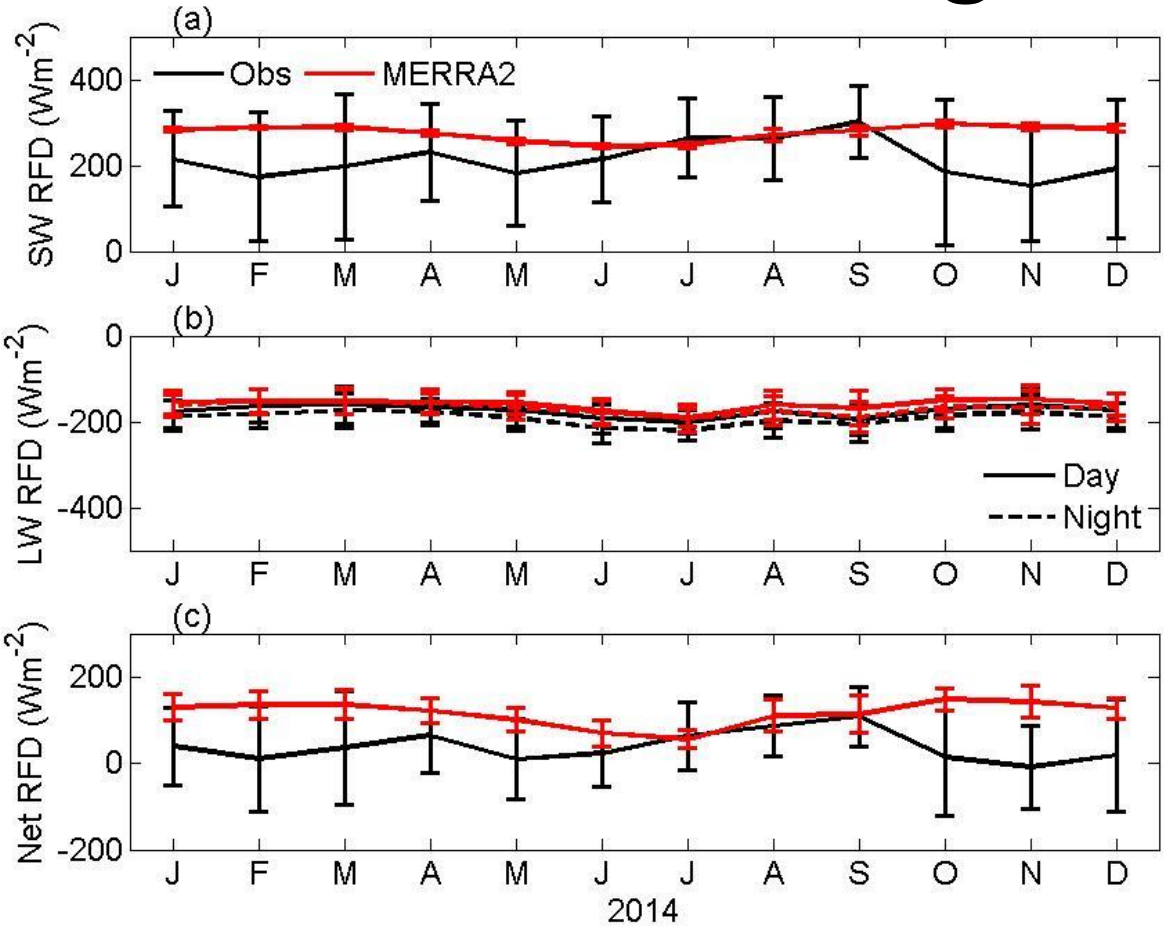
- MERRA-2 overestimates outgoing SW: known problem, seen in other regions
- Little variation in OLR – column saturated with vapor
- Impact of clouds seen in SW

Surface Radiative Fluxes from the AMF and MERRA-2

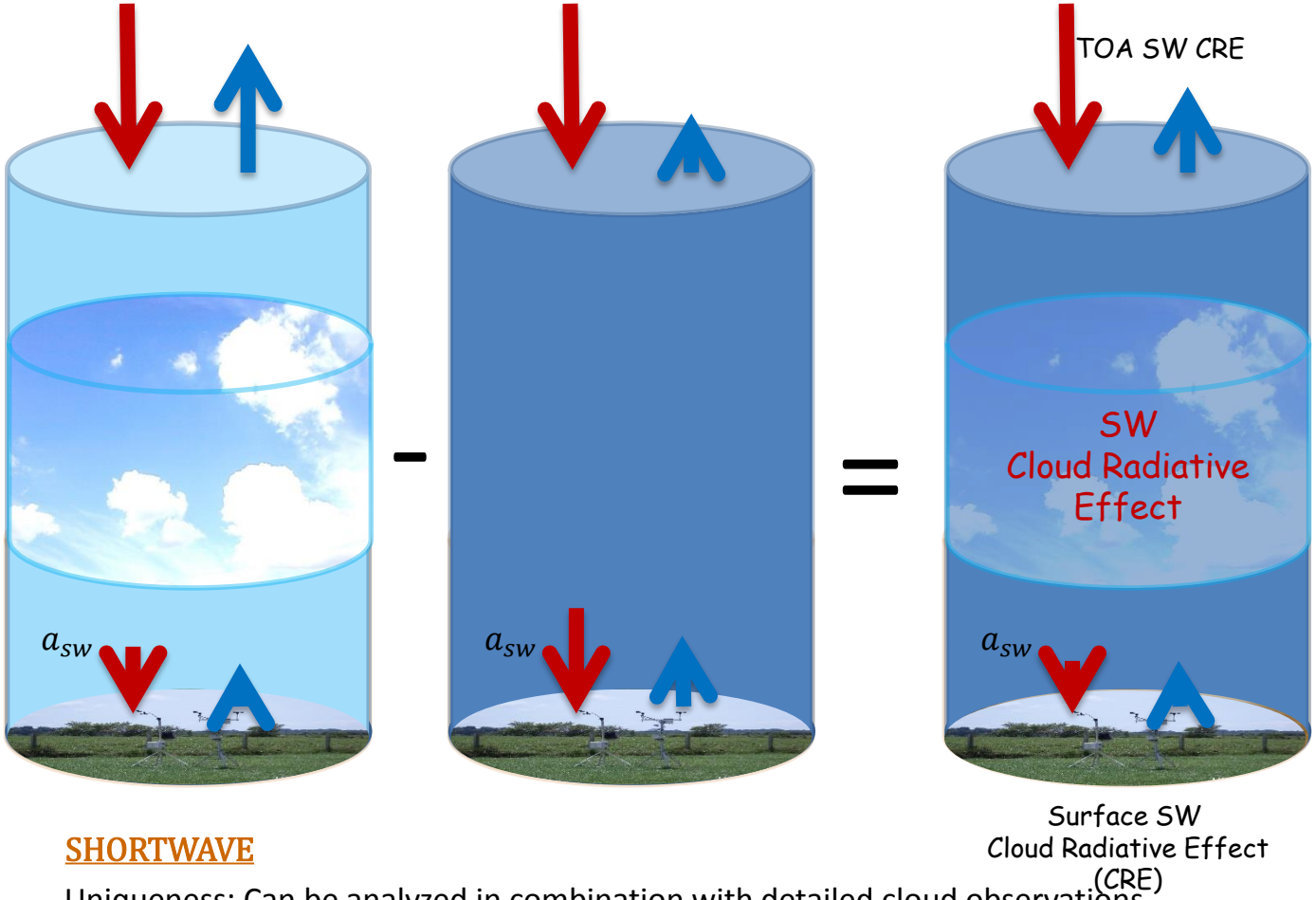


- Good agreement in the LW
- MERRA-2 underestimates upwelling SW and does not match the observed SW variability

Radiative Flux Divergence



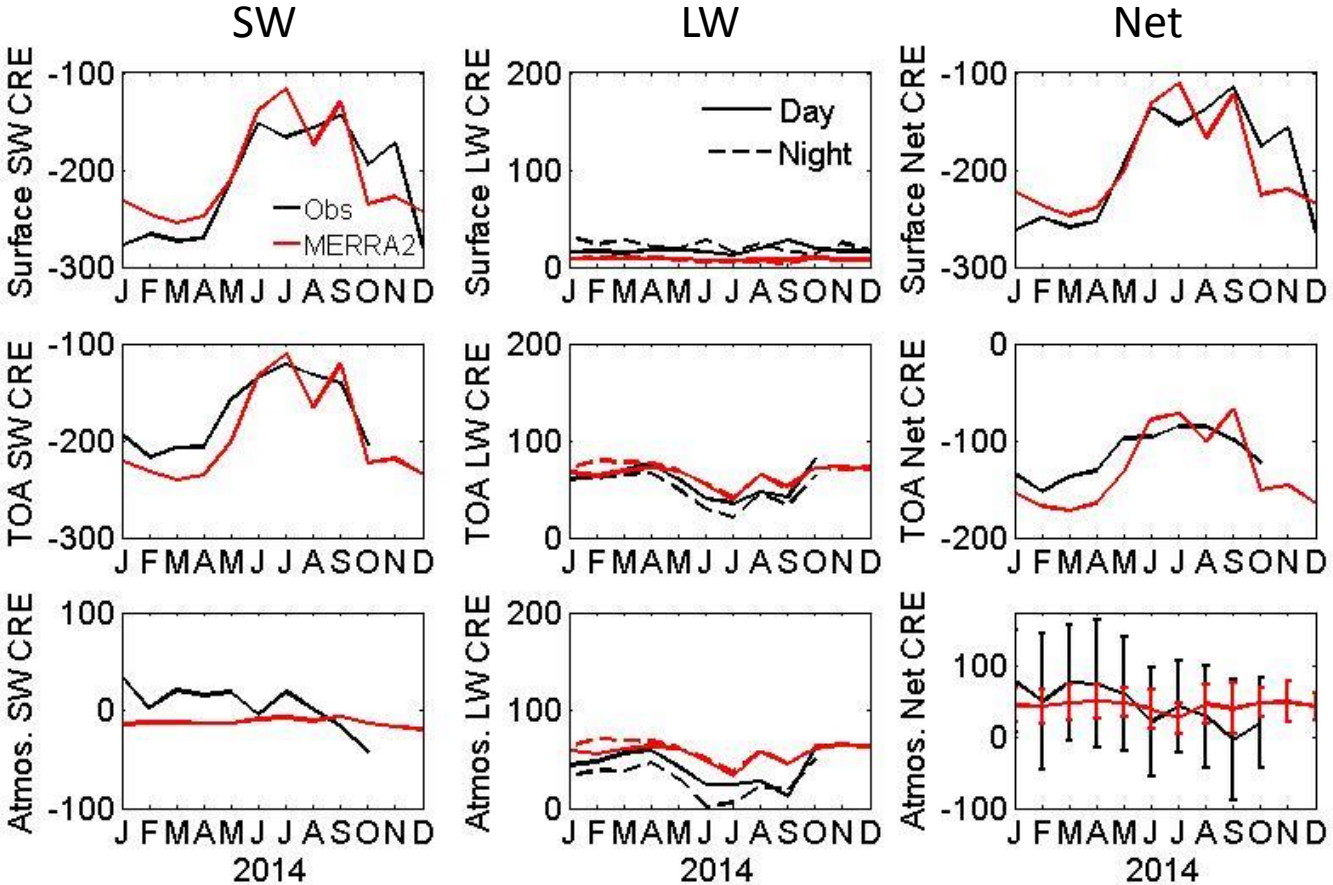
Cloud Radiative Effect



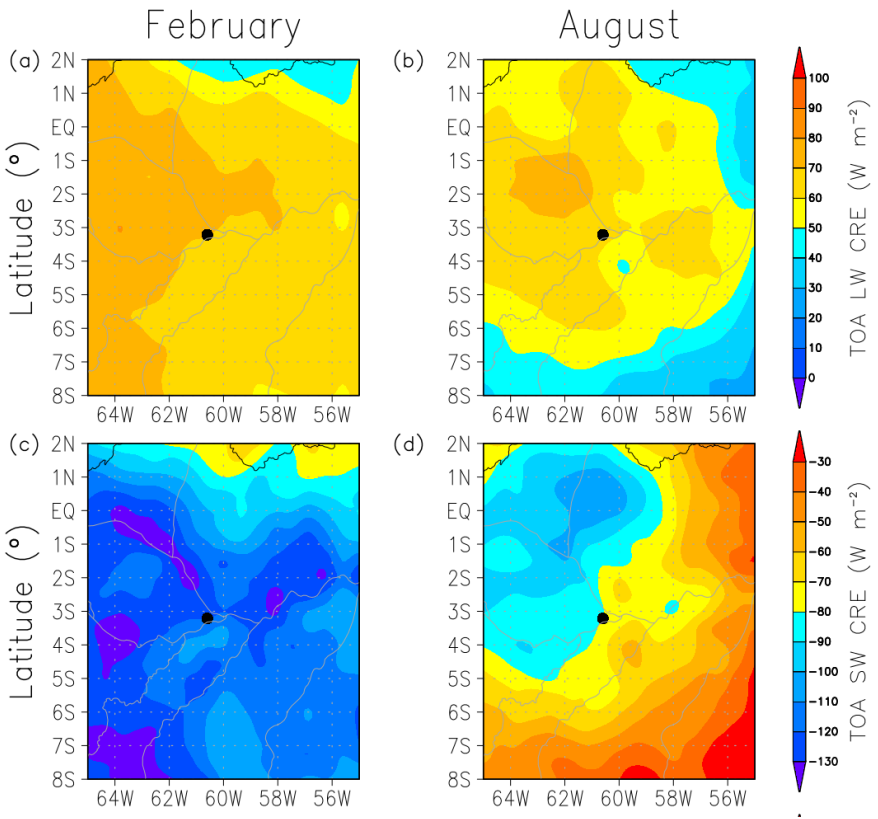
SHORTWAVE

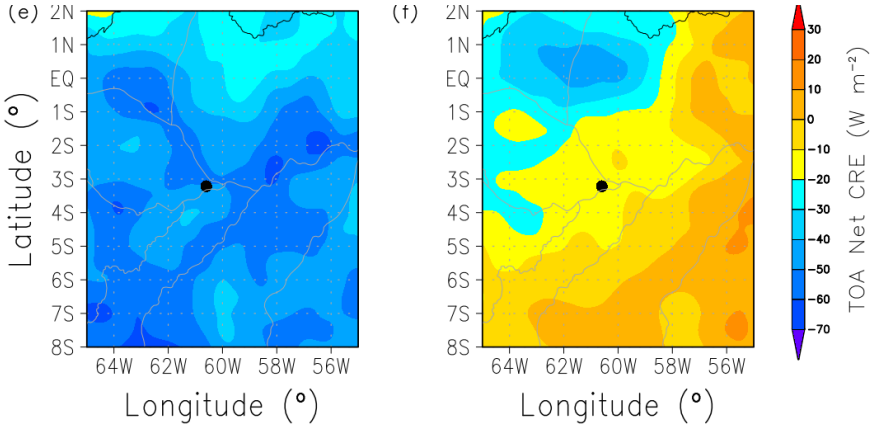
Uniqueness: Can be analyzed in combination with detailed cloud observations

Cloud Radiative Effect (W m-2)



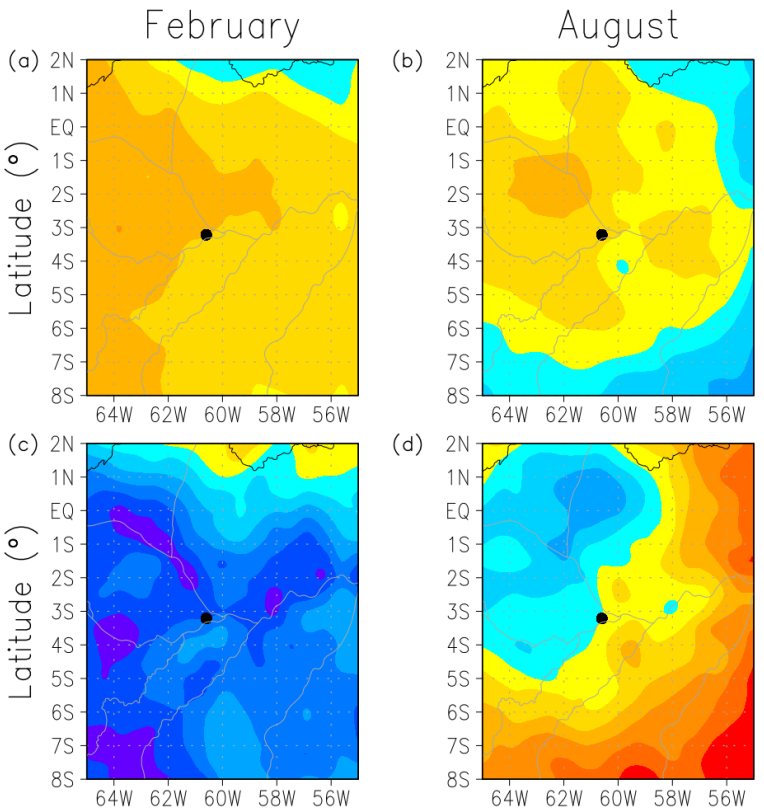
Top of the Atmosphere Cloud Radiative Effect

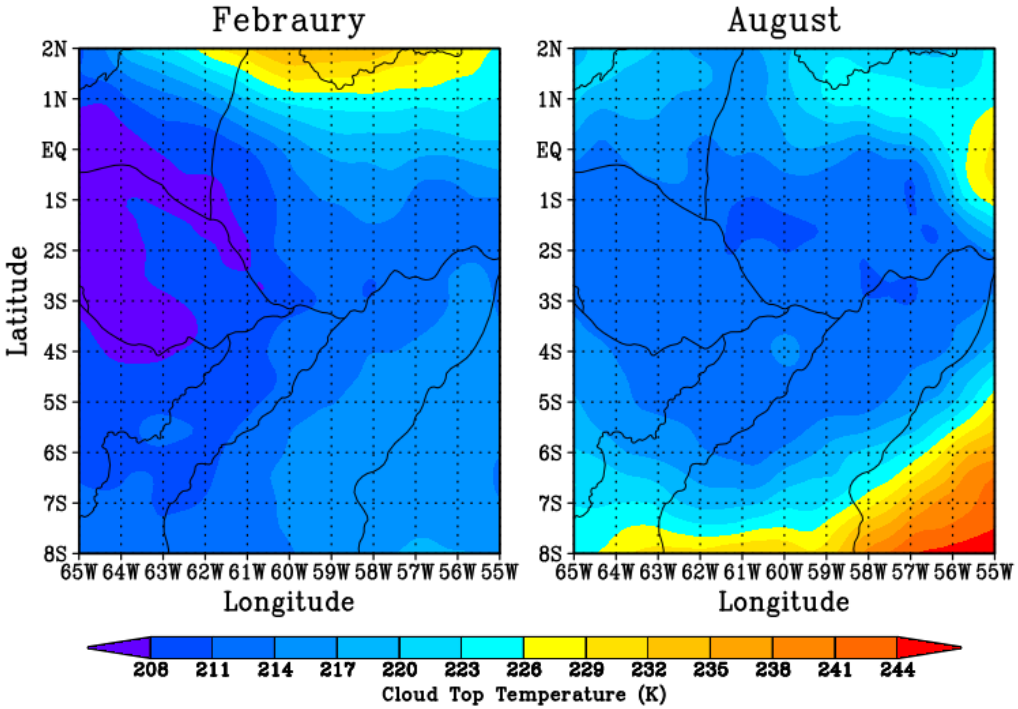




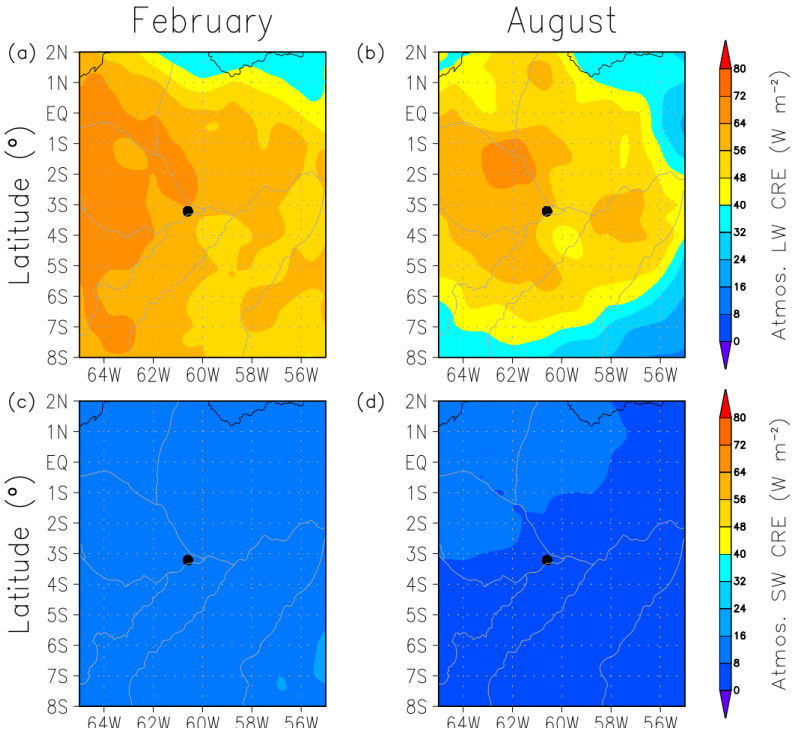
Surface CRE has a similar spatial pattern

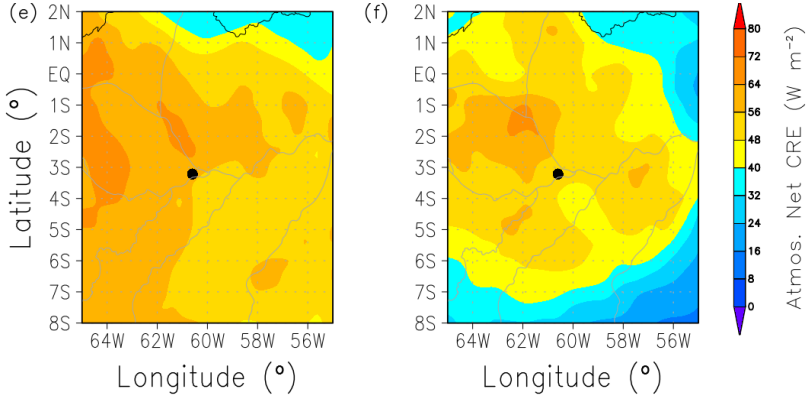
Top of the Atmosphere Cloud Radiative Effect





Atmospheric Cloud Radiative Effect





Conclusions

- A northward shift in the Hadley circulation creates a drying of the middle troposphere during the dry season
  - Dry season sees a reduction in cloudiness and precipitation but an increase in high clouds and the percentage of intense precipitation events
- There is a negative correlation between LCL height and the fraction of clouds below 5 km
- Land surface influences the height of the LCL and therefore low clouds
- Dry season clouds have double the impact on the surface shortwave CRE than wet season clouds in other tropical regions
- Abundant water vapor saturates the longwave budget year-round throughout the region
- Clouds are very reflective – the majority of warming within the column due to clouds is in the longwave