Investigating the Variability of Oceanic Warm Rain Processes

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Guiding Questions

1. How prevalent is warm rain globally?
2. How does the character of latent heating from condensational processes vary across general circulation regimes?

Motivations

- Latent heating connects the hydrologic and energy cycles of the planet:
  - Water evaporating from the surface stores energy through a phase transition.
  - When water vapor condenses into cloud and rain droplets, it releases energy in the form of latent heat.
  - Some of that rain then falls back to the surface, restoring surface water and energy potential.
- A full understanding of energy movement within the planetary system is important for accurately modeling the climate (Simpson, Adler, and North, 1988).
- Prior estimates of latent heating have leveraged satellite instruments that underestimate shallow, lightly precipitating clouds–a key characteristic of warm rain systems (Berg et al., 2010; Lebsock and L'Ecuyer, 2011).
- Warm rain is an important component in cloud feedback uncertainties (e.g. Bony and Dufresne, 2005), so better understanding the processes and variability therein may help improve their representation within climate models.

Methods

- We employ the Wisconsin Algorithm for Latent heating and Rainfall Using Satellites (WALRUS) to quantify latent heating from warm rain systems over the ocean.
- WALRUS is a Bayesian algorithm built on a database of cloud-resolving model oceanic warm rain simulations that represent a wide range of environmental conditions (Nelson et al., 2016).
- WALRUS is run on observations from CloudSat's Cloud Profiling Radar, a nadir-pointing W-band (94 GHz) radar that provides vertical profiles of reflectivity and attenuation.
- Data from 2007-2010 are used, and only raining profiles completely below the freezing level are included.
- We also derive information about the environment from MERRA, like estimated inversion strength (Wood and Bretherton, 2006).

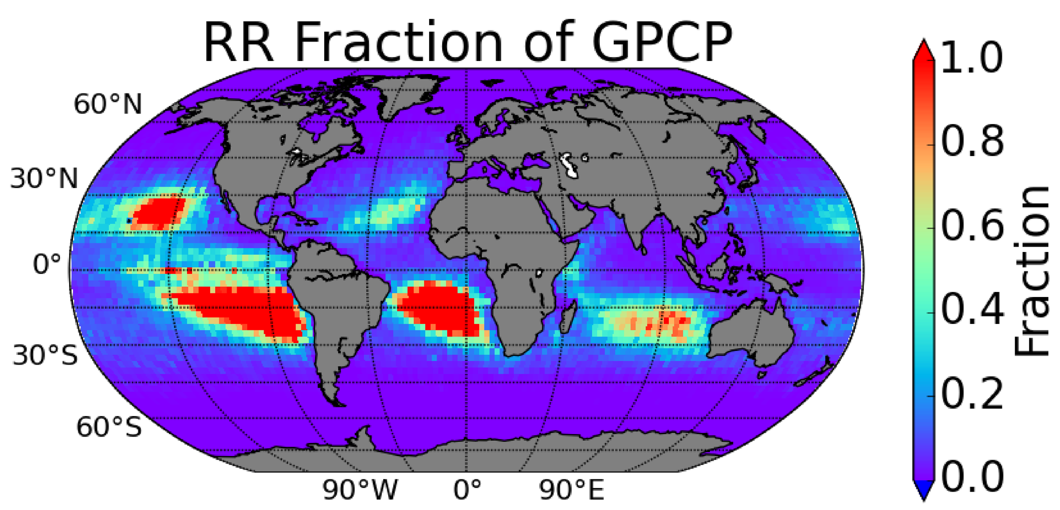
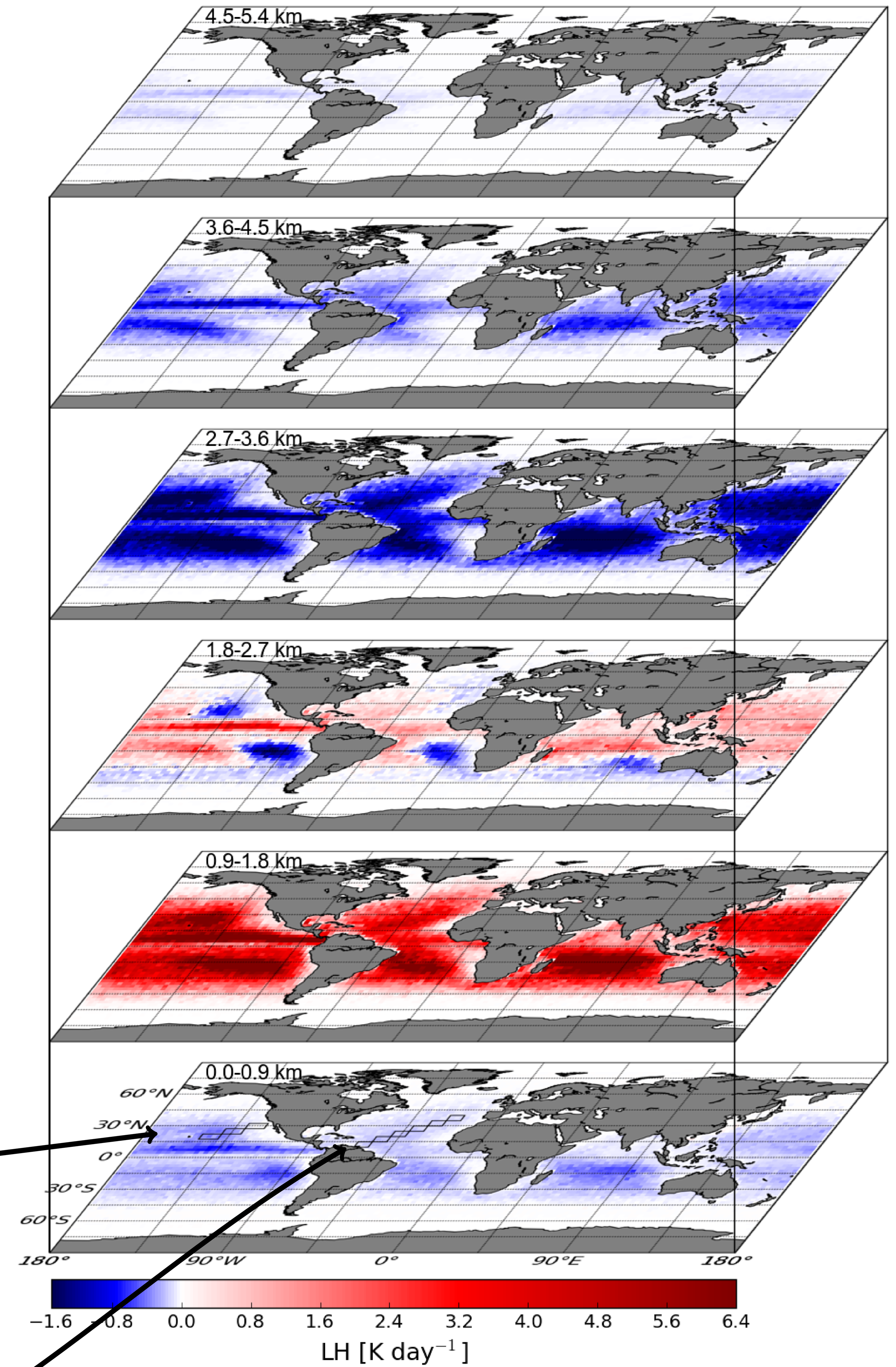
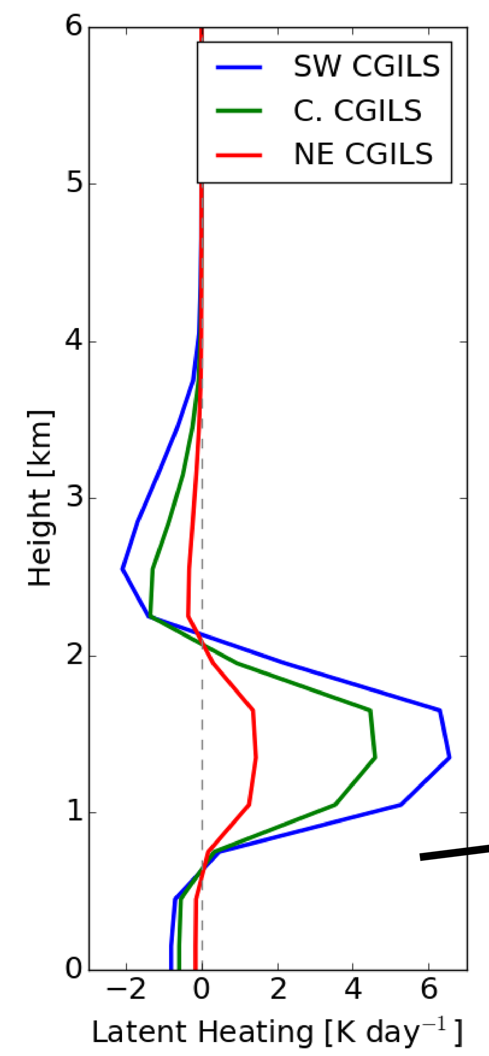


Figure 1: Fraction of Global Precipitation Climatology Project rainfall accumulation retrieved as warm rain.





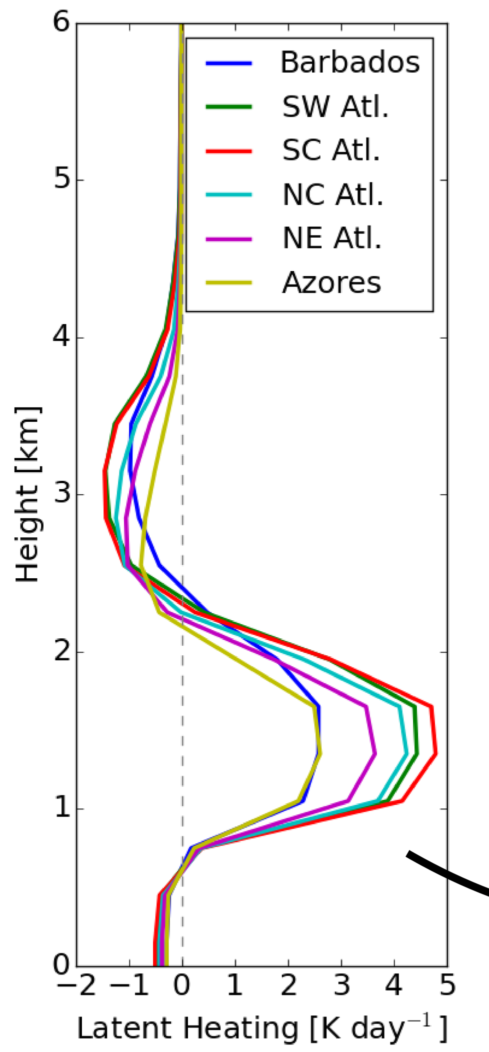


Figure 2: (right) Global layer-averaged latent heating for 2007-2010 using WALRUS. (left) Full profiles of regions highlighting the CFMIP-GASS Intercomparison of Large Eddy Models and single column models (CGILS) and North Atlantic Ocean regions. See boxes in the bottom right figure for the exact locations chosen (indicated by arrows).

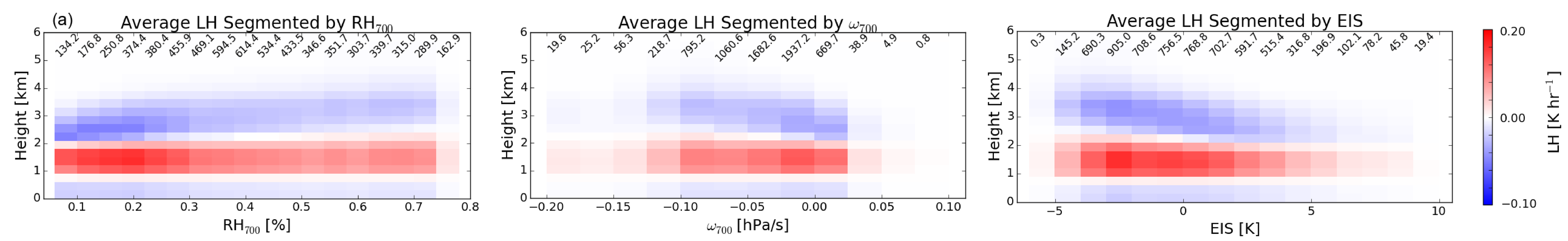


Figure 3: Bin-average latent heating profiles grouped by environmental parameters derived or taken from MERRA: (a) relative humidity at 700 mb, (b) vertical motion at 700 mb, and (c) estimated inversion strength. Counts in thousands of profiles are shown above each bin.

Preliminary Results

- Warm rain is responsible for 15% of global and 30% of tropical GPCP rainfall (Figure 1).
- Subsiding regions at the eastern ends of ocean basins have a shallow heating layer and enhanced below cloud cooling (Figure 2-right).
- Convective areas contain a heating layer that extends higher and a deeper cooling extent above heating.
- The difference between regimes creates a dipole in eastern ends of ocean basins around 2 km.
- This regime difference is further demonstrated when viewing regionally averaged profiles (Figure 2-left).
- By many metrics, more stable environments lead to shallower extents of latent heating and cooling (Figure 3).

Key Takeaways

- Warm rainfall processes are responsible for a majority of precipitation that falls in many tropical and subtropical areas.
- On average, latent heating from warm rain generates a net heating within the atmosphere of 0.39 K day^{-1} globally.
- While latent heating is mostly confined within a $\sim$1-km deep layer in all stabilities, cooling above the heating layer varies in depth with environmental stability.

References

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Acknowledgments

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