A Preliminary Investigation of the Thermodynamics Supporting Non-/Weakly Baroclinic Tropical Cyclone Overland Maintenance and Intensification

Michael Vossen and Clark Evans

University of Wisconsin-Milwaukee, Atmospheric Sciences Program

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Background

- Over the ocean, it is well known that tropical cyclones gain enthalpy from warm ocean waters, but overland it is still much debated on what process provides enthalpy fluxes to tropical cyclones.
- There are two conflicting hypotheses on where tropical cyclones overland gain enthalpy fluxes.
  - Emanuel et al. (2008): Hot sandy soils moistened by the rainfall from the tropical cyclone produces strong enough enthalpy fluxes under the tropical cyclone to cause maintenance overland.
  - Evans et al. (2011): Abnormally wet soils under inflowing trajectories outside the tropical cyclone help maintain tropical cyclones overland.

Hypotheses

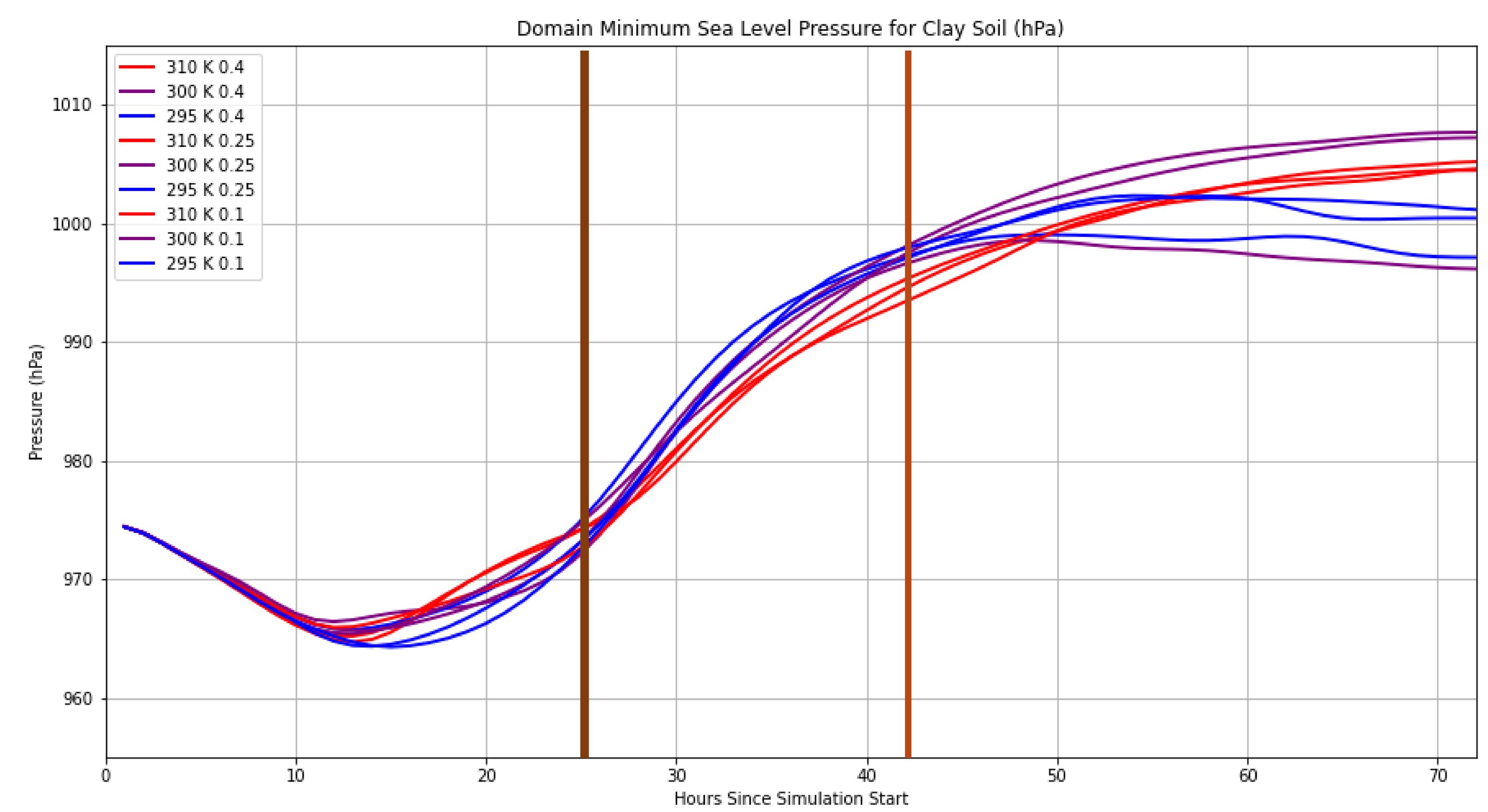
- Wet sandy soils have the greatest ability to have surface enthalpy fluxes strong enough to maintain a tropical cyclone.
- Remote surface enthalpy fluxes (rather than those directly under the tropical cyclone) are the primary driver of tropical cyclone maintenance over land.

Methods

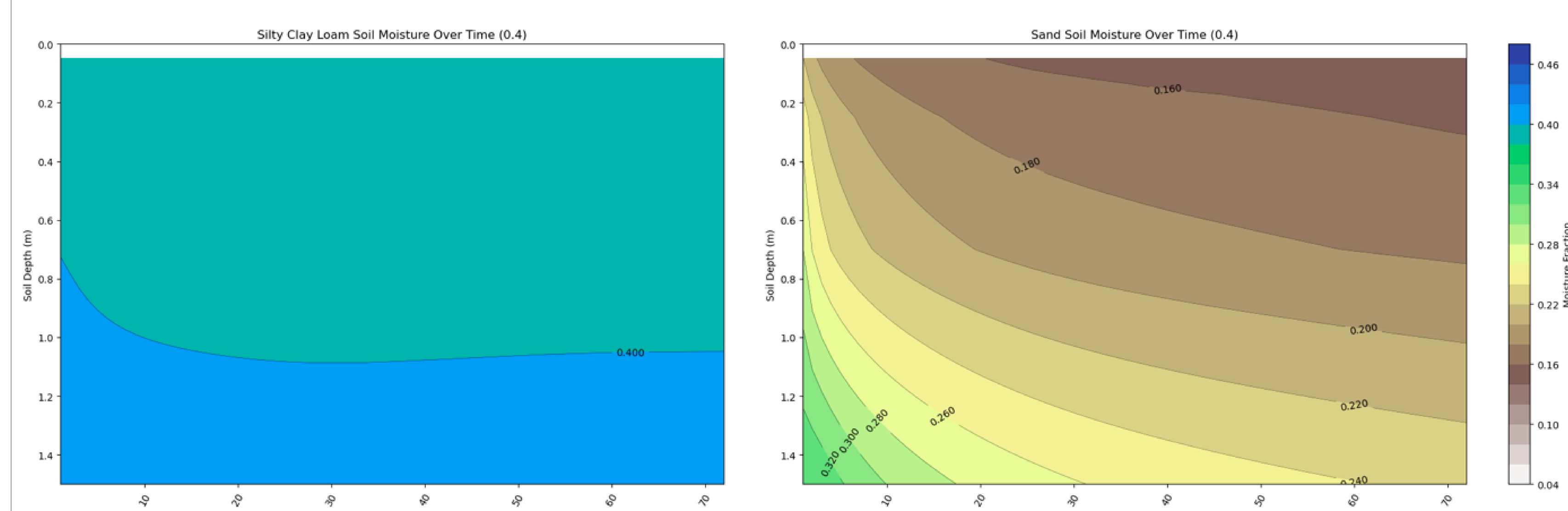
- Used a quasi-idealized WRF setup
  - The real data setup was used.
  - Input files were created using the Dunion (2011) moist tropical sounding and setting the background winds to 5 m/s out of the west. Also, SST was set to a constant 300 K.
  - There was no radiation included.
- 27 soil sensitivity runs
  - Simulations varied in moisture, temperature, and soil type.
  - Initially a simulation was integrated forward for 24 h over the ocean to let the tropical cyclone spin up. Then all simulations were restarted from the end of the 24 h simulation and integrated forward 72 h with the soil variables changed to the different permutations.

Soil Types	Soil Temperatures (K)	Soil Moisture Fraction
Silty Clay Loam, Sand, Rock	310, 300, 295	0.4, 0.25, 0.1

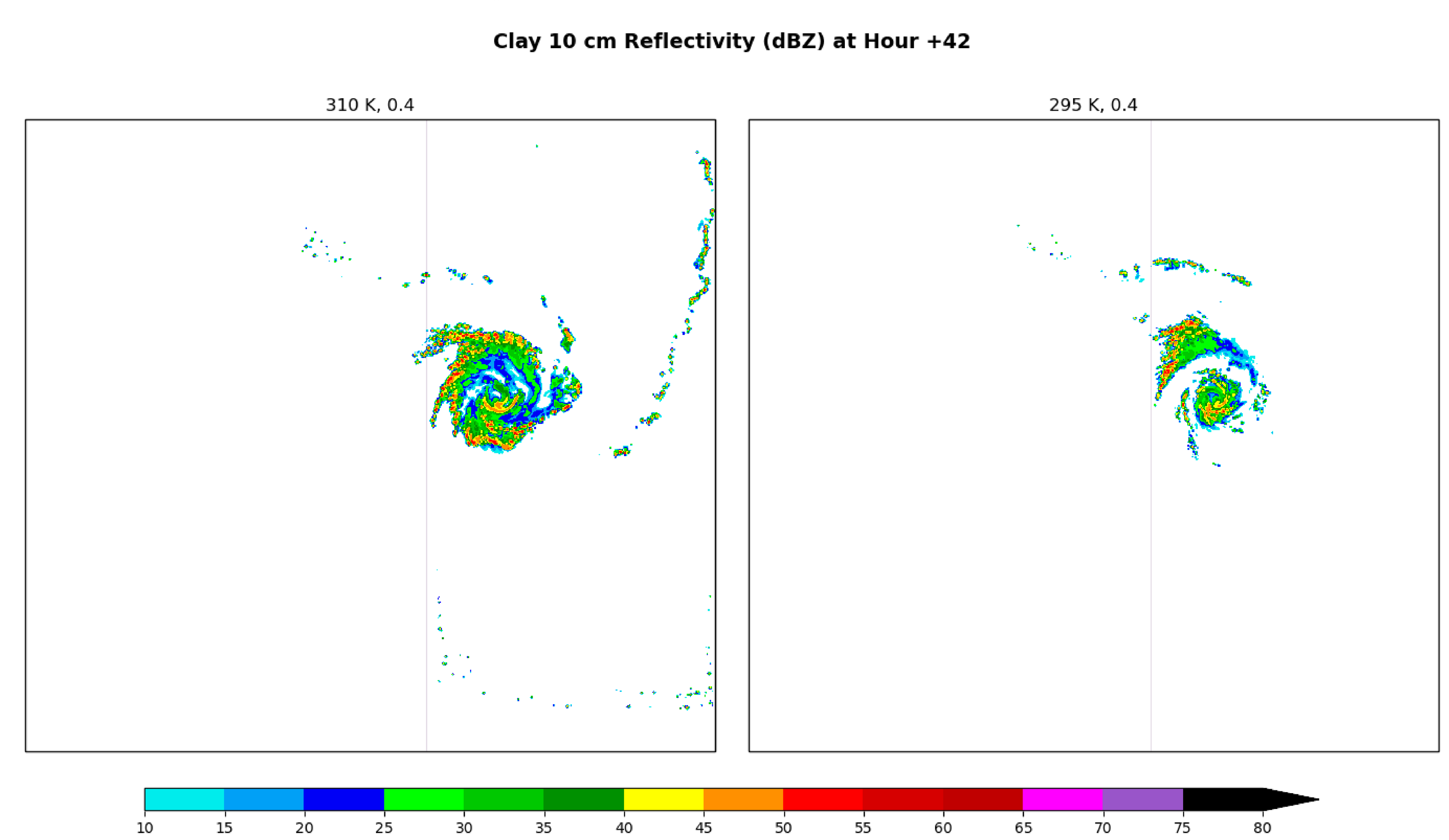
Results



Domain-minimum sea level pressure for all clay runs. Cold land surface temperatures produced a tropical cyclone that can maintain itself around 42 hours after the restart shown by the blue line. The brown line represents the time of landfall.

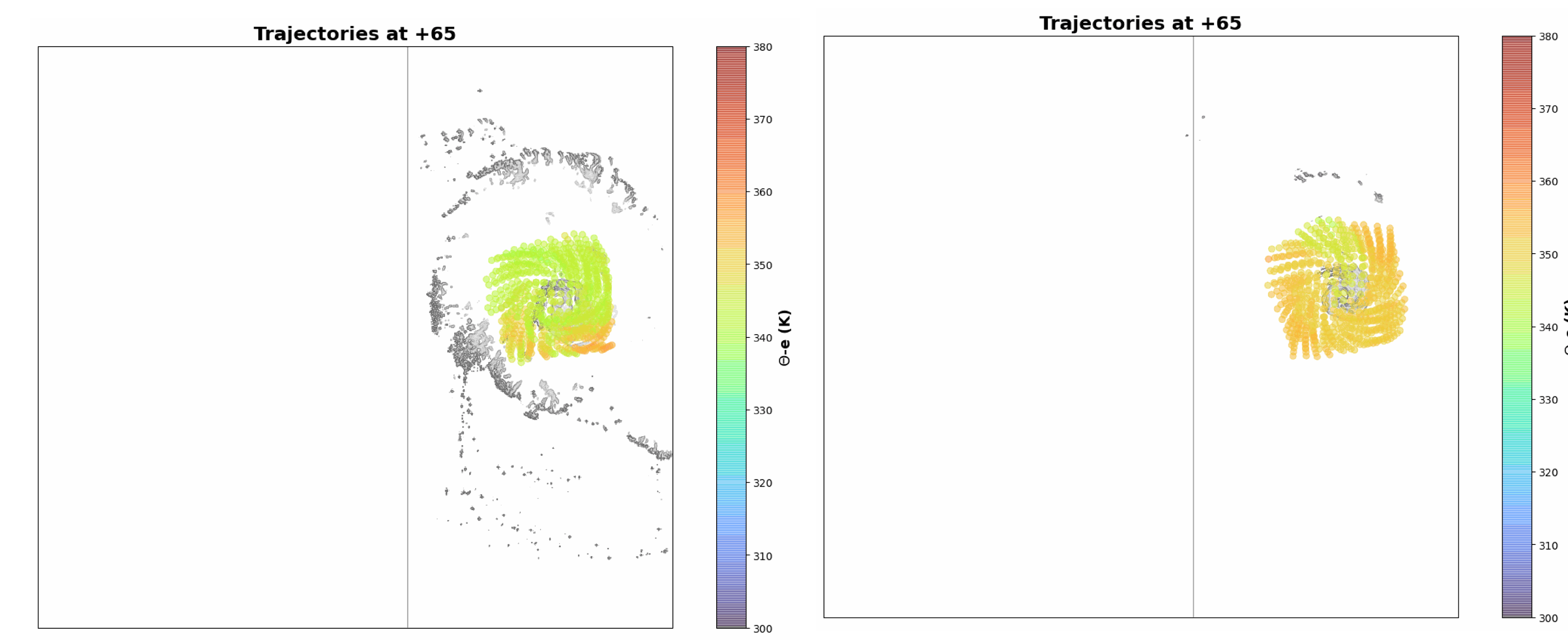


Soil moisture fraction over time for both the clay and sand 0.4 initial moisture fraction runs. The sand quickly has the soil moisture drain out resulting in lower soil moisture values near the surface.



Simulated 10 cm reflectivity for the high moisture 310 K and 295 K clay soil runs at 42 hours. 310 K soil temperature simulations produce more extensive outer rain bands than the 295 K simulations.

Silty Clay Loam 310 K 0.4 **Silty Clay Loam 295 K 0.4**



Backward trajectories originating at the surface at the end of the simulation in a 500 km x 500 km grid around the center of the tropical cyclone showing cold land surface temperature prevent trajectories from losing equivalent potential temperature by being flushed by rainband downdrafts. The coloring of trajectories shows the equivalent potential temperature of the trajectory. Gray shading shows simulated 10 cm radar reflectivity with darker colors being lower reflectivity values.

Summary

- Nighttime environments are the best for tropical cyclone maintenance.
  - Colder soil temperatures maintain tropical cyclones the best due to a nighttime-like inversion near the surface that prevents convection from initiating until the near-surface air is near the center of the tropical cyclone.
- Suppression of the rain bands is needed to allow diabatic heating to focus near the tropical cyclone's center.

Future Work

- Simulations on a 20 °N f plane
  - Switch to an idealized framework with a triple nest and nudging
- Simulations with radiation
- Factor separation simulations
  - Turn off LH and SH fluxes both outside and under the TC

References

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Emanuel, K., J. Callaghan, and P. Otto, 2008: A hypothesis for the redevelopment of warm-core cyclones over Northern Australia. *Mon. Wea. Rev.*, **136**, 3863–3872, https://doi.org/10.1175/2008MWR2409.1.

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