Impacts of Tropopause Height and Radiation on Idealized Tropical Cyclones

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TCI-2015: Goals

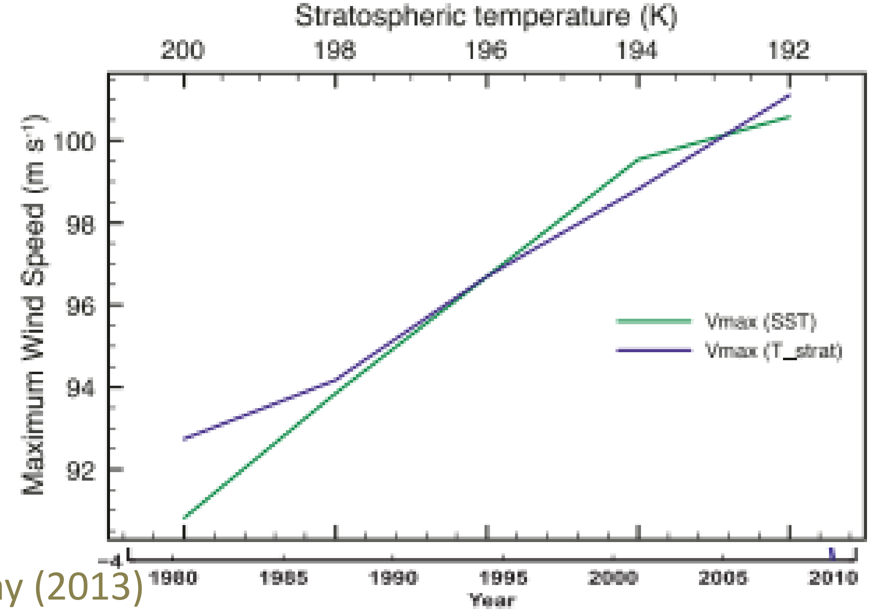
"The specific focus is an improved understanding of TC upper-level outflow layer processes and dynamics."

Specific Project Goals & Questions (UH)

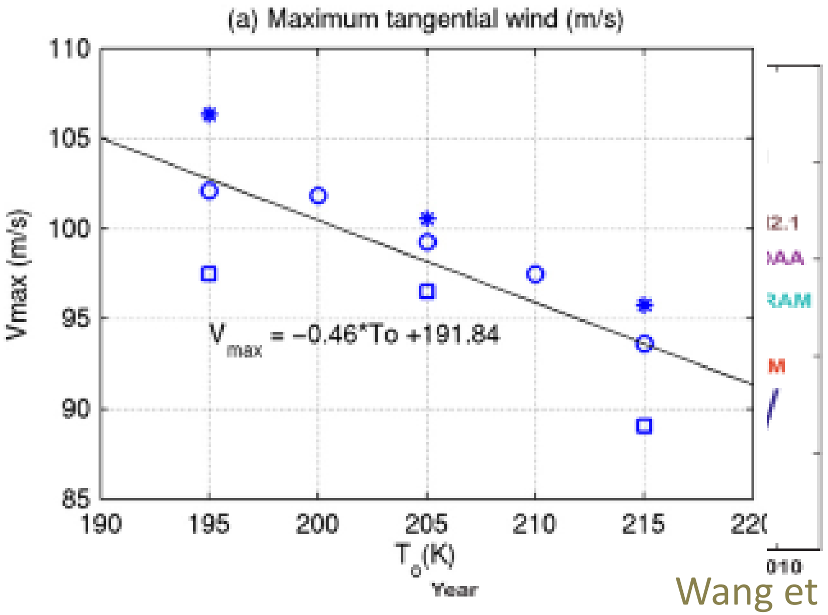
- Create an idealized (yet realistic) experimental framework for testing the role of the tropopause and outflow layer on the structure and intensity of a tropical cyclone
  - How is/should the outflow be defined and what is its relationship to the tropopause?
  - How does the height and/or temperature of the tropopause affect the intensity of the TC?
  - How does the outflow interact with atmospheric radiation?

Background

- Background: Chavas & Emanuel (2014, JAS), Emanuel et al (2013, J. Clim.), Ramsay (2013, J. Clim.), Wang et al (2014, JAS)
  - E-PI theory indicates intensity should go up as outflow temperature decreases
  - RCE simulations exhibit this theorized behavior



Ramsay (2013)



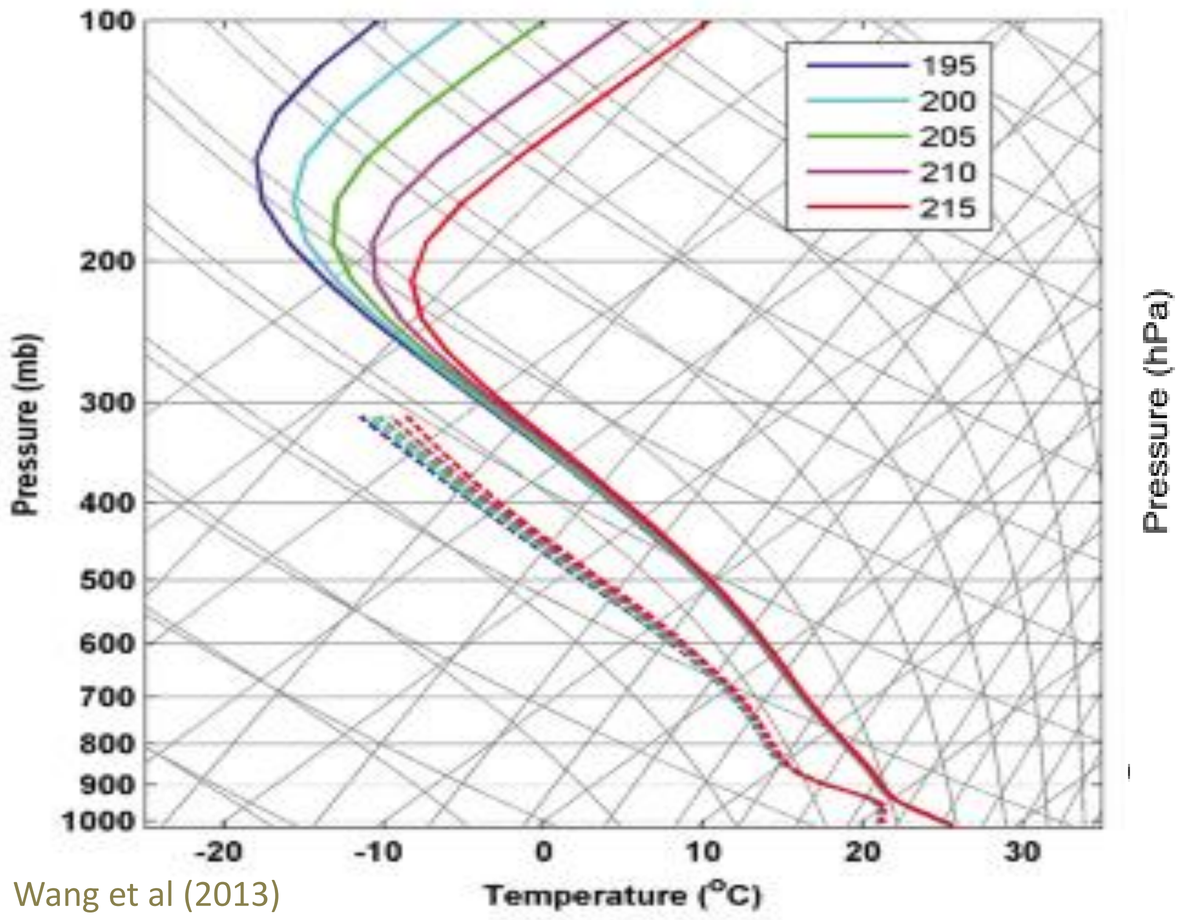
Emanuel et al (2013)

Wang et al (2013)

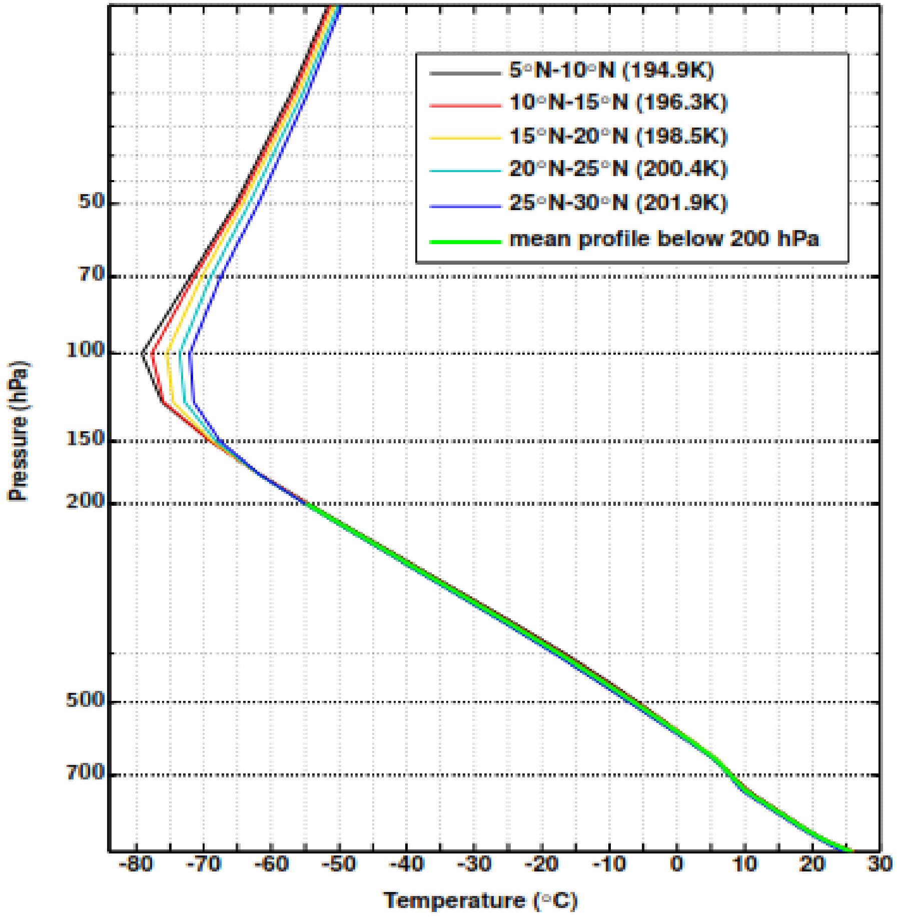
Idealized Experimental Framework

- WRF Ideal TC – initialized with a uniform sounding (see next slide) and weak vortex
- 18, 6, and 2km resolution two-way nested domains
- Thompson aerosol-aware microphysics, Tiedtke convective parameterization (18 and 6 only),
- Full radiation, longwave-only (perpetual night), and no radiation
- Eight day simulations

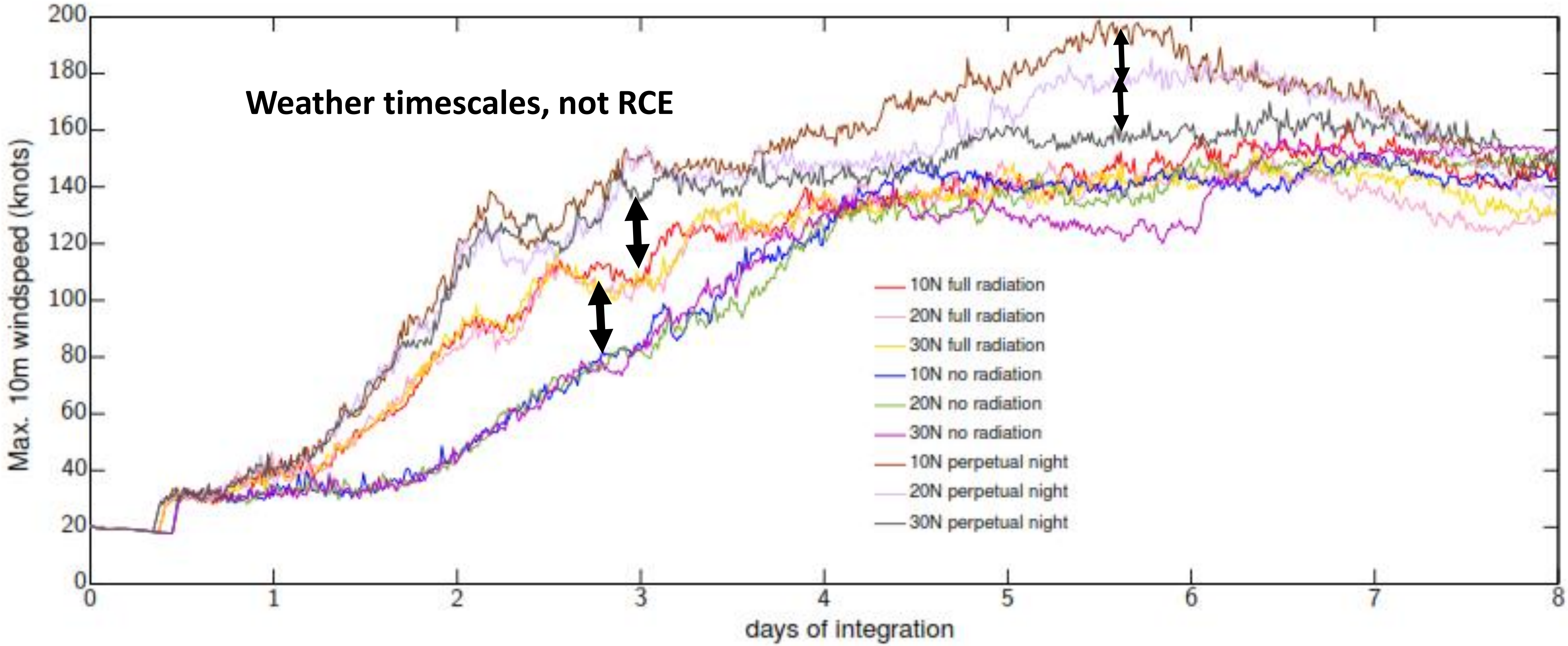
CFSR Initialization



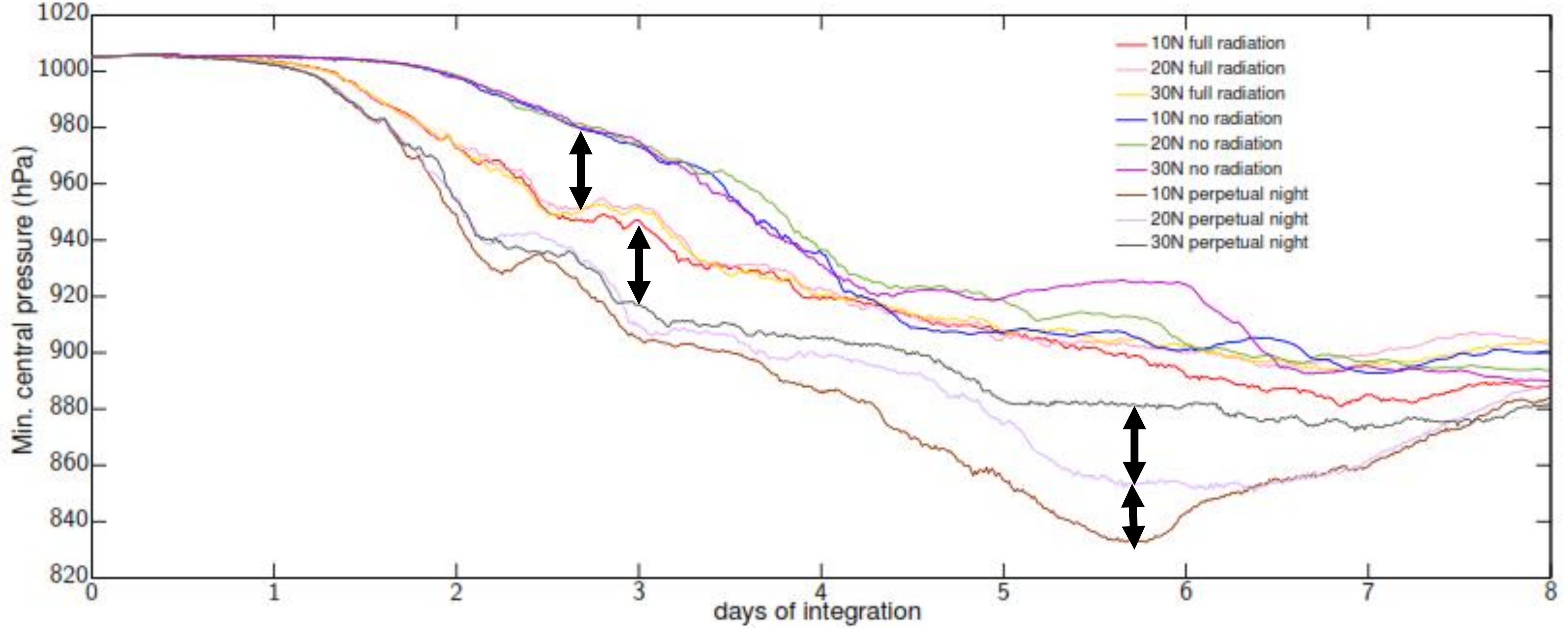
Wang et al (2013)



Maximum 10m Wind Speed

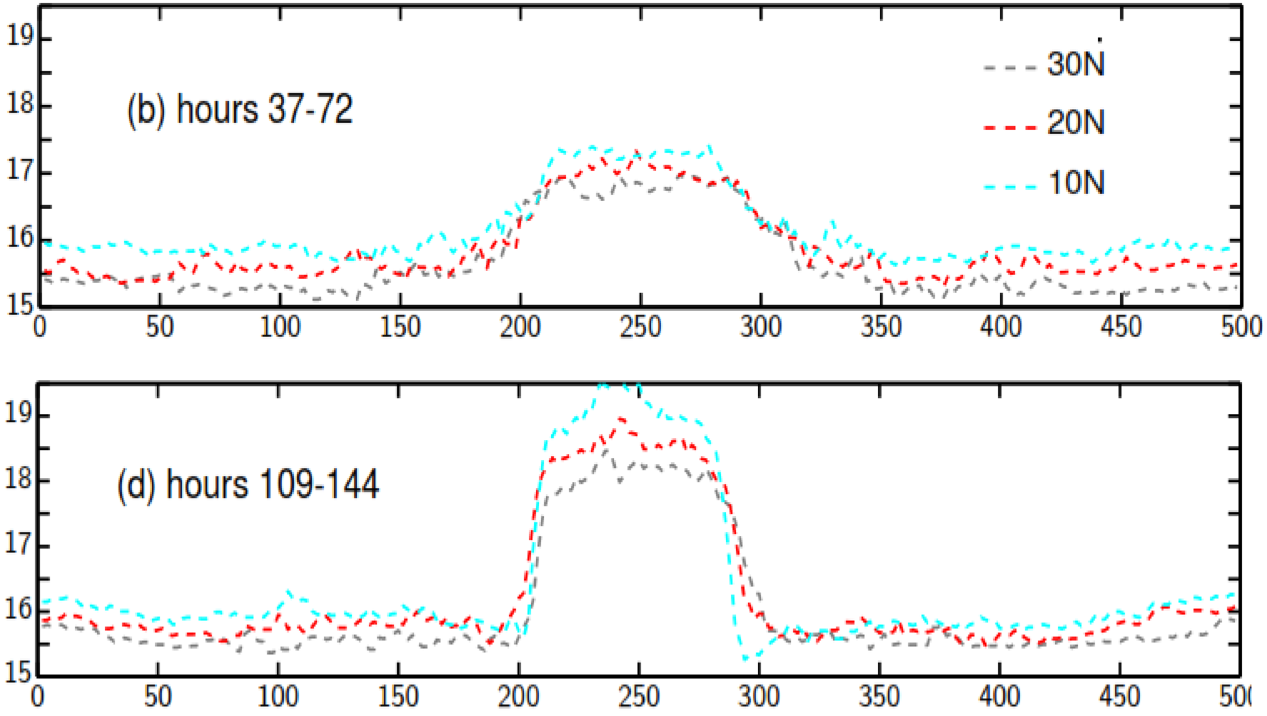


Minimum Central Pressure

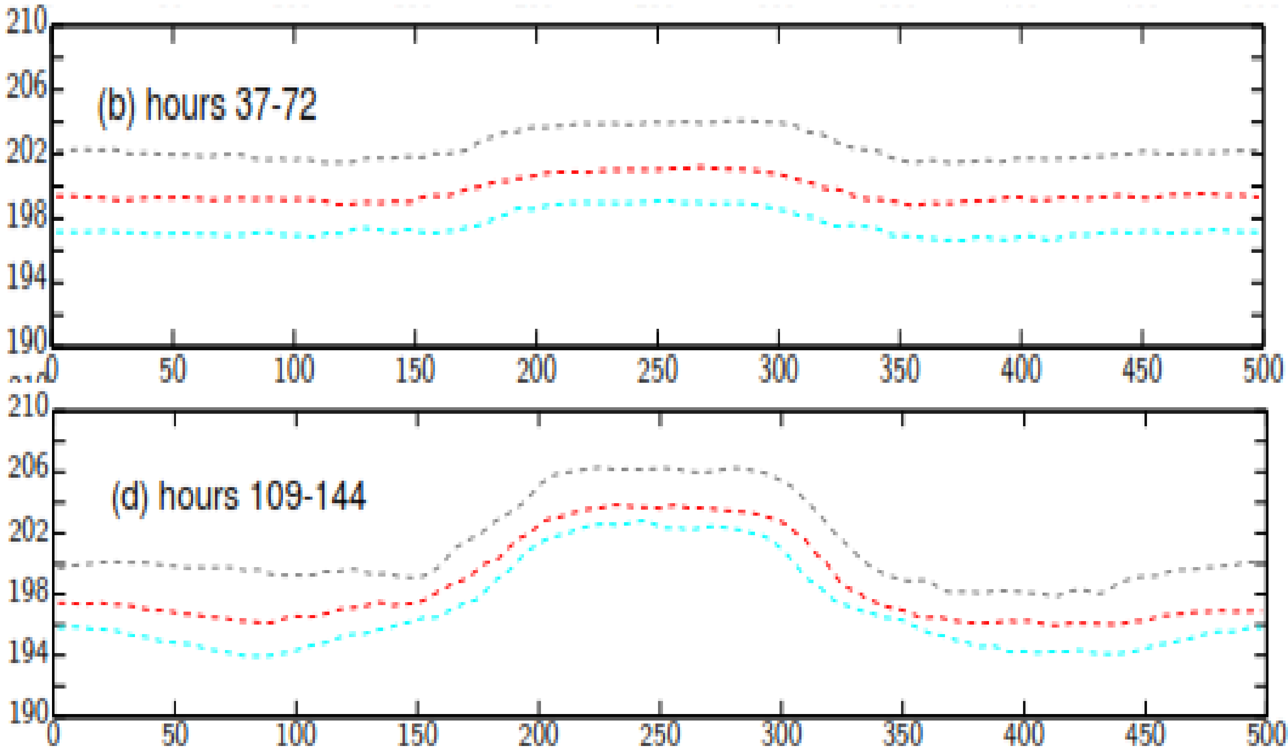


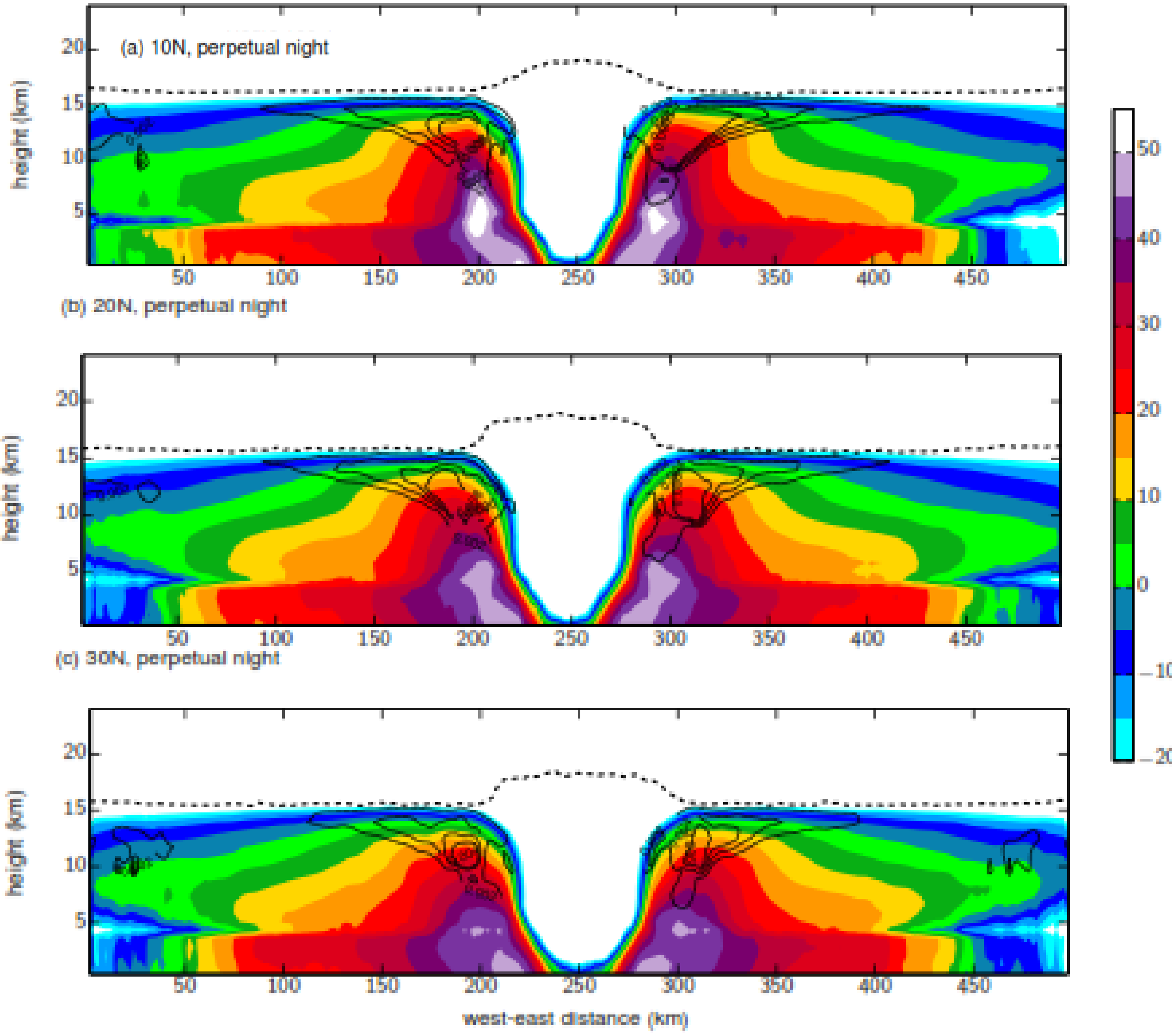
Cross-section: Perpetual night

Cold-point tropopause height (km)



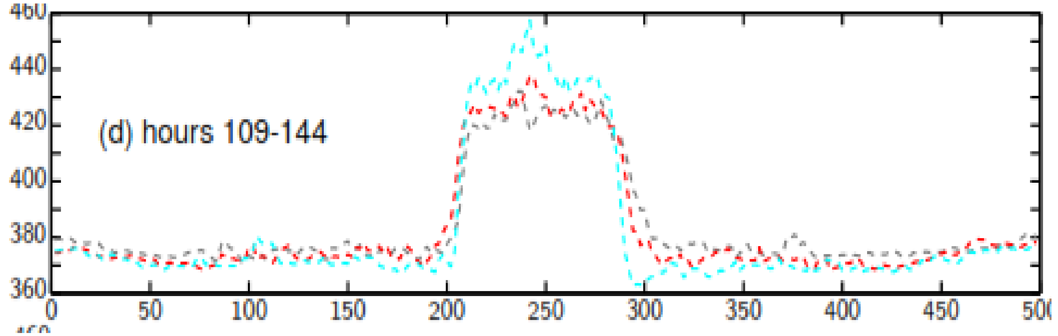
Cold-point tropopause temperature (K)



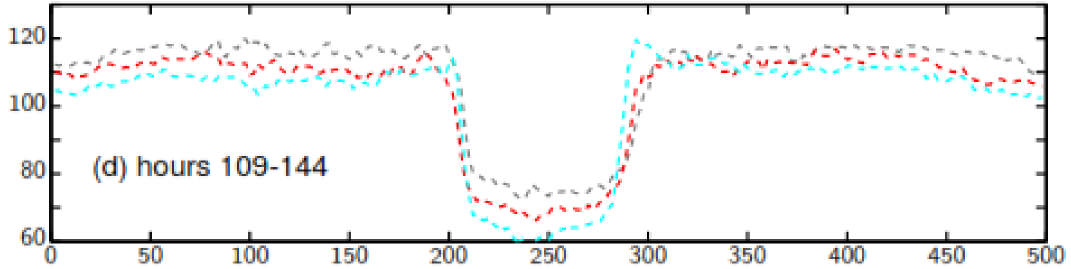


PERPETUAL NIGHT
Time-mean reflectivity (shading, dBZ),
cloud ice mixing ratio (contours),
and cold-point tropopause height (dashed)
for hours 109-144

Tropopause equiv. pot. Temperature (K)

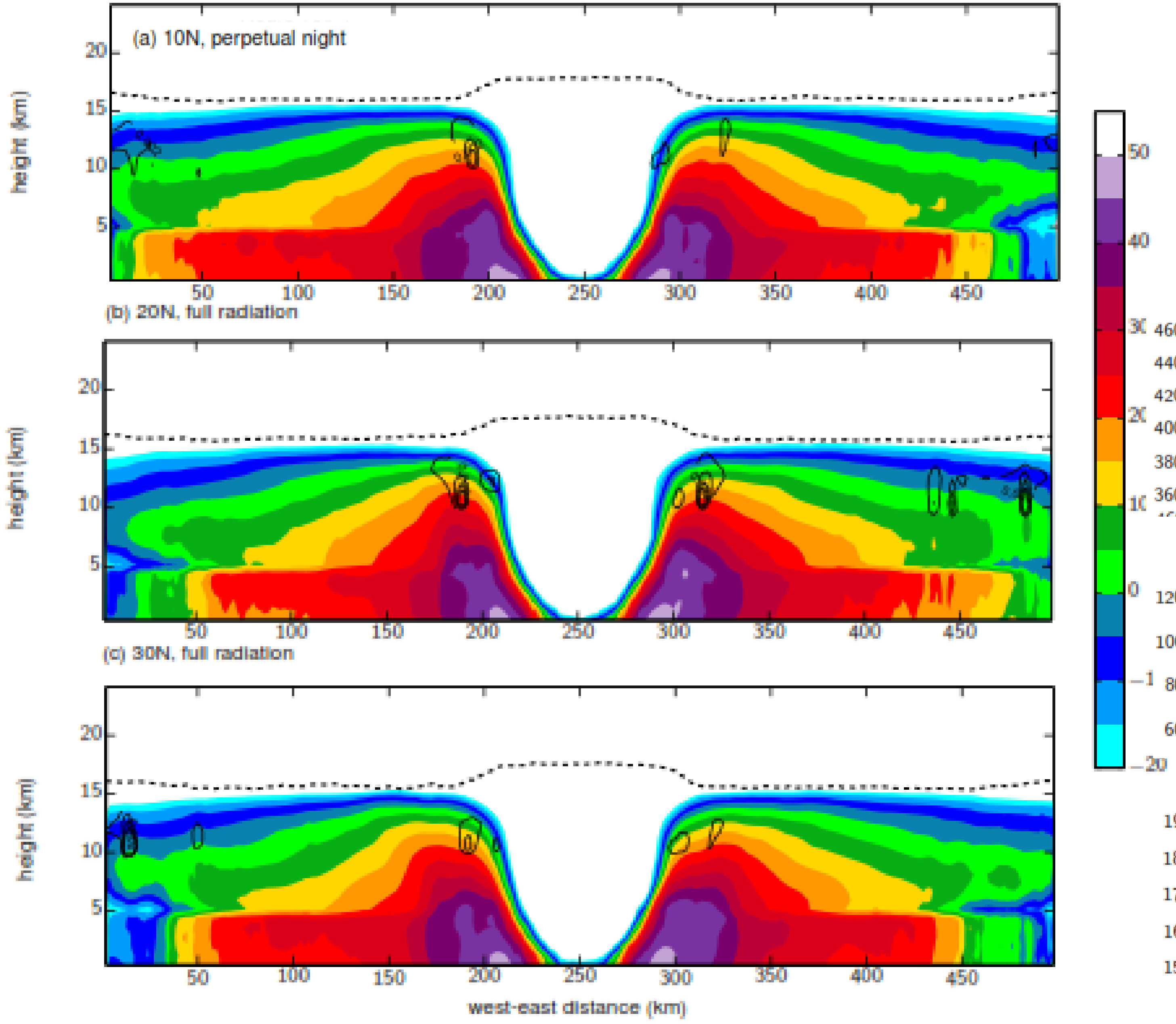


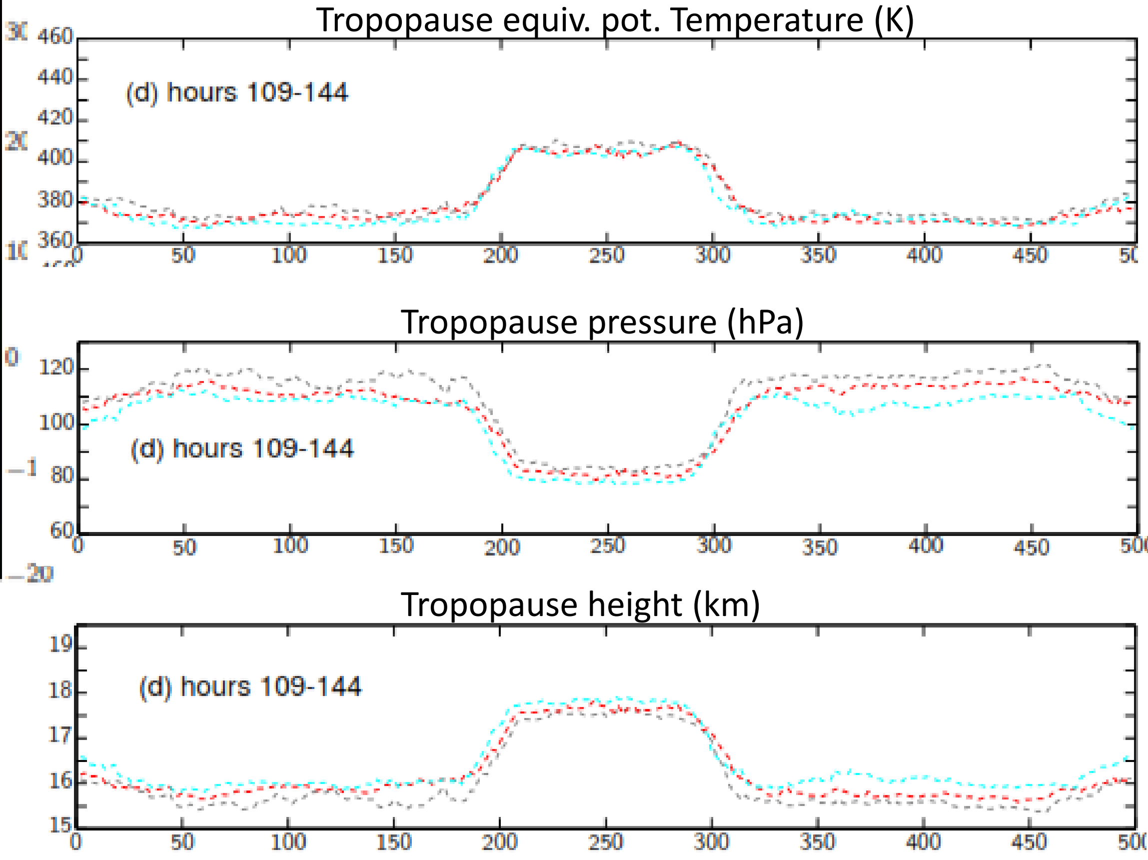
Tropopause pressure (hPa)

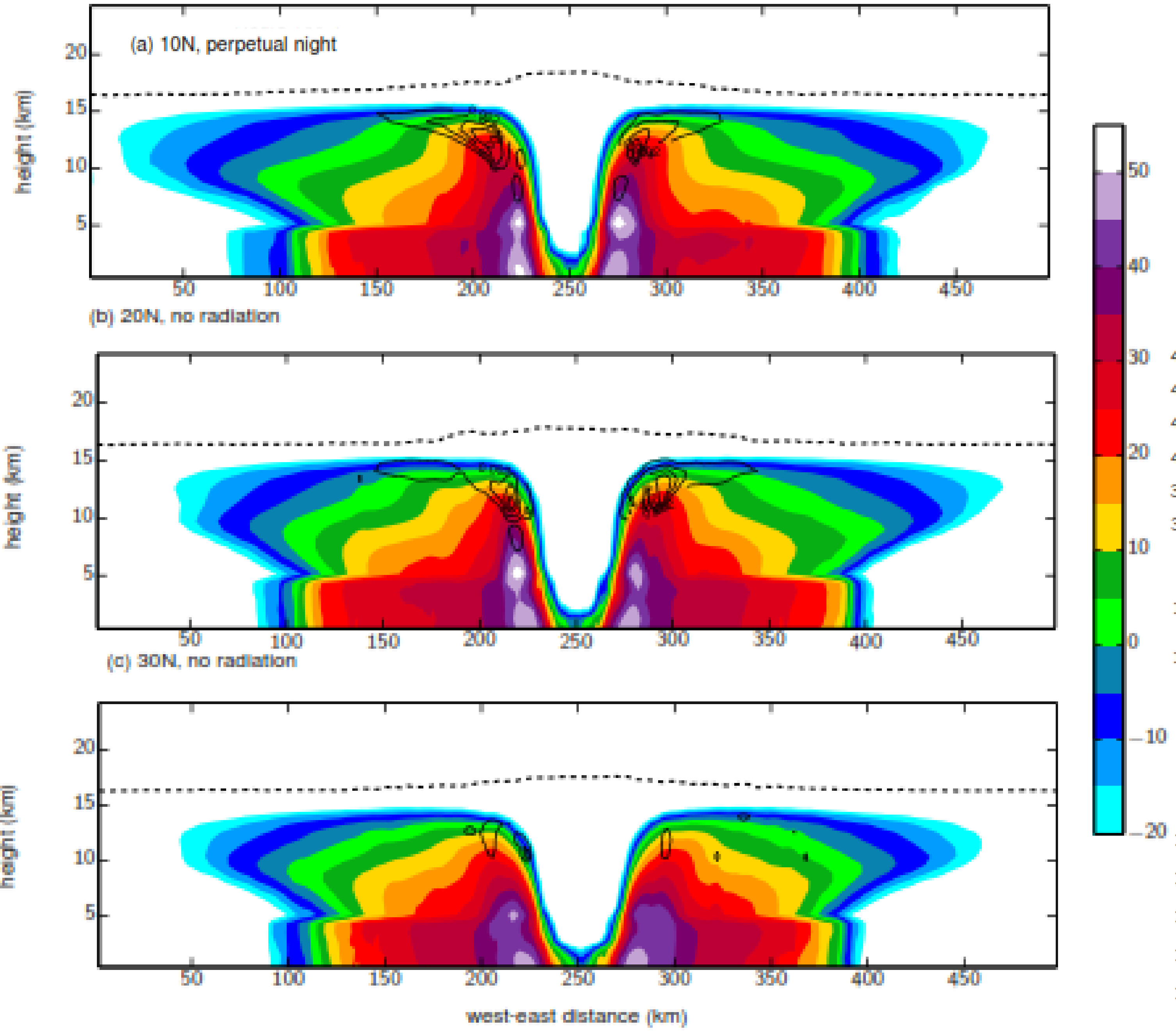


FULL RADIATION

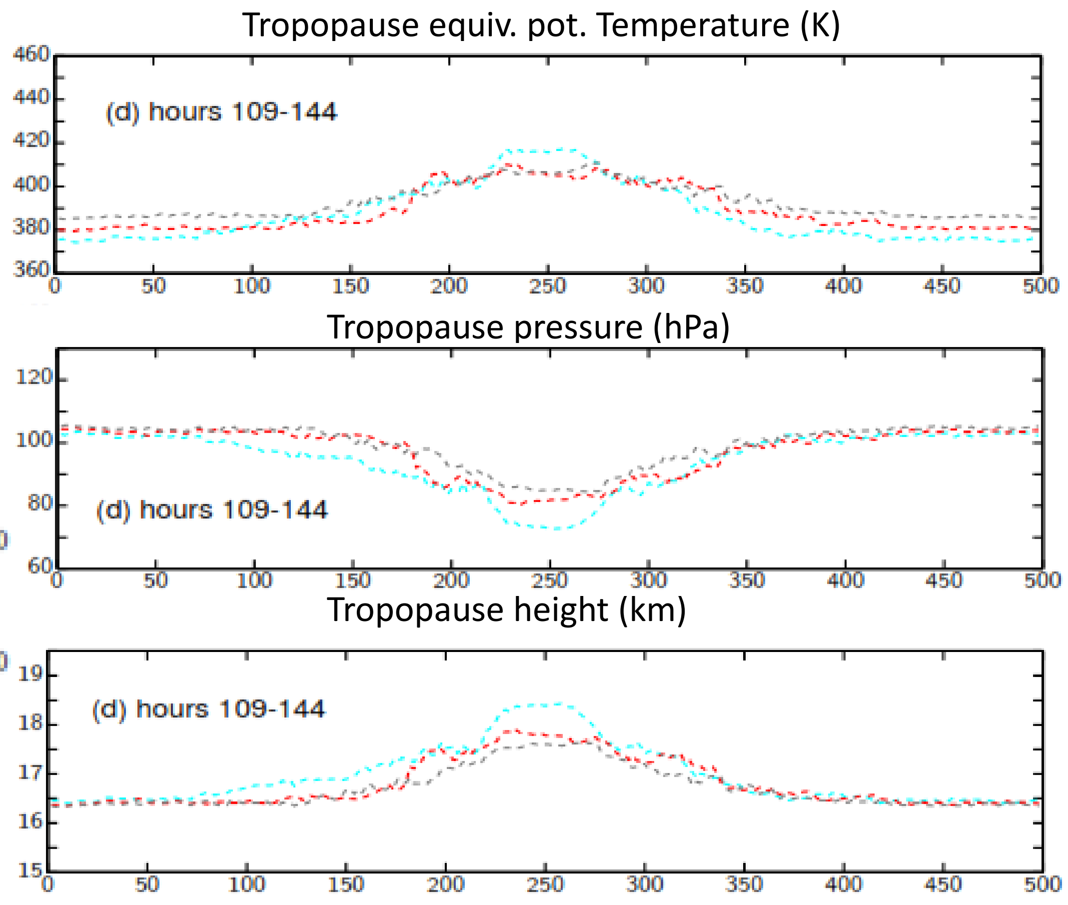
Time-mean reflectivity (shading, dBZ), cloud ice mixing ratio (contours), and cold-point tropopause height (dashed) for hours 109-144







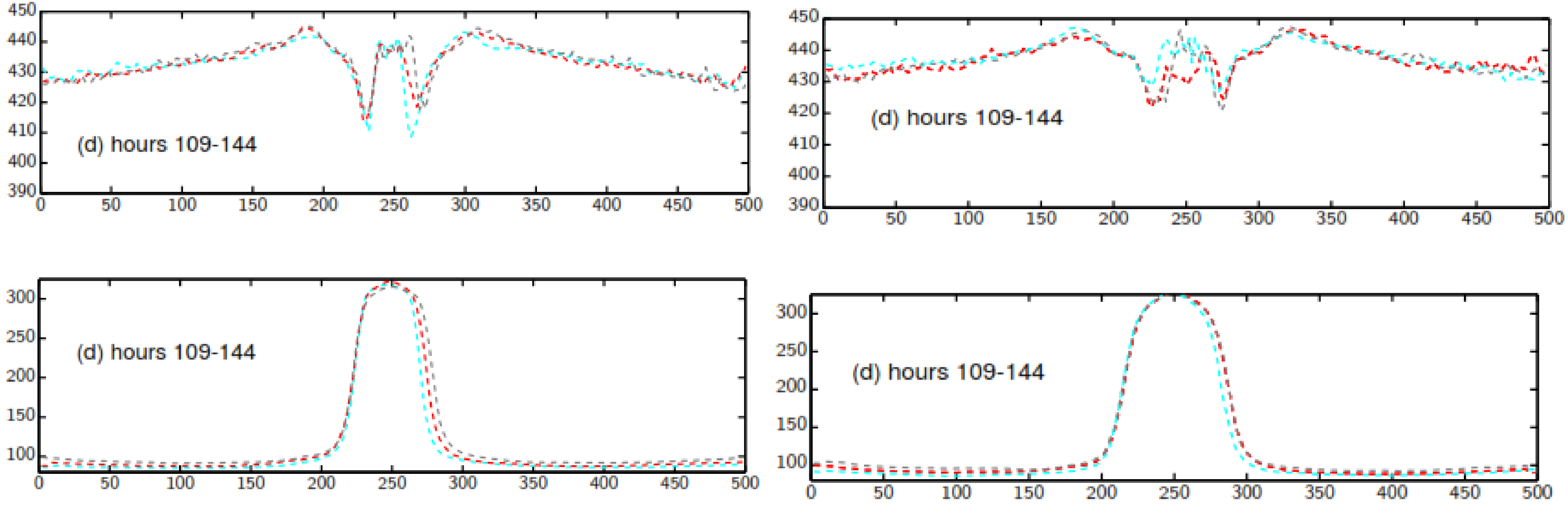
NO RADIATION
Time-mean reflectivity (shading, dBZ),
cloud ice mixing ratio (contours),
and cold-point tropopause height (dashed)
for hours 109-144



Longwave Radiation

PERPETUAL NIGHT

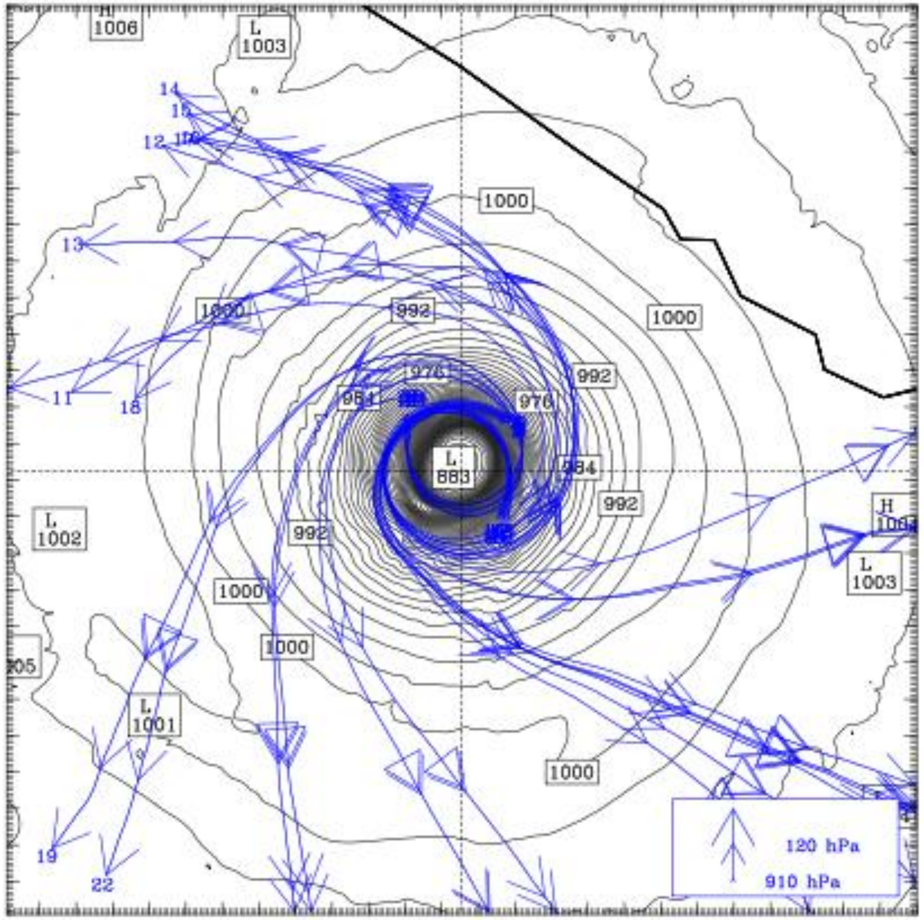
FULL RADIATION

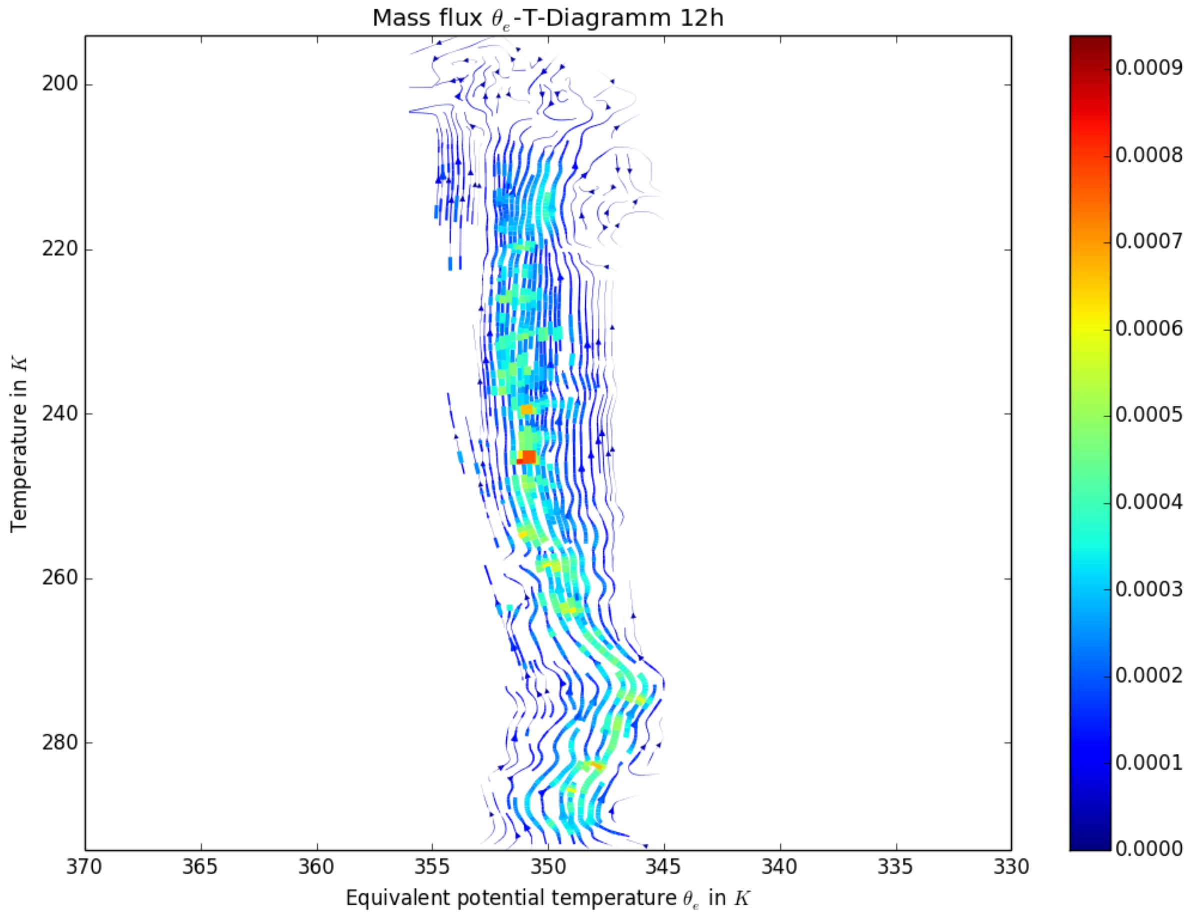


Downwelling (W m-2)

Outgoing (W m-2)

Trajectory Analysis – 1 min output for 12 hours!





Conclusions

- Both tropopause temperature and radiation play a role in the **intensity** and **intensification rate** of ideal TCs on weather timescales
- For all experiments, the TC tropopause is elevated above the eye and shows inner warm core
  - Taller but colder eye for colder initial tropopause leading to a more intense storm
  - **Wider, more intense storm** with longwave radiation (perpetual night) vs. no radiation
    - Wider storm with full radiation as well
  - More separation between tropopause experiments in perpetual night

Future Work

- High temporal resolution subsets will allow more **trajectory analysis**
  - Identification of outflow layer and its relationship to tropopause
  - Thermodynamic processes
- **Ensembles** will allow more general conclusions
  - Found variability when running on different cluster architectures and model configurations
- **Collaboration welcome!** This is meant to provide an idealized basis for comparing to **TCI observations** of TC tropopause and connection to intensity