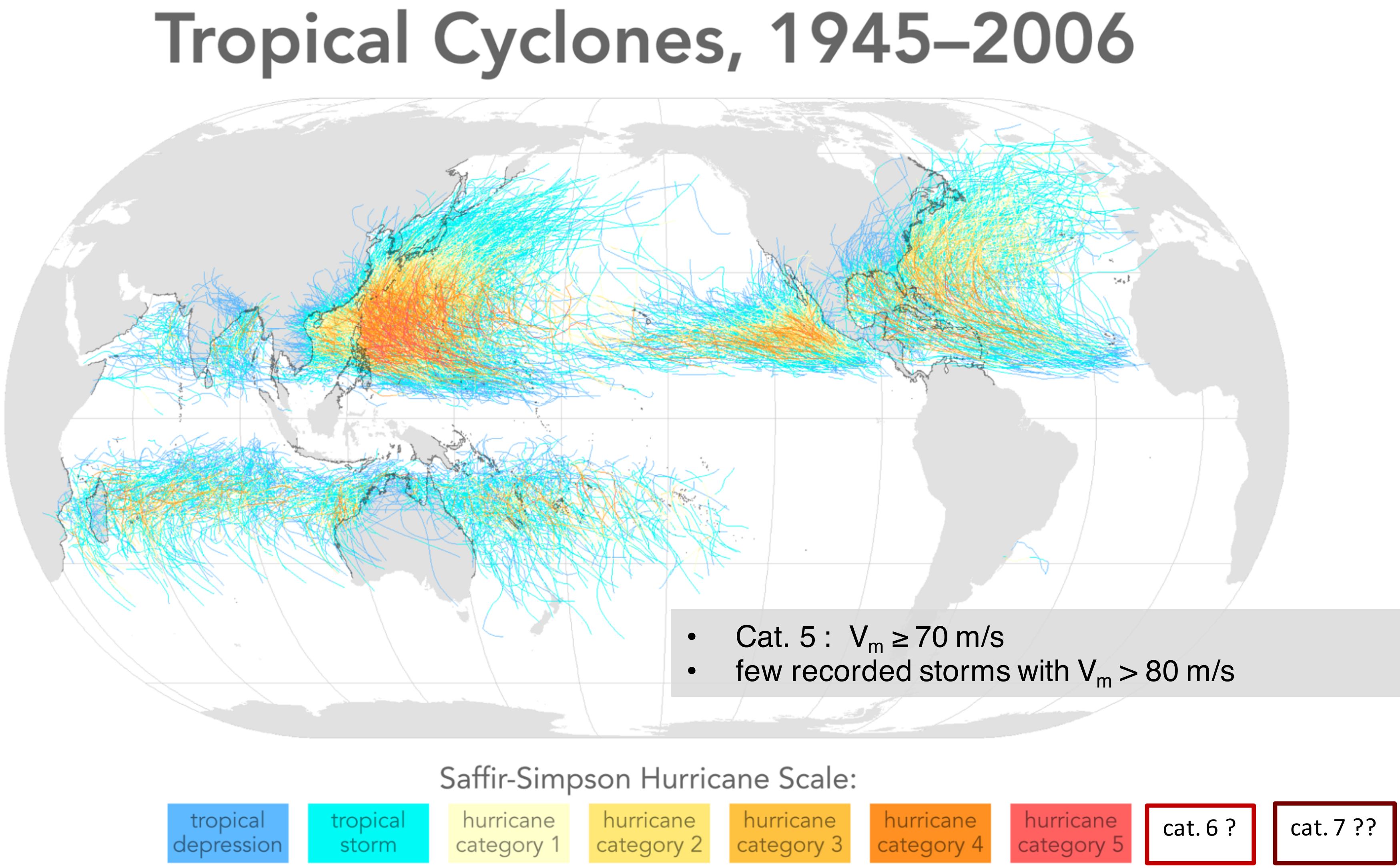
Outline

- Motivation
- Research hypotheses
- Methods
- Results
- Concluding remarks

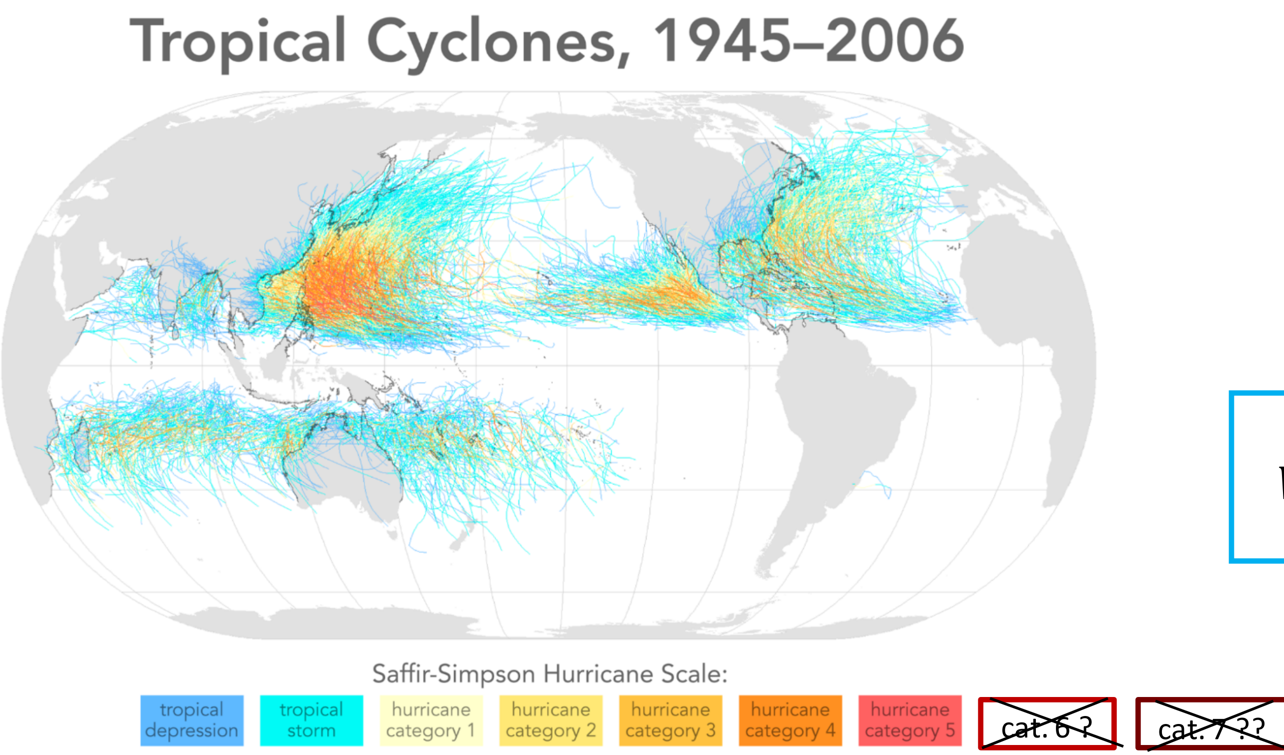
Motivation – TC global distribution



- Cat. 5 : $V_m \geq 70$ m/s
- few recorded storms with $V_m > 80$ m/s

Wikipedia user Citynoise,
JTWC and NOAA TC track data

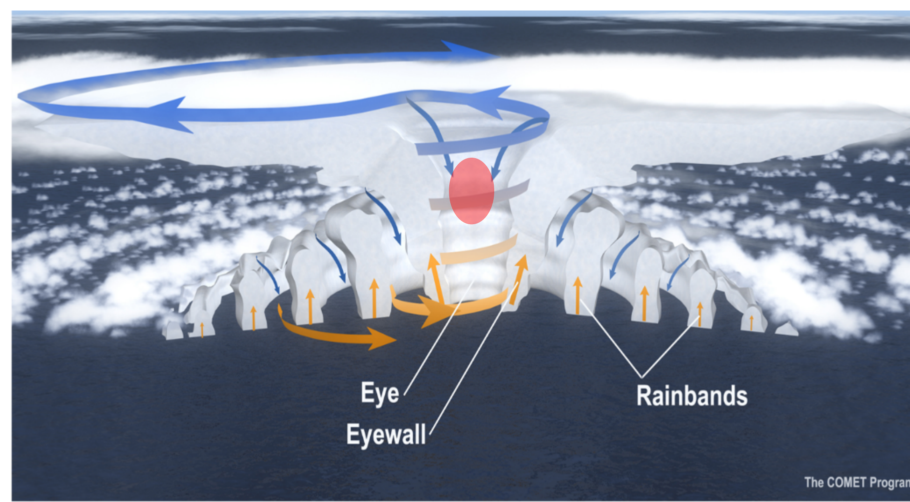
Motivation – potential intensity



MPI theory

$$V_m^2 = \frac{C_k}{C_d}\frac{(T_s - T_o)}{T_s}(k_s^* - k_a)$$

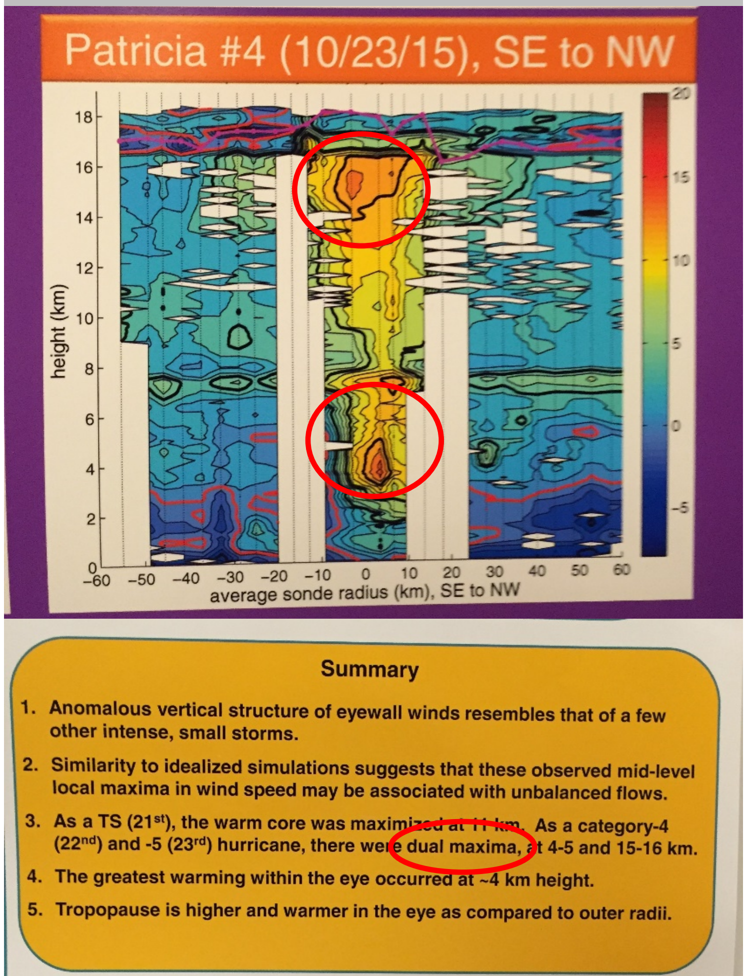
Emanuel (1986)



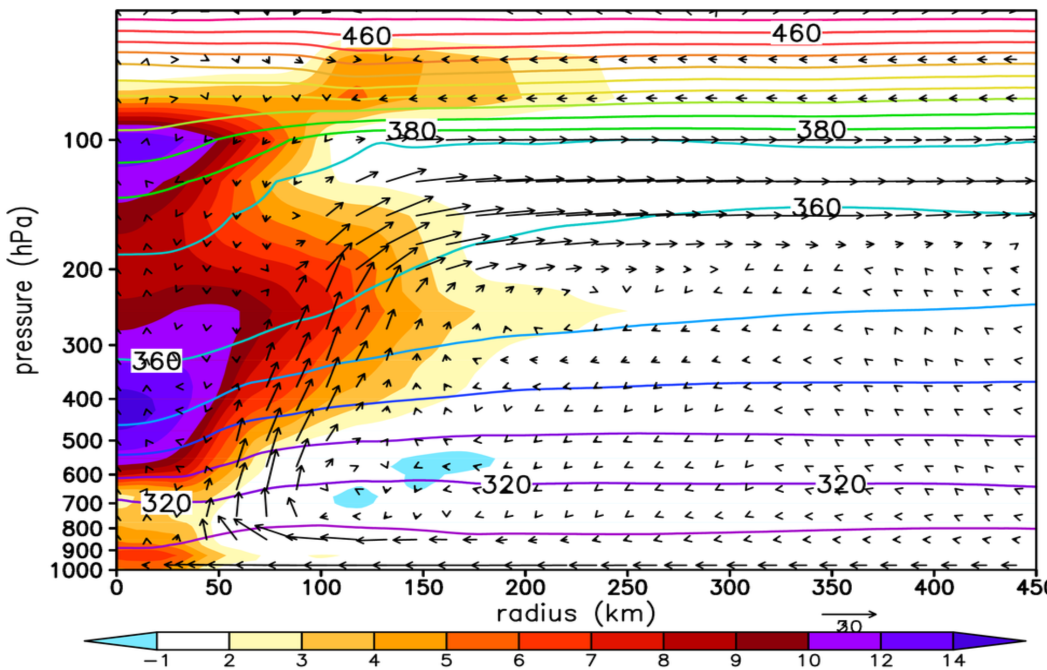
Motivation – double warm-core

Observation …

Daniel Stern et al 2016



Double warm core (DWC) also observed in **operational forecasts** of most super typhoons (cat. 4-5) in 2012-2014



Radius-height cross section of temperature anomaly (shaded) from a real-time forecasting of Super Typhoon Francisco (2013) using the HWRF in the Western Pacific (WPAC) basin [Tallapragada and Kieu 2014]

Research questions

Questions

- What are the effects of tropopause height on DWC development?
- What about stratification (N^2) of the lower stratosphere?
- Are the effects the same among different TC basins?

Hypothesis

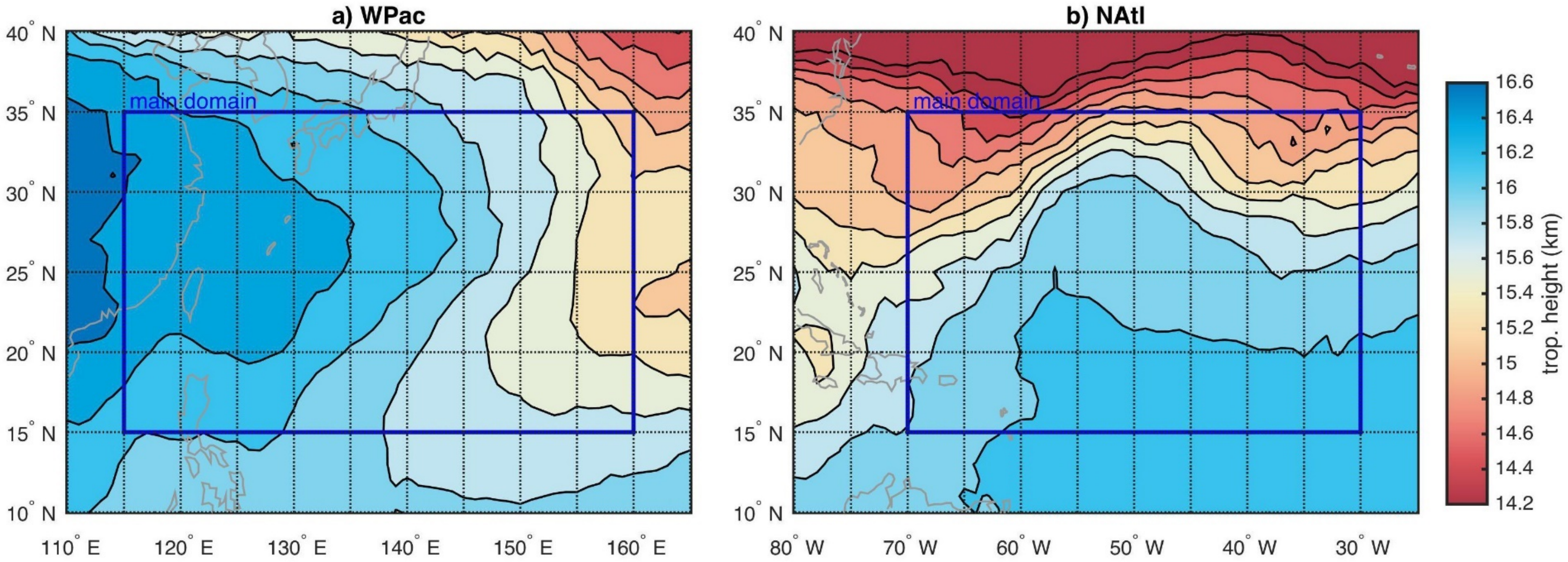
Tropopause height and lower stratosphere stratification play a role in development of DWC structure and subsequent intensity development due to their effects on upper-level inflow

- lower tropopause height → more intense storm
- lower N^2 in LS region (less stable) → more intense storm

Experiment design

Hurricane Weather Research and Forecasting model (HWRF)

- idealized, f-plane, constant SST = 302 K
- 900 m resolution in central domain



NCEP FNL operational global analysis data

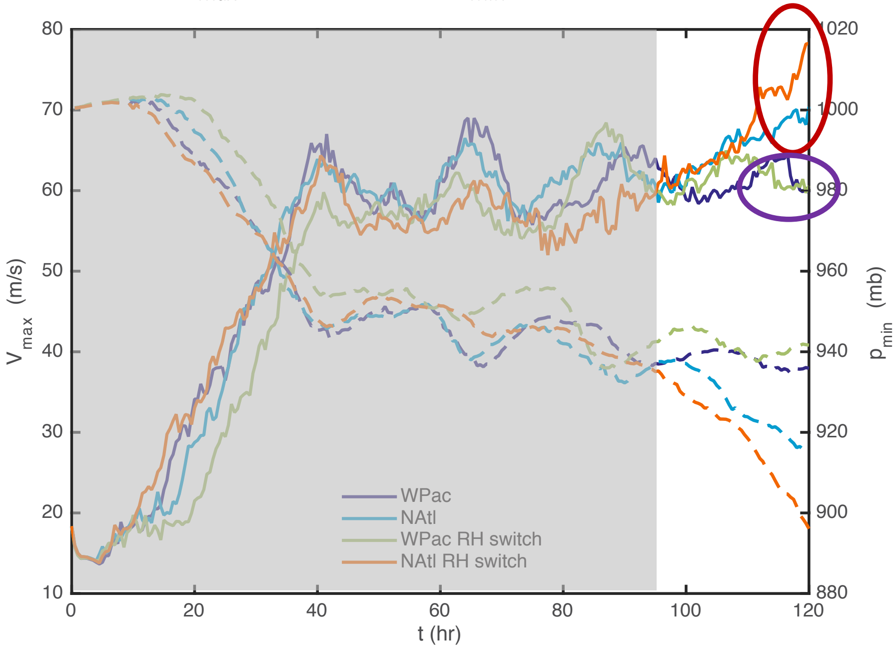
Initialization: August 2013 average soundings

- Western Pacific & North Atlantic tropical cyclone basins (main domain regions)
- Mean temperature & relative humidity profiles in 2 basins → 4 experiments

Results – control exp

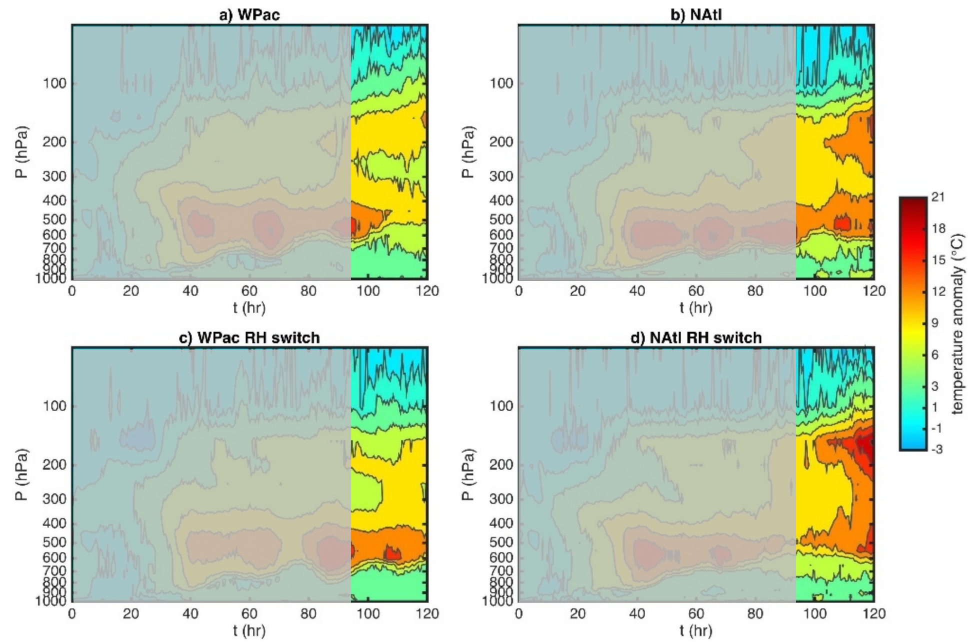
time series

solid: V_{max} dashed: p_{min}



Hovmöller diagrams

vertical temperature anomaly profile at center of storm

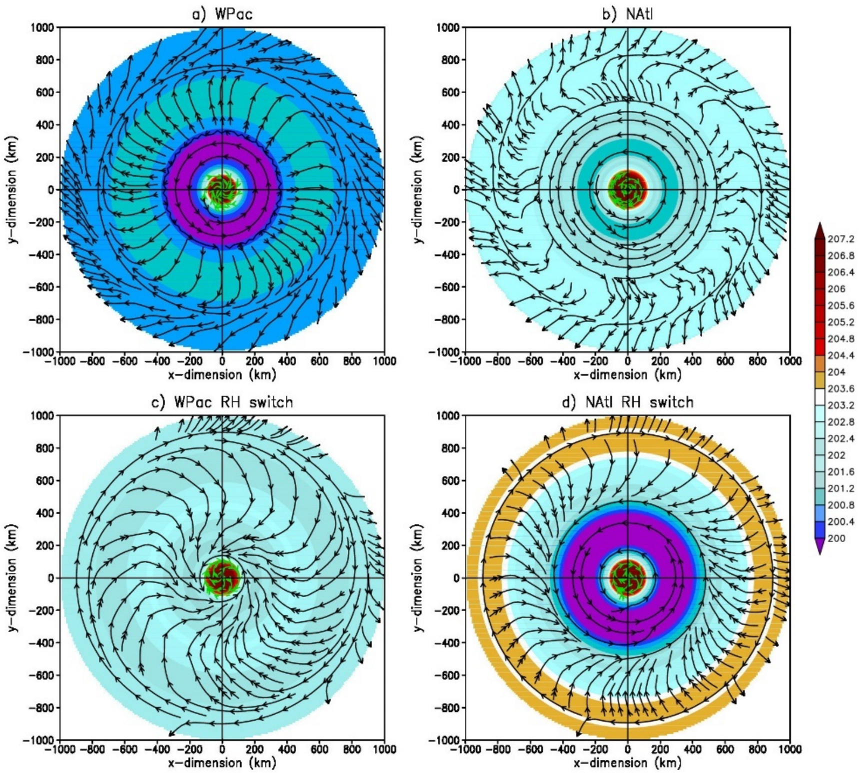


- NAtl storms tend to be stronger than WPac storms (consistent with hypothesis)
- Switching moisture profiles between the NAtl and WPac experiments still captures more intense at maturity in the NAtl basin → temperature profile is controlling/limiting

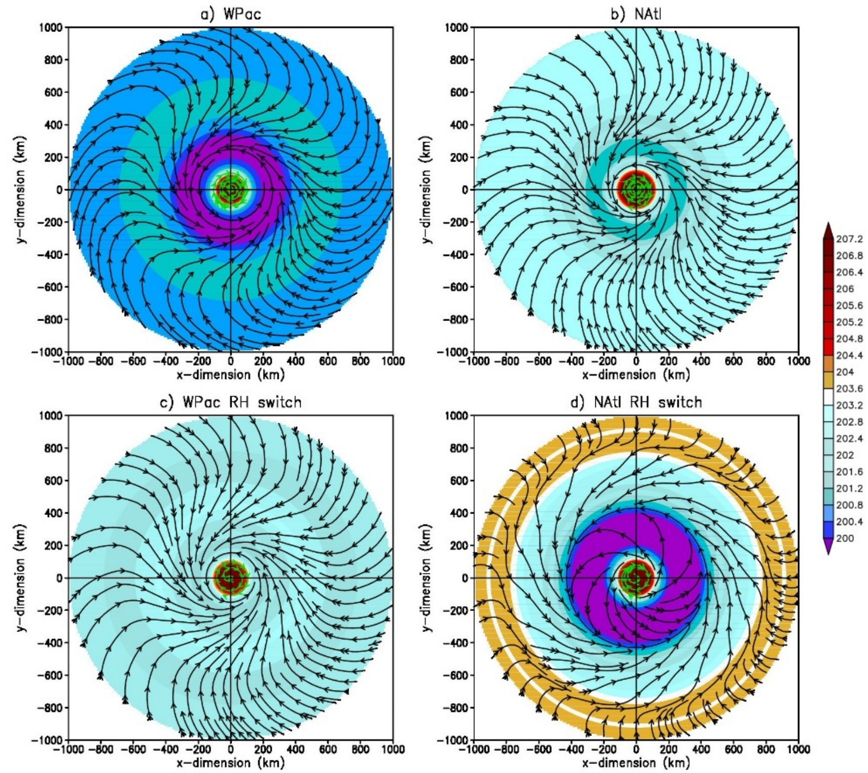
Results – control exp

upper-level inflow

- all show inflow in at least 1 of the 2 layers



70 to 50 mb

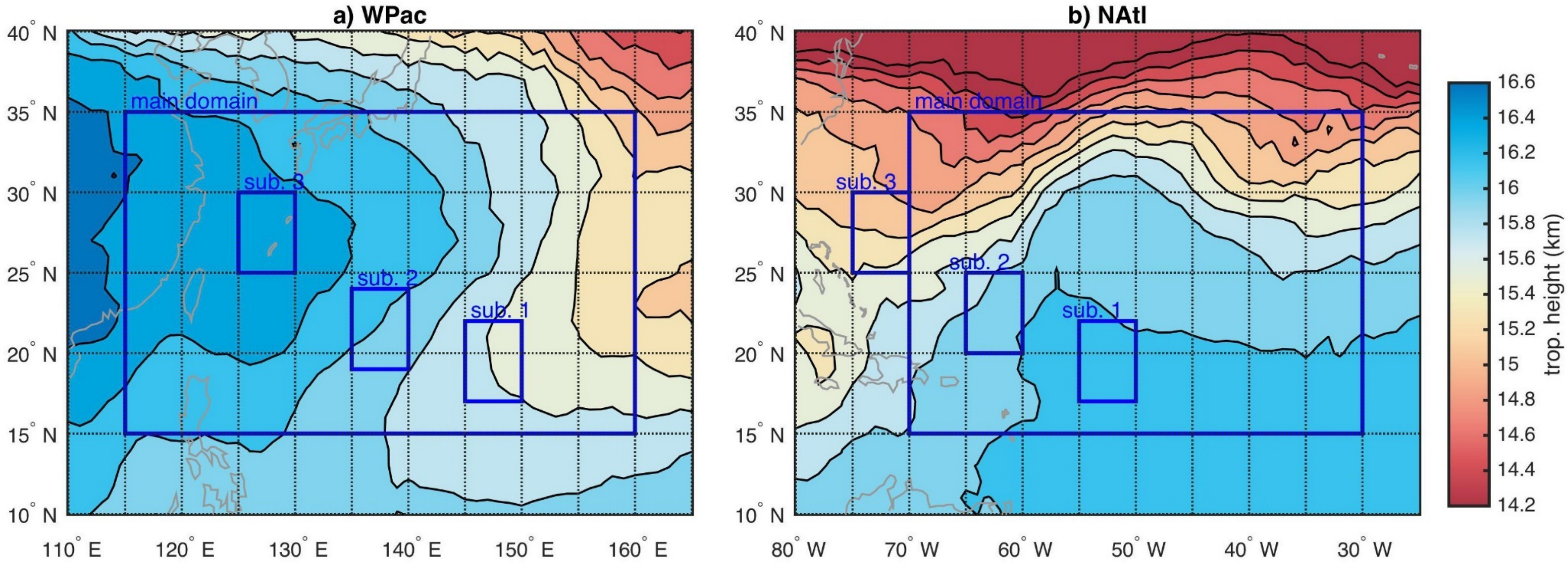


100 to 75 mb

streamlines: average flow (at 5 days)
shading: tropopause temperature (K)

Experiment design – sensitivity exp

Given the more important role of the temperature profiles in determining TC intensity, how does the tropopause height impact TC intensity?



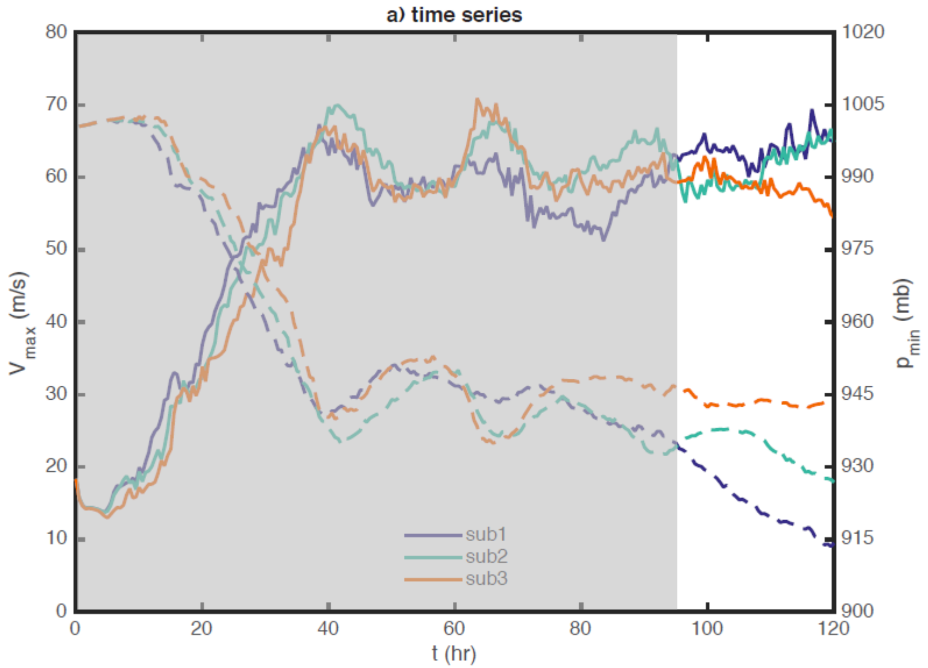
Tropopause height increases towards coastline

Tropopause height decreases towards coastline

note: moisture profile fixed

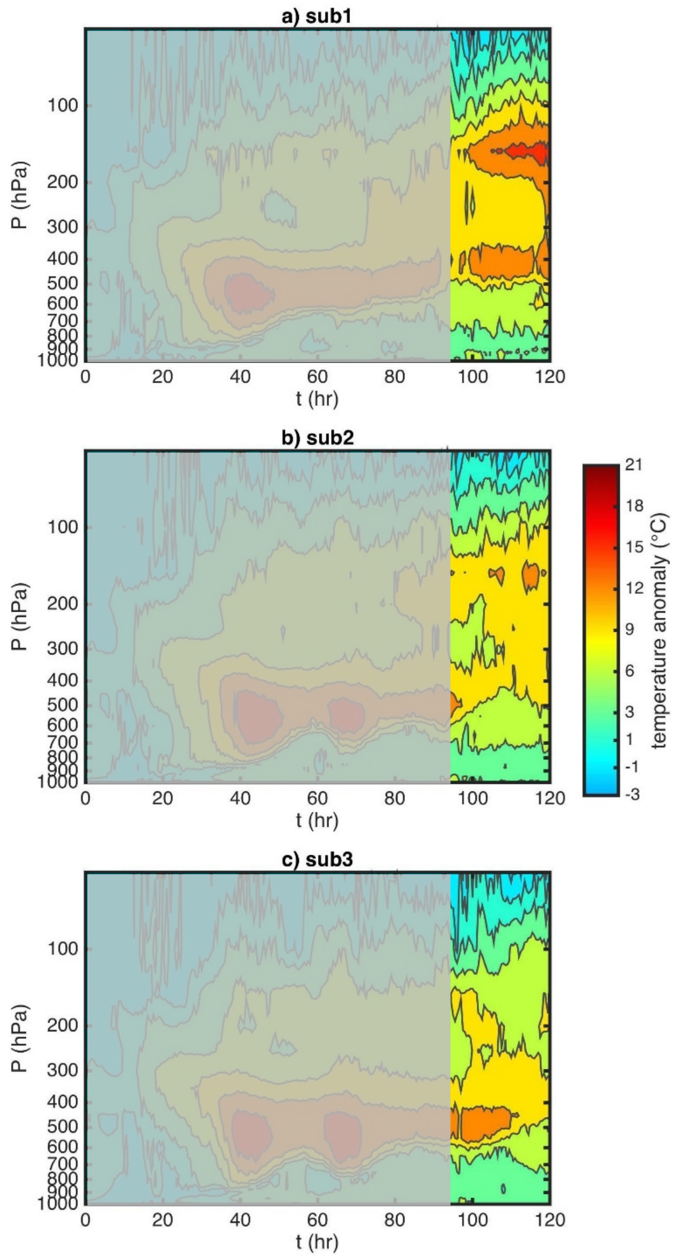
Results – sensitivity exp

WPac subdomains



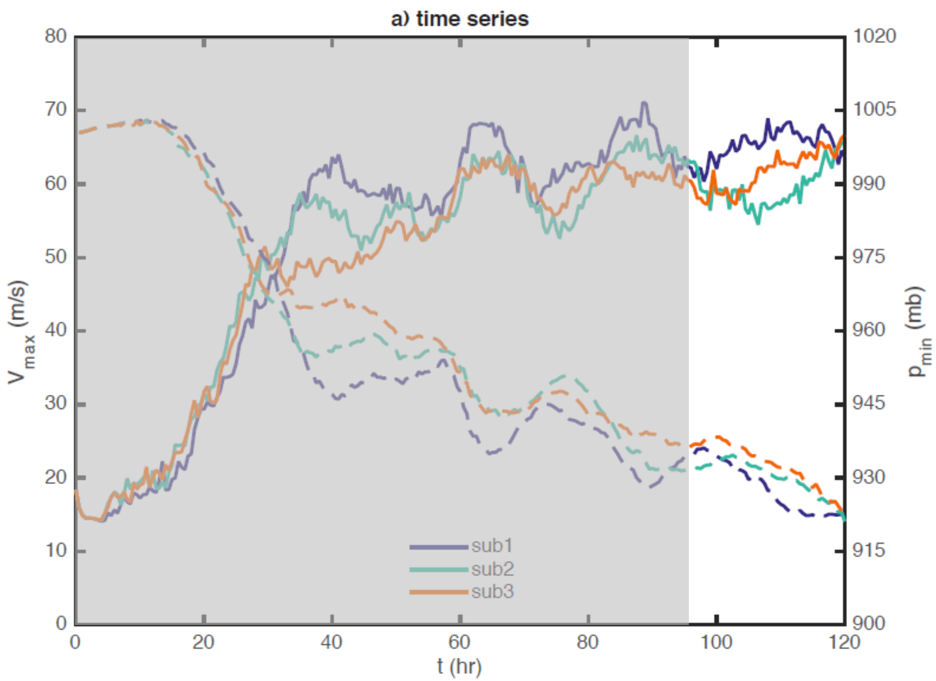
- trop. h: sub1 < sub2 < sub3
- intensity: sub1 > sub2 > sub3

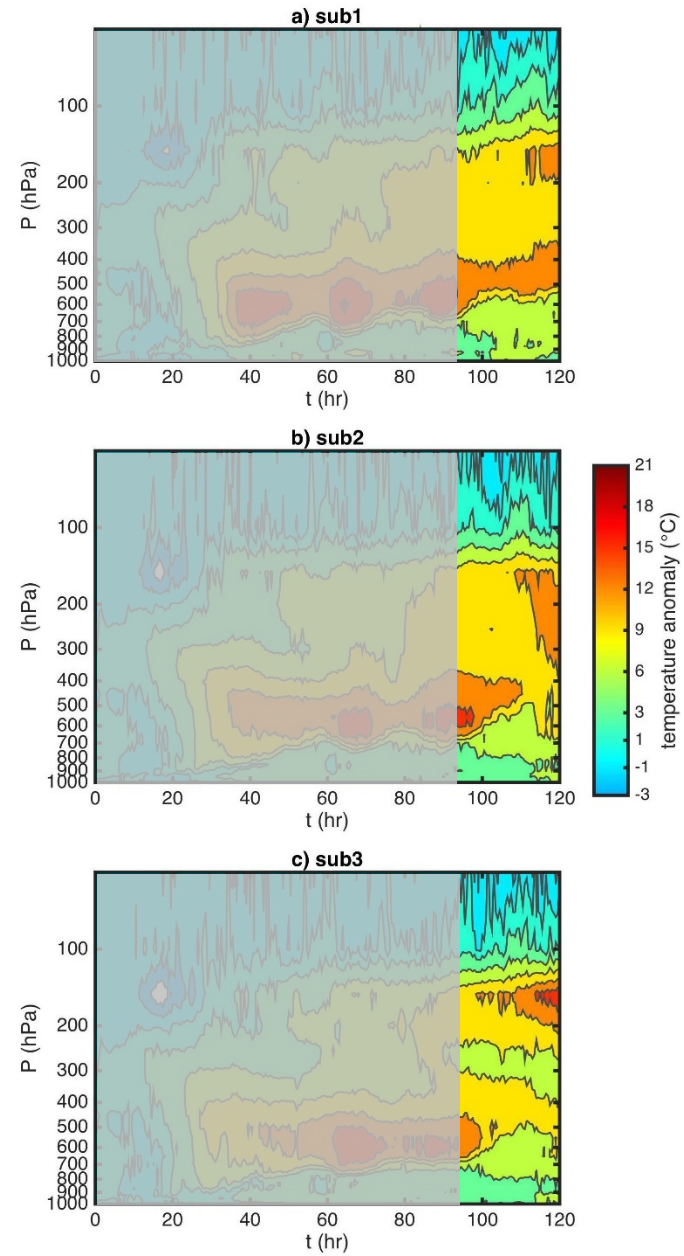
The lower the tropopause, the stronger the storm, as in the hypothesis



Results – sensitivity exp

NAtl subdomains





- trop. h: sub3 < sub2 < sub1
- intensity: sub1 > sub3 > sub2

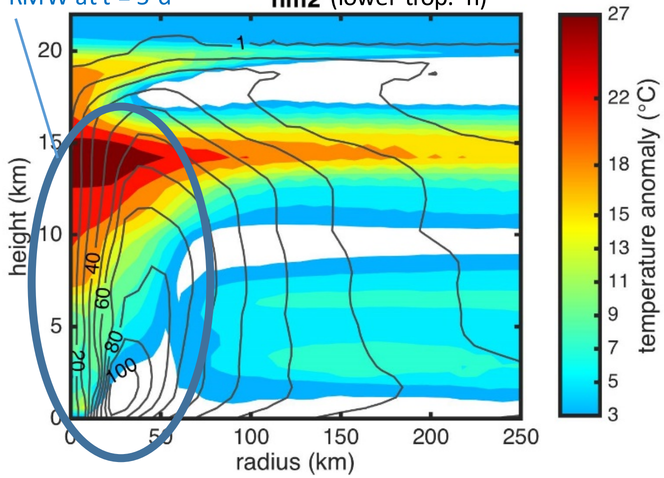
No clear signal of the lower the tropopause, the stronger the storm
(i.e., no support for hypothesis)

Axisymmetrical model results

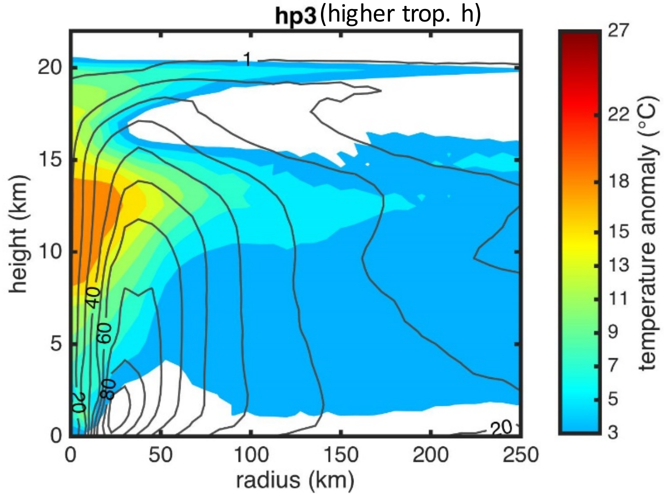
tropopause height experiments
- same N^2 but different trop. height

more prominent upper-level warm core and larger V_m and the RMW at t = 5 d

hm2 (lower trop. h)

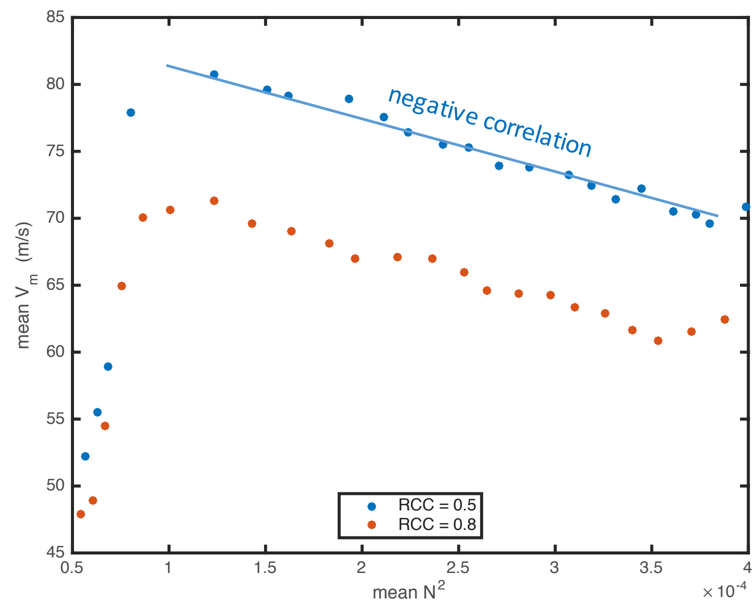


hp3 (higher trop. h)



Rotunno and Emanuel (1987) model
- to verify that DWC is seen in other models
- more flexible: easy to focus in on the 2 LS region effects in turn

lower stratosphere experiments:
- same trop. height but changing lower stratosphere N^2
- the chosen radiative cooling cap (RCC) values lead to quasi-stable intensity state after ~15 days; 1000 day experiments



Concluding remarks

- Temperature vertical profile has more of an impact than RH, controlling for other factors.
- The tropopause height plays a noticeable role in development of DWC structure and accompanied intensity increase.
- Sensitivity to tropopause height is more realized in the WPac than in NAtl (for August 2013 average soundings).
- Negative correlation between lower stratosphere stability and storm intensity

So, tropopause characteristics definitely seem to be important and should be considered in intensity predictions for real, mature, intense (Cat. 3+) TCs.

- Future directions: other time periods, basins, …
- Looking for correlations in the historical record: Madison Ferrara (3C.7)

thank you!

Appendix – DWC formation

Why do we care about DWC?

- interesting, beyond traditional view of TC structure
- allows TCs to intensify beyond traditional theoretical limits (MPI)

How does DWC form?

- One hypothesis (Kieu et al. 2016, in review):
    1. formation of upper-level cold annulus from radiative cooling
    2. inward pointing pressure gradient (far environment warm relative to cold annulus)
    3. development of upper-level inflow in lower stratosphere
    4. advection of potential warm air from stratosphere
    5. building of upper-level warm core

This pathway is more favorable with a lower tropopause and lower lower stratosphere stratification (N^2)

Appendix – Experiment design

IU HPC Big Red II

1 experiment:

- 5 days simulation time, 24 hr wall time
- 20 nodes, 32 ppn = 640 processors
- output: ~ 1 TB
- post-processing → +100 GB

A total of 24 experiments requires a storage on Data Capacitor II (available 3.5 PB)