How Much Do Tropical Cyclones Grow in Size During Extratropical Transition?

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1. Introduction

Motivation

- Approximately half of North Atlantic (NA; Hart and Evans 2001) and western North Pacific (WNP; Kitabatake 2011) tropical cyclones (TCs) undergo extratropical transition;
- Prior work has suggested that NA outer region TC size increases by, on average, ~20% during extratropical transition (Hart et al. 2006);
- Greater understanding of outer region TC size during extratropical transition is important in assessing TC structure changes and their hazards and risks.

Objective

Determine whether outer region TC size grows larger during extratropical transition for NA and WNP TCs using reanalysis-derived TC size dataset.

2. Methodology

Datasets

- NA and WNP TCs (max 10-m wind ≥ 34 kt) over ocean during 1979–2010 in IBTrACS (Knapp et al. 2010) are examined;
- TC wind field is obtained from 6-h 0.5° NCEP CFSR (Saha et al. 2010).

Extratropical Transition Definition

- Extratropical transition in NCEP CFSR defined using cyclone phase space (Hart 2003):
  1. **Warm Core Prior to Extratropical Transition Start:** Lower-tropospheric warm core ($-V_T^L > 0$) for 48 hours prior to extratropical transition or from TC genesis to extratropical transition (whichever is shortest);
  2. **Extratropical Transition Start:** Lower-tropospheric thermal structure of TC becomes asymmetric (B >10) **and** lower-tropospheric TC structure remains warm core ($-V_T^L > 0$);
  3. **Extratropical Transition End:** Lower-tropospheric thermal structure of TC remains asymmetric (B >10) **and** lower-tropospheric TC structure becomes cold core ($-V_T^L < 0$).

Outer Region TC Size Definition

- **Outer region TC size metric: Radius of 8 m s^{-1} azimuthal-mean 10-m azimuthal wind (r_8);**
- Reanalysis r_8 defined according to Chavas and Vigh (2014):
  1. TC-centered grid constructed for 10-m wind vectors masking out grid points over land;
  2. Remove environmental wind from TC-centered wind vectors following Lin and Chavas (2012);
  3. Compute azimuthal wind field and calculate its azimuthal-mean;
  4. Interpolate azimuthal-mean azimuthal wind profile to 0.5 times reanalysis grid spacing masking out radii with insufficient data;
  5. Extract r_8 from radial profile of azimuthal-mean azimuthal wind;
- **Only TCs with continuously defined r_8 before and during extratropical transition in NA (N=39; 36% of ET cases in CFSR) and WNP (N=60; 46% of ET cases in CFSR) are analyzed.**

3. Results: TC Track and Location of Extratropical Transition

Overview

Analysis of track and location of extratropical transition start and end for TCs in present study.

Synopsis

1. Extratropical transition TCs in this study have variety of tracks in both basins (Fig. 1);
2. Latitude of start and end of extratropical transition for WNP TCs (Fig. 1b) are generally equatorward of NA TCs (Fig. 1a).

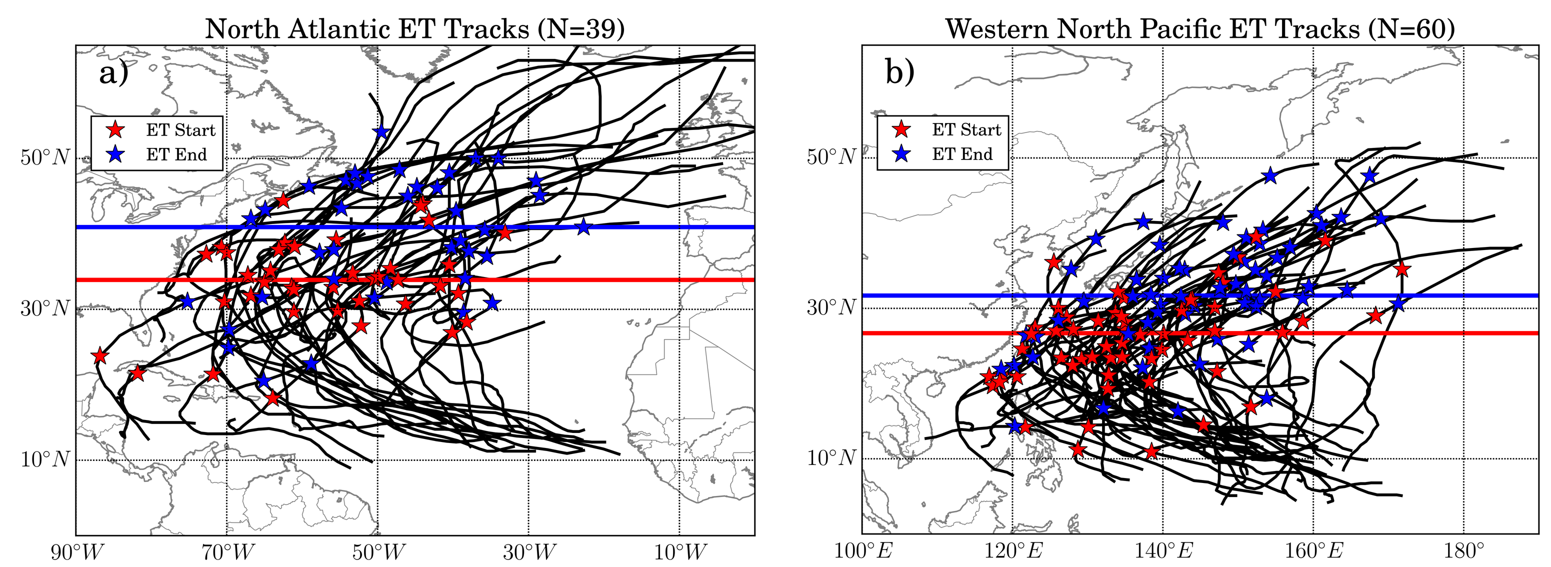

Fig. 1: Track and locations of extratropical transition start and end for (a) NA TCs and (b) WNP TCs examined in this study. The median latitude of extratropical transition start and end are denoted by the red and blue lines, respectively.

4. Results: Evolution of r_8 Before and During Extratropical Transition

Overview

Examination of changes in r_8 distributions before and during extratropical transition in NA and WNP.

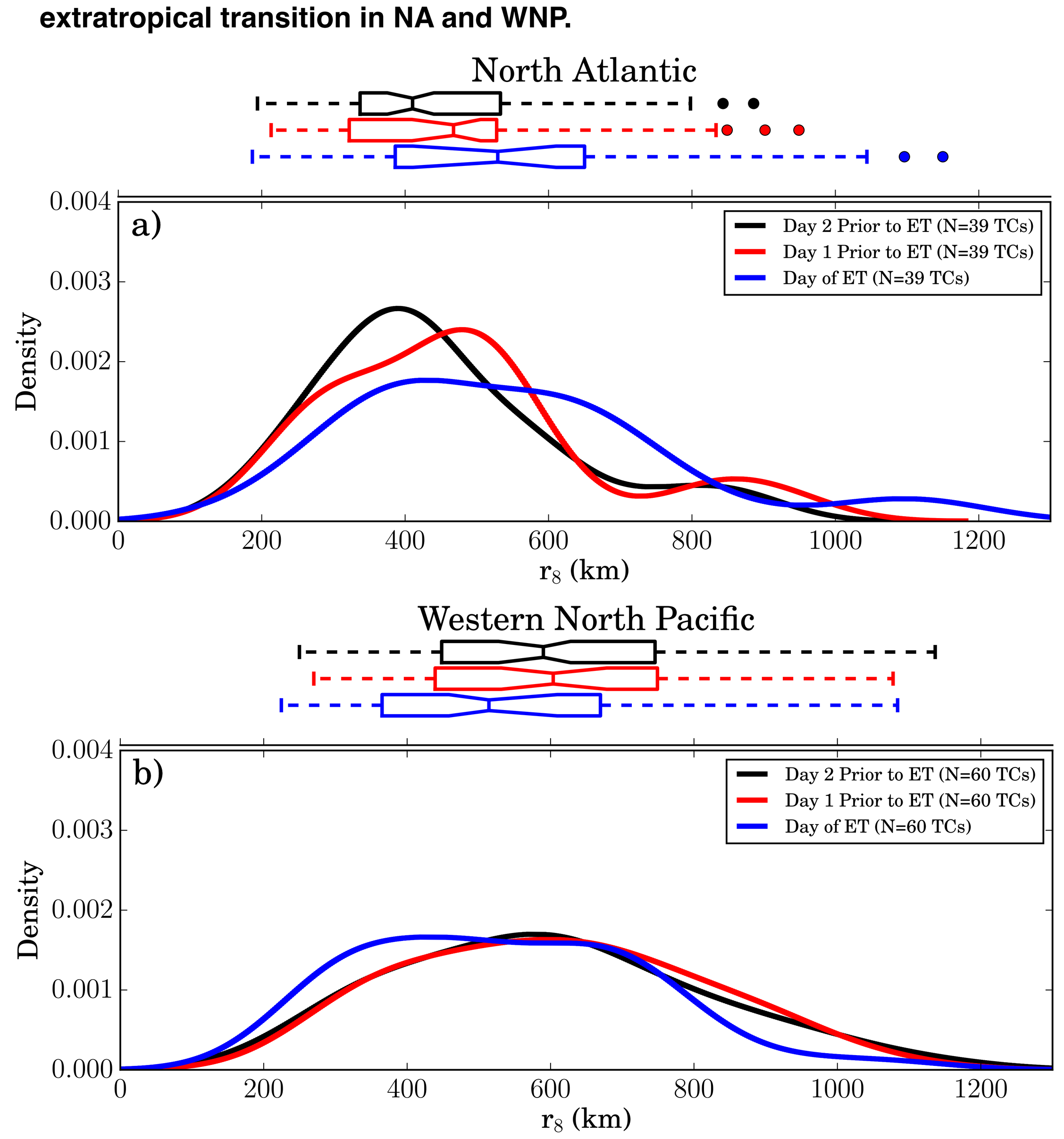

Fig. 2: Box-and-whiskers and kernel density estimates of r_8 (km) at day 2 prior to extratropical transition, day 1 prior to extratropical transition, and during day of extratropical transition for (a) NA and (b) WNP TCs.

Synopsis

1. 69% of NA TCs grow in size during 1—2 days prior to extratropical transition (Fig. 2a);
2. 82% of NA TCs more strongly expand in size during extratropical transition compared to 1—2 days prior to extratropical transition (Fig. 2a);
3. WNP TCs exhibit minimal size change prior to extratropical transition (Fig. 2b);
4. 65% of WNP TCs decrease in size during extratropical transition (Fig. 2b).

6. Results: Case-to-Case Variability in Changes to r_8 During Extratropical Transition

Overview

Examine case-to-case variability in both maximum r_8 and rate of change in r_8 during extratropical transition through comparison with pre-extratropical transition values.

Synopsis

1. 40% of NA TCs grow in size by 25% or more during extratropical transition, with several TCs doubling or tripling in size (Fig. 3a);
2. 15% of WNP TCs grow in size by 25% or more during extratropical transition, with majority of TCs decreasing in size during extratropical transition (Fig. 3b);
3. 69% of NA TCs grow more quickly in size during extratropical transition compared to before extratropical transition (Fig. 4a), while 60% of WNP TCs grow in size more quickly prior to extratropical transition (Fig. 4b);
4. 60% of NA TCs during extratropical transition exhibit rate of change in size between 5–30 km (6 h)$^{-1}$ (Fig. 4a).

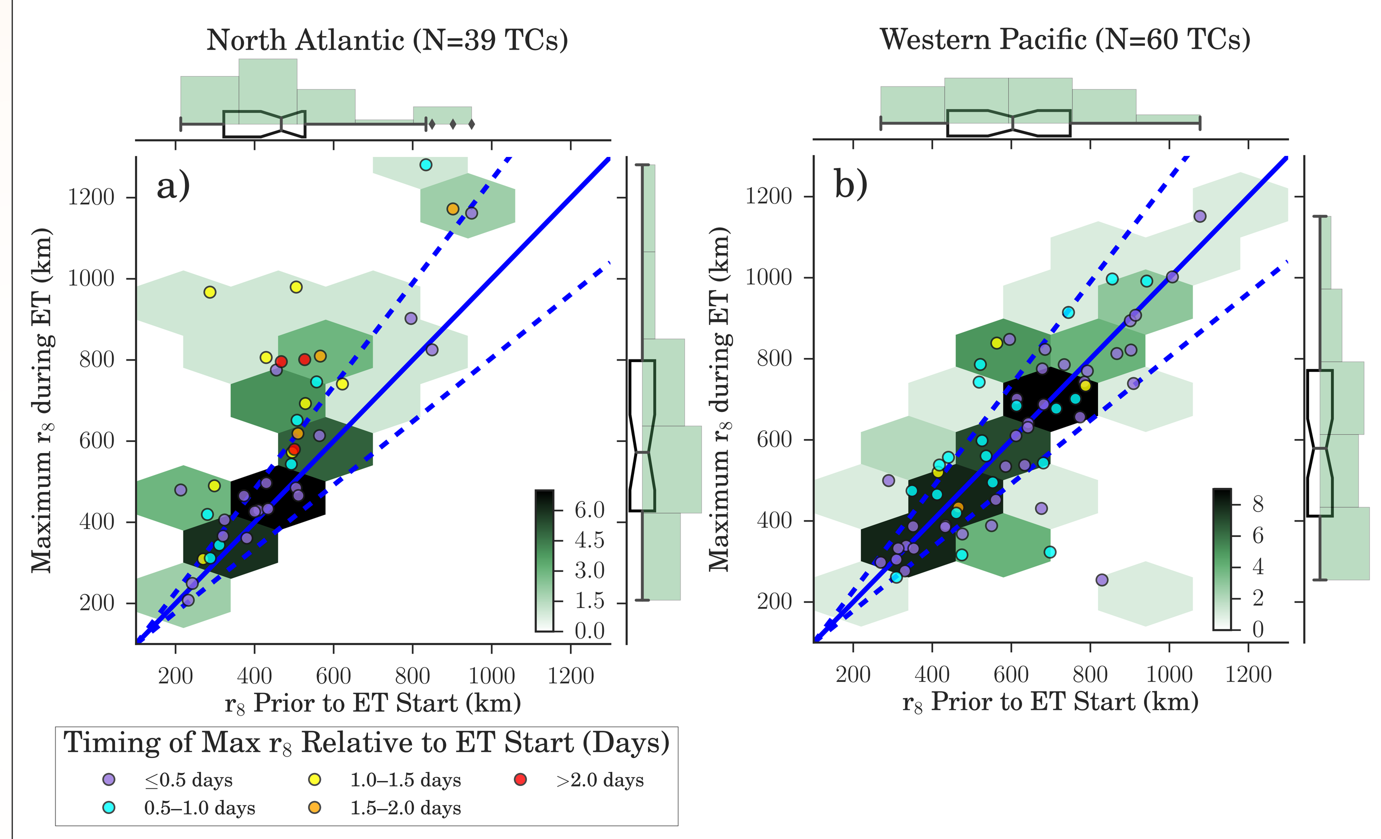

Fig. 3: Joint histograms (shaded hexagons) of r_8 prior to extratropical transition start (km) versus maximum r_8 during extratropical transition (km) for (a) NA and (b) WNP TCs. The dots indicate individual cases shaded according to time of maximum r_8 relative to extratropical transition start (days). The solid blue line indicates the line of no change in r_8, whereas the dashed lines indicate ±25% change in r_8.

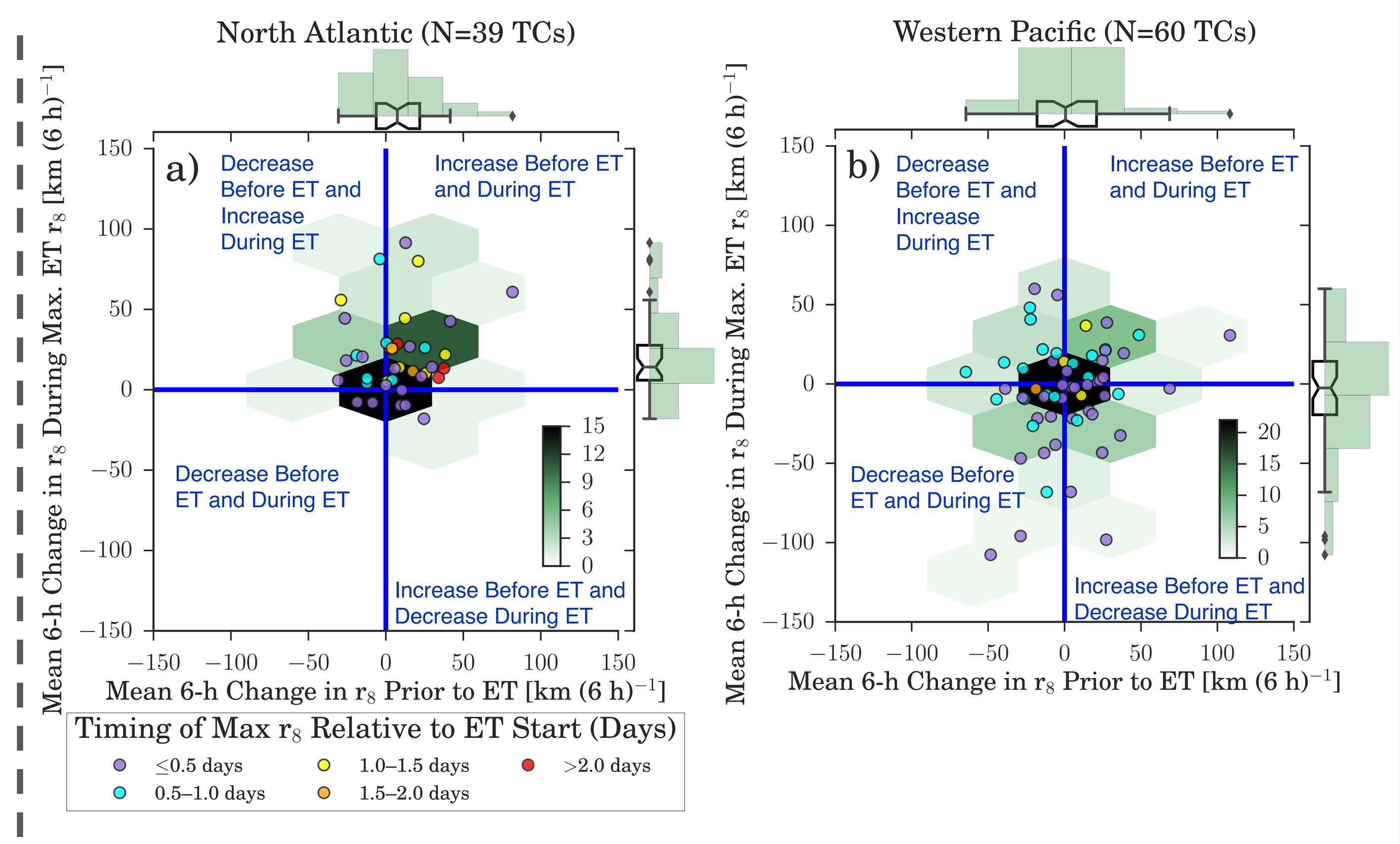

Fig. 4: Joint histograms (shaded hexagons) of rate of change in r_8 1–2 days prior to extratropical transition (km) versus rate of change in r_8 during extratropical transition (km) for (a) NA and (b) WNP TCs. The dots indicate individual cases shaded according to time of maximum r_8 relative to extratropical transition start (days). The solid blue lines demarcate no change in r_8 for each respective variable.

6. Results: Comparison of r_8 for Poleward-Moving ET and Non-ET TCs

Overview

Compare r_8 distributions for poleward-moving extratropically transitioning TCs and non-extratropically transitioning TCs to quantify importance of extratropical transition process versus changes in TC latitude.

Synopsis

1. 70% of non-extratropically transitioning NA TCs grow in size as they move poleward (Fig. 5a);
2. Growth in r_8 for non-extratropically transition TCs is relatively small compared to extratropically transitioning TCs (Fig. 5a);
3. Both WNP extratropically and non-extratropically transitioning TCs show little change in r_8 as TCs move poleward (Fig. 5b).

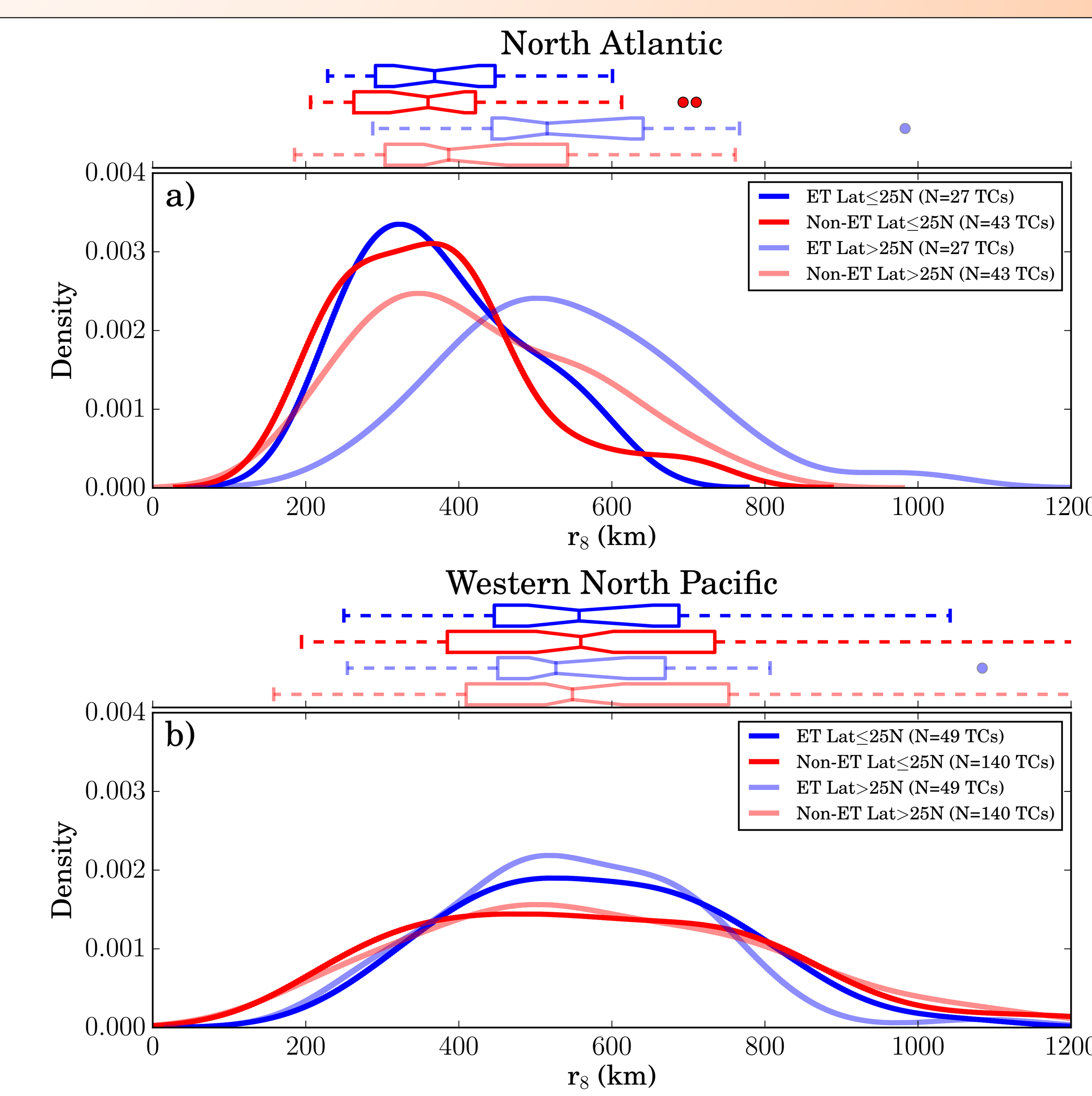

Fig. 5: As in Fig. 2, but for poleward-moving extratropically and non-extratropically transitioning TCs equatorward and polewards of 25N.

7. Summary and Discussion

- Majority of NA TCs increase in size before and during extratropical transition (Figs. 2a, 3a);
- Most NA TCs grow in size more quickly during extratropical transition than before ET (Fig. 4a);
- Majority of NA TCs grow in size between 5—30 km (6 h)$^{-1}$ during extratropical transition (Fig. 4a);
- Most WNP TCs decrease in size during extratropical transition (Figs. 2b–4b) potentially due to WNP TCs initially being larger in size prior to extratropical transition;
- Extratropical transition process more important than latitude change in growth of TC size for NA TCs (Fig. 5a).

8. Acknowledgments and References

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