Cold Pool and Vortex Characteristics in Idealized HSLC QLCSs

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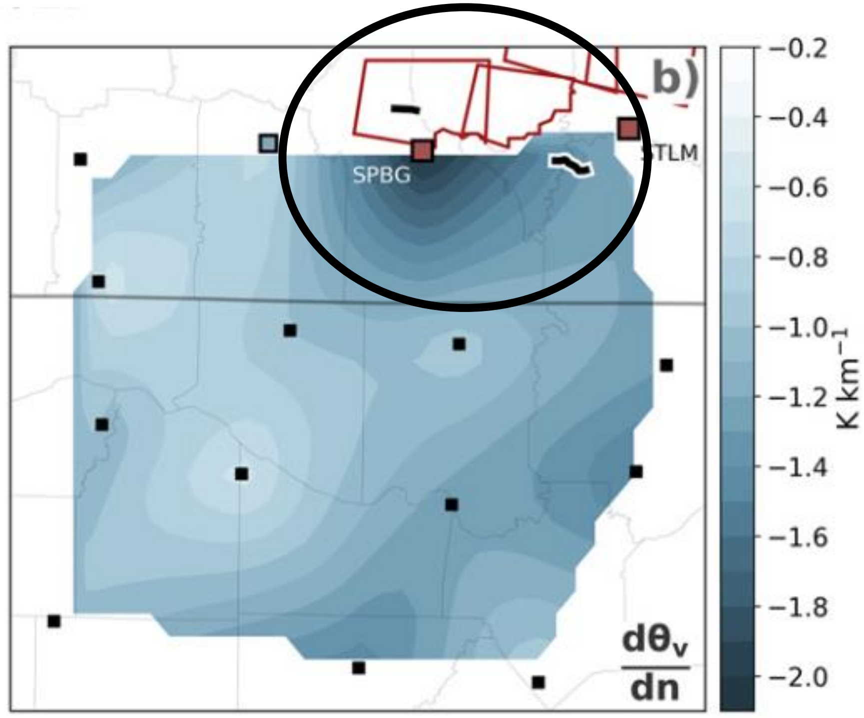
Motivation

- McDonald and Weiss (2021) found relatively stronger θ_v gradients near tornadoes in two QLCSs during VORTEX-SE
  - Further investigation of PERiLS data set found additional relationships between gradients and MVs
- Ostaszewski and Weiss (2023) continued this work
  - Found stronger gradients during/after QLCS tornadoes
- Baroclinically-generated vorticity mechanisms play a role in QLCS vortex development
  - Tilting of baroclinically generated vortex lines into the vertical by downdraft or updraft (Trapp and Weisman 2003, Wheatley and Trapp 2008, Atkins and St. Laurent 2009, Flournoy and Coniglio 2019, Parker et al. 2020)
- Outside of genesis mechanisms, baroclinity/density currents can also strengthen existing vortices
  - Lee and Wilhelmson 1997b, Marion and Trapp 2021, etc)



From Fig. 14 in McDonald and Weiss 2021

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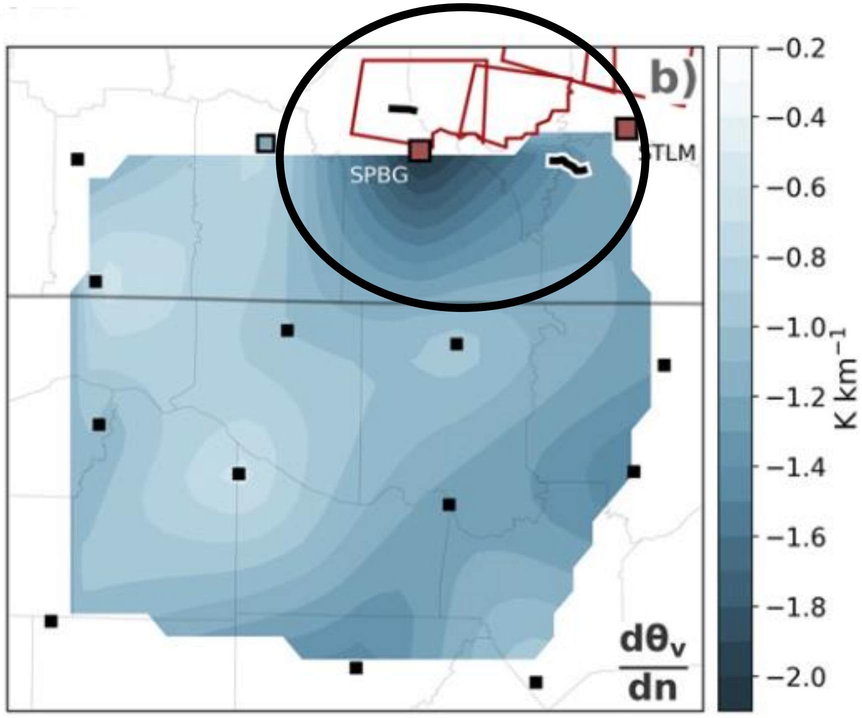
What role does baroclinic vorticity generation play in HSLC QLCS vortices?



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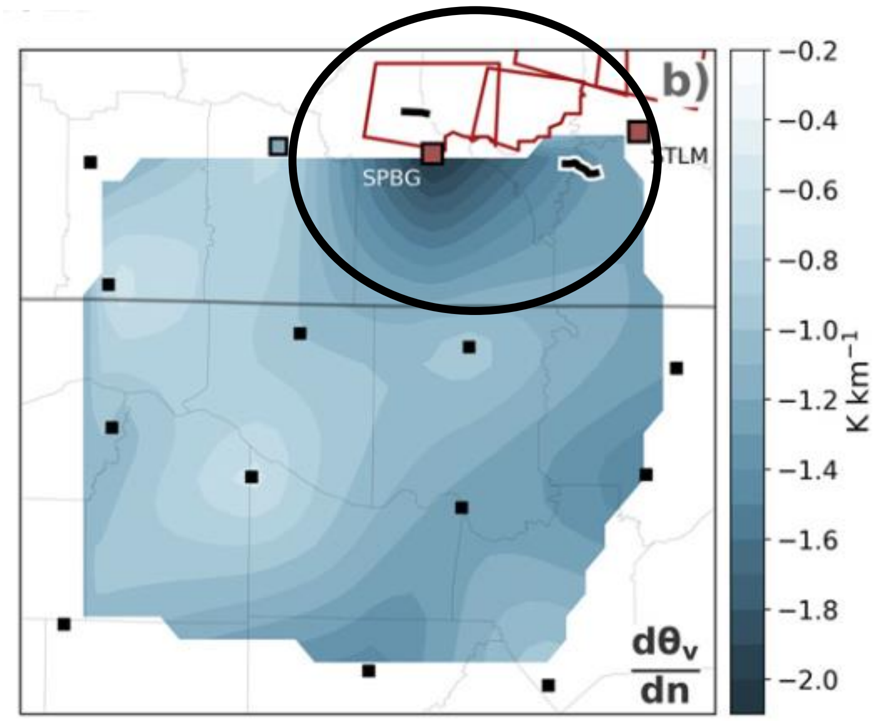

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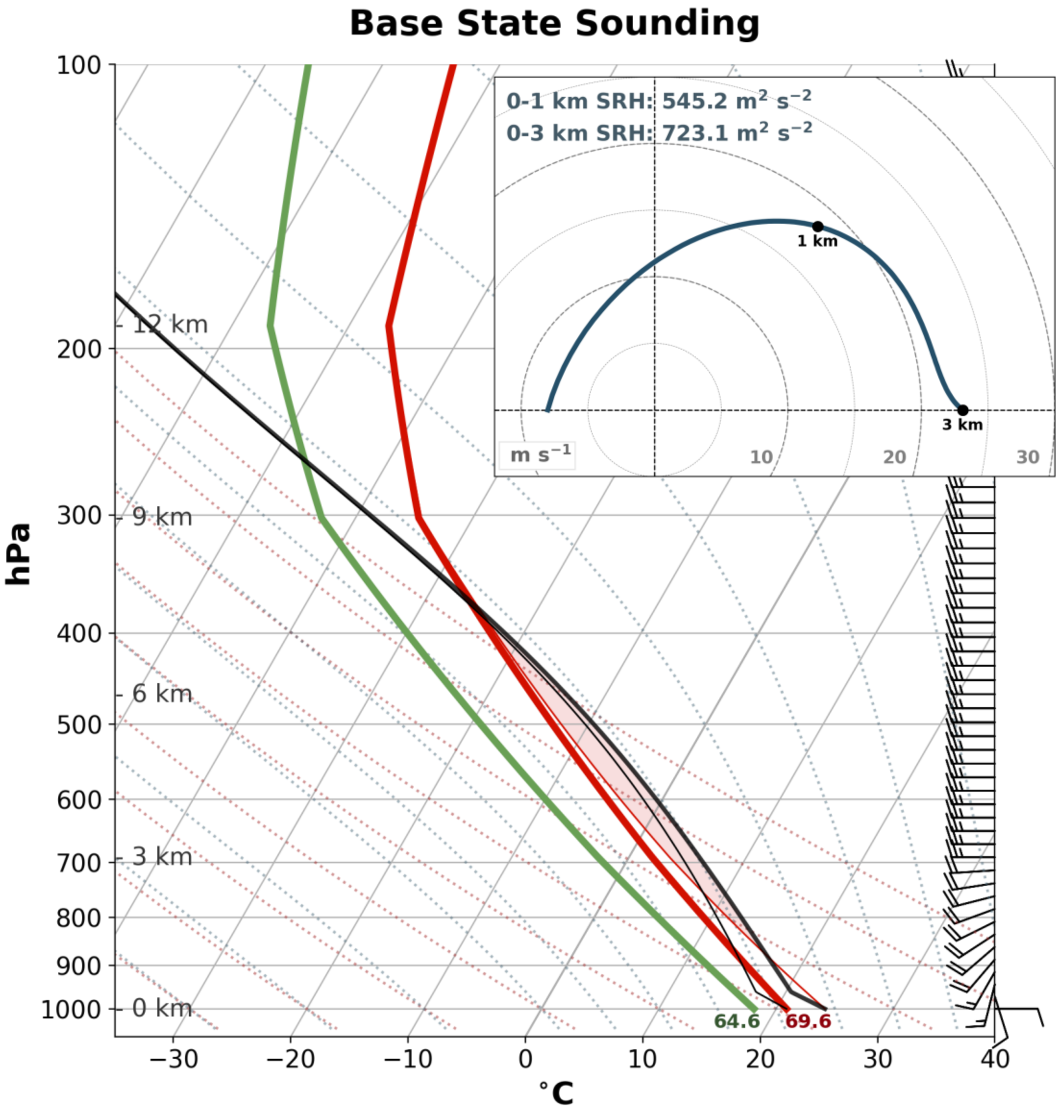
What are cold pool and vortex structures in HSLC QLCSs?

Model Parameters

2 different CM1 simulations: varying boundary conditions

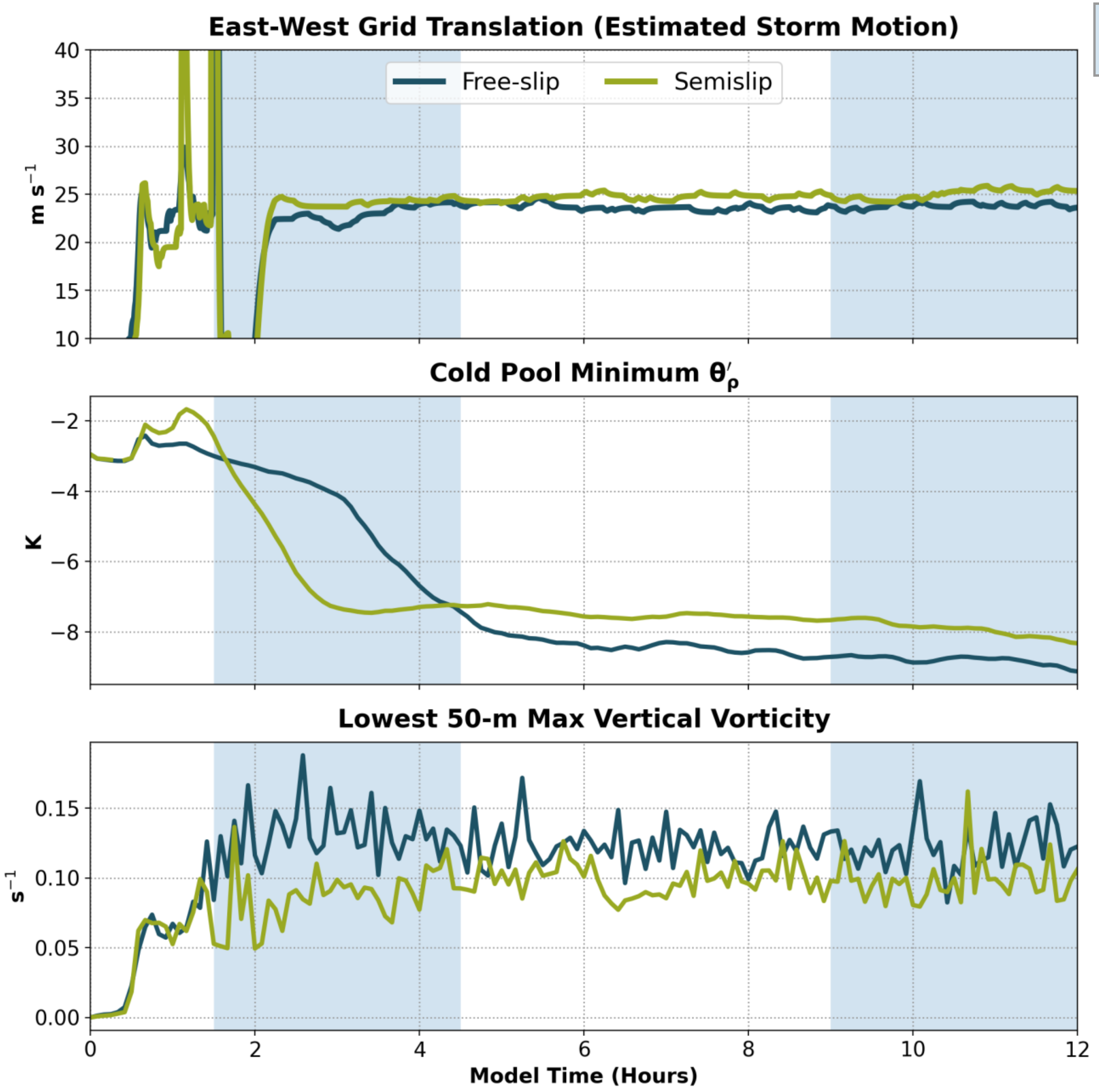
Parameter	Description
Model	CM1v19.5 (modified to include several fixes through 19.10)
Domain Size	309.5 x 202 x 18 km
Horizontal Grid Spacing	Δx = 250 m
Vertical Grid Spacing	Δz = 10 m, stretched to 250 m at 9.75 km (23 grid points in the lowest 1 km)
Lateral Boundaries	X: open radiative, Y: Periodic
Bottom Boundaries	**Free-slip OR semislip (C_d = 0.01)**
Microphysics	NSSL double-moment (hail and graupel)
Coriolis	None
Run time	43200 s (12 hours)
Grid Translation	Dynamic (Schueth et al., to be submitted)

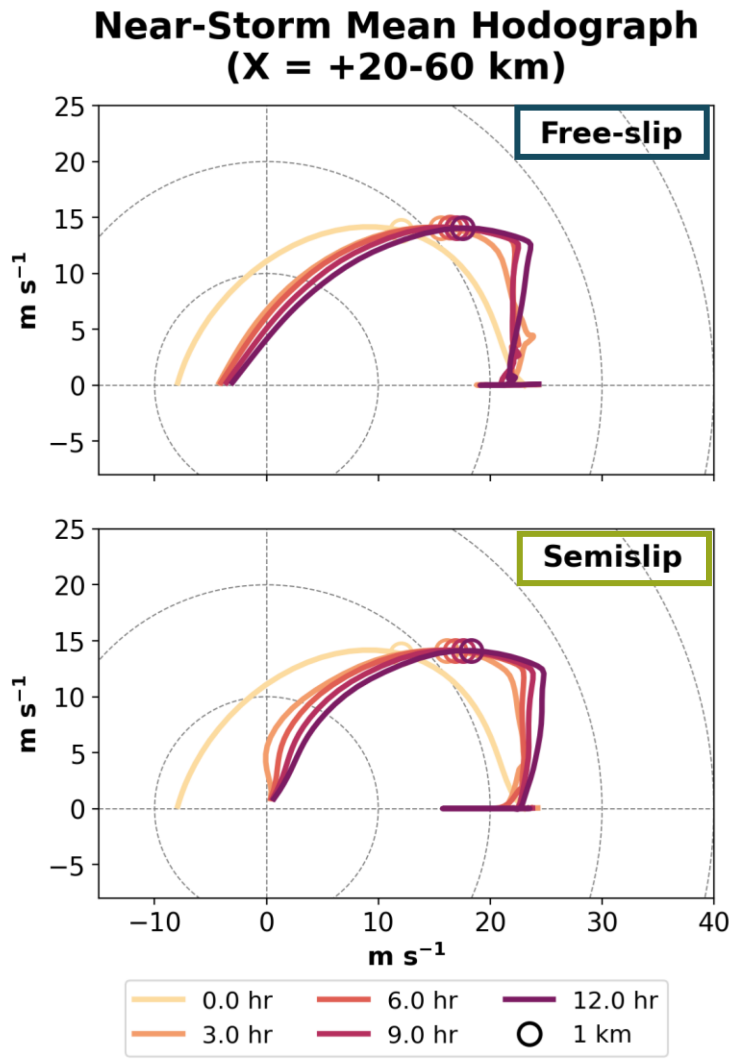
Sounding based on Sherburn and Parker (2019)



Model Results Overview

Vortex analysis periods





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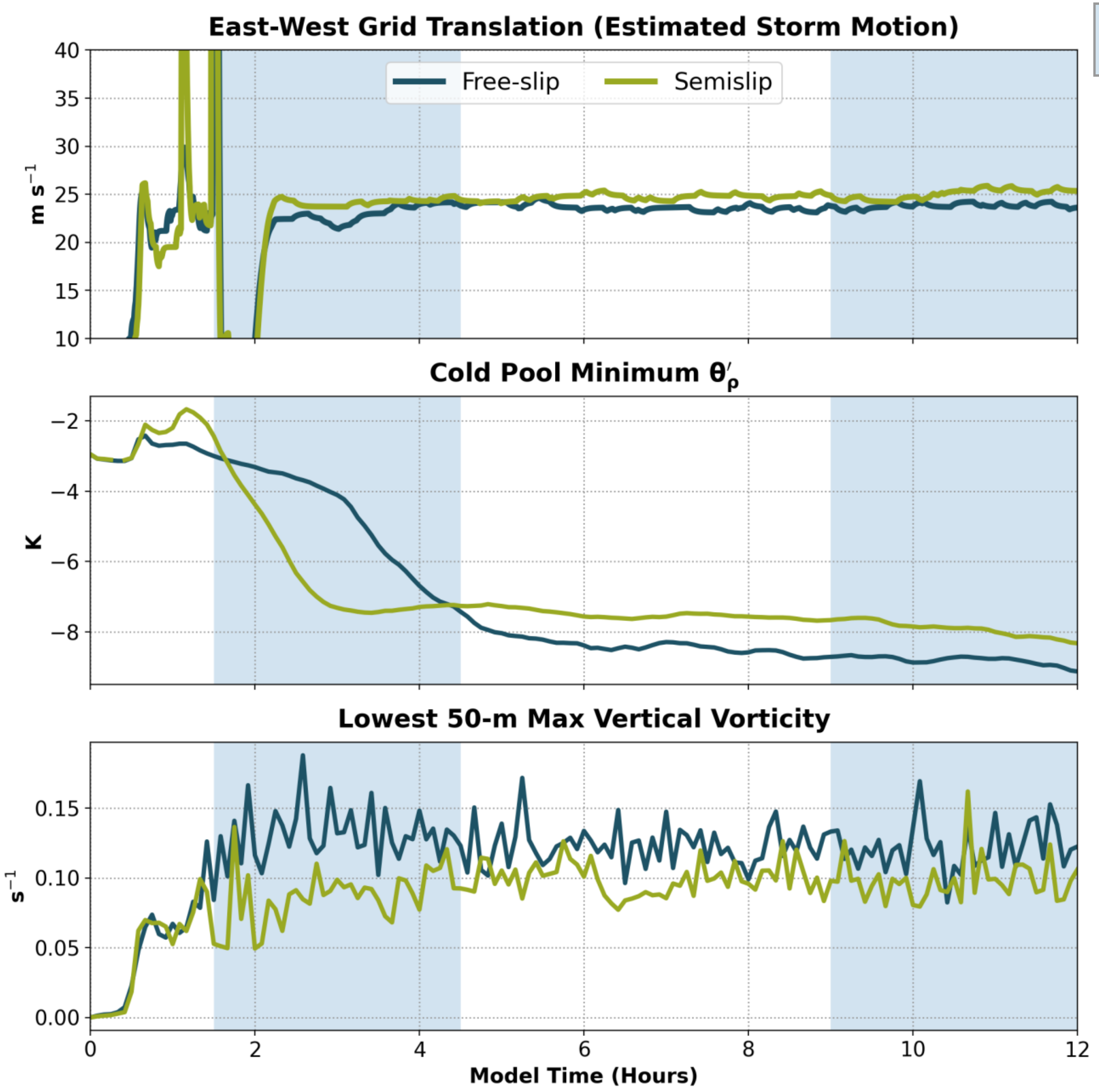

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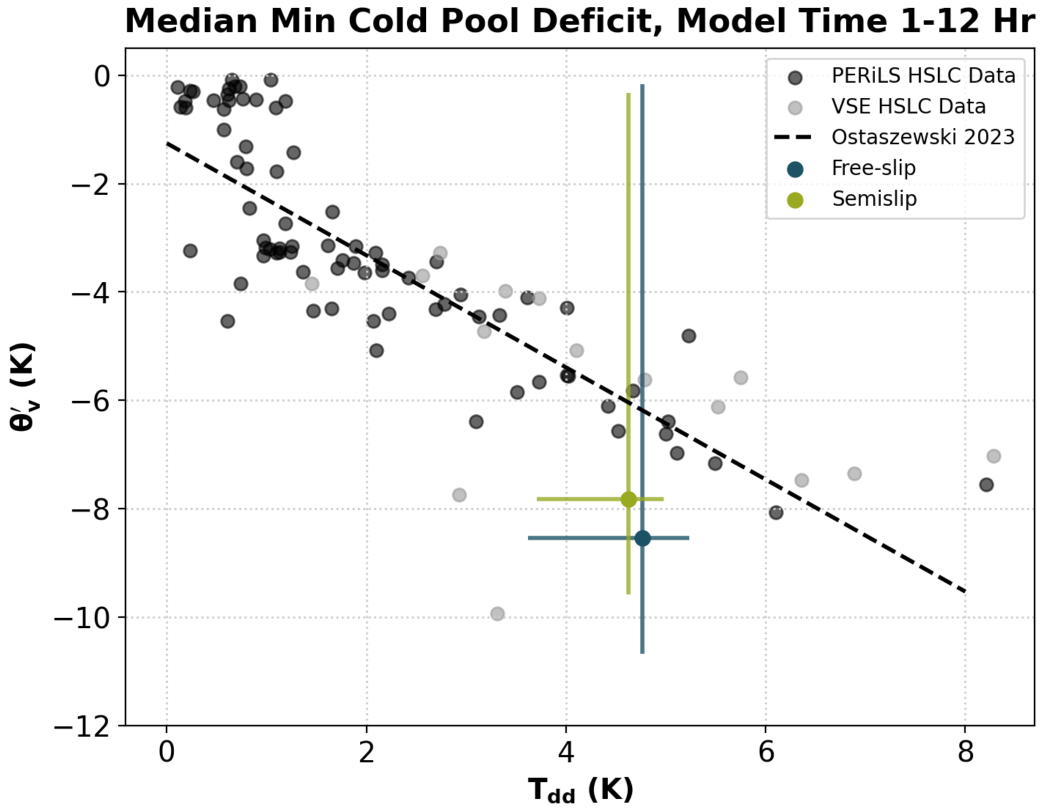


Comparison to observations shows reasonable cold pool deficits and dew point depression (T-Td) relationship

Vortices and TLVs

Okubo-Weiss (OW) = $S_n^2 + S_s^2 - \zeta^2$

S_n = normal strain component, S_s = shear strain component, ζ = vertical vorticity

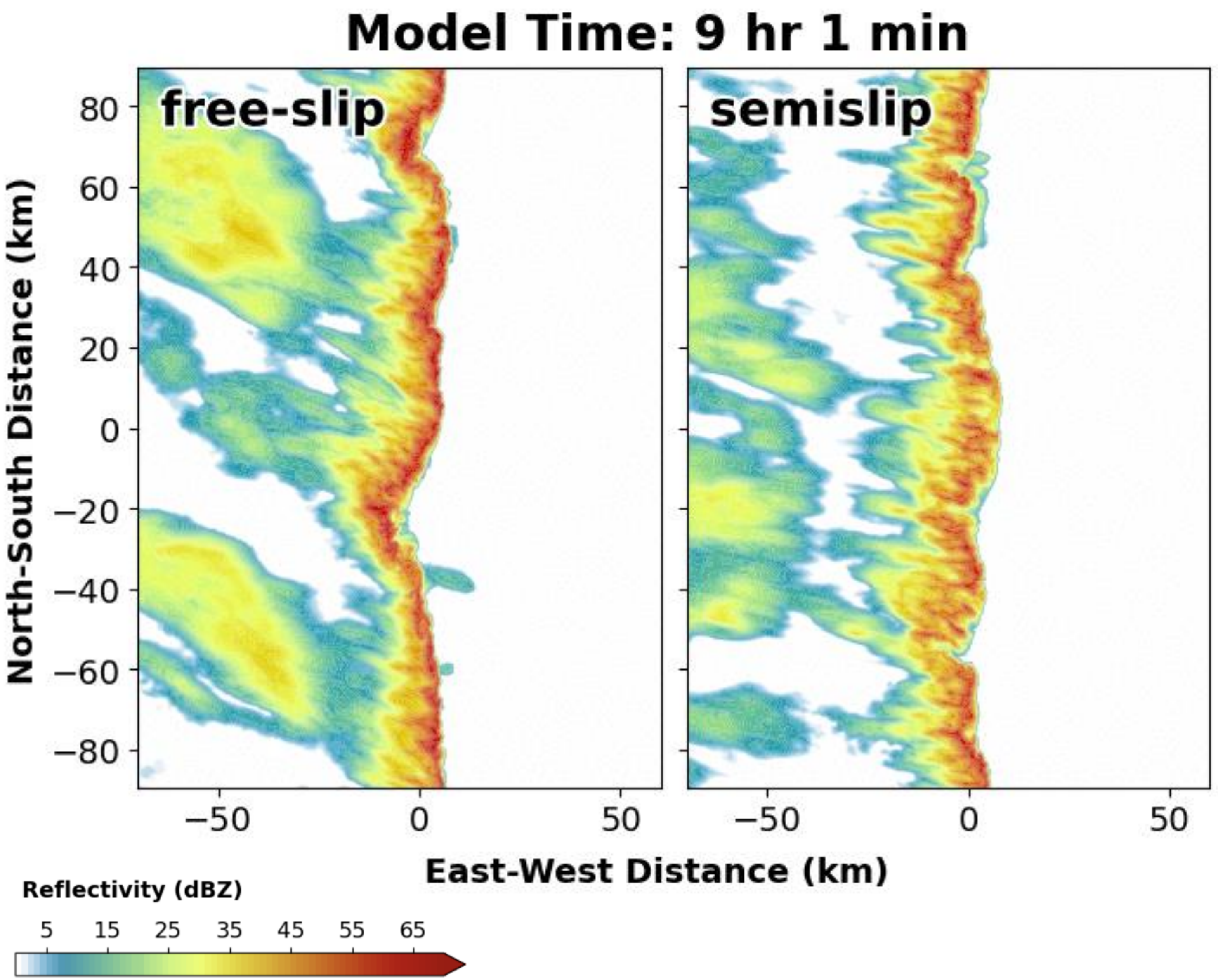
Vortex definition:

- Contiguous object of **OW ≤ -0.001 s^{-2}**
  - depth ≥ 500 m
  - lowest grid point < 30 m AGL
- Exists for at least 1 minute

TLV definition:

- Vortex definition
- Contains min **OW ≤ -0.01 s^{-2}**

	N Vortices	N TLVs
Free-slip	373	84
Semislip	211	22

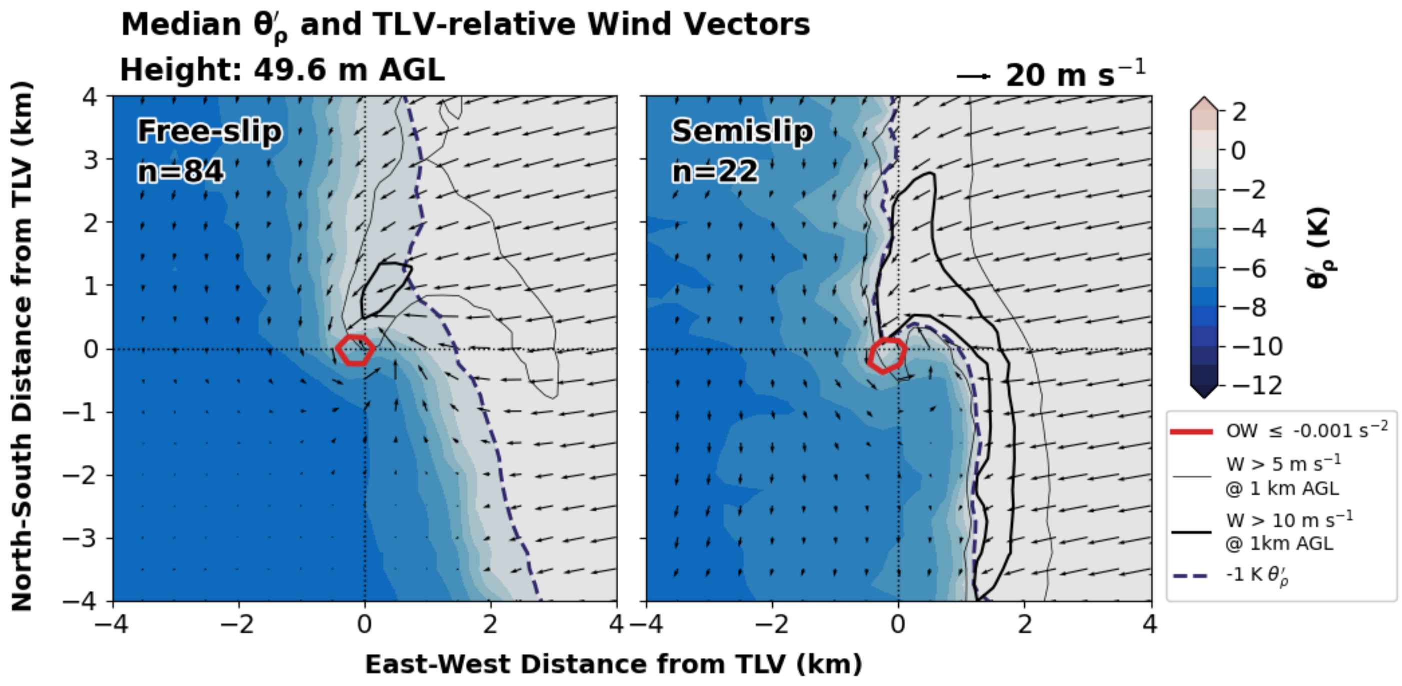


TLVs

Composites around each TLV at their strongest time

- Majority/all vortices caused by HSI release

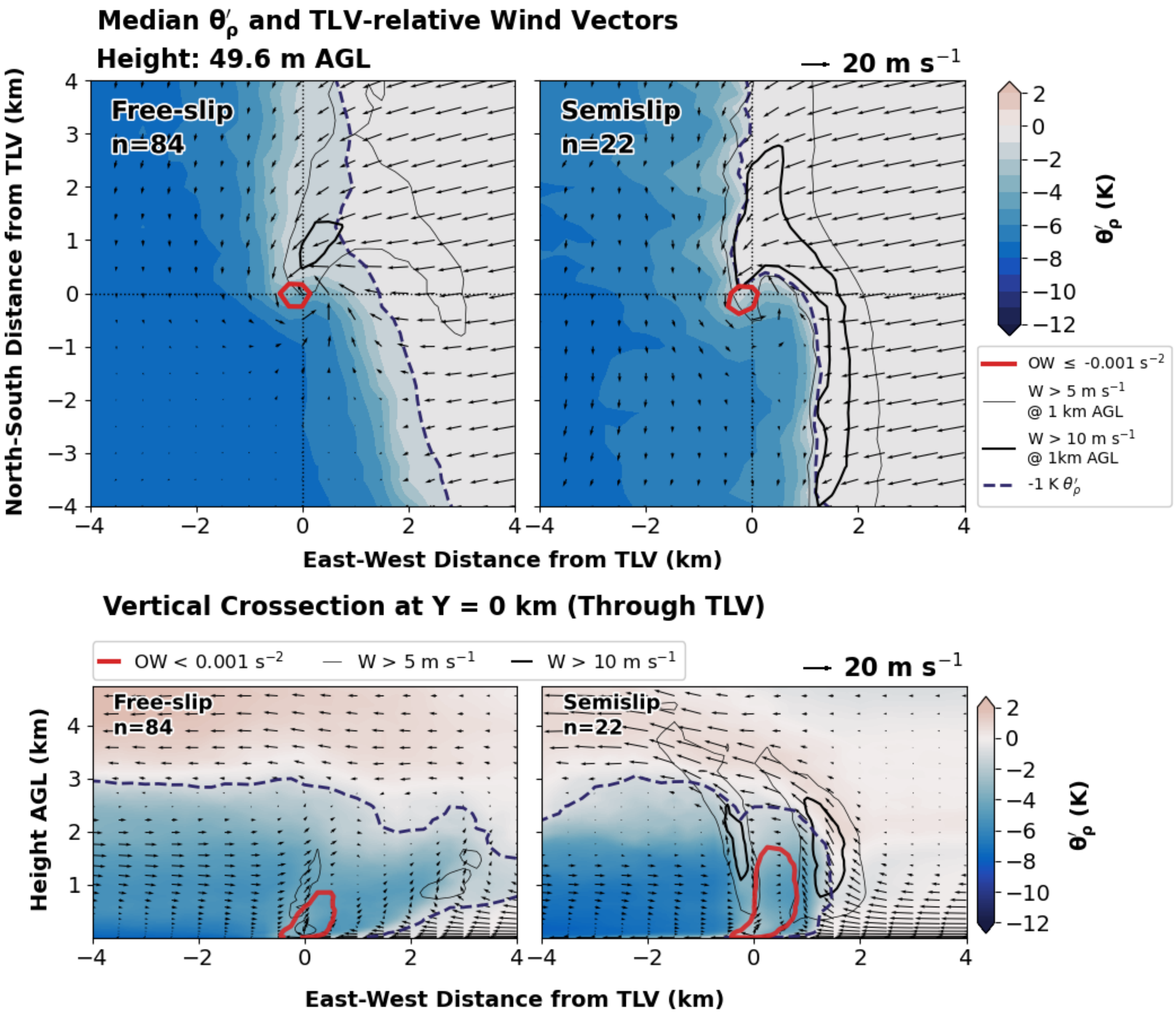
- Free-slip vortices are more occluded and have weaker updrafts than semislip



TLVs

Composites around each TLV at their strongest time

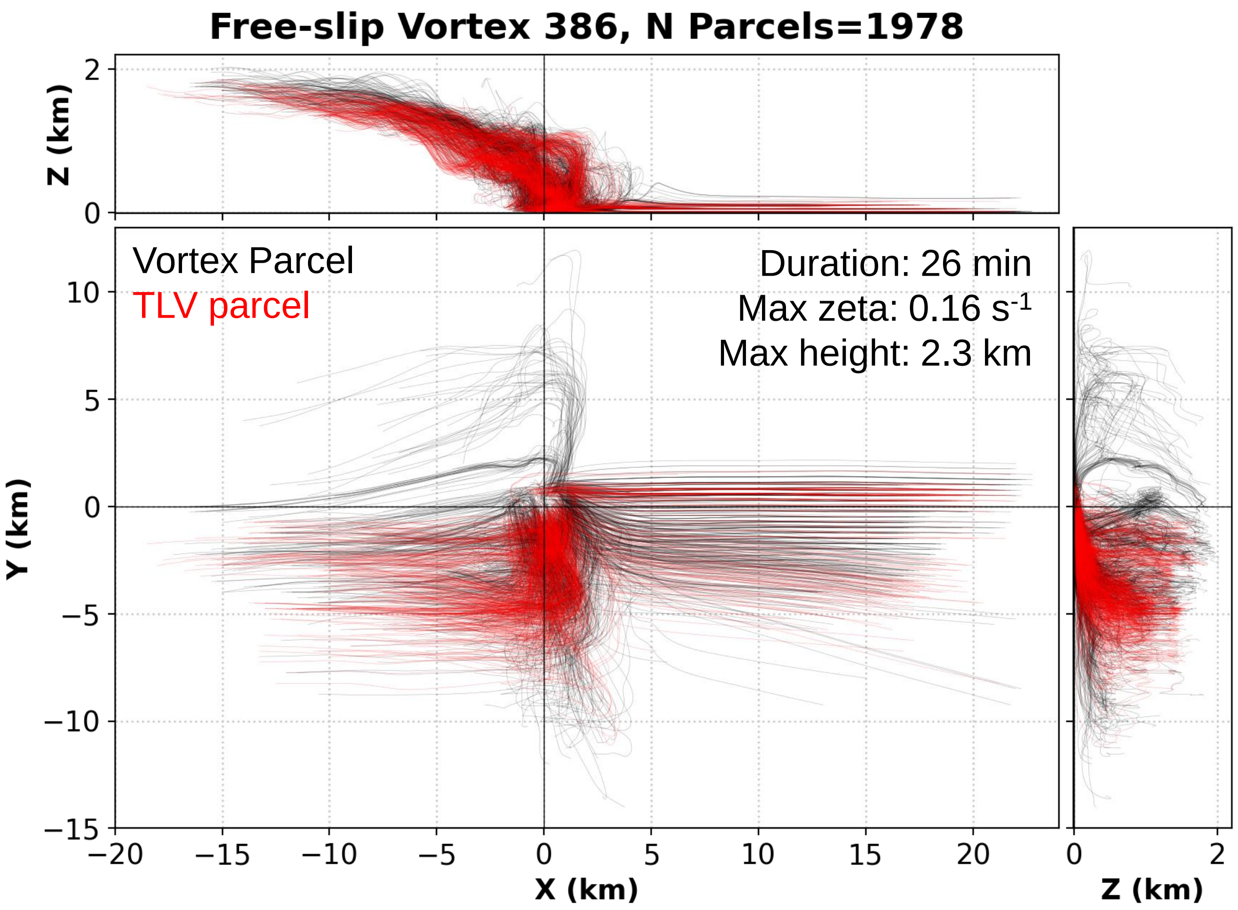
- Majority/all vortices caused by HSI release
- Free-slip vortices are more occluded and have weaker updrafts than semislip
- Semislip cold pools are more upright, colder air aloft (relative to environment)
- Median cold pool depth is 3 km for both
- Semislip vortices are weaker than free-slip, but they're taller

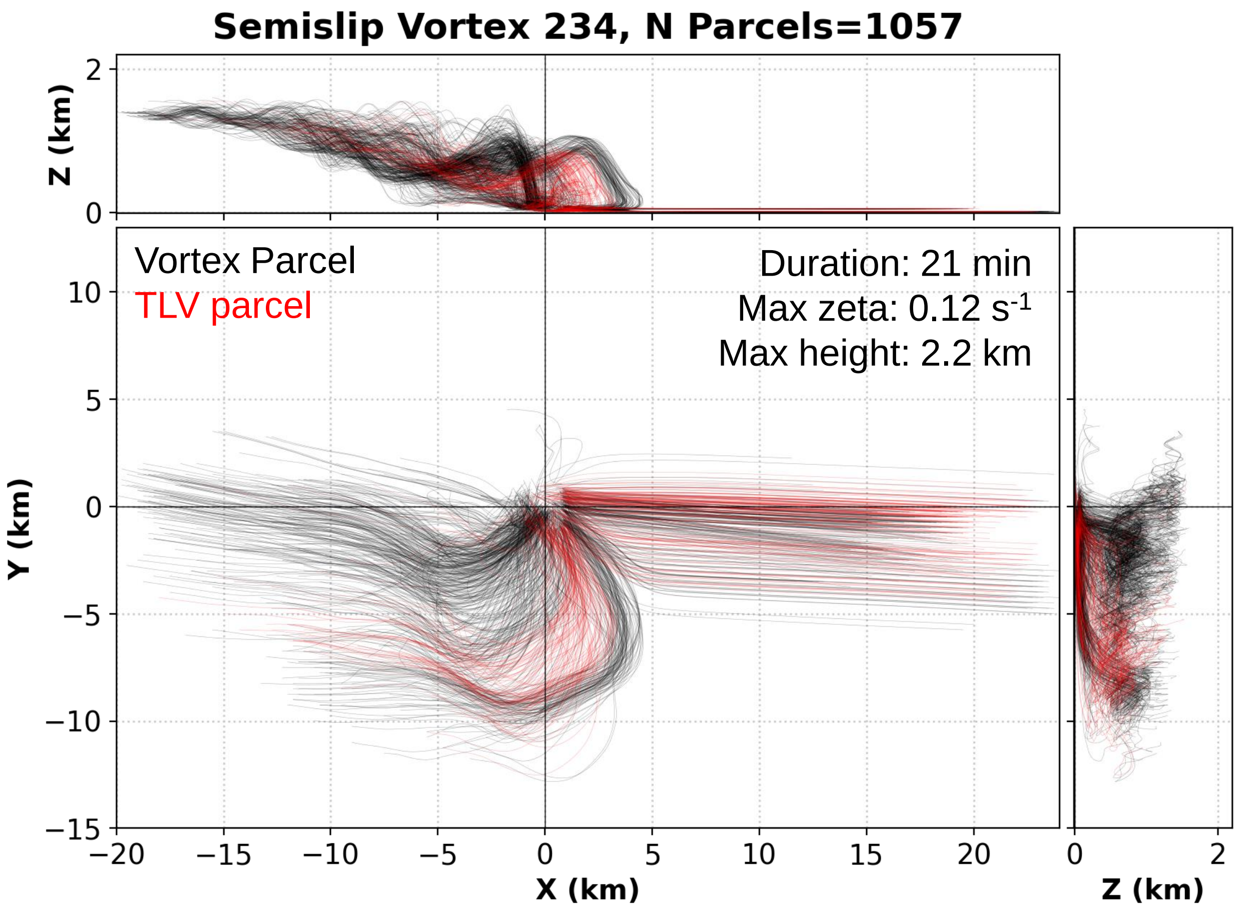


Parcel Trajectories

Typical HSI vortex/TLV from each simulation has 3 source regions for parcels:

A: environmental parcels
B: cold pool parcels that descend and approach the vortex from the south
C: cold pool parcels that descend and immediately enter the vortex from the west





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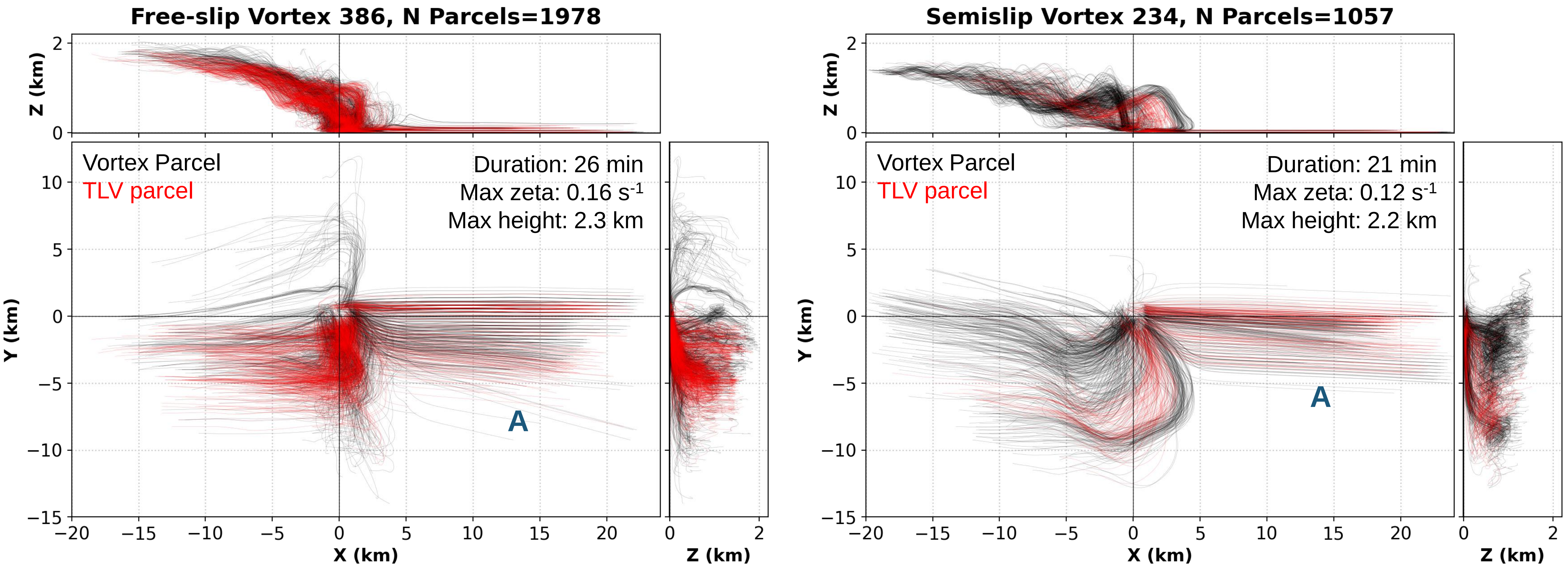

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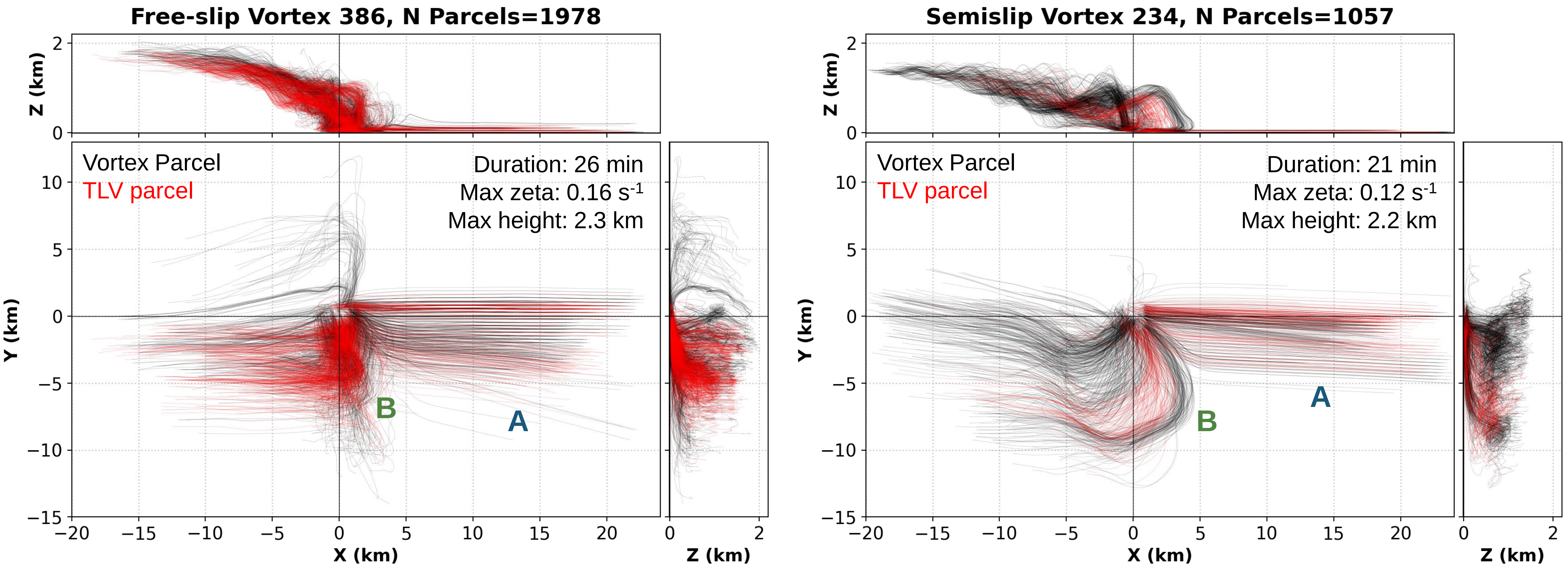

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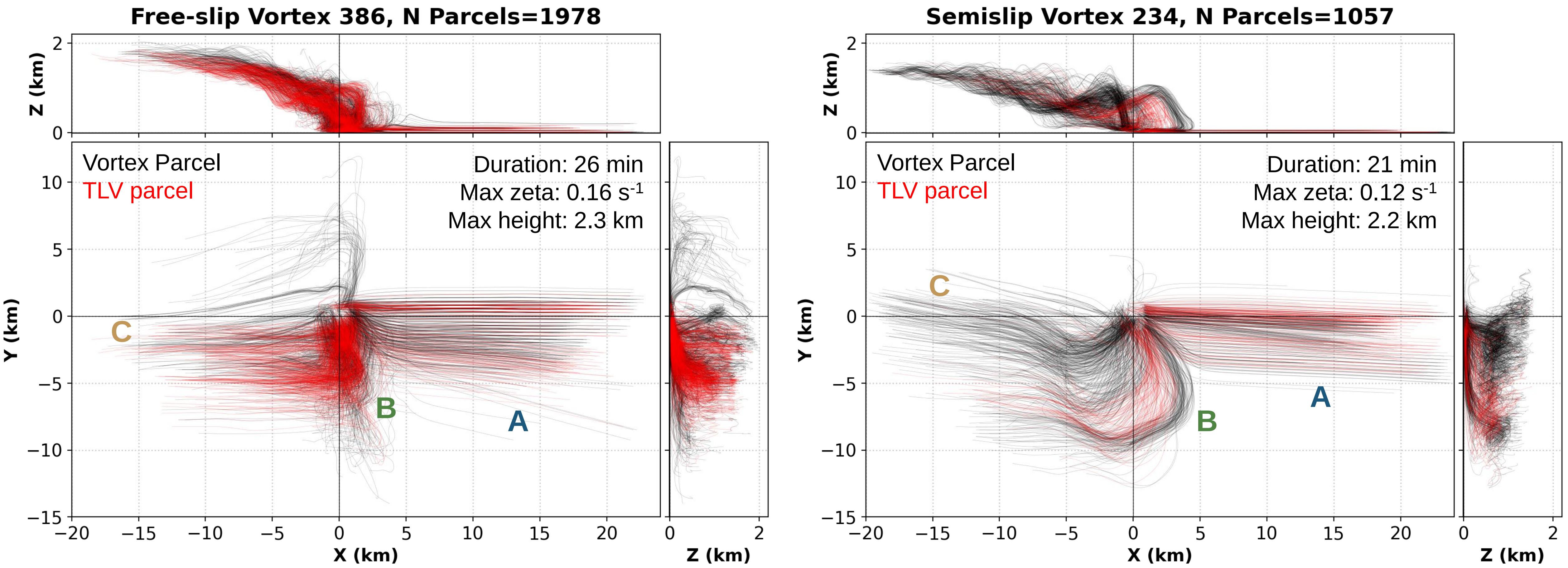
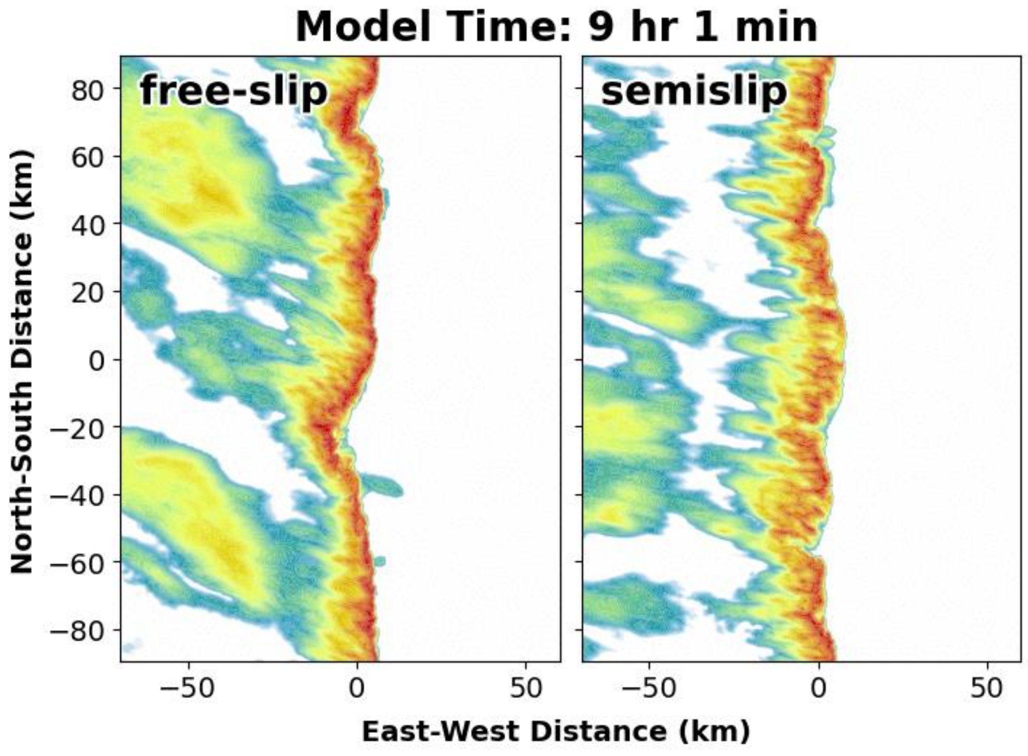


Summary and Future Work

- Two HSLC QLCS simulations with varying boundary conditions – Free-slip and semislip
- Cold pool deficits match observations fairly well
- HSI is main/dominant(???) vortex formation mechanism for the 3-hr period observed
    - Cold pool composites align with past studies of HSI and different boundary conditions
- Vortices have similar parcel source regions, regardless of boundary condition



Future Work:

- Vorticity budget analysis of the HSI vortices
    - Preliminary work suggests that tilting of baroclinically generated vorticity is a source of vertical vorticity
- Analysis of the earlier period with more supercell-like vortexgenesis mechanisms
    - Preliminary work suggests vortices from this time period are taller, stronger, and last longer

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