TC inner-core structure and intensification

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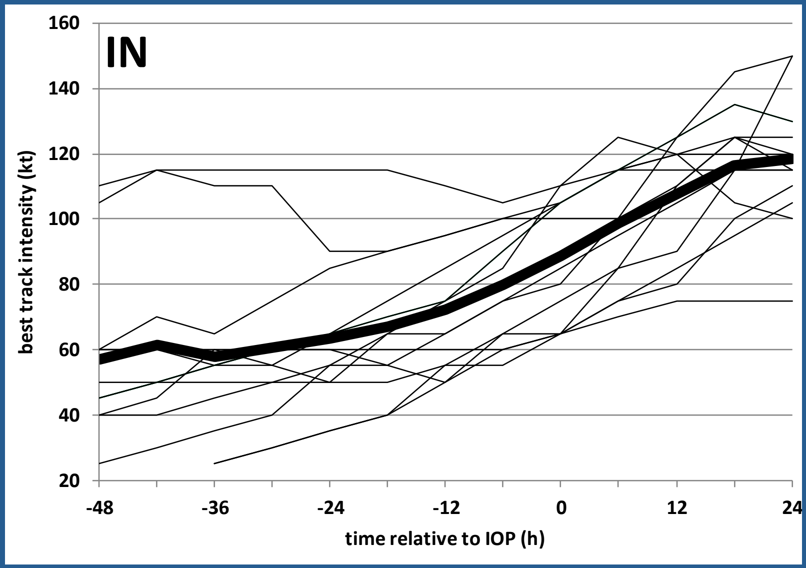
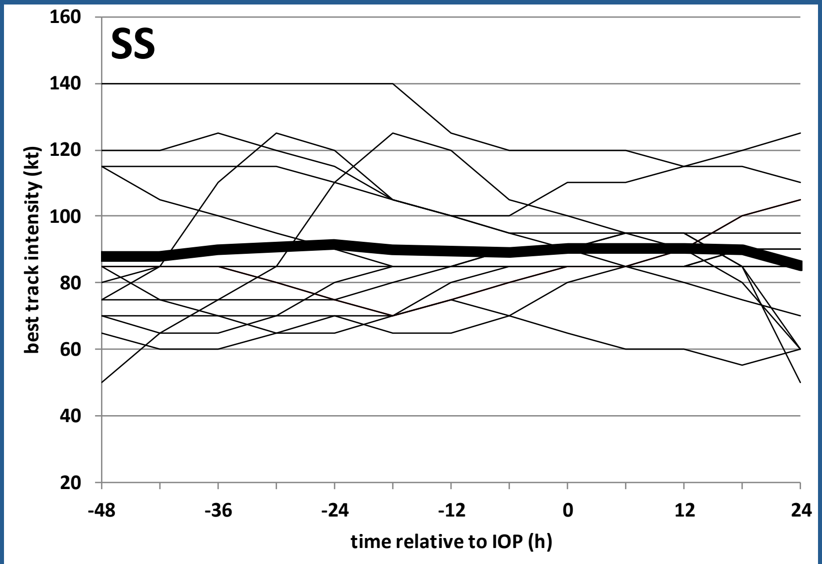
Background

- Comparisons of composites of airborne Doppler radial passes in multiple cases show statistically significant differences in inner-core structure of TCs that are intensifying compared with those that are remaining steady-state (Rogers et al., MWR, 2013, in press)
    - Intensifying (IN) – 40 radial passes in 8 different TCs
    - Steady-state (SS) – 53 radial passes in 6 different TCs

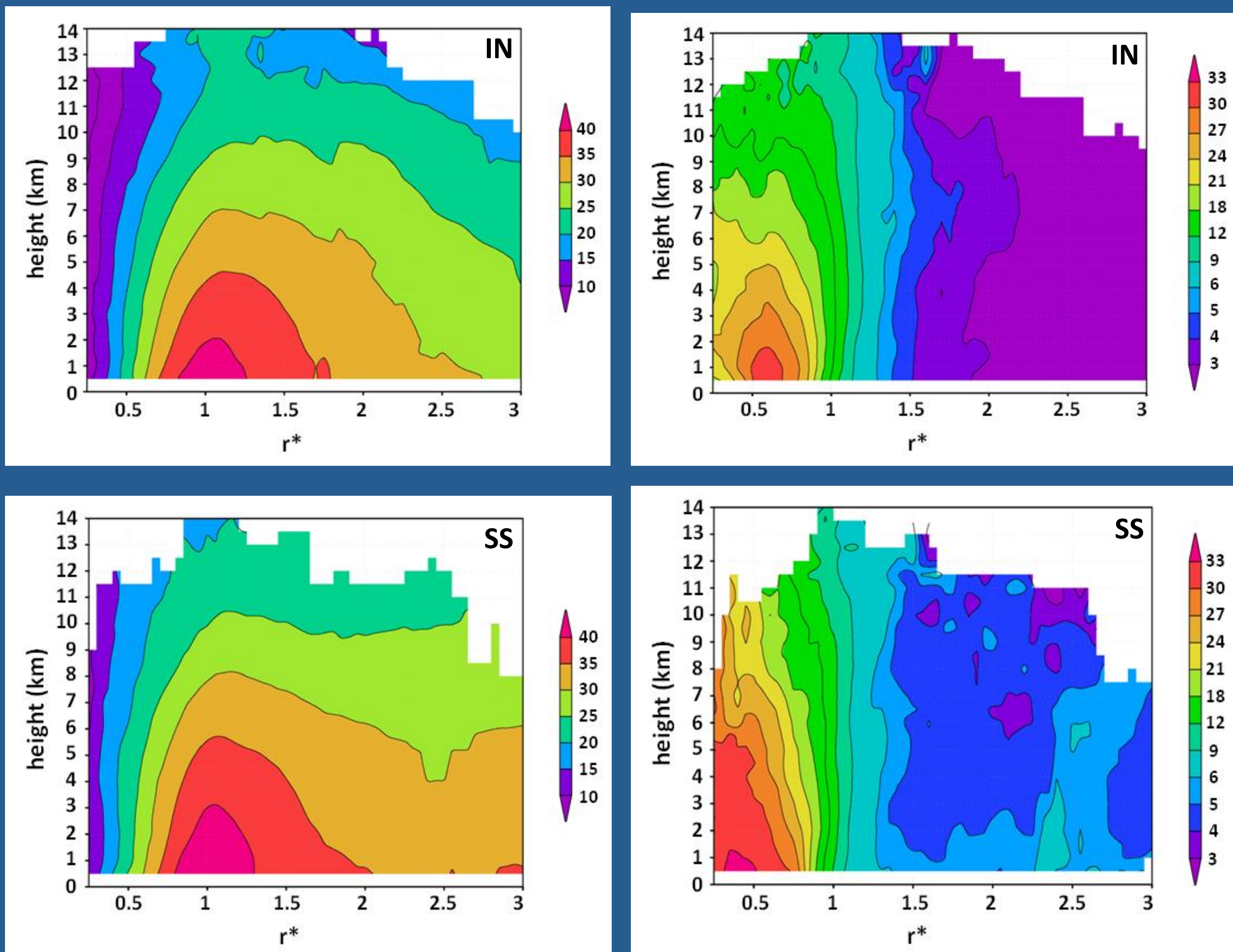
Best track intensity trace relative to IOP





Symmetric vortex structure and TC intensification

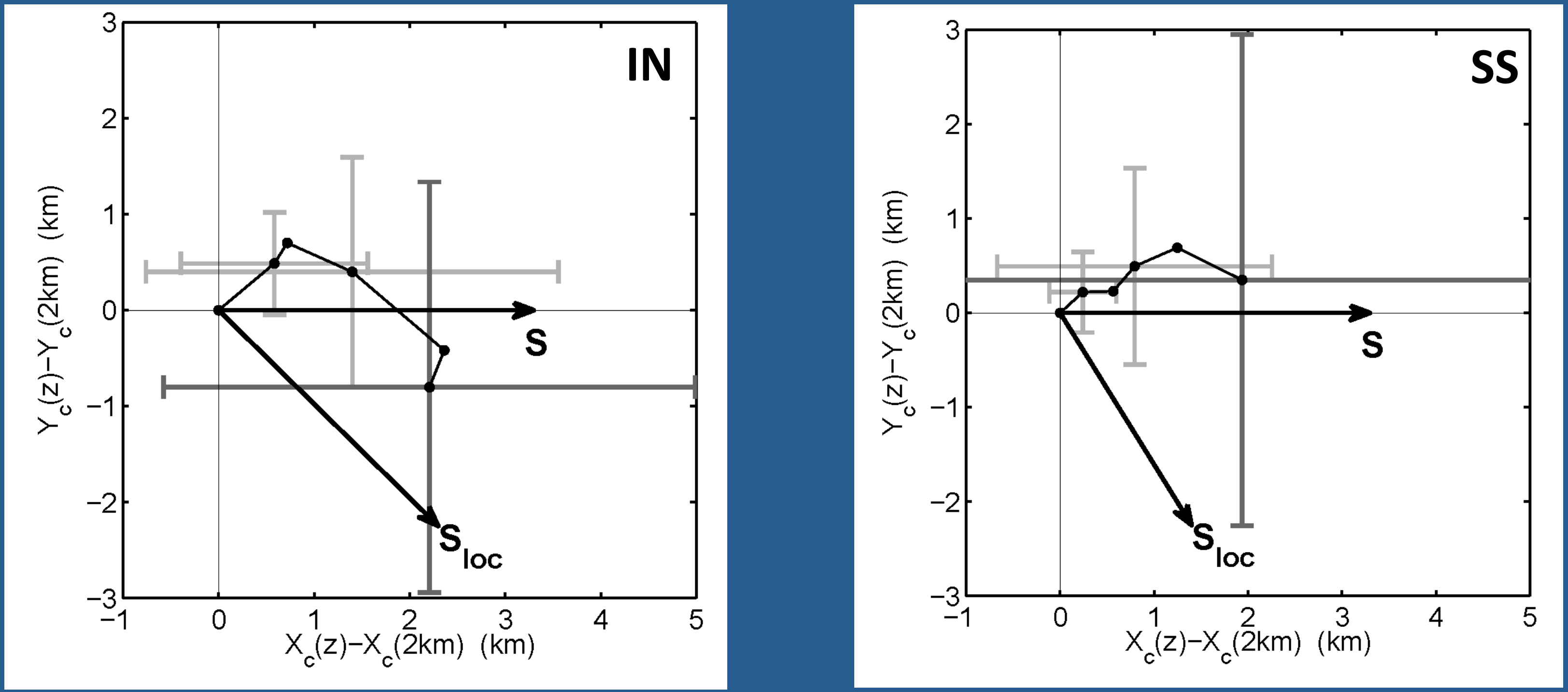
Axisymmetric tangential wind (m/s) Axisymmetric vorticity (x 10-4/s)



- Tangential wind decreases more rapidly with radius outside RMW for IN cases
- IN cases have a ring-like vorticity structure inside RMW
- IN cases have weaker vorticity outside RMW

Asymmetric vortex structure and TC intensification

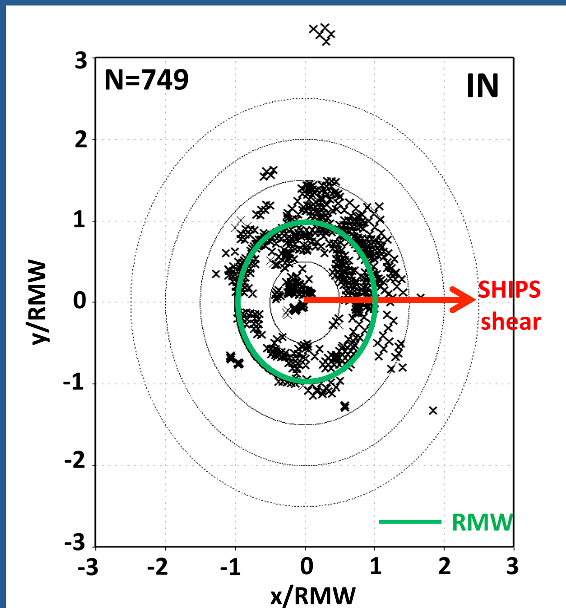
Shear-relative tilt (km) between 2 and 7-km altitude

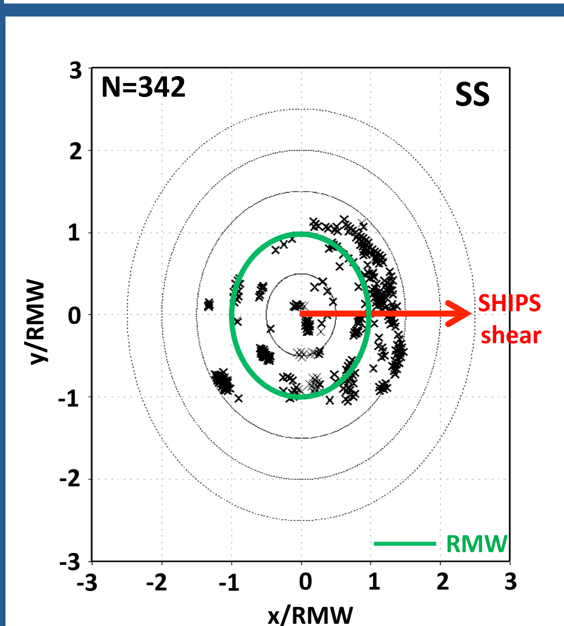


• negligible difference in tilt magnitude between IN and SS cases

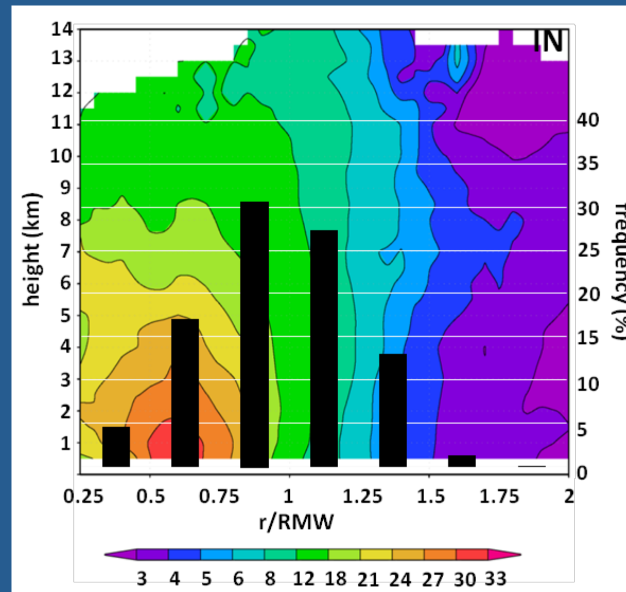
Convective bursts and TC intensification

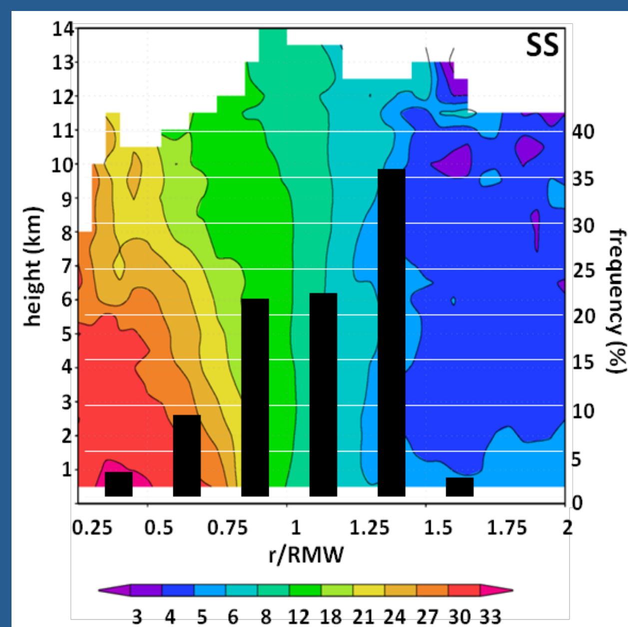
Number and shear-relative location of convective bursts





Radial distribution of convective bursts (%) and axisymmetric vorticity (shaded, x 10^{-4} s^{-1})





- Bursts defined as top 1% of vertical velocity distribution at 8 km altitude (i.e., 5.5 m/s)
- IN cases have more bursts, more of them inside RMW compared with SS cases

Questions to consider

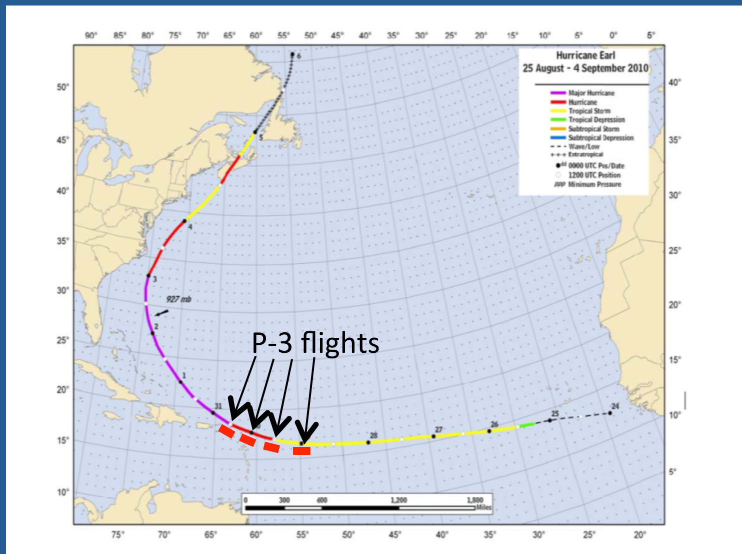
- Composites consist of snapshots – Do these structures appear in individual case studies, with observations collected serially?

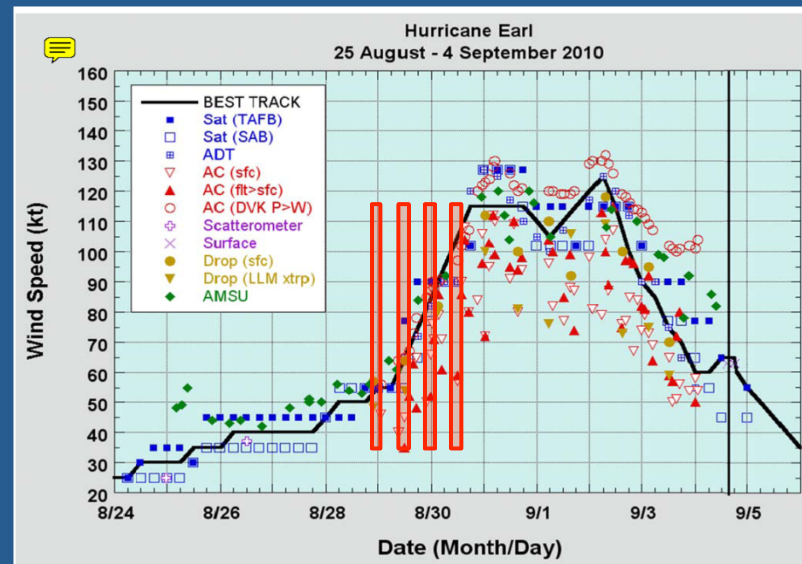
- Does HWRF capture inner-core structures associated with intensification?

- Can HWRF distinguish between IN and SS cases based on inner-core structure?

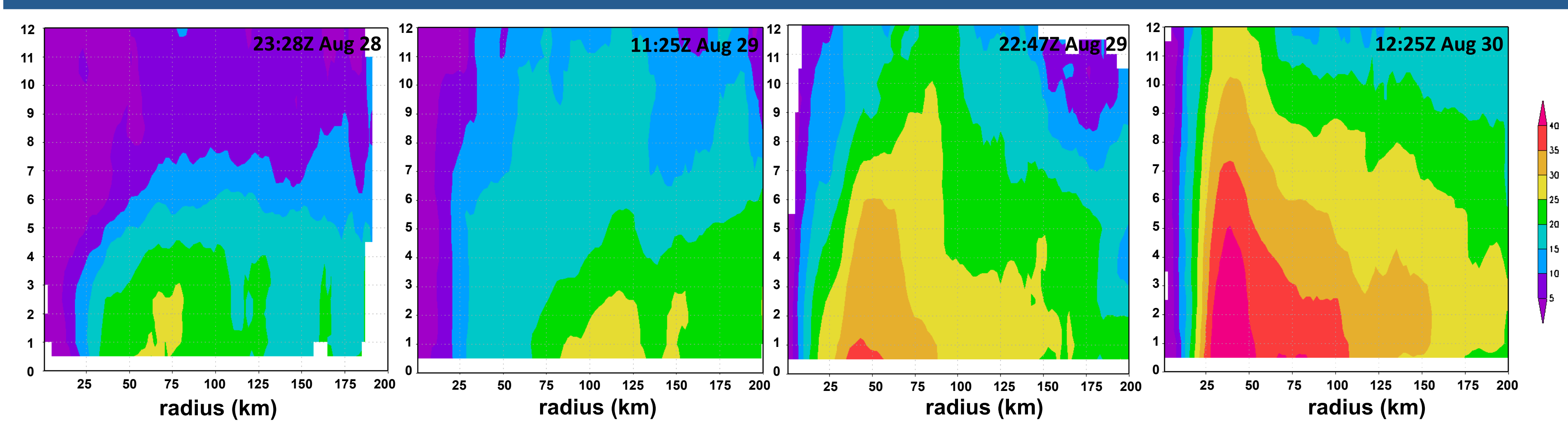
Do structures associated with IN appear in individual case studies?

Case study: Earl 2010





Axisymmetric tangential wind (m/s)

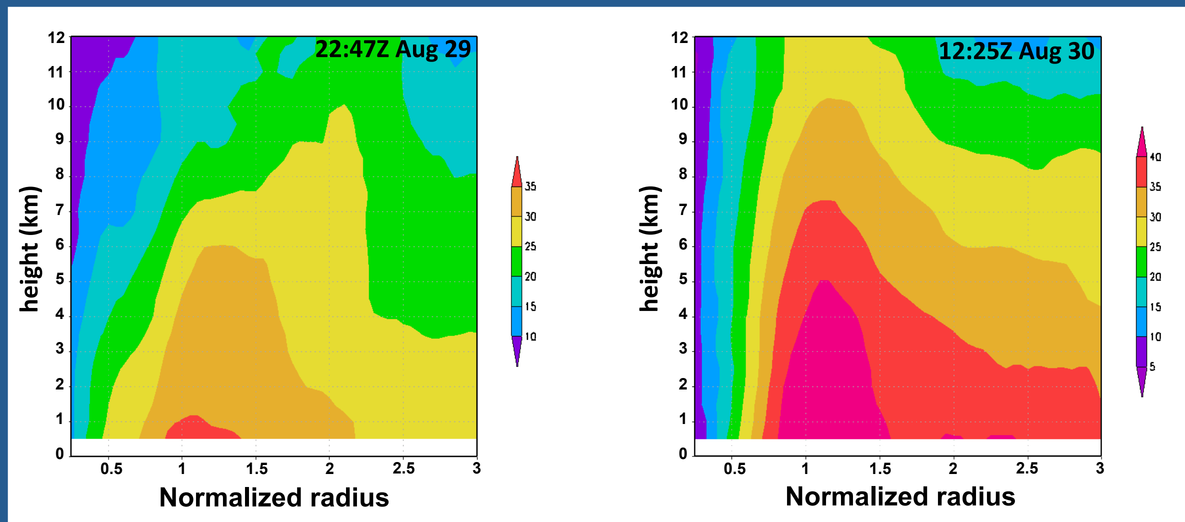


Do structures associated with IN appear in individual case studies?

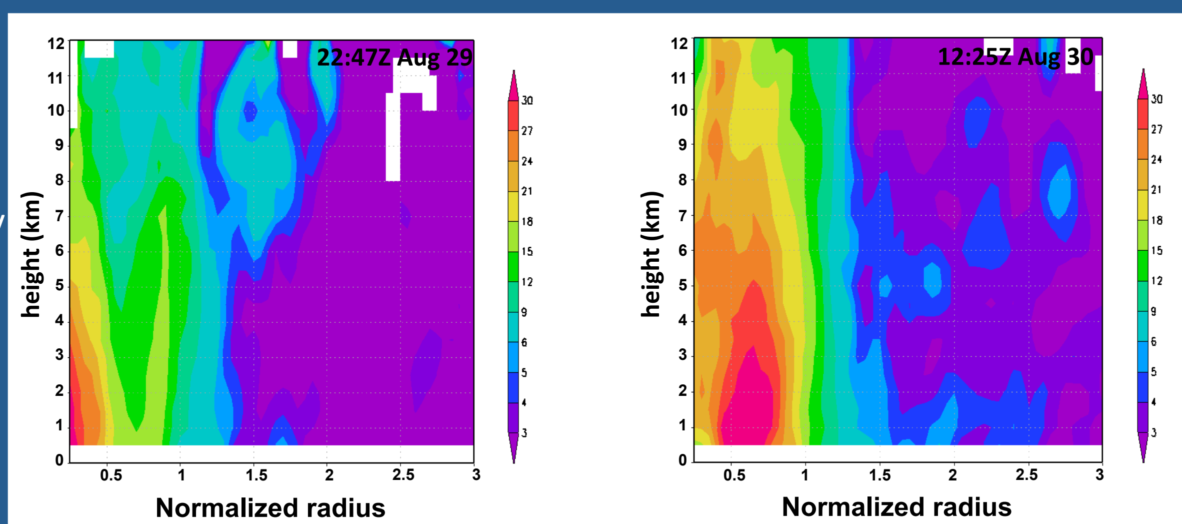
Doppler-derived axisymmetric structure

Third flight   Fourth flight

Tangential wind (m s^{-1})



Vertical vorticity ($\times 10^{-4}$ s^{-1})



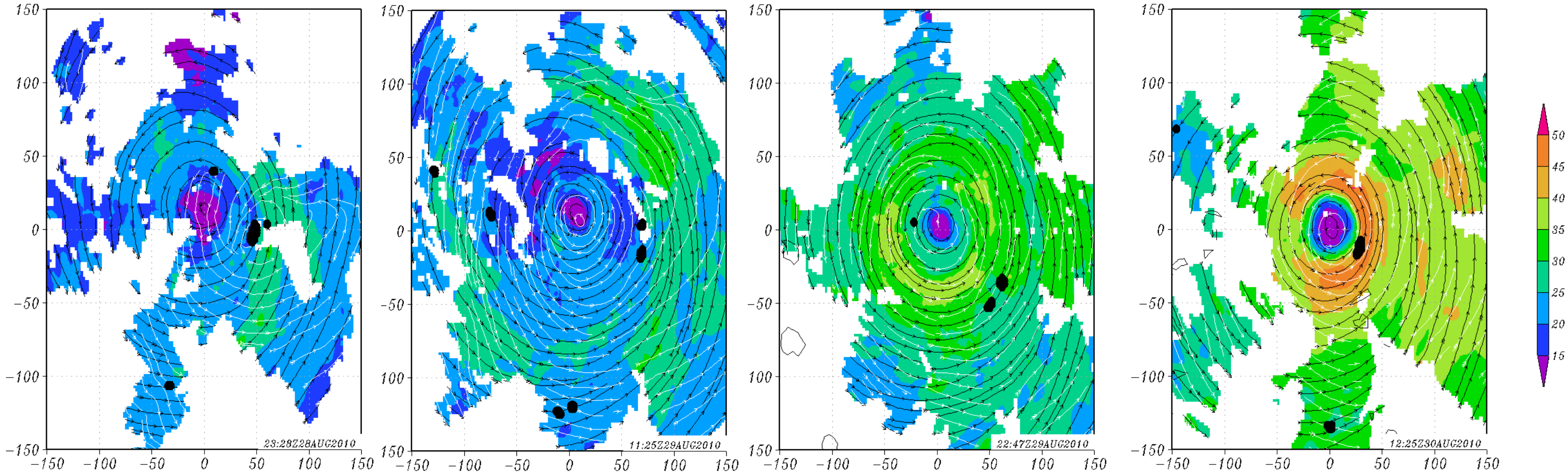
- Decrease of tangential wind with radius outside RMW
- Ring-like structure inside RMW
- Weaker vorticity outside RMW

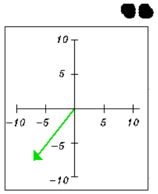
Do structures associated with IN appear in individual case studies?

Vortex structure and convective burst distribution

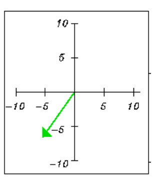
Streamlines and wind speed (shaded, m/s) at 2 km (black) and 8 km (white)
Convective burst locations (top 1% of w distribution at 8 km) denoted by black dots

23:28 UTC 28 Aug | 11:25 UTC 29 Aug | 22:47 UTC 29 Aug | 12:25 UTC 30 Aug





SHIPS 850-200 hPa shear (m/s)



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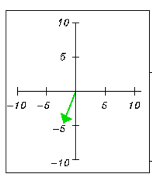

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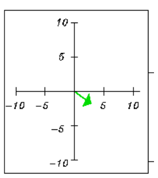
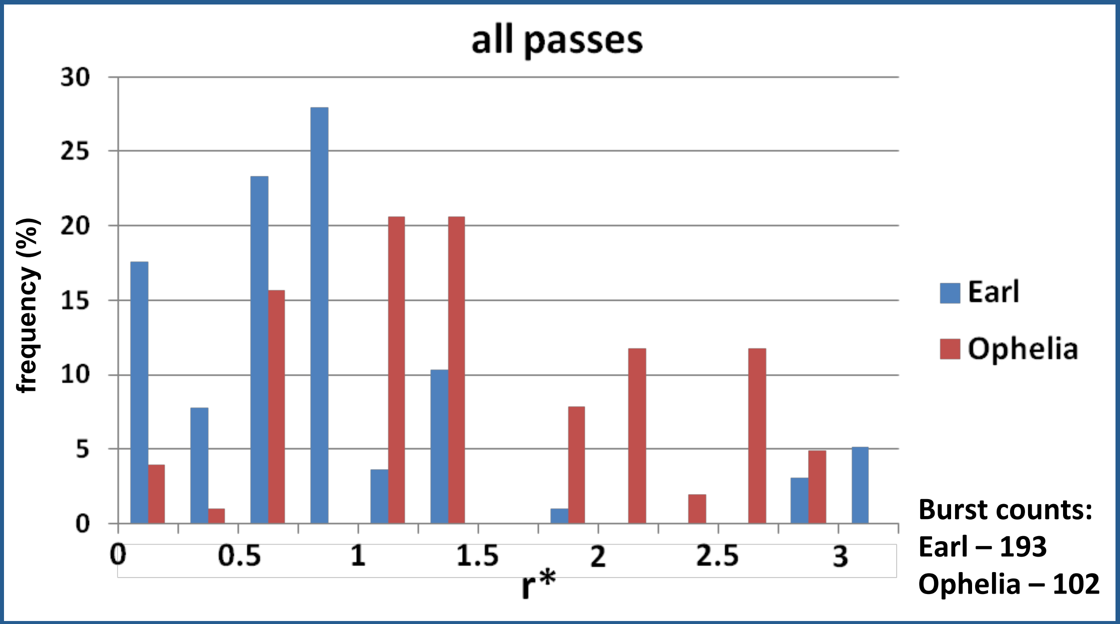


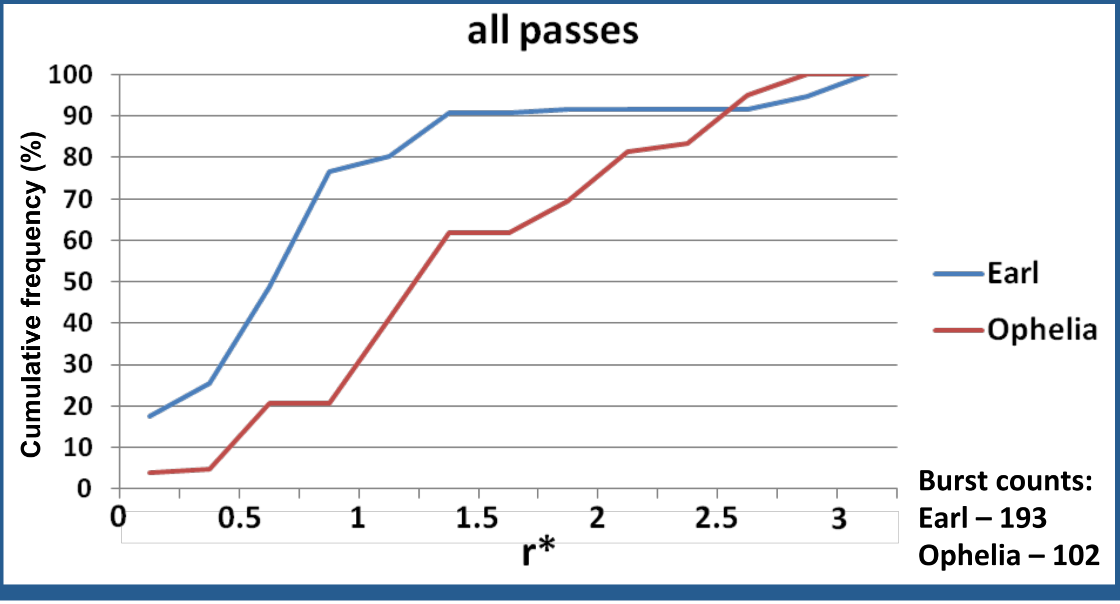
SHIPS 850-200 hPa shear (m/s)

- Significant displacement of vortex during first flight
- Vortex nearly aligned by second flight (~12 h later), after RI onset
- Many bursts located inside RMW for most flights, generally downshear and downshear left

Do structures associated with IN appear in individual case studies?

Number and radial distribution of convective bursts for Earl and Ophelia





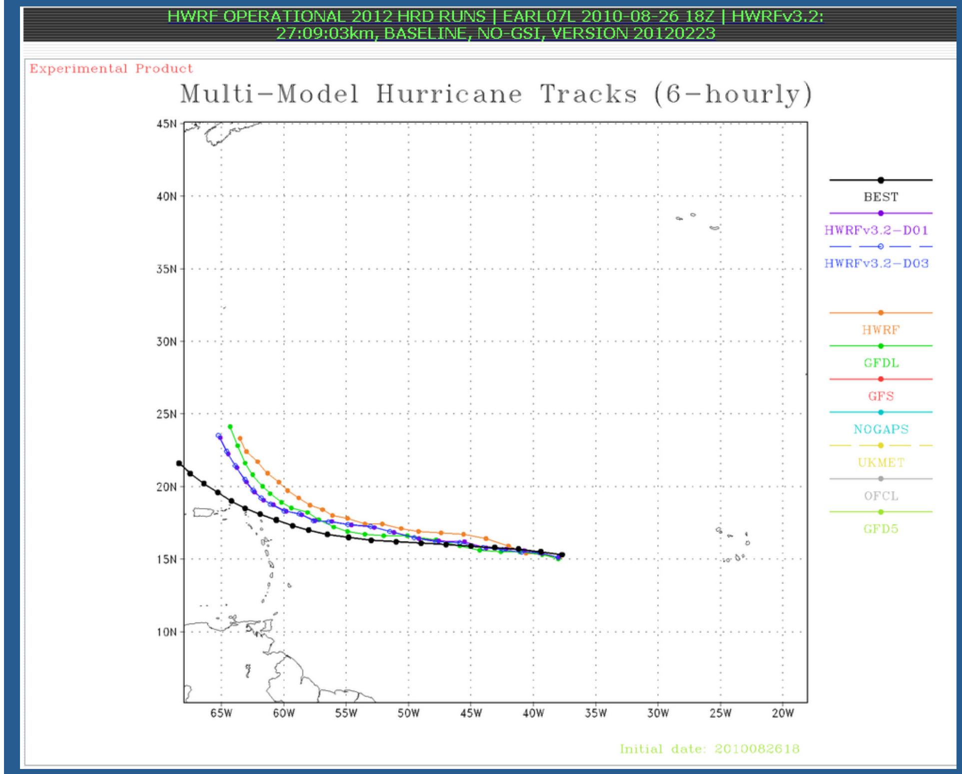
- 80% of convective bursts are at or inside RMW for Earl (IN)
- 30% of convective bursts are at or inside RMW for Ophelia (SS)

Does HWRF capture inner-core structures associated with IN?

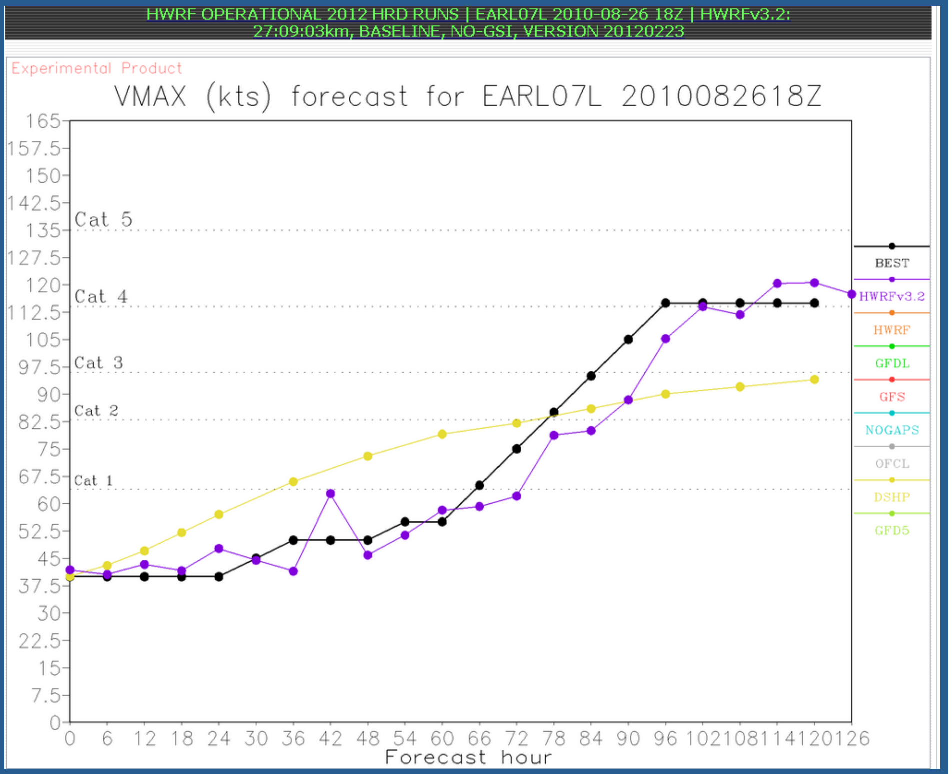
Earl 2010: HWRF 3-km baseline run

Model initialized at 18 UTC August 26 (2618 run)

Track



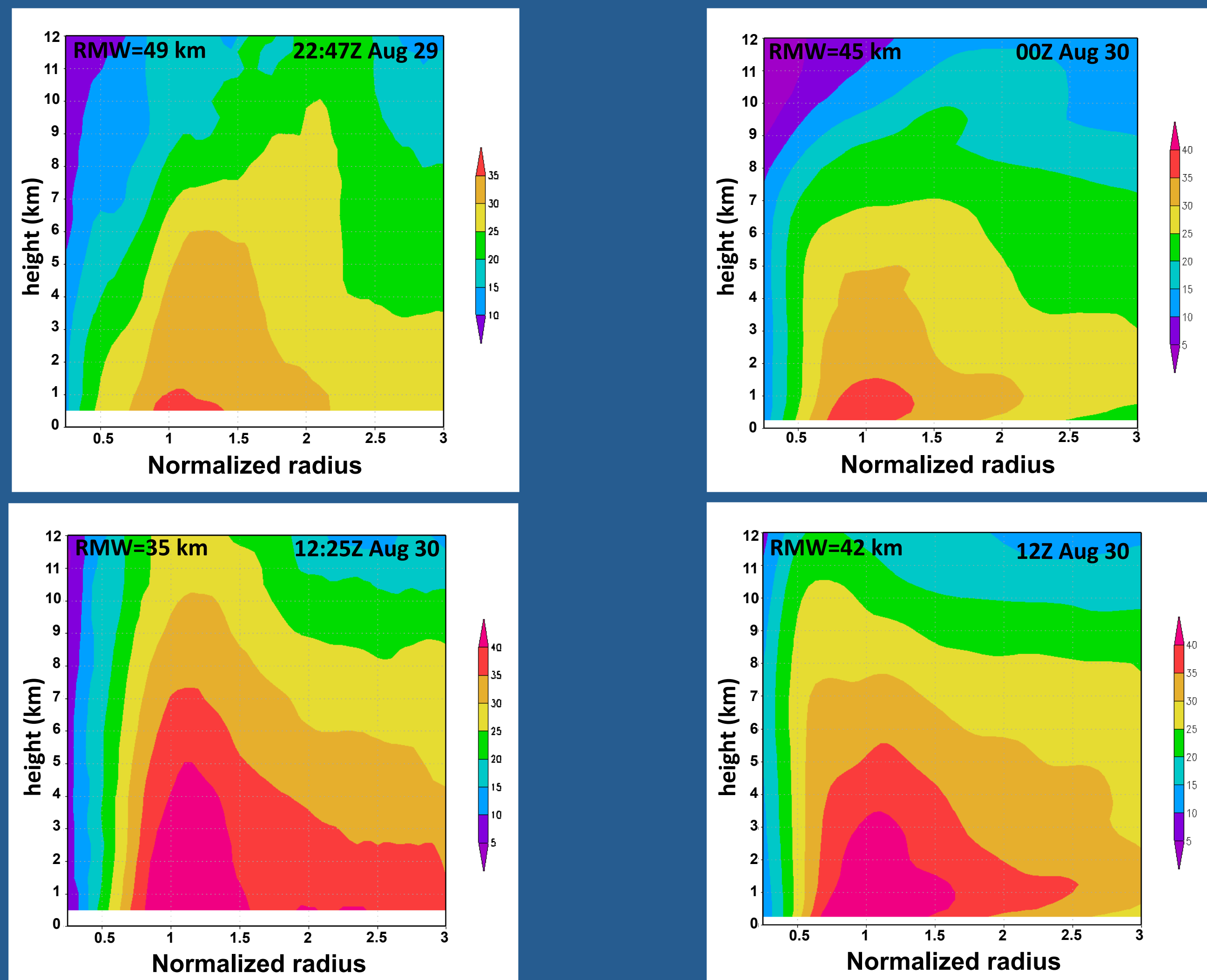
Intensity



Does HWRF capture inner-core structures associated with IN?

Axisymmetric structure – tangential wind (m s^{-1})

Doppler HWRF

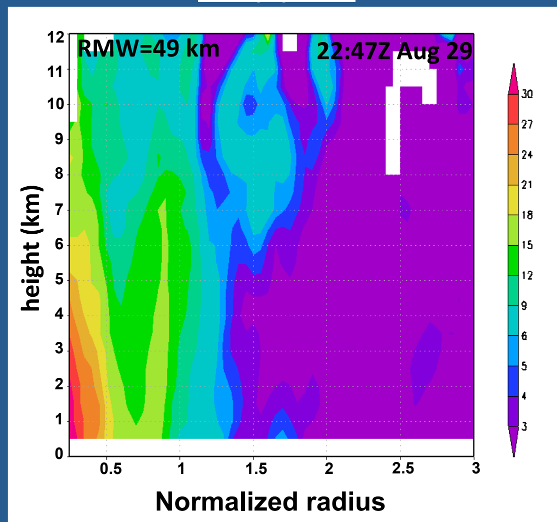


- Similar magnitudes of peak tangential wind
- Similar radial profiles of tangential wind outside RMW

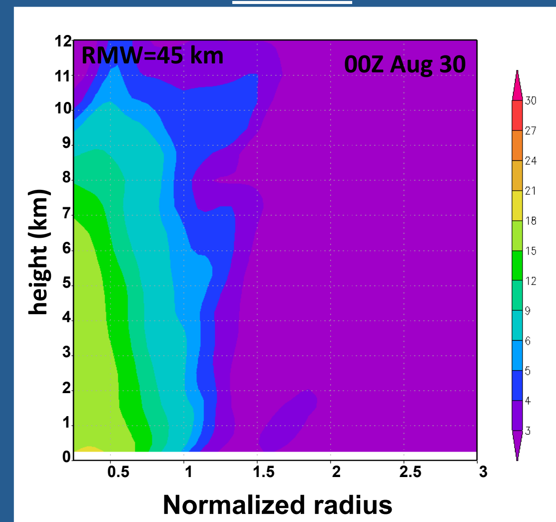
Does HWRF capture inner-core structures associated with IN?

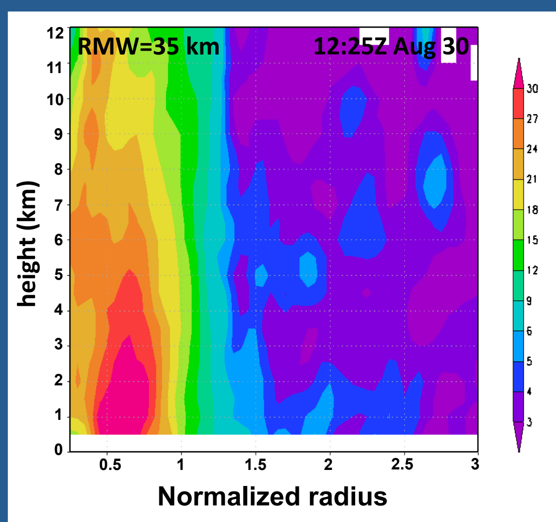
Axisymmetric structure - Vertical vorticity (x 10^{-4} s^{-1})

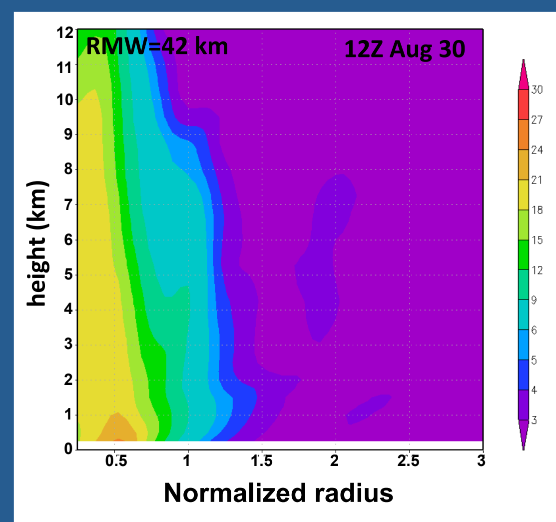
Doppler



HWRF







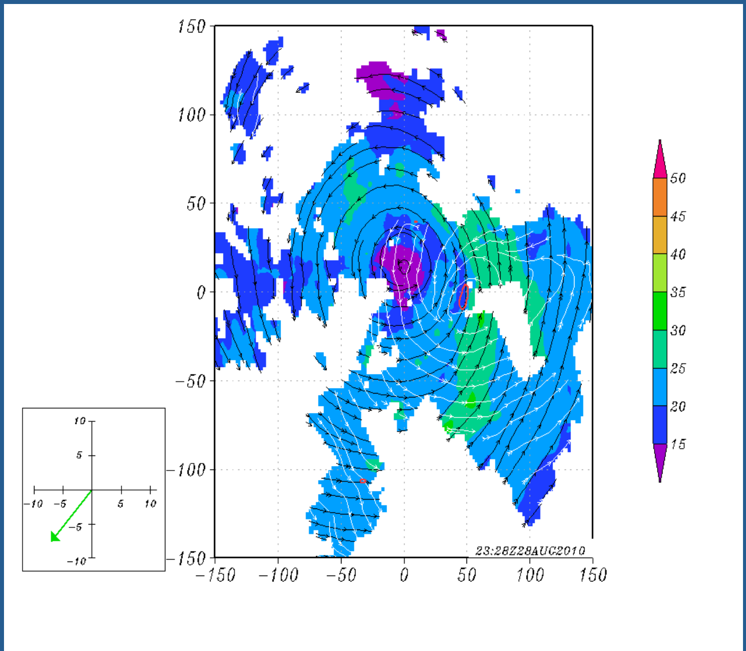
- Weaker magnitudes of vorticity inside RMW (resolution limitation?)
- Suggestion of vorticity ring in HWRF at 12Z
- Similar decrease in vorticity outside RMW

Does HWRF capture inner-core structures associated with IN?

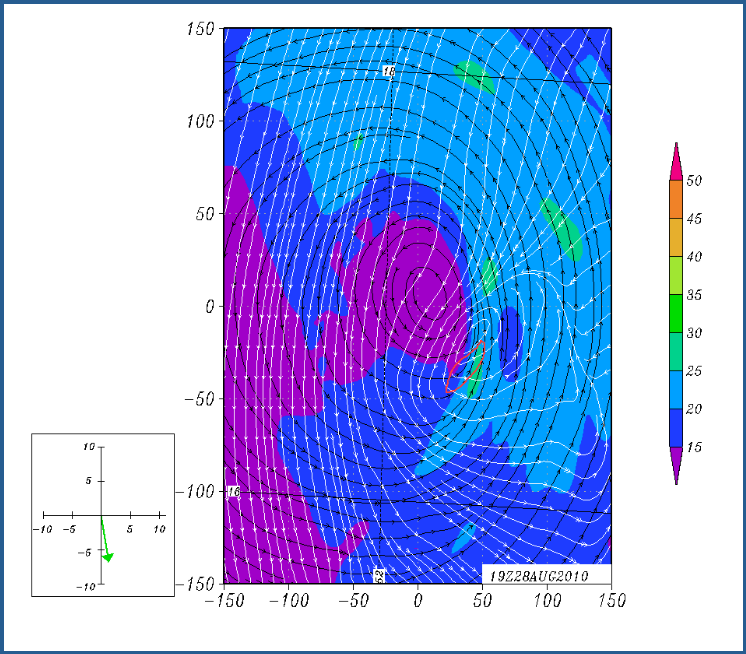
Vortex structure and convective burst distribution

Streamlines and wind speed (shaded, m/s) at 2 km (black) and 8 km (white)
Convective burst locations (top 1% of w distribution) denoted by red contour

Doppler analysis centered at
23:28 UTC 28 Aug



2618 HWRF output valid
19-20 UTC 28 Aug



- Direction of 2-8 km vortex displacement similar between Doppler and HWRF
- Vortex precession seen during 19-20 UTC in HWRF
- Burst area located inside RMW southeast of low-level center, downshear left

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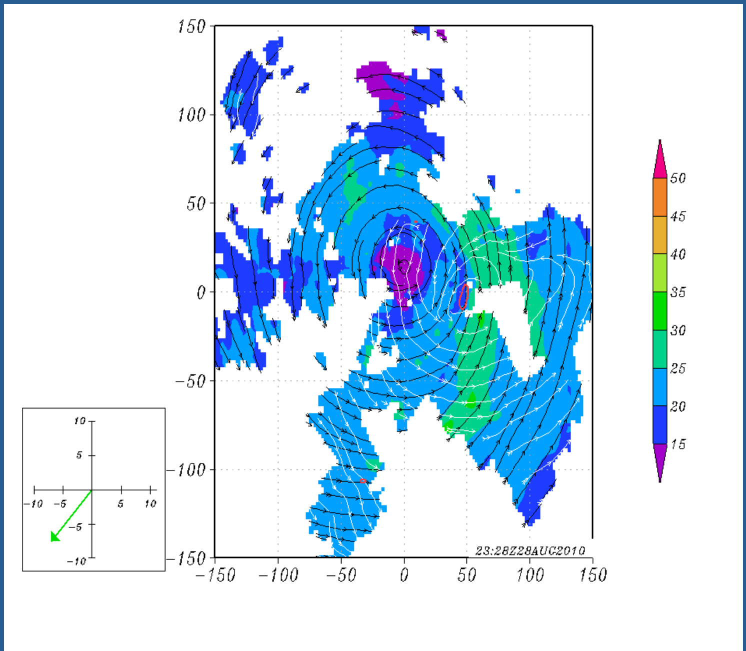

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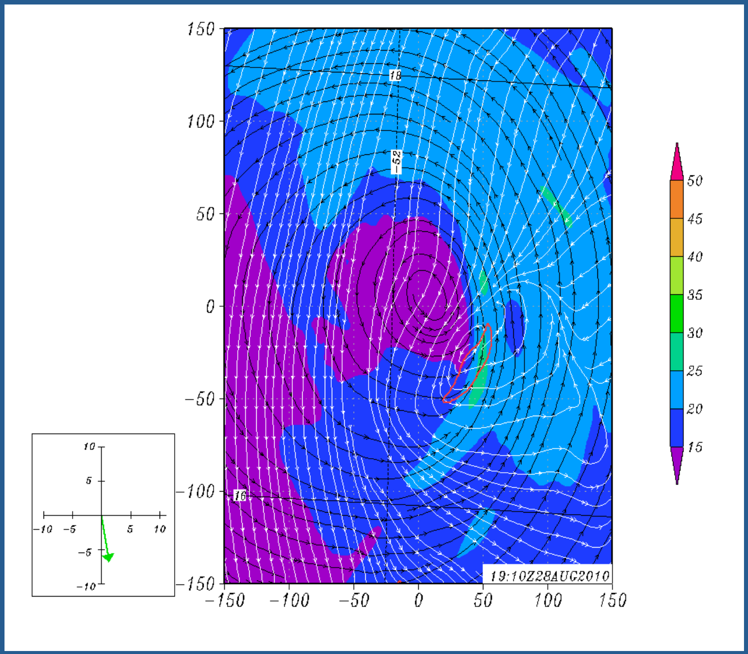

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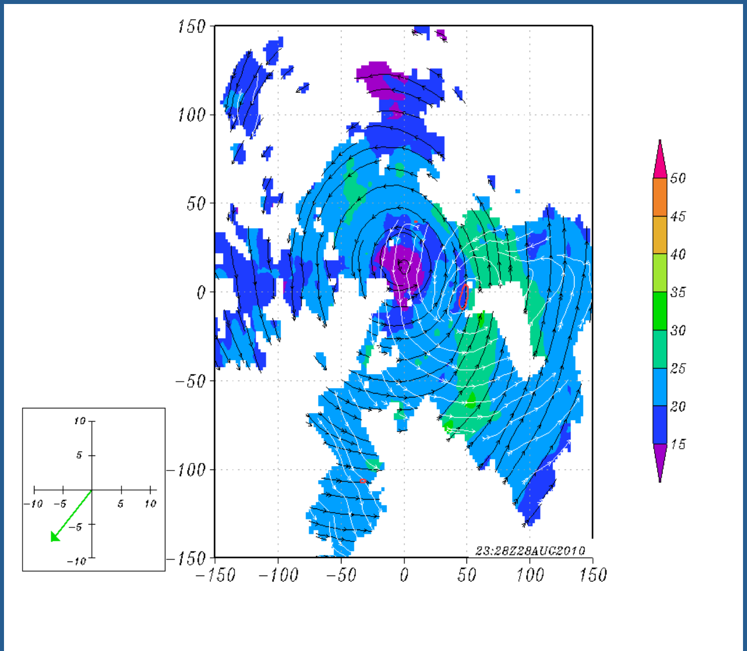

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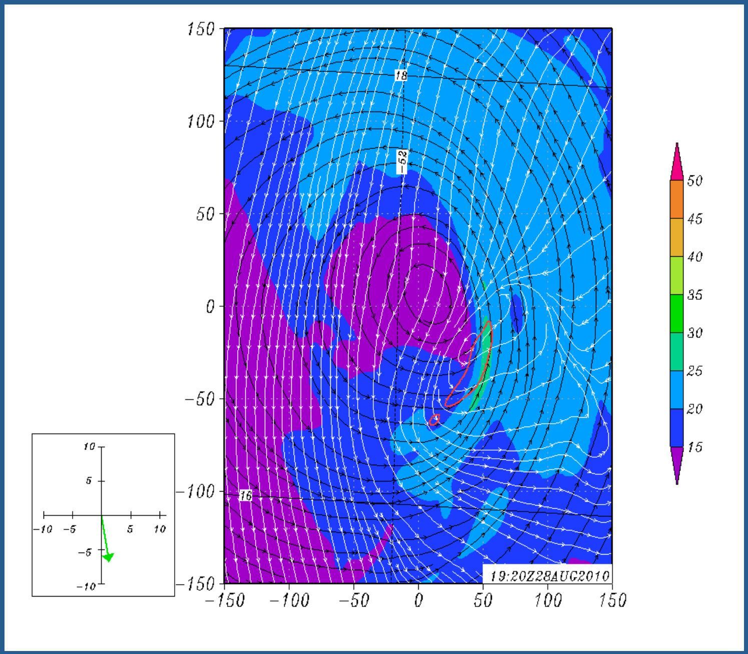

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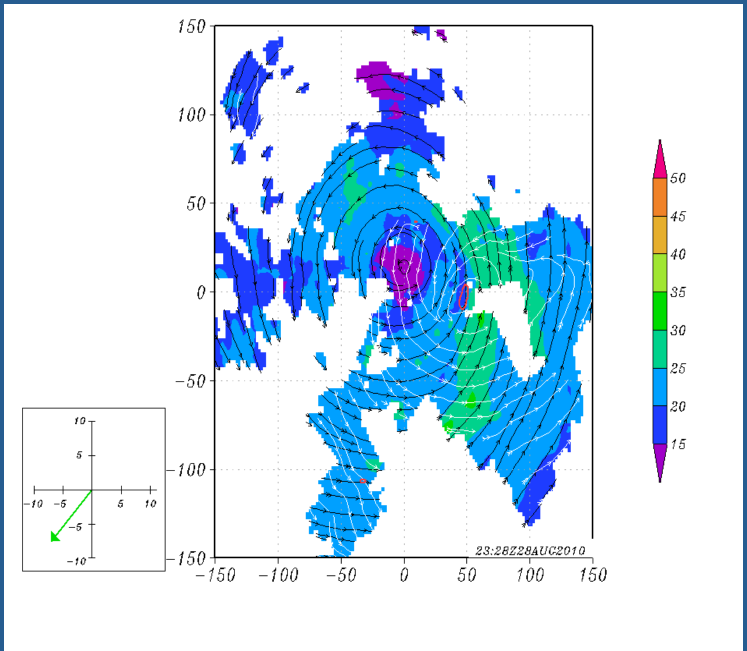

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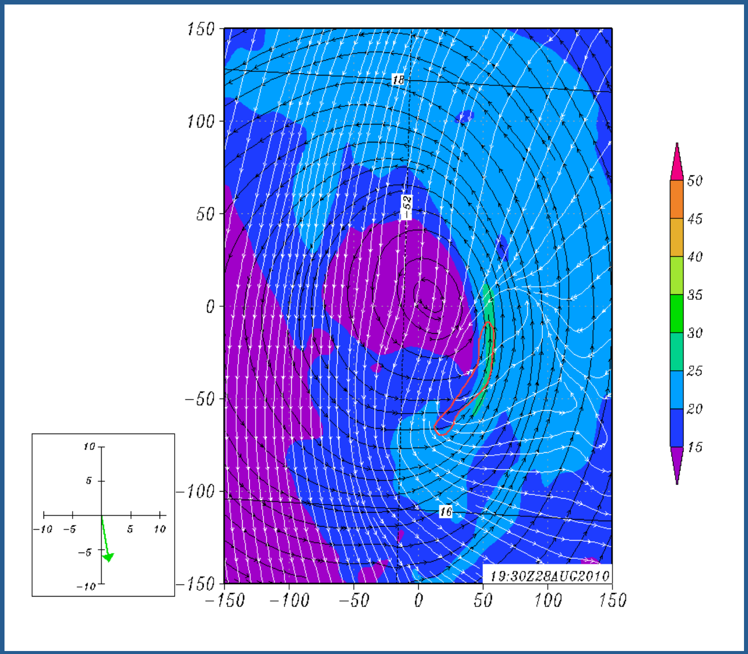

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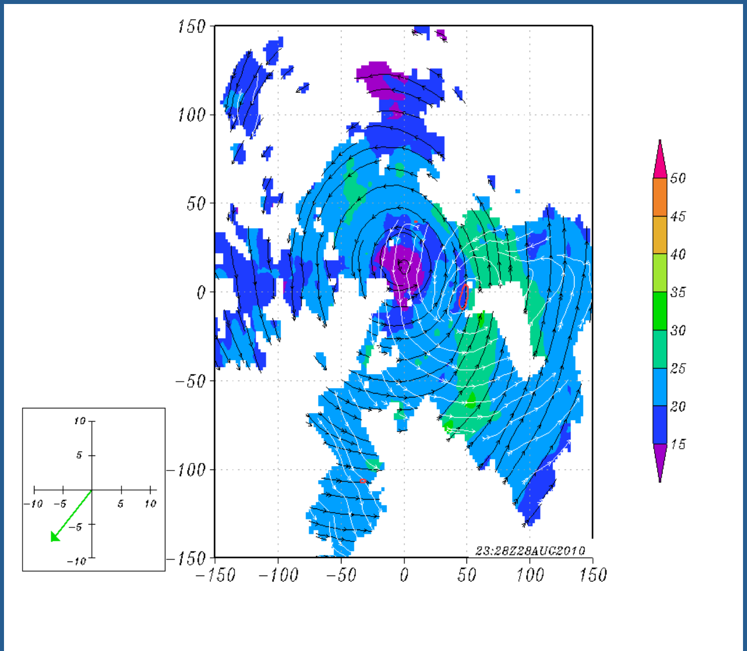

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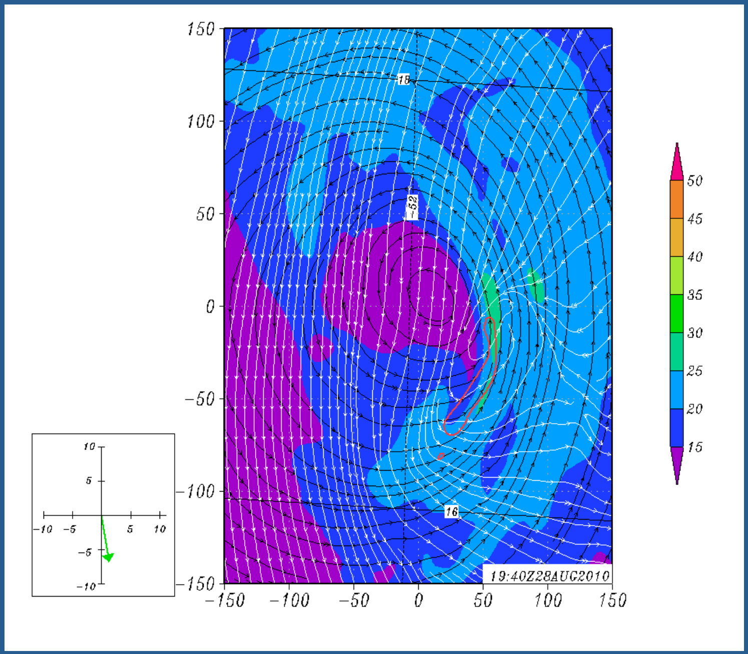

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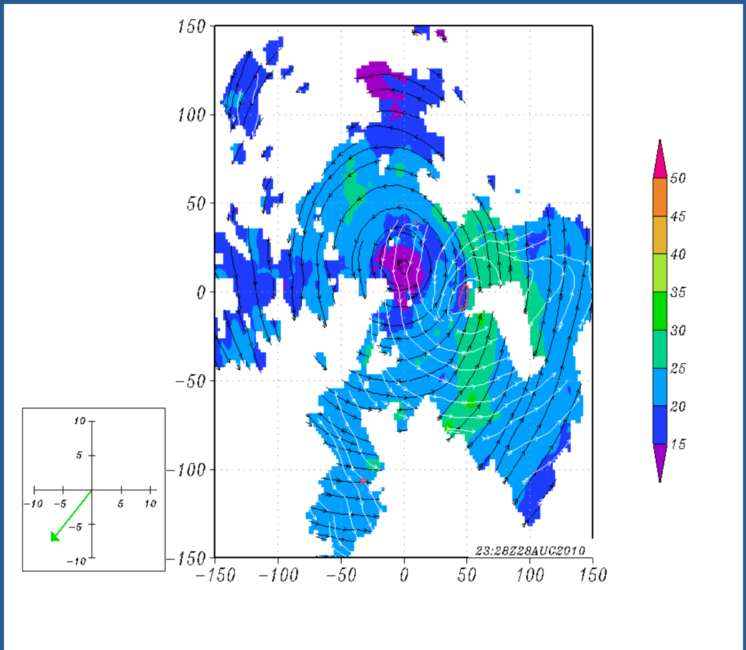

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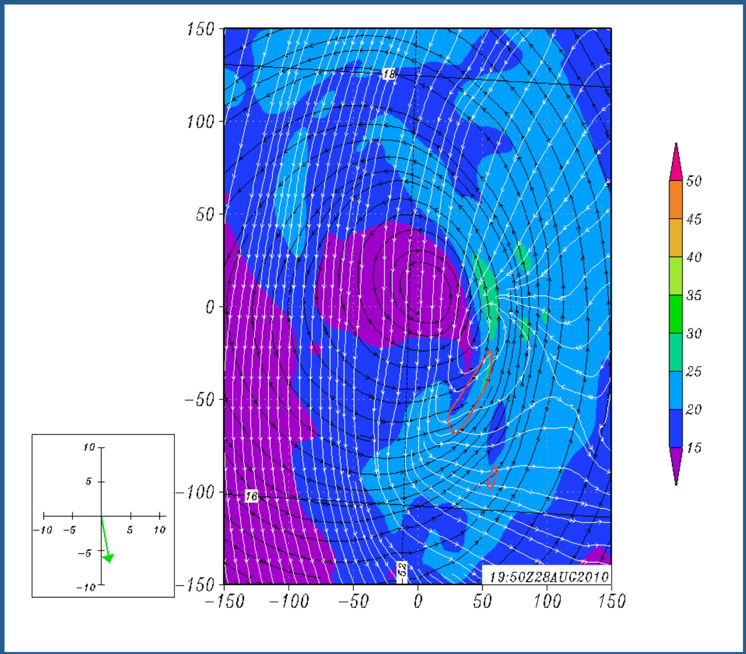

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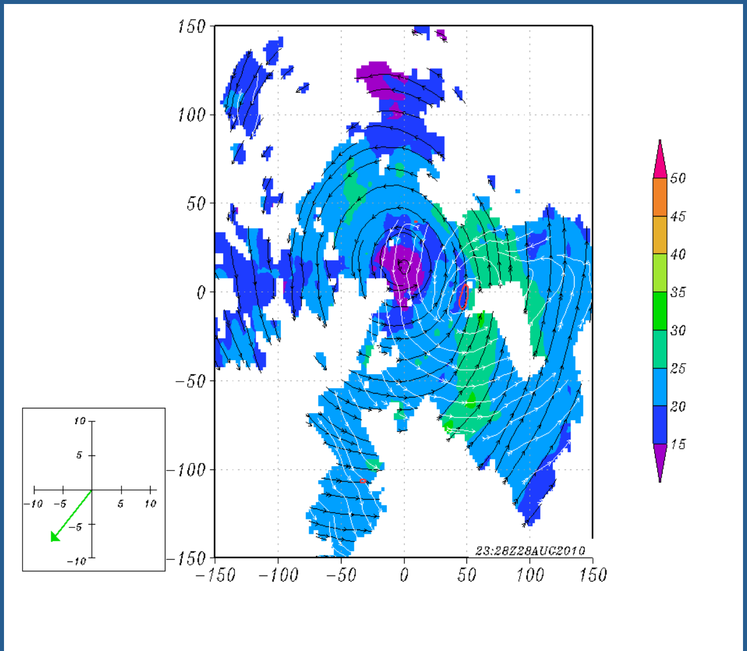

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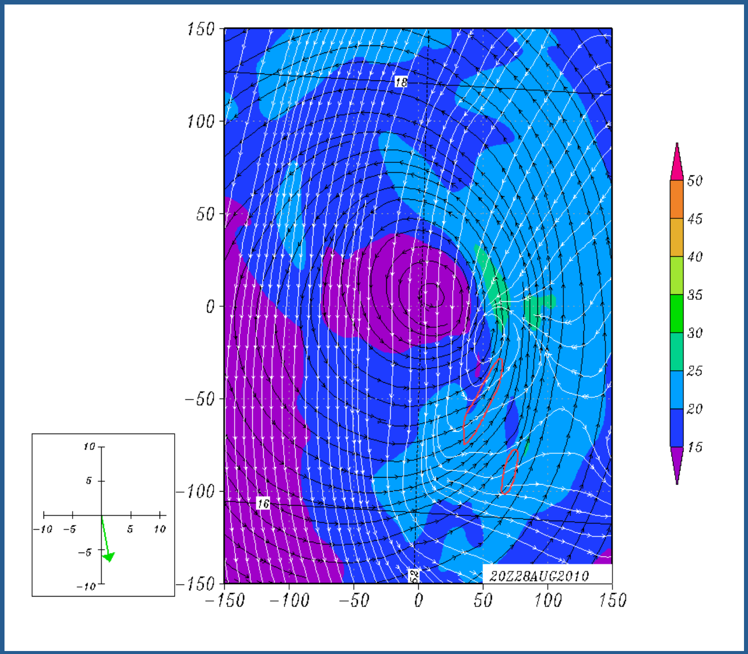

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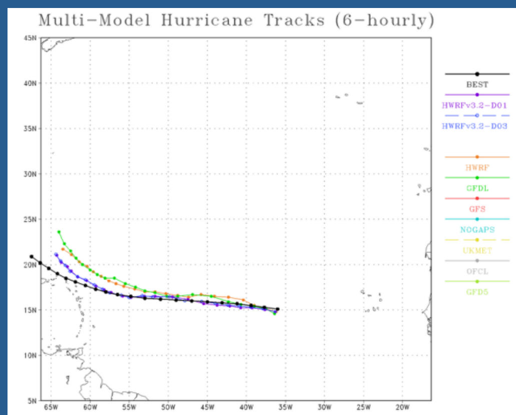
- Burst area located inside RMW southeast of low-level center, downshear left

Can HWRF distinguish between IN and SS cases based on inner-core structure?

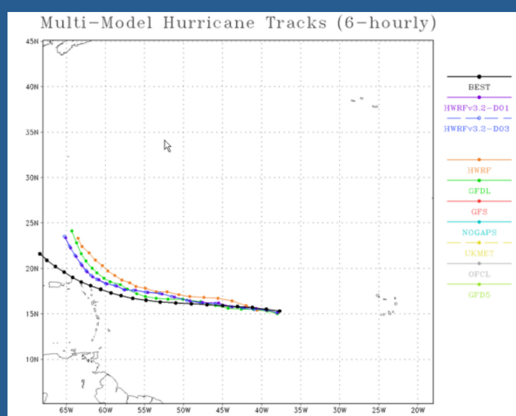
Two HWRF runs: initialized at 12 UTC (2612 run) and 18 UTC August 26 (2618 run)

Storm tracks

26/12 run

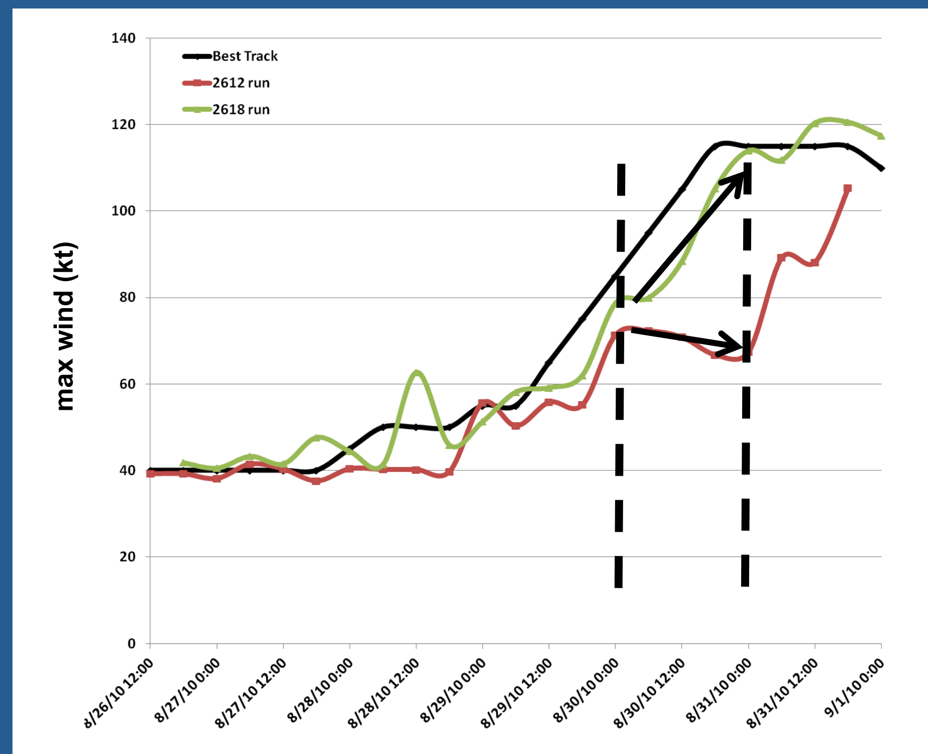


26/18 run



• tracks similar between two runs

Intensity



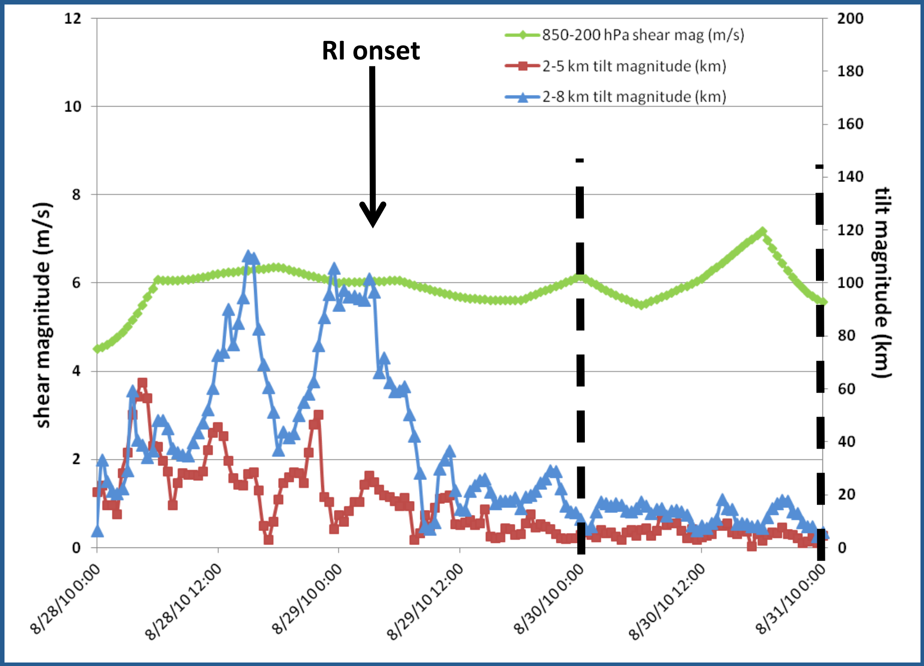
• bifurcation point in intensity trace – between 00 UTC Aug 30 and 00 UTC Aug 31

Can HWRF distinguish between IN and SS cases based on inner-core structure?

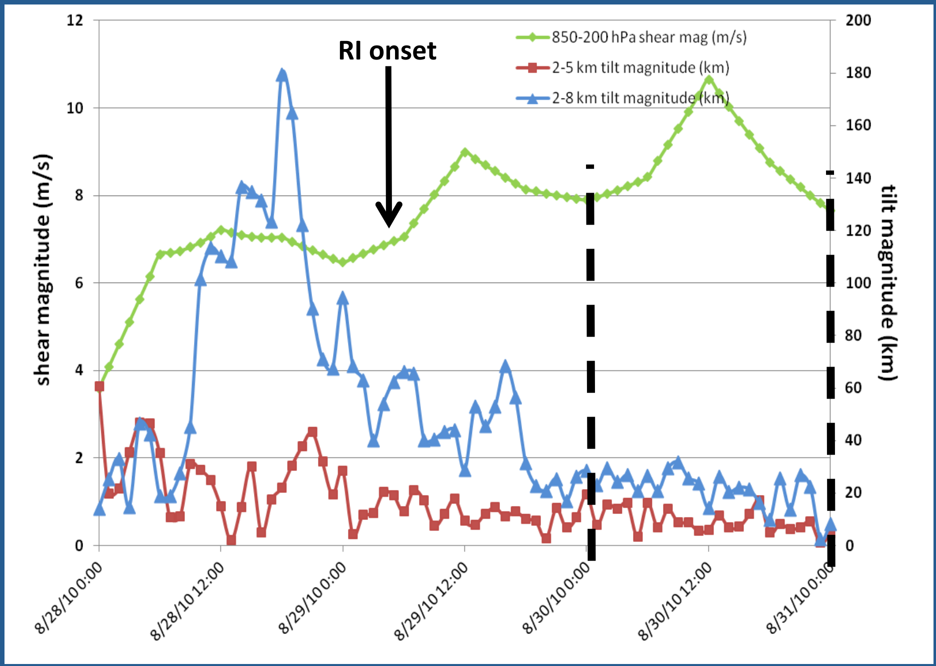
Asymmetric structure

Time series of SHIPS-derived 850-200 hPa shear (m/s), 2-5 km and 2-8 km tilt magnitude (km)

2618 HWRF



2612 HWRF



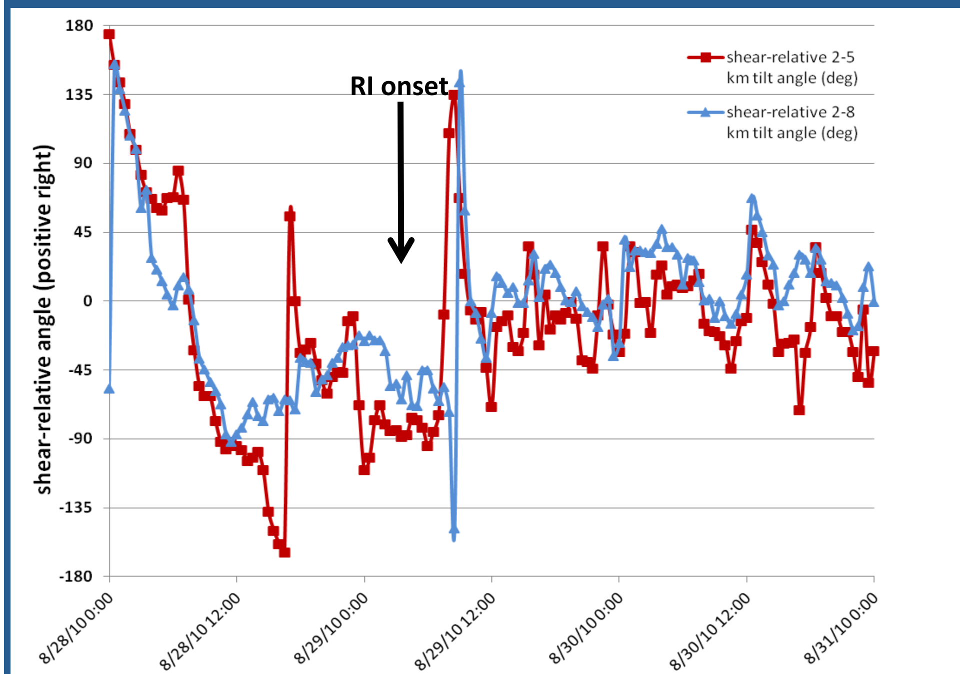
- shear marginally (2 m/s) higher in 2612 run
- both runs show large displacement prior to RI onset, both show continued large displacement at RI onset
- bulk of displacement above 5 km altitude
- vortex becomes nearly aligned several hours after RI onset
- vortex tilt small during bifurcation period, slightly smaller for 2618 run

Can HWRF distinguish between IN and SS cases based on inner-core structure?

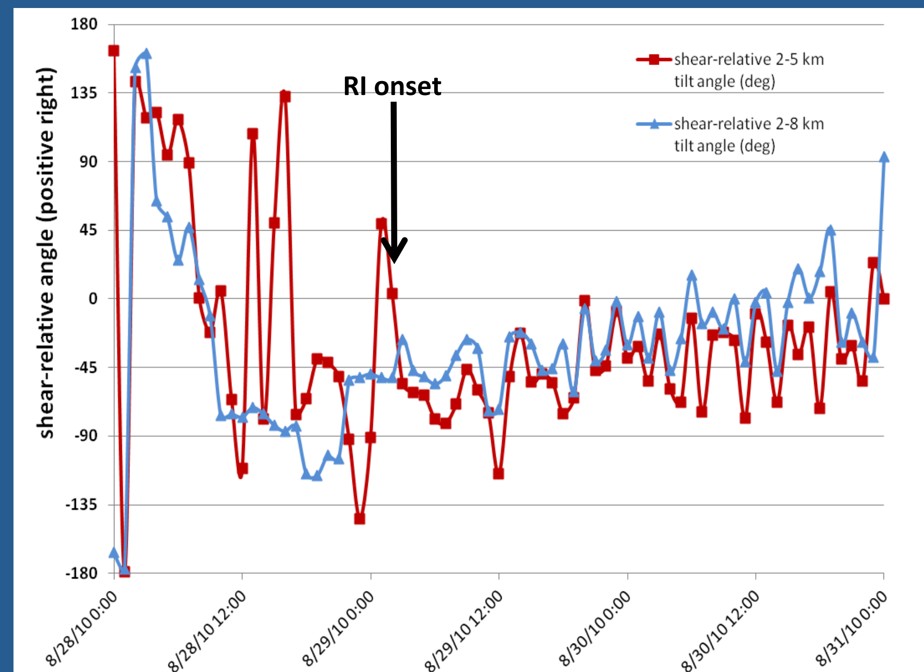
Asymmetric structure

Time series of 2-5 km and 2-8 km tilt phase (degrees, relative to shear vector)

2618 HWRF



2612 HWRF



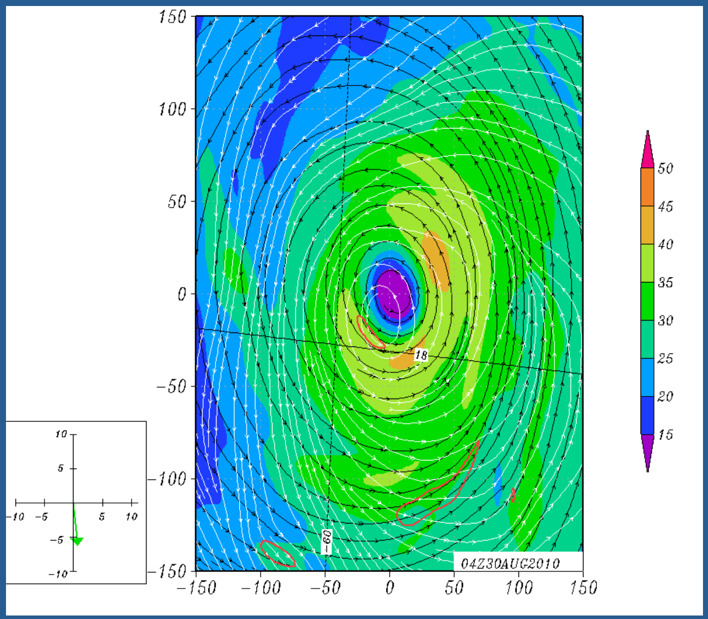
- both runs show vortex that tilts 45-90 degrees left of shear vector prior to RI
- both runs show vortex oscillates between 45 degrees right and left of shear after RI, during bifurcation period

Can HWRF distinguish between IN and SS cases based on inner-core structure?

Vortex structure and convective burst distribution

Streamlines and wind speed (shaded, m/s) at 2 km (black) and 8 km (white)
Convective burst locations (top 1% of w distribution) denoted by red contour

2618 HWRF output valid
04-09 UTC 28 Aug



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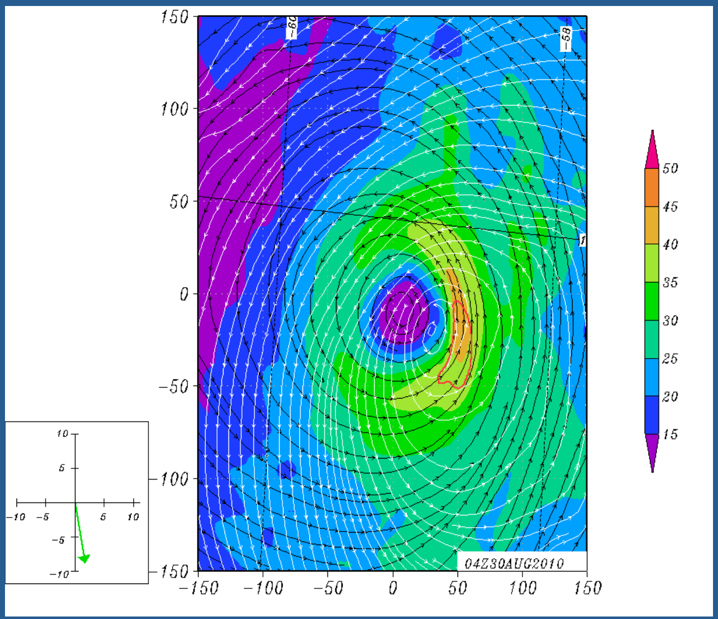

- both runs show convective bursts near, within eyewall at various times during bifurcation period
- 2618 run shows persistent burst in downshear, downshear-left region inside RMW
- 2612 run has transient burst activity during 5-h period shown here
- RI occurrence tied to distribution of moist convection – limited predictability? (Zhang and Tao 2013)

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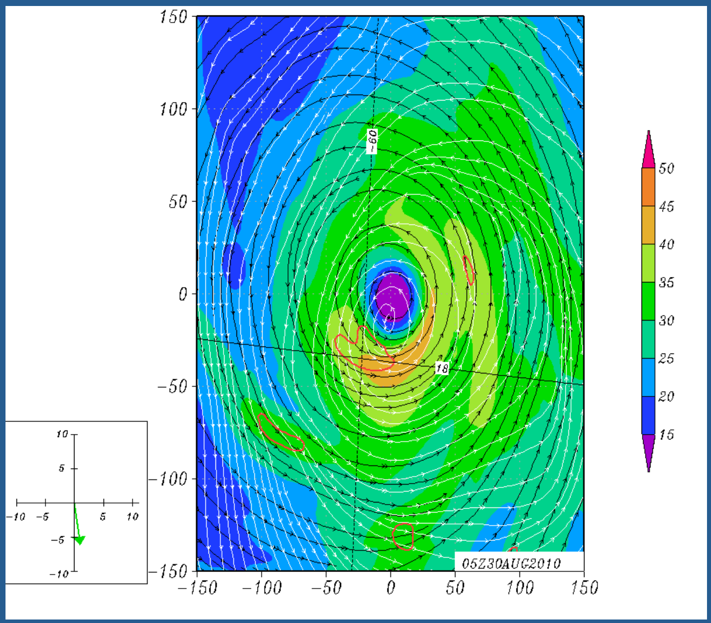

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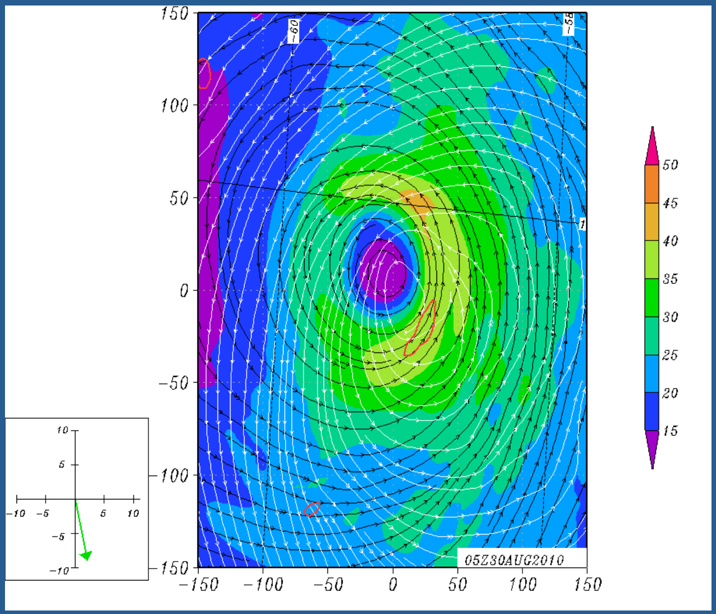
04-09 UTC 28 Aug



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- 2618 run shows persistent burst in downshear, downshear-left region inside RMW
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Can HWRF distinguish between IN and SS cases based on inner-core structure?

Vortex structure and convective burst distribution

Streamlines and wind speed (shaded, m/s) at 2 km (black) and 8 km (white)
Convective burst locations (top 1% of w distribution) denoted by red contour

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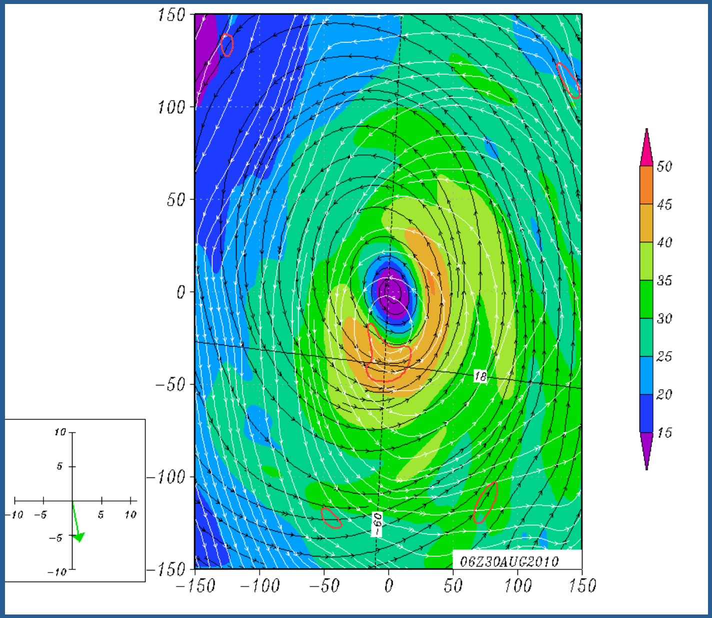

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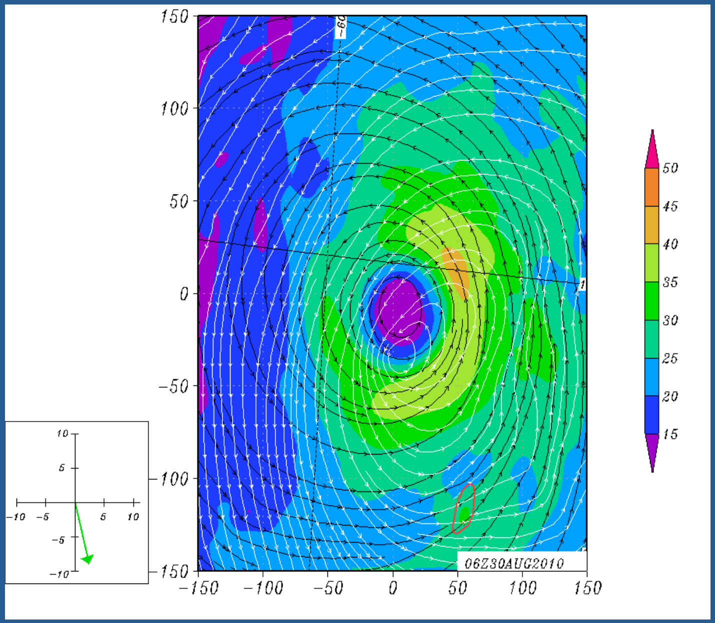

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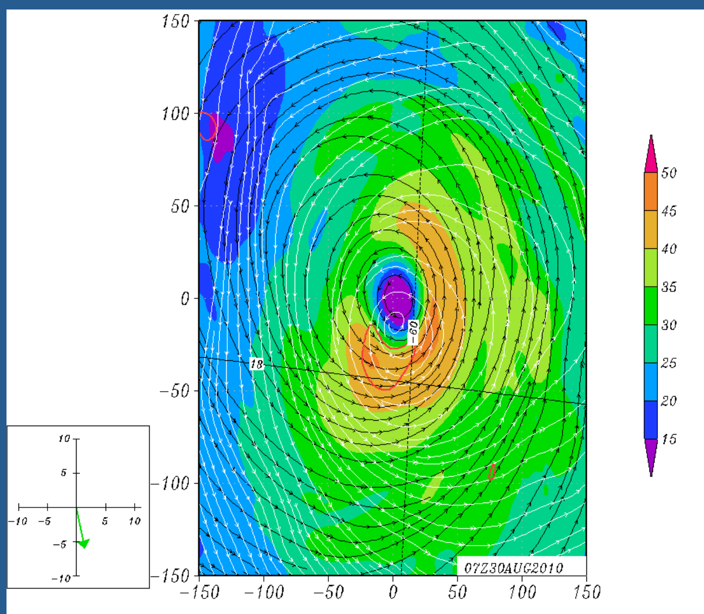

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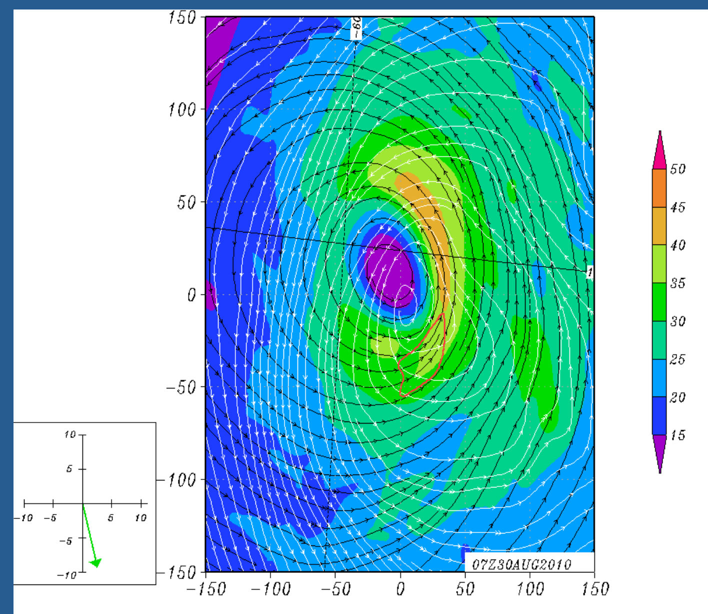

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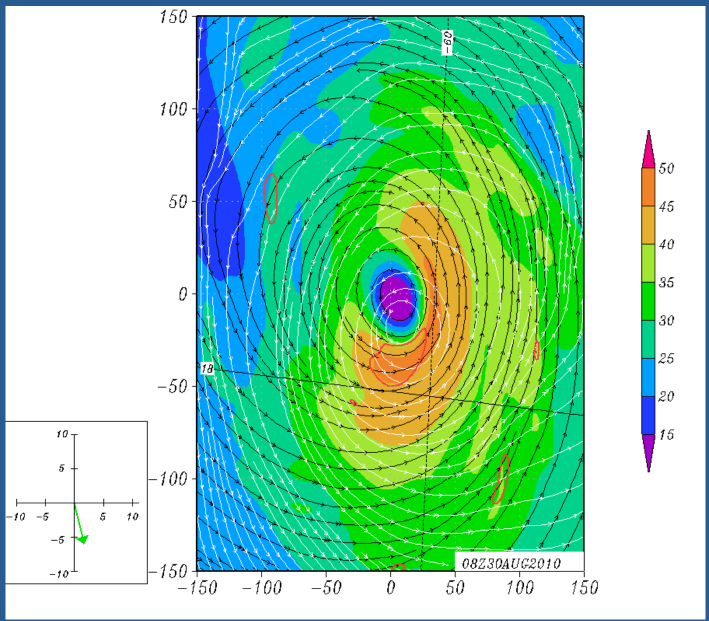

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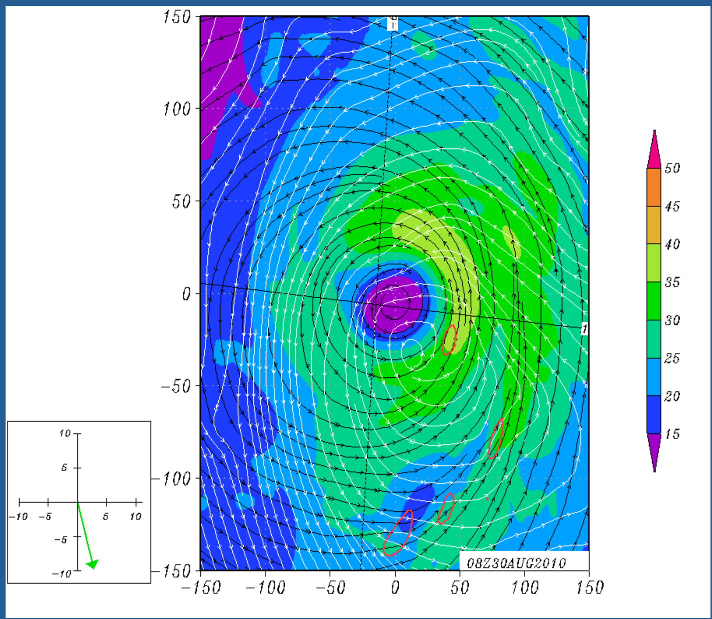

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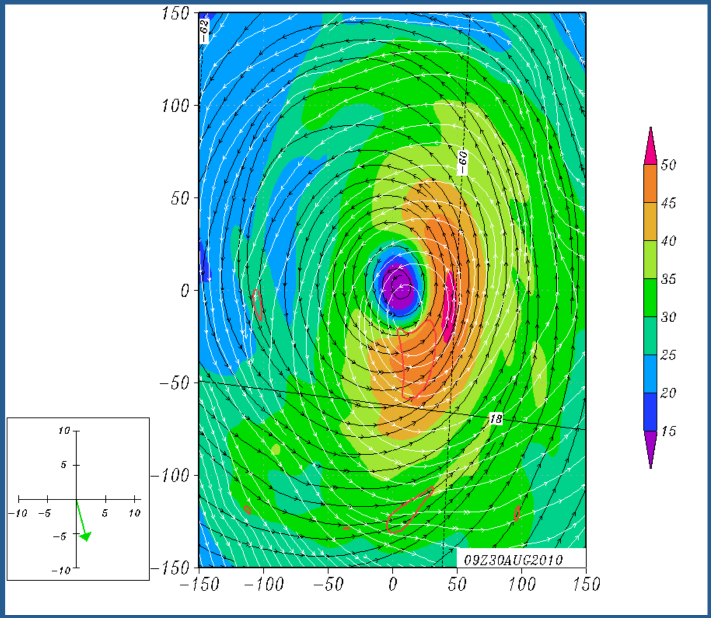

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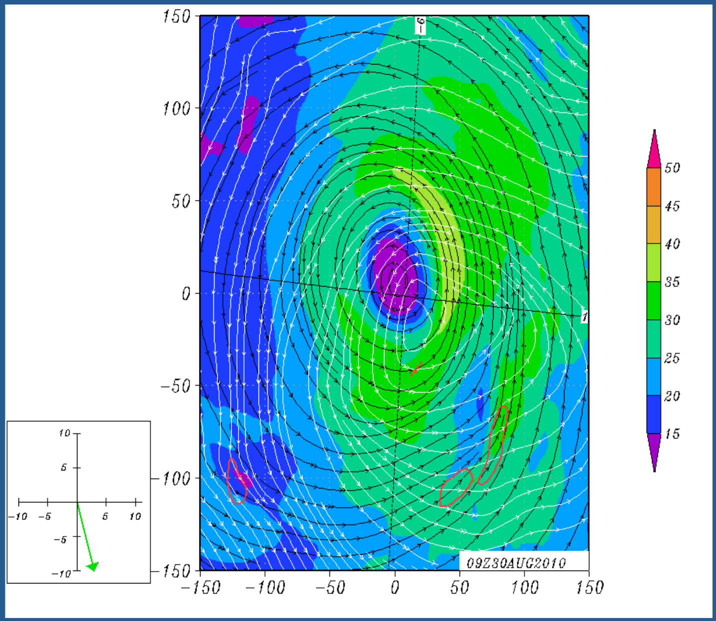

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Ongoing/future work

- continue analysis of Earl aircraft observations, HWRF simulations
    - symmetric and asymmetric structure
    - convective statistics
    - thermodynamic properties

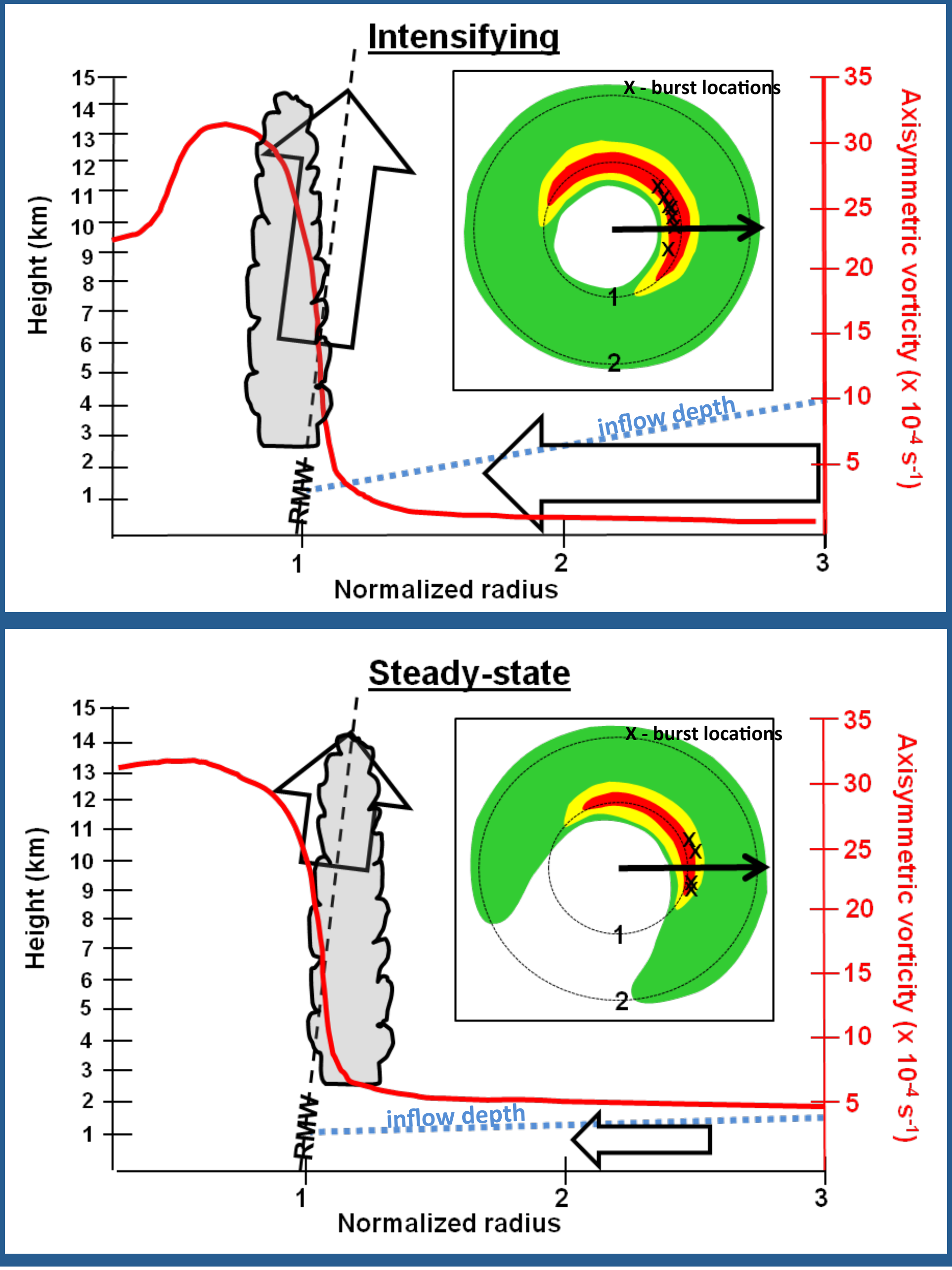
- can we explain reason for transience of convective bursts for 2612 run vs. 2618 run?
    - environmental, vortex structure?
    - predictability limit due to stochastic nature of moist convection?

- expand HWRF analysis to multiple cases for compositing

Extra slides

TC inner-core structure and intensification

Summary schematic



Rogers et al., MWR, 2013