Investigating the factors responsible for secondary eyewall formation in an ensemble of high-resolution hurricane simulations

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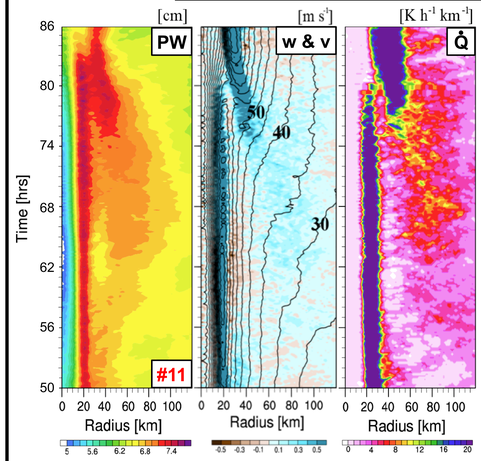
Introduction and Motivation

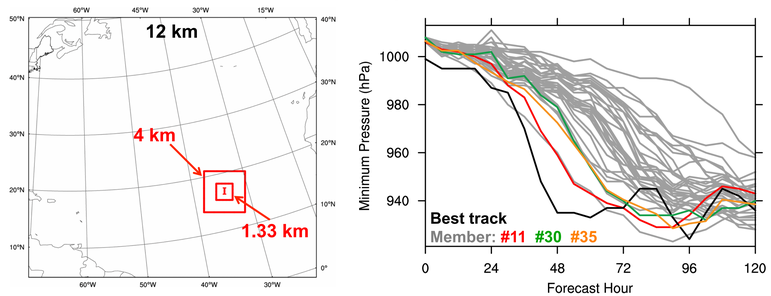


A variety of numerical frameworks have been used to support hypotheses of secondary eyewall formation (SEF); however, it is unclear whether idealized models are appropriate to study the problem, and convection permitting studies often examine just one case, preventing any assessment of the generality of the conclusions.

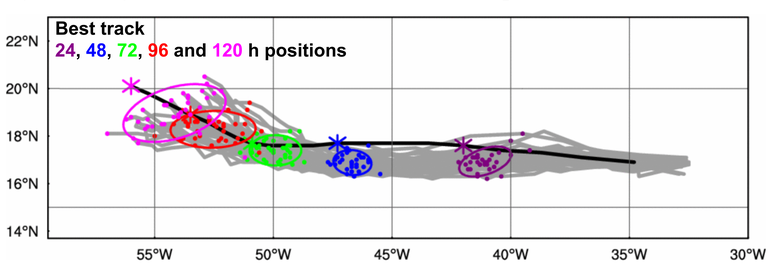
To explore the physical processes responsible for SEF, a cycling, ensemble Kalman filter (EnKF) approach is combined with the full physics NCAR Advanced Hurricane WRF (AHW) model to generate ensemble forecasts of Hurricane Igor (2010).

Model Setup and Methodology

The AHW EnKF data assimilation system generated a 96 member analysis ensemble every 6 h for a basin scale 36 km domain, and a 12 km TC-following nested domain.

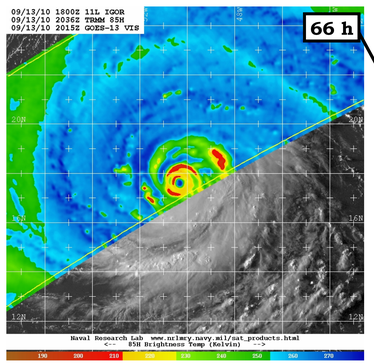


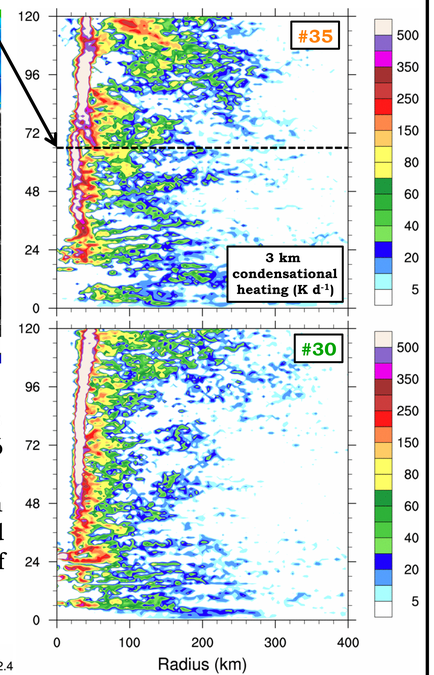
Analyses from 36 members were used to initialize high-resolution (1.33 km) forecasts from 0000 UTC 11 September out to 120 h.



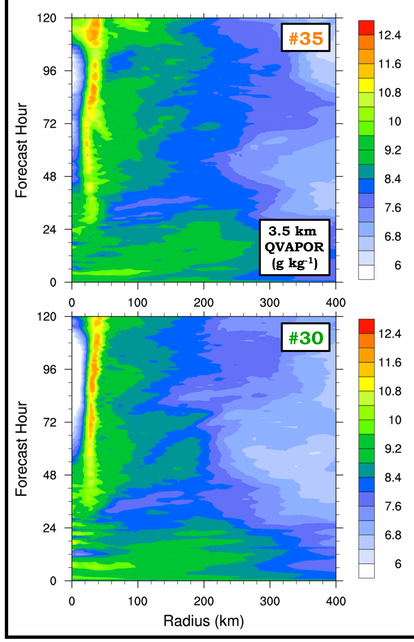
Ensemble Variability

9 of the 36 ensemble members exhibited a clear secondary eyewall inside the 100 km radius and completed an eyewall replacement cycle (ERC) between 54 and 84 h, consistent with observations.

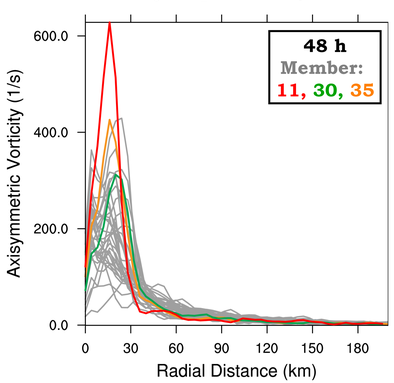




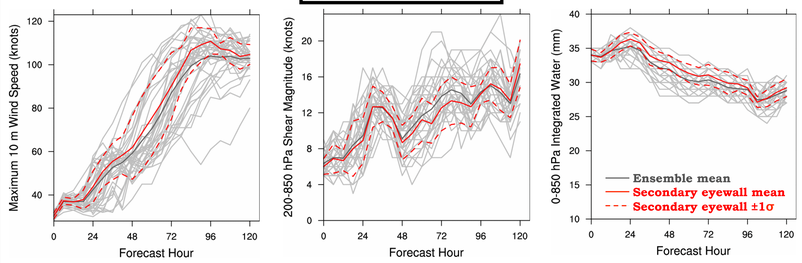
A comparison between two of the strongest members reveals a classic SEF/ERC between 66 and 78 h, followed by a strong moat and second SEF ~96 h in **#35**; in contrast, **#30** exhibited the slow, outward movement of the eyewall and expansion of the convective field.



Only subtle differences are seen in storm structure with **#30** exhibiting a stronger moisture gradient between the inner core and environment, and **#35** featuring a slightly more radially expansive β-skirt.

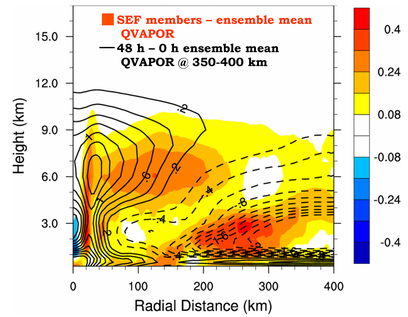


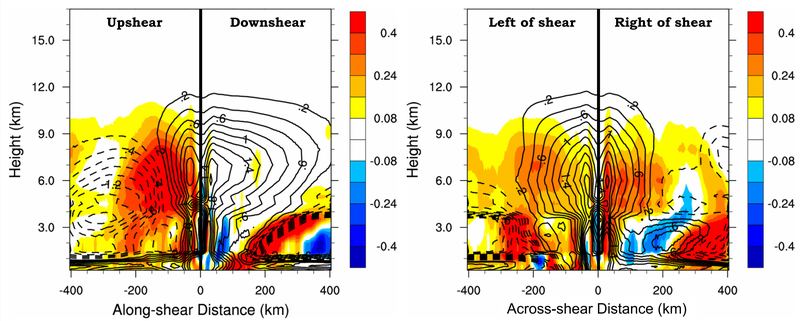
Composites



The members exhibiting secondary eyewalls are more intense on average, especially in the time period after the eyewall replacement cycles are complete (78-102 h). The time period of SEF featured below ensemble mean vertical wind shear and significantly higher upshear 0-850 hPa vertically integrated water within 500 km.

At 48 h, the largest water vapor mixing ratio anomalies in the SEF cases are seen: 1) in the eyewall upshear and right of shear, 2) at middle levels 50-200 km upshear of the center, and 3) at low levels outside of 200 km. The first hints of SE development can be seen in the double maxima of anomalous QVAPOR at 3 km.





Future Work

- ~ Assess hypothesized secondary eyewall formation mechanisms, e.g. vortex Rossby waves, β-skirt axisymmetrization, etc.
- ~ Examine the mechanisms of moat generation and its role (if any) in SEF
- ~ Investigate the differences between SEF in the inner core versus outer rainband region
- ~ Explore the environmental factors conducive for SEF