Diagnosing Track Bias of Hurricane Barry in the UFS Short-Range Weather Application

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Motivation and Background

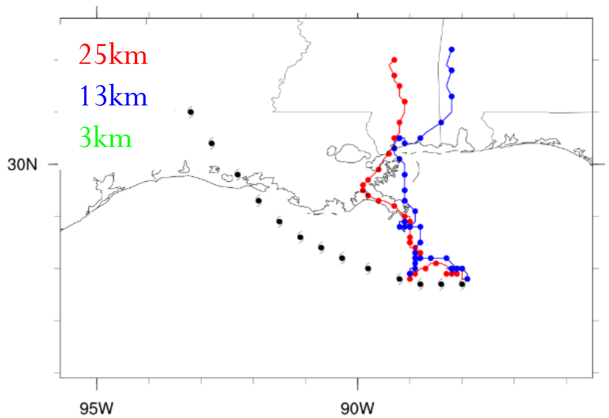
- Case study of larger DTC project investigating scalability of UFS physics suites.
- Hurricane Barry (July 2019)
  - Highly asymmetrical (most convection south of TC center) due to strongly sheared environment
  - Substantial right-of-track bias in UFS forecasts (up to 350 km)

Physics Suites

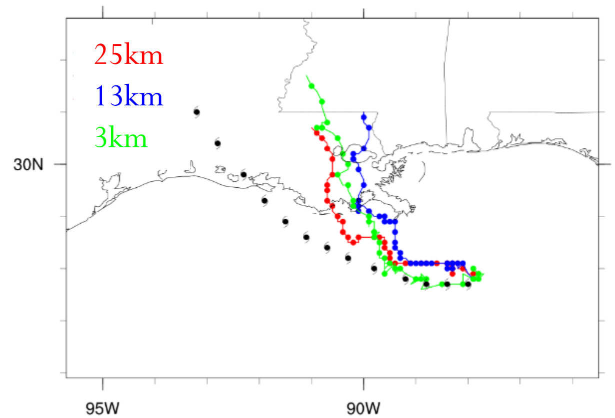
- GFS
  - GFDL-MP (Like GFSv14 physics + GFDL MP)
  - GFSv15.2 (Current operational GFS physics)
  - GFSv16beta (Proposed for GFSv16)
- GSD
  - GSDv0 (Like RAP/HRRR + GFS Surface Layer)
  - GSD_noah (GSDv0 + Noah LSM)
  - GSD_nomy (GSDv0 + Noah LSM + MYNN Surface Layer)
- Initialized UFS SRW app with GFS IC/BCs

Track Bias

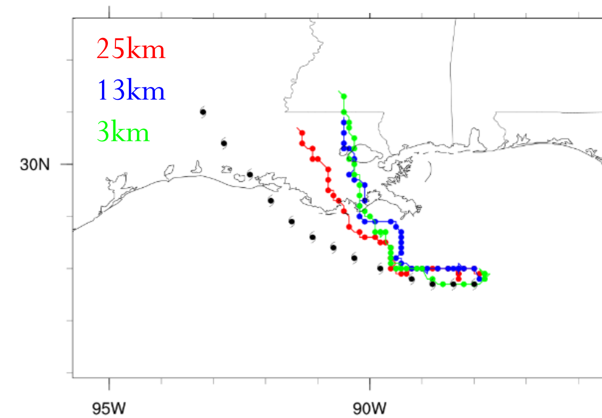
GFDL-MP



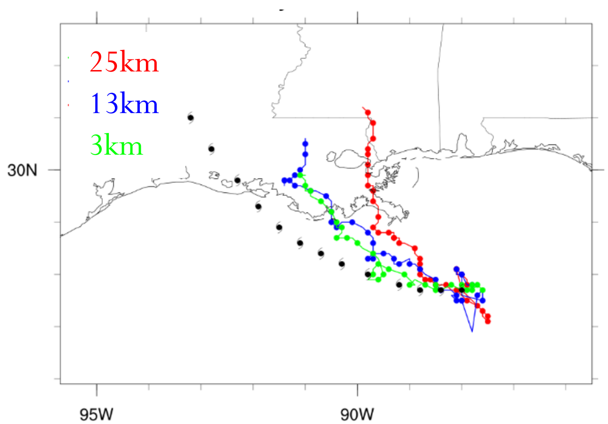
GFSv15.2



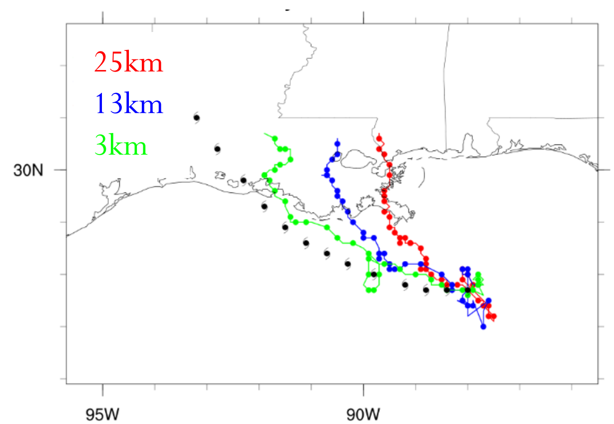
GFSv16beta



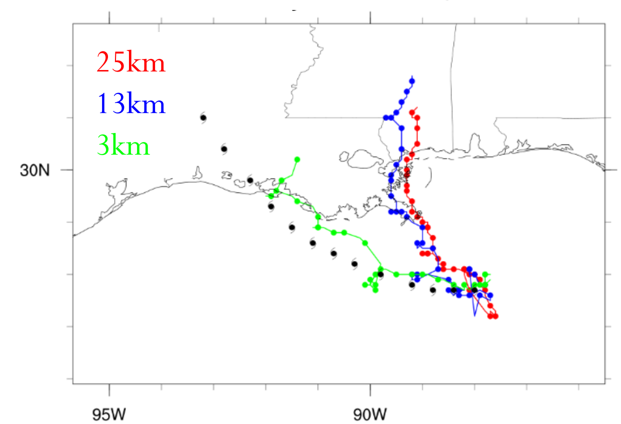
GSDv0



GSD_noah

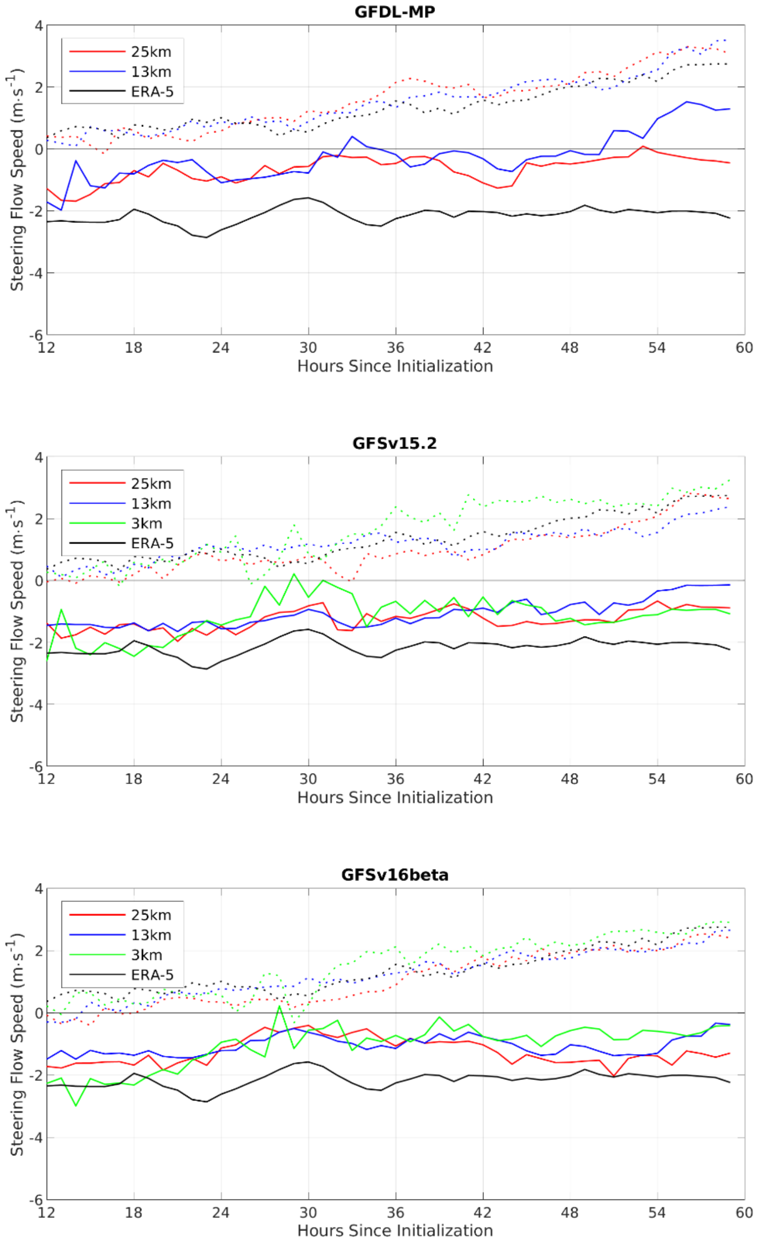


GSD_nomy



Courtesy: Kathryn Newman

Steering Flow (GFS)



Computed as in Galarneau and Davis (2013)

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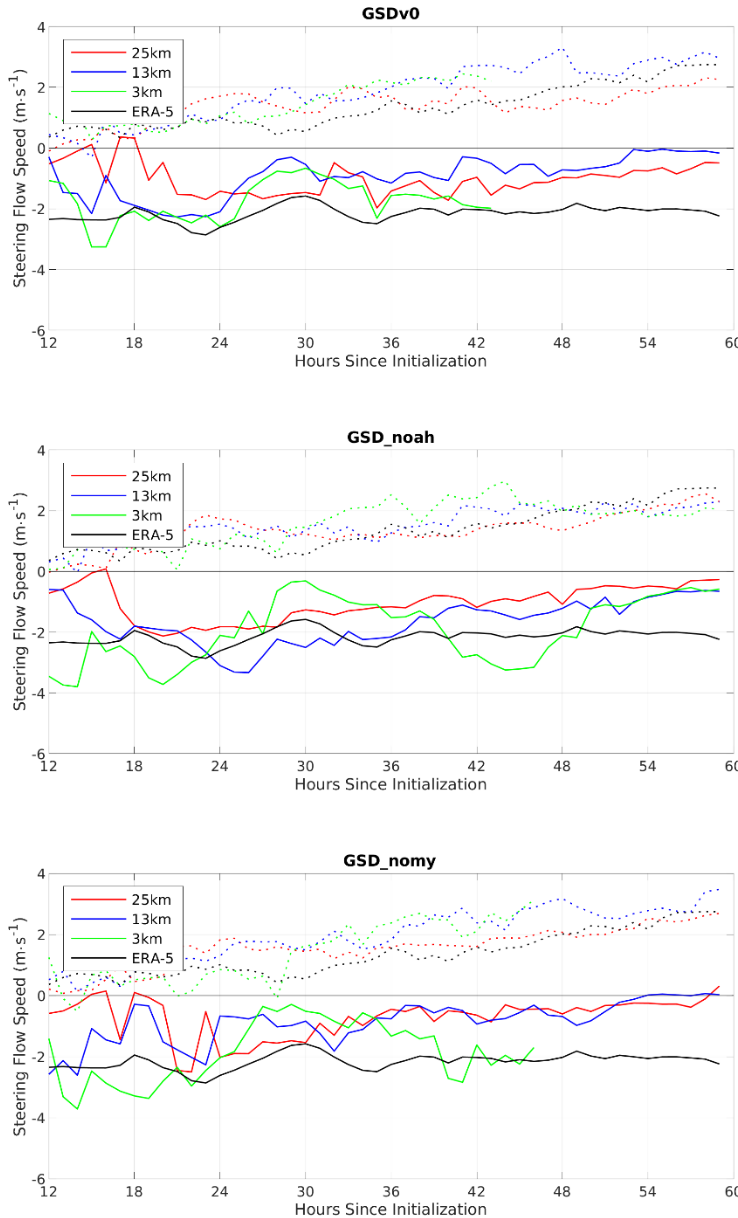
Steering Flow (GSD)



Computed as in Galarneau and Davis (2013)

Convection, Vortex Tilt, and Warming

- Convective heating favors coupling between vortex centers on different vertical levels, so overactive convection would tend to reduce vortex tilt and accelerate precession more rapidly.
  - *Convective heating has two effects on the evolution of vortex tilt. The first is that convective heating aids the coupling between vortices at different levels, and thus prevents further departures of upper-level vortices from lower-level vortices… The second effect is that enhanced coupling also leads to higher precession rates…* (Gu et al., 2019).
- Vortex warming follows from convective burst concentration in downshear-left and upshear-left quadrants, (SE and NE of TC center, respectively, in this case).
  - *…when* [convective bursts (CBs)] *occur in the downshear-left and upshear-left quadrants, convective-scale subsidence induced at the downstream by the CBs is superposed on the mesoscale descent in the upshear region, and the net effect of the warming will be amplified"* (Chen and Gopalakrishnan, 2015).
- When convective bursts occur further away from TC center, it becomes less likely that the temperature advection associated with this superposition of mesoscale and convective scale subsidence will be advected into the storm center (Chen and Gopalakrishnan, 2015).

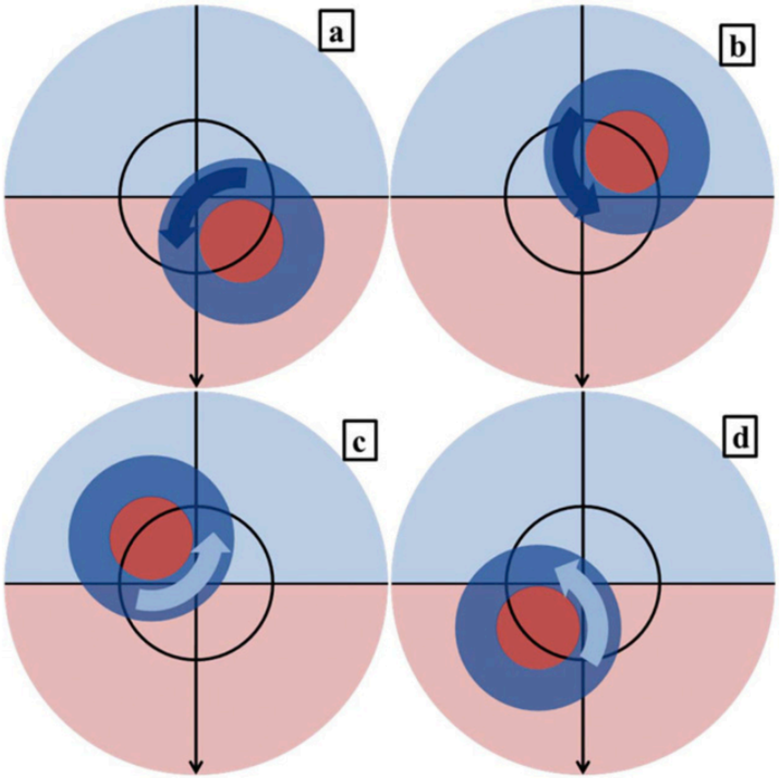
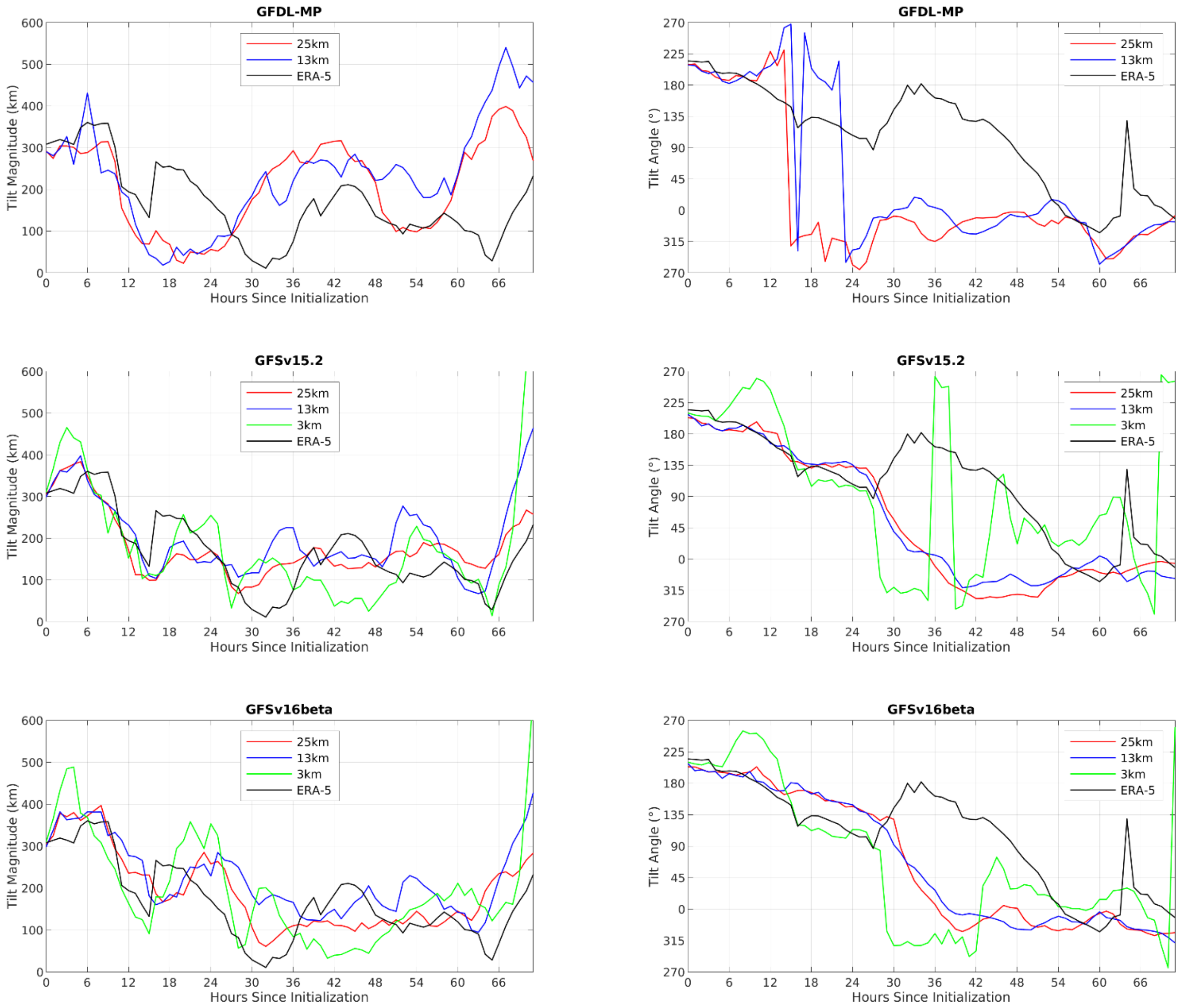


FIG. 12. Schematic depiction of configuration of shear-induced mesoscale subsidence (light blue semicircles), mesoscale ascent (light red semicircles), CBs (dark red circles), and convective-scale compensated subsidence (dark blue rings). The black circle indicates the RMW at the surface, and the black downward arrows show the shear direction (northerly shear). The thick blue curved arrows indicate the upper-level flow associated with CBs. For CBs located in (a) downshear left and (b) upshear left, convective-scale subsidence is superposed on the mesoscale subsidence. For CBs located in (c) upshear right and (d) downshear right, convective-scale subsidence is superposed on the mesoscale ascent.

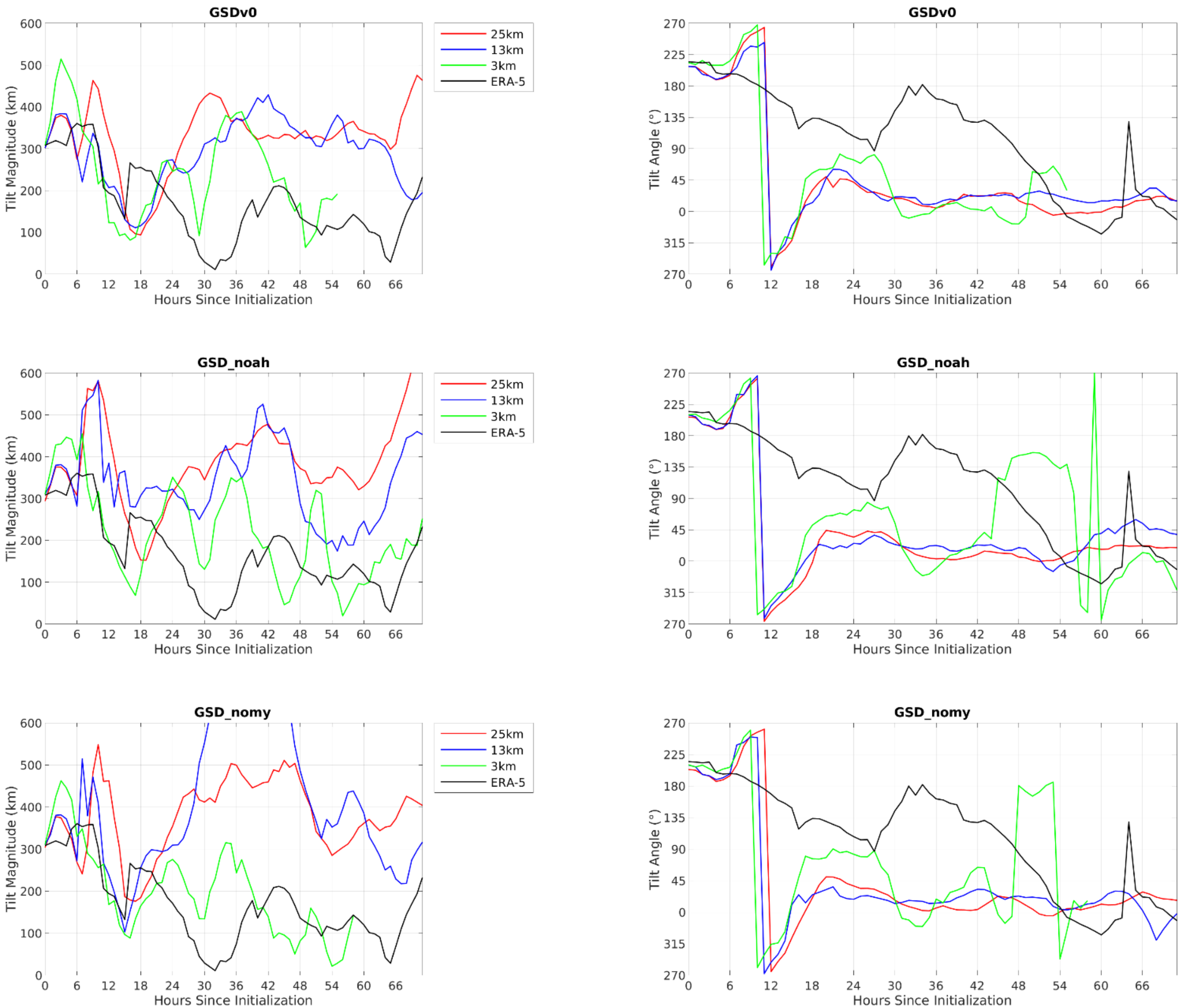
Courtesy: Chen and Gopalakrishnan (2015)

Vortex Tilt



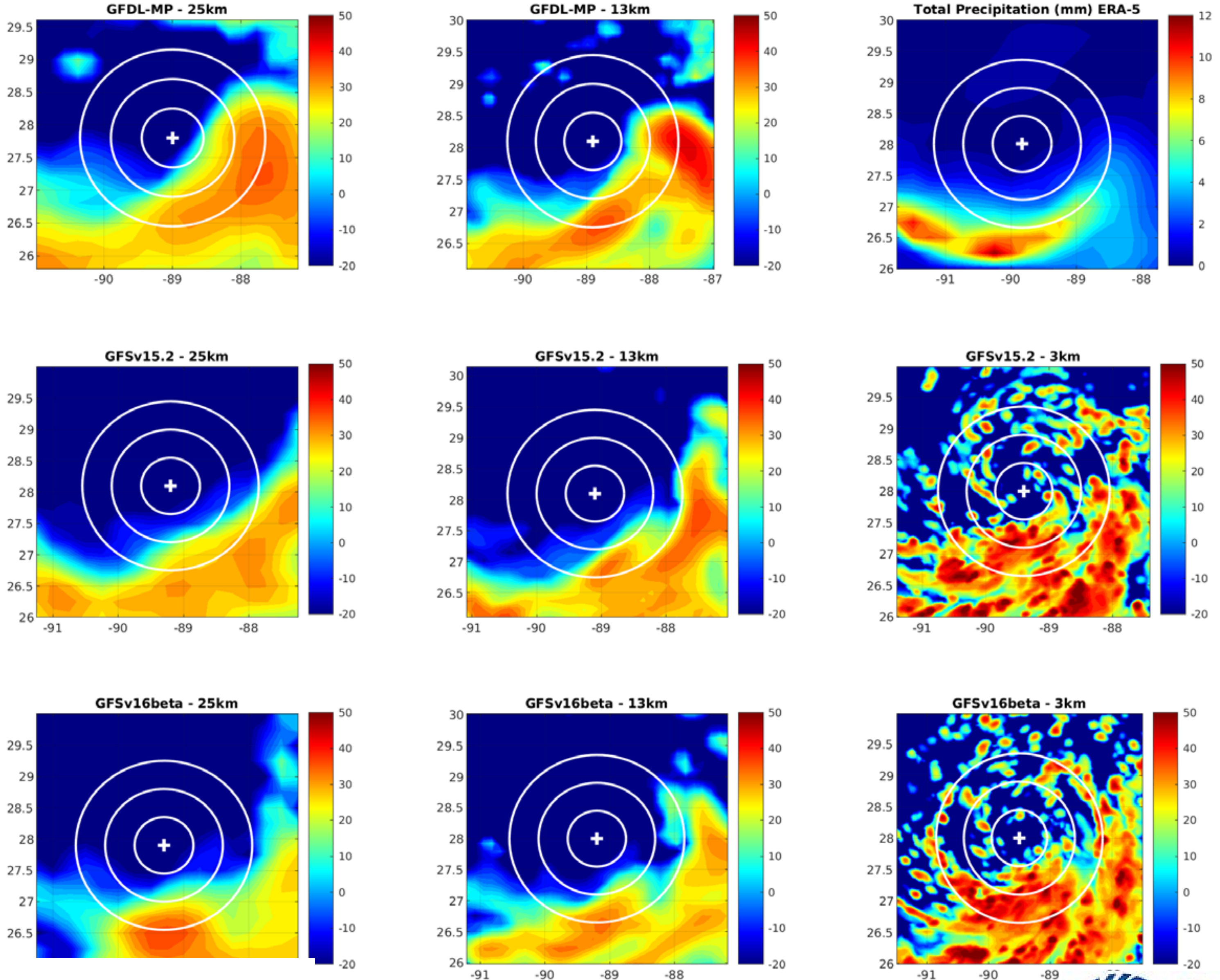
GFDL-MP
Tilt Magnitude (km)
Hours Since Initialization
25km
13km
ERA-5
GFDL-MP
Tilt Angle (°)
Hours Since Initialization
25km
13km
ERA-5
GFSv15.2
Tilt Magnitude (km)
Hours Since Initialization
25km
13km
3km
ERA-5
GFSv15.2
Tilt Angle (°)
Hours Since Initialization
25km
13km
3km
ERA-5
GFSv16beta
Tilt Magnitude (km)
Hours Since Initialization
25km
13km
3km
ERA-5
GFSv16beta
Tilt Angle (°)
Hours Since Initialization
25km
13km
3km
ERA-5

Vortex Tilt



GSDv0
GSD_noah
GSD_nomy
Tilt Magnitude (km)
Tilt Angle (°)
Hours Since Initialization
25km
13km
3km
ERA-5

Composite Reflectivity (dB) (24h)



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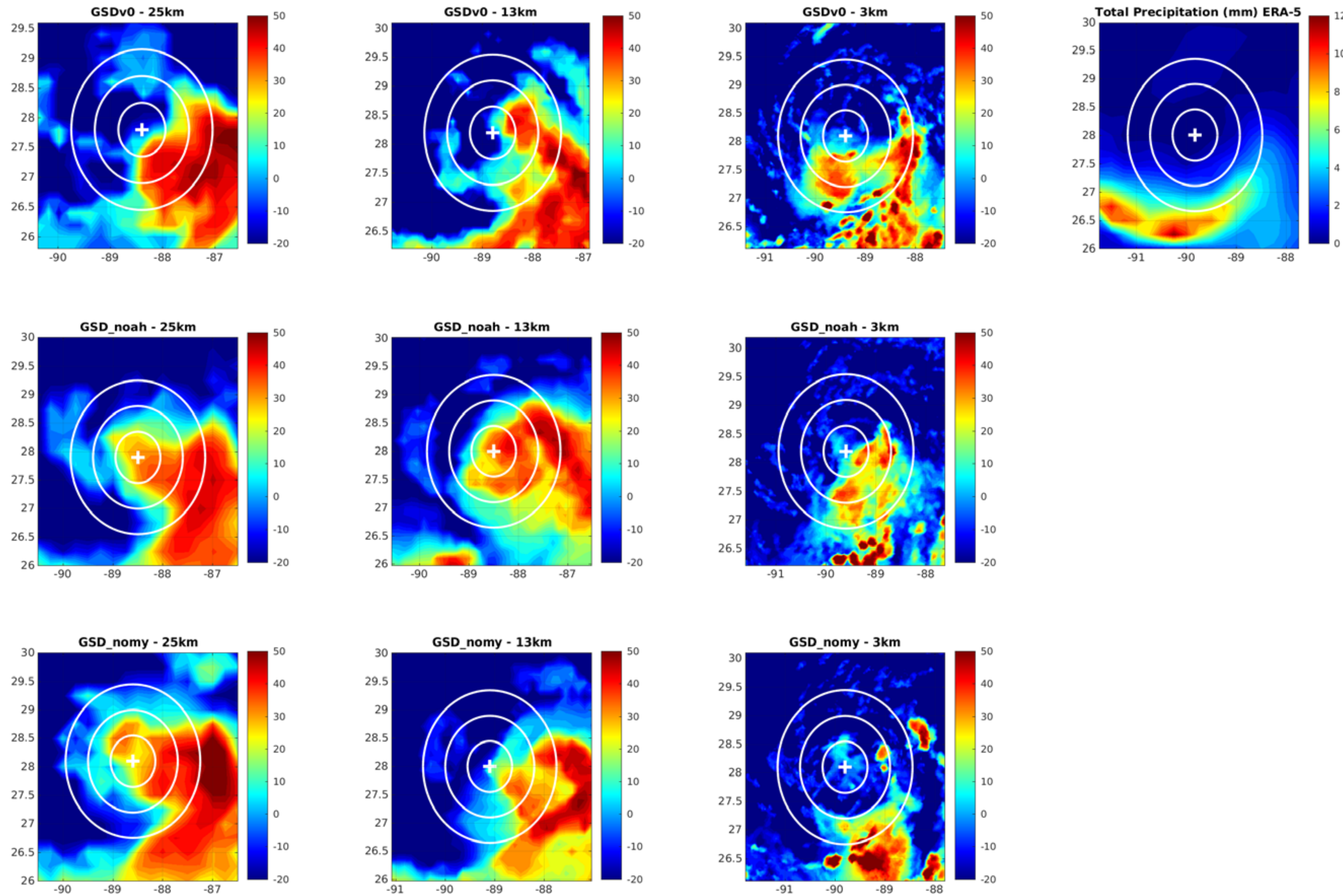
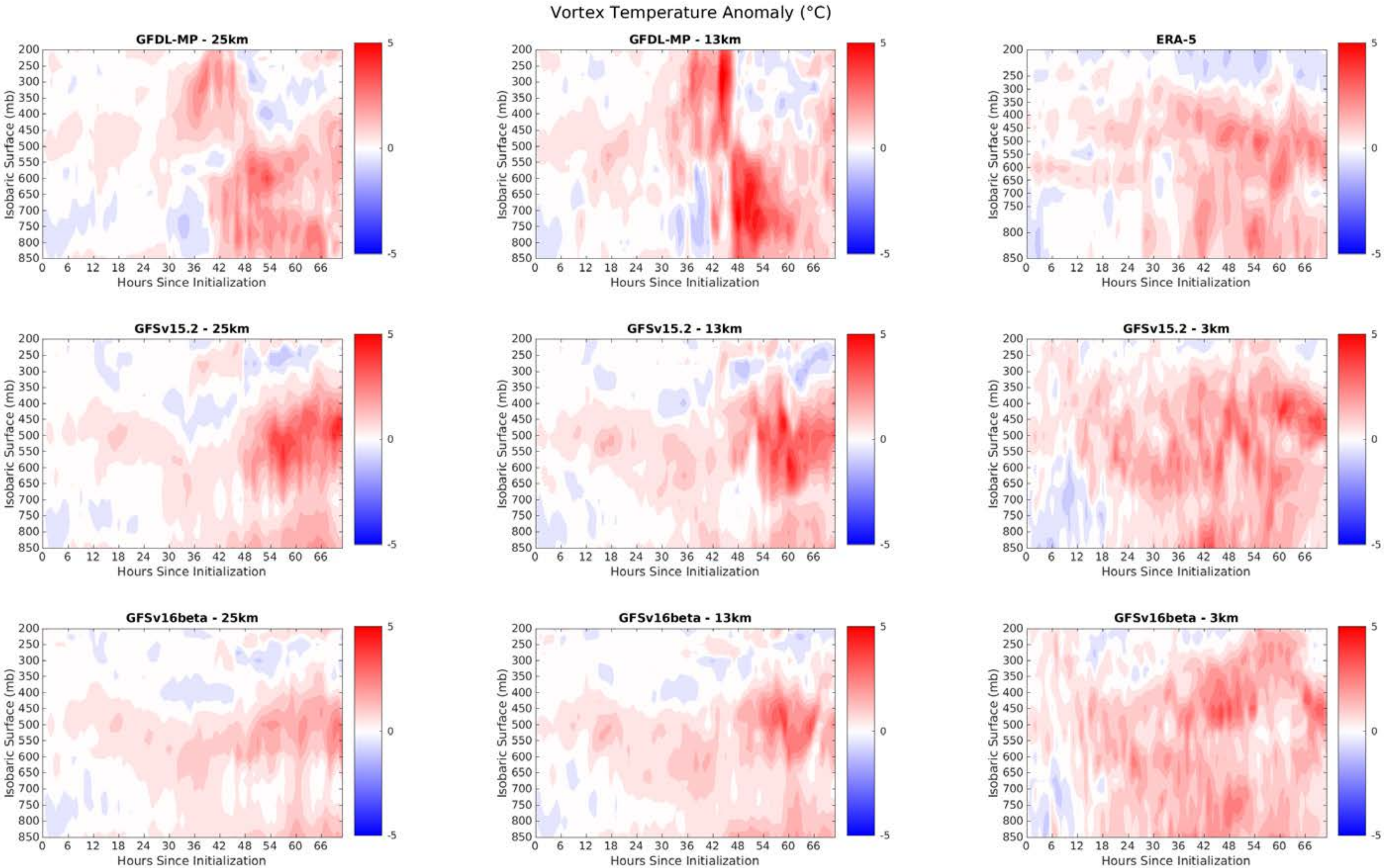
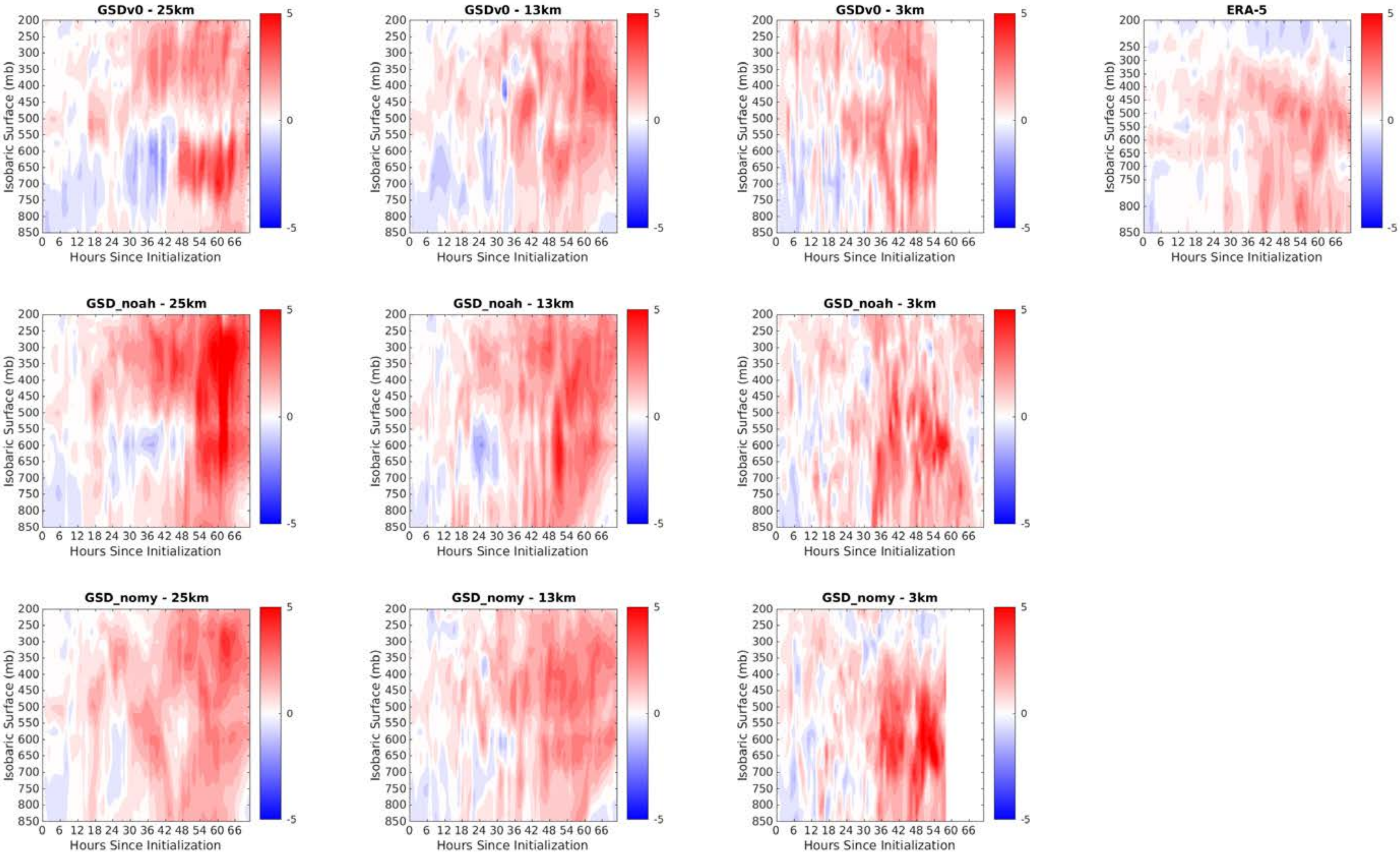
Composite Reflectivity (dB) (24h)



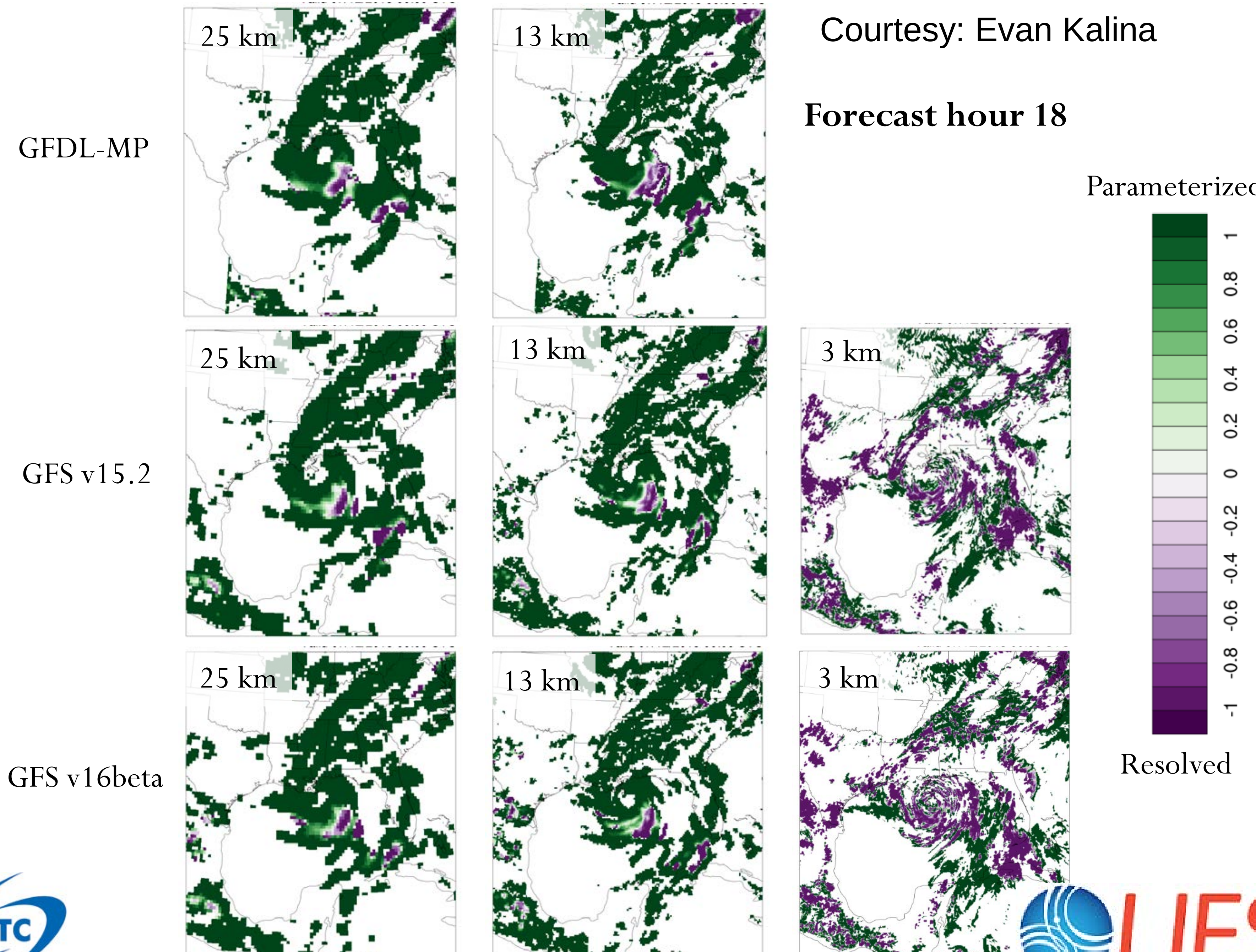

Vortex Temperature Anomaly (°C)
GFDL-MP - 25km
GFDL-MP - 13km
ERA-5
GFSv15.2 - 25km
GFSv15.2 - 13km
GFSv15.2 - 3km
GFSv16beta - 25km
GFSv16beta - 13km
GFSv16beta - 3km
Isobaric Surface (mb)
Hours Since Initialization

Vortex Temperature Anomaly (°C)



Conclusions and Future Work

- Feedback between overactive convection and vortex tilt tends to produce convection in downshear-left and upshear-left quadrants earlier in forecast runs.
  - This induces convergence toward that aggregated convection, affecting the steering flow and thus introducing track bias.
  - Forecast runs also tend to show warm bias in vortex centers, consistent with convection bias in upshear-left quadrant (Chen and Gopalakrishnan, 2015).
- Forecast runs with convection scheme turned off will be performed, though considering the relative fidelity of 25 km GFS runs, convective scheme not necessarily at fault.
  - Superposition of scheme-produced and resolved convection causing issues?



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