UW-Madison Efforts as Part of the HFIP HRH Test

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Outline

- Overview of Model Physics, Dynamics and Configuration
- Results and Lessons Learned

  (aka Trials, Tribulations and ... Simulations)
- Future Plans

UW-NMS Dynamics

$$\frac{\partial u_i}{\partial t} = -\varepsilon_{i,j,k}(\zeta_j + f_j)u_k - \frac{\partial k}{\partial x_i} - \theta\frac{\partial \pi}{\partial x_i} + \delta_{i3}g$$

$$\varepsilon_{i,j,k} = \begin{cases} 0 & if \quad \text{i=j, or j=k, or i=k} \\ 1 & if \quad \text{i,j,k are 1,2,3 or 2,3,1 or 3,1,2} \\ -1 & if \quad \text{i,j,k are 3,2,1 or 2,1,3 or 1,3,2} \end{cases}$$

$$\pi = c_p\left(\frac{p}{1000mb}\right)^{\frac{R}{c_p}}$$

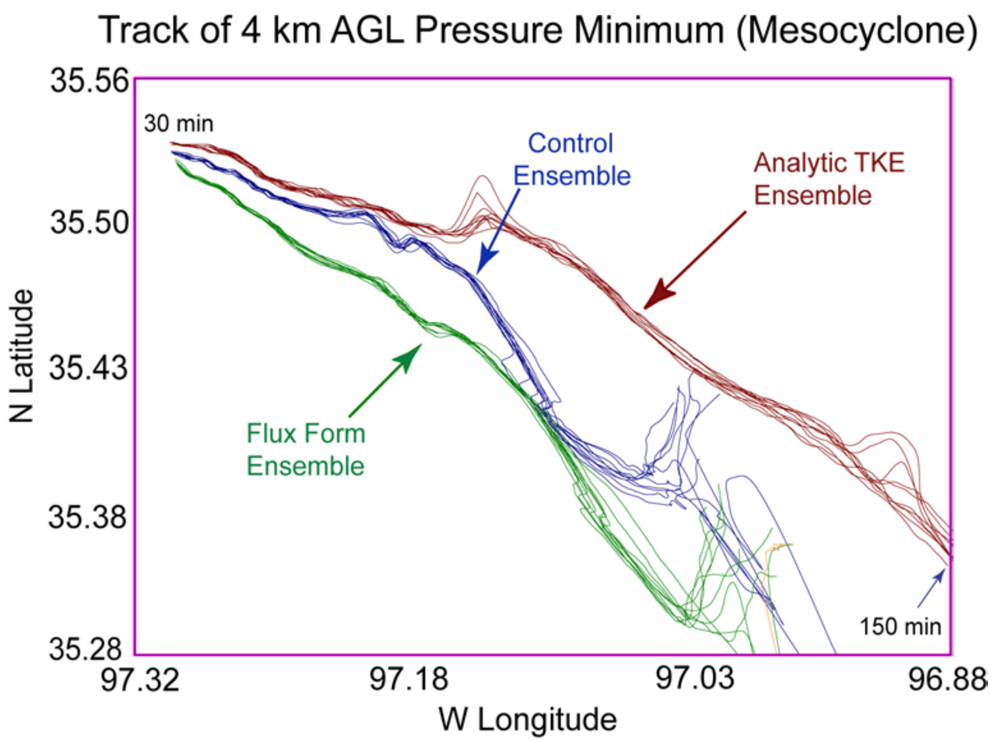
$$k = \frac{1}{2}\left(u_i^2\right)$$

$$\zeta_i = \varepsilon_{i,j,k}\frac{\partial u_j}{\partial x_k}$$

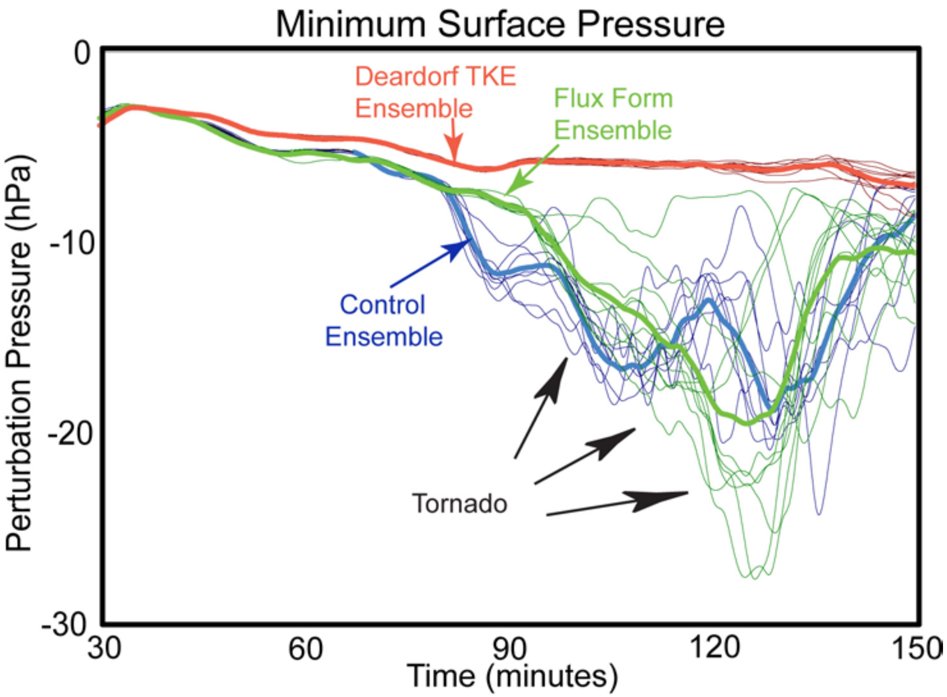
$$\varepsilon_{i,j,k}A_j B_k = \vec{A}\times\vec{B}$$

Finite differencing accomplished with Arakawa and Lamb (1981) vorticity, kinetic energy and enstrophy conserving scheme.

Conservative Dynamics Impact



Conservative Dynamics Impact



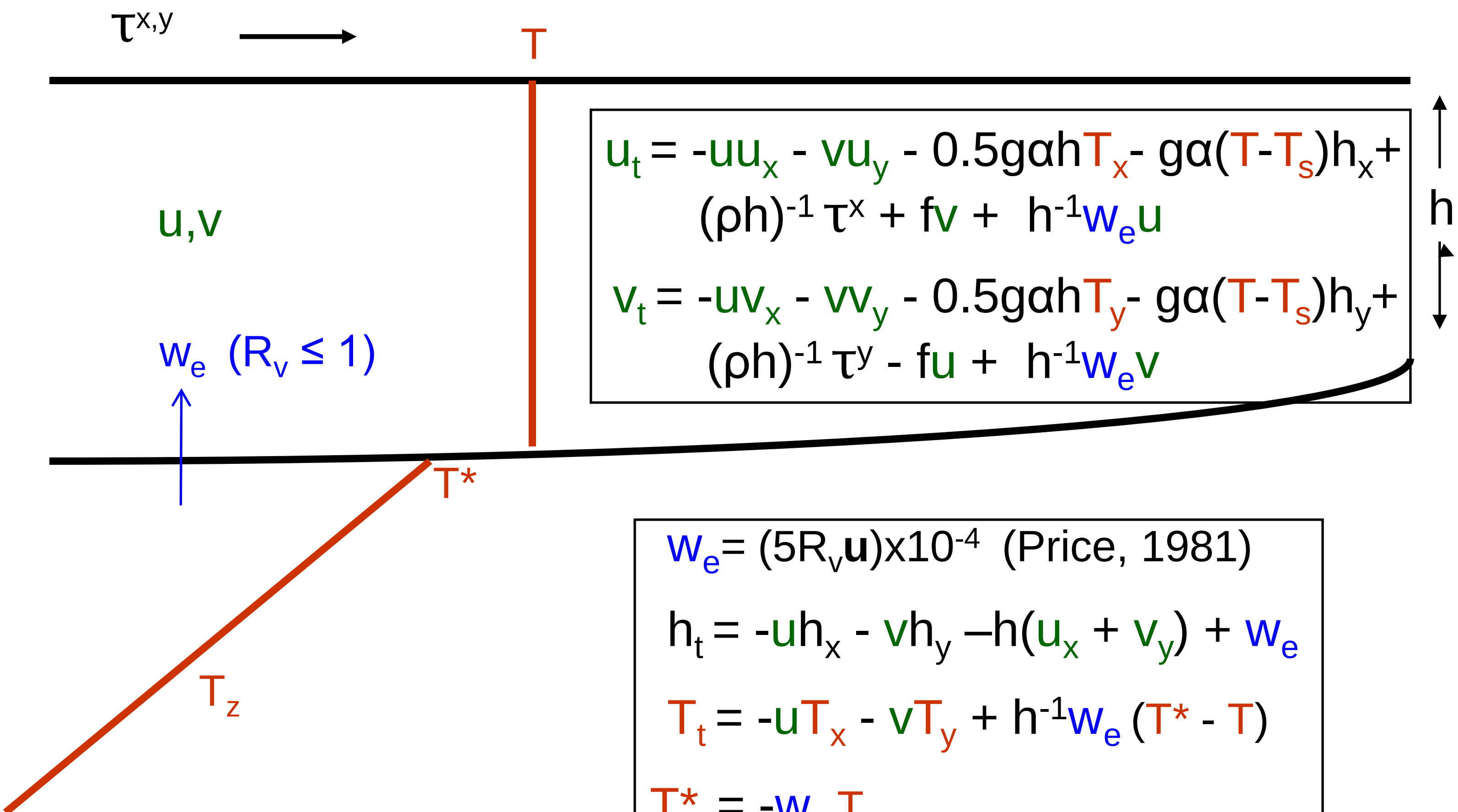
Impact on TC simulation remains to be verified – coming soon to a theater near you....

Physics

Cumulus	None
Microphysics	Flatau (1989) and Tripoli; 2-moment prognostic scheme (spedific humidity and number concentration) for all species except cloud water
PBL	K theory (horizontal), TKE (vertical)
Surface Layer	Simple Bulk ($C_H = C_M = C_D$)
Land Surface	1d soil model (Tremback and Kessler, 1985)
Radiation	RRTM (Mlawer et al., 1997a; Mlawer and Clough, 1997b)

Ocean

- 1.5 – layer ocean (mixed-layer, thermocline)



$$u_t = -uu_x - vu_y - 0.5g\alpha hT_x - g\alpha(T-T_s)h_x + (\rho h)^{-1}\tau^x + fv + h^{-1}w_e u$$

$$v_t = -uv_x - vv_y - 0.5g\alpha hT_y - g\alpha(T-T_s)h_y + (\rho h)^{-1}\tau^y - fu + h^{-1}w_e v$$

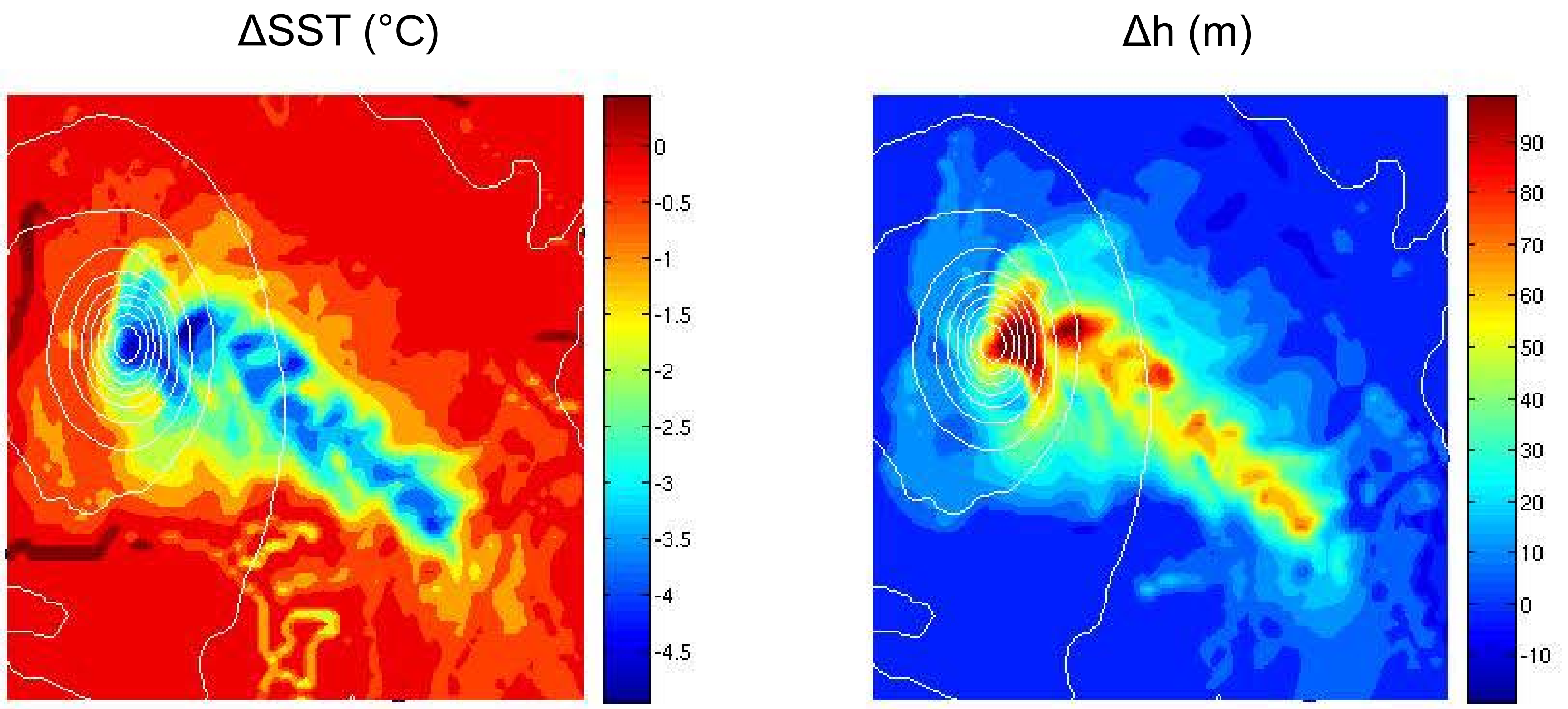
$$w_e = (5R_v\mathbf{u})x10^{-4} \quad \text{(Price, 1981)}$$

$$h_t = -uh_x - vh_y - h(u_x + v_y) + w_e$$

$$T_t = -uT_x - vT_y + h^{-1}w_e(T^* - T)$$

$$T^*_t = -w_e T_z$$

Wilma 2005101800 48-hr FCST



Configuration

- Atmosphere
  - 12km (640x640), 3km (302x302), 1km (353x353)
  - 46 levels (200m through 2km, stretched to 700m at 22.8km)
  - GFDL IC, GFS BC

- Ocean
  - 12km (640x640); u,v,h,T interpolated to grids 2 and 3.
  - Initial SST, ML depth and subsurface temperature gradient from HYCOM north and equatorial Atlantic analyses.

Tribulations

- Porting UW-NMS Code to Bluefire turned out to be a non-trivial task
- Complete OMP implementation and optimization ~ several months
- Output module was less a problem for us (though Ligia may disagree!)

Trials

- Shared-memory environment (max 32 CPUs per run on Bluefire) BCS*:
  - 2 days for 126-hr forecast on 1 grid
  - 5 days for 126-hr forecast on 2 grids
  - 12 days for 126-hr forecast on 3 grids

- Clearly, we need (re)distributive change!

* Best Case Scenario given queue vicissitudes

Simulations

- Complete*:
  - Wilma 2005101600 (1 and 2 grids)
  - Wilma 2005101700 (1, 2 and 3 grids)
  - Wilma 2005101800 (1 and 2 grids)

- Current plan: finish the Wilma cases before 27 May (at least 3 runs at high resolution)

* Though currently being re-run

Why High Resolution?

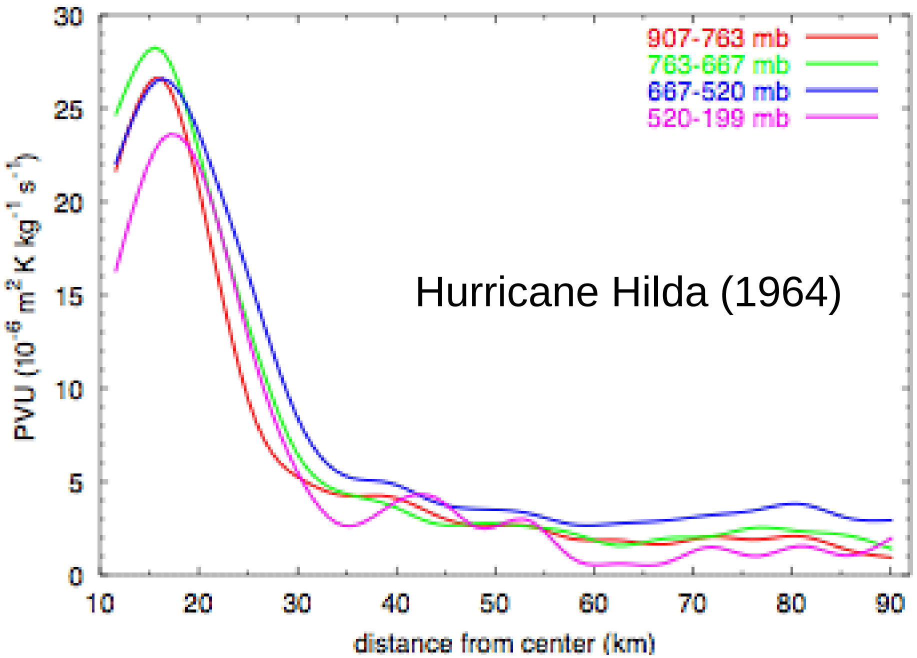
No doubt many processes / phenomena important in TC evolution benefit from an increase in resolution.

Which of these have been studied in simpler, more easily understood settings? We'll look at one.

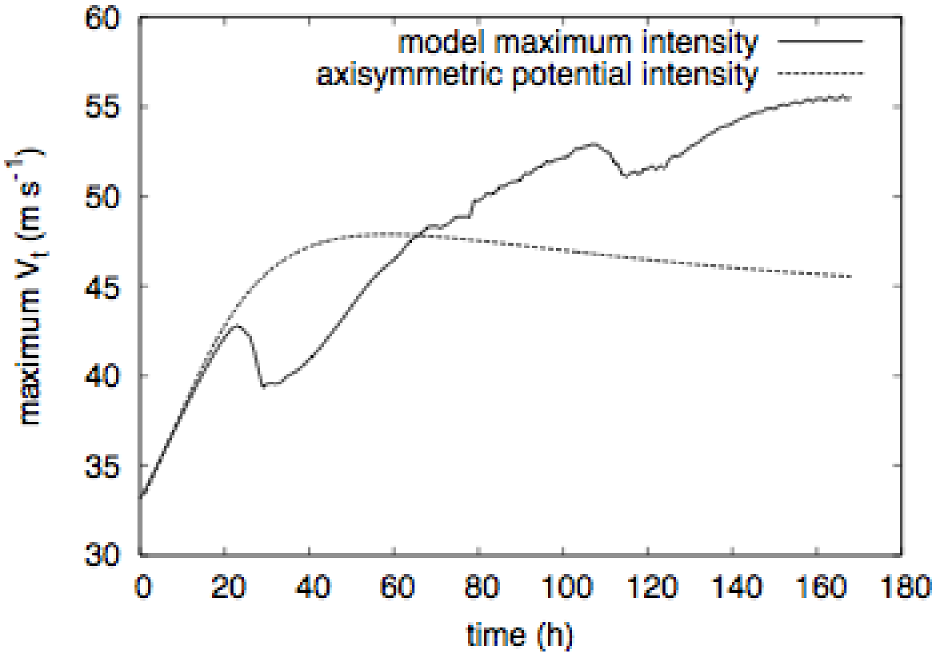
PV Mixing: application to hurricanes (Kossin et al, Rozoff et al)

As a nascent tropical storm develops, persistent diabatic heating forms a “tower” of PV. When an eye develops, diabatic heating and PV production is confined to an annulus. This results in a “hollow tower” PV structure (Möller and Smith 1994).

The radial gradient of PV changes sign and the flow can support barotropic instability (Schubert et al. 1999).

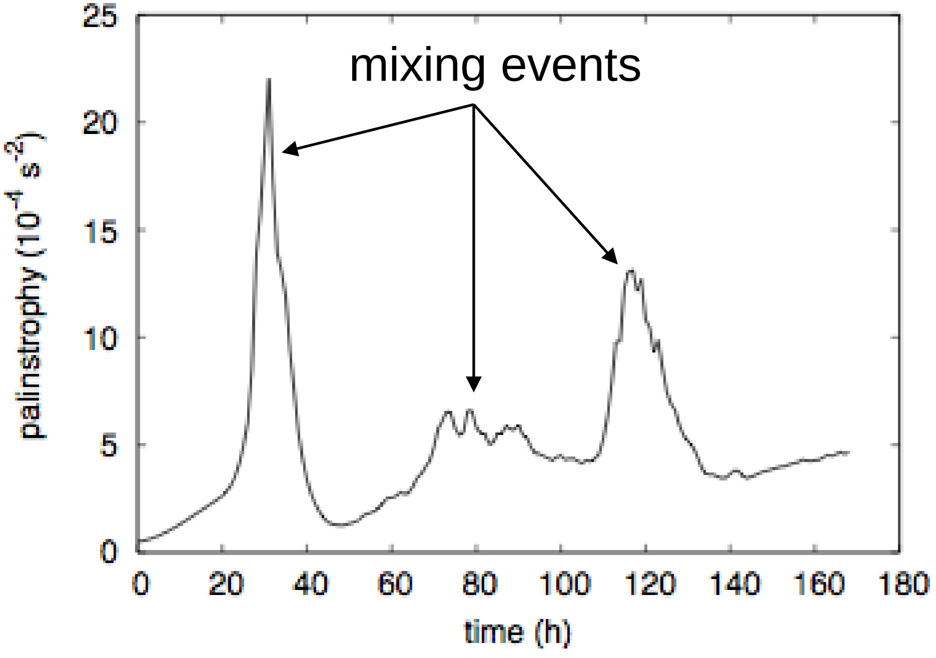


Intensity evolution



Palinstrophy evolution

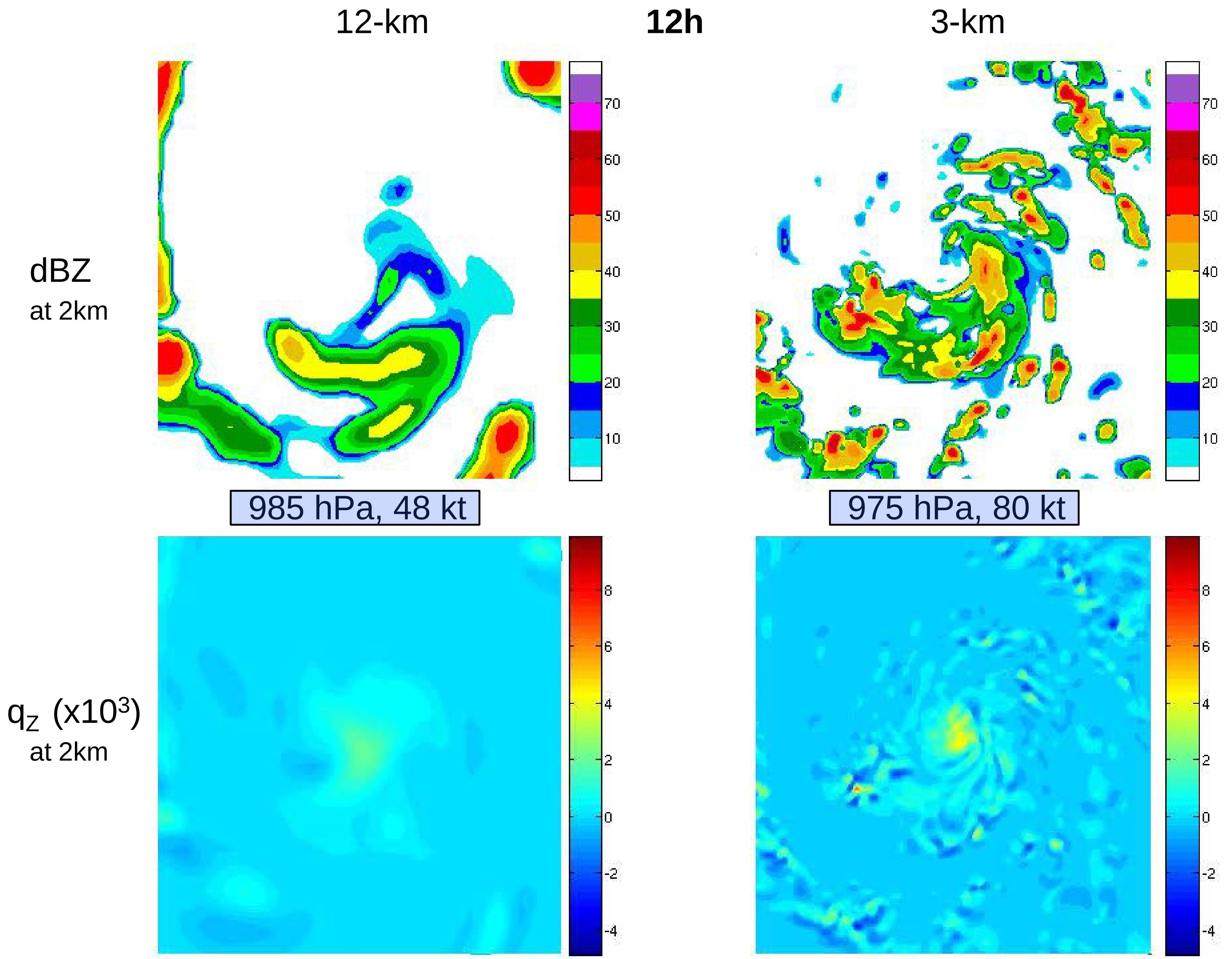
$$\mathcal{P} = \iint \frac{1}{2} \nabla\zeta \cdot \nabla\zeta \, dx dy$$



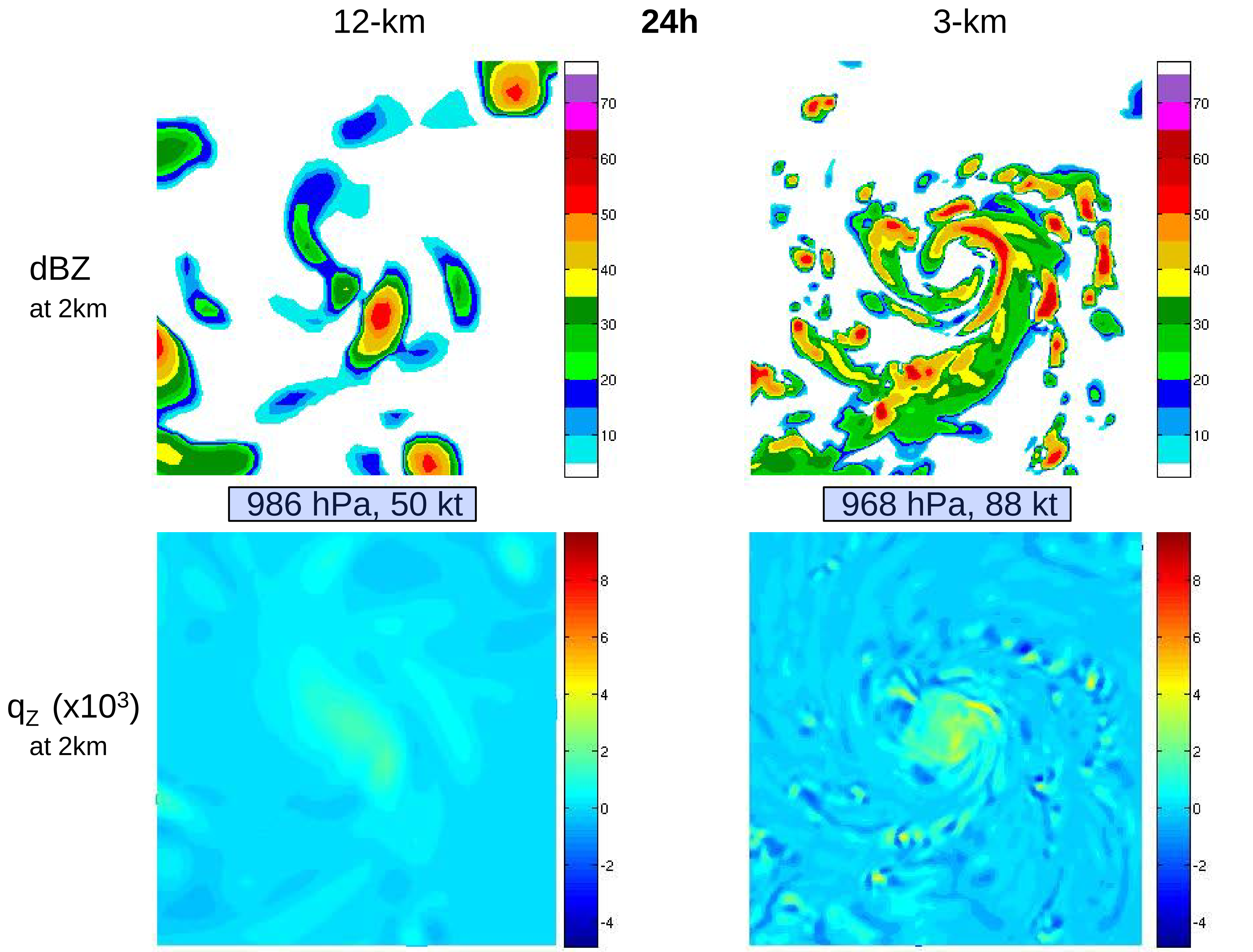
Questions

Outside the idealized framework, what is the role of model resolution in the PV mixing process?

In particular, can a hurricane simulated at 12-km support the establishment of sharp (➔ vortex sheet) PV gradients?



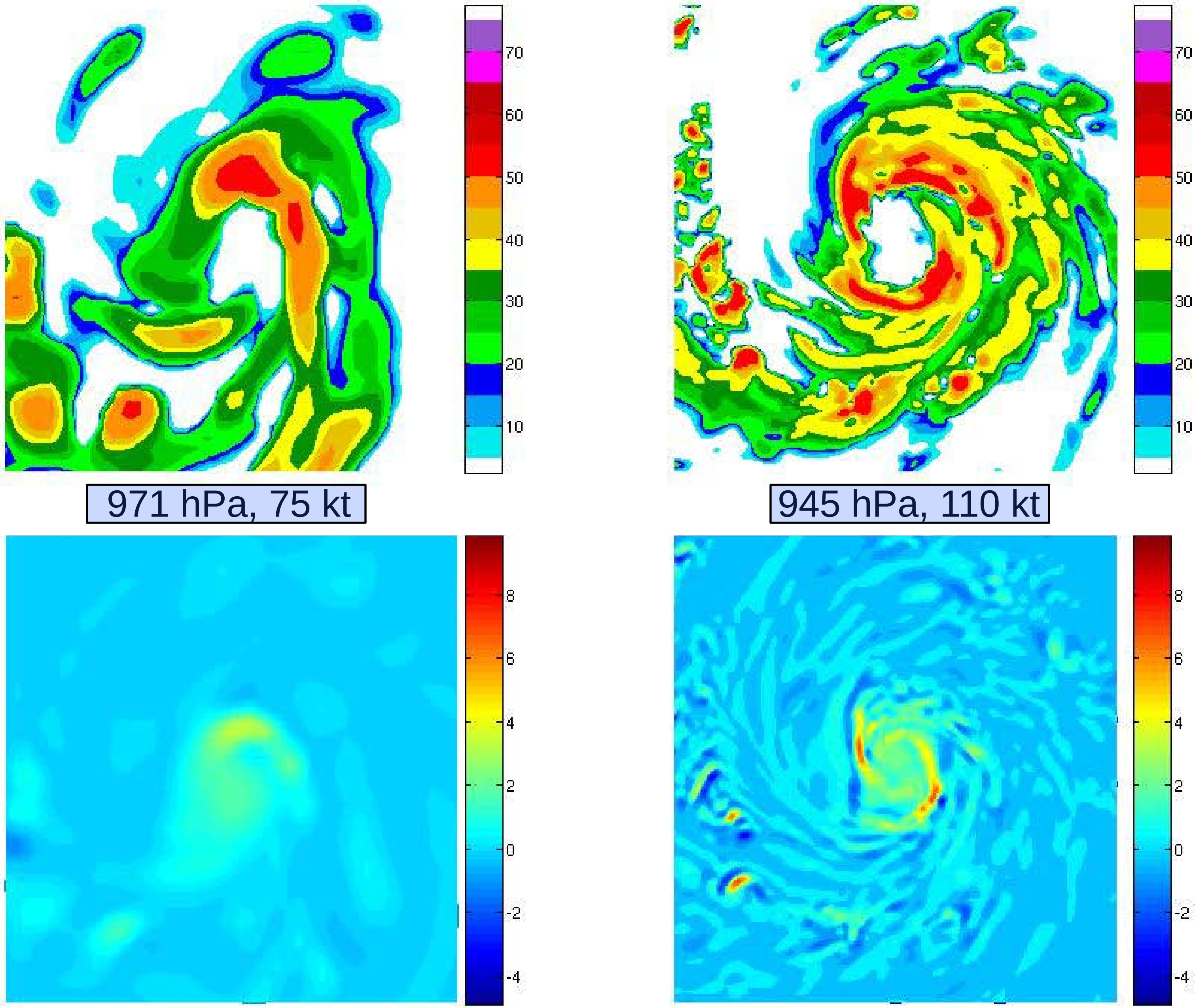
12-km
12h
3-km
dBZ
at 2km
985 hPa, 48 kt
975 hPa, 80 kt
q_Z (x10^3)
at 2km
70
60
50
40
30
20
10
8
6
4
2
0
-2
-4

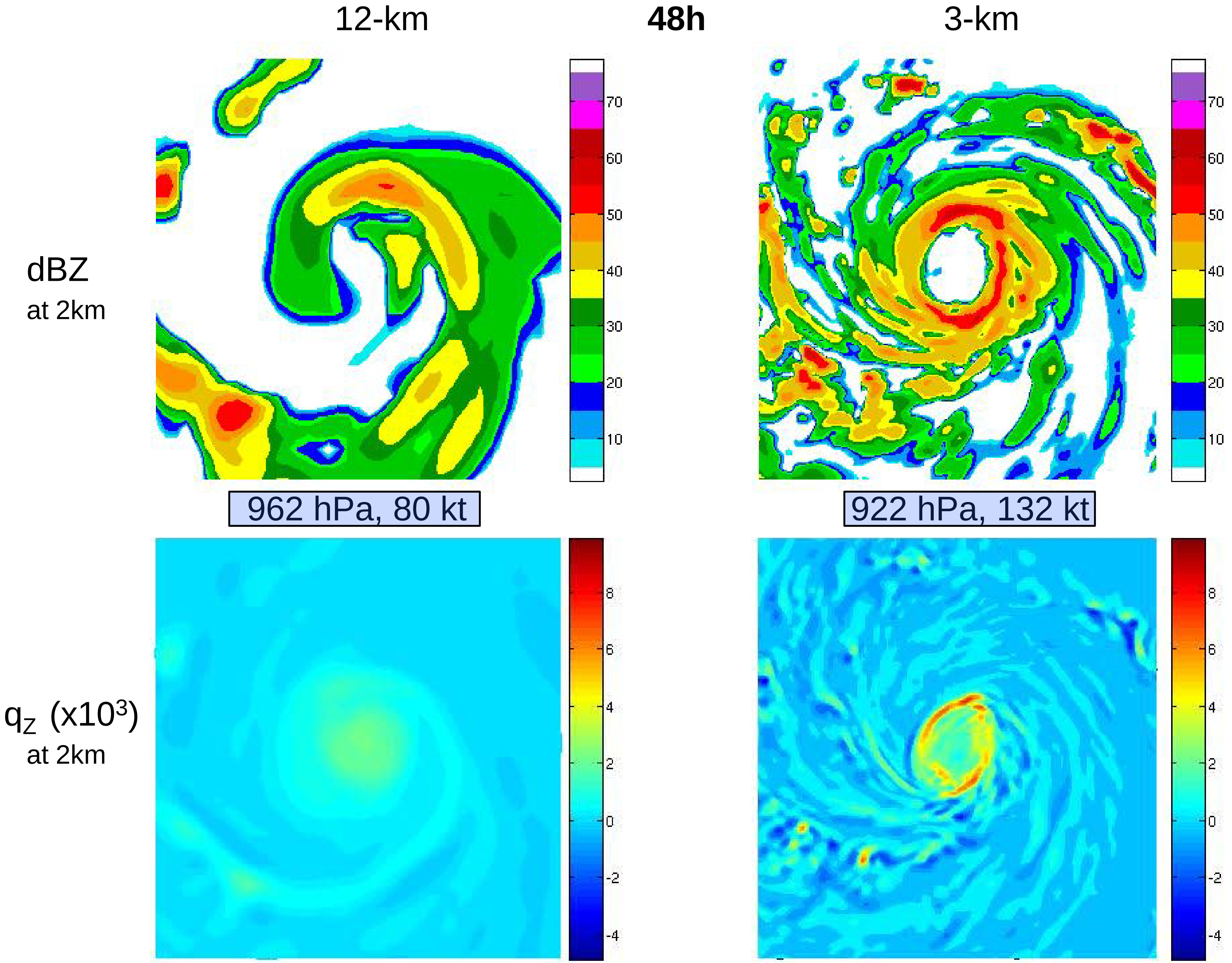

12-km
24h
3-km
dBZ
at 2km
70
60
50
40
30
20
10
986 hPa, 50 kt
968 hPa, 88 kt
q_Z (x10^3)
at 2km
8
6
4
2
0
-2
-4

12-km **36h** 3-km

dBZ at 2km

q_Z ($\times 10^3$) at 2km




12-km
48h
3-km
dBZ
at 2km
962 hPa, 80 kt
922 hPa, 132 kt
q_Z ($x10^3$)
at 2km
70
60
50
40
30
20
10
8
6
4
2
0
-2
-4

Plans

- Finish analysis of HRH runs (PV-mixing episodes) at 12-, 3- and 1-km. Intensity and resolution relationships?

- Ensemble applications (group dependent):

  Single vs. multi-model

  Resolution vs. sample size

- EnKF (+TMI, SSM/I, GOES)

UW-NMS Upgrades

- NOAH LSM ☑
- Sea Spray (Andreas) ☑
- YSU PBL
- 3-D Ocean w/ wave model
- **MPI!!**
- AMPS microphysics
- PPM scalar advection