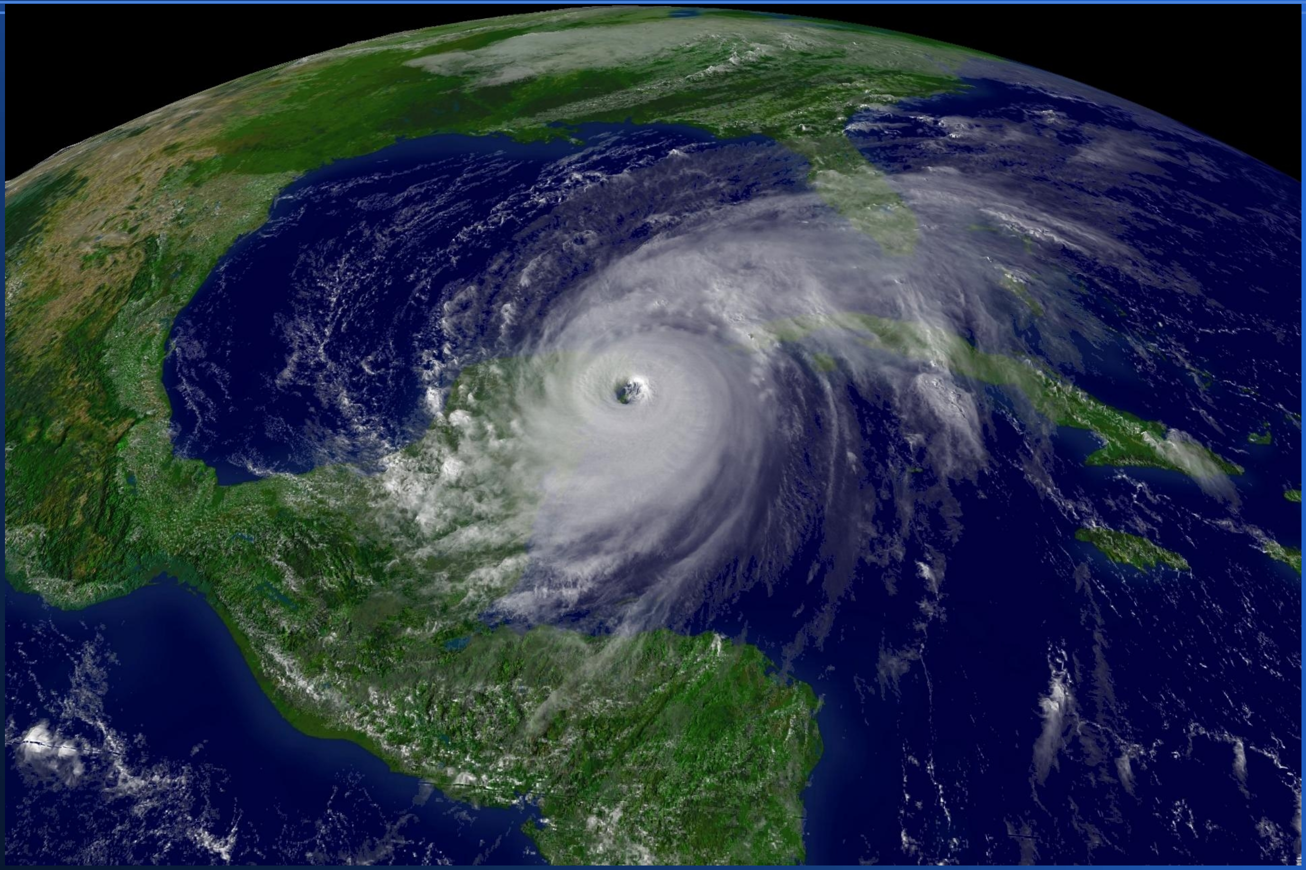
Impact of numerical grid spacing and time step on Vortex Rossby-Waves in secondary eyewall formation in hurricane Wilma (2005)



Jonathan Gadoury and M.K. (Peter) Yau
McGill University

Outline

- Motivation
- Methodology*
  - Case
  - Model setup
- Results**
  - Control run
  - Coarse resolution
  - High resolution
- Conclusion

**For theory, refer to Konstantinos Menelaou's presentation*
***Only gird length variations will be shown in this presentation*

Motivation

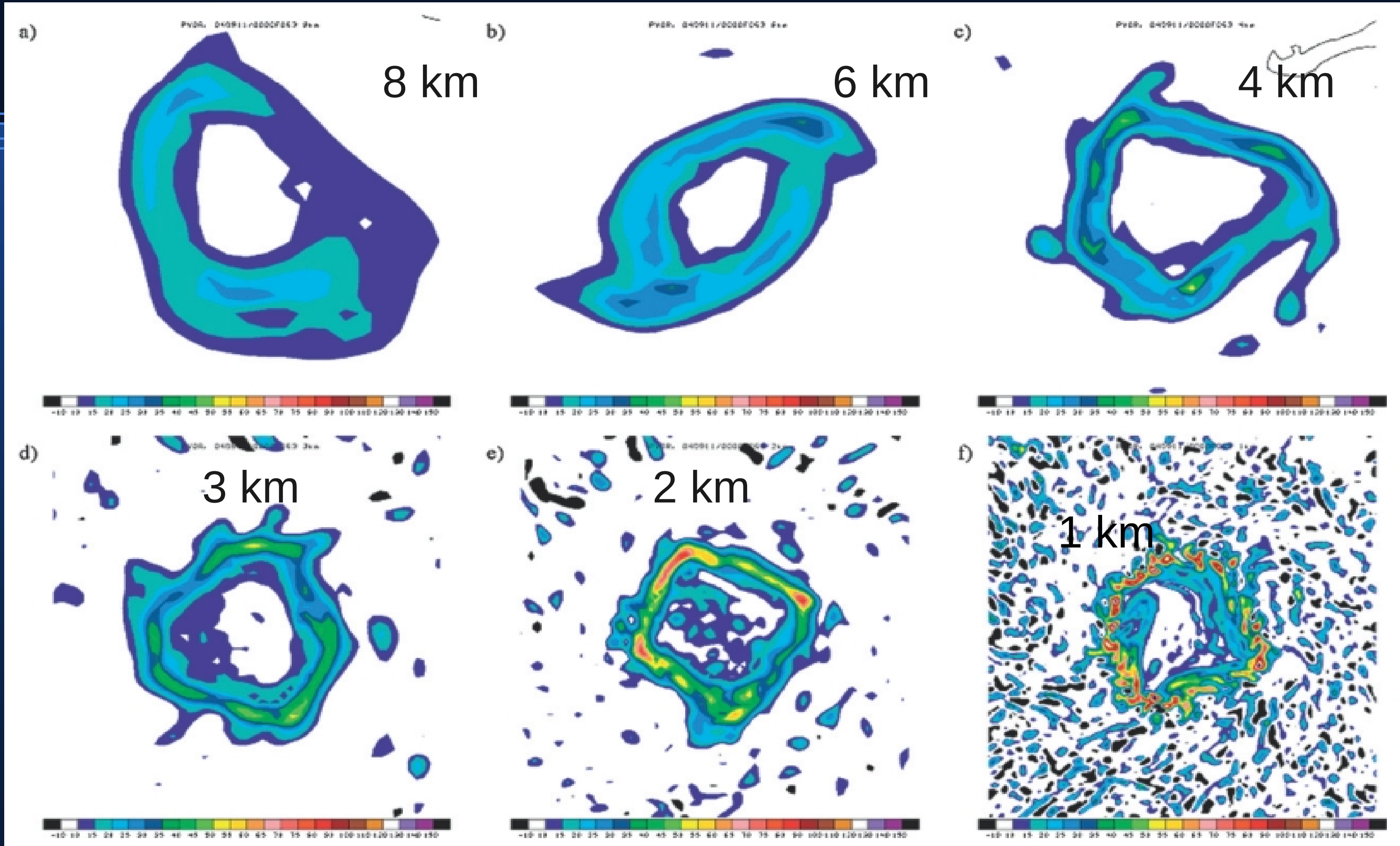


FIG. 6. 850-hPa PV at 63 h into the simulation scaled by 10^{-6} and contoured every 5 PVU from 10 PVU, shown for the (a) 8-, (b) 6-, (c) 4-, (d) 3-, (e) 2-, and (f) 1-km runs. Note that both this figure and the next one are representative of the appearance of the PV field at different times throughout the run.

Gentry et al. (2009)

Different eyewall shape and PV gradient might have impact on Vortex Rossby-waves, and therefore the hurricane structure and intensity

Hurricane Wilma

From October 15 to 26, 2005

Min. pressure : 882 mb

Rapid intensification : 981 to 882 mb in 24 hours, including a 53 mb drop in 6 hours

Reached category 5

NHC Tropical Cyclone Report : Hurricane Wilma

Model setup

- WRF 3.2.1
- From October 18 00Z to 21 00Z, 2005
- One static domain of 1860 x 1860 km
- 30 vertical levels
- GFDL initial and boundary conditions
- GFS surface data
- NCEP SST data -> 0.5° resolution
- For control run :
  - 2 km grid length
  - 10 s time step

Model setup

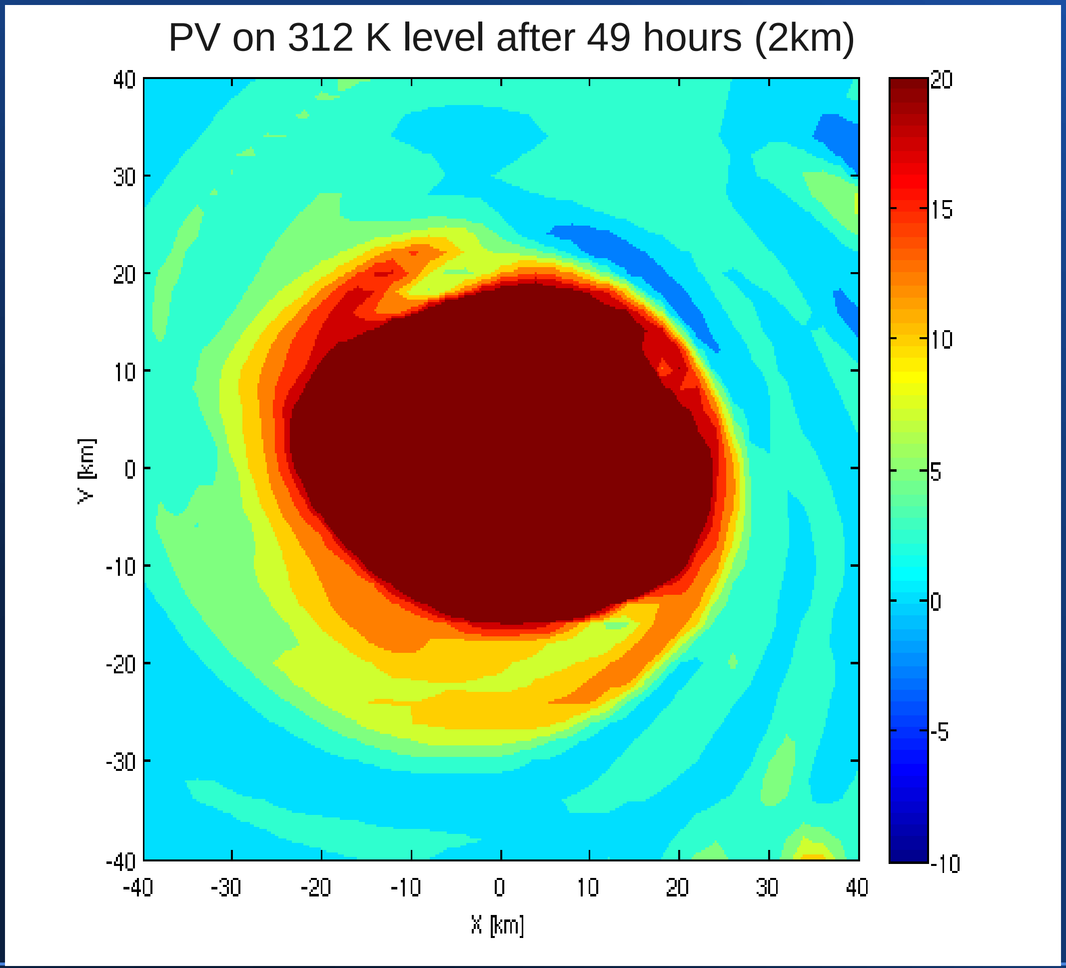
- *Microphysics*
  - Thompson scheme (ice, snow, graupel)
- *Longwave rad.*
  - Rapid Radiative Transfer Model scheme (multiple bands, trace gases)
- *Shortwave rad.*
  - Goddard scheme (multiple band, ozone from climatology, cloud effects)
- *Planetary Boundary Layer*
  - Mellor-Yamada-Janjic scheme (local vertical mixing, turbulent kinetic energy)
- ***Cumulus parametrization***
  - **OFF**

Experiments

		Δt (s)				
		5	**10**	**15**	**20**	**30**
Δx (km)	**1**	x				
	2		x			
	3		x	x		
	4		x	x	x	
	6		x		x	x

Only the experiments with red marks will be shown here

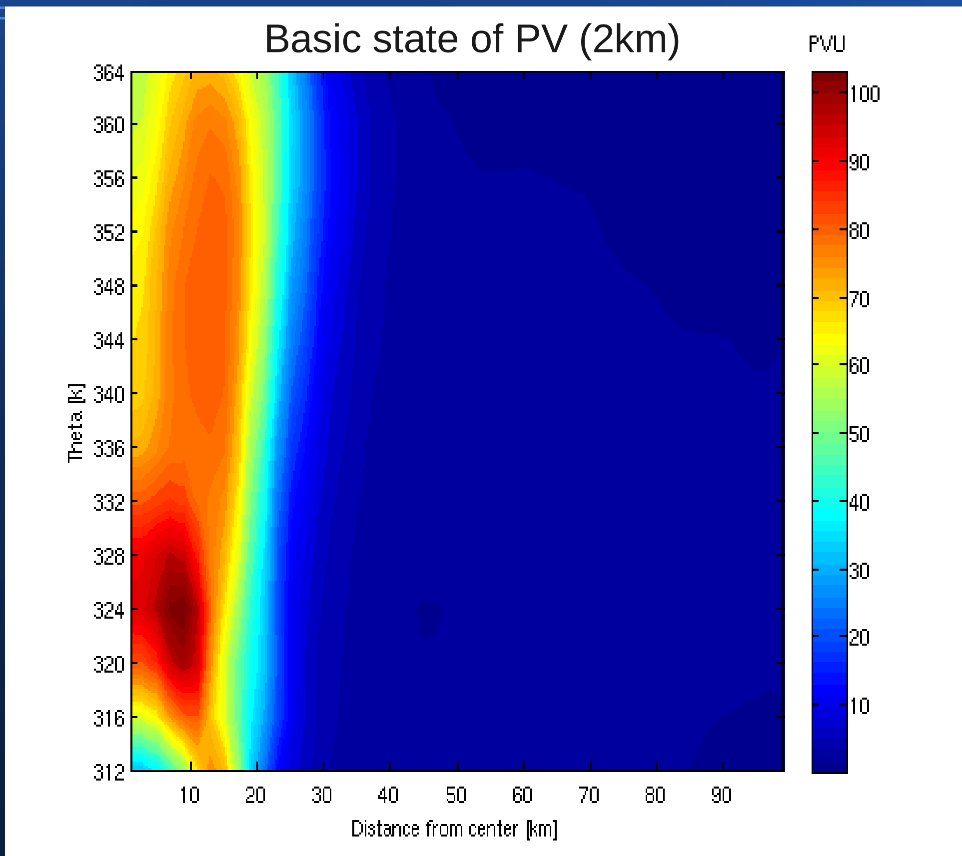
ENM analysis



For ENM analysis

- Wavenumber 2
- Interpolation to cylindrical, isentropic and storm-following coordinates
- 14 Θ levels
- 24 hours period
- 721 modes
- Initial time of analysis is 9 hours before minimum pressure is reached

ENM analysis



Basic state is a time and azimuthal average. It must not change during the period of analysis.

$$J = -r\sigma' v' - \frac{r\sigma_0^2 q'^2}{2\gamma}$$

Gravity term Vortical term

$$\mathcal{F} = -r\sigma_0 \langle u'v' \rangle \hat{\mathbf{e}}_r + \left\langle \frac{p'}{g} \frac{\partial \Psi'}{\partial \lambda} \right\rangle \hat{\mathbf{e}}_\theta$$

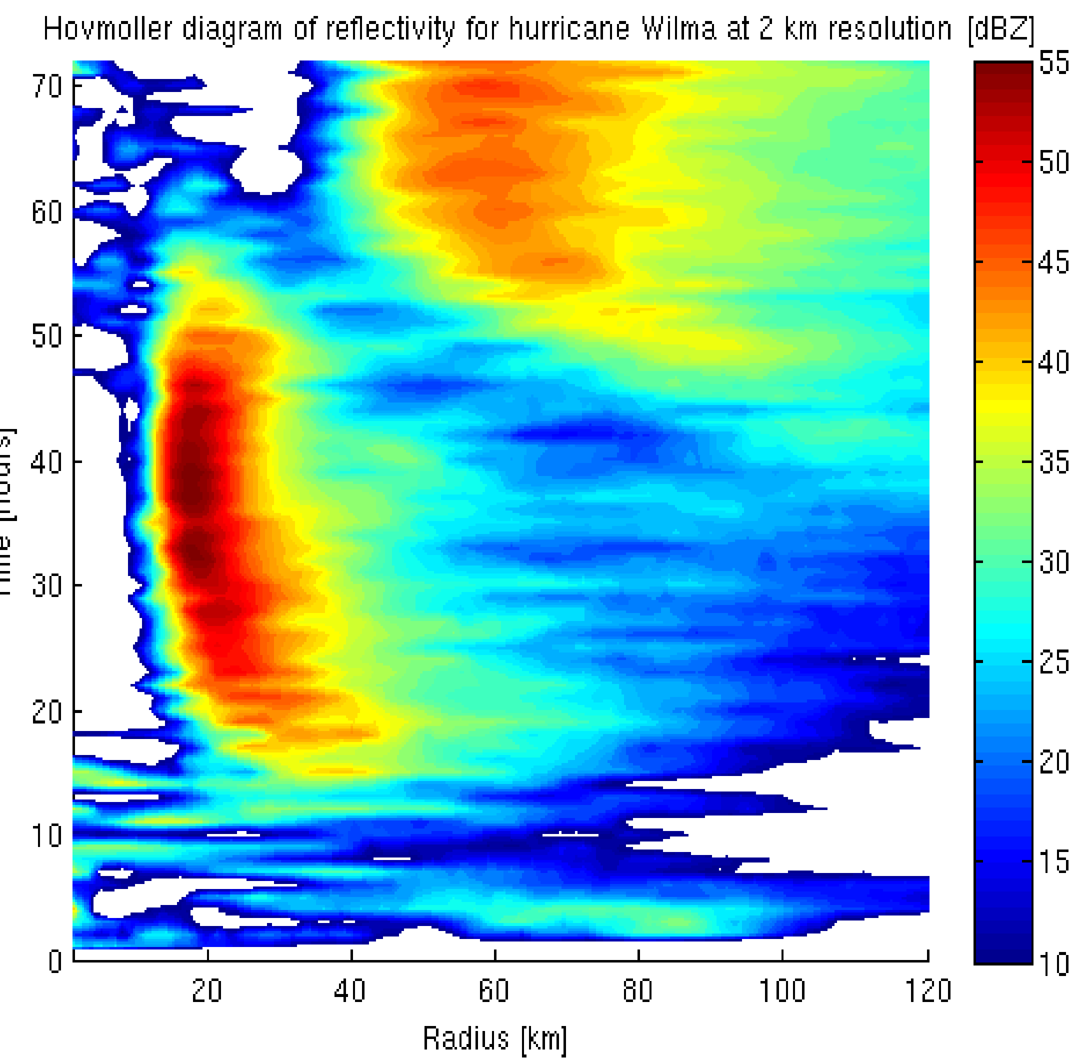
$$\nabla \cdot \mathcal{F} = \frac{1}{r}\frac{\partial}{\partial r}\left(-r^2 \sigma_0 \langle u'v' \rangle\right) + \frac{\partial}{\partial \theta}\left\langle \frac{p'}{g} \frac{\partial \Psi'}{\partial \lambda} \right\rangle$$

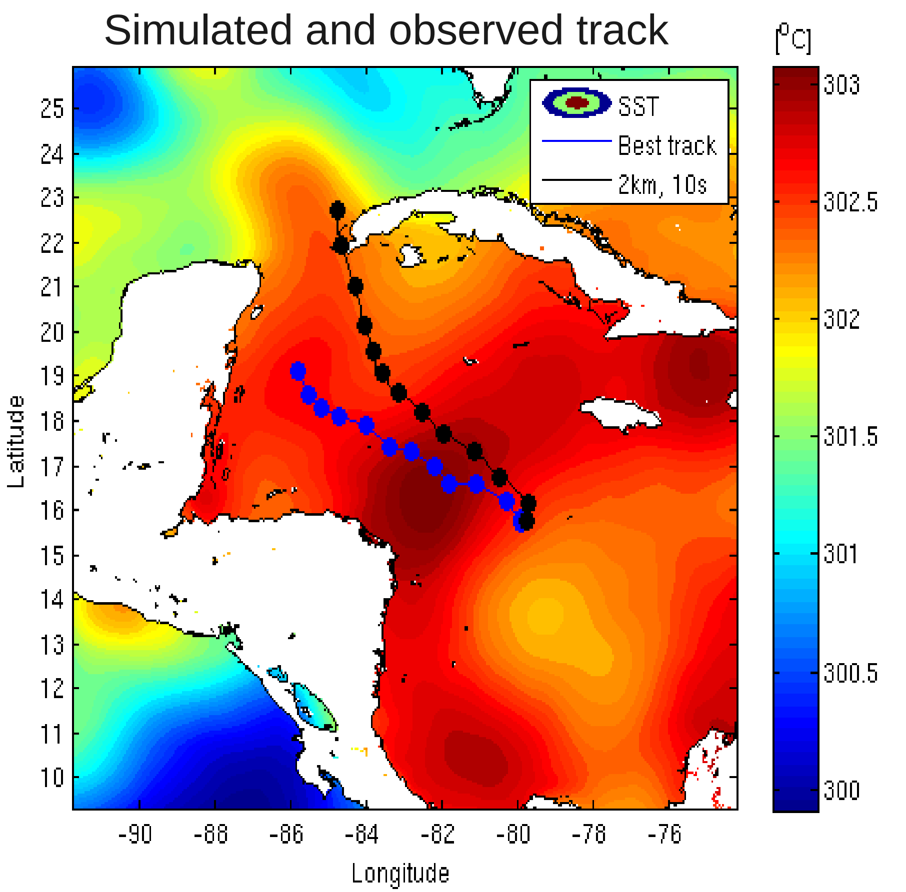
The EP flux (F) and its divergence

Where ∇ • F > 0, VRWs transfer momentum to the mean flow and accelerate the winds

→ Good indicator of where SE forms

Control run (Δx = 2 km)

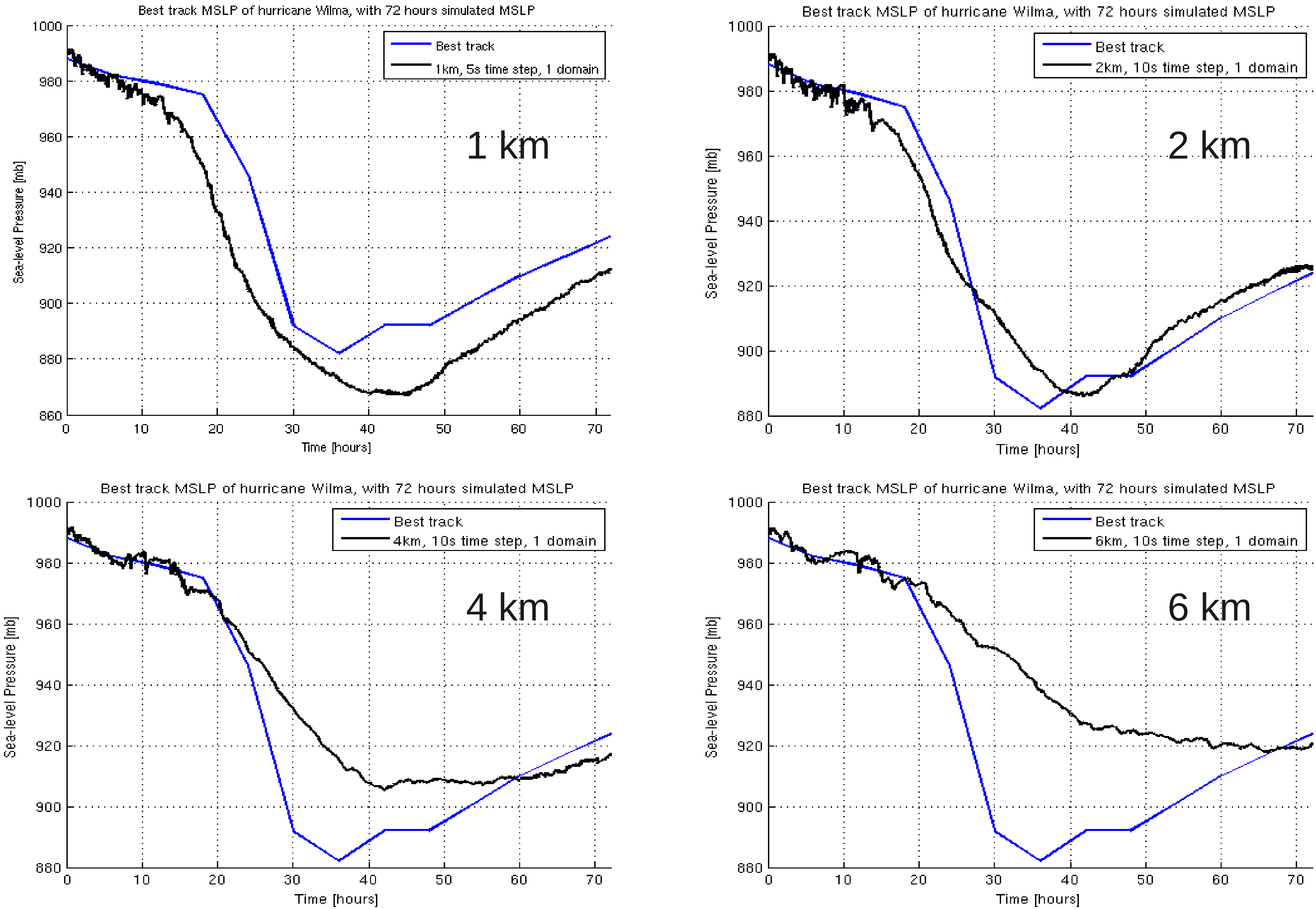




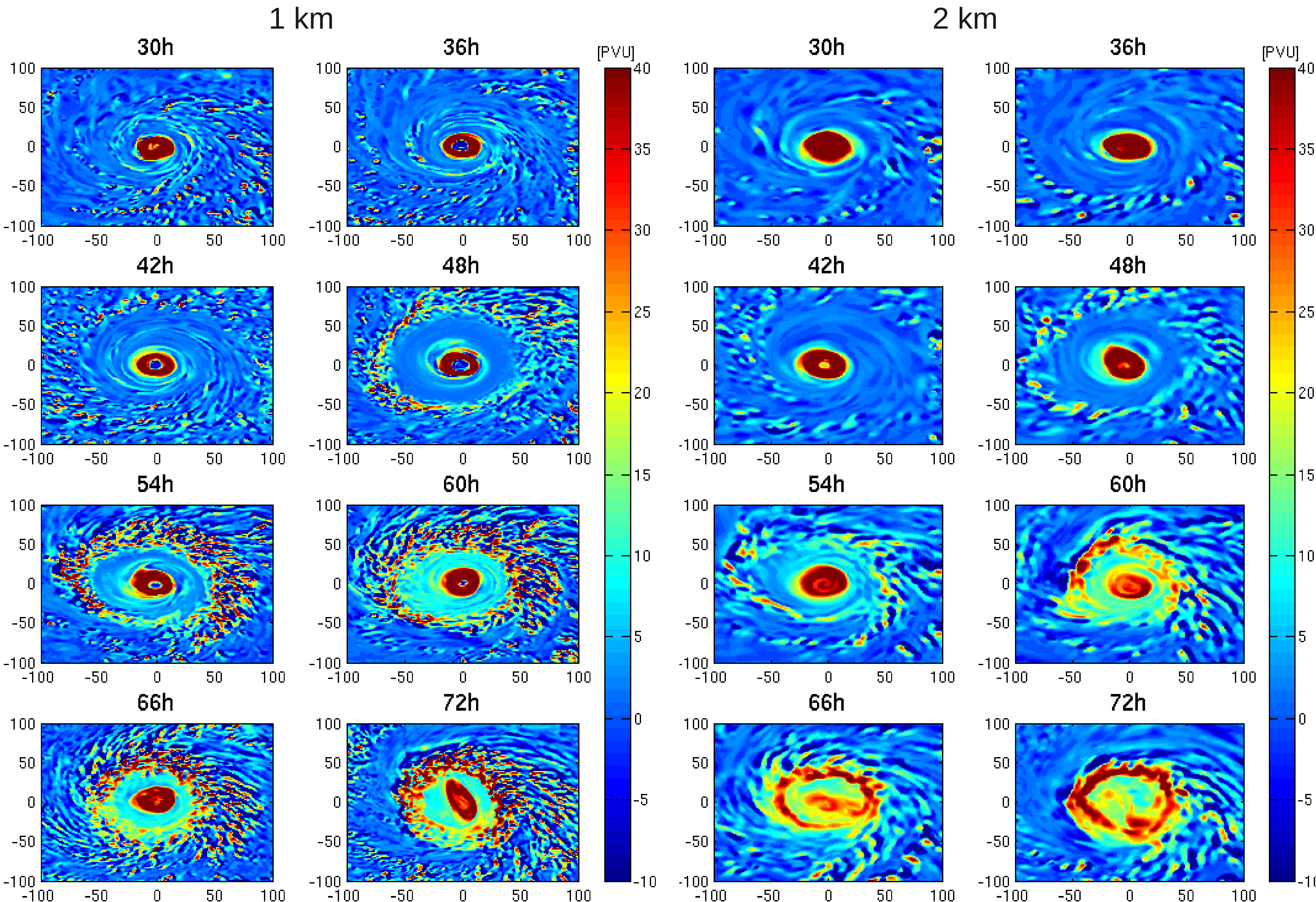
Simulated track has a bias to the North

Eyewall replacement cycle takes place

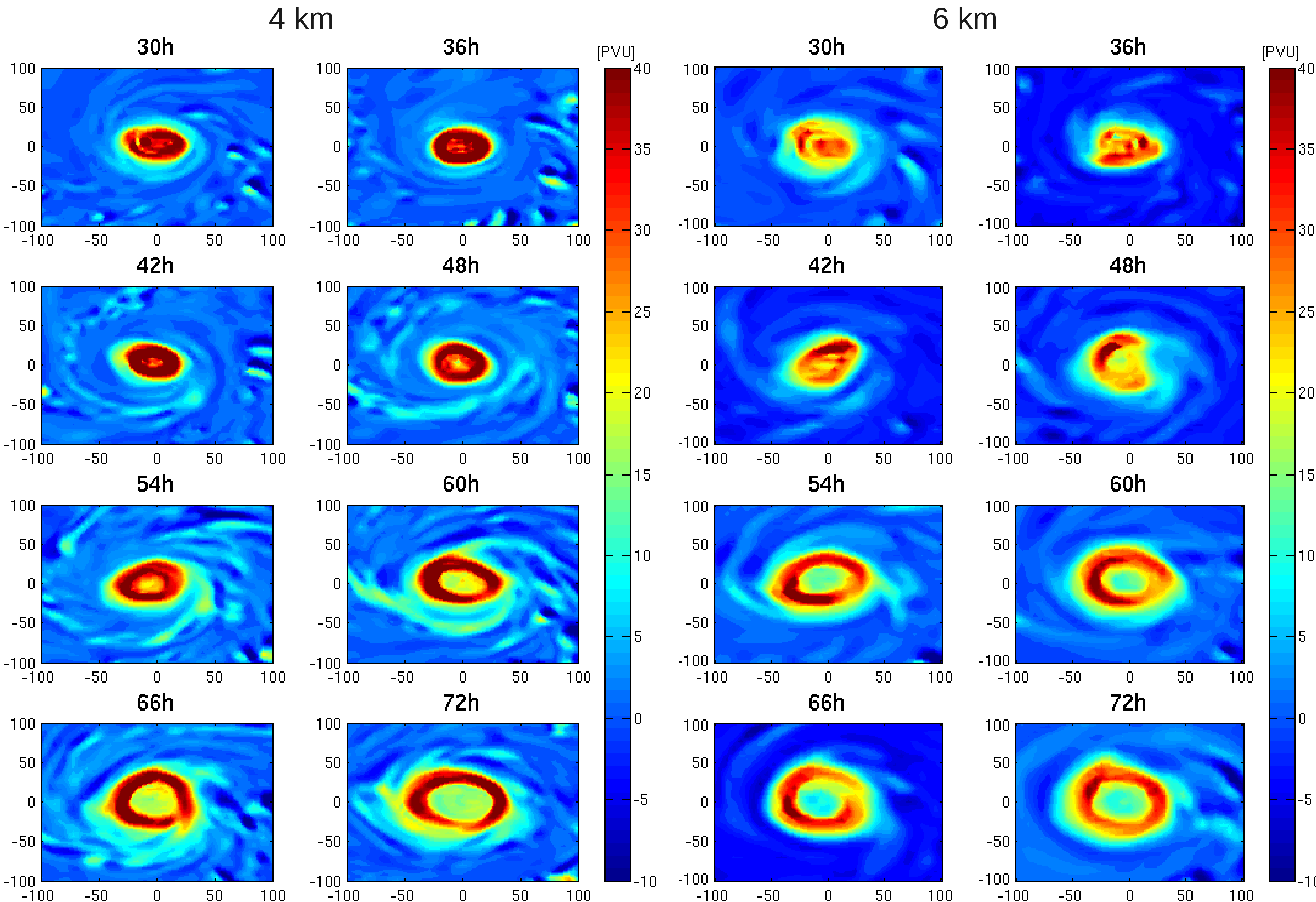
Minimum sea-level pressure



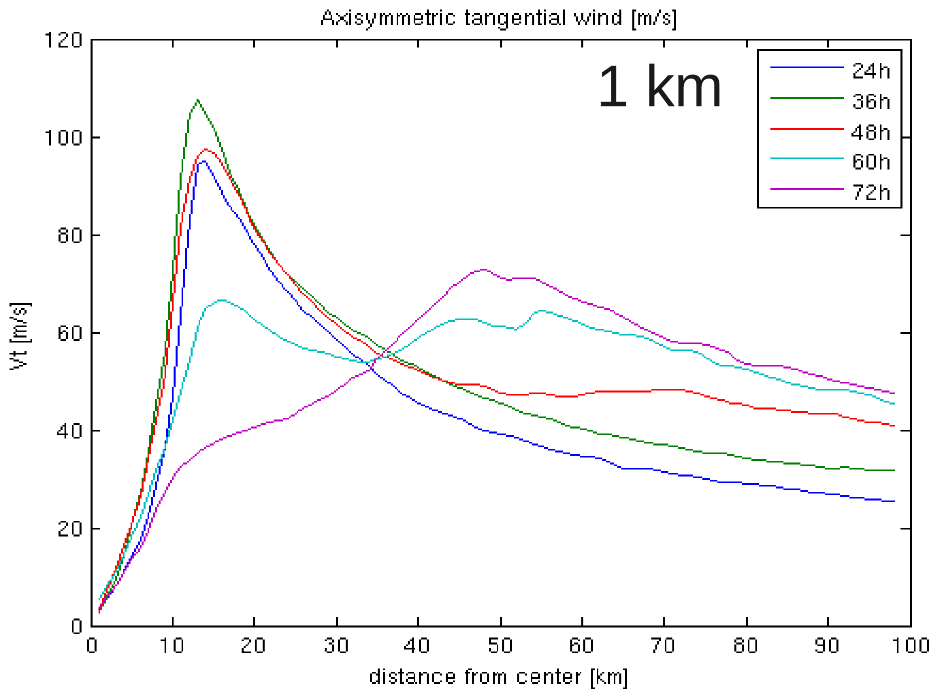
Horizontal PV at 312 K level

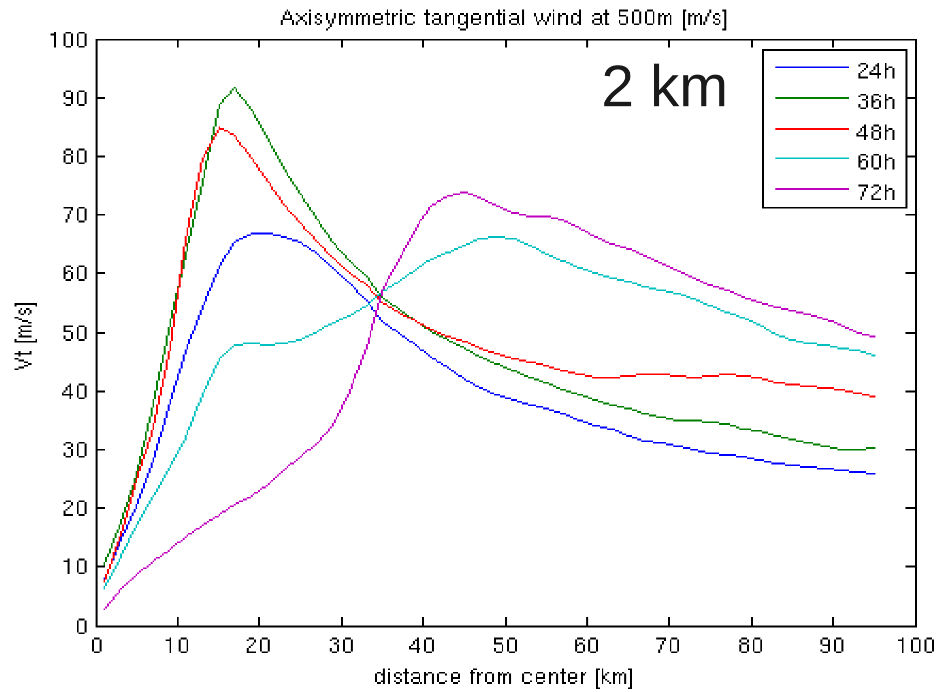


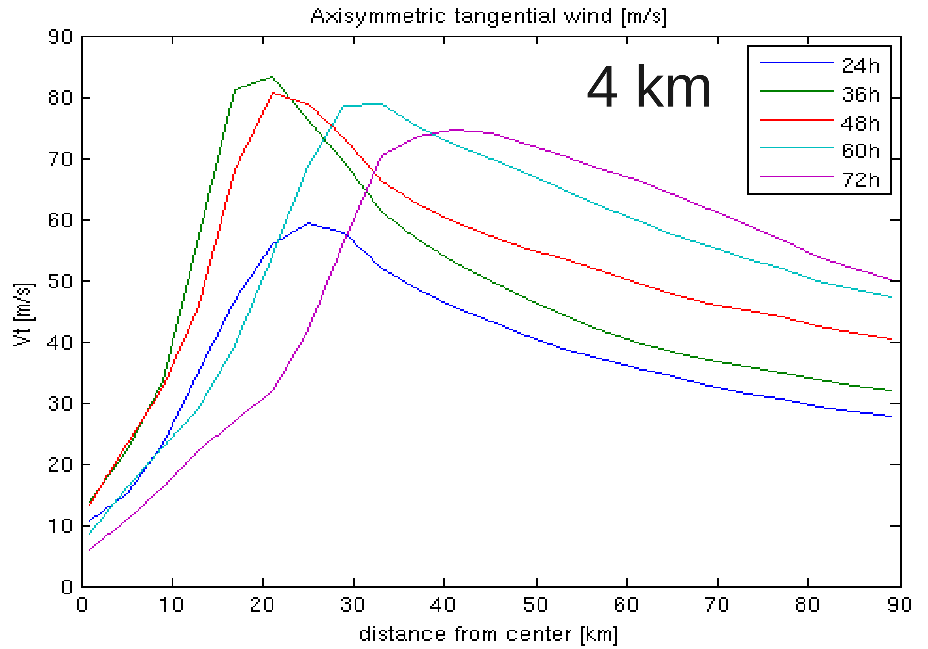
Horizontal PV at 312 K level

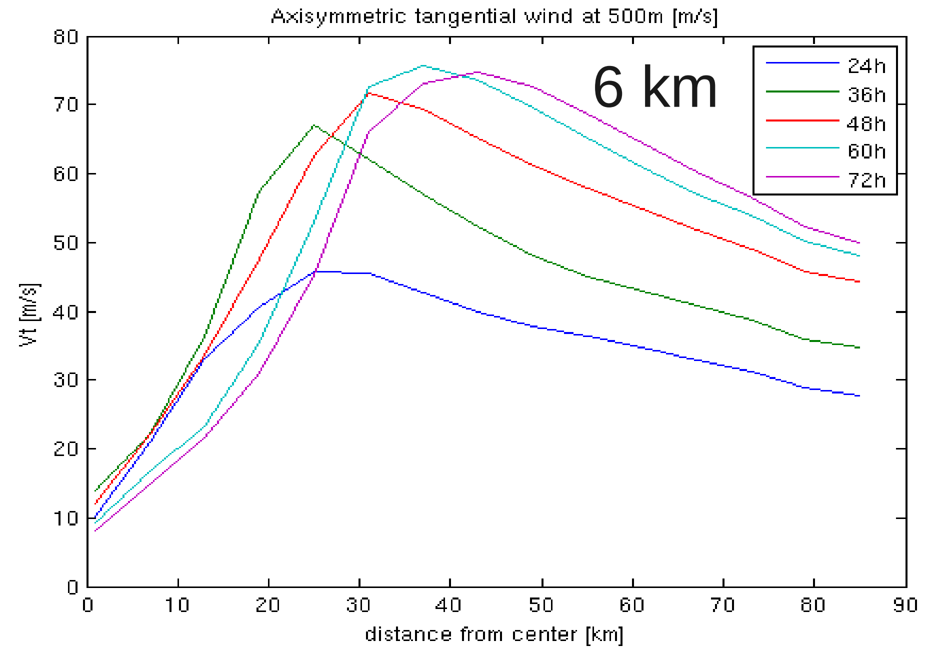


Axisymmetric tangential winds [m/s]

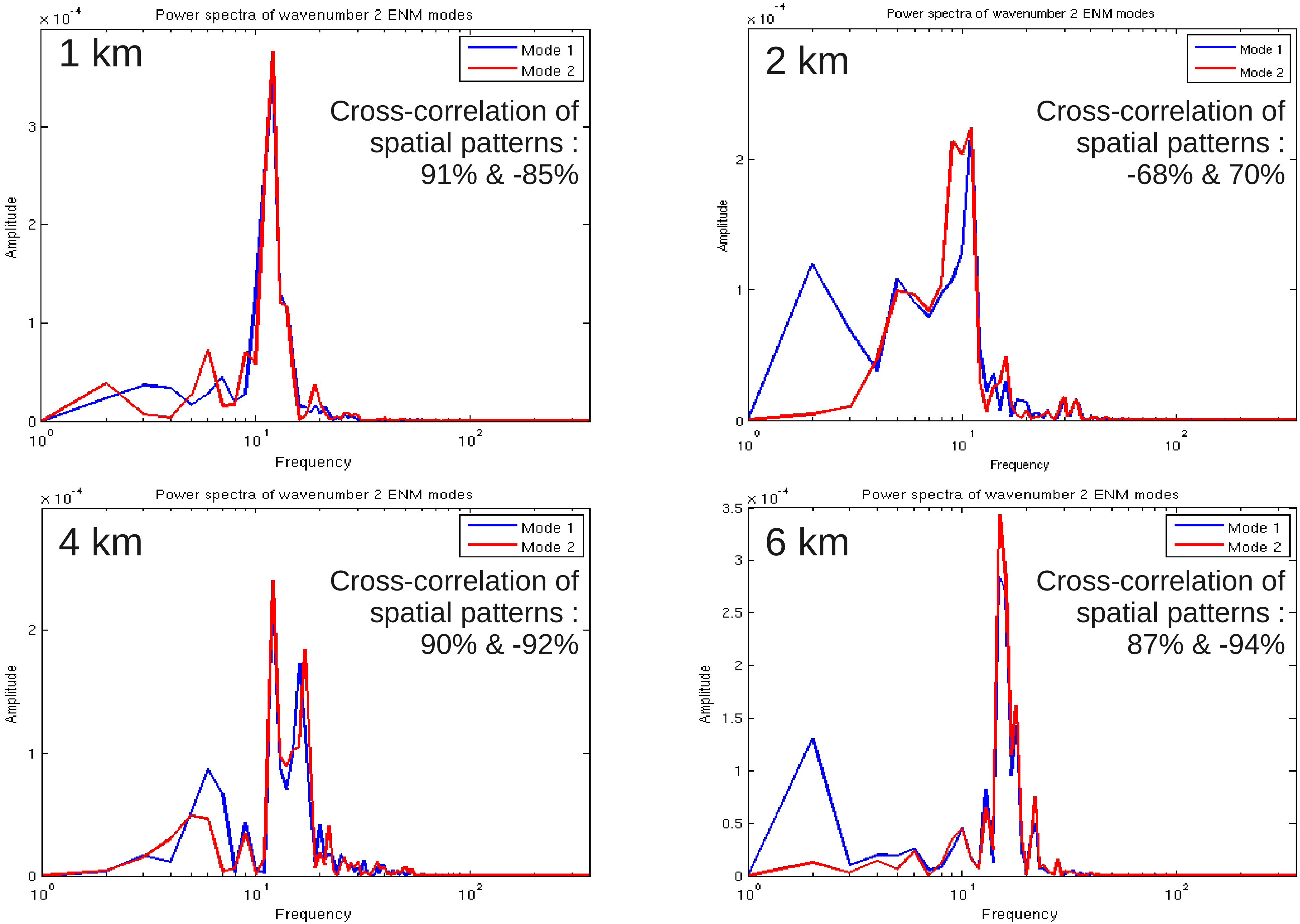




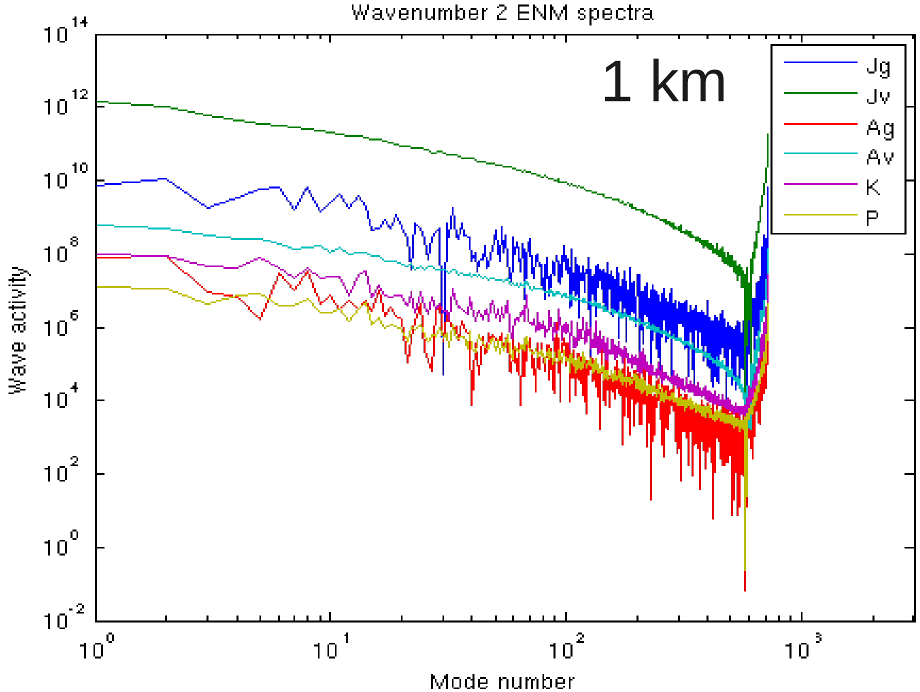


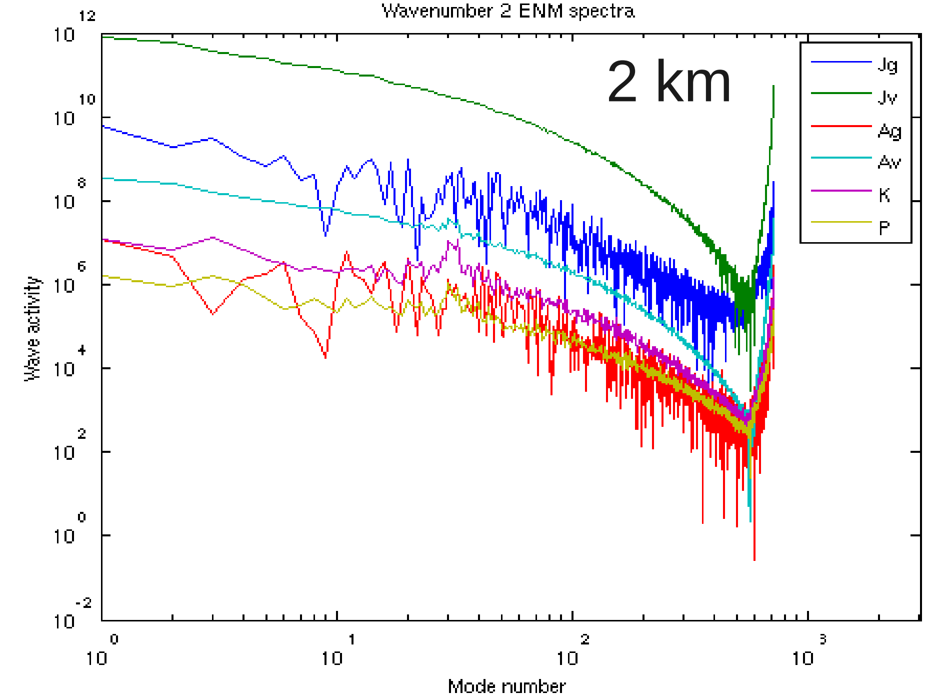


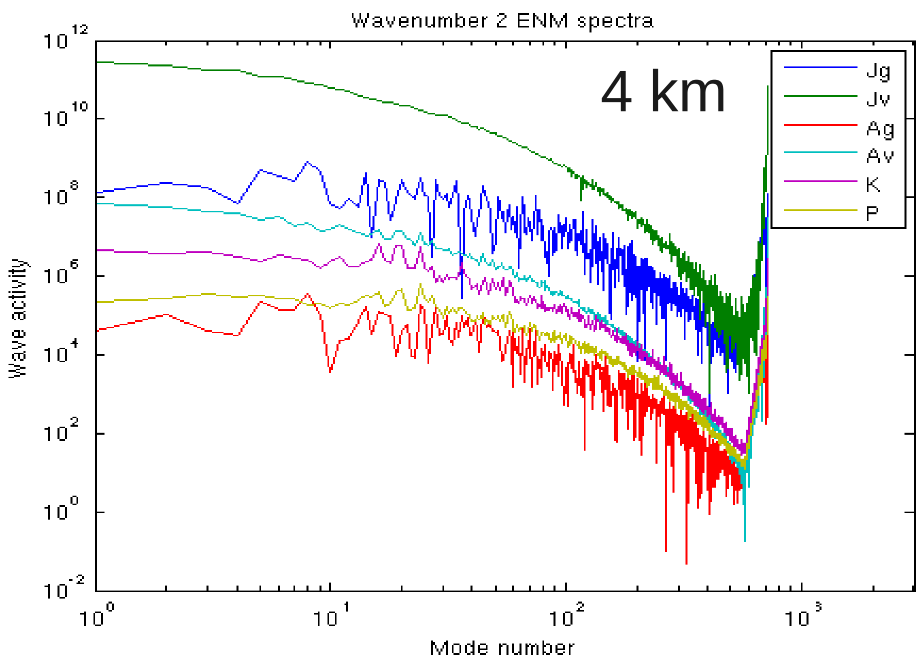
Power spectrum of wavenumber 2 ENM modes

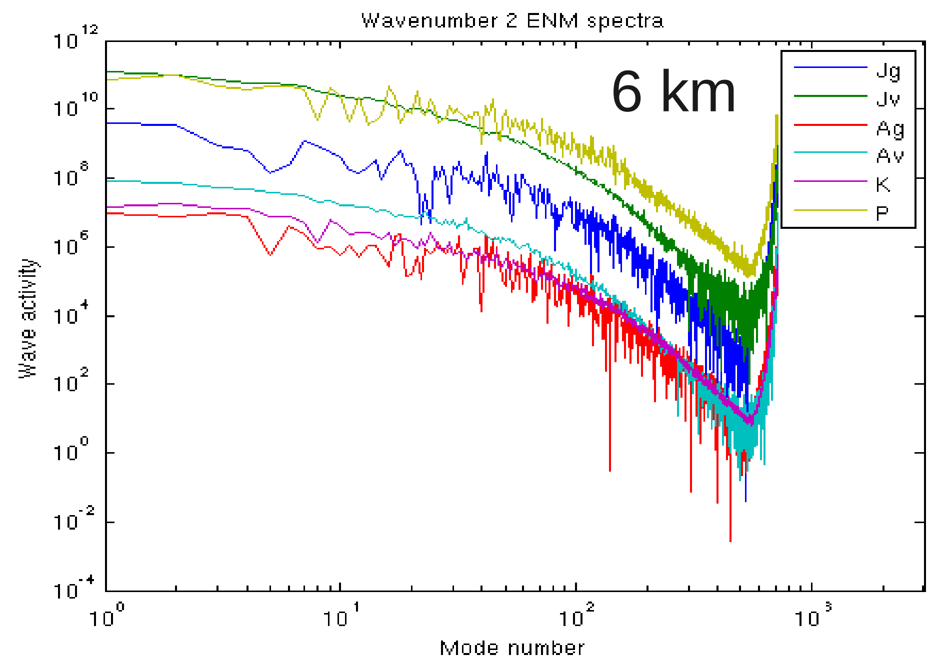


Wave activity spectra for wavenumber 2

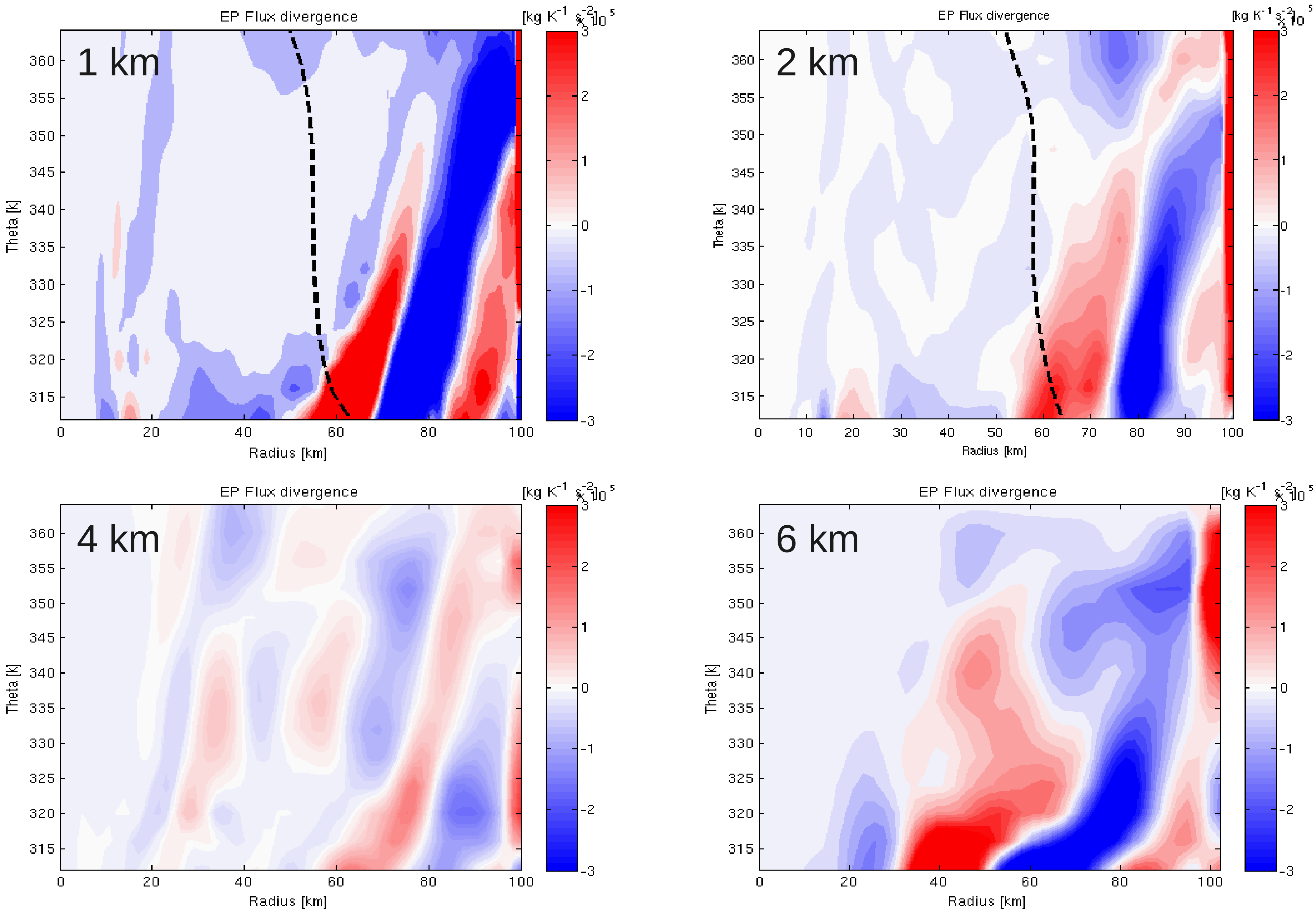








EP flux divergence [kg k^{-1} s^{-2}]



Conclusions

- Horizontal resolution affects Vortex Rossby-wave propagation
- This therefore affects the structure of the hurricane, ie. the secondary eyewall
- High resolution is required to get a secondary eyewall and a realistic simulation

Thank you!

Questions?