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

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Motivation

Methodology*
  - Case
  - Model setup

Results**
  - Control run
  - Coarse resolution
  - High resolution

Conclusion

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

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
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

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<th>Δx (km)</th>
<th>Δt (s)</th>
<th>5</th>
<th>10</th>
<th>15</th>
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<th>30</th>
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</table>

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 $\Omega$ 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.

The EP flux (F) and its divergence

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

Gravity term  Vortical term

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

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

Where \( \nabla \cdot \mathbf{F} > 0 \), VRWs transfer momentum to the mean flow and accelerate the winds

→ Good indicator of where SE forms
Control run ($\Delta x = 2$ km)

Simulated track has a bias to the North

Eyewall replacement cycle takes place
Minimum sea-level pressure

Best track MSLP of hurricane Wilma, with 72 hours simulated MSLP

- **1 km**
- **2 km**
- **4 km**
- **6 km**
Horizontal PV at 312 K level

1 km

30h 36h

42h 48h

54h 60h

66h 72h

2 km

30h 36h

42h 48h

54h 60h

66h 72h

PVU
Horizontal PV at 312 K level

30h, 4 km, 42h, 48h, 54h, 60h, 66h, 72h, 36h, 6 km, 42h, 48h, 54h, 60h, 66h, 72h, 30h, 36h, 6 km, 42h, 48h, 54h, 60h, 66h, 72h

[PVU]
Axisymmetric tangential winds [m/s]

1 km

2 km

4 km

6 km
Power spectrum of wavenumber 2 ENM modes

Cross-correlation of spatial patterns:
- 1 km: 91% & -85%
- 2 km: -68% & 70%
- 4 km: 90% & -92%
- 6 km: 87% & -94%
Wave activity spectra for wavenumber 2

1 km

Wave activity spectra

2 km

4 km

6 km

Wave activity spectra

Mode number

Wave activity

Jg
Jv
Ag
Av
K
P
Conclusions

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

Thank you!
Questions?