P2.141

The Role of the Asymmetric Mode in a Turbulent Regime: Motivation and Preliminary Results

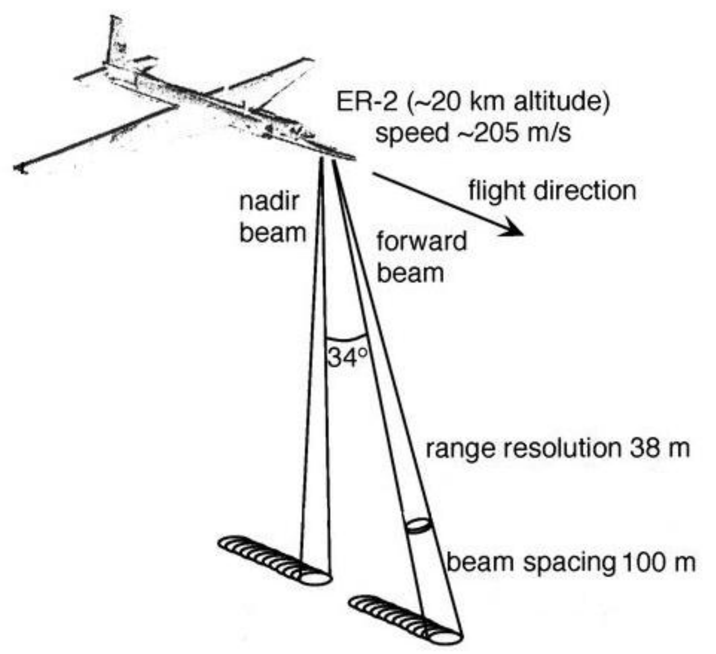
Stephen R. Guimond[1] and Jon M. Reisner[2]

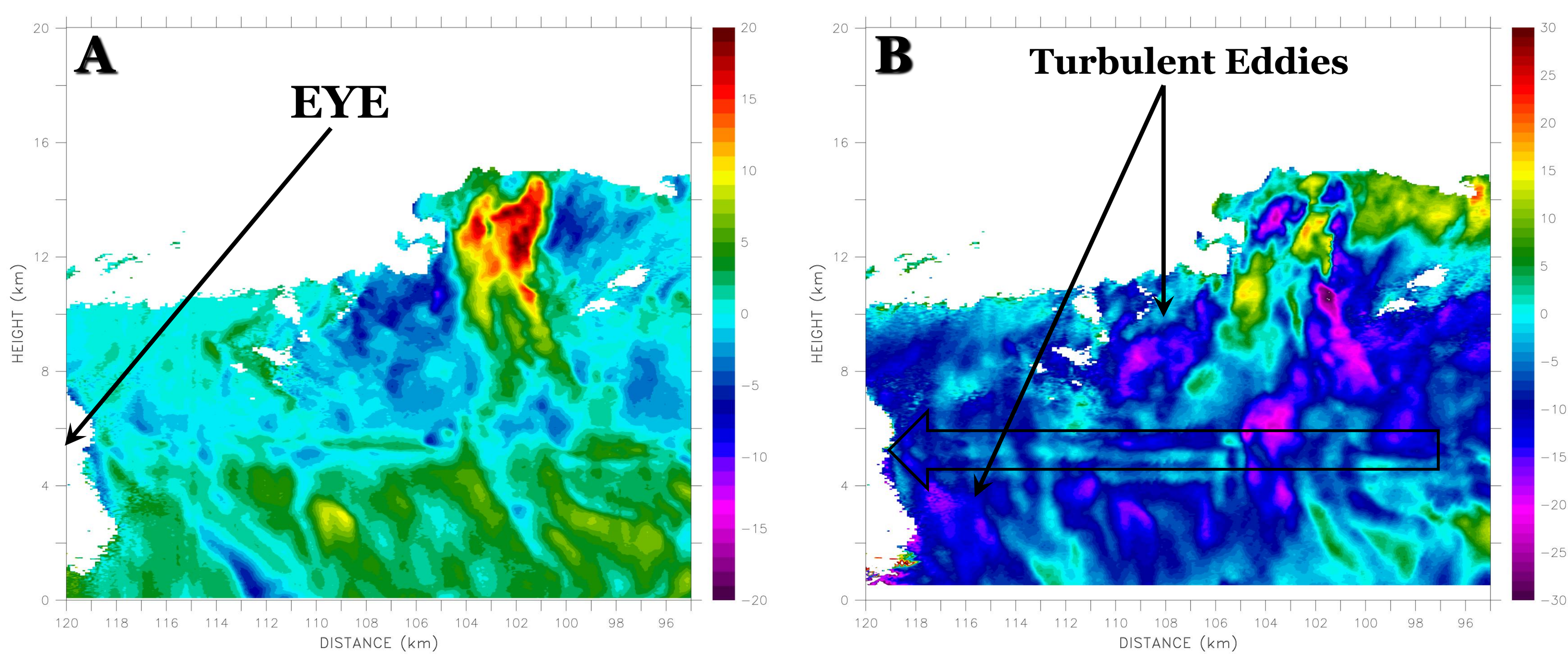
[1] Center for Ocean-Atmospheric Prediction Studies, Florida State University, Tallahassee, FL

[2] Earth and Environmental Sciences Division, Los Alamos National Laboratory, Los Alamos, NM

Point of Contact: guimond@coaps.fsu.edu

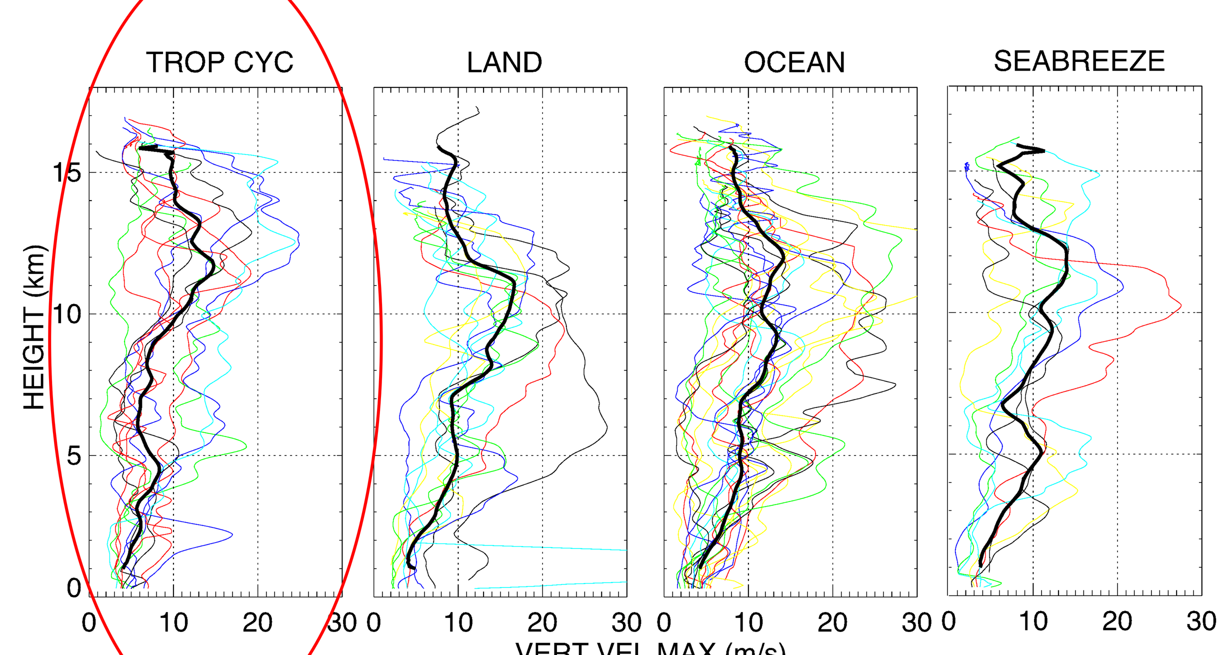
Hot Tower Structure in Hurricane Dennis (2005)

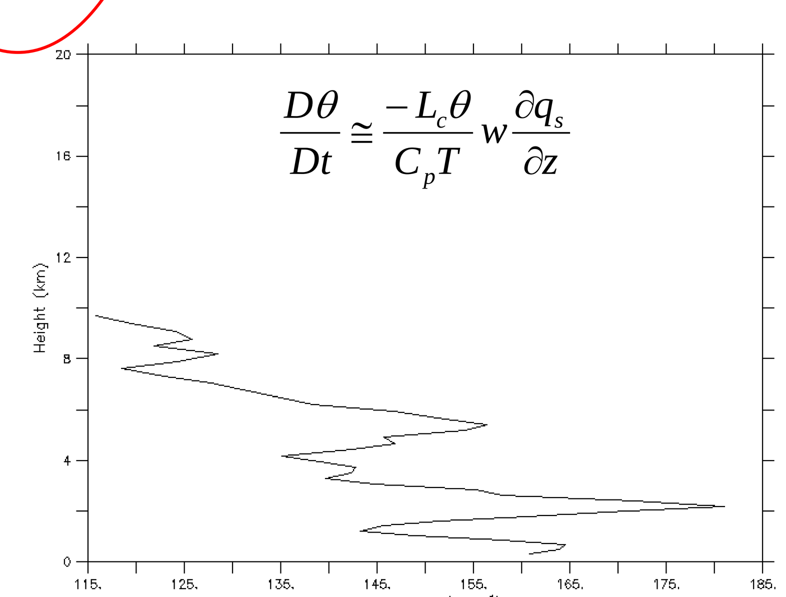




Top: The scan geometry of EDOP. Bottom: EDOP observations of the eyewall of Hurricane Dennis (2005) during NASA's TCSP experiment (Guimond et al. 2010). (A) retrieved vertical velocity (m s⁻¹) (B) retrieved storm-relative radial velocity (m s⁻¹). The effective horizontal resolution of EDOP is ~0.55 km at surface and ~0.30 km at 10 km altitude. The length scales of the radial turbulent eddies in Fig. B are variable, but are generally between 2 – 3 km.

EDOP Derived Heating Pulse





$$\frac{D\theta}{Dt} \cong \frac{-L_c\theta}{C_pT} w \frac{\partial q_s}{\partial z}$$

Top: EDOP vertical velocity climatology for deep convection in TCs and other environments (Heymsfield et al. 2010). There are 13 samples for the TC cases with the black line showing the mean. Bottom: Mean latent heat of condensation profile for the top five updrafts in the top figure (represents mature hot tower). A composite, high-altitude dropsonde from the eyewall of several TCs is used for the thermodynamic information.

Abstract

Localized pulses of heating from convection project onto two broad classes of dynamical modes in the TC: axisymmetric and asymmetric. Nolan and Grasso (2003) and Nolan et al. (2007) have shown that the response of the TC to linear, localized heating in 3D is dominated by the axisymmetric mode with purely asymmetric heating playing an insignificant, negative role in the intensification of the vortex. Whether these results hold in a fully nonlinear, turbulence resolving regime using very high-resolution hot tower heating structure is the topic of this work.

In this poster, we show that the structure of vortex Rossby waves and their feedbacks onto the basic-state vortex depend on uncertain aspects of the turbulence parameterization (eddy diffusivity coefficient). As a result, Large Eddy Simulations (LES) and very high-resolution observational analyses are needed to reduce the uncertainty in our understanding of the asymmetric mode and the role turbulence plays in these processes.

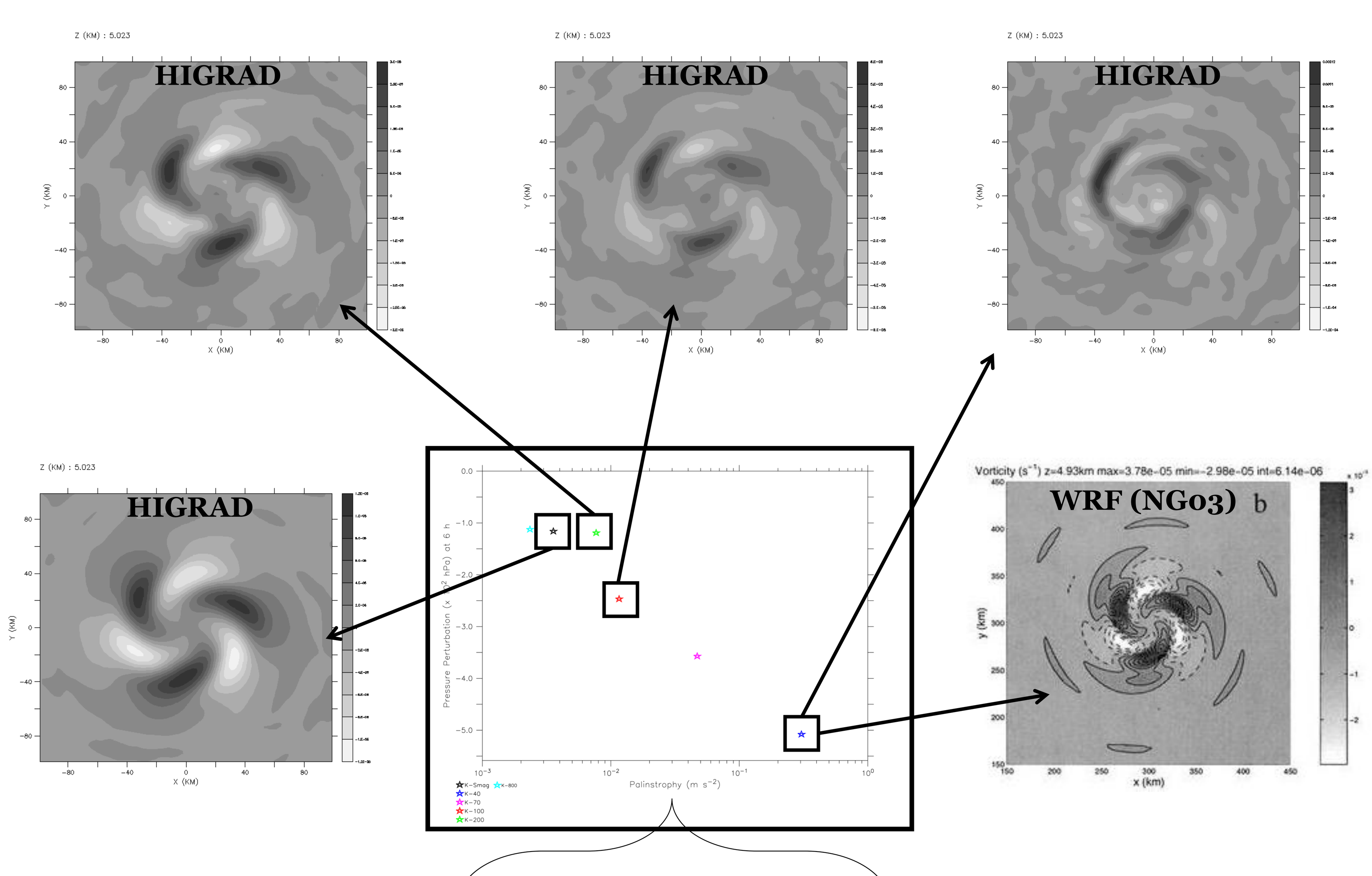
In addition, we show radar observations (EDOP) of radial turbulent eddies in rapidly intensifying Hurricane Dennis (2005; Guimond et al. 2010) as well as preliminary LES modeling (HIGRAD) of the response of an idealized vortex to heating perturbations derived using EDOP measurements.

Axisymmetrization in LANL's HIGRAD Model

Los Alamos National Laboratory's (LANL) HIgh GRADient (HIGRAD) model is a compressible, nonlinear Navier-Stokes (including stress tensor) solver along with a state-of-the-art cloud microphysical model (Reisner et al. 2005; Reisner and Jeffery 2009).

We have conducted simulations of the axisymmetrization process in an idealized environment (quiescent, dry, free-slip) with exponentially stable, baroclinic, tropical storm and hurricane strength vortices. The initial perturbations are small amplitude (linear) thermal anomalies reproduced from the work of Nolan and Montgomery (2001) and Nolan and Grasso (2003; NG03).

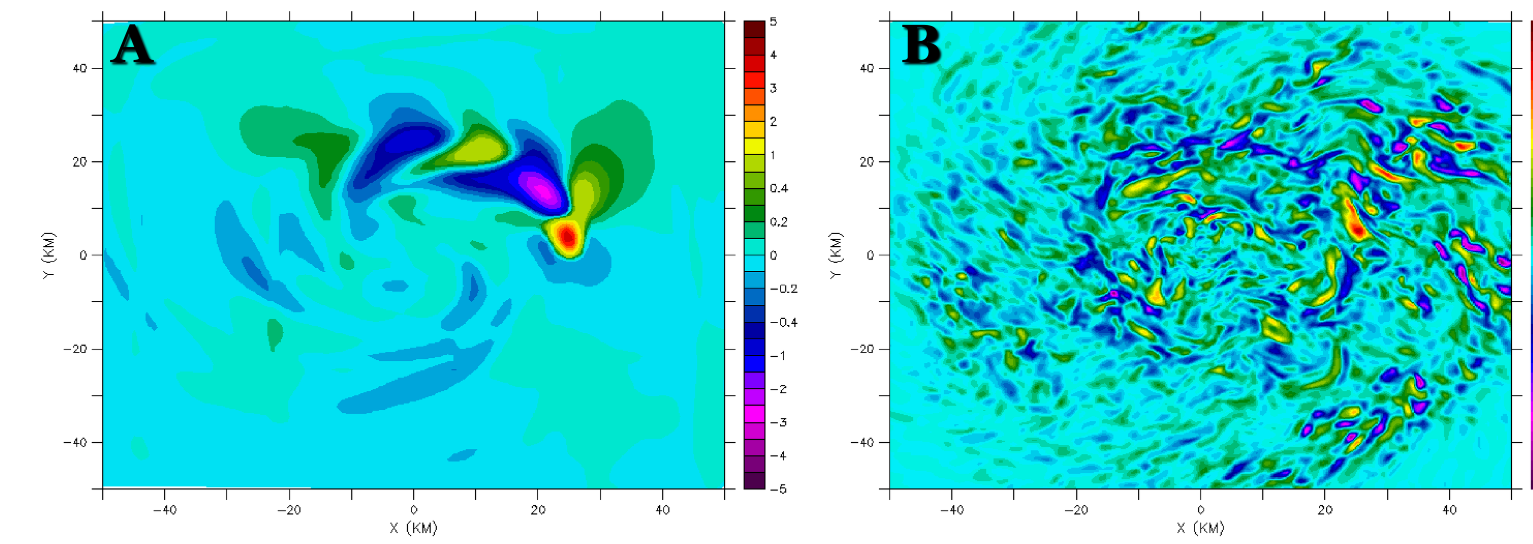
We also consider the EDOP retrieved heating structure shown in the bottom left of this poster in moderate and very high-resolution simulations to compare with the evolution described in NG03.



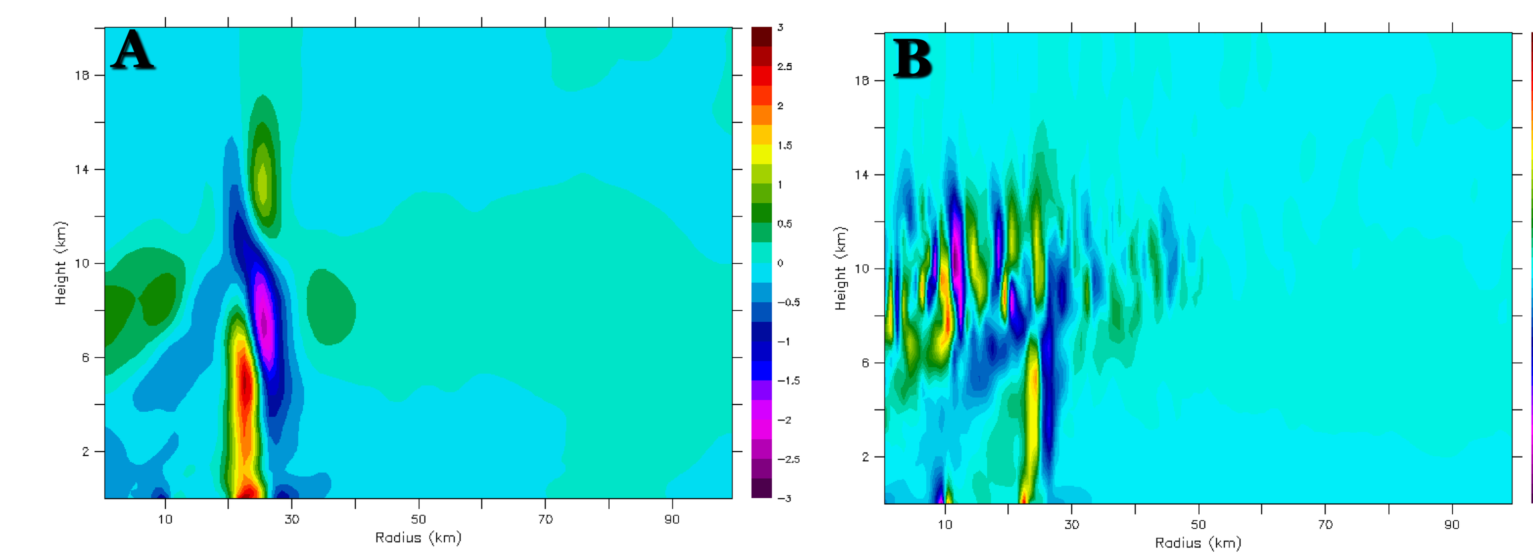
$$\int_{0km}^{10km}\int_{-100km}^{100km}\int_{-100km}^{100km} \frac{1}{2}\left(\vec{\nabla}\zeta' \bullet \vec{\nabla}\zeta'\right) dxdydz$$

Above: Structure of an impulsive 1K wavenumber 3 thermal perturbation (same as NG03) in HIGRAD. The basic-state vortex is very similar to that of NG03. Center figure shows the domain integrated vorticity gradient as a function of 6 h pressure perturbation for different eddy viscosities in HIGRAD. The side figures show the vorticity anomalies at 2 h into each simulation with the WRF results of NG03 shown for reference.

Balanced Adjustment in Turbulent Flow



Above: horizontal cross sections of perturbation vertical velocity (m s⁻¹) in the inner-core of the simulated vortex at 10 km height after 1 h of model time using the EDOP heating pulse. (A) 1 km horizontal resolution and (B) 200 m horizontal resolution.

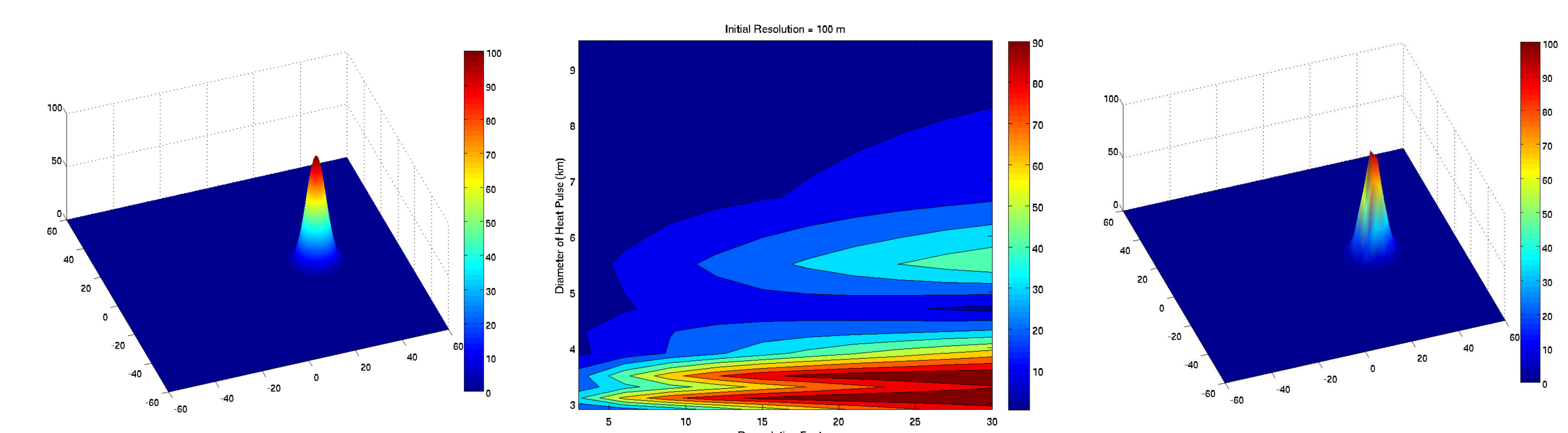


Above: azimuthal mean perturbation vertical vorticity (x 10⁴ s⁻¹) after 1 h of model time using the EDOP heating pulse. (A) 1 km horizontal resolution and (B) 200 m horizontal resolution.

Questions to be addressed with LES Simulations

(1) How does the structure and role of asymmetric processes (e.g. vortex Rossby waves) change as turbulence becomes explicitly resolved?

(2) What scales of convective heating is the TC most efficient at converting to kinetic energy and how does the adjustment process change in a turbulent regime?



Summary and Conclusions

➢ We have provided motivation for the study of turbulence in TCs and deep convection by showing very high-resolution airborne radar observations as well as the sensitivity of the axisymmetrization problem to turbulence in a numerical model.

➢ Preliminary results show a vastly different structure in the gravity wave field at near turbulence resolving scales (200 m), suggesting a potential impact on the balanced adjustment process.

➢ Future work will address the questions above. The final results are expected to have implications for understanding asymmetric processes as well as for observing systems that monitor convection in TCs.

Acknowledgements

This research was supported by Los Alamos National Laboratory through an LDRD project entitled "Flash Before the Storm: Predicting Hurricane Intensification Using LANL Lightning Data" with Dr. Chris Jeffery the PI. In addition, this research was also supported by Dr. Mark Bourassa through a NASA Ocean Vector Winds Science Team grant. Thank you to Paul Reasor for insightful discussions.