ASSESSING THE SENSITIVITY OF THE TROPICAL CYCLONE SECONDARY CIRCULATION TO PERTURBED OUTFLOW VIA IDEALIZED COAMPS-TC SIMULATIONS

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Background
- Observational data have suggested structural differences in the outflow of intensifying versus non-intensifying tropical cyclones (TCs), with stronger radial outflow in intensifying systems and more curved anticyclonic flow in non-intensifying systems (Merrill 1988).
- Multiple outflow channels, with one often to the north and one to the south, can develop in intensifying TCs; the outflow also may thicken in the vertical to a greater degree during intensification (Merrill and Velden 1996).
- Idealized modeling results suggest that a zonal jet to the north of TC may enhance outflow by generating a minimum in inertial stability, allowing the TC to intensify beyond what it otherwise would (Rappin et al. 2011).

3D structure of the mature tropical cyclone (TC)

Key Questions
- How does TC outflow couple with inner-core convection and what is its relationship to intensity changes?
- What is the relationship between the upper-level outflow and the low-level wind field?
- How does TC outflow interact with larger scale features?
- Seek to investigate these questions via idealized TC simulations using COAMPS

Interaction between TC and an approaching jet

Methodology

Model Configuration
- COAMPS-TC (v1.4)
  - Skin: 80x80 grid points
  - Fixed SST: 26 °C
  - 0 km radius (as per Dunion (2011) MT sounding)
- 40 vertical levels
- No Okubo-Weiss parameterization
- Typhoon (as, wall boundary conditions)
- Modified Mellor-Yamada PBL scheme
- Radiation off

Goal: explore sensitivity of TC intensity and structure to enhancing outflow:
- Directly via enhancing ψ, and thereby divergence in the outflow region (∼300-100mb)
- Indirectly by decreasing v, in the outflow region, thereby decreasing deformation and creating an environment more favorable for outflow expansion

Inertial stability:

\[ f = \frac{\Omega}{\beta y} \]

where \( \frac{\Omega}{\beta} \) = 20

Perturbing the outflow:

Technique 1: Direct perturbation of radial wind in outflow region

Added as a tendency to the RHS of the v' momentum equations:

Since \( \frac{\partial \psi}{\partial t} = \frac{\partial \psi}{\partial t} - \psi \frac{\partial \psi}{\partial y} \) we increase divergence by introducing \( \frac{\partial \psi}{\partial t} \) to the north of the TC (or \( \frac{\partial \psi}{\partial t} \) of the outflow)

Perform large set of perturbed simulations, varying:
- Initial location of perturbation in x and y
- Radius of perturbation from 300 to 1100 km
- Vertical maximum from 0-0.5 km to 30 km
- Timing at which perturbation is turned on and off

Technique 2: Add in zonal jet

From υ and ψ momentum equations:

At t=0 we let \( \psi = \psi_0(x, y) \)

Results from perturbing outflow wind tendency

TC MSLP from simulations with 3 m/s easterly flow: turn on perturbation at 96h, turn off at 144h

The effect this has on the structure of the outflow is perhaps underestimated in the idealized modeling community

Results from TC/jet interaction

A few runs stronger than the control(s) from 72-, 120-, but why?

For an "ideal" TC/jet interaction, divergence increases while shear does not; however, here we have more of the opposite occurring, which is likely producing conflicting signals in TC intensity

Summary:
- We have observed sensitivity of TC intensity and structure to perturbed outflow. Outflow is perturbed more directly via adding ψ, and indirectly by decreasing v, in the outflow region to reduce inertial stability
- While intensity and structure have been found to be sensitive to these perturbations, they appear to be of comparable or lesser magnitude to thermal fluctuations in TC intensity
- TC intensity and structure are highly sensitive to the complex combination of shear, divergence and inertial stability, all of which vary with changes in upper-level flow

Future Work
- Construct moisture perturbations (enhancing latent heat release) with wind perturbations to see if dynamic thermodynamic enhancement has greater effect on TC intensity than other factor alone
- Perturb P instead of ψ to see if a stronger pressure gradient → sub-geostrophic winds → outflow deflecting away from TC

References

Acknowledgments
We acknowledge the support of the Office of Naval Research (ONR) Program Element (PE) 0604574N and 0602065N. Computing time provided by the DoD HPCMP DHPI program.