Convective Contribution to the Genesis of Hurricane Ophelia (2005)

Written by: Houze et al.
Presented by: Julie Barnum
Date Presented: 12 May 2016
Introduction

- Figure shows a variety of convective entities that can exist in a developing depression
- Two hypotheses to explain how the population of convective towers and/or MCSs contribute to upscale enhancement of tropical cyclogenesis
  - MCVs in the stratiform region of MCSs
    - Downdrafts don’t appear to be very strong
  - Active, buoyant convective cells of MCSs occurring in a transitioning depression
    - Actually find here that deep convective cells have vortical updrafts
Ophelia Background

Ophelia’s track

Satellite and radar overview of Ophelia’s genesis
Aircraft Mission

- RAINEX mission occurred on 6 September 2005, conducted by Naval Research Laboratory (NRL) P3 aircraft with NOAA P3 aircraft
- Electra Doppler Radar (ELDORA) was onboard the NRL P3
  - \( \lambda = 3.2 \text{ cm}, P_t = 32 \text{ kW}, \text{beam width} = 1.8^\circ, \text{gate spacing} = 150\text{m}, \text{operates with two beams points} \sim 16.5^\circ \text{fore and aft and often overlap with NOAA P3 fly by with} \sim 400 \text{ m sampling distance}\)
- NOAA P3 had 5.5-cm wavelength scanning radar
- Flight Plan
  - Doppler radar aircraft circumnavigates the MCS
  - Fly by of most intense convective element

Idealized flight plan for a “convective burst”
The Convective Cell

• Convective cell was deep (with deep inflow)
  • 40-dBZ echo reached above 12 km
• Convective updraft also wide
• Vertical velocities everywhere 10-20 m/s above 6 km
• Convective cell displayed no gust front convergence
  • Evident in figure to right
• How can lifting to saturation occur without occur without strong downdraft gust front?
  • Cooling produced by evaporation of rain → density gradient

(a)-(c) ELDORA radar reflectivity at 2km for three fly-bys of convective cell, (d) vertical cross section (red line), (e) vertical cross section (white line)
The Convective Cell (contd.)

- Figure shows the results of the thermodynamic retrieval at 8 km altitude
  - Perturbation wind field took form of a closed cyclonic vortex
  - Pressure perturbation contours conformed to perturbation wind field
- Figure shows vertical cross section through convective cell at 2108 UTC
  - Cell accounts for much of mass transport from mid- to upper troposphere
    - Vertical mass transport pattern implies strong max. of heating aloft
    - PV proportional to vertical gradient of latent heating, generating it throughout low- to mid-troposphere
Stratiform Region

- Figure (top) shows flight track relative to mostly stratiform radar echo
- Figure (bottom) shows perturbation wind pattern at 6 km derived from ELDORA
  - Numerous centers of positive vorticity
  - Perturbation winds show cyclonic circulation
- Recall that the upper portion of the convective cell had a cyclonic circulation that conformed to pressure perturbation
  - If all previously-active convective cells were like this, each would have kept and contributed positive vorticity
Stratiform Region (contd.)

- Figure (top) shows mean vertical mass flux profile and mass-flux-weighted contoured frequency by altitude diagrams (CFADs)
  - Based on vertical air motions derived from ELDORA
  - See both downdrafts and updrafts
  - No net downward motion in mid- to low-levels of the stratiform region
  - Melting was occurring, and likely evaporation, but still not enough to switch signs
- See in figure (bottom) that there was not a signature of strong subsidence
- This and the radar image on the previous slide show dominant upward air motion in stratiform regions
Summary of Contributions to Cyclonic Circulation

- Figure to left shows distribution of relative vorticity
- Blue curve is area-averaged vertical vorticity ($\zeta$) shown by ELDORA (stratiform)
- Recall that the stratiform region forms from old, weakening convective cells...
  - No PV at low levels
- Vorticity in upper-levels of convective cells and in stratiform cells can be brought into larger circulation
- Stratiform region vorticity in this MCS primarily enhanced depression development via midlevels
  - Didn’t have to advect vorticity down, convective cells handled that