# **Background & Objectives**

NASA's Global Precipitation Mission (GPM) and Aerosol Chemistry Ecosystem (ACE) Mission Formulation have conducted the Integrated Precipitation and Hydrology Experiment (IPHEx) during May-June, 2014 with the center of operations in Asheville, NC.

NASA ER-2 remote sensing aircraft was instrumented with 3 radars @ 4 frequencies from X- to W-band. Also, the UND Citation, NASA Polarimetric radar (NPOL), and ground-radars participated.

Here we highlight the structure of severe hail storms from the IPHEx on 23-24 May 2014 with emphasis on the vertical structure and wind retrievals from the ER-2 radar measurements. Cloud Radar System (CRS)

ER-2 Remote sensing package: Radar: 9.6, 13.5, 35., 94 GHz Radiometer: 10.7 (H&V), 19.35 (H&V), 37.1 (H&V), 50.3, 52.6, 85.5(H&V), 89 (H&V), 165.5 (H&V), 183.3+/1, 183.3+/-3, 183.3+/-7 GHz



### **ER-2 Radars**

- 3 downlooking radars were flown: High-altitude Imaging Wind and Rain Airborne Profiler (HIWRAP; Ku and Ka-band; nadir pointing), Cloud Radar System (CRS; W-band; nadir pointing), and ER-2 X-band Radar (EXRAD; X-band; nadir-pointing and conical scanning).
- EXRAD's conical scanning beam is approximately 28° off-nadir. The 2-D (curtain below plane) and 3-D winds can be calculated from EXRAD data.

Radar Sensitivities at 10 km range

- HIWRAP Ka-band: -12 dBZ
- HIWRAP Ku-band: -10 dBZ
- CRS W-band: -28 dBZ
- EXRAD X-band: -8 dBZ



### Hail Storms on 23-24 May 2014



hail@2335

Strong winus

KGSP Greer. SC

23 May 14 @ 231742 UTC

>23 May 2014 storms photographed from 65kft by ER-2 pilot.



 Large hail reported in SPC GPM overpass at 23:16 UTC Far from IPHEx network but within range NPOL & 88Ds KGSP, KCAE, NPOL all >65 dBZ.



Columbia, SC 23 May 14 231742 UTC 1.6 deg elev.

• Charleston, SC 24 May 2014 @ 0 UTC sounding showed most instability • High CAPE ~2700 J/kg • Winds are toward southeast at all levels, not much directional shear. • Storm motion is ~16.7 ms<sup>-1</sup> toward  $125^{\circ}$ . • A few large cells dominated, but generally multicellular behavior.

# Structure of Hailstorms in North Carolina Obtained from EXRAD Airborne Radar During IPHEx

Gerald Heymsfield<sup>1</sup>, Lin Tian<sup>1,2</sup>, Stephen Guimond<sup>1,3</sup>, Lihua Li<sup>1</sup>, Matthew McLinden<sup>1</sup>

<sup>1</sup>Goddard Space Flight Center, <sup>2</sup>GESTAR/Morgan State3University, <sup>3</sup>UMBC/JCET









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# **3DVAR Wind Retrieval**

- in.
- right.
- toward the southeast.



northwest

This flow configuration is conducive for hail development via recycling since ascending hail will fall back into the inflow/updraft.

### First Echoes Captured by Airborne Data

23 May 2014 ~23:16. 4 frequencies of reflectivity (left) and vertical velocity (right).

- First echoes develop at about 7 km altitude --> typical for very strong updrafts.
- Vertical velocities in these first echoes are at least 20 m/s.

## Summary & Future Work

- progress.

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• Preliminary study hints at mechanisms that produced copious hail exceeding 5 cm in North and South Carolina. • WSR88D polarimetric data analysis is in progress for these storms. Multifrequency radar retrievals in progress. • Examination of Ku/Ka-band polarimetric (LDR) observations in