Using Large Ensembles of Low-Cost Lagrangian Drifters for Tropical Cyclone Analysis & Forecasting

John Manobianco, Joseph G. Dreher, Mark L. Adams, and Jonathan L. Case
ENSCO, Inc.

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Outline
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Methodology
PRELIMINARY Results
Summary/Future Efforts
**Concept Description**

- **Global Environmental Micro Sensors (GEMS)** – multi-year feasibility study
- **Ensemble of super pressure, constant density balloons (Lagrangian drifters)**
- **Drastically reduce mass, size, and cost by integrating micro and eventually nanotechnology**
  - Components
  - Balloon material (12.5-\(\mu\)m Mylar\textsuperscript{TM} GL-AE)
  - Current (70 gm; 40 cm; beach ball)
  - Target (<1 gm; 10 cm; grapefruit)
- **Self-contained with power source for**
  - Sensing
    - Dropsonde quality micro sensors
    - T, p, RH, velocity (micro GPS)
  - Communication (Iridium-class satellites)
  - Limited signal processing/computation
Motivation

- Improve density / distribution of in situ observations especially over data sparse oceanic regions
- Significantly enhance adaptive or targeted observing campaigns
  - Research & operational missions
  - Synoptic observing capabilities spanning a broad range of time/space scales
  - Tropical cyclone reconnaissance where it is only cost effective & practical to obtain in situ, high-resolution, measurements over limited domains
Preliminary Data Impact Study

• Dynamic simulation models
  – Virtual weather scenarios - ARPS (Advanced Regional Prediction System)
  – Probe deployment & dispersion - Lagrangian particle model
  – Data assimilation (DA) - NCAR/PSU MM5 (Mesoscale Model v5)

• Hurricane Floyd case (Sep 1999)

• Simulated observations
  – GEMS probes deployed from aircraft
    • 1140 probes every 12 h
    • 1 per minute during typical recon flight pattern
  – 5-min observation frequency
  – No measurement errors or instrument failures
  – No simulated aircraft, satellite, or dropsonde data

• Value added of probe data
  – Observe/analyze 4D tropical cyclone structure
  – Initialize tropical cyclones using high resolution models
Experiment Design

ARPS 15-km
0 3 6 9 12 15 18 21 24 27 30 (forecast hour)
18Z 00Z 06Z 12Z 18Z 00Z
9 Sep 10 Sep

ARPS 3-km
0 3 6 9 12 15 18 21 24 27 30 (forecast hour)
18Z 00Z 06Z 12Z 18Z 00Z
9 Sep 10 Sep

MM5 12-km run
0 1 2 3 4 5 6 (forecast hour)
18Z 19Z 20Z 21Z 22Z 23Z 00Z
10 Sep 11 Sep

Simulated GEMS data (u, v, RH, T) assimilated using MM5 Newtonian relaxation (nudging)

Experiment Avg # obs per ingest time

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<thead>
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<th>Experiment</th>
<th>Avg # obs per ingest time</th>
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<tr>
<td>Full</td>
<td>4785</td>
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<tr>
<td>10%</td>
<td>478</td>
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<tr>
<td>1%</td>
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Simulated “Truth”

15-km ARPS clouds & probes
6-day loop with 1 frame every hour

3-km ARPS clouds & probes
29-h loop with 1 frame every 5 min
Simulated “Truth” (2)

- ARPS "Truth" 3 km
- GEMS Probes 3 km
DA Results

900 hPa
Velocity (m s$^{-1}$)
0000 UTC
11 Sep 1999

ARPS 3-km

MM5 12-km (all obs)

MM5 12-km (10% obs)

MM5 12-km (1% obs)
DA Results (2)

Speed (m s\(^{-1}\))
Theta (K)
0000 UTC
11 Sep 1999

ARPS 3-km

MM5 12-km (all obs)

MM5 12-km (10% obs)

MM5 12-km (1% obs)
DA Results (3)

**Hurricane Floyd Mean Sea-Level Pressure**

- **ARPS 3 km**
- **MM5 12 km - Full**
- **MM5 12 km - 10%**
- **MM5 12 km - 1%**

**Hurricane Floyd Maximum Wind**

- **ARPS 3 km**
- **MM5 12 km - Full**
- **MM5 12 km - 10%**
- **MM5 12 km - 1%**

Forecast Hour ranges from 18 to 24.
Summary & Future Efforts

• Summary
  – Low cost, low mass, ensemble of Lagrangian drifters (GEMS)
  – Map 4D tropical cyclone structure including intensity changes
  – Initialize high resolution models without bogus vortex

• Operational Issues
  – Deployment scenarios (cost, practicality, etc.)
  – Aviation hazards
  – Robustness to harsh conditions in tropical cyclones (e.g. rain out)

• Future Efforts
  – Prototype development in progress (functional device by fall 2006)
  – Expand data impact studies
    • Limitations of a single case
    • Use more advanced modeling/assimilation systems (e.g. H-WRF, 3D/4DVAR)
    • Include full data suite & assess impact relative to track/intensity forecasts over broader range of space/time scales