Fine Scale Hail Hazard Prediction using the WRF Model

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Outline

- Motivation
- Case Overview
- Modeling Strategy
- Validation
- Sensitivity Experiments
- Conclusions
Motivation

Loss (USD): 0.5 billion (Oklahoma) / 100 Million (Texas)
Overview: 28 – 30 May 2012 Oklahoma Storms

500 hPa Ht (dam) + Isotherms

RADAR Refl.(dbZ) + MSLP (hPa)

All 3 storms:
Weak
-synoptic forcing
-MSLP gradient
Dry Line.
MCS

Hail Impacted Region

00 UTC 28 May 2012

21 UTC 29 May 2012

Hail Impacted Region
Overview: 24 April 2015 San Antonio Storm

The storm:
- Weak
- synoptic forcing
- MSLP gradient
- Outflow Boundary
- Not a MCS

Hail Impacted Region

00 UTC 24 April 2015

06 UTC 24 April 2015

Hail Impacted Region
Modeling Strategy

San Antonio, Texas

- 4 km
- 1 km
- 250 m
- 601 x 601 / 18 UTC
- 201 x 201 / initialized: 12 UTC

Oklahoma City, Oklahoma

- 8 km
- 2 km
- 500 m
- 401 x 401 / 03 UTC

- 40 levels
- Hourly boundary conditions
- YSU, NSSL-2 moment, no CPS
- NAM initial & LB conditions.
- 3DVar assimilation (coarsest only)
- Modification: Hail swath outputs

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# Verification Metrics

<table>
<thead>
<tr>
<th></th>
<th>OBS</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCST</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>YES</td>
<td>Hits (a)</td>
<td>False Alarms (b)</td>
</tr>
<tr>
<td></td>
<td>NO</td>
<td>Misses (c)</td>
<td>Correct Negatives (d)</td>
</tr>
</tbody>
</table>

**Probability of Detection (POD):**

\[
POD = \frac{a}{a + c}
\]

**Probability of False Detection (POFD):**

\[
POFD = \frac{b}{b + d}
\]

**POD:** What fraction of the OBSERVED hail events were correctly forecast?

**POFD:** What fraction of the NOT OBSERVED hail events were incorrectly forecast?

**OBS:** Hail YES/NO events at point locations.

**FORECAST:** Last 24-h / 12-h swath of hail mixing ratio for OK/TX storms converted to hail YES/NO events.
### Verification: POD

#### 2012: Oklahoma City, Oklahoma

<table>
<thead>
<tr>
<th>Resolution</th>
<th>28 May</th>
<th>29 May</th>
<th>30 May</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 km</td>
<td>1.00</td>
<td>0.99</td>
<td>0.59</td>
</tr>
<tr>
<td>2 km</td>
<td>0.97</td>
<td>0.99</td>
<td>0.94</td>
</tr>
<tr>
<td>500 m</td>
<td>0.88</td>
<td>0.99</td>
<td>0.00</td>
</tr>
</tbody>
</table>

High POD for OK storms but the 30 May storm showed complex small scale interactions (Bluestein 2014).

#### 2015: San Antonio, Texas

<table>
<thead>
<tr>
<th>Resolution</th>
<th>24 April</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 km</td>
<td>0.00</td>
</tr>
<tr>
<td>1 km</td>
<td>0.01</td>
</tr>
<tr>
<td>250 m</td>
<td>0.83</td>
</tr>
</tbody>
</table>

Smaller storm and fine resolution helps.
## Verification: POD & POFD

<table>
<thead>
<tr>
<th>Grid</th>
<th>POD</th>
<th>POFD</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 km</td>
<td>0.00</td>
<td>0.04</td>
</tr>
<tr>
<td>1 km</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>250 m</td>
<td>0.83</td>
<td>0.35</td>
</tr>
</tbody>
</table>

### Maps
- **Bexar County**
- **NAM IC & LBCs, 24 April 2015: San Antonio, Texas**

- **Grids**:
  - 4 km: POD 0.00, POFD 0.04
  - 1 km: POD 0.01, POFD 0.02
  - 250 m: POD 0.83, POFD 0.35

- **Markers**:
  - **Hits**
  - **Misses**
  - **False Alarm**
  - **Correct Negatives**
Sensitivity: RAP IC & LBCs

<table>
<thead>
<tr>
<th>Grid</th>
<th>POD</th>
<th>POFD</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 km</td>
<td>0.00</td>
<td>0.05</td>
</tr>
<tr>
<td>1 km</td>
<td>0.01</td>
<td>0.15</td>
</tr>
<tr>
<td>250 m</td>
<td>0.9</td>
<td>0.57</td>
</tr>
</tbody>
</table>

24 April 2015: San Antonio, Texas
## Sensitivity (NAM): Initialization Time

<table>
<thead>
<tr>
<th>Grid/Start Time</th>
<th>POD</th>
<th>POFD</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 km / 00 UTC</td>
<td>0.00</td>
<td>0.04</td>
</tr>
<tr>
<td>1 km / 03 UTC</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>250 m / 03 UTC</td>
<td>0.83</td>
<td>0.35</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grid/Start Time</th>
<th>POD</th>
<th>POFD</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 km / 00 UTC</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>1 km / 00 UTC</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>250 m / 00 UTC</td>
<td>0.14</td>
<td>0.09</td>
</tr>
</tbody>
</table>

24 April 2015: San Antonio, Texas
## Sensitivity (NAM): Data Assimilation

**Probability of Detection**

<table>
<thead>
<tr>
<th>Date / Resolution</th>
<th>With</th>
<th>Without</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 April 2015 / 250 m</td>
<td>0.83</td>
<td>0.07</td>
</tr>
<tr>
<td>28 May 2012 / 500 m</td>
<td>0.88</td>
<td>0.03</td>
</tr>
<tr>
<td>29 May 2012 / 500 m</td>
<td>0.99</td>
<td>0.00</td>
</tr>
<tr>
<td>30 May 2012 / 500 m</td>
<td>0.00</td>
<td>0.99</td>
</tr>
</tbody>
</table>
Conclusions & Future Work

The **hindcasts** showed high:
POD scores for all storms.
POD and low POFD for the TX storm.

**Sensitivity** Experiments:
For TX storm, the RAP IC and LBCs gave high(low) POD(POFD).
The 3DVar assimilation resulted in high POD scores for many of the storms.
Hindcast accuracy favorably impacted by using delayed initialization of the fine meshes.

Thus, the fine scale hail modeling system is **robust** and produces reasonable hail information.

**Future Work:**
Estimation of property loss from hindcasted hail information.
Test robustness of the hail modeling system by applying to other geographies.

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18th Conference on Atmospheric Chemistry
698: Impacts of an Unknown Daytime HONO Source on the Mixing Ratio and Budget of HONO, and Hydroxyl, Hydroperoxyl and Organic Peroxy Radicals, in the Coastal Regions of China

23rd Conf. on Probability and Statistics in the Atmospheric Sciences
14.5: Verification of High-resolution WRF-ARW Forecasts for Vermont Utility Applications

30th Conference on Hydrology
538: Modulation of Urban Heat Island and Heat Waves under Current and Future Climate

20th Conf. on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS)
676: An Integrated Modeling, Observing and Visualization System for the Study of the Ecology of Lake George in the Jefferson Project