Forecasting Convective Downburst Potential Using GOES Sounder Derived Products

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Topics of Discussion

• Convective Downbursts
• Description of the GOES Microburst Products
• Case Studies/Microburst Prediction Exercises
• Use of the GOES Microburst Products with Other Satellite Data
Introduction

• The **downburst** is defined as a strong downdraft produced by a **convective storm** (i.e., thunderstorm) that induces an **outward burst of damaging winds** on or near the earth's surface (Fujita and Wakimoto 1983).

• Due to the **intense wind shear** they produce, downbursts are a **hazard to aircraft** in flight, especially during takeoff and landing phases.
Microburst Aircraft Hazards

Microburst

Headwind
Slows and lifts plane above normal path

Downdraft
While pilot compensates for headwind by dipping nose, plane enters downdraft

Downdraft

Tailwind
Dangerously reduces plane’s speed

Normal landing glide path

Airport runway

UCAR
Historic Microburst-Related Airline Disasters

- Eastern 66, New York (JFK), June 1975
- Continental 426, Denver, August 1975
- Pan American 759, New Orleans, July 1982
- Delta 191, Dallas-Ft. Worth (DFW), August 1985
- USAIR, Charlotte (CLT), July 1994
- American Airlines, Little Rock (LIT), June 1999
Introduction

• GOES sounder-derived parameters have been shown to be useful in assessing the potential for convective downbursts. Products include:
  • Wet Microburst Severity Index (WMSI)
  • Dry Microburst Index (DMI)
  • Microburst Windspeed Potential Index (MWPI)
Downburst Types

- **Macrobust**: Outflow size $> 4$ km, duration 5 to 20 minutes (Fujita 1981)
- **Microburst**: Outflow size $< 4$ km, duration 2 to 5 minutes (Fujita 1981)
- Microbursts (or clusters of microbursts) can evolve into larger downbursts.
GOES Microburst Products

• Generated hourly at the NOAA Science Center in Camp Springs, MD
• Available on the GOES Microburst Products web page at the following URL: http://www.orbit.nesdis.noaa.gov/smcd/opdb/aviation/mb.html
GOES Microburst Products

- Microburst program ingests the vertical temperature and moisture profiles derived from GOES sounder radiances, using a subset of single field of view.
- Microburst products are available approximately 50 minutes after sounder scan.
- Based on the *thermodynamic structure* of the ambient atmosphere.
Algorithm Development

Table 1: Predictor and response variables utilized in the study

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predictors based on a local sounding</td>
<td></td>
</tr>
<tr>
<td>DPD7</td>
<td>Dew-point depression at 700 mb</td>
</tr>
<tr>
<td>DPD5</td>
<td>Dew-point depression at 500 mb</td>
</tr>
<tr>
<td>DPDS</td>
<td>Extrapolated dew-point depression in °C at surface</td>
</tr>
<tr>
<td>LAP75</td>
<td>Lapse rate of temperature between 700 and 500 mb</td>
</tr>
<tr>
<td>PRESS</td>
<td>Pressure at surface in mb</td>
</tr>
<tr>
<td>WDIR5</td>
<td>Wind direction in degrees at 500 mb</td>
</tr>
<tr>
<td>Predictor based on regional data</td>
<td></td>
</tr>
<tr>
<td>TEMUP5</td>
<td>Temperature upwind at 500 mb</td>
</tr>
<tr>
<td>LDNHF5</td>
<td>Location of Denver in the 500-mb height field pattern</td>
</tr>
<tr>
<td></td>
<td>(synoptic forcing: 0, 1, 2, 3)</td>
</tr>
<tr>
<td>SWTRH</td>
<td>Shortwave trough approaching, present, or past Denver (+1, 0, -1)</td>
</tr>
<tr>
<td>Response</td>
<td></td>
</tr>
<tr>
<td>BEDCNT</td>
<td>Bedard's count of number of microbursts observed on each day in JAWS</td>
</tr>
<tr>
<td>FUJCNT</td>
<td>Fujita's count of number of microbursts observed on each day in JAWS</td>
</tr>
<tr>
<td>RADCNT</td>
<td>Radar and chase team count of number of microbursts observed on each day in JAWS</td>
</tr>
</tbody>
</table>

Fig. 2: Two extreme microburst environments: a) virga-type, and b) wet.

From Caracena and Flueck (1988)
Wet Microburst

From Atkins and Wakimoto (1991)
Theta-e Deficit (TeD)

- Maximum vertical difference in equivalent potential temperature ($\theta_e$) from the surface to the middle troposphere (Atkins and Wakimoto 1991).
Wet Microburst Severity Index (WMSI)
Wet Microburst Severity Index (WMSI)

\[ \text{WMSI} = \frac{(\text{CAPE})(\text{TeD})}{1000} \]

- Large convective available potential energy (CAPE) results in strong updrafts that lift the precipitation core within a convective storm to minimum theta-e level.
- TeD indicates the presence of a dry (low theta-e) layer in the middle troposphere that would be favorable for the production of large negative buoyancy due to evaporative cooling.
Wet Microburst Severity Index (WMSI)
Dry Microburst

From Wakimoto (1985)
Dry Microburst Index (DMI)

DMI = $\Gamma + (T - T_d)_{700} - (T - T_d)_{500}$

- $\Gamma$ = temperature lapse rate (°C km$^{-1}$) from 700 to 500 mb
- $T$ = temperature (°C)
- $T_d$ = dew point temperature (°C)

Dry microbursts may occur when the DMI > 6 (Ellrod et al 2000)
Hybrid Microburst

DFW Interpolated VAS Sounding - 2218 UTC

[Graph showing meteorological data with labeled axes and points: P (mb) on the y-axis, T (°C) on the x-axis, with points labeled EL, PBE, LFC, and NBE.]
Microburst Windspeed Potential Index (MWPI)

MWPI = CAPE/100 + \Gamma + (T - T_d)_{850} - (T - T_d)_{670} (Pryor2009a)

- \Gamma = temperature lapse rate (°C km\(^{-1}\)) from 850 to 670 mb
- T = temperature (°C)
- T_d = dew point temperature (°C)
- Severe microbursts may occur when the MWPI > 50
Microburst Windspeed Potential Index (MWPI)
Summary of Microburst Generation Processes

- **DMI**: subcloud evaporative and sublimational cooling (Caracena and Flueck 1988)
- **WMSI**: precipitation loading and evaporative cooling from the entrainment of dry ambient air into the precipitation core (Wakimoto 2001)
- **MWPI**: combination of above processes
Statistical Relationships

\[ y = 0.3173x + 33.287 \]

**MWPI vs Wind Speed**

- MWPI<50, gusts 35 to 50 knots
- MWPI>50, gusts > 50 knots
GOES-West Imager Product

- Multispectral GOES imager product (Pryor 2009a):
  - Improved spatial and temporal resolution (4 km, 30 minutes) over sounder products (10 km, 60 minutes).
  - Split-window channel (band 5, 12 μm) allows for the inference of boundary layer moisture content.
  - Strong negative correlation between 6.7 μm brightness temperature ($T_b$) and layer-averaged relative humidity (RH) between the 200 and 500-mb levels.
- Output brightness temperature difference (BTD) is proportional to microburst potential:
  - $\text{BTD} = \{T_5 - T_3\} - \{T_4 - T_5\}$
- Best suited for assessment of dry microburst potential
GOES-West Imager Product

GOES-11 transmittance weighting functions and Amarillo RAOB
GOES-West Imager Product

Guthrie, Texas
Case Studies
Case 1: High Plains Downbursts
Case 1: High Plains Downbursts
Case 1: High Plains Downbursts

McIDAS-V visualization
Case 1: High Plains Downbursts

Hereford, Texas

Kenton, Oklahoma
Case 1: High Plains Downbursts

Hereford, Texas

Kenton, Oklahoma
Case 2: Oklahoma Downbursts
Case 2: Oklahoma Downbursts
Case 2: Oklahoma Downbursts

Output BTD ~ 50K
Wind gust potential ~ 50 knots

Weatherford El Reno
Case 2: Oklahoma Downbursts

Weatherford, Oklahoma

Medford, Oklahoma
Case 2: Oklahoma Downbursts

Weatherford, Oklahoma

Medford, Oklahoma
Case 3: Chesapeake Bay Downbursts
Case 3: Chesapeake Bay Downbursts
Case 3: Chesapeake Bay Downbursts

Tolchester Beach, Maryland
Future Research Direction

• Refinement and validation of GOES sounder and imager microburst products:
  – Focus over eastern U.S. using NOS observation data

• Investigate and develop nowcasting technique employing GOES imager product and radar reflectivity imagery.

• ArXiv.org:
  – http://arxiv.org/find/physics/1/au:+Pryor_K/0/1/0/all/0/1
Conclusions

• GOES sounder MWPI and GOES-W imager products have demonstrated capability in the assessment of wind gust potential over the Great Plains and Atlantic Coast regions.

• Case studies and statistical analysis for convective storm events have demonstrated effectiveness of the microburst products:
  – Significant correlation between risk values and microburst wind gust magnitude.

• The GOES sounder and imager products are especially useful in the inference of the presence of intermediate or “hybrid” microburst environments, especially over the Great Plains region.
References


References


Questions?
Thank You!