Thunderstorm Downburst Prediction: An Integrated Remote Sensing Approach

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Topics of Discussion

- Thunderstorm Life Cycle
- Thunderstorm downbursts and downburst prediction technique
  - GOES Sounder
  - Dual polarization Doppler radar
- Case Study: Jacksonville, Florida, June, 2014
- Conclusions
Thunderstorm Life Cycle

- **Cumulus Stage:**
  - vertical growth, updraft dominated, influenced by positive buoyant energy

- **Mature Stage:**
  - Maximum updraft intensity, mixed-phase precipitation, downdraft initiation and development

- **Dissipating Stage:**
  - Downdraft dominated, precipitation diminishes, cloud debris evaporation
Thunderstorm Downburst

- Strong downdraft produced by a convective storm (or thunderstorm) that causes damaging winds on or near the ground.
- Precipitation loading, sometimes combined with entrainment of subsaturated air in the storm middle level, initiates the downdraft.
- Melting of hail and sub-cloud evaporation of rain result in the cooling and negative buoyancy that accelerate the downdraft in the unsaturated layer.

Since 2000, the NTSB has documented ten fatal microburst-related general aviation aircraft accidents, mostly over the southern and western U.S.
Downburst Types

- **Macroburst**: Outflow size > 4 km, duration 5 to 20 minutes (Fujita 1981)
- **Microburst**: Outflow size < 4 km, duration 2 to 5 minutes (Fujita 1981)
- **Wet Microburst**: Heavy rain observed on the ground.
- **Dry Microburst**: Little or no rain observed on the ground.

Courtesy USA TODAY
Microburst Windspeed Potential Index (MWPI)

- Based on factors that promote thunderstorms with potential for strong winds:
  - Convective Available Potential Energy (CAPE): Strong updrafts, large storm precipitation content (esp. hail, rain)
  - Large changes of temperature and moisture (humidity) with height in the lower atmosphere.
  - Index values are positively correlated with downburst wind strength.

MWPI ≡ CAPE /1000 + \( \frac{\Gamma}{5^\circ C \text{ km}^{-1}} + \left[ (T - T_d)_{\text{LL}} - (T - T_d)_{\text{UL}} \right] /5^\circ C \)

- \( \Gamma \) = temperature lapse rate \( (^\circ C \text{ km}^{-1}) \) between lower level (LL) and upper level (UL). \( \text{LL} = 850 \text{ mb/1500 m} \quad \text{UL} = 670 \text{ mb/3500 m} \)

- Based on analysis of 50 downburst events over Oklahoma and Texas, scaling factors of 1000 J kg\(^{-1}\), 5\( ^\circ \)C km\(^{-1}\), and 5\( ^\circ \)C, respectively, are applied to the MWPI algorithm to yield a unitless MWPI value that expresses wind gust potential on a scale from one to five.
GOES Sounder-MWPI

- Geostationary Operational Environmental Satellite (GOES) 13-15 Sounder:
  - Radiometer that senses specific data parameters for atmospheric temperature and moisture profiles.
  - MWPI program ingests the vertical temperature and moisture profiles derived from GOES sounder radiances.
  - Generated hourly at the NOAA Center for Weather and Climate Prediction (NCWCP).

18 infrared wavelength channels
Thunderstorm Wind Prediction

\[
WS = 3.7753(MWPI) + 29.964
\]

Wind Gust Speed (kt)

MWPI

< 34 kt 34 – 38 kt 38-42 kt 42 -45 kt 45 – 49 kt ≥50 kt

MWPI

0 1 2 3 4 5 6

60

55

50

45

40

35

30

< 34 kt 34 – 38 kt 38-42 kt 42 -45 kt 45 – 49 kt ≥50 kt
Dual-Polarization Doppler Radar

- Reflectivity factor (Z):
  - Power returned to the radar receiver, proportional to storm intensity.
  - Values > 50 dBZ indicate strong storms with heavy rain and possible hail.

- Differential reflectivity (ZDR):
  - Ratio of the horizontal reflectivity to vertical reflectivity. Ranges from -7.9 to +7.9 in units of decibels (dB)
  - ZDR values near zero indicate hail while values of 2 – 5 indicate melted hail/heavy rain.
A confirmed downburst event on 10 June 2014 in Jacksonville, Florida demonstrated an effective application of the MWPI predictive model.

During the afternoon of 10 June, clusters of strong thunderstorms developed along the Atlantic Coast sea breeze front in east-central Florida and then moved northward toward the Jacksonville area.

Outflow boundary interaction with the sea breeze front and the subsequent merger of a cluster of thunderstorms over the western portion of the city of Jacksonville during the late afternoon resulted in the development of a large, intense thunderstorm over Jacksonville.

Produced a strong downburst at Whitehouse Naval Outlying Field with a peak wind speed measured at 25 m s\(^{-1}\) (48 kt).
MWPI: 10 June 2014

Barnes analysis

McIDAS-V visualization
WS = 3.7753(MWPI) + 29.964

Wind Gust Speed (kt)

MWPI

0 1 2 3 4 5 6

34 – 38 kt 38-42 kt 42 -45 kt 45 – 49 kt ≥50 kt

1947 UTC 2047 UTC

NEXRAD PPI: 10 June 2014
NEXRAD RHI: 10 June 2014

Liquid water lofting

ΔZDR

Hail core
Conclusions

• Downbursts are an important component of hazardous winds produced by thunderstorms.
• MWPI demonstrates conditional capability to forecast, with up to four hours lead time, thunderstorm-generated wind gusts that could present a hazard to aviation transportation.
• Most intense downburst occurrence is found near local maxima in MWPI values.
• The GOES MWPI product can be effectively used with NEXRAD imagery to nowcast downburst intensity.
References


