Thunderstorm Downburst Prediction: An Integrated Remote Sensing Approach

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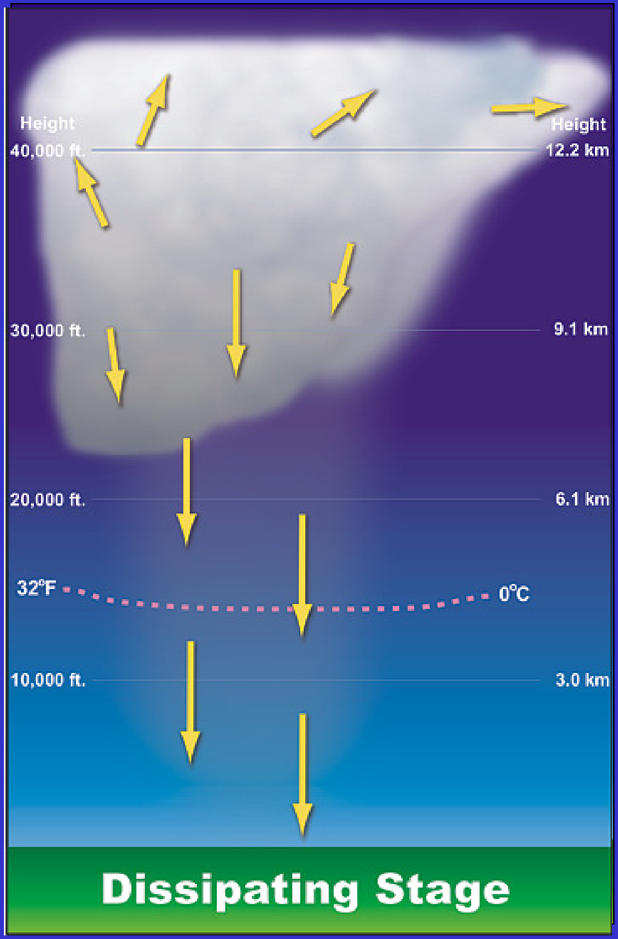
Topics of Discussion

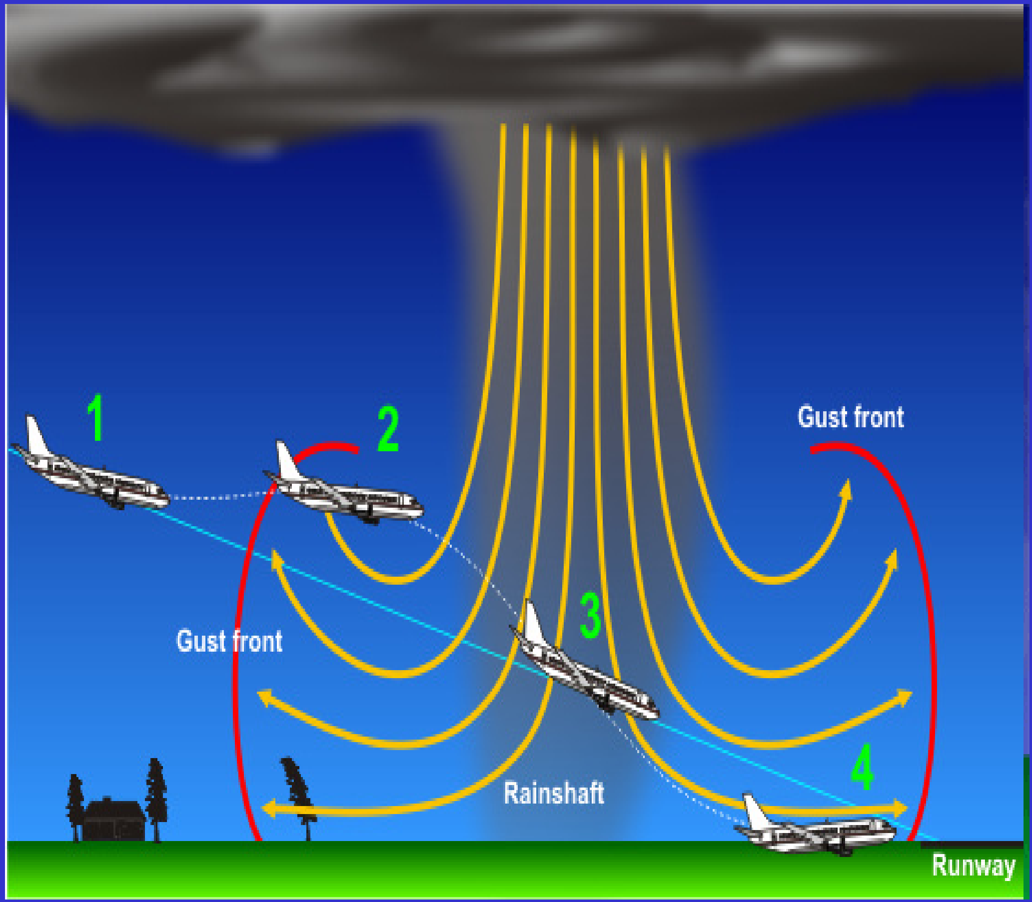
- Thunderstorm Life Cycle
- Thunderstorm downbursts and downburst prediction technique
  - GOES Sounder
  - Dual polarization Dopper radar
- Case Study: Jacksonville, Florida, June, 2014
- Conclusions

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

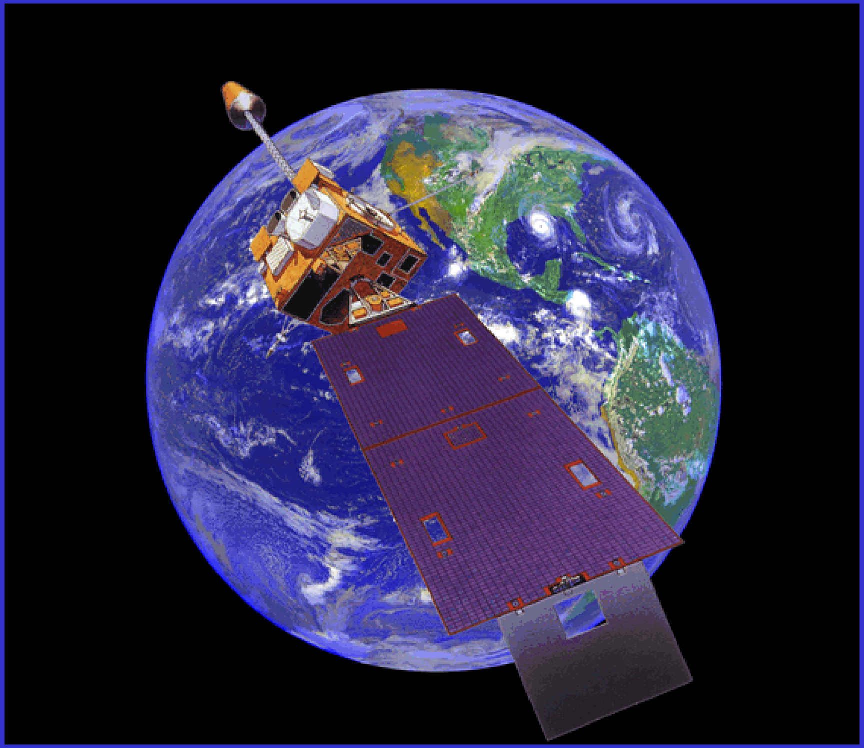
Courtesy USA TODAY

- 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.

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.
- $MWPI \equiv CAPE/1000 + \Gamma/5^{\circ}C\ km^{-1} + [(T - T_d)_{LL} - (T - T_d)_{UL}]/5^{\circ}C$
  - Γ = temperature lapse rate ($^{\circ}C\ km^{-1}$) between lower level (LL) and upper level (UL). **LL = 850 mb/1500 m UL = 670 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.

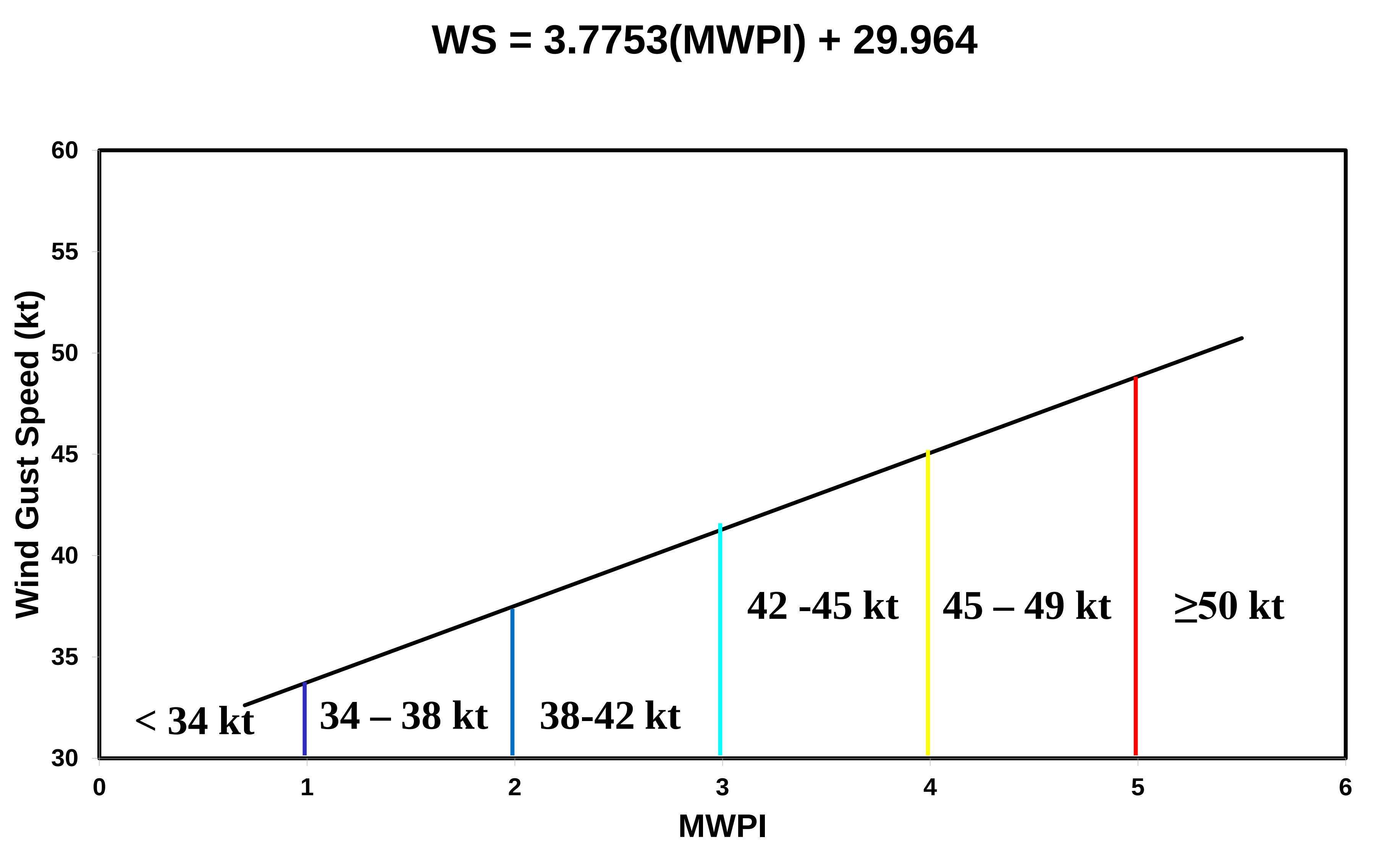
GOES Sounder-MWPI



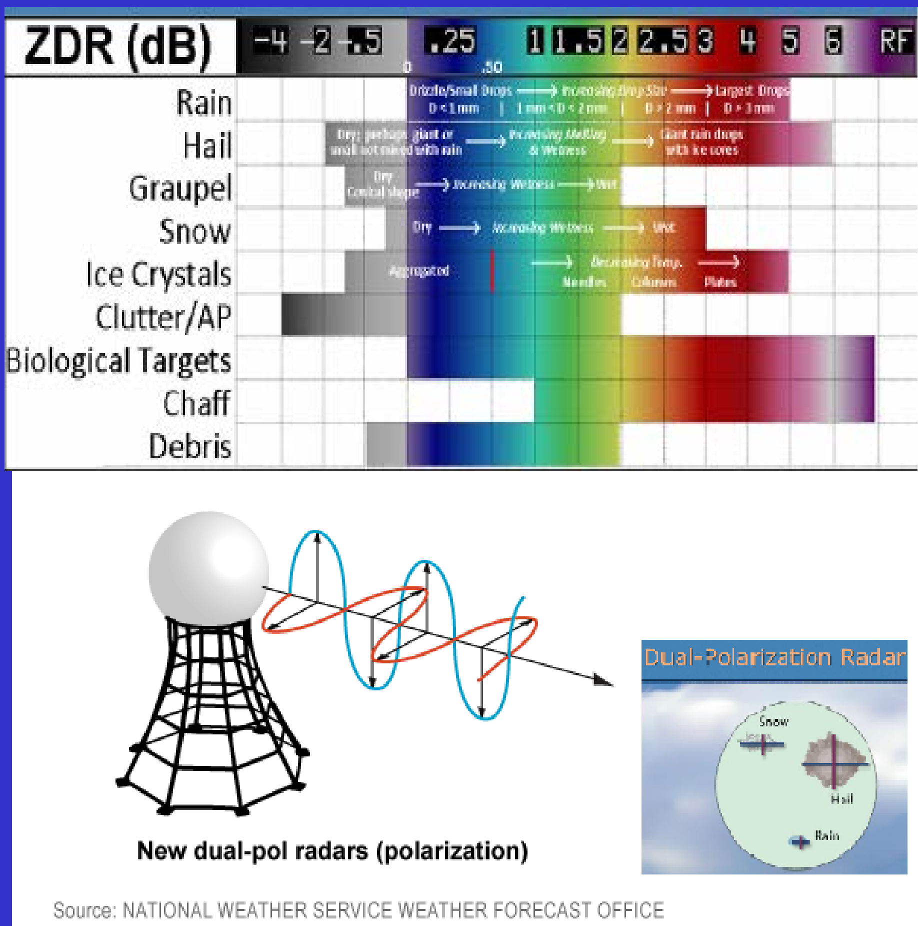
18 infrared wavelength channels

- 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).

Thunderstorm Wind Prediction



Dual-Polarization Doppler Radar



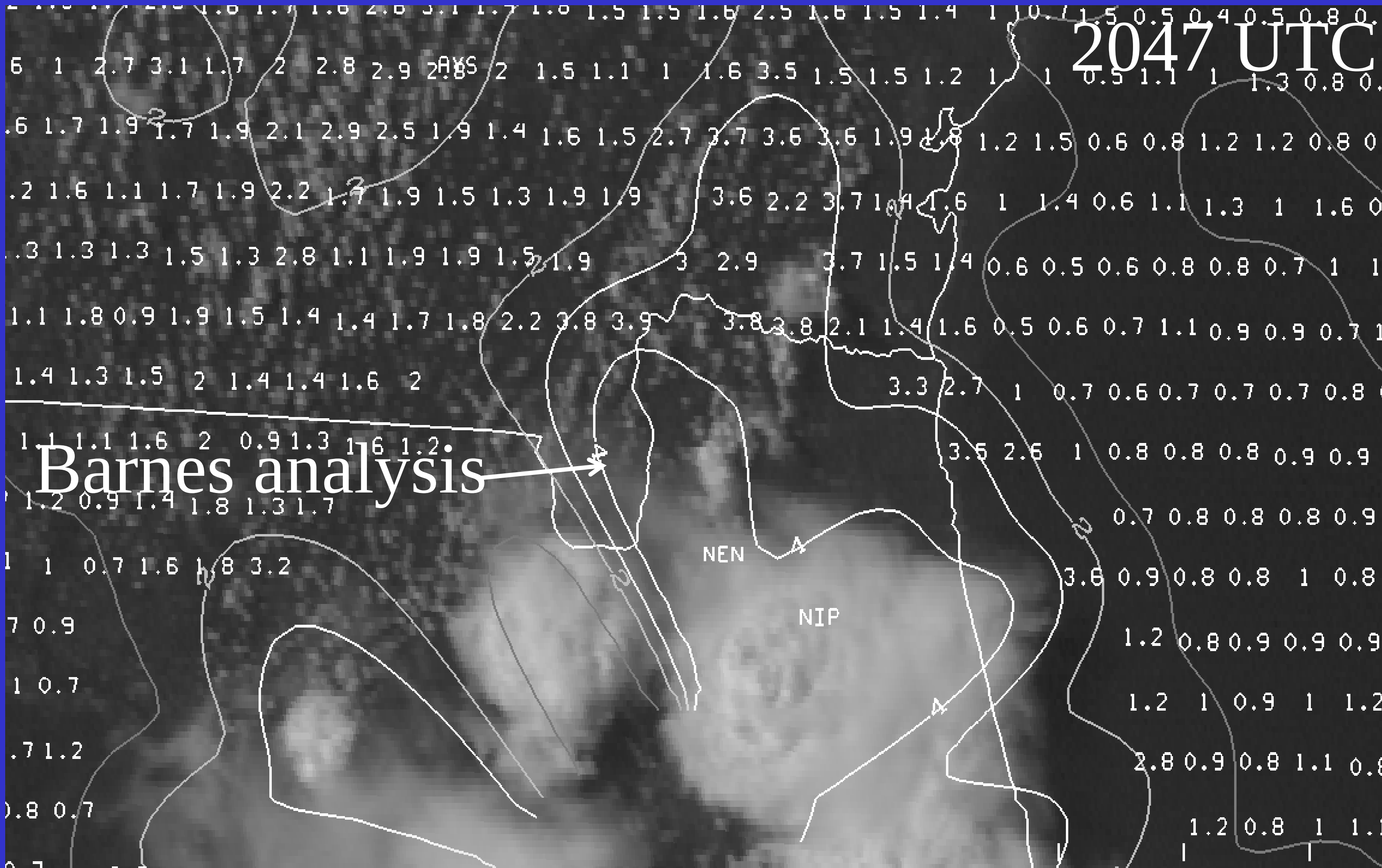
NEXRAD: Next Generation Radar

- 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.

Case Study:
June 2014
Jacksonville, Florida Downburst

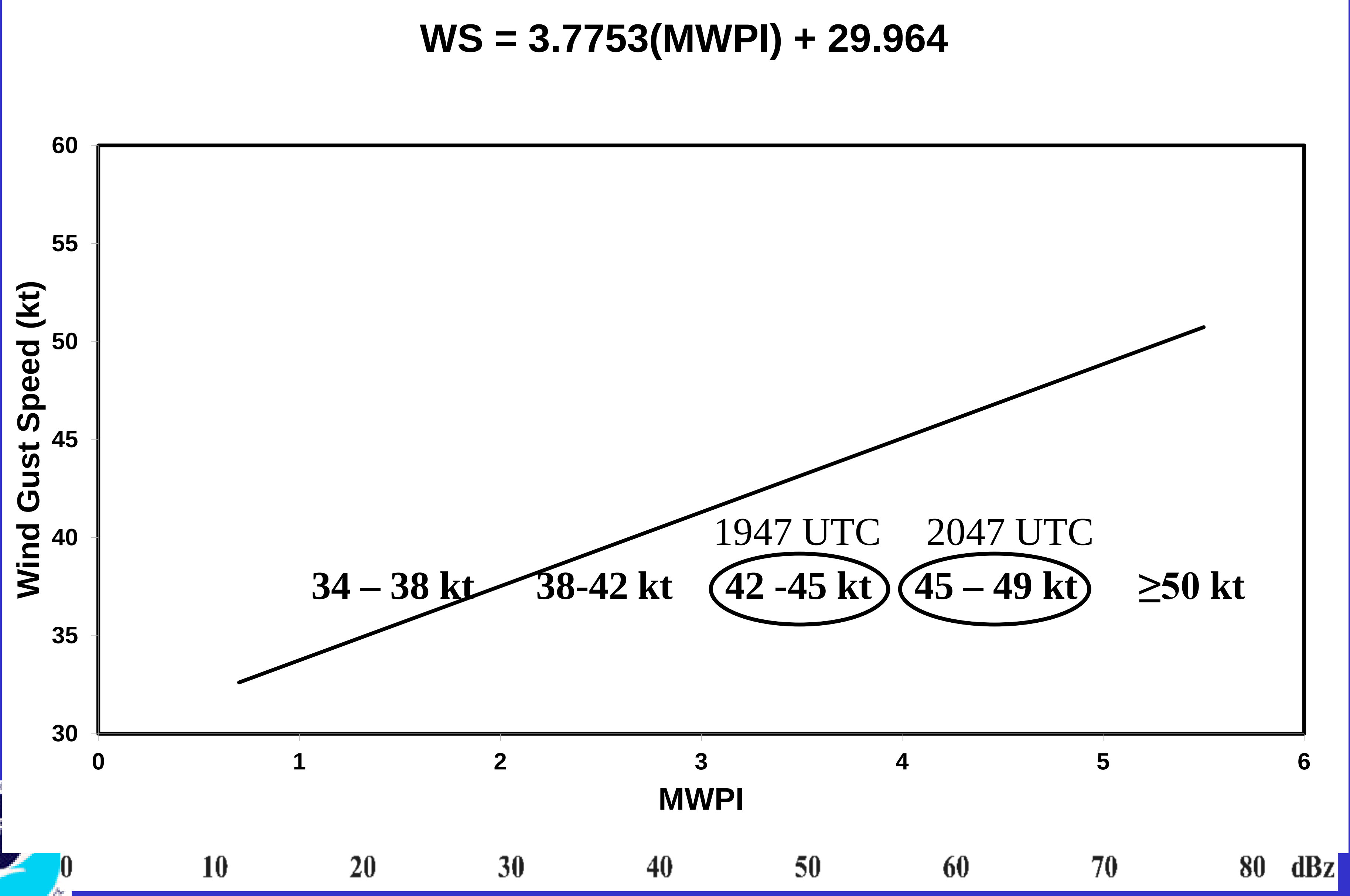
- A confirmed downburst event on 10 June 2014 in Jacksonville, Florida demonstrated an effective application of the MWPI predictive model.
- During the afternoon of 10 June, clusters of strong thunderstorms developed along the Atlantic Coast sea breeze front in east-central Florida and then moved northward 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

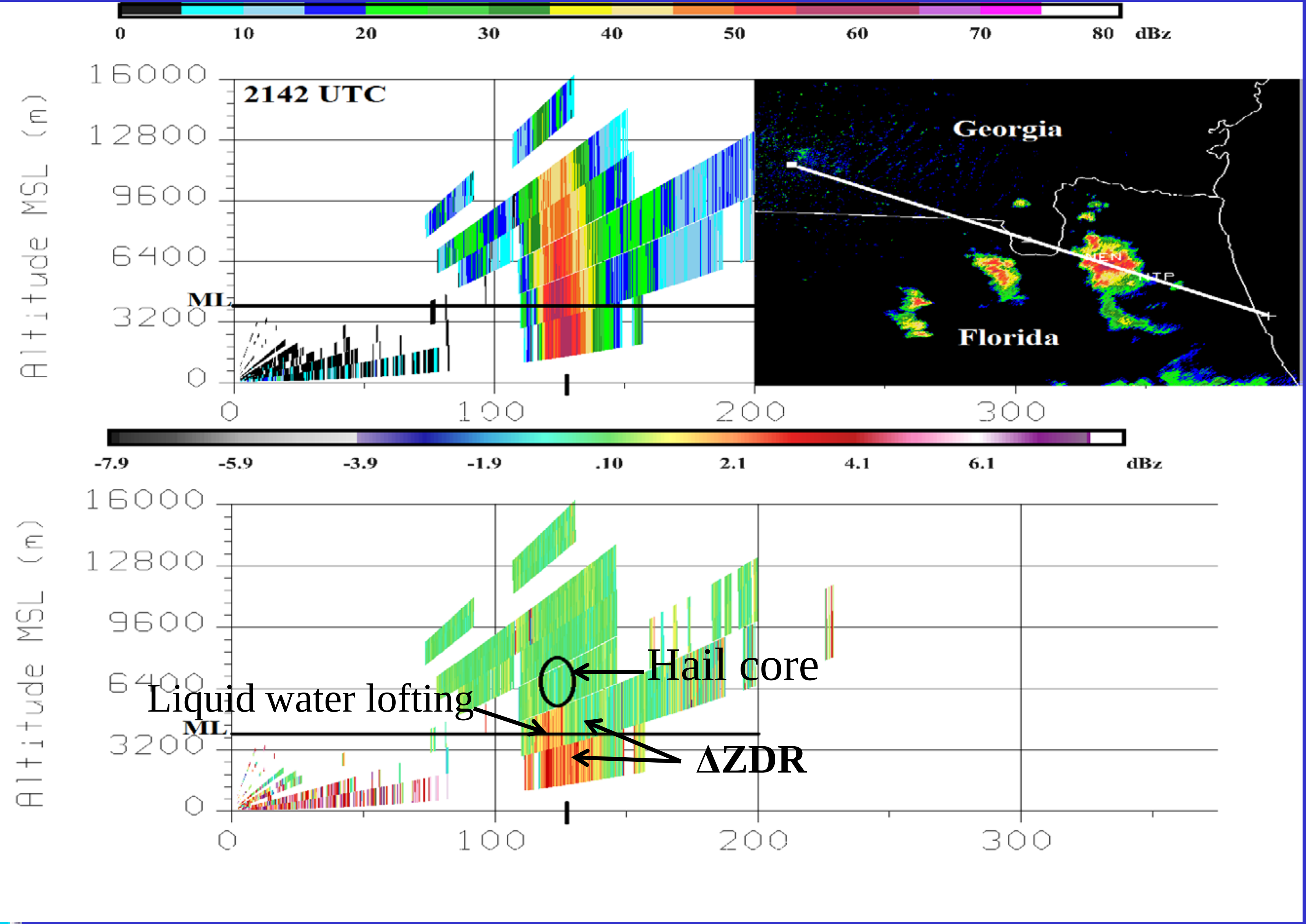


McIDAS-V visualization

NEXRAD PPI: 10 June 2014



NEXRAD RHI: 10 June 2014



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

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