38 THE MICROBURST WIND POTENTIAL INDEX: APPLICATIONS FOR POST-STORM SURVEYS AND FORENSIC REVIEWS

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1. INTRODUCTION

Historically, post-downburst research and damage surveys have been limited to damage assessments, review of nearby wind measurements and estimations, and weather radar review. However, there are limitations to each of these high-wind indicators, including differences in building materials, codes, and structural integrities, unknown tree and soil health (if trees are downed; e.g. Frelich and Ostuno 2012), overestimation of winds (Doswell et al. 2005; Edwards et al. 2018), lack of reliable nearby wind measurements (e.g. Horel et al. 2002), and limited-to-non-ideal radar base velocity imagery (e.g. Tirone et al. 2024).

Meanwhile, operational forecasters routinely utilize various atmospheric parameters to predict severe wind gust potential associated with downbursts, most notably downdraft convective available potential energy (DCAPE; Emanuel 1994), but also the wind index (WINDEX; McCann 1994), and T1/T2 indices (Fawbush and Miller 1954; Miller 1972), the microburst wind potential index (MWPI; Pryor 2015), among others. Radar-based methods including a comparison of 18 dBZ reflectivity echo tops to vertically integrated liquid (VIL) have been long-utilized in some environments (Stewart 1991), as well as peak wind gust relationships to outflow boundary propagation speeds (Sherburn et al. 2021). In some cases, even low-level radar base velocity scans of nearby high wind pockets can assist in determining surface wind speeds (Hjelmfelt 1988).

Typically, in during daily forecasting operations, meteorologists are concerned with three categories of downburst wind speeds: sub-severe (< 50 knots), severe (50-64 knots), and significant severe (≥ 65 knots). Little attention is paid directly to a particular speed, other than those outlined placing the magnitude of the maximum gust into one of the three categories.

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Such categorization may be useful for warning purposes but identifying the true maximum gust speed (or range of speeds) is crucial for forensic purposes. This precision is due to implications for building codes, insurance claims, and other forms of liability (for example: construction defects, roofing installation errors, transportation safety, premises liability, etc.).

While each of these methods for operational forecasting downburst wind speed potential can also be utilized for forensic, post-storm analysis, the focus of this case study is on the applications of the highly adaptable MWPI to different storm modes within different climatic environments and different geographies.

2. THE BASICS OF THE MWPI EQUATION

The MWPI was first developed by Pryor (2010) and is designed to quantify the most relevant factors in convective downburst generation in by incorporating 1) surface-based or most unstable CAPE, 2) the temperature lapse rate between the 670- and 850-mb levels, and 3) dew point depression difference between the 670- and 850-mb levels. The MWPI is then incorporated into predictive linear and quadratic regression models and consists of a set of predictor variables (i.e., dewpoint depression and temperature lapse rate) that generates output of expected microburst risk and wind gust potential. In general, the MWPI algorithm is found to be most effective in assessing downburst wind gust potential associated with ordinary cell and multi-cell convective storms in weak wind shear environments.

Equation 1:

$$MWPI = \left(\frac{CAPE}{1000\,J\,kg^{-1}}\right) + \left\{\frac{\Gamma}{5°C\,km^{-1}} + \frac{(T-Td)lower-(T-Td)upper}{5°C}\right\}$$

In Equation 1, Γ represents the temperature lapse rate between the upper and lower pressure levels selected, which is based largely on the sub-cloud convective mixed layer in the parent environment. Traditionally, the MWPI has, by default, selected a layer of 850-670 mb for this layer based on Ellrod

(1989) and Maddox et al. (1995; Pryor 2015). However, in higher elevation geographies, a 500-700 mb layer has been considered (Pryor and Miller 2016; Pryor 2017; based on Caplan et al. 1990), while in maritime, daytime environments, even surface or near-surface based convective mixing levels have been considered (e.g. Pryor 2016).

The unitless MWPI is then applied to either Equation 2 or Equation 3 (depending on geography) to result in a wind gust magnitude:

Equation 2 (Eastern United States):

$$Wind\ Gust\ (knots) = (0.35435365777\ x\ (MWPI^2) + (1.29598552473\ x\ MWPI) + 33.8176788073$$

Equation 3 (Western United States):

$$Wind\ Gust\ (knots) = (1.1)MWPI^2 + (-3.8)MWPI + 43.7$$

This adaptability and versatility to the local storm environment showcases the MWPI's utility in a variety of geographies and convective modes, as the user of the index can customize the computation to match the most unstable atmospheric parcel in any scenario.

Such a customization is valuable to a post-storm, forensic analysis when a downburst is already known to have occurred. Instead of relying nearly entirely on damage indicators and their many documented limitations for localized wind speed estimations, meteorologists now have an accurate, adaptable tool at their disposal to environmentally estimate the maximum gust potential of a downburst.

Three case studies are presented in which the versatility of the MWPI is showcased.

3. CASE STUDY 1: APRIL 2023 SPACE & TREASURE COAST FLORIDA SUPERCELL EVENT

A long-track supercell thunderstorm moved across Brevard, Indian River, St. Lucie, and Martin Counties Florida on the afternoon and evening of April 26, 2023. This supercell resulted in several reports of significant-severe wind gusts and surveyed wind damages, published in the NOAA *Storm Events Database*.

This storm resulted in an area of damage in West Melbourne (Brevard County) in which the National Weather Service (NWS) determined was between 70-75 miles per hour (mph). Specifically mentioned within this damage survey was a nearby measured wind report from a personal weather station (PWS) of 62 knots (71 mph).

Utilizing a virtual parcel most-unstable CAPE (MUCAPE) from the 1500 UTC Cape Canaveral radiosonde of 5,451 J kg^{-1} and temperature and dew point measurements from the 925-753 mb levels (including a lapse rate of 6.18°C km^{-1}), a unitless MWPI of 6.3065 was obtained.

This resulted in a downburst wind gust speed potential of 56 knots. Adding one-third of the radar-measured forward storm motion (in general relation to the method of adding one-third of the surface-5,000-foot mean wind speed to overall downburst speed recommended by Miller 1972), a resultant 62 knots was established – identical to that measured by the personal weather station located proximate to the downburst swath surveyed by the NWS.

4. CASE STUDY 2: JULY 2023 VALLEY, NEBRASKA LINEAR THUNDERSTORM WIND EVENT

A bow-echo linear event moved across eastern Nebraska and western Iowa on the early morning of July 12, 2023. This event resulted in several severe to significant severe wind gusts across the region, including a 62-knot (71 mph) wind gust at the Valley NWS office.

Because this storm event occurred prior to the launch of the 1200 UTC radiosonde from the Valley NWS office, we reviewed the 0000 UTC radiosonde data from this same location and selected the elevated convective mixed layer (assuming radiational cooling of the surface mixed layer) between the 850-683 mb levels. A virtual parcel MUCAPE of 3,279 J kg^{-1} was measured, with a lapse rate between the selected layers of 5.39°C km^{-1}. This resulted in an MWPI of 3.95658 and a downburst wind speed potential of 44 knots.

The bow echo was progressing forward at a speed of 50 knots, based on radar imagery. Similar to Case Study 1, adding one-third of this forward storm momentum (17 knots) resulted in a calculated peak wind gust potential speed of 61 knots (70 mph) – within 1 knot of the measured wind gust at the Valley NWS office.

5. CASE STUDY 3: JULY 2014 WESTERN NEVADA DRY DOWNBURST EVENT

A dry microburst occurred near Carson City on the afternoon of July 1, 2014, resulting in a measured significant severe wind gust of 68 knots (78 mph) at the Little Valley remote automated weather station (RAWS; Zachariassen et al. 2003) at about 6,500 feet above sea level. This storm produced an outflow boundary which travelled into Reno, resulting in severe wind gusts, including a 59 knot (68 mph) wind gust at Reno-Tahoe Airport and a 62 knot (71 mph) wind gust at the Reno NWS office.

The 0000 UTC radiosonde from Reno indicated a virtual parcel MUCAPE of 357 J kg^{-1}, with a 9.676°C km^{-1} lapse rate between the selected layers of 761-568.8 mb. A very strong “inverted-V” profile was exhibited, typical of dry downbursts, with nearly a 37°C surface dew point depression with a dry-adiabatic layer stretching from the surface to above 500 mb (Wakimoto 1985).

A unitless MWPI value of 5.7922 was calculated, and applied to Equation 3, resulted in a 59-knot potential wind gust. Once one-third of the forward storm motion was added (6 knots), a potential wind gust of 65 knots (75 mph) resulted. This is remarkably close to the 68 knots measured at the Little Valley RAWS. Shortly after this burst, the parent storm decayed and only the outflow boundary remained, still resulting in severe-caliber winds in the populated areas of the Truckee Meadows.

5. DISCUSSION AND CONCLUSIONS

The MWPI can be demonstrably employed in any situation where convective downdraft and/or downburst activity is suspected due to its versatility and adaptability across various geographies, climate zones, and convective modes.

The MWPI has also been utilized internationally, including with documented positive results in Australia (Grundstein et al. 2017), as well as in the United Kingdom (currently ongoing). Even the April 16, 2024, historic rainfall and severe weather event in the United Arab Emirates (UAE) indicated reliable uses of the MWPI originating both from observed polar-orbiting meteorological satellite sounders as well as measured radiosondes from Abu Dhabi.

This versatility of the MWPI is due to the customizable nature of the index’s variables. For example, the user may define specific atmospheric levels corresponding with the steepest sub-convective-cloud base layer lapse rates, and equations are presented to determine a maximum wind gust speed based on western and eastern U.S. geographies (though we suspect that these can apply anywhere in the world with similar geography and climate zones).

We also have introduced the recommended, demonstratively accurate method of applying one-third of the radar-measured forward storm motion to the organic wind gust speed obtained through the MWPI equations, as this method further adapts the MWPI wind gust speed to the parent storm itself.

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