P1.5 Lightning Prediction by WFO Grand Junction using Model Data and Graphical Forecast Editor Smart Tools

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1. Introduction and Background

The leading weather-related killer in Colorado is lightning. The number of injuries and deaths may be underestimated since the number of injuries and deaths may be underreported (Lopez et al, 1993). There are indications that lightning casualties related to outdoor recreation continue to increase (Lopez and Holle 1995), including those casualties due to more seemingly benign isolated short-lived thunderstorms over mountain tops (Hodanish et al. 2004). Nationwide, lightning is the number two weather-related killer, exceeding the number of fatalities from hurricanes and tornadoes combined. On average, lightning injures 1000 people a year in the nation, potentially inflicting severe lifelong debilitating injuries.

The National Weather Service (NWS) forecasts for lightning indirectly through thunderstorm forecasting in its public products. The NWS public forecast for thunderstorms is tied to precipitation probabilities, not lightning potential. Rain and lightning are two different threats; the probability of lightning is not necessarily the same as rain. For example, cloud-to-ground lightning may occur outside a narrow rain shaft, referred to as "dry lightning." In the western states, it's not unusual to have dry lightning outbreaks.

The NWS also provides a Lightning Activity Level (LAL) for the fire weather community, but this forecast product is not geared to the public. The LAL product is more subjective in nature since there is no direct objective method for lightning forecasting.

Lightning prediction is a challenge due to its high spatial and temporal variability. The causes of lightning are fairly well understood: the separation of charges created by strong electric fields within a thunderstorm. Understanding how these charges separate may help lightning forecasting, but this is a subject of continuing research. However, recent research and experiments suggest that high relative humidity and temperatures in the -12° C to -18° C range promote stronger negative charging (Berdeklis and List 2001), which strengthens the electric field that precedes lightning.

Solomon and Baker (1994) looked at the electrification of New Mexico thunderstorms and observed that CAPE above 400 J/kg was useful in predicting lightning. But they also noted that one stability parameter, the lifted index, was not a useful lightning predictor. Hoadley and Latham (1998) did an empirical analysis that covered much of the northern intermountain region (an area that covered eastern Washington

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into the western half of Montana, and extending south into southern Idaho and northern Utah). They observed that CAPE, lifted index, and theta-e were the best meteorological parameters for forecasting lightning. Both studies agreed that CAPE is a useful parameter to forecast lightning.

From a public safety standpoint, there is a need for lightning forecasts or outlooks. How does one go ahead and make a lightning forecast since the mechanism that creates lightning is not fully understood? What meteorological parameters may be used as lightning predictors?

2. Creation of the Lightning Potential Index

The National Weather Service Graphical Forecast Editor (GFE) in the Advanced Weather Interactive Processing System (AWIPS) allows forecasters to create or edit gridded meteorological data (Paxton and Hansen 2002; Roberts 2004). Writing Python scripts, called smart tools, enables forecasters to manipulate model and meteorological data to create gridded products. The National Weather Service Forecast Office in Grand Junction, Colorado, has written a smart tool called the Lightning Potential Index (LPI). The motivation behind this product is to improve lightning forecasting. Groups who would find such a product helpful include people who hike into the high country during the summer months, when afternoon thunderstorms occur. The agencies who fight western wildfires and the fire weather community may find a lightning potential index useful. Also, the news media may find this product interesting.

The LPI was experimental during 2008 and user feedback was encouraged on its web page, (http://www.crh.noaa.gov/gjt/?n=lightningpotentialindex). Feedback was varied but many stated that this product was needed.

Meteorological parameters used to create the LPI are:

- CAPE
- Lifted Index
- Theta-E lapse rates
- 850 mb temperature
- Precipitable water
- Relative humidity at -10° C

The first three parameters measure instability, required for thunderstorms. Interestingly, the higher values of CAPE or a lower lifted index do not necessarily increase lightning forecasting skill. Higher CAPE values do not translate into higher spatial and temporal coverage of lightning. The 850 mb temperature is used to negate over-prediction of lightning during the cold months. The last two parameters measure moisture in the atmosphere in some form. Subjective observations suggest that the last parameter, relative humidity at -10° C, adds skill to lightning forecasting.

The equation to calculate the LPI is empirical and evolving. During the 2008 convective season, the following equation was used.

$$A = (RH)^2 \cdot (\Theta e\Gamma) \cdot (LI)^2 \cdot (-1)$$

In A: LI = 0 if LI > 0

$$B = (muCAPE) \cdot (PW) \cdot (RH) \cdot 0.001$$

$LPI = (A + B) \cdot (T_{850} - 272)$

$LPI = 0$ if $LPI < 0$
$LPI = 20000$ if $LPI > 20000$

Where:

RH: Relative Humidity at -10º C

$\Theta e\Gamma$: Equivalent Potential Temperature Lapse Rate at 600 mb

LI: Lifted Index

muCape: Most Unstable CAPE in the 0-3 km AGL range

PW: Precipitable Water

T_{850}: 850 mb Temperature in Kelvin

To adjust for Kelvin degrees, 272 is subtracted from the 850 mb temperature. This subtraction brings the LPI to zero in subfreezing weather. However, 272 is used instead of 273.15 (where -273.15º C is 0º K) to allow for thundersnow. The empirical equation is subject to change based on lightning observations, or to incorporate a new idea that enhances the LPI.

The LPI graphic (see Figure 1) is divided into four levels of risk: low, moderate, high, and extreme. They are defined as:

- Low Risk (light green): The lightning threat may either be negligible or low. Isolated thunderstorms may occur, but the probability of thunderstorms is low.

- Moderate Risk (dark green): The lightning threat is considered moderate. Isolated thunderstorms are expected within the green area.

- High Risk (yellow): The lightning threat is considered high. Expect scattered thunderstorms within the yellow area. Plan accordingly, as there is a high probability of lightning in the yellow area. Be aware of lightning safety guidelines.

- Extreme Risk (red): Lightning in the red area will occur. Practice lightning safety, as the threat of lightning is extremely high.

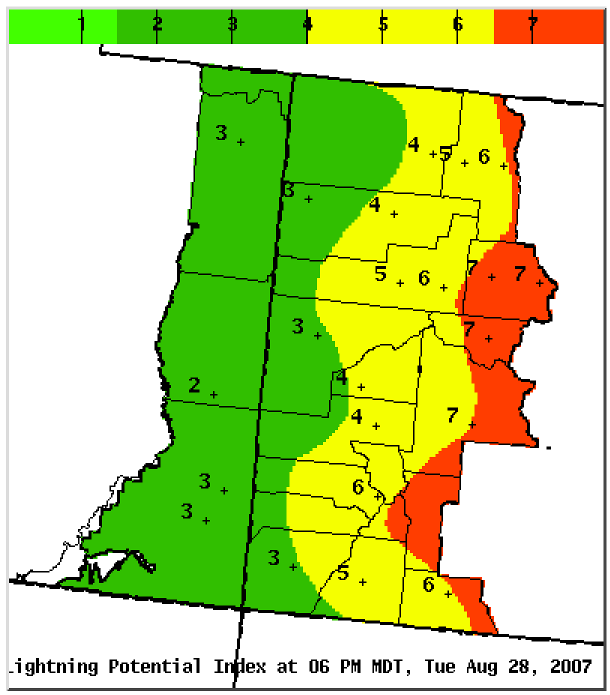

Figure 1- Example of LPI image for WFO Grand Junction

The LPI is also available in AWIPS Display Two Dimensions (D2D) at the Grand Junction office. AWIPS is where the experimental LPI is tested first before changes to the smart tool algorithm are made. Having the LPI in D2D enables subjective verification with real-time lightning data (Figure 2). LPI performance between the NAM and GFS is also observed. If improvements to the LPI equation are made in D2D, then these changes will be incorporated into the smart tool.

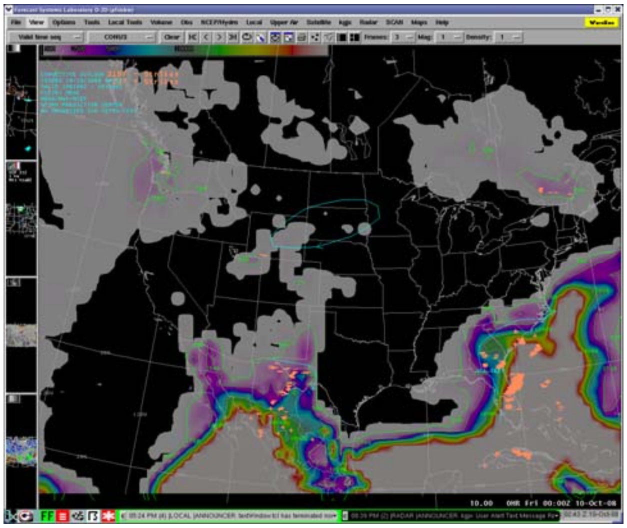

Figure 2 – LPI overlaid with 1-hour lightning strikes.

3. Advantages and Drawbacks of the LPI Observed in 2008

Advantages:

- Gave general idea where lightning will occur. Highest values mean increased lightning frequency and areal coverage.
- Excellent forecast skill that lightning will not occur with very low values.

Drawbacks:

- Underestimated lightning potential in regions of strong dynamical lift and marginal instability or low stability (e.g., lifted index of +1 or +2 in the model data).
- If models underestimate instability or moisture, the LPI will be underestimated.
- Does not consider slantwise convection.

4. Future Adjustments

Three meteorological parameters are needed for thunderstorms: conditional instability, moisture and lift. In the LPI smart tool, instability and moisture were included, but lift was not a factor in the LPI equation. This was not an oversight; but quantifying quasi-geostrophic forcing into an empirical equation was not straightforward. After one convective season of subjective analysis, it became apparent that some meteorological parameter that accounts for dynamical lift is necessary. Different techniques will be tried to see if lightning forecasting skill can be improved for the 2009 convective season.

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