

# When Warnings Matter Most: Spatial Patterns & Messaging Differences During Hurricane Helene

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## Project Overview

**Purpose:** The project's overall goal was to uncover and evaluate physical and social dynamics within Tropical Storm/Hurricane Helene's impact area from a geographical perspective. This subset of the study specifically examines how spatial variation in warning issuance, message language, and message strength during Helene (September 2024) relates to life-safety outcomes across 300 disaster-declared counties of the southeastern U.S.

**Partner:** National Weather Service (NWS) Greenville-Spartanburg (GSP) Weather Forecasting Office (WFO), which serves Western North Carolina, Upstate South Carolina, and Northern Georgia.

### Research Questions

RQ 1

How do areas impacted by Hurricane Helene differ based on urban-rural dynamics and social vulnerability?

RQ 2

Were there differences in warning and evacuation orders across the study area during Hurricane Helene?

## Spatial – Statistical Results

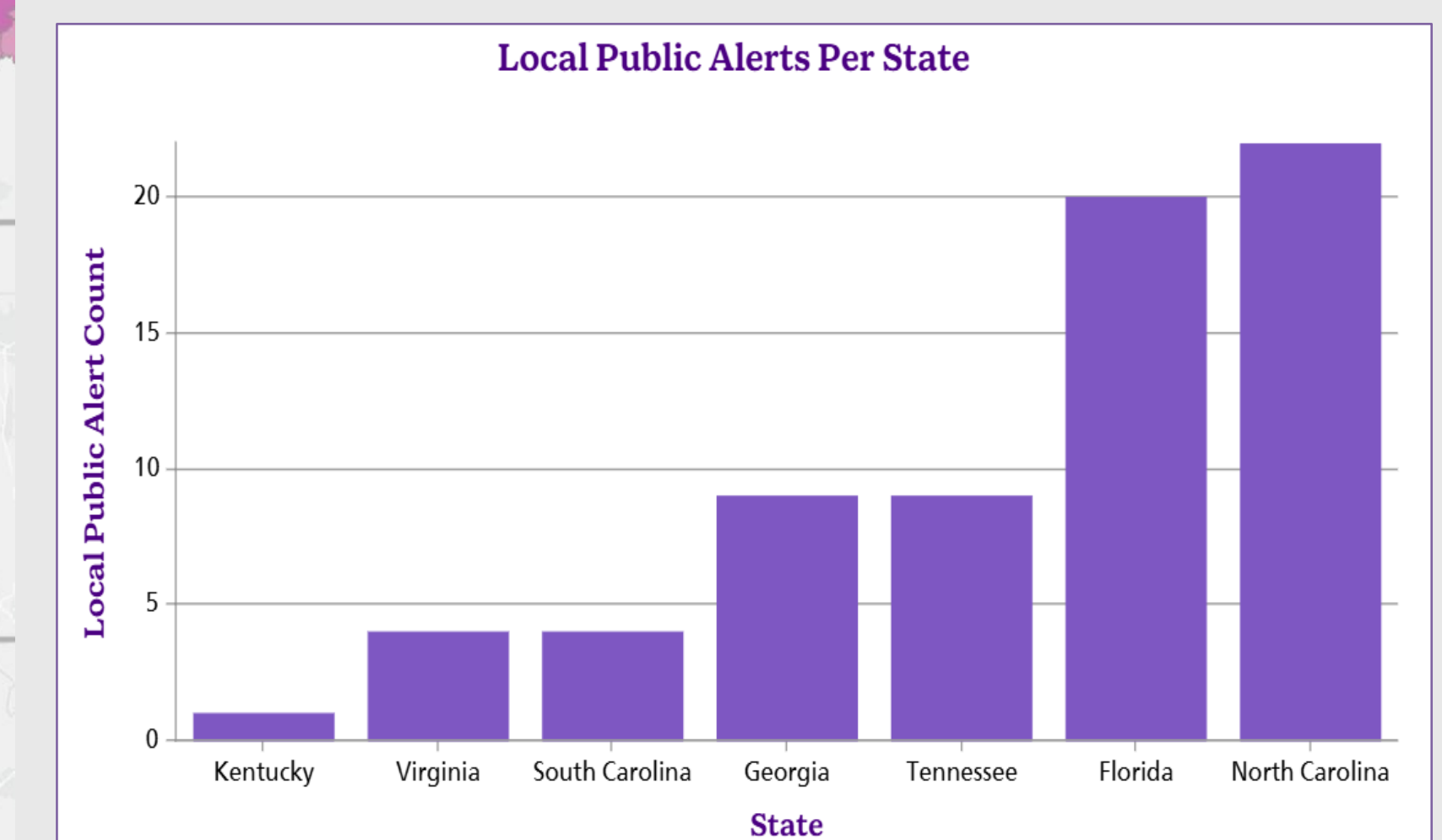
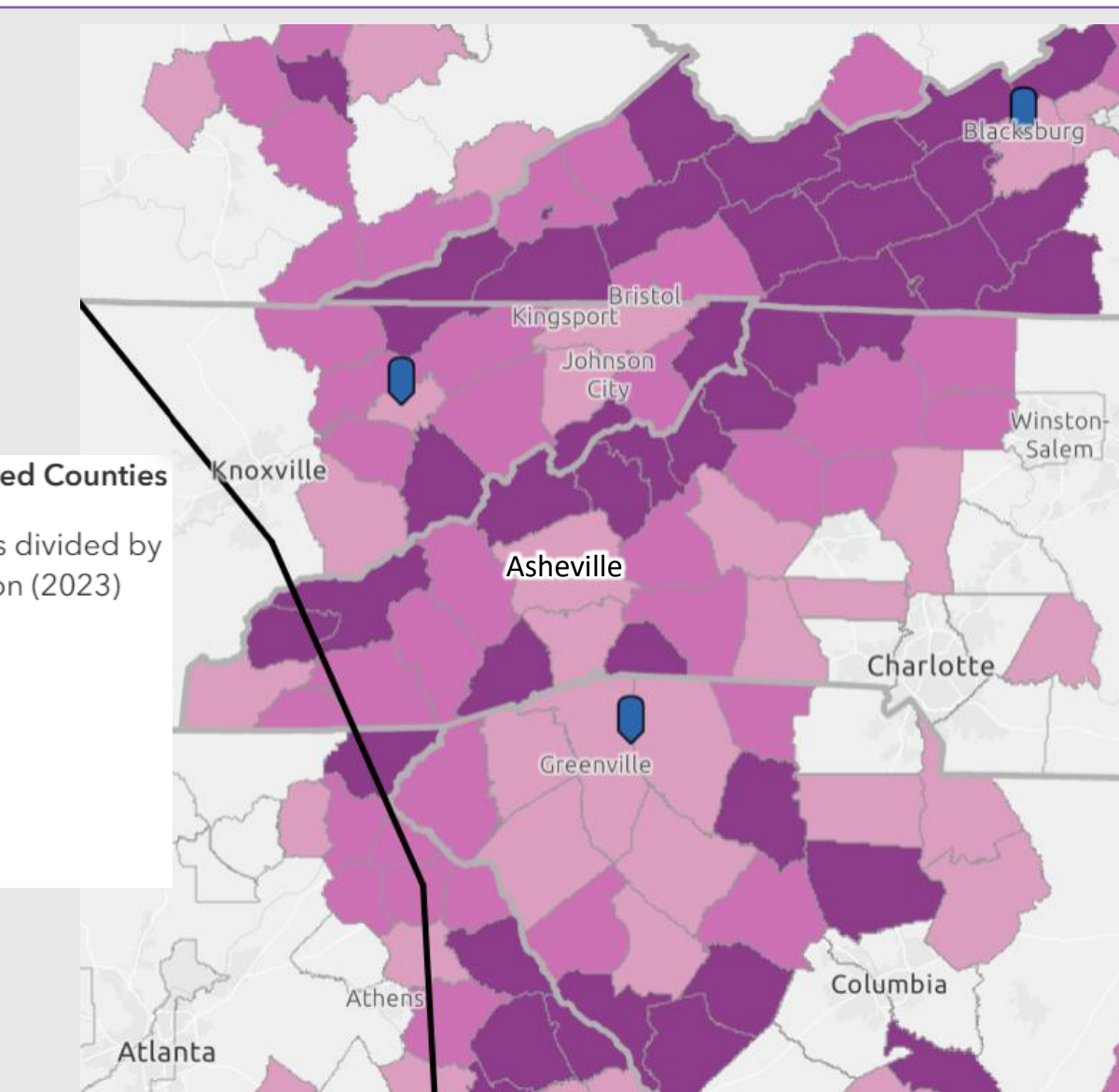
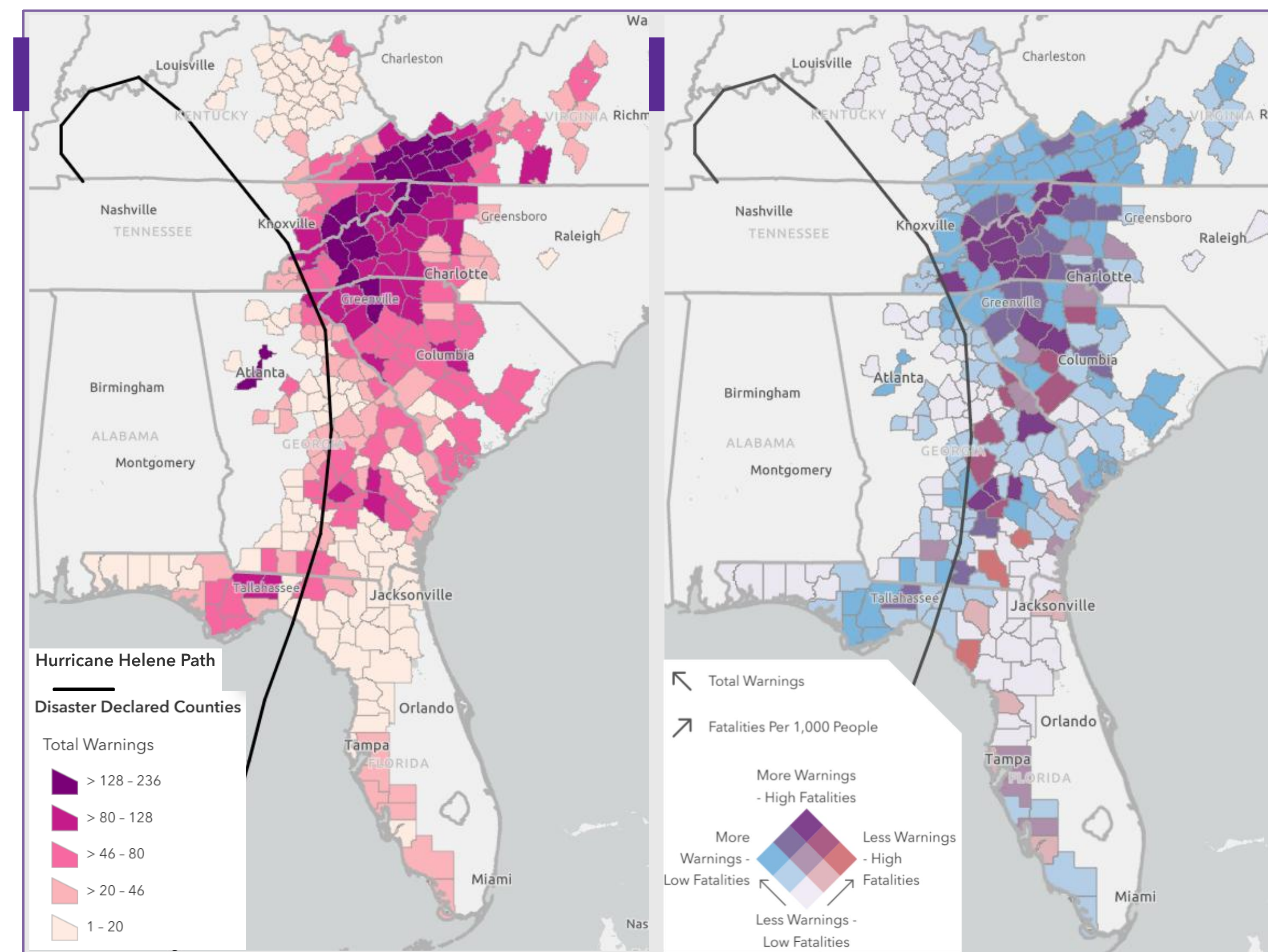
4,740+ NWS Warnings -- 69 Public Safety Alerts -- 32 Flash Flood Emergencies

County warning averages by WFO are significantly higher in Southern Appalachia:

1. RNK, Blacksburg, VA ( $n=93$ )
2. MRX, Morristown, TN ( $n=87$ )
3. GSP, Greenville-Spartanburg, SC ( $n=84$ )

Warnings significantly correlate with:

1. Fatalities
2. Precipitation rates
3. Landslides
4. FEMA Losses



## Methods

A mixed-methods design integrates *geospatial & statistical analyses* with *qualitative content assessment* of warnings from 9/23/2024 - 10/5/2024

1. Public Warnings issued by the NWS – WFOs
2. Wireless Emergency Alerts (WEAs) issued by local officials
3. Flash Flood Emergencies issued by the NWS GSP Office

**Spatial-Statistical Analysis:** The locations of NWS warnings and WEAs were compared across the disaster area, where loss of life, FEMA assistance needs, and social vulnerability were high.

NWS Warnings and Local Public Alerts were counted per county & evaluated for significant inferential and geospatial relationships.

**Warning Language Analysis:** Descriptive and interpretive *Codes* were generated from the WEAs and linked to wider *Themes*.

Each WEA was also evaluated for message completion using the 5 essential warning elements (*source, hazard, location, guidance, time*).

### Summary of Study Variables

Dataset	Source
Disaster Damages	OpenFEMA – Registrants, Damage, etc.
Fatalities	NWS Report - Direct/Indirect
Precipitation Averages	XMACIS2 - verified with NWS GSP data
Landslides	USGS
Social Vulnerability Index	US Census American Community Survey
Warnings	Iowa Environmental Mesonet, PBS Warn, NWS GSP
Urban-Rural Designation	USDA Rural Urban Continuum Codes (1-9)
NWS WFO Areas	NWS County Warning Areas - NOAA

## Warning Language & Messaging Results

Over 1,000 coded words or phrases:

- 30% of WEAs failed to clarify a time component.
- 91% of WEAs included location descriptors. Only 6 failed to provide location information.
- 80% of WEAs included general protective action guidance such as 'Seek safe shelter'.
- Only 30% included specific guidance such as 'Report to the docks at 8:45 am for the last ferry off the island'.

4 Warning Language Themes Emerged:

(1) **Message Structure** (e.g., *When, Where, Who, Source/Sender, URL included*)

(2) **Message Emphasis** (e.g., *exclamation points, capitalizing, 'catastrophic' or 'extreme'*)

(3) **Orders & Guidance** (e.g., *evacuation, shelter, contact number, donations*)

(4) **Hazards, Risks, & Impacts** (e.g., *flood, storm surge, tornado, dams, transportation*)

Strong Messaging in NWS-issued Flash Flood Emergencies:

30 out of 32 FFEs used phrases 'life-threatening', 'unprecedented', 'catastrophic', and/or 'historic'. By contrast, only 4 WEAs used the word 'catastrophic' (3 for storm surge, 1 for dam emergency).



## Applications

The project is intended to inform the NWS, public administrators, and local Emergency Management agencies of future disaster-preparedness and risk-communication approaches.

- ✓ Improve public warning language by providing critical and timely information in alerts.
- ✓ Encourage county-level EMs to become IPAWS-certified (Integrated Public Alert and Warning System) to send alerts. Train local emergency managers and other alerting authorities on the Message Design Dashboard, which ensures messages contain the five key elements.
- ✓ Continue supporting/funding our NWS workforce and providing free public forecasting and warning for severe weather events.

## Discussion

- Helene's warning density was linked to hazard impacts (spatially clustering in Western NC, Eastern TN, and Western VA). Consistent, comprehensive messaging appears critical for effective risk communication and emergency response to reduce disaster losses.
- The research showed that emergency warnings from local officials and the NWS were distributed across urban and rural areas without bias. NWS messages were consistently high-severity and concentrated in the hardest-hit areas, while other public alerts varied widely in content and completeness.
- The densest warning area was NWS GSP, where significant clustering of impacts and vulnerability exists. Areas that were issued the most warnings also corresponded spatially to those with the highest fatalities during Helene. This rural, inland, mountainous region suffered disproportionate devastation from the Helene disaster.
- There was a strong relationship between GSP locations that received a Flash Flood Emergency and clusters of fatalities in this area. All GSP Flash Flood Emergencies contained the 5 critical elements of a WEA (*source, hazard, location, guidance, time*). Whether individuals received/acted on these warnings could be investigated further.
- Warnings not issued by the NWS, but by local officials, often left out key information. This includes information such as specific place, time, specific risk, and actions to take. The use of jargon is also notable in local warnings, where words that the general public may have struggled to interpret were used (e.g., 'voluntary evacuation order').

Thank you to the NC Collaboratory for funding this work and the NWS Greenville-Spartanburg WFO (Trisha Palmer & Ashley Rehnberg) for your partnership.

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