engineering laboratory

Tornado Hazard Characteristics

Performance of Buildings, Shelters, Designated Safe Areas, and Lifelines

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Progress – Measuring Tornado Wind Fields

R1: Development and deployment of instrumentation systems that can measure and characterize actual tornadic near–surface wind fields, for use in the engineering design of buildings and infrastructure.

2018 NIST Disaster Resilience Research Grants Program[1] includes development of wind sensors as a focus area

- **"This program supports research to improve the understanding of windstorms (hurricanes, tornadoes, thunderstorms, and others) and … Proposals are solicited to conduct research on:**

  …

  3) development of new sensors and methods to collect spatiotemporal data on windstorm phenomena, including surface-level winds and near ground velocity profiles, atmospheric pressure, and …"

- **Proposals were due August 27. Awards anticipated mid-2019**

[1] https://www.nist.gov/el/disaster-resilience/disaster-resilience-federal-funding-opportunity-ffo

Progress - Tornado Databases

R2: Improve publicly available tornado databases

Actively working since May 2016 with multiple NOAA offices, including:

- **NWS Storm Prediction Center (SPC)** on tornado database structure and data collection procedure improvements, including to the NWS Damage Assessment Toolkit
- **NWS Performance Branch (PB)** to improve the Storm Data application and database
- **National Centers for Environmental Information (NCEI – formerly NCDC)** to improve data archival/ease of access
- **Office of the Federal Coordinator for Meteorological Research and Support Services (OFCM)** to develop an annex to the National Plan for Disaster Impacts and Assessments: Wind and Water Data (NPDIA) specific to collection of data for tornadoes and other windstorms

Representatives from each of these offices also participate in the ASCE Tornado Wind Speed Estimation Standards Committee (see R4)

Progress – Improvement of the EF Scale

R4: Standardize the Enhanced Fujita scale and improve through addition of scientific/quantifiable damage indicators, particularly those better distinguish between the most intense tornado events

ASCE/SEI/AMS Standard on Wind Speed Estimation in Tornadoes and Other Windstorms is well under development

- New approach to assigning wind speeds for each Degree of Damage (DoD) for all Damage Indicators (DIs) in the Enhanced Fujita scale, based on qualitative assessment of the resistance (normal/typical, above, below)
- Many new DIs under development, including several specific to rural areas where there are few buildings
  - Vehicles, Rail Cars, Grain Bins, Silos, Jersey Barriers, Churches, Center-Pivot Irrigation Systems, and others
- Subcommittees are nearing completion of respective chapters

NIST is building a detailed database of residential tornado damage

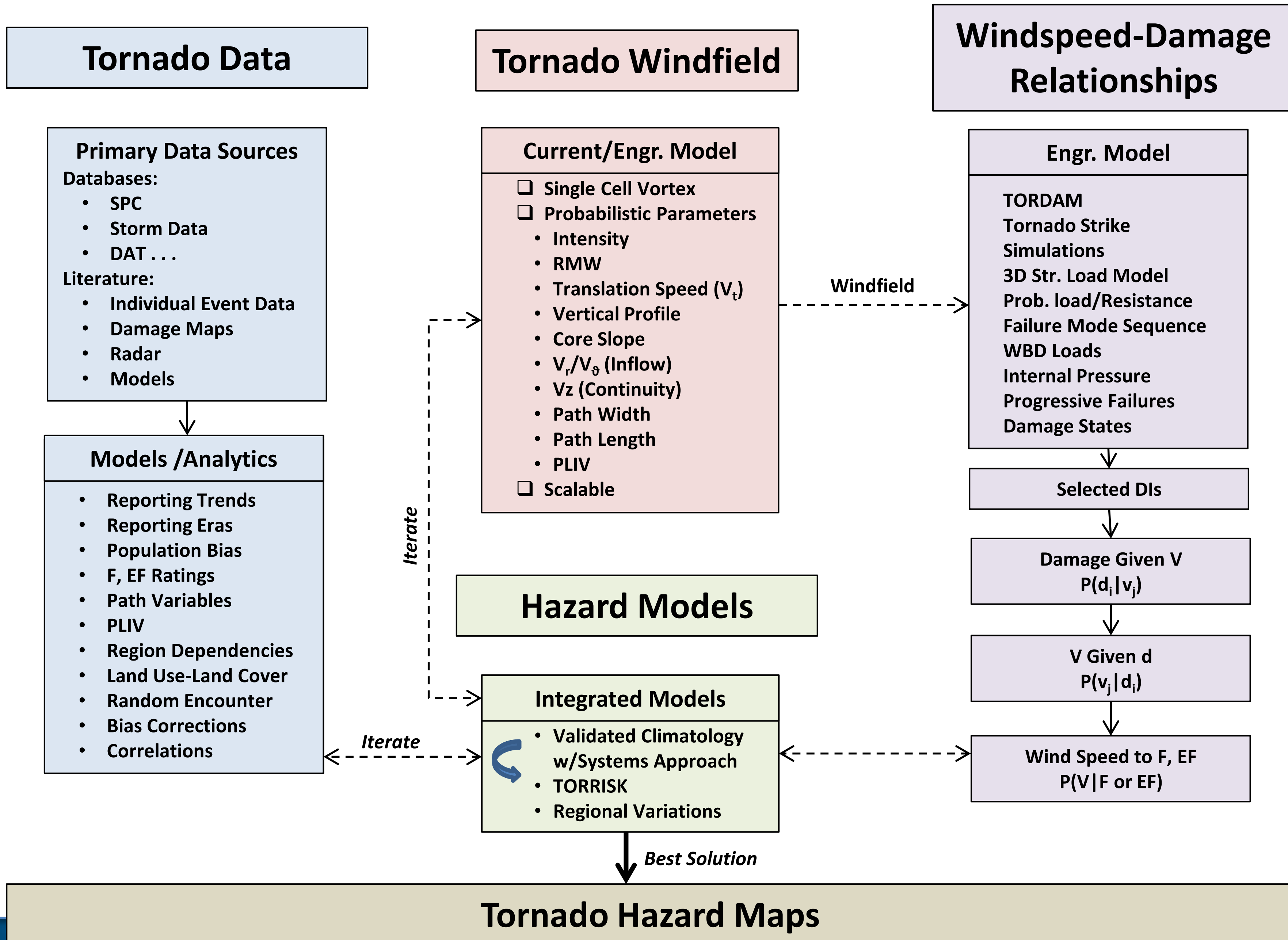
- Will enable significant improvements to the DI for 1 & 2 family homes

Progress – Tornado Hazard Maps

R3: Development of tornado hazard maps for use in the engineering design of buildings and infrastructure, considering spatially based estimates of the tornado hazard instead of point–based estimates.

- **Extended tornado regionalization scheme to also handle sub-regional variations**
- **Finalized approach to account for population bias**
- **Developed approach for explicit consideration of epistemic uncertainties**
  - Identified seven main components of the tornado wind speed risk modeling process that will be modeled
- **Planning for 2nd Tornado Mapping Stakeholder Workshop**
  - Present draft maps/underlying methodology to ASCE 7 committee and other stakeholders
  - Obtain feedback prior to submission of formal proposals
  - January 15, 2019, at ASCE HQ in Reston VA, prior to ASCE 7-22 Wind Load Subcommittee meeting

Tornado Map Development Process

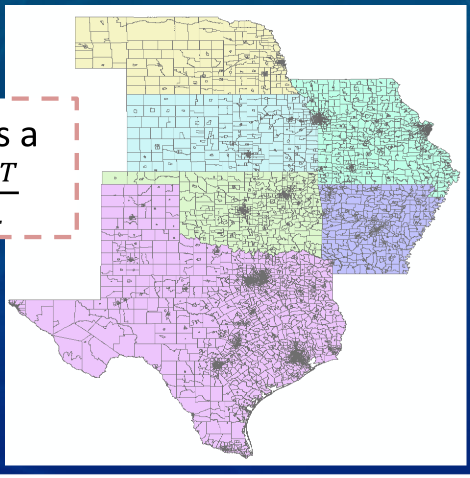


Tornado Occurrence Rate Analysis

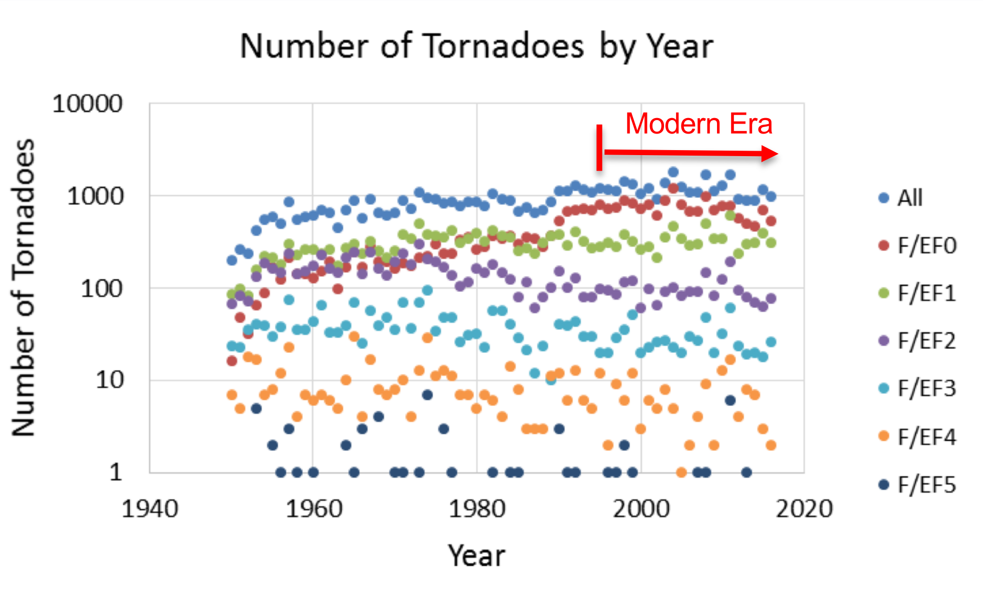
1. **Nominal Tornado Occurrence Rate Analysis**
   a. **Uses reported data, by region**
2. **Tornado Reporting Efficiency (Population Bias using Modern Era Data and Building Density data)**
   a. **<u>Assumes high reporting efficiency in High Building density (HBD) areas (CT level)</u>**
   b. **Analysis uses 1995-2016 Storm Prediction Center (SPC) data coupled with 2000 and 2010 Census information coupled with HAZUS building stock data to obtain building densities in each CT**
3. **Validation of empirical Population Bias analysis using random encounter modeling**

Analysis at Census Tract Level (2000,2010) with Tornadoes from 1995-2016 (22 yrs)

Each Census Tract (CT) has a Building Density $= \frac{\#BldgCT}{Area_{CT}}$

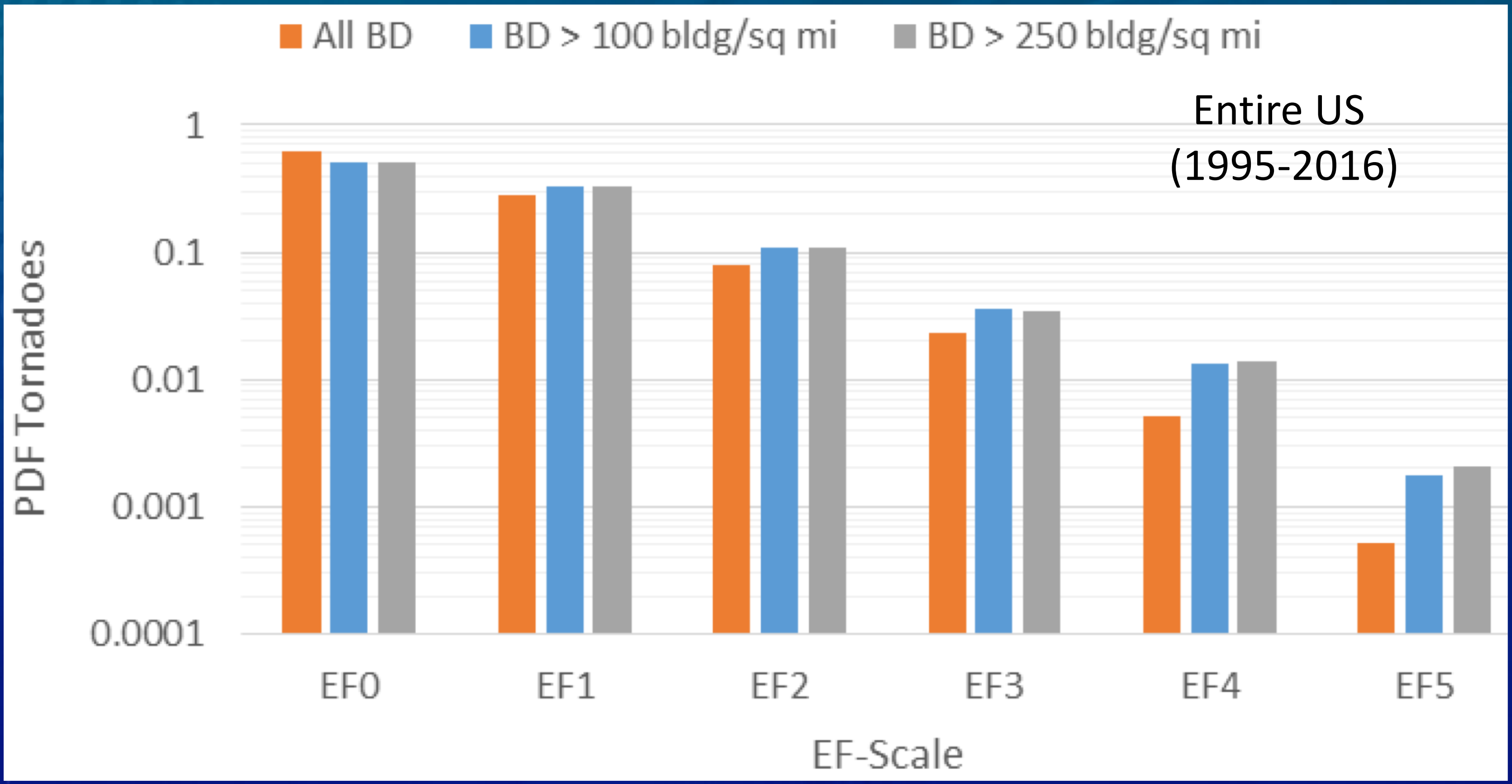


Data Source: U.S. Census Bureau



Data Source: SPC

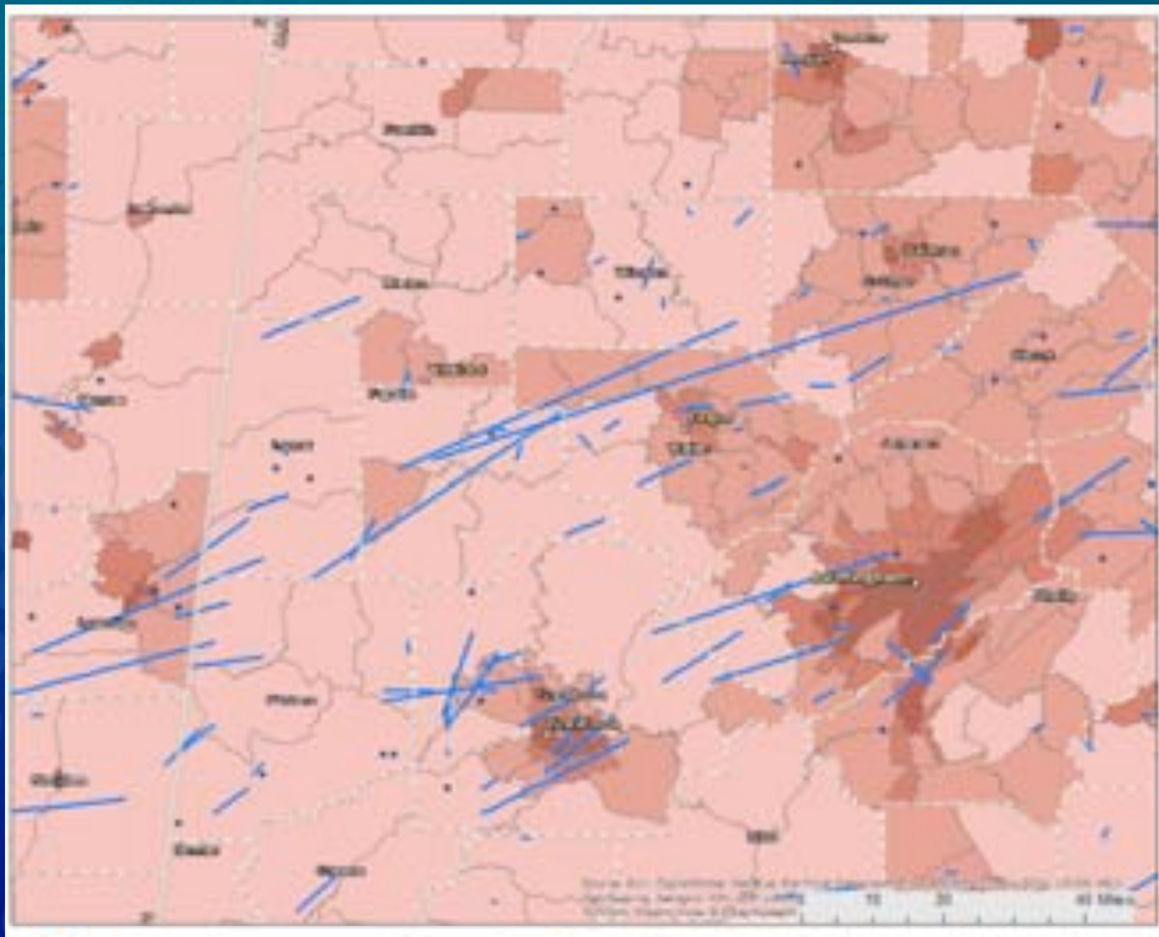
EF-Scale Distribution of Tornadoes - Variation with Building Density (BD)[1]



Significantly higher frequencies of more intense tornadoes are reported in High Building Density Census Tracts (HBD CTs)

[1]Data sources and analysis: see item 2 on slide 14

Example of Population Bias[1]



Tornado tracks in Alabama

Approximate Building Spacing (ft)

- >2,640
- 2,640-1,000
- 1,000-500
- 500-250
- 250-100
- 100-25

Visual comparison of tornadoes reported in high building density areas (darker red) to low building density areas (lighter red)

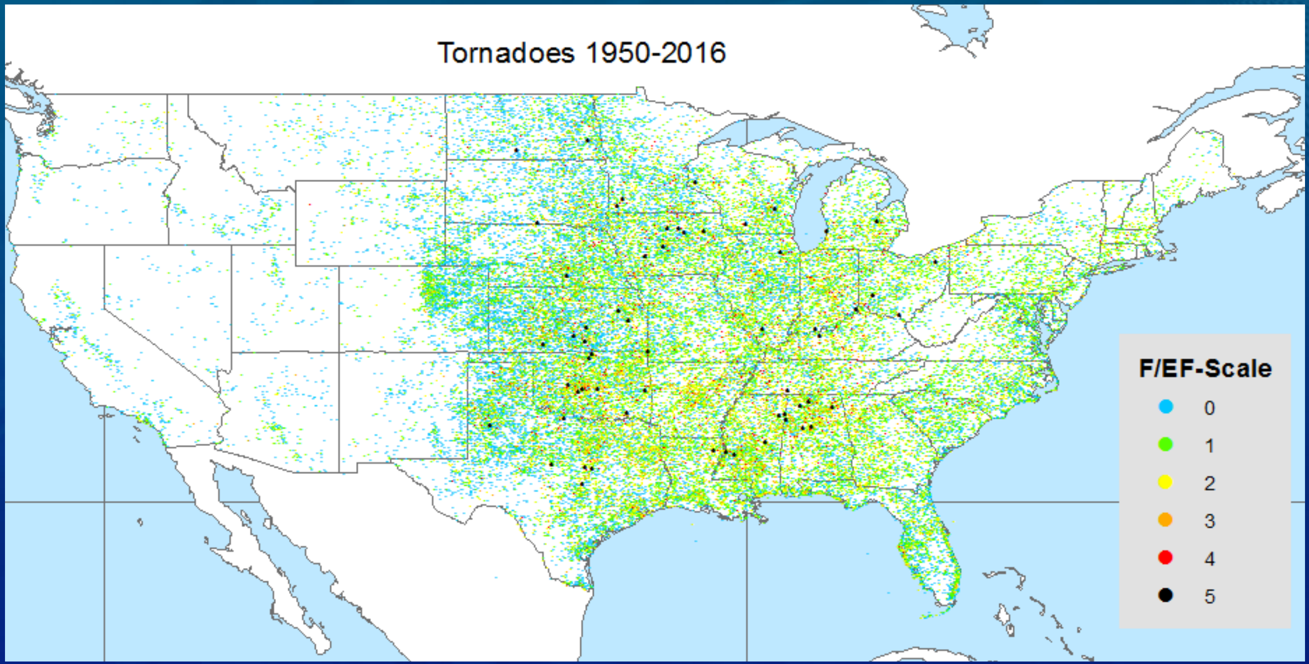
[1]Data sources and analysis: see item 2 on slide 14

Illustrates that more tornadoes are reported in areas of higher building density

(in those areas, there is a greater chance that the tornado has something to hit)

Tornado Regionalization

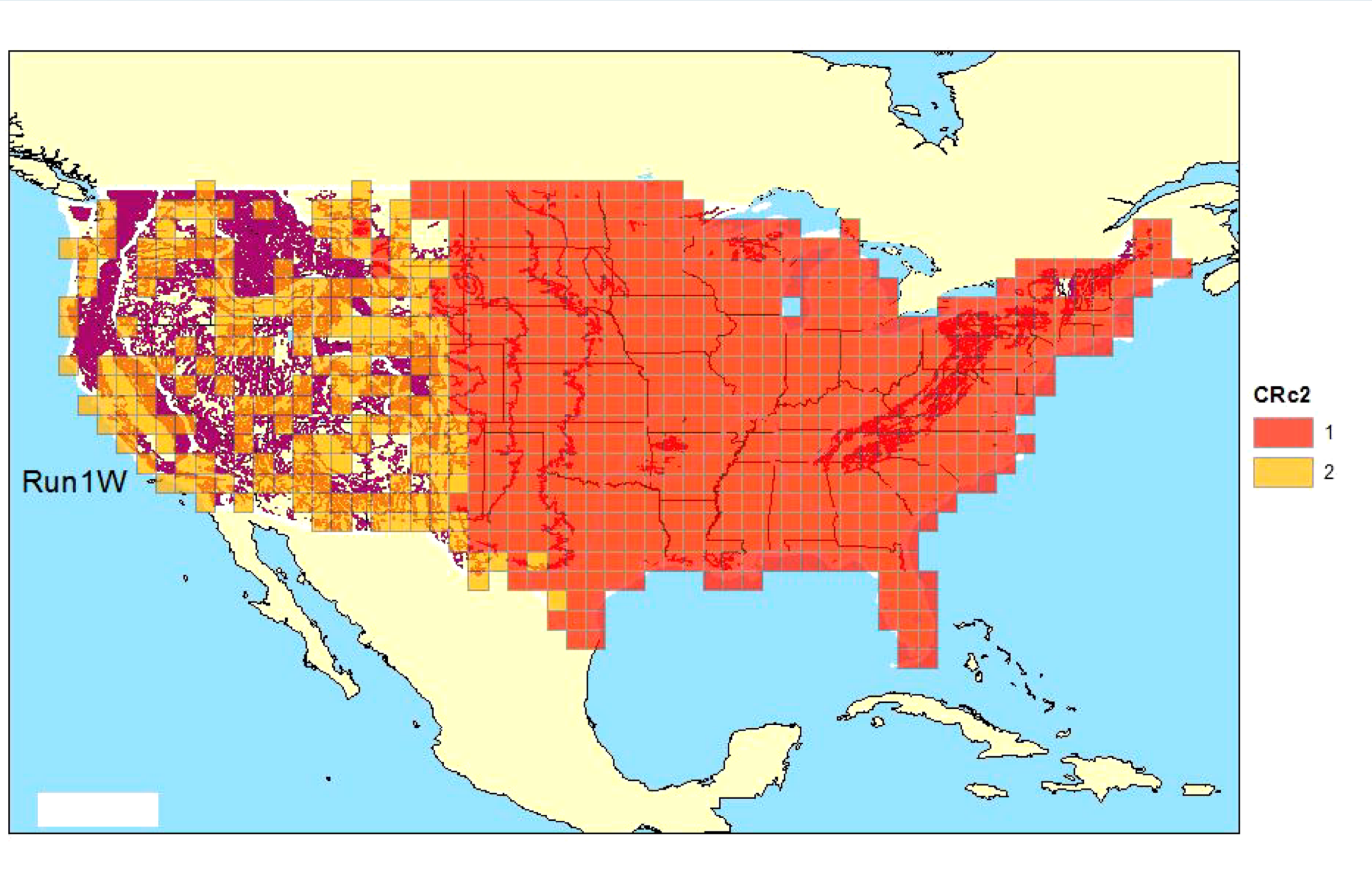
1. Broad Tornado Regions provide the starting point for the analysis and reflect the variation of tornado climatology across the US, using the reported historical data (1950-2016)
2. Work is based on SPC data, with some cleansing, per Faletra and Twisdale (2016).



Data Source: SPC

3. Tornado regions are determined using cluster analysis, to identify areas with similar tornado risk metrics. The CLUSTER procedure of the SAS/STAT (SAS Institute, 1992) module was used.

Sequential Cluster Formation - 1° Grid[1]



Variables Include

Latitude, Longitude

Elevation

Std Dev Elevation

Land Fraction

Tornado Days/Yr

Path Length

Occurrence Rates

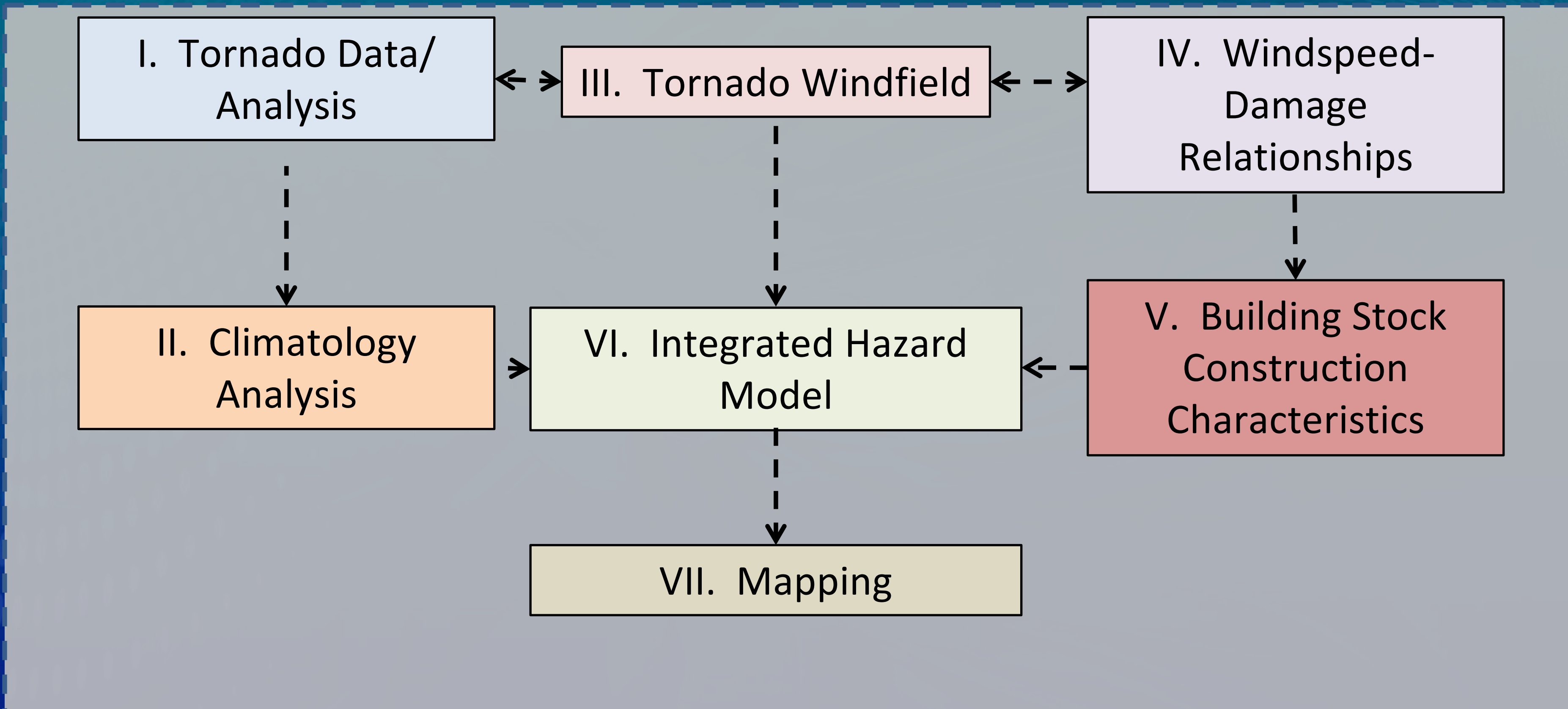
- All Intensities
- Moderate
- Strong

Point Strike Probability

Also ran 2° grids and repeated 1° and 2° cluster analyses with grids shifted over half a grid cell

[1]Data sources and analysis: see items 1-3 on slide 17

Treatment of Epistemic Uncertainty



- Evaluate epistemic uncertainties
- Propagate uncertainties to produce derived mean tornadic wind speeds
- Produce maps that reflect aleatory and epistemic uncertainties

Epistemic Uncertainties Being Considered

1. Tornado Regionalization (I, II)
2. Tornado Occurrence Rates (I, II)
3. Tornado Intensity and Path Variables (I, II)
4. Tornado Windfield (I, III, IV)
5. Damage Wind Speeds (IV) & Building Stock (V)
6. Wind Speed Frequency (VI)
7. Hazard Map Development (VII)

Progress – PBD / Design Methodologies

R5: Development of performance-based stds for tornado-resistant design
R6: Development of performance-based tornado design methodologies

Efforts related to the ASCE 7-22 Wind Load Subcommittee

- **The ASCE/SEI Ad-hoc Committee on PBD for Wind Hazards, which NIST co-led, has now been folded into the ASCE 7-22 WLSC**
  - Plan to add provisions to ASCE 7-22 that enable PBD for wind hazards, including tornadoes
  - Planned development of ASCE guidance document for Wind PBD
- **NIST is chairing a new WLSC Tornado Task Committee**
  - First meeting - Jan 2018, approximately monthly thereafter
  - Developing tornado maps/provisions for existing return periods used in ASCE 7 Chapter 26 basic wind speed maps
  - Developing tornado maps and load provisions for higher return periods to support Tornado PBD
  - Developing higher return period non-tornadic wind speed maps needed for Wind PBD

Progress – Tornado Shelter Standard

R7a: Development of tornado shelter standard for existing buildings

- **NIST and FEMA collaborated on submission (Dec 2017) of 10 proposals for ICC 500-2020, including provisions for**
  - Evaluation of existing slabs on grade for the applicable loads
  - Risk category determination
  - Revised scope and charging language for the structural design chapter
  - Rainfall rate and rainwater drainage
- **ICC 500 Committee (IS/STM) has begun a new cycle**
  - First meeting held on August 16, 2018
  - NIST representative elected to chair the committee
  - NIST will leverage its significant efforts underway in tornado mapping and loading mechanisms for ASCE 7-22 to submit additional internal proposals for Chapter 3: Structural Design Criteria
  - Timeline: the revised standard must be published by December 2020 to be incorporated into the 2021 I-Codes

Progress – Ban on Aggregate Surfaced Roofs in Tornado Prone Regions

R10: Prohibition of aggregate used as surfacing for roof coverings and aggregate, gravel, or stone used as ballast on buildings in a tornado–prone region.

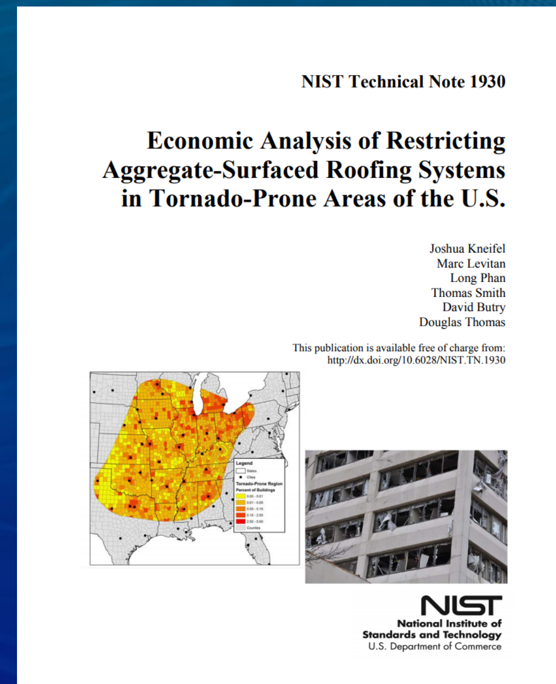
- Developed code change proposal for 2018 IBC, in coordination with the BCAC, to ban loose aggregate, gravel, and stone surfacing and ballast on roofs of Risk Category III and IV buildings in the tornado-prone region of the U.S.
- Research by NIST Applied Economics Office showed negligible cost impact
- Proposal was not successful
- **Working on Revision/Resubmission for 2021 IBC**

Economic Analysis of Restricting Aggregate-Surfaced Roofs

The percentage of new roof construction and re-roofing potentially impacted by the proposed code change was identified by combining building stock data by occupancy type and roofing system construction market share data.

Potential impacts were found to be:

- < 0.1 % of roof construction in the U.S.
- < 1.0 % of all U.S. non-low-rise residential roof construction
- < 0.3 % of roof construction in the tornado-prone region
- < 3.0 % of all non-low-rise residential roof construction in the tornado-prone region.


NIST Technical Note 1930

Economic Analysis of Restricting Aggregate-Surfaced Roofing Systems in Tornado-Prone Areas of the U.S.

Joshua Kneifel
Marc Levitan
Long Phan
Thomas Smith
David Butry
Douglas Thomas

This publication is available free of charge from: http://dx.doi.org/10.6028/NIST.TN.1930

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The previously adopted code change that similarly prohibited aggregate-surfaced roofs in the hurricane-prone region impacted more than four times as much roof construction.

Of the five most common types of built-up and single ply roofs, the only type of new roof construction or re-roofing that would be negatively impacted from a construction cost perspective by the code change are those that would have otherwise installed a ballasted single-ply membrane on a concrete deck

Progress – Public Tornado Sheltering Strategies

R8: Development and implementation of uniform national guidelines that enable communities to create safe, effective public sheltering strategies

Planning a public workshop on Public Tornado Sheltering

- **VENUE**: National Tornado Summit (March 4, 2019)
- **GOAL:** Capture information on challenges, research needs, solutions, and best practices related to issues surrounding public tornado shelters, as groundwork for development of guidance documents for communities, emergency managers, and others involved in tornado threat communications and tornado shelter planning, design and operations.
- **FOCUS AREAS**
  1. Communications Challenges
  2. Best Practices for Design
  3. Public Tornado Shelter Operations
- **WORKSHOP PARTNERS**
  FEMA, NOAA (NSSL and SPC), University of Oklahoma, Industry

This workshop also supports elements of R13 and R16

engineering laboratory

Emergency Messaging and Communication

Erica Kuligowski, *Research Social Scientist*
Wildland-Urban Interface Fire Group

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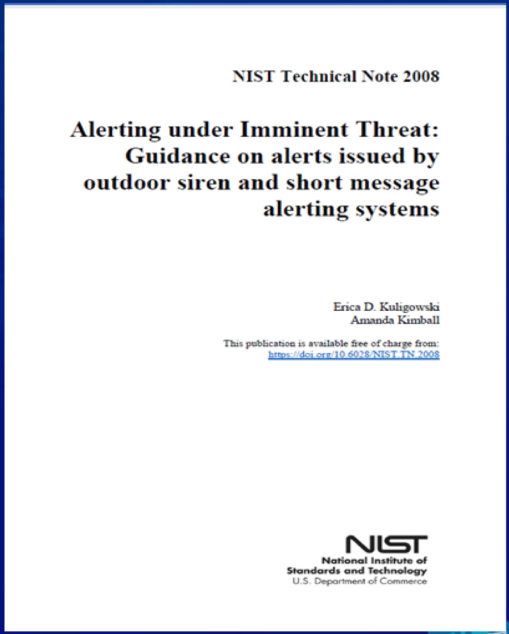
Progress - Emergency Communications (1/2)

R13: Development of national codes, standards and guidance for clear, consistent, recognizable, and accurate emergency communications, encompassing alerts and warnings, to enable safe, effective, and timely responses among individuals, organizations, and communities in the path of storms having the potential to create tornadoes.

NIST Project: Development of guidance for community-wide public alerts in emergencies
Year 2 focus: Short message alerts (e.g., wireless emergency alerts and Twitter)

- **Published NIST Technical Note on alerting guidance (Aug 2018)**
  - Provides background on alerting systems (outdoor siren systems and short messages alerts)
  - Discusses methods for developing the guidance, including performing 2 literature reviews, developing preliminary guidance, and holding workshop with experts
  - Presents guidance on the use of outdoor siren systems for public alerting and guidance on the use of short message alerting for those under imminent threat


NIST Technical Note 2008

Alerting under Imminent Threat: Guidance on alerts issued by outdoor siren and short message alerting systems

Erica D. Kuligowski
Amanda Kimball

This publication is available free of charge from: https://doi.org/10.6028/NIST.TN.2008

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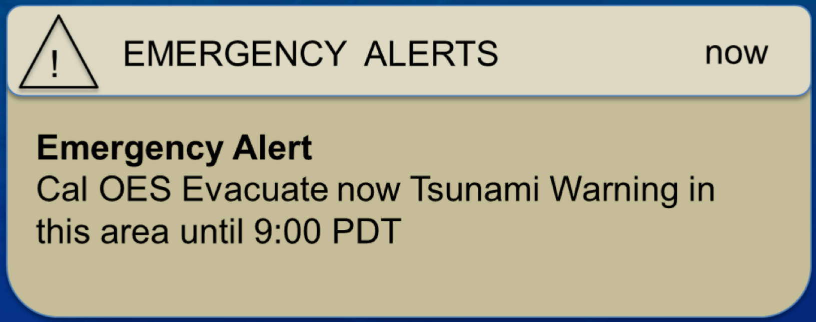
Progress - Emergency Communications (2/2)

- **Developed new short message templates (280-character Twitter and 360-character WEA template messages), with J. Sutton[1]**
  - Templates presented as a poster at the 43rd Annual Natural Hazards Research and Application Workshop (Colorado)
  - Templates incorporated into a journal article submitted to Natural Hazards Review (in review)



Example of a current 90-character WEA message (which is restricted in length and, therefore also restricted in the information that can be delivered)

- **Proposed incorporation of guidance into NFPA 1600**
  - During Second Draft Ballot, Annex K (Emergency Communications: Public Alerts and Warnings in Disaster Response) passed technical committee vote
  - Next edition of standard is currently open for NITMAM (Notice of Intent to Make a Motion), closing on August 30, 2018

[1]University of Kentucky, Department of Communication

Progress on Implementation of Joplin Tornado Recommendations

August 30, 2018
NCST Advisory
Committee Meeting

QUESTIONS?

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