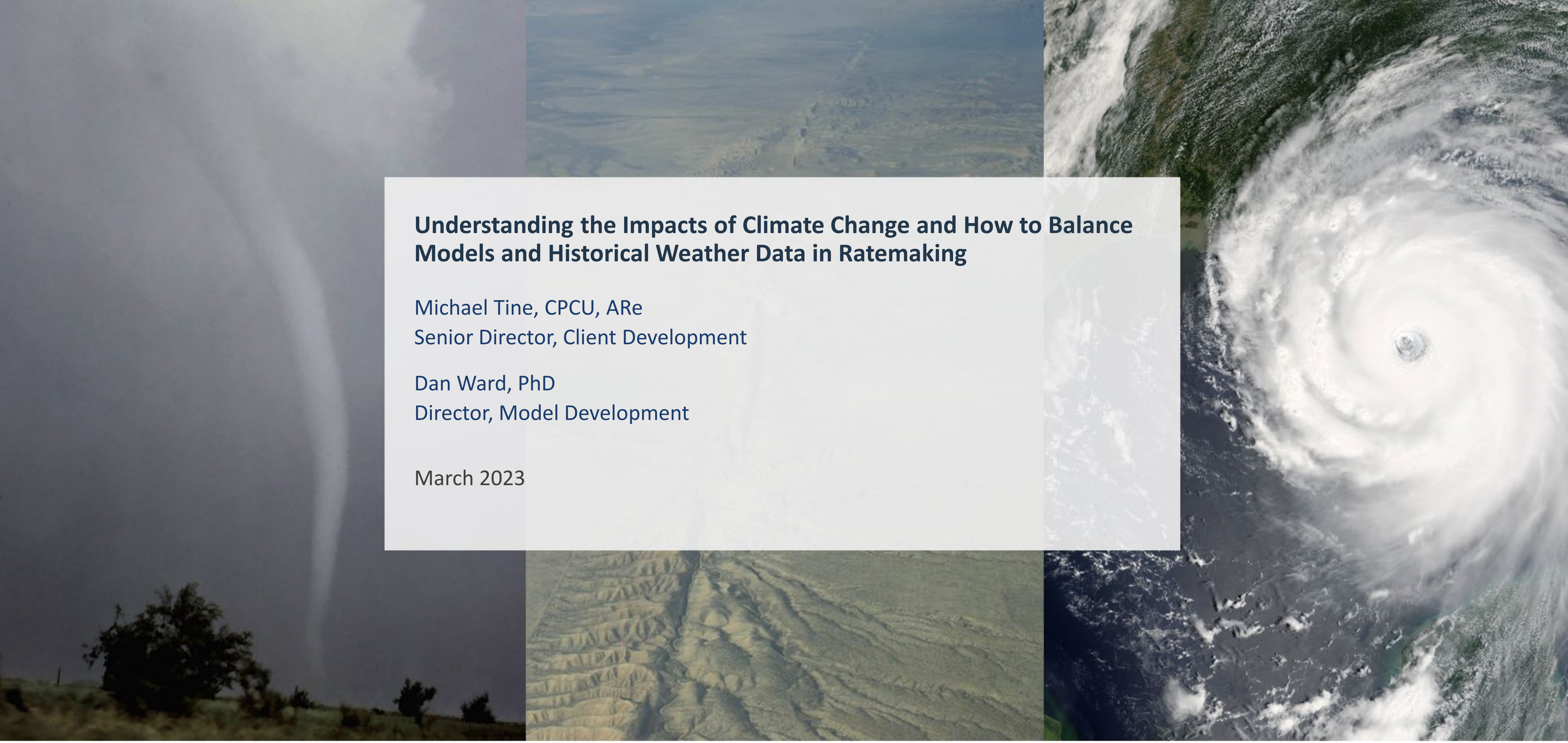

# Understanding the Impacts of Climate Change and How to Balance Models and Historical Weather Data in Ratemaking

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Senior Director, Client Development

Dan Ward, PhD
Director, Model Development

March 2023

KC &CO

*The Innovation and Technology Leader in Catastrophe Risk Modeling*

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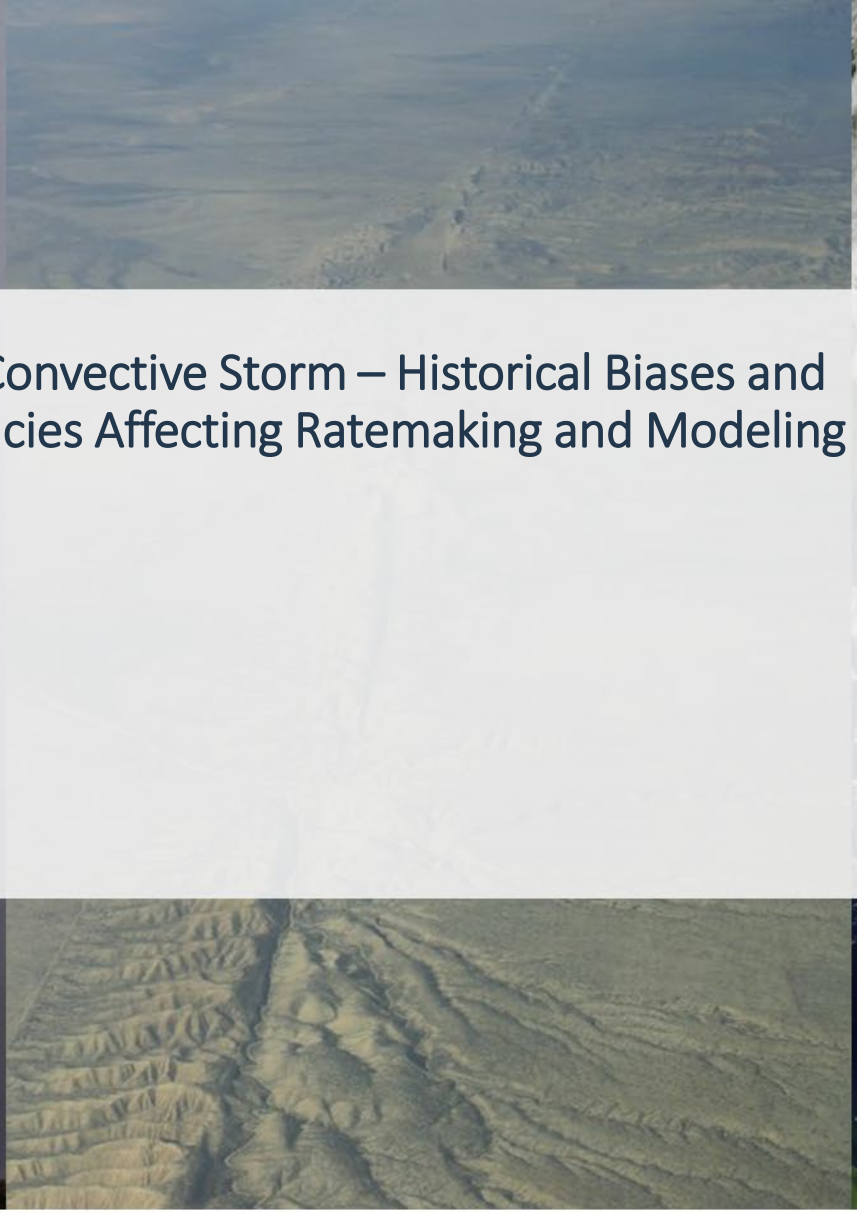
# Agenda

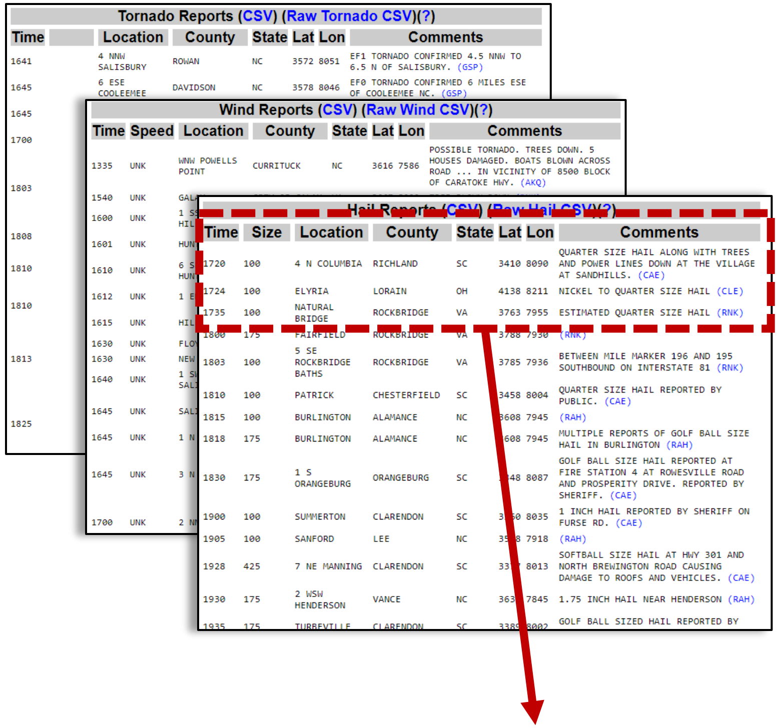
- Sampling Bias in Company Historical Losses and First-Generation Catastrophe Models
- Next-Generation Modeling Overview – Severe Convective Storm and Wildfire
- Climate Change Shifting Geography of Loss Potential
  - Making Historical Losses Less Credible
- Replacing Historical Data with Next-Generation Model Output
  - Reduce Bias for Ratemaking at Higher Resolution


# Severe Convective Storm – Historical Biases and Inaccuracies Affecting Ratemaking and Modeling

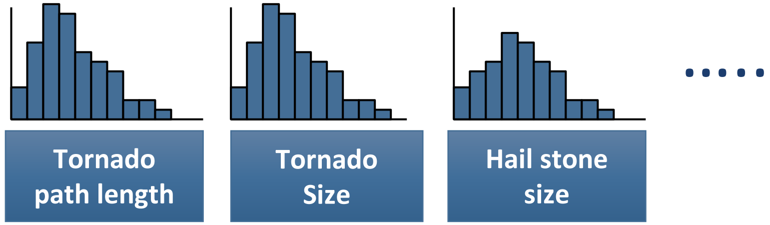
# Why Do the First Generation SCS Cat Models have Significant Sampling Bias?

## 1) Collect Available Data

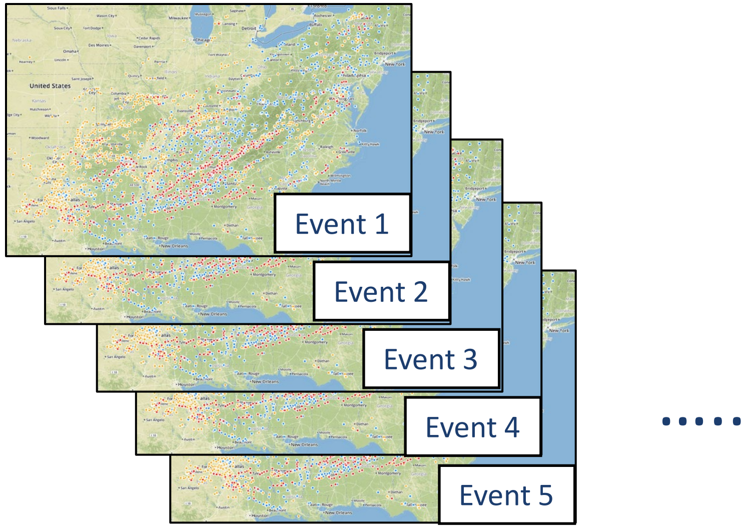



| Time | Size | Location | County | State | Lat | Lon | Comments |
|---|---|---|---|---|---|---|---|
| 1720 | 100 | 4 N COLUMBIA | RICHLAND | SC | 3410 | 8090 | QUARTER SIZE HAIL ALONG WITH TREES AND POWER LINES DOWN AT THE VILLAGE AT SANDHILLS. (CAE) |
| 1724 | 100 | ELYRIA | LORAIN | OH | 4138 | 8211 | NICKEL TO QUARTER SIZE HAIL (CLE) |
| 1735 | 100 | NATURAL BRIDGE | ROCKBRIDGE | VA | 3763 | 7955 | ESTIMATED QUARTER SIZE HAIL (RNK) |

## 2) Calculate Statistics and Fit Distributions to Peril Parameters

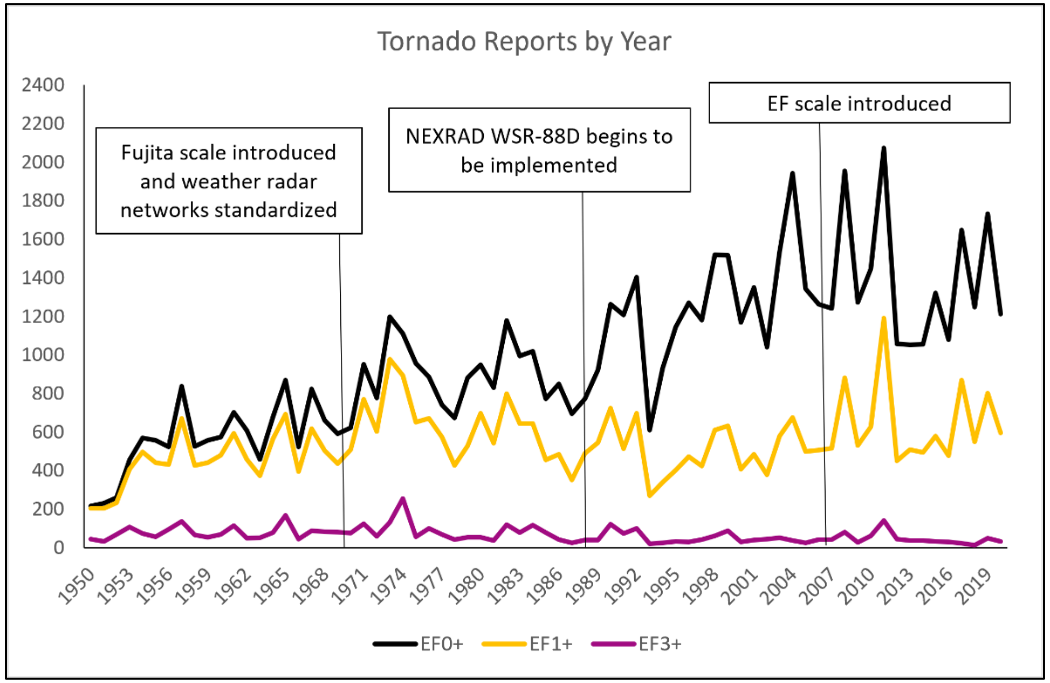


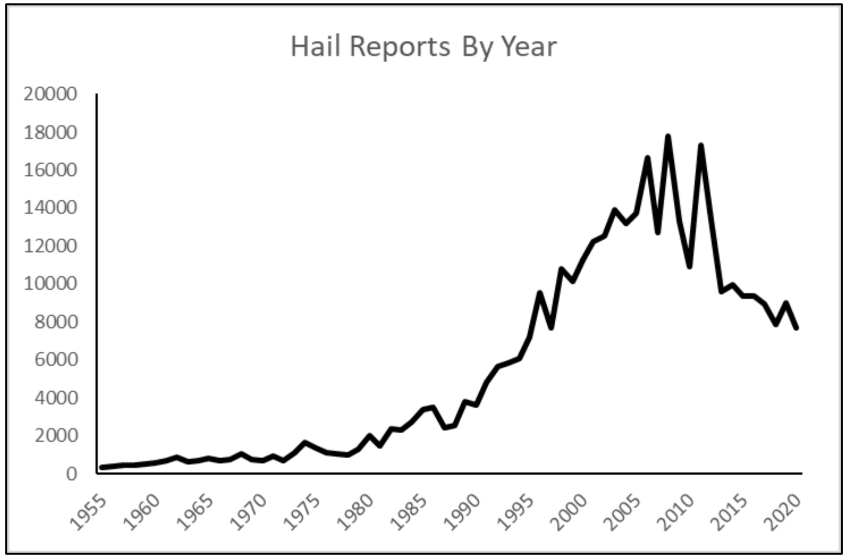

## 3) Simulation Creates Random Events

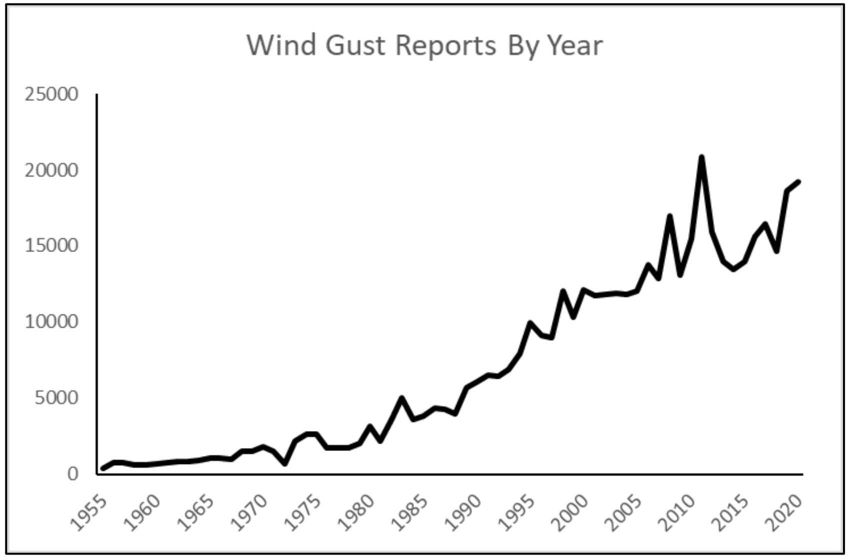


# They Use Inaccurate Historical Statistics, and…

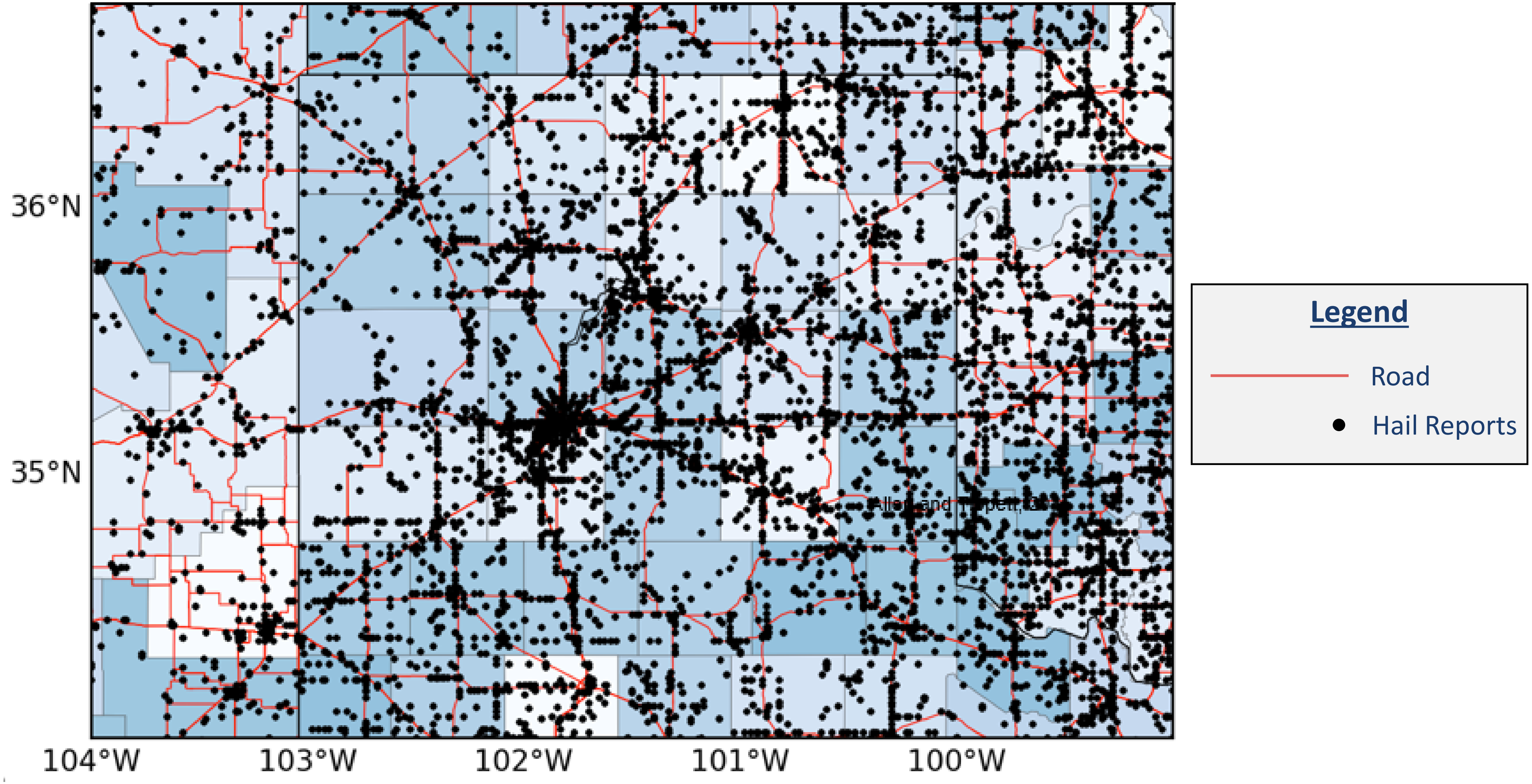
1. Obtain tornado, hail, and wind reports since 1950
2. Augment the data for missing reports, population bias, etc.
3. Calculate statistics on tornado path lengths, path widths, hail stone size, etc.
4. Randomly generate hypothetical tornadoes, hail swaths, and wind using parameterized distributions
5. Arbitrarily group these isolated occurrences into 'events'



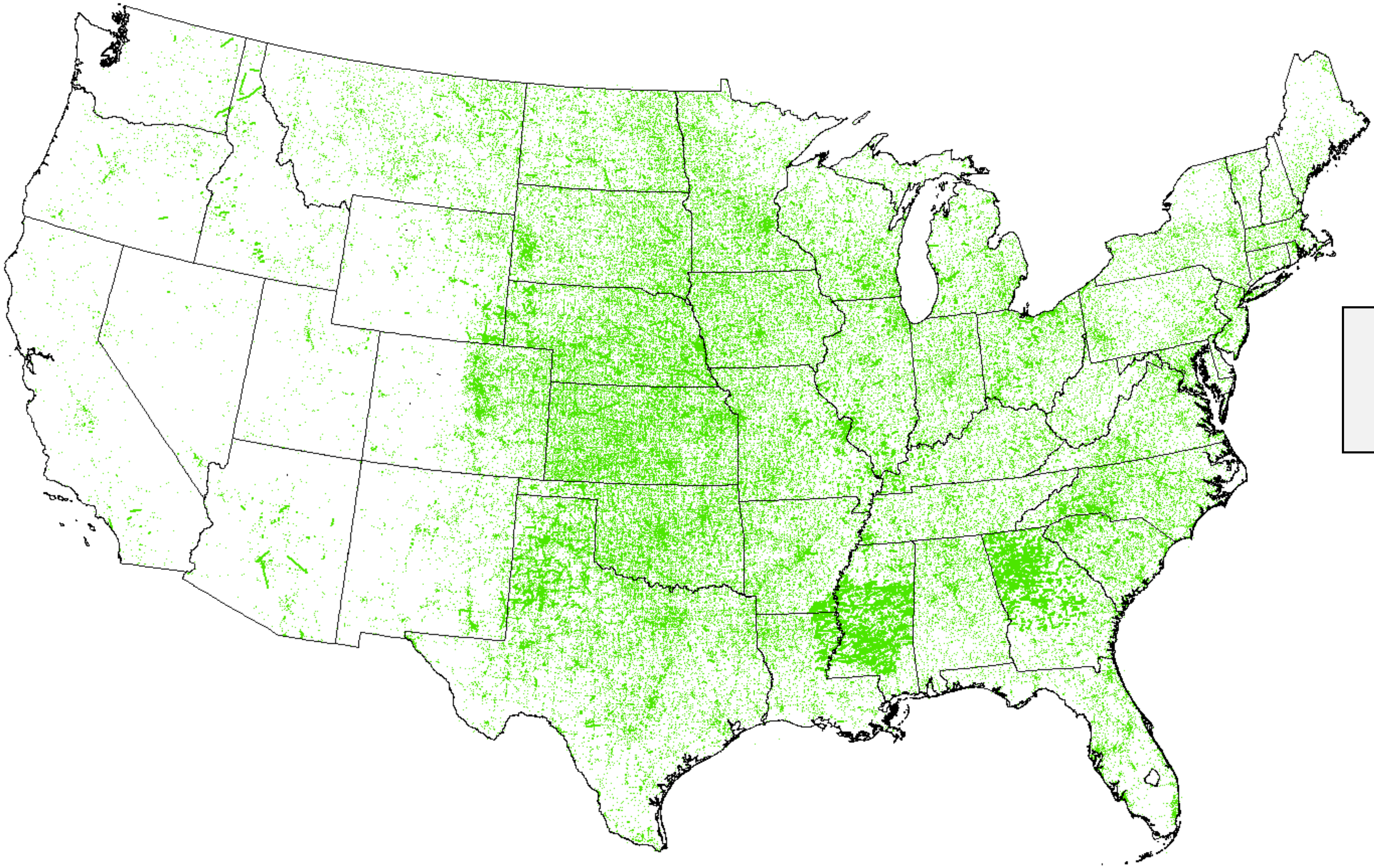



# They Use Historical Hail Reports Focused Around Population (Amarillo, TX Example), and…



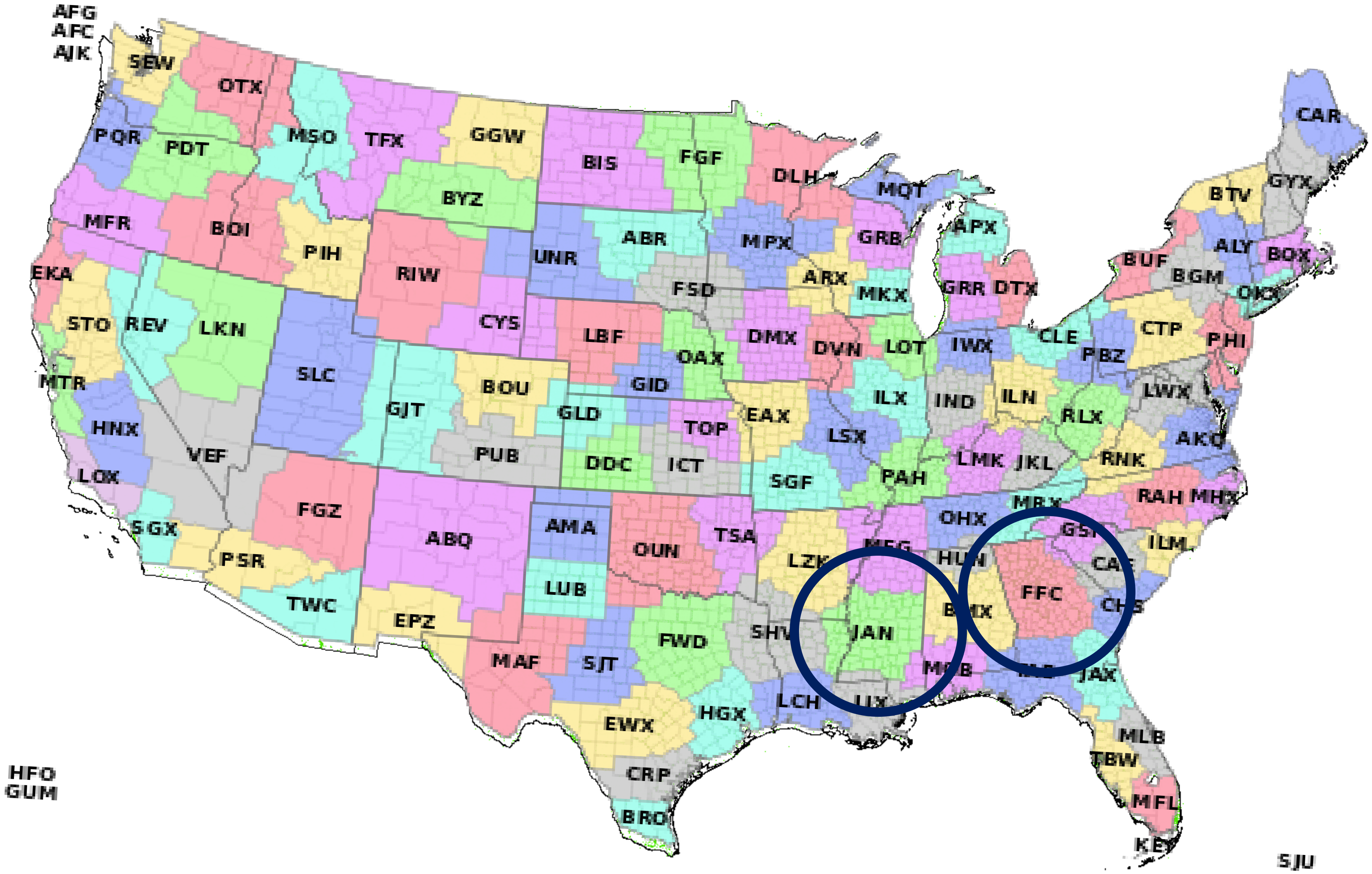
# There Are Geographical Biases in Hail Reporting



**Legend**

Hail Reports

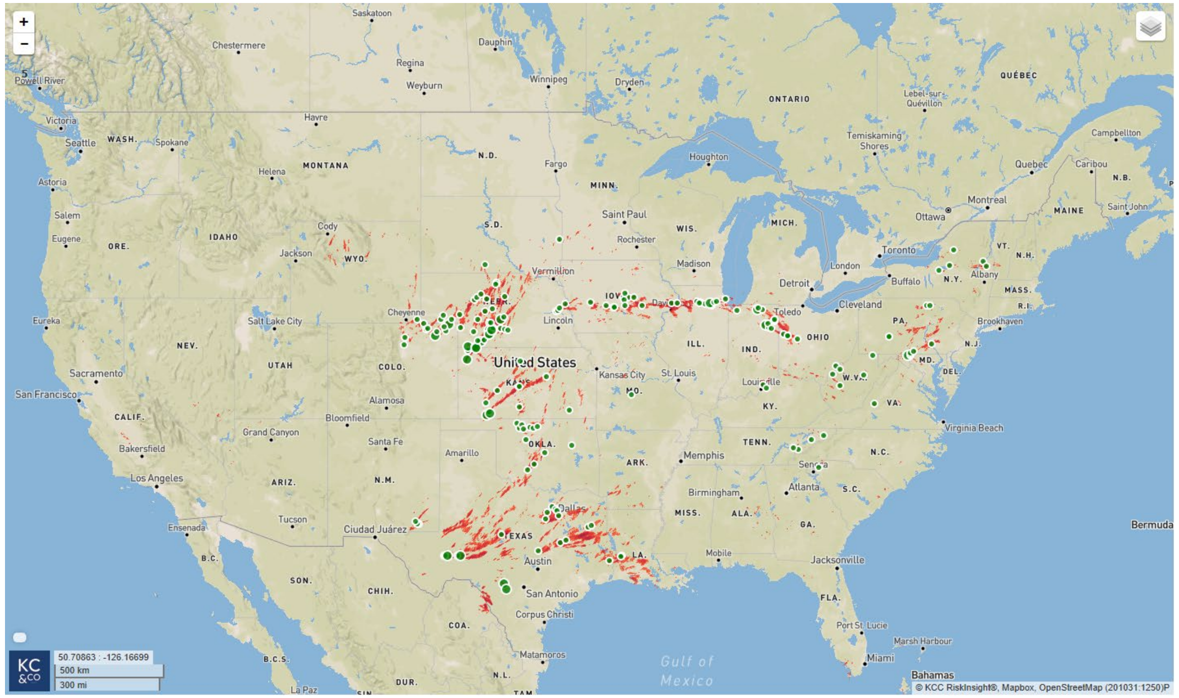
# There Are Geographical Biases in Hail Reporting, and…

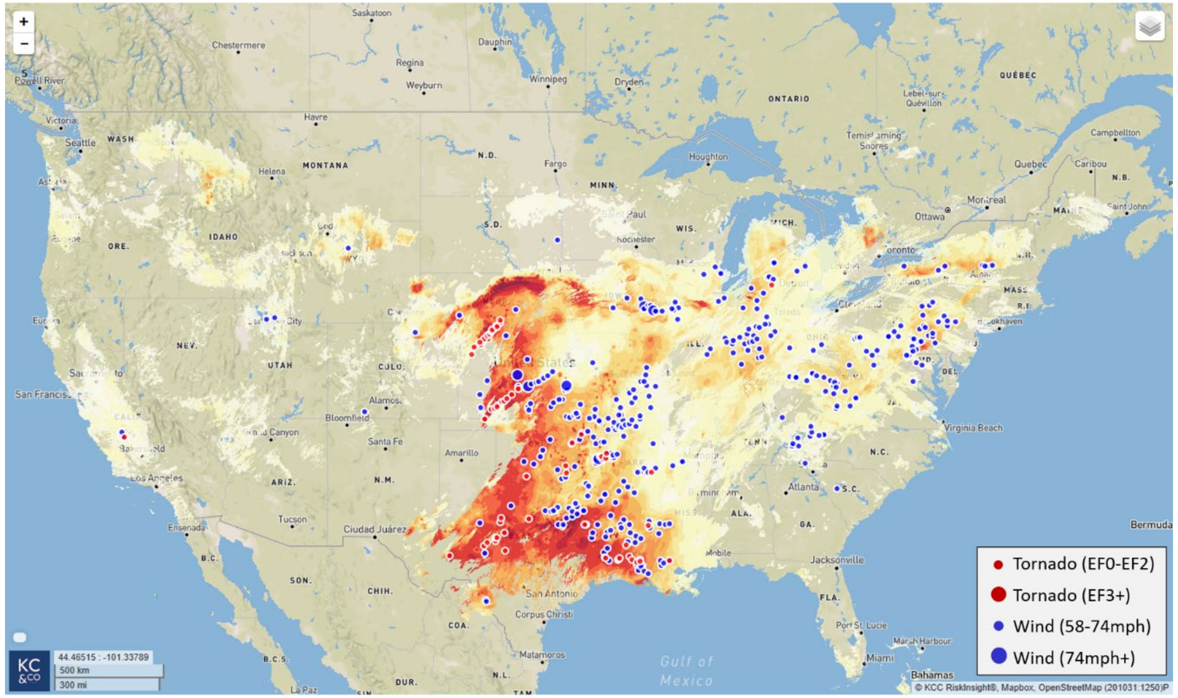


# A Significant Percentage of SCS Losses Occur Outside of "Numbered Cat" Events and Loss Estimates

| Event (2019-05-16 to 2019-05-17) | | |
|---|---|---|
| IA | $ | 105,400,000 |
| IL | $ | 437,100,000 |
| IN | $ | 121,050,000 |
| TOTAL-US | **$** | **663,550,000** |

| Event (2019-05-17 to 2019-05-18) | | |
|---|---|---|
| TX | **$** | **100,670,000** |





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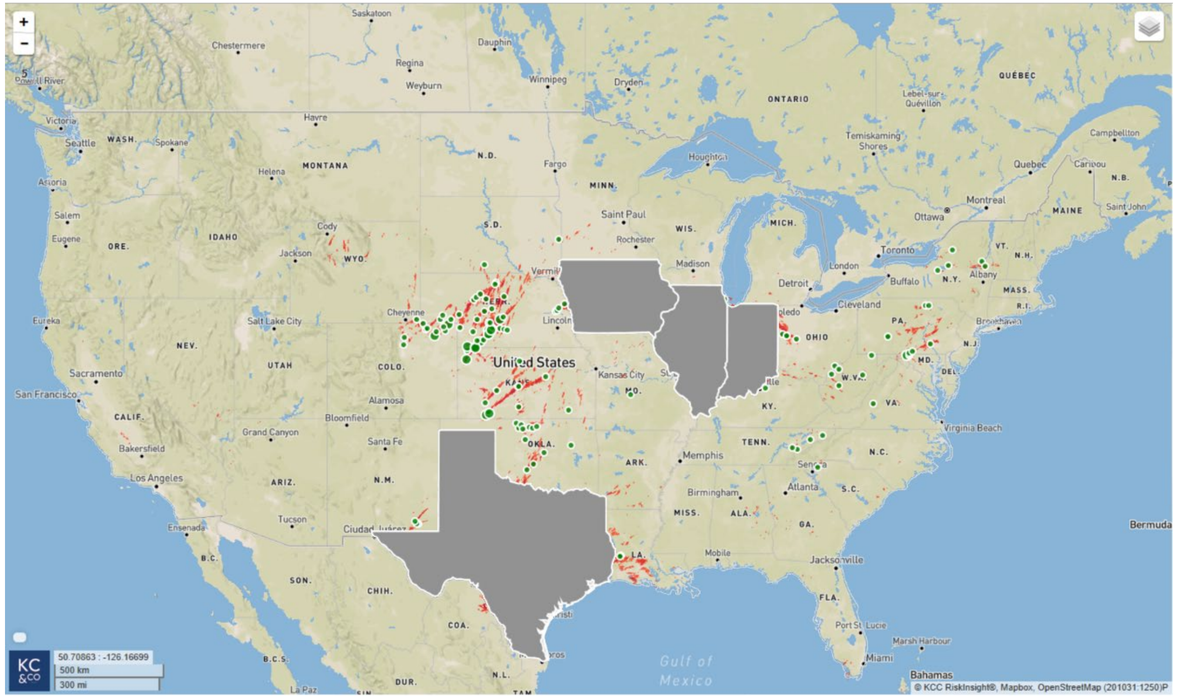
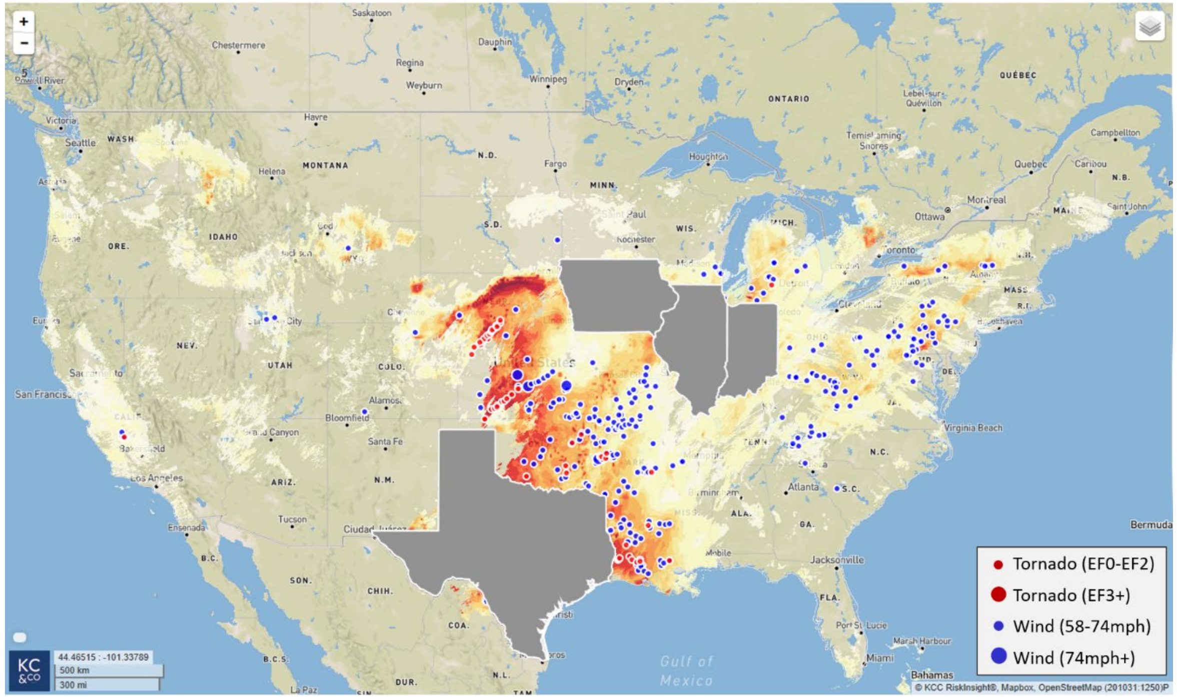
| Event (2019-05-17 to 2019-05-18) | | |
|---|---|---|
| TX | **$** | **100,670,000** |

How does your company track SCS claims?

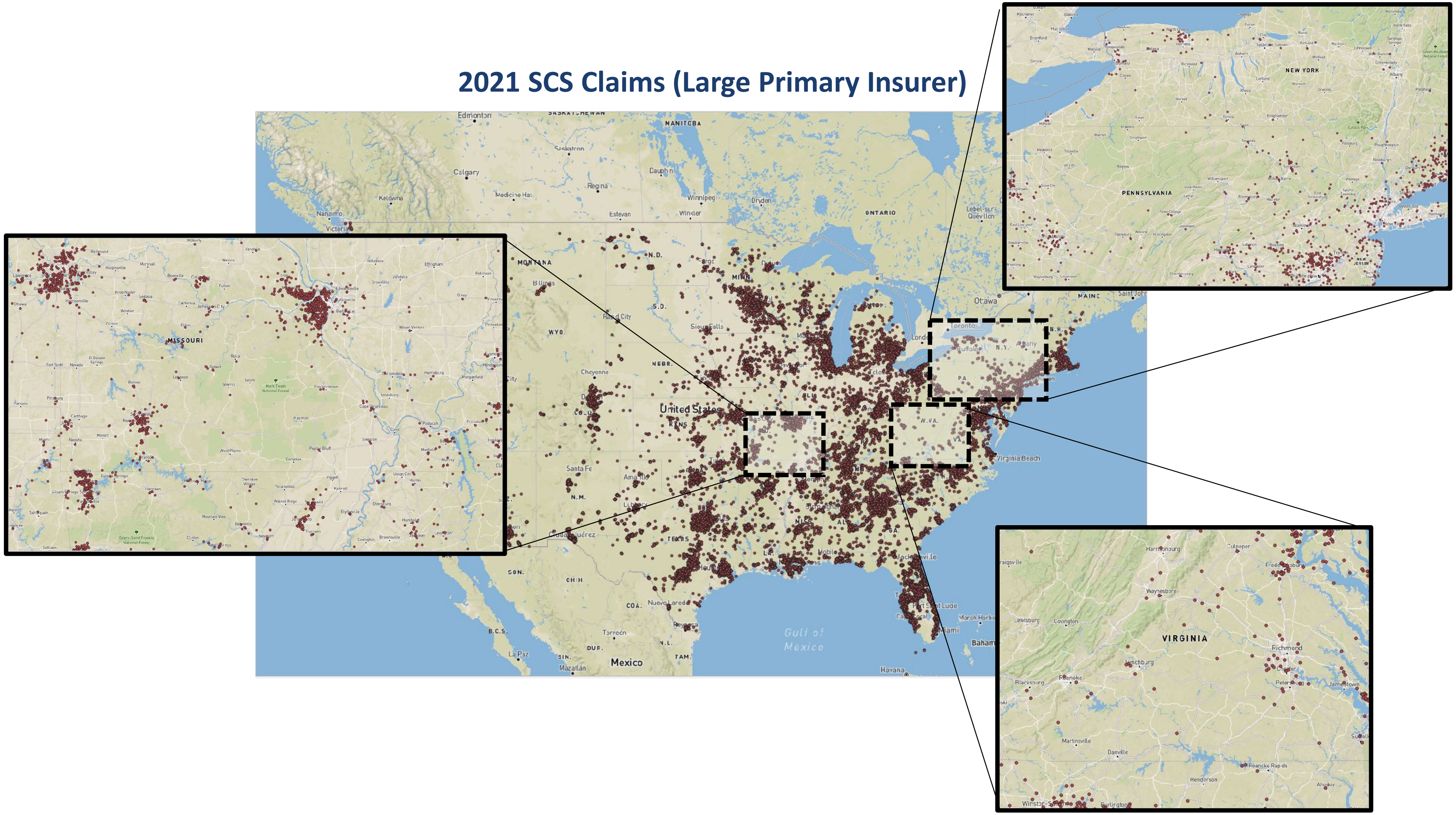


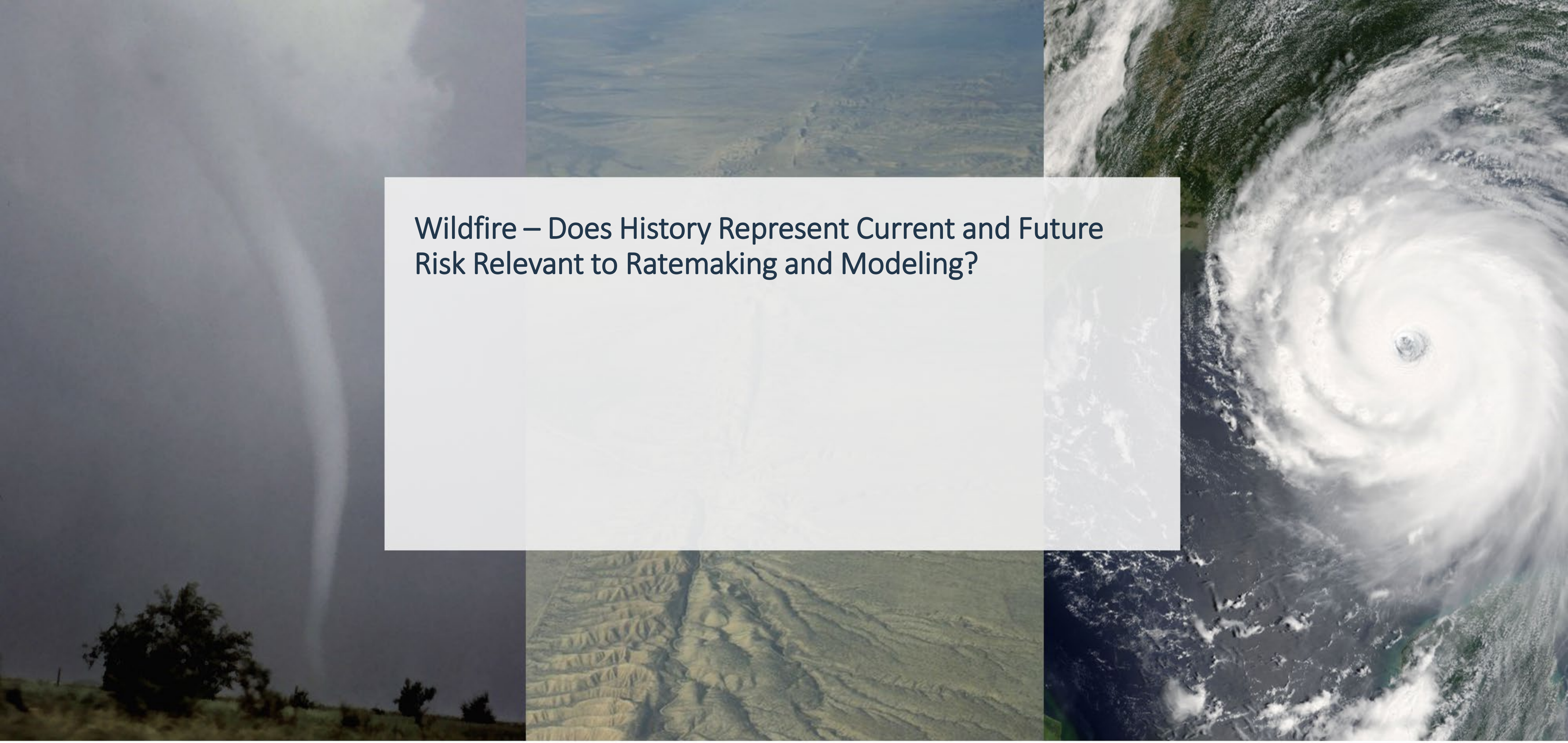



**Remainder: $251,000,000 SCS Losses Outside of Designated Cat States**

# Reported Claims/Hazard Have Gaps, Especially When Looking at County or Lower

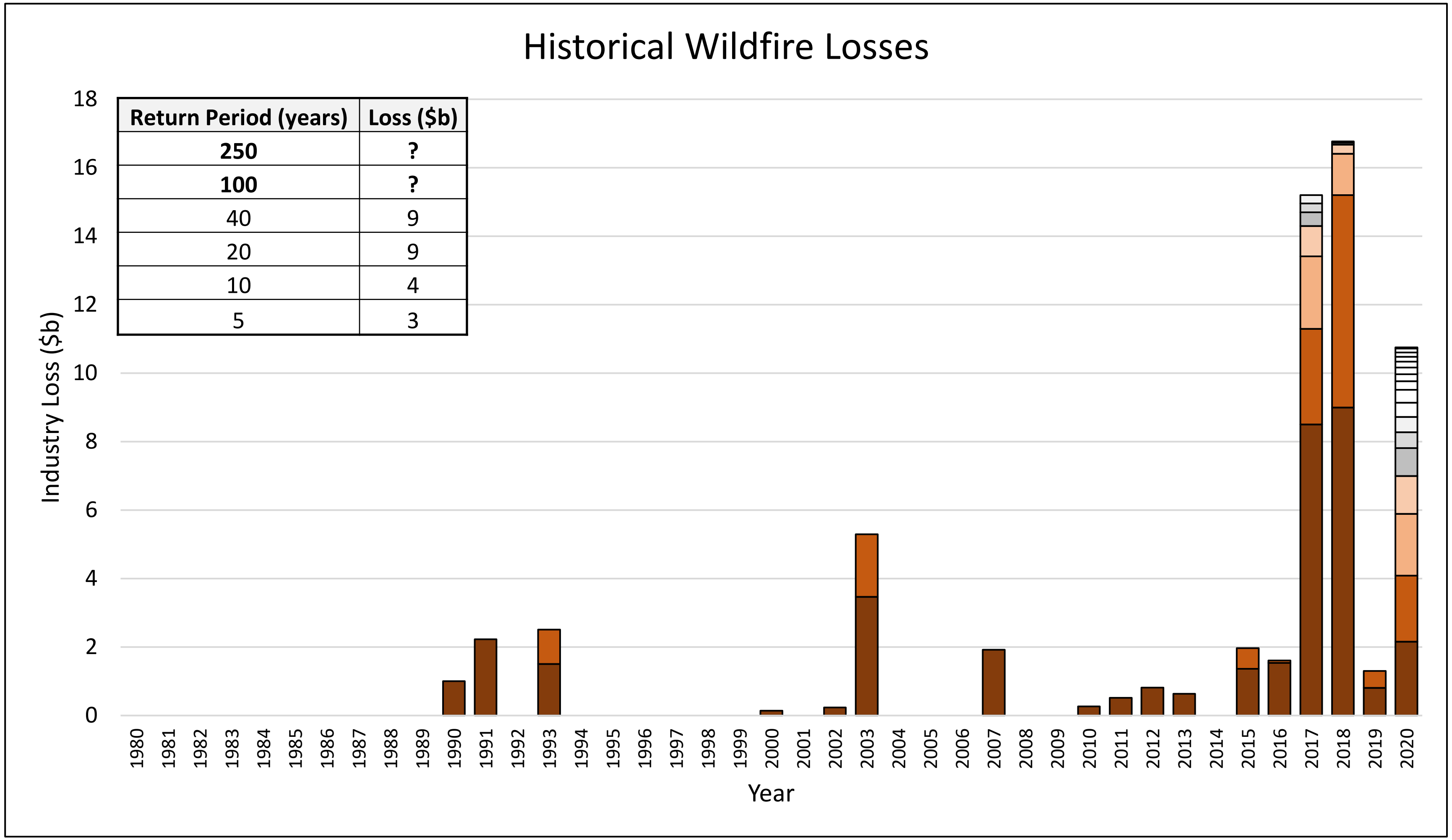
**2021 SCS Claims (Large Primary Insurer)**





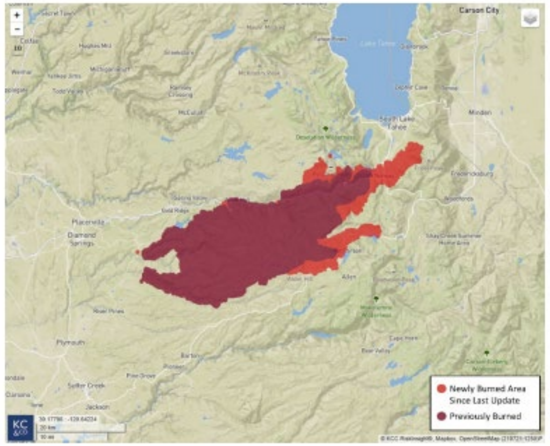
# Wildfire – Does History Represent Current and Future Risk Relevant to Ratemaking and Modeling?

# Wildfires are Now a Major Driver of Losses in the US, Particularly in California

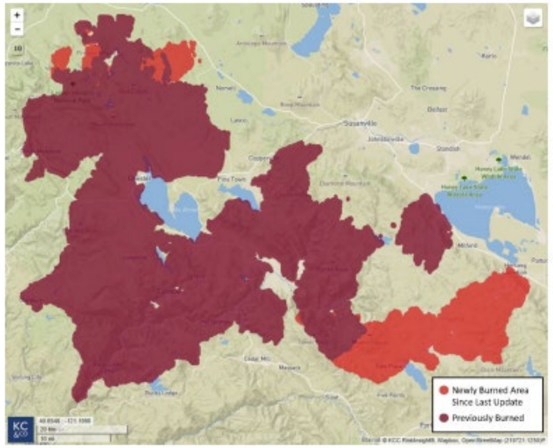



| Return Period (years) | Loss ($b) |
|---|---|
| **250** | **?** |
| **100** | **?** |
| 40 | 9 |
| 20 | 9 |
| 10 | 4 |
| 5 | 3 |

KCC Fire Footprint – Caldor Fire

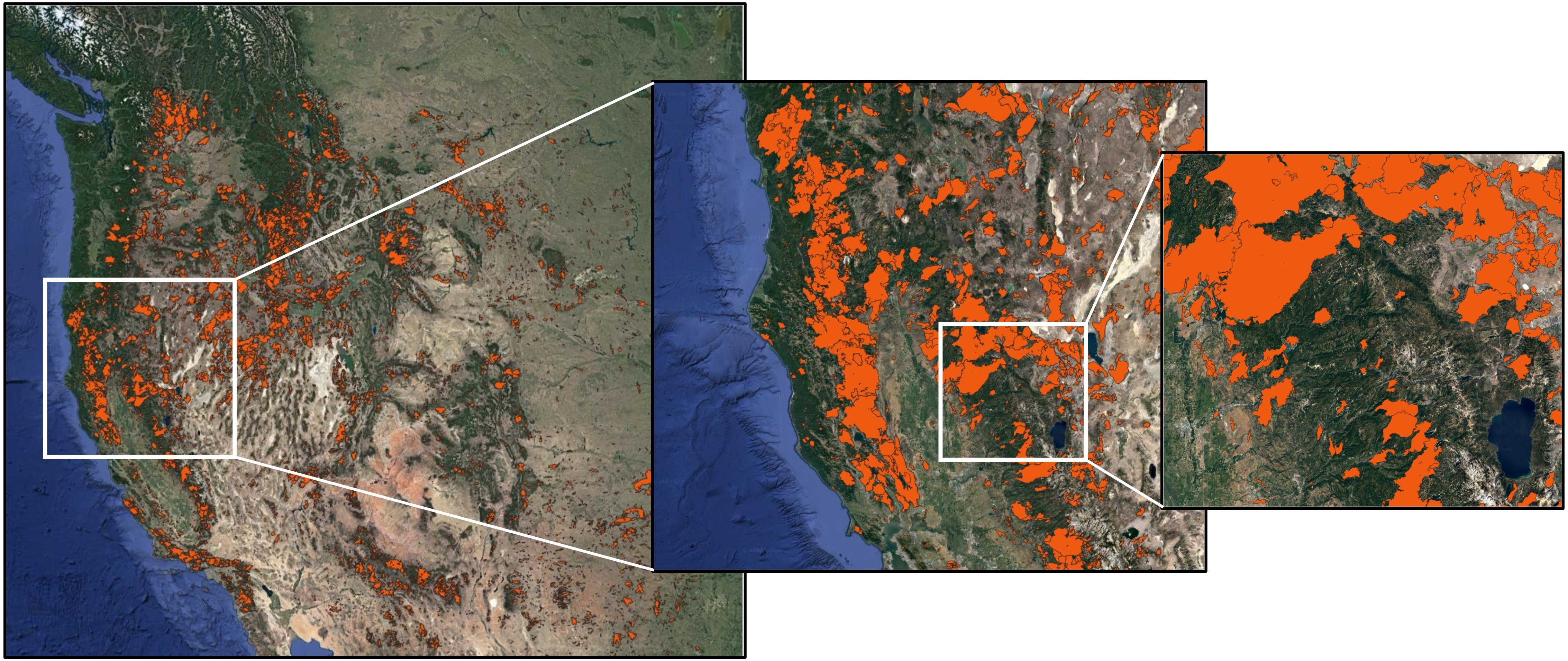


KCC Fire Footprint – Dixie Fire



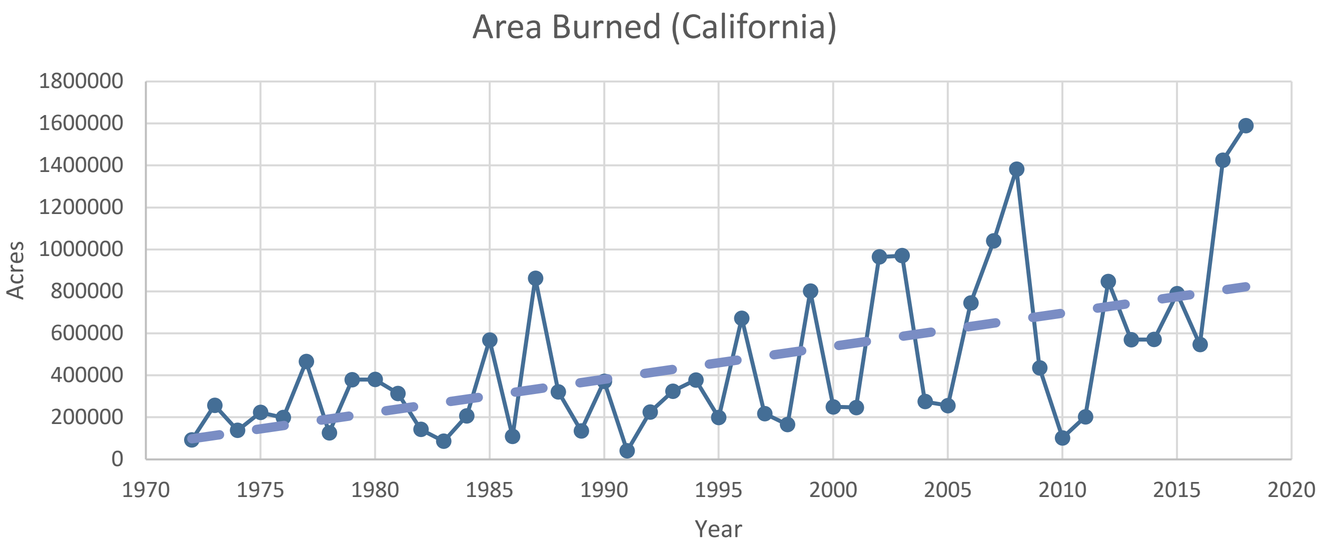
# Even in Historically Active Areas, Gaps Exist in Wildfire Historical Data – Affects Hazard and Loss Trending

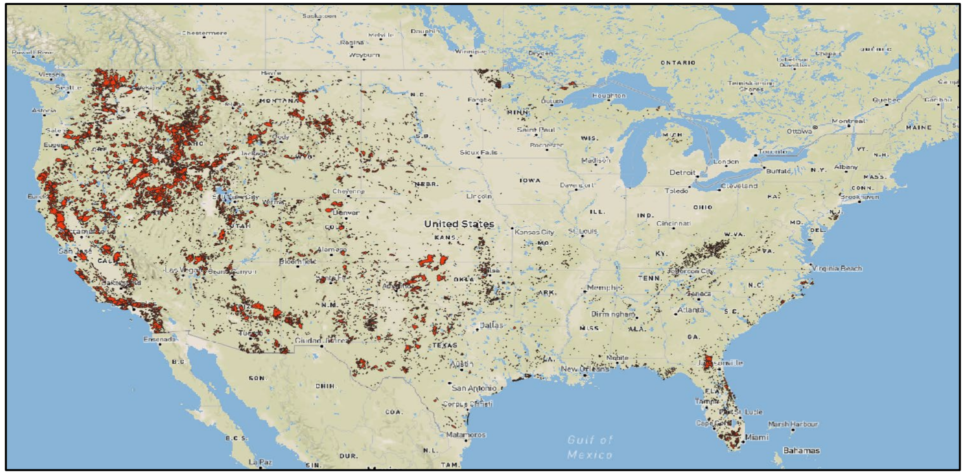
- Large areas of the western United States are at risk from fires but have not experienced a wildfire in recent history

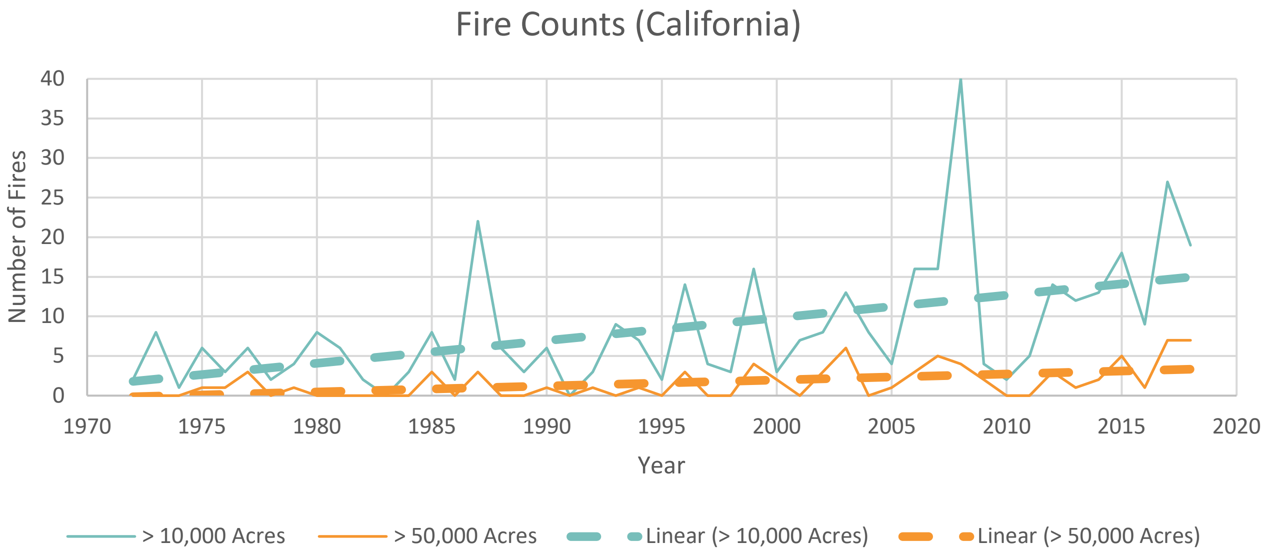


# Both the Area Burned and the Fire Frequency Have Increased since 1980

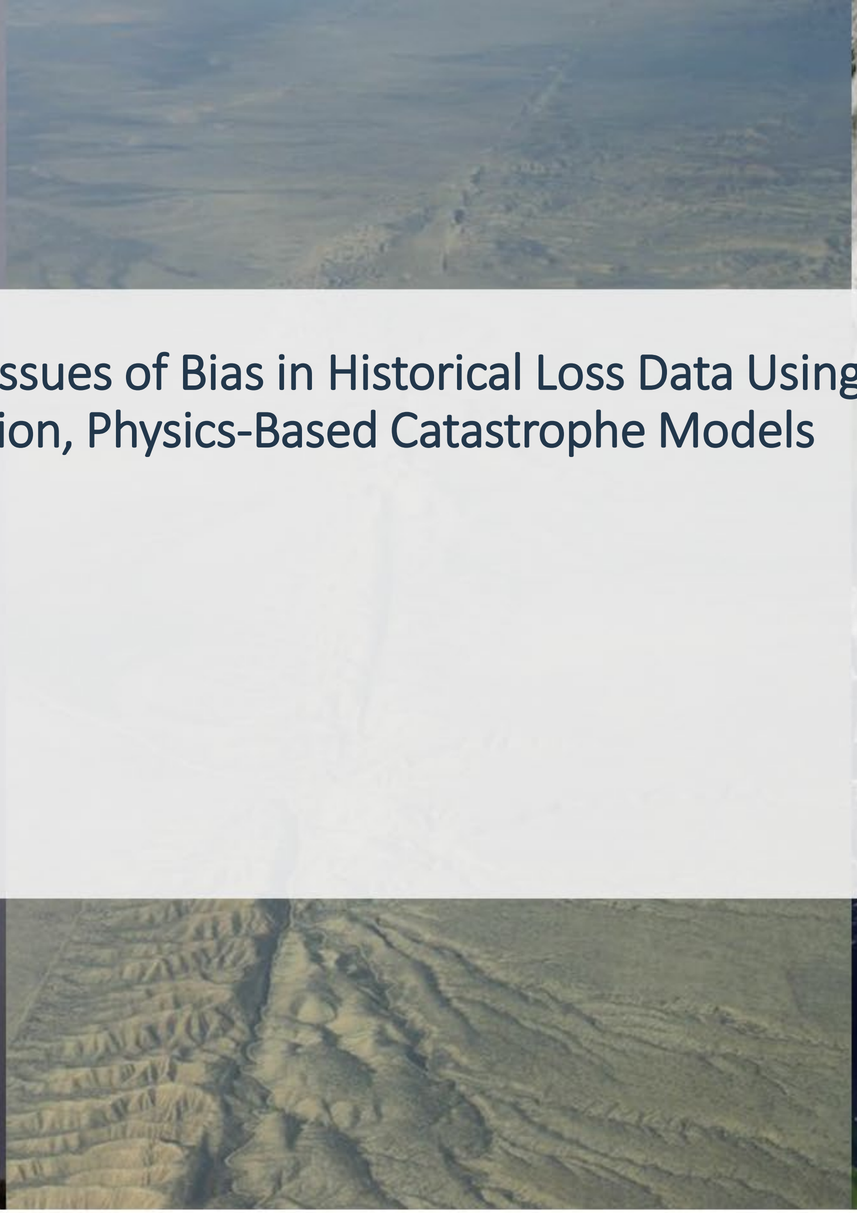
- In California the annual area burned has increased by 300% since 1980
- In 1980 it was typical to have 5 fires larger than 10,000 acres in a year – now the norm is 15 such fires per year

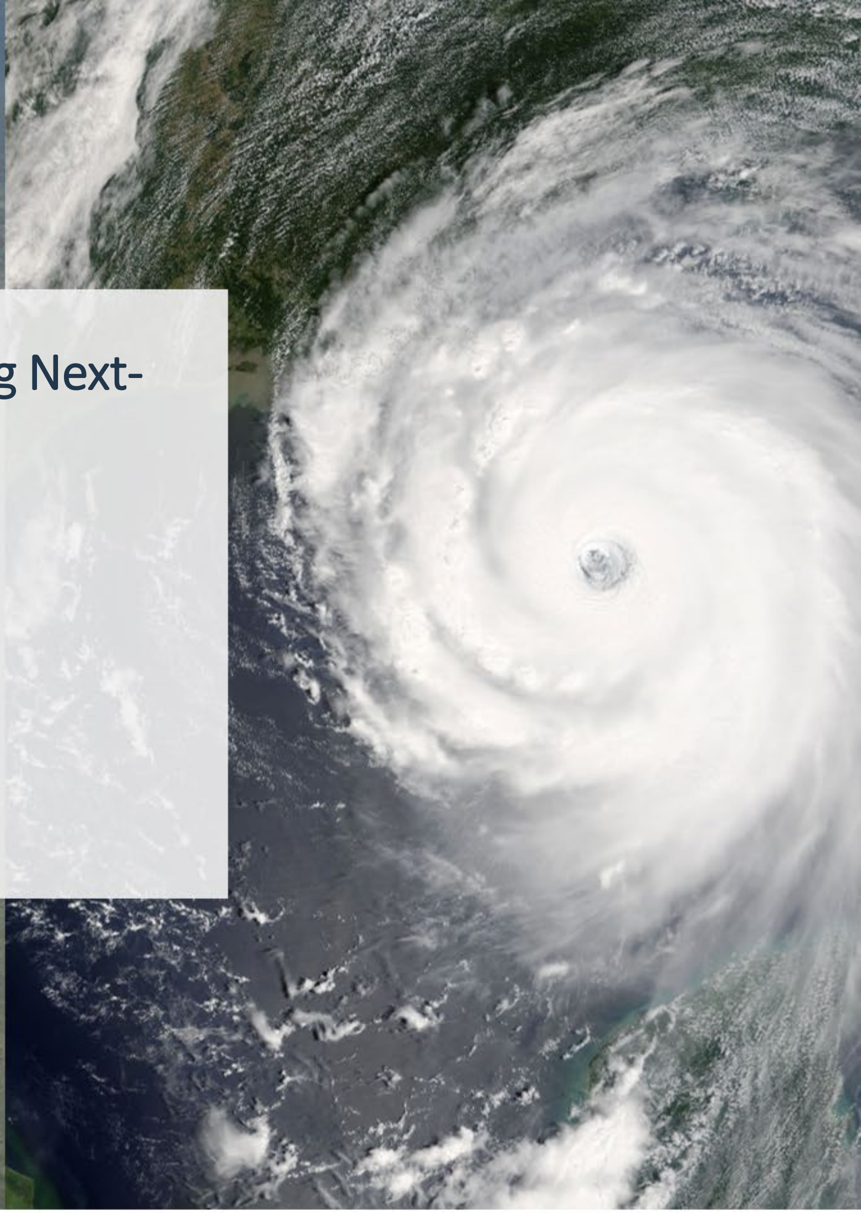


# Solving Issues of Bias in Historical Loss Data Using Next-Generation, Physics-Based Catastrophe Models



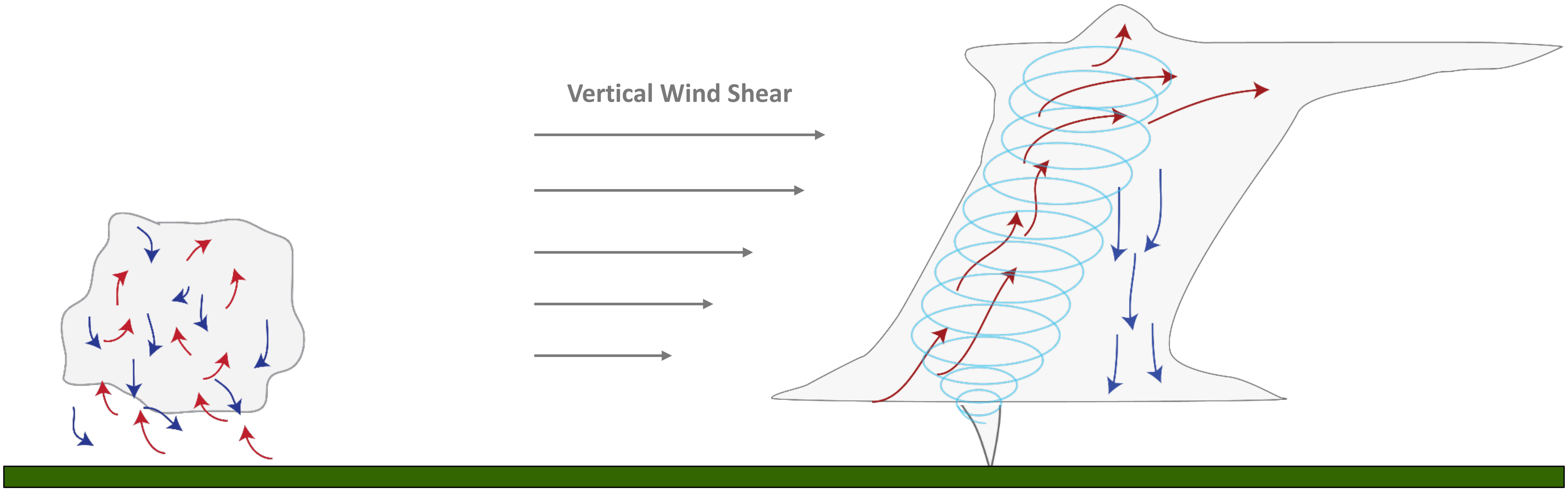


# Solving Issues of Bias in Historical Loss Data with Physics-Based Catastrophe Models

- Research the **physics** underlying severe convective events
- Determine the **atmospheric variables** that best correlate with reported hail, tornadoes, and straight-line winds
- Develop a **physical model** of SCS events
- Reproduce **actual losses** for over 300 historical events
  - Verify event footprints
  - Validate damage functions
- Generate a stochastic catalog of **hypothetical events**

# The Physics of SCS: Updrafts, Downdrafts, Wind Shear, and Rotation

- **Rising warm air → updrafts**
- **Sinking cool air → downdrafts**
- **Wind shear** influences processes leading to organized storm cells




**SCS Environment = Convection + Shear + Rotation**

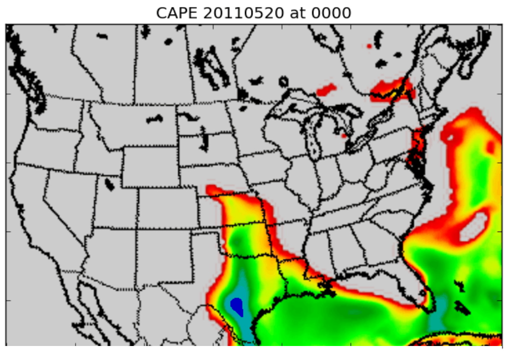
# Atmospheric Parameters Required for Modeling Tornado/Wind

- Instability Parameters:
  - Convective Available Potential Energy (CAPE)
  - Convective Inhibition (CIN)
- Shear Parameters:
  - Wind Velocities
  - Vertical Wind Shear (SHEAR)
  - Storm Relative Helicity (SRH)
- Lifted Condensation Level (LCL)

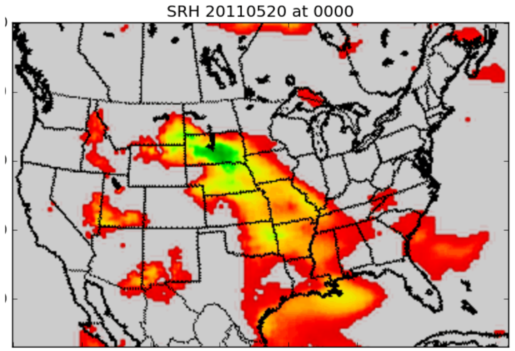
# Validation of Footprints:  Time Lapse of Most Significant Variables—Three Hour Intervals May 20-27

## May 2011 Outbreak

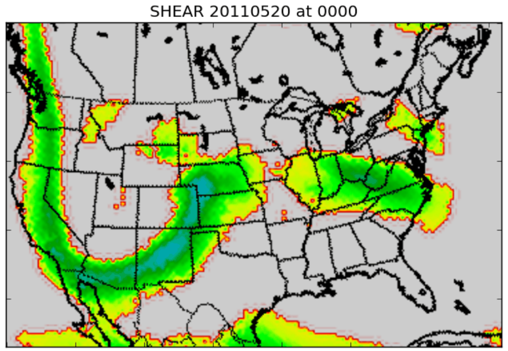
**CAPE**



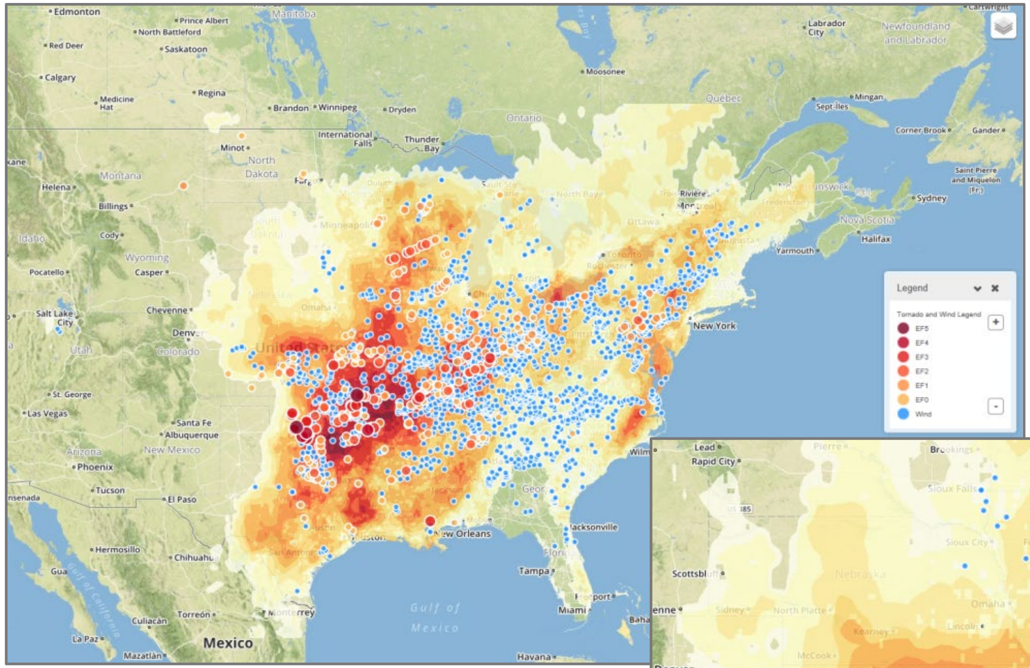

**SRH**

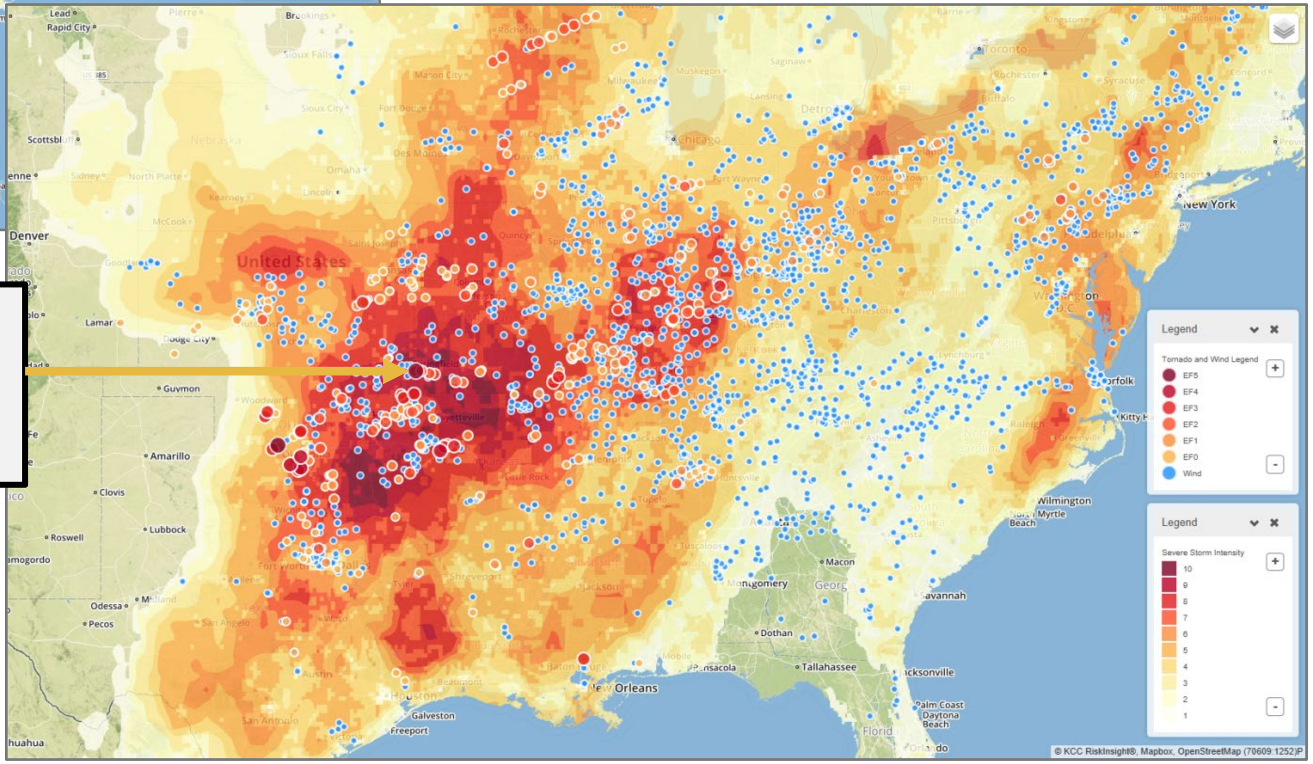



**Shear**



# Validation of Footprints: Event Footprint and Reported Tornadoes and Wind Gusts for May 2011 Event

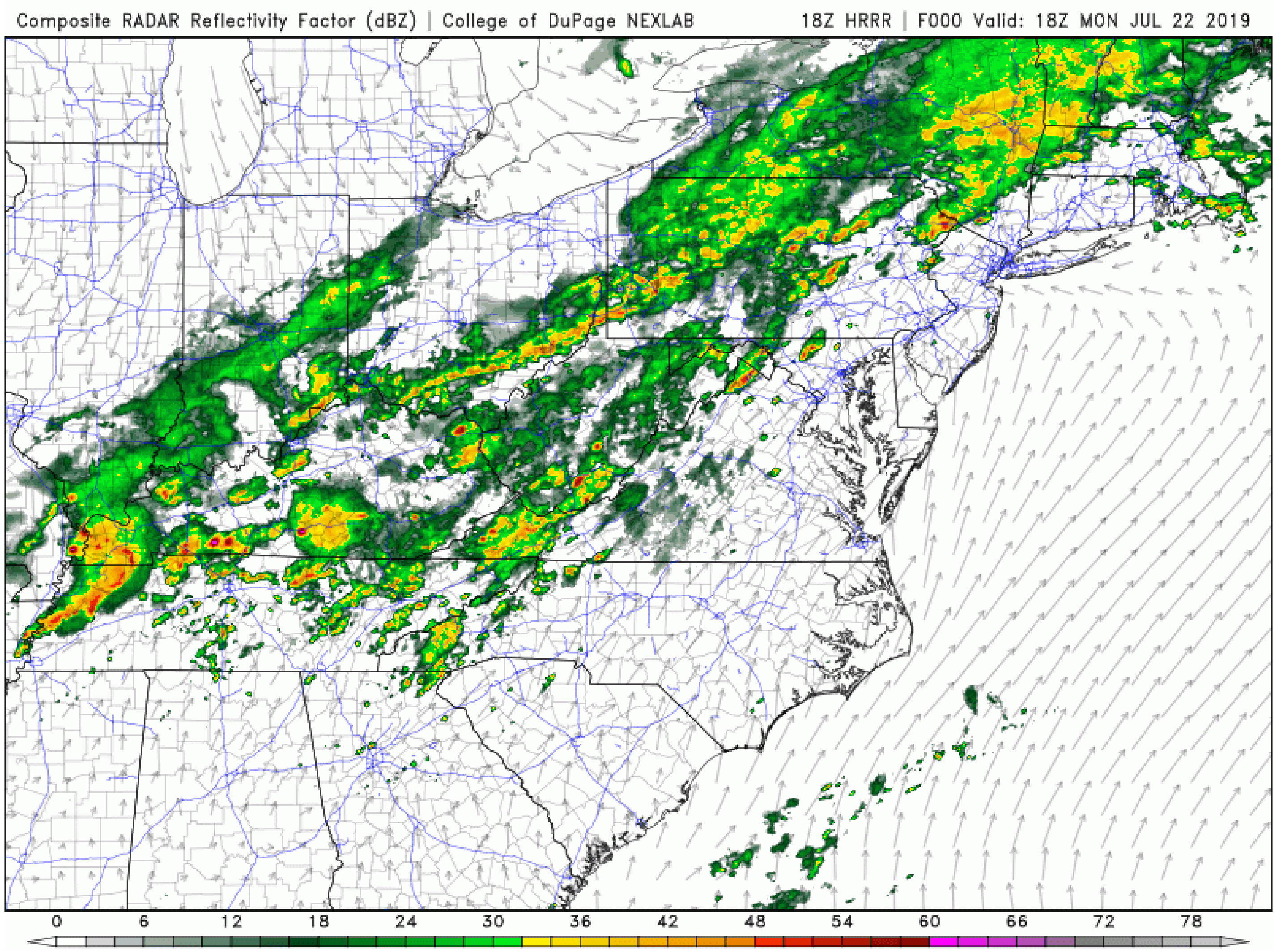



Joplin
EF-5

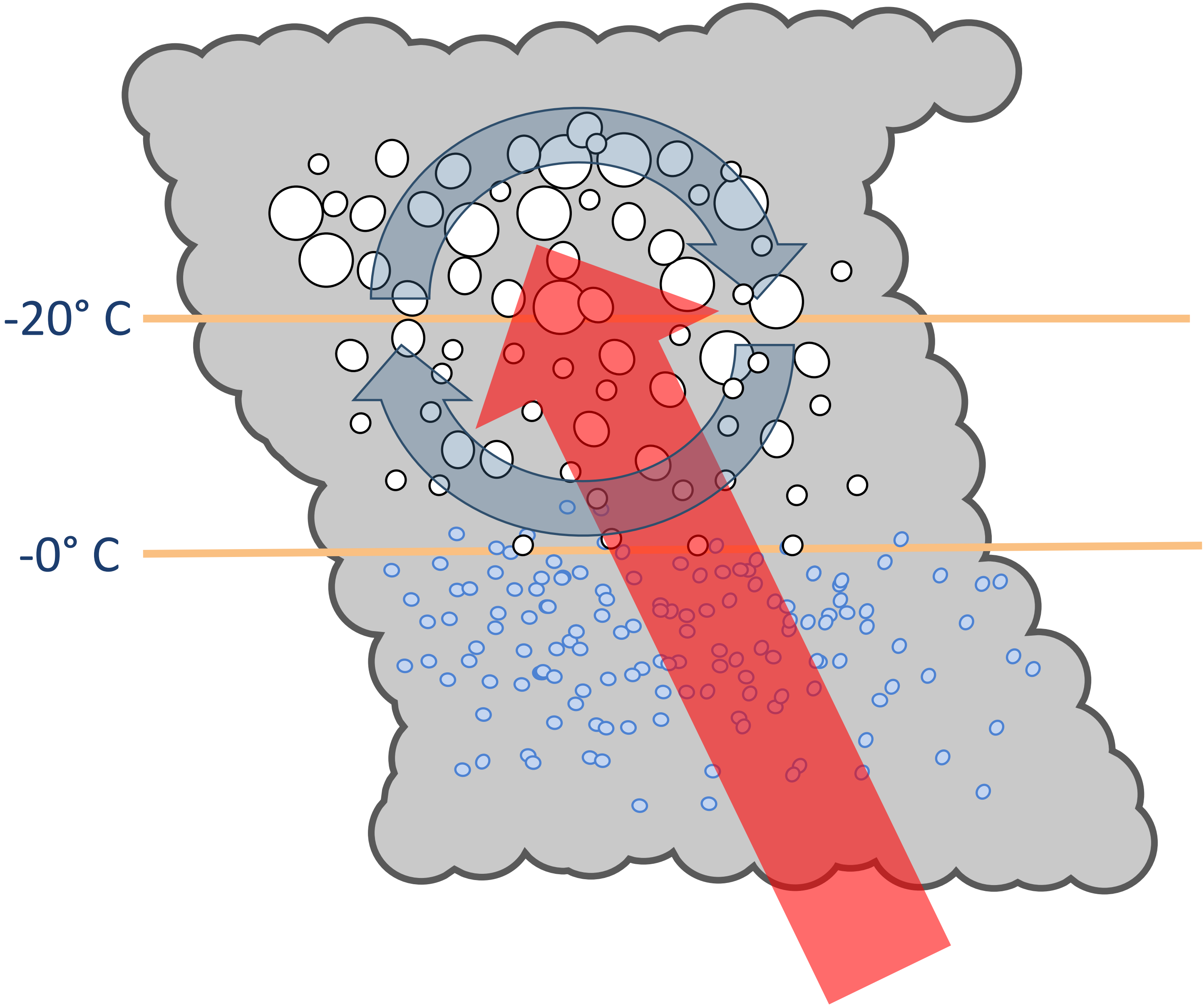
# Data Sources- Tornado and Straight-line Wind

- North American Regional Reanalysis (NARR)
  - 1979 – present
  - precipitation, wind, temp, pressure, etc.
  - 45 vertical layers
  - KCC has archives 20Tb of data
- High Resolution Rapid Refresh Model (HRRR)
  - 2018 - present
  - precipitation, wind, temp, pressure, etc.
  - Hourly update cycle
  - 10x resolution increase over NARR



# Hail Formation

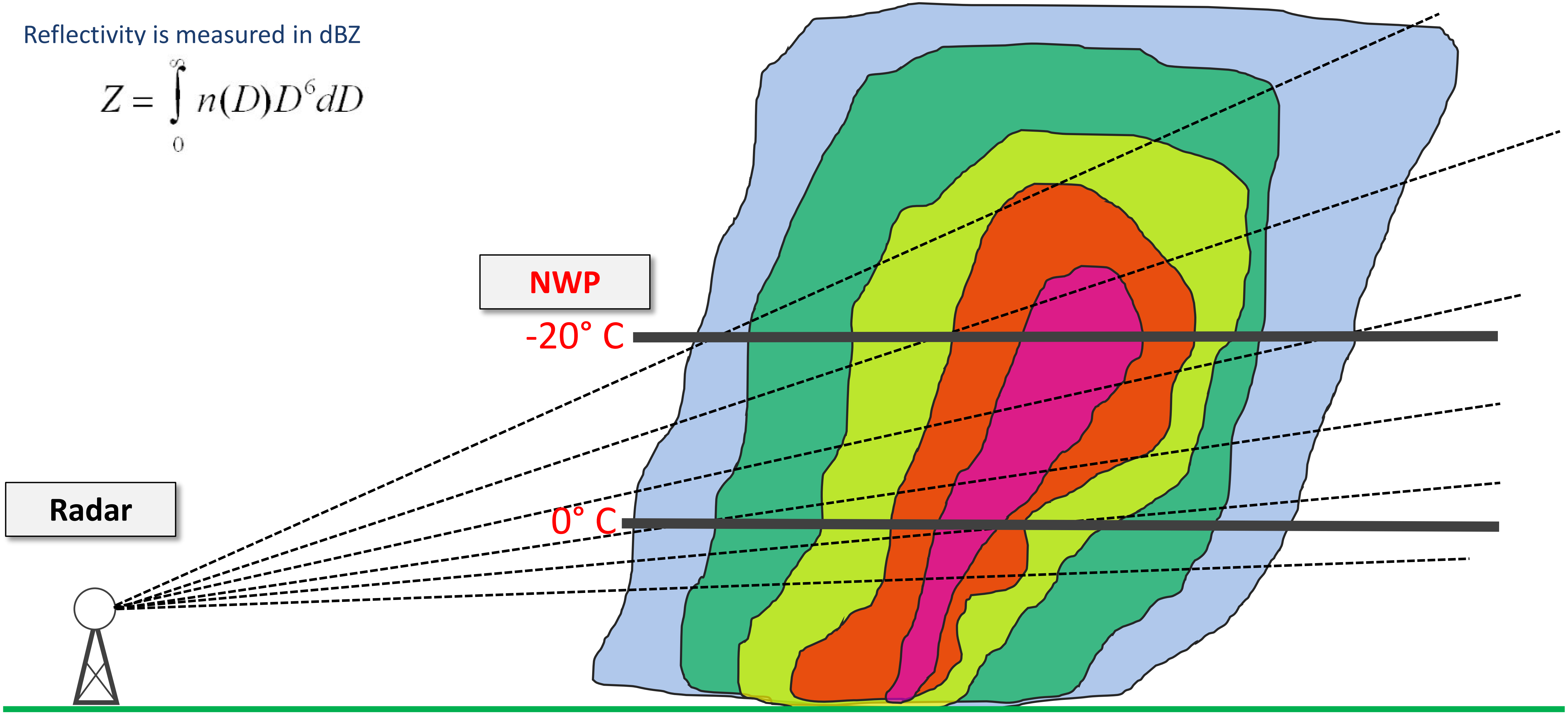
- Updrafts bring water past the freezing line
- Supercooled water droplets nucleate and freeze to form “Hail Embryos”
- Hail embryos grow until the can no longer be held aloft by the updraft
- Hail falls out, but can be caught back up into the updraft continuing to grow
- Hail finally falls to ground



# Advanced Hail Detection - MESH Combines Radar and NWP to Distinguish Hail from Heavy Rain

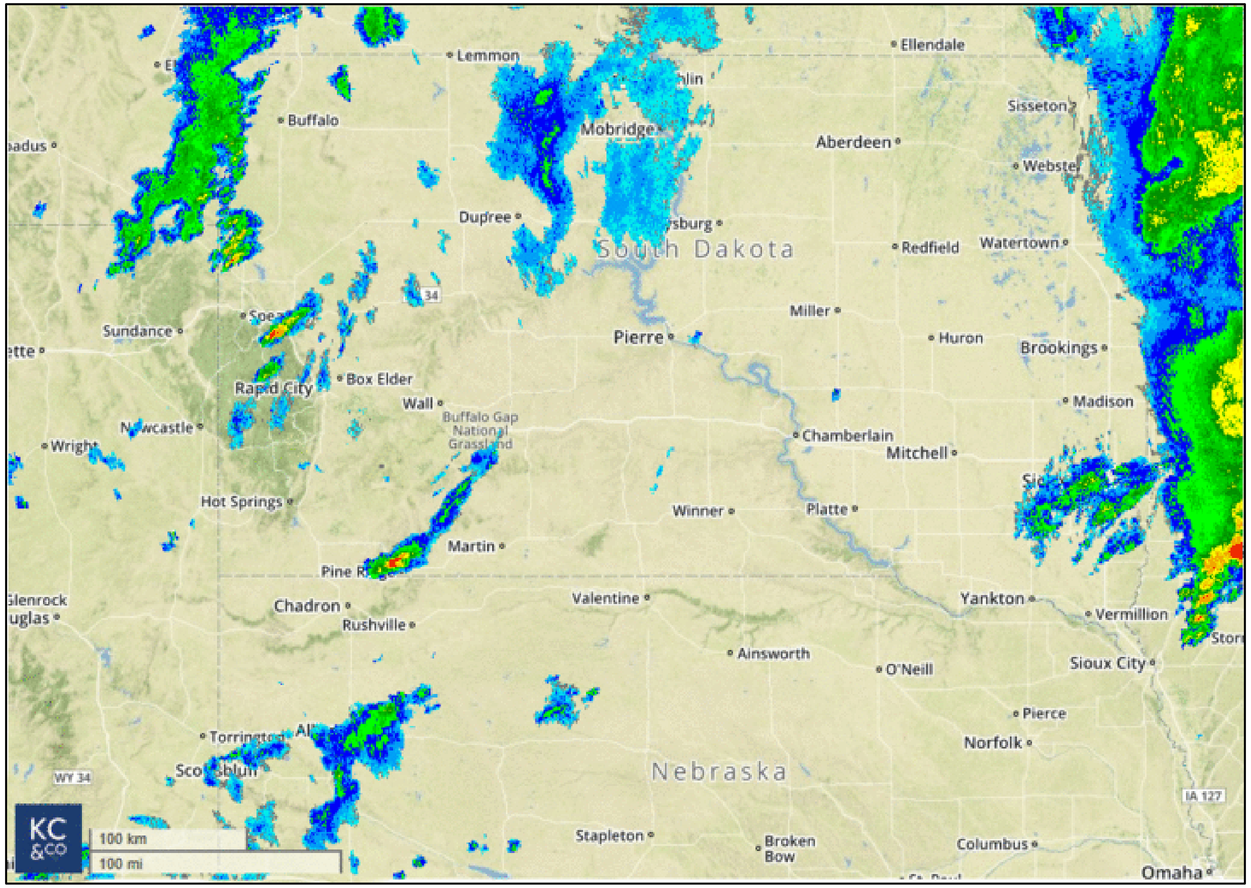
- Reflectivity is measured in dBZ

$$Z = \int_0^\infty n(D) D^6 dD$$



# Data Sources- Hail

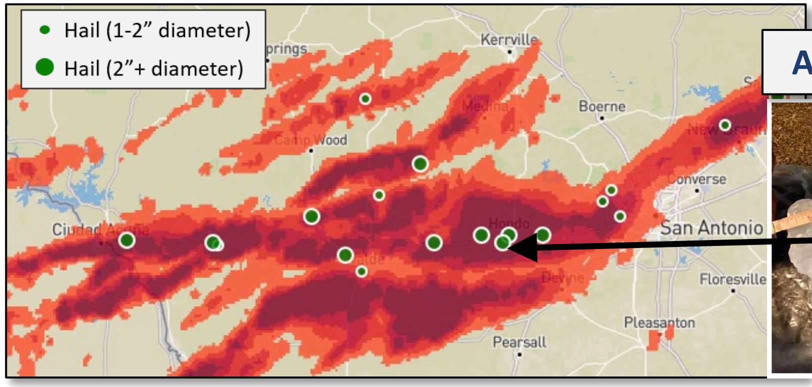
- NEXRAD Radars
  - 5-minute data archived since 1995
  - ~1 km resolution
  - Radar Reflectivity- size and concentration of particles
- Multi-Radar/Multi-Sensor System (MRMS)
  - 2018 - present
  - multiple radars, satellites, surface observations, upper air observations, numerical weather prediction (NWP), etc.
  - “Maximum Estimated Size of Hail” (MESH)



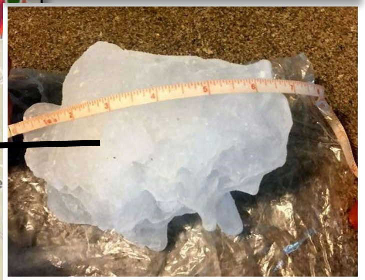
# Validation of Hail Footprints

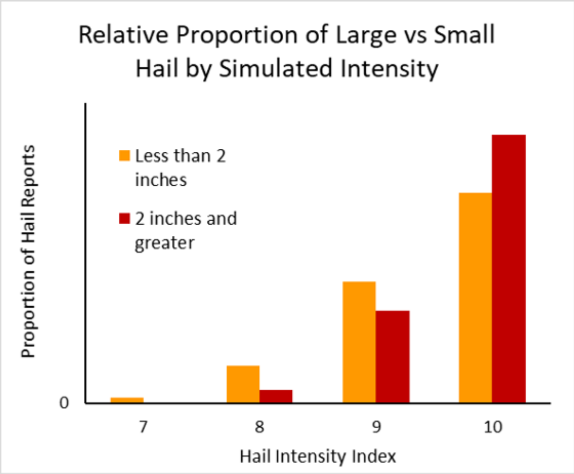
- Over 300 historical events were validated

## Hail Reports

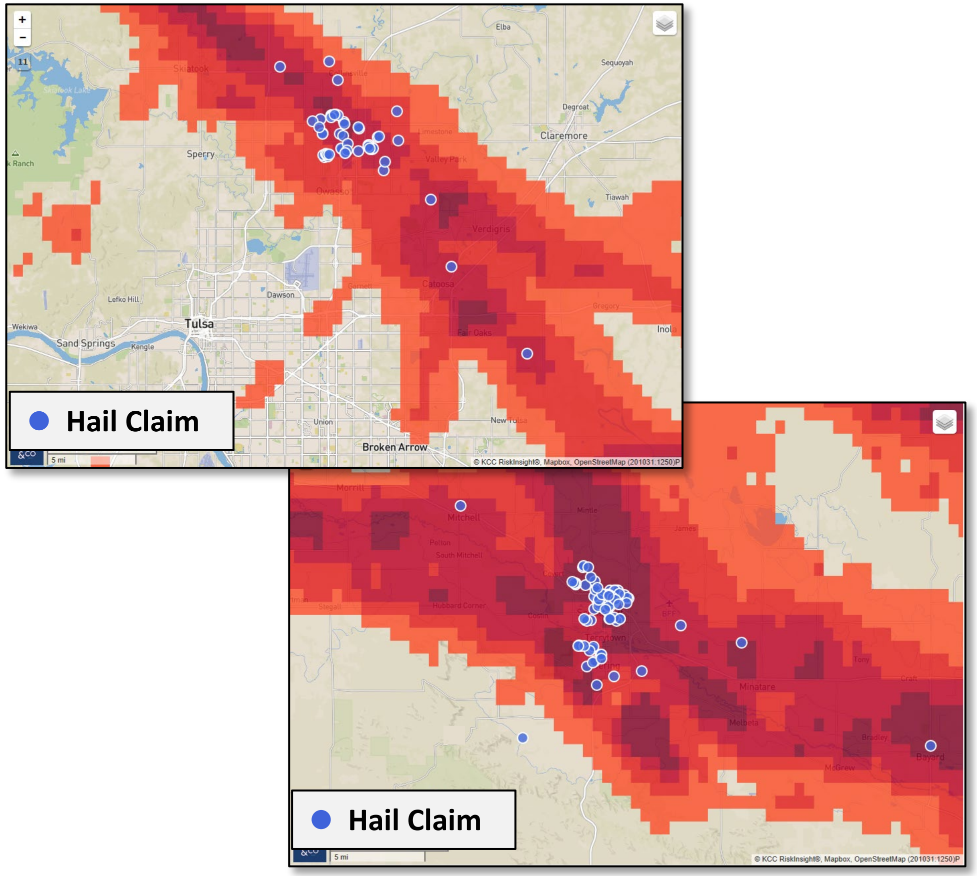



April 28, 2021: 6.4”






## Claims



# Using Numerical Weather Prediction to Generate Stochastic Events

- **Weather Research and Forecasting Model** (WRF) can be used to model hypothetical weather

- WRF simulates the **atmosphere**:
  - Wind (3 components)
  - Temperature
  - Pressure
  - Humidity

Cheyenne supercomputer at NCAR

$$\partial_t U + m_x\left[\partial_x(Uu) + \partial_y(Vu)\right] + \partial_\eta(\Omega u) + (m_x/m_y)(\alpha/\alpha_d)\left[\mu_d(\partial_x\phi' + \alpha_d\partial_x p' + \alpha'_d\partial_x\bar{p}) + \partial_x\phi(\partial_\eta p' - \mu'_d)\right] = F_U$$

$$\partial_t V + m_y[\partial_x(Uv) + \partial_y(Vv)] + (m_y/m_x)\partial_\eta(\Omega v) + (m_x/m_y)(\alpha/\alpha_d)\left[\mu_d(\partial_x\phi' + \alpha_d\partial_x p' + \alpha'_d\partial_x\bar{p}) + \partial_x\phi(\partial_\eta p' - \mu'_d)\right] = F_U$$

$$\partial_t W + (m_x m_y/m_y)[\partial_x(Uw) + \partial_y(Vw)] + \partial_\eta(\Omega w) - m_y^{-1}g(\alpha/\alpha_d)[\partial_\eta p' - \bar{\mu}_d(q_v + q_c + q_r)] + m_y^{-1}\mu'_d g = F_W$$

$$\partial_t\mu'_d + m_x m_y[\partial_x U + \partial_y V] + m_y\partial_\eta\Omega = 0$$

$$\partial_t\phi' + \mu_d^{-1}[m_x m_y(U\partial_x\phi + V\partial_y\phi) + m_y\Omega\partial_\eta\phi - m_y g W] = 0.$$

$$\partial_t\Theta + m_x m_y[\partial_x(U\theta) + \partial_y(V\theta)] + m_y\partial_\eta(\Omega\theta) = F_\Theta$$

$$\partial_t Q_m + m_x m_y[\partial_x(Uq_m) + \partial_y(Vq_m)] + m_y\partial_\eta(\Omega q_m) = F_{Q_m}.$$

$$F_{U_{cor}} = \frac{m_x}{m_y}\left[fV + \frac{uV}{r_e}\tan\psi\right] - \frac{uW}{r_e} - eW\cos\alpha_r$$

$$F_{V_{cor}} = \frac{m_y}{m_x}\left[-fU - \frac{uU}{r_e}\tan\psi - \frac{vW}{r_e} + eW\sin\alpha_r\right]$$

$$F_{W_{cor}} = +e(U\cos\alpha_r - (m_x/m_y)V\sin\alpha_r) + \left(\frac{uU + (m_x/m_y)vV}{r_e}\right)$$

$$R^{t^*}_{U_{adv}} = -\,m_x[\partial_x(Uu) + \partial_y(Vu)] + \partial_\eta(\Omega u)$$

$$R^{t^*}_{V_{adv}} = -\,m_y[\partial_x(Uv) + \partial_y(Vv)] + (m_x/m_y)\partial_\eta(\Omega v)$$

$$R^{t^*}_{\mu_{adv}} = -\,m_x m_y[\partial_x U + \partial_y V] + m_y\partial_\eta\Omega$$

$$R^{t^*}_{\Theta_{adv}} = -\,m_x m_y[\partial_x(U\theta) + \partial_y(V\theta)] - m_y\partial_\eta(\Omega\theta)$$

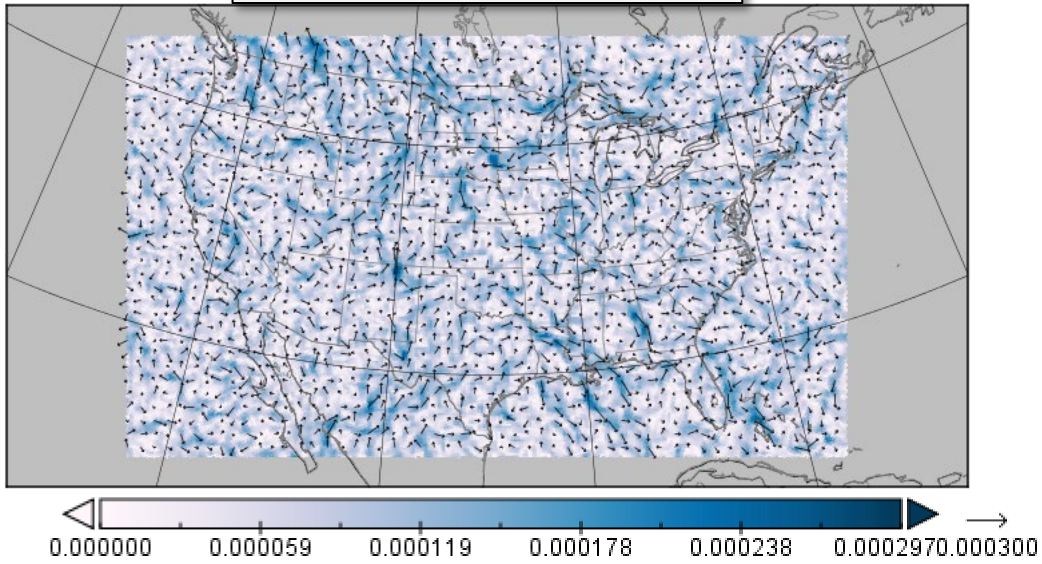
$$R^{t^*}_{W_{adv}} = -\,(m_x m_y/m_y)[\partial_x(Uw) + \partial_y(Vw)] + \partial_\eta(\Omega w)$$

$$R^{t^*}_{\phi_{adv}} = -\,\mu_d^{-1}[m_x m_y(U\partial_x\phi + V\partial_y\phi) + m_y\Omega\partial_\eta\phi].$$

# Generate Event Variations with SKEBS

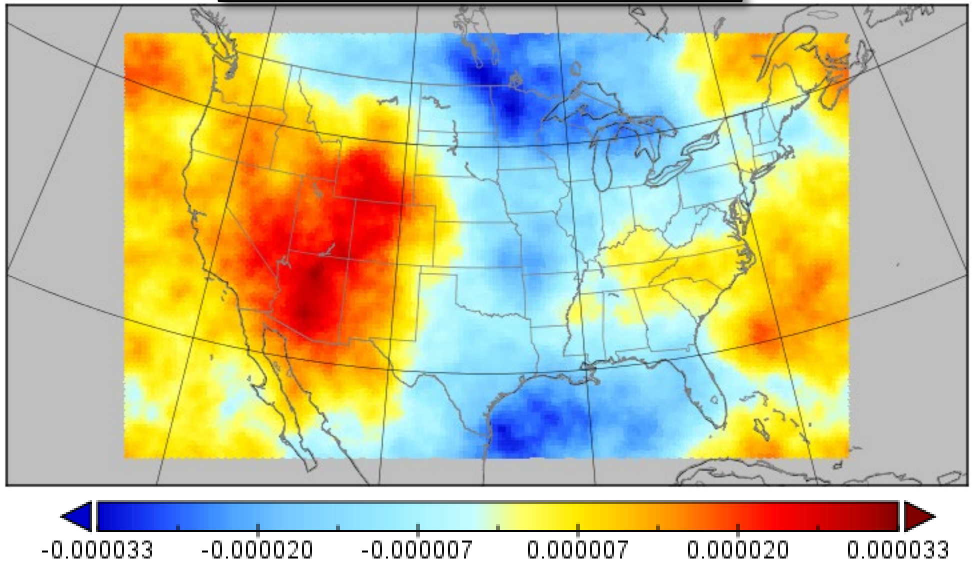
- **Stochastic Kinetic Energy Backscatter Scheme (SKEBS):** Apply random perturbations in a physically realistic way
  - Unresolved energy at fine-scale would ‘backscatter’ into the simulation
  - Recapture fine-scale energy
  - Generate event variations

**Wind Speed Perturbations**



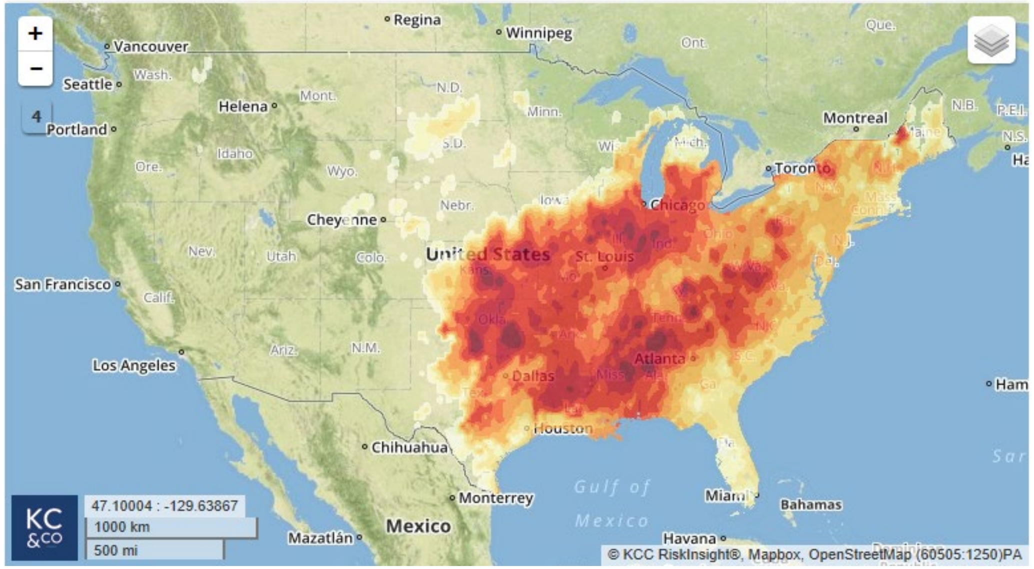

$m/s^2$

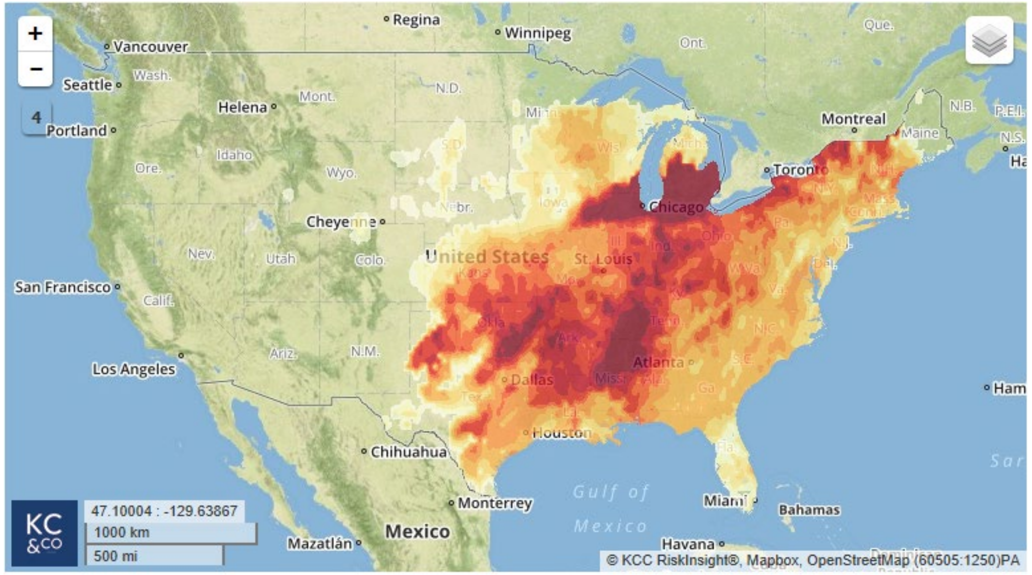
**Temperature Perturbations**

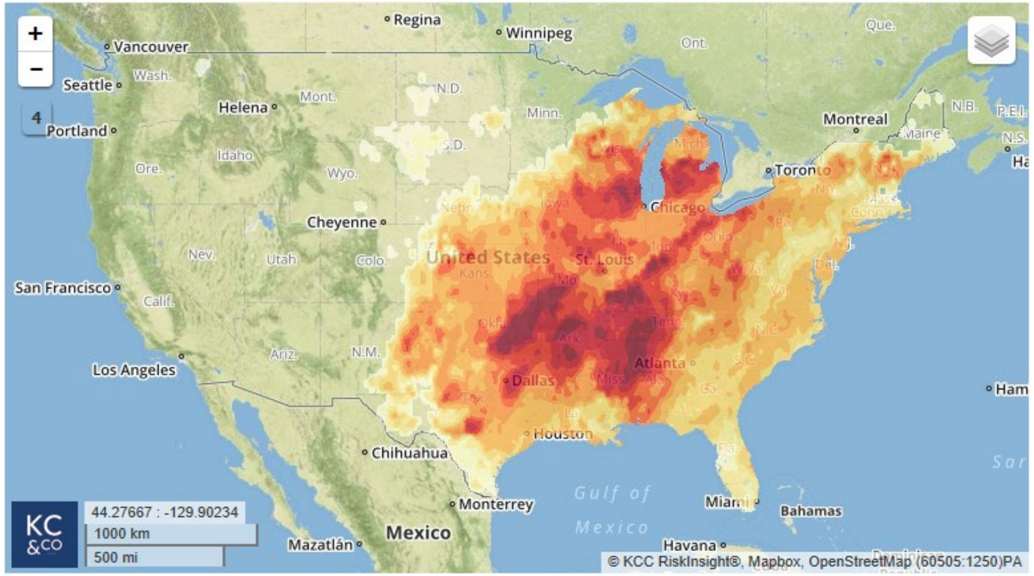


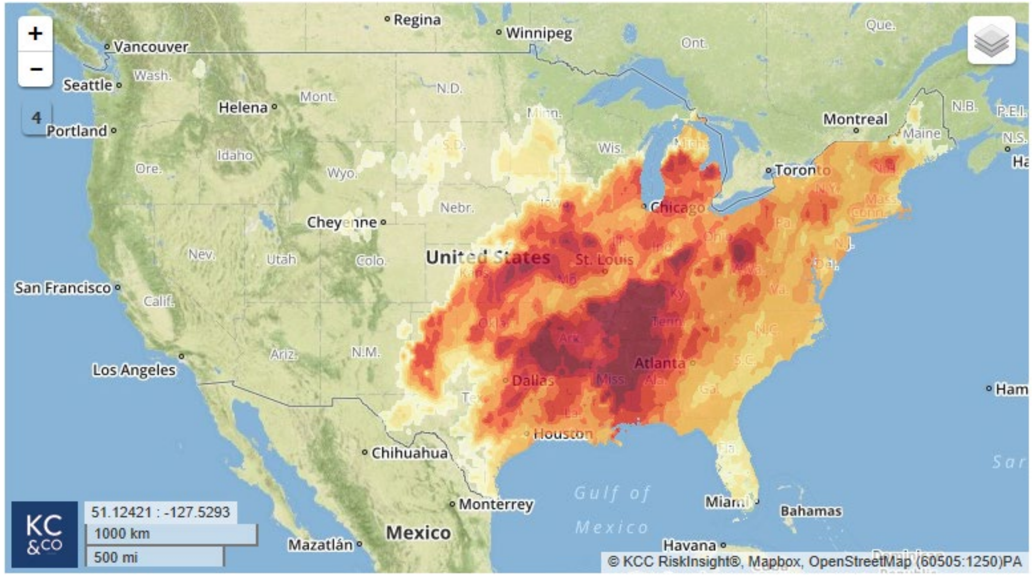

C°/s

# Create New Stochastic Tornado/Wind Footprints



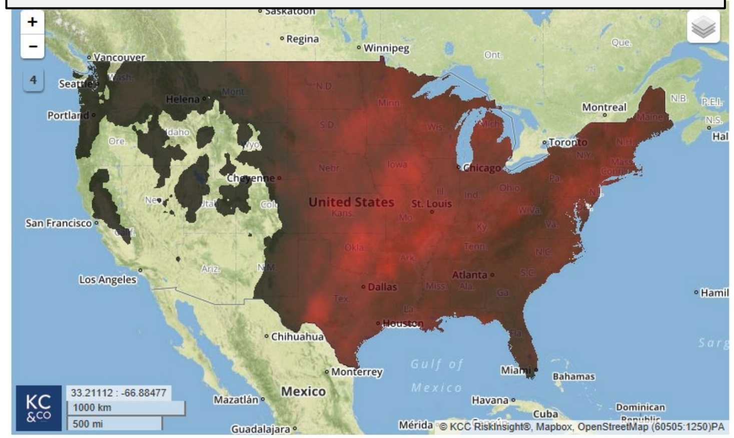



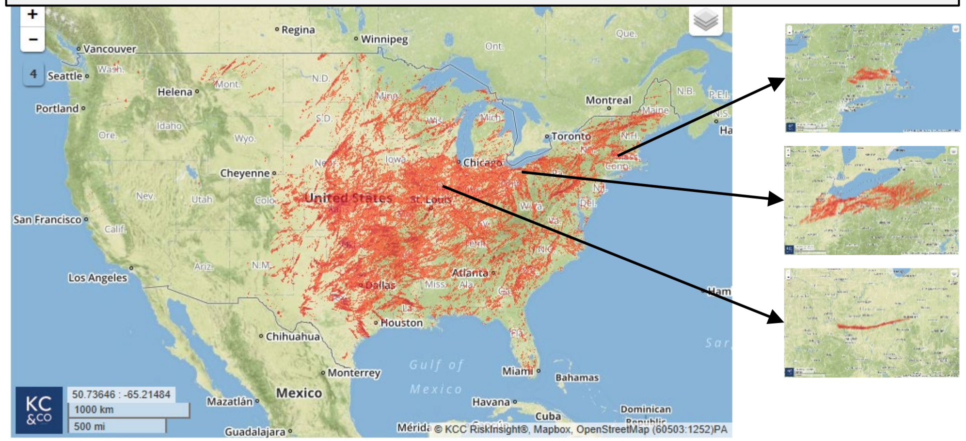
# Create New Stochastic Hail Footprints

## 1) Calculate Historical SHIP

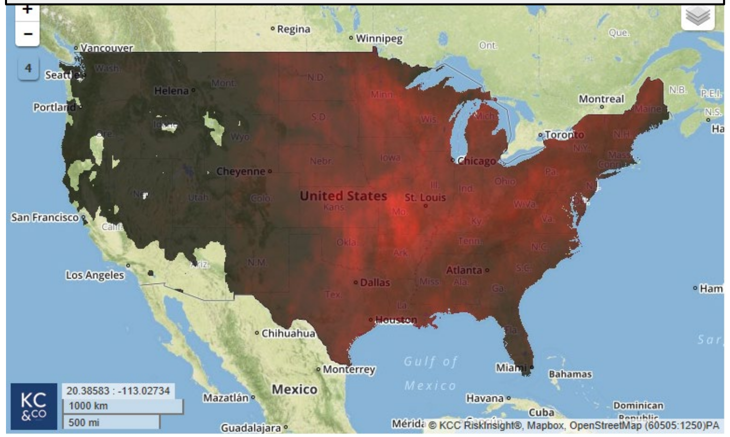



## 3) Analyze correlation

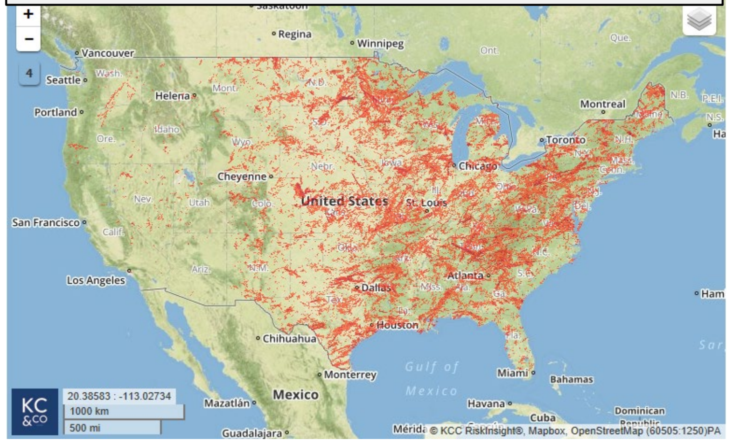
## 2) Identify Historical Hail Swaths



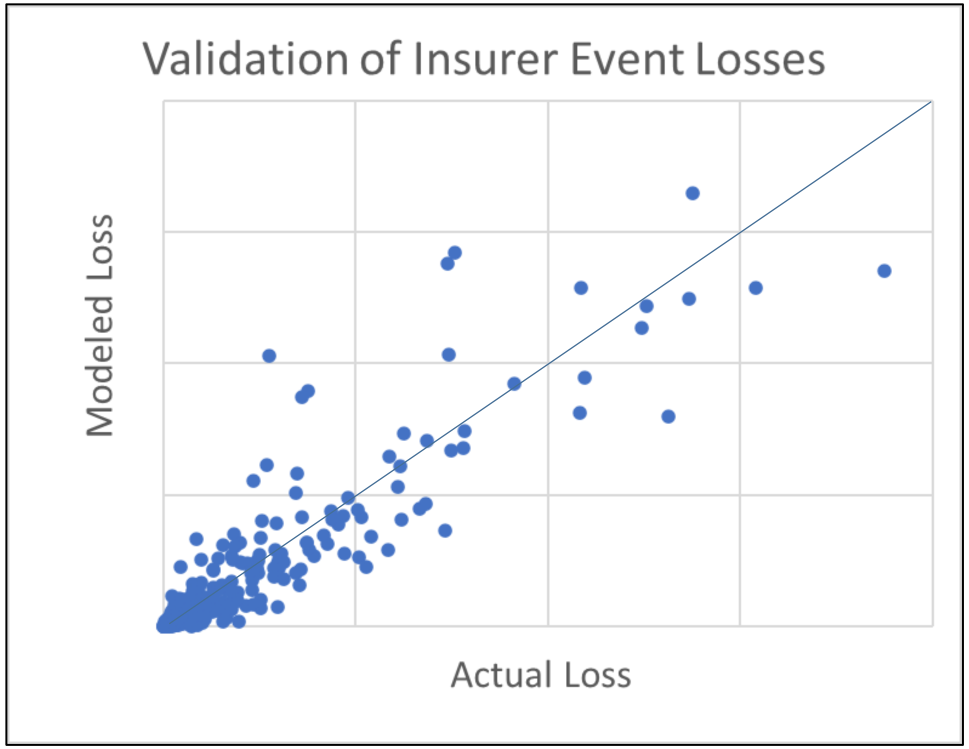

## 4) Calculate SHIP from WRF

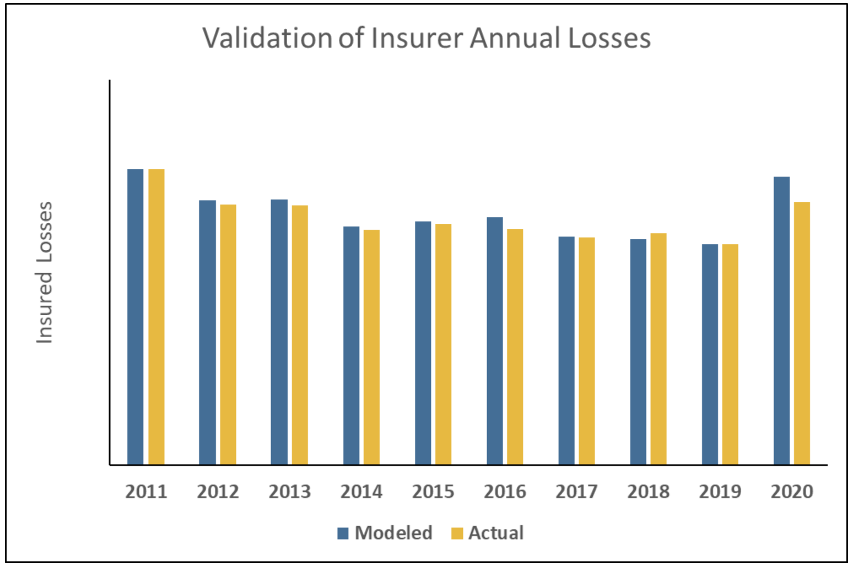


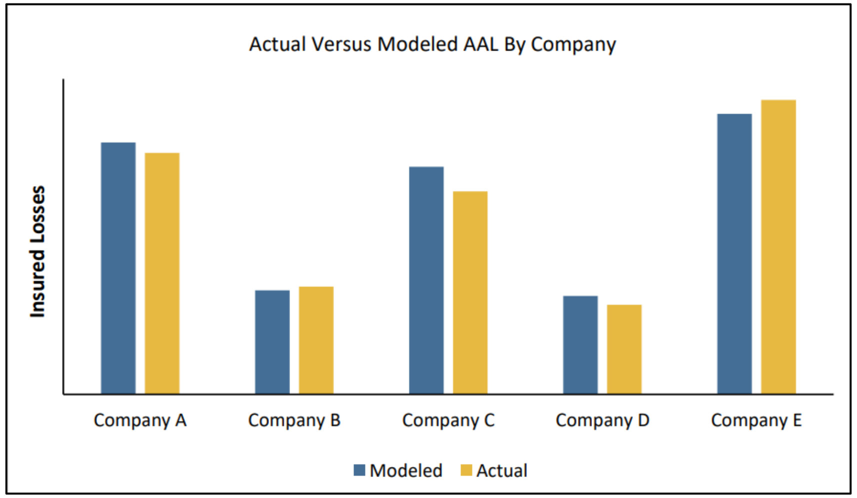

## 5) Place Swaths Based on SHIP



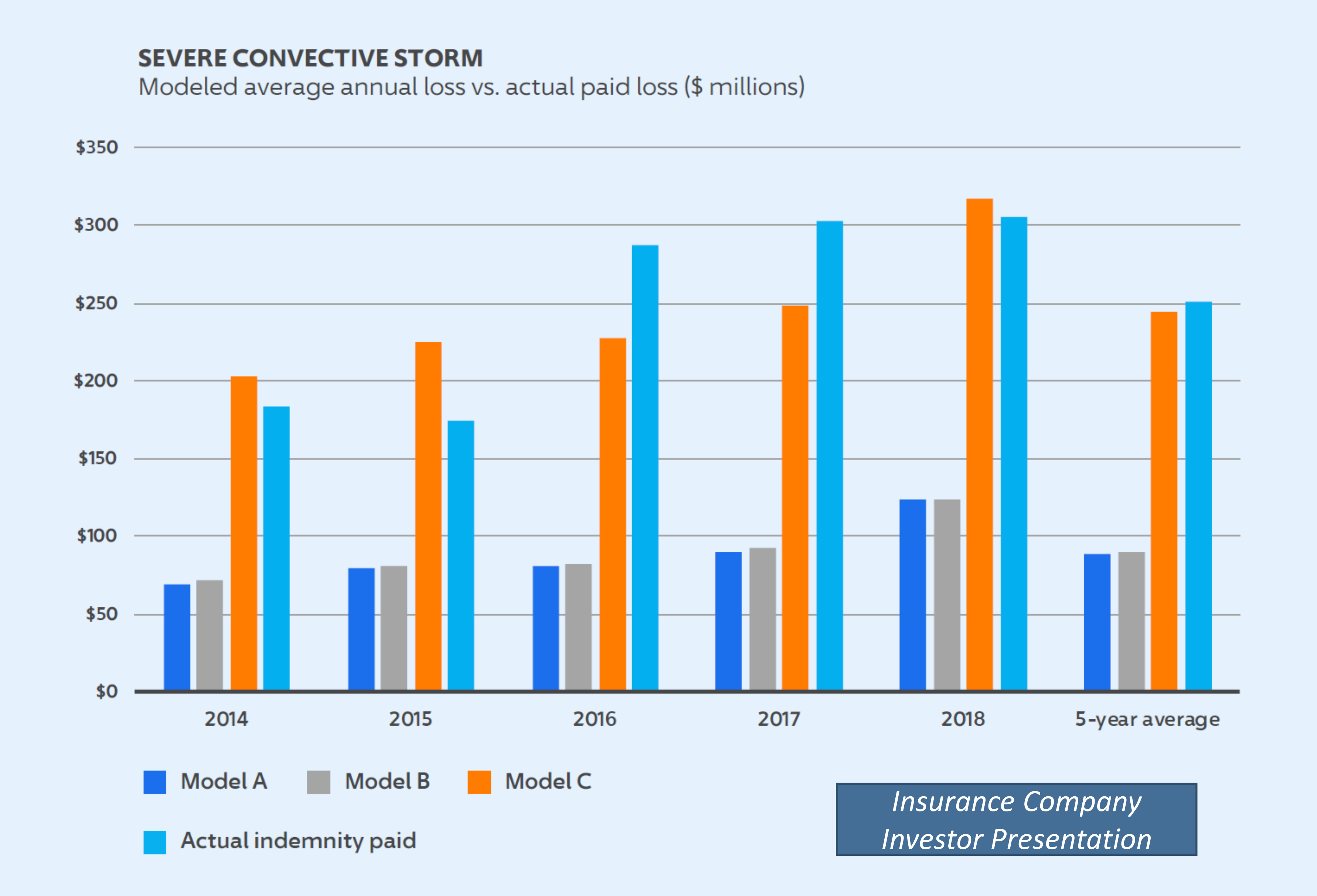
# Validate Models with $ Billions of High-Resolution and Verified Insurer Claims Data



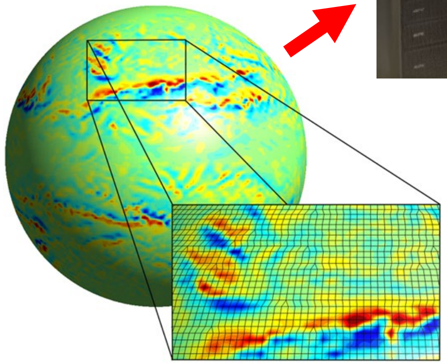



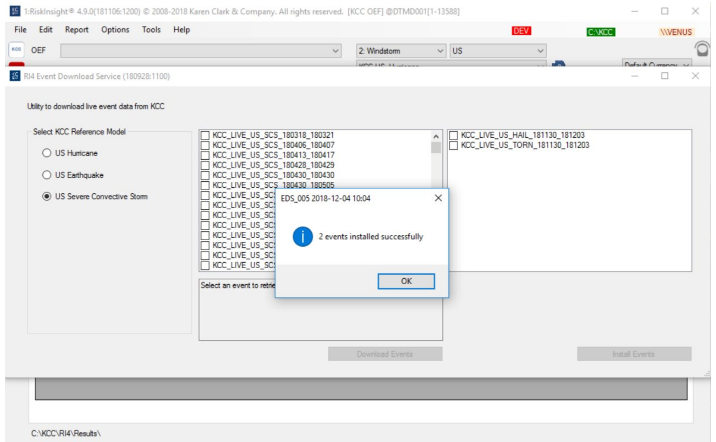
# How Insurers Can Independently Verify the Accuracy of the Model

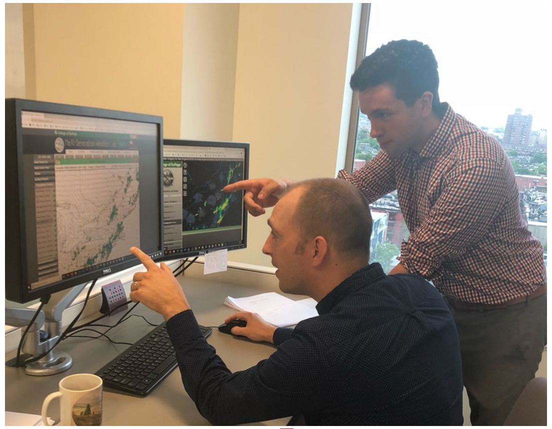


# KCC SCS Daily Live Events Process Continuously Captures SCS Activity

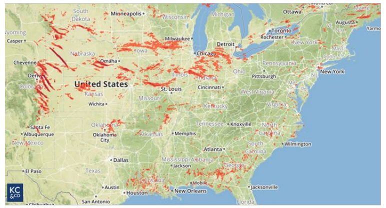
- KCC automatically downloads and archives **~30 GB** of data per day to support SCS Live Events

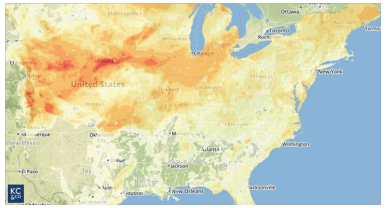


Hail Intensity Footprint



Tornado/Wind Intensity Footprint



Hail and Tornado/Wind Claims and Losses by State and ZIP

| State | LOSS Gross | Pct of Total TIV | Pct of Total LOSS | Claims | Avg Claim |
|---|---|---|---|---|---|
| US:CO | 319,134,000 | 4.19 | 64.11 | 52,185 | 6,100 |
| US:IN | 21,548,000 | 8.77 | 4.33 | 3,057 | 7,000 |
| US:NE | 18,687,000 | 0.84 | 3.75 | 2,853 | 6,600 |
| US:OK | 11,504,000 | 4.94 | 2.31 | 2,544 | 4,500 |
| US:OH | 11,763,000 | 6.62 | 2.36 | 1,551 | 7,600 |

| State | LOSS Gross | Pct of Total TIV | Pct of Total LOSS | Claims | Avg Claim |
|---|---|---|---|---|---|
| US:CO | 29,190,000 | 2.56 | 8.41 | 5,376 | 5,400 |
| US:IN | 35,625,000 | 3.85 | 10.27 | 5,092 | 7,000 |
| US:IL | 52,951,000 | 8.62 | 15.26 | 4,912 | 10,800 |
| US:MI | 35,886,000 | 5.94 | 10.34 | 4,750 | 7,600 |
| US:OK | 12,301,000 | 1.54 | 3.55 | 2,394 | 5,100 |

| ZIP | LOSS Gross | Pct of Total TIV | Pct of Total LOSS | Claims | Avg Claim |
|---|---|---|---|---|---|
| US:CO:80138 | 133,111,000 | 0.14 | 26.74 | 8,917 | 14,900 |
| US:CO:80911 | 33,190,000 | 0.12 | 6.67 | 8,214 | 4,000 |
| US:CO:80910 | 20,687,000 | 0.15 | 4.16 | 6,792 | 3,000 |
| US:CO:80904 | 6,540,000 | 0.1 | 1.31 | 3,879 | 1,700 |
| US:CO:80905 | 9,843,000 | 0.06 | 1.98 | 3,848 | 2,600 |

| ZIP | LOSS Gross | Pct of Total TIV | Pct of Total LOSS | Claims | Avg Claim |
|---|---|---|---|---|---|
| US:IA:51501 | 1,192,000 | 0.02 | 0.34 | 458 | 2,600 |
| US:IA:51503 | 924,000 | 0.02 | 0.27 | 447 | 2,100 |
| US:IA:52501 | 1,022,000 | 0.01 | 0.29 | 411 | 2,500 |
| US:WY:82007 | 897,000 | 0.01 | 0.26 | 381 | 2,400 |
| US:NE:68046 | 764,000 | 0.01 | 0.22 | 357 | 2,100 |

Confidential KCC SCS Activity Report

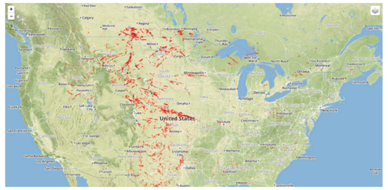
Event Start: 6 July 2019 Event End: 14 July 2019

**Accumulated Industry Loss: $ 791,010,000**

Daily Summary

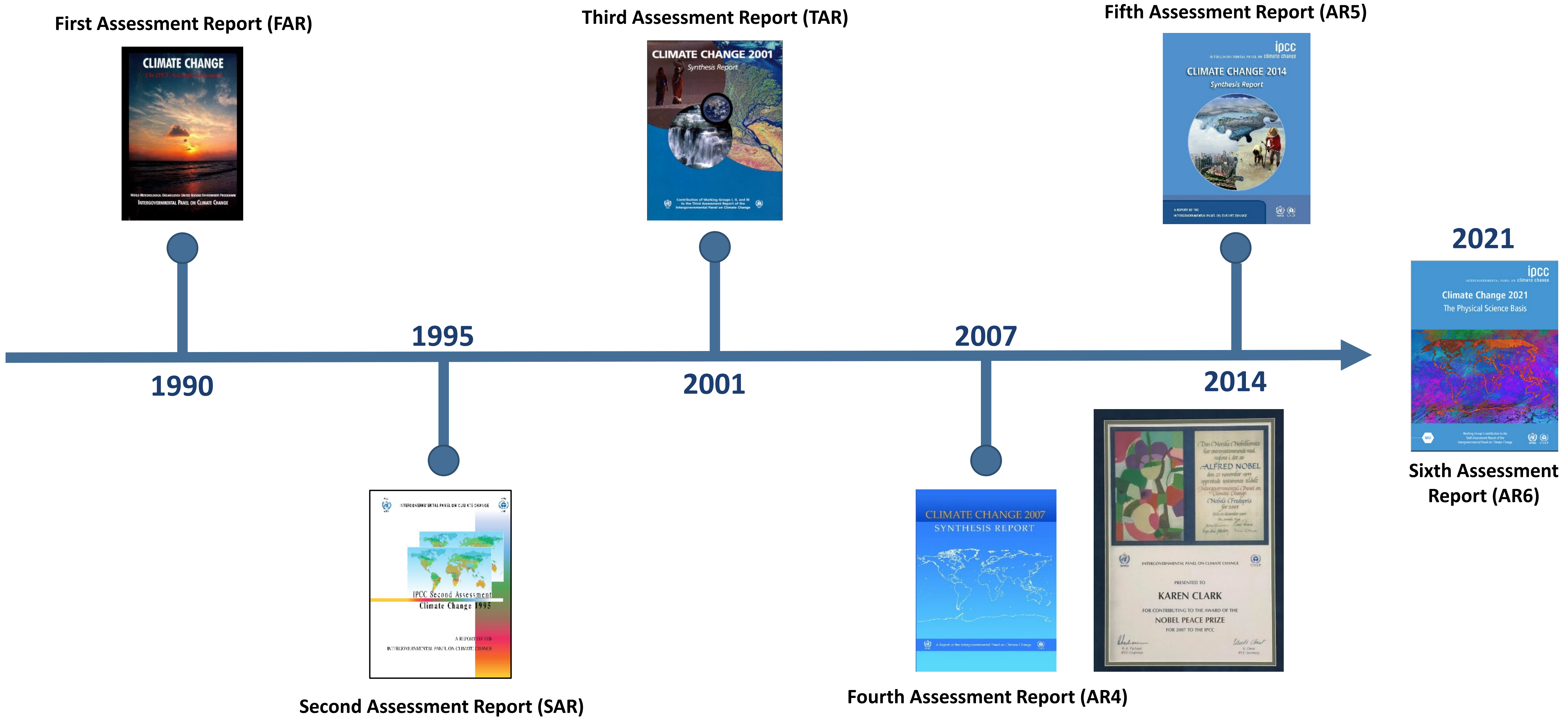
Most of the weekend severe storm activity occurred in Montana and the Dakotas where golf-ball size hail fell and several wind gusts over 85mph were reported. Multiple damaging wind gusts also occurred just south of Minneapolis/St. Paul. In addition, a line of storms formed over central Illinois on Sunday evening where a wind gust over 75mph was reported. The threat of severe storms continues today for the Northern Plains states of Montana, Wyoming, North and South Dakota and Minnesota, with impacts also possible further south in the Mississippi River Valley as the remnants of tropical cyclone Barry move through the region.

Modeled Hail Footprint with Reports



# Climate Change is Shifting the Geography of Loss Potential

# The Intergovernmental Panel on Climate Change (IPCC) Assessment Reports (AR)

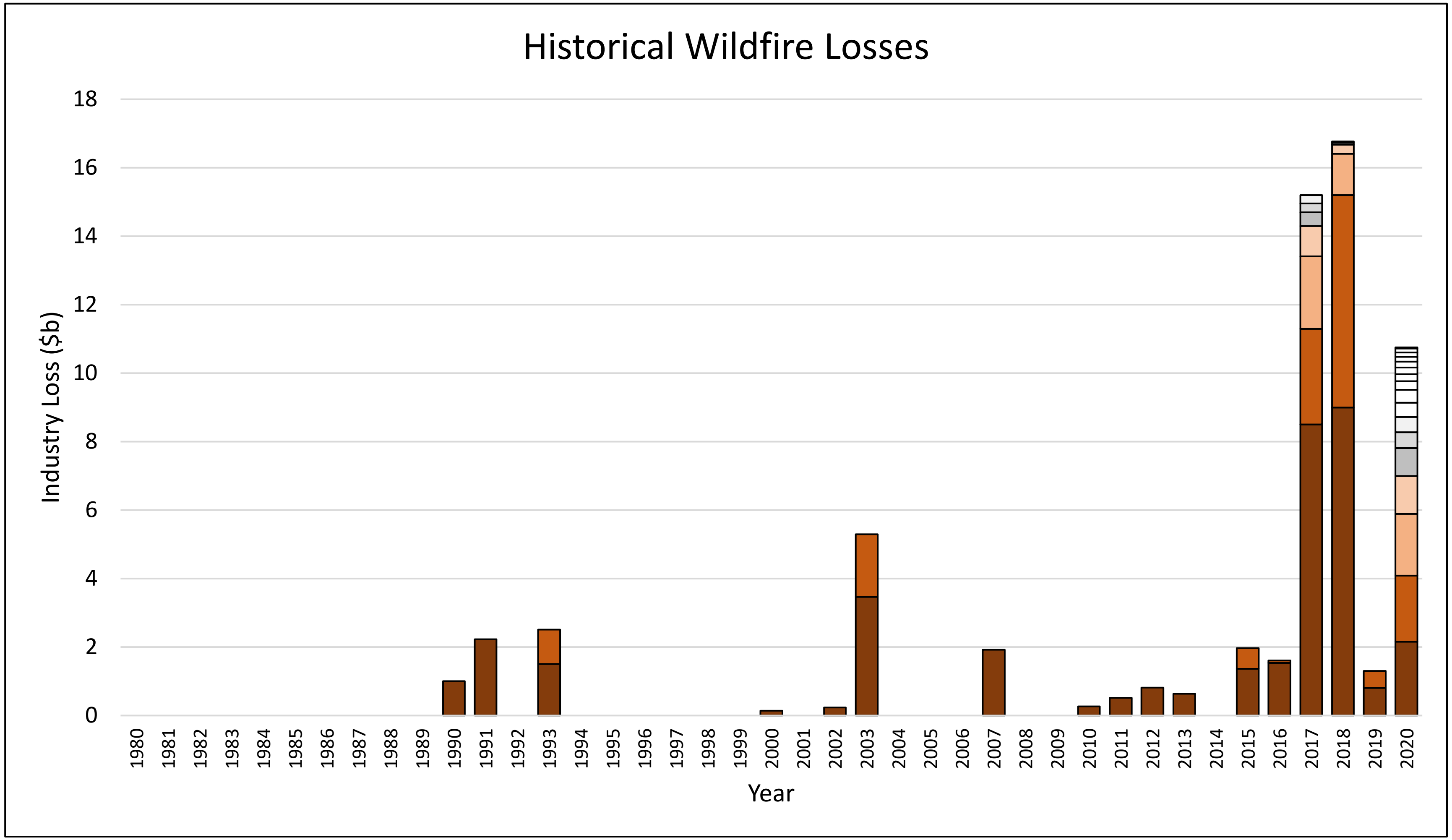


# The AR6 Consensus on How Atmospheric Perils Will Change in the Future

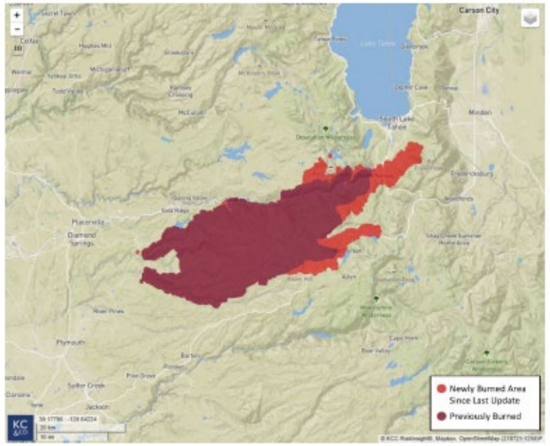
| | Frequency | Severity | Confidence |
|---|---|---|---|
| **Hurricanes** | No change | Increase | High |
| **Coastal Flooding** | Increase | Increase | High |
| **Wildfires*** | Increase | Increase | High |
| **Inland Flooding*** | Increase | Increase | Medium |
| **Winter Storms** | Uncertain | Increase | Medium |
| **Severe Convective Storms** | Uncertain | Uncertain | Low |

*Impacts of climate change on these hazards is highly region-dependent

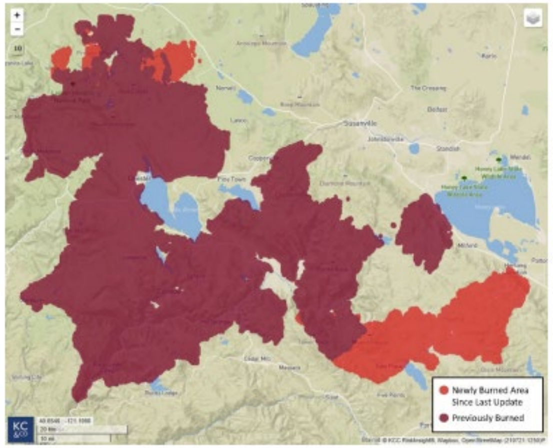
# Recent Historical Losses: Long Term Trend or Abberation?




KCC Fire Footprint – Caldor Fire

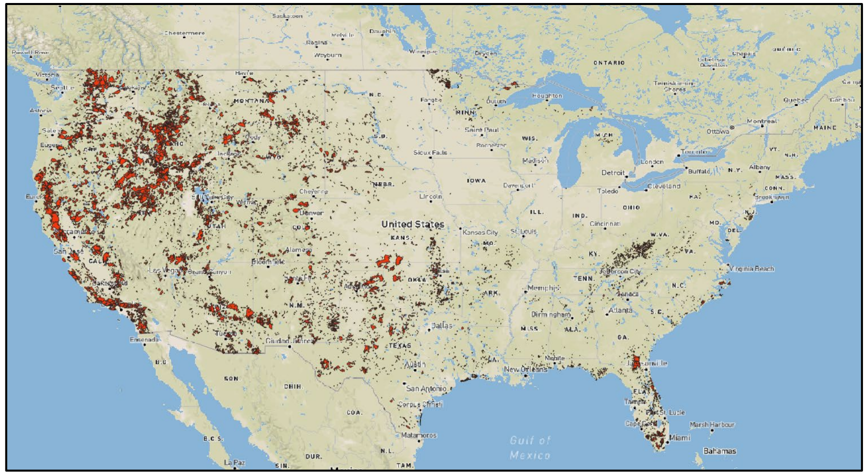


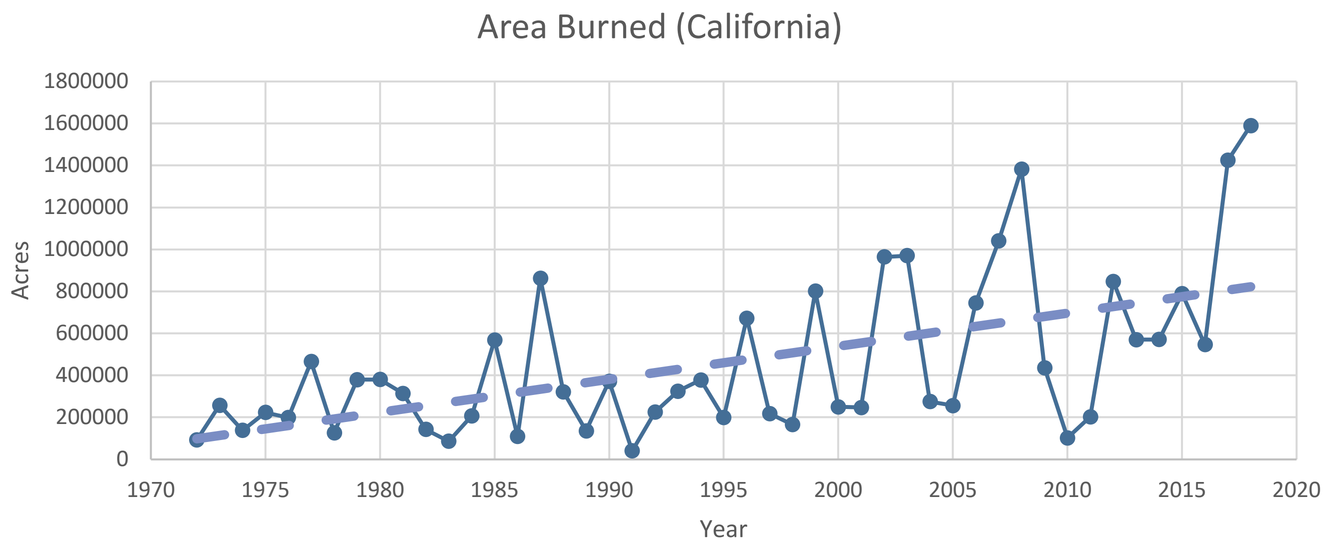

KCC Fire Footprint – Dixie Fire

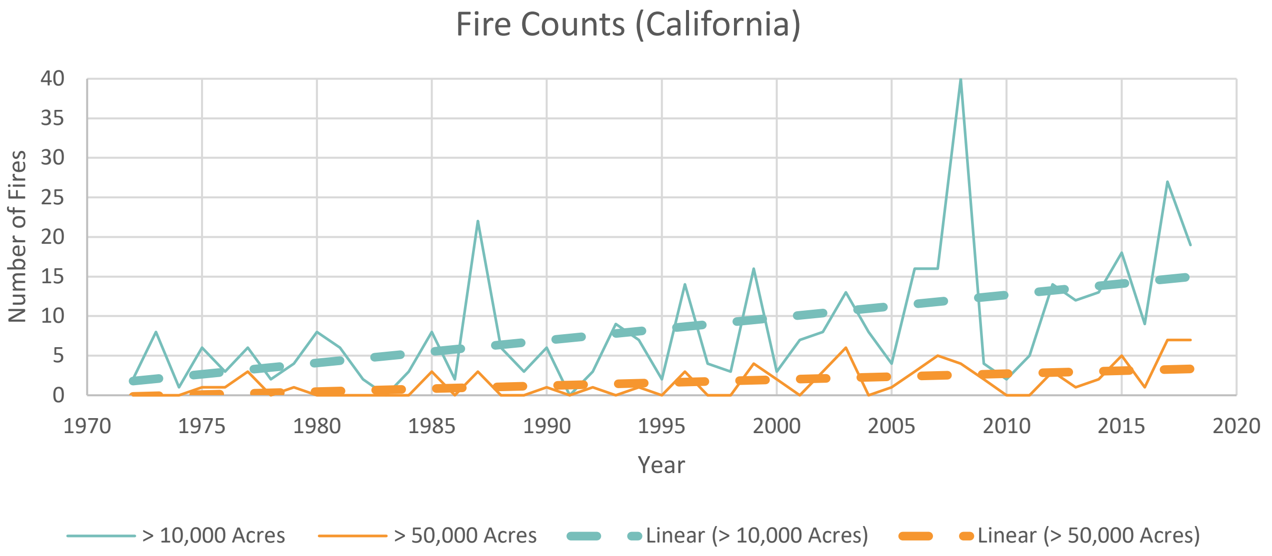


# Both the Area Burned and the Fire Frequency Have Increased since 1980

- In California the annual area burned has increased by 300% since 1980
- In 1980 it was typical to have 5 fires larger than 10,000 acres in a year – now the norm is 15 such fires per year

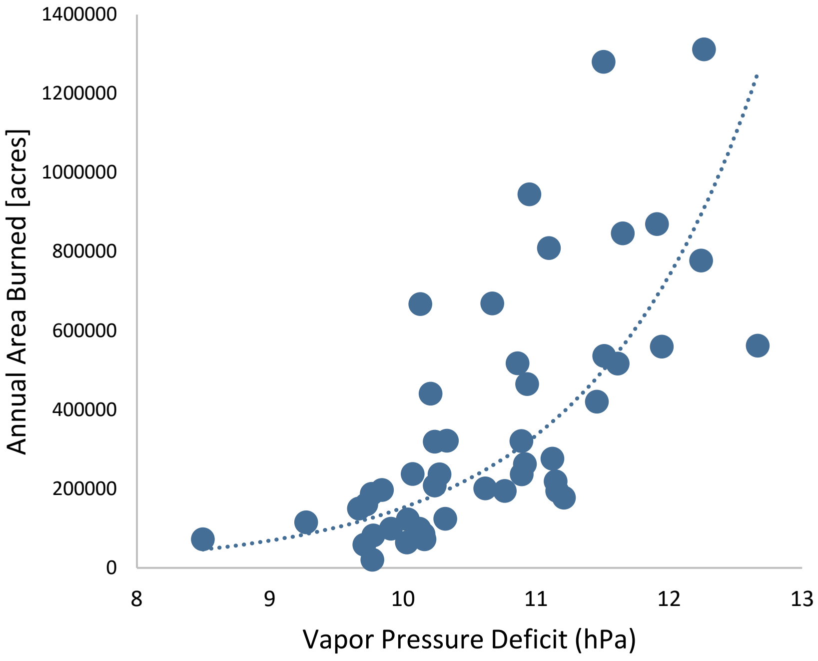




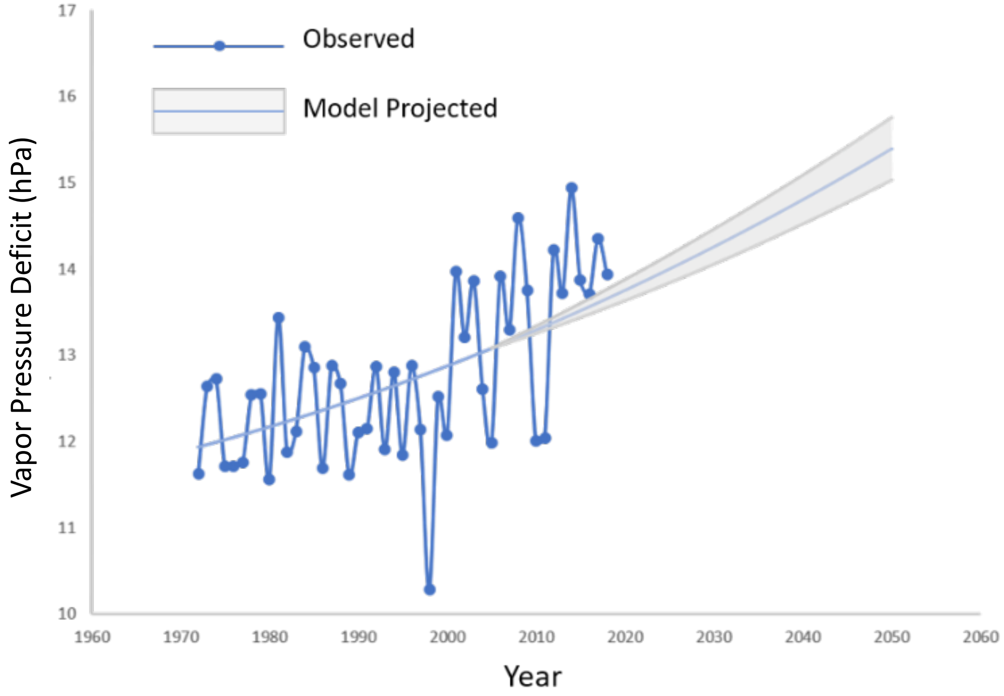



# Increases in Vapor Pressure Deficit Connected to More Wildfires

## Response of Fires to VPD Changes (Western US)



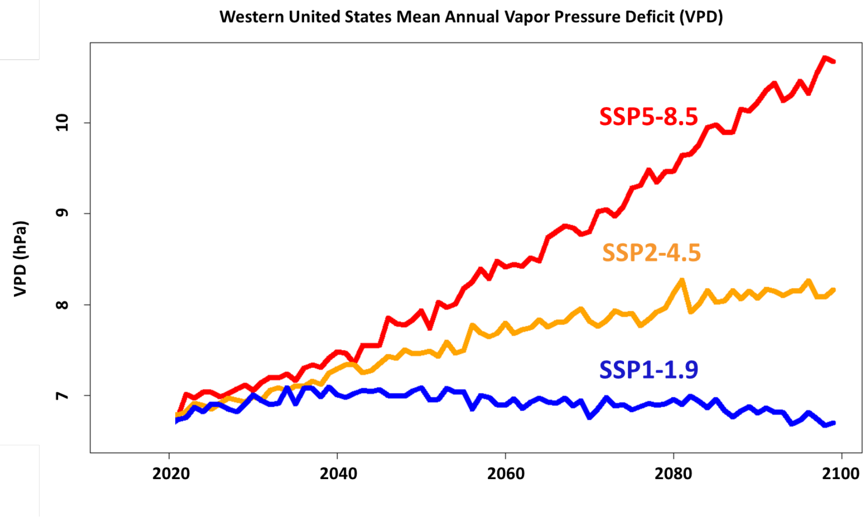

## Projected Increase in VPD (Western US)



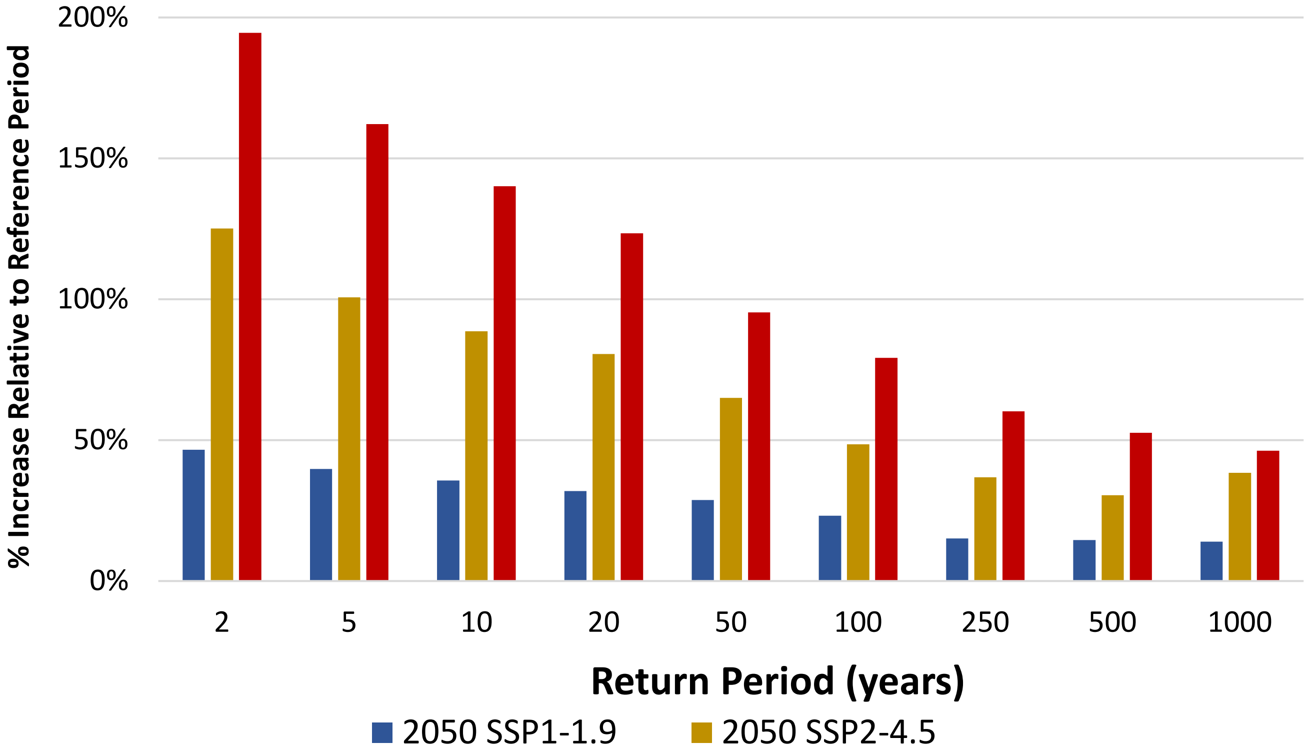

**Vapor Pressure Deficit (VPD):** Capacity of an airmass to hold moisture beyond what is available in the atmospheric environment

*Increases directly with warming air temperature*

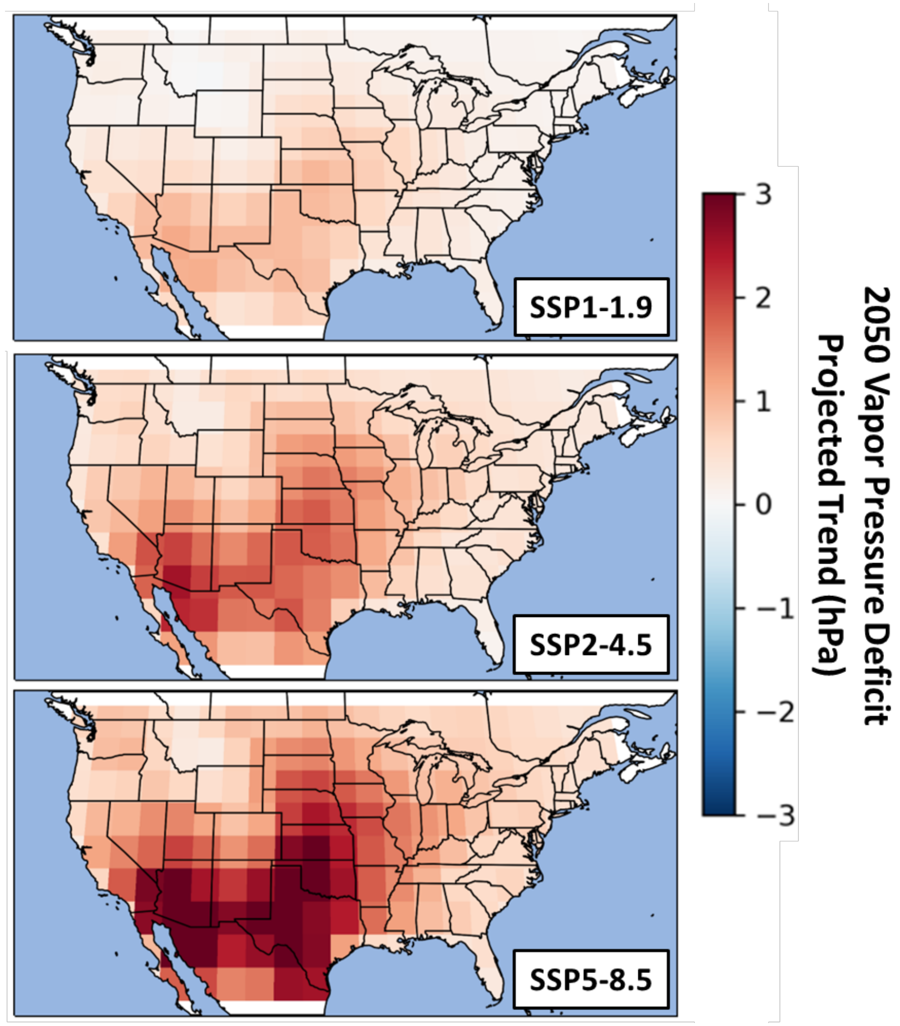
# Vapor Pressure Deficit Projected to Increase with Future Warming in Middle-to-High Emissions Scenarios



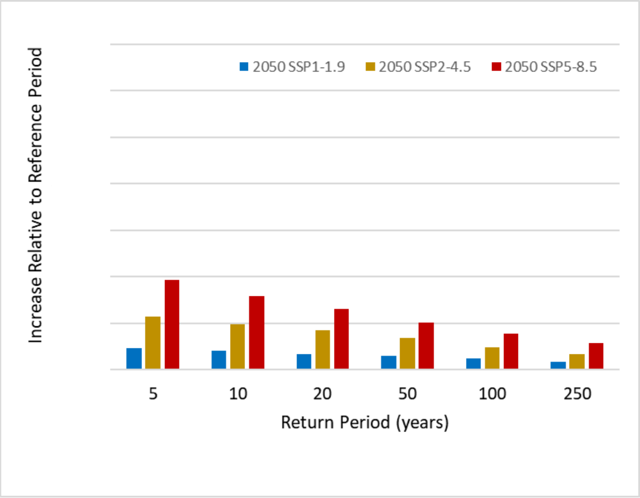

| | VPD Change Relative to 2020 (%) | | |
|---|---|---|---|
| | 2025 | 2030 | 2050 |
| SSP1-1.9 | 3.2 | 4.5 | 5.2 |
| SSP2-4.5 | | | 11.8 |
| SSP5-8.5 | | | 17.5 |



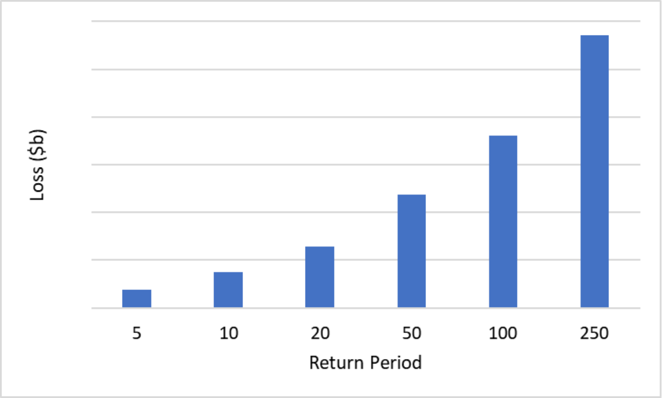
# Geographic Variability in VPD Trend and Increase in Wildfires



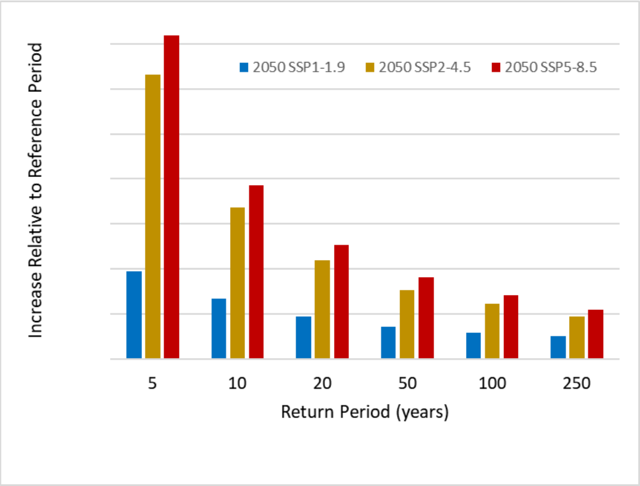

## California



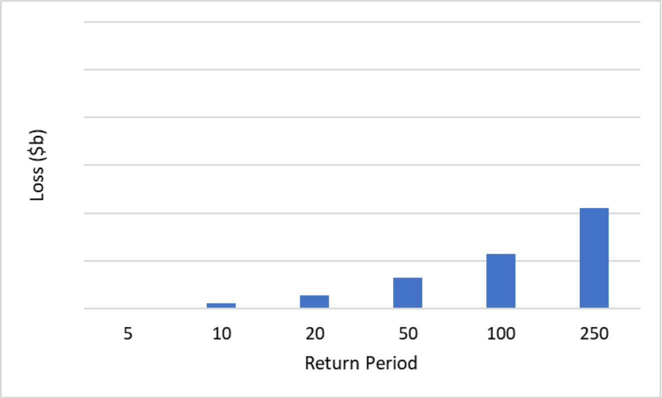

## California Wildfire EP



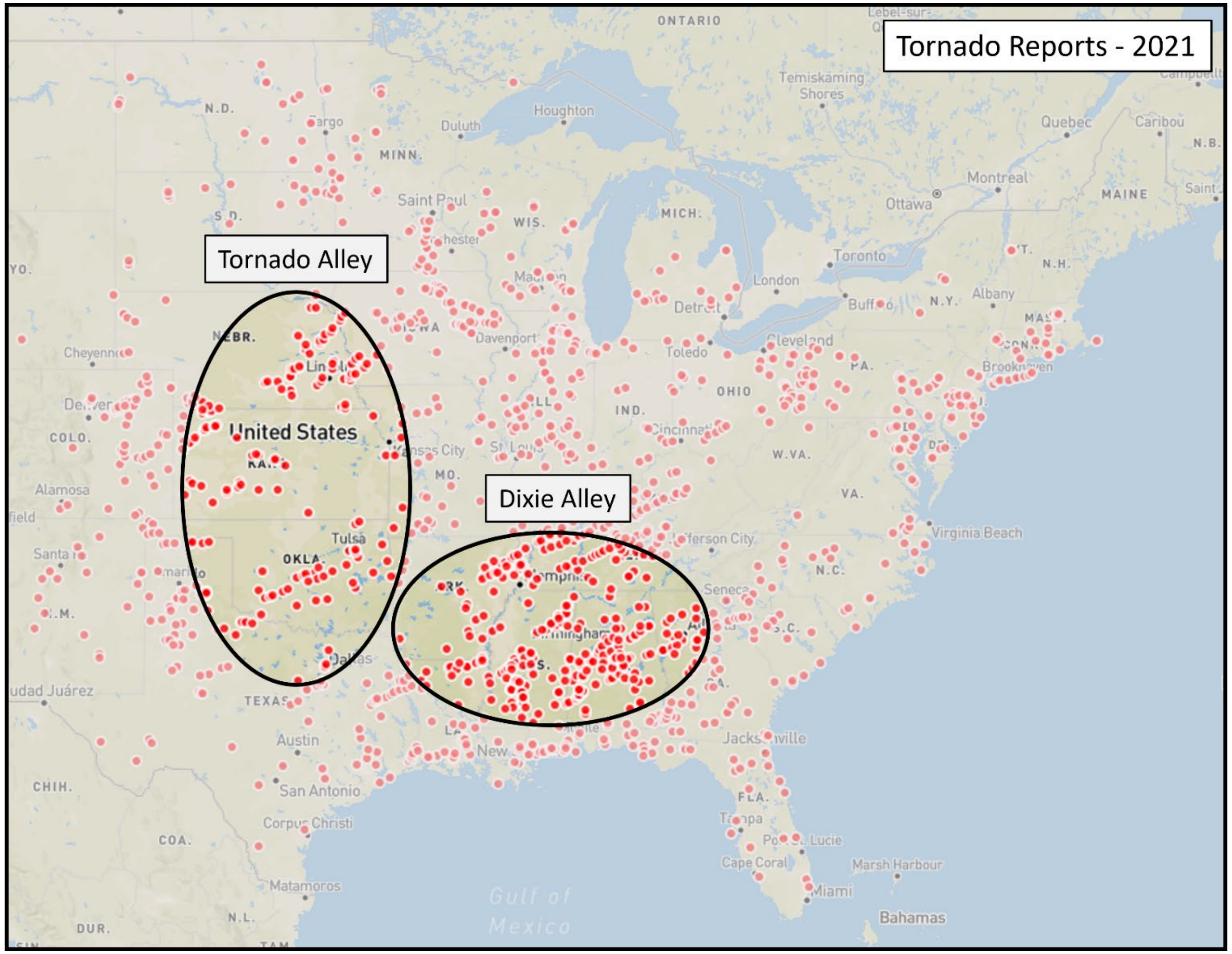

## Texas



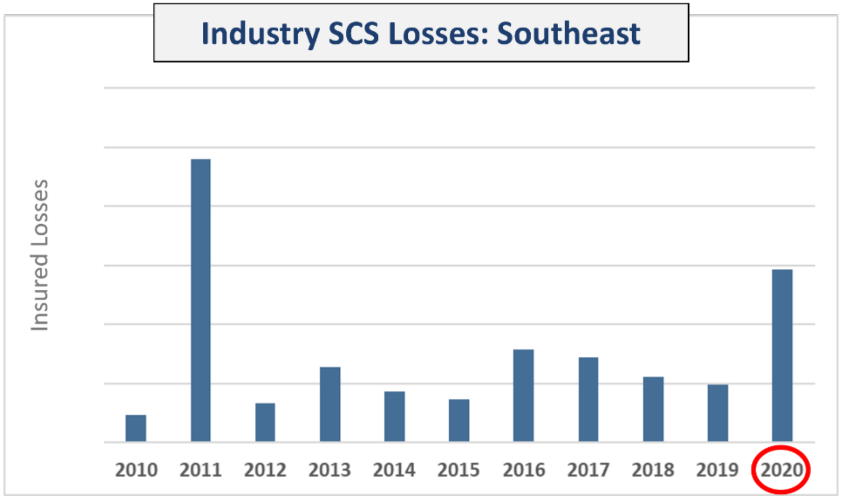

## Texas Wildfire EP

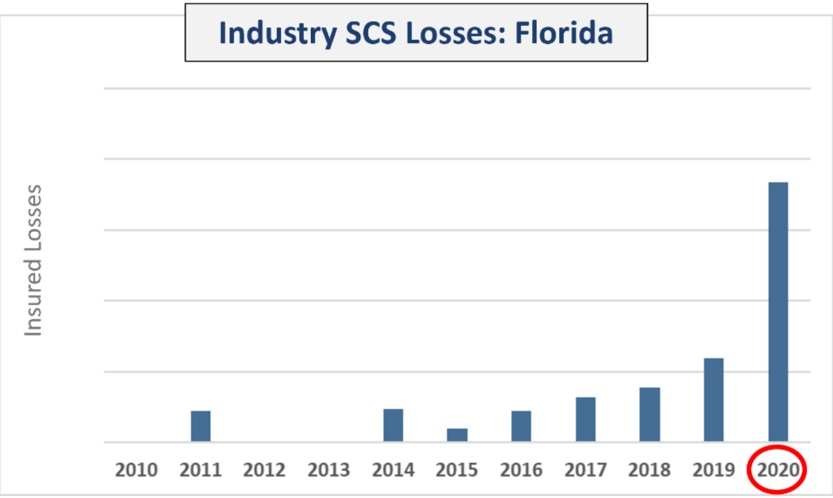


# Shift in Tornado Activity Toward Dixie Alley

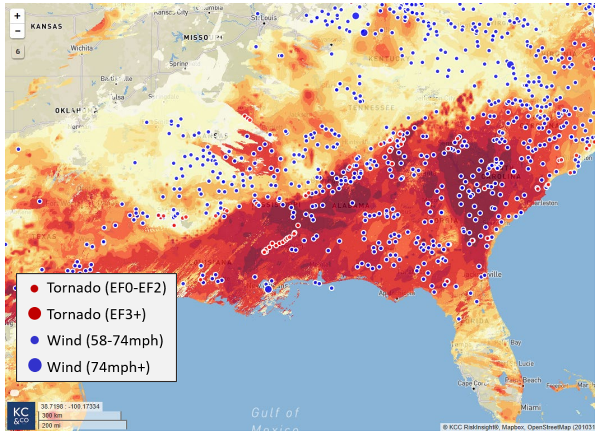


# Why Was 2020 a Bad Year for the Southeast and Florida?

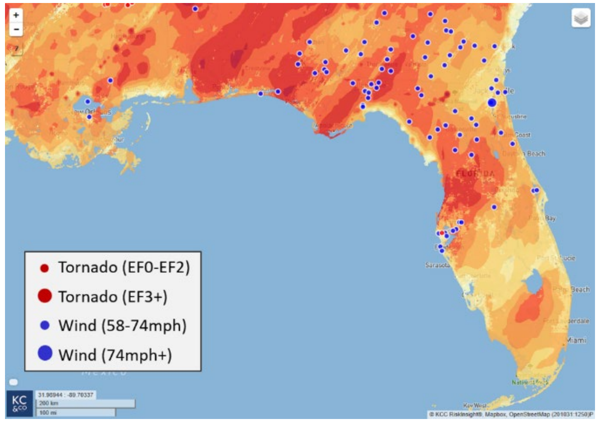


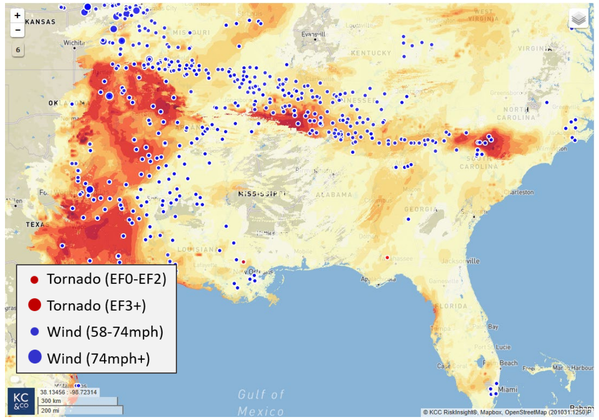

## Major Southeast SCS Events in 2020



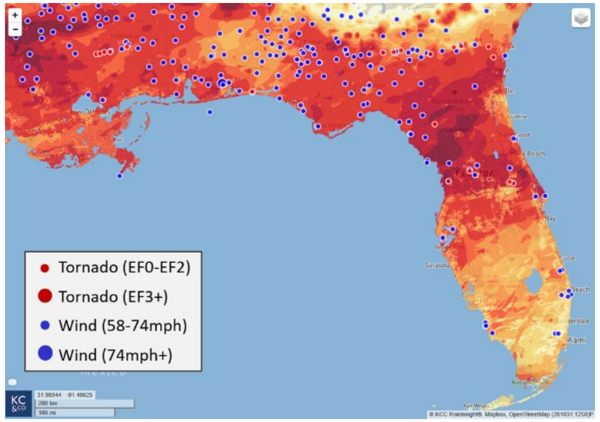

April 7–15, 2020




February 4–8, 2020



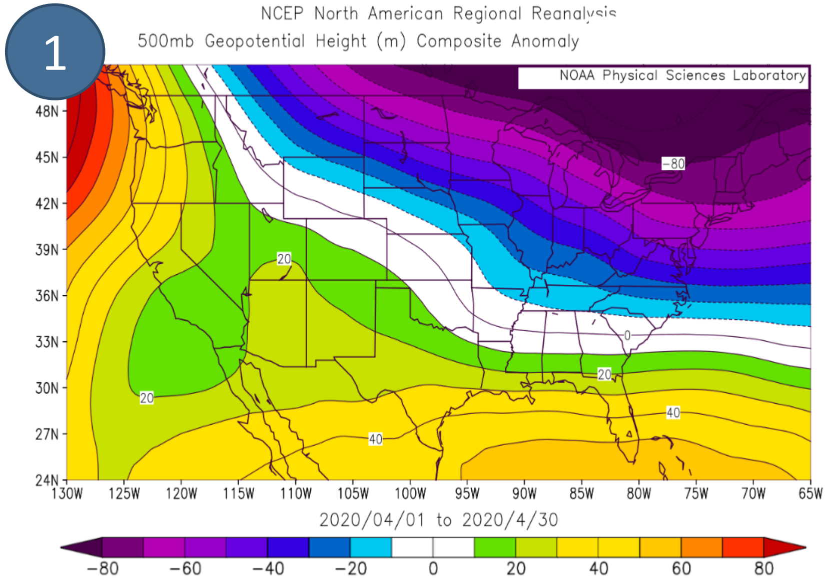

April 28 – May 6, 2020




April 16–27, 2020

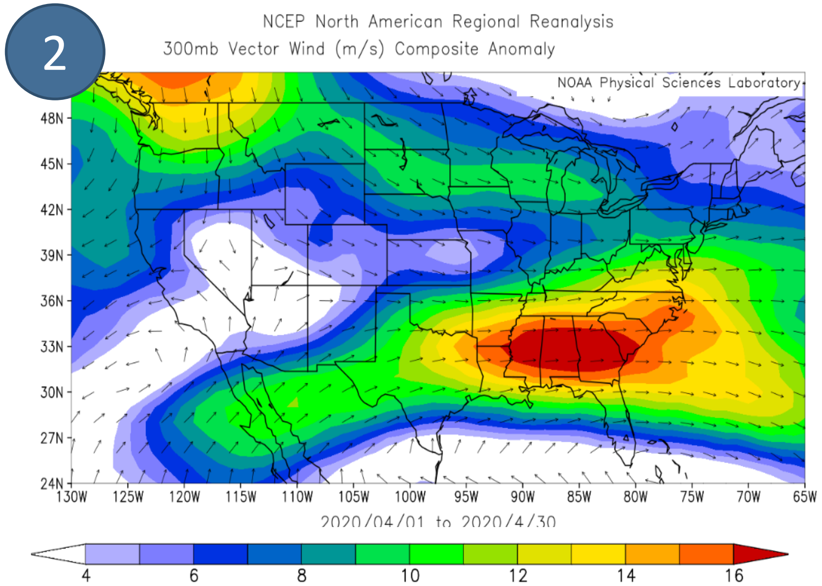
# Three Reasons Why the Southeast Experienced Above-Average SCS Activity in 2020

1



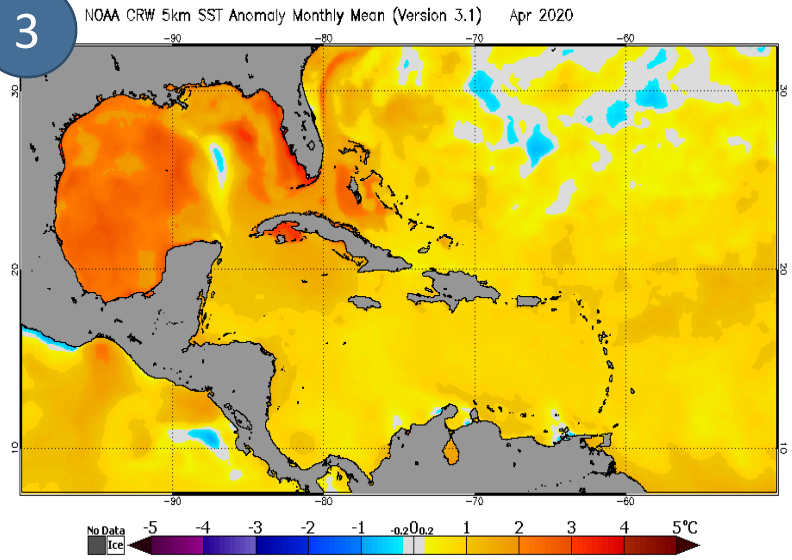

A deep, anomalous pressure trough dipped down into the Southeast creating frontal boundaries providing the forcing mechanism for severe thunderstorms further south than normal.

2




A much stronger than normal jet stream was positioned over the Southeast. The anomalous weather pattern (in red) increased vertical wind shear which led to more intense storms.

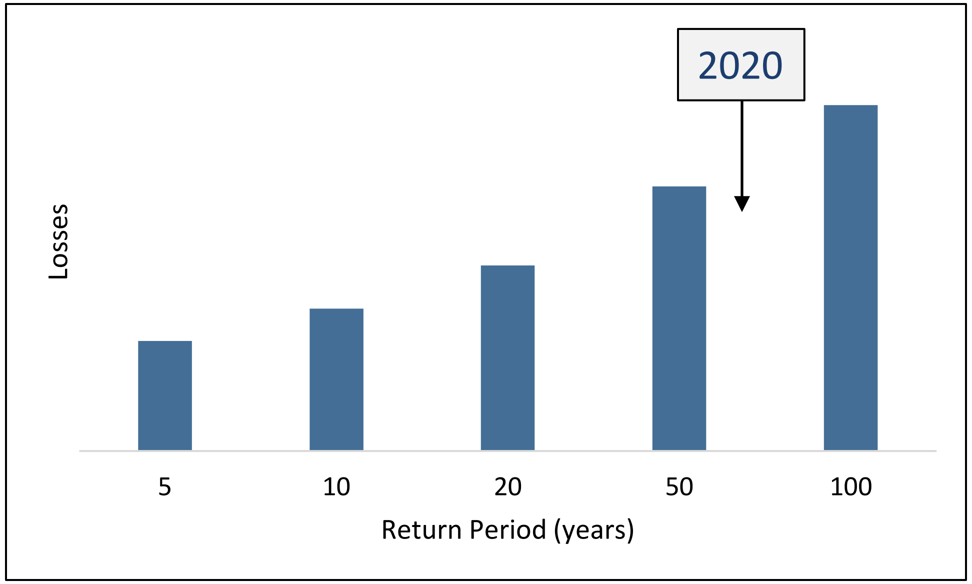
3



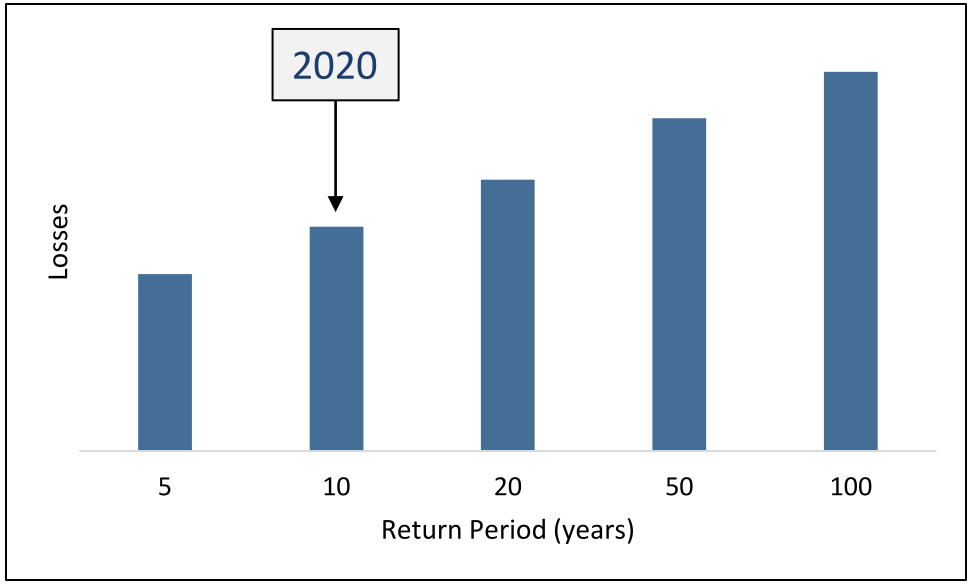

Sea surface temperatures off the coast of Florida were well above normal. **March 2020 had the warmest sea surface temperatures ever recorded in the Gulf of Mexico**. The entire spring was notable for record warmth for Florida and the Gulf Coast.

# How Unusual Were the 2020 SCS Losses in Florida and the Southeast US?

## Florida – SCS EP Curve



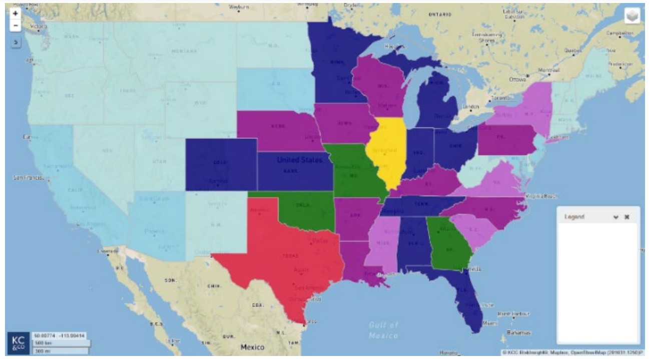

## Southeast US – SCS EP Curve

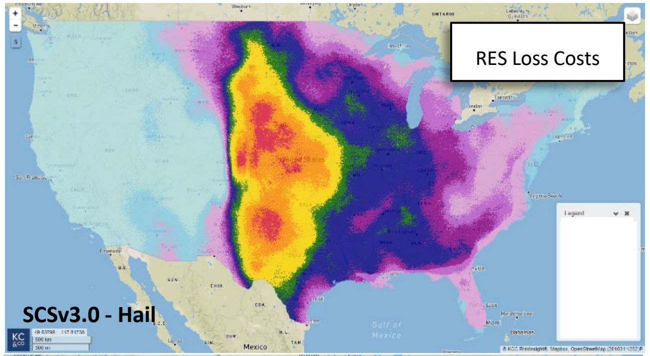


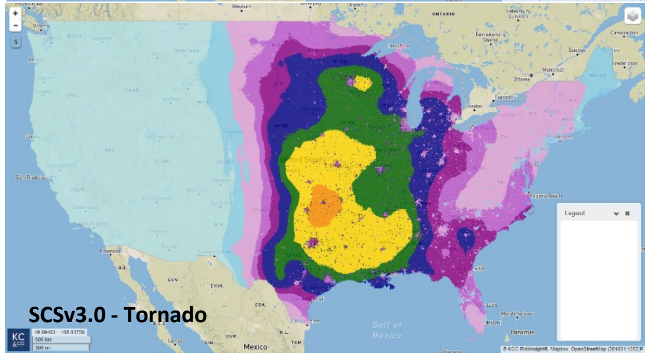
# Use of Catastrophe Models for Ratemaking – Summary

- Historical hazard and loss data isn't reliable for predicting future loss potential, particularly at finer resolutions
- This lack of reliability makes it difficult, if not impossible, to appropriately use for ratemaking
    - This same lack of reliability has caused issues for first-generation, statistical-based models
- This historical data can, however, be used to validate models to be used
    - Ensure reported hazards occur within the modeled footprints and over recent time
    - Ensure reported losses occur within the modeled footprints and over recent time
- Instead, we suggest using next-generation, physics-based modeled Average Annual Loss (AAL) as the baseline for formulating rates by state, by region, etc.
    - Avoid SCS biases caused by population and reporting inaccuracies as well as consider impacts from a changing climate
    - Avoid Wildfire biases caused by rapid impacts from a changing climate

Ground Up Average Annual Loss

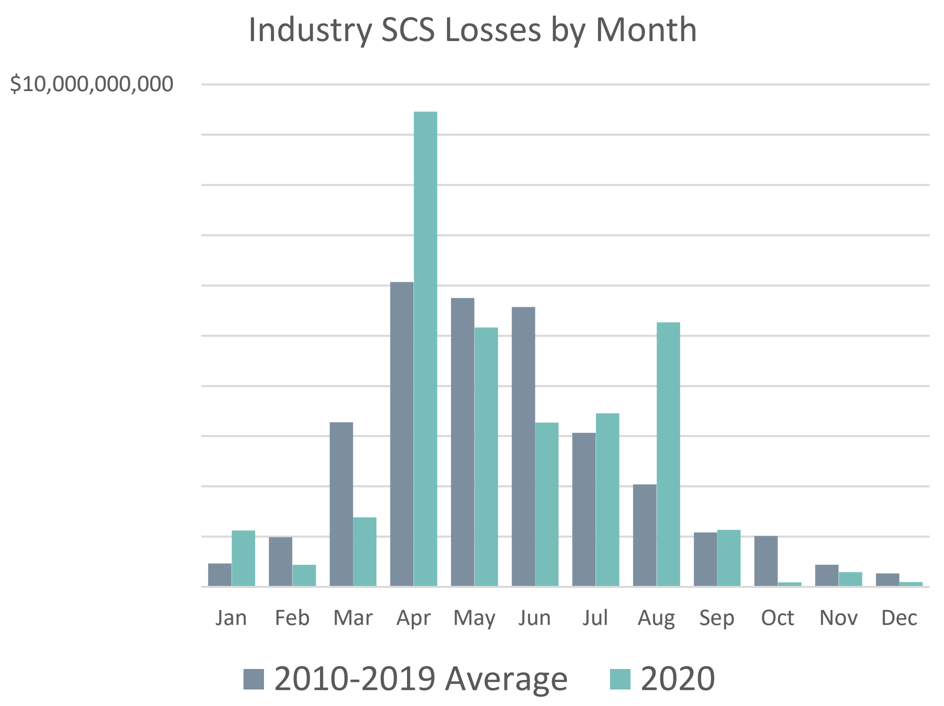


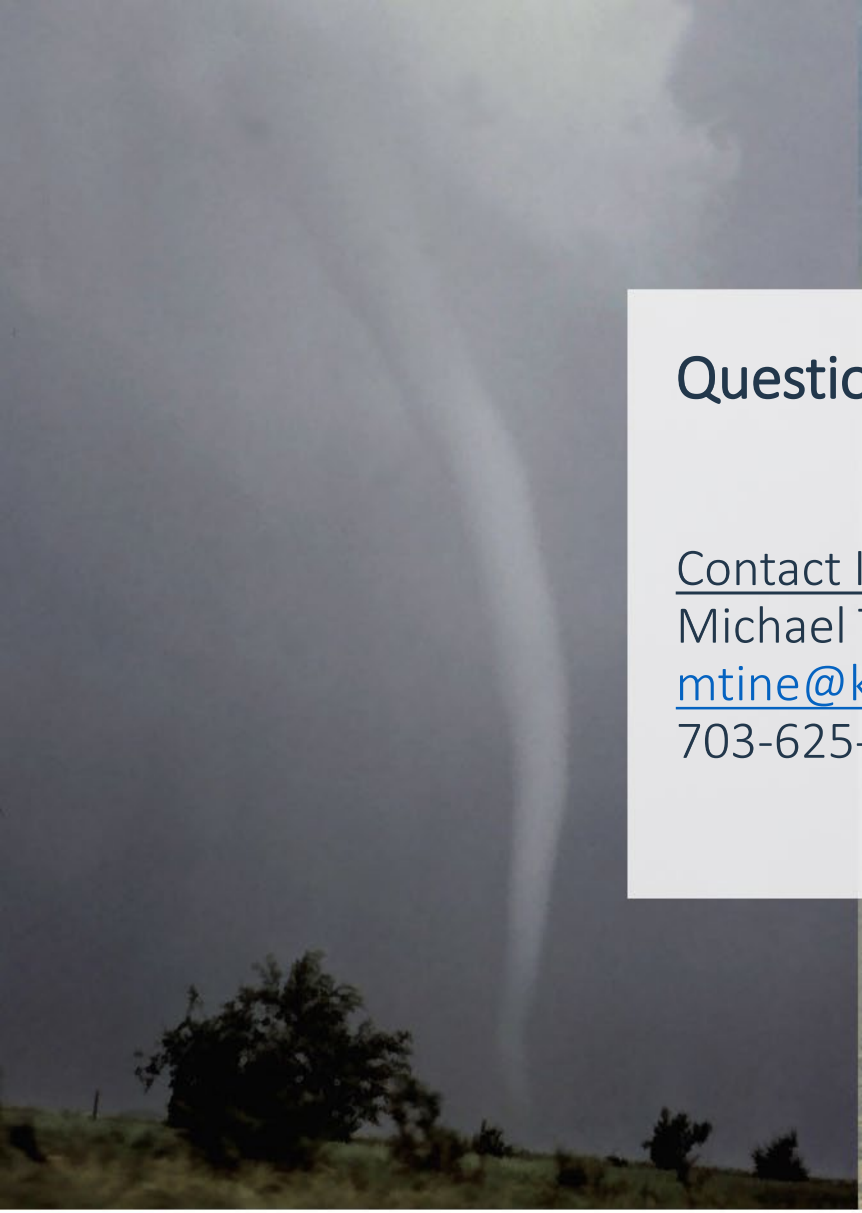
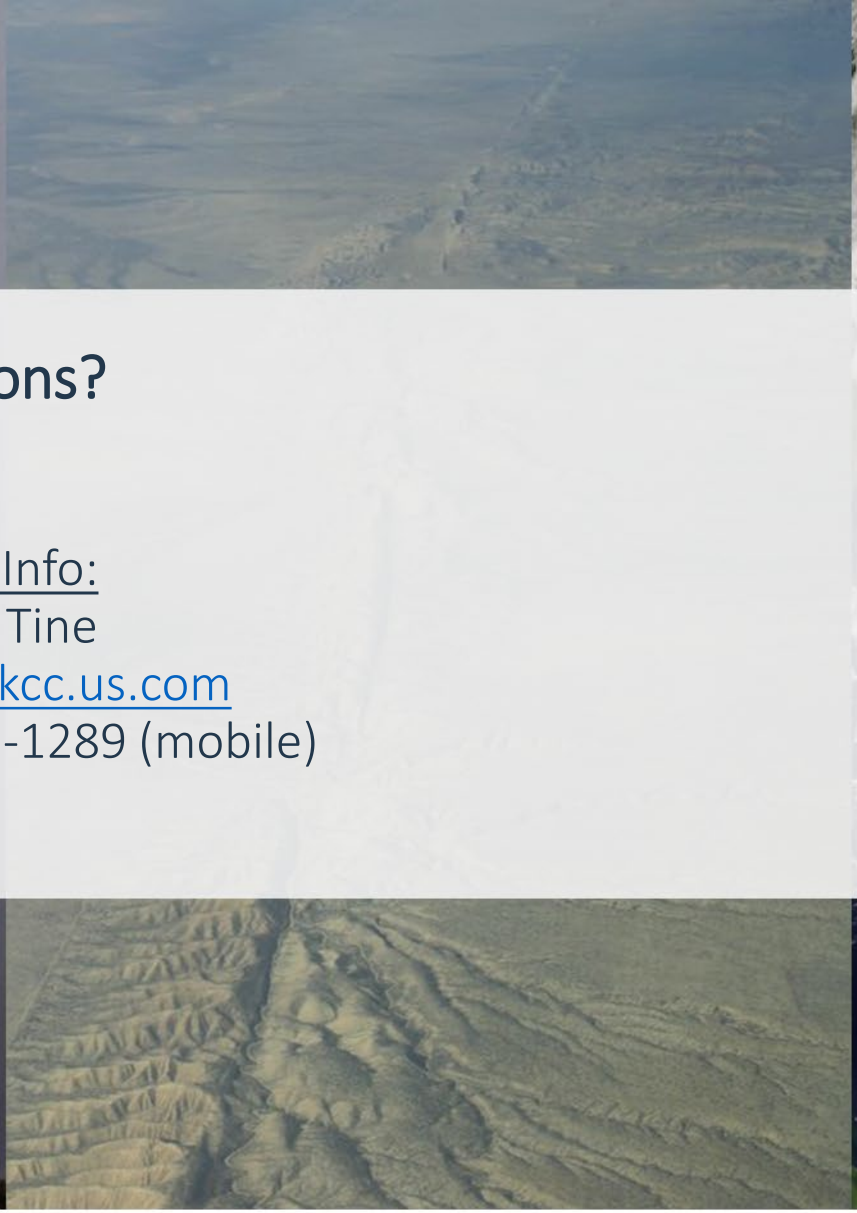


# Use of Catastrophe Models for Ratemaking – Summary

- Seasonal volatility should likely also be considered in risk loads for both SCS and Wildfire
  - Single events, even large ones, won't cause a loss the size of large hurricanes
  - Active seasons, however, can cause even larger annual losses that need to be considered in risk loads (e.g. 2020)
- Future climate models should likely also be considered in risk loads for Wildfire
  - Wildfire loss potential is changing rapidly from the VPD impacts evidenced in the changing climate




# Questions?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mtine@kcc.us.com

703-625-1289 (mobile)