UNDERSTANDING RECENT TRENDS IN U.S. THUNDERSTORM LOSSES

Mark C. Bove, CPCU
Senior Research Meteorologist
Munich Re America

CAS Special Interest Seminar
30 September 2013

Munich RE

Agenda

Munich RE

- Trends in U.S. Thunderstorm Losses
- Difficulties in Thunderstorm Peril Modeling
- Thunderstorms in a Changing Climate
  - Thunderstorms & Natural Climate Variability
  - Thunderstorms & Anthropogenic Climate Change

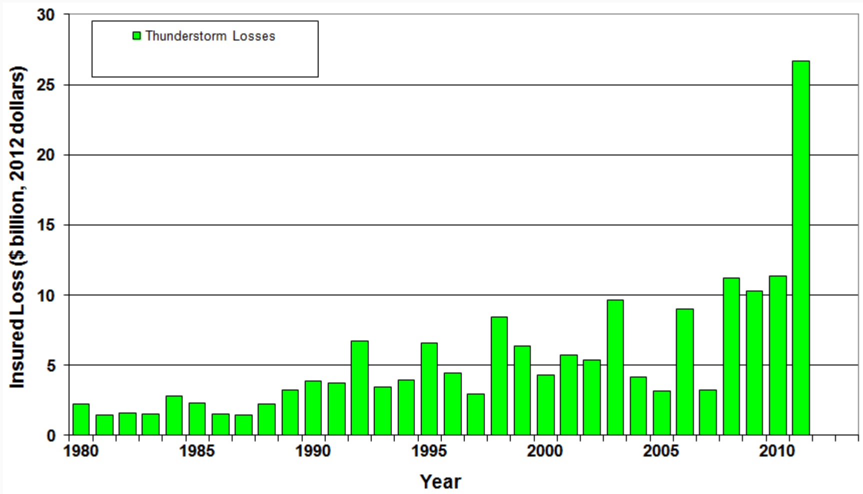
2

Trends in U.S. Thunderstorm Losses

Munich RE

Insured Thunderstorm Losses in the United States, 1980-2013 YTD

Munich RE



Title of presentation and name of speaker 9/18/2013 4

Tornado Statistics for 2011

Munich RE

- Deadliest tornado year since 1925: 551 direct fatalities
- Deadliest single tornado since 1947: Joplin, Missouri, 158 fatalities
- Most observed tornadoes in a month: 748, April
- Largest number of tornadoes in a day: 226, April 27
- Most EF5 Tornados in a year: 6 (tied for first with 1974)
- Aggregate Insured Thunderstorm Losses: $25.9 billion
- Billion-dollar insured loss outbreaks: 6
- Late April (Alabama) and May (Joplin) outbreaks each caused insured losses in excess of $6 billion, and are among top 10 largest natural catastrophe losses in U.S. history, based on original dollars.

5

Largest Insured Thunderstorm Losses in U.S. History

Munich RE

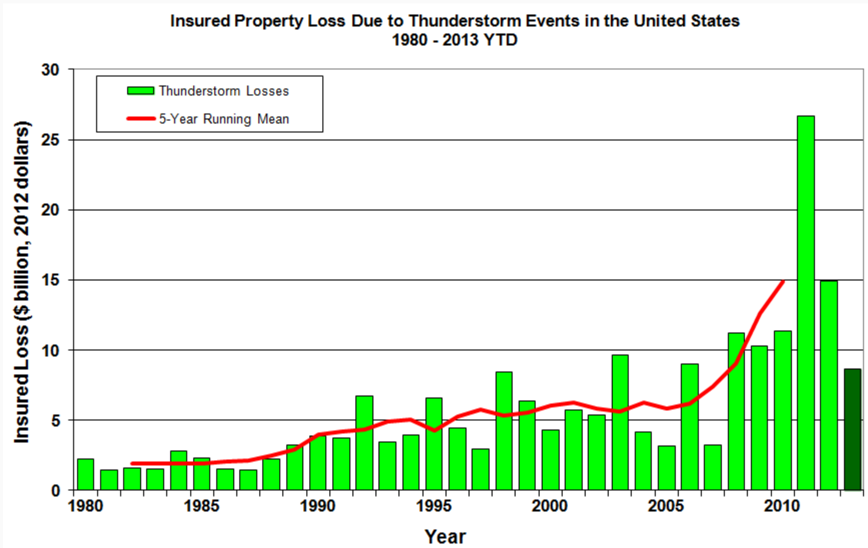
Rank	Date	Fatalities	Losses
1	22 – 28 April 2011	350	$7.4 bn
2	20 – 27 May 2011	179	$7.0 bn
3	2 – 11 May 2003	42	$4.0 bn
4	5 May 1995	32	$3.1 bn
5	6 – 12 April 2001	3	$2.9 bn
6	2 – 3 March 2012	41	$2.5 bn
7	28 – 29 April 2012	1	$2.5 bn
8	27 April – 3 May 2002	2	$2.1 bn
9	2 – 5 April 1974	320	$2.1 bn
10	12 – 16 May 2010	3	$2.1 bn

- Number of thunderstorm outbreaks with $1 billion in insured losses before 1994: **1**
- Number since 1994: **29**

Source: MRNatCatSERVICE
Insured losses adjusted for inflation to 2012 values

Insured Thunderstorm Losses in the United States, 1980-2013 YTD

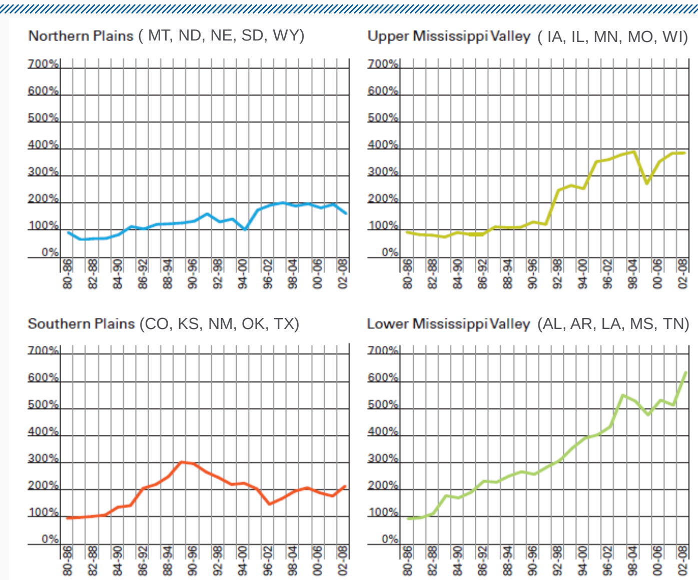
Munich RE



Source: MRNatCatSERVICE

Thunderstorm Losses by Region, 6-Year Running Average as a Percentage of 1980-1986 Average Loss (1)

Munich RE

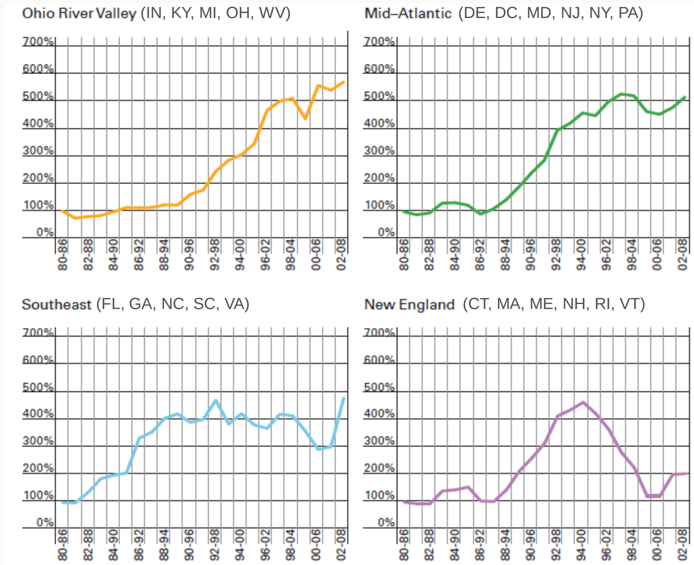


Source: Munich Re Topics Geo 2008

8

Thunderstorm Losses by Region, 6-Year Running Average as a Percentage of 1980-1986 Average Loss (2)

Munich RE

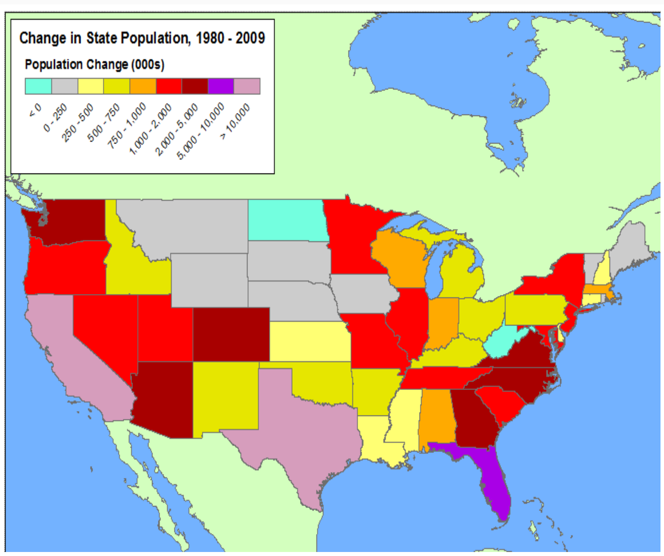


Source: Munich Re Topics Geo 2008

9

Socioeconomic Factors Increasing Thunderstorm Losses: Population Shift

Munich RE



Source: U.S. Census Bureau

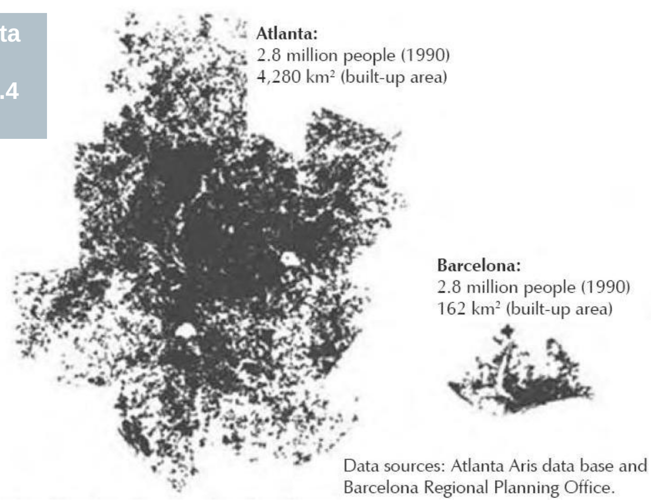
10

Socioeconomic Factors Increasing Thunderstorm Losses: Urban and Suburban Sprawl

Munich RE

The Built-up areas of Atlanta and Barcelona represented at the same scale

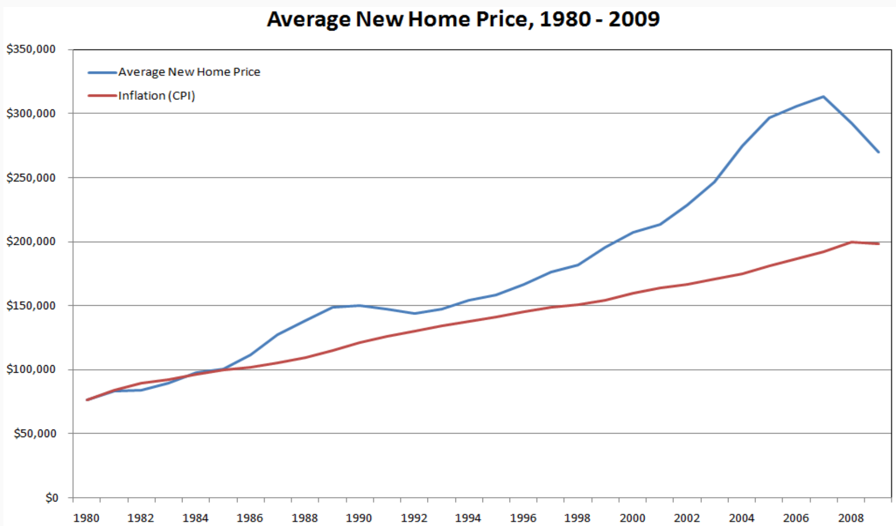
Current Atlanta Metro Population: 5.4 million



11

Socioeconomic Factors Increasing Thunderstorm Losses: Increased Values

Munich RE



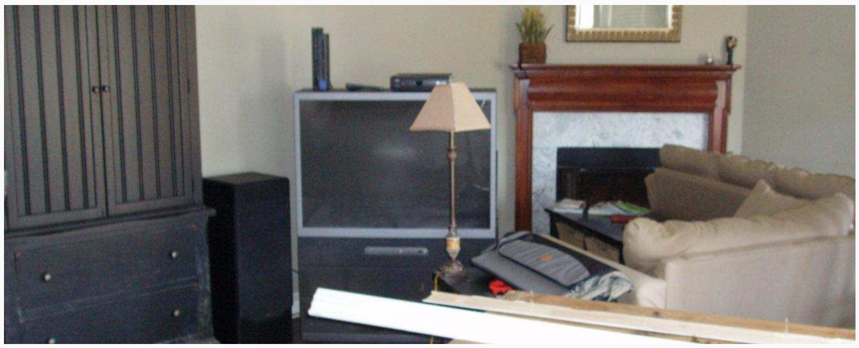
Source: U.S. Census Bureau

12

Socioeconomic Factors Increasing Thunderstorm Losses: Changes in Personal Property

Munich RE

- Lightning has become a larger driver of loss over the past thirty years due to the increased ubiquity of electronic devices in homes and businesses.



Source: Munich Re

Socioeconomic Factors Increasing Thunderstorm Losses: Building Age / Construction Quality

Munich RE

Source: Munich Re / Mark Bove

Difficulties in Thunderstorm Peril Modeling

Munich RE

Difficulties in Thunderstorm Peril Modeling

Munich RE

- **Explicitly Modeled Perils** (Perils included in Event Set/Intensity Calculation):
  - Tornado
  - Hail
  - Straight-Line Winds
- **Implicitly Modeled Perils** (Perils included via vulnerability curves):
  - Lightning
- **Non-Modeled Perils**:
  - Inland Flooding
  - Secondary fires (i.e., fire after lightning strike)
  - Other secondary disasters stemming from SCS event (i.e., tornado hits a nuclear power plant).

16

Difficulties in Thunderstorm Peril Modeling

Munich RE

Thunderstorm models have the same 4 basic components as other models:

- **Stochastic Event Set**
- **Intensity Calculation**
- **Damage Estimation**
- **Loss Evaluation**

However, the small scale nature of the thunderstorm perils cause unique modeling challenges for each component that do not exist for other perils.

17

Difficulties in Thunderstorm Peril Modeling

Munich RE

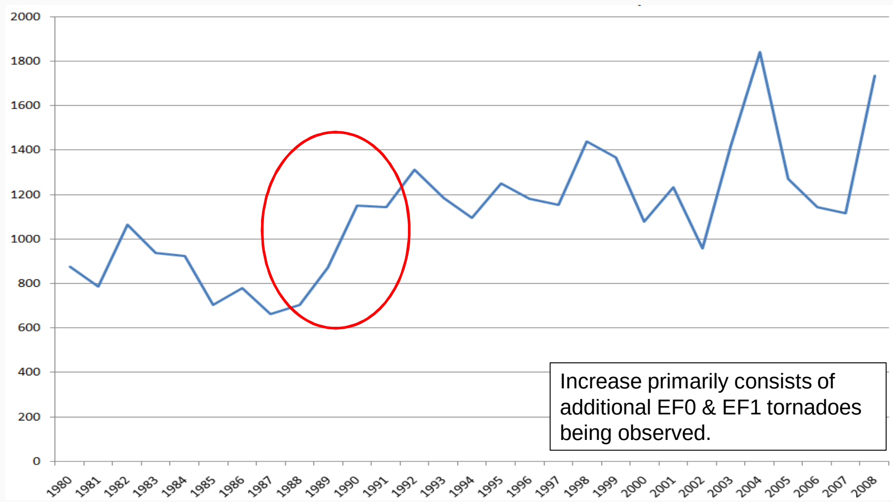
There are several key difficulties in creating a thunderstorm event set:

1. Determining accurate hazard frequencies / return periods for any given location for different hazards and event intensities.
2. Determining what constitutes an “event” in the model.
3. What do you do with high frequency/low severity SCS events?
4. The very small nature of individual hazard swaths

18

Difficulties in Thunderstorm Peril Modeling
Underreporting of Historical Events

Discontinuity due to introduction of NEXRAD Radar and better observing practices.

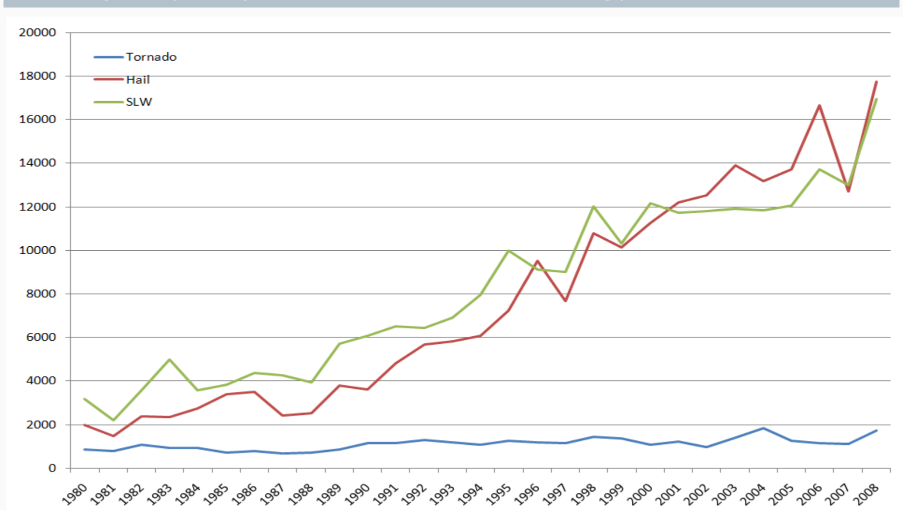


Source: NOAA / SPC

19

Difficulties in Thunderstorm Peril Modeling
Underreporting of Historical Events

Increasing trend primarily due to NEXRAD and better observing practices.



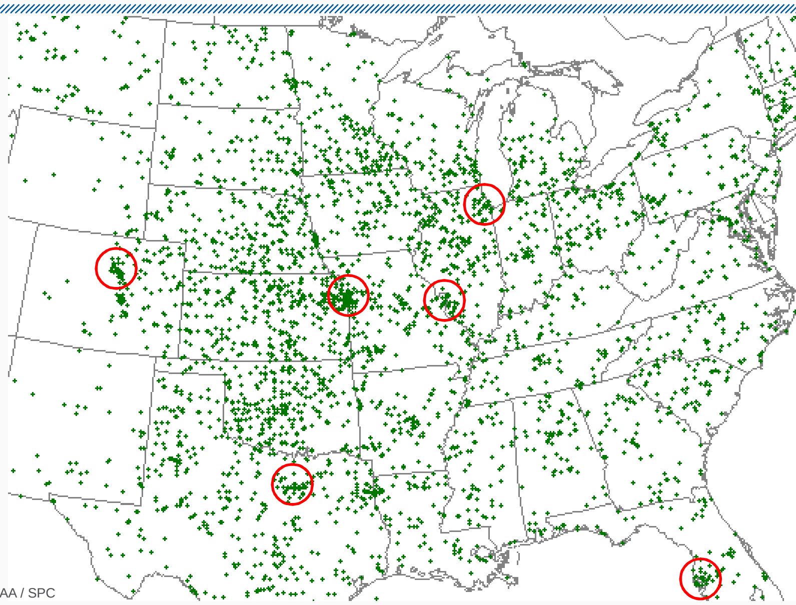
Source: NOAA / SPC

20

Difficulties in Thunderstorm Peril Modeling

Other Biases in SCS Historical Record

Munich RE



Source: NOAA / SPC

21

Difficulties in Thunderstorm Peril Modeling

Addressing Historical Data Problems

Munich RE

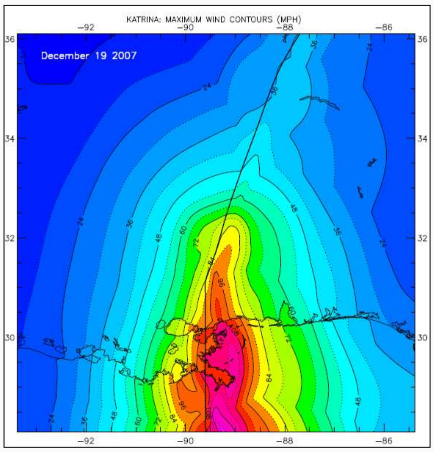
- Very large trend in observed severe thunderstorm hazards over database time period.
  - Modelers assume recent years (with better observations) more accurately reflects true activity rates.
  - However, only 10-15 years of "accurate" data to work with. May introduce biases due to lack of data in inactive regions, climate variability, etc.
- Tornado, hail and wind observations are heavily concentrated around urbanized areas, particularly at the beginning of the data record.
  - Modelers smooth historical activity to account for biases in historical observations due to urbanized areas.
  - How best to smooth in areas of low activity, near large bodies of water, or international borders?

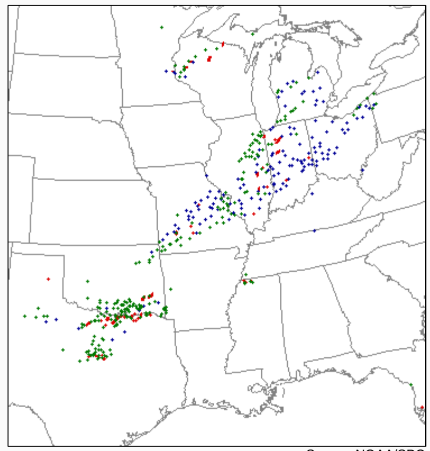
22

Difficulties in Thunderstorm Peril Modeling
Subjective Nature of Defining an "Event"

Munich RE

- Are the SCS reports on the right from one event? Two? Three?
- What is appropriate gap (geographic and time) between SCS events?



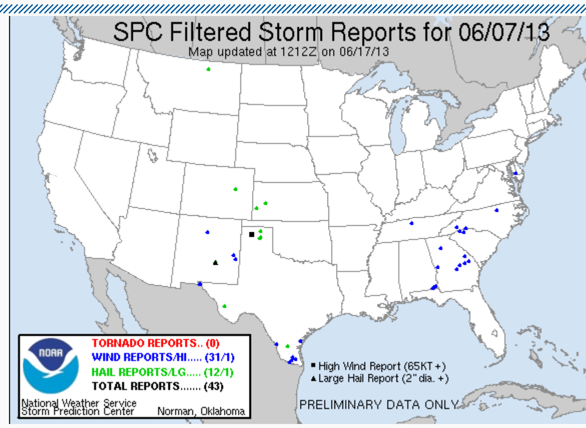


Source: NOAA/SPC

23

Difficulties in Thunderstorm Peril Modeling
High Frequency vs. Low Frequency Events

Munich RE



Source: NOAA/SPC

- High frequency/low severity SCS events happen almost daily in the United States. These types of events can contribute significantly to SCS AAL at some locations, but don't impact the tail of the EP curve, which is influenced by low frequency/high severity events.

24

Difficulties in Thunderstorm Peril Modeling
High Frequency vs. Low Frequency Events

Munich RE

- High frequency/low severity (HF) events are even more problematic to model than low frequency/high severity events.
  - More random than low frequency events, and occur over a much larger geographic area.
  - Very time consuming to model, and provides only marginal additional information on SCS financial impacts to property.
- Potential model response:
  - Include HF events in event set
  - Create “pseudo-events” that calculate the HF losses to a location/policy or portfolio.
  - Implicitly include via vulnerability curves.

25

Difficulties in Thunderstorm Peril Modeling
Ensuring Adequate Event Set Coverage

Munich RE

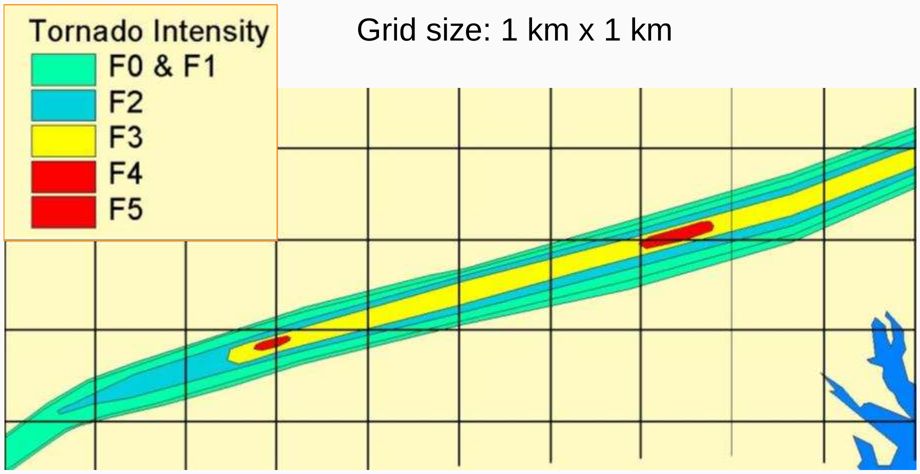
- The small-scale nature of thunderstorm hazards requires a very large stochastic catalog to accurately model the risk across the entire model domain.
  - If too small, not all regions covered fully and will not be statistically stable, particularly at tail of EP curve.
  - If too large, model run times will take too long for operational needs.
- Solution: Assign all events to a high-resolution grid. Any event that occurs within the grid can potentially cause loss to property in the same grid box.
- However, current spatial resolutions of T/H/SLW events are too small to accurately capture intensity variability.
  - Current lowest grid resolution: 1 km^2
  - Desired grid resolution: 100 m^2 or better

26

Difficulties in Thunderstorm Peril Modeling
Ensuring Adequate Event Set Coverage

Munich RE

Grid size: 1 km x 1 km



Information of event intensity kept for each grid box, but otherwise the actual swaths generated are not explicitly used in the actual model.

Original Shapefile Data: NOAA / NWS / Norman, OK WFO

Difficulties in Thunderstorm Peril Modeling
Difficulties with Intensity Calculation

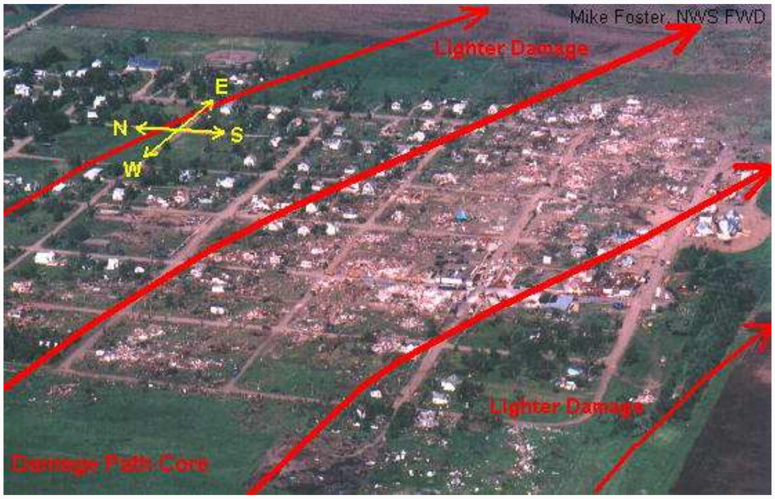
Munich RE

- Unlike hurricane and earthquake peril models, distance from source is not a major factor in calculating intensities. However, tornado/hail intensity can vary within a single event swath.
- Tornado intensities in a model grid box can vary from no impact to EF5! Depending on grid size, hail and SLW swaths can also experience a similar problem.
- **If a grid box is impacted by an event in the model, all locations within that grid box sustain a loss!**
- Intensity of peril in a grid box in the model are based on a weighting of (1) wind speed and/or (2) hail size or hail impact energy, based on the area covered by that intensity within a grid box.

28

Difficulties in Thunderstorm Peril Modeling
Tornado Damage Path & Intensity Calculation

Munich RE



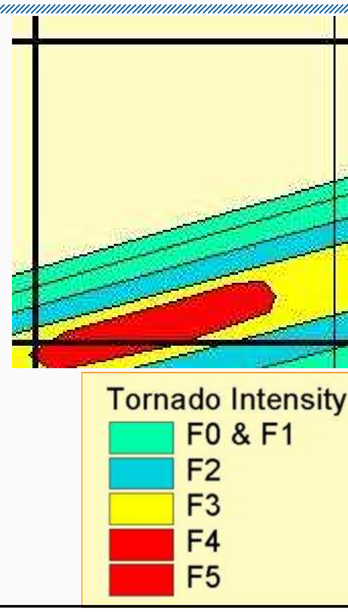
NOAA / NWS / Storm Prediction Center; http://www.spc.noaa.gov/misc/spencer/spendmg.htm

29

Difficulties in Thunderstorm Peril Modeling
Intensity Calculation Example

Munich RE

- For this grid box, the calculated mean damage factor (MDF) would be:
  - [(EF4 DF * impacted area) + (EF3 DF * impacted area) + (EF2 DF * impacted area) + (EF1 DF * impacted area) + (EF0 DF * impacted area)] / total impacted area
  - Essentially adds an additional layer of "secondary uncertainty" to model results
  - Reduces extreme tail loss potential



Original Shapefile Data: NOAA / NWS / Norman, OK WFO

Thunderstorms in a Changing Climate


Photo: NOAA

Definitions

Weather- Climate - Climate variability – Climate change

Weather
Description of the combination of short-term meteorological conditions such as temperature, precipitation, pressure, etc. occurring at a particular time and place

Climate
Description of the average and the variability of weather conditions at a specific location from a given period of time including its extreme peaks;
Typical physical parameters: wind speed, air temperature, precipitation, air pressure

Climate variability
Deviation of the average conditions or the frequency of extremes of a specific period from conditions as inferred from other periods

Natural climate variability
Climate variability caused by interactions of natural forces (e.g. interaction of the ocean and the atmosphere)

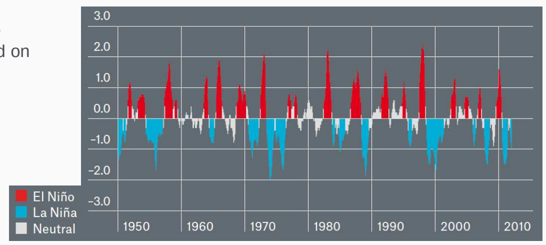
Anthropogenic climate change
Climate variability caused by human intervention (e.g. emissions of CO_2)

Source: Munich Re – Severe weather in North America, 2012

Thunderstorms & Natural Climate Variability
Influence of the El Niño - Southern Oscillation

- El Niño Southern Oscillation: Climate anomaly comprising oceanic and atmospheric components in the tropical Pacific, with alternating opposing phases, centered around the turn of the year
- El Niño: Phase with a sporadic rise in sea surface temperatures in the tropical central and eastern Pacific
- La Niña: Phase of exceptionally low sea surface temperatures in the tropical eastern Pacific

Sea surface temperature anomalies in the central tropical Pacific. The graph is based on the anomalies of three-month averages between 1950 and 2011



Source: Munich Re – Severe weather in North America, 2012

Thunderstorms & Natural Climate Variability
Influence of the El Niño - Southern Oscillation

The El Niño – Southern Oscillation (ENSO) also has impacts on severe thunderstorm activity in the United States

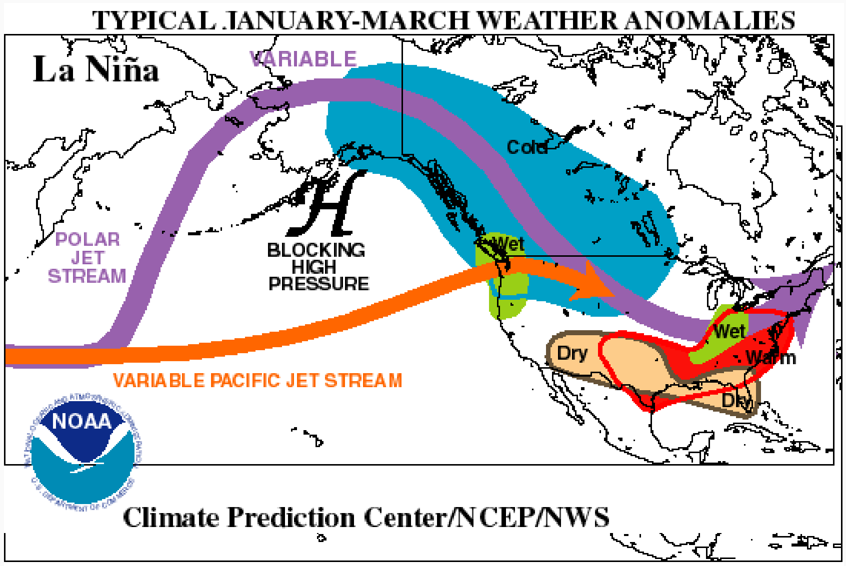
- El Niño: Reduction of severe thunderstorms over south central plains states; fewer large outbreaks and long-tracked, violent tornadoes.
- La Niña: Increase in severe thunderstorms over Deep South and Ohio River Valley; more large outbreaks and long-tracked, violent tornadoes.

34

Thunderstorms & Natural Climate Variability

Influence of the El Niño - Southern Oscillation

Munich RE

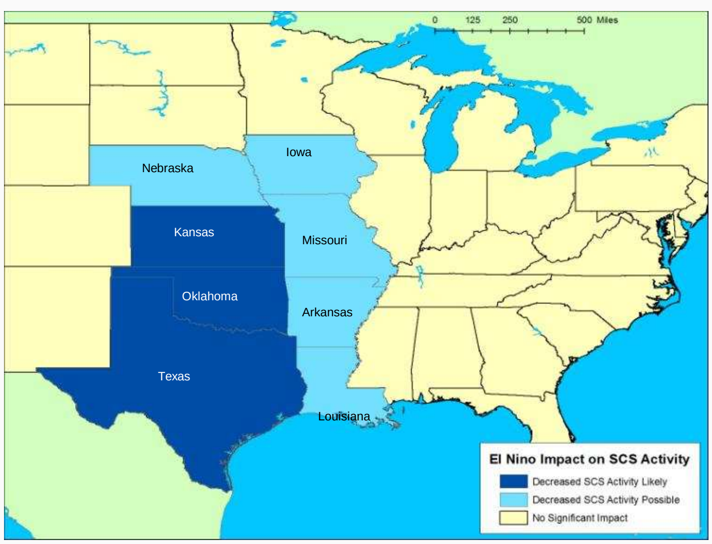


35

Thunderstorms & Natural Climate Variability

Influence of the El Niño - Southern Oscillation

Munich RE



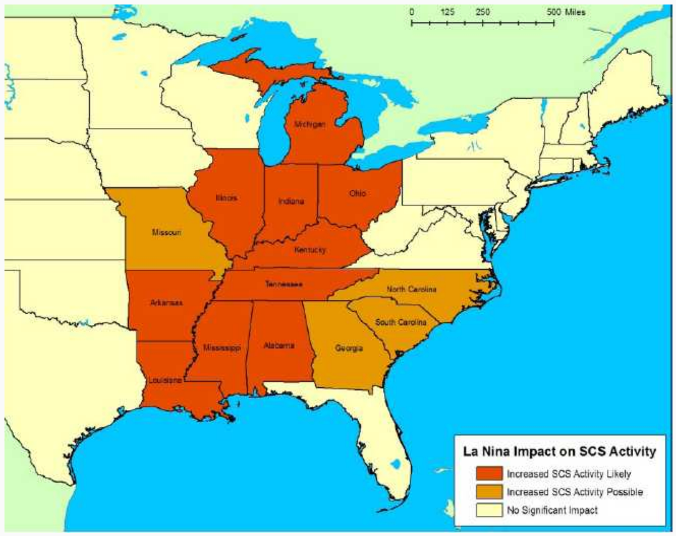
Source: Munich Re America, Based on Bove (1998)

36

Thunderstorms & Natural Climate Variability

Influence of the El Niño - Southern Oscillation

Munich RE



Source: Munich Re America, Based on Bove (1998)

37

Thunderstorms and Anthropogenic Climate Change

Munich RE

- Due to the small-scale, localized nature of severe thunderstorms and their associated hazards, it is hard to tell what impact climate change will have on these storms.
- Increased atmospheric moisture and heat will likely increase the number of days per year that severe thunderstorms are possible in certain areas of the globe.
- Some studies already indicating more large hail events over past 50 years; unclear if naturally driven change or influence by human activity.
- Socioeconomic factors will likely dominate thunderstorm loss potential for the foreseeable future.

38

THANK YOU! ANY QUESTIONS?

Mark Bove mbove@munichreamerica.com

Munich RE

© Copyright 2013 Munich Reinsurance America, Inc. All rights reserved. "Munich Re" and the Munich Re logo are internationally protected registered trademarks. The material in this presentation is provided for your information only, and is not permitted to be further distributed without the express written permission of Munich Reinsurance America, Inc. or Munich Re. This material is not intended to be legal, underwriting, financial, or any other type of professional advice. Examples given are for illustrative purposes only. Each reader should consult an attorney and other appropriate advisors to determine the applicability of any particular contract language to the reader's specific circumstances.

Munich RE