A Historical Analysis of Severe Hail Outbreaks over the CONUS

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Hypothesis

The frequency of severe hail outbreaks over the U.S. is hypothesized to be increasing and is related in some way to the larger-scale forcing of tornado and hail producing storms.

- ▶ Tornado outbreak frequency has increased over the past 40 years (Brooks et al. 2014)
- ▶ A considerable fraction of severe hail events coincide with tornado events (Brooks et al. 2003)

Background

- Historical trends in "severe hail outbreaks" (SHO) over the United States are currently not well understood

- Few studies exist regarding changes in hail production
  - Focused on Europe and China (Xie et al. 2008 and Mohr et al. 2015)
  - Don't cover hail outbreaks

- Increases in environments supportive of severe thunderstorms over the U.S are observed
  - No distinction between severe hail and other associated severe thunderstorm hazards
  - Trapp et al., 2007, 2009; Marsh et al., 2007; Diffenbaugh et al., 2013; Seeley and Romps 2015

Background

- Inherent biases exist within U.S. severe hail report databases
  - Localized to population centers
    - Hail size underestimated and/or largest hailstones unreported
  - Size descriptions related to objects
    - Size ranges not direct measurements
  - Lack of information on size or path of hail swaths
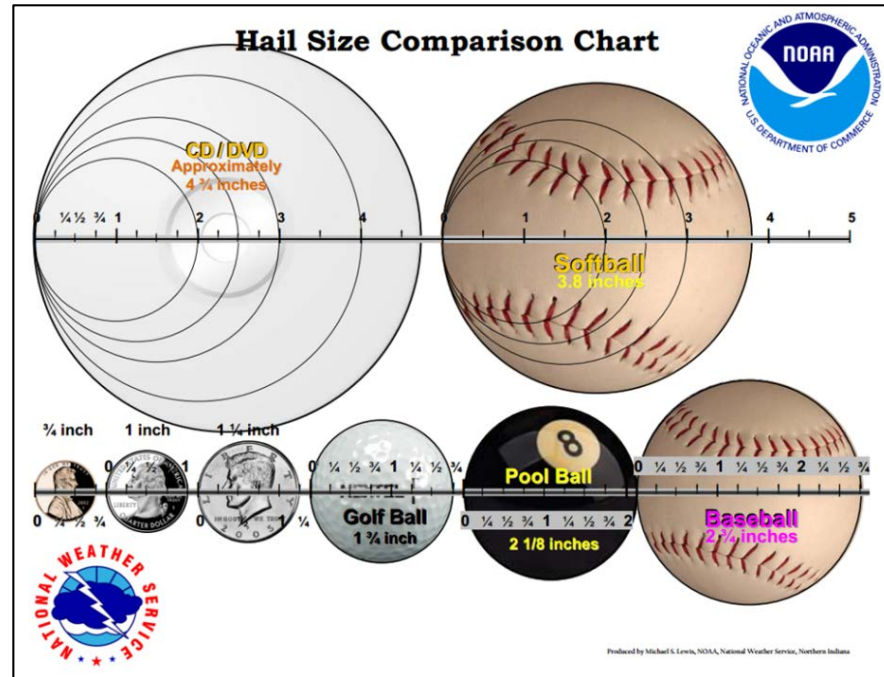
(Schaefer and Edwards 1999; Schaefer et al. 2004; Doswell et al. 2005; Allen and Tippett, 2015)

Project Objectives

- Investigate historical changes in the spatial extent and frequency of SHOs over the U.S.

  - Define a SHO in terms of hail proxy (MESH)

  - Use 12 years of MESH data to train/understand 38 years of severe hail environmental parameters from the North American Regional Reanalysis (NARR)

    - Determine a "SHO environment" in the NARR

  - Analyze short and long term SHO trends in MESH and NARR respectively

- Aim for ability to apply same methodology to climate model projections of future SHO environments

What is MESH?

Maximum Expected Size of Hail (MESH): Estimation of the maximum potential hail size in a storm cell (Witt et al. 1998)

- ▶ Utilizes a thermally weighted vertical integration of a storm's reflectivity profile

- ▶ Multiradar multisensory (MRMS) algorithms used to provide better spatial coverage

- ▶ Not dependent on storm reports

- ▶ More data availability

- ▶ Verification tool to detect the presence of severe hail (Cintineo et al. 2012)

  - ▶ Severe hail: MESH ≥ 29 mm

Severe MESH Dataset Development

Severe MESH occurrences for 2005
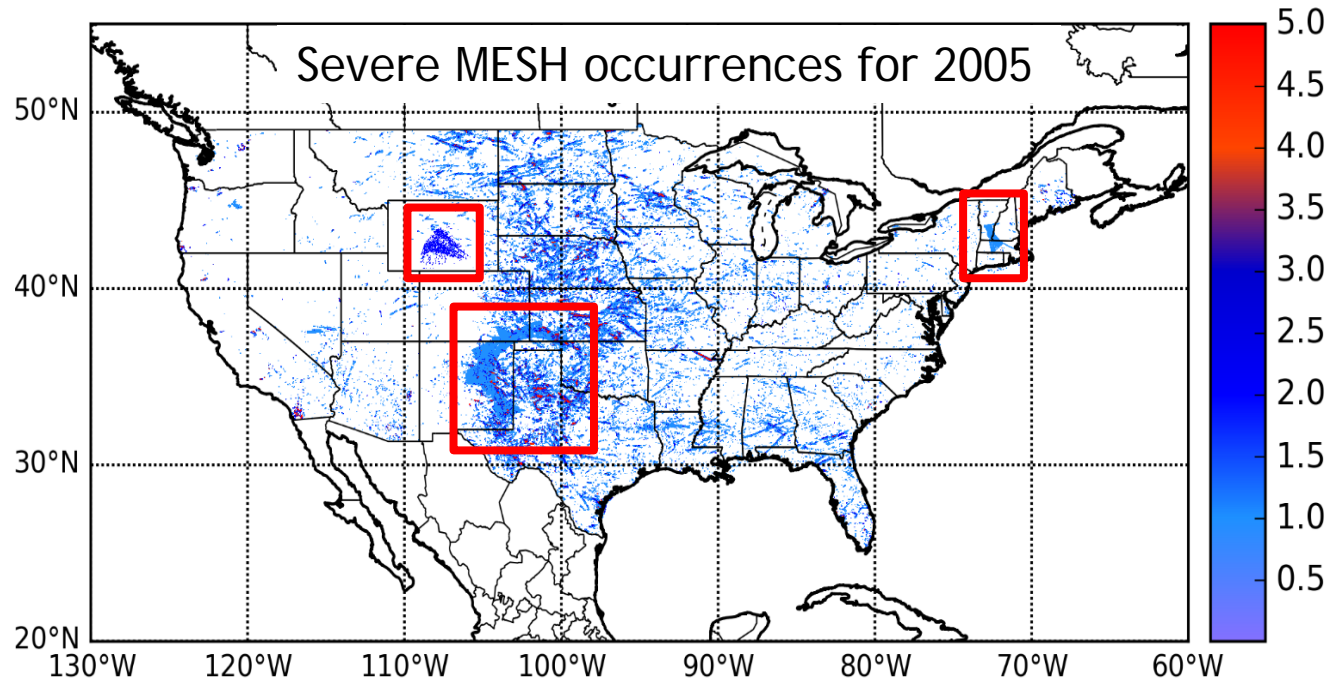
- ▶ NOAA's NEXRAD Reanalysis
  - ▶ 2000-2011, 5-minute temporal resolution, 0.01 by 0.01 degree spatial resolution
- ▶ Daily severe MESH occurrences summed for every grid point
  - ▶ 29 mm ≤ MESH < 100 mm

MESH Quality Control

▶ Non-hydrometeorological data removed (Ground clutter, interference spikes etc...)

▶ Additional QC

  ▶ MESH constrained by composite reflectivity (CREF)

  ▶ Severe MESH 5 minute composite totals > 3000 removed

   ▶ 52 instances of 5 minute severe MESH composite totals > 3000

Severe MESH occurrences for 2005
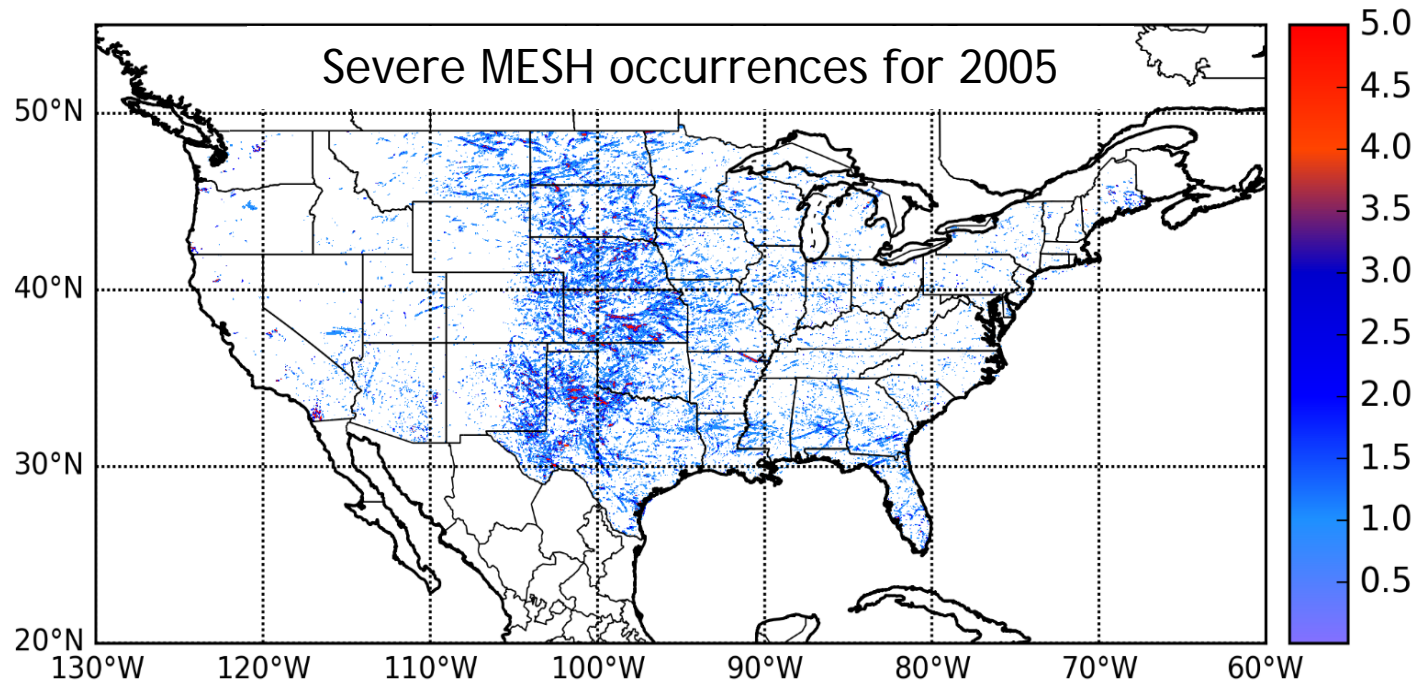
Defining a "severe hail outbreak" with MESH

Daily MESH counts: Sum of severe MESH occurrences over all grid points

Daily MESH area: Sum of all grid points with severe MESH occurrences > 0

Outbreak Case	MESH Counts	MESH Area	SPC Reports
March 26th 2000	8415	5915	273
May 18th 2000	15596	12183	293
April 18th 2002	17452	13866	369
April 28th 2002	8850	7584	290
Null Case	**MESH Counts**	**MESH Area**	**SPC Reports**
April 6th 2002	405	279	11
June 8th 2001	1583	1133	33
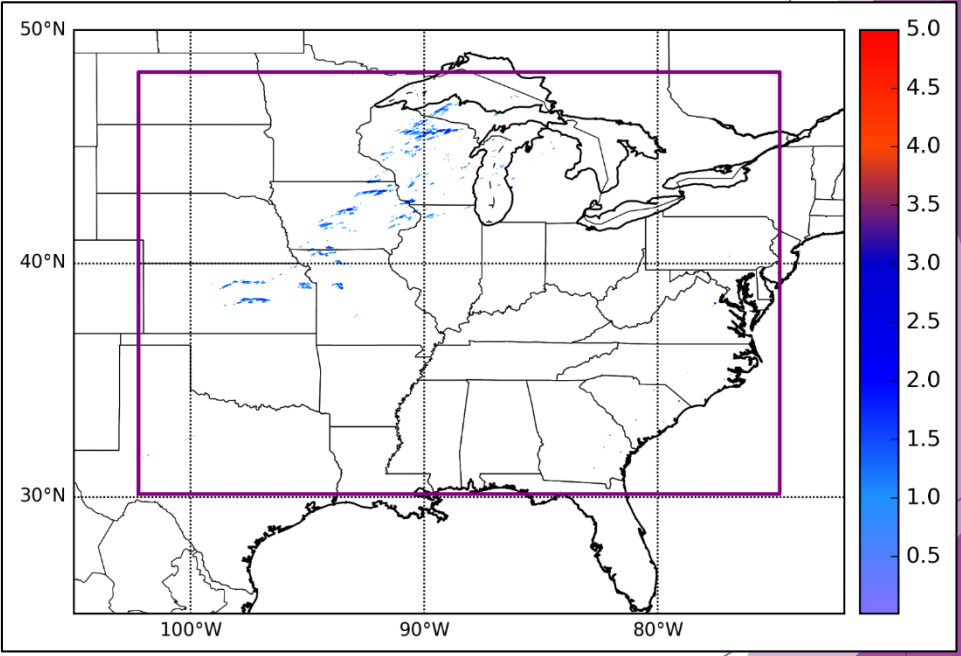
MESH Outbreak Day Thresholds

- Severe Hail Outbreak
  - Daily MESH counts ≥ 5000
  - Daily MESH area ≥ 5000

- Significant Severe Hail Outbreak
  - Daily MESH counts ≥ 10000
  - Daily MESH area ≥ 5000

Severe Hail Outbreak Environment

"Significant hail, non-tornado" events are largely the product of discrete cells." – Grams et al. (2011)

► Supercell Composite Parameter (Thompson et al. 2003)

  ► SCP = (MUCAPE/1000 J kg^{-1}) x (0-3 km SRH/100 m^2 s^{-2}) x (BRN shear/40 m^2 s^{-2})

► Convective Precipitation

  ► Must be greater than zero for grid point to be considered

Defining a Severe Hail Outbreak with NARR

▶ Same outbreak and null cases from MESH revisited

▶ Determine SCP threshold for severe hail potential

  ▶ SCP > 0 and CP > 0

  ▶ SCP ≥ 1 and CP > 0

  ▶ SCP > 5 and CP > 0

  ▶ SCP > 10 and CP > 0

▶ Defining an outbreak day

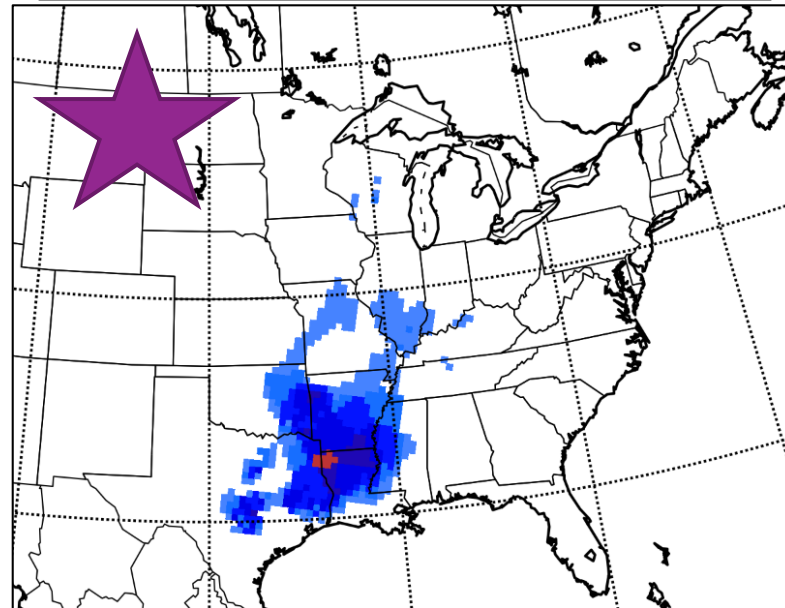 ▶ NARR severe hail counts and area

March 26th, 2000

MESH area on NARR grid
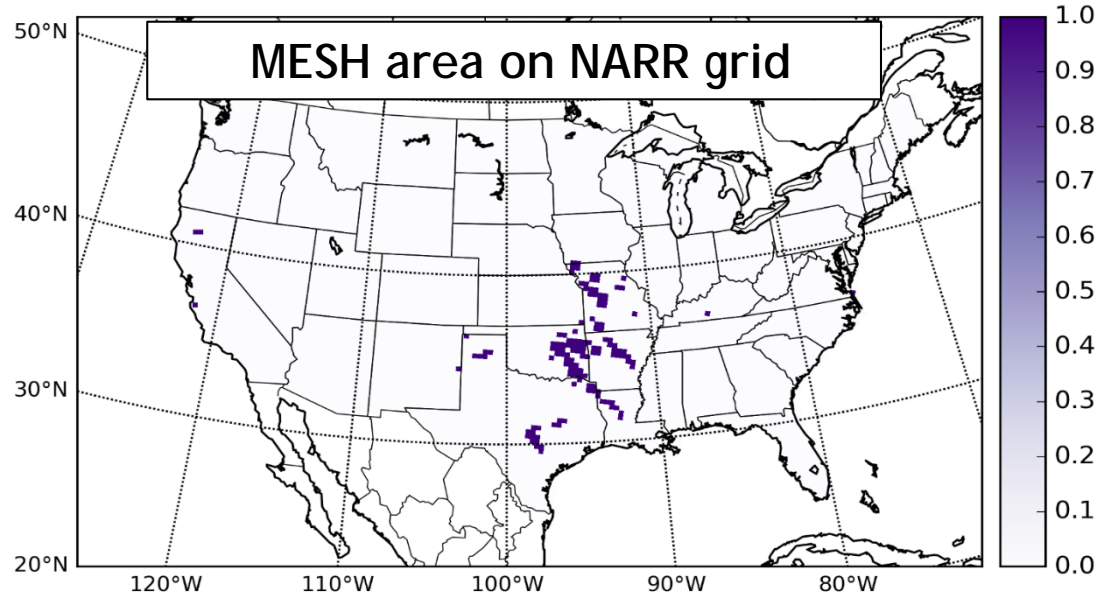
Results for the other 3 outbreak cases similarly show that SCP ≥ 1 and CP > 0 best represents the MESH outbreak area
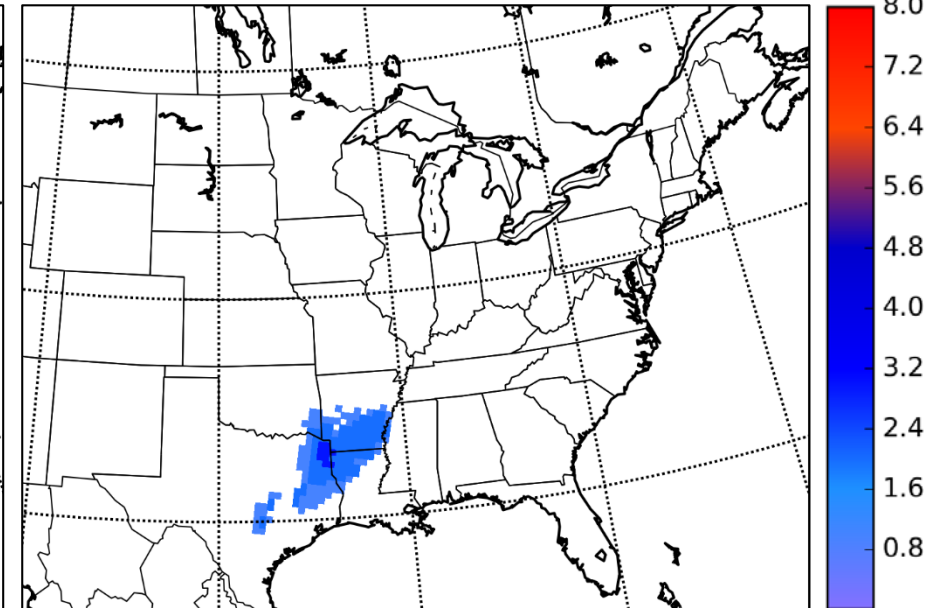
NARR hail counts for SCP > 0
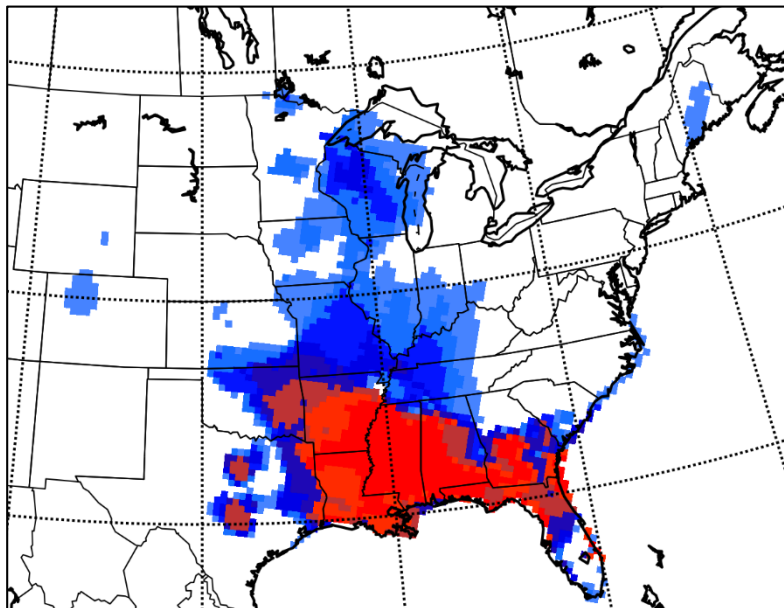
NARR hail counts for SCP ≥ 1

NARR hail counts for SCP > 5

Defining an Outbreak Day

► NARR hail counts ≥ 1000
► NARR hail area ≥ 500

Outbreak Case	NARR Hail Counts (SCP >= 1, CP > 0)	NARR Hail Area (SCP >=1, CP > 0)
March 26th 2000	1487	620
May 18th 2000	4070	1394
April 18th 2002	3776	1423
April 28th 2002	4440	1940
Null Case	**NARR Hail Counts**	**NARR Hail Area**
April 6th 2002	618	331
June 8th 2001	742	347

Future work

- Determine SHO statistics for NARR using MESH

- Analyze short and long term trends in SHO spatial extent and frequency for MESH and NARR respectively

- Apply hail methodology to determine tornado outbreak environments within NARR

  - Analyze spatial trends within tornado outbreak environments

- Methodology can be applied to climate model projections to study future trends in severe hail and tornado outbreak environments

Thank you – Questions?