A Catalogue of Extremely Damaging Hailstorms

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1. Background

Average annual insured hail losses (property and crop) in the U.S. are about $1.65 billion, but with considerable interannual variability (Changnon et al. 2009).

Hail risk is a function of (Brown et al. 2015):

I. Intensity

- Size/number of hailstones, windblown hailstones, and duration of a hailstorm

II. Frequency

- Number of days with severe hail

III. Vulnerability/Exposure

- Type/density of insured assets, building materials, and material age

Goal: Construct a catalogue of the intensity of the costliest hailstorms to better assess evolving and hypothetical hail risk

2. Methodology

Events from 1995 to 2016 ranked using National Centers for Environmental Information property loss data, supplemented by state/regional insurance data

For each event, calculate two radar-derived products:

A. Hail Kinetic Energy (HKE) (Waldvogel et al. 1978)

- Measure of the energy per unit area of falling hailstones (J m^{-2})

$$\mathrm{HKE} = \int_0^T 5\times10^{-6}\times10^{0.084Z}W(Z)dt$$

- Evaluate HKE at z = 1.5 km
- Good spatial correlation with mean damages in case studies (Hohl et al. 2002)

B. Maximum Estimated Size of Hail (MESH) (Witt et al. 1998)

- Estimate of the potential size of hailstones (cm)

$$\mathrm{MESH} = \max_{0\rightarrow T}\left\{8.03\times10^{-2}\left[\int_{H_0}^{H_T}\mathrm{HKE}\times\mathrm{W(H)}\right]^{0.5}\right\}$$

HKE and MESH swaths may be used to evaluate expected loss ratios when combined with vulnerability/exposure data.

3. Distribution of Events

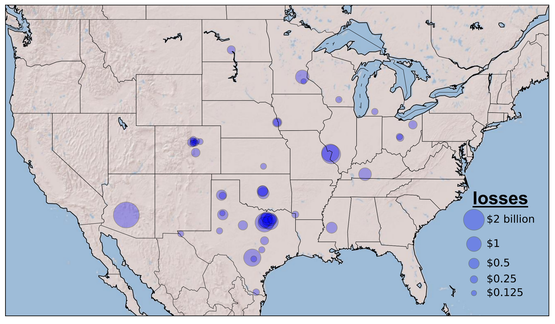

Fig. 1. Location of top-50 costliest hailstorms and losses (inflation adjusted to 2016 dollars)

TX: 22 events (9 in Dallas/Ft. Worth area)

CO: 9 events (8 in Denver area)

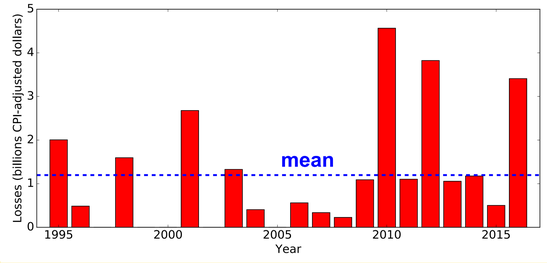

Fig. 2. Annual hail losses from top-50 events

2010, 2012, and 2016 are outlier years

4. Select Cases

Phoenix, AZ ($3.07 billion)
1800 UTC 5 October 2010 – 0100 UTC 6 October 2010

St. Louis, MO ($1.66 billion)
1800 UTC 28 April 2012 – 0300 UTC 29 April 2012

Dallas/Ft. Worth, TX ($1.16 billion)
2200 UTC 13 June 2012 – 0200 UTC 14 June 2012

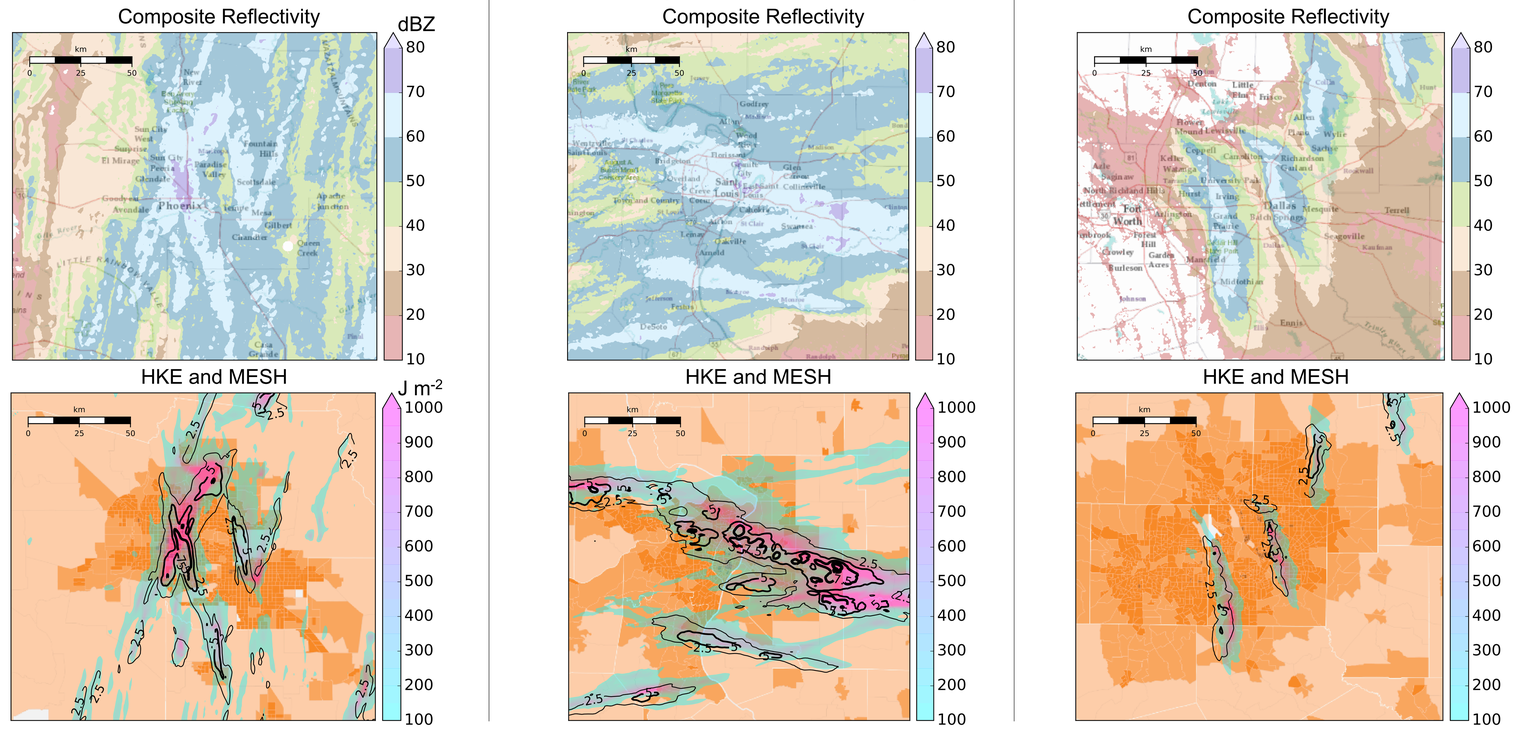

Fig. 3. (top row) Maximum composite reflectivity over duration of event (dBZ), (bottom row) HKE (shaded, J m^{-2}) and MESH (contoured, cm). Background map is the population density, with darker oranges indicating higher population density.

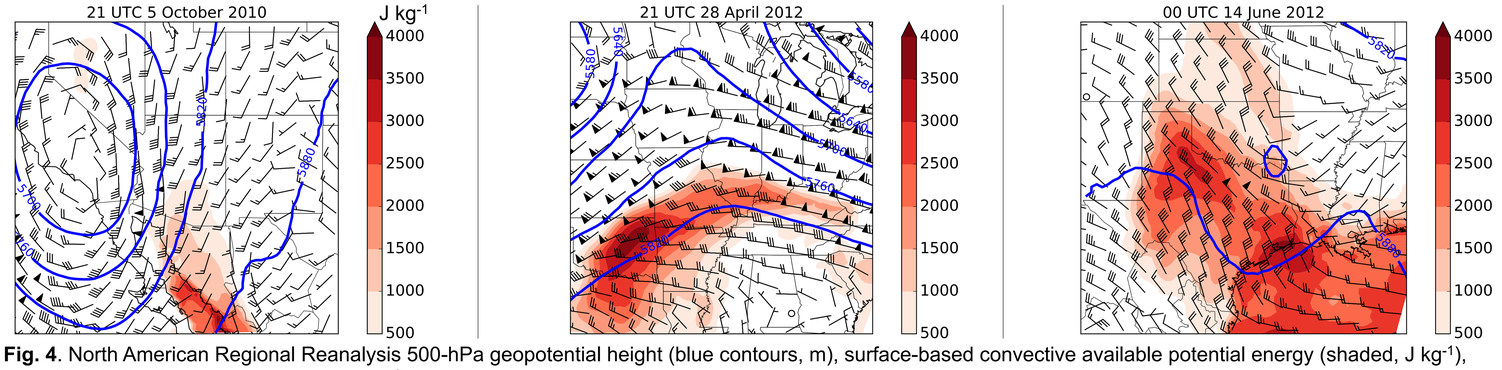

Fig. 4. North American Regional Reanalysis 500-hPa geopotential height (blue contours, m), surface-based convective available potential energy (shaded, J kg^{-1}), and 500–1000 hPa wind shear (barbs, m s^{-1})

5. Conclusions

- Intersection of high HKE (≥500 J m^{-2}) and large MESH (≥5 cm) over populated areas (dense insured assets) yields large property losses.
- Timing around evening rush hour exacerbates automobile losses.
- Storm mode is predominately supercellular. Events with largest losses have multiple supercells moving over the same area either serially or in parallel.
- Storm motion roughly parallels instability boundaries (warm/stationary fronts).
- Catalogue may be used to study the characteristics of damaging hailstorms from both meteorological and insurance perspectives.

6. References and Acknowledgements

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