Severe thunderstorms and climate change

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Whatever may be the progress of science, NEVER will observers who are trustworthy, and careful of their reputation, venture to foretell the state of the weather.

1846
2011 Tornadoes

- April was biggest calendar month ever
- One of ~6 biggest days (1974, 1932, 1920, 1908, 1884)
- One of smallest first three weeks of May ever (1987)
- Joplin
- Trends on really rare events?
A logical place to start

- Reports
  - In US and ESWD, target of opportunity
  - Changes in *de jure* and *de facto* standards

- Hail in other countries
  - China-yes/no reports available at >500 sites with some size data
  - Italy, France, and Spain-hailpad networks
F1+ Tornadoes Per Year (Black Dots)
F2+ per 1000 F1+ (Red)

F-scale adopted  Engineering, QRT
China-Hail Frequency

Xie et al. 2008 (GRL)
Impact of environment changes on hail size

(a) CAPE (UL)  Precipitable Water (UR)
(b) FLH (LL)

Xie et al. 2010 (J. Clim.)
France/Italy Hailpad Data

Occurrence

Berthet et al. (ECSS 2009)

Kinetic Energy

Eccel et al. (2011)
Hail Obs Summary

- Little change to slight decrease in occurrence
- Small decrease in mean size, but increase in kinetic energy of hailfalls
  - Start with slightly larger hail at beginning of fall
  - Melt more because of higher FLH, particularly impacting small
  - Leaves distribution shifted to larger stones
- Does it extend to larger sizes?
Using large-scale conditions

- **Downscaling**
  - Statistical (look at favorable conditions, ingredients-based)
  - Dynamical (nested models-Robinson et al-NEXT TALK)

- Applicable to past observations, climate models

- Define events in terms of environmental conditions
  - Storm “strength”-CAPE or $W_{\text{max}}$
  - Organization-0-6 km wind shear
  - Initiation?
Reanalysis Proximity Soundings (1997-9)

From Brooks et al (ECSS 2002)
Probability of Sig Severe

From Brooks et al (ECSS 2007)

Line ~ k * CAPE^*S06^*1.6
(Allen et al. -10:45)

From Brooks et al (ECSS 2007)
Satellite Estimate of Hail

AMSRE Hail Count All Months 200207–200806

Storms per month per (500 km)^2, for 4 overpasses/day

(Cecil et al., in press)
Individual threats

- Consider probability of different threats, given significant severe
- Probability of big event given any event
- Focus on patterns
Conditional Probability of Events Given Any Significant Event
Probability (%) of Sig Severe (US)
Hail (3 in)

Wind (75 kt)

Tornado (F3)

Tornado (F2-ESWD)

Grunwald and Brooks (ECSS 2009)
Importance of shear

- Big tornado years typically have hail as dominant non-tornadic event
  - Predominantly shear
- Intensity of tornado/hail increases with increasing shear
What will happen in the future

• Mean expected changes
  o CAPE goes up (related to moisture increase)
  o Shear goes down (decrease in equator-to-pole gradient)

• Climate model simulations
  o Three main groups (so far)
    ▫ GISS (parameterized updraft)
    ▫ Oklahoma/Melbourne
    ▫ Purdue
  o Look at favorable conditions (statistical modelling)
    ▫ Concentrate on changes in model world
Trapp et al. (2007, *PNAS*)

**21st Century-20th Century (RegCM)**

*CAPE*

*6-km Shear*

MAM

JJA

Trapp et al. (2007, *PNAS*)
Regional Climate Model simulations (RegCM)

Mean # days when CAPE x 6 km shear > 10,000

MAM

JJA

Trapp et al. (2007, PNAS)
Trapp et al. (2008) Regional Analyses
Updraft

Shear

Combination
Fractional Coverage of Shr6>=20 (CAPE>0), Central US

Year

Fraction

1880 1900 1920 1940 1960 1980 2000
Probability (%) of Sig Severe (US)
Closing thoughts

- Applicability of US to rest of world?
  - Thermodynamics dominated by boundary-layer moisture
  - China may follow, but other locations may not show same
- Need to improve environment-event relationships
- Higher resolution, better reanalyses
- Increased use of high-res models