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CLIMATE-DRIVEN INCREASE IN VARIABILITY AND MULTI-YEAR MEAN OF SEVERE THUNDERSTORM-RELATED LOSSES AND FORCING ENVIRONMENTS IN THE U.S. SINCE 1970

3 June 2013, ECSS 2013, Helsinki

Eberhard Faust

Munich RE

Source

Sander, J., J. Eichner, E. Faust*, and M. Steuer, 2013:
Rising variability in thunderstorm-related U.S. losses as a reflection of changes in large-scale thunderstorm forcing.
***Weather, Climate, and Society* (AMS)** (Early Online Release),
DOI: 10.1175/WCAS-D-12-00023.1

*Corresponding author:
efaust@munichre.com

Download:
http://journals.ametsoc.org/doi/abs/10.1175/WCAS-D-12-00023.1

Loss data source and normalizing past losses to current levels of destructible wealth

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- **Loss data** from global loss data base of reinsurer Munich Re.
  Most comprehensive global loss data base (Kron *et al.*, 2012, NHESS, **12**).

- Remove signal of increasing destructible wealth (= economic growth) from loss time series

  Normalization of past **direct economic losses** to current levels of wealth:

$$loss_{normalized\ \ today} = loss_{yr\ of\ event} * \frac{nominal\ destructible\ wealth_{today}}{nominal\ destructible\ wealth_{yr\ of\ event}}$$

- Two **proxies** for wealth used:

  - **building stock**
    (number of home units) x (nominal median value of homes)

  - **GDP**
    (population) x (nominal GDP per capita)

Why selecting events exceeding a threshold of normalized loss - $250m economic / $150m insured?

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- *Potential for **non-homogeneity** in norm. losses over time**:***
  Expanding built-up areas ⇨ increasingly detected losses over time.

  Causes: E.g., **shifts of population** from northeast to southern parts,
  simple local **population growth**.

- To ensure **homogeneity of the normalized loss events covered**:

  - Find **threshold** selecting **sizeable normalized loss events** (that would have been detected at any time).

  - Here: per-event threshold of US$ 250m (US$ 150m insured) in normalized loss, **associated with multi-state loss** during all of the analysis period

- Normalized loss events exceeding US$ 250m account for **80%** of the total loss aggregate in the analysis period.

Effect of normalization and selection of a high loss threshold on thunderstorm-related losses

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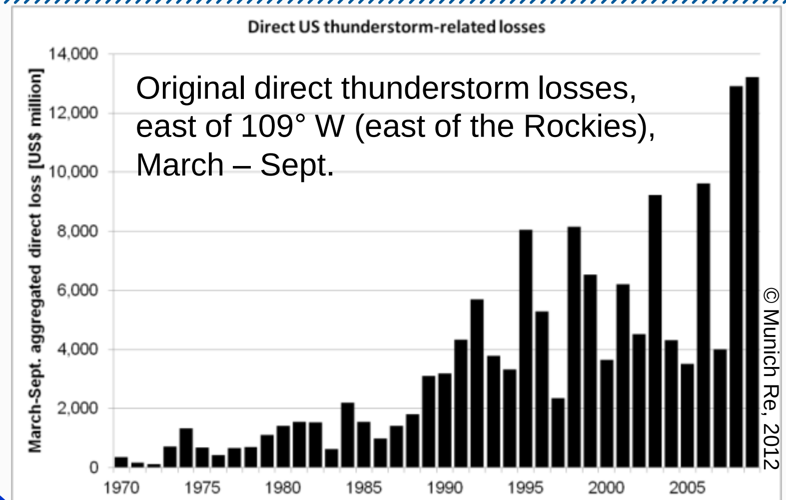
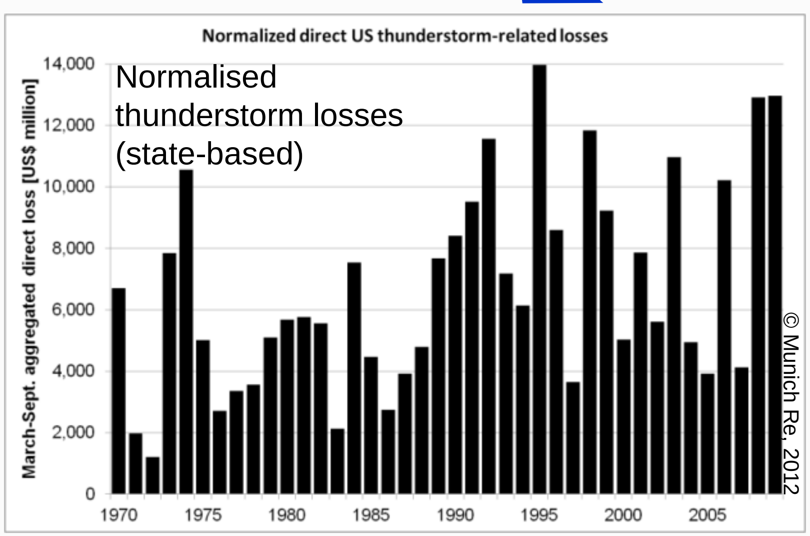
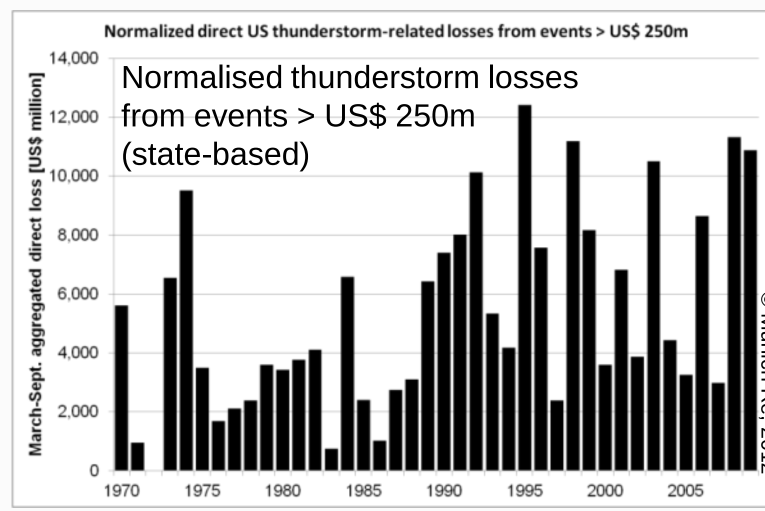


Normalisation using *housing stock* as a proxy for destroyable wealth



Selecting sizeable multi-state loss events (> $250m) to ensure homgeneity in detection.



Time series 1970 – 2009 of annually aggregated direct and insured losses from US thunderstorms

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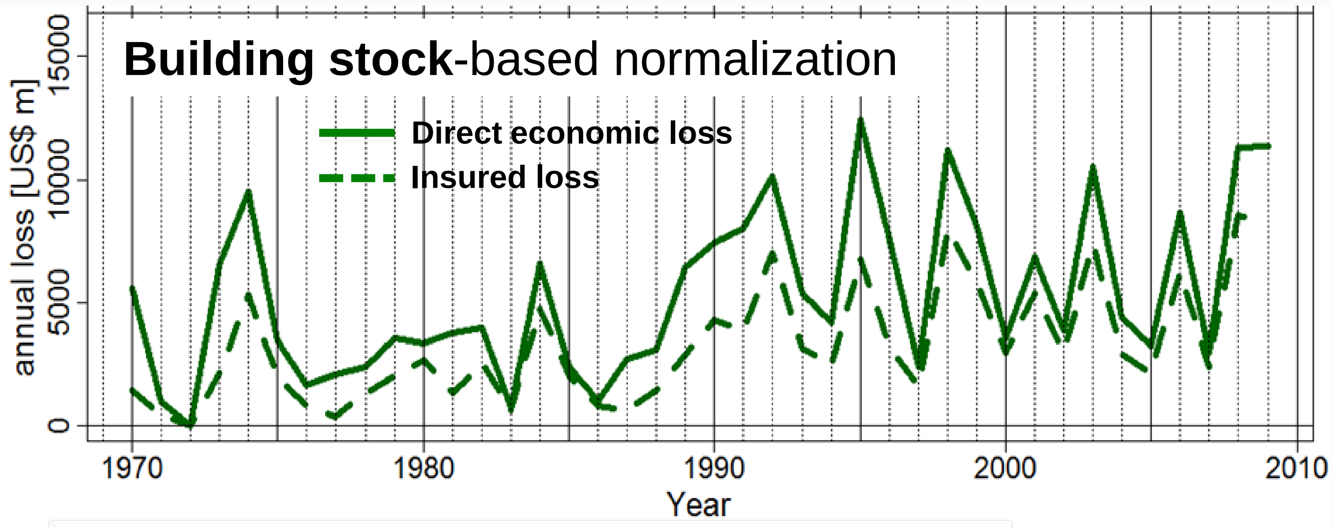
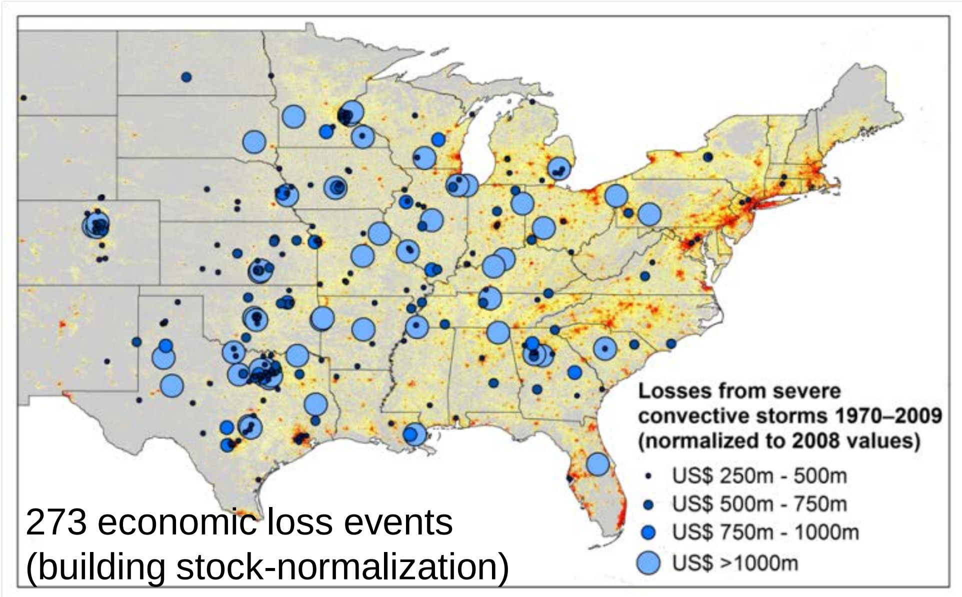


Loss events exceeding **$250m** (direct economic) and **$150m** (insured); Season March – September, contiguous USA, east of 109° W.



Positions of thunderstorm-related damage events, i.e. main focus of loss (normalized loss ≥ $250m)

Source: Sander, J., J. Eichner, E. Faust, and M. Steuer, *Weather, Climate, and Society*, March 2013, DOI: 10.1175/WCAS-D-12-00023.1

Analysis domain covered by reanalysis data and *Thunderstorm Severity Potential* (TSP)

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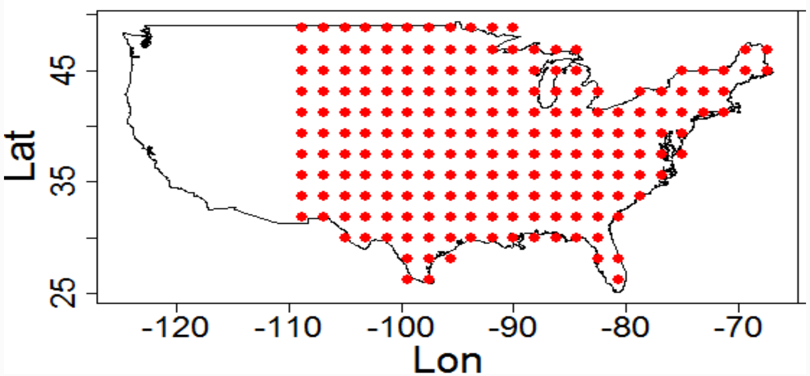

- 6-hourly NCEP/NCAR reanalysis data, (1.875° x 1.915°)
- 1970 – 2009, March – September.

- Potential for **non-homogeneity in reanalysis** (use of satellite data from 1970s onwards, changing number of soundings since the late 1980s, etc.).

- **Potential for severe thunderstorms to develop**

Thunderstorm Severity Potential $\mathbf{TSP = w_{max} \times DLS_{6km\ AGL\ -\ GL}}$ [J kg^{-1}]

with $w_{max} = \sqrt{2 \times CAPE_{mixed\ layer\ 100\ hPa}}$ (potential *maximum updraft velocity*)

TSP: ***thunderstorm forcing variable.*** Trigger mechanisms are not accounted for.

- Severe thunderstorm forcing environments defined by very high value of **TSP = 3,000 J kg^{-1}**, corresponding to 99.99th percentile of distribution.

Distribution properties

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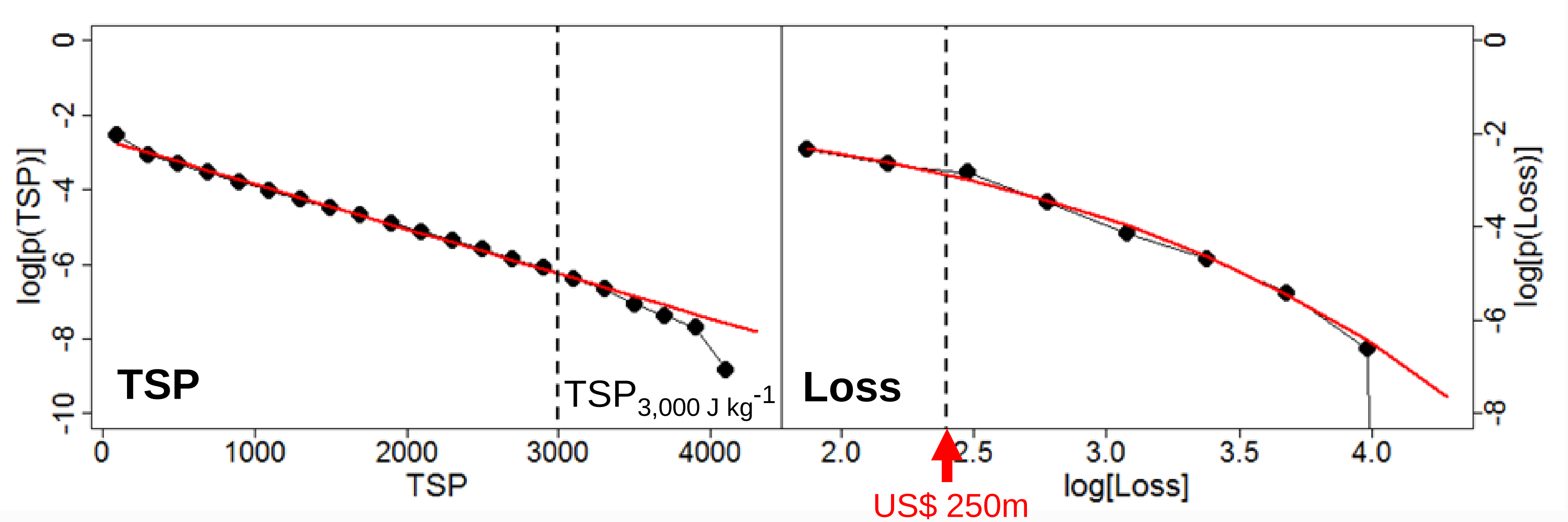

Exponential shape, **short-tail** behavior, upper limit at ~ 4,000 J kg^{-1} ,
→ small variability among extreme TSP

Stretched exponential distribution type, **fat-tail** behavior
→ large variability among extreme losses

Correlating TSP environments and norm. **economic** losses on a seasonal basis (counts and aggregated values)

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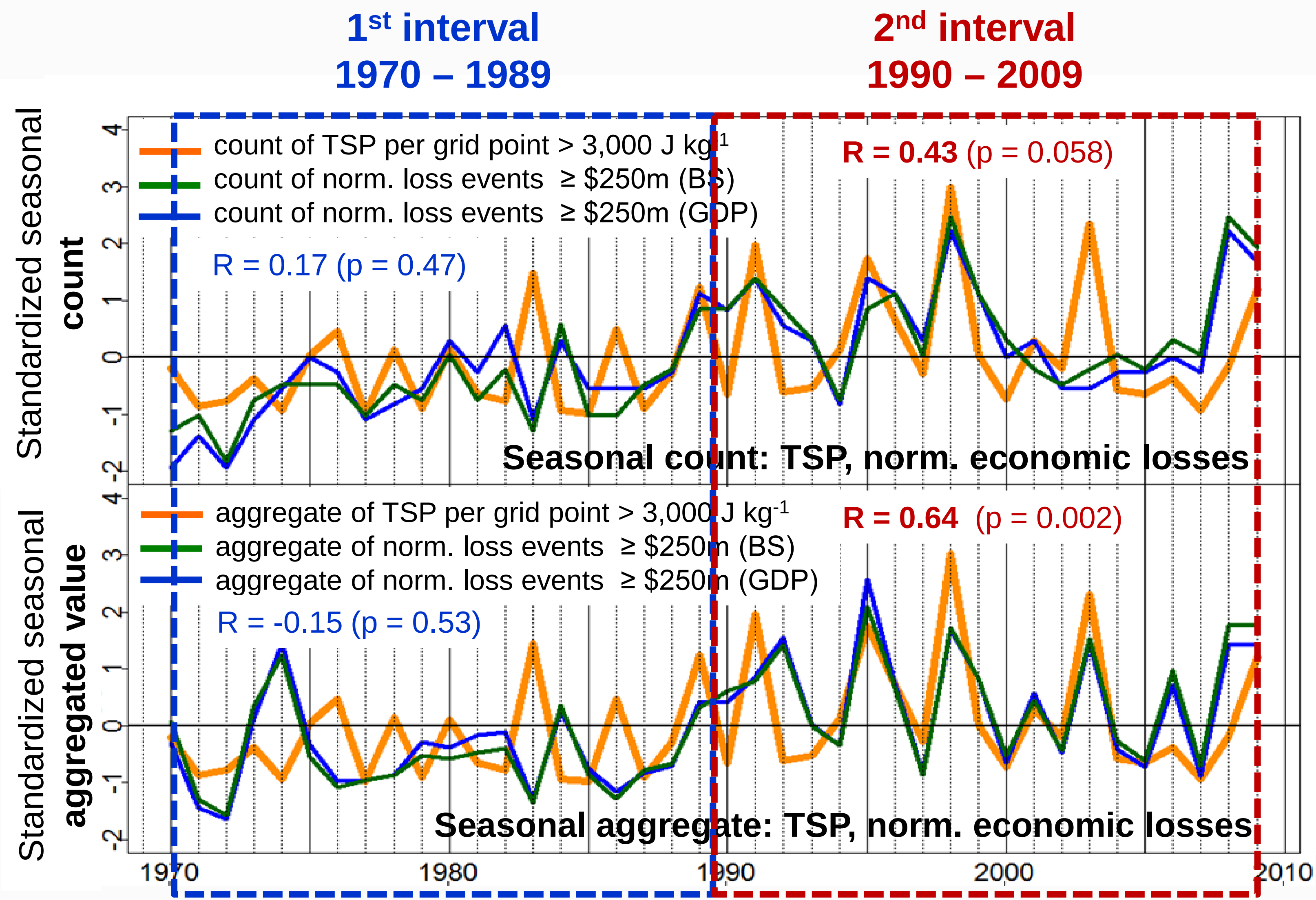


Change 1st ⇨ 2nd interval (loss):

Variability (StDev): ~ factor 1.5

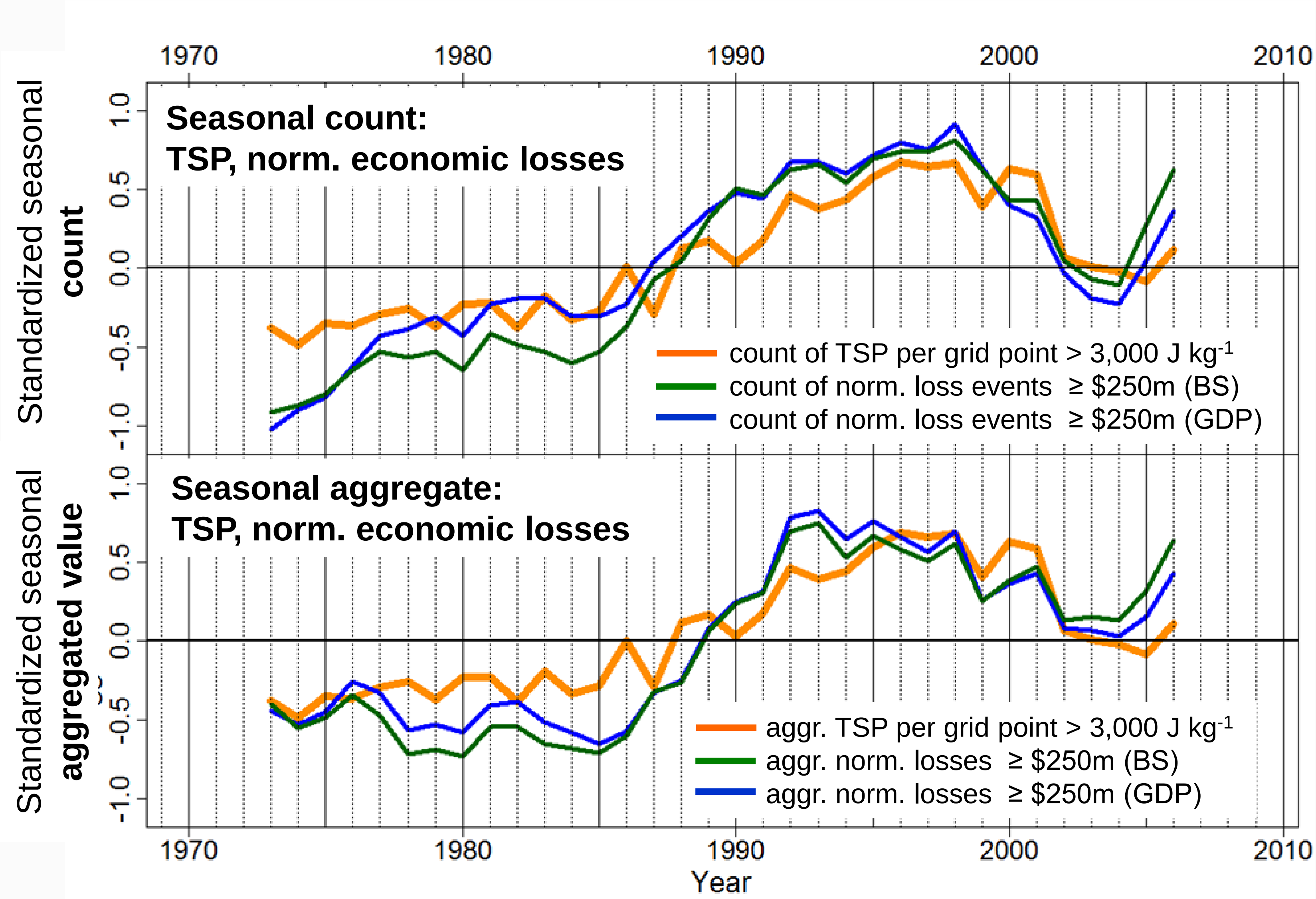
Mean: ~ factor 2.0

Variability (StDev): ~ factor 1.4

Mean: ~ factor 2.0

BS, GDP: different normalization approaches using either building stock (BS) or GDP (GDP) as a proxy for wealth

Filtering for longer-term variability: 7-year running means



March-Sept. aggregate of maximum potential thunderstorm updraft velocity (US, east of 109°W)

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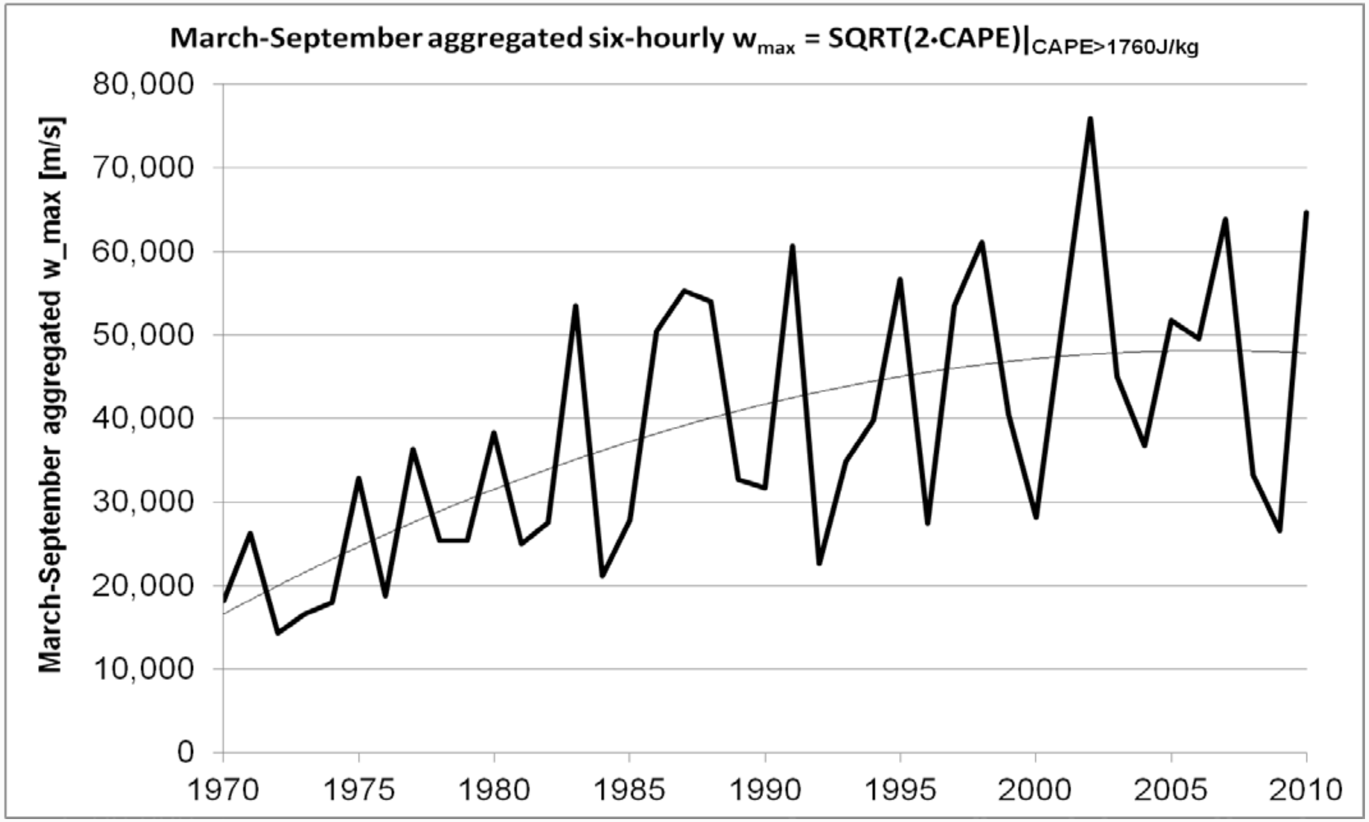
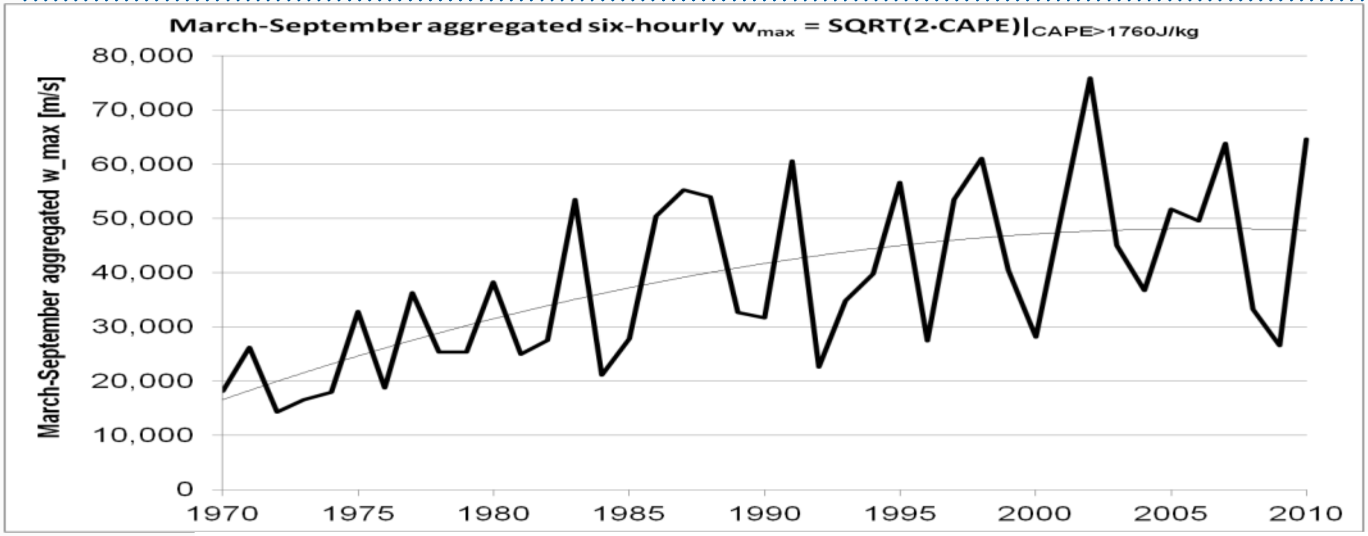


Seasonal aggregate of maximum thunderstorm cell updraft velocity (exceeding a threshold) is rising.

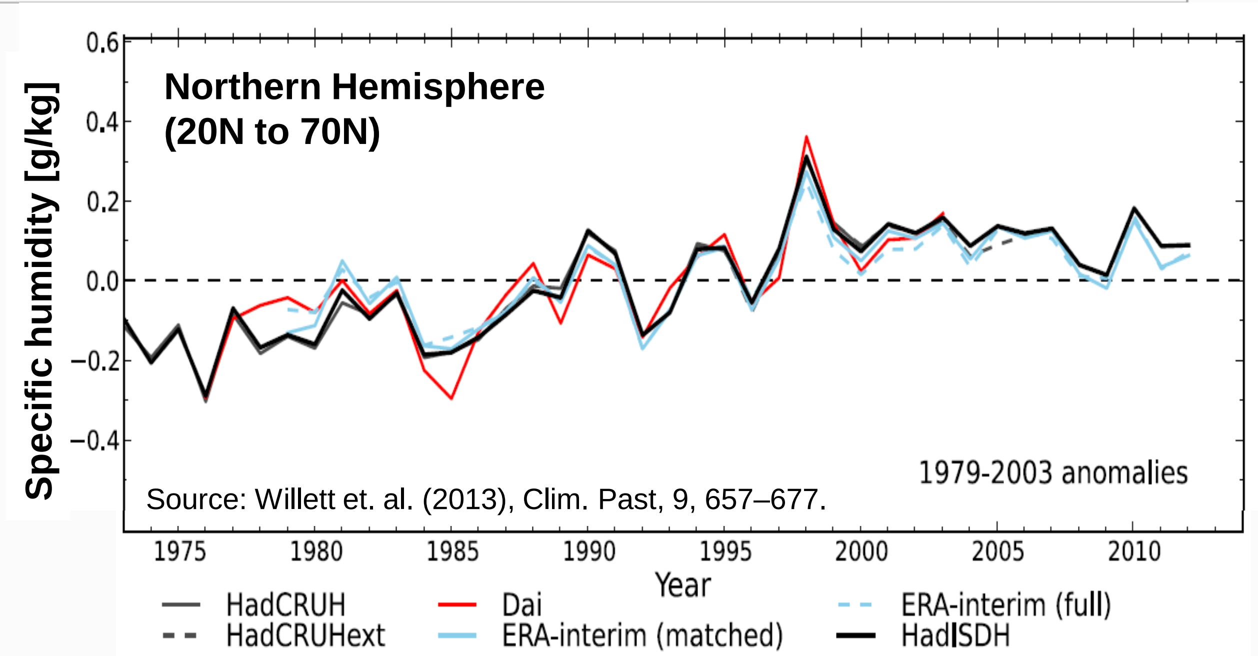
Six-hourly w_{max} over period 1970-2010, aggregated per March – September season from analysis domain (NCEP/NCAR reanalysis).
Threshold of SQRT(CAPE) = 42 m s^{-1} (corresponding to $CAPE_{ml}$ ~ 1,760 J kg^{-1}) was applied.

March-Sept. aggregate of maximum potential thunderstorm updraft velocity (US, east of 109°W)



Six-hourly w_{max} aggregated per March – September season (1970-2009) from analysis domain (NCEP/NCAR reanalysis).

Threshold of SQRT(CAPE) = 42 m s^{-1} (corresponding to $CAPE_{ml}$ ~ 1,764 J kg^{-1}) was applied.



Source: Willett et. al. (2013), Clim. Past, 9, 657–677.

Specific humidity has risen in large parts of northern hemisphere

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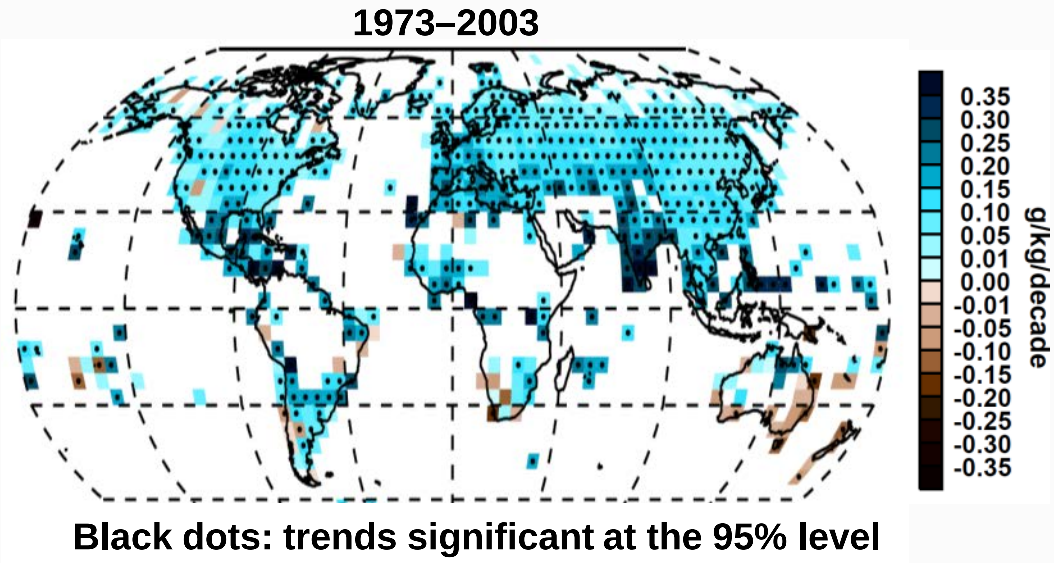

Source: Willett et. al. (2013), Clim. Past, 9, 657–677.

Wide-spread rise in near-surface **specific humidity** in NH over period 1973-2003 (HadISDH).

Climate model study:
Increase is to be expected from anthropogenic climate change (Willet et al., 2010, Environ. Res. Letter, **5**; see also Santer et al., 2007, PNAS, **104**)

Climate change projection study of severe thunderstorm environments (CAPE, Deep Layer Shear) by Trapp et al., 2009:

- **Increase** in number of days with severe thunderstorm environments projected over the period 1950 – 2100.
- **Increasing specific humidity** as an **essential contributor to increasing CAPE levels** identified as the main driver (Trapp, Diffenbaugh, Gluhovsky, 2009, GRL, **36**)

Findings in summary

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- **Increase** in **variability** and **mean level** of **severe thunderstorm-related normalized losses** (USA east of Rockies, 1970 – 2009, March – September).

- Changes in losses are **reflecting the increasing variability and mean level in thunderstorm forcing**, i.e. changing **climatic conditions.** This finding contradicts the opinion that changing socio-economic conditions are the only driver of change in thunderstorm-related losses.

- Changes coincide with a **rise in low-level specific humidity**, and in **seasonally aggregated potential convective energy** (or maximum potential updraft velocity). These effects are seen **consistent with the modeled effect from anthropogenic climate change**, that other studies have demonstrated.

Further research that is underway

Can we identify a variability signal similar to the one identified in the observation also in climate change projections?

THANK YOU FOR YOUR INTEREST

Eberhard Faust

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