RISING VARIABILITY IN THUNDERSTORM-RELATED U.S. LOSSES AS A REFLECTION OF CHANGES IN LARGE-SCALE THUNDERSTORM FORCING

14 March 2013, Workshop “Severe Convection and Climate“
Columbia University, New York

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Resources of this talk

This talk is based the following paper that was accepted for publication on 1 March 2013 by the AMS journal *Weather, Climate and Society*:

Sander, J., J. Eichner, E. Faust*, M. Steuer, 2013:
Rising variability in thunderstorm-related U.S. losses as a reflection of changes in large-scale thunderstorm forcing.

* Corresponding author.

Loss data source

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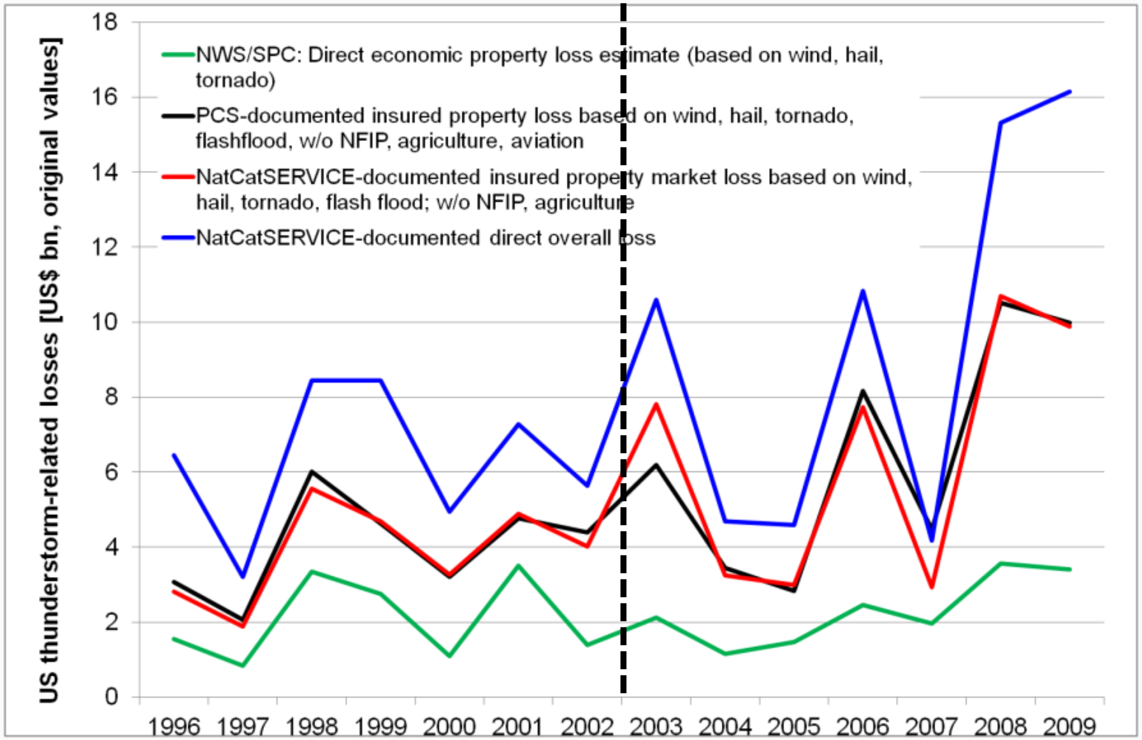
- **Loss data** taken from global loss data base of reinsurance company Munich Re: NatCatSERVICE. Documented by Kron *et al.*, 2012, NHESS, **12**, 535-550. Most comprehensive global loss data base.
- NWS-based *Storm Data* loss information (used by Simmons, Sutter, Pielke, 2011): *Massive underestimation* of aggr. direct thunderstorm losses at least since 1996.



1996-2002:
SPC *economic* losses = **53%** of *insured* losses

2003-2009:
SPC *economic* losses = **36%** of *insured* losses

Error!!!

Also decrease in volatility (SPC) is opposite to the other data sources and deemed as being flawed.

Normalizing past losses to current levels of destructible wealth

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

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

- Normalization based on **building stock** as a **proxy** of wealth:

$$loss_{norm\ .\ today} = loss_{yr\ of\ event} * \frac{[no.\, home\ units\ * nom.\, median\ home\ value]_{today}}{[no.\, home\ units\ * nom.\, median\ home\ value]_{yr\ of\ event}}$$

- Normalization based on **GDP** as a **proxy** of wealth:

$$loss_{norm\ .\ today} = loss_{yr\ of\ event} * \frac{[nom.\, GDP\ p.c.\ * population]_{today}}{[nom.\, GDP\ p.c.\ * population]_{yr\ of\ event}}$$

- Normalization of past **insured losses** to current levels of insured wealth:

$$insured\ loss_{norm\ .\ today} = loss_{norm\ .\ today} * \frac{insurance\ penetration_{today}}{insurance\ penetration_{yr\ of\ event}}$$

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

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- *Time series of normalized losses could be rendered* ***non-homogeneous*** *by increasingly built-up locations leading to increasingly detected losses over time.*
- Might be caused, for instance, by **shifts of population** over time from northeast to southern parts of the USA, or by simple local **population growth**.
- Route to ensure **homogeneity of the normalized loss events covered**: a **threshold** has to be found selecting **sizeable normalized loss events** that would have been detected at any time within the analysis period, i.e. particularly in the early years.
- We chose a per-event threshold of US$ 250m (US$ 150m insured) in normalized loss, which is **associated with multi-state loss** (on average, more than 6 states per event within a bin $250m ≤ loss < $300m in first decade 1970-1979).
- Aggregating all normalized loss events exceeding US$ 250m accounts for **80%** of the total loss aggregate in the analysis period.

Effect of normalization on thunderstorm-related losses

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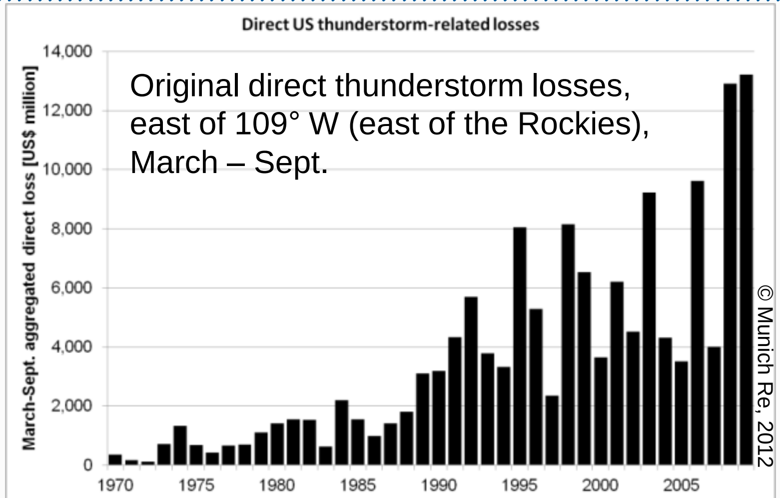
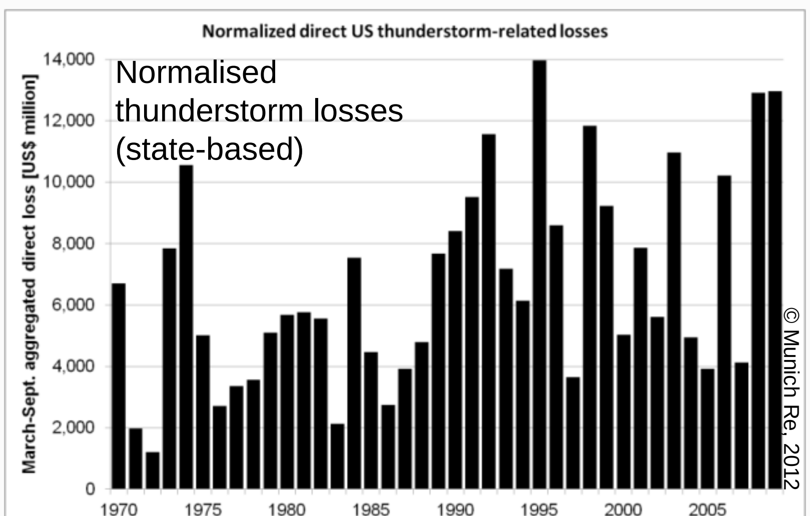
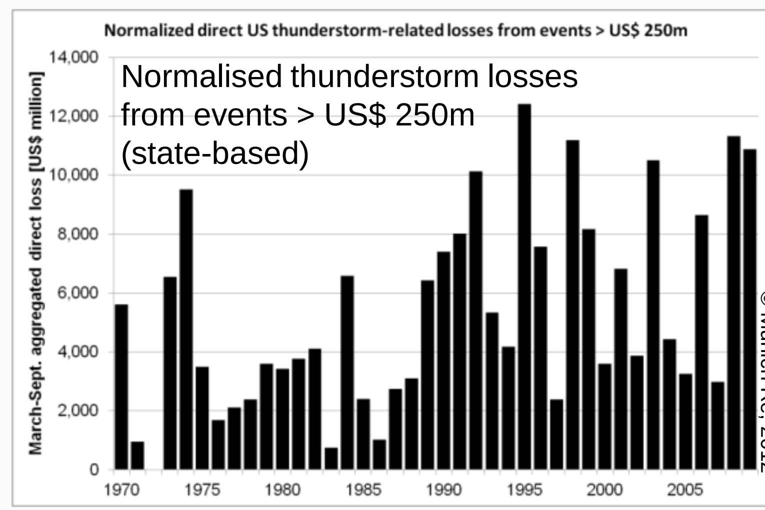
Normalisation using *housing stock* as a proxy for destroyable wealth







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

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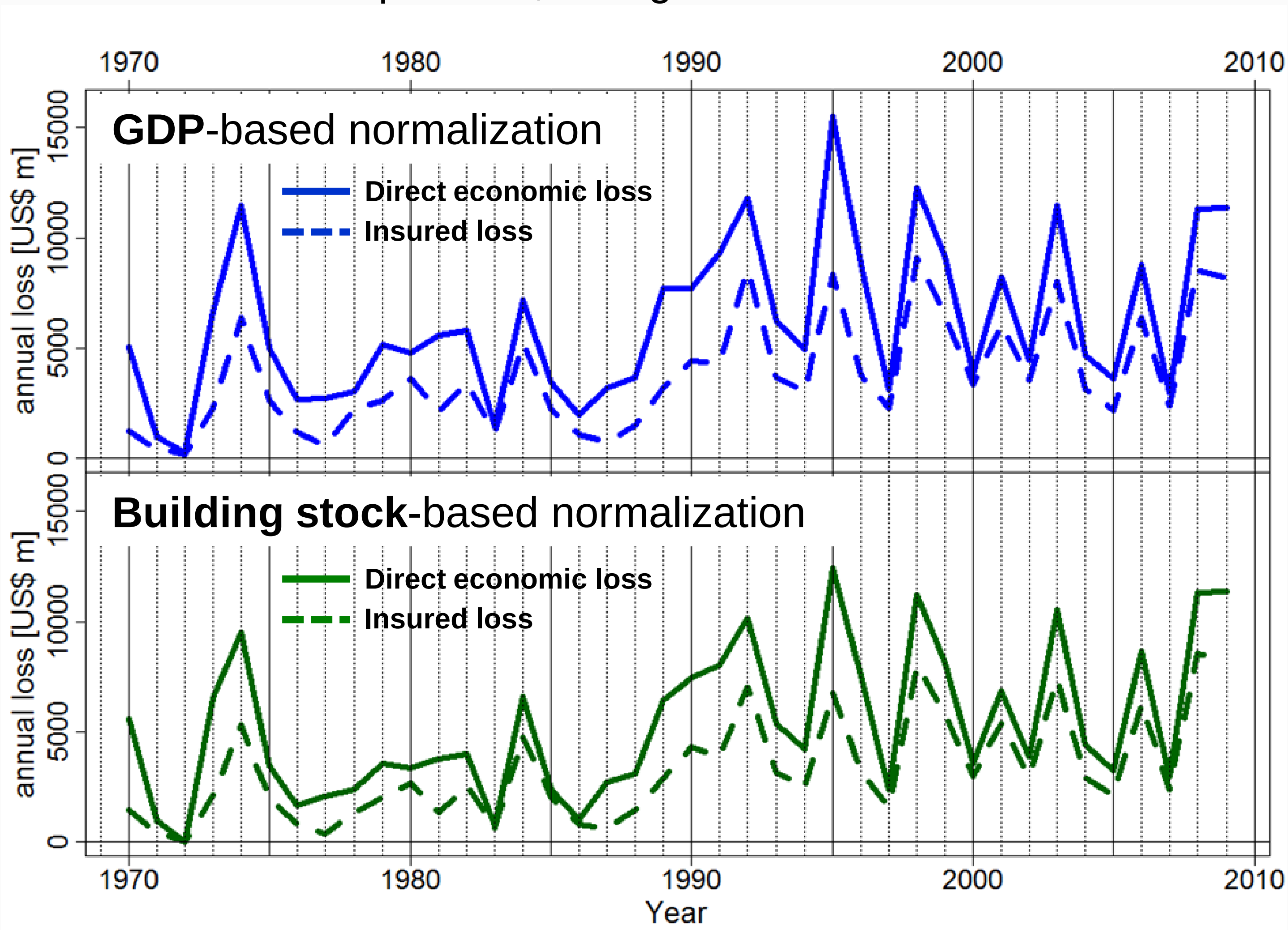
Loss events exceeding **$250m** (direct economic) and **$150m** (insured);
Season March – September, contiguous U.S.A. east of 109° W.



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

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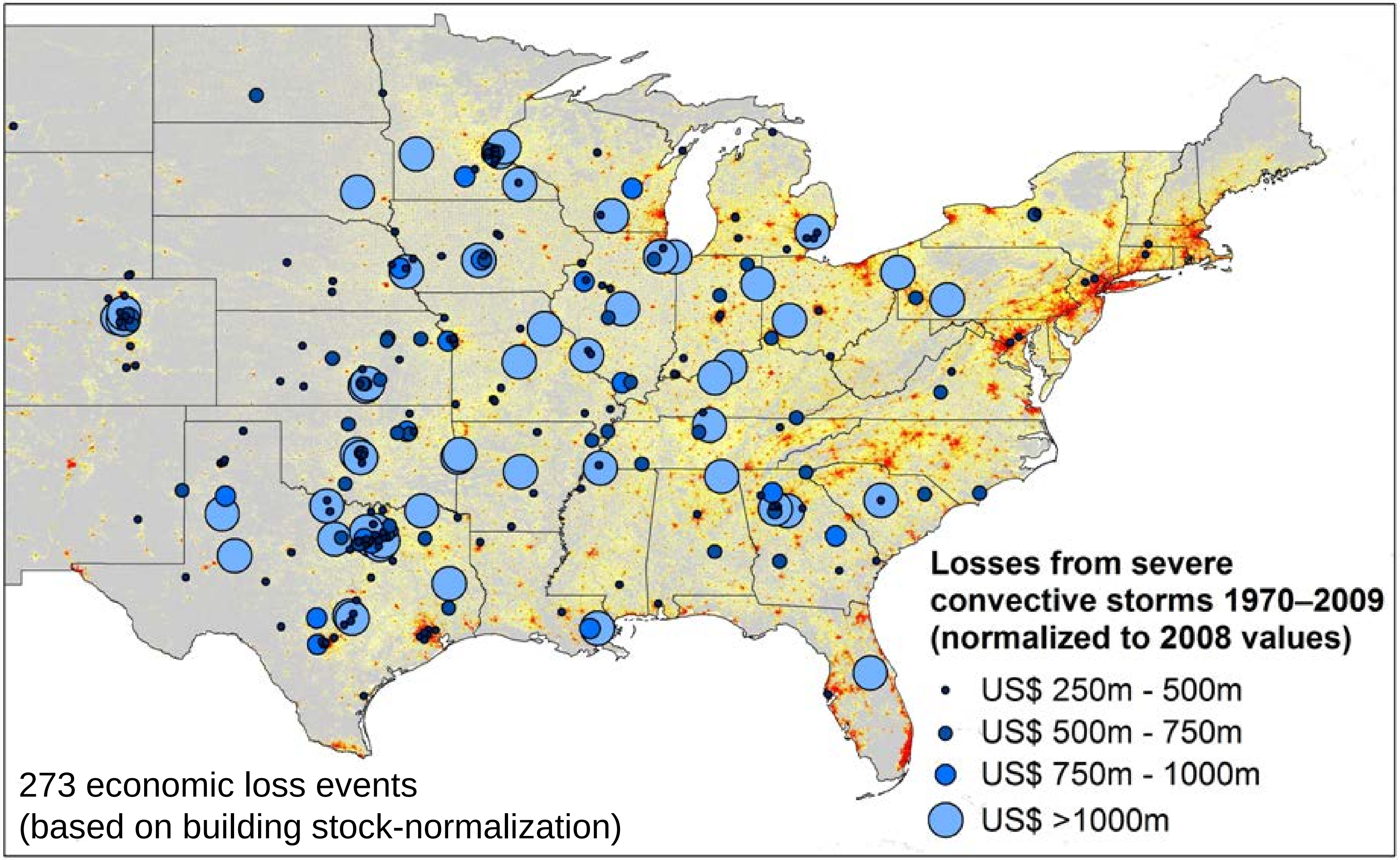

Analysis domain covered by reanalysis data and *Thunderstorm Severity Potential* (TSP)

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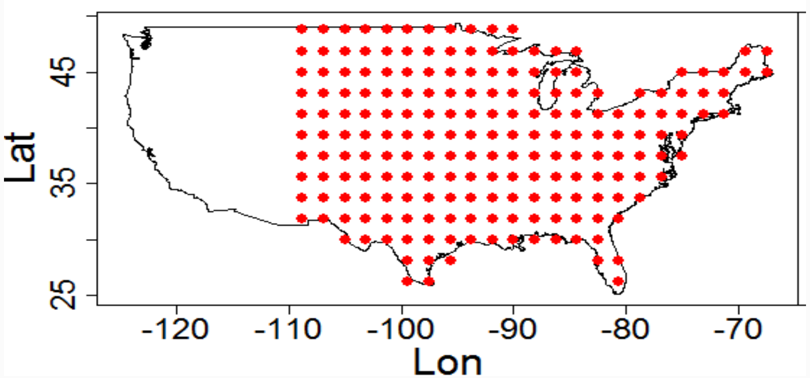

- 6-hourly NCEP/NCAR reanalysis data, resolution 1.875° in longitude, 1.915° in latitude
- 1970 – 2009, March – September.

- 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 is measured by combining $CAPE_{\text{mixed layer 100hPa}}$ and deep-layer vertical wind shear ($DLS_{\text{6km AGL - GL}}$):

Thunderstorm Severity Potential **TSP = $\mathbf{w_{max} \times DLS_{6km\ AGL\ -\ GL}}$** [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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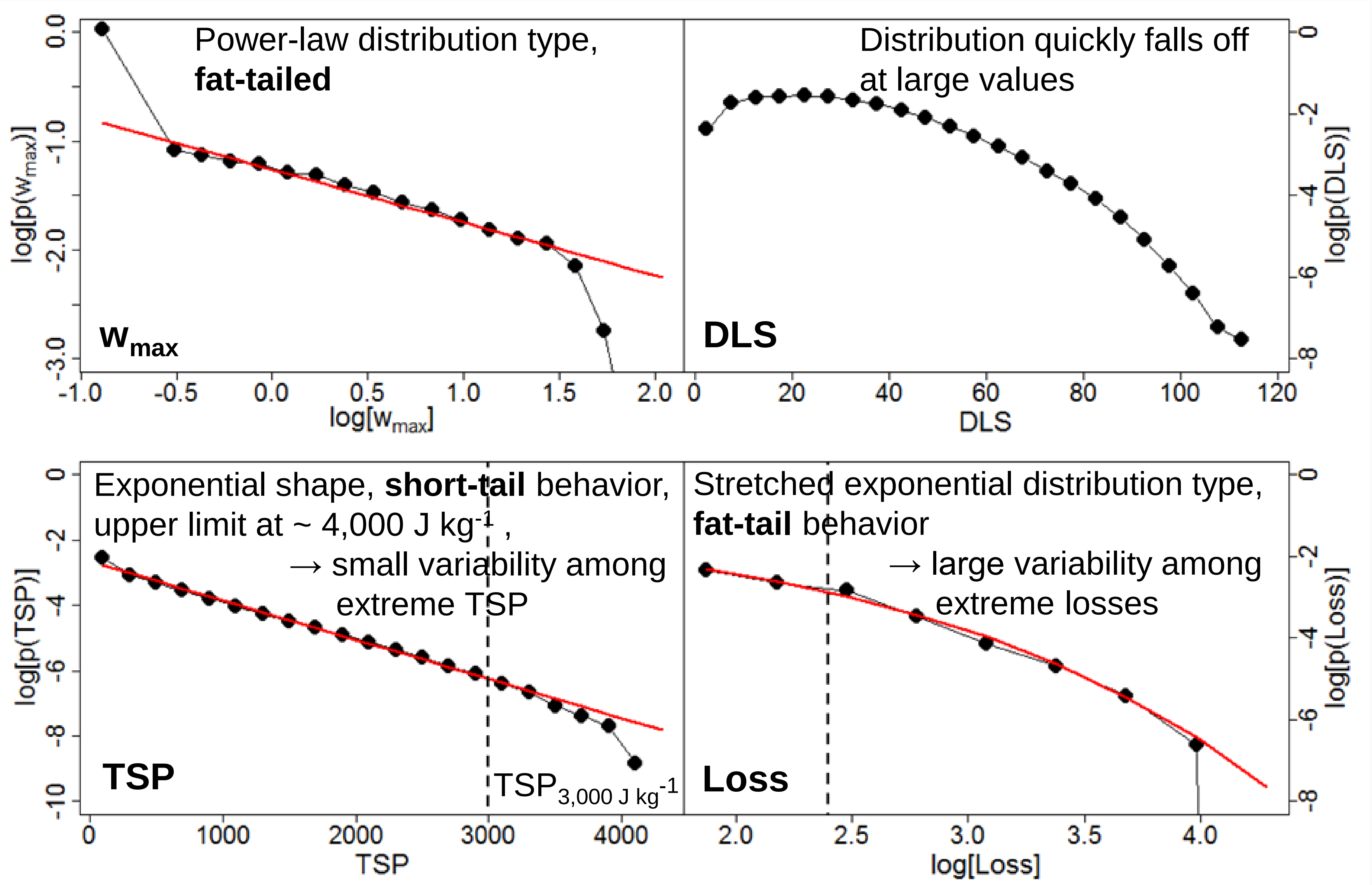
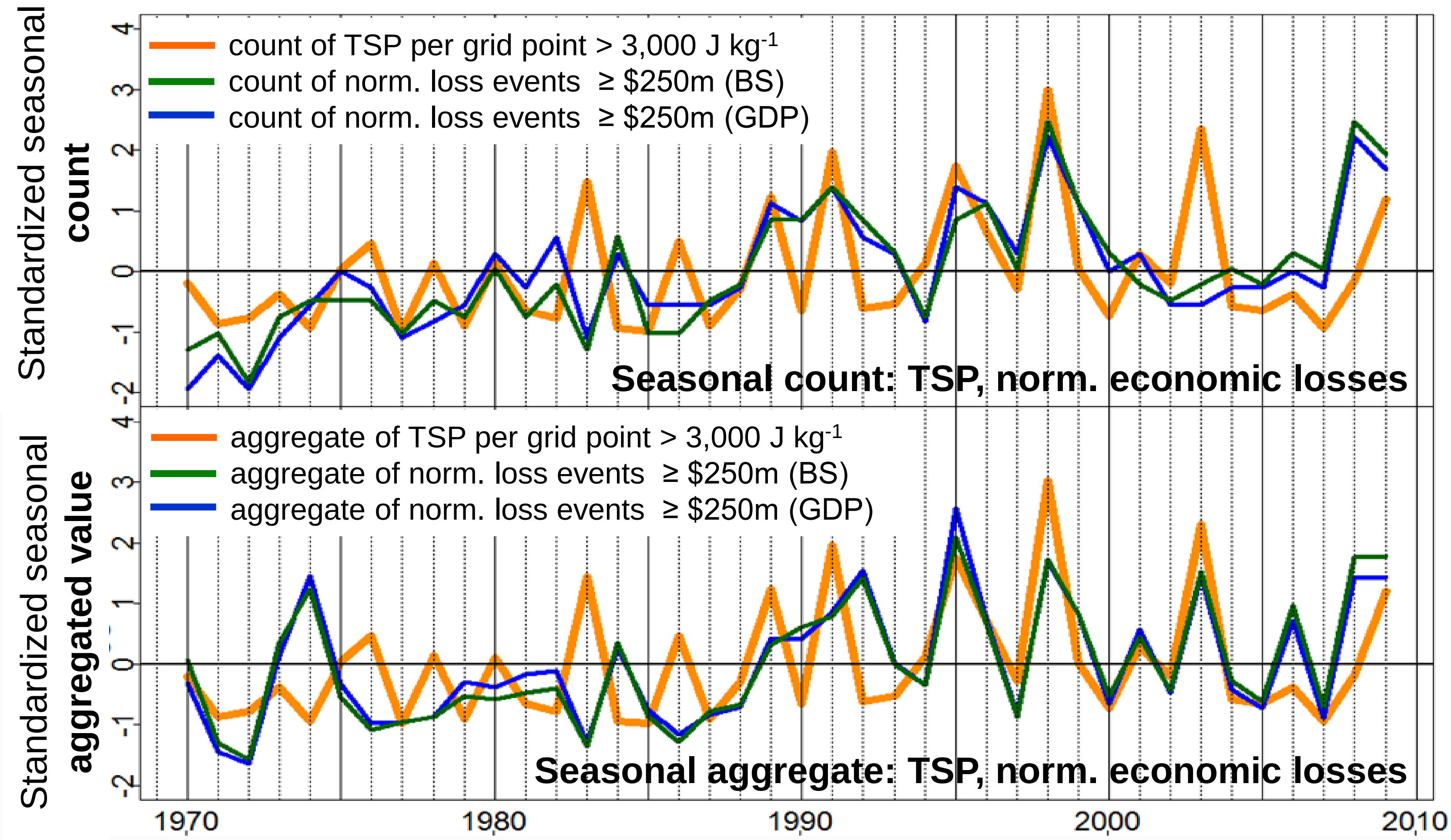


Correlating TSP environments and norm. **economic** losses on a seasonal basis (counts and aggregated values)



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

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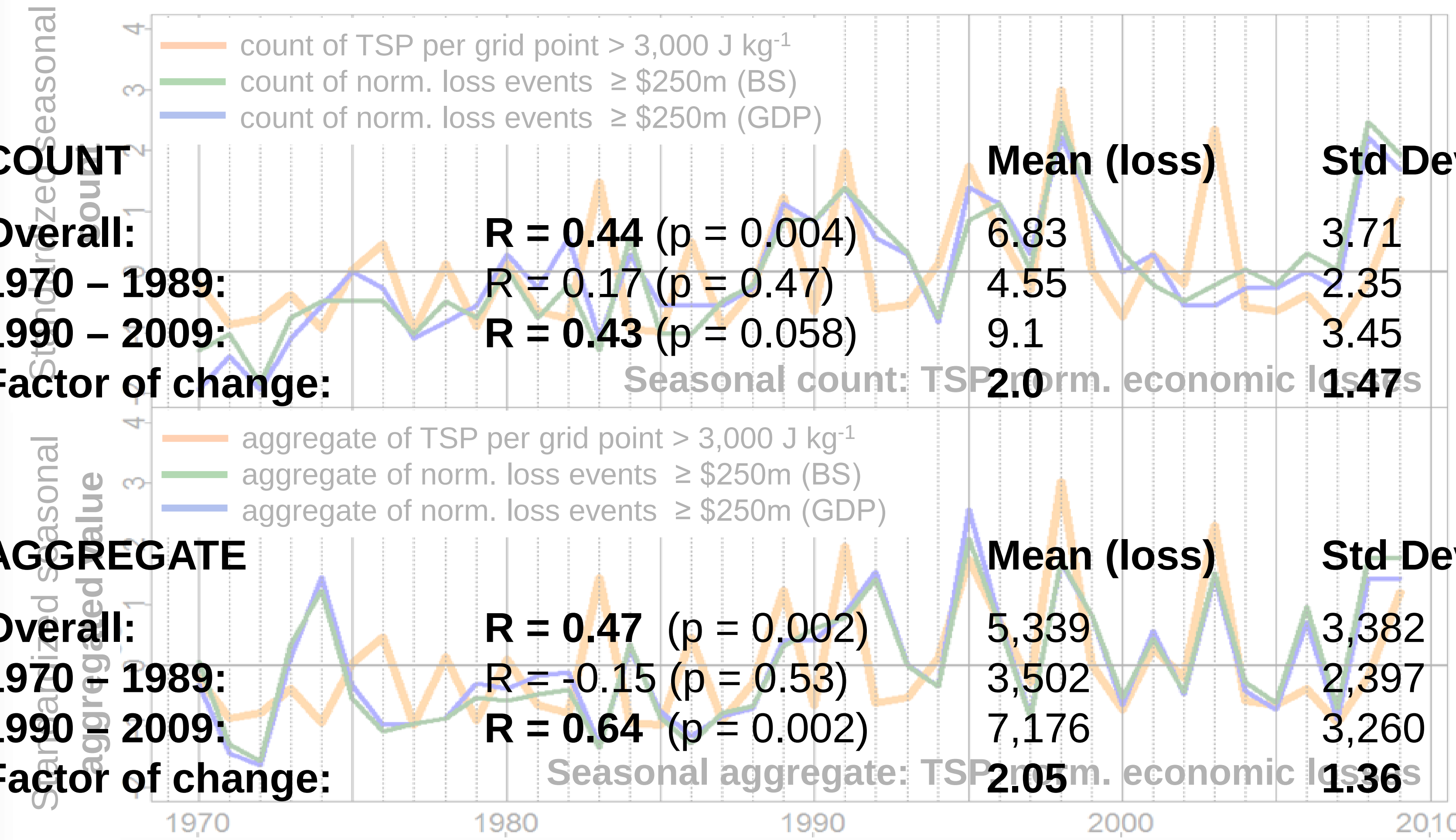

COUNT		**Mean (loss)**	**Std Dev (loss)**
Overall:	**R = 0.44** (p = 0.004)	6.83	3.71
1970 – 1989:	R = 0.17 (p = 0.47)	4.55	2.35
1990 – 2009:	**R = 0.43** (p = 0.058)	9.1	3.45
Factor of change:		**2.0**	**1.47**

AGGREGATE		**Mean (loss)**	**Std Dev (loss)**
Overall:	**R = 0.47** (p = 0.002)	5,339	3,382
1970 – 1989:	R = -0.15 (p = 0.53)	3,502	2,397
1990 – 2009:	**R = 0.64** (p = 0.002)	7,176	3,260
Factor of change:		**2.05**	**1.36**

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

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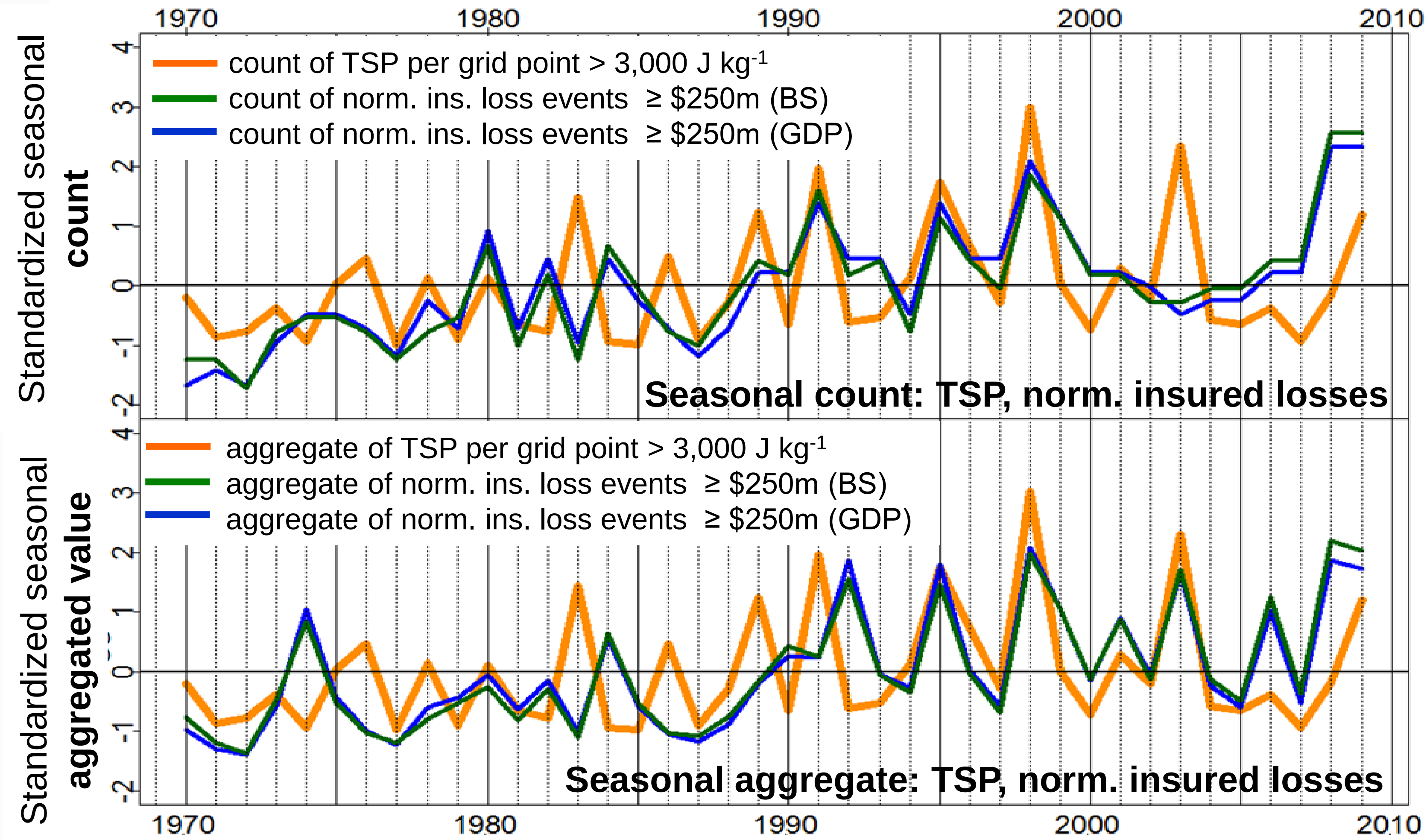
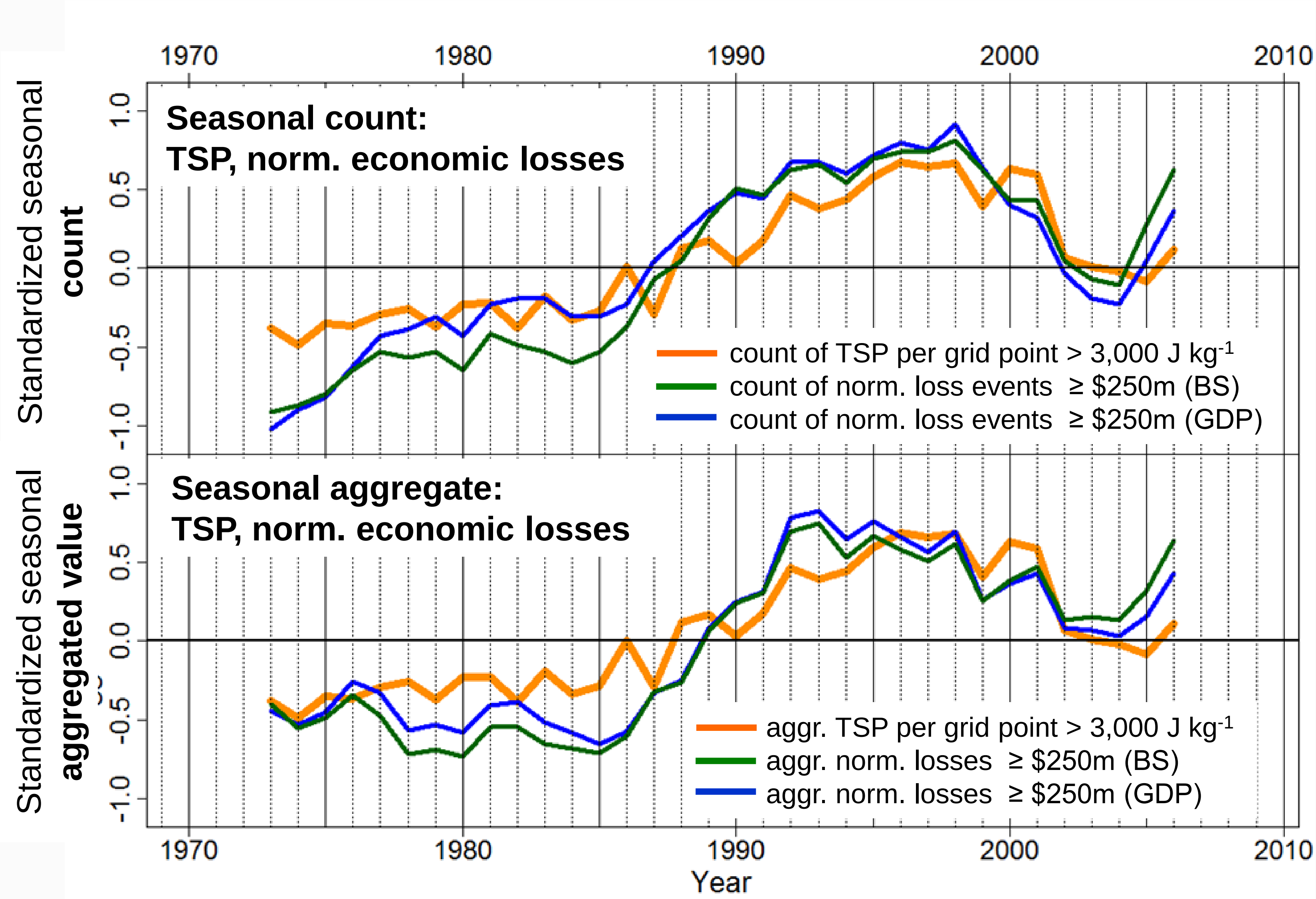


Filtering for longer-term variability:
7-year running means



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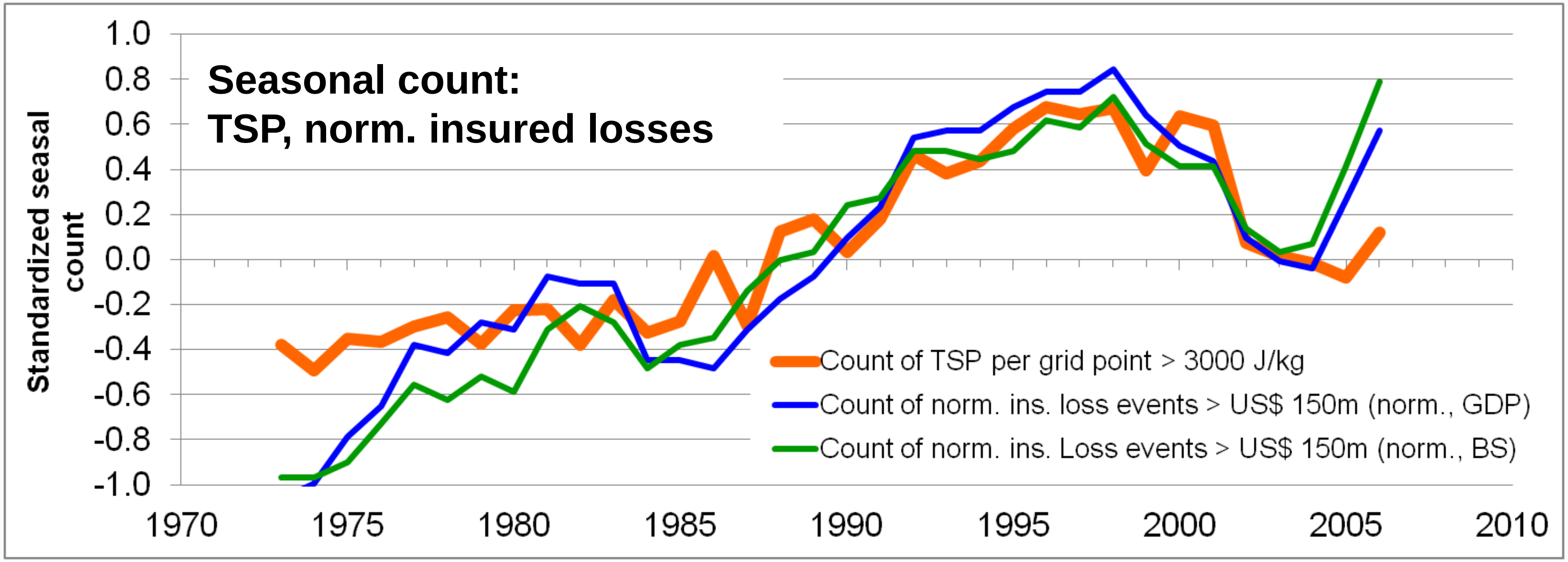
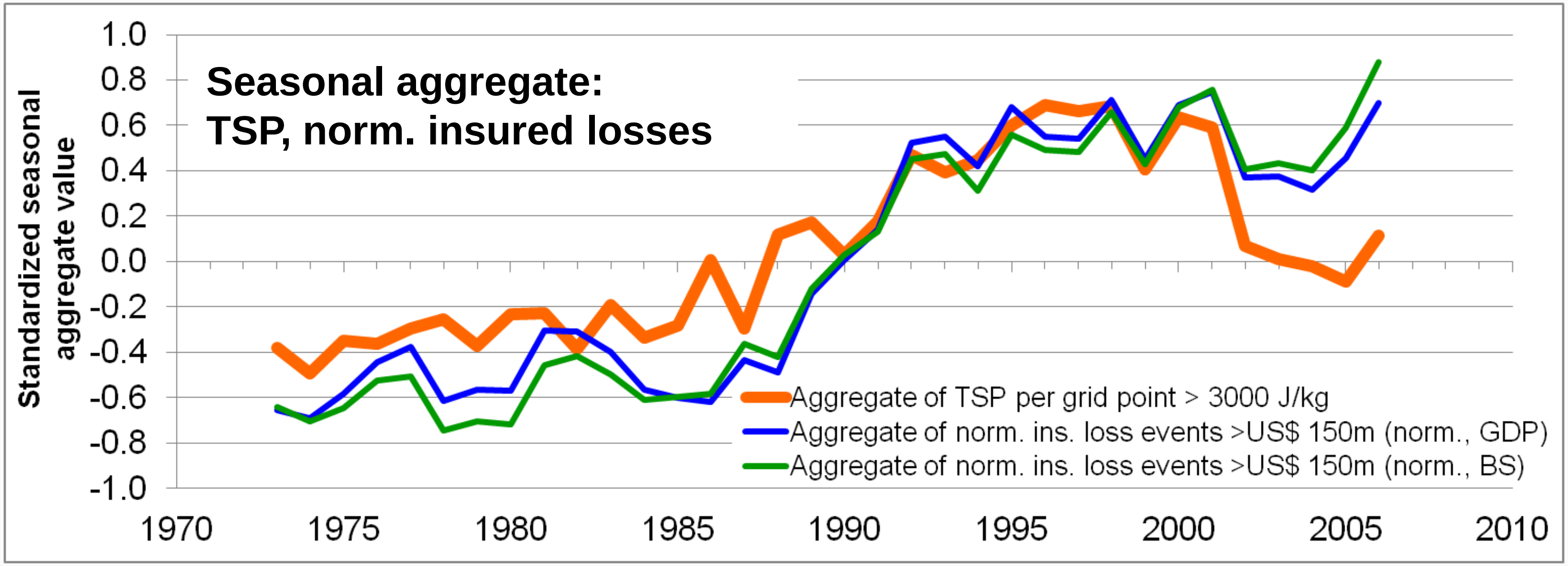
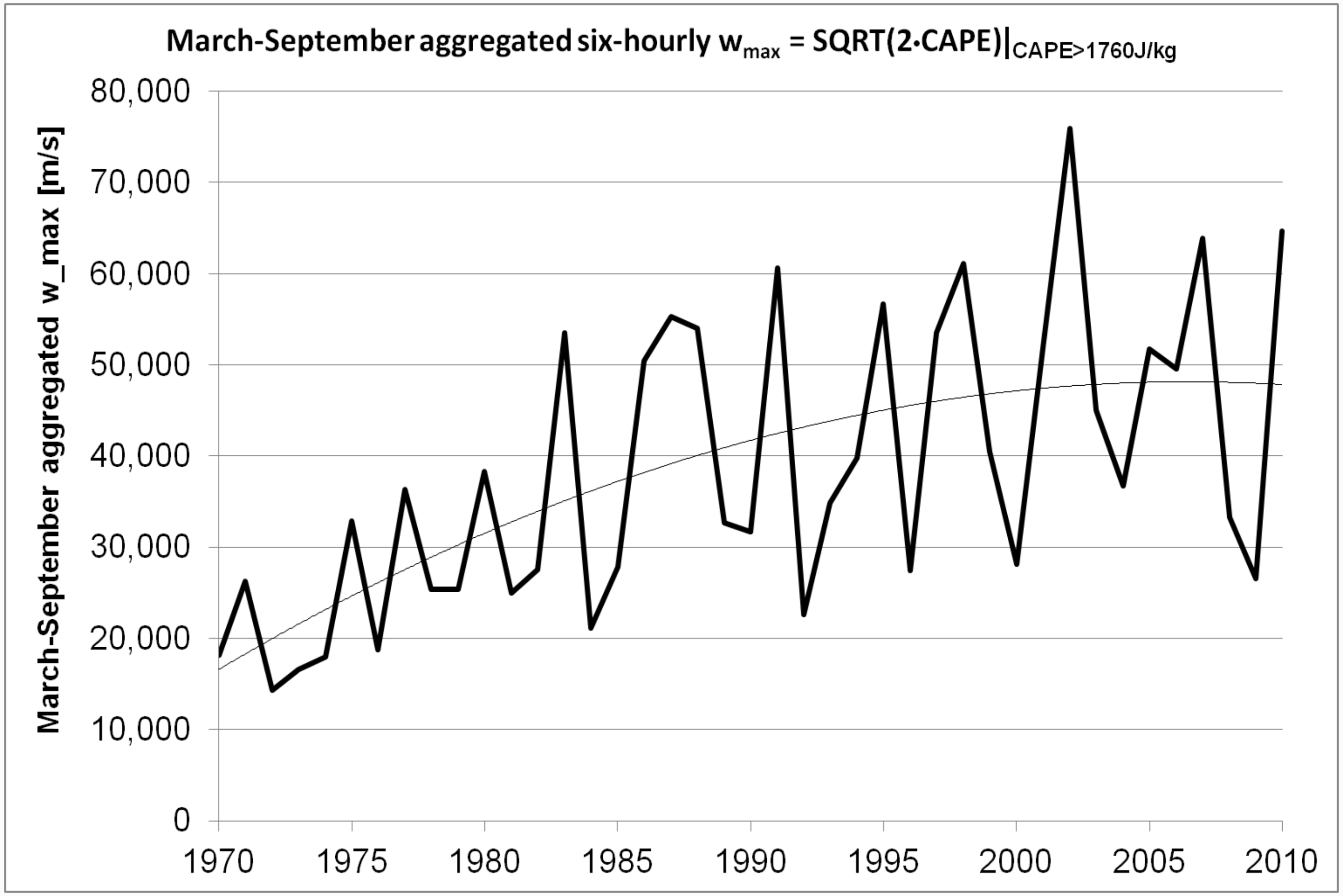




March-Sept. aggregate of maximum potential thunderstorm updraft velocity (US, east of 109°W)



Seasonal aggregate of maximum thunderstorm cell updraft velocity is rising.

Time series of six-hourly w_{max} over the period 1970-2010, aggregated per March – September season from all NCEP/NCAR reanalysis grid points within the analysis domain. A lower threshold of = 42 m s^{-1} (corresponding to $CAPE_{ml}$ = 1,764 J kg^{-1}) was applied. A $CAPE_{ml}$ value of approx. 1760 J kg^{-1} was identified in an analysis informed by German insurance hail-loss data as a threshold criterion for hail versus non-hail days (Kunz 2007).

Expected changes in severe-thunderstorm environments under climate change

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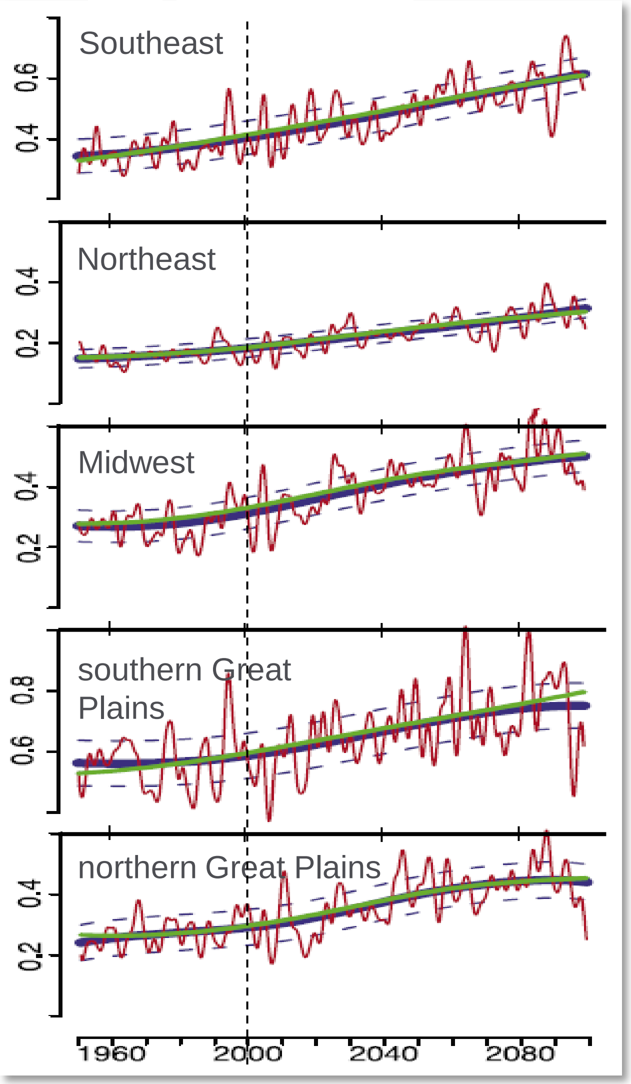
Trapp, Diffenbaugh, Gluhovsky, 2009, GRL, **36**: Number of days per grid point with severe thunderstorm environments as projected by a climate model ensemble for the period 1950 – 2010 (given that convective precipitation was simultaneously projected at this grid point)



Trapp et al., 2009: Indications of **increasing specific humidity (**as the main contributor to CAPE) that is driving up the annual frequency of severe thunderstorm environments in a transient climate model experiment.

Source:
Trapp, R.J., N.S. Diffenbaugh, A. Gluhovsky (2009): Transient response of severe thunderstorm forcing to elevated greenhouse gas concentrations, GRL 36

Specific humidity has been rising almost globally

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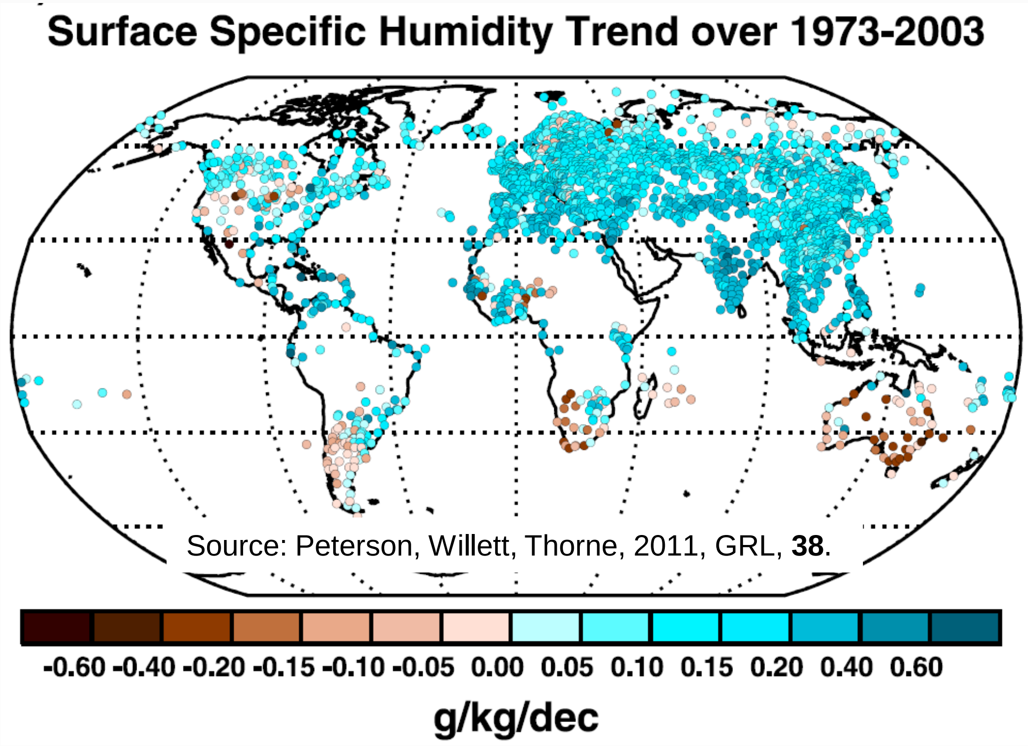

In the period 1973-2003, near-surface **specific humidity** has risen over most parts of the globe, as observed within the HadCRUH global land surface data.

- Increase has been shown to be in **sufficient statistical agreement with the results from (anthropogenically forced) climate model runs** over this period. (Willet et al., 2010, Environ. Res. Letter, **5**.)

- Similarly, climate model runs have corroborated changes in atmospheric moisture content over the oceans as inferred from satellite data (Santer et al., 2007, PNAS, **104**.)

To sum up…

An increase in the variability of severe thunderstorm-related normalized losses over the period 1970 – 2009 has been identified. This increase in variability can be demonstrated as **driven by increasing variability in thunderstorm forcing**, i.e. by **climate**.

The increasing volatility in seasonal thunderstorm forcing coincides with a rise in specific humidity and seasonally aggregated CAPE (or maximum potential updraft velocity) and CAPE volatility over time as inferred from reanalysis data. These effects are seen consistent with the modeled effect from anthropogenic climate change.

Further research that is underway

From the heuristic perspective of optimizing the correlation between losses and reanalysis data we found the best correlation for a very high exceedance threshold of TSP = 3,000 J/kg. Why is it such an extremely high TSP threshold that translates into a good proxy of overall thunderstorm loss from sizeable events (integrating across all the thunderstorm perils)?

THANK YOU FOR YOUR INTEREST

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