SPACE WEATHER RISKS FROM AN INSURANCE PERSPECTIVE

26.04.2011

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Geo Risks Research Group

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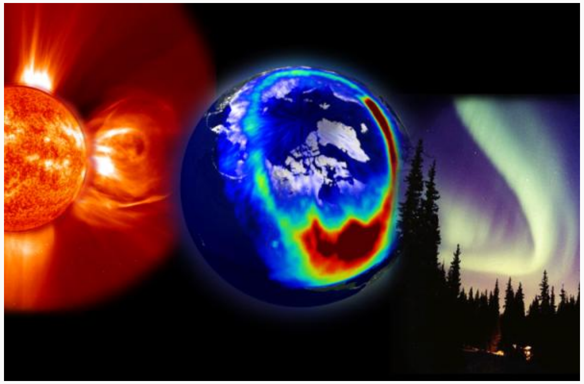
- *Reinsurance* = “Insurance for Insurance Companies”
- Geo Risks Research Group’s responsibility:
  - screening of all aspects in the field of natural hazards and disasters, including geophysical hazards, weather-related hazards and potential consequences of climate change,
  - in particular impacts of **novel hazards** and hazards that emerge from **changes in vulnerability** (such as space weather).
- Linking geo-scientific research with business expertise in risk assessment, risk modeling, and risk management in the natural catastrophe reinsurance sector.



Definition of Risk in an Insurance Context

Risk ~ Hazard x **Vulnerability** x **Exposure**

All three components CAN & DO change over time!

Space Weather Risks
A) Exposure

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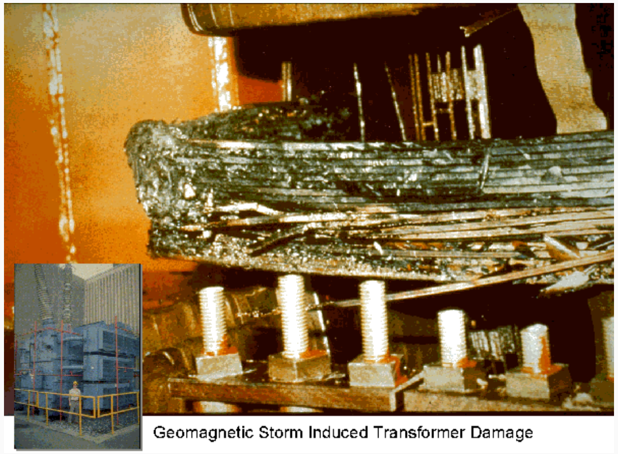
Space-weather-prone property and infrastructure includes:

- satellites (e.g., solar panels & electronics: exposed to particle radiation)
- aviation (crews exposed to higher radiation dose)
- radio communication (affects aviation, telecommunication, internet, GPS etc.)
- utility components (e.g., transformers: exposed to geomagnetic induced currents)

Wide-ranging and long-lasting **power outage** could substantially affect the economy. Extreme impact on social and economic life would also have severe consequences on the insurance industry. Large loss potentials could arise from, e.g., business interruptions.

→ **Hence, protection of the electric power supply is particularly under focus!**



Geomagnetic Storm Induced Transformer Damage

Source: www.swpc.noaa.gov/Media/graphics/Transformers.gif

Space Weather Risks
B) Vulnerability

Most of today`s operative **transformers** in the North American grid were built in the 1970s – typically designed for a life time of ~40 years

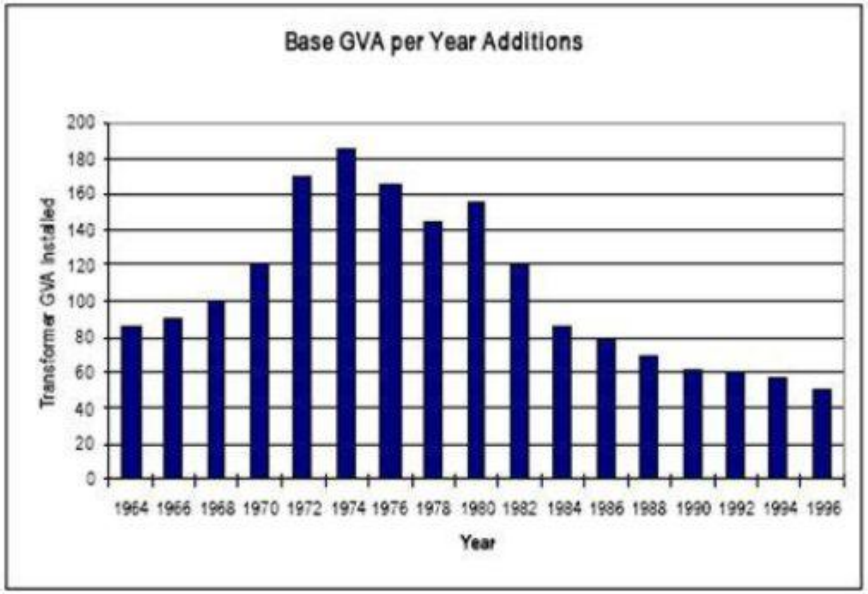


Table 4 – Distribution of Losses by Age of Transformer

Age at failure	Number of Failures	Cost of Failure
0 to 5 years	9	$ 11,246,360
6 to 10	6	$ 22,465,881
11 to 15 ...	9	$ 3,179,291
16 to 20 ...	9	$ 10,518,283
21 to 25 ...	10	$ 16,441,930
Over 25 years	16	$ 15,042,761
Age Unknown *	35	$ 207,734,306

** This line includes the one claim with a business interruption element of $80 million Euros or $86 million US*

Source: W. Bartley, The Hartford Steam Boiler Inspection & Insurance Co., on behalf of the IMIA Task Group Report "Analysis of Transformer Failures", presented at the International Association of Engineering Insurers 2003 (content does NOT reflect HSB experience)

Aged infrastructure: increasing vulnerability

Transformers exposed to a strong GIC might not fail, but **degrade** during GIC. Effective age of equipment increases from GIC and components might fail later when exposed to complete different disturbances.

Space Weather Risks
Need for mitigation of possible space weather induced blackouts

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technical solutions / options:

- DC blocking devices…?
- 3-phase transformers instead of three 1-phase transformers…? Or back-up transformers, e.g., four 1-phase transformers with one as a backup…?
- Hardening of equipment…? Or determined breaking points and controlled triggering of relays, digital filters…?
- Improved grid topology, dependent on the underneath geology…?
- Modify operating / maintenance procedures to assure sufficient capacity to buffer geomagnetic storm events…?
- Improved Space Weather Forecasts and modeling of GIC impacts on individual power grids sections…?

possible role of insurance industry:

- Insurers as risk bearers have high interest in mitigating space weather risks.
- Hence, insurers would argue for improved technological prevention and safety standards.
- Insurers will engage in supporting businesses and clients in tackling space weather risks.

Space Weather Risks
Realization of mitigation measures in new technology design

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ABB:
(homepage)

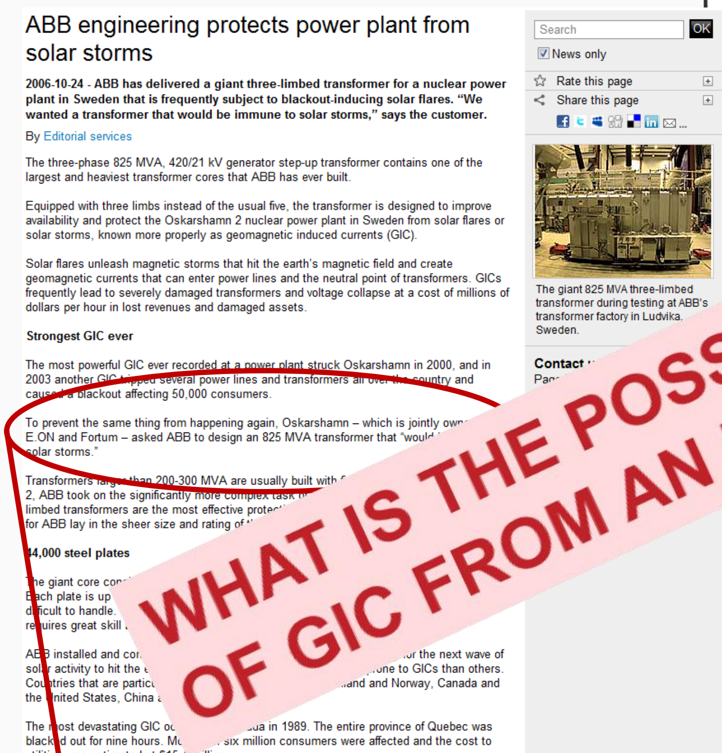
ABB engineering protects power plant from solar storms

2006-10-24 - ABB has delivered a giant three-limbed transformer for a nuclear power plant in Sweden that is frequently subject to blackout-inducing solar flares. "We wanted a transformer that would be immune to solar storms," says the customer.

By Editorial services

The three-phase 825 MVA, 420/21 kV generator step-up transformer contains one of the largest and heaviest transformer cores that ABB has ever built.

Equipped with three limbs instead of the usual five, the transformer is designed to improve availability and protect the Oskarshamn 2 nuclear power plant in Sweden from solar flares or solar storms, known more properly as geomagnetic induced currents (GIC).

Solar flares unleash magnetic storms that hit the earth's magnetic field and create geomagnetic currents that can enter power lines and the neutral point of transformers. GICs frequently lead to severely damaged transformers and voltage collapse at a cost of millions of dollars per hour in lost revenues and damaged assets.

Strongest GIC ever

The most powerful GIC ever recorded at a power plant struck Oskarshamn in 2000, and in 2003 another GIC tripped several power lines and transformers all over the country and caused a blackout affecting 50,000 consumers.

To prevent the same thing from happening again, Oskarshamn – which is jointly own... E.ON and Fortum – asked ABB to design an 825 MVA transformer that "would... solar storms."

Transformers larger than 200-300 MVA are usually built with ... 2, ABB took on the significantly more complex task ... limbed transformers are the most effective protec... for ABB lay in the sheer size and rating of ...

...4,000 steel plates

...he giant core con... Each plate is up ... difficult to handle. ... requires great skill ...

ABB installed and co... for the next wave of solar activity to hit the ... prone to GICs than others. Countries that are partic... ...land and Norway, Canada and the United States, China ...

The most devastating GIC oc... ...a in 1989. The entire province of Quebec was blacked out for nine hours. M... six million consumers were affected and the cost to utilities was estimated at $15.4 million.

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The giant 825 MVA three-limbed transformer during testing at ABB's transformer factory in Ludvika, Sweden.

Contact ...

Siemens:
(brochure)


Siemens Power Transformers: in operation all over the planet

Power transformers are needed to supply energy to more and more people and growing economies.

Siemens is a worldwide partner for power supply and industrial companies – accordingly, the examples of our work are global: Whether in South America, Asia or Europe, whether in the desert or in specially demanding applications 15 meters underground. Ten thousands of plants run efficiently and reliably with our technology.

When will we have the opportunity to present your project here?

Hydro power for China
15 three-phase generator step-up transformers 800/1,092 MVA/550 kV for the largest hydro power plant world-wide – delivered from our Nuremberg plant in Germany

Whispering in New York City
A three-phase autotransformer, 420 MVA/345 kV in extreme... design. The optimiz... resulted in a 20... by our ...

Factoring sol... solution...

...A/525 kV auto- ...-loss design – delivered ...e factory in Jinan for a power ... in Shandong province

...omestic performance for ...ican Power
Three generator step-up transformers 420 MVA/375 kV have been delivered for two large hydroelectric power stations in the state of Coahuila in the north of Mexico from our domestic factory in Guanajuato

Brazilian excellence for the USA
Two three-phase autotransformers 800 MVA/345 kV, designed for simultaneous loading of HV, LV and tertiary according to ANSI/IEEE standards (C57.12.00) – delivered by our Brazilian factory in Jundiaí, São Paulo

Low losses for hot regions
A 320 MVA/... kV three-phase network transformer for extremely high ambient temperatures in Abu Dhabi (+ 52 °C) – delivered with a special low-loss design by our Nuremberg factory in Germany

Factoring solar winds in the Croatian solution for South Africa

Four three-phase 450 MVA/420 kV generator step-up transformers in a special hot-spot design for the geomagnetic induced currents (GIC) – delivered by our Croatian factory in Zagreb

WHAT IS THE POSSIBLE MAXIMUM STRENGTH OF GIC FROM AN ENGINEERING PERSPECTIVE?

To prevent the same thing from happening again, Oskarshamn – which is jointly owned by E.ON and Fortum – asked ABB to design an 825 MVA transformer that "would be immune to solar storms."

Space Weather Risks
Political Measures: **GRID Act** (**G**rid **R**eliability and **I**nfrastructure **D**efense Act)

In 2009 **N**orth-American **E**lectric **R**eliability **C**orporation (NERC) has identified solar storms as a relevant high-impact, low-frequency (HILF) event.

In accordance with the NERC geomagnetic storm scenario the Bill **GRID Act** was designed and passed the House of Representatives on 9 June 2010 (H.R.5026). Still missing: Senate vote & sign-off by the President…

Most important regarding geomagnetic storms:

SEC.215A (c) (4): NERC will be commissioned to develop reliability standards "*adequate to **protect the bulk-power system** from any reasonable foreseeable geomagnetic storm event*."

SEC.215A (c) (5): NERC will be commissioned to develop reliability standards of "*adequate **availability of large transformers** to promptly restore …the bulk power system in the event that any such transformer is destroyed or disabled as a result of …a geomagnetic storm event*."

SEC.215A (g) (1) (2): The Secretary of Energy "*shall establish a program … to develop technical expertise in the protection of systems for the generation, transmission and distribution of electric energy against geomagnetic storms…. Such program shall include the identification and development of appropriate technical and electronic resources….*"

Space Weather Risks

C) Hazard

WHAT is the hazard? Is it… …Solar Flares or CMEs?

…geomagnetic storms?

…geoelectric disturbances?

…or GIC itself?

Of course we are interested in GIC. Availability of long measured GIC data sets is poor and so it is difficult to extrapolate to really big events.

Causal dependence between geomagnetic storms, the geoelectric field and GIC allows geomagnetic storm data (such as D_{st} or *AE* index, dating back until 1957) to be used as a **rough proxy for possible occurrences** of strong GIC events.
[A. Pulkkinen,et al., Statistics of extreme geomagnetically induced current events, Space Weather, Vol. 6, S07001 (2008)]

Risk of occurrence: expressed by **Return Periods** ("once-in-a-hundred-years-event")
It's inverse of the probability of occurrence for events of a given magnitude.

"In practice": What are the **magnitudes** of a 100-/500-/1000-year event? And what is the (un-)certainty of these estimates?

Space Weather Risks
C) Hazard: analysis of D_{st} index

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Tsurutani et al. in J. Geophys. Res., 108(A7), 1268 (**2003**) state that the for very strong geomagnetic storms (with –Dst > 400nT) “the probability of occurrence cannot be assigned within any reasonable accuracy”.

Analysis performed by **Tsubouchi et al.** in Space Weather, Vol. 5, S12003 (**2007**) yields a **~60yr RP** for an event of magnitude of the **Quebec event** in 1989.

In the Workshop Report *Space Weather Events – Understanding Societal and Economic Impacts* of the National Academy of Science (**2008**) a GEV analysis based on D_{st} maximum values within blocks of 20 days associates an event as strong as the **Carrington event** with an occurrence probability of 10^{-4} in any given 20-day interval. This corresponds to a **RP of ~500 to ~600 years**.

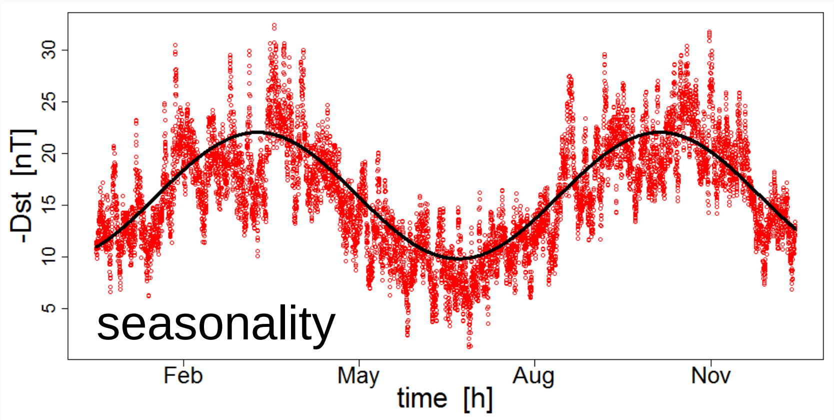
However, uncertainty bands around these estimates are enormous. Our own EVS analysis of the data provides RP ranges between 50 to 200 years for the Quebec event, and 300 to 8000 years for the Carrington event.

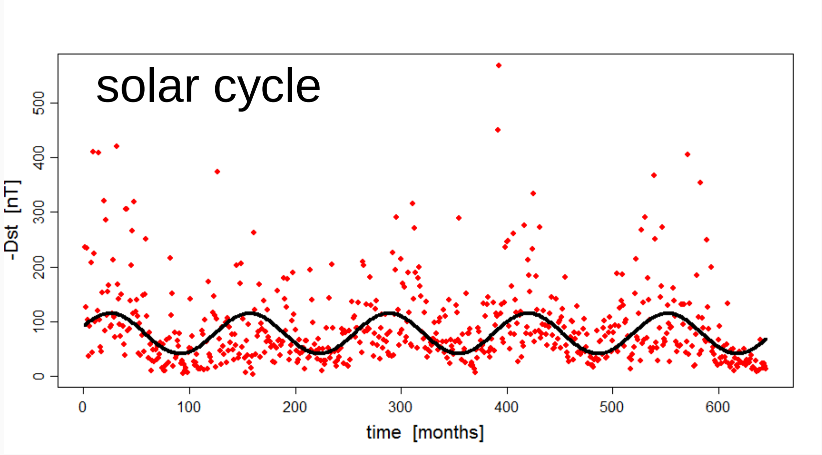
Space Weather Risks
C) Hazard: analysis of D_{st} index

***D**isturbance **s**torm **t**ime index* of hourly geomagnetic variation:

"The $\boldsymbol{D_{st}}$ index is an index of magnetic activity derived from a network of near-equatorial geomagnetic observatories that measure the intensity of the globally symmetrical equatorial electrojet." (Source: http://www.ngdc.noaa.gov/stp/geomag/dst.html)

Periodicities in the D_{st} data:





Perform extreme value statistics analysis on:

A) the **original** $\boldsymbol{D_{st}}$ data

B) the **anomalies**, i.e. after subtracting periodicities from original data

Space Weather Risks
C) Hazard: analysis of D_{st} index

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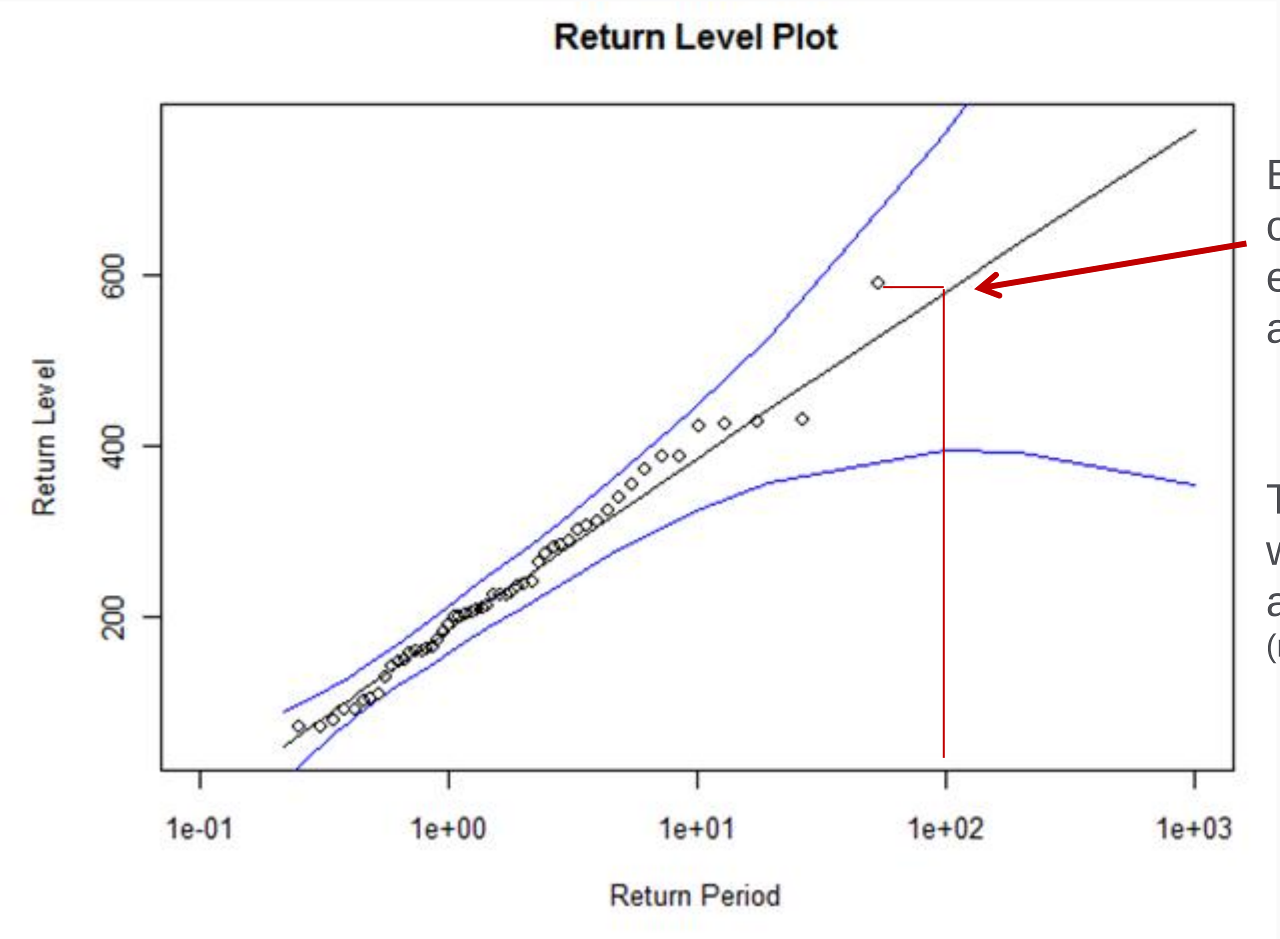
I) Method of choice: **GEV** or Box-Maxima-Method



Based on annual maxima of $|-D_{st}|$ the1989 Quebec event with 589 nT ranks as a ~**100yr** event

The1859 Carrington event with 850 nT would rank as a ~1600yr event
(not within plot boundaries)

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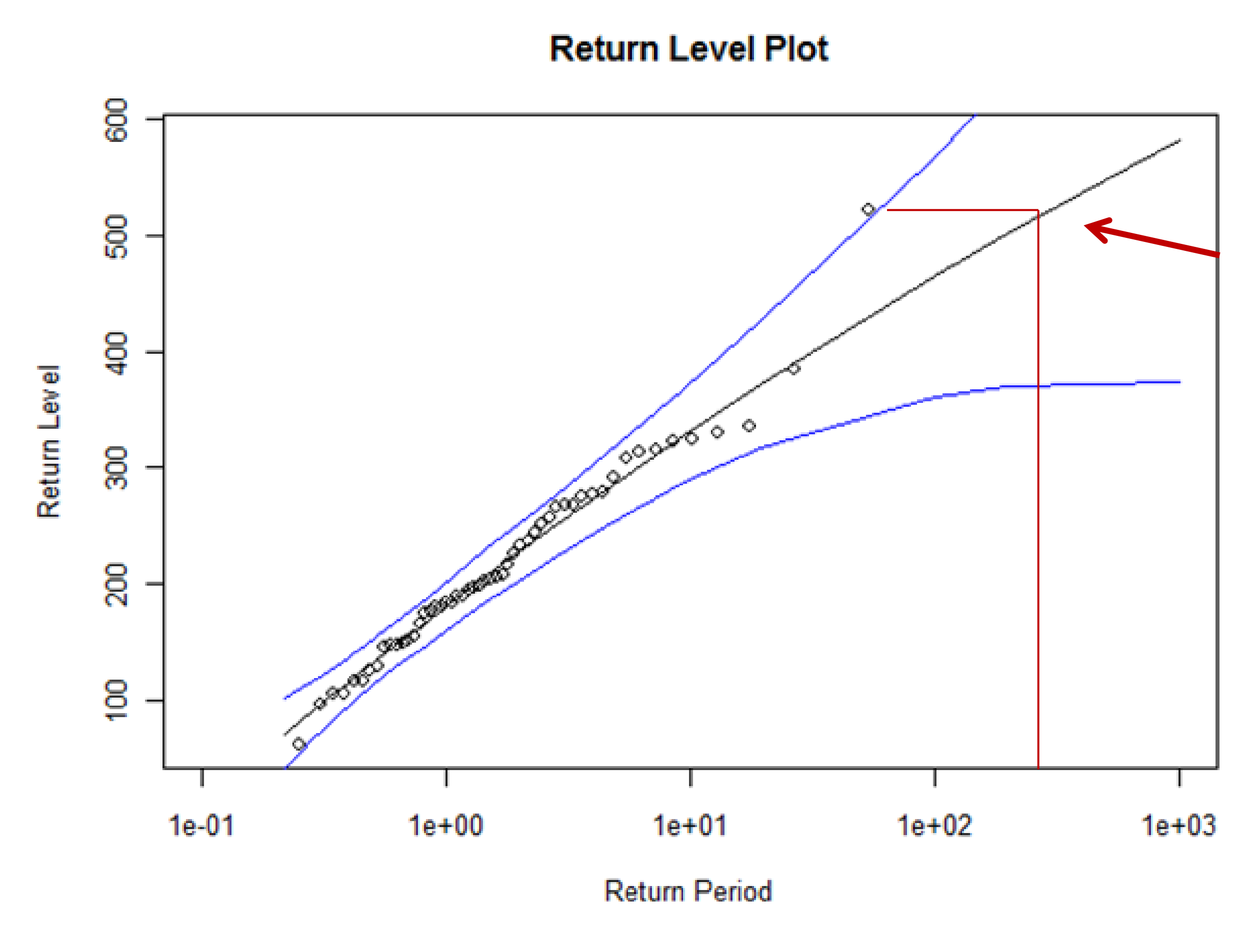
C) Hazard: analysis of D_{st} index

II) Method of choice: **GEV** or Box-Maxima-Method on ***D_{st}* anomalies**



Based on annual maxima **anomaly** of D_{st} the1989 Quebec event with 522 nT ranks as a ~**200yr** event, but reaches boundaries of confidence!

The1859 Carrington event with 747 nT **anomaly** would rank as a ~10k yr event (not within plot boundaries)

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C) Hazard: analysis of D_{st} index

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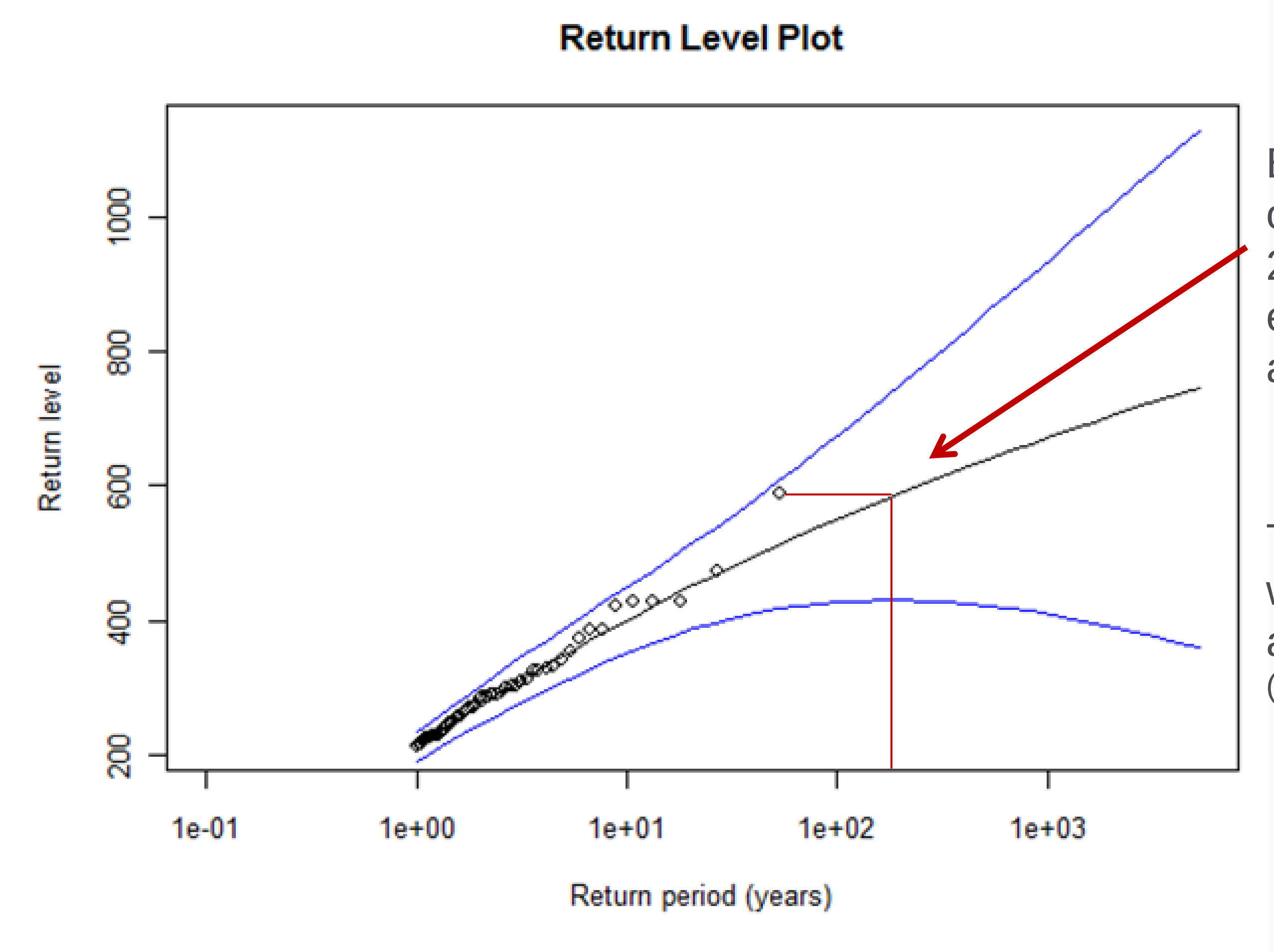
III) Method of choice: **GPD** or Peaks-Over-Threshold-Method



Based on monthly maxima of $|-D_{st}|$ and a threshold of 212 nT, the 1989 Quebec event with 589 nT ranks as a ~**150yr** event

The1859 Carrington event with 850 nT would rank as a ~10k yr event
(not within plot boundaries)

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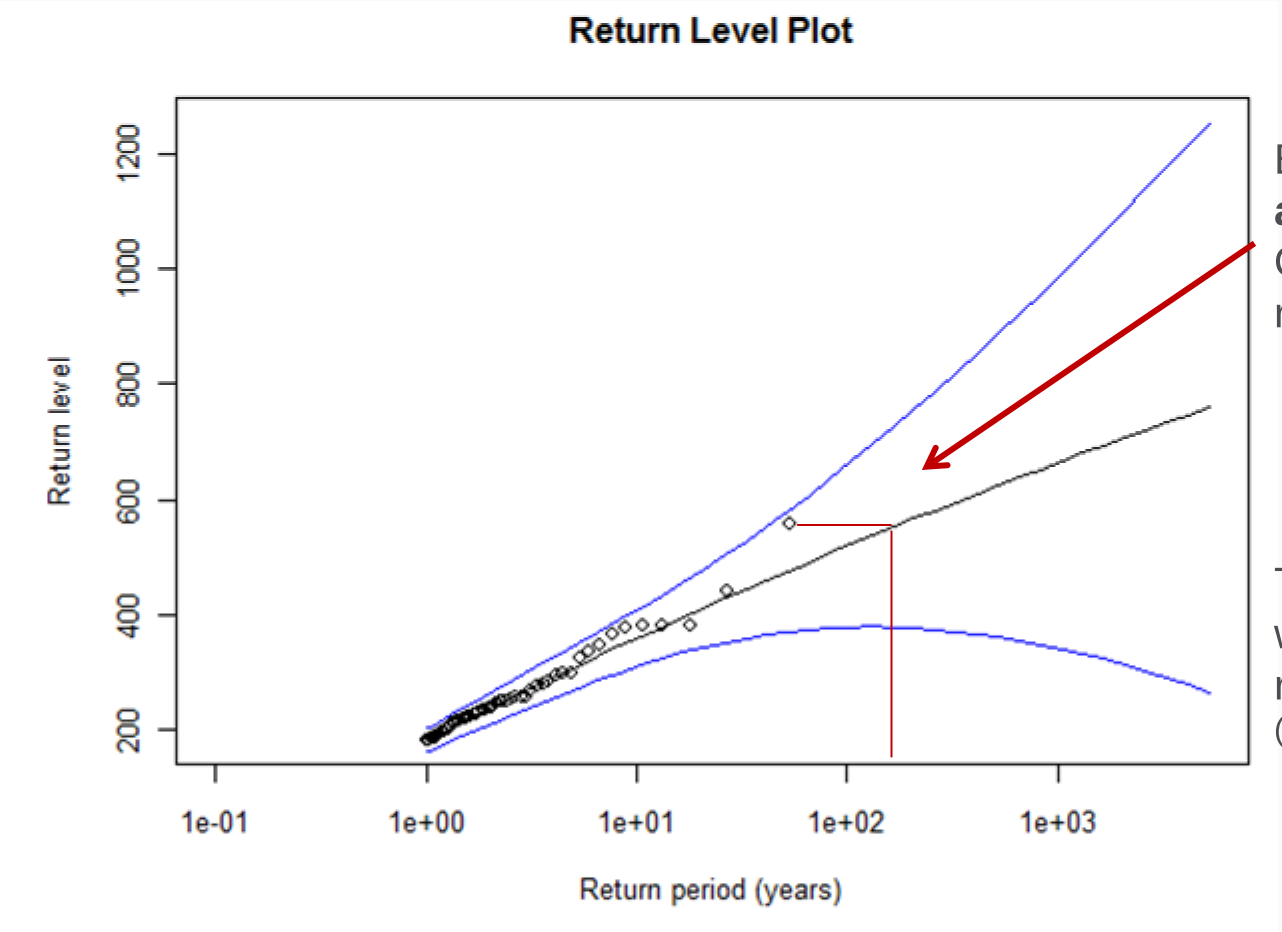
C) Hazard: analysis of D_{st} index

IV) Method of choice: **GPD** or Peaks-Over-Threshold-Method on ***D_{st}* anomalies**



Based on annual maxima **anomaly** of D_{st}, the1989 Quebec event with 522 nT ranks as a ~**120yr** event.

The1859 Carrington event with 747 nT **anomaly** would rank as a ~8k yr event (not within plot boundaries)

Space Weather Risks
C) Hazard: analysis of GIC

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In *Statistics of extreme geomagnetically induced current events* in SPACE WEATHER, Vol. 6, S07001 (**2008**), **Pulkkinen et al.** studied D_{st}-conditioned geoelectric field magnitudes from conductivity ground models, which transfer linearly into GIC (considering geology, topology and electrical properties of the systems affected by the GIC).

An event like the **Carrington event** could cause geoelectric fields of 4 V/km and GICs would peak at 2000 A (with durations of at least 10 sec) at certain locations. The associated frequency ranks as more **than 10 times in 100 years**. Stil, this is in strong contrast to the above statements derived from D_{st} only. But it is a statement about GIC itself!

10sec-GIC of 200 A:	more than 10 times per year
10sec-GIC of 2000 A:	more than 10 times per 100 years

Question: Do these numbers compare with the orders of magnitude considered by the engineers of Siemens and ABB?

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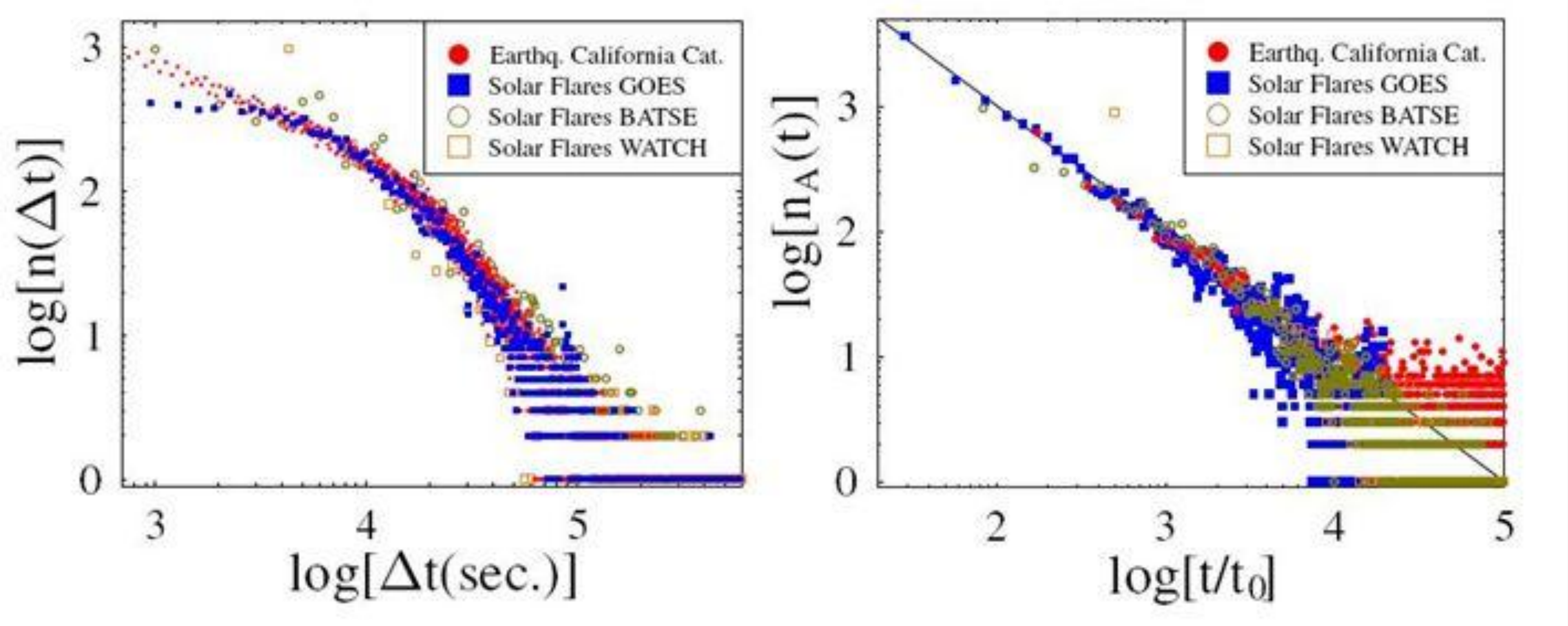
C) Hazard: clustering of extreme events

…clustering affecting extreme value statistics?

Example:

(Arcangelis et al., Phys. Rev. Let. Vol. 96, 2006)



Comparison of after-shock statistics for earthquake and solar flare data:

→ both follow **Omori-law** of after-shock statistics!

→ clustering of GIC due to natural clustering of Solar Flares and CMEs?

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THANK YOU!