Overview of the Short to Long-term Risks and Consequences of Space Weather

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A growing risk

Space weather has existed since birth of the Earth: advanced technologies create our vulnerability

Limited sensitivities

No sensitivities

No sensitivities

Comms, navigation, radiation, digital systems

Power & control

Power, control & comms

Space weather risk factors

System & threat	*Environ*
Power grid – induced currents	Rat … field, dB/dt
Aviation: human radiation exposure, ups… in electronics, communications (& …	… flight … neutron fluxes … nd max HF fr…
GPS/Galileo – error co…	Rate of chang… …ent Scintill…
Satellite o… …s, damage to p… …electronics.	Pl… …rature …gy electrons …ence of solar energetic …es Upper atmosphere density
Digital control sys…	Cosmic ray neutron fluxes at surface
Wireless devices – i…	Solar radio flux

Space weather is diverse – just as with normal weather: need climatology

Assessment: What are impacts on technology, esp. infrastructures?

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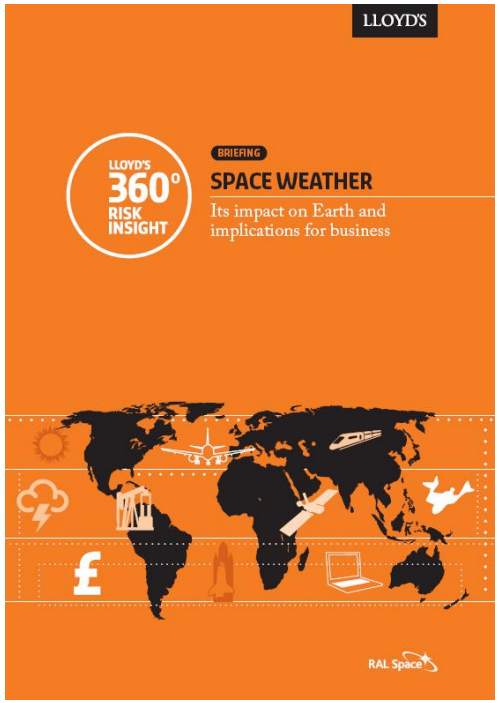
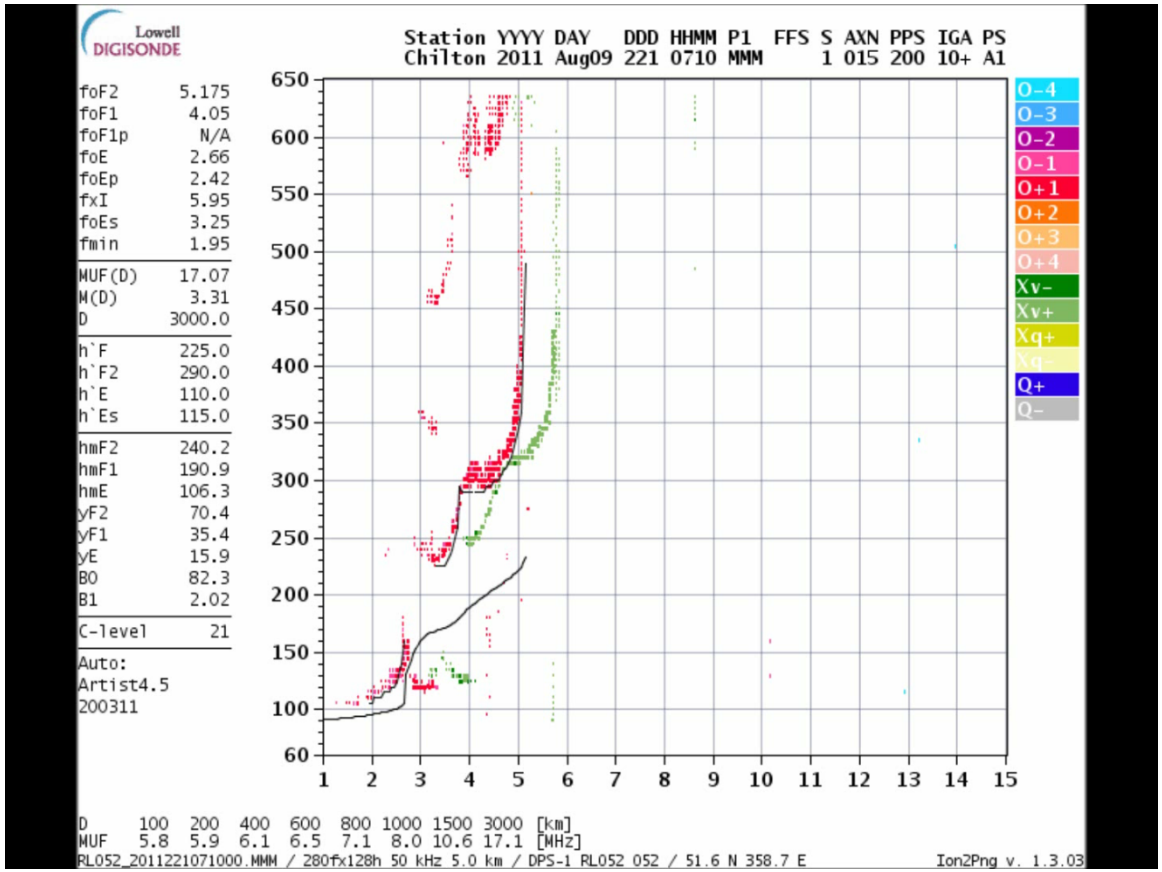
Engineering matters!

Central to assessment of impact of space weather environments - and to impact mitigation



Fast effects – solar flares



X6.9 flare at 08:05

X-ray flash

- Creates layer that absorbs HF radio
- Blackout – aviation & military comms
- Need backup systems
- Patchy knowledge in users, e.g. omitted in contract metrics!
- Also extra ionisation: affects GPS
- Speed-of-light so look for pre-cursors

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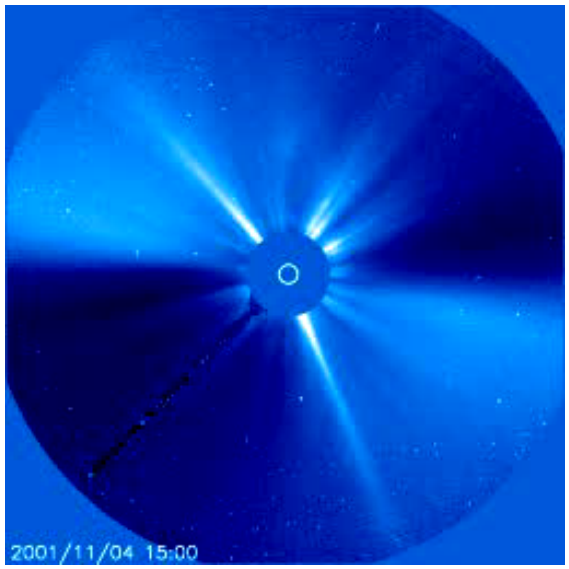
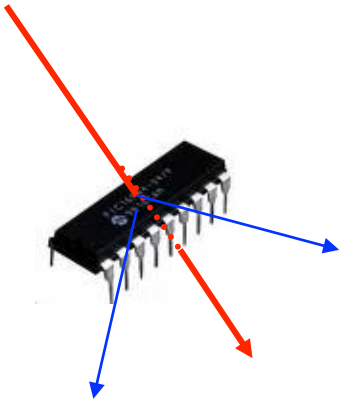
Fast effects – particles



- Energetic (> MeV) ions penetrate spacecraft electronics
  - Single event effects: bit flips, latch-up, ..
  - Need redundancy & hardening
  - Nowcasts valuable to operators
- Travel to Earth in tens of minutes
  - So again look for pre-cursors

- Create atmospheric neutrons
- Critical for avionics
- Also ground-based electronics:
  - chip vendors keen to warn designers



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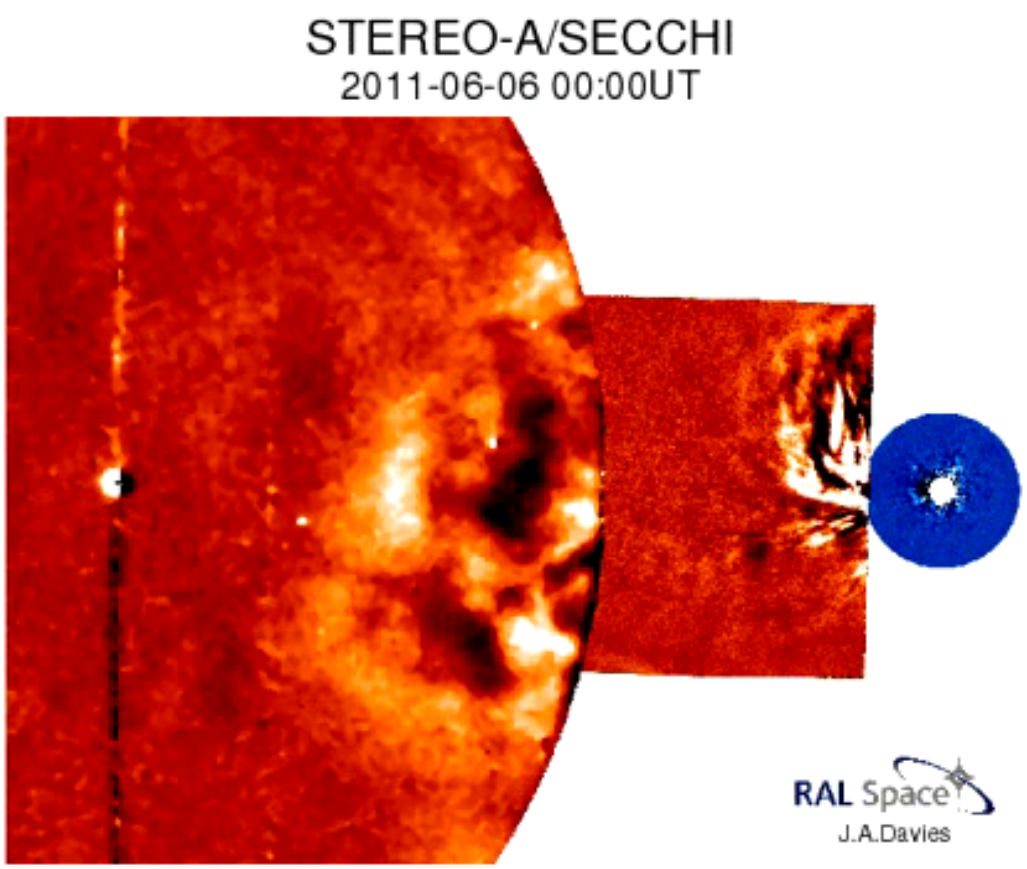
The main event – plasma



CMEs, CIRs, etc

- Solar wind carries energy to Earth
- Magstorms, rad belt enhancements
- Prompt impacts on many systems: power, GPS, spacecraft, exploration & survey
- Can harden systems
- 1-4 days travel,so can see them coming
- Procedural measures increase resilience

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Wear and Tear

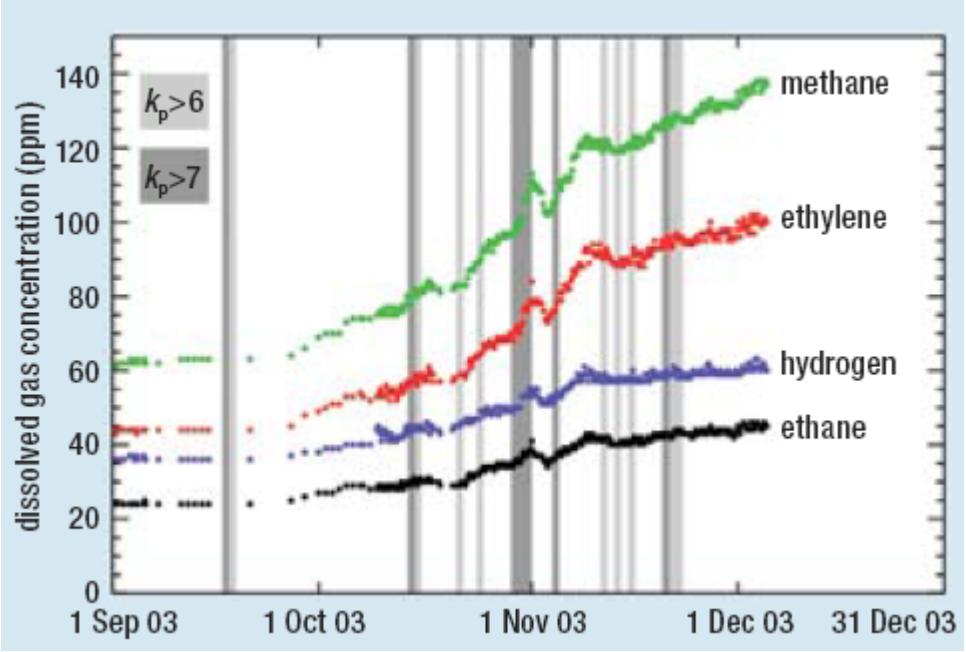
Space weather also causes cumulative damage

> MeV particles

- damage chip structures, also rad risk to humans (dose)

Magstorms

- gradual loss of insulation in power transformers (right)
- pipeline corrosion
- spacecraft orbit changes: collision risk & decay



Thomson & Wild, 2010: cumulative damage to transformer in S Africa

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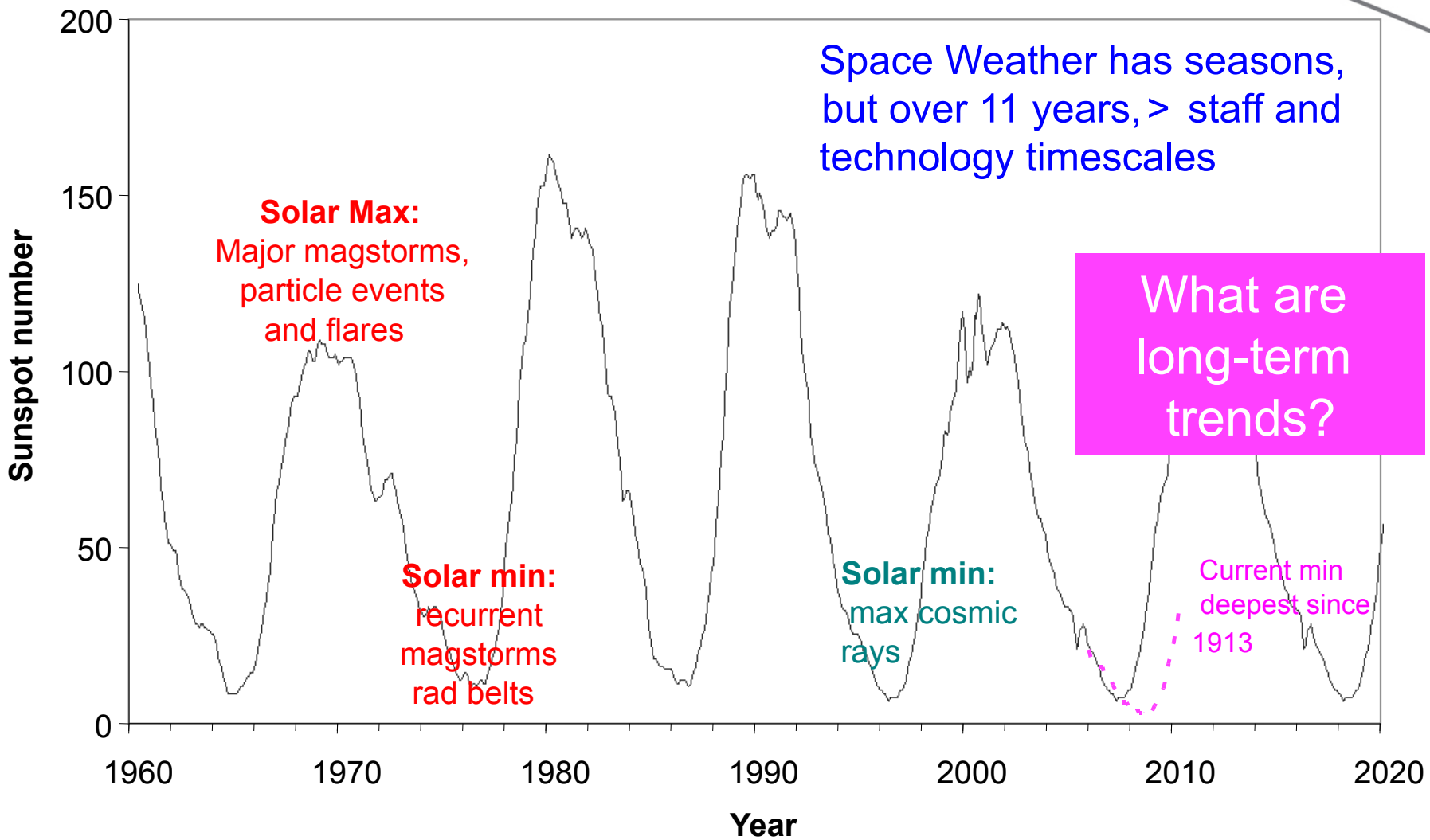
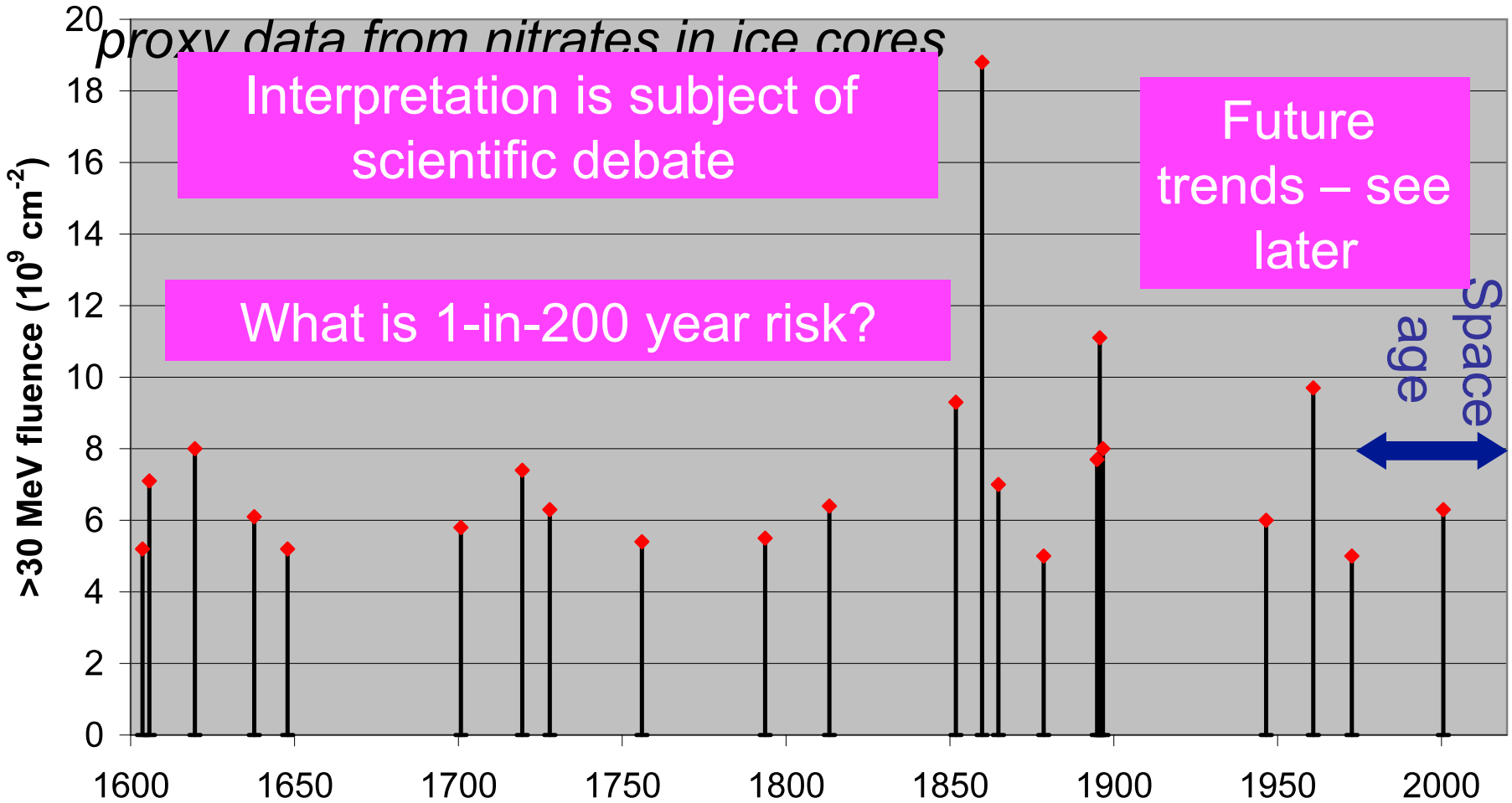
11 (13?) year cycle

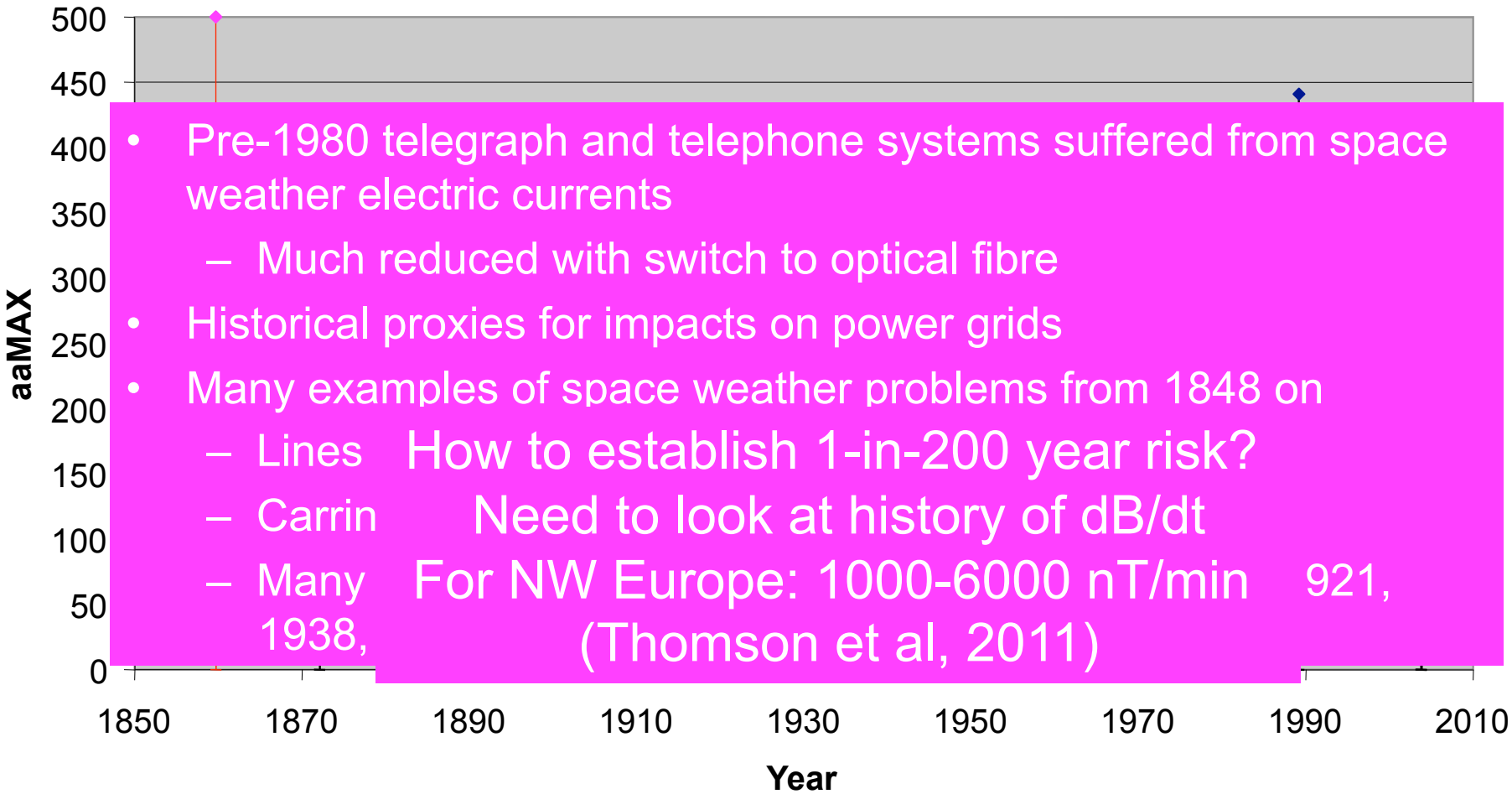


Long-term – particle events:



Long-term – magstorms:

From ground magnetometers



- Pre-1980 telegraph and telephone systems suffered from space weather electric currents
  - Much reduced with switch to optical fibre
- Historical proxies for impacts on power grids
- Many examples of space weather problems from 1848 on
  - Lines
  - Carrin
  - Many 921, 1938,

How to establish 1-in-200 year risk?

Need to look at history of dB/dt

For NW Europe: 1000-6000 nT/min

(Thomson et al, 2011)

Amplifying the threat - interconnectivity

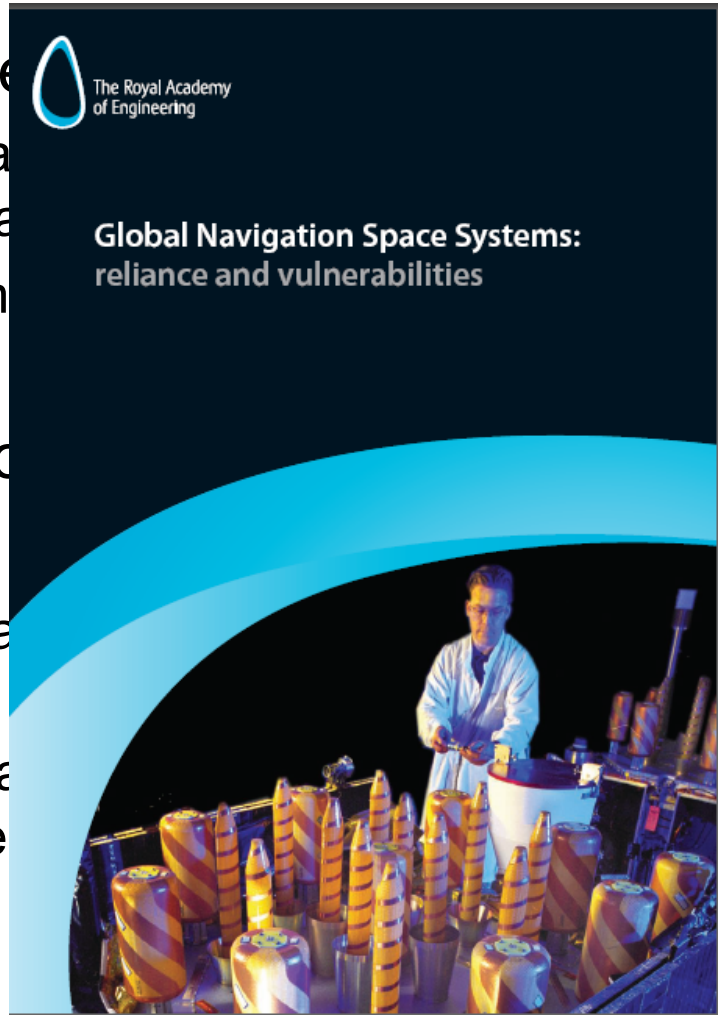
- Space weather affects ke
  - Power – THE fundamenta
    water/sewerage, retail fina
    im

e.g. RAoE report published 8 March

- So huge potential for kno
- Links into wider issue of
  eta

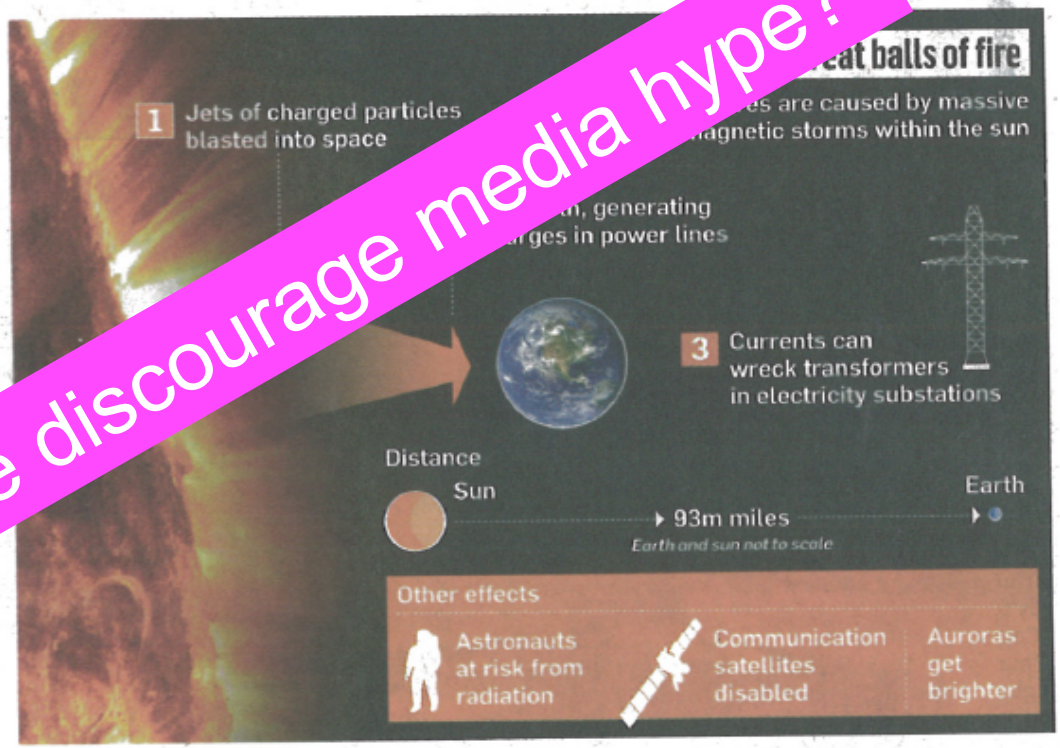
New RAoE SpW study proposed

  - Growing attention to huma
    operation of infrastructure



Blast from sun may shut down Britain

The national grid is being reinforced against a looming solar storm, writes **Marie Woolf**



Can one discourage media hype?

MINISTERS ar
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years.

T
ve been warned that a massive surge of energy from the sun could hit the Earth within the next 18 months. In a worst-case scenario, it could blow out the national grid and leave parts of the country without electricity for months.

The most extreme form of solar storm could knock out computers and the banking system, throw satellites off course and disrupt GPS technology.

Scientists have warned that

Huhne said: "The latest scientific research raises the possibility of a severe event with the potential to hit many parts of the grid simultaneously.

"That is why the Department of Energy and Climate Change is working with the national grid and experts from the UK

them at lower altitudes to reduce exposure to radiation.

The emission of billions of charged particles towards the Earth would also cause red, green and purple auroras — usually only seen at the Earth's poles — around the globe.

The first recorded solar flare,

spacecraft into different orbits, causing ground controllers at Nasa to lose contact with them.

Experts are issuing warnings about a class five storm, on a par with the 1859 event, may hit the Earth in 2012/13 as the sun reaches an active stage in its cycle.

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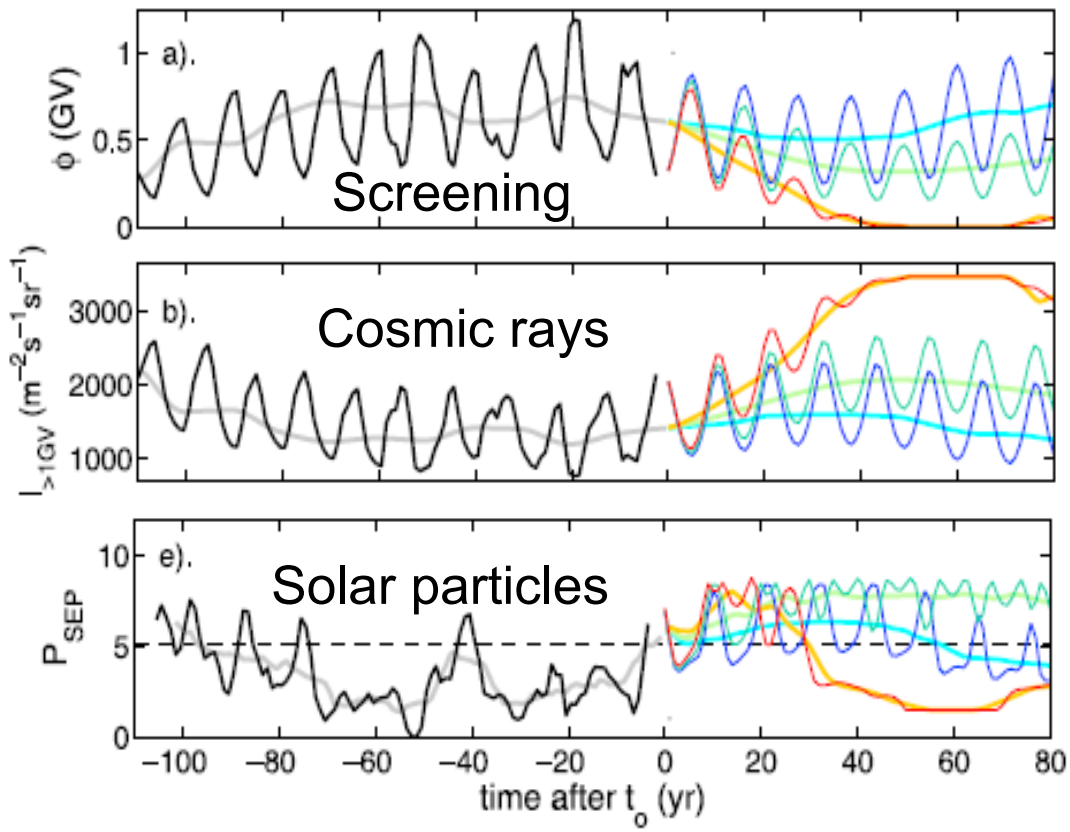
Long-term particle trends

- Be^{10} in ice cores is proxy for cosmic ray/ solar activity
- Have 9000 years data
- Can project forward using statistics



Barnard et al, 2011

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Business interest

- Insurance industry
  - Major commercial sector
  - Now well engaged with SpW effects on spacecraft
  - Wants to look at ground & aviation effects
  - *Strong links to environmental science*
- Business continuity/emergency planning
  - Strong private-public sector, growing interest in SpW
- End user sectors
  - Some good sectors: power, location & timing, exploration
  - Others patchy: aviation, satcom,

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