International Space Weather Summer Camp 2022: How to turn measurements into an analytical model – at the example of VLF data

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Aftermath

Model applications: AMELIE

Analysis of the **Me**sosphere and **L**ower **I**onosphere fall **E**ffect

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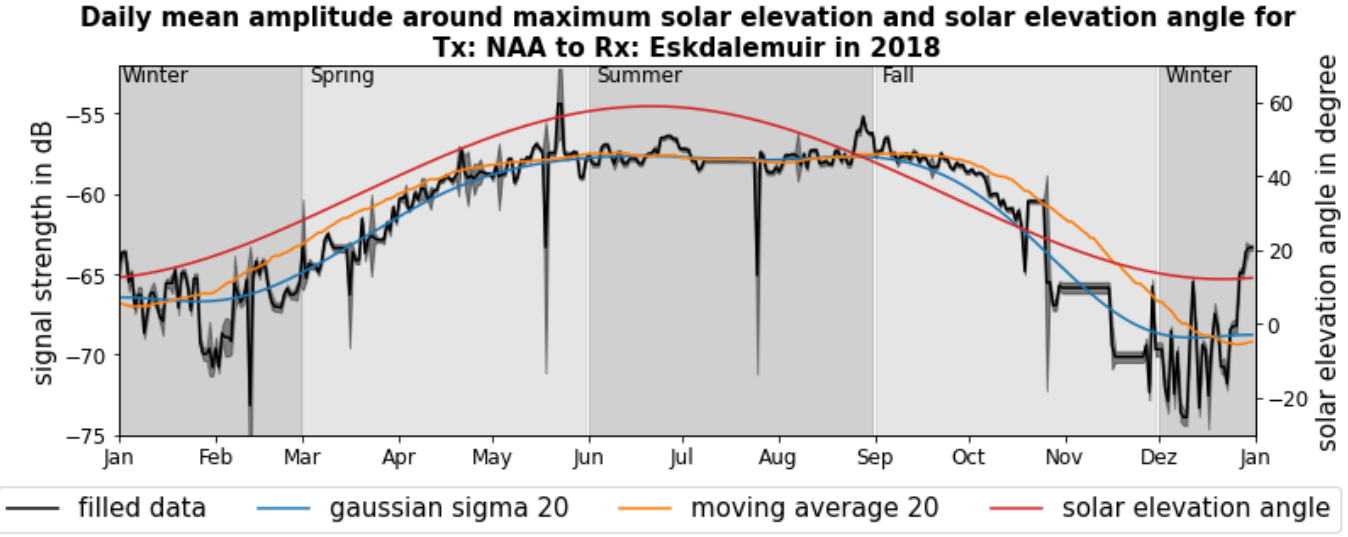
- target: locate and quantify the fall effect
- strongest slope identifiable also with mean/filter

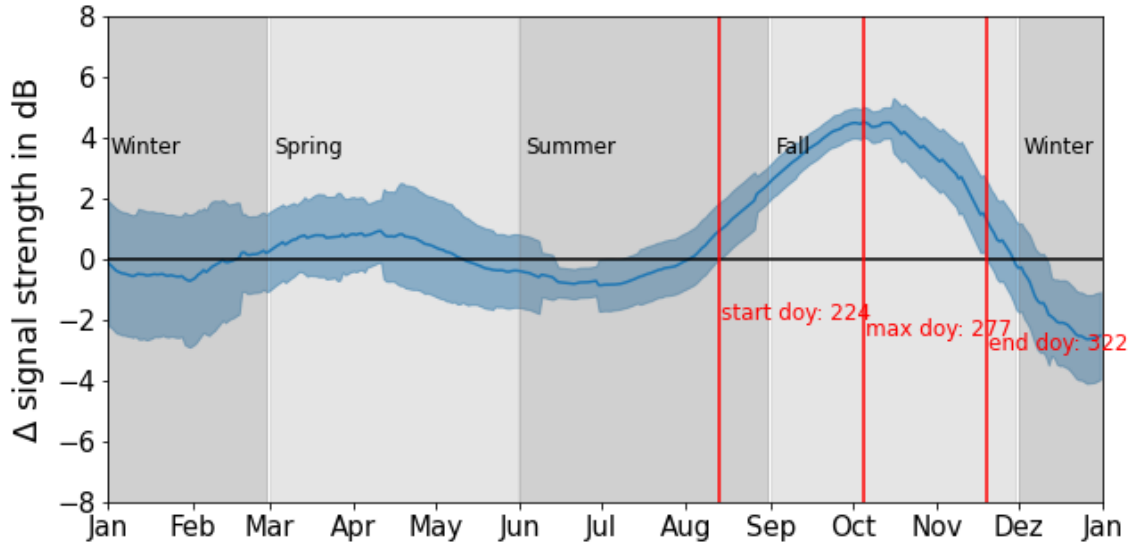
- extremes can make troubles as not unique
- smoothing may yield to delays

→ prescribed function can be treated analytically



Possibilities:

- decompose into symmetric and anti-symmetric part
- compare influence of non-symmetries for Tx-Rx links

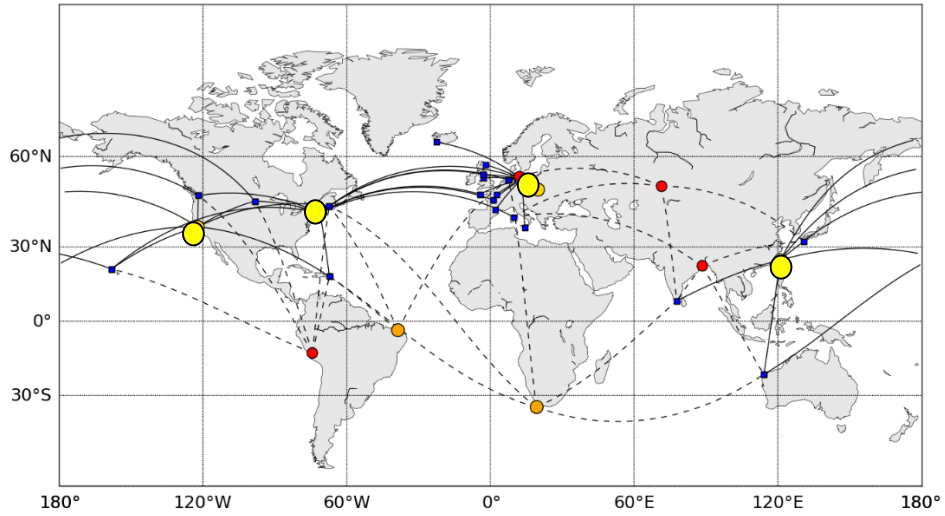


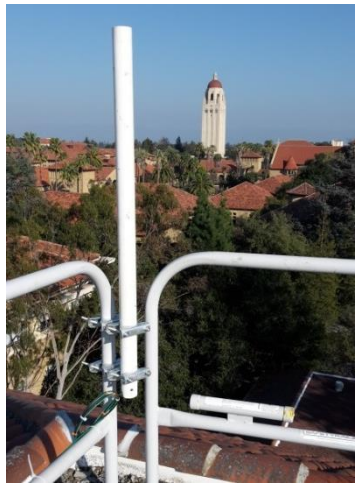
DLR

GIFDS

Global Ionospheric Flare Detection System

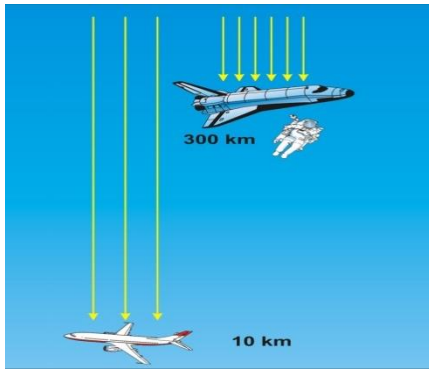
- now cast detection of SIDs caused by solar flares using a ground-based VLF system
- amplitude and phase measurements of various VLF transmitters
- industrial PC + SDR + MiniWhip antenna





Effects of space weather:

- increasing radiation exposure
  → Oct. 1989: extreme solar storm would be deadly for astronauts in protective clothing



- energetic particles can destroy satellite electronics
  leading to outages in communication and navigation
  → Jan. 1994: interruption of canad. telecom satellite Anik-E2 over 5 months

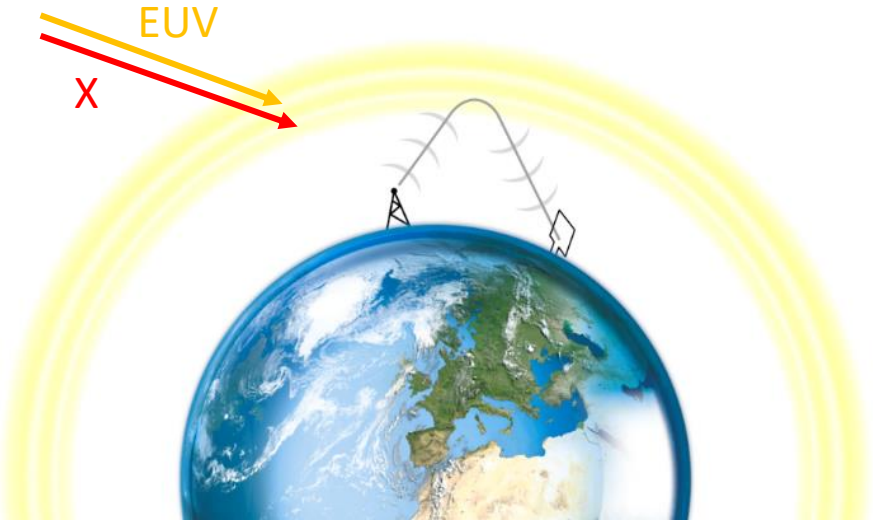
- induction of voltage on terrestrial line systems
  → Mar. 1989: power outage in Quebec for 9 hours

- deceleration of space debris due to the heating of the thermosphere
  → 1979: crash of the US space station Skylab

GIFDS

Ground-based system
- easier maintenance than satellites
- measures actual effect → protecting technological devices on Earth

VLF monitor
- widespread use from navigation
- cost-efficient to receive
- X-ray flares detectable

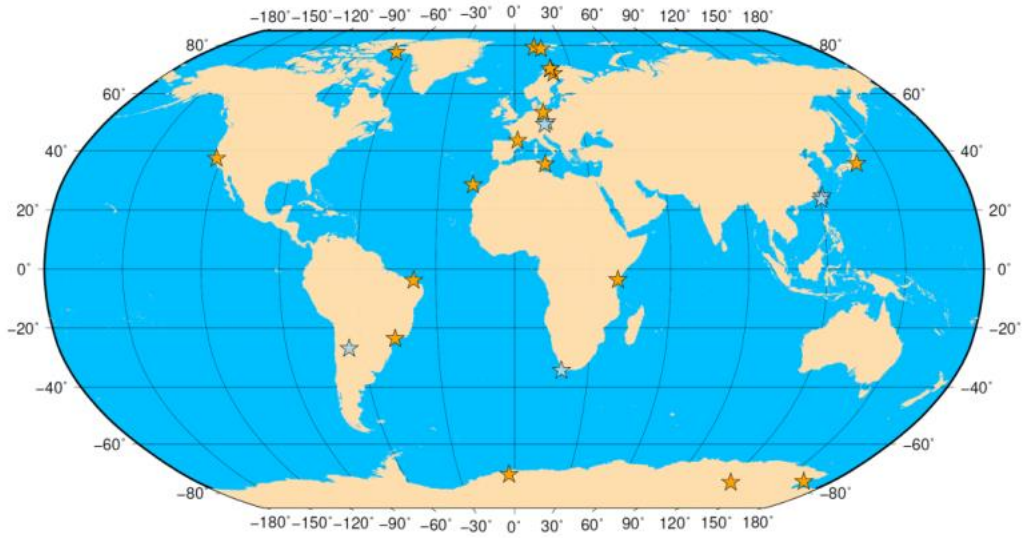


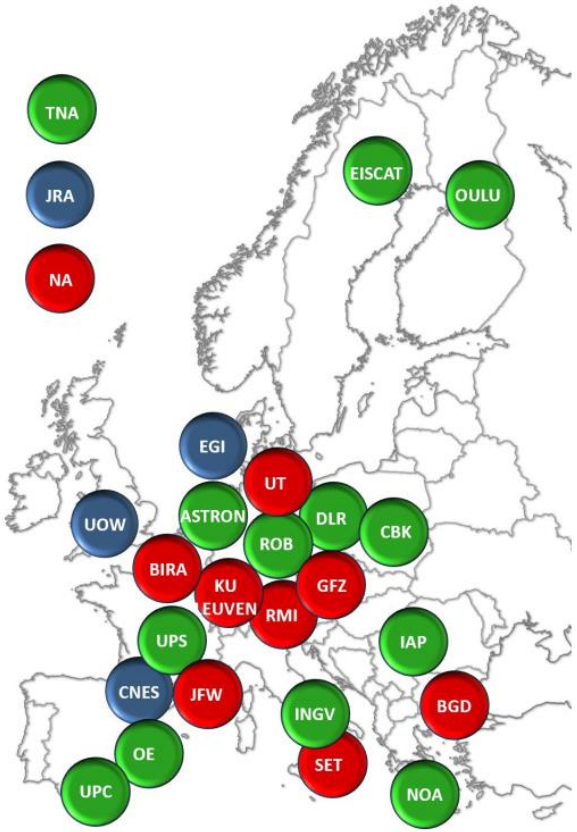
Ionosphere Monitoring and Prediction Center
- space weather observation and forecast
- TEC maps from satellite measurements
- integration of GIFDS data and warnings

PITHIA-NRF

Plasmasphere Ionosphere Thermosphere Integrated Research Environment and Access services: a Network of Research Facilities

- Horizon2020 project
- combining different data (e.g. GNSS and VLF) for access and modelling



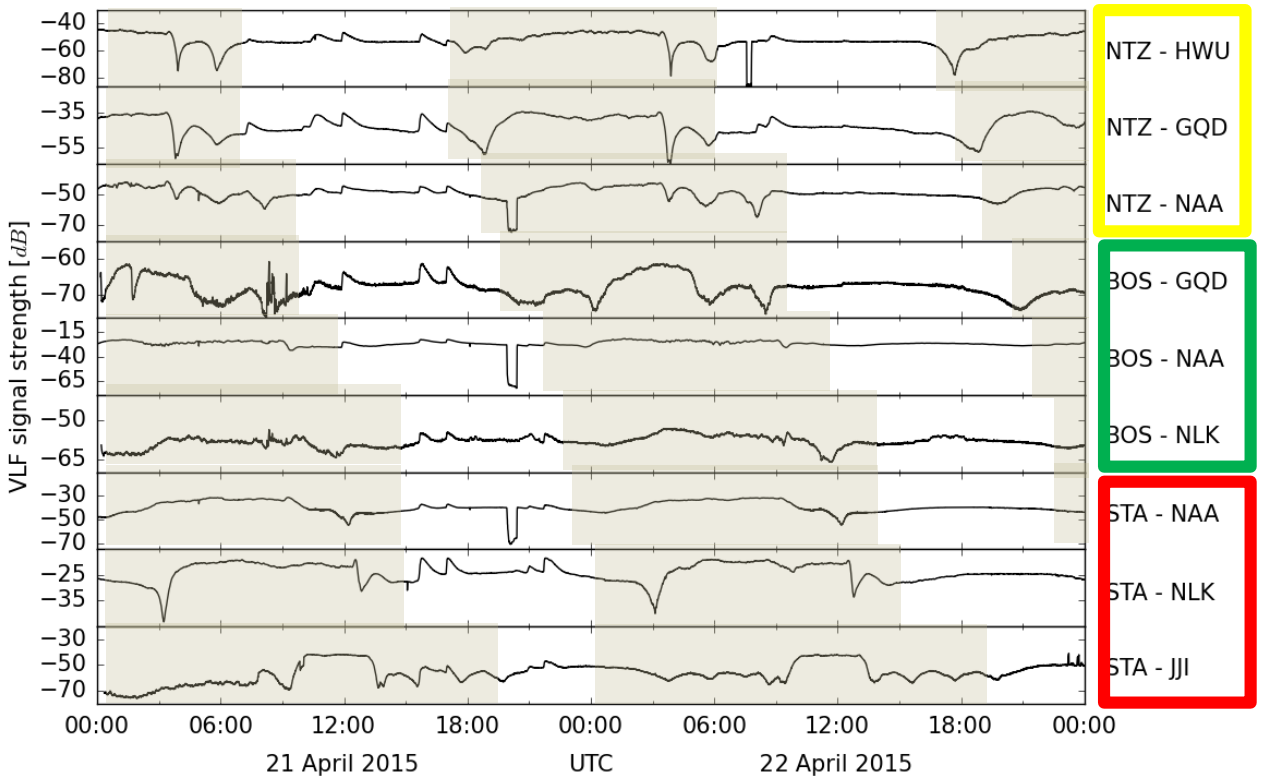


Model applications: GIFDS

- target: real-time flare warning
  → smoothing delays inacceptable
- need several links to cover globe
  → different levels critical to fade
- size estimation for source and effect
  → day parabola interferes with slope meaning

Possibilities:

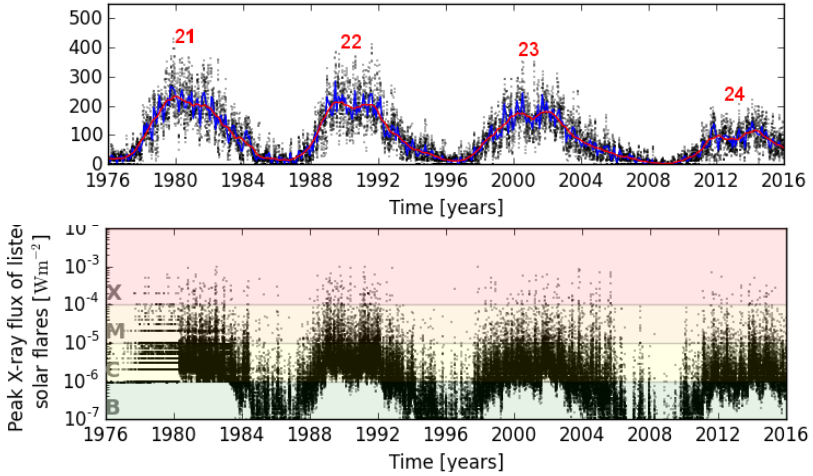
- normalisation by subtracting "expected" value
  → comparable levels of individual signals
  → averaging to ongoing compound signal
  → detect and down-weight bad links
- equalise flare slopes and peak heights

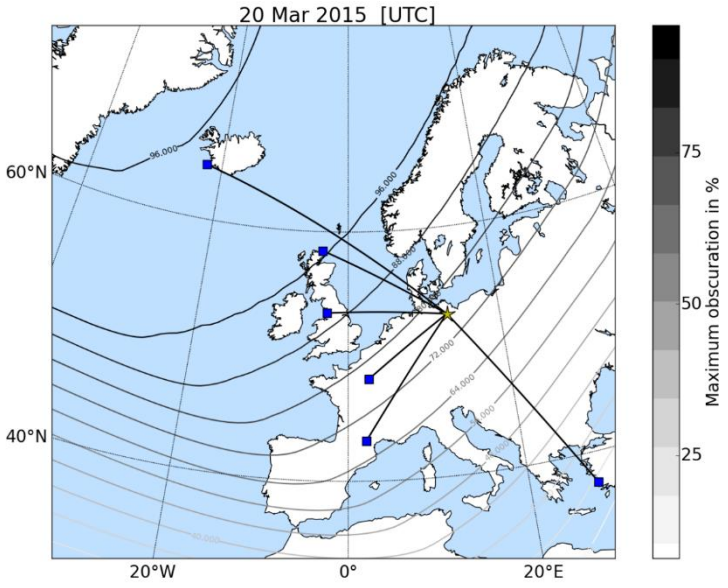


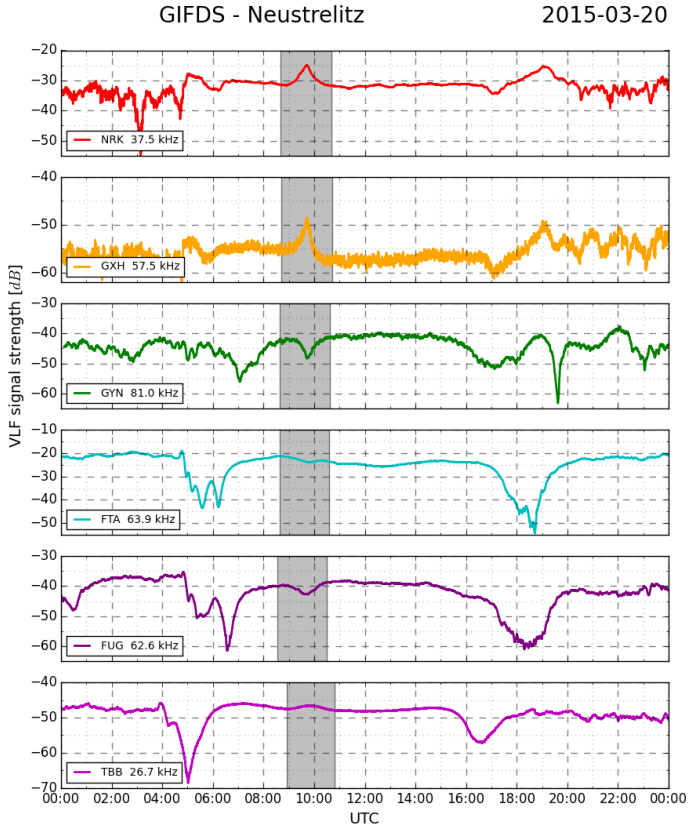
Other influences

- normal radiation level not constant
  → another adjustment over the solar cycle (when enough measurements)

- ionisation change during lightnings or eclipse
  → affected links can be down-weighted
  → known change might be added







What about the phase?

Observation:

- amplitude
  → has heavier small-scale oscillations
  (difficult to detect anomalous increases)
- phase
  → results in a "cleaner" measurement

Problem:

- phase experiences a drift

➔ similar evaluation techniques,
but harder to measure

5 Nov 2013: C8.0 Flare 11:51-12:01