Space Weather Opportunities

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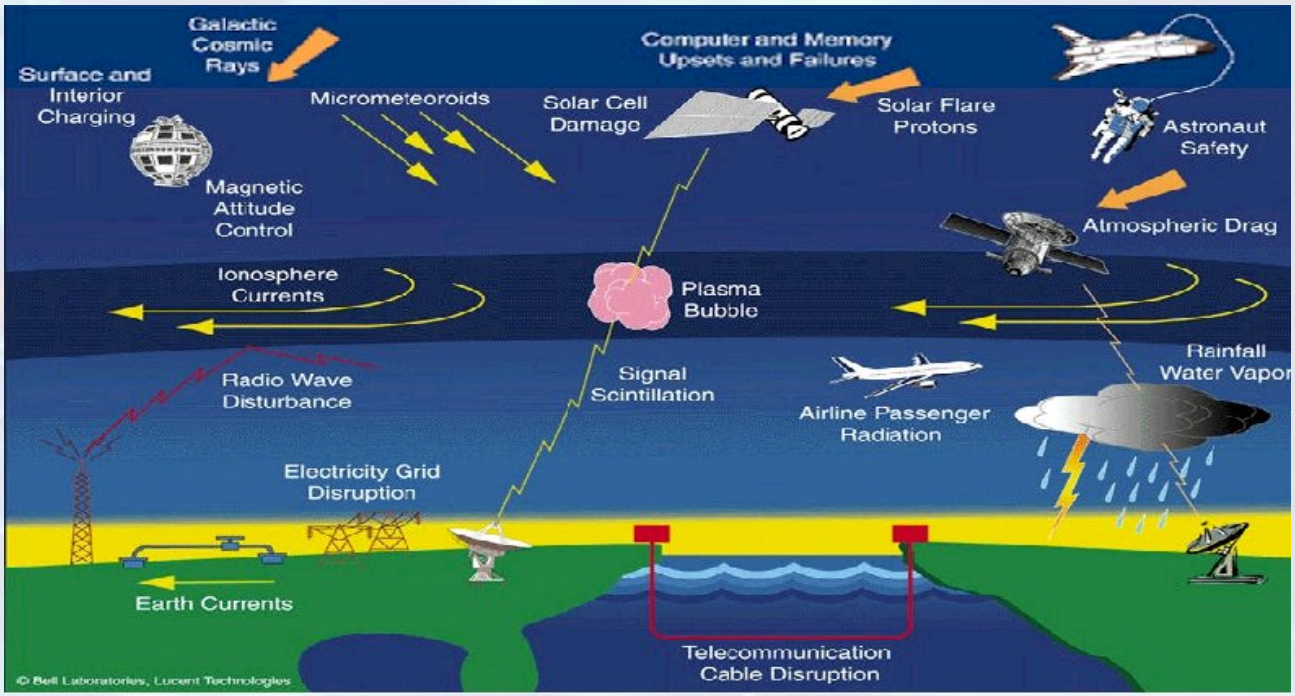
STRUCTURE

- What is Space Weather?
- Space Weather Working Team
- Scope for cross-disciplinary links
- Key case - SpW in upper atmosphere

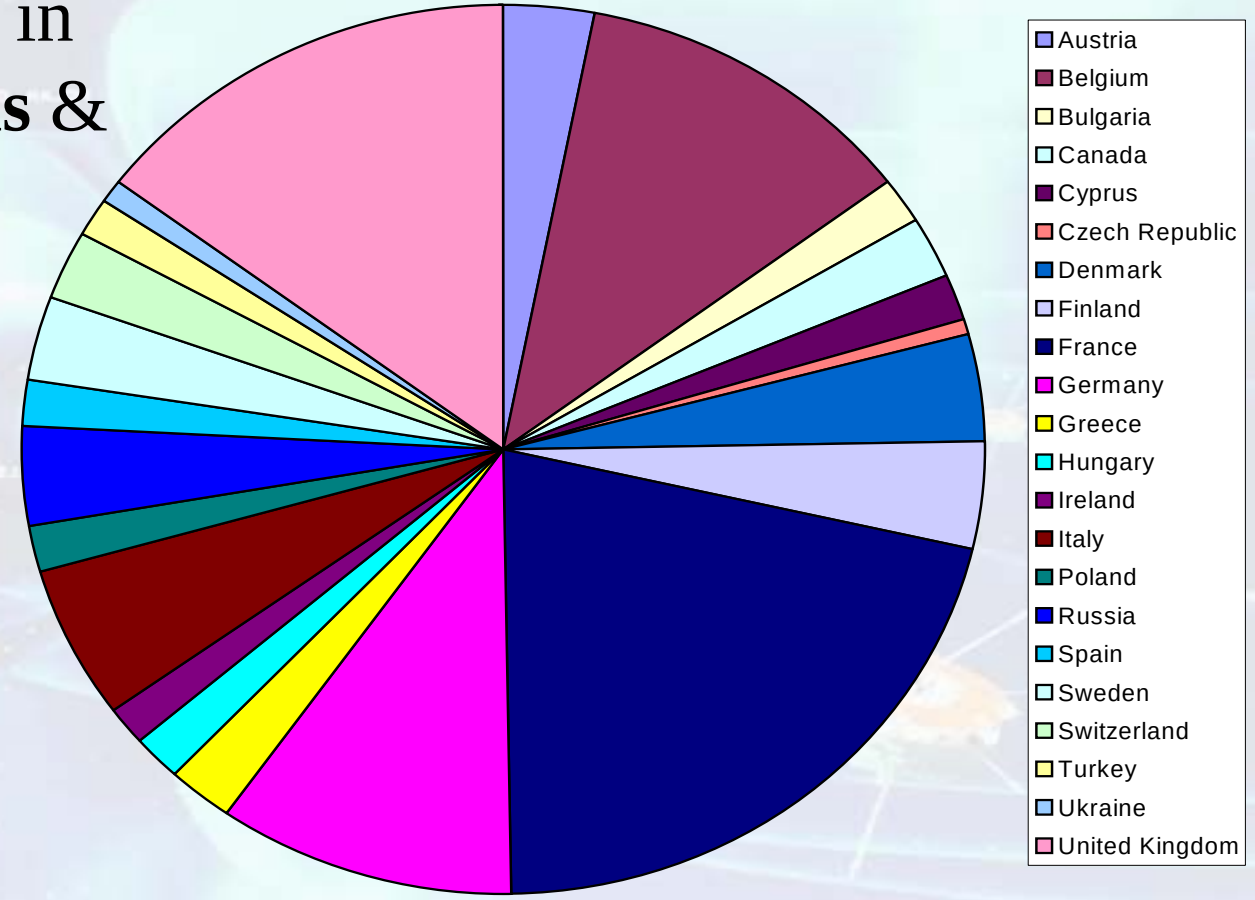
What is Space Weather?

- **Time-varying** phenomena in space that affect human beings and/or technological systems
- Diverse impacts on **environments** in which people & machines operate
- **Design, operation & regulation** of affected systems must be space-weather aware
- **Knowledge transfer** = migrate science models to applications



What is SWWT?

Open forum for European experts in SpW **applications** & related science

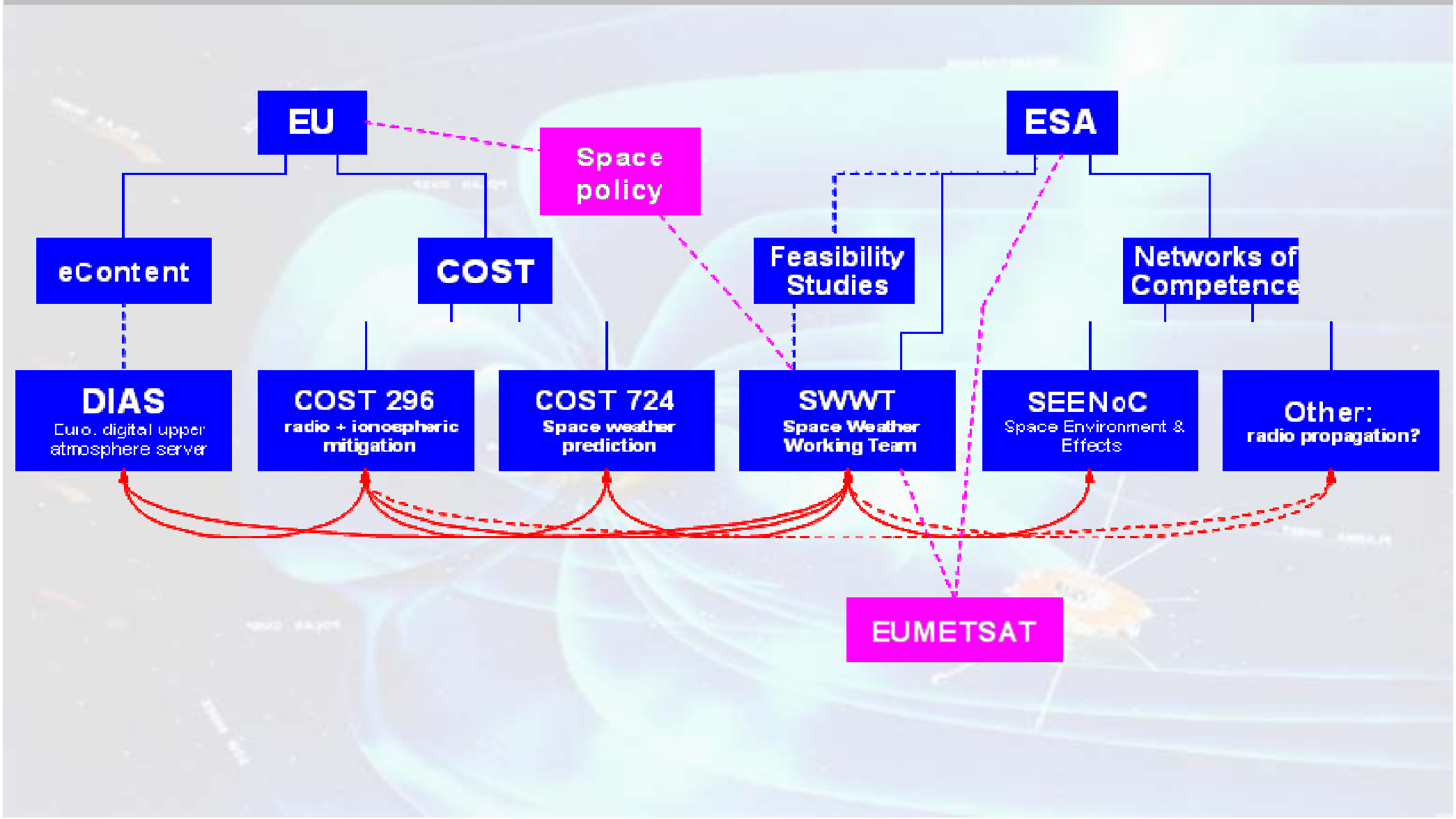


159 members @ 17 Oct 2006

Role of SWWT

- Investigate applications requirements, services, underpinning R&D.
- Advise ESA on strategies and activities related to SpW
- Promote development of European operational SpW capabilities:
  - European, national and industry levels.
- Identify & discuss collaborations & synergies with other organisations
- Facilitate exchange of information on European, national and industrial activities,
- Make recommendations to European and national agencies and industry

SWWT European SpW landscape



European space weather services

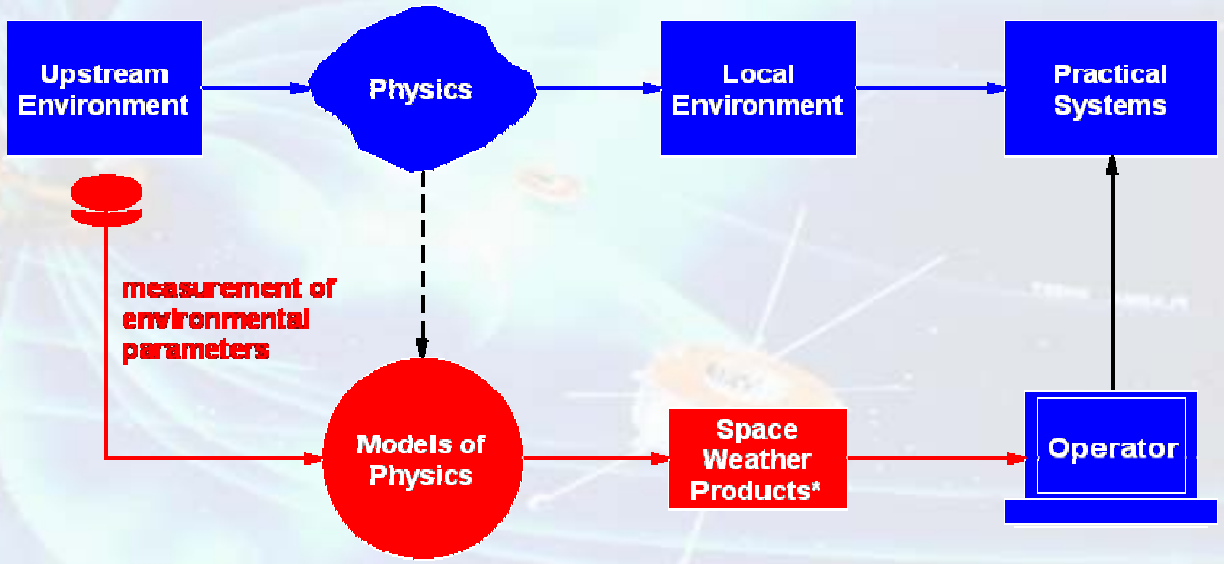
- ESA Space Weather Applications Pilot Project
  - Federate service development activities
  - A network and support infrastructure
  - Benefits assessment
- Space Weather European Network
  - ~ 27 services
  - Spacecraft effects
  - Ionospheric effects
  - Ground effects

- http://esa-spaceweather.net/

Space weather services

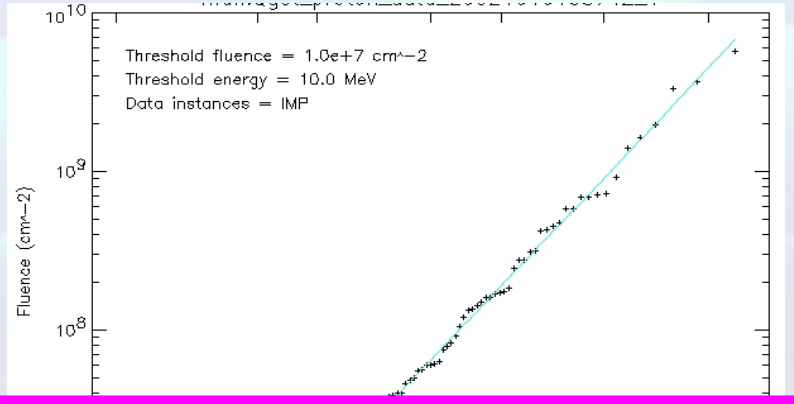
- Ideal is to mitigate problems by engineering design
  - **specification** of environment + **modelling** of system at risk
- But full mitigation is rarely feasible
  - mix engineering & situational awareness (**nowcast/forecast)**

- Physics models
  - better estimate of engineering margins
  - otherwise conservative statistical models => large margins



Scope for cross-disciplinary links

- Modelling methods include:
  - Statistical models
  - Neural networks
  - Physics models
- Physic
  - Sola
  - **Upp**
- How c
  - Build
  - Use in operational context (run-time < need-time)
  - Data assimilation



Methods used in Meteorology Applied to Space Weather

Session at European Space Weather Week, 15 Nov pm, Brussels

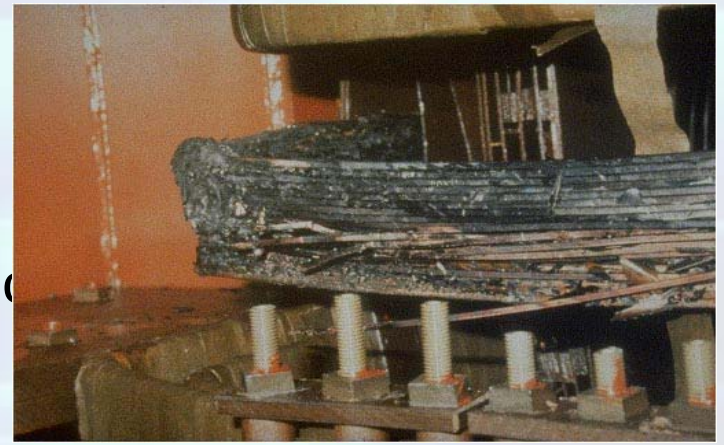
Topics include:

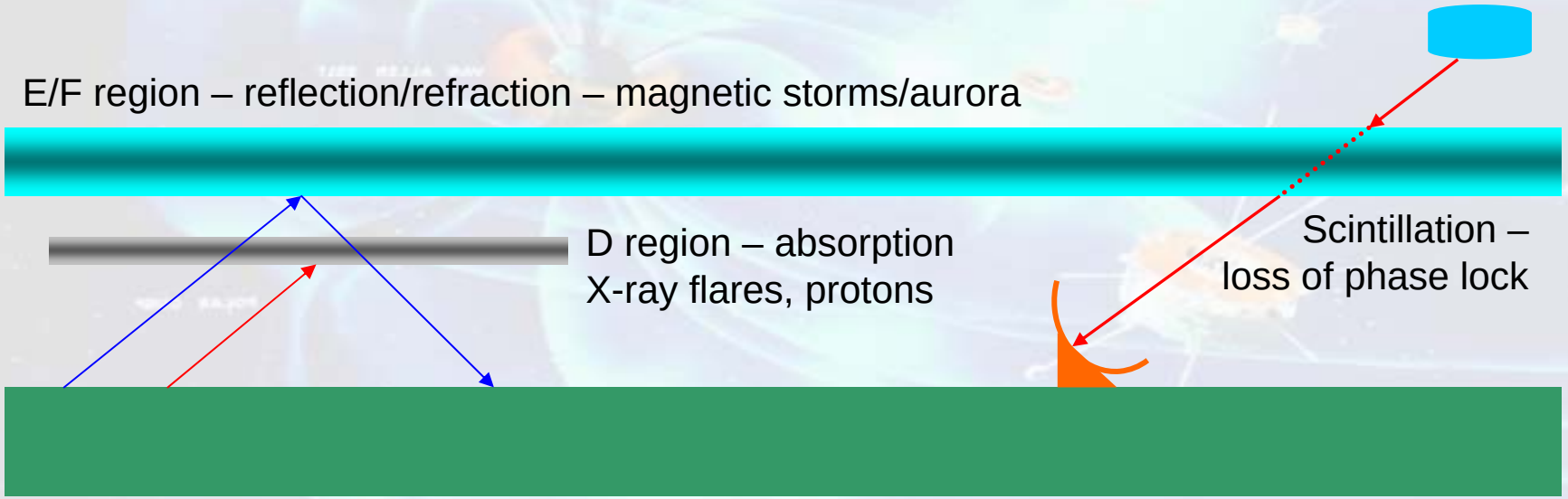
- Meteorological data assimilation techniques applied to ionospheric data
- EUMETNET GPS Water Vapour programme
- Observation operators for GPS slant delays
- Atmospheric data management

SpW in Earth's upper atmosphere

Many SpW effects above 50 km

- Ionospheric currents => GIC
- Spacecraft drag
- Radio wave propagation: absorption, reflec & refraction, phase delay, scintillation





Upper atmosphere modelling

- Two co-located components > 100 km
  - Thermosphere – neutrals (e.g. O), behaves as fluid < 800 km
  - Ionosphere – plasma, trace concentration (0.1% @ 300 km), behaves as MHD fluid
- Weak coupling via collisions
  - Significant momentum transfer (both ways)
  - Molecular neutrals critical for plasma loss via charge exchange and dissociative recombination
- Key target for physics-based numerical modelling
  - Scope to apply meteorological expertise in new domain: overlap includes fluid component, operational modelling, data assimilation

Data inputs

- Diversity of data including
- Spacecraft measurements of energy inputs
- GPS (Galileo) => line-of-sight data
  - "Total electron content" aka TEC
- Ionosondes measure bottomside density profile
  - Absolute measure of peak density
- Much scope for work on data assimilation
  - Direct assimilation of ionosonde data?

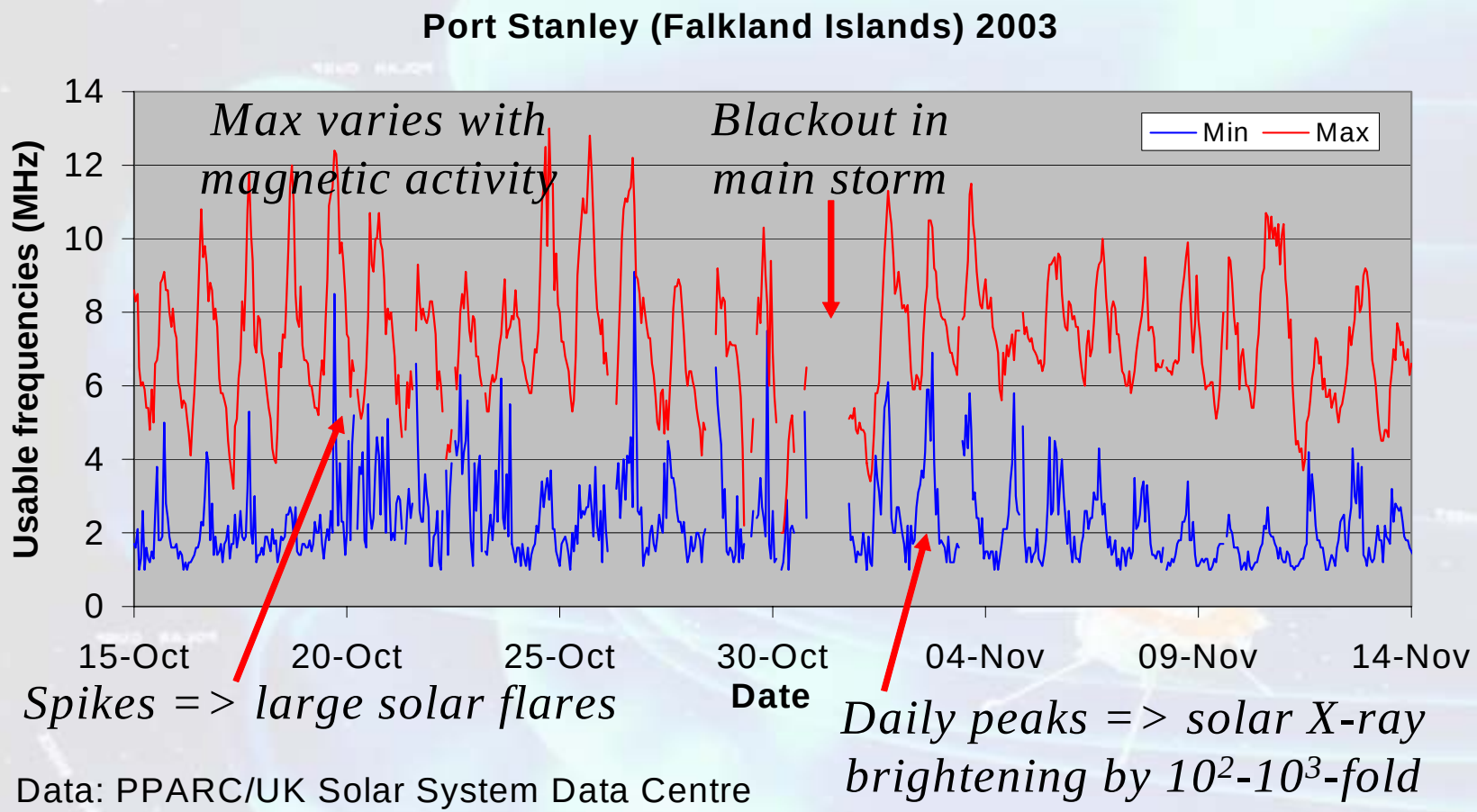
Modelling aims & examples

- Predict 3D electron density profiles, occurrence of scintillation
- US
  - Global Assimilative Ionospheric Model (GAIM) from JPL, USC & Utah; http://iono.jpl.nasa.gov/gaim/intro.html
  - Ononumerics, Fusion Numerics, Boulder; http://ononumerics.com/
- Do we need similar capacity in Europe?
  - CTIM (Coupled Thermosphere Ionosphere Model) at UCL; http://www.apl.ucl.ac.uk/research/earth_modelling/
  - Research funding more aimed at other planets

RADIO APPLICATIONS

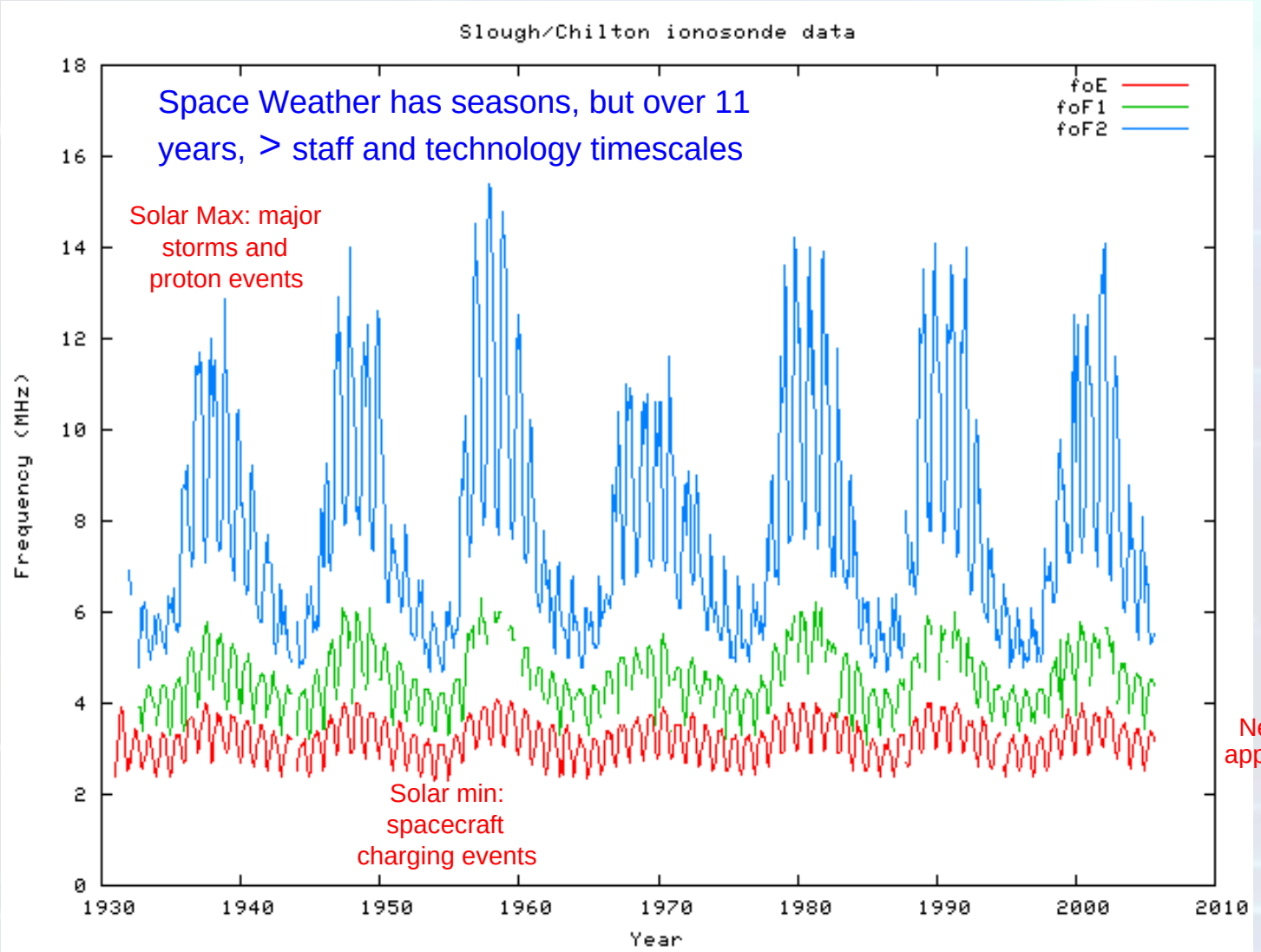
- HF radio – major growth area!
  - Cheaper than satcom if SpW issues are mitigated
  - Digital services growing, WRC 2007
- Satcom + GPS
  - Scintillation problems, also phase delay for GPS
- Ray tracing applications
  - Over-the horizon radar
  - Single-station location direction finding
  - Jamming and interception vulnerability estimation
  - Tracking of satellites/orbiting debris/ballistic projectiles
  - Satellite geolocation of VHF transmitters

SWWT Severe event: Halloween 2003 storm

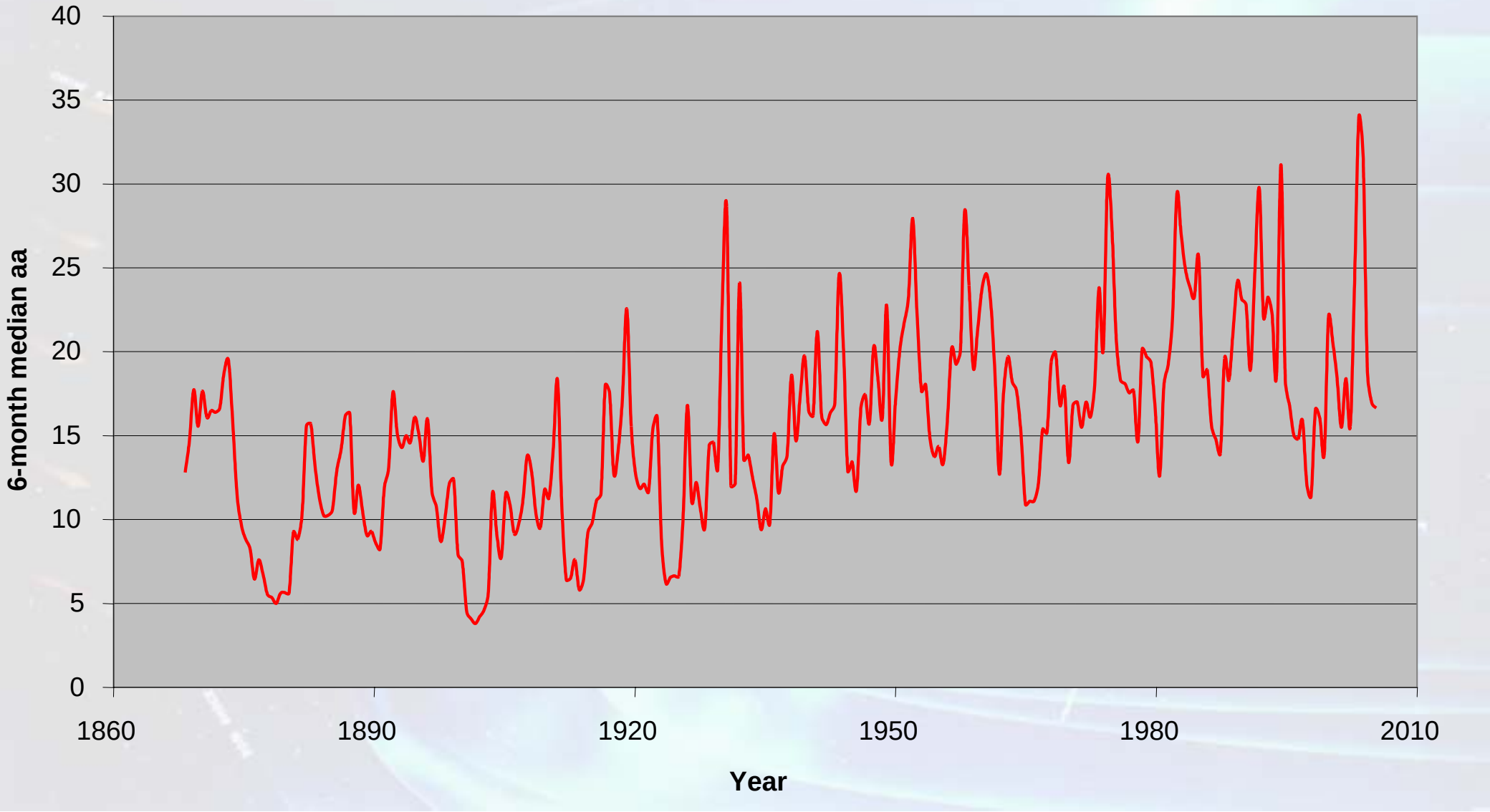


Data: PPARC/UK Solar System Data Centre

SWWT SEASONS OF SPACE WEATHER

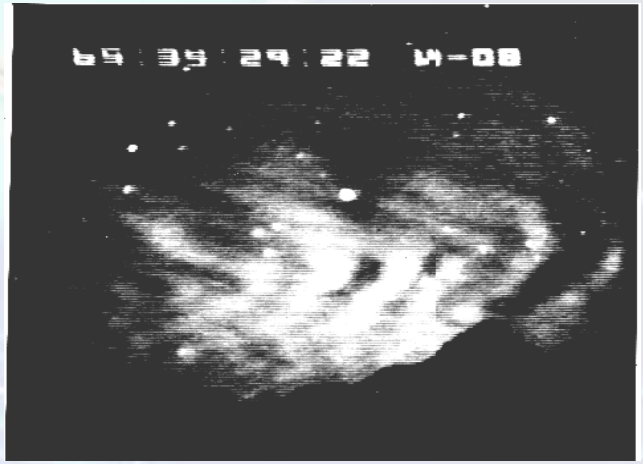


SWWT ... and CLIMATE CHANGE



Upward coupling in the atmosphere

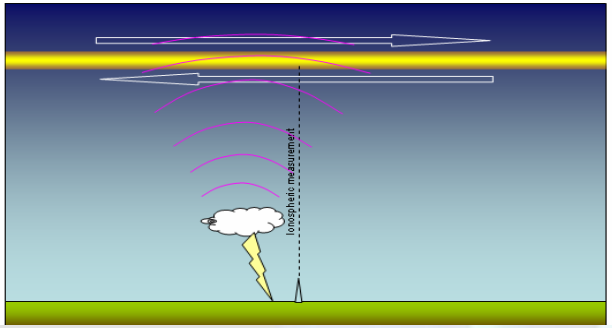
- Thunderstorms have major upward influences:
  - Sprites etc
  - Infrasound & gravity waves
  - Gamma rays/electrons
- Effects include
  - Enhanced Es layer
  - Heating (wave breaking)
  - Wave perturbations



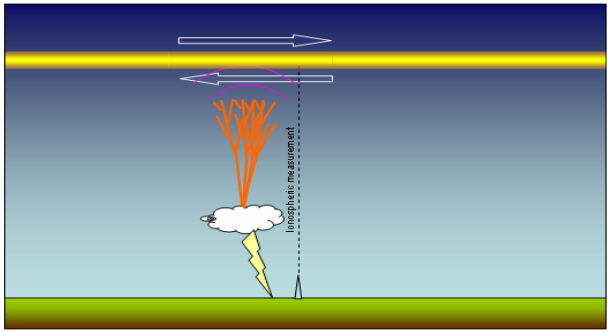
SWWT Thunderstorm-Es mechanisms

Some mechanisms enhance the ionosphere directly above a thunderstorm

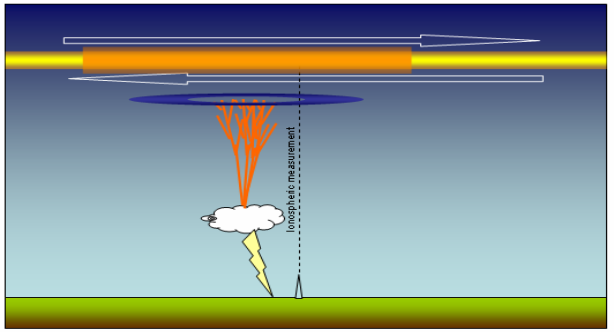
Infrasonic waves act vertically
- enhancing the wind-shear?



Sprites launch waves
- enhancing local ionosphere?

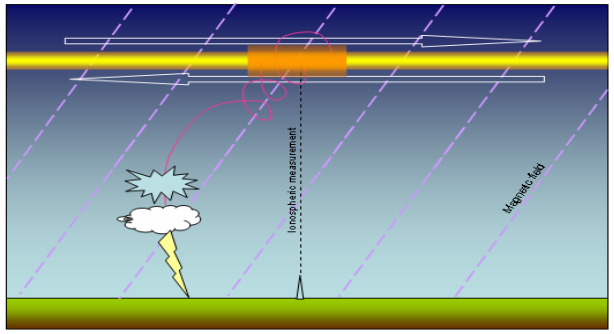


EMP associated with ELVES
- heat local ionosphere reducing loss rate?

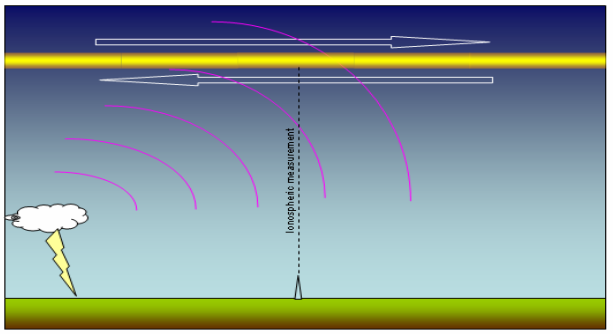


…others act from a distance.

Relativistic electrons from gamma-ray bursts
- enhance ionisation equatorwards of storm



Gravity waves act from a distance
- gathering ionisation at the nodes?



SUMMARY

- Space weather has diverse & significant effects
  - Radio, aircraft & spacecraft, power systems, etc
- Now evolving as an environmental science
  - Little in common with astronomy
  - Can learn much from meteorology
- Physics-based forecasting desirable
  - Data management/assimilation
  - Operational use of models
  - Coupling with lower atmosphere