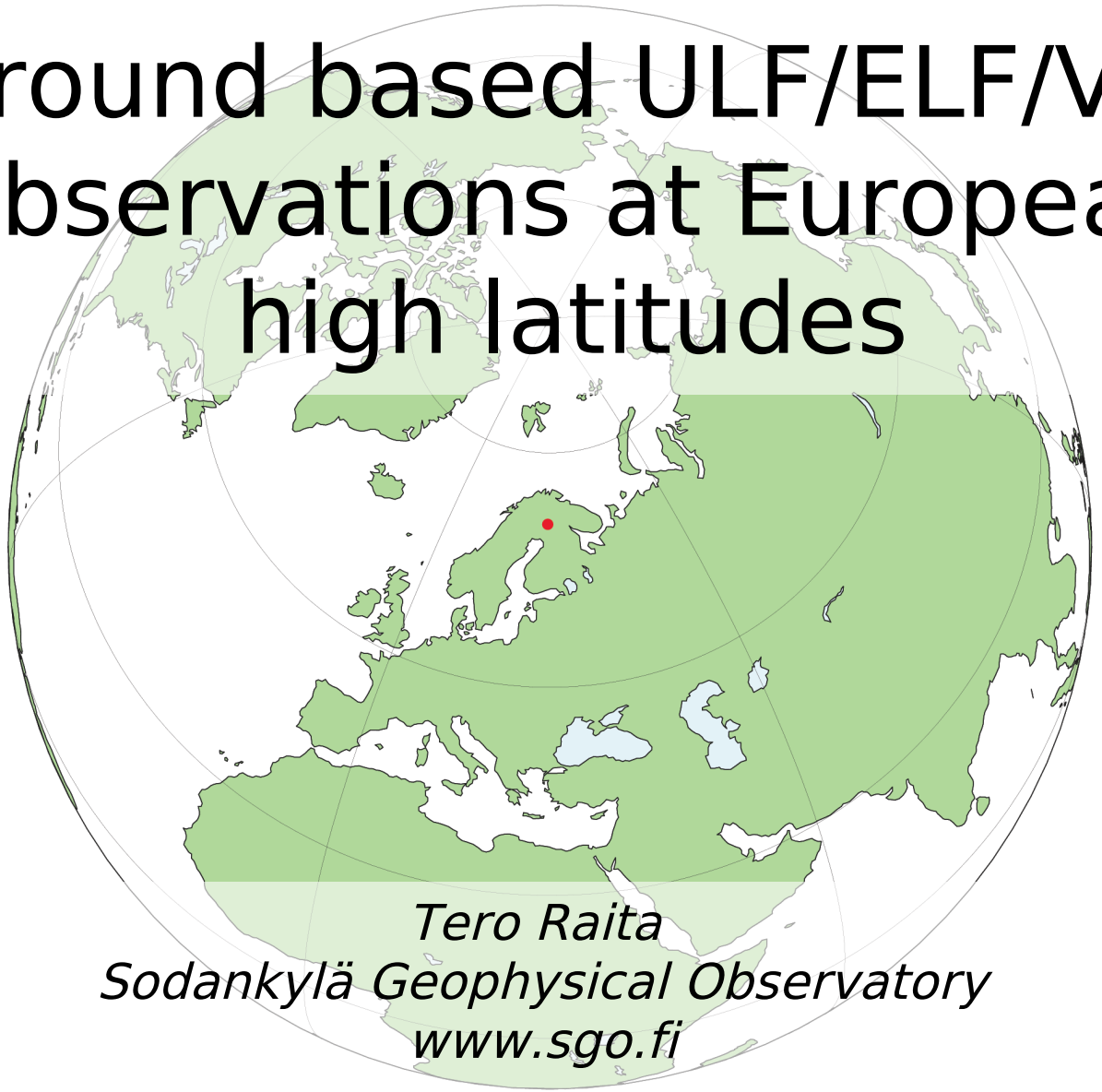
Ground based ULF/ELF/VLF observations at European high latitudes



Tero Raita
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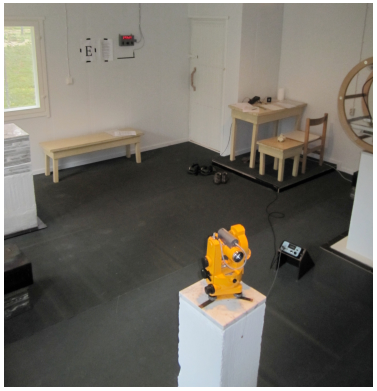
www.sgo.fi

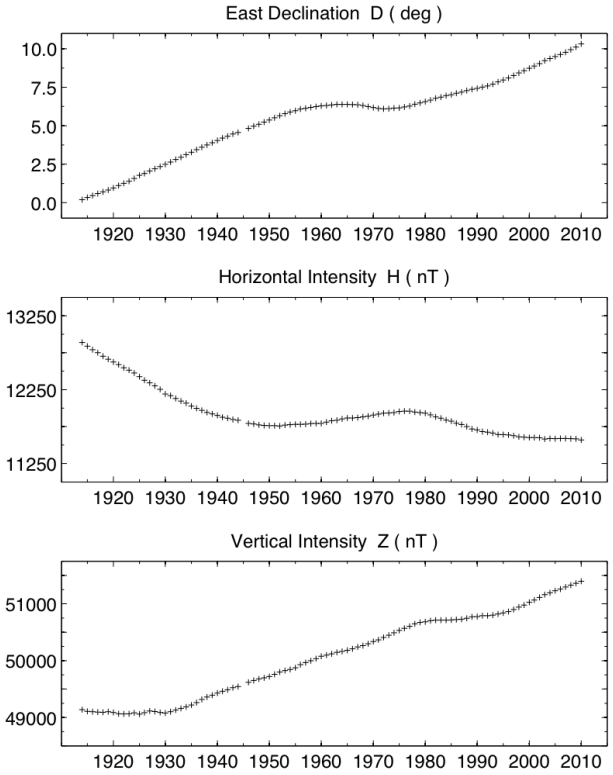
Outline

- magnetic observatory
- Finnish pulsation magnetometer chain
- analysis method for ULF/ELF/VLF data
- VLF receivers

Sodankylä geomagnetic observatory (1914 -)

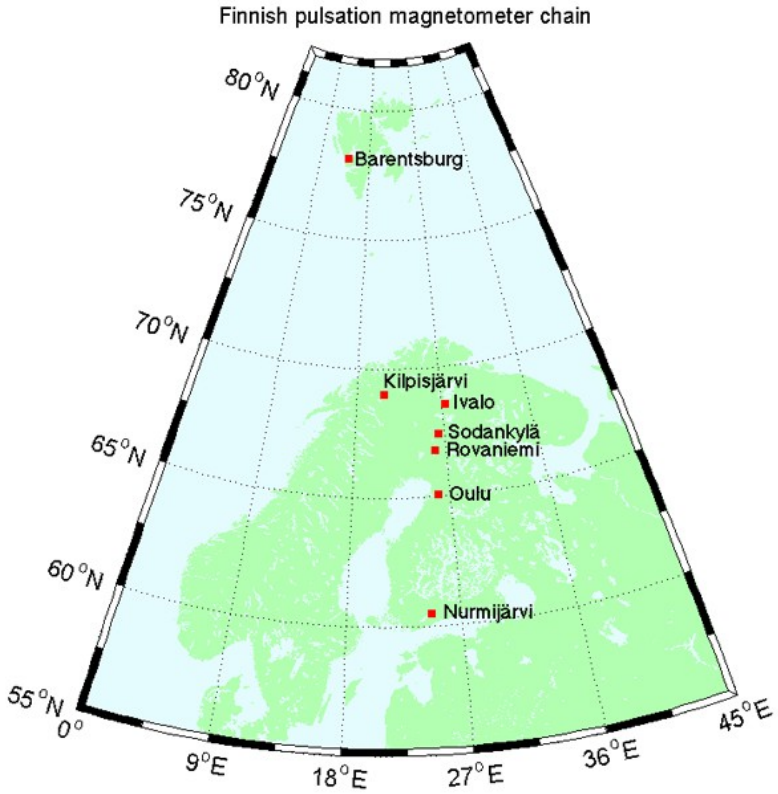


- three independent systems in operation:
  DMI fluxgate, PSM and Russian ring core magnetometer
- rawdata sampled by 2 Hz, part of the
  INTERMAGNET and IMAGE networks
- buildings renovated in 2009-2010,
  updating of instrumentation and dataloggers starting



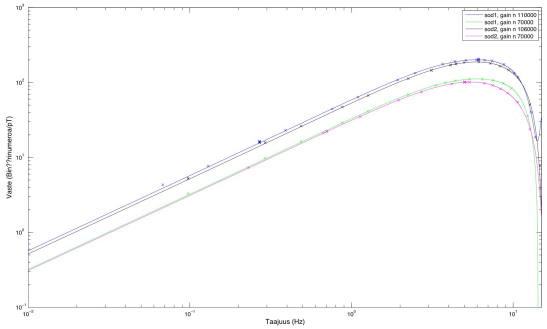
Finnish pulsation magnetometer chain

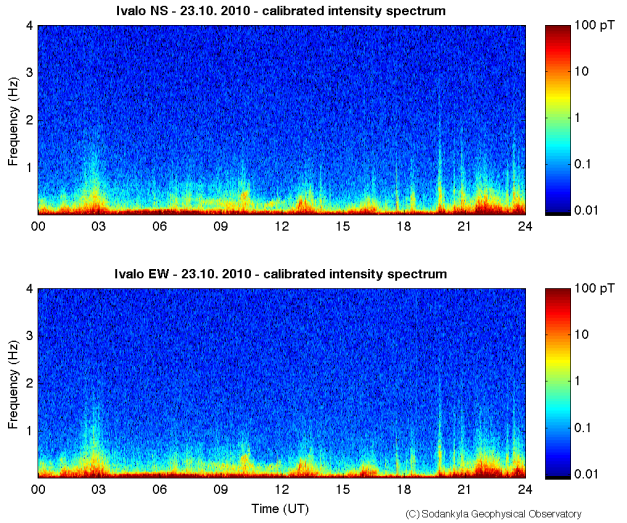
- three component stations
- network covers L-values from 3.2 to 6.4 (BAB not active at the moment)
- 3rd generations of the search coils has been in use since 2002-2003, when instrumentation was renewed
- coils: 19500 turns, μ-metal core, length 110cm



Signal properties of the induction coils

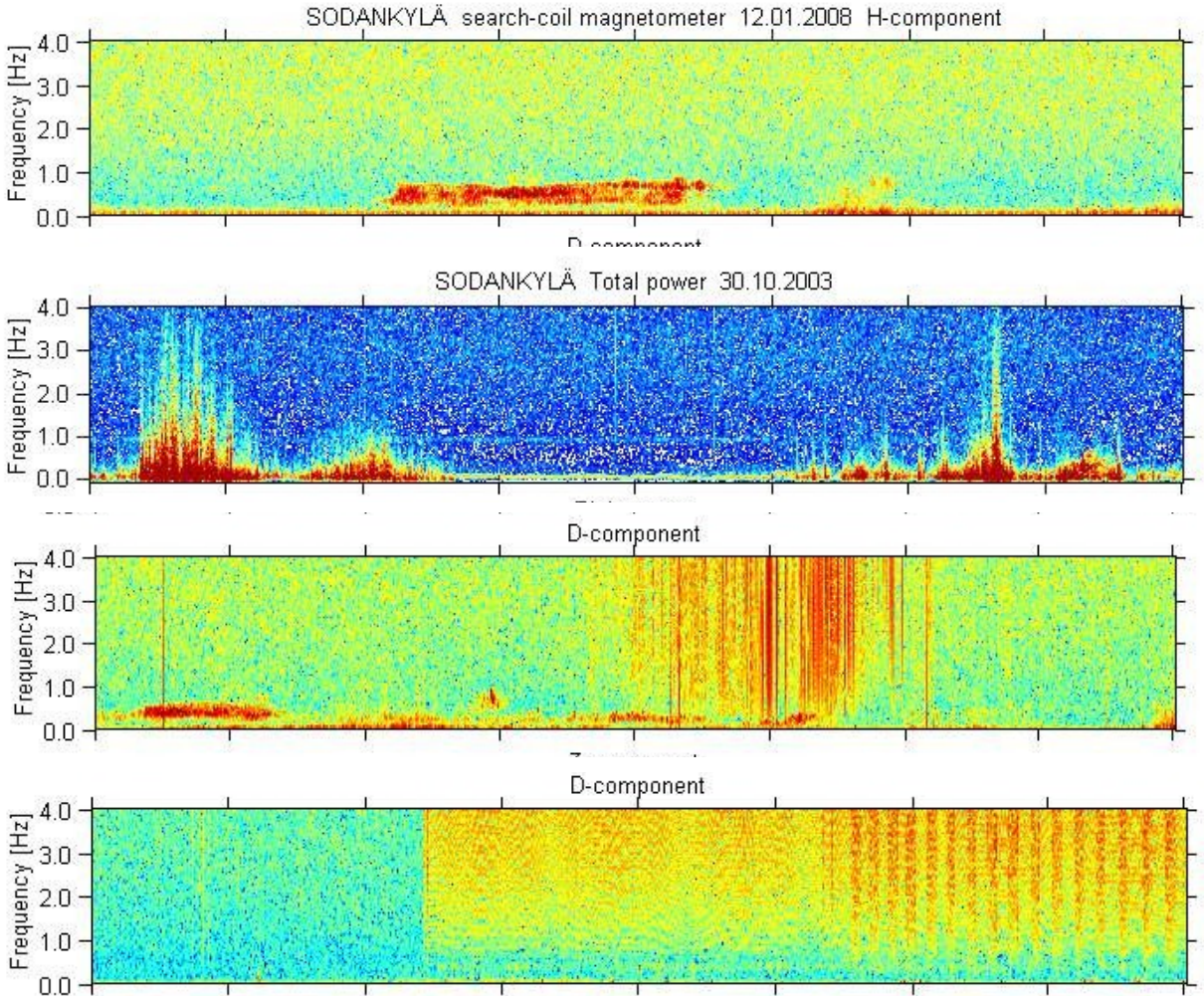
- analg pre-amplification and filtering made by combination of 5-pole Chebyschev and 10-pole Bessel filters; cutoff frequency at 10 Hz, gain ~70 000
- noise level: ~0.3 pT/√Hz
- sampling rate: 40 Hz, 16-bit AD-converters with GPS timing (PPS)
- data stored to MATLAB 4.0 format
- calibrated with external coil system on the field, frequency response highly linear up to 5 Hz



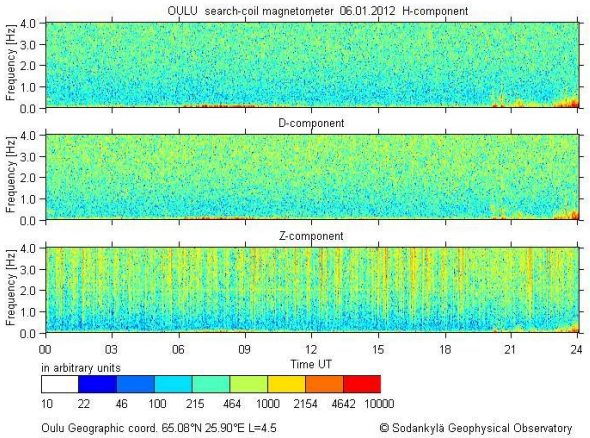


What we observe?

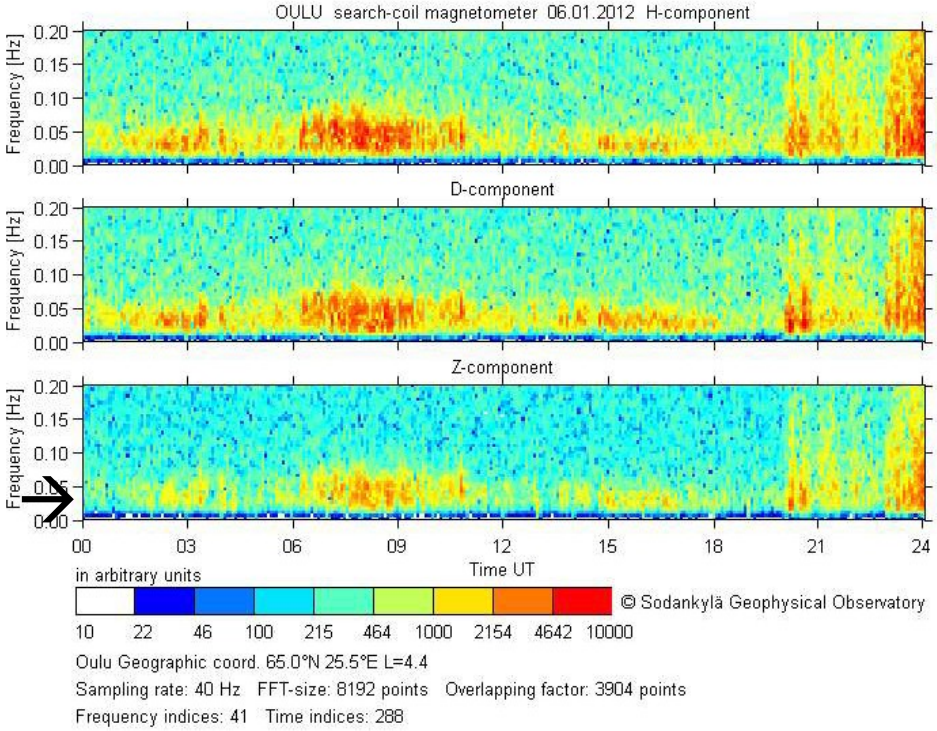
- Pc events, lasting many hours
- substorm related events (Pi)
- local thunder storms
- sometimes local noise



Pc3 (10-45s) pulsations from the induction coil data



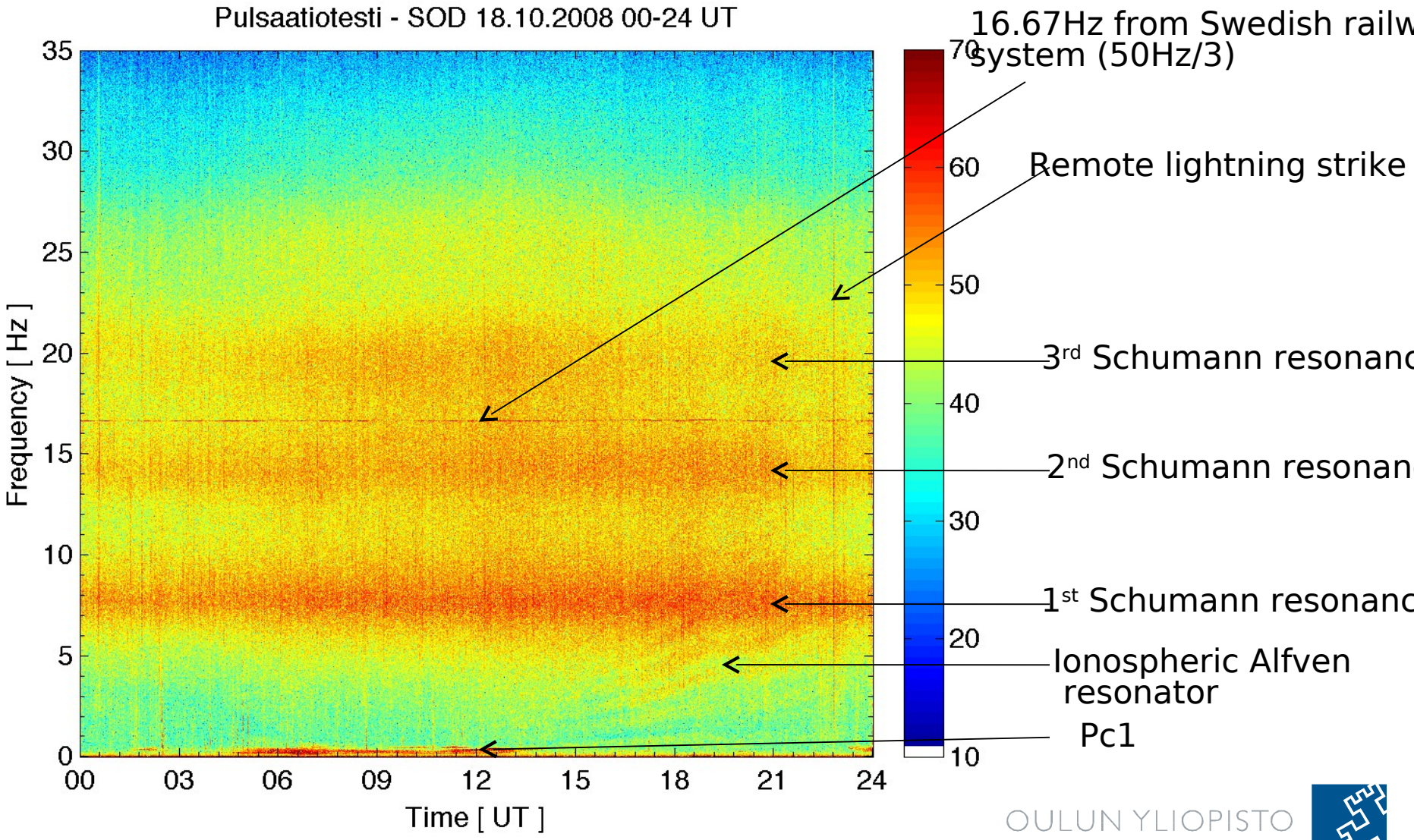
filter and decimation →



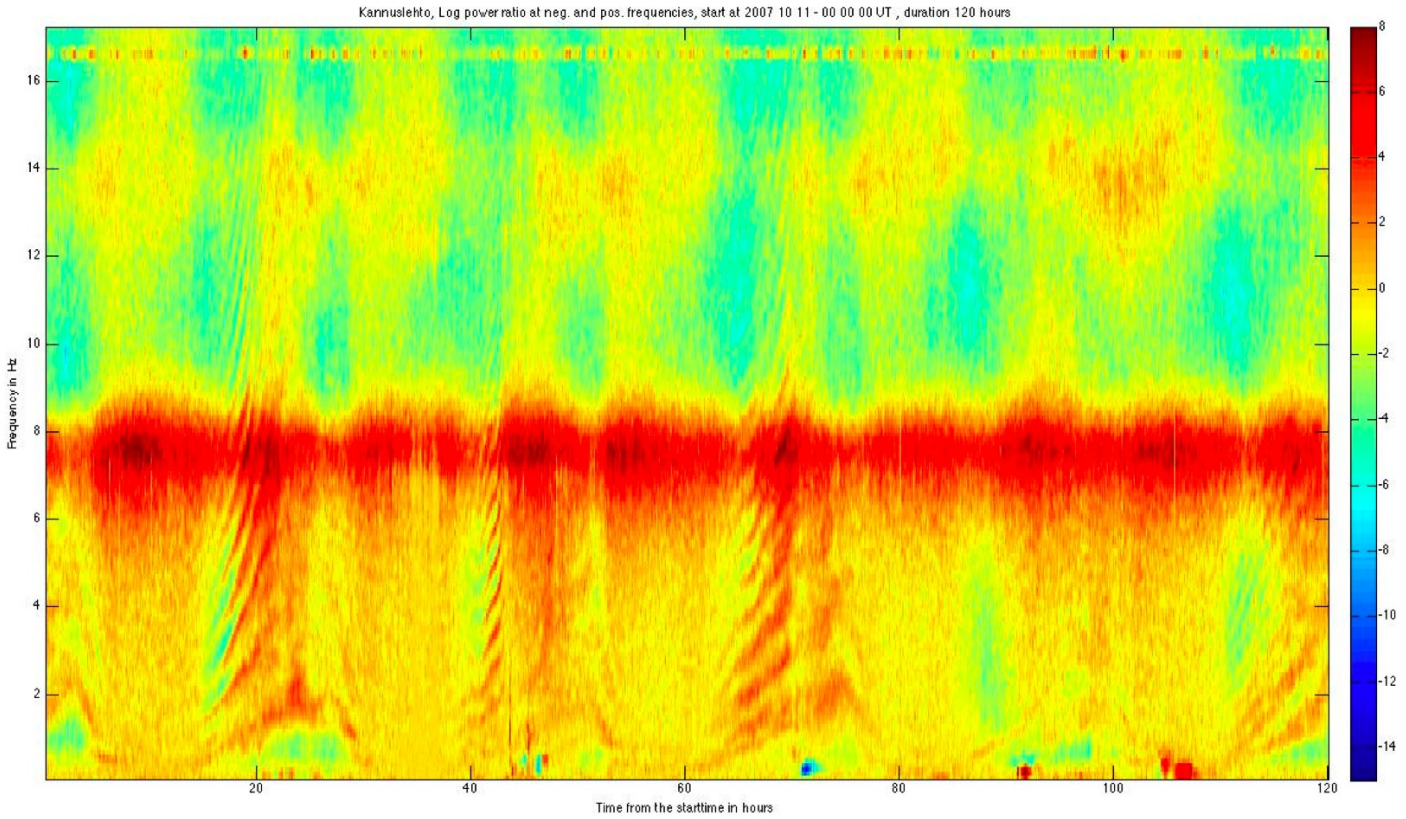
Pulsation data availability

- 20Hz digital data since 1995 from SOD, 40Hz data from all stations since 2000
- data coverage is high (>95%), main problems from thunder storms in summer time
- daily data transfer to Sodankylä, possible to improve for real-time purposes, when needed
- quick-look spectrograms generated automatically from all the stations and available online for browsing in web
- raw data available to anyone by email request

Better SNR possible for the present induction coils by different filter solution



Improved SNR helps to monitor IAR



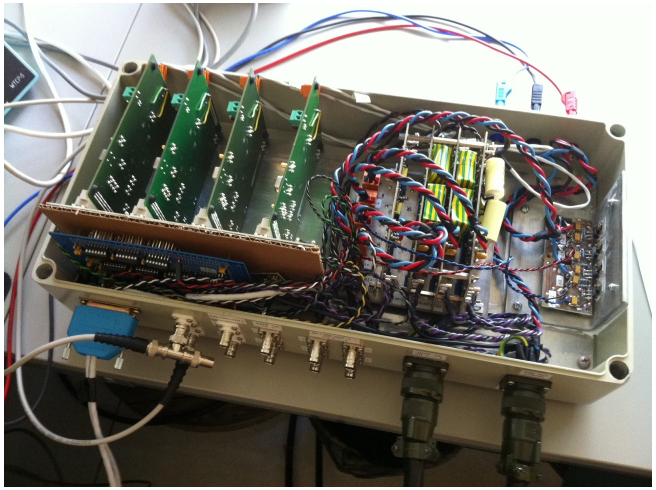
5 days of IAR observed in October 2007.

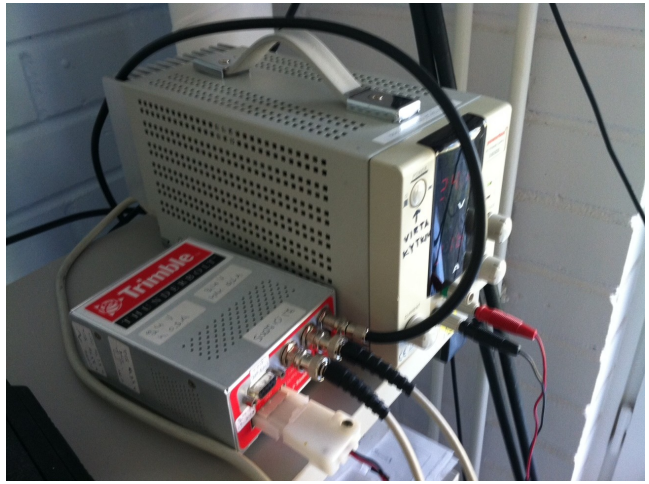
Upgrading of the present chain

- building of the electronics for the set of pulsation magnetometers is in process
- testing of the new system continues parallel to the present system in SOD
- SNR improves to the level of tens of fT
- fully upgraded station network will be coherent receiver network: data can be used to study properties of the observed events in new level

Prototype of the 24-bit system

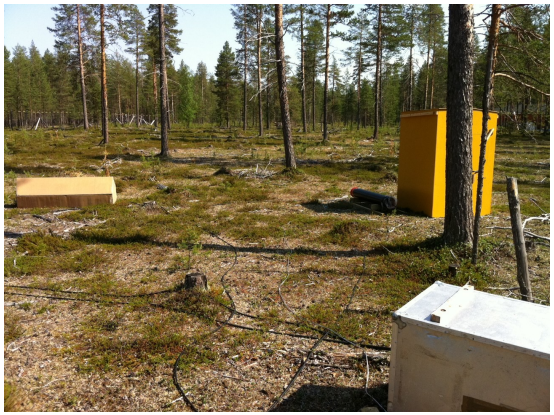
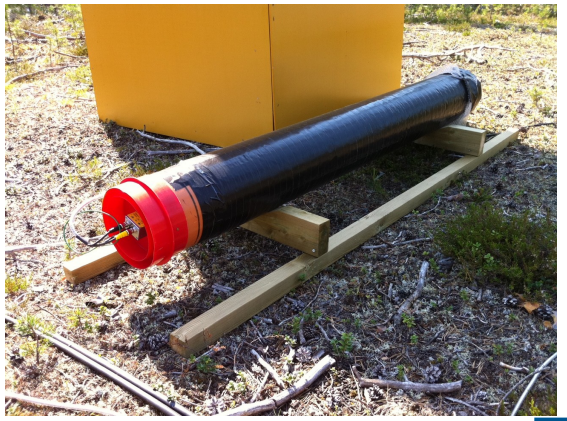
- new electronics: differential input, parallel amplifiers and filtering
- 24-bit A/D-converters (Analog Devices), 250Hz sampling
- synchronizing of the A/D converters: 10 MHz reference signal from GPS
- data storing in Linux (Fedora)



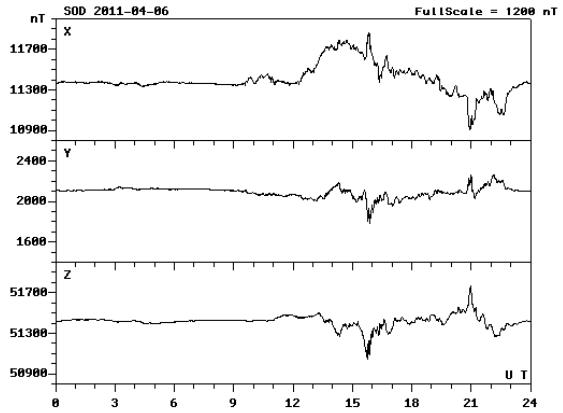


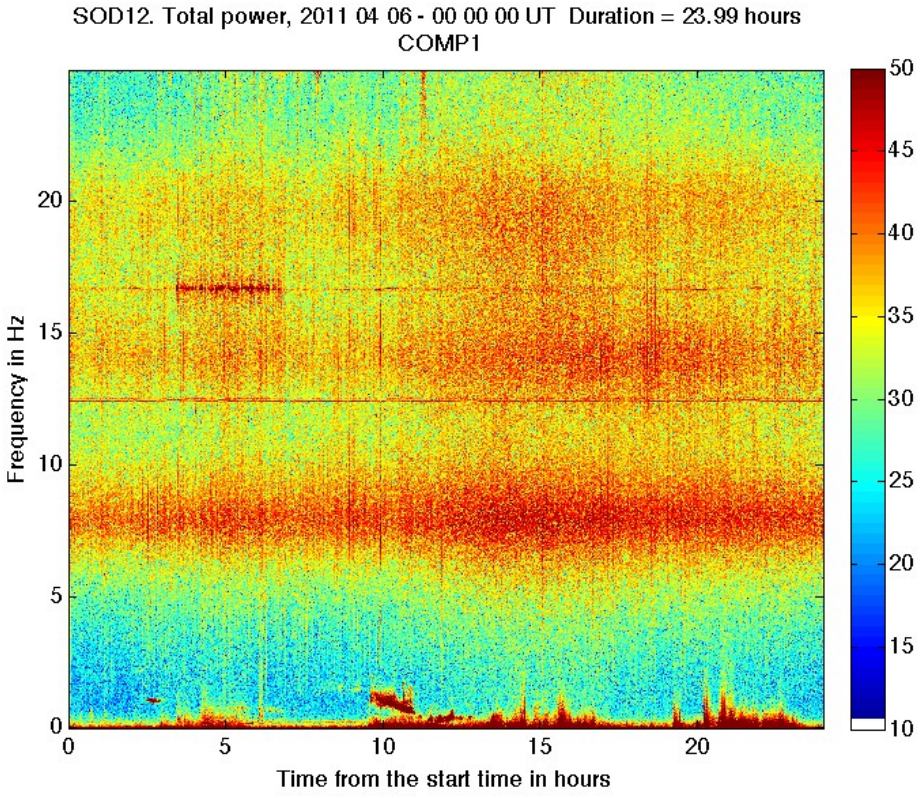
Stability test of the 24-bit system is going on

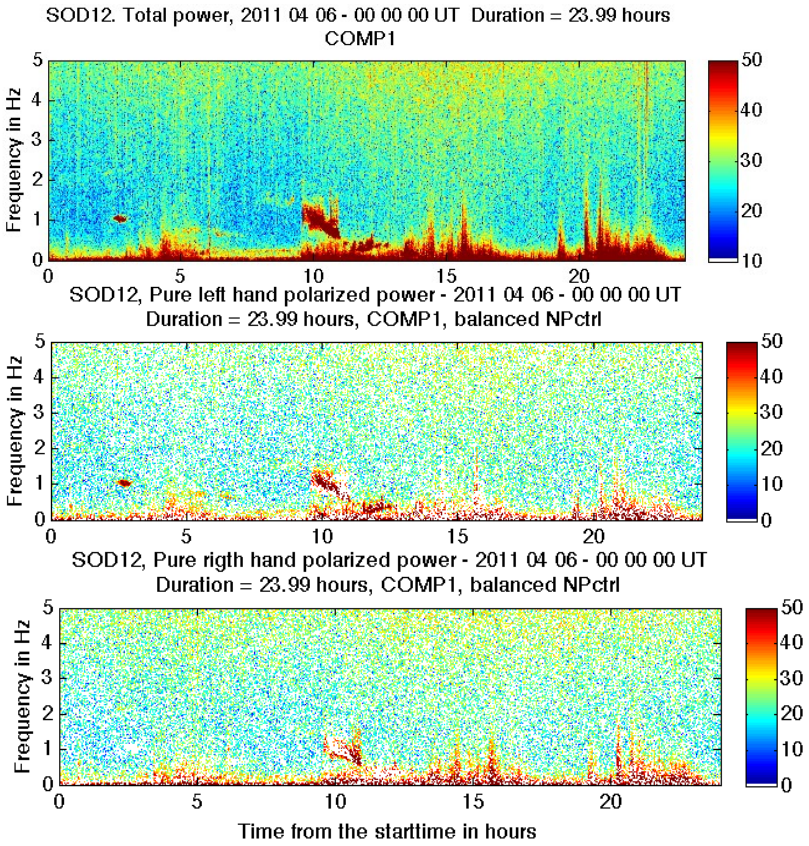
- system test started during the winter 2010-2011at the observatory area
  - extreme temperatures below -30°C revealed weakness of one capacitor type, which is now replaced
  - local EM-noise time to time strong, especially during the coldest periods of winter, when heating systems for buildings have the highest duty
  - A/D converters reseted couple of times, reason unknown

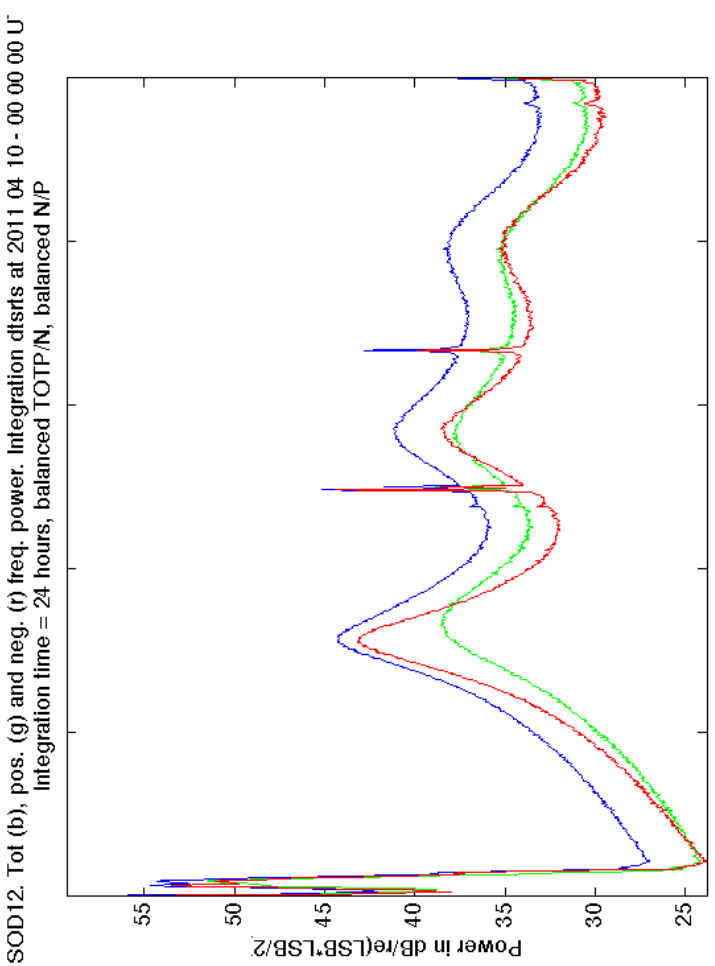
Sample data of the 24-system - 6.4.2011

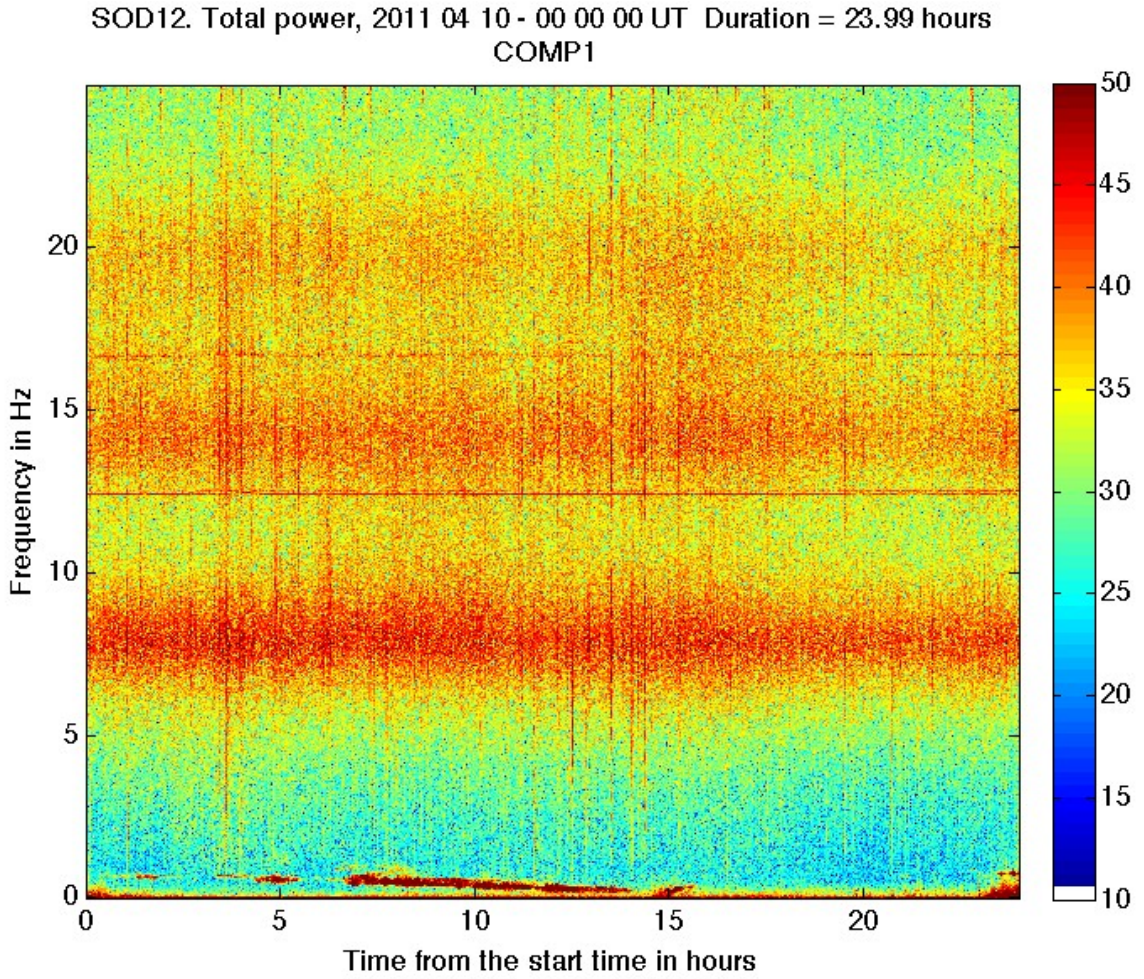






Sample of the 24-bit data - 10.4.2011





SGO analysis tool for ULF/ELF/VLF data

- Matlab analysis software developed by T. Turunen
- data from two orthogonal components (XY, XZ or YZ) is handled as complex matrix pair
- main parameters: total power, polarization features of the signal calculated in time-frequency-intensity analysis
  - polarization ellipse is formed from each pair of complex Fourier coefficients
  - axis ratio, orientation and sense of rotation of the polarization ellipse computed
- several filtering possibilities (power levels, eccentricity, sense of rotation and orientation in numerous combinations)

VLF operations : ARDDVARK, WWLLN and AWDA networks

Monitoring of VLF transmitter signals:

- OmniPAL receiver since 2002 in collaboration with BAS
- UltraMSK (AARRDDVARK) receivers since 2007

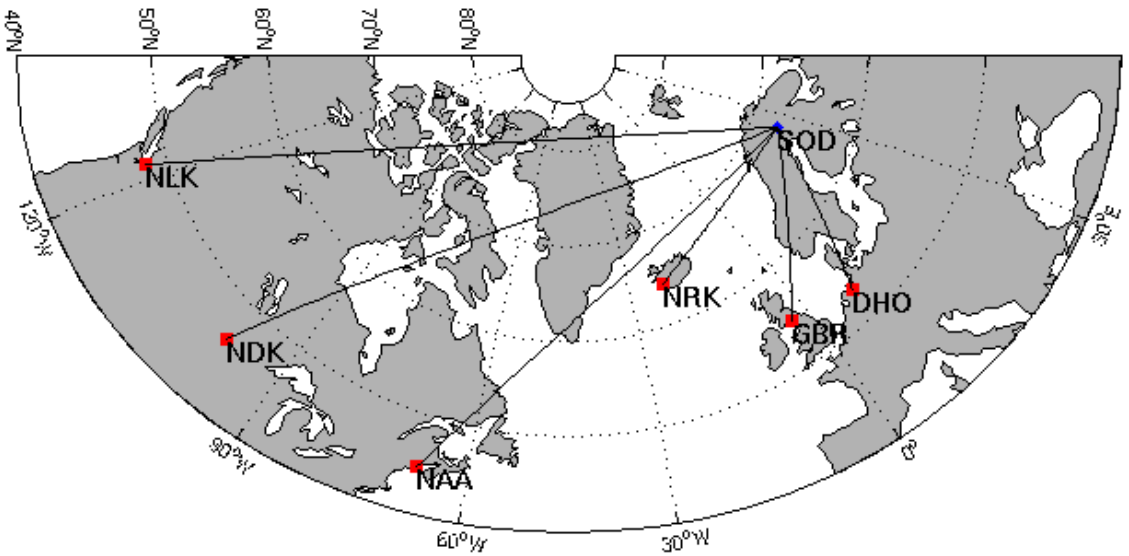
Lightning detector:

- WWLLN station in operation since 2004

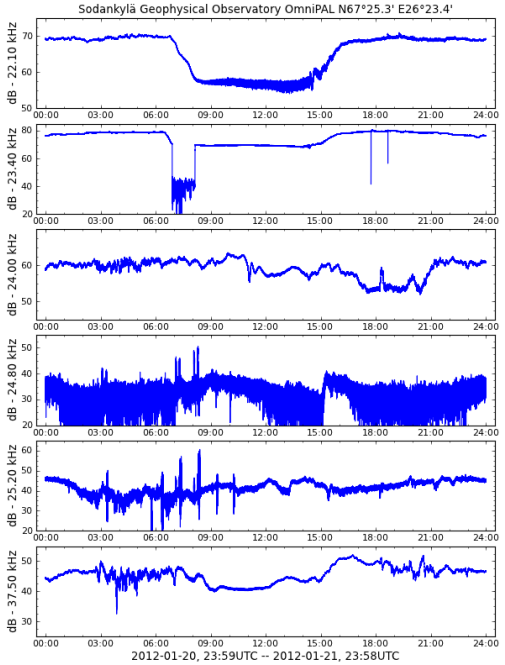
Whistler detection by AWDAnet receivers:

- receiver at Tvärminne (L=3.2) installed in 2009: site has noise problems, new location needed
- test for new location for Oulu receiver will be started in spring 2012

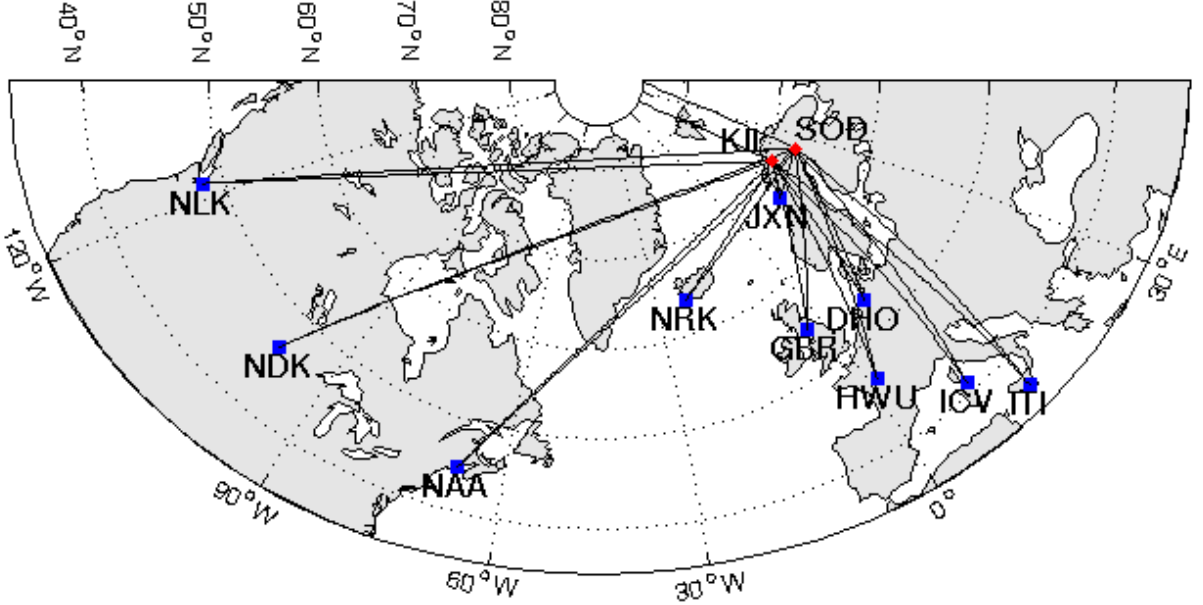
OmniPAL



- single magnetic loop antenna receiver at SOD
- amplitude and phase of 6 stations monitored by 10 Hz sampling
- UltraMSK receivers is built to replace OmniPAL, but it will be in operation until bigger events are observed simultaneously for data calibration



AARDDVARK



two magnetic loop antennas (3m x 3m, effective area 90 m²), two stationsoperation since 2007
both stations monitor 11 transmitters simultaneously

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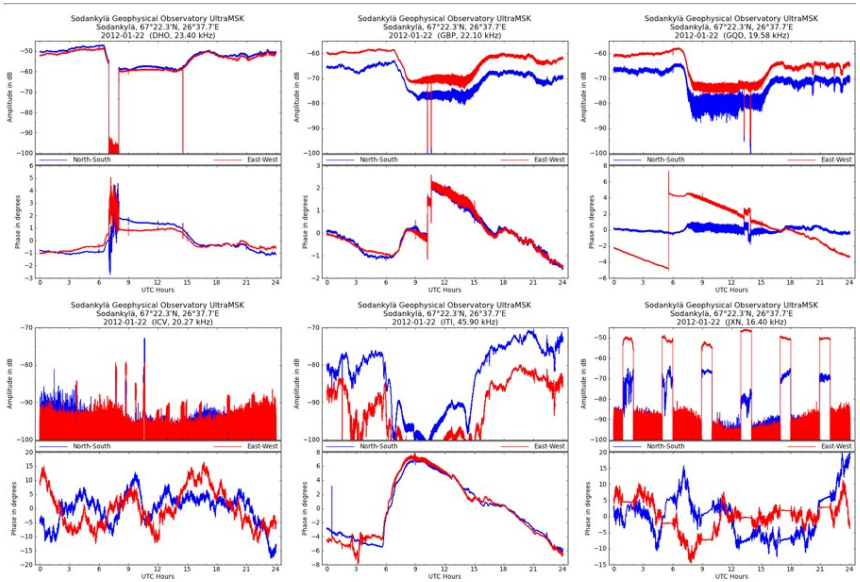
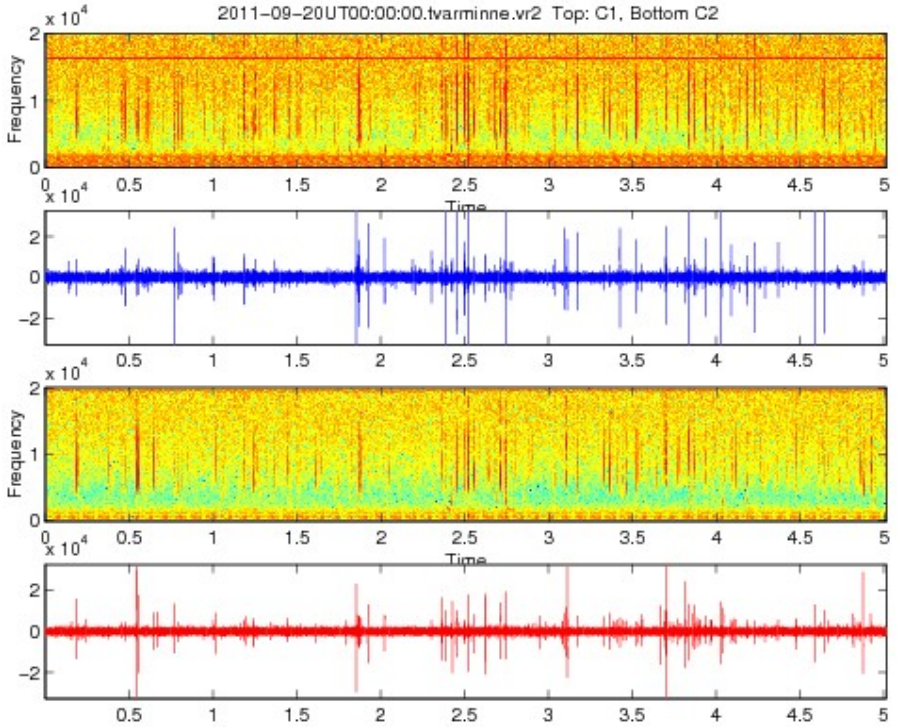


OULUN YLIOPISTO
UNIVERSITY of OULU

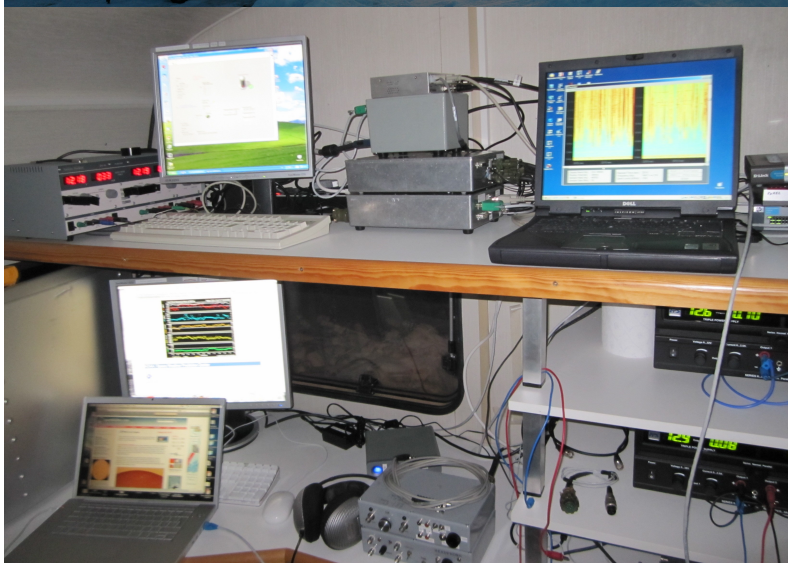
AWDAnet in Finland

magnetic loop antennas from SGO, AWD from ELTE

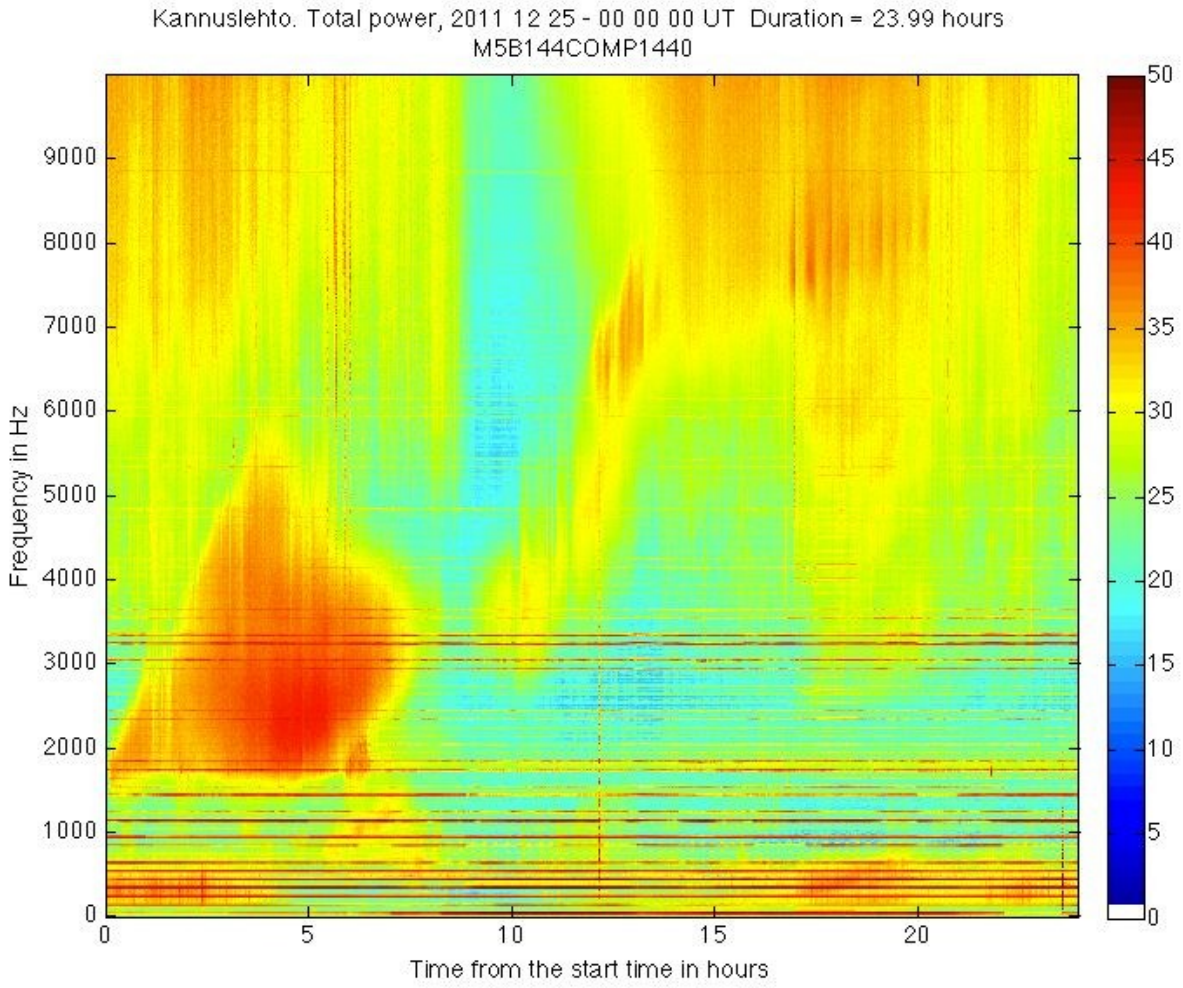


Broad band VLF campa

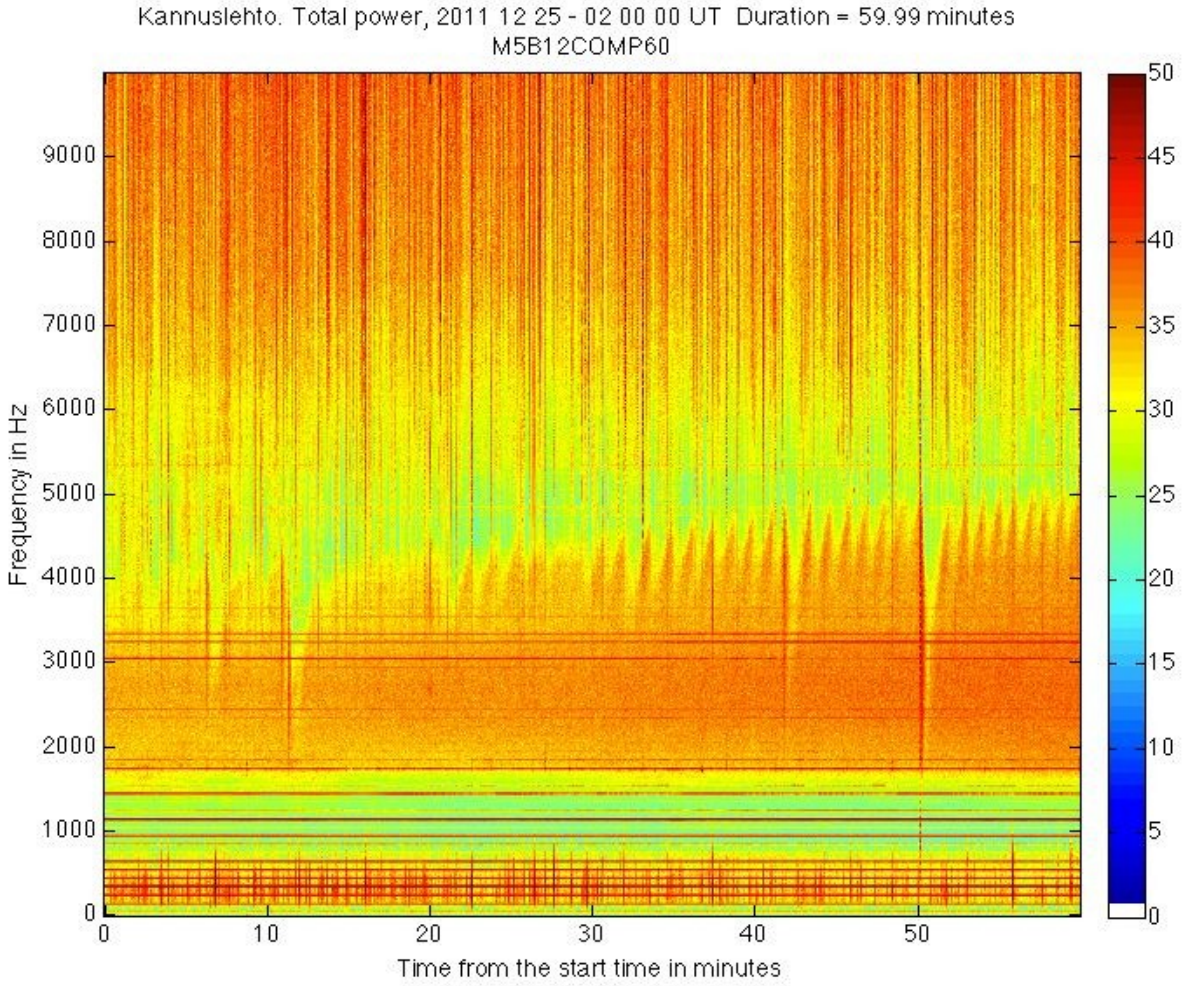
- orthogonal 10m x 10m antennas, effective area 1000 m^2
- receiver located in wilderness, 20km off from the 20kV power lines
- typical campaign lasts 2-3 weeks related to the Finnish EISCAT campaigns
- continuous measurement, sampling rate 78 kHz



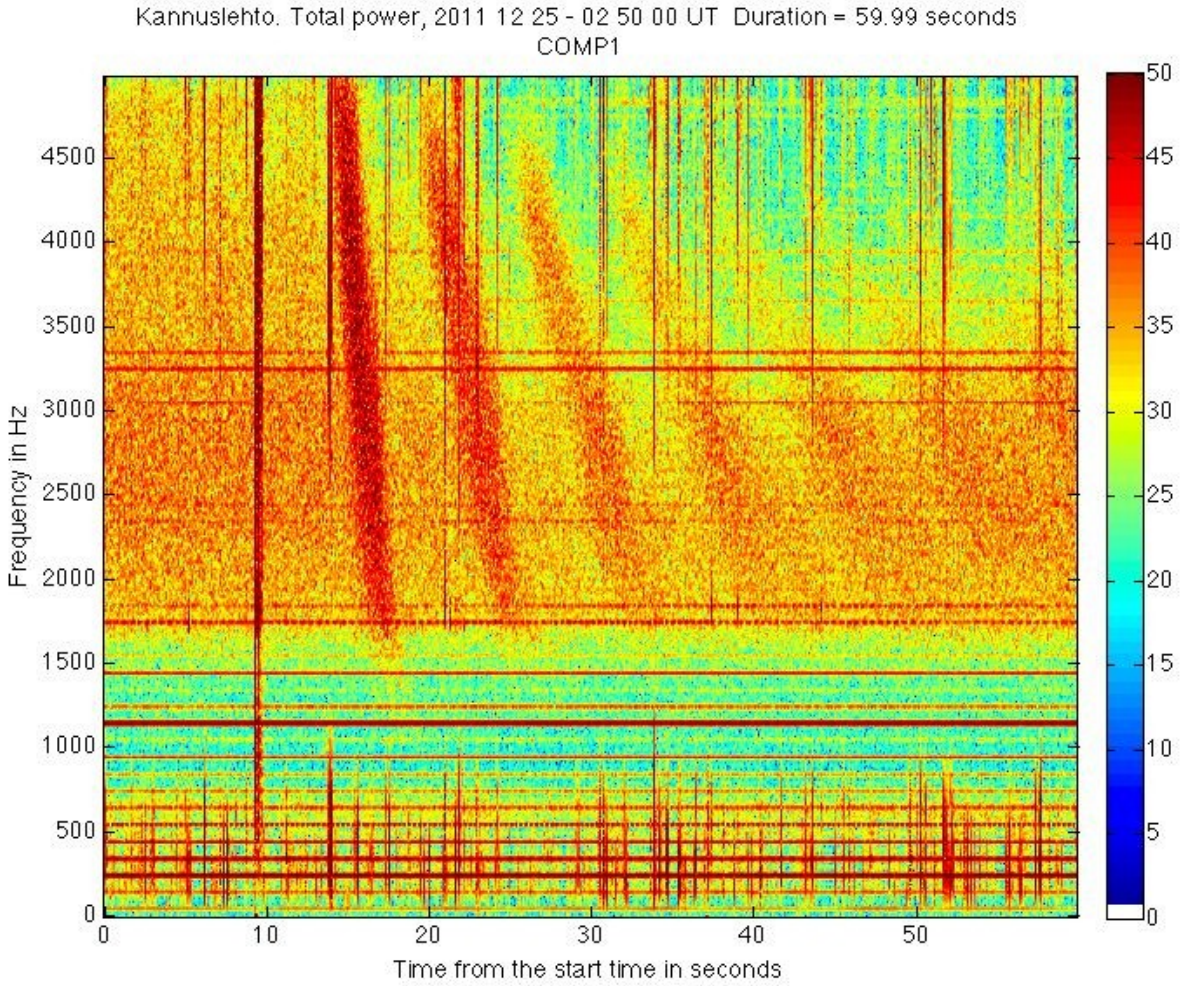
Broad band VLF campaigns – 24h data sample



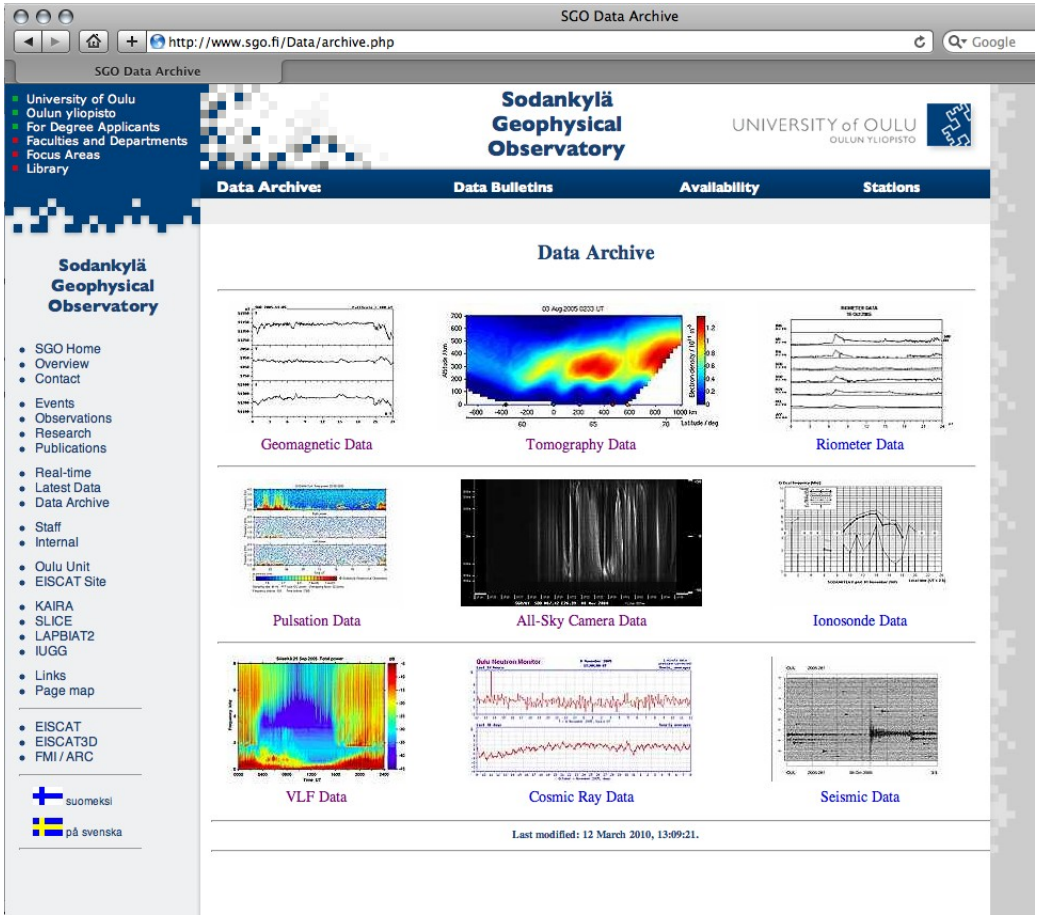
Broad band VLF campaigns – 1h data sample



Broad band VLF campaigns – 1 min data sample



Interested about ULF/ELF/VLF data?



- browse the quicklooks at www.sgo.fi > Data Archive

- send email request to:

  tero.raita @ sgo.fi (geomagnetic data)

  jyrki.manninen @ sgo.fi(broadband VLF data)