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Geomagnetic Observatories

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Geomagnetic Observatories

Content

- **Global ground magnetometer data**
  - SuperMAG
  - World Data Centres / IMAGE
  - INTERMAGNET

- **Our activities:**
  - *Kp* index
  - new, *Kp*-like, hourly and half-hourly Hpo index
  - mesospheric magnetometry

Some global ground magnetometer networks

Network	# of sta-tions	latency	time resolution	orientation
SuperMAG	>220	1-2 yrs	1 minute, some 1 Hz	local magn. NEZ
IMAGE	44	0.1 yrs	0.1 Hz	geographic XYZ
WDC	>130	1-2 yrs	1 minute	geographic XYZ
INTERMAGNET	>100	1h, 0.1 yrs, 1-2 yrs	1 minute, some 1 Hz	geographic XYZ

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science driven, data plus products and services*

consortia of data providers, mostly data

* plots, movies, indices, solar wind parameters, ULF parameters, ...

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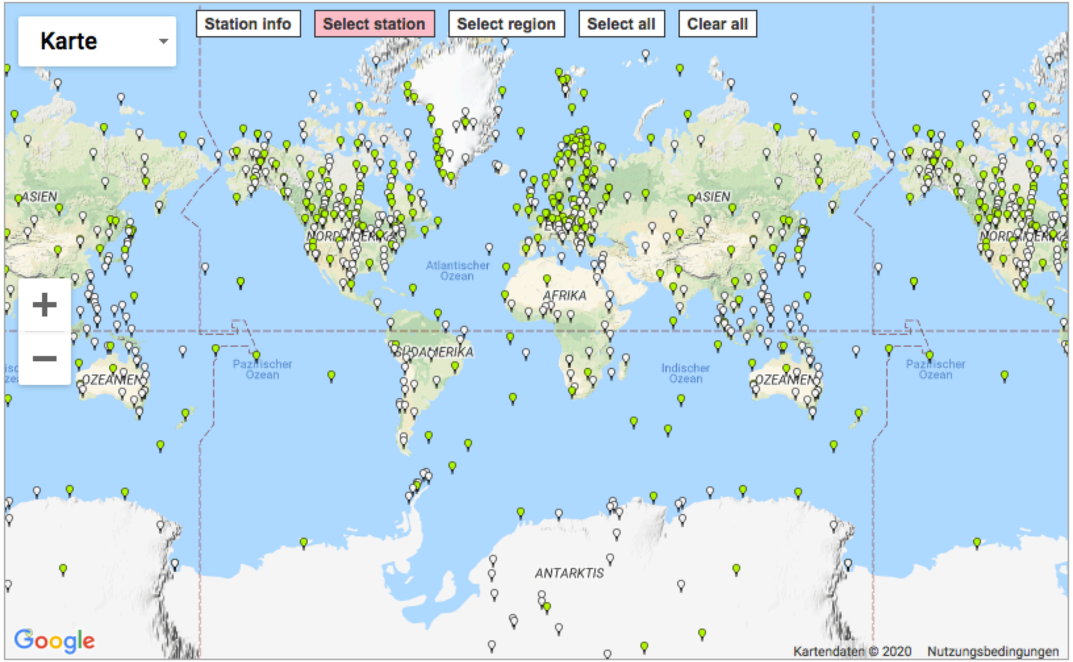

- accepts all kind of data
- automatic quality control by SuperMAG
- rotates data into local magnetic coordinate system according to IGRF (Gjerloev, 2012)
- removes geomagnetic main field from data
- optionally removes estimate of solar quiet variation
- no near real-time (NRT) data

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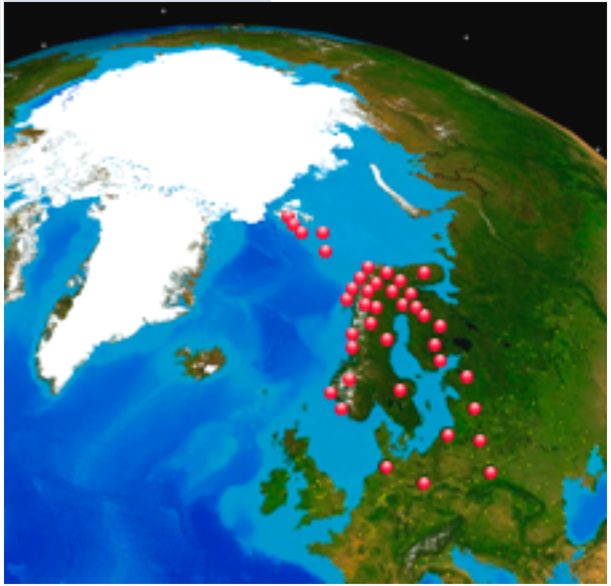

- IMAGE is one example for a magnetometer network, there also exist others
- IMAGE is a consortium of 8 data providers
- quality control by data providers
- FMI operates the data service
- data becomes available very fast (a month)
- 0.1 Hz = 10 s time resolution

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- WDC collects and distributes final geomagnetic observatory data (at BGS)
- INTERMAGNET is consortium of ~60 data providers
- used for secular variation studies
- important for ESA's Swarm mission
- WDC latency similar to SUPERMAG
- INTERMAGNET latency is NRT

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Northern hemisphere, high-latitude NRT variometer data at TGO

Magnetometer Stackplots

Norwegian line
Finnish line
Greenland, West
Greenland, East
Alaska
Mid-Europe
Russia
East-West
USGS-data
Custom sites -->

Component:

- D
- H
- Z
- I
- F

Reset page

DD MM YYYY

TGO
Tromsø Geophysical Observatory,Norway

- Ny Ålesund
- Longyearbyen
- Hopen
- Bjørnøya
- Jan Mayen
- Nordkapp
- Sørøya
- Tromsø
- Andenes
- Røst
- Jäckvik
- Dønna
- Rørvik
- Dombås
- Solund
- Harestua
- Karmøy
- Tristan Da Cunha (Tristan before 2019)

FMI
Finnish Meteorological Institute

- Kevo
- Masi
- Kilpisjarvi
- Ivalo
- Muonio
- Pello
- Ranua
- Oulujarvi
- Mekrijarvi
- Hankasalmi
- Nurmijarvi
- Tartu

SGO
Sodankylä Geophysical Observatory

- Sodankyla

University of Iceland
Leirvogur Magnetic Observatory

- Leirvogur

DTU Space
Technical University of Denmark

Denmark/Greenland:

- Brorfelde
- Rømø
- Hov, Føroyar

- Stasjon Nord (not realtime)
- Qaanaaq (Thule)
- Thule Air Base
- Savissivik
- Kullorsuaq
- Upernavik
- Summit
- Danmarkshavn (East Gr)
- Uummannaq Umanaq
- Qeqertarsuaq (Godhavn)
- Attu
- Kangerlussuaq (Søndre Strømfjord)
- Narsarsuaq
- Ittoqqortoormiit (Scoresbysund)
- Maniitsoq (Sukkertoppen)
- Nuuk (Godthåb)
- Tasiilaq (Ammassalik) (East Gr)
- Paamiut (Frederikshåb)

Sweden:

- Kiruna
- Tormestorp

Geophysical Institute University of Alaska Fairbanks

- Kaktovik
- Fort Yukon
- Poker Flat
- CIGO
- Gakona
- Trapper

AARI, Russia:

- Baranov
- Barentsburg
- Dikson
- Tixie Bay
- Amderma
- Lovozero
- Vize
- Pevek

Institute of Geophysics Polish Academy of Sciences
Poland

- **Hornsund**

USGS science for a changing world

- Deadhorse
- Barrow
- College
- Sitka
- Newport
- King Sejong Island
- Shumagin
- Boulder
- Fredericksburg
- Stennis Space Center
- Fresno
- Tucson
- San Juan
- Honolulu
- Guam

ZAMG

- Wien

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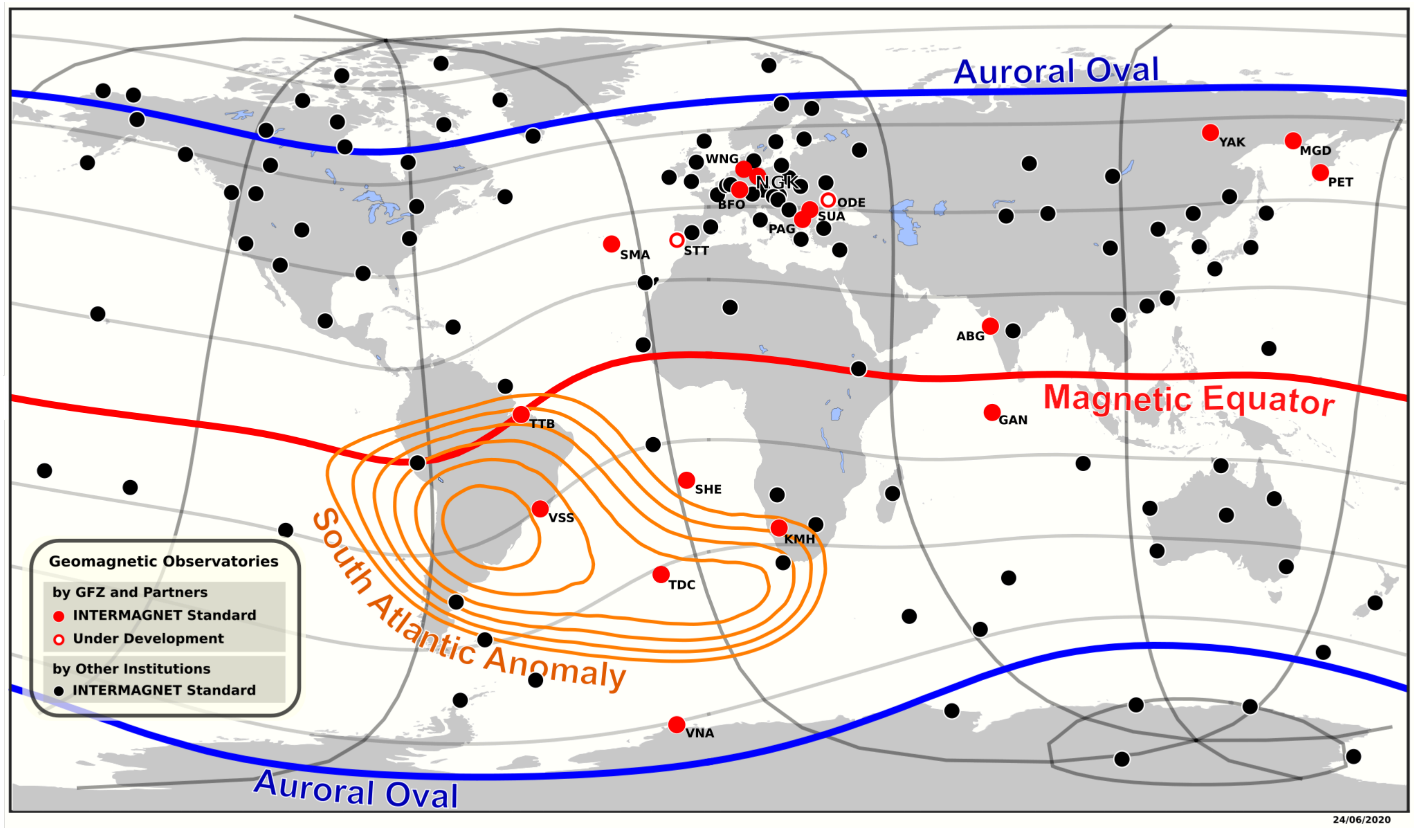
- Wingst
- Niemegk
- Santa Maria
- St. Helena
- Tristan Da Cunha (after 2019)
- Neumayer Station III

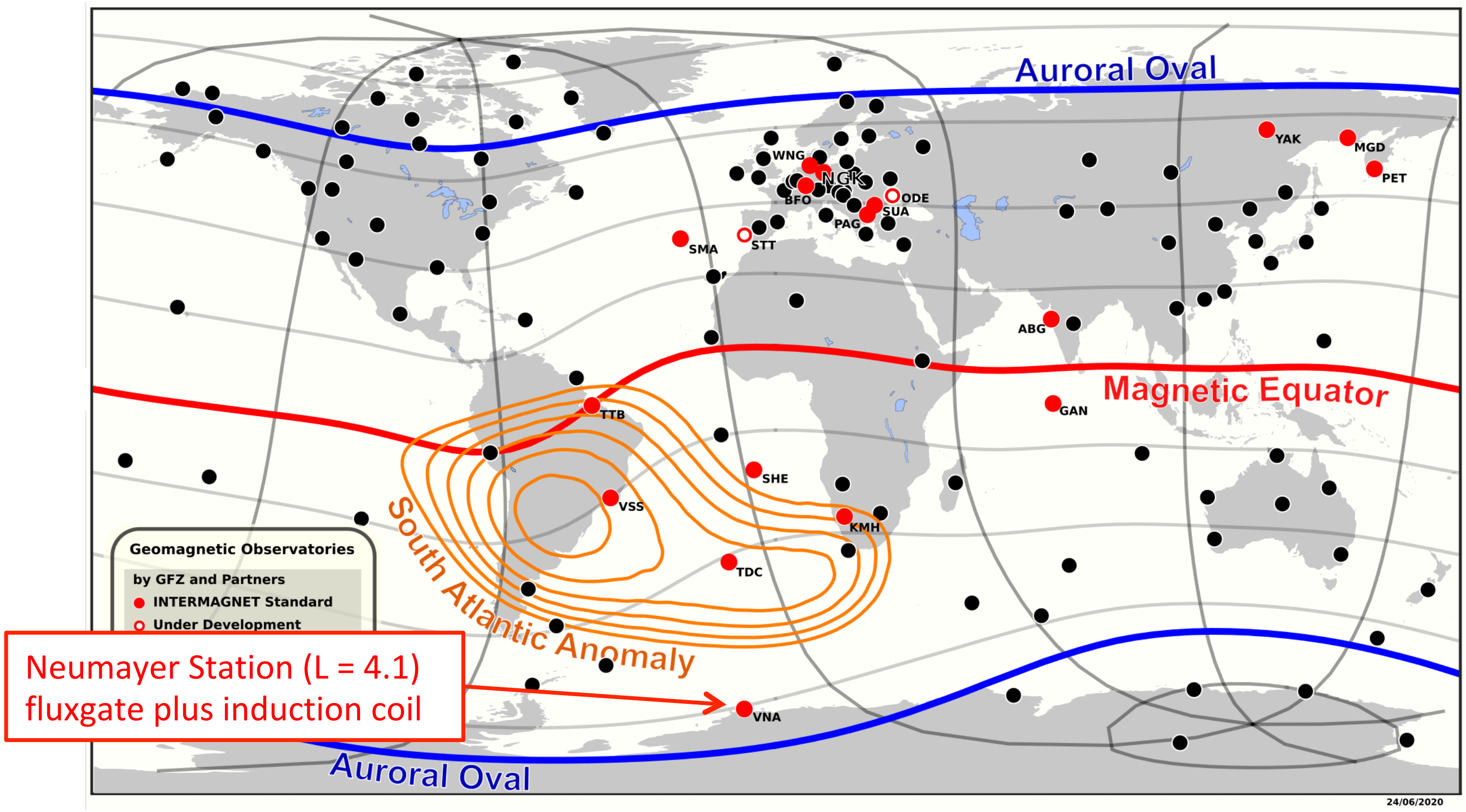
~80 stations in near real time (NRT) on https://geo.phys.uit.no/ some overlap w. IMAGE, INTERMAGNET, combine with INTERMAGNET NRT!

Global ground magnetometer data – geomagnetic observatories



Red dots: GFZ INTERMAGNET observatories, black dots: other INTERMAGNET

Global ground magnetometer data – observatories

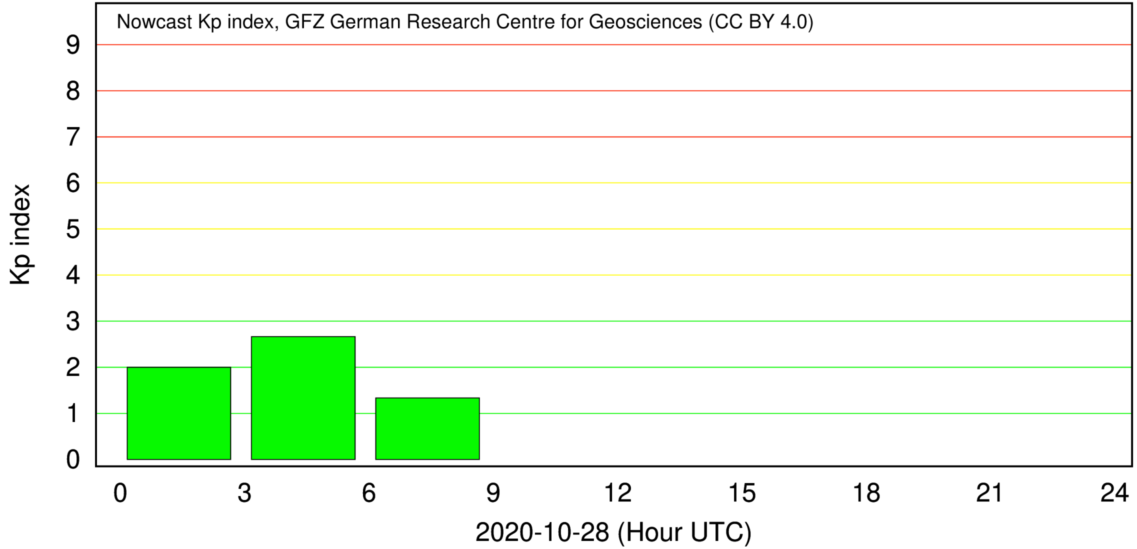


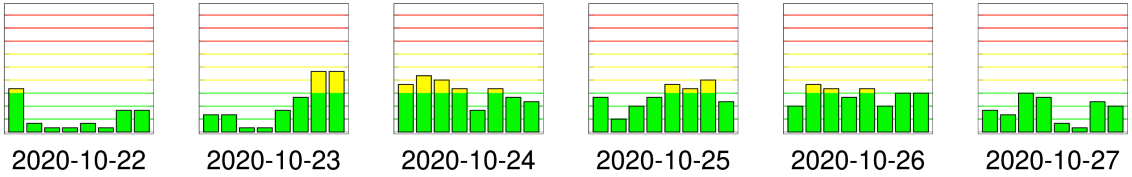
Red dots: GFZ INTERMAGNET observatories, black dots: other INTERMAGNET

Kp index – an international product by GFZ

Recent developments (soon to be released):

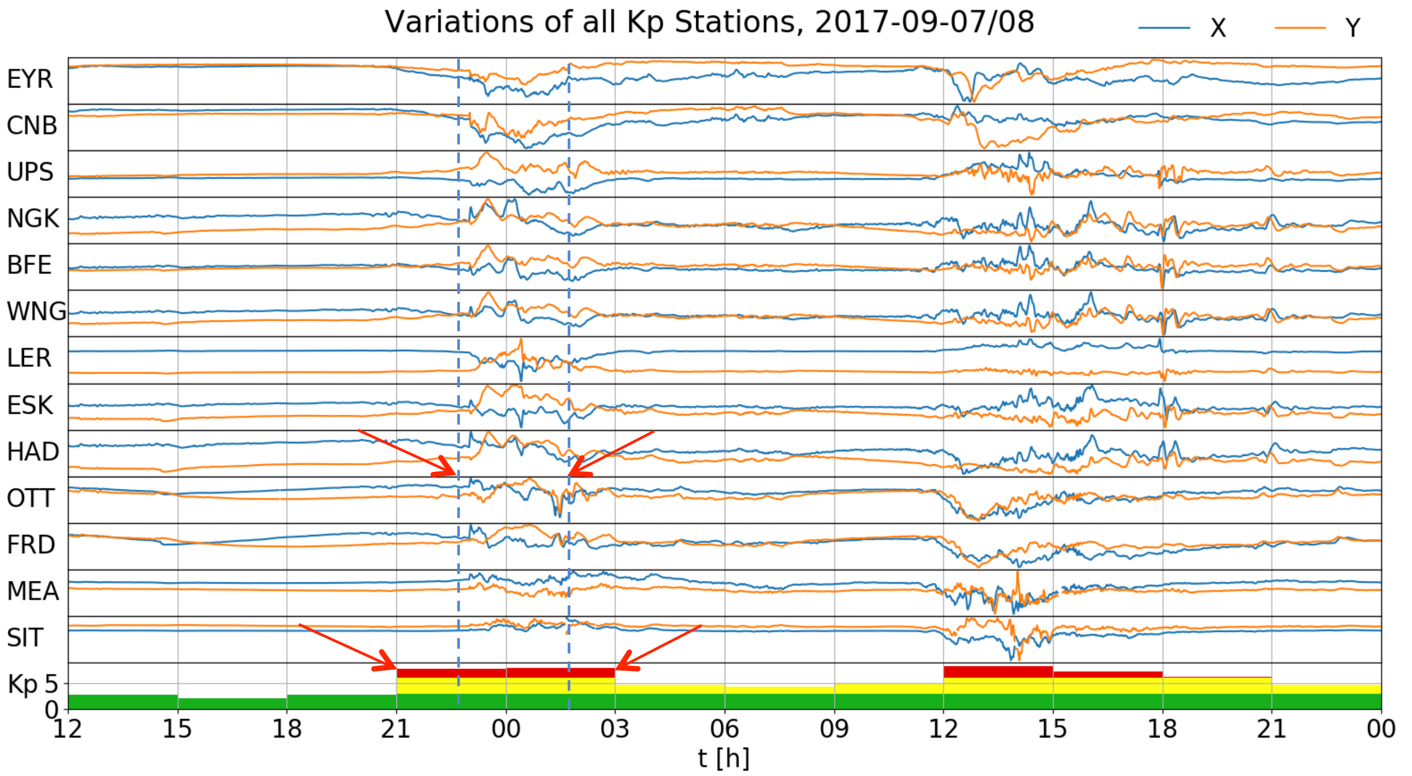
- DOI, CC BY 4.0 licence
- online tool to plot nowcast and historic values
- new, convenient format (nowcast and final values, S_N and F10.7)
- improved nowcast





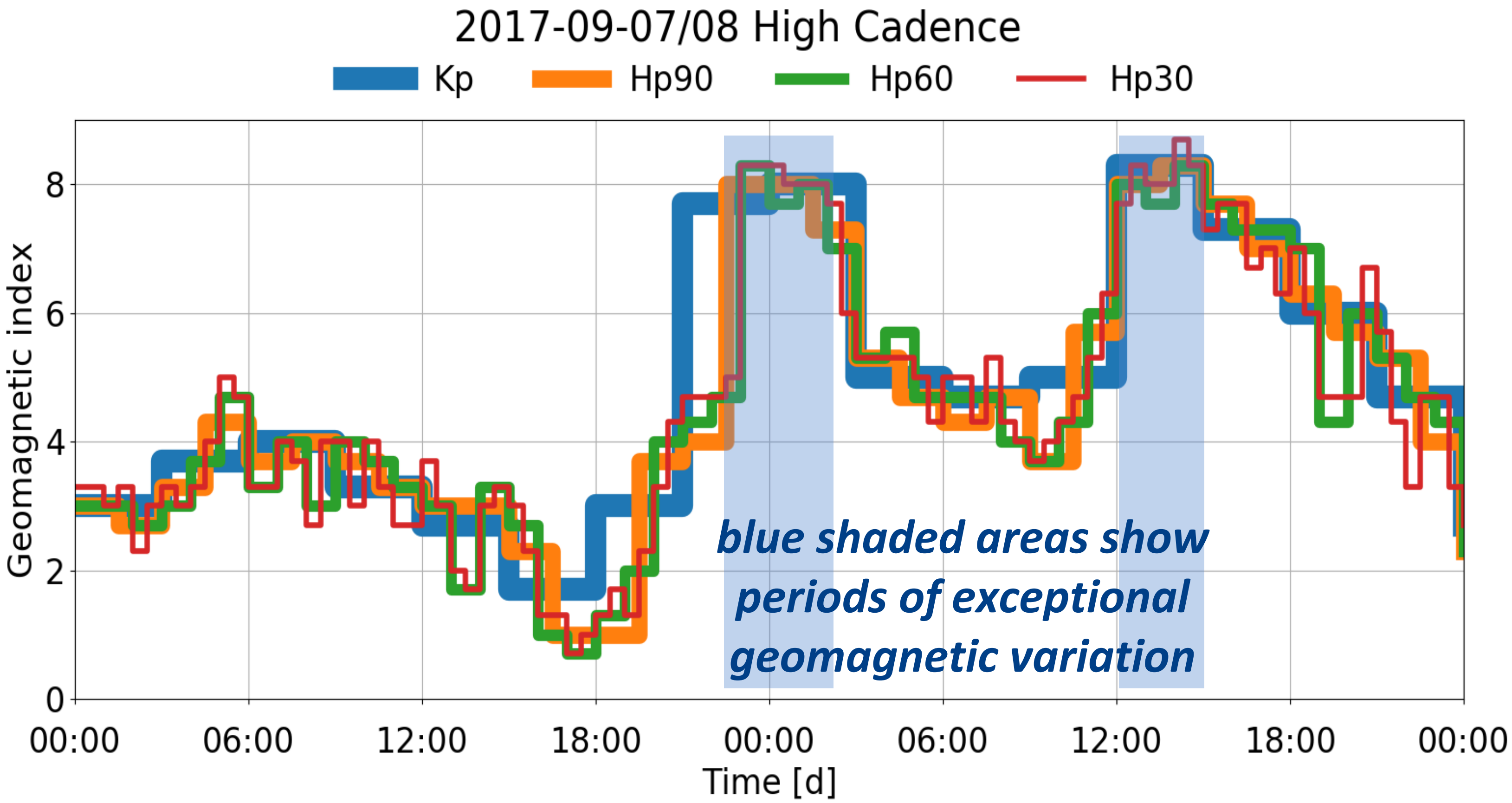
Kp is a three-hour index of geomagnetic disturbance at 13 subauroral geomagnetic observatories

Example: geomagnetic variations at 13 *Kp* stations and *Kp* index for Sept. 7 & 8, 2017 -> case for a higher cadence index



Strong geomagnetic disturbance starts on Sept. 7 at 22:30 UT and stops at about 01:30 UT. The *Kp* index by definition (and somewhat misleadingly) shows elevated values from 21:00 UT until 03:00 UT.

Kp, Hp90, Hp60, Hp30 indices



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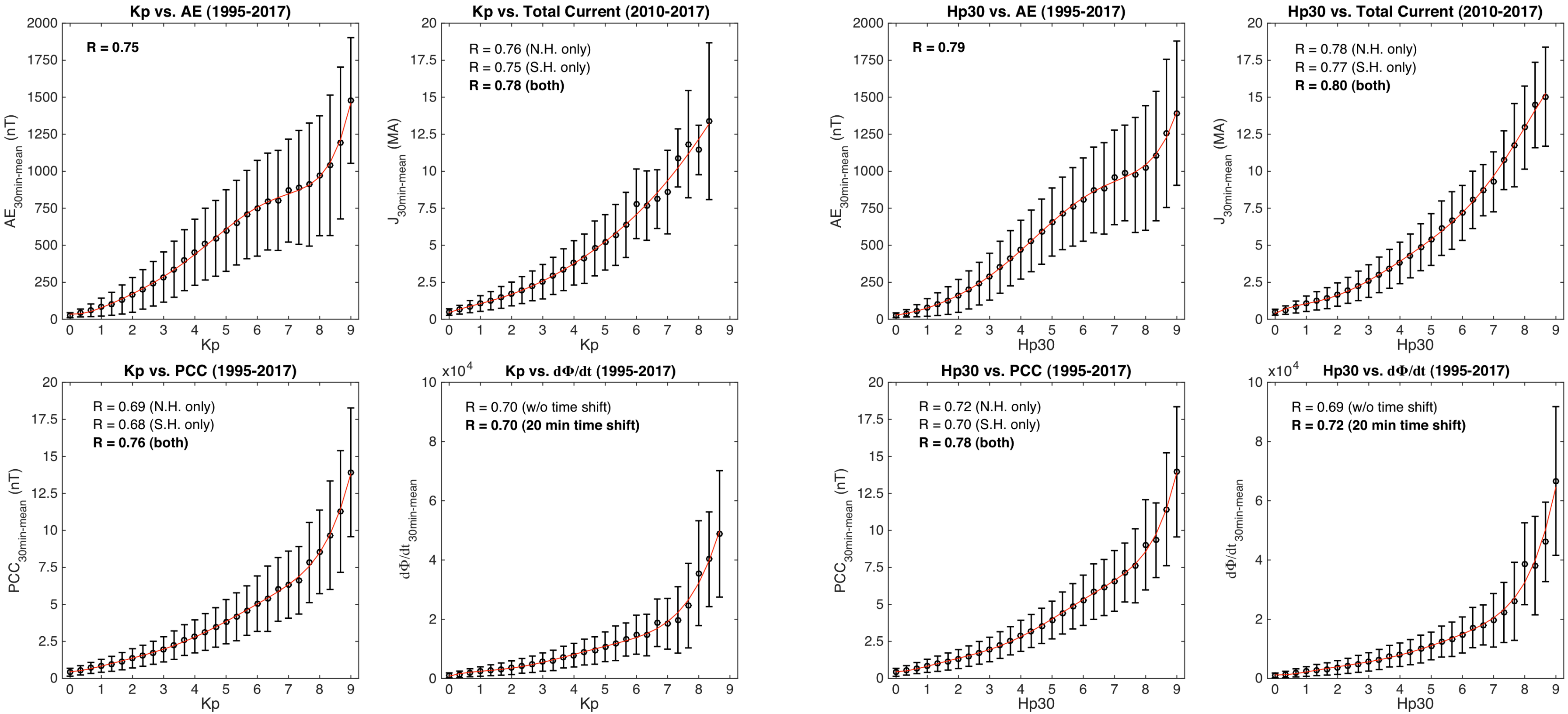
Hpo index family (Hp60, ap60, Hp30, ap30)

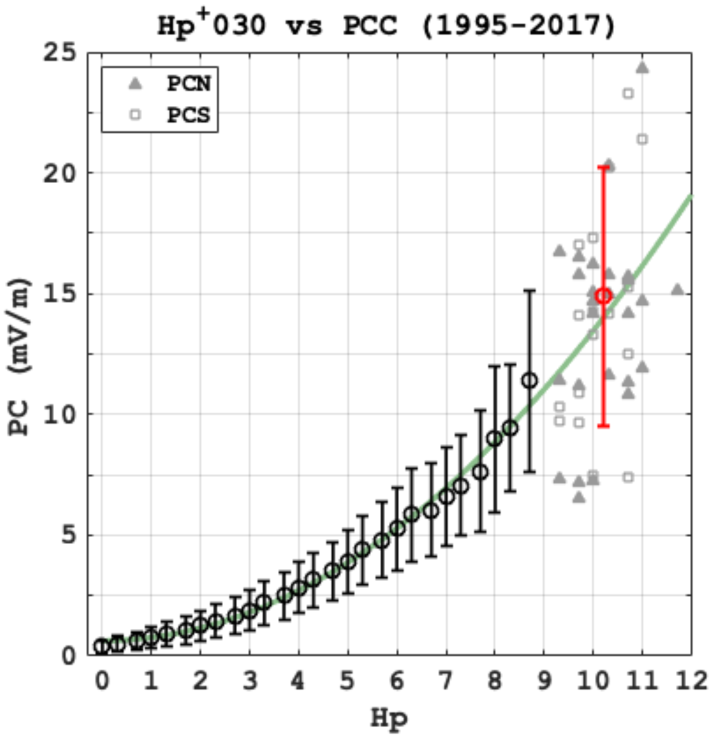
- based on the same observatory data as *Kp*
- same frequency distribution as *Kp*
- Hpo stands for <u>h</u>igh-cadence (hourly Hp60 and half-hourly Hp30), <u>p</u>lanetary, <u>o</u>pen-ended
  - For *Kp* = 9, we split Hpo into several, open-ended levels Hpo = 9, 9+, 10-, ...,
  - comes with linear index ap60, ap30
- development is part of the H2020-project ‘Swami’

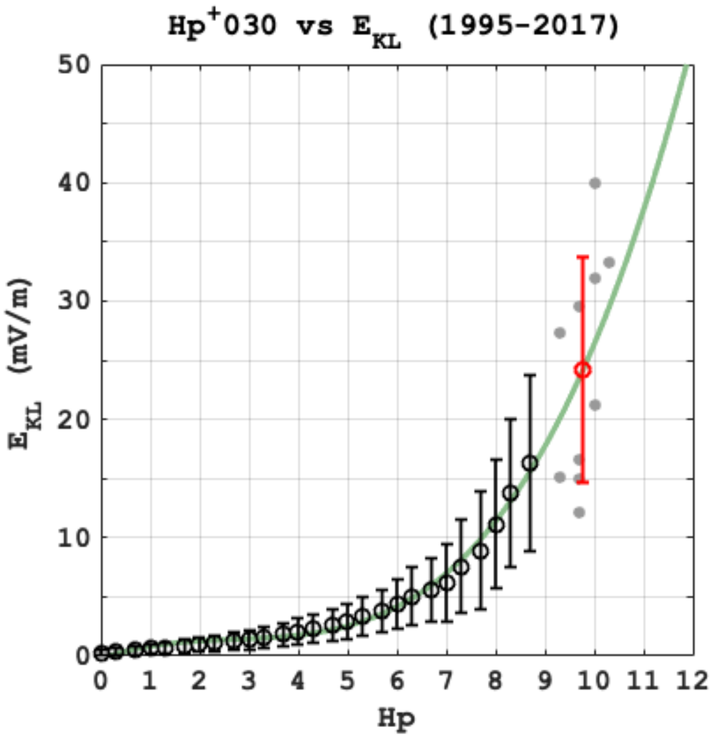
Kp (left) and Hp30 (right) vs. AE index, AMPERE Total Current, PC index, Newell coupling function: 1995 – 2017



Similar relationship of *Kp* and Hp30 to other space physics parameters

Open-ended Hp30 versus PCC and KL-coupling function





Prediction of PCC and E_{KL} (3^{rd}-order polynomial fit for Hpo = 0 to 9-, green) compared to data for Hpo ≥ 9

Mesospheric magnetometry

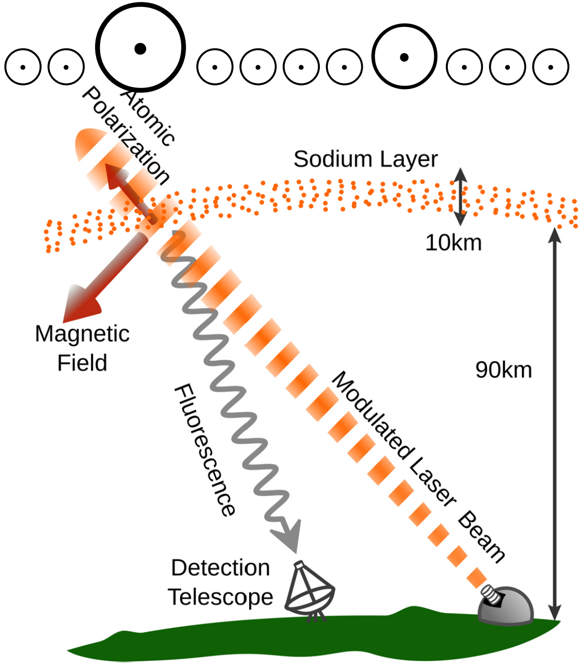


Figure 1. Diagram of measurement scheme (not to scale). A modulated laser beam interacts with sodium atoms in the mesosphere. When the modulation frequency matches the atomic Larmor frequency, the atoms experience efficient optical pumping into a spin-polarized state. A detection telescope observes the modified fluorescence.

Ionospheric currents

- here westward
- structured in the auroral zone (line currents)
- 120 km altitude

Method

- Na-laser (589 nm)
- Mesospheric Na-layer (meteorite ablation)
- Larmor frequency (350 kHz at F = 50000 nT)
- pulse repetition rate at Larmor frequency
  ---> increase in back-scattered signal

Principles

- only total field F, not vector
- no other data from 20 km to 250 km (except rockets and mesospheric O_2 Zeeman splitting of 118 GHz, Aura satellite, line of sight)
- small distance to the source -> high spatial resolution

(Fig. from Higbie et al., 2011)

Mesospheric magnetometry – auroral scenario

Particle precipitation during substorm

- ionization below 100 km (electron density is shown)
- expect small-scale structures in the electric currents

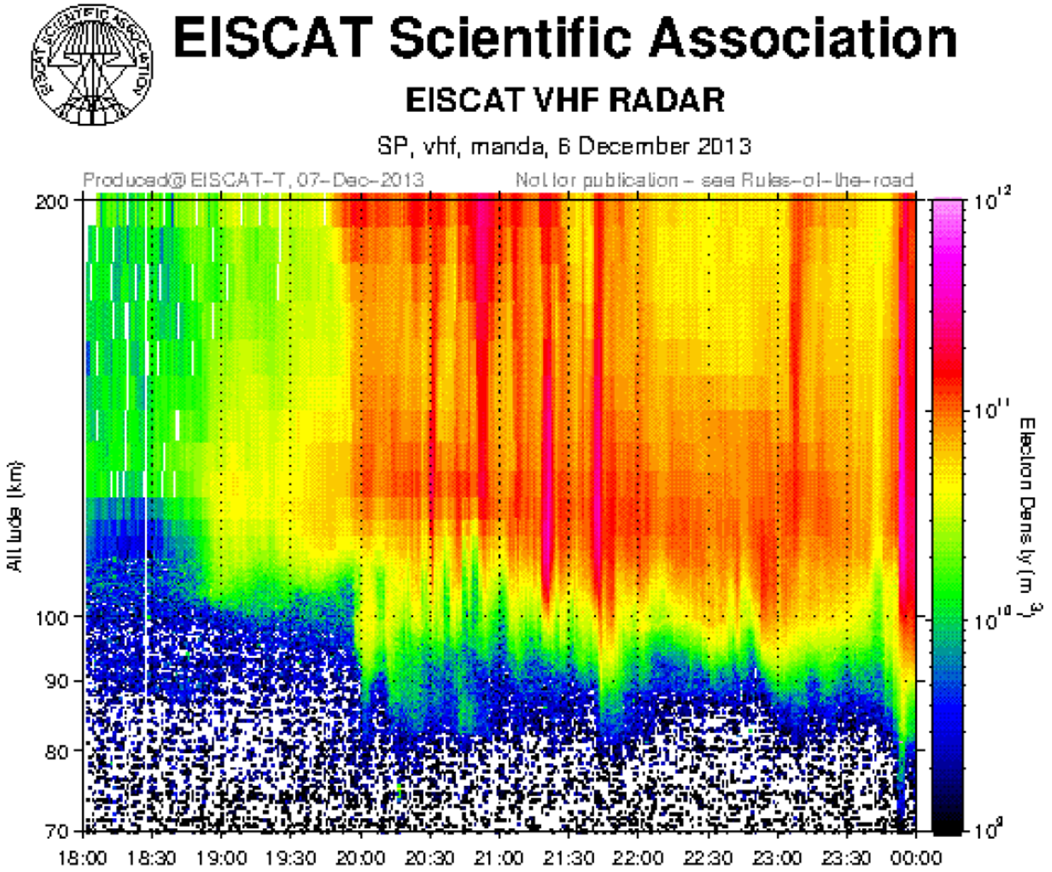
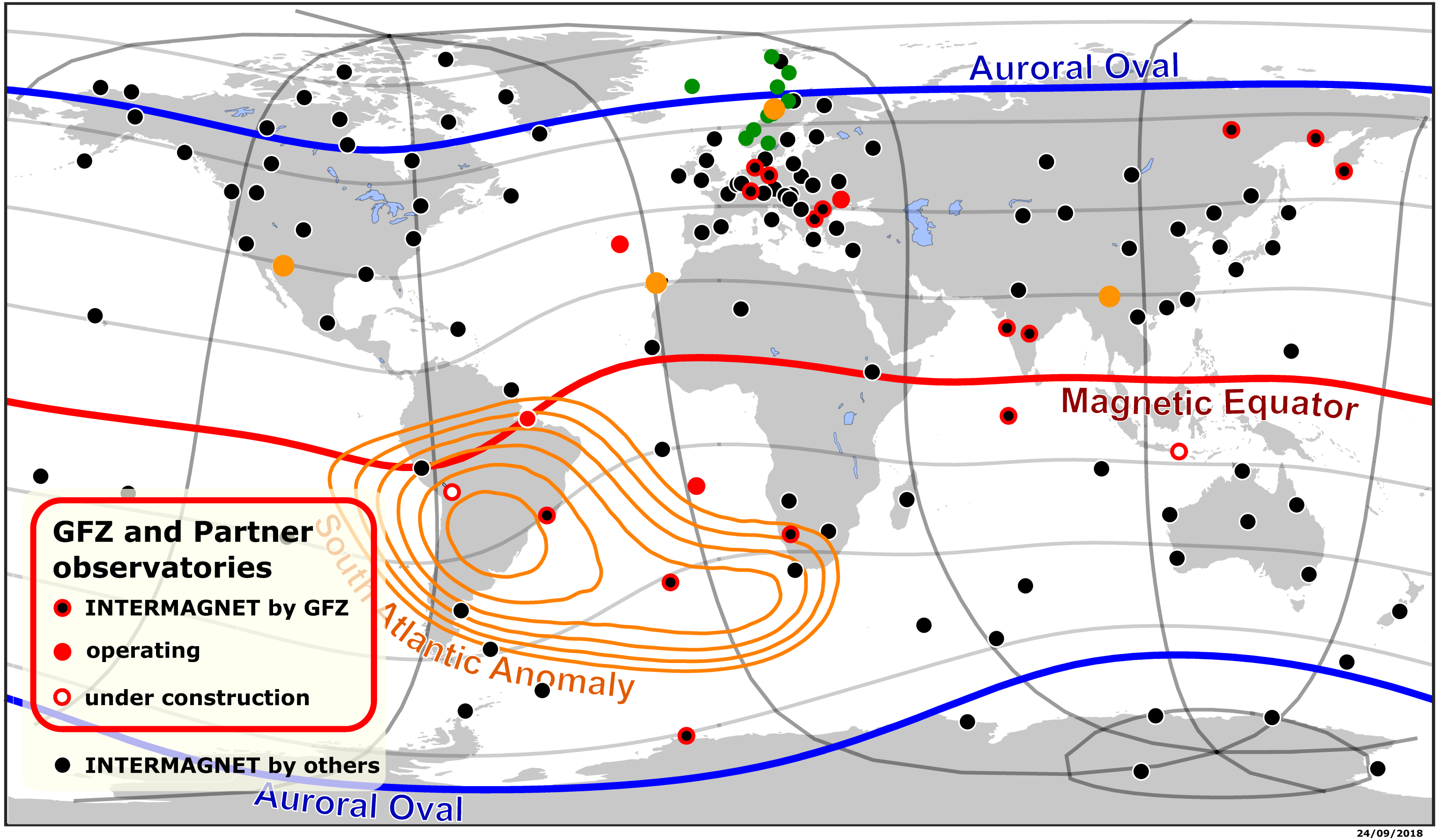


Figure 2: Vertical electron density as measured by the EISCAT VHF radar.

Mesospheric magnetometer - experiments



GFZ ground magnetometer

TGO ground magnetometer

other ground magnetometer

mesospheric magnetometry

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Mesospheric magnetometry – our plans

Successful measurements:

- Kane et al. (2018)	162 nT/√Hz, Arizona, mid- to low latitude
- Pedreros et al. (2018)	28 nT/√Hz, La Palma, mid- to low latitude
- Fan et al. (2019),	849 nT/√Hz, southern China, mid- to low latitude
- MOM project (TGO, GFZ)	Kane et al.-system, northern Norway, auroral latitude

Excellent case for mesospheric magnetometry in auroral/polar latitudes:

- nighttime phenomena (no daylight capability)
- steep magnetic field (not ideal, a challenge)
- small scale source currents (scientifically interesting)
- large magnetic field amplitudes in the mesosphere
- 1 minute time resolution, 4 nT sensitivity (corresponding to 30 nT/√Hz)
- time series (a couple of hours)
- parallel time series from several spots (-> north-south gradients)

Next step: Optimizing the observational system:

- Excellent team with expertise in quantum physics, laser guide star, lidar, atmospheric physics, geomagnetism and instrument development

29.09.2019
Mesospheric magnetometry
at ALOMAR Observatory
in Andøya, Northern Norway
photo by Njål Gulbrandsen