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COGEAR: COupled seismogenic GEohazards in Alpine Regions

COGEAR

MODULE 2:

GPS instrumentation in the Valais

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GNSS Instrumentation in the Valais:

Monitoring System and Documentation

Report October 2011

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GNSS Network in the Valais

Since 1998 the Federal Office of Topography (swisstopo) has established its new national first order GPS based Reference Network LV95 (Landesvermessung 95), and for that purpose built up an Automated GNSS[1] Network for Switzerland (AGNES). The network consists of 30 stations which cover the whole country and are operating continuously. Three of the permanent stations are located in the canton Valais (MART, HOHT, ZERM, see Figure 1). In order to obtain a better coverage in the Valais area new permanent GNSS sites have been installed by the Geodesy and Geodynamics Lab (GGL) in the frame of project TECVAL[2] and COGEAR[3]. If possible GNSS sites were co-located with other sensors installed in the course of the COGEAR-project such as seismic stations, meteorological sensors, displacement sensors etc.

The obtained GNSS data is integrated in the GNSS national network and is processed by swisstopo (Brockmann, swisstopo) using Bernese GNSS software (Dach 2007).

For velocity estimation with reasonable accuracy the observations need to be recorded for several years to precisely determine and reduce seasonal effects and increase the reliability of the obtained results (Hollenstein et al., 2008). If velocities from all sites are available local deformation will be better constrained and more significant comparisons with focal mechanisms (Kastrup, 2007) can be envisaged.

1 GNSS: Global Navigation Satellite System
2 TECVAL: Tectonic in the Valais, Hazard Network of ETH (HazNETH) project of GGL
3 COGEAR: Coupled seismogenic Geohazards in Alpine Regions

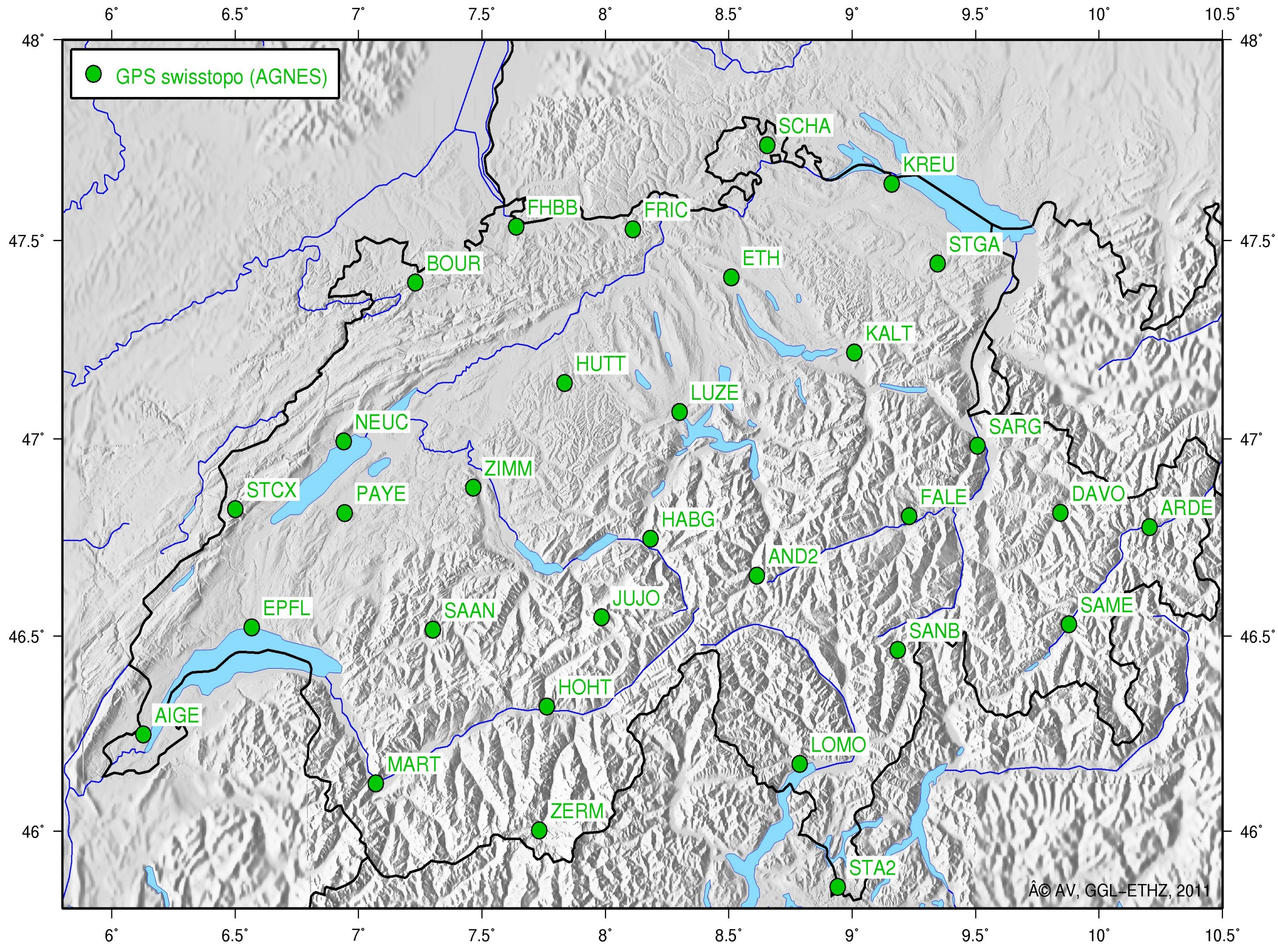


Figure 1: *AGNES network operated by swisstopo since 1998.*

GNSS and COGEAR

In the course of the COGEAR project the GNSS network is being enlarged and densified in the upper Valais. The GGL (TECVAL) stations have been incorporated into COGEAR. In first priority it was tried to co-locate the additional GNSS-Stations with the existing seismic sensors. Due to the different requirements of GNSS and seismic sensors it was not possible to co-locate all GNSS receivers with seismic stations. Despite to terrain and infrastructure problems a close co-location could be achieved for the GNSS stations SIMP (Simplon) and FIESA (Fiescheralp). This allows to compare GNSS data directly with seismometer data. In second order priority the GNSS receivers were distributed evenly to gain a spatially denser network which allows better detection of regional tectonic deformations. The original, pre-COGEAR/TECVAL state of instrumentation is shown in Figure 1 The final state of GNSS instrumentation is shown in Figure 2. A detailed overview of the COGEAR study site with GNSS and seismometer network is shown in Figure 3.

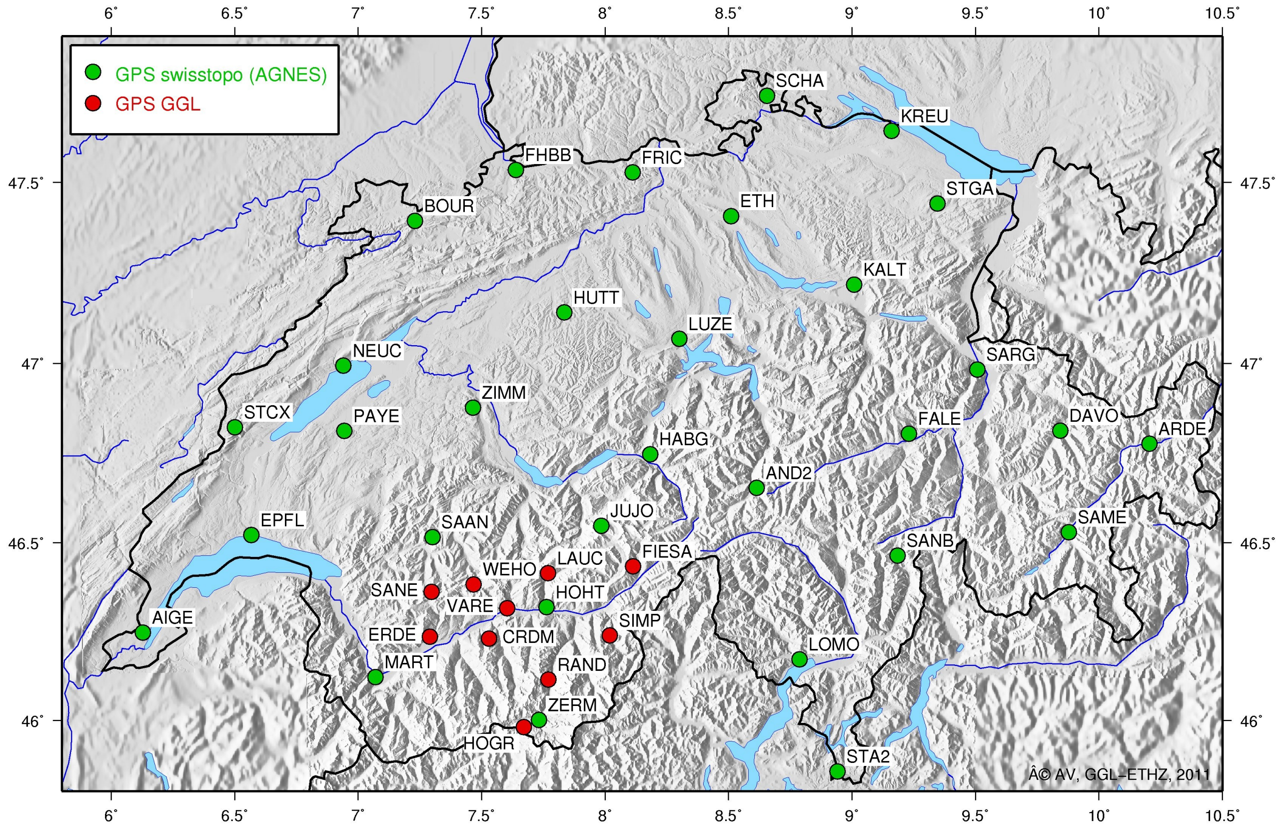


Figure 2: *GNSS networks in Switzerland operated by swisstopo (AGNES, green) and GGL (red). In the course of the COGEAR project a clear densification of the GNSS network in the upper part of the Valais could be achieved.*

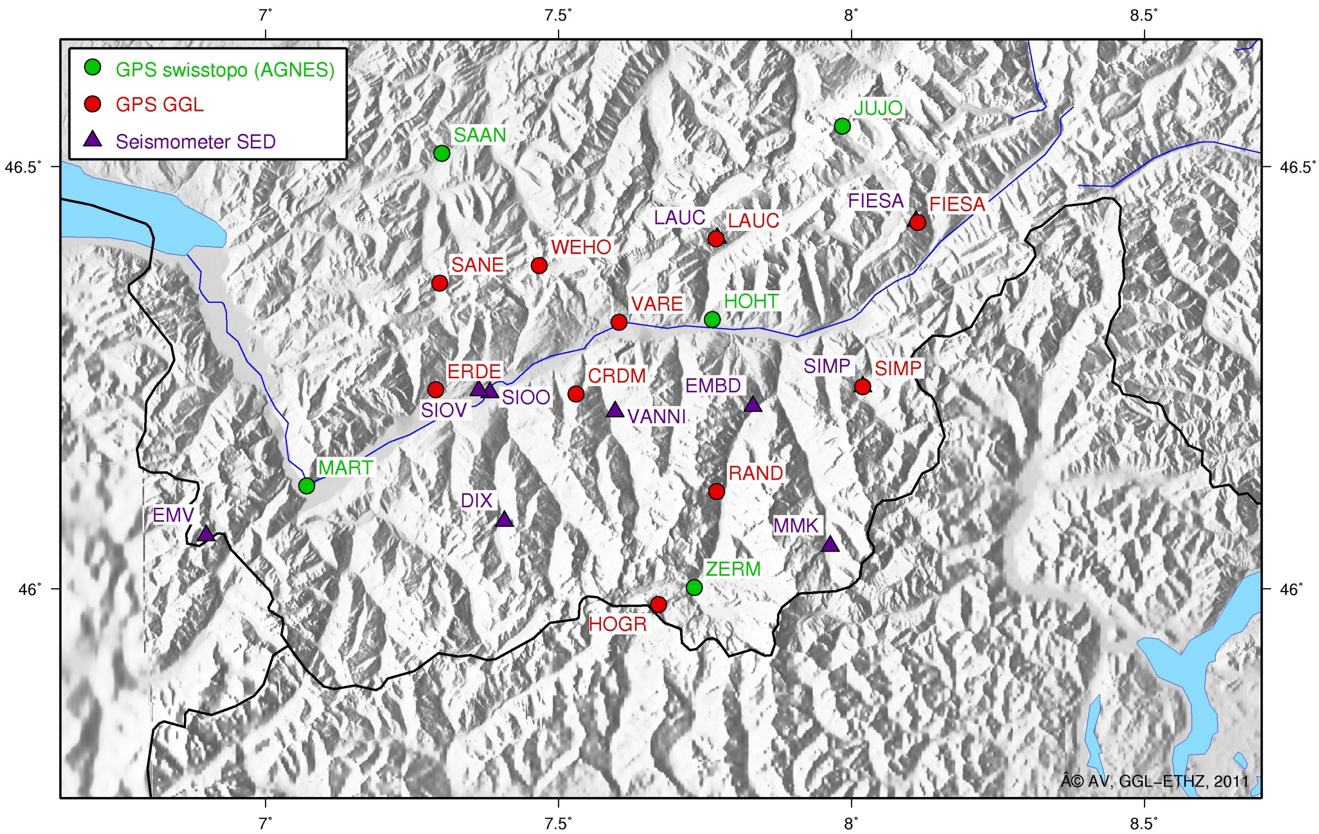


Figure 3: *Overview of the COGEAR study site. At the sites SIMP and FIESA the GNSS stations are closely co-located to the seismometers.*

Instrumentation

Five sites at Crêt du Midi (CRDM), Erde (ERDE), Varen (VARE), Sanetsch (SANE) and Weisshorn (WEHO) are equipped with geodetic Trimble NetRS GNSS receivers and Trimble Zephyr Antennas. In order to detect small tectonic displacements these stations are set up with a sampling rate of 30 s. ERDE, VARE, and WEHO have an online connection and are able to send data continuously. The other stations CRDM and SANE log the data locally. All stations are operating continuously since 2005/06.

The new permanent GNSS sites are equipped with the GNSS 1200+ receiver and choke-ring antenna AR25 from Leica. The use of choke-ring antennas will reduce multipath effects and lead to better results which is vital since the expected relative annual displacements are very small (1 mm range). In addition the Leica receivers are able to log data up to a sampling rate of 20 Hz.

The application of the above described modern equipment yields most accurate state-of-the-art GNSS data suitable for both tectonic and seismic monitoring.

Antenna mounting system

At the stations Crêt du Midi (CRDM), Erde (ERDE), Sanetsch (SANE), Varen (VARE), Weisshorn (WEHO) the antennas are mounted to small buildings. In order to provide a stable foundation for the antennas the buildings are simple one-floor concrete constructions. The antenna itself is mounted to the building with a massive steel bar. The length of the mounting bar is optimized to be as small as possible but still high enough to preserve the antenna from snow coverage and to minimize topographic shading.

A special system is installed at the station on Hörnligrat (HOGR). Despite the high alpine conditions almost no snow accumulation takes place. The exposed location on the Hörnligrat (Matterhorn) allows to install the antenna on a small steel bar which is mounted directly to solid rock.

At the stations in Randa (RAND), Simplon (SIMP), Fiescheralp (FIESA), and Lauchernalp (LAUC) a different system is used. The antennas are mounted with a special steel construction developped by swisstopo (Fig. 4). The thin steel framework of the pillar is very stable and deformation due to wind forces and snow pressure is reduced to a minimum. Additionally, a special drilling gauge was developed by GGL to install the pillar on uneven rock surface. This system reduces external influences such as thermo-elasic deformation of buildings and single steel bars to a minimum which allows to monitor small tectonic deformations as well as seismic displacements. Furthermore an antenna mast adapter is used to level the antenna to the exact horizontal orientation. The position of the antenna center is adjusted to a marked steel bolt in the ground (Figure 5)

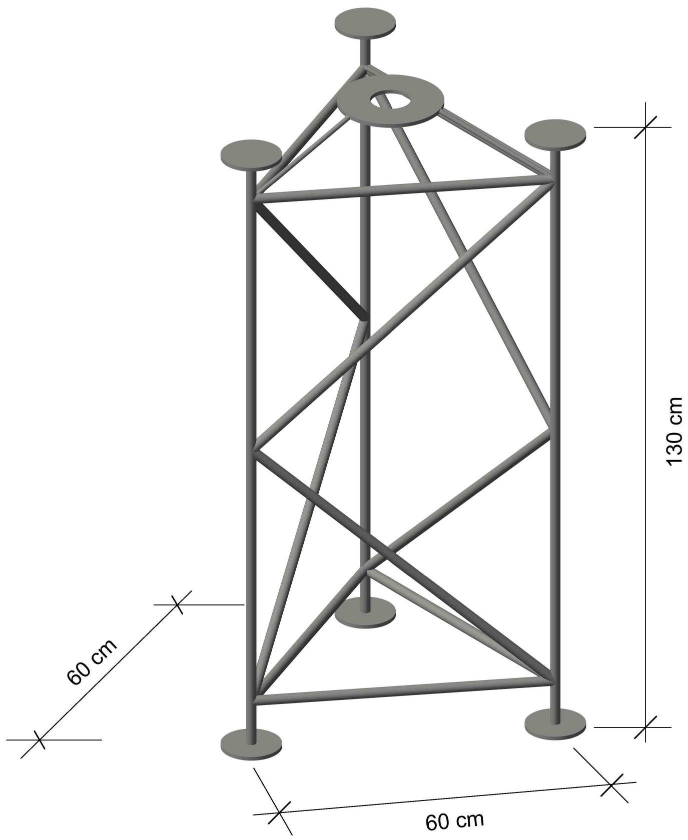


Figure 4: Steel pillar *for precise permanent GNSS monitoring (system: swisstopo)*

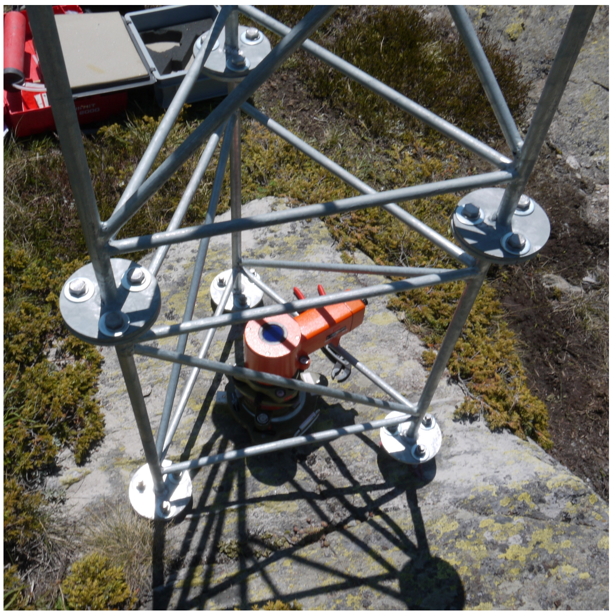


Figure 5: *Mounted pillar with centered bolt (left) and antenna position adjusting perpendicular to the center bolt using a pillar base and an optical plummet (right)*

Receiver installation

At all stations the receiver is installed separately in a protected case while cable length are kept to a minimum.The installation of the receivers has to provide redundancy of the power supply, protection against weather and lightning as well as data redundancy and transmission. To power the receiver continuously an uninterrupted power supply unit (UPS) was developed. A block schema is shown in Figure 6. The UPS system consists of a direct 12 V power supply for the receiver, a 12 V battery with an adequate charger as well as an especially developed automatic switch. In case of an interruption of the primary power supply the switch supplies the receiver from the secondary power supply (12 V battery). Additionally, the switch is able to reboot the receiver automatically transmitting a predefined code sequence over the first serial port in case of a complete loss of power. This way the receiver will also start up if it is switched of remotely which reduces gaps in the record to a minmum.

For lightning protection an EMP-protector is installed between the antenna and the receiver. The EMP-Protector is always installed before the antenna cable enters a building or -if installed outside- a case while the unprotected side of the protector needs to be connected to the ground (Figure 6).

The antenna cable is fixed to the ground with a flexible tube to protect the cable from weathering, mechanical impacts and animals.

The case for the receiver is preferably made of metal which allows to ground the case as well as to shield the equipment and to keep the whole system on the same electromagnetic potential.

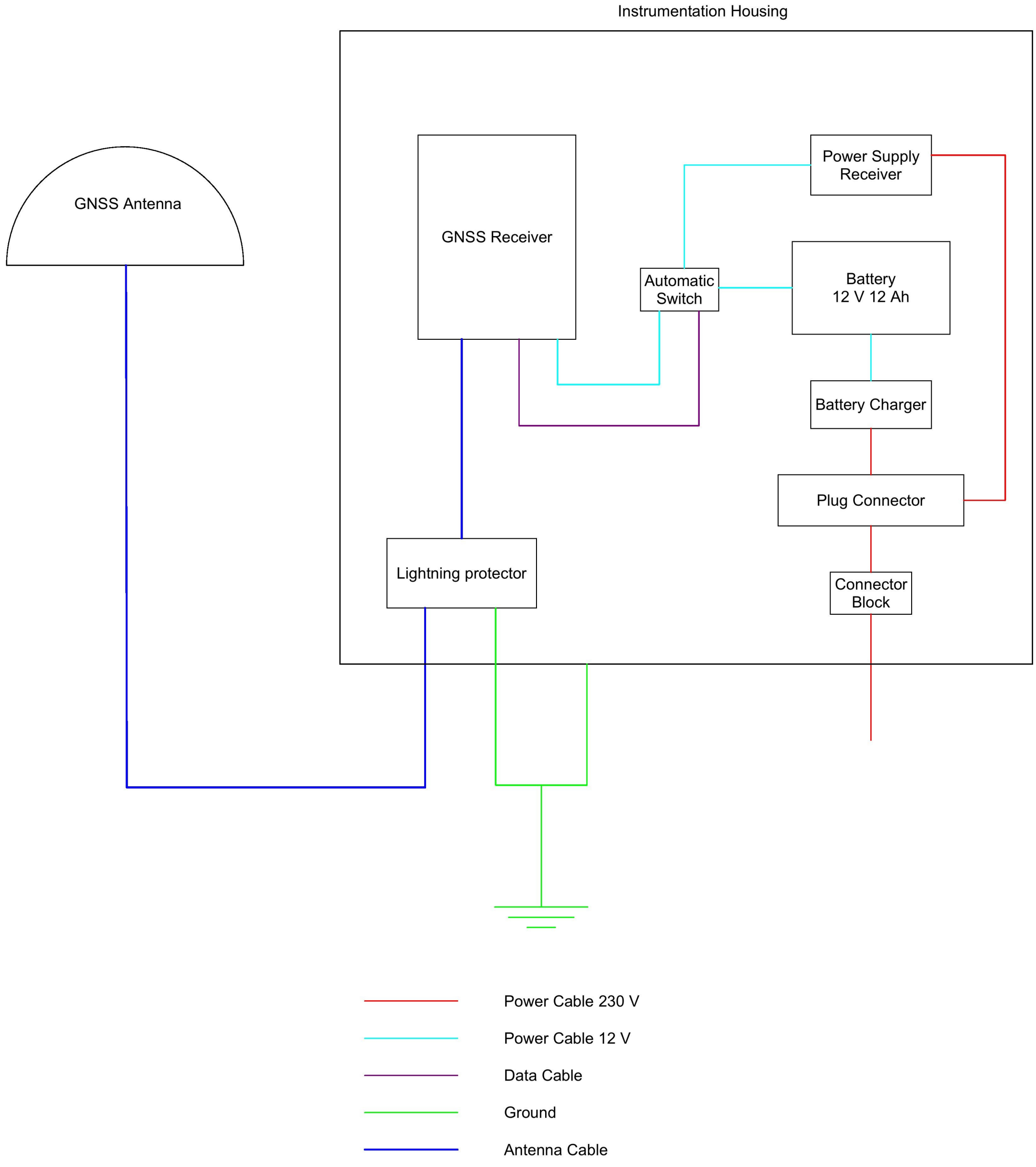
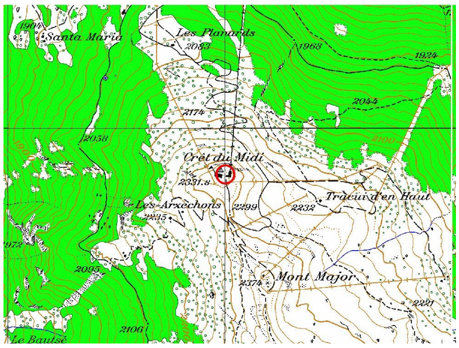


Figure 6 *Block Schema of the instrumentation with uninterrupted power supply unit (UPS).*

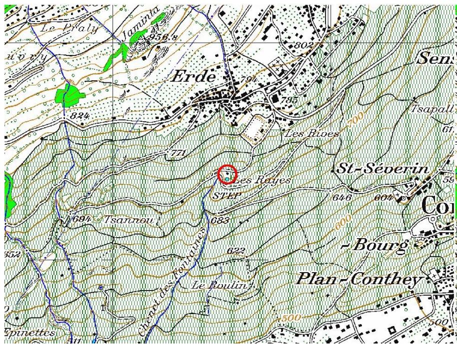
Site Documentation

Crêt du Midi (CRDM)



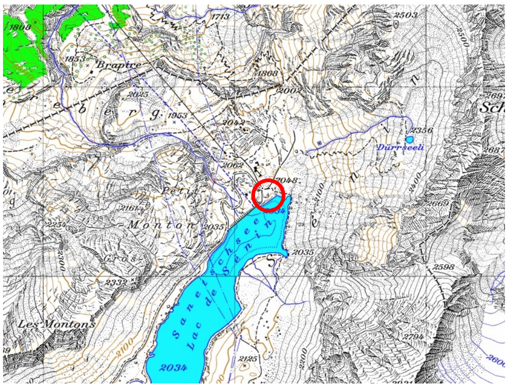
Location: Restaurant du Crêt du Midi	
LV95: 2607002 m / 1119788 m Altitude: 2332 m	WGS 84: Longitude: 7.5294° Latitude: 46.2295°
Equipment:	
Receiver: Trimble Zephyr Geodetic	*Antenna:* Trimble NetRS
Settings:	
Sampling Rate: 30 s	*Download Connection:* None

Erde (ERDE)



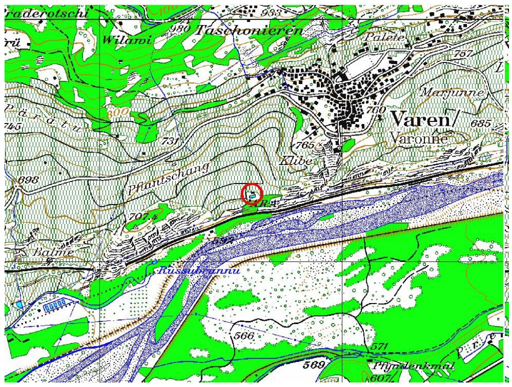
Location: Sewage plant, Erde	
LV95: 2588526 m / 1120395 m Altitude: 782 m	WGS 84: Longitude: 7.2899° Latitude: 46.2349°
Equipment:	
Receiver: Trimble Zephyr Geodetic	*Antenna:* Trimble NetRS
Settings:	
Sampling Rate: 30 s	*Download Connection:* Analogue

Sanetsch (SANE)



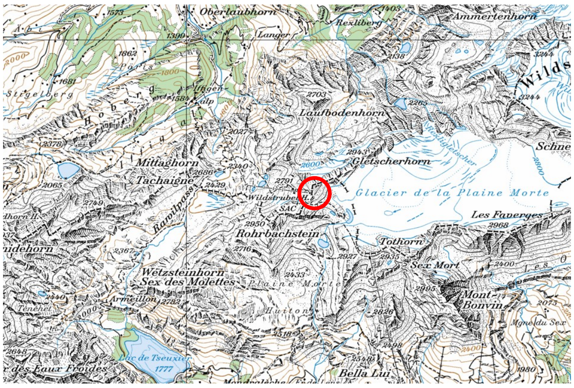
Location: Machine building, Dam Sanetsch	
LV95: 2589052 m / 1134434 m Altitude: 2077 m	WGS 84: Longitude: 7.2964° Latitude: 46.3612°
Equipment:	
Receiver: Trimble Zephyr Geodetic	*Antenna:* Trimble NetRS
Settings:	
Sampling Rate: 30 s	*Download Connection:* None

Varen (Vare)

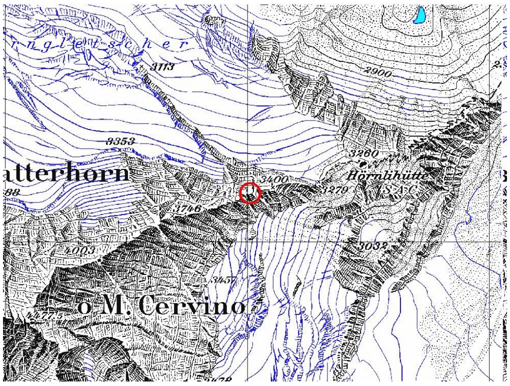


Location: Sewage Plant, Varen	
LV95: 2612629 m / 1129280 m Altitude: 703 m	WGS 84: Longitude: 7.6026° Latitude: 46.3148°
Equipment:	
Receiver: Trimble Zephyr Geodetic	*Antenna:* Trimble NetRS
Settings:	
Sampling Rate: 30 s	*Download Connection:* Analogue

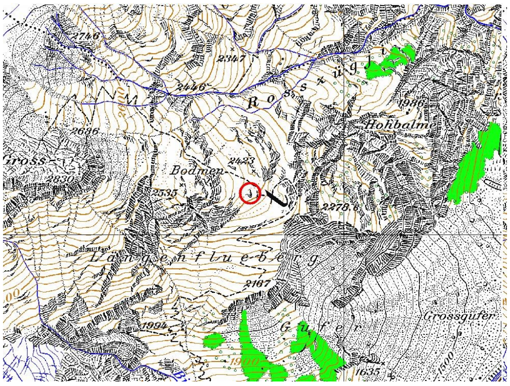
Weisshorn (WEHO)

Intentionally left blank	
Location: Weisshorn	
LV95: 2602628 m / 1136748 m Altitude: 2967 m	WGS 84: Longitude: 7.4728° Latitude: 46.3821°
Equipment:	
Receiver: Trimble Zephyr Geodetic	*Antenna:* Trimble NetRS
Settings:	
Sampling Rate: 30 s	*Download Connection:* Analogue

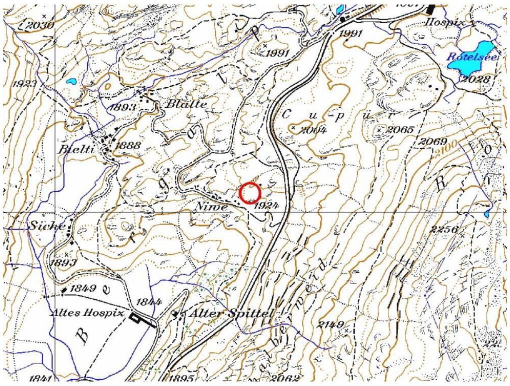
Hörnligrat (HOGR)

	
Location: Hörnligrat, Matterhorn	
LV95: 2618012 m / 1092200 m Altitude: 3463 m	WGS 84: Longitude: 7.6711° Latitude: 45.9811°
Equipment:	
Receiver: Leica GNSS1200+	*Antenna:* Leica LEIAR10
Settings:	
Sampling Rate: 30 s / 20 Hz (Ring Buffer)	*Download Connection:* WLAN / Broadband DSL (TIK ETHZ)

Randa (RAND)

	
Location: Hut above rockfall area	
LV95: 2625641 m / 1107160 m Altitude: 2407 m	WGS 84: Longitude: 7.7703° Latitude: 46.1154°
Equipment:	
Receiver: Leica GNSS1200+	*Antenna:* Leica LEIAR25
Settings:	
Sampling Rate: 30 s / 20 Hz (Ring Buffer)	*Download Connection:* WLAN / Broadband DSL (TIK ETHZ)

Simplon (SIMP)

	
Location: Hut above rockfall area	
LV95: 2644806 m / 1121079 m Altitude:1951 m	WGS 84: Longitude: 8.0195° Latitude: 46.2396°
Equipment:	
Receiver: Leica GNSS1200+	*Antenna:* Leica LEIAR25
Settings:	
Sampling Rate: 30 s / 20 Hz (Ring Buffer)	*Download Connection:* ISDN (SED)

Fiescheralp (FIESA)

The preliminary search for seismometer stations suitable for co-location with GPS showed that the station at Fiescheralp despite some problems is suitable for a GPS station. The detailed view of the site location is shown on a map together with a polar plot of the topographic shading in Figure 7.

Due to the quiet remote and exposed location of the site a comprehensive installation strategy had to be developed. First, the distance between the position of a possible installation of the antenna and the infrastructure such as power supply and internet connection is approximately 80 m. Due to this long distance it is necessary to use an antenna cable with very low damping in the frequency band of approximately 1.2 - 1.5 GHz. Our test measurements using a 100 m antenna cable showed that it is still possible. Second, the antenna needs to be installed on the top of the tunnel entrance face (Figure 8). Due to the steep slope of the hillside above the tunnel there might be some problems with snow pressure and even avalanches. At our resent state of knowledge we think that an installation is possible.

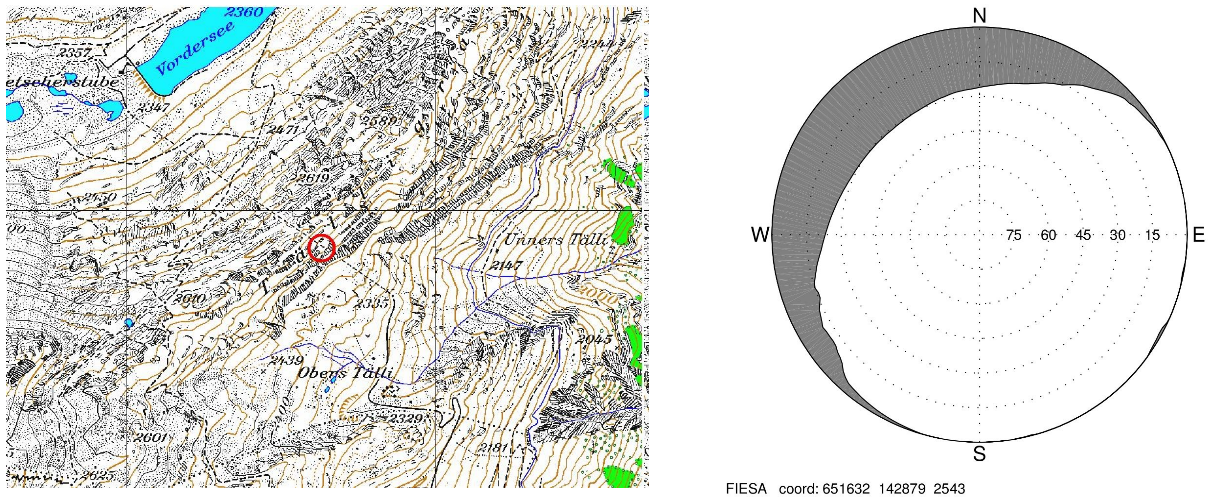


Figure 7: *Topographic map showing the site location (left) and polar plot of the topographic shading at the site.*

Figure 8: *Location for a possible antenna installation (red dot) at Märjelentunnel*

Lauchernalp (Lauc)

Some suitable sites for the GPS station are already found. Between Märwig and Gandegg a potential location of solid rock and low topographic shading was discovered (see Figure 9). Power supply can be provided from the recently installed snowmaking facility.

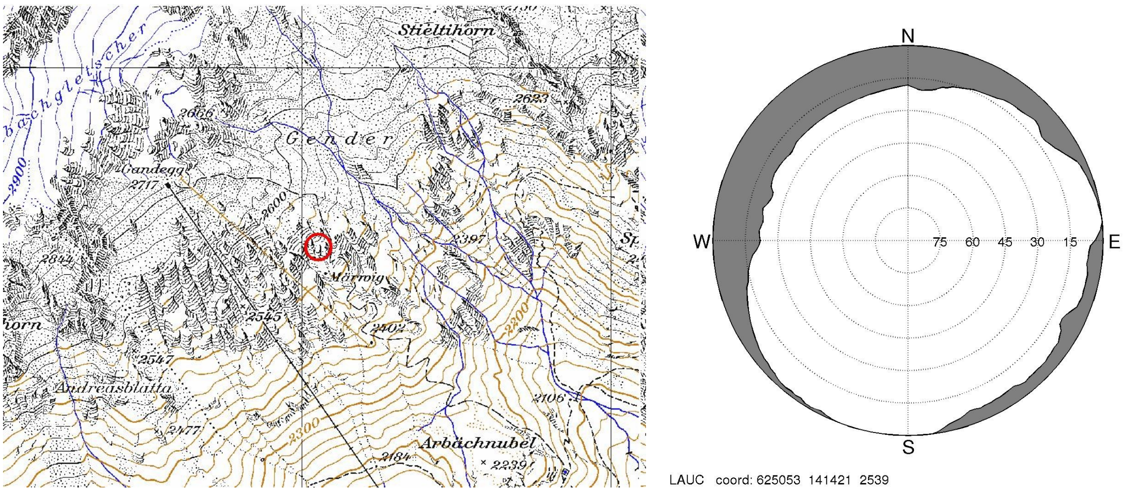


Figure 9: *Topographic map showing the site location (left) and polar plot of the topographic shading at the site.*

GNSS Data

At CRMD and SANE the data is logged locally and needs to be read-out manually in the field. At ERDE, VARE and WEHO are automatically downloaded over an analogue data connection. These stations all have a sampling rate of 30 s which keeps the required bandwidth low.

The new station both are logging with a rate of 30 s and 20 Hz. Sampling GNSS data with a rate of 20 Hz results in a large amount of data which requires a large bandwidth if the data is streamed. Hight rate data is only useful if quick displacements i.e. a seismic event take place. Because of the above mentioned reasons high rate data is logged continuously on a ring buffer. In case of a seismic event these data can either be downloaded or if the local bandwidth does not allow any additional downloads it needs to be collected in the field. The size of the ring buffer is kept large enough to guarantee some days time before the data will be overwritten.

Additionally at FIESA a 100 Hz receiver will be installed for high rate GNSS seismology and some test measurements in a third party project.

Integration of GNSS data into COGEAR and SwissEx IT platform

Acquisition, storage and processing of GNSS data is performed on a file-based system. As described above the data is included into the AGNES network operated by swisstopo for a common calculation. Due to diverse projects GGL will also process data of different GNSS based monitoring systems.

GSN has been designed for single sensor data streams such as temperature, precipitation, air pressure etc, where each value describes a relevant physical property. GNSS raw data however does not provide any useful information in this context.

For deriving very small tectonic displacements most accurate instruments and sophisticated post-processing algorithms are used. Therefore processing the data in real time will not provide the required accuracy and will probably lead to misinterpretations.

For detecting fast seismic displacements high sampling rates up to 100 Hz are used. This high sampling rates require very high bandwidths and are clearly beyond the design specifications of GSN. Additionally, the processing of such data still remains a challenging task and is the subject of an other project in cooperation with the Swiss Seismological Service (SED).

For these reasons GGL will not offer any GNSS data over GSN but provides the metadata of each station in the GSN. Data can be optained from GGL on request at the provided contacts.

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