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17. Synergies between Advancements in Geodesy and other Geosciences

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17. Synergies between Advancements in Geodesy and other Geosciences

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Swiss Geodetic Commission

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17.1

Station velocities in Switzerland derived from 20 years of geodetic satellite navigation observations

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Between 1988 and 1995, the Federal Office of Topography (swisstopo) installed the Swiss Reference Network LV95 (Landesvermessung 95) as the national first network which is completely based on satellite observations to the global positioning system GPS. Together with the operation of the 30 permanent GPS stations of the automatic GNSS network Switzerland (AGNES) starting 1998, the LV95 stations represent the backbone of the geodetic reference frame and the national geodata infrastructure, the Swiss Terrestrial Reference Frame (CHTRF).

As a quality check and for studying the stability of the reference frame, swisstopo re-observed the whole network three times: 1998, 2004 and 2010. The comparison of the horizontal coordinates proved the stability of the reference frame on the cm level.

Furthermore, the detection of possible tectonic movements in the order of below 1 mm/year is achievable with the data set. Horizontal velocity vectors derived from the adjustment of the campaign data can also be compared with results of velocities derived from the permanent AGNES network. Reliable vertical velocities can be estimated only for the permanent stations and from the kinematic adjustment of all national leveling data since 1903. The analysis of the horizontal and vertical velocities is a further step towards the determination of a kinematic model for the recent crustal deformations in Switzerland.

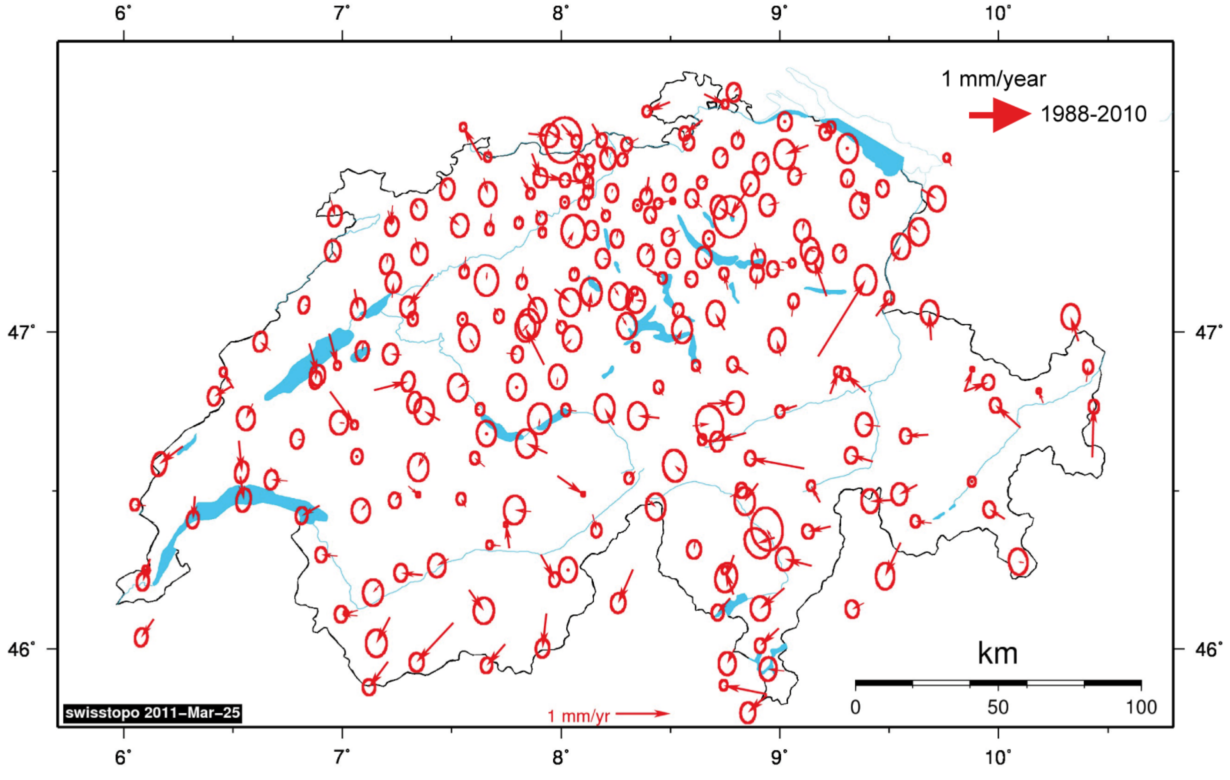

Figure 1. Horizontal velocities derived from GPS campaigns covering an time span of more than 20 years.

REFERENCES

Brockmann E., A. Schlatter (2011): 20 years of maintaining the Swiss Terrestrial Reference Frame CHTRF. In: Ihde, J. and H. Hornik (Eds): Subcommision for the European Reference Frame (EUREF), Chisinau, 2011 (in prep.)

17.2

GPS-equipped wireless sensor network for geodetic positioning applications

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We present the prototype architecture of a novel, power optimized and cost effective Wireless Sensor Network (WSN) node that allows the acquisition of L1 GPS data for highly accurate determination of position and motion based on differential processing of GPS signals [1]. With respect to the differential GPS processing involved it is mainly of importance that the required GPS data (RAW format) is synchronously captures at both a non-moving positions and positions in motion in order to be able to solve for position and velocity at great accuracy. The accuracy of the solutions resolved by this method [1] depends on the amount of GPS data captured, typically on the order of multiple hours for sub-cm accuracy. A configurable measurement schedule, power optimized operation and robustness against harsh environmental conditions makes it well suited for geodetic applications in remote areas, e.g. in high-alpine research. Compared to other approaches [5,6] we exploit low-power operation and real-time data access to allow longer lifetime and the application in natural hazard warning scenarios where data latency is critical [7].

The WSN node presented integrates seamlessly with the PermaSense WSN architecture [2]. In this architecture a multihop network of ultra-low power wireless sensor nodes is used to gather environmental monitoring data, i.e. crack dilatation or temperatures. The system is designed for delivering a continuously high data yield over long observation periods (multi-year) tolerating outages of system components at the node, base station, server and communication link level. Novel and challenging from the perspective of GPS sensors are the considerably higher amounts of sensor data generated and higher power requirements due to the long active time required for the GPS sensor.

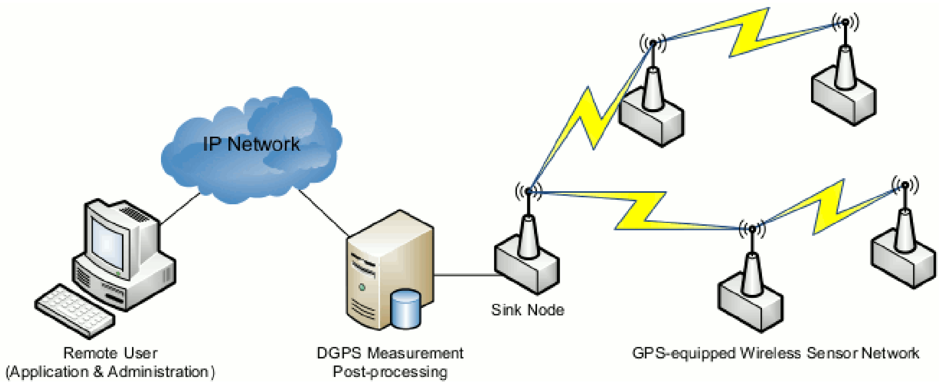

Figure 1. PermaSense GPS-equipped wireless sensor network.

The wireless sensor nodes are based on a commercial low power sensor module (TinyNode 184) coupled with a low-cost off-the-shelf single frequency GPS receiver (u-blox LEA 6T). Each node captures the range and timing information of all visible satellites, and communicates this data to the sink node for application-specific post processing on a backend server [3]. When not acquiring data, the GPS receiver is turned off for power savings. Network-wide synchronized GPS measurements are necessary for dGPS processing. This is achieved by periodically querying the timing information from the GPS unit to synchronize the schedule on the sensor node. The prototype system has been implemented and validated in a testbed setting [4]. A deployment for an outdoor application to monitor rock glacier creep is currently pending.

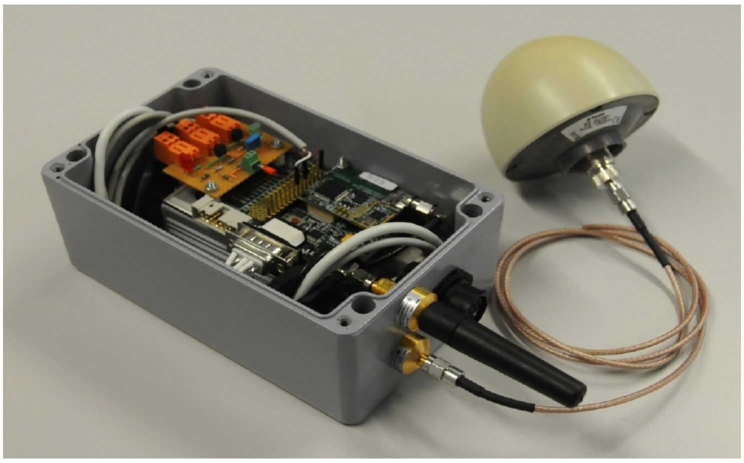

Figure 2. System prototype housed in a water-proof enclosure with EMP-protected antenna connectors for harsh environmental conditions.

REFERENCES

[1] P. Limpach and D. Grimm, “Rock glacier monitoring with low-cost GPS receivers.” in 7th Swiss Geoscience Meeting, August 2009.

[2] J. Beutel, S. Gruber, A. Hasler, R. Lim, A. Meier, C. Plessl, I. Talzi, L. Thiele, C. Tschudin, M. Woehrle and M. Yuecel: PermaDAQ: A Scientific Instrument for Precision Sensing and Data Recovery under Extreme Conditions. Proc. 8th ACM/IEEE Int’l Conf. on Information Processing in Sensor Networks (IPSN/SPOTS ‘09), pages 265-276, April 2009.

[3] N. Burri et al. Dozer: Ultra-low power data gathering in sensor networks. In ACM IPSN, 2007.

[4] F. Sutton, GPS-equipped Wireless Sensor Node for PermaSense. Semester Thesis, ETH Zurich, 2010.

[5] M. den Ouden et al. Stand-alone single-frequency GPS ice velocity observations on Nordenskioeldbreen, Svalbard. In The Cryosphere, Volume 4, Issue 4, pages 593-604, 2010.

[6] L. Garin. Wireless sensor network-based distributed GNSS receiver architecture for infrastructure monitoring. In PhD Thesis, 2010.

[7] Jan Beutel, Bernhard Buchli, Federico Ferrari, Matthias Keller, Lothar Thiele, Marco Zimmerling: X-Sense: Sensing in Extreme Environments. Proceedings of Design, Automation and Test in Europe, 2011 (DATE 2011), Grenoble, France, March, 2011.

17.3

Impact of troposphere modelling on GNSS satellite antenna PCV estimation

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The antenna phase center variations (PCV) of GNSS-satellites (GNSS: Global Navigation Satellite system) are traditionally estimated from the data of a terrestrial tracking network (e.g., from the International GNSS Service, IGS). These measurements are affected (among others) by tropospheric delay considered in the data processing procedure by models (e.g., GPT/GMF or ECMWF/VMF1).

In particular Systematic deficiencies of the mapping function could map into the PCV estimates. We will assess this phenomenon by comparing the resulting GNSS satellite antenna PCV corrections when using different troposphere models for processing the data from the ground network.

On the other hand, GPS-data collected by low Earth Orbiters (LEOs) are not affected by the troposphere. When using these measurements for computing GNSS satellite antenna PCV corrections other problems arise, e.g., the number of different antenna models is very limited, the data are affected by multipath from the LEO environment, and only GPS-satellites can be calibrated in this way sofar. Nevertheless, the results from such an analysis seems also be useful to evaluate the impact of troposphere models on the GNSS satellite PCV corrections derived from a terrestrial network of tracking stations.

17.4

Geodetic water vapor monitoring campaign in Zermatt, summer 2010

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Extreme rain events as the one that occured in the Valais in October 2000, often cause large fatalities and economic losses. This motivates our research to understand and predict the location, time and intensity of heavy precipitation in a river's catchment area. In the classical approach, radar images are used to predict rain several hours ahead (radar nowcasting). Since high humdity in the atmosphere is a precursor of heavy rain, additional knowledge of the tropospheric water vapor distribution might support radar nowcasting. Processed data of a Global Navigation Satellite System (GNSS) receiver delivers information on integrated tropospheric water vapor. A receiver network then allows 3D retrieval of atmospheric water vapor from the integrated values. This so-called water vapor tomography has been a research focus of the Geodesy and Geodynamics Lab, ETH Zurich, for several years. Our recent activities include software development, longterm validation and a GNSS campaign.

The Zermatt area in the Mattertal was chosen as study area to investigate water vapor and its relation to rainfall in an alpine catchment area. As the mountainous topography has a strong influence on both, rainfall and associated water vapor distribution with structures at kilometer-scale, a dense measurement network was required. In the campaign setup, 33 geodetic GNSS receivers with an average inter-station distance of 2 kilometers and 4 additional low-cost receivers were deployed during one month in summer 2010. For validation of the water vapor retrieval by GNSS, 25 radiosondes were launched. The network was supplementd by a rain gauge transect (hydrology group of Prof. Burlando, ETH Zurich).

Data collection and processing issues of the campaign data are discussed and first results are presented. These include integrated water vapor path delays from the GNSS processing and their validation using radiosonde measurements and numerical weather model data. Also preliminary tomographic reconstructions will be shown and it will be shortly outlined, how the GNSS information can be used to better understand the devolution of rain events in an alpine region.

17.5

Gravity Field Determination at AIUB: From CHAMP and GRACE to GOCE

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Gravity field recovery at the Astronomical Institute of the University of Bern (AIUB) is rigorously treated as an extended orbit determination problem, which avoids the introduction of any a priori gravity field information from the CHAMP-, GRACE-, or GOCE-era. The so-called Celestial Mechanics Approach is applied to GPS high-low satellite-to-satellite tracking (hl-SST) data of low Earth orbiters (LEOs), via the use of previously established kinematic LEO positions, to K-band low-low satellite-to-satellite tracking (ll-SST) data of the GRACE mission, and to gradiometer data of the GOCE mission.

We use CHAMP and GOCE hl-SST data to fully exploit the long wavelength part of the Earth's gravity field. We validate the derived gravity field models by performing LAGEOS orbit determination using Satellite Laser Ranging (SLR) measurements and demonstrate that GPS hl-SST gives access to high-quality estimates of the lowest degree coefficients. We also assess the contribution of GPS hl-SST to the recovery of time variable gravity signals and show that large-scale variations may be captured.

We present the latest release AIUB-GRACE03S based on 6 years of K-band ll-SST and GPS hl-SST data, consisting of a static gravity field resolved up to degree 160 and a series of monthly gravity field models resolved up to degree 60. We compare the AIUB-GRACE03S release with results from other research groups and assess the quality of the monthly solutions.

As opposed to the commonly applied filtering techniques for GOCE gravity field recovery based on gradiometer data, empirical parameters are set up in addition to the gravity field coefficients to absorb the non-physical part of the gradiometer measurements. We study the impact of different empirical parametrizations on the GOCE gradiometer solutions and compare them with solutions relying on empirically derived covariance information.

17.6

Ein permanentes GNSS-Netz zur Aufzeichnung tektonischer Bewegungen in der Nordschweiz

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Das bisher bekannte Muster der grossräumigen neotektonischen Bewegungen und Verschiebungsraten in der Schweiz basiert auf Präzisionsnivellements (Schlatter 2007), GNSS Kampagnenmessungen (Schlatter & Brockmann 2010) sowie Daten des GNSS Permanentnetzes AGNES (Brockmann et al. 2006). Die niedrigen Deformationsraten stellen diese Messungen allerdings vor einige technische Herausforderungen. Die Nationale Genossenschaft für die Lagerung radioaktiver Abfälle (NAGRA) initiierte deshalb das Projekt NaGNet, um die bestehenden tektonischen Modelle mittels Langzeitbeobachtungen permanenter GNSS-Stationen zu verfeinern.

Das entworfene Messnetz weist einen Stationsabstand von ca. 12 – 32 km auf (Abb. 1). Die Stationen wurden auf den wichtigsten tektonischen Blöcken abseits von bekannten regionalen Störungszonen platziert. Daneben wurde eine möglichst regelmässige gleichmässige Netzgeometrie angestrebt.

Weitere Faktoren bei der Standortwahl waren eine bestmögliche Anbindung an das anstehende Festgestein bzw. die Stabilität (Rutschanfälligkeit) und Setzungsempfindlichkeit des oberflächennahen Untergrundes (u.a. im Bereich der Stationsfundamentierung), der freie Horizont und die Qualität der empfangbaren GNSS-Signale (z. B. Signal-Rauschverhältnis, Multipath).

Potentielle Standortbereiche wurden zuerst mit topographischen und geologischen Karten voreingegrenzt und anschliessend begangenen; geeignete Standorte wurden entsprechend eines detaillierten Kriterienkatalogs bewertet und ausgewählt. Die Tauglichkeit der Standorte bezüglich des Empfangs von GNSS-Signalen wurde mit einer Testmessung von mindestens 72 Stunden Dauer geprüft. Nach dem Einholen des Einverständnisses der betroffenen Eigentümer und der Erteilung der Bewilligungen durch die zuständigen Behörden, konnten die Stationen gebaut werden.

Die mit dem Bau und Betrieb der Stationen betraute BSF Swissphoto AG hat mittlerweile neun der elf geplanten Stationen realisiert (Abb. 1) und in Betrieb genommen (die ersten Stationen im Oktober 2010).

Für die tektonische Interpretation der gewonnene Messdaten ist die Qualität der Gründung von entscheidender Bedeutung. Eine direkte Gründung auf Festgestein kann lokale Einflüsse z. B. durch gravitative Bewegungen verhindern. Wo eine direkte Fundierung auf anstehendem Fels nicht möglich war, wurde das Fundament mit drei bis zu 15 m tiefen Injektionsbohrpfählen im Anstehenden verankert. Zusätzlich wird zur Erfassung etwaiger lokaler Bewegungsphänomene halbjährlich eine vermessungstechnische Kontrollmessung von Lage und Höhe der Stationen bezüglich Rückversicherungspunkten durchgeführt.

Auf dem Fundament wurde ein 2.5 m hoher Eisengittermast aufgeschraubt, der die GNSS-Antenne trägt (Abb 2). Das GNSS-Equipment an jedem Standort umfasst eine Choke-Ring GNSS-Antenne vom Typ Leica AR25 und einen GNSS-Empfänger von Typ Leica GRX-1200+. Neben dem Empfänger wurden die verschiedenen Komponenten zur Stromversorgung und für die Datenübermittlung in einer thermisch isolierten Kabine untergebracht. Bis zu einer mittleren Leitungslänge von 400 m wurden Kabel zur Strom- und Datenübertragung installiert. Wo dies nicht möglich war, liefert eine Photovoltaikanlage den Strom und die Daten werden über das GSM-Netz übertragen.

Die GNSS-Positionsdaten werden mit 0.1 s und 30 s Messintervall aufgezeichnet und in zwei Pufferspeicher geschrieben. Die hochauflösenden 0.1 s Daten werden nur lokal zwischengespeichert und können bei Bedarf (z.B. Analyse von co-seismischen Bewegungen) abgerufen werden. Die Übertragung der 30 s Daten erfolgt automatisch jede Stunde auf einen zentralen Rechner, wo die Daten auf Vollständigkeit und Qualität überprüft werden. Die aktuellen Resultate dieser automatischen Auswertung können auf einem web-basierten Kundenportal abgerufen werden. Sie dienen auch der Netzüberwachung und informieren bei Datenausfall oder ausserordentlichen Verschiebungsraten das zuständige technische Personal mit Email und SMS.

Die qualitätsgeprüften Rohdaten fliessen zum Rechenzentrum PNAC von swisstopo, wo sie zusammen mit den GNSS-Daten der AGNES-Stationen ausgewertet werden. Die präzisen Modelle, welche der Bernese-Software zu Grunde liegen, erlauben die Berechnung von hochgenauen Standortskoordinaten als Stunden-, Tages- oder Wochenlösungen. Die Wiederholbarkeit der bisher für die NaGNet-Stationen berechneten Wochenlösungen ist im Allgemeinen besser als 1 mm in der Lage und 2-3 mm in der Höhe. Diese Resultate werden in einigen Jahren zur Verfeinerung der bestehenden Modellvorstellung der neotektonischen Bewegungen in der Nordostschweiz beitragen.

REFERENZEN

Brockmann, E., Grünig, S., Ineichen, D. & Schaer, S. (2006): Monitoring the Automated GPS Network of Switzerland AGNES. In: Torres, J.A. & Hornik, H. (Eds.): Rep. on the Symp. of the IAG Sub-commission for Europe (EUREF) in Riga, 14-17 Juni 2006, EUREF Publication No 16, pp. 176-83.

Schlatter, A. & Brockmann, E. (2010): Dritte Wiederholungsmessung im GNSS-Landesnetz LV95, Messkampagne und erste Resultate. Swisstopo Kolloquium 1. April 2011. http://www.swisstopo.admin.ch/internet/swisstopo/de/home/docu/Kolloquien/110401.parsys.14332.downloadList.31708.DownloadFile.tmp/chtrf2010teil2200.pdf.

Schlatter, A. (2007): Neotektonische Untersuchungen in der Nordschweiz und Süddeutschland. Kinematische Ausgleichung der Landesnivellementlinien CH/D. Nagra Arb. Ber. NAB 07-13.

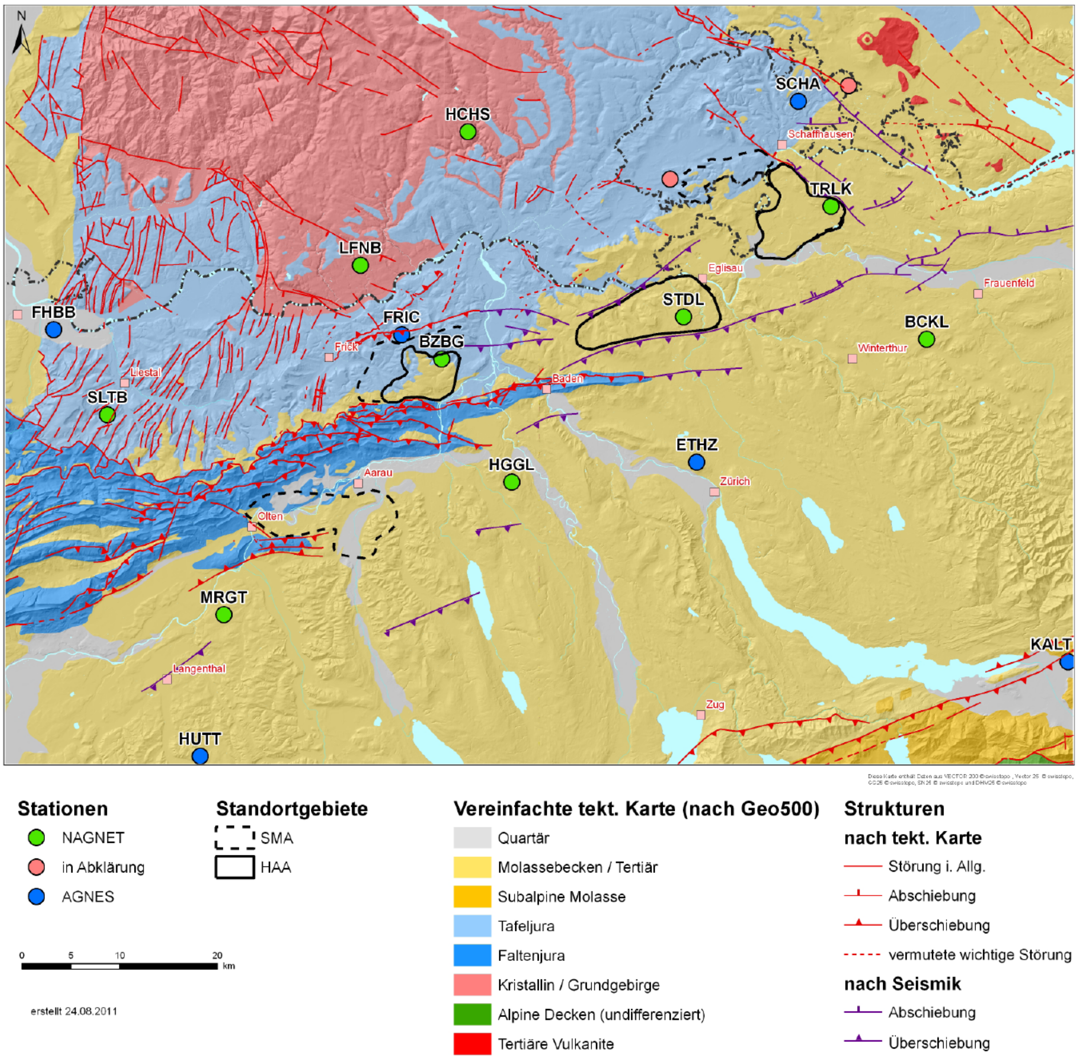

Abb. 1. Vereinfachte tektonische Karte und Verteilung der NaGNet- (grün) und AGNES-Stationen (blau) im Projektgebiet. Rot: NaGNet Standorte in Abklärung. Zur Orientierung sind die in der Nordostschweiz liegenden Standortgebiete für geologische Tiefenlager für schwach- und mittelaktive (SMA) sowie hochaktive (HAA) Abfälle eingezeichnet.

Abb 2. Eine fertig gestellte NaGNet-Station.

17.7

Positioning improvements with stochastic clock modelling

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The synchronization of the receiver clock with the satellite clocks is always an integral task of GNSS positioning. In current GNSS applications, all receiver clocks are typically determined for every measurement epoch to reach a high positioning precision. The fact that the clocks, especially very good clocks, do not jump by arbitrary values from one epoch to the next is hardly used at present. Making optimal use of the quality of the receiver clocks should, therefore, stabilize the solutions significantly and improve the positioning results.

Experiments with kinematic solutions for static stations equipped with H-Maser clocks have confirmed this. To access the achievable improvement, the least square adjustment algorithmus have been modified to allow for constraints between clock values of subsequent epochs. The weight of the relative constraint and the receiver clock quality are the essential factors for an improvement in the kinematic solutions. We will present first results of the investigation with different relative constraints on very good clocks showing that appropriate constraints improve the precision of the estimated kinematic coordinates, especially in the less accurate vertical direction, bis up to a factor of two. The improved performance of kinematic solutions is evaluated in detail and the benefit for the real-time monitoring of crustal deformation and earthquakes will be discussed.

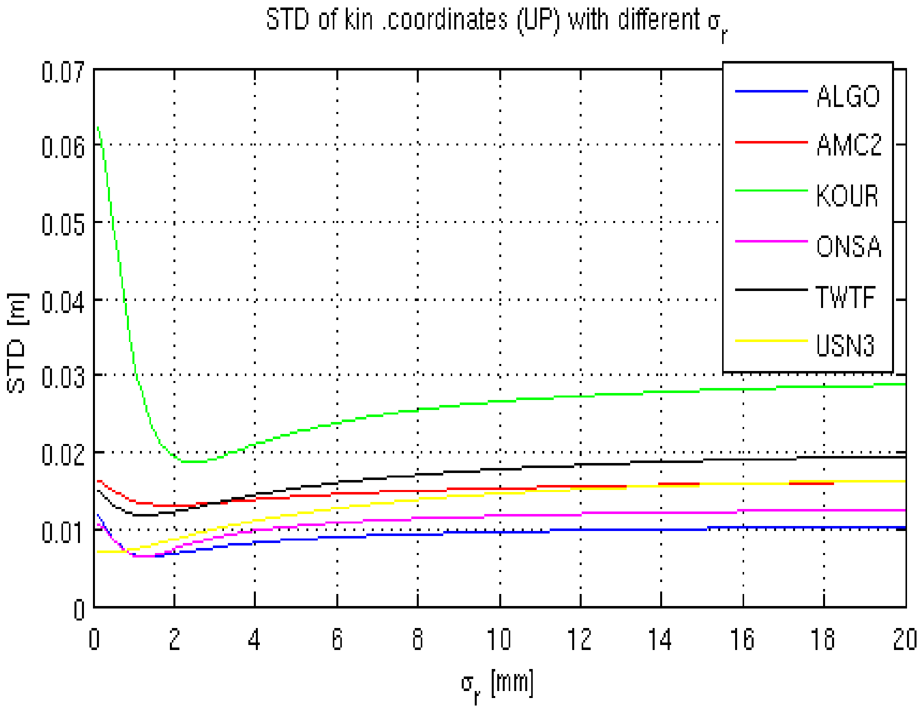

Figure 1. Repeatability of kinematic coordinates (height) using relative constraints $\sigma_r\sigma_r$ between subsequent epochs for clock parameters for some H-Maser clocks. X-axis represents the relative constraint $\sigma_r\sigma_r$ applied. As the constraint get smaller, i.e., stronger, the precision of the kinematic coordinates improves significantly per 5 minutes until an optimum is reached at about $\sigma_r \approx 1\ mm$.

REFERENCES

Dach, R. & Hugentobler, U. & Fridez, P. & Meindl, M. 2007: Bernese GPS Software Version 5.0. Astronomical Institute, University of Bern.

P 17.1

Permanent monitoring of rock glaciers with low-cost GPS

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Since winter 2010/2011, a network of permanent GPS stations is being set up in the Matter Valley in the framework of the X-Sense project, currently totaling 20 stations. X-Sense is an interdisciplinary project for monitoring alpine mass movements at multiple scales, funded by the Swiss federal program Nano-Tera. The X-Sense stations consists of low-cost GPS receivers coupled with inclinometers. Some prototype stations allow for on-line data transmission.

The geodetic potential of low-cost GPS receivers for the precise monitoring of slope instabilities in mountain areas was previously investigated in a feasibility study. Based on a small GPS test network operated on Dirru rock glacier, Matter Valley, since June 2009, it was shown that low-cost GPS units are able to provide reliable and continuous time series of surface displacements at cm-level accuracy, using adequate differential processing techniques.

Enhanced algorithms were developed to derive accurate time series of surface velocities based on the GPS displacements. It was shown that the low-cost GPS receivers allow to reliably observe surface velocities even below 1 cm/day, as well as to detect small and short-term velocity changes. In addition, the time series of more than 2 years obtained from the test network reveals the capability to detect seasonal velocity variations, as well as inter-annual variations of the velocity pattern. By providing continuous observations of surface motion, the GPS-based permanent monitoring contributes to the understanding of processes linked to permafrost-related slope instabilities.

P 17.2

Displacement detection on rock glaciers using webcam images: A case study in the Mattertal

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Several fast moving rock glaciers in the Mattertal Valley, Switzerland, are exposed to intensive studies due to their possible harmful impact on human infrastructures. Historical but also very recent events show the high activity of the relatively fast moving rock masses. In order to understand possible correlations between environmental changes and the rock glacier behavior, displacement mapping is a good method to analyze these interactions. Over the last two years, several webcam observation platforms were installed by the University of Fribourg which deliver images of several rock glacier tongues on a relatively high sampling rate.

This work presents first results of motion detection based on webcam images taken over several months. Because of the coarse surface structures of the rock glaciers and hence the good small scale gradients in the images, feature tracking is the prefered method for the optical flow estimation. By applying a subpixel accuracy detection algorithm, highly accurate velocity fields can be extracted.
Due to an accuracy estimate of the displacement detections, a robust algorithm for outlier identification can be applied to clean the data. Having a clean dataset allows to compute displacement trajectories as well as strain and stress components of individual areas of the rock glacier.

By analyzing image sequences, the behavior of temporal and spatial variations of the rock glacier surface displacements can be studied. This is a fundamental data basis which might result in new insights of the complex behavior and interaction between a rock glacier and its environment.

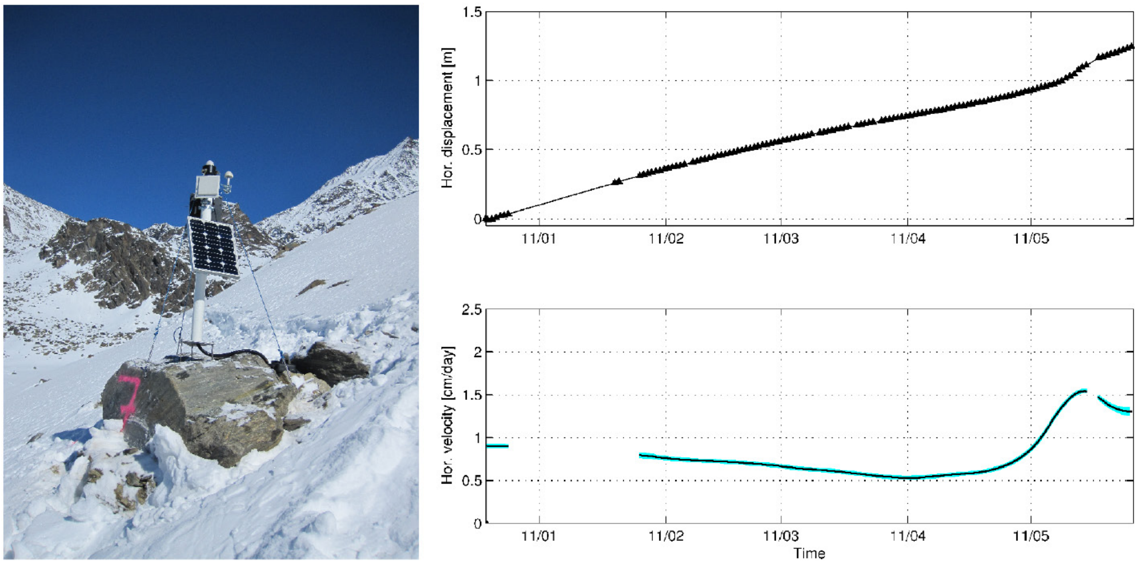

Figure 1. Example of an X-Sense GPS station at Dirru rock glacier, Matter Valley, with horizontal displacement and velocity as a function of time (year/month), from December 2010 to June 2011.

P 17.3

Improving sub-daily solutions of single-frequency GPS using antenna PCV

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Nowadays, GPS positioning is widely used as an efficient tool for mass movement monitoring. Geodetic-grade GPS equipment can easily achieve centimetre positioning accuracy in real-time and sub-centimetre accuracy in post-processing mode. However, deploying geodetic-grade equipment
in hostile areas, like landslide or rock-glacier areas, is too expensive because of the high risk of damaging instruments due to rock fall, landslides, etc..

Meanwhile the investigation and research on low-cost, single-frequency GPS technology shows the possibility to provide an economical solution with a positioning accuracy comparable to geodetic-grade products. Therefore in the project X-Sense, low-cost, single-frequency GPS antennas and receivers are used and densely mounted in hostile areas.

The main factors that degrade the accuracy of low-cost, single-frequency GPS equipment are ionospheric delay, multipath, antenna PCV (phase center variations) and others. Investigations of each individual factor shall be carried out and algorithms for solving the problems shall be developed for short baseline processing, in order to achieve a high accuracy with a near real-time, single-frequency GPS positioning technique.

The influence of PCV is prominent especially for sub-daily coordinate resolution because of the satellite constellation change. In the first phase of the study, the PCV of the low-cost, single-frequency antennas are modelled and applied to test runs (using a 24-hour set of data with a 30-second time interval and baseline lengths around 15 meters) for computing 2-hour solutions. The result is shown in Figure 1. By applying antenna PCV, the RMS is improved by 57.68% in north, 28.95% in east and 49.30% in up direction (see Table 1).

Axis	RMS (Solution without PCV)	RMS (Solution with PCV)	Improvement
N [mm]	1.8	0.78	57.68%
E [mm]	1.6	1.1	28.95%
U [mm]	5.5	2.8	49.30%

Table 1. RMS of the estimated coordinates in north, east and up direction for both solutions with and without the applying of antenna PCV.

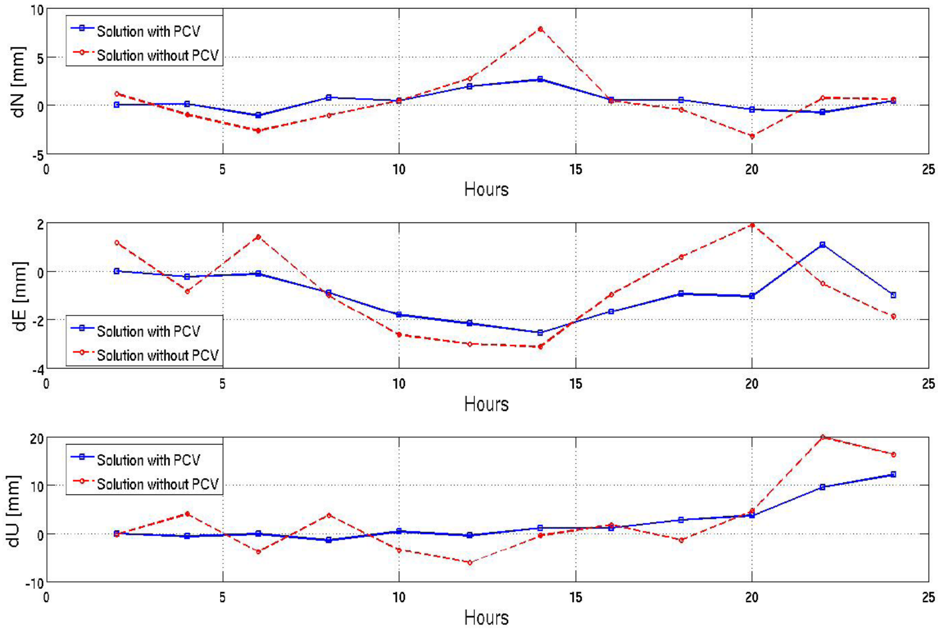

Figure 1.Time series of 2-hour solution (north, east and up) with and without applying antenna PCV

REFERENCES

Geiger, A., 1988: Modeling of Phase Center Variation on its Influence on GPS Positioning, International GPS-Workshop, Darmstadt, FRG, April, 11-13, 1988

Rothacher, M., Schaer, S., Mervart, L., & Beutler, G. 1995:Dertermination of Antenna Phase Center Variations Using GPS Data, Proceedings of the IGS Workshop “Special Topics and New Directions”, Potsdam, May, 15-18, 1995, Gendt, G. / Dick, G., pp. 205-220, GeoForschungsZentrum Potsdam, Potsdam.

Schwieger, V., 2009: Accurate High-Sensitivity GPS for Short Baselines, FIG Working Week 2009, Eilat, Israel, May, 3-8, 2009

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SWISS 4D: Estimation of the tectonic deformation field of Switzerland based on GPS measurements

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In 2010 the federal office of topography, swisstopo, carried out a GNSS measurement campaign for the CHTRF 2010. The measurements cover whole Switzerland and lead to an updated set of velocity data on more than 230 points. This dense network allows to search for tectonic deformations even though the magnitudes of deformation are very small. Velocities relative to station Zimmerwald are mostly below 1 millimeter per year. The small velocities increase the importance of separate the deformation into local and regional effects as both are of similar magnitude. The latter are assumed to represent the ongoing tectonic processes whereas local effects might be caused by landslides or monument instabilities.

To obtain a continuous velocity field representing the tectonic deformations from the noisy velocity data an adaptive least square collocation is used. It allows to extract a statistically significant velocity field separating tectonic and local deformation parts. This is achieved assuming tectonics is correlated over wider area whereas local effects are only correlated within a smaller area. Apart from the separation between the two effects the tectonic model is estimated introducing adjustments to the trend metric. Therefore, areas with high strain rates are decorrelated in an iterative process. This processing allows to extract information about the deformation field identifying regions with higher strain rates than surrounding areas.

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Investigating the reliability of kinematic source inversion with dynamic rupture models and high rate GNSS data

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An essential element of understanding the earthquake source processes is obtaining a reliable source model via geophysical data inversion. However, the epistemic uncertainties in the kinematic source inversion produce a variety of source models estimate for any given event. Thus, as done in the Source Inversion Validation (SIV) project, it is important to validate our inversion methods with synthetic data by testing forward Green's function calculation and comparing various inversion methods. Spontaneous dynamic rupture modeling, that incorporates conservation laws of continuum mechanics and constitutive behavior of rocks under frictional sliding, is capable of producing physically self-consistent kinematic description of the fault and its associated seismic wave propagation resulting in ground motions on the surface. Here we develop accurate dynamic rupture simulation of a vertical strike sip fault. Our source model is composed by well-defined asperities (patches of large stress drop) and we assume that fault rupture is governed by the linear slip weakening friction model. The resulting near-source ground motion dominated by low frequency (up to 1Hz) is used for testing our inversion method. We performed various inversion tests and compared estimated solutions with true solutions obtained by the forward dynamic rupture modeling. Our preliminary results show that estimated model spaces could be significantly perturbed, depending on data and modeling schemes used in the inversion, not only in terms of spatial distribution of model parameters, but also in terms of their auto- and cross-correlation structure. The Bayesian approach in source inversion becomes more and more popular because of the recent common availability of high performance computing capabilities. We adopted the Bayesian approach in our source inversion test, so that we can more effectively analyze the uncertainty of estimated models and also implement physically guided regularization in the prior. In addition, the recent emergence of high-rate Global Navigation Satellite Systems (GNSS) data can considerably improve the observation capabilities for dynamic surface movements (sampling up to 100 Hz) during large earthquakes. GNSS receivers are used to accurately measure both dynamic and static ground displacements without saturation or sensitivity to tilt and with a sampling interval below 1 second and sub-centimeter accuracy across the frequency spectrum. We expect that we can resolve an issue of relative weighting we often face in multiple data inversion, i.e., joint inversion of both geodetic and seismic data, by inverting ground displacement data recorded by the GNSS receivers.