Automated GNSS Network Switzerland (AGNES)

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1. Project description

The station is part of the Automated GNSS Network of Switzerland (AGNES) consisting of 31 sites, equipped with GNSS receivers and antennas. In Spring 2015, the complete AGNES network, with the exception of Jungfraujoch, was enhanced from GPS and GLONASS (the Russian equivalent of GPS) to a Multi-GNSS network which is capable to track also satellites of the European Galileo System and the Chinese BeiDou System. Jungfraujoch station was enhanced to Multi-GNSS together with the installation of the new MeteoSwiss observation platform end of 2017.

AGNES is a multi-purpose network which serves as reference for surveying, real-time positioning (positioning service swipos GIS/GEO) and for scientific applications (geotectonics and GNSS-meteorology). The station JUJO/JUJ2 is mainly contributing to scientific applications. Troposphere path delays derived from the swisstopo processing are provided to MeteoSwiss on an hourly basis. Furthermore, the data are sent to the European meteo community EUMETNET, where the data are available for all meteo agencies for numerical weather predictions. At the moment, UK METO, MeteoFrance, DMI, and KNMI are using the GNSS-derived troposphere models routinely in the weather forecasts. This activity is coordinated by the EGVAP project. Currently, a continuation of this EUMETNET project is planned. The results are also sent to the Institute of Applied Physics (IAP) of the University of Berne where the data contribute to the STARTWAVE database. It is worth to mention that our final troposphere products (delivered with a 1-2 weeks delay) are also used by PMOD/WRC Davos for the calibration of the pyrgeometer.

In 2013 the new COST project named GNSS4SWEC (Advanced Global Navigation Satellite Systems tropospheric products for monitoring severe weather events and climate) started. The focus of swisstopo's investigations is the long-term behaviour of the troposphere parameters. Due to the fact that we re-processed all Swiss and European GNSS data since 1996 with a homogeneous set of modelling parameters, we have a first data set which might help to detect possible changes in water vapour over time. Till now, the time series suffered from software changes and also from modelling changes which resulted in "jumps" in the troposphere time series. With a complete reprocessing of all data from 1996 – 2014 a long time span is covered with identical modelling of observations. This modelling is also continued till today. Nevertheless, antenna changes at stations have a significant influence to the long-term consistency (e.g. also the new Jungfraujoch mast installation and the new antenna which is capable to track all modern GNSS satellite system whereas the old antenna was only capable to track GPS. The GNSS4SWEC project finished 2017. The final report was drafted Mid 2018 and was made available in written form end of 2019. Below we show some figures, showing the troposphere long-term data of JUJO (GPS-only) and JUJ2 (Multi-GNSS).

swisstopo operates a monitor web platform pnac.swisstopo.admin.ch where all important results are available online. Fig. 1 shows the long-term troposphere estimates for JUJO and JUJ2 (after the interruption), its internal formal errors (RMS) and the corresponding amplitude spectrum. The annual variations are obvious.

Bernet et al. (2019) calculated trends of integrated water vapor (IVW), after converting ZTD to IVW, for all Swiss permanent sites (Fig. 2). JUJO/JUJ2 shows a quite small trend compared to other stations. If this is due to the high altitude is not proofed. Generally, we see a positive trend for all Swiss sites pointing in the direction that with a higher temperature more water vapor can be stored in the atmosphere.

Coordinate time series in the local system North, East and Up of JUJO/JUJ2 are shown in Fig. 3. The time series covers data from 1999 till 2019 – in total about 20 years. Our reference station Zimmerwald (ZIMM) covers a time span of 24 years. The estimated station velocity is easily visible – mainly for the height component we see an uplift of 3 mm/yr with respect to the European Plate. This is the strongest uplift signal compared to all other Swiss permanent stations. Removing this signal from the coordinate time series shows that some seasonal effects are visible in all three components (see Fig. 4). This is due to the instability of the meteo mast. The effect is visible with the new setup, only, because the daily repeatability was considerably improved with the new Multi-GNSS equipment.

Interestingly, we recognized a jump in the time series on Jan. 16, 2019 in the east component (see Fig. 5 and also the brown line in Fig. 4) already 6 weeks later. After some investigations, we got the validation from Meteoswiss that they did the annual maintenance of all sensors on the bridge on that day. Due to heavy ice beneath the antenna at the ventilator, they broke all ice. This obviously resulted in a physical displacement of about 3-4 mm in east component (direction in-line with the bridge holding the instruments). January 2020 we setup a "jump" to model this displacement (compare Fig. 4 and Fig. 6). The estimated displacements are dNorth = 1.8 mm, dEast = 1.4 mm and dUp = -0.1 mm. It seemed that the displacement took mainly place in the east direction. Setting up an arbitrary offset together with asking for a linear movement of JUJO and JUJ2 covering more than 20 years, the parameter estimation estimated also a quite noticeable offset for the north component. This shows, how sensitive such introductions of offsets are. It weakens the complete long-term series. Introductions of an offset in only one component are, unfortunately, not possible. The offset estimation will (hopefully) change as the time series get longer.

Further results of the processing is available online (updated routinely):
http://pnac.swisstopo.admin.ch/pages/en/qsumjuj2.html

New official coordinates were published for JUJ2 based on a new adjustment including also campaign data since 1988 (Brockmann, 2018) in July 2018. Details are published on: http://pnac.swisstopo.admin.ch/pages/en/chtrf.html

References

Brockmann E. (2018), LV95 / CHTRF2016 (Swiss Terrestrial Reference Frame 2016): Teil 2: Auswertung der GNSS-Messungen 2016 und Resultate der Gesamtausgleichung, Report 16-19, Wabern, 2018.

Willi D., S. Lutz, E. Brockmann, M. Rothacher (2020): "Absolute field calibration for multi-GNSS receiver antennas at ETH Zurich", GPS Solutions (2020) 24:28, https://doi.org/10.1007/s10291-019-0941-0

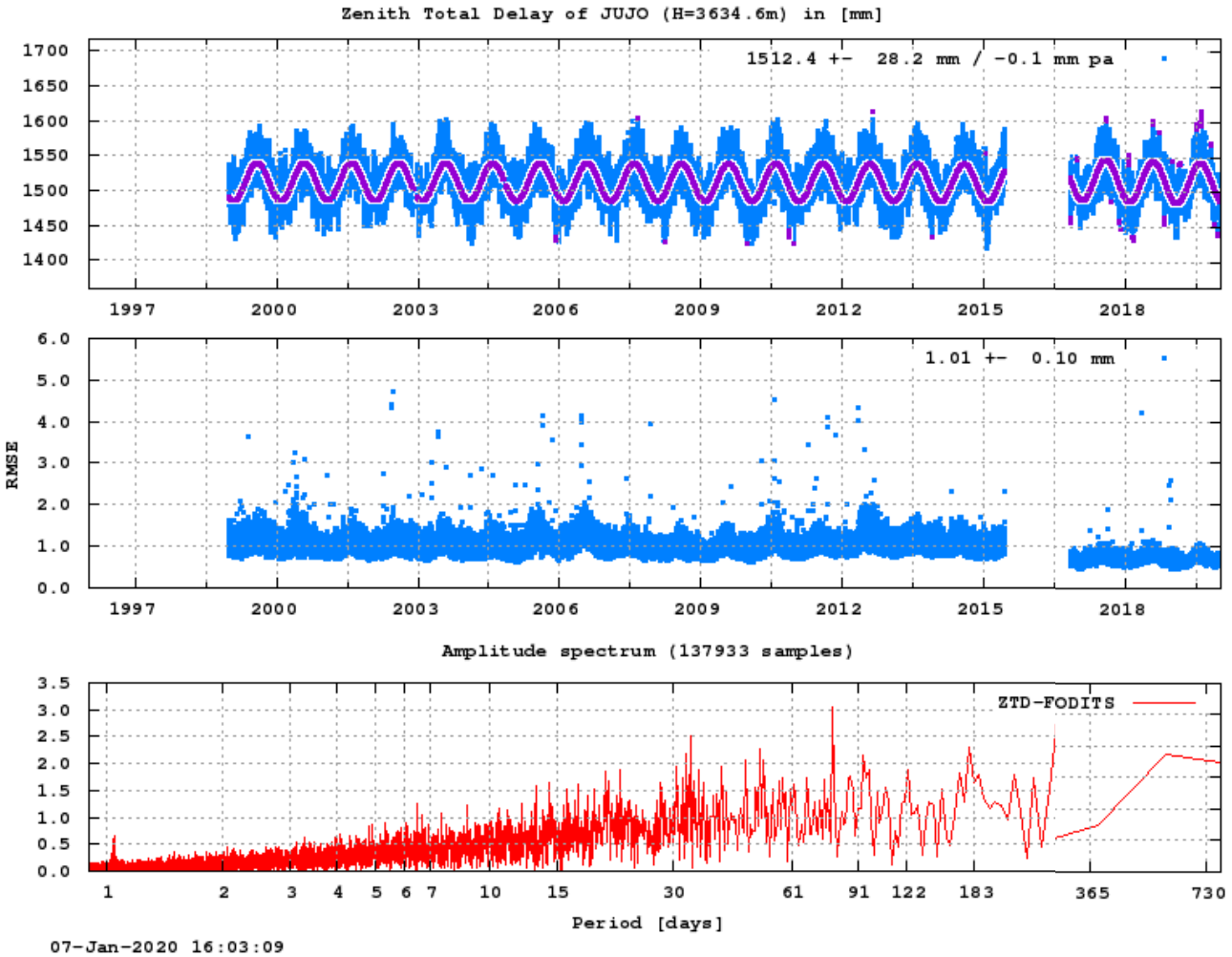

Figure 1. Long-term troposphere estimates for JUJO / JUJ2 (http://pnac.swisstopo.admin.ch/resplt/juj2_trp.gif).

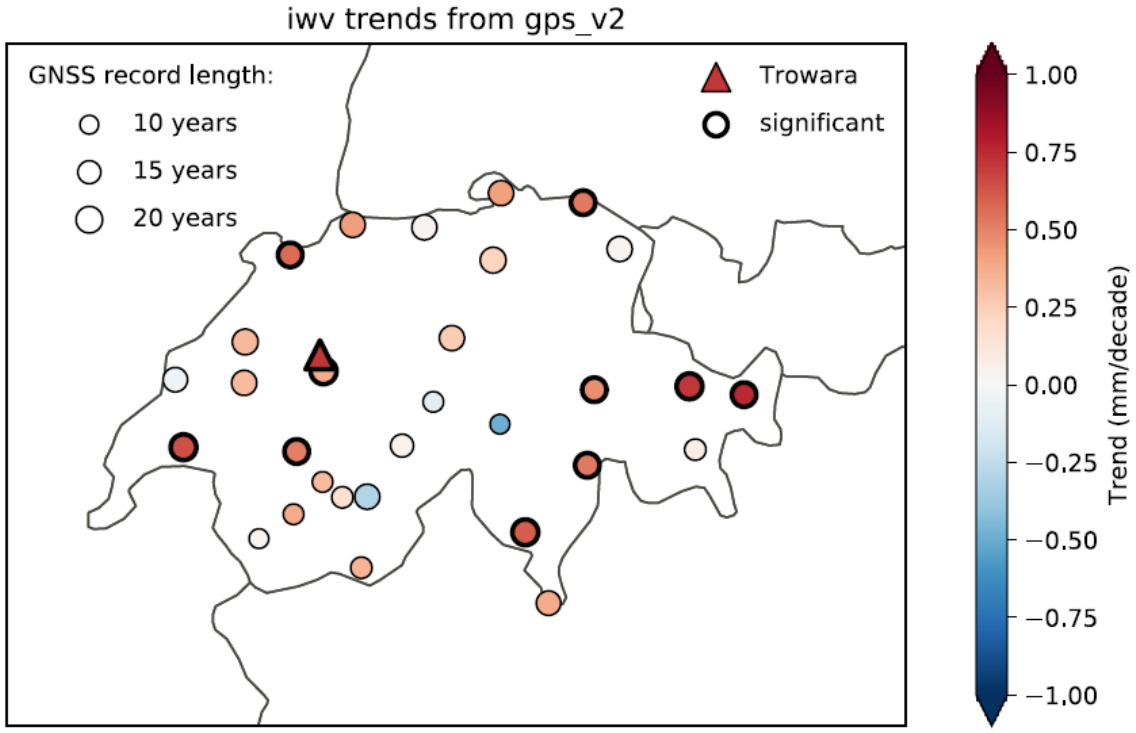

Figure 2. Trend analysis of long-term troposphere ZTD parameters converted to IVW for all Swiss permanent sites (Bernet et al., 2019).

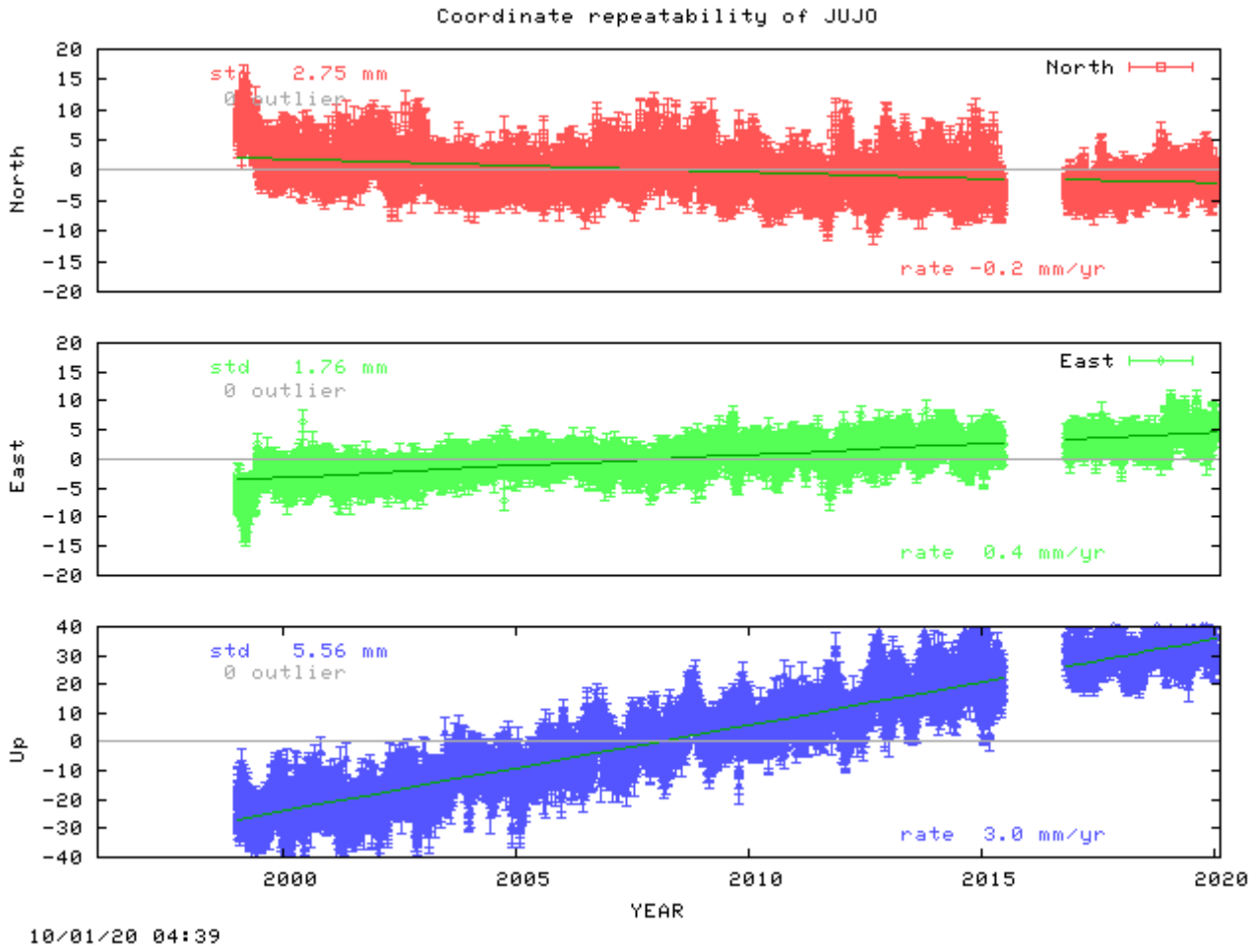

Figure 3. Long-term coordinate estimates for JUJO / JUJ2 (horizontal movement with respect to Zimmerwald, vertical movement w.r.t European Plate; http://pnac.swisstopo.admin.ch/resplt/juj2_vel.gif).

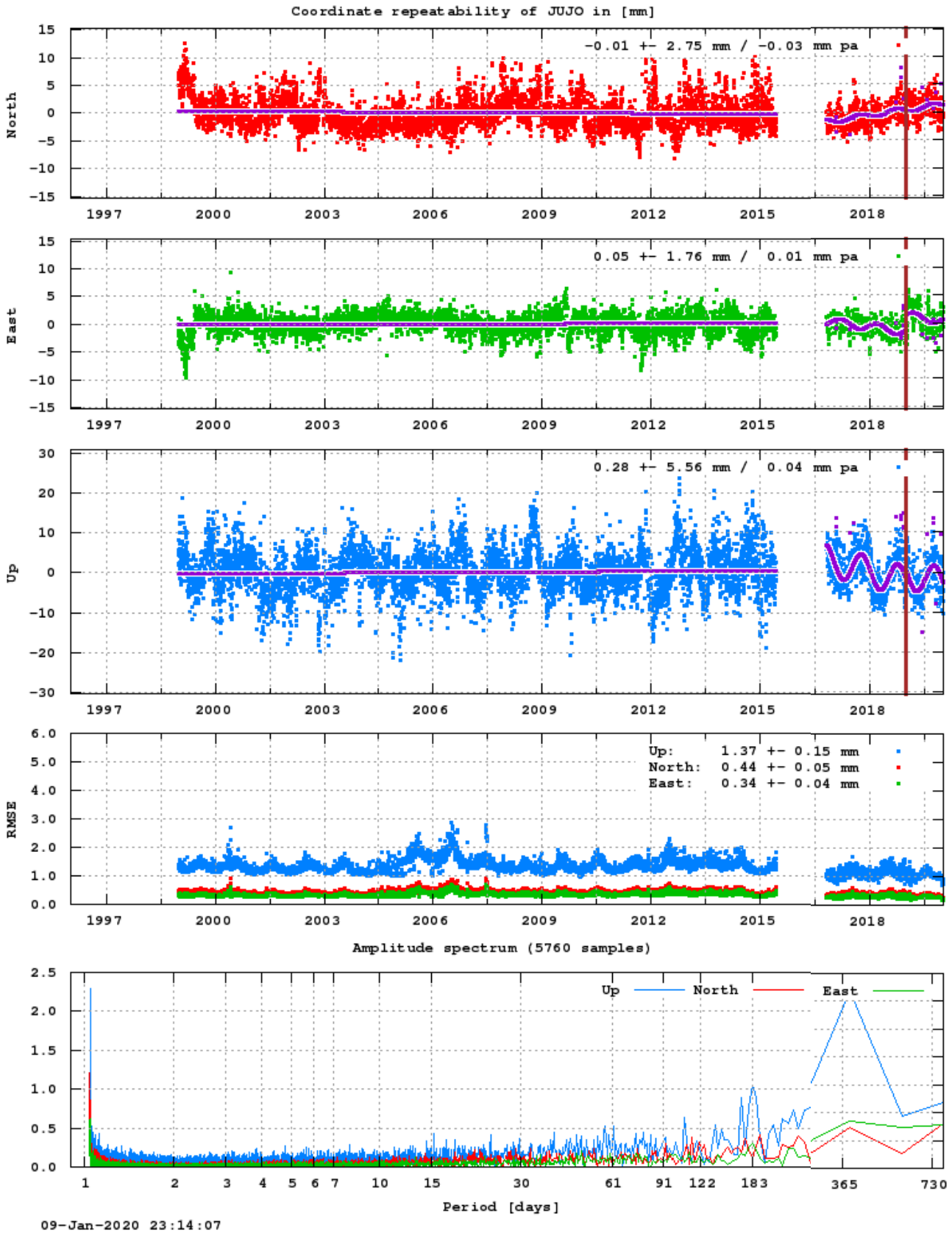

Figure 4. Long-term coordinate estimates for JUJO / JUJ2 (velocities removed; rms and fourier spectrum added; http://pnac.swisstopo.admin.ch/resplt/juj2_fft.gif).

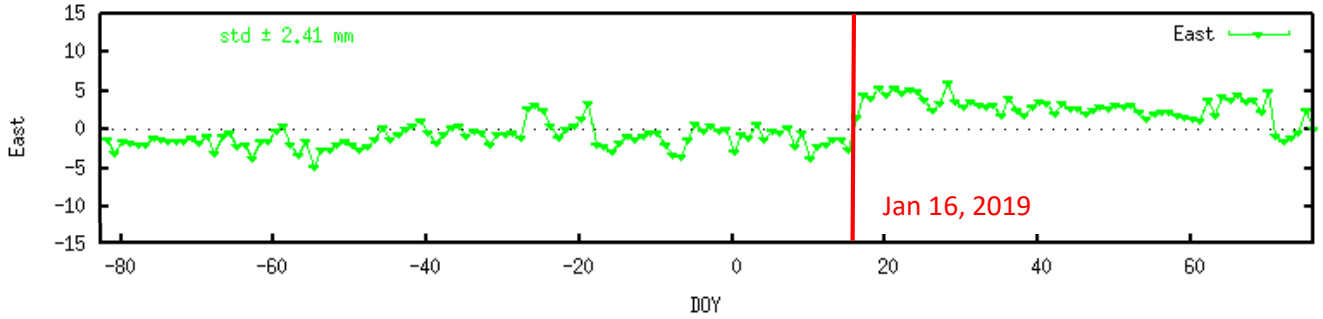

Figure 5. Time series of JUJ2 for the east component in the actual coordinate monitoring when MeteoSwiss removed heavy ice for all sensors of the bridge on Jan. 16, 2019.

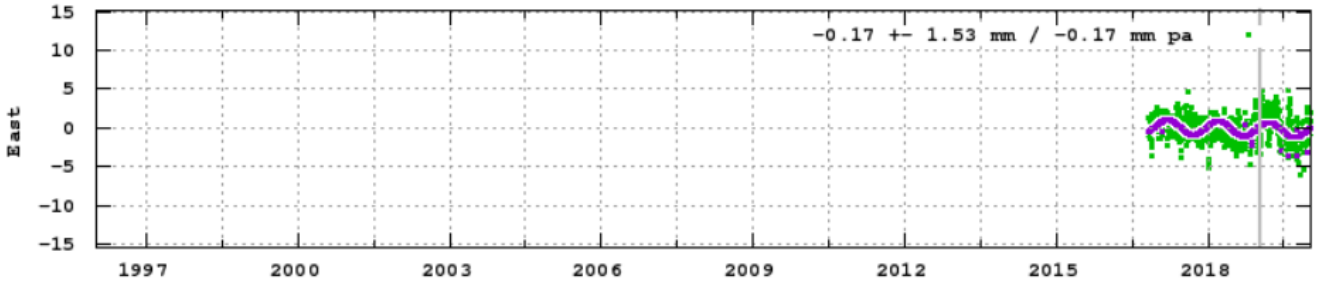

Figure 6. Time series of JUJ2 for the east component in the final coordinate estimation after estimation of an east displacement at Jan. 16, 2019.

Internet data bases

http://www.swisstopo.ch
http://pnac.swisstopo.admin.ch

Collaborating partners / networks

Dr. Alexander Haefele, Dr. Rolf Rüfenacht, MeteoSwiss, Payerne
Dr. Philippe Steiner, Dr. Daniel Leuenberger, MeteoSwiss, Zürich
Dr. Rolf Dach, Prof. Dr. A. Jäggi, University Berne, Astronomical Institute
Dr. Klemens Hocke, Dr. Leonie Bernet, University Berne, Institute for Applied Physics
Dr. Julian Gröbner, Dr. Christine Aebi, PMOD/WRC Davos
Prof. Alain Geiger, Dr. Karina Wilgan, Dr. Roland Hohensinn, Dr. Endrit Shehaj, ETH Zurich, Dep. of Civil, Env. and Geomatic Eng., Geodesy and Photogrammetry

Scientific publications and public outreach 2019

Conference Papers

Bernet, L., E. Brockmann, Ch. Mätzler, N. Kämpfer, and K. Hocke, Water vapour trends in Switzerland based on data from ground-based microwave radiometry and GNSS ground stations, 7th International Colloquium on Scientific and Fundamental Aspects of GNSS, ETH Zürich, Switzerland, September 4-6, 2019.

Brockmann, E., S. Lutz, J. Zurutuza, A. Caporali, M. Lidberg, C. Völksen, L. Sánchez, E. Serpelloni, S.I. Bitharis, C. Pikridas, A. Fotiou, E. Mathis, J.A. Sánchez Sobrino, M. Valdés Péres De Vargas, P. Vernant, A. Baron, M. Westerhaus, J. Legrand, C. Kreemer, M. Gianniou, G. Nykiel, M. Figurski, A. Kenyeres, K. Ali Ihsan, Towards a Dense Velocity Field in Europe as a basis for Maintaining the European Reference Frame, 27th IUGG Assembly, Montreal, Canada, July 8-18, 2019.

Brockmann, E., D. Ineichen, J. Liechti, S. Lutz, Impact of Multi-GNSS observations on precise geodetic applications used at the Swiss Mapping Agency swisstopo, 7th International Colloquium on Scientific and Fundamental Aspects of GNSS, ETH Zürich, Switzerland, September 4-6, 2019.

Brockmann, E., swisstopo Report for EGVAP 2019, EGVAP expert meeting, Offenbach, Germany, November 28-29, 2019.

Brockmann, E. et al., National Report of Switzerland, EUREF-Symposium in Tallinn, Estonia, May 22–24, 2019.

Brockmann, E., S. Lutz, Towards a European Dense Velocities Field as a basis for Maintaining the European Reference Frame, EUREF-Symposium in Tallinn, Estonia, May 22–24, 2019.

Brockmann, E., M. Clausen, PROJ – usage of transformations in Switzerland (swisstopo), Tutorial contribution to the EUREF-Symposium in Tallinn, Estonia, May 22–24, 2019.

Brockmann, E., D. Ineichen S. Lutz, Multi-GNSS activities at swisstopo, EUREF LAC Workshop, Warsaw, Russia, October 16-17, 2019.

Los, M., E. Shehaj, J.D. Wegner, S. D'Aronco, A. Geiger, E. Brockmann, Machine learning assessment for tropospheric pathdelays prediction using meteorological parameters in Switzerland, 17th Swiss Geoscience Meeting 2019, Fribourg, Switzerland, November 22-23, 2019.

Lutz, S., E. Brockmann, Status report of the Working Group European Dense Velocities, 16th European Geosciences Union – General Assembly, Vienna, Austria, April 8-12, 2019.

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