Report of the GNSS field work in Afghanistan and Kyrgyzstan 2014-2018

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1 Introduction

The Pamir is situated north-west of the Tibetan Plateau and is a result of the collision of the Indian with the Eurasian plate. With a plate convergence rate of 34 mm/yr the Pamir has accommodated at least ~300 km of shortening (Burtman and Molnar, 1993). Most of the recent deformation takes place at the Northern margin of the Pamir along the Pamir Thrust System (PTS) with shortening rates of 15 mm/yr across the Alai valley that runs parallel to the MPT (Zubovich et al., 2010, 2016). This active zone of underthrusting is well outlined by shallow seismicity (Sippl et al., 2013, Schurr et al., 2014) and magnitude 6.5 to 7.5 earthquakes with decennial repeat times, such as the 2015 M_w7.2 Sarez, Central Pamir earthquake (Metzger et al., 2017, 2020, in prep.). High strain is also accumulated at the northwestern margin of the Pamir, where the crust extrudes into the Tajik Depression (Metzger et al. 2020). Here, survey GNSS-based slip-rate estimations reach 15+4/-2 mm/yr of shortening, 16+/-3 mm/yr of shear on the dextral-transtensive Vakhsh fault and ~10 mm/yr extension and ~15 mm/yr of shear at the sinistral-transtensive Darvaz fault.

We present here raw Global Navigation Satellite System (GNSS) data in Receiver Independent eXchange (RNX) format from two sub-regional projects (Figure 1, Table 1, supporting information), acquired between 2014 and 2020. The Kyrgyz GNSS surveys help to localize strain and fault kinematics at the northern front of the Pamir (PTS). The data complement a N-S oriented, continuous GNSS profiles operating since 2013, resp. 2015 (Zubovich et al., 2016, in prep.). The GNSS time-series are affected by the 2015 Central Pamir earthquake. The Afghan GNSS surveys present the first of their kind taking place in the inaccessible Hindu Kush that links to the southwestern Pamir and of which recent crustal kinematics are nearly unknown (Shnizai, 2020, Perry et al., 2018). These data were collected across the NNE-trending Badakhshan faults (7.3±1.0 mm/yr sinistral slip) and, further to the southwest, the NE-trending Panjsheer fault (4.3±1.5 mm/yr of sinistral-transtensive slip, Kufner et al., 2021).

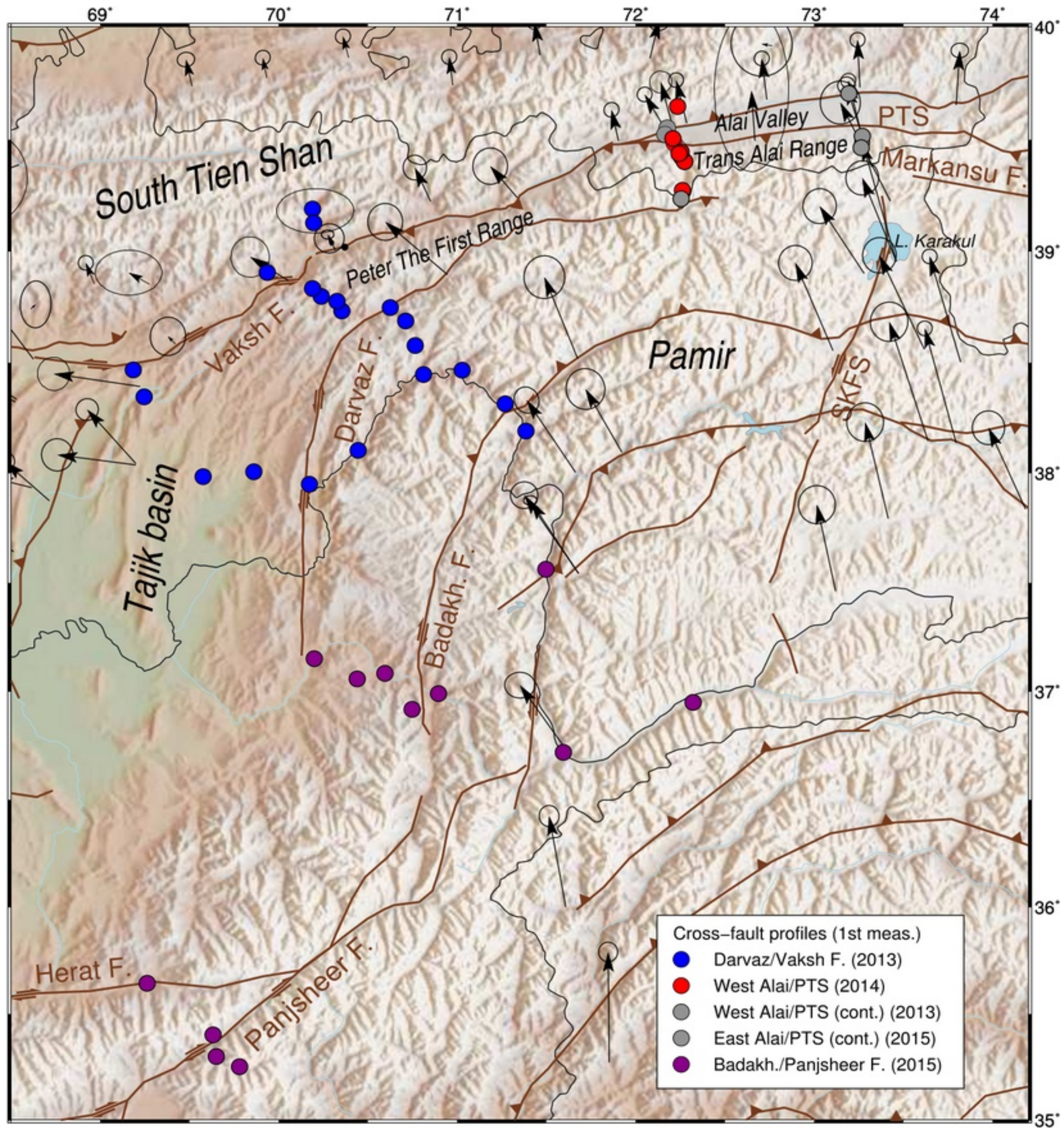

Figure 1: Recent kinematics of the Greater Pamir, active fault zones and marker locations of GNSS surveys conducted 2013-2020. The RNX data of the purple and red profiles are provided here, the RNX data of the blue profiles are provided in Metzger et al. (2019).

2 Logistics

2.1 Participants

The Kyrgyz network was installed and designed and initially measured in 2014 by Sabrina Metzger, Alexander Zubovich and Sofia-Katharina Kufner. In subsequent surveys until 2019, the measurements were conducted by Mikhail Borisov and Joldosh Okoev.

In Afghanistan, the markers were installed and initially measured in 2015/216 by Saifurrahman Saif, Abdul Habib Panjsheri, Jalil Rahman Rahmani, Mohamad Yatim Zaryab and Mohammad Taher Rezai. Their work was supervised by local project leader Najibullah Kakar.

2.2 Instrumentation

In Kyrgyzstan, we used Topcon GB-1000 receivers and Topcon TPSPG_A1 antennas (Figure 2). In Afghanistan we used Trimble NetR9 receiver and Trimble Zephyr Geodetic 2 antenna (TR-M57971.00, Figure 3). Power supply was given by car batteries and solar panels.

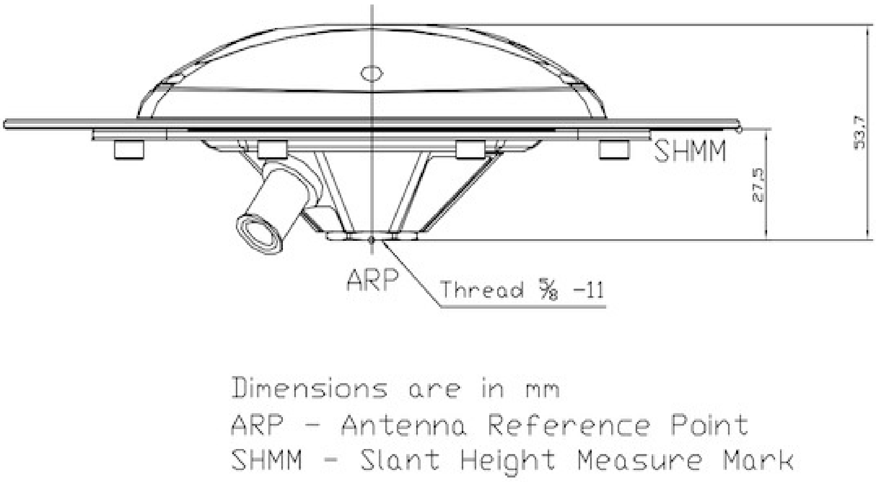

Figure 2: Technical drawing of Topcon TPSPG_A1 antenna.

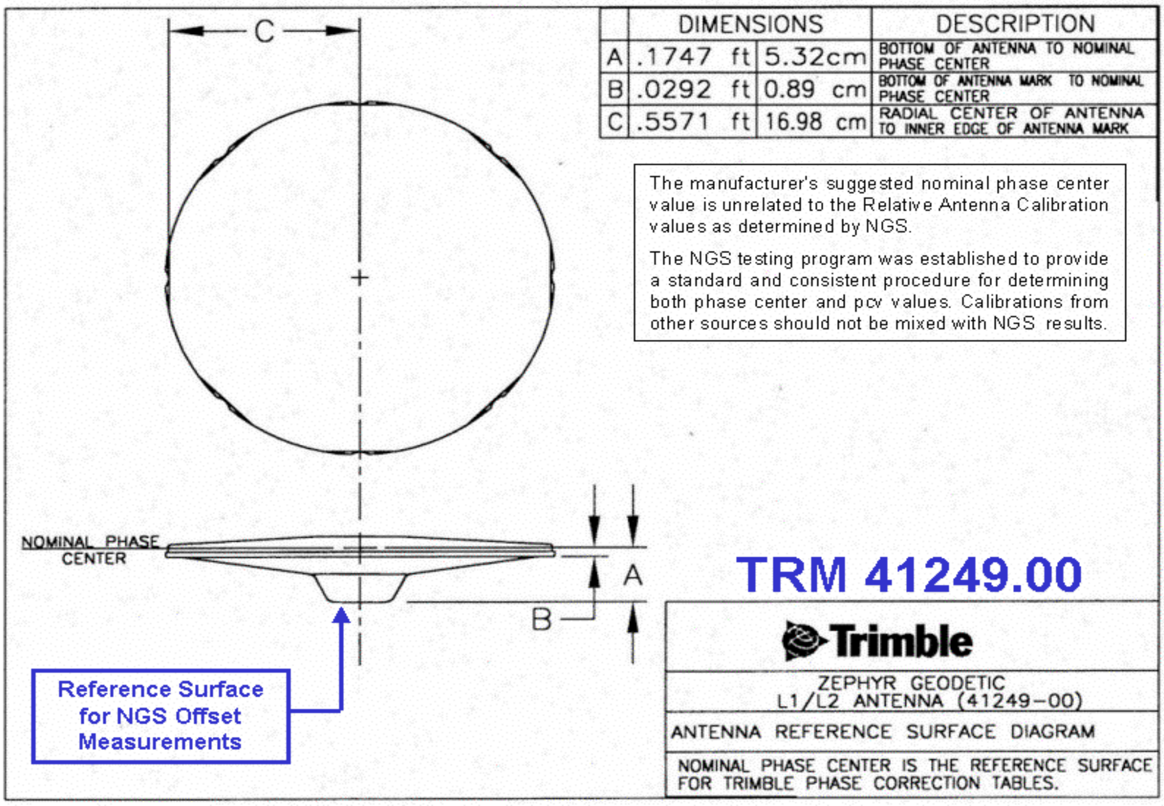

Figure 3: Technical drawing of Zephyr Geodetic Antenna.

2.3 Funding

Kyrgyz fieldwork was funded by the Helmholtz Centre, German Research Centre for Geosciences (GFZ) via program-oriented funding (POF, Topic 2 Plate-Boundary Systems). The instruments were provided by the Central Asian Institute of Applied Geosciences (CAIAG) in Bishkek. Afghan fieldwork was funded by GFZ POF 2, University of Montana and the Norwegian Afghanistan Committee. The instruments were provided by Uni Montana and are in storage at the Afghan Geological Survey.

3 GPS Measurements

3.1 Site selection and marker installation

The network was design such that we can obtain cross-fault rate information that help to assess slip-rates and eventually locking depths of the active faults, with the highest marker density in the proximity of the fault surface traces. The sites were located on stable bedrock with best-possible aperture towards the sky, which is often limited, given the significant topography. Marker WA03 was installed in alluvial sediments of the Alai valley. All markers are located in the vicinity (few hundred meters) of car roads. Afghan sites are often within the (private) compound of local agencies.

The markers consist of 10 cm-long, stain-less steel bolts with a diameter of 8 mm, drilled and glued into the ground (Figure 4). The marker of station WA04 consists of a 1.5 m-long rod that was hammered into the alluvial sediments (Figure 5).

Figure 4: Installation of a stain-less steel bolt drilled (left) and glued (right) into unscattered bedrock.

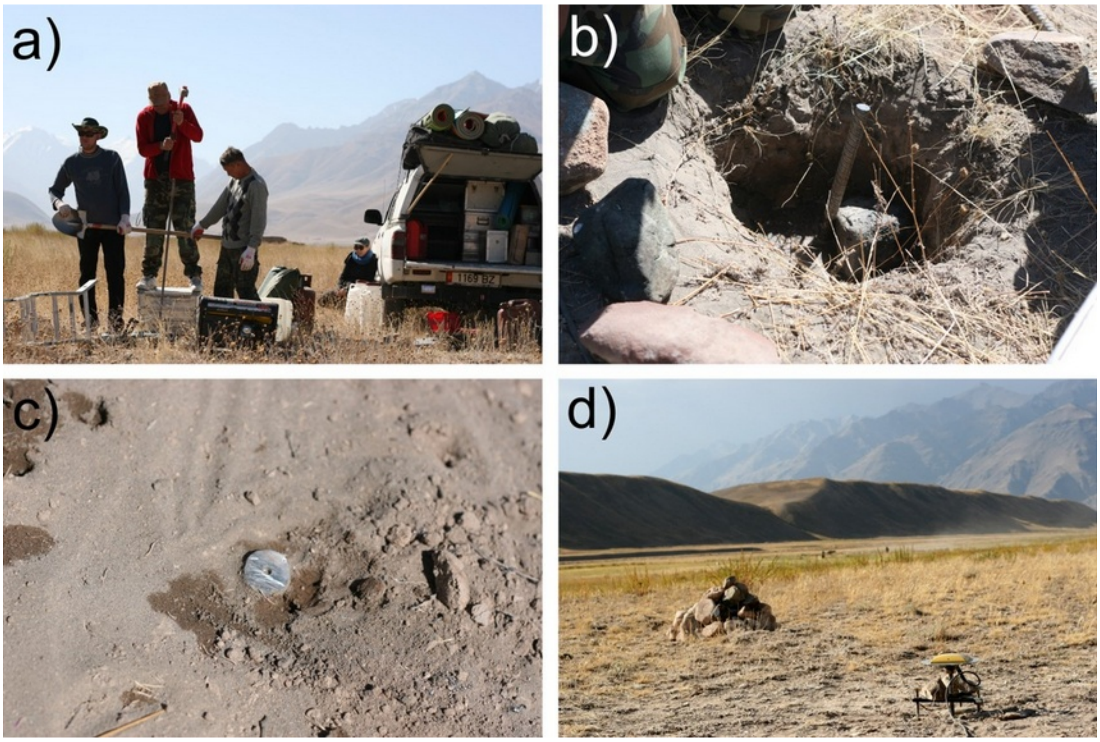

Figure 5: Installation of marker WA04 in alluvial sediments, that consists of a) a steel rod that is hammered and b) cemented into the ground. c) A small hole defines the marker for the d) GNSS instrument set up that is stabilized with smaller rocks.

3.2 Data acquisition and GPS Instrument set up

Each measurement point was acquired for two full nights, that is, nearly 48 hours. With local time being UTC+5 (or less) we tried to measure until at least 11am at the third day so that each of the three (UTC) measurement days contains a minimum of 6 hr of data, ensuring an acceptable signal-to-noise ratio for each UTC day.

In Afghanistan, we installed the antenna on a short-braced spike mount installed directly on top of the GPS marker's center with a fixed height of 12.2 cm. The TRM57971.00 antenna model is then directly screwed onto the spike mount, with the reference surface directly adjacent to the top of the spike mount (Figure 7). The legs of the spike mount were spread in a right angle and leveled with a water level. Then, the end of the legs were fixed with rocks, where the rocks mustn't overtop the antenna. Finally, the antenna was screwed and fixed onto the spike mount, oriented towards magnetic North (given a current magnetic declination of N4°E). After antenna-receiver connection was installed the receiver was placed slightly below the antenna and recorded data with a sampling rate of 30 s.

In Kyrgyzstan, we installed the Topcon TPSPG_A1 antenna on a 15 cm long spike mount, positioned in the middle of a triangular adjustment table, that itself was stabilized by three additional vertical screws at each corner of the table (Figure 6). This quasi-four-legged set up proved to be difficult to stabilize and might have caused artifacts in the data. The antenna was oriented towards magnetic North (if possible) and connected to the receiver that was located slightly below the antenna. Data were recorded with a sampling rate of 30 s.

The measurements were acquired in different seasons of the year, but where repeated in the same season, after that. The Afghan measurements occurred in October-December near the Badakhshan fault, and in April-June, except for 2020 where the measurements took place in August. The Kyrgyz measurements were collected in late July to early October. Table 1 provides an overview on the available data.

Figure 6: Typical GNSS antenna set up in Kyrgyzstan, using a three-legged adjustment table with a central spike mount, which was sometimes difficult to stabilize.

Noticeable circumstances of the individual surveys were logged (see log sheets in the supporting information). The log sheets of the first survey should contain detailed way point descriptions. Photos were taken, if possible, from each measurement.

3.3 Raw data conversion

Both the Trimble and Topcon receiver produce raw data in proprietary binary format. They were converted to ASCII-data using the Trimble software “runpkr00” and then to RNX format using "TEQC" (https://doi.org/10.1007/PL00012778), which both can be downloaded from the UNAVCO webpage. During the second step, important metadata such as antenna and receiver types and serial numbers, marker names and antenna offsets were added to the RNX header information.

The RNX files, sorted by survey year and day of year (“RNX/YYYY/DOI”), example photos of the instrumental set up and marker installation (“photos”), and logsheets (“logsheets”) are all found in the supporting information to this report.

Figure 7: Typical GNSS antenna set up in Afghanistan, using a short-braced spike mount with a fixed height.

4 Co-seismic activation of the Pamir thrust system in 2015 and 2016

The December 7 2015, M_w7.2 Sarez, Central Pamir earthquake activated an 80 km long segment of the NE-trending Sarez Karakul fault system ~150 km SE of the Kyrgyz GNSS surveys in the Altyndara valley (labeled with WA*) (Metzger et al., 2017). Maximum slip at the Sarez Karakul fault system was estimated to be ~3 meters, but co-seismic interferograms and 1 Hz-GNSS time-series recorded in the Altyndara valley show that the Pamir thrust system was co-seismically activated during the earthquake and exhibits distinct surface displacement of up to 20 mm (Zubovich et al., in prep).

On June 26 2016, the M6.4 Sary-Tash thrust earthquake activated a 20 km long segment of the Pamir thrust system with a maximum slip of ~50 cm (He et al. 2018). The rupture occurred ~100 km east of the Altyndara GNSS profile. The 1 Hz-GNSS time-series have not been significantly affected by this event (Zubovich et al., in prep).

Given the shaky instrument set up and the co-seismic affection of the Kyrgyz survey data, the observed time-series probably contain a significant amount noise, which makes it difficult to calculate interseismic rates.

Table 1: Station names, locations and years of surveys taking place

Afghanistan, Badakhshan fault										
STATION	LONGITUDE	LATITUDE	2014	2015	2016	2017	2018	2019	2020
ARG1	70.439208	37.058275		x	x	x	x		
ARG2	70.199078	37.151188		x	x	x	x		
BAH1	70.894903	36.990911		x	x	x	x		
ESHK	71.594512	36.719152			x	x			
FYZ2	70.594658	37.083590		x	x	x	x		
KASH	74.427318	38.061913		x	x	x	x		
SHUG	71.496773	37.561566			x	x			
WAKH	72.321318	36.949873			x	x			
Afghanistan, Panjsheer fault									
STATION	LONGITUDE	LATITUDE	2014	2015	2016	2017	2018	2019	2020
BAG1	69.262273	35.643829			x	x	x		
BAG2	68.682070	35.973421				x			
PAN2	69.650207	35.299799			x	x	x		x
PAN3	69.780093	35.251270			x	x	x		x
PANJ	69.631625	35.401825			x	x	x		x
Kyrgyzstan, Alai valley									
STATION	LONGITUDE	LATITUDE	2014	2015	2016	2017	2018	2019	2020
ALA5/ALD4	72.257804	39.421344			x	x	x	x	
BRDB	72.667882	39.494717			x	x	x	x	
KOKD	73.243259	39.639799			x	x	x	x	
WA01	72.228055	39.652215	x	x	x	x	x	x	
WA02	72.208982	39.504687		x	x	x	x	x	
WA03	72.215886	39.484092	x	x	x	x	x	x	
WA04	72.260527	39.272717	x	x	x	x	x	x	
WA05	72.254498	39.236142	x	x	x	x	x	x	
WA06	72.242993	39.438032	x	x	x	x	x	x	

5 *Citations*

Papers that are based on data presented here are marked with an asterisk (*)

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