A new permanent multi-parameter monitoring network in Central Asian high
mountains – From Measurements to Data Bases

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Reply & Comments for: Anonymous Referee #1
The Reviewer's comments are in bold & italic.

***The manuscript describes the development of a remote multi-parameter monitoring
station including power considerations and communication through satellite to a
processing facility. The focus is on hydrometeorological parameter retrieval,
although the system is not limited to those and easily incorporated GNSS and
seismic measurements. While the manuscript provides an excellent overview of the
project, its instrumentation and software components, it may be difficult to
repeat or establish similar Stations/Software without further details. This may
be a fact of limited space in a single manuscript, but let us trust in the
willingness of the authors to support requests by readers. A more detailed
project report of documentation should be referenced if available.***

Site Information documents, format specifications, and to some extend, technical
specifications, will be available via the CAWA web site. However, the concept is
open and initiative to use our design will be supported.

***The manuscript is well structured and the use of tables and figures is
supportive of the objective. While the use of references is acceptable, there
could be more weight on similar systems from other disciplines using sensor
networks. There are some indications that this is a unique and first time
system, but there must be independent predecessors which should be included.***

There are installations of hydrometeorological stations by different agencies
and nations. Nevertheless, to our knowledge, not large network exits in this
region delivering such a multitude of different hydrometeorological, geophysical
and geodetically information. The final version we will add a small review of
other installations in this area.

***The manuscript is fundamentally important as it provides information about a
wide range of potential obstacles in establishing multi-parameter stations,
communication and control systems which can easily be ported to other
disciplines.***

***Specific comments: page 303, line 22: why are more stations needed, any spatial
coverage required to solve fundamental science questions? What area are the
basins? Why at higher altitude?***

The Central Asian headwater catchments cover a total area of roughly 500,000 km²
if we are considering the Aral Sea basin in a broader sense. They are located in
a high mountain region characterized by a steep topography reaching elevations
above 7000 m a.s.l. and several orographic systems with varying climate
characteristics (Northern / Western Tien Shan, Inner/Central Tien Shan, Hissar–
Alai, Pamir). Hence, the spatial variability in the main water balance
components and the related hydrological processes is substantial. More
monitoring stations are needed to capture this variability adequately and thus
provide more reliable information on the spatial patterns within the flow
formation zone.

This information is needed to improve the reliability of operational tasks in water management such as 1) the seasonal flow forecast which is of great importance for the water and land use planning especially for the vegetation season in all riparian states, 2) water allocation.

Beside the mentioned operational tasks a fundamental scientific question remains the impact of global climate change on the water resources in Central Asia. In the past two decades, this question has been addressed previously in a number of studies using data from selected climate stations (for an overview see Sorg et al., 2012; Unger-Shayesteh et al. – in preparation) - but the small number of stations and their location below 3000 m a.s.l. (with only 3 exceptions) does not provide reliable information on the spatial patterns of the ongoing changes. In particular, researchers face a substantial lack of observations in the higher elevations (above 3500 m a.s.l.) where important water balance components such as glaciers and seasonal snow pack are occurring.

Additional arguments are included in the revised version of this manuscript.

page 303, line 28: Why do they need real-time access? Flooding forecast, weather models? Comment on this.

For the hydrometeorological variables an "every three hour" data transmission scheme would meet the current WMO requirements for synoptic weather stations. However, the establishment of the VSAT communication line can take up to 20', which limits the in-time delivery of the data if the communication is switched off between transmissions. Moreover, VSAT provides a small (e.g., 14kbps) bandwidth, but on a continuous basis. Block transmissions have side effects, e.g. drops in available bandwidth, to continuous stations using the same VSAT line card. For potential future applications, e.g. in Early-Warning systems for floods or GLOFs, the stations should be capable of near real-time data transmission.

In addition, real-time access is supporting the data delivery from seismological sensors and GNSS receivers and their integration into the real-time services of global monitoring networks (the seismological Geofon network and the IGS network, respectively).

page 305, line 26: bad weather comes in different forms, what is it exactly which causes low power levels? More specifics.

Figure 9a shows the annual cycle of sunshine (right hand side axis) for the full year. During winter times significant shorter daytimes exist, especially in mountains, where the sun hardly goes above the mountain peaks. The number of days with totally cloud cover is higher; and for low air temperatures the capacity of the batteries is lower (less storage capacity).

page 306, section 2.2: Can you describe the motivation for the sampling intervals of 5/15 minutes? Give science and technical requirements.

The sampling interval of 5' for the hydrometeorological components is in support of the derivation of precipitable water vapor (PWV) (zenith path delay) using the GNSS component of the ROMPS. For each PWV of the tropospheric product (which has a 5' sampling) of the International GNSS Service (www.igs.org) air temperature/relative humidity/air pressure are needed. Higher sampling rates are not supported since there is dead-times (sensor heat-up, data integration, etc.) for all sensors connected to the Campbell CR1000 data logger.

For the runoff sampling two reasons exist. The sampling interval of 15' is for future applications in hazard monitoring applications (e.g., GLOF monitoring). The second reason is technically defined. The RQ24 sensors are connected by a

local RF link. Data transmission is in a transparent mode using an RF modem, which is not fault-tolerant. Higher sampling reduces the number of failed transmissions.

This information will be added to the final version of the paper.

page 307, line 29: What is the sampling rate for the pictures, what lenses and field of view is used? Could hyperspectral cameras be integrated? Later is says 2 frames per day.

Initially, sampling was 1/hour during daytime. Since this had created a significant volume of data, the sampling was reduced to twice a day with one hour separation. This separation allows the identification of shadows at the glacier surface originated from clouds supporting the identification of the equilibrium snow line.

The camera used is a Mobotix M24M camera. The information will be integrated into the final version.

The ROMPS stations can integrate any sensor type, if (a) the device can be operated via a local LAN or RS232 (or SDI12), is (b) IP66 or higher protected, (3) has a moderate power consumption.

page 309, line 3: Is Angermann 2010 the original reference for VSAT? If not, please give the original one.

Angermann et al. 2010 give an excellent overview about the communication in field installations with special attention to VSAT. In contrast to IRIDIUM or BGAN, where a single system provider exist, VSAT is offered by many providers, some of them offering hardware and bandwidth, some only the one or the other. We have refrained from naming one specific provider and refer instead to Angermann et al., 2010.

page 312, line 4: What are current limits in number of parameters, sampling rate, etc, or overall data amount per day?

The ROMPS can suite roughly hydrometeorological 30 devices, some of the with more complex sensor structures (e.g. the SPA delivers 10 values, the RQ24 three quantities). In addition the station serves up to 8 serial lines, and equipment attached to the Ethernet port. The limit in sampling rate is roughly 2' for the hymet sensor (data logger cycling time). The data amount from the station is ~16MByte/day, mainly by the 1Hz GPS data. Cameras or seismological stations are adding significant numbers to this amount.

page 316, line 6: What are the costs involved for sensors, installation and VSAT bandwidth? Estimates would help the reader to assess implementation in other areas. If you cannot give those numbers, you cannot comment about high initial costs.

In principle, we agree with the reviewer, that numbers should be able to illustrate our argument. Yet, we suspect that the cost estimations be may give from our experience may not be representative and hence not of use for other researchers around the world. The stations were developed and assembled at GFZ which involves staff time which principally would have to be considered in the cost estimation as well. Prices of individual station components have been negotiated between GFZ and the suppliers and may have changed by now. The installation costs vary greatly depending on the location of the station (e.g. required helicopter costs) and the existing infrastructure available at the monitoring site.

Hence, we think the use of more detailed cost estimations is very limited and might even confound the reader. We suggest the following revision of this paragraph:

"… is the high initial investment for the additional station components, in particular for station control, power management, redundant communication devices."

In general, I recommend that the sensors, sampling rates and locations are scientifically motivated a little better. In addition, a comparison, or at least referencing of similar systems should be attempted (besides the tsunami example). There are a few grammatical errors which are acceptable and do not hinder the reader.

We hope that this concern is addressed by the comments above. The information will be added to the final version of the paper.

Additional References:
Annina Sorg, Tobias Bolch, Markus Stoffel, Olga Solomina & Martin Beniston (2012): Climate change impacts on glaciers and runoff in Tien Shan (Central Asia). Nature Climate Change, Vol 2 Issue 8,

Unger-Shayesteh et al. (in preparation): What do we know about past changes in the water cycle of Central Asian headwaters? A review. Global and Planetary Change, Special Issue "Water in Central Asia", 2013