From Mountains to Data: Low-Cost Weather Stations in Kyrgyzstan's Challenging Terrain

IoT WG: Wednesday, 30 October 11:00 – 12:30

RIPE 89 Meeting, Prague, Czechia

Aziz Soltobaev, Internet Society Kyrgyz Chapter

Kyrgyzstan

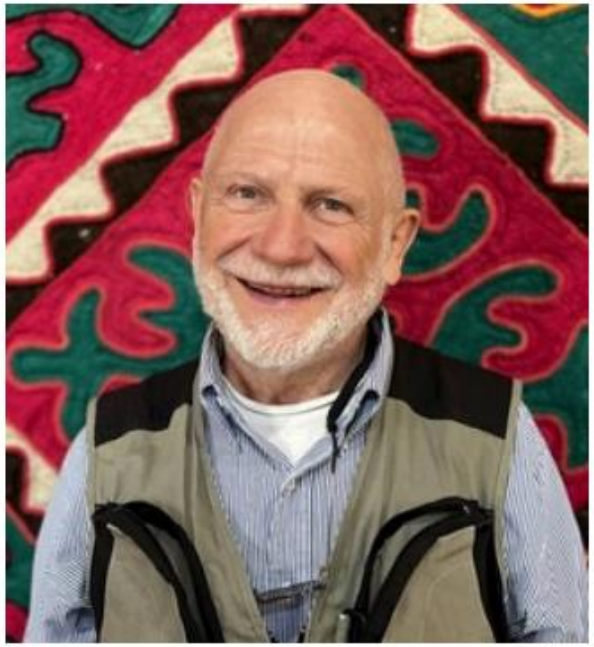
About the Project

Creating an open and secure IoT infrastructure for monitoring and preventing emergencies in landlocked mountainous countries: the case of Kyrgyzstan

- Internet Society Kyrgyzstan Chapter
- Abdus Salam International Center for Theoretical Physics
- Central Asian Institute for Applied Geosciences
- The Ministry of Emergency Situations
- Academy of Sciences of the Kyrgyz Republic

The research project is funded by the ISOC Foundation Research Grants Project:
https://www.isocfoundation.org/grant-programme/research-grant-programme

Meet the Team



Ermanno Pietrosemoli - Researcher

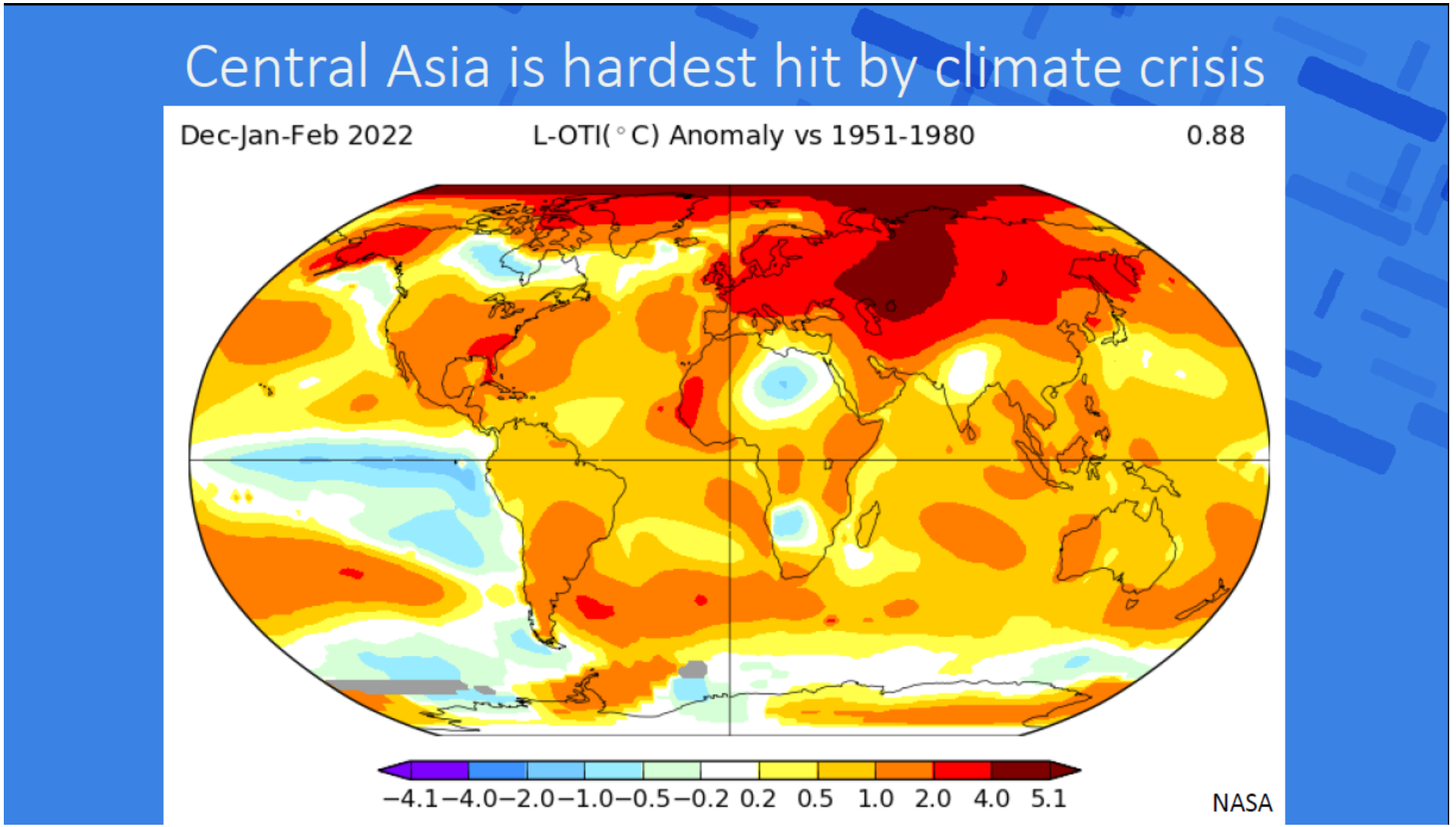
Marco Zennaro - Researcher

Aziz Soltobaev - Project Manager and Researcher

Talant Sultanov - Chair of the ISOC Kyrgyz Chapter - Researcher

The Team

Why Central Asia?



The Third Pole: the largest reserve of freshwater outside the polar regions

This region is the source of the 10 major river systems that provide irrigation, power and drinking water to almost 2 billion people in Asia – a quarter of the world's population

Why Kyrgyzstan

Geography

- 93% area - mountains
- Sharply continental climate
- Avg altitude 2750 m a.s.l
- Over 2000 mountain lakes

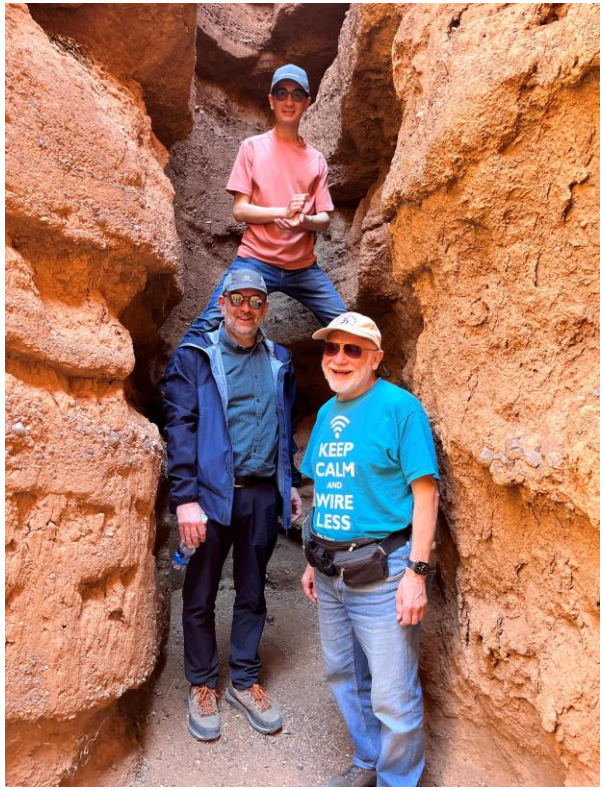
Impact of climate change:

- The number of natural disasters had increased,
- Six times more floods in 2024 compared to 2023
- The highest temperature peak registered in 2024

Cellular network coverage in Kyrgyzstan (areas in pink color) showing that rural areas with low population density and remote areas are not served

Cellular coverage in Kyrgyzstan

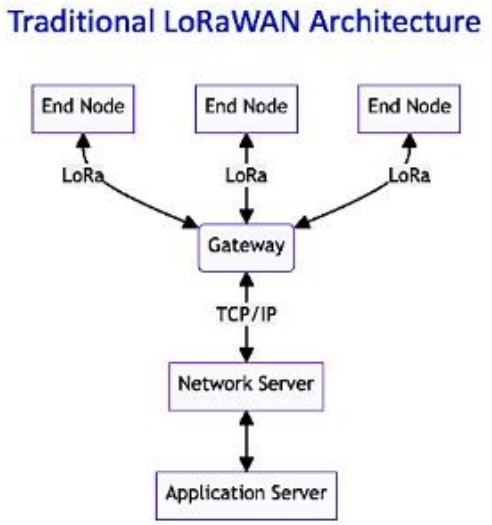
Terrain and topography of Kyrgyzstan

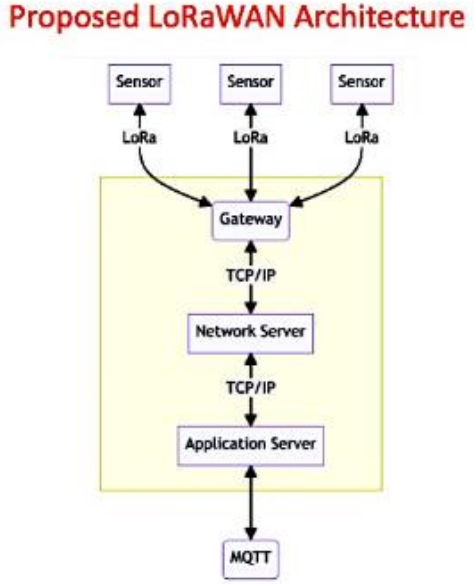


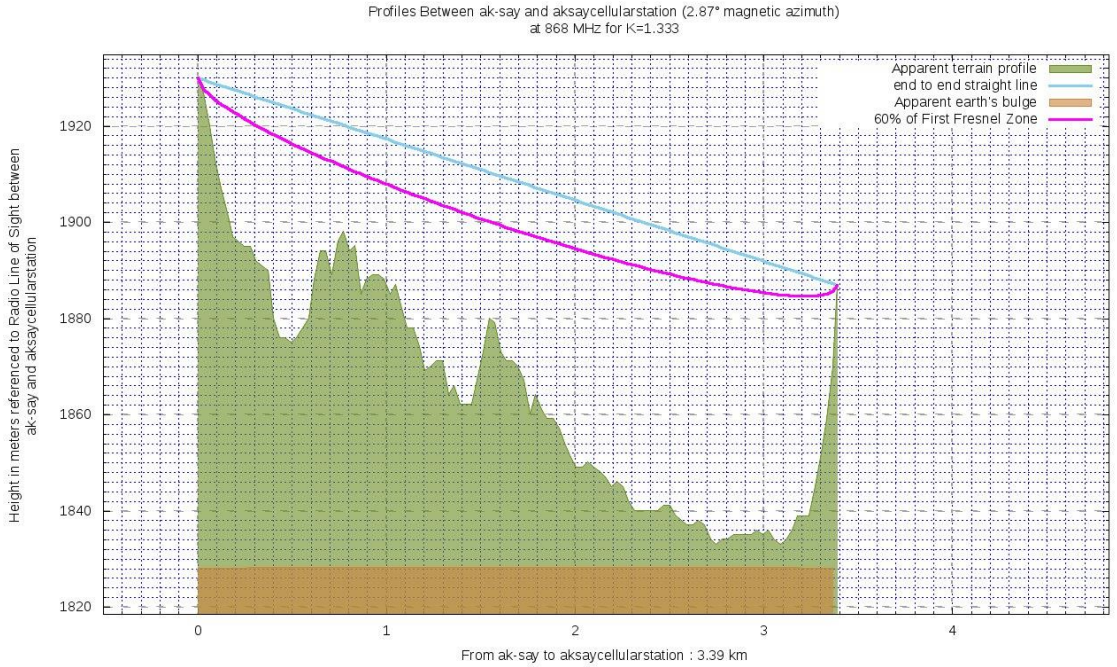
Tools: Internet of Things: sensors, end-devices

- 2nd tier weather stations
  - Barani Design Meteohelix,
  - Barani Design MeteoRain,
  - Barani Design MeteoWind
- Soil (soil moisture and temperature, triaxial accelerometer sensors)
  - Seeed Studio
  - Milesight
- Water (ultrasound distance sensors)
  - Meratch
  - Milesight

Tools: Communication technology

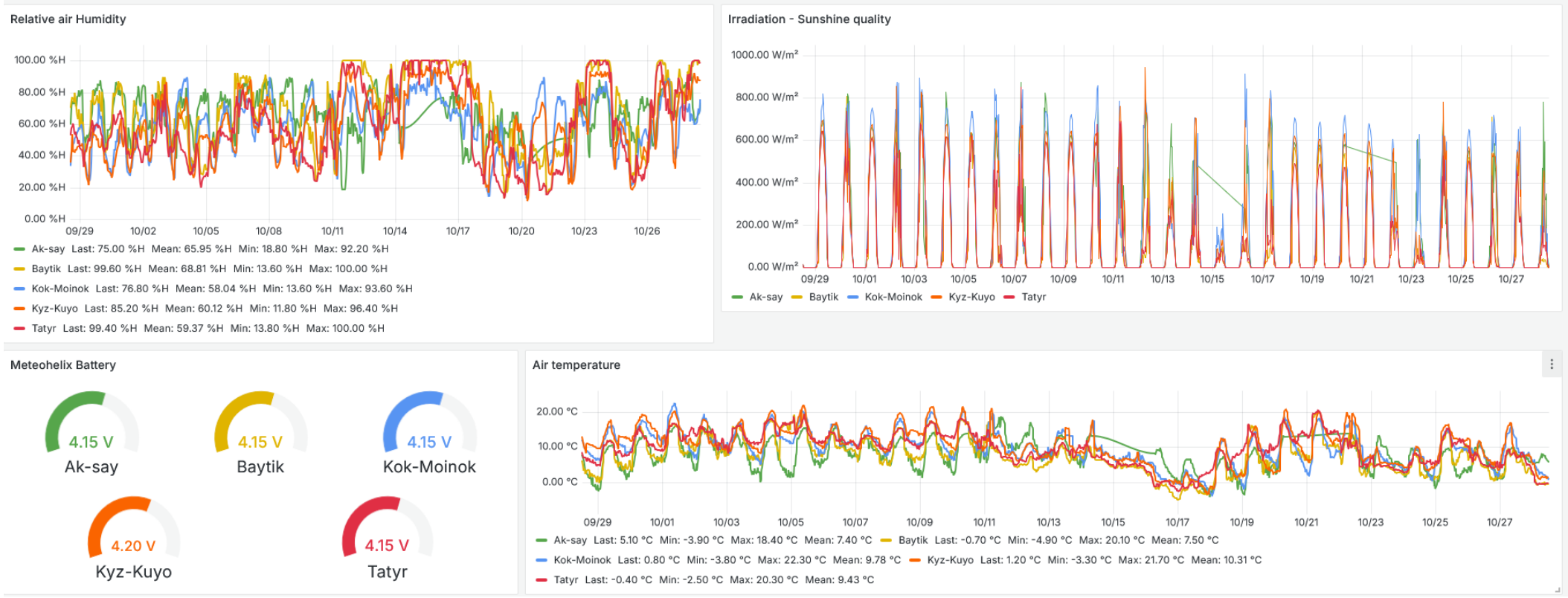






Technology: LoRaWAN data transmission | Disruption tolerant Milesight UG67 Gateways | BotRF for terrain profile.

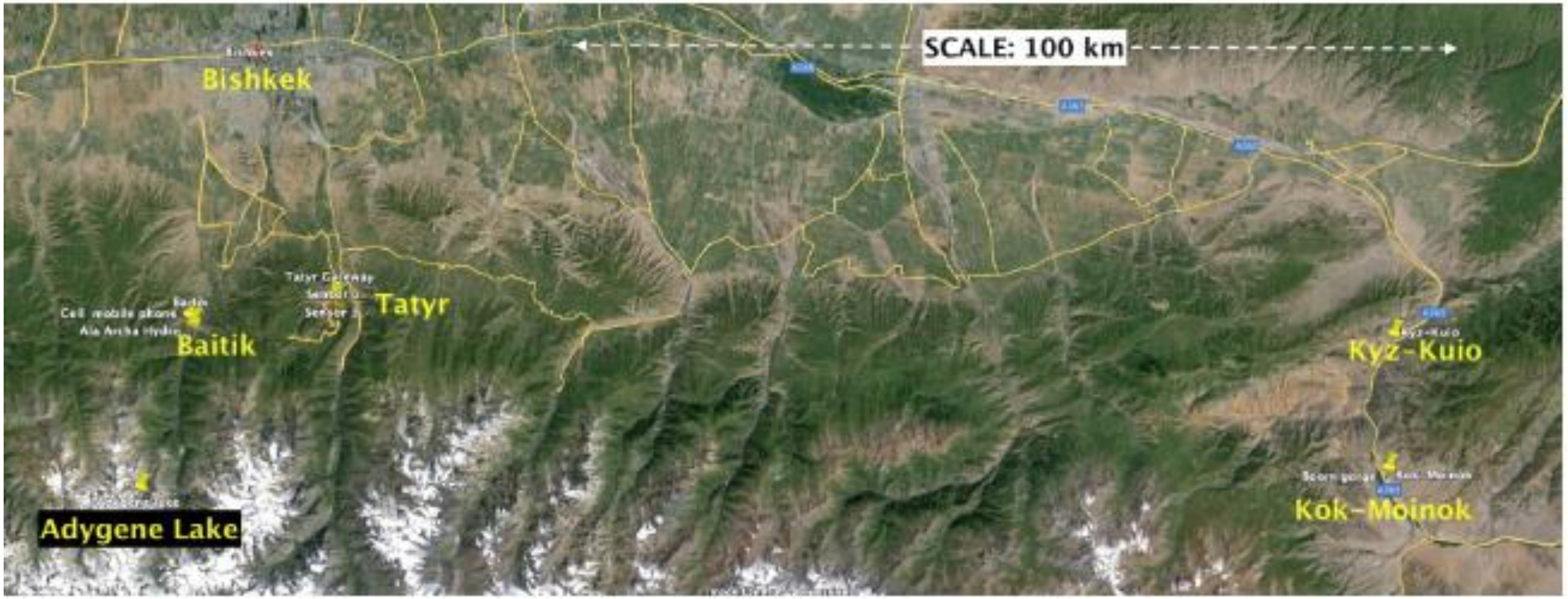
Tools: Software



Open-source software: OpenVPN | MQTT Protocol | Telegraf | InfluxDB | Grafana

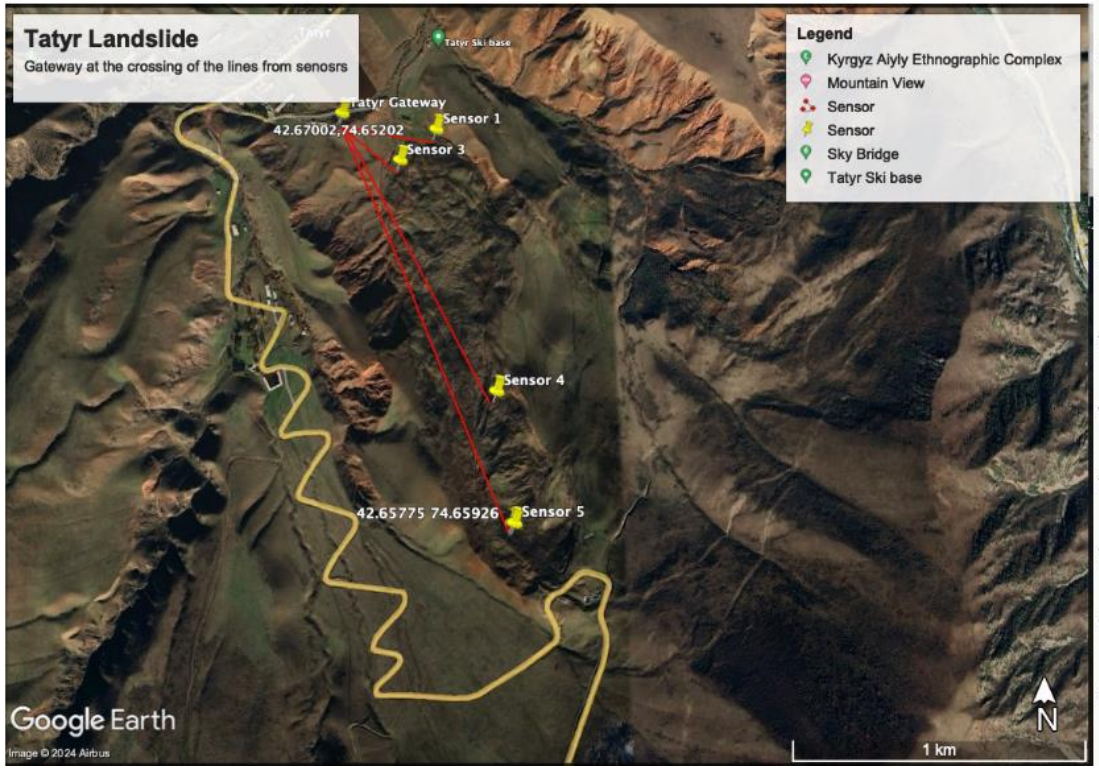
Pilot locations

- Reference weather station: Baitik (Baytik)
- Tatyr landslide
- Mudflows: Kyz-kuio, Boom Gorge | Kok-moinok, Boom Gorge
- Glacier lake outburst floods (GLOFs): Ak-say, Issyk-kul lake (1950m), Adygene glacier lake (3500m)



Implementation: IoT installation

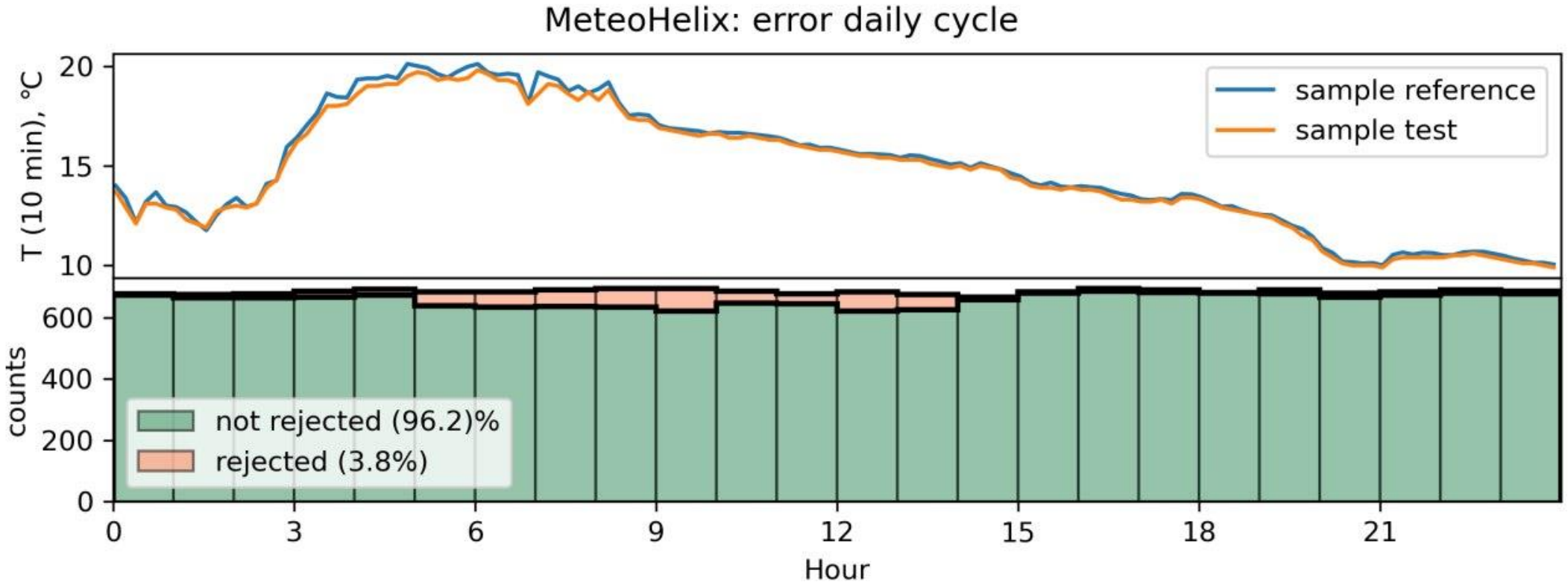
Implementation: Tatyr landslide



Tatyr landslide - tilt sensors

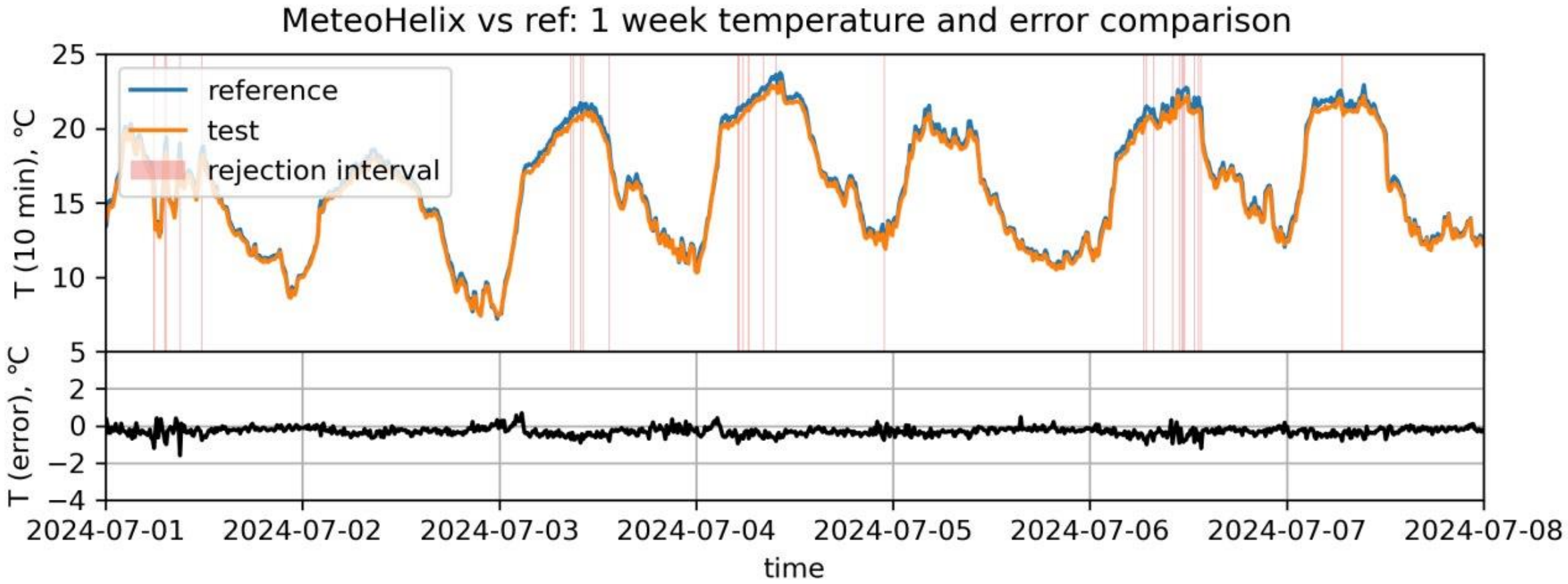
Tatyr tilt1 angle x	-9.48 °	-9.58 °	-9.70 °	-9.35 °	-9.72 °	-9.71 °	-9.85 °	-9.89 °
Tatyr tilt2 angle y	2.70 °	3.01 °	2.32 °	3.01 °	4.11 °	4.21 °	3.63 °	3.96 °
Tatyr tilt2 angle x	3.14 °	2.52 °	3.39 °	2.86 °	1.45 °	1.54 °	2.37 °	0.790 °
Tatyr tilt2 angle y	-2.64 °	-2.08 °	-2.63 °	-2.52 °	-2.39 °	-2.62 °	-2.37 °	4.49 °
Tatyr tilt3 angle x	0.0800 °	1.03 °	-0.550 °	-0.290 °	1.17 °	1.24 °	1.14 °	1.52 °
Tatyr tilt3 angle y	-2.60 °	-2.04 °	-3.20 °	-3.02 °	-1.65 °	-1.26 °	-0.990 °	-1.30 °
Tatyr tilt4 angle x	-2.22 °	-2.21 °	-1.46 °	-1.38 °	-1.55 °	-2.02 °	-1.65 °	-1.33 °
Tatyr tilt4 angle y	-3.12 °	-2.26 °	-1.58 °	-1.14 °	-2.09 °	-1.37 °	-3.55 °	-3.57 °
Tatyr tilt5 angle x	-5.55 °	-5.81 °	-5.17 °	-4.89 °	-5.87 °	-5.95 °	-6.32 °	-6.60 °
Tatyr tilt5 angle y	3.38 °	4.30 °	1.74 °	1.07 °	4.23 °	4.96 °	5.91 °	7.02 °
	04/30 06:00	05/01 06:00	05/02 06:00	05/03 06:00	05/04 06:00	05/05 06:00	05/06 06:00	05/06 19:17

Insights: weather stations

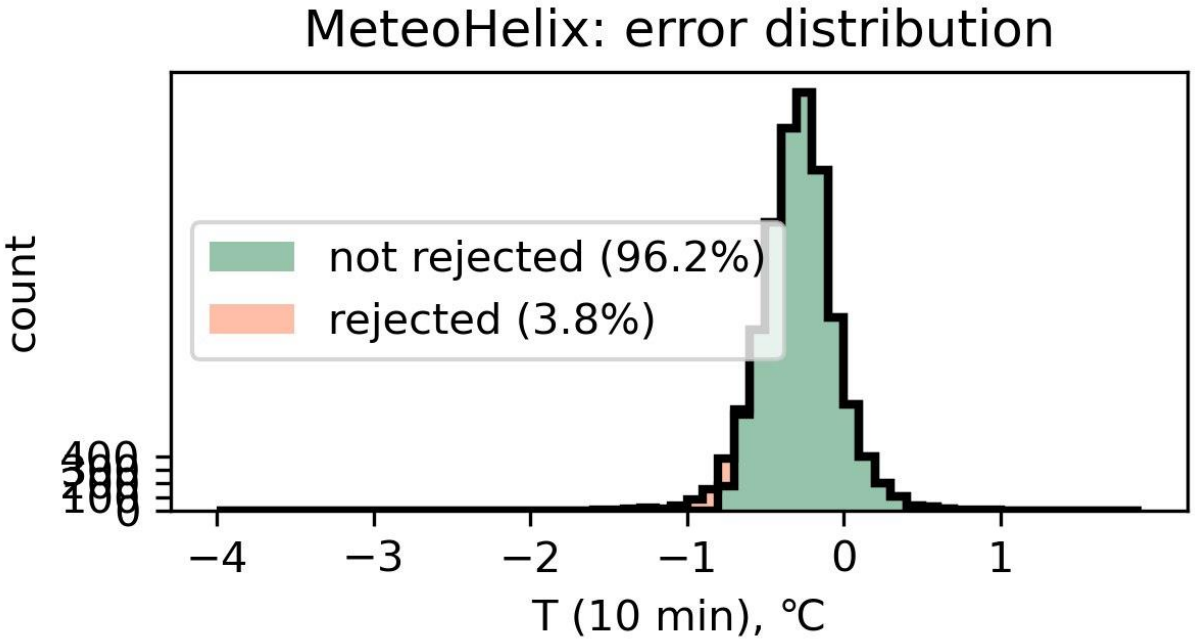


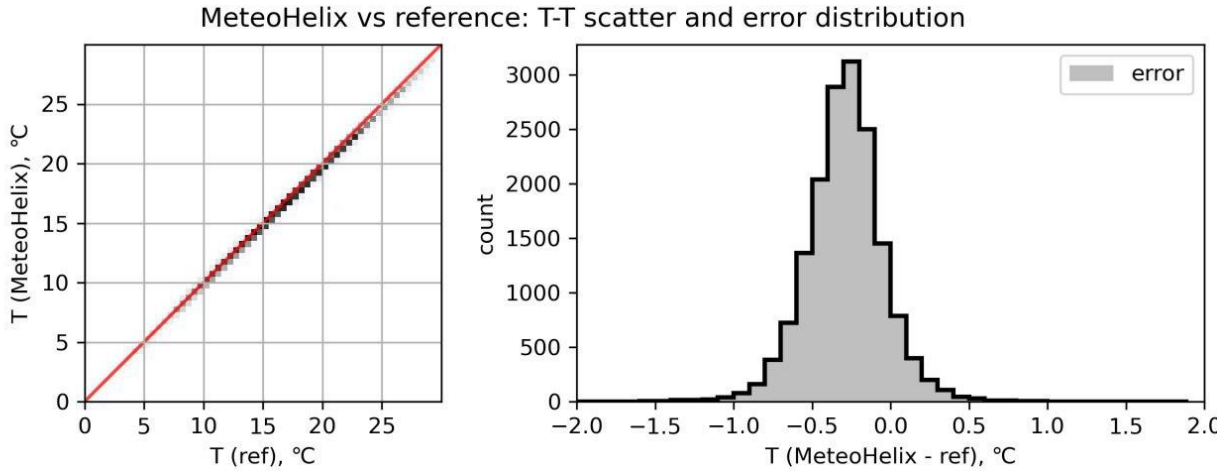
The histogram presents the error distribution of temperature measurements for the MeteoHelix sensor, indicating how many values fall within specific error ranges. The majority of the data points (96.2%) are in the “not rejected” category, centered close to zero degrees Celsius difference, suggesting minimal measurement error and reliable performance. This distribution demonstrates that the sensor predominantly provides accurate readings, with a small fraction of outliers.

Insights: 2nd tier vs 1st tier weather stations



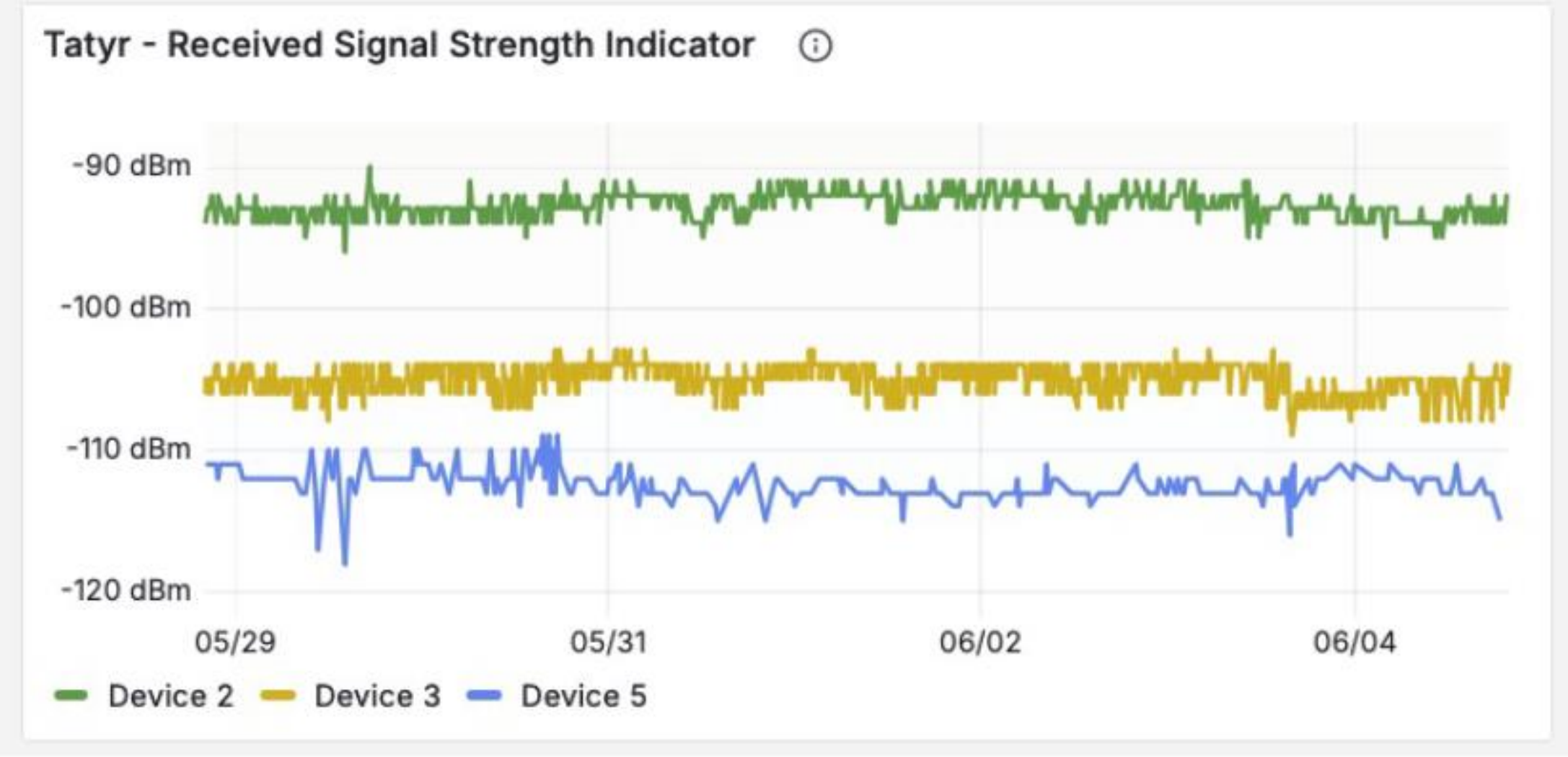
Insights: weather station outputs: error distribution





A smaller proportion (3.8%) of the data points fall into the “rejected” category, which likely represents measurements with significant deviations that exceed acceptable error thresholds. This distribution demonstrates that the sensor predominantly provides accurate readings, with a small fraction of outliers.

Insights: received signal strength indicator



Insights

- LoRaWAN technology provides good opportunity to monitor locations with no/low cellular connectivity
- Gateways with built-in LoRaWAN servers, local data buffer and automatic retransmission after backhaul failures, implement delay tolerant networks, well suited to operate well in extreme weather conditions
- Adoption of 2nd tier weather stations provides an opportunity for monitoring wider audiences with lower budgets
- Mountainous areas are challenging for communication, both wired and wireless, but they also offer opportunities for long distance wireless, by using high altitude sites and leveraging diffraction in sharp edges.
- Soil moisture and temperature sensors using resistant measuring method are not well suited for rocky mountainous areas
- Glaciated, rocky, loamy soils (landslides, mudflows) would require special type of sensors
- Ultrasound sensors for river water level measurements are not suited for mountainous highly

  turbulent rivers in steep gradient terrains
- Massive amount of generated data require machine learning algorithms to analyze and monitor natural disasters

Thank You!

Contact information

- Project: Creating an open and secure IoT infrastructure for monitoring and preventing emergencies in landlocked mountainous countries: the case of Kyrgyzstan
- Presentation: From Mountains to Data: Low-Cost Weather Stations in Kyrgyzstan's Challenging Terrain, RIPE 89 Meeting, Prague, Czechia, October 30, 2024
- Pre-print: https://www.preprints.org/manuscript/202406.1898/v1
- Implementing organizations:
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