Development of a dedicated nation-wide geodetic monitoring network
The Tsunami Early Warning System of the Sultanate of Oman

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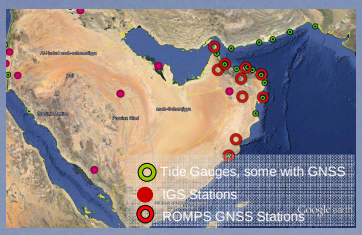


Monitoring changes in the Earth System requires dedicated networks with highly specialized hardware. Based on installations for early tsunami warning systems, GFZ has developed remotely operated multi-parameter stations (ROMPS). They allow a wide range of applications and are operated in various environments. In the past years, such stations have been installed in Indonesia, Iran, Tanzania, South Africa, Pakistan, Yemen and Comoros. Most stations serve as combined GNSS and tide gauge stations for the Indian Ocean Tsunami Warning System. Recently, a large network of combined GNSS and hydrometeorological ROMPS has been installed in Central Asian countries and Afghanistan. The stations operate in different altitudes (sea level to up to more than 4000m) and various climate conditions (-45°C to +45°C).

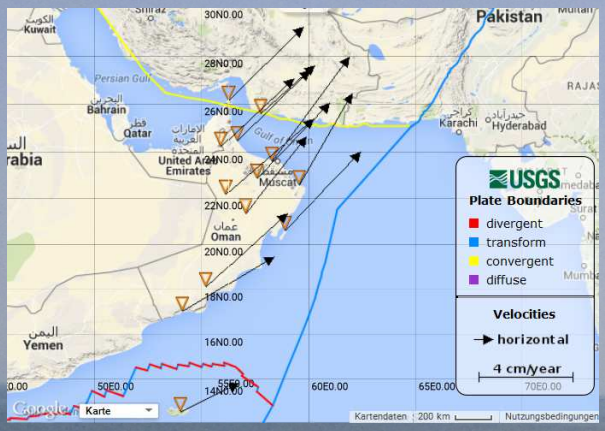
Based on the ROMPS concept a network of real time GNSS stations for the national Tsunami and Hazard Monitoring System of Oman has been installed along the northern and eastern coastline of the Sultanate of Oman. The GNSS data is transmitted to and processed in near real-time at the warning center in Muscat. A newly developed processing and live displaying system enables the warning center to access and evaluate station displacements immediately.

National Hazard Monitoring with GNSS in Oman

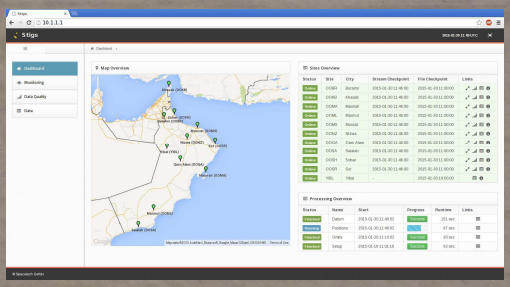
The Sultanate of Oman's coastline is endangered to tsunami waves generated along the Makran subduction zone (along the Iran/Pakistan coastline) and to lesser extend to trans-oceanic tsunamis generated off Indonesia. For the latter, existing tide gauge stations in Indonesia and e.g., at the Maldives provide sufficient monitoring. In case of tsunamigenic earthquakes at Makran fault, a dedicated monitoring network in Oman is built.

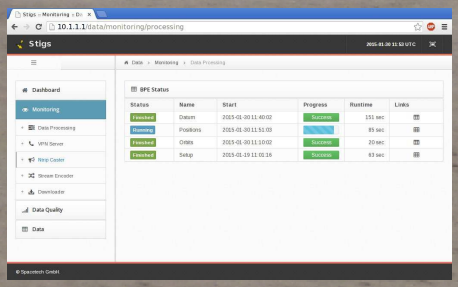
The National Hazard Monitoring Program of Oman requires, among tide gauge and seismological stations, a network of real-time capable GNSS stations. Based on the heritage of GFZ's ROMPS stations, a SpaceTech GmbH lead consortia has installed GNSS-ROMPS, complemented by a Processing Facility at a Tsunami warning Center in Muscat. The network configuration was designed to monitor the tectonic related northwards movement of the Arab peninsula and for detecting surface stress accumulation. Ten stations have been installed in several lines parallel to the Makran Trench. The GNSS network provides information about the current rates of surface motion and evolution of motion rates (possible locking). In case of strong earthquakes, the near real-time GNSS provides 1Hz displacements in support of the Tsunami Decision Support System.

All stations are equipped with a Septentrio PolaRx4 GNSS receiver. GNSS data is collected, locally stored and, additionally streamed to Muscat. The Warning Center provides tools to estimate daily station coordinates and 1Hz data outputs with a short latency. Thus, also displacement vectors can be estimated in case of strong earthquakes.



Velocities Map. Variations in velocity may help to evaluate the future risk of tsunamigenic earthquakes. Some stations are NCC (Iran)/GFZ, NSOC (Yemen)/GFZ, and PDO. Their contribution is acknowledged.





The live processing results (North, East, Up) as well as technical details (performance, quality, status) are displayed instantly by **STIGS**. A map provides a comprehensive status view. Color coding indicates status information and/or performance problems.

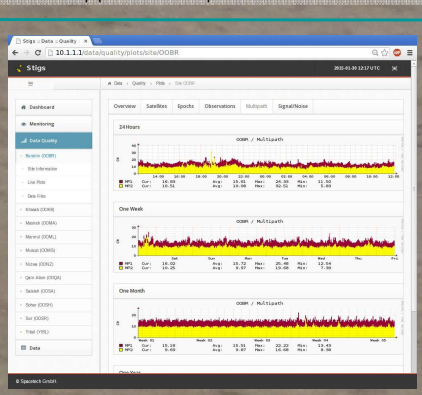
GNSS Processing and Display

At the warning center, the "**S**oftware frontend for **T**errestrial hazard **I**dentification by **G**NSS **S**tations **(STIGS)**" provides the functionality for the data processing and live displaying of results.

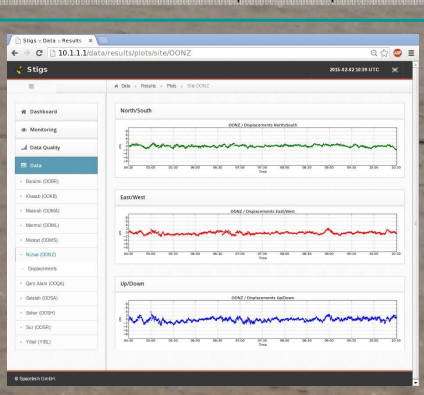
STIGS uses the Bernese GNSS Software which is developed by AIUB and available for educational and commercial customers.

The processing is performed every two minutes with a frequent update of the background models (predicted orbits and clocks, reference stations of the IGS network, datum definition).

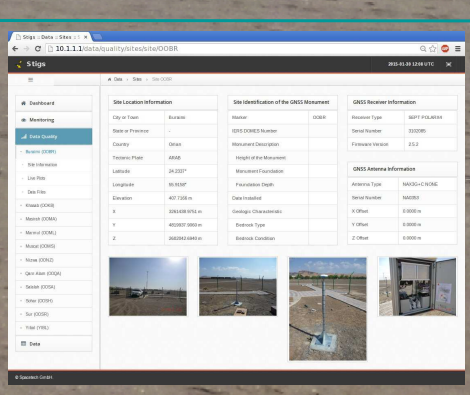
The modularity of the hard- and software concepts allows an easy adaptation to new implementations in other areas and a seamless integration of further GNSS stations.



Quality Assessment using multi-path information



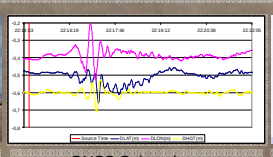
Station Displacements for North/East/Up



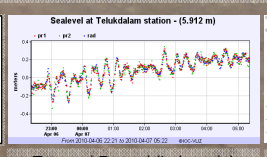
Station Metadata Information

ROMPS stations are installed around the world. They are used for **tide gauges**, **hydrometeorological stations**, operate **cameras** for hazard monitoring, and integrate **seismic** stations (seiscomp software) and **arbitrary sensor combinations**. Numerous options for communication (satellite, terrestrial), power (solar, wind, mains) and sensors make them easily adaptable to new applications.

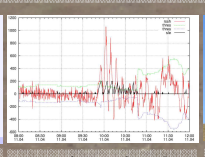
ROMPS Tide Gauges in Indonesia



GNSS Seismology



Tsunami Record (Indonesia)



Tsunami Detection GFZ

ROMPS (Hydrometeorology) in Central Asia