Journal of
Applied Hydrography

HYDROGRAPHISCHE NACHRICHTEN 06/2026 HN 134

Hydrographie im Kontext der Nachhaltigkeit

Beiträge vom
38. Hydrographentag
und DVW-Seminar

DEUTSCHE HYDROGRAPHISCHE GESELLSCHAFT e.V.
DHyG

DOI: 10.23784/HN134-06

Cost-effective seafloor geodesy with GNSS-acoustic measurements from a wave glider

An article by JAMES FOSTER

subduction zones | seafloor observations | wave glider | sound speed
Subduktionszonen | Meeresbodenbeobachtung | Wellengleiter | Schallgeschwindigkeit

Author
Prof. Dr. James Foster is Chair of Geodetic Space Techniques at the University of Stuttgart.

james.foster@gis.uni-stuttgart.de

Over 70 % of Earth's surface and 90 % of plate boundaries are under water and inaccessible using standard geodetic observing techniques. In particular, subduction zones generate earthquakes and tsunamis that represent some of the most destructive natural hazards. Critical science questions for subduction zones include: How are stresses transferred within the structures? What are the roles played by secular slip, earthquakes and slow slip events? Understanding these structures and the hazard that each represents requires accurate observations of the ground motions above the portions of these systems where these active processes are taking place. Land-only observation systems suffer from fundamental geometric limitations for observing processes occurring under the ocean. Without seafloor observations, there will always be significant uncertainty in our ability to model and interpret the processes operating at these and similar structures. To address these science questions, we must acquire cost-effective geodetic observations of the horizontal and vertical motions of the seafloor. At the University of Stuttgart, we have constructed an autonomous seafloor geodetic system that has equipped a Liquid Robotics SV3 wave glider with a GNSS-acoustic ranging system from Sonardyne. The wave glider is an extremely cost-effective platform from which to perform seafloor geodetic measurements: it uses wave motions for propulsion and solar panels and batteries to provide power for its control systems and its science payload. It is able to operate at sea for months at a time for a fraction of the cost of a traditional research vessel. The GNSS-acoustic seafloor geodetic technique employs standard kinematic positioning using a GNSS+IMU system for a sea-surface vehicle, and pairs it with precisely timed acoustic ranging capability. The acoustic portion of the system ranges to a set of transponders deployed to the seafloor and determines the »centroid« position of those transponders to cm-level accuracy.

For our system we have chosen a GNSS-acoustic module that is able to interrogate transponders down to 6,000 m water depth, rather than the more commonly used module that is only able to reach to 3,000 m. This allows us to access the deepest portions of the subduction zones where the megathrust fault approaches the seafloor, and is the portion of the system from which dangerous tsunamis are most likely to be generated. We are working closely with the seafloor geodesy group at Geomar, and they have built a similar system equipped with the 3,000-m acoustic module. Between us we will be able to acquire accurate positions of seafloor stations over the entire range of depths at subduction zones.

The primary source of error for GNSS-acoustic are changes in the ocean sound speed field. Our observing strategy, using the slow-moving wave glider to perform ranging from above the centre point of the seafloor transponder array, is designed to mitigate vertical changes in the sound speed profile. The impacts of lateral variations in sound speed, however, are only somewhat reduced through this observing geometry. Sound speed variations will particularly impact the long ranges involved in making measurements down to 6,000 m, and we will need to implement strategies to effectively identify and mitigate errors due to sound speed lateral variations. The acoustic ranging error structure reflects the contribution of many different oceanographic processes. For 10 to 60 minute time periods, perturbations from internal waves are the dominant feature. Longer period perturbations are generated by tidal currents, transient events such as eddies and seasonal processes. We will define an approach that combines analysis of the recorded time delays themselves to identify short-period perturbations, along with sampling of high-resolution numerical ocean models to explore the lateral variations of the sound speed field at longer spatial and temporal scales. Combining these strategies will allow us to generate full a-priori variance-covariance matrices for modelling our positions, and the resulting time-series, as well as extracting representative confidence levels on our results. //