

Submarine Groundwater Discharge: Combining offshore autonomous monitoring with onshore groundwater modeling and monitoring in the Salalah coastal plain, Oman

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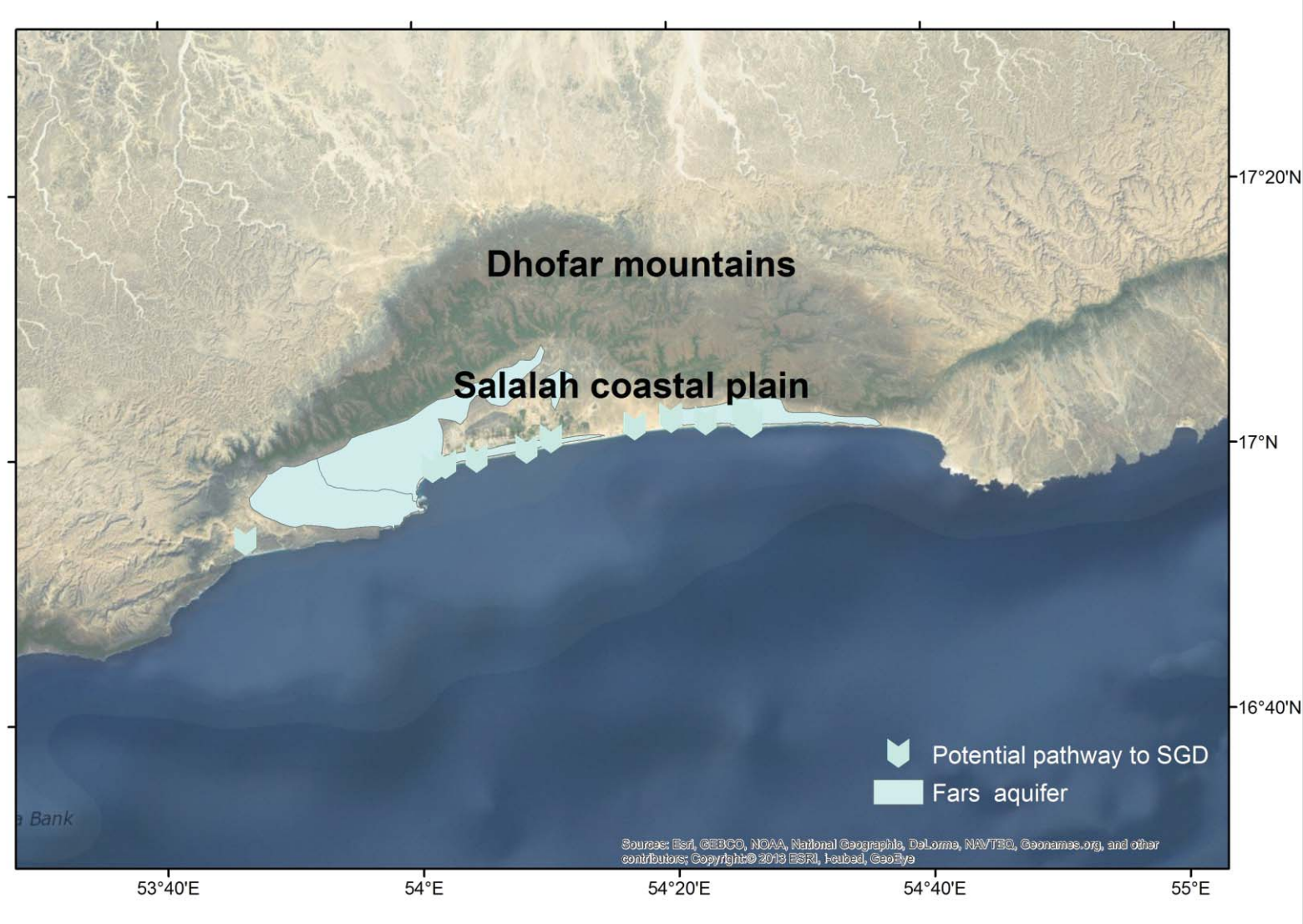
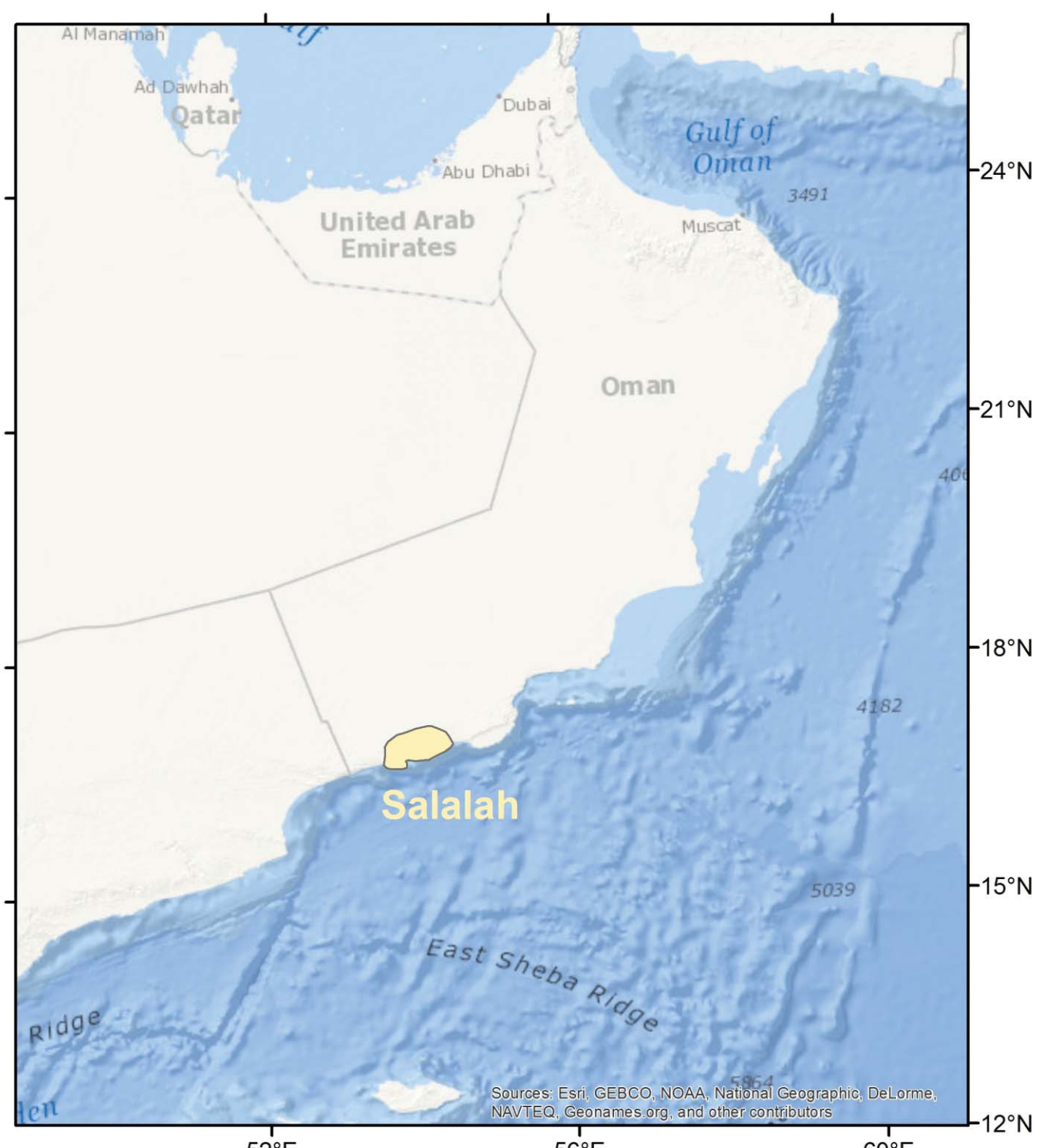
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Introduction

Coastal aquifer systems are among the most vulnerable water resources worldwide. Estimates assume that more than one billion people live in coastal regions. While these aquifer systems may differ in lateral and vertical extent, they all have in common that they interact with the salt waters of the world's oceans. Excessive groundwater extraction can cause salt water intrusion from the sea to the aquifers, resulting in negative impacts on the groundwater body. However, the discharge of aquifer water to the sea, is possible as well. For the Salalah coastal plain in Oman we present a concept that combines onshore monitoring and modeling with an offshore autonomous robotic monitoring system (wave glider). This approach will be utilized to identify flow pathways from the source (mountains) to the sea and to quantify SGD fluxes for large coastal regions.



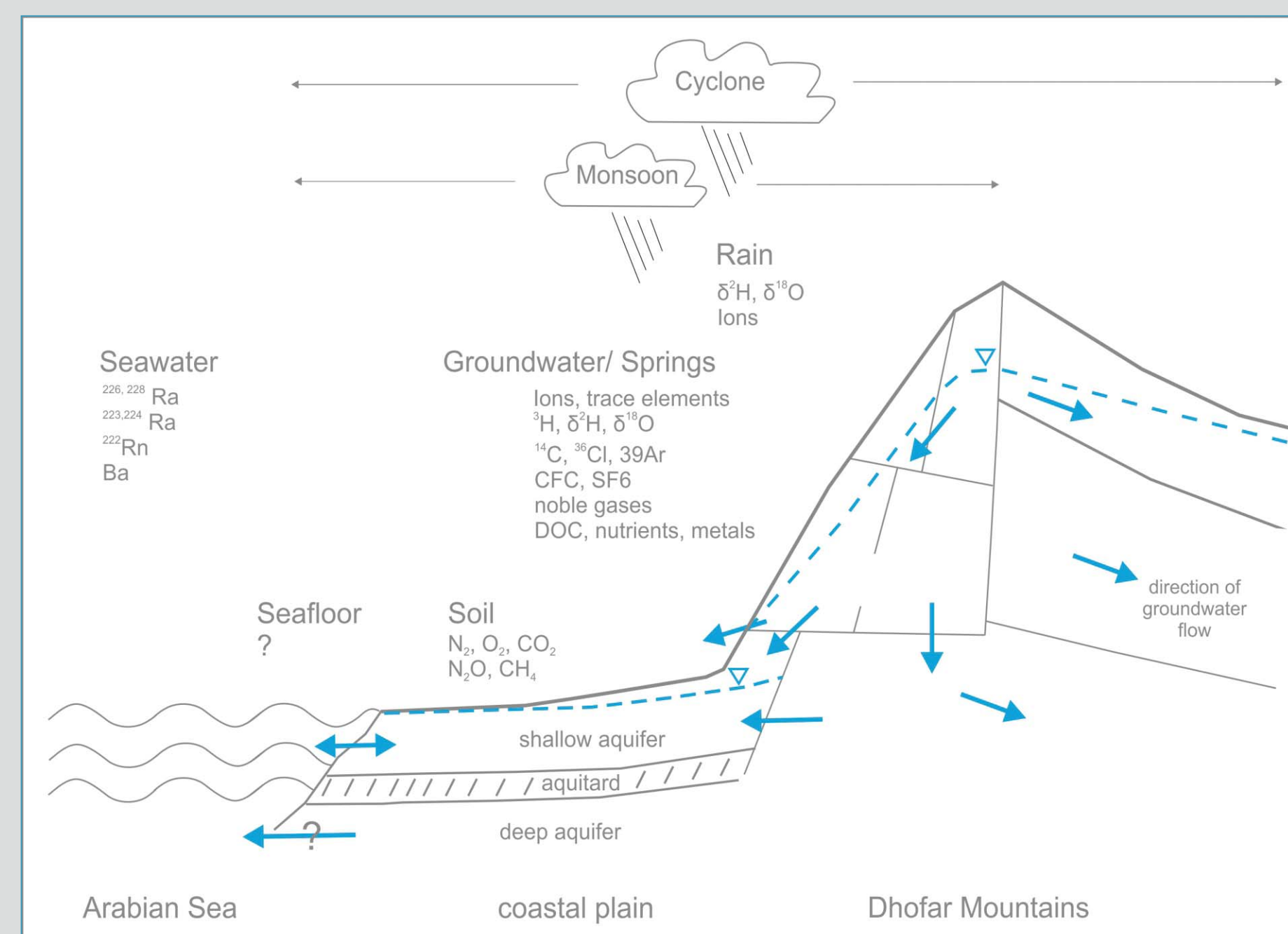
The Salalah coastal plain in the Dhofar governorate of the Sultanate of Oman exhibits a unique climatic event with the annual Monsoon rain and fog season ('Khareef') between June and September.

Precipitated water at the Dhofar Mountains infiltrates the upper FARS aquifer, fills up Wadis in the Salalah plain, and induces shallow subsea groundwater discharge (SGD from a deep aquifer is unknown).

Agricultural, industrial, and domestic use of groundwater, as well as evaporation, induces saltwater intrusion.

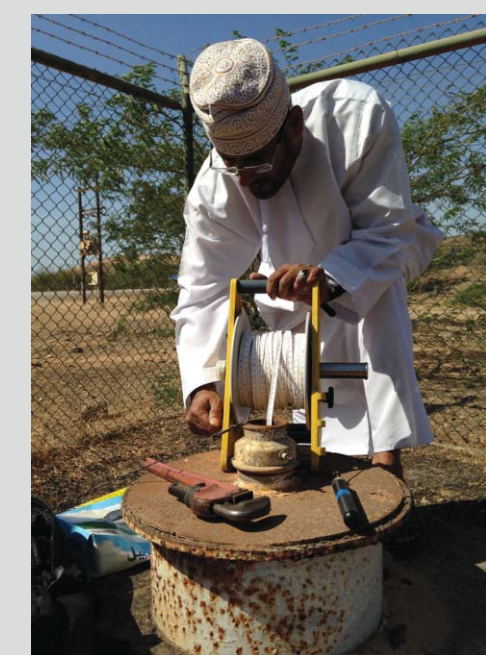


Concepts and methods



Schematic groundwater flow system from the Dhofar Mountains towards the Arabian Sea.

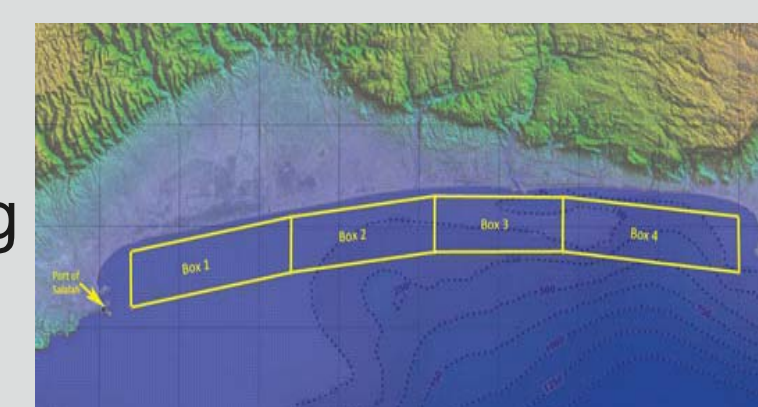
A seasonal/annual quantification of input (precipitation) and outflow will be performed by surface water measurements, well monitoring, chemical tracer analyses, and hydrodynamic flow modelling.



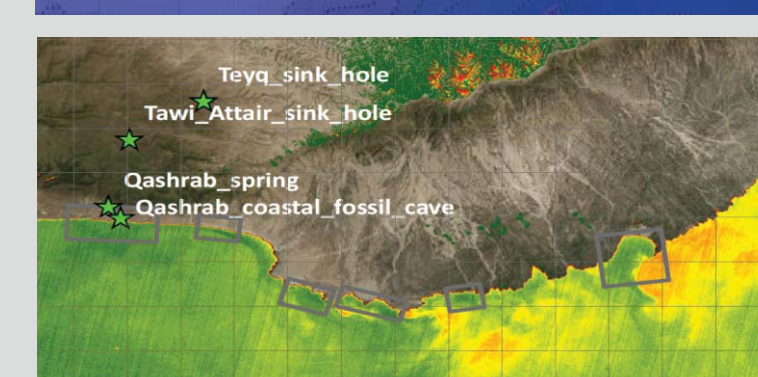
Long-term oceanographic monitoring campaigns offshore Salalah using the Wave Glider on standard parameters (weather, water temperature, oxygen content, conductivity), new sensor technologies, and smart plume heading software.



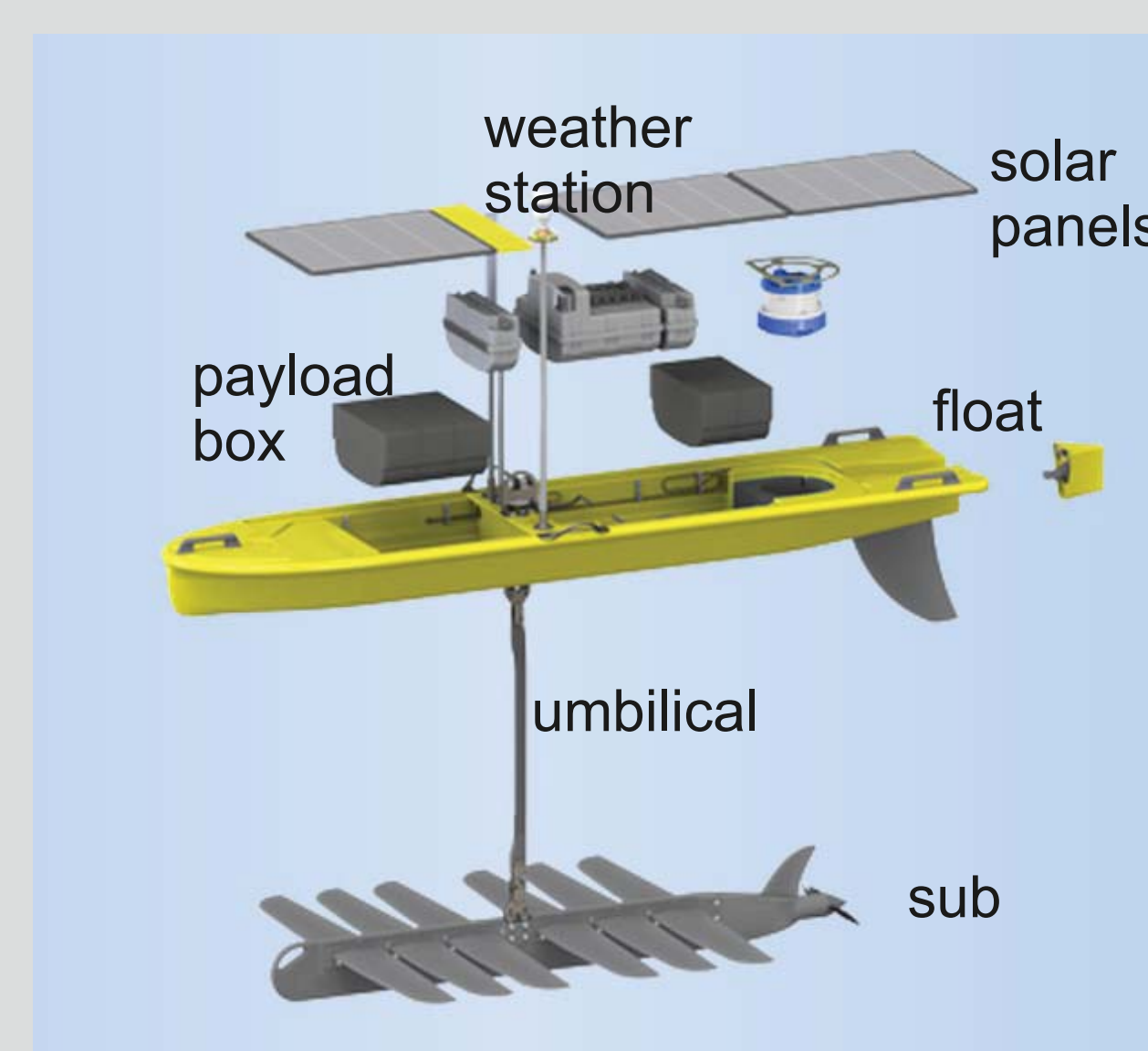
Multibeam campaign (EM2040C) of coastal waters at Salalah (bathymetry, water column imaging of micro-bubbles, characterisation of fluid seepage morphology).



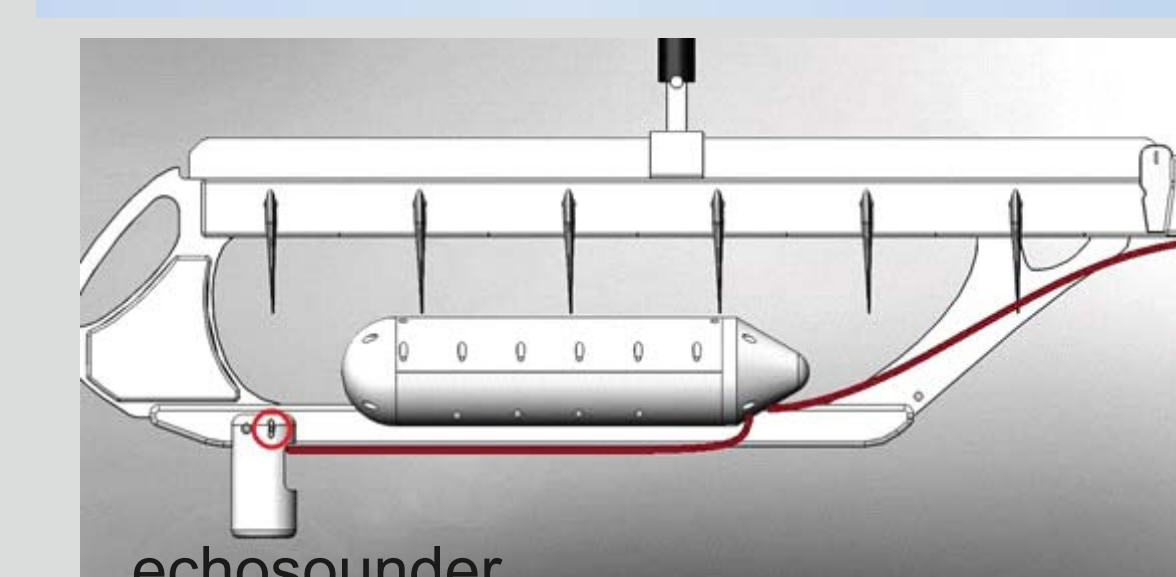
Satellite imagery is analyzed for thermal anomalies of sea surface waters (statistical approach).



Technology integration

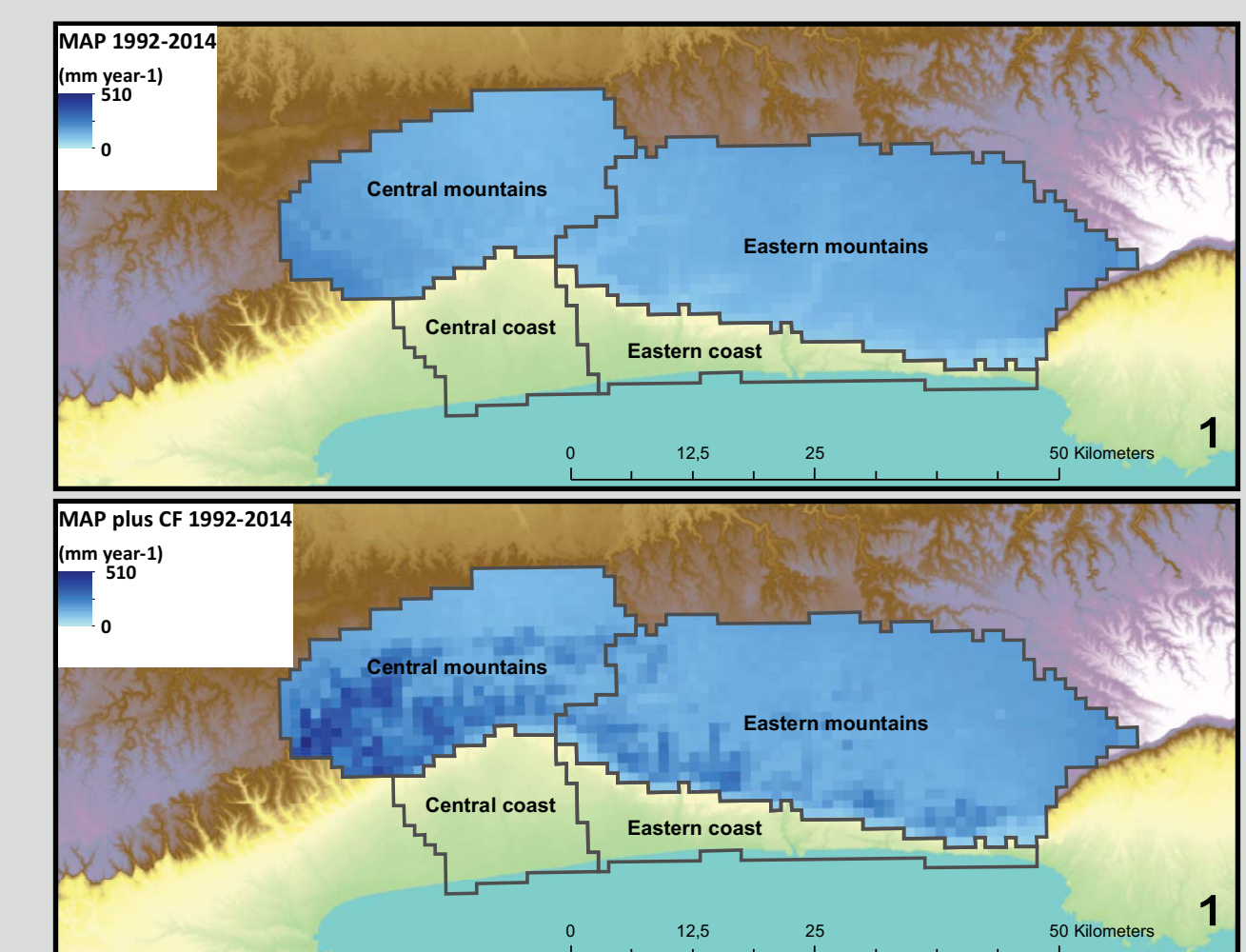


New pumped Rn-sensor technology and membrane mass spectrometry will be integrated into the Wave Glider float (payload box).

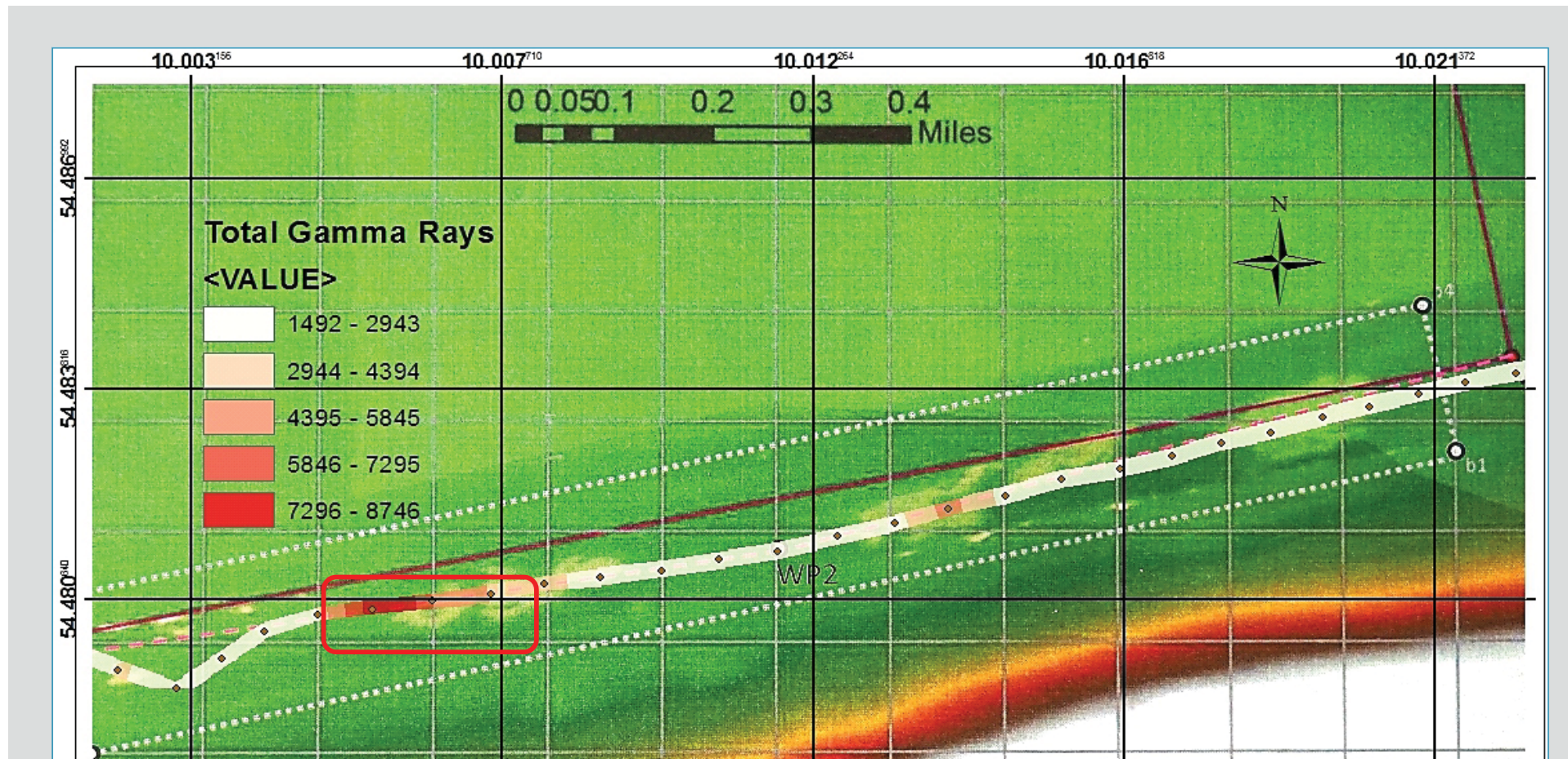


Hydroacoustic seafloor and water column imaging is adapted to the Wave Glider sub.

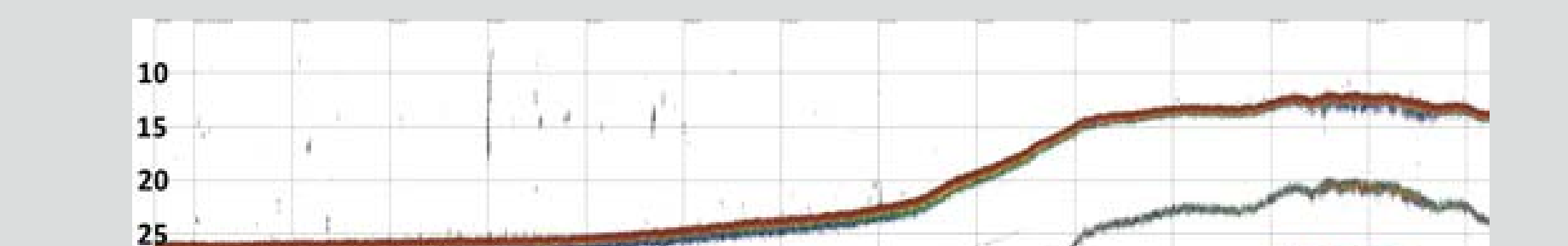
First activities



A mean annual precipitation analysis (MAP) and groundwater recharge measurements/modelling indicate 20% more recharge by cloud forest (CF) land coverage of Dhofar Mountains.



The towed in-situ gamma-ray spectrometer KATERINA indicates radon and thoron anomalies related to pockmarks at our SGD test site in Eckernförde Bay (RV Littorina cruise 2016); visualisation by D. Patiris (HCMR, Greece).



First data of a 200 kHz echosounder integrated in the Wave Glider platform (Sub), indicates good performance during hydroacoustic mapping in shallow waters of the Eckernförde Bay test site.

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