Short Term Scientific Mission – Report

STSM Title: Preparation of in situ monitoring of radioactive gases (radon/thoron) emanation upon shallow pockmarks in Eckernförde Bay, Baltic Sea, Germany. **Date of STSM:** 29 May – 5 June 2016

STSM Participants:

Home Institution: Hellenic Centre for Marine Research – Institute of Oceanography

Host Institution: GEOMAR Helmholtz Centre for Ocean Research Kiel

Summary of the report: (half page)

During this STSM Dr. Dionisis Patiris, postdoctoral researcher of HCMR, was hosted by the GEOMAR Helmholtz Centre for Ocean Research at Kiel for a period of one week (29 May – 5 June 2016). According to the proposed work plan, all necessary preparation works for common deployment of the gamma-ray spectrometer KATERINA of HCMR along with GEOMAR flow-through sensors and field utilities were accomplished. KATERINA was adapted on a platform containing a CTD meter and battery pack. Dr. Dionisis Patiris and PD Dr. Mark Schmidt joined in two daily cruises of RV Littorina on May 31st and June 2nd into the Eckernförde Bay and data of radon/thoron radioactive gases along with data of water conductivity and temperature were acquired upon a pockmark area of the bay. The scope of the first trip was to obtain spatial profile of radon/thoron and radioactive potassium along a predetermined transect covering the area of pockmarks. In three regions, the temperature and the number of gamma rays were increased with a simultaneous decrement of water salinity. These observations indicated groundwater emanation from the seabed. The scope of the second trip was to gather gamma-ray spectra upon an area of groundwater emanation with the aim to quantify radon, thorn and potassium activity concentrations. The scopes of both trips were achieved and a first dataset of in situ observation of radioactive gas emanation was obtained. The analysis of the data is still in progress (concerning the quantification of radon concentration) and the final results is expected to constitute the scientific base for upcoming publications in the form of article and/or conference presentations. Moreover, the basis for future common operational actions between HCMR and GEOMAR was established concerning the identification of submarine groundwater sources.

Purpose of the STSM:

The scope of the proposed mission was the accomplishment of all necessary preparation works for common deployment of the gamma-ray spectrometer KATERINA of HCMR along with GEOMAR flow-through sensors and field utilities. Also, it was planned to carry out a first deployment at specified areas upon shallow pockmarks in Eckernförde Bay. The deployment provided in situ radioactive gas emanation data obtained simultaneously with seawater parameters in the area. Thus, new scientific information was provided regarding identification of groundwater seepage from an area of pockmarks based on in situ radio-tracing technique.

Description of the work carried out during the STSM:

The work carried out during this STSM could be summarized under the following tasks:

a. Adaptation of gamma-ray spectrometer on an appropriate platform: During this STSM the gamma-ray spectrometer of HCMR KATERINA was transported to GEOMAR's facilities at Kiel with the aim to be adapted onto a platform for in situ measurements simultaneously with a Conductivity Temperature and Depth (CTD) logger. Prior the STSM, continues communication between the involved researchers and technicians had the aim to determine the technical needs (e.g. sensors physical characterises, dimension, weight, power needs, and communication ports) for the adaptation. The task was successfully achieved by the valuable contribution of GEOMAR's technical support team. On the figure 1 the preparation stages are presented.

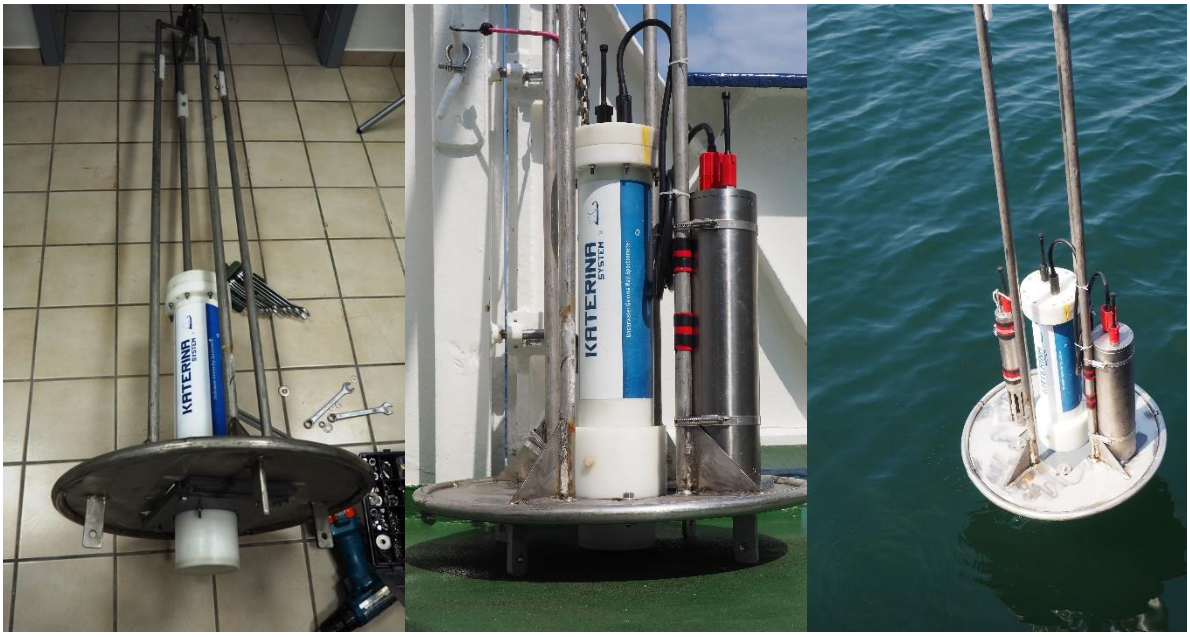

Figure 1. Adaptation of the gamma-ray spectrometer KATERINA onto application specified platform along with CTD meter and battery pack. Attention was paid to the proper exposure of the detection crystal to seawater and its protection from accidental bump on the seabed

b. Trip day 1, 31 May 2016, spatial profiling of gamma-ray along transect: The scope of the first trip was to obtain spatial profile of radon, thoron and radioactive potassium along a predetermined transect covering the pockmark area presented in the figure 2.

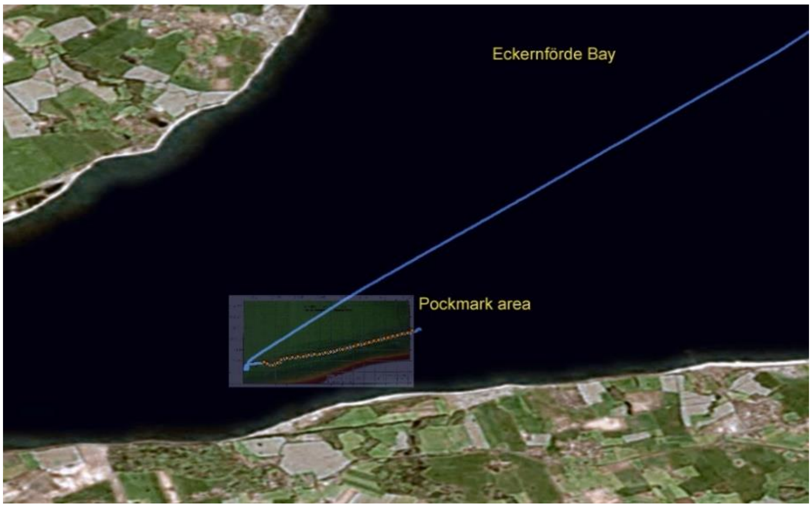

Figure 2. Study area, the transect and the position of gamma-ray spectra acquisition are presented

The platform with the sensors was held by RV Littorina winch and remained constantly 2 meters upon the seabed. At this distance, the contribution of gamma-rays emitted from the seabed sediment is minimized while the sensors still can gather data from the seawater. The profiling plan was based on acquiring gamma-ray spectra every 200sec while RV Littorina will travel along the transect with minimum speed (0.5knt or 15m min^{-1}). By this way, every spectrum contains the sum of gamma-rays obtained from a spatial interval of approximately 50m (orange marks on the figure 2). As indicator of radon/thoron presence the total gamma-ray counts and the counts on energy windows (specified according to gamma-ray energy emitted by radon and thoron progenies) were used. As indicator of groundwater emanation water salinity and temperature records

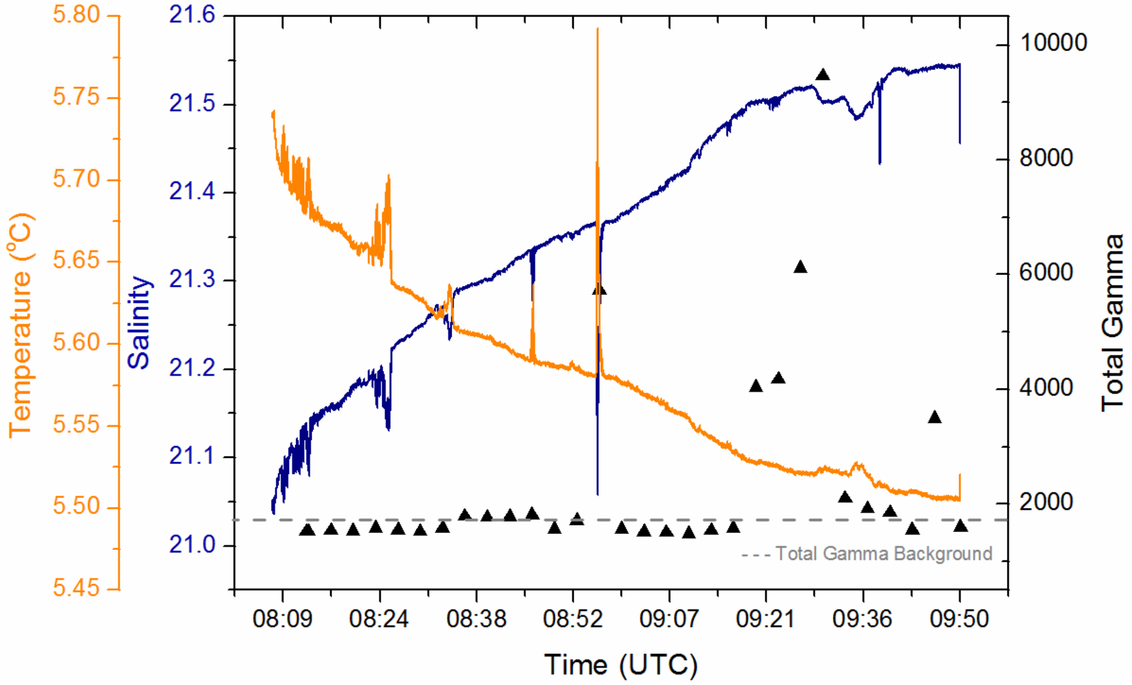

Figure 3. Results of total gamma-ray counts profiling along with salinity and temperature

of CTD were used. The results are presented in figure 3. The background of total gamma-ray counts represents the total gamma-ray record received in a location of the bay that is not influenced by the pockmarks. For that, another gamma-ray spectrum received (acquisition time 3167sec) in a location away from the pockmark area at the same depth as the profiling phase. At the figure 4, the spatial profiling of the total counts of gamma-rays is depicted where three regions of enhanced number of counts can be observed. The area of groundwater emanation that strongly contribute to the gamma-ray counts is also depicted in the figure 4 and it was selected as the area of measurements for the next trip.

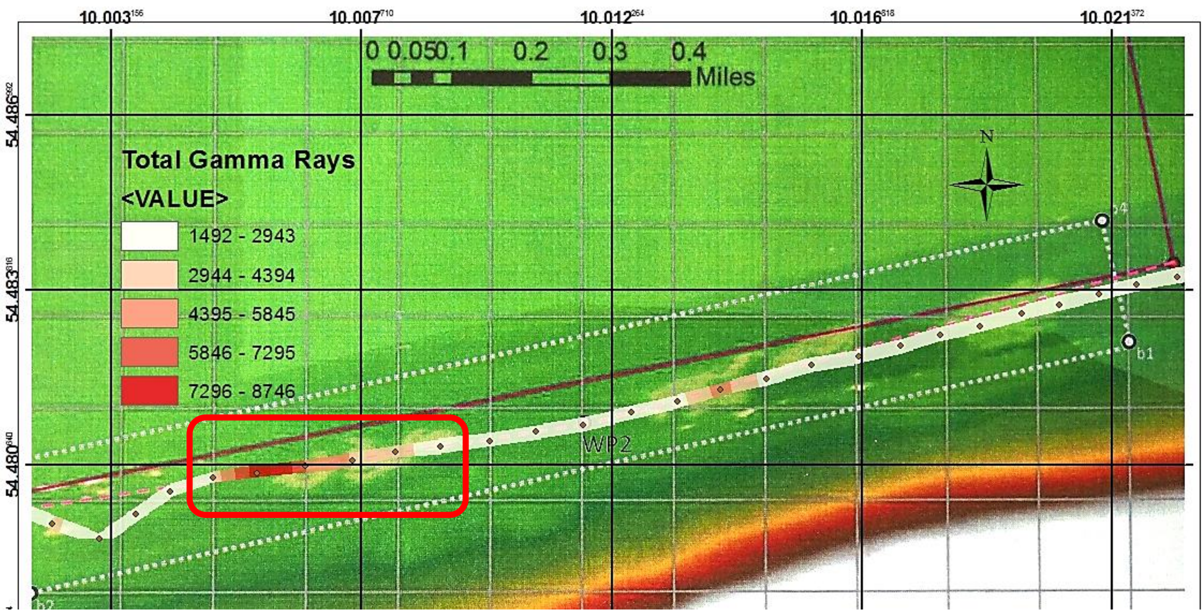

Figure 4. Total gamma-rays profiling map where three regions with enhanced counts can be observed

c. Trip day 2, 2 June 2016, gamma-ray spectra gathering upon a pockmark area: The scope of the second trip was to acquire gamma-ray spectra upon the area where the emanation of groundwater resulted in enhanced counts of total gamma-rays. The spectra of the second trip were gathered with the aim to

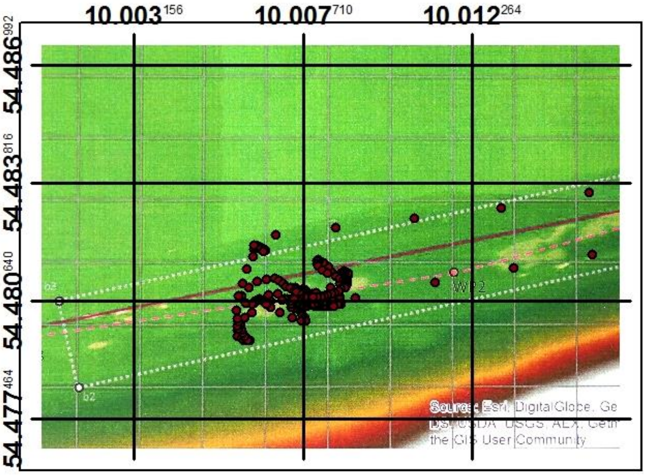

Figure 5. Positions of RV Littorina upon selected the area

quantitatively estimate the activity concentrations of radon, thoron and radioactive potassium ^{40}K. The same set up was used, as well as, the same plan was followed except that, instead of transect, RV Littorina remained as near as possible to the predetermined area upon the location of groundwater emanation. At the figure 5 indicative positions (two positions per minute) of the ship are depicted. During the trip, a total of 30 spectra acquired with acquisition time of 200sec. The spectrum obtained from the sum of the 30 spectra was used for a first estimation of an average value of radon, thoron and potassium activity concentrations in the area. For this end, the full spectrum analysis (FSA) method [Androulakaki et al., 2016] was used. The method is based on the reproduction of the experimental spectrum (which contains gamma-ray peaks of all radioisotopes) with a number of theoretically obtained spectra (each one of them contains gamma-ray peaks of only one radioisotope). For the reproduction, theoretically obtained spectra of the following radioisotopes were used; corresponding to thorium series, actinium ^{228}Ac and thalium ^{208}Tl (thoron daughter), corresponding to uranium series ^{238}U, bismuth ^{214}Bi and ^{214}Pb lead (both radon daughters) as well as the radioactive isotope of potassium ^{40}K. The reproduction process are summarized in the figure 6.

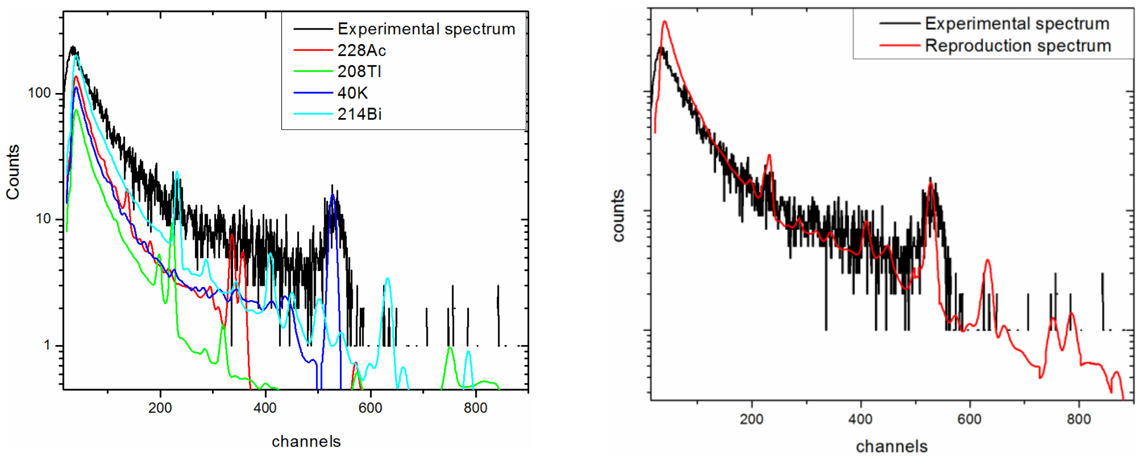

Figure 6. The reproduction of the spectrum obtained during the second trip by the FSA method

The use of the method resulted in the activity concentrations presented in the table 1. The uncertainty of the measurements range between 25-30% due to the poor statistics of using short acquisition time. In case of potassium ^{40}K, the activity concentration corresponds to salinity values in the range of 20-21 which is close enough with the results obtained by the CTD. Further analysis of the separated spectra is expected to provide spatial

Radioisotope	Activity concentration (Bq/l)
^{214}Bi (radon daughter)	1.0
^{214}Pb (radon daughter)	0.9
^{228}Ac	0.1
^{208}Tl (thoron daughter)	0.2
^{40}K	7.0

Table 1. Activity concentration of radioisotopes involved in the FSA method

distribution of the aforementioned radioisotopes in the vicinity of the area where the second trip was focused on.

Description of the main results obtained in light of the objectives of the FLOWS action:

The data acquired during this STSM activities are in accordance with the main COST-FLOWS objective of "distinguish potential (bio) geochemical proxies that could be used in the future physico-chemical sensors to detect precursory seismic activity". Specifically, introducing radio-tracers (radon, thoron, potassium) upon "fluid-emitting structures" as the pockmarks of Eckernforde Bay will support the efforts for "crucial insights to the connectivity of deeply buried crust, overlying sediments and water" which is a goal of the working group 3 of the project. The same working group encourages combined measurements of "temperature, gaseous hydrocarbons, and radioisotopes" using in-situ devices as well as the combination of in-situ measurements with laboratory ones. Moreover, common field work and interference among scientist of different disciplines realized strengthening the communication of novel technological and methodological aspects and promoting the integration of early-stage researchers in a frame of expert research group in the earthquakes precursors' field.

Future collaboration with the host institution (if applicable):

During this STSM, the basis for future common operational actions between HCMR and GEOMAR was established concerning the identification and monitoring of submarine groundwater sources (or other fluids emanation). Combination of in situ radio-tracing techniques and seawater analysis methods may provide spatial profiling and/or temporal monitoring in areas with hydrogeological and geophysical interest.

Foreseen publications/articles resulting from the STSM (if applicable):

The analysis of a portion of the data (concerning the quantification of radon concentration) is still in progress. The quantification of radon concentration is based on recent published methods (Androulakaki et al., 2016; Tsabaris and Prospathopoulos, 2011). Both of them are automated and user-independent methods to analyse gamma-ray spectra even in the case of low concentrations and poor statistics. Both methods will be utilized to the analyses of the spectra obtained during this STSM. Also, it is the first time, the in situ gamma-ray spectrometry technique is followed in the investigation of the STSM area of study. Thus, the final results is expected to constitute the scientific base for upcoming publications in the form of article and/or conference presentations.

Confirmation by the host institution of the successful execution of the STSM:

The successful STSM will help to further constrain joint activities in deep sea monitoring, as it is summarized in a recently submitted ITN proposal sent to the COST-FLOWS board.

Signatures:

Kiel, 04.07.2016, PD Dr. Mark Schmidt (GEOMAR)

References

Androulakaki, E.G., Kokkoris, M., Tsabaris, C., Eleftheriou, G., Patiris, D.L., Pappa, F.K., Vlastou, R. "In situ γ-ray spectrometry in the marine environment using full spectrum analysis for natural radionuclides", Applied Radiation and Isotopes 2016, 114, pp 76-86.

Tsabaris, C., Prospathopoulos, A. "Automated quantitative analysis of in-situ NaI measured spectra in the marine environment using a wavelet-based smoothing technique", Applied Radiation and Isotopes 201, 69(10), pp 1546-53.