Unmanned Vehicles for Autonomous Sensing and Sensing

Ga. Bruzzone[1], A. Argentieri[1], Gi. Bruzzone[1], M. Caccia, M. Giacopelli[1], A. Odetti[1], E. Spirandelli[1], P. Soria[1], M. Azzaro[2], G. Caruso[2], G. Zappalà[2]

[1]Institute of Intelligent Systems for Automation - National Research Council of Italy, Via de Marini 6, 16149, Genova, Italy - gabriele.bruzzone@ge.issia.cnr.it , argentieri@ba.issia.cnr.it, gio@ge.issia.cnr.it, massimo.caccia@ge.issia.cnr.it, mauro.giacopelli@ge.issia.cnr.it, angelo.odetti@ge.issia.cnr.it, ed@ge.issia.cnr.it, soria@ba.issia.cnr.it;

[2]Institute of Marine and Coastal Environment - National Research Council of Italy, Via S. Ranieri 4, 98122, Messina, Italy - maurizio.azzaro@iamc.cnr.it , gabriella.caruso@iamc.cnr.it , giuseppe.zappala@iamc.cnr.it

Abstract

In the global warming process the Arctic region is heating up faster than other places on Earth. This has brought to a rapid environmental change which is increasingly evident in the observations of many geophysical and biological properties.

The interactions between atmosphere, ocean, cryosphere and biosphere are responsible for the phenomenon of "Arctic amplification". The complex system of interactions involving heat exchanges and water cycle (vapor and liquid) in the Arctic Ocean that is generated by these climate changes is at the base of the instabilities inducing large uncertainties and errors in climate models. Within this scene extreme and unpredictable events, especially the collapse of the ice sheets, appear to be not so remote.

The ARCA project aims to develop a conceptual model on the mechanism(s) behind the release of large volumes of cold and fresh water from melting of ice caps, investigating this complex system from both paleoclimatic and modern air-sea-ice interaction process point of view.

Ice process of melting depends on the energy balance at the surface of the glaciers which is controlled by mutual interactions between the atmosphere and the surface of the glacier thus depending on weather conditions (temperature, radiation, turbidity, etc.) and on ice surface properties.

Among the others, ARCA project focuses on the analysis of the interface between the melting glaciers fronts and the sea inside the Arctic fjords and studies the actual sedimentary processes by analysing the ice and sediments collected in the inner part of the fjords. The Svalbard Archipelago is considered a suitable region to explore the impacts of possible climate changes, being characterised by Atlantic water influx and melting of tidal glaciers, both linked to climate variability.

The retreat of the glacier front has been particularly pronounced in recent decades and has led to the accumulation of sediments in the depressions inter-moraine near the sea-ice interfaces. Particularly interesting is the case of the Kongsfjorden where high sedimentation rates have been recorded.

Kongsfjorden is an Arctic glacial fjord located on the west coast of the Svalbard at 79° N, 12° E. In the inner part of the fjord, many glaciers reach the sea and the shape of the glacier front is an almost vertical wall of ice above seawater. For this reason direct measurements in the proximity of the glacier front are very critical due to the possible sudden fall of ice blocks causing extreme conditions which are dangerous for human beings carrying out operations in the surrounding area.

Within the ARCA project a first prototype of automatic equipment was designed to perform discrete sampling of waters in the area close to the Kronebreen glacier in the Kongsfjorden. The aim was to obtain in situ data to study the heterotrophic bacterial distribution and functional metabolism near the glacier to better understand the hydrology cycle and its consequences on the climate in the Boreal hemisphere.

The Shark USSV (Unmanned Semi-Submersible Vehicle) designed and built by CNR-ISSIA was used for collecting samples in the stretch of sea near the Kronebreen glacier; this was the first time that an autonomous sampling was carried out near the front of the glacier.
Shark was used to tow along a transect and via an adequate rope a small catamaran carrying an Automatic Water Multisampler designed on the experience of CNR-IAMC.
Using the USSV+Sampling System has unquestionable advantages:

- possibility of carrying out real-time or near real-time acquisition of physical, chemical and biological data series;
- avoiding the presence of manifold (small and medium) drifting icebergs obstructing the passage to the glacier;
- protecting the operators from falling of ice blocks that can be directly or indirectly (due to the produced waves) dangerous.

During the mission the vehicle was piloted by a human operator using the semi-automatic working mode (auto-heading and auto-speed). The floating ice block obstacles were avoided with the help of a visual feedback, transmitted through a Wi-Fi channel, coming from an Ethernet camera mounted on the bow of Shark. A serial communication link was provided between the robotic vehicle and the catamaran Multisampler. This link (bridged through the Wi-Fi of Shark) made it possible for the operator to send commands to the Multisampler and to remotely start water sampling in the chosen points of interest.
In the framework of ARCA project the sampling of water near the Kronebreen was necessary to assess the Arctic microbial communities and carbon processing relation with environmental changes.
Taking into account the short time between the sample collection and analysis and the low temperature, it was decided to work on the fresh sample, so making it unnecessary to fix it as in previous versions of the Multisampler.
In June 2015, surface water samples were collected by the automatic Multisampler along a transect from the glacier to the open sea. The samples were recovered aseptically from the system and treated to assess the bacterial abundance and metabolism. For the determination of the viable heterotrophic psychrophilic bacteria, water volumes of 100 microliters were spread on the surface of Marine Agar plates, further incubated at +5°C for 15 days. Enzymatic measurements of the potential leucine aminopeptidase, beta-glucosidase and phosphatase activities (involved in the decomposition of proteins, polysaccharides and organic phosphates respectively) were carried out using a fluorimeter, after addition of increasing concentrations of specific fluorogenic substrates. The counts of the heterotrophic psychrophilic bacteria obtained on Marine agar showed a maximum concentration (5.65x102 CFU/ml) closest to the glacier, followed by an abrupt decrease (7.0x101 CFU/ml). Bacterial counts increased again moving along the transect. The enzymatic patterns showed the relative predominance of AP compared to LAP and Beta-GLU. Bacterial metabolism underwent significant spatial changes, with high potential GLU activity at points close to the glacier until the middle of the transect; LAP showed peaks of activity far from the glacier, while AP levels were not clearly affected by the presence of this hydrological structure. Spatial variations were significant for heterotrophic bacteria and at a lesser extent for LAP and GLU.
For the first time in Kongsfjorden, the air-sea-ice could be studied at minimum distance from glacier front by using an autonomous semi-submersible vehicle with remotely-controlled instrumentation operated from a vessel with personnel kept at a safe distance from the melting and collapsing ice walls.
Due to the possibility to plan the sampling schedule, this device may be particularly suitable in future studies where dynamics vary on a daily scale. Moreover, thanks to the communication channel made available by the USSV, the operator can also send commands to the automatic water Multisampler to take samplings in chosen points of interest (adaptive sampling).

The collected data showed the extracellular enzymatic profiles of the bacterial isolates and pointed out that lipids, proteins and organic phosphates play a major role in bacterial metabolism in Svalbard Archipelago.
The results obtained show the usefulness and the effectiveness of using robotic autonomous vehicles for monitoring environmental and biological parameters in the proximity of glaciers and for evaluating the response of polar ocean ecosystems to the effects of climate changes.

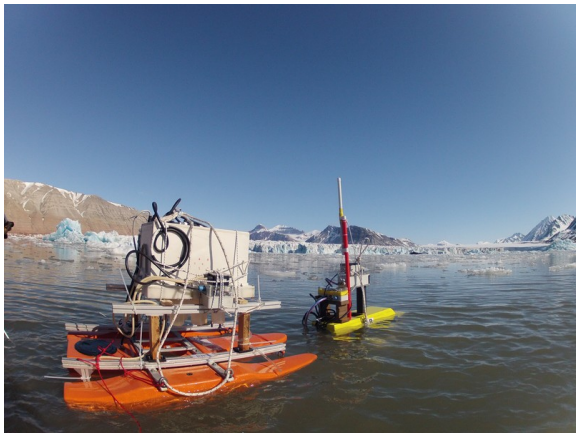

Figure 1: *Shark unmanned semi-submersible vehicle and the automatic water multisampler in proximity of the Kronebreen glacier*

References

Bibuli M, Bruzzone G, Caccia M, Lapierre L (2009) Path-following algorithms and experiments for an Unmanned Surface Vehicle. J Field Robotics 26(8): 669-688, doi 10.1002/rob.20303

Caccia M, Bibuli M, Bono R, Bruzzone G (2008) Basic navigation, guidance and control of an Unmanned Surface Vehicle. Autonomous Robots 25(4): 349-365, doi:10.1007/s10514-008-9100-0

HONDA M. C. and WATANABE S. (2007) Utility of an Automatic Water Sampler to Observe Seasonal Variability in Nutrients and DIC in the Northwestern North Pacific. Journal of Oceanography, 63: 349 -362.

Kirchman DL, Moran XAG, and Ducklow H (2009) Microbial growth in the polar oceans–role of temperature and potential impact of climate change. Nat Rev Microbiol 7:451–459, doi: 10.1038/nrmicro2115

Hop H, Pearson T, Nøst Hegseth E, Kovacs KM, Wiencke C, Kwasniewski S, et al (2002) The marine ecosystem of Kongsfjorden, Svalbard. Polar Res 21 (1): 167-208, doi: 10.1111/j.1751-8369.2002.tb00073.x

Zappalà G., Caruso G, Crisafi E (2003) An automatic multisampler for bacteriological water quality evaluation: some applications. Geophys Res Abstracts, 5: 11447. Abstracts of the contributions of the 28th General Assembly of the European Geophysical Society, Nice (France), 6-11 April 2003

Zappalà G. (2009) A versatile software-hardware system for environmental data acquisition and transmission. In: Brebbia CA, Carlomagno GM (eds) Computational Methods and Experimental Measurements XIV, WIT Press, Southampton (UK), pp 283-294, doi 10.2495/CMEM090261

Zappalà G, Caruso G, Crisafi E (2004a) Coastal pollution monitoring by an automatic multisampler coupled with a fluorescent antibody assay. In: Brebbia CA, Saval Perez J.M. Garcia-Andion L, Villacampa Y. Coastal Environment V: incorporating oil spill studies. WIT Press, Southampton, UK, pp 125-133