# Automated Photogrammetric
3D/4D Characterization of Marine Gas Bubbles

In many places free gas (e.g. methane, CO_2) escapes from the seafloor into the water of oceans or lakes, forming bubble streams that rise up towards the atmosphere or that interact with the water column. But how much does gas release from the oceans contribute to global warming or ocean acidification? How effective is subsea carbon storage? Are abandoned oil+gas drill sites really closed? What factors impact the stabilities of gas hydrates? How is gas release correlated to earth quakes or other external factors like sea level change, internal waves or seafloor processes ?


Small bubbles (<1mm) are often spherical, but larger bubbles show a more complex shape.
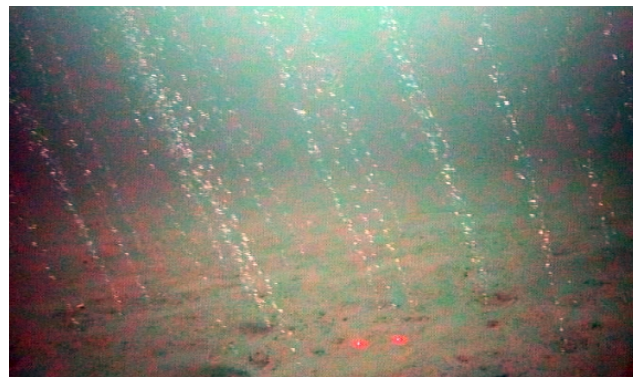

Natural methane seepage in the North Sea

Several questions with respect to cause and effect of marine gas seepage require a detailed quantification, mapping and monitoring of the release processes. While sonar systems are effective means for detecting bubble streams, detailed characteristics are required for quantification, and those can be obtained by photogrammetric methods, i.e. imaging with calibrated cameras and 3D machine vision technology.

GEOMAR has built a high-speed, in-situ observation system (the *BubbleBox*) to capture gas bubbles while rising. It is deployed and operated using remotely operated vehicles or by divers and records enormous amounts of synchronized stereo data that need to be evaluated automatically.
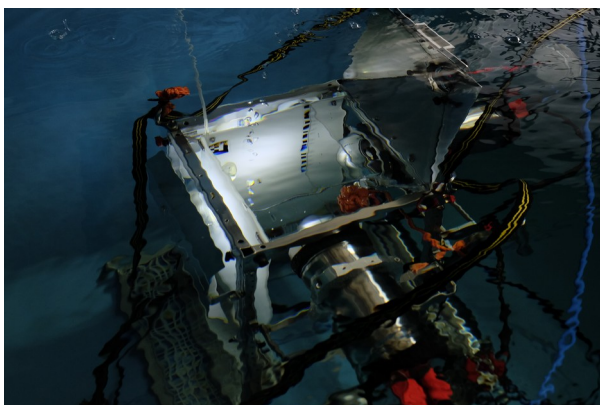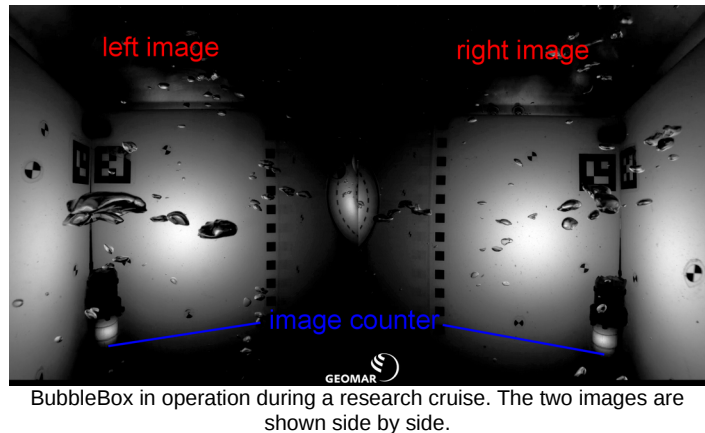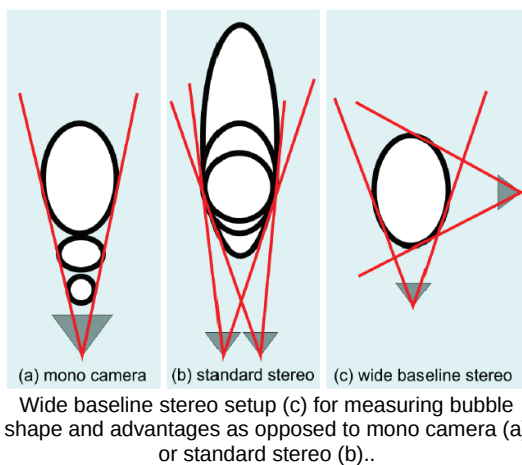

BubbleBox in GEOMAR's test tank
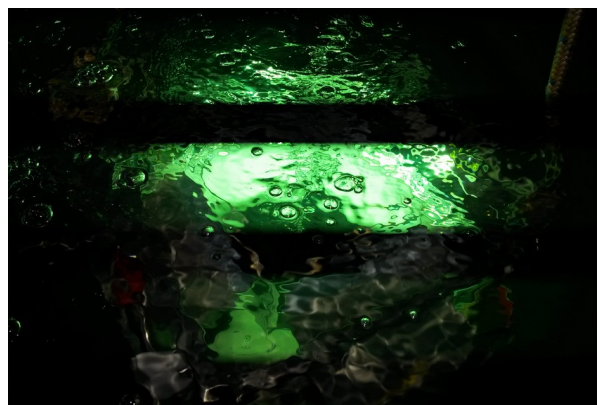
Operating with green LEDs

The general idea is that the intersection of the cones obtained by backprojecting bubble contours will determine the visual hull of the bubble, an upper limit on its volume. This can be refined by

tracking bubbles over time, which also provides rise speeds that can depend on factors like water properties, pressure or coating of bubbles. Physical bubble and refraction models (only interface effects between transparent gas bubbles in transparent water are observed) and state-of-the-art image processing techniques (sub-pixel registration) are expected to improve accuracy.

(a) mono camera   (b) standard stereo   (c) wide baseline stereo

Wide baseline stereo setup (c) for measuring bubble shape and advantages as opposed to mono camera (a) or standard stereo (b)..

BubbleBox in operation during a research cruise. The two images are shown side by side.

Goals:
The goal of this research project is to extract bubble shape, gas flux and bubble rise speed (distributions) automatically from the imagery by implementing robust and fast algorithms (many GBs to TBs of data per cruise). Later, we would like to quantify gas bubbles also from moving platforms in the wild, which is a challenge in its own right.

Requirements:
This project requires basic physics and optics understanding, good programming skills in C++(this cannot be done in Matlab), 3D computer vision background (contour detection, tracking, epipolar geometry, visual hull).

Possibilities for Collaboration:
If you fulfill the requirements, several levels of getting involved into this project are possible, from internships, HiWi-jobs, or master theses to even a PhD project (currently we dont have funding for that). If time and schedule permits, participation in research cruises is possible in general and we intend also to deploy the BubbleBox within Ocean Networks Canada and other places like European lakes. If you are interested and would like to get involved please contact us.

Further Reading:
Jordt, A.; Zelenka, C.; von Deimling, J.S.; Koch, R.; Köser, K. (2015) *The Bubble Box: Towards an Automated Visual Sensor for 3D Analysis and Characterization of Marine Gas Release Sites. Sensors* 2015, *15*, 30716-30735. http://www.mdpi.com/1424-8220/15/12/29825

Urban, P.; Köser, K.; Greinert, J. (2017) *Processing of multibeam water column image data for automated bubble/seep detection and repeated mapping.* Limnology and Oceanography: Methods, 15 (1). pp. 1-21. http://dx.doi.org/10.1002/lom3.10138

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http://www.geomar.de/en/research/fb2/fb2-mg/deepsea-monitoring/