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Bubble video experiments in the marine waters off Panarea Island (Italy): real-world data for modelling CO_2 bubble dissolution and evolution

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Carbon capture and storage is expected to provide an important, short-term contribution to mitigate global climate change due to anthropogenic emissions of CO_2. Offshore reservoirs are particularly favourable, however concerns exist regarding the potential for CO_2 leakage into the water column (with possible ecosystem impacts) and the atmosphere. Although laboratory experiments and modelling can examine these issues, the study of natural systems can provide a more complete and realistic understanding. For this reason the natural CO_2 emission site off the coast of Panarea Island (Italy) was chosen for study within the EC-funded ECO_2 project. The present paper discusses the results of field experiments conducted at this site to better understand the fate of CO_2 gas bubbles as they rise through the water column, and to use this real-world data as input to test the predictive capabilities of a bubble model.

Experiments were conducted using a 1m wide x 1m deep x 3m tall, hollow-tube structure equipped with a vertical guide on the front face and a dark, graduated cloth for contrast and depth reference on the back. A Plexiglas box was filled with the naturally emitted gas and fixed on the seafloor inside the structure. Tubes exit the top of the box to make bubbles of different diameters, while valves on each tube control bubble release rate. Bubble rise velocity was measured by tracking each bubble with a HD video camera mounted in the guide and calculating values over 20 cm intervals. Bubble diameter was measured by filming the bubbles as they collide with a graduated Plexiglas sheet deployed horizontally at the measurement height. Bubble gas was collected at different heights using a funnel and analysed in the laboratory for CO_2, O_2+Ar, N2, and CH4. Water parameters were measured by performing a CTD cast beside the structure and collecting water samples at four depths using a Niskin bottle; samples were analysed in the laboratory for all carbonate system species, DO, and dissolved gases. An in-house developed GasPro sensor was also mounted on the structure to monitor pCO_2 over the entire 2.5 hour duration of the experiment.

The obtained data were used as input into the Discrete Bubble Model (DBM) (e.g., McGinnis et al., 2011, doi:10.1029/2010JC006557). The DBM uses mass balance to predict the gas flux across the bubble surface, whereby gas flux direction depends on internal bubble gas concentration and ambient concentration, and considering the Henry's coefficient and partial pressure of the gas. The model uses bubble-size dependent relationships for the mass transfer rate and the bubble rise velocity. Important model input parameters include: bubble size; depth; ambient dissolved gas concentrations, temperature and salinity; and initial bubble gas concentrations.

Measured and modelled results are compared, showing good general agreement. Based on the concentrations measured at the lowest level, the modelled and measured bubble concentrations match very closely. Bubble size values do not match as well if this initial concentration is used, however they improve as a value closer to 100% CO_2 is applied. This preliminary study has shown promising results and highlight areas where experimental design and data quality should be improved in the next phase of the study.