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## Browser based state-of-the-art software for automated data reduction, quality control and dissemination for marine carbon data

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Essential Ocean Variable Inorganic Carbon observations collected from instruments at sea are typically processed by individual PIs before submitting to data centres and other data archives. Often this work is done on an ad-hoc basis using unpublished, self-built software, and published in unique formats. This conflicts with the Interoperability and Reusability aspects of the FAIR data principles: such data requires significant reformatting efforts by data centres and/or end users, and reproducibility is impossible without a full record of the processing performed and QC decisions made by PIs. The manual nature of this process implies additional workload for PIs who need to submit their data to multiple archives/data product. There is a clear need to standardise the data workflow from measurement to publication using common, open source, and documented tools whose algorithms are fully accessible and all processing is recorded for full transparency.

The Ocean Thematic Centre of the European Research Infrastructure ICOS (Integrated Carbon Observation System) is developing QuinCe, a browser-based tool for uploading, processing, automatic and manual quality control, and publication of data from underway pCO<sub>2</sub> systems on ships and moorings. Data can be uploaded directly from instruments in any text format, where it is standardised and processed using algorithms approved by the scientific community. Automatic QC algorithms can detect many obvious data errors; afterwards PIs can perform full quality control of the data following Standard Operating Procedures and best practises. All records of QC decisions, with enforced explanatory notes, are recorded by the software to enable full traceability and reproducibility. The final QCed dataset can be downloaded by the PI, and is sent to the ICOS Carbon Portal and SOCAT project for publication. The ICOS Carbon Portal integrates marine data with ICOS data from the ecosystem and atmosphere on a regional scale and data is integrated via SOCAT in the annual Global Carbon Budgets of the Global Carbon Project where it informs policy/decision makers, the scientific community and the general public.

For platforms with operational data flows, the data is transmitted directly from ship to shore, QuinCe processes, quality controls and publishes Near Real Time data to the ICOS Carbon Portal

and to Copernicus Marine Environmental Monitoring Services In Situ TAC as soon as it is received with no human intervention, greatly reducing the time from measurement to data availability.

Full metadata records for instruments are kept and maintained at the ICOS Carbon Portal, utilising existing standardised vocabularies and version control to maintain a complete history. The correct metadata for any given dataset is available at any time, and can be converted to any required format, allowing compliance with the United Nations Sustainable Development Goal 14.3.1 methodology 'average marine acidity (pH) measured at agreed suite of representative sampling stations' and ICOS data relevant to SDG 14.3 is distributed to IOC UNESCO's IODE. While much of this work is currently performed manually, international efforts are underway to develop fully automated systems and these will be integrated as they become available.