Overview for the European Space Agency (ESA) project, satellite datasets for ocean acidification (OceanSODA)

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https://esa-oceansoda.org/
Objectives

**OBJ-1:** Deepen acquaintance with the state of the art of the OA research and investigate the relevant scientific and operational requirements that will drive the development activities of the project.

**OBJ-2:** Collate an extensive suite of satellite, in-situ and modelled datasets and generate a match-up database as a basis to perform algorithm development, validation activities and scientific analyses.

**OBJ-3:** Perform a thorough assessment of the datasets investigating the spatio-temporal natural variability of the carbonate system parameters and the satellite data sensitivity to them.

**OBJ-4:** Quantify satellite data uncertainties and propagate the errors into related carbonate system parameters in order to establish a solid scientific basis for the development of new retrieval methods and algorithms.

**OBJ-5:** Explore and develop novel algorithms and methods to advance the synergistic exploitation of the satellite data to produce carbonate system parameter estimates.
Objectives

**OBJ-6:** Validate the developed products against a reliable and representative ensemble of in-situ data, models and climatologies investigating the range of validity of the different approaches.

**OBJ-7:** Produce a public, properly documented, experimental datasets of long-term products at global and regional scales and perform relevant scientific analyses over long temporal windows.

**OBJ-8:** Explore the potential impact of the products on science, applications and society through dedicated test cases carried out in collaboration with scientific, governmental and operational institutions outlining the benefits/limitations of the products and assessing their potential impact in different scientific and application domains.
Project team composition and partners

Team
Jamie Shutler (Science lead), Tom Holding
Peter Land, Helen Findlay
Nicolas Gruber, Luke Gregor
Yves Quilfen, Emmanuelle Autret, Jean-Francois Piolle

Scientific advisors
Dr Nicholas Reul (CCI), Prof. Richard Bellerby (GOA-ON), Dr Jo Salisbury, Dr Doug Vandemark, Dr Shubha Sathyendranath (CCI), Dr Kitack Lee, Dr Rik Wanninkhof (NOAA)

Partners
for impact and downstream studies.
**OceanSODA approach and timeline**

**OceanSODA (KO – KO+24)**

- **KO**
- **KO+3**
- **KO+8**
- **KO+12**
- **KO+15**
- **KO+18**
- **KO+22**
- **KO+24**

- **Task 1**
  - Reference Baseline (RB)

- **Task 2**
  - Algorithm development (ATBD)

- **Task 3**
  - Product validation (PVR)

- **Task 4**
  - Experimental dataset and scientific analysis (EDS, EDS-UM)

- **Task 5**
  - Impact assessment (IAR)

- **Task 6**
  - Scientific Roadmap (SR)

- **Task 7**
  - Project management (PMP, QRs, TDP, MR, FR)

- **Task 8**
  - Outreach, promotion and workshop (website, journal papers, workshop summary, brochure etc)

**Notes:**
- OceanSODA approach and timeline.
- KO to KO+24 timeline.
- Task 1: Reference Baseline (RB).
- Task 2: Algorithm development (ATBD).
- Task 3: Product validation (PVR).
- Task 4: Experimental dataset and scientific analysis (EDS, EDS-UM).
- Task 5: Impact assessment (IAR).
- Task 6: Scientific Roadmap (SR).
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**Testing:**
- Quasi-operational product supply.
Main project components

• Focus on basity (pH), Total alkalinity ($A_T$), aragonite saturation state ($\Omega_A$), but all analyses will also include total dissolved carbon ($C_T$) and partial pressure of $CO_2$ ($pCO_2$).
• Generation of a large matchup database, radial sampling of data around in situ data, and any missing parameters will be calculated (e.g. by using SeaCarb).
• Retraining for all empirical algorithms for each geographic region of interest.
• Develop an empirical pH.
• Develop neural network type approaches for $A_T$ (e.g. building on existing approaches for $pCO_2$).
• Inter-comparison to determine the combined uncertainties for each approach and region.

These results will then be used for:
• Three dedicated science and downstream impact/case studies (i) large river flows, ii) upwelling and iii) extreme ocean acidification and compound events.
• Co-created downstream impact studies in collaboration with WWF and NOAA.
• Stakeholder workshop.
• Scientific roadmap identifying future direction and opportunities.
Team responsibilities

**University of Exeter**: Overall science and management lead, river outflow case study and downstream study, quasi operational framework, contact with partners, website, stakeholder workshop.

**Plymouth Marine Laboratory**: in situ dataset collation, matchup database, algorithm retraining, algorithm inter-comparison, pH algorithm.

**ETH Zurich**: neural network approaches for all carbonate parameters, extreme OA and compound events case study and downstream study, stakeholder workshop.

**Ifremer**: EO data collation, radial extraction of data, upwelling case study and downstream study, quasi operational updating of EO datasets
OceanSODA will perform global analyses for extreme ocean acidification and compound events, characterise areas of large river outflows (freshwater discharge) in the Amazon (A), Congo (B), Mississippi (C), St Lawrence outflow (D); vulnerable eastern boundary upwelling systems, in the Benguela (E), Mauritanian (F) and Californian (G) systems and assess algorithms in Arctic waters (H).

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Inter-comparison of all approaches

Approaches for the carbonate estimates to be inter-compared and evaluated:
• Existing published algorithms.
• OceanSODA retrained algorithms.
• OceanSODA neural network approaches.
• CMIP6 model outputs.
• Regional model outputs (if appropriate).

• Main validation (reference) \textit{in situ} data: GLODAPv2 (Olsen \textit{et al.}, 2016) + updates.
• Round-robin inter-comparison and validation of all approaches for all regions.
• Use a suite of performance metrics.

Where possible all training data will be independent of test data.

Uncertainties
• All uncertainties will be propagated and/or used within the analysis (input data uncertainties, algorithm uncertainties and the GLODAPv2 \textit{in situ} data uncertainties).
• To achieve this we will have to estimate Type A uncertainties (from BIPM, 2008) for some datasets. e.g. WOA salinity, nitrate climatology, CORA re-analysis data.


Dedicated study 1: large river outflows

These episodic acidification events can damage marine life, including sensitive tropical reefs, wild fisheries and coastal aquaculture.

**Downstream study**: Quantifying the inorganic outputs of large rivers and identifying reef resilience to long term ocean acidification.
Dedicated study 2: Upwelling and its impact on the carbonate system

Downstream study: investigating links between upwelling driven changes in the carbonate system, and fisheries catches and recruitment.
Dedicated study 3: extreme ocean acidification and compound events


**Downstream study:** investigating the ecosystem and fisheries impact of extreme ocean acidification events and compound events.
Case studies: Science and downstream analysis

3 studies with each including scientific analysis and downstream impact studies. Each study will provide data for the WWF Atlas (to be used for guiding conservation efforts).

Study 1: Large river outflows

**Scientific analysis**
1. Identify the best regional empirical algorithm/inputs approach.

**Downstream impact study**
2. Quantify inorganic riverine inputs (temporal and spatial variability, extent and volume) into the N. Atlantic.
3. Identify regions where surface conditions imply high coral reef calcification rates (indicator of higher reef resilience to ocean acidification).

Study 2: Upwelling systems

**Scientific analysis**
1. Algorithm development.
2. Regional assessment of temporal frequency and spatial extent of upwelling.
3. Identify empirical linkages between upwelling flows and carbonate system.

**Downstream impact analysis**
3. Identify linkages between upwelling driven changes in carbonate system and fishery catches and recruitment.

Study 3: Extreme ocean acidification and compound events

**Scientific analysis**
1. Algorithm and method development.
2. Global scale assessment of extent and frequency of extreme ocean acidification and compound events.

**Downstream impact analysis**
3. Investigate the ecosystem and fisheries impacts of selected compound events (eg Eastern Pacific during 2014 and 2018).

Co-developed downstream studies

WWF

NOAA
Stakeholder workshop
To be held at the WWF ‘Living Planet Centre’ during 2020.