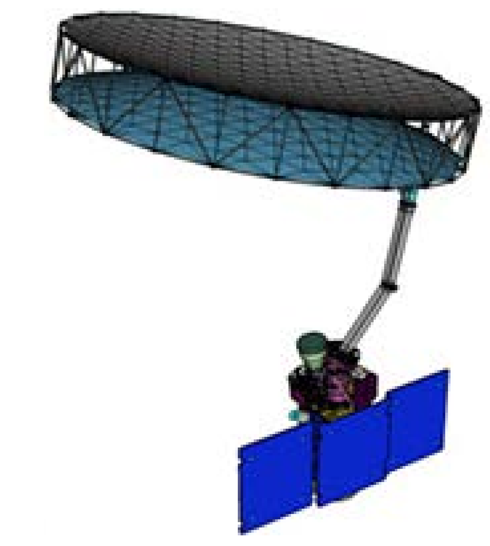
Implementing Operational Satellite Sea-surface Salinity Data Assimilation at NOAA



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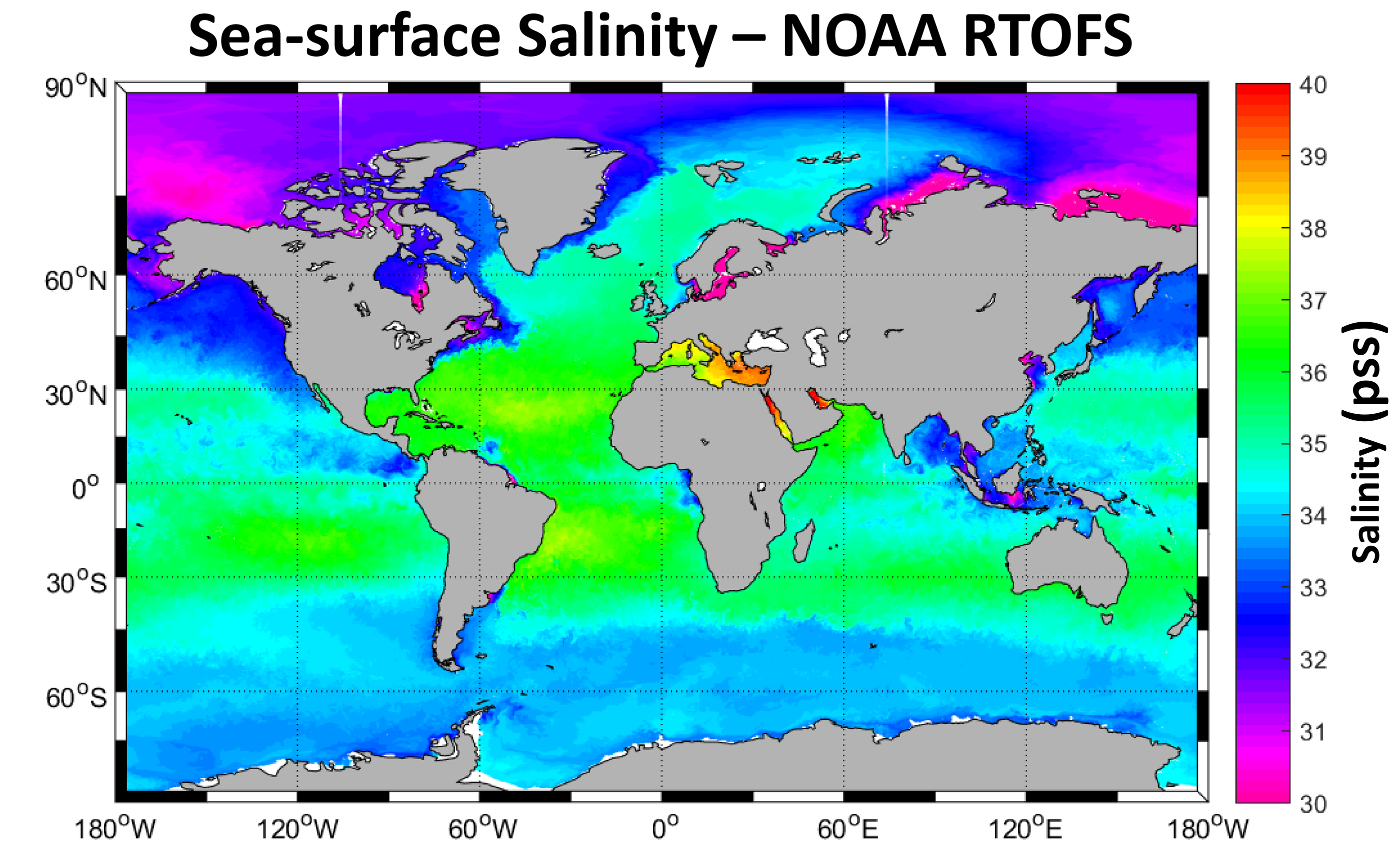
ABSTRACT: The assimilation of sea-surface salinity (SSS) data into numerical prediction models serves to extract value from the observations, as well as integrates those observations with other data to produce an optimal output. Sea-surface salinity observations from the European Space Agency's (ESA) Soil Moisture – Ocean Salinity (SMOS) mission and the National Aeronautics and Space Agency's (NASA) Soil Moisture Active-Passive (SMAP) mission are now sufficiently mature for assimilation into NOAA's operational models, in particular the Real-time Ocean Forecast System (RTOFS) and the Global Ocean Data Assimilation System (GODAS), the ocean component of NOAA's operational Climate Forecast System (CFS). The development of operational SSS data assimilation has now commenced full time. NOAA is operationally implementing the Navy Coupled Ocean Data Assimilation (NCODA) system; consequently, NCODA's SSS capability will be fully developed/refined and implemented. The development path is discussed.

Data:

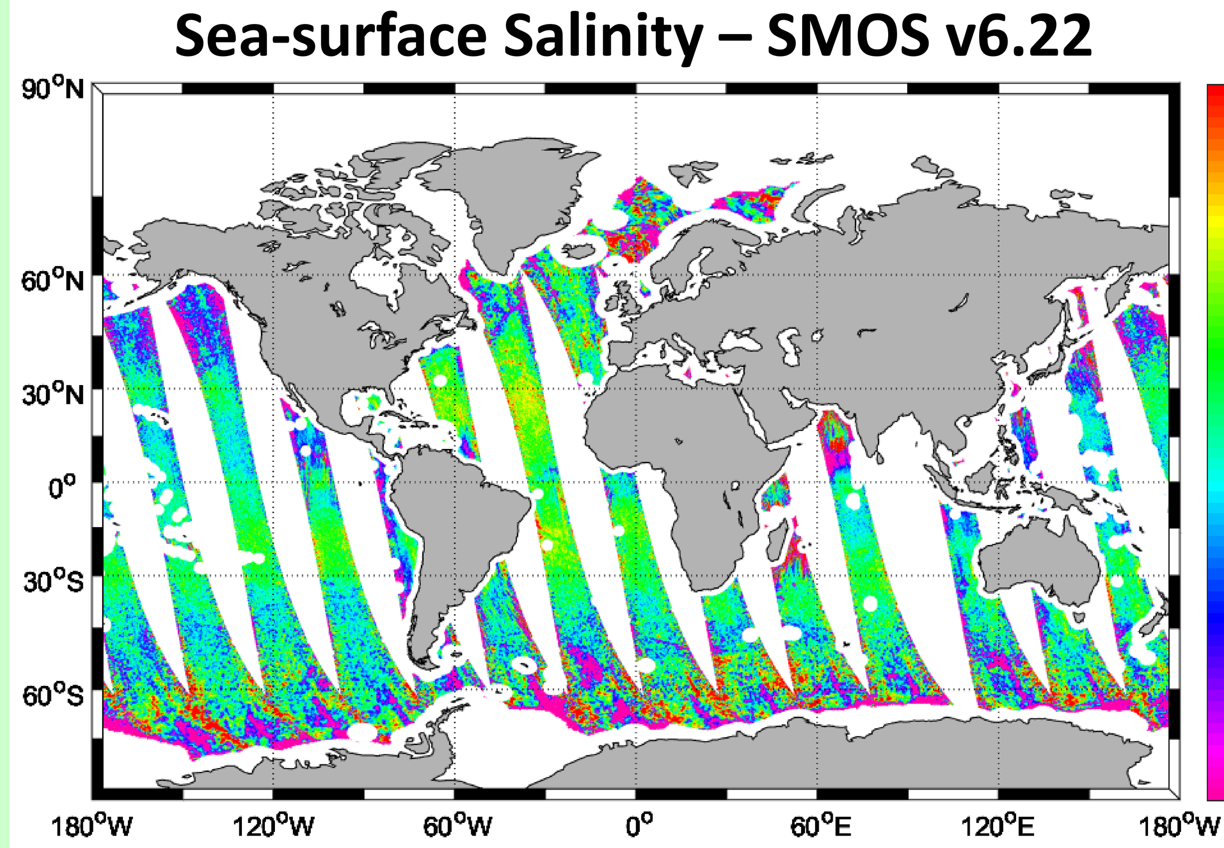
- SSS field from the NOAA operational 1/12th-degree RTOFS for 20 Apr 2017
- ESA SMOS SSS Level-2B v6.22 composite for 20 Apr 2017 (Data provided by the European Space Agency)
- NASA Jet Propulsion Laboratory (JPL) SMAP Level-2B Combined Active-Passive (CAP) v3.0 for 20 Apr 2017

Sea-surface Salinity – NOAA RTOFS

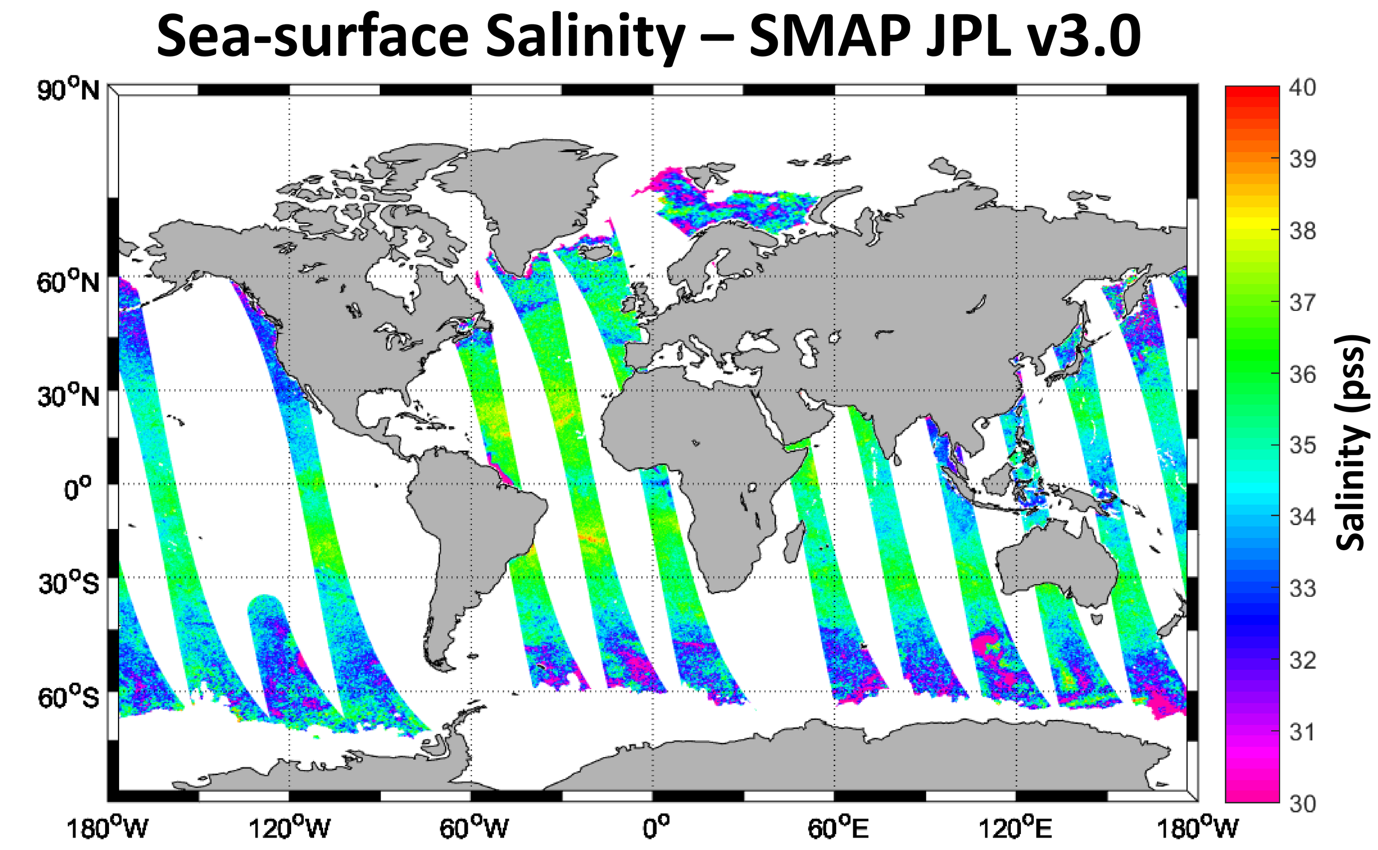


20 Apr 2017

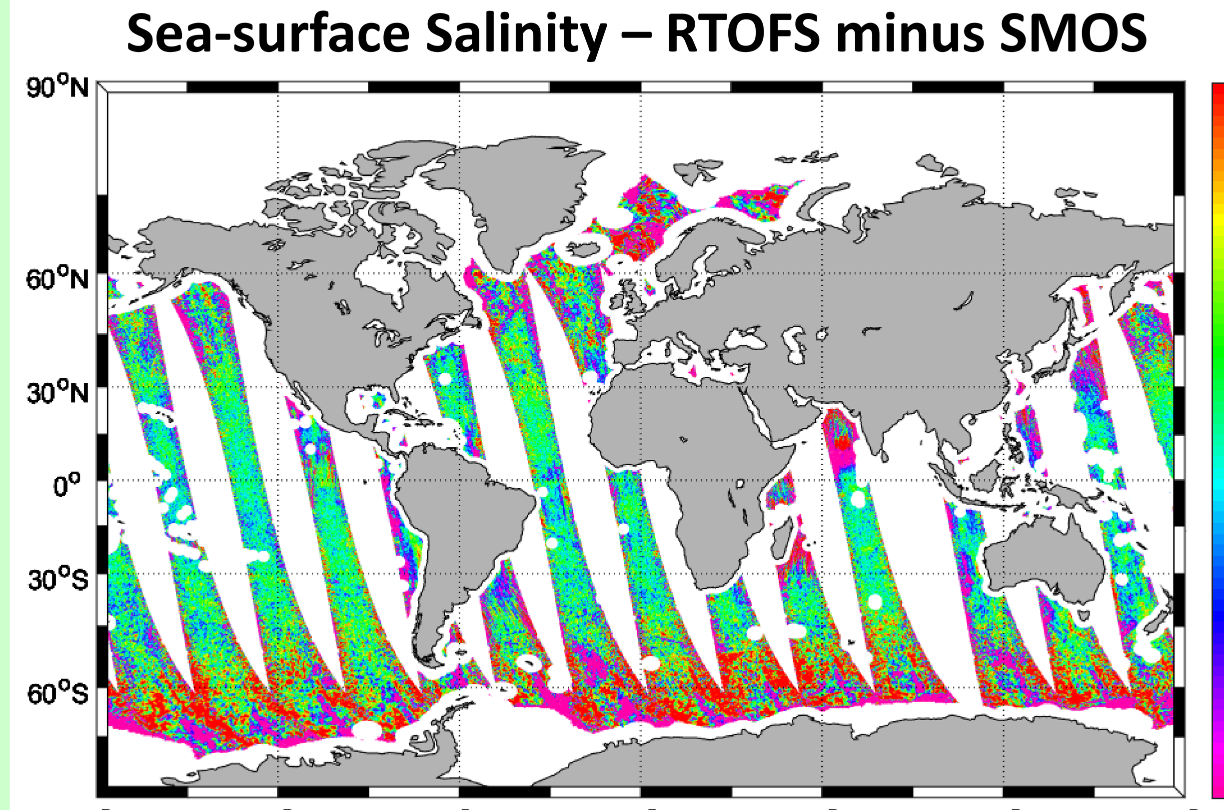
Sea-surface Salinity – SMOS v6.22



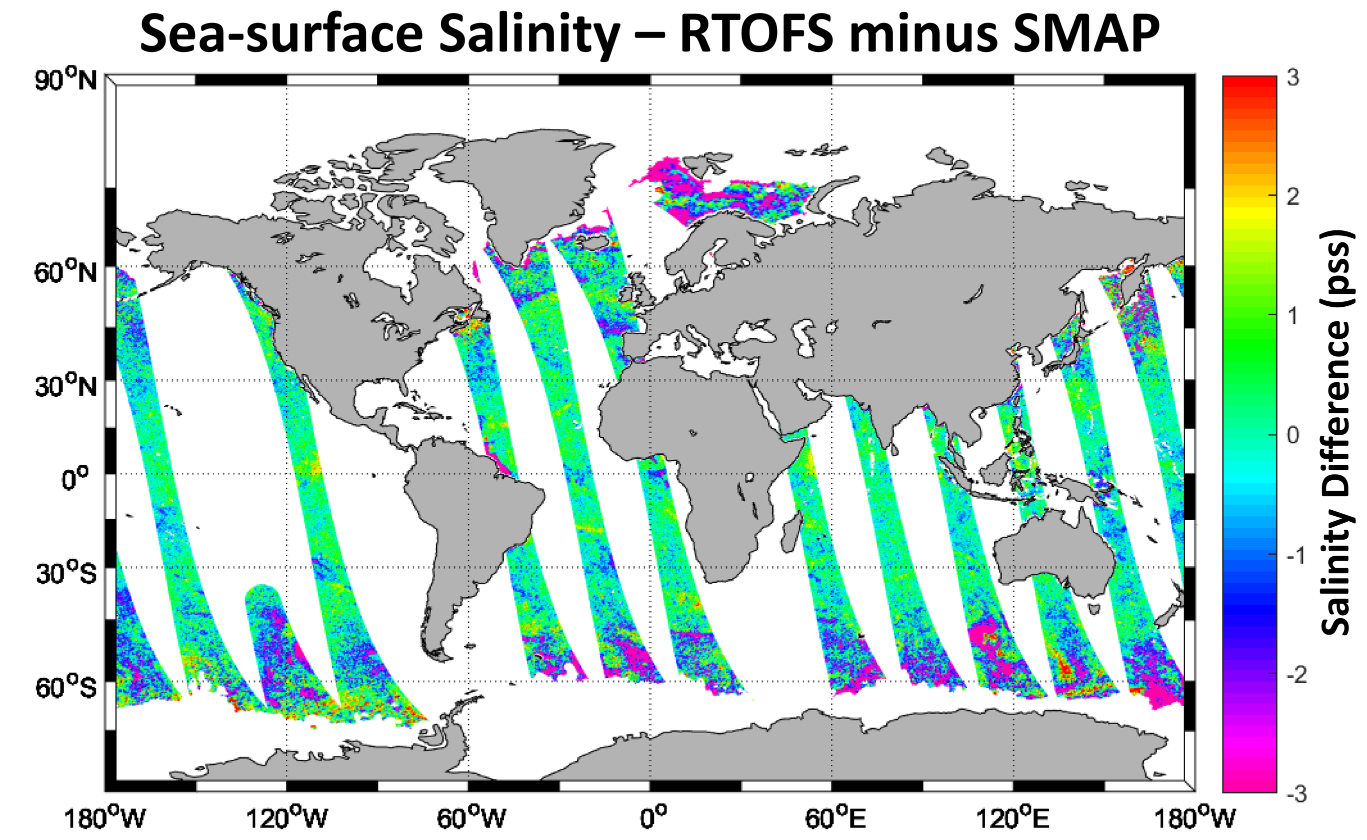
Sea-surface Salinity – SMAP JPL v3.0



Sea-surface Salinity – RTOFS minus SMOS



Sea-surface Salinity – RTOFS minus SMAP



For illustration purposes, all available data are shown (no flagging was applied). Pre-assimilation QA/QC can filter the data based on different flags reflecting ice contamination, wind speed, constraints of retrieval algorithm, rain intensity, radio frequency interference (RFI), etc. Suspect quality retrievals are noticeable along coastal boundaries (likely land/RFI contamination), as well as in the polar extremities of each swath due to reduced salinity signal at lower sea-surface temperatures and potentially higher wind speeds. RFI contamination is noticeable 100s km off coasts.

DATA ASSIMILATION CONSIDERATIONS:

In situ salinity observations for constraining numerical ocean models are relatively sparse, particularly with respect to typical model resolutions; consequently, satellite SSS observations, even with acknowledged uncertainty/accuracy, provide a constraint that is significant for surface density and associated thermohaline circulation. Satellite SSS also provides an additional constraint for the assimilation of satellite altimetry data and corresponding representations of mesoscale dynamics and upper-ocean heat content. When assimilating satellite SSS data, the SMOS and SMAP data streams have their own characteristics due to notably different instrument designs. The figures depict a sample (20 April 2017) of the NOAA RTOFS SSS field, along with the corresponding SMOS and SMAP data that would be considered for assimilation. Also depicted are the differences between the SMOS and SMAP observations and the model field, highlighting the relative magnitude and where assimilating those data streams would influence model results.

SMOS:

- An important consideration when using SMOS data is that SMOS Level-1 brightness temperatures (T_b) data are not statistically independent, but, rather, are correlated in a non-trivial way. Individual SMOS T_b measurements are quite noisy; therefore, to suppress noise, each reported T_b value is actually an estimate derived from measurements belonging to different snapshots and made with different incidence angles and radiometric characteristics. The number of measurements used to determine a single T_b estimate also varies depending on the across-track location for the estimate.
  - For data assimilation purposes, regridding the SMOS Level-2 data to a more optimal grid should be considered, one that reduces correlations between adjacent data (Talone *et al*., 2015)
- SMOS data have been shown to exhibit spatially and temporally varying biases versus other types of salinity measurements, as well as between ascending and descending passes.
- Uncertainty in some open ocean areas have been shown to be on the order of 0.3-0.5 Practical Salinity Scale 1978 (pss; UNESCO, 1981) for ascending passes, averaged over 10 days and 100x100 km (Boutin *et al*., 2012), but uncertainty substantially increases (5 pss and higher) towards coasts and ice-covered areas.
- Martin (2016) estimates that SMOS versus model SSS differences are 3-10 times higher than those for ARGO near-surface observations versus model SSS. Yet, Martin (2016) also demonstrates that SMOS SSS data include information about underlying ocean dynamics which can be used to correct the ocean state via data assimilation.

SMAP:

- The SMAP design is notably different from the SMOS instrument, relying on a scanning radiometer, rather than applying interferometry in conjunction with a synthetic aperture, as is done with the SMOS design.
- Increased uncertainty due to lower signal to noise **ratio** resulting from shorter radiometer dwell time and lack of aperture synthesis.
- Data include both a forward and a backward look, reducing ascending/descending directional biases.
- Notably less land contamination, effectively increasing usable coverage.
- Notably less radio-frequency interference (RFI), effectively increasing usable coverage.

TRANSITION PATH:

- Fiscal Year 2017 – During the reminder of FY17, efforts will focus on SSS data quality assurance (QA) / quality control (QC) for both the SMOS and SMAP data streams.
- FY18 – The initial task during FY18 will be setting up the Navy Coupled Ocean Data Assimilation (NCODA) system for SSS data assimilation, targeting completion during the first quarter (Q1). NOAA is currently implementing the NCODA system for NOAA operational use with Global RTOFS (HYCOM), with planned operational implementation at the beginning of FY19. During Q2 and Q3, a NCODA (SSS) proof-of-concept regional domain will be established and assessed, conducting hindcast feasibility experiments and assessing model stability, specifically evaluating a region with a major river outflow for artifact generation using data assimilation versus masking. During Q4, the objective is conducting global SSS data assimilation experiments with NOAA's Global-RTOFS.
- FY19 – Provided that the planned schedule is achieved, the objective is to integrate SSS data assimilation into the initial NCODA operational implementation; otherwise, SSS data assimilation will be implemented during the first NCODA upgrade. This alternate path provides for parallel RTOFS runs with SSS data assimilation during Q2 and Q3, followed by transition to operational implementation during Q3/Q4.

VALUE:

- Improved modeling of thermohaline circulation:
  - o Better representation and constraint of upper-ocean stability, thereby improving coupled ocean-atmosphere modeling, particularly with respect to moisture/freshwater and temperature fluxes
  - o Improved representation of upper-ocean heat content through better constraints when assimilating satellite altimetry data
  - o Improved representation of salinity and density fronts
- Improved state representation for ecosystem analysis and ecological forecasting
  - o Important parameter for biogeochemical modeling, in particular for modeling ocean acidification and habitat assessment

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