PREDICTING BOTTOM CURRENT DEPOSITION AND EROSION ON THE OCEAN FLOOR

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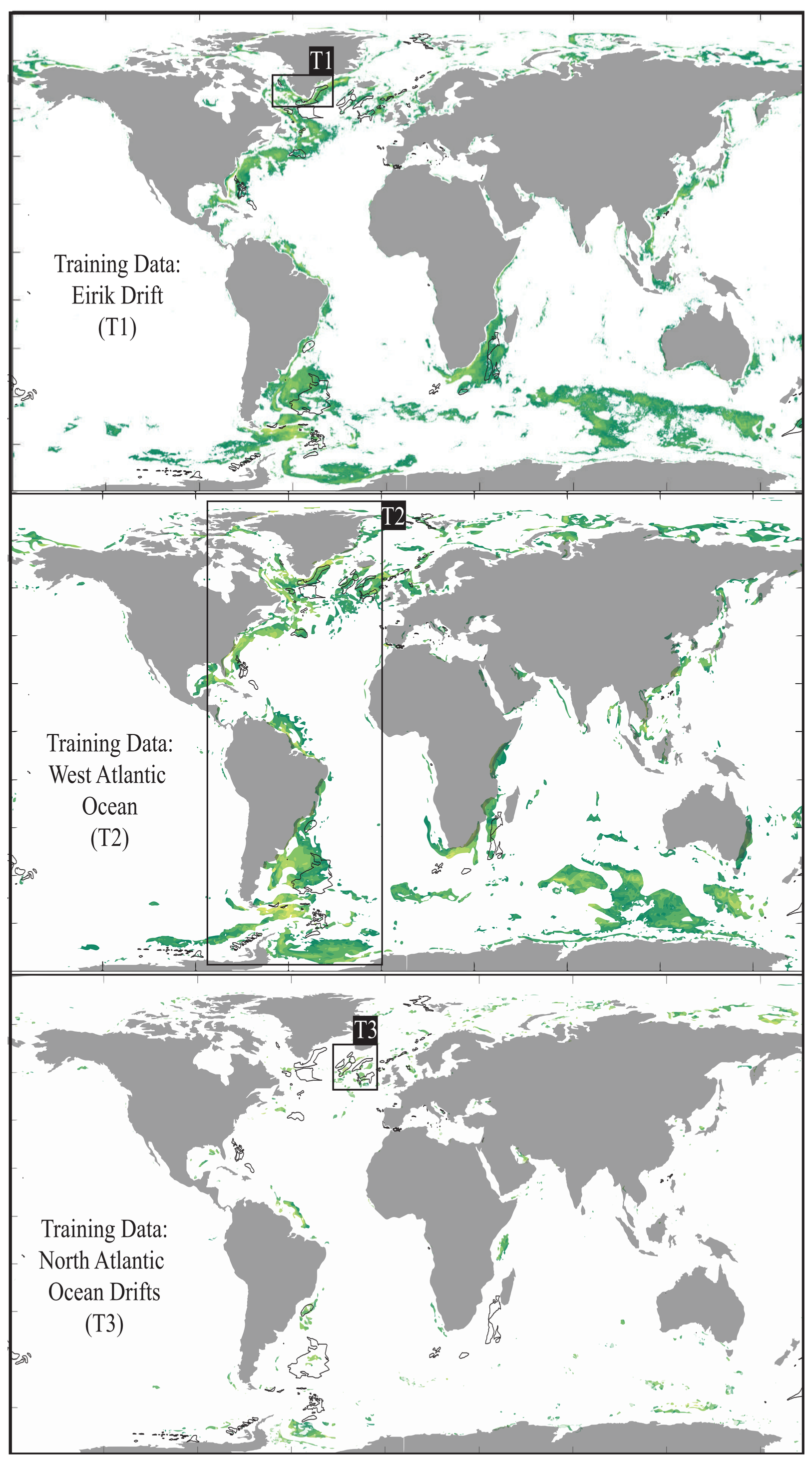
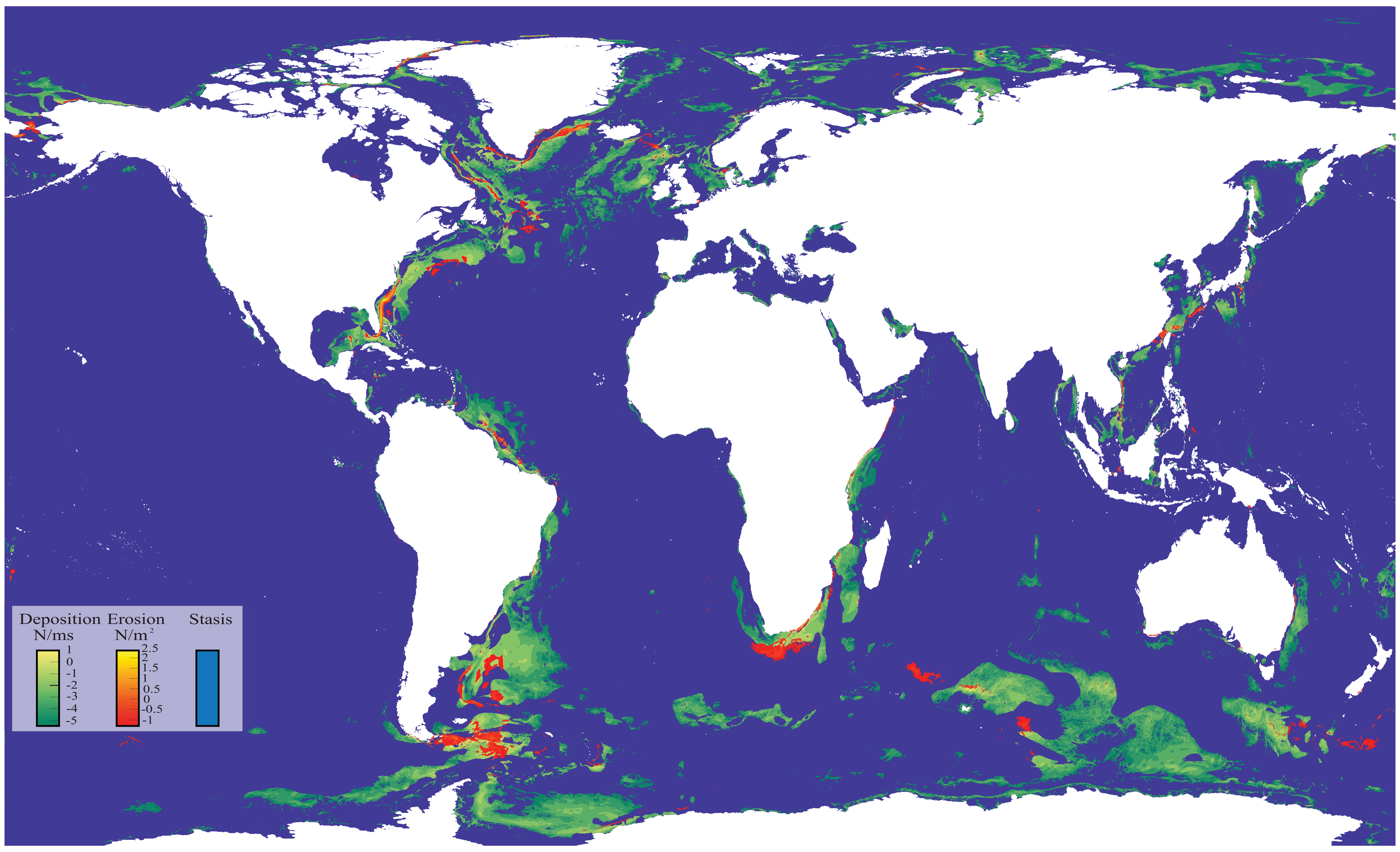
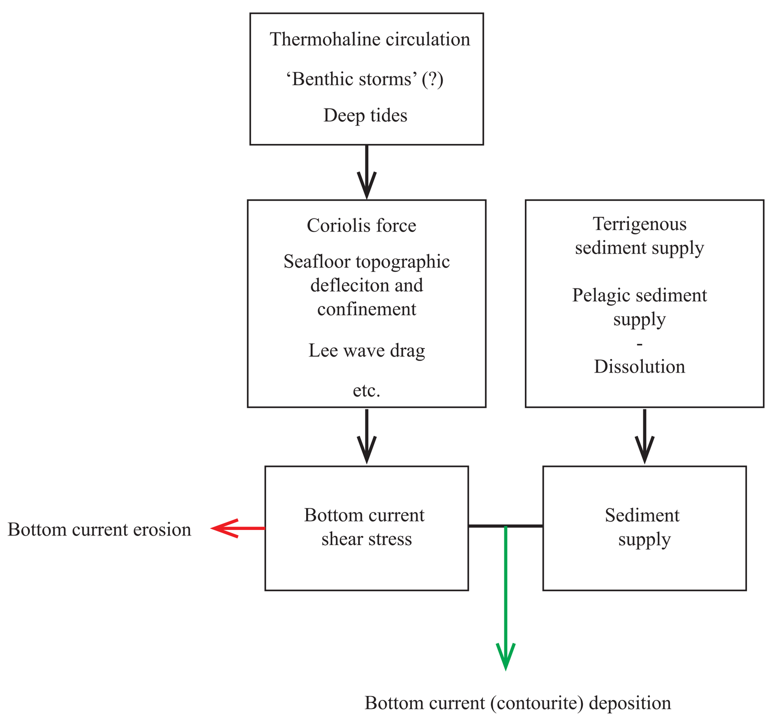
Abstract
Mapping sediment deposition and erosion by thermohaline ocean bottom currents is important for the development of ocean infrastructure, future geo resources and understanding the sedimentology of contourites and abyssal dunefields. However, only a limited percentage (estimated 20%) of the ocean floor has been mapped directly through seismic or sonar imaging. To better delineate where zones of bottom current deposition and erosion exist, we develop a prediction from numerical model solutions and sedimentological measurements of the ocean floor. This is achieved by integrating three types of data, which include: 1) Bottom current shear stress from a model run of the HYCOM numerical ocean model (Chassignet et al., 2019). 2) Sedimentation rates from ocean lithospheric age (Müller et al. 2008) and sediment thickness from the GlobSed Model (Straume et al., 2019). 3) The measured extents of bottom current deposits from sonar observations (the contourite atlas by Claus et al., 2017). Shear stresses and sedimentation rates inside and outside the mapped extents of bottom current deposits allow us to quantify the conditions that are conducive for bottom current deposition. These conditions are then extrapolated and displayed on a 1/12° arcsecond resolution map of the world's oceans, and validated through comparison with known mapped systems. Based on our prediction, around 12% of the ocean has significant deposition by bottom currents while only 1% has erosion. Most bottom current activity occurs where thermohaline currents impinge upon the ocean floor like on continental slopes or on some areas of the abyssal plain. Deposition and erosion also occur where constriction of ocean bottom currents takes place as in straits and seaways. Inland basins (i.e., seas) and continental shelves are mostly-disconnected from global-ocean thermohaline bottom current conveyers and therefore have limited bottom current deposition and erosion. Mid ocean ridges also have little bottom current deposition due which is due to low sediment supply.

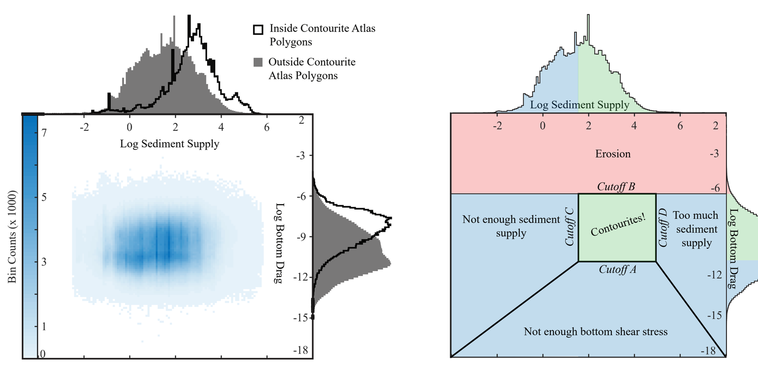


Right: Map prediction showing bottom current deposition (green) and erosion (red) and stasis, neither deposition nor erosion by bottom currents (blue). Input for this prediction is training dataset T2, which covers most of the Western side of the Atlantic Ocean. Various shades of green represent differences in the multiplicative of sediment supply and shear stress (energy flux density). Shades of red represent the amount of bottom shear stress. Note that deposition and erosion are in a different unit. All values in the legend are in log scale.

Left: Contourite atlas published in Claus et al. (2017). Locations of contourites and bottom current deposits in this dataset are determined from direct observations using sonar and drill core data. Black polygons represent the mapped extents of contourites and abyssal dunefield. Black boxes titled T1, T2 and T3 show the outlines of the various Training datasets. Table 2. Prediction cutoff values following model training on the West Atlantic training data subset (T2). Values in the legend are in log scale

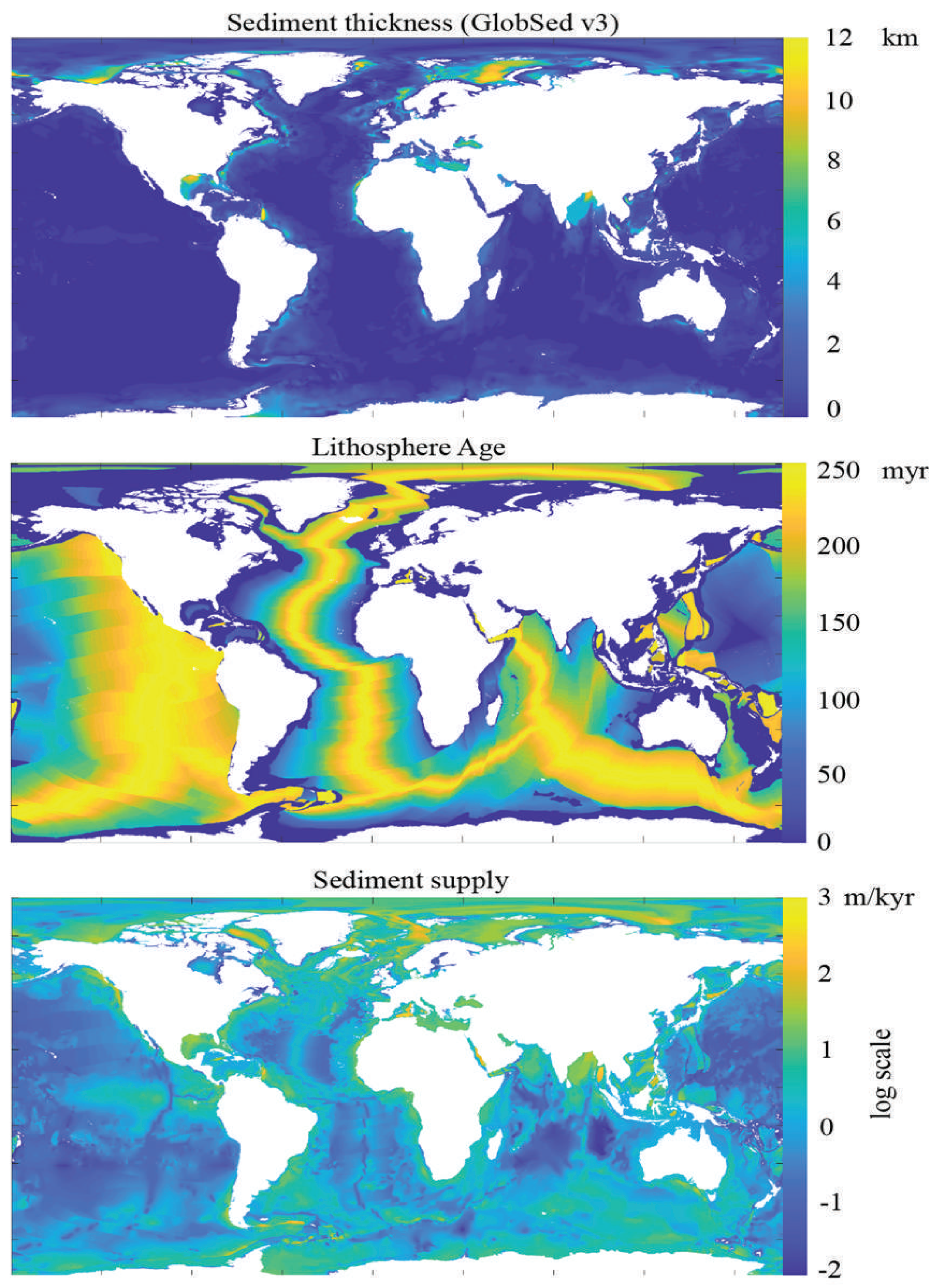


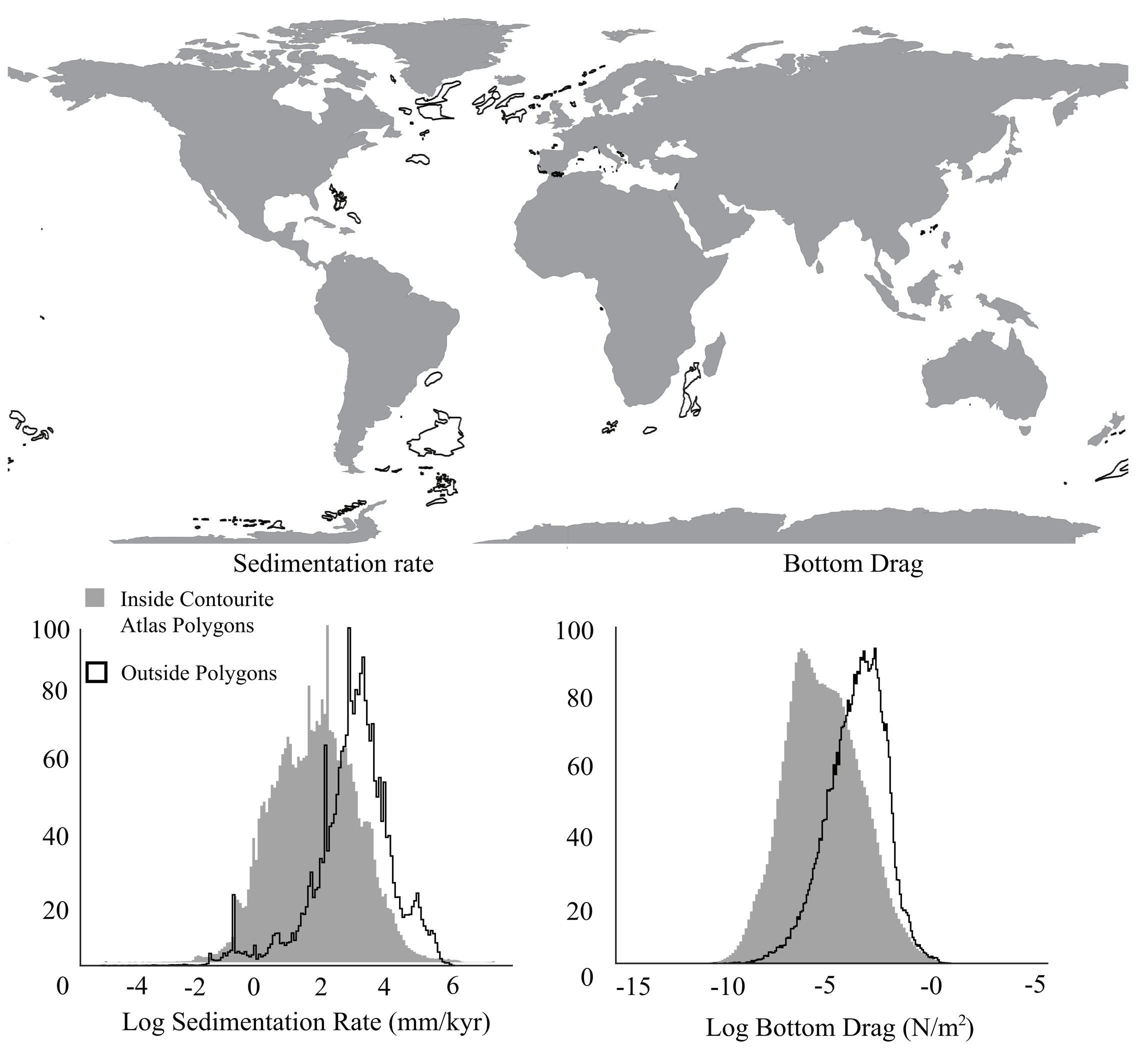




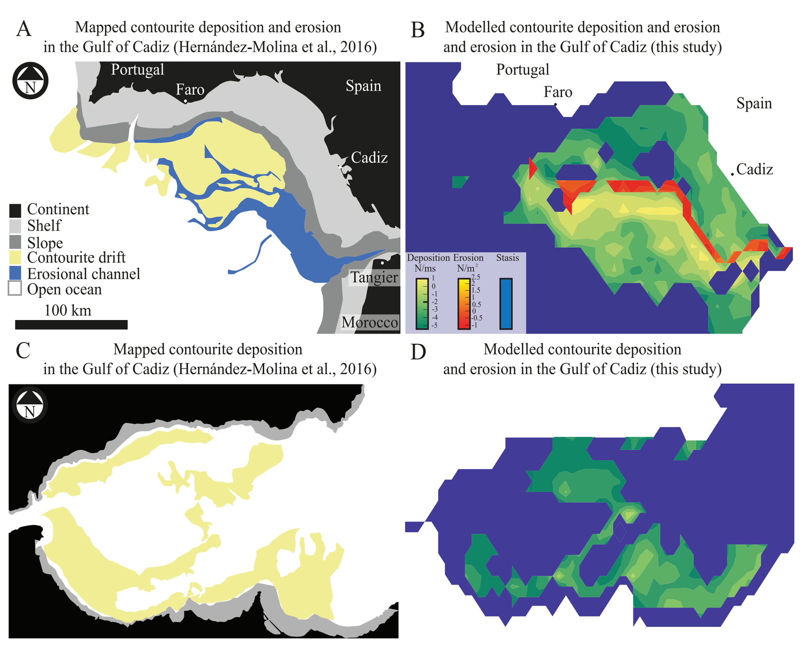
Top: Schematic diagram showing the interactions of processes to form bottom current deposits. Thermohaline circulation and some other processes combine with Coriolis force to generate bottom shear stress. Sediment supply is mostly from terrigenous input transported into the ocean through gravitational processes. Bottom shear stress and sediment supply can combine locally to generate bottom current deposits. When bottom shear stress is too strong for deposition, erosion occurs. Adapted from Faugères et al. (1993). An illustration portraying a similar concept is in Rebesco et al. (2014).

Bottom: Density scatter plot with Sediment supply on the X-axis and bottom shear stress on the Y-axis (both are log axes). Both parameters are lognormally distributed across the ocean. Density scatter shown the frequency of data points with a certain value. Histograms show the same data. Black polygon shown sediment supply and bottom shear stresses inside the mapped polygons of the contourite atlas, showing contourites form in areas with relatively high sediment supply and bottom shear stress. B. Same as in A but with the various regimes that indicate bottom current deposition, erosion and stasis visualized.

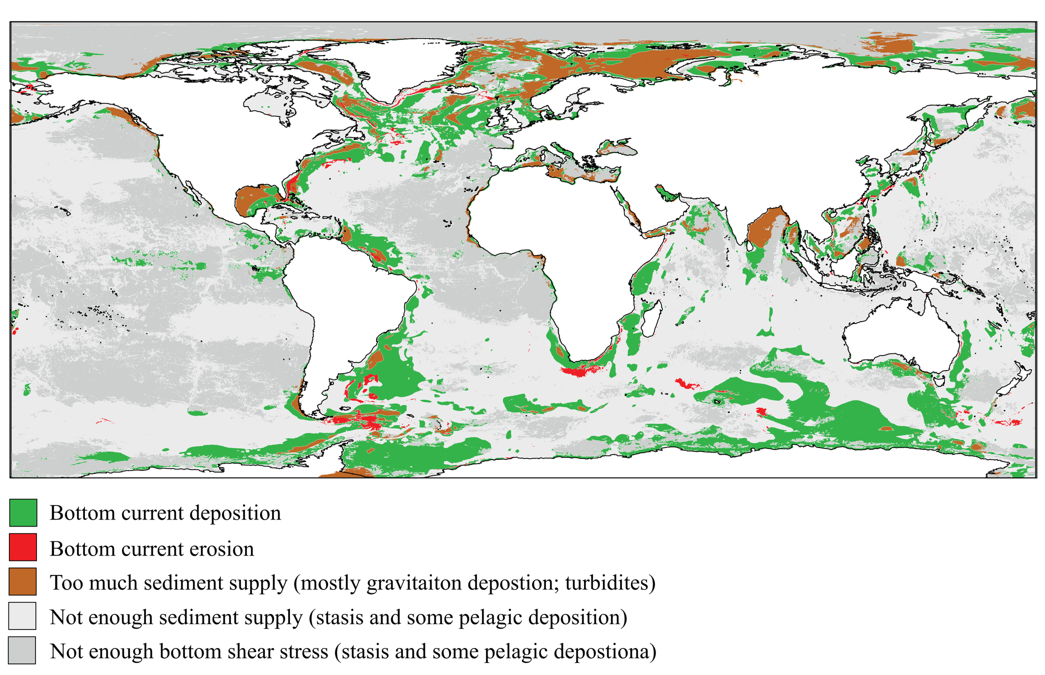


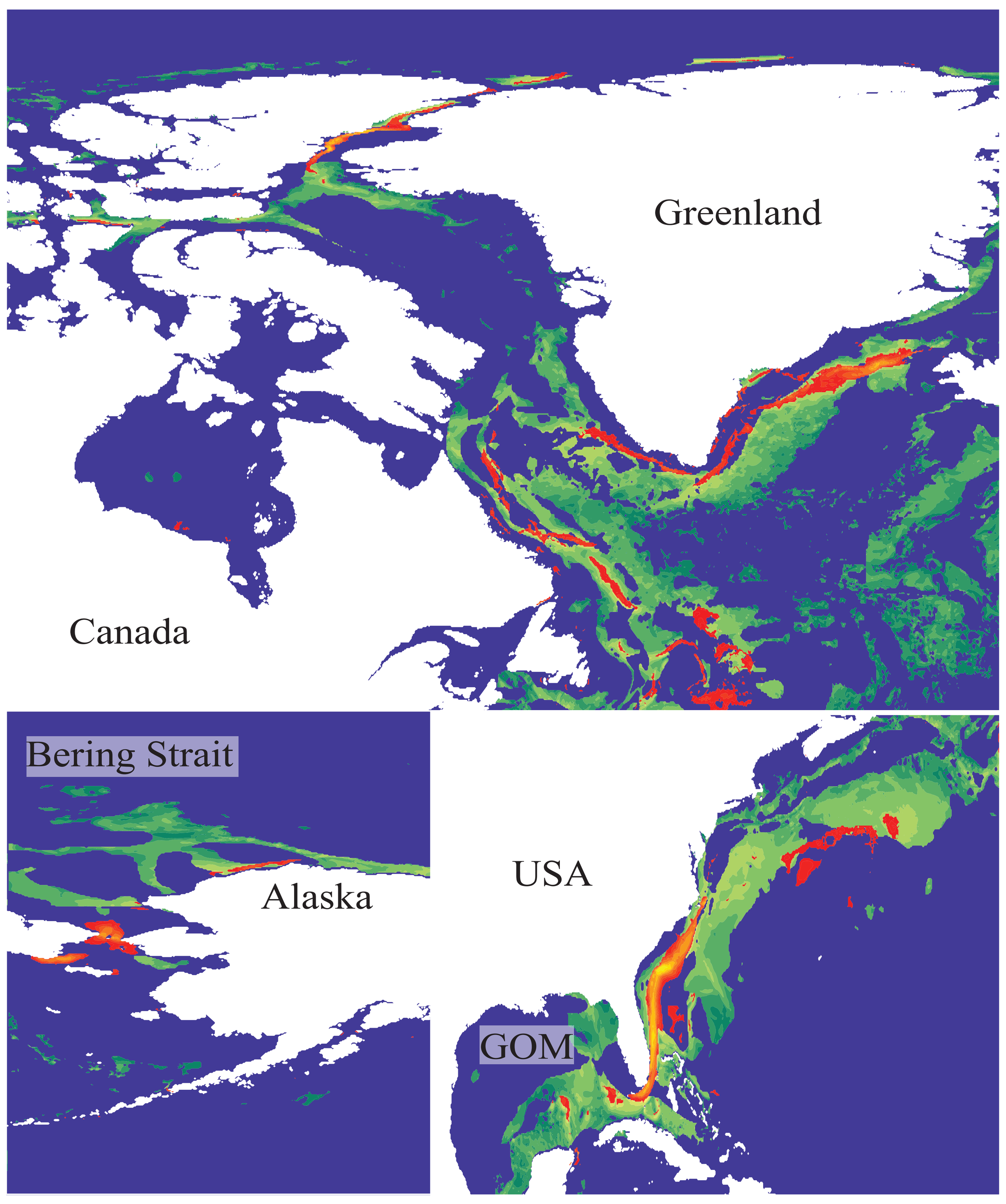


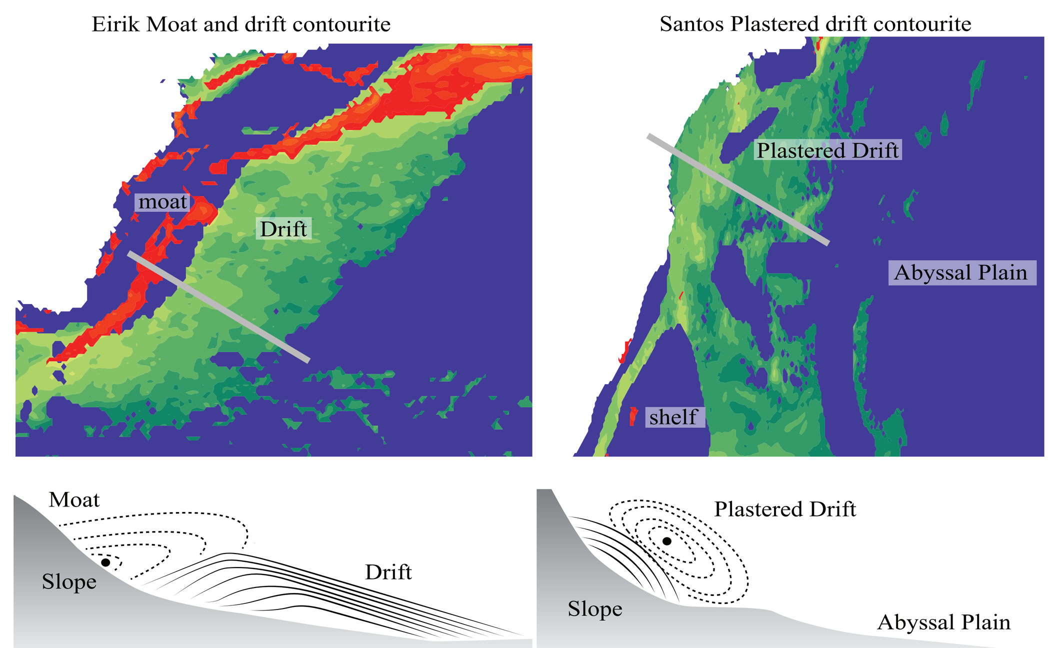
Top: World map showing polygons from the contourite atlas (Claus et al., 2017). Frequency histograms showing values for sedimentation rate (bottom left) and values of bottom shear stress (bottom right) across the world's oceans. Data represented in the filled grey histograms represent the entire ocean. Data represented by the transparent histograms represent values inside the contourite atlas polygons and thus represent sediment supply and shear stresses across mapped contourites. Although there is a lot of overlap in the data, contourites tend to have significantly higher amounts of sediment supply and bottom shear stress than regions of the oceans where no contourites have been detected.



Validation of the map prediction through comparison of plan-form extents and geometries of contourites that are outside of the input training data. A: map prediction of the Gulf of Cadiz shows an erosional moat surrounded by contourite depositional systems flanking the moat. C: map prediction of the Alboran Sea contourites shows a distribution of contourites that is similar to the mapped extents of plastered and elongated drifts according to Ercilla et al. (2016). Values in the legend are in log scale.







Conlusions
This study integrates three types of oceanographic data to prediction the distribution of bottom current deposition and erosion. These data types are: 1), models of bottom shear stress from the HYCOM numerical ocean model (Chassignet et al., 2019), 2) sediment thickness from the GlobSed ocean sediment thickness map (Straume et al., 2019) and 3) a map of known contourites and bottom current deposit occurrences (the contourite atlas) by Claus et al. (2017). We utilize an especially well-mapped area of the Western Atlantic Ocean as a subset of our data to train our model to known occurrences of bottom current deposits. Regimes for likely bottom current deposition and erosion are derived from this model training exercise and these regimes are then used to develop a global prediction. We define three condition across the ocean floor; bottom current deposition, bottom current erosion, and bottom current stasis (neither deposition nor erosion). The planform dispersal of these conditions is then used to formulate generalized patterns that govern the incidence and dispersal of depositional and erosional bottom current systems across the world's oceans. Areas showing high probability for bottom current deposition include continental slopes affected by boundary currents and barotropic vortices, and around submarine mounds, platforms and other obstructions on the seafloor. Areas showing high probability of erosion include confined areas (e.g. sea straits) and continental slopes affected by strong erosional boundary currents. Areas showing a high probability for stasis include zones of deep water upwelling, zones of deepwater formation, mid-ocean ridges, some continental shelves that have limited bottom shear stress, and enclosed basins and seas.
The results presented here can lead to improved models for seafloor mining and energy extraction as well as a more complete understanding of the conditions of thermohaline deposition and erosion on the ocean floor. Future improvements to this study can be made by populating the data presented here, with additional information that includes various ocean floor lithologies and sediment grainsizes.