Science II: Large Scale Ocean Circulation Variability and Change summary

Summary

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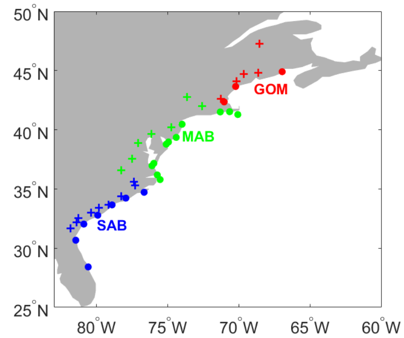
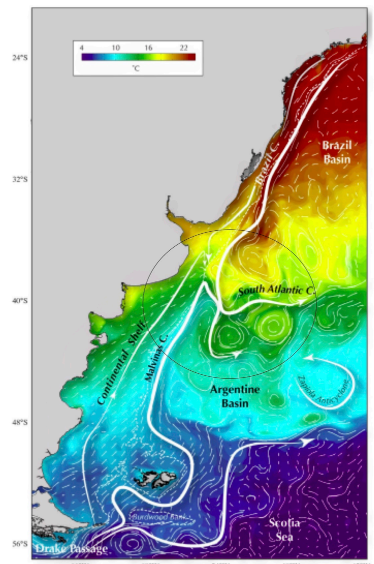
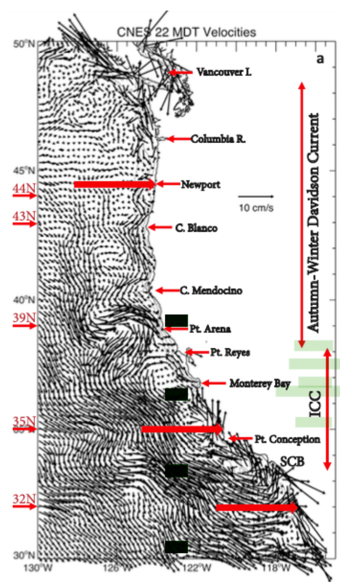
Using satellite altimeter data, tide gauge observations and analytical models combined with empirical model, it has been shown that interannual sea level anomalies (SLA) along the U.S. northeast coast – in the Mid-Atlantic Bight (MAB) and Gulf of Maine (GOM) - since 1993 are dominated by local forcings through longshore wind and atmospheric pressure over the shelf, with remote forcing from the subpolar ocean also having significant contribution. In contrast, in the U.S. southeast coast (i.e., the South Atlantic Bight (SAB)), remote forcings from the open ocean (via westward propagating Rossby waves and the upstream Gulf Stream variability) have comparable contribution to the local forcings over the shelf (W. Han, the University of Colorado, USA).



In the Southwestern Atlantic basin, interannual variability of the cross-shelf transport is suggested to be driven by variability of the Brazil Current. By analyzing the eddy permitting ORAP5.0 ocean reanalysis product from ECMWF which assimilated satellite altimeter data, Bodnariuk and coauthors showed that the leading EOF mode of velocity normal to the coast exhibits a dipole pattern, with onshore (offshore) flow in the north corresponding to offshore (onshore) flow in the south. This dipole pattern is related to the latitude of separation of the Brazil Current (LSBC), which shows 2-year, 4-year and 10-year pseudo periodicities. The westward propagating 1st baroclinic mode Rossby waves across the Atlantic impinge onto the Brazil Current, modulating the BC and cross-shelf transport. The 2-year cycle of the Rossby waves is thought to be linked to the Indian Ocean Dipole (N. Bodnariuk, Universidad de Buenos Aires, Argentina).

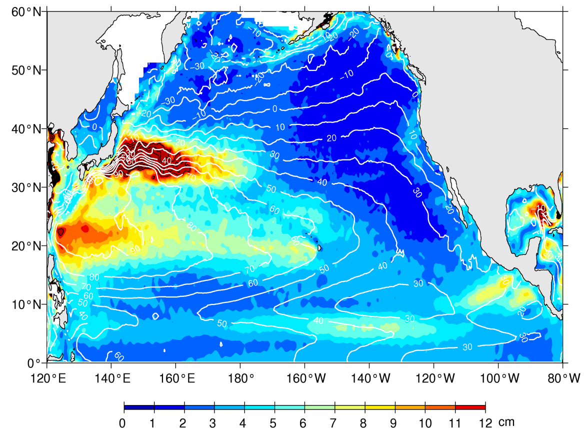


In the northeastern Pacific, the absolute geostrophic velocities derived from satellite altimeter (both two-sat and all-sat), together with the OSCAR Ekman transport in the top 30m, are used to calculate the daily Lagrangian trajectories using the "Parcels" software, to track the poleward transport and zooplankton distributions in the California Current System. It is shown that in one year, passive water parcels can arrive off Oregon coast from the Southern California Bight (30°N), and in multiple years, from ~26°-27°N and from the west. During years with greater numbers of parcels reaching 43°N and 45°N, there appear southern "warm water" species and greater "species richness" off Oregon which are often associated with El Niño warm events or Marine Heat Waves. The water parcels travel in the semi-permanent poleward Inshore California Current in the south during summer-fall and in the poleward Davidson Current during fall-winter, and horizontal eddy-diffusion makes them more likely to reach higher latitudes (T. Strub, Oregon State University, United States).

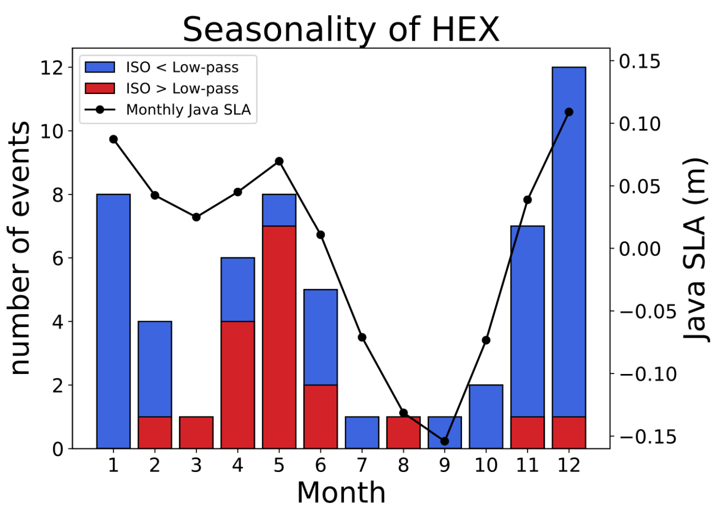


In the northwestern Pacific, the Kuroshio extension (KE) system alternates between unstable and stable states, and SLAs in the southern recirculation gyre region (31°N-

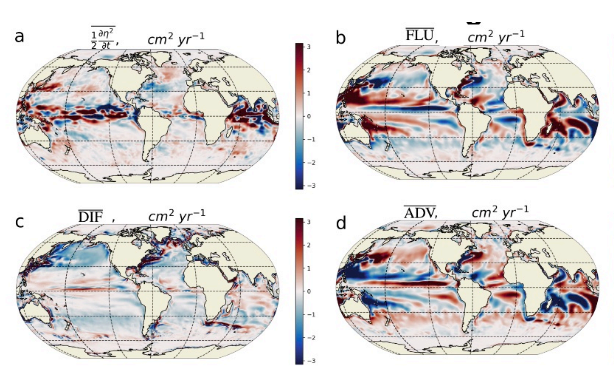
36°N, 140°E-165°E) can well represent the synthesized KE index. After 2018, the KE system entered a super stable state, which reduced eddy perturbations east of Izu Ridge and facilitated large-meander (LM) paths. The persistent LM contributed to a poleward migration of the KE jet, and the northerly KE path further strengthened the stable KE system. The question is: What caused the super stable KE and prolonged Kuroshio LM after 2018? The dipolar interior wind stress curl anomalies across ~32°N weakened the southern part of the subtropical gyre and the upstream Kuroshio, which is inducive to the LM path; but they strengthened the northern part of the subtropical gyre, KE, and northerly KE path, which is inducive to KE's poleward migration, less KE eddies east of Izu Ridge and stronger recirculation gyre, stabilizing the upstream LM, and reinforcing the stability of the KE state (B. Qiu, University of Hawaii, USA).



In the Indian Ocean, daily satellite altimeter data together with tide gauge observations since 1993 were used to detect sea surface High EXtreme (HEX) events along the Indonesian coasts that border the eastern tropical Indian Ocean. The role of atmospheric intraseasonal oscillations (ISOs), which are dominated by the Madden-Julian Oscillation (MJO), in causing the HEXs are examined. It has been shown that intraseasonal SLAs induced by atmospheric ISOs are significant contributors to HEXs in coastal Indonesia. In 32% of the 56 HEX events detected, the amplitude of ISO-induced SLAs exceeds that of seasonal-to-decadal SLAs. Both the remote zonal wind stress from the equatorial Indian Ocean and alongshore wind stress at the Indonesian coasts play important roles in driving the HEXs. The ISOs caused more HEX events during boreal spring than winter, because during spring the MJOs are associated with stronger convective anomalies over the eastern equatorial Indian Ocean compared to winter, which drive stronger zonal winds across the equatorial basin that lead to more HEXs in spring (W. Kamp, the University of Colorado, USA; poster).

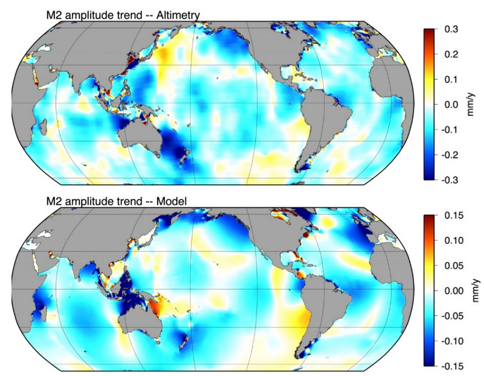


In the Northern Hemisphere winter, sea level can reach 20 cm below its summer values. It is customary to associate these variations to the seasonal cycle of sea surface net heat flux. The prevailing hypothesis is that, the excess of heat received by the ocean leads to a thermal expansion of the surface water that in turns creates a positive steric sea level anomaly. Using a novel framework based on steric sea level variance budget applied to

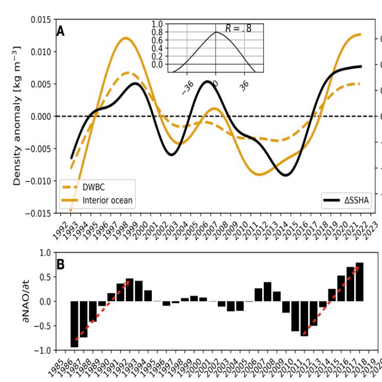


observations and to the ECCO v4r3 model, A. Hochet et al. demonstrate that the seasonal cycle of steric sea level results from a balance between the seasonal sea surface net heat flux and oceanic advection (see figure). At midlatitude and in the eastern parts of low-latitude regions, surface heat fluxes act to damp the seasonal steric sea level cycle generated by oceanic advection processes. Eddies also play an important role in damping the steric sea level seasonal cycle. (A. Hochet et al., Laboratoire d'Oceanographie Physique et Spatiale (LOPS), Brest, France).

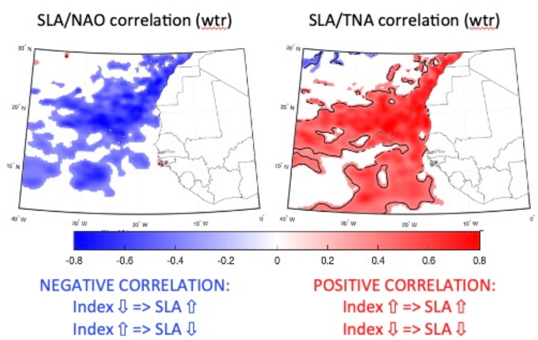
A number of investigations have reported ocean stratification increasing over the past half-century. Increasing stratification induces an increase in barotropic-to-baroclinic tidal conversion, with a tendency for amplified internal tides at the expense of the surface tide. Such changes in both barotropic and baroclinic tides are revealed by three decades of satellite altimetry and 3-D numerical ocean simulations. The latter delineate how the tides change in response to stratification. Analyses are based strictly on Topex-Poseidon, Jason, and Sentinel-6 data on the primary ground-track. Altimetric trends in the barotropic tide are prone to potentially large systematic errors, especially from tidal leakage in the DAC correction, which is partly caused by errors in ECMWF atmospheric tides. For the 30-y trend in the M2 barotropic tide, altimetry and model simulations both show open-ocean amplitude trends predominantly negative, roughly 0.1-0.2 mm/y (see figure). Mapped baroclinic tides usually display positive trends, at least near large generation sites, with some exceptions (R. Ray, et al., NASA/GSFC, U.S.).



The overturning circulation of the subpolar North Atlantic (SPNA) plays a fundamental role in Earth's climate variability. Increased density anomalies are seen at the intergyre boundary in the eastern SPNA since 2016, due to enhanced subpolar overturning driven by the NAO in the preceding years (see figure). As deep positive density anomalies spread southward along the western boundary, they enhance the North Atlantic Current and associated meridional heat transport, leading to an increased influx of subtropical heat into the eastern SPNA. This result is confirmed by a Lagrangian analysis based on altimetry-derived geostrophic velocities. The increased heat transport can mainly be explained by the gyre circulation, as shown in a range of ocean reanalyses, and has a specific large-scale sea-surface height imprint in the North Atlantic Ocean (C. Leon, Stockholm University, Sweden).



This study by Cardoso et al. analyses the mean annual and seasonal ocean circulation and mesoscale ocean dynamics in the Eastern Tropical Atlantic Ocean (ETAO) region (3°-30°N; 40°W-0°) over a 28-year period (1993-2020) and correlation with climate indices. Sea level anomaly (SLA; see figure), eddy kinetic energy (EKE) and surface geostrophic currents show pronounced seasonality. The mean rising rate in the ETAO region is 3.25 mm/year, higher than global average. Highest values (5 mm/year) of the northeastern area at (28°-30°N, 40°-27°W) may be associated with the Azores Current. Moderate values (3.5-4 mm/year) south of 10°N might be influenced by the North Equatorial Counter Current (NECC). Linear trends of EKE and surface geostrophic currents exhibit decreasing rates, in contrast to the positive linear trends observed globally, that may be influenced by the NECC. SST appears to be the primary driver explaining the correlation between SLA and climate indices. Wind forcing also contributes to the correlation between SLA and some CI although its influence is confined to the northernmost area of the study region. Sea level pressure contribution explains part of the correlation only for some indices and during limited seasons. The magnitude of surface geostrophic current anomalies appears influenced by the NECC (I. Cardoso, Faculdade de Ciências, Universidade do Porto (FCUP), Porto, Portugal).



SSH measurements collected in the Kuroshio twice a day from the Global Navigation Satellite System (GNSS) are used by K. Ichikawa et al. to study the impact of the Izu Ridge on changes in the meandering path of the Kuroshio (see figure). SSH is determined by the antenna height from a reference surface, with correction of the distance between the antenna and the sea surface. Observations capture the signature of the northern branch of the Kuroshio at 35°N downstream of Oshima Island, and the southward meander of the Kuroshio at 139°E. Postprocessed kinematic positioning is necessary to provide accurate SSH variations. Additional calibration and validation are necessary to provide reliable estimates (K. Ichikawa, RIAM, Kiushu University, poster).