IODP Proposal Cover Sheet

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Campeche Bank Sediment Drifts

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Title	In the Loop: western boundary current onset and evolution in the southeastern Gulf of Mexico
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Proponent Information

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Abstract

The North Atlantic western boundary current represents the northward-flowing limb of Atlantic Meridional Overturning and thus plays a key role in hydrography and climate on both a regional and global scale. Recent analyses of instrumental observations of the best-known part of this western boundary current, the Gulf Stream, indicate a reduction in current flow as a result of anthropogenic warming. The possible outcomes of such a slowdown, and its implications for global climate, hydrography, ecosystems, and the people who depend on them, are still uncertain. An important part of the urgent effort to answer those questions is reconstructing the history of the western boundary current in order to determine how it responded to past warming events, the mechanisms controlling its behavior, and how that behavior impacted climate and ecosystems. The Loop Current is the main feeder current for the Gulf Stream and a key component of the western boundary current system. As it flows into the Gulf, the Loop Current impinges on the seafloor on the eastern Campeche Bank, leaving a record of its passing in the form of contourite drifts. These drift deposits are sedimentary archives of western boundary current flow which record the inception and evolution of the Loop Current, and can provide an important way to reconstruct western boundary current flow through the Cenozoic and how that current changed in response to events on a range of timescales, from millennial-scale events like deglacial transitions and shifts in the intertropical convergence zone to long-termer term warm climate states like the mid Pliocene Warm Period and Miocene Climate Optimum, to tectonic gateway changes like the closure of the Central American Seaway. Understanding the response of the Loop Current to these events can help us understand how sensitive it is to such changes, and whether it is susceptible to threshold behavior.

We propose a Mission Specific Platform expedition utilizing a standard geotechnical vessel to drill the pelagic carbonates of the eastern Campeche Bank sediment drifts to 1) date key reflectors and tie shifts in depositional regime to the climatic and tectonic history of the Cenozoic, 2) utilize a suite of proxy tools to reconstruct changes in current flow in response to those climatic and tectonic events and 3) reconstruct ecosystem changes in response to changing current properties. This work addresses the Flagship Objective “Ground Truthing Future Climate Change” and a number of Strategic Objectives.

Scientific Objectives

The primary objective of drilling on the Campeche Bank is to reconstruct the history of the western boundary current flow through the Gulf of Mexico through time, and then tie that history to key climatic, tectonic, and ecological transitions to understand the drivers and impact of changing western boundary current flow. To achieve this objective we aim to test the following hypotheses:

Hypothesis 1: Western boundary current flow drives changes in North Atlantic circulation and thus the global climate system, and flow dynamics are recorded by Campeche Bank sedimentation patterns.
a. Unconformities in the Campeche Bank drifts correlate with global circulation changes recorded in other drift deposits in the North Atlantic and elsewhere.
b. Western Boundary Current flow is sensitive to external forcings at a variety of timescales, ranging from gateway changes and major climate transitions to sea level variability, freshwater input, and shifts in the position of the Intertropical Convergence Zone (ITCZ).
c. Disruptions to low latitude ocean circulation facilitate abrupt climate change.
d. The Loop Current exerts an important control on Gulf of Mexico and North American climate, and also influences Northern Hemisphere (i.e., downstream) climate regimes.

Hypothesis 2: Changes in western boundary current flow impacts marine ecosystems
a. Strengthening western boundary current flow drives marine ecosystem distribution.
b. The evolution of western boundary current flow is coupled to upwelling dynamics and nutrient cycling that impacts marine ecosystems.

Non-standard measurements technology needed to achieve the proposed scientific objectives

Have you contacted the appropriate IODP Science Operator about this proposal to discuss drilling platform capabilities, the feasibility of your proposed drilling plan and strategies, and the required overall timetable for transiting, drilling, coring, logging, and other downhole measurements?

yes

Science Communications Plain Language Summary

Using simple terms, describe in 500 words or less your proposed research and its broader impacts in a way that can be understood by a general audience.

Ocean currents help distribute heat across the world, and so they play in important role in global and regional climate. In the North Atlantic, warm salty water is transported from the tropics to the polar region by the western boundary current. The best known part of this current is the famous Gulf Stream, which flows from the Florida Straits up along the Atlantic coast of the United States. Recent observations have shown that the Gulf Stream (and by extension, the entire western boundary current system) is weakening due to global warming. While such instrumental observations are a critical way to understand the behavior of current systems, they are limited to the scope of change in the recent past, which likely doesn't represent the full range of changes that can occur. To understand that, we need to reconstruct the history of currents on geologic time scales. Doing so allows us to see how currents behaved under past warm states similar to what is projected to occur under current emissions, and it also allows us to see whether currents respond linearly to change or whether they exhibit threshold behavior. That is, whether a slow accumulation of change eventually causes the current to dramatically shift into a new state.

A good place to study the history of the North Atlantic western boundary current is in the Gulf of Mexico, where the Loop Current flows in from the Caribbean and then out through the Florida Straits, where it joins with several smaller currents to become the Gulf Stream. The Loop Current is also important for Gulf of Mexico climate, as it sometimes spins off warm eddies which drift west, disrupting fisheries and providing a warm water fuel source for hurricanes (notably including hurricanes Katrina and Harvey). It is still unknown whether eddy shedding will become more or less frequent in the future, although this is broadly tied to the strength of the current. As it flows across the seafloor east of the Yucatán Peninsula, the Loop Current pushes sediments around, forming big deposits called contourite drifts. These drifts represent sedimentary archives of the history of the Loop Current. We propose to drill those drifts to reconstruct that history, in order to improve our understanding of how the modern current is changing.

Review Response

Submission Type: Resubmission from previously submitted proposal

This proposal builds off 917-PRE “Revisiting the Mesozoic to Pleistocene in the Southeastern Gulf of Mexico: Plate Tectonics, Ocean Circulation, and Climatic Evolution.” SEP highlighted indicated excitement for several aspects of this proposal and recommended submission of a full proposal that addressed the points raised in the review.

The SEP suggested a narrower focus, and so this full proposal is focused on hypotheses about evolution of the western boundary current (specifically investigating the Loop Current, the portion of the western boundary current that flows through the Gulf of Mexico and is the main feeder of the Gulf Stream), its role in North Atlantic Circulation and thus the global climate system, and its implications for marine ecosystems. These objectives are aligned with the “2050 Science Framework: Exploring Earth by Scientific Ocean Drilling” (Koppers and Coggon et al., 2021). The hypothesis testing outlined in the proposal will permit evaluating the susceptibility of the Loop Current (and precursor flows/conditions) to abrupt and irreversible change, and the potential for inducing tipping points in Atlantic Meridional Overturning dynamics that currently modulate earth’s climate regime. The SEP review highlighted the need to define a drilling plan; the full proposal details a plan for drilling five sites (with options for the implementation of MSP expeditions of different lengths) that include late Cenozoic deposits that likely record initiation of the modern Loop Current, along with underlying Paleogene and Cretaceous strata that record conditions of the Western Boundary Current (such as proto-Loop Current and/or precursor current flow) during high pCO2 “hothouse” climatic conditions.

A key requirement identified by SEP was the need for new seismic data to generate digital high to medium resolution imaging of intervals of interest and regional context and for development of robust stratigraphy for the scientific objectives. A multichannel seismic survey cruise was carried out in July 2022 on the R/V Justo Sierra by a joint team of US and Mexican scientists. This cruise was focused solely on the Eastern Campeche Bank sediment drifts, although it was not able to extend the seismic coverage to nearby DSDP Site 95, because we were unable to get permission to survey in the Cuban EEZ. SEP review requested a full explanation of the methodological approach and proxies that would be used to assess environmental change, and we now lay out key proxies and other approaches to test each hypothesis with the core material we expect to recover.
Finally, SEP noted that the proponent list was entirely American (a result of this the pre-proposal coming out of a US workshop) and requested diversification of the nationalities represented by proponents. To that end, we held the USSSP workshop to develop the present proposal in August 2023 at the National Autonomous University of Mexico in Mexico City, and were able to secure limited MagellanPlus funding for ECORD participation. As a result, the proponent group includes five Mexican, one French, one British, and one Portuguese researchers, representing collaboration between the regions impacted by the Loop Current and the Gulf Stream.

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Proposed Sites (Total proposed sites: 7; pri: 5; alt: 2; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
CB-01A (Primary)	24.18678 -87.32817	751	410	0	410	Site CB-01A is situated at a thick, continuous succession of contourite drift deposits which will provide an expanded sedimentary archive of the Loop Current through time (Hypothesis 1b-d), and the biotic response to those changes (Hypothesis 2a-b). The onset of drift deposits here is marked by horizon H4; The TD is planned to be 40 m in the underlying predrift sequence to determine the duration of this unconformity (Hypothesis 1a). An internal drift horizon, H5, appears conformable in this location, and drilling here will provide an age for this shift in drift deposition (Hypothesis 1a).
CB-02A (Primary)	22.96684 -86.59342	648	390	0	390	Site CB-02A is the proximal site of a stratigraphic transect along seismic line 1006. This site is chosen because both sequence boundaries H5 and H4 are conformable and thus will record the age of the onset of the drift (H4) and the major reorganization of the current that occurs at the time of the formation of sequence boundary H5 (Hypothesis 1a). In addition, the upper drift sequence above H5 is expanded here and potentially contains a record of current changes related to glacial-interglacial cycles (Hypothesis 1b).
CB-03A (Primary)	23.02050 -86.42609	969	450	5	455	CB-03A forms the middle of our depth transect. The drift here are thin, but separated by conformable sequence boundaries, allowing dating to reconfirm the onset and reorganization of the current deposits (Hypothesis 1a). These drifts overlay a relatively thin pre-drift sequence. Thus, this site is designed to reconstruct early Cenozoic and Late Cretaceous current flow across the Campeche Bank, prior to the development of drift deposits (Hypothesis 1b). This site will also contain a Cretaceous/Paleogene boundary sequence. TD is planned in the underlying platform carbonates, to reconstruct the transition from platform carbonate to pelagic sedimentation (Hypothesis 1a).
CB-04A (Primary)	22.45198 -86.09336	1127	375	0	375	CB-04A is the deepest primary site, located on seismic line 1004 at the far southeast of the survey (Figure 10). This site targets a thick sequence of MSB3 drift deposits in the Yucatan Channel that likely record an earlier phase of deepwater circulation, prior to the onset of modern-day Loop Current activity (Hypothesis 1a-d). TD is planned in the Upper Cretaceous interval, just below the ~75 m thick K-Pg boundary deposit.
CB-05A (Primary)	23.89116 -87.19259	585	250	0	250	CB-05A is located at the intersection of seismic lines 1003 and 1009 at the northern end of the survey. This site has been selected to drill a shallow section (50 m penetration) through CWCs that are developed in this area of the Campeche Bank (Hypothesis 2b). CWCs on the Campeche Bank are directly related to current strength, which shifts with changing sea level between glacial and interglacial times (Hypothesis 1b). In the event we carry out Operational Plan C, we will extend CB-05A to Horizon H3, to provide age constraints on the key bounding unconformities of the contourite sequence.
CB-06A (Alternate)	22.2970 -86.3331	690	450	0	450	CB-06 provides an alternative site at which to recover the entire sequence of Cenozoic units on the Campeche Bank in a relatively condensed interval, but one that is more expanded than CB-05A, which fills this role in our primary sites.
CB-07A (Alternate)	22.27419 -86.40650	432	560	0	560	CB-07 is an alternative site at which to recover the entire sequence of stratigraphic units on the Campeche Bank