IODP Proposal Cover Sheet

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North Sea Late Cenozoic Environments

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Title	Late Cenozoic Glaciers, LAndscapes, Climates, and Ecosystems of the North Sea (GLACE-NS)
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Area	North Sea

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Abstract

Intensification of glacial-interglacial cycles at the Pleistocene onset (~2.6 Ma) was a critical transition in Earth's climate history. The increased severity of cold conditions triggered the development of continental-scale ice sheets, which then affected the global climate system through complex ocean-atmosphere-cryosphere linkages. Besides estimates of global ice volume with poor spatio-temporal control, little is known about late Plio-Pleistocene ice sheet fluctuations during the shift from 'Greenhouse' to 'Icehouse' conditions, or the change to greater ice volumes during the Middle Pleistocene Transition (~1.2-0.8 Ma). Our inability to reconstruct the extent of ice sheets through these major climate shifts limits our understanding of the causes of long-term climate change and the ways in which ice sheet feedback loops influence environmental change. The North Sea Basin (NSB) contains a ~1.2 km-thick marine record of the late Plio-Pleistocene that, unlike the land-based record, preserves an almost complete archive of erosion and deposition by Europe's ice sheets and large river systems. Thus, the sequence preserved in the NSB is a significant palaeo-climate archive of late Plio-Pleistocene climate-environmental linkages. While the NSB is extensively-covered by industry data, the late Plio-Pleistocene interval lacks samples providing geological control on existing palaeo-climate interpretations. This proposal outlines the merits of drilling the NSB to unravel how glaciers, landscapes, climate, and ecosystems evolved and interacted through the late Plio-Pleistocene. The expedition would contribute knowledge on natural climate variability, analogues of past warmer climates, tipping points, and rates of change. The mid-latitude location of the NSB allows for linkages between low- and high-latitude records, and potential feedbacks and teleconnections of northwest European climate with other parts of the climate system – e.g., European ice sheet influence on North Atlantic storm tracks. A particular focus on ecosystem evolution will reveal climate- and biology-related feedbacks, resilience, recovery, and carbon cycle dynamics. The results would tie into IODP Strategic Objectives 3-5 and Flagship Initiative 1 (ground-truthing future climate change) and will contribute to better calibration of numerical Earth-system models, knowledge on climate sensitivity and variability, and a wider appreciation of feedbacks within the Earth-system. The ability to cover such a wide range of themes, at a scale that captures changes from across northwest Europe, can only be achieved through continuous coring of this uniquely-complete late Plio-Pleistocene succession. The fact such insight can be generated from a modest amount of drilling emphasises why the NSB should be considered a high-value IODP target.

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Scientific Objectives

The principle aim of this drilling campaign is to unlock the North Sea sedimentary record of climate and environmental evolution in northwest Europe through the late Plio-Pleistocene. This will help us to unravel how Glaciers, Landscapes, Climate, and Ecosystems evolved and were coupled through the late Plio-Pleistocene glacial-interglacial cycles, including the transitions to warmer-than-present intervals that may act as analogues for future climate transitions. The specific objectives are:

1. To document the first ice sheet advances into the North Sea Basin (NSB) and the linkages between ice-ocean-climate fluctuations in northwest Europe and global climate forcings (e.g., orbital insolation cycles).

2. To characterise the sediments in the NSB and determine the spatio-temporal connections of the associated landscape-forming processes (e.g., fluvial systems, ocean currents, and glaciers) with the boundary conditions controlling palaeo-ice sheet dynamics, allowing for testing of hypotheses on global ice volume changes and ice sheet geometries through the Pleistocene.

3. To investigate how the climate of northwest Europe evolved across the Pliocene-Pleistocene boundary, through the Early Pleistocene, the Middle Pleistocene Transition, and between different glacial-interglacial cycles, demonstrating how these climate changes influenced other parts of the Earth-system through oceanographic and ice sheet transitions.

4. To document the nature and speed of productivity turnover in marine and lowland terrestrial ecosystems, investigate their role in the carbon cycle, and understand the response (and resilience) of communities to climate tipping points in successive glacial-interglacial cycles, including the super-interglacials that act as an analogue for contemporary warming.

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.

The shape of the Earth's orbit around the Sun is not static and changes on different timescales. This affects the amount of energy received from the Sun through time. From about 3.3 million years ago the Earth's climate transitioned from warmer conditions to colder conditions as greenhouse gas levels decreased and reduced the warming blanket that it ordinarily provides. This made the climate more susceptible to changes in the Earth's orbit, eventually leading to the onset of the ice ages at about 2.6 million years ago. Since then, the Earth experienced approximately 50 ice ages, with warmer periods in between. The North Sea Basin (NSB) is an area that was heavily impacted by these ice age cycles as climate fluctuated between fully glacial to warmer-than-present conditions. A major consequence of successive glaciations is that the evidence for one glaciation can be wiped out by the next. In a marine setting with ample space for continuous sediment accumulation, this pattern does not always hold true, resulting in greater potential to preserve all the sediments deposited. These sediments should be thought of as a 'tape recorder' that contain an almost complete record of these glacial-interglacial episodes, providing insight on Europe's past climate, ecology, and large river systems over the last ~3.3 million years. In the NSB, this record is preserved in a ~1.2-km-thick sediment package beneath the contemporary seafloor. Relatively little is known about how Europe evolved during repeated ice age cycles, except for that we know roughly when the ice ages occurred and what impact they possibly had on global sea level. In this drilling campaign, we aim to collect geological samples from three boreholes that will be used to unlock the North Sea 'tape recorder' and the climatic, environmental, and ecological information it contains. This will help us to unravel how glaciers, landscapes, climate, and ecosystems evolved and interacted through the ever more intense ice age cycles since 2.6 million years ago. This is crucial because we know that ice sheets of the past, and present, have feedback loops whereby one part of the Earth's climate system can impact another, but these relationships are not fully understood. In a contemporary context, our records of observation are too short in time to get a handle on the rates of environmental changes that we are currently experiencing and whether comparable rates were common in the past. The extraordinary NSB record contains episodes of rapid environmental changes under conditions that can be considered as analogues for modern changes. Hence, the record will tell us about baseline dynamics and thresholds for depositional and ecosystem regime shifts, and biodiversity turnover driven by rapid climate changes – in essence, the inner workings and impact of the climate system. Understanding these feedback loops will help us to envisage the environmental responses to modern day warming, and allow for more appropriate plans to be put in place to minimise the potential consequences.

Review Response

Submission Type: Resubmission from previously submitted proposal

The proponents are grateful to the Science Evaluation Panel for their positive comments of the Pre-Proposal and the helpful suggestions for where improvements could be made for the Full Proposal. In response to the specific comments from the panel, the proponent list has been widened to improve diversity in expertise, location, career stage, and gender. This was already agreed at an associated workshop for when the project progressed to a Full Proposal. The full proposal provides more detail on how the GLACE-NS project relates to the 2050 Science Framework. Detailed description of the proposed drill sites is provided – e.g., their anticipated lithological characteristics and drilling considerations – including how these relate to the stated objectives. Three independent drilling plans have been developed and include drill site locations and drilling strategies. Each plan is discussed with the associated logistical trade-offs and how the scientific deliverables relate back to the objectives. The full proposal expands on specific themes noted by the panel – e.g., the global and regional context and significance. Links to other projects have been developed, including current preparations for IODP drilling on the British-Irish margin and offshore northeast Greenland. The panel requested that Exp347 in the Baltic Sea should be discussed. Since Exp347 covers only the last interglacial-glacial-interglacial cycle, the insights into the development of multiple glacial-interglacial cycles and feedback loops are limited. This is a key reason why our own proposal seeks to investigate the full suite of cycles through the late Plio-Pleistocene. However, despite the differences in timelines, Exp347 does showcase the wealth of detail that can be extracted through one cycle when sedimentation rates are high (>100 cm per 1000 years). Although the stratigraphic setting of this proposal is not directly comparable (e.g., maximum sedimentation rates are generally up to ~50-70 cm per 1000 years), the detailed insights from Exp347 on a single cycle will be beneficial for the tens of cycles that this project will work on. Such a synthesis will allow us to see if the mechanisms from the single Exp347 cycle can be identified in all cycles, and, if not, what the possible implications of that may be.

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Proposed Sites (Total proposed sites: 11; pri: 3; alt: 8; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
NSN-01A (Primary)	57.6967 1.5550	94	1200	0	1200	Recover a high-resolution palaeo-climatic/environmental record of Early-Middle Pleistocene succession in the North Sea Basin. Site NSN-01A is targeting stratigraphic units SU4 to Brunhes-Matuyama magnetic reversal event representing an expanded Calabrian interval and the Mid-Pleistocene Transition (MPT). The upper stratigraphy (~300 m) is likely to cover the Middle and Late Pleistocene period and will consist of pro-to-subglacial sediments.
NSN-02A (Alternate)	57.5118 1.2290	90	1200	0	1200	Recover a high-resolution palaeo-climatic/environmental record of Early-Middle Pleistocene succession in the North Sea Basin. Site NSN-01A is targeting stratigraphic units SU4 to Brunhes-Matuyama magnetic reversal event representing an expanded Calabrian interval and the Mid-Pleistocene Transition (MPT). The upper stratigraphy (~300 m) is likely to cover the Middle and Late Pleistocene period and will consist of pro-to-subglacial sediments.
NSN-03A (Alternate)	57.6756 1.6819	89	1200	0	1200	Recover a high-resolution palaeo-climatic/environmental record of Early-Middle Pleistocene succession in the North Sea Basin. Site NSN-01A is targeting stratigraphic units SU4 to Brunhes-Matuyama magnetic reversal event representing an expanded Calabrian interval and the Mid-Pleistocene Transition (MPT). The upper stratigraphy (~300 m) is likely to cover the Middle and Late Pleistocene period and will consist of pro-to-subglacial sediments.
NSN-04A (Alternate)	57.5078 1.3908	91	1200	0	1200	Recover a high-resolution palaeo-climatic/environmental record of Early-Middle Pleistocene succession in the North Sea Basin. Site NSN-01A is targeting stratigraphic units SU4 to Brunhes-Matuyama magnetic reversal event representing an expanded Calabrian interval and the Mid-Pleistocene Transition (MPT). The upper stratigraphy (~300 m) is likely to cover the Middle and Late Pleistocene period and will consist of pro-to-subglacial sediments.
NSC-01A (Primary)	55.3042 3.6715	28	1200	0	1200	Recover a high-resolution palaeo-climatic/environmental record of late Pliocene and Early Pleistocene successions in the North Sea Basin. Site NSC-01A is targeting seismic stratigraphic units SU3 to SU9 representing the Plio-Pleistocene transition and an expanded Gelasian sections. The upper stratigraphy (~300 m) is likely to cover the Middle and Late Pleistocene period and will consist of pro-to-subglacial sediments.
NSC-02A (Alternate)	55.2189 3.7026	37	1200	0	1200	Recover a high-resolution palaeo-climatic/environmental record of late Pliocene and Early Pleistocene successions in the North Sea Basin. Site NSC-01A is targeting seismic stratigraphic units SU3 to SU9 representing the Plio-Pleistocene transition and an expanded Gelasian sections. The upper stratigraphy (~300 m) is likely to cover the Middle and Late Pleistocene period and will consist of pro-to-subglacial sediments.
NSC-03A (Alternate)	55.3494 3.6812	28	1200	0	1200	Recover a high-resolution palaeo-climatic/environmental record of late Pliocene and Early Pleistocene successions in the North Sea Basin. Site NSC-01A is targeting seismic stratigraphic units SU3 to SU9 representing the Plio-Pleistocene transition and an expanded Gelasian sections. The upper stratigraphy (~300 m) is likely to cover the Middle and Late Pleistocene period and will consist of pro-to-subglacial sediments.
NSC-04A (Alternate)	55.8990 3.5534	60	1200	0	1200	Recover a high-resolution palaeo-climatic/environmental record of late Pliocene and Early Pleistocene successions in the North Sea Basin. Site NSC-01A is targeting seismic stratigraphic units SU3 to SU9 representing the Plio-Pleistocene transition and an expanded Gelasian sections. The upper stratigraphy (~300 m) is likely to cover the Middle and Late Pleistocene period and will consist of pro-to-subglacial sediments.
NSS-01A (Primary)	52.8975 3.6242	32	980	0	980	Recover a high-resolution palaeo-climatic/environmental and expanded record of the late Pliocene and Early Pleistocene succession in the North Sea Basin. Site NSS-01A also targets super interglacials (e.g. MIS 11, 31), coupling to on shore graben continental records (Rhine catchment). The upper stratigraphy (~150 m) is likely to cover the Middle and Late Pleistocene period and will consist of proglacial and fluvial sediments.
NSS-02A (Alternate)	52.9057 3.6062	26	980	0	980	Recover a high-resolution palaeo-climatic/environmental and expanded record of the late Pliocene and Early Pleistocene succession in the North Sea Basin. Site NSS-01A also targets super interglacials (e.g. MIS 11, 31), coupling to on shore graben continental records (Rhine catchment). The upper stratigraphy (~150 m) is likely to cover the Middle and Late Pleistocene period and will consist of proglacial and fluvial sediments.

Proposed Sites (Continued; total proposed sites: 11; pri: 3; alt: 8; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
NSS-03A (Alternate)	52.9091 3.4113	30	980	0	980	Recover a high-resolution palaeo-climatic/environmental and expanded record of the late Pliocene and Early Pleistocene succession in the North Sea Basin. Site NSS-01A also targets super interglacials (e.g. MIS 11, 31), coupling to on shore graben continental records (Rhine catchment). The upper stratigraphy (~150 m) is likely to cover the Middle and Late Pleistocene period and will consist of proglacial and fluvial sediments.