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Marine record of Holocene climate, ocean, and cryosphere interactions: Herbert Sound, James Ross Island, Antarctica

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ABSTRACT

The sediment record offshore James Ross Island, northeast Antarctic Peninsula presents an unparalleled opportunity to directly compare marine and terrestrial climate records spanning the Holocene in maritime Antarctica. An 11 m drill core was collected between Herbert Sound and Croft Bay as part of the SHALDRIL NBP-0502 initiative and produced the southernmost sediment record from the eastern side of the AP. Thirty-eight radiocarbon ages are used to construct an age model of centennial-scale resolution. Multi-proxy records, including magnetic susceptibility, pebble content, particle size, total organic carbon, and diatom assemblages, were interrogated in the context of nearby Holocene-age ice core, lake, and drift records from James Ross Island. Differences in the timing and expression of Holocene events reflect marine controls on tidewater glaciers, such as water mass configurations and sea ice. Glacial behavior mimics ice core paleotemperatures during the Holocene, with the exception of distinct ocean warming events. Herbert Sound was fully occupied by grounded ice during the Last Glacial Maximum, and experienced rapid lift-off, followed by a floating ice phase. The canopy of floating ice receded by 10 ± 2.4 cal kyr BP, presumably in response to Early Holocene warming. Herbert Sound and Croft Bay fully deglaciated by 7.2 cal kyr BP, when the Mid Holocene Hypsithermal commenced and the sound became open and productive. An extreme peak in productivity ~6.1 cal kyr BP indicates an oceanic warming event that is not reflected in atmospheric temperature or lacustrine sediment records. Increase in sea ice cover and ice rafting mark the onset of the Neoglacial ~2.5 cal kyr BP, when pronounced atmospheric cooling is documented in the James Ross Island ice core. Our comparison facilitates more holistic understanding of atmosphere-ocean-cryosphere interactions that may aid predictions of glacial response to future warming and sea-level scenarios.

1. Introduction

The Antarctic Peninsula (AP; Fig. 2a) is the most rapidly warming region in the Southern Hemisphere, with a documented increase in atmospheric temperature of 3.7 ± 1.6 °C per century, ~6 times higher than the global mean (Houghton et al., 2001; Vaughan et al., 2003; Turner et al., 2005; Zagorodnov et al., 2012; Vaughan et al., 2013). The southward shift of isotherms is associated with recent catastrophic break-up of several ice shelves, with the greatest losses in the Larsen Ice Shelf (LIS) in 1995 and 2002 (Figs. 1 and 2; Vaughan and Doake, 1996; Scambos et al., 2003; Rignot et al., 2004; Scambos et al., 2009; Vaughan et al., 2013). Today, ice shelves exist where mean annual atmospheric temperatures average less than −9 °C, and appear to become unstable and disintegrate where temperatures rise above this threshold (Fig. 1; Mercer, 1978; Morris and Vaughan, 2003). Less understood are oceanographic thresholds on ice shelf stability, although upwelling of warmer water masses has been attributed to basal melting and ice-shelf recession in the Ross Sea (Jacobs et al., 1979), Pine Island Bay (Jacobs et al., 2011), and the western AP (Fig. 1; Cook and Vaughan, 2010; Pritchard et al., 2012; Peck et al., 2015). In drainage systems associated with disintegrated ice shelves, glaciers have accelerated, causing concern for the mass balance of the AP Ice Sheet (APIS; e.g., DeAngelis and Skvarca, 2003; Scambos et al., 2004). In addition, 87% of AP glaciers (Cook et al., 2005) are receding due to dynamic

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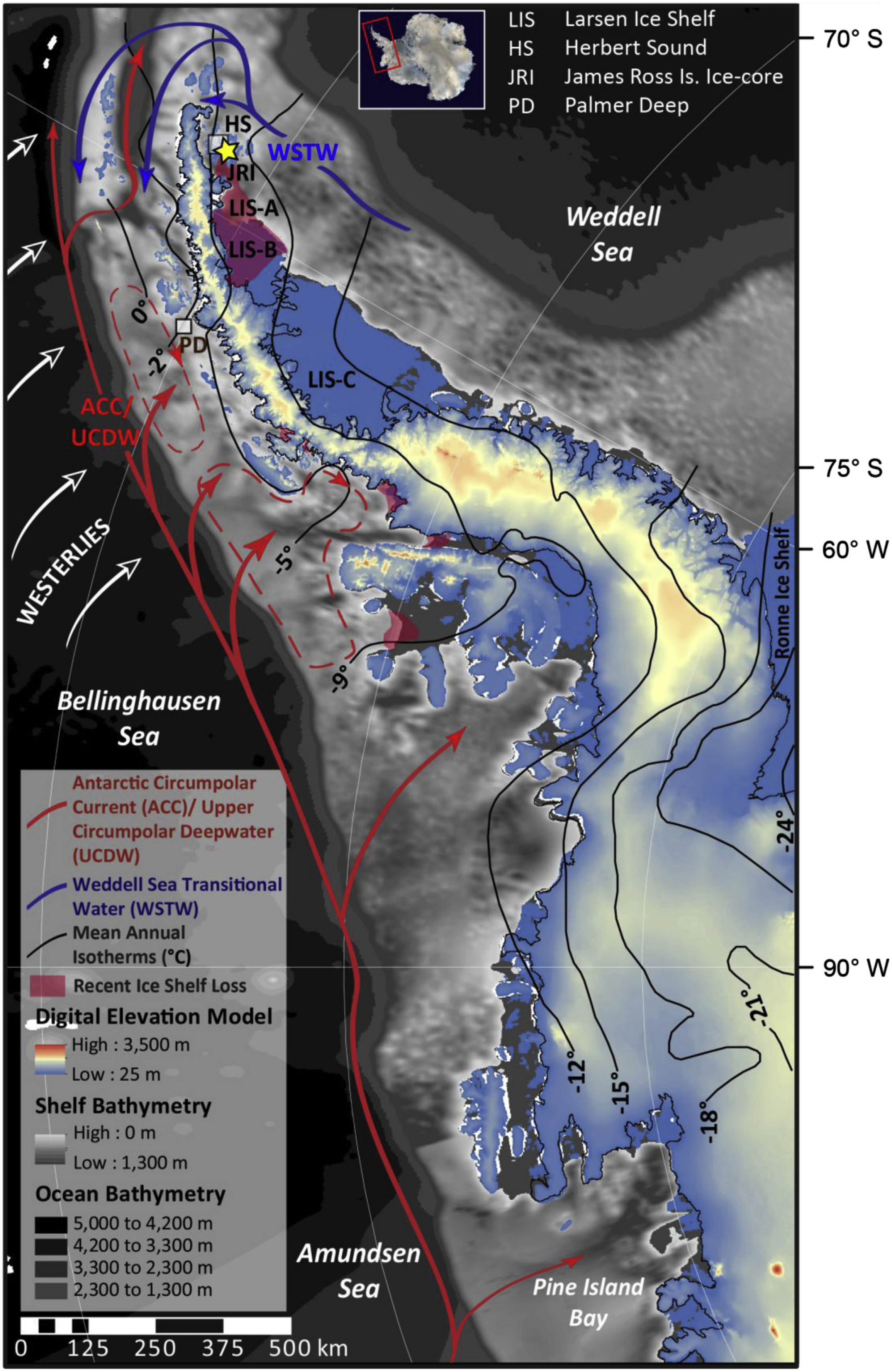
LIS Larsen Ice Shelf
HS Herbert Sound
JRI James Ross Is. Ice-core
PD Palmer Deep
70° S
75° S
60° W
90° W
HS
JRI
LIS-A
LIS-B
LIS-C
PD
WSTW
Weddell Sea
ACC/ UCDW
WESTERLIES
Bellinghausen Sea
Amundsen Sea
Pine Island Bay
Ronne Ice Shelf
0°
-2°
-5°
-9°
-12°
-15°
-18°
-21°
-24°
Antarctic Circumpolar Current (ACC)/ Upper Circumpolar Deepwater (UCDW)
Weddell Sea Transitional Water (WSTW)
Mean Annual Isotherms (°C)
Recent Ice Shelf Loss
Digital Elevation Model
High : 3,500 m
Low : 25 m
Shelf Bathymetry
High : 0 m
Low : 1,300 m
Ocean Bathymetry
5,000 to 4,200 m
4,200 to 3,300 m
3,300 to 2,300 m
2,300 to 1,300 m
0 125 250 375 500 km