Internal Tidal Waves under the Landfast Sea Ice in the Southeast Hudson Bay

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Introduction

Internal waves in the Arctic regions have been of recent scientific interest due to their role in vertical mixing, and their influence on the heat budget of the upper ocean and ice cover. Until now internal tidal waves observations in Hudson Bay have not been conducted. The Belcher Islands archipelago would be an interesting region for internal tidal waves observation in Hudson Bay due to its unique shoreline and bottom topography.

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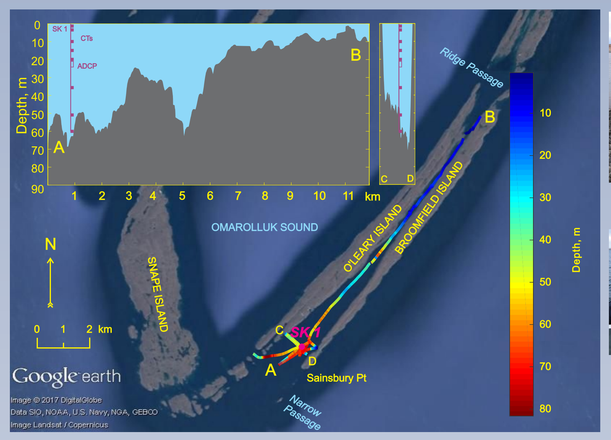
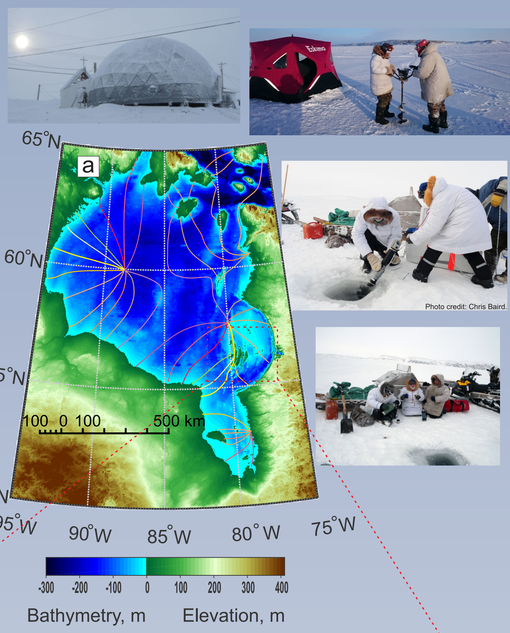
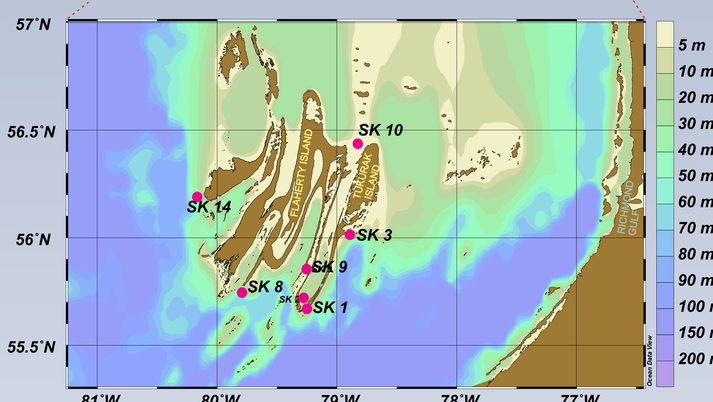
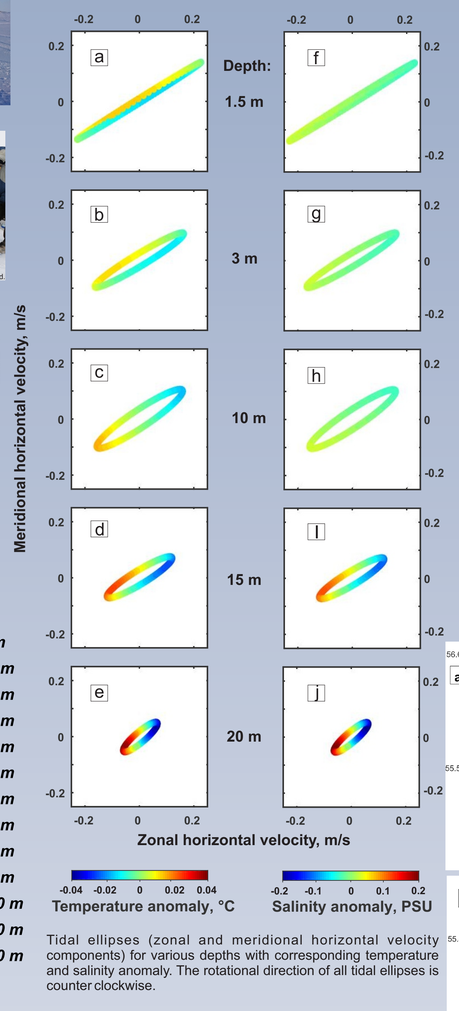
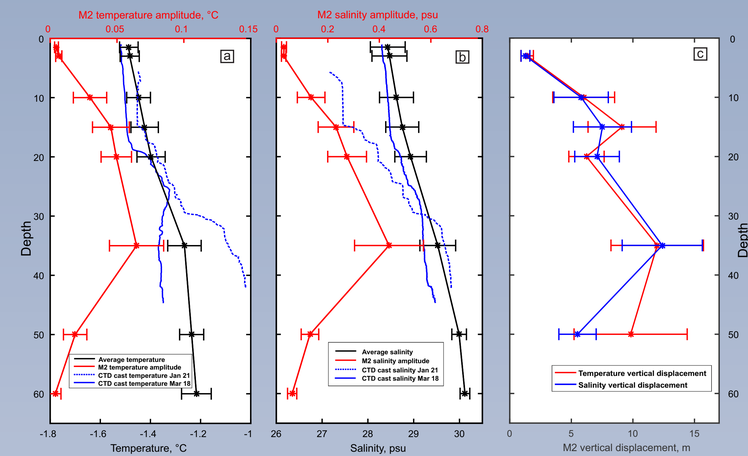






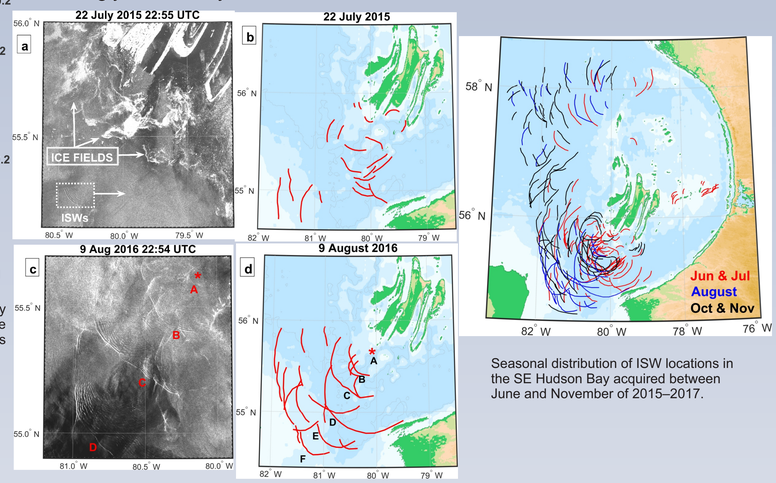


Tidal ellipses (zonal and meridional horizontal velocity components) for various depths with corresponding temperature and salinity anomaly. The rotational direction of all tidal ellipses is counter clockwise.



The tidal harmonic analysis performed for M2 tidal constituent showed dominance of the baroclinic tide with maximum velocity amplitudes in the surface and decreasing with depth.

High-resolution satellite radar imagery analysis conducted for the open water season revealed that the region to the south-east of Belcher Islands archipelago is strongly affected by internal tidal waves.

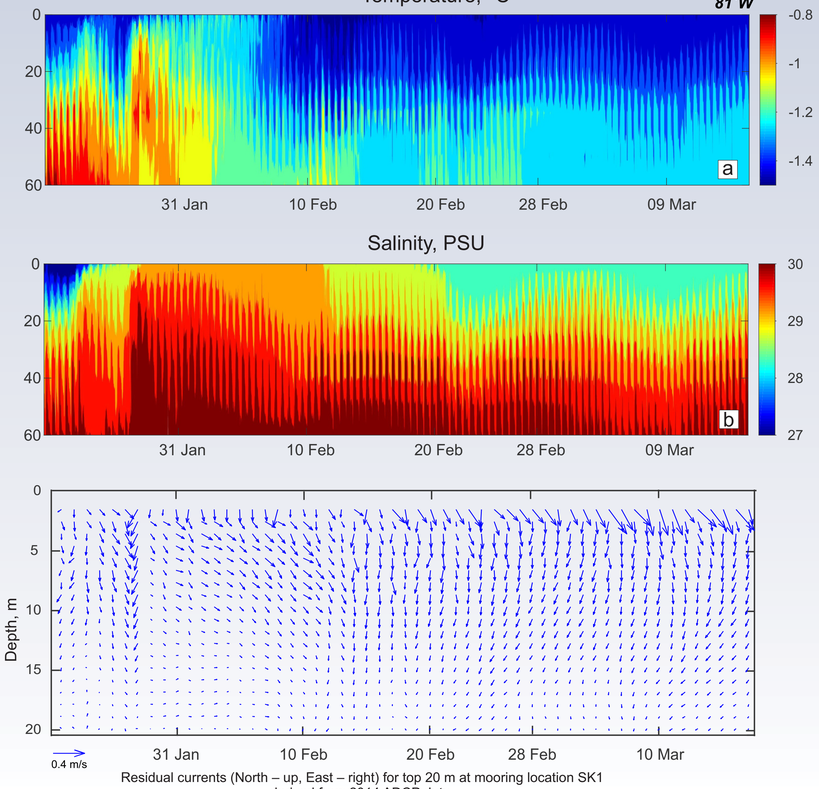


Seasonal distribution of ISW locations in the SE Hudson Bay acquired between June and November of 2015–2017.

Sentinel-1 SAR images of the SE Hudson Bay showing distinct signatures of internal solitary waves on various dates in 2015 and 2016. ©Copernicus Sentinel data [2017]

Data and Methods

- An ice-tethered mooring (SK1) consisting of eight conductivity and temperature sensors and an acoustic Doppler current profiler was deployed in January–March 2014 in a narrow channel between Broomfield and O'Leary islands located in the south-east tip of Belcher Islands group in Hudson Bay.
- The mooring data were complemented by CTD casts made at various stations (SK1, SK2, SK3, SK8, SK9 and SK10) surrounding Belcher Islands in January and February 2014.
- In October 2016, a bathymetric survey was conducted in the narrow channel between Broomfield and O'Leary islands where mooring SK1 was deployed in 2014.

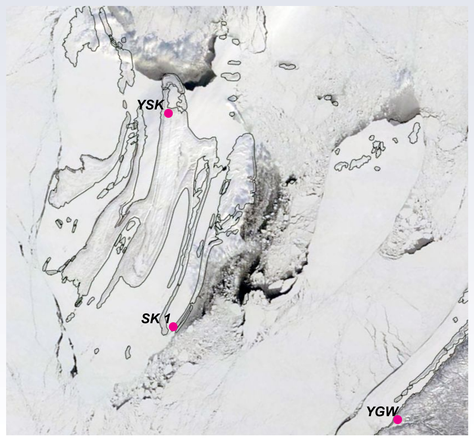


Residual currents (North – up, East – right) for top 20 m at mooring location SK1 derived from 2014 ADCP data.

Results

The mooring recorded oscillations of temperature and salinity through the whole water column, which could be attributed to the vertical displacement caused by internal tidal waves.

During the storm event on 27-28 January 2014, the weather stations located ~100 km from the mooring site recorded significant westerly and southwesterly winds. On 27 January, the mooring recorded increased residual currents to NNW (off-shore) that was directed about 90° to the wind direction. On 28 January, direction of the residual currents shifted to NNE, i.e., aligned with the channel at SK1. This direction of currents corresponds to the Ekman's transport. During the storm event, the mooring recorded an episode of isohaline and isothermal uplift by ~10 m that was consistent with upwelling.



EOSDIS (Terra/MODIS corrected reflectance and OpenStreetMap coastline) imagery of Belcher Islands taken on 29 January 2014 shortly after the winter storm event. YSK – location of Environment Canada weather station in Sanikiluaq Airport, YGW – weather station at Kuujjuarapik airport and SK1 mooring location.

Conclusions

- The tidal driven oscillations of velocity, temperature and salinity through the whole water column were observed in a channel at the south-east tip of the Belcher Islands group. The tidal harmonic analysis and calculated vertical displacements of water parcels showed the pattern characteristic for internal waves generated in the presence of stratification and rough bottom topography. Most likely, the main source of such internal tidal waves was interaction of high tides typical for Hudson Bay with sill-like features located below the halocline in the narrow channel between the islands.
- Analysis of SAR data clearly showed that ISWs were present in the study region throughout the entire ice-free season, while the first (and last) manifestations of internal solitary waves were observed in May (November-December) under the presence of land fast ice, suggesting that ISW generation is also active in winter. General pattern of ISWs in SAR images expressed through high radar contrasts and relatively large spatial scales and located to the south of Belcher Islands suggests that the ISWs were similar to intensive internal waves observed in other Arctic regions .
- While the tidal-driven variability in temperature and salinity recorded by the mooring was large, the high stratification to the south of Belcher Islands restricted vertical mixing. It appears to be insignificant as evidenced from the occurrences of the double diffuse staircases. The upwelling-favourable storms can be another efficient mechanism of vertical mixing; however, the land-fast ice eliminates wind stress from the water column.