NEW COASTS EMERGING FROM THE RETREAT OF NORTHERN HEMISPHERE MARINE-TERMINATING GLACIERS IN THE 21ST CENTURY

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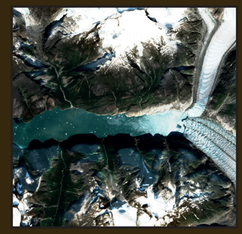
2000



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Uniwersytet Wrocławski

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Outstanding Student & PhD candidate Presentation contest

poster abstract:

GENERAL INFORMATION

STUDY AREA

all Arctic and subarctic regions where marine-terminating glaciers are present

STUDY PERIOD: 2000-2020

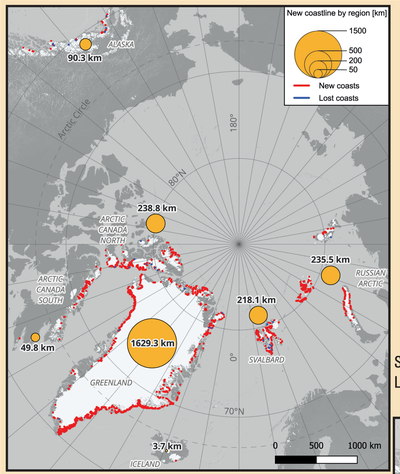
WHY ARE NEW COASTS SPECIAL?

- Initial lack of permafrost and permafrost aggradation
- Rapid changes in internal rock stress after glacier retreat ⟶ debuttressing
- Very steep slopes due to glacial erosion
- Abundance of glacial and fluvioglacial sediments

NEWLY EXPOSED COASTLINE - GIS DATASET

GOAL

- Identifying all coastline segments emerged due to glacier retreat from 2000 to 2020 as well as coastline segments lost due to glacier advance
- Creating an easily accessible dataset of new coastlines



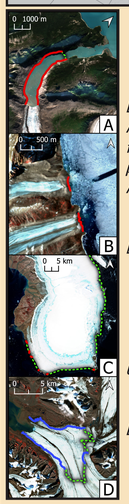
METHOD & DATA

Manual satellite imagery (Sentinel) analysis in QGIS with the help of marine-terminating glaciers 2000-2020 retreat database (Kochtitzky and Copland 2022)

RESULTS

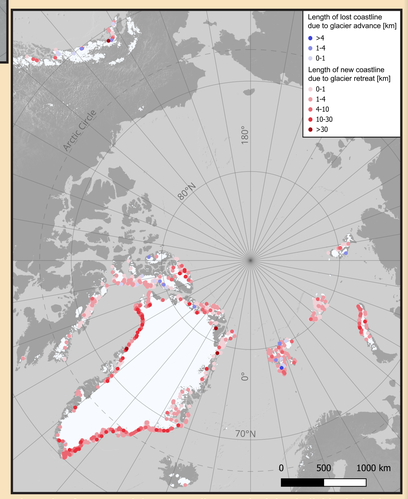
- We identified nearly 2500 km of new coastline, giving an average length of 123 km/year
- Two-thirds of this coastline was exposed in Greenland
- Only about 50 km of coastline present in 2000 was covered by glaciers in 2020
- Open dataset on Zenodo

Spatial distribution of new (red) and lost (blue) coastline.
Lost coastline displayed as the top layer in the map.



Examples of new and lost coastline in the Arctic from 2000-2020 shown by photos from 2020 with marked glaciers front positions in 2000 (green dotted lines):

A. Alaska example of Sawyer Glacier with relatively long new coastline due to narrow topography;
B. Baffin Island example of the outlet glaciers which became land-terminating during the study period resulting in relatively long new exposed coastline (glacier fronts positions in 2000 are similar to the coastline position in 2020);
C. Russian Arctic example of ice cap retreat with little coastline change on Graham Bell Island;
D. Nathorstbreen glacier (Svalbard) responsible for almost half of the hemisphere's lost coastline due to the major surge.



Length of new and lost coastline marked by individual glaciers. Glaciers connected with the longest new and the longest lost coastline are displayed in the front.

IS THE LENGTH OF NEW COASTLINE PROPORTIONAL TO GLACIER RETREAT AREA?

New coastline length to retreat area (NC-RA) ratio for the period 2000-2020 for individual glaciers. Data on glacier areal retreat adjusted from Kochtitzky and Copland (2022).

GOAL

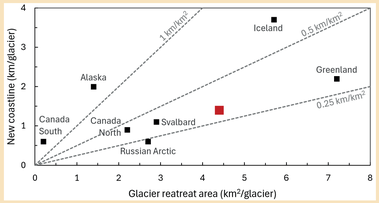
Comparing new coastline length to retreat area for individual glaciers and regions; checking if glacier retreat area is a good approximation of the length of new coastline emerged.

METHOD & DATA

- Combining our new coastline dataset with retreat area dataset (Kochtitzky and Copland 2022) in QGIS; use of Randolph Glacier Inventory (v.6) for standarization
- Calculating a new coastline to area retreat (NC-RA) ratio and applying it for individual glaciers and for regions

RESULTS

- Wide variation in NC-RA ratios (illustrating effectiveness in new coastline emergance) between glaciers
- Huge regional variation in NC-RA ratios:
  - the most effective in new coastline emergance: south-west Alaska (narrow fjords) and Baffin Island (large number of small glaciers changing from marine- to land-terminating in study period)
  - the least effective: Russian Arctic islands (ice caps and ice shelfs)



Regional differences in glacier areal retreat and resulting new coastline origin. All marine terminating glaciers are included. Data on glacier areal retreat adjusted from Kochtitzky and Copland (2022). Red square represents hemisphere average. Note that „Canada South" refers to the south part of Canadian Arctic Archipelago.

NEW ISLANDS IN THE ARCTIC

GOAL

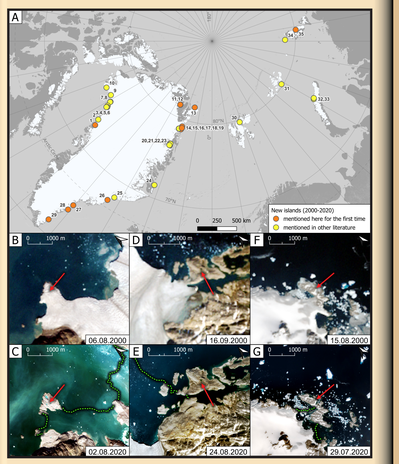
Identifying all new islands (>0.5 km²) that were completely uncovered, or which lost their glacial connection with the mainland during the period 2000-2020

METHOD & DATA

Manual satellite imagery (Sentinel) analysis in QGIS with the help of marine-terminating glaciers 2000-2020 retreat database (Kochtitzky and Copland 2022)

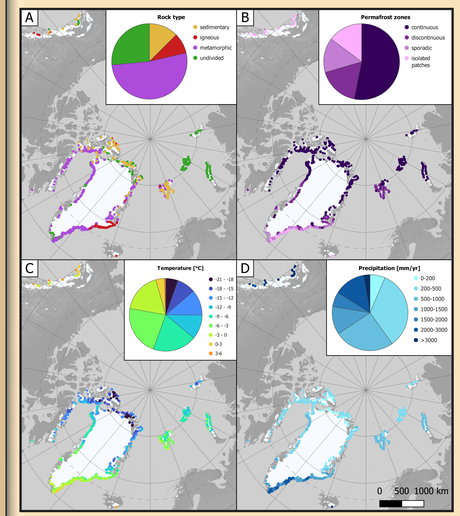
RESULTS

- 35 new islands larger than 0.5 km²
- We report 13 of these islands for the first time
- Most (n=29) new islands are in Greenland



Map and examples of new islands detected from the period 2000 – 2020 in the Arctic: A) map of new islands; B, C) island nr 1; D, E) island nr 29; F, G) island nr 27.

ENVIRONMENTAL CONDITIONS ON NEW COASTS



Geological and climatic summaries of newly emerged coastlines:
A. general rock types – data source: Harrison et al. (2011)
B. permafrost zones – data source: Obu et al. (2018)
C. mean annual temperatures (mean for period 2000-2020) – data source: Hersbach et al. (2023)
D. annual precipitation (mean for period 2000-2020): data source: Hersbach et al. (2023)
Diagrams refer to the total length of new coastline segments attributed to the particular class.

GOAL

Characterizing new coasts by rock type, recent climatic conditions and location in particular permafrost zone in order to illustrate recently initiated paraglacial coastal evolution potential and enable to show hotspots in terms of expected geomorphological coastal dynamics.

METHOD & DATA

- Dividing new coastline into 500 m long sections
- Attributing rock type (Harrison et al. 2011), permafrost zone (Obu et al. 2018) and climatic data for study period (ERA5) to each segment
- Illustrating spatial distribution of each characteristic in QGIS
- Illustrating summary of each charactericitc by diagrams refering to overall coastline length in particular class

RESULTS

- The majority of new coastline is formed in areas of metamorphic bedrock
- More than half of new coastline is formed in continuous permafrost zone, where permafrost aggradation is expected
- Climatic indices are highly variable on new coasts, with average air temperature spanning from −20 to+6°C and precipitation from <100 to >4,000 mm

IMPLICATIONS & FUTURE RESEARCH CHALLENGES

IMPLICATIONS

- New coasts are special due to initial lack of permafrost. Where new coasts are exposed in continuous permafrost zone (majority of new coastline) permafrost aggradation is expected.
- The majority of new coast is forming in relatively resistant bedrock, continuous permafrost zone and relatively harsh climatic conditions, which may prevent rapid coastal erosion.
- Changes in internal rock stress may cause rapid slope deformations, such as rockfalls or landslides, in extreme cases triggering tsunamis (already reported from Alaska and Greenland).
- In regions characterized by an abundance of sediments from retreating glaciers, such as Svalbard, Alaska and southern Greenland, rapid formation of accumulative landforms is expected and observed.

FUTURE RESEARCH CHALLENGES

- Rate and mechanisms of geomorphological change on newly exposed coasts
- Permafrost aggradation mechanisms on newly exposed coasts
- Tsunamigenic landslides susceptibility and mitigation

SOURCE PAPER

Kavan, J., Szczypińska, M., Kochtitzky, W., Farquharson, L., Bendixen, M., & Strzelecki, M. C. (2025). New coasts emerging from the retreat of Northern Hemisphere marine-terminating glaciers in the twenty-first century. Nature Climate Change, 1-10.

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NATIONAL SCIENCE CENTRE POLAND

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