Procedure for examining long-term Arctic shoreline displacement from multispectral satellite data

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Climate change and Arctic coastline

- Arctic coast facing rapid, irreversible changes due to melting sea ice and permafrost
- Coastal communities need local-scale information to adapt to further changes
- Local high-resolution dataset and global coarse-resolution dataset exist

Call for pan-Arctic, ”high”-resolution shoreline displacement information

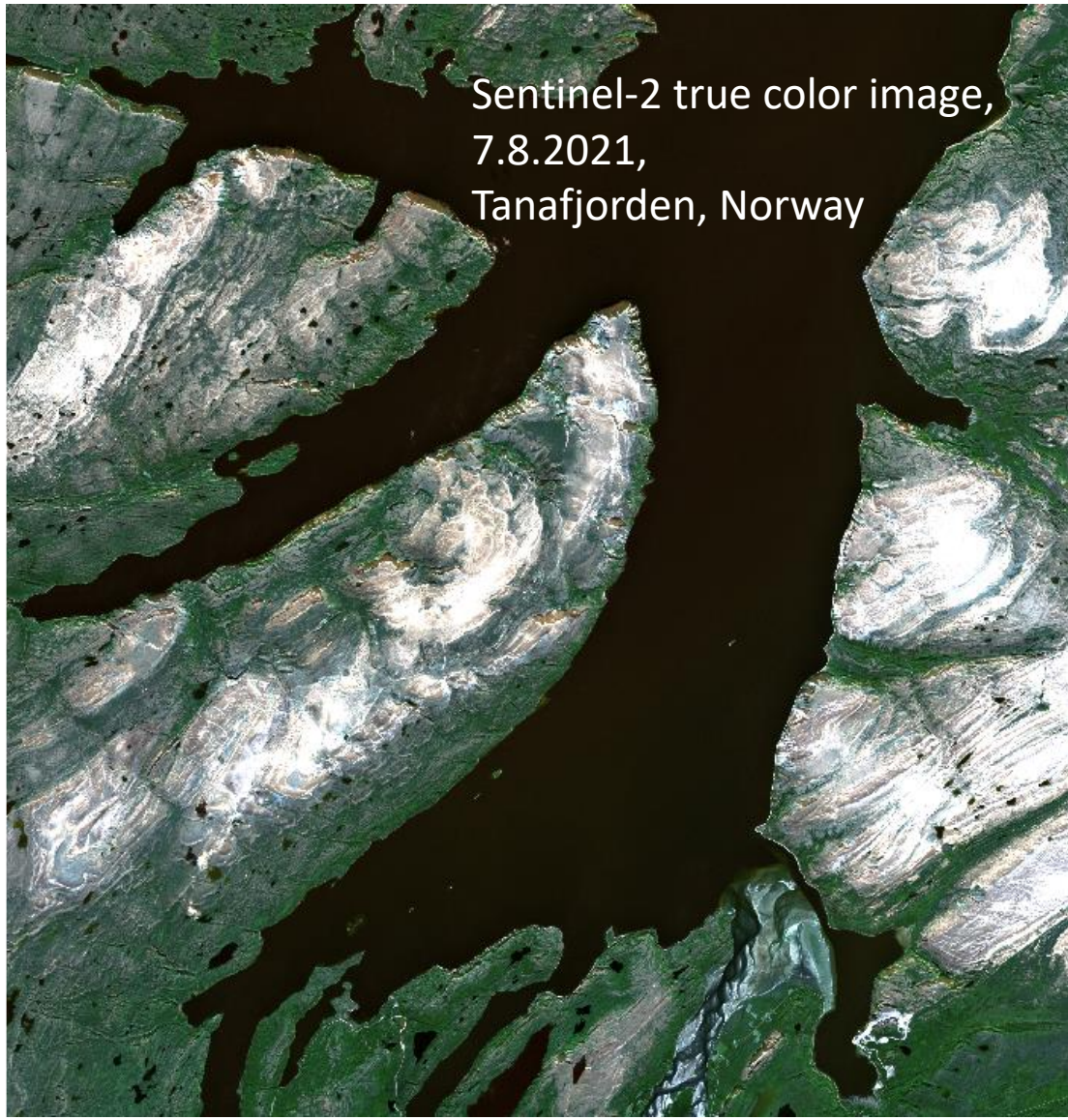
Aims

Step 1

1. Develop scalable and transferable approaches for producing 40-year Arctic shoreline time-series at 30-meter resolution
2. Report remaining challenges and limitations
3. Exemplify geomorphological applications of the outputs: mapping change hotspots, coastal erosion and deposition, delta development

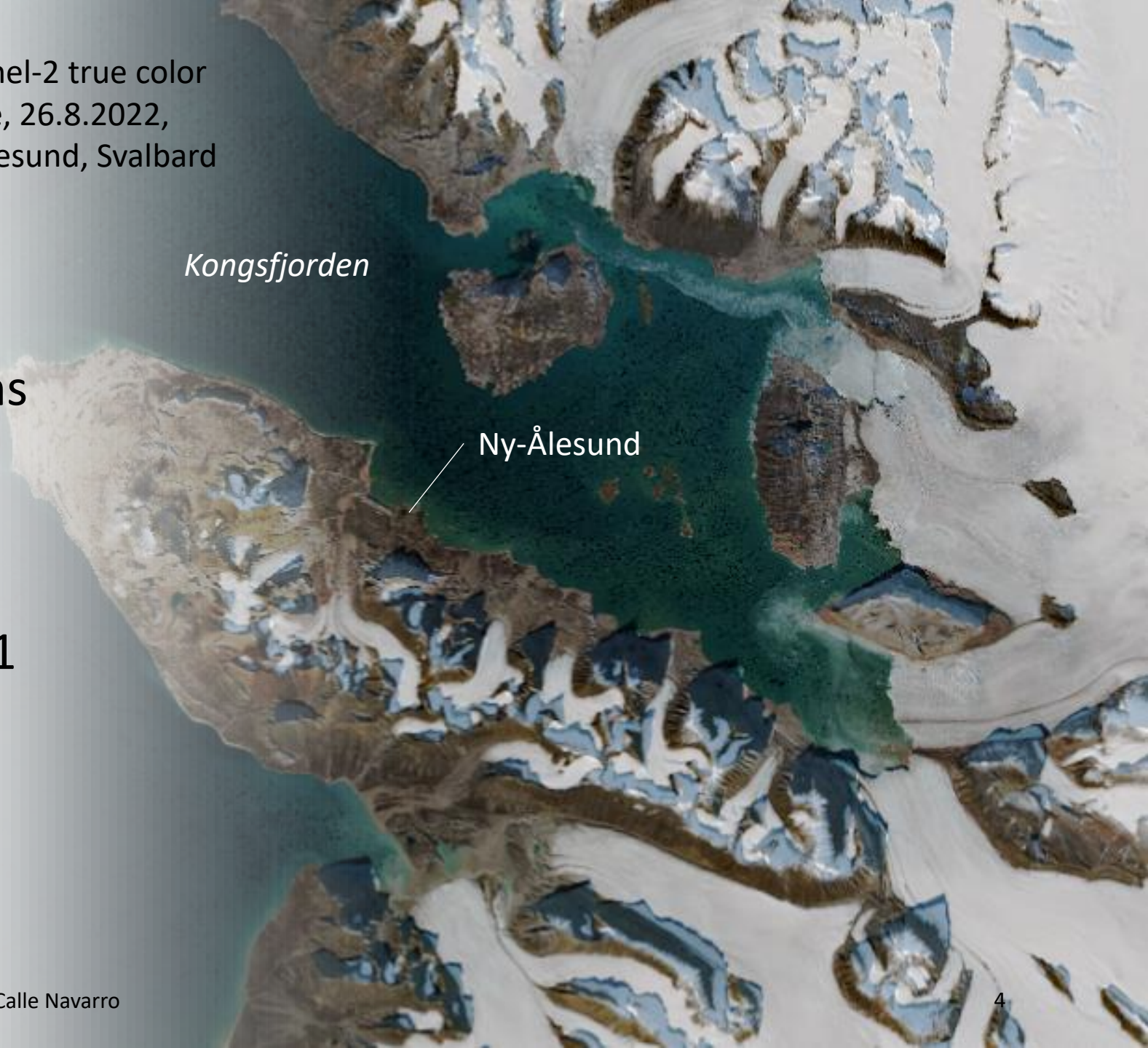
Step 2

- First circumpolar maps of Arctic shoreline displacement between 1984 and 2022



Data

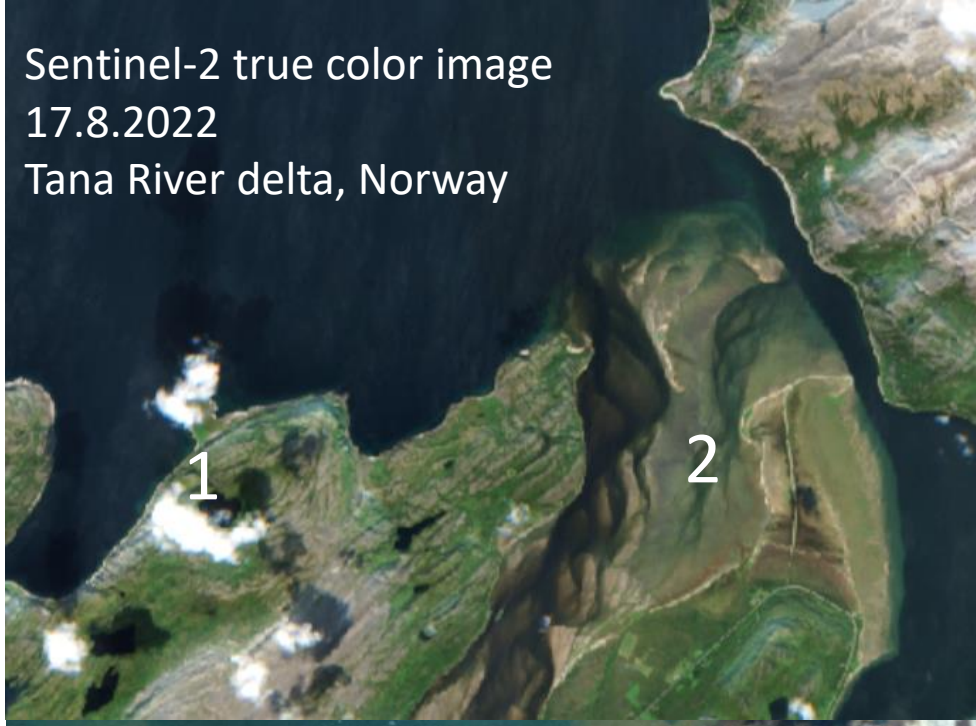
- Open multispectral satellite image collections
- Provide global coverage, long time-series and local-scale data
  - Landsat 5: 1984–2011
  - Landsat 7: 1999–
  - Landsat 8: 2014–
  - Sentinel-2: 2017–
  - (Landsat 9: 2022–)

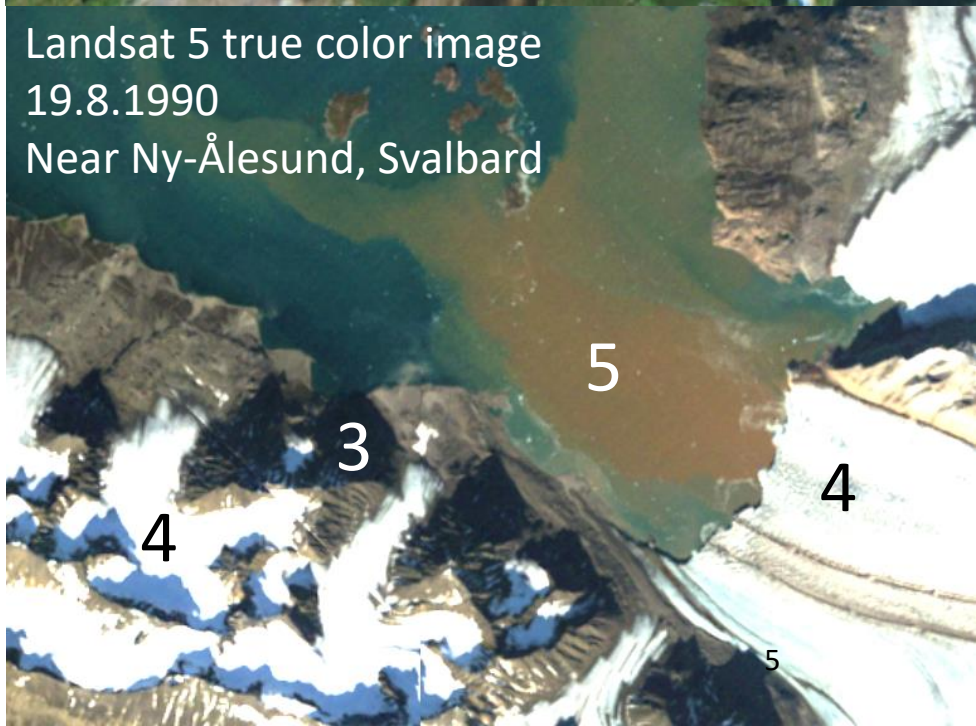


Sentinel-2 true color image, 26.8.2022, Ny-Ålesund, Svalbard

Main challenges

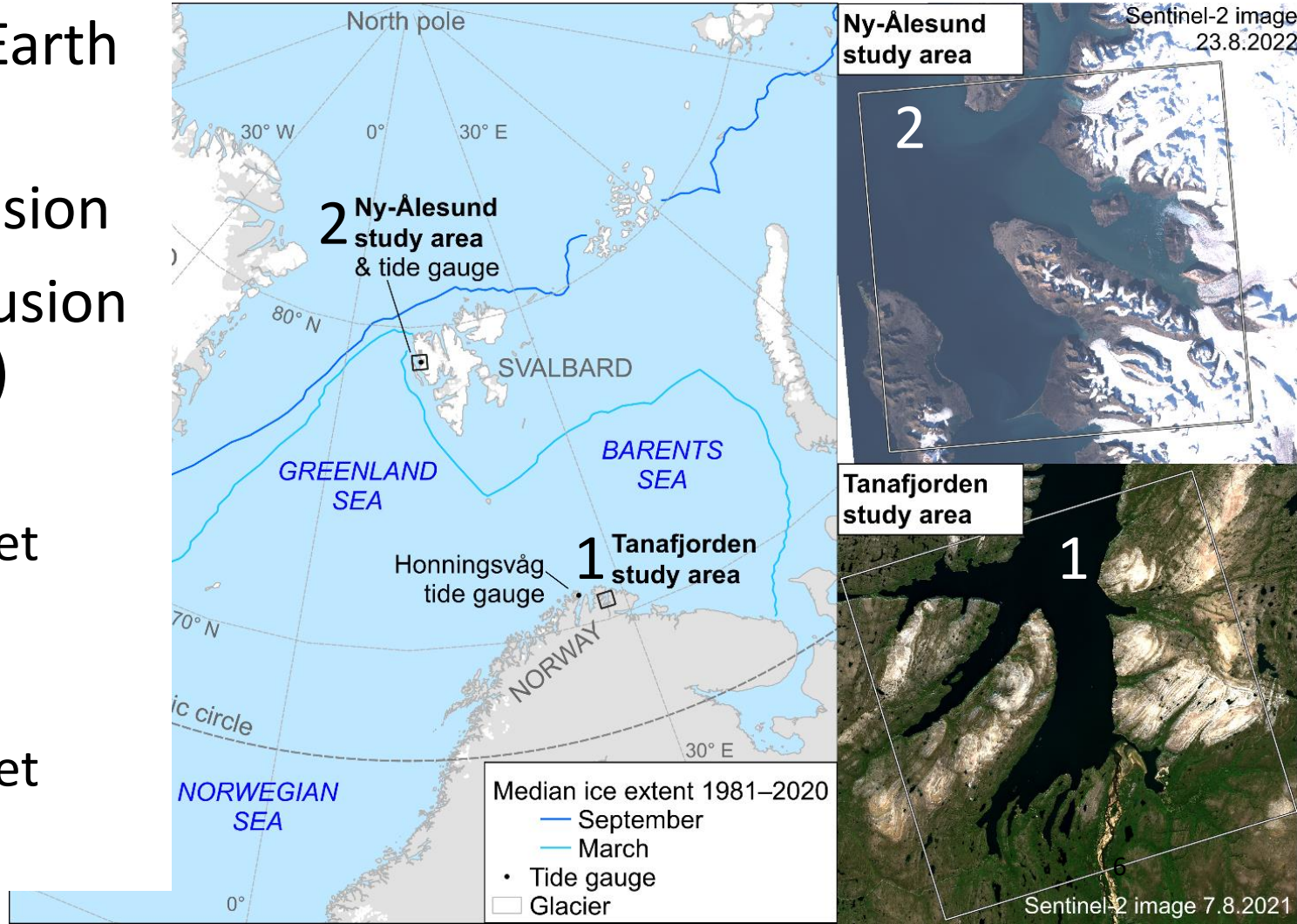
- Size of the area
- Number and size of satellite images
- Data availability and quality due to climate and light conditions
- Classification challenges:
  1. Clouds and cloud shadows
  2. Extensive intertidal zones (cause by short-term water level fluctuations)
  3. Mountain shadows
  4. Ice and snow
  5. Suspended sediment





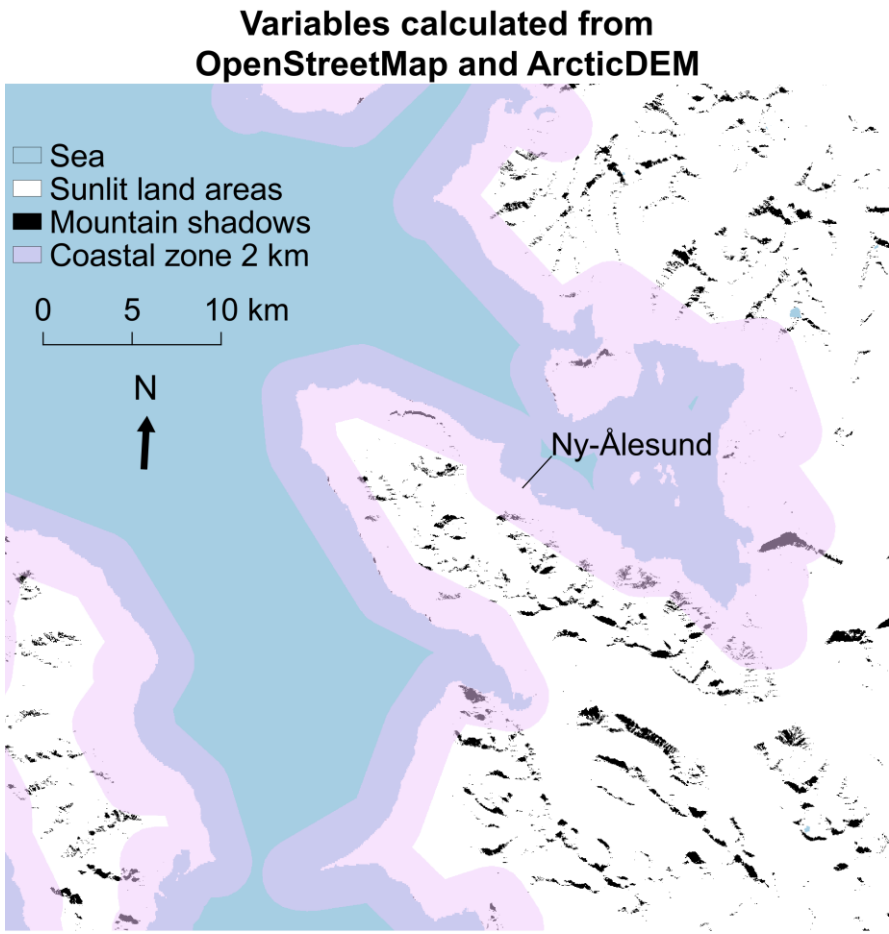
Approach

- Cloud computing in Google Earth Engine
- Data fusion and algorithm fusion
- Post-classification decision fusion over long time-steps (5-year)
- Calibration (study area 1)
  - Independent validation dataset 2021–2022
- Validation (study area 2)
  - Independent validation dataset 2021–2022



Data fusion & algorithm fusion

- Data fusion: complementary spatial data to focus analysis and train classifier
  - OpenStreetMap coastline
  - MERIT Hydro hydrological land cover data
  - Arctic DEM 2 m
- Algorithm fusion: calculating final class layer as composite of two initial classes
  - Sunlit areas: NDWI (normalized difference water index)
  - Mountain shadows: random forest supervised classification



Efficiency

- Reproducible code in GitHub (to be published soon)
- Recommended tile size: up to 50 km * 50 km
- Images processed: 400-600 / tile
- Processing time: 30-60 min / tile
  - Several tiles in parallel
- Output file size: < 1.5 MB / tile

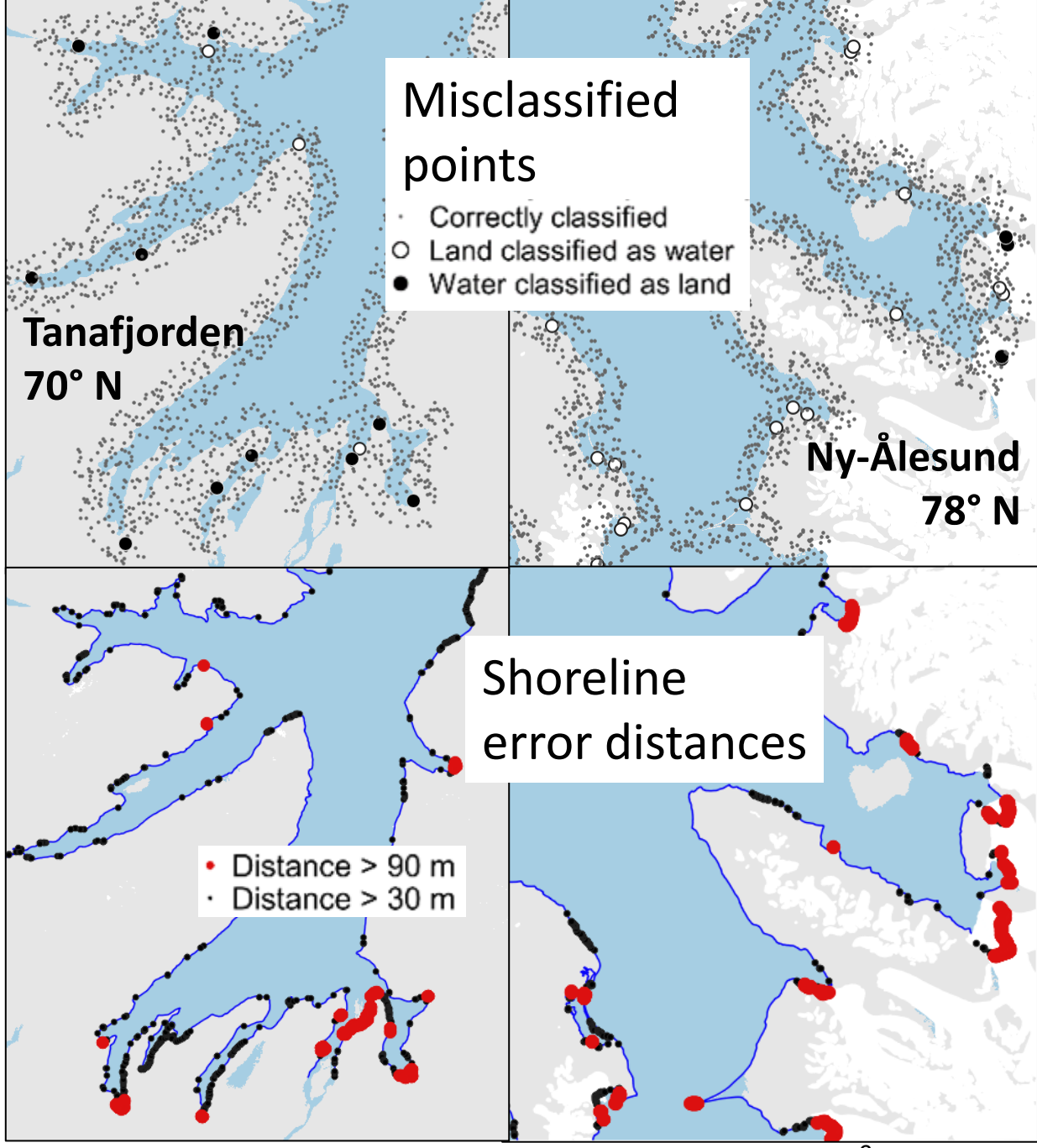
Images processed, Tanafjorden

Time-step	Landsat 5	Landsat 7	Landsat 8	Sentinel-2	ALL
1984–88	56	-	-	-	56
1989–93	39	-	-	-	39
1994–98	35	-	-	-	35
1999–2003	1	28	-	-	29
2004–08	38	24	-	-	62
2009–13	21	25	15	-	61
2014–18	-	33	35	29	97
2019–22	-	35	30	55	120
Total	**123**	**143**	**80**	**84**	**430**

Validation results

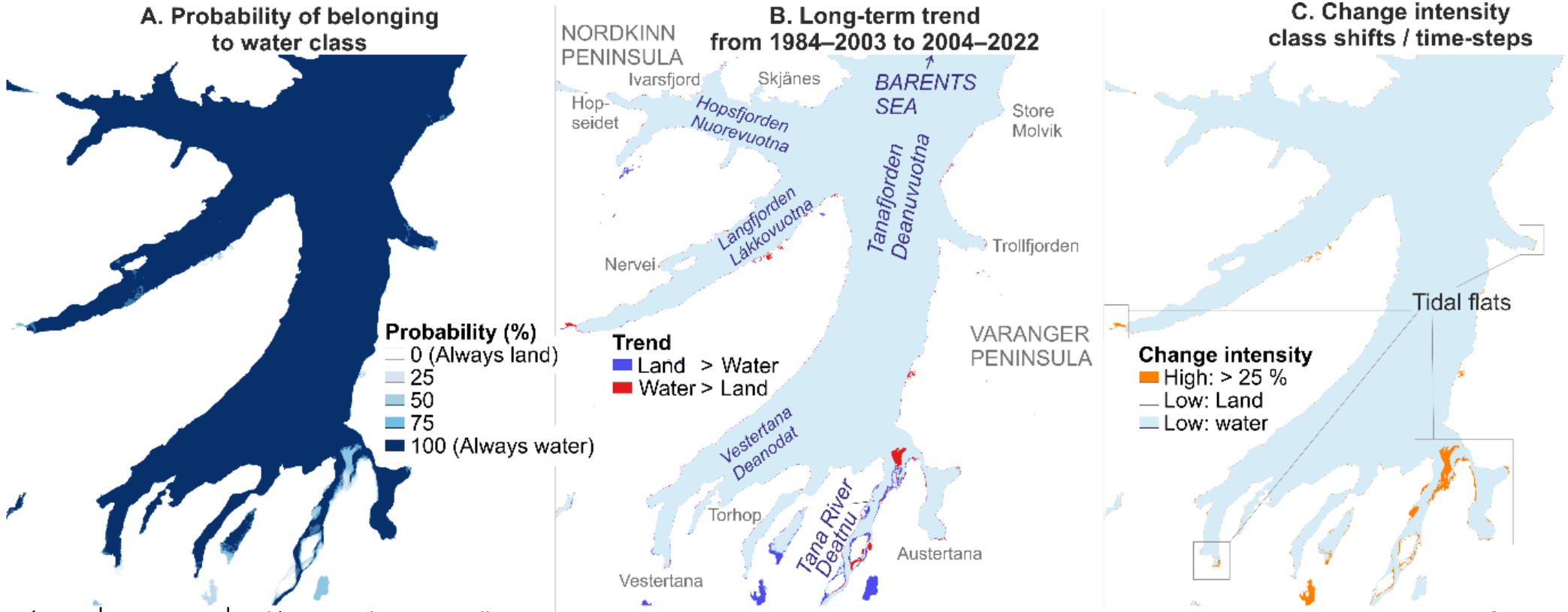
Accuracy of the 2019–2022 outputs:

- Overall accuracy: **99 %**
- Median error distance of the shoreline: < **15 m** (< half of pixel size)
  - 13 m for Tanafjorden
  - 9 m for Ny-Ålesund
- Remaining inaccuracies:
  - Moving glacier margins
  - Intertidal zones
- (Older time-steps currently not validated)



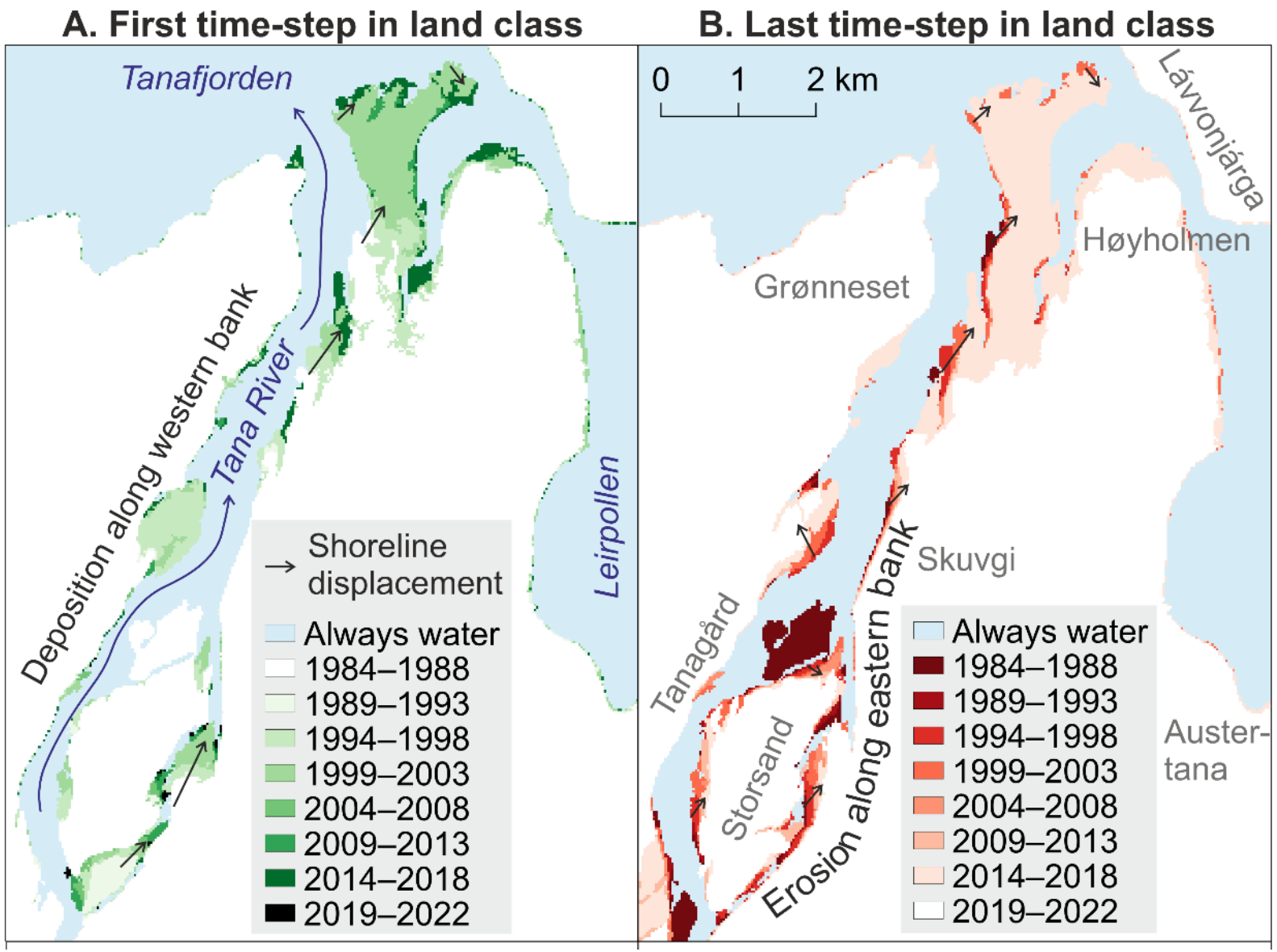
1. Identifying coastal change

- Examples of calculating change intensity and trends
- Tanafjorden hotspots: tidal flats, Tana River delta



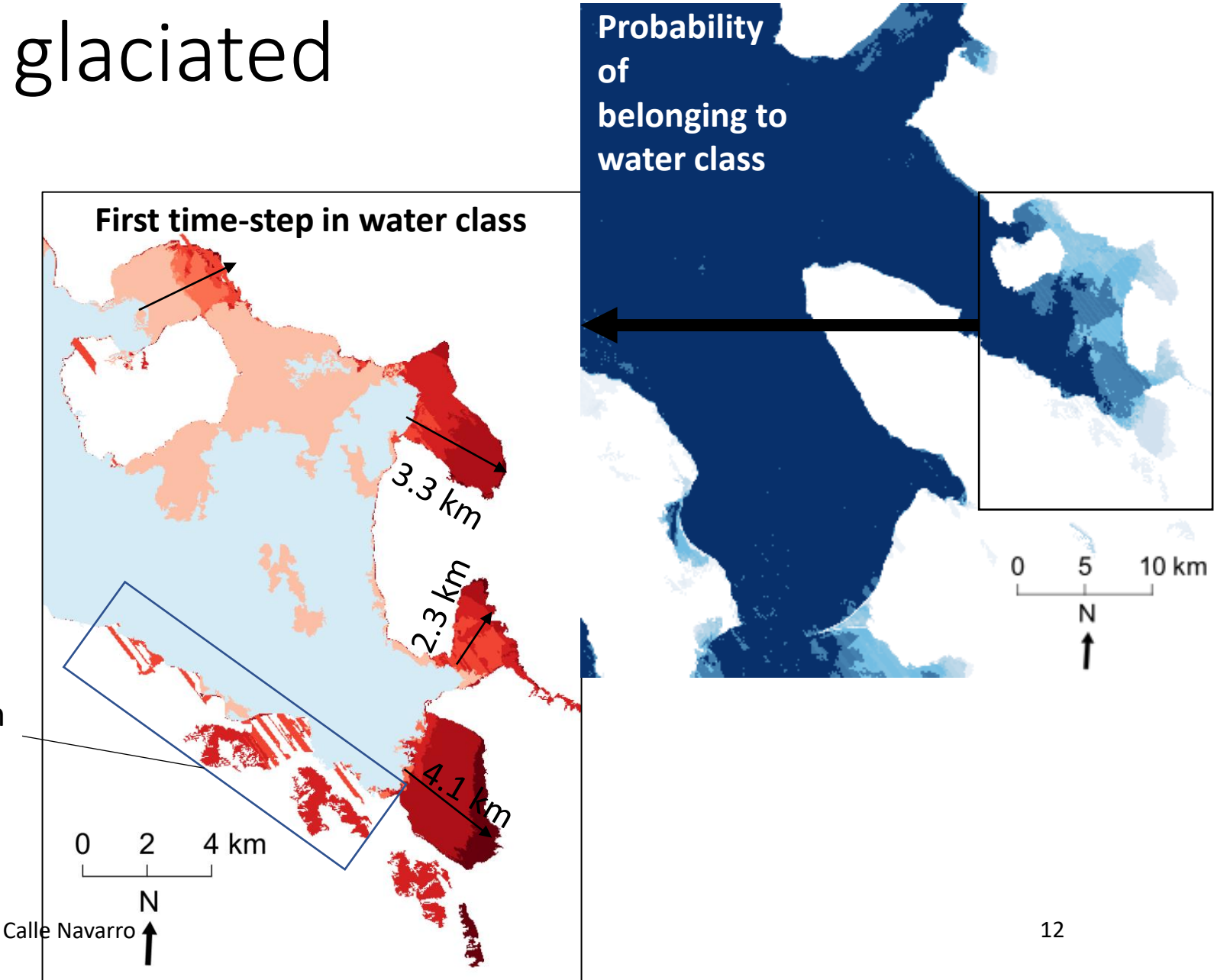
2. Tana delta hotspot

- Outputs indeed provide data in resolution sufficient for examining local-scale processes
- High amount of new spatial-temporal information
  - Even small scale pier construction visible



3. Change in the glaciated coast

- Lower data availability in 80s and 90s still issue
- Long-term glacier margin retreat visible
  - Up to 1000 m / decade



Thank you!

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Slides available as supplementary material

GitHub repository available upon request

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