NATIONAL CENTRAL UNIVERSITY
Graduate Institute of Applied Geology

Shoreline Changes and Glacier Retreats under Climate Change Conditions in Svalbard Using Remote Sensing and GIS Technique

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Date: 2023/07/04

Introduction

Methods

Results

Conclusion

Introduction

Climate change: long-term change in the average weather patterns

Key indicators

Temperature increases;

Rising sea levels;

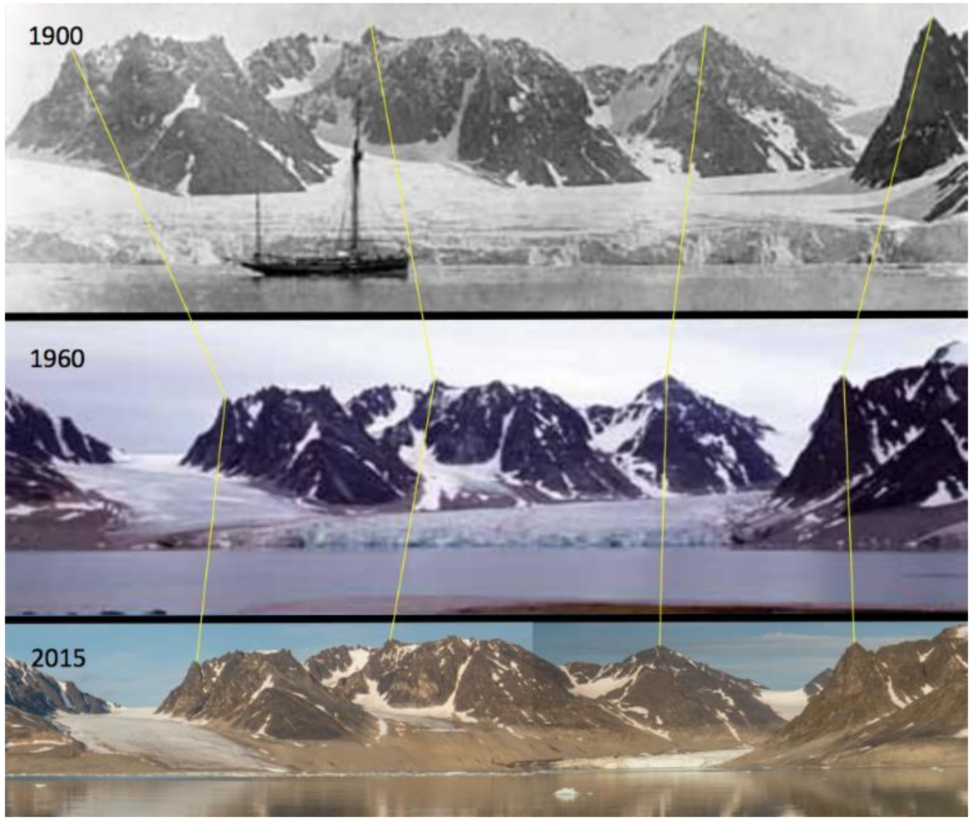
Ice loss at poles & in mountain glaciers;

Frequency & severity changes in extreme weather: hurricanes, heatwaves, wildfires, droughts, floods, precipitation;

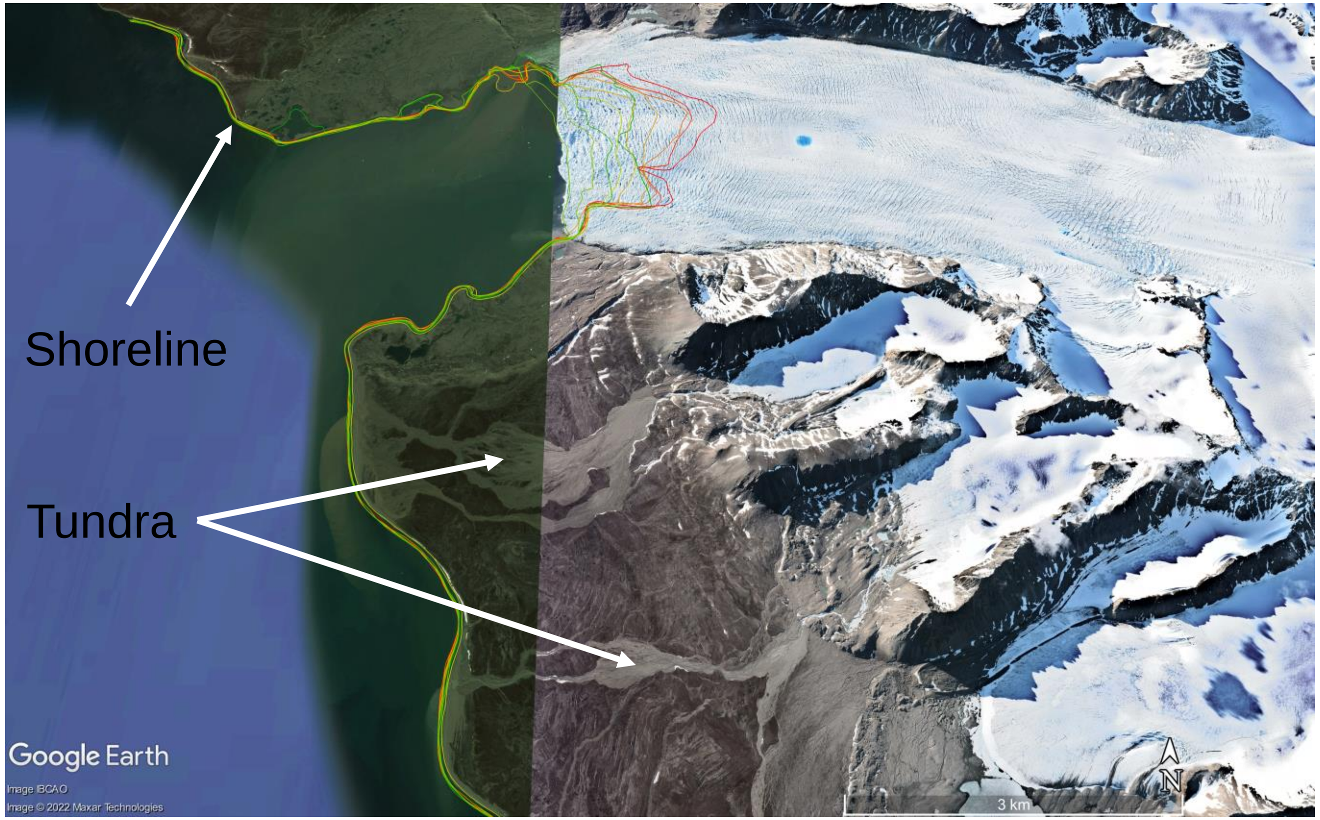
Cloud & vegetation cover changes.

https://www.pinterest.com/pin/17944098493519189/

Introduction



Glacier decrease on Svalbard in the years 1900, 1960, 2015



Shoreline change and tundra in Svalbard

What is the behavior of landforms in 37 years?

Introduction

Objectives

Quantifying the shoreline change rates from 1985 – 2022 by Landsat images

Determining the changes of glacier and tundra area

Analyzing and evaluating the impact of climate change on Svalbard’s landform

Methods

Study Area

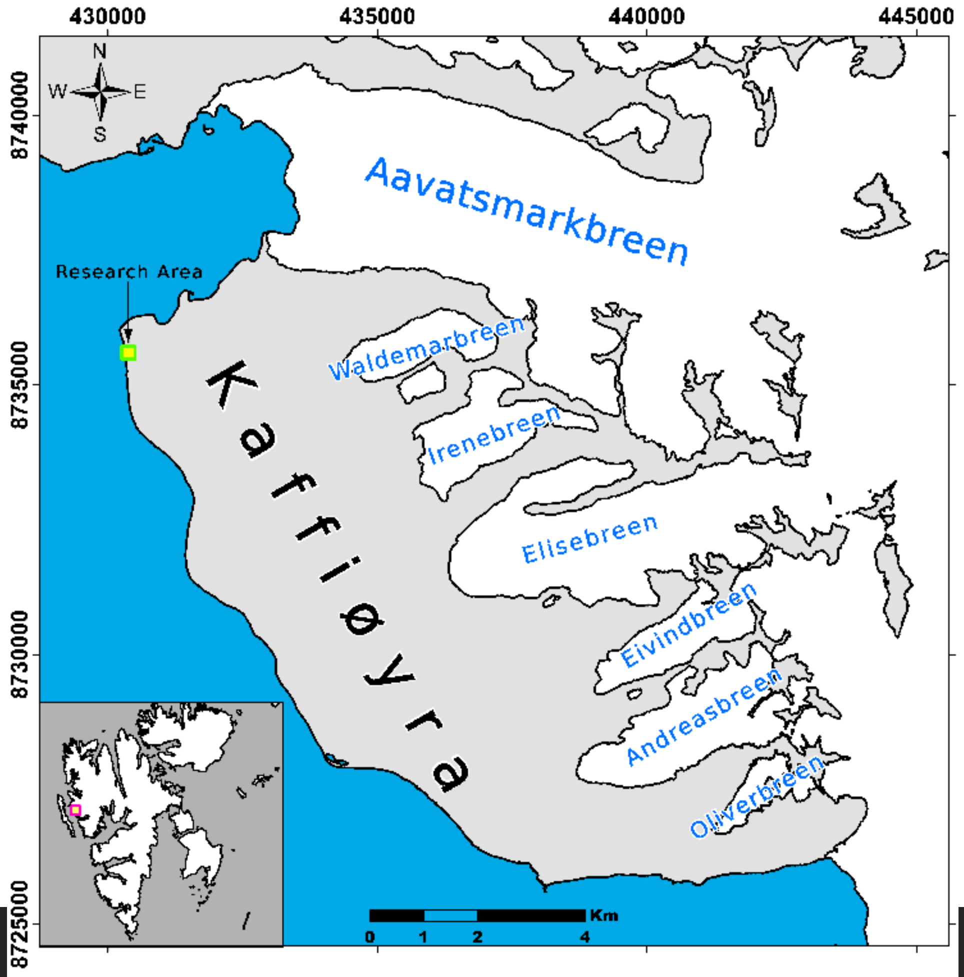
Svalbard place in High Arctic

Glaciers cover ~ 60% of the land

Mean T vary -14ºC (winter) - +6ºC (summer)

Annual precipitation: 200–300 mm

Kaffiøyra ~ 25 km



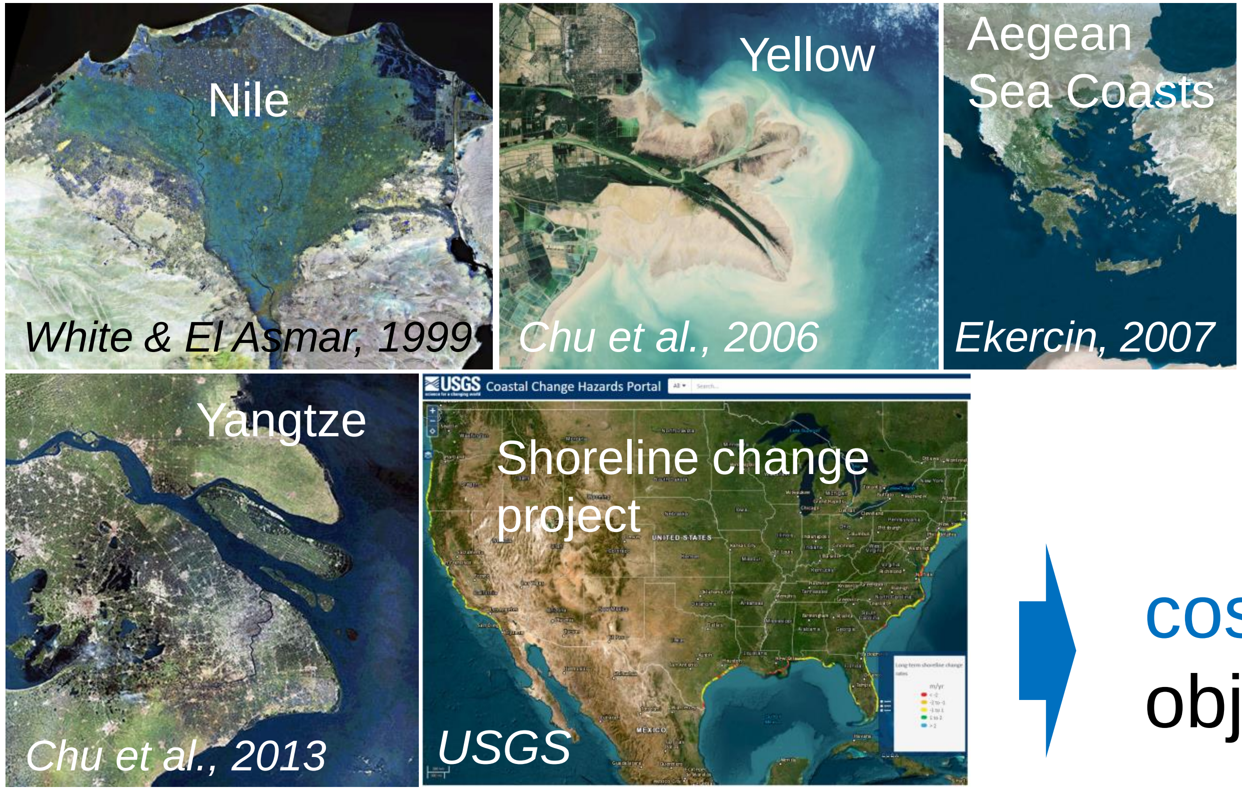
Methods

Monitoring long-term shoreline changes => Big problem

Integrating remote sensing + GIS technique

Landsat images

Digital Shoreline Analysis System (DSAS)

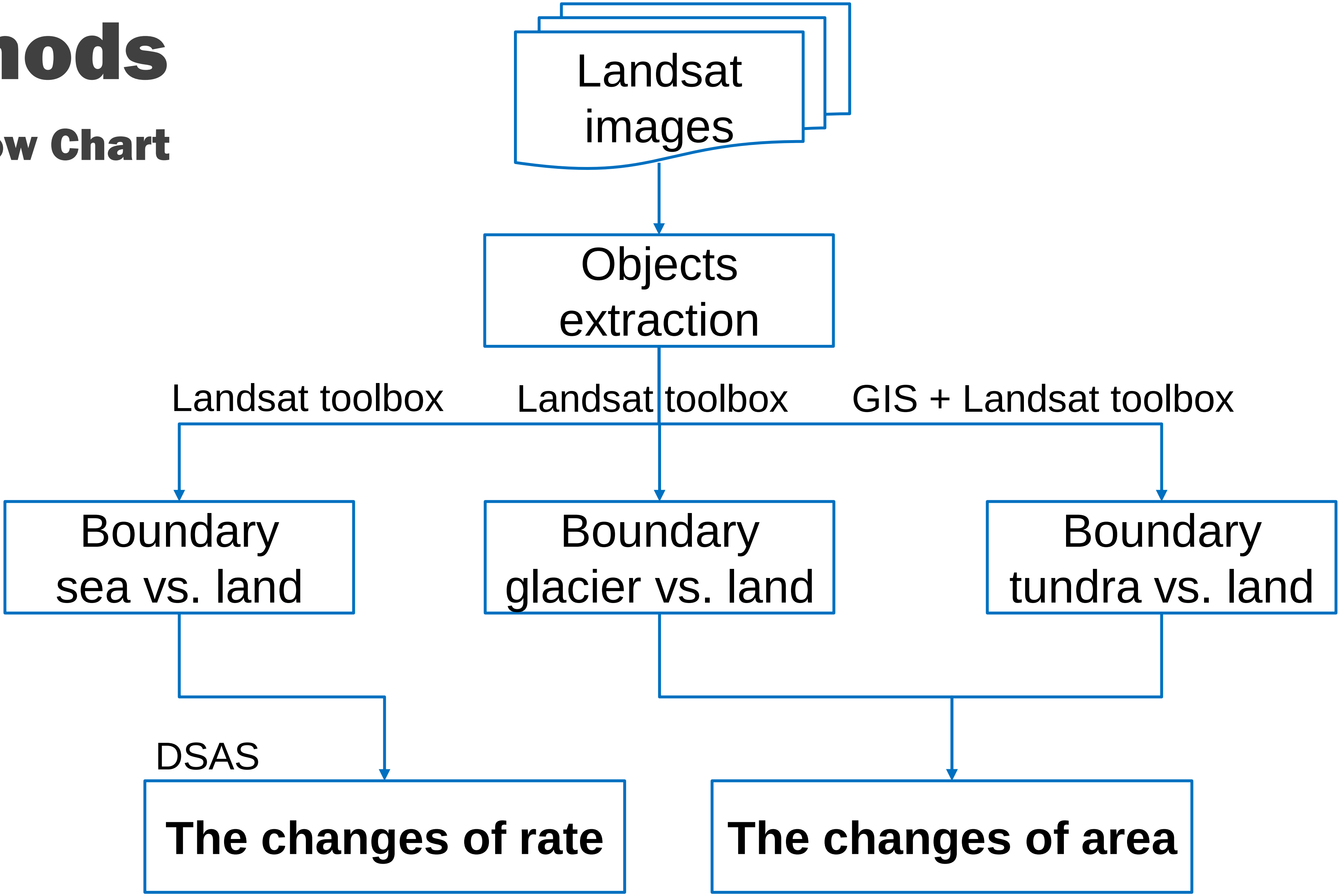


- Freely software work with ArcGIS
- Computing the rate-of-change statistics for a time series of shoreline (Himmelstoss et al., 2021)

cost-efficient tool for monitor long-term objects change

Methods

Flow Chart



Digital Shoreline Analysis System

Methods

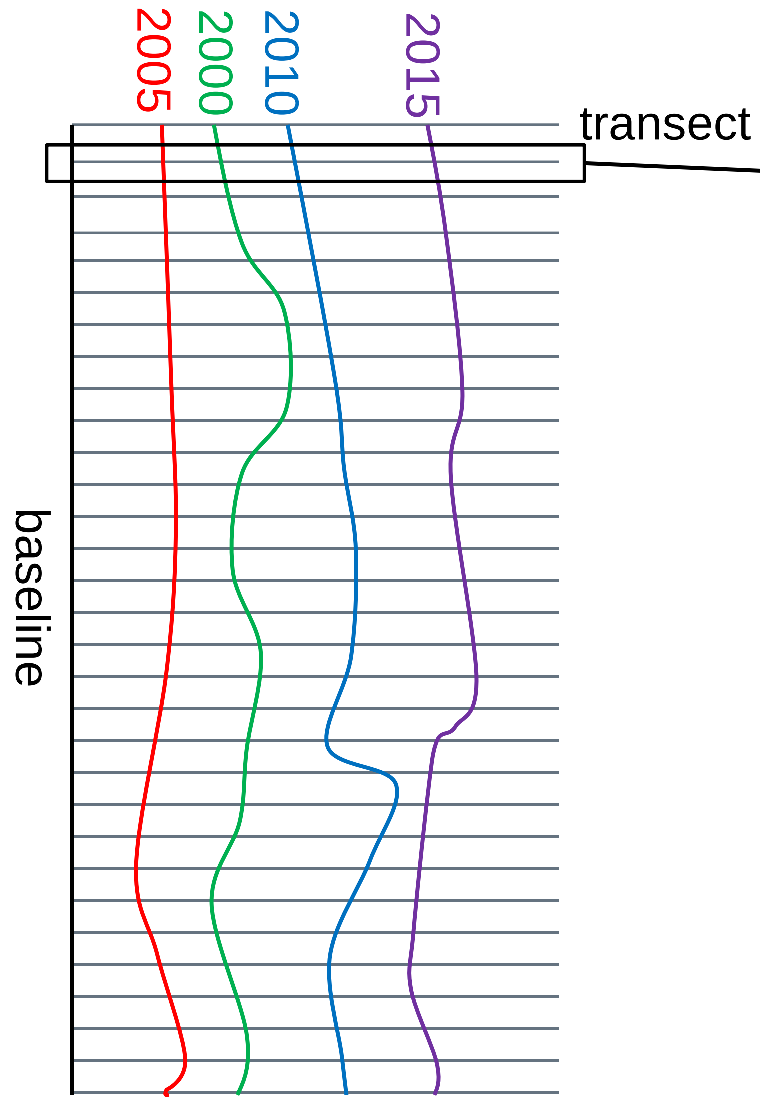
Landsat toolbox

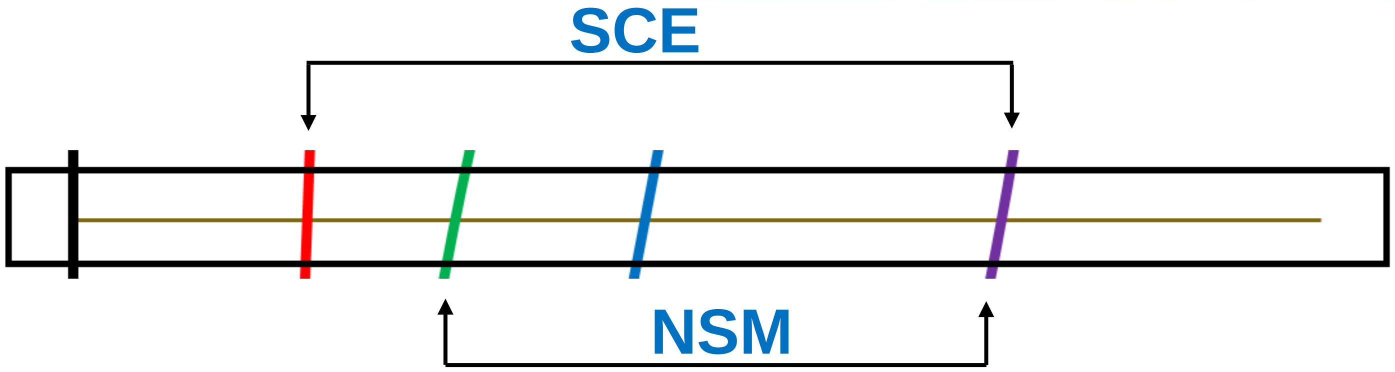
No.	Processes	Descriptions
1	Download and Extract images	*https://eathexplorer.usgs.gov/*
2	Landsat Tasseled Cap	Calculate the Tasseled Cap brightness, greenness, and wetness transformations. Normalize the band values to 0-255.
3	NDMI/NDVI	Calculate the Normalize Difference Moisture Index (NDMI) and Normalized the band values to 0-255.
4	Category Creation for Land & Sea	Take Tasseled Cap and NDMI bands as input and create a 10-class land cover data set and dendrogram (note any band combination could be used).
5	Classify Land and Sea	Reclass the land cover data set from 10 to 2 classes.
6	Create Shore Boundary	Create a shoreline from the 2-class land cover data set using Majority filtering, Contour, and Smooth line commands.
7	Output shorelines	Correct for cloud/surf/beach.

NDMI: Normalized Difference Moisture Index
NDVI: Normalized Difference Vegetation Index

Methods

DSAS module





EPR = NSM/time

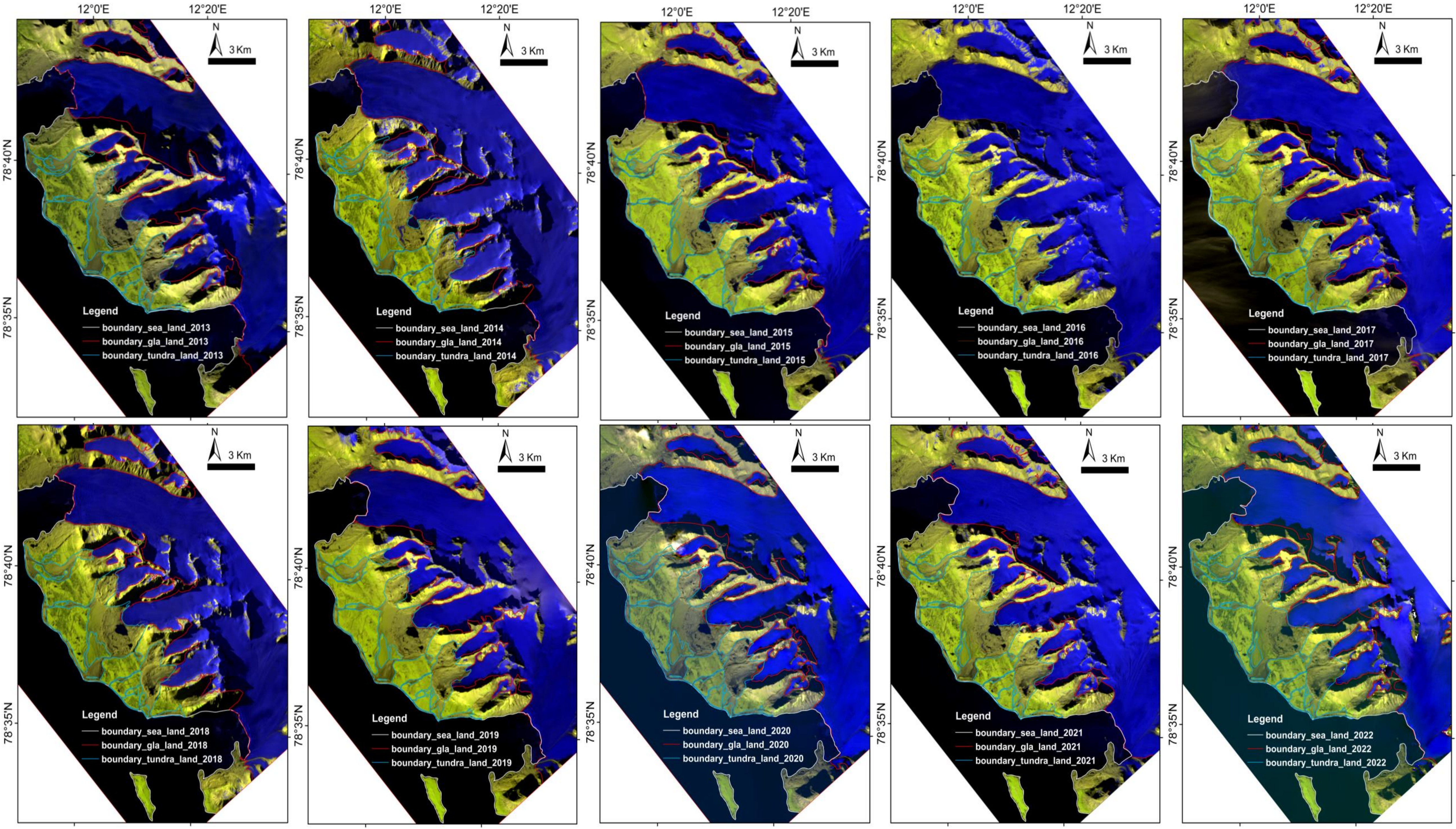
NSM: net shoreline movement (m)
SCE: shoreline change envelope (m)
EPR: end point rate (m/yr)
LRR: linear regression rate (m/yr)

LRR: rate-of-change statistic by fitting a least square regression to all shorelines at each transect

Transects **cast perpendicular** from reference **baseline** to **shorelines**

No.	Sensors	Frame	Acquisition date	Spatial resolution (m)	No.	Sensors	Frame	Acquisition date	Spatial resolution (m)
1	Landsat 4-5 TM	216/004	1985/08/30	30	20	-			
2	Landsat 4-5 TM	217/004	1986/07/07	30	21	Landsat 7 ETM+	220/003	2005/07/24	scan line error
3	Landsat 4-5 TM	217/004	1987/07/10	30	22	Landsat 4-5 TM	216/004	2006/07/23	30
4	Landsat 4-5 TM	216/004	1988/09/23	30	23	-			
5	Landsat 4-5 TM	217/004	1989/07/31	30	24	-			
6	Landsat 4-5 TM	221/003	1990/06/28	30	25	-			
7	-				26	Landsat 7 ETM+	219/003	2010/07/31	scan line error
8	Landsat 4-5 TM	221/003	1992/07/03	30	27	Landsat 7 ETM+	220/003	2011/07/25	scan line error
9	Landsat 4-5 TM	220/003	1993/07/15	30	28	-			
10	Landsat 4-5 TM	219/003	1994/08/28	30	29	Landsat 8 OLI/TIRS	217/004	2013/09/19	30
11	Landsat 4-5 TM	215/004	1995/08/19	30	30	Landsat 8 OLI/TIRS	029/240	2014/07/15	30
12	-				31	Landsat 8 OLI/TIRS	216/004	2015/08/01	30
13	-				32	Landsat 8 OLI/TIRS	216/004	2016/07/02	30
14	-				33	Landsat 8 OLI/TIRS	220/003	2017/08/20	30
15	Landsat 7 ETM+	218/003	1999/07/10	30	34	Landsat 8 OLI/TIRS	025/241	2018/07/30	30
16	Landsat 7 ETM+	214/004	2000/08/17	30	35	Landsat 8 OLI/TIRS	215/004	2019/08/21	30
17	Landsat 7 ETM+	214/004	2001/06/17	30	36	Landsat 8 OLI/TIRS	215/004	2020/08/23	30
18	Landsat 7 ETM+	221/003	2002/07/07	30	37	Landsat 8 OLI/TIRS	216/004	2021/08/10	30
19	-				38	Landsat 8 OLI/TIRS	221/003	2022/08/23	30

Landsat images collected


12°0'E
12°20'E
78°40'N
78°35'N
N
3 Km
Legend
boundary_sea_land_2013
boundary_gla_land_2013
boundary_tundra_land_2013
Legend
boundary_sea_land_2014
boundary_gla_land_2014
boundary_tundra_land_2014
Legend
boundary_sea_land_2015
boundary_gla_land_2015
boundary_tundra_land_2015
Legend
boundary_sea_land_2016
boundary_gla_land_2016
boundary_tundra_land_2016
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boundary_sea_land_2019
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boundary_tundra_land_2019
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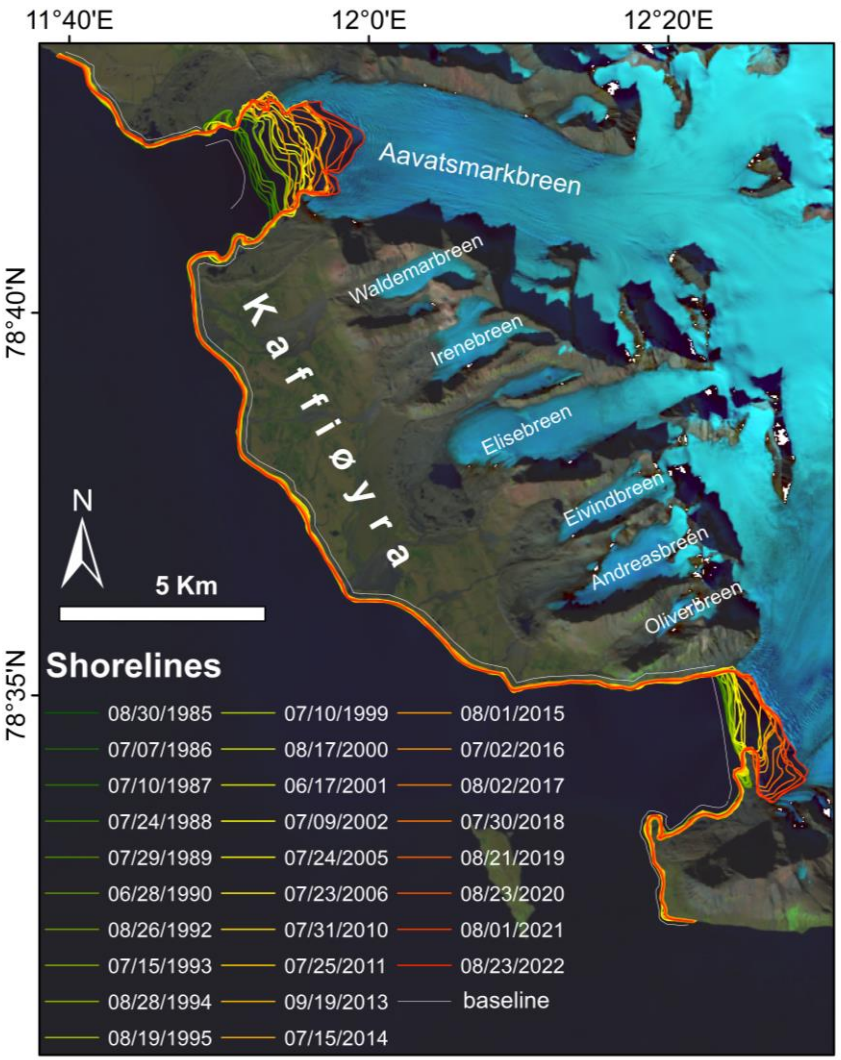
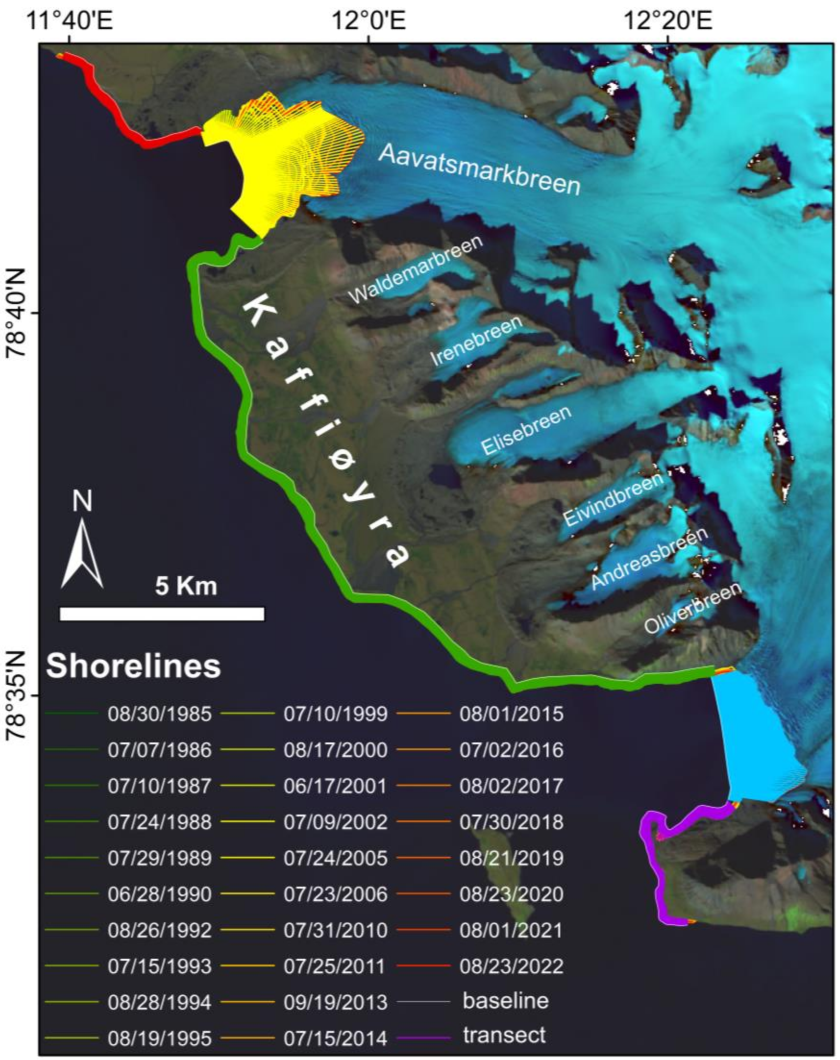
boundary_sea_land_2020
boundary_gla_land_2020
boundary_tundra_land_2020
Legend
boundary_sea_land_2021
boundary_gla_land_2021
boundary_tundra_land_2021
Legend
boundary_sea_land_2022
boundary_gla_land_2022
boundary_tundra_land_2022

Results

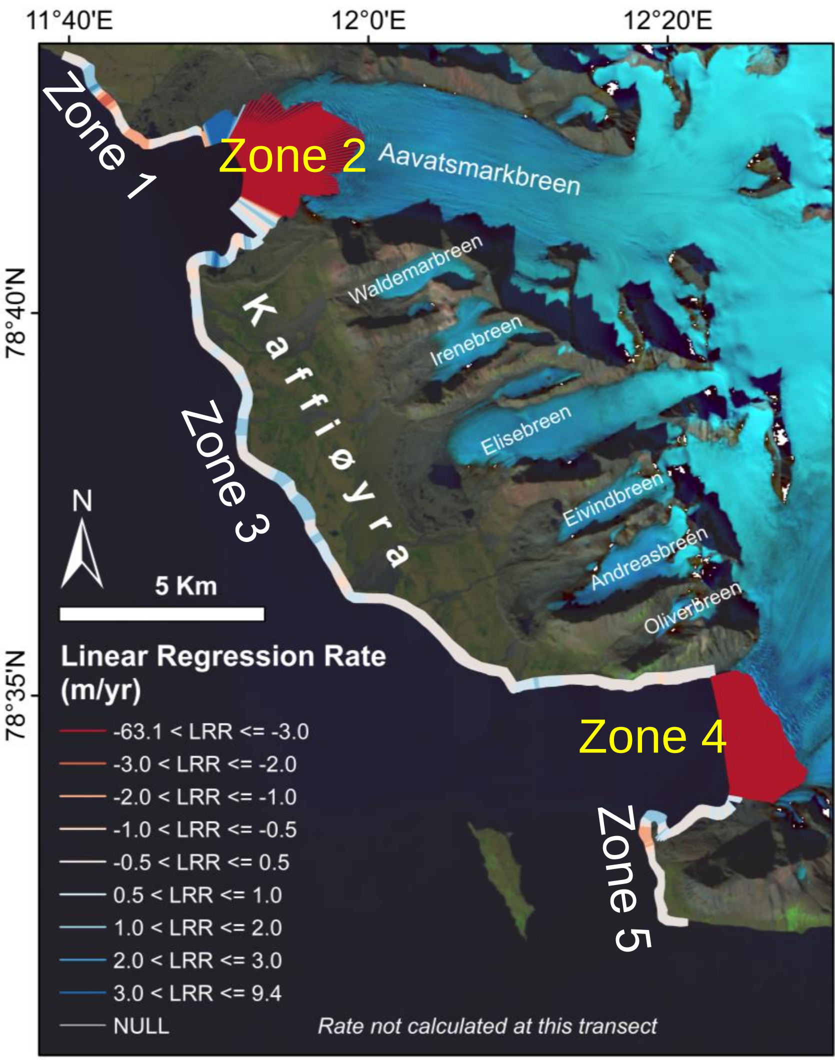
①



②



③



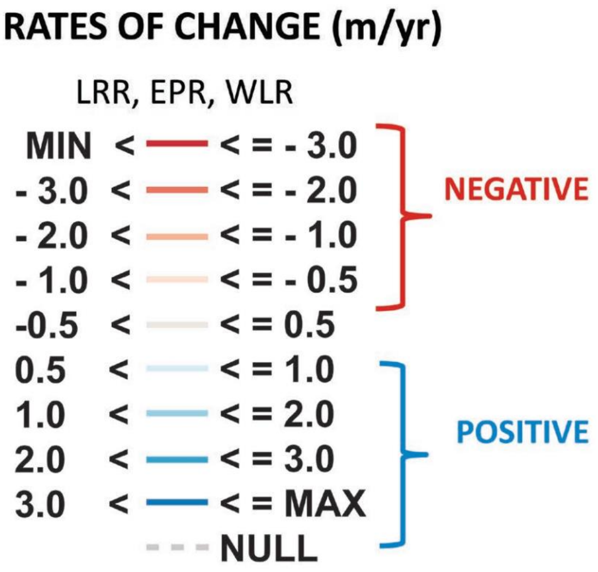
Shorelines | Create transect | Calculate LRR

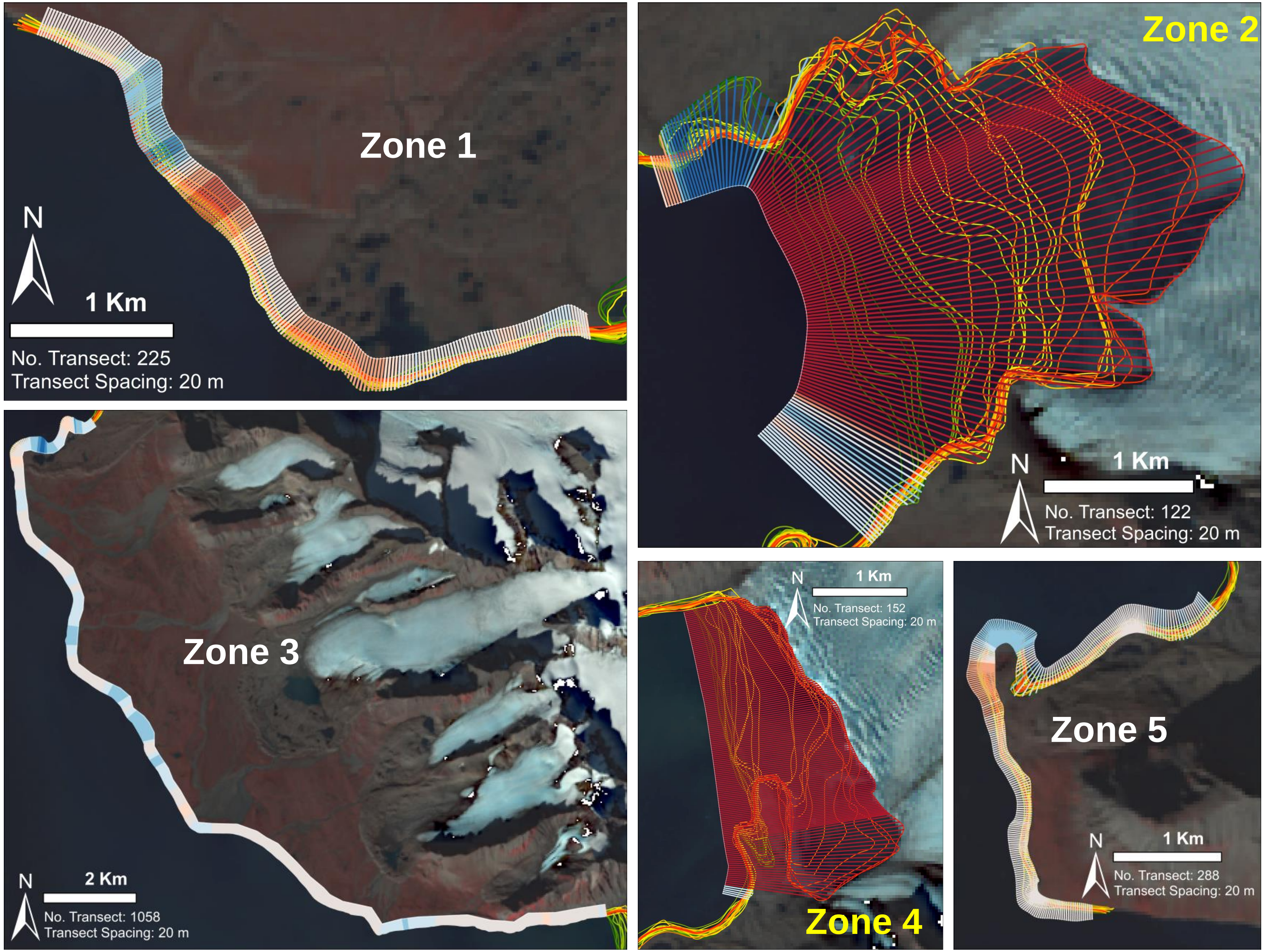
Results

2 types of shorelines

Zone 1, 3, 5: relatively stable shoreline

Zone 2, 4: extremely change shoreline

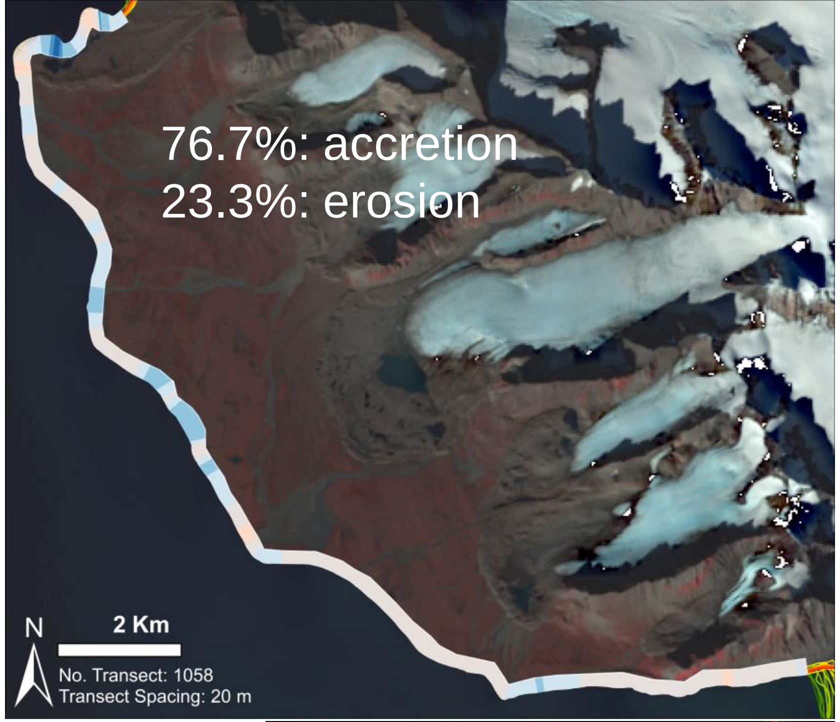


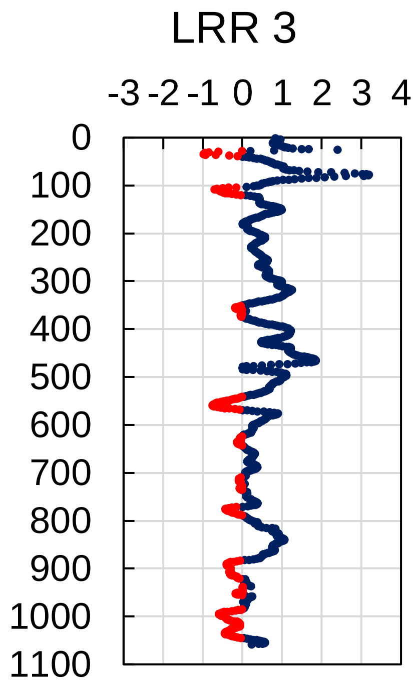


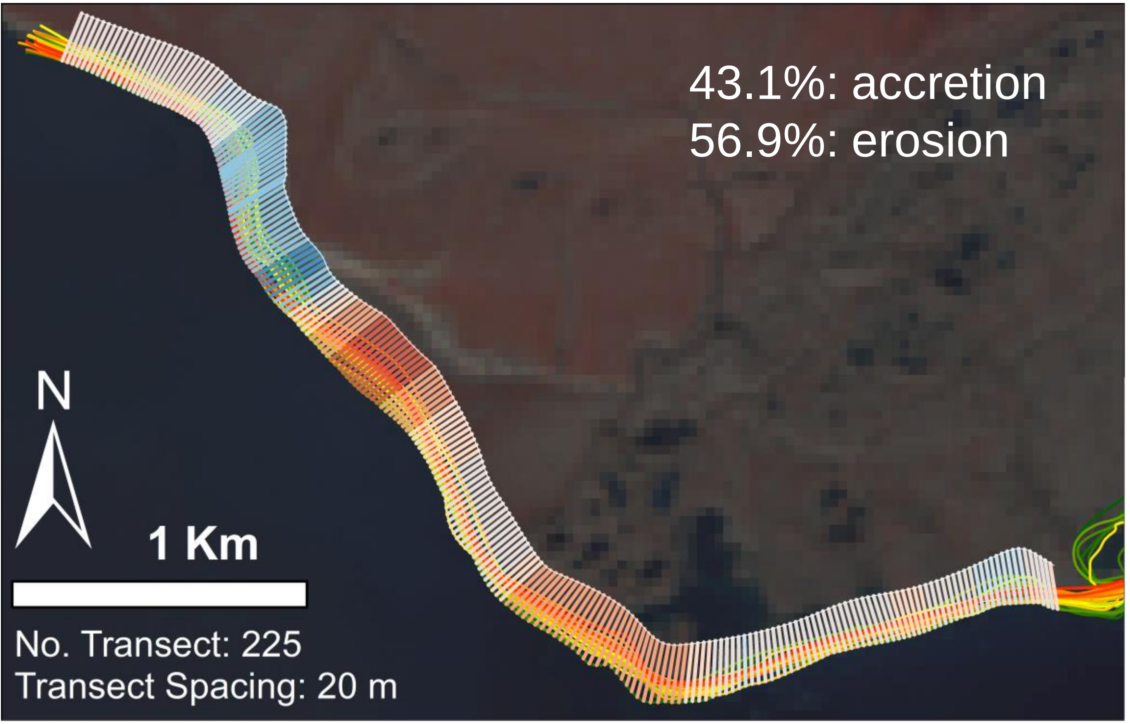
Results

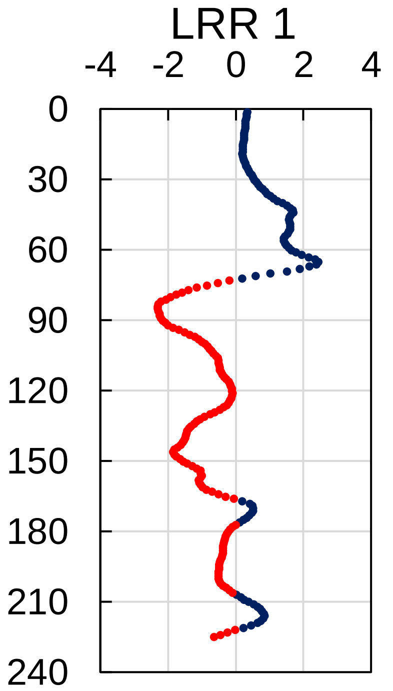
Zone 1, 3, 5: relatively stable shoreline

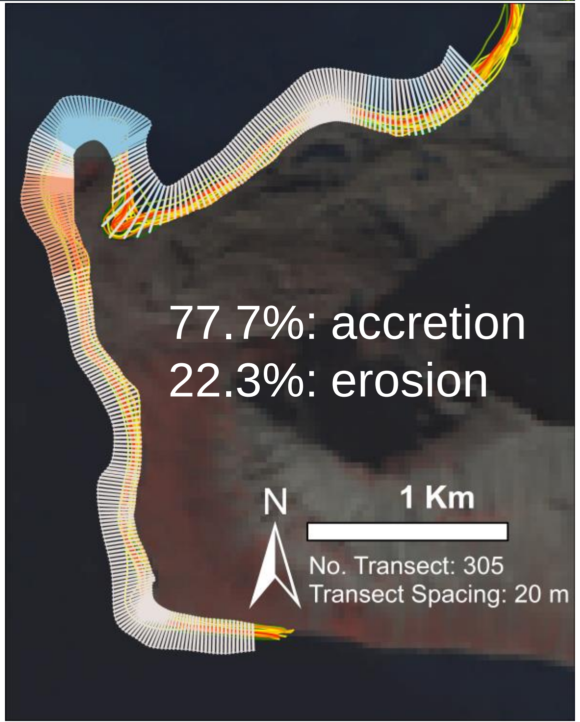
Rate vary: -2 to +3 m/yr

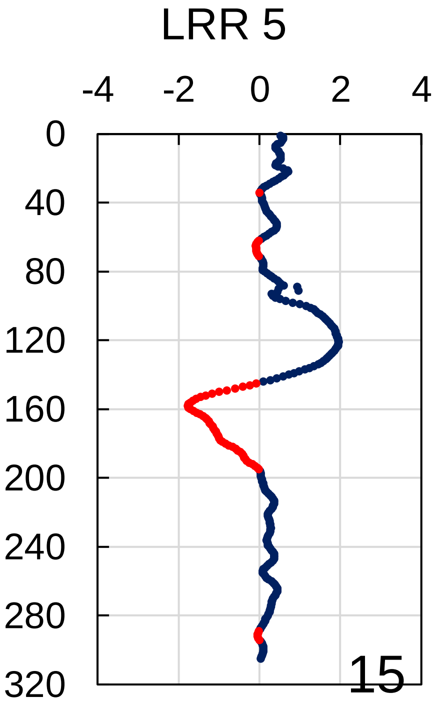








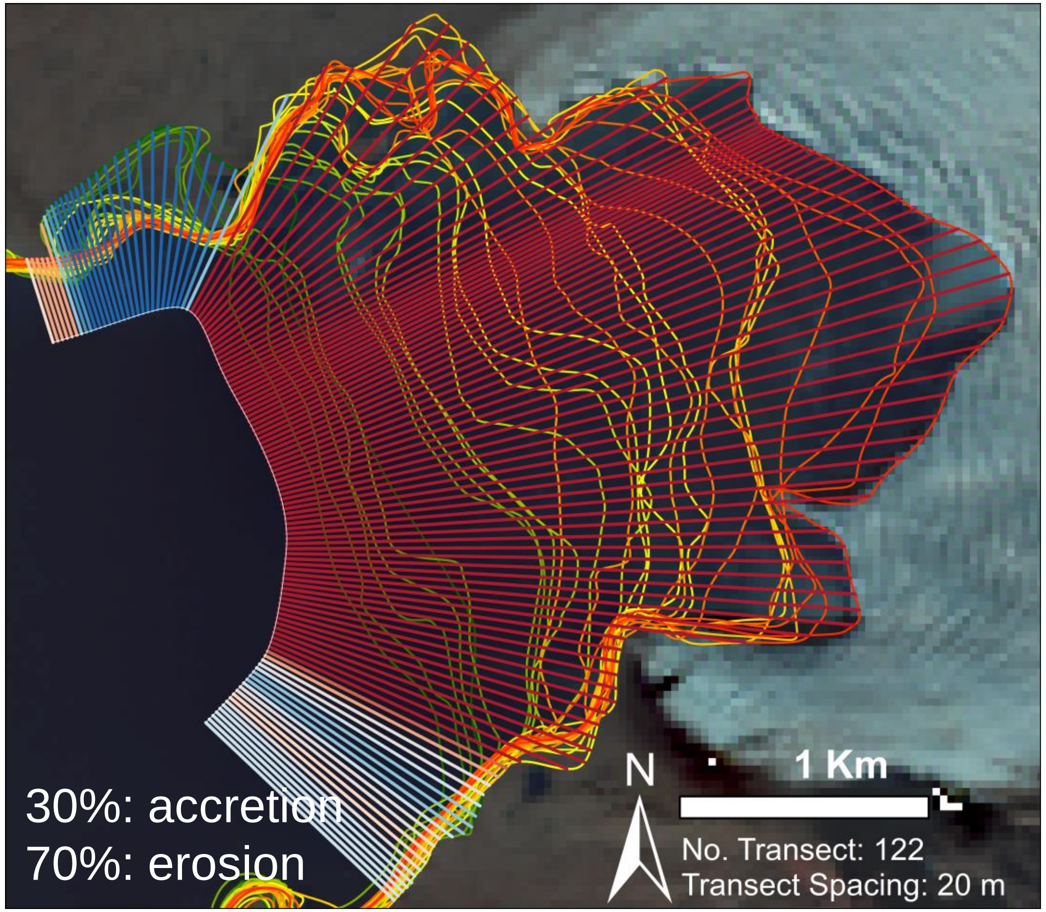


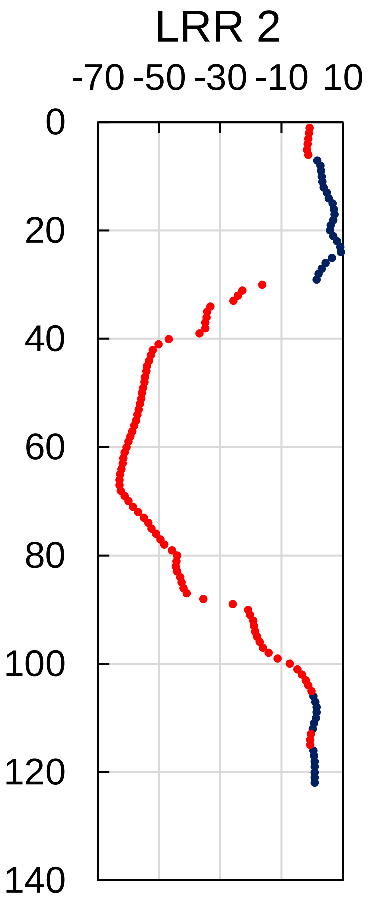


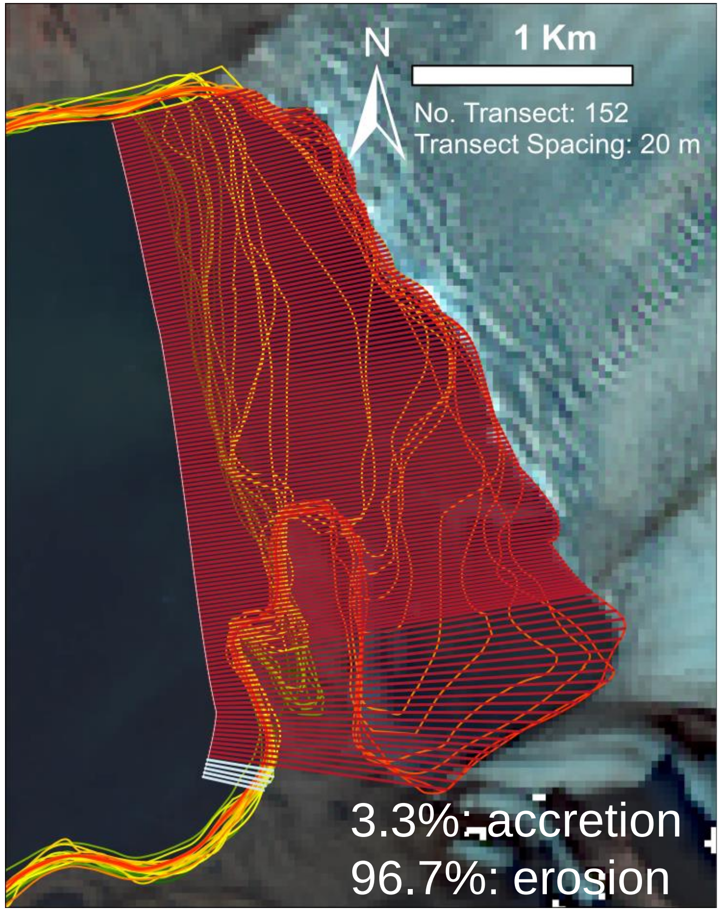
Results

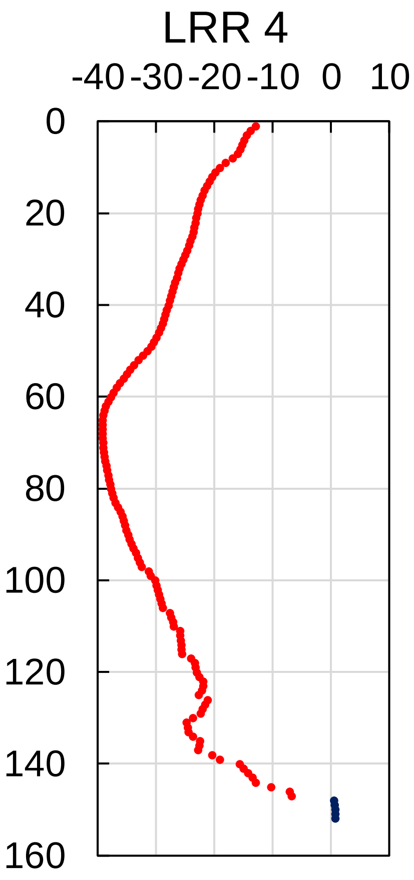
Zone 2, 4: extremely change shoreline

Rate vary: -65 to +10 m/yr





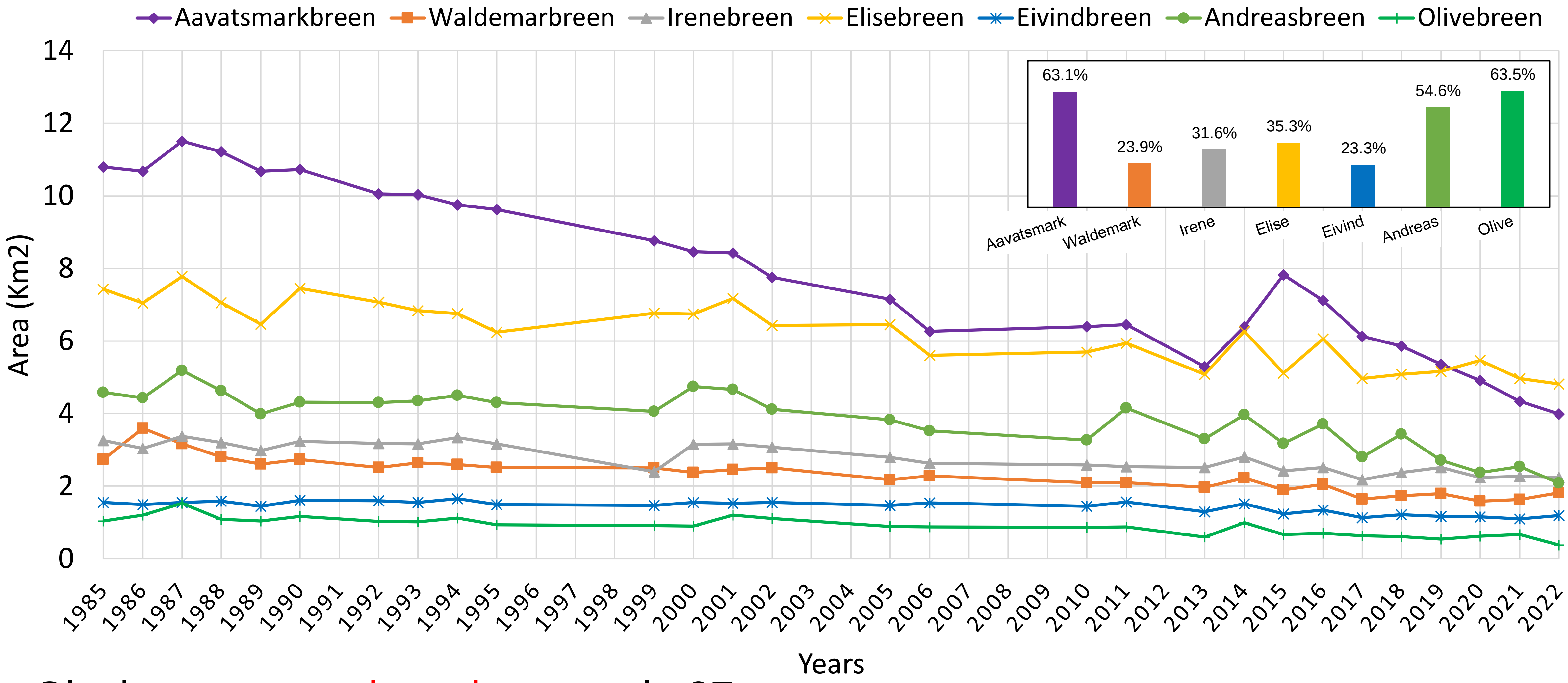




➡ The shoreline is relatively stable, except for the glacier’s shoreline is strongly eroded

Results

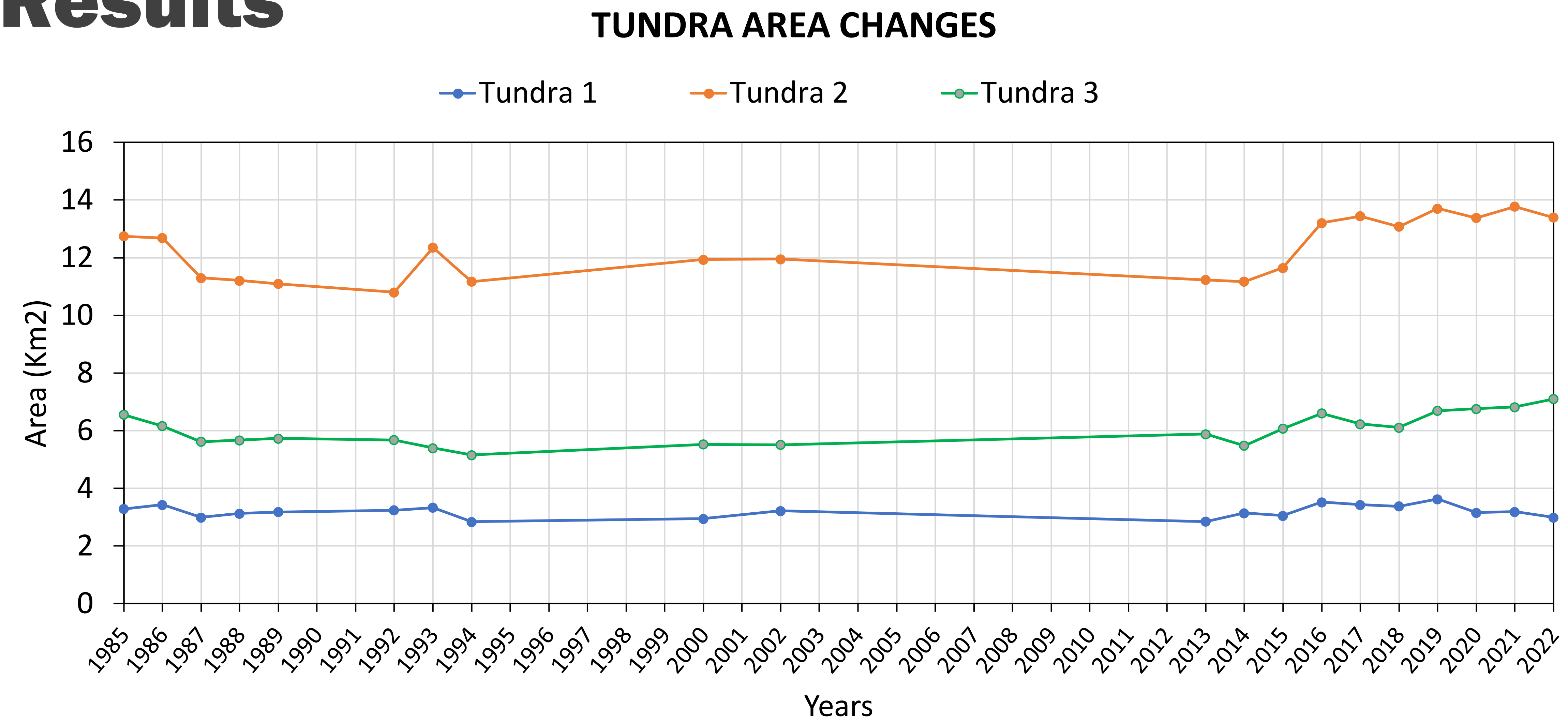
GLACIER AREA CHANGES



Glaciers area tends to decrease in 37 years

Aavatsmark, Andreas, Olive has lost more than 50% area

Results



Tundra area tends to increase, but not significantly

20/37 years are extracted, images unavailable or boundary difficult to determine

Conclusion

Remote Sensing + GIS Technique: suitable for monitoring long-term object changes (37 years)

(1) Shoreline change

Relatively stable in zone 1, 3, 5: LRR vary -2 to +3 m/yr, accretion predominate

Strongly eroded in zone 2, 4: LRR vary -65 to +10 m/yr, erosion predominate

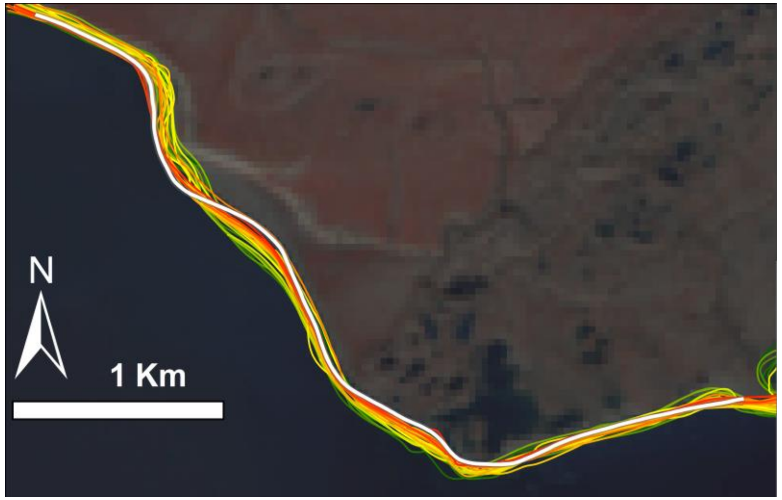
➧ Changes are mainly in glacier’s shoreline, the remaining shoreline are not significant

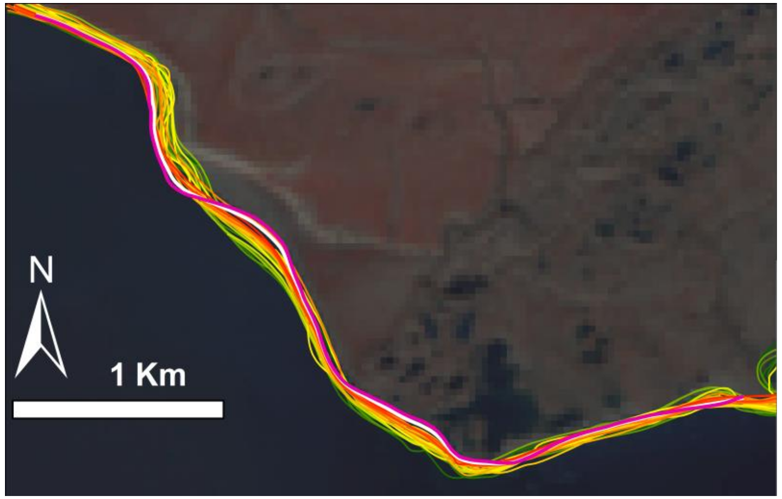
(2) Glaciers area tend to decrease

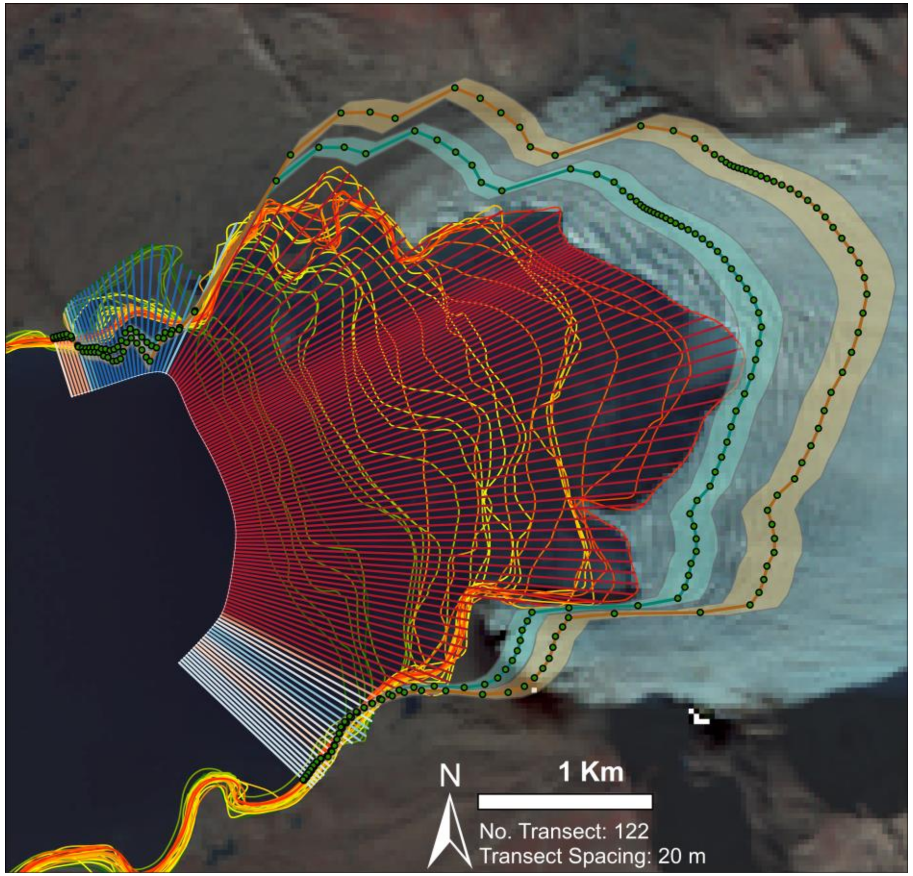
Top 3 largest glaciers area: Aavatsmark, Elise, Andreas lost 63.1%, 35.3%, 54.6%, respectively

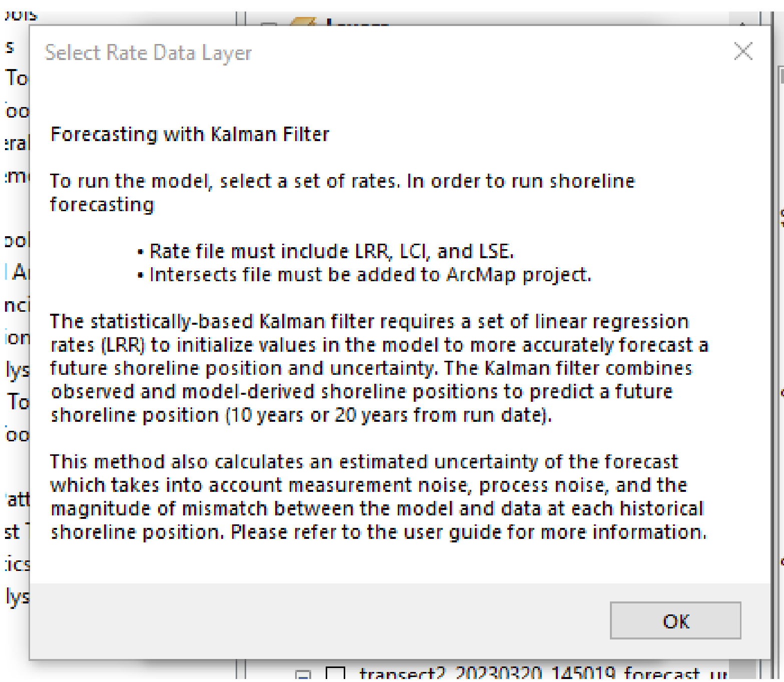
(3) Tundra area tend to increase, but not significantly < 10%


THANK YOU!
Q & A



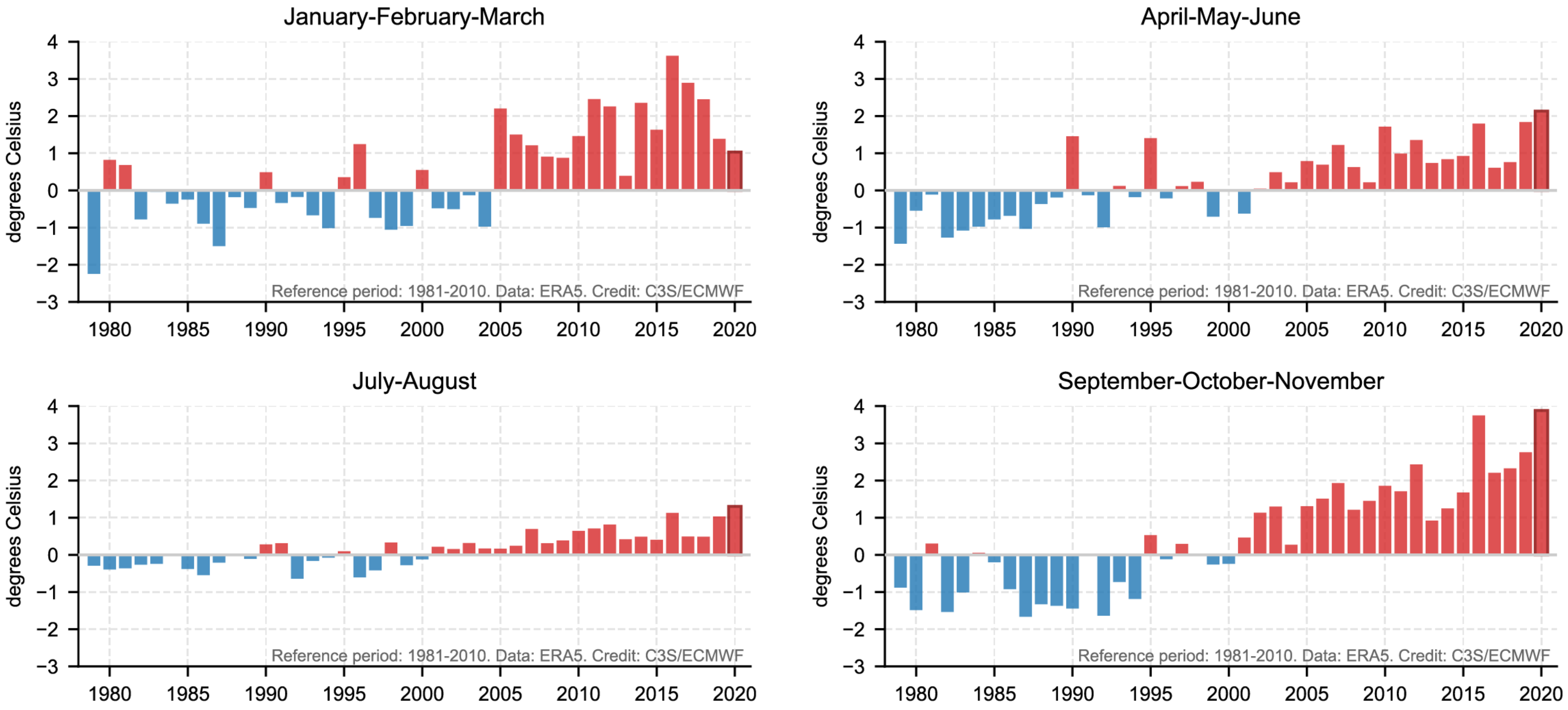


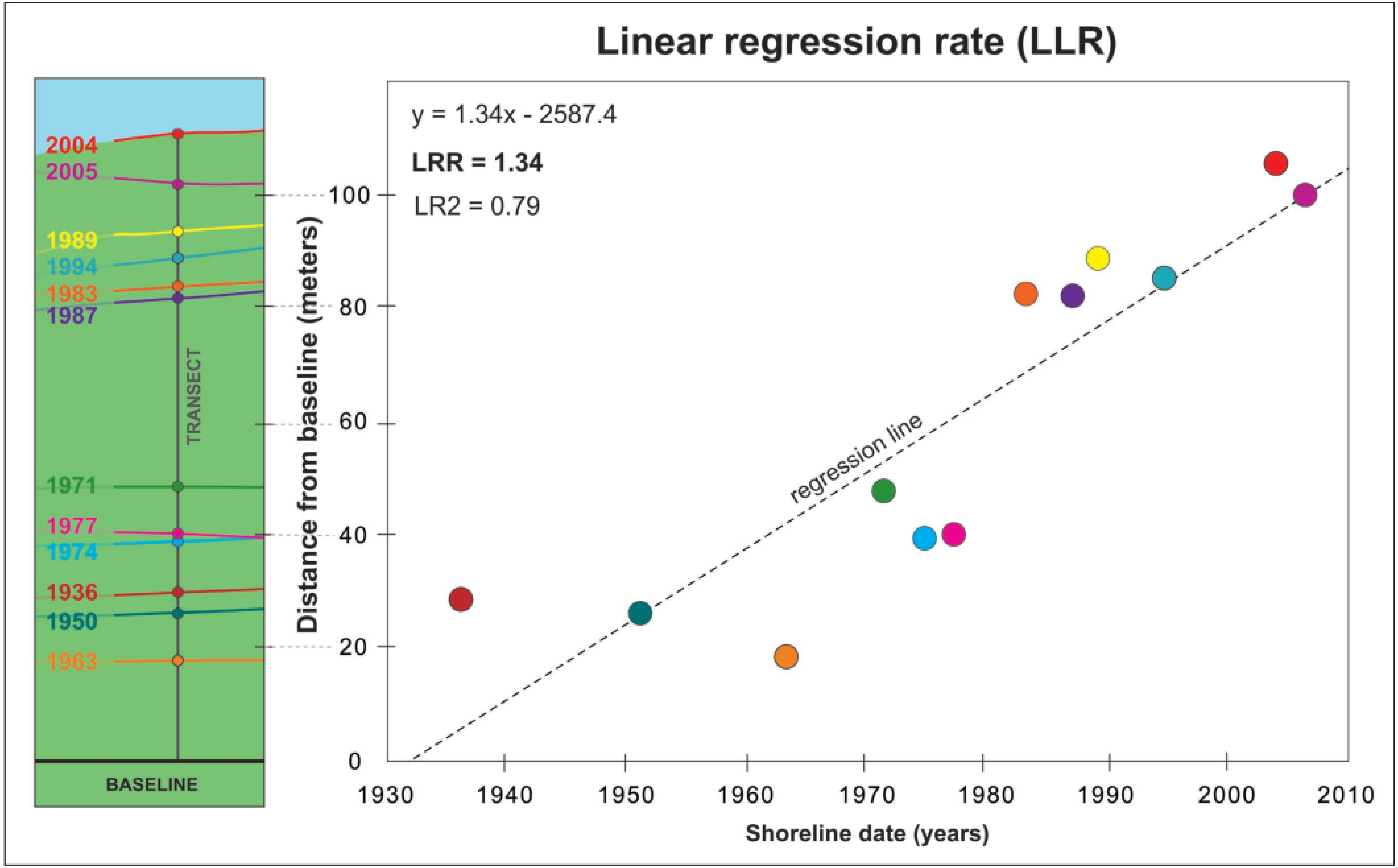




U.S. Geological Survey, National Assessment of Coastal Vulnerability to Sea-Level Rise: Preliminary Results for the U.S. Gulf of Mexico Coast, Open File Report 00-179, Coastal Vulnerability Index (C.V.I.) (usgs.gov)

Multi-month average surface temperature anomalies for the Arctic




Linear regression rate (LLR)
2004
2005
1989
1994
1983
1987
TRANSECT
1971
1977
1974
1936
1950
1963
BASELINE
y = 1.34x - 2587.4
LRR = 1.34
LR2 = 0.79
regression line
Distance from baseline (meters)
0
20
40
60
80
100
1930
1940
1950
1960
1970
1980
1990
2000
2010
Shoreline date (years)