

Glaciology
EESCGU4220

Lecture 11: Glacial hydrology

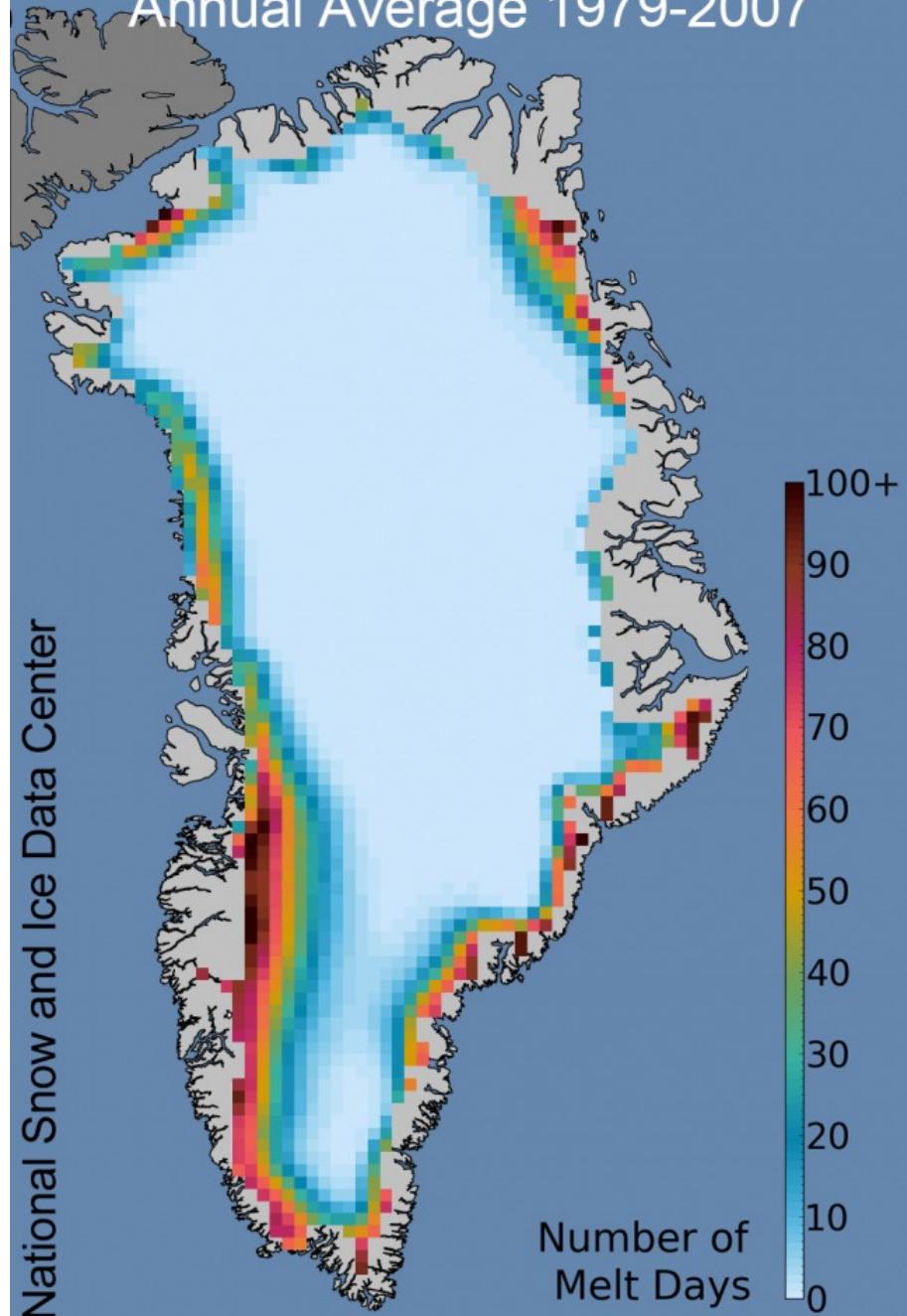
Why?

Where?

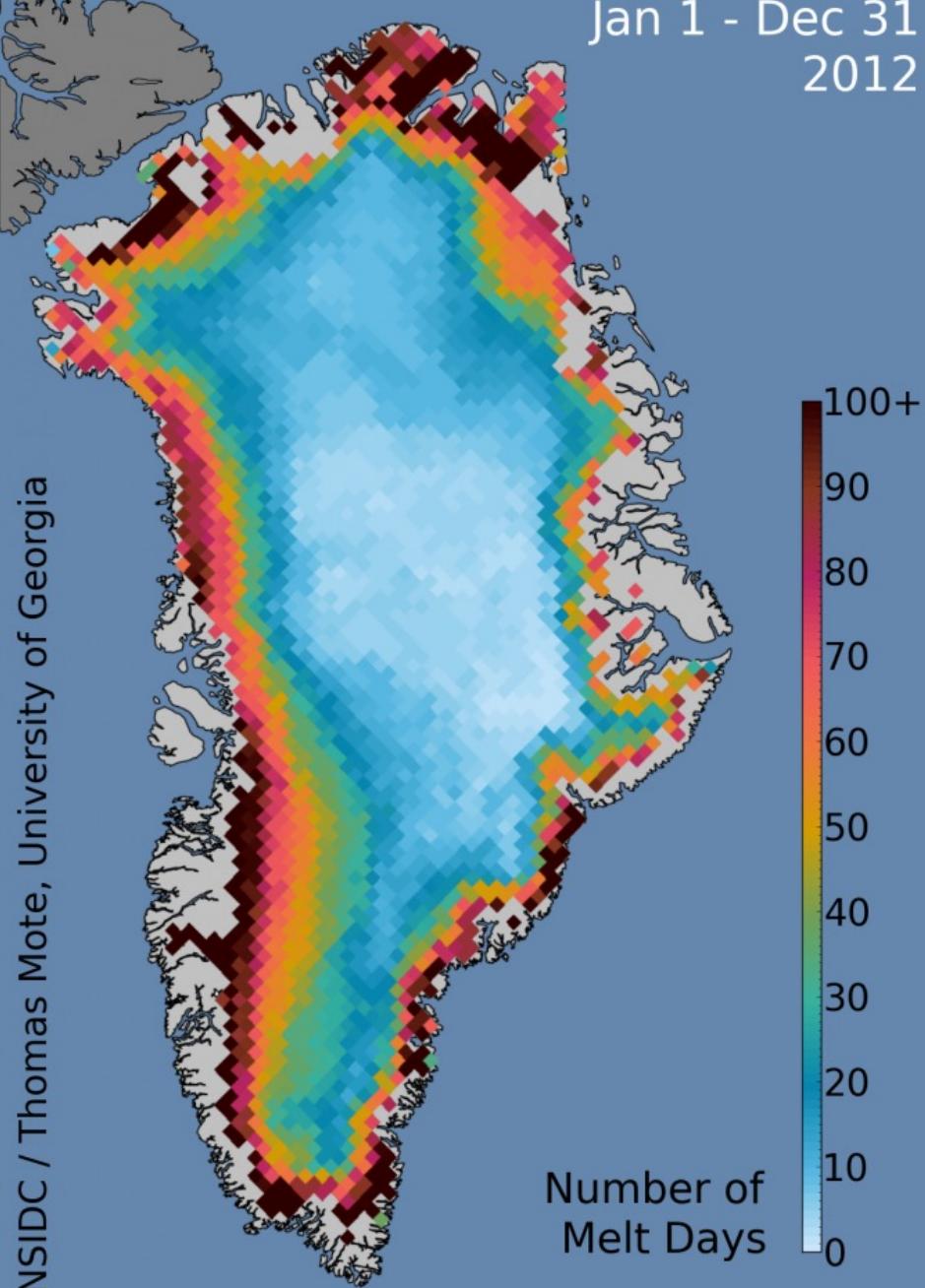
What?

How?

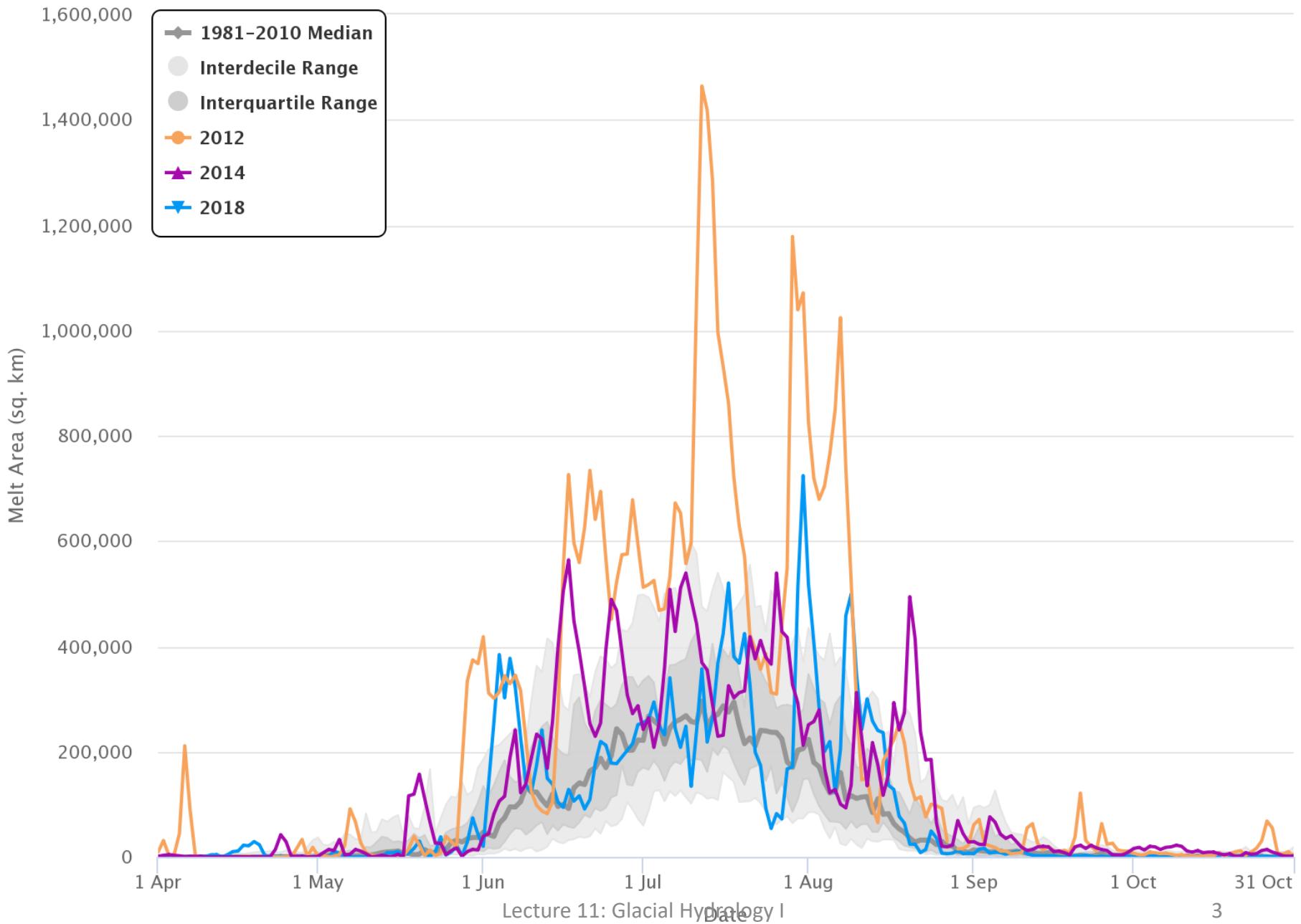
Greenland Cumulative Melt Days
Annual Average 1979-2007

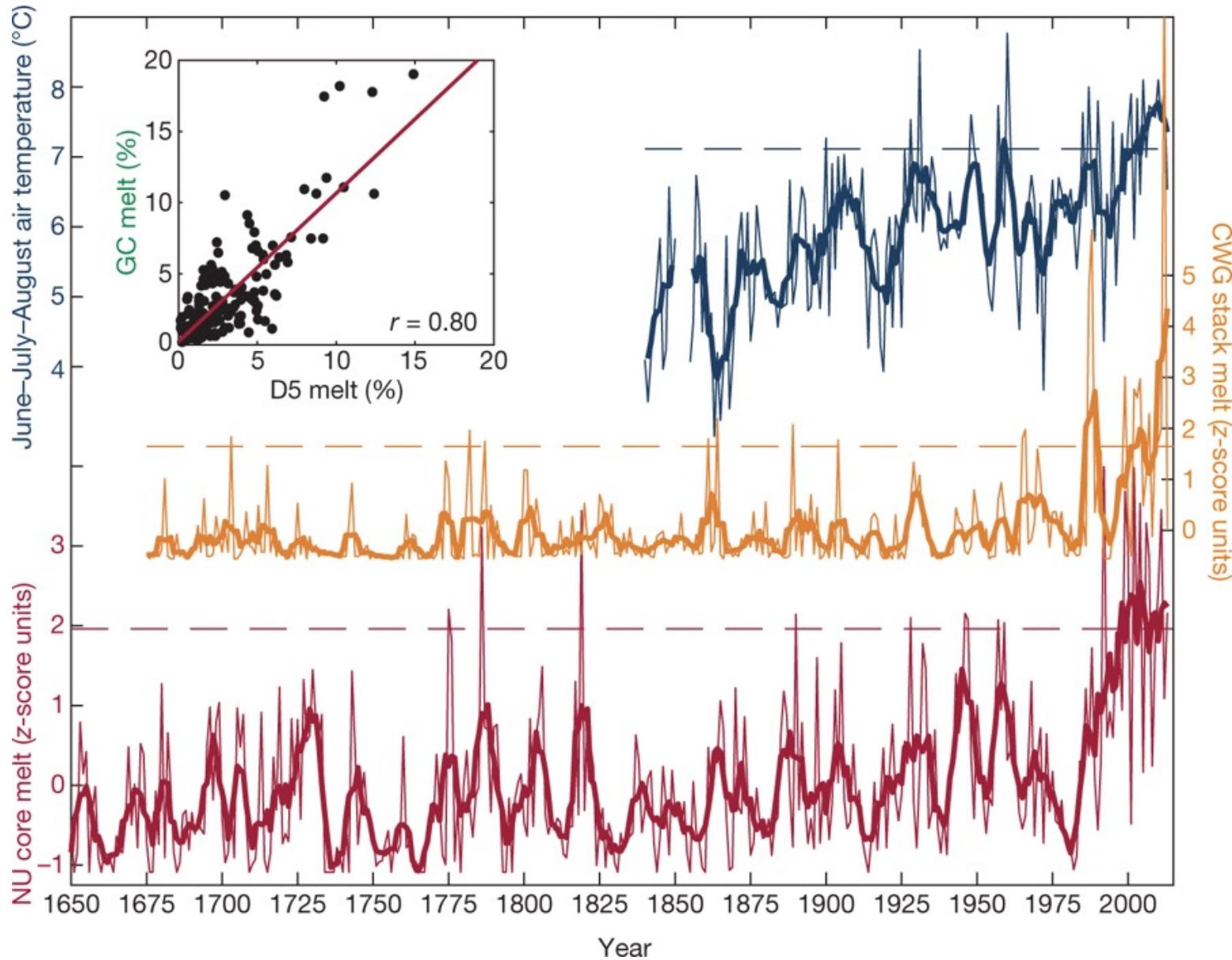


Greenland Cumulative Melt Days
Jan 1 - Dec 31
2012



Greenland Surface Melt Extent





Trusel et al., 2019







© 2018 Google
Image © 2018 Asiaq
Image © 2018 DigitalGlobe



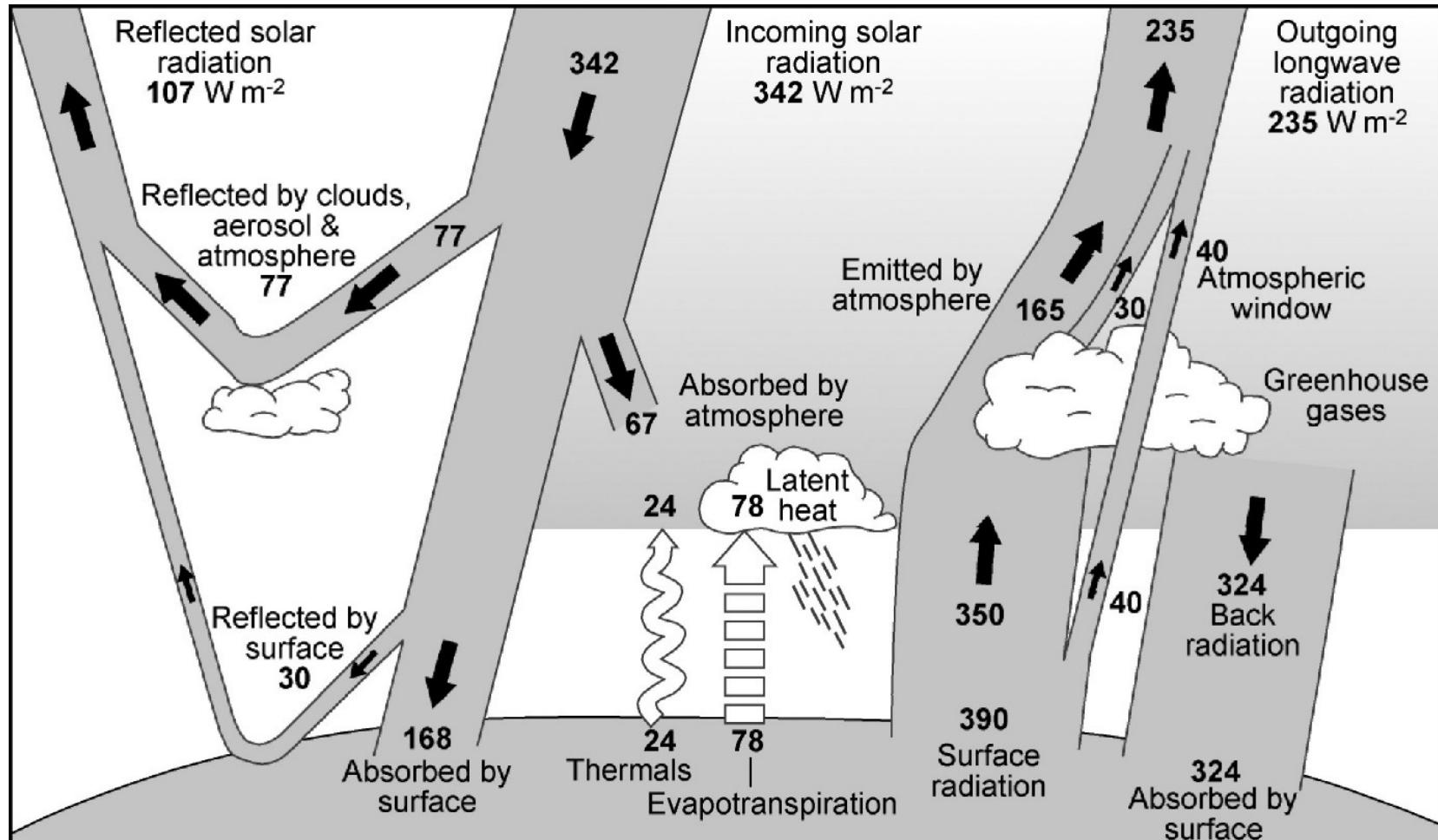
Image © 2018 Asiaq

Google earth

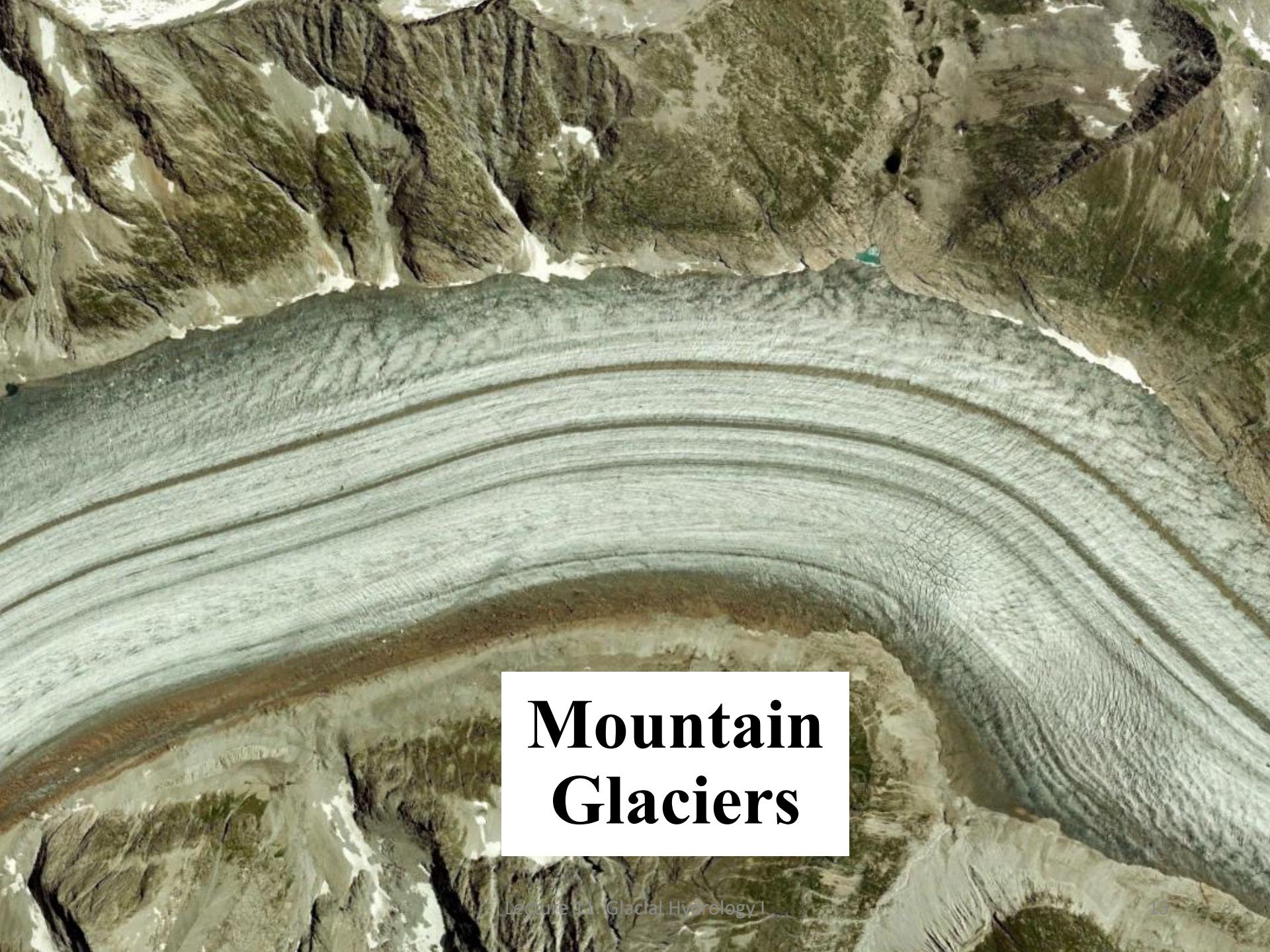


Why?

Why? – energy balance

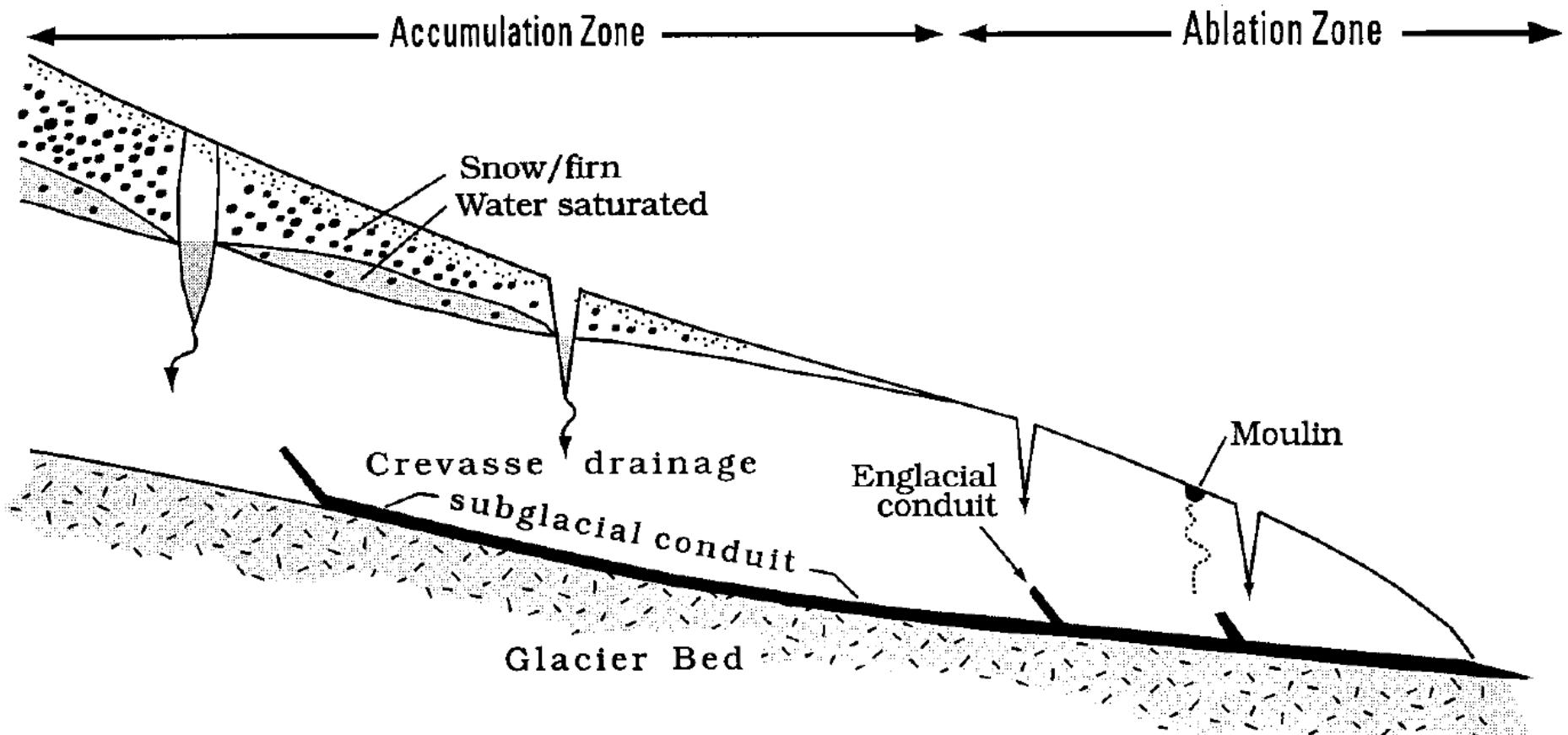


$$E_N = E_S^\downarrow + E_S^\uparrow + E_L^\downarrow + E_L^\uparrow + E_H + E_E$$

An aerial photograph of a large mountain glacier. The glacier's surface is covered in prominent, wavy, light-colored streaks called surface striations, which indicate the direction of ice movement. The glacier flows from the bottom left towards the top right. It is surrounded by rugged, rocky mountain peaks. Some patches of snow and ice are visible at the higher elevations.

Mountain Glaciers

Where? Mountain glaciers



Fountain (1998)

Where? Mountain glaciers



Data SIO, NOAA, U.S. Navy, NGA, GEBCO

© 2018 Google

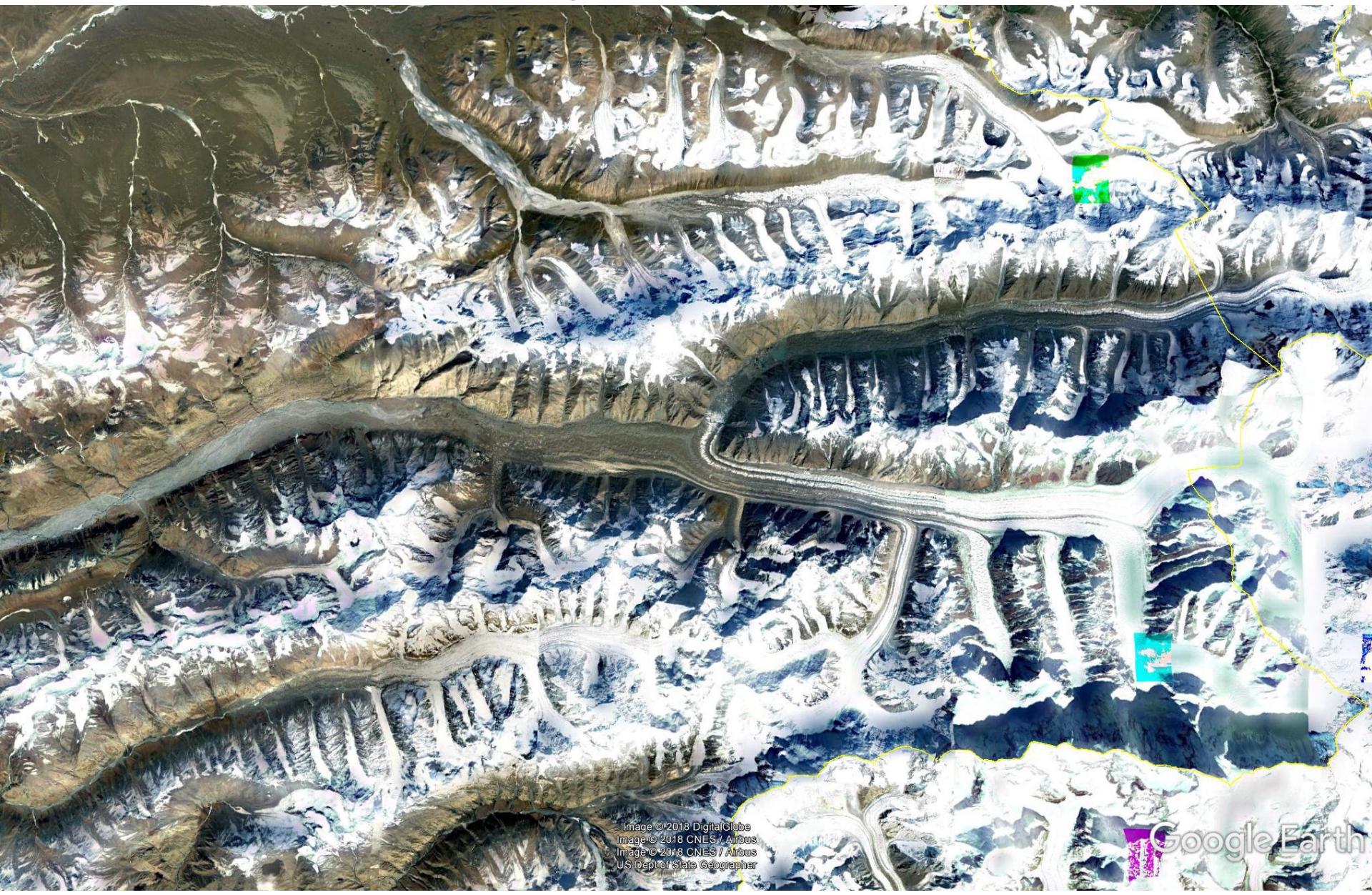
Image Landsat / Copernicus
US Dept of State Geographer

Google Earth

Where? Mountain glaciers



Where? Mountain glaciers



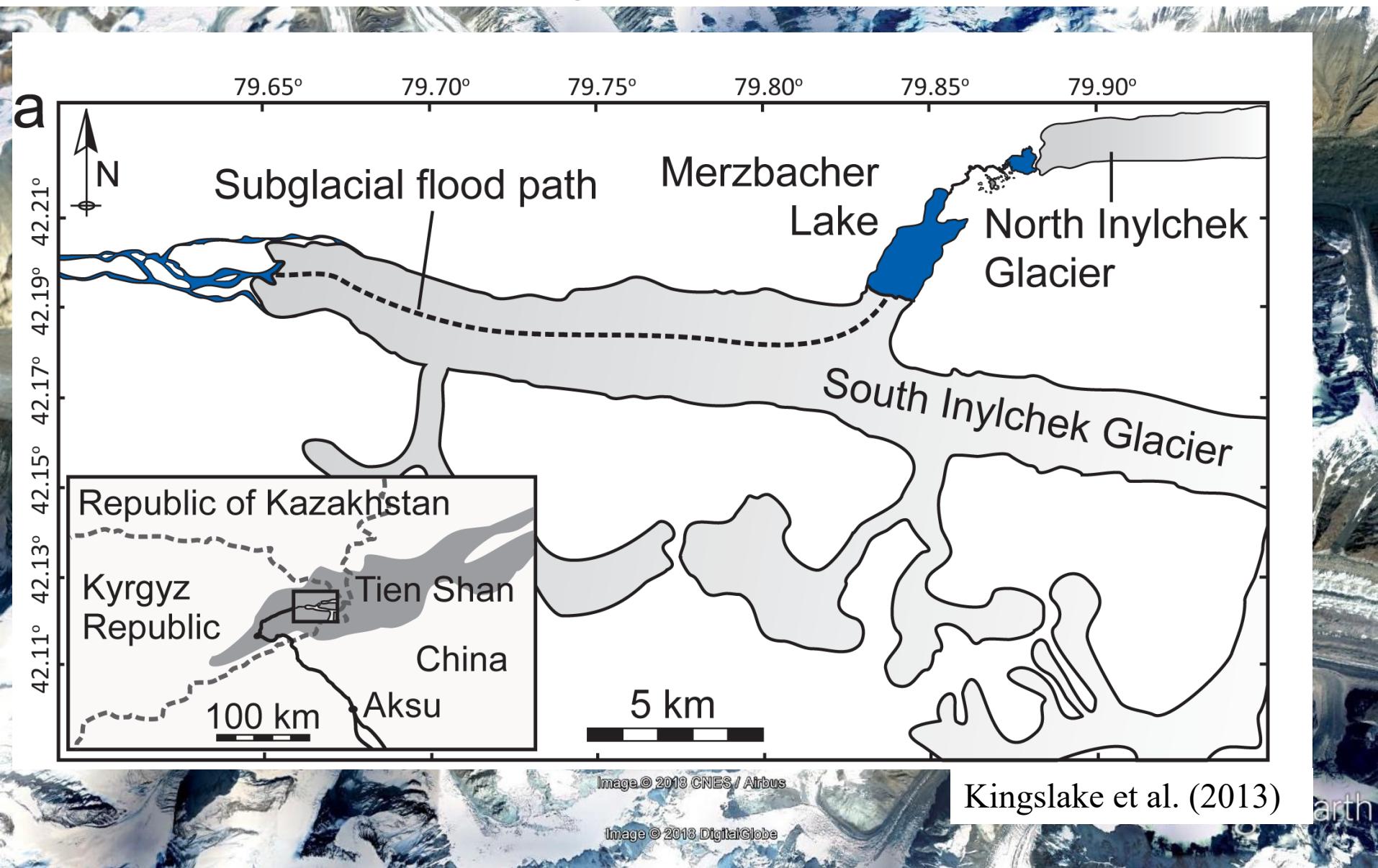
Where? Mountain glaciers



Image © 2018 CNES / Airbus

Image © 2018 DigitalGlobe

Where? Mountain glaciers



Where? Mountain glaciers

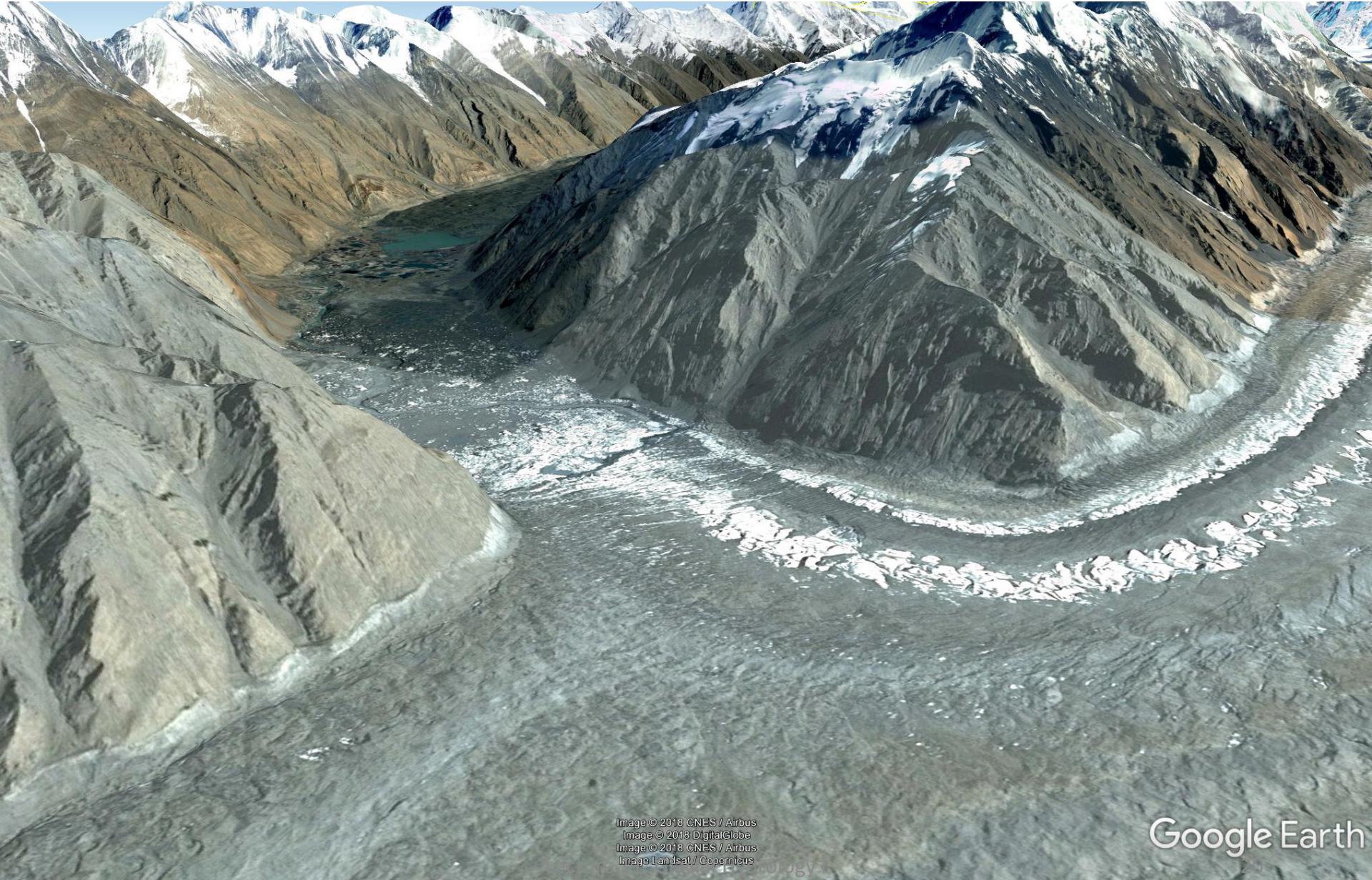
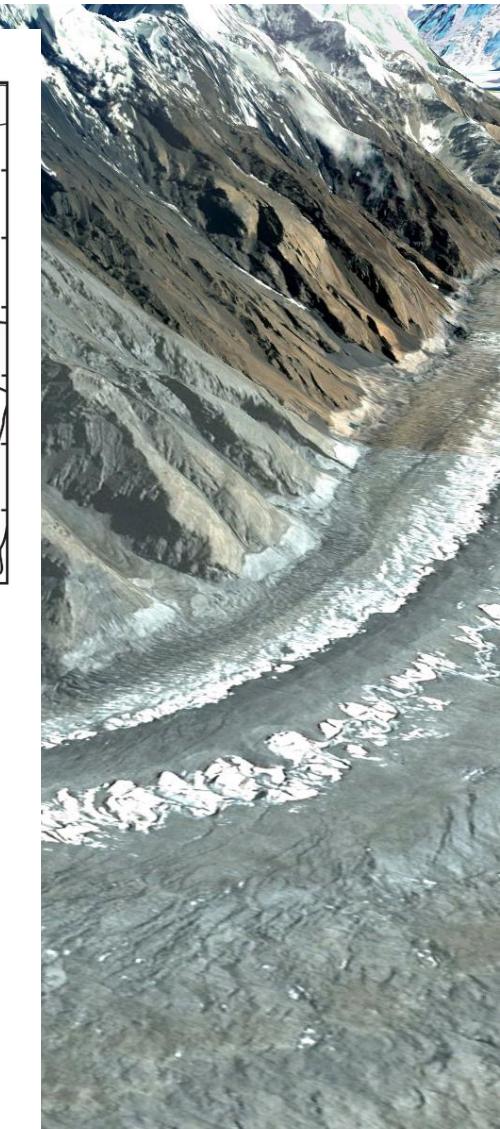
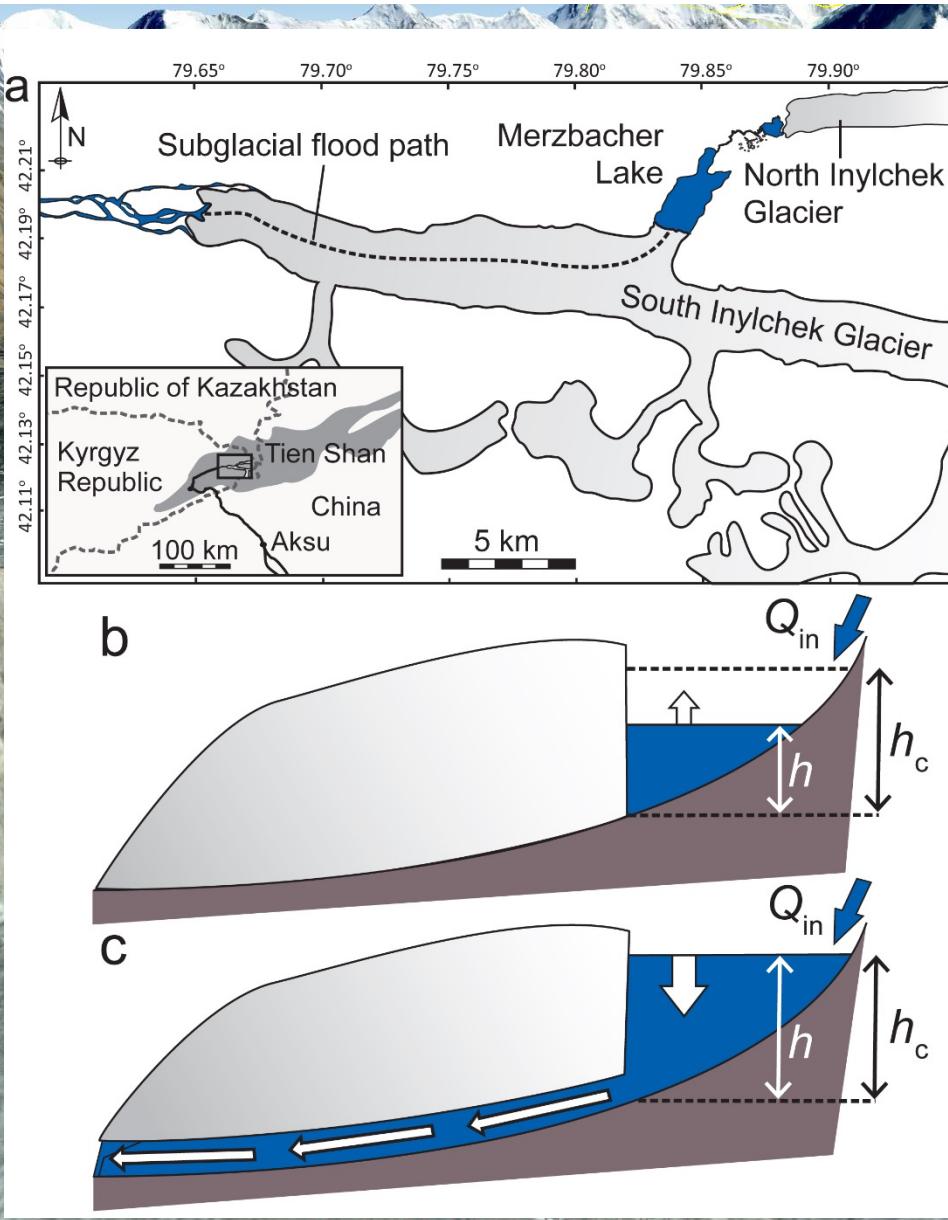


Image © 2018 CNES / Airbus
Image © 2018 DigitalGlobe
Image © 2018 CNES / Airbus
Image Landsat / Copernicus

Lecture 10: Glaciology

Google Earth
20

Where? Mountain glaciers



Kingslake et al. (2013)



Greenland

Image IBCAO

Image Landsat / Copernicus

Image U.S. Geological Survey

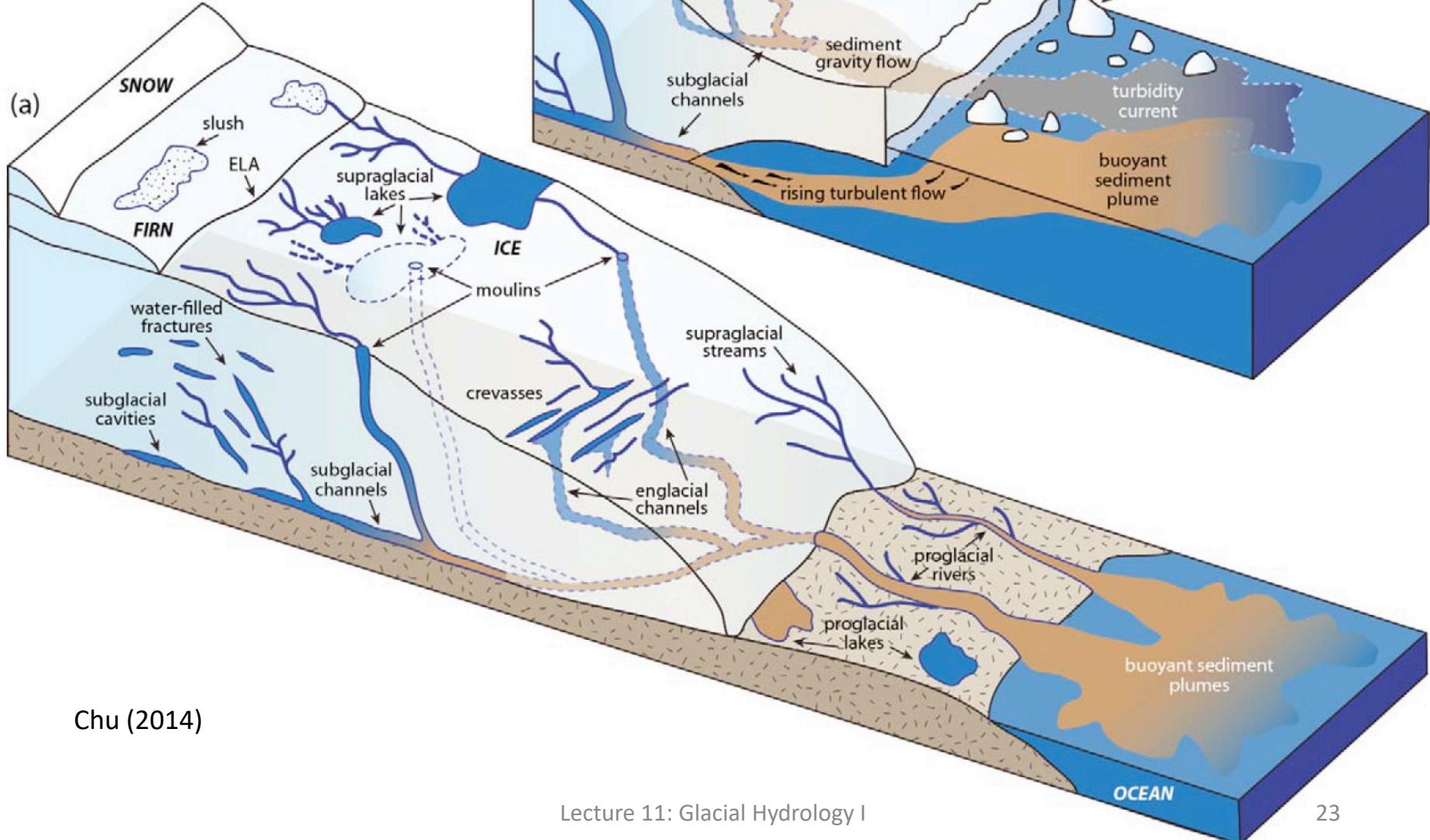
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Lecture 11: Glaciers and ice sheets

22

GO

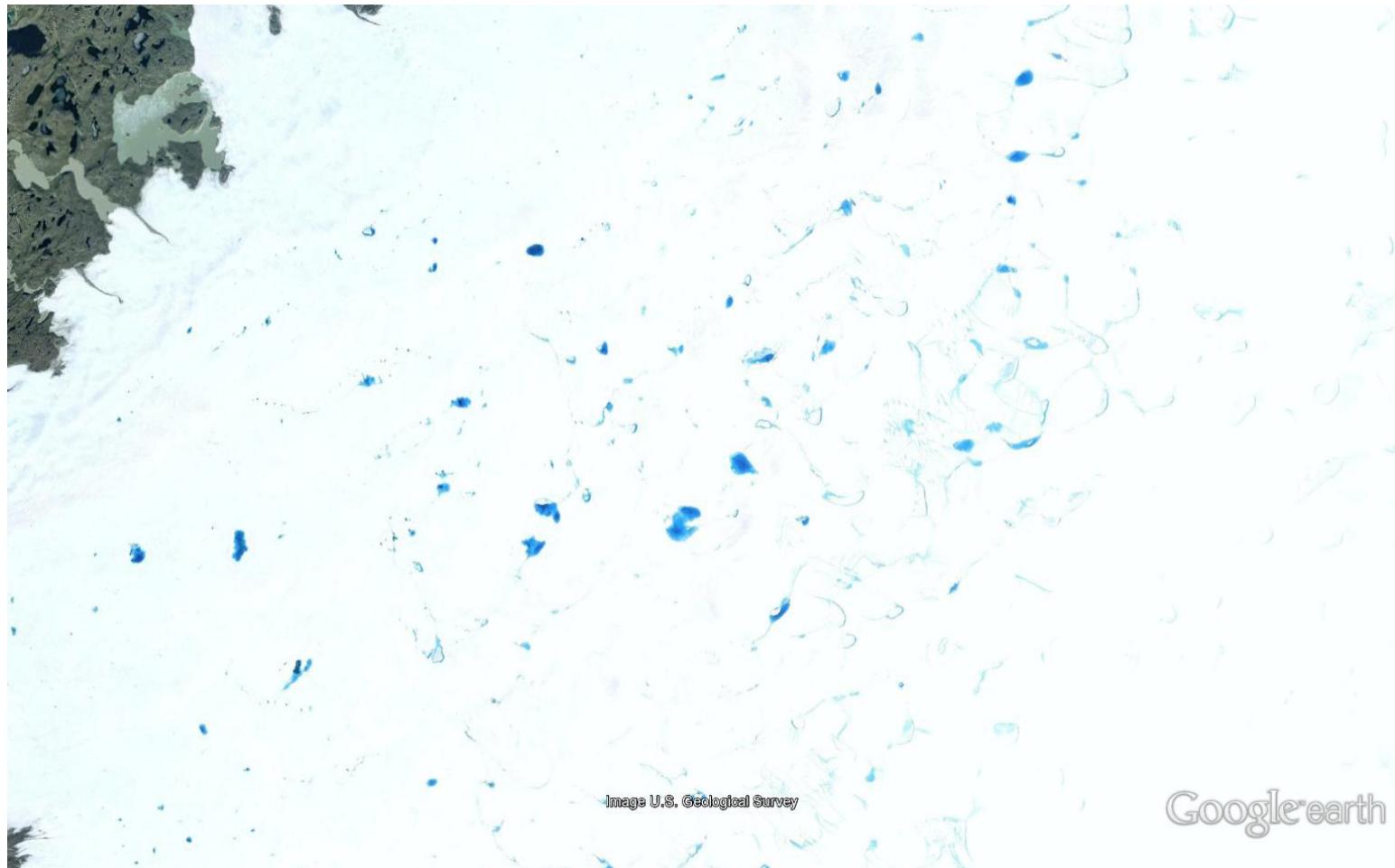
Where? Greenland



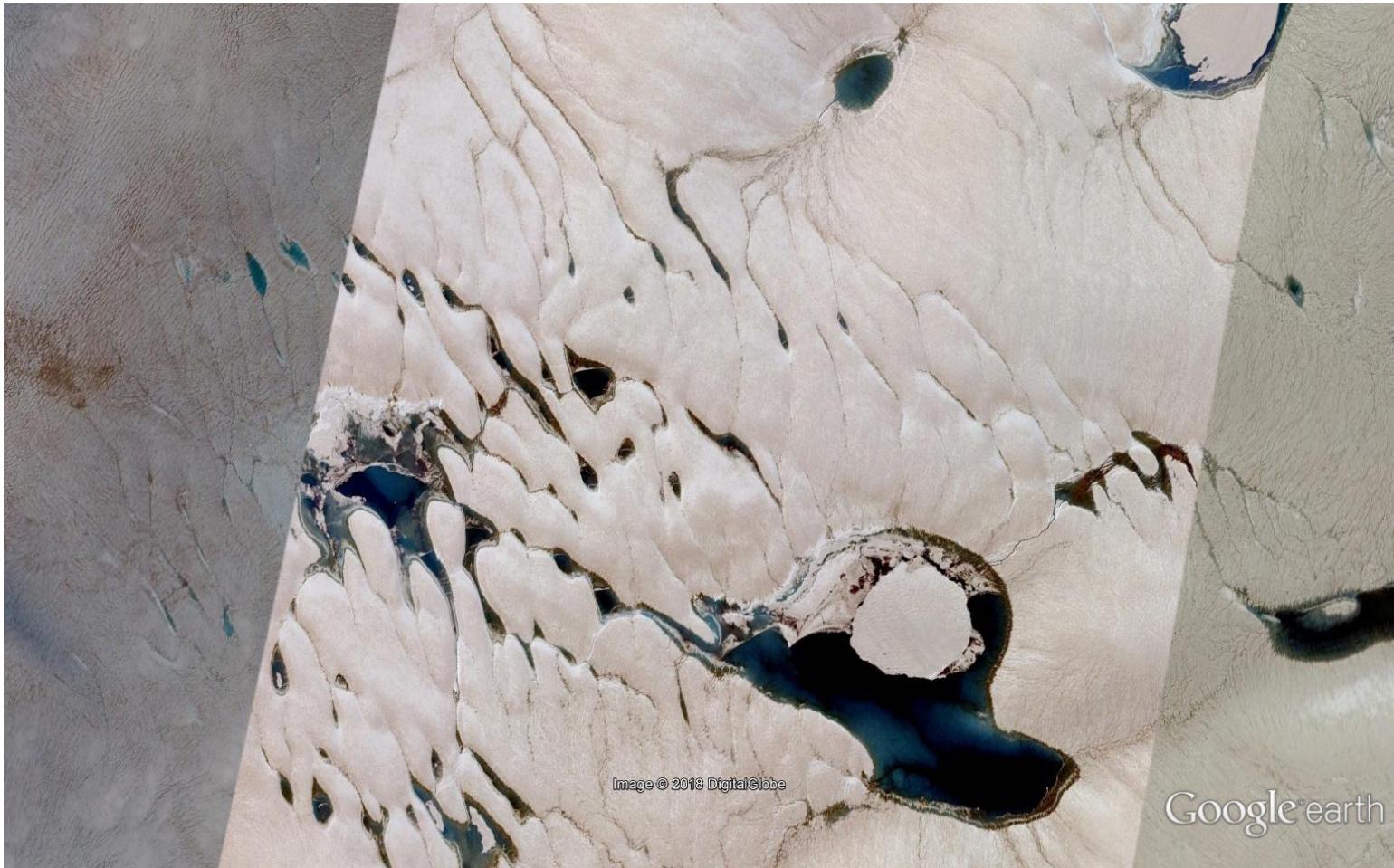
Supraglacial Greenland



Supraglacial Greenland



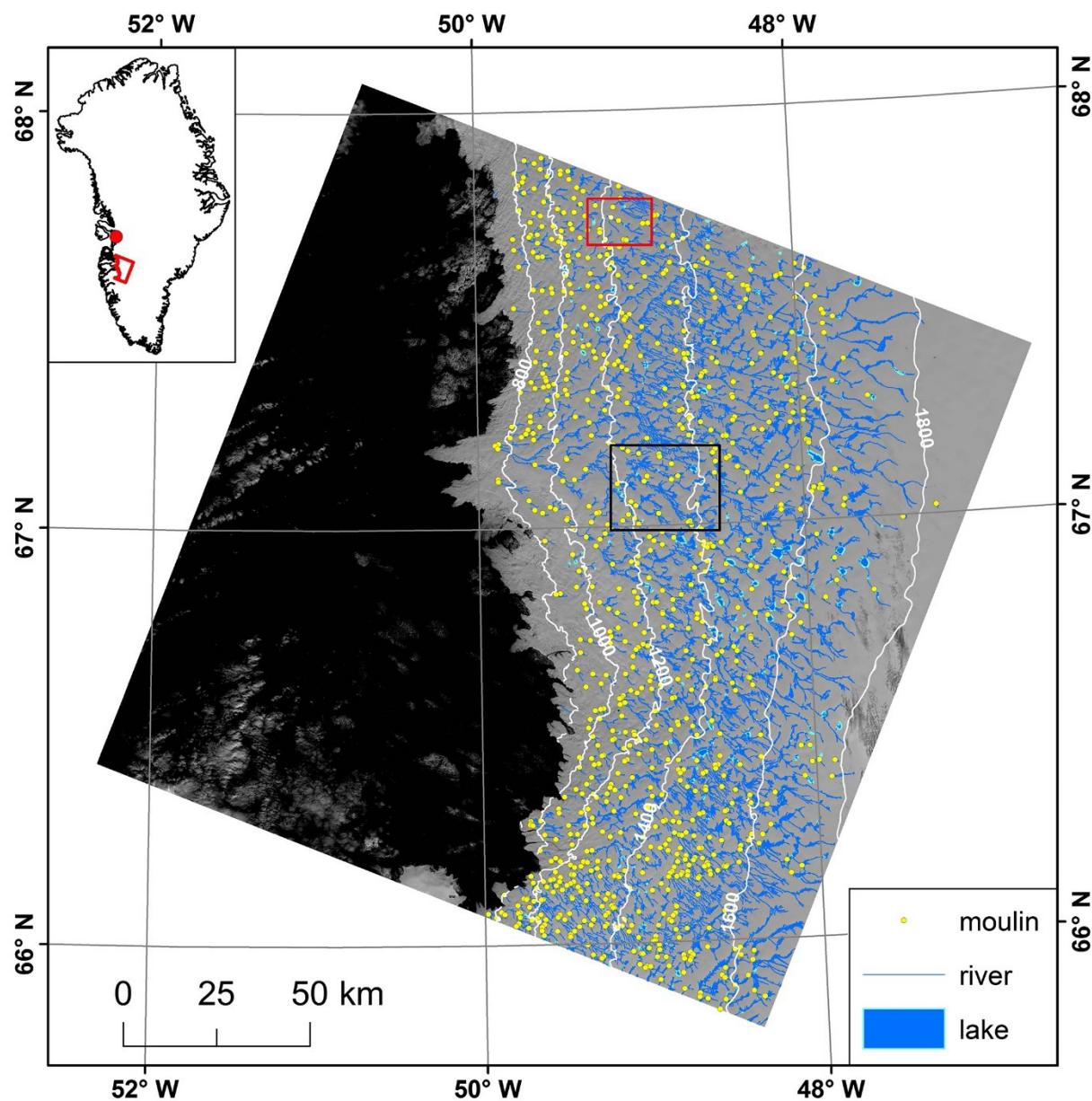
Supraglacial Greenland



Supraglacial Greenland

“Internally-drained
catchments” in South-
west Greenland

Yang and Smith (2016)



Englacial Greenland



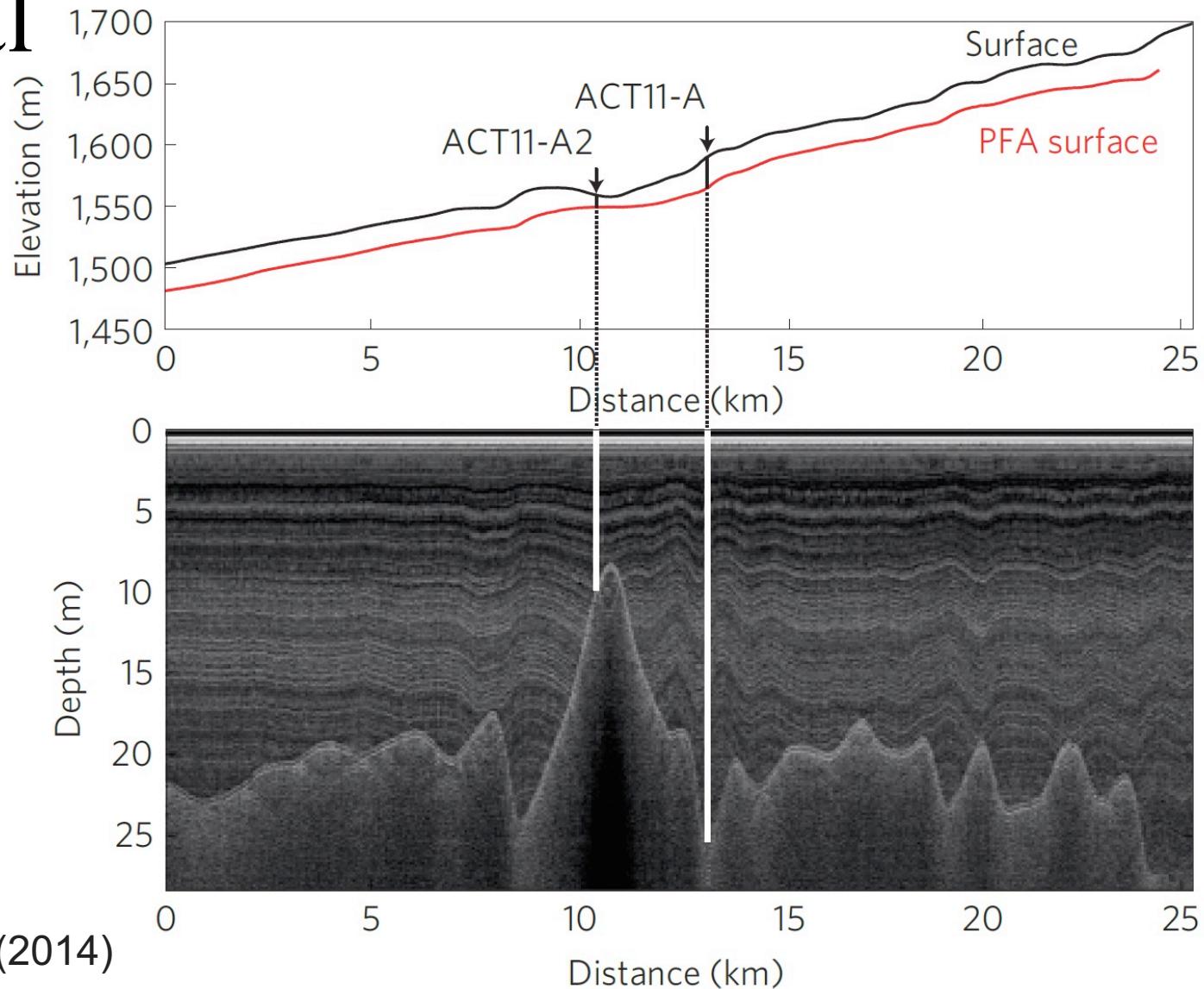
PHOTO COURTESY: ROGER BRAITHWAITE, UNIVERSITY OF MANCHESTER

MELTING WATER FLOWING INTO A HUGE MOULIN
IN THE GREENLAND ICE SHEET

Englacial

Greenland

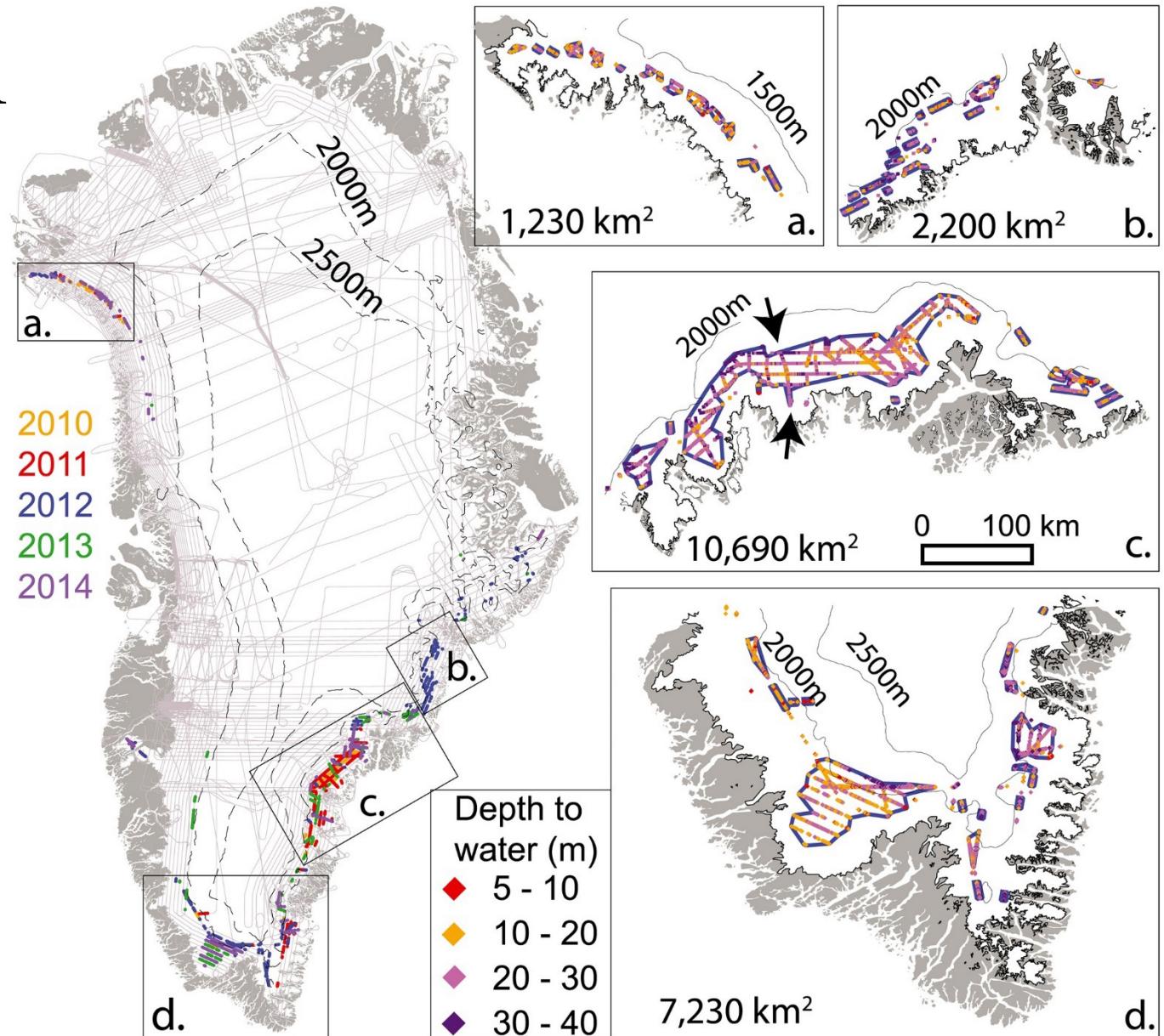
Radar can see the top of a firn aquifer in Greenland



Forster et al. (2014)

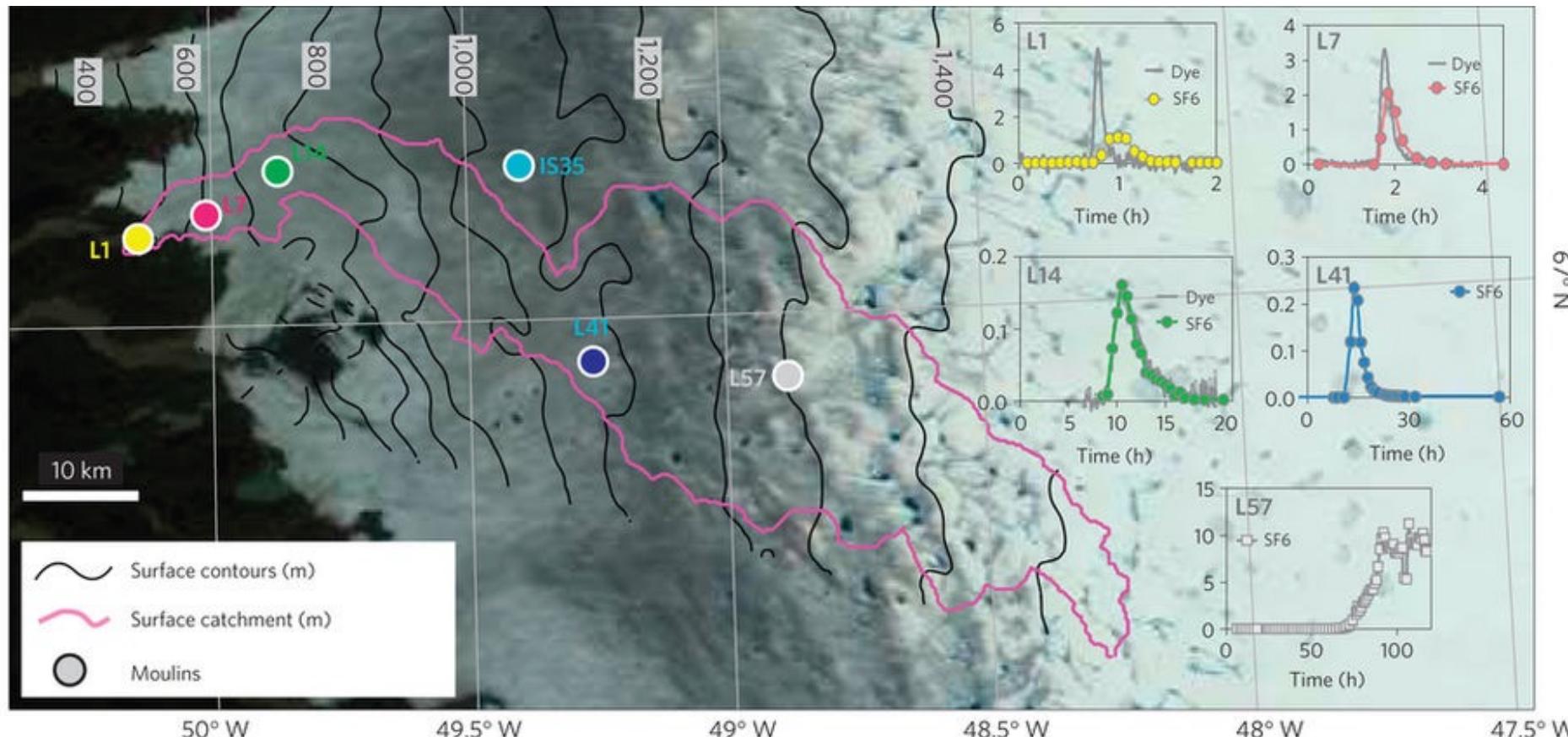
Englacial Greenland

Radar can see the top of a firn aquifer in Greenland



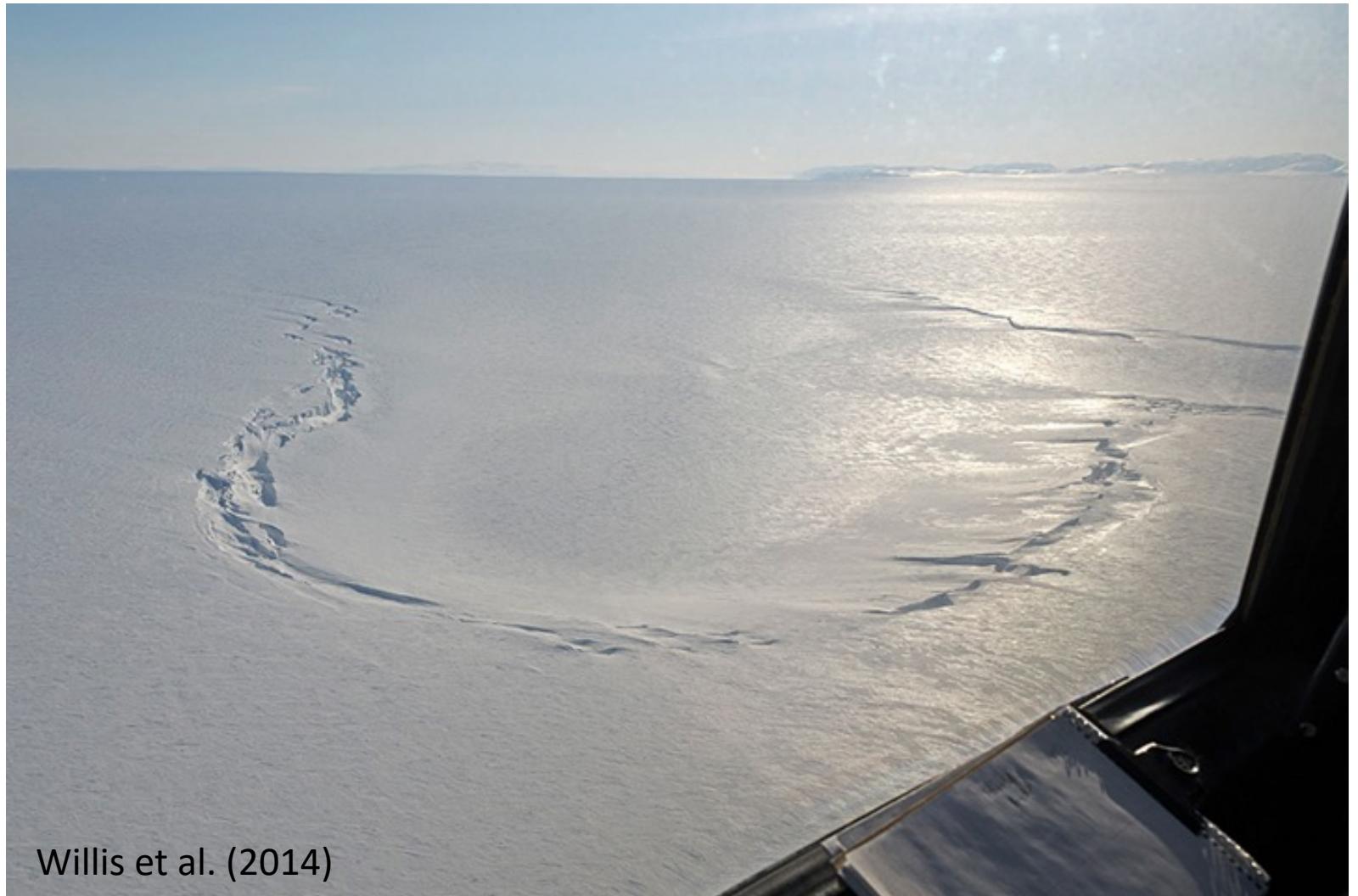
Miège et al. (2016)

Subglacial Greenland



Chandler et al. (2013)

Subglacial Greenland



Willis et al. (2014)



Antarctica

Image U.S. Geological Survey

Image Landsat / Copernicus

Image PGC/NASA

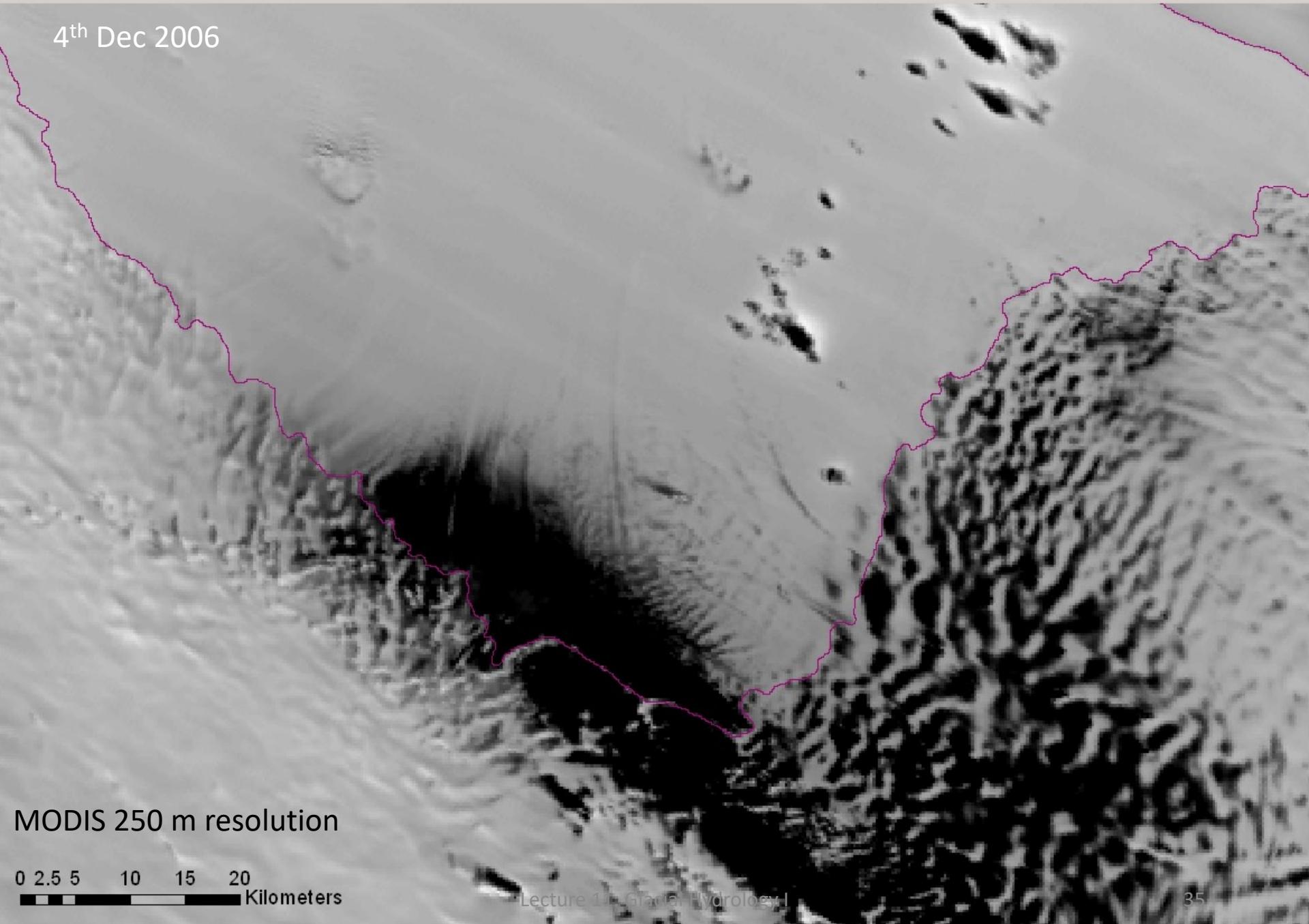
Lecture 11: Glacial Hydrology I
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Google Earth
3S.

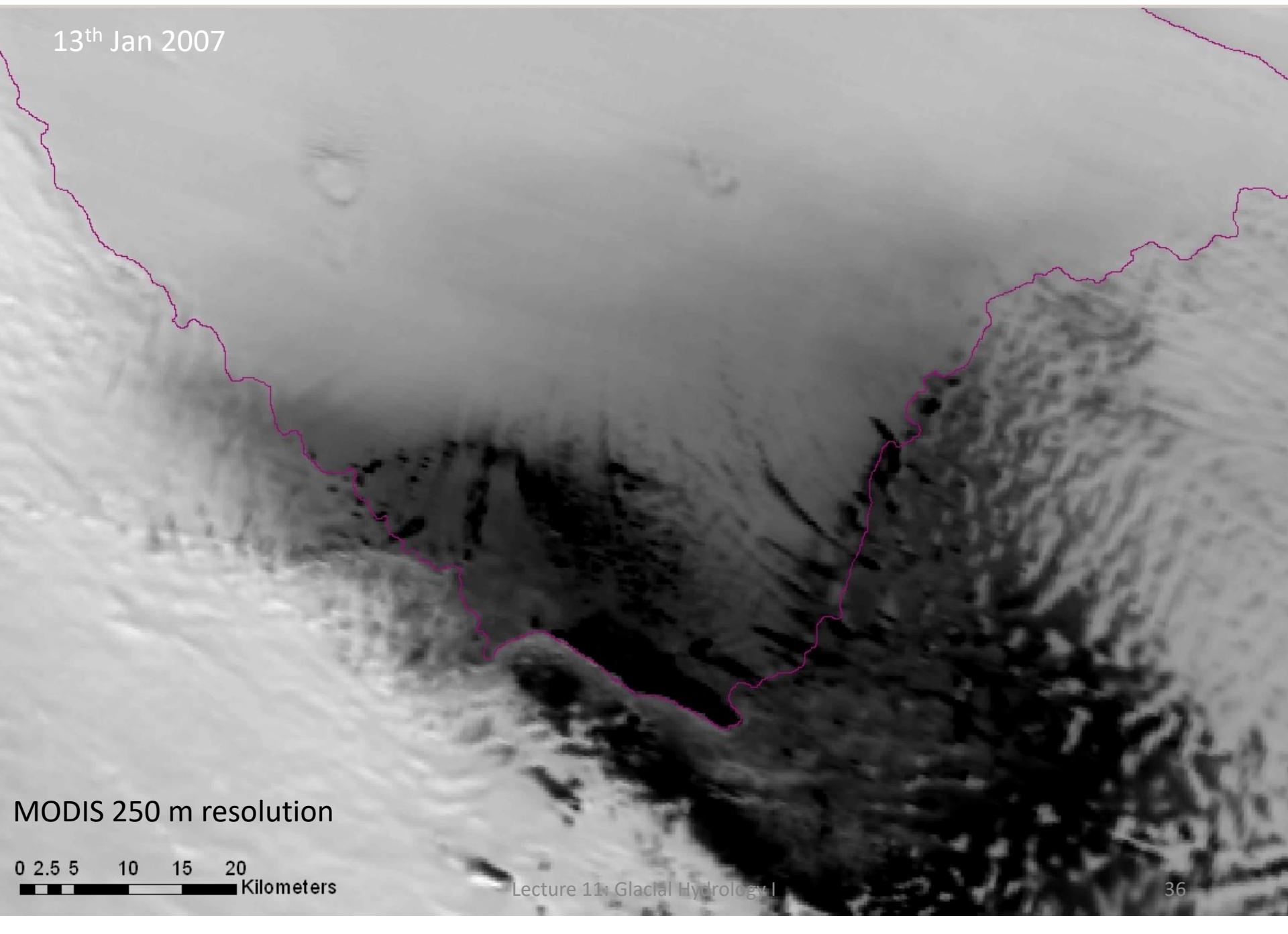
Nivlisen Ice Shelf, East Antarctica

2006 – 2007 summer

4th Dec 2006



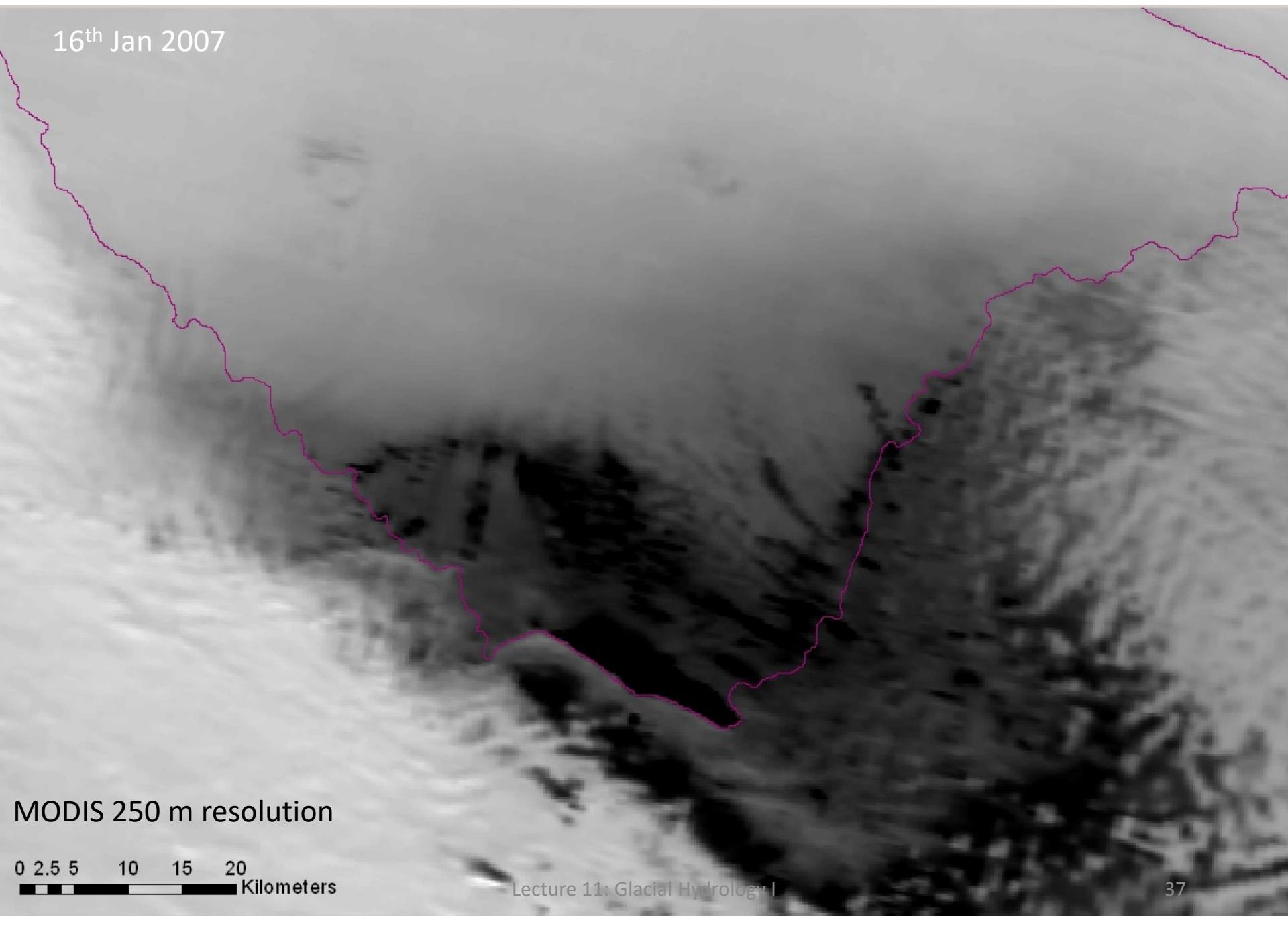
13th Jan 2007



MODIS 250 m resolution

0 2.5 5 10 15 20 Kilometers

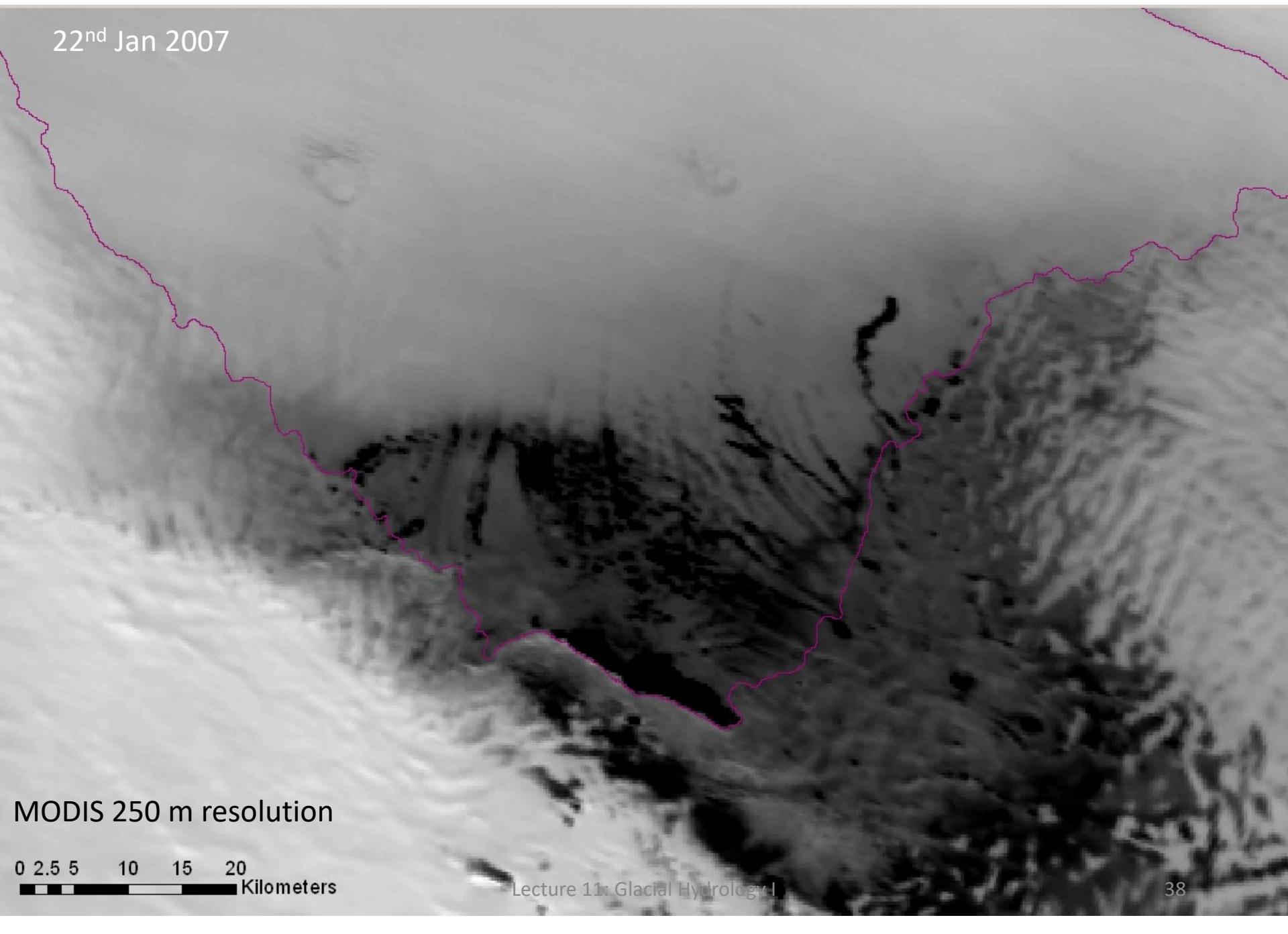
16th Jan 2007



MODIS 250 m resolution

0 2.5 5 10 15 20
Kilometers

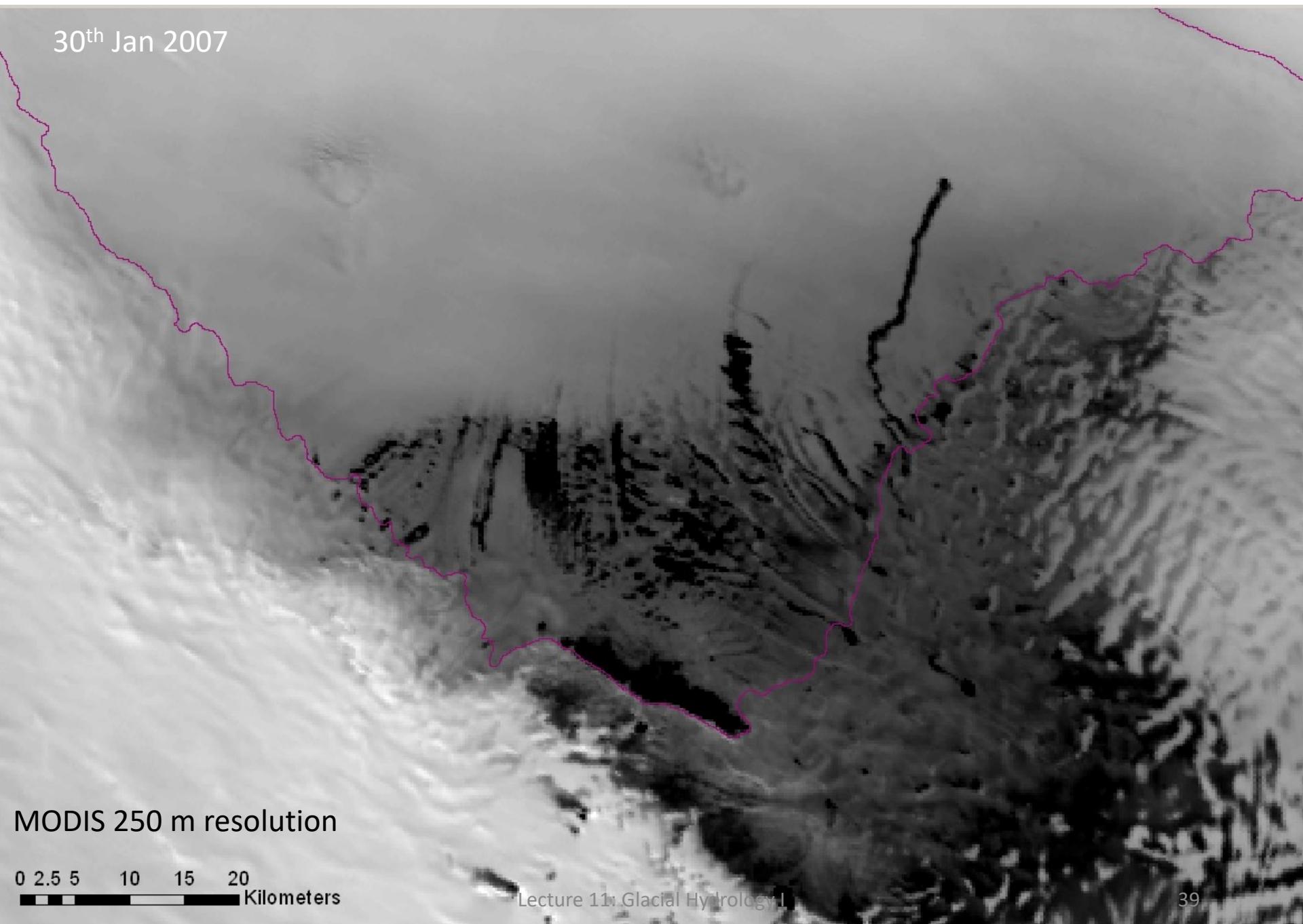
22nd Jan 2007



MODIS 250 m resolution

0 2.5 5 10 15 20 Kilometers

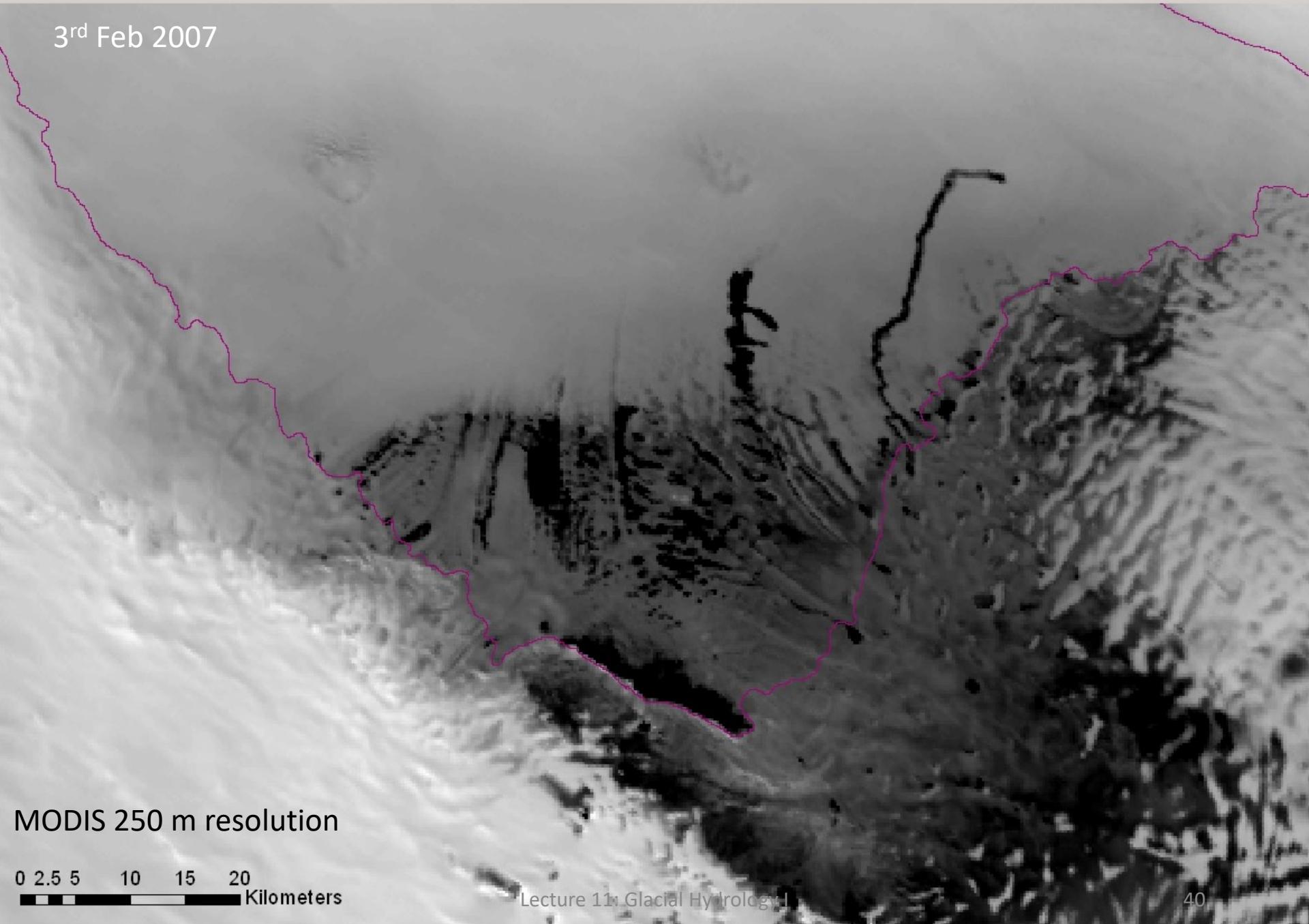
30th Jan 2007



MODIS 250 m resolution

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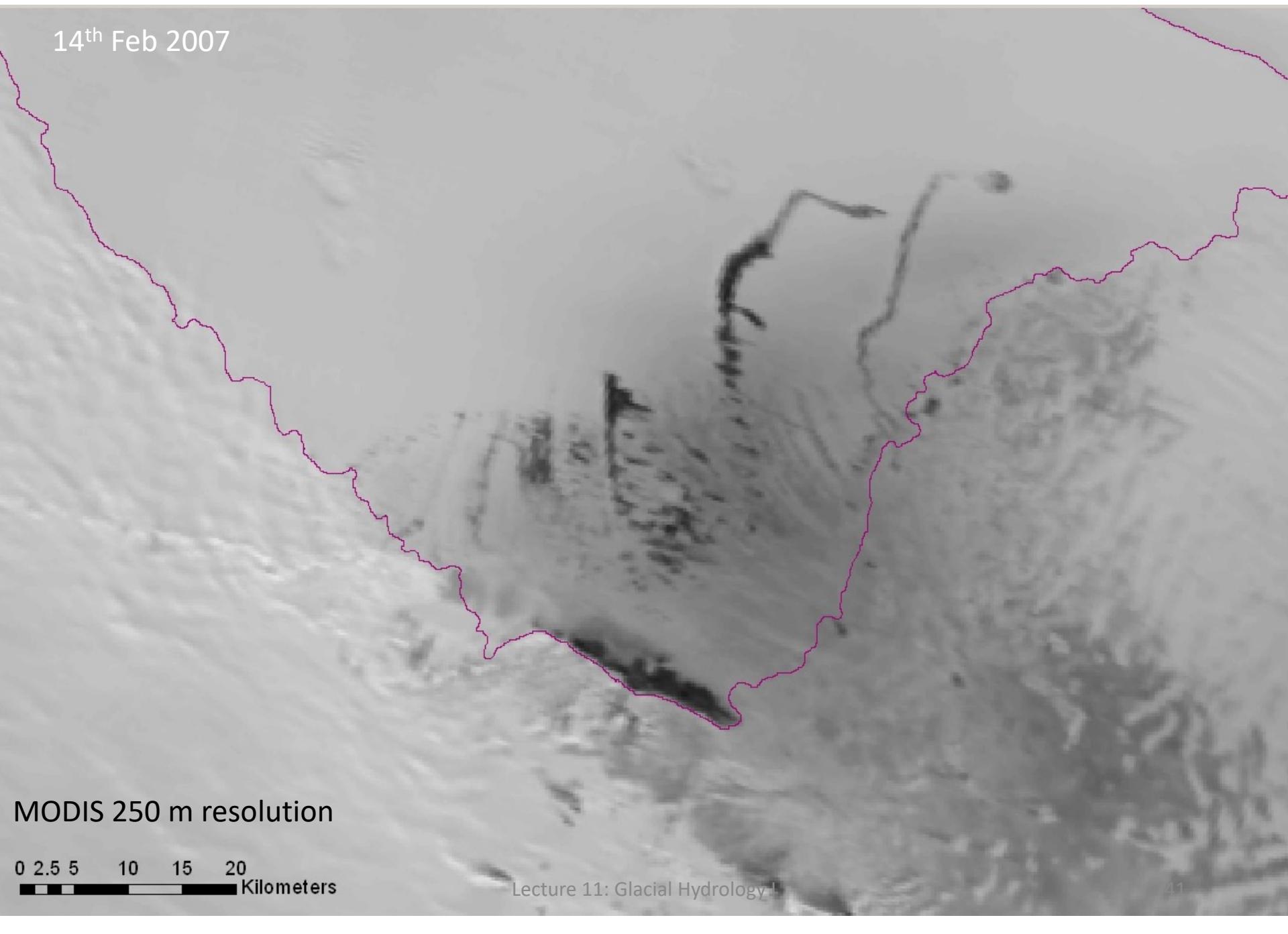
3rd Feb 2007



MODIS 250 m resolution

0 2.5 5 10 15 20 Kilometers

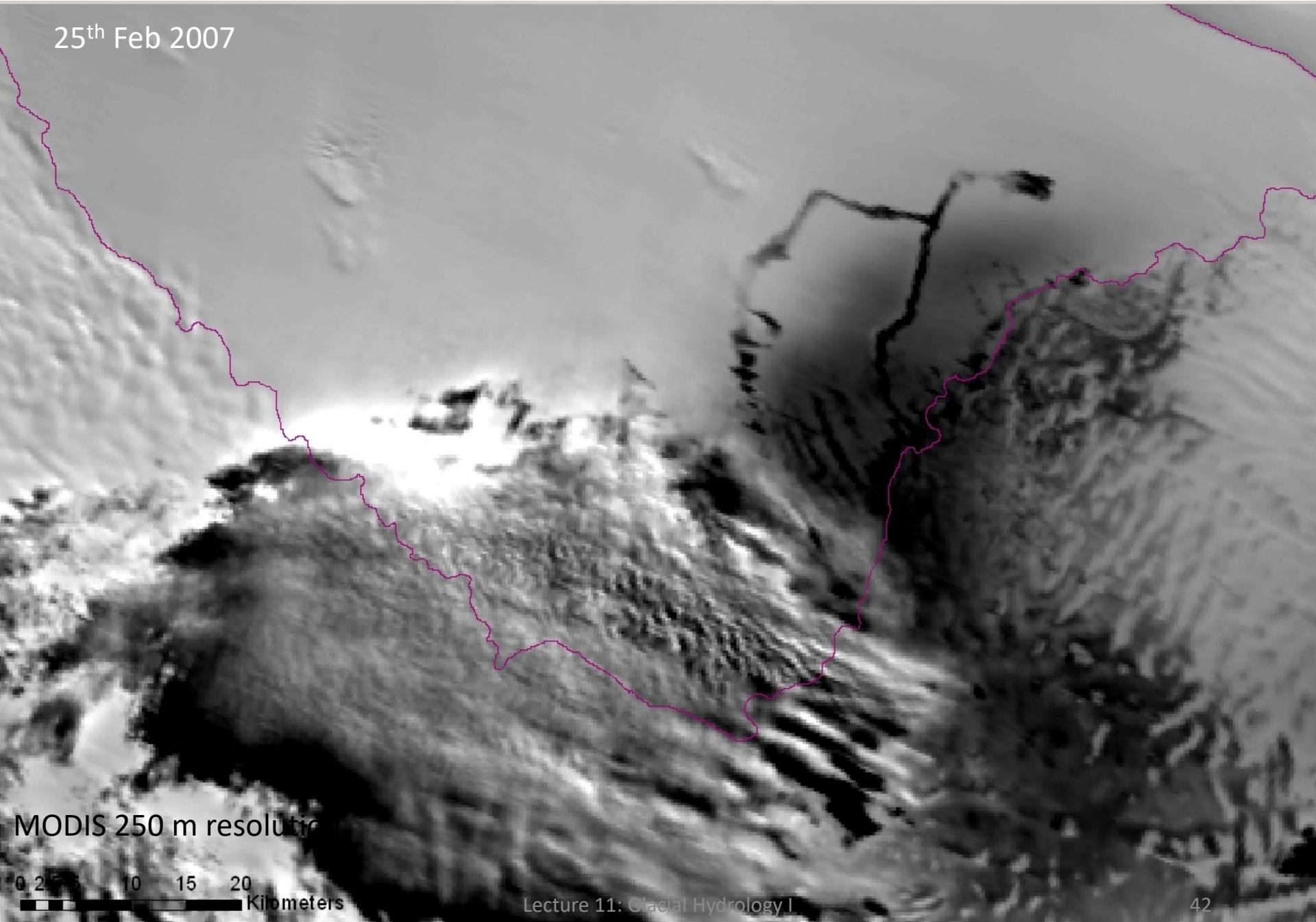
14th Feb 2007



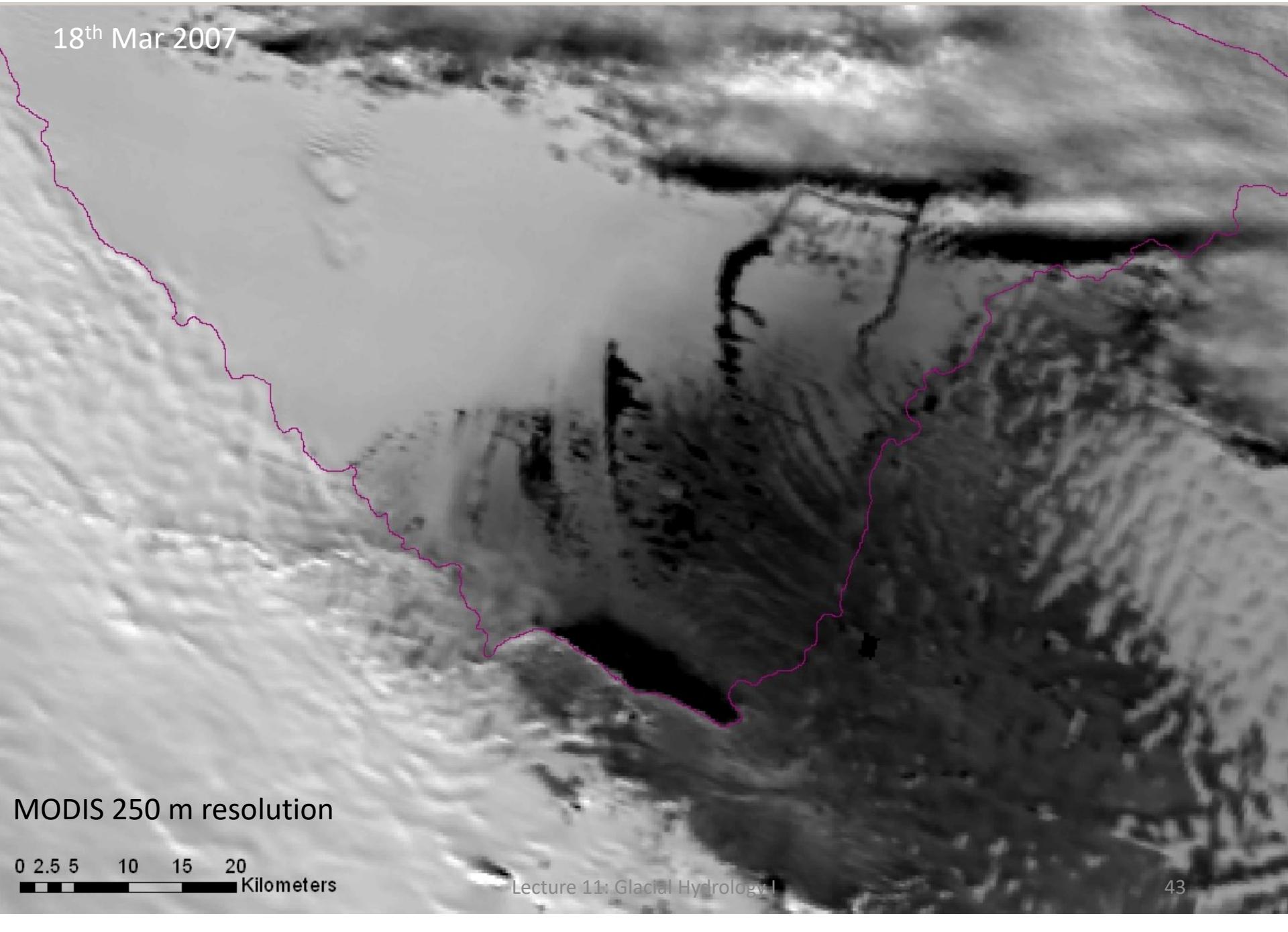
MODIS 250 m resolution

0 2.5 5 10 15 20 Kilometers

25th Feb 2007



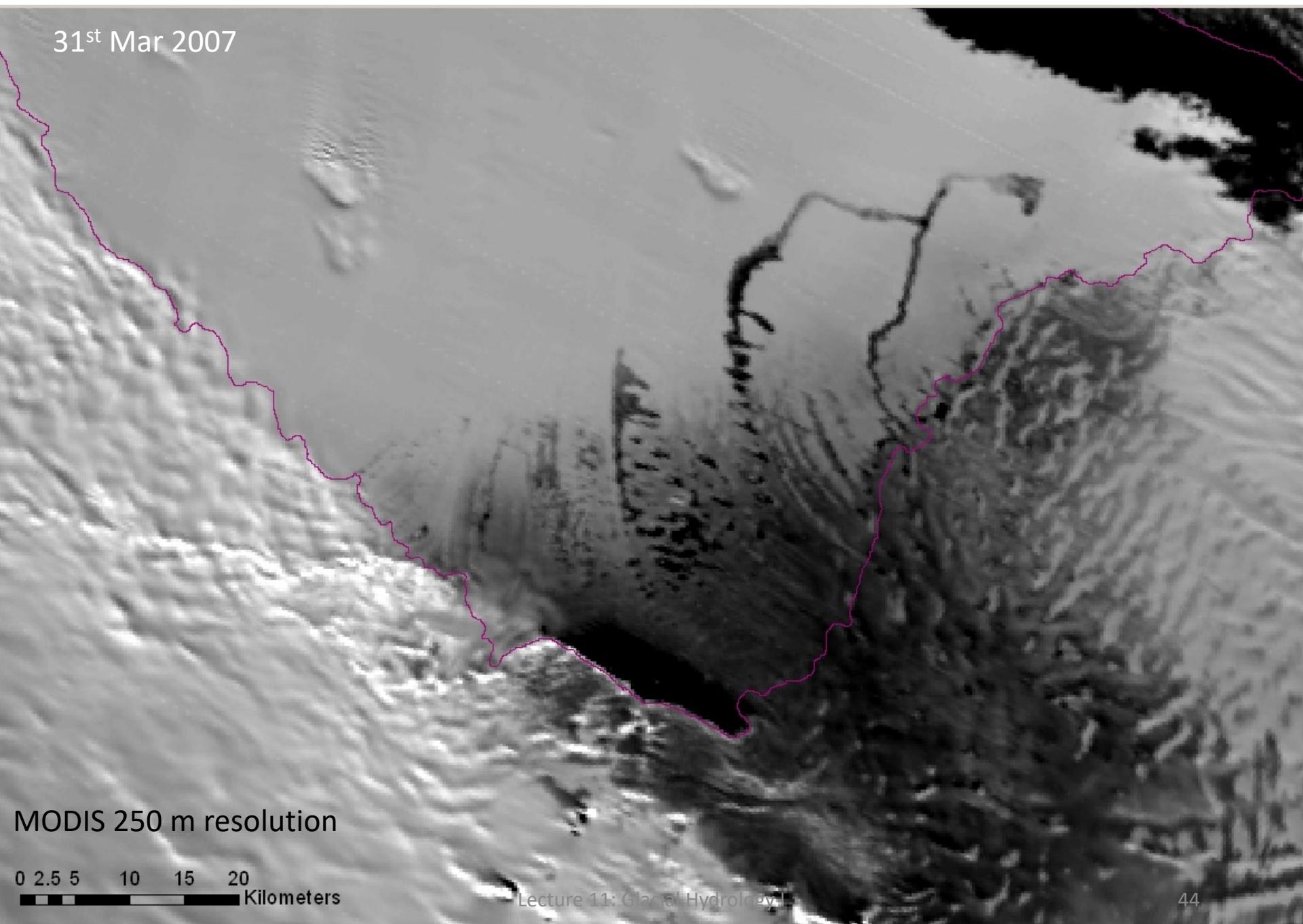
18th Mar 2007



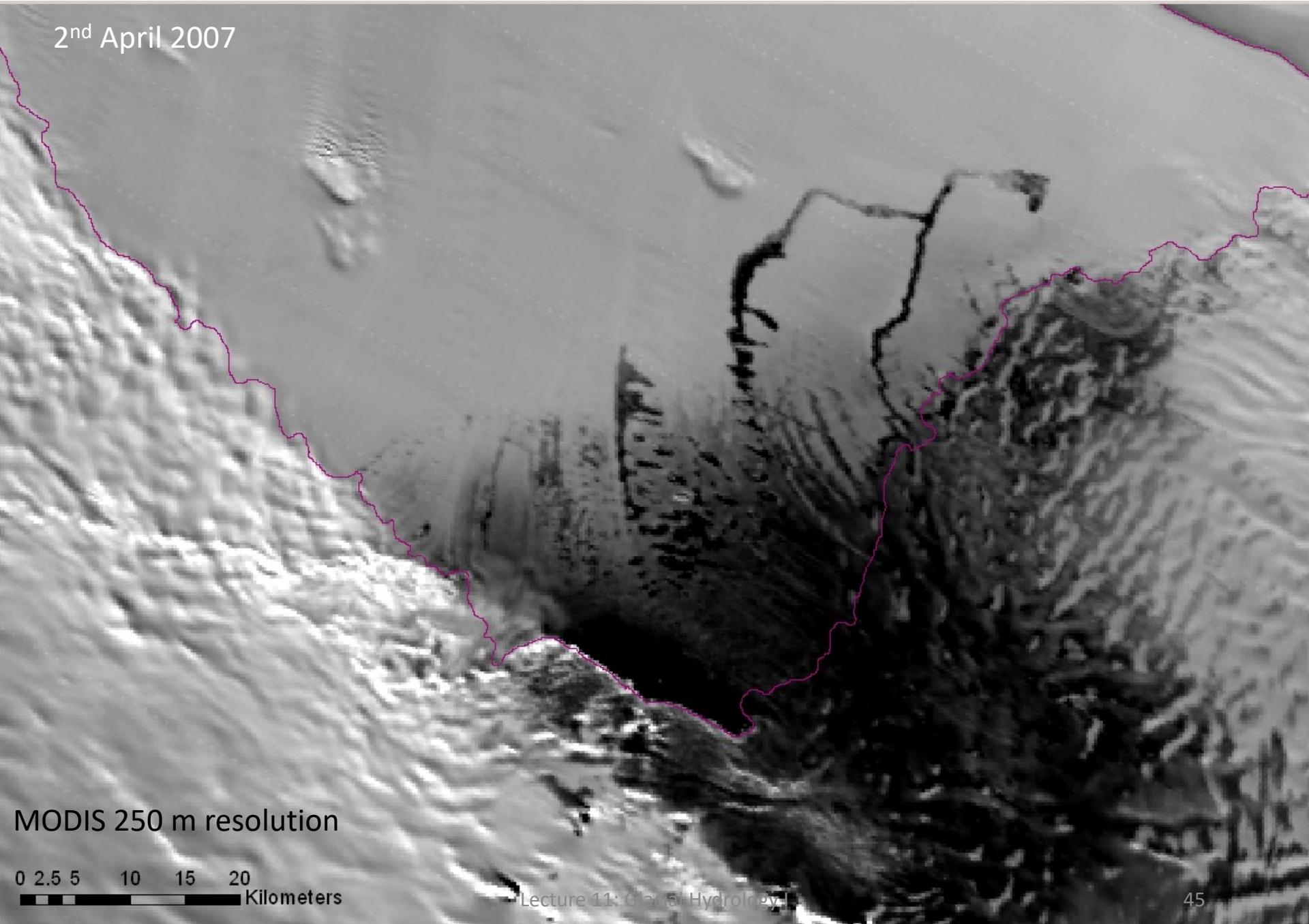
MODIS 250 m resolution

0 2.5 5 10 15 20 Kilometers

31st Mar 2007



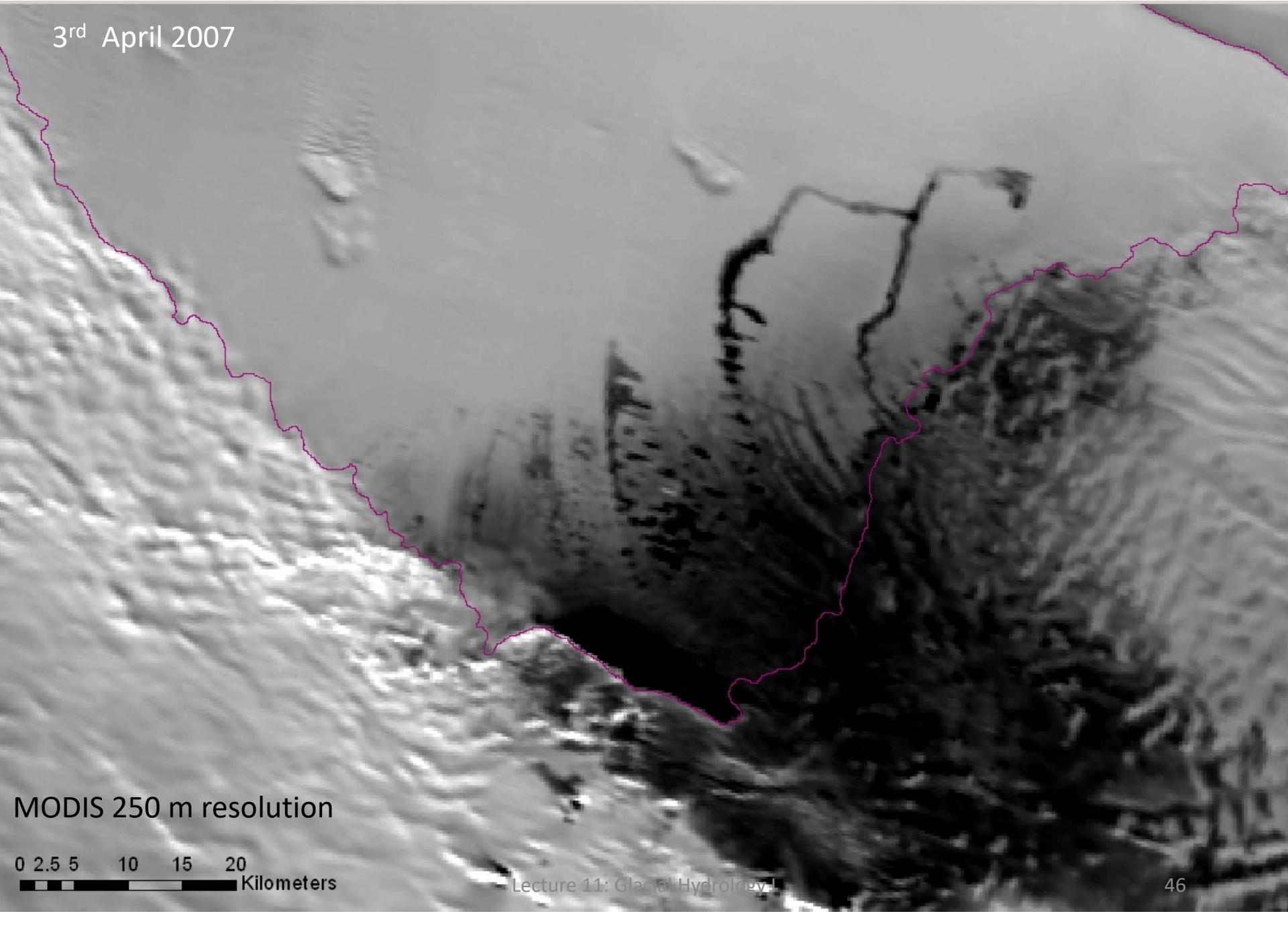
2nd April 2007



MODIS 250 m resolution

0 2.5 5 10 15 20 Kilometers

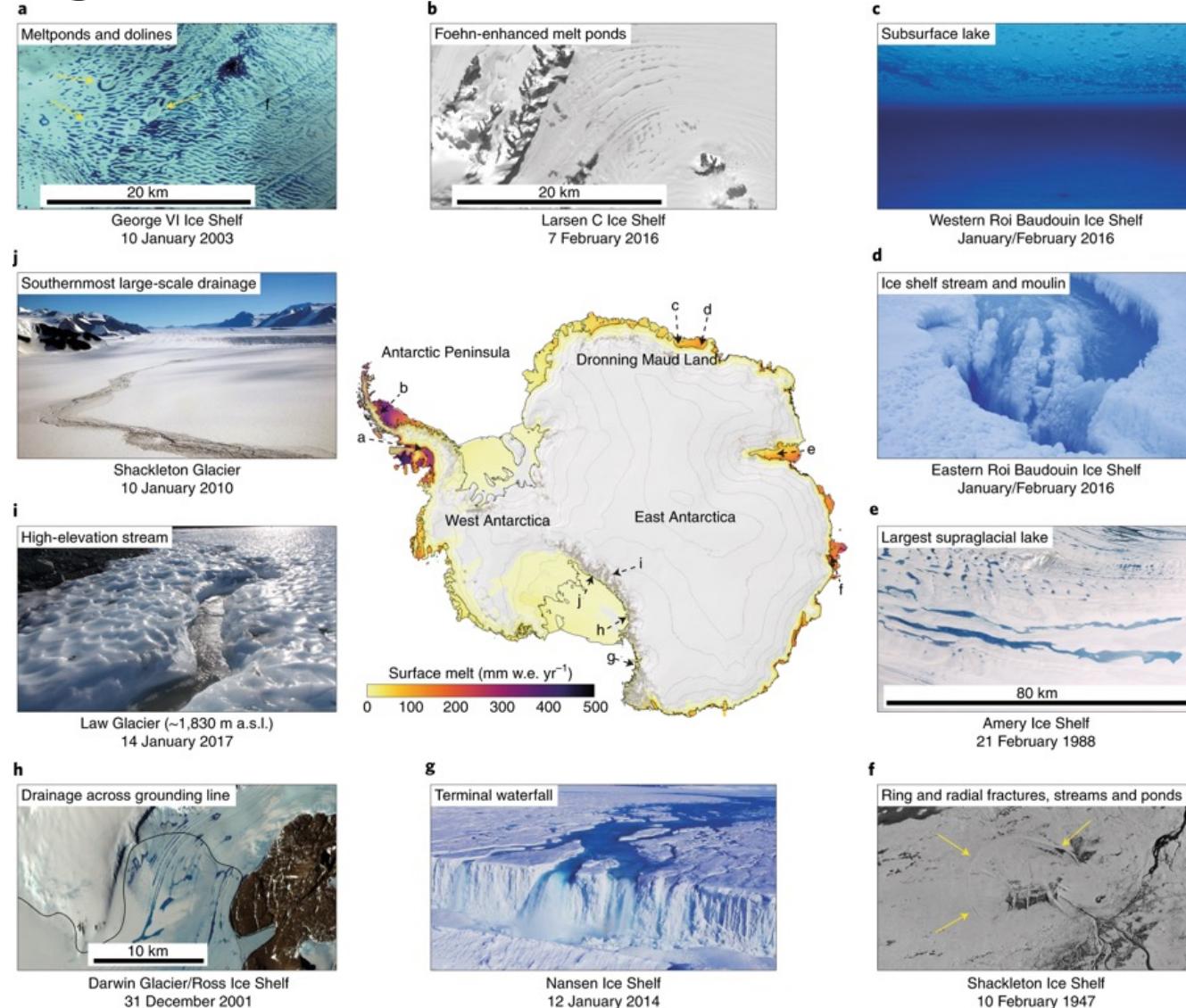
3rd April 2007



MODIS 250 m resolution

0 2.5 5 10 15 20 Kilometers

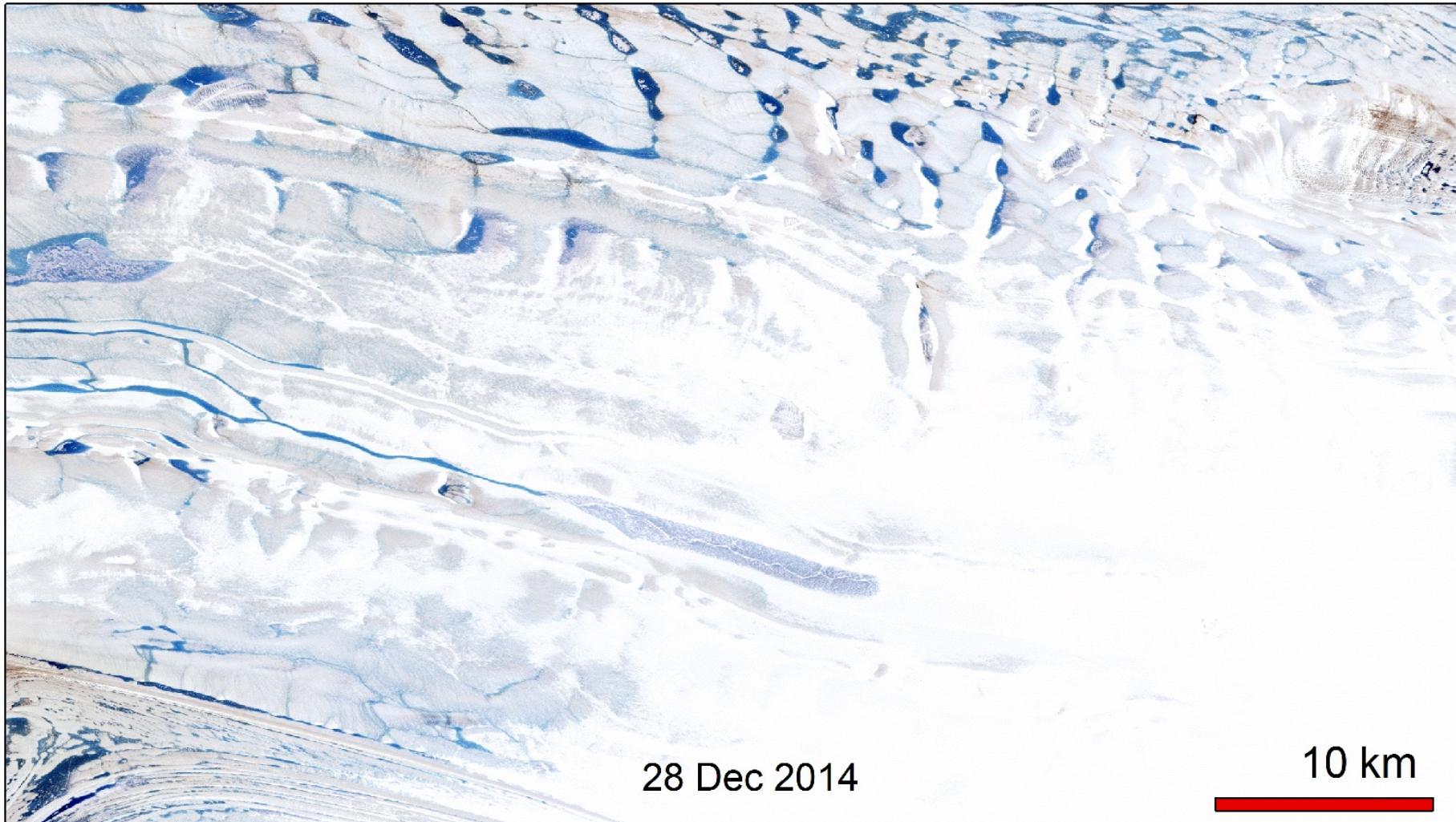
Supraglacial Antarctica



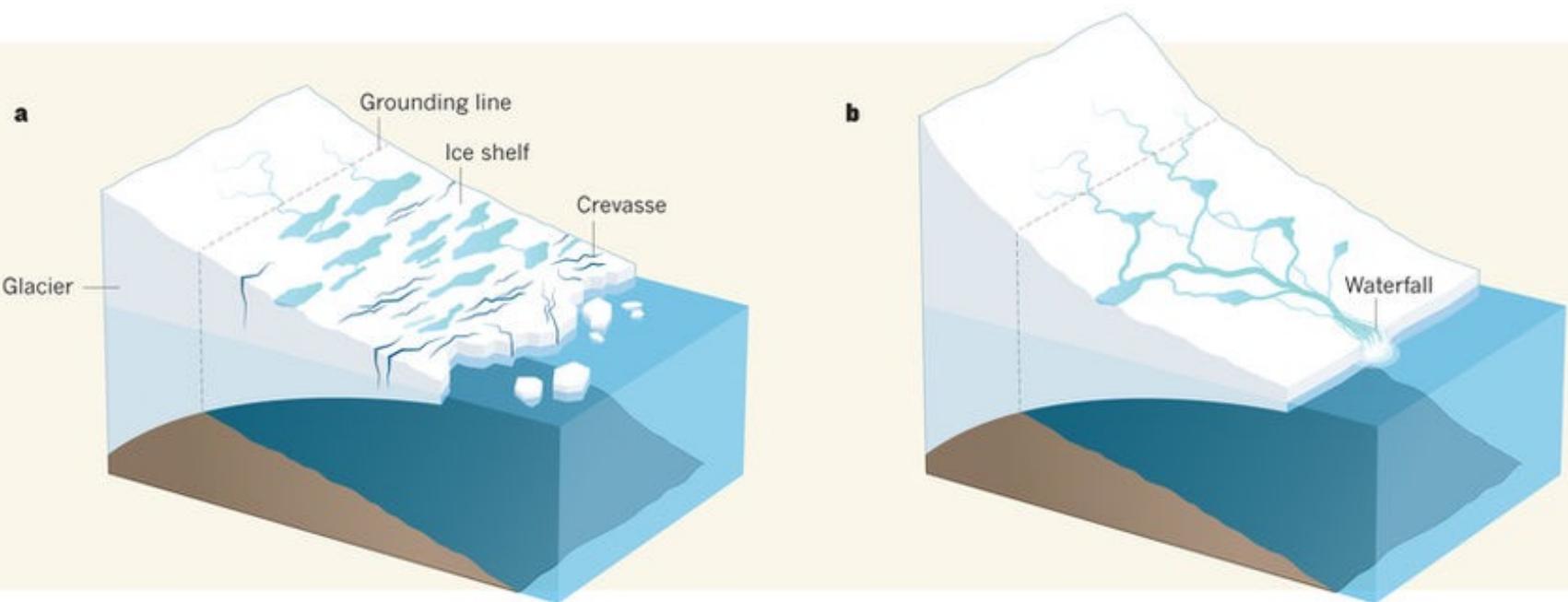
Bell et al. (2018)

Lecture 11: Glacial Hydrology I

Supraglacial Amery Ice Shelf

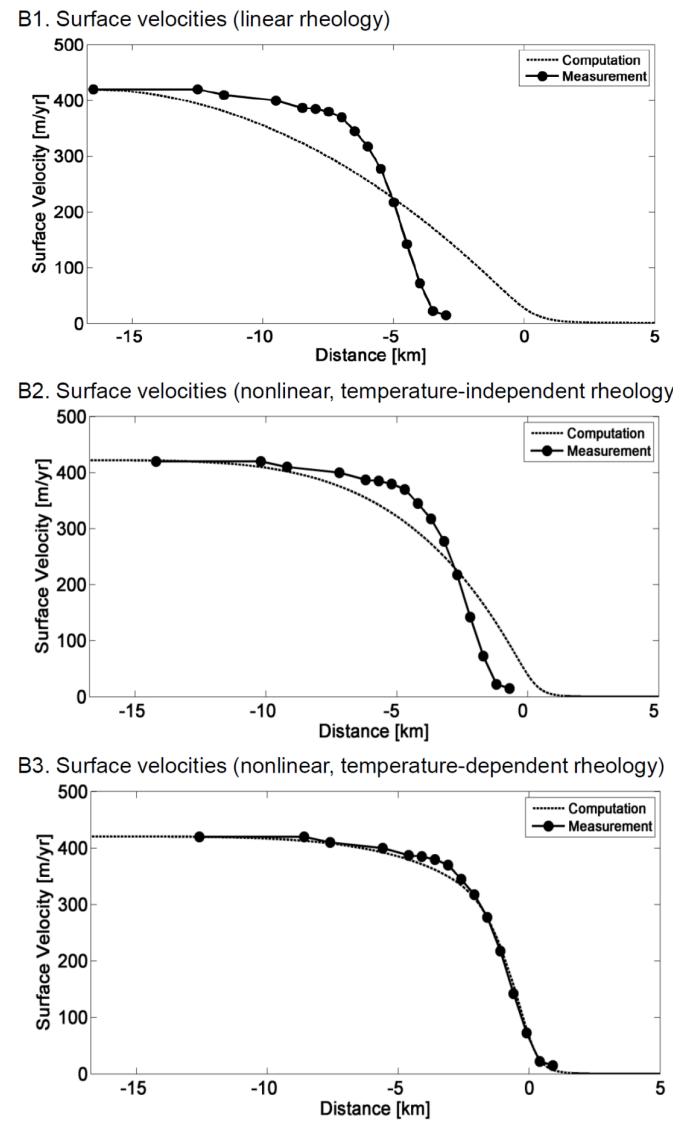
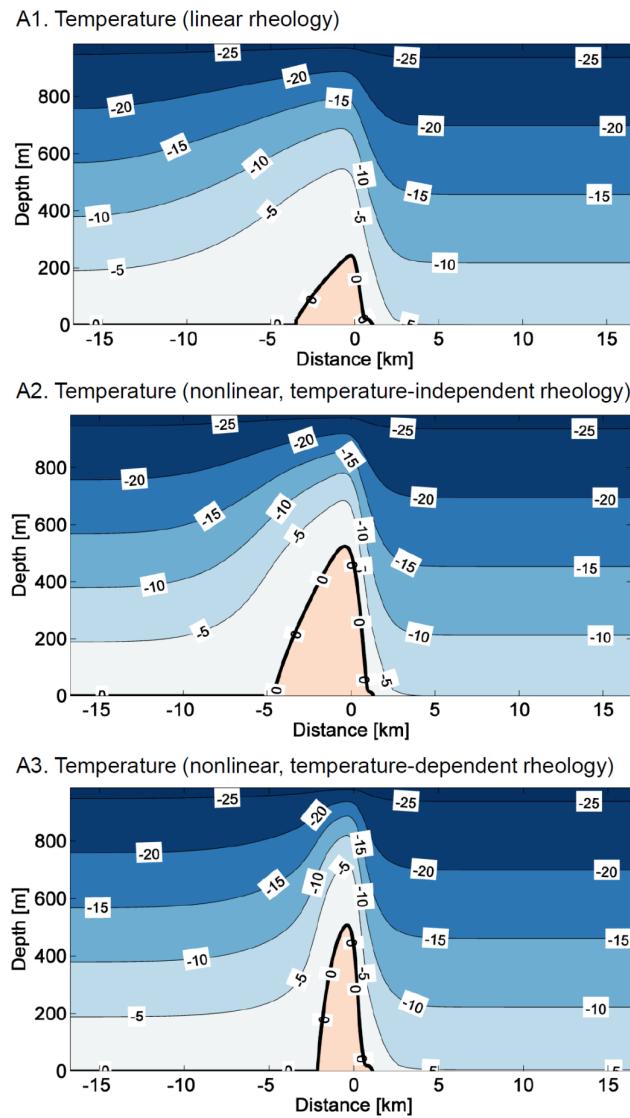


Supraglacial Antarctica

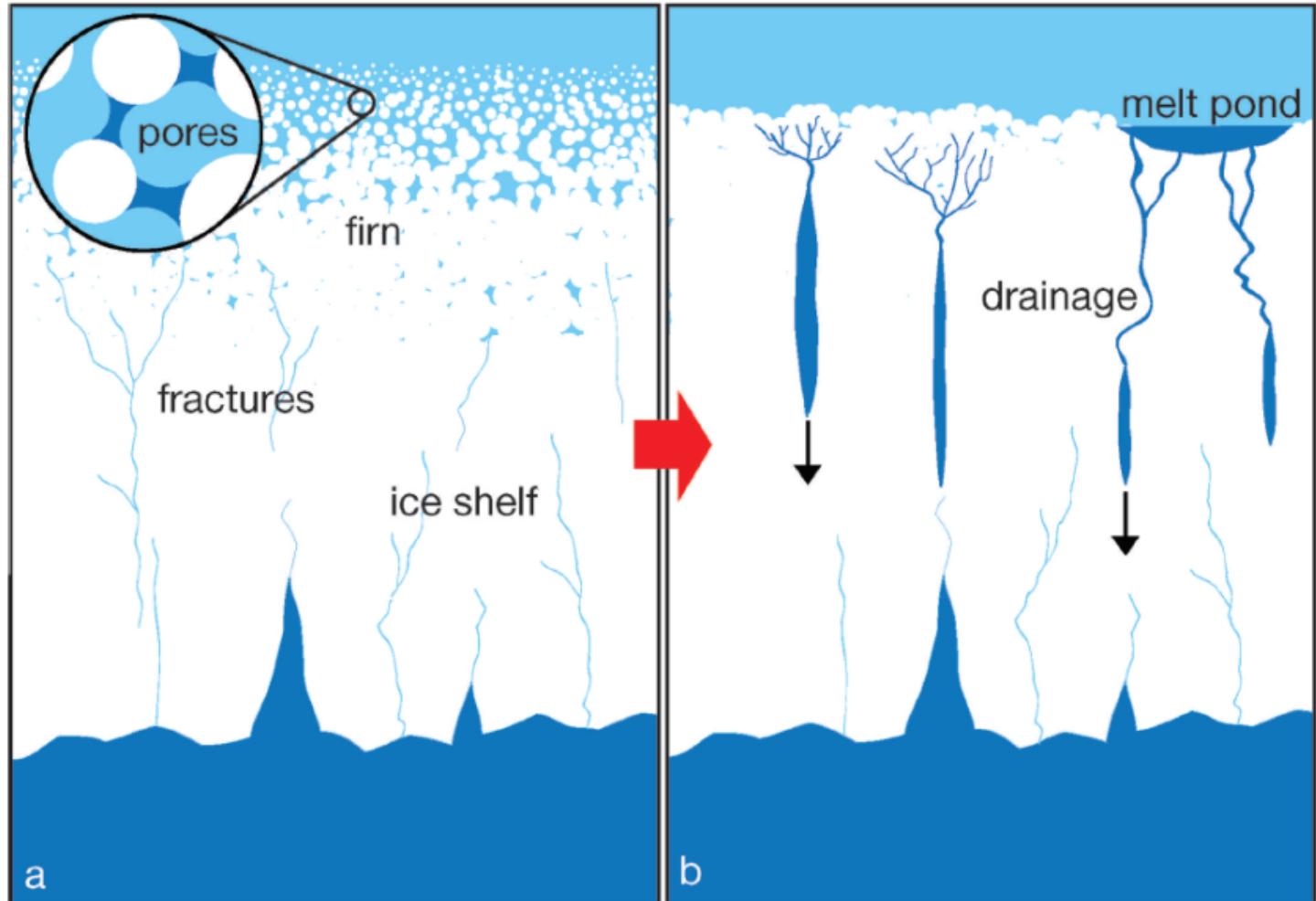


Banwell (2014)

Englacial Antarctica

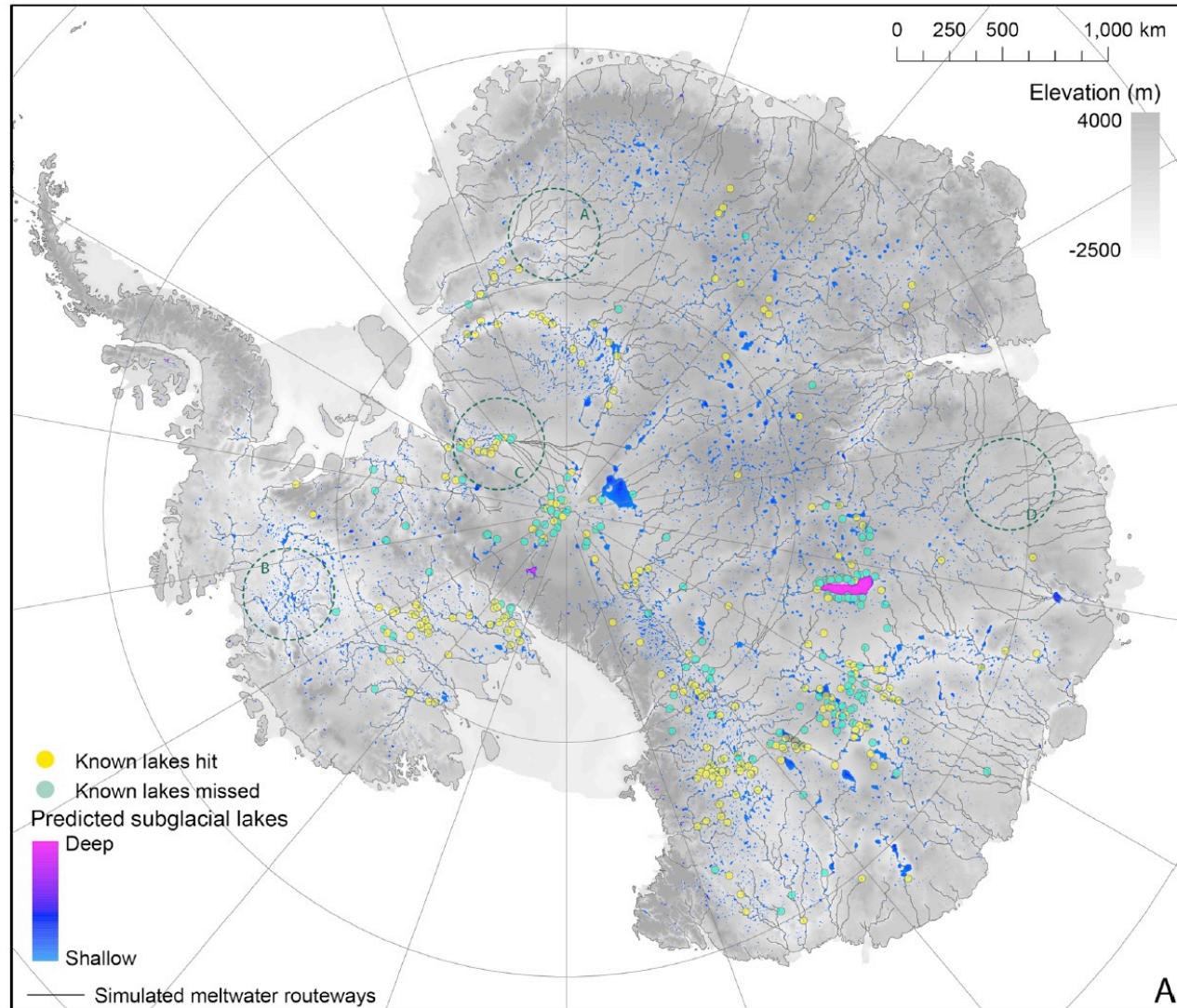


Englacial Antarctica



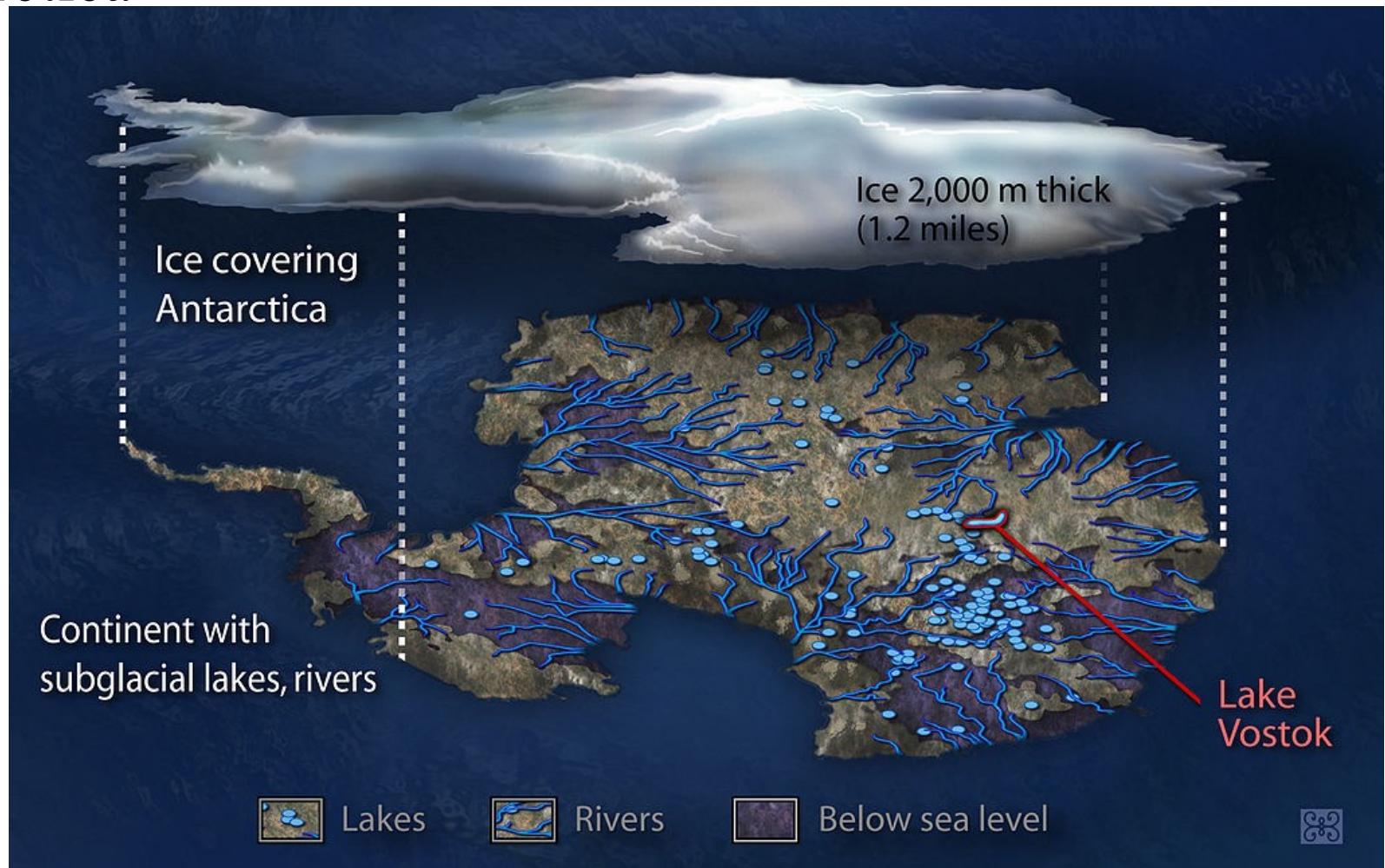
Kuipers Munneke et al. (2014)

Subglacial Antarctica



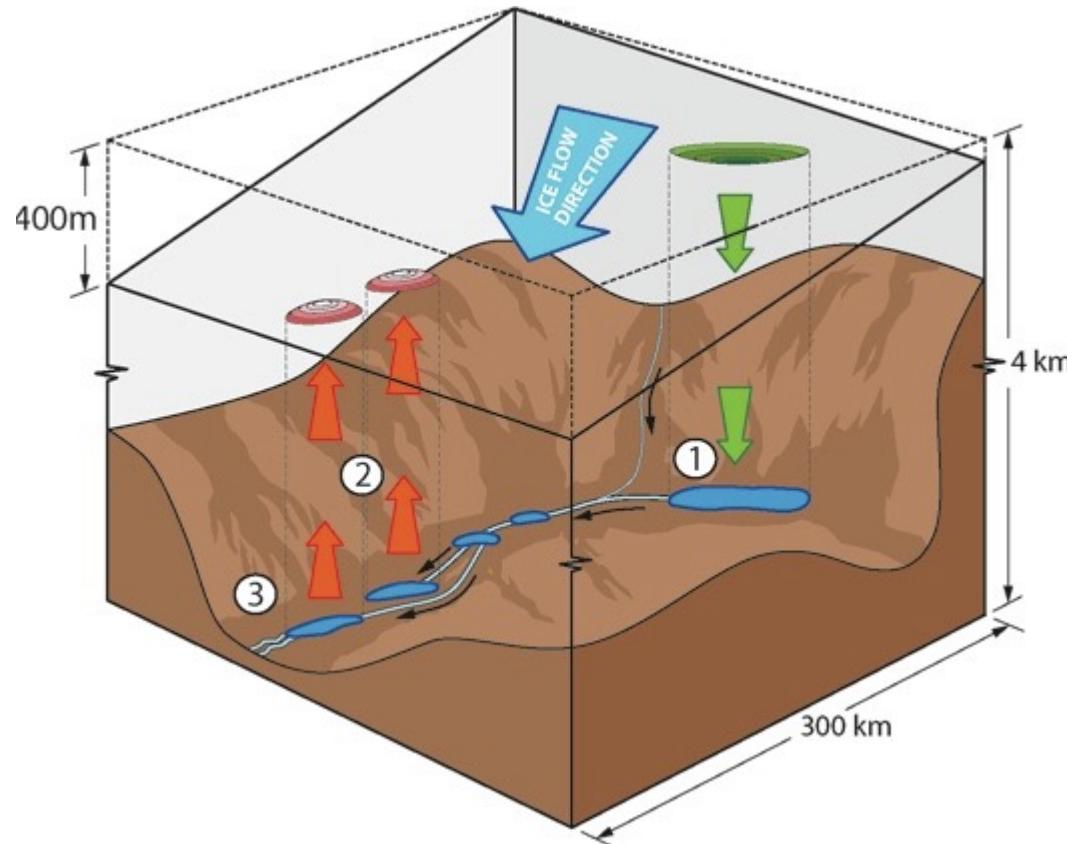
Livingstone et al. (2013)

Subglacial Antarctica



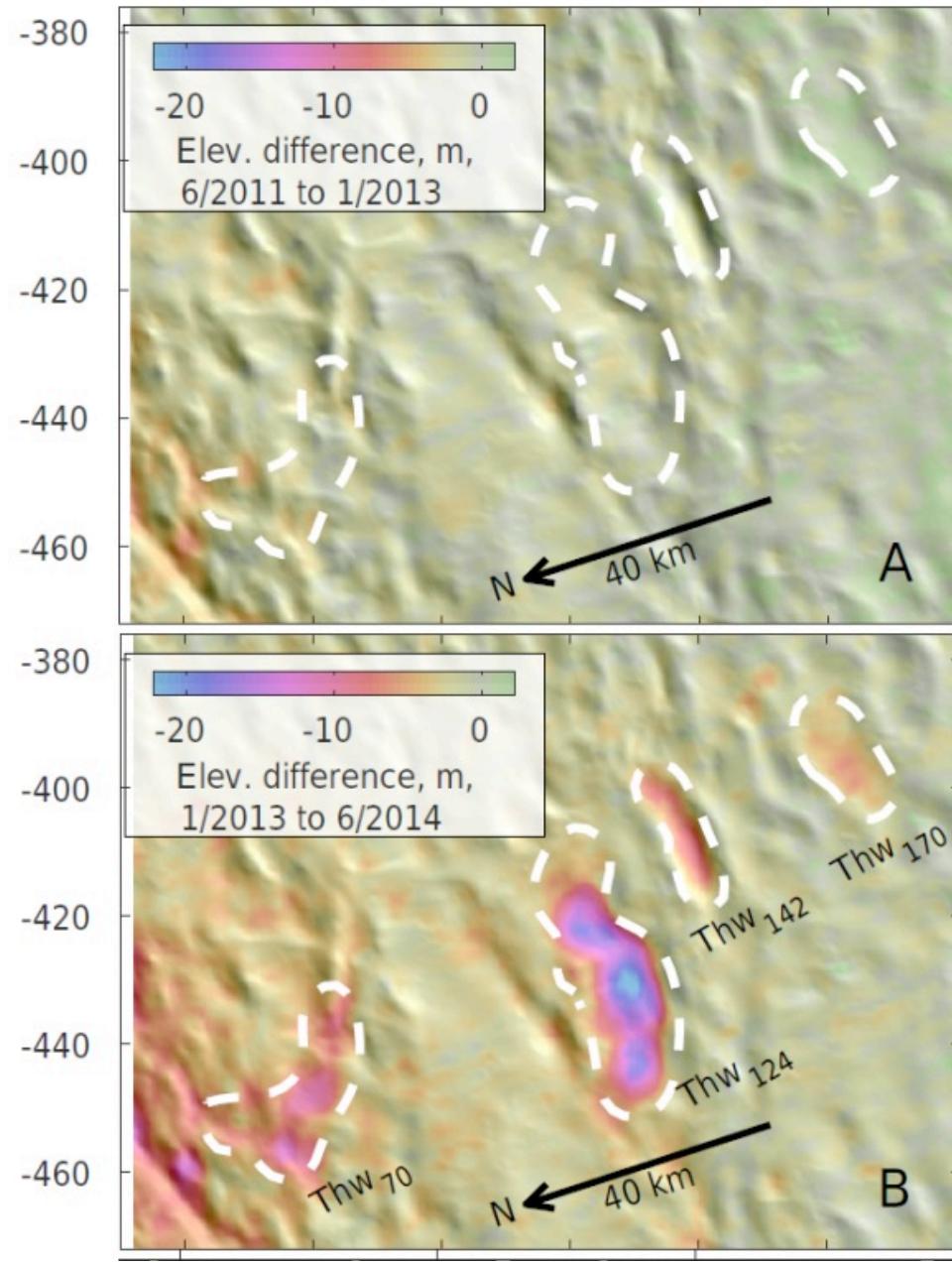
Zina Deretsky / NSF (US National Science Foundation), via Wikimedia Commons

Subglacial Antarctica



Wingham et al. (2006)

Subglacial Antarctica



Smith et al. (2017)

Impacts (Greenland, Antarctica and glaciers):

Impacts (Greenland, Antarctica and glaciers):

- Mass movement
- Albedo
- Ice-shelf calving
- Control input of water into fjords, proglacial environment, sub-shelf cavity.
- Basal sliding
- Downstream water resources
- Erosion
- Proglacial landscaping
- Moves heat around – rheology/viscosity
- Changes humidity over the surface

Summary

Supraglacial: lakes, firn aquifers, streams, buried lakes.

Englacial: moulin, crevasses, shear margins.

Subglacial: channels, water sheets, linked cavities, saturated till, lakes.

These are complex, interconnected hydrological systems!

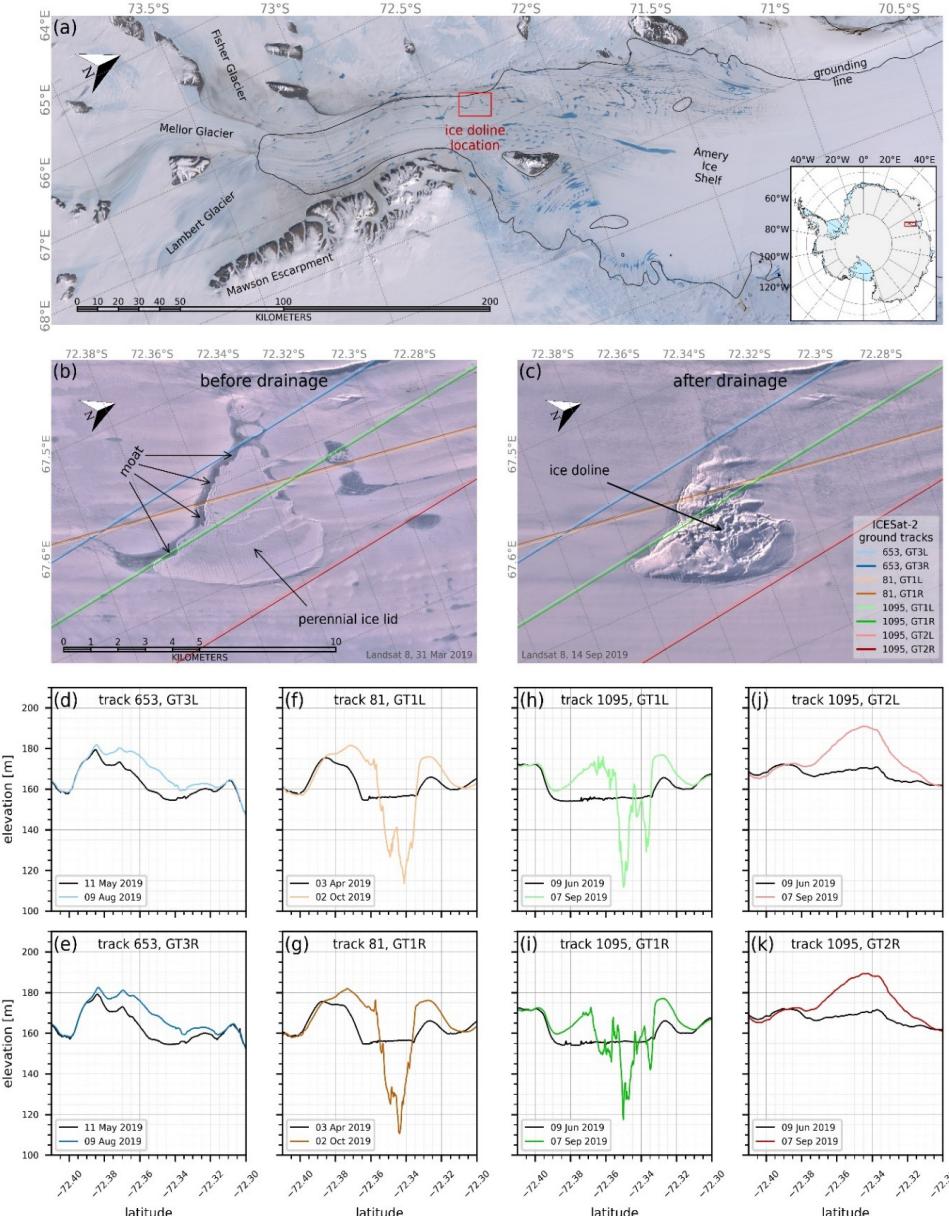
Wide-ranging impacts, from ice dynamics to SMB.

Theory is not well developed and observations of some aspects (englacial, subglacial) is very difficult

References

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Doline formation on ice shelves



Warner et al., 2021

