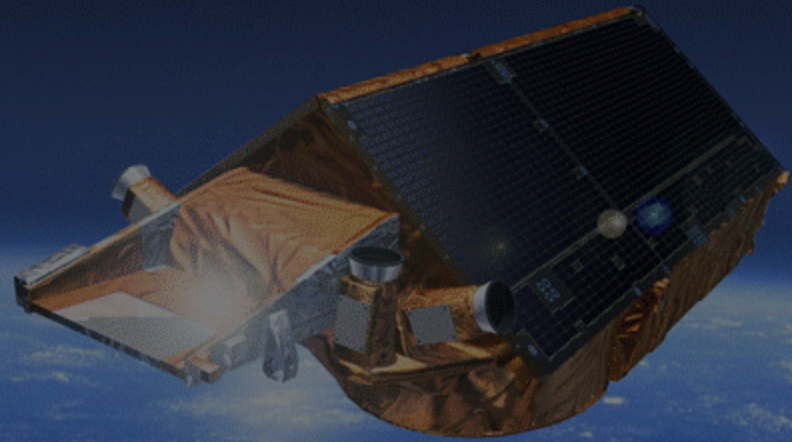
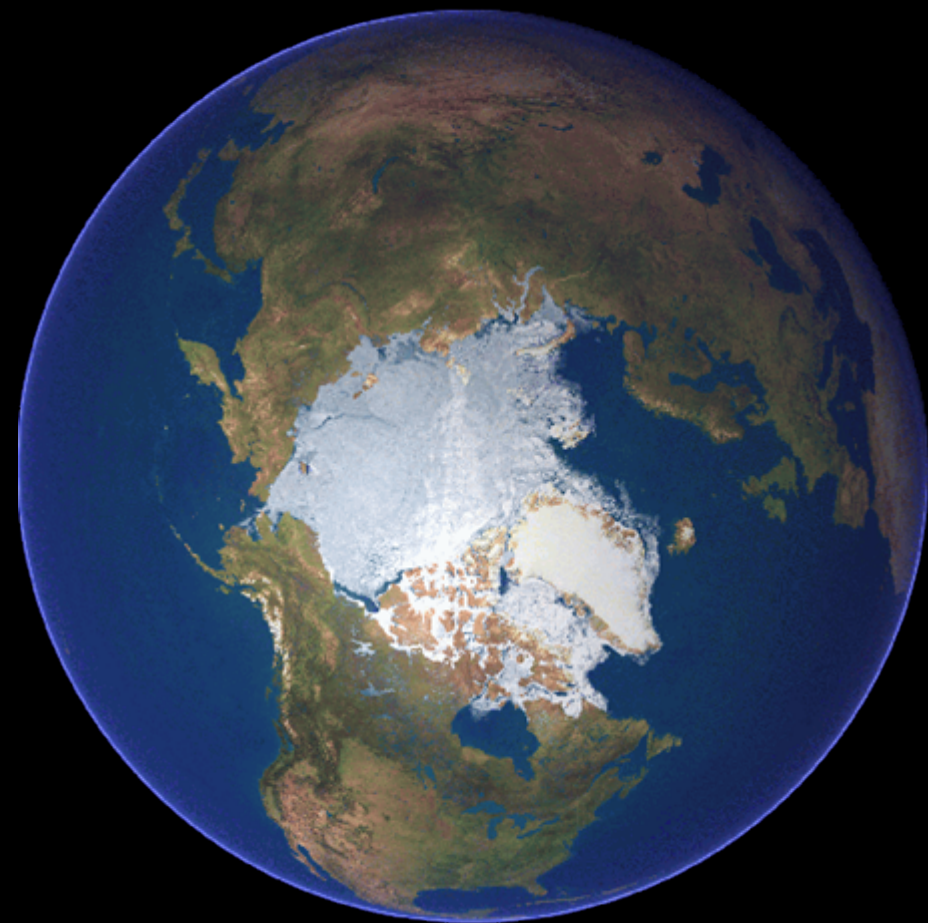


# Cryosphere Training Course 2016

Kate Briggs, Tamsin Edwards, Sinead Farrell, Rene Forsberg, Noel Gourmelen, Andreas Groh, Anna Hogg, Andrew Hooper, Malcolm McMillan, Andrea Minchella, Twila Moon, Jeremy Mouginot, Pete Nienow, Frank Paul, Robert Ricker, Eero Rinne, Andrew Shepherd, David Small, Louise Sørensen, Marco Tedesco, Rachel Tilling, Michiel van den Broeke, Isabella Velicogna







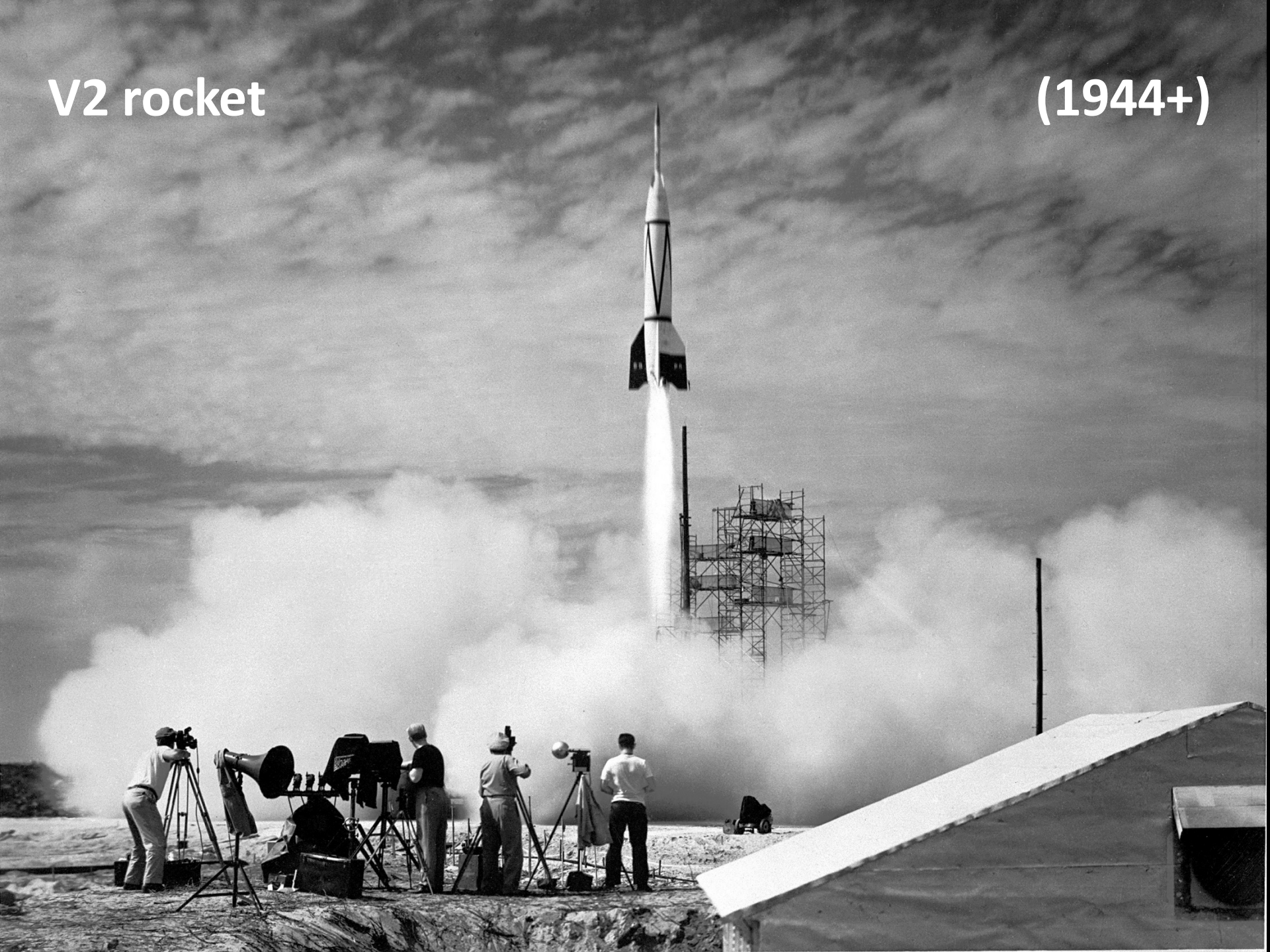
Earth Observation

The Cryosphere

Course Overview

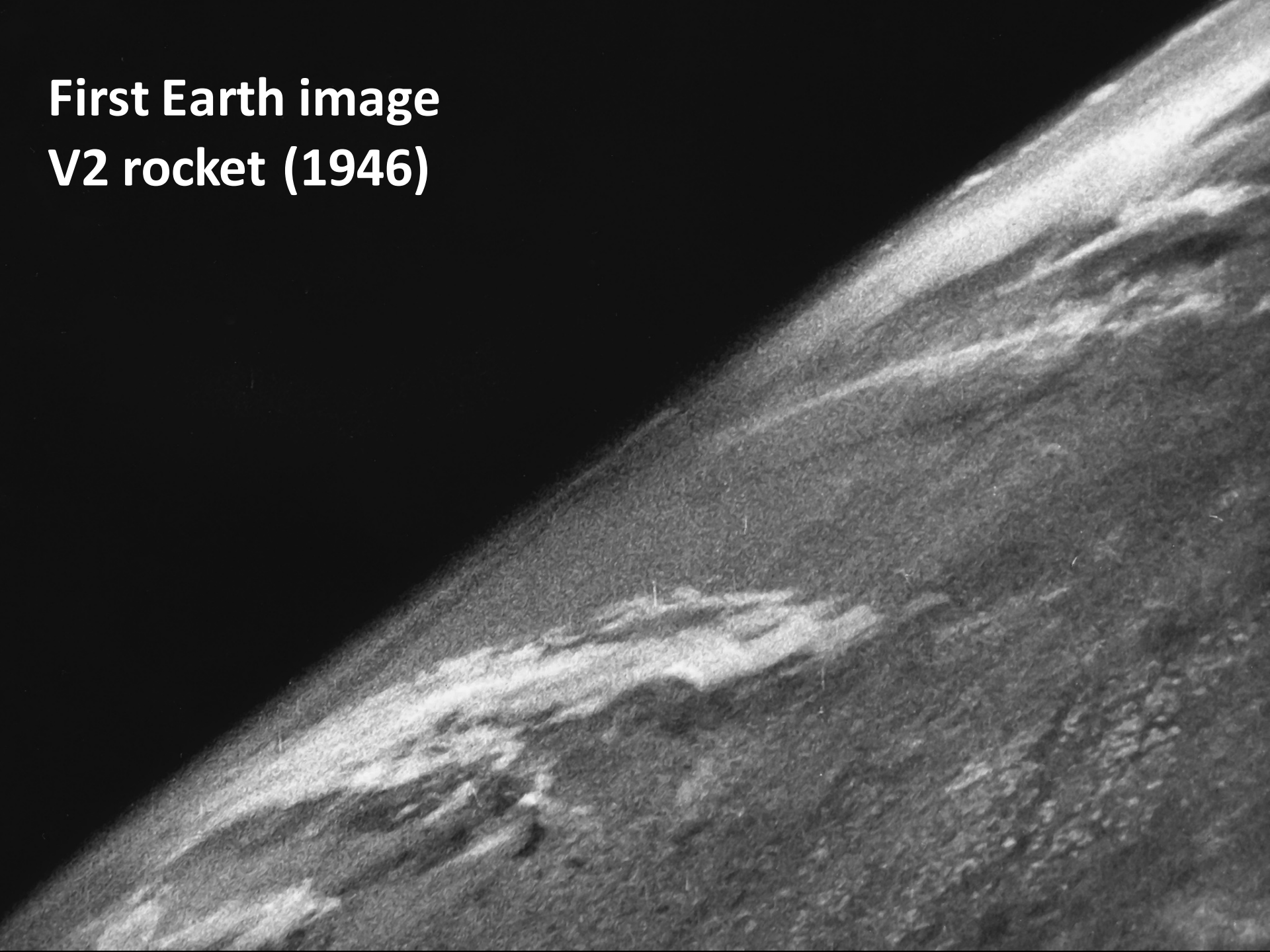
V2 rocket

(1944+)





**First Earth image  
V2 rocket (1946)**





First telemetry

C119 & DMSP (1959)



**First weather satellite**

**TIROS (1960)**





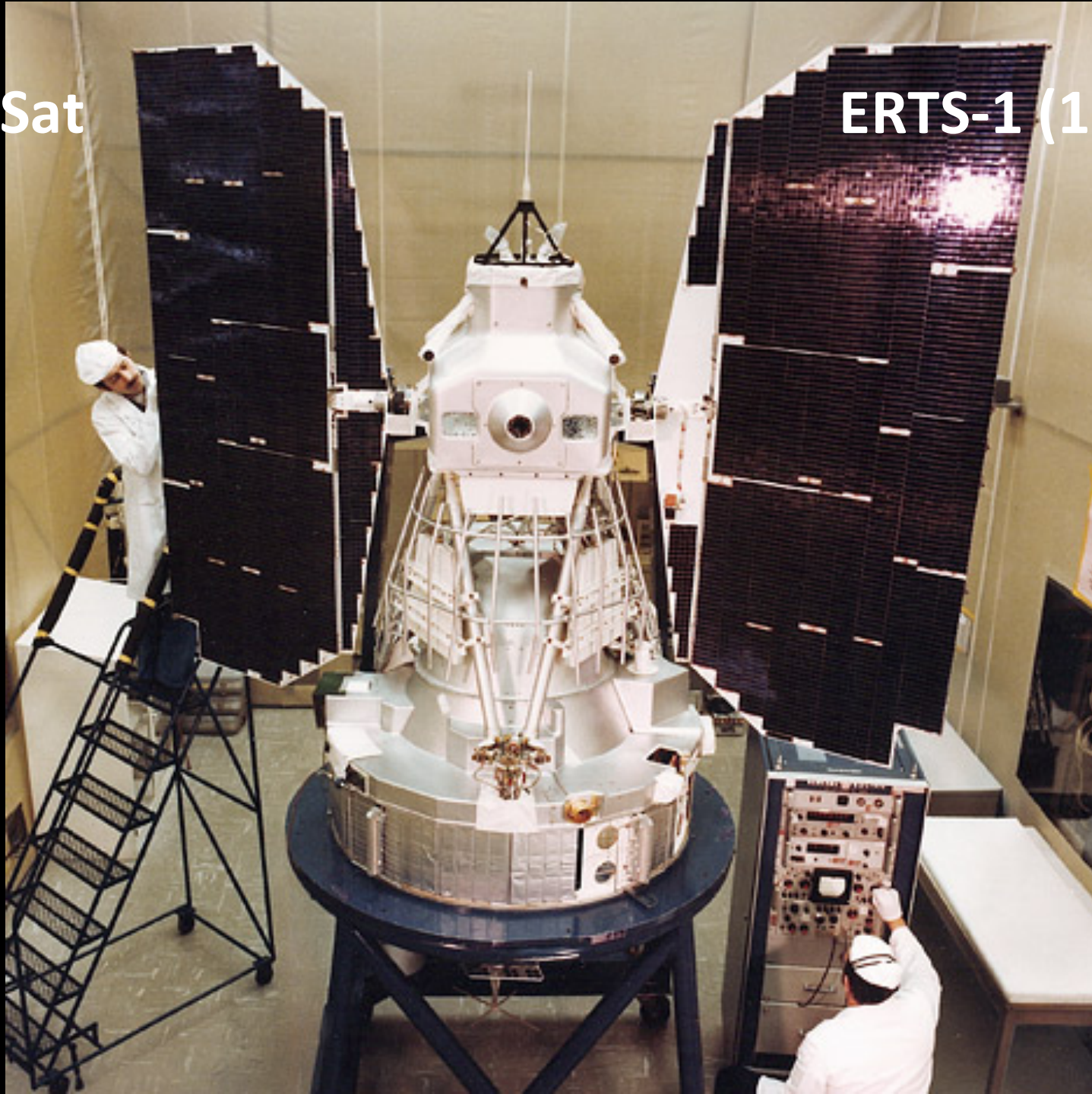
**Earthrise**

**Apollo 8 (1968)**



LandSat

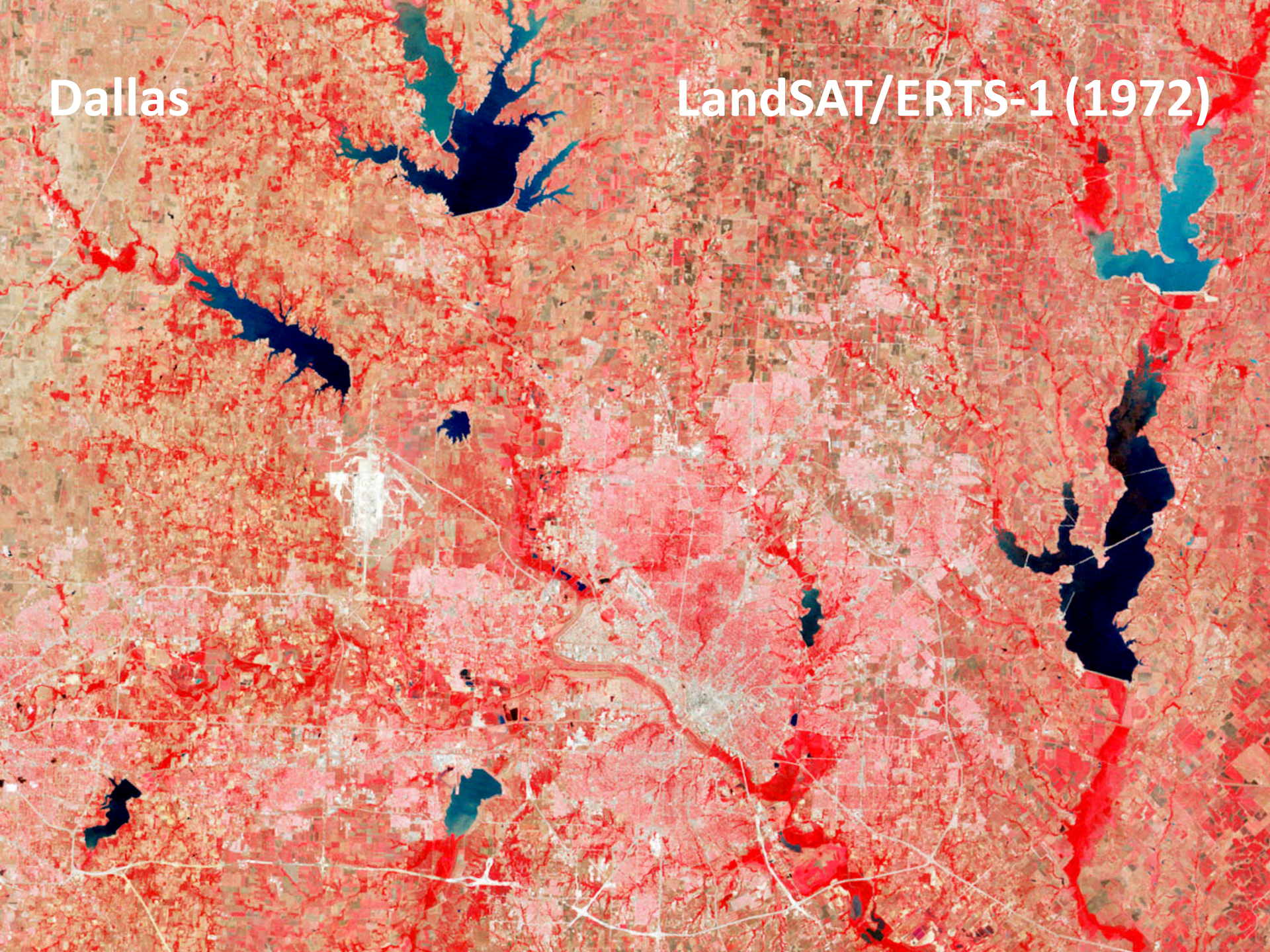
ERTS-1 (1972)





Dallas

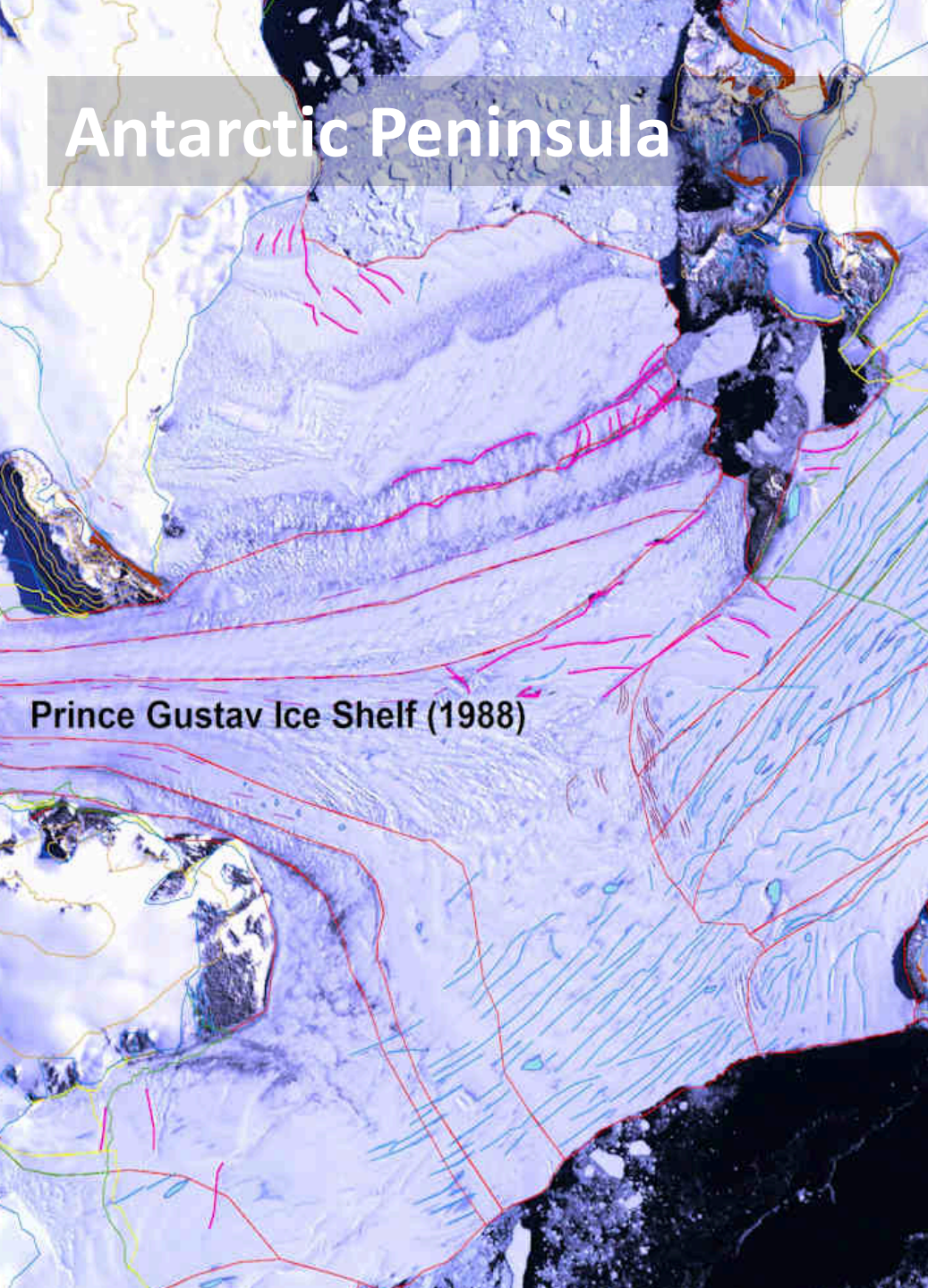
LandSAT/ERTS-1 (1972)



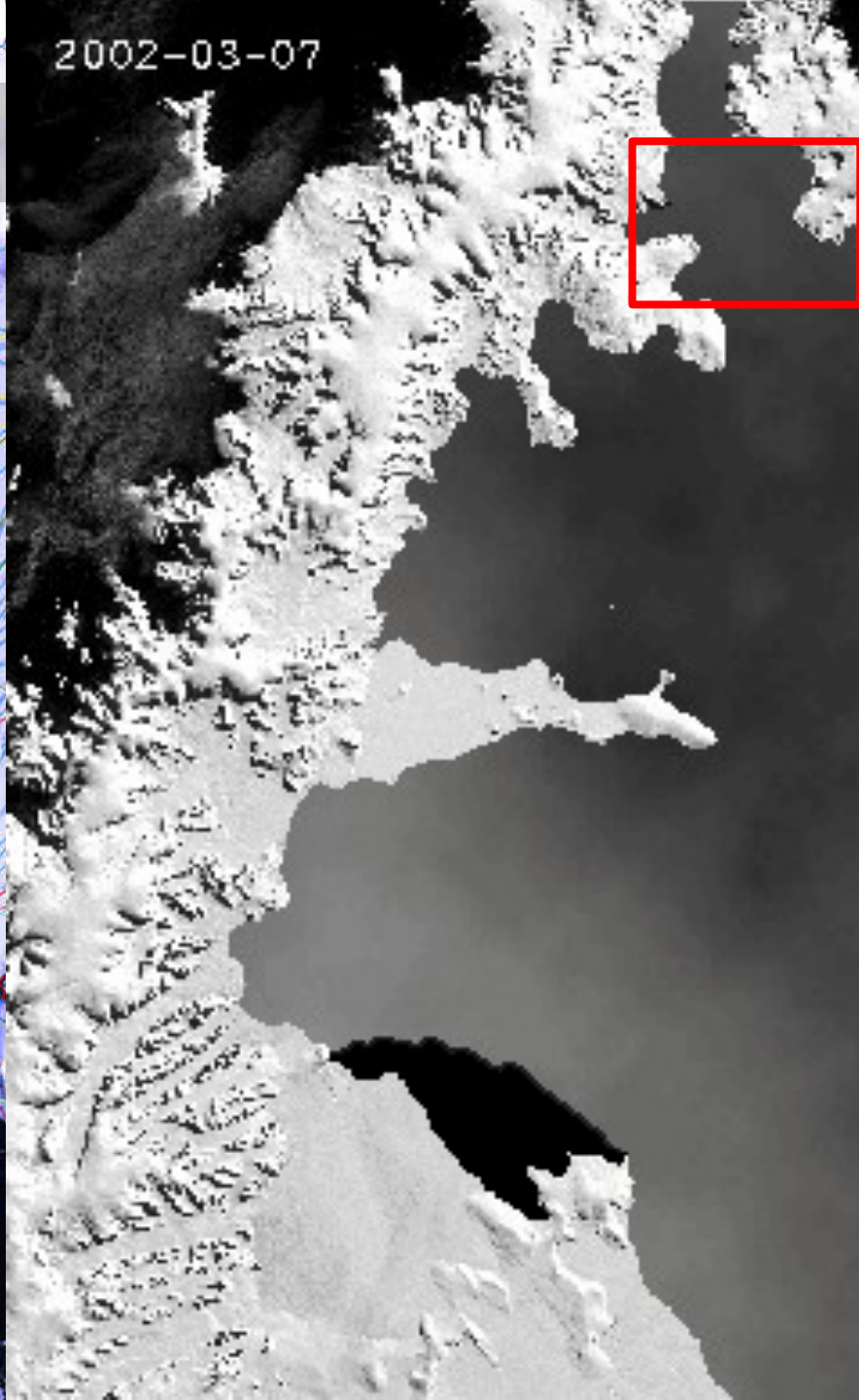


# Antarctic Peninsula

Prince Gustav Ice Shelf (1988)



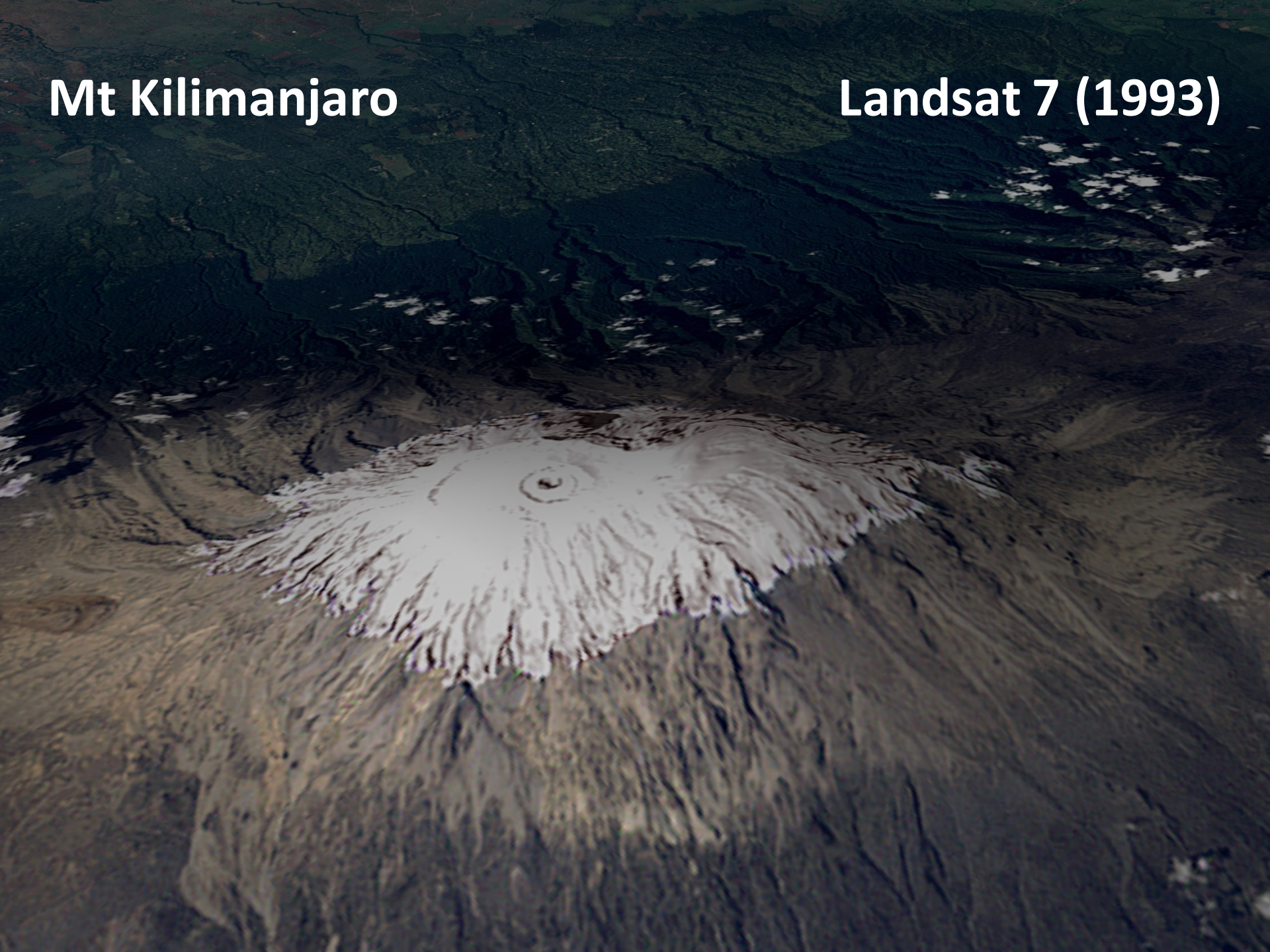
2002-03-07





**Mt Kilimanjaro**

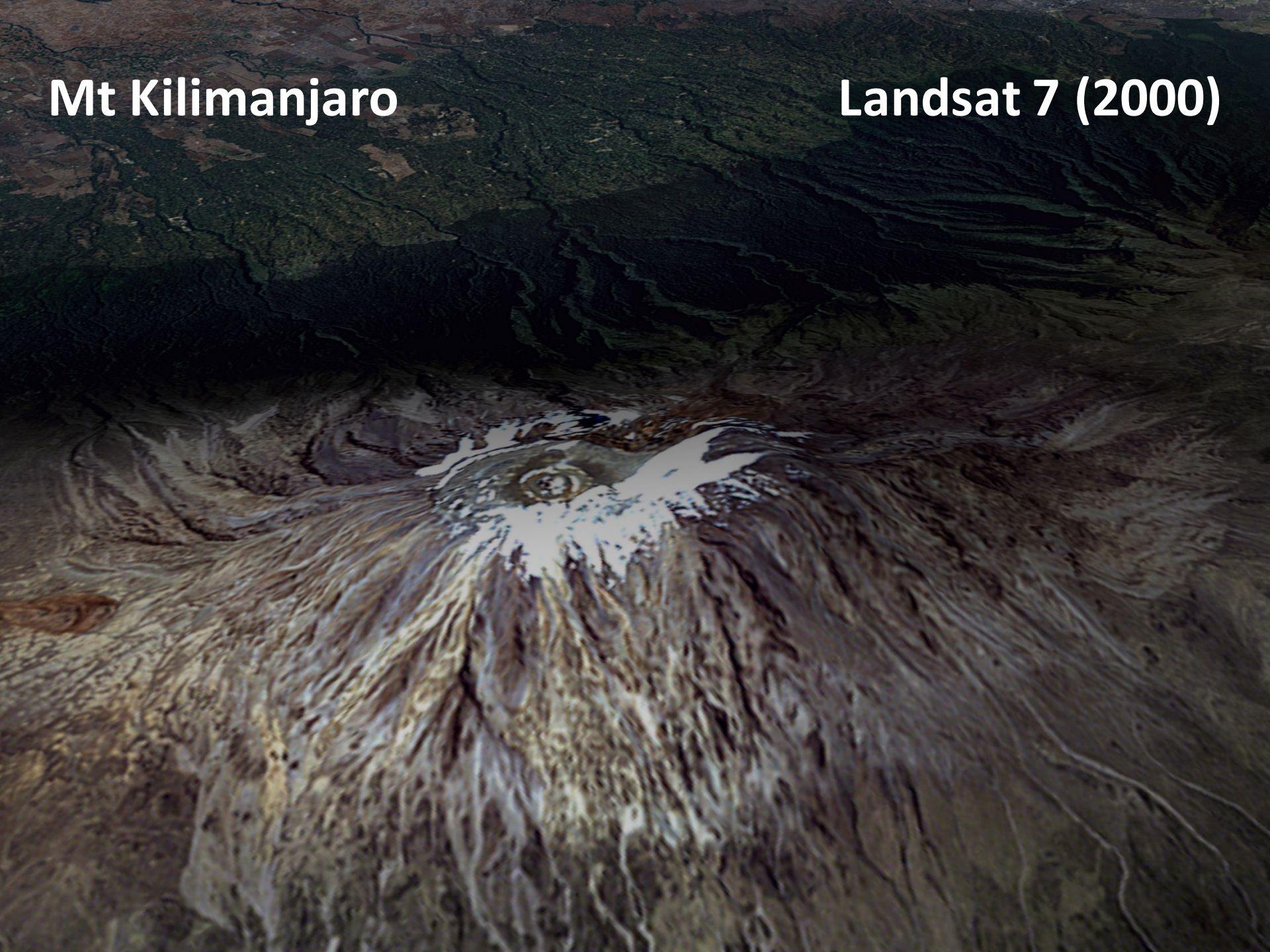
**Landsat 7 (1993)**





**Mt Kilimanjaro**

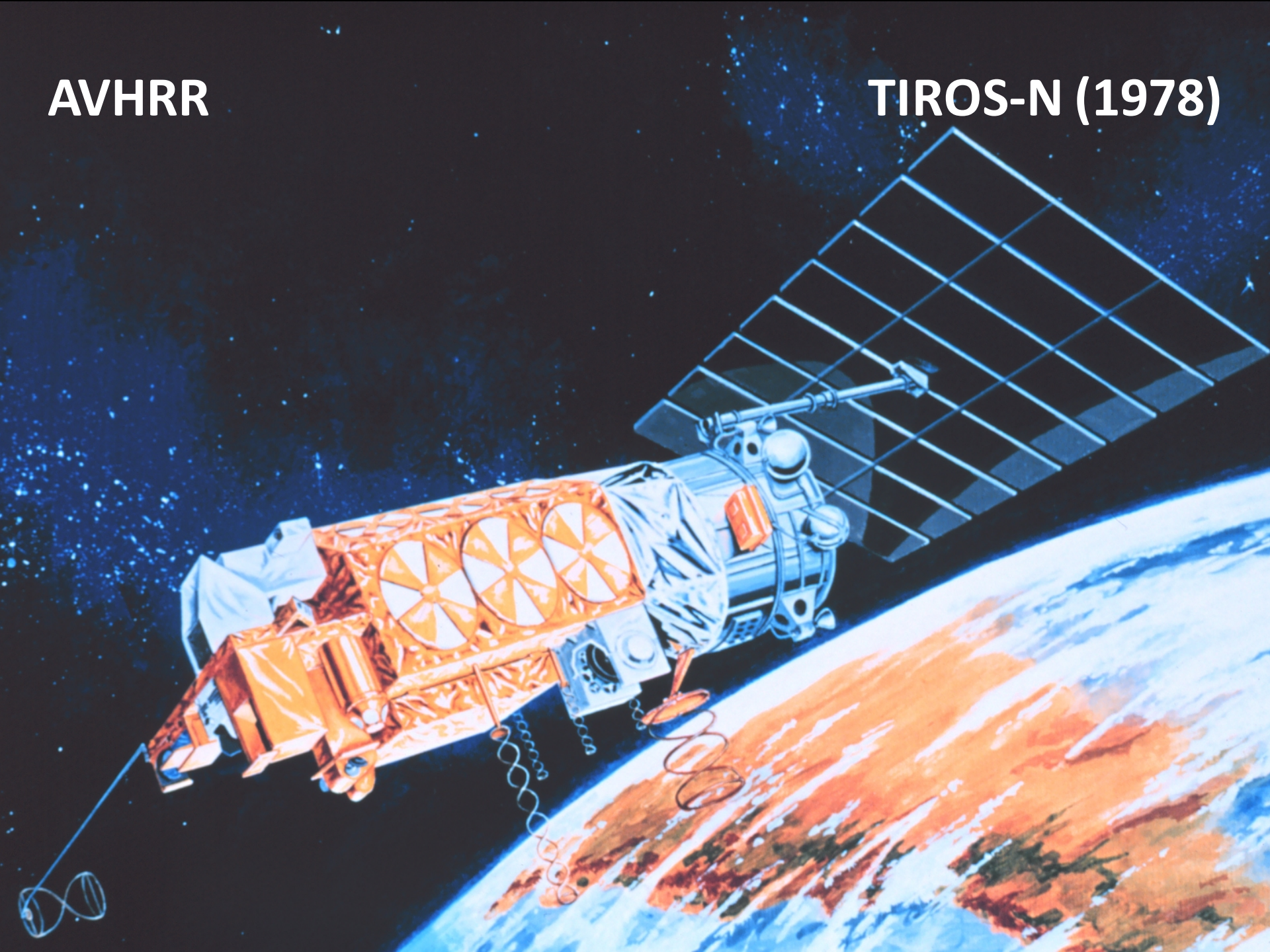
**Landsat 7 (2000)**





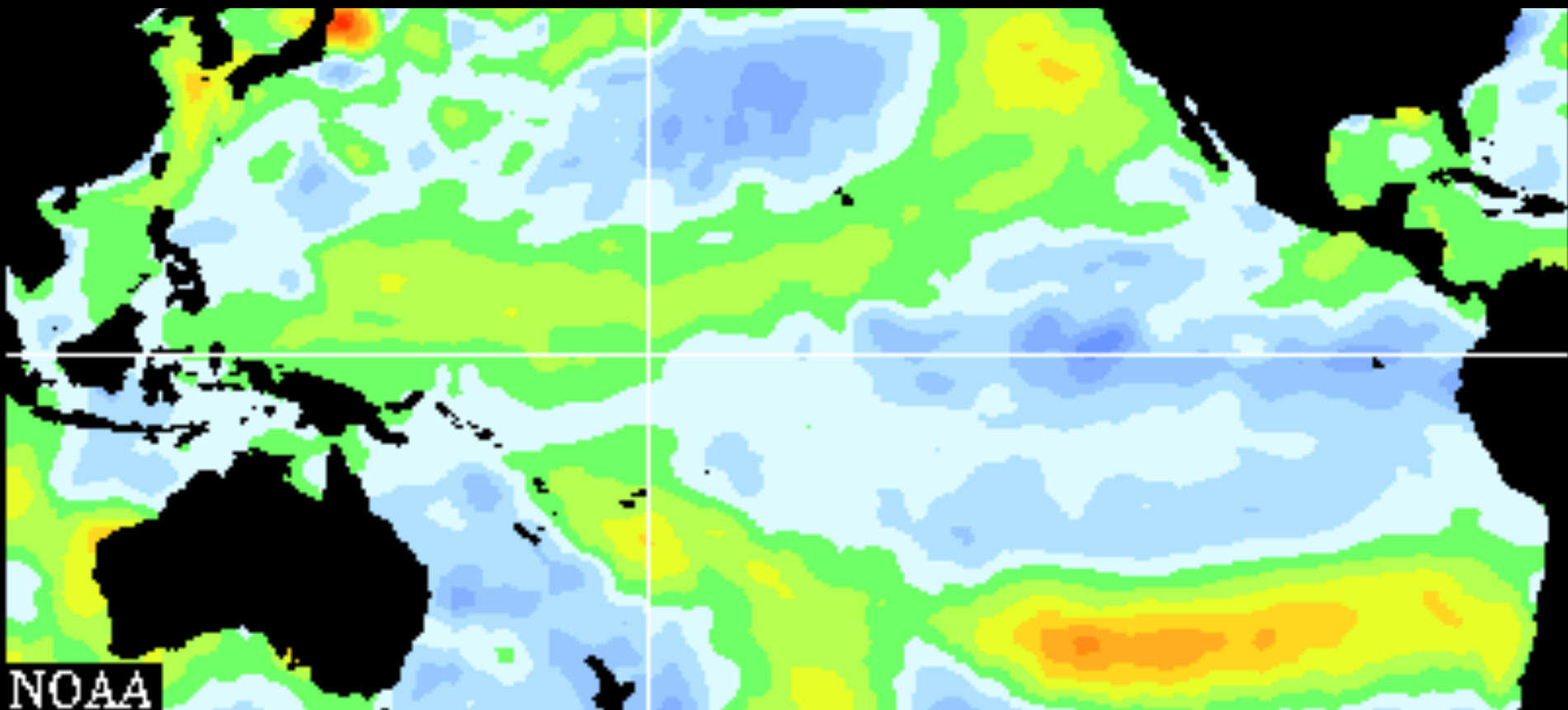
**AVHRR**

**TIROS-N (1978)**



**El Nino (1982)**

**AVHRR (1997)**



120E

150E

180

150W

120W

90W

-5

-4

-3

-2

-1

0

1

2

3

4

5



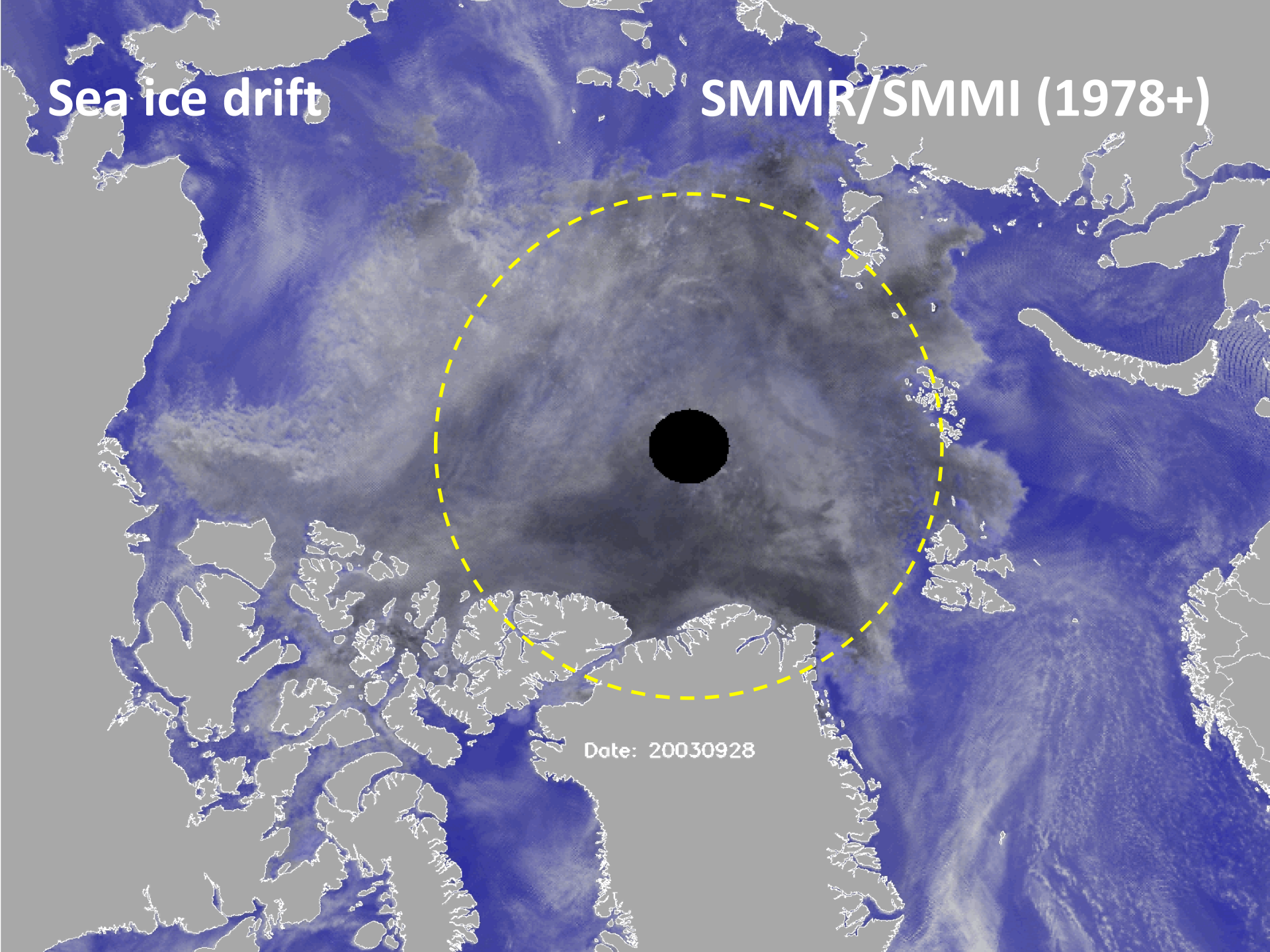
**SeaSat**

**(1978)**



Sea ice drift

SMMR/SMMI (1978+)

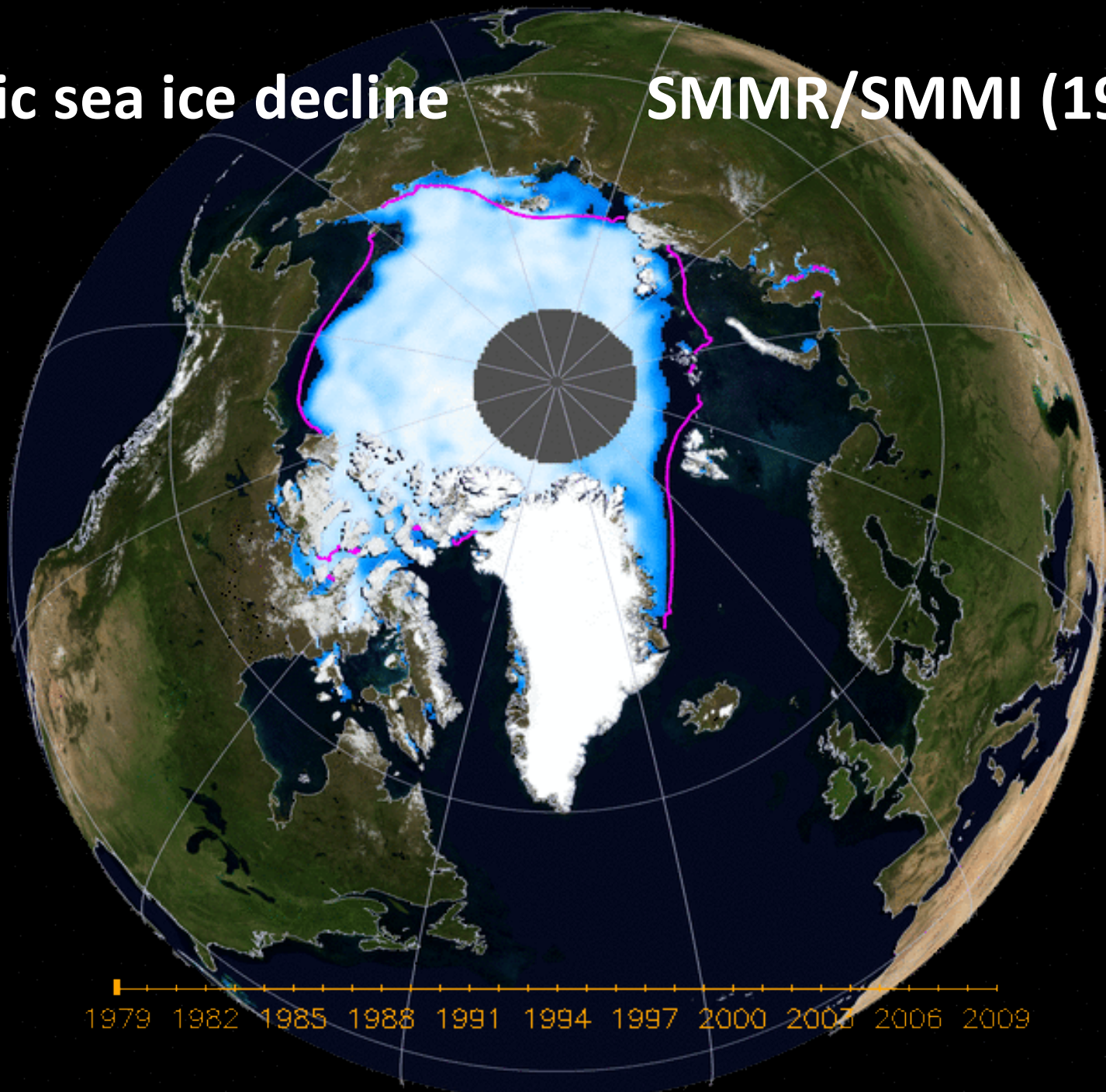


Date: 20030928



Arctic sea ice decline

SMMR/SMMI (1978+)





# Greenland melt

# SMMR/SMMI (1978+)





Space shuttle

(1981)





**Greenland**

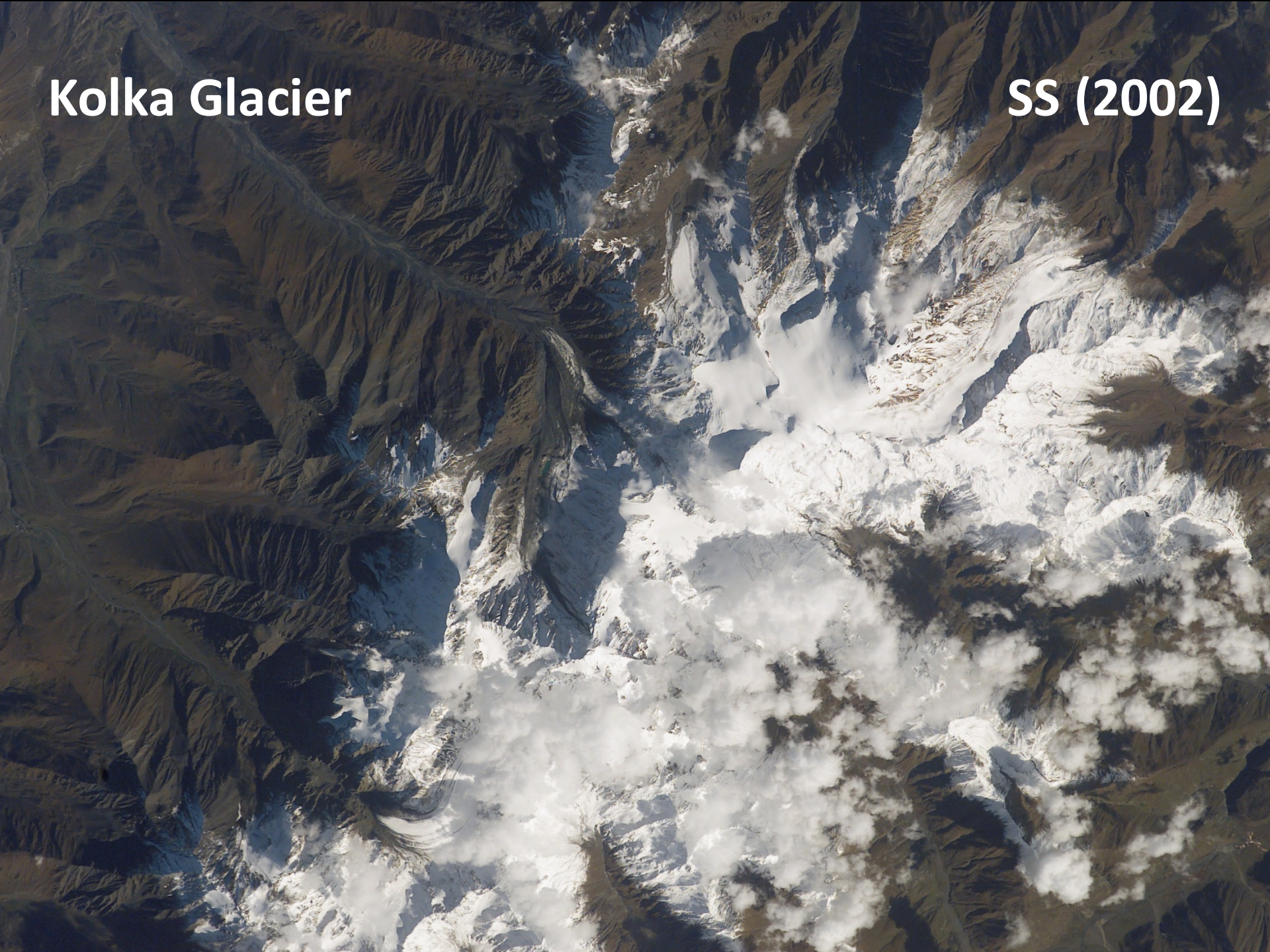
**SS (1992)**





**Kolka Glacier**

**SS (2002)**





ERS-1

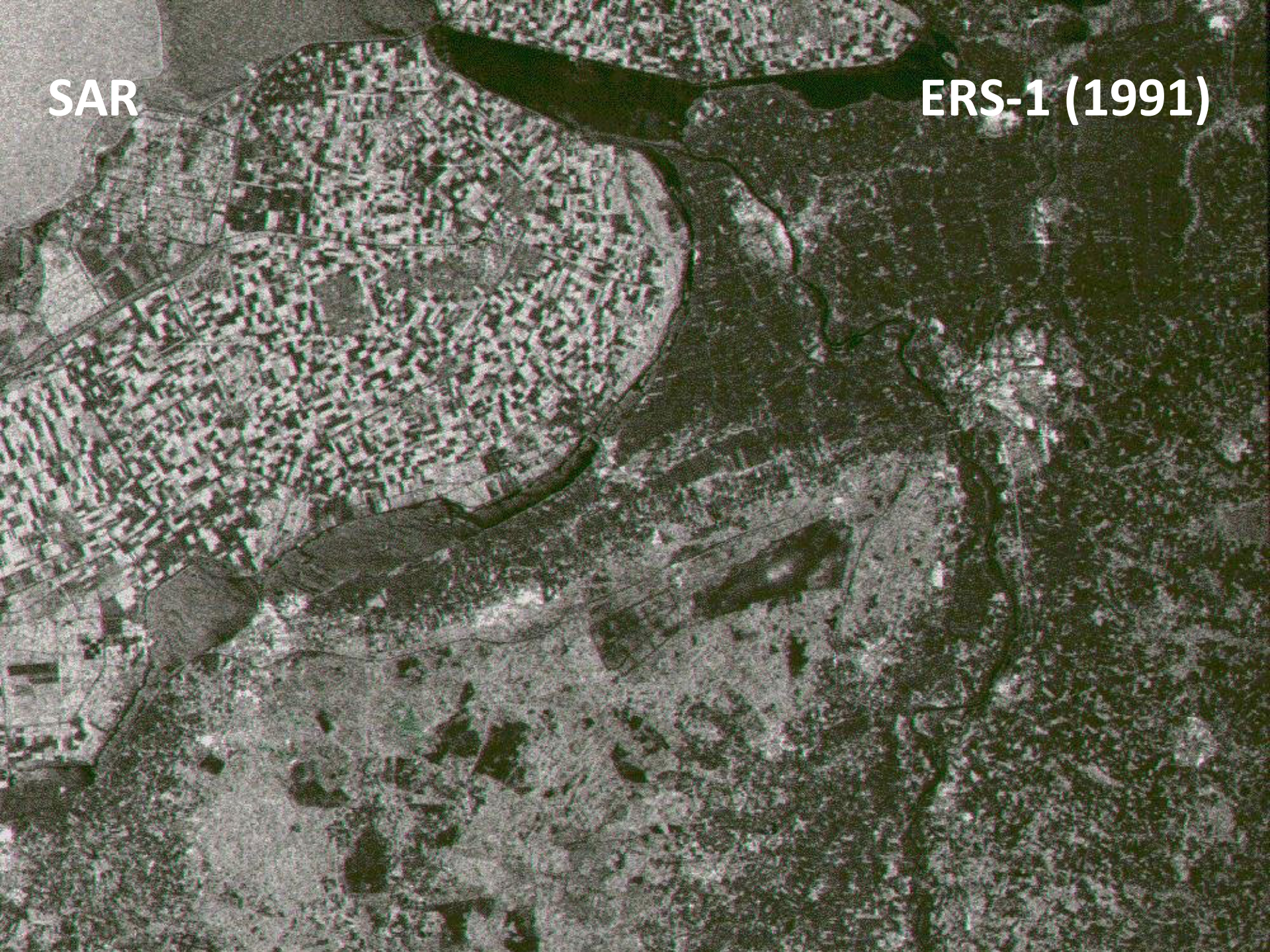
SPOT-4 (1998)





SAR

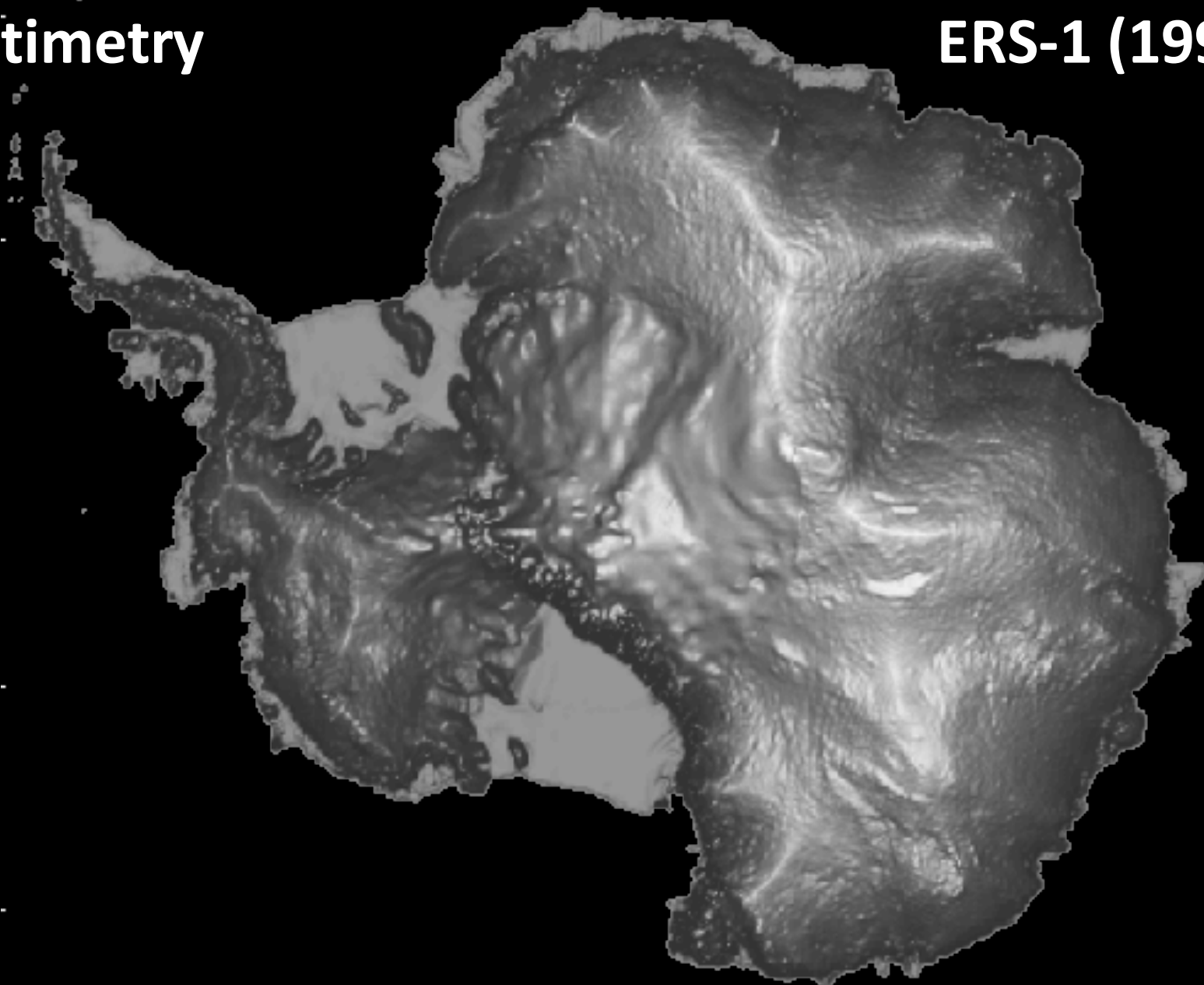
ERS-1 (1991)





**Altimetry**

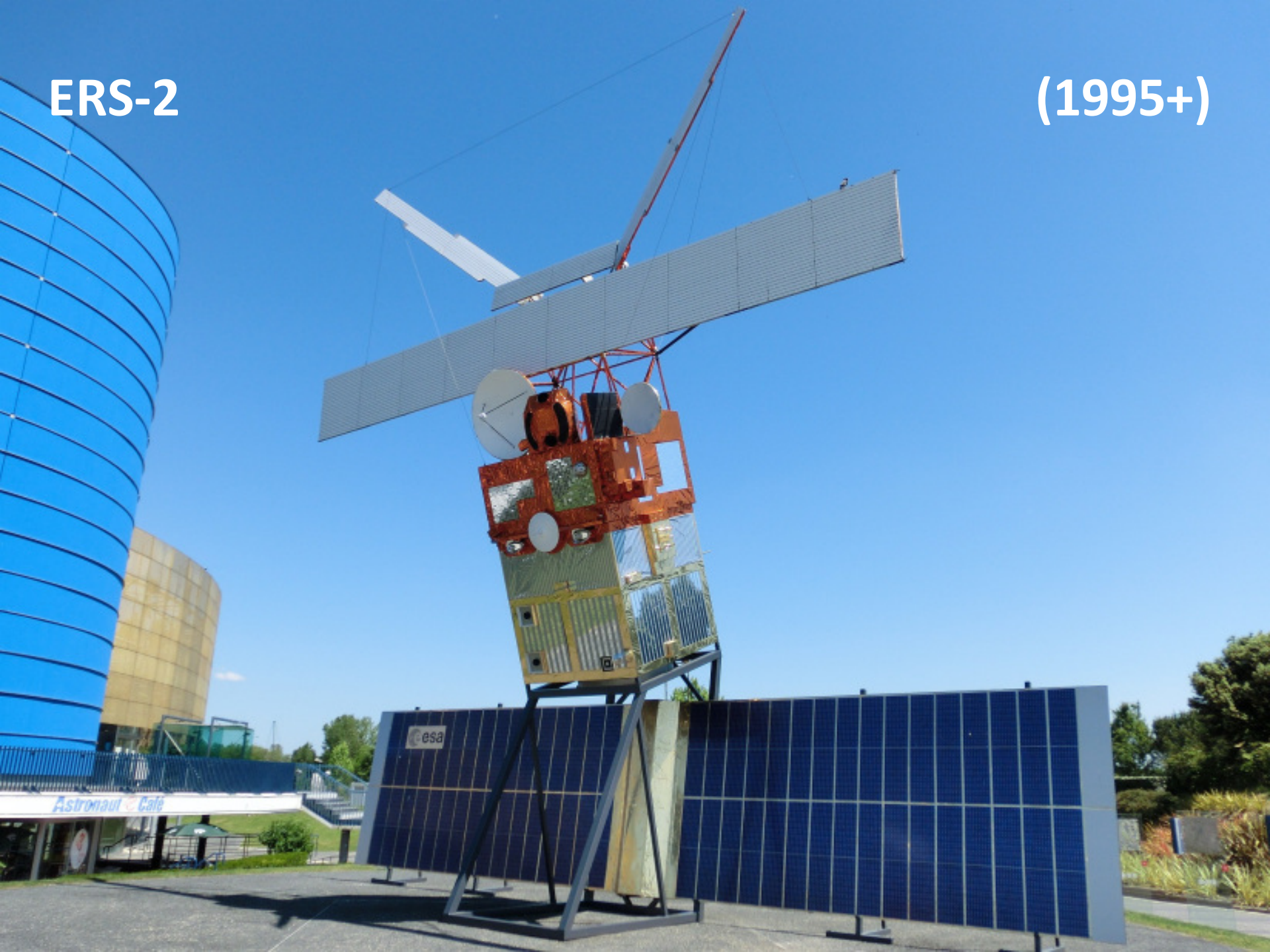
**ERS-1 (1991+)**





ERS-2

(1995+)





InSAR

ERS-1/2 (1995)





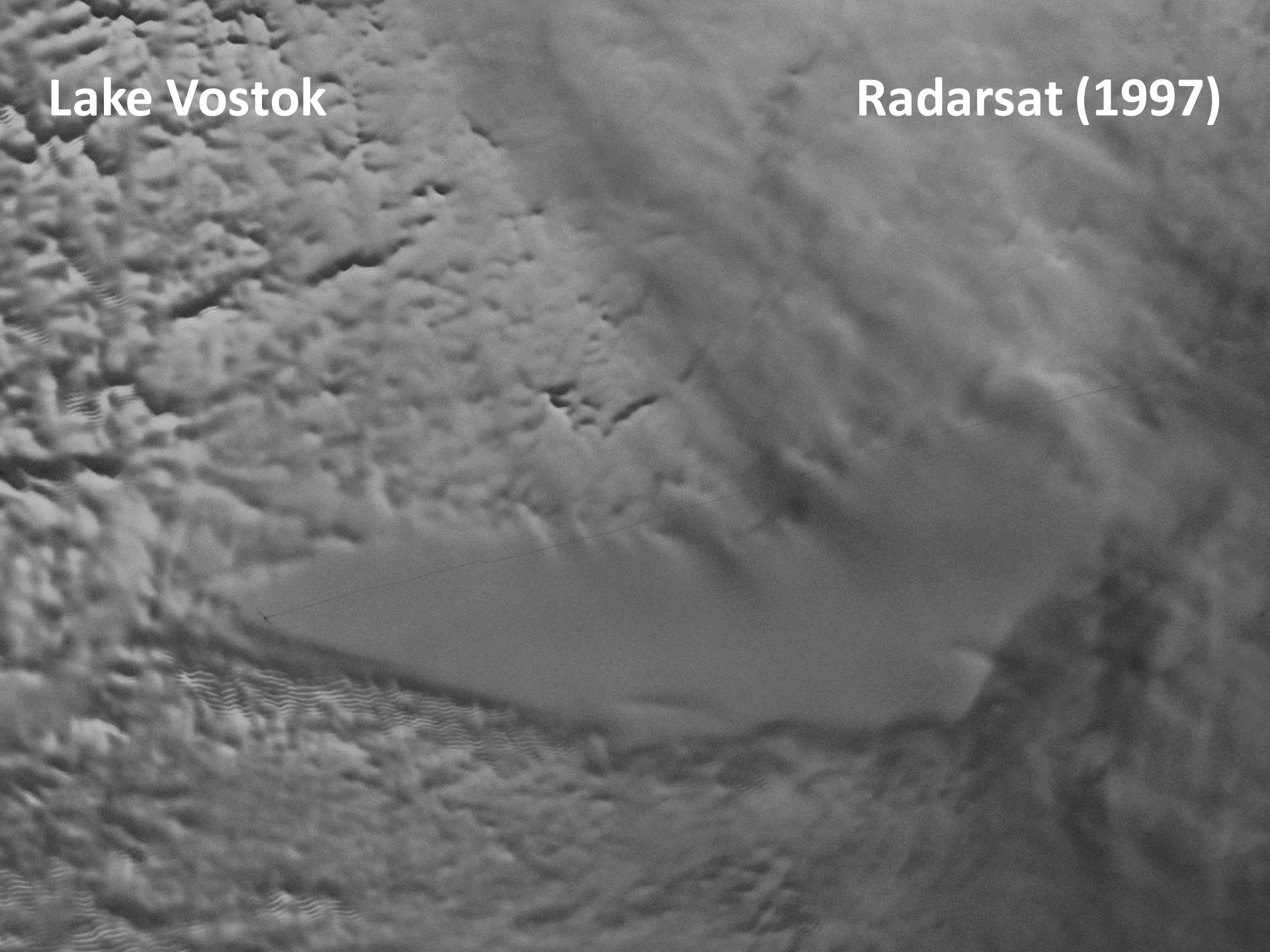
**Ice flow**

**(1978+)**



Lake Vostok

Radarsat (1997)





# Grounding line

(1992+)

## Sustained Retreat of the Pine Island Glacier

*Park, Gourmelen, Shepherd et al (2013), GRL*  
University of Edinburgh, University of Leeds

with data contribution from  
University of Washington, CATS tide model, BEDMAP2 topography

Animation by  
Planetary Visions

Funded by ESA's Support to Science Element (STSE)



**Mars global surveyor**

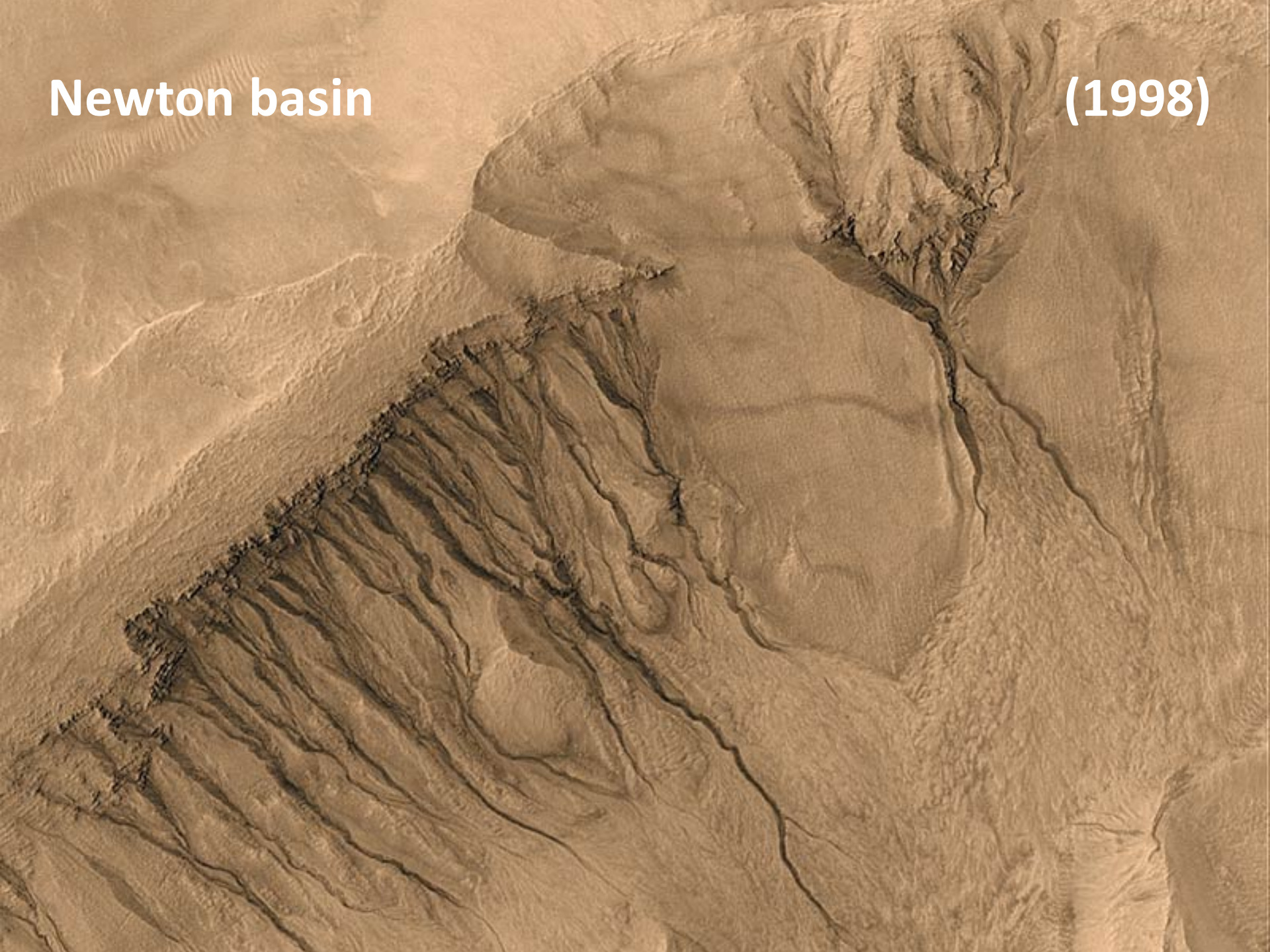
**(1996)**





**Newton basin**

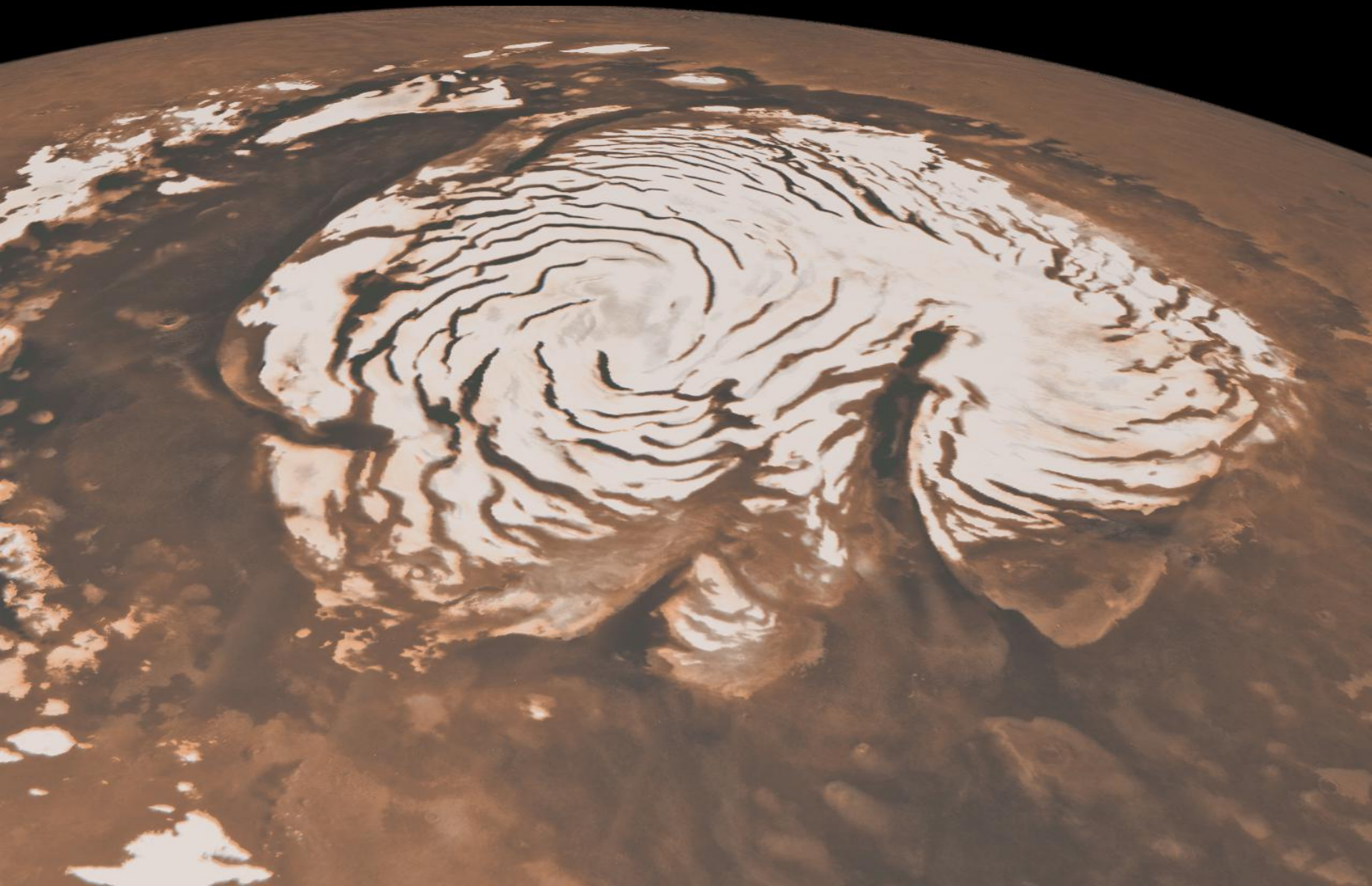
**(1998)**





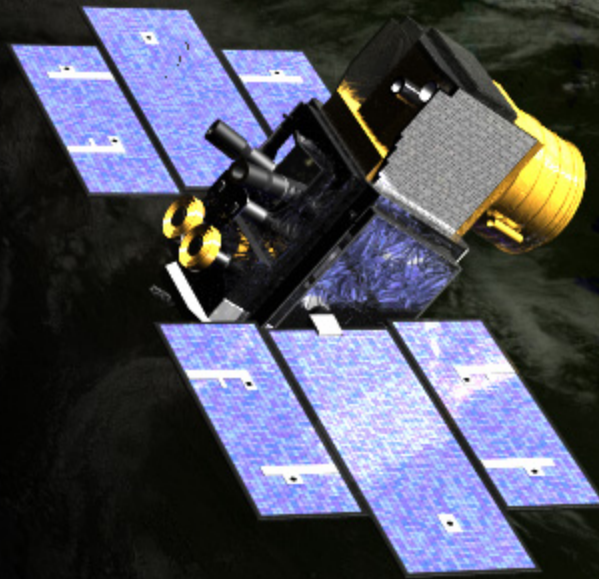
**Mars ice cap**

**Mola (1996)**



**ICESat**

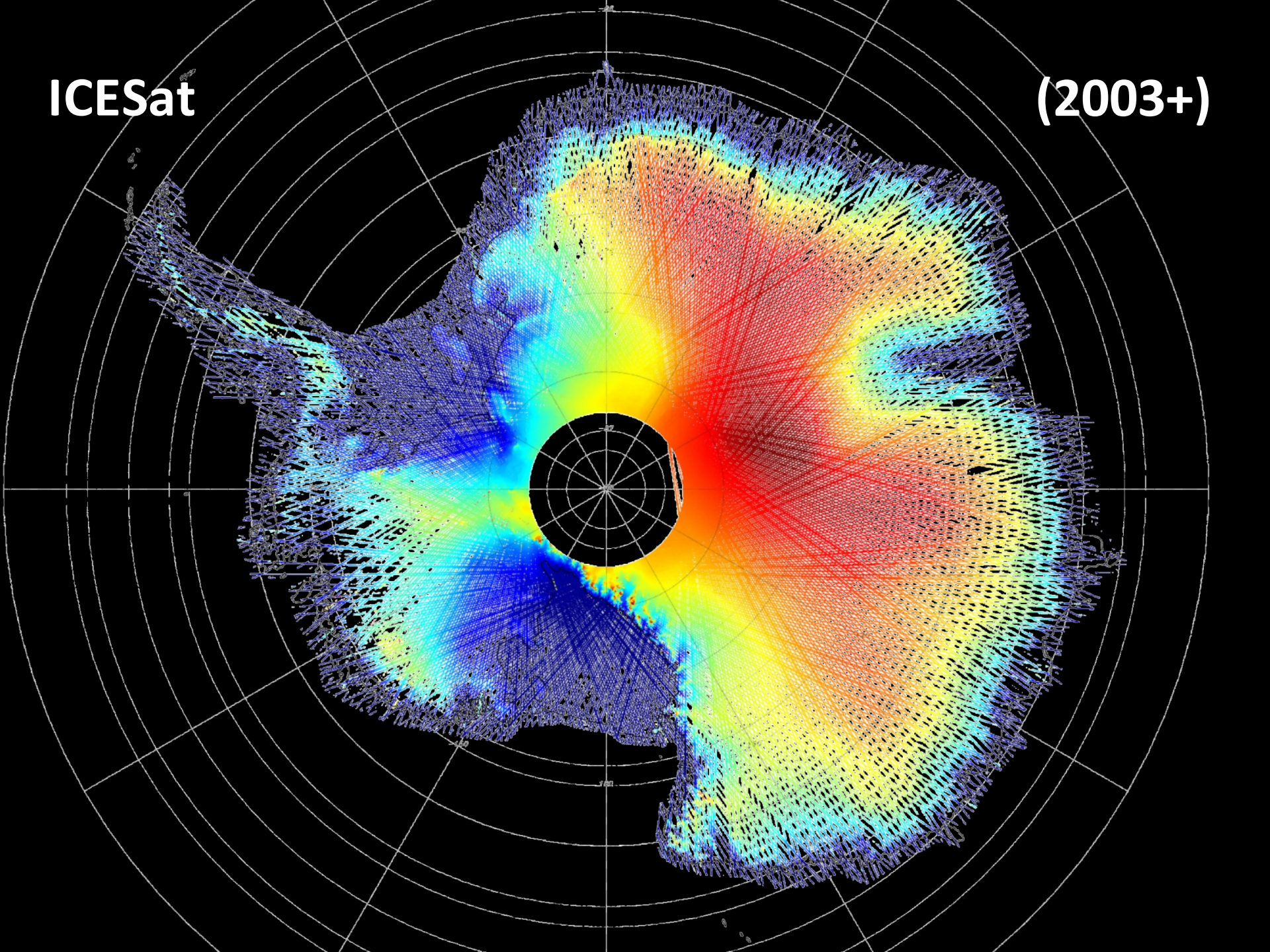
**(2003)**





ICESat

(2003+)





**Subglacial lakes**

**(2006+)**





# International Space Station

(1998)





Upsala Glacier

ISS (2001)





Upsala Glacier

ISS (2004)





**Hurricane**

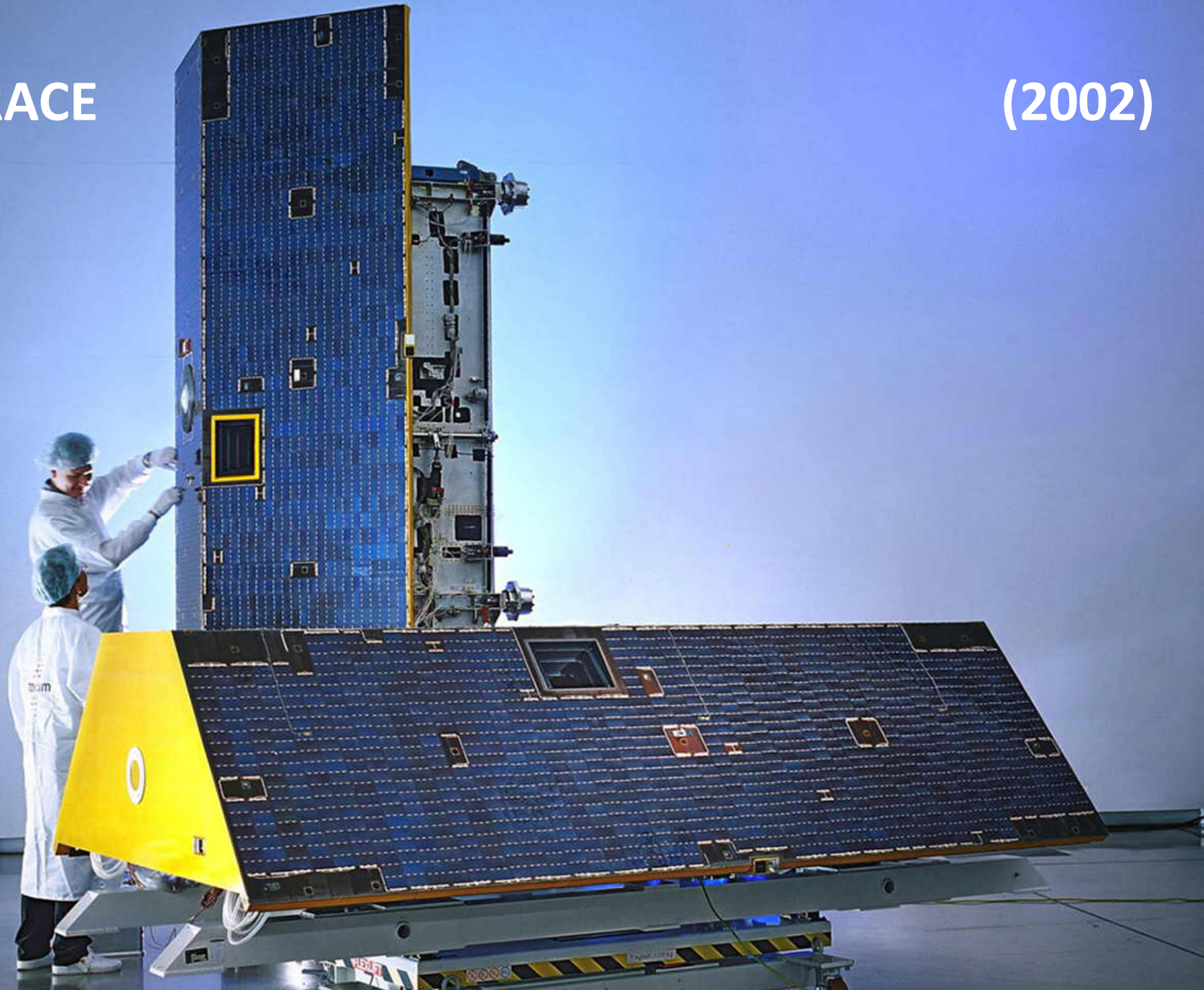
**ISS (2007)**





GRACE

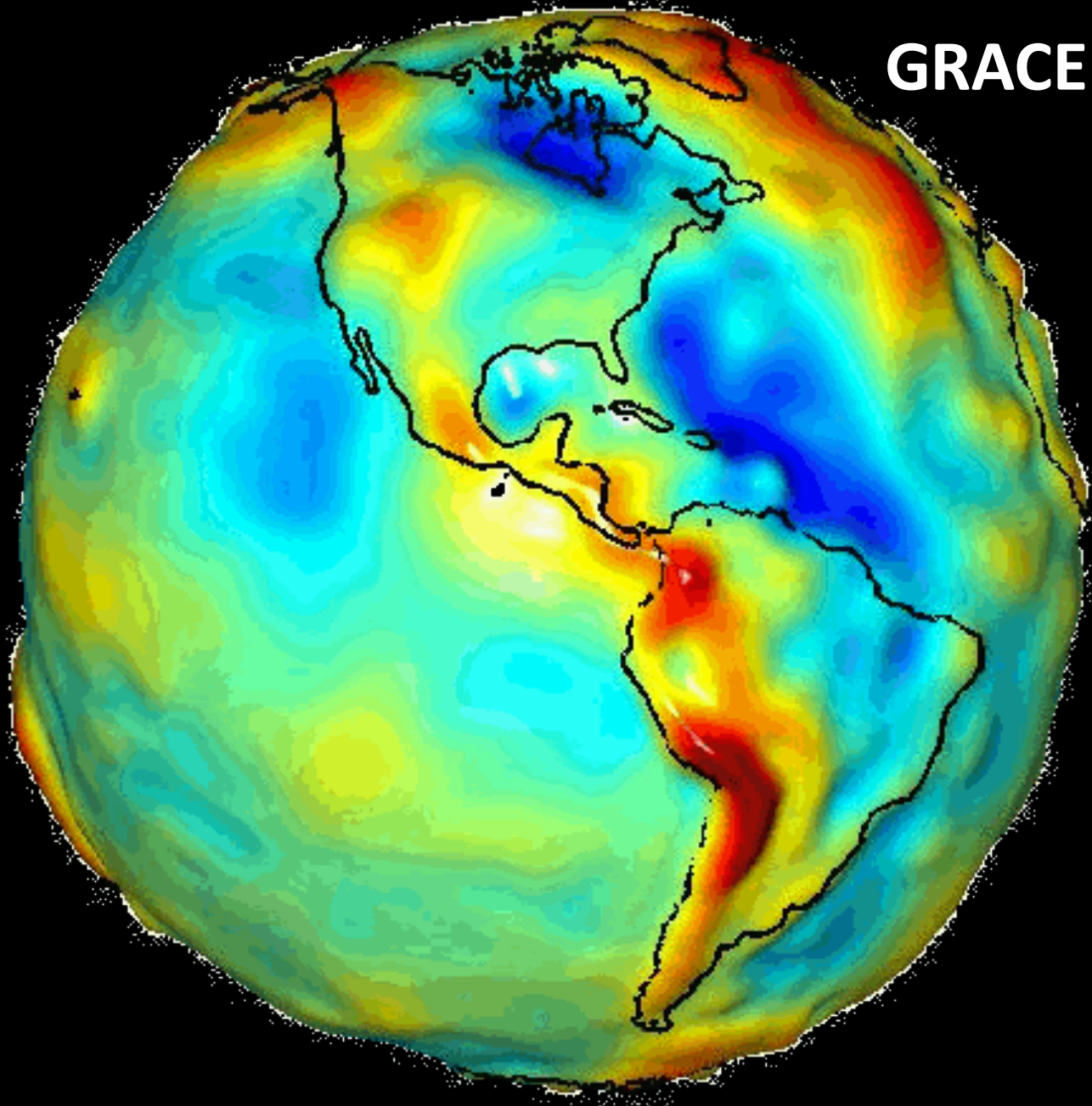
(2002)





**Geoid**

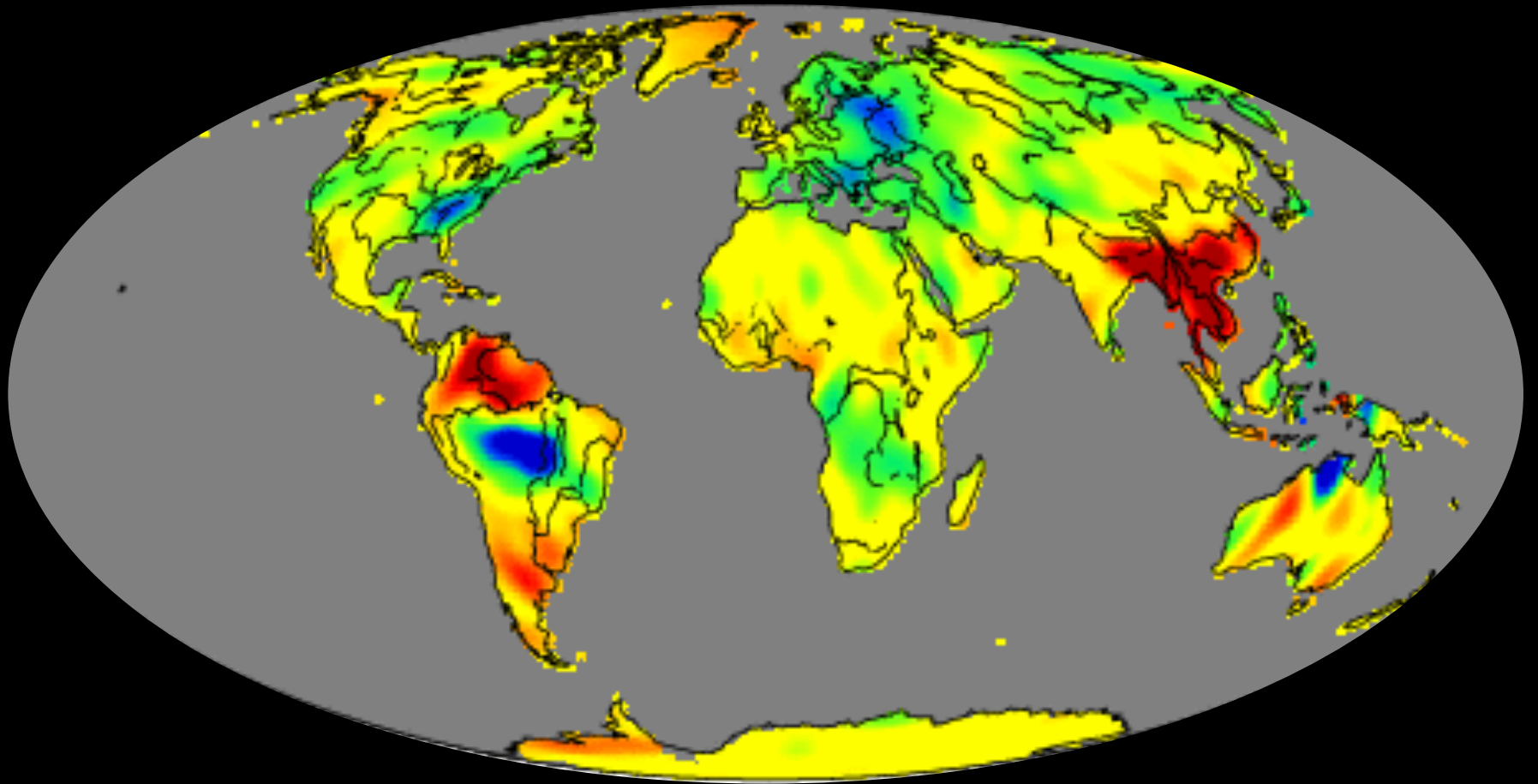
**GRACE (2003)**





**Mass transport**

**GRACE (2009)**





CryoSat-2

(2010)





**CryoSat-2**

**(2010+)**





<b>Day</b>	<b>Topic</b>	<b>Lecturers</b>		<b>Workshop</b>
Monday	Glaciers	Andy Shepherd Pete Nienow	Frank Paul Tamsin Edwards	Mapping Glacier Area using Sentinel-2
Tuesday	Ice flow	Andy Hooper Anna Hogg	Andrea Minchella Twila Moon	Tracking ice motion using Sentinel-1
Wednesday	Ice thickness change	Louise Sorensen Noel Gourmelen Sinead Farrell	Eero Rinne Rachel Tilling Andy Shepherd	Determining sea ice thickness using CryoSat-2
Thursday	Ice mass balance	Kate Briggs Jeremie Mouginot	Rene Forsberg Andreas Groh Isabella Velicogna	Computing ice sheet mass balance using GRACE
Friday	Surface mass balance	David Small Marco Tedesco	Robert Ricker Michiel van den Broeke	