Fri. Apr. 06, 2018

- Map Projections
- "Environmental" Applications

- Reading:
  - Finish Chapter 9 ("Environmental" Remote Sensing")
    - Once again -- Satellites old but principles still apply
  - Skim Sabins Chapter 10. Oil Exploration
  - Start reading Hewson et al. 2005 "Seamless geological map generation using ASTER in the Broken Hill-Curnamona province of Australia." Remote Sensing of theEnvironment 99: 159-172
    - (link on class website "Reading List" Page

Independent Labs

- Independent labs next and following week
  - Think about possible remote sensing topics
  - Talk with me by next Friday about it, and about possible data sources

Chapter 9: Environmental Apps.

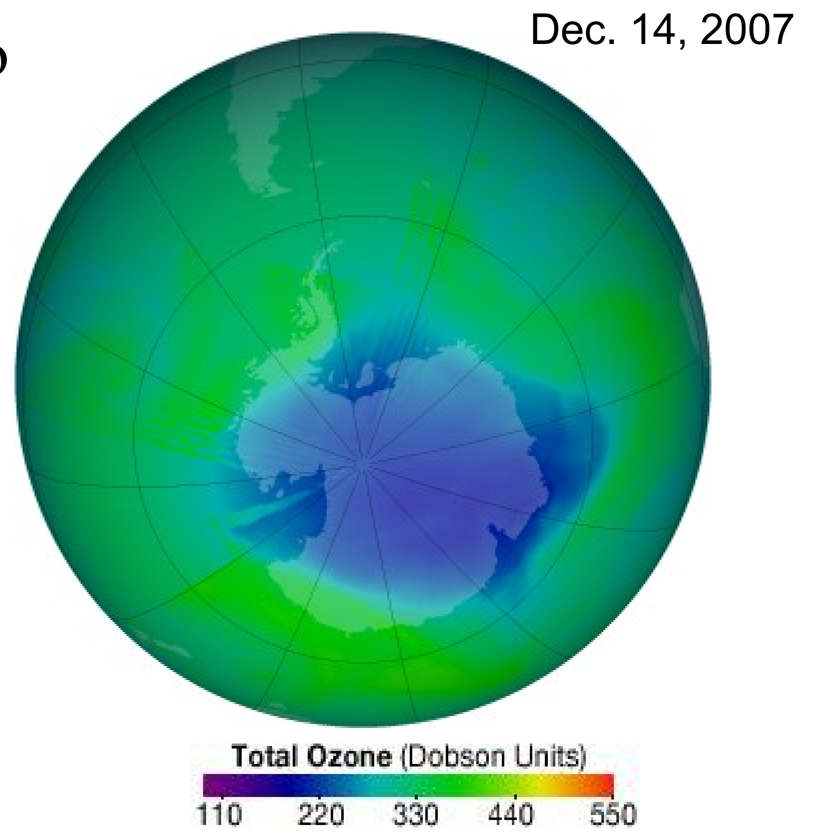
- Misc. Topics from chapter 9 (Environmental Remote Sensing)
  - Won't go into it in as much detail as Sabins
  - Ozone mapping
  - Precipitation
  - Ice (just summary – we discussed this earlier)
  - Ocean observations
    - Bathymetry
    - Ocean bottom geology from sonar
    - Ocean Productivity

TOMS: Total Ozone Mapping Spectrometer

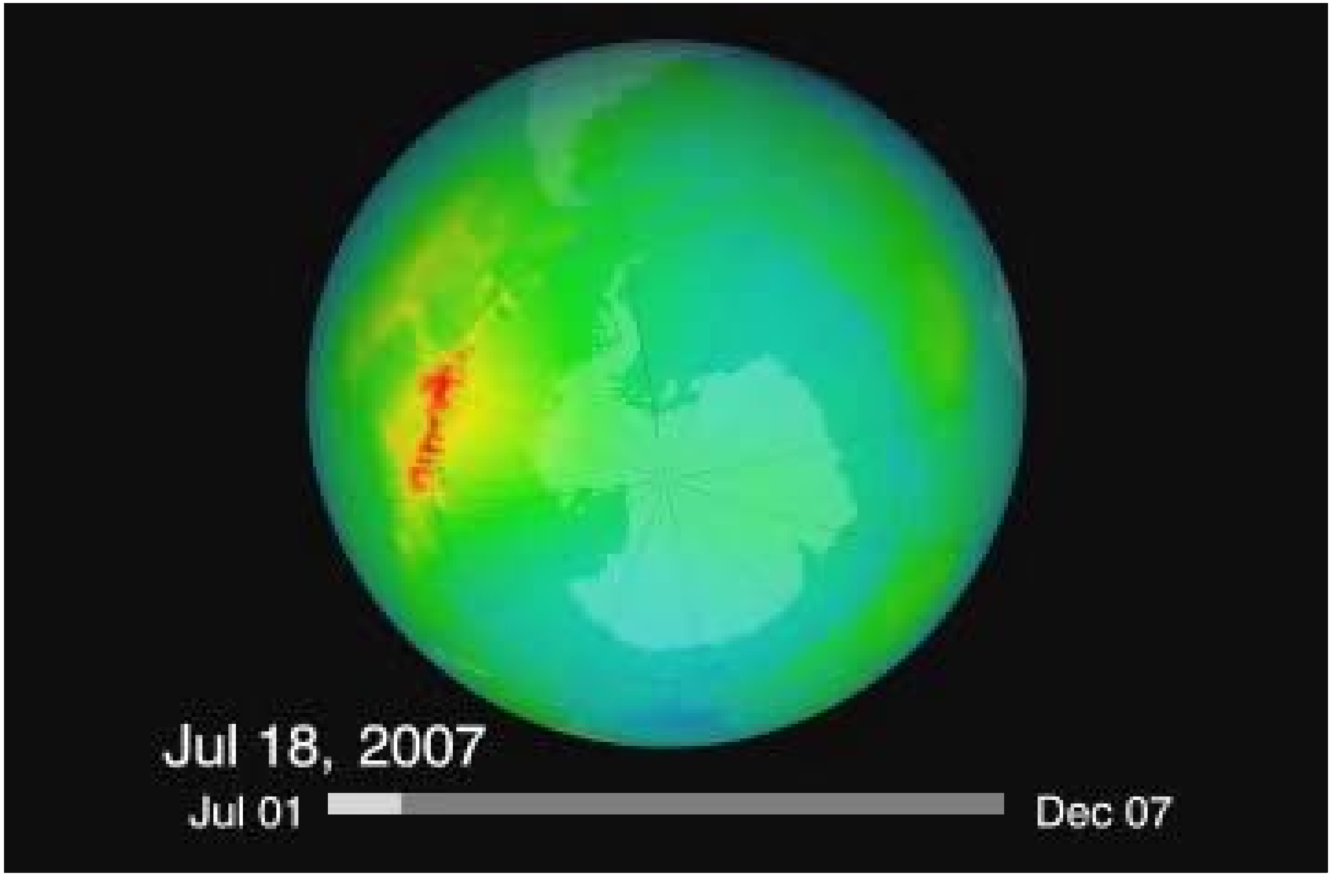
- Measure UV radiation in 0.3125 to 0.3800 μm range
- Compare incoming solar to "backscattered" light from lower atmosphere

- More Ozone means less UV makes it back out of atmosphere

- 1 Dobson unit = 0.001 cm-atm
  - 1 cm-atm = amount of gas which would form layer 1 cm deep – if at STP

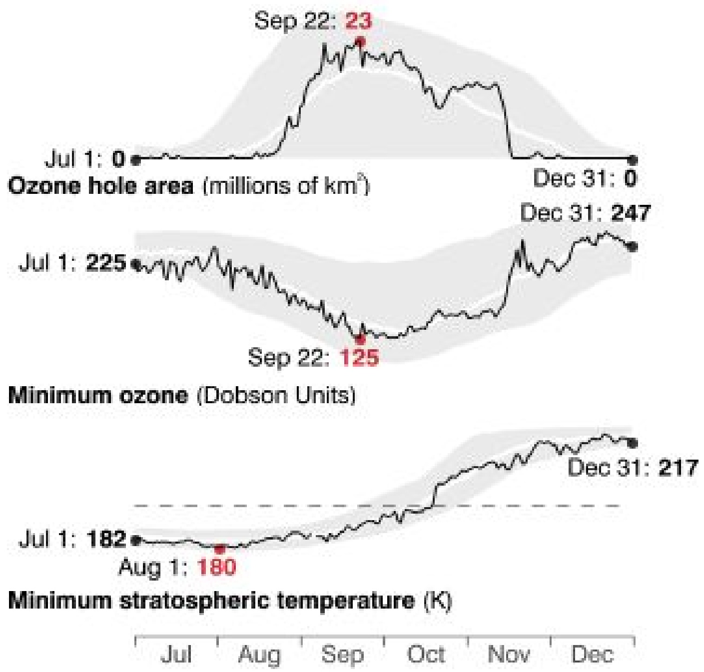


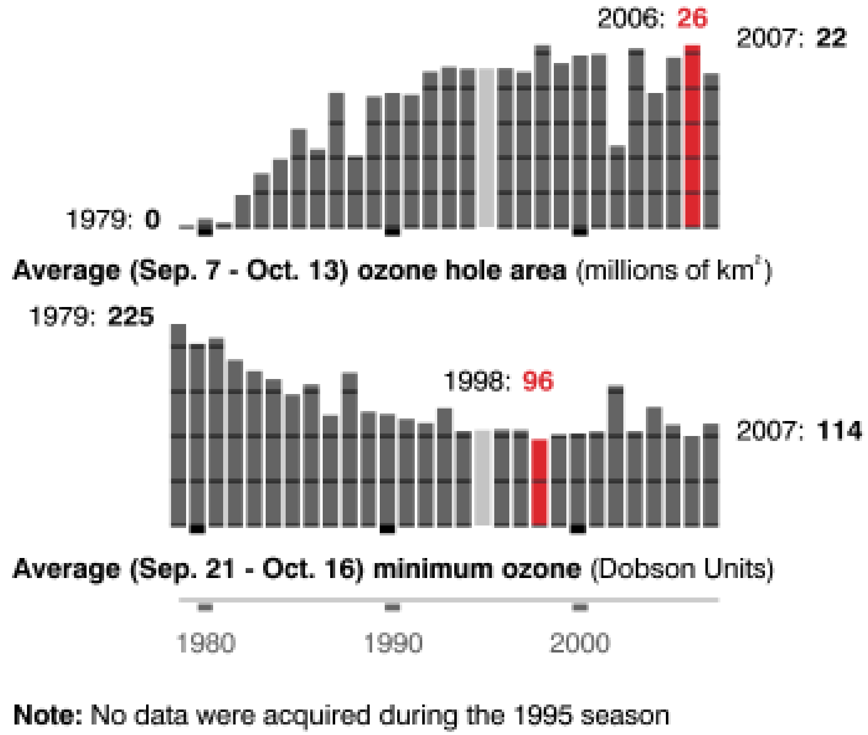
TOMS: Seasonal Formation of Hole



- 1 Dobson unit = 0.001 cm-atm
  - 1 cm-atm = amount of gas which would form layer 1 cm deep – if at STP

Antarctic Ozone: Monthly, Yearly variations

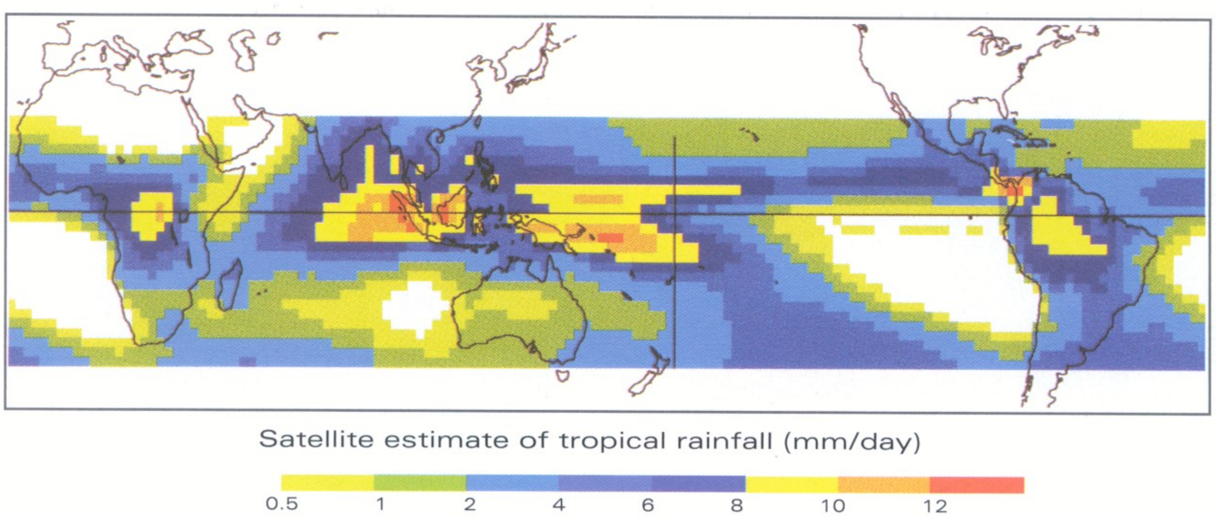




- Hole reappears each Antarctic Spring
- Effects leveling off now Freon releases have stopped

Rainfall Mapping, 1

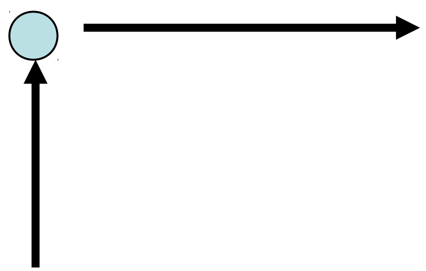
- Precipitation critical for vegetation forecasts
  - Rain gauges are just "point" measurements – sparse over many regions – and missing over oceans
- Radar estimates
  - Use fact that radar is scattered by raindrops, not cloud particles
  - Coverage is limited (GPM just launched)
- GOES Precipitation index: GPI
  - Uses frequent IR cloud measurements
  - In <u>Tropics</u> Coldest (<235K) clouds most associated with rain



A. Mean annual rainfall (1986 to 1994) derived from cloud temperatures.

Rainfall Mapping, 2

- Passive Microwave Images
  - Uses thermal emission from 0.3 – 1.55 cm wavelength range
- Emission methods
  - Looks for varying thermal emission over oceans
  - Won't work over land – too non-uniform
- Scattering methods
  - Ice (present in high clouds) scatters upgoing thermal radiation
  - Comparing Horizontal vs. Vertical Polarization indicates how much scattering has occurred



Scattered light is polarized in horizontal plane
(in & out of plane of paper.

- Newer work:
  - http://daac.gsfc.nasa.gov/precipitation/ and
  - http://gpm.gsfc.nasa.gov/

GPM (Global Precipitation Mission)

- JAXA/NASA Launched Feb. 27, 2014
- 10-183 GHz Microwave Imager
- DPR: Dual-Frequency Precipitation Radar Ku, Ka (13.6, 35.5 GHz)
-

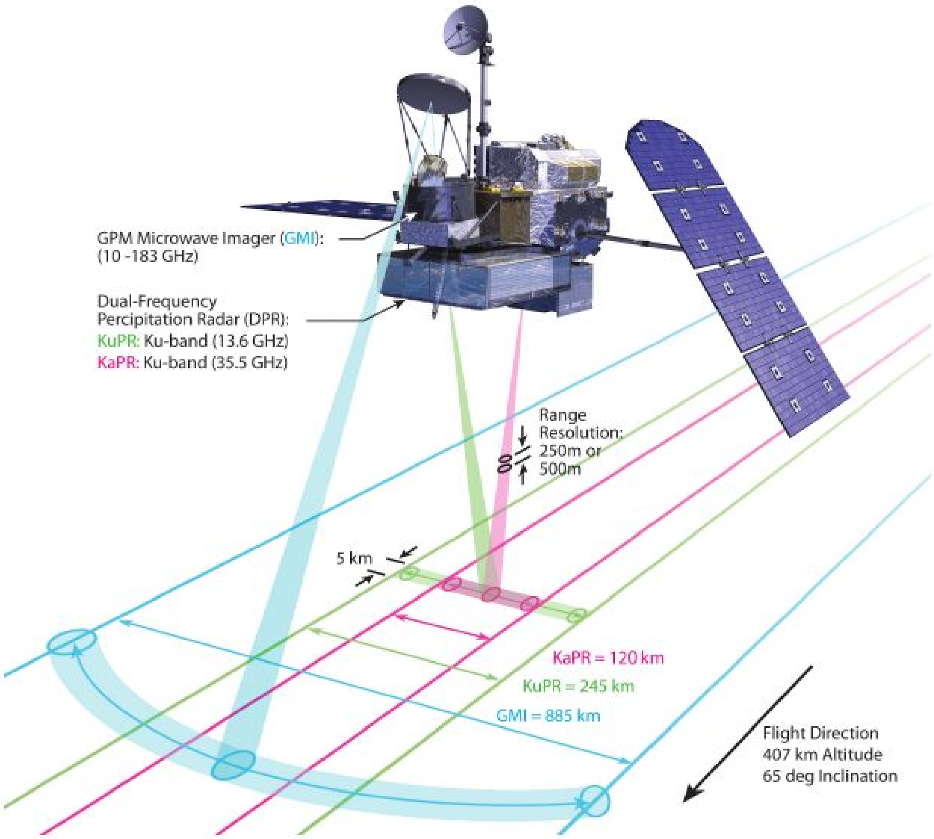
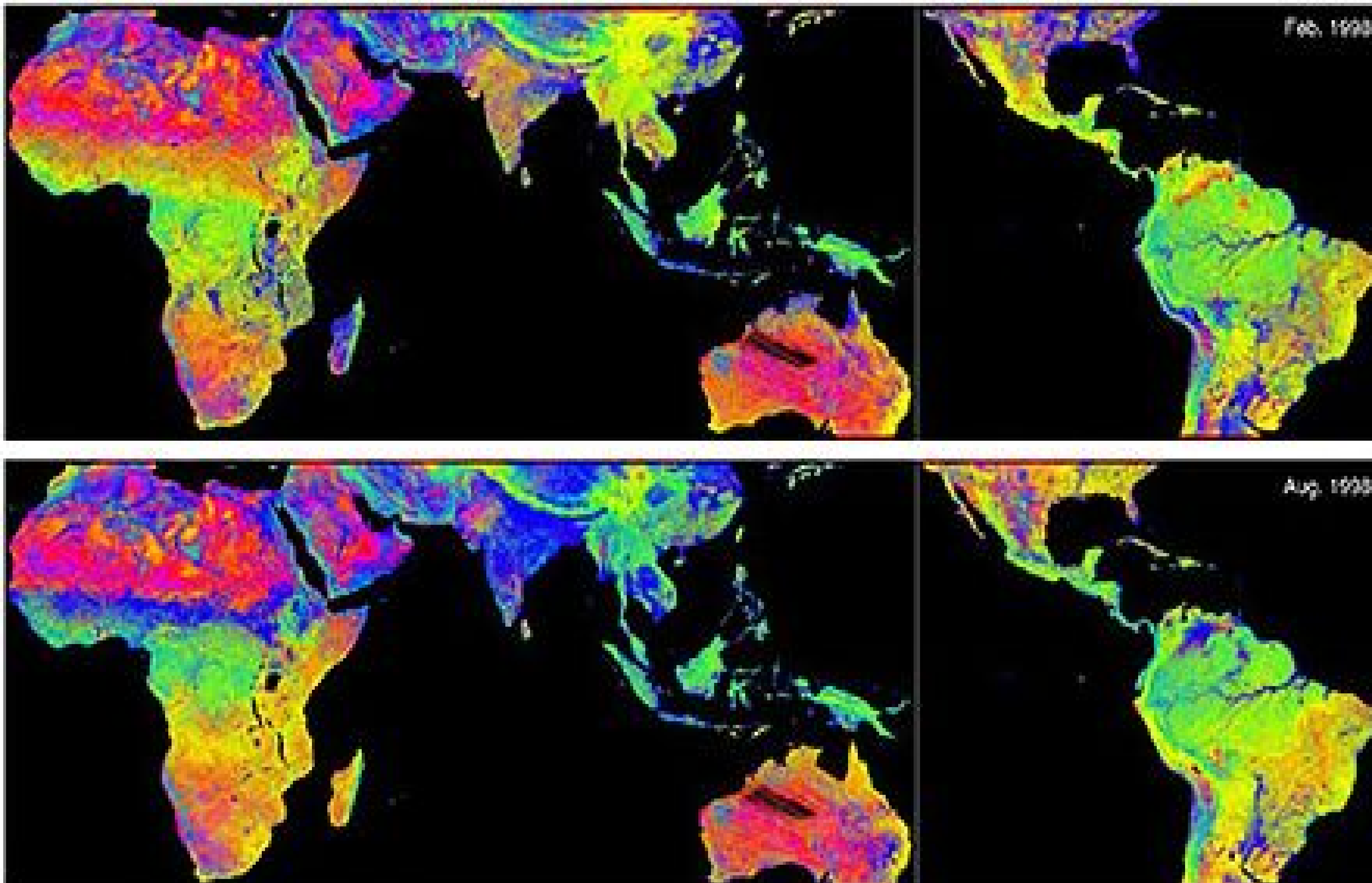


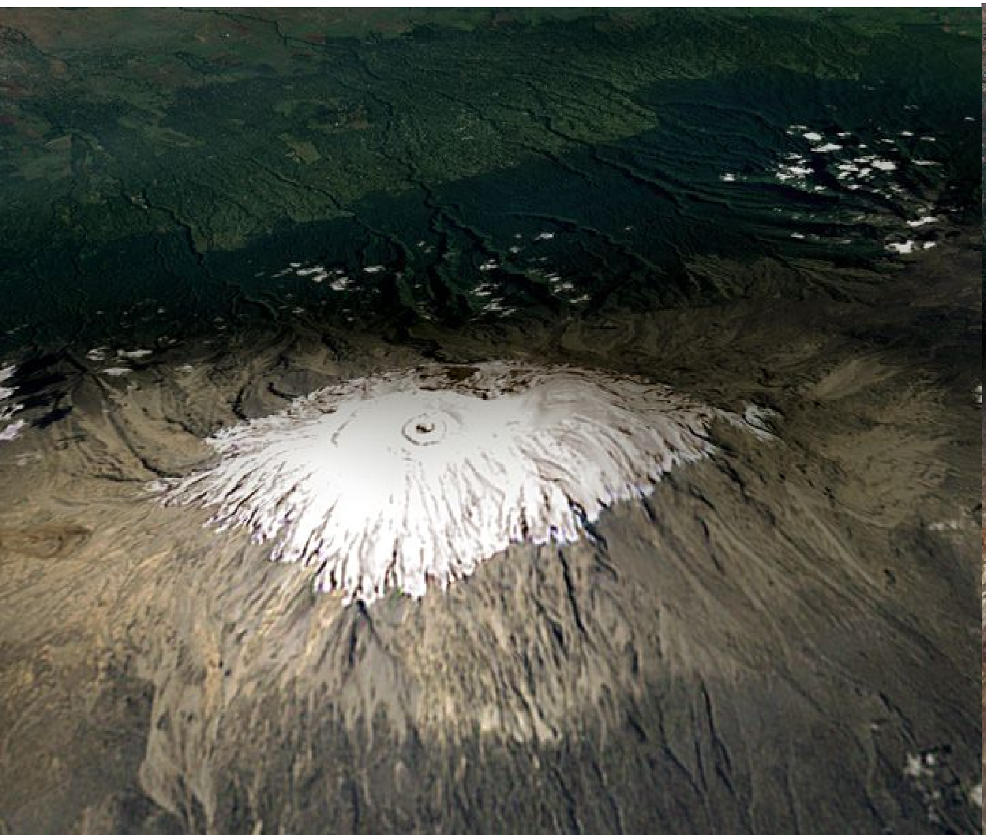
Diagram of swath coverage by GPM sensors

Global Rainfall Estimates (monthly)

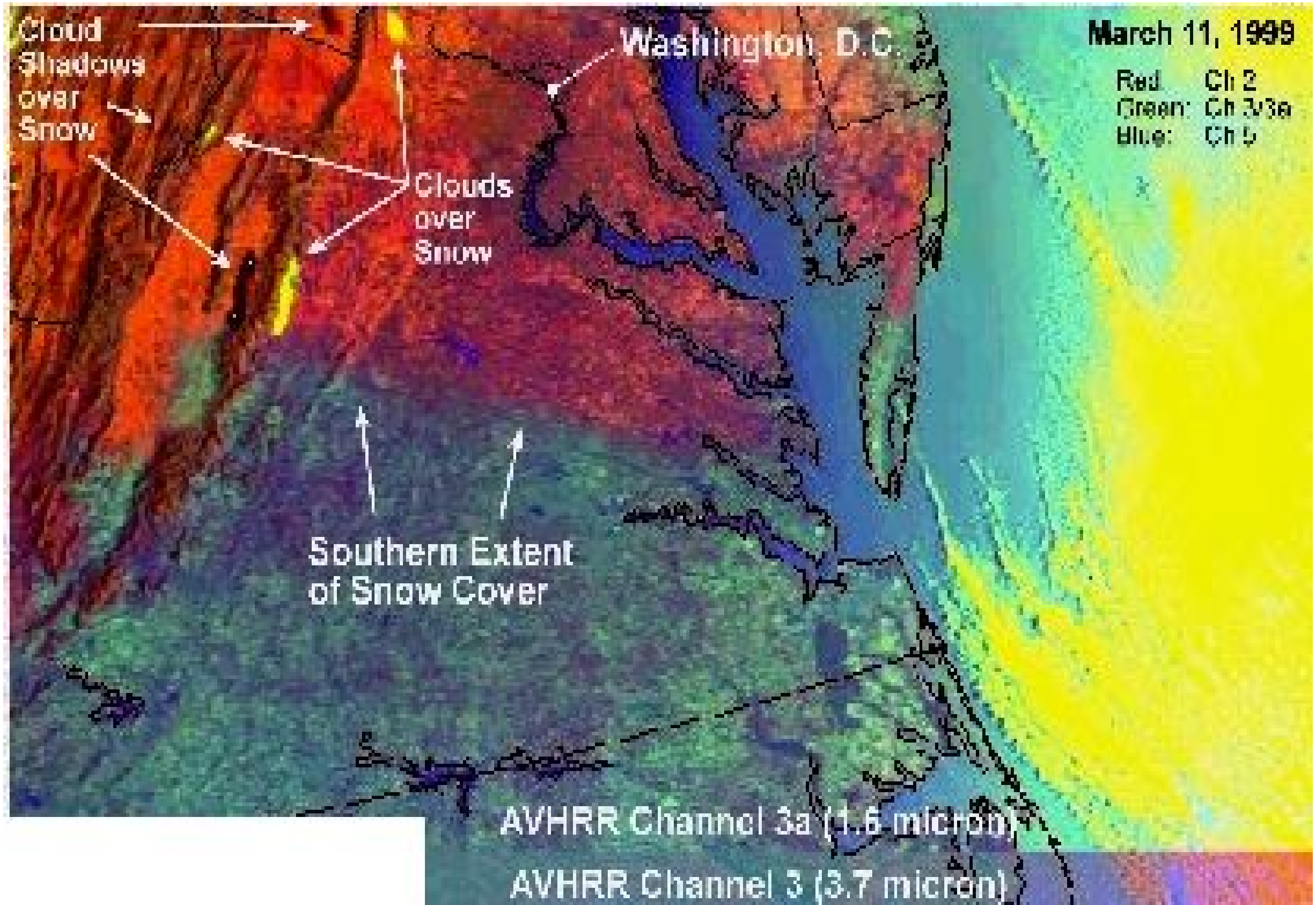


Monitoring snow fields, mountain snow pack and glaciers

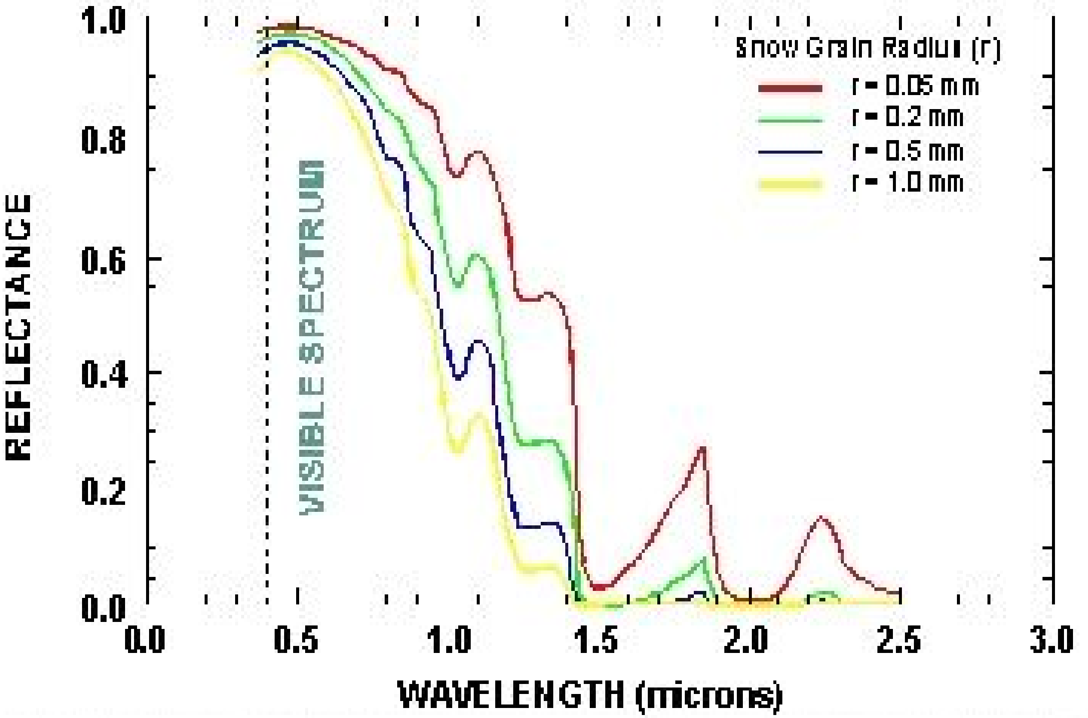
The snow cap of Mount Kilimanjaro may be gone in two decades. The ice fields on Africa's highest mountain shrank by 80 percent in the past century. The snow cap formed some 11,000 years ago. Landsat captured these images of Kilimanjaro February 17, 1993 and February 21, 2000.

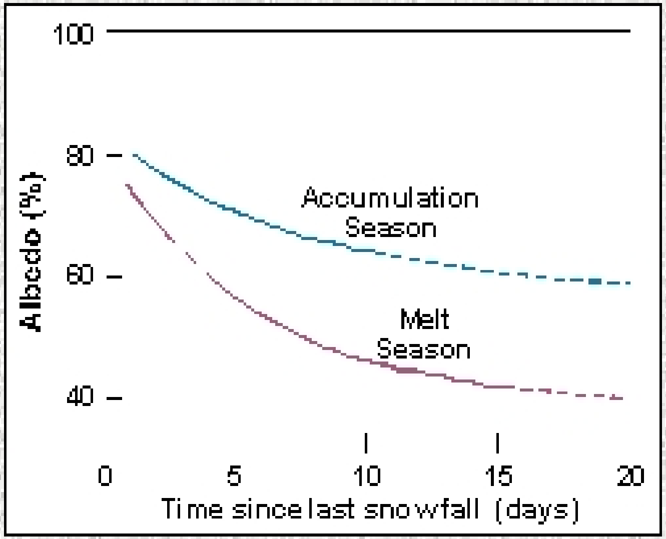


Snowcover from AVHRR image

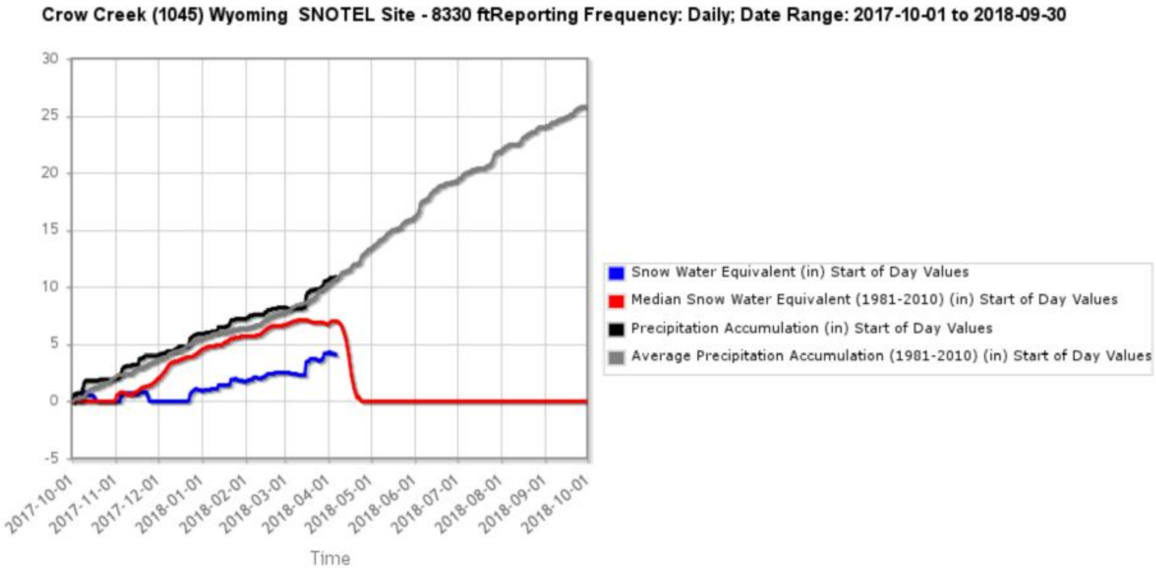


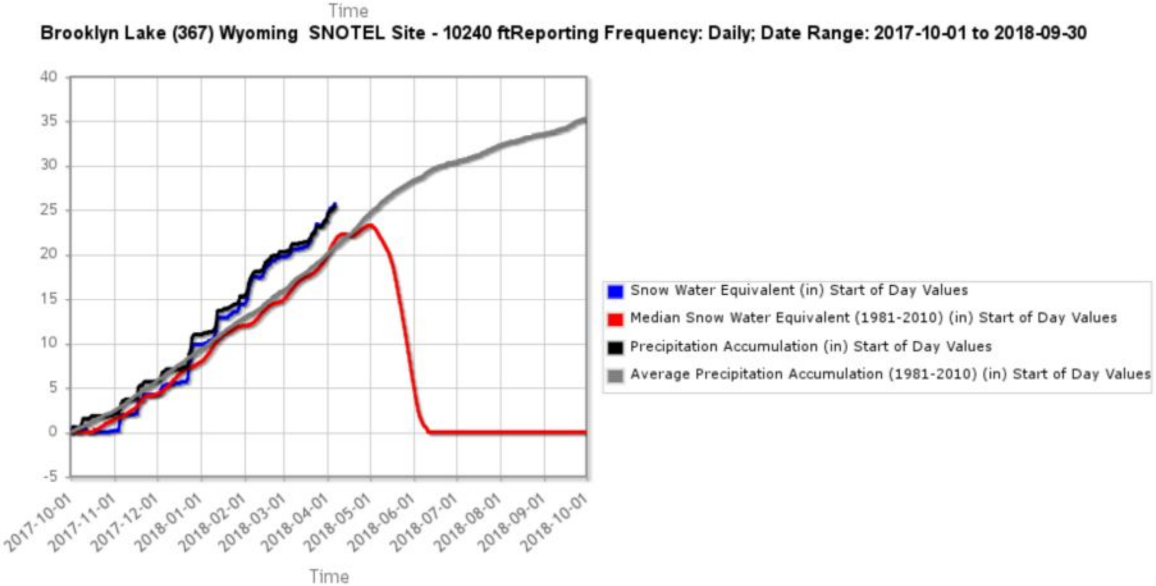
Snowpack and reflectance

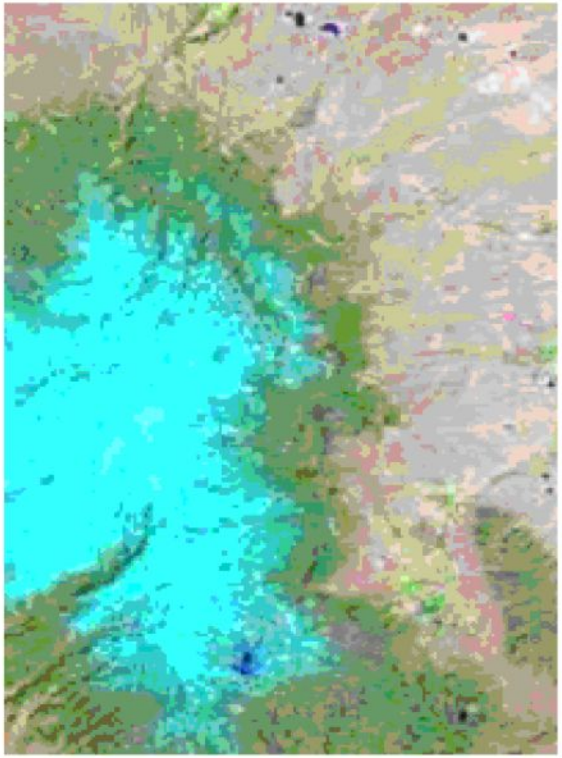




Snow cover measurements & runoff prediction



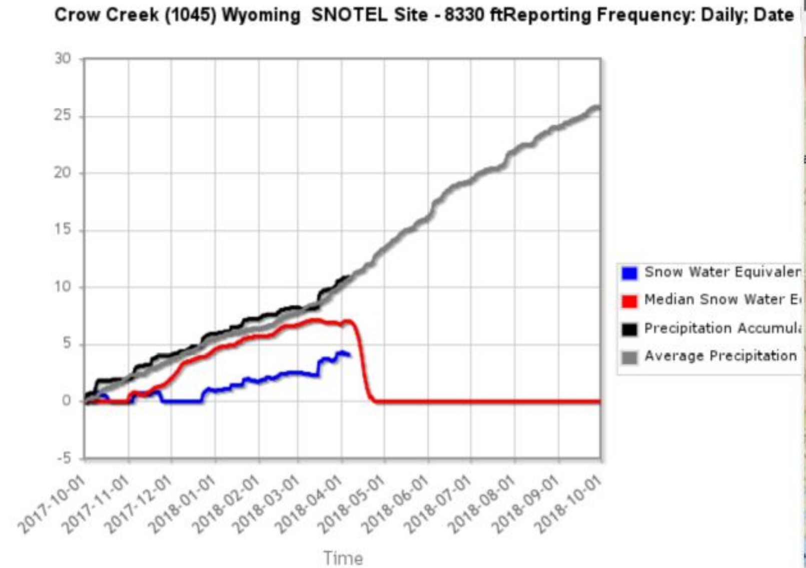


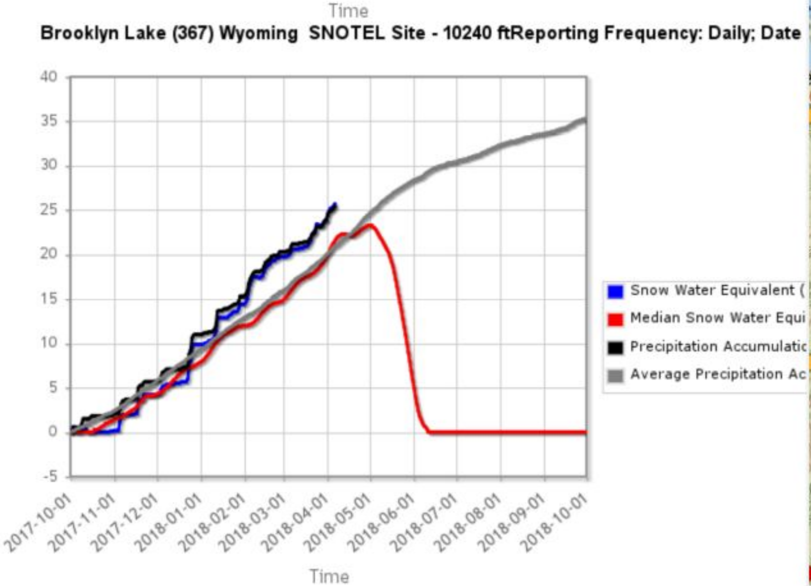


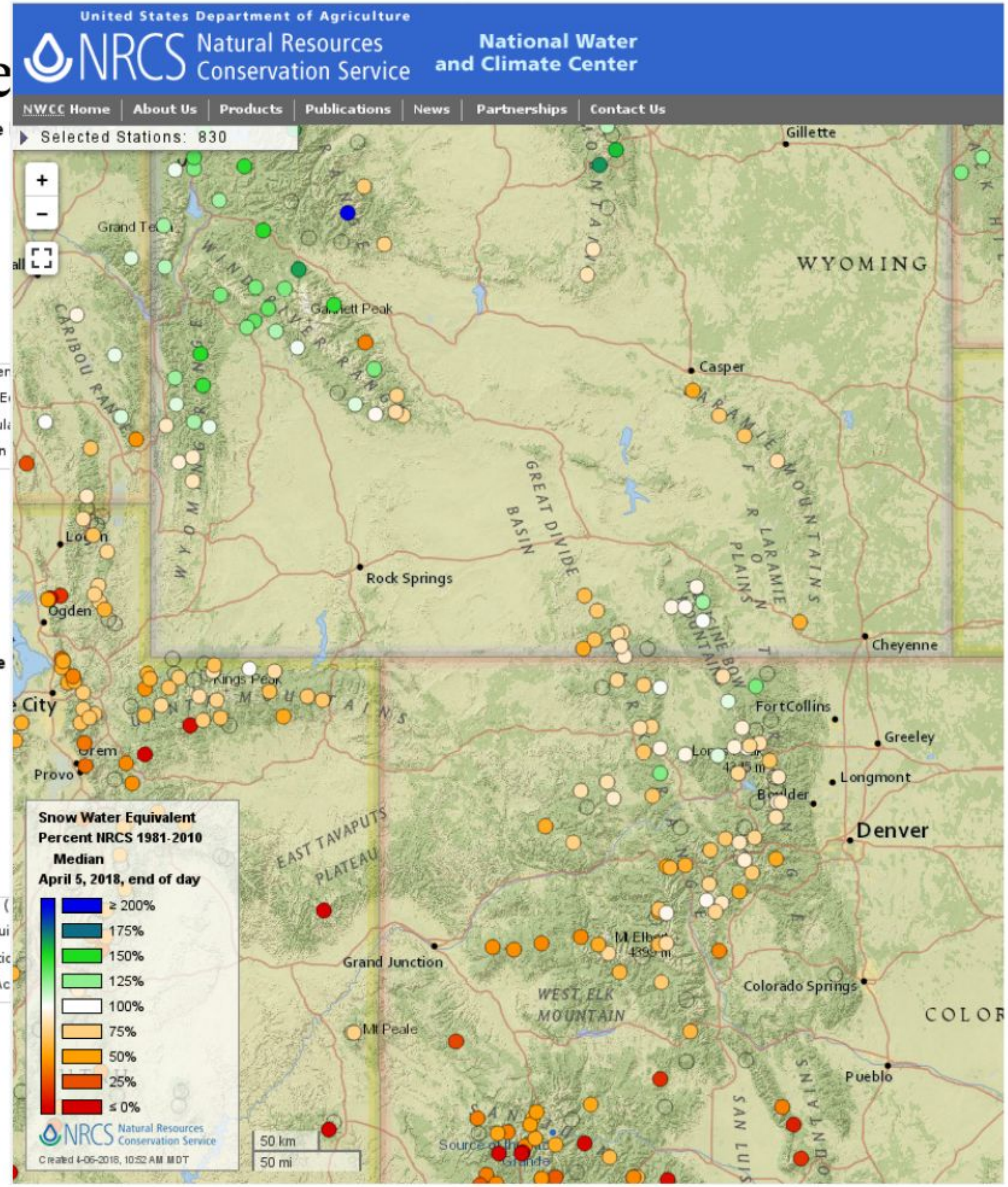
Extend coverage with satellite images

Ground truth from “Snotel”.
https://www.wcc.nrcs.usda.gov/webmap

Snow cover measure

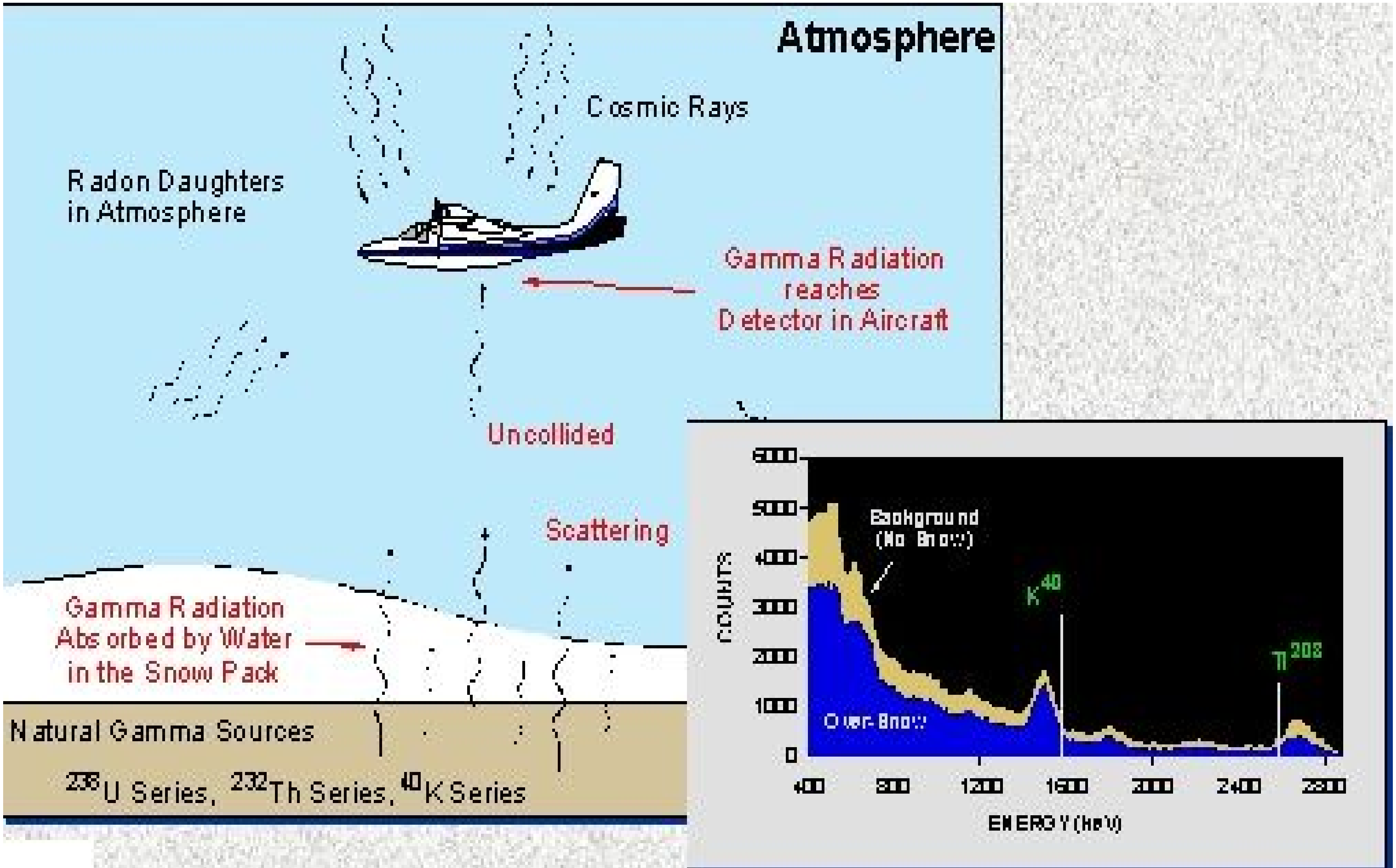






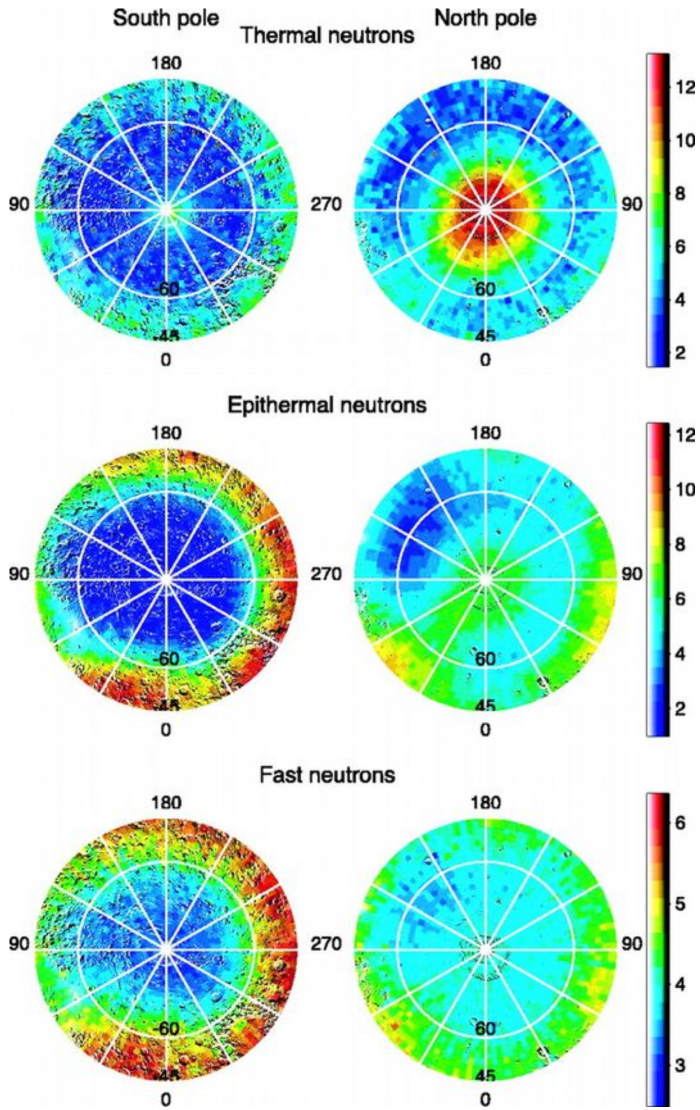
Ground truth from “Snotel”.
https://www.wcc.nrcs.usda.gov/webmap

Gamma Ray Surveys for Snow Water

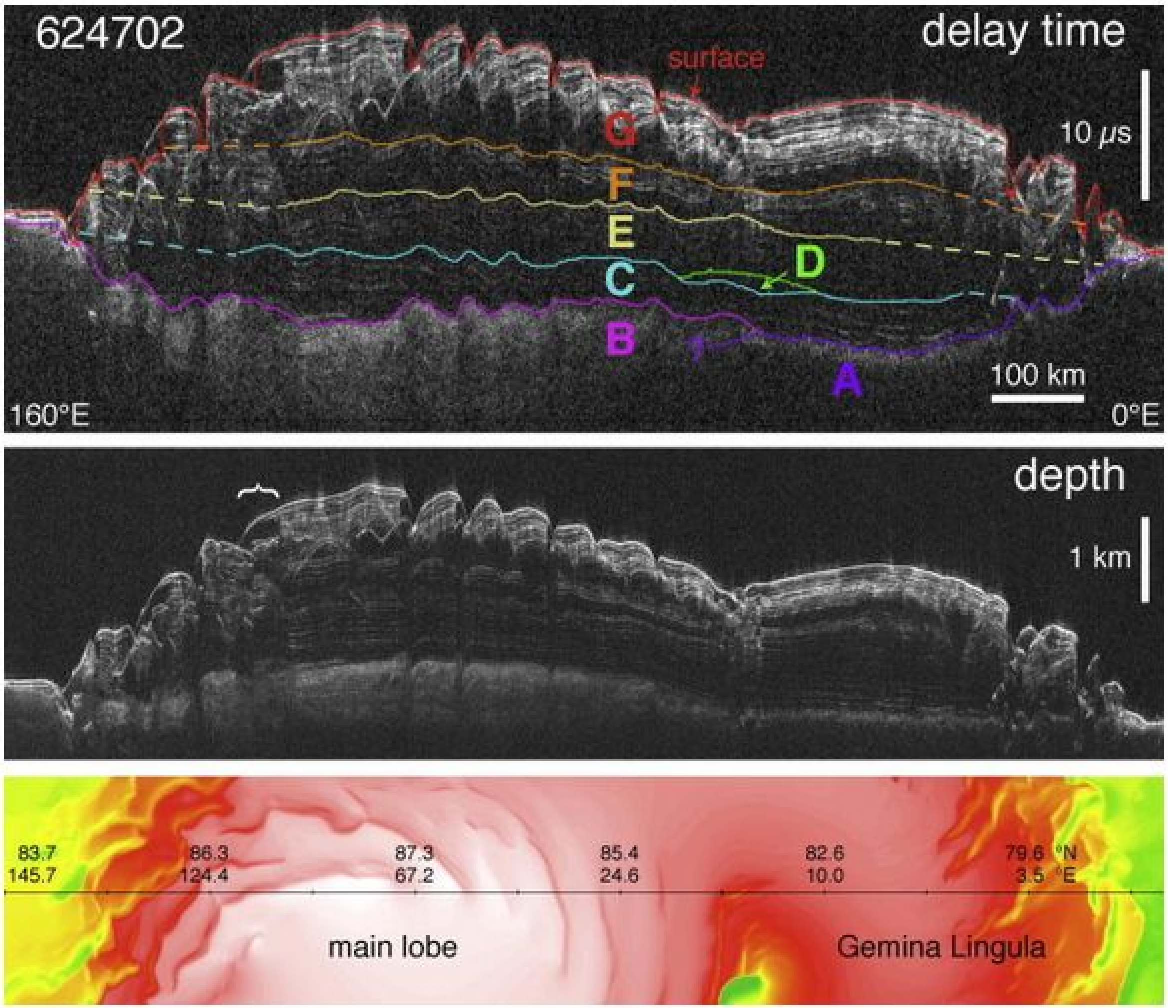


Planetary Ice

- Mars H_2O Inventory -- polar caps, ground ice
- Lunar Polar Ice
- Mercury Polar Ice
-
- Sensing technique:
-
- Polarization effects in radar
-
- Measure amount of neutrons of various speeds
  - Presence of H “moderates” fast neutrons
-



Ground Penetrating Radar



Sharad Ground Penetrating Radar on Mars

from RadarsatTeam

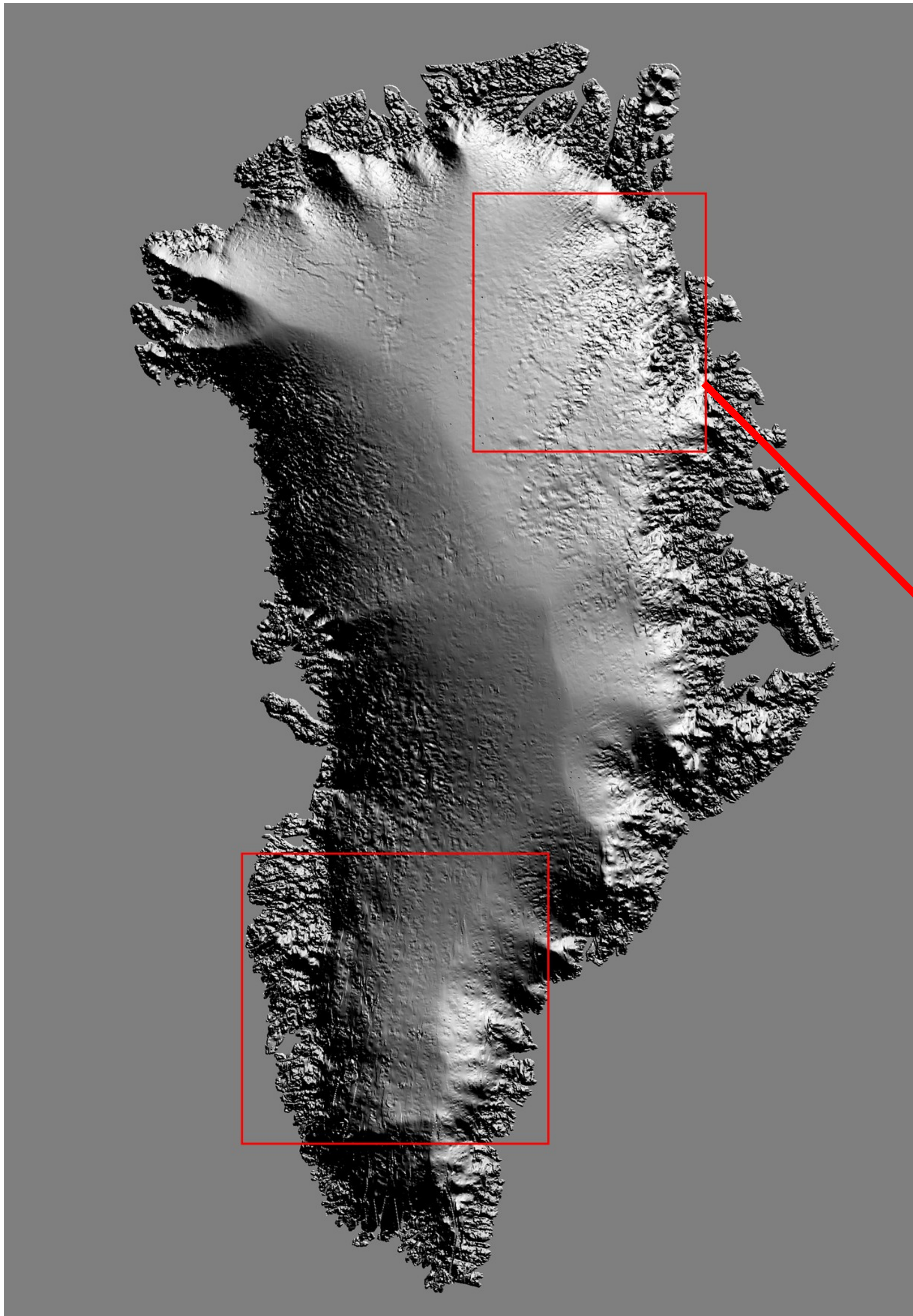
Antarctic Ice and Sea Ice

- Ship information for arctic waters
- Global Change

- Imaging, Laser Altimeter, and Radar data important
  - Radar can observe in cloudy regions
  - Radar can help characterize ice types based on roughness
  - Radar (interferometry) can measure flow rates

- Much of radar data <u>in text</u> is from Seasat
  Oct. 1978 – June 1978

- Newer RadarSat (Canadian satellite) and
  ERS and ENVISAT (European satellites) data available
  - CryoSat 2 launched Spring 2010
  - ENVISAT failed April 2012



Laser Elevation from "IceSat: Ice, Cloud, and Elevation Satellite: Greenland

2003 launch – laser died in October 2009
follow-on satellites should give more coverage

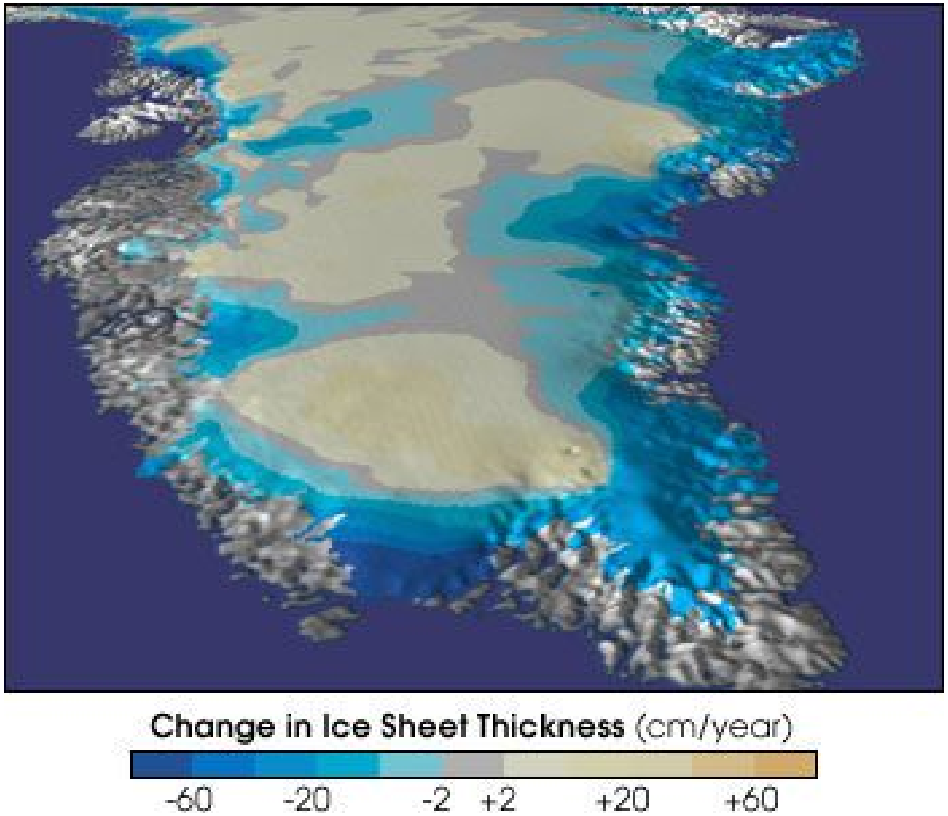
Monitor changing ice thickness

Laser pulses:	40 per second (170m spacing)
Laser spot size:	70 m
Vertical resolution:	5 cm for single pulse
Repeat cycle:	8 days early in mission, 183 days during multiyear phase

Theses images from Korn et al. on-line poster

- from Korn et al. on-line poster

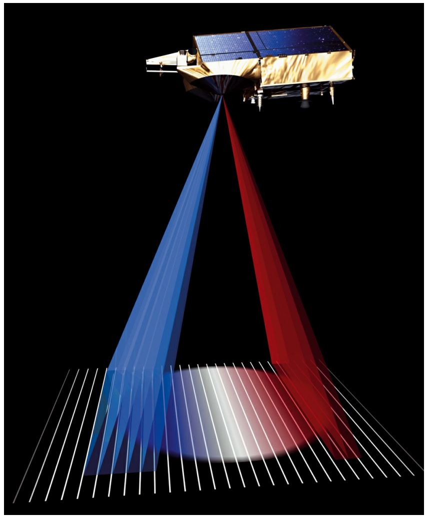
Changes in Greenland Ice thickness

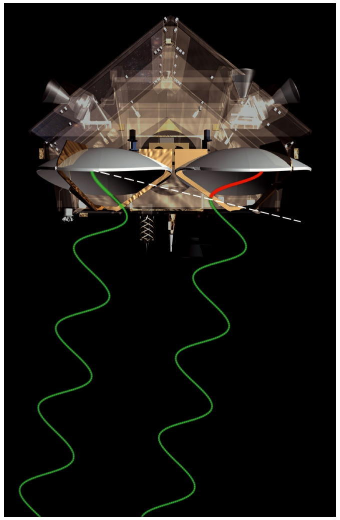


- Previously observed changes in Greenland ice thickness, from various airborn measurements:
- Edges thinning by up to 60 cm/yr
  Center thickening by 10 cm/yr
- Image from IceSat web site
- IceSat data available as DEM's from NSIDC (National Snow and Ice Data Center) at NSIDC.ORG

CryoSat 2 Launched Spring 2010

- European Radar mission to monitor changes in Arctic ice
  - Improved version of techniques tested on earlier "ERS" radar satellite
  - Radar avoids problems with clouds





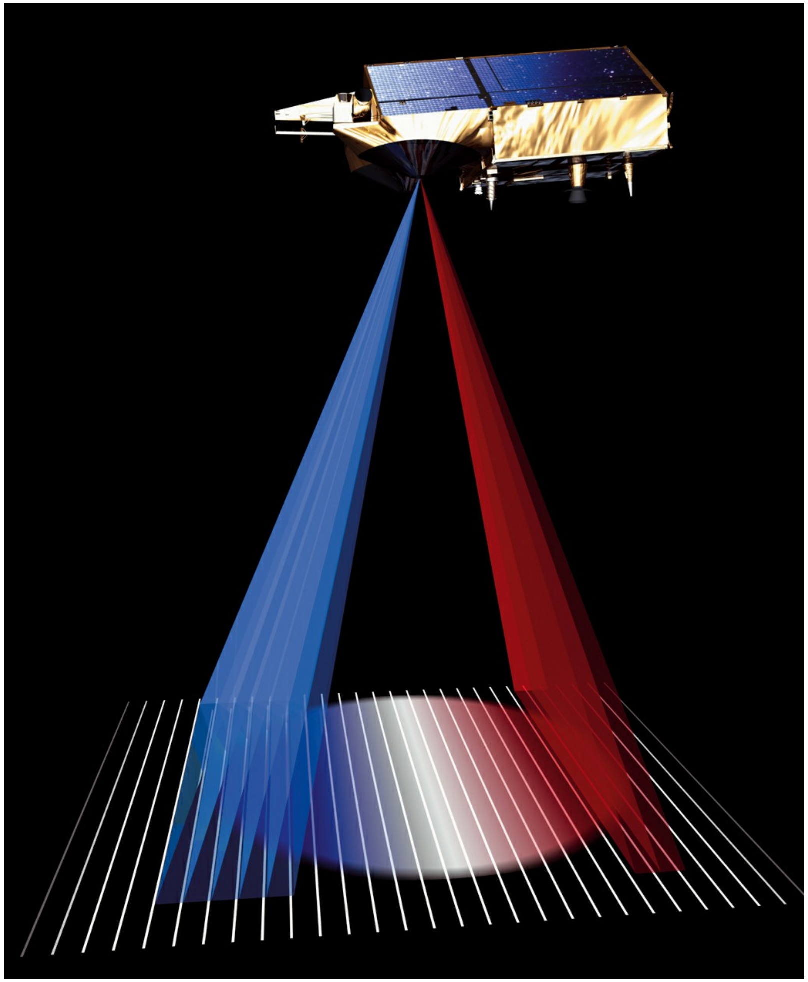
- Original CryoSat lost in launch failure Oct. 2005
  (on converted Russian ICBM)

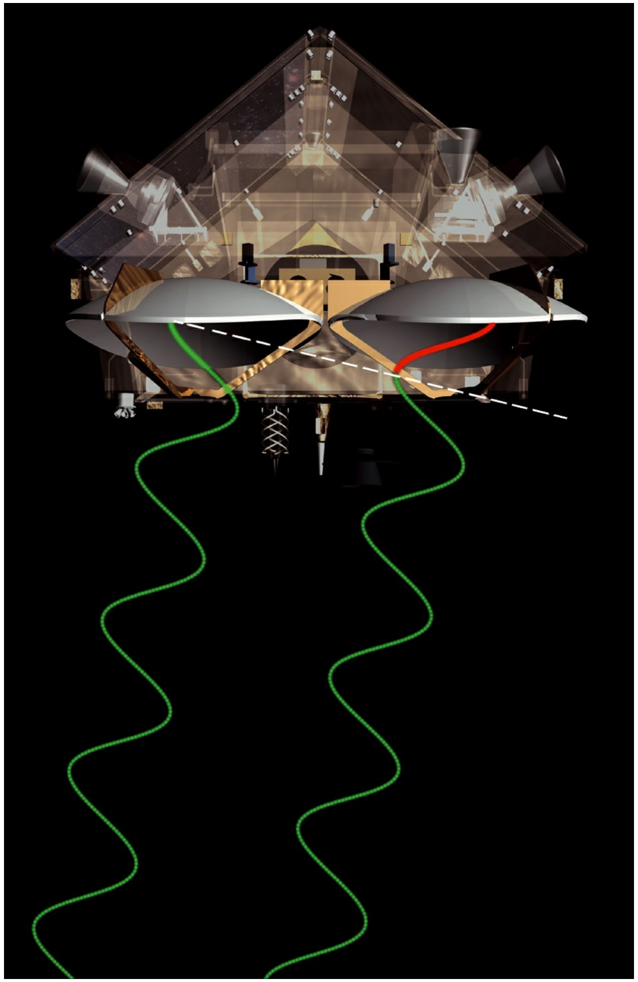
- Orbit
  - High inclination 92°
    (data up to 88° lat.)
  - 700 km altitude
  - NON sun synchronous

- Main instrument = SIRAL: SAR Interferometric Radar Altimeter
  - 250 m resolution along track from SAR
  - Two-antenna interferometry for cross-track resolution
  - Can measure "freeboard" of floating ice as well as mapping location
  - Can monitor changes in thickness of grounded ice sheets

- Has other radio receivers and laser retroreflectors so satellite position can be determined very accurately (since you want absolute elevation of ice)

CryoSat 2 Doppler SAR + Interferometry



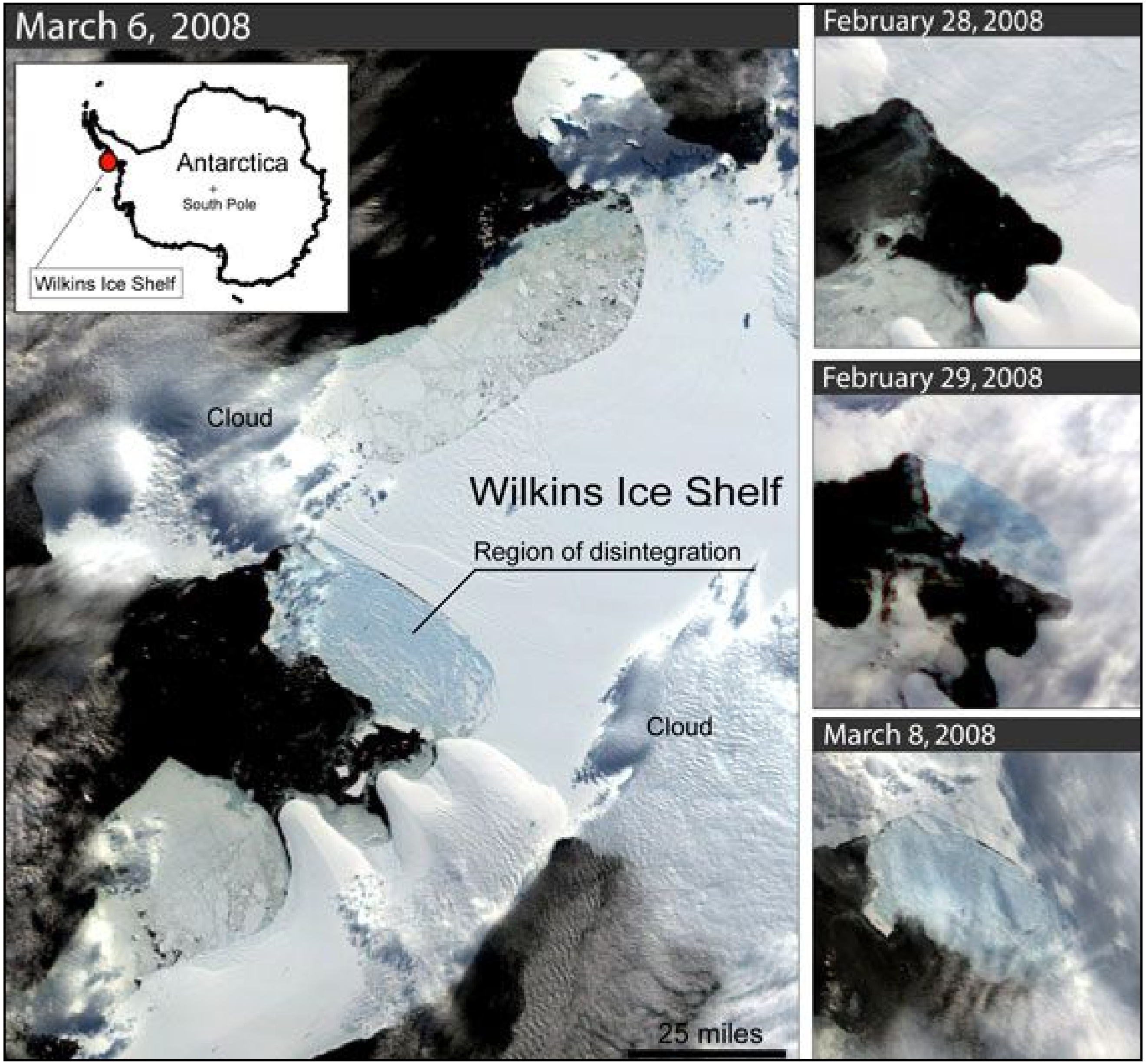


- Main instrument = SIRAL: SAR Interferometric Radar Altimeter
  - 250 m resolution along track from SAR
  - Two-antenna interferometry for cross-track resolution

CryoSat 2

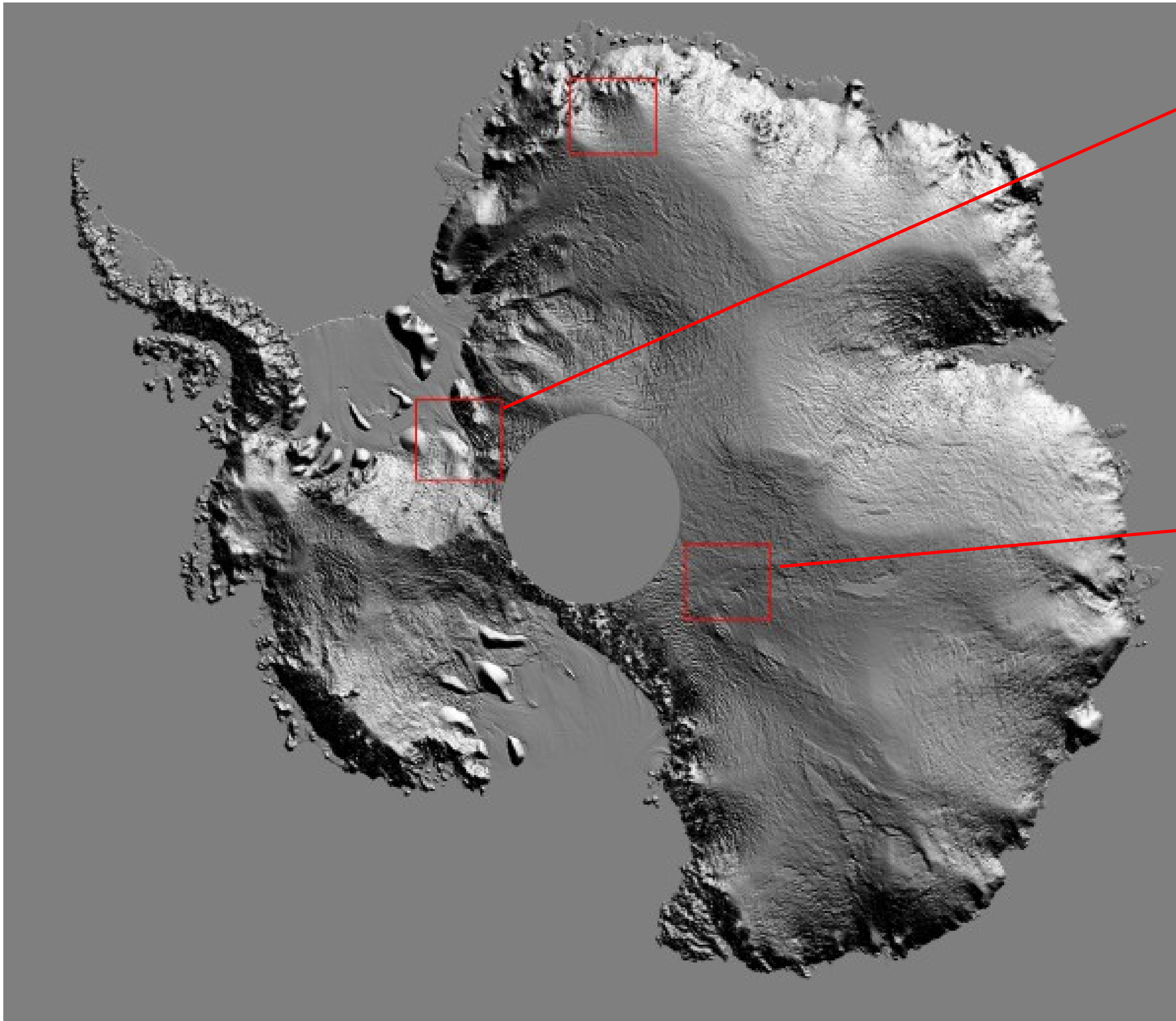
- Primary Goals:
  - Determine regional trends in Arctic perennial sea-ice thickness and mass;
  - Determine the contribution that the Antarctic and Greenland ice sheets are making to mean global rise is sea level.
- Secondary Goals
  - Observe the seasonal cycle and inter-annual variability of Arctic and Antarctic sea-ice mass and thickness;
  - Observe the variation in the thickness of Earth's ice caps and glaciers.
- Measurement goals:
  - At least 3 years of measurements
  - Arctic Sea Ice 1.6 cm/yr
  - Regional Scale Ice Sheets 3.3 cm/yr
  - Antarctic Ice Sheets 0.17 cm/yr

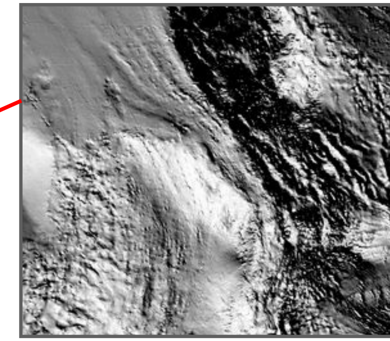
Wilkins Ice Shelf Collapse: MODIS Images



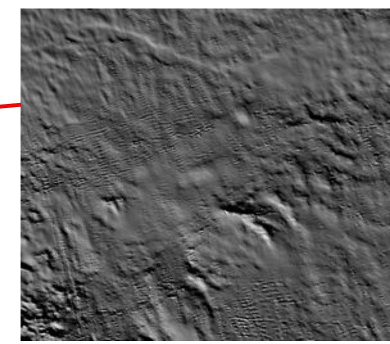
IceSat: Antarctic Data

From Korn et al. on-line poster



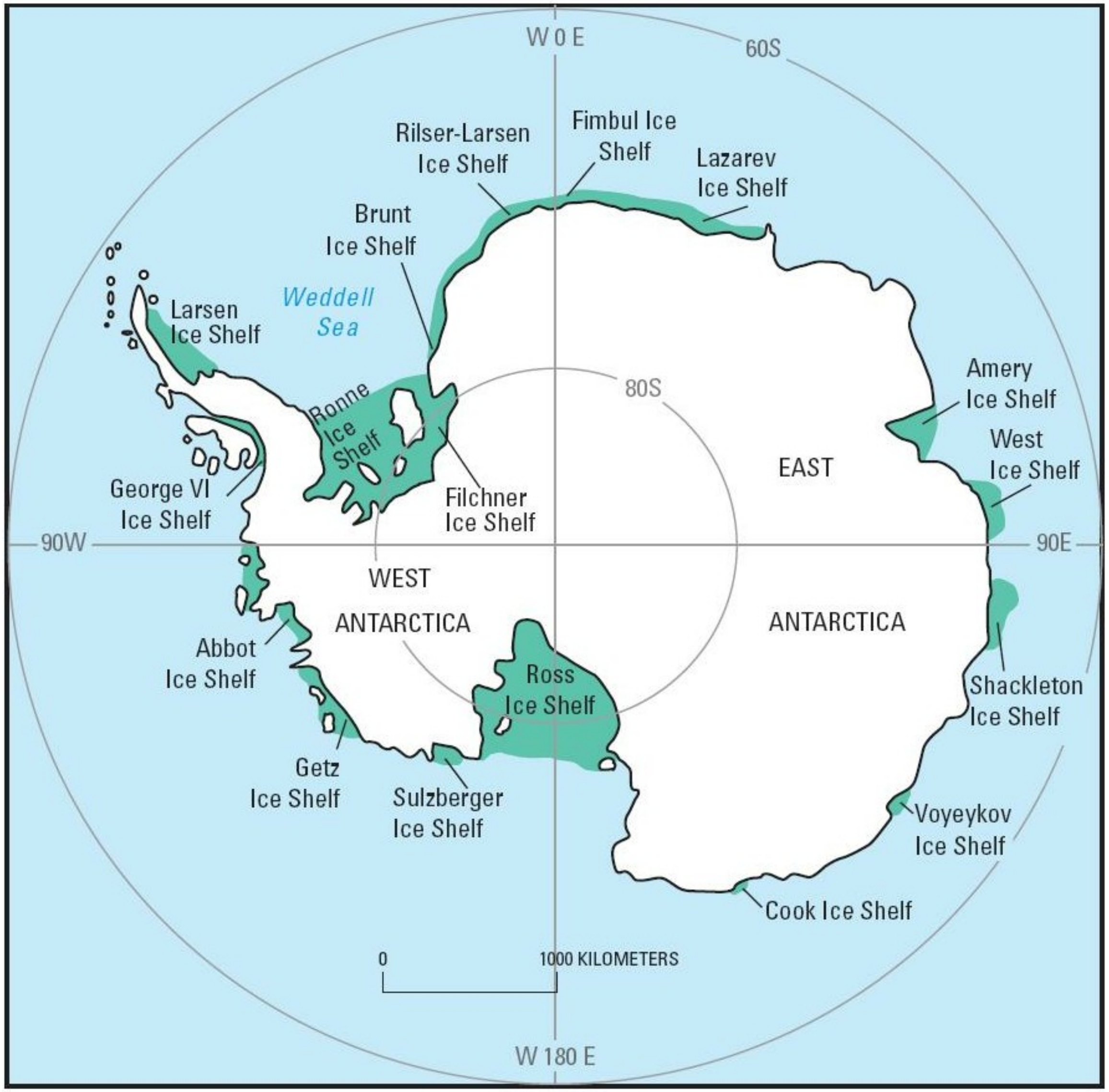


Foundation Ice Stream



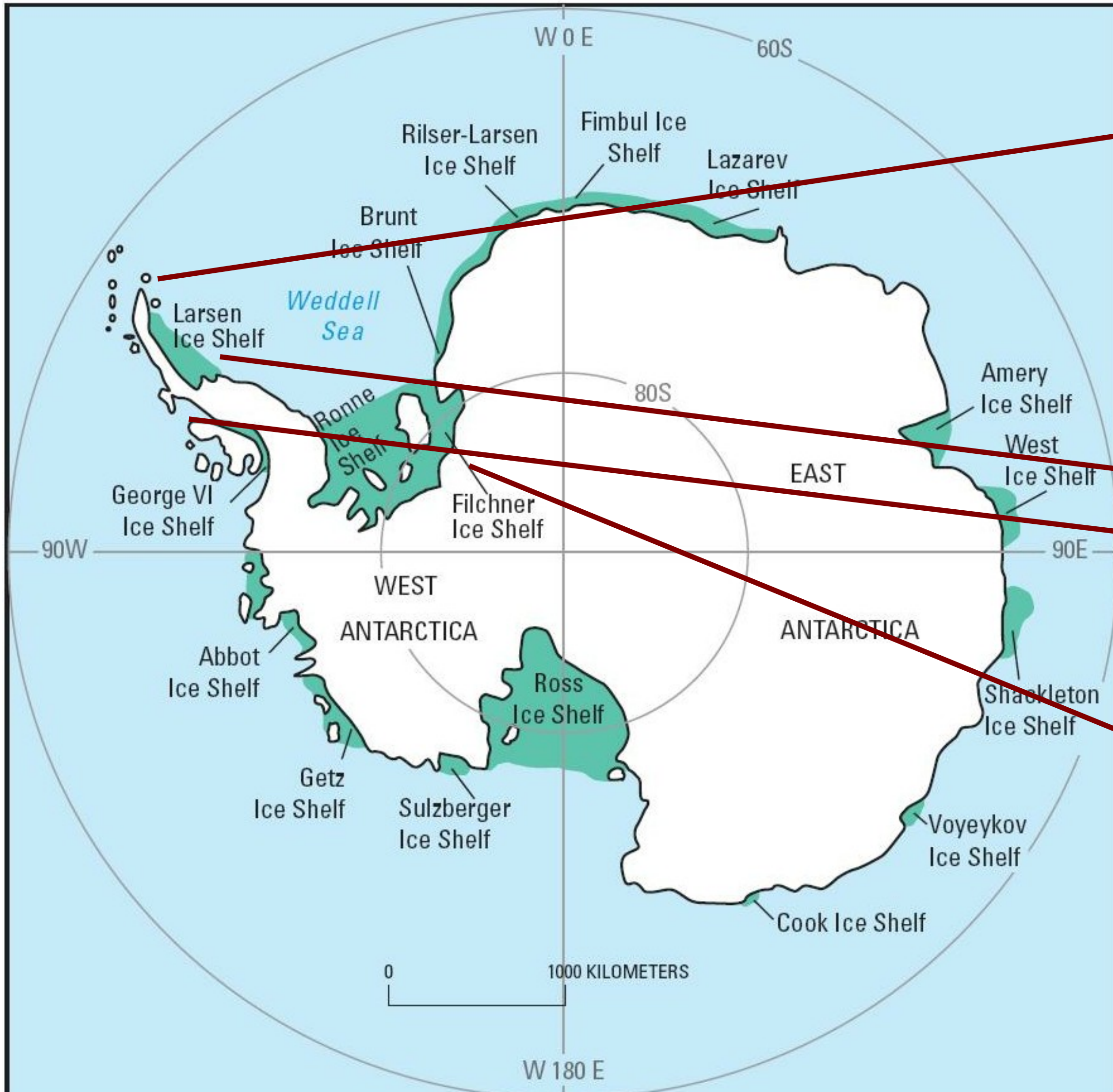
Megadunes

Antarctic Geography, Summary



- Ice <u>shelves</u> floating, their melting doesn't raise sea level
  - but may enable on-land ice <u>sheets</u> to flow to oceans more easily
  - symptom of climate change
- W Antarctic Ice Sheet: 6 m of sea level rise
- E Antarctic Ice Sheet: 73 m of sea level rise
- (Greenland ~ 7 m)
- USGS assembling archive of Landsat MSS and other data back to early 1970's

Antarctic Geography, Summary

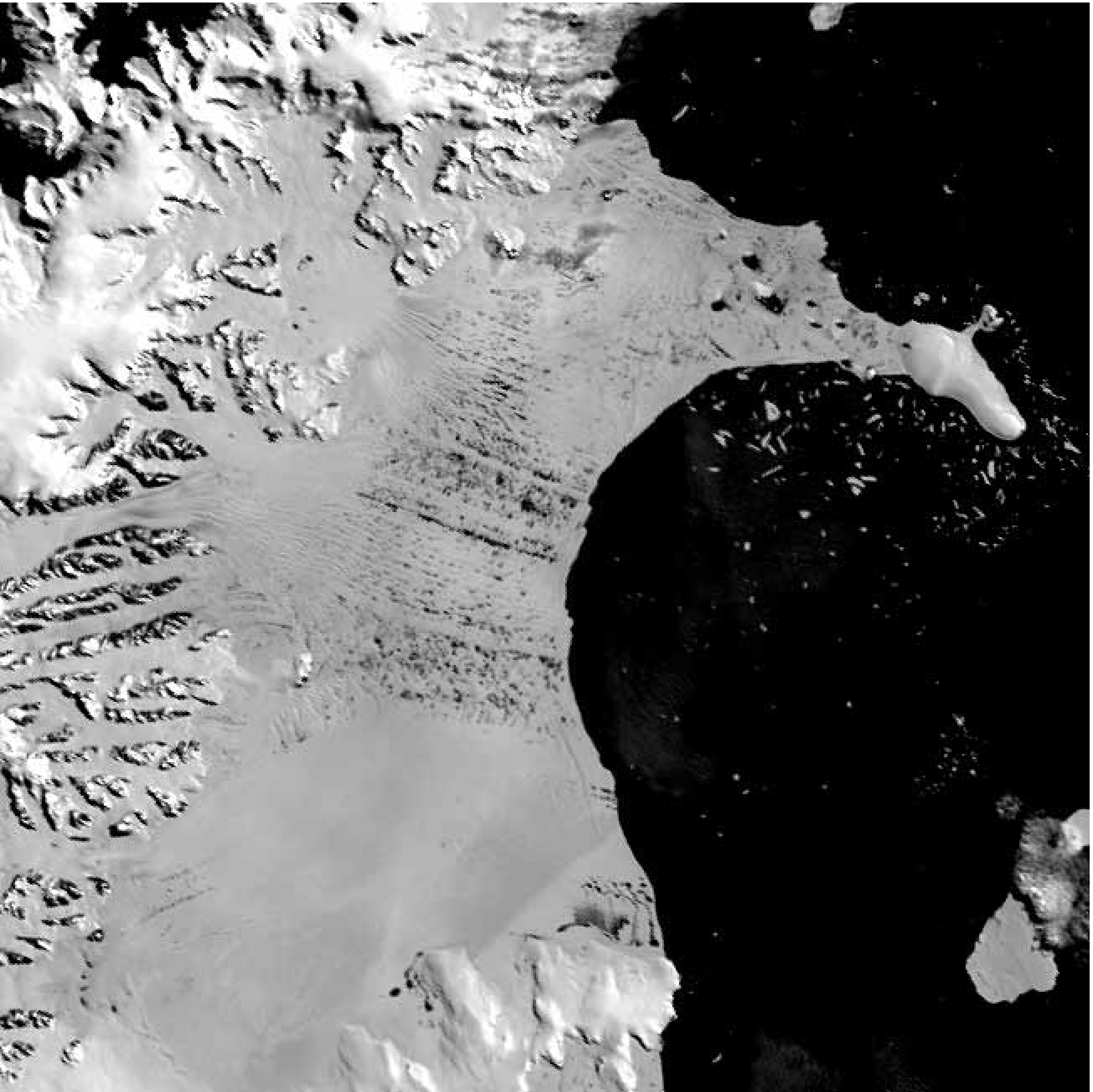


- Largest warming along Antarctic Peninsula:
- 0.5°C / decade for last 5 decades

- Several ice shelve there have collapsed
  - Larsen Ice shelf
  - Wilkens Ice shelf

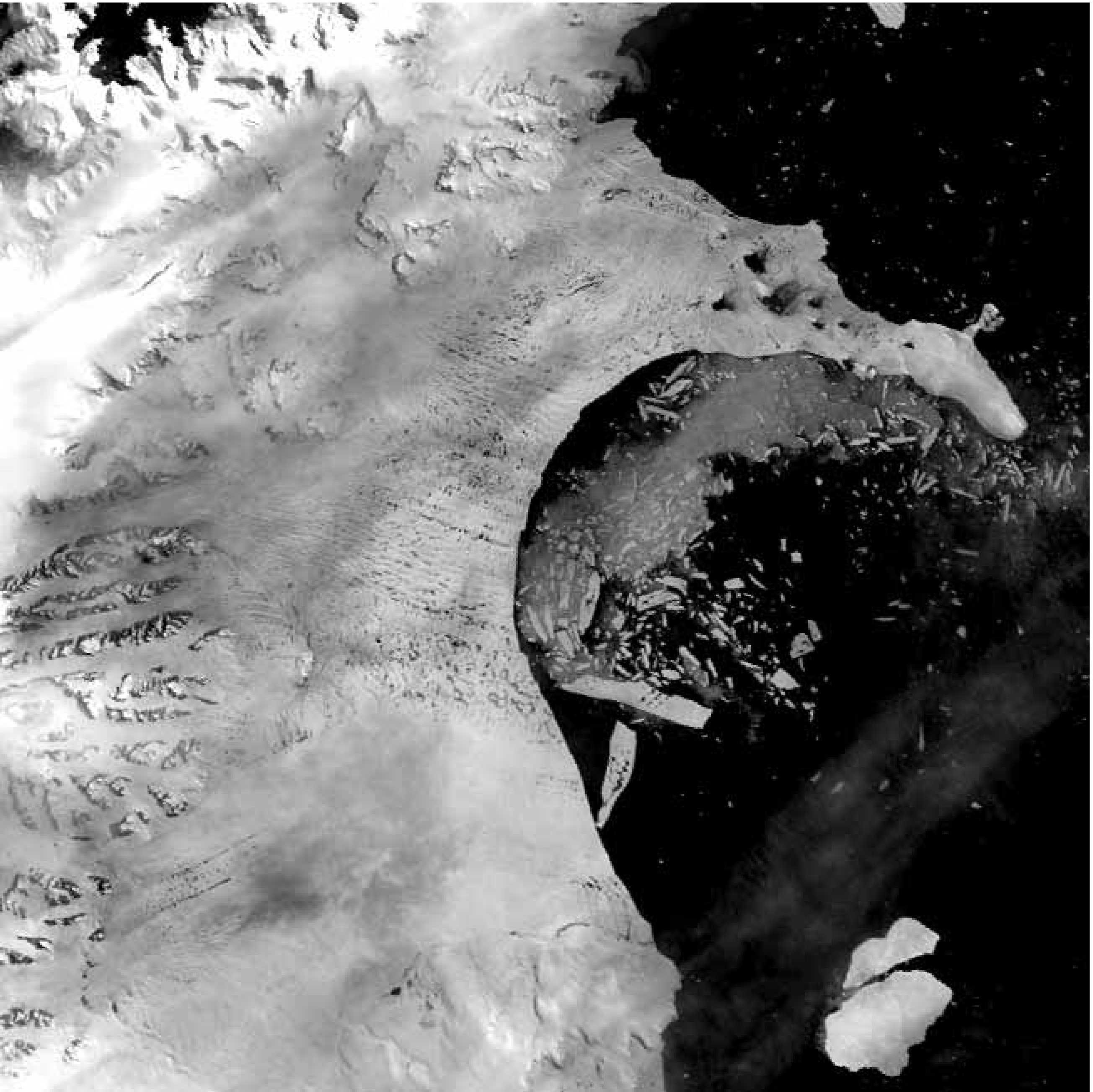
- Other locations we'll discuss:
  - Filchner Ice Shelf

Larsen B Ice Shelf Break-up: 2002 event



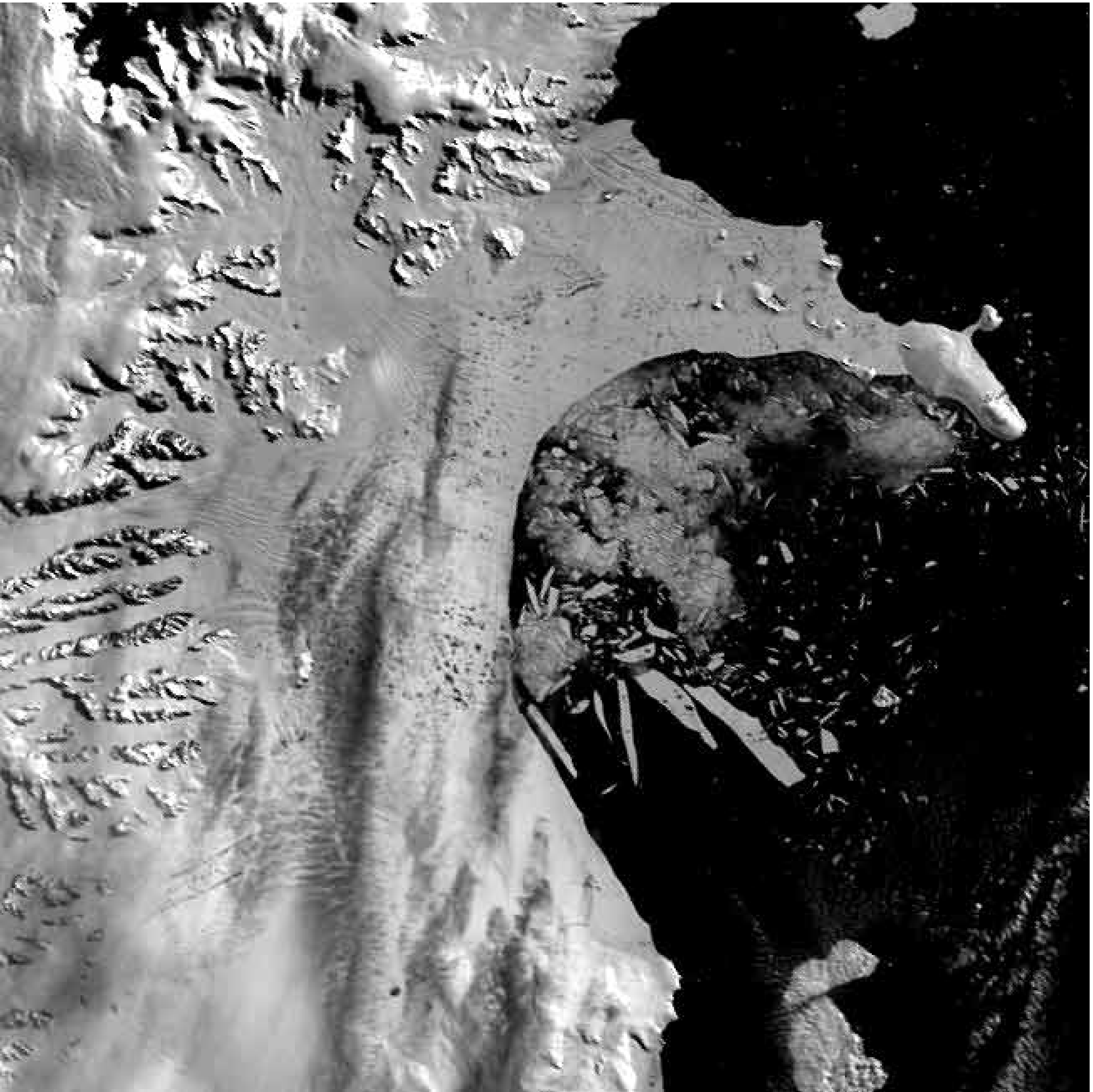
- Break-up events in late 1990's and 2002
- Recent studies of seafloor (drop stones) suggests such break-ups unusual
- Terra MODIS data from NSIDC
- 2002_01_31

Larsen B Ice Shelf Break-up: 2002 event



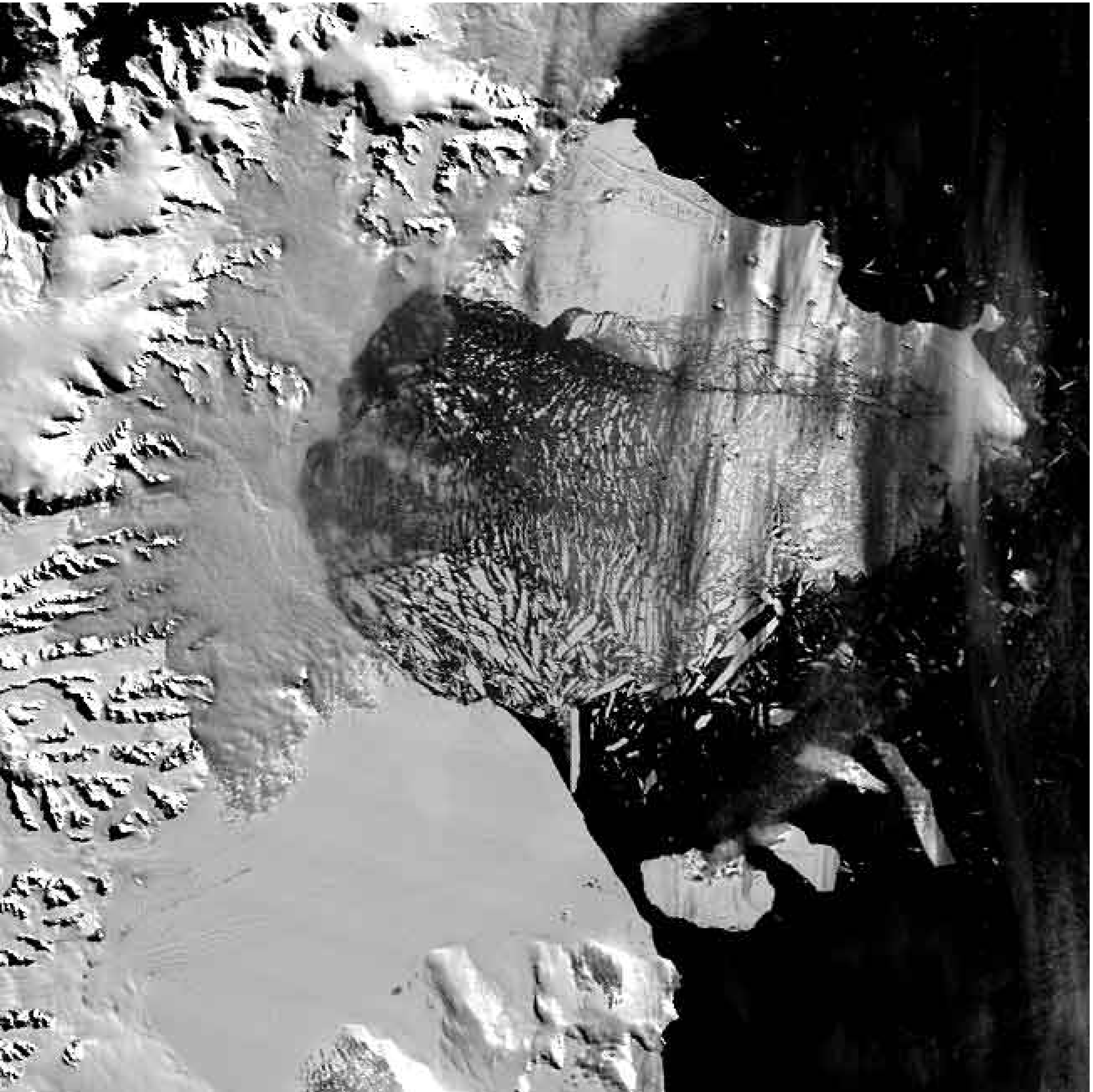
- Break-up events in late 1990's and 2002
- Recent studies of seafloor (drop stones) suggests such break-ups unusual
- Terra MODIS data from NSIDC
- 2002_02_17
- 790 km^2 lost

Larsen B Ice Shelf Break-up: 2002 event



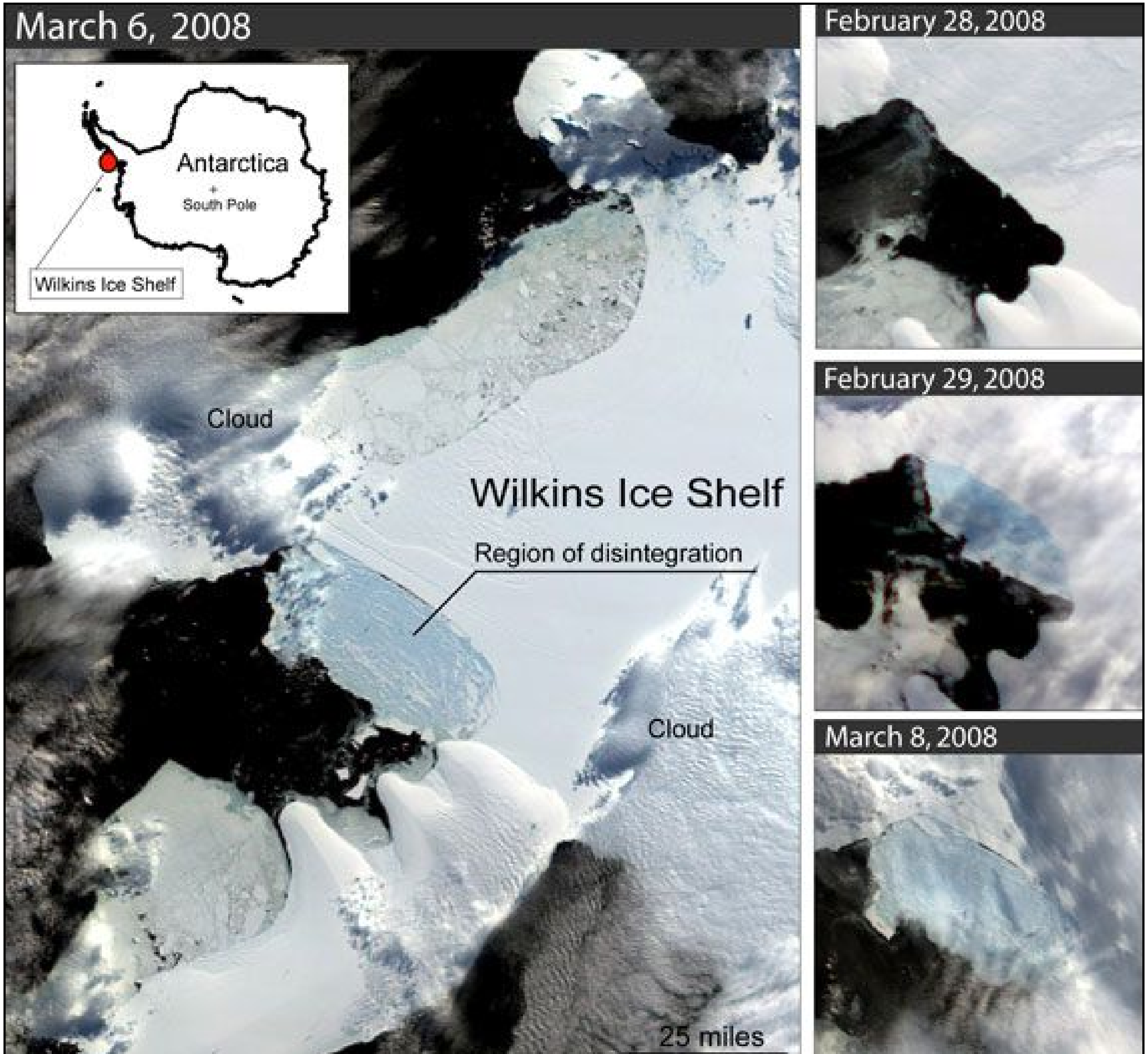
- Break-up events in late 1990's and 2002
- Recent studies of seafloor (drop stones) suggests such break-ups unusual
- Terra MODIS data from NSIDC
- 2002_02_23
- 1960 km^2 lost

Larsen B Ice Shelf Break-up: 2002 event



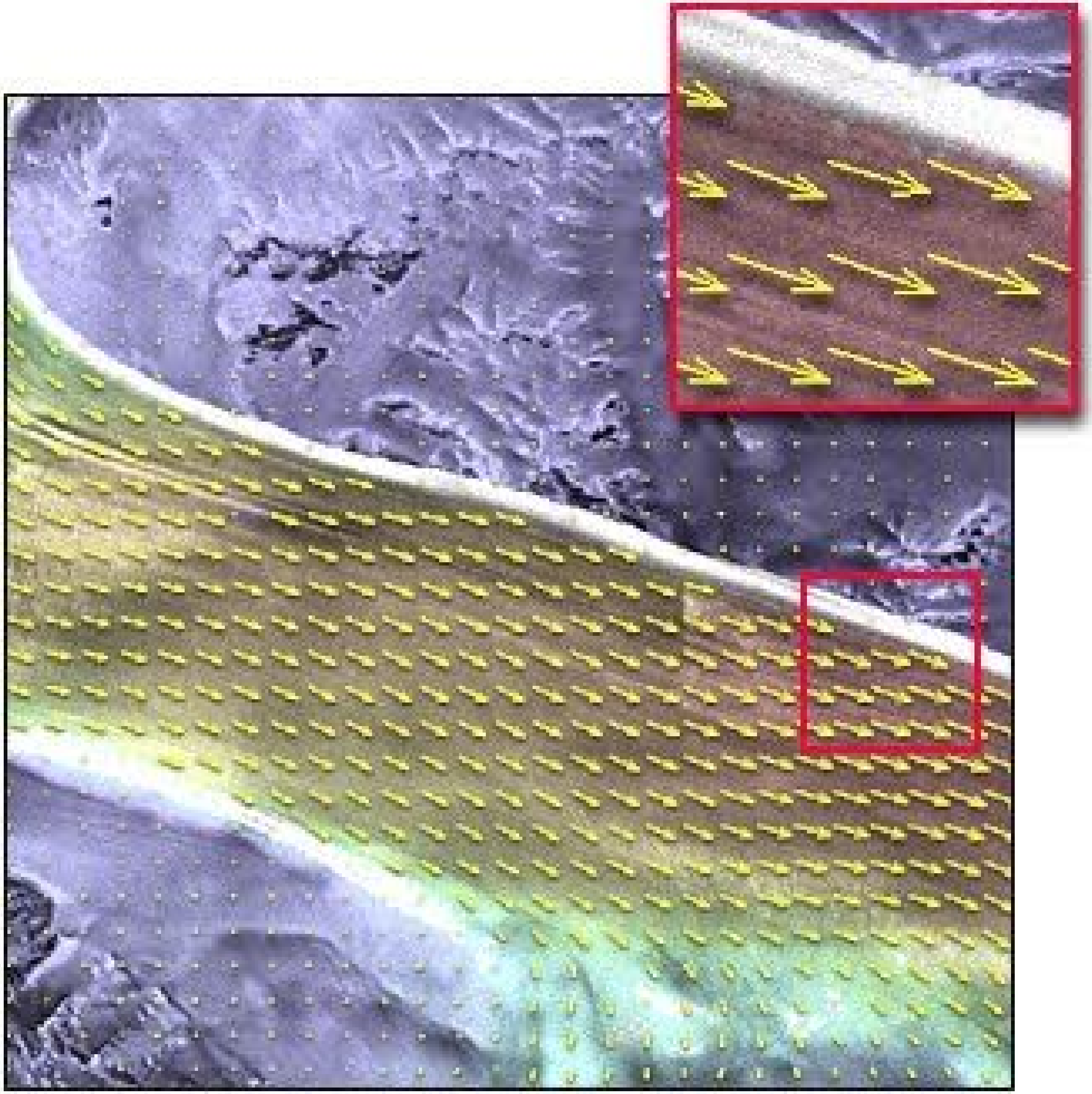
- Break-up events in late 1990's and 2002
- Recent studies of seafloor (drop stones) suggests such break-ups unusual
- Terra MODIS data from NSIDC
- 2002_03_05
- 525 km^2 lost

Wilkins Ice Shelf Collapse



- MODIS Images
- Blue = deep glacial ice
- 41 x 2.5 km iceberg separated
- Triggered 405 km^2 collapse
- 13680 km^2 region probably about to go

RadarSat (1) Observations of Glacier Flow



from RadarsatTeam

- Radarsat (1) <u>interferometric</u> measurements of glacier movement over 24 days
- 100x100 km Recovery Glacier, drains to Filchner Ice Shelf
- Speed color coded: slow → fast
  blue, green, yellow, red
- Fastest measured rates are 340 m/yr
- ~ 1 km/yr at end of glacier where interferometry fails