Satellite Remote Sensing - Introduction

Seasat 1978

- **definition for this class**
- **three essentials**
- **examples**
- **notes on human perception and display of information**

NUCLEAR WEAPONS > SPACE SECURITY

UCS Satellite Database

In-depth details on the 1,738 satellites currently orbiting Earth.

Satellite Database Downloads *(includes launches through 8/31/17)*

- Database (Excel format)
- Database (text format)
- Database, official names only (Excel format)
- Database, official names only (text format)

Already a database user? We'd love to hear your thoughts.

Assembled by experts at the Union of Concerned Scientists (UCS), the Satellite Database is a listing of the more than 1000 operational satellites currently in orbit around Earth.

Our intent in producing the database is to create a research tool for specialists and non-specialists alike by collecting open-source information on operational satellites and presenting it in a format that can be easily manipulated for research and analysis.

It is available as both a downloadable Excel file and in a tab-delimited text format. A version is also provided in which the "Name" column contains only the official name of the satellite in the case of government and military satellites, and the most commonly used name in the case of commercial and civil satellites.

Resources:

- Changes to the database (includes additions and deletions) (pdf)
- Quick guide to using the database (pdf)
- User's manual (pdf)
- Common misconceptions (pdf)

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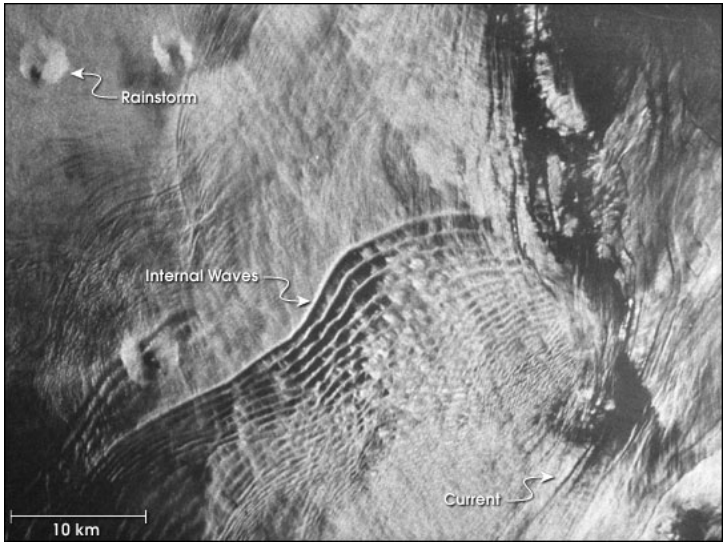
Seasat 1978

Satellite Quick Facts *(includes launches through 8/31/17)*			
Total number of operating satellites: 1,738			
United States: 803	Russia: 142	China: 204	Other: 589
LEO: 1,071	MEO: 97	Elliptical: 39	GEO: 531
Total number of US satellites: 803			
Civil: 18	Commercial: 476	Government: 150	Military: 159

http://www.ucsusa.org/nuclear_weapons_and_global_security/solutions/space-weapons/ucs-satellite-database.html

Definition for this class



SAR Image - Seasat

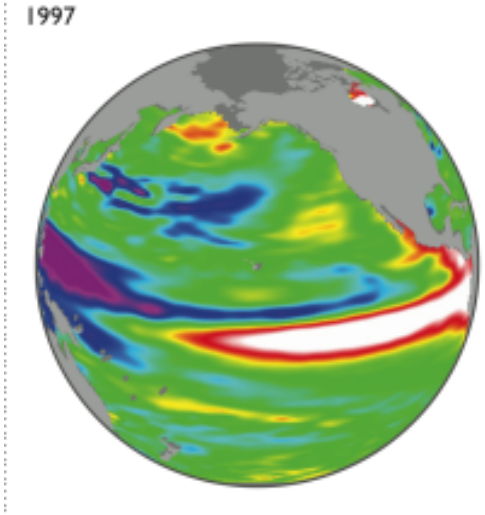
- **satellite or aircraft remote sensing**

  of the Earth or other planets

- **information carried by electromagnetic waves**

- **sensing of land, ocean, and ice (will not cover atmosphere)**

Advantages and disadvantages of satellite remote sensing



El Nino - Topex

advantages

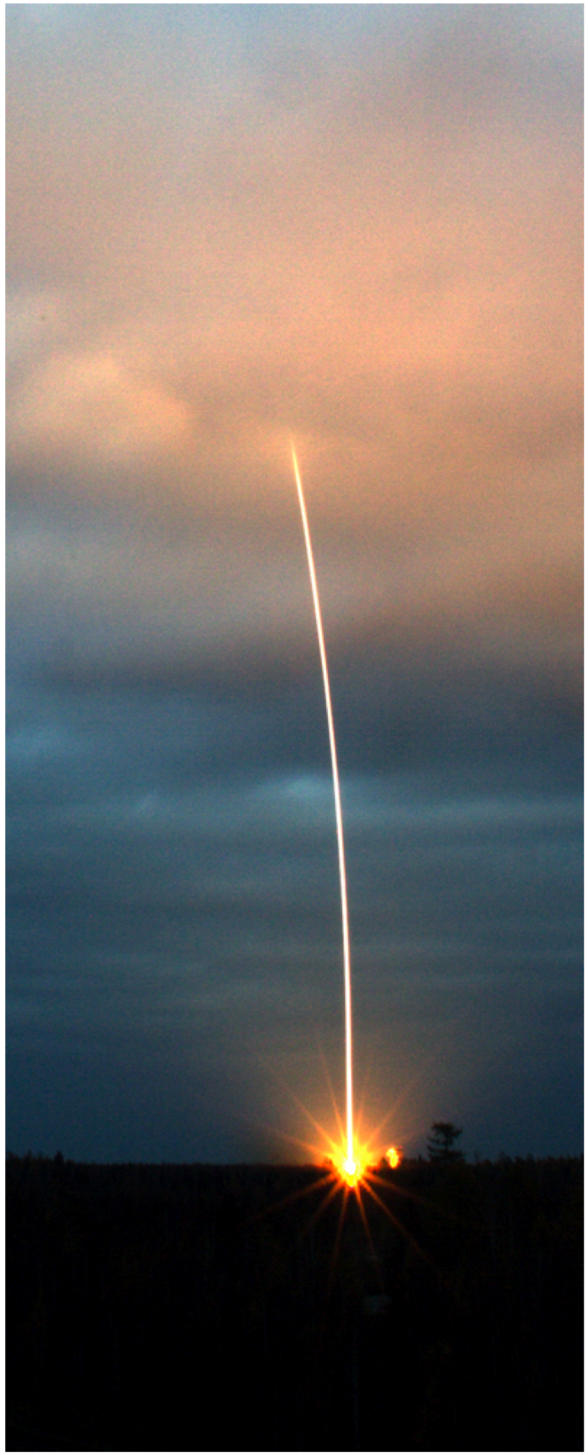
- global data set of uniform quality
- rapid data acquisition
- no need to obtain permission to gather data
- can revisit on a regular basis for lifetime of satellite (5-10 years)
- spacecraft provide stable platforms

disadvantages

- high cost of satellite systems
- takes 10 years + to develop, build, test, and launch
- possibility of single point failure

CryoSat I failure
October 2005

CryoSat-2
April 8, 2010



CryoSat Mission lost due to launch failure

8 October 2005
ESA PR 44-2005. Today at 21.00 CEST Mr Yuri Bakhvalov, First Deputy Director General of the Khrunichev Space Centre on behalf of the Russian State Commission officially confirmed that the launch of CryoSat ended in a failure due to an anomaly in the launch sequence and expressed his regret to ESA and all partners involved.

Preliminary analysis of the telemetry data indicates that the first stage performed nominally. The second stage performed nominally until main engine cut-off was to occur. Due to a missing command from the onboard flight control system the main engine continued to operate until depletion of the remaining fuel.
As a consequence, the separation of the second stage from upper stage did not occur. Thus, the combined stack of the two stages and the CryoSat satellite fell into the nominal drop zone north of Greenland close to the North Pole into high seas with no consequences to populated areas.

Space is a risky business, it always has been, it doesn't always go perfectly Prof Duncan Wingham, Cryosat chief scientist

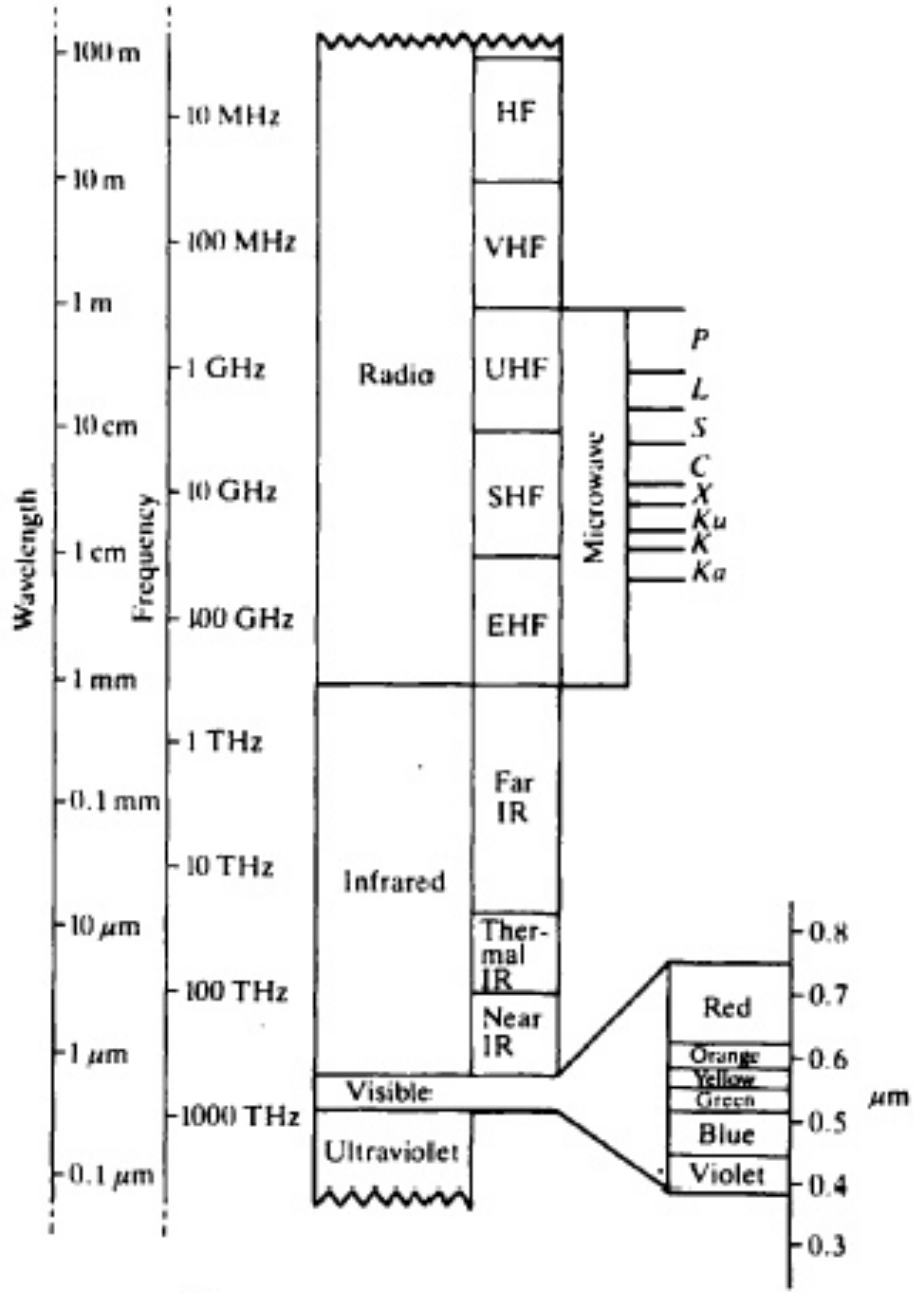
"It is a very sad event for many scientists around Europe and also for the teams involved in industry which built the satellite," he said.

http://www.esa.int/esaCP/SEMR3Q5Y3EE_index_0.html

Applications of Remote Sensing

- *Meterology* - profiling of atmospheric temperature, pressure, water vapor, and wind velocity.
- *Oceanography* - measuring sea surface temperature, mapping ocean currents, and wave energy spectra.
- *Glaciology* - measuring ice cap volumes, ice stream velocity, and sea ice distribution.
- *Geology* - geomorphology, identification of rock type, mapping faults and structure.
- *Geodesy* - measuring the figure of the earth and its gravity field.
- *Topography and cartography* - improving digital elevation models
- *Agriculture, forestry, and botany* - monitoring the biomass of land vegetation, monitoring the health of crops, mapping soil moisture, forecasting crop yields.
- *Hydrology* - assessing water resources from snow, rainfall and underground aquifers.
- *Disaster warning and assessment* - monitoring of floods and landslides, monitoring volcanic activity, assessing damage zones from natural disasters.
- *Planning applications* - mapping ecological zones, monitoring deforestation, monitoring urban land use.
- *Oil and mineral exploration* - locating natural oil seeps and slicks, mapping geological structures, monitoring oil field subsidence.
- *Military* - developing precise maps for planning, monitoring military infrastructure, monitoring ship and troop movements . . . (This is where most of the US funding for remote sensing goes.)

Electromagnetic Spectrum



Rees, 2001

Three Essentials for Remote Sensing

source of radiation

sunlight or thermal emissions or active sensor

transmission

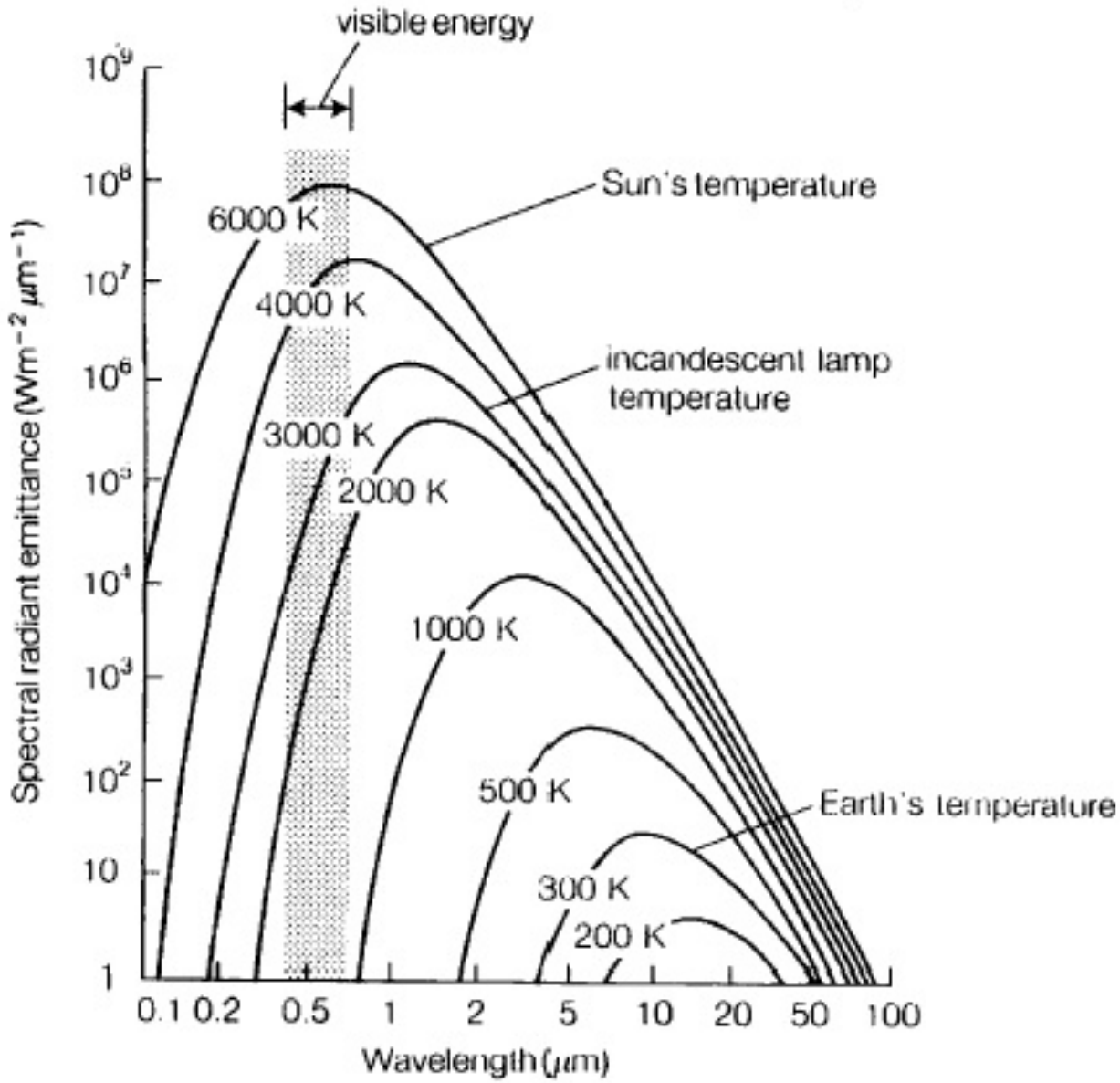
attenuation and phase delay of waves in atmosphere and ionosphere

receiver

sensor, platform, and orbit selection

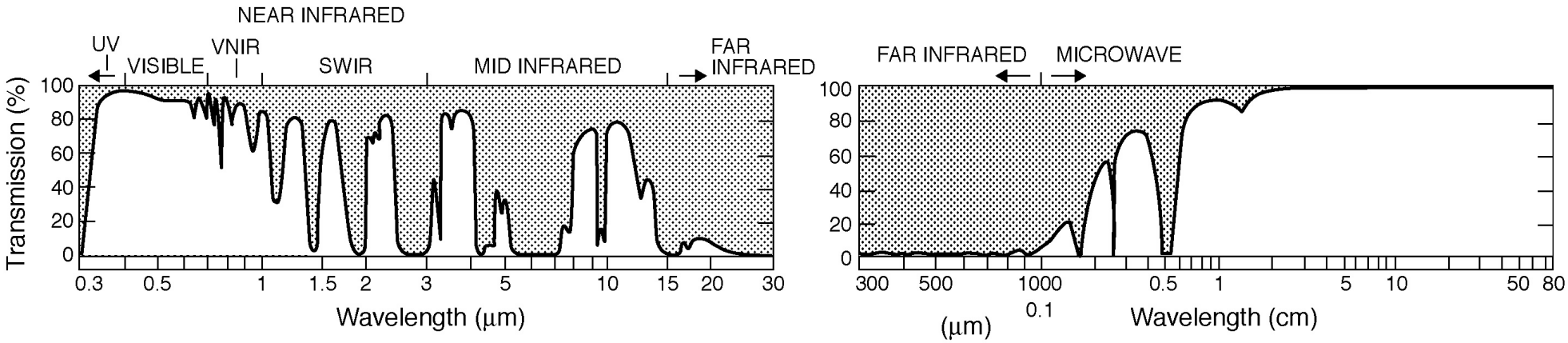
Source

Blackbody Radiation

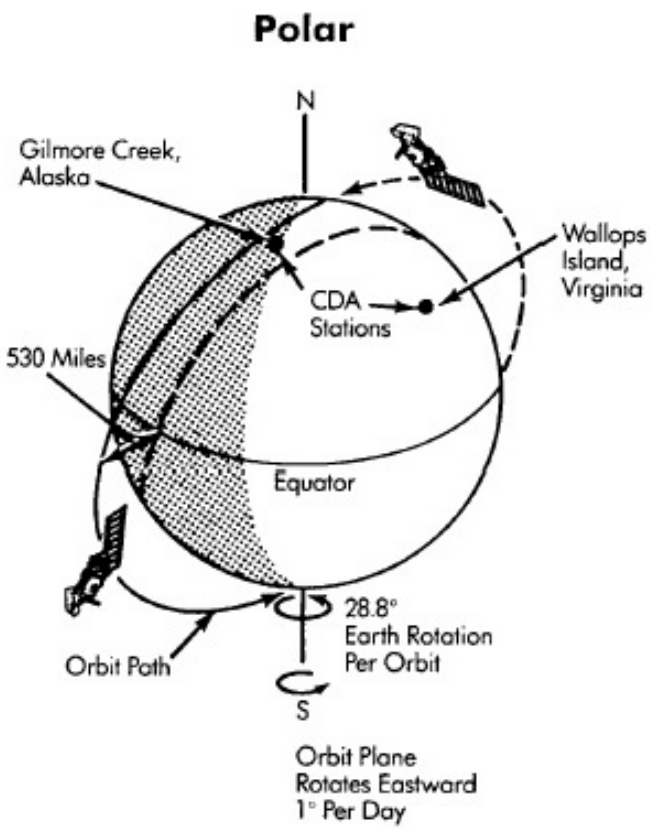


Rees, 2001

Transmission through atmosphere and ionosphere



Receiver and Orbits



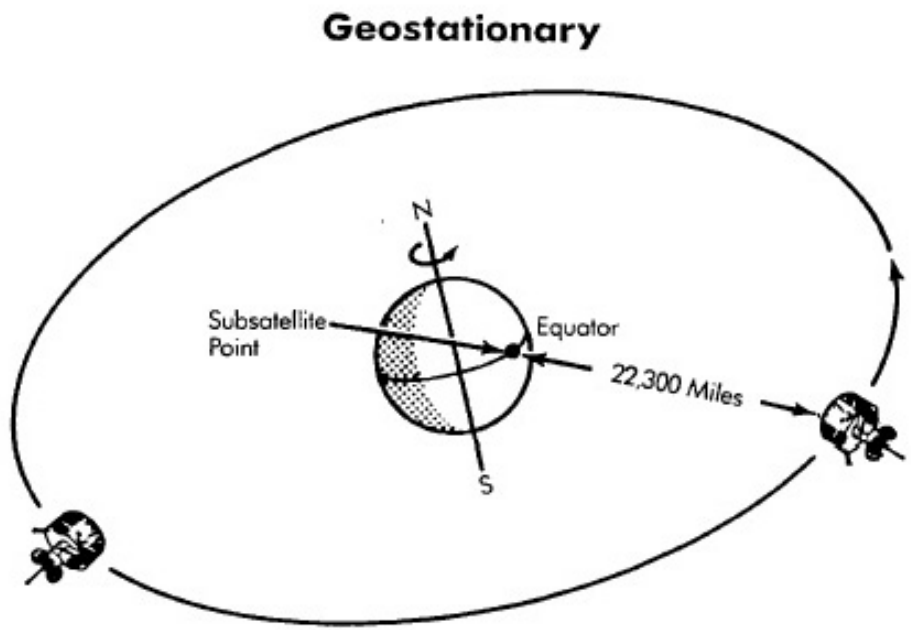
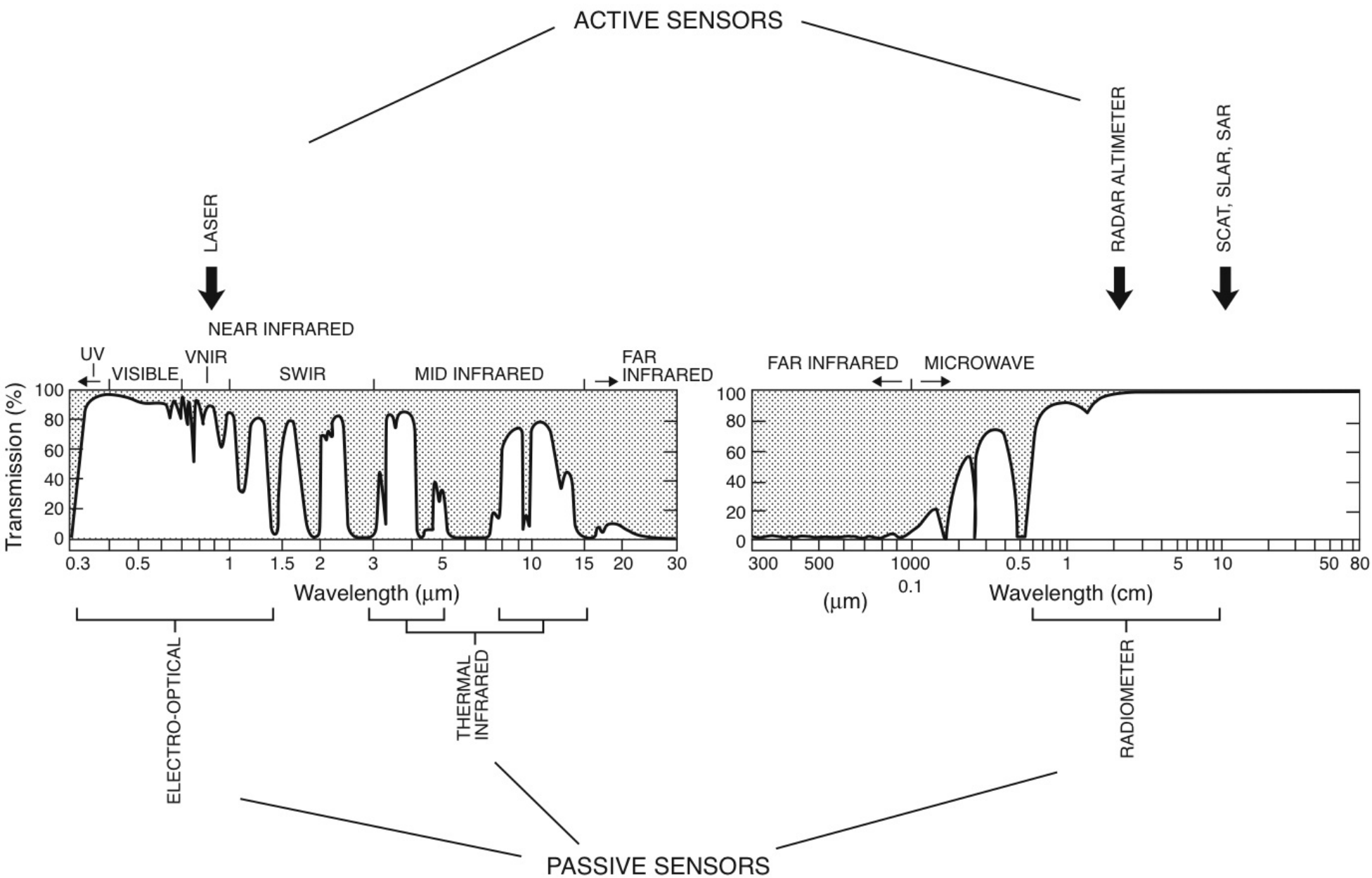
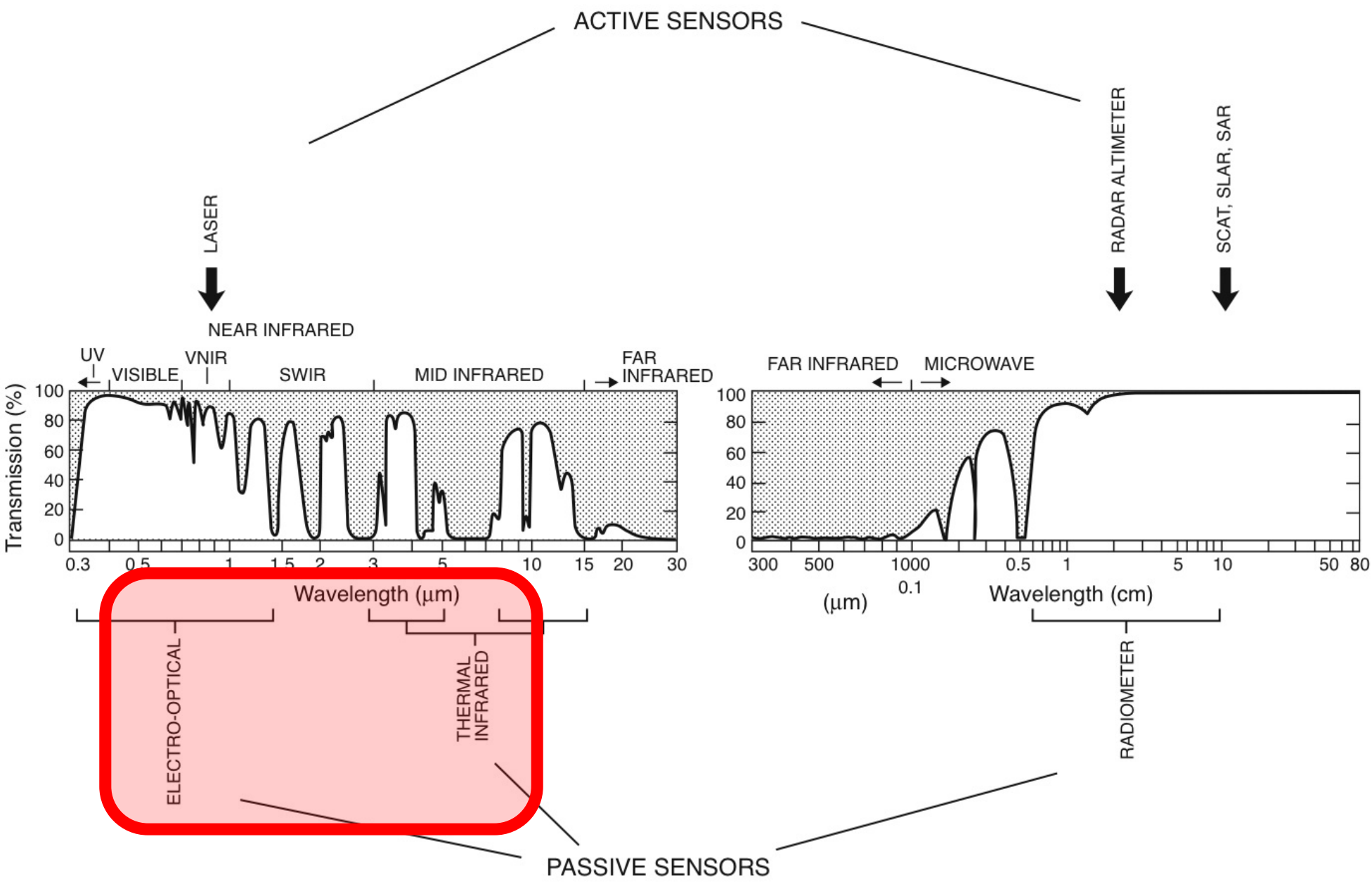


Figure 4. Opposite and above: polar and geostationary orbits for NOAA satellites. Note that the polar orbit rotates one degree per day; this is to make it synchronous with the sun. The geostationary satellite stays continuously above one spot on Earth.

Possible Instruments (Earth)




ACTIVE SENSORS
LASER
RADAR ALTIMETER
SCAT, SLAR, SAR
NEAR INFRARED
UV
VISIBLE
VNIR
SWIR
MID INFRARED
FAR INFRARED
Transmission (%)
100
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Wavelength (μm)
FAR INFRARED
MICROWAVE
300
500
1000
0.5
1
5
10
50
80
0.1
(μm)
Wavelength (cm)
ELECTRO-OPTICAL
THERMAL INFRARED
RADIOMETER
PASSIVE SENSORS

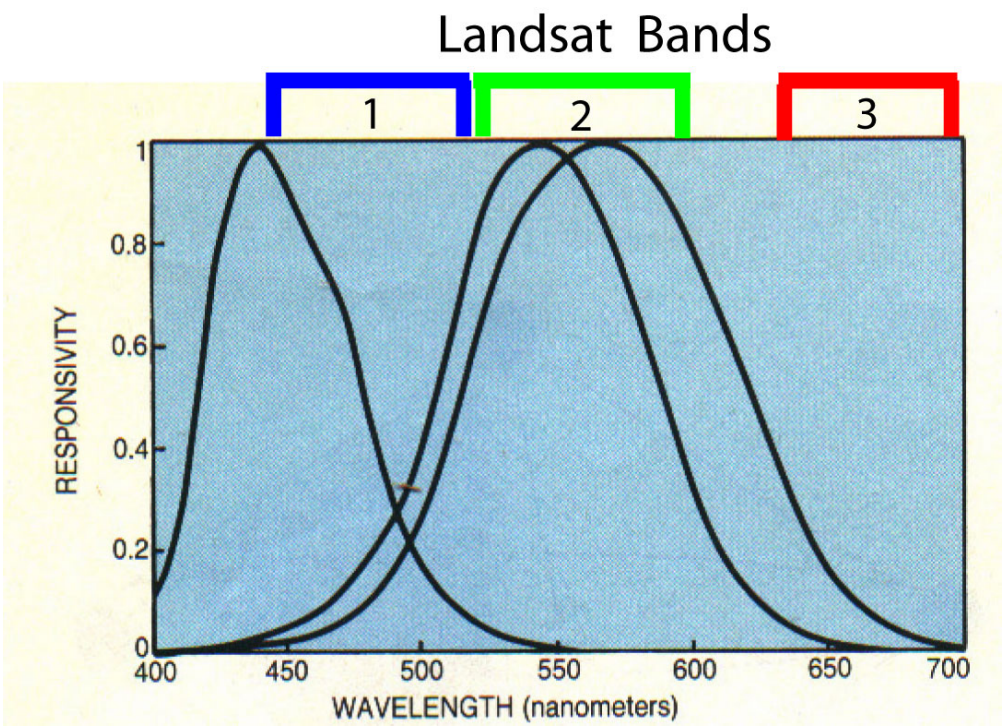
human vision (see notes online)

photoreceptors

cones
- 6-7 million
- sensitivity in 3 bands

rods
- 75-100 million
- broadband and low light sensitivity

2 eyes = stereo



Robertson, 1992

passive visible - IKONOS

Spatial and Spectral Resolution					
	Panchromatic	Multispectral			
Spectral Characteristics	Black & White	Blue	Green	Red	Near IR
	450 to 900-nm	450 to 520-nm	520 to 600-nm	630 to 690-nm	760 to 900-nm
Pixel Resolution[1]	61-cm to 72-cm (2 to 2.4-ft)	2.44 to 2.88-m (8 to 9.4-ft)			
Scene Dimensions	27,552 x 27,424 pixels	6,888 x 6,856 pixels			
Scene Size[2]	272-km2 (nadir) to 435-km2 (25° off-nadir) (105 to 168-mi2)				
	16.5-km2 (nadir) to 20.8-km2 (25° off-nadir) 10.3 to 12.9-mi2)				

Image Accuracy		
Positional Accuracy[3]	CE 90%	RMSE
	23-meters (75-feet)	14-meters (46-feet)

passive visible – IKONOS – multispectral 2.5 m

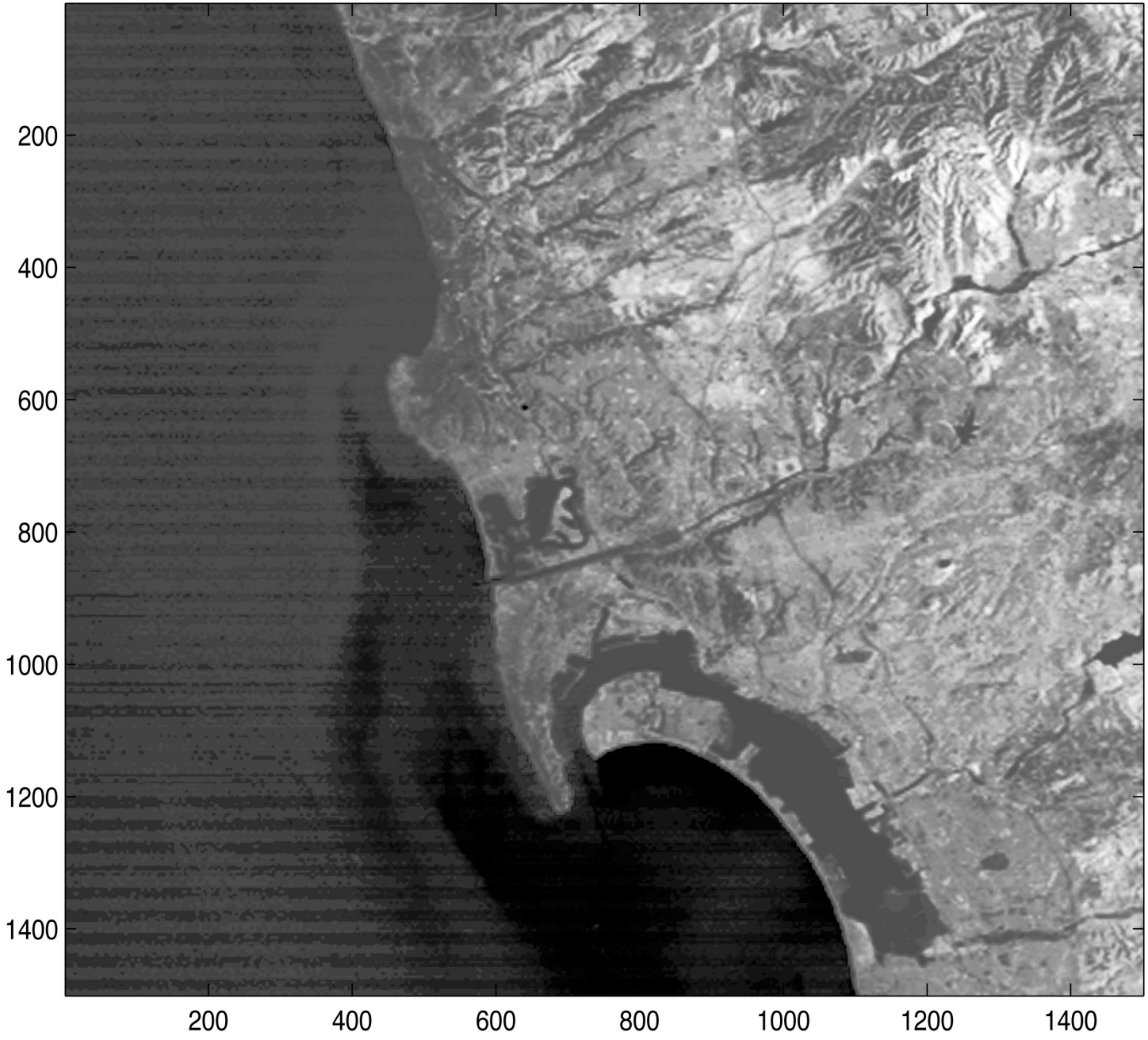
passive visible – IKONOS – panchromatic 0.7 m

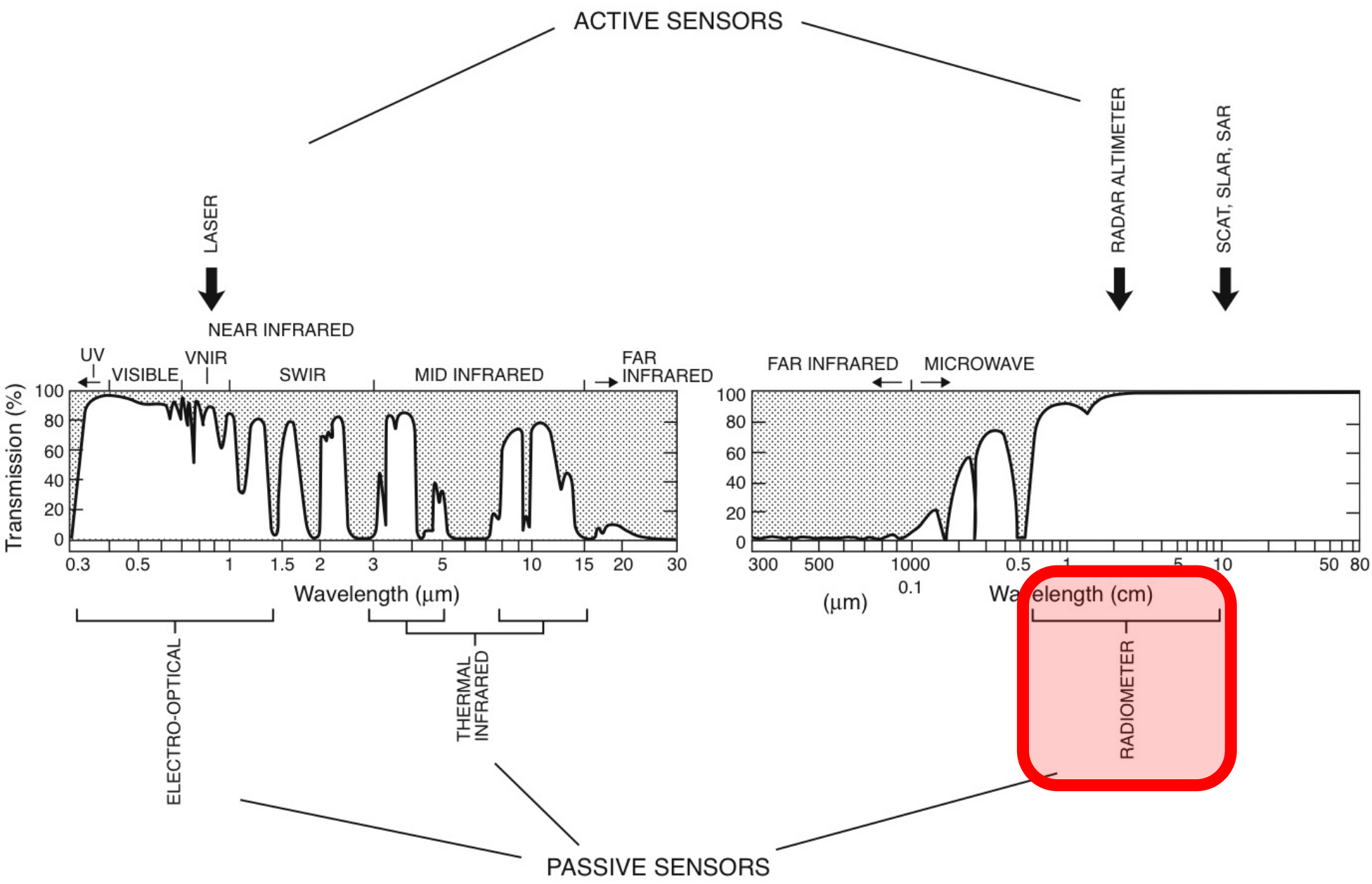
passive visible and IR - LANDSAT

Band	Spectral Range (microns)	Electromagnetic Spectrum	Ground Resolution (m)
1	.45 to .515	Visible blue-green (reflected)	30
2	.525 to .605	Visible green (reflected)	30
3	.63 to .690	Visible red (reflected)	30
4	.75 to .90	Near Infrared (reflected)	30
5	1.55 to 1.75	Mid-Infrared (reflected)	60
6	10.40 to 12.5	Thermal Infrared (emitted)	30
7	2.09 to 2.35	Mid-Infrared (reflected)	30
Pan	.52 to .90	Visible light (reflected)	15

Landsat TM - 0.48 μm, 0.56 μm, 0.66 μm (MATLAB)

Landsat TM -10.40 μm (MATLAB)




ACTIVE SENSORS
LASER
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Transmission (%)
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Wavelength (μm)
FAR INFRARED
MICROWAVE
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1000
0.1
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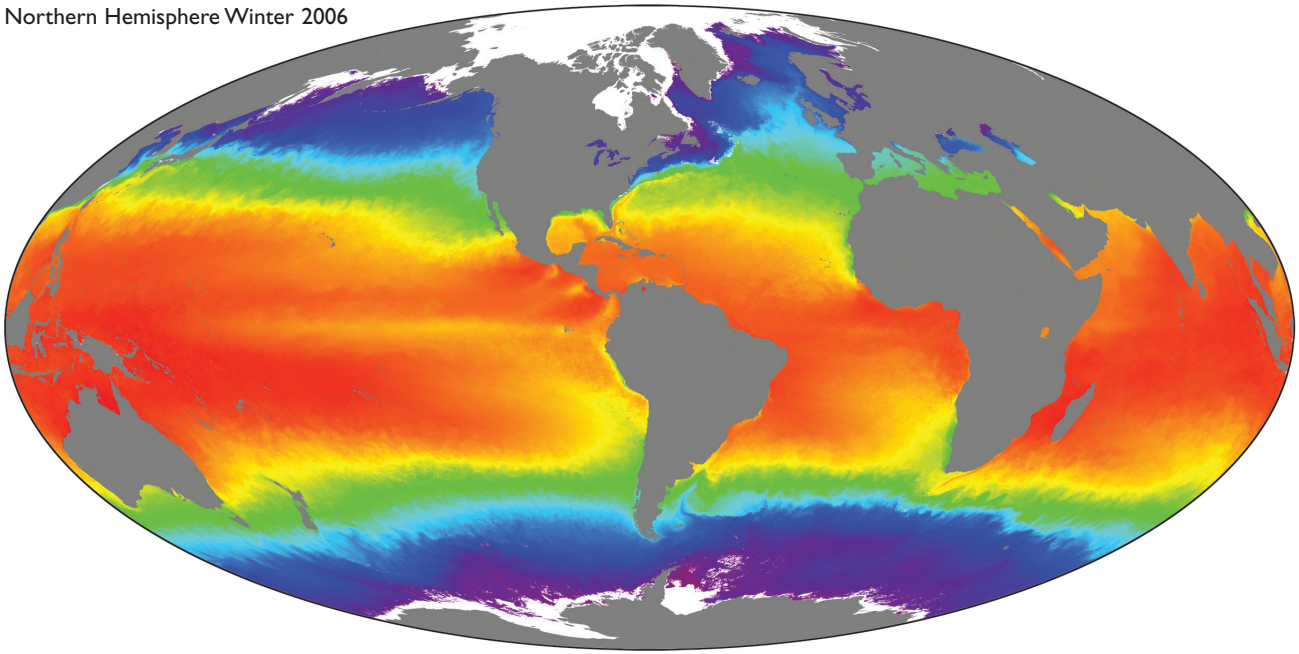
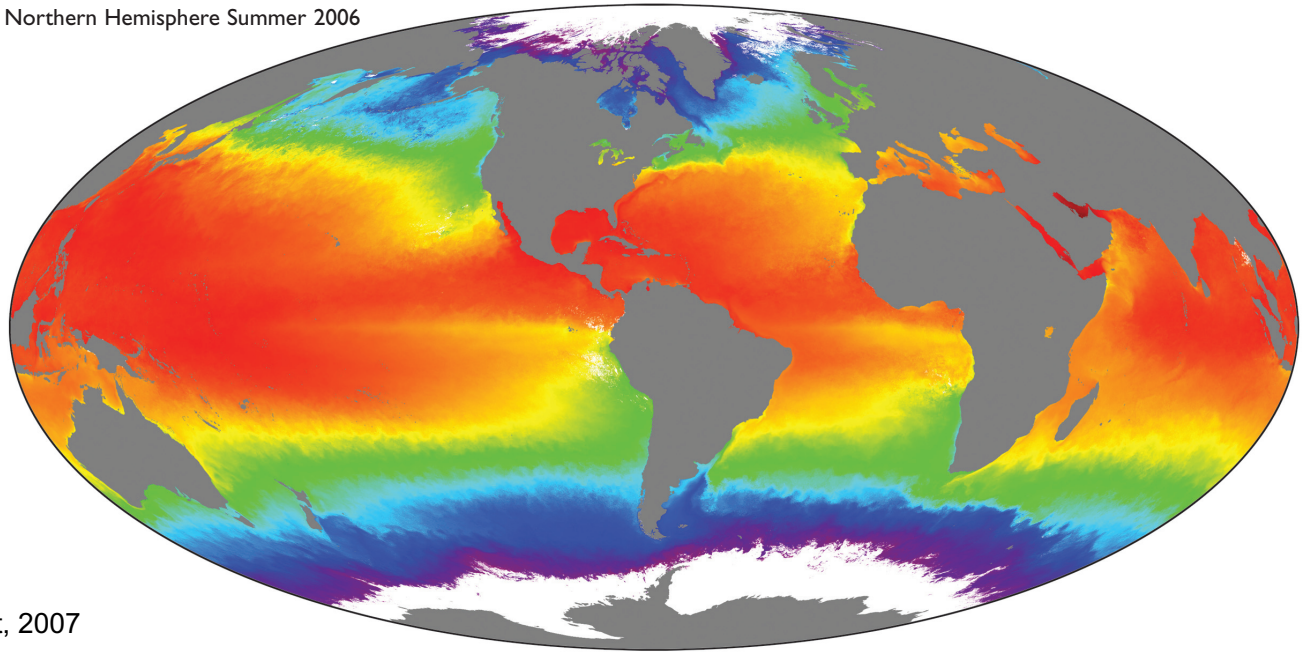
(μm)
Wavelength (cm)
ELECTRO-OPTICAL
THERMAL INFRARED
RADIOMETER
PASSIVE SENSORS

passive microwave – Aqua – AMSR-E

Northern Hemisphere Winter 2006



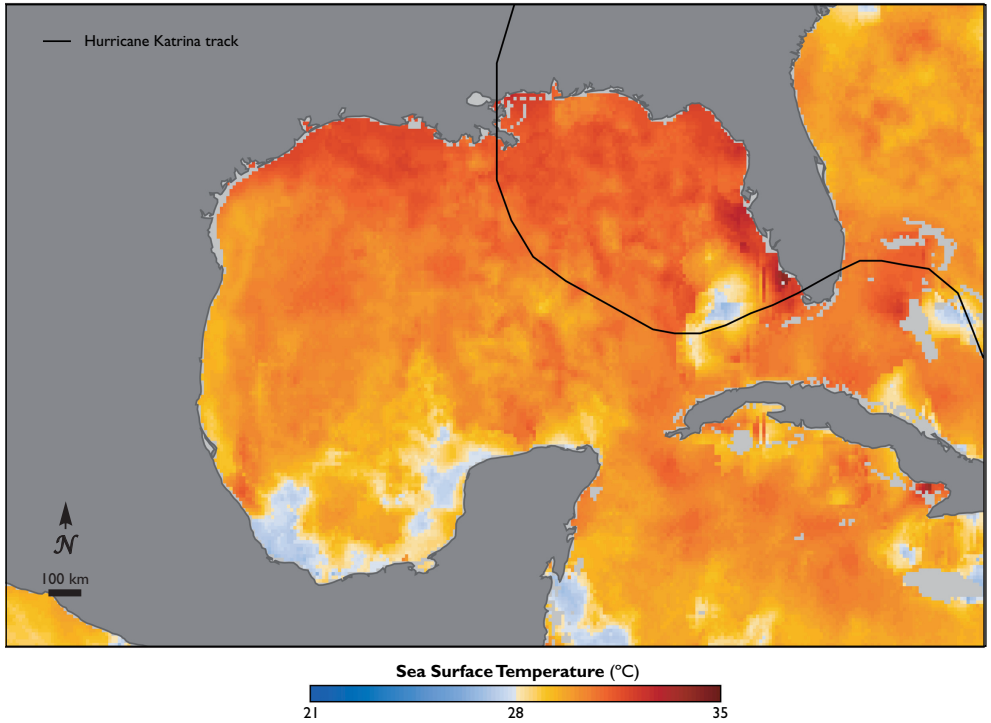
Northern Hemisphere Summer 2006



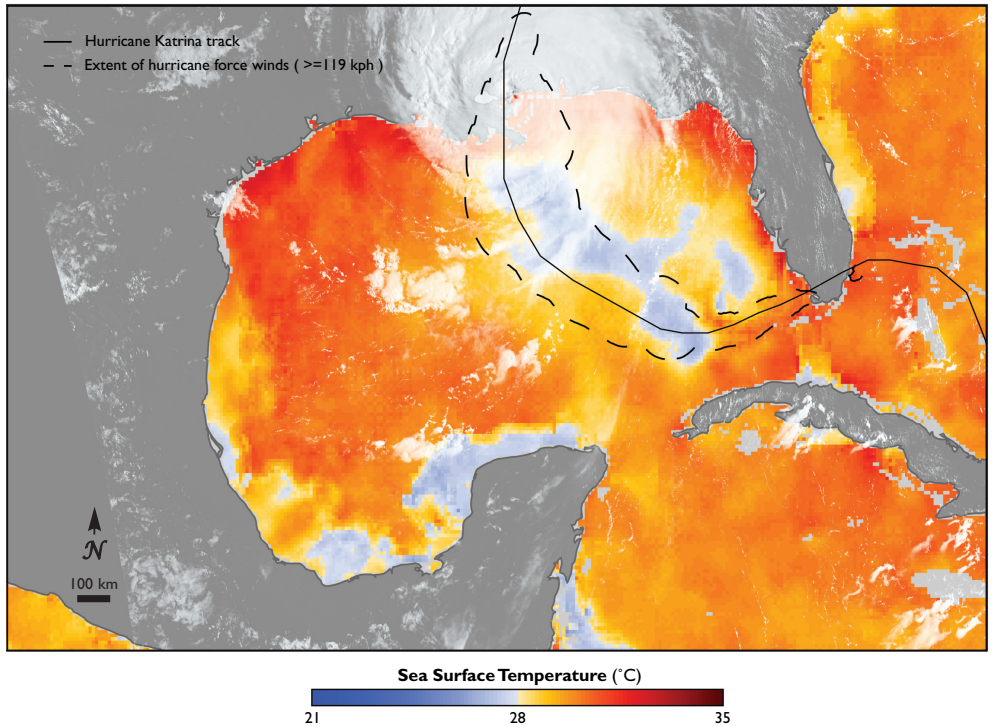
Minnett, Our Changing Planet, 2007

passive microwave – Aqua – AMSR-E

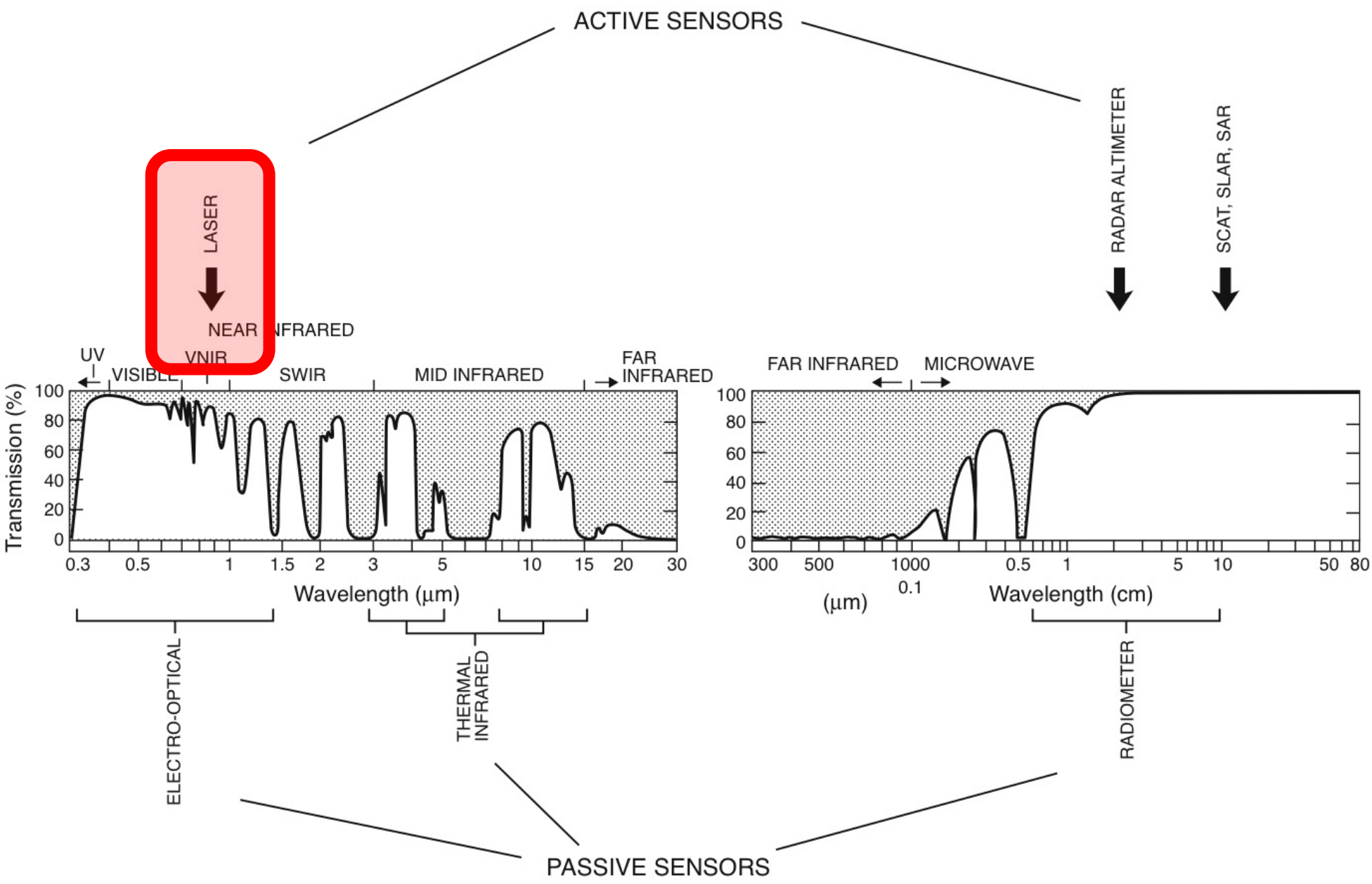
August 27, 2005



August 29 and 30, 2005



Minnett, Our Changing Planet, 2007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Transmission (%)
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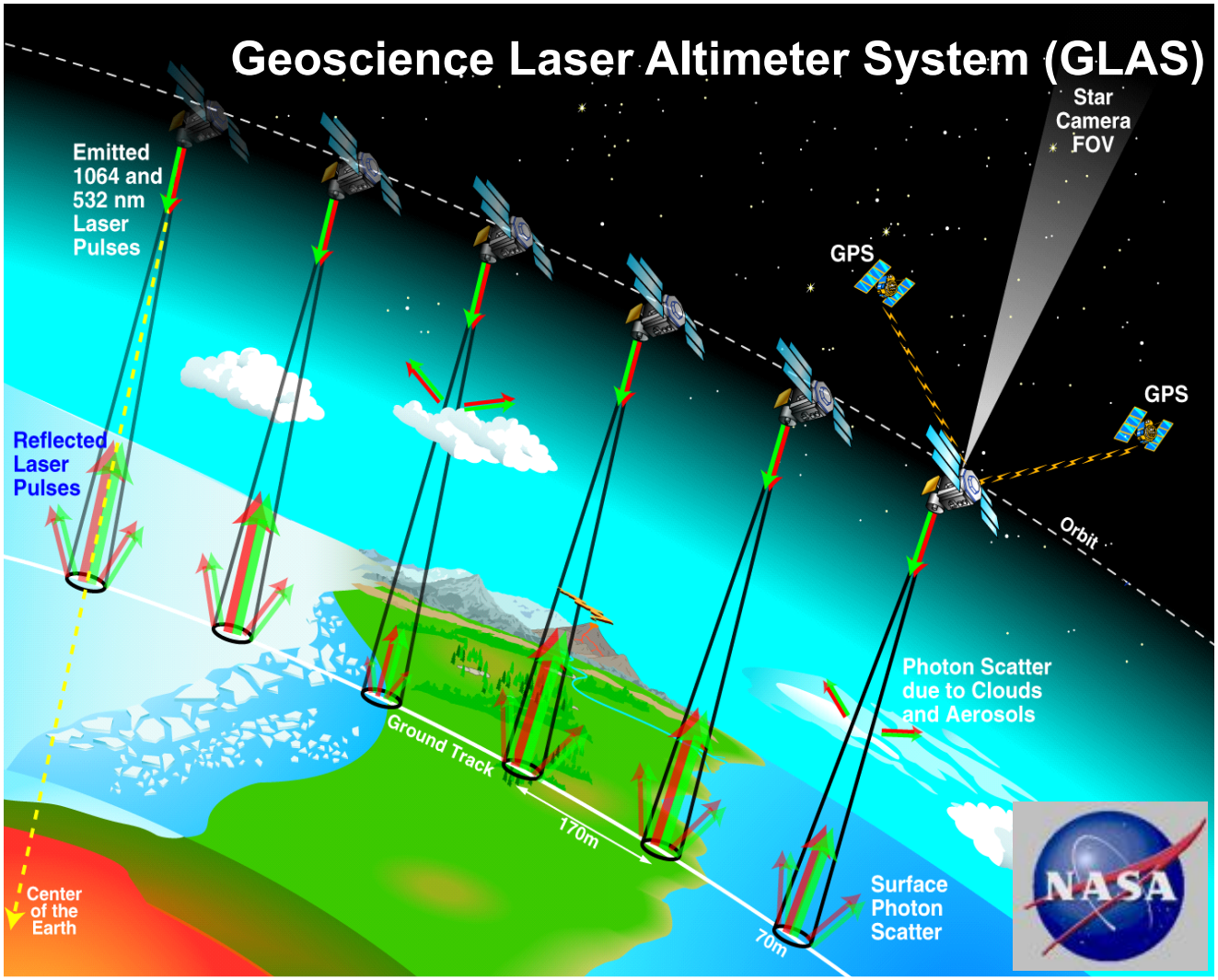
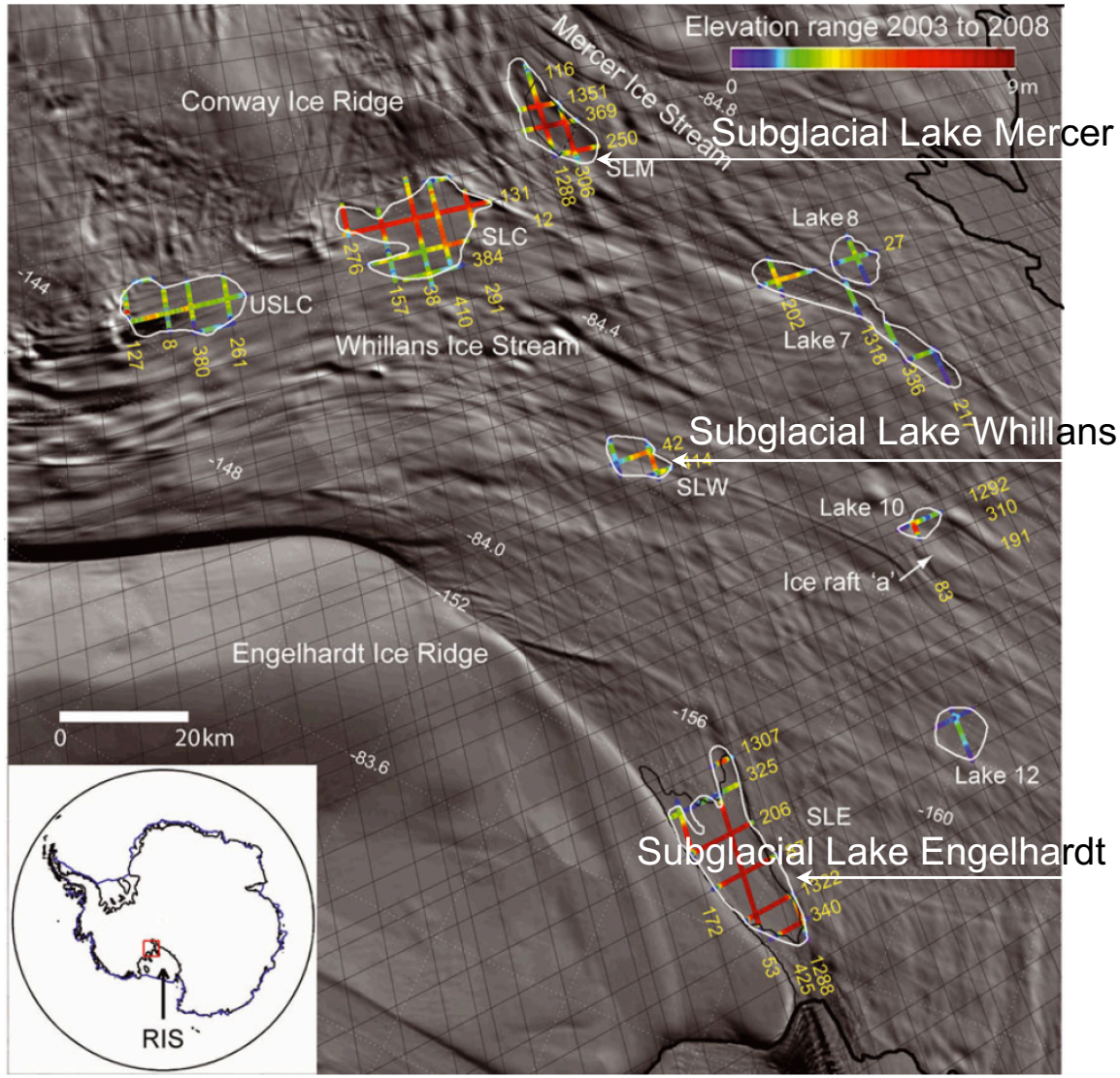
Wavelength (cm)
ELECTRO-OPTICAL
THERMAL INFRARED
RADIOMETER
PASSIVE SENSORS

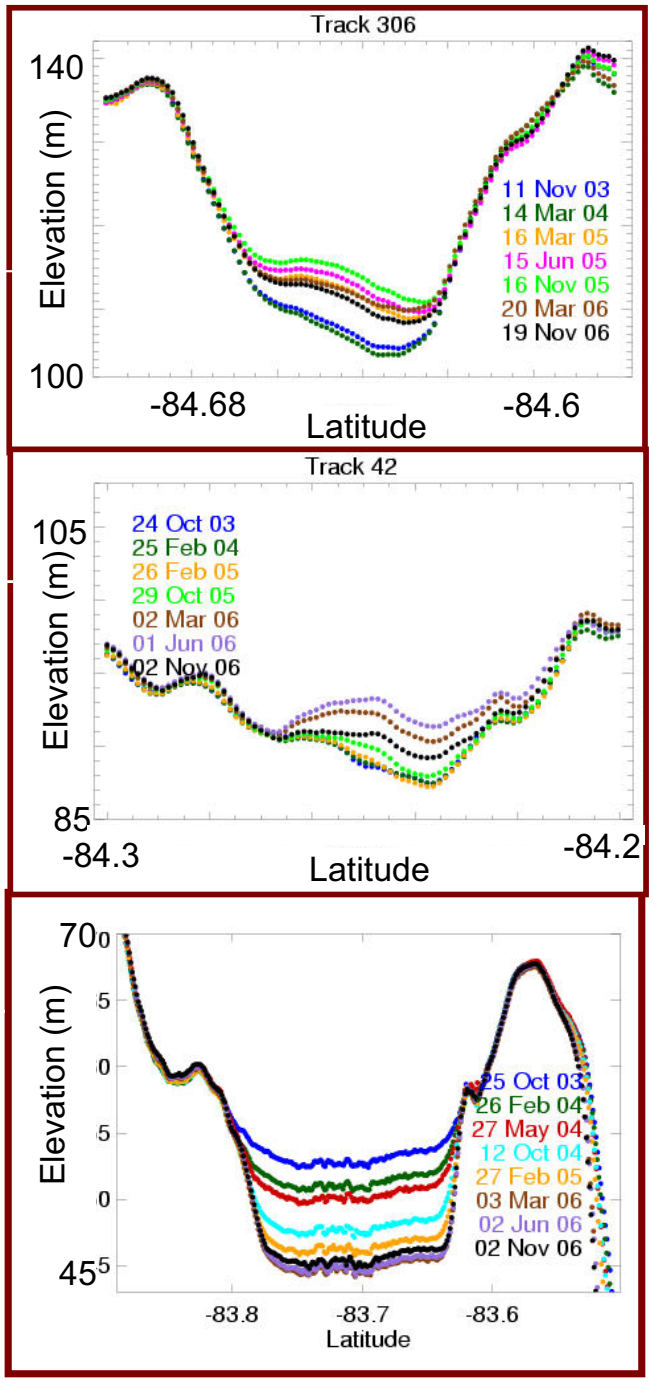
ICESat laser altimeter



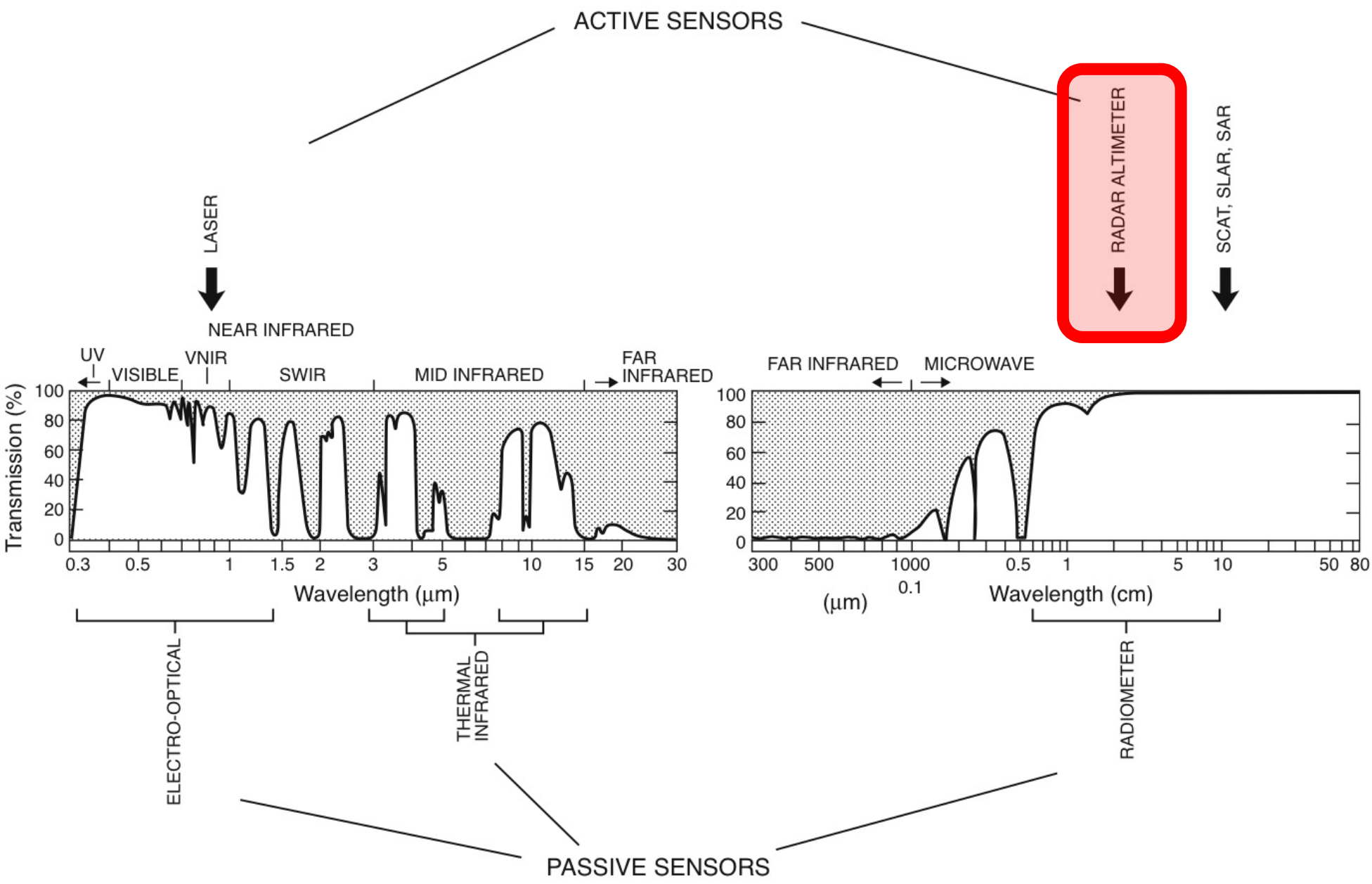
- Surface elevations along a ground track determined from laser time of flight, combined with precise orbit and pointing information
- Laser-beam pointing determined from star-trackers and internal angle system
- ICESat had 3 lasers

ICESat's detection of Antarctic subglacial lakes





Fricker et al., 2007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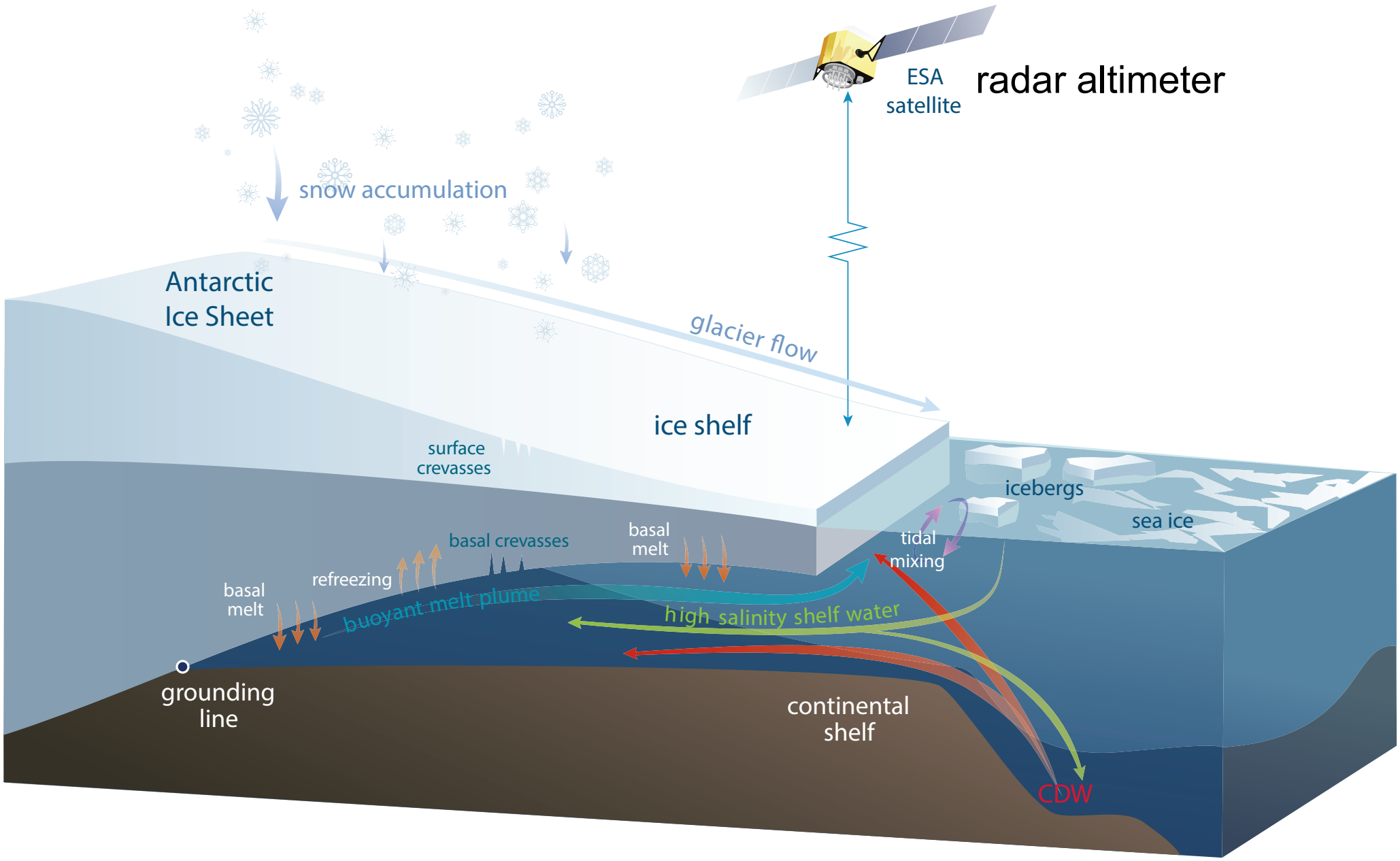
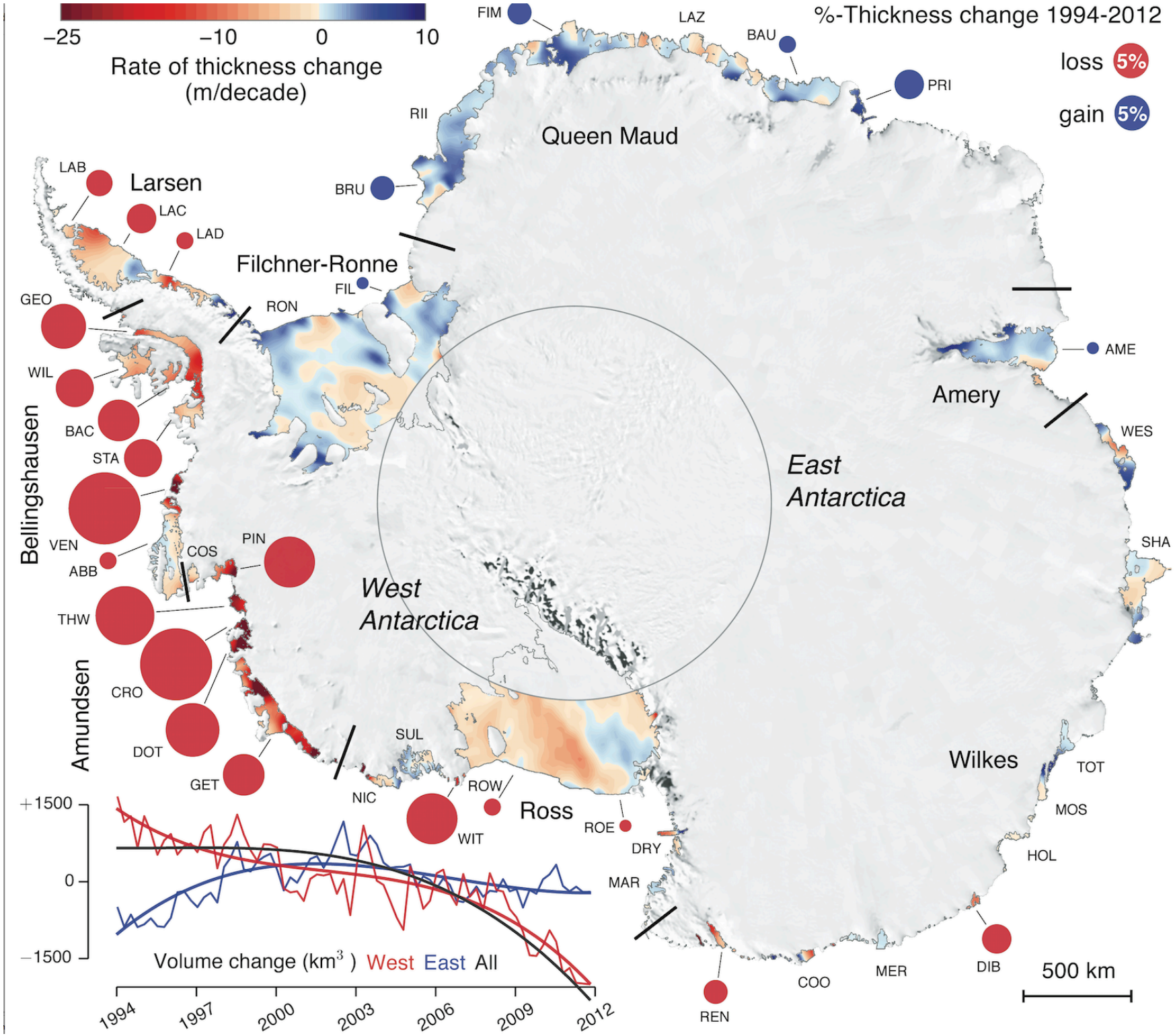
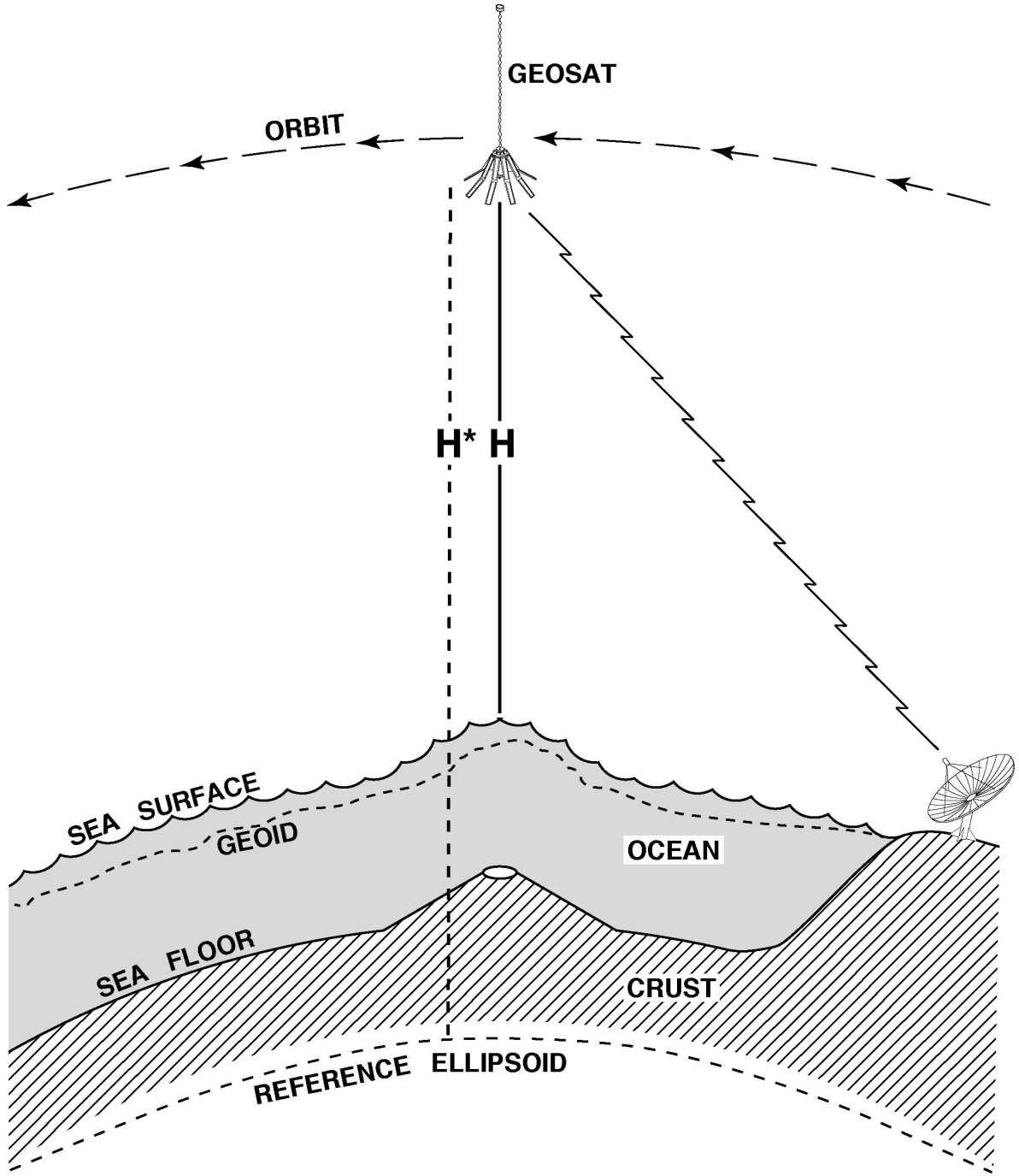
Detecting changes of Antarctica's ice sheet

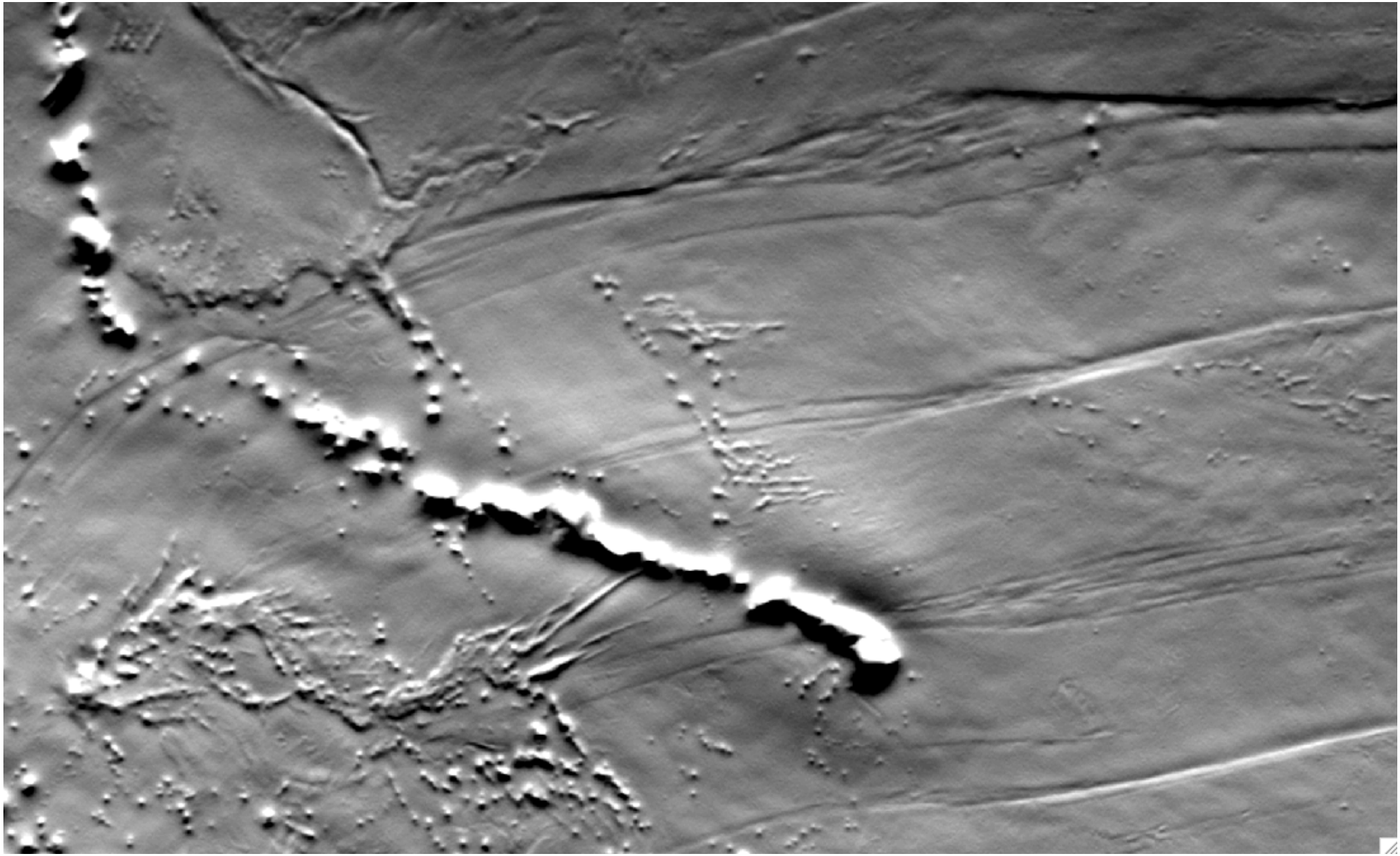



−25
−10
0
10
Rate of thickness change
(m/decade)
%-Thickness change 1994-2012
loss 5%
gain 5%
FIM
LAZ
BAU
PRI
RII
Queen Maud
BRU
LAB
Larsen
LAC
LAD
Filchner-Ronne
FIL
RON
GEO
WIL
BAC
STA
VEN
ABB
COS
PIN
Bellingshausen
THW
CRO
DOT
GET
Amundsen
West
Antarctica
East
Antarctica
AME
Amery
WES
SHA
SUL
NIC
ROW
WIT
Ross
ROE
DRY
MAR
Wilkes
TOT
MOS
HOL
DIB
MER
COO
REN
500 km
+1500
0
−1500
Volume change (km³) West East All
1994
1997
2000
2003
2006
2009
2012

active microwave – radar altimetry

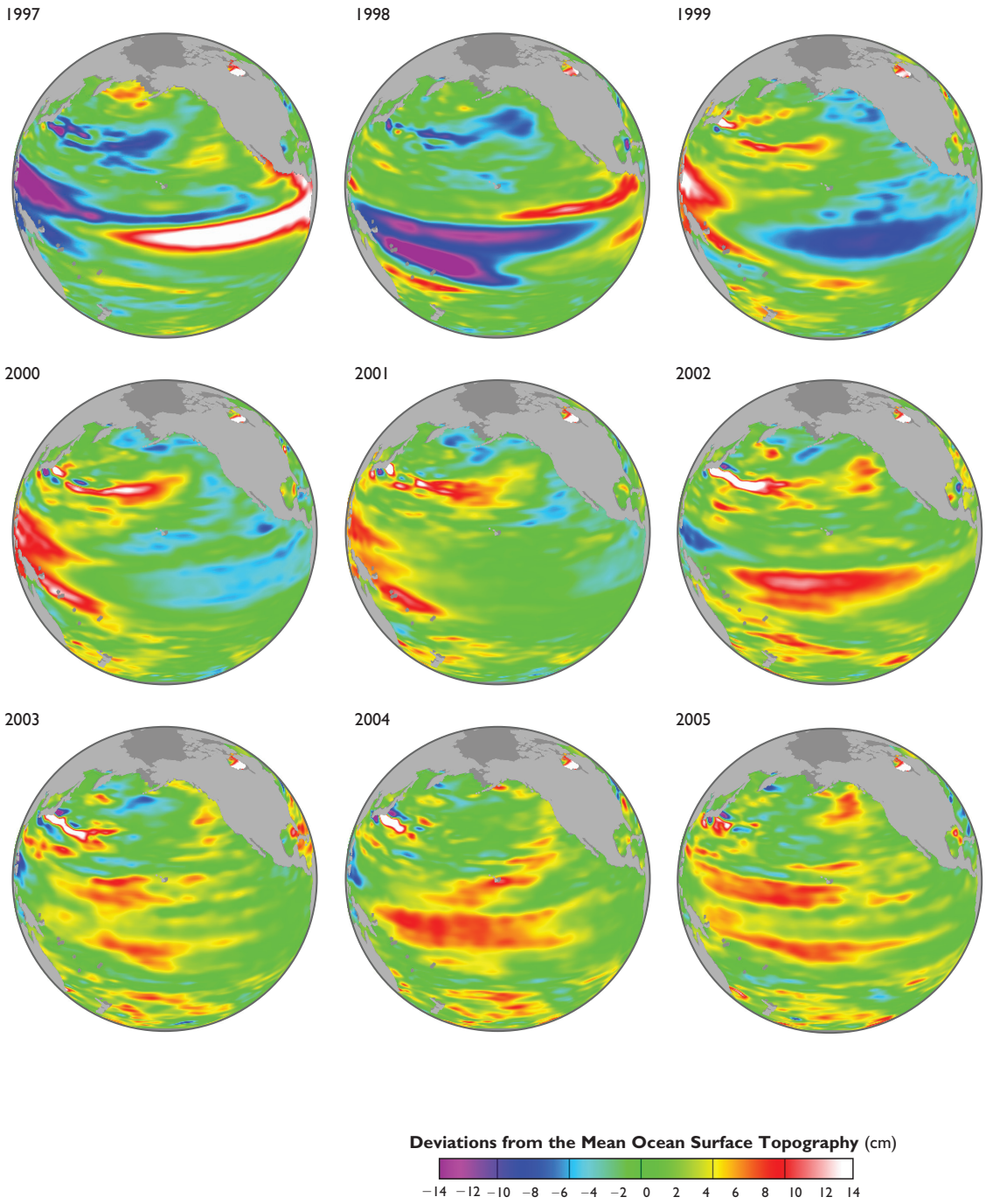


active microwave – Geosat altimetry



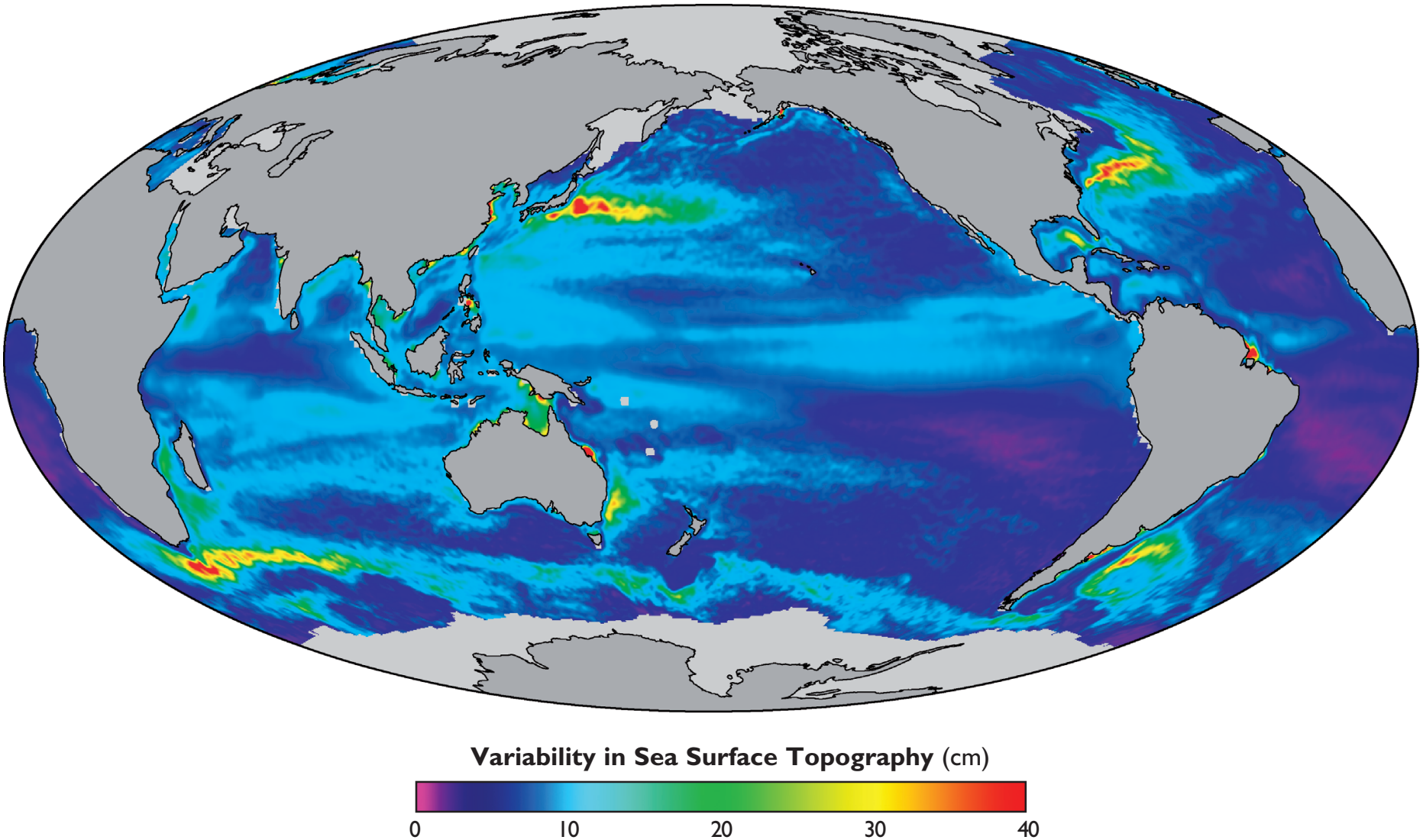
Sandwell and Smith
J. Geophys. Res., 2008

active microwave – TOPEX altimetry

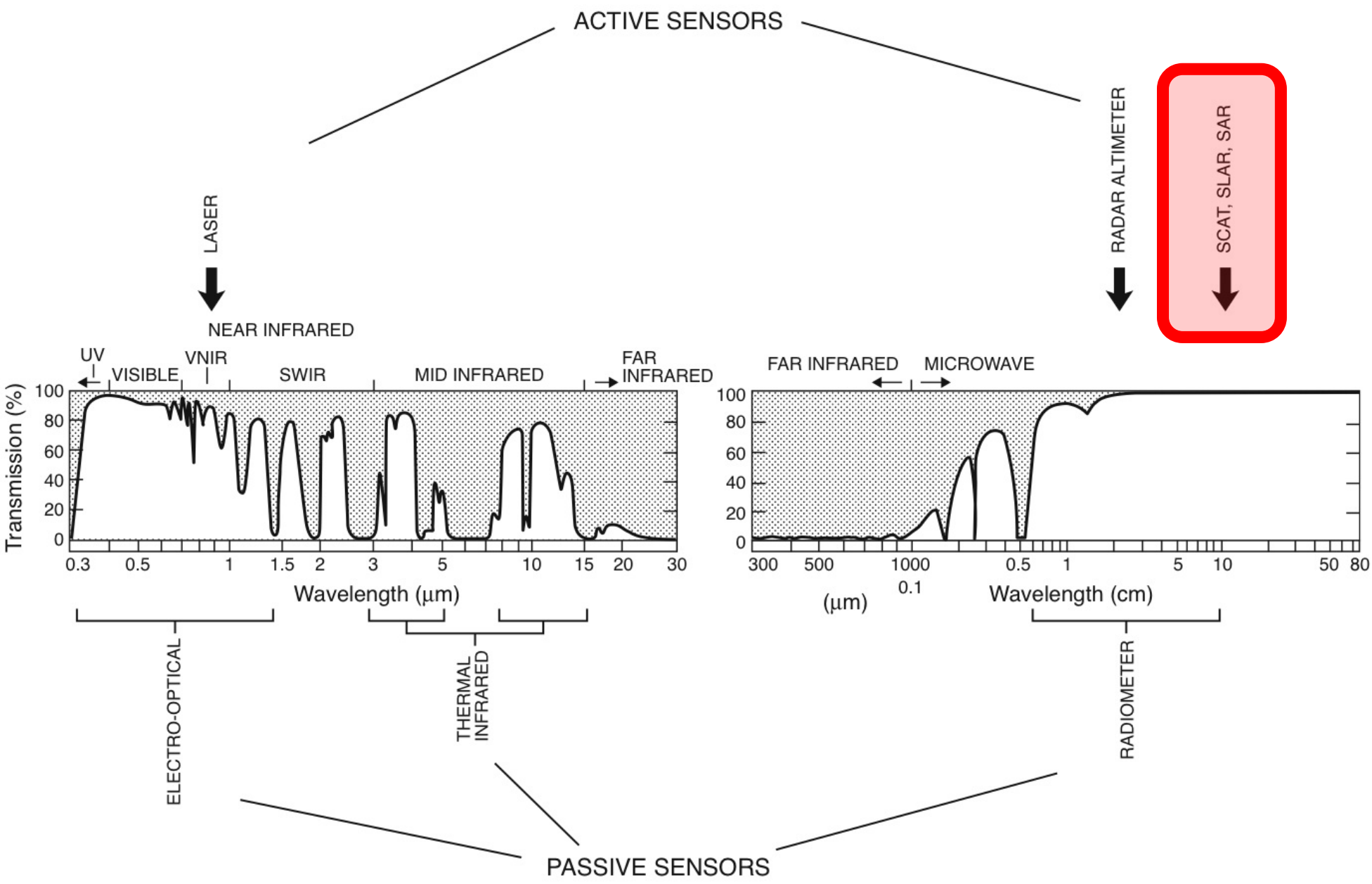


Fu, Our Changing Planet, 2007

active microwave – TOPEX altimetry



Fu, Our Changing Planet, 2007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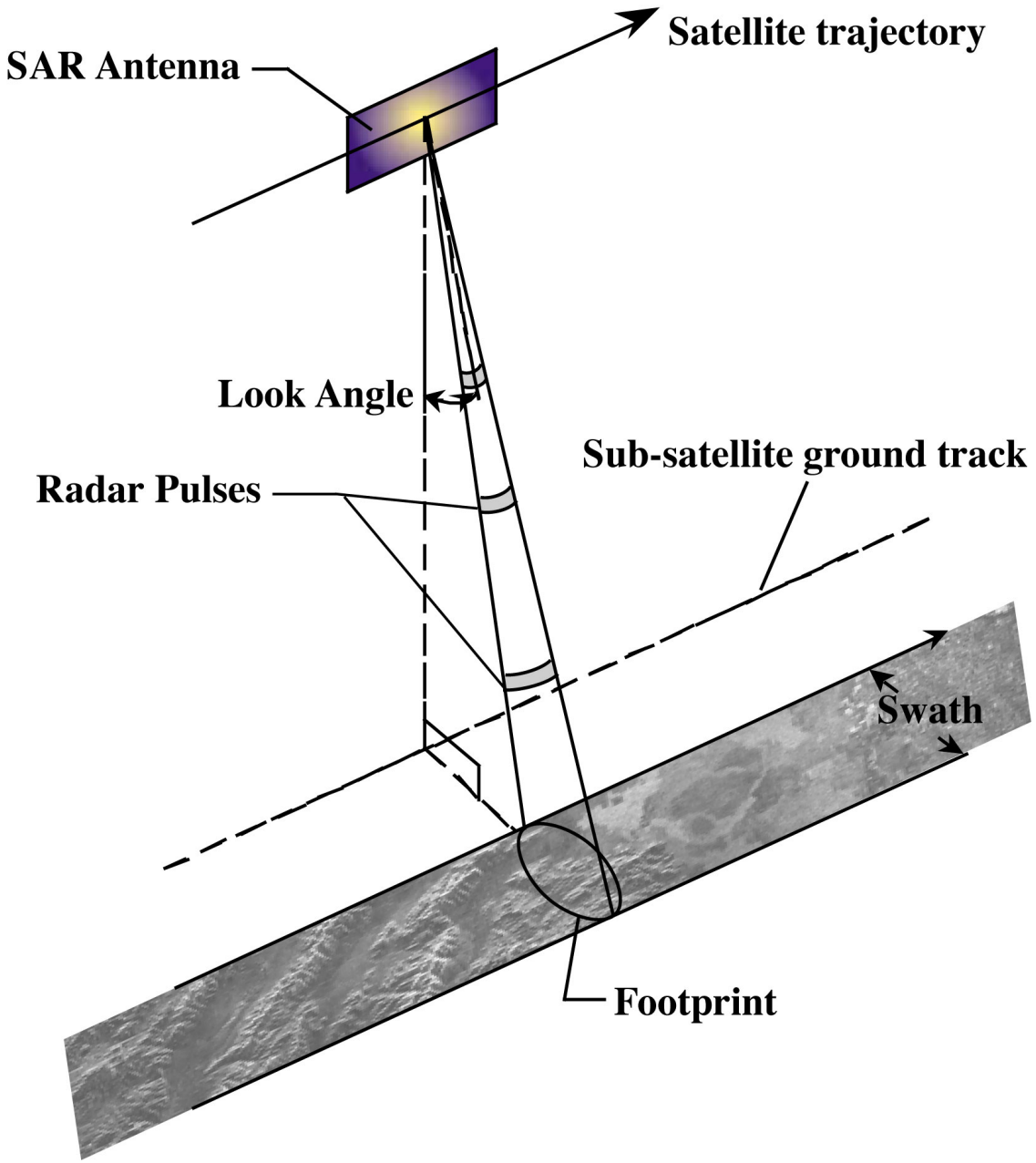
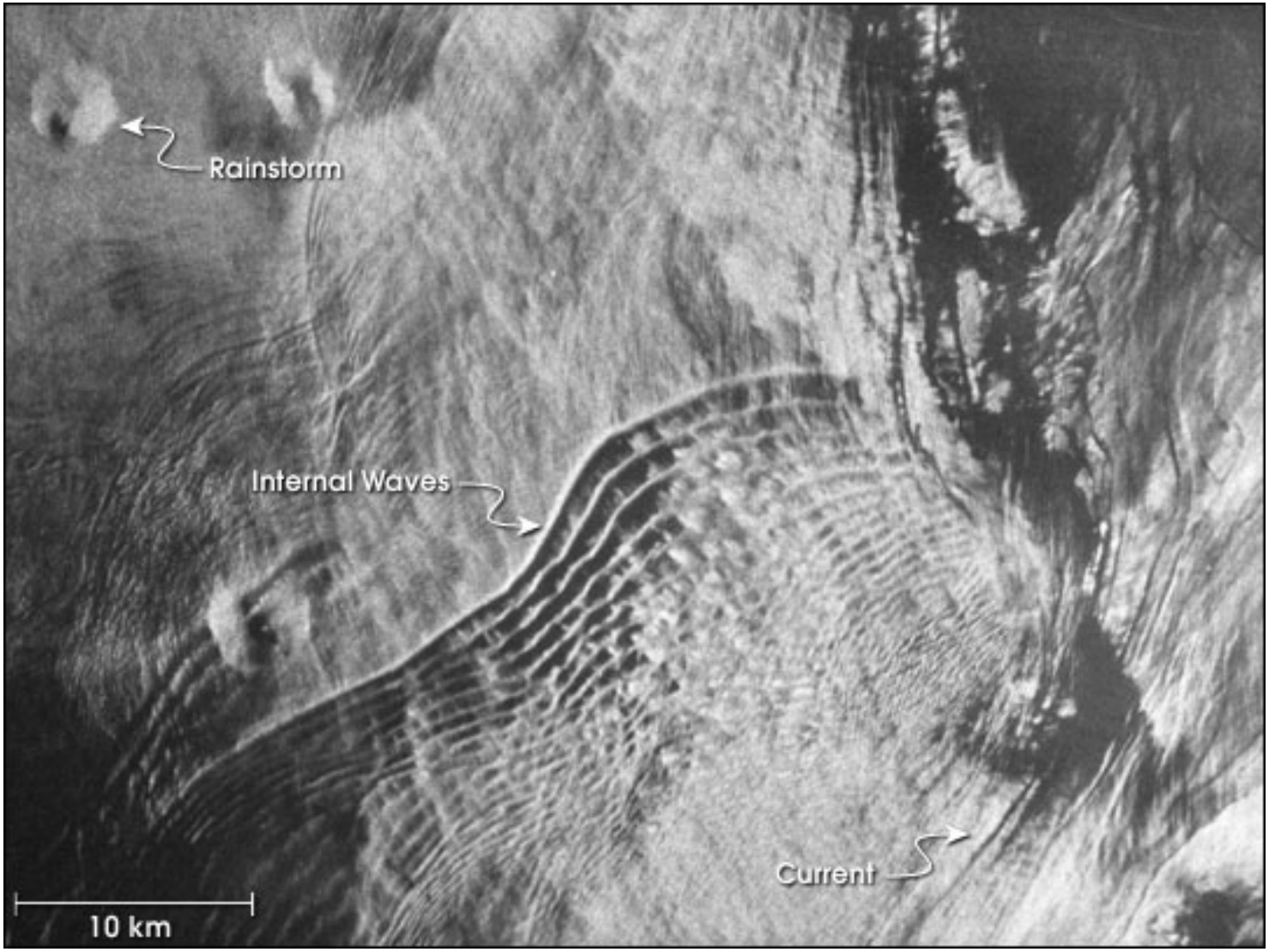
Wavelength (cm)
ELECTRO-OPTICAL
THERMAL INFRARED
RADIOMETER
PASSIVE SENSORS

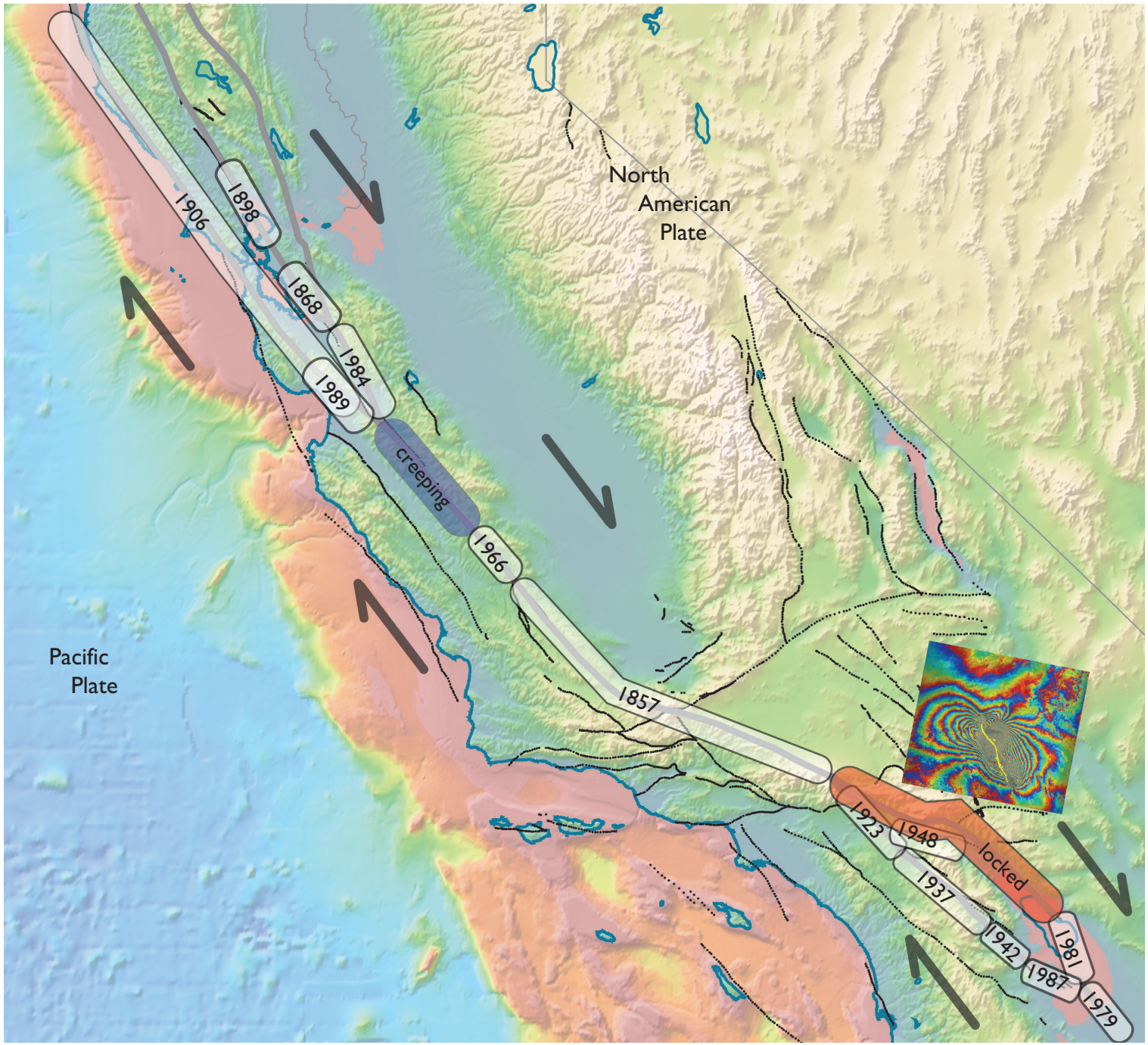
active microwave – ERS SAR



active microwave – Seasat SAR

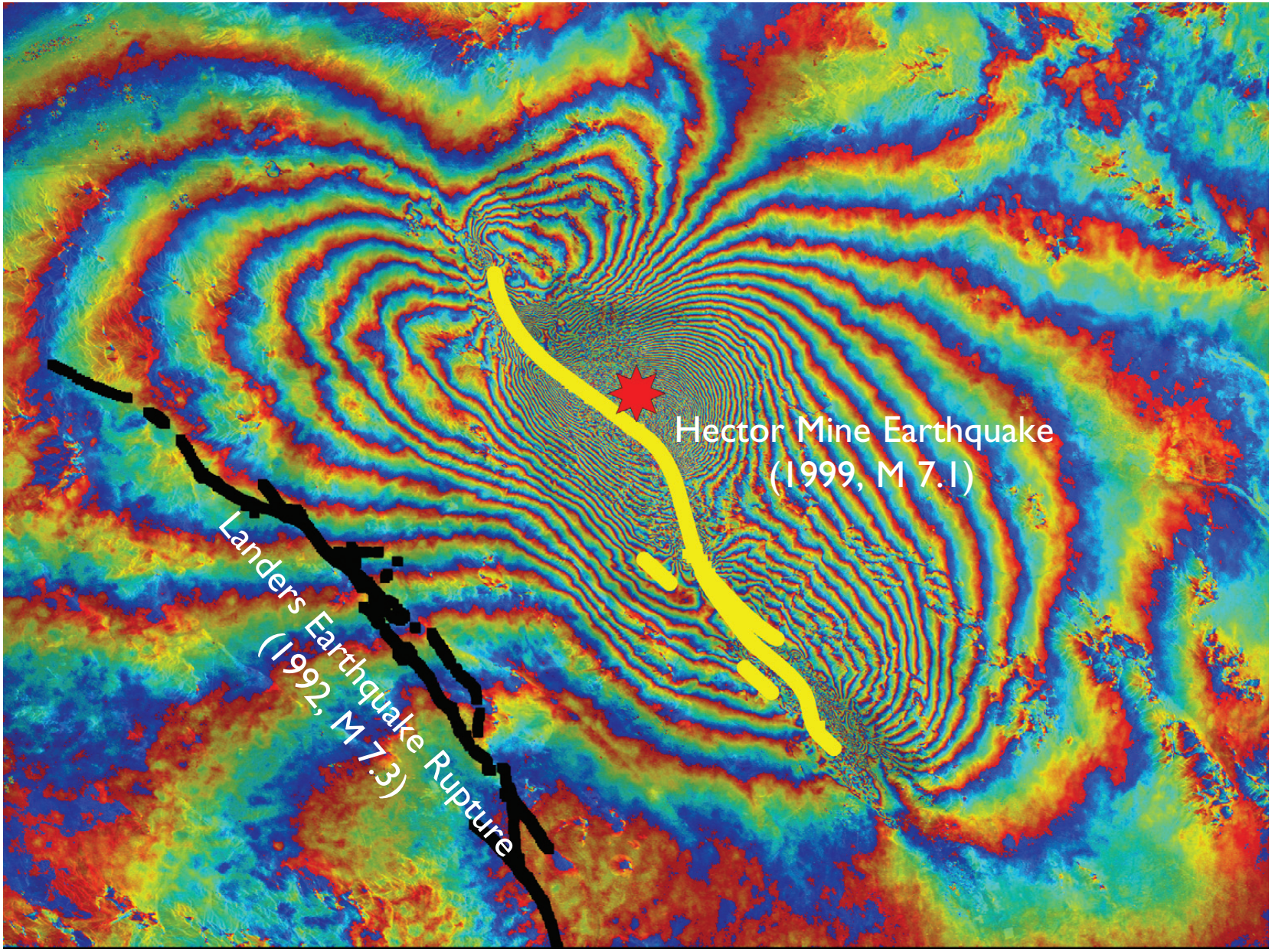


active microwave – ERS SAR



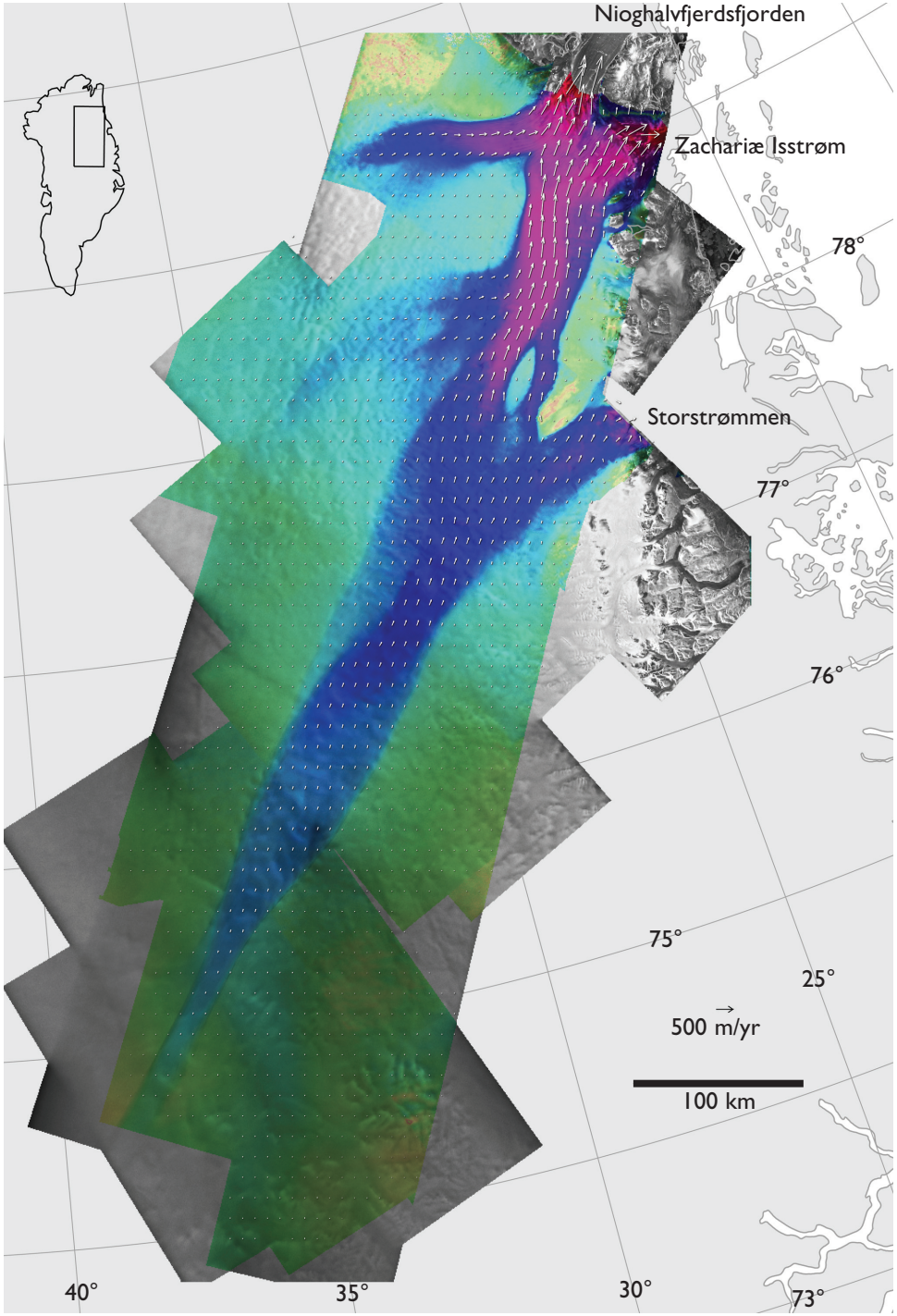
Sandwell and Smith
Our Changing Planet, 2007

active microwave – ERS SAR



Sandwell and Smith
Our Changing Planet, 2007

active microwave – ERS SAR



Rignot and Joughin
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Conclusions

- Study the electromagnetic spectrum. Should know the basic categories and their typical wavelengths.
- Sources of EM radiation: passive - Sun and Earth; active – spacecraft.
- Blackbody radiation – coming lecture
- Transparency of atmosphere: “windows” in visible, IR, and microwave, otherwise opaque.
- Main categories of remote sensing: passive visible; passive IR; passive microwave; active visible; active microwave.
- Types of orbits and their applications: geostationary – communications and weather; low Earth polar orbit (LEO) – all types of remote sensing; sun synchronous – passive visible remote sensing.