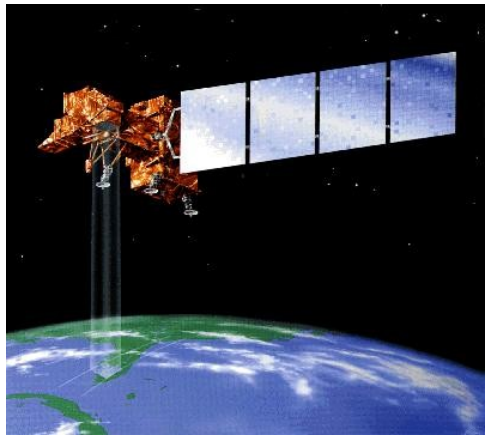
Satellite Remote Sensing
SIO 135/SIO 236

Lecture 6: Thermal Radiation

Helen Amanda Fricker



Thermal satellite sensors

Landsat Thematic Mapper (Landsat-4 onwards)

Advanced, multispectral scanning, with improvements over MSS:

- higher spatial and radiometric resolution
- finer spectral bands
- seven vs four spectral bands acquired simultaneously.

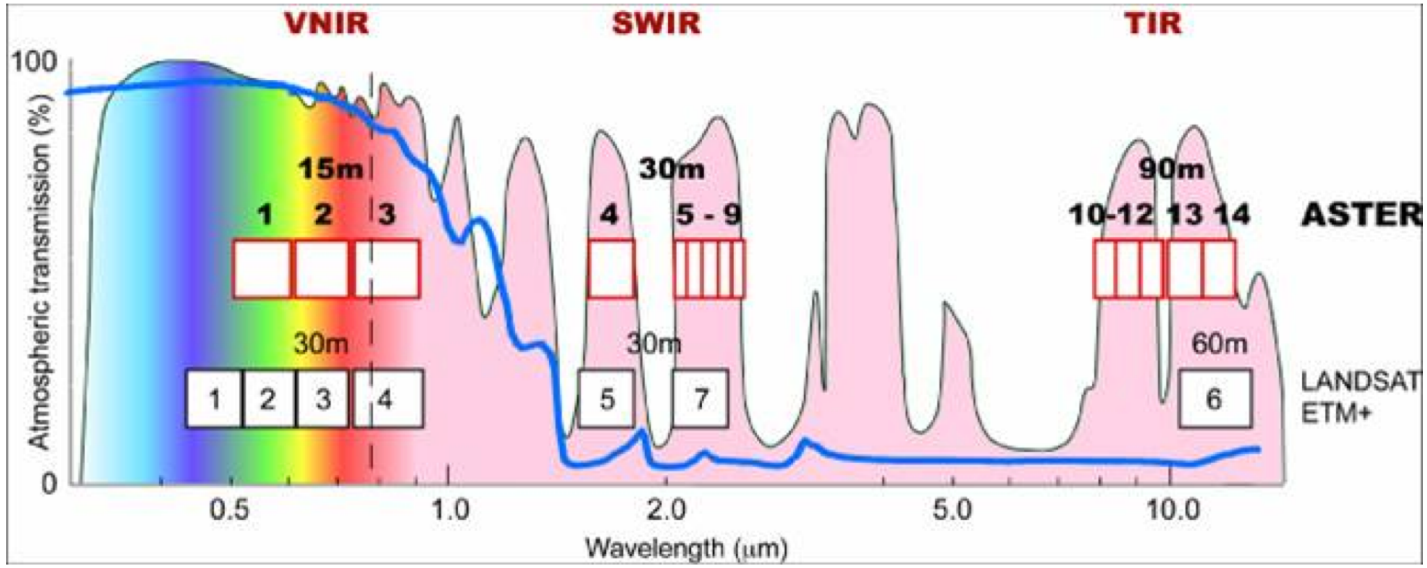
Band 6 senses thermal (heat) infrared radiation. Landsat can only acquire night scenes in Band 6.

Channel	Wavelength Range micrometer	Resolution	Spectrum
TM 1	0.45 - 0.52	30 m	Blue
TM 2	0.52 - 0.60	30 m	Green
TM 3	0.63 - 0.69	30 m	Red
TM 4	0.76 - 0.90	30 m	Near IR
TM 5	1.55 - 1.75	30 m	Short Wave IR
TM 6	10.4 - 12.5	120 m	Thermal IR
TM 7	2.08 - 2.35	30 m	Mid IR

TM replaced MSS completely after Landsat-5

Thermal satellite sensors

ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) on Terra (launched 1999)



The broad spectral coverage and high spectral resolution of ASTER provides critical information for surface mapping, and monitoring of dynamic conditions and temporal change.

E.g.: monitoring glaciers; monitoring volcanoes; identifying crop stress; determining cloud morphology and physical properties; wetlands evaluation; thermal pollution monitoring; coral reef degradation; surface temperature mapping of soils and geology; measuring surface heat balance.

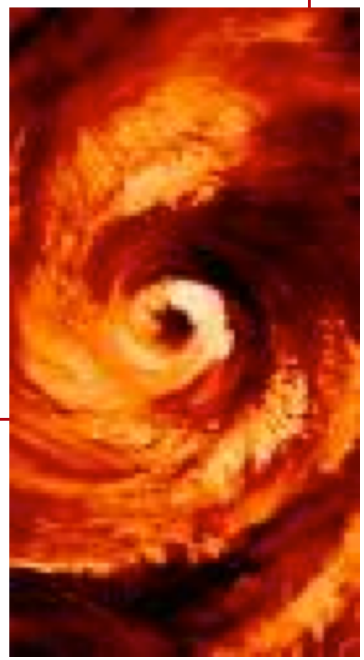
Thermal satellite sensors

Along-Track Scanning Radiometer ATSR

ATSR on ERS-1 (1991-19
ATSR-2 on ERS-2
AATSR on Envisat

ATSR consists of two instruments, an Infra-Red Radiometer (IRR) and a Microwave Sounder (MWS). On board ERS-1 the IRR is a four-channel infra-red radiometer used for measuring sea-surface temperatures (SST) and cloud-top temperatures, whereas on board ERS-2 the IRR is equipped with additional visible channels for vegetation monitoring. The MWS is a two channel passive radiometer.

ATSR-1/2 Spectral Bands (10^{-6} m)
0.545 - 0.565 (only ATSR-2)
0.649 - 0.669 (only ATSR-2)
0.855 - 0.875 (only ATSR-2)
1.580 - 1.640
3.550 - 3.930
10.40 - 11.30
11.50 - 12.50



ATSR nighttime false color image of Typhoon Saomai over the East China Sea.

Thermal satellite sensors

Bands are carefully chosen!

AVHRR 3.7μm window sits in the small overlap region between reflected solar radiation & emitted radiation from the earth and clouds.
At night there is no solar radiation component & the radiation in this channel comes from the earth.
By day there is a mixture of radiation of solar & terrestrial origin, but the solar radiation dominates.
At night, enhancing the resolution at the warm end of the grey scale can provide better discrimination of the low cloud cover than can be obtained from other IR images.

Resolution: 1.1 km at nadir

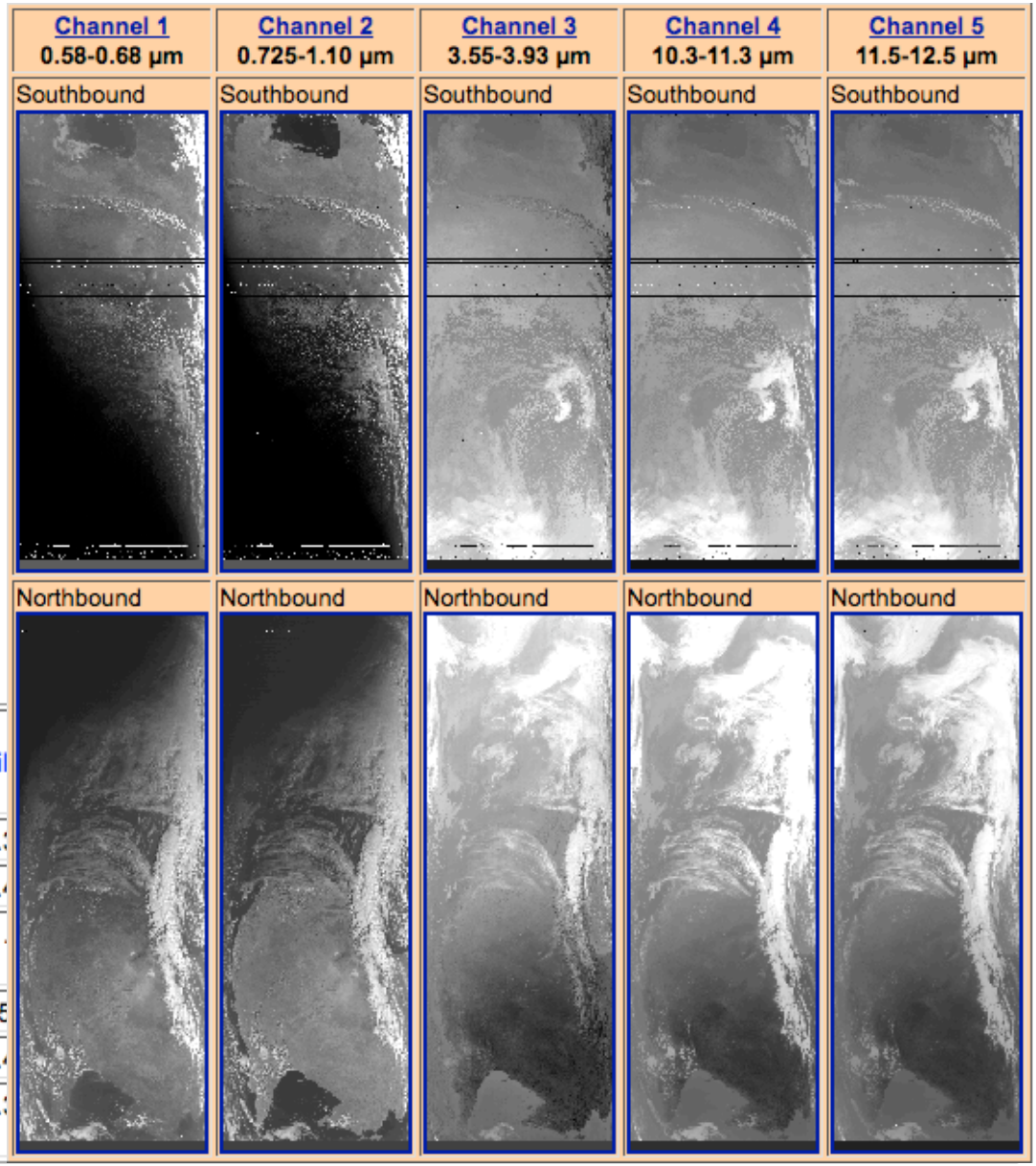
Channel Number	Wavelength (micrometers) NOAA-6,8,10,12	Wavelength (micrometers) NOAA-7,9,11	IFOV (milliradians)	Primary Uses
1	0.58 - 0.68	0.58 - 0.68	1.39	Daytime cloud/surface and vegetation mapping
2	0.725 - 1.10	0.725 - 1.10	1.41	Surface water, ice, snow melt, and vegetation mapping
3A	-	1.58-1.64 (NOAA 15-16)	1.3	Snow and ice detection
3B	3.55 - 3.93	3.55 - 3.93	1.51*	Sea surface temperature, night-time cloud mapping
4	10.50 - 11.50	10.3 - 11.3	1.41	Sea surface temperature, day and night cloud mapping
5	Channel 4 repeated	11.5 - 12.5	1.30	Sea surface temperature, day and night cloud mapping

Thermal satellite sensors

Advanced Very High Resolution Radiometer (AVHRR)

AVHRR is a broad-band, 4 or 5 channel (depending on model) scanner, sensing in the visible, near-infrared, and thermal infrared portions of EMS.

Carried on the NOAA's Polar Orbiting Environmental Satellites (POES), beginning with TIROS-N in 1978.



Channel Number	Wavelength (micrometers) NOAA-6,8,10,12	Wavelength (micrometers) NOAA-7,9,11	IFOV (mil
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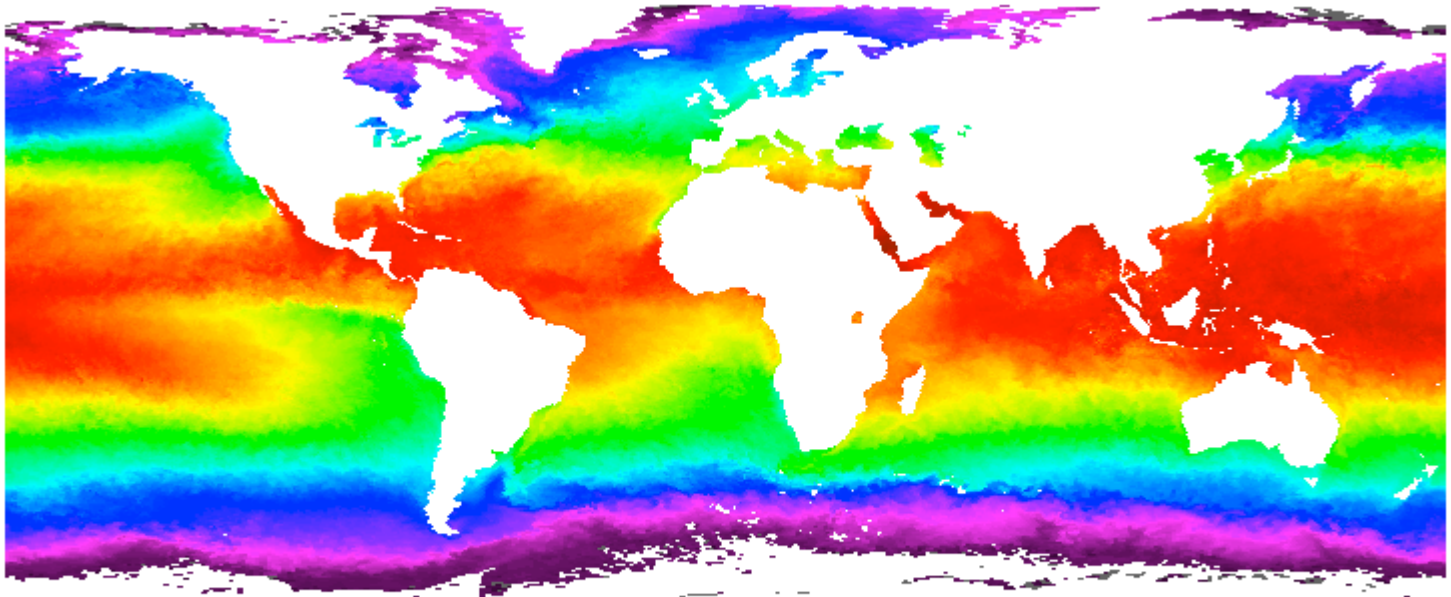
4	10.50 - 11.50	10.3 - 11.3	1.
5	Channel 4 repeated	11.5 - 12.5	1.

Some Applications of Thermal Remote Sensing

ASTER thermal IR image taken at night, showing (in light tones signifying warmer temperatures) the Red Sea and a small land area (dark; cooler) in Eritrea in eastern Africa.

Sea surface temperature

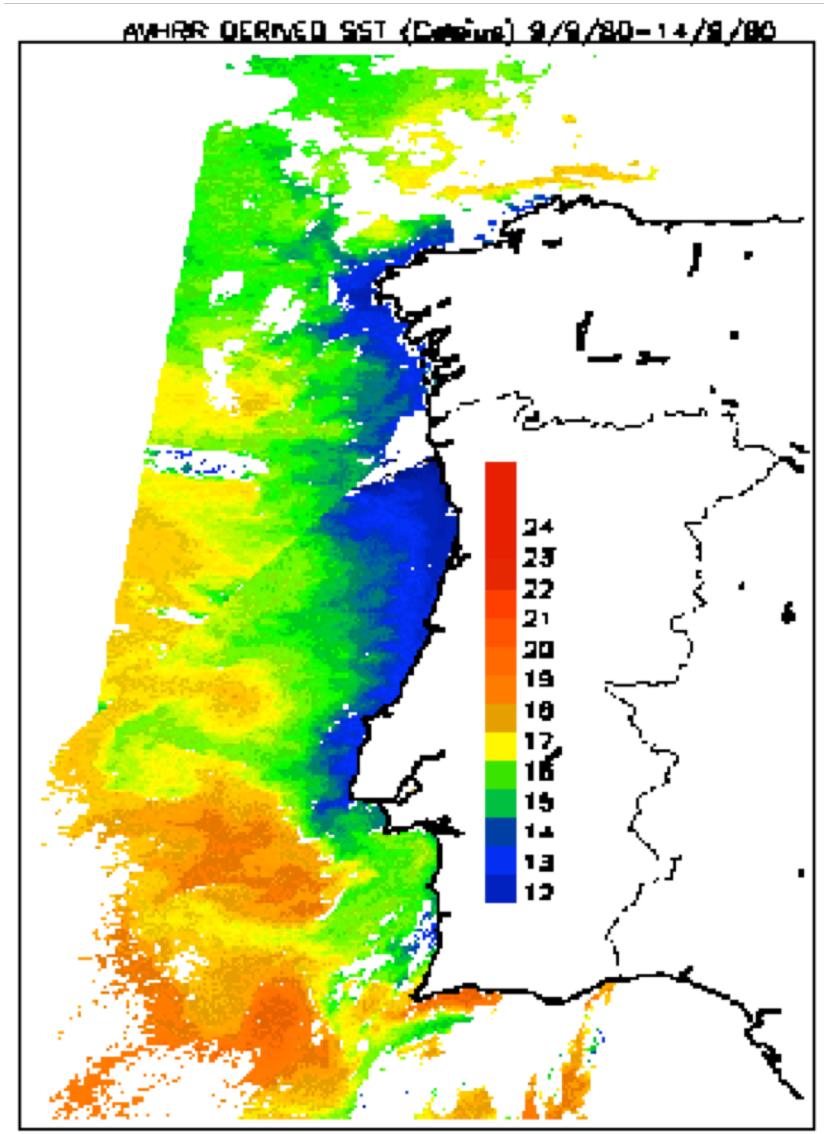
- Sea surface temperature (SST) is an important geophysical parameter, providing the boundary condition used in the estimation of heat flux at the air-sea interface.
- On the global scale this is important for climate modeling, study of the earth's heat balance, and insight into atmospheric and oceanic circulation patterns and anomalies (such as El Niño).
- On a local scale, SST can be used operationally to assess eddies, fronts and upwellings for marine navigation and to track biological productivity.

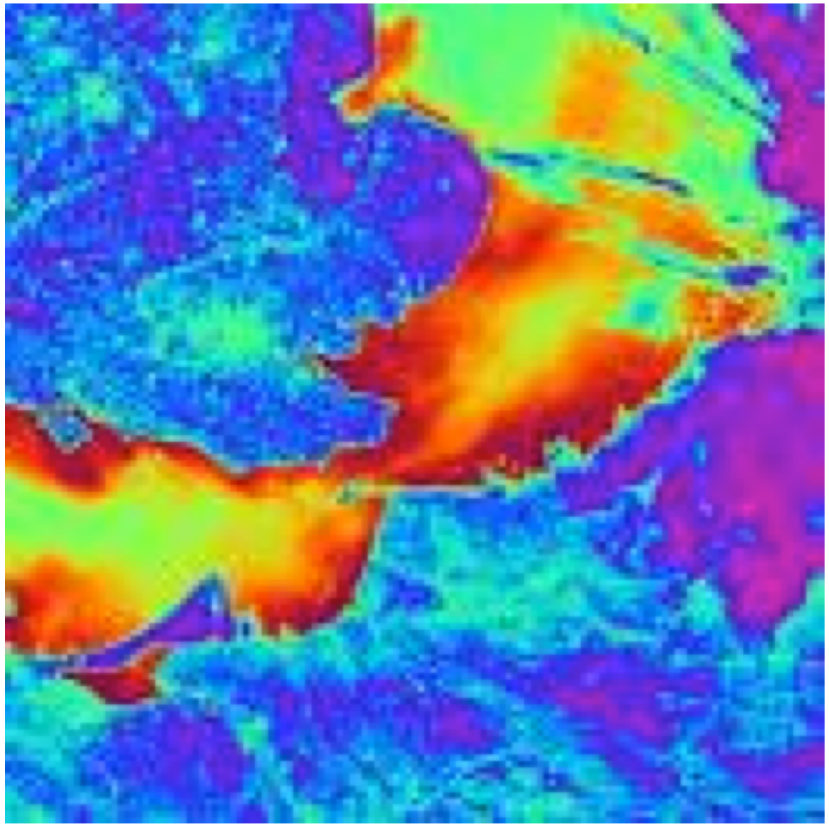


Calibration is very important for trends in SST!

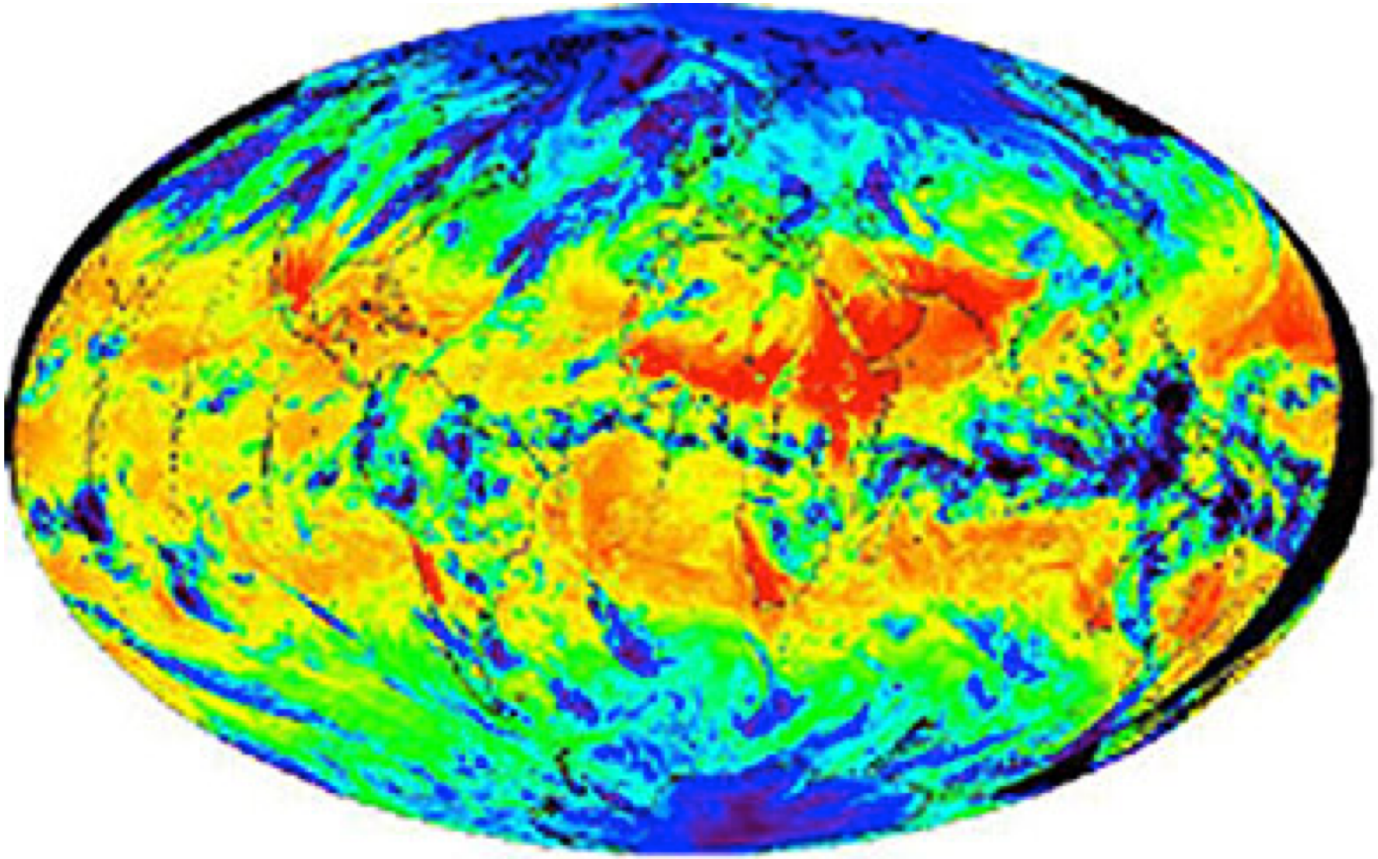
AVHRR Sea Surface Temperature, October 2001 (NASA/JPL PO.DAAC)

Sea surface temperature





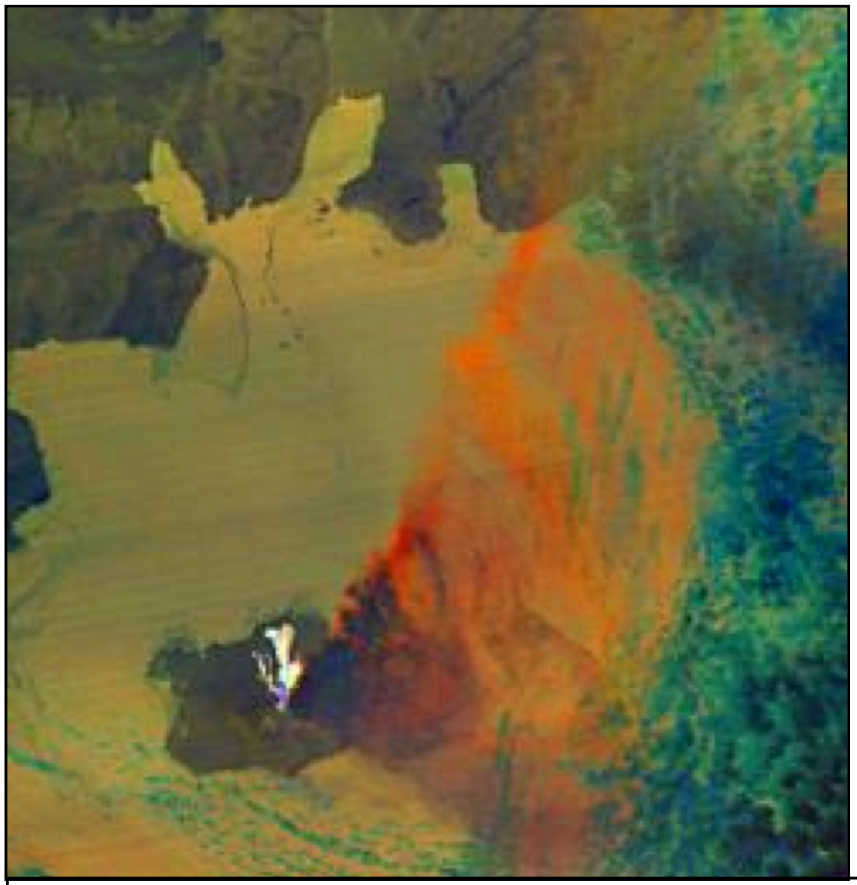
Thermal radiation from Earth



Emitted thermal radiation from both the atmosphere and land surfaces (with color assignments of red/yellow to warm and green/blue to cooler). From MODIS on Terra.

Thermal satellite sensors

ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) on Terra (launched 1999)



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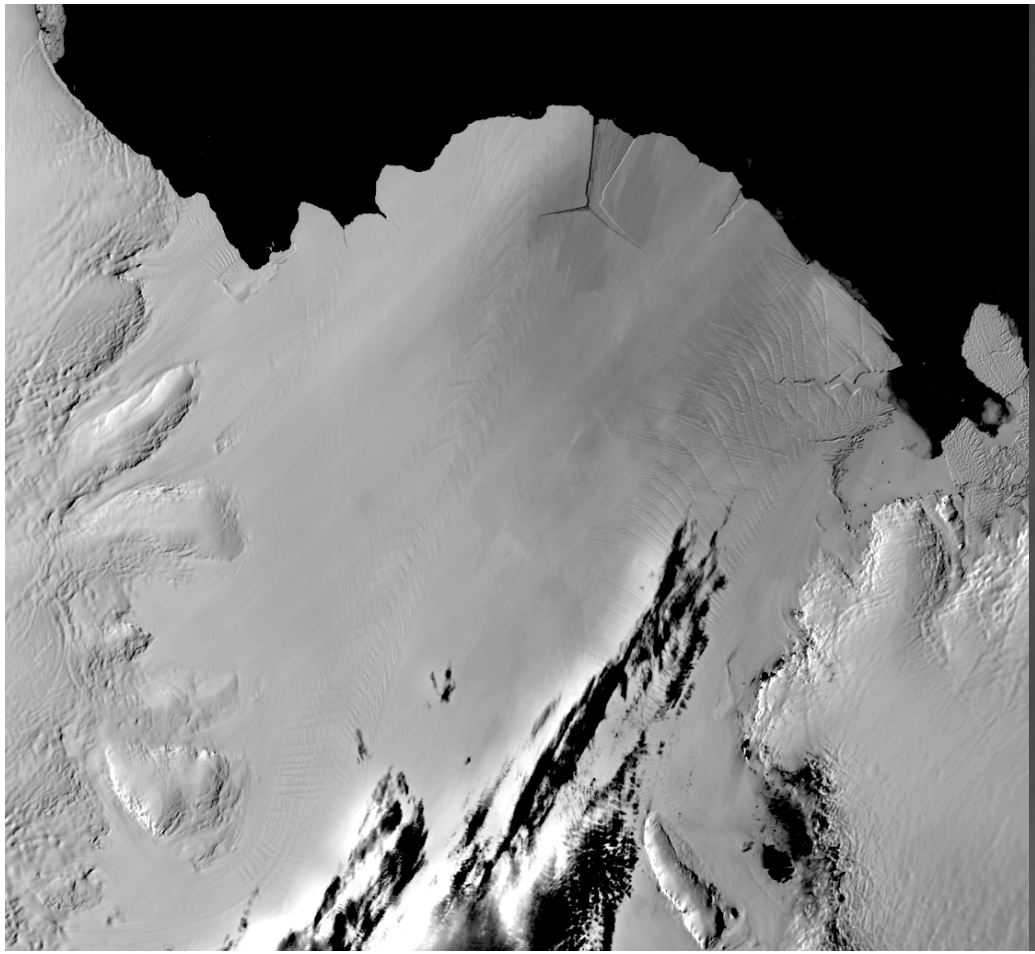
E.g.: monitoring glaciers; monitoring volcanoes; identifying crop stress; determining cloud morphology and physical properties; wetlands evaluation; thermal pollution monitoring; coral reef degradation; surface temperature mapping of soils and geology; measuring surface heat balance.

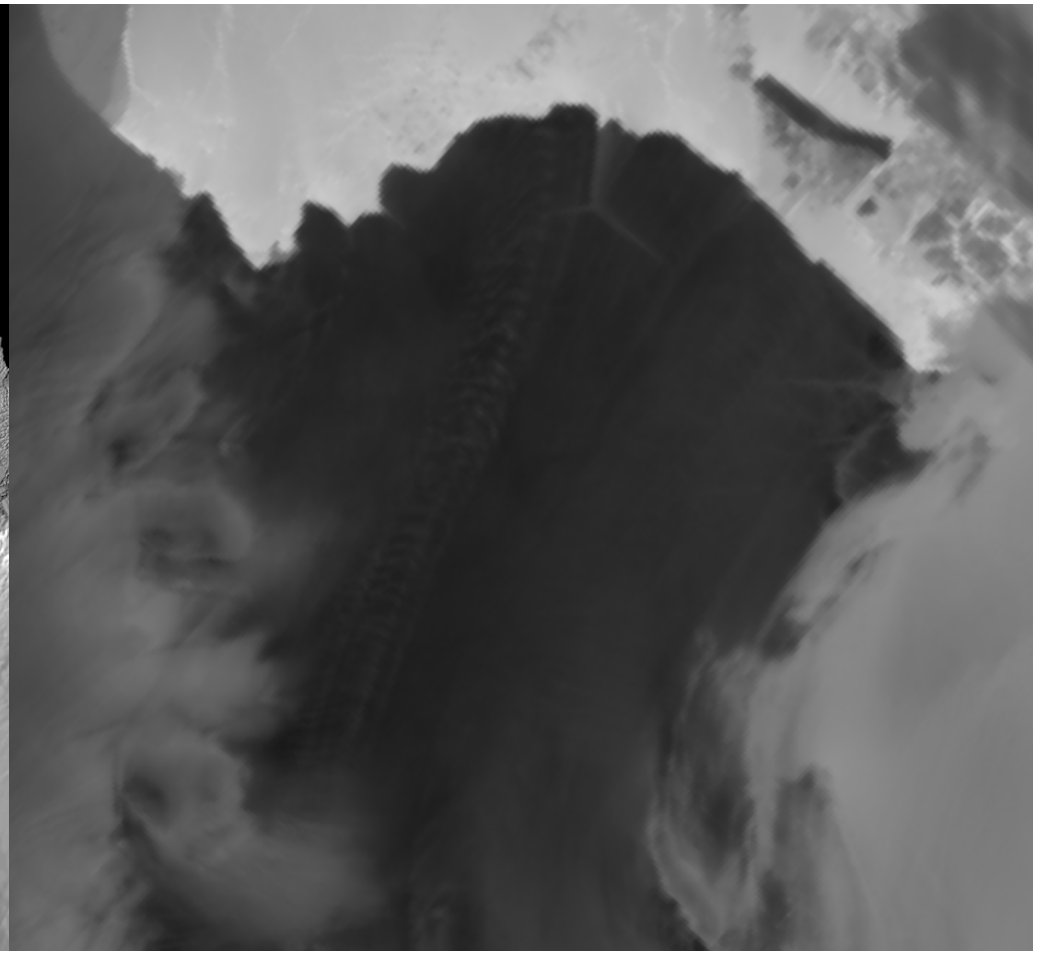
Augustine Volcano, Cook Inlet, Alaska (22:50 AST January 31, 2006).
This ASTER thermal image was acquired at night during an eruptive phase.

Monitor the ice sheets during polar winter

- During polar darkness, cannot get visible images from Antarctica
- Thermal helps to lengthen time series (although lower resolution) λ/d!



MODIS Terra visible 13 March 2009



MODIS Aqua thermal 6 April 2009

Monitor the ice sheets during polar winter

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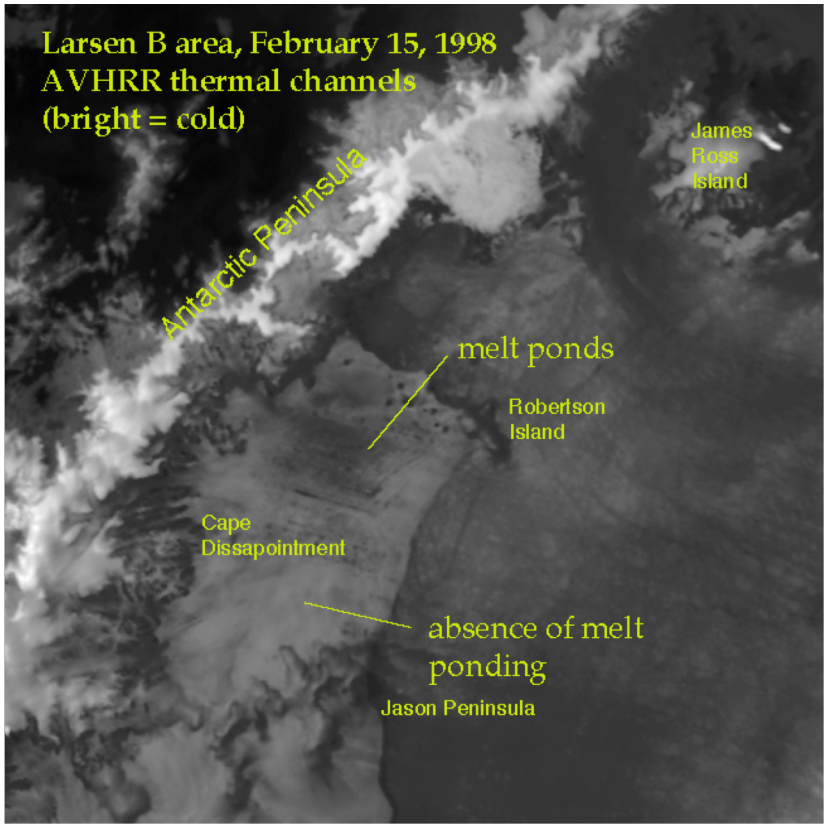
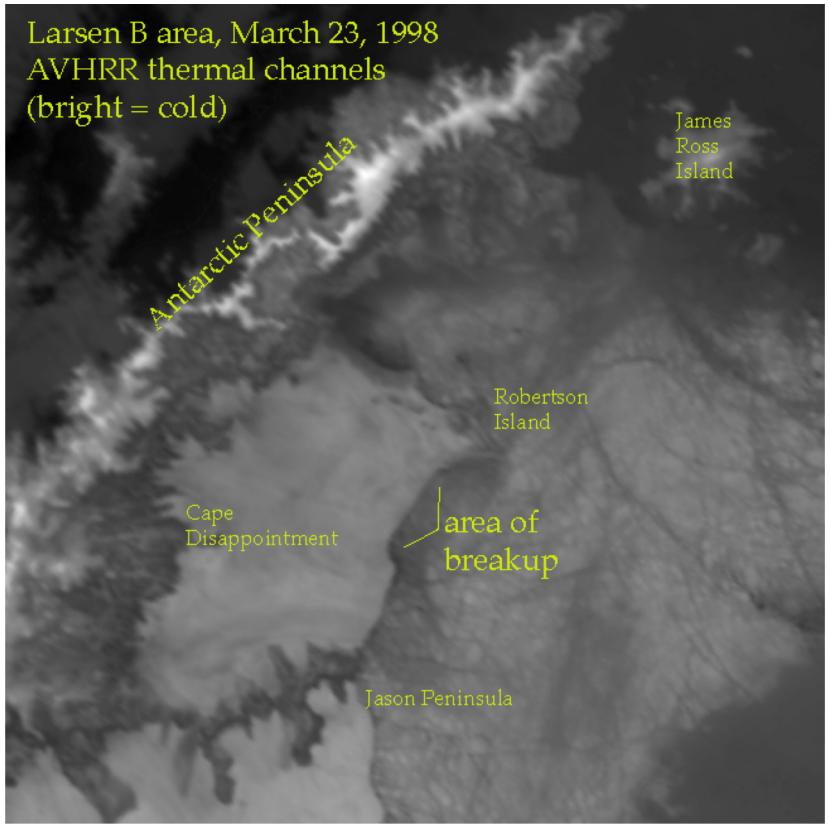
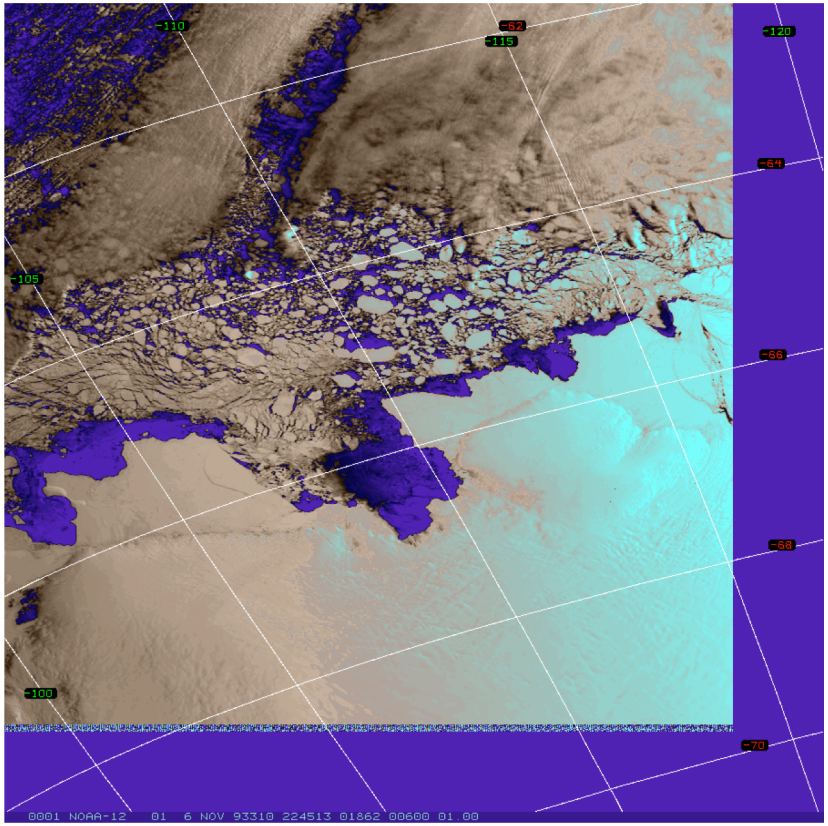




Sea-ice mapping

- Monitor extent of sea-ice in the Arctic and Antarctic

- Thermal remote sensing can distinguish between the sea-ice and “leads” (open water between the sea-ice) -- useful for navigation and for science



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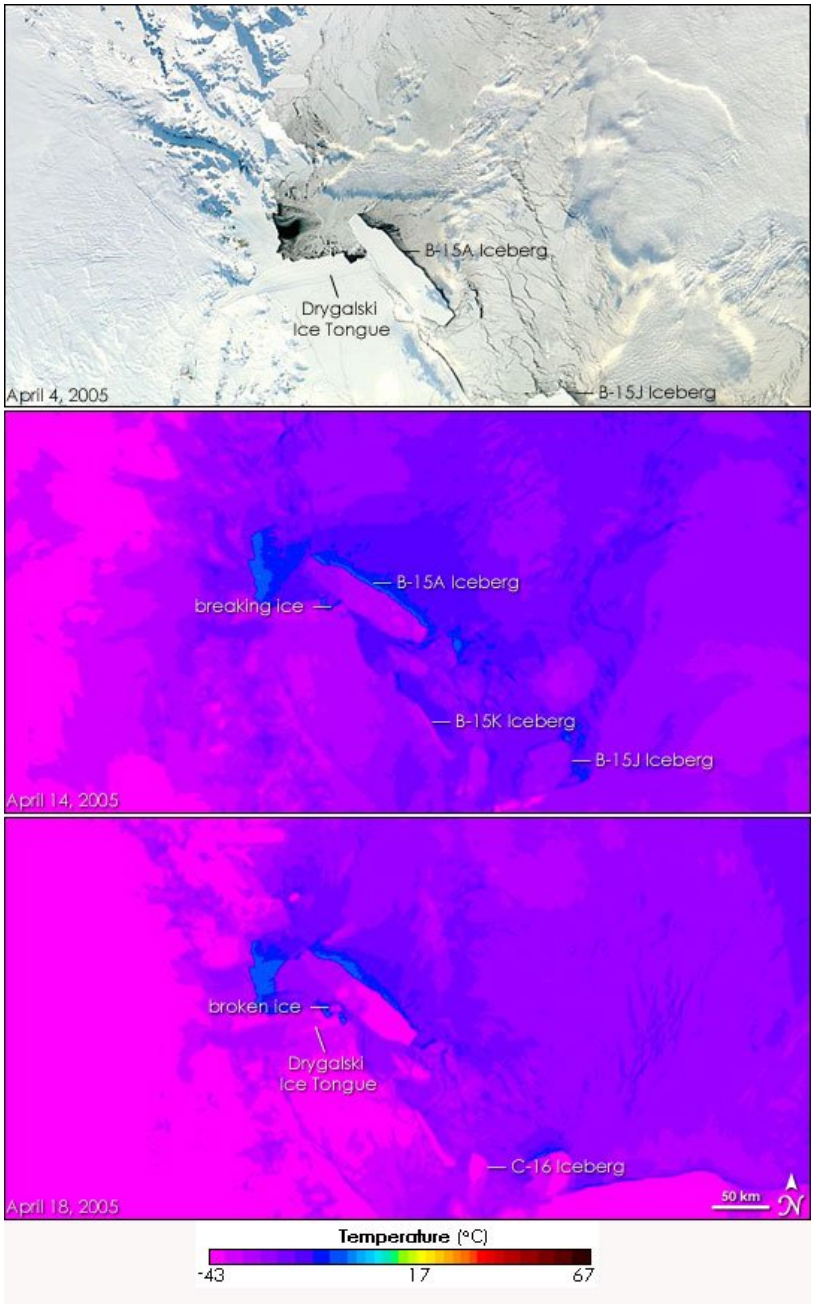
Thermal satellite sensors

NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) has several bands in the thermal IR

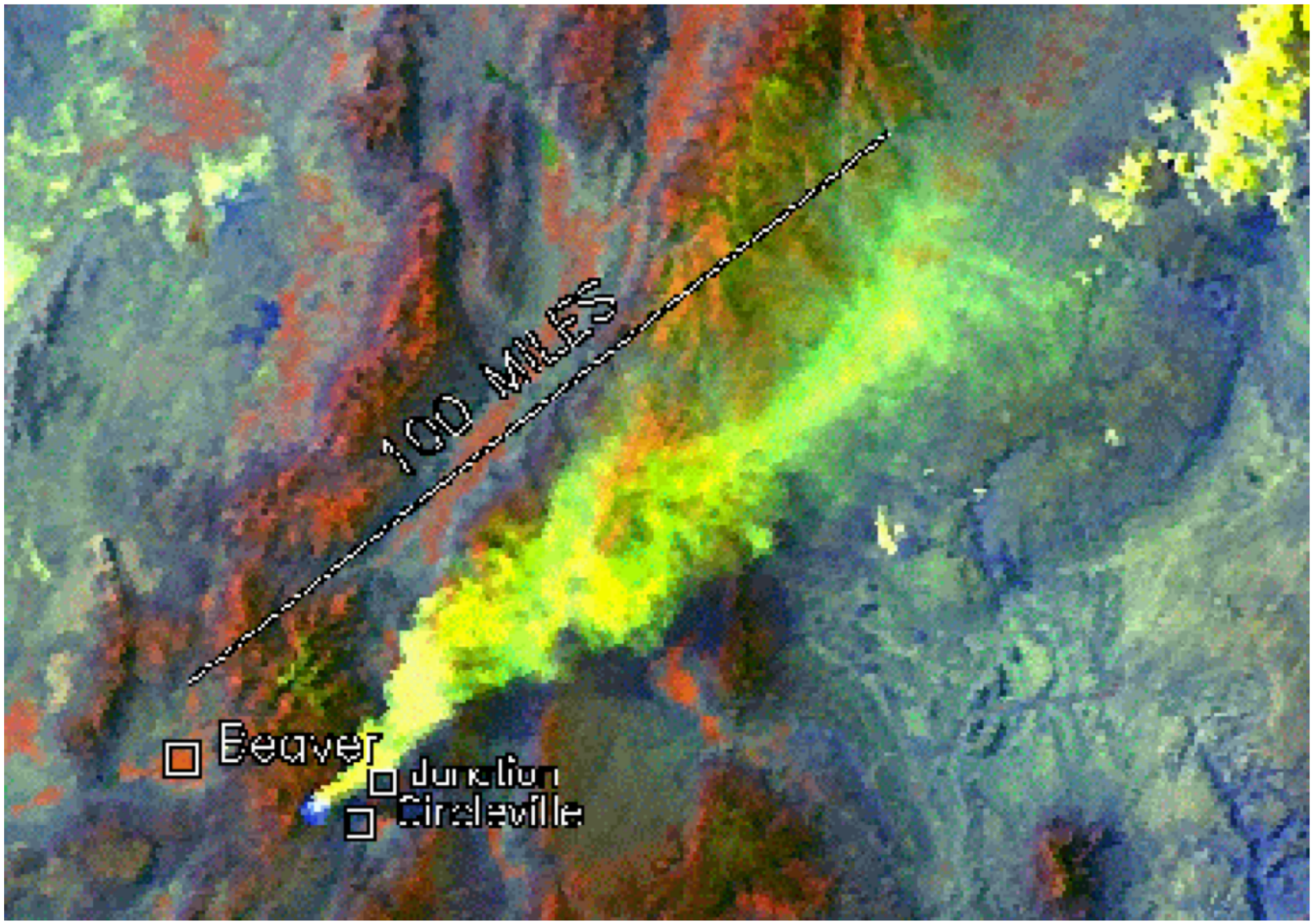


Fire monitoring

Images of 1988 Yellowstone fires. Visible image is what you'd see flying over a forest fire - smoke! Right image combines several infrared bands (reflective and thermal infrared) to cut through the smoke. Bright yellow areas are actively burning fire lines.

Fire monitoring

Major fires are commonly imaged by satellites, and the extent of the burn damage is easily assessed afterwards by the dark patterns in the visible bands.



“False color” AVHRR composite (made by assigning channel 1 image to red, channel 2 to green, and channel 3 to blue). In this version, the smoke shows as yellow and the fire, at the head of the smoke column, appears as bright blue.