Low and medium resolution imagery

Low/medium res. imagery

- Affordable, accessible
- Large ground coverage
- Decades of historical imagery
- Low level of detail

High Res. Imagery

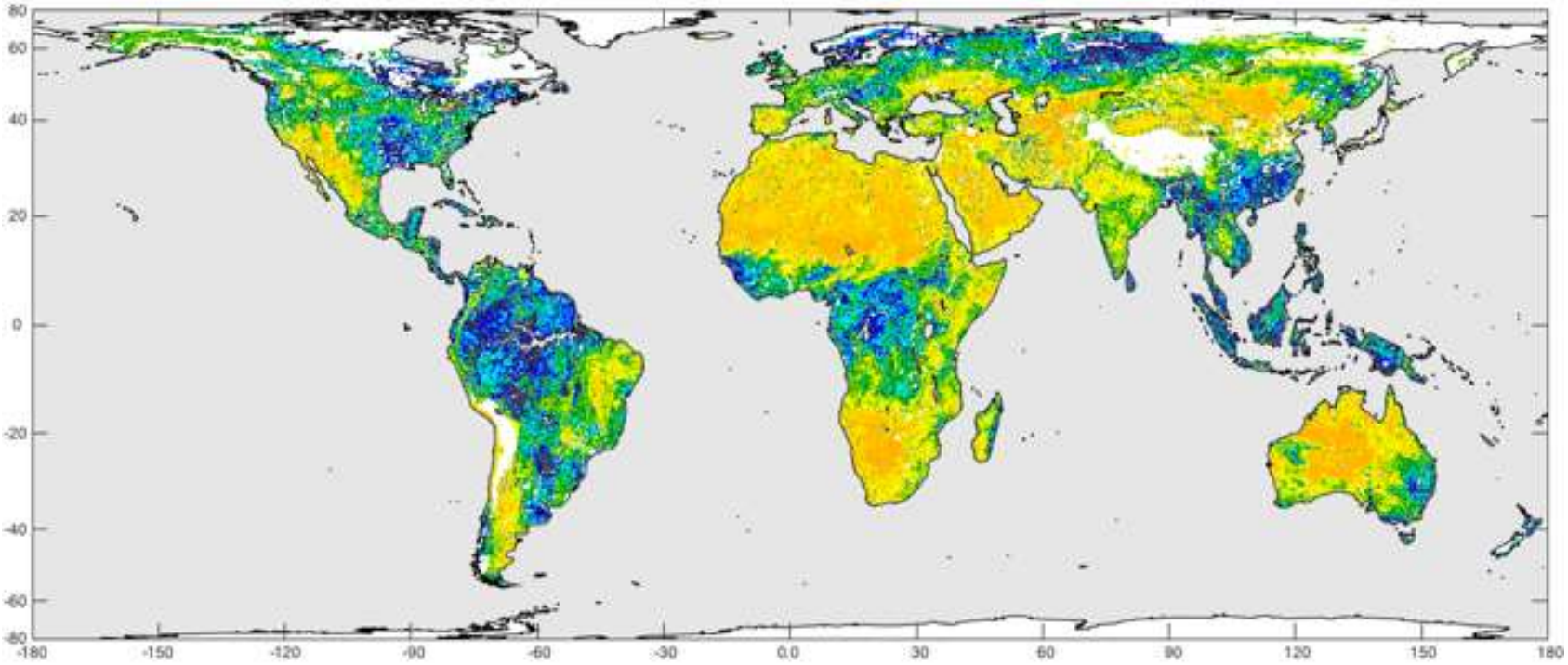
- High level of detail
- On demand coverage
- Expensive, inaccessible
- Small ground coverage

Soil Moisture Active Passive (SMAP) mission, 2015

Active: RADAR; Passive Microwave : Radiometer (9km)

SMAP is designed to measure soil moisture, every 2-3 days.

RADAR portion failed quickly, replaced by Sentinel-1 (radar)

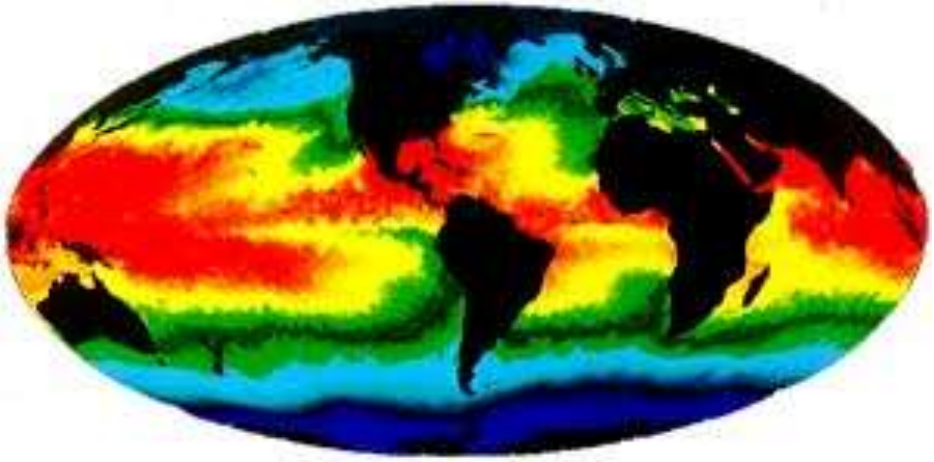


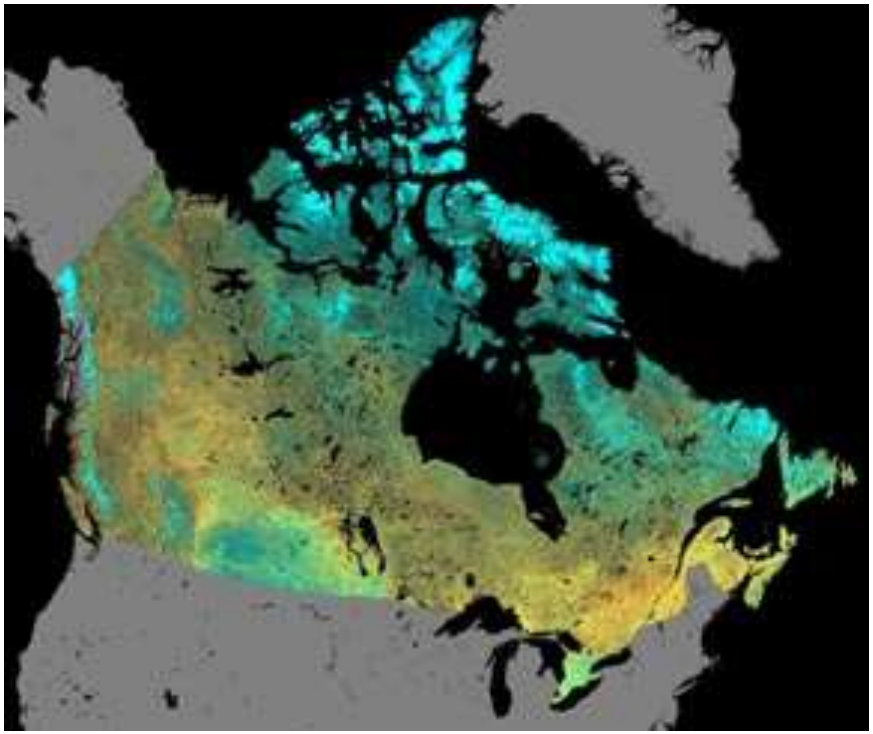
Retrieved soil moisture based on the SMAP “active” and “passive” radiometer data. SMAP Active-Passive Soil Moisture Product (9 km). Three Days Composite May 21- 23, 2015

Advanced Very High Resolution Radiometer (AVHRR), 1978->

NOAA AVHRR Bands

Band	Wavelength Range (μm)	Spatial Resolution	Application
1	0.58 - 0.68 (red)	1.1 km	cloud, snow, and ice monitoring
2	0.725 - 1.1 (near IR)	1.1 km	water, vegetation, and agriculture surveys
3	3.55 -3.93 (mid IR)	1.1 km	sea surface temperature, volcanoes, and forest fire activity
4	10.3 - 11.3 (thermal IR)	1.1 km	sea surface temperature, soil moisture
5	11.5 - 12.5 (thermal IR)	1.1 km	sea surface temperature, soil moisture





NOAA satellites: Advanced Very High Resolution Radiometer (AVHRR)

'High resolution' refers to temporal coverage not spatial size (1.1km)

NOAA-1	1970-71	NOAA-2	1972-75	These carried the VHRR
NOAA-3	1973-76	NOAA-4	1974-78	mostly experimental for weather
NOAA-5	1976-79			

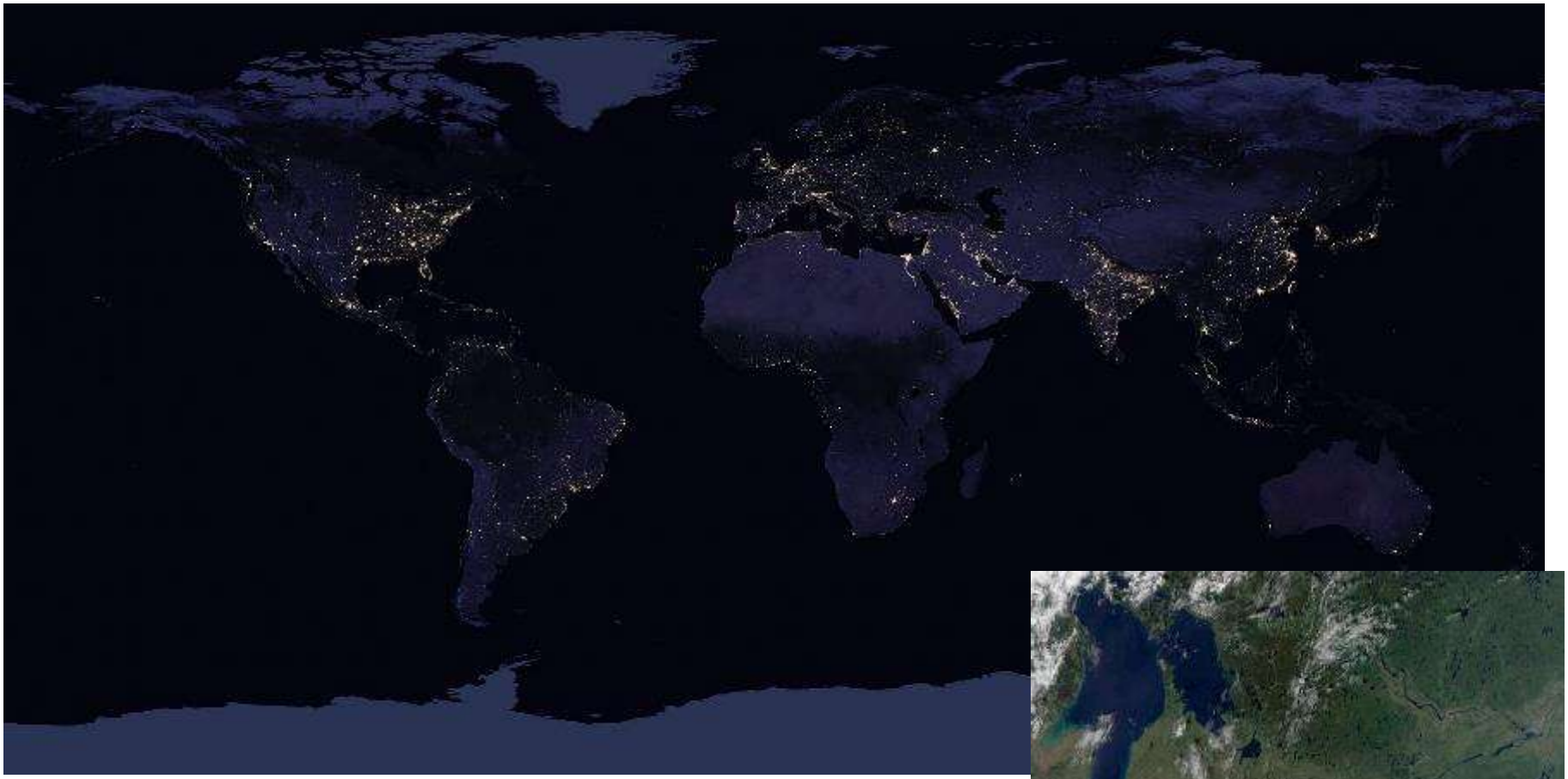
TIROS: Television Infrared Observation Satellites (since 1960)

	Equator Crossing Times		
Satellite	**Ascending**	**Descending**	**Service**
TIROS-N	1500	0300	10/19/78 - 01/30/80
NOAA-6	1930	0730	06/27/79 - 11/16/86
NOAA-7	1430	0230	08/24/81 - 06/07/86
NOAA-8	1930	0730	05/03/83 - 10/31/85
NOAA-9	1420	0220	02/25/85 - Present
NOAA-10	1930	0730	11/17/86 - Present
NOAA-11	1340	0140	11/08/88 - 09/13/94
NOAA-12	1930	0730	05/14/91 - stand by
NOAA-14	1340	0140	12/30/94 - Present
NOAA-15	1930	0730	05/13/98 - Present
NOAA-16	1400	0200	21/09/00 - Present
NOAA-17	2200	1000	24/06/02 - Present
NOAA-18	1400	0200	20/05/05 - Present

NOAA-19	1400	2009->
NOAA-20	**VIIRS (SUOMI)**	2017 ->

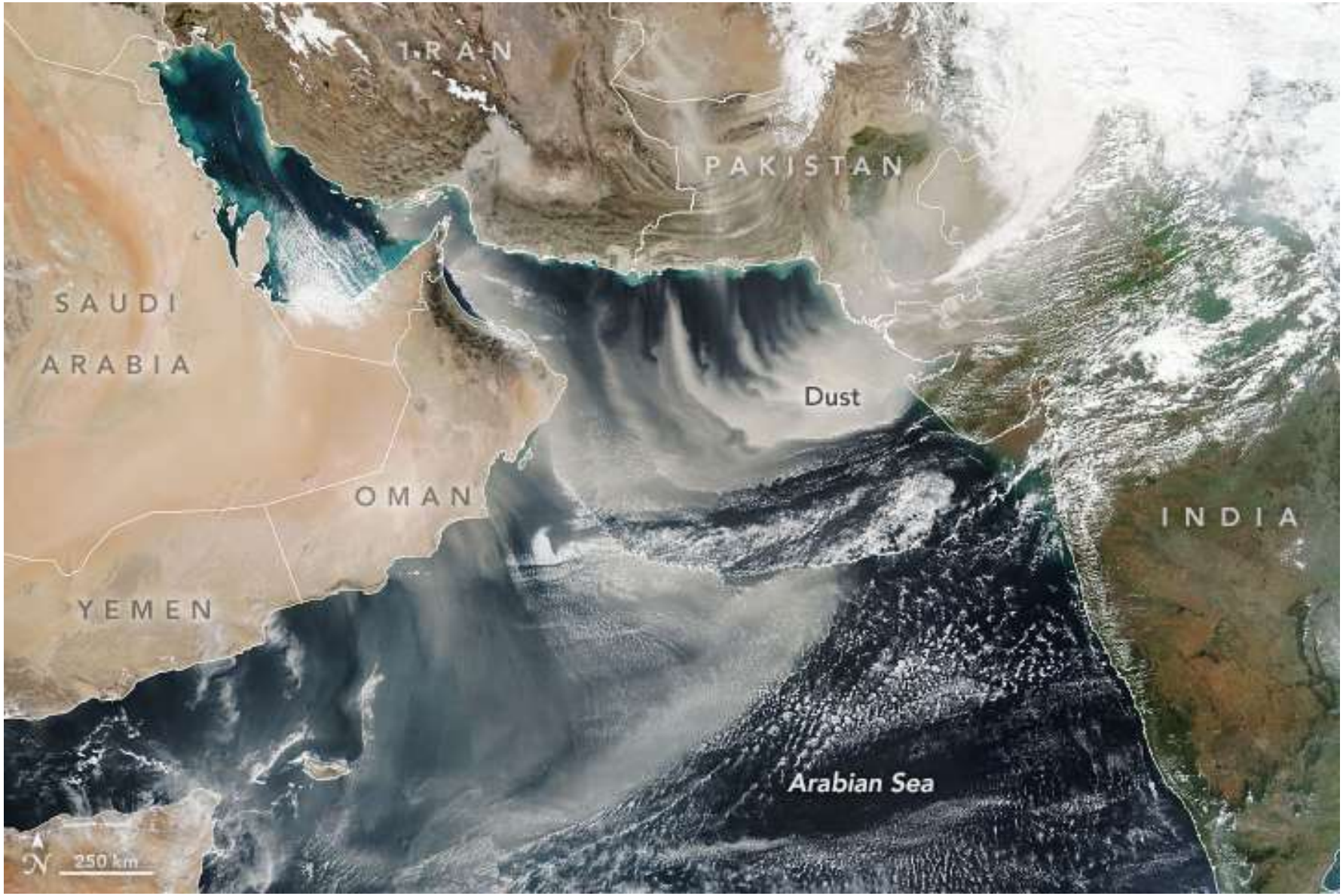
Visible Infrared Imaging Radiometer Suite (VIIRS)

22 bands (superspectral) – 16 have 750m resolution, Blue->Thermal
Higher resolution than AVHRR, modelled on MODIS

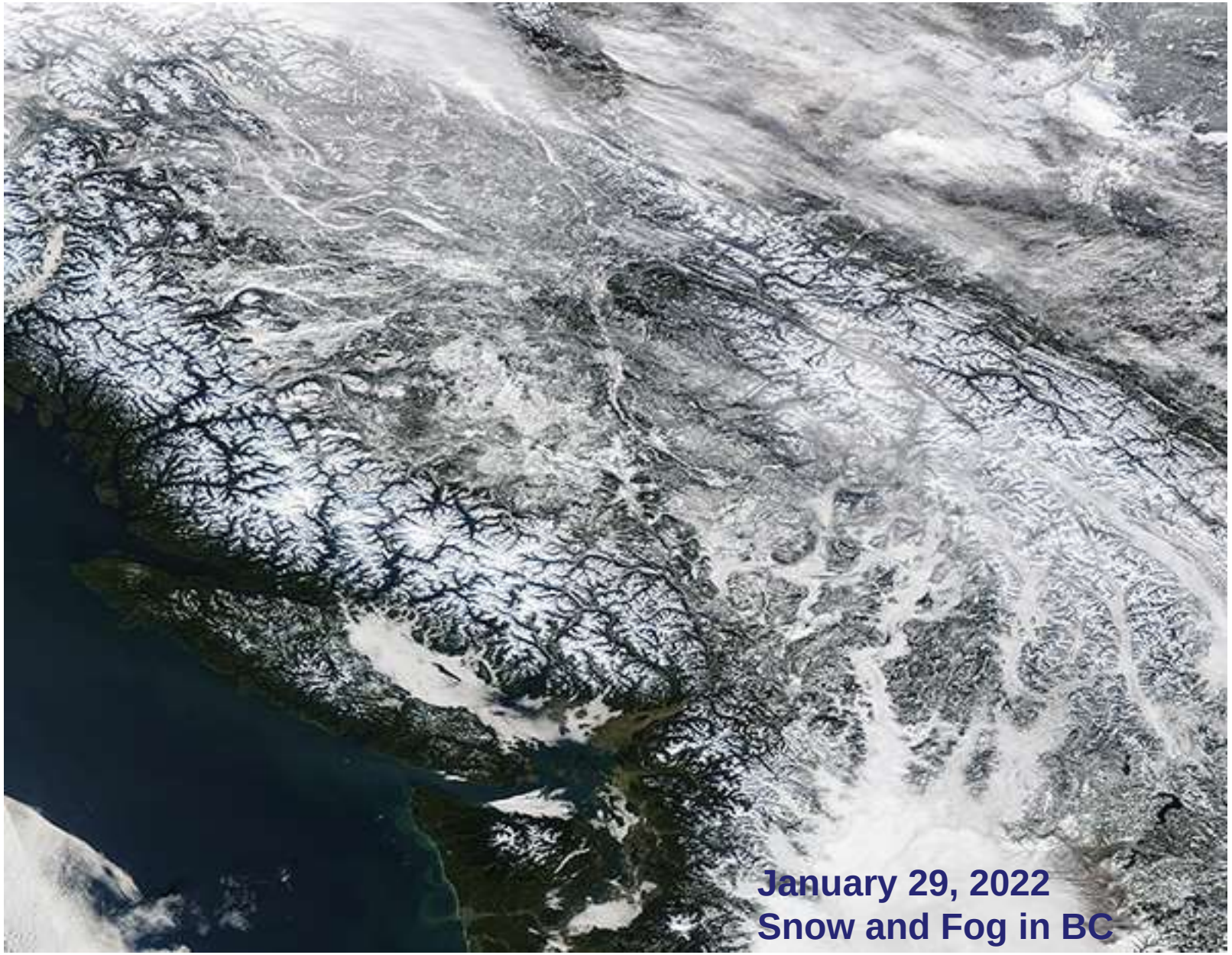


Canada's human footprint reveals large intact areas juxtaposed against areas under immense anthropogenic pressure (2021) DOI:10.1101/2021.06.11.447577

Dust Storm VIIRS, January 22, 2022



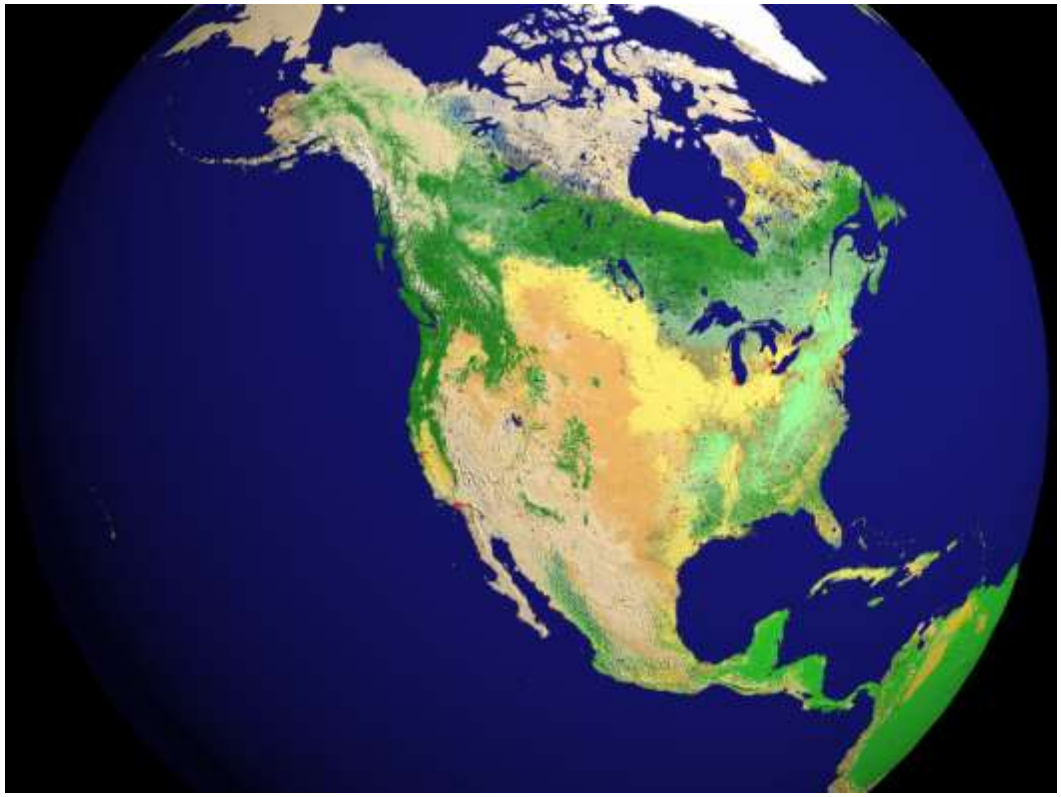
MODIS (Moderate-resolution Imaging Spectroradiometer)



Launched by NASA in Dec. 1999 on the Terra (EOS AM) satellite, and in May 2002 on the Aqua (EOS PM) satellite.

Designed to combine some characteristics of AVHRR (1978->) and Landsat TM (1982->) plus atmospheric /cloud parameters

It is the predominant global medium scale sensor



MODIS (Moderate-resolution Imaging Spectroradiometer)

- 36 spectral bands range in wavelength: 0.4 to 14.4 μm
- spatial resolutions: 250m to 1km
- Terra: 10.30am descending
- Aqua: 1.30pm ascending
- Swath: 2330 km; Earth covered in 1-2 days
- Data: 12-bit; design life 6 years (going on 22 …)

MODIS superspectral bands, wavelengths

Reflected Solar Bands			Emissive Bands
Aggregrated 250 m	*Aggregrated 500 m*	*1 km*	*1 km*
Band 1 (620-670 nm)	Band 3 (459-479 nm)	Band 8 (405-420 nm)	Band 20 (3.660-3.840 µm)
Band 2 (841-876 nm)	Band 4 (545-565 nm)	Band 9 (438-448 nm)	Band 21 (3.929-3.989 µm)
	Band 5 (1230-1250 nm)	Band 10 (483-493 nm)	Band 22 (3.939-3.989 µm)
	Band 6 (1628-1652 nm)	Band 11 (526-536 nm)	Band 23 (4.020-4.080 µm)
	Band 7 (2105-2155 nm)	Band 12 (546-556 nm)	Band 24 (4.433-4.498 µm)
		Band 13L (662-672 nm)	Band 25 (4.482-4.549 µm)
		Band 13H (662-672 nm)	Band 27 (6.535-6.895 µm)
		Band 14L (673-683 nm)	Band 28 (7.175-7.475 µm)
		Band 14H (673-683 nm)	Band 29 (8.400-8.700 µm)
		Band 15 (743-753 nm)	Band 30 (9.580-9.880 µm)
		Band 16 (862-877 nm)	Band 31 (10.780-11.280 µm)
		Band 17 (890-920 nm)	Band 32 (11.770-12.270 µm)
		Band 18 (931-941 nm)	Band 33 (13.185-13.485 µm)
		Band 19 (915-965 nm)	Band 34 (13.485-13.785 µm)
		Band 26 (1.360-1.390 µm)	Band 35 (13.785-14.085 µm)
			Band 36 (14.085-14.385 µm)

MODIS BANDS and their PRINCIPAL AREAS OF APPLICATION

Primary Use	Band	Bandwidth (nm)	Central Wavelength (nm)	Pixel Size (m)
Land/Cloud /Aerosols Boundaries	1	620 - 670	645.5	250
	2	841 - 876	856.5	250
Land/Cloud /Aerosols Properties	3	459 - 479	465.6	500
	4	545 - 565	553.6	500
	5	1230 - 1250	1241.6	500
	6	1628 - 1652	1629.1	500
	7	2105 - 2155	2114.1	500
Ocean Color/ Phytoplankton/ Biogeochemistry	8	405 - 420	411.3	1000
	9	438 - 448	442.0	1000
	10	483 - 493	486.9	1000
	11	526 - 536	529.6	1000
	12	546 - 556	546.8	1000
	13	662 - 672	665.5	1000
	14	673 - 683	676.8	1000
	15	743 - 753	746.4	1000
	16	862 - 877	866.2	1000
Atmospheric Water Vapor	17	890 - 920	904.0	1000
	18	931 - 941	935.5	1000
	19	915 - 965	935.2	1000
Surface/Cloud Temperature	20	3.660 - 3.840	3.785	1000
	21	3.930 - 3.989	3.960	1000
	22*	3.930 - 3.989	3.960	1000
	23	4.020 - 4.080	4.056	1000
Atmospheric Temperature	24	4.433 - 4.498	4.472	1000
	25	4.482 - 4.549	4.545	1000
Cirrus Clouds	26	1.360 - 1.390	1.383	1000
Water Vapor	27	6.535 - 6.895	6.752	1000
	28	7.175 - 7.475	7.334	1000
Cloud Properties	29	8.400 - 8.700	8.518	1000
Ozone	30	9.580 - 9.880	9.737	1000
Surface/Cloud Temperature	31	10.780 - 11.280	11.017	1000
	32	11.770 - 12.270	12.032	1000
Cloud Top Altitude	33	13.185 - 13.485	13.359	1000
	34	13.485 - 13.785	13.675	1000
	35	13.785 - 14.085	13.907	1000
	36	14.085 - 14.385	14.192	1000

The moderate resolution imaging spectroradiometer (MODIS): Land remote sensing for global change research. 1998. *IEEE Transactions on Geoscience and Remote Sensing*, *36*(4), 1228-1249. https://doi.org/10.1109/36.701075

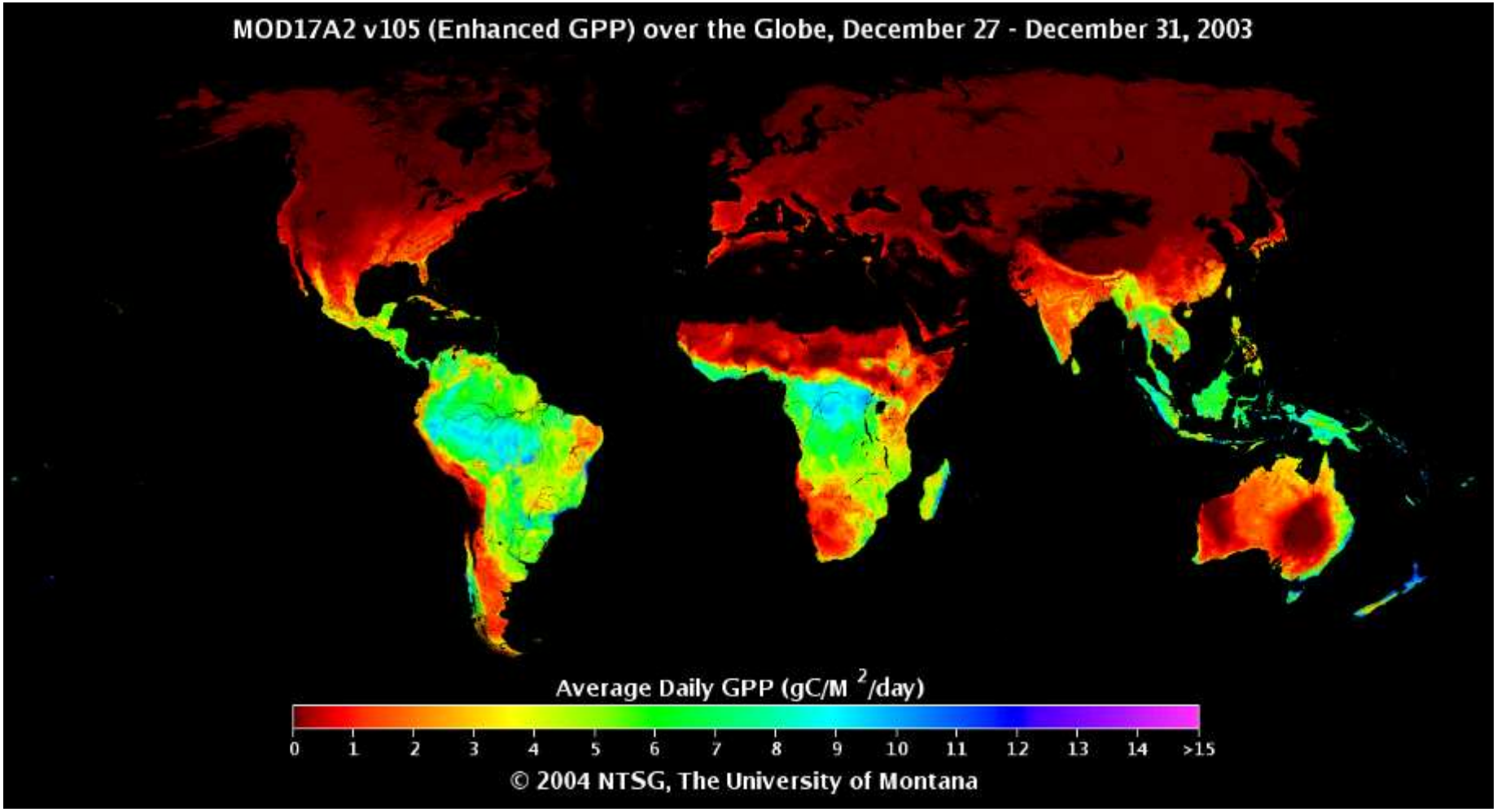
MODIS SPECIAL THEMES

MODIS Team Member	MODIS Product
E. Vermote	Surface Reflectance
Z. Wan	Land Surface Temperature
A. Strahler/J.-P. Muller	BRDF/Albedo
A. R. Huete/C. O. Justice	Vegetation Indexes
R. B. Myneni/S. W. Running	LAI/FPAR [1]
C. O. Justice/Y. J. Kaufman	Fires/Burned Area
D. Hall	Snow/Ice/Sea Ice
J. R. G. Townshend/A. Strahler	Land Cover/Land Cover Change
S. W. Running	PSN/NPP [2]

1. Leaf Area Index / fraction of photosynthetically active radiation

2. Net Photosynthesis/ Net Primary Productivity

GPP: The rate at which light energy is converted to plant biomass …
The sum total of the energy is called gross primary productivity



MODIS Land Products / Research Themes

- *Energy Balance Product*
  - Surface Reflectance
  - Land Surface Temperature
  - Albedo
  - Snow Cover

Global Water Cycle and Energy Balance

- *Vegetation Parameters*
  - Vegetation Indices
  - LAI/FPAR
  - NPP/PSN

Biology and Biogeochemistry of Ecosystems and Global Carbon Cycle

- *Land Cover Land Use*
  - Land Cover
  - Vegetation Continuous Fields
  - Vegetation Cover Change
  - Fire and Burned Area

Land Cover and Land Use Change

Atmospheric Chemistry and Aerosols

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

+ NASA Homepage

SEARCH GO

MODIS Web

+ ABOUT MODIS | + NEWS | + DATA | + IMAGES | + SCIENCE TEAM | + RELATED SITES | + SEARCH | + MODARCH

DATA

The MODIS Data section contains everything from ATBDs to Product Descriptions to tutorials on ordering MODIS data from the various DAACs. Peruse the Data section today.

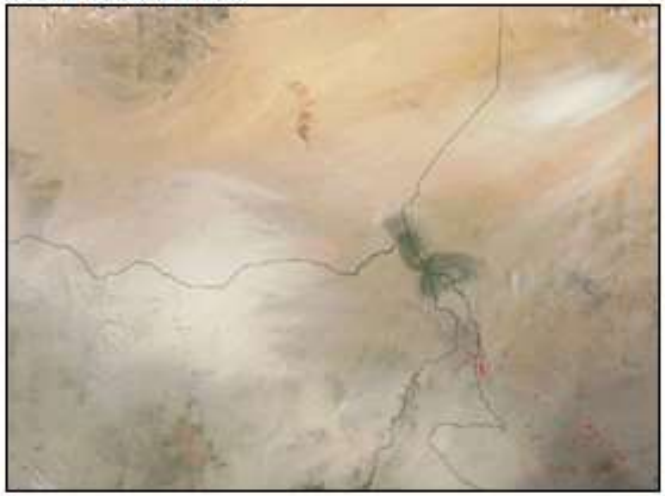
NEWS

The MODIS news section details all the developing news surrounding the MODIS project.

MODIS Atmosphere Team Releases New Data Products Calendar

IMAGES

Dust in Central Africa



This image of dust over central Africa was captured by the MODIS on the Terra satellite on February 11, 2009. Shown are Niger (upper left half of image), Chad (right side), Nigeria (lower left), Cameroon (bottom center), and the...

DISCIPLINES


Atmosphere


Land


Ocean


Calibration

http://modis.gsfc.nasa.gov/

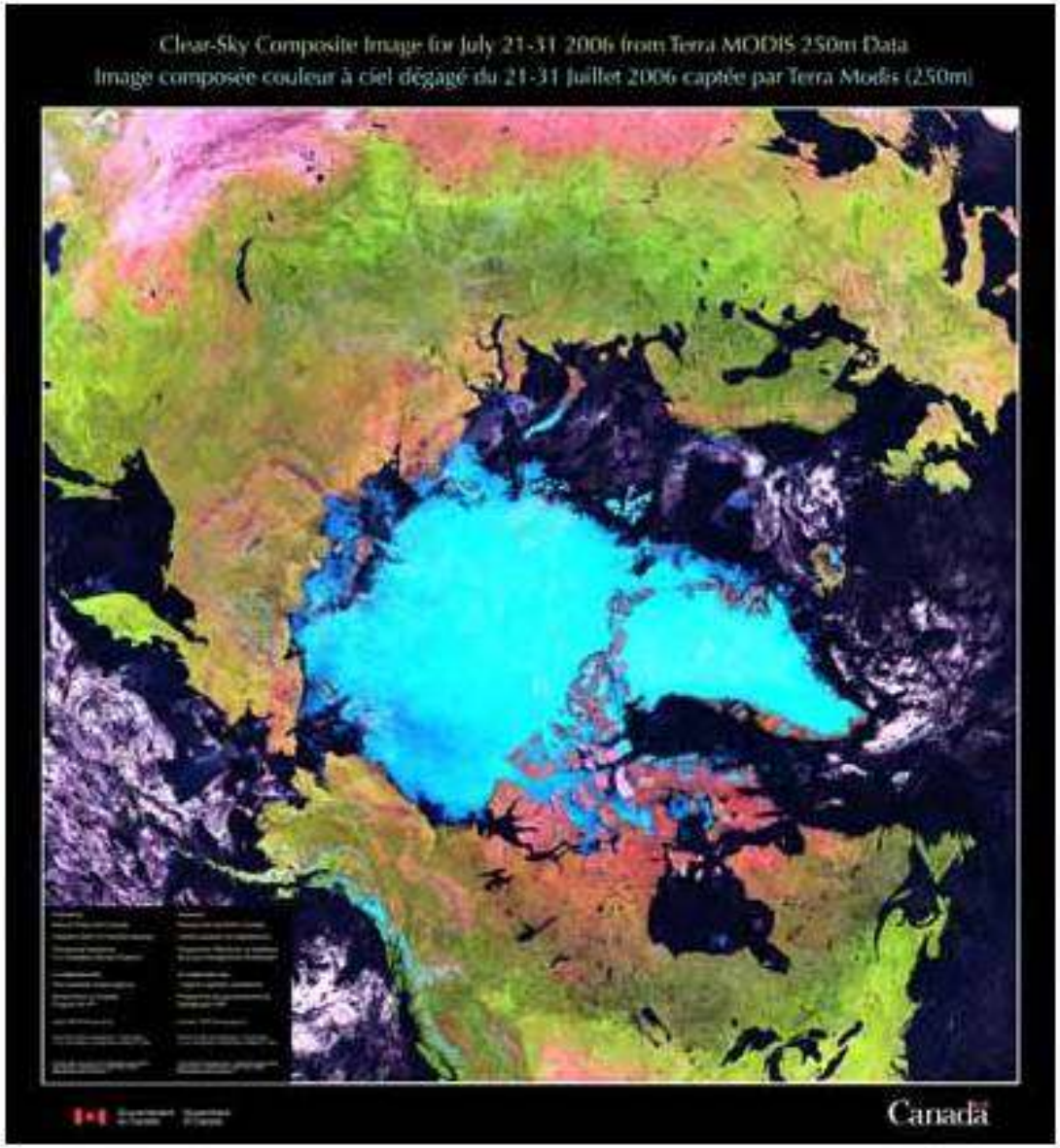
MODIS : available data

Product	Acronym	Spatial Resolution	Temporal Frequency	Terra V005 SIN	Aqua V005 SIN	Terra/Aqua Combined V005 SIN
Surface Reflectance	SREF	500 m	8 day composites	MOD09A1	MYD09A1	----------
Land Surface Temperature and Emissivity	TEMP	1 km	8 day composites	MOD11A2	MYD11A2	----------
Land Cover	LC	500m	annual	----------	----------	MCD12Q1
Normalized Difference Vegetation Index and Enhanced Vegetation Index	NDVI EVI	250 m	16 day composites	MOD13Q1	MYD13Q1	----------
Leaf Area Index and Fraction of Photosynthetically Absorbed Radiation	LAI FPAR	1 km	8 day composites	MOD15A2	MYD15A2	----------
Gross Primary Productivity	GPP	1 km	8 day composites	MOD17A2 MOD17A2_51	MYD17A2	----------
Net Primary Productivity	NPP	1 km	Annual	MOD17A3	----------	----------
Reflectance Nadir BRDF-Adjusted (NBAR)	NBAR	500 m	16 day composites	----------	----------	MCD43A1
Calculated Albedo		500 m	16 day composites	----------	----------	MCD43A
Reflectance Nadir BRDF-Adjusted (NBAR)	NBAR	500 m	16 day composites	----------	----------	MCD43A4
MODIS/Terra+Aqua BRDF/Model Quality		500 m	16 day composites	----------	----------	MCD43A2

https://earthdata.nasa.gov/http%3A/earthdata.nasa.gov/about-eosdis/system-description/lance/modaps/about-modaps/data-products

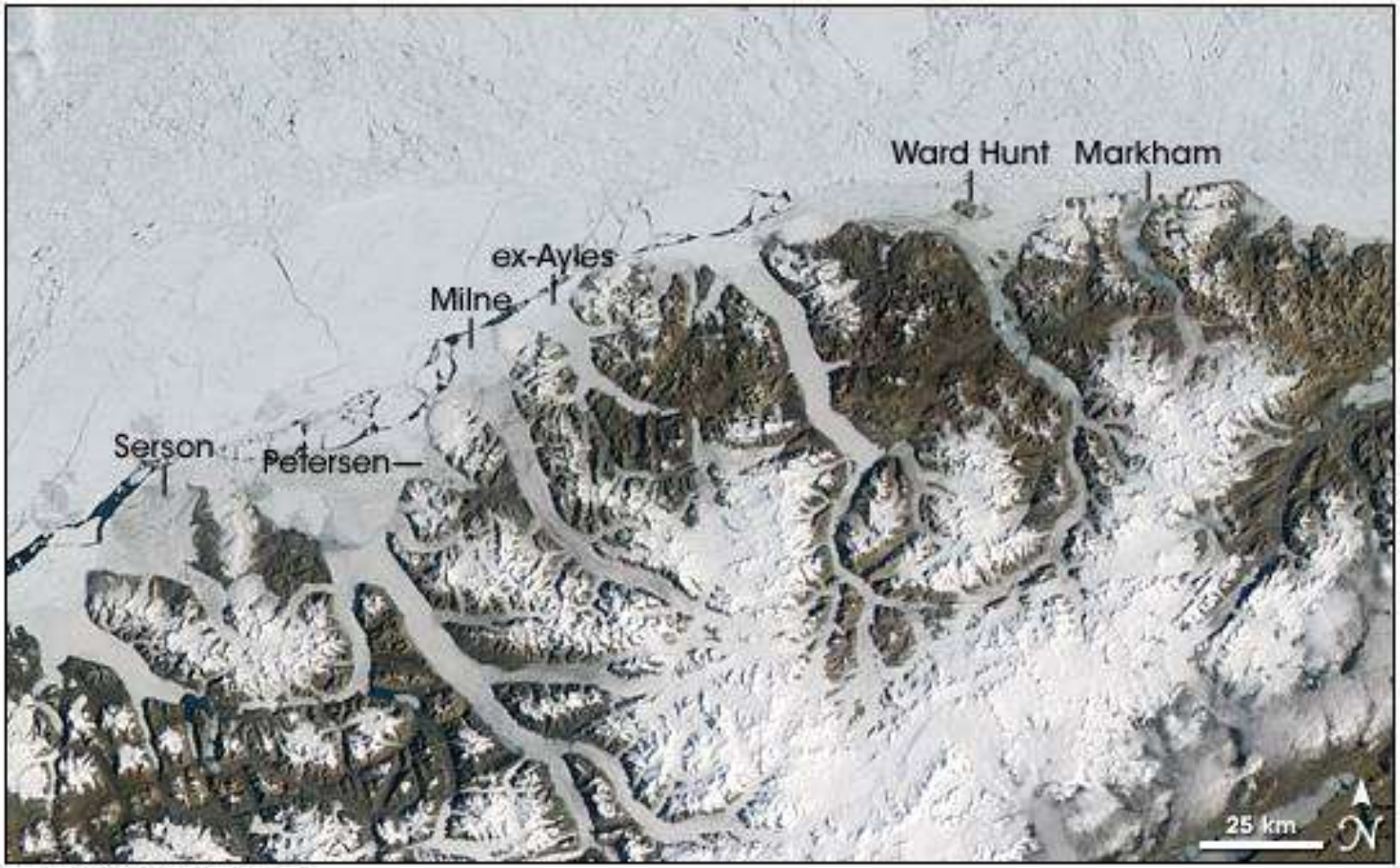
CCRS produced the first-ever, high-medium resolution, circumpolar satellite image by compositing cloud-free images from the MODIS sensor

http://www.nrcan.gc.ca/earth-sciences/land-surface-vegetation/land-cover/north-american-landcover/9144



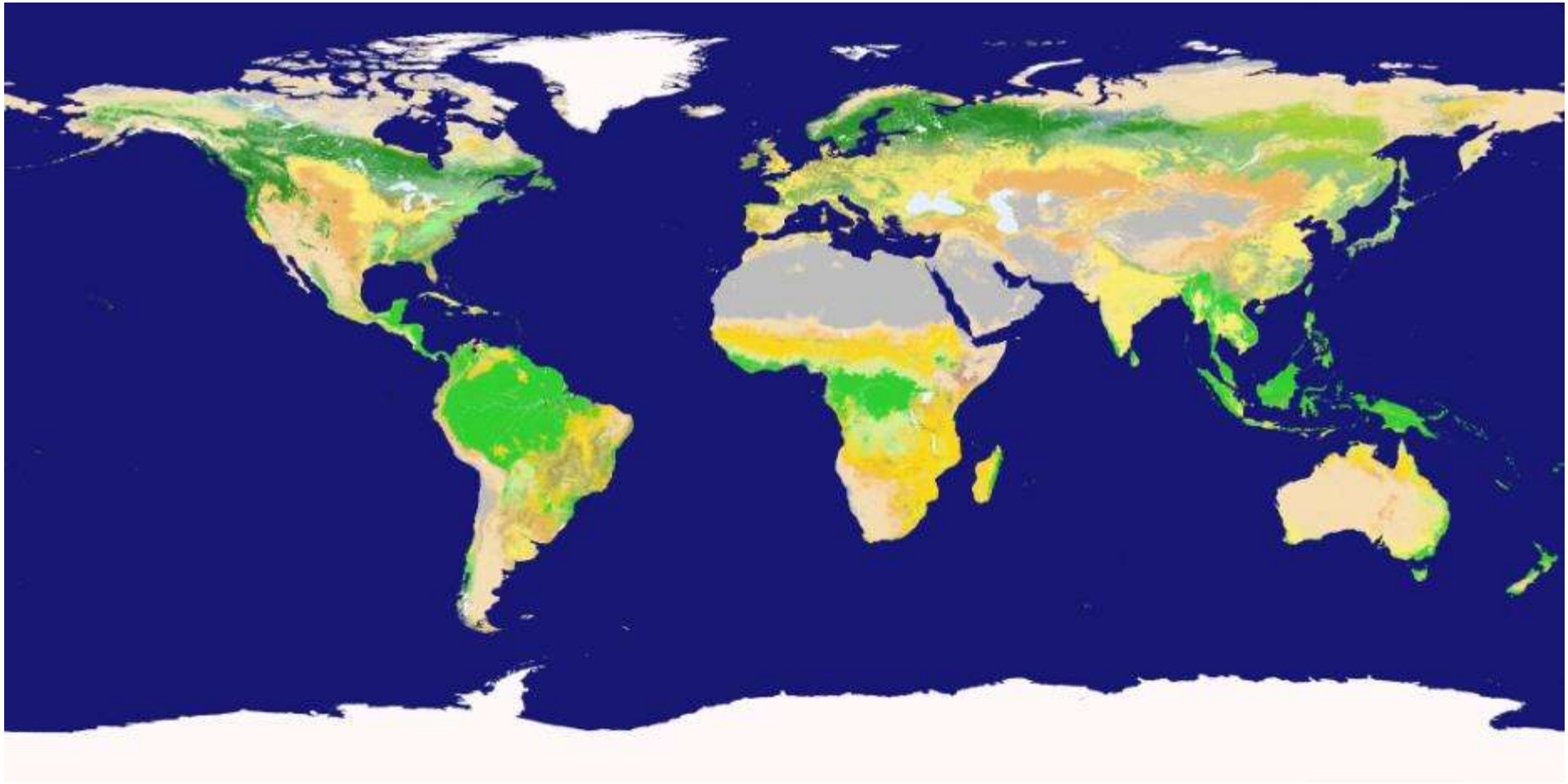
Retreat of the Ellesmere Island Ice shelf

http://earthobservatory.nasa.gov/Features/Ellesmere



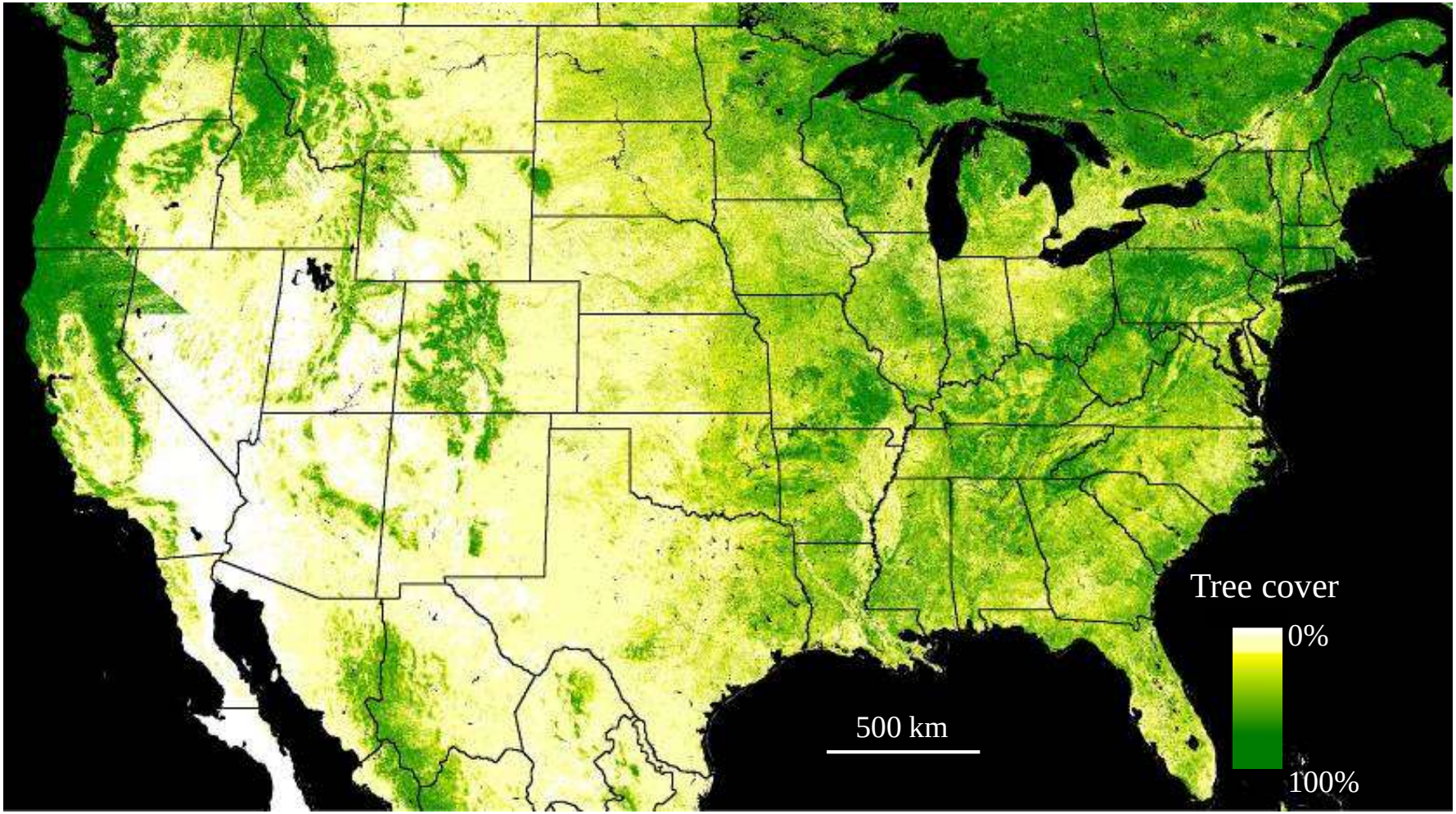
July 22, 2008 (Aqua)

Land cover



http://earthobservatory.nasa.gov/Newsroom/view.php?id=22585

Vegetation – see also http://glcf.umd.edu/data/modis/index.shtml



Percent tree cover map of the U. S. from 250 meter MODIS data using maximum NDVI composite for summer 2000 acquisitions

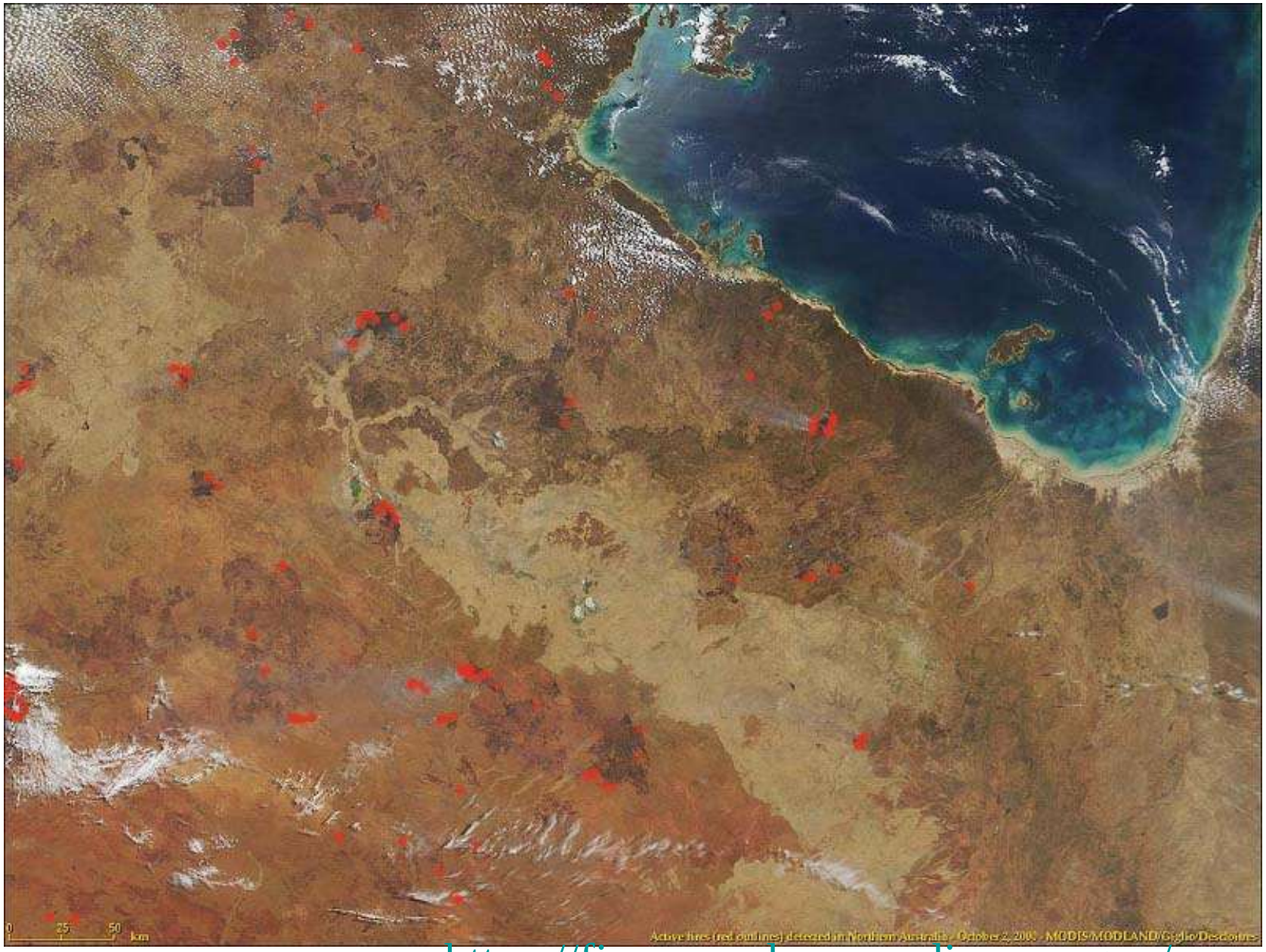
MODLAND/Townshend et al

32 day composite: bands 1-7, 700mb (August):

http://glcf.umd.edu/data/modis/index.shtml

Feb-March

MODIS Fires, NW Australia, Oct 2, 2000

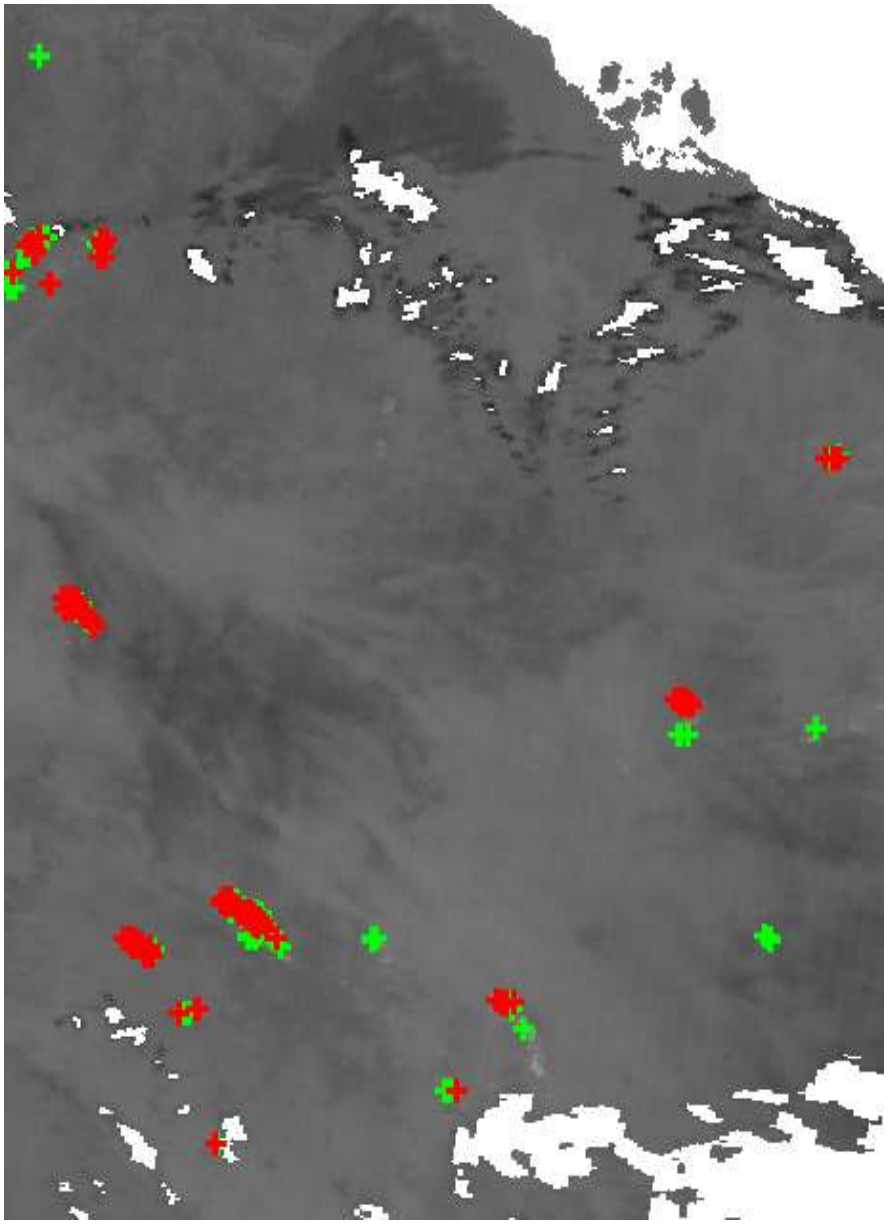


MODLAND/Justice et al

https://firms.modaps.eosdis.nasa.gov/map

AVHRR (3.45am)

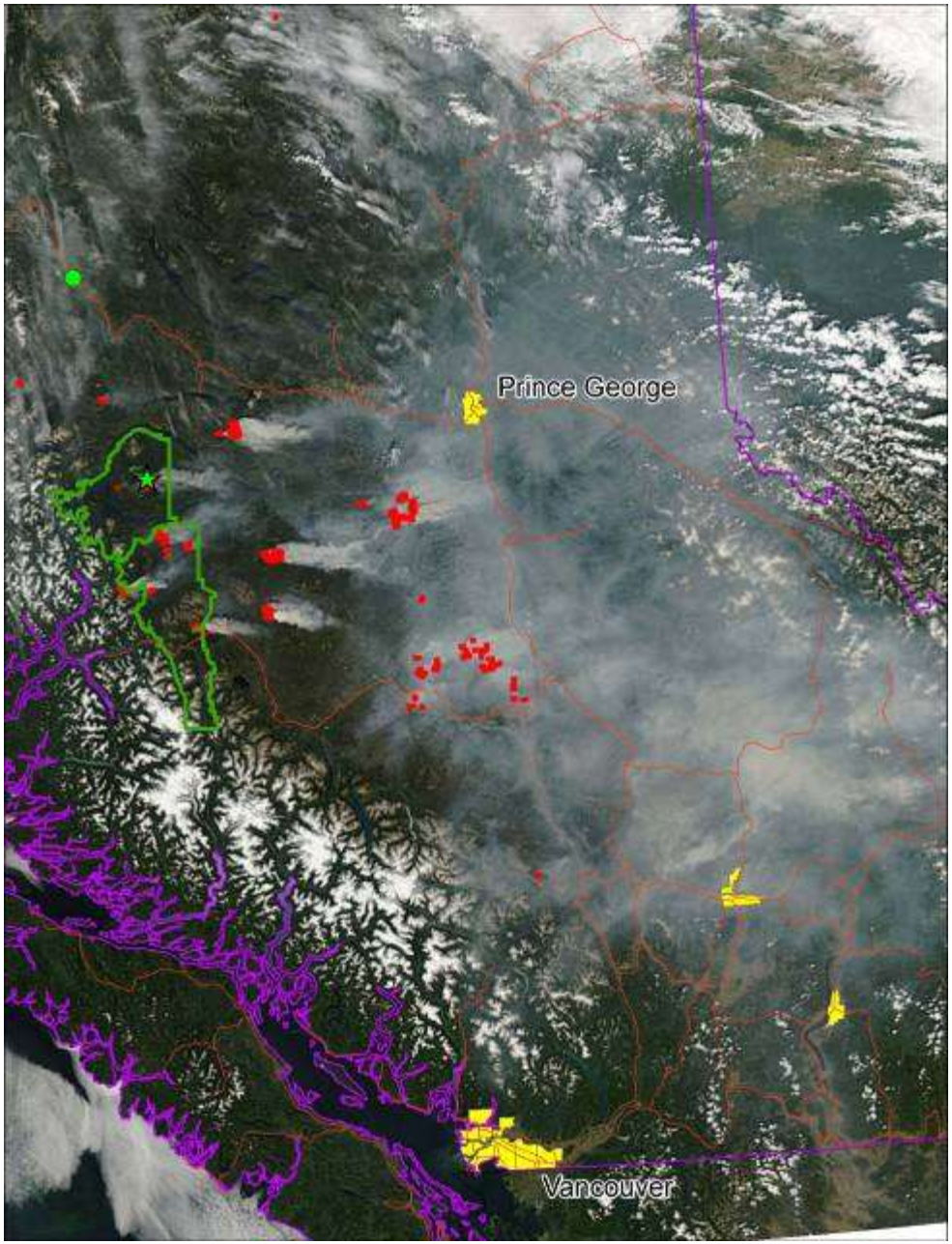
MODIS (10.30am)

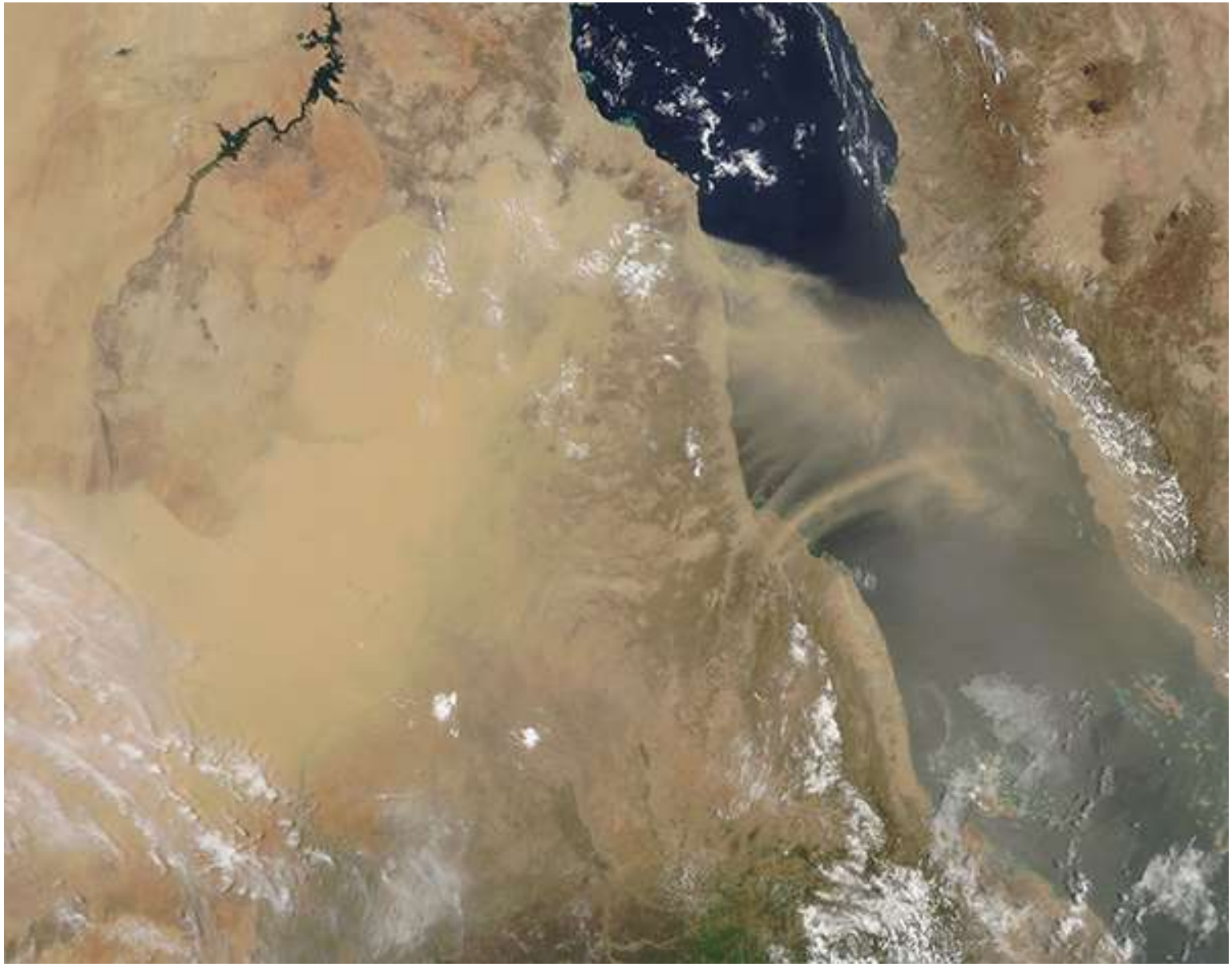


MODLAND/Justice et al

Oct 2, 2000

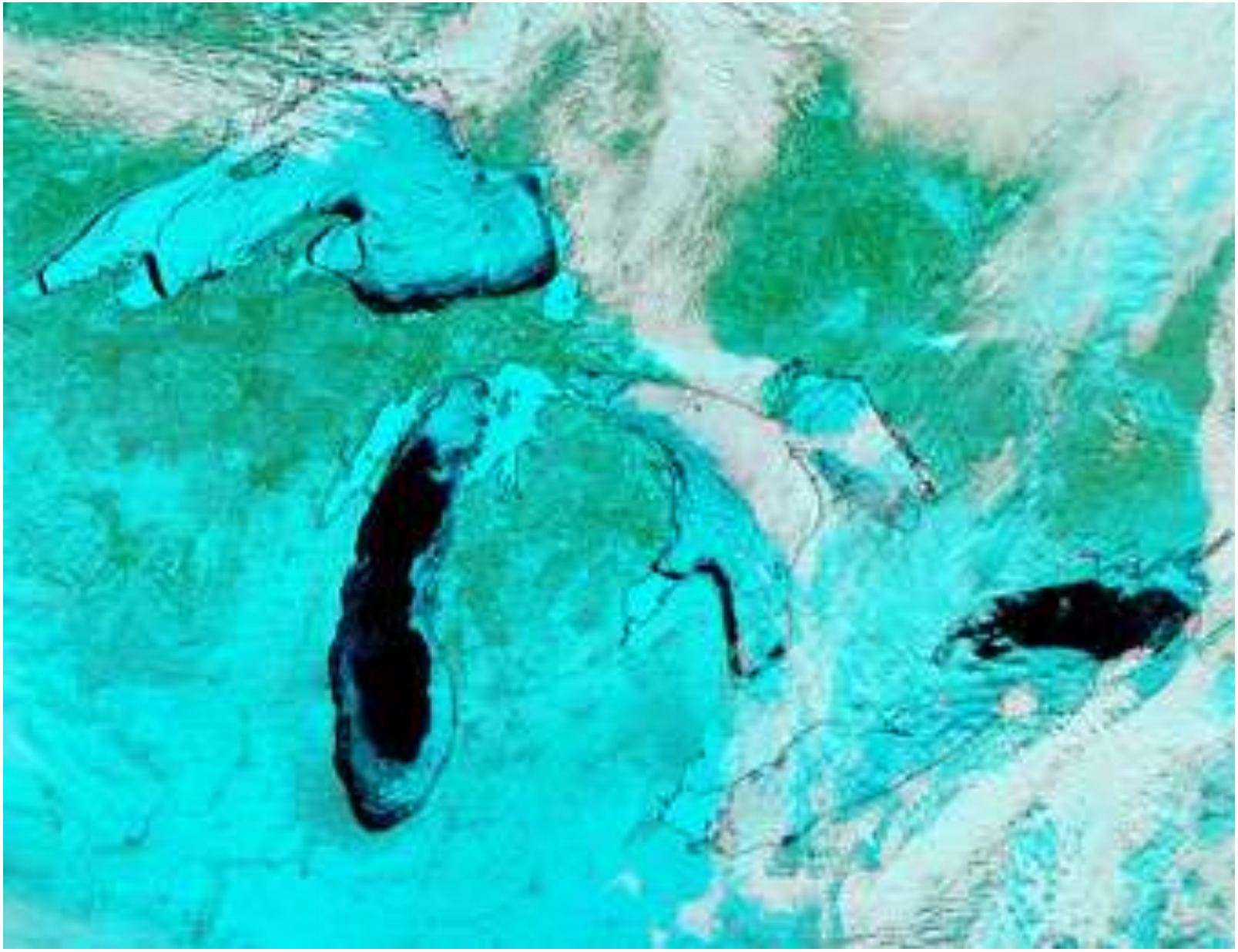
BC fires, August 2010



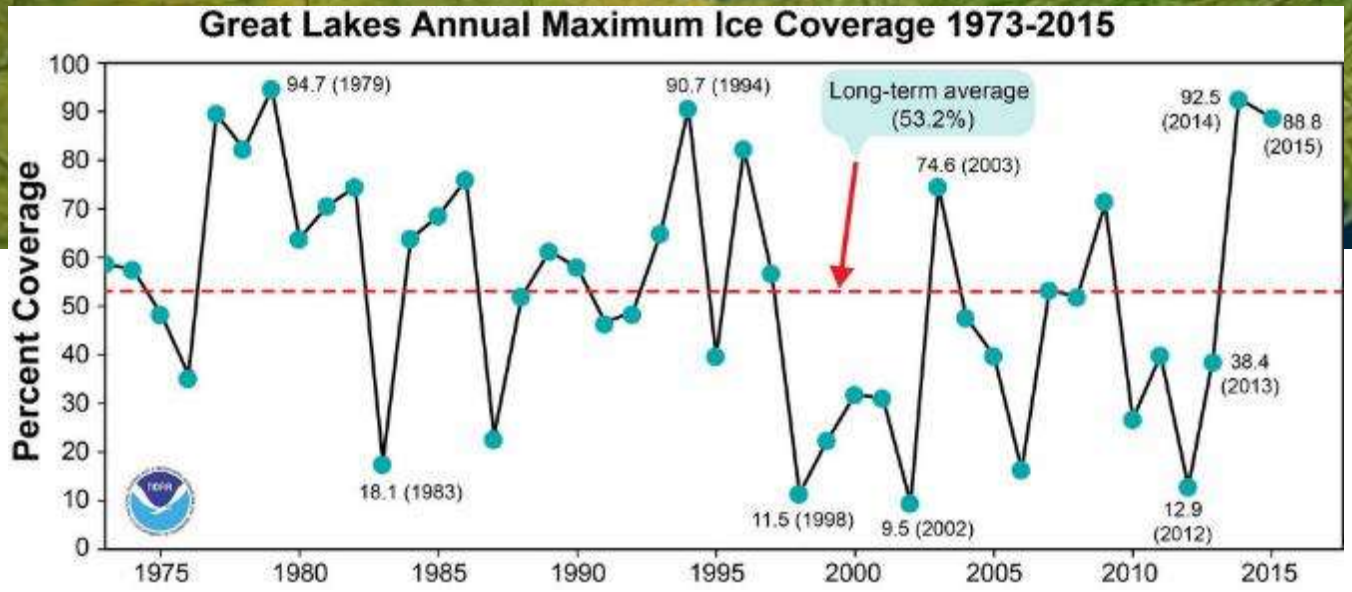


August 12, 2017, the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard NASA's Terra satellite acquired a true-color image of a massive dust storm over Sudan.

Great Lakes: Feb 29 2014: record ice cover ? – 92.5%

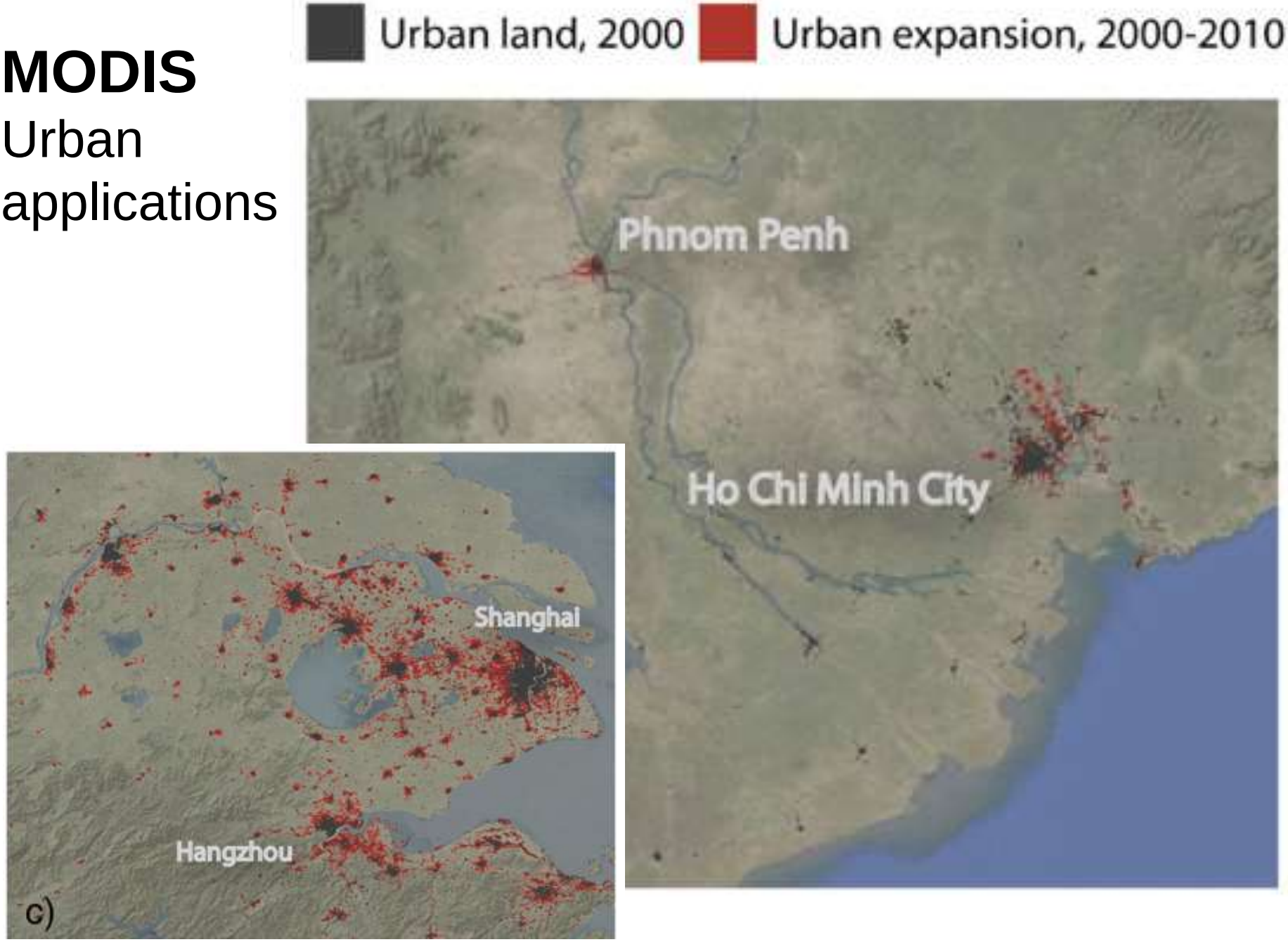



Great Lakes Ice Cover
AS OF SUNDAY
Sunday 9 March 2014
Thunder Bay
Wawa
95 %
Sault Ste Marie
Parry Sound
89 %
96 %
Kingston
36 %
Muskegon
Toronto
Chicago
Windsor
95 %


Great Lakes Annual Maximum Ice Coverage 1973-2015
Percent Coverage
100
90
80
70
60
50
40
30
20
10
0
1975
1980
1985
1990
1995
2000
2005
2010
2015
94.7 (1979)
18.1 (1983)
90.7 (1994)
11.5 (1998)
9.5 (2002)
74.6 (2003)
Long-term average
(53.2%)
92.5
(2014)
88.8
(2015)
38.4
(2013)
12.9
(2012)

MODIS – snow cover – volume estimate / runoff

MODIS
Urban applications



MODIS themes for next Monday's class talks

3 minutes each as for the High Res.Talks

request/suggest your topic this week

send to me by Sunday evening - ppt?

4 Slides: background- importance - bands used; examples and special websites / application references

Land
Fire detection / areas burned
NDVI / vegetation
Land cover / change – urban/rural
Vulcanology
LAI / Evapotranspiration
Land surface temperature
GPP / NPP

Cryosphere
Snow cover
Lake ice / sea ice
Glacier albedo

Ocean
Oil spills
Pollution
Sea surface temperatures
Ocean colour - bacteria

Atmosphere
Ozone layer - aerosols
Pollution
Dust storms
Water vapour

Other ……

https://modis.gsfc.nasa.gov/data/dataprod

MODIS and applications in harmful algal blooms (HABs)

Sample class talk from a previous year

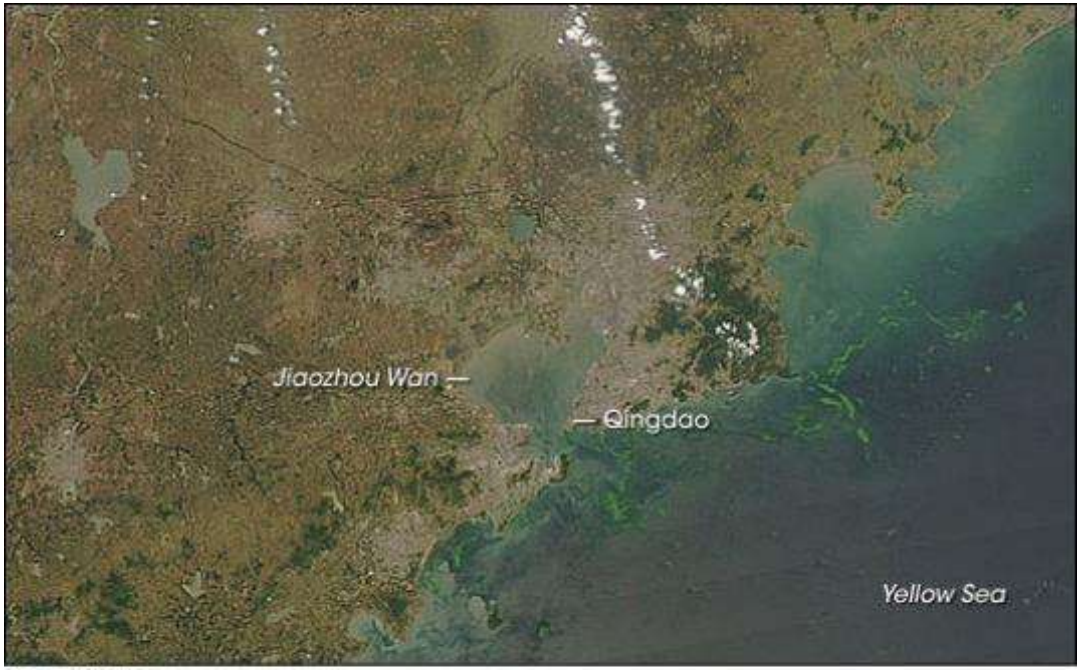
- Algal blooms can be bad:
  - Some contain toxins
  - Decreases dissolved oxygen potentially killing aquatic species
- Can be caused by increased concentrations of nitrogen and phosphorus

- Bands typically used: visible, NIR and SWIR
  Cui: used red (620-670nm), NIR (841-876nm)
  Hu: used red, NIR, SWIR

The Oyashio algal bloom off the coast of Japan

(http://oceancolor.gsfc.nasa.gov/FEATURE/IMAGES/A2009141033700.OyashioKuroshio.quarter.jpg)

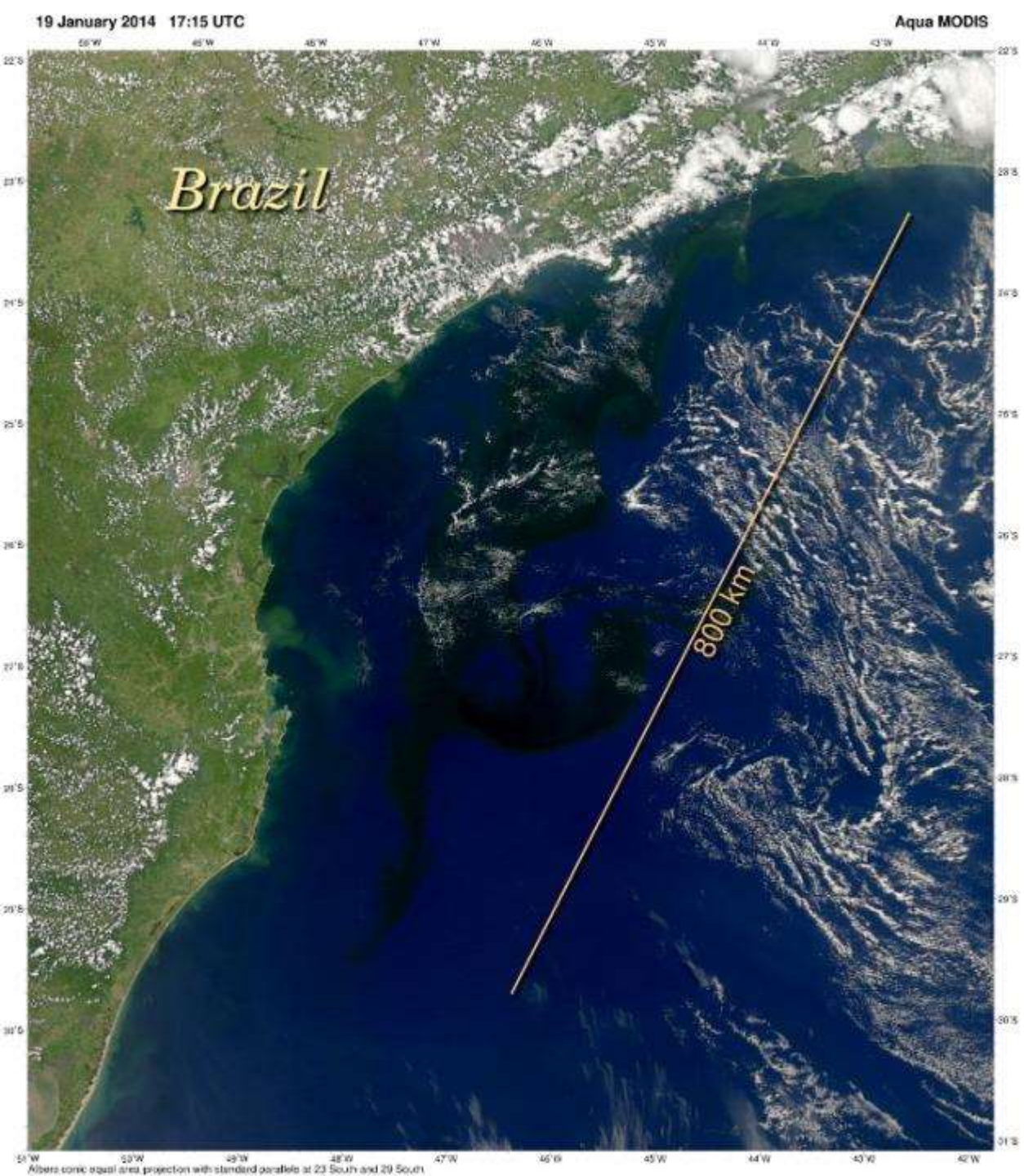
- Algal bloom in the Yellow Sea shown in Natural colour (above) and false colour (below)
- False colour makes algae show up better due to high reflection in NIR bands (just like plants)
- Algal blooms are widely studied due to impact on humans and animals



Natural Color

False Color (Shortwave, Near-Infrared, and Red)

http://earthobservatory.nasa.gov/IOTD/view.php?id=8897



- NDVI is also used (Cui's paper)
- Develop a FAI: Floating Algal Index (Hu's paper) to quantity algal blooms

Algal bloom stretching 800km off the coast of Brazil (Jan. 2014)

http://oceancolor.gsfc.nasa.gov/FEATURE/Brazil_plume.html

Websites:

- Algal blooms: http://www.sciencedaily.com/articles/a/algal_bloom.htm
- MODIS: http://modis.gsfc.nasa.gov/

Scientific Papers:

- Cui, T. *et al.* "Satellite monitoring of massive green macroalgae bloom (GMB):," *International Journal of Remote Sensing* **33**(10), Sept. 2012, pp. 5513 – 5527.

- Hu, C. "A novel colour ocean index to detect floating algae in global oceans," *Remote Sensing of Environment* **113**, 2009, pp. 2118 – 2129.

- Siswanto, E et al. "Detection of harmful algal blooms of *Karenia mikimotoi* using MODIS measurements: A case study of Seto-Inland Sea, Japan," *Remote Sensing of Environment* **129**, 2013, pp. 185 – 196.