MODIS APPLICATIONS FOR OCEAN OIL SPILLS

By: McKenna Christianson

- Oil spills can lead to algae blooms
- Oil kills algae grazers like snails which increases the favorable growth period for algae to grow
- Monitoring oceans for spills is important for early detections and response time for clean up of large mass spills
- Using MODIS for oil spill monitoring can be applied to provided a size estimate as well as the movement of the slick

- Bands typically used:
  - Visible spectrum (620-670nm)
  - Near infrared (841-876nm)

- The reflectance from these bands was found to be greater than using MODIS seawater reflectance

MODIS RGB Image. Oil spill is circled in green.

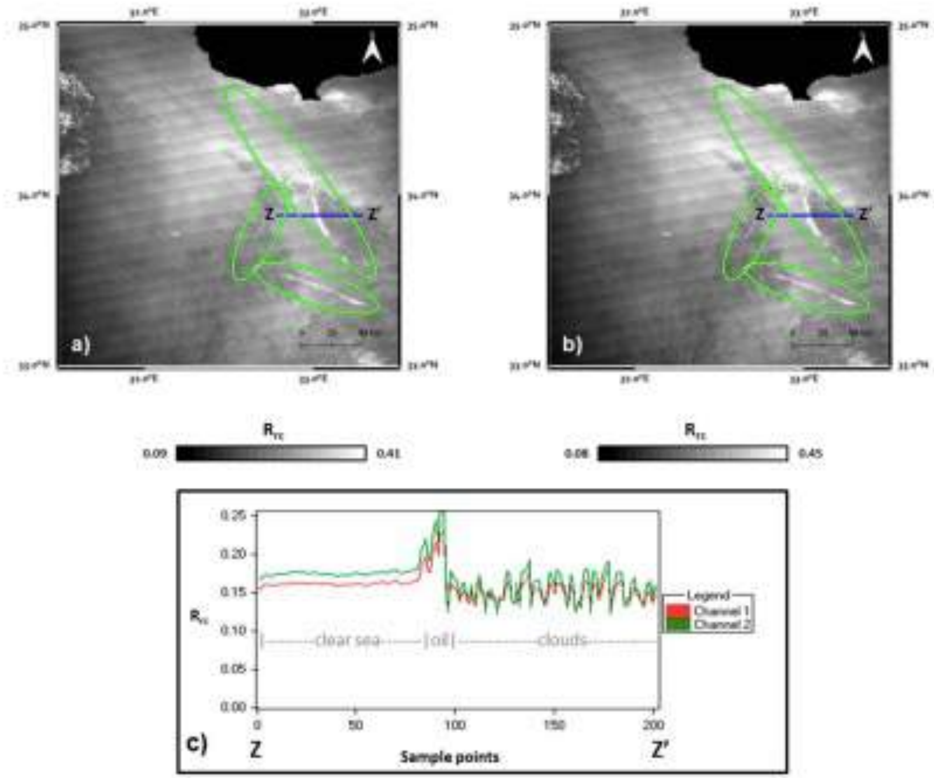

Figure 5. R_{rc} images of (**a**) channel 1 and (**b**) channel 2 of the MODIS-Aqua image of 18 June 2007 at 10:50 a.m. GMT. The grey bars show the sea surface R_{rc} range of variation for each of the image; land is masked in black. (**c**) Variation of R_{rc} signal along the Z-Z′ blue transect in (**a**,**b**).

DEEPWATER HORIZON EXAMPLE

The big spill from the Deepwater horizon had been the start of using imagery to monitor spills

The use of IR imagery helps to define where the slick is and isn't

Used NIR to estimate the oil thickness

Uses IR to create the contrast between the water and oil

IR cannot detect thickness of oil

Used imagery from MODIS-Terra, and MODIS-Aqua

Figure 1. An example image from MODIS during the DWH (Deepwater Horizon) spill in the U.S. Gulf of Mexico. The MODIS sensor is on the NASA Aqua satellite. The oil slick is shown by the white rectangle. Note the many clouds in the image. (Photo from NASA website, www.nasa.gov).

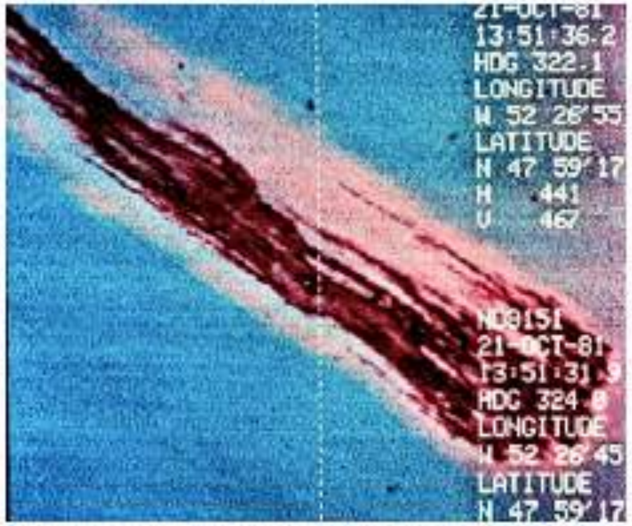

Figure 4. A simultaneous view of a test slick (shown in Figure 3), but using IR. The inclusion of infrared creates additional contrast between the slick and water as well as removing the sun glitter (Photo from Environment Canada).

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https://www.mdpi.com/2072-4292/9/2/128/htm

https://www.ioccg.org/handbook/casestudy2_hu_etal.pdf

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Miro Nuetzi
230131283
Feb 6th, 2022

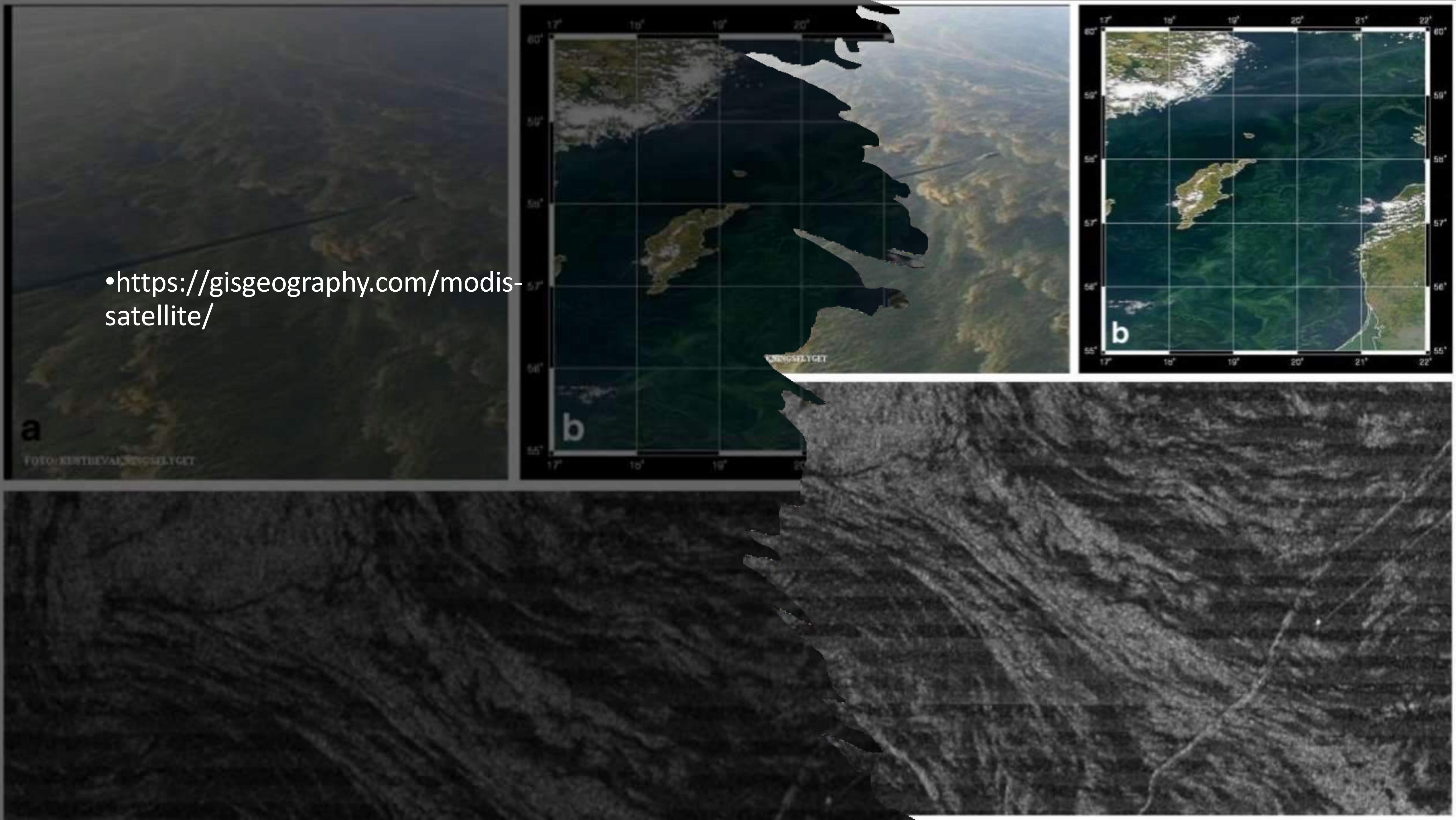
Bacteria Detection using MODIS

- Cyanobacteria and Pathogenic Bacteria detection
- Colour chlorophyl and Bioluminescence
- 500 meter resolution
- 10–20 nm wide bands that have 400 to 700 nm for hyperspectral sensors for bioluminescence
- 443 nm and 520 nm for chlorophyl

Reflective Bands

Band	Bandwidth (µm)	Resolution (m)	Application
8	0.405-0.420	1000	Ocean Biology and Colour, Phytoplankton
9	0.438-0.448	1000	
10	0.483-0.493	1000	
11	0.526-0.536	1000	
12	0.546-0.556	1000	
13	0.662-0.672	1000	
14	0.673-0.683	1000	
15	0.743-0.753	1000	
16	0.862-0.877	1000	

https://gisgeography.com/modis-satellite/



- https://gisgeography.com/modis-satellite/


Broad Sound
Swain Reefs
Trichodesmium

Types and studies

- *Vibrio harveyi* - Milkey Sea
- *Nodularia* Blooms
- *Trichodesmium*
- *V. vulnificus*
- *V. parahaemolyticus*

- Viewing Marine Bacteria, Their Activity and Response to Environmental Drivers from Orbit
- Cyanobacterial blooms cause heating of the sea surface. *Mar Ecol Prog Ser.* 1993;191:1–7.
- Observations and measurements of planktonic bioluminescence in and around a milky sea. *J Exp Mar Biol Ecol.* 1988;119:55–81.
- A historical analysis of the potential nutrient supply from the N2 fixing marine cyanobacterium *Trichodesmium* spp. to *Karenia brevis* blooms in the eastern Gulf of Mexico. *J Plankton Res.* 2010;32:1421–1431. [Google Scholar]

MODIS - SEA SURFACE TEMPERATURE (SST)

- Temperature measured at the top millimetre of the ocean surface
- SST influences weather, such as hurricanes and typhoons
- Also impacts oceanic and atmospheric patterns, including cloud formation
- Correlated to phytoplankton availability
- Significantly impacts life both in the ocean and on land

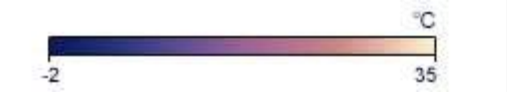
- MODIS SST measurements are accurate to half a degree Celsius
- Mid- and far-infrared radiances
- Typical bands used: Bands 20, 22, 23, 31, and 32
- Short-wave SST Algorithm uses bands 22 and 23 (3.959 and 4.050 μm)
- Long-wave SST Algorithm uses bands 31 and 32 (11 and 12 μm)

- https://modis.gsfc.nasa.gov/data/dataprod/mod28.php
- https://neo.gsfc.nasa.gov/view.php?datasetId=MYD28M&date=2021-11-01

Sea surface temperature (1 month – Aqua / MODIS)

November 2021

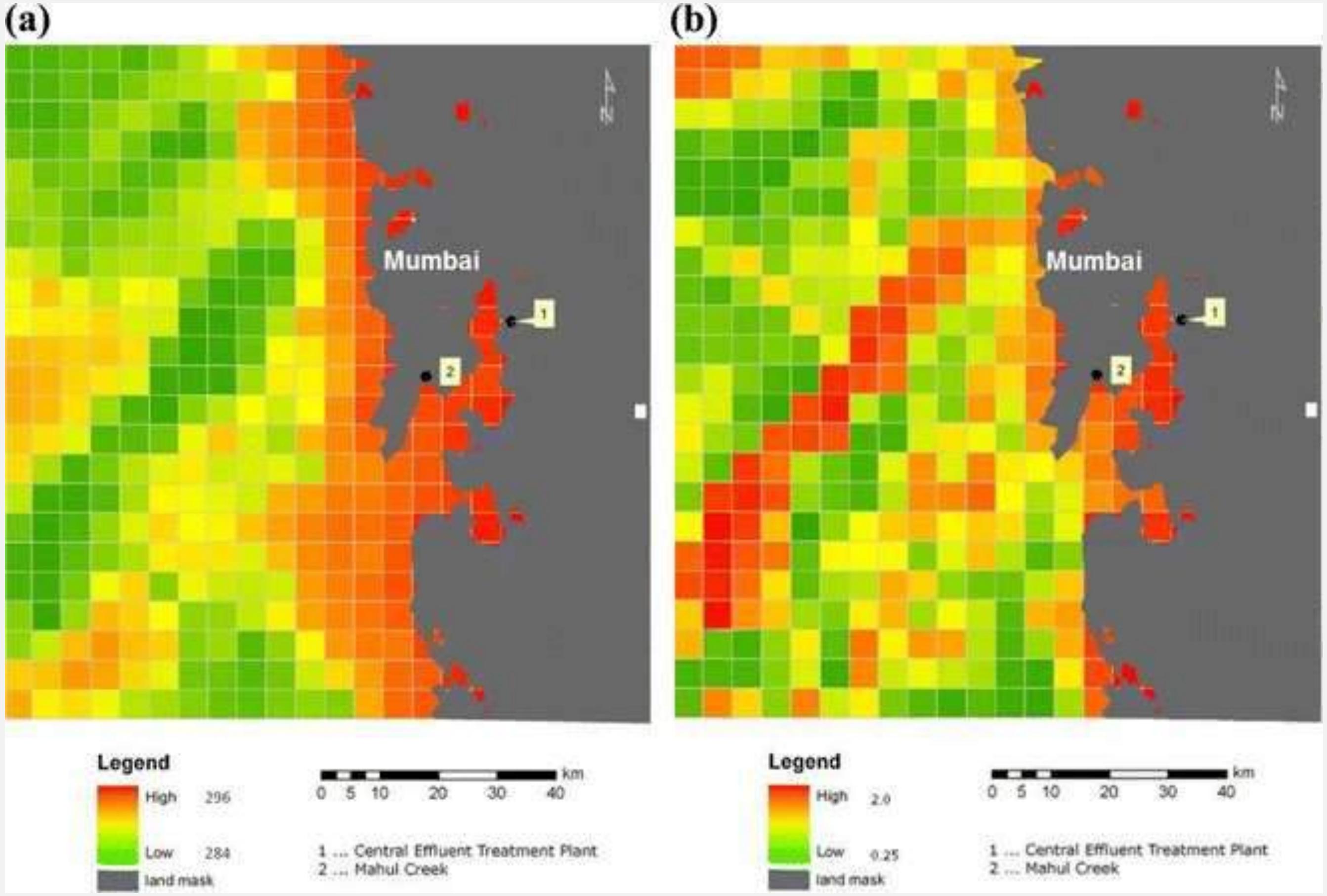
Image from NEO (NASA Earth Observations)



- Colder near the poles, and warmer near the equator
- Some ocean currents are visible in SST imagery

- https://neo.gsfc.nasa.gov/view.php?datasetId=MYD28M&date=2021-11-01

- Azmi et al. (2015) used MODIS data to monitor sea surface temperature on the coast of Mumbai
- Results indicate significant anthropogenic sources of thermal pollution



a Monthly aggregated average and **b** standard deviation of SST for March (2005–2010)

Azmi, S., Agarwadkar, Y., Bhattacharya, M., Apte, M., & Inamdar, A. B. (2015). Monitoring and trend mapping of sea surface temperature (SST) from MODIS data: a case study of Mumbai coast. *Environmental Monitoring and Assessment*, *187*(4), 1-13. https://doi-org.prxy.lib.unbc.ca/10.1007/s10661-015-4386-9

- Sutton and Lakshmi (2017) compared MODIS SST data with local water temperature measurements from NOAA buoys and onshore stations along the coast of Oregon
- Goal was to estimate temperatures of submerged intertidal mussel loggers

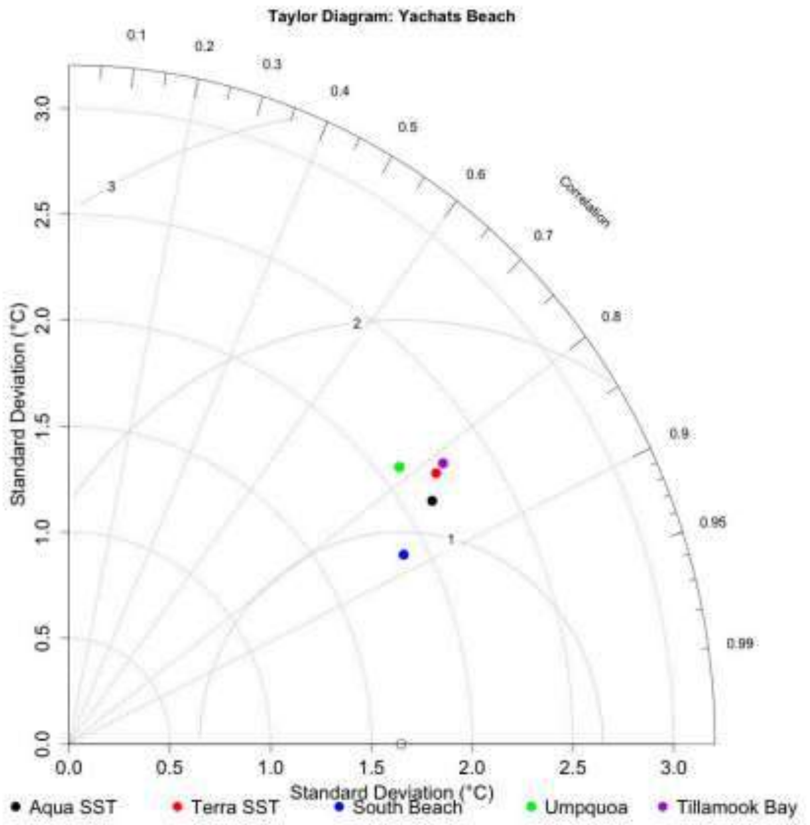


Figure 5. Taylor diagram for Yachats Beach where each water temperature estimate (Aqua SST, Terra SST, South Beach water temperature, Umpquoa Offshore water temperature, and Tillamook Bay water temperature) was used to predict daily submerged mussel logger temperature. South Beach water temperature was the best predictor of daily submerged mussel logger temperature when compared to the other water temperature estimates. The second-best predictor for logger temperature at Yachats Beach was Aqua SST.

Sutton, J. R. P., & Lakshmi, V. (2017). From Space to the Rocky Intertidal: Using NASA MODIS Sea Surface Temperature and NOAA Water Temperature to Predict Intertidal Logger Temperature. *Remote Sensing*, *9*(2), 162. https://doi.org/10.3390/rs9020162

Sea Ice Background

Geography 457
Branden Kabel

- Developed by Dorothy Hall
- Collects two main types of data: Sea Ice Temperature and Reflectance
- Primarily 1km resolution for sea ice

Importance / Bands used

Often uses true colour bands. See example on right.

Can also use false colour (7,2,1)

Some band combinations that I've seen:
(20-31-32) (RGB)
(3-6-7) (RGB) (Mäkynen, 2017)

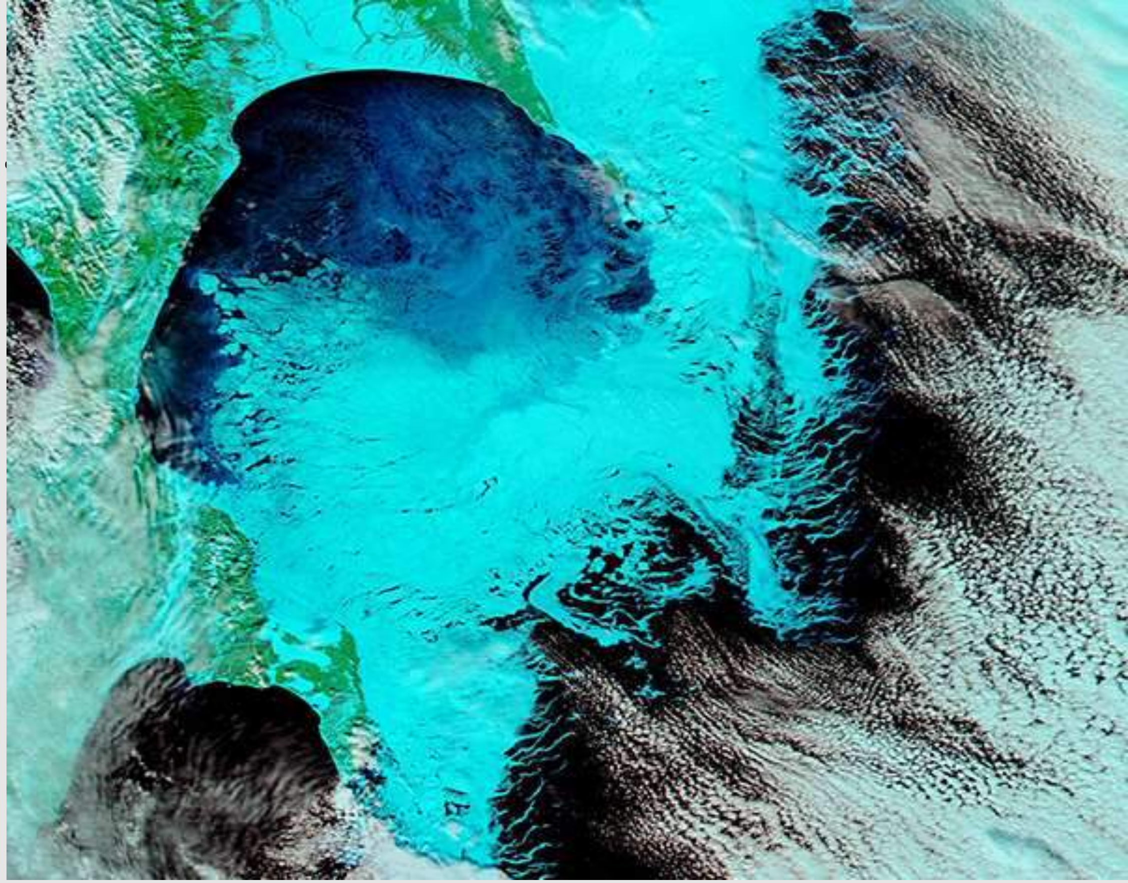
MODIS can tell different types of Sea Ice apart due to their different reflectance

Alaskan Sea Ice, April 2, 2018
Bands 1-4-3

Examples and Special Websites

- Use in tracking long-term sea ice extent
- Sea Ice Extent based on the NDSI
- (Normalized-Difference Snow Index)
- NDSI = (Green – SIR / (Green + SIR))

- https://worldview.earthdata.nasa.gov



February 4, 2022 - Sea Ice off Sakhalin Island
Bands 7,2,1

References

- Schmaltz, J. (2018). *Alaska*. https://modis.gsfc.nasa.gov/gallery/individual.php?db_date=2018-04-07
- *Sea Ice off Sakhalin Island.* https://modis.gsfc.nasa.gov/gallery/individual.php?db_date=2022-02-04
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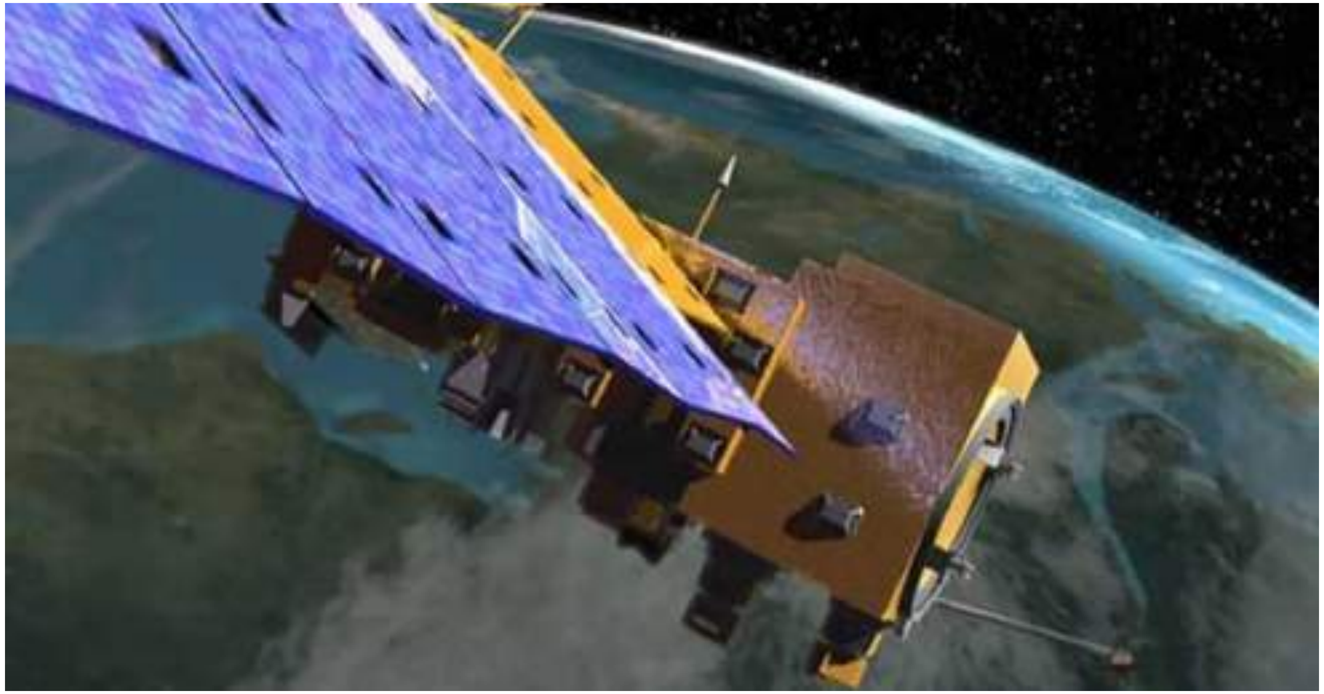
- Su, H., Wang, Y., & Yang, J. (2012;2011;). Monitoring the spatiotemporal evolution of sea ice in the bohai sea in the 2009-2010 winter combining MODIS and meteorological data. *Estuaries and Coasts, 35*(1), 281-291. https://doi.org/10.1007/s12237-011-9425-3

Snow-cover using
Moderate Resolution Imaging Spectroradiometer (***MODIS***)

Summary:

- Production of daily snow maps since year 2000
- Snow maps at 500-m spatial resolution
- Can discriminate snow from most clouds
- Automated algorithms reduce or eliminate human subjectivity (e.g., use of NDSI)
- NDSI bands: visible and shortwave near IR
    - high reflectance (Band 4)
    - Low reflectance (Band 6)

(Riggs et al., 2006)



(MODIS Satellite)

Most snow cover occurs in remote and inaccessible areas over large spatial scales.

Satellite acquired data is the most efficient means of monitoring snow cover.

Importance:

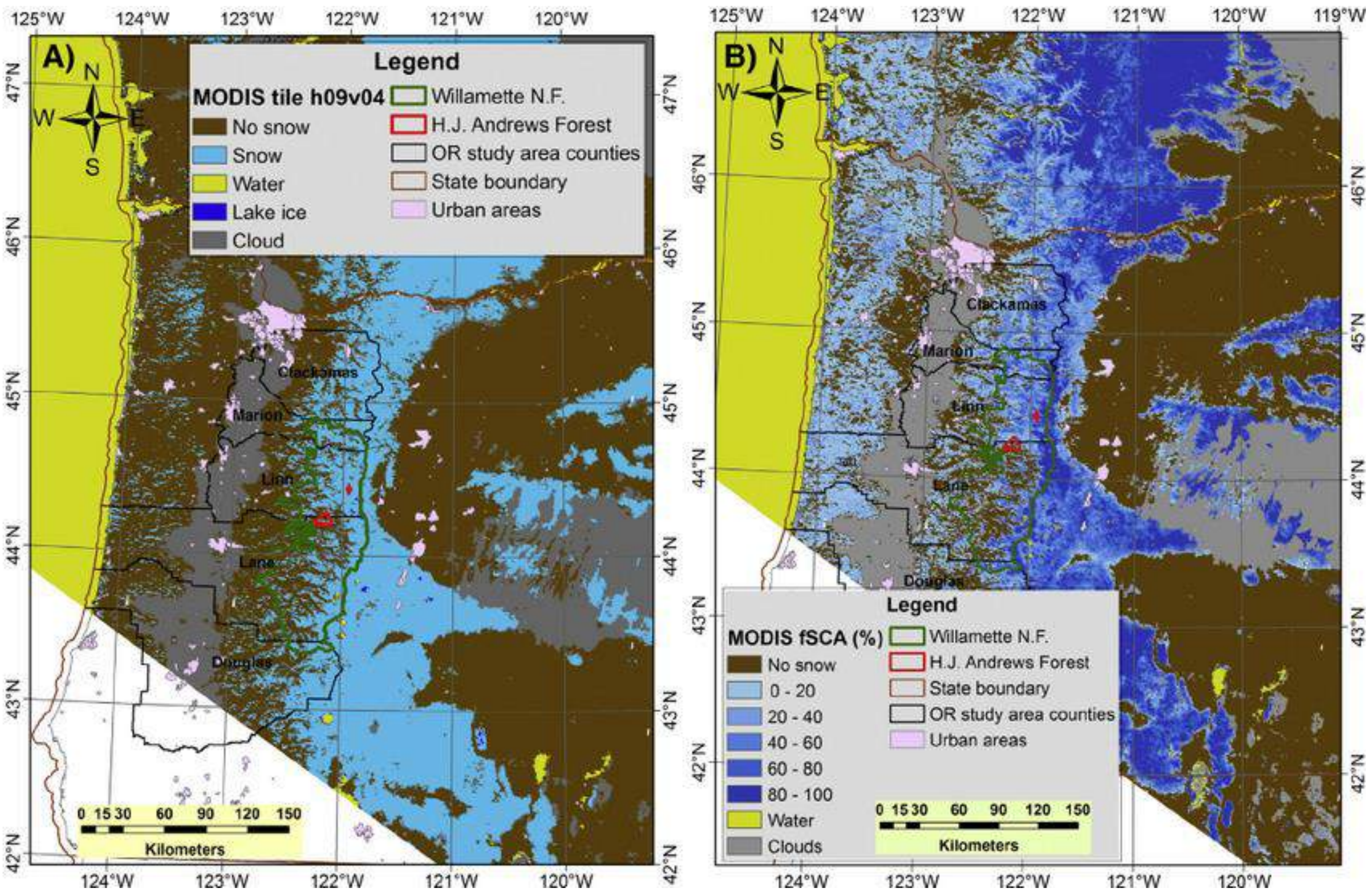
- Local and global monitoring of snow variability and trends
- Atmospheric modelling
- Energy balance and water budgets (needs improvement)
- Climate record keeping

(NASA, snow cover winter of 2001-02)

Average max. snow cover in the N. Hemisphere occurs:

- Month of February
- Covering 46.2 million sq.km

MODIS Terra snow cover data for the American Pacific Northwest

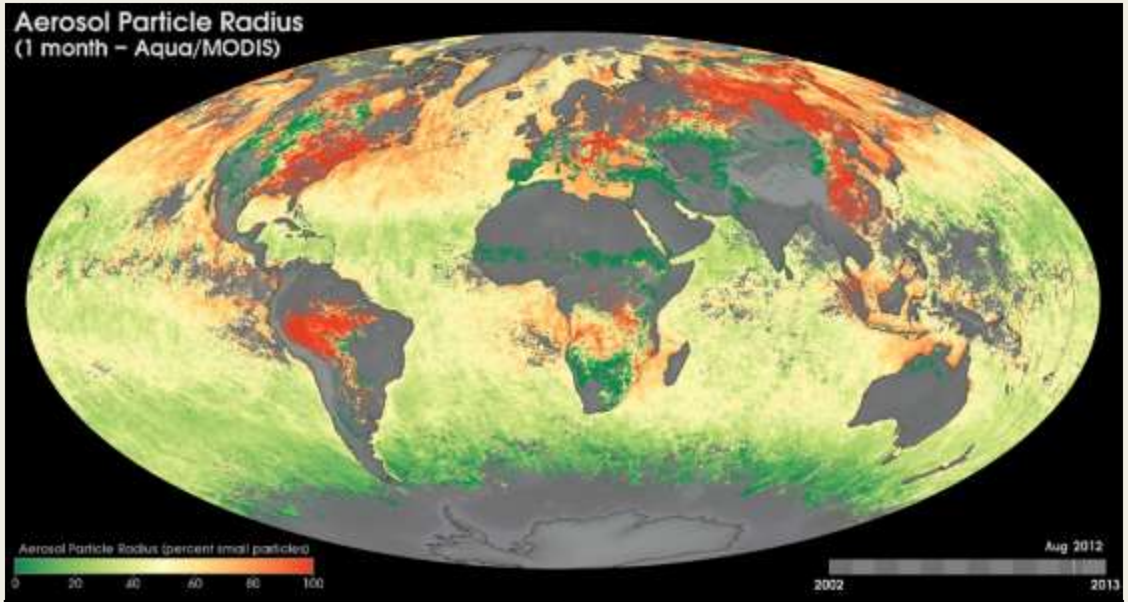


MODIS: Aerosols

MOD04_L2 and MYD04_L2
(Terra) (Aqua)

Aerosols:

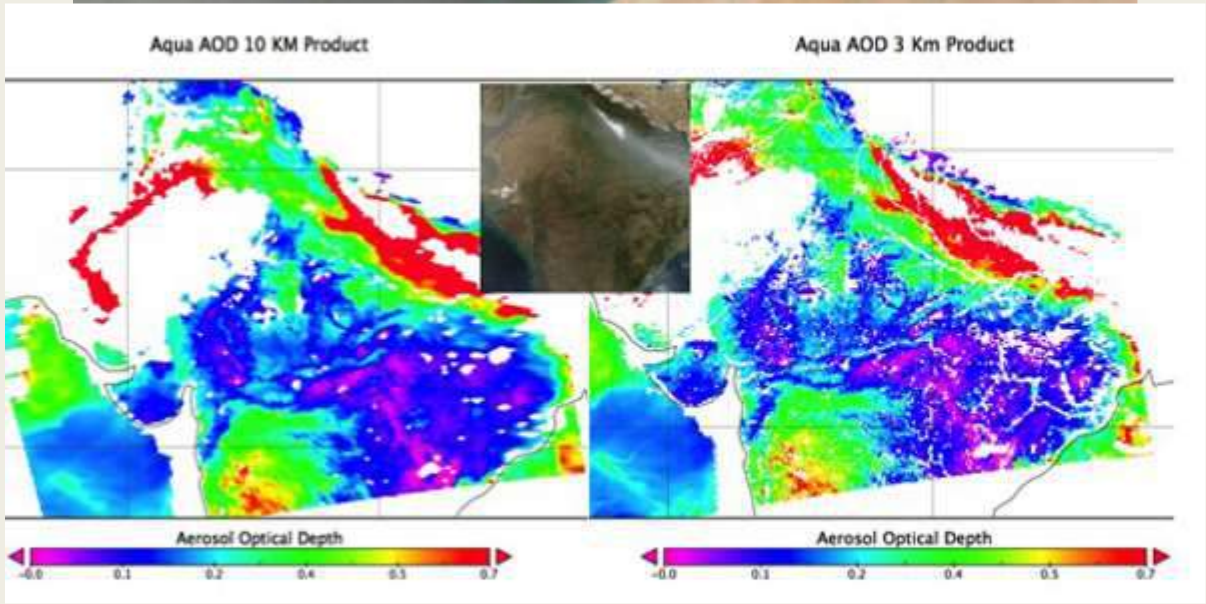
- Comprised of smoke and ash, dust, industrial pollution, sea spray, and more
- Can scatter and absorb solar and thermal energy, and affect weather patterns like the formation of clouds
- Particulate matter 2.5μm or smaller can deeply penetrate the lungs, causing a risk to human health
- MODIS reflectance data (Level 1B data) is used to monitor global aerosol movements and their effects on the environment
- Two algorithms are used to achieve this: Dark Target and Deep Blue, which generate data at 10km and 3km resolutions



Dark Target		Deep Blue	
Wavelength (nm)	MODIS Band	Wavelength (nm)	MODIS Band
440	9	412	8
550	4	470	3
650	1	490	10
860	2	650	1
1240	5		
1380	26		
1630	6		
2110	7		

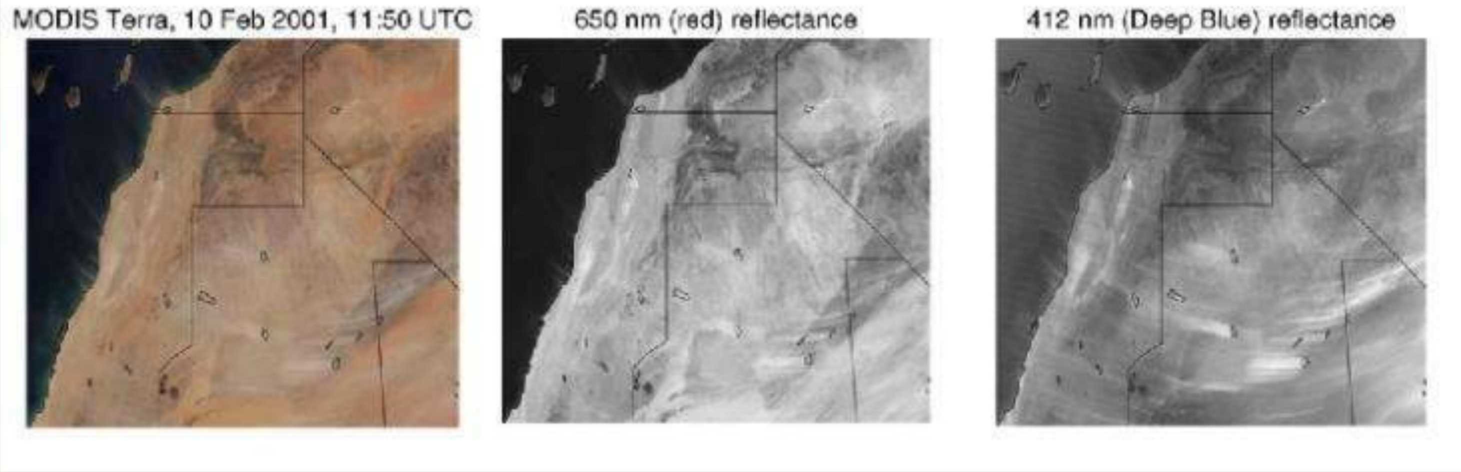
Dark Target

- Suited towards data in which features are darker, like oceans and forests, hence the name
- Ineffective for lighter features, like deserts and ocean glint
- Uses three resolutions of L1B data: 250m, 500m, and 1km
- Groups 1km pixels into 10x10 boxes for 10km or 3x3 boxes for 3km, which are generally classified as either water or land
- Estimates aerosol optical depth (AOD, or aerosol optical thickness, AOT)

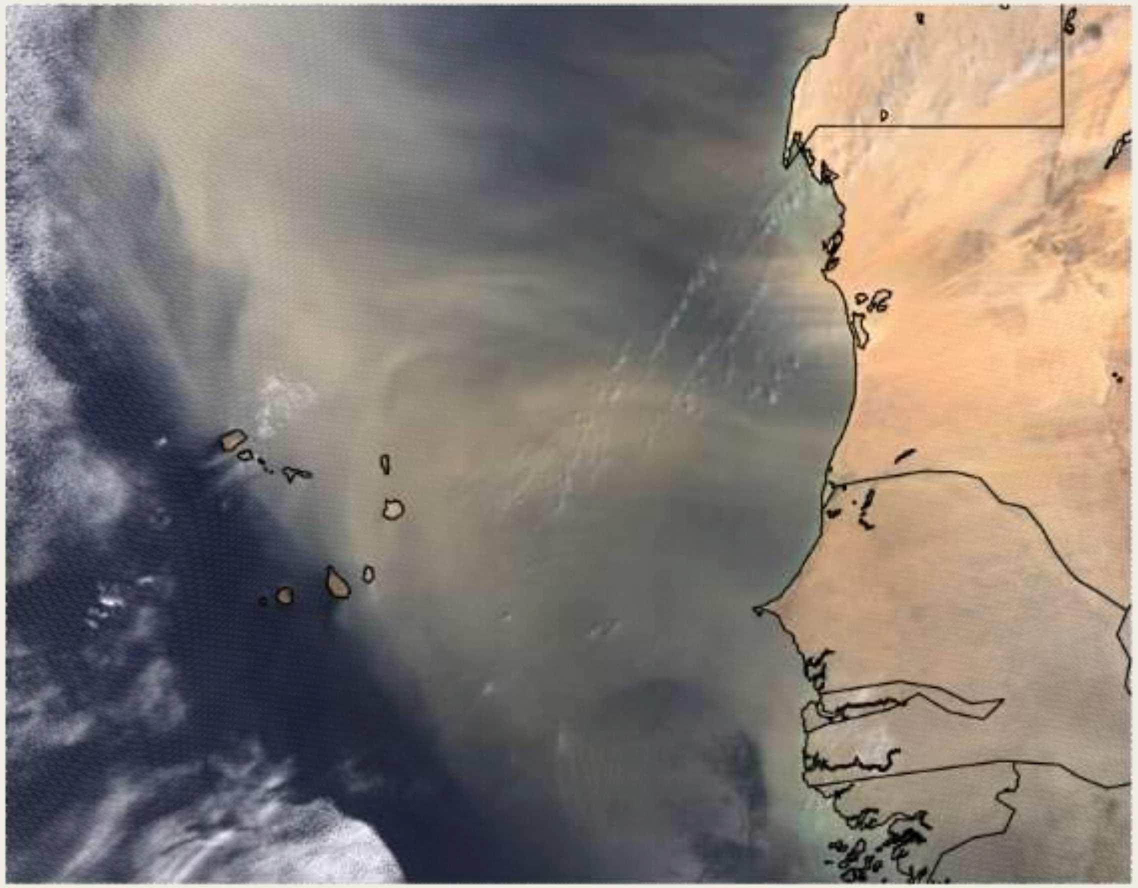


Deep Blue

- Suited towards data in which features are lighter
- Ineffective for ocean/water features
- Primarily uses the 412nm band due to its greater contrast between aerosols and land
- The 412nm band is also known as the “deep blue” band, hence the name
- Calculates both AOD and Ångström Exponent (AE), which is a measure of how AOD changes depending on wavelength of light, related to particle size
- AE can suggest type of particle, like ash and dust (coarse) or smoke and sea spray (fine)



MODIS Terra, 2 Mar 2003 11:55 UTC



References

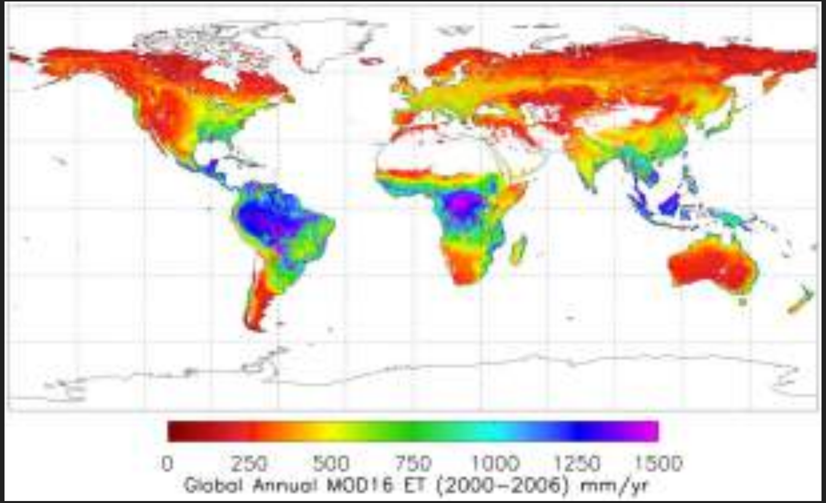
- https://atmosphere-imager.gsfc.nasa.gov/products/aerosol
- https://darktarget.gsfc.nasa.gov/
- https://deepblue.gsfc.nasa.gov/
- https://svs.gsfc.nasa.gov/30395
- https://visibleearth.nasa.gov/images/66963/ship-tracks-off-the-western-united-states

- Aerosols affect the formation of clouds
- Water accumulates to the particulate matter, causing cloud droplets to be smaller than in clean air
- Aerosol clouds tend to be more reflective

Terra/MODIS - Evapotranspiration

NASA Project using Terra MODIS since 2000 as a means of quantifying regional water resources and land surface energy change

- Water resource management
- Changes in climate
- Changes in land use
- Ecosystem disturbances & effect on evapotranspiration (wildfires, insect outbreaks etc.)
- Can be used to predict drought



Terra/MODIS - Estimating Global Terrestrial Evapotranspiration

- Latent Heat Flux (soil water status, wet canopy surface, albedo)
  Bands 1-7
  620 - 2155(nm)

- Potential Evapotranspiration/Potential Latent Heat Flux(Net radiation of soil, wet soil surface, land cover)
  Bands 17 - 25
  890 - 4549 (nm)

- Evapotranspiration (wet/dry canopy surface, canopy evapor., plant transpiration, precipitation)
  Bands 1-7 & 17 - 32
  620 -2155(nm) & 890 - 12’270(nm)

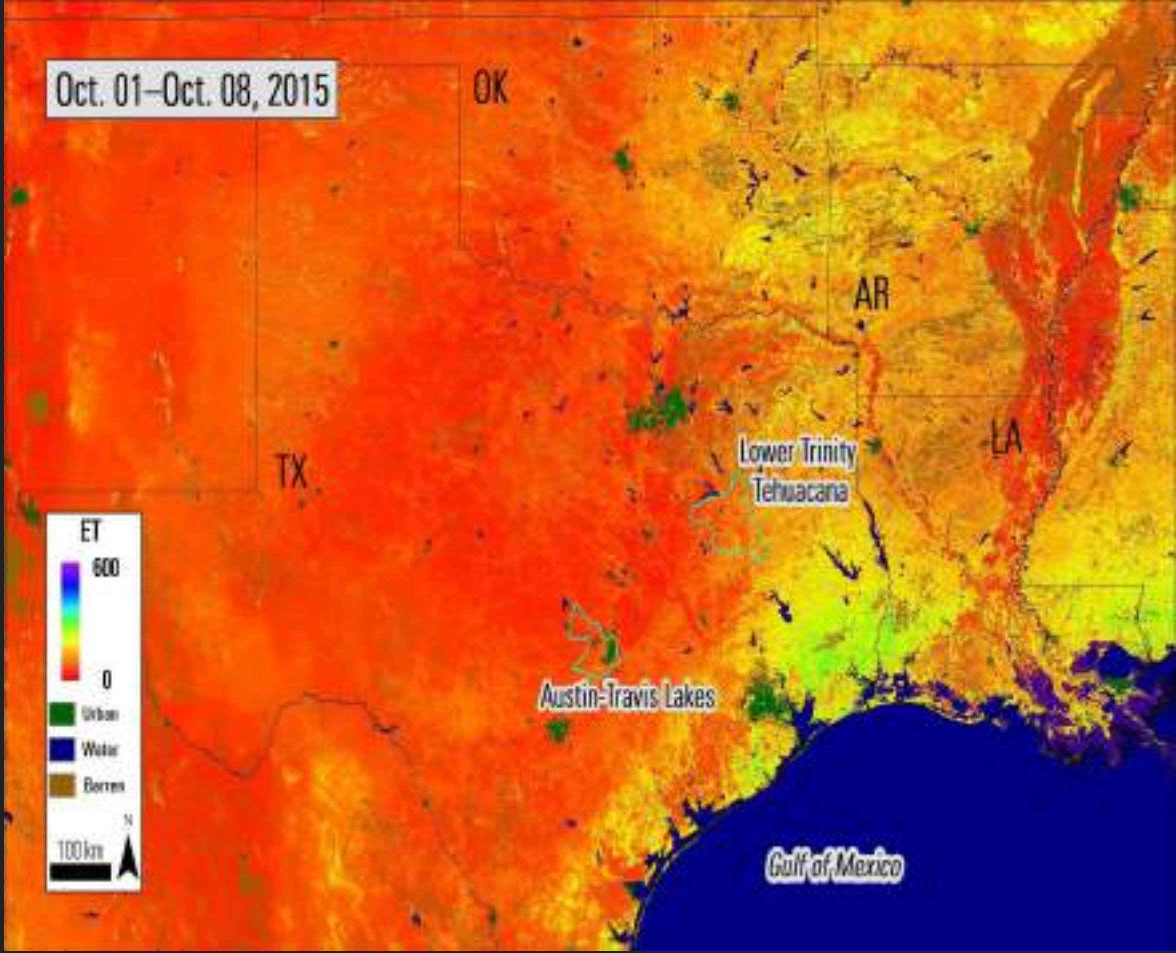
500m pixel resolution
8-day composite data sets

Terra MODIS 500-meter Evapotranspiration 8-day composite from October 01-08, 2015, over Texas and the south central United States

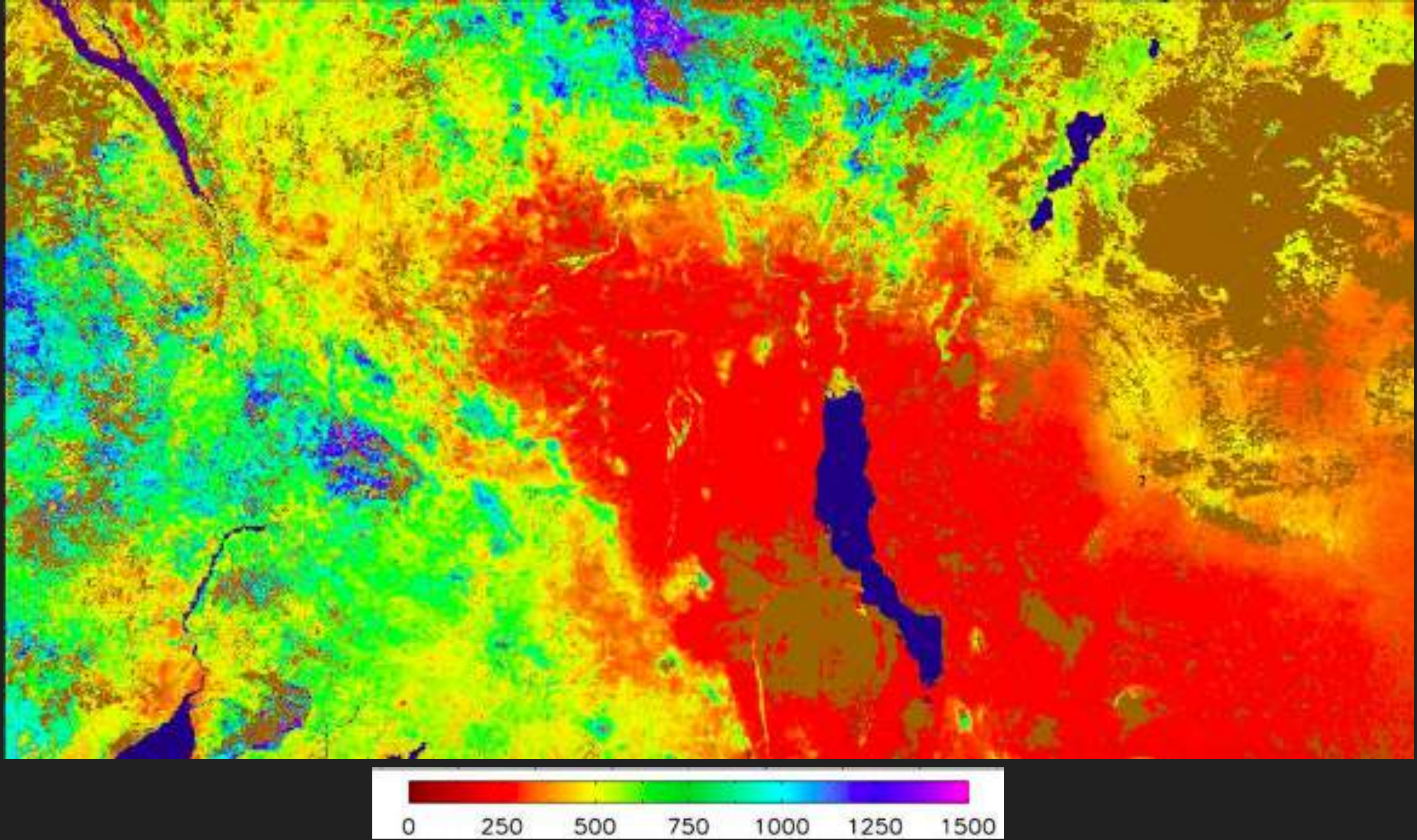
Measuring ET and soil moisture to predict drought in “Barren” ranchland settings

https://modis-land.gsfc.nasa.gov/pdf/MOD16ATBD.pdf

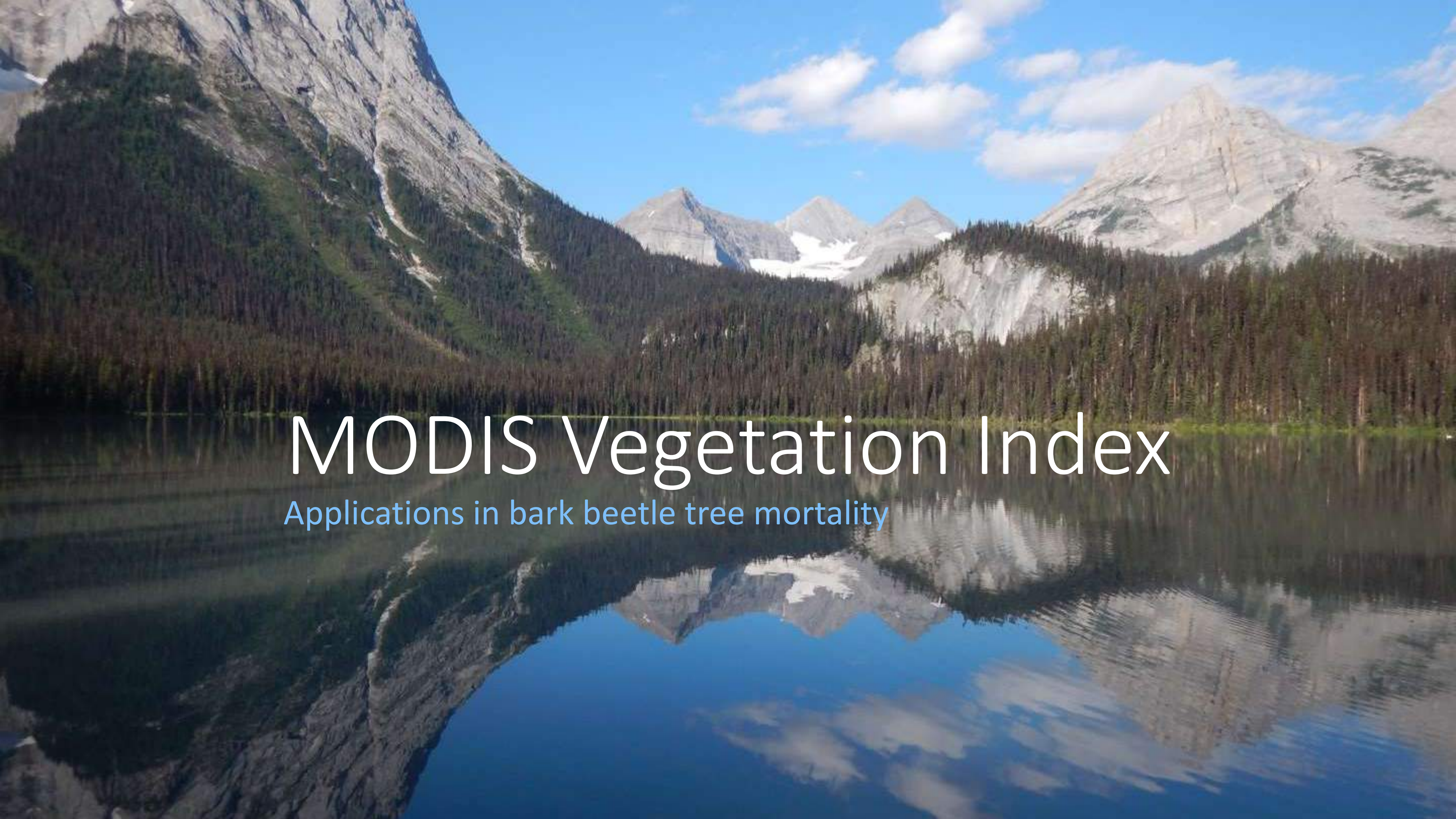
Have been collecting evapotranspiration data since 2000, using both Aqua and Terra



https://lpdaac.usgs.gov/resources/data-action/two-sensors-are-greater-one-observing-drought-smap-and-modis/



Averaged ET values east Africa from August 13 - 20, 2018 in mm/yr
Cumulation of 5 different layers: canopy wetness, leaf area index, soil moisture, plant transpiration, soil net radiation



MODIS Vegetation Index

Applications in bark beetle tree mortality

Normalized difference vegetation index and enhanced vegetation index

- NDVI – Red and NIR
- EVI – Red, NIR, and Blue
- MIR

- Show vegetation canopy greenness
- Measures of vegetation activity

- Inputs for LAI and FPAR, NPP, and more.

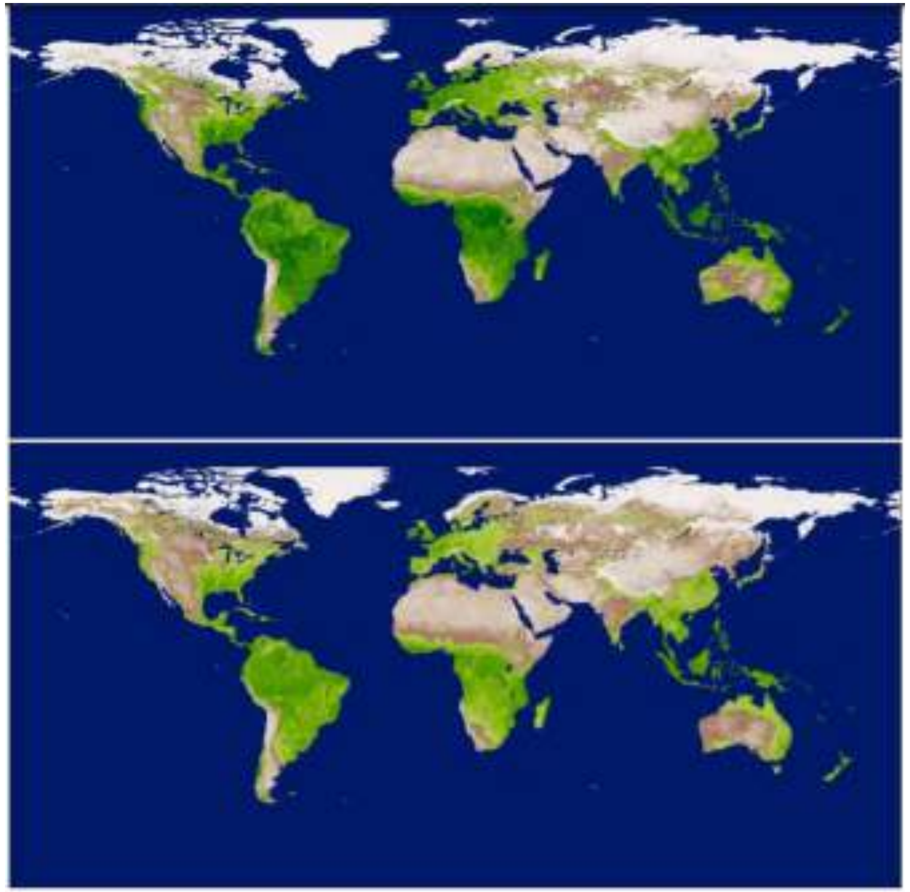
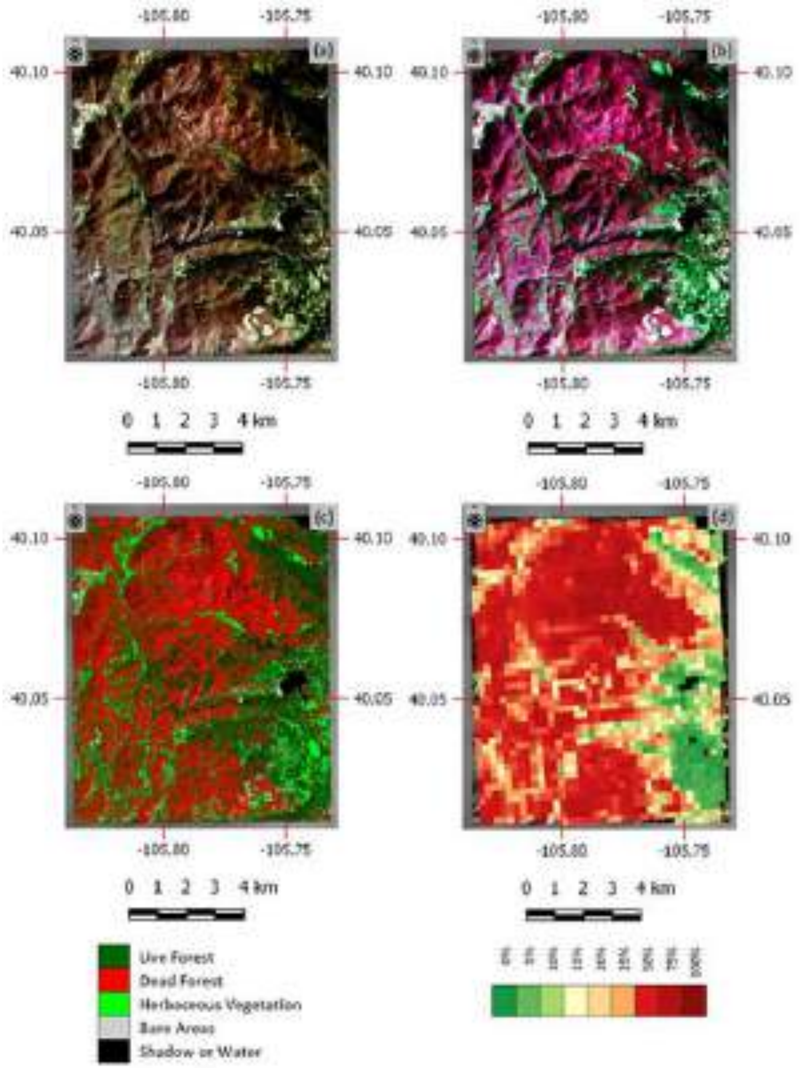


Figure 9: 0.05-deg 16-day MOD13C1 NDVI (upper) and EVI (lower) sample images. The VI values have been pseudo-colored to represent biomass health across the globe using data acquired during April 6-22, 2000.

Detection and mapping of Mountain Pine Beetle

- Pine beetle outbreaks cause widespread tree mortality
- Quantifying area lost
- Rapid detection of recent attacks
- More frequent than aerial flights



Aerial and NDVI maps from Spruce et al., 2019.

Literature

Pine beetle

Use of MODIS NDVI products to map tree mortality levels in forests affected by mountain pine beetle outbreaks by Spruce et al., 2019.

Near-real time detection of beetle infestation in pine forests using MODIS data by Anees et al., 2014.

Other land classification

Exploring the use of MODIS NDVI-based phenology indicators for classifying forest general habitat categories by Clerici et al., 2012.

Mapping cropland-use intensity across Europe using MODIS NDVI time series by Estel et al., 2016.

MODIS Fire Detection

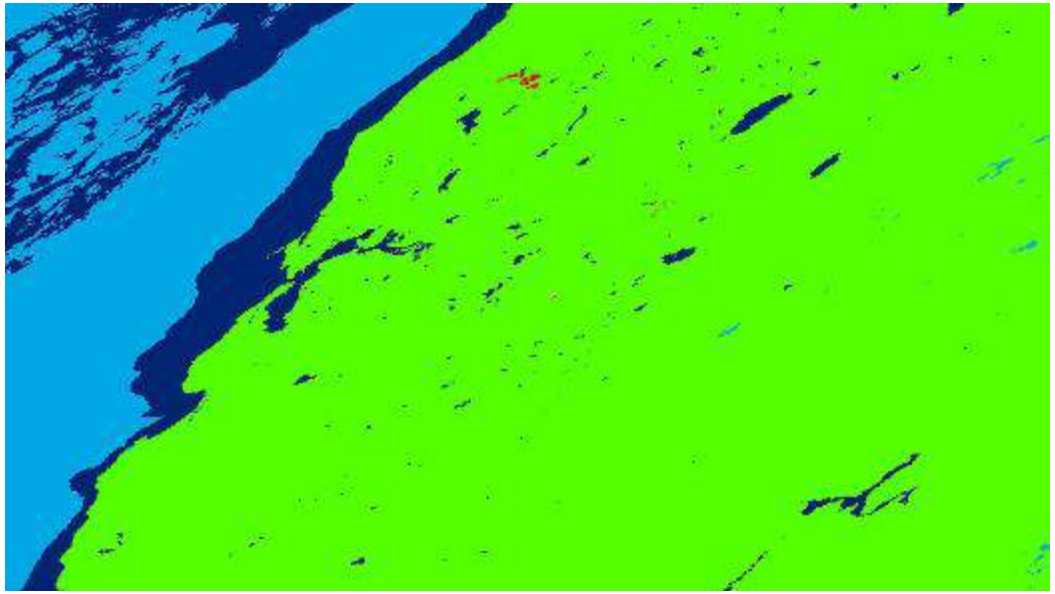
Travis Fortune

230099642

GEOG457

Features

- Used to detect remote wildfires, very cost effective
- MODIS sensors on NASA's Terra (2000) and Aqua (2002) satellites
- Slow transition to VIIRS at 375m vs 1km resolution
- Data used extensively in Canada and USA and is available worldwide
- Programming is heavily algorithemed to eliminate glare, cloud, urban areas, other anomalies
- Manual observations still needed to discern wildfires from industrial burning



Imagery from Terra of the Western United States, 2018

Channel	Wavelength (μm)	Use
1	0.62-0.67	Cloud Mask, Sun Glint Rejection
2	0.84-0.87	Cloud Mask, Sun Glint and Bright Surface Rejection
7	2.11-2.16	Sun Glint Rejection
21	3.93-3.99	High Range Fire Detection (More Temp. Sensitive)
22	3.93-3.99	Low Range Fire Detection (Less Temp. Sensitive)
31	10.78-11.28	Active Fire Detection, Cloud Mask
32	11.77-12.27	Cloud Mask

Examples

All imagery from Fire Information for Resource Management (FIRMS), a joint venture between NASA and the USFS.

References

- FIRMS. 2021. https://firms.modaps.eosdis.nasa.gov/usfs/map/#d:24hrs;@-100.0,40.0,4z. Accessed February 5, 2022.
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- NRCAN. 2022. Fire Monitoring, Mapping, and Modeling (Fire M3). https://cwfis.cfs.nrcan.gc.ca/background/dsm/fm3. Accessed February 5, 2022.
- USGS. 2018. https://lpdaac.usgs.gov/products/mod14a1v006/. Accessed February 5, 2022.

Landslide Detection and Observance

Dylan Broeke, GEOG 457

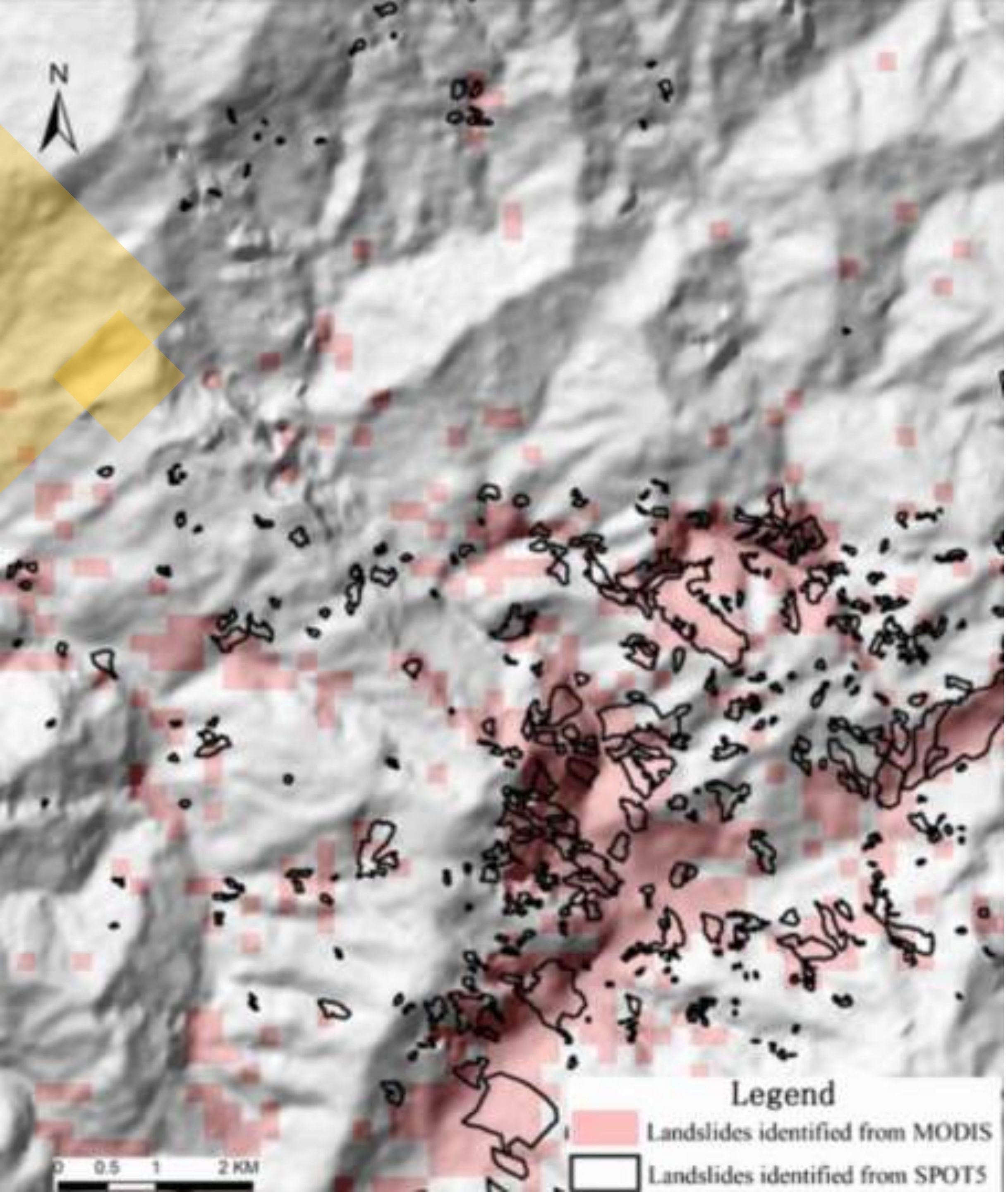
Why not use High-Res Sensors for Landslide Detection/Mapping?

- High-res imagery can be expensive which can prevent study in mountainous and rural areas and can lead to incomplete data.
- When covering large areas (thousands of km^2) using high-res imagery can be very time consuming.
- Time series imagery from high-res sensors is very limited, which could lead to inaccurate comparison of before and after a landslide.

Details

- MODIS land products use four resolutions to create imagery: 250m, 500m 1000m and 5600m. These resolutions can be used on different temporal rates; daily, 8-day, 16-day, monthly, quarterly, and yearly.
- For Landslide detection, NDVI imaging is used to show any abrupt and unexpected changes in the vegetation. This is usually produced in rural areas where the NDVI is somewhat constant.
- NDVI imaging is stacked to create a time-series of NDVI values of an area.
- NDVI values are tested within a training area to ensure accuracy.

- In the study I was looking at, they used this formula to minimize noise from atmosphere and cloud and to clearly map any abrupt change in NDVI.
- difference=max{NDVI(i:j)}−max{NDVI(k:l)}
- Where i, j, k, l are sequential NDVI images, both before and after an earthquake. In this, i and j are the window before the earthquake, and k, l is the window after.
- Calculating max NDVI values before and after an earthquake allows any change to be apparent. This change would most likely be a landslide.



MODIS vs SPOT5

- Here, MODIS landslide detection was put up against SPOT5 high-res sensor for comparison. This was of the Wenchuan earthquake in the mountains of China.
- This image was taken 25 days after the initial quake and was plotted on NDVI using an 8-day temporal range.
- Because of the location, NDVI values were not expected to change
- As you can see, MODIS found, and was able to identify more landslides then SPOT5
- From MODIS, a 75% accuracy is achieved.

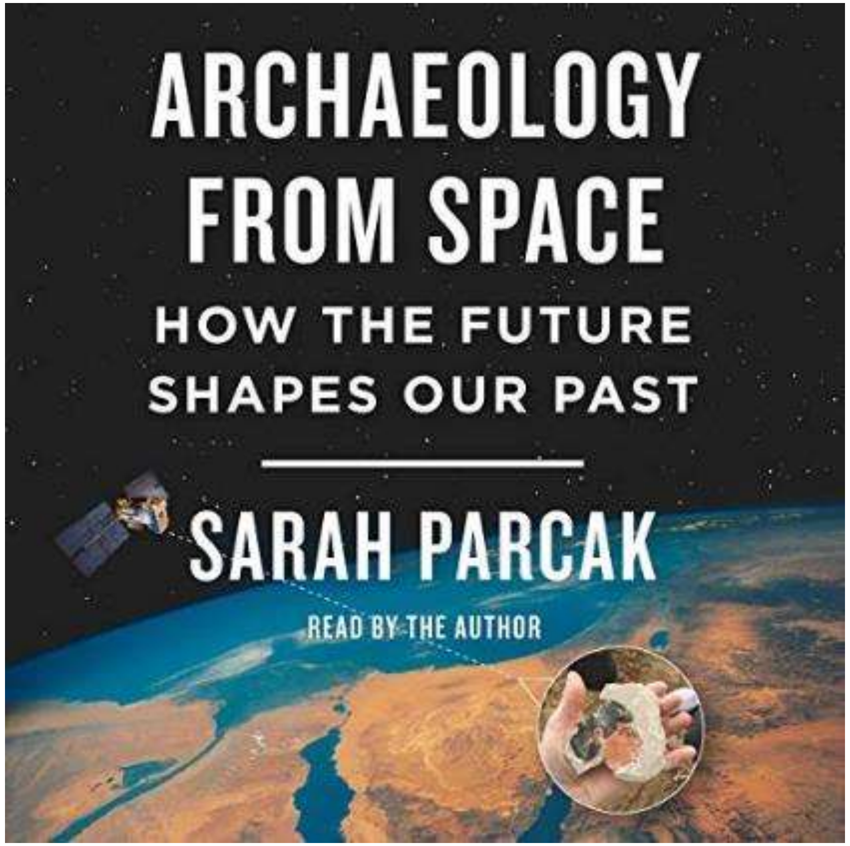
References

- Using MODIS NDVI time series to identify geographic patterns of landslides in vegetated regions. IEEE Xplore. (n.d.). Retrieved February 4, 2022, from https://ieeexplore.ieee.org/abstract/document/6341795
- NASA. (n.d.). Modis website. NASA. Retrieved February 6, 2022, from https://modis.gsfc.nasa.gov/sci_team/pubs/abstract.php?id=08744

MODIS: Application in Archaeology

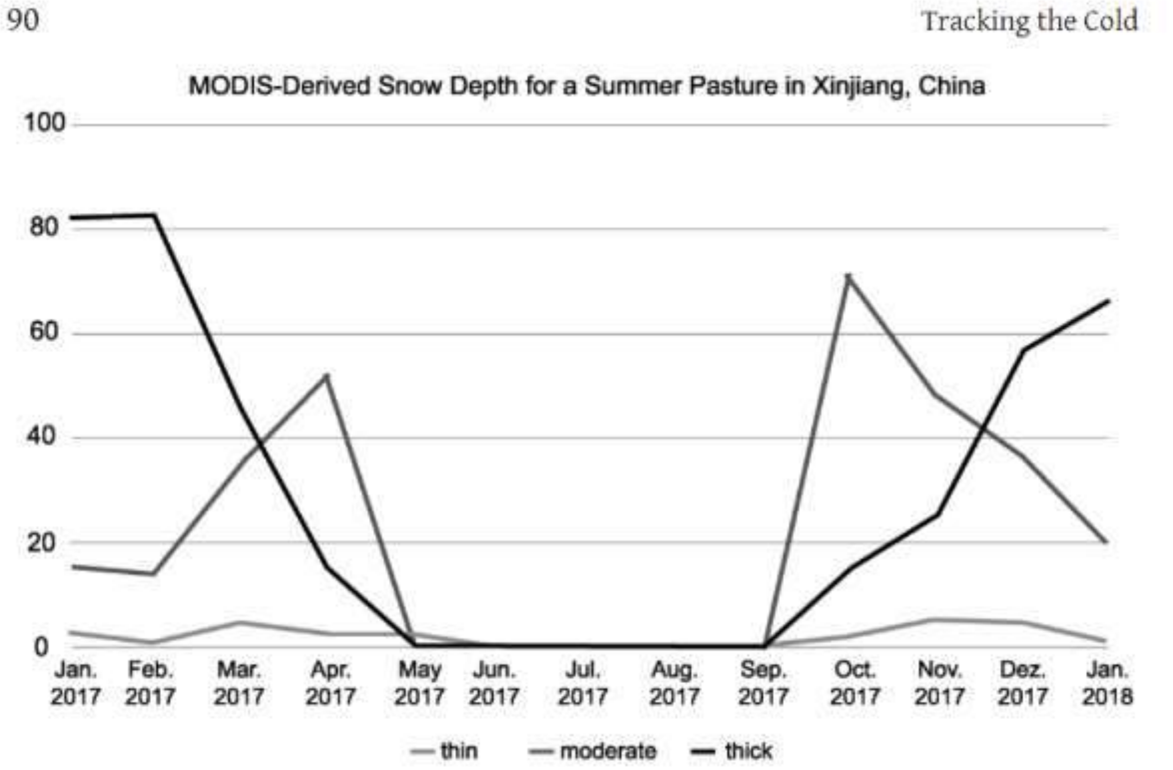
Geog 457 Winter 2022 – Kyra Egan

- Relatively new application
- Common Bands: Visible (Red, Green Blue), NIR, SWIR
- Common uses:
  - Determine likely location of sites
  - Create models of the present to help model the past
- Why did people move across the landscape in the past?

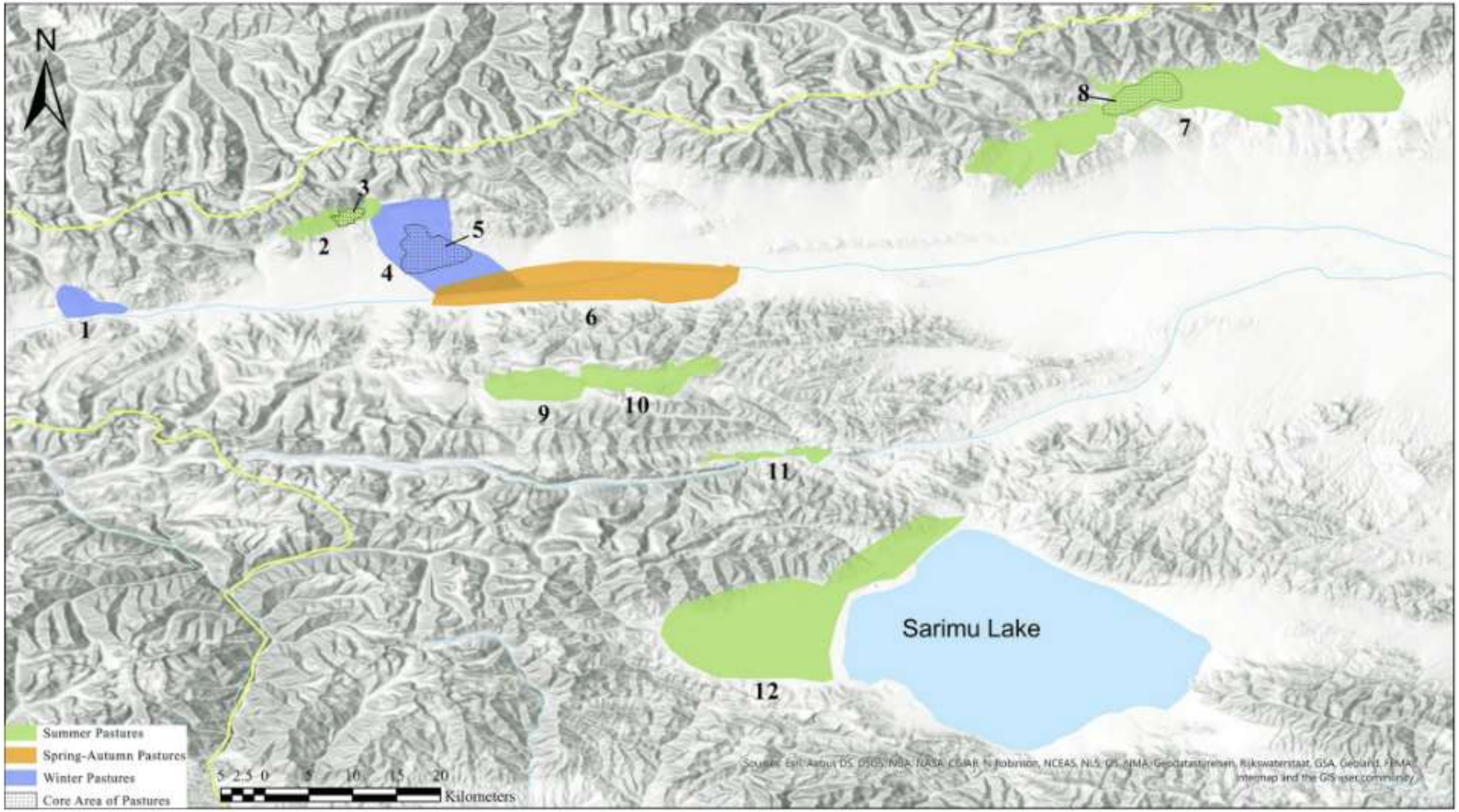


Case Study: Movement Across Glacial Landscapes

- Track melting rates of snow and glaciers to plan surveys
- Examine mobility of past peoples
- Example: Bronze Age mobile pastoralists in the Xinjiang Region, China
- Combination of Red, NIR, Visible, and SWIR to create NDVI and NDSI
- Current evidence shows a climate pattern similar to the present day in this region



(Jia et al., 2020)



(Caspari, 2021)

Used MODIS (in conjunction with other data) to determine settlement patterns for the pastoralists

Websites

- https://earthobservatory.nasa.gov/images/92338/going-going-gone-summer-clears-ice-from-krasnoye-lake?src=ve
- https://www.researchgate.net/figure/a-MODIS-image-of-the-LM-and-map-of-South-America-Main-rivers-are-represented-as-blue_fig1_299370210

Papers

- Caspari, G. (2021). Tracking the cold. *Journal of Glacial Archaeology*, *5*, 85–102. https://doi.org/10.1558/jga.19823
- Jia, P., Caspari, G., Betts, A., Mohamadi, B., Balz, T., Cong, D., Shen, H., & Meng, Q. (2020). Seasonal movements of Bronze Age transhumant pastoralists in western Xinjiang. *PLOS ONE*, *15*(11). https://doi.org/10.1371/journal.pone.0240739

Volcanology with MODIS

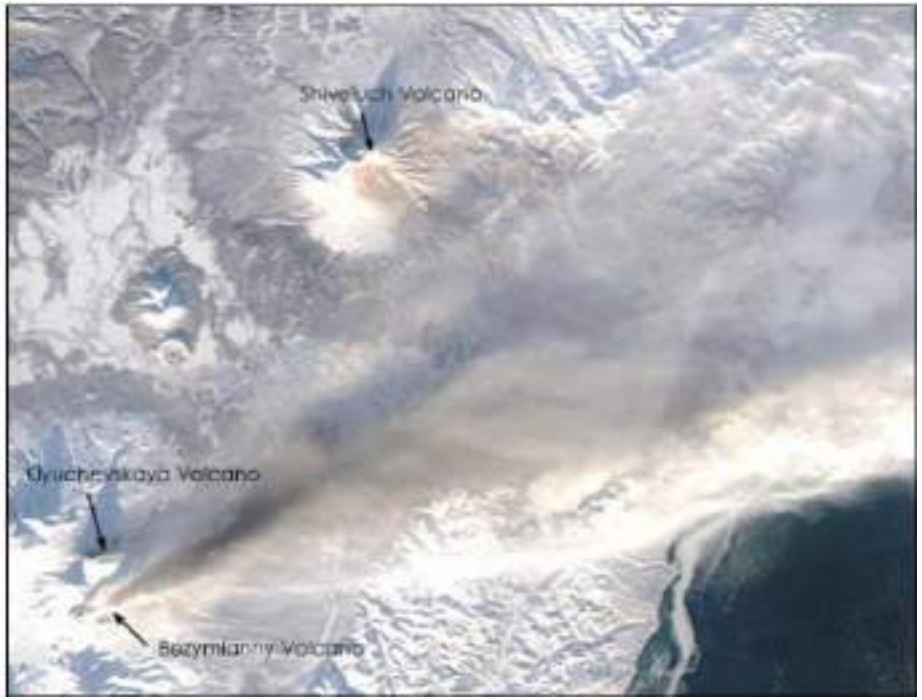
GEOG 457 Advanced Remote Sensing

Mackenzie. Hamm

Why use MODIS?

- Volcanic eruptions pose a risk of catastrophic damage to both human life and property
- Typical bands used include Bands 28-32 which use the water vapor and infrared portion of the spectrum
- MODIS can:

- Detect airborne volcanic ash
- Has a Thermal Alert System which detect hot spots (lava flows, lava domes, etc…)

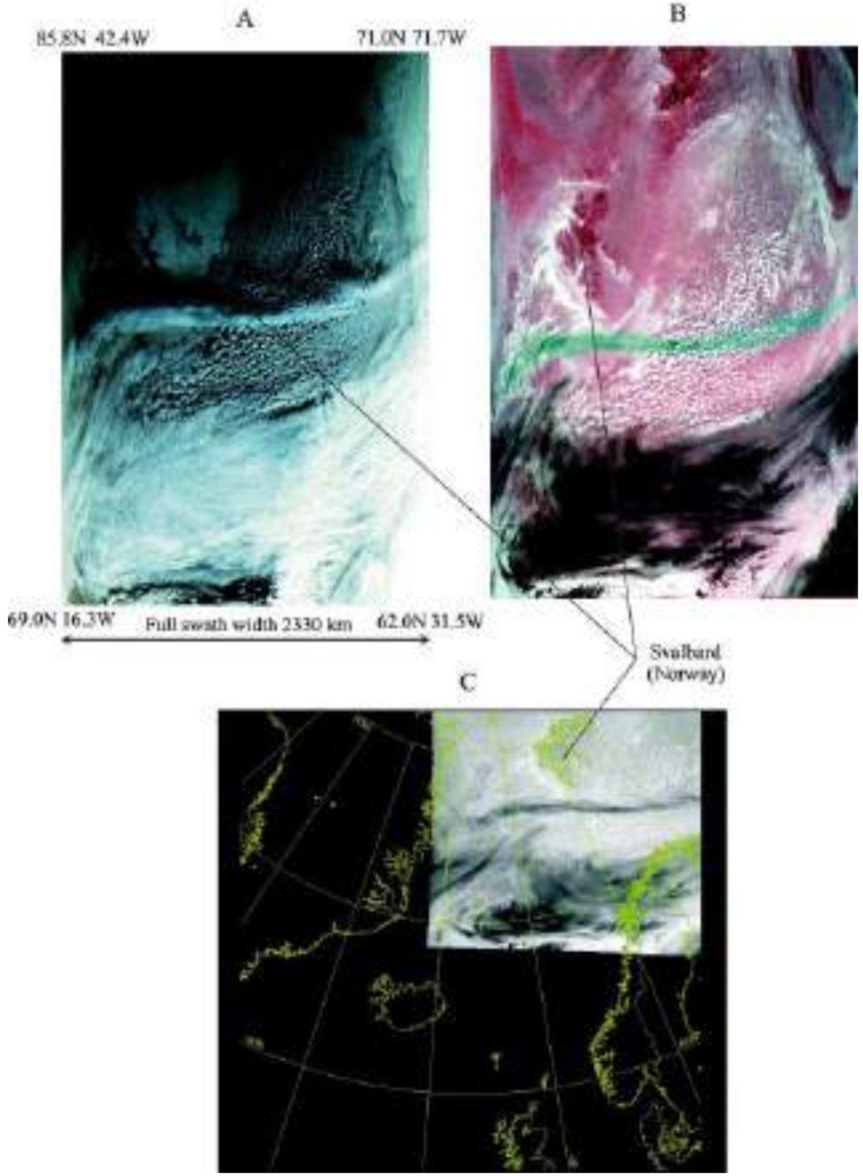


https://earthdata.nasa.gov/learn/sensing-our-planet/sensing-remote-volcanoes

https://modis.gsfc.nasa.gov/sci_team/pubs/abstract.php?id=03417

Identifying Plume Characteristics from Hekla Volcano, Iceland

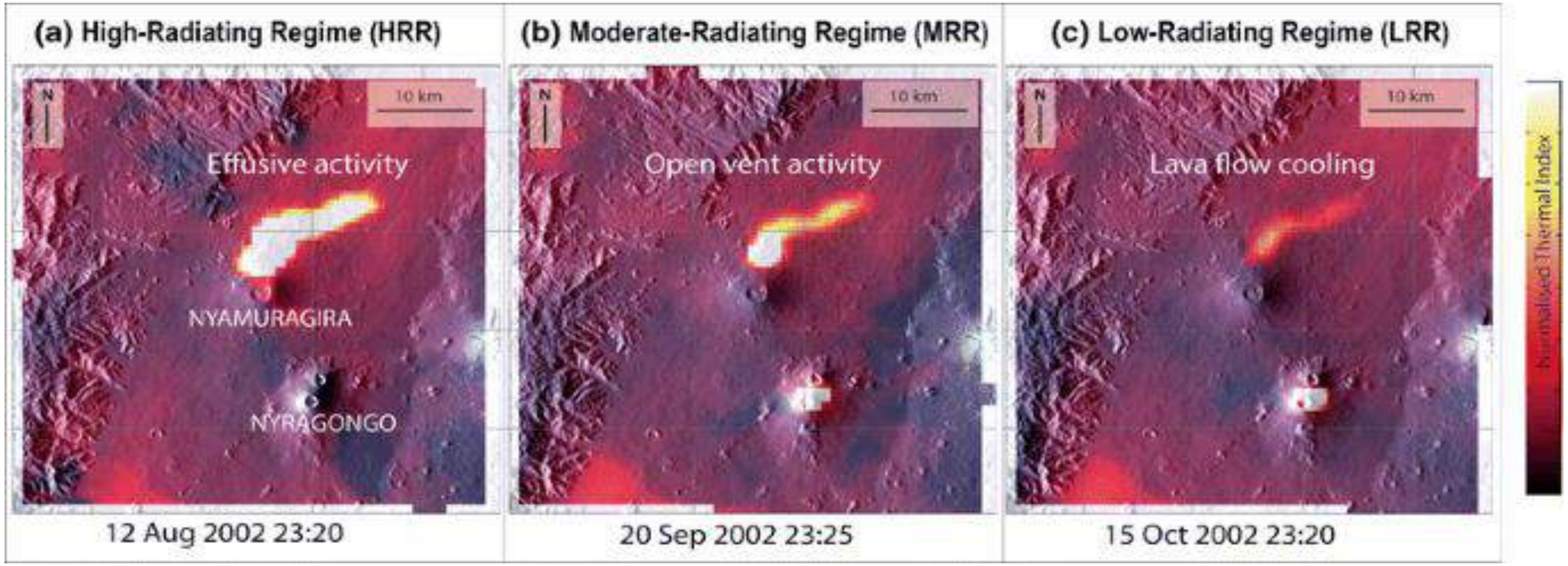
- Eruption on February 26th, 2000.
- Plume reach over 12km in height
- MODIS imagery detected a lighter ash plume which indicated higher water content due to ice in the cloud
- Image A used visible radiance data
- Image B used infrared channels (28,31,31)
- Image C is a geolocated map of channel 28 which is sensitive to SO_2 emission



https://www-sciencedirect-com.prxy.lib.unbc.ca/science/article/pii/S0377027304000307

Detecting Volcanic Radiative Energy (VRI)

- Determined that Volcanic Radiative Energy from a volcano is inversely proportional to the silica content and therefore the "characteristic "thickness" of lavas.
- Volcanic Radiative Energy could estimate lava discharge rate and erupted volumes from volcanoes



https://link-springer-com.prxy.lib.unbc.ca/article/10.1007/s00445-013-0744-z
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