Scioly Summer Study Session 2017

Remote Sensing (Answers)

Topic: Climate Change Processes*

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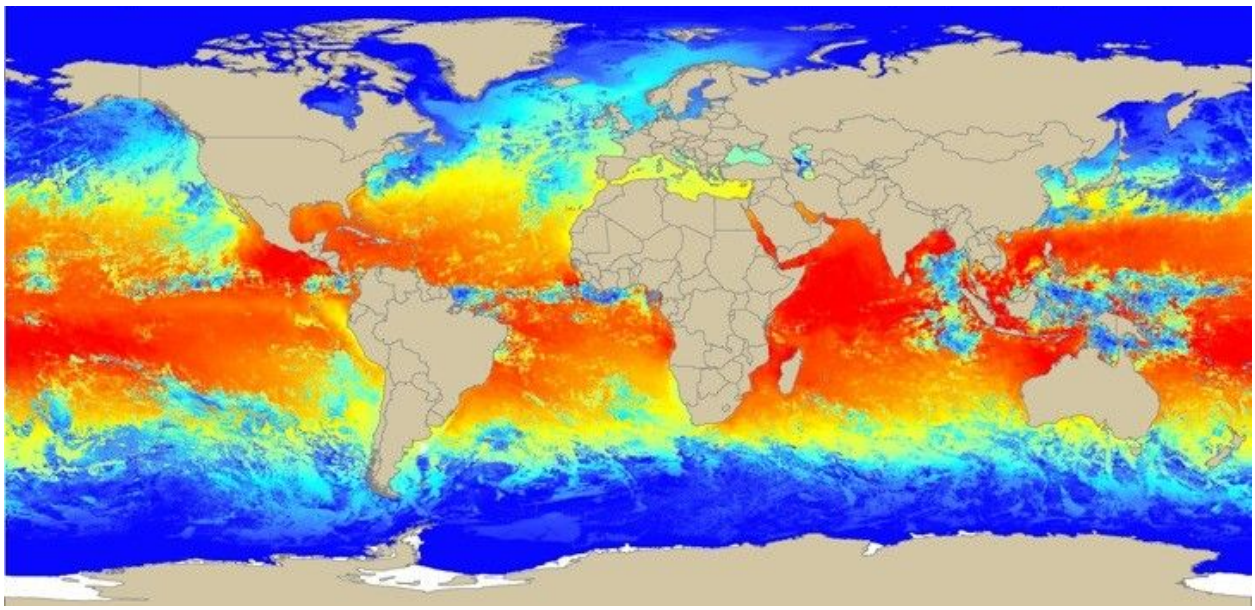
By user whythelongface (merge)



Name(s): _____

Test format:

This test is worth **180 points.** There are **four** sections:

1. Remote Sensing Technology and techniques (**50 points**) **__ /50**
2. Data Use and Manipulation (**20 points**) **__ /20**
3. Image Interpretation (**30 points**) **__ /30**
4. Weather and Climate Processes (**80 points**) **__ /80**

Total: __ /180

As of the 2016-2017 season, **each person** is allowed **one** double-sided 8.5 × 11" notesheet. Each partnership is allowed a protractor, ruler, writing implements, and a **scientific** calculator. Graphing calculators are not allowed. The author wishes you best of luck on this test and in the 2017-2018 Science Olympiad season.

*The topic for the 2017-2018 season is still unknown at the time this test is being written, so it will focus on the same topic as that of the 2016-2017 season.

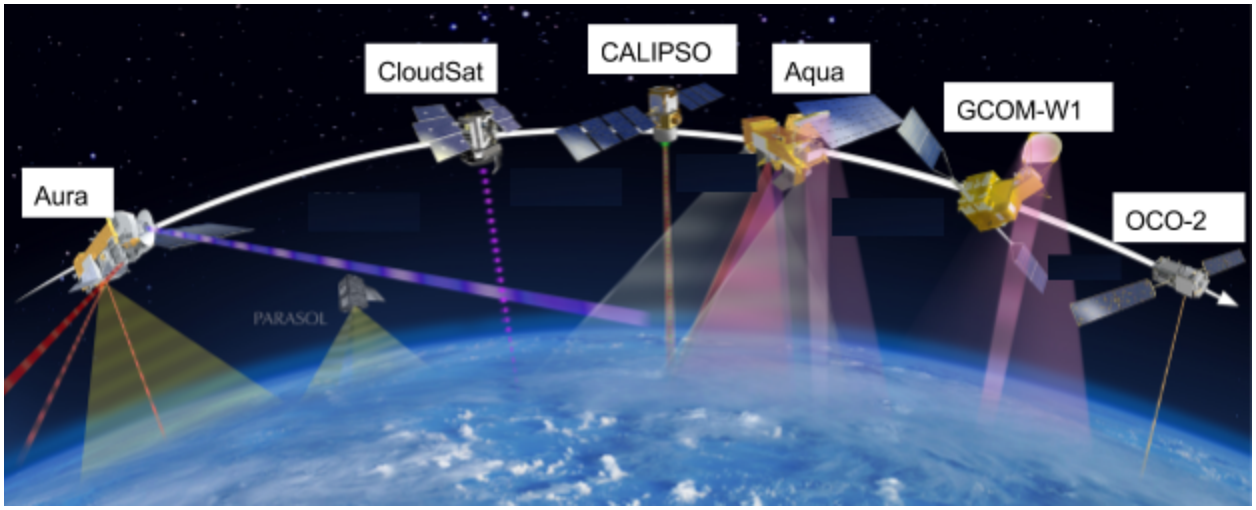
Part 1: Remote Sensing Technology

Multiple Choice (1 point each)

1. Medium Earth orbits are generally at what altitude range?
    a. 2000-10000 km
    b. 2000-36000 km
    c. 500-2000 km
    d. 36000-50000 km
2. As a general rule of thumb, _____ wavelengths penetrate _____.
    a. Shorter; more
    b. Shorter; less
    c. Longer; more - for example, longwave microwave can penetrate tree canopy and the ground
    d. Longer; less
3. AMSR2 is an instrument flown on which satellite?
    a. Terra
    b. Aqua
    c. GCOM-W1 "SHIZUKU" - the Advanced Microwave Scanning Radiometers are JAXA instruments, with the original AMSR2 flown on GCOM-W1
    d. CloudSat
4. Which of the following satellites are active members of the Morning Constellation (EOS AM)?
    a. Landsat-7 - Terra and Landsats -7 and -8 comprise of the Morning Constellation. EO-1 is no longer active.
    b. EO-1
    c. CALIPSO
    d. Jason-2
5. How many Navstar satellites are theoretically necessary to locate and track a GPS receiver?
    a. 2
    b. 3
    c. 4 - Navstar relies on a three-dimensional triangulation method, requiring four satellites
    d. 5

6. Which two satellites were launched in the same payload?
    a. CloudSat and CALIPSO - both satellites were launched from Vandenberg AFB in April 2006 in a Delta-II rocket
    b. Radarsat-1 and -2
    c. SPOT-6 and -7
    d. Suomi NPP and SMAP
7. What is band 8 on the Landsat-8 OLI?
    a. SWIR, measuring in a range of 2.1-2.3 μm
    b. VNIR, measuring in a range of 0.84-0.89 μm
    c. PAN, a panchromatic band measuring across 0.5-0.68 μm
    d. Cirrus, a special band monitoring high altitude clouds, measuring across 1.36-1.39 μm
8. What is OCO-2 data most commonly expressed as?
    a. [CO_2], the concentration of CO_2 in the air column
    b. χ_{CO2}, the mole fraction of CO_2 in the air column - while OCO-2 measures reflectance, the data is expressed as a mole fraction
    c. P_{CO2}, the reflectance of the air column
    d. τ_{CO2}, the transmittance of the air column
9. This data format is easy to manipulate mathematically and is stored very efficiently, but is limited by spatial resolution
    a. Vector
    b. Raster
    c. Dot-grid
    d. Kernel
10. On a cross-track scanner, objects seemingly fall _____ the _____.
    a. Towards; center of image
    b. Away from; center of image
    c. Towards; nadir line
    d. Away from; nadir line
11. Cities often turn up very bright in radar images due to the _____.
    a. Orthogonal effect
    b. Cardinal effect - so named for the cardinal directions, since cities are usually oriented in those directions
    c. Directional effect
    d. Urban dielectric effect

Label the following diagram of the A-train (6 points)



What year did PARASOL cease operations? *(1 point)* **2013**

How much time separates a CALIPSO pass from an Aura pass? *(1 point)* **375.5 seconds (6 minutes, 15.5 seconds is acceptable)**

The A-train has to orbit low enough to obtain good data, but it has to orbit high enough to avoid atmospheric drag, which creates a need for constant maintenance. What is the orbital altitude of the A-train? *(1 point)* **~705 km**

How are radar images different from photographs? Explain three major differences. *(6 points)*

1. **Instead of capturing a perspective, radar images record slant ranges**
2. **Radar images never include the nadir, because of how the active sensor works.**
3. **The brightness of objects depends heavily on their surface properties and not solely on incident radiation**
4. **Anything that is logical**

What is Synthetic Aperture Radar and why is it used? *(3 points)*

Synthetic Aperture Radar works on the principle that the longer an aperture is, the higher the resolution. SAR uses either multiple arrays or the motion of the aperture to synthesize an "antenna" that is larger than the real antenna. Thus more efficient than a real aperture radar while achieving the same resolution.

Assume the Earth is a 288K blackbody. What is the dominant wavelength emitted by the Earth? What instrument would you use to measure this radiation? Be specific. *(5 points)*

Using the Wien's Displacement Law, $\lambda_{max} = 2.898 \times 10^{-3}$ m·K/T, the value of λ_{max} can be calculated to be 1.006×10^{-5} m, or 10.06 μm. The answer makes sense, because it is in the far IR region of the EM spectrum.

Suppose you flew a thermal infrared imager over a neighborhood to identify heat loss. At what time should you make the overhead pass? Explain. *(3 points)*

During predawn, since the surroundings have cooled sufficiently to not obscure TIR readings from the houses.

What is a panchromatic band? Why does it offer better spatial resolution than most other multispectral bands? *(2 points)*

A panchromatic band covers a wide range in the spectrum, and thus receives higher readings per pixel than a normal band. Normally, spatial resolution is limited by spectral resolution, since too high a spatial resolution would cause insufficient readings per pixel and cause the image to be too dark. Panchromatic bands thus can support a higher spatial resolution than other MS bands.

The SPOT satellites have a finer temporal resolution than one might expect from its revisit time. Why? *(2 points)*

The HRV sensors on the SPOT satellites have off-nadir viewing capabilities and thus can view a target location even when not directly overhead.

You are researcher monitoring the effects and spread of coral bleaching in the Great Barrier Reef, off Australia. You have access to the Landsat-7 ETM+ data sets. Which band would you use to observe coral? Why? *(3 points)*

Band 2, as that is the green band. Green light penetrates water better any other wavelength, and thus shallow water features (such as coral) can be visible in band 2 when the water absorbs frequencies monitored by any other band to the extent where water just looks dark.

Suppose that you just received additional funding from a generous grant. You have enough money to purchase exactly ONE additional data set from any currently operational satellite to augment your ETM+ data on the Great Barrier Reef. Which instrument and which satellite would you choose? Explain. *(4 points)*

Coral bleaching is tied directly to SST, and so any SST-sensing instrument is acceptable. Examples include: AMSR-E (Aqua), AMSR2 (GCOM-W1), VIIRS (Suomi NPP). These were chosen because of spatial resolution roughly compatible with ETM+ data (for this reason, only award 2 points to "*AVHRR (POES)*" because of lower spatial resolution.

Part 2: Data Use and Manipulation

Multiple choice (1 point each)

1. What is the process of dividing DNs into discrete subintervals and assigning each subinterval a DN called?
    a. Low pass
    b. Histogram stretch
    c. Density slicing
    d. Fourier analysis
2. Hyperspectral data is usually stored in a:
    a. Raster
    b. Data cube
    c. Histogram
    d. Data cloud
3. You fly two passes with an interferometric SAR and use the data to create:
    a. A DTM - IFSAR is used to calculate phase changes and therefore terrain geography can be used to create digital terrain models.
    b. An orthophoto
    c. A stereopair
    d. A histogram
4. All of the following are reasons why lidar is good at creating DSMs EXCEPT:
    a. High sampling rate, hence more data points
    b. Ability to measure several returns, producing canopy stratification data
    c. Properties of the surface can be measured
    d. Large IFOV and swath, making data collection more efficient - lidar has a very small IFOV, relying on a large sampling rate to create a data collection. That is also why lidar is so precise.

5. You analyze some raw data from the Landsat-7 ETM+ and realize that the image is weird. Upon closer examination, you realize every seventh line of pixels is completely dark (DN = 0). What is this called?
    a. Line striping
    b. Line dropoff
    c. Partial line loss
    d. Periodic line failure
6. The effects of speckle can be partially rectified by:
    a. Getting more radar looks - there is an equation relating the number of looks and the average speckle.
    b. Synthesizing a longer antenna
    c. Obtaining a higher-quality sensor
    d. Setting the antenna to only record only cross-polarized data
7. Nearest-neighbor resampling involves the use of:
    a. Kernels
    b. Grains
    c. Matrix determinants
    d. Cubic convolution
8. The process of assigning the lowest DN a value of 0, the highest a value of 2^n-1, and adjusting all intermediate values based on best-fit:
    a. Histogram stretch
    b. Density slicing
    c. Extreme adjustment
    d. Linear contrast stretch - Histogram stretching adjusts values by frequency, not best-fit.

Fourier transforms are very complicated mathematical analyses. Given this fact, why are Fourier transforms so useful in data manipulation? Give two reasons. *(4 points)*

Fourier transforms are a better way of storing data, by turning the image into a mathematical set that can be expanded back into the original image - it is a mathematical compression. In addition, it is easier to manipulate transformed data. This is because instead of manipulating matrices, transformed data instead allows for the manipulation of frequency and signal, which is what many image processing techniques do.

Explain the three main color systems: YMC, RGB, and IHS. What applications is each used for? *(6 points)*

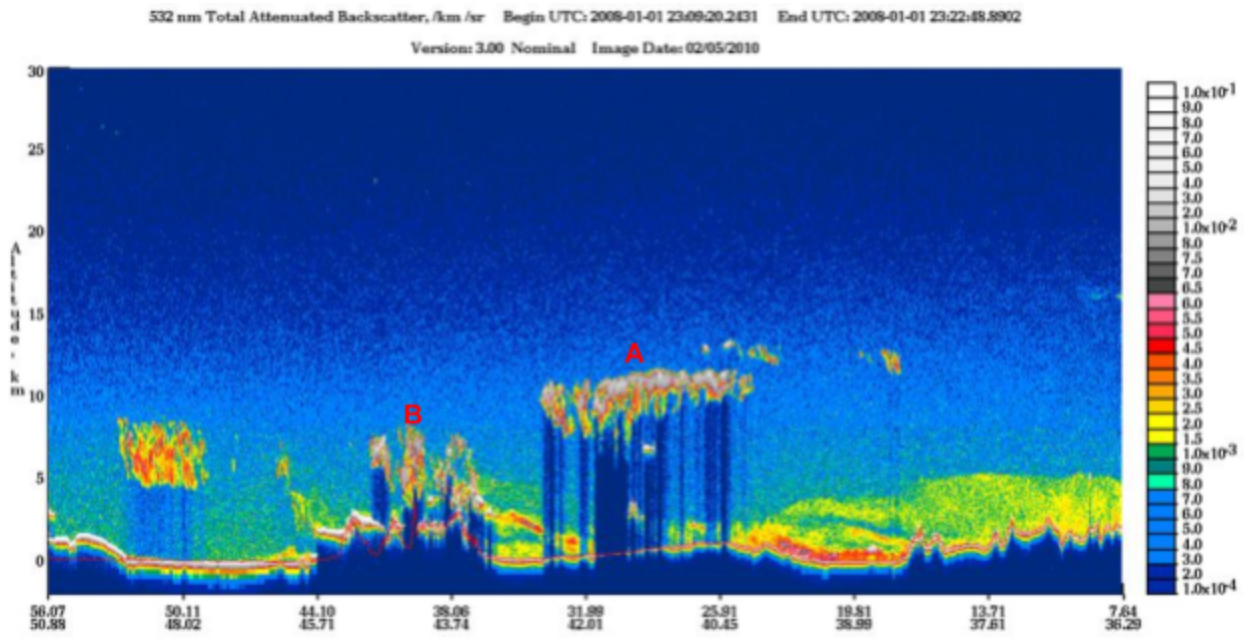
Yellow, magenta, and cyan are the subtractive colors, are are used in pigments to achieve the full color space. These colors are sensed by the human eye as a combination of the additive colors red, green, and blue, as the cone cells in the eye detect those three colors. Intensity hue saturation (IHS, which is also known by a slew of other abbreviations) is a restructuring of the RGB color space, from a cubic space (where each axis is an additive color) to a cylindrical form. This is used in many applications where simplification of the RGB model is desired.

Briefly explain how haze distortion is corrected in an image. *(2 points)*

Since haze is for the most part fairly uniform over a local area, the easiest way to correct haze distortion would be to calibrate the DNs by viewing a standard reference which has a known DN.

Part 2: Image Interpretation

The following image was produced by the CALIOP cloud lidar.



What accounts for the uniform dark blue at the top of this image? What about the lines beneath A? *(2 points)*

At the top of the image, the lack of particles causes little backscattering, resulting in low measured values. The lidar cannot penetrate A, which is a cloud, causing a lidar shadow at that location.

What causes the yellow-green coloration at 0-5 km? *(2 points)*

Aerosol backscattering (0 points for "low clouds")

What kind of cloud is A? How about B? *(2 points)*

A is a cirrus cloud; B is a convective cloud of some sort, probably cumulus.

The following image was taken by Landsat-8 on March 30, 2014.

What is that brown dot near the bottom of the image? *(1 point)*

Volcanic island (0 points for just *volcano* or *island*)

Suppose we collected samples of the clouds. What kinds of gases would you expect to find? Provide at least two examples. *(2 points)*

Nitrogen/sulfur oxides, hydrogen sulfide, water vapor, carbon dioxide, hydrochloric/nitric/sulfuric acid. (0 points for just *water vapor*)

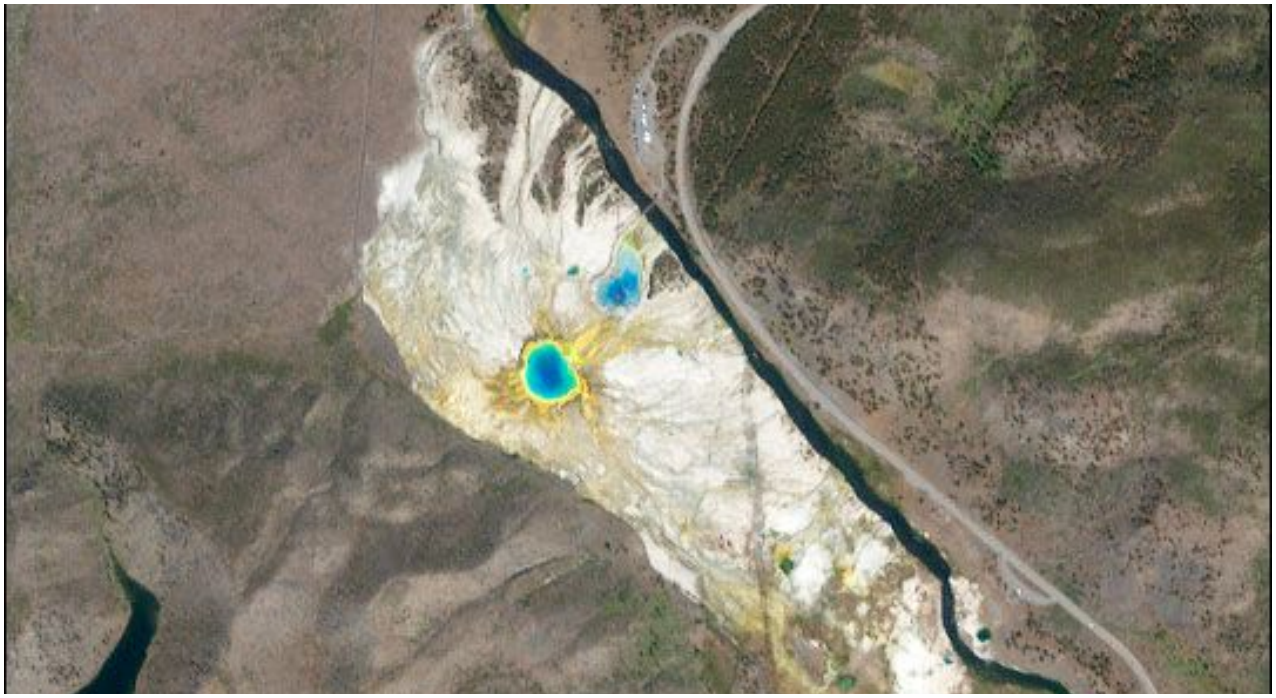
This picture is of Niijima, a new island near Japan. Where else would you expect to find this kind of phenomenon? *(2 points)*

Accept any answer involving volcanic island archipelagos, including: Hawaii, Marianas, Surtsey

What causes the small curl of green located to the right of the island in the image? *(1 point)*

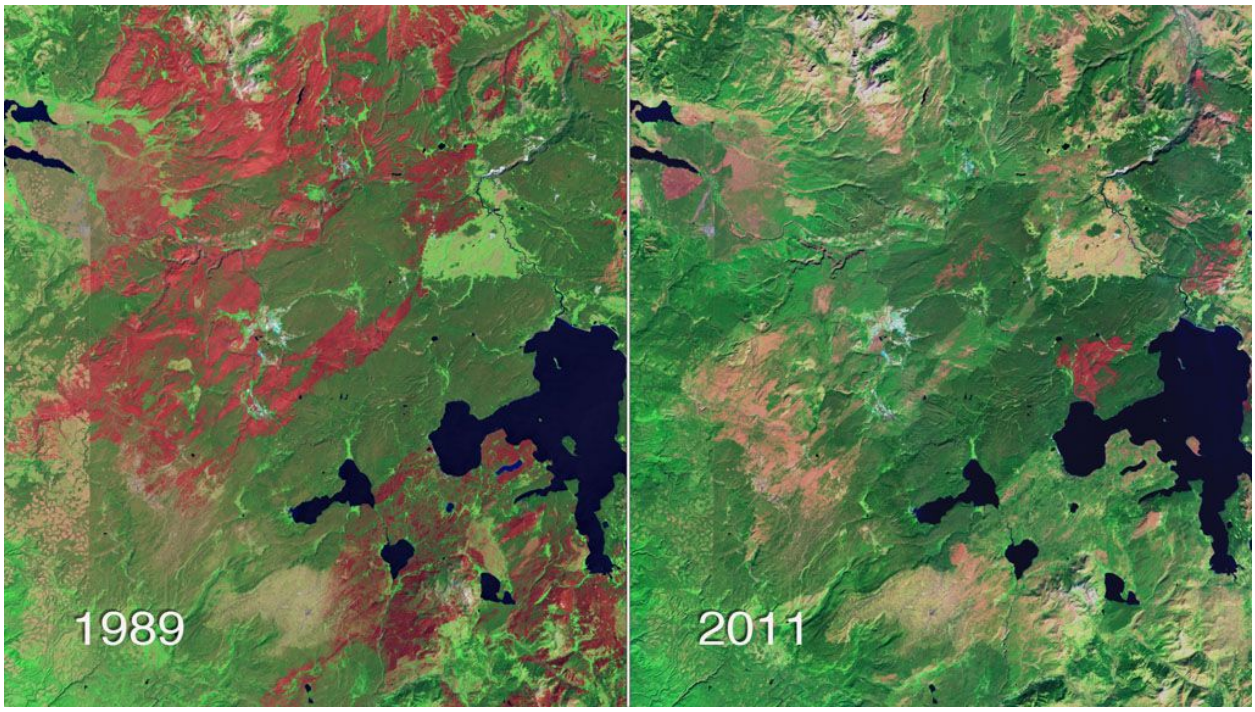
Suspended sediments (0 points for *algal blooms*)

The following images are of Yellowstone National Park, where geological and climate processes are often very much entwined.



The colorful area in the center of the image is the Grand Prismatic Spring, a hot pool colored by extremophilic microorganisms. What causes the white coloration of the area surrounding it? *(2 points)*

Mineral deposits from the water from the spring.



What happened to the red areas? Why is it not as prevalent in 2011 as it was in 1989? *(2 points)*

The red areas are burn scars (accept *forest fires*) from the massive 1988 Yellowstone Fires; by 2011, most of the areas had healed, except some areas which had experienced newer burns.

Why is the event pictured here important to the Yellowstone ecosystem? *(2 points)*

The Yellowstone ecosystem depends on frequent forest fires to clear old trees and replace them with younger trees. Additionally, some trees only germinate after a fire.

The following is an image of Lake Erie taken in 2011.

What is being pictured here? Hypothesize as to what triggered this event and support your claim. *(4 points)*

Algal bloom, likely caused by runoff of agricultural fertilizer, as evidenced by the cultivated fields in the top left corner. (2 points for just "Algal bloom")

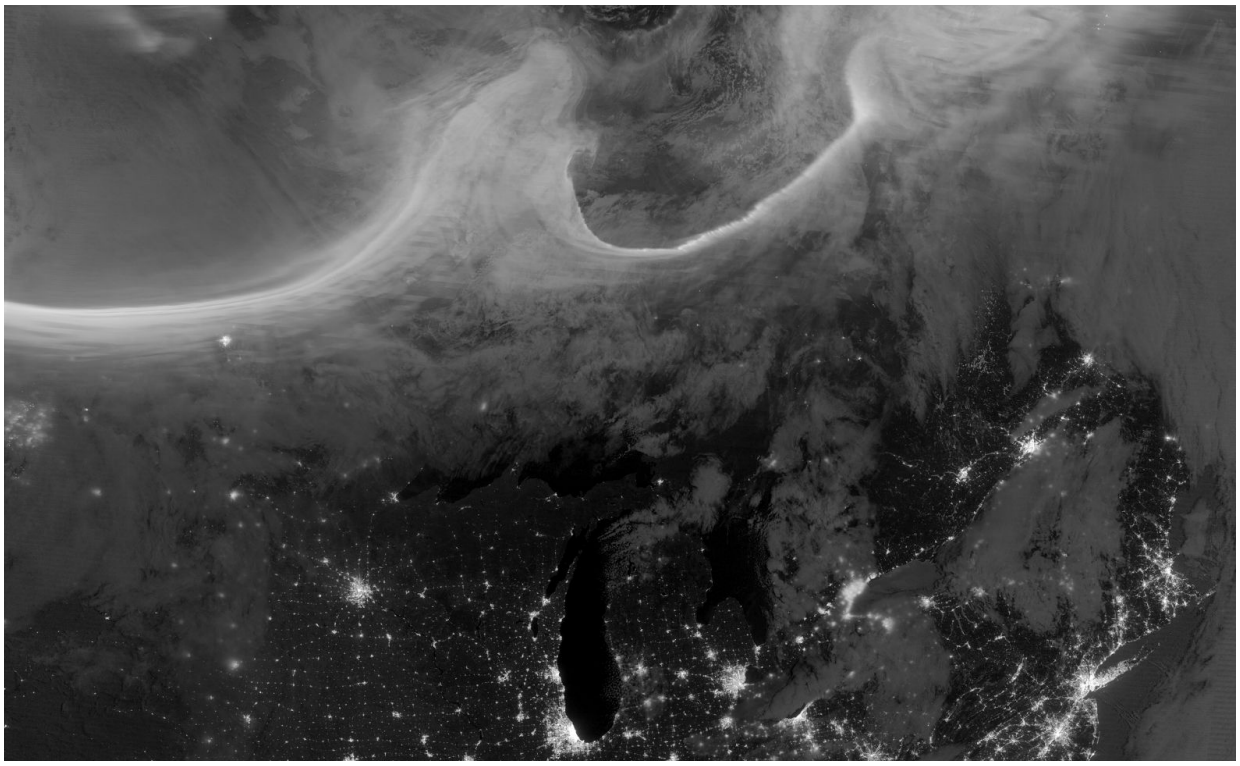
What is a potential impact this event could have on humans? *(2 points)*

Algal blooms can release toxins and induce eutrophication, causing mass kills of fish and potentially harming humans near contaminated water.

Suppose you wanted to study similar events on a larger scale. You obtain MODIS data. What variable does MODIS measure that could be of use to you? *(2 points)*

MODIS measures chlorophyll concentrations, and therefore phytoplankton/algal concentrations by proxy.

The following image was captured by the VIIRS instrument on Suomi NPP in October 2012.



What location is being imaged in this image? What layer in the atmosphere is this event taking place? *(2 points)*

Great Lakes region, as evidenced by the "mitten" that is Michigan in the bottom center of the image. The event is occurring in the ionosphere.

What is that undulating light line? *(2 points)*

A particularly intense aurora borealis.

What problems might this event pose for humans? *(2 points)*

The ionization energy of excited particles in the upper atmosphere can disrupt communications, causing outages and potentially damaging satellite electronics.

Part 4: Weather and Climate Processes

Where does ozone come from? Why, and how, does ozone interact with other naturally occurring gases and radiation in the atmosphere? With human pollutants? Be as specific as possible. *(4 points)*

There are two sources of ozone: natural ozone is formed from the bonding of free oxygen with oxygen molecules, and anthropogenic ozone is emitted by humans. Ozone absorbs ultraviolet because ultraviolet radiation breaks ozone back its reactants. Naturally occurring halogens, nitrogen oxides, and hydroxyl free radicals can break down ozone as well. However, human pollutants used to include massive amounts of chlorine in the form of oxides of chlorine and as CFCs. Free chlorine is a catalyst in the breakdown of ozone; one Cl atom can break down 100,000 molecules of O_3.

Ozone is also an anthropogenic pollutant. Name one source of ozone emissions. *(2 points)*

Automobiles contribute much of the anthropogenic ozone released into the atmosphere.

Anthropogenic ozone also forms a layer in the atmosphere. Name three differences between this artificial ozone layer and the natural ozone layer. *(6 points)*

While the natural ozone layer is high in altitude, in the stratosphere, the artificial ozone layer is closer to the ground. Natural ozone also fluctuates by season, and it also fluctuates in altitude depending on latitude. Anthropogenic ozone largely does not.

Assume the Earth is a perfect blackbody in thermal equilibrium. Given the solar insolation σ_0, 1367 W/m^2, find the average radiative temperature of the Earth. *(5 points)*

$E_{in} = E_{out}$, because the Earth is in thermal equilibrium.

$E_{in} = \sigma_0 \pi r^2$, as the incoming radiation is modelled as a disk with the radius of the earth.

$E_{out} = 4\sigma\pi r^2 T^4$, where σ is the Stefan-Boltzmann constant and the exitance is modelled as a sphere with the radius of the Earth.

$\sigma_0 \pi r^2 = 4\sigma\pi r^2 T^4$

1367 W/m^2 = $4\sigma T^4$

$T \approx$ 277 K

The Earth is not a perfect blackbody - it has an average emissivity of 0.612. Recalculate the average radiative temperature of the Earth. *(5 points)*

Substitute $E_{out} = 4\epsilon\sigma\pi r^2 T^4$ into the model, where $\epsilon = 0.612$. Solving yields $T \approx 315$ K.

Your previous models don't account for the fact that the Earth is very shiny. In fact, the albedo of the Earth approaches 0.3. Again, recalculate the average radiative temperature of the Earth. *(5 points)*

Substitute $E_{in} = (1-a)\sigma_0\pi r^2$ into the improved model, where $a = 0.3$. Solving yields $T \approx 288$ K.

Previously it was mentioned that the Earth is not a perfect blackbody. Most of the land on Earth approximates a blackbody *very* well, with emissivities of 0.96-0.99. So why is the average emissivity of the Earth ($\epsilon = 0.612$) so *low*? *(3 points)*

Clouds and ice all have much lower emissivity values, lowering the average emissivity.

Sulfur oxides are damaging pollutants released by both volcanic and human activity (burning of fossil fuels). Describe in detail one way fuel plants attempt to limit the amount of sulfur oxide gases released into the atmosphere. *(4 points)*

The gases can be passed through a scrubber first, before emission. The scrubber will usually contain lime, CaO. The gas will react with whatever scrubbing reagent after the reagent is sprayed into the gas, and will precipitate and can be collected and filtered out.

Ship tracks and contrails often have a higher-than-normal cloud albedo. Why? What is the name of the effect that describes this? *(6 points)*

Because the pollutants serve as cloud condensation nuclei, according to the Twomey effect, the CCNs cause the creation of more, smaller droplets of water, increasing albedo. (Award 1 point if "Albrecht effect" was used instead of "Twomey effect"; the two are similar, but not interchangeable).

What kind of cloud contributes most to atmospheric heat retention? (2 points)

Cirrus clouds have low albedo and high absorbance of outgoing IR, and contributes the most to atmospheric heat retention.

What is stratospheric aerosol injection and how does it work? Discuss *in detail* the benefits and costs of implementing this method. (8 points)

Stratospheric aerosol injection is the method of injecting sulfur aerosols into the stratosphere. This mimics natural processes like volcanic eruptions, and the Twomey

and Albrecht effects dictate that this should cause a global dimming effect by increasing cloud albedo. This would partially counteract the effects of global warming. SAI is projected to be very efficient. However, possible downsides include ozone depletion, depending on the amount of aerosols injected, and the short lifespans of tropospheric sulfur aerosols, requiring continued injection to be successful.