

# Remote Sensing Key BirdSO Mini Invitational 2022

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Page:	2	3	4	5	6	7	8
Points:	11½	9	7	16½	10	13½	12
Score:							
Page:	9	10	11	12	13		Total
Points:	13	14½	15	9	6		137
Score:							

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Tiebreakers are labelled. Good luck, and enjoy the test!

1. (1 point) Before we begin, do you confirm that you and your team will follow all of BirdSO's rules and guidelines while taking this test? By selecting "I confirm," you are affirming your commitment to honesty and integrity in Science Olympiad!

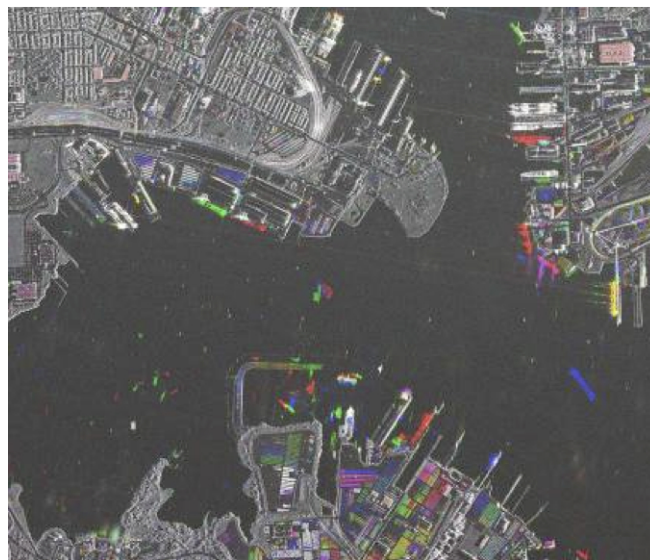
DO NOT SUBMIT UNTIL SELECTING "I confirm." (if you do, you're forfeiting a free point!)

**A. I confirm.**

2. (1 point) What is Earth's approximate albedo?
- A. 0.15    **B. 0.3**    C. 0.41    D. 0.73
3. (2 points) Images sometimes appear slightly to the west of each previous scan due to the eastward rotation of the Earth. This results from...
- A. Skew distortion**  
B. Relief displacement  
C. Tangential scale distortion  
D. Foreshortening
4. (2 points) For interpolation of satellite data used for monitoring dynamic changes that occur on the earth surface, the most suitable orbit for the satellite is...
- A. sun-synchronous orbit**  
B. Relief displacement  
C. Tangential scale distortion  
D. Foreshortening
5. (2½ points) In an effort to prepare for Remote Sensing, you are studying soil moisture in a vegetated terrain and its responses to active and passive sensing. Let's start with active sensing first. Which of the following is not a factor you should include while looking for contributing factors to radar backscattering? Choose all that apply! (Tiebreaker #7!)
- A. Scattering by clouds**  
B. Scattering by the ground  
**C. Scattering by nearby buildings**  
D. Scattering by the soil layer
6. (1 point) How does the index of refraction of seawater change? (Tiebreaker #11!)
- A. It increases with salinity.**  
B. It increases with temperature.  
C. It decreases with salinity.  
D. It decreases with temperature.
7. (2 points) Which of the following is true for creating and balancing planetary energy models?
- A. Snow and ice coverings do not significantly affect outgoing longwave radiation  
B. Atmospheric aerosols do not significantly affect outgoing longwave radiation  
C. Cloud cover doesn't significantly affect outgoing longwave radiation

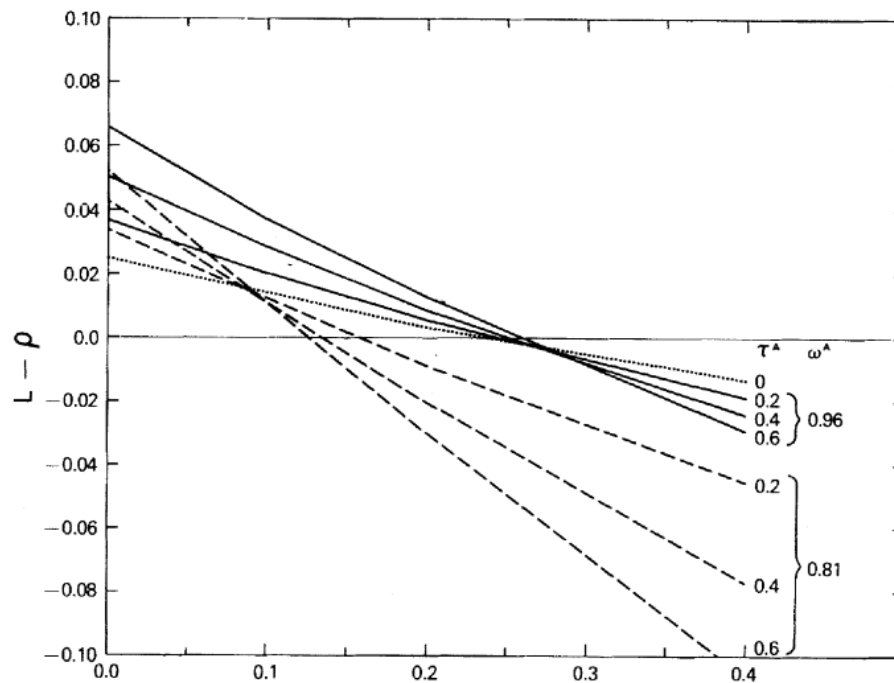
**D. Stratosphere doesn't significantly affect outgoing longwave radiation**

8. (2 points) Which of the following should not be used as a factor in passive sensing analysis?
- A. Surface emission
  - B. Upward emission from the vegetation layer
  - C. Downward emission from the vegetation layer scattered by ground surface
  - D. Downward emission scattered by clouds**
9. (2 points) Consider the factors which you did not choose. When moisture increases, what increased factor plays a role in emphasizing particular elements of your model?
- A. Albedo
  - B. Permeability
  - C. Porosity
  - D. Permittivity**
10. (1 point) Based on your answer to the previous question, which method do you think would be more precise and accurate to measure moisture in a highly-vegetated area?
- A. Active sensing**
  - B. Passive sensing
11. (2 points) Pictured here is Baltimore Harbor imaged over time using a SAR system. What do the colors represent?



- A. Thermal radiation detection, showing changes in temperature in the harbor
  - B. Amplitude change detection, showing activity in the harbor**
  - C. Radar shadows, blanks in radar detection that were filled in later
  - D. Conductive properties, colored areas indicate conductive material anomalies
12. (2 points) Which collection scenario is most useful for 3D applications?
- A. Stereo acquisition**
  - B. Corridor acquisition
  - C. Strip mapping
  - D. Target collection

13. (1 point) Chappius absorption bands result when light interacts with which molecule?
- A. Methane    B. Water vapor    C. Carbon dioxide    **D. Ozone**
14. (1 point) Chapius absorption contributes to the sky's blue color, along with what other kind of scattering?
- A. Raman scattering  
B. Mie scattering  
C. Compton scattering  
**D. Rayleigh scattering**
15. (2 points) Consider this graph for questions 15 to 18. The Y-Axis is the radiance of the earth-atmosphere system minus the surface radiance. What quantity is represented on the X-Axis?



- A. Albedo  
B. Reflectance Radiance  
**C. Surface Reflectance**  
D. Emissivity  
E. Wavelength
16. (3 points) Consider a place on Earth which has reached its critical surface reflectance, or  $p_c$ . What properties can you expect to increase due to an increase in aerosol amount? Choose all that apply!
- A. Atmospheric radiance ( $L_o$ )**  
B. Atmospheric transmission ( $T$ )  
**C. Attenuation of light**  
D. Incident of flux on ground ( $F_D$ )

17. (5 points) Consider the terms presented in the last two questions, and derive an equation that you can use to relate  $L - p$ ,  $L_0$ ,  $p$ ,  $F_D$ , and  $T$ . (HINT: Consider the relationship between those choices which you did and did not pick for the previous question!) (Tiebreaker #1!)

**Solution:**  $L - p = L_0 - p(1 - F_D * T)$

18. (3 points) Briefly explain why this relationship is functional; how is balance maintained in your formula? (Tiebreaker #2!)

**Solution:** Increase in some quantities (aerosol amount -  $\alpha$  attenuation,  $L_0$ ) leads to decrease in other quantities (smaller  $F_D$ , smaller  $T$ ), so things change by the same magnitude but with the opposite sign.

19. (2 points) You are conducting remote sensing in a mountainous region and experience radar layover. What is happening here?

- A. The mountains are blocking the higher edge of the radar pulse from hitting the ground.
- B. Slopes facing the radar experience shortening in the image which they do not exhibit in real life.
- C. The radar wavelength is too large and is causing interference with the peaks of the mountain by lying over it.

**D. The higher parts of the mountain reflect the radar pulse before the base, leading to distortion.**

20. ( $2\frac{1}{2}$  points) What is the range of a LiDAR measurement process where the travelling time of a laser pulse is 0.0185 seconds?

**Solution:**  $2.775 * 10^6$  m

$$\text{Range} = \frac{c * \text{travel time}}{2}$$

$$\frac{3 * 10^8 * 0.0185}{2}$$

21. (1 point) Josh is a hard-working student. As he sits in his room and studies, he absorbs all incident radiation. What kind of object is he?

- A. Black body**    B. Gray body    C. Black hole    D. White body

22. (3 points) Let's say Josh's room is exactly 22 degrees Celsius, and he has exactly  $1.67m^2$  of skin surface area. How much energy does he absorb per second from his room?

**Solution:** 717.11 W

$$L = A\sigma T^4$$

$$1.67 * (5.67 * 10^{-8}) * 295^4 = 717.11 \text{ W}$$

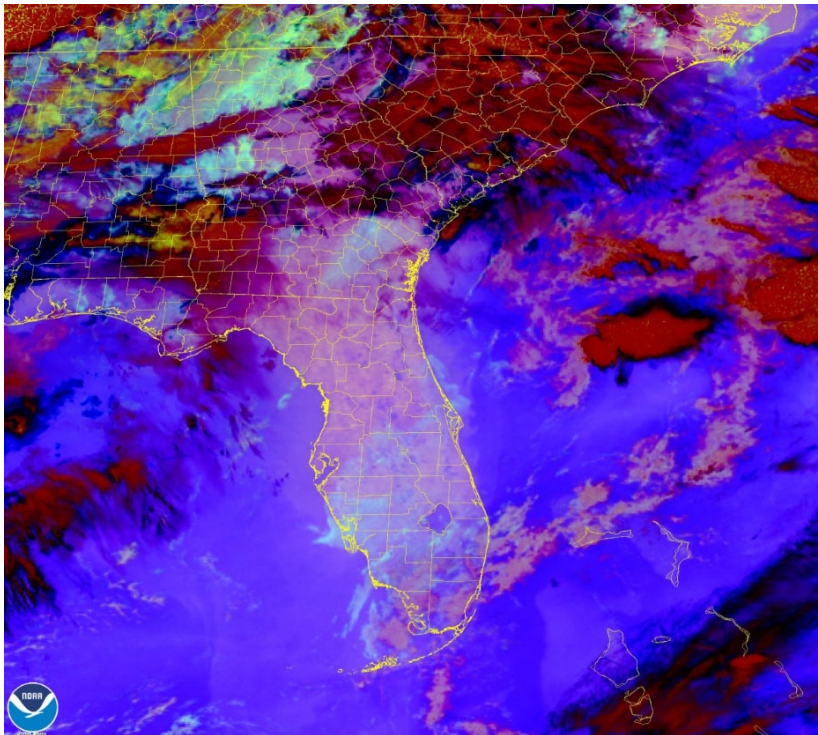
23. (3 points) Let's say Josh himself is 37 degrees Celsius. How much energy does he lose per second?

**Solution:** 157 W. Do Stefan-Boltzmann Law with Josh's temperature instead. Just subtract that number (874) from the previous answer to get net energy loss, 717.  $874 - 717 = 157 \text{ W}$  lost per second

24. (3 points) Briefly explain LiDAR intensity measurement. What is it? What is a disadvantage to using such a measurement? Provide two potential applications for it.

**Solution:** LiDAR systems record intensity, the strength of the backscattered echo, for each measured point. This intensity tells about the surface's reflectance and other important properties. A disadvantage would be the lack of standardization across measurements since this technology is used differently by a wide range of sensors, its results might mean different things without full context, making interpretation difficult; Applications can be practically anything, but include, vegetation analysis, mapping coasts, flood modeling, assessment of buildings/their weak points, identification of different rock layers, etc.

25. (2 points) Consider this image for questions 25-29. This image was produced in RGB by which satellite?



A. GOES-16   B. MODIS   C. CALIPSO   D. CloudSat

26. (2 points) What does this image primarily represent? What do its colors mean?

**Solution:** This image is intended to distinguish between fog and clouds using color differences

27. (4 points) South Carolina is mostly covered by a deep red. How does that compare to the blue wisps covering southwest Florida? How can you tell based off of the colors?

**Solution:** South Carolina is covered by high, thick clouds, while the bluish wisps represent fog and low, warm clouds. We can tell through the color band lengths used by GOES. Since 12.4-10.4 micrometers is the red band relating to optical thickness, it contrasts well with the blue 10.4 band, which primarily picks up warm surfaces (so fog and low, warm clouds)

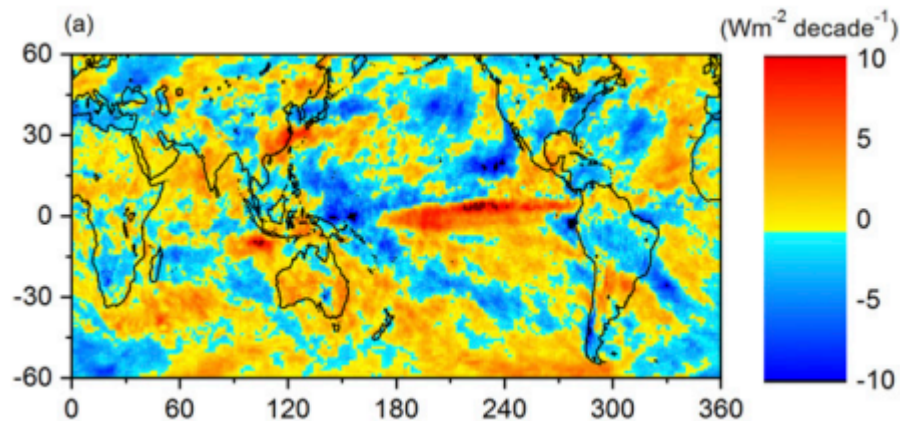
28. (2 points) This image was taken at 5:01 AM EST (10:01 UTC) in early December, so it was nighttime. (This should give you an idea of when my primary test writing hours were.) How might this image be interpreted differently during the day?

**Solution:** This measurement is not useful at all during the day, since shortwave IR band is influenced by solar reflectance during the day. Hence, this is known as a "Nighttime Microphysics RGB" measurement.

29. (2 points) What might be some secondary applications for this data?

**Solution:** This might also measure cloud height, phase, hot spots within fire, and moisture boundaries.

30. ( $3\frac{1}{2}$  points) Attached is an image, let's call it Figure A. What does this image represent?



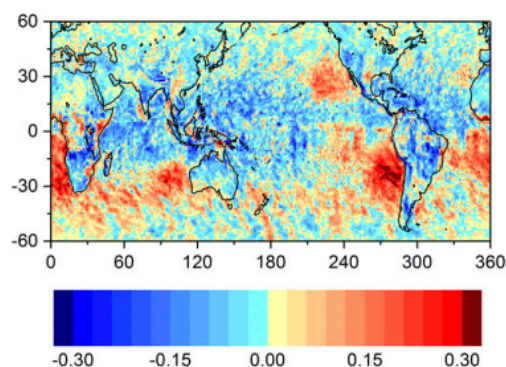
**Solution:** This image represents the trend in the shortwave flux top-of-atmosphere flux anomalies for July 2002 - September 2016

31. (2 points) What satellite produced the above image? Which specific instrument(s) (if any) took the image?

**Solution:** SSF1deg-Terra-Aqua (1 point for CERES)



32. (1 point) This image (Figure B) is from the same dataset as Figure A. Depicted below is the monthly regional mean DAR for October 2008. What does DAR stand for?



**Solution:** Diurnal asymmetry ratio

33. (3 points) How is DAR related to the data presented in Figure A?

**Solution:** DAR is the difference between morning and afternoon TOA SW fluxes, normalized by daily 24 hour flux

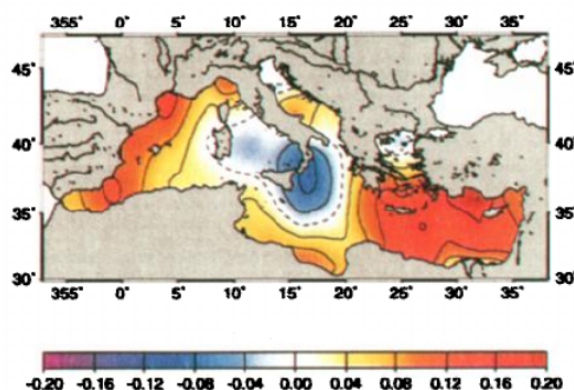
34. (4 points) As you can see, DAR is primarily negative over continents but positive on western coasts. Why do you think this is? (Tiebreaker #8!)

**Solution:** DAR is positive off coasts because cloud fraction reaches a maximum in the early morning and decreases in the afternoon due to solar insolation and absorption. Meanwhile, DAR is negative over land because convection is stronger in the afternoon.

35. (2 points) Which of the following is not a shortwave narrowband-to-broadband spectral channel used to infer broadband radiances from MODIS narrowband channels?

A.  $0.47 \mu m$    B.  $0.65 \mu m$    C.  **$0.71 \mu m$**    D.  $0.86 \mu m$    E.  $1.63 \mu m$

36. (2 points) Use this image for questions 36-39. What does the scale represent in this image? What unit is it measured in?





**Solution:** Change in sea surface temperature, measured in degrees Celsius/year

37. (3½ points) What is happening off of the southern coast of Italy (in the Ionian Sea)? Make a connected hypothesis about if, and if so, how and why, sea level is changing there, as well.

**Solution:** The Ionian Sea is cooling at approximately -12 degrees C/year. Concurrent data shows that sea level is similarly decreasing. There are a number of potential reasons, like decrease in precipitation, increase in evaporation, thermal contraction, etc.

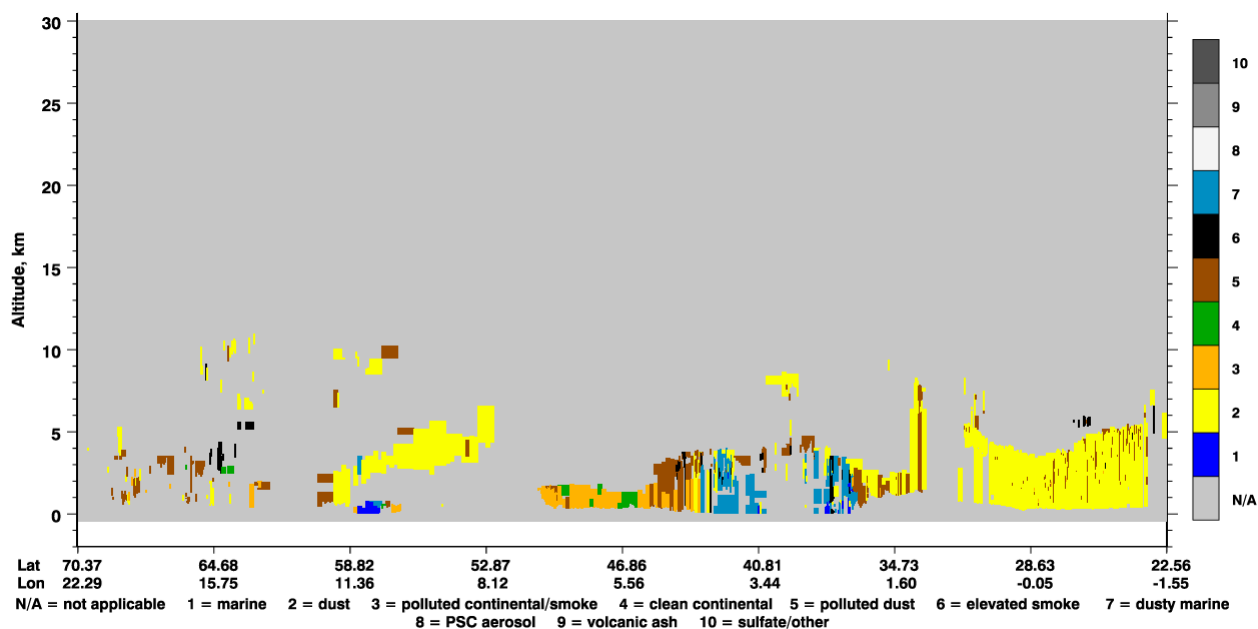
38. (1 point) This data was collected by Topex-Poseidon. Knowing that, what decade do you think this data was collected during?

A. 1980s    **B. 1990s**    C. 2000s    D. 2010s

39. (1½ points) Which of TOPEX's microwave channels is used as the primary channel for water vapor measurement? (HINT: The others are used to removed effects of wind speed and cloud cover.)

A. 18 GHz    **B. 21 GHz**    C. 37 GHz

40. (2 points) Consider this image for questions 40-44. What does this image display? (i.e. what are the numbers on the bottom classifying?) (Tiebreaker #3!)



**Solution:** Aerosol type/subtype

41. (2 points) This data is from which satellite?

A. OCO-2    B. MODIS    C. GRACE    D. Aura    **E. CALIPSO**

42. (3 points) Describe the LiDAR system used by this satellite. What is unique about it? What

wavelengths does it make use of? (Tiebreaker #9!)

**Solution:** CALIOP is a three channel LiDAR which makes use of orthogonal polarization to divide 532 nm wavelengths according to their polarization, and a third channel for 1064 nm.

43. (2 points) The image included in number 40 is a VFM image. What does VFM stand for? Explain what it is.

**Solution:** Vertical feature mask. It shows the vertical and horizontal locations of features according to what CALIPSO is searching for. These layers are plotted according to their latitude and longitude, as well as their altitude.

44. (2 points) What is one other thing that this satellite might plot on a VFM?

**Solution:** Acceptable answers are: Ice/water phase, horizontal averaging required for detection, cloud type, layer type (cloud vs aerosol)

45. (2 points) Consider a photon interacting with an aerosol. What the the ratio between the scattering and the extinction called?

- A. Single Scattering Albedo
- B. Absorption Aerosol Optical Depth
- C. Asymmetry Parameter
- D. Scattering Aerosol Optical Depth

46. (3½ points) The sun shines light on a material with an albedo of 0.9. Would aerosol forcing at the top of the atmosphere be higher or lower here than at a place with an albedo of 0.6? Explain your answer.

**Solution:** 0.9 would have the higher radiative forcing. In this case, higher surface reflection causes more aerosol absorption and thus forcing. Aerosol forcing acts on upwards reflected radiation in addition to downwards radiation

47. (3 points) Hypothesize where on earth the aerosol optical depth would be greatest. Where do you believe it is? Why?

**Solution:** Higher AOD results from increased aerosol content, so the highest AOD is found at deserts, such as the Sahara, Gobi, and their downstream segments. It is also large over places where fossil fuels and biomass are burned.

48. (2 points) Assume a constant wavelength. Assuming an aerosol optical depth of 0.812, how much is direct radiation from the sun reduced by?

**Solution:** Reduced by a factor of 0.444. This is a negative exponential function, so the answer is just  $e^{-0.812} = 0.444$

49. (5 points) Attached is a table (use this for questions 49 to 53) comparing the effect of increased GHG (greenhouse gases) and AP (aerosol particles) on the hydrologic cycle of earth. You can see that in the GHG experiment, there is a small decrease in solar radiation, yet the net change in surface radiation is still positive. What accounts for this overcompensation? (Tiebreaker #5!)

		Global	NH land	NH ocean	SH land	SH ocean
GHG	Evaporation (mm day <sup>-1</sup> ),	0.08	0.05	0.07	0.07	0.08
	PC	2.8	3.9	2.5	3.9	2.4
	Precipitation (mm day <sup>-1</sup> ),	0.07	0.09	0.06	0.13	0.07
	PC	2.5	4.7	1.8	5.1	2.3
	Cloud cover fractional %, PC	-0.4	-0.9	-0.3	-0.4	-0.2
	PC	-0.6	-1.6	-0.4	-0.8	-0.3
AP	Cloud water path (g m <sup>-2</sup> ),	4.2	4.2	4.5	2.2	4.3
	PC	5.0	7.1	4.8	3.4	4.7
	Evaporation (mm day <sup>-1</sup> ),	-0.11	-0.12	-0.15	-0.09	-0.08
	PC	-3.5	-8.2	-3.8	4.2	2.3
	Precipitation (mm day <sup>-1</sup> ),	-0.11	-0.17	-0.16	-0.16	-0.04
	PC	-3.5	-7.7	-4.3	-5.2	-1.3
GHG-AP	Cloud cover fractional %, PC	0.7	1.1	0.9	0.4	0.5
	PC	1.1	1.9	1.3	0.7	0.7
	Cloud water path (g m <sup>-2</sup> ),	8.7	8.4	12.7	8.5	5.6
	PC	10	13	13	14	6
	Evaporation (mm day <sup>-1</sup> ),	-0.03	-0.04	-0.06	-0.01	-0.01
	PC	-1.1	-3.1	-1.8	-0.6	-0.3
	Precipitation (mm day <sup>-1</sup> ),	-0.03	-0.06	-0.07	-0.04	0.01
	PC	-1.1	-3.2	-2.2	-1.6	-0.4
	Cloud cover fractional %, PC	0.02	-0.1	0.06	0.3	0.00
	PC	0.03	-0.2	0.09	0.7	0
	Cloud water path (g m <sup>-2</sup> ),	11.0	12.5	13.2	14.2	7.9
	PC	11	17	11	16	8

**Solution:** Downwelling longwave radiation from the atmosphere makes it positive

50. (3 points) Using the same table, what phenomenon is causing the cloud water path increase in the AP experiment? Explain how this phenomenon works.

**Solution:** The second indirect effect (or the Albrecht effect) can be used to explain AP's effect on cloud water path. Higher aerosol content within clouds leads to drizzle suppression, increased cloud height/cover, and increased lifetime.

51. (4 points) Based on this table, which factor, GHG or AP, causes a larger surface energy flux, assuming the same global mean radiative forcing? Support your answer using data from the table.

**Solution:** Aerosol load causes larger changes in surface energy flux. In table 5, changes in evaporation and precipitation are larger in AP than GHG, despite the higher forcing and temperature changes in the GHG experiment. This confirms AP causes more energy flux near the surface.

52. (3 points) Consider the phenomenon you used to explain the increased cloud water path. Can you develop an analogous effect/phenomenon to describe aerosols in the atmosphere? (Tiebreaker #6!)

**Solution:** The aerosol lifetime effect can be described by a positive feedback loop. An increase in aerosols reduces precipitation efficiency of warmer clouds by increasing albedo, so clouds live longer (This is what was described in the previous question). Thus, aerosols have longer residence time in these clouds and stay there longer. This same effect can be considered with temperature.

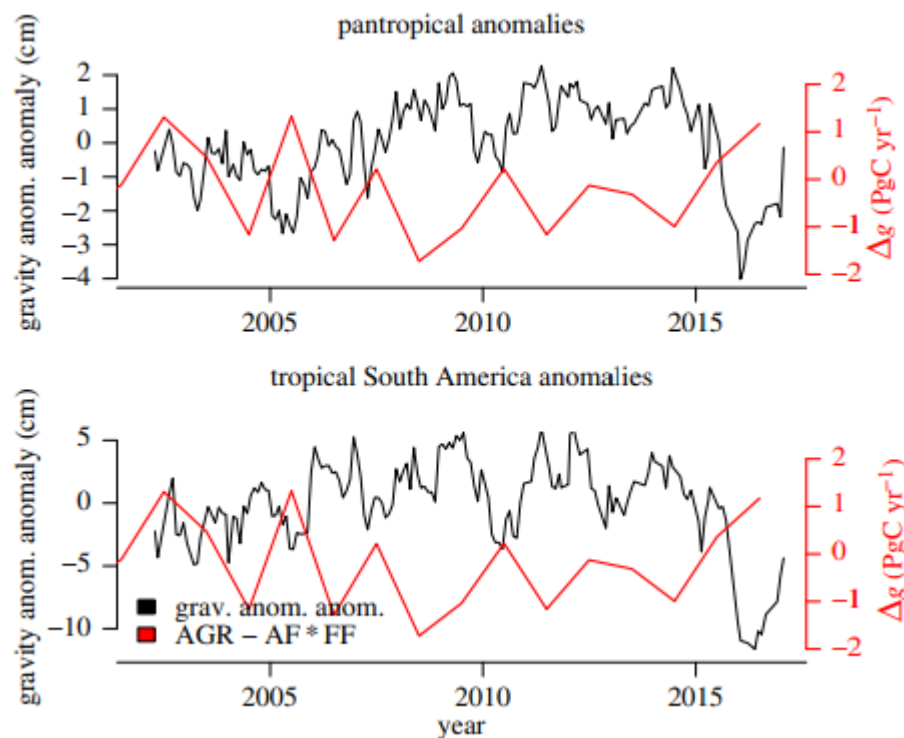
53. (3 points) Finally, for your conclusion about atmospheric aerosols, consider how this rule might vary across latitudes. (Tiebreaker #10!)

**Solution:** The main aerosol sources are located in the Northern Hemisphere. Additionally, in higher latitudes, aerosol removal rate is decreased due to lower precipitation. So, aerosols likely have higher residence time in higher latitudes.

54. (2 points) Which greenhouse gas has the highest residence time within the atmosphere?

A. Ozone    B. Methane    C. Nitrous oxide    **D. Sulfur hexafluoride**

55. (4 points) This graph (used for questions 55 to 58) measures tropical land gravity anomaly anomalies and global  $CO_2$  growth rate anomalies in South America. What stresses acting on vegetation are recorded in these graphs? (Tiebreaker #4!)



**Solution:** Plant water stress caused by anomalies of the abundance of soil water are stressing plants. The gravity anomaly anomalies are a proxy for soil water stress.

56. (1 point) What meteorological event may be causing the stress acting on these plants?

**Solution:** (2015/2016) El Niño

57. (1 point) What satellite was used to measure gravity anomaly anomalies?

**Solution:** GRACE

58. (4 points) What is the correlation between the gravity anomaly anomalies and the global atmospheric  $CO_2$  production? Explain this correlation in relation to the phenomenon you identified earlier.

**Solution:** There is a negative correlation between the gravity anomaly anomalies and the  $CO_2$  growth rate. This implies that as there is more water, there is more photosynthesis occurring (and less  $CO_2$  as a result). El Nino causes droughts throughout tropical South America, so that explains the decrease in soil water stress suddenly occurring after 2015.

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**-Aidan**