Introduction to the GLOBE Atmosphere Protocols

The GLOBE Program

G Global

L Learning and

O Observations

B to Benefit the

E Environment

Welcome to GLOBE 's Atmosphere Investigations!

Overview and Objectives

This module:

- Introduces the GLOBE Atmosphere Investigation Area
- Introduces the GLOBE protocols associated with the atmosphere

After completing this module, you will be able to:

- Describe the structure and composition of the atmosphere
- Explain how differential heating of the Earth's surface generates winds
- Identify the components of the Earth system
- Explain the difference between weather and climate
- Be familiar with where and when to take atmosphere measurements
- Recognize various GLOBE atmosphere investigation protocols
- Identify the importance of atmospheric data for your students and for NASA scientists

Estimated time to complete this module: 1.5 hours

1. What is the Atmosphere?

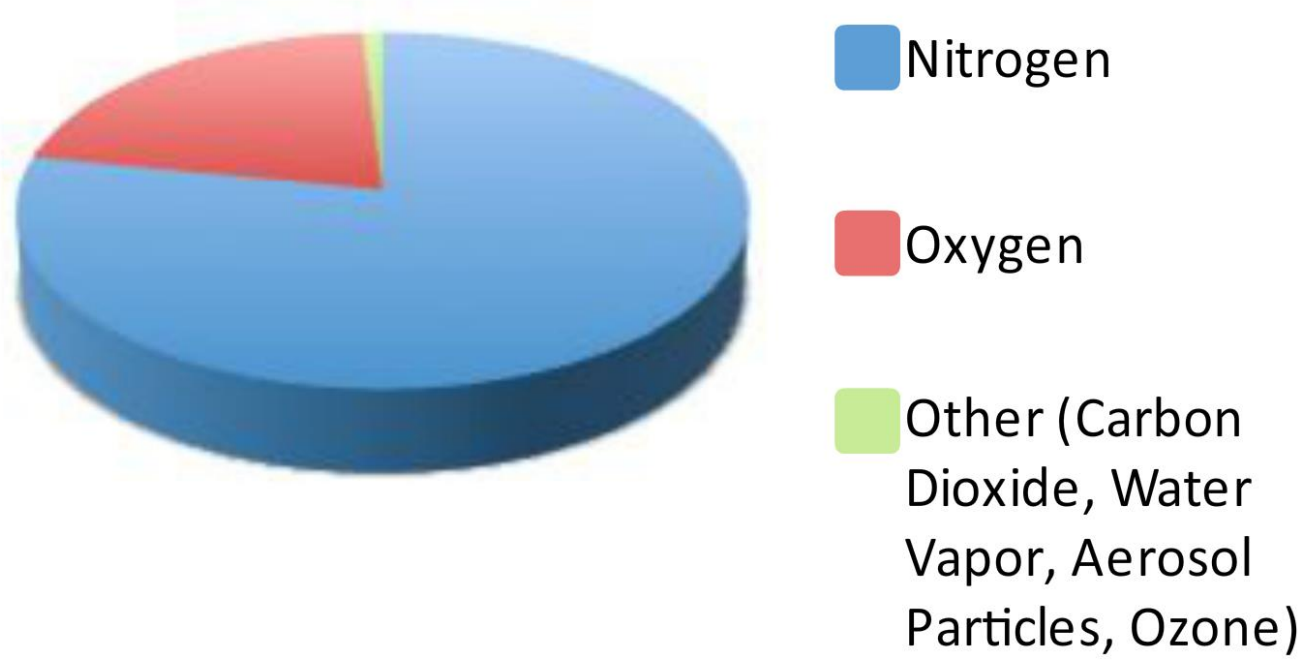
The Earth's atmosphere is an extremely thin sheet of air extending from the surface of the Earth to the edge of space. The Earth is a sphere with a roughly 8000 mile diameter; the thickness of the atmosphere is about 60 miles.

In this picture, taken from a spacecraft orbiting at 200 miles above the surface, we can see the atmosphere as the thin blue band between the surface and the blackness of space. **If the Earth were the size of a basketball, the thickness of the atmosphere could be modeled by a thin sheet of plastic wrapped around the ball!**

Image: NASA

The atmosphere is composed of a mixture of gases

Air is composed of approximately 78% nitrogen, 21% oxygen, and small amounts of other gases.



The Atmosphere has Structure

Image Credit: NASA/JSC Gateway to Astronaut Photography of Earth

International Space Station astronauts captured this photo of Earth's atmospheric layers on July 31, 2011, revealing the troposphere (orange-red), stratosphere and above. Satellite instruments allow scientists to better understand the chemistry and dynamics occurring within and between these layers. Let's look at some of the layers of the atmosphere in the next slides.

At the Top of the Atmosphere: Exosphere and Ionosphere

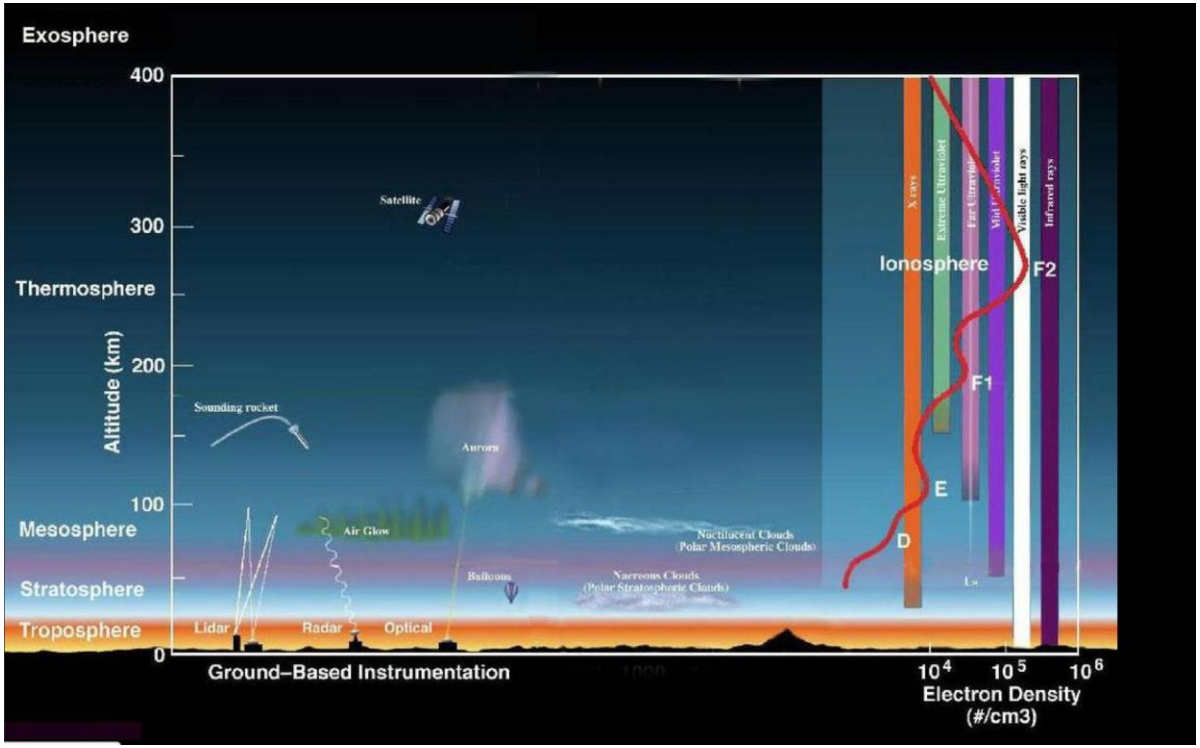


Image Credit: NASA Goddard

Exosphere: This is the upper limit of our atmosphere. It extends from the top of the thermosphere up to 10,000 km (6,200 mi). **Satellites orbit in this layer.**

Ionosphere: The ionosphere is an abundant layer of electrons and ionized atoms and molecules that stretches from about 48 kilometers (30 miles) above the surface to the edge of space at about 965 km (600 mi), overlapping into the mesosphere and thermosphere. This region is what makes radio communications possible.

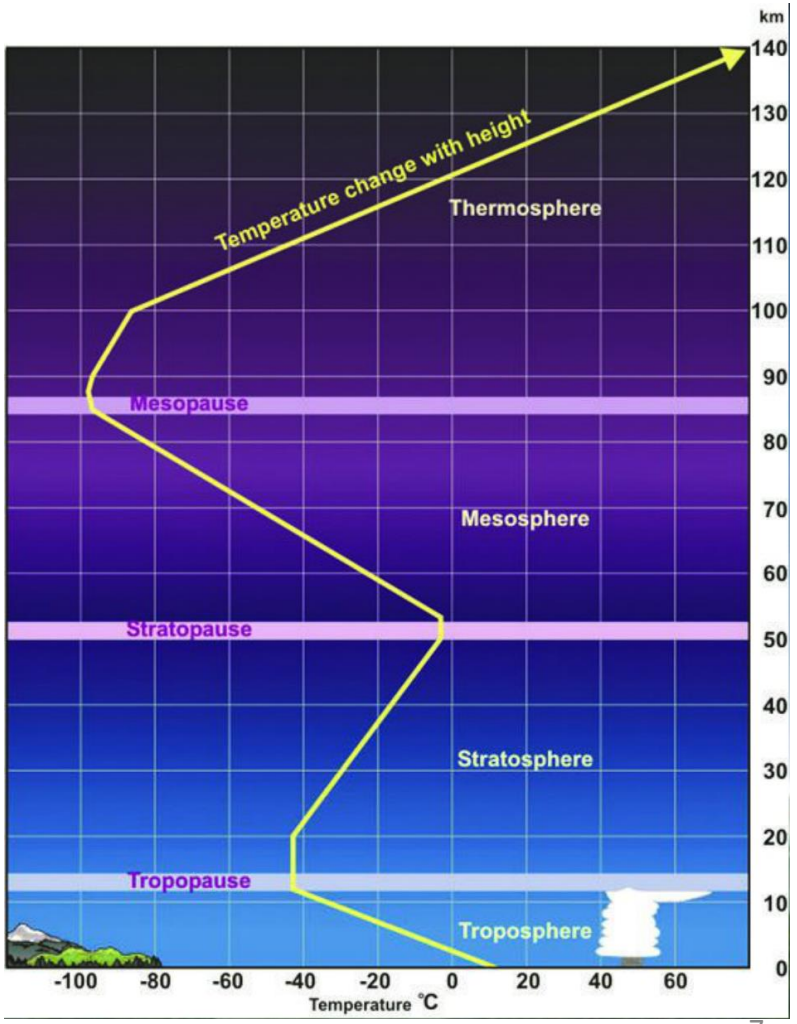
Below the Ionosphere: Thermosphere-Troposphere

Thermosphere: The thermosphere starts just above the mesosphere and extends to 600 kilometers (372 miles) high. **Aurora and some other satellites occur in this layer.**

Mesosphere: The mesosphere starts just above the stratosphere and extends to 85 kilometers (53 miles) high. Meteors burn up in this layer.

Stratosphere: The stratosphere starts just above the troposphere and extends to 50 kilometers (31 miles) high. **The ozone layer, which absorbs and scatters the solar ultraviolet radiation, is in this layer.**

Troposphere: The troposphere starts at the Earth's surface and extends 8 to 14.5 kilometers high (5 to 9 miles). This part of the atmosphere is the most dense. **Almost all weather is in this region.**

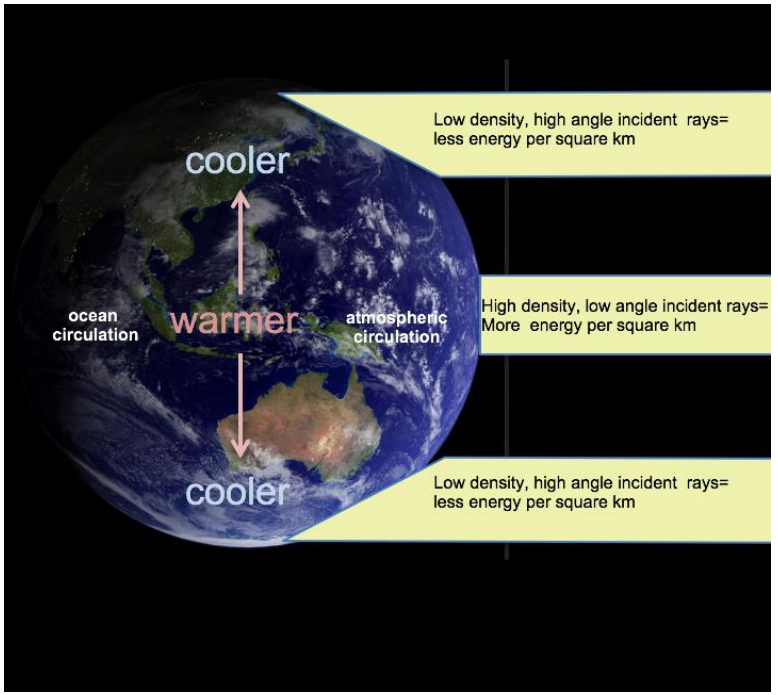


Uneven Heating of the Earth Drives Air and Ocean Circulation

The unequal heating of the Earth's surface drives air and ocean circulation and causes climate to vary by latitude.

Air and water circulation is initiated at the equator, where insolation is greatest. Masses of air and ocean transport heat energy from areas of high concentration to low concentration.

The movement of these masses of air and ocean establish an equilibrium state of heat distribution which we determine the general climate bands, or zones that we see at different latitudes.



At the higher latitudes, solar energy reaches the Earth as Low density, high angle incident rays, so there is less energy reaching the Earth's surface per km2, compared to the equator. Image: Blue Marble from NASA Earth Observatory

The Atmosphere is part of the Earth System

To summarize, atmospheric properties are not uniform; fluid properties are constantly changing with time and location. We call this change **the weather**.

The atmosphere's properties and the weather it generates affects all parts of the Earth, but at the same time, properties of the Earth's components- the hydrosphere (water), lithosphere (earth) and biosphere (life) affects the atmosphere. These interactions characterize the Earth system.

The Earth system behaves as a single, self-regulating *closed* system comprising physical, chemical, biological and human components.

The focus of Earth system science is understanding the interactions between the oceans and ice, atmosphere, life, geological processes and the land surface, and how those interactions impact each other and lead to changes on our planet.

The Earth system is also responsible for generating Earth's **climate.**

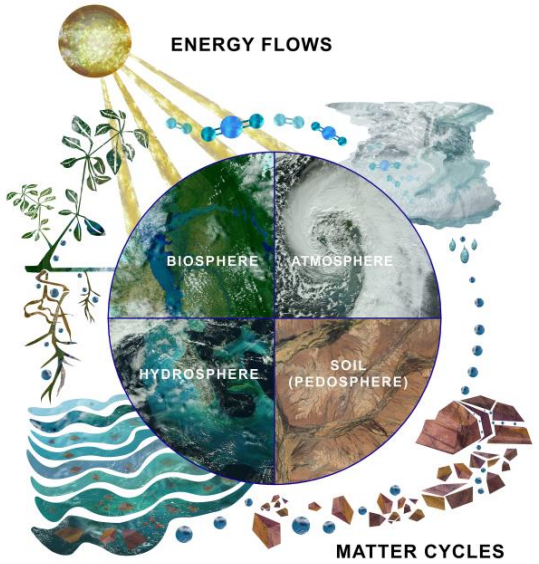
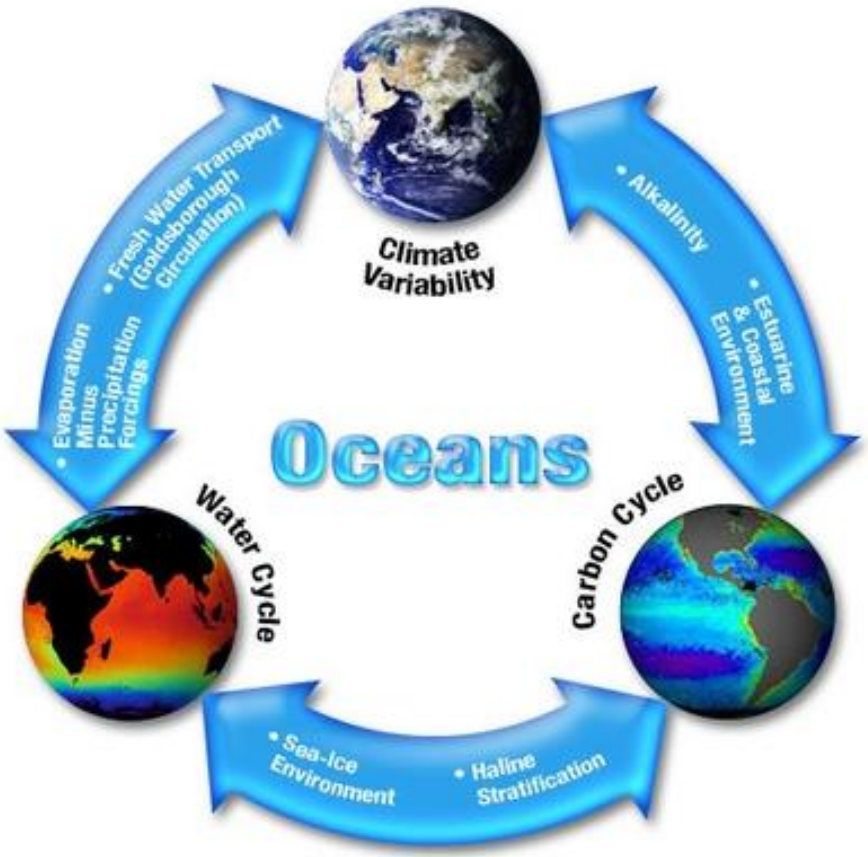


Image: GLOBE.gov

In the Earth system, changes in one part of the system will affect the other parts.

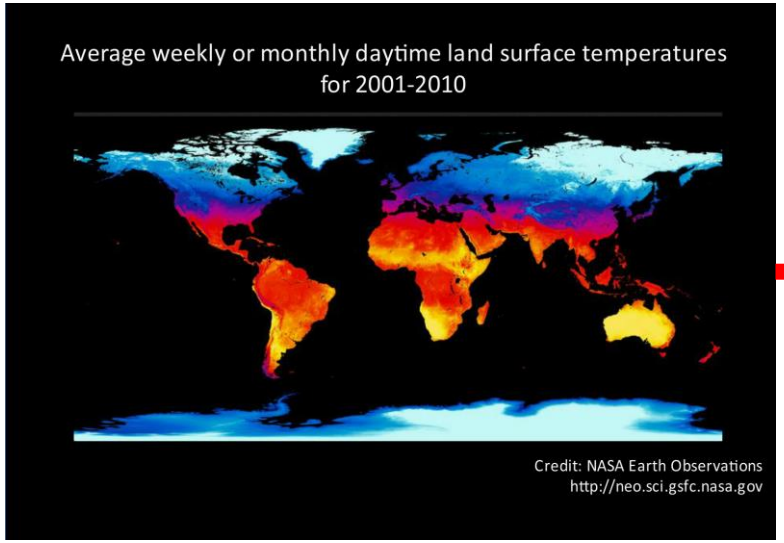
This diagram shows some of the ways that elements of the Earth system affect other elements of the Earth system.



In the Earth system, "**Everything is connected to everything else**."

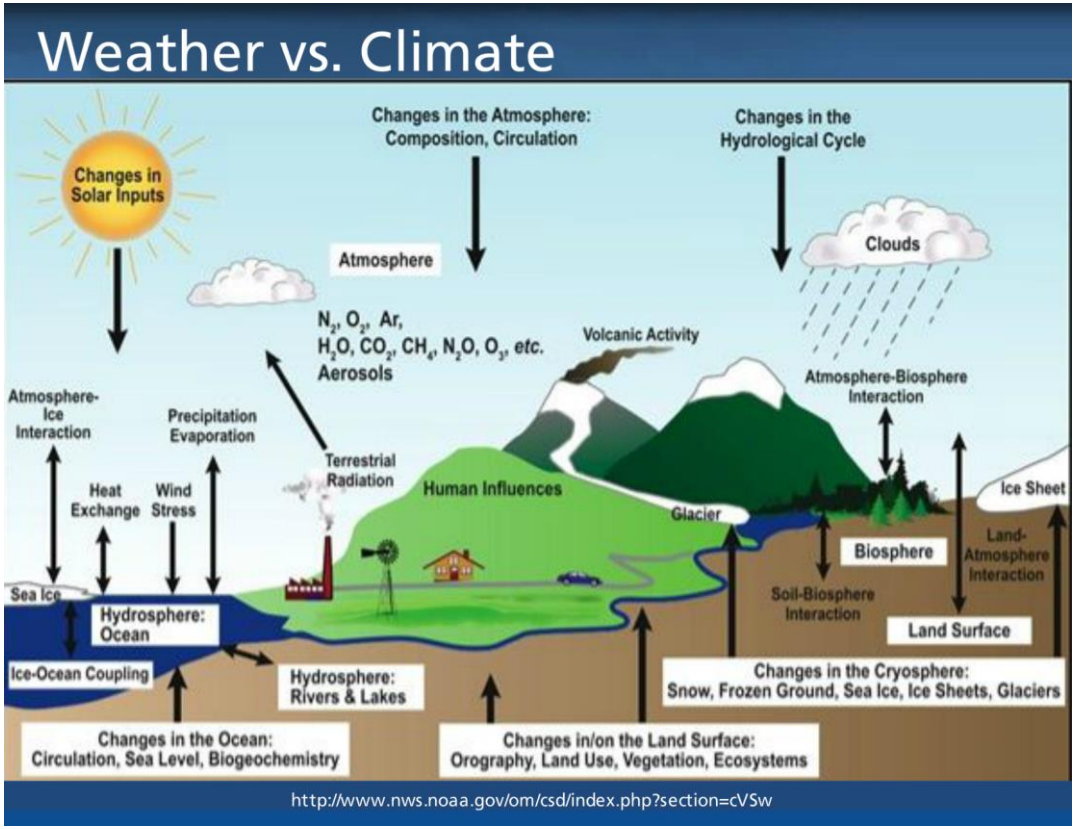
Image: NASA

The interactions of the Earth's system generates weather and climate.



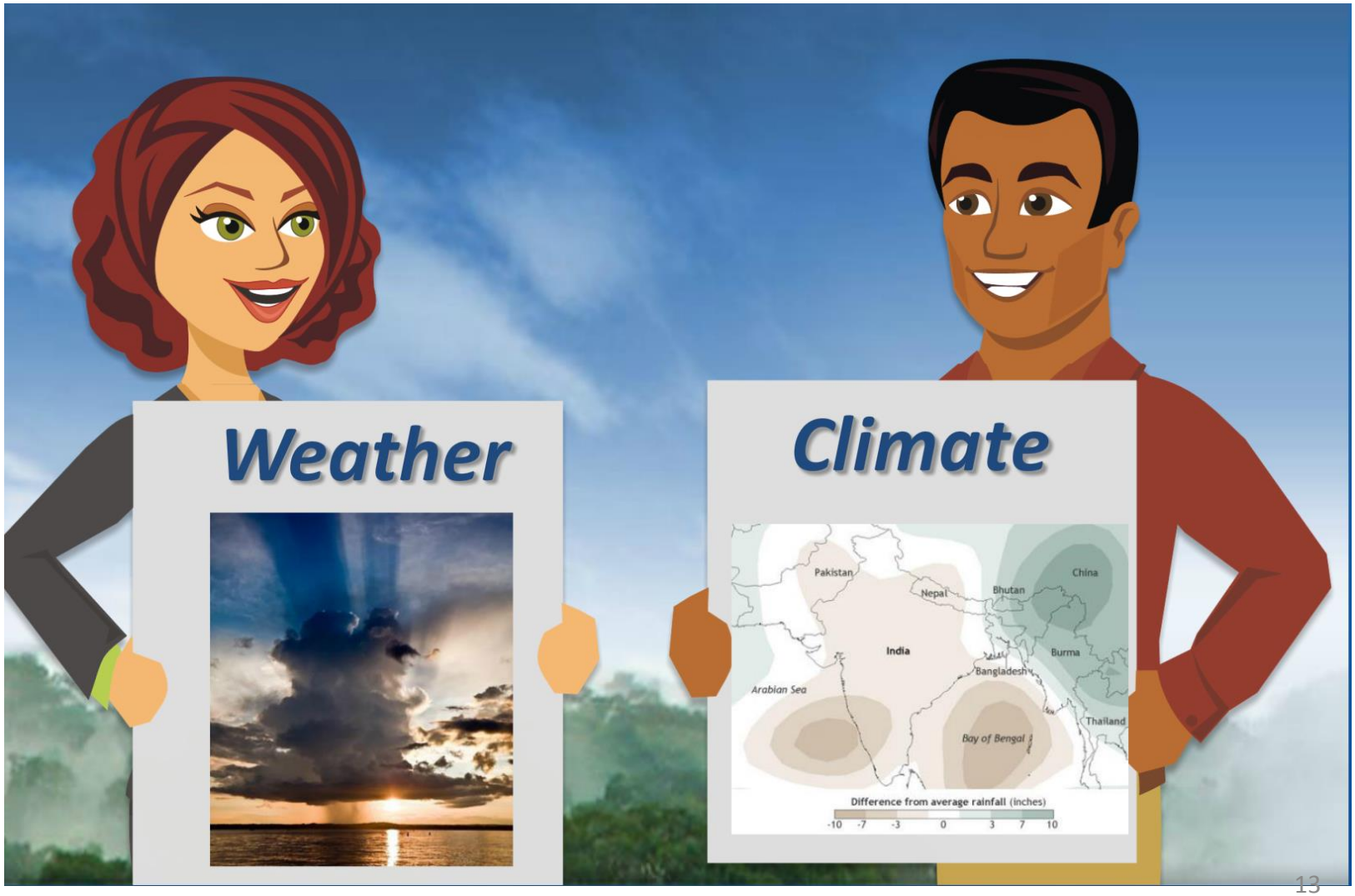
Unequal heating of the Earth's surface by the Sun, and interactions between the atmosphere, biosphere, hydrosphere and lithosphere creates the Earth's climate zones, which have characteristic weather conditions and life forms.

In the Earth system, changes in one part of the system will affect the other parts.



This diagram summarizes some of the factors that influence weather and climate and are responsible for differentiation of climate zones. Don't worry about the details, but you should be aware that in the Earth system, "**Everything is connected to everything else**." Note: Cryosphere is another term for the Earth's ice, and in GLOBE materials, the cryosphere is treated as part of the hydrosphere.

So, what is the difference between weather and climate?



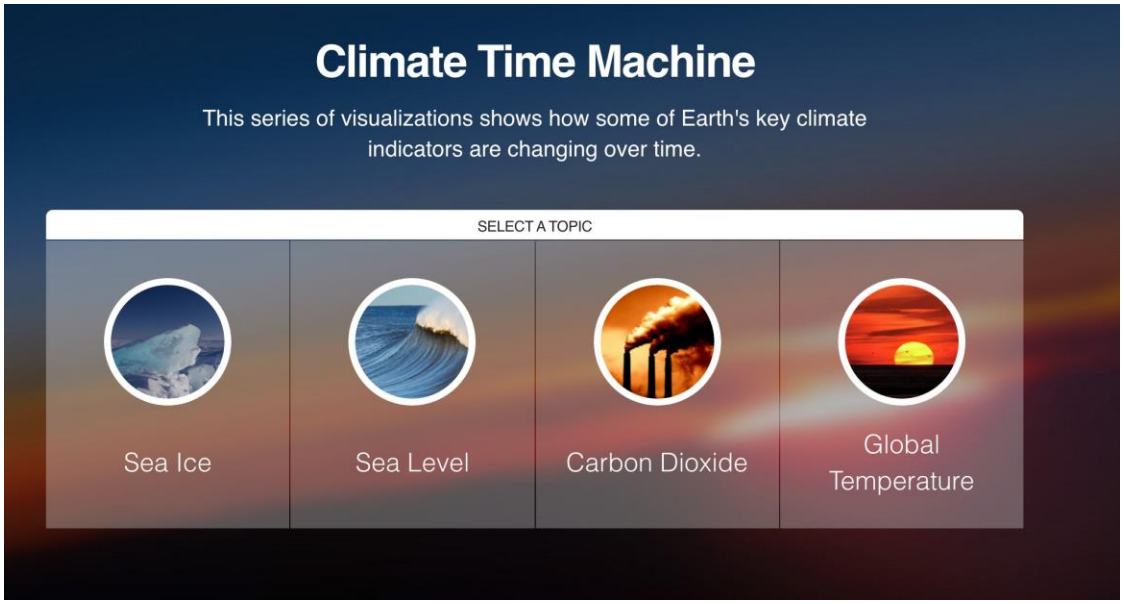
Weather and Climate operate on Different Timescales

Image: NASA

Weather and climate are easily confused but they're not the same ... they operate on different timescales. **Weather describes how the atmosphere behaves over weeks or less**. **Climate the average behavior of weather over long timescales, typically 30 years or more**. So climate refers to seasonal and longer periods, out to centuries and millennia.

Is it Weather or is it Climate?

In most places, weather can change from minute-to-minute, hour-to-hour, day-to-day, and season-to-season. Climate, however, is the average of weather over time and space. An easy way to remember the difference is that **climate is what you expect**, like a very hot summer, **and weather is what you get**, like a hot day with pop-up thunderstorms.



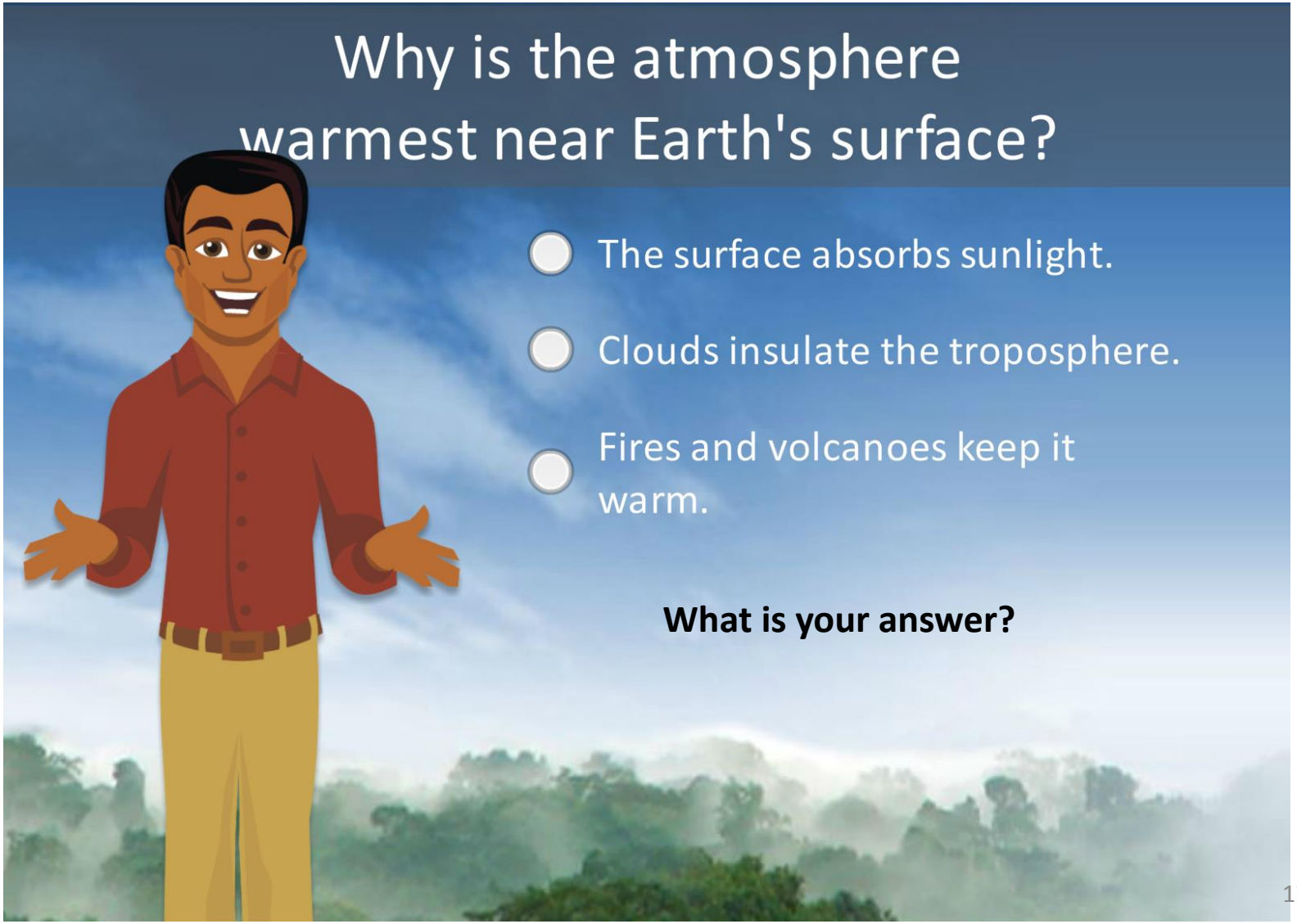
To see how climate has changed over time, explore NASA's Climate Time Machine.

Link to the Climate Time Machine

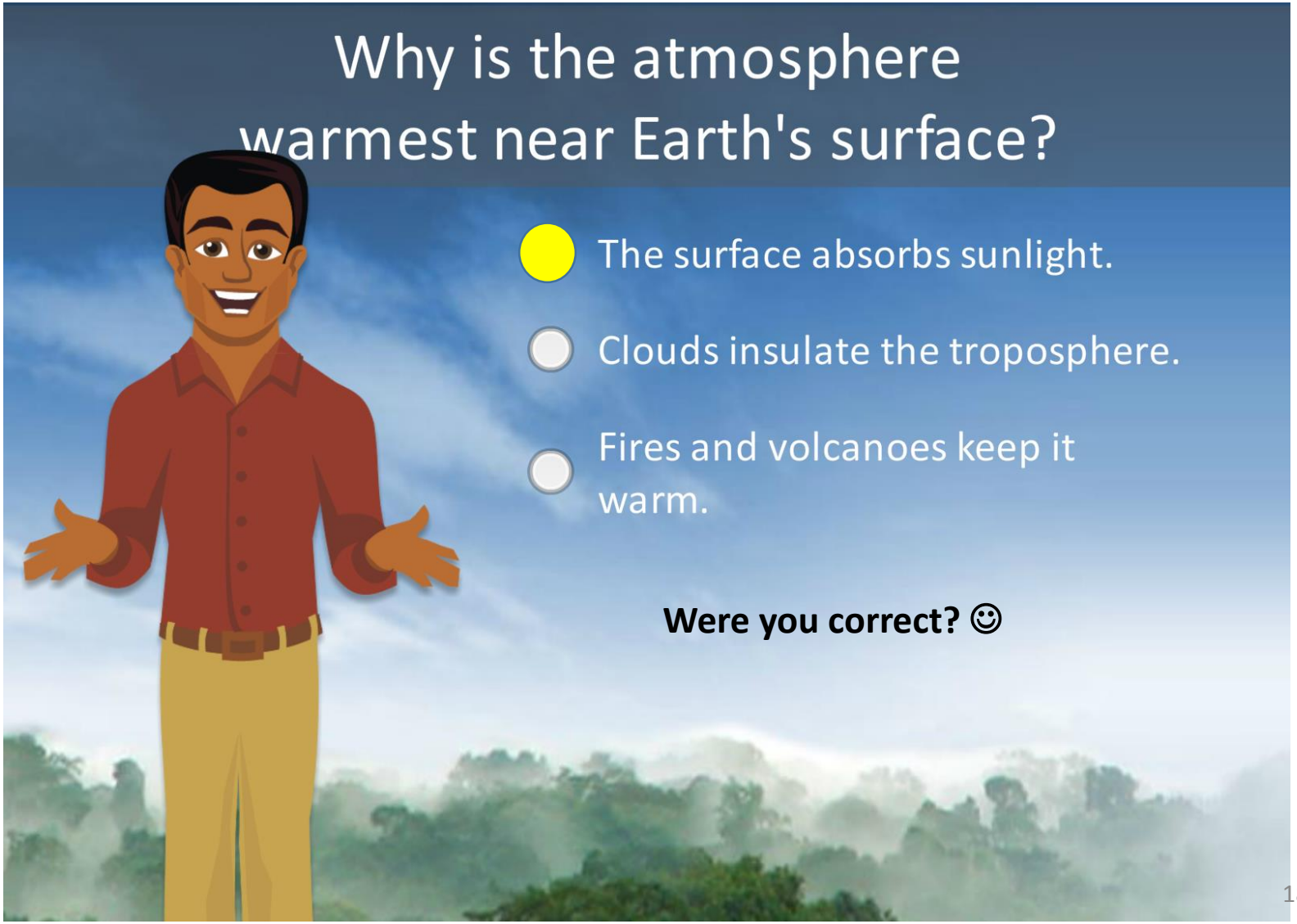
Let’s review our progress so far!

See if you can answer the following questions!

Review your Understanding! Question 1



Answer to Question 1



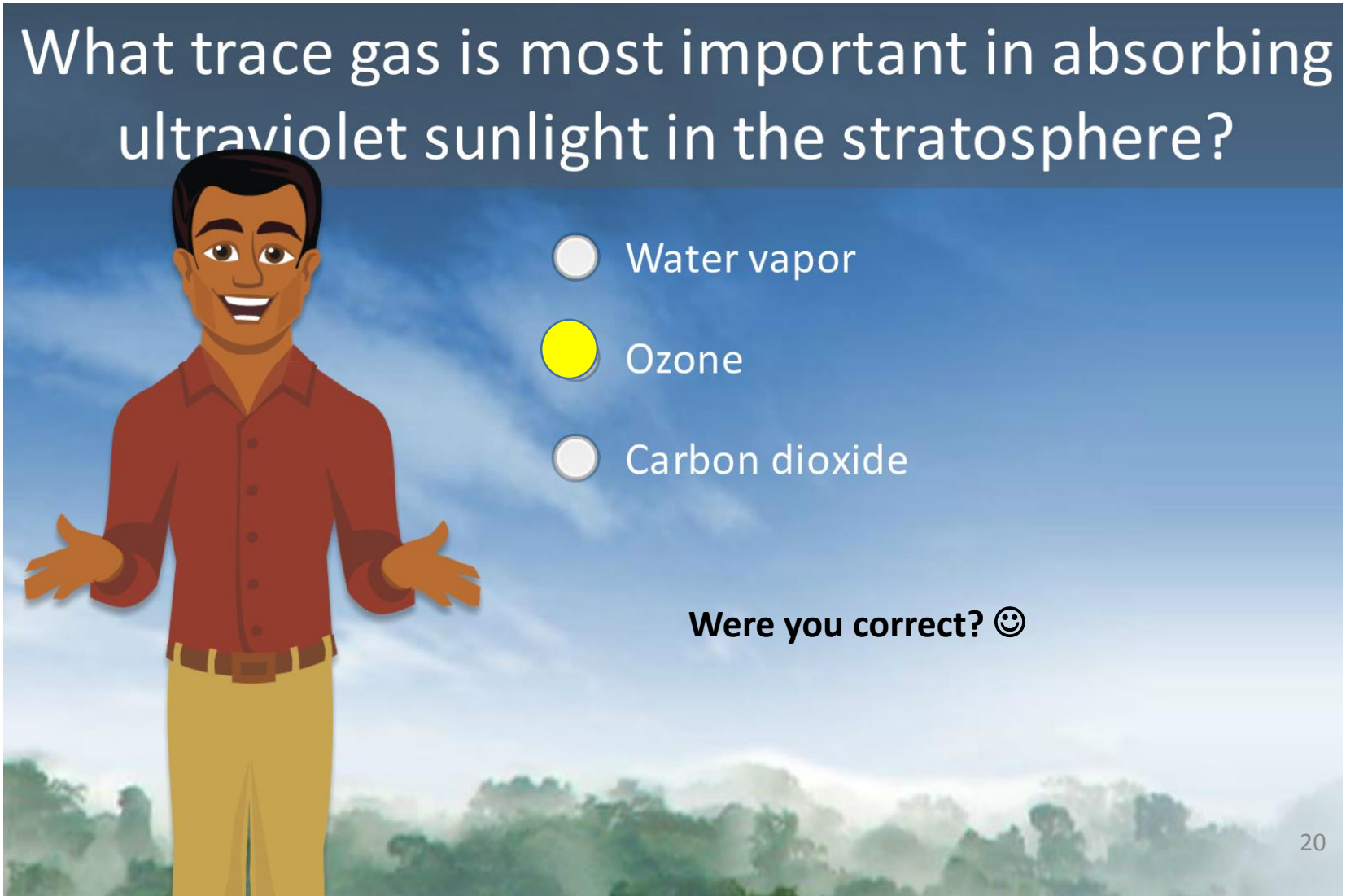
Review your Understanding! Question 2

What trace gas is most important in absorbing ultraviolet sunlight in the stratosphere?

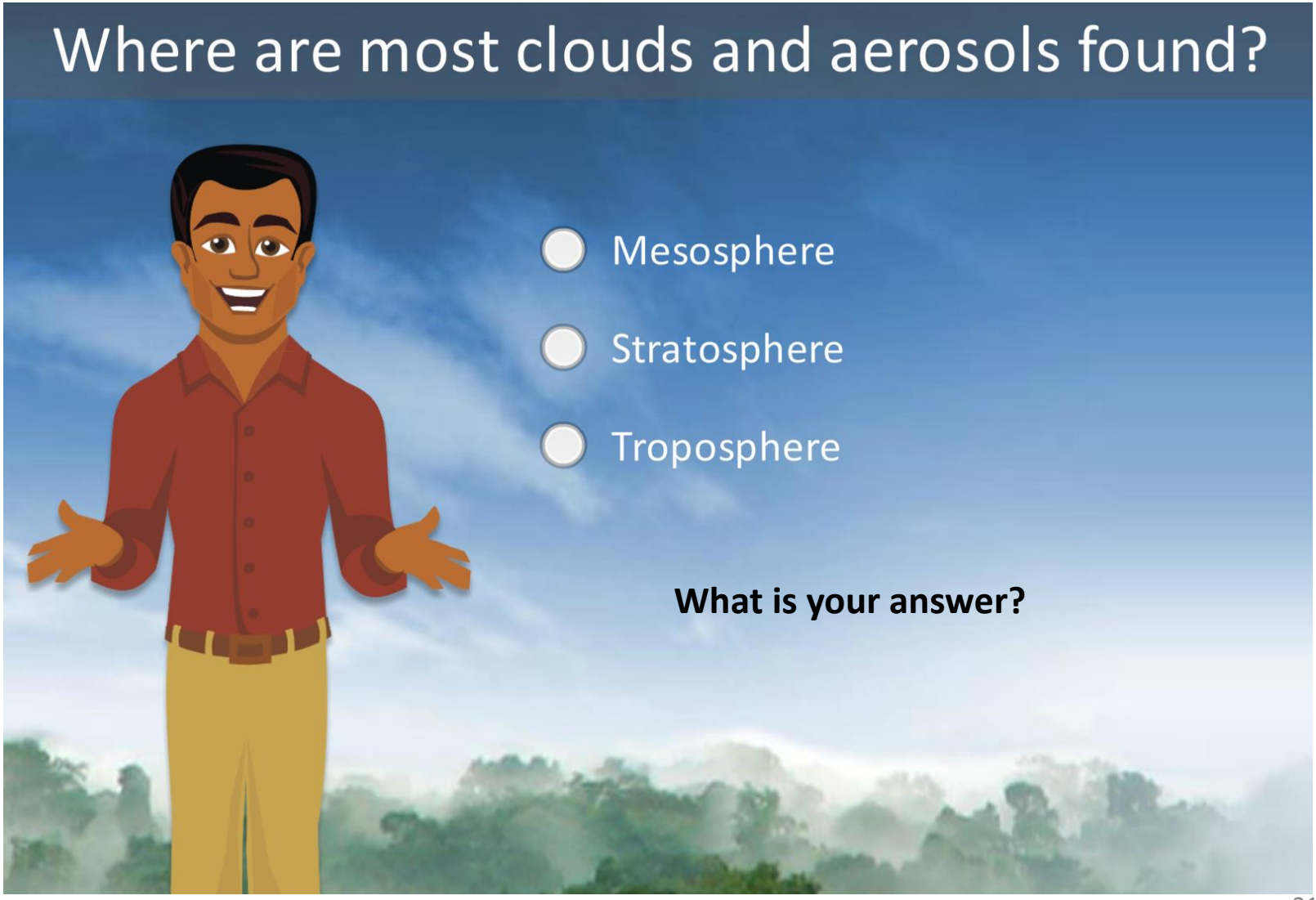
- Water vapor
- Ozone
- Carbon dioxide

What is your answer?

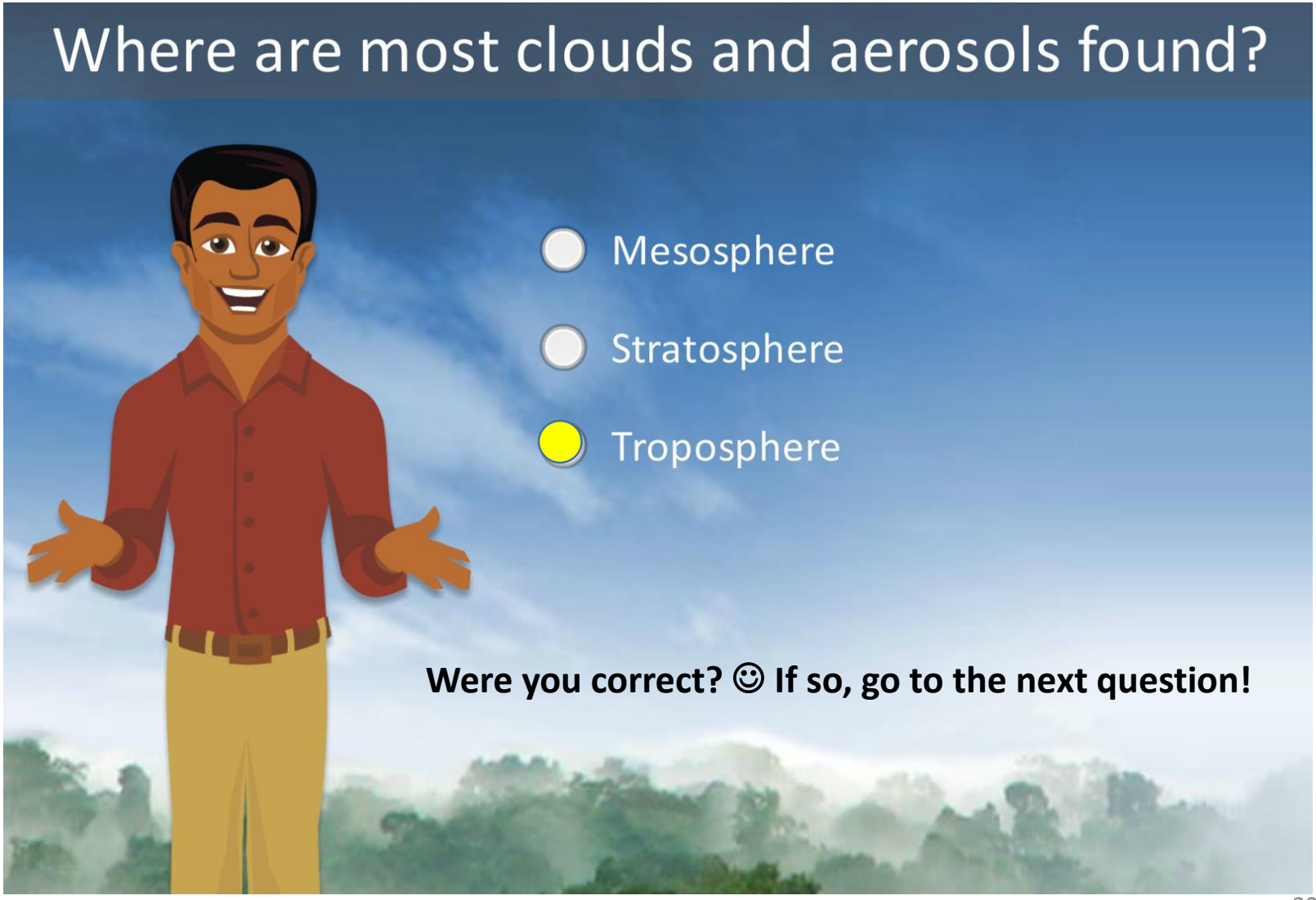
Answer to Question 2



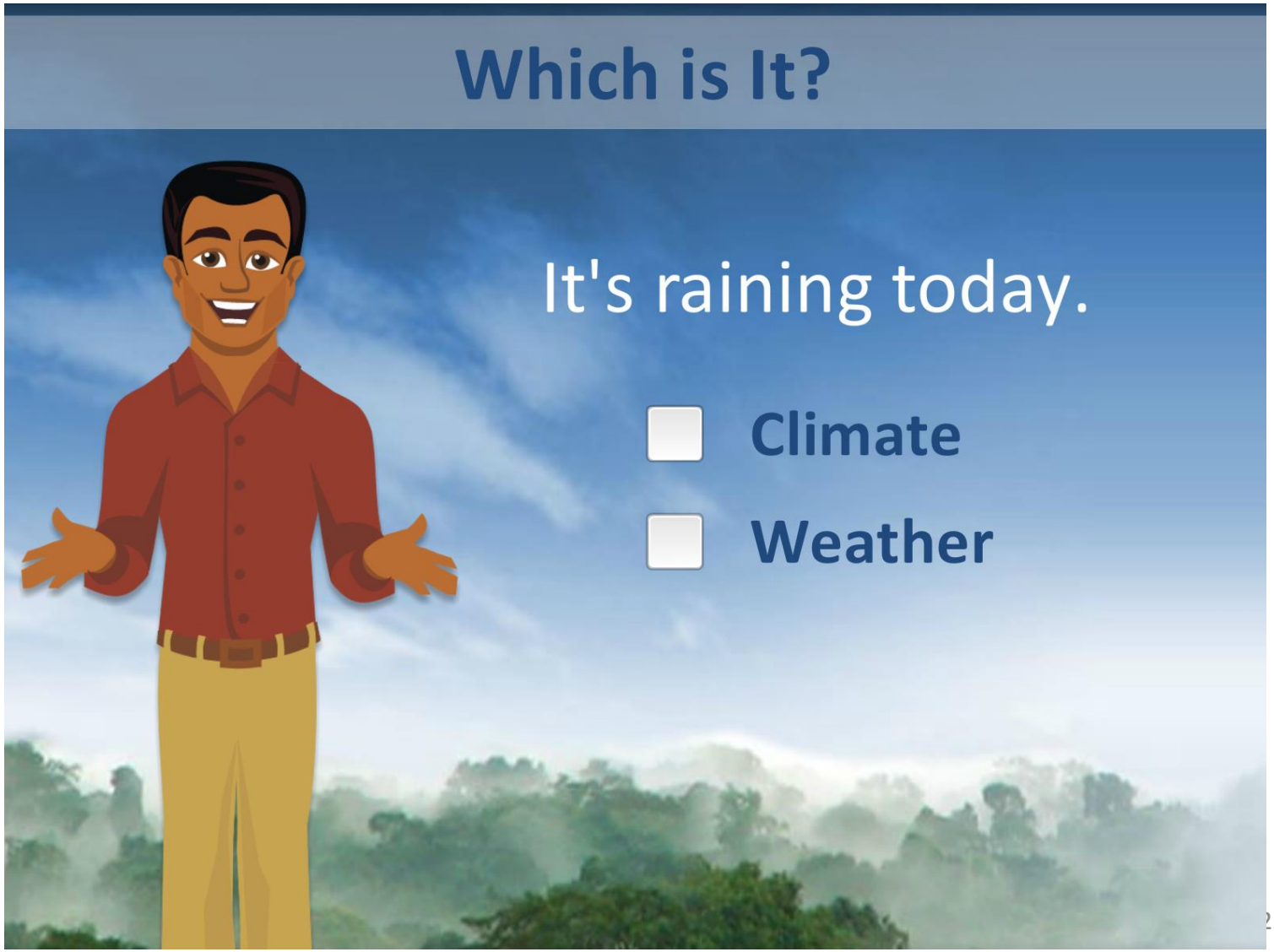
Review your understanding! Quiz Question 3



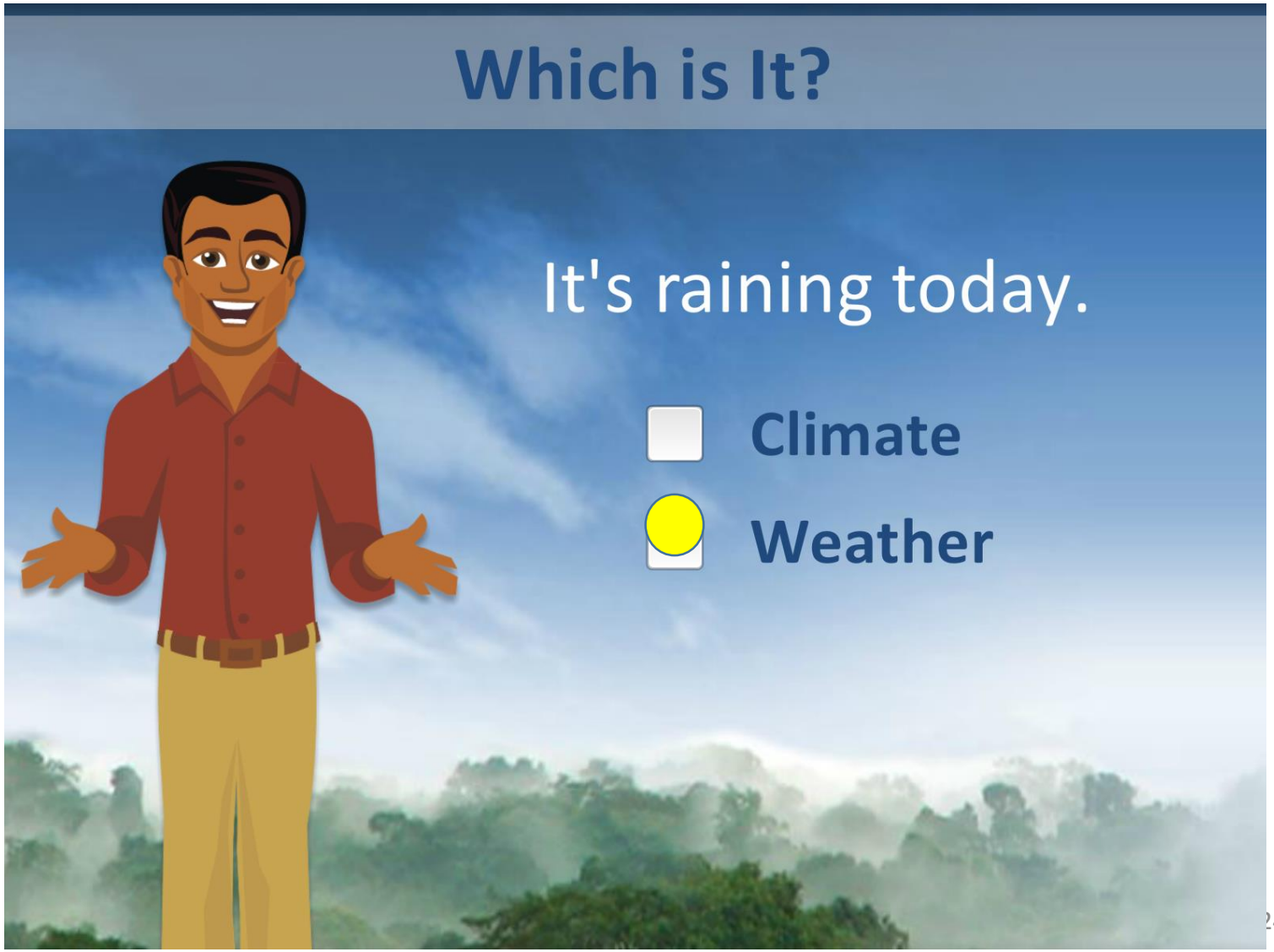
Answer to Quiz Question 3



Review your Understanding: Question 4

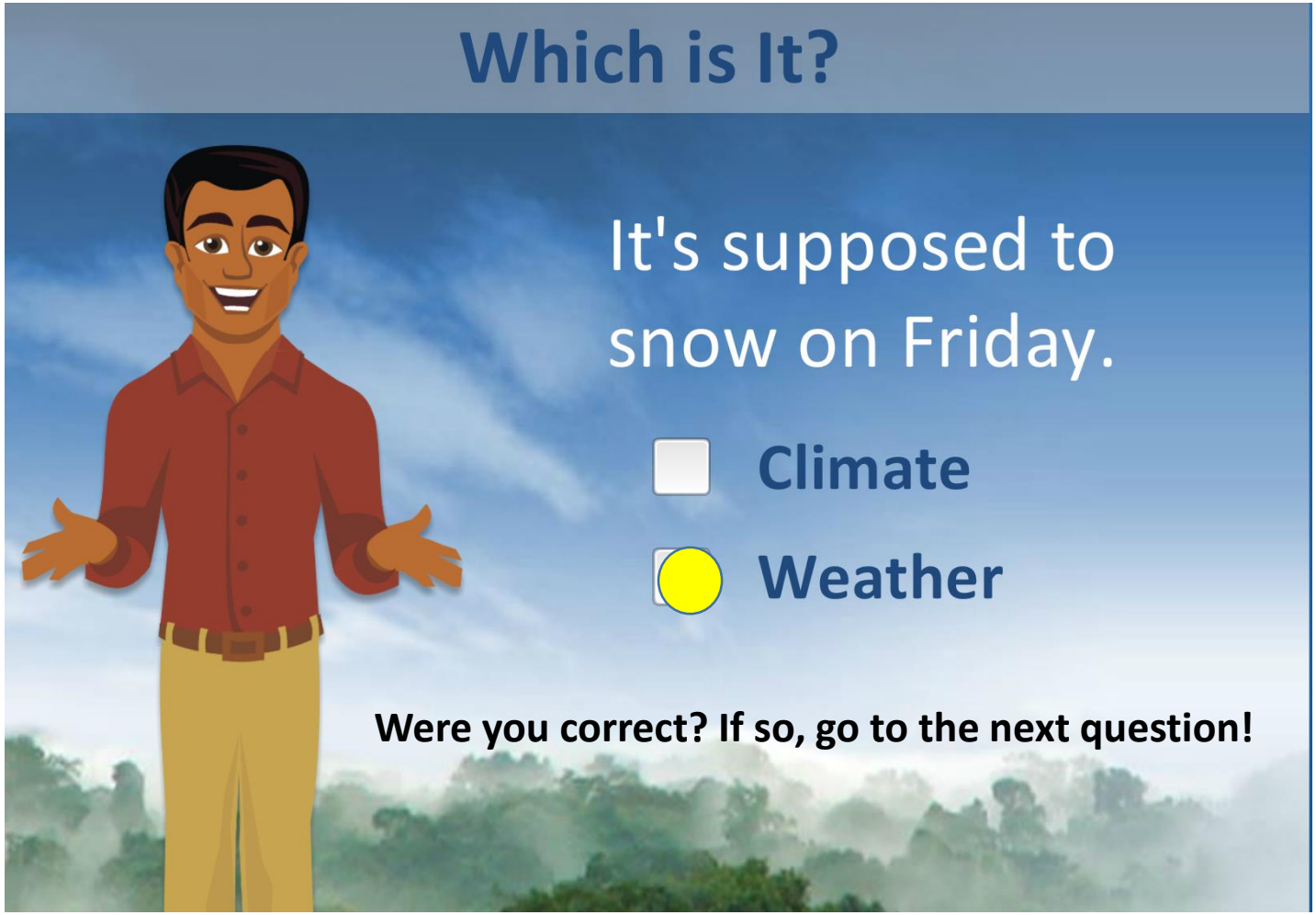


Answer to Question 4

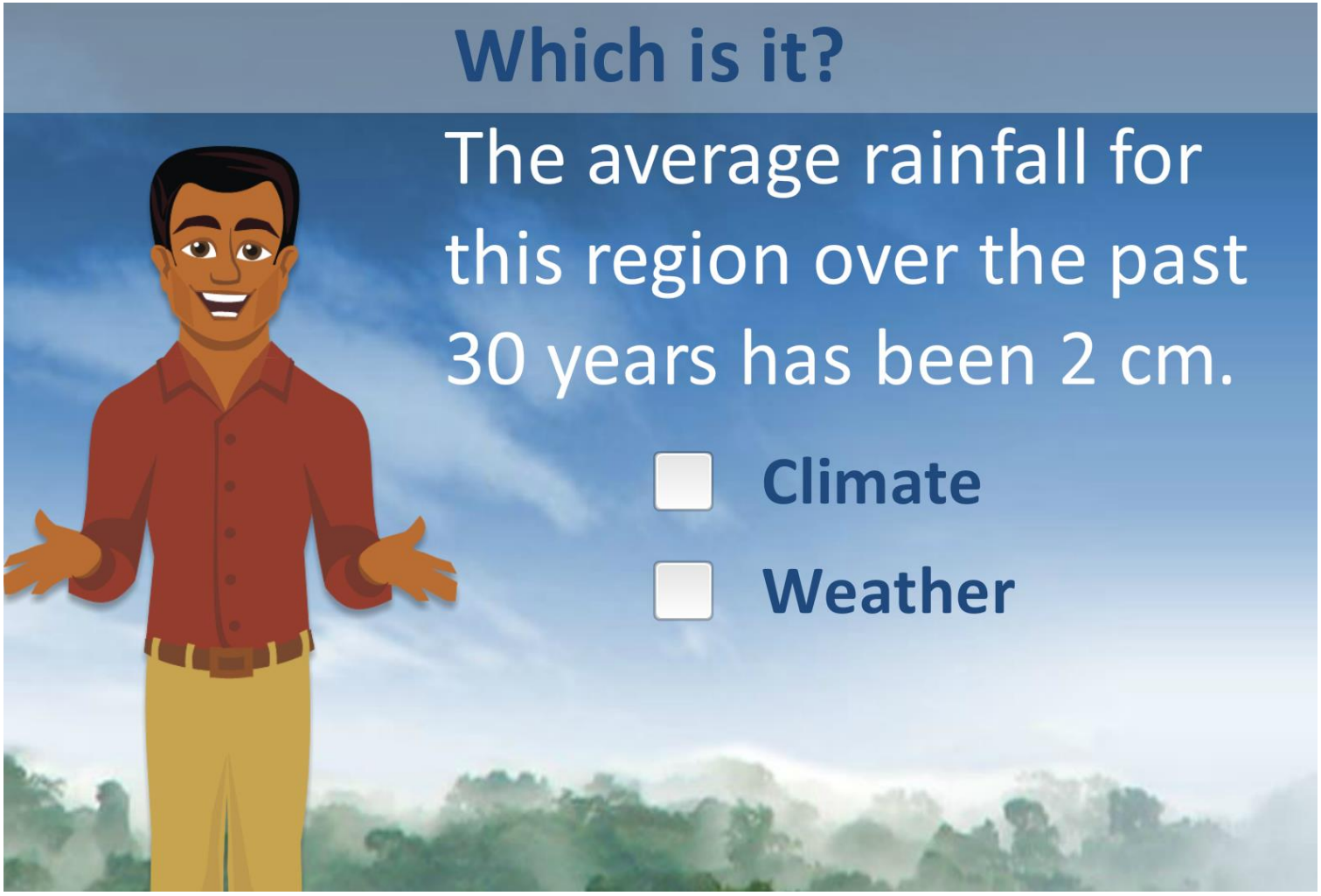


Review your Understanding! Question 5

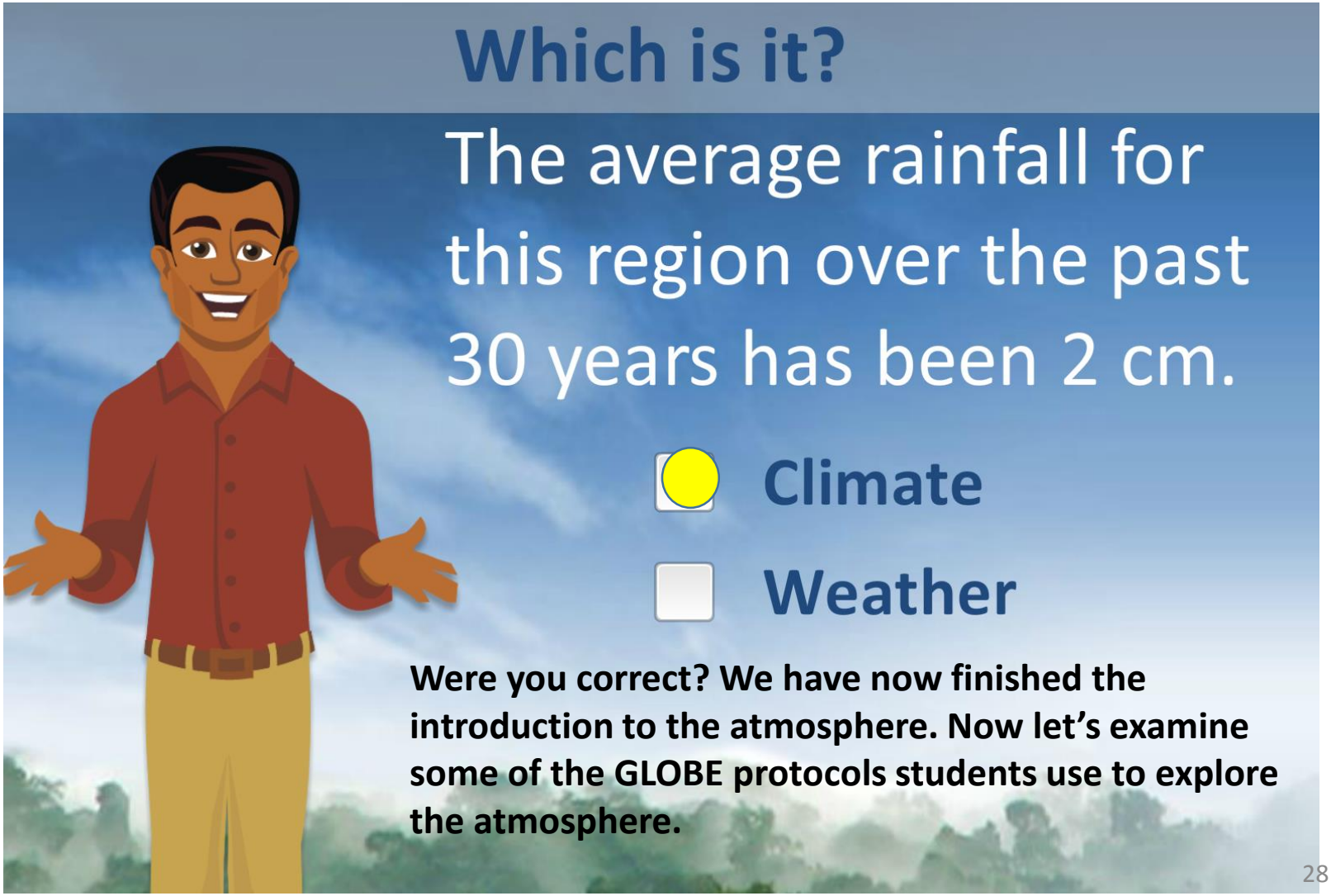
Answer to Question 5



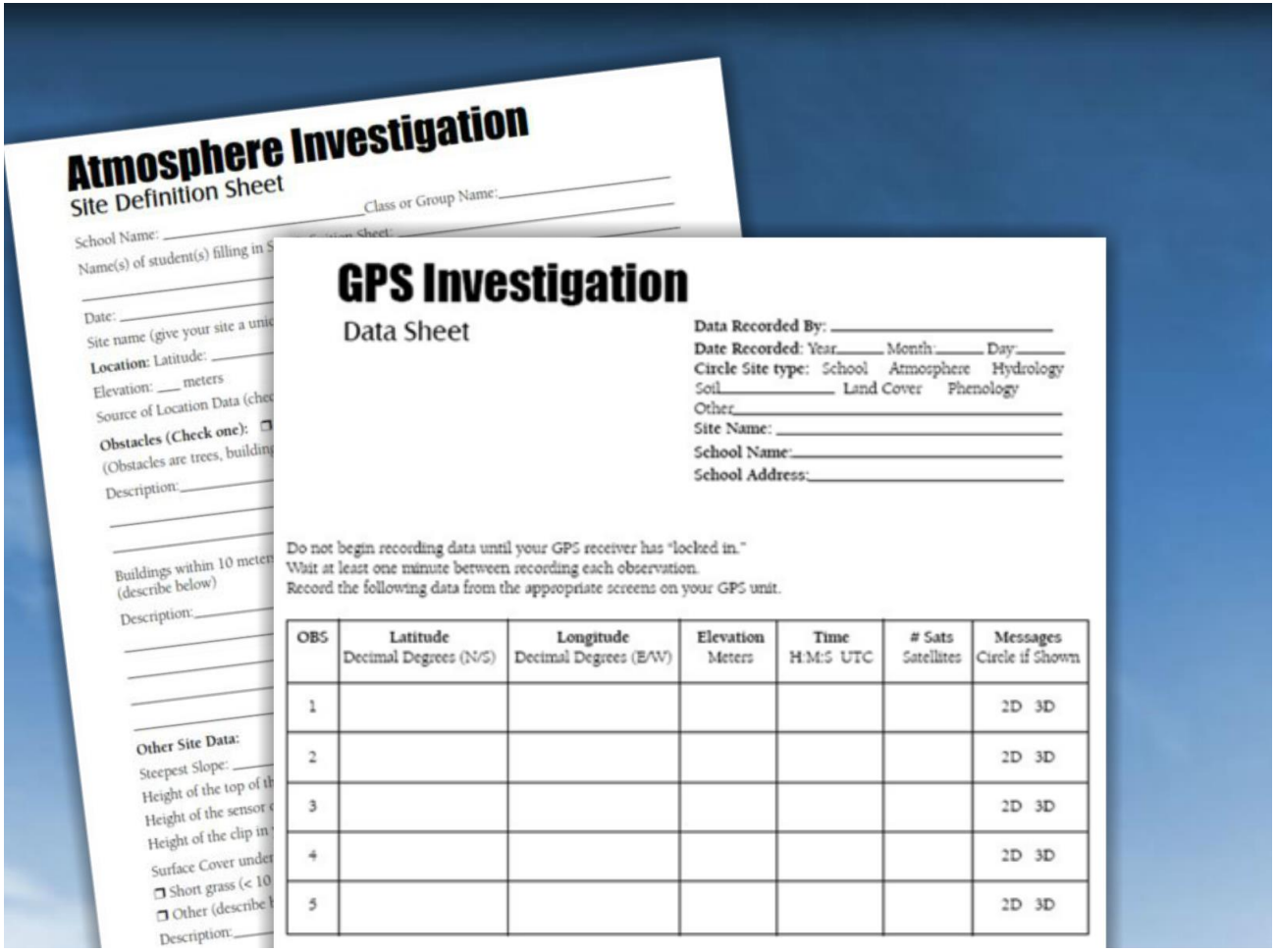
Review your Understanding! Question 6



Answer to Question 6



2. Overview of GLOBE Atmospheric Protocols



Atmosphere Investigation
Site Definition Sheet

School Name: Class or Group Name:
Name(s) of student(s) filling in
Date:
Site name (give your site a uni
Location: Latitude:
Elevation: ___ meters
Source of Location Data (che
Obstacles (Check one):
(Obstacles are trees, buildin
Description:
Buildings within 10 meter
(describe below)
Description:
Other Site Data:
Steepest Slope:
Height of the top of t
Height of the sensor
Height of the clip in
Surface Cover under
Short grass (< 10
Other (describe
Description:

GPS Investigation
Data Sheet

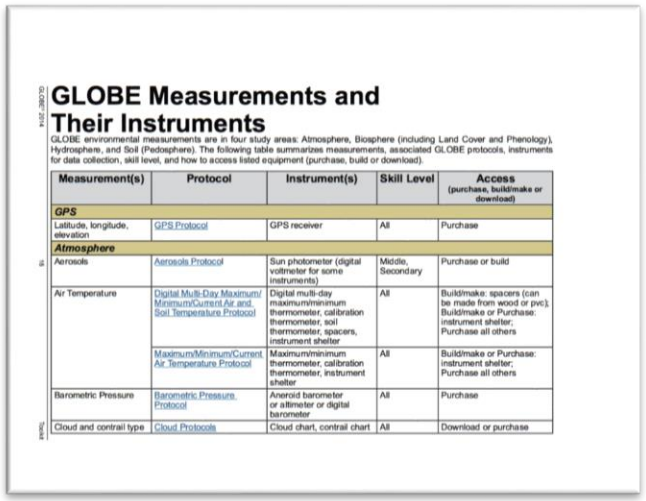
Data Recorded By:
Date Recorded: Year Month Day
Circle Site type: School Atmosphere Hydrology
Soil Land Cover Phenology
Other
Site Name:
School Name:
School Address:

Do not begin recording data until your GPS receiver has "locked in."
Wait at least one minute between recording each observation.
Record the following data from the appropriate screens on your GPS unit.

OBS	Latitude Decimal Degrees (N/S)	Longitude Decimal Degrees (E/W)	Elevation Meters	Time H:M:S UTC	# Sats Satellites	Messages Circle if Shown
1						2D 3D
2						2D 3D
3						2D 3D
4						2D 3D
5						2D 3D

Before we start, here are some things you should know about GLOBE's Atmosphere Investigations

- **Grade Level:** Some measurements, such as cloud and contrail type can be conducted by all students, Including those in the youngest grades. When combined with concepts such as parts per billion or relative humidity, these measurements are also very appropriate for older students.
- **Link to GLOBE Toolkit**



GLOBE Measurements and Their Instruments

GLOBE environmental measurements are in four study areas: Atmosphere, Biosphere (including Land Cover and Phenology), Hydrosphere, and Soil (Pedosphere). The following table summarizes measurements, associated GLOBE protocols, instruments for data collection, skill level, and how to access listed equipment (purchase, build or download).

Measurement(s)	Protocol	Instrument(s)	Skill Level	Access (purchase, build/make or download)
GPS				
Latitude, longitude, elevation	GPS Protocol	GPS receiver	All	Purchase
Atmosphere				
Aerosols	Aerosols Protocol	Sun photometer (digital voltmeter for some instruments)	Middle, Secondary	Purchase or build
Air Temperature	Digital Multi-Day Maximum/ Minimum/Current Air and Soil Temperature Protocol	Digital multi-day maximum/minimum thermometer, calibration thermometer, soil thermometer, spacers, instrument shelter	All	Build/make: spacers (can be made from wood or pvc); Build/make or Purchase: instrument shelter; Purchase all others
	Maximum/Minimum/Current Air Temperature Protocol	Maximum/minimum thermometer, calibration thermometer, instrument shelter	All	Build/make or Purchase: instrument shelter; Purchase all others
Barometric Pressure	Barometric Pressure Protocol	Aneroid barometer or altimeter or digital barometer	All	Purchase
Cloud and contrail type	Cloud Protocols	Cloud chart, contrail chart	All	Download or purchase

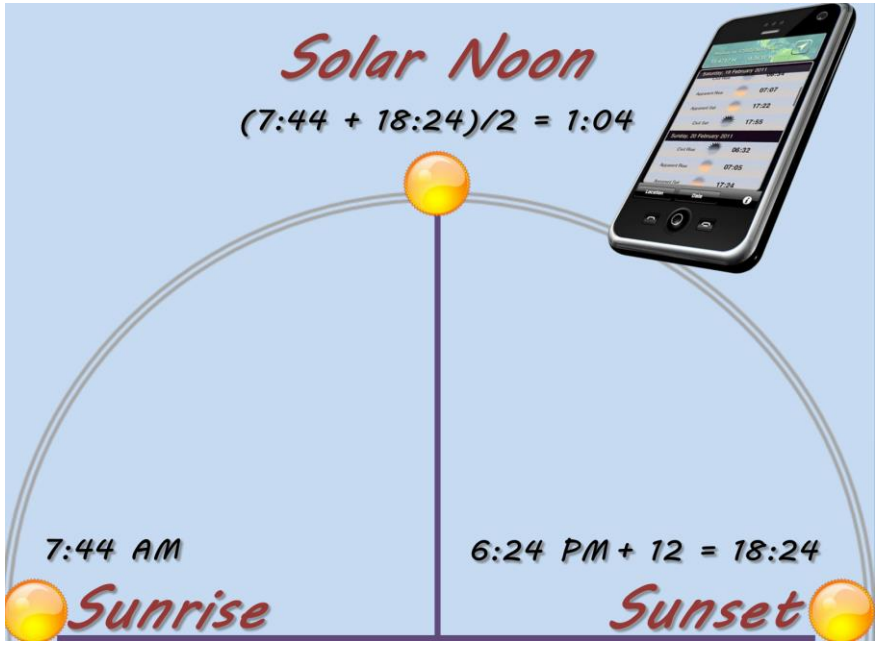
Where to find out about the instruments you need

Instrumentation: Some instruments are available on the GLOBE website, such as the Cloud Chart. Others you may already have at school, such as thermometers and meter sticks. There are instruments that can be made, such as instrument shelters for temperature measurements and snow boards. All instruments are available for purchase, including automated weather stations, that provide an optional way to collect atmosphere data.

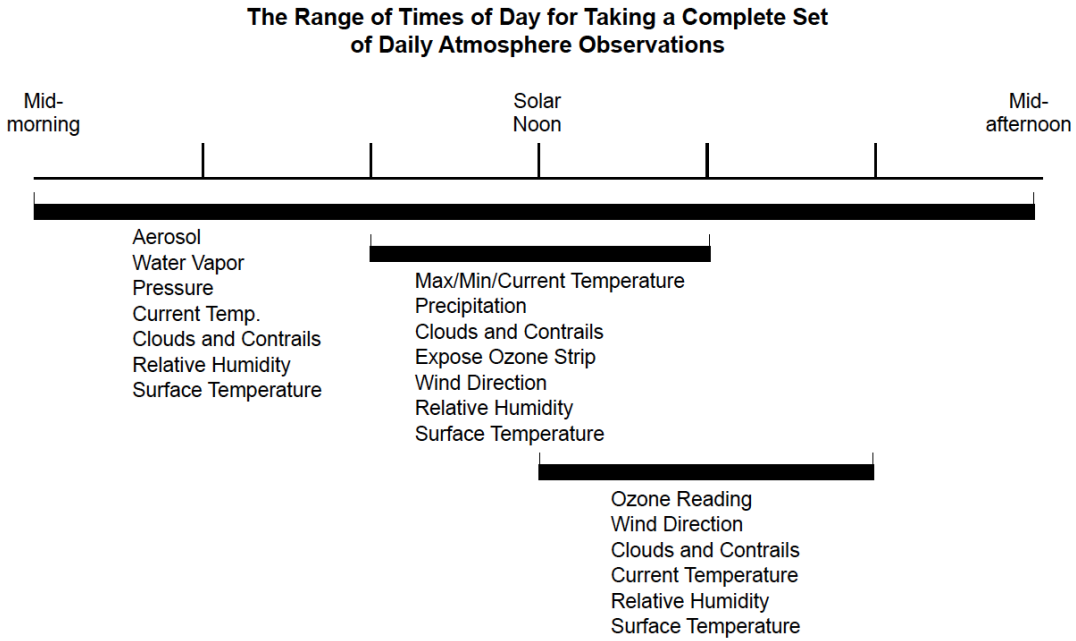
To find the specifications for instruments you need, you can consult the GLOBE Toolkit.

Many of your measurements should be taken at local solar noon

To ensure comparability of measurements worldwide, it's best to take your atmospheric measurements at your **local solar noon**. This time is usually not 12 pm on your local clock. You can look up the real time for local solar noon, or calculate by finding the average time between the published sunrise and sunset for your area. You will report your time as UTC, or Coordinated Universal Time. This is automatically calculated automatically for you when you input your data to GLOBE.



Most of the GLOBE atmosphere measurements should be taken during a two hour window surrounding your local solar noon.



Remember, you don't have to do all the measurements! You can select the measurements that fit with the times that work with your classroom schedule.

Atmospheric Protocols: When to take your measurements, and how long you will need to take them

Time: Most of the measurements take just a few minutes and can be collected at about the same time every day, within a two-hour window, one hour before or after **local, solar noon.** However, other data can be taken at any time of day, such as clouds or relative humidity.

Which measurements your students collect may be restricted due to the time available at the atmosphere study site.

Measurement	Taken within one hour of local solar noon	Other times measurements may be taken
Cloud Cover and Type Contrail Cover and Type	Yes	Required in support of aerosols, water vapor, surface temperature, ozone, and water transparency measurements; additional times are acceptable
Aerosols Water Vapor	Variable. Ideal time varies with location and season	When the sun is at least 30° above the horizon or at local solar noon when the sun doesn't reach 30° above the horizon; additional times are acceptable
Relative Humidity	Yes for the psychrometer; the digital hygrometer reading may be reported up to one hour later at the same time as the ozone measurement	Additional times are acceptable. Required in support of aerosols, water vapor, and ozone.
Precipitation	Yes	No
Current Temperature	Yes	Required for comparison with soil temperature measurements and in support of aerosols, water vapor, ozone, and relative humidity measurements; additional times are acceptable
Surface Temperature	Not required	Important for comparisons with soil and current temperature measurements
Maximum and Minimum Temperature	Yes	No
Barometric Pressure	Not required	Within one hour of aerosols and water vapor measurements if they are taken; otherwise as convenient
Ozone	The observation is started at this time and completed one hour later	Other one-hour periods are acceptable in addition to the near-noon measurement

Atmospheric Protocols: How long measurements take

Most of the measurements take just a few minutes. Which measurements your students collect may be restricted due to the time available at the atmosphere study site.

Measurement	Approximate Time required (in minutes)
Cloud and contrail cover and type	10
Aerosols including supporting measurements	15 - 30
Water Vapor including supporting measurements	15 - 30
Aerosols and water vapor combined including supporting measurements	20 - 40
Relative Humidity	5 - 10
Precipitation	5 - 10
Precipitation pH using meter including calibration	10
Handling of snow samples in the classroom for snow or snow pack water equivalent	5
Snow water equivalent once the snow has melted	5
1-day maximum, minimum, and current temperature	5
Multi-day max/min/current air and soil temperature	5 - 10
Surface temperature including supporting measurements	10 - 20
Ozone deploying the strip and taking supporting measurements	10
Ozone reading the strip and taking supporting measurements	10 - 15
Entire set of local solar noon measurements: clouds and contrails, relative humidity, precipitation amount and pH, max/min/current temperature, surface temperature, and deploying the ozone strip*	15 - 25

Atmospheric Pressure Protocol

Atmospheric Pressure

Students use either a barometer or an altimeter to measure atmospheric/barometric pressure.

- **Skill Level: All grades**
- **Time required 15-25 minutes**

Cloud Protocol

Skill Level: All grades
Time required:10 minutes

Clouds

Students use a cloud and/or contrail chart to identify types of clouds and contrails.

Automatic Weather Station

Students can collect various atmospheric measurements using an automatic weather station.

Skill Level: All grades
Time required 10 minutes

Automatic Weather Station Protocol

Skill Level: All grades
Time required 10-15 minutes

Surface Ozone

Students use a chemically-treated strip exposed for one hour in the atmosphere and use a strip reader to read the amount of ozone at that location.

Surface Ozone Protocol

Skill Level: All grades
Time required: 10-15 minutes

Surface Temperature Protocol

Surface Temperature

Students use a handheld infrared thermometer (IRT) to measure the temperature of the ground at nine widely-spaced places at the measurement site.

Air Temperature Protocol

Air Temperature

Students use a thermometer to measure maximum and minimum air temperature over a 24-hour period. The thermometer is housed in an instrument shelter.

Skill Level: All grades
Time required: 5 minutes

Water Vapor Protocol

Water Vapor

Students use a water vapor instrument to measure water vapor in the atmosphere.

Skill Level: Middle, Secondary
Time required: 15-30 minutes

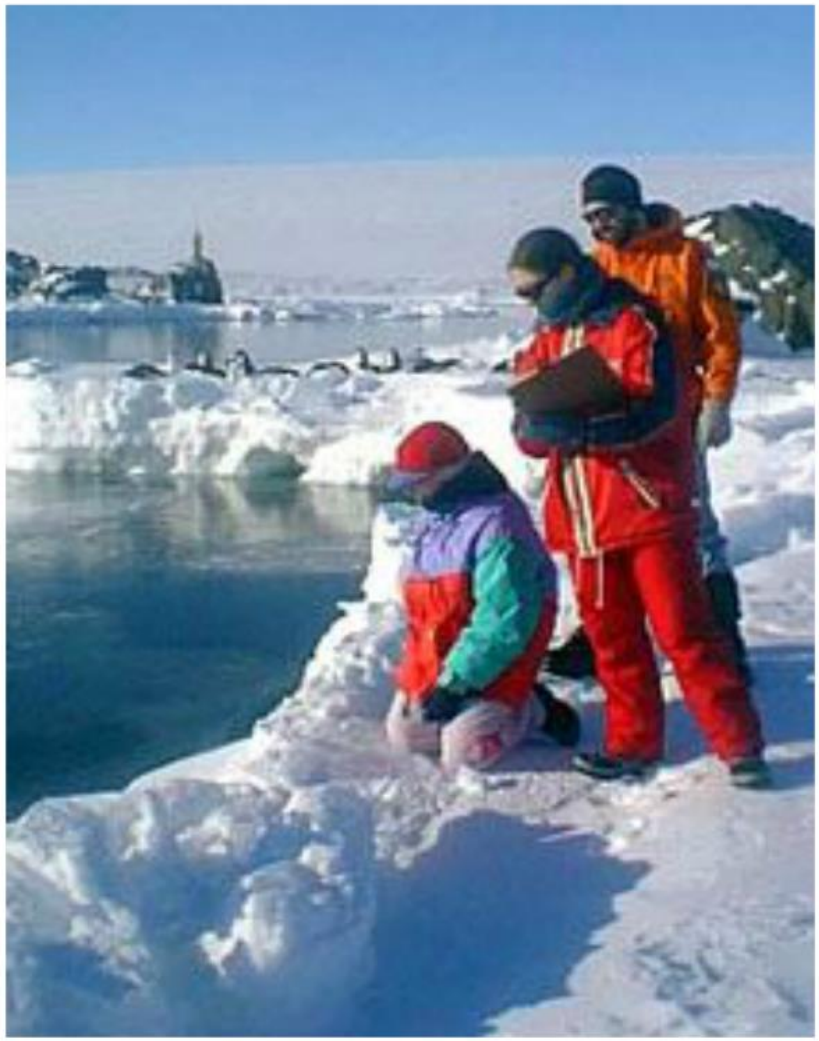
Aerosols Protocol

Skill Level: Middle or Secondary
Time required 15-30 minutes

Aerosols

Students use a sun photometer (and in some cases, a voltmeter) to measure aerosol optical thickness.

Precipitation (Solid) Protocol



Precipitation (Solid)

Students use a snow board and metric ruler to measure snowfall and snowpack. Students can also measure pH.

Skill Level: All
Time required 10 minutes

Relative Humidity Protocol

Relative Humidity

Students use either a sling psychrometer or a digital hygrometer to measure relative humidity.

Skill Level: All
Time required 5-10 minutes

Skill Level: All
Time required 5-10 minutes

Precipitation (Liquid) Protocol

Precipitation (Liquid)

Students use a rain gauge to measure rainfall. Students can also measure pH.

Review your Knowledge! Question 7

Which of the following protocols requires no purchased equipment?

a. Aerosols

b. Cloud

c. Relative humidity

d. Water vapor

What is your answer?

Answer to Quiz Question 7

Answer to Question 7

Which of the following protocols requires no purchased equipment?

a. Aerosols

b. Cloud- ☺ correct!

c. Relative humidity

d. Water vapor

Were you correct?

Review your Knowledge!

Question 8

Most Atmosphere Protocols can be conducted by students of all ages. Which is one of the protocols that may be more appropriate for older students?

a. Precipitation

b. Cloud

c. Air Temperature

d. Water vapor

What is your answer?

The GLOBE Program

Answer to Quiz Question 8

Most Atmosphere Protocols can be conducted by students of all ages. Which is one of the protocols that may be more appropriate for older students?

a. Precipitation

b. Cloud

c. Air Temperature

d. Water vapor ☺ Correct!

Were you correct?

The GLOBE Program

Review your Knowledge! Question 9

Most of the GLOBE atmosphere measurements should be taken during a two hour window around

a. noon local time

b. local solar noon

c. dawn or sunset

d. Noon UTC (coordinated universal time)

What is your answer?

The GLOBE Program

Answer to Quiz Question 9

Most of the GLOBE atmosphere measurements should be taken during a two hour window around

a. noon local time

b. local solar noon ☺ Correct!

c. dawn or sunset

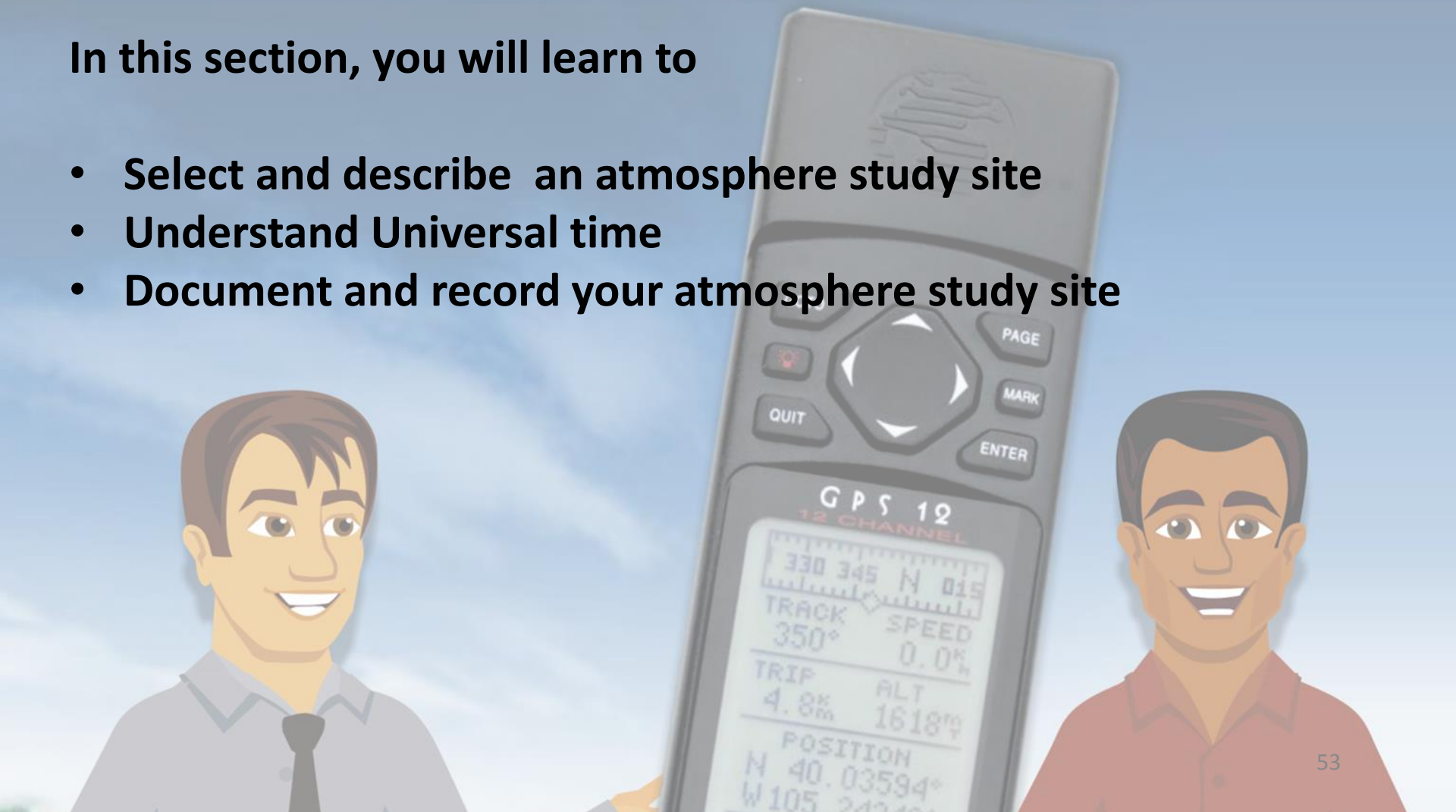
d. Noon UTC (coordinated universal time)

Were you correct?

3. Setting up your Atmosphere Study Site

In this section, you will learn to

- **Select and describe an atmosphere study site**
- **Understand Universal time**
- **Document and record your atmosphere study site**



Documenting your Atmosphere Study Site

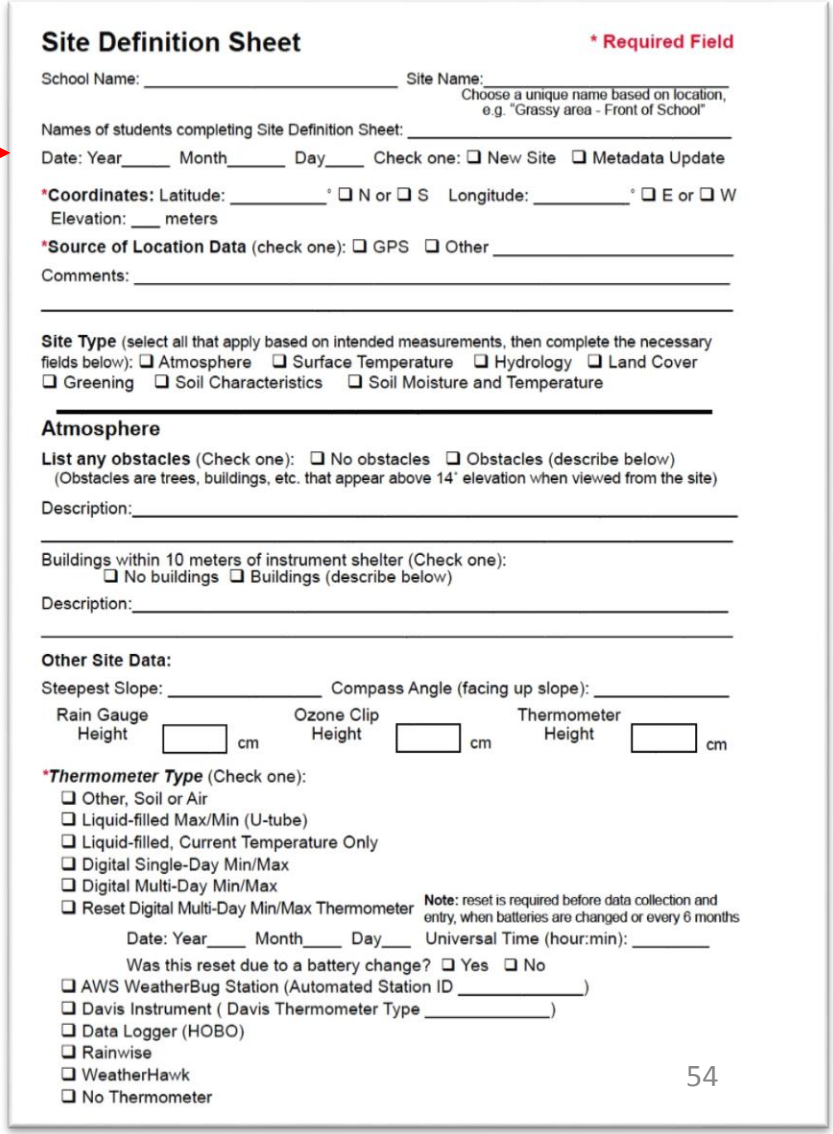
Let's go through the steps in the next slides…

Use a GPS

Evaluate your school yard and identify any obstacles to the sky

Ensure no building is within 10 m

Use compass to determine the slope



Site Definition Sheet * Required Field

School Name: _____ Site Name: _____
Choose a unique name based on location, e.g. "Grassy area - Front of School"

Names of students completing Site Definition Sheet: _____

Date: Year____ Month____ Day____ Check one: ❑ New Site ❑ Metadata Update

*Coordinates: Latitude: _____° ❑ N or ❑ S Longitude: _____° ❑ E or ❑ W
Elevation: ___ meters

*Source of Location Data (check one): ❑ GPS ❑ Other _____

Comments: _____

Site Type (select all that apply based on intended measurements, then complete the necessary fields below): ❑ Atmosphere ❑ Surface Temperature ❑ Hydrology ❑ Land Cover ❑ Greening ❑ Soil Characteristics ❑ Soil Moisture and Temperature

Atmosphere

List any obstacles (Check one): ❑ No obstacles ❑ Obstacles (describe below)
(Obstacles are trees, buildings, etc. that appear above 14° elevation when viewed from the site)

Description: _____

Buildings within 10 meters of instrument shelter (Check one):
❑ No buildings ❑ Buildings (describe below)

Description: _____

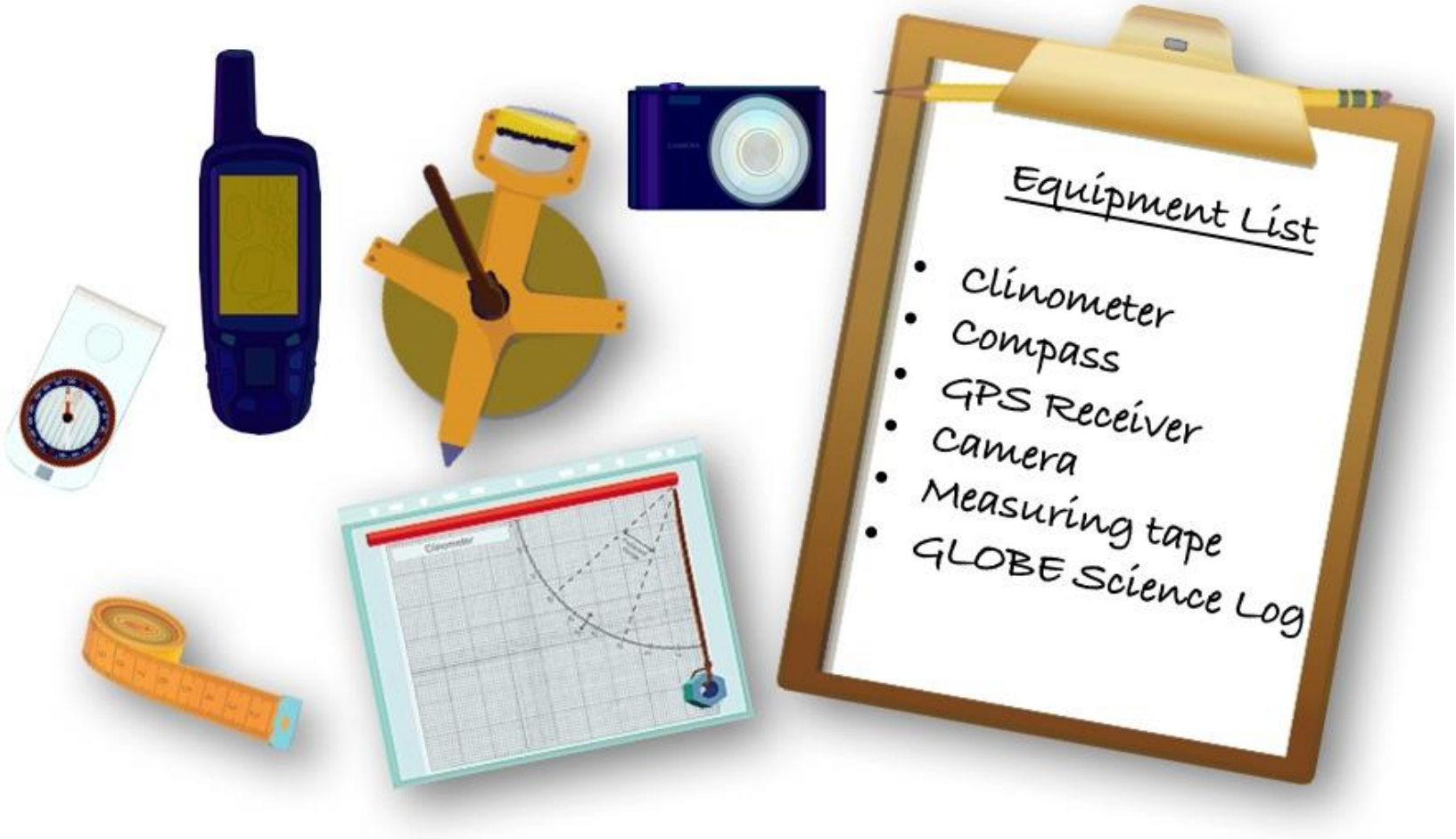
Other Site Data:

Steepest Slope: _____ Compass Angle (facing up slope): _____

Rain Gauge Height ____ cm Ozone Clip Height ____ cm Thermometer Height ____ cm

*Thermometer Type (Check one):
❑ Other, Soil or Air
❑ Liquid-filled Max/Min (U-tube)
❑ Liquid-filled, Current Temperature Only
❑ Digital Single-Day Min/Max
❑ Digital Multi-Day Min/Max
❑ Reset Digital Multi-Day Min/Max Thermometer
Note: reset is required before data collection and entry, when batteries are changed or every 6 months
Date: Year____ Month____ Day____ Universal Time (hour:min): _____
Was this reset due to a battery change? ❑ Yes ❑ No
❑ AWS WeatherBug Station (Automated Station ID _____)
❑ Davis Instrument (Davis Thermometer Type _____)
❑ Data Logger (HOBO)
❑ Rainwise
❑ WeatherHawk
❑ No Thermometer

Equipment you need to document your Atmosphere Study Site



Where is a good place to locate the Atmosphere Study Site?

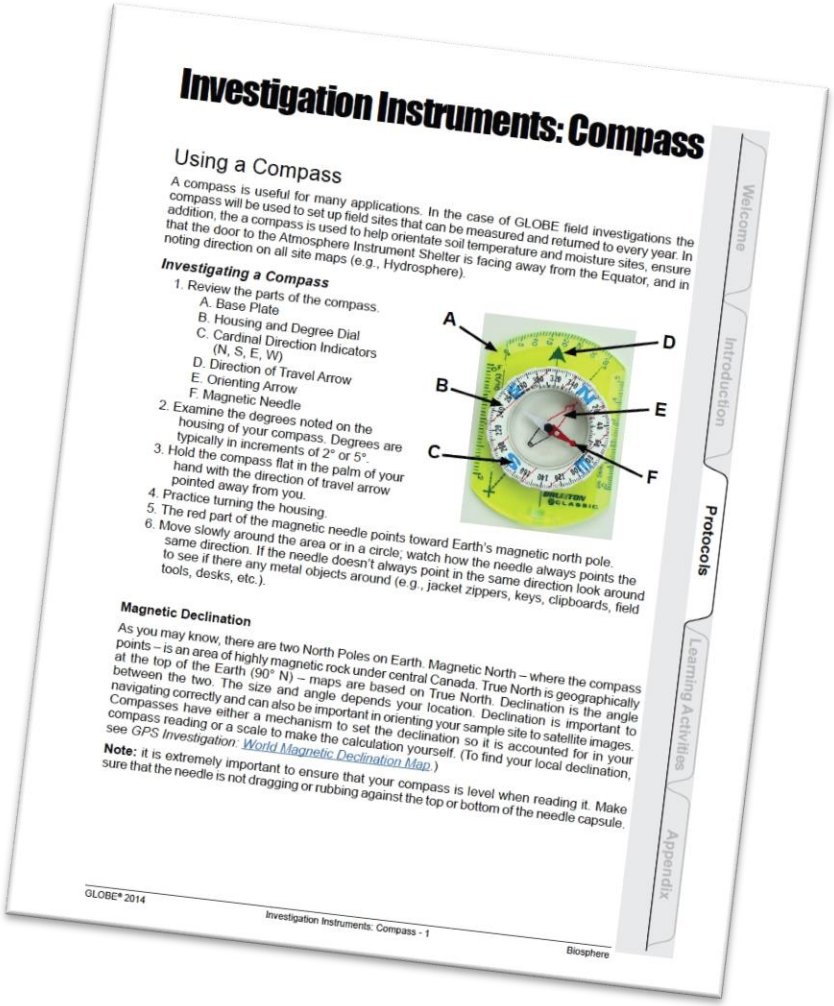
An open grass-covered area is optimal.

It is best to be in an open area away from buildings

Don’t worry if you don’t have the perfect sampling site

Method to determine location if using a GPS Receiver

The GLOBE Teacher's Guide tells you how to use a compass and determine the slope



Investigation Instruments: Compass

Using a Compass

A compass is useful for many applications. In the case of GLOBE field investigations the compass will be used to set up field sites that can be measured and returned to every year. In addition, the a compass is used to help orientate soil temperature and moisture sites, ensure that the door to the Atmosphere Instrument Shelter is facing away from the Equator, and in noting direction on all site maps (e.g., Hydrosphere).

Investigating a Compass

1. Review the parts of the compass.
   - A. Base Plate
   - B. Housing and Degree Dial
   - C. Cardinal Direction Indicators (N, S, E, W)
   - D. Direction of Travel Arrow
   - E. Orienting Arrow
   - F. Magnetic Needle
2. Examine the degrees noted on the housing of your compass. Degrees are typically in increments of 2° or 5°.
3. Hold the compass flat in the palm of your hand with the direction of travel arrow pointed away from you.
4. Practice turning the housing.
5. The red part of the magnetic needle points toward Earth's magnetic north pole.
6. Move slowly around the area or in a circle; watch how the needle always points the same direction. If the needle doesn't always point in the same direction look around to see if there any metal objects around (e.g., jacket zippers, keys, clipboards, field tools, desks, etc.).

Magnetic Declination

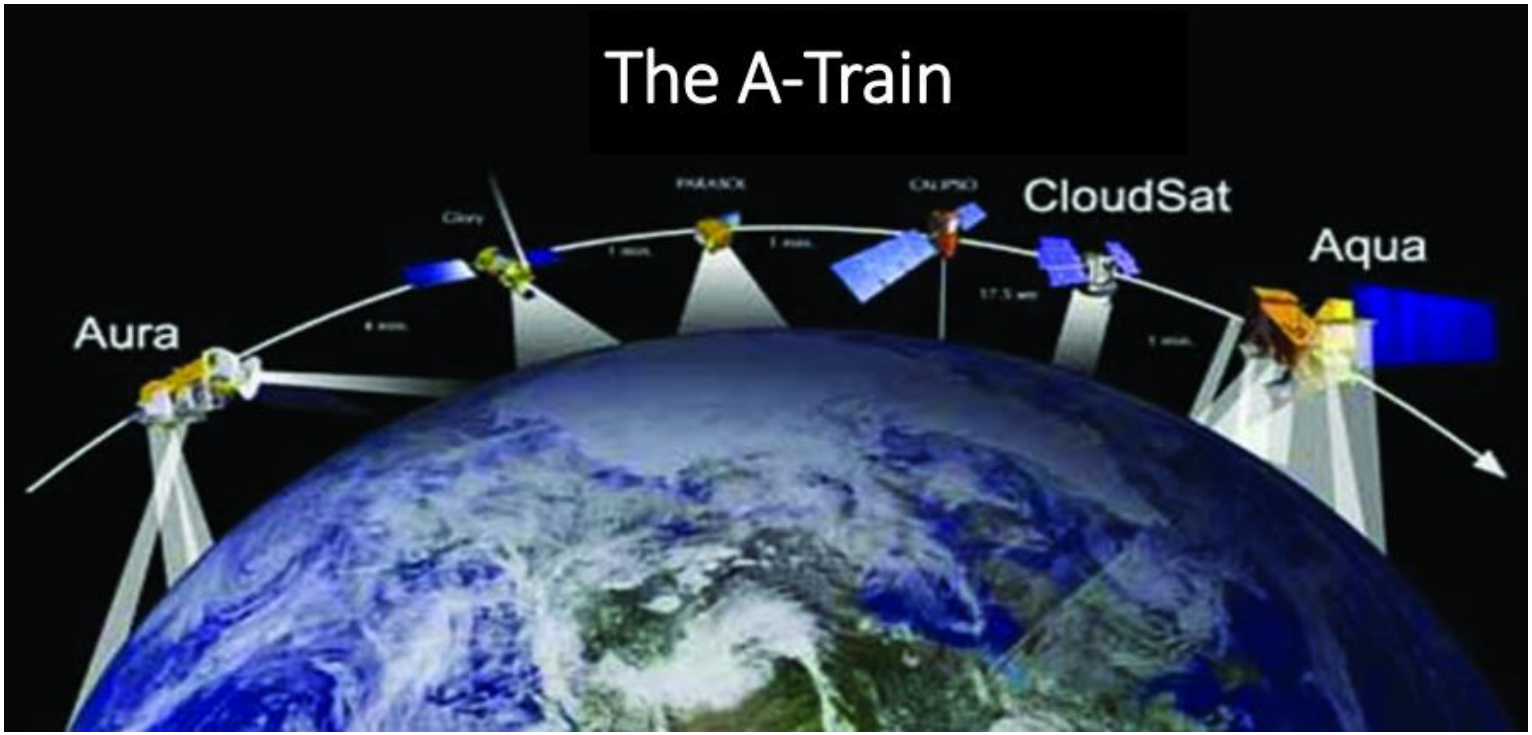
As you may know, there are two North Poles on Earth. Magnetic North – where the compass points – is an area of highly magnetic rock under central Canada. True North is geographically at the top of the Earth (90° N) – maps are based on True North. Declination is the angle between the two. The size and angle depends your location. Declination is important to navigating correctly and can also be important in orienting your sample site to satellite images. Compasses have either a mechanism to set the declination so it is accounted for in your compass reading or a scale to make the calculation yourself. (To find your local declination, see *GPS Investigation*: World Magnetic Declination Map.)

Note: it is extremely important to ensure that your compass is level when reading it. Make sure that the needle is not dragging or rubbing against the top or bottom of the needle capsule.

The A-Train

NASA monitors Earth's vital signs from land, air and space with a fleet of satellites and ground-based observation campaigns.

One of the ground-based observation campaigns is GLOBE.



Find out more here: Link to NASA article about the A-Train

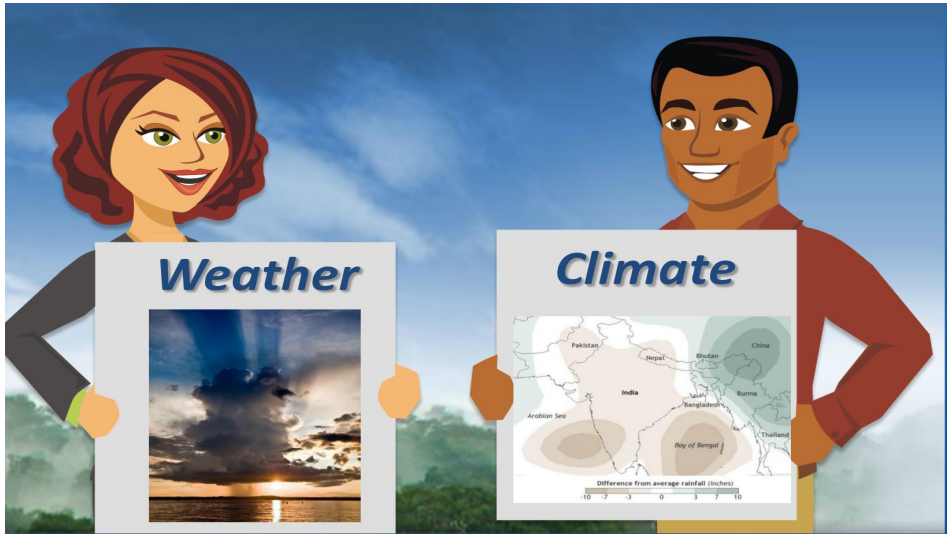
These are some of the important ideas we have covered!

Important Concepts

- Mixture of gases in the atmosphere
- The four layers of the atmosphere
- Weather and climate
- GLOBE's Atmosphere Protocols
- Latitude, longitude, and elevation
- The location of an atmosphere study site
- Solar noon and Universal Time
- The GLOBE Atmosphere Site Definition Sheet.

Before you end this session, review your knowledge of these important concepts!

1. What is the difference between weather and climate?



(Find the Answer: slides 14-16)

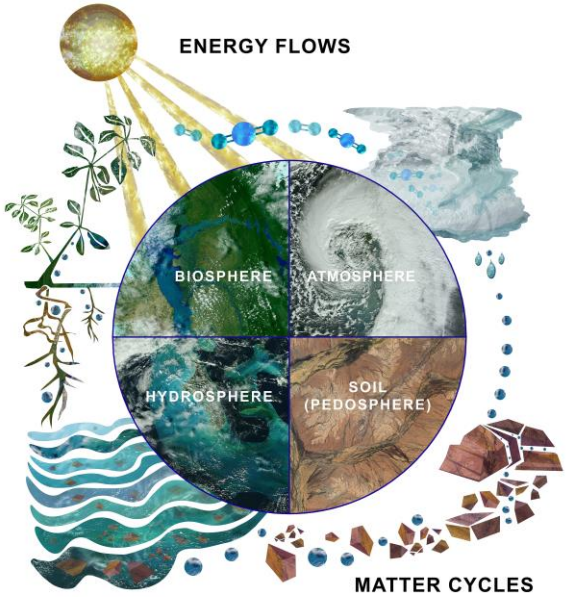
Before you end this session, review your knowledge of these important concepts!

2. Describe the characteristics of the atmosphere

(Find the Answer: Slides 4-8)

Before you end this session, review your knowledge of these important concepts!

3. What do we mean when we say that in the Earth system, “Everything is connected to everything else?”



(Find the Answer: Slides 10-13)

Before you end this session, review your knowledge of these important concepts!

4. What are some of the measurement protocols used in GLOBE Atmosphere investigation?

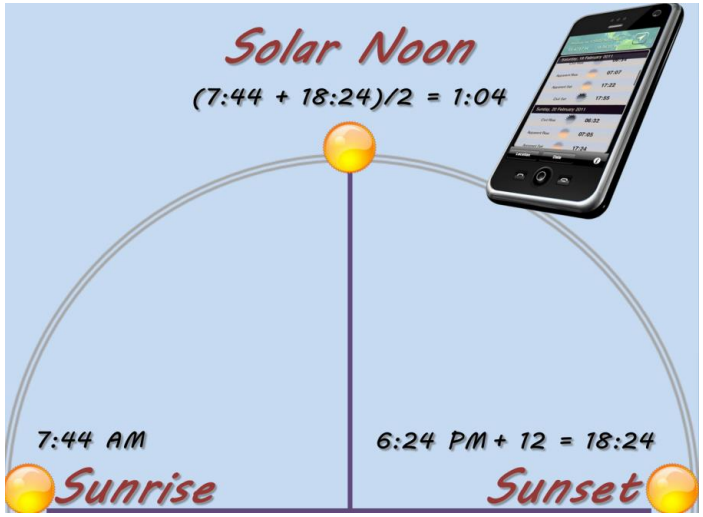
(Find the Answer: slides 36-46)

Before you end this session, review your knowledge of these important concepts!

5. What should you consider when determining placement of an Atmosphere Study Site?

(Find the Answer: Slides 56-59)

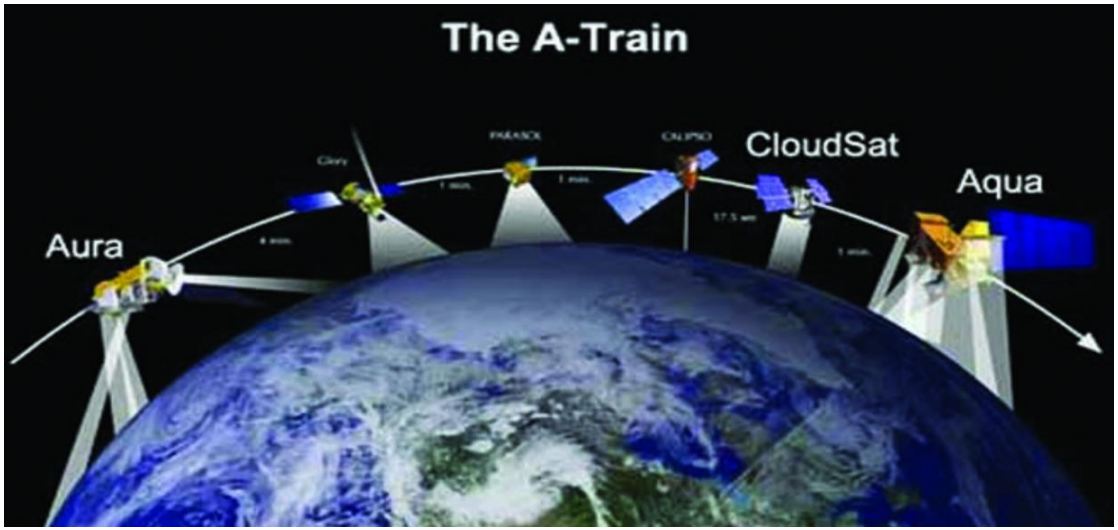
6. When do you take measurements?



(Find the Answer: Slides 32-33)

Before you end this session, review your knowledge of these important concepts!

7. What is the relationship between NASA satellite measurements such as those taken by the "A-Train" and GLOBE?



(Find the Answer: slide 62)

If you feel you are ready to take the Introduction to Atmosphere Quiz, you will see a link next to where you found this module.

Welcome to GLOBE's Atmosphere Investigations!

Please provide us with feedback about this module. This is a community project and we welcome your comments, suggestions and edits! Comment here: eTraining Feedback

Questions about this module? Contact rlow@ucar.edu

For More Information:

The GLOBE Program

NASA Wavelength NASA's Digital Library of K-16 Earth and Space Educational Resources

NASA Global Climate Change: Vital Signs of the Planet

The GLOBE Program is sponsored by these organizations:

Version 12/1/16. If you edit and modify this slide set for use for educational purposes, please note "modified by (and your name and date " on this page. Thank you.