This is REMO. REMO is a Remote Earth-Monitoring Observer. He uses *remote sensing*, which is studying something from a distance, to look at Earth.

Together with his satellite friends, he orbits Earth, always recording things that he finds out. And then he tells us all about them.

With the help of NASA satellites, we can understand how Earth’s climate works and changes over time.

Let’s see what REMO has found out so far...
REMO has learned that Earth is a special place. He gets together with other spacecraft to talk about their journeys to other planets. They tell him Venus is like an oven and Mars is like a freezer. REMO tells them, “Earth isn’t too hot or too cold; it’s just right for life!”

<table>
<thead>
<tr>
<th></th>
<th>Venus</th>
<th>Earth</th>
<th>Mars</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average surface pressure</strong> (relative to Earth’s atmosphere)</td>
<td>93.0</td>
<td>1.0</td>
<td>0.007</td>
</tr>
<tr>
<td><strong>Carbon dioxide (CO₂)</strong> (percent of planet’s atmosphere)</td>
<td>96.5%</td>
<td>0.04%</td>
<td>95.3%</td>
</tr>
<tr>
<td><strong>Oxygen (O₂)</strong> (percent of planet’s atmosphere)</td>
<td>0</td>
<td>20.9%</td>
<td>0.13%</td>
</tr>
<tr>
<td><strong>Average Surface Temperatures</strong></td>
<td>465°C (870°F)</td>
<td>15°C (59°F)</td>
<td>-65°C (-85°F)</td>
</tr>
</tbody>
</table>
How Do REMO’s Satellite Friends Work?

Many NASA satellites use their sensors to collect information about Earth. Some sensors measure the amount of light reflected from Earth and record that information as numbers. The satellite transmits the numbers down to Earth in the form of binary code—zeroes and ones—where computers store the data until people analyze it.

In addition to visible light, some satellite sensors can detect other forms of light that the human eye cannot see. This non-visible light data give scientists important information about the Earth’s atmosphere, land, ocean, and cryosphere (sea ice and land snow/ice) and make satellite instruments indispensable tools for understanding our climate.

Images generated from satellite data are often made to highlight features of interest to scientists. “False-color” composite images are not true to real-life color, but provide contrast to features that are not readily seen with the human eye. They are made with a combination of visible and/or non-visible light data.

A natural-color image of wildfires in southern California and the northern Baja California Peninsula on October 26, 2003. It is made by combining separate images from different parts of the visible color spectrum and overlaying hot fires from an infrared channel.

Natural color
Infrared
Red
Green
Blue
What's in a Name?

REMO’s satellite friends below are members of NASA’s Earth Observing System (EOS) fleet. Each satellite name tells a story about what part of Earth it studies. Using the name’s meaning as your guide, draw a line to the satellite’s favorite subject.

<table>
<thead>
<tr>
<th>REMO’s Friend</th>
<th>Meaning</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>CALIPSO</td>
<td>Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation</td>
<td>Earth’s continents and land surfaces (2 possible answers)</td>
</tr>
<tr>
<td>OSTM</td>
<td>Ocean Surface Topography Mission</td>
<td>A flagship satellite of the Earth Observing System</td>
</tr>
<tr>
<td>ICESat</td>
<td>Ice, Cloud, and land Elevation Satellite</td>
<td>Precipitation from hurricanes and other storms</td>
</tr>
<tr>
<td>TRMM</td>
<td>Tropical Rainfall Measuring Mission</td>
<td>How clouds and aerosols affect climate</td>
</tr>
<tr>
<td>Aqua</td>
<td>Latin word for “water”</td>
<td>Air quality, ozone, composition of Earth’s atmosphere</td>
</tr>
<tr>
<td>Terra</td>
<td>Latin word for “earth”</td>
<td>Earth’s gravitational field</td>
</tr>
<tr>
<td>Landsat-7</td>
<td>The seventh Land Satellite</td>
<td>Ocean wave heights, current speeds, and circulation</td>
</tr>
<tr>
<td>GRACE</td>
<td>Gravity Recovery and Climate Experiment</td>
<td>Ice sheet mass, clouds over polar regions, land features</td>
</tr>
<tr>
<td>Aura</td>
<td>Latin word for “breeze, wind, or air”</td>
<td>All forms of water: ice, water vapor, rain, snow</td>
</tr>
</tbody>
</table>

Answers are below.
Facts about Aerosols.

Aerosols are itny particles in the atmosphere. You see them as the ezha that is sometimes gginahn around cities.

Desert stdu and eruptions from volcanoes are ssoorela that occur in enautr.

Pollutants from industrial activity and from vehicles create man-made aerosols, like those generated from tsauhx.

Aerosols can affect climate by reflecting and absorbing solar radiation. Some cta as “seeds” around which a cudol of droplets forms, in a process called nucleation. giHh aerosol concentrations in clouds can potentially change precipitation by limiting the size and number of spordniar.

Water molecules stick to aerosol particles, eventually forming cloud droplets.

One of REMO’s friends is CALIPSO. CALIPSO’s ojb is to study how aerosols and clouds affect climate.

Answers are below.
Aerosol Word Find

The 21 words from the word list below are related to aerosols. Circle them in the Word Find box. They can run horizontally, vertically, and diagonally.

**WORD LIST**

- DUST
- ERUPTION
- SOLAR
- POLLUTANT
- AEROSOL
- PARTICLE
- TROPOSPHERE
- NUCLEATION
- DROPLET
- WIND
- DESERTIFICATION
- PRECIPITATION
- VOLCANO
- EXHAUST
- RAINFALL
- HAZE
- CONCENTRATION
- CLOUDS
- ATMOSPHERE
- CONTRAIL
- INDUSTRIAL

Solution can be found on page 18.
REMO says...

Ozone (O_3) is a gas found in tiny amounts in our upper atmosphere, the stratosphere. This “good” ozone forms a layer that protects us by absorbing dangerous ultraviolet radiation from the sun. Human activity creates “bad” ozone closer to the ground, where it is a harmful pollutant.

“Good” ozone can be destroyed when it reacts with chlorine, introduced into the atmosphere by human activity. During August through October, the amount of ozone in the stratosphere over Antarctica drops. Additionally, polar stratospheric clouds that form during this time help chlorine deplete ozone. This region of low ozone amount is called the ozone “hole,” though it’s not an actual hole in the stratosphere.

This map of the world (right) shows Antarctica in false colors. The purple area shows the ozone hole on September 12, 2008. The map was made from data sent down from orbit by NASA’s Aura satellite.

Facts About Ozone True or False

Mark these statements about ozone true (T) or false (F):

1. Ozone (O_3) is a molecule made up of three oxygen atoms. ______
2. The ozone layer shields us from the sun’s ultraviolet radiation. ______
3. The cause of the ozone hole is related to ozone reacting with carbon dioxide. ______
4. Each year, the ozone hole over Antarctica is largest during September-October. ______
5. The ozone “hole” is an actual hole in the stratosphere. ______
6. Polar clouds in the stratosphere help shield ozone from chlorine. ______
7. Ozone in the troposphere, the lower part of the atmosphere, can be found in smog. ______
8. The concentration of ozone is highest in Earth’s stratosphere. ______

Answers are below.

1. True.
2. True.
3. False. The ozone hole is caused by molecules of ozone reacting with chlorine in the stratosphere.
4. True.
5. False. The “hole” is an area where ozone is less than in surrounding regions, but it isn’t an actual hole.
7. True. Smog is a type of air pollution in the troposphere, the lower layer of the atmosphere, that can contain many chemical ingredients, including ground-level ozone.
8. True. 90% of ozone is in the stratosphere, the layer between the troposphere and mesosphere.
Facts About Ozone.

Here are some facts to know about Earth's ozone:

Ozone is a molecule and exists as a gas in the atmosphere.

About 90% of atmospheric ozone is located in the stratosphere.

The atmosphere is Earth's life support.

Chlorine is a pollutant that was introduced by humans into the atmosphere that depletes ozone.

It is important to remember that our ozone layer protects life on Earth from dangerous ultraviolet radiation from the sun.

---

Ozone Hole Double Puzzle

Twelve words from Ozone Facts are scrambled below. Unscramble them and copy the letters in their numbered boxes to the boxes at bottom of this page to find a message about ozone.

1. NAACCATRIT

2. SRSEHATOTREP

3. RUTOILEATVL

4. DAITIANOR

5. HINROELC

6. OMLEUCEL

7. SEPMERTOHA

8. NOXYGE

9. NOEZO

10. CONREITAONNTC

11. PORAL

12. SMGO

Something important we all should know:

Answers are below.
Earth's 'Radiation Budget' - Fill in the Blanks

Earth is a welcome place for life because radiative energy from the sun is distributed “just right.” REMO can speak in terms of watts per square meter (W/m²), or power per unit of area, to tell us how the sun's energy interacts with Earth. Fill in the blanks below using this picture as your guide.

The average daily amount of solar radiation reaching the top of Earth's atmosphere is __ __ __ watts per square meter (W/m²).

The atmosphere absorbs __ __ __% of the sun's radiation.

The amount of solar radiation absorbed by Earth's surface is __ __ __%.

Thirty percent (30%) of solar radiation is reflected back into space by clouds, aerosols, the atmosphere, and Earth's __ __ __ __ __ __ __.

The amount of average radiation emitted by Earth's surface is __ __ __ W/m², but only __ __ W/m² actually escapes all the way back into space.

This kind of radiation is called __ __ __ __ __ __ __ __ radiation and is, relative to visible light, from the “long” wavelength part of the spectrum. It can sometimes be perceived as heat.

Answers are below.

On the next page, see how some greenhouse gases can affect the sun’s radiation.
**Greenhouse Gas Match Up**

Earth’s ‘radiation budget’ can change when the amount of greenhouse gases in the atmosphere goes up. Greenhouse gases absorb heat from the sun and trap it in the atmosphere.

Draw a line connecting each source of greenhouse gas in the column on the left with its “fun fact” in the middle. Then write in the blank if the source is natural or man-made.

<table>
<thead>
<tr>
<th>Source</th>
<th>Fun Fact</th>
<th>Natural or Man-made?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cars</td>
<td>These insects are the second biggest source of methane after wetlands.</td>
<td></td>
</tr>
<tr>
<td>Cows</td>
<td>It’s estimated there are 600 million of these carbon dioxide emitters on the road.</td>
<td></td>
</tr>
<tr>
<td>Termites</td>
<td>These were kept cold with ozone-depleting CFCs, but now use HFCs, which are a potent greenhouse gas.*</td>
<td></td>
</tr>
<tr>
<td>Refrigerators</td>
<td>The digestion of food in these creatures’ four stomachs produces methane.</td>
<td></td>
</tr>
</tbody>
</table>

* CFCs stand for chlorofluorocarbons and HFCs stand for hydrofluorocarbons

**Answers are below.**

**REMO says...**

SORCE, the SOlar Radiation and Climate Experiment, studies the sun’s energy and how it affects Earth’s climate.
How We Change Earth

Fill in the blanks with words from the word bank to discover some ways in which climate can be affected by humans changing Earth’s surface.

Word Bank: carbon dioxide, coral, cut down, water, cities, temperatures, acidification, carbonic, ocean, hydrochloric, denitrification, clouds

_______ grow.

Sometimes trees are _____ _____.

Then, there are less trees to absorb_______ _________.

The ________ also absorbs carbon dioxide.

Ocean ________________ occurs because carbon dioxide + _________ = __________ acid.

Wildlife is impacted. For example, _________ growth may slow.

Answers are below.
The following four statements are facts about land use, the growth of cities, and population. Unscramble each set of tiles to reveal a fun message about how humans change Earth.

For example: ABO UT 2 ER . PAP N OF EES
IT T 4 TR TO M AKES AKE A TO

IT TAKES ABOUT 24 TREES TO MAKE A TON OF PAPER. *

* Paper used for printing and writing, not newspaper.

1. OF T THER 2.7 MIITY OPLE
ER 1 N PE E AR PAN . E OV IN T
OKYO HE C L L IO J A IN G

E AR

2. N NE TONS OF ARE GAR B CH D
AGE RK C OVERITY. ECTE W YO
000 D EA AY I 1 2, COLL

TONS

** One US ton is 2000 pounds or about 907 kilograms.

3. IN C D. HOT AUST ROUN TEMP
URES R PE LIV ESID D Y. HE R
OOBE SO E UN A TH ENTS RALI
ERAT D E R G ARE AT T

OOBE

Answers are below.
REMO says...
CloudSat studies clouds in detail to help us better understand their role in regulating our climate.

What's this?
Smoke from fire is a type of aerosol. Here is a photo-like image of fires in Los Angeles County, California. But, this picture is not a photograph. It is made from data collected from orbit by NASA's Terra satellite on August 30-31, 2009 and processed on a computer. The red areas show where the fires' hot test spots are located. See the smoke moving from the lower left to upper right?

Climate Change Crossword (Each answer can be found somewhere in this book.)

Across

2. Planet with more oxygen than carbon dioxide
4. Cloud particles resulting from jets in the sky
7. Number of solar panels on the Landsat satellite
8. Greenhouse gas absorbed by trees
12. Absorbs 20% of the average daily amount of incoming solar radiation
14. Often cut down when cities grow
15. Asian city with HUGE population
16. Studied by the satellite Aqua
17. Ground-level ozone is part of this
18. Planet with no oxygen in its atmosphere
Down

1. Measured by satellite sensors
2. REMO’s shoes
3. REMO’s shoes
4. Layer that protects us
5. Distribution of radiative energy from the sun
6. Increases ozone’s destruction by chlorine
7. Can be a product of desertification
8. Tiny particles in the atmosphere
9. Trapped by greenhouse gases

Solution can be found on page 18.
Climate Change
(These “items” can be found somewhere in this book.)

1. Find the name of the numerical code that just uses zeroes and ones.

2. How many oxygen atoms make up a molecule of ozone?

3. What condensed water in the atmosphere emits infrared radiation back to Earth’s surface?

4. Where does a satellite send its data to?

5. When does the ozone hole reach its largest size?

6. How many more stomachs does a cow have than you do?

7. What type of radiation is from the “long” wavelength part of the spectrum?

8. What do REMO’s satellite friends look at all the time?

9. What’s the biggest natural source of methane? (hint: it’s a type of place)

10. What volcano erupted in Russia in February 2008?
**Scavenger Hunt**

And now, here are the answers, below.


**What’s this?**

A dust storm blows off the coast of the United Arab Emirates and the Persian Gulf on February 28, 2009. Dust is a type of aerosol. This satellite image was made from data from the Terra satellite. It is not a photograph.


**Earth’s surface?**


**Stomachs does a cow have than you do?**

7. Three.

**“Long” wavelength part of the spectrum?**


**Source of methane? (hint: it’s a type of place)**

10. Three.

**Answers are below.**
Crossword Puzzle (pages 14 and 15):

**Across:**
1. Earth
4. Contrails
7. Four
8. Carbon dioxide
9. Coober Pedy
12. Atmosphere
14. Trees
15. Tokyo
16. Water
17. Smog
18. Venus

**Down:**
1. Light
3. High-tops
5. Ozone
6. Budget
10. Polar clouds
11. Dust
12. Aerosols
13. Heat
Resources

For more information, go to:

http://climate.nasa.gov/

http://eos.nasa.gov

http://earthobservatory.nasa.gov

http://visibleearth.nasa.gov

http://neo.sci.gsfc.nasa.gov

http://svs.gsfc.nasa.gov