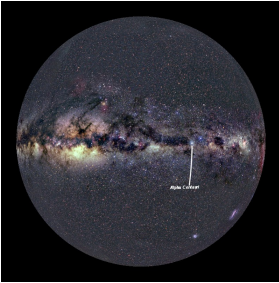
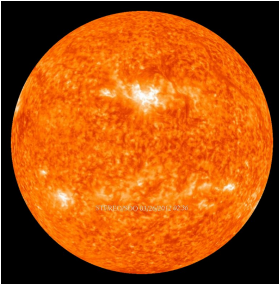

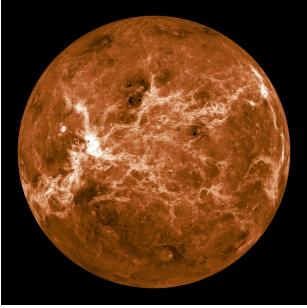
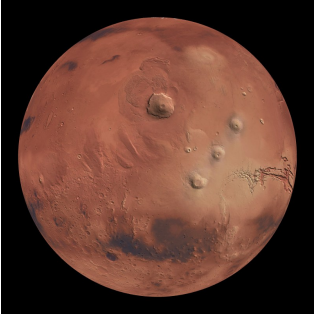






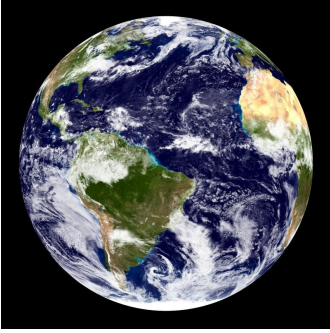
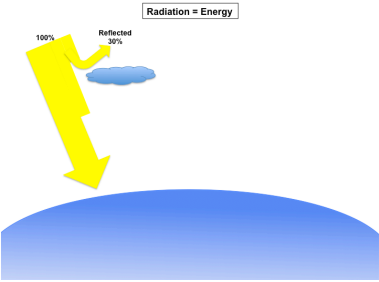

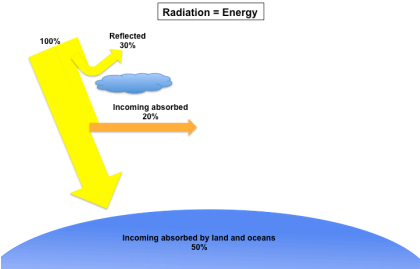
SOS SCRIPT: WHAT MAKES EARTH HABITABLE?

Key Points	Visuals
<p><u>The Milky Way:</u> This is a visible-light image of our galaxy.</p> <p>The Milky Way includes more than 200 billion stars, including our own star, Sun.</p> <p>Hundreds of planets orbit other stars. Could any of these planets have the right conditions to support life?</p>	<p>1) All Sky Panorama</p> 
<p><u>Sun:</u> Eight planets in our solar system. Only one has just the right conditions to support life. What makes a planet just right for life?</p> <ul style="list-style-type: none"> - right distance from the Sun, our primary energy source - right temperature for liquid water - right chemical composition of its atmosphere (not too much carbon dioxide) <p>Not emphasized here:</p> <ul style="list-style-type: none"> - right size or mass (within order of magnitude of Earth's size for just the right amount of gravity to hold an atmosphere, active geology, iron core forms magnetic field protecting planet from stellar wind and cosmic radiation) - stable orbit, nearly circular, and fast enough rotation for magnetic dynamo that produces magnetic field, day-night cycle not too long <p>WATER IS NEEDED FOR LIFE</p>	<p>2) Sun, STEREO/SDO</p> 
<p>Scientists call a planet with the right temperature for liquid water a <i>Goldilocks planet</i>. Recall the children's story: Goldilocks went searching for porridge that was not too hot or too cold, but just the right temperature.</p>	<p>3) Goldilocks over Sun</p>  <p>Illustration by Mary Ellsworth, used with permission</p>



<p><u>Venus:</u></p> <ul style="list-style-type: none"> - right distance from the Sun - right size to hold an atmosphere - atmosphere mostly carbon dioxide (traps heat) - too hot (average temperature 870°F) <p>NO LIQUID WATER</p>	<p>4) Venus Movie: clouds, brightness, topography</p> 
<p><u>Mars:</u></p> <ul style="list-style-type: none"> - right distance from the Sun - thin atmosphere mostly carbon dioxide - temperature just right during the day (70°F) but too cold at night (-100°F) <p>NO LIQUID WATER NOW FROZEN WATER IN POLAR ICE CAPS</p>	<p>5) Red Mars (25 degree tilt)</p> 
<p><u>Imagine Mars with water :</u> Based on topography and erosion patterns, this image is shaded blue where there may have been water on Mars in the past.</p> <p><i>NEWS FLASH: IN SEPTEMBER, 2013 NASA ANNOUNCED CURIOSITY ROVER DISCOVERY THAT MARTIAN ROCK CONTAINS WATER MOLECULES THAT TURN TO STEAM WHEN HEATED!!! SOIL ANALYSIS SO FAR HAS NOT FOUND ORGANIC CHEMICALS (LIFE INDICATOR).</i></p>	<p>6) Wet Mars with Curiosity PIP</p> <p>Curiosity Rover PIP after 30 seconds</p> 
<p><u>Earth's Moon:</u></p> <ul style="list-style-type: none"> - right distance from the Sun - no atmosphere = no insulation: too hot facing the Sun (250°F) too cold away from the Sun (-380°F) <p>NO LIQUID WATER</p>	<p>7) Earth's Moon</p> 



<p>Earth:</p> <ul style="list-style-type: none"> - right distance from the Sun - right temperature for liquid water - right size, rocky planet with enough gravity to hold an atmosphere - atmosphere mostly nitrogen & oxygen <p>EARTH 70% COVERED IN WATER</p>	<p>8) Blue Marble (23 degree tilt)</p> 										
<p>Earth's Energy Budget: incoming Solar radiation = energy</p> <p>From 100% (340.4 W m^{-2}) incoming solar energy at the top of Earth's atmosphere</p> <p>About 30% (100 W m^{-2}) scattered back to space by clouds, atmospheric gases, and bright surfaces like snow and ice</p>	<p>9) Earth's Energy Budget: incoming (1)</p> 										
<p>Albedo: Fraction of solar energy (shortwave radiation) reflected from Earth back to space is called <i>albedo</i>, expressed as a fraction from 0 (very dark surface) to 1 (very bright surface)</p> <p>Examples:</p> <table border="0"> <tr> <td>snow = 0.9</td> <td>*MOST REFLECTIVE*</td> </tr> <tr> <td>polar ice caps = 0.7</td> <td></td> </tr> <tr> <td>desert sand = 0.4</td> <td></td> </tr> <tr> <td>bare soil = 0.15</td> <td></td> </tr> <tr> <td>fresh asphalt = 0.04</td> <td>*LEAST*</td> </tr> </table> <p>EARTH AVERAGE ALBEDO = 0.3</p>	snow = 0.9	*MOST REFLECTIVE*	polar ice caps = 0.7		desert sand = 0.4		bare soil = 0.15		fresh asphalt = 0.04	*LEAST*	<p>10) Snow and Ice Cover: realtime</p> 
snow = 0.9	*MOST REFLECTIVE*										
polar ice caps = 0.7											
desert sand = 0.4											
bare soil = 0.15											
fresh asphalt = 0.04	*LEAST*										
<p>Earth's Energy Budget: incoming (con't) About 20% (68.1 W m^{-2}) absorbed by clouds and atmospheric gases</p> <p>About 50% (163.3 W m^{-2}) is absorbed by land and oceans</p>	<p>11) Earth's Energy Budget: incoming (2)</p> 										

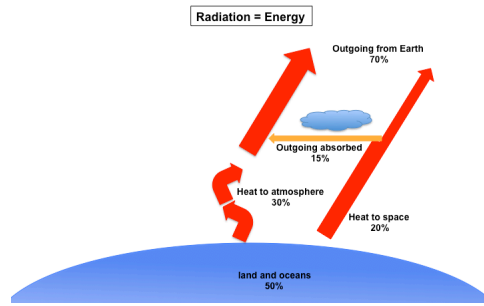


Earth's Energy Budget: outgoing
50% absorbed by land and oceans eventually transferred back to the atmosphere or space as longwave radiation or heat

~20% by outgoing radiation loss

~30% by heat loss from evaporation and transpiration from plants, thermal conduction and convection

12) Earth's Energy Budget: outgoing



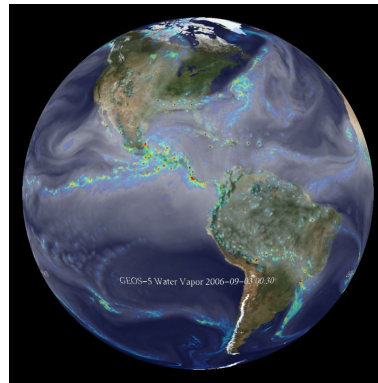
Greenhouse gases:

About 15% of outgoing heat is absorbed by clouds and greenhouse gases in our atmosphere, acting like insulation

- water vapor, 40-70% contribution, natural
- carbon dioxide (CO₂), 10-20%, fossil fuels
- methane (CH₄), 5-10%, landfills, agriculture
- nitrous oxide (N₂O), <5%, fertilizers

Without greenhouse gases, Earth would be ~59°F colder than present average (57°F), but fossil fuel emissions have caused an additional (0.6 W m⁻²) heat gain by Earth (oceans, land) or 2.7°F warming since 1900

13) GEOS-5 Modeled Water Vapor



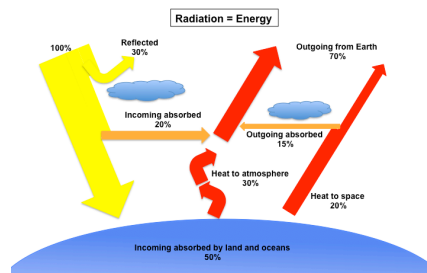
Earth's Energy Budget: total

The Earth's energy budget is in balance.

Clouds and atmosphere work like insulation
- during day: reflect radiation back to space
- during night: reflect heat back to Earth

WITHOUT ATMOSPHERE, EARTH WOULD BE -436°F AND OCEANS WOULD FREEZE

14) Earth's Energy Budget: total



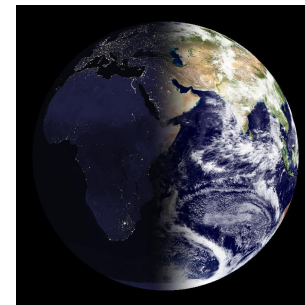
Day-night temperatures changes on Earth vary as little as 1°F over the ocean to 50°F or more over deserts

Water on Earth:

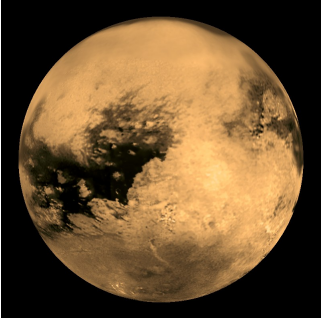
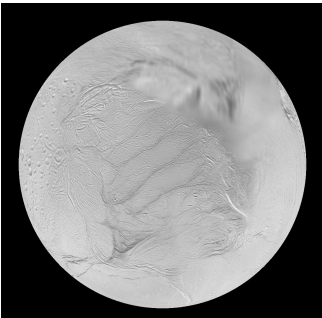
- in our oceans
- on land and in the ice caps
- in our atmosphere as water vapor and clouds

makes a *Goldilocks planet*, just right for life

15) Blue Marble and Nightlights





<p><u>Exceptional cases: Titan</u></p> <ul style="list-style-type: none"> - evidence of water ice - thick atmosphere, largely nitrogen - weather includes wind and rain, methane and ethane clouds, methane lakes, rivers - cryovolcanoes, rocky center, molten core <p>Considered a prebiotic environment with organic chemicals needed for life, perhaps similar to primordial Earth but lacking water vapor. In five billion years, as the Sun becomes a red giant, temperatures could rise and Titan could become habitable</p>	<p>16) Saturn's moon Titan</p> 
<p><u>Exceptional cases: Enceladus</u></p> <ul style="list-style-type: none"> - icy surface with liquid water underneath - cryovolcanoes at its south pole - small, reflective, very cold <p>Two voyager missions and more recent Cassini mission fly-bys have revealed discovery of water vapor and complex hydrocarbons. Future mission to send a probe proposed jointly by NASA, European Space Agency</p>	<p>17) Saturn's moon Enceladus</p> 
<p><u>Exceptional cases: Europa</u></p> <ul style="list-style-type: none"> - thick surface ice - liquid water under ice? <p>Galileo mission fly-by collected magnetic field data suggesting tidal ocean under ice, rocky mantle of silicate rock, iron core</p>	<p>18) Jupiter's moon Europa</p> 