MWD Water Dialogue, April 28, 2021

Water as a Greenhouse Gas

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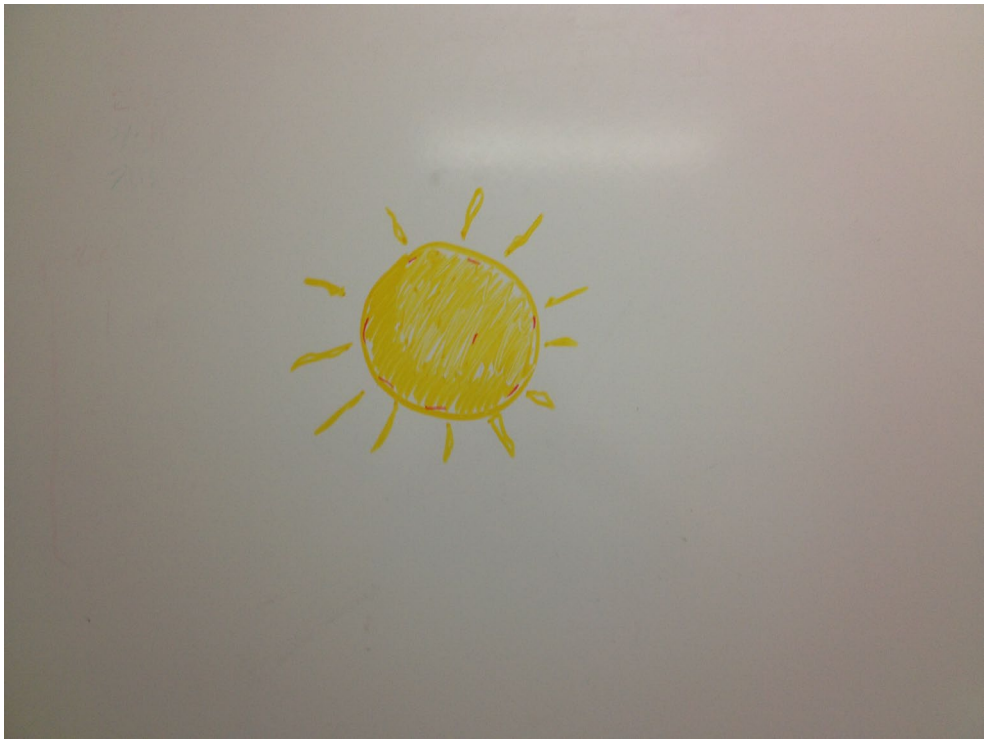
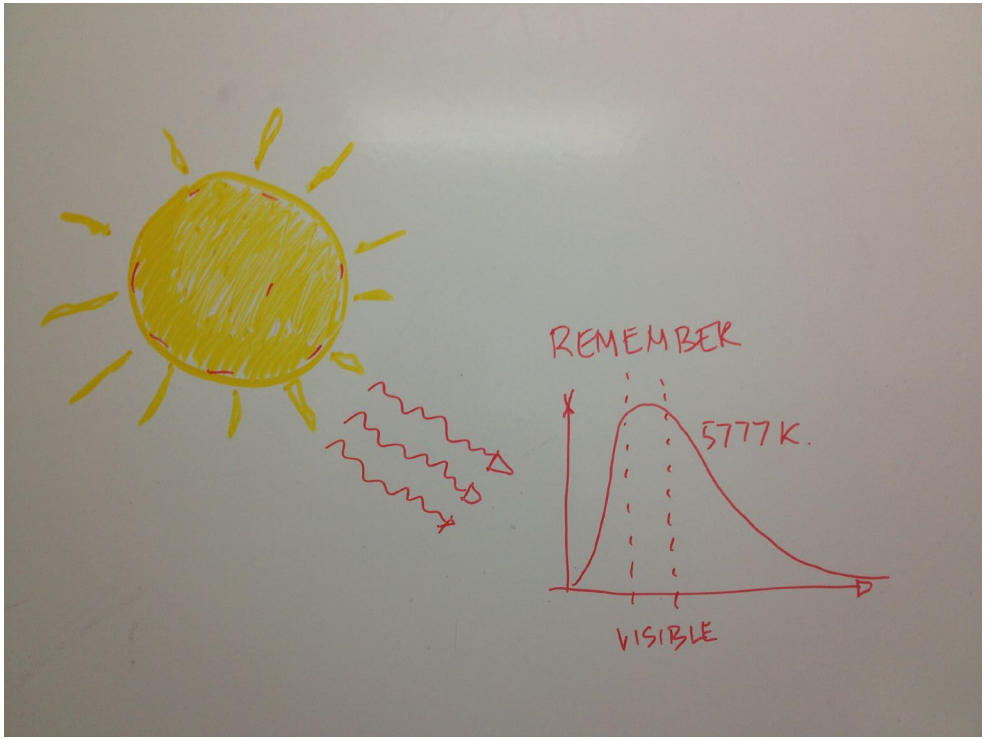
- What is the greenhouse effect?
- What are greenhouse substances? E.g. gases, clouds, and aerosols
- Importance of water. Ice, liquid water, and water vapor
- Why we are concerned about CO2?
- “Feedbacks” and “direct” climate forcing. Water cycling and carbon cycling
- Clouds, rain, and storms.
- How much do human activities contribute?
- Where does about half of it go?
- How will this change in the future?
- Big questions about future climate change?

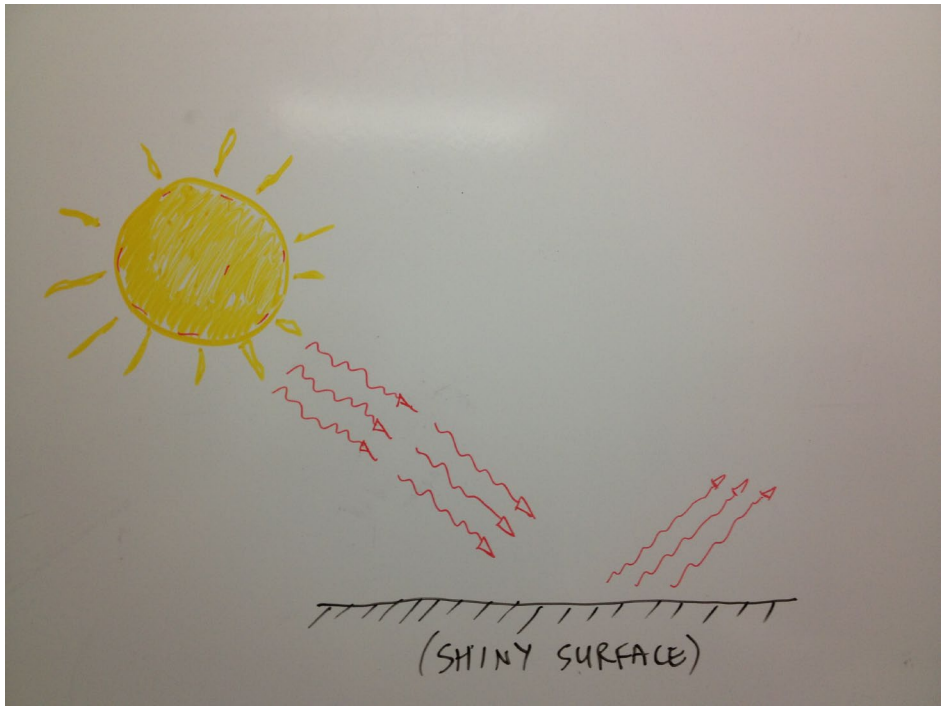
And with apologies …



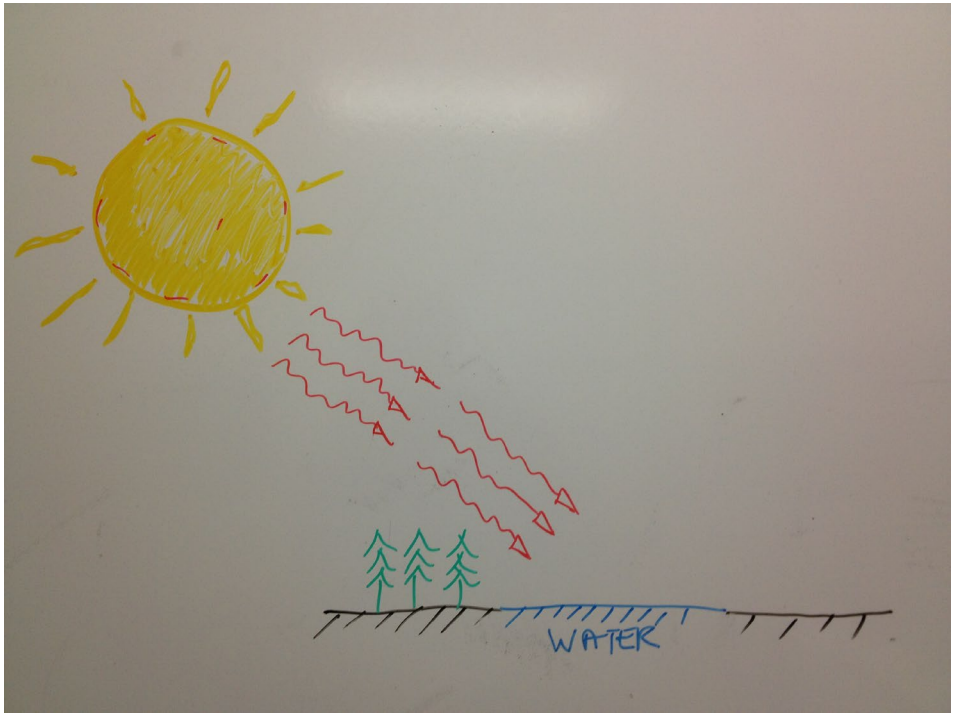
Remember for later …



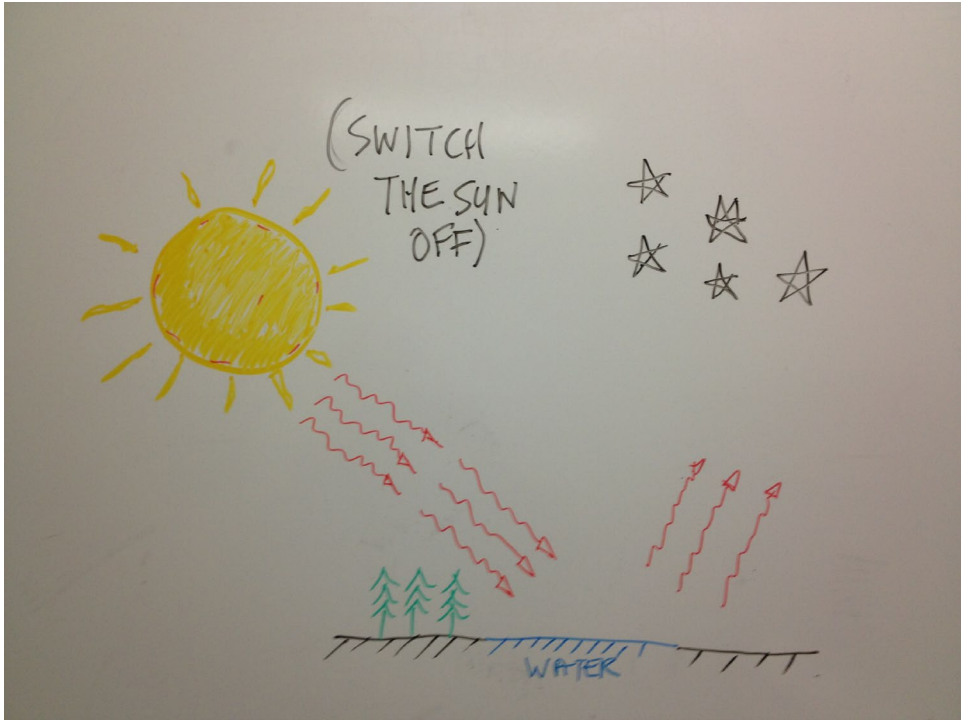
What if the Earth had a shiny surface …



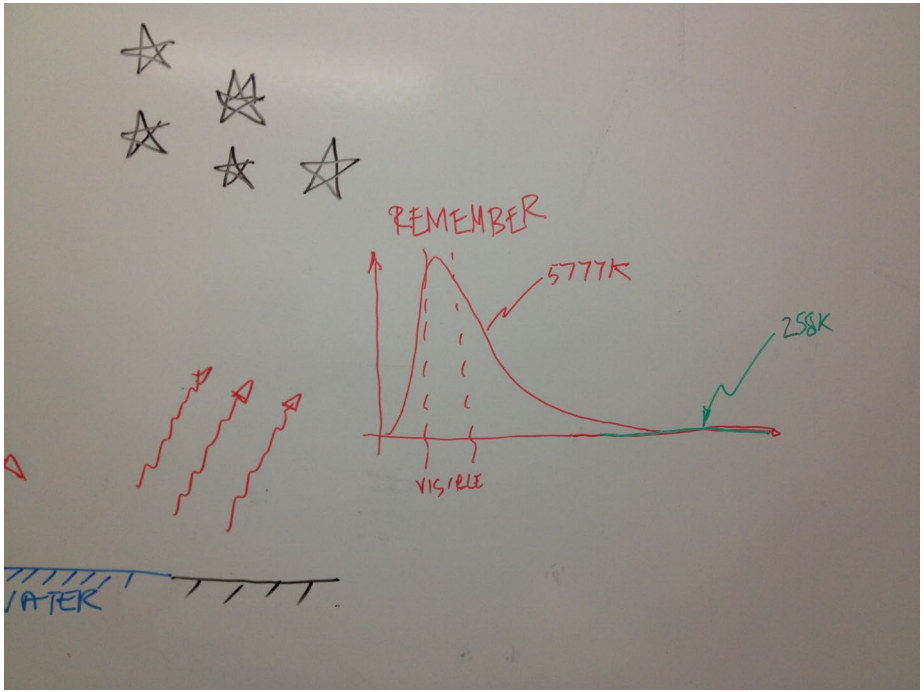
What if the Earth had a “real” surface …



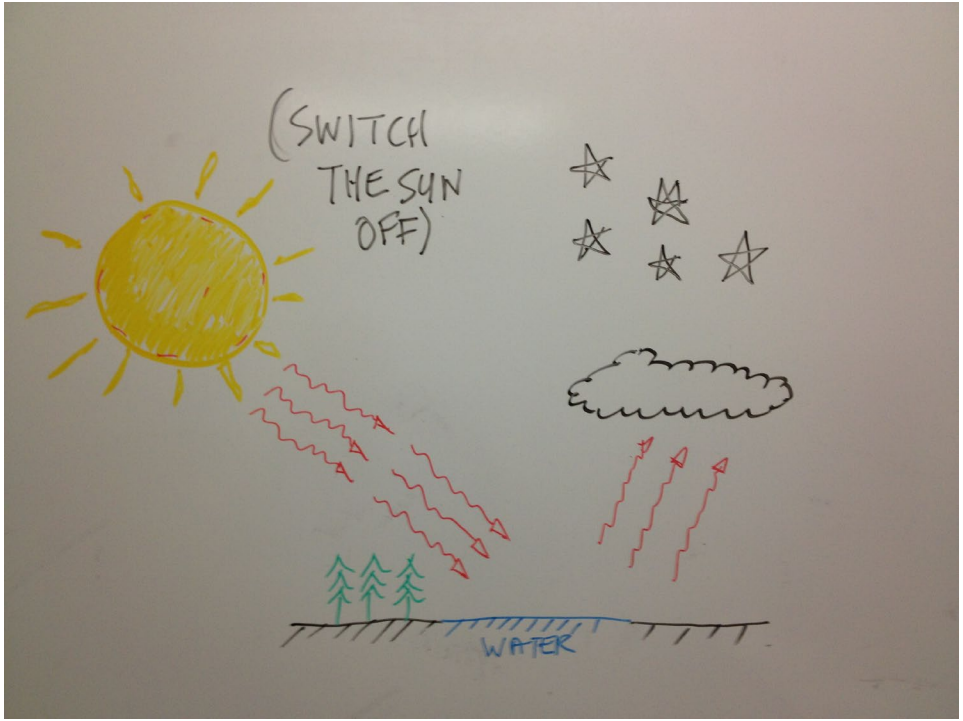
… at night



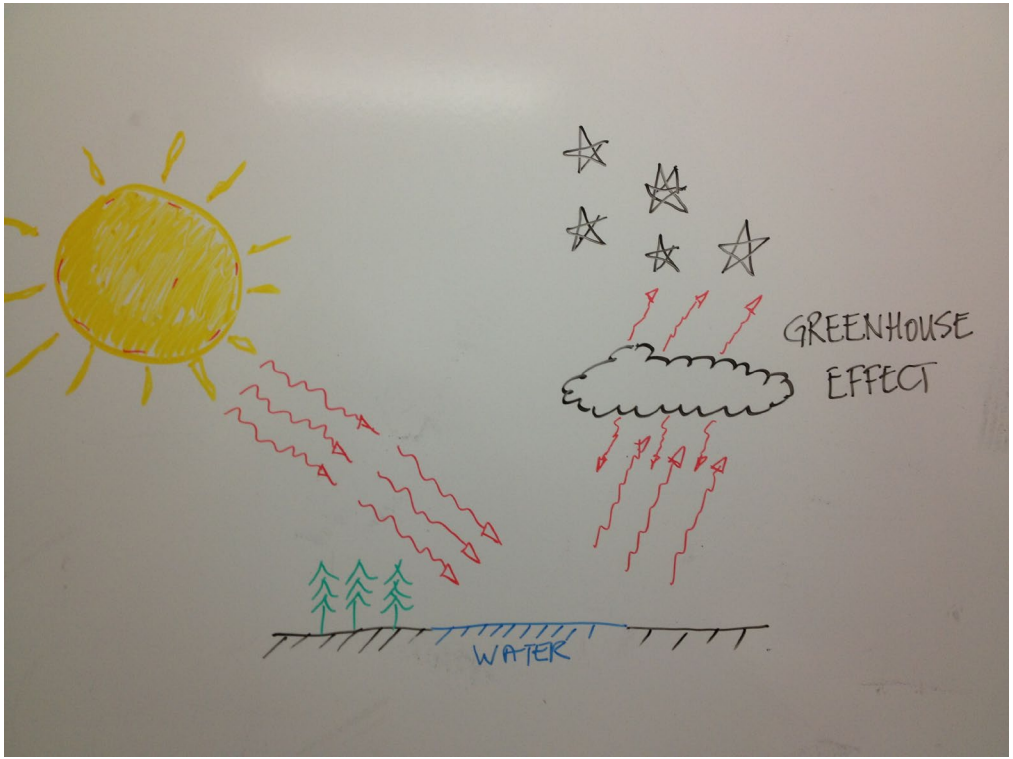
… remembering that it is still really cold



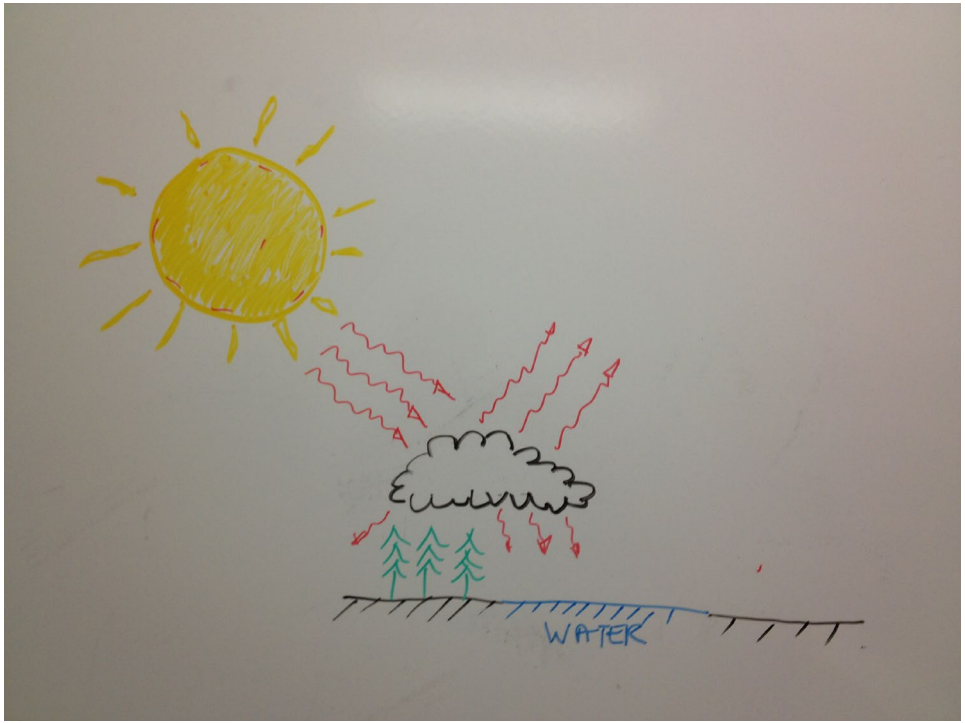
Add clouds



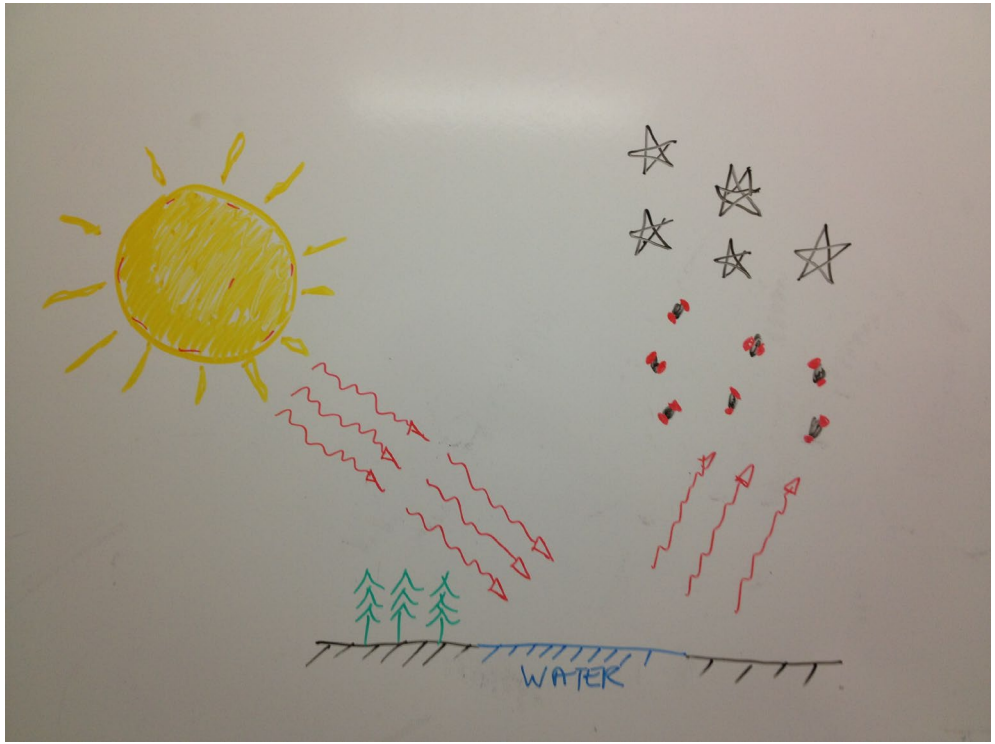
A greenhouse effect



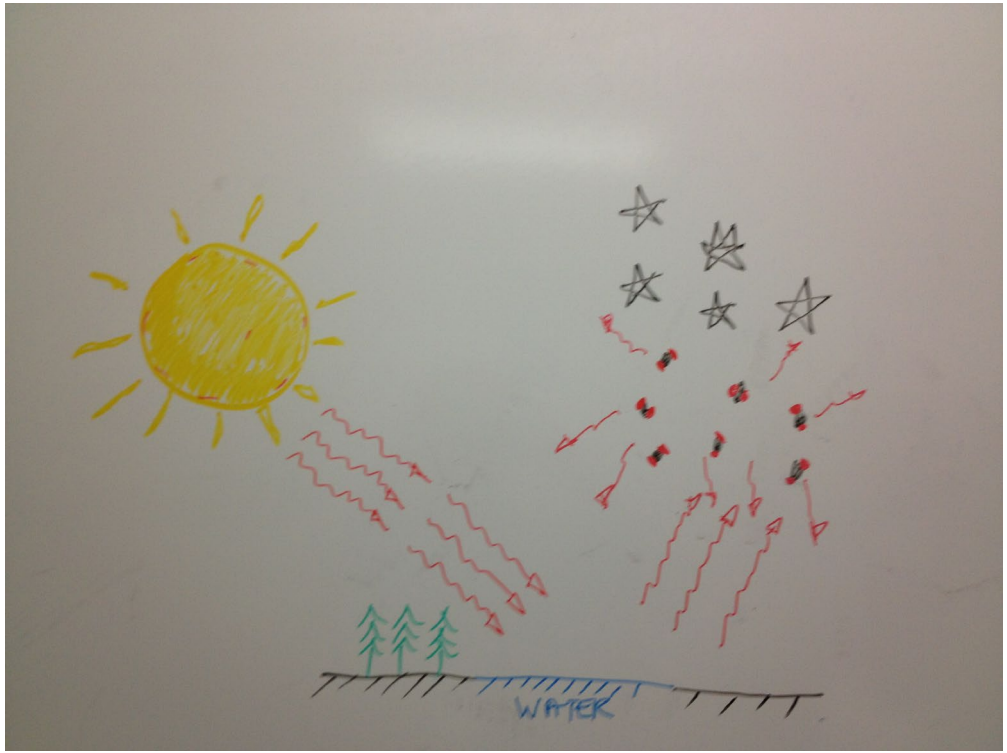
Clouds make for complicated effects



Add gases



And greenhouse gases

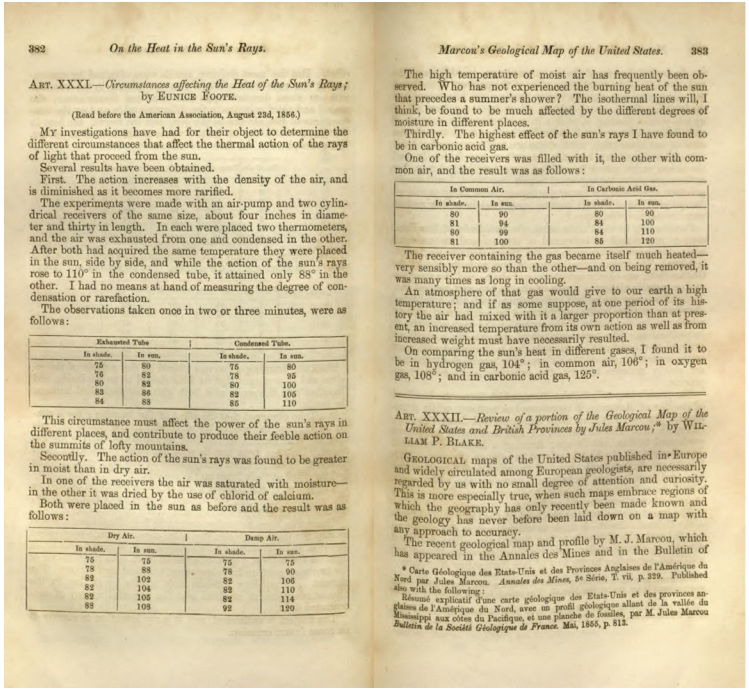


A US Pioneer: Eunice Newton Foote

Bell jars filled with different gases exposed to sunlight

“Secondly: The action of the sun’s rays was found to greater in moist air than in dry air.”

https://www.nytimes.com/2020/04/21/obituaries/eunice-foote-overlooked.html



382 *On the Heat in the Sun's Rays.*

ART. XXXI.—*Circumstances affecting the Heat of the Sun's Rays;* by EUNICE FOOTE.

(Read before the American Association, August 23d, 1856.)

MY investigations have had for their object to determine the different circumstances that affect the thermal action of the rays of light that proceed from the sun.

Several results have been obtained.

First. The action increases with the density of the air, and is diminished as it becomes more rarified.

The experiments were made with an air-pump and two cylindrical receivers of the same size, about four inches in diameter and thirty in length. In each were placed two thermometers, and the air was exhausted from one and condensed in the other. After both had acquired the same temperature they were placed in the sun, side by side, and while the action of the sun's rays rose to 110° in the condensed tube, it attained only 88° in the other. I had no means at hand of measuring the degree of condensation or rarefaction.

The observations taken once in two or three minutes, were as follows:

Exhausted Tube		Condensed Tube.	
In shade.	In sun.	In shade.	In sun.
75	80	75	80
76	82	78	95
80	82	80	100
83	86	82	105
84	88	85	110

This circumstance must affect the power of the sun's rays in different places, and contribute to produce their feeble action on the summits of lofty mountains.

Secondly. The action of the sun's rays was found to be greater in moist than in dry air.

In one of the receivers the air was saturated with moisture—in the other it was dried by the use of chlorid of calcium.

Both were placed in the sun as before and the result was as follows:

Dry Air.		Damp Air.	
In shade.	In sun.	In shade.	In sun.
75	75	75	75
78	88	78	90
82	102	82	106
82	104	82	110
82	105	82	114
83	108	92	120

Marcou's Geological Map of the United States. 383

The high temperature of moist air has frequently been observed. Who has not experienced the burning heat of the sun that precedes a summer's shower? The isothermal lines will, I think, be found to be much affected by the different degrees of moisture in different places.

Thirdly. The highest effect of the sun's rays I have found to be in carbonic acid gas.

One of the receivers was filled with it, the other with common air, and the result was as follows:

In Common Air.		In Carbonic Acid Gas.	
In shade.	In sun.	In shade.	In sun.
80	90	80	90
81	94	84	100
80	99	84	110
81	100	85	120

The receiver containing the gas became itself much heated—very sensibly more so than the other—and on being removed, it was many times as long in cooling.

An atmosphere of that gas would give to our earth a high temperature; and if as some suppose, at one period of its history the air had mixed with it a larger proportion than at present, an increased temperature from its own action as well as from increased weight must have necessarily resulted.

On comparing the sun's heat in different gases, I found it to be in hydrogen gas, 104°; in common air, 106°; in oxygen gas, 108°; and in carbonic acid gas, 125°.

ART. XXXII.—*Review of a portion of the Geological Map of the United States and British Provinces by Jules Marcou;** by WILLIAM P. BLAKE.

GEOLOGICAL maps of the United States published in Europe and widely circulated among European geologists, are necessarily regarded by us with no small degree of attention and curiosity. This is more especially true, when such maps embrace regions of which the geography has only recently been made known and the geology has never before been laid down on a map with any approach to accuracy.

The recent geological map and profile by M. J. Marcou, which has appeared in the Annales des Mines and in the Bulletin of

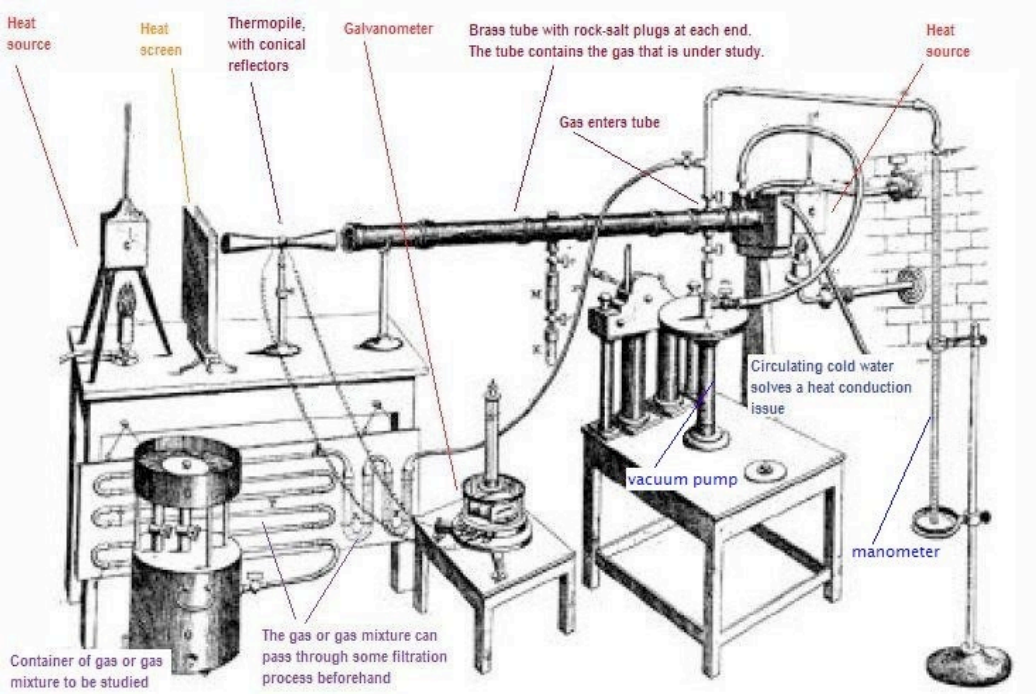
* Carte Géologique des Etats-Unis et des Provinces Anglaises de l'Amérique du Nord par Jules Marcou. *Annales des Mines*, 5e Série, T. vii, p. 229. Published also with the following:

Résumé explicatif d'une carte géologique des Etats-Unis et des provinces anglaises de l'Amérique du Nord, avec un profil géologique allant de la vallée du Mississipi aux côtes du Pacifique, et une planche de fossiles, par M. Jules Marcou *Bulletin de la Société Géologique de France*. Mai, 1855, p. 813.

Page from America Journal of Science, 1857

https://www.climate.gov/news-features/features/happy-200th-birthday-eunice-foote-hidden-climate-science-pioneer

1859 and John Tyndall



Influence of CO_2 on climate - 1896

THE

LONDON, EDINBURGH, AND DUBLIN

PHILOSOPHICAL MAGAZINE

AND

JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

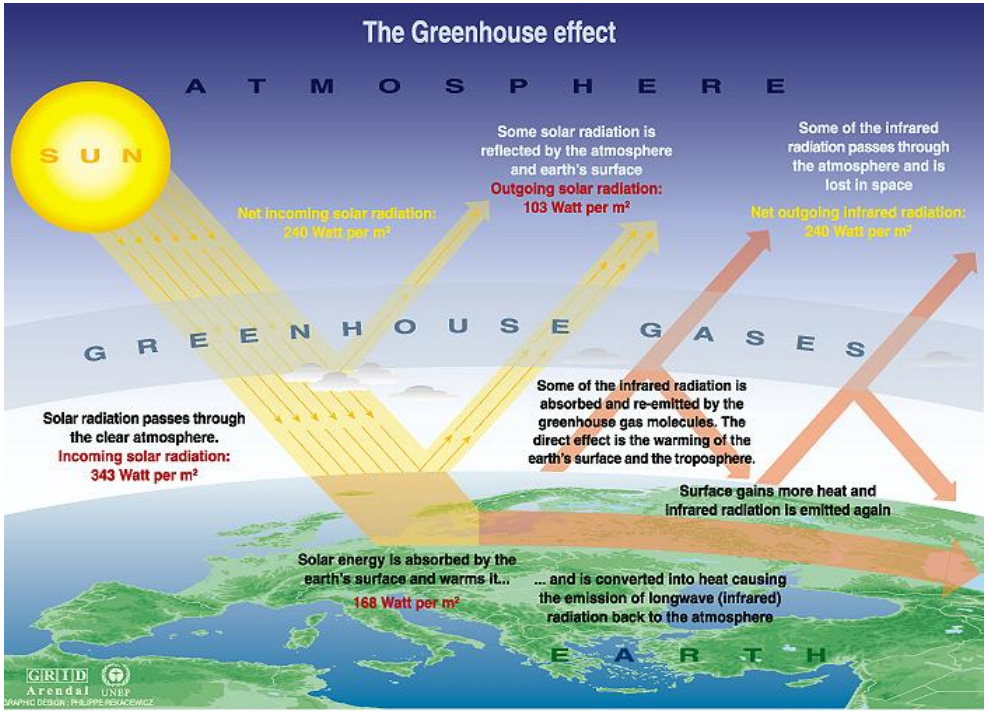
XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* By Prof. SVANTE ARRHENIUS *.

I. *Introduction : Observations of* Langley *on Atmospherical Absorption.*

A GREAT deal has been written on the influence of the absorption of the atmosphere upon the climate.

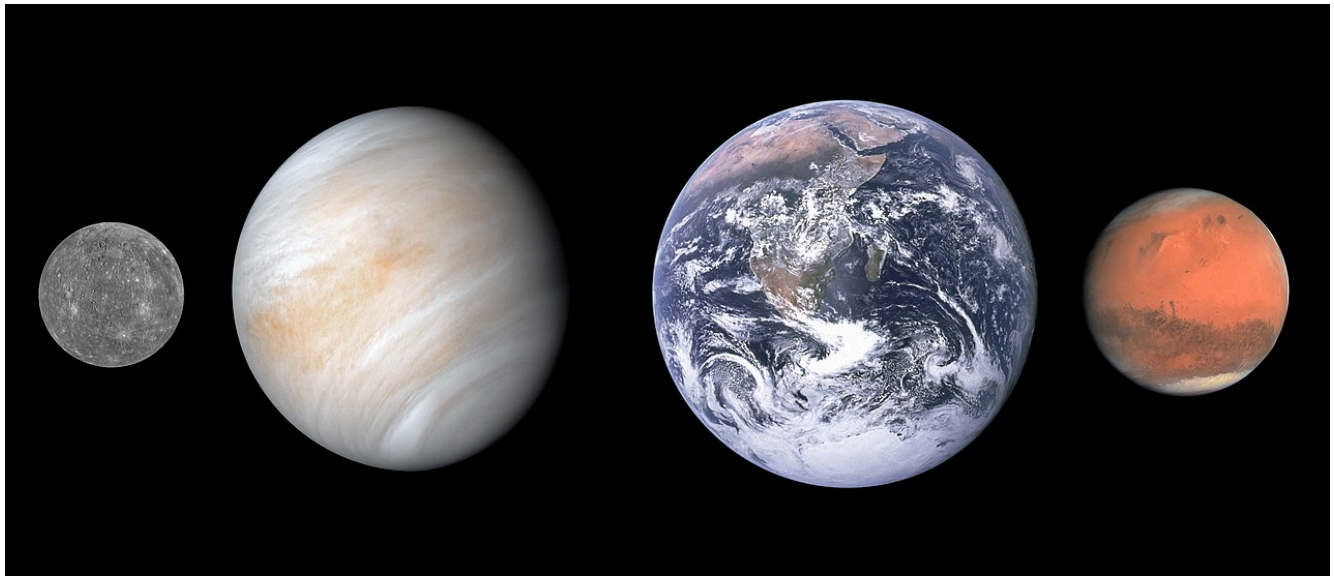
Svante August Arrhenius, born February 19, 1859

With numbers



Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

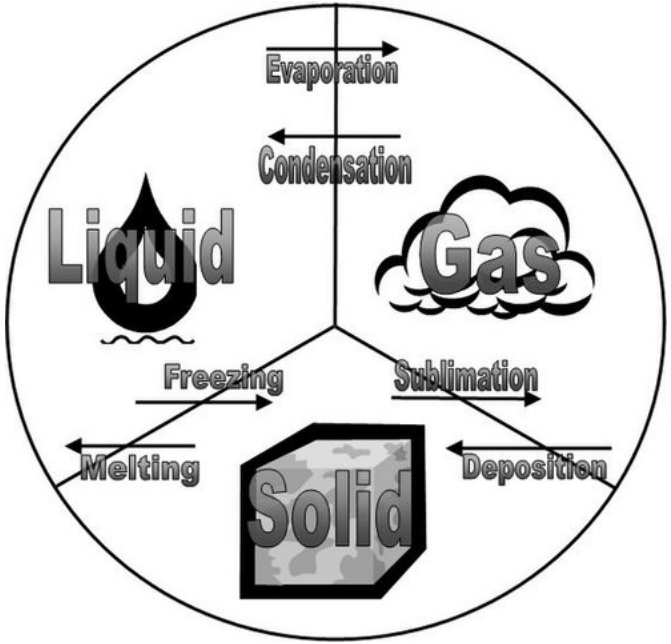
The Terrestrial Planets



By Mercury image: NASA/JHUAPL
Venus image: NASA/JPL-Caltech
Earth image: NASA/Apollo 17 crew
Mars image: ESA/MPS/UPD/LAM/IAA/RSSD/INTA/UPM/DASP/IDA
Public Domain, https://commons.wikimedia.org/w/index.php?curid=92818238

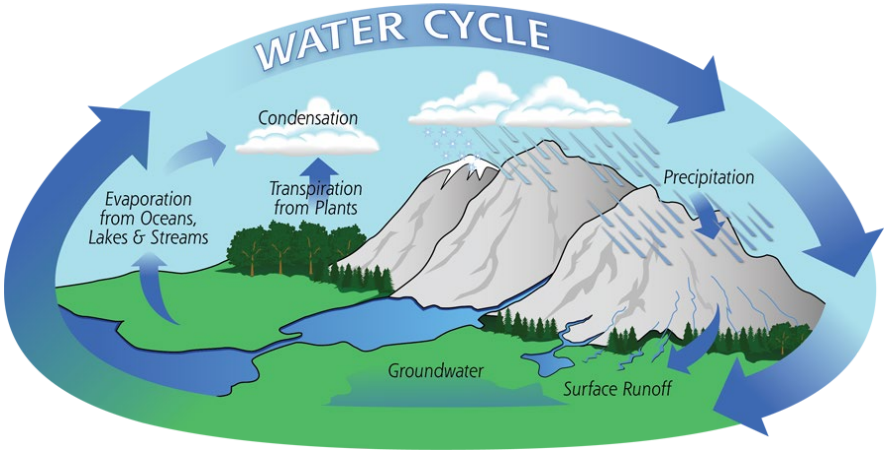
What is challenging about water?

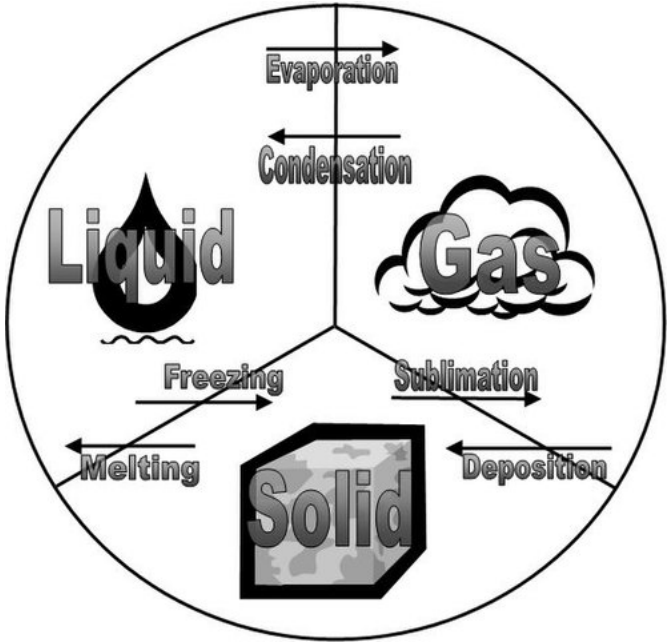
The Blue Marble from Apollo 17



Public domain; Wikipedia; original uploaded by M. Manary

The Water Cycle





https://gpm.nasa.gov/education/water-cycle

Big questions

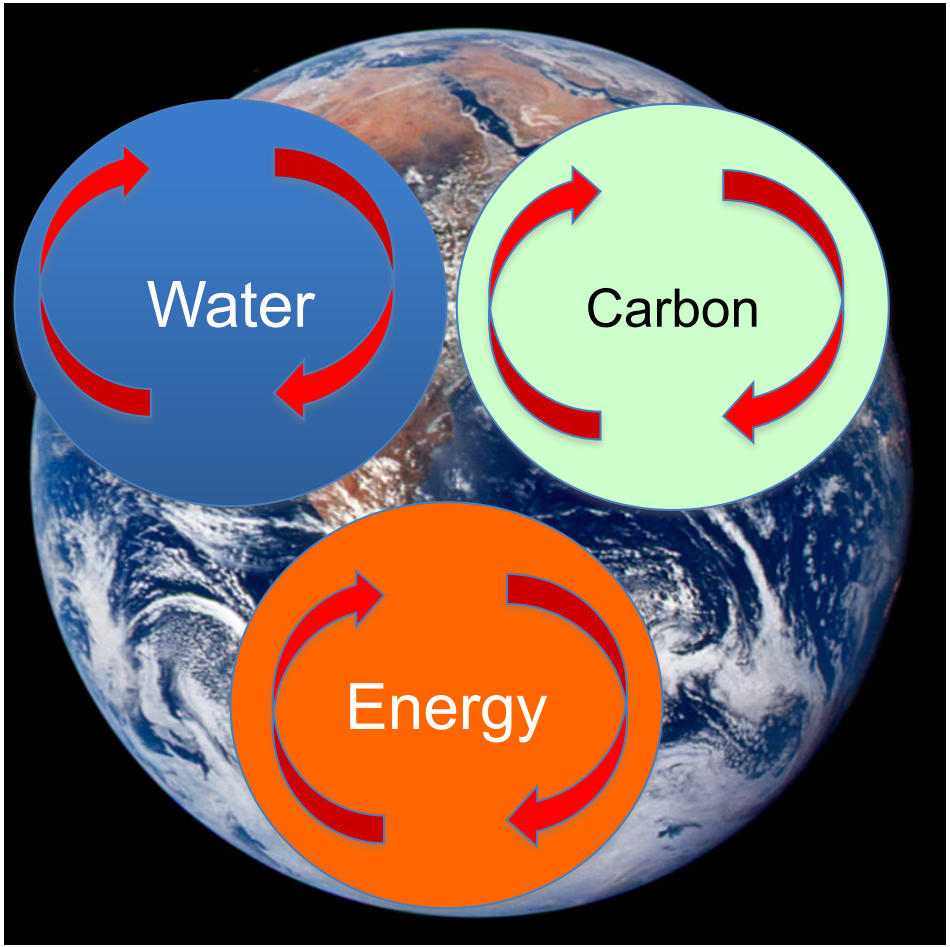
Climate feedbacks from water

- How will the water cycle change?
  - More precipitation?
  - Increased storm intensity?
- Reduced snow/ice cover
  - Surface get even warmer?
- How will clouds change?
  - High clouds? – trap heat?
  - Low clouds? – reflect more sunlight?

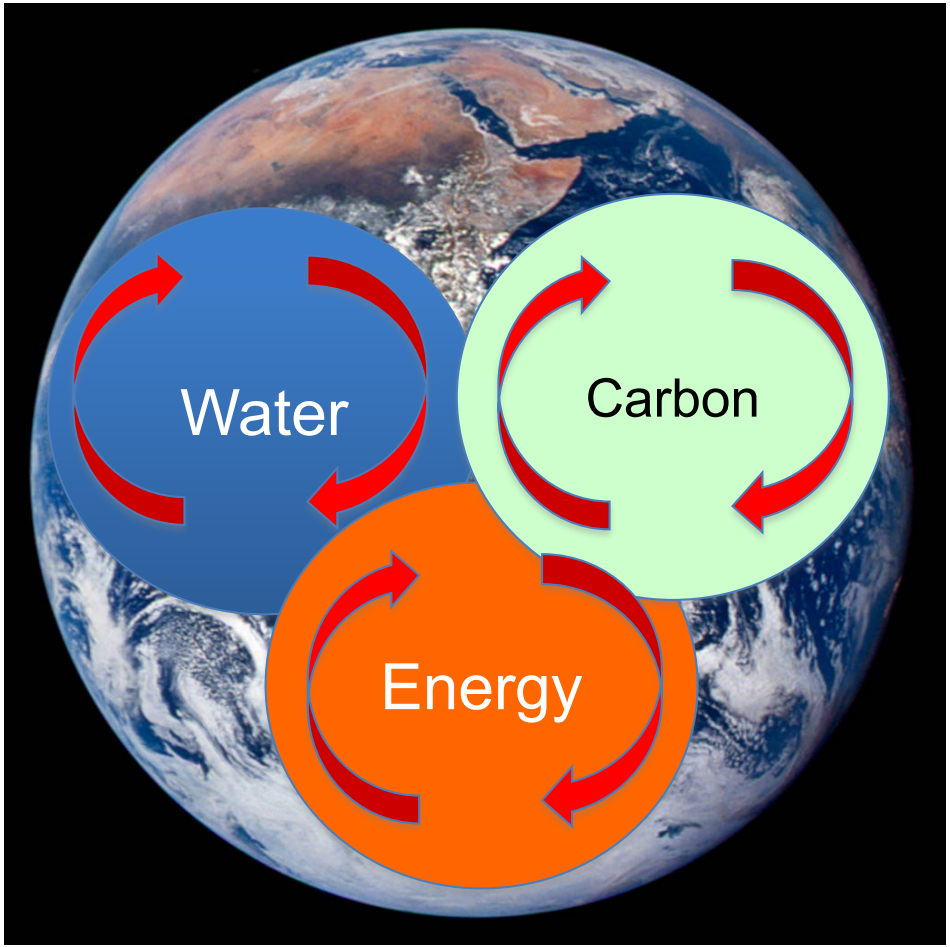
Snow from the recent storms that passed through Southern California cover the San Gabriel Mountains, serving as a beautiful backdrop to homes in north Orange County in a view from the hills in Orange, on Friday, December 7, 2018. (Photo by Mark Rightmire, Orange County Register/SCNG)

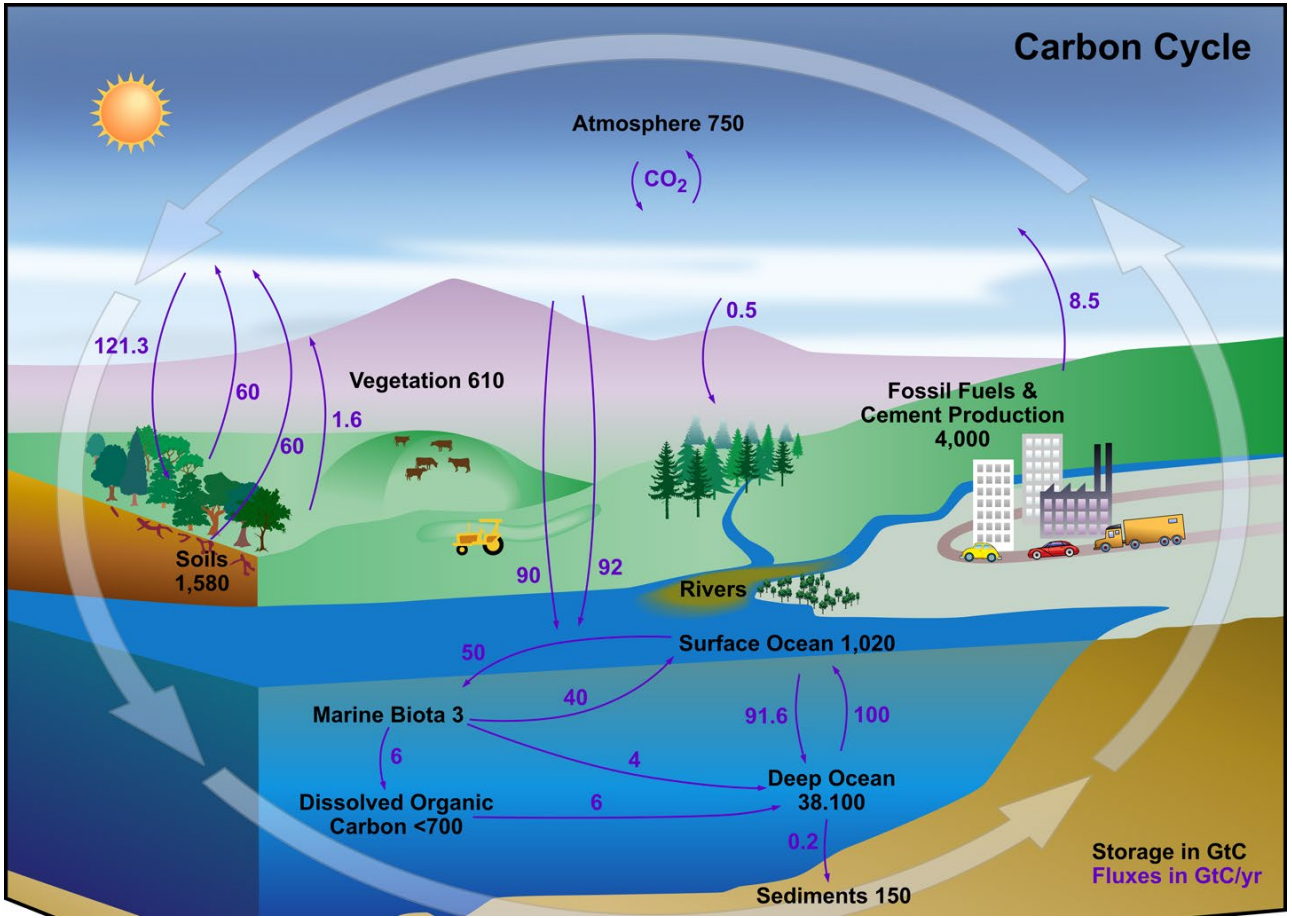
→ Water availability

The Big Three



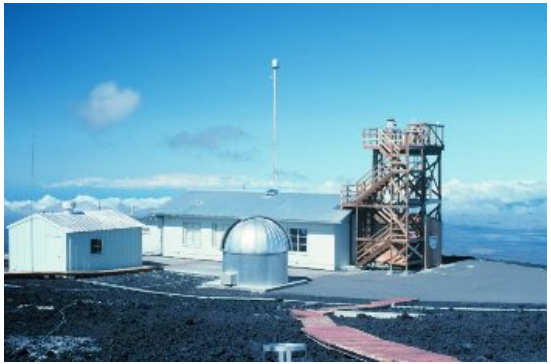
The Big Three

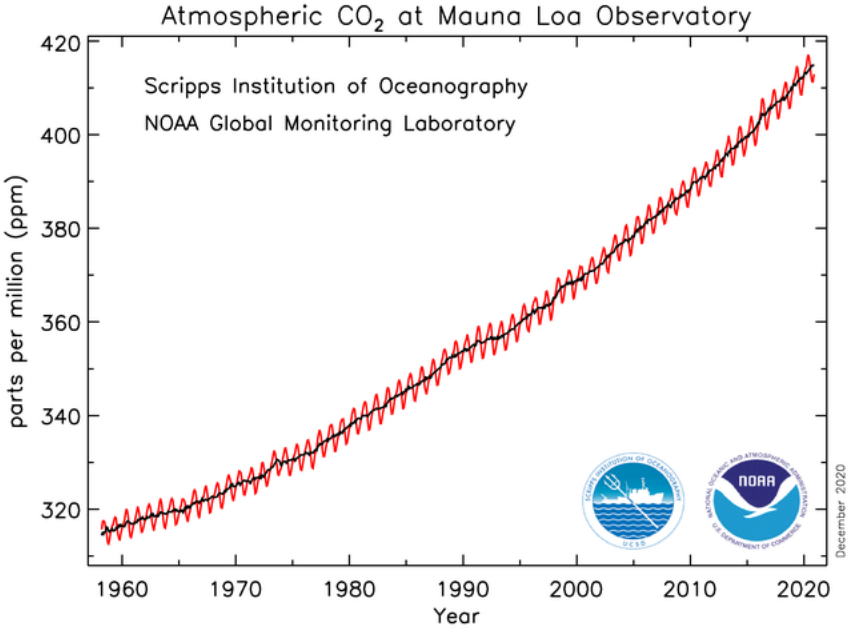


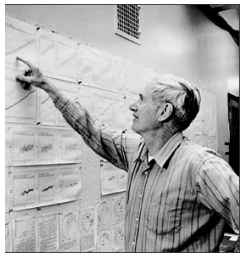


What about carbon dioxide?

Keeling Curve



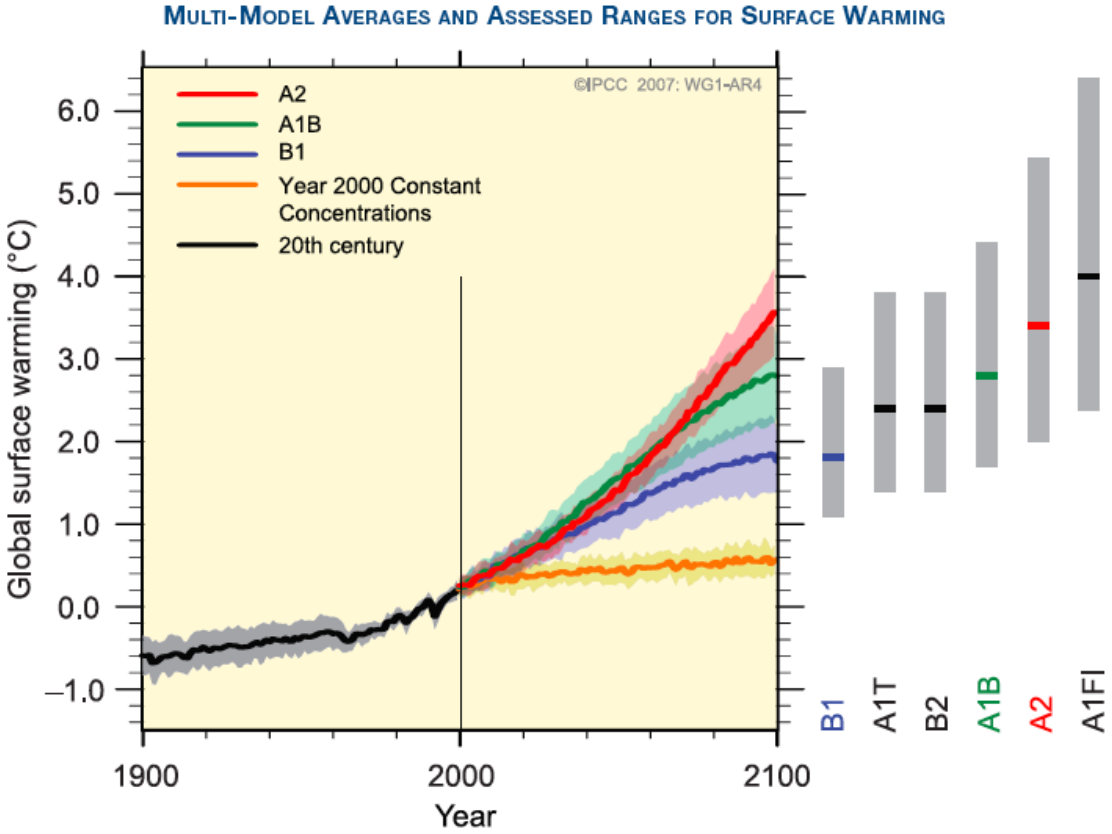




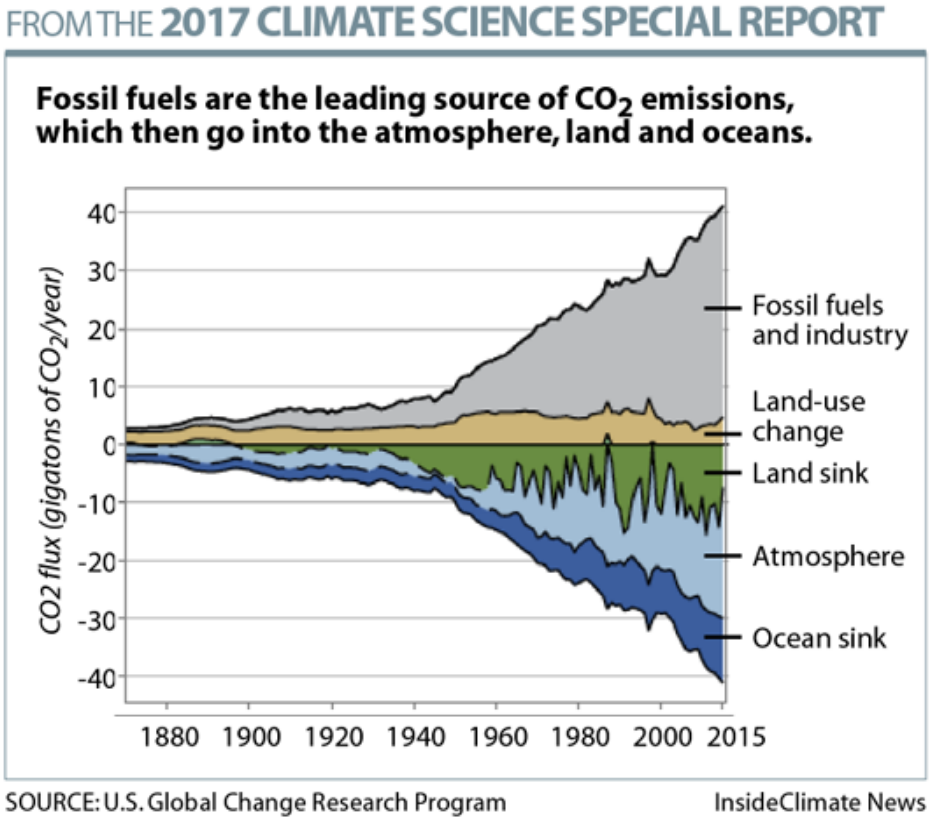
https://www.esrl.noaa.gov/gmd/ccgg/trends/mlo.html

Big questions (again)

- How much carbon dioxide will we put in the atmosphere?
- How much can the oceans and biosphere absorb?



Global Carbon *Cycling*



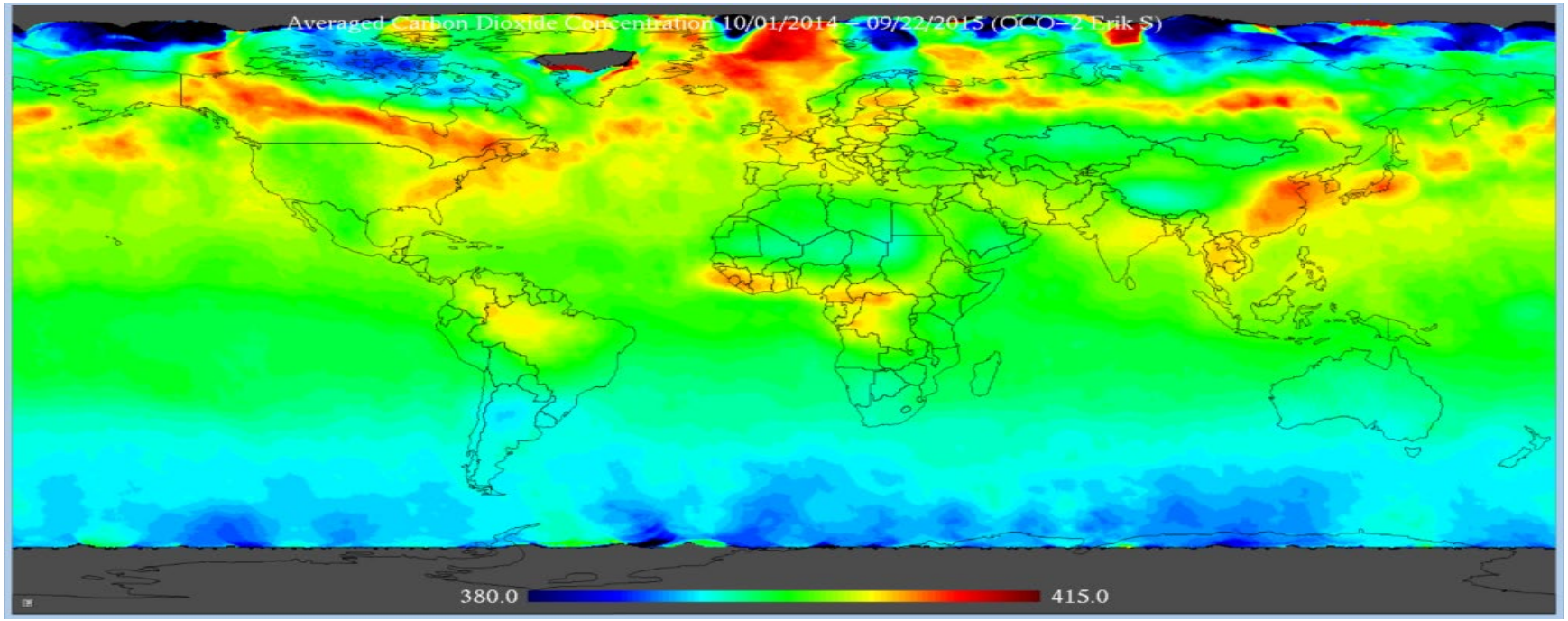
Are the assumptions correct?

What is happening on the regional scale?

How are they changing with time?

OCO-2 Launched July 2, 2014

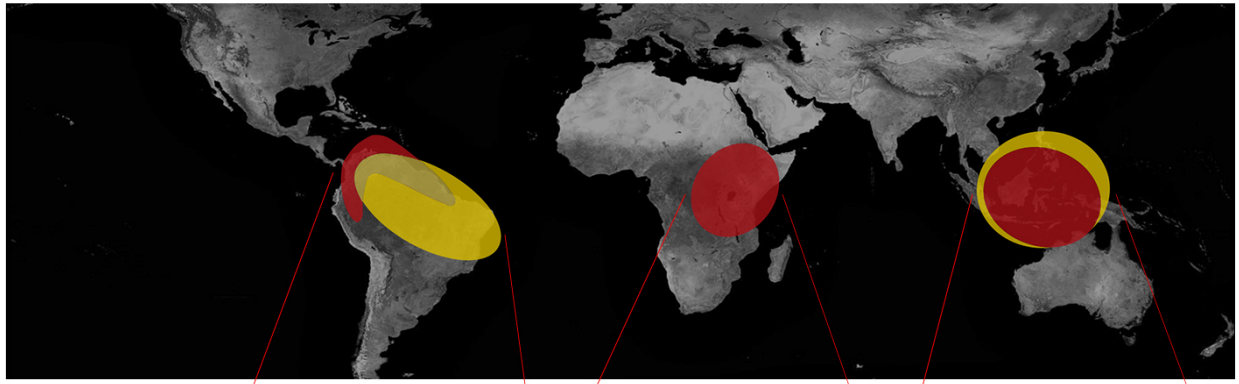
One year smoothed map of CO_2



Rainforests – Lungs of the Planet?

By Andyb3947 - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=90146764

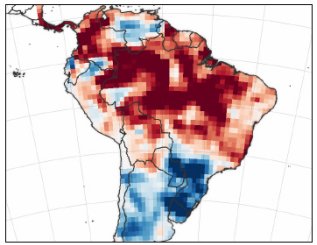
Changes in the Tropics (2015 relative to 2011).



Warm

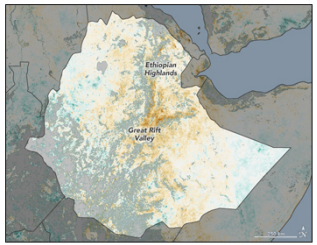
Dry

Driest in the last 30 years
Decreased Photosynthesis



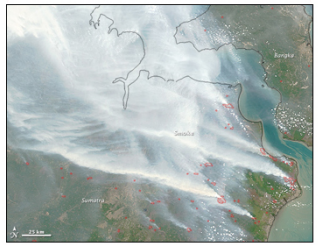
0.9 ± 0.29 GtC

Hotter than normal
Increased Decomposition



0.8 ± 0.22 GtC

2nd Driest in the last 30 years
Increased Fires



0.8 ± 0.28 GtC

[Junjie Liu et al., Science 2017]

OCO-2 and Los Angeles

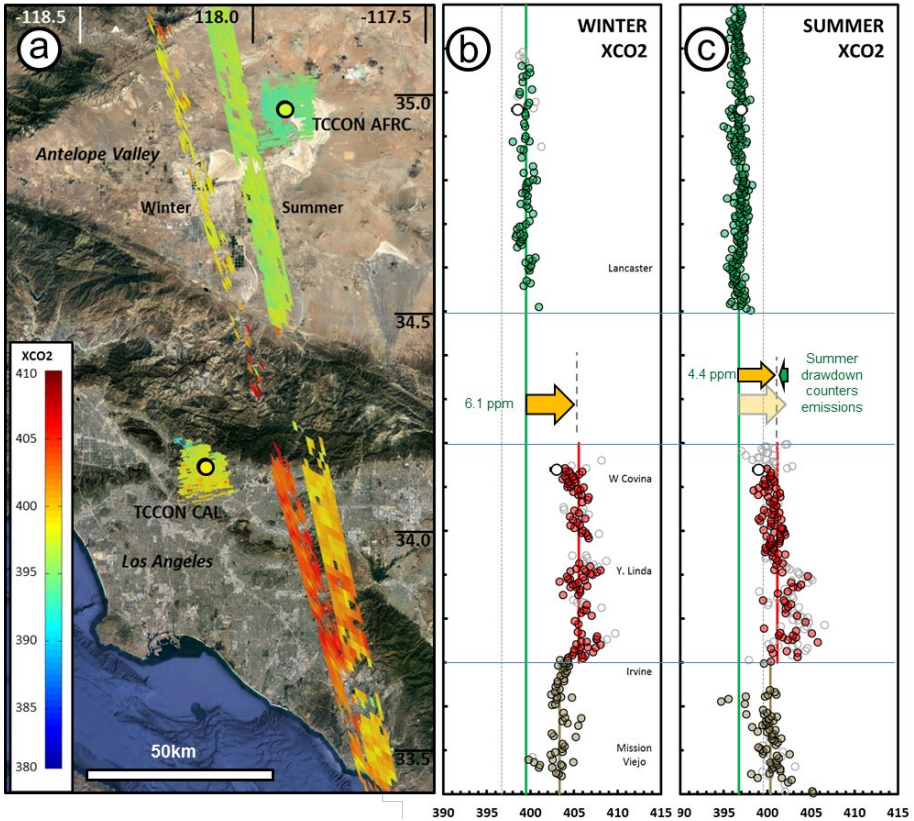


Figure from Schwandner et al., Science, (2017)

Takeaways

- Instead of greenhouse gases, we should think greenhouse substances
  - Aerosols
  - Clouds
  - And not just gases
- Climate change is forced by changes to atmospheric carbon dioxide
  - How much will it increase
  - How much can be taken up by the oceans and land
- **The exact climate change response is tied to changes in the water cycle**

Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov