



Hybrid Learning in Earth and Space Science

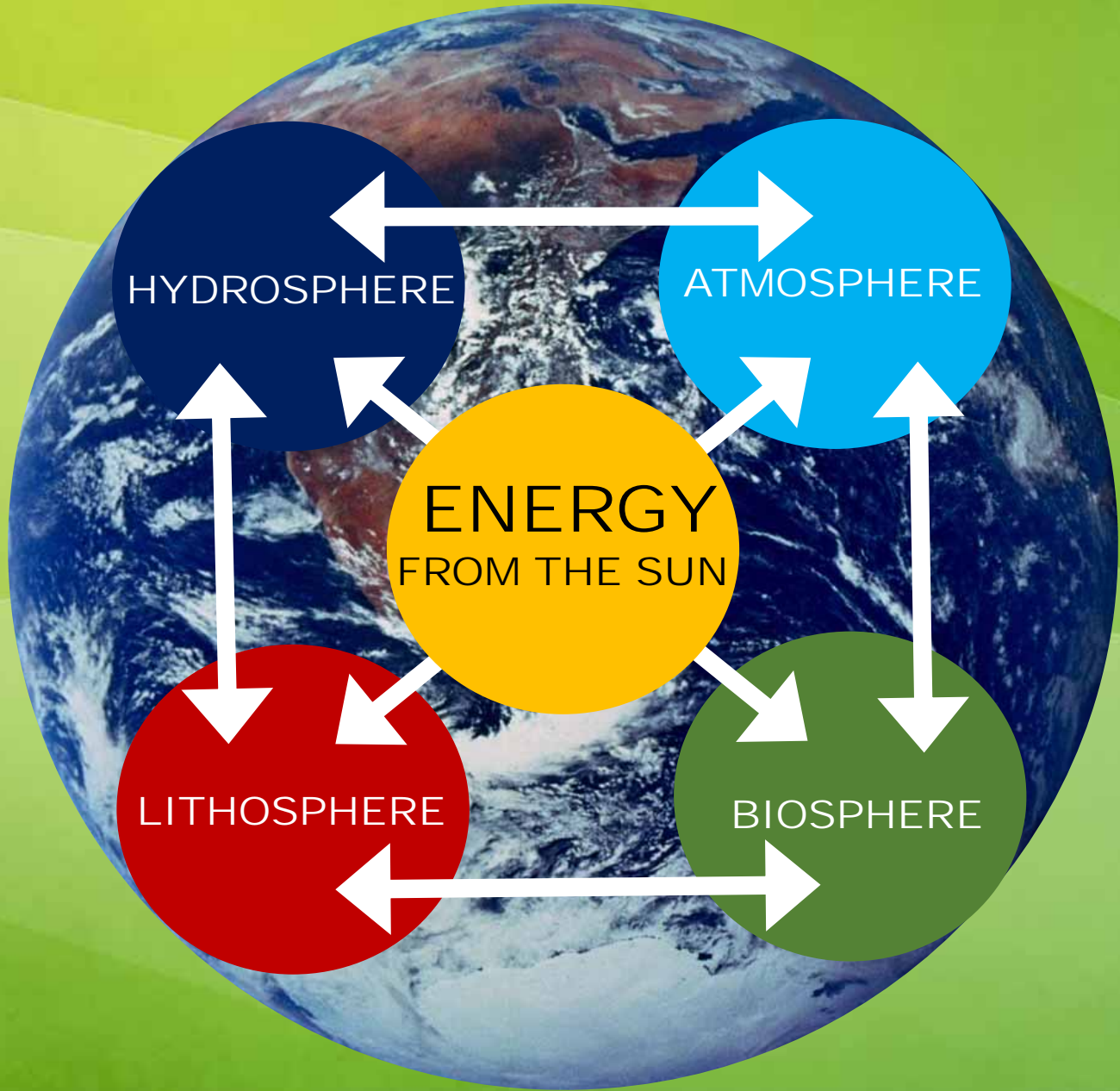


BOULDER CREEK
CZO



NATIONAL SCIENCE FOUNDATION
LTER NETWORK
LONG TERM ECOLOGICAL RESEARCH

Energy and Earth's Systems





NATIONAL SCIENCE FOUNDATION

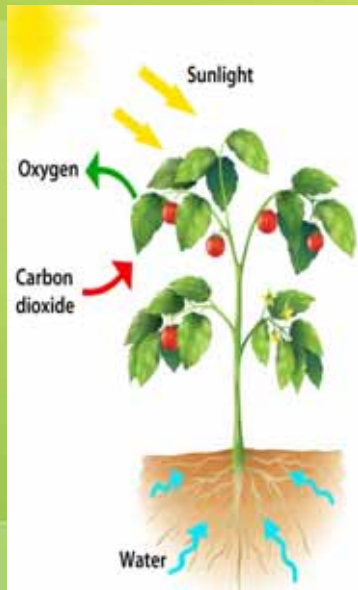
LTER NETWORK

LONG TERM ECOLOGICAL RESEARCH



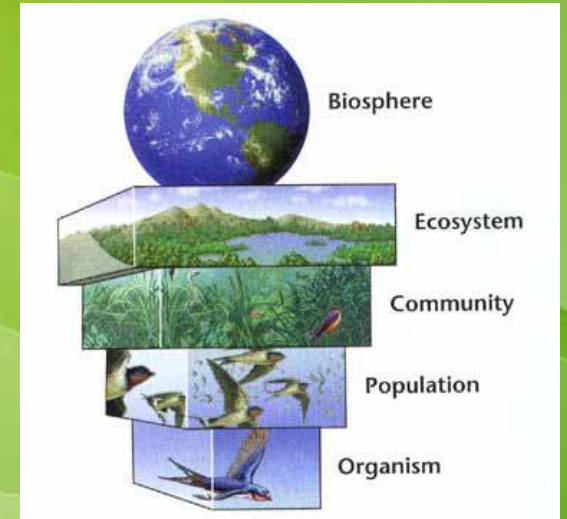
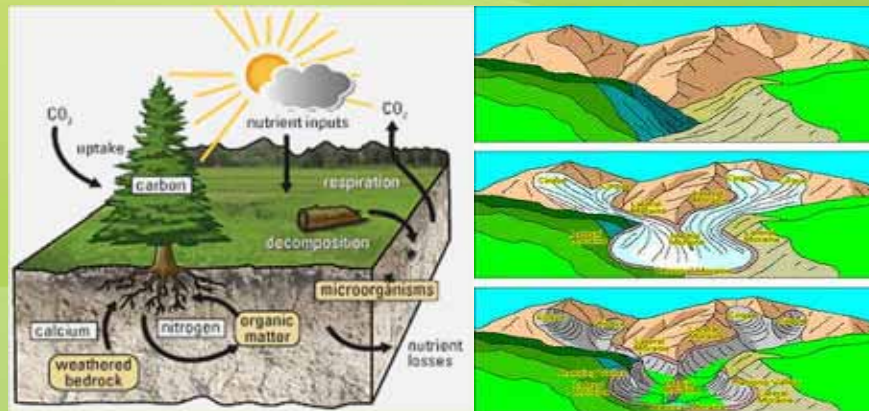
McMurdo Dry Valleys
LTER

Long-Term Ecological Research ~ Core Areas



Primary Production

Movement of Organic & Inorganic Materials

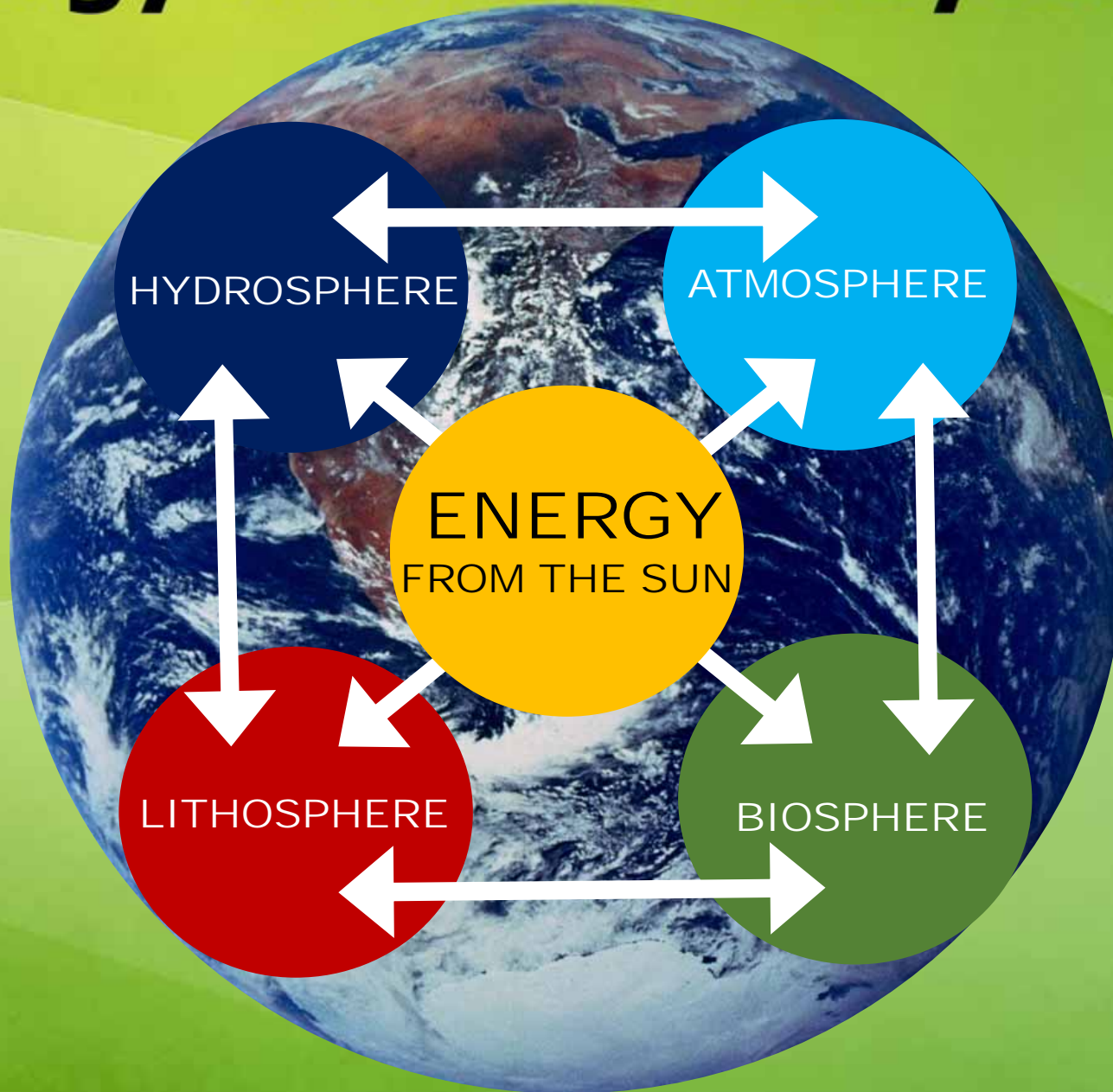


Communities & Populations



Disturbances and Change

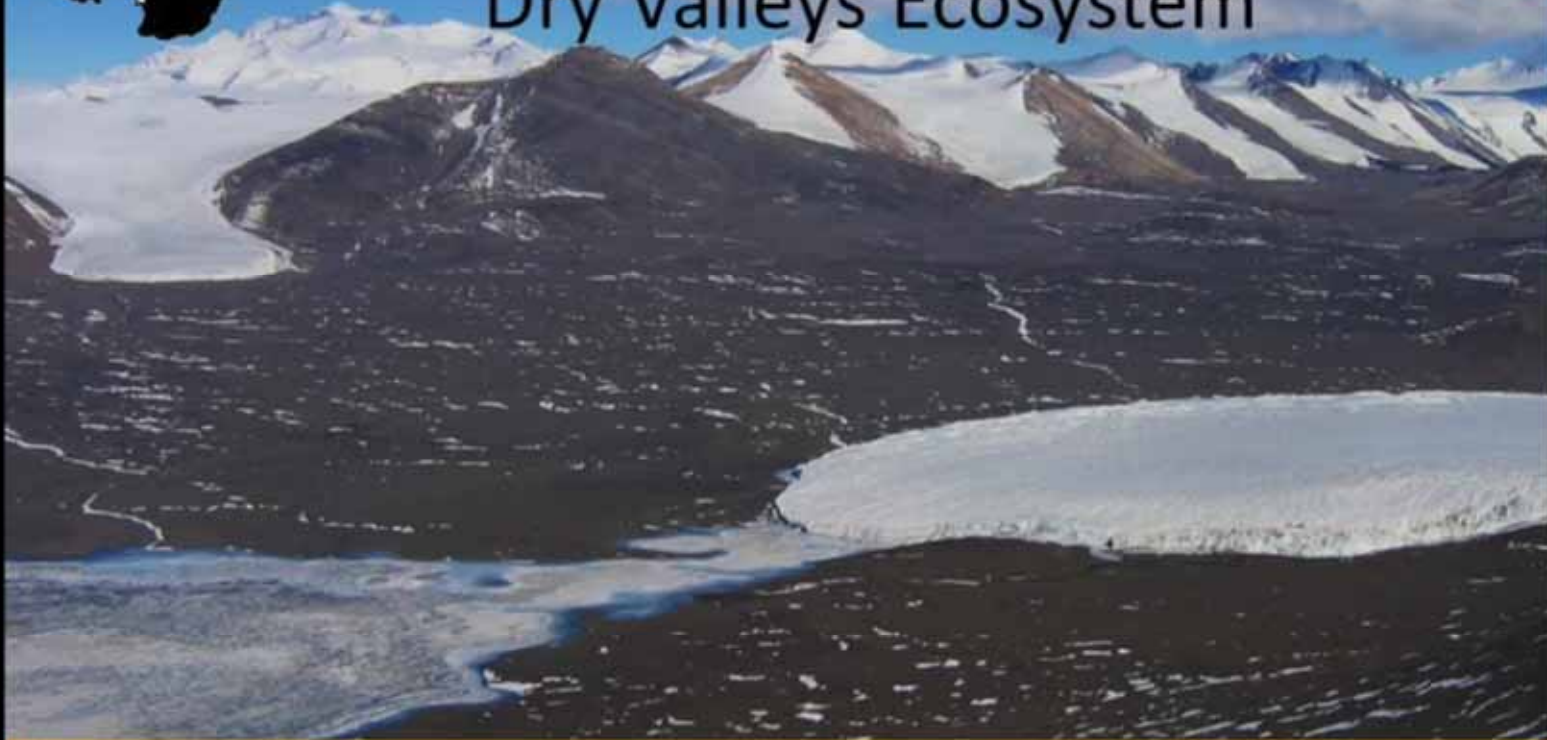
Energy and Earth's Systems



Long-Term Ecological Research Program



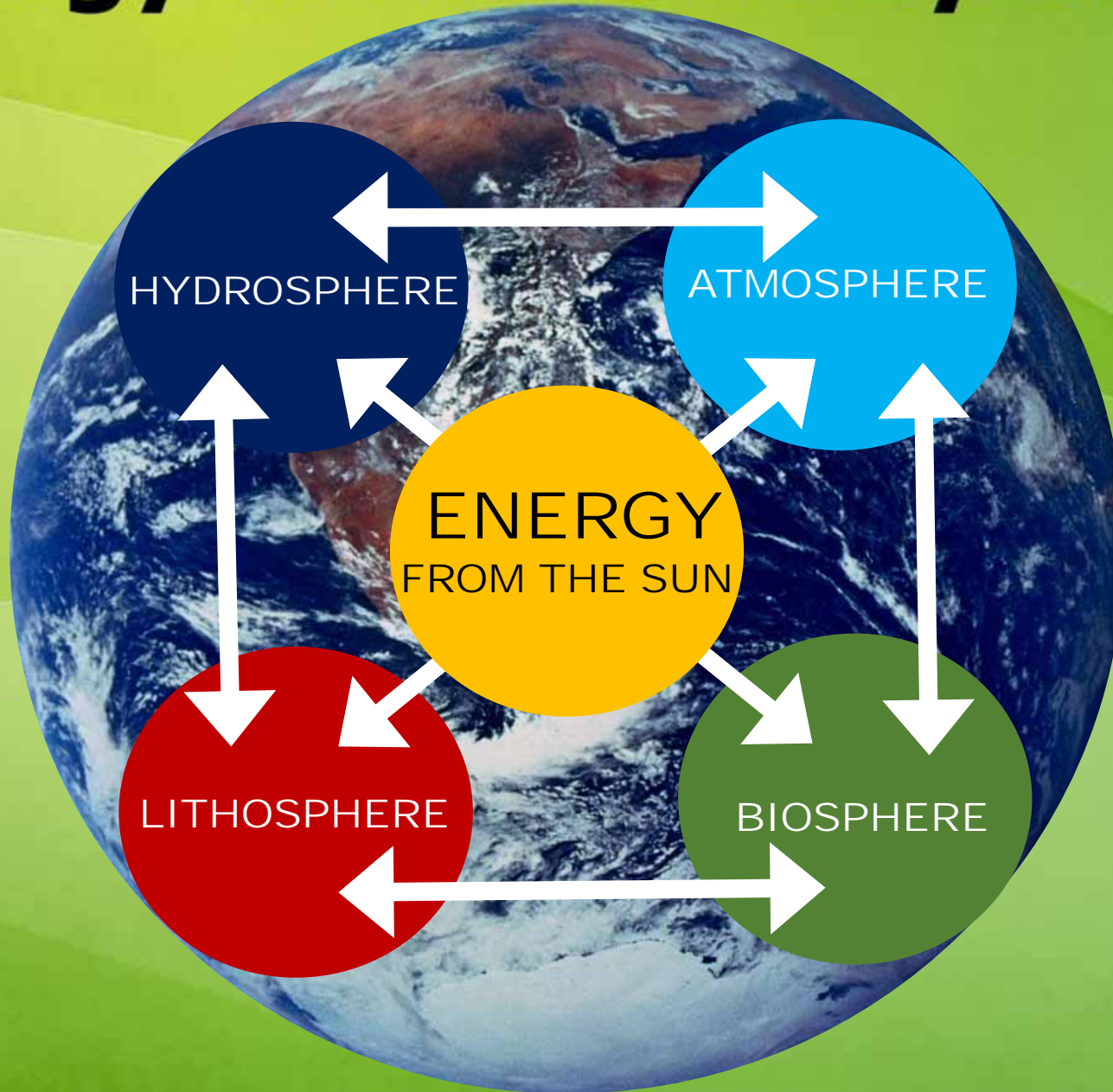
Two Decades of Research on the
Dry Valleys Ecosystem

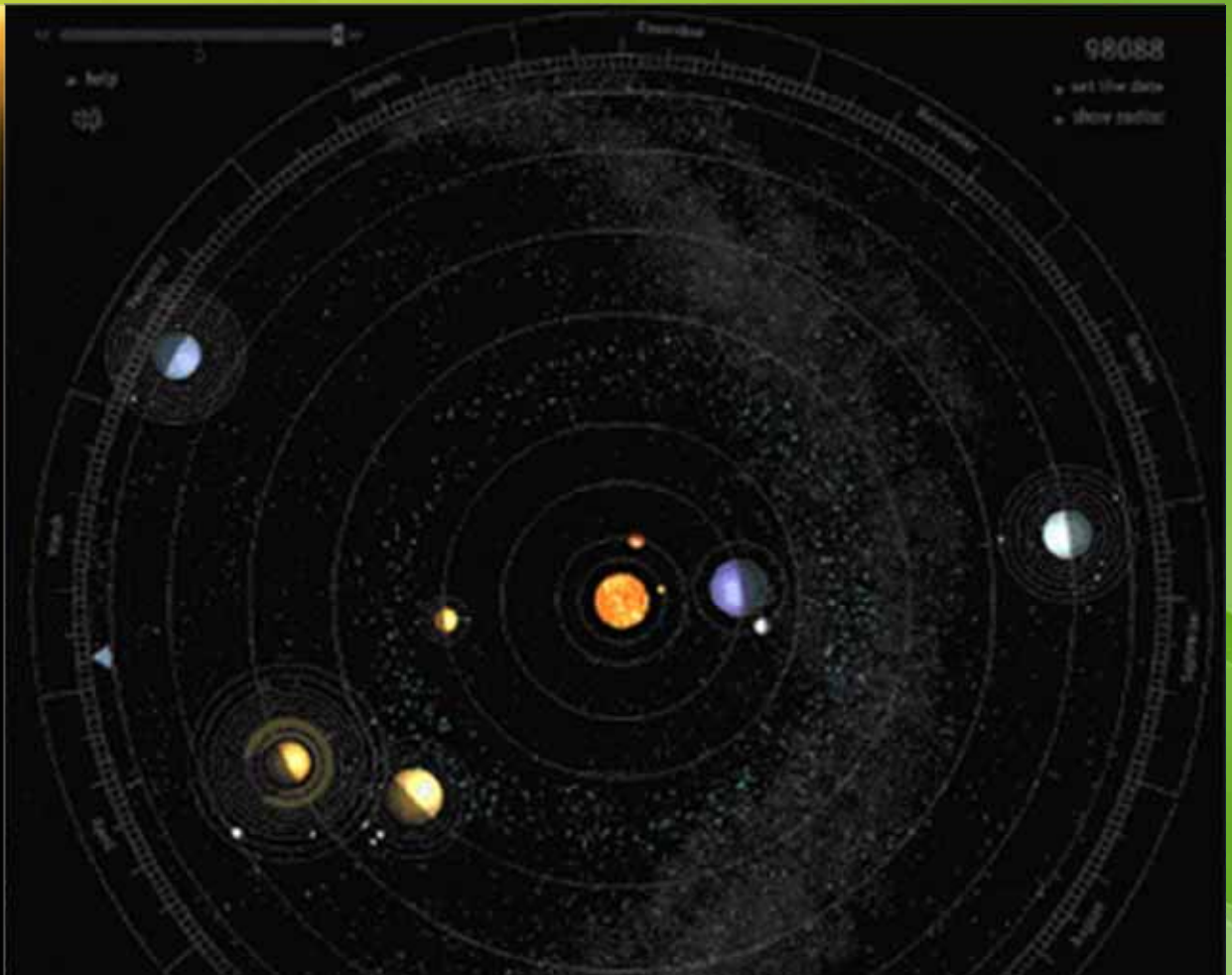


Mike Gooseff

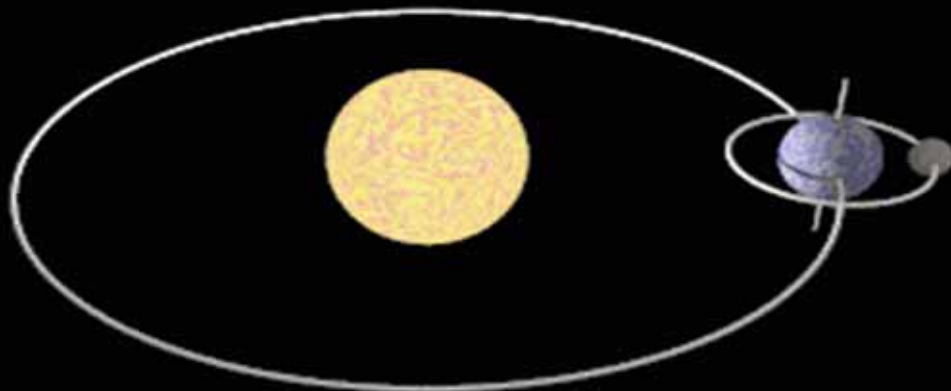
Institute of Arctic & Alpine Research, University of Colorado

Energy and Earth's Systems

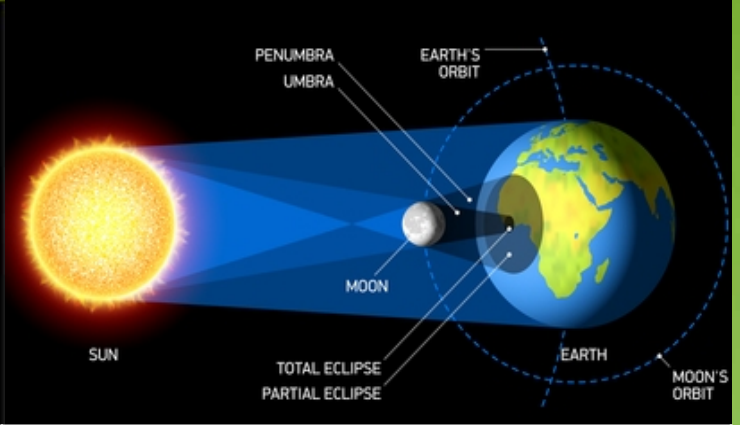




Planets Diameter (km)		Scale	Planets Orbit (km)		Scale
Sun	1,392,000	145 Feet	Earth	150,000,000	15,700 Feet
Earth	12,756	16 inches	Moon	384,000	145 Feet
Moon	3,476	4.4 Inches			



© Friedrich A. Lohmüller, 2006

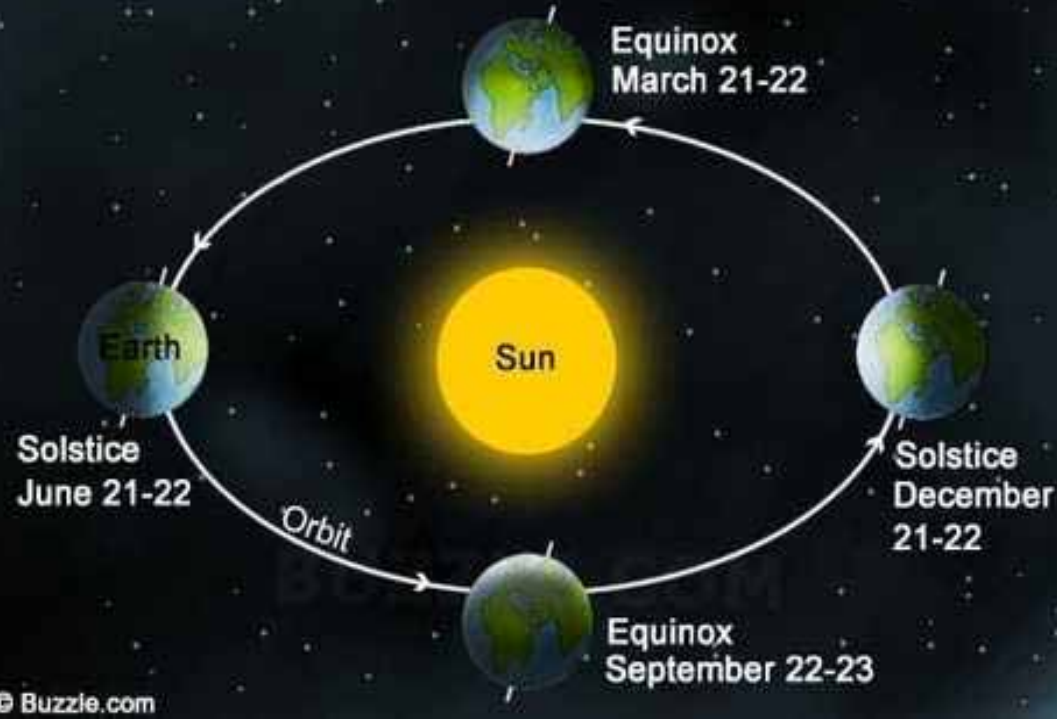


Planets Diameter (km)

Sun	1,392,000
Earth	12,756
<u>Moon</u>	<u>3,476</u>
Sun/Moon	400

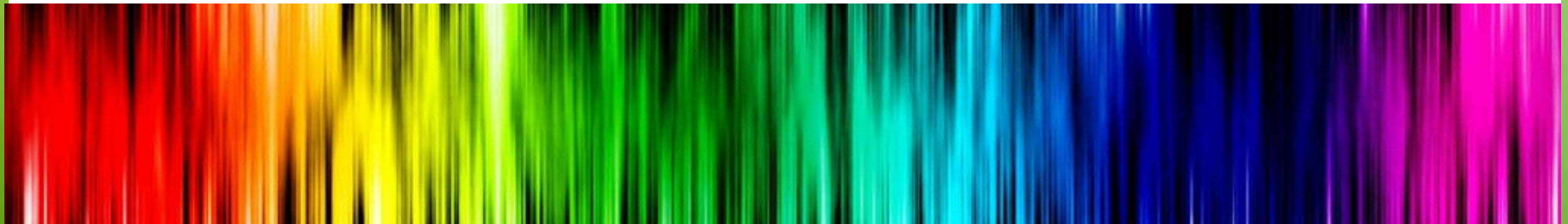
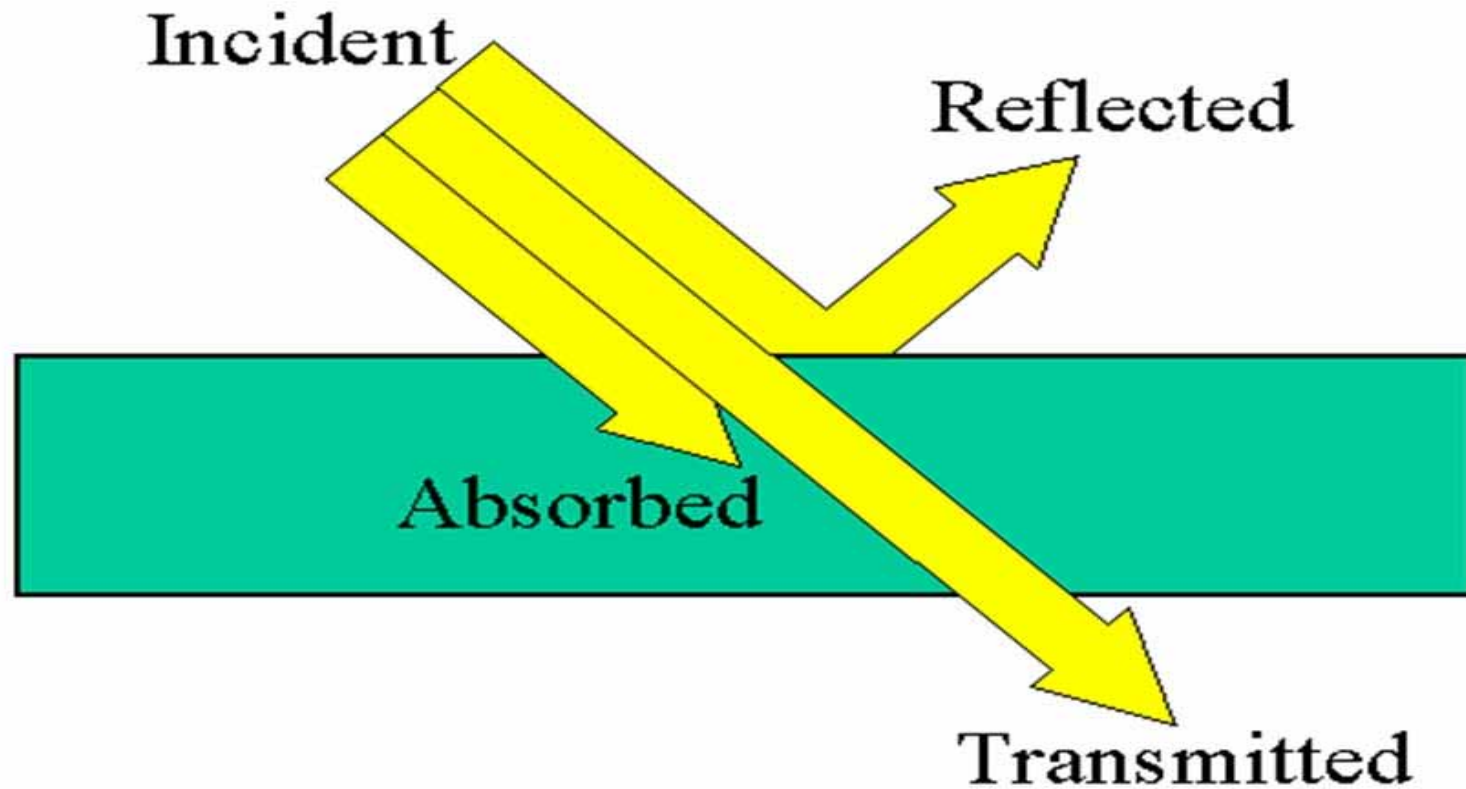
Planets Orbit (km)

Sun	
Earth	150,000,000
<u>Moon</u>	<u>384,000</u>
Earth/Moon	390



© Buzzle.com

Seasons/Ecliptic Simulator



Seasons Interactive

Introduction

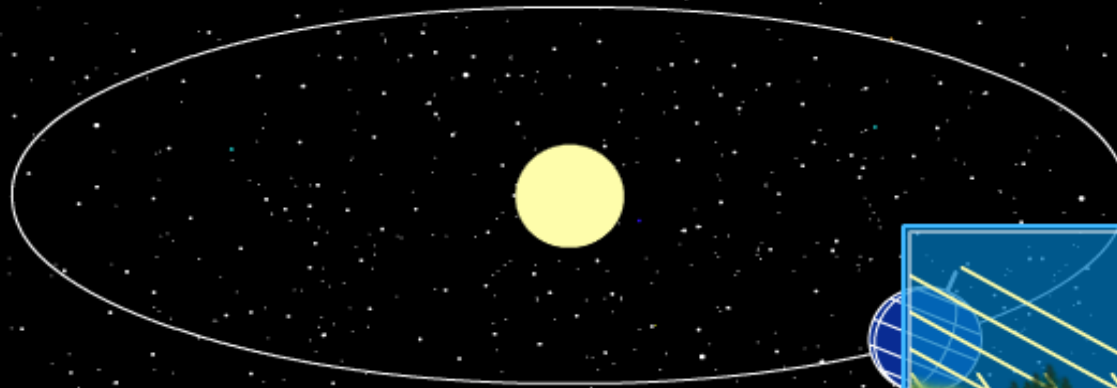
How To

Interactive

Exercises

Solutions

Seasons

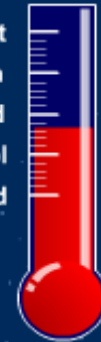


Sizes and distances not to scale



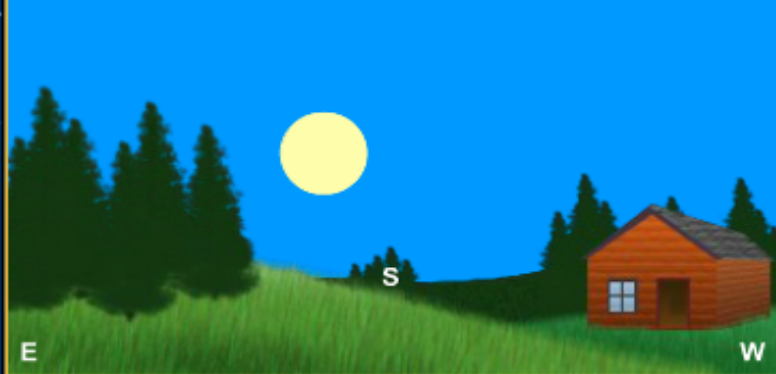
Average Daily Temperature at Observation Site

Hot
Warm
Mild
Cool
Cold



Autumn

11:00 AM



Inclination Angle: 23°



Fast

Slow

Stop

Slow

Fast



Trace Sun's Path

Clear Trace

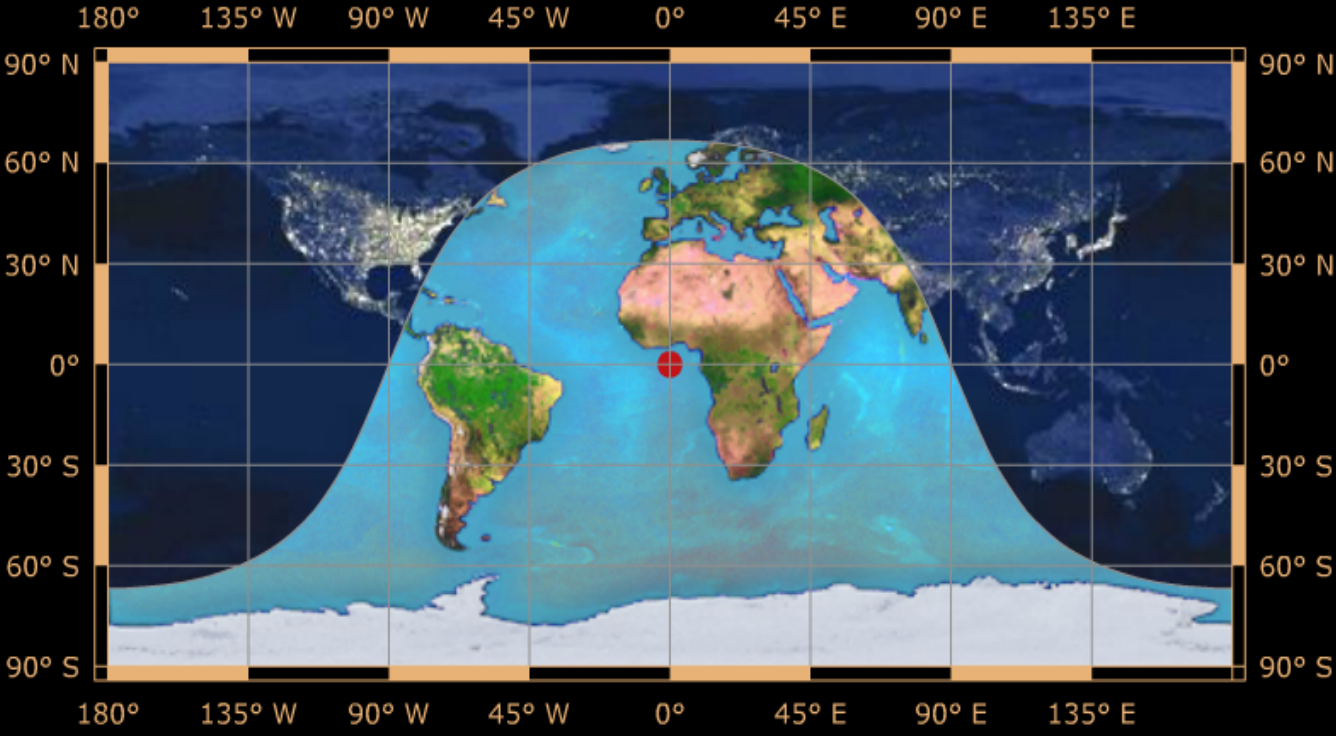
Set Earth's Inclination to that of:

Earth

Venus

Uranus

Daylight Simulator



Date: December 30
Time: 12:00 PM
Sun Declination: -23.23
Latitude of Direct Rays: 23.23° S
Daylight Hours: 12.12 hours

Longitude 0
180 W 180 E

Latitude 0
90 S 90 N

Animation Mode
 Yearly
 Daily

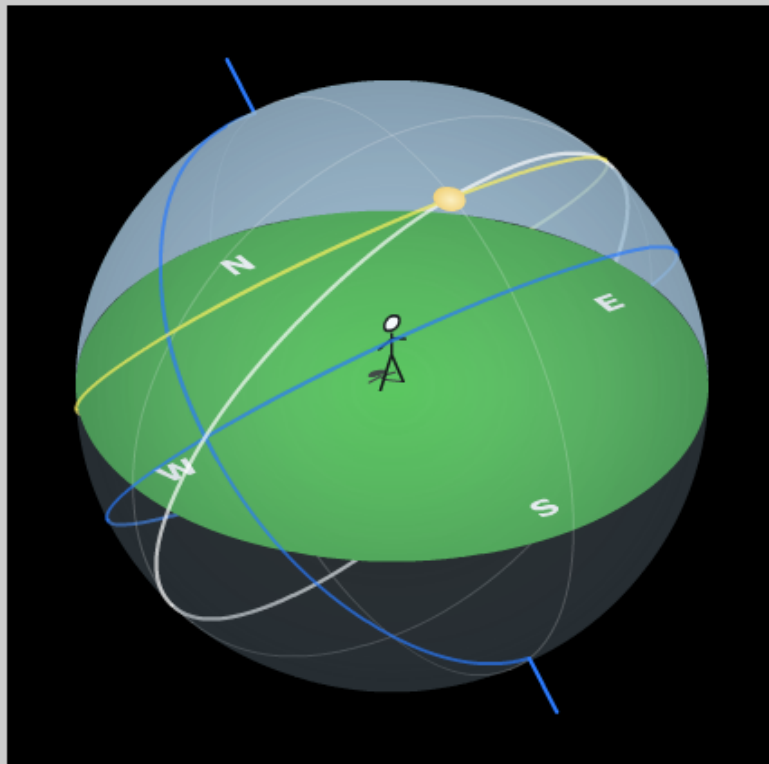
Animation Speed 5
1 10

Image Credit: NASA Goddard Space Flight Center

Sun Motion Demonstrator

Motions of the Sun Simulator

reset help about



Time and Location Controls

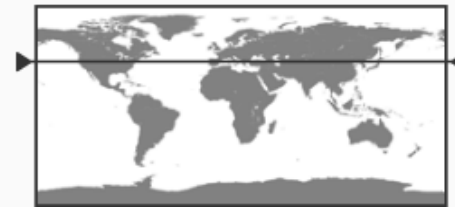
the day of year:

| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |

the time of day:



the observer's latitude:



Information

The horizon diagram is shown for an observer at latitude 40.8° N on 27 May at 12:00 (12:00 PM).

advanced

sun's hour angle: 0h 2m

sidereal time: 4h 21m

equation of time: 2:49

show analemma

sun's altitude: 70.6°

sun's azimuth: 182.0°

sun's right ascension: 4h 19m

sun's declination: 21.4°

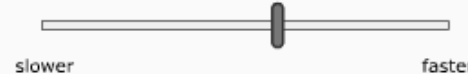
Animation Controls

animation mode:

continuous loop day

step by day

animation speed: 3.0 hrs/sec



use lower quality graphics when animating to improve performance

General Settings

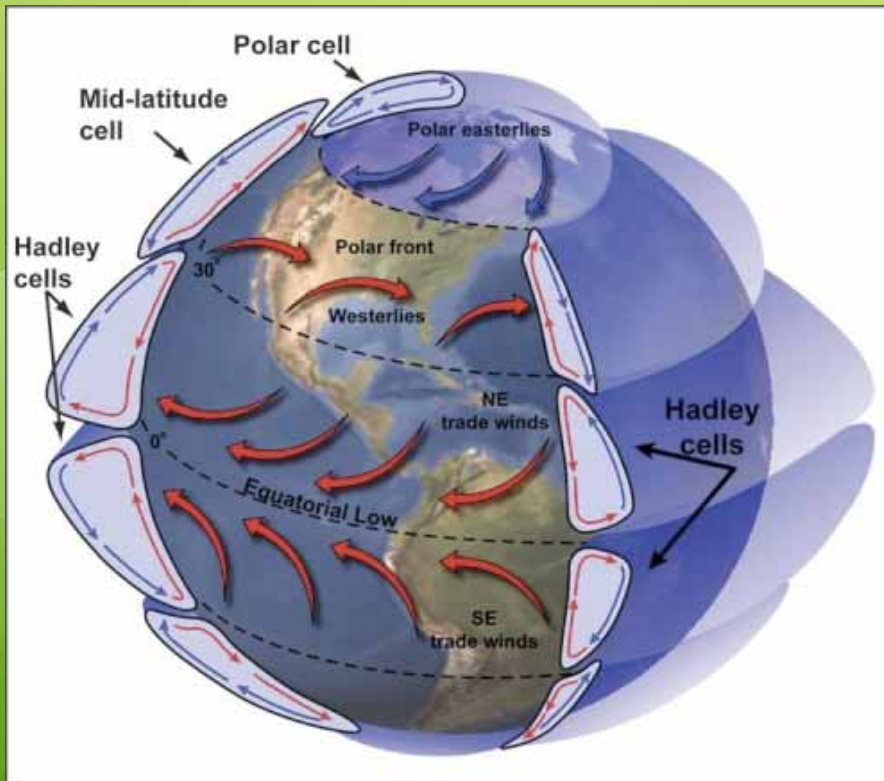
- show the sun's declination circle
- show the ecliptic
- show month labels
- show underside of celestial sphere
- show stickfigure and its shadow

dragging the sun's disk changes the ...

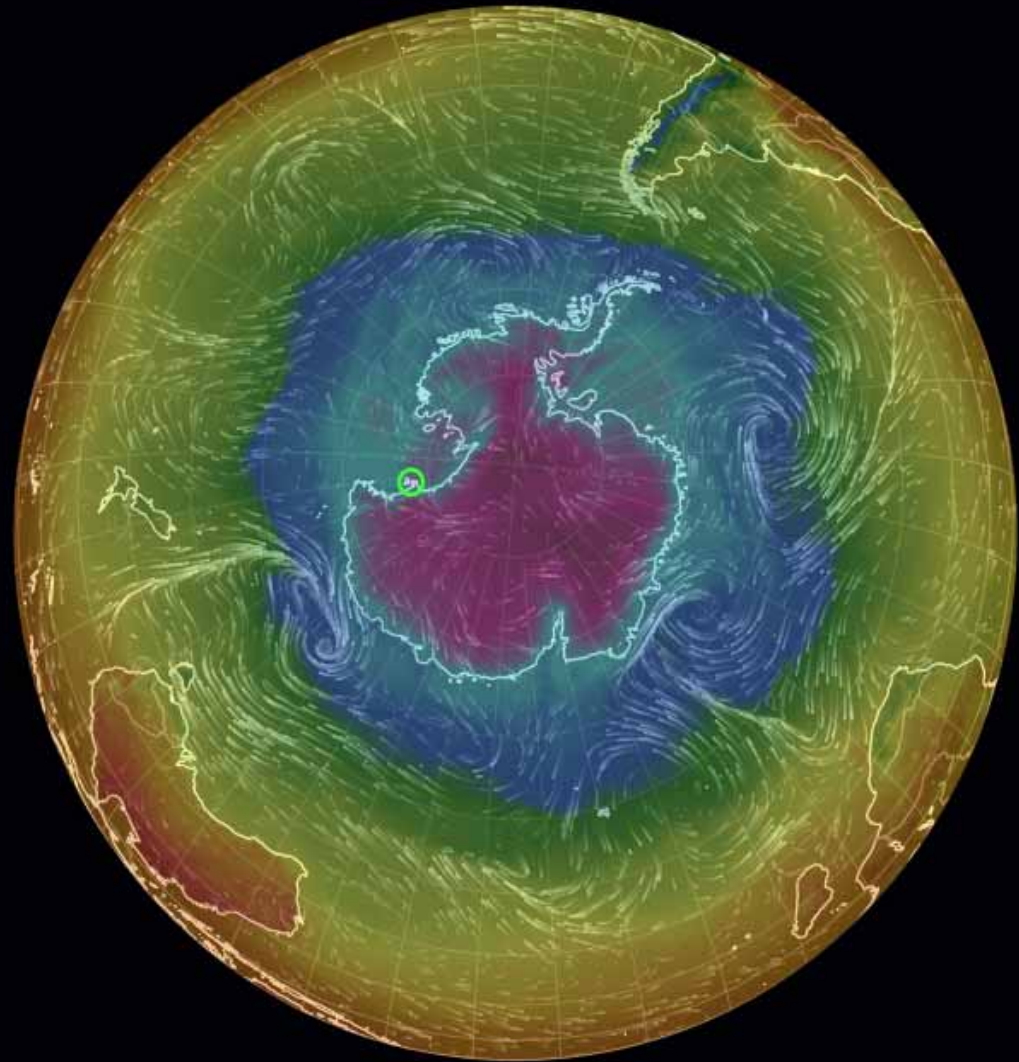
- time of day
- day of year



Parts of the Earth receive varying amounts of energy throughout the year. This energy is redistributed in the system to reach a balance.



Earth Visualization Tool



77.97° S, 166.85° E ×

70° @ 8 km/h

-24.1 °C

earth

HHMI World Biome Viewer



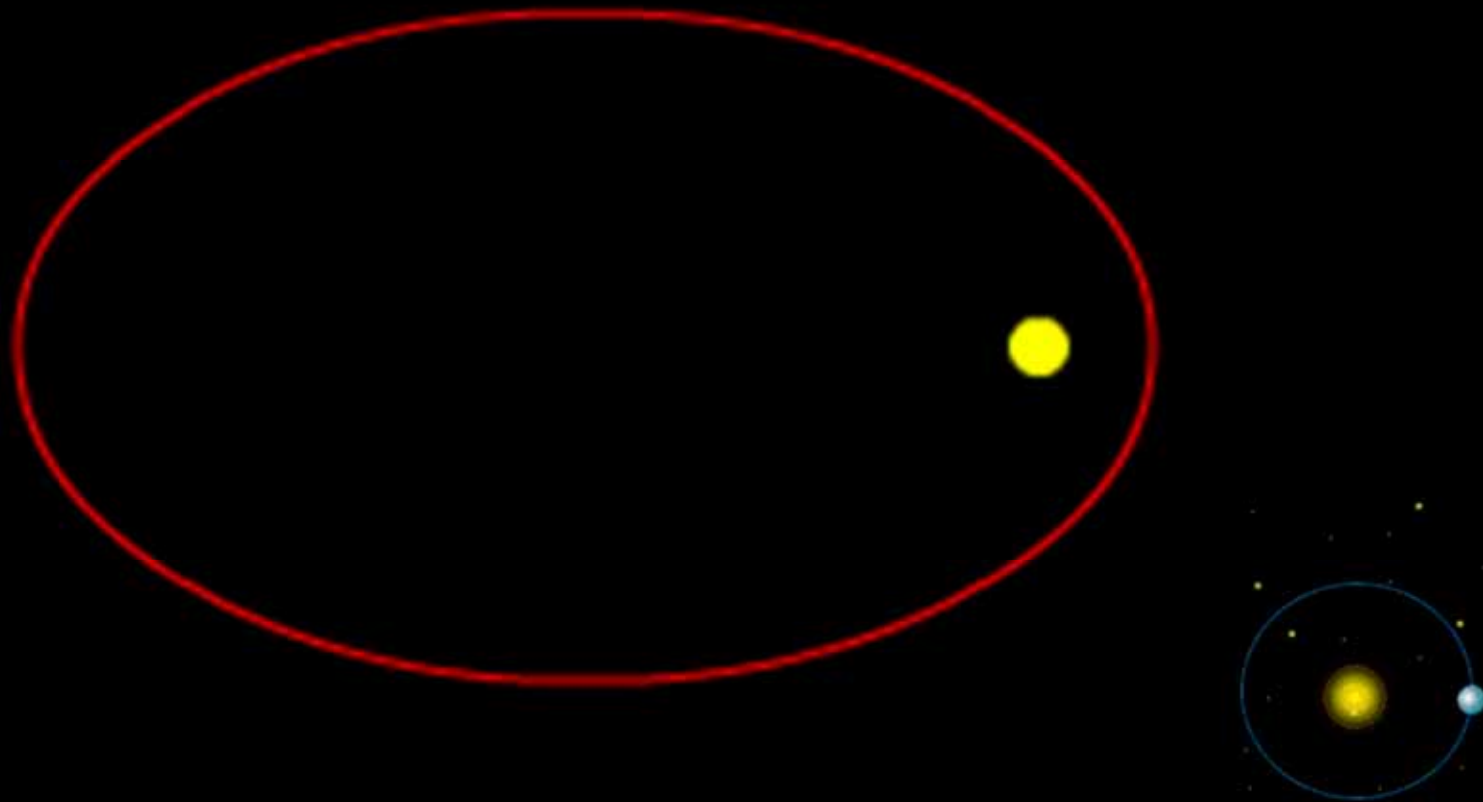
The screenshot displays the HHMI World Biome Viewer interface. On the left, a vertical menu titled "Biomes" lists 14 different biomes, each with a corresponding color swatch. The biomes listed are: Tropical Rain Forest (green), Tropical Dry Forest (light green), Savanna (tan), Desert (light brown), Chaparral (dark brown), Temperate Grassland (yellow-green), Temperate Deciduous Forest (medium green), Temperate Coniferous Forest (dark green), Boreal Forest (very dark green), Tundra (blue-grey), Alpine (light blue-grey), and Polar Ice (grey). The menu is set against a dark background with a starry pattern. To the right of the menu is a circular globe of the Earth, showing the distribution of these biomes across the continents. The globe is centered on the Americas, with North and South America visible. The background of the entire interface is a dark, starry space.

Biomes
Communities of plants and animals defined by their climate and dominant vegetation.

- Tropical Rain Forest
- Tropical Dry Forest
- Savanna
- Desert
- Chaparral
- Temperate Grassland
- Temperate Deciduous Forest
- Temperate Coniferous Forest
- Boreal Forest
- Tundra
- Alpine
- Polar Ice

Changes in Orbit and Angles

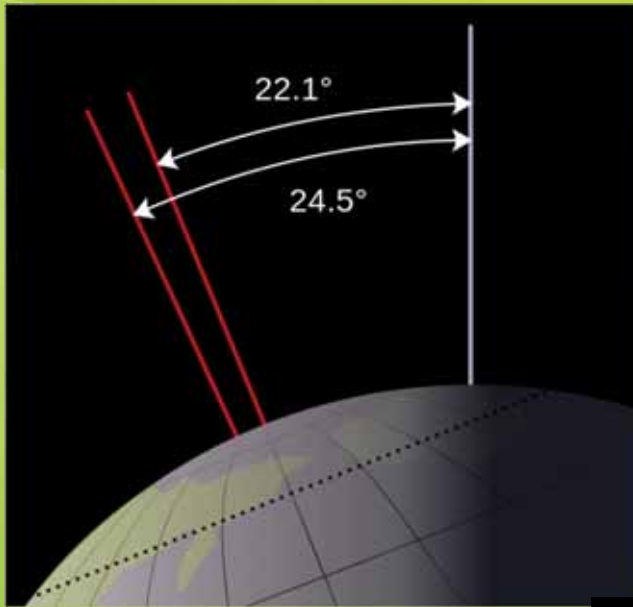
eccentricity = 0.8



150 Mkm Average

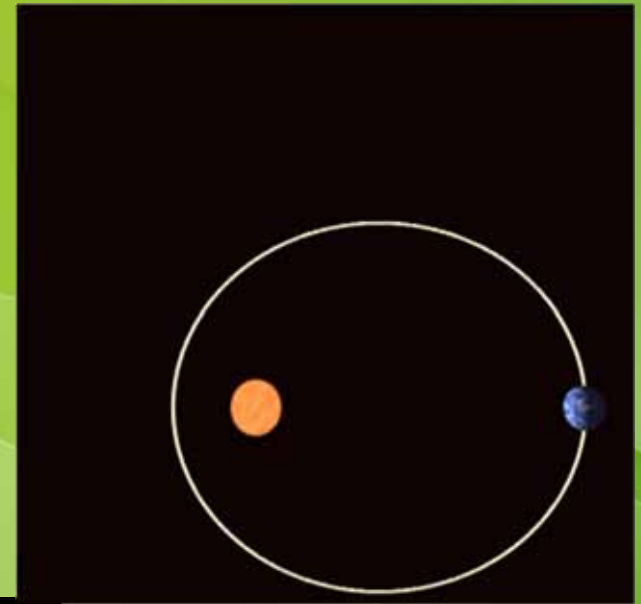
From 139.9 to 159.8 Mkm

Changes in Orbit and Angles



**Axial
Precession
23K Year Cycle**

North Pole in
Canada in 13K

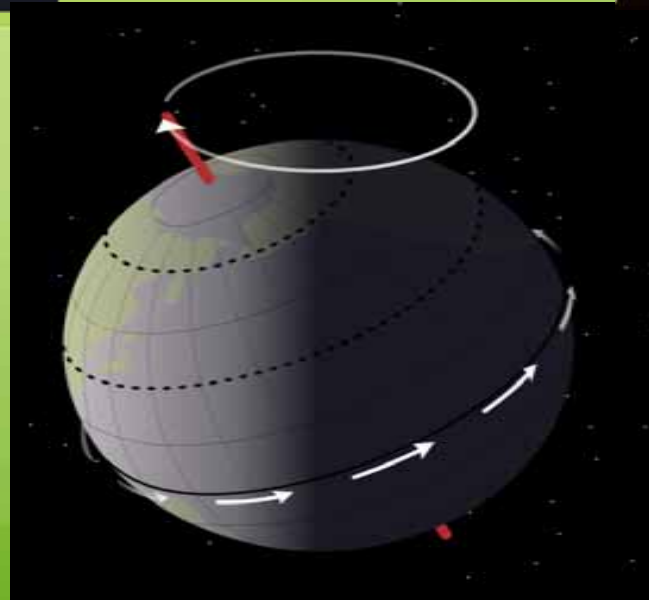


**Orbital
Precession**

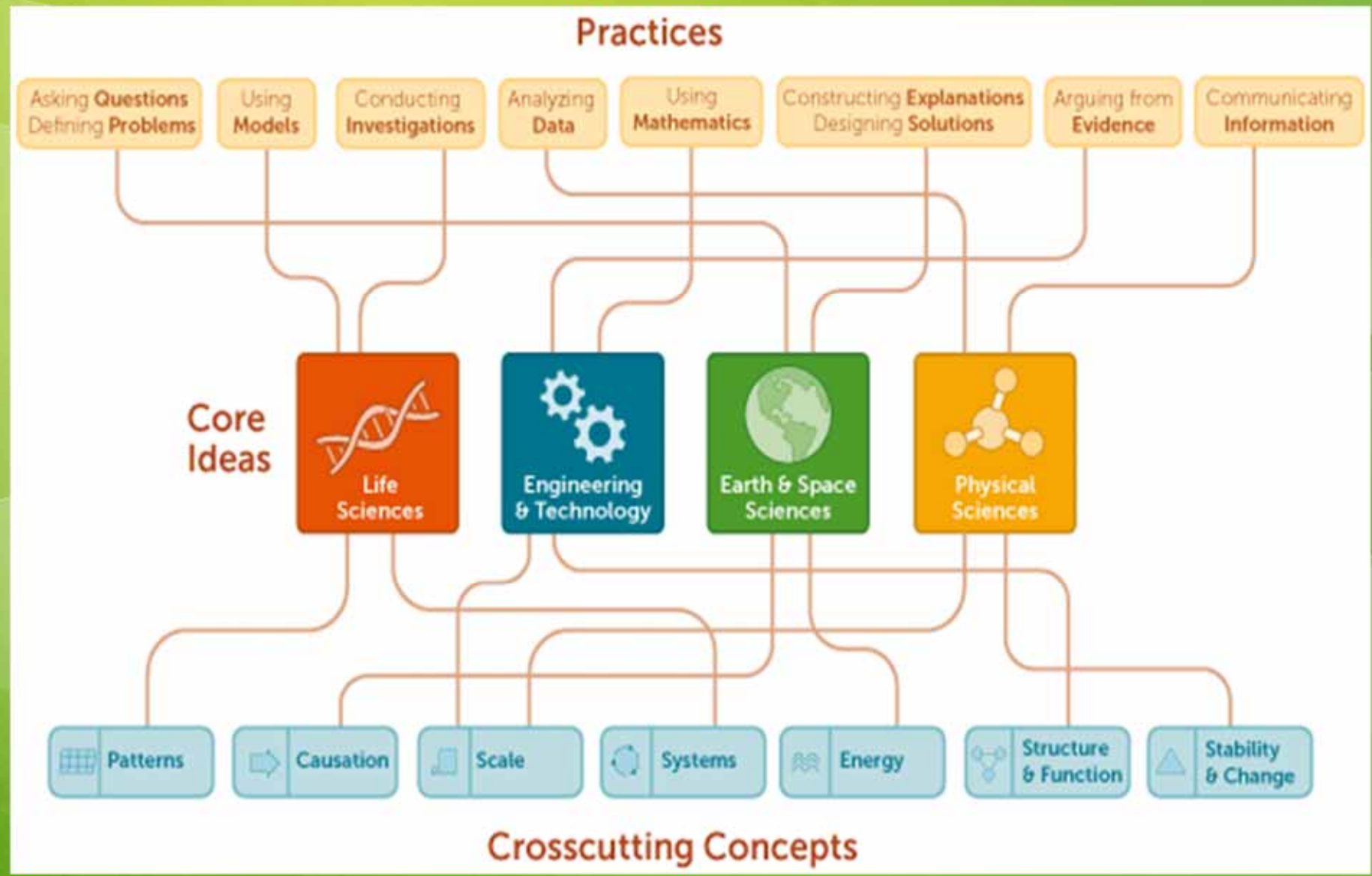
112K Year Cycle
Changes
Seasons 2 ways

**Axial Tilt:
23.44°**

41K Year Cycle
and Decreasing

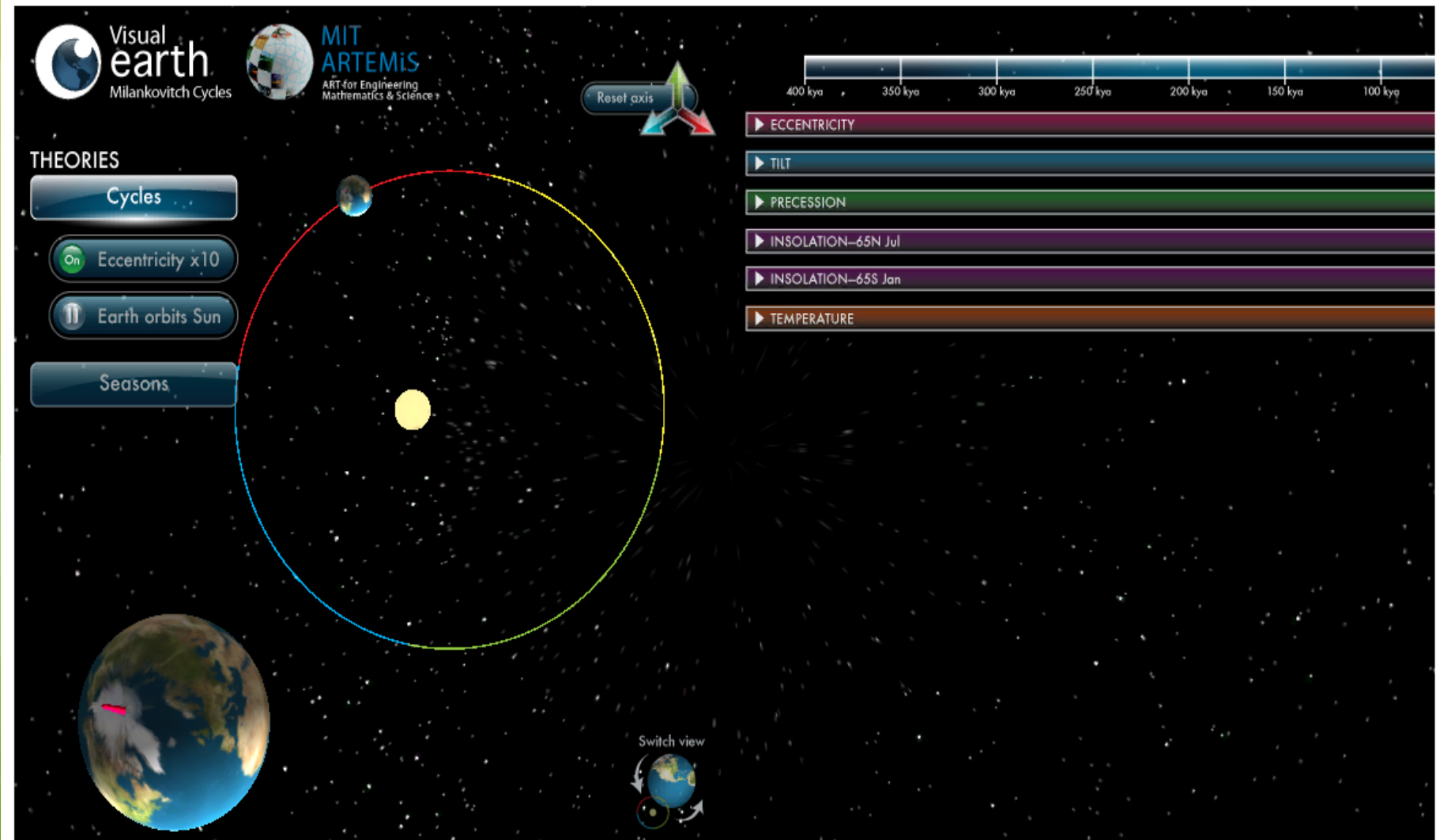


Changes in Orbit and Angles

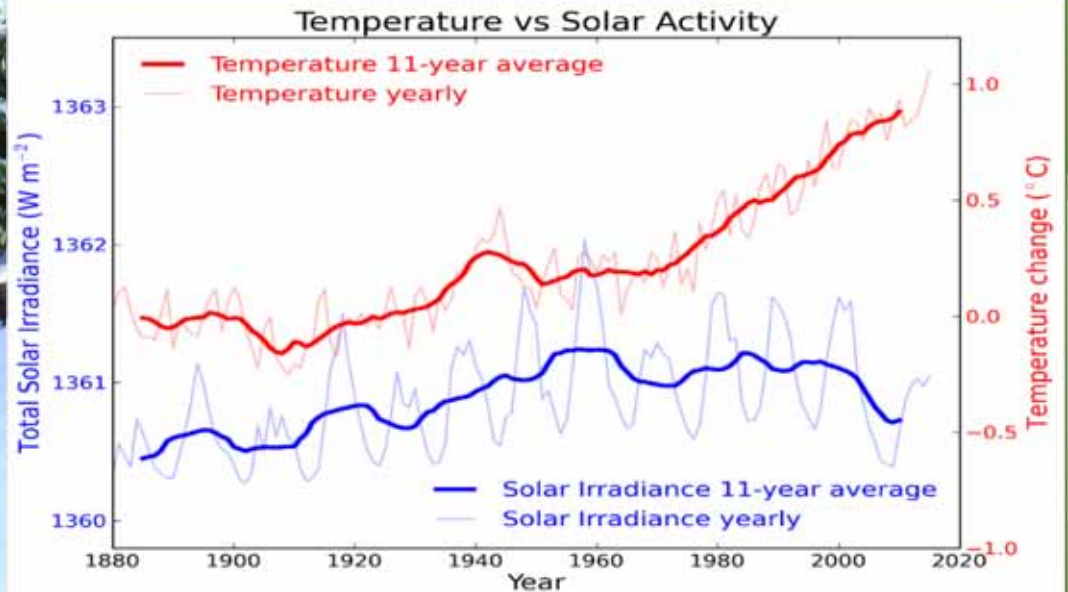
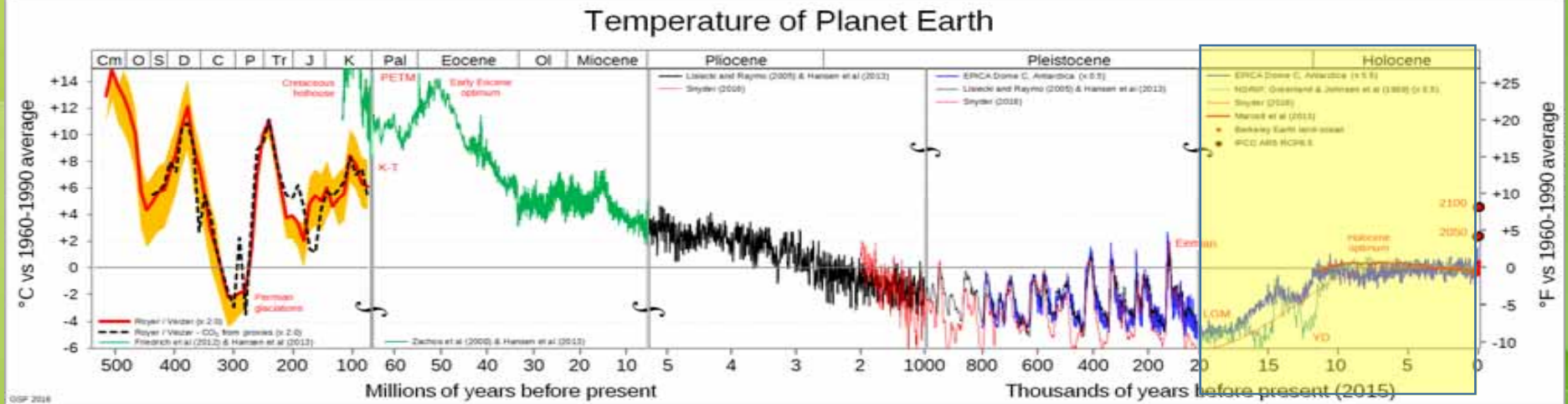


Visual Earth: Milankovitch

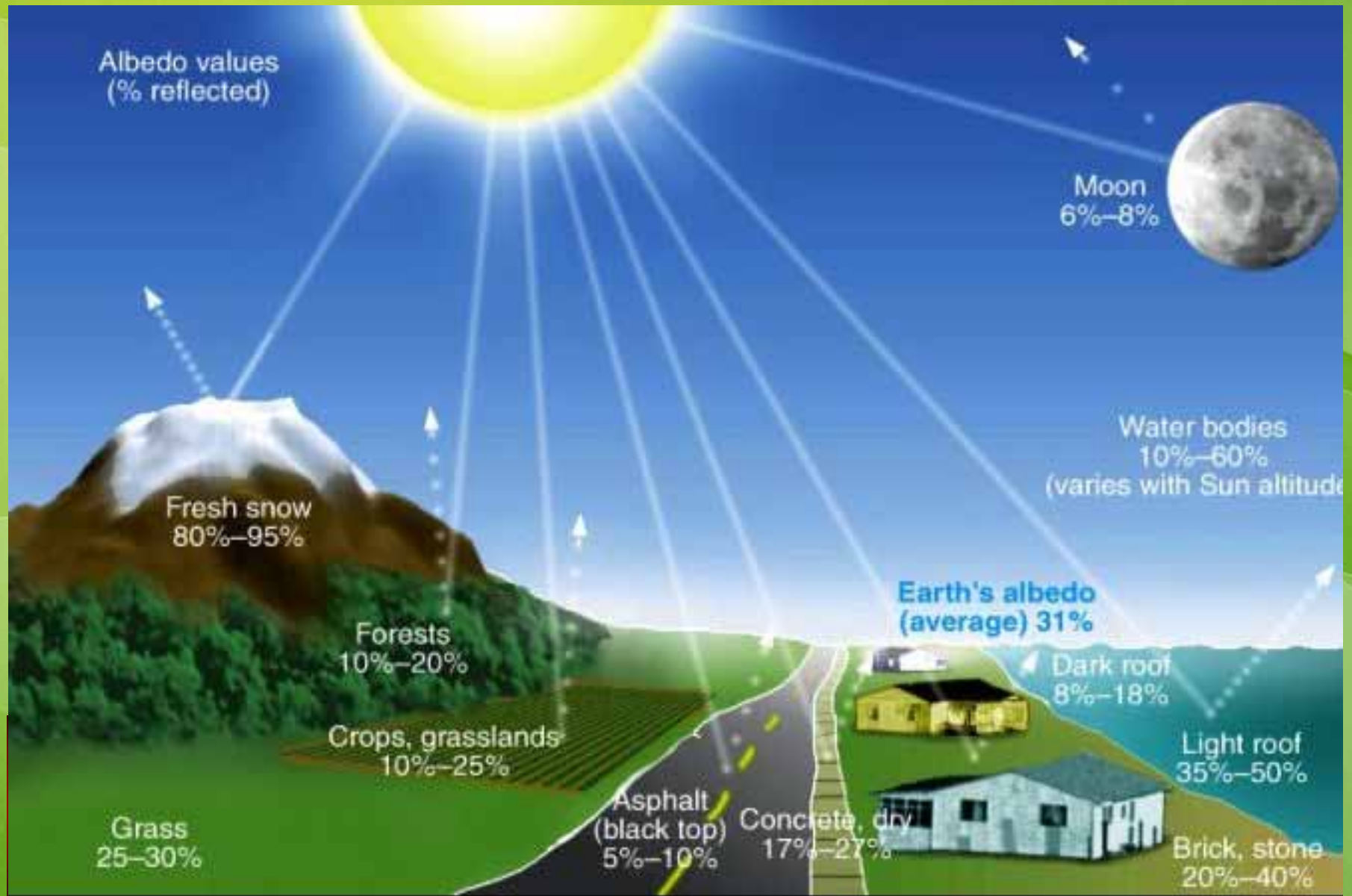
MIT ARTEMIS | Visual Earth: Milankovitch Cycles



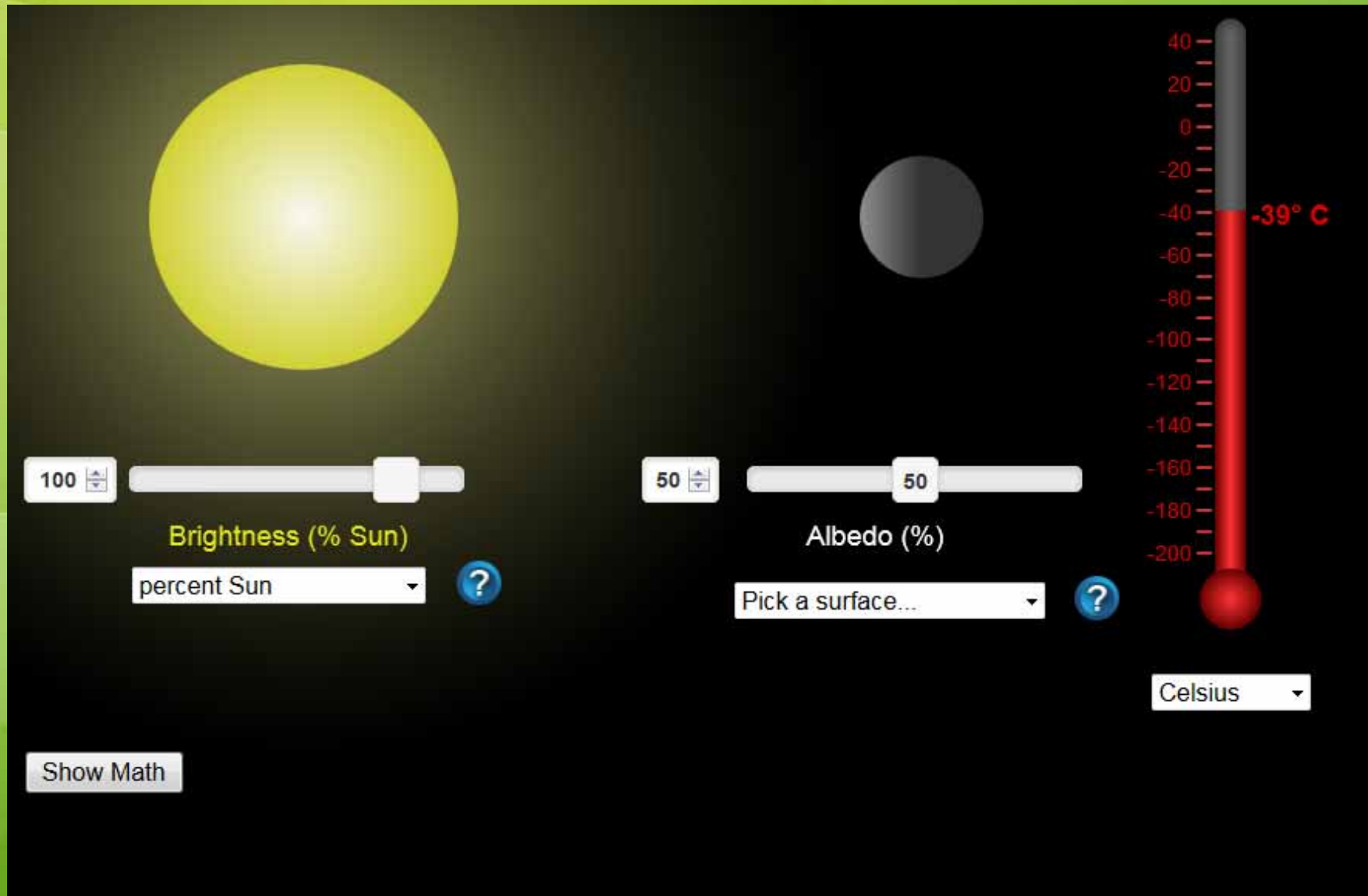
Milankovitch Cycles-Patterns



Albedo and Absorption



Earth's Energy Balance



Extraterrestrial Factors

Solar Output

Earth-Sun Geometry

Interstellar Dust

Earth's Climate

Volcanic Emissions

Atmospheric Chemistry

Mountain Building

Atmospheric Reflectivity

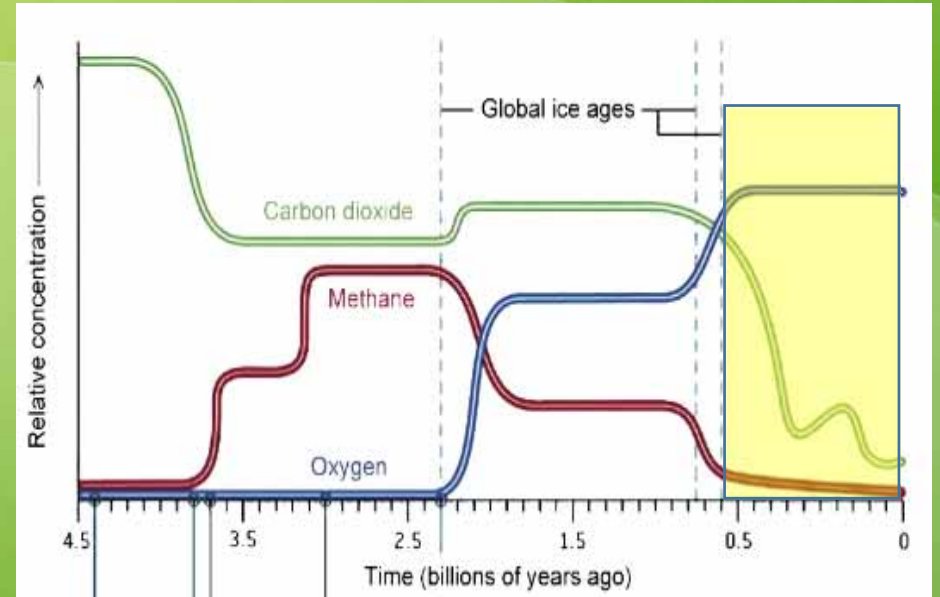
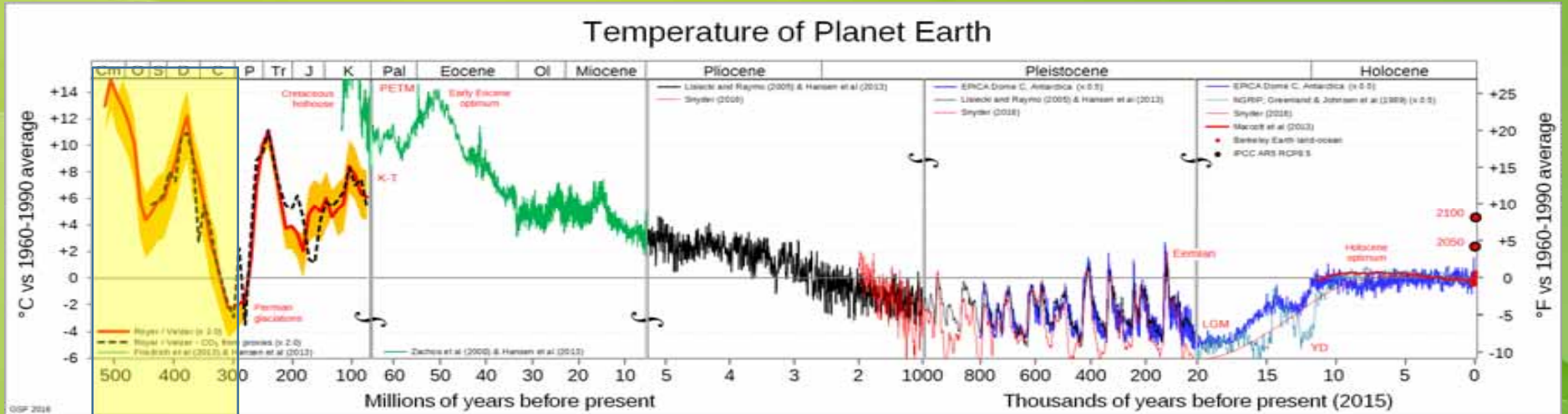
Continental Drift

Atmosphere/Ocean Heat Exchange

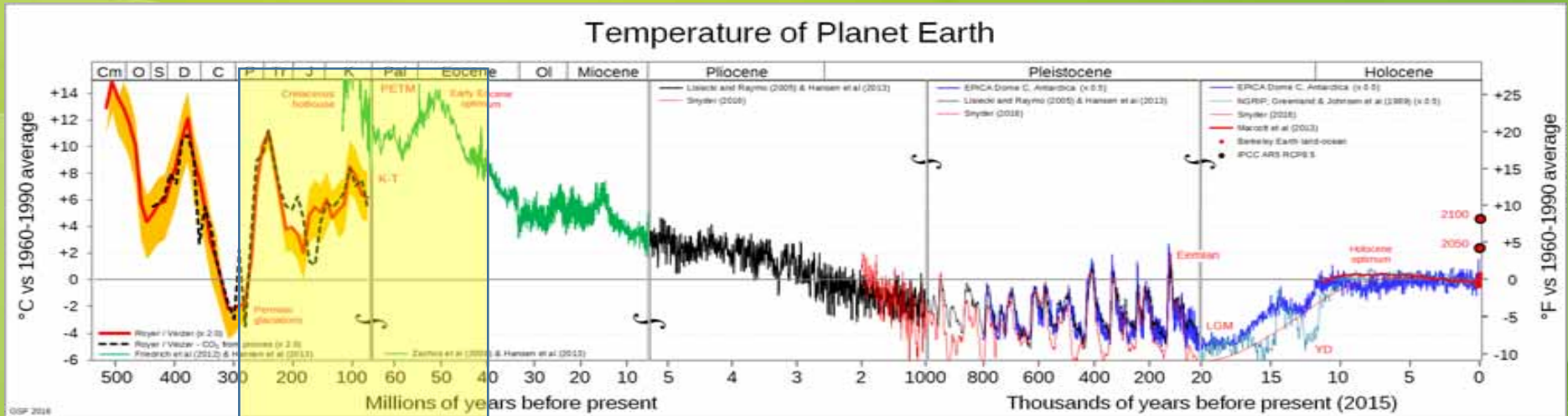
Surface Reflectivity

Ocean, Atmosphere, and Land Factors

Earth's Climate - Patterns

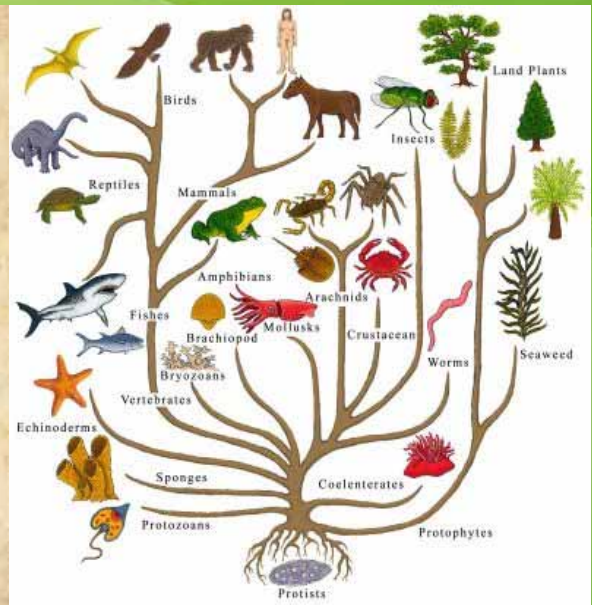
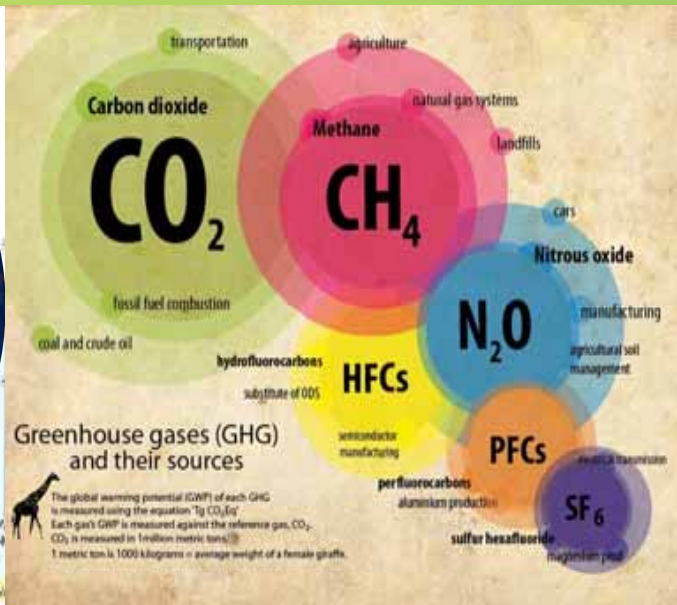
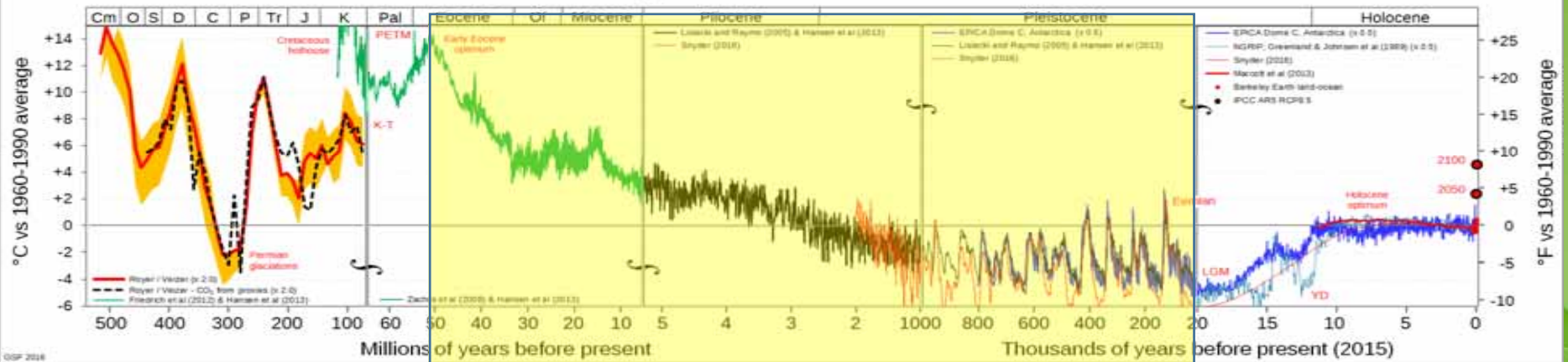


Earth's Climate - Patterns



Milankovitch Cycles-Patterns

Temperature of Planet Earth



The Greenhouse Effect

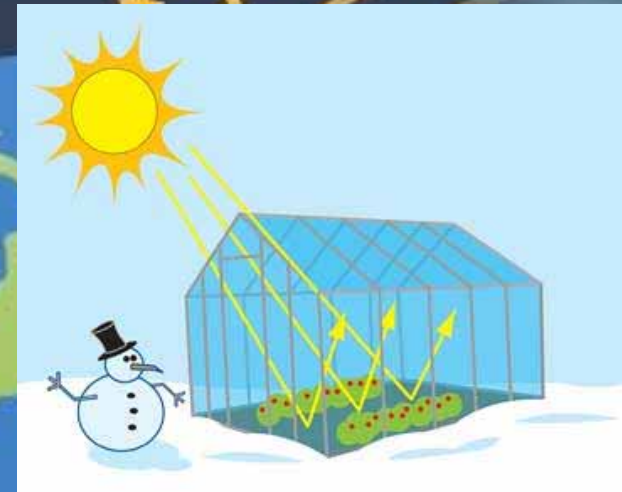
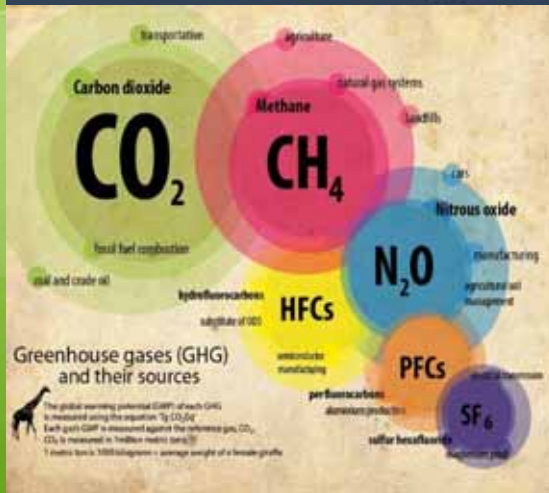
Greenhouse Effect

CO₂ and other gases in the atmosphere trap heat, keeping the Earth warm

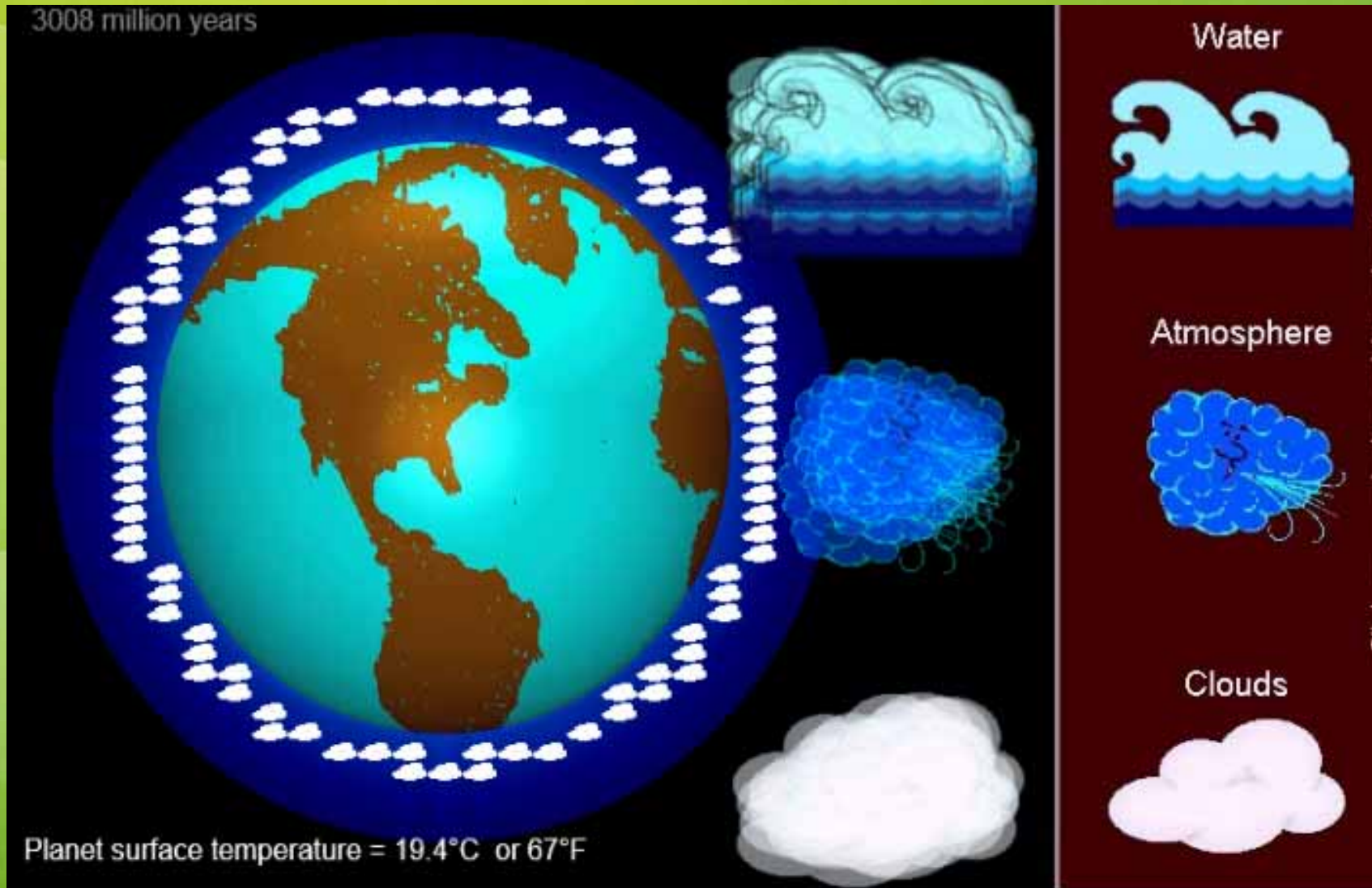


Short wavelength

Long wavelength



Make A Planet Simulator



Temperature Target: 60 Degrees F or 16 C

PHET: Greenhouse Effect

File Help

Greenhouse Effect Glass Layers Photon Absorption

The simulation shows a night scene with a satellite in the sky. A thermometer on the left indicates a temperature of 285K (53°F). The sky is dark blue with several yellow stars and red dots representing photons. A green hill with a yellow house and a red building is visible. The interface includes a legend, greenhouse gas concentration slider, atmosphere selection, greenhouse gas composition table, and options panel.

Legend

- Sunlight photon
- Infrared photon

Greenhouse Gas Concentration

None | | Lots

Atmosphere during...

- Today
- 1750
- Ice age
- Adjustable concentration

Greenhouse Gas Composition

H ₂ O	70% rel. humidity
CO ₂	388 ppm
CH ₄	1.843 ppm
N ₂ O	0.317 ppm

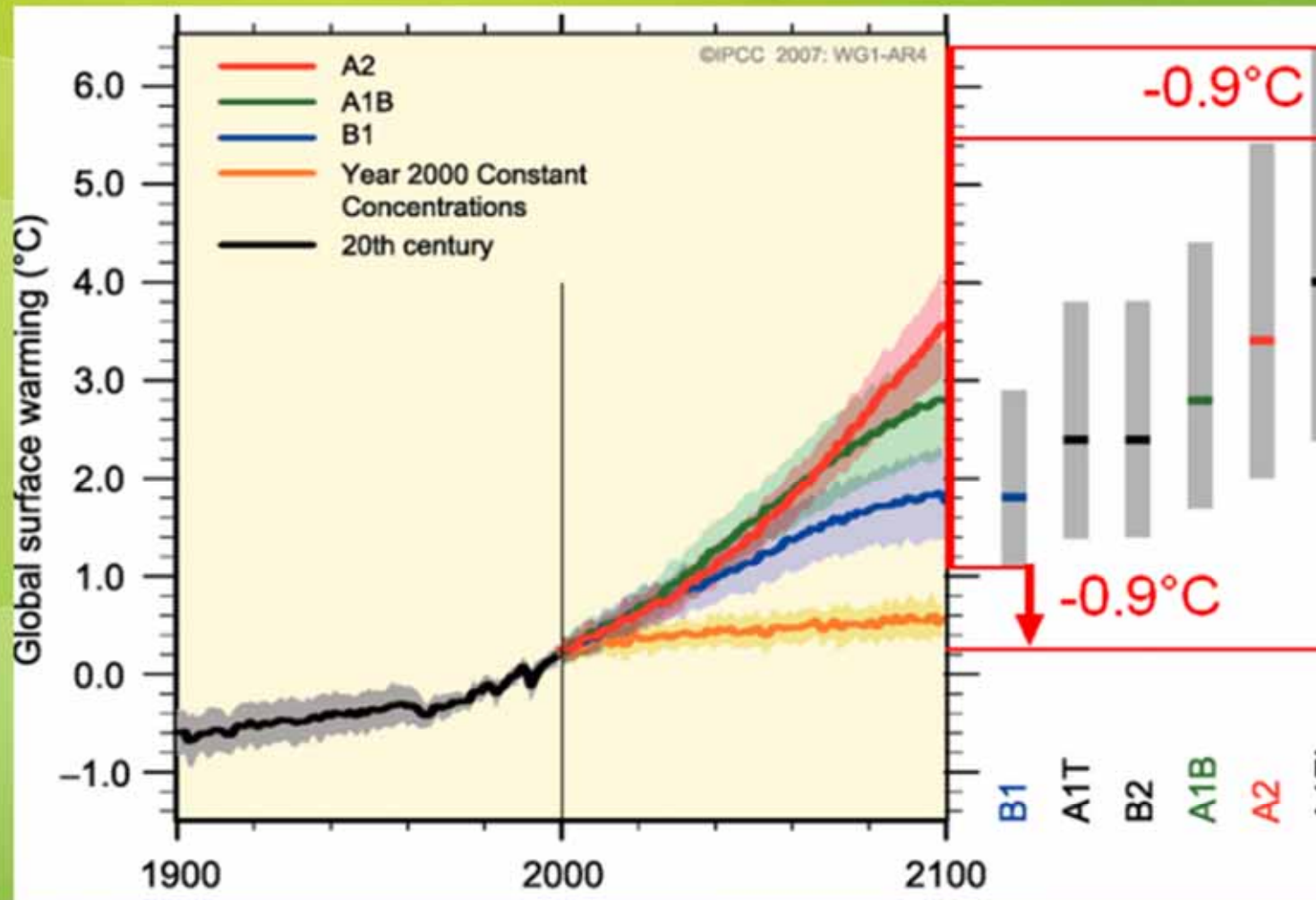
Options

- 0 Number of Clouds
- Thermometer
- Fahrenheit Celsius
- View all photons

slow fast

Reset All

IPCC Model Projections



The World's Scientists Trying To Predict A Number Of "What If" Situations and Impacts

Compare IPCC Scenarios

Scenario B2

Credits

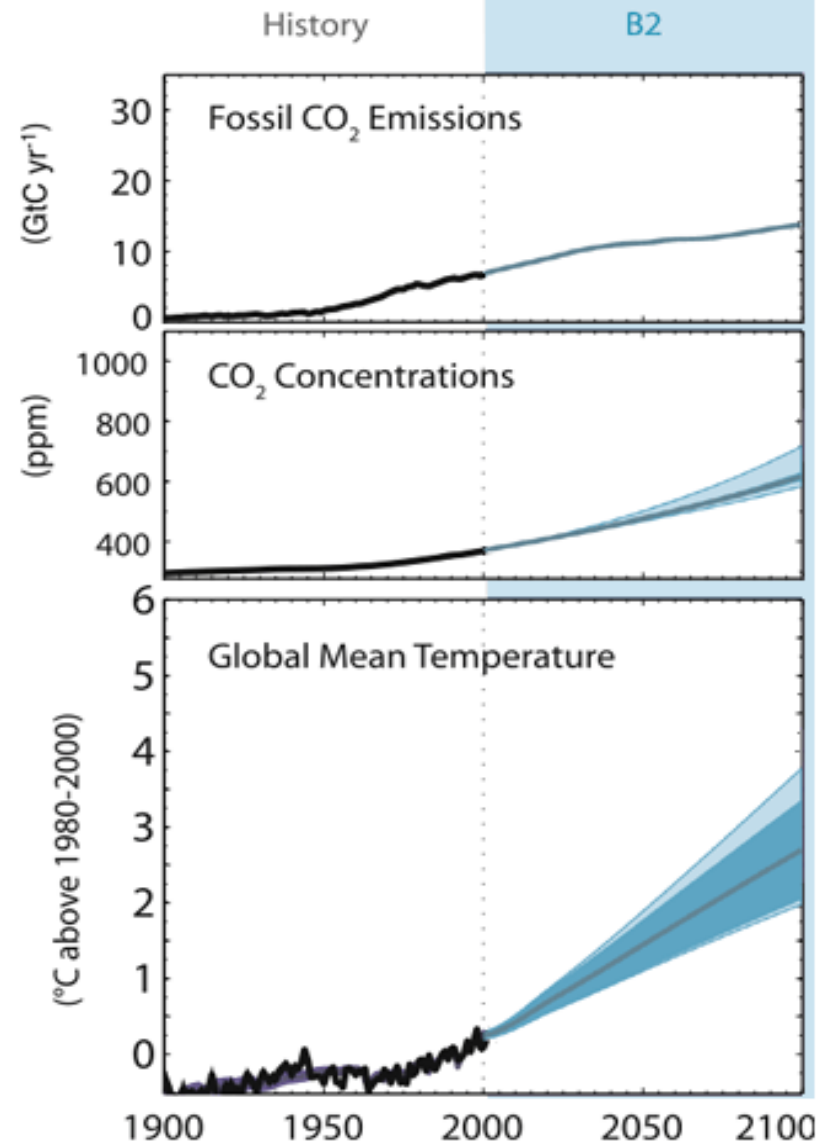
The **B2** storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

Population: Medium (~10 billion in 2100)

Economic Growth: Medium

Primary Energy Use: Medium

Land-use Change: Medium



Nature Conservancy Wizard



ClimateWizard



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[FAQ's](#)

[Contact Us](#)

[Follow @climatewizard](#)

Analysis Area	Time Period	Map Options	Measurement	Resources
<input checked="" type="radio"/> United States <input type="radio"/> Global <input type="text" value="United States"/>	<input type="radio"/> Past 50 Years <input type="radio"/> Mid Century (2050s) <input checked="" type="radio"/> End Century (2080s)	<input type="radio"/> Map of Average <input checked="" type="radio"/> Map of Change Compare & Animate Models	<input checked="" type="radio"/> Average Temperature <input type="radio"/> Precipitation <input type="text" value="Annual"/>	Case Studies Documentation Developer Data and Map Image Download ClimateWizard Custom Analysis Printer Friendly Version

Future Climate Model

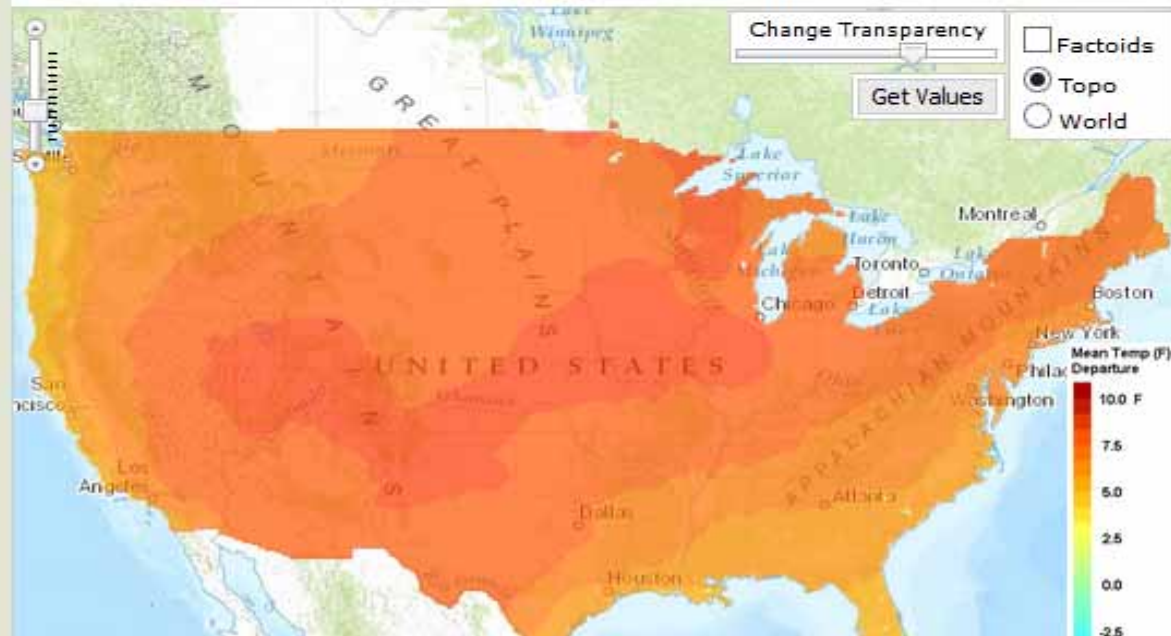
IPCC Fourth Assessment

Emission Scenario

General Circulation Model

Change in Annual Temperature by the 2080s

Model: Ensemble Average, SRES emission scenario: A2



50%: This map shows the temperature change projected by the middle model. That is, half of the models project a greater amount of change, and half of the models project less change as compared to the 1961-1990 baseline AVERAGE

NWT Niwot Ridge

Long Term Ecological Research (LTER)



LTER Network Member





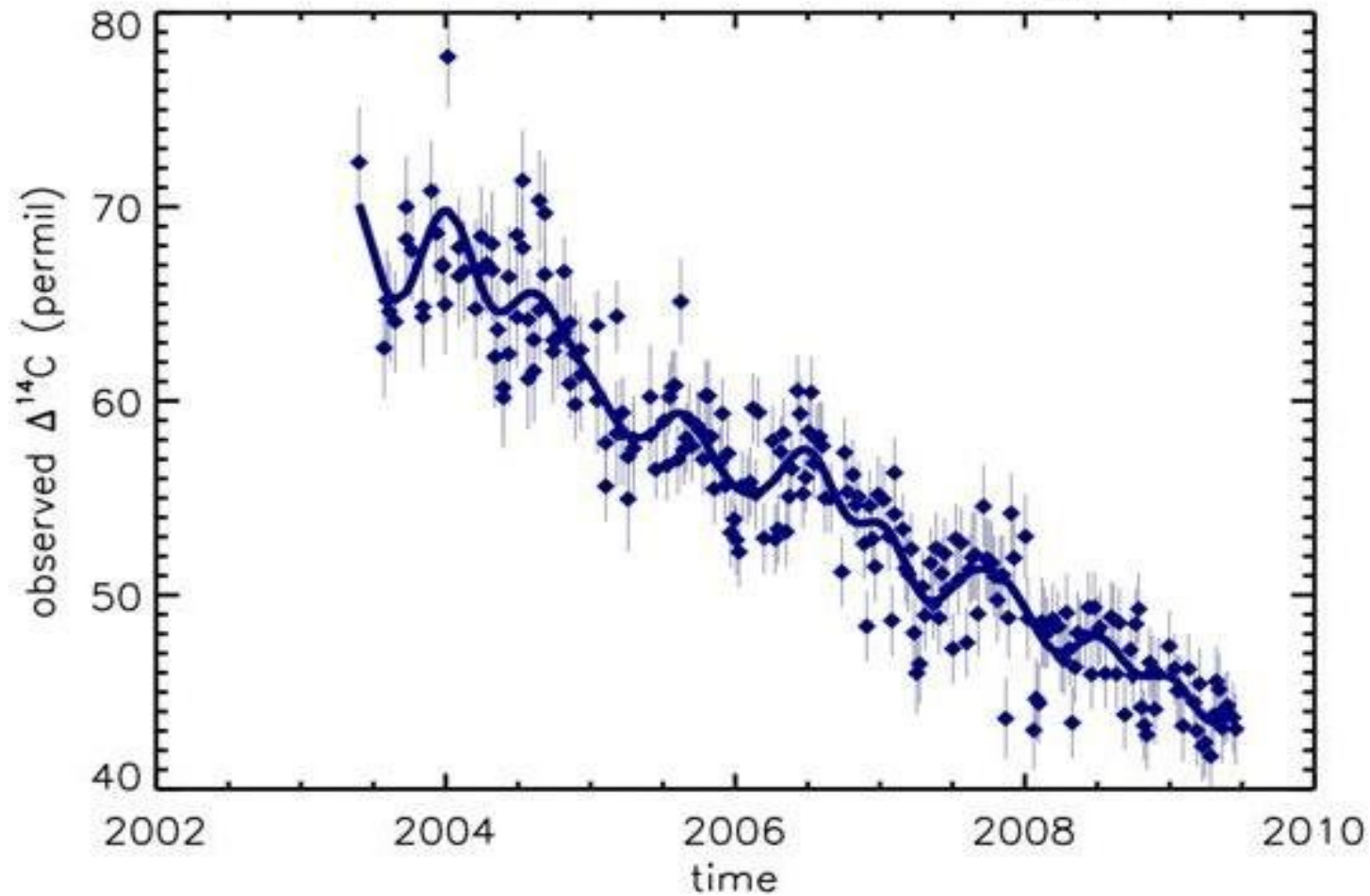
Niwot Ridge

Long Term Ecological Research (LTER)



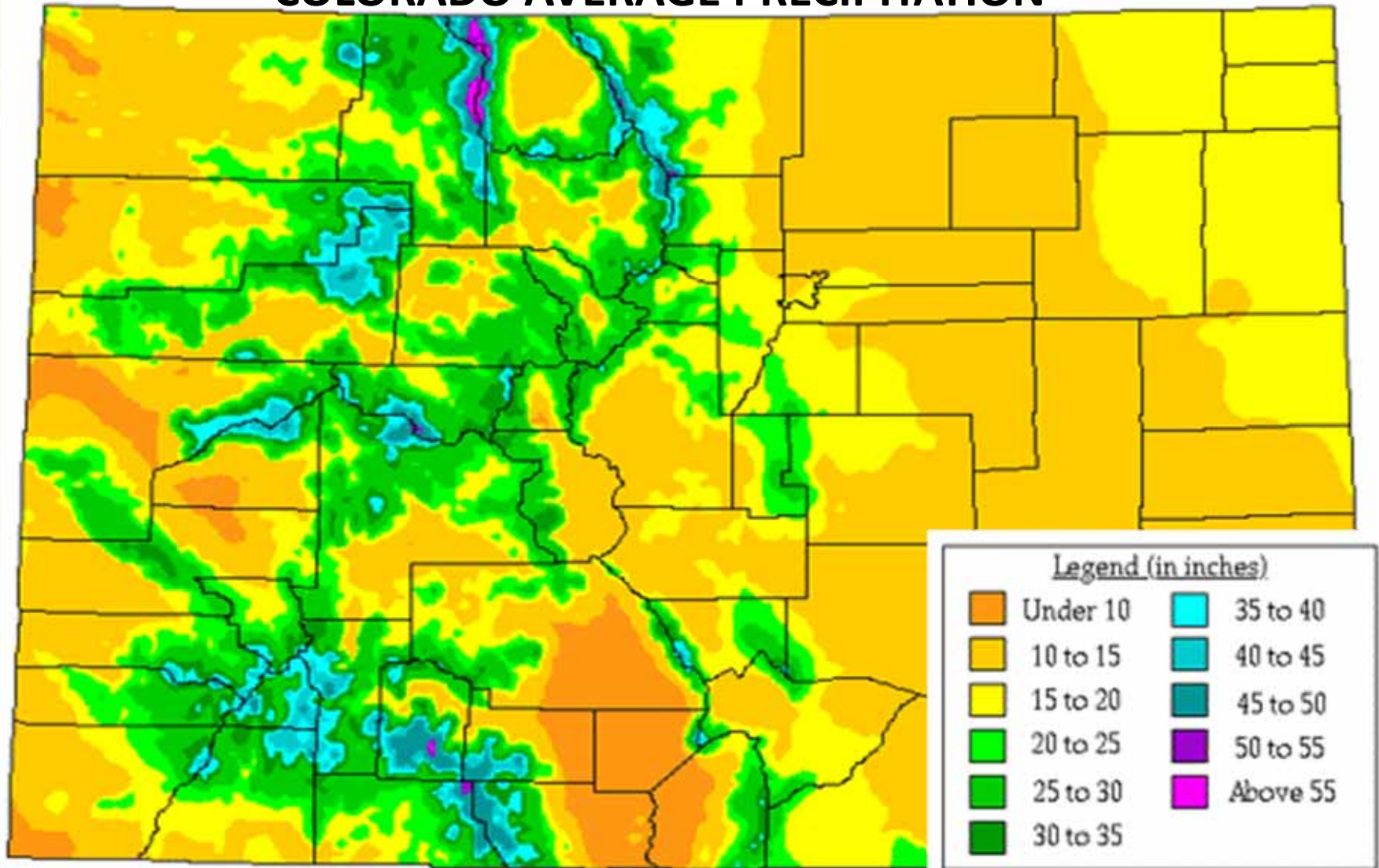
LTER Network Member

Clean Air Measurements at Niwot Ridge, Colorado



Climates Close To Home

COLORADO AVERAGE PRECIPITATION



Climate at a Glance ~ NOAA

Climate at a Glance

- Climate Monitoring
- State of the Climate
- Temp, Precip, and Drought
- Climate at a Glance
- Extremes
- Societal Impacts
- Snow and Ice
- Teleconnections
- GHCN Monthly
- Monitoring References

[Time Series](#) | [Mapping](#) | [Data Information](#) | [Background](#)

NCEI added Alaska climate divisions to its nClimDiv dataset on Friday, March 6, 2015, coincident with the release of the February 2015 monthly monitoring report. For more information on this data, please visit the Alaska Climate Divisions FAQ.

Time Series

[U.S.](#) | [Globe](#)

Choose from the options below and click "Plot" to create a time series graph.

Please note, Degree Days are not available for Agricultural Belts, NWS Regions, Alaska and Cities; Palmer Indices are not available for NWS Regions, Alaska and Cities.

Parameter:

Time Scale:

Month:

Start Year:

End Year:

State/Region:

Climate Division/City:

Options

Display Base Period
Start: End:

Display Trend
 per Decade per Century
Start: End:

Smoothed Time Series
 Binomial Filter LOESS

Plot

Move mouse towards an axis until highlighted. Left-click mouse to pan. Shift key + left-click to zoom.

Critical Zone Observatories



The Critical Zone is Earth's porous near-surface layer, from the tops of the trees down to the deepest groundwater. It is a living, breathing, constantly evolving boundary where rock, soil, water, air, and living organisms interact.

Resilience in Natural and Built Systems: Opportunities and Innovations in Community Sustainability

Colorado, Headwaters of the West:



Colorado Receives 2.8 Billion Gallons of Water/Year
80% falls as snow, and we only use about 33%.
67% is passed downstream to other users.



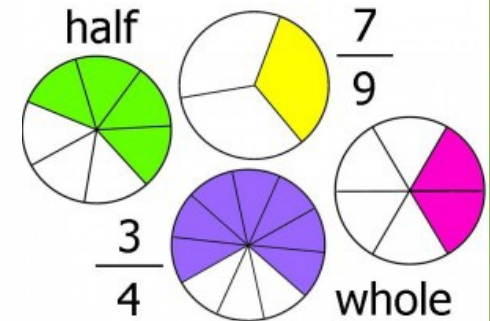
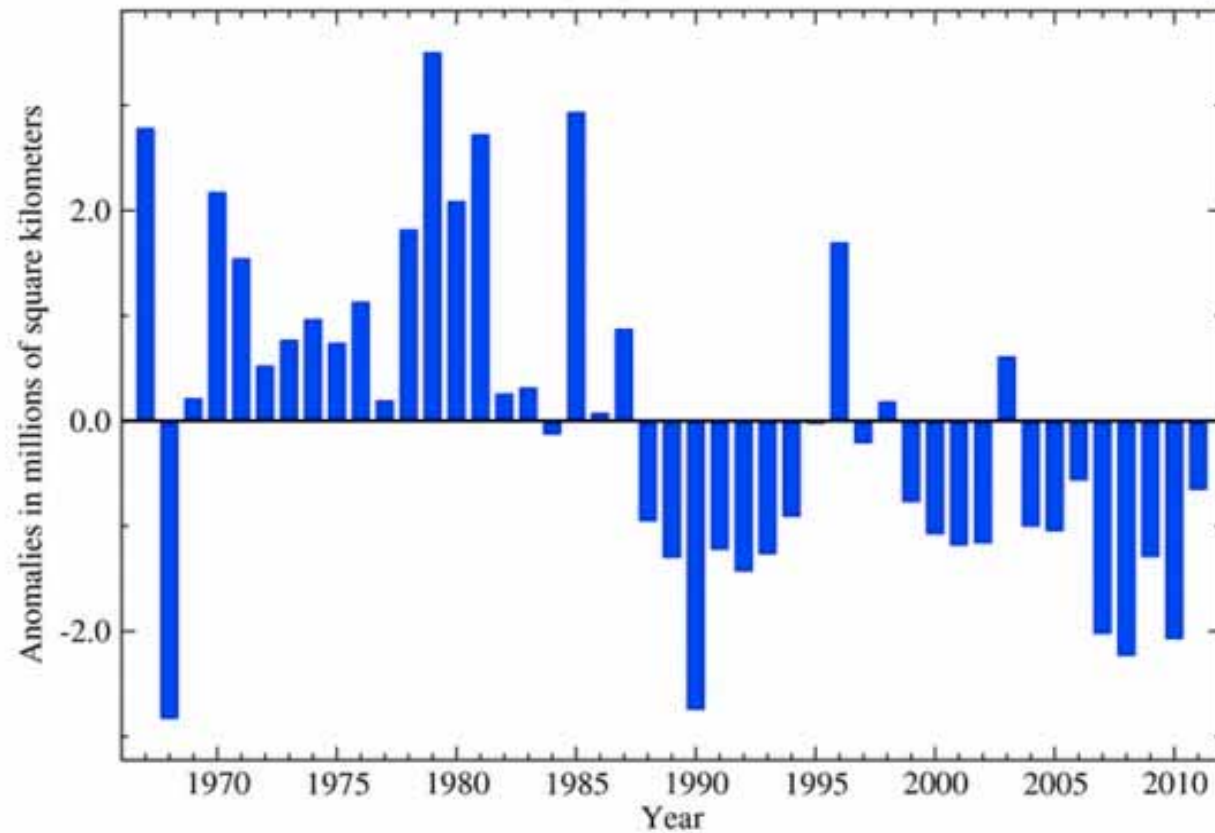
Snow Fractioning and Colorado's Water

Boulder Creek Critical Zone Observatory



Snow Fractioning and Colorado's Water

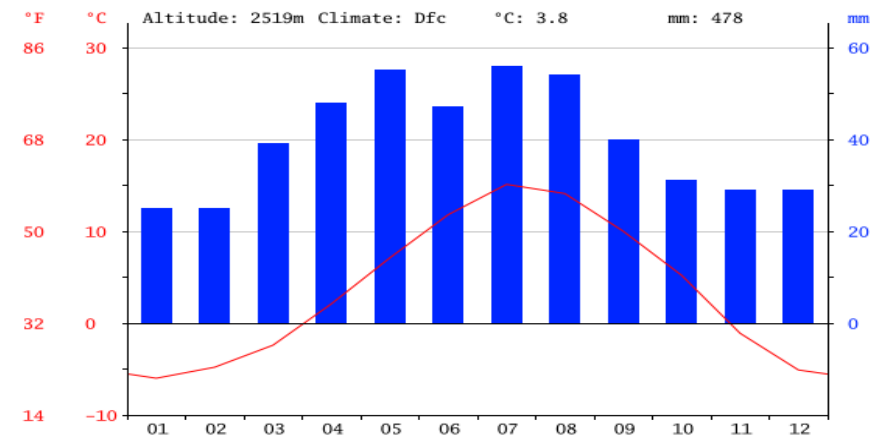
Northern Hemisphere Snow Cover Anomalies
Spring (1967-2011)



Snow Fractioning and Colorado's Water

Snow Fractioning for the Colorado Front Range in 2016-2017

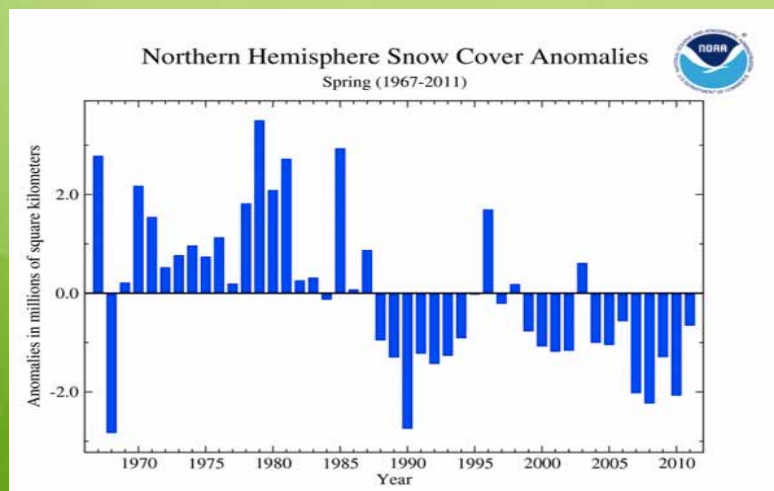
Month	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Precip. Total	40	30	20	30	30	40	20	60	40
Snow Fraction	<u>S/R</u> 25% 75%	<u>S/R</u> 66% 33%	<u>S/R</u> 100% 0%	<u>S/R</u> 100% 0%	<u>S/R</u> 100% 0%	<u>S/R</u> 100% 0%	<u>S/R</u> 100% 0%	<u>S/R</u> 75% 25%	<u>S/R</u> 25% 75%
Snow (ml)	10 ml	20 ml	20 ml	30 ml	30 ml	40 ml	20 ml	45 ml	10 ml
Rain (ml)	30 ml	10 ml	0 ml	0 ml	0 ml	0 ml	0 ml	15 ml	30 ml



Snow Fractioning and Colorado's Water

Snow Fractioning for the Colorado Front Range in 1990-1991

Month	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Precip. Total	40	30	20	30	30	40	20	60	40
Snow Fraction	$\frac{S}{R}$ 0% 100%	$\frac{S}{R}$ 33% 66%	$\frac{S}{R}$ 50% 50%	$\frac{S}{R}$ 66% 33%	$\frac{S}{R}$ 100% 0%	$\frac{S}{R}$ 100% 0%	$\frac{S}{R}$ 25% 75%	$\frac{S}{R}$ 50% 50%	$\frac{S}{R}$ 0% 100%
Snow (ml)	0 ml	10 ml	10 ml	20 ml	30 ml	40 ml	5 ml	30 ml	0 ml
Rain (ml)	40 ml	20 ml	10 ml	10 ml	0 ml	0 ml	15 ml	30 ml	40 ml



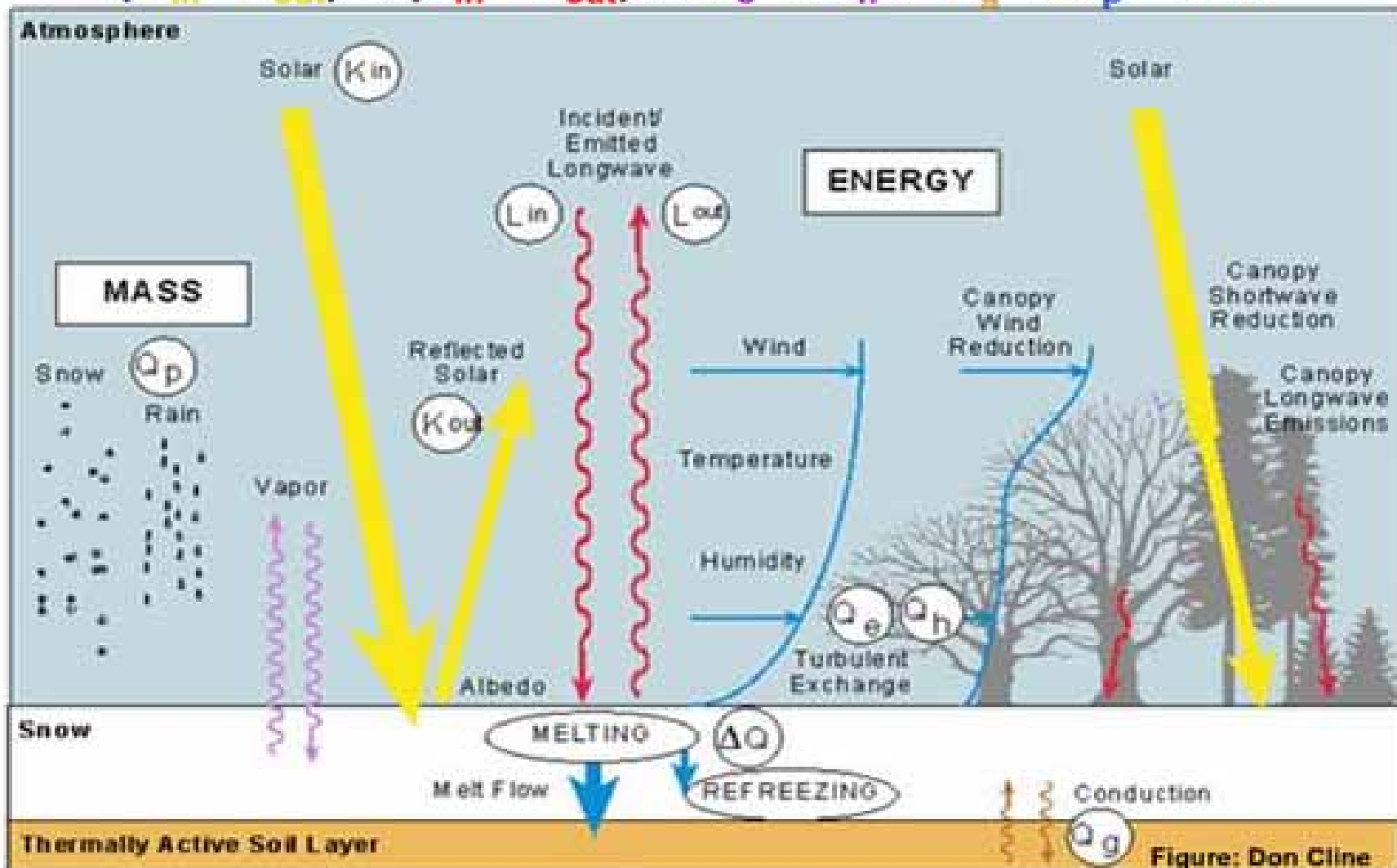
Snow Fractioning for the Colorado Front Range in 2016-2017

Month	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Precip. Total	40	30	20	30	30	40	20	60	40
Snow Fraction	<u>S/R</u> 25% 75%	<u>S/R</u> 66% 33%	<u>S/R</u> 100% 0%	<u>S/R</u> 100% 0%	<u>S/R</u> 100% 0%	<u>S/R</u> 100% 0%	<u>S/R</u> 100% 0%	<u>S/R</u> 75% 25%	<u>S/R</u> 25% 75%
Snow (ml)	10	20	20	30	30	40	20	45	10
Rain (ml)	30	10	0	0	0	0	0	15	40

Snow Fractioning for the Colorado Front Range in 1990-1991

Month	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Precip. Total	40	30	20	30	30	40	20	60	40
Snow Fraction	<u>S/R</u> 0% 100%	<u>S/R</u> 33% 66%	<u>S/R</u> 50% 50%	<u>S/R</u> 66% 33%	<u>S/R</u> 100% 0%	<u>S/R</u> 100% 0%	<u>S/R</u> 25% 75%	<u>S/R</u> 50% 50%	<u>S/R</u> 0% 100%
Snow (ml)	0 ml	10 ml	10 ml	20 ml	30 ml	40 ml	5 ml	30 ml	0 ml
Rain (ml)	40 ml	20 ml	10 ml	10 ml	0 ml	0 ml	15 ml	30 ml	40 ml

$$(K_{in} - K_{out}) + (L_{in} - L_{out}) + Q_e + Q_h + Q_g + Q_p = \Delta Q$$



K = shortwave

Q_e = latent heat flux

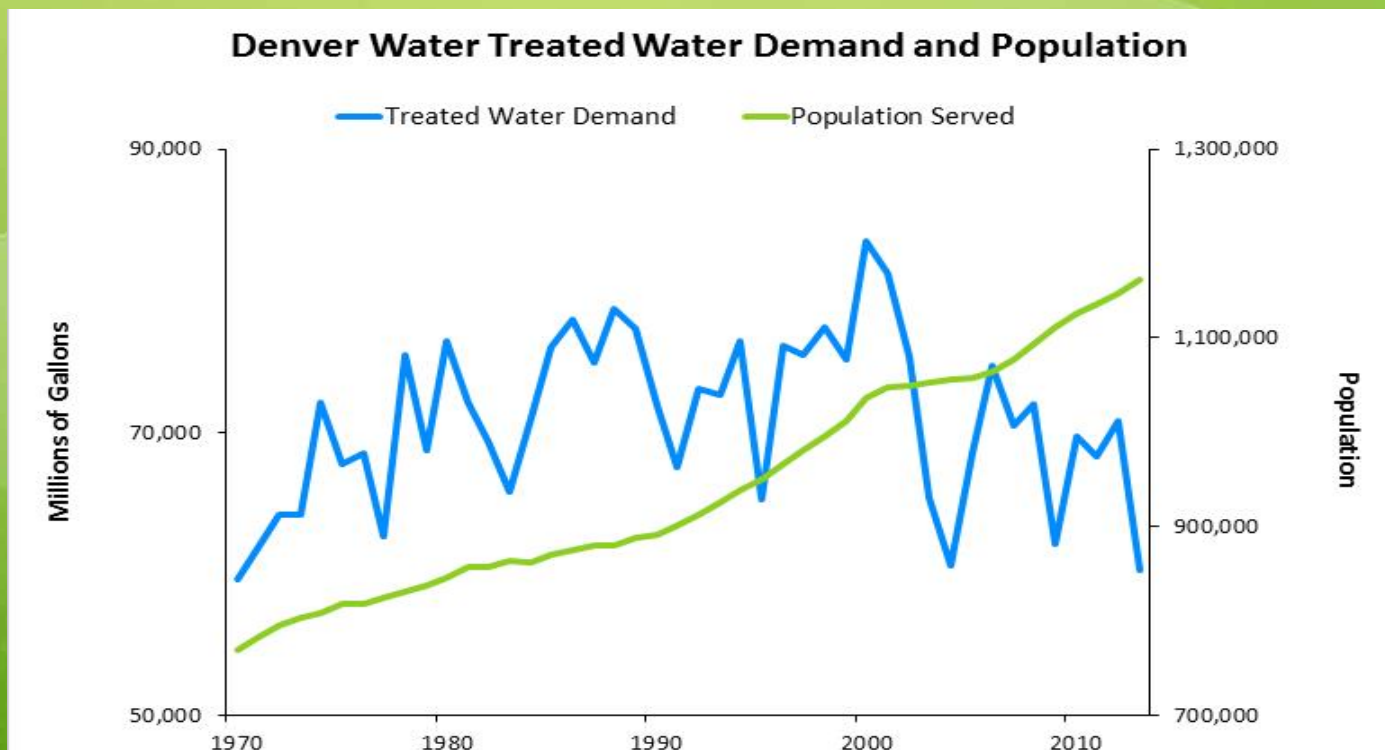
Q_g = ground source

L = longwave

Q_h = sensible heat flux

Q_p = precip source

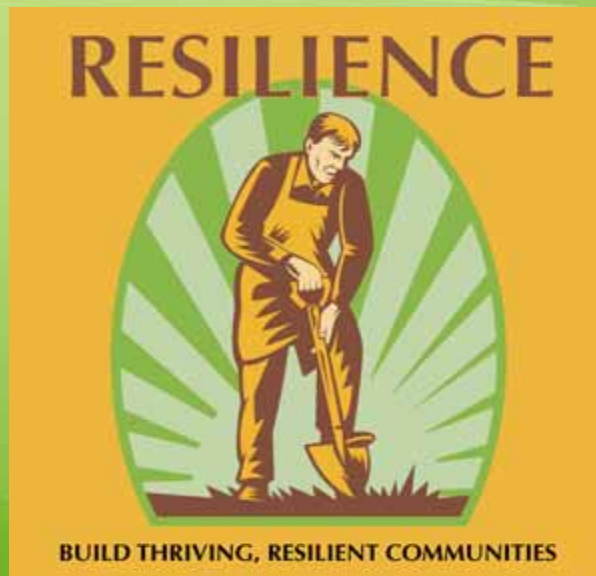
Resilience in Natural and Built Systems: Opportunities and Innovations in Community Sustainability



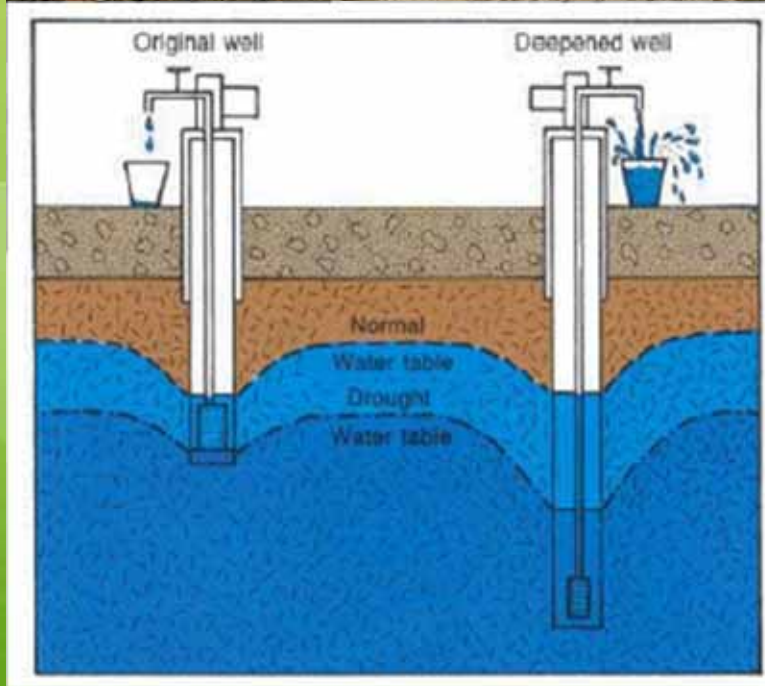
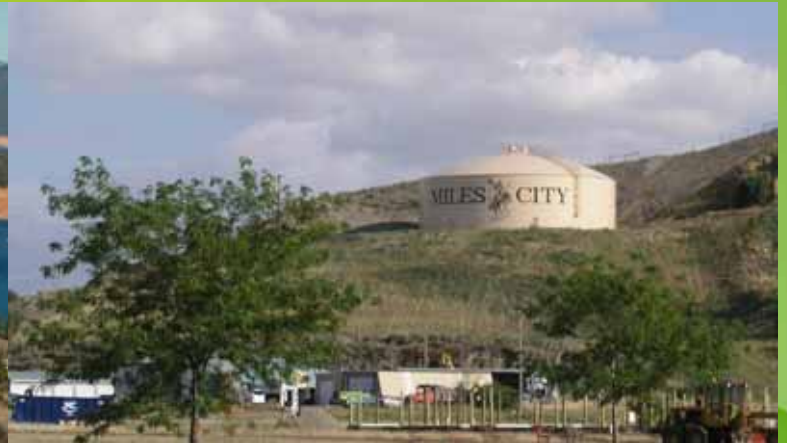
Colorado's Boulder Creek CZO

Boulder
Creek





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RESILIENCE



BUILD THRIVING, RESILIENT COMMUNITIES