But
What are the Questions?

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Non Sequitur by Wiley Miller

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C'MON, JEFFREY... MY PLAN IS PERFECT
NOTHING IS PERFECT, DANNIE. USING TIME TRAVEL FOR PERSONAL GAIN ALWAYS HAS UNINTENDED CONSEQUENCES
NO, NO... IT'S MY GIFT TO THE WORLD! HEY, WHO WOULDN'T WANT AN ENDLESS SUMMER?
I'M GUESSING PEOPLE IN THE OTHER HEMISPHERE WOULD HAVE AN ENDLESS WINTER

ANOTHER UTOPIAN PICNIC RAINED OUT BY SCIENCE
SORRY... REALITY IS A HARSH TASKMASTER
Useful Simile

“Weather ~ Mood
Climate ~ Personality”
Causes of Weather

Daily changes in the weather are due to winds and storms. Seasonal changes are due to the Earth revolving around the sun. Because the Earth is round and not flat, the Sun's rays don't fall evenly on the land and oceans. The Sun shines more directly near the equator bringing these areas more warmth. Differential heating and cooling of the Ocean and land areas may cause movement of air.

Heating and cooling of the atmosphere causes air to move from one place to the other.

Heating causes air to rise and is less dense than cold air
Cooling causes air to fall because of the density change
Thus we have vertical movement

Water contained in the atmosphere increases with the warming of the air and decreases with the cooling of the air
Warm air can hold more moisture than cold air
Thus, we have the mechanisms that cause weather

In Summary
1) Factors that interact to cause weather are heat energy, air pressure, winds, and moisture in the air.
2) Heat energy is transferred by conduction, convection, or radiation.
3) Air temperature varies depending upon the angle at which the sun's rays strike the earth.
4) Air pressure depends on the density of the air.
Causes of Climate

The basic factors that determine climate are temperature and precipitation.

Factors that affect temperature are latitude, elevation, and the presence of ocean currents.

Factors that affect precipitation are prevailing winds and the presence of mountain ranges.

The earth's three major climate zones are the polar, temperate, and tropical zones.

Marine climates and continental climates occur within each of the three major climate zones.

Natural factors that may cause changes in climate are continental drift, changes in the sun's energy output, and variations in the tilt of the earth's axis and the shape of the earth's orbit.

Or it can be said that the effects of human activities, continental drift, volcanic eruptions, where the earth is in its orbit, and where the solar system is in its travel through the galaxy. All these factors determine or lead to global warming or cooling and overall climate change.
Issues Associated With Climate Study

1. What is the evidence that the Earth’s climate is changing?
2. What controls the Earth’s climate?
3. How are Earth’s climate controls changing?
4. What is responsible for these changes?
5. What is the future for Earth’s climate?
Essential for Life?

Water
Essential for Life

Carbon
Essential for Life

Energy
Water
Carbon
Energy
LIFE
Whoa – Way too Complicated

Still too Complicated
Come on – Way too Simple
Greenhouse Effect

1. Short-wavelength IR light from the Sun passes through the glass.

2. Everything in the greenhouse absorbs short-wave-length IR light and becomes warmer.

3. Now warmed, the objects give off long-wave-length IR light.

4. In turn, the glass absorbs the long-wavelength IR and warms up. It gives off long-wavelength IR, which mostly shines back into the greenhouse.
The Greenhouse Effect

(a) Rays of sunlight penetrate the lower atmosphere and warm the earth's surface.

(b) The earth's surface absorbs much of the incoming solar radiation and degrades it to longer-wavelength infrared radiation (heat), which rises into the lower atmosphere. Some of this heat escapes into space and some is absorbed by molecules of greenhouse gases and emitted as infrared radiation, which warms the lower atmosphere.

(c) As concentrations of greenhouse gases rise, their molecules absorb and emit more infrared radiation, which adds more heat to the lower atmosphere.
Earth’s climate controls

Energy balance: effect of atmospheric gases
Key Role for the Atmosphere:

Planet Temperatures Predicted If NO ATMOSPHERES

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*-18 Celsius ~ 0 Fahrenheit

Source: ACS
### Climate Science Basics

#### Actual Earth Temperature is 15 Celsius, ~60 Fahrenheit

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**Why?**

[www.acs.org/climatescience](http://www.acs.org/climatescience)
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Temperature depends upon how much atmosphere is present and its composition.

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Climate Science Basics

Electromagnetic radiation and planetary energy balance

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15 Celsius
~60 Fahrenheit

| Atmosphere: Pressure, kPa composition | 101
N$_2$(0.78), O$_2$(0.21), Ar(0.009), [CO$_2$, H$_2$O] | 0.64
CO$_2$(0.95), N$_2$(0.03), Ar(0.02), [O$_2$, CO] |

[trace gases]

Source: ACS

Measured Atmospheric Pressures
The Science of Climate

**HOWEVER**

Earth’s climate is changing!
Sea Level Rise, Updated 2013

Rate = 3.2 ± 0.4 mm/yr
Seasonal signals removed

http://sealevel.colorado.edu/content/2013rel5-global-mean-sea-level-time-series-seasonal-signals-removed
If All The Ice Melted
Evidence that Earth’s climate is changing

Grinnell Glacier, Glacier Nat’l Park, 1940

Grinnell Glacier, Glacier Nat’l Park, 2006

Source: NOAA

Disappearing Land ice
Sea Ice

At the North Pole

Total extent = 4.7 million sq km
The Science of Climate

Evidence that Earth’s climate is changing

Are extreme weather events—droughts, wildfires, storms, floods—increasing?
Why the Abrupt Changes?

Earth’s climate controls have changed

Source: Robert A. Rohde, Wikimedia Commons
Why the Abrupt Changes?

Earth’s climate controls have changed

Source: Robert A. Rohde, Wikimedia Commons
Industrial Revolution and Climate Science

The Industrial Revolution:

Enormous benefit for humanity.

Energy price tag paid by burning fossil fuel.

Unintended consequence--changing Earth's climate.

Plausible Mitigation Approaches:

Use All energy sources efficiently.

Employ alternative non-carbon-emitting sources.

Reduce the impact of carbon-emitting sources.
Not Necessarily a Great Solution

Later this century...

Somehow I thought that we'd have come up with a better solution to global warming than gas-powered, air-conditioned heat suits.
In Our Lifetime

Atmospheric CO$_2$ at Mauna Loa Observatory

Scripps Institution of Oceanography
NOAA Earth System Research Laboratory

In 2013
Cause of climate changes
Mainly fossil fuel burning

Greenhouse Gases

Source: IPCC
Electromagnetic radiation and planetary energy balance
Since the Industrial Revolution, burning coal, oil, & gas has added large amounts of greenhouse gases to Earth's atmosphere.

energy imbalance - larger
...atmosphere — with all the clouds and gases in there — acts, metaphorically, like a thick, insulating blanket; ...warms via the same mechanism that blankets keep you warm: by absorbing its own heat and re-radiating it back on itself.

A heavier blanket will keep you warmer, and more blankets will increase the effect as well. It’s not hard, with enough blankets, to heat yourself up to well above your normal body temperature; you have to be careful not to overdo it!

The Science of Climate

Earth’s climate controls have changed
Effect on energy and temperature

Our planet is building up heat

- **Ocean Heating**
- **Land & Atmosphere Heating**

Source: Skeptical Science

CO2 and Temperature over the 20th Century

- CO2: Law Dome, Antarctica
- CO2: Mauna Loa
- Global Temperature Anomaly (NASA GISS)

Source: Skeptical Science
The Science of Climate

Earth’s climate future

More of what we already observe

Source: Colorado University Sea Level Research Group
Future of Climate Change?
Pessimism/Optimism

Worst case scenario:

Mid-2009: The U.N. Environment Programme predicts a 3.5°C increase by 2100. Such an increase would remove habitat for human beings on this planet, .... Humans have never lived on a planet at 3.5°C above baseline.

A briefing provided to the U.N. Conference of the Parties in Copenhagen: “The long-term sea level that corresponds to current CO2 concentration is about 23 meters above today’s levels,......based on real long-term climate records, not on models.”
Climate Change Simply Put
CLIMATE SUMMIT

WHAT IF IT'S A BIG HOAX AND WE CREATE A BETTER WORLD FOR NOTHING?

- ENERGY INDEPENDENCE
- PRESERVE RAINFORESTS
- SUSTAINABILITY
- GREEN JOBS
- LIVABLE CITIES
- RENEWABLES
- CLEAN WATER, AIR
- HEALTHY CHILDREN
- ETC. ETC.
Simple US Example?
Latest Intrigue – Climate Change?
Here is A Scary Explanation
What Is Really Scary – Even Tree Rings Are Telling Us

Tree ring data show a warming trend

Roughly 1880
The Trees Talk and are all saying the same thing
"That's all Folks!"

http://aspoireland.org/