Energy Balance Model: Planetary Variability

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Agenda

Masks

Solar variability

Longwave radiation

Obliquity

Eccentricity

Exoplanets

Questions at the end

Introduction

I am looking at factors that influence global equilibrium temperatures by changing planetary properties.

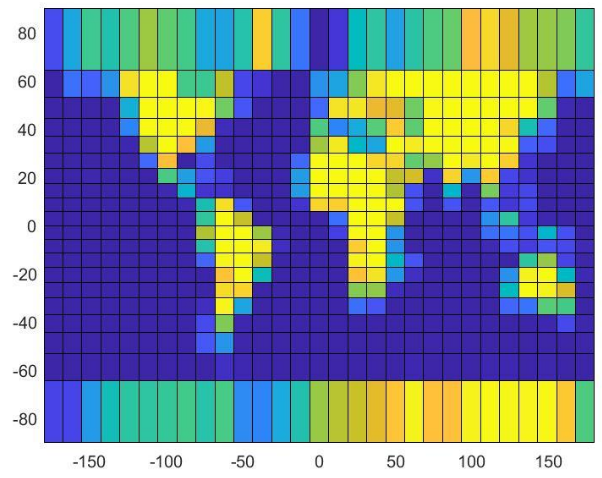
We experimented with some parameter adjustments in class, but here we'll look at changes to the central star of the system, as well as orbital changes and other properties one at a time to see which have the biggest impact.

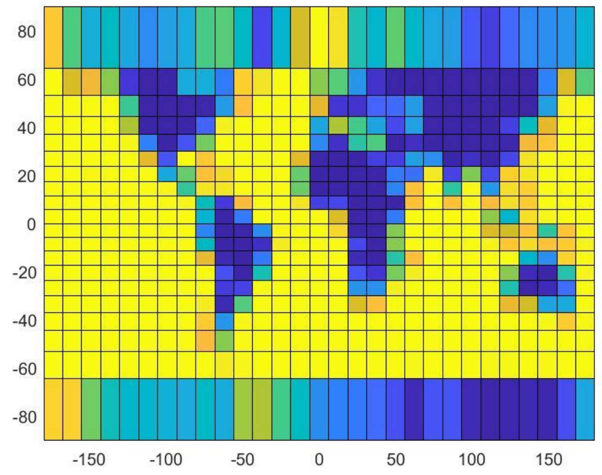
At the end, the goal will be to examine combinations of these features that might be found in exoplanets to see what happens.

Planetary Masks

Other worlds

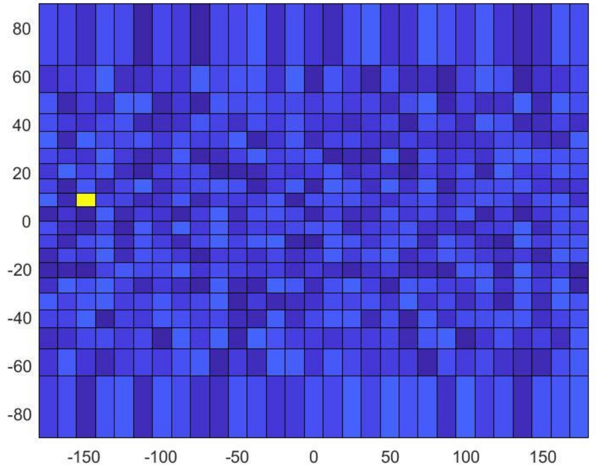
Planetary Masks

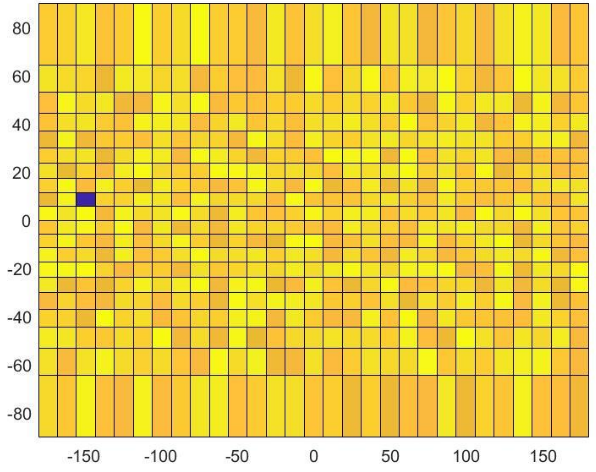




Earth (original) and Reverse Earth

Planetary Masks

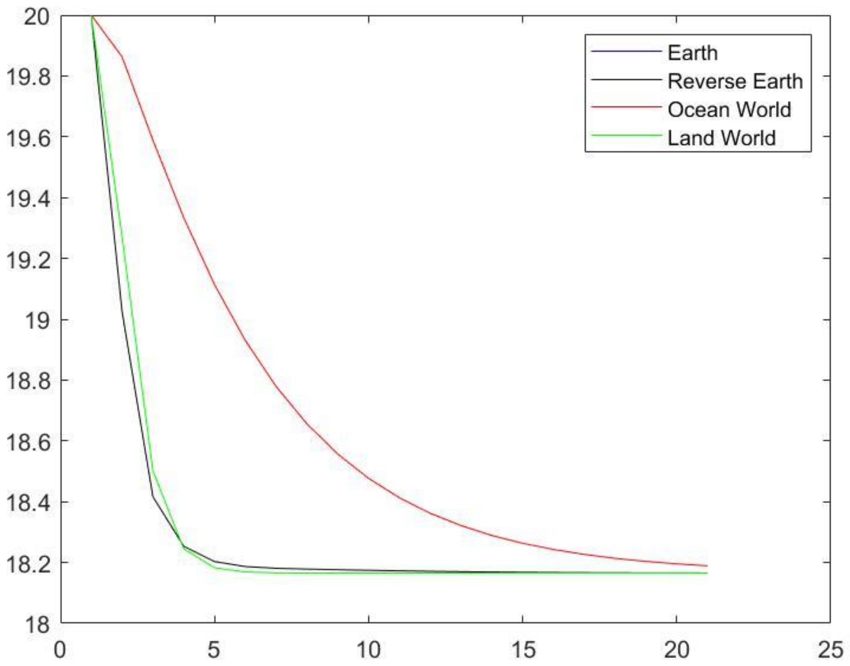




Ocean world, and Land world

Global Equilibrium Temperatures

	Earth Mask	Reverse Earth	Ocean Mask	Land Mask
Global Mean Temp	18.1652	18.1674	18.1892	18.1652



Global Equilibrium Temperature for different masks in degrees Celsius

Solar Variability

Different suns, different times

Timeline

When the Solar System formed, solar output was only 68% of its present value. But the Earth was also still molten

Humans have evolved to survive in present climate conditions, with global mean temperatures around 18 degrees Celsius.

Eventually, the Sun will expand to a gas giant and probably swallow the Earth whole, but before that happens, solar energy output will increase so much that the oceans will boil away. Energy output in 5 billions years will be 61% higher than it is now.

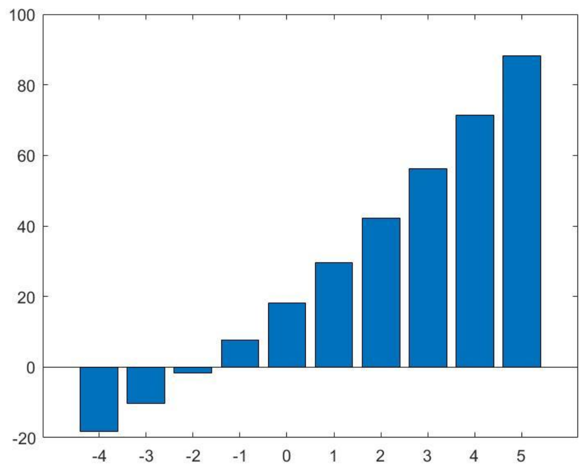
Snowball Earth? | Old Earth | Now | Future Earth | Endtimes

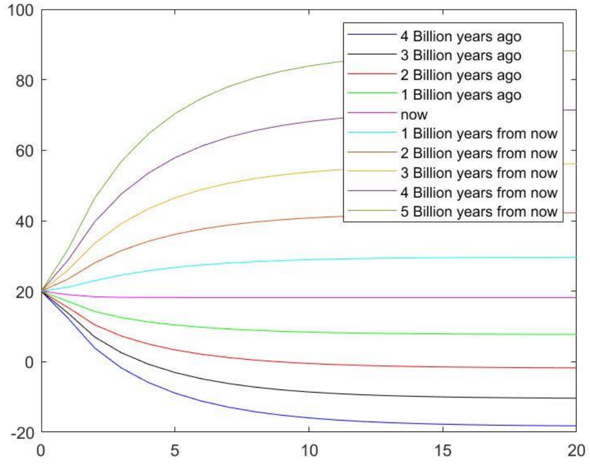
As the Sun ages, its output increases. Without more greenhouse gasses, global mean temperatures would still be below freezing 2 billion years ago.

As the Sun ages, its energy output continues to increase. In 2 billion years, the global mean temperature will be over 40 degrees Celsius: too hot for humans.

Solar Variability over the Life of the Sun

Epoch	Solar Constant (Wm^{-2})	Global Mean Temperature (Celsius)
4 billion years ago	928.9	-18.2078
3 billion years ago	1021.8	-10.3629
2 billion years ago	1124.0	-1.7419
1 billion years ago	1236.4	7.7395
Now	1360.0	18.1656
1 billion years from now	1496.0	29.6377
2 billion years from now	1645.6	42.2570
3 billion years from now	1810.2	56.1417
4 billion years from now	1991.2	71.4097
5 billion years from now	2190.3	88.2045





As the Sun ages, its energy output increases

Other possible areas to explore:

changing distance
solar flares

Red dwarfs are particularly volatile and
may endanger exoplanet habitability:
may test with Monte Carlo simulation?

Outgoing Longwave Radiation

Not all planets emit the same amount of energy

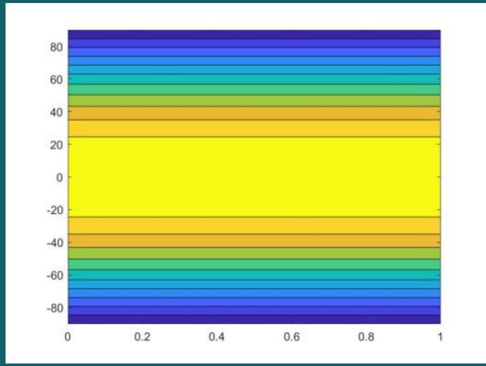
Coming Soon

- We experimented with adjusting these values in the Week 5 practical, but my goal here is to add context to adjusting these numbers.
- We know Venus is hot. What are the numbers for the Longwave radiation for Venus?
- We know Mars is cold. What are their numbers?
- I’ve found some values but looking for a complete set for both planets.

Obliquity

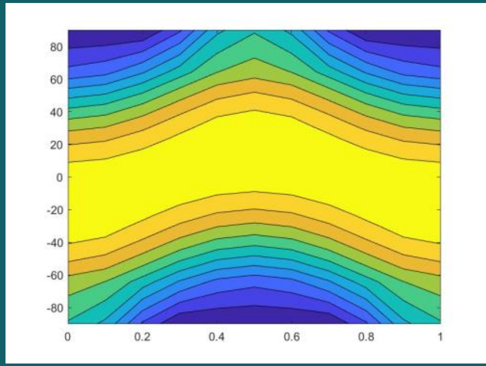
How does axial list impact climate?

Obliquity impact on insolation



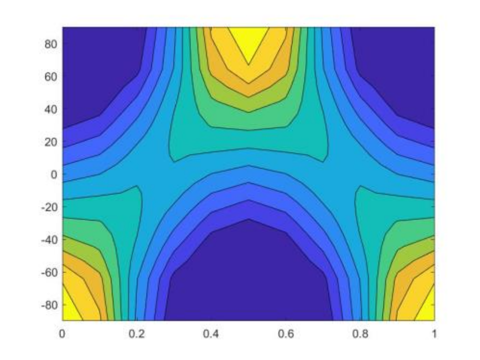
0-degree tilt

Variation only by latitude, not time of year



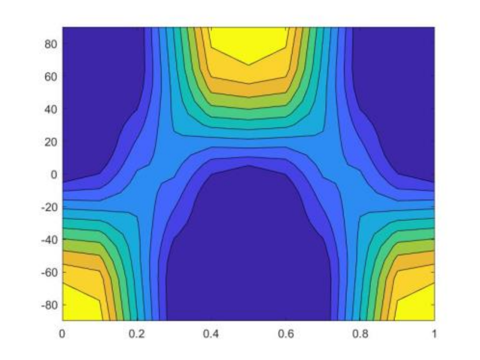
10-degree tilt

Variation pattern forms wavelike pattern as angle increases



45-degree tilt

Periods of bright sun and little sun creep towards the equator



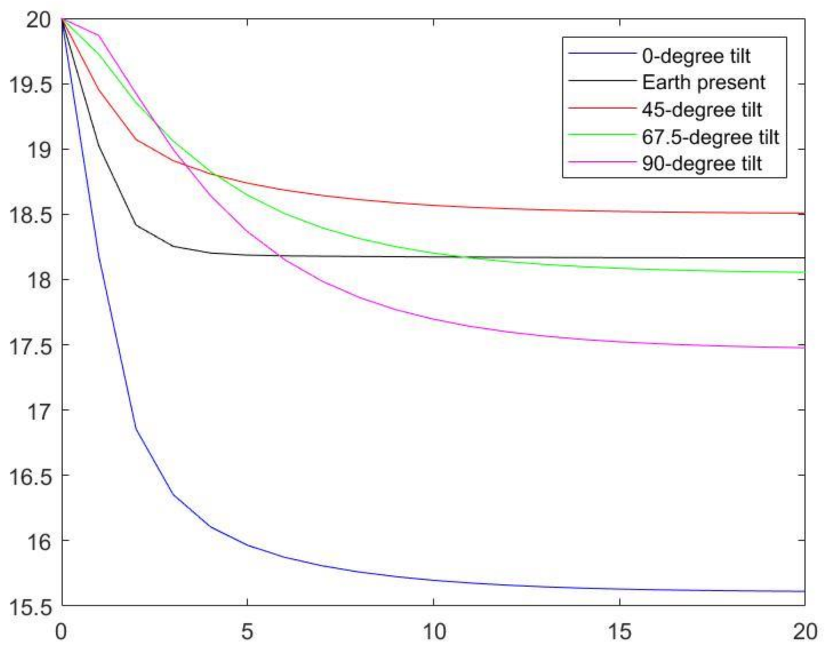
90-degree tilt

Periods of darkness extend to the equator, extremes increase

Insolation is the amount of sunlight reaching the surface at a given latitude

Obliquity affects global mean temp

- Obliquity has some impact on global mean temperatures. 0-degree tilt has the lowest global mean temperature
- Highest global mean temperatures at 45-degrees
- Global mean temperature at 90-degrees is higher than at 0-degrees.

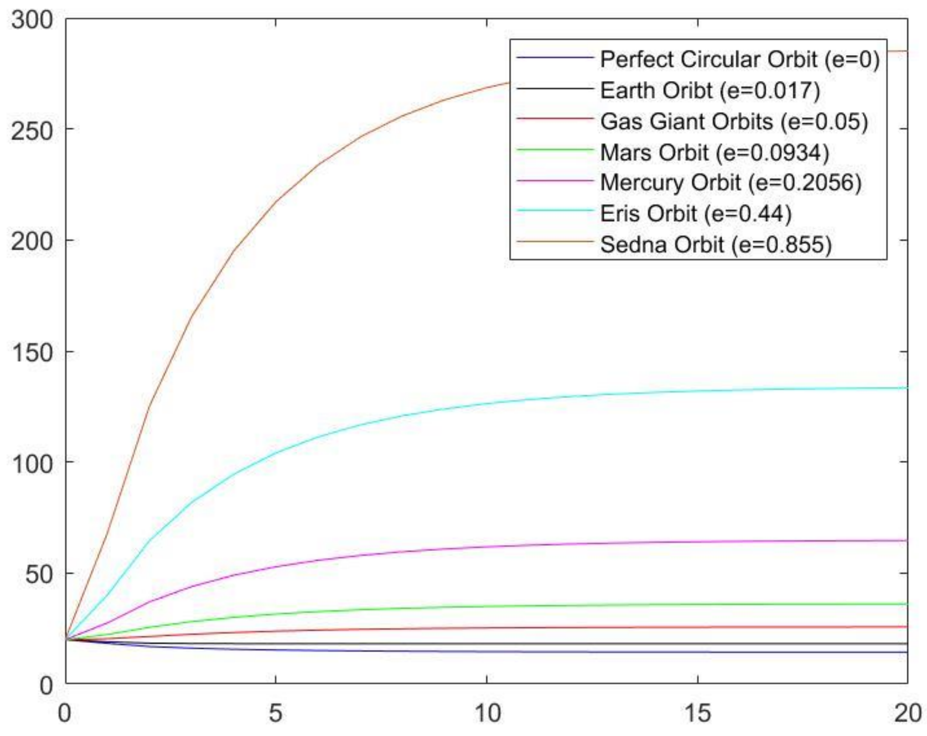


Orbital Eccentricity

Not all planetary orbits are nearly circular

Orbital Eccentricities

Planet	Eccentricity	Global Mean Temperature
Perfect Circle	0	14.3623
Earth	0.017	18.1656
Gas Giants (Uranus, Jupiter, and Saturn)	~0.05	25.7314
Mars	0.0934	36.0494
Mercury	0.2056	64.6604
Eris	0.44	133.4438
Sedna	0.855	285.1156

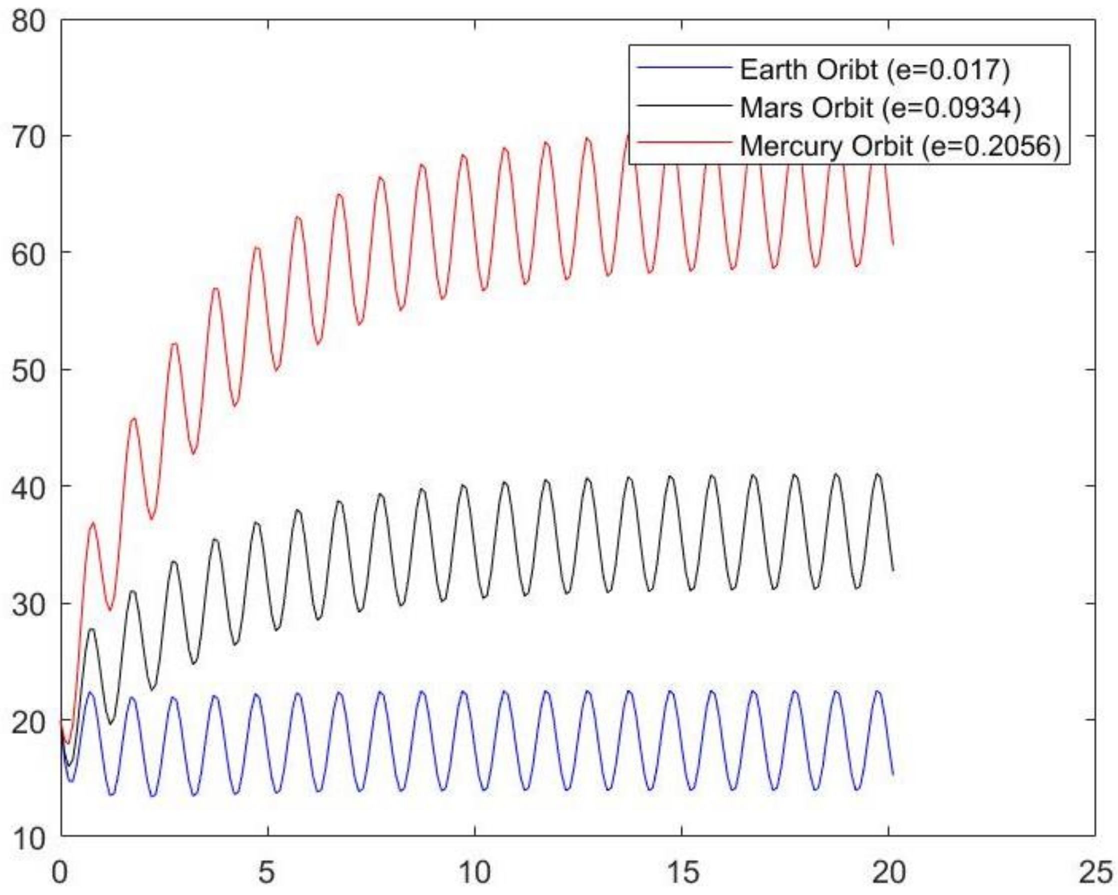


"ecc" variable in code is actually e+1

Temperature Variability for Three Orbital Eccentricities

Orbital eccentricities mean that the planet gets closer to the Sun and takes up more energy and can't radiate it away fast enough. This drives up the temperature. And the more eccentric the orbit, the higher the temperature rises in this model.

I'm not sure how realistic this is. As the temperature rises, the planet would have to radiate more energy into space, but in this model the outgoing radiation values are constant.



Exoplanets

Planetary systems don’t only differ from the Earth in one dimension.

Coming Soon

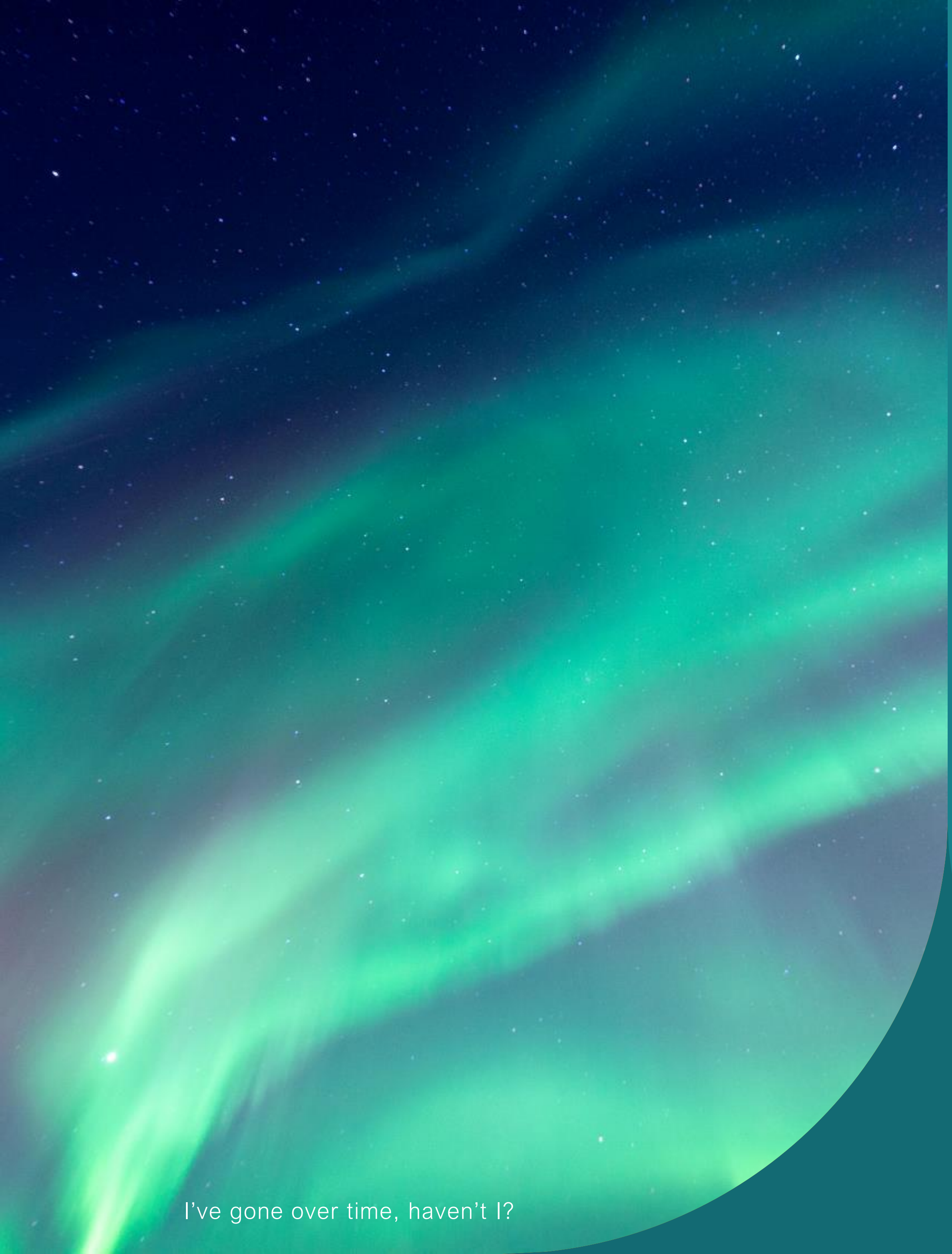
- Gotta work out the outgoing longwave radiation values before tackling this.

Summary

Planetary bodies differ on many dimensions.

- Incoming radiation
- Eccentricity
- Axial Tilt
- Outgoing Radiation
- Surface features

Each one impacts the energy balance in small or large ways. Turns out size doesn't do anything in this model.



Questions?

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