Amalthea Meteorological Collaboration

Modeling Research Division

Simulating Pavala – Release 1

9938 ăvokoipa 13

Amalthea Meteorological Collaboration
Modeling Research Division
Saelunavvk, Solea

Introduction

Over the course of the coming months, we expect to conduct several experiments to understand the climate regimes of hypothetical habitable worlds with various planetary properties. We will use PlaSim, a general circulation model, to analyze the global circulation, temperature, and precipitation patterns that define the climate of each of these worlds. In this release, we begin with a control run of Earth, a planet with a radius of 6371 km, day length of 24 hours, year length of 365 days, and axial tilt of 23 degrees. This simulation was run for five years, and is therefore known as "CONTROL5". A second simulation, "SMALL5", was run where the radius was decreased to 4900 km, the radius of Pavala, and all other parameters remained the same. Further simulations are expected to increasingly approach the likeness of Pavala, but this release will deal only with the comparison between the CONTROL5 and SMALL5 runs.

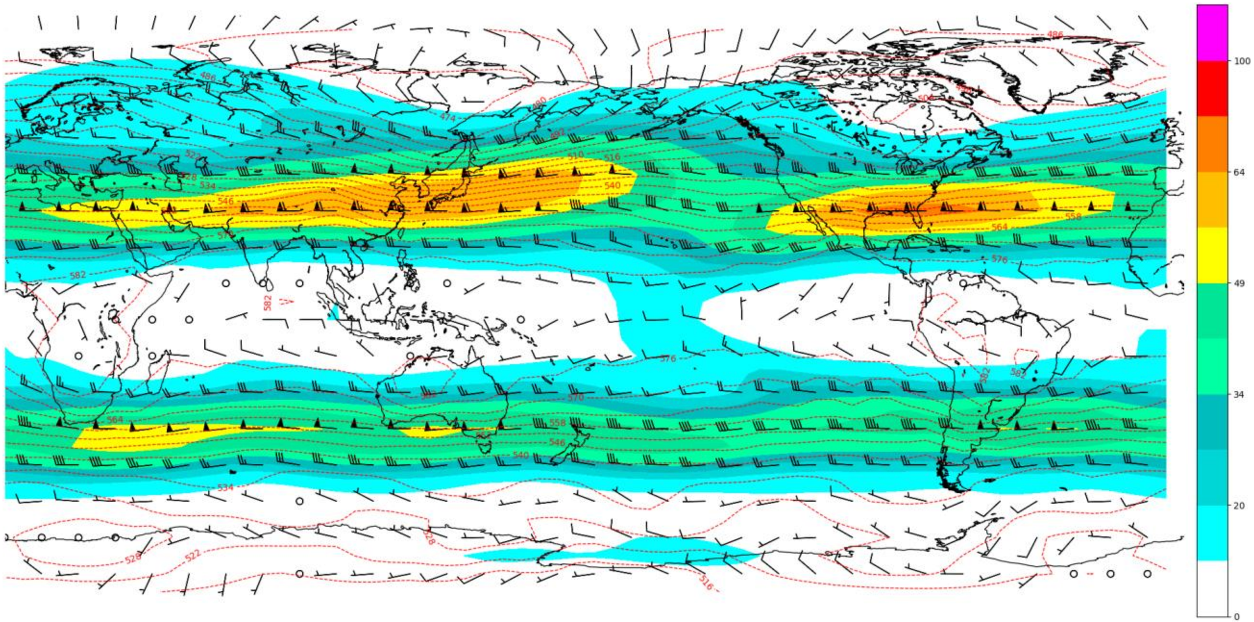

Fig 1a – 1000-500 hPa thickness in dam (dashed, red) and 200 hPa winds in kts (filled & barbs) for December, Year 4 in the CONTROL5 run

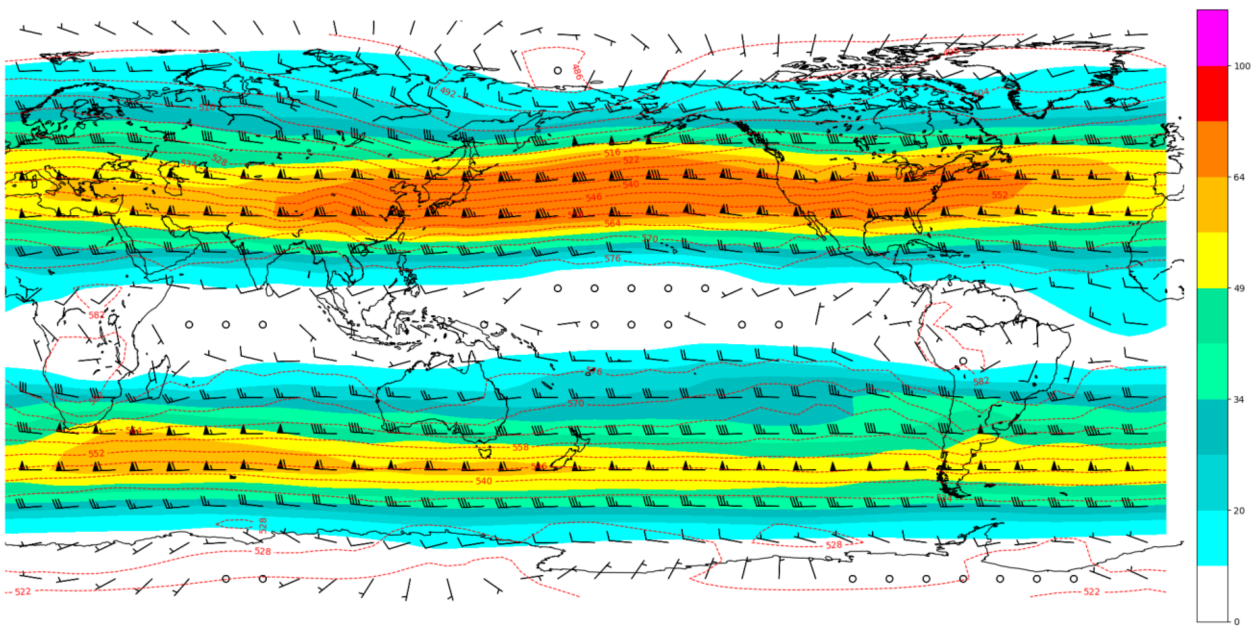

Fig 1b – 1000-500 hPa thickness in dam (dashed, red) and 200 hPa winds in kts (filled & barbs) for December, Year 4 in the SMALL5 run

Circulation

Based on previous research,[citation needed] one would expect the polar regions on a smaller planet to be comparatively warmer than the polar regions on a larger one, all other factors set aside. Indeed, *Figure 1* shows that the northern polar region specifically has a much higher minimum thickness[1] on the smaller planet. However, the jets on the small planet are stronger. This might initially be confusing when we ponder how a seemingly weaker temperature gradient from equator to pole can produce stronger winds, but we must remember that we are dealing with different sized planets. The temperature gradient may actually be tighter on the small planet because the poles are a lot "closer" to the equator.

With a thickness of around 576 dam at the equator for both planets, but a minimum thickness at the pole of 474 dam on the larger planet and 486 dam on the smaller planet, and taking the equator-pole distance to be pi/2*r, we can calculate the equator-pole thickness gradient. This turns out to be 10.2 dam per 1000 km on Earth, and 11.7 dam per 1000 km on the smaller planet. This shows that there is a tighter thickness gradient in the SMALL5 simulation. By the thermal wind shear relation, this will lead to a greater acceleration of the winds aloft, resulting in a stronger jet.

Additionally, there is a latitudinal variation throughout the year (not pictured) seen in the smaller planet's jets that is not particularly evident in the control run. However, just looking at the December, Year 4 plots we can see that the summer jet in the southern hemisphere is displaced poleward in SMALL5 as compared to CONTROL5, possibly due to an expanded Hadley cell. This would have the effect of shifting the region of active storms and precipitation, which will need to be investigated later.[2]

Figure 2 shows the 1000-500 hPa thickness anomalies (SMALL5 minus CONTROL5) at the same time at the previous figure. They show a +24 dam anomaly over eastern Siberia and general extreme positive thickness anomalies in the northern (winter) polar region, further supporting the analysis that the lower troposphere is warmer in the polar regions on a smaller planet. In the southern polar region, we instead see the poleward shift of the mid-latitude jet creating positive thickness (warm) anomalies where it previously lie on Earth. It should also be noted that, with the

[1] The 1000-500 hPa thickness used in the plots is a measure of the average temperature of the low to mid troposphere. The hypsometric equation demonstrates the relationship between the thickness of a layer of atmosphere and its mean virtual temperature.

[2] Other results of the expanded Hadley cell include a larger tropical region during the summer and the migration of the subtropical highs (arid climates with subsiding air) poleward.

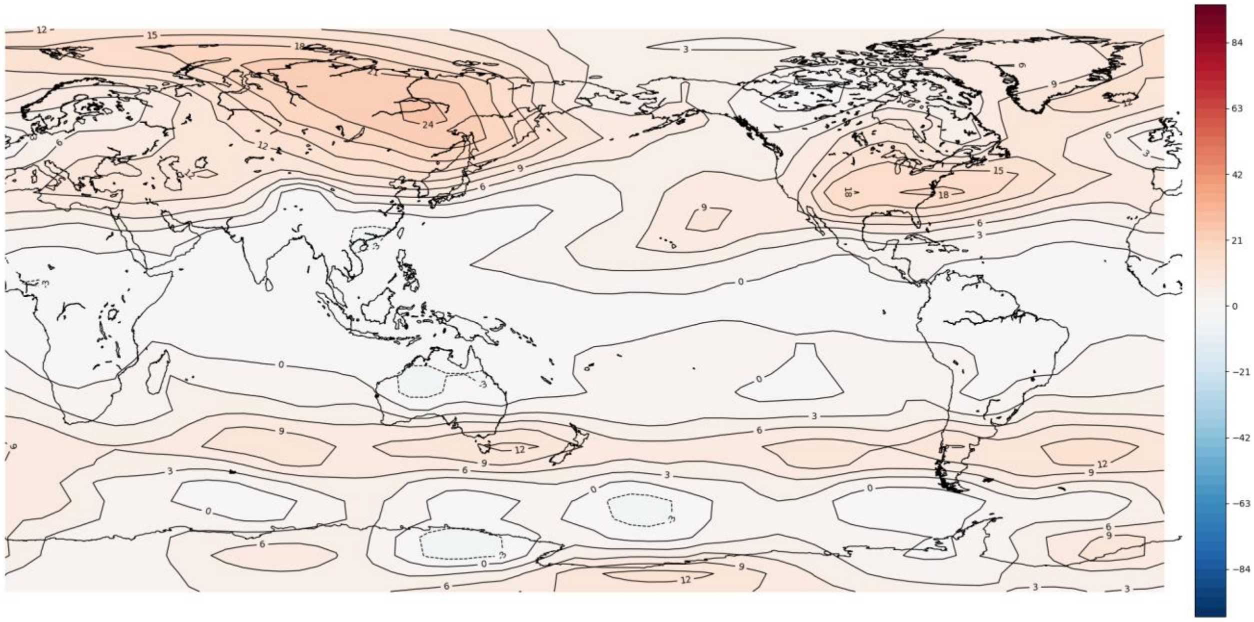

Fig 2 – 1000-500 hPa thickness anomalies (SMALL5-CONTROL5) in dam (black & filled) for December, Year 4

exception of the southern hemisphere, there is strong dependence on longitude and time (again, not pictured) with the regions of positive (warm) anomalies.

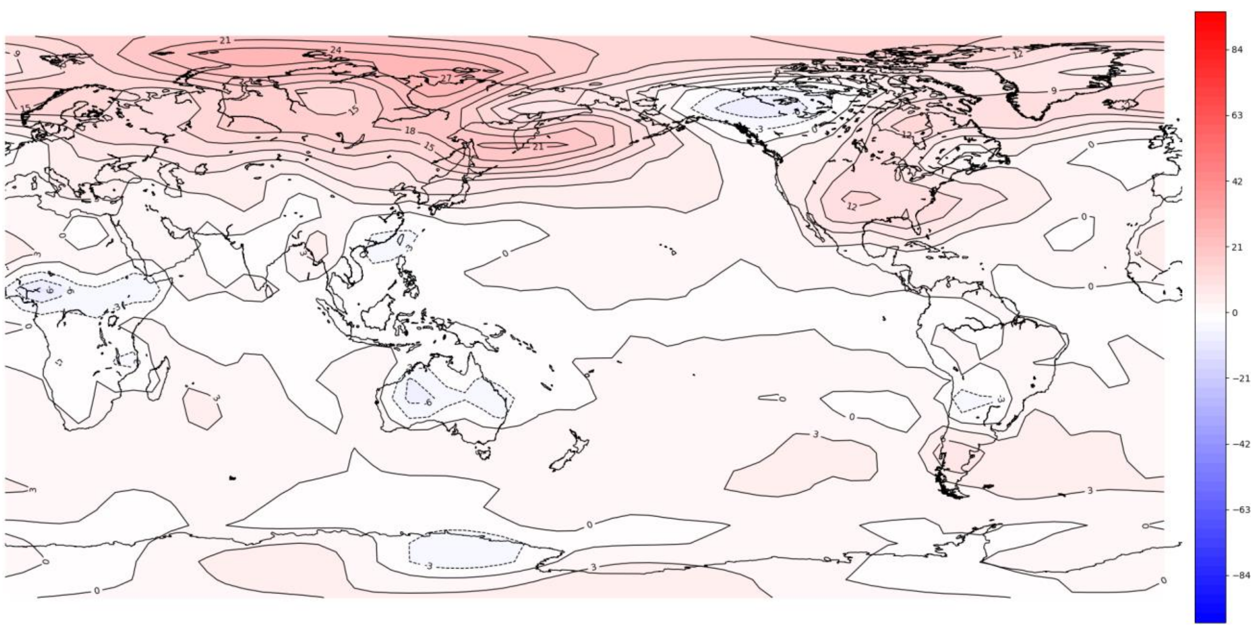

Fig 3 – 2m temperature anomalies (SMALL5-CONTROL5) in Kelvin (black & filled) for December, Year 4

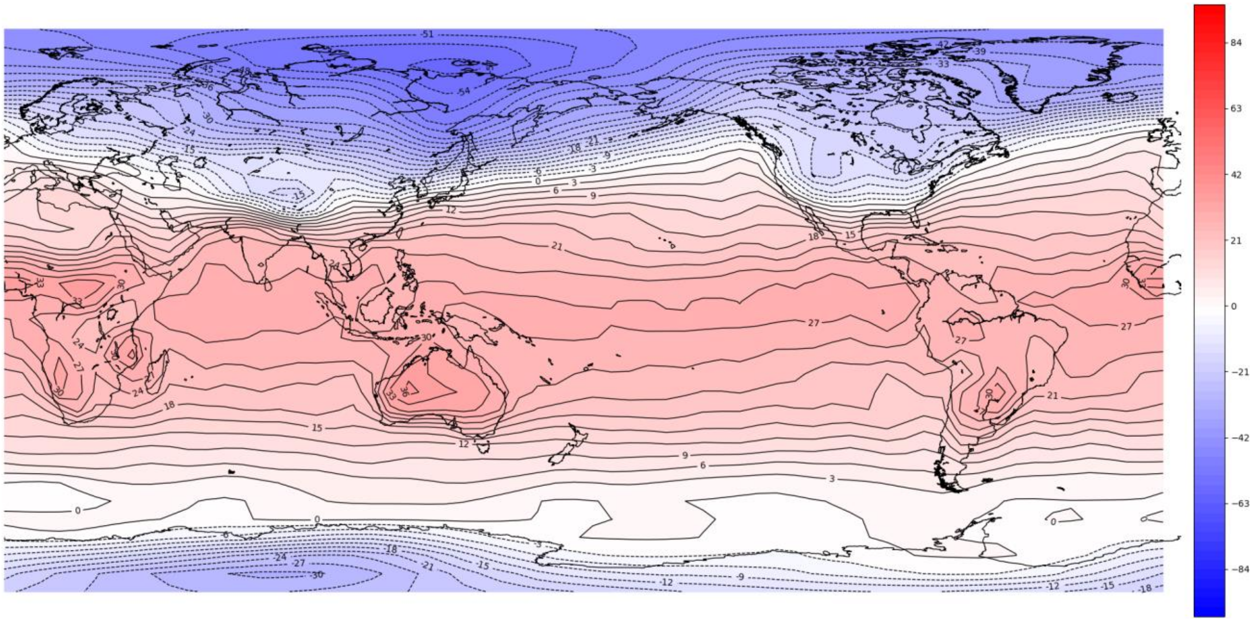

Fig 4a – Average 2m temperature (black & filled) for December, Year 4 in the CONTROL5 run

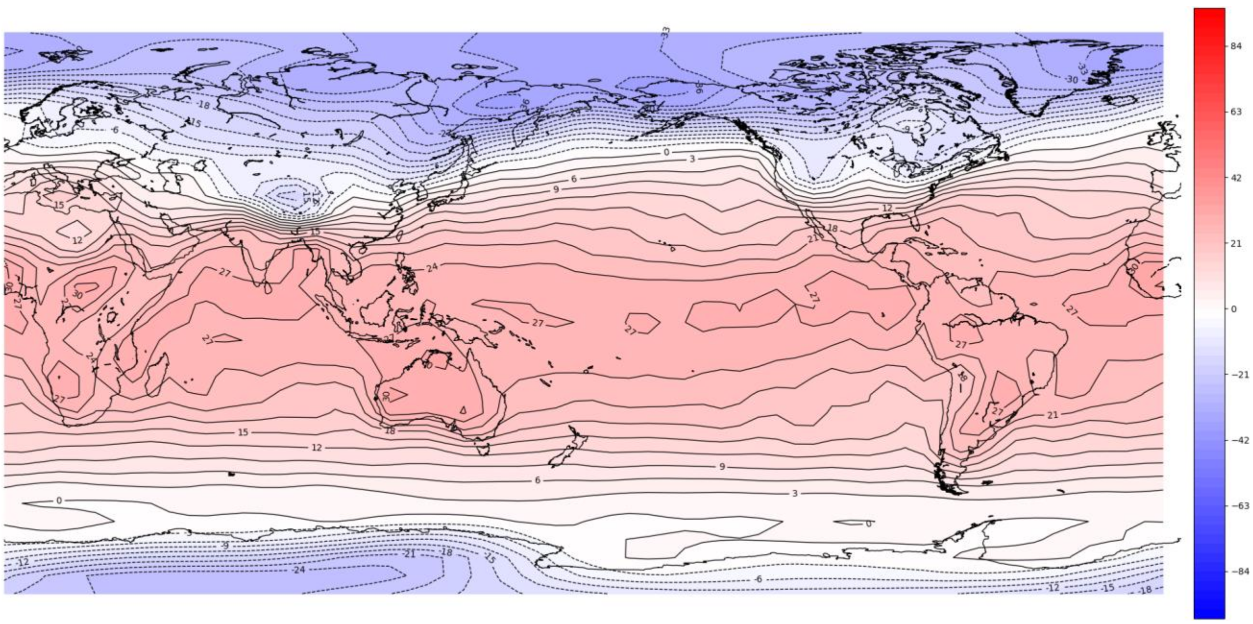

Fig 4b – Average 2m temperature (black & filled) for December, Year 4 in the SMALL5 run

Temperature

Figure 3 shows the 2-meter temperature anomalies for the same analyzed time period. The pattern in anomalies roughly corresponds to those of the low to mid tropospheric thickness. The highest positive anomalies (+27K) lie over or near eastern Siberia. A band of slight warm anomalies resembling the thickness anomalies corresponding to the displaced southern hemisphere mid-latitude jet is also evident.

Some potentially important features which need more investigation include the cool anomalies over land in the summer (southern) hemisphere and subtropics (the Andes, Australia) and tropics (central and west Africa). India also experiences a prominent cold anomaly during the northern hemisphere summer (not pictured) which may have significant impacts on the Asian monsoon.

These changes may bring up the question: "How cold is it actually is at the poles on the smaller planet?" *Figure 4b* shows that while the poles are significantly warmer on a smaller planet, they are still well below zero over a monthly average, with some regions averaging near -36 °C. This, however, is not near the blistering -57 °C seen in the Earth run (*Figure 4a*). How this warmer polar climate affects sea and land ice distribution will need investigation.

Conclusion

Based on this analysis, decreasing the radius of a planet increases the temperature of its polar regions, particularly during the winter (we suspect). However, the warming of the polar regions is not enough to offset the increase in temperature/thickness gradient that a smaller planet necessitates, resulting in stronger jets. These jets are suspected to migrate poleward in the summer under the influence of an expanded Hadley cell.

Future Work

Further work will be conducted analyzing the effects of decreasing the radius of a planet using the CONTROL5 and SMALL5 runs based on feedback from the AMC MRD userbase. Future focuses are likely to include land/sea ice distribution, precipitation patterns, and annual variation.

Further simulations will be conducted to investigate changes in rotation rate, year length, and landmass distribution/topography.