The Climate of the world of Game of Thrones

Samwell Tarly[1,*,2]

[1]The Citadel, Oldtown, Westeros.
[*]Previous address: The Wall, The North, Westeros.
[2]The Cabot Institute, University of Bristol, UK.

Correspondence to: cabot-enquiries@bristol.ac.uk ; @ClimateSamwell

Abstract. It is well known that the climate of the world of Game of Thrones is chaotic; the durations of the seasons are essentially unpredictable (whatever the quack-scientists of King's Landing may try to tell you about predicting the onset of winter), and the seasons last several years. In this paper, inspired by the terrible weather on the way here to Oldtown, I attempt to understand and explain this fascinating and mysterious climate. I start by presenting observational evidence from various ancient manuscripts from the Citadel Library, and then, with the aid of a Climate Model, present a theory for the changing seasons based on variations in the orbit of the planet around the Sun. I then explore the implications of this theory for phenomena such as the likely attack plans of invading dragon hordes from Essos, the dominance of the seas by the Iron Fleet, the hibernation zones of White Walkers in summer, and the trading routes between Westeros and the Free cities across the Narrow Sea. Following this, I compare the climate of various regions in the world of Game of Thrones with those of the 'real' Earth, and show that the climate of The Wall in winter resembles very closely that of Lapland in Sweden/Finland, and Fairbanks, Alaska, whereas the climate of Casterly Rock, home of the scheming Lannisters, resembles that of Changsha in China, and Houston, Texas. Finally, I make a prediction of the "Climate Sensitivity" of the world of Game of Thrones, the amount of global warming that would occur if concentrations of greenhouse gases in the atmosphere were to be doubled (due to the recent increase in carbon dioxide and methane emissions from dragons, and the excessive use of wildfire). I show that this warming would likely be accompanied by sea level rise that could lead to the inundation of coastal cities, including the outskirts of King's Landing (which may be a good thing… unless you are unfortunate enough to live there).

---

1 Introduction

The Citadel library of Oldtown holds some ancient manuscripts in its collections that provide observational evidence for the climate of the world of the Game of Thrones. Here I first summarise some of this evidence. There are several manuscripts that tell of the severity of autumn storms: "Winter storms are worse, but autumn's are more frequent" (Martin, 1998a, p245); "Autumn is a bad season for storms" (Martin, 2011a, p590); "The seas are dangerous, and never more so than in autumn" (Martin, 2011b, p353); "Have the autumn storms begun yet?" (Martin, 2000, p346). Hidden between copies of "Battles I have won" by Jaime Lannister and "A history of Tyrion's lovers" (the two largest books in the library), there are manuscripts that tell tales of the daily temperature cycles: "In Volantis, the nights were almost as hot as the days" (Martin, 2011a, p101). Of course, there are also records of the severity and extent of winters in Westeros: "…this great summer done last. Ten years, two turns, and sixteen days it lasted" (Martin, 1998b, p5).

There have also been several theories postulated for the causes of the changing seasons. These include winter being caused by reduced carbon dioxide concentration (Mera, 2014), increased volcanic activity (@Semyorka_, 2017), decreased sunspot activity (New York Post, 2016), decreased ocean circulation strength (Farnsworth and Stone, 2015), changes to the planet's orbit around the Sun (e.g. Laughlin, 2013; Delcke, 2015), or just plain magic (Martin, 2015). However, few of these theories are consistent with the observational evidence highlighted above. In addition, the carbon dioxide, volcanic, ocean circulation, and sunspot theories all fail to explain the fact that winters correspond to shorter day length (Martin, 2011a, p531).

Therefore, in this paper I explore more closely the climate of world of Game of Thrones, focusing on the orbital theory. To do this, I make use of a "Climate Model" that was installed on a computing machine that I found in the cellars of the Citadel (luckily I learned how to code when I was back in Horn Hill avoiding sword practice). Furthermore, I make some comparisons with a fictional planet called the 'real' Earth, whose climate is described in detail in manuscripts that Gilly discovered in the Citadel library (IPCC, 2013).

The aims of this paper are:

- To demonstrate the flexibility of climate models, arising from their basis in fundamental science.
- To explain a theory for the extended seasons, and discuss the resulting climate and its implications in the context of the world of Game of Thrones.
- To assess the sensitivity of the world of Game of Thrones to a doubling of carbon dioxide in the atmosphere, and some of the potential impacts of such an increase.

2 Methodology

Climate models are computer programs that are designed to simulate the weather and climate. They are based on the fundamental equations of "fluid mechanics" (the movement of fluids such as air and water). Climate models solve these equations by breaking the atmosphere and ocean up into a network of "gridboxes", somewhat like lego blocks, that cover the planet and extend up into the atmosphere and down in the ocean. A climate model calculates the flows of heat and "momentum" (speed and mass) between these gridboxes, stepping forward in time as they go. The size of the gridboxes is termed the "resolution" of the model; smaller gridboxes give more detail (higher resolution), and larger gridboxes give less detail (lower resolution). The available computing power determines how small the gridboxes can be made. However, some climate processes (such as clouds, downdraughts in thunderstorms, and small circulations in the ocean) occur on scales smaller than the size of a typical model gridbox. These processes have to be approximated in the model, often based on observations of their average behaviour in the real world. Different climate models give different results to each other primarily because these approximations, or "parameterisations", can be represented in several different ways. For my experiments, I used the "CitCM3" model (Citadel Coupled Model version 3, Valdes et al., 2017). It has a resolution of 3.75° in longitude by 2.5° in latitude, equivalent to about 400×275 km at the equator. On the computing machine in the cellars of the Citadel (www.bristol.ac.uk/acrc), the CitCM3 model can simulate about 200 years of climate per 'real' day.

Because climate models are based on fundamental scientific principles, they can be used to simulate any planet (real or imagined). However, there are some important characteristics of a planet and its solar system that the model cannot predict itself, but need to be provided by the programmer. These characteristics are called "boundary conditions", and include aspects such as the positions of the continents, the depth of the ocean, the height and positions of mountains, the concentration of atmospheric greenhouse gases such as carbon dioxide, the strength of the sun, and the characteristics of the planet's orbit around its sun.

1

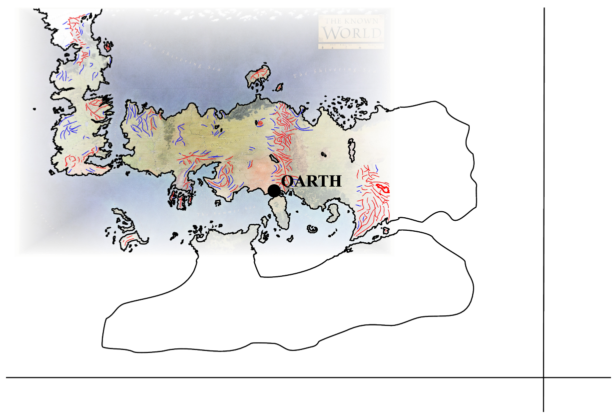

Figure 1. The map of the Known World (Martin, 2012), overlain with my tracing of continental outline (black lines), mountains (red regions) and hills (blue regions). Qarth is placed at the centre (Martin, 1998b, p383); the vertical and horizontal black lines show the resulting extent of the globe. Outside of the Known World the continents are of my own invention.

For my climate model simulations, I created many of these boundary conditions using a map of the Known World (Martin, 2012) that Gilly found in the Citadel library (inside a long-lost copy of Littlefinger's accounts). It is well known from legend that the city of Qarth is "the center of the world, the gate between north and south, the bridge between east and west..." (Martin, 1998b, p383), so I placed Qarth at the center of the planet, traced the continental outlines and mountains and hills, and invented continents outside the Known World (Figure 1).

1

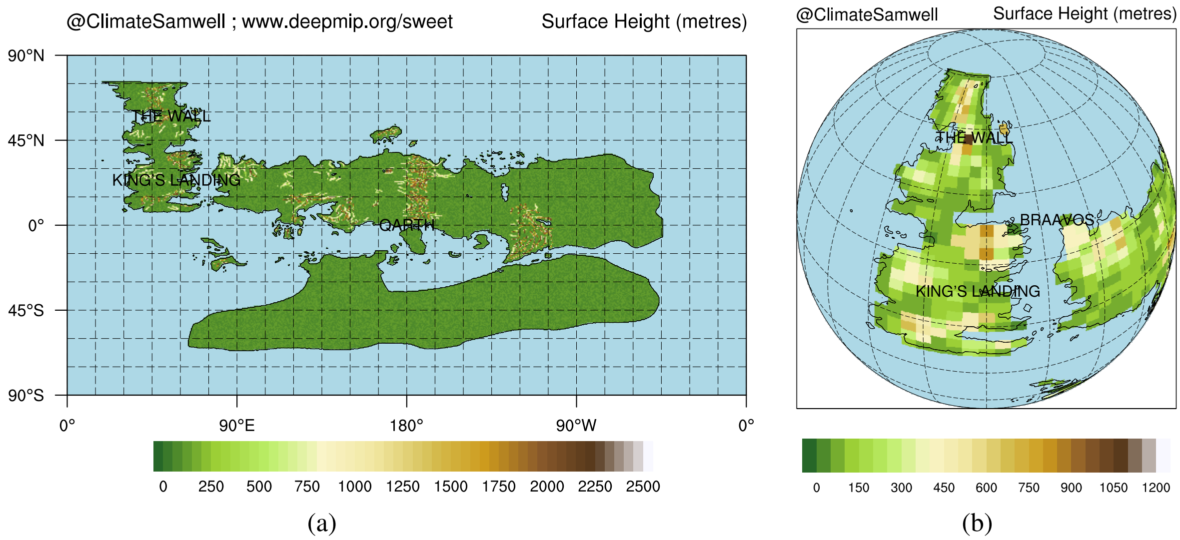

Figure 2. (a) High-resolution (0.5°longitude ×0.5° latitude) mountain height for the whole planet. (b) Model-resolution (3.75°longitude ×2.5° latitude) mountain height for the region of Westeros and western Essos. Note the difference in colour scale between (a) and (b).

I then converted this into a digital form that can be input to the climate model, as a series of gridboxes of resolution 0.5° longitude by 0.5° latitude. I assumed that mountains had an average height of 2000m, hills an average height of 1000m, coastal regions a height of 20m, and all other land an average height of 100m. I then added a random height of 1000m, 500m, 10m, and 90m respectively to each box. I also assumed that the ocean depth increased with distance from the coast, to a maximum depth of 4000m. The resulting map, or "digital elevation model" is shown in Figure 2(a). This then has to be "interpolated" to the same resolution as the climate model; resulting finally in the boundary condition shown in Figure 2(b). Note that some information is lost in going from the high resolution to the low resolution. However, some of the high-resolution information is retained by the model for use in the representation of "gravity waves" in the upper atmosphere, without which the model would not give a good representation of atmospheric flow.

The model was originally set up with values of the planet radius, rotation rate, incoming sunlight, and orbit around the Sun, appropriate for the 'real' Earth (some of these were then modified later, see Section 3).

The model requires "initialisation" from a starting point. The atmospheric initialisation is fairly unimportant in this case, as the atmosphere adjusts to the boundary conditions very quickly, on the order of months. However, the ocean initial condition is important because the ocean takes much longer to adjust, typically longer than can be simulated even on a supercomputing machine. Here, I chose to initialise the model ocean in the same way as some previous work investigating the 'real' Earth under past climate conditions (Lunt et al., 2016), with relatively warm ocean temperatures in the equatorial and polar regions of 32°C and 11°C respectively. Note that the experimental design is very similar to that of Brown (2013).

The first model simulation was started with the boundary and initial conditions described above, and set to run for 100 years.

3 Results

Unfortunately, the first run of the model simulated a total of 3 months of climate before "crashing". The crash occurred because the model generated "negative mass" in the atmosphere, due to super-high strength winds that removed all the air from one of the gridboxes. This happened because the ocean literally boiled at the south pole, because the ocean current strength was too large for the relatively small size of the gridboxes in that region. This problem was overcome by applying a form of smoothing to the south polar ocean. This was originally turned on in the north polar ocean in the model, but not in the south, because the original model was set up for the 'real' Earth with land (Antarctica) at the south pole. With this smoothing in place, the model simulated 100 years of climate. I then ran an additional 100 years,

1

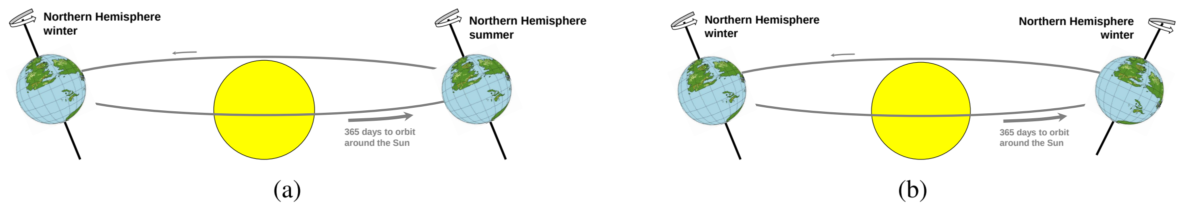

Figure 3. Configuration of Earth's orbit for (a) the 'real' Earth, in which the angle of tilt of the spinning axis of the Earth stays constant through the year, and (b) the world of the Game of Thrones, in which the tilt "tumbles" as the planet rotates round the Sun, such that the angle of tilt changes, so that the same Hemisphere always faces the Sun, giving a permanent season (permanent Northern Hemisphere winter for the case illustrated in (b)).

but including an extra component in the model that allows it to predict the vegetation of the planet (whereas for the first 100 years, the model was set up with the whole world covered in grass, similar to the Dothraki Sea).

The resulting climate looked reasonable, but at this stage the model was not set up with the extended seasons of the world of Game of Thrones, but was set up for a world with four seasons in a single year. That is because in the original model the tilt of the spinning axis of the planet was at a fixed angle throughout the year, as in the 'real' Earth (Figure 3(a)); it is the spinning that gives day and night, the tilt that gives seasons, and a year is defined as the planet completing exactly one orbit around the Sun. As a result, the seasons change through the year. One way that seasons can be made to last longer is to allow this tilt of the spinning axis to change throughout the year, so that the Earth 'tumbles' on its spin axis, a bit like a spinning top. If the Earth 'tumbles' exactly once in a single year, then the spin axis always points towards (or away) from the Sun, and the winter (or summer) is then permanent (Figure 3(b)). This extended winter or summer would come to an end if the tilt flipped such that the opposite hemisphere pointed towards the sun.

Therefore, I set up an experiment (initialised from the end of the 200 years already simulated) with the planet tumbling on its axis in this way, to give a permanent Northern Hemisphere winter and a permanent Southern Hemisphere summer. This time, the model simulated 3 years and then crashed. This was because the model developed a super-warm Southern Hemisphere and a super-cold Northern Hemisphere (Figure 4), which led to such intense winds that, as before, negative mass was produced. In an attempt to overcome this issue, I shortened the time period over which the model steps forward in time (I "reduced the timestep"), allowing the model to simulate stronger winds without crashing. This enabled the model to run an extra few months, but it then crashed again as the winds intensified even further.

1

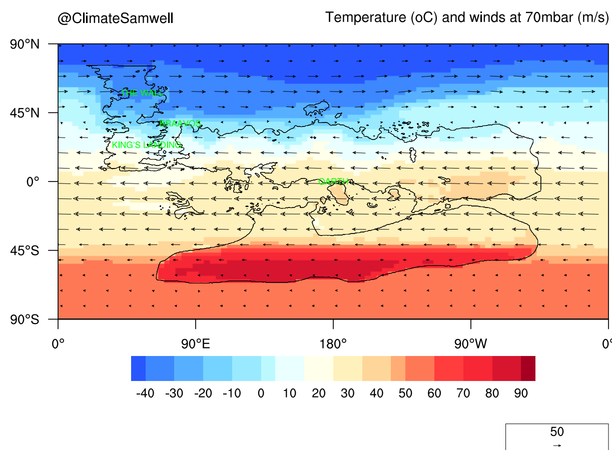

Figure 4. Near-surface air temperature [°C] and 70mbar winds [m/s] in an experiment with permanent Northern Hemisphere summer, 3 years into the simulation, just before it crashed. Note that the temperature is close to the boiling point of water in the Southern Hemisphere. In this simulation, the angle of tilt of the spinning axis (the "obliquity") is 23.5°. The legend shows the length of a wind arrow corresponding to 50 m/s.

In order to reduce the temperature difference between the winter and summer hemisphere, I then decreased the tilt of the spinning axis of the planet (the "obliquity") from 23.5° (the value in the 'real' Earth) to 10°. This had the desired effect, giving a less extreme winter in the Northern Hemisphere and less extreme summer in the Southern Hemisphere, and the model ran happily for 10 years (Figure 5).

I then set up an equivalent simulation but with permanent Northern Hemisphere summer. These two simulations represent my final best estimate of the climate

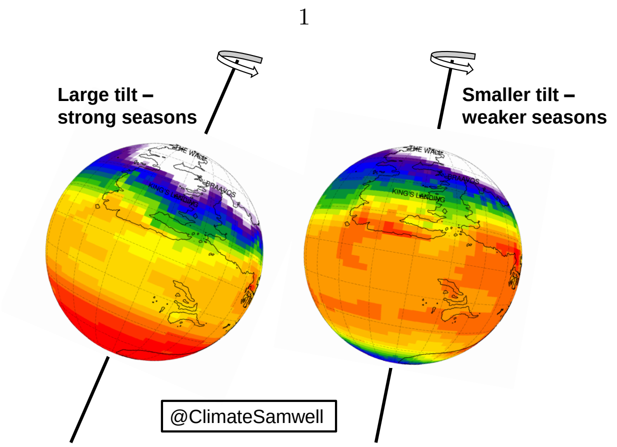

Figure 5. Near-surface air temperature, 3 years into the simulation with permanent Northern Hemisphere winter, with an angle of tilt of rotation of (left) 23.5° as in the 'real' Earth, and (right) 10°. The temperatures in the left figure are identical to those in Figure 4.

of the world of Game of Thrones. This is illustrated in terms of temperature, rainfall and snowfall ("precipitation"), and surface pressure/winds in Figure 6.

In terms of temperature, in winter (Figure 6(a)) much of the North is below freezing, but Dorne remains relatively warm, up to 30°C. There is also a west to east change in temperature such that the east of Westeros is cooler than the west. This is likely due to the ocean circulation, which is strong to the west of Westeros in the wide Sunset Sea, allowing transport of equatorial heat towards the polar regions, but is weak to the east of Westeros through the Narrow Sea, resulting in cooler temperatures to the east. In summer (Figure 6(d)), only the high altitude Frostfangs beyond The Wall remain below freezing (a potential hibernation zone for the White Walkers in summer - must remember to let the Lord Commander know), and the rest of Westeros is very warm, particularly The Reach and King's Landing.

In terms of rainfall and snowfall, in winter (Figure 6(b)) the southern half of Westeros is very dry, with little rain or snowfall. The north receives more precipitation, primarily in the form of snow, in particular on the western coastal regions near Stony Shore and The Rills. This is caused by intense storm tracks in the Sunset Sea in winter, that result in high precipitation when they make landfall, in particular over the hilly regions southwest of Winterfell. In summer (Figure 6(e)), the southern regions of Westeros receive intense precipitation, as they sit under the "Intertropical Convergence zone". As such, The Reach is characterised by a strong monsoonal climate, as is this beautiful city of Oldtown (maybe explaining why this is a centre for climate studies). Dorne, however, remains very dry in both winter and summer. Beyond The Wall, there is intense precipitation in summer, associated with the high mountain ranges of the Frostfangs leading to ascent of air masses, and condensation of water droplets in the cooler air above.

In terms of surface pressure and winds, in winter (Figure 6(c)) there is a region of intense low pressure to the west of northern Westeros, and high pressure to the west of central Westeros. Associated with this are strong winds that blow onshore in central Westeros, including in the Iron Islands; it is no wonder that the Ironborn are such famed sailors, having to contend with storms of such severity. To the east of Westeros, there are strong westerlies that blow across the Narrow Sea towards Braavos, but further south the situation is reversed. In summer (Figure 6(f)) this whole system is reversed, with winds blowing from Braavos to The Vale of Arryn but from Dorne to Pentos. This may explain the seasonal dependence of the complex trade routes across the Narrow Sea between the cities of Westeros and the Free Cities of Essos. It also means that any attack on Westeros (whether by dragons, or ships, or both), may come via Dorne or Storm's End in winter, but via the Vale of Arryn, or even direct to King's Landing, in summer. Also in summer there is an intense low pressure northern polar cell, with associated strong circumpolar westerlies in the North.

In terms of the transition between the two seasons, my assumption is that the planet is fixed in a permanent season over several years due to the tumbling of the tilt of its spinning axis, but that the tilt flips every few years to give the opposite season. The reason for this flip is unclear, but may be a passing comet, or just the magic of the Seven (or magic of the red Lord of Light if your name is Melisandre).

It is of interest to compare the climate of the world of Game of Thrones with that of the 'real' Earth. Following the methodology of Brown (2013), here I identify those places in the 'real' Earth that have similar winter or summer climates to familiar landmarks in Westeros. For the purposes of this work, I consider a 'similar' climate to be one that is within 3.5°C in terms of seasonal temperature, and within about 0.4 mm/day in terms of seasonal rainfall/snowfall. This analysis (see Figure 7) shows that The Wall in winter has a similar climate to several regions in the 'real' Earth, including parts of Alaska (including Fairbanks), Canada, western Greenland, and Russia. In addition, there is a small region in northern Sweden and Finland, encompassing parts of Lapland, that also has a similar winter climate to that of the Wall (I always suspected that Maester $S^{t.}$ Nicholas was a member of the Night's Watch). In a similar way, the analysis shows that climate of Casterly Rock (The Lannister's stronghold) is similar to that of the Sahel and eastern China (including Changsha). There is also

1

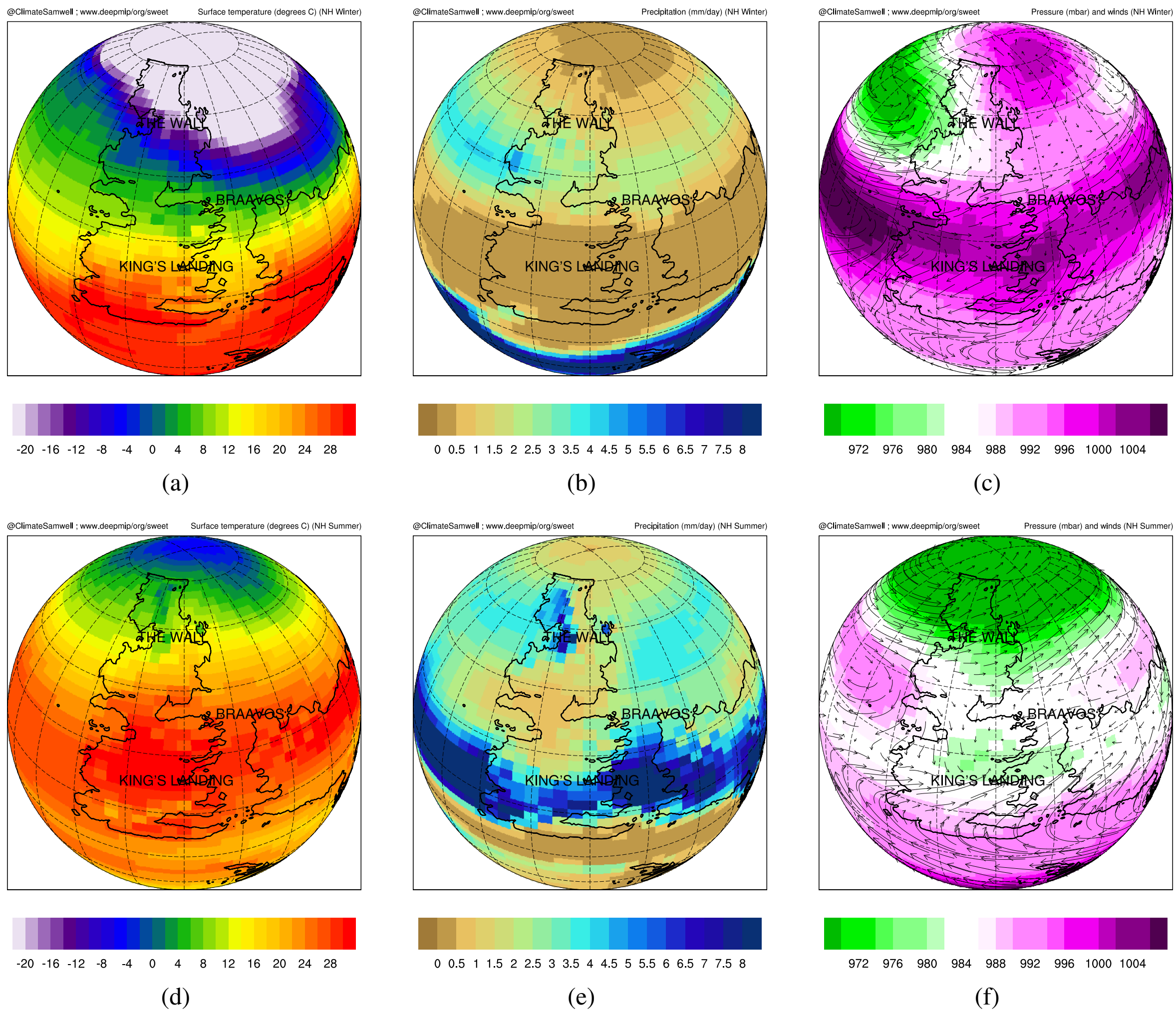

Figure 6. The Northern Hemisphere winter (top row (a,b,c)) and summer (bottom row (d,e,f)) modelled climate, in terms of surface temperature (°C; left column (a,d)) precipitation (mm/day; middle column; (b,e)) and surface pressure and winds (mbar; right column (c,f)).

a small region very close to Houston, Texas, that shares a similar climate.

4 Discussion

The theory presented above is consistent with much of the observational evidence available in the Citadel library. However, there are some indications in the ancient manuscripts that navigators have used the stars as a guide; "The blue star in the dragon's eye pointed the way north" (Martin, 2000, p331). With the proposed 'tumbling orbit', the North Star and Southern Star would vary throughout a calendar year. For the 'real' Earth, a similar tumble but on much longer timescales of 20,000 years results in changes to the pole star, and in substantial changes to climate. These observations could be reconciled by postulating that the entire heavens are also rotating at the same rate as the planet tumbles (again, likely due to magic).

As with any prediction from a single climate model, there are uncertainties associated with this work. As stated in the introduction, different climate models can give differing results due primarily to their differing representation of small-scale climate features. To assess the robustness of these results, other models would have to repeat similar experiments. This is common practice in climate science, and in particular the "Coupled Model Intercomparison Project" (Eyring et al., 2016) defines many climate modelling experiments that are carried

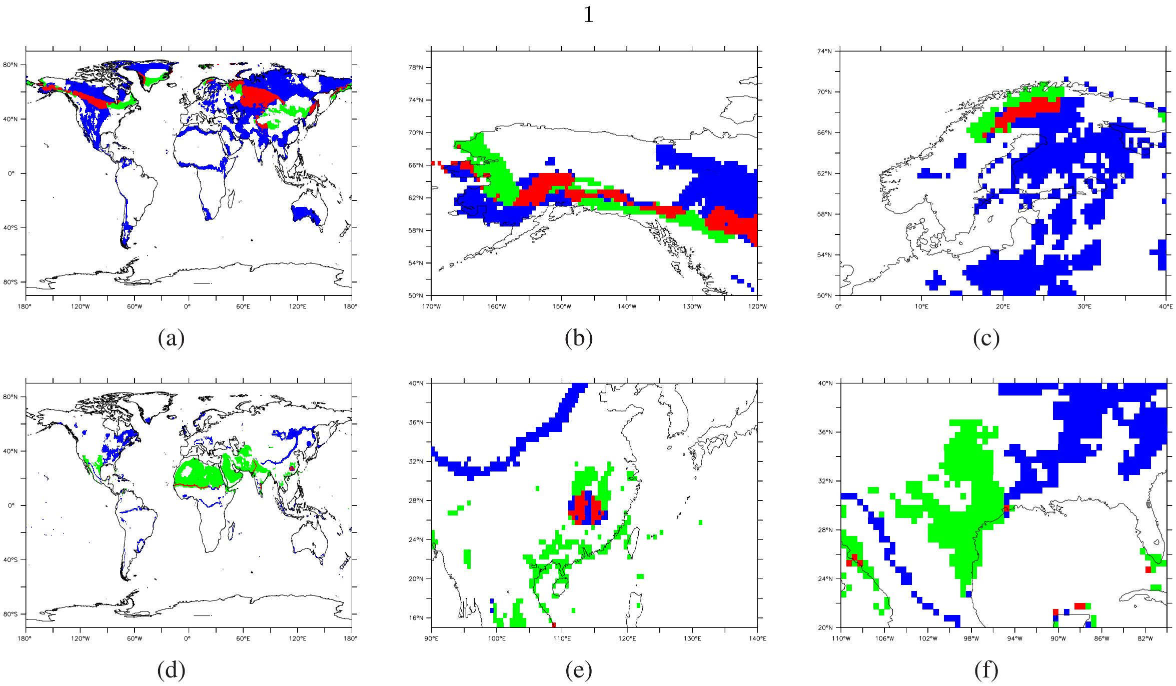

Figure 7. (a,b,c) Blue regions show where on the 'real' Earth is most like The Wall in terms of winter rainfall/snowfall; Green regions show where on the 'real' Earth is most like The Wall in terms of winter temperature; and Red regions show where on the 'real' Earth is most like The Wall in terms of winter rainfall/snowfall and temperature. (c,d,e) The same as (a,b,c), but for Casterly Rock in summer instead of The Wall in winter.

out by multiple groups. The spread of model results in these experiments provides an assessment of the uncertainty in a prediction, and when many models agree on a result, we have high confidence in their predictions. This form of uncertainty assessment is a critical component of the reports of the Intergovernmental Panel on Climate Change (Houghton et al., 2001; Solomon et al., 2007; IPCC, 2013).

There have been several recent worrying reports from monitoring stations on the island of Lys that the concentrations of methane and carbon dioxide in the atmosphere are increasing. This is likely due to the recent increase in dragon population in Essos, the deforestation of many regions associated with the increase in shipbuilding throughout Westeros and Essos, and the excessive use of wildfire. It has been suggested that increases in such greenhouse gases could lead to substantial warming, and possible impacts on society and ecosystems. Here, I use the climate model to carry out an additional simulation with a doubling of atmospheric carbon dioxide. The resulting temperature change given this doubling in carbon dioxide is shown in Figure 8. It can be seen that the greatest warming is in the polar regions - this is because the warming there is amplified due to seaice and snow melt, which decreases the reflectivity of the planet surface, leading to additional warming, and hence more melting (a "positive feedback"). Outside of the polar regions, warming is in general greater on land than over ocean, due in part to the lower heat capacity of land that allows the land surface to warm faster, and in part due to the fact that the land surface has a limited ability to cool by evaporation in the warmer climate.

"Climate Sensitivity" is the global average warming given a doubling of atmospheric carbon dioxide, and is a commonly-used metric to assess climate change. The value of climate sensitivity for the world of Game of Thrones (i.e. the global average of Figure 8) is 2.1°C. This is within the range of 1.5-4.5°C as assessed by the Intergovernmental Panel on Climate Change for the 'real' Earth (IPCC, 2013), albeit at the lower end of that range. However, the relatively short length (100 years) of my doubled carbon dioxide simulation means that my results need to be treated with caution, as a longer simulation may have resulted in greater warming. The warming for a doubling of carbon dioxide could also have implications for sea-level, due to expansion of the warmer oceans, and melting of glaciers (and, Mother forbid, The Wall). Predicting future sea-level change is highly complex, but a very approximate long-term prediction can be made by considering that during the Pliocene period of the 'real' Earth, 3 million years ago, tempera-

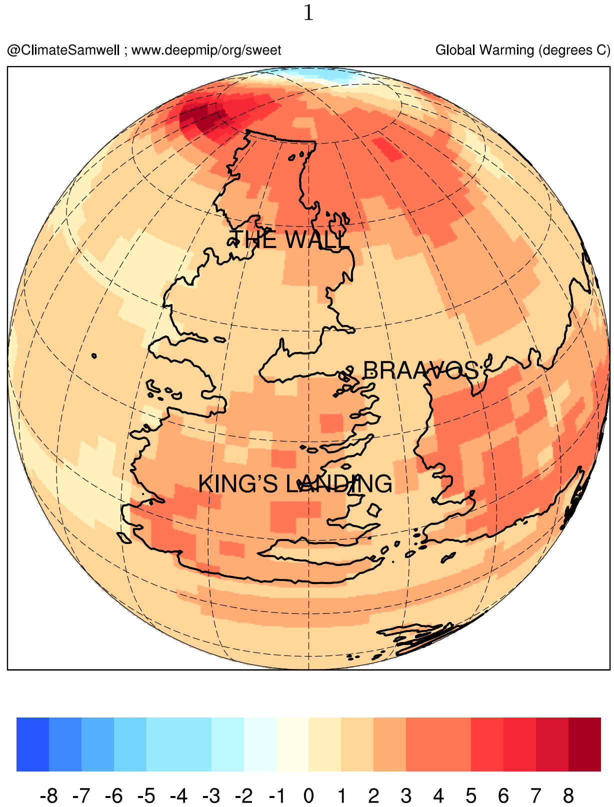

Figure 8. Temperature change [°C] given a doubling of atmospheric carbon dioxide, i.e. the Climate Sensitivity of the world of Game of Thrones.

tures were about 3°C warmer than today and sea level was around 15 metres higher than today (IPCC, 2013), due to melting of the Greenland and west Antarctic ice sheets. This suggests that my modelled 2.1°C increase in temperature for a doubling of carbon dioxide could result in a sea level rise of about 10 metres in the long term, surely enough to inundate parts of coastal cities (including King's Landing), towns and villages, with resulting social unrest and instability, and possibly (even more) wars and deaths. As such, as a climate scientist I strongly encourage all the Kingdoms of our planet to reduce their emissions of carbon dioxide, and seek alternative 'renewable' energy (such as windmills).

5 Conclusions and Future Work

In this paper, I have shown that:

- Climate models, because they are based on fundamental physical principles and not 'tuned' to a particular climate state, can be used to simulate planets other than the 'real' Earth.
- A 'tumbling' orbit of the planet around the Sun, combined with an angle of tilt of about 10°, results in permanent seasons and a modelled climate in broad agreement with the observational data as documented in the Citadel library.
- The modelled climate can be used to explain the likely attack plans of invading dragon hordes from Essos, the dominance of the seas by the Iron Fleet, the hibernation zones of White Walkers in summer, and the trading routes between Westeros and the Free cities across the Narrow Sea.
- The winter temperature and precipitation in the region of The Wall resembles very closely that of Lapland in Sweden/Finland, and Fairbanks, Alaska; the climate of Casterly Rock resembles that of Changsha in China, and Houston, Texas.
- The climate sensitivity of the world of Game of Thrones is 2.1°C; this amount of warming could result in sea level rise of about 10m in the long term.

Future work could include carrying out similar simulations with different climate models, as suggested above, perhaps in the framework of a formal "Model Intercomparison Project", e.g. 'GoTMIP'. In particular, higher resolution models with smaller gridboxes could better resolve geographical features that could influence atmospheric circulation (such as the Frostfangs north of The Wall, the Eyrie and even The Wall itself). I have assumed that the radius, rotation rate, and incoming sunlight of the planet is the same as the 'real' Earth, and this could also be further explored. Further analysis of the atmospheric circulation, for example the "Hadley Cells" that transport air and energy from the tropical regions towards the poles could be carried out, and similarly for the ocean circulation (for example the transport of energy though the Narrow Seas). The autumn and spring transitional seasons also need to investigated, in particular whether the model can reproduce the evidence documented in the Citadel library of the severity of autumn storms. I am sure that this will keep me and others busy for years to come!

Acknowledgements. Of course, I thank George R.R. Martin for inspiration. This work forms part of the 'Pathways to Impact' of NERC grant 'SWEET:Super-Warm Early Eocene Temperatures and climate: understanding the response of the Earth to high CO_2 through integrated modelling and data', NE/P01903X/1, but the work was unfunded, and the simulations were set up in my spare time. The modelling work was carried out using the computational facilities of the Advanced Computing Research Centre, University of Bristol, www.bris.ac.uk/acrc.

Huge thanks to Gilly, who carried out much of the research in the Citadel library and helped set up the model (I offered her a co-authorship but she declined, saying that she did not want to be associated with a journal edited by Kneelers). Many thanks to CHL and GLF for their useful comments on the manuscript, and their support through my investigations. Thanks to GJLT for the Dothraki and High Valyrian translations. Thanks to all the followers of @ClimateSamwell for your support and Retweets - I'll keep you updated with any further developments!

References

Brown, R.: The Climate of Middle Earth, J. Hobbitlore, 1, 1–8, 2013.

Delcke, D.: Theory of orbits for seasons of Game of Thrones(2), goo.gl/QVBsME, 2015.

Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., and Taylor, K. E.: Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization, Geoscientific Model Development, 9, 1937–1958, doi:10.5194/gmd-9-1937-2016, https://www.geosci-model-dev.net/9/1937/2016/, 2016.

Farnsworth, A. and Stone, E.: Weathermen of Westeros: does the climate in Game of Thrones make sense?, The Conversation, goo.gl/o6yFrh, 2015.

Houghton, J. T., Ding, Y., Griggs, D. J., Noguer, M., van der Linden, P. J., Dai, X., Maskell, K., and Johnson, C. A.: Climate Change 2001: The Scientific Basis, Cambridge University Press, 2001.

IPCC: Climate Change 2013: The Physical Science Basis, Cambridge University Press, http://www.climatechange2013.org/images/uploads/WGIAR5_WGI-12Doc2b_FinalDraft_All.pdf, 2013.

Laughlin, G.: Theory of orbits for seasons of Game of Thrones(1), https://www.space.com/20433-game-of-thrones-seasons-science.html, 2013.

Lunt, D. J., Farnsworth, A., Loptson, C., Foster, G. L., Markwick, P., O'Brien, C. L., Pancost, R. D., Robinson, S. A., and Wrobel, N.: Palaeogeographic controls on climate and proxy interpretation, Climate of the Past, 12, 1181–1198, 2016.

Martin, G. R. R.: A Feast for Crows, Harper Voyager, 1998a.

Martin, G. R. R.: A Clash of Kings, Harper Voyager, 1998b.

Martin, G. R. R.: A Storm of Swords. 1: Steel and Snow, Harper Voyager, 2000.

Martin, G. R. R.: A Dance with Dragons. 1: Dreams and Dust, Harper Voyager, 2011a.

Martin, G. R. R.: A Dance with Dragons. 2: After the Feast, Harper Voyager, 2011b.

Martin, G. R. R.: The Lands of Ice and Fire, Harper Voyager, 2012.

Martin, G. R. R.: Theory of magic for seasons of Game of Thrones, https://www.reddit.com/r/asoiaf/comments/45qy0z/spoilers_everything_irregular_seasons_and_their/, 2015.

Mera, R.: Theory of carbon dioxide for seasons of Game of Thrones, https://blog.ucsusa.org/roberto-mera/climate-change-game-of-thrones-559, 2014.

New York Post: Theory of sunspots for seasons of Game of Thrones, https://goo.gl/4g5NpT, 2016.

@Semyorka_: Theory of igneous provinces for seasons of Game of Thrones, https://twitter.com/Semyorka_/status/935791177684660224, 2017.

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., and Averyt, K. B.: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2007.

Valdes, P. J., Armstrong, E., Badger, M. P. S., Bradshaw, C. D., Bragg, F., Crucifix, M., Davies-Barnard, T., Day, J. J., Farnsworth, A., Gordon, C., Hopcroft, P. O., Kennedy, A. T., Lord, N. S., Lunt, D. J., Marzocchi, A., Parry, L. M., Pope, V., Roberts, W. H. G., Stone, E. J., Tourte, G. J. L., and Williams, J. H. T.: The BRIDGE HadCM3 family of climate models: HadCM3@Bristol v1.0, Geoscientific Model Development, 10, 3715–3743, doi:10.5194/gmd-10-3715-2017, 2017.