EXPANSION OF THE TROPICS

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INTRODUCTION

The atmosphere is a vastly perplexing, dynamic and interconnected system that is regulated by various mechanisms to sustain a form of equilibrium to maintain conditions for life on earth [12]. However, the onset of climate change has been triggered through greenhouse gas emissions from combustion of fossil fuels such as Carbon Dioxide (CO2) and Methane (CH4). This onset of climate change has altered atmospheric dynamics, and thus changes in climate. Climate change has led to a range of impacts such as: expansion of the tropics, uncertainty in climate stability, intensification of severity of extreme weather events, and distinct fluctuations in temperature [12]. Temperature is one of the most fundamental factors that influences all organisms on earth [18]. Consistently above average temperatures in recent times are causing an onset of biological, behavioural and migratory changes within flora and fauna populations world-wide [18]. The atmospheric dynamics are fluctuating, which has resulted, amongst other changes, in the expansion of the tropical climatic zone.

CLIMATE ZONES

In climatology, each climate zones are defined by the descending and ascending air from the Global Circulation Cells (Hadley Cell, Ferrel Cell and Polar Cell). Therefore, the tropic zone has been identified as a region between the ascending and the descending arm of the Hadley cell located between the Equator and the 30th latitude [30].

Hadley cells are large atmospheric cells in the troposphere that are controlled by thermal and pressure gradients between the lithosphere, and the atmosphere. These cells are seasonally impacted, and can be influenced by the conditions of the hydrosphere, and the cryosphere ([9]; [16]; [27]; [15]. The Hadley cell produces subtropical highs on the edge of the tropical region, which is an atmospheric marker utilised to identify the "edge" of the tropical [9]. Air at the equator is transported vertically as a result of high solar radiation [28]. This causes adiabatic cooling of air which forces condensation thus producing precipitation [28]. As a result, a large portion of the earth's rainforests which, provide habitat for a diverse range of flora and fauna population, are located on the equator [28]. However, the descending arm of the Hadley cell coincides with the earths largest deserts [28]. Attitudinally descending air is the most stable form of air, therefore little rainfall is experienced in these regions [28]. Shin et al found that due to tropical expansion the subtropical dry zones have been gradually expanding since the 1950's [28]. From this period, the Hadley circulation has also shown evidence of strengthening, as a result of global warming [28]. This could potentially cause an expansion of desert climates to a point of irreversibility [28]. During the study performed by Shen et al (2012) the models that were utilised are highly seasonal, and are influenced by multiple variables. Coupling can cause changes in model outputs [28]. However, the observational data provided an unequivocal link between the intensification of the Hadley cell and a growth in desertification [28].

PRIMARY DRIVERS OF TROPICAL EXPANSION

The expansion of the tropics is driven mainly by greenhouse gases [14]. The two most prominent and potent greenhouse gases that are being emitted into the atmosphere are Carbon Dioxide (CO2) and Methane (CH4). The industrial revolution has exponentially increased the use of combustion of fossil fuels as a source of energy. The subsequent result of combustion levels of Carbon Dioxide concentrations that have not been reached on earth in the last 800k years [17]. Methane concentrations have been measured to be in concentrations that have not been recorded on earth in the last 420 k years [23]. The high concentration flux of these potent greenhouse gases has resulted in an increase in average temperatures world-wide. This change has caused alterations in thermal gradients, and have ultimately changed dynamic atmospheric processes, causing global changes such as expansion of the earth's tropical region [1].

Allen et al (2012) performed a study that suggests that greenhouse gases are not the only gases responsible for tropical expansion. Evidence in his study found that the decline in concentration of ozone could be a contributing driver of tropical expansion in the southern hemisphere [1]; [33]. Through the utilisation of climate models and aerosol physics, it was identified that tropospheric ozone (O3), CO2 and CH4 could potentially be the main sources of tropical expansion in the mid latitudes [33]. These atmospheric variations have caused triggers in changes of other atmospheric processes such as the polar jets migration as a result of the fluctuating concentrations of O3, CO2 and CH4 [1]. In Allen et al's (2012) study there seem to be knowledge gaps in the data [1] and a need for further research in the field of atmospheric physics and climate modelling to fully understand that dynamics of ozone and its full extent of impact on the expansion of the tropics [1].

Another contributor to the expansion of tropic that has been explored in the literature is solar radiation. In 2008 Georgieva and Kirov released a paper disputing the claim that the tropics are expanding as a result of climate change [8] and instead suggesting that the cause is more likely to be solar radiation. According to the authors, evidences suggest that even though greenhouse gases are increasing, the intensity of solar radiation has also shown signs of increase, specifically in the frequency of sunspots and strengthening of solar EMR (electromagnetic radiation) [8]. Their study found that an increase in stratospheric heating resulted from the absorption of short wave radiation by the earth's surface, which furthermore triggered the weakening of the Hadley cell [8]. A mechanism that supports this claim is the potential variation of spatial variables such as solar energy, electrons, ionospheric potential and magnetic fluxes all of which are capable of interfering with atmospheric dynamics [8]. This paper heavily relies on the Haigh et al (2005) and does not reach out to other papers to support their claim. It does however do well to establish a possible link between solar activity and expansion of the tropics. Further research is needed to establish a clearer, and a more scientifically supported relationship between tropical expansion and solar radiation.

DISCOVERY

The expansion of the tropics is not a new discovery. Observations performed by a number of studies have concluded that the earth's tropical region has expanded by approximately 2-5 degrees since 1979 [26]. The latitudinal expansion of the tropics is predicted to further expand at a rate of 1.3-2.5 degree every quarter of a century [26]. This is equivalent to an expansion rate of approximately 208km/25years [31]. A paper released by You et al in 2015 found that the rate of expansion is 1.57 degrees per decade. Therefore between 1979 and 2013 the tropics have already lengthened by approximately 5.5 degrees [35]. According to Turton (2016) the tropical ocean boundary is also predicted to enlarge by 300km over the next century [28]. These figures are consistently fluctuating through the release of updated academic articles, and are likely increasing [31].

BIOLOGICAL IMPACT

Biodiversity loss is one of the most concerning issues of the 21st [32]. Climate change has threatened the habitat and existence of life on earth [32]. It has been identified that climatic zones impact an organism's vulnerability to climate change [32]. A study performed by Madeira et al (2012) found that temperate regions have a higher quantity of variable climatic factors which sustain consistent favourable conditions for organisms to sustain inhabitation [18]. However, tropical habitats are exposed to more extreme conditions and, inhabit vulnerable species that have a low temperature tolerance [32]. Climate change has impacted all tropical species, including marine, amphibians, insects, mammals and flora [32].

Climate change and the followed consequential expansion of the tropics has triggered phenological adaptations [22]. The extent of the impact is more evident in some species of flora than others [22]. Flora and fauna of the earth are very temperature and climate sensitive [22]. Many organisms rely on temperature for development, therefore with the changing temperature, the life cycles of many species are being [22] affected. As the temperatures are found to be increasing in earlier stages of the month's multiple species of flora and fauna are triggering their natural processes earlier than they did a few decades ago [22]. For example, remote sensing was utilised by the Penualas and Filella study (2001) in the Mediterranean region where it was observed that flowering plants have been initiating flower blooming up to 2 weeks earlier than half a century ago, as well as the fall of leaves observed to be triggered two weeks later than 50 years ago [22].

CONCLUSION

Expansion of the tropics has been an issue that has been discussed, reviewed and studied for the last 50 years. A range of meteorological, observational, satellite and modelling data has been utilised to model, predict and understand the impact the full extent of impact of tropical expansions impact on the biosphere. Most of data collected has built a body of concurring and factual evidence supporting tropical expansion.

Currently there are still numerous knowledge gaps in the data that restricts the scientific community from understanding the full impact tropical expansion on the biosphere and the subtropics. There is a wide range of knowledge and studies on tropical expansion, however papers that focus on the impact of tropical expansion on the subtropics is more challenging to locate. There are numerous studies that can be utilised as vital points of reference when understanding the changes experienced by the expansion of attenuation of these climatic zones, such as the paper provided by Yuanqing et al (2003) which concentrates on the impact of climatic changes on temperate glaciers in south west China.

Funding for research should be focussed on the impact of tropical expansion on the subtropics, and hence the consequent impact on the biosphere. This will allow for scientists to identify the appropriate decisions for conservation and options needed to mitigate against climate change.

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