Revista Geográfica de Chile Terra Australis, Vol.60, No.2 (2024) 100-107 ISSN 0719-9562

https://doi.org/10.23854/07199562.2024602.escalona.leiva

IMPACT OF CLIMATE CHANGE AND TEMPERATURE VARIATION, EVIDENCE AND GENERAL PERSPECTIVES IN THE SOUTHERN HEMISPHERE

IMPACTO DEL CAMBIO CLIMÁTICO Y VARIACIÓN DE TEMPERATURA, EVIDENCIA Y PERSPECTIVAS GENERALES EN EL HEMISFERIO SUR

Erik Escalona Aguilar[1], Antonio Alexis Valdez Loera[1] Jorge Leiva-González[2*]

ABSTRACT

Climate change is a global issue with significant implications for ecosystems, societies, and socioeconomic structures. It is primarily caused by increased fossil fuel consumption, leading to rising global temperatures and shifting weather patterns. The Southern Hemisphere is experiencing significant temperature fluctuations and climate-induced changes, affecting regional economies, ecosystems, and communities. This research examines the impact of climate change on the southern hemisphere from 1880 to the present day, focusing on temperature variations and the relationship between temperature changes and carbon dioxide emissions. The data was sourced from NASA's database and the Mauna Loa Observatory in Hawaii. The study used Stata software to analyze the data, revealing significant summertime temperature fluctuations. The results show the seasonal variation of CO_2; the ascending curve indicates that the increase in the concentration of CO_2 in the atmosphere does not stop. The study concluded that there is a constant increase in average temperatures in the southern hemisphere, depending on the increasing CO_2 levels in the atmosphere

Keywords: Climate change, temperature variation, carbon dioxide emissions, southern hemisphere.

RESUMEN

El cambio climático es un problema global con implicaciones significativas para los ecosistemas, las sociedades y las estructuras socioeconómicas. Se debe principalmente al aumento del consumo de combustibles fósiles, lo que provoca un aumento de las temperaturas globales y cambios en los patrones climáticos. El hemisferio sur está experimentando importantes fluctuaciones de temperatura y cambios inducidos por el clima, que afectan las economías, los ecosistemas y las comunidades regionales. Esta investigación examina el impacto del cambio climático en el hemisferio sur desde 1880 hasta la actualidad, centrándose en las variaciones de temperatura y la relación entre los cambios de temperatura y las emisiones de dióxido de carbono. Los datos se obtuvieron de la base de datos de la NASA y del Observatorio Mauna Loa en Hawaii. El estudio utilizó el software Stata para analizar los datos, revelando importantes fluctuaciones de temperatura durante el verano. Los resultados muestran la variación estacional del CO_2; la curva ascendente indica que el aumento de la concentración de CO_2 en la atmósfera no se detiene. El estudio concluyó que hay un aumento constante de las temperaturas medias en el hemisferio sur, dependiendo del aumento de los niveles de CO_2 en la atmósfera y, por tanto, de la comprensión de los patrones climáticos globales. Para abordar estos desafíos, se necesitan estrategias específicas de adaptación y mitigación. Se necesitan enfoques multifacéticos en todo el mundo, incluida la reducción de las emisiones de gases de efecto invernadero. Las partes interesadas, incluidos gobiernos, empresas privadas, inversores e individuos deben colaborar para lograr el desarrollo sostenible y proteger a las personas y los ecosistemas vulnerables.

Palabras clave: Cambio climático, variación de temperatura, emisiones de dióxido de carbono, hemisferio sur.

[1] Escuela de Administración & Negocios, Facultad de Ingeniería, Ciencia y Tecnología, Universidad Bernardo O'Higgins, Chile
[2] Escuela de Ingeniería Civil, Facultad de Ingeniería, Ciencia y Tecnología, Universidad Bernardo O'Higgins, Chile
[*]Corresponding author: jorge.leiva@ubo.cl

1. INTRODUCTION

Climate change is a critical global issue with profound implications for ecosystems, societies, and socioeconomic structures worldwide. The consequences of climate change, which have become more visible in recent years, result from increased fossil fuel consumption since the Industrial Revolution: rising global temperatures and shifting weather patterns (IPCC, 2021). Although the global scale of climate change is generally understood, understanding its regional implications is critical for developing mitigation and adaptation strategies tailored to local contexts (Rosenzweig et al., 2014). For example, the Southern Hemisphere is experiencing significant temperature fluctuations and other climate-induced changes that affect regional economies, ecosystems, and communities (Salinger, 2005).

Temperatures in the Southern Hemisphere have increased, illustrating how climate change could aggravate climatic variability (Leiva González & Onederra, 2022). For example, in Chile, extreme heat waves and forest fires set temperature records in the country, setting a precedent regarding negative effects of climate change on climate variability and ecosystems in general. Cordero et al. (2024) describe how the combination of climate change and the El-Southern Oscillation (ENSO) has increased fire activity in Central Chile, significantly increasing burned areas over the last decade. The extreme weather conditions increase the risk of wildfires and indicate a disturbing pattern of increased fire risk owing to climate-related issues. Climate change-induced droughts, heatwaves, and the influence of ENSO occurrences exacerbate the local fire danger, stressing the critical need for proactive steps to address the Southern Hemisphere's growing climate concerns (Cordero et al., 2024).

In the Southern Hemisphere, the temperature rise is one of the most evident consequences of climate change, particularly in some fragile ecosystems such as the Antarctic and the Andes. Indeed, investigations have illustrated the accelerated rate at which the Antarctic ice and glaciers are melting, identifying climate change as a precursor (Cavanagh et al., 2021). Temperature and precipitation patterns are experiencing alterations within the Southern Hemisphere, leading to more regular and severe droughts; however, other areas have higher rainfall and flooding (Dai, 2013). Indeed, there is a clear link between changing precipitation patterns and climate change impacts in the Southern Hemisphere, emphasizing the importance of adaptive strategies to mitigate the adverse effects on agriculture, water resources, and human health (Dai, 2013). These precipitation fluctuations can have far-reaching consequences for ecosystems and human civilizations, especially where water scarcity and extreme weather events offer considerable barriers to sustainable development and resilience initiatives (Winckler Grez et al., 2014).

The way various populations respond to climate change determines the degree of effect on ecosystems. Understanding the local environment and the particular reactions of the people to climate change is essential to designing appropriate conversation and management plans to improve regional resilience because various populations respond to climate change to varying degrees (Louthan & Morris, 2021). Furthermore, it is worth noting that terrestrial and freshwater populations do not demonstrate any apparent trend in heat tolerance. Conversely, as the environmental temperature drops below previous levels, populations of marine and intertidal species experience a reduction in heat tolerance (Sasaki et al., 2022). Therefore, climate change has multidimensional effects in the Southern Hemisphere that significantly impact ecosystems. It urges effective conservation and management plans for specific locations to ensure local strategies to face climate change, which starts with understanding the local context and specific population responses.

The area's distinctive vegetation is at risk due to climate change. The depletion of biodiversity can profoundly affect ecosystems and their capacity to deliver essential services to humanity, including agricultural productivity, water supply, and climate regulation (Cardinale et al., 2012). Different parts of the ocean are warming up at different rates. A human-induced forced signal over natural variability has been seen in the subtropical region north of the Antarctic Circumpolar Current (ACC) (Cai et al., 2023). The warming of the Southern Ocean affects worldwide climate patterns because it controls the global heat budget, which refers to the balance between incoming and outgoing heat in the Earth's system, and ocean circulation, which is the large-scale movement of waters in the ocean (Cai et al., 2023). Climate change affects Southern

Hemisphere habitats outside the ocean, including forests and grasslands. Temperature and precipitation variation also change plant and animal distribution and abundance. These alters can have cascading consequences for ecosystem functioning and human services (Cardinale et al., 2012).

The main contributor to climate change is the buildup of carbon dioxide (CO_2) in the atmosphere, primarily due to human activities like burning fossil fuels and cutting down trees (IPCC, 2021). Because of this rise in CO_2, the Earth's temperature is rising, causing global warming and other climate change effects. In fact, all the issues previously discussed can be related to the increase in greenhouse gas (GHG) emissions, where CO_2 has numerous and extensive impacts on climate change (Leiva González et al., 2022). For that reason, understanding the evolution of CO_2 in the atmosphere is crucial for mitigating climate change (Friedlingstein et al., 2019). CO_2 concentration has increased because of human activities associated with fossil fuel consumption; therefore, it is necessary to constantly measure CO_2 levels to understand the carbon cycle and what human activities impact can have on the atmosphere.

Monitoring carbon dioxide (CO_2) concentrations over time enables scientists to identify consistent patterns and trends. The information helps to enhance their understanding of climate change's underlying causes and consequences (Houghton, 2014). Furthermore, practical strategies to mitigate climate change depend on thoroughly examining the trajectory of CO_2 emissions. By understanding the relationship between different scenarios and the variations in CO_2 concentrations, scientists and politicians may develop more accurate predictions of future climate change and more effective programs to reduce emissions.

This research aims to improve our understanding of the scope of climate change by observing the behavior of environmental variables over time. The investigation will examine the variables associated with temperature in greater detail. Further, the research will investigate the relationship between temperature changes and carbon dioxide emissions to investigate the correlation between both variables. With the help of this analysis, the objective is to acquire additional information that will help us better comprehend the mechanisms responsible for climate fluctuations.

2. MATERIALS AND METHODS

2.1. Information sources.

The research investigates the patterns of temperature variation in the southern hemisphere from 1880 until the present day. The study's goal is to observe and determine patterns over time and examine the long-term trends and implications of climate change in this region connected with variations in temperature and carbon dioxide levels.

The temperature data is obtained from the database on the National Aeronautics and Space Administration of the United States of America (NASA) website (GISTEMP Team 2024; Lenssen et al., 2019). On the other hand, the data on CO_2 levels was extracted from the following webpage of the Mauna Loa Observatory in Hawaii (Tans, 2023).

3. METHODOLOGY

The present study used Stata software to carry out the research. With this, it is expected to explore the impacts of climate change and temperature variations in the southern hemisphere, considering that this software is suitable for performing in-depth statistical analyses on complex data sets. The data covers temperatures from several sites in the southern hemisphere, offering a comprehensive picture of the region's climatic conditions. The study includes a summary of significant findings, a trend analysis to identify notable long-term patterns, and a correlation analysis to examine the correlations between temperature and CO_2 emissions.

Figures 1 and 2 show how the data is uploaded to the Stata software and how it is analyzed, respectively.

4. RESULTS

In figures 3 to 7, It is observed that the increase in temperature begins to be reflected approximately between the 1970s and 1980s.

In the aforementioned figures 3 to 7, the ordinate axis corresponds to the temperature anomaly and the abscissa axis corresponds to time.

In systematizing information through the summer average graphs, the temperature of that year's season is observed and compared with the annual average temperature, observing more significant

average temperature fluctuations in the summer months than the annual average (Krishnapriya et al., 2022).

Due to this methodology, one can reflect on the importance and role that governments should have. Suppose there are reasons for them to be concerned about the degradation of the environment as a result of global warming that has an international impact. In that case, the lack of water, scarcity of food, and the decline in agricultural and livestock production will seriously affect the economy, with a decrease in growth and unemployment, inflation, and poverty levels.

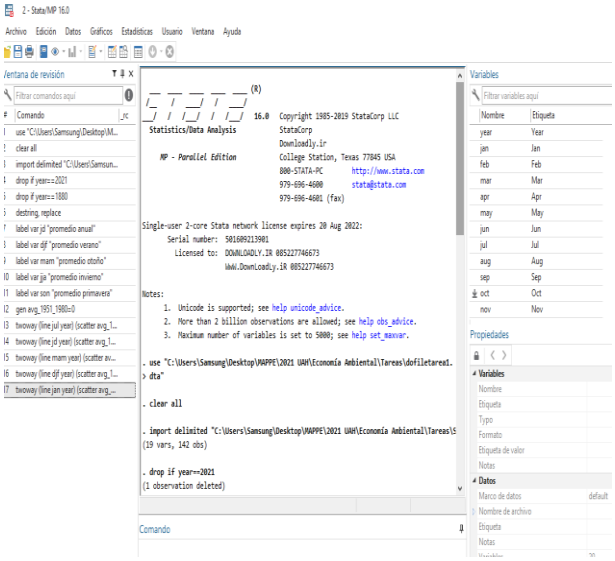

Figure 1. Data uploaded into Stata software.

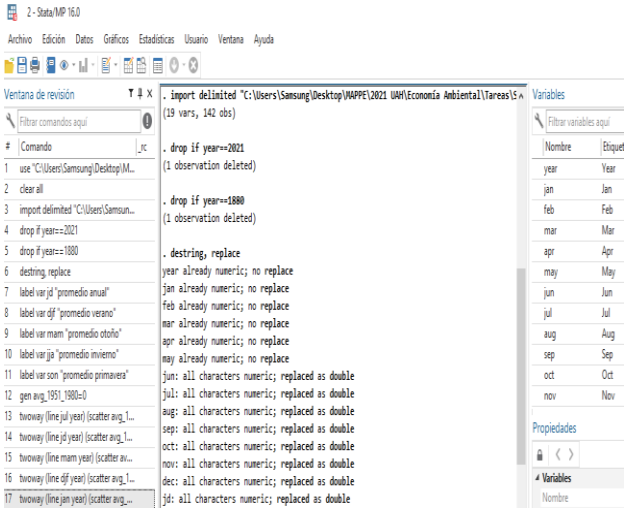

Figure 2. Analysis of data and variables in Stata software.

Climate migrations will occur since, due to desertification, families will look for places where there is water, there will be a depreciation of housing in cities and deterioration of increasingly arid soils, as we can currently see from the central area of Chile to the south due to the lack of precipitation and high temperatures, with the results of sub-urbanization that will make the agricultural lands already exhausted and contaminated by pesticides and acid rain more scarce.

The concern of the governments of this hemisphere, especially the Chilean government, is to promptly increase and achieve the design of efficient public policies (normative economy: regulation to be adopted to the given problem) based on objective studies, anticipating the scenario of the coming decades (Dardati, 2020).

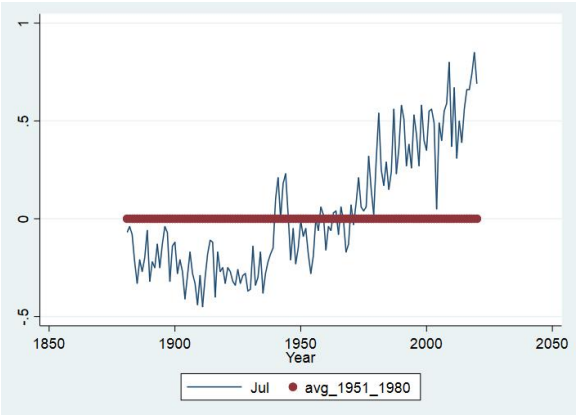

Figure 3. Month of July in relation to the reference average 1951-1980. Source: Own elaboration in Stata software

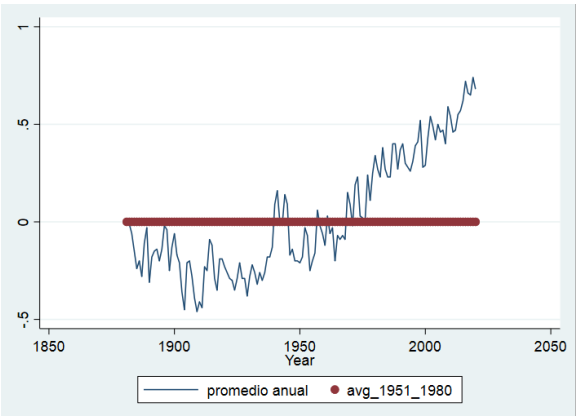

Figure 4. Annual average in relation to the reference average 1951-1980. Source: Own elaboration in Stata software

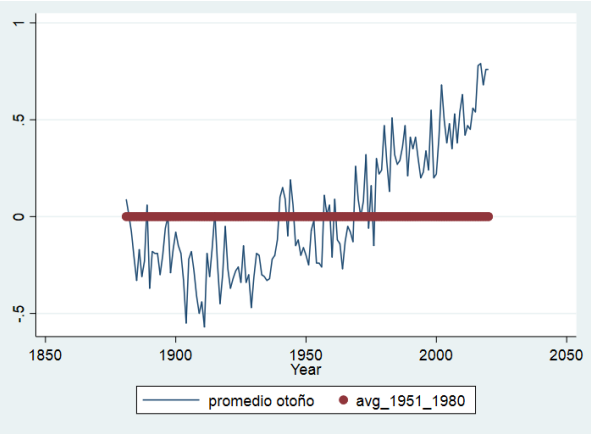

Figure 5. Autumn Season in relation to the reference average 1951-1980. Source: Own elaboration in Stata software

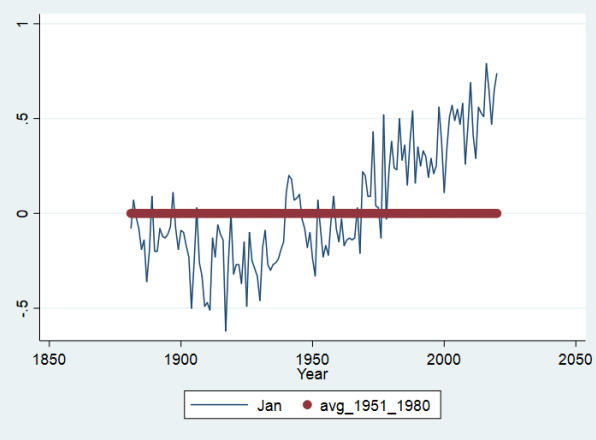

Figure 6. Month of January in relation to the reference average 1951-1980. Source: Own elaboration in Stata software

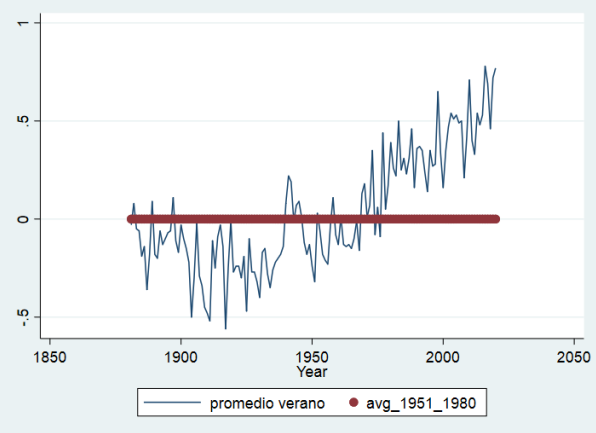

Figure 7. Summer average in relation to the reference average 1951-1980. Source: Own elaboration in Stata software

For example, regulating the production of multinationals that pollute in less strict countries, creating incentives to reduce fossil fuels (franchises and tax reductions for the creation of clean energy), applying taxes to goods and services that consume more energy, reducing production pollutants by recycling waste, reducing waste emissions and limiting water consumption, similar to what they did in South Africa in the face of the extreme drought that affected them between 2015 and 2018 (Muller, 2018). Cape Town, with 7M inhabitants, only had 10% of its single reservoir; water rates for companies doubled, and that for households increased by 40% by seeking innovative alternative solutions, such as meters that automatically cut off the supply when a household consumed more than 350 liters per day, in hotels 5-minute showers, new wells were drilled in the mountains and the city, some unfair laws were corrected, there was an increase in investment and research that, together with a cultural change, helped overcome the crisis (Enqvist & Ziervogel, 2019).

In this city, they are hiring people to eliminate plants that consume much water from the groundwater, the invasive Australian acacias. They are creating new jobs to eliminate them in 30 years. (In Chile, avocado trees, eucalyptus, and radiata pine represent high water consumption in the south, affecting the communities.)

In Africa, clean water is scarce (many children die), so people must boil it. In Uganda, for example, they boil it with wood and charcoal, which increases CO_2 emissions and eliminates the little existing forestry. To address this problem, some local entrepreneurs created sand-based filters and installed them in schools and for home use.

The abovementioned measures may offer short-term solutions by modifying production and consumption behaviors. Still, in the long term, they will contribute to the sustainability of biodiversity and favor future generations.

5. DISCUSSIONS

The investigation has yielded substantial findings concerning the impacts of climate change and temperature fluctuations in the Southern Hemisphere. The data analysis demonstrates a steady increase in average temperatures throughout the study. Statistical examination of trends has additionally demonstrated a

considerable and consistent growth in temperature, offering strong evidence of climate change over a prolonged period.

In addition, distinct temperature trends were observed in different southern hemisphere regions. Certain regions exhibited more pronounced temperature rises than others, indicating the presence of localized climatic impacts. Correlation research revealed connections between temperature fluctuations and other climate factors, such as precipitation and sea surface temperature. The difference is that interpolation creates continuity (the line passes through all points) that varies smoothly on surfaces to represent the increase in temperature. At the same time, trends allow us to evaluate how temperature data has changed over the years. By checking their increases or decreases, the trend allows us to indicate the direction or course of the temperature increase, decrease, or stabilization.

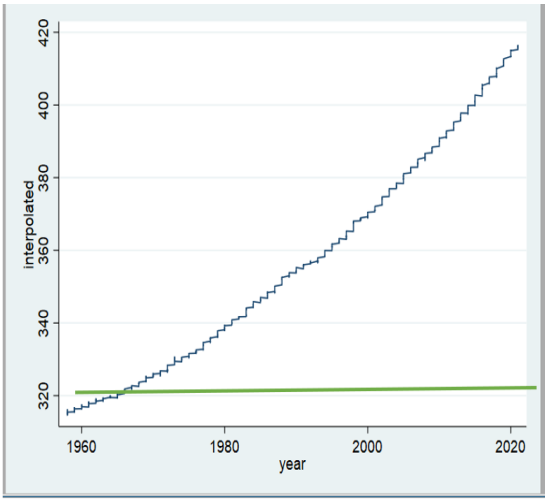

Figure 8. Interpolated and trending CO_2 levels on the vertical axis and time (from January 1960) on the horizontal axis. Source: Own elaboration in Stata software

Regarding the relationship between CO_2 and the passage of years from January 1960 to 2020 (see Figure 8), it is possible to see that CO_2 levels not only continue to grow but do so at an accelerated rate, that is, an abrupt increase in atmospheric concentrations of CO_2. In 2020, almost 420 CO_2 molecules were observed for every million molecules in the air, a figure close to 450 ppm that many scientists consider we should not cross to avoid the most catastrophic effects of climate change. Some scientists maintained in the past that the safe limit was 350 ppm (green line), which we already exceeded in 1990—seasonal changes in CO2 uptake cause the annual zigzags in the curve.

6. CONCLUSIONS

In conclusion, temperature fluctuations and climate change impacts in the Southern Hemisphere are intricate and multifaceted challenges demanding prompt attention and action. By collectively crafting targeted adaptation and mitigation strategies and deepening our understanding of the regional repercussions of climate change, each person can contribute positively to steering the planet toward a sustainable and resilient future. Urgent action is imperative to address the climate-induced challenges faced in the Southern Hemisphere and other regions. Thus, there is a need for further research related to climate change resilience, strategies, plans, and policy implementations, especially focused on local necessities, which will lead to coordinated efforts.

From the previous study of climate change's effects and temperature variation in the Southern Hemisphere from 1880 to the present, the statistical analysis has shown a steady increase in average temperatures, supporting the evidence of long-term climate change. Regional variation in temperature patterns points to the importance of considering specific geographical and climatic characteristics when assessing the impacts of climate change in different areas of the Southern Hemisphere.

Multifaceted approaches are required around the world to face climate change. One central aspect is greenhouse gas (GHG) emissions, which need to be the primary reduction and adaptation strategies to make people more able to deal with the changes. All the stakeholders, including governments, private companies, investors, and individuals, must be involved and collaborate to achieve sustainable development and protect vulnerable people and ecosystems. Thus, countries need to work together and use several strategies to deal with climate change, so reducing this threat and increasing resilience are huge challenges for countries.

7. ACKNOWLEDGMENTS

Conflicts of interest or competing interests: The authors declare no conflict of interest.

8. REFERENCES

Cai, W., Gao, L., Luo, Y., Li, X., Zheng, X., Zhang, X., Cheng, X., Jia, F., Purich, A., Santoso, A., Du, Y., Holland, D. M., Shi, J. R., Xiang, B., & Xie, S. P. (2023). Southern Ocean warming and its climatic impacts. Science Bulletin, 68(9), 946–960. https://doi.org/10.1016/j.scib.2023.03.049

Cardinale, B. J., Duffy, J. E., Gonzalez, A., Hooper, D. U., Perrings, C., Venail, P., Narwani, A., Mace, G. M., Tilman, D., Wardle, D. A., Kinzig, A. P., Daily, G. C., Loreau, M., Grace, J. B., Larigauderie, A., Srivastava, D. S., & Naeem, S. (2012). Biodiversity loss and its impact on humanity. Nature, 486(7401), 59–67. https://doi.org/10.1038/nature11148

Cavanagh, R. D., Melbourne-Thomas, J., Grant, S. M., Barnes, D. K. A., Hughes, K. A., Halfter, S., Meredith, M. P., Murphy, E. J., Trebilco, R., & Hill, S. L. (2021). Future Risk for Southern Ocean Ecosystem Services Under Climate Change. Frontiers in Marine Science, 7. https://doi.org/10.3389/fmars.2020.615214

Cordero, R. R., Feron, S., Damiani, A., Carrasco, J., Karas, C., Wang, C., Kraamwinkel, C. T., & Beaulieu, A. (2024). Extreme fire weather in Chile driven by climate change and El Niño–Southern Oscillation (ENSO). Scientific Reports, 14(1). https://doi.org/10.1038/s41598-024-52481-x

Dai, A. (2013). Increasing drought under global warming in observations and models. Nature Climate Change, 3(1), 52–58. https://doi.org/10.1038/nclimate1633

Dardati, E. (2020). Ley de Marco de Cambio Climático en Chile. Observatorio Económico, 150, 5. https://doi.org/10.11565/oe.vi150.399

Enqvist, J. P., & Ziervogel, G. (2019). Water governance and justice in Cape Town: An overview. WIREs Water, 6(4). https://doi.org/10.1002/wat2.1354

Friedlingstein, P., Jones, M. W., O'Sullivan, M., Andrew, R. M., Hauck, J., Peters, G. P., Peters, W., Pongratz, J., Sitch, S., Le Quéré, C., Bakker, D. C. E., Canadell, J. G., Ciais, P., Jackson, R. B., Anthoni, P., Barbero, L., Bastos, A., Bastrikov, V., Becker, M., . . . Zaehle, S. (2019). Global Carbon Budget 2019. Earth System Science Data, 11(4), 1783–1838. https://doi.org/10.5194/essd-11-1783-2019

GISTEMP Team (2024): GISS Surface Temperature Analysis (GISTEMP), version 4. NASA Goddard Institute for Space Studies. Dataset accessed 20YY-MM-DD at https://data.giss.nasa.gov/gistemp/.

Houghton, R. (2014). The Contemporary Carbon Cycle. Treatise on Geochemistry, 399–435. https://doi.org/10.1016/b978-0-08-095975-7.00810-x

IPCC. (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Krishnapriya, M., Nayak, R. K., Naidu, C. V., Allaudheen, S., Bhuvanachandra, A., Dadhwal, V. K., & Seshasai, M. V. R. (2022): Consistency of seasonal variability in regional CO2 fluxes from GOSAT-IM, NASA-GEOS, and NOAA-CT. Journal of Earth System Science, 131(3). https://doi.org/10.1007/s12040-022-01934-w

Leiva González, J., & Onederra, I. (2022). Environmental Management Strategies in the Copper Mining Industry in Chile to Address Water and Energy Challenges—Review. Mining, 2(2), 197–232. https://doi.org/10.3390/mining2020012

Leiva González, J., Diaz-Robles, L. A., Cereceda-Balic, F., Pino-Cortés, E., & Campos, V. (2022, August 2). Atmospheric Modelling of Mercury in the Southern Hemisphere and Future Research Needs: A Review. Atmosphere, 13(8), 1226. https://doi.org/10.3390/atmos13081226

Lenssen, N., G. Schmidt, J. Hansen, M. Menne, A. Persin, R. Ruedy, and D. Zyss, (2019): Improvements in the GISTEMP uncertainty model. J. Geophys. Res. Atmos., 124, no. 12, 6307-6326, doi:10.1029/2018JD029522

Louthan, A. M., & Morris, W. (2021). Climate change impacts on population growth across a species' range differ due to nonlinear responses of populations to climate and variation in rates of climate change. PLOS ONE, 16(3), e0247290. https://doi.org/10.1371/journal.pone.0247290

Muller, M. (2018). Cape Town's drought: don't blame climate change. Nature, 559(7713), 174–176. https://doi.org/10.1038/d41586-018-05649-1

Rosenzweig, C., Elliott, J., Deryng, D., Ruane, A. C., Müller, C., Arneth, A., Boote, K. J., Folberth, C., Glotter, M., Khabarov, N., Neumann, K., Piontek, F., Pugh, T. A. M., Schmid, E., Stehfest, E., Yang, H., & Jones, J. W. (2013). Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison. Proceedings of the National Academy of Sciences, 111(9), 3268–3273. https://doi.org/10.1073/pnas.1222463110

Salinger, M. J. (2005). Climate Variability and Change: Past, Present and Future – An Overview. Climatic Change, 70(1–2), 9–29. https://doi.org/10.1007/s10584-005-5936-x

Sasaki, M., Barley, J. M., Gignoux-Wolfsohn, S., Hays, C. G., Kelly, M. W., Putnam, A. B., Sheth, S. N., Villeneuve, A. R., & Cheng, B. S. (2022). Greater evolutionary divergence of thermal limits within marine than terrestrial species. Nature Climate Change, 12(12), 1175–1180. https://doi.org/10.1038/s41558-022-01534-y

Tans, D. P. (2023). NOAA/GML (gml. noaa. gov/ccgg/trends/) and Dr. Ralph Keeling, Scripps Institution of Oceanography (scrippsco2. ucsd. edu/).

Winckler Grez, P., Aguirre, C., Farías, L., Contreras-López, M., & Masotti, T. (2020). Evidence of climate-driven changes on atmospheric, hydrological, and oceanographic variables along the Chilean coastal zone. Climatic Change, 163(2), 633–652. https://doi.org/10.1007/s10584-020-02805-3