1. Introduction

The average temperature increase on the planet has been 1ºC since 1880 (IPCC 2021), but it has been three times higher in the Arctic region (AMAP 2021); in fact in some areas, such as the Barents Sea, warming has been seven times faster (Isaksen et al., 2022). This phenomenon, known as polar amplification, is much more pronounced in the Arctic (Pithan et al., 2014; Yamanouchi et al., 2020; Walsh, 2021; Chylek et al., 2022, 2023) than in the Antarctic (Salzmann 2017, Intergovernmental Panel on Climate Change, 2001). The reason is that the Arctic is an ocean covered by sea ice with a combination of feedback mechanisms that make it particularly vulnerable (Serreze et al., 2007; Miller et al., 2010), while the Antarctic is a high continent covered by ice and snow, and the ocean water comes from great depths and from such distant sources that it takes centuries before the water reaching the surface warms up (Cox et al., 2024).

The warming of the Arctic has various effects, such as the decrease in sea ice, which has reached historically low levels in recent years (Kinnard et al., 2011; United Nations Environment Programme, 2019), and in its thickness (Lindsay et al., 2015), which causes greater transmission of solar radiation to the ocean, accelerates the migration of ice and favours the formation of cyclones, among other climatic phenomena. The fact that there has also been an increase in the frequency of extreme weather events in mid-latitudes has led researchers to search for a causal relationship with Arctic amplification (Cohen et al., 2020). The AMAP 2021 report concludes that warming in the Arctic, between 1971 and 2019, has been three times faster than in the rest of the planet which is affecting global climate change.

The present paper provides new evidence on the role of polar amplification by analysing the stochastic behaviour of temperature anomaly series for the two poles as well as for the two hemispheres, and then the linkages between developments in the Arctic (Antarctic) and the

Northern (Southern) hemisphere as a whole. For this purpose, we use techniques based on fractional integration which shed light on the long memory feature observed in most climatological series and their long-run relationships (Gil-Alana et al., 2022; Yuan et al., 2022; etc.). The rest of the paper is structured as follows: Section 2 provides a short literature review; Section 3 outlines the methodology; Section 4 describes the data and discusses the empirical results; Section 5 offers some concluding remarks.

2. Literature Review

occurred without historical changes in greenhouse gases or aerosols. Johannessen et al. (2016) studied variability and trends in SAT between 1900 and 2014 for the entire Arctic and its different regions using an Arctic Amplification Index (AAI) that relates absolute values of Arctic and Northern Hemisphere (NH) trends calculated over successive 30-year periods, the index being calculated only for years in which both the NH and Arctic trends are significant at the 95 % confidence leve

Wang et al (2021) calculated the annual and seasonal mean surface air temperature (SAT) trend during 1979-2019 for the Antarctic and the mean trend of different southern sectors of Antarctic subregions. The observed temperature anomalies indicate that the smallest fluctuations occur in the austral summer and the largest ones in winter and spring, which implies that the mechanism of Antarctic amplification is unclear and suggests the need for future research on this issue. Zhu et al. (2023) noted that the largest amplification occurs in East Antarctic, followed by West Antarctic, whilst Antarctic amplification is absent in the Antarctic Peninsula. Xie et al. (2023) found a positive correlation between temperature changes in East and West Antarctic, but a negative one between Antarctic Peninsula temperatures and those in the Southern Hemisphere (SH). It appears therefore that Antarctic amplification is weaker than the Arctic

3.1 Short and Long Memory

A covariance stationary process is said to exhibit short

memory

ii) short memory (if $d = 0$),

iii) stationary long memory (if $0 < d < 0.5$),

iv)

v) unit roots (if $d = 1$),

vi) explosive patterns (if $d > 1$).

Reversion to the mean (which implies that shocks only have transitory effects) will occur as long as d is smaller than 1. On the contrary, if d is equal to or higher than 1, the series will not revert to its mean following a shock, namely the effects of the latter will be permanent.

4. Data Description and Empirical Results

We analyse temperature anomaly data for both the Arctic and Antarctic, as well as the Northern and Southern hemispheres. These provide information about departures from long-term averages, with positive (negative) values indicating warmer (cooler) temperatures than the reference values. The data source, as in several other global climate studies, is the NOAA (National Center for Environmental Information) archive. The series are monthly and span the periods from 1880 to 2022; they are the combined global land and ocean temperature anomalies, i.e., deviations from the 1901-2000 mean for each of the two hemispheres and from the 1910-2000 one for the Arctic and Antarctic.[1]

The estimated model is the following:

1

the 1901

(9)

L stands for the backshift operator, and d is the required differencing to make x_t a stationary I(0) process, where x_t are the integrated regression errors of order d or I(d); this impl nBT/F2 12 Tf1 0 01tBT0, and

As can be seen, the evidence concerning the time trends is very similar to the previous case: the estimated coefficients are 0.00107 and 0.00017 for the Arctic and Antarctic, and 0.00064 and 0.00034 for the Northern and Southern hemispheres respectively. The estimates of d are also very close to the previous ones: 0.31 and 0.20 for the Arctic and Antarctic, and 0.52 and 0.62 for the Northern and Southern hemispheres respectively. These findings confirm that polar amplification occurs in the Arctic

5. Conclusions

This paper uses fractional integration methods to obtain new evidence on polar amplification, namely the phenomenon that changes in the net radiation balance typically produce larger changes in temperature near the poles than in the corresponding hemisphere or the planet as a whole. The adopted modelling framework is very general since it allows the differencing parameter to take any real value, including fractional ones, and thus it does not impose any restrictions on the stochastic behaviour of the series of interest and provides useful information on both their short- and long-run properties.

The analysis is carried out using monthly temperature anomaly data for both the Arctic and the

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References

Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/

Isaksen, K., Nordli, Ø., Ivanov, B. (2022). Exceptional warming over the Barents area. Scientific reports 12, 9371. https://doi.org/10.1038/s41598-022-13568-5

Johannessen, O.M., Kuzmina, S.I., Bobylev, L.P., Miles, M.W. (2016). Surface air temperature variability and trends in the Arctic: new amplification assessment and regionalisation, Tellus (Series A) Dynamic Meteorology and oceanography, 68, 1. https://doi.org/10.3402/tellusa.v68.28234

Kantelhardt J.W., Koscielny-Bunde E., Rego H.H.A., Havlin S., Bunde A. (2001). Detecting long-range correlations with detrended fluctuation analysis. Physica A 295(3-4): 441 454. https://doi.org/10.1016/S0378-4371(01)00144-3.

Kinnard, C., Zdanowicz, C., Fisher, D., Isaksson, E., De Vernal, A., Thompson, L.G. (2011), Reconstructed changes in Arctic Sea ice over the past 1,450 years, Nature, 479, 509 512, https://doi.org/10.1038/nature10581

Kuzmina, S., Johannessen, O. M., Bengtsson, L., Aniskina, O., Bobylev, L. (2008). High northern

NOAA National Centers for Environmental information, Climate at a Glance: Global Time Series, Turner, J., Holmes,C., Harrison, T.C., Phillips, T., Jena, B., Reeves-Francois, T.G., Fogt, R.,Thomas, E.R., Bajish, C.C. (2022). Record Low Antarctic Sea Ice Cover in February 2022. Geophyicals. Reearchs Letter. 49, 12, e2022GL098904. https://doi.org/10.1029/2022GL098904

United Nations Environment Programme (2019). Global Linkages A graphic look at the changing Arctic. https://www.unep.org/resources/publication/global-linkages-graphic-look-changing-arctic

Vogelsang, T.J., Franses, P.H. (2005). Are winters getting warmer? Environmental Modelling and Software, 20(11), 1449-1455, https://doi.org/10.1016/j.envsoft.2004.09.016

Walsh, J.E. (2021). Arctic Climate Change, Variability, and Extremes. In: Yang, D., Kane, D.L. (eds) Arctic Hydrology, Permafrost and Ecosystems. Springer, Cham. https://doi.org/10.1007/978-3-030-50930-9_1

Wang, Sm., Xie, Ah., Zhu, Jp. (2011). Does polar amplification exist in Antarctic surface during the recent four decades?. Journal of Mountain Science 18

Yuan, N., C.L.E. Franzke, F. Xiong, Z Fu and W. Dong, 2022, The impact of long-term memory on the climate response to greenhouse gas emissions, *npj Climate and Atmospheric Science* volume 5, Article number, 70.

Zhu, J., Xie, A., Qin, X., Xu, B., Wang, Y. (2023) Assessment of Antarctic Amplification Based on a Reconstruction of Near-Surface Air Temperature. Atmosphere 2023, 14, 218. https://doi.org/10.3390/ atmos14020218

Table 1 : Estimated coefficients in the model given by Equation (1). Seasonal MA errors

Series	d (95% band)	Intercept (tv)	Time trend (tv)	Seasonality
ARTIC	0.32 (0.29, 0.36)	-0.87633 (-4.33)	0.00107 (6.42)	0.0417
Northern Hem.	0.50			

Table 3: Correlation cofficients among the variables

	ARTIC	NORTHERN H	ANTARCTIC	SOUTHERN H
ARTIC	**-----**	**-----**	**-----**	**-----**
NORTHERN H	**0.7906**	**-----**	**-----**	**-----**
ANTAR				