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ORIGINAL ARTICLE

Reassessing the Climate Change Narrative

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Abstract
We note that the atmosphere has distinct tropical and extratropical regimes. The tropical regime is significantly dependent on the greenhouse effect and is characterized by temperatures that are largely horizontally homogenized. The extratropical regime is dominated by large scale unstable convective eddies that transport heat between the tropics and the poles (leaving the poles warmer than they otherwise would be) and serve to determine the temperature difference between the tropics and the poles. Changes in tropical temperature and in the tropics-to-pole temperature difference both contribute to changes in global mean temperature. It turns out that changes in global mean temperature associated with major climate change (i.e., the last glacial maximum and the warm period of the Eocene about 50 million years ago) were associated primarily with changes in the tropics-to-pole temperature differences. By contrast, changes in global mean temperature over the past 150 years or so are almost entirely associated with changes in tropical temperature. Thus, there is no intrinsic amplification associated with a change in the tropics-to-pole temperature difference. However, model simulations of climate behave differently from both observations and from each other. In particular, they all show more significant contributions for the tropics-to-pole temperature difference – sometimes much more significant. They also show excessive tropical warming.

Keywords Climate change · Tropics-to-pole temperature · Baroclinic instability · Test of models

1 Introduction and Basic Concepts

The narrative underlying current concerns over Global Warming is that the Greenhouse effect is the essential control knob for major climate change on the earth.[1] The present paper will, we hope, clarify why this narrative is an incorrect view of major climate change on the Earth. The present paper is an expansion of ideas presented earlier.[2]

We begin by noting that the atmosphere has two distinct flow regimes: One describes the *tropics* (approximately -30° to + 30° latitude), and the other, the *extratropics* (~poleward of ± 30° latitude). This results from the rotation of the Earth and the Coriolis force associated with the component of the Earth's rotation vector perpendicular to the surface. This component is small in the tropics, but of dominant importance in the *extratropics*. When the Coriolis force is dominant, we have what is called *quasi-geostrophic* motion where the air flows primarily horizontally and primarily along isobars rather than across isobars. This is the situation outside the tropics. Within the tropics, where the Coriolis force is weak, the motion across isobars acts to eliminate horizontal gradients. It is generally referred to as *ageostrophic*. However, there are zonally-directed winds in the tropics (i.e. the trade winds) due to conservation of absolute angular momentum (Schneider 1977; Held and Hou 1980) that are not crossing isobars. These winds are largely easterly (i.e., from east to west).[3] By contrast, the prevailing winds in the extratropics are largely westerly (Fig. 1).

The two flow regimes are illustrated in the following figure.[4,5]

[1] An explanation of the Greenhouse Effect itself may be found in https://www.thegwpf.org/content/uploads/2022/09/Lindzen-global-warming-narrative.pdf

[2] An earlier discussion of the mechanism described in this paper can be found in Lindzen (2020).

[3] For simplicity, this overview glosses over westerly monsoon flow in certain zonal sectors. Monsoon westerlies originate in association with cross-equatorial air motion that is driven by land-heating effects and the ensuing Coriolis deflection to produce westerly flow.

[4] It should be emphasized that this is a schematic representation. In reality, the isentropes are hardly parallel straight lines. Moreover, those originating at the surface are distorted due to arctic inversions. The observed picture can be found in Fig. 2 of Sun and Lindzen 1994.

[5] ITCZ refers to the Intertropical Convergence Zone where cumulonimbus convection is concentrated.

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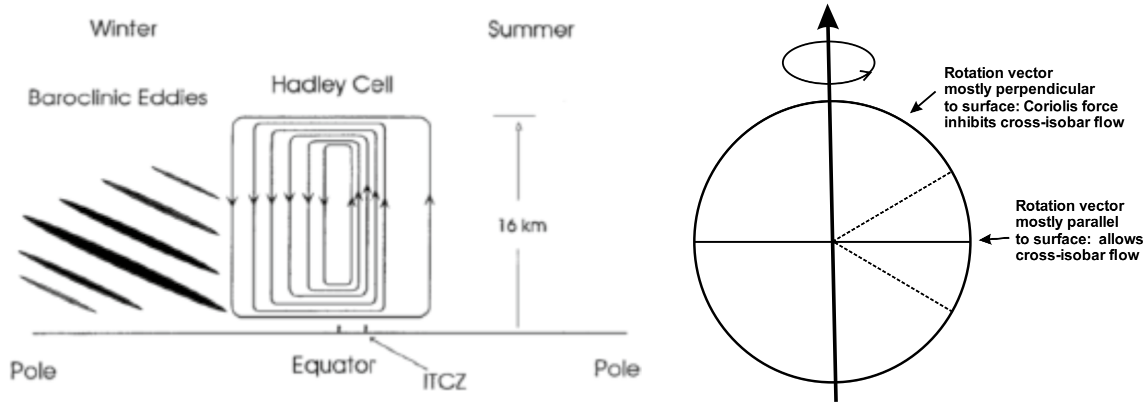

Fig. 1 Schematic representation of the Earth's two flow regimes. The summer hemisphere is characterized by weaker baroclinic activity. Of course, this is a simplification of the actual plethora of climate regimes that arise from the earth's complex topography. The data upon which the schematic is based can be found in Sun and Lindzen 1994

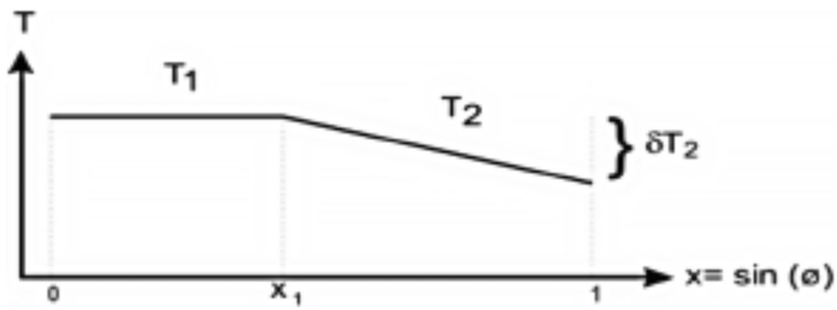

Fig. 2 Crude depiction of the Earth's meridional temperature distribution. T1 is the tropical temperature, T2 is the extratropical temperature, and δT2 is the temperature difference between the tropics and the pole. × 1 is the boundary between the tropics and the extratropics (i.e., the latitude of the jump in tropopause height from about 16 km in the tropics to about 12 km in the extratropics). φ is latitude

The Hadley circulation occurs in the tropics. Here, cumulonimbus convection acts in aggregate to rapidly establish a moist adiabatic lapse rate for the vertical temperature profile, and the circulation acts to establish this lapse rate throughout the tropics. The demarcation between the tropics and the extratropics is clearly indicated in the zonally averaged general circulation by the subtropical jet and the sharp decrease of the height of the tropopause from about 16 km in the tropics to about 12 km in the extratropics. This occurs sufficiently close to 30^0 latitude in both models and nature that the temperature variations are small.

Large scale disturbances known as baroclinic eddies appear in the extratropics and act to transport heat to high latitudes, thus reducing the temperature difference that would exist in their absence. These eddies operate collectively as a heat pump regulating the temperature gradient between the equatorial region and the polar region. They are the eastward moving cyclonic and anticyclonic systems that one sees on weather maps of the extratropics. The black objects in the schematic correspond to surfaces of equal potential temperature[6] (called *isentropes*) along which transport occurs. The slope of the isentrope that leaves the surface at the edge of the tropics determines the boundary between the polar troposphere and the stratosphere (i.e., the polar tropopause), and when this slope is less than a certain value, the baroclinic eddies cease to grow (Jansen and Ferrari 2013).[7] Note that over much of the extratropics, isentropes originate in the tropics, and, since these isentropes are roughly parallel to each other, they approximately produce lapse rates similar to those in the tropics. It can be said that this is due to convection in the tropics. However, it is not due significantly to moist convection in the extratropics.

[6] Entropy in meteorology is given by potential temperature which is the temperature of a parcel of air that is brought to the pressure at the surface.

[7] An idealized example of the tropical-extratropical regimes can be found in Lewis and Langford 2008.

The eddies act to bring this slope to a neutral value where they cease to grow in amplitude and the corresponding heat pump then turns off. This establishes the tropics-to-pole temperature difference at the polar tropopause to a value of about 20°C which is what is observed (Newell et al 1972). This was also, significantly, the difference at the surface during the Eocene Period.[8] However, the isentropes below the critical isentrope originate on the non-tropical surface and depend on surface conditions there, like the presence or absence of ice. The presence of ice leads to arctic inversions in which temperature increases rather than decreases with altitude for several kilometers and results in larger tropic-to-pole temperature differences at the earth's surface compared with the same difference at the polar tropopause.

2 Major Climate Change of the Past

By the 1980's, with advances in paleoclimatology, several aspects of climate history emerged with greater clarity. We began to see the cyclic nature of the glaciation cycles of the past million years or so. Warm periods like the Eocene (about 50 million years ago) became better defined. The data suggests that for both glacial periods and the Eocene, equatorial temperatures differed little from the present values, but the temperature difference between the tropics and high latitudes varied greatly. The following are the estimated differences (note that ΔT refers to the change in T between the tropics and the poles).

Eocene	$\Delta T \approx 20$°C (Shackleton and Boersma 1981)
Glacial Maximum	$\Delta T \approx 60$°C (Imbrie and Imbrie 1979)
Present	$\Delta T \approx 40$°C (Newell et al 1972)

The following is a simplified[9] picture of the meridional temperature between the equator (sin (φ) = 0) and the pole (sin(φ) = 1 ($x_1 = 0.5$ for φ = 30°):

$$\Delta\overline{T} = \Delta T_1 - \Delta\left(\delta T_2\right)\frac{1-x_1}{2} = \Delta T_1 - \Delta(\delta T_2)\frac{1}{4} \tag{1}$$

In general, variations in $\Delta\overline{T}$ are dominated by $\Delta(\delta T_2)$ and $\Delta(\delta T_2)$ is determined by the dynamics of the extratropics and not primarily the tropics which are subject to the Greenhouse Effect.

[8] In principle, this suggests that 20 °C is the minimum tropics-to-pole temperature difference.

[9] The crudeness of paleoclimate data hardly justifies any more than the simplified picture in Fig. 2. However, we will be able to use the far more detailed instrumental data available for modern times in assessing present climate.

The above leads to the following conclusions with respect to *major climate changes*:

1. From paleoclimatic records it appears that temperature in the tropics has been relatively constant, compared to variations of temperature at the Poles.
2. Greenhouse gasses are relevant to temperature change in the tropics and have relatively little to do with the forces that influence differences in temperature between the tropics and the poles.[10]
3. Historically, temperature differences between the poles and the tropics have fluctuated far more than temperature changes at the equator.
4. These fluctuations depend on conditions on the earth's surface outside the tropics and are not primarily affected by Greenhouse Effects.
5. If Greenhouse effects were a significant factor on climate, the temperature in the tropics would be the main factor in changes of average earth temperature. Studies of historical temperature changes show the opposite: It is the difference between polar and tropical temperature which has varied, and this has little to do with Greenhouse Effects. Thus, comparing changes in past $\Delta\overline{T}$ with Greenhouse estimates is inappropriate. Note that doing so has been largely the basis for claiming that relatively small changes in $\Delta\overline{T}$ due to greenhouse changes are associated with major climate change.
6. Note that the changes in $\Delta\overline{T}$ associated with these major climate changes are only on the order of 5C, which is the basis for claiming that inflated (due to assumed positive feedbacks) estimates of climate sensitivity based on the greenhouse mechanism are close to changes associated with major climate changes, but the changes associated with these changes were not due to greenhouse forcing.
7. A factor that we have not tried to estimate is the change in the heat flux drawn from the tropics as a result of the changes in the tropics to pole temperature differences. However, the fact that such changes seem to have yielded little change in tropical temperature may have important implications for climate sensitivity.

[10] It would be difficult to rule out any tropical influence (other than as a constant of integration; viz the first term on the right-hand side of Eq. (1)) on the extratropics. However, such effects as have been identified like the distance of the ITCZ from the equator (Lindzen and Hou 1988), the concentration of the ITCZ (Hou and Lindzen 1992), or the role of changing topography (Molnar 2008) are, themselves largely unrelated to the Greenhouse Effect. To be sure, the modest greenhouse warming affecting the extratropics could alter the distribution of snow and ice cover and result in some additional warming. However, as we will see in Fig. 3, this does not appear to be significant for the current warming.

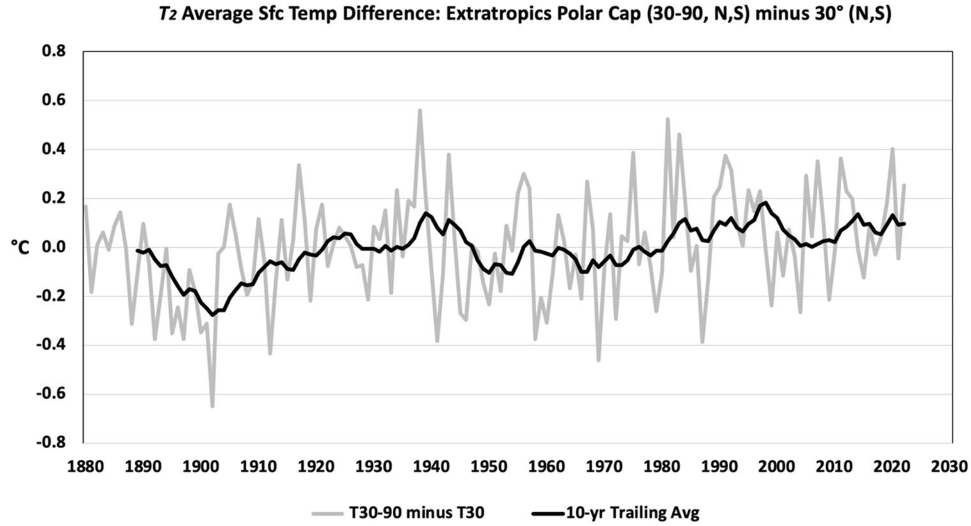

Fig. 3 Contribution to mean temperature change from polar cap (30° to 90°) to tropics (30° latitude band) temperature difference

To be sure, the Greenhouse picture is of use in comparing the overall climates of different planets. In this case changes in mean temperature are indeed dominated by changes in tropical temperature. Changes in climate within a given planet are a very different matter.

3 How Does Climate Change on Earth Since the 19th Century Compare with Major Climate Changes of the Past?

In comparing the climate change since the nineteenth century with major climate changes of the past, it is legitimate to ask whether such a comparison is even relevant. Recent climate change has been associated with increasing levels of CO_2 while for the glaciation cycles, changes in summer insolation changes in the arctic due to orbital variations are found to be drivers (Milankovitch 1941, Roe 2006, Edvardsson et al. 2002) and changes in CO_2 appear to follow rather than lead changes in temperature. The situation with respect to the warm Eocene is less clear, but again processes other than changes in CO_2 appear to be at issue. However, in arguing that the relatively small changes in mean temperature anomaly associated with current warming could represent major climate change, it is noted that in the major climate change of the past, the large changes in the tropics to pole temperature difference were also associated with relatively small changes in mean temperature. It was suggested that tropical changes would be accompanied by polar amplification that would render the small seeming changes in mean temperature anomaly much more important. It is this hypothesis that we wish to investigate.

In using both the instrumental record and model outputs, there is no need to use the crude depiction of Fig. 2 and Eq. 1. Instead, we will use the actual distributions of annual mean temperature anomalies (viz Lindzen and Christy 2020). The surface temperature data indices we use were calculated from the NOAA gridded surface temperature data downloaded from here: https://psl.noaa.gov/data/gridded/data.noaaglobaltemp.html.

Here, $\overline{T}$ will simply be the average temperature anomaly from -90° to +90°.

T_1 average = average of T between -30° and + 30° applied to -90° to 90°. This is basically the contribution of tropical temperature change to global mean temperature.

$T_2 = 0$ for φ between -30° and + 30°, $T_2 = T(\varphi) - T(30°)$ for φ between 30 and 90 °, $T_2 = T(\varphi) - T(-30°)$ for φ between -30 ° and -90 °, T_2 average = average of T_2 from -90 ° to 90 °. This is basically the contribution of the tropics (at 30° latitude)-to-poles temperature difference to global mean temperature.

We next compare time series of T_2 average, T_1 average, and T average. The point of this comparison is to see the extent to which changes in tropical temperature and changes in the tropics-to-pole temperature difference have contributed to the observed changes in global mean temperature.

Note that the contribution in Fig. 3 is irregular and small, and manifests almost no trend.

Note that the tropical mean and the annual mean are almost identical (Figs 4 and 5), while the contribution from changes in the tropics-to-pole temperature difference contribute negligibly and irregularly. This is profoundly different from the situation characterizing major climate change in the paleoclimate record.

4 How Does the Data Compare with What Models Have Projected?

In this section we repeat the analysis of Sect. 3 for the outputs of IPCC models with data for comparison. The model outputs are taken from 12 climate models participating in the

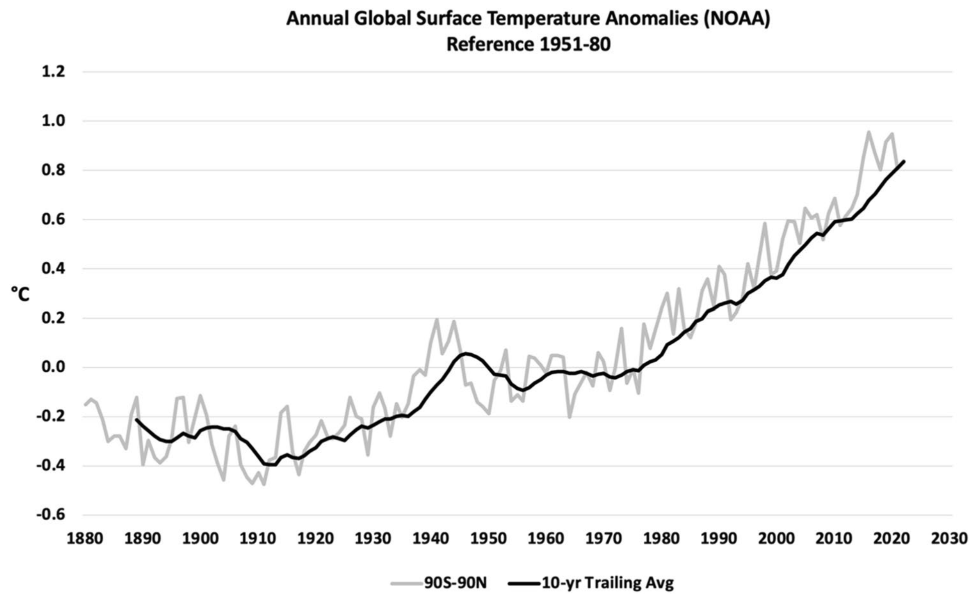

Fig. 4 Mean annual temperature v. year

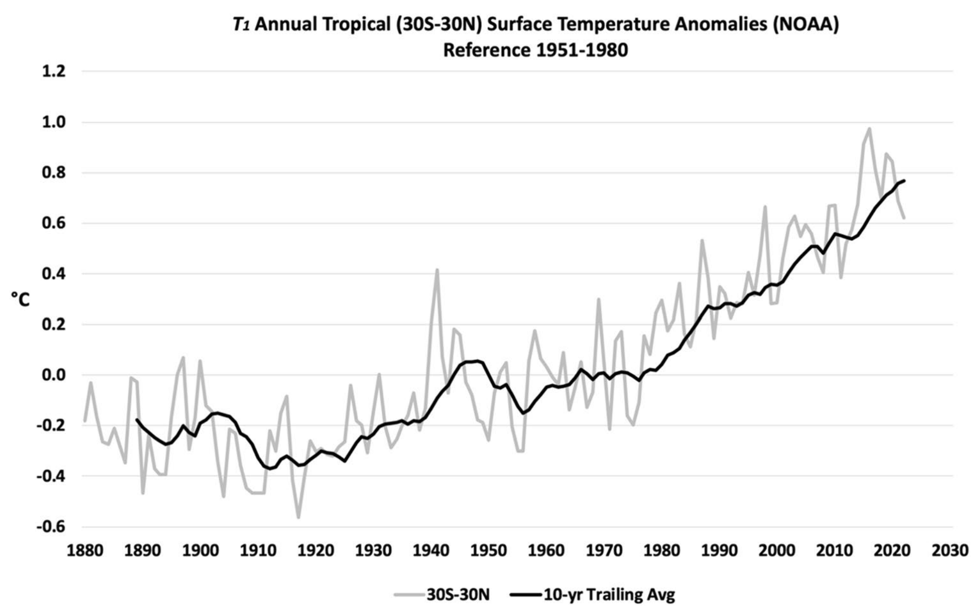

Fig. 5 Mean tropical temperature v. year

Climate Model intercomparison Project #6 or CMIP6 downloaded from the Climate Explorer archive (https://climexp.knmi.nl/start.cgi). For clarity of presentation we have selected characteristic examples from the models used by the IPCC in the most recent Assessment Report #6 or AR6.

The differences from the observed behavior are clear and pronounced. This is especially clear after 1973 as quantified in the next figure where we see polar temperatures increasing much faster for the models than for the observational data.

As noted in Figs. 6 and 7, the average-pole-to-subtropics surface temperature gradient is decreasing in the models (poles warming relative to subtropics) which is not evident in the observations. We note that the models do show a wide range of values. We examined the hemispheres separately and found opposing results in the observations, i.e. the gradient (pole minus subtropics) was modestly strengthening (pole cooling relative to subtropics) in the SH and modestly relaxing in the NH with magnitudes of approximately 0.3 °C each in the past 50 years. In contrast, the average model result indicated a slight lessening of the SH gradient (rather than a strengthening as observed) and a stronger reduction of the NH gradient than observed.

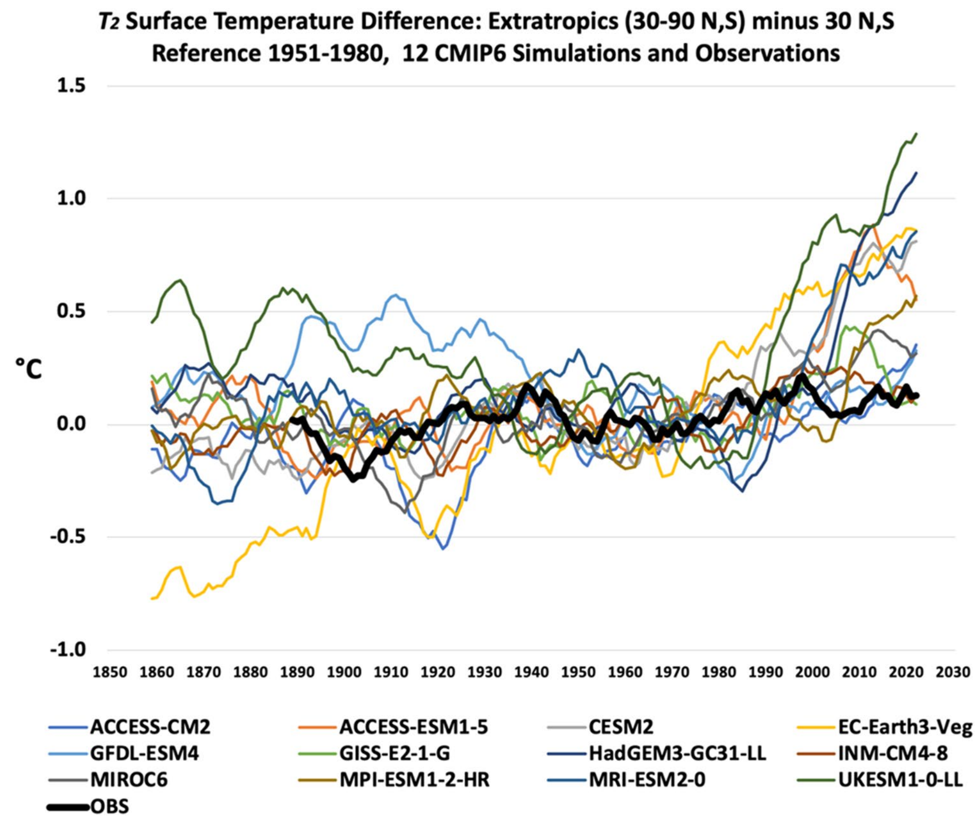

Fig. 6 Annual Mean of the difference between the temperature anomaly for the area average of 30°-90°N,S and the latitude band at 30°N,S. Values are 10-year trailing means ending in 2022

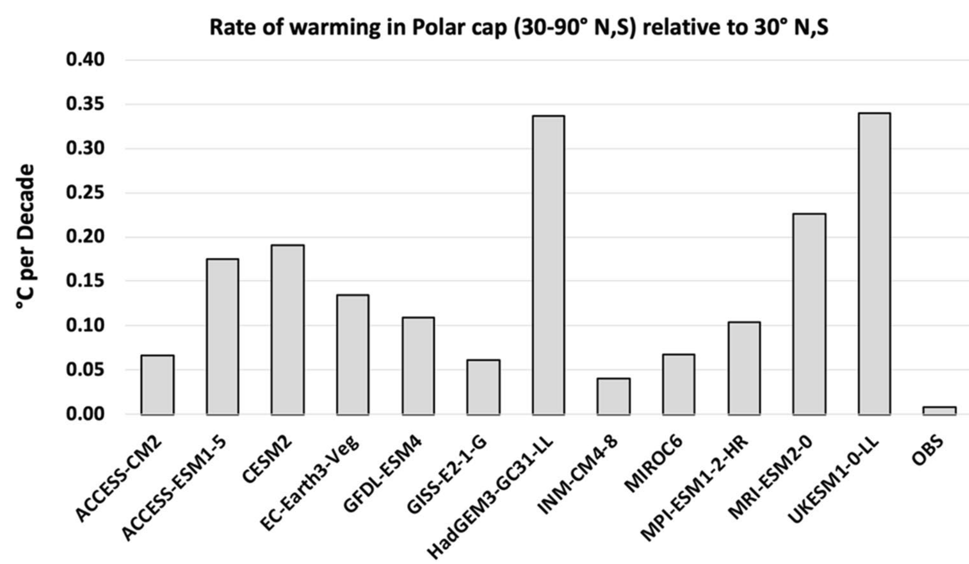

Fig. 7 Rate at which polar temperatures are warming relative to ± 30o between 1973 and 2022

Whereas the observed temperatures in Figs. 8 and 9 are essentially indistinguishable, the same cannot be said of most of the model results.

The full extent of the difference between the models (as well as the national origin of the individual models) is shown in Table 1 below.

While major climate regimes like the present, the Last Glacial Maximum, and the equable climate of the Eocene differed primarily in the difference in temperature between the tropics and the poles, the data shows that current warming is almost entirely due to tropical warming with essentially no significant contribution from alleged polar amplification (Fig. 3). However, the same cannot be said of most model results (Figs. 7, and 8). This is almost certainly related to the fact that the models all tend to run hot (McKitrick and Christy 2020, Table 1). That at least some

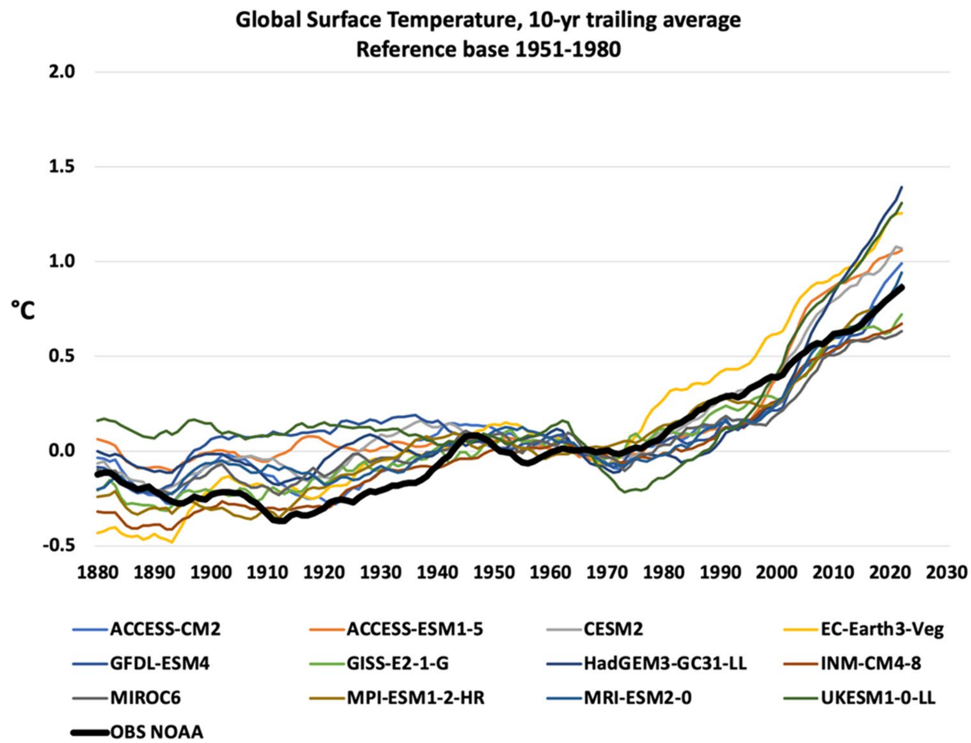

Fig. 8 Annual Mean Temperature, 10-year trailing mean temperature anomalies relative to 1951–1980 mean

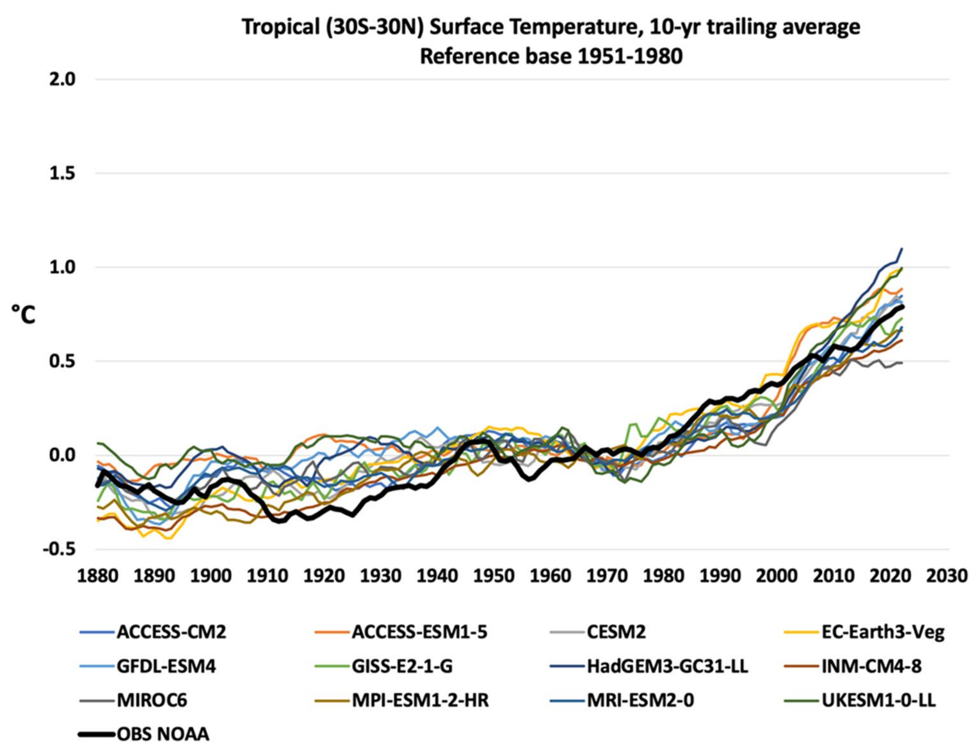

Fig. 9 Annual Mean Tropical (30S-30N) 10-year trailing mean temperature anomalies relative to 1951–1980 mean

models are having problems correctly depicting the tropics-to-pole temperature differences has long been evident. Thus, attempts to model the Eocene warm period by cranking up CO_2 have generally produced tropics-to-pole temperature distributions almost identical to the present distribution despite the absence of ice (Barron and Washington 1985; Huber and Sloan 1999; Huber and Caballero 2011). This, in turn, required that tropical temperatures increase about as much as polar temperatures – in distinct contrast to the data. Such problems were already noted by Greenwood and

Table 1 Table of models used. All were forced with historical forcing through 2014 then forced with the ssp2-4.5 scenario thereafter, which is considered to be the "middle of the road." Modest correlations of + 0.68 and + 0.73 respectively are calculated between the Equilibrium Climate Sensitivity of each model and (a) the value of the Pole-Eq gradient trend and (b) the tropical tropospheric temperature trend during the satellite era (1979–2022, McKitrick and Christy 2020 updated to 2022)

Model ID	Run ID	Source	Equilibrium Climate Sensitivity °C	Polar cap minus 30°Lat gradient trend °C/decade	Tropics (20S-20°N) Tropospheric Trend 79–22 °C/decade
ACCESS-CM2	r1i1p1f1	Australia	4.8	+ 0.06	+ 0.32
ACCESS-ESM1-5	r1i1p1f1	Australia	4.0	+ 0.17	+ 0.36
CESM2	r1i1p1f1	United States NCAR	5.2	+ 0.19	+ 0.27
EC-Earth3-Veg	r1i1p1f1	European Community	4.3	+ 0.14	+ 0.33
GFDL-ESM4	r1i1p1f1	United States NOAA	2.7	+ 0.11	+ 0.31
GISS-E2-1-G	r1i1p3f1	United States NASA	2.7	+ 0.16	+ 0.27
HadGEM3-GC31-LL	r1i1p1f3	United Kingdom	5.6	+ 0.34	+ 0.43
INM-CM4-8	r1i1p1f1	Russia	1.8	+ 0.04	+ 0.25
MIROC6	r1i1p1f1	Japan	2.6	+ 0.07	+ 0.18
MPI-ESM1-2-HR	r1i1p1f1	Germany	3.0	+ 0.10	+ 0.25
MRI-ESM2-0	r1i1p1f1	Japan	3.1	+ 0.23	+ 0.21
UKESM1-0-LL	r1i1p1f1	United Kingdom	5.4	+ 0.34	+ 0.39
Observations				**+ 0.01**	**+ 0.13**

Wing (1995). Even the fact that the various models that we have examined have very different results for the tropics-to-pole temperature differences (as well as excessive tropical warming) indicates a significant problem.

5 Concluding Remarks

We noted that major changes in the Earth's paleoclimate were characterized by large changes in the tropics-to-pole temperature difference and relatively small changes in tropical temperature. In contrast to this, warming since 1880 is almost entirely due to changes in tropical temperature, with insignificant changes in the tropics-to-pole surface temperature difference. This has profound implications since the small tropical warming is not indicative of larger warming in the extratropics. However, all the models we examined not only displayed greater tropical warming than has been observed for the period 1880–2022, but also, in distinct contrast to the observations, all the models displayed significant increases in the tropics-to-pole temperature difference. The greater tropical warming is likely associated with the radiative feedbacks associated with the greenhouse impact of water vapor and clouds and the reflectivity of clouds. These are all associated with major sources of uncertainty. This was noted in Sect. 7.2.2 of the Intergovernmental Panel on Climate Change's 3rd Assessment report (https://www.ipcc.ch/site/assets/uploads/2018/03/WGI_TAR_full_report.pdf) and remains so to the present (Mauritsen and Stevens 2015; Trenberth and Fasullo 2009; Lindzen and Choi 2021). The anomalous change in tropics-to-pole temperature difference points to model problems with meridional hydrodynamic heat flux. For models to be useful, these problems need to be identified and corrected. In fact, the results in this paper suggest that an eventual model for climate would be characterized by a relatively insensitive tropics including those extratropical isentropes originating in the tropics (as in Fig. 1)[11] with major climate changes associated with behavior at the surface in the extratropics which is determined by a variety of influences including orbital variations in high latitude insolation (i.e., the Milankovitch mechanism: Milankovitch 1941, Roe 2006, and Edvardsson et al 2002) and the variety of ocean circulations which carry heat to and from the surface with time scales ranging from years to millenia.

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[11] Note that even a warming of a few degrees in the tropics would only be a relatively minor matter in the absence of polar amplification.

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