Stuck!

By John Benson, August 2021

1. Introduction

I've known for some time that, in the U.S., in summer, weather patterns can stall in one place for some time. For at least the last month, a large high-pressure cell has been stuck over the four-corner area (Utah, Colorado, Arizona and New Mexico). This cell will occasionally move to the west a bit and the weather in California heats up, and then back to the east, and it cools down. It is pumping large amounts of monsoonal moisture from the Pacific off of Baja mostly into the four corner states (there is currently (8/2) a "heavy rain/flash flooding alert" for Arizona New Mexico and Colorado). Little of this moisture makes it into Central California where we have an exceptional drought.

I've known about the science around this for a few years, because I read an article in Scientific American about it in 2019, and consequently researched it further then wrote the paper described and linked below.

Emerging Negative Effects of Climate Change: *Climate change is caused by greenhouse gases (GHG), primarily carbon dioxide (CO_2) and methane, increasing in the atmosphere. This results in atmospheric warming. There are also many secondary, tertiary and higher order effects, including the following:*

- *The sea-level rise*
- *Both heat and CO_2 enter the oceans and the latter acidifies them.*
- *Disruption of the Meridional Overturning Circulation (MOC, the Gulf Stream and other major ocean currents).*
- *Increasing atmospheric temperatures and the MOC disruption have caused major changes to weather patterns around the world.*

This paper is about an emerging understanding of the last bullet, and the impacts (so far), especially in North America.

https://www.energycentral.com/c/ec/emerging-negative-effects-climate-change

I occasionally reference writings by Dr. James Hansen. If you know anything about climate science, you know who Dr. Hansen is, but for the few that don't:

Dr. James Hansen, formerly Director of the NASA Goddard Institute for Space Studies, is an Adjunct Professor at Columbia University's Earth Institute, where he directs the Program on Climate Science, Awareness and Solutions. He was trained in physics and astronomy in the space science program of Dr. James Van Allen at the University of Iowa. His early research on the clouds of Venus helped identify their composition as sulfuric acid. Since the late 1970s, he has focused his research on Earth's climate, especially human-made climate change. Dr. Hansen is best known for his testimony on climate change to congressional committees in the 1980s that helped raise broad awareness of the global warming issue. [1]

I'm on Dr. Hansen's mailing list, and once or twice a month his team sends me a brief paper. The words and images in the first 3 sections below are from his most recent

[1] Climate Science Awareness and Solutions, Earth Institute, Columbia University, James E. Hansen, Director, https://csas.earth.columbia.edu/about/people/james-e-hansen

paper (7/13/2021). This is referenced and linked below.[2] Other references from these sections (except reference 6) are from the original paper.

2. Shifting Climate Change Temperature Distribution

Global temperature in June was +1.13°C (relative to the 1880-1920 base period, which is our best estimate of preindustrial temperature); it was +0.85°C relative to the 1951-1980 base period. High temperature anomalies were notable in northwest North America, northeast Siberia, an… area covering much of Europe and western Asia (Fig. 1). The Pacific Northwest heatwave continued into July with daily temperatures exceeding prior records by several degrees, an extreme that merits discussion.

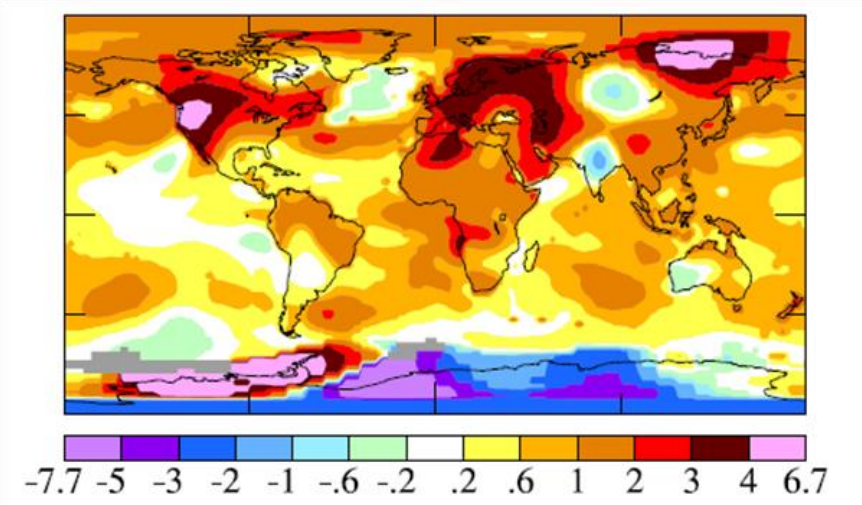

Fig. 1. June 2021 surface temperature anomaly (°C) relative to the 1951-1980 base period.

One proffered explanation is the "fat tail" of climate sensitivity, but that fat tail refers to different physical effects and is a wrong explanation for the Pacific Northwest heat wave.[3] A correct partial explanation is implicit in the "bell curve" for interannual variability of local temperature based on observations.[4] Fig. 2 shows that the warming of the past half-century has caused the bell curve to shift to the right and develop a long, fat tail. A

[2] Dr. James Hansen and Makiko Sato, "June 2021 Global Temperature Update", July 13, 2021, http://www.columbia.edu/~mhs119/Temperature/Emails/June2021.pdf

[3] The fat tail for climate sensitivity is illustrated and explained by Sherwood, S.C., M.J. Webb, J.D. Annan, K.C. Armour, P.M. Forster, J.C. Hargreaves, G. Hegrl, S.A. Klein, K.D. Marvel, E.J. Rohling, M. Watanabe, T. Andrews, P. Braconnot, C.S. Bretherton, G.L. Foster, Z. Hausfather, A.S. von der Heydt, R. Knutti, T. Mauritsen, J.R. Norris, K.B. Tokarska and M.D. Zelinka: An assessment of Earth's climate sensitivity using multiple lines of evidence, *Rev. Geophys*, **58**, e2019RG000678, 2020. That fat tail – for the probability of climate response to a climate forcing – is pronounced because Earth's long-term climate change is dominated by amplifying feedbacks. Uncertainty of a feedback on the high side has a larger effect on the net response because it is pushing the system toward a less stable regime. Thus, already in 1984 when paleoclimate data allowed a best estimate for climate sensitivity of about 3°C for doubled CO_2, we gave the uncertainty range as 2.5 to 5°C (Hansen, J., A. Lacis, D. Rind, G. Russell, P. Stone, I. Fung, R. Ruedy, and J. Lerner: Climate sensitivity: Analysis of feedback mechanisms. In *Climate Processes and Climate Sensitivity*. J.E. Hansen, and T. Takahashi, Eds., AGU Geophysical Monograph 29, Maurice Ewing Vol. 5. American Geophysical Union, 130-163, 1984).

[4] Hansen, J., M. Sato, and R. Ruedy: Perception of climate change. *Proc. Natl. Acad. Sci.*, **109**, 14726-14727, 2012.

summer that is three or more standard deviations warmer than the 1951-1980 average – which almost never occurred during 1951-1980 – is now rather common…

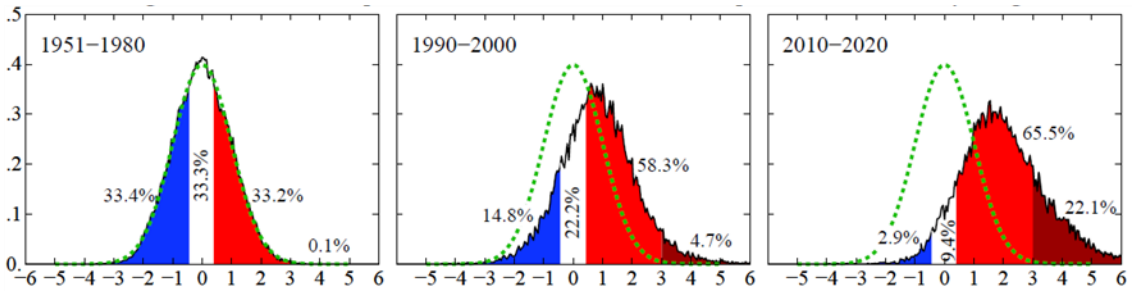

Fig. 2. Shifting distribution of temperature anomalies for Northern Hemisphere land for June-July-August. The graph shows the frequency of occurrence (y-axis) of local temperature anomalies divided by the local standard deviation (x-axis) obtained by binning all local results for the indicated region and period into 0.05 frequency intervals. Area under each curve is unity. Standard deviations are for the 1951-1980 period.

3. Rossby Waves

The shifting bell curve due to global warming can account for record temperatures in the U.S. Southwest this week, but a special factor contributed to the remarkable Pacific Northwest heat wave. Jacob and Reeder[5] discuss the meteorologic origin of an extreme atmospheric Rossby (planetary) wave with a slow-moving high-pressure system that essentially parked over the Pacific Northwest. Rossby waves are associated with waggles (undulations) of the upper tropospheric jet stream and are a normal part of mid-latitude weather systems.

Rossby waves, the upper tropospheric jet stream, and storm tracks guided by the jet stream are all related, and all are affected by the global warming caused by increasing greenhouse gases. The jet stream is driven by the temperature gradient from middle to polar latitudes. An especially cold Arctic tends to cause a strong, tightly-wound jet stream. However, an increased greenhouse effect warms the Arctic more than mid-latitudes, reducing the temperature gradient, thus slowing the jet stream and allowing it to have more extreme waggles. This was likely a contributing factor in the Pacific Northwest heat wave.

Such dynamical effects are of course included in the Fig. 2 bell curves – because they are based on observations – but Fig. 2 is for seasonal mean temperature anomalies. Effects of a more undulating jet stream may be more prominent in a similar analysis for short-term heat waves.

3.1. More Evidence from Europe

The Science article referenced here[6] and quoted below suggest that the recent flooding in Germany and Belgium also may be linked to the effect described above.

New research suggests such risks could grow if climate change slows the jet stream—the high-altitude winds circling the Northern Hemisphere—causing drenching rainstorms

[5] Jakob, C. and M. Reeder, Monash University, The North American heatwave shows we need to know how climate change will change our weather, *The Conversation*, 2 July 2021.
[6] Warren Cornwall, Science, "Europe's deadly floods leave scientists stunned," July 20, 2021, https://www.sciencemag.org/news/2021/07/europe-s-deadly-floods-leave-scientists-stunned

to linger longer over flood-prone landscapes. Storms that stall over Europe were once exceedingly rare. But according to a study published last month in Geophysical Research Letters, in a worst case scenario such storms could become as much as 14 times more common in 2100 than they were at the start of this century.

The exact weather pattern driving the current storm is different, says the paper's lead author, hydro-climatologist Hayley Fowler of Newcastle University. But the overall dynamic is similar, she adds: A slow-moving storm overwhelms a region's river system.

Floods already rank as the most destructive natural hazard in Northern Europe. Past events—including deadly floods in 2002—led the European Commission to launch the European Flood Awareness System, meant to provide emergency managers with early warnings. But last week the speed and intensity of the flooding in Germany—especially in towns perched next to smaller creeks—took most people by surprise. "There was simply no time," Hattermann says. "Then, of course, people run to save their cars and whatever and bad things happen."

4. Other Recent Climate Data

Global temperature in June 2021 was close to being a record (Fig. 3), despite the fact that global temperature now is under the influence of the recent strong La Nina (Fig. 4). Global temperature is correlated with ENSO (El Nino Southern Oscillation), with global temperature lagging the Nino 3.4 index by 5 months on average.[2]

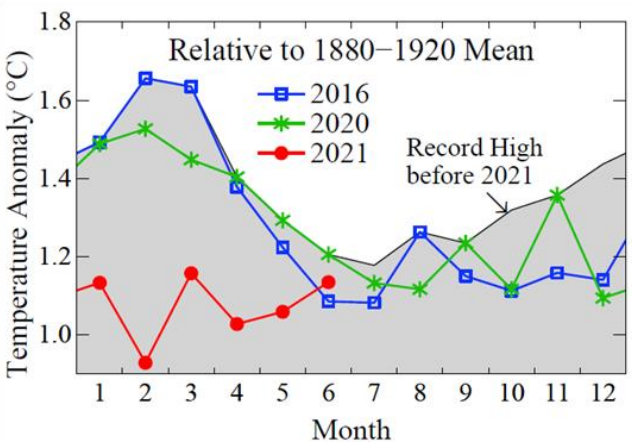

Fig. 3. Monthly global temperature anomalies relative to 1880-1920 average.

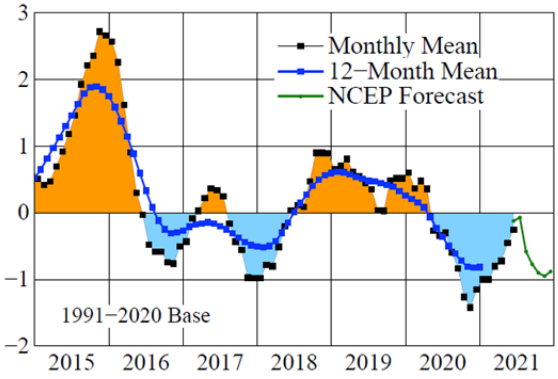

Fig. 4. Nino3.4 temperature anomaly in °C relative to 1991-2020 base period.

By Northern Hemisphere summer, ENSO forecasts for the following winter become reasonably reliable, so the NOAA NCEP forecast of a double-dip La Nina (Fig. 4) is probably reliable. Nevertheless, the 12-month running-mean global temperature (Fig. 5) is probably near a minimum, because it is not difficult for global temperature in upcoming months to match the temperatures 12-month-earlier temperatures that were cooled by a strong La Nina.

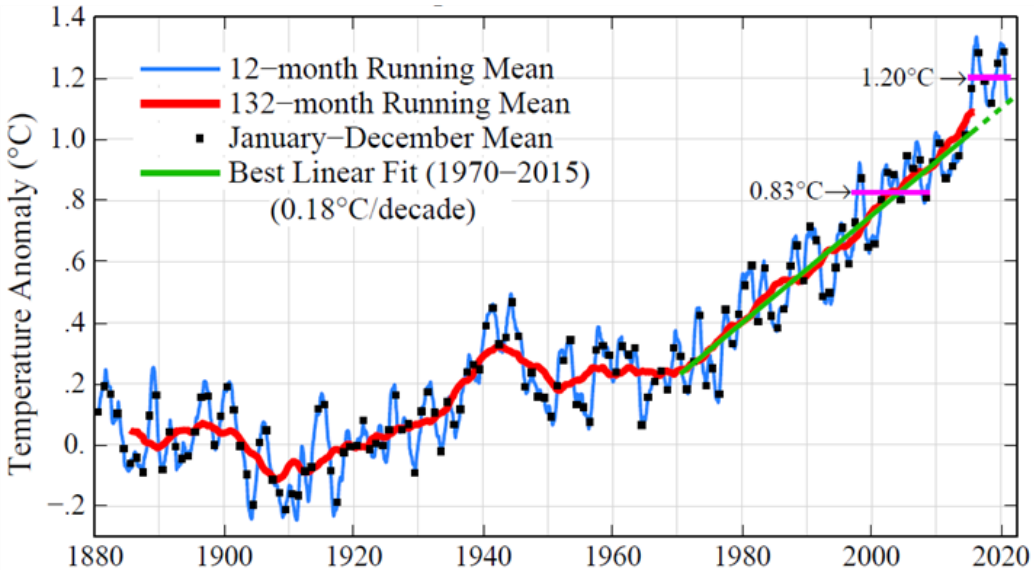

Fig. 5. Global surface temperature relative to 1880-1920 average. The two "hiatus" periods (purple bars) are taken as 1997-2008 and 2015-2021 (June).

Thus it is of interest to compare the current "hiatus" in global warming with the prior, more "famous" hiatus, as shown by the horizontal purple bars in Fig. 5. Global warming between those two periods is 0.37°C, which is a rate of 0.24°C per decade. That rate exceeds the longer term trend of 0.18°C per decade, indicative of the global warming acceleration during the past decade. In our November 2020 Temperature Update we attribute the acceleration to the measured increase in greenhouse gas growth rate and a presumed (but unmeasured) absolute decrease of atmospheric aerosols.

Global temperature anomalies in the two hiatus periods are compared in Fig. 6, with the change between the two periods shown in the map on the right. Arctic warming is remarkably about 2°C in just this short period of time (15 years). Other noteworthy features of the temperature change during this period are the cooling southeast of Greenland and the absence of any significant warming in the Southern Ocean around Antarctica. These latter two features are consistent with our conclusion that most current ocean models are unrealistically insensitive to fresh water injection from increasing ice melt, as described in our Ice Melt paper.[7]

[7] Hansen, J., M. Sato, P. Hearty, R. Ruedy, M. Kelley, V. Masson-Delmotte, G. Russell, G. Tselioudis, J. Cao, E. Rignot, I. Velicogna, B. Tormey, B. Donovan, E. Kandiano, K. von Schuckmann, P. Kharecha, A.N. Legrande, M. Bauer, and K.-W. Lo: Ice melt, sea level rise and superstorms:/ evidence from paleoclimate data, climate modeling, and modern observations that 2 C global warming could be dangerous *Atmos. Chem. Phys.*, **16**, 3761-3812, 2016.

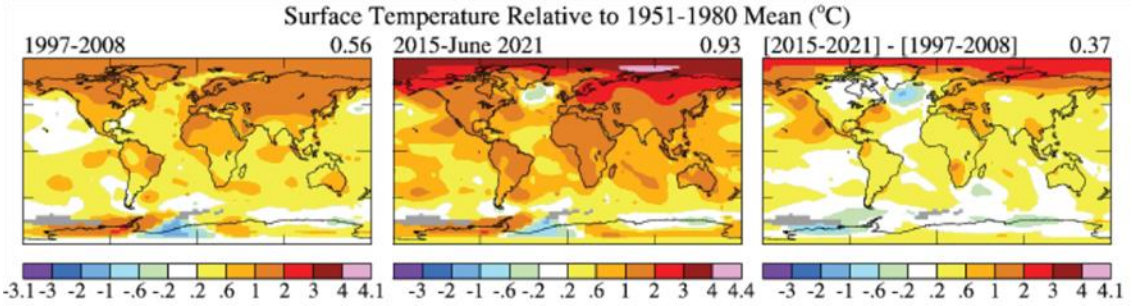

Fig. 6. Global surface temperature relative to 1951-1980 average for the two "hiatus" periods in Fig. 5, and the difference between these two maps.

Failure of models to simulate well the effects of increasing ice melt lead the Intergovernmental Panel on Climate Change (IPCC) to conclude that even scenarios with increasing greenhouse gas emission will only show a slowdown of the Atlantic Overturning Meridional Circulation (AMOC) and a sea level rise only of the order of 1 meter or less. We conclude, on the contrary that such greenhouse gas scenarios will cause complete shutdown of the AMOC and SMOC (Southern Ocean overturning circulation), with the latter spurring sea level rise of several meters.[8]

Authors Note: I wanted to be sure to include the above three paragraphs of text and the above figure. If you go through the link in reference 7 above and read that paper (it's rather long and uses climatologist lingo), you will see that, in 2016, it predicted much of what is now described in the above three paragraphs.

5. A Timely Point

The above-referenced post by Dr. Hansen, and the Scientific American article mentioned in the Introduction (by Dr. Michael Mann) have alerted us to serious effects of climate change. Of course there are many more effects both known and yet to be discovered. But an article in this issue of Time reminded me (again) of the most serious climate change consideration:

EVEN THE GREENEST governments and the most rapid emissions cuts will not be able to reverse the nascent destabilization of our climate. A certain amount of further warming is already baked into our future, since carbon dioxide lingers in the atmosphere for at least 300 years and will keep trapping more heat. Recent extremes are not a "new normal;' scientists say, but likely evidence of the end of any kind of normal or stable climate altogether.[9]

For that reason, experts say that in the coming months, governments urgently need to widen their priorities to include adapting to climate instability. It's something developing countries in the global south have long known. But so far, wealthier countries have dedicated just 5% of international climate finance to adaptation initiatives, despite a long-held pledge to split aid so-so between emissions cuts and adaptation. As world leaders gear up for COP26, a major U.N. climate summit in November, this summer's events may finally force wealthy countries to take adaptation seriously.

[8] See also the discussion in *Uncensored Science*

[9] Ciara Nugent, Time (hardcopy only), "Floods expose the West's hubris" Aug 2 / Aug 9, 2021, page 7.

This will mean preparing to deal with an inevitable increase in natural disasters. "We need to reshape disaster management;' Baerbock, the Green candidate for Chancellor, told local media in July. "and the federal government needs to take more responsibility for it:'

It will mean costly efforts to make homes, transport and infrastructure much more resilient to heat, rain and droughts. It may also mean expanding and formalizing our systems for cleaning up after disasters. At the very least, it means better warning systems and more public awareness that extreme weather is a real threat-whatever country you live in.

Author's comment:, about 93% of the excess heat energy stored by the Earth over the last 50 years has been absorbed by in the oceans. However this is not a free pass, but rather a loan of cooling capacity. At some point there will be payback. Our best climate models may make reasonable guesses over what period this payback will occur. Also they may describe some of the simpler negative effects that will be involved. However they cannot predict the wild-cards (like the stuck Rossby waves). If Dr, Hansen is right about the total shutdown of the AMOC and SMOC (and his track record is very good), all bets are off.