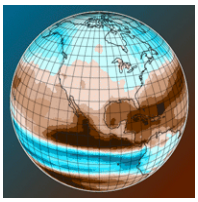



# Causes and consequences of nineteenth century droughts in North America

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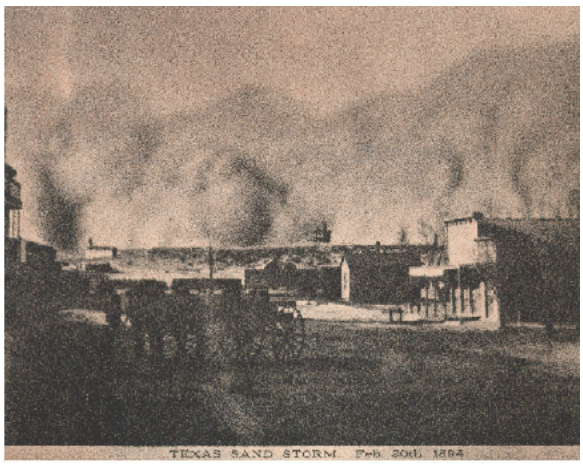

A sandstorm approaches a Texas town in 1894 during the 1890s drought

Between the mid and late nineteenth century three severe droughts struck North America and each had its own effect on the social, ecological and environmental state of the Plains and the West. The drought of the mid 1850s to the mid 1860s, or Civil War drought, added to the complex mix of factors leading to the near extinction of the American bison. The 1870s drought aided in creating the conditions for horrific locust swarms that devastated the West. The 1890s drought took a serious toll on settlers trying to practice dry farming on the high plains, led to a reopening of the frontier through depopulation, and to the 1902 Reclamation Act and the increasing involvement of the federal government in the settling of the West.

**The Civil War drought and the emerging impact of man on the Plains**

As described in 'The Way to the West', by Elliot West (university of New Mexico Press, 1997), by the middle of the Nineteenth Century the Plains were already feeling the impact of ever larger numbers of humans. In the preceding decades the Indian population had increased as they moved onto the Plains in the face of the westward expansion of European settlement. Indians made this decision during an unusually wet period when grasses were high, bisons abundant, and a switch to a horse and hunting-based lifestyle seemed viable. At the same time European emigrants were heading across the Plains bound for the West accompanied by large numbers of horses, mules and oxen. The U.S. Army had also spread across the region.

This peopling of the Plains greatly impacted the bison through an increased competition for resources. During drought the bison would move to the river valleys where grasses would still survive. But these valleys now also were home to Indian camps and the emigrants headed West and their animals, all for the same reason of better water supply.

From the mid 1850s to the mid 1860s the West and Plains were struck by a severe drought. Years ago David Stahle of the University of Arkansas had used tree ring analyses to suggest that, in Texas, this was the worst drought to strike in the last 300 years, worse than the Dust Bowl drought. As shown in Figure 1 the rain gauge data for this time is very sparse and cannot be used to really discern a drought. However the new and complete tree ring data in the North American Drought Atlas (developed by Ed Cook of LDEO), also shown, make clear that this

was a time of unusually severe and widespread drought.

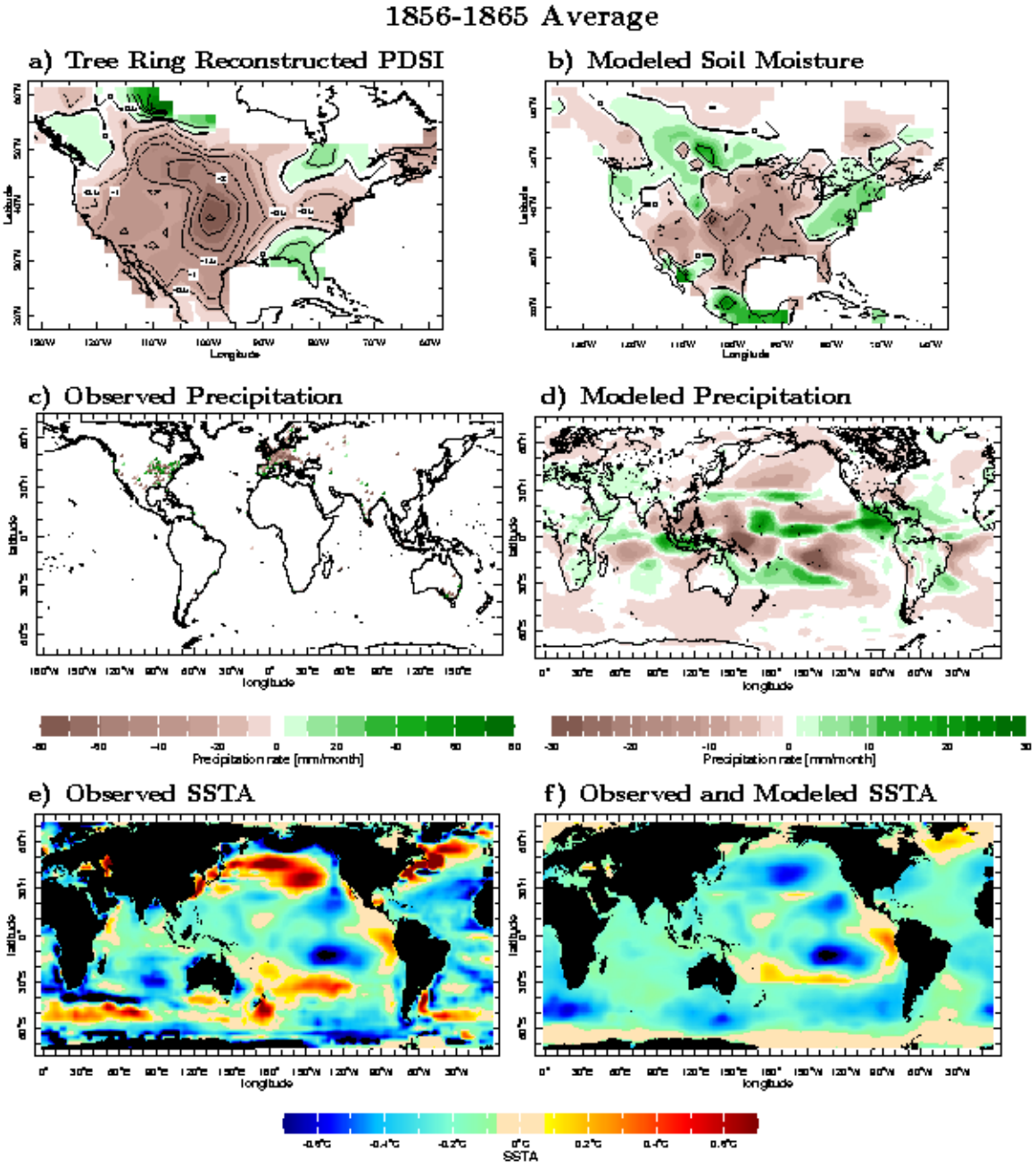


Figure 1. The 1856-1865 Civil War drought. Top left: the tree ring reconstructed Palmer Drought Severity Index (PDSI, a measure of summer drought severity). Top right: the soil moisture anomaly as simulated by the climate model forced by tropical Pacific SSTs alone. Middle row: the observed from rain gauges (left) and modeled (right) global precipitation anomaly. Bottom left: the observed SST anomaly during the drought is shown. Bottom right: the SST anomaly in the POGA-ML model which is the observed SST anomaly in the tropical Pacific and that computed by a simple ocean model elsewhere. Units are mm per month for precipitation and deg C for temperature.

Figure 1 also shows the simulations of the drought generated within climate model simulations conducted at LDEO. The model was forced by historical observed sea surface temperatures (SSTs). Amazingly enough the simulated Civil War drought bears a clear resemblance to that which occurred. As for the twentieth century droughts, the Civil War drought is simulated when the forcing is restricted to the tropical Pacific Ocean alone (the POGA-ML - tropical Pacific Ocean-Global Atmosphere-Mixed Layer Ocean - model). During this time tropical Pacific SSTs

were persistently colder than normal, a la Niña-like state.

Given that SST observations from ships only began in 1854 (by American ships) and in 1856 (by European ships), and are quite sparse for decades to come, this model result is quite remarkable. It testifies to the methodology used (developed by Alexey Kaplan at Lamont-Doherty Earth Observatory) to reconstruct global SST data sets using sparse (in time and space) data. Geochemical coral records from the tropical Pacific confirm the existence of a persistent La Niña at this time.

This severe drought could not have come at a worse time for the Plains bison. Normally during droughts, of which they had seen many in their thousands of years on the Plains, they would have moved to the valleys but this time those ecological niches were occupied by Indians and emigrants and by their grazing animals. With the best grasses unavailable to them the bisons died in vast numbers. This was just one of the many factors (including more hunting) that led to their near extinction a few decades later. La Niña did its part in causing one of the most storied events in American environmental history.

**The 1870s drought: La Niña and locusts**

Until they mysteriously became extinct at the turn of the century the Plains were often plagued by vast swarms of the Rocky Mountain Locust. The locust swarms of the bible or current day Africa are nothing compared with the swarms in the West. According to measurements at the time, and a lot of informed extrapolation, the 1875 swarm involved 3.5 trillion insects and covered an area of the West equivalent to the entire area of the mid-Atlantic states and New England (see Lockwood, 'Locust', Basic Books, 2004, for a fascinating account, by an entomologist, of the Rocky Mountain Locust and its extinction and for an online account for educational purposes see sciencecases.org.). The locust swarms ate everything in their way and ruined crops and was a terrible impediment to settlement of the West.

Locusts love drought. The dry conditions increases the nutritional value of vegetation due to concentration of sugars and nutrients and reduces plant defenses. The dry conditions also reduce fungal diseases that attack locusts. The accompanying heat accelerates locust maturation and helps them win the battle against predators. Finally, during drought, the locusts group in small areas of remaining lush vegetation (e.g. watered farms) and that population density is needed for the locust to transform into its migratory, swarming, phase (Lockwood 2004).

The worst swarms during the period of European settlement occured in the 1870s. As seen in Figure 2 this decade was also one of severe drought. This is barely seen in rain gauge data but is very clear in the tree ring reconstructions. The models forced with both global SSTs and with tropical Pacific SSTs alone reproduce this drought. Once more, as for the drought a decade before, a cold tropical Pacific Ocean, La Niña-like conditions, prevailed. It is these SSTs that forced the changes in atmospheric circulation that created the 1870s drought over North America and created the conditions for the devastating locust swarms.

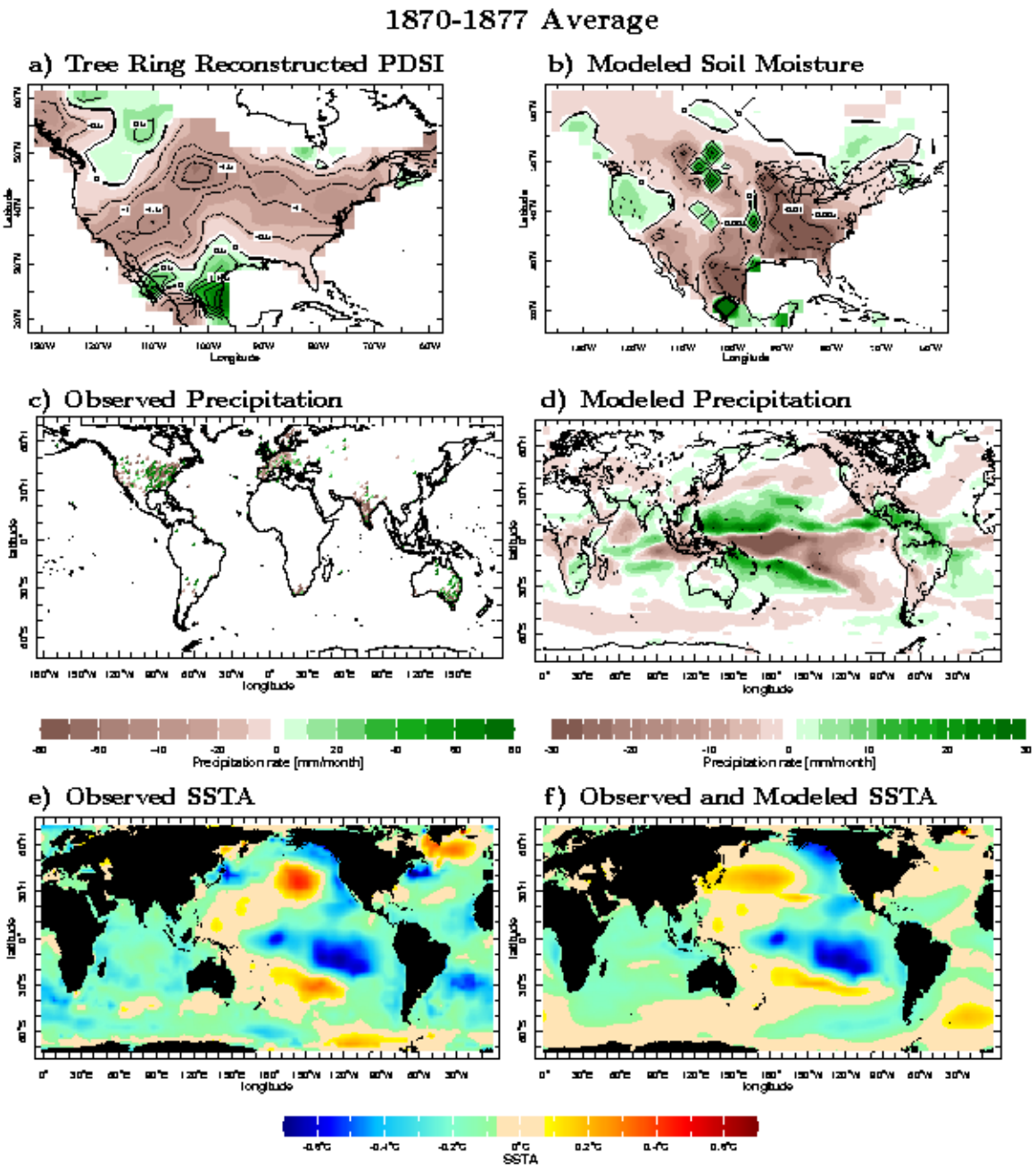


Figure 2. Same as for Figure 1 but for the 1870-77 drought.

**The 1890s drought and the move to federalize development of the West**

The 1890s drought began in the late 1880s (following close on the severe winter in 1886 that killed vast numbers of cattle) and went on until 1896. Reisner in 'Cadillac Desert' (1986, Penguin) and Worster in 'Rivers of Empire: Water, Aridity and the Growth of the American West', (1985, Oxford University Press) ably describe the feverish period of migration to the West, encouraged by the railroad companies and boosted by state and federal governments averse to bad news about the land's true carrying capacity. By and large the settlement since the 1870s drought had gone along with a period of wetter than usual conditions that encouraged widespread belief that 'rain follows the plow'. In 1890 Frederick Jackson Turner announced the closing of the American frontier - defined as a region below a minimum population density. By that definition, depopulation of areas of the high plains during the 1890s drought reopened the frontier.

The 1890s drought made clear that the methods of 'dryfarming', never based on sound science, were wholly inadequate for settling the arid regions of the West. The drought also ended the idea that sturdy settlers, working alone, would be able to transform the West. In the arid lands the amount of land needed to support even a family was much larger than specified in the Homestead Act but, more crticially, also larger than a family working alone could irrigate. The 1890s drought was a wake up call that in the future, if further catastrophes were to be prevented, the Federal government would have to take the lead role in development of water resources, irrigation and power. The 1890s drought is partly responsible for the beginning of Federally-driven irrigated agriculture with the Reclamation Act of 1902.

The dust storms of the 1930s were unprecedented, during the historical record, in their severity. Before the expansion of agriculture in the Plains the natural prairie grass bound the surface together even during droughts. It was the removal of these grasses, and replacement with wheat that could not survive, that exposed the soil to wind erosion in the 1930s. However, even during the 1890s, it was clear that trouble was brewing. Dust storms did afflict the Plains during that drought (see picture above), probably as a result of overgrazing of natural grasses by imported cattle.

By the 1890s rain gauges are sufficiently widespread that they well record the drought as seen in Figure 3. Tree ring records even more clearly show the drought. Just as for the two prior droughts the climate models reproduce drought across North America and this is also the case when only the tropical Pacific forcing is included which implicates the prevailing La Niña conditions also shown in Figure 3.

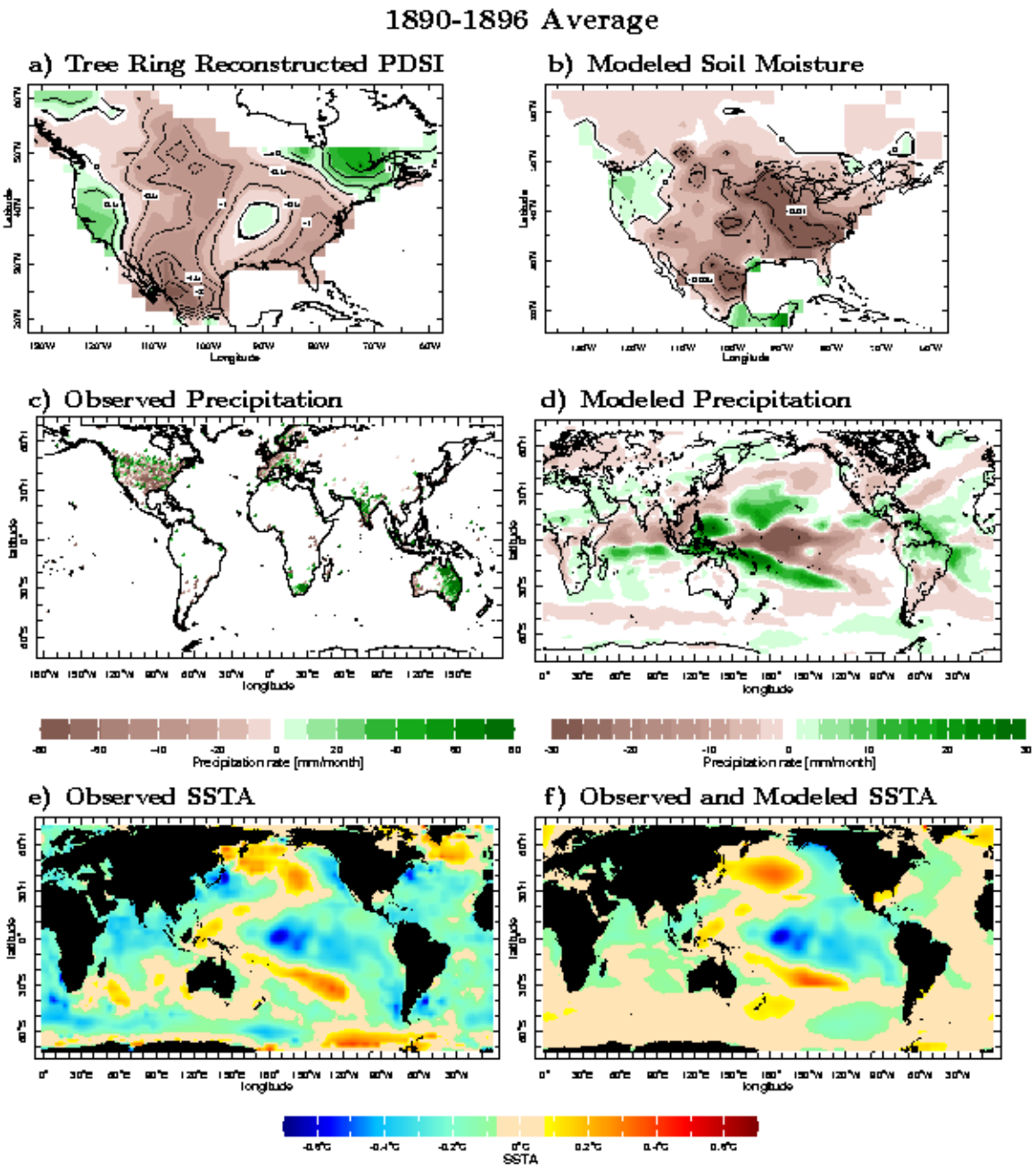


Figure 3. Same as for Figure 1 but for the 1890-96 drought. Note in these figures that the POGA-ML model can simulate much of the SST anomaly pattern outside of the tropical Pacific as a response to tropical Pacific SST forcing. This says that, while those SST anomalies outside the tropical Pacific may play a role in the drought maintenance and evolution, they are not themselves causative.

## Summary

In summary the three major droughts of the mid to late Nineteenth Century, each of which had serious consequences of varying stripes, on the Plains and in the West, can be reproduced in climate models forced by historical SSTs. This work implicates ocean forcing as the cause of the droughts. When the imposed SSTs are limited to the tropical Pacific alone the droughts can still be reproduced which indicates that the ultimate cause arose from the endless variations of tropical Pacific SSTs. When these create year after year of colder than usual SSTs the atmospheric circulation adjusts in such a way that drought strikes North America. The mechanisms whereby this occurs are laid out in more detail on the pages that concern the

Twentieth Century droughts.

**Hemispheric symmetry of the Nineteenth Century droughts**

The model simulations suggest that the North American droughts of the Nineteenth Century were part of a larger global pattern in which drought struck across the mid-latitudes of each hemisphere. For this period the instrumental data is sparse outside of Europe. To the extent that there is rain gauge data in South America at this time it supports the model results of notable hemispheric symmetry. Tree ring records there too, although also sparse compared to North America, also support the existence of droughts in the 1870s and 1890s. Europe also experienced droughts during the three North American droughts suggesting that the models are correct in pointing to a zonal symmetry to the mid-latitude droughts. The case for the zonal and hemispheric symmetry is made in a paper by Herweijer and Seager (2006, in the International Journal of Climatology). The symmetry argues for the importance of interactions between the cooler tropical troposphere during extended La Niñas, a poleward shifted jet stream, its impact on transient eddy propagation and, finally, the descent in mid-latitudes induced by eddies, which is stronger during the drought periods.

Maintained by: Virginia DiBlasi , Lamont-Doherty Earth Observatory of Columbia University

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