Research Article

Why Is the Influence of Sunspot Peaks on the Ocean and Atmosphere in Northern Winter Seen Mainly in the Pacific Region?

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The sun at sunspot peaks enhances the climatological means in the Pacific region from the stratosphere to the surface of the sea. The robust signal is physically consistent and statistically significant in the 14 sunspot peaks for which sea-level pressure and sea-surface temperature data are available. No other place shows such a strong influence of the sunspot peaks in the northern winter. Why in the Pacific and why a cooling of equatorial surface waters at sunspot peaks? I suggest that in the Indonesian region the strong convection, higher and colder tropopause, warmer water, and Indonesian topography are conducive to channel the solar influence mainly to this region, leading to an enhancement of the Walker and Hadley circulations, expansion and intensification of the dry zone, and cooler equatorial surface waters.

1. Introduction

Several studies have shown that the Pacific Ocean and its surroundings are sensitive to a solar influence at the peaks of the sun's decadal oscillation, the sunspot cycle. See, for instance, Wexler, 1956 [1]; Favorite and Ingraham, 1976 [2]; Christoforou and Hameed, 1997 [3]; van Loon et al., 2007 [4] and van Loon and Meehl, 2008 [5]; van Loon and Meehl, 2011 [6]. As described by van Loon et al. [4] and van Loon and Meehl [5, 6], the solar influence in the Pacific is the following. Just south of the equator, the sea-level pressure (SLP) is above normal in the southern summer/northern winter when the sunspots are at or near their peak numbers; the SE trades blowing across the equator are then stronger than average, the equatorial upwelling of cool water is above normal, and the equatorial sea-surface temperature (SST) is below normal. This is accompanied by polewards expansion of the tropical convergence zones and drier than normal conditions in the equatorial belt. The SLP in the Gulf of Alaska is then above normal, and the Walker and Hadley circulations are accelerated. The solar effect reaches into the stratosphere where quasi-biennial oscillation is modulated, though

whether the effect comes from below or above, or both, cannot yet be determined. An attempt to model the influence of the sunspot peaks was described by Meehl et al. [7].

In the following text, I shall focus on the area between Australia/Indonesia and the central Pacific Ocean, using the data in the various websites established by the Physical Science Division/ERL/NOAA, which makes it easy to reproduce our results. The years of peak sunspot numbers can be found in this NOAA website: http://ngdc.noaa.gov/STP/SOLAR_DATA/SUNSPOT_NUMBERS/INTERNATIONAL/maxmin/MAXMIN.

2. Anomalies of SLP, SST, and Rainfall Rate in Sunspot Peaks

The preferred pattern in the sunspot peaks, which is both robust in time, physically coherent, statistically significant, and lasting from the year before the peak into Year₀, the year of the peak, is shown in Figure 1(a). In this paper, we shall be dealing with the tropical part of this figure, and a Student *t*-test of this part in Figure 1(b) shows that the SLP anomaly

FIGURE 1: SLP anomalies in January-February of 14 sunspot peaks. A Student t -test of the SLP anomalies in the 14 sunspot peaks. The stippled areas are above the 95% confidence level. SST anomalies, January-February, in the 14 sunspot peaks. A Student t -test of the SST anomalies in the 14 sunspot peaks. The stippled areas are above the level of 95% confidence.

pattern in 14 sunspot peaks is significant well above the 5% confidence level. The test assesses the confidence level of the difference between the sunspot years and a long-term mean which does not contain the 14 peak Years₀. In the stippled areas, the values are above the 95% confidence level.

Figure 1(a) indicates that, on average in the southern summer/northern winter, the geostrophic wind anomalies in the tropics have a northerly component south of the equator and a southerly component north of the equator west of the largest positive SLP anomalies. To the south of the equator,

south-easterly anomalous geostrophic wind are conducive to increased upwelling of cooler water, which is confirmed by Figure 1(c), and was shown in our earlier papers [4, 5] to be as robust a feature as the SLP anomalies. The SST anomalies are also statistically significant above the 95% confidence level, Figure 1(d), which was arrived at in the same manner as Figure 1(b).

The mean rainfall rate in January-February for the period 1948–2011 (Figure 2(a)) outlines the positions of the tropical convergence zones: the ITCZ about 5°N and the ITCZ

FIGURE 2: Average rainfall rate in January-February, 1948–2011. Anomalies of the rainfall rate in five recent sunspot peaks.

at 10°S–15°S, separated by the equatorial dry zone. The positions of the heavier rainfall coincides with the rising branches of the Hadley circulation, the dry zone outlines the sinking branch of the Walker circulation, and the heavy rainfall over Indonesia/northern Australia is in the rising branch of the Walker circulation on the western flank of the Pacific warm pool.

In the five recent sunspot peaks *for which rainfall is available* (see, anomalies of rainfall in Figure 2(b)), the heavy rains over Indonesia are enhanced and the maxima in the convergence zones extend polewards of their mean position in Figure 2(a). The dry zone is likewise enhanced and widened over the cooler water. These anomaly patterns are identical to those for 12 months earlier.

3. The Hadley and Walker Circulation Anomalies and the “Stratospheric Fountain”

The influence of the sun at its decadal peaks is reflected in the anomalies of vertical motion in the Walker and Hadley circulation of the region (Figure 3). As expected from the rainfall-rate anomalies in Figure 2(b), the upward vertical motion anomalies in the Hadley circulations (Figure 3(a)) are widened toward the poles, and the downward anomalies between 5°N and 15°S show an intensified, reverse anomalous Hadley circulation in the dry zone, commensurate with the decreased rainfall in Figure 2(b). The latter is substantiated by the west-east vertical motion anomalies in Figure 3(b); they show that the Walker circulation was accelerated and enhanced in the five sunspot peaks with both the rising and sinking branches being at above normal strength. Further evidence of the stronger Walker circulation is found in the zonal wind anomalies in Figure 3(c): The easterlies at the bottom of the Walker branch across the Pacific Ocean are above normal strength and the westerlies above are too. *These westerlies are the outflow aloft from the rising branch over Indonesia-northern Australia from where the*

air flows out and sinks over the Pacific Ocean, in this case at an accelerated rate in the five sunspot peaks.

The enhancement of the toroidal cells in the Pacific, Australian, and Indonesian regions during sunspot peaks and their evident association with the rainfall in the warm pool-Indonesian area suggests that the latter region—named “The Stratospheric Fountain” by Newell and Gould-Stewart [8]—plays a major role in transmitting the solar influence to the troposphere. Since the region is characterized by warm water and a topography that are both conducive to strong convection, it is no surprise that the mean temperature of the tropopause levels is lower in this area than elsewhere and that the lower temperature is more extensive there than anywhere else, Figure 4(a) (see, e.g., [9, 10]).

The tropical 100-mb temperature *anomalies* for the rainy season on the Southern Hemisphere (November–March) in the five sunspot peaks (Figure 4(b)) were negative along the earth’s circumference and least so above the dry zone—but *they were lowest by far in Newell’s Stratospheric Fountain pointing to the most amplified convection being there in the sunspot maxima.*

On the basis of these observations, I suggest that in sunspot peaks the convection in the Fountain area is enhanced more than anywhere else in the tropics, lifting and cooling the tropopause levels there and that the outflow at upper levels enters the lower latitudes in the Pacific, where it sinks. The dry zone is thus strengthened and widened—that is, the Walker circulation widens and accelerates—and the tropical convergence zones are pushed polewards (the Hadley circulation). I cannot explain *how* the interaction between the sun and the troposphere takes place. One might suggest that the sun changes the stability in the lower stratosphere through wave motion related to the differential heating created by the observed absorption of increased UV by the increased ozone in the sunspot peaks. This would allow the convection in the tropics to reach higher levels. If so, that effect would be strongest in the Fountain area.

FIGURE 3: Anomalies of vertical motion in January-February in five recent sunspot peaks: 30N–30S, 125E–125W (Hadley circulation). Anomalies of vertical motion, January-February, in five recent sunspot peaks: 120E–125W, 5N–10S (Walker circulation). Anomalies of zonal wind in five recent sunspot peaks: 10S–5N, 120E–125W.

4. Conclusions

- (1) The sun at the peaks of sunspot numbers affects the ocean and atmosphere circulations, as described in van Loon et al. [4], van Loon and Meehl [5], and van Loon and Meehl [6], by raising the SLP east of the date line and lowering it to the west. Above normal pressure just south of the equator is accompanied by stronger SE trades and cooler equatorial water.
- (2) The tropical convergence zones widen polewards, and the dry zone expands and strengthens.

- (3) The solar effect is robust, physically consistent, and statistically significant from northern Australia/Indonesia to South America, and nothing similar is found elsewhere. I suggest that that is because the solar irradiance in the sunspot peaks interacts with the convection in the Indonesian region, amplifies the convection, and thus lifts and cools the tropopause layers there. An increased outflow from the upper troposphere into the Pacific Ocean region sinks over the ocean and accelerates the Walker circulation. The increased easterlies in the low troposphere cause upwelling of cool water; the rainfall in the extended tropical convergence zones

FIGURE 4: Average 100-mb temperature in November–March, 1948–2011. 100 mb temperature anomalies in five recent sunspot peaks, November–March.

increases, and the rising branches of the Hadley circulation extend polewards.

- (4) The sun thus enhances the climatological mean features in a preferred manner in the sunspot peaks, but not to extremes. Outside the sunspot peak years, any anomaly pattern can occur in the Pacific from cold to warm extremes in the Southern Oscillation.

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