WARM AND COLD YEAR IMPACTS ON TYPHOON ACTIVITY IN THE PACIFIC OCEAN

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EDITOR'S NOTE: This year's pattern of tropical cyclone activity in the Northwest Pacific, which spared Japan but besieged the Philippines and southern China, prompted AIR project manager Dr. Peter Sousounis and AIR research meteorologist Dr. Mélicie Desflots to look for explanations.

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While no single climate factor can fully explain typhoon behavior in any given season, the El Niño-Southern Oscillation has long been known to have a significant effect on many characteristics of typhoon activity in the Northwest Pacific basin. In this article, we take a closer look at some of the specific effects of El Niño and La Niña and their implications on typhoon activity in that basin, with an additional focus on Japan.

THE ENSO PHENOMENON

The El Niño-Southern Oscillation (ENSO) is an interannual perturbation of the climate system characterized by aperiodic weakening or strengthening of easterly winds and a warming or cooling of the surface layers in the tropical Pacific Ocean every 3 to 8 years. ENSO oscillates between El Niño (warm phase), neutral, and La Niña (cool phase) periods. While the occurrence and the strength of an El Niño (or La Niña) event can be defined by indexes based on meteorological parameters from the Pacific basin, its repercussions can be felt around the world for many months. In particular, ENSO modulates tropical cyclone (TC) activity across the different ocean basins.

During an ENSO neutral year in the tropical Pacific basin, easterly winds near the equator (the trade winds) push the waters to the western part of the basin. In the eastern tropical Pacific, cold waters from below are brought to the surface to replace the waters displaced to the west. This phenomenon is called upwelling.

During El Niño years, this process is suppressed. Anomalous westerlies develop in the tropical Pacific, sometimes reversing the direction of the trade winds. This leads to warming of the central tropical Pacific and reduced upwelling in the eastern part of the basin. During La Niña years, the opposite happens; that is, the trade winds strengthen and upwelling increases, resulting in cooler-than-normal waters in the eastern tropical Pacific and warmer-than-normal waters in the western tropical Pacific.

In the North Atlantic, El Niño events produce higher vertical wind shear, which tends to suppress hurricane activity. During La Niña events, the opposite occurs, with lower vertical wind shear and increased hurricane activity.

ENSO has an almost reverse effect on the typhoon activity in the Northwest Pacific basin. During El Niño events, typhoon activity increases (especially in the late season) in the eastern part of the basin, while falling to below normal during September and October in the South China Sea.[1, 2, 3] La Niña events typically bring the opposite conditions in the South China Sea, with more typhoons in September and October. However, in the rest of the Northwest Pacific basin, typhoon activity tends to be below normal from August to November.

IMPACTS ON NORTHWEST PACIFIC BASIN TYPHOON ACTIVITY AND JAPAN LANDFALLS

In order to illustrate the magnitude and significance of the difference in typhoon activity between El Niño and La Niña phases, we compare the activity for several years from each phase. For convenience, we refer to El Niño years as warm years* and La Niña years as cold years.

Based on a metric called the Niño 3.4 SST anomaly (which covers the region 5°N to 5°S; 170°W to 120°W) for the months from August to October, the seven warmest years are 1965, 1972, 1982, 1987, 1997, 2002, and 2004; the seven coldest years are 1970, 1973, 1975, 1988, 1998, 1999, and 2007. Table 1 is a summary of the typhoon activity for the warm and cold years based on data from the Japanese Meteorological Agency (JMA).

Cold Year	SST Anomaly (Niño 3.4 Index in °C)	Number of Storms	Number of Storm Days	Number of Storms that Reach 30°N	Average Minimum Sea-Level Pressure (mb)
1970	−1.043	25	76	11	960
1973	−1.200	21	72	8	967
1975	−1.337	20	81	13	960
1988	−1.550	26	118	15	974
1998	−1.173	16	57	8	971
1999	−1.007	20	58	15	980
2007	−0.917	24	94	16	964
Average ± Stdev	−1.175 ± 0.216	21.7 ± 3.5	79.4 ± 21.3	12.3 ± 3.4	968 ± 7.5

Warm Year	SST Anomaly (Niño 3.4 Index in °C)	Number of Storms	Number of Storm Days	Number of Storms that Reach 30°N	Average Minimum Sea-Level Pressure (mb)
1965	+1.397	32	141	20	969
1972	+1.477	30	165	15	963
1982	+1.583	25	166	14	953
1987	+1.703	22	142	12	953
1997	+2.357	28	163	20	955
2002	+1.243	26	133	20	962
2004	+0.817	29	164	20	958
Average ± StDev	+1.511 ± 0.470	27.4 ± 3.4	153.4 ± 14.1	17.3 ± 3.5	959 ± 6.0

Table 1. Typhoon activity in warm and cold years. (Source: AIR based on data from the Japanese Meteorological Agency and the Climate Prediction Center)

Table 1 shows that in warm years, the number of named storms is 26% higher than in cold years, the number of storm days is 93% higher, and the minimum sea-level pressure is 9 mb lower on average. All the differences between warm and cold years are statistically significant at the P=0.05 level using a two-sided unpaired Student's t-test.

The difference in typhoon activity between the warm and cold years is further illustrated in Figure 1, which shows the storm intensity distribution for each ENSO phase.+ There is a markedly higher frequency of more intense storms in the warm years, with over half of the storms reaching Category 3 or higher. Fewer than one-quarter reach that intensity in cold years.

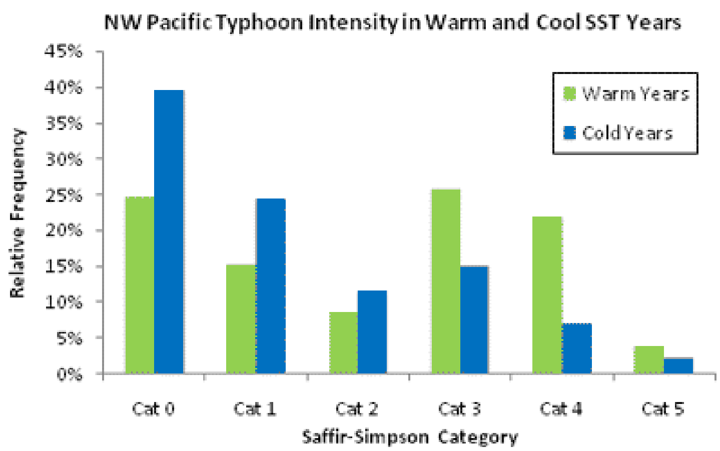

Figure 1. Typhoon intensity distribution in warm and cold years as noted in Table 1. (Source: AIR)

Perhaps more striking than the higher frequency and intensity of storms in the warm years is the increased likelihood that these storms reach the mid-latitudes, e.g., north of 30°N (see Table 1). Once there, they are more likely to recurve to the north and, ultimately, east.

Additionally, the results suggest that typhoons are less likely to impact the mainland of Japan in cold years than in warm years. The 2004 season was the seventh warmest since 1965 and had a record-breaking 10 landfalls in Japan. The 1988 season was the coldest (since 1951) and had no landfalling named storms. Figure 2 illustrates the difference in landfalls for the seven-year warm and cold periods. The results show that 73 landfalls (from 37 storms) occurred in warm years, whereas only 33 landfalls (from 19 storms) occurred in cold years. Equally important to note is that 13 landfalls were Category 3 or higher in the warm years, while there were only 6 in the cold years.

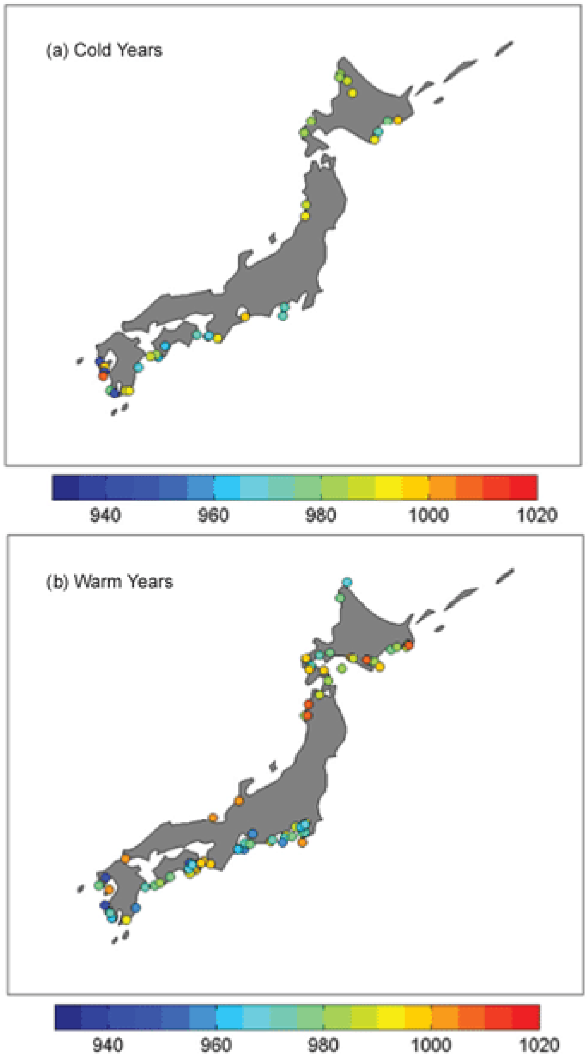

Figure 2. Japan landfalling typhoon activity during (a) cold (1970, 1973, 1975, 1988, 1999 and 2007) and (b) warm (1965, 1972, 1982, 1987, 1997, 2002 and 2004) years. Colors indicate central pressure (in mb) at landfall. (Source: AIR)

AN EXPLANATION

The impact of ENSO on three aspects of Northwest Pacific typhoon climatology noted in this article can be explained by several characteristic features of ENSO. First, the increased activity during El Niño years occurs in part because there is a greater expanse of water warmer than 26.5°C to support the formation of tropical cyclones. Recall that El Niño years are considered warm years because warm water from the tropical western Pacific extends eastward. Indeed, during such years, storm formation occurs farther east,[4, 5] which accounts for some of the difference in frequency between warm and cold years.

This also explains the second aspect—the higher proportion of intense storms during El Niño years. Because the storms develop farther eastward and the water is warmer, there is a greater opportunity both from a time and energy standpoint for them to achieve a higher intensity.[4]

Finally, the third aspect is the effect on tracks. During El Niño years, a higher proportion of storms reach Japan because the anomalous southerly flow that develops over the East China Sea and the Sea of Japan is more likely to steer storms north. In contrast, during La Niña years, storms that form east of the Philippines are more likely to be steered west into the South China Sea by an enhanced high-pressure system centered at mid-latitudes and strong easterly winds. Figure 3 provides a schematic view of the differences in typhoon activity and ENSO conditions during cold and warm years.

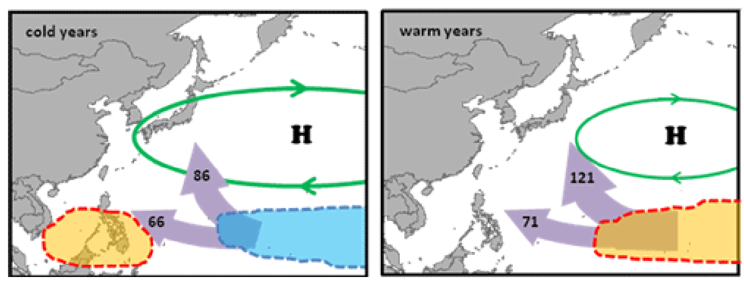

Figure 3. Schematic differences in typhoon activity (heavy arrows) as a result of differences in strength and extent of high-pressure ridge (as indicated by H and encompassing oval), and sea surface temperature anomalies as indicated by orange (warm) and blue (cool) shaded regions during cold (La Niña) and warm (El Niño) years. (Source: AIR)

ENSO AND TYPHOON DAMAGE

While the statistics are heavily skewed toward increased frequency and intensity of storms that have the potential to reach farther north in warm years, the ENSO signal by itself is not the bellwether when it comes to determining insured losses—either in Japan or basinwide. One complicating aspect is that landfall activity actually increases in cold years, despite lower overall numbers, because the storms that do form are more likely to be steered due west where they are more likely to make landfall in Mainland China, Hong Kong, the Philippines, or Taiwan.

A second complicating factor is that even though these southern-restricted storms during cold years may not be as likely to achieve super typhoon status, they can do considerable damage because of flooding precipitation.

Finally, a third and most obvious complicating factor is that the presence of a cold year does not guarantee typhoon immunity to Japan. In 1999 (a cold year), Bart caused over 3bn USD of insured losses, which remains today Japan's third highest typhoon related loss, according to the General Insurance Agency of Japan.[6]

CLOSING REMARKS

In closing, it is important to note that the differences presented here come from comparing two periods of the seven strongest El Niño and La Niña years since 1965. It is therefore quite possible that less warm years will not exhibit such robust differences when compared to less cool years, or to the entire historical climatological record. This may be especially true given that there are other climate factors besides ENSO responsible for controlling typhoon activity, and that their effects may be even more prevalent in the presence of weaker ENSO forcing.

This past year, 2008, is a good example. As 2008 transitioned from a cold year to a neutral year (around June), Japan managed to get through the heart of the typhoon season (August to October) without a single typhoon landfall. Historically, this has only happened twice before—in 1951 and in 1988 (both cold years).

As pointed out by several climate centers (e.g., NOAA's Climate Prediction Center, Bureau of Meteorology), even if the Oceanic Niño Index has been neutral since June, the atmospheric circulation over the western and central tropical Pacific continues to reflect lingering aspects of La Niña. Therefore, it is not surprising that the bulk of the activity has in fact been confined to the southern half of the basin, with Guangdong Province of Mainland China, the Philippines, and Taiwan being the primary targets.

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* NOTE THAT SUCH REFERENCE IS DIFFERENT FROM AND SHOULD NOT BE CONFUSED WITH THAT USED IN DAILEY ET AL. (2008)5 FOR DISCUSSING TC BEHAVIOR IN THE NORTH ATLANTIC BASIN.

+ THE JMA DATA INCLUDES WIND SPEED INFORMATION AFTER 1980. THUS, THE INTENSITY DISTRIBUTION IN FIGURE 1 IS BASED ON THE FOUR MOST RECENT YEARS FROM BOTH THE WARM AND COLD SETS. A SIMILAR ANALYSIS BASED ON CENTRAL PRESSURE THAT INCLUDED ALL SEVEN YEARS FROM EACH SET SHOWED AN ALMOST IDENTICAL RESULT.

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