JP4.5 THE CLIMATE OF 2006 IN HISTORICAL PERSPECTIVE

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1. INTRODUCTION

The Climate Monitoring Branch at NOAA's National Climatic Data Center (NCDC) routinely produces climate assessments on a monthly, seasonal, and annual basis. The purpose of these reports is to put the observed climatic conditions into historical perspective on global and regional scales. In this paper, we present the major climate and weather events of 2006, focusing on the temperature and precipitation patterns observed during the past year and their relationship to inter-annual trends in these parameters across the U.S. and globe.

It is important to note that this article is being written and submitted to the AMS before the conclusion of 2006. Therefore, the products and analyses presented here emphasize the year-to-date conditions (Jan-Sep) and seasonal values during the past winter (DJF), spring (MAM) and summer (JJA). In addition to the standard parameters of temperature and precipitation, other important regional and global climatic conditions are included, such as the ongoing drought conditions in parts of the U.S., flash flooding in the western Equatorial Pacific, the record U.S. wildfire season, and the state of the El Niño/Southern Oscillation (ENSO).

2. GLOBAL CLIMATE

The year-to-date (Jan-Sep) globally averaged temperature anomalies for both land and ocean surfaces are shown in Figure 1. With an anomaly of +0.51°C, the average global temperature is the 5th warmest on record for this period. The warmest year on record was 1998 with an anomaly of 0.63°C. Land surface temperatures were 5th warmest on record, while ocean temperatures were 6th warmest. This continues a trend toward warmer global temperatures that has occurred throughout the period of reliable global surface temperature records (1880-present). Although not a monotonic increase, global average temperatures have risen at a rate approximately 0.06º C/decade since 1900. During the past 30 years, the rate of increase is almost 3 times as great (0.17º C/decade).

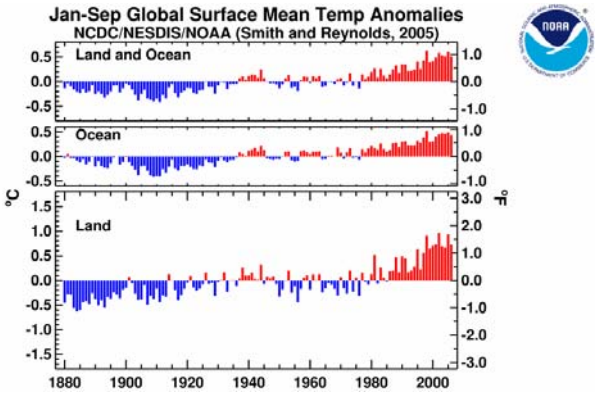

Figure 1. Global surface mean temperature anomalies (°C left and °F right) averaged over January-September for the period 1880-2006: (Top) land and ocean surfaces, (middle) oceans surfaces only, and (bottom) land surfaces only. Quayle et al. 1999

January to September temperatures were warmer than average throughout much of the world. Anomalies of 2-3ºC were present across large parts of North America, northern Africa, the Middle East much of Asia and parts of Europe. Areas with cooler than average temperatures included western Australia, Siberia and Alaska. In part due to a very active tropical cyclone season in the Western North Pacific Ocean in 2006, year-to-date precipitation in parts of the Equatorial Pacific and Southeast Asia was above average. Widespread anomalously warm conditions were present in all three seasons as shown in Figure 2 along with fewer regions of colder-than-average temperatures. Seasonal global precipitation patterns are illustrated in Figure 3.

During boreal winter (DJF), much of Europe and Asia experienced temperature anomalies below the 1961-1990 base period. In India, frost was observed in New Delhi for the first time in 70 years as cold air from the Himalayas produced low temperatures near freezing in early January. A severe cold wave in Russia during mid-January brought some of the coldest temperatures in decades to the region. Temperatures in Moscow dropped to -30°C, the coldest observed temperatures since the winter of 1978-1979. In contrast, warm anomalies were present across the United States and parts of the Middle East and Australia.

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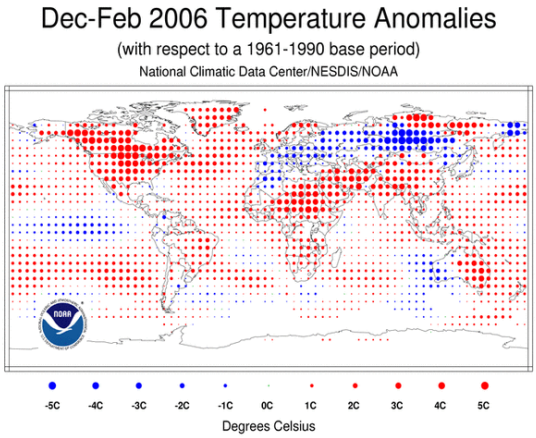

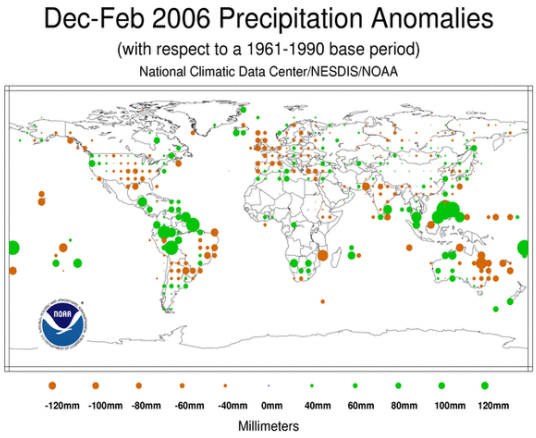

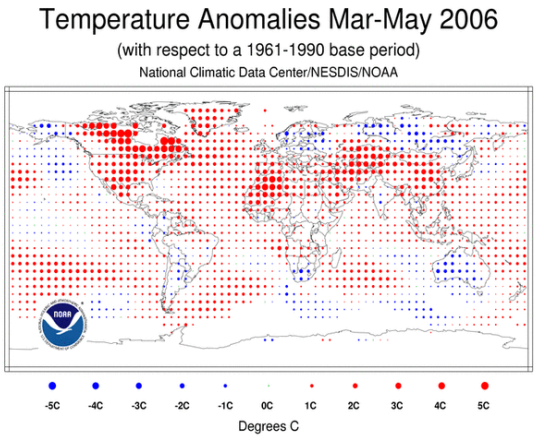

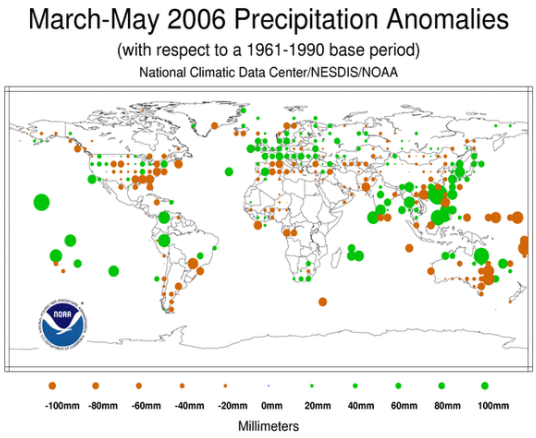

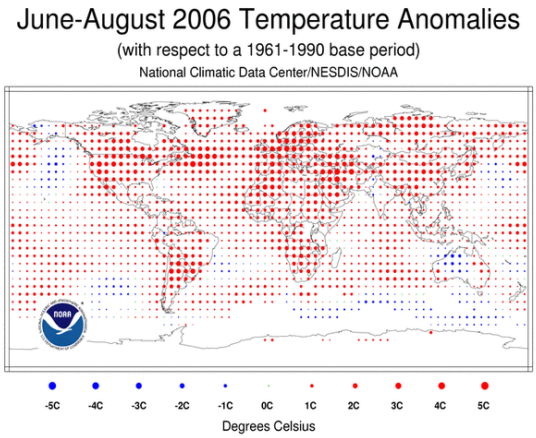

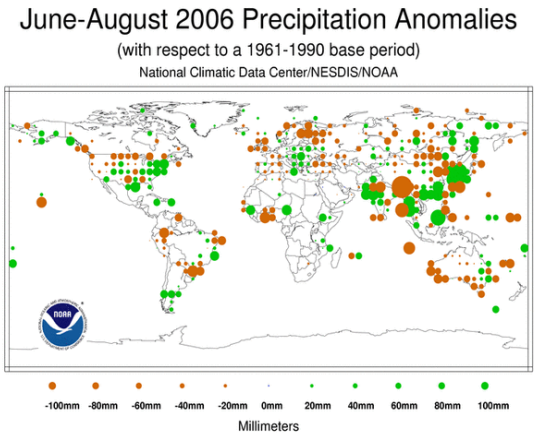

Figure 2. Seasonal global land surface mean temperature anomalies (in °C) for 2006: (Top) winter, (middle) spring, and (bottom) summer. Anomalies were determined relative to the 1961-1990 base period. Smith and Reynolds, 2005.

Figure 3. Seasonal global land surface precipitation anomalies (% of normal relative to the 1961-1990 base period) for 2006: (Top) winter, (middle) spring, and (bottom) summer.

Precipitation anomalies for the same period were well above average across northern South America and the western Equatorial Pacific. Heavy rainfall caused flash flooding and landslides across many islands in the East Indies. Dry conditions prevailed across portions of the central United States, Europe, central South America and eastern Australia.

The MAM boreal spring was also drier than average throughout eastern Australia as well as the southeastern U.S. Above average precipitation was reported across much of Europe and portions of Southeast Asia. Three days of heavy rainfall during the latter part of May brought devastating flooding and mudslides to parts of northern Thailand. Many fatalities were reported as a result of flash flooding which began at the start of the rainy season, which typically lasts until October. The province of Uttaradit was severely impacted by the excessive rainfall. Temperatures were above average from the U.S. to northern Africa, across the Middle East and Asia. In India, more than 100 deaths resulted from a heatwave in May, which produced temperatures above 40°C.

Boreal summer (JJA) temperatures across the globe were warm with very few exceptions. Global temperatures for the summer season were 4th warmest on record. Hot weather enveloped much of Europe during mid-to-late July, with temperatures surpassing 32°C. In Wisley, Great Britain, temperatures reached 36.5°C, the hottest July temperature ever recorded in Britain. By the end of the month, several European countries including Spain, France, Italy and the Netherlands reported more than 1000 fatalities, which resulted from the extreme and prolonged heat. Precipitation deficits as a percent of normal were greatest in parts of Southeast Asia, southern and western Australia and across Scandinavia.

3. ENSO AND THE TROPICAL PACIFIC

The year began with a continued yet brief negative phase of ENSO in the equatorial Pacific. Monthly sea surface temperatures in the Niño 3.4 and Niño 4 regions (Figure 4) began a steady climb throughout the year. By September 2006, a brief neutral phase gave way to weak El Niño conditions.

Cooler than average temperature anomalies in the Niño 3.4 region peaked in January 2006 at just over 1.0º C below average. Monthly mean temperatures in this region rose above -0.5ºC during April and continued to climb through August. By the end of September, a weak El Niño had begun as temperature at and below the surface of the central and eastern equatorial Pacific continued to warm. Warm phase conditions are expected to persist throughout the remainder of the year.

The monthly-averaged Outgoing Longwave Radiation (OLR) index remained positive through May 2006 before becoming more neutral and shifting signs on almost a monthly basis from June through September. In March, the OLR was at its peak, the highest value since January 2001, near the end of the most recent previous La Niña episode. High frequency variability in OLR is typically associated with the Madden-Julian Oscillation and its related convective activity that propagates west to east in the near-equatorial region from the Indian Ocean into the Pacific Ocean approximately every 30-60 days.

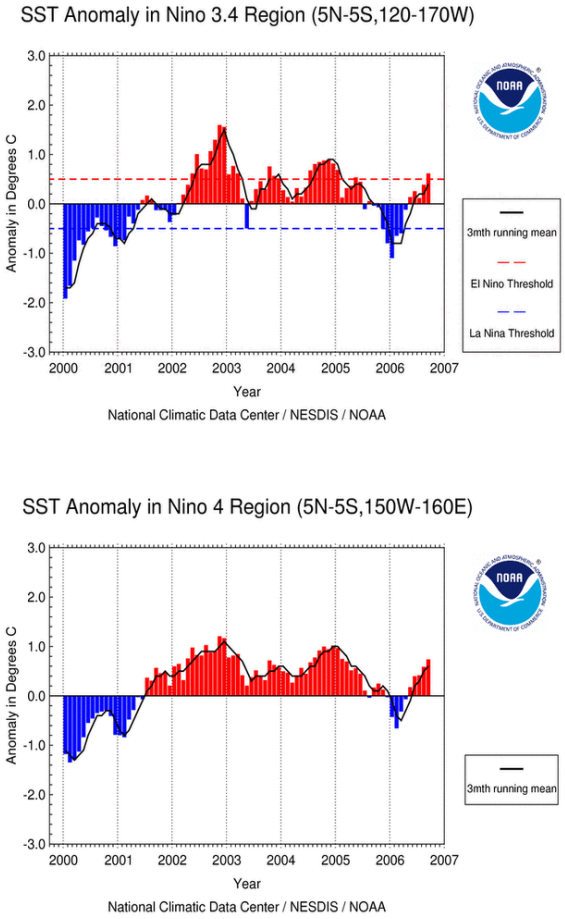

Figure 4. The monthly averaged sea surface temperature (SST) anomaly (red/blue bars in °C), and the three-month running mean SST anomaly (black line in °C), in the Niño 3.4 (top) and Niño 4 (bottom) regions during the period January 2000 to September 2006.

The Southern Oscillation Index (SOI) was approximately 2 in January and became negative by May. The SOI remained negative for five consecutive months. The only month through September with near-neutral conditions, was February 2006.

4. U.S. CLIMATE

The climate of the U.S. during six of the first nine months of 2006 was much warmer than average to record warm. The only cooler than average month

occurred during September, when the contiguous U.S. temperature was the 31st coolest since records began in 1895. The January-September mean temperature for the contiguous U.S. was 1.3ºC above the 20th century (1901-2000) mean and the warmest such year-to-date period on record. As shown in figure 5, Montana was record warmest for this period and 4 other states (North and South Dakota, Nebraska and Oklahoma) were 2nd warmest. Thirty-one of the remaining 47 states had year-to-date temperature ranks which were much above average (within the top 10% of warmest years on record). No state in the contiguous U.S. ranked near to or below average for this year-to-date period.

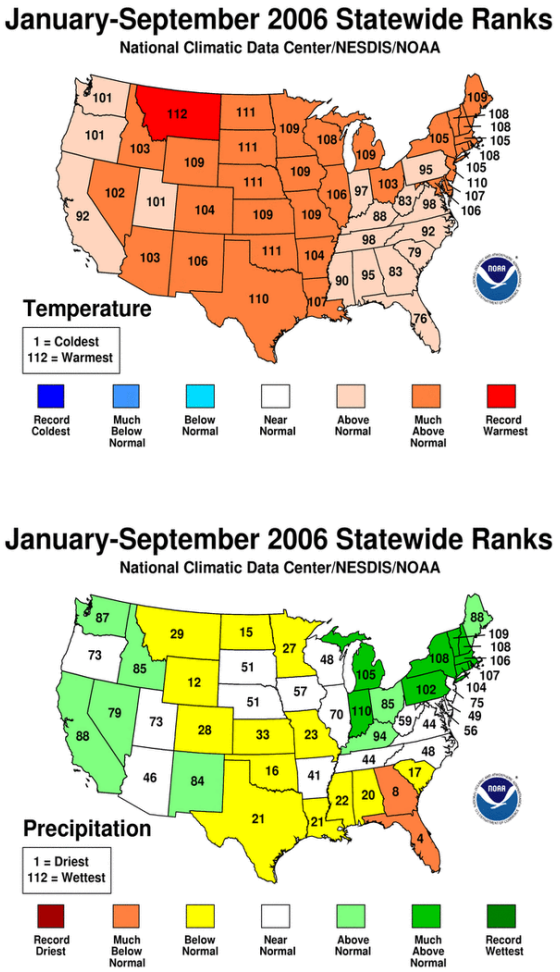

Figure 5. (Top) Statewide temperature (top) and precipitation (bottom) ranks for the contiguous U.S. during the January-September 2006 period.

National precipitation patterns across the country during 2006 were highly variable. February was 9th driest while August and September were the 17th and 37th wettest such months on record, respectively. Year-to-date (Jan-Sep) national precipitation ranked 29th driest. Regions with above average precipitation included the Northeast, portions of the eastern Great Lakes, parts of the Northwest and the West. This contrasted with drier than average conditions in the northern and central Plains, the South and parts of the Southeast. Florida ranked 4th driest January-September period on record during 2006.

As shown in figure 6, at the end of September, 29% of the contiguous U.S. was in moderate to extreme drought, based on the Palmer Drought Index (Palmer, 1965). This was down from the July 2006 peak of 51%. At that time, drought covered much of the northern Plains, the Southwest and parts of the South and Southeast. Dry conditions combined with much warmer than average temperatures to produce severe drought in the northwest Great Lakes, northern Plains and the Southwest. Severe to extreme drought in Texas remained intact throughout much of 2006, yet abated in northern Illinois. Large precipitation deficits adversely impacted agriculture and led to federal disaster declarations in many affected states.

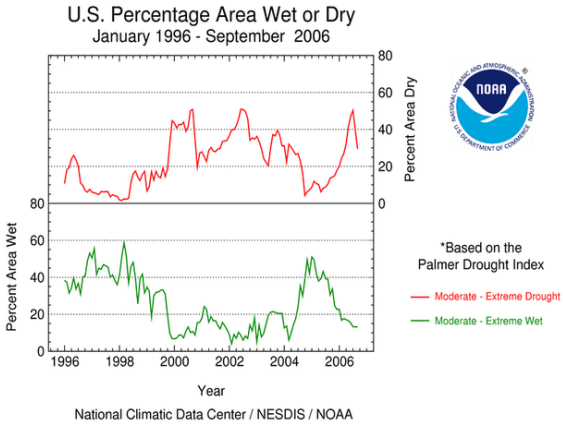

Figure 6. Percent of contiguous U.S. in moderate to extreme drought (top)/moderate to extreme wetness (bottom) on a monthly basis from January 1900 through September 2006 based on the Palmer Drought Index.

Since the beginning of 2006, approximately 84,000 wildland fires covering over 9 million acres burned across the contiguous U.S. This preliminary number of acres burned is a record for an entire year, with or without Alaskan and Hawaiian totals. The previous record for the contiguous U.S. was set in 2000 when 7.6 million acres were consumed. In 2005, 8.7 million acres burned across all 50 states. Figure 7 illustrates that even though the number of acres consumed has been increasing since the mid 1980s, the total number of fires has been decreasing. This implies that wildfires over the last 20 years are in general larger than they were prior to this period. Reasoning for this is documented in Westerling et al., 2006. One of the largest fires of the year and the 5th largest on record in California was the Day fire, located in the Los Padres National Forest in southern California. This fire began on September 4th

and burned the entire month of September before finally being contained in early October, 28 days later. Nearly 163,000 acres were consumed in this one fire.

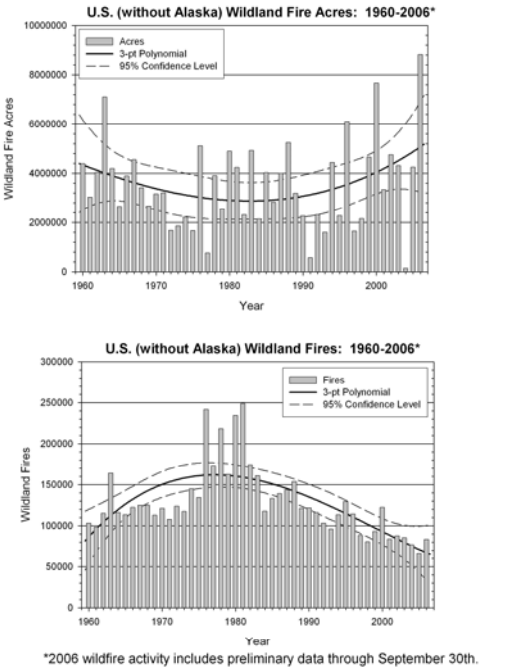

Figure 7. (Top) Number of U.S. (without Alaska) wildland fire acres burned from 1960 through September 2006 and (bottom) number of U.S. (without Alaska) wildfires from 1960 to September 2006.

5. NORTH ATLANTIC TROPICAL CYCLONES

Following the most active hurricane season in the Atlantic Basin record, 2006 was near the 1951-2000 average, yet below the average during the current phase of the Atlantic Multidecadal Oscillation (AMO) (1995-2005) with 5 hurricanes (2 major) and 4 tropical storms forming through the end of August (Figure 8). Two tropical storms made landfall in Florida and no hurricanes impacted the continental U.S. this season-to-date.

Tropical Storm Alberto made landfall near Apalachicola Bay in Florida on June 13th with winds near 40 knots. Rainfall produced by this storm was well-received and helped alleviate the dry conditions which exacerbated forest fire activity across north-central Florida. Tropical Storm Ernesto made two U.S. landfalls in August. One in Plantation Key, Florida with winds sustained at 29 knots on the 29th. The second landfall occurred at Long Beach, North Carolina on the 31st with winds of 61 knots, just shy of hurricane strength.

Only 2 major hurricanes (Category 3-5 on the Saffir-Simpson scale) had formed by early October. Northeast of the Lesser Antilles, Gordon formed on September 10th. The storm attained Category 3 status with winds of 105 knots on the 13th, the first major hurricane of the Atlantic season. Gordon remained in the central Atlantic before becoming extratropical later in the month. Helene began as a tropical wave, which formed off the African coast on September 11th. The storm went from a tropical depression to a major hurricane in just 5 days and remained in the central Atlantic before dissipating. While a major hurricane, Helene's maximum sustained winds were reported at 110 knots.

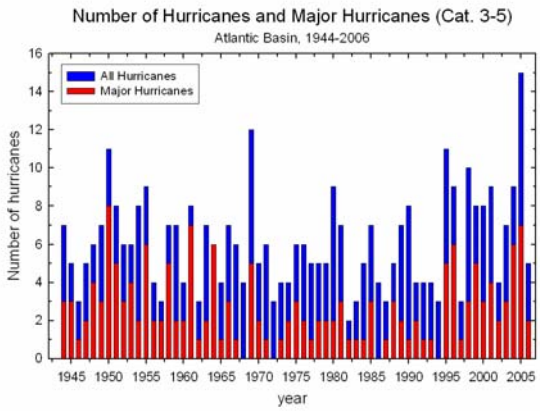

Figure 8. The annual number of tropical storms and hurricanes in the Atlantic basin from 1944-2006 (data from 2006 are preliminary through September). The blue bars indicate all named storms, while the red bars indicate only major hurricanes (i.e. Category 3-5 on the Saffir-Simpson scale).

6. SUMMARY

This paper summarized the global and U.S. climate conditions in 2006, focusing on the January to September period and seasonal values of temperature and precipitation. Additional data and information are available on the National Climatic Data Center website (2006). It should also be noted that this work is a prelude to the much larger effort of preparing the Annual State of the Climate report that appears in the *Bulletin of the American Meteorological Society* each June (e.g., Levinson, 2005). A number of important climate parameters and related issues were not included, but will be addressed in the *State of the Climate in 2006* article.

On a global scale, anomalously warm global temperatures continued in 2006, with many regions experiencing average to much above average temperatures. Over the January-September period, surface temperatures in 2006 remained well above the 1961-1990 average, with the January-September globally averaged temperature ranking 5th warmest on record.

The oceanic and atmospheric conditions in the tropical Pacific Ocean began the year in a weak La Niña state before transitioning to El Niño conditions by the end of September. The running three-month mean anomaly of SSTs in the Niño 3.4 region was less than 0.5°C through September, although the September anomaly was 0.61°C. The SOI and OLR indices also reflect a transition from La Niña to neutral and perhaps emerging El Niño conditions during same period.

The January-September mean temperature for the contiguous U.S. was 14.1º C, which was 1.3º C above the 20th century (1901-2000) mean and the warmest such period since national records began in 1895. Year-to-date precipitation for the contiguous U.S. was drier than average, but anomalously wet areas were offset by drier than average conditions in other parts of the country. Unusually dry conditions affected parts of the South, Southwest and northern Plains by end of September and the wildfire season for the contiguous U.S. was a record in 2006 with more than 9 million acres burned through the end of September.

The Atlantic Basin hurricane season through the end of September was slightly below average in 2006 with 5 hurricanes (2 major) and 4 tropical storms. This followed the most active season on record when 12 tropical storms and 15 hurricanes (7 major) formed in the Atlantic.

7. REFERENCES

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