The Impact of Tropical Cyclone Remnants on the rainfall of the North American southwest region

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Introduction:

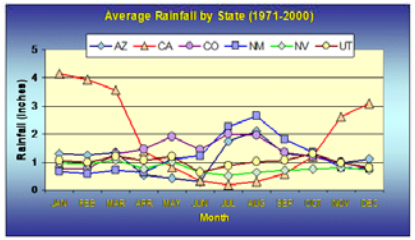
The North American southwest has a mild, arid or semiarid, continental climate characterized by low annual precipitation, abundant sunshine, low relative humidity, and a relatively large annual and diurnal temperature range. Summer rains fall almost entirely during brief, but frequently intense thunderstorms. It is common for over 90 percent of the summer monthly rainfall to fall on fewer than 5 days. July, August, and September are the rainiest months, producing on average, approximately 45 percent of the annual moisture.

A source of tropical moisture is occasionally advected into the southwest region from the Eastern Pacific in the form of tropical cyclone remnants. Although the tropical cyclone-strength winds rapidly diminish upon making landfall, these systems still carry a large quantity of tropical moisture and, upon interaction with mountainous topography, have the potential to produce up to 30% of the annual rainfall in localized areas. However, these systems are traditionally difficult to forecast accurately due to the nature of their interaction with the midlatitude flow.

In this poster we describe results of an ongoing study of the impact of eastern Pacific tropical cyclone remnants on rainfall in the North American southwest region. The overall goals of this project are to:

(1) Assess the portion of warm-season rainfall in the southwest region that is attributable to tropical cyclone remnants; and

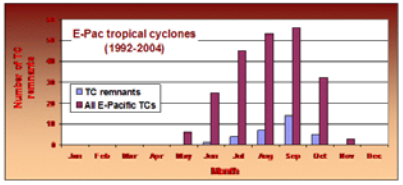
(2) Describe the common large-scale patterns that contribute to advection of TC remnants into the southwest region.



Warm-season rainfall climatology of the southwest region

States generally considered part of the U.S. southwest region include AZ, CA, CO, NM, NV, and UT. Note the annual rainfall distribution for each of these states. CA, NV, and UT have distinctively different annual rainfall distributions compared with AZ, CO, and NM. NV and UT have the lowest annual rainfall and their rain is distributed evenly across all months. CA receives 80% of its rainfall from Nov-Mar. However, AZ, CO, and NM receive about 50% of their rainfall in Jul-Sep and are strongly impacted by summertime weather systems from the tropics and subtropics in which much of this precipitation may fall in only a few days . It is these states that we concentrate on in this study.

Climatology of Pacific Tropical Cyclones (1992 – 2004)



Histogram of the total number of TCs that formed in the eastern North Pacific and the number of TCs that impacted the southwest region during the period 1992-2004 by month. On average 2.7 TC remnants impact the southwest each year bringing between 0 and 31% of the annual rainfall.

	PHX	TUS	ABQ	LUB
# Rain Days	1.7	4.1	3.9	2.5
% Annual Rain	0-6	0-17	0-24	0-32
% Monthly Rain	0-100	0-100	0-100	0-100
Total Rain	9.5 cm	29 cm	27 cm	28 cm

Total rain, average rain days, and percentage of annual and monthly precipitation, for four NWS sites representing a west to east cross-section of the southwest region. There is a gradient in the amount of precipitation delivered by tropical cyclone remnants, with a minimum in the western part of the region and a maximum in the eastern part of the region.

Note, the southwest remnants histogram (blue) is skewed slightly toward the latter months compared to the total distribution of tropical cyclones in the eastern North Pacific. This is because a seasonal change in the large-scale circulation pattern affects the tracks of Pacific tropical cyclones such that they are more likely to move northward toward the U.S. southwest in the latter part of the season.

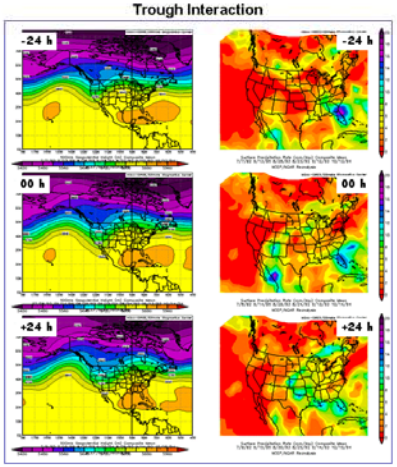
Large-scale patterns:

Examination of the rainfall and 500-hPa geopotential height patterns for all 35 cases revealed five characteristic large-scale patterns associated with tropical cyclones that move northward toward the U.S. southwest. Of these, four are associated with remnants that generate rainfall somewhere in the region. Each of these four patterns is associated with the presence of a midlatitude trough. The pattern in which no rainfall occurs is associated with a ridge that builds westward and blocks the tropical cyclone from moving into the U.S. southwest region.

Composite 500-hPa geopotential height and rainfall patterns are calculated for each pattern from the NCAR/NCEP reanalysis data. The two most distinctive 500-hPa patterns are shown below along with the rainfall patterns. Fourteen cases (40%) are associated with the strong trough (most rainfall) pattern and 5 cases (14%) are associated with the building ridge (least rainfall) pattern. The remaining cases fall into various weaker trough interaction regimes and are not shown here.

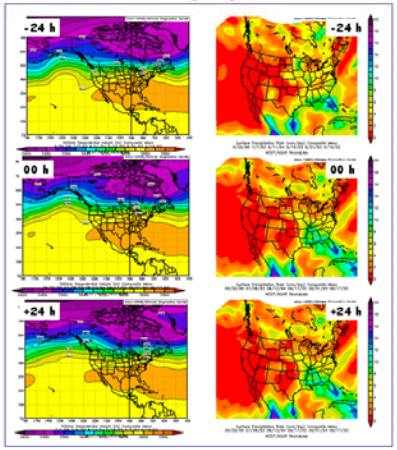
Large-scale patterns associated with northward-moving Pacific Tropical Cyclones

Trough Interaction



Note the southward digging midlatitude trough along the west coast of the U.S. The TC remnants move up into the divergent part of the trough in a process known as extra-tropical transition. Rainfall associated with this pattern can be heavy but is generally of short duration as the highly mobile trough moves rapidly eastward through the area. This pattern is associated with the most rainfall in Tucson, AZ and Albuquerque, NM with an average of 2.1 cm/storm.

Building Ridge



Note the westward building ridge, which blocks the northward movement of the tropical cyclone. Note also the midlatitude trough to the north of the ridge, which moves rapidly eastward. The ridge blocks any possible interaction between the TC and the trough. The TC eventually begins to move westward and dissipates. Any rainfall that falls in the SW during these events is not associated with the TC remnants.

Conclusions and Research in Progress:

All tropical cyclone remnant patterns identified that bring rain to the southwest region are associated with midlatitude troughs. Patterns range from
i) a strong interaction
ii) a partial interaction (where the tropical cyclone breaks away from the trough after about 24 h)
iii) a delayed interaction (the TC moves north of the southwest region before interacting with a trough)
iv) a missed interaction (the trough passes by before the TC moves far enough north).

Currently the years 1992-2004 have been studied in detail, and we are in the process of extending the database back to 1985. As more years are added we expect to refine the pattern categories. As our confidence in each pattern improves with more cases, we will investigate the physical processes behind each case with the aim of improving our ability to predict future rainfall.