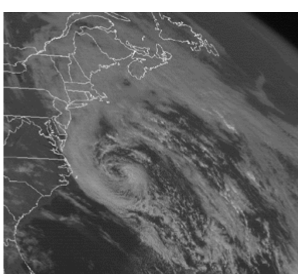
P1.43 **A FIFTY YEAR HISTORY OF SUBTROPICAL CYCLONES**

David Mark Roth
Hydrometeorological Prediction Center, Camp Springs, MD

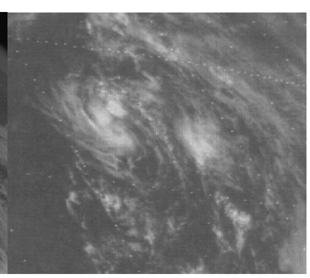
1. HISTORY

Subtropical cyclones are defined as hybrids between tropical and nontropical cyclones. These cyclones tend to form in central and western sections of ocean basins where the contrast between the ocean temperature and 500 hPa is the most extreme, and can be quite small in scale. The central Pacific ocean is the first area subtropical cyclones were documented due to the proximity of the Hawaiian Islands. Subtropical lows give Hawaii between half and three-quarters of their yearly rainfall (Simpson 1952). The notion of these systems existing in areas such as the Atlantic, was put forth by Dr. R. H. Simpson, former director of the National Hurricane Center in Miami. In the early days of the satellite era, these systems were seen from an entirely new perspective... the first such cyclone being photographed by Tiros I (Jones 1961). By 1972, these cyclones were given their own category after several years of debate. Certain types of subtropical cyclones were referred to as neutercanes in 1970; there was apparently such an uproar on its use, it was quickly abandoned (Padgett, personal communication). In the early 1970's, the National Hurricane Center began writing advisories on these cyclones to warn shipping of their hazards. By 1975, a satellite technique had been developed to diagnose their strength when ship observations were sparse/absent (Hebert et. al. 1975).

2. SUBTROPICAL CYCLONE CHARACTERISTICS



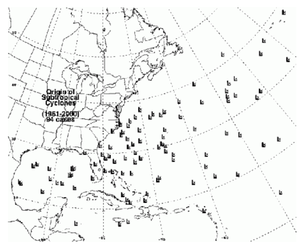
October 31, 1991 Type A

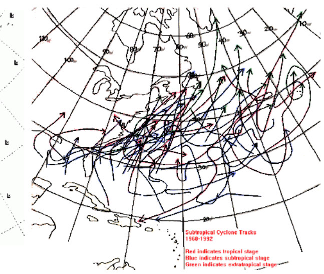


May 24, 1992 Type B

There are two varieties of these "hybrid" cyclones: Type A (55% of the sample) and Type B (45% of the sample). Type A is defined as a cold low with circulation extending to the surface layers, maximum sustained winds of gale or storm strength generally occurring at a radius of about 100 mi or more from the pressure center. Type B subtropical cyclones are defined as mesoscale cyclones originating near an old front with maximum sustained winds of gale or storm strength with a radius of maximum winds generally less than 30 mi ; the entire circulation sometimes encompassing an area initially no more than 100 mi in diameter. These marine cyclones may vary in structure from cold to warm core. While generally short lived, they may ultimately evolve into major hurricanes or extratropical wave cyclones. (Hebert 1973) Both varieties of cyclones share common characteristics. Both have a "neutral" core; i.e. a core that can be warm like a tropical cyclone near the surface, but cold similar to an extratropical cyclone aloft with the circulation strengthening with height. These systems get their energy from both latent heat of condensation and potential energy related to weak temperature gradients.

3. SUBTROPICAL CYCLONE ORIGINS/TRACKS



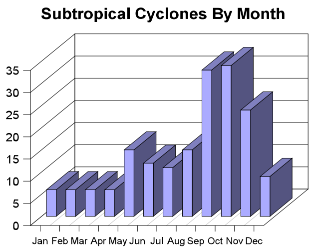


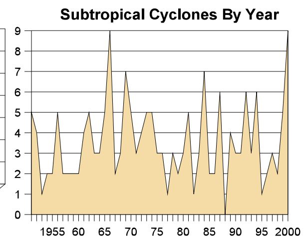
The density of subtropical storm formation is highest along the Gulf Stream off the Southeast U.S. coast, with 75% of all subtropical cyclogenesis west of the 60th meridian. The subtropical cyclones that get picked up by the next upper trough tend to have the parabolic tracks, while the systems that form from a cutoff cold core low have a more sinusoidal or lemniscate shape to the storm's track.

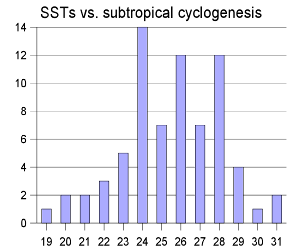
Lemniscate/ sinusoidal tracks are more common in the Pacific than the Atlantic. This could be due to the fact that the oceanic ridge in the Pacific is usually much more expansive than its Atlantic counterpart. Therefore, the chances of a system remaining cutoff from the westerlies and stalling for long periods of time south of a stagnant ridge in the Atlantic are quite small, whereas in the Pacific it is more frequent. The figure on the left shows several Pacific subtropical cyclone tracks (Simpson 1952). Of the known origins of subtropical cyclones, 48% began as frontal waves, 34% as tropical disturbances, 12% as tropical cyclones, and 6% from the center of occluded cyclones.

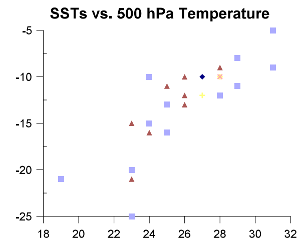
4. FREQUENCY/TIMING OF FORMATION

Simpson found in his twenty-year Pacific sampling that in that 3.9 subtropical lows formed per year, while Hebert and Poteat found an average of 4.6 storms annually in their eight year Atlantic sample. According to the smooth track database maintained at the National Hurricane Center for the Atlantic Basin, the average is only 1.8 subtropical cyclones annually, barely more than one-third of what Hebert and









Poteat found (Neumann et. al. 1999). Once additional sources of data are included, such as an exhaustive map search and satellite overview of the past 20 years, the declining trend seen in the TPC database after 1984 disappears, the number per decade is relatively constant, and a better statistical trend is realized. This total gives an average of four subtropical cyclones per year in the Atlantic Basin, dead in the middle of the averages obtained from the NHC track database and the work of Hebert and Poteat. Worldwide, it is hypothesized that an average of 16 subtropical cyclones form annually.

In the monthly distribution, there is an initial higher plateau of activity from June through August, before the major peak in September and October. The least active months for these storms are December through April, when the temperature differences between the Atlantic SST's and the 500 hPa temperatures reach their nadir.

During certain years bordering or during a warm ENSO event, an increase in subtropical cyclone genesis occurs. This seems to be correlated to the appearance and disappearance of warm ENSO events, which allows waters of the subtropical Atlantic to warm well above normal. The southward displacement of the jet during warm/neutral events would also contribute to their increased formation. Potentially cooler air aloft and the passage of stronger vorticity maxima through the warmer waters would significantly decrease atmospheric stability, creating conditions more favorable for subtropical cyclone formation.

5. DYNAMIC REQUIREMENTS FOR FORMATION

Looking at a subset of subtropical cyclone cases (68), the range of water temperatures for their development varies from as cool as 19 Celsius upwards to 31 Celsius. The mode of the SST distribution is 24 Celsius, with secondary modes of 26 and 28 Celsius. If the water as warm as 26 Celsius, cyclones quickly become tropical. Of the cyclones in the survey, 13% winds that never left depression status, 84% became gales, while 3% peaked with hurricane force winds.

Temperatures at 500 hPa were compared to SSTs to see if any link could be found for cases where subtropical cyclogenesis occurred. There is a relationship between the two for subtropical cyclogenesis, which is due to the instability of the environment in which they form. For the 22 cases where both the 500 hPa temp and SSTs are known, it is seen in the data that, on average, there needs to be a 38-40 degree Celsius temperature difference between the surface and the 500 hPa level. This gives you a sounding that is, on average, conditionally unstable between the two layers (6.7 degrees per km). If the environment becomes saturated, the atmospheric profile will become unstable and any disturbance that passes by could lead to convective development. This could be why subtropical cyclones not only need the presence of a closed upper low (which sets the stage for further development) but some additional shortwave or vorticity maximum to pass by in order to be initiated. This was noted in the development of Dorothy in 1966 (Erickson 1967).

6. REFERENCES

Erickson, Carl O., 1967: Some Aspects of the Development of Hurricane Dorothy. Monthly Weather Review, 95, 121-130.

Hebert, Paul J., 1973: Subtropical Cyclones. Mariners Weather Log, 17, 203-207.

_____, Kenneth O. Poteat, 1975: A Satellite Classification Technique for Subtropical Cyclones. NOAA Technical Memorandum NWS SR-83, Scientific Services Division, Fort Worth.

Jones, J. B. , 1961. A Western Atlantic Vortex Seen By Tiros I. Monthly Weather Review, 89, 383-390.

Neumann, Charles J., Brian R. Jarvinen, Colin J. McAdie, Gregory R. Hammer, 1999. Historical Climatology Series 6-2: Tropical Cyclones of the North Atlantic Ocean, 1871-1998. National Climatic Data Center: Asheville.

Simpson, Robert H., 1952: Evolution of the Kona Storm, A Subtropical Cyclone. Journal of Meteorology, 9, 24-35.

Spiegler, David A., 1972: Cyclone Categories and Definitions: Some Proposal Revisions. Bulletin of the American Meteorological Society, 53, 1174-1177.