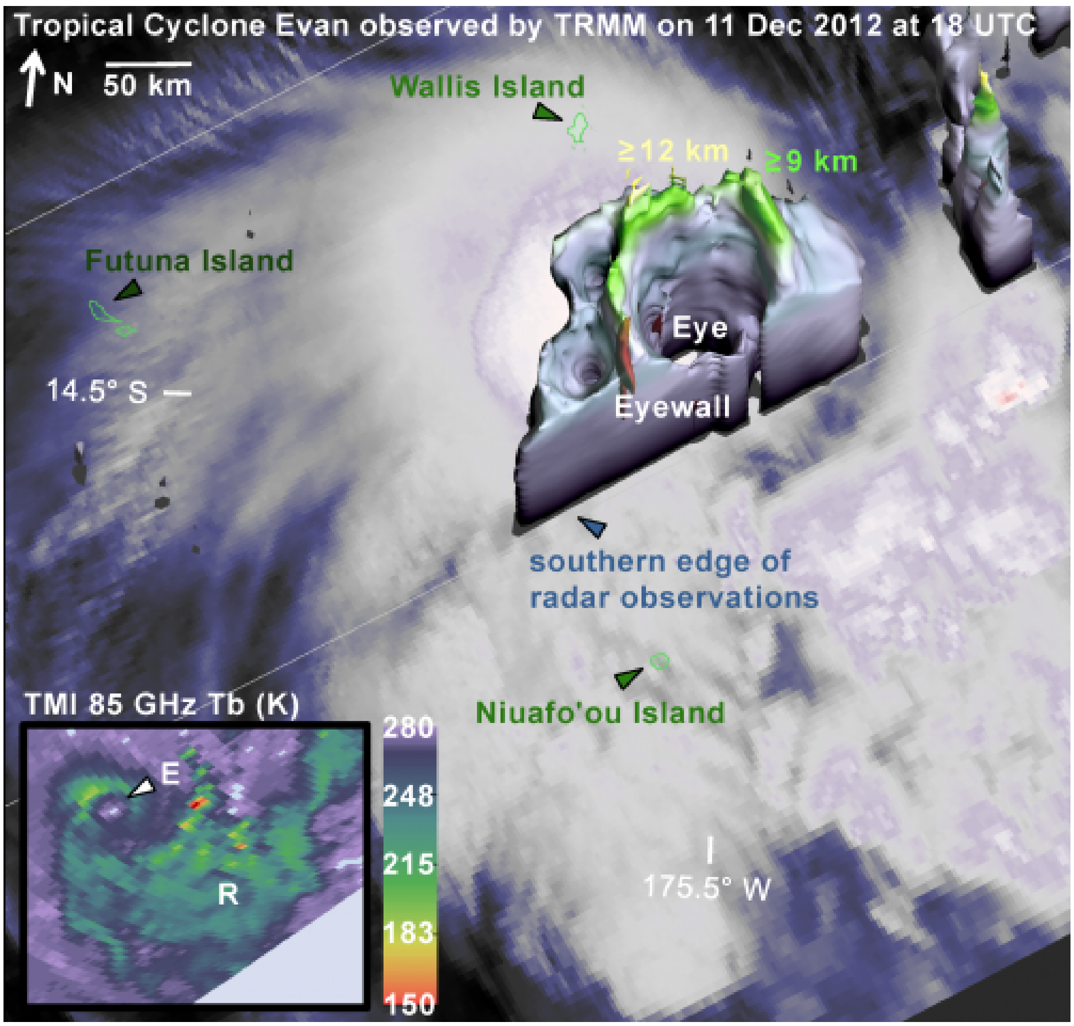
A need to look again: TRMM satellite observations of Tropical Cyclone Evan

December 17 2012, by Owen Kelley



The radar on NASA's Tropical Rainfall Measuring Mission (TRMM) satellite had observed Tropical Cyclone Evan four times as of Sunday, Dec. 16, and two of those overflights merit a closer examination. Credit: NASA/Owen Kelley

The radar on NASA's Tropical Rainfall Measuring Mission (TRMM) satellite had observed Tropical Cyclone Evan four times as of Sunday, Dec. 16, and two of those overflights merit a closer examination.

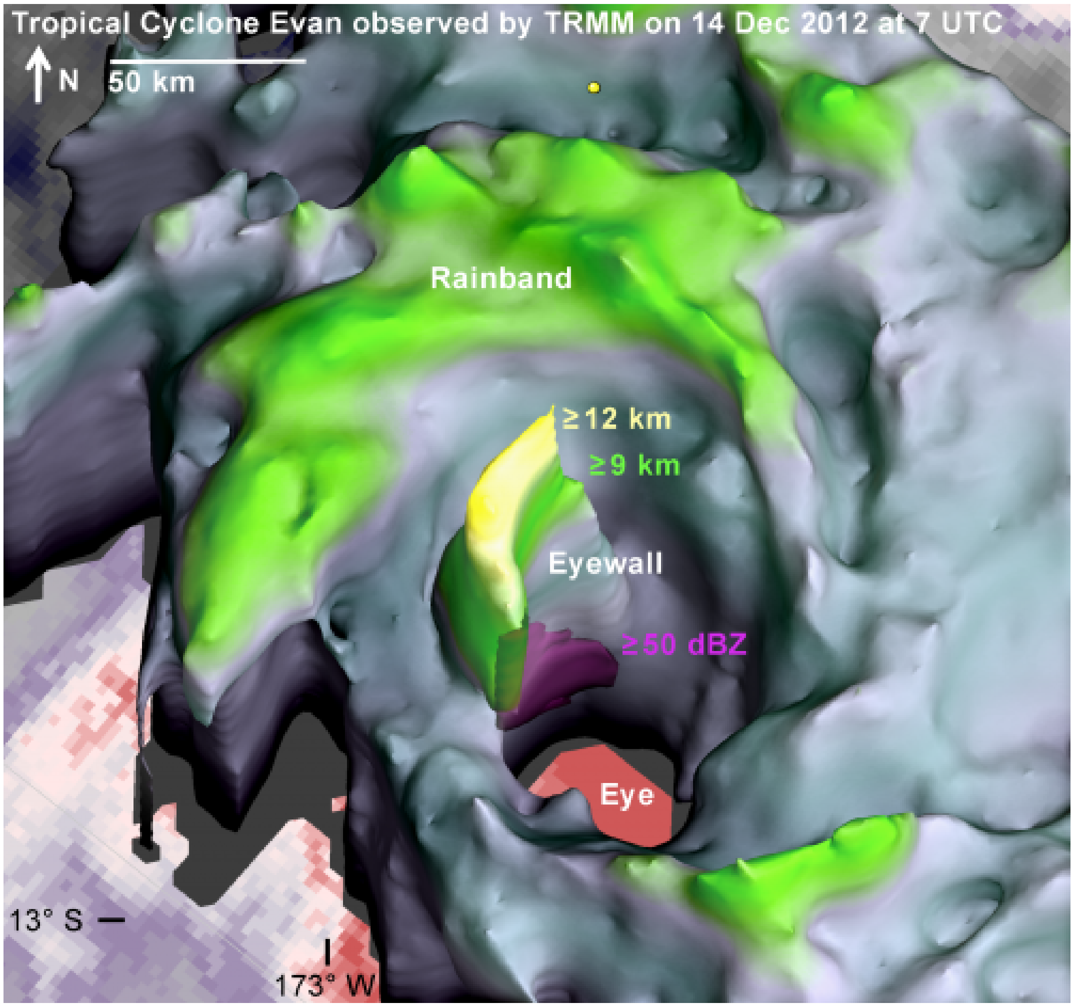
On Tuesday, Dec. 11, the TRMM satellite saw Evan about 24 hours before the storm struck American Samoa, and the radar data at first seem incongruous for such a weak system. At the time, Evan was estimated to be less than tropical "cyclone" strength, and had 35 knot (40.2 mph/64.8 kph) surface winds, making it a tropical storm. More specifically, the TRMM radar saw a "complete eyewall," i.e. an eyewall that circled all the way around the eye.

Either the TRMM radar was showing that Evan was much stronger than 35 knots (40.2 mph/64.8 kph) on Dec. 11 or perhaps Evan was a member of a rare breed of 35-knot systems with well-formed eyewalls that are known to rapidly intensify (1). After the South Pacific tropical cyclone season is over, researchers and operational agencies alike should take a closer look at Evan on Dec. 11. Through informal channels, an unofficial debate on this question has already begun.

The infrared cloud top imagery collected by the TRMM satellite isn't much help on this question (as seen in the background of the TRMM image). The infrared instrument finds the eyewall obscured by upper-level outflow.

Meanwhile, the TRMM radar observed light precipitation under the cloud tops (as shown in the image by the gray-green-yellow volume) of 20 dBZ radar reflectivity.

The term "dBZ" means "decibels relative to Z." Basically, dBZ is a measure of equivalent reflectivity (Z) of a radar signal bouncing off an object. "Reflectivity" of a cloud depends on the number and rain, snow, and hail, and their size. In respect to size, a large number of small raindrops will reflect the same as one large raindrop.



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A respectable 30-dBZ radar-reflectivity signal reached most of the way around the eye. A close look at the radar data reveals that, with increasing altitude, the inner edge of the volume of precipitation slopes outward from the eye, like seating in a football stadium.

Launched in 1997 by NASA and the Japanese Space Agency known as JAXA, the TRMM satellite has observed enough systems of this strength to suggest that it is rare, but not unheard of, for them to have complete eyewalls. Most new systems, upon reaching tropical-storm strength, still look like poorly organized "blobs" in TRMM radar overflights not football stadiums, like Evan did.

The (insert, lower left) passive microwave observations were collected by the TRMM Microwave Imager (TMI) at 85 GHz. Colder temperatures at 85 Ghz locates where storm cells have more ice-phase precipitation because these upper-level ice chunks are scattering out radiation coming up from the ocean's surface. TMI's coarser horizontal resolution and limited information in the vertical, causes the compact eye of the storm (labeled "E" in the image) to be harder to distinguish from the large region of less-organized rain cells to the southeast (labeled "R") in the image. More specifically, the microwave observations are spaced 5 by 14 km (3.1 by 8.6 miles) apart compared the TRMM radar's 5 by 5 km (3.1 by 3.1 mile) horizontal resolution and 250 meter (0.15 mile) vertical resolution.

While there were overcast skies at Wallis and Futuna Island within a couple of hundred kilometers (miles) to the north and west of Evan's eyewall on Dec. 11, the TRMM radar shows a complete absence of precipitation anywhere near these islands and the approximately 15,000 people who live there. Having spared them on Dec. 11, Cyclone Evan would ironically loop back and strike these two islands directly on its return trip west, four days later.

On Friday, Dec. 14, NASA's TRMM satellite saw Evan after it had hovered near Samoa for about a day. At the time of the Dec. 14 overflight, Evan was one day from striking the islands of Wallis and Futuna and two days from striking the larger island nation of Fiji. There was an unusually strong radar signal on the northwest side of Evan's eyewall, a few kilometers (miles) above the ocean surface.

An initial interpretation might be that such a strong signal would indicate that the eyewall was working particularly vigorously to inject energy into the tropical-cyclone heat engine that converts latent heat of vaporization into increased tropical cyclone wind intensity. One might think this low altitude, strong radar signal would indicate intensification, but think again.

A more careful analysis would suggest that the strong radar signal at the base of the eyewall on December 14 did not signal intensification. In the Dec. 14 TRMM overflight of Evan, the feature in question (shown in the image as the purple volume) locates the where the radar signal equals or exceeds 50 dBZ.

Since reflectivity is reported on a logarithmic scale, the 50 dBZ signal in the Dec. 14 overflight suggests that a factor of 10 more scattering from precipitation is occurring on Dec. 14 than the 40 dBZ signal in the Dec. 11 overflight would imply. Other factors being equal, the stronger the radar signal, the more water vapor is condensing into liquid or ice precipitation in the eyewall. Condensation releases latent heat, the fuel of tropical cyclones. However, the multiple energy transformations that occur within the inner core of a tropical cyclone contain subtleties that decades of research have yet to fully describe.

A statistical analysis of years of TRMM satellite overflights of tropical cyclone's world-wide found that high-altitude light precipitation (a 20 dBZ radar reflectivity above approximately 14.5 km (9.0 miles) altitude) is associated with tropical cyclone intensification. In contrast, the same statistical analysis found that very intense precipitation (50 dBZ) occurs rarely in tropical cyclones, and close to equally rarely regardless of whether or not the tropical cyclone is intensifying (2).

Tropical cyclone simulations suggest that strong precipitation fixed on one side of the eyewall can be caused by persistent large-scale wind-shear (3). Such wind shear threatens to tear the tropical cyclone apart and can make it difficult, though not impossible, for a tropical cyclone to maintain, let alone increase, its intensity. Consistent with this interpretation, passive microwave observations of Evan from multiple satellites showed a persistent precipitation maximum on the north side of Evan's eyewall during several days centered on the Dec. 14 TRMM overflight.

Furthermore, operational analyses suggested Evan was holding steady or weakening slightly at the time the TRMM saw radar reflectivity in excess of 50 dBZ at the base of the eyewall. In short, the strong radar signal at the base of the eyewall on Dec. 14 is noteworthy but not the sign of a tropical cyclone that is about to become a monster storm.

Provided by NASA's Goddard Space Flight Center