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WIND FIELDS OF ANDREW, OMAR, AND INIKI, 1992

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1. INTRODUCTION

Three violent hurricanes/typhoon visited South Florida, Guam, and Kauai within an 18-day period between 24 August and 11 September 1992. In an attempt to clarify the nature of the damage-causing winds, an unroofing scene on video and several thousand aerial photos were analyzed along with the standard meteorological data. The following subjects have been evidenced and confirmed:

(a) One- to four-second gusts were obtained by computing the deformation of the roof recorded by a 30 frames-per-second video. The unroofing was completed by a single gust in one second, followed by a 3.5-second flight before ground impact.

(b) Small but violent vortices, only 50 to 150 m in diameter and up to estimated 90 m/s maximum wind were found inside the damage area of Andrew in South Florida. They were classified as spin-up vortices and called **hurricane swirls.** Their rotation was either cyclonic or anticyclonic.

(c) Approximately 10 downburst patterns of blown-down trees were confirmed inside the area of Iniki damage. Some were located on flat terrain while others were in mountains. In spite of the moist environment of the hurricane, **hurricane downbursts** induced estimated 50 to 70 m/s peak winds.

2. EYEWALL WINDS IN TYPHOON OMAR

Omar's eye passed directly over the Naval Air Station inducing the 65.7+ m/s (147+ mph) peak wind on the west side of the eyewall (Fig. 1).

Gusts imply the fluctuation of windspeeds on both sides of the mean wind. Although the sequence of gusty winds is caused mainly by ground friction along with instability, the sub-mesoscale disturbance corresponding to individual gusts cannot always be identified.

Without knowing the nature of individual gusts, so-called gustiness factors of 20 to 30% are used in determining the wind load for designing structures. The 147 mph peak wind is 84% larger than the 80 mph mean wind. The peak windspeed is so prominent that it is not a garden-variety gust but a peak wind induced by a sub-mesoscale meteorological disturbance, such as an intense vortex, microburst, or an unknown wind system. Usually, an aerial survey with high-resolution photographs will solve the mystery of peak winds.

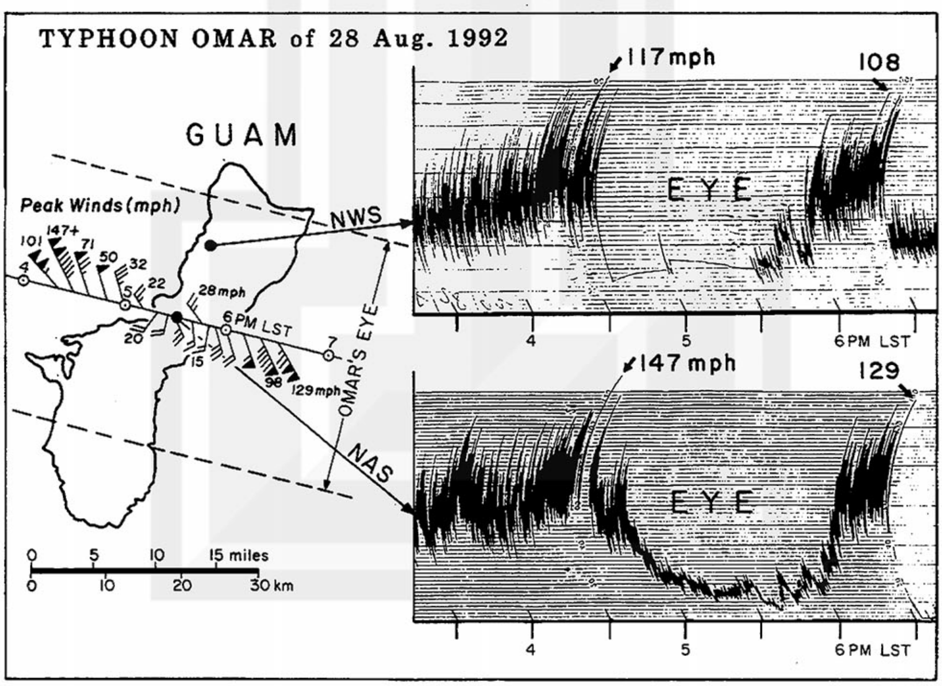

Fig. 1 Gust-recorder traces of Typhoon Omar recorded as the eye moved across the center of Guam. Wind direction and speed traces were converted into the wind symbols placed along the path of the eye.

3. DOWNBURSTS IN HURRICANE INIKI

The eye of Iniki landed at Waimea on the south shore of Kauai, known as Garden Island. After the storm, the author mapped the entire island with damage vectors, direction of the f-scale damage left behind by the first (frontside) and the second (backside) winds. 300 color photos (9"x9"), 500 infrared (9"x9"), and 3,000 color photos (35 mm) were used.

Unexpectedly, beautiful pattern of a microburst was found (Fig. 2). Initially, it was assumed that any microburst damage should be wiped out by hurricane winds during the post-microburst period. The perishable damage survived, probably because the microburst winds were stronger than the hurricane winds. An intensive downburst/microburst hunt began immediately, finding at least 10 damage patterns indicating **hurricane downbursts.**

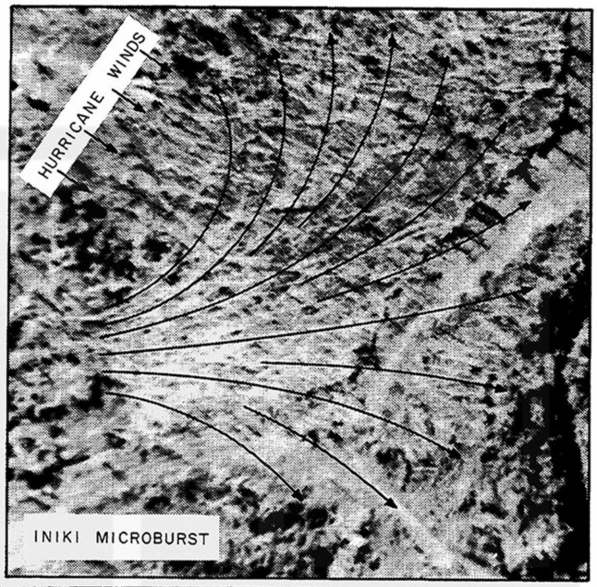

Fig. 2 Pattern of a microburst damage found in the forest 11 km NNW of Lihue, Kauai.

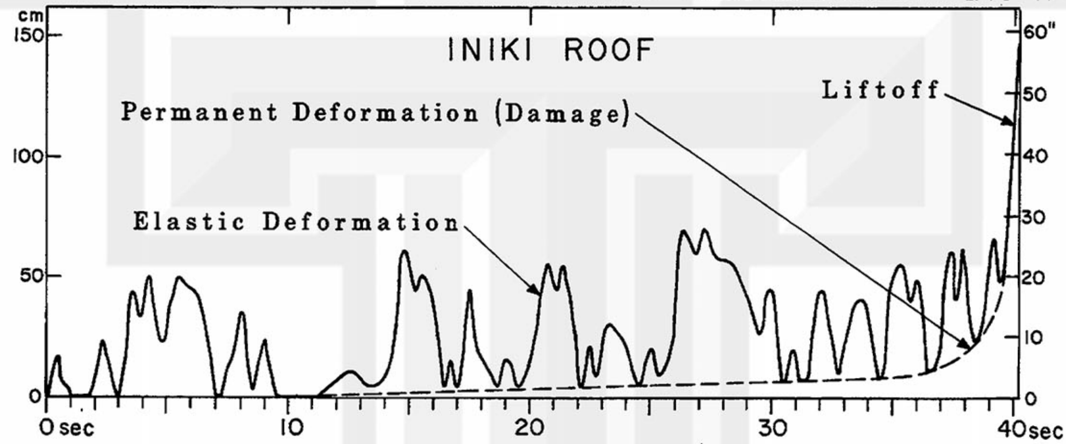

Fig. 3 Deformation of a roof of a house at Princeville, Kauai unroofed by a hurricane downburst embedded in Iniki winds. The downburst landed 5.5 km to the south of the unroofed house.

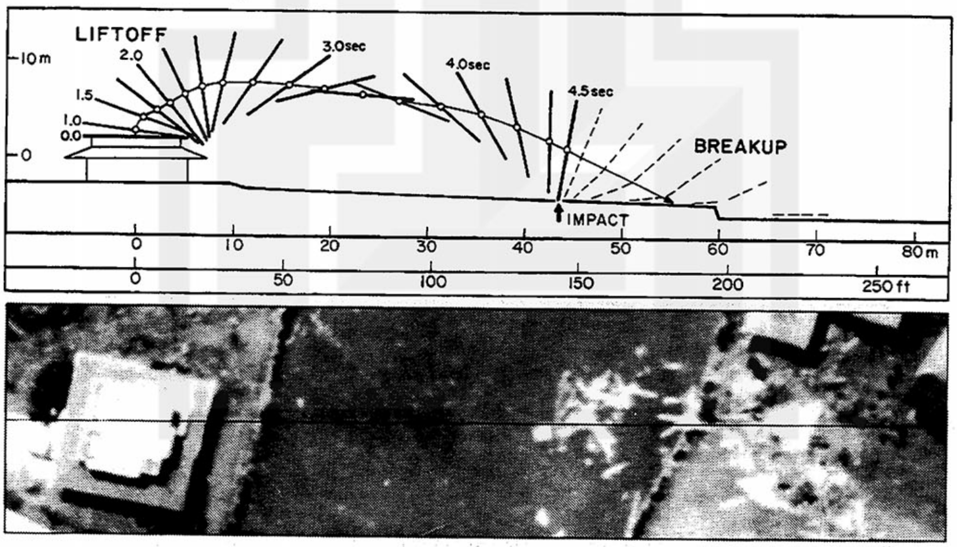

Fig. 4 Flight of the roof and an aerial photo showing the unroofed house, the impact hole, and the broken-up roof.

While a downburst was in progress immediately after the passage of the eye, Mr. Dean Marshall took a video of a roof which bent convex upward during 1- to 4-sec gusts and returned flat in dull periods. The amount of the bulge, recorded at 30 frames per second, was used as the record of very high resolution gusts (Fig. 3).

Finally, the roof became airborne (Fig. 4) for only 3.5 sec. The maximum airborne speed was 47 mph, because the peak wind was too short to accelerate the roof close to the windspeed (Fig. 5).

Now we should realize that an unroofing in a 100 mph wind can be accomplished in a matter of 1 to 2 seconds and in a 200 mph wind, in a fraction of a second. This evidence indicates that the sustained wind of 60 seconds is not the prerequisite to unroof a house. Everybody knows that tornadoes do not induce sustained winds.

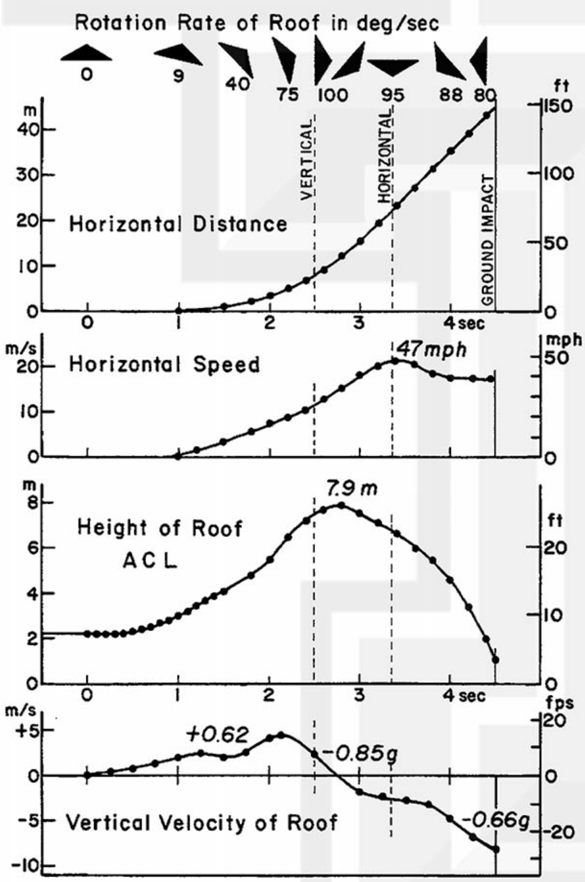

Fig. 5 Time-dependent analysis of the airborne roof which rotated 270°. The roof accelerated downwind for 2.3 sec., reaching a constant speed during a brief horizontal flight. The aerodynamic force accelerated the roof upward during the topside-up position and then downward during the topside-down position. Evidently, the gust speed relative to the airborne roof decreased only 2 sec. after the lift-off.

4. HURRICANE SWIRLS FOUND IN ANDREW

After Andrew, the author made his first aerial survey on 7-8 September, noticing the existence of a number of damage streaks at Pine Woods Villa and Naranja Lakes area. These damage areas were visited and inspected on 9 September with Drs. Bob Sheets, Director of NHC and Peter Black of NHD. Our ground survey revealed the trunk of a large pine tree cut one-third by a flying plywood. Also found is a narrow band of high-speed debris including a dumpster blown 100 to 150 meters from its estimated source (Fig. 6).

Both ground and aerial photos suggest that the damage was caused by small vortices which spun-up very rapidly into violent swirls 50 to 150 m in diameter. If these vortices traveled at 120 mph, while rotating at 80 mph, the total wind of 200 mph could be induced. However, the duration of the peak wind caused by such small and fast-moving vortices will be less than one second. So far, thirty-seven spin-up vortices were found inside the Andrew area. Of these, 18 were cyclonic (counterclockwise) while 19 others were anticyclonic (clockwise) vortices. These spin-up vortices in hurricane are called **hurricane swirls**.

Currently, various flight modes of concrete tie beams reinforced by steel rods not connected to the foundation are being studied. Modes under consideration are:

Mode 1: Flight with entire roof attached
Mode 2: Flight with trusses attached
Mode 3. Flight with concrete beam(s) only
Mode 4. Flight in wind-parallel direction
Mode 5: Flight in broadside direction

Irrespective of these flight modes, the peak winds lasting only one second or less must achieve the initial acceleration and velocity of airborne tie beams.

It is likely that **hurricane swirls** in Andrew occurred in the vicinity of the eyewall where sustained winds decrease rapidly toward the eye. A significantly large rate of windspeed decrease is expected to occur beneath an active convective tower, resulting in the fields of large vorticity and convergence. The vorticity field will generate slow-rotating vortices which are stretched and tightened into spin-up vortices while traveling toward the eye. The rotation of these vortices are either cyclonic or anticyclonic (Fig. 7).

5. CONCLUSIONS

This research on **Andrew, Omar,** and **Iniki** of 1992 uncovered that:

(1) The gustiness periods of damage-causing winds are only 1 to 4 seconds, significantly shorter than 20 to 30 seconds which have been assumed. Because structural damage could occur in several seconds, the sustained winds with added gustiness factor may not always explain the different damages in hurricanes.

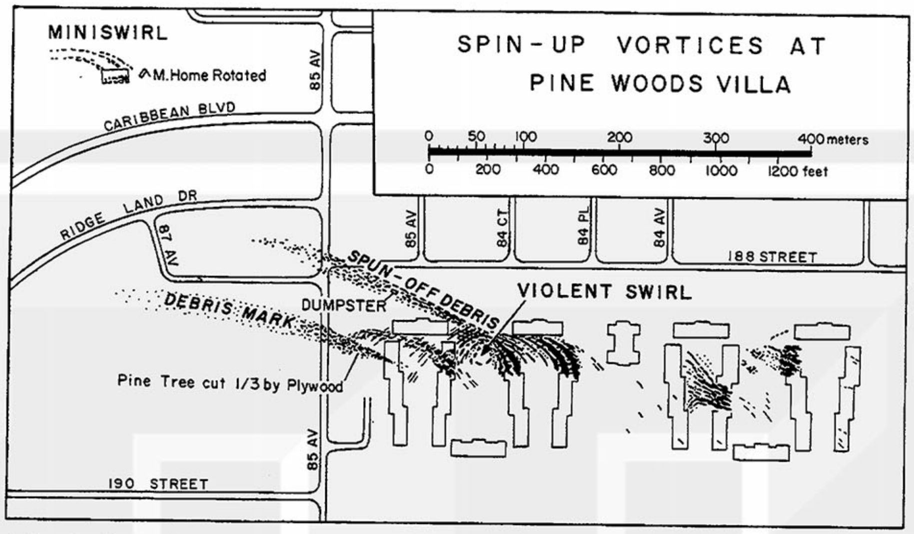

Fig. 6 Preliminary analysis of the debris pattern generated by hurricane swirls at Pine Woods Villa near 190th St. and 85th Ave., Miami. Aerial photos were taken on 28 AUG, 01 SEP, 07 SEP, 11 SEP, and 14 SEP.

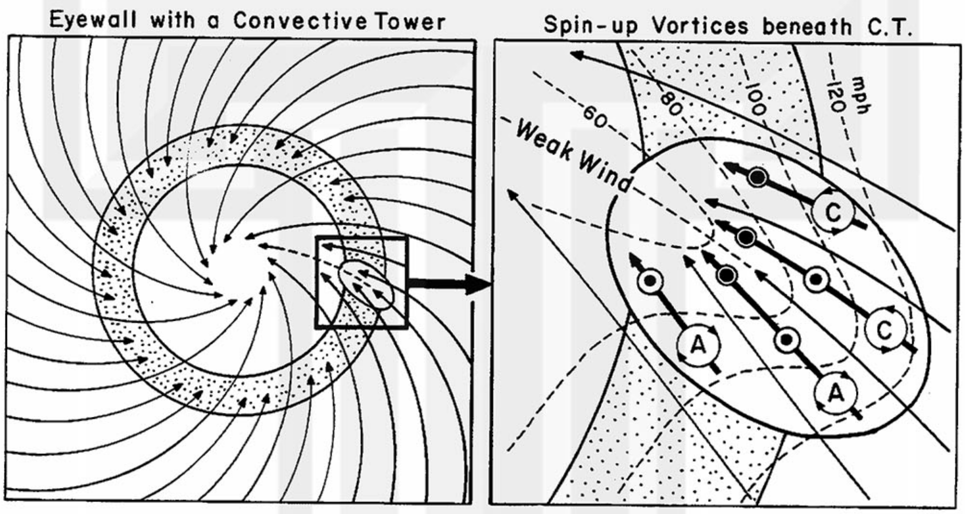

Fig. 7 Author's model of hurricane swirls which form and spin up beneath a strong convective cloud in the eyewall. Both cyclonic and anticyclonic vortices are expected to develop.

(2) Extreme winds embedded in gusty winds cannot be regarded as strong gusts of unknown origin. They have been identified as **hurricane downbursts** (10 in Iniki) and **hurricane swirls** (37 in Andrew). Although the point probability of these extreme winds is less than 1:100,000 per year, 160 mph peak winds could occur in **hurricane downbursts** and 200 mph peak winds in **hurricane swirls.**

The new evidence of damaging winds suggests strongly that patterns of extreme winds in hurricanes and typhoons could vary significantly. The damage on structures also vary according to their strength as well as their wind-relative orientations.

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	ANDREW	OMAR	INIKI
N A S A	Major		
O N R	Partial	Major	Partial
N W S			Major
U C A R			Partial
U. of C.	Partial	Partial	Partial