AHEAD OF THE WAVE: THE CHANGE COMING TO THE SAFFIR-SIMPSON CLASSIFICATION SYSTEM

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EDITOR'S NOTE: In 2009, the National Hurricane Center announced that it was updating the Saffir-Simpson Hurricane Scale after 35 years of operational use. In this article, Dr. Tim Doggett, AIR's Principal Scientist, Atmospheric Science Research, and Jason Butke, Scientist in AIR's Atmospheric Science Research group, describe the origins of the Saffir-Simpson Scale and what it was meant to achieve. They also explain why the National Hurricane Center is changing the scale—and, from the modeler's perspective, whether that matters.

By Dr. Tim Doggett and Jason Butke

INTRODUCTION

"Hurricane Alex has intensified on its approach to the Gulf Coast and is now a Category 4 storm on the Saffir Simpson Scale!" After four decades of hurricane warnings, news headlines like this have become familiar. But how many people actually know what "The Saffir-Simpson Scale" is? And from the catastrophe modeler's point of view, how relevant is it? The five discrete categories defined by the Saffir-Simpson Scale are a useful convention for characterizing individual events for the public. However, because hurricane damage increases non-linearly with wind speed, a spectrum of *continuous* intensity is used when modeling hurricane risk.

In this article, we take a look back at the history of the Saffir-Simpson Scale, discuss why and how the National Hurricane Center (NHC) is changing it, and describe how the change has been incorporated into the upcoming release of the AIR U.S. Hurricane Model (Version 12.0).

UNCERTAIN BEGINNINGS

Early in the morning of August 17, 1969, a Hurricane Hunter reconnaissance aircraft flew into the eye of Hurricane Camille, then about 250 miles south of Mobile, Alabama. Camille was moving rapidly toward the Gulf Coast and was expected to make landfall in less than a day. What was known about Camille was that it had crossed the western tip of Cuba as a small hurricane and entered the Gulf of Mexico with sustained winds of about 105 mph. At the time, meteorological data of the sort that today are routinely available for forecasters were sparse. The first satellite of the fledgling and still provisional NIMBUS weather-monitoring program had been placed into orbit only five years earlier, the National Hurricane Center had been centralized just four years earlier, and the National Oceanic and Atmospheric Administration wouldn't come into existence for another year.

The Hurricane Hunter recorded Camille's central pressure at 905 mb—the lowest ever recorded by a reconnaissance aircraft and one of the lowest ever recorded anywhere. Camille's surface sustained wind speed was estimated at 160 miles per hour. Serendipitously, the U.S. Weather Bureau had just developed the first computer model designed to forecast storm surge, a major cause of hurricane damage. When officials at the NHC put the aircraft observations into the model, they were shocked. Expecting a maximum storm surge of 12 feet, the model instead predicted surge heights of up to 20 feet.

NEEDED: A MEANS OF QUANTIFYING THE THREAT

At a loss for how to convey to local authorities and people living along the coast just how powerful Camille was expected to be, the NHC broke a long-standing Weather Bureau rule against using specific numbers in a forecast. It said outright that Camille's storm surge might be as high as 20 feet and its winds as high as 200 mph—and vigorously publicized the numbers. This action was credited with prompting the evacuation of nearly 100,000 residents, thereby saving lives.

Even so, when Hurricane Camille came ashore west of Biloxi, Mississippi, it killed nearly 150 people. The hurricane descended on the small towns of the Mississippi coast destroying virtually everything before it. A storm surge in excess of 22 feet was recorded at the town of Pass Christian. The storm's sustained winds were estimated to be near 190 mph—*estimated* since the storm's intensity damaged or destroyed all official wind speed recording instruments in the landfall vicinity. The damage Camille caused was estimated at $1.5 billion (in 1969 dollars).

Figure 1. Aftermath of Hurricane Camille (Source: NOAA)

THE SAFFIR-SIMPSON HURRICANE SCALE

The Director of the National Hurricane Center at the time was Robert Simpson. Unhappy with his inability to effectively communicate the intensity of a hurricane like Camille in terms of the danger it posed and the destruction it could cause, Simpson adopted and modified a classification schema devised earlier by Herbert Saffir, a Florida structural engineer who had been engaged by the United Nations in the late 1960s to study the vulnerability of buildings to wind. Saffir had developed a scale that correlated five wind speed increments with five levels of structural damage. Simpson added comparable storm surge heights to correspond with Saffir's wind speed ranges. The "Saffir-Simpson Hurricane Scale" came into full operational use in 1975, with central pressure included as an intensity measure to extend the utility of the scale.

Figure 2 below lays out the Saffir-Simpson categories and the wind speed, central pressure, and storm surge criteria that Simpson used to define each categories.

SAFFIR-SIMPSON SCALE	MAXIMUM SUSTAINED WIND SPEED (MPH)	CENTRAL PRES-SURE (MB)	STORM SURGE (FEET)
Category 1	74-95	Greater than 980	4-5
Category 2	96-110	979-965	6-8
Category 3	111-130	964-945	9-12
Category 4	131-155	944-920	13-18
Category 5	Over 155	Less than 920	Over 18

Figure 2. Saffir-Simpson Hurricane Scale (Source: NOAA)

Accompanying each category was also a description of the kind of damage that could be expected, as well as a selection of historical hurricanes in that category. For example, an NHC web page today includes this information with its description of a Category 3 hurricane:

"Some structural damage to small residences and utility buildings. Large trees blown down. Mobile homes and poorly built signs destroyed. Flooding near the coast destroys smaller structures with larger structures damaged by floating debris. Terrain may be flooded well inland. **Examples:** Keith 2000, Fran 1996, Opal 1995, Alicia 1983, and Betsy 1965."

OTHER SCALES

Since 1975 the Saffir-Simpson Hurricane Scale has been used to categorize all tropical cyclones (hurricanes) that form in the Atlantic Ocean and the northern Pacific Ocean east of the International Date Line. The scale's five categories have given public officials, emergency responders, insurers and reinsurers, and the public at large a good sense of the risks they face from an approaching storm—and therefore of the measures they should take to prepare for it.

The scale's efficacy inspired imitations, and today there are at least a half-dozen similar official scales in use around the world. The scale that perhaps looks the most like Saffir-Simpson—at least at first glance—is the 5-step scale used by the Australian Bureau of Meteorology. However, a Category 3 tropical cyclone on the Australian scale is a storm having a wind speed between 102.5 mph and 139.8 mph. On the Saffir-Simpson Scale the same storm could be classified as low as a mid-level Category 2 hurricane—or as high as a mid-level Category 4 hurricane.

However, even that comparison is misleading. The Australian Bureau of Meteorology measures wind speed by three-second wind *gusts*; the NHC wind speed measure is based on *sustained winds* of one-minute duration. And other weather agencies use other measures. Perhaps most common is a measure endorsed by the World Meteorological Organization. It is also based on sustained winds, but defined as winds averaged over a period of ten minutes.

THE NEW "SAFFIR-SIMPSON HURRICANE WIND SCALE"

By the mid-2000s, the National Hurricane Center decided that, after 30 years, the Saffir-Simpson scale should be revised to make it better suited to its immediate purpose of warning people of the expected threat posed by an approaching hurricane. In 2009, the NHC completed an internal review and issued a draft of a new scale, "The Saffir-Simpson Hurricane Wind Scale (Experimental)," and asked for public comment. The new scale will be put into official use for the 2010 hurricane season.

As its slightly altered name indicates (Wind Scale), the new scale uses only wind speed to designate the five Saffir-Simpson categories. This is consistent with the fact that the single most direct predictor of potential danger and damage from a hurricane is wind. Additionally—although incidental to the NHC's concerns—for the past 20 years the media have been referring only to wind speed when reporting hurricane intensity. As a consequence, wind speed has become the most familiar indicator associated with the Saffir-Simpson categories—if not the only one.

Central Pressure Not Included

Central pressure figured prominently in the original Saffir-Simpson scale not least because it had been the most readily available and reliable measure of hurricane intensity. Wind speed is a function of the difference—over a given distance—between the pressure at a hurricane's center (minimum central pressure) and the environmental pressure at the storm's periphery (peripheral pressure). That is, because air flows from areas of relative high pressure to areas of relative low pressure, the greater the difference between peripheral and central pressure, the more rapid will be the inflow of air (and the higher the wind speed). Other forces and variables also come into play depending on the specific circumstances at any particular moment.

In fact, the relationship between central pressure and wind speed is rather more complex than this explanation would suggest—and can even vary by ocean basin. Indeed, a storm can fall into different Saffir-Simpson categories depending on whether it is ranked by wind speed or by central pressure. Just this kind of classifying conundrum occurred with Hurricane Katrina. At landfall, Katrina had a wind speed of 125 mph—indicating that, according to the Saffir-Simpson Scale, it was a little stronger than a mid-Category 3 hurricane. But it also had a central pressure of 920 mb at landfall—indicating that, according to the Saffir-Simpson Scale, it was at the upper bound of the very strongest *Category 4* hurricane.

In order to eliminate such occasional and potentially confusing ambiguities, the NHC has decided to no longer include central pressure measures to define the five Saffir-Simpson categories. (In the case of Katrina: later analysis showed that it had relatively weaker winds at landfall because its pressure field had broadened in the hours just before landfall, thus decreasing the pressure gradient out from the storm's center over a distance much greater than normal.)

Storm Surge Not Included

While the National Hurricane Center's warnings of Hurricane Camille in 1969 were undoubtedly fortuitous, nearly four decades of experience since then have shown that using storm surge heights to define hurricane intensity is also problematic. Storm surge is a major cause of hurricane damage, and while the height of storm surge and the level of central pressure and wind speed are related, several factors independent of wind and central pressure also contribute to surge height at a *specific location.*

These other factors have less to do with the nature of a tropical cyclone than with the characteristics of the specific location where landfall happens to occur, such as the depth of near-shore waters (bathymetry) and the topography of the shoreline and the land beyond it. The hurricane's size, forward speed, and the angle at which it makes landfall also can affect storm surge—and, for that matter, whether the tides are in or out, or whether the moon is full.

Hurricane Ike, for example, struck the upper Texas coast in 2008 as a Category 2 hurricane. According to the Saffir Simpson Scale, Ike should have been accompanied by a storm surge of six to eight feet. Instead, Ike produced peak storm surge heights of 15 to 20 feet, in part because of the shallow waters that characterize that part of the Gulf of Mexico and in part because of the storm's size. Ike's hurricane force winds extended outward from the center more than 100 miles—and thus made landfall with a much larger area of ocean waves converging on shore. Conversely, in 2004, Hurricane Charley—a tightly wound storm whose hurricane-force winds extended only 25 miles from its eye—made landfall in Florida as a Category 4 hurricane. According to the Saffir-Simpson Scale, Charley should have brought a storm surge of 13-18 feet, yet in fact the peak height of Charley's surge was just 6-7 feet.

Thus because there is no clear one-to-one relationship between wind speed and storm surge, the NHC is dropping surge from the Saffir-Simpson Scale. However, because of the destructive potential of storm surge and the need to warn coastal residents, the NHC will be providing probabilistic estimates of inundation (the probability that various storm surge heights will be exceeded) this year. These estimates, however, are issued independently of Saffir-Simpson Category.

HURRICANE MODELING AND THE NEW SAFFIR-SIMPSON WIND SCALE

Whether Hurricane Katrina was classified—using central pressure—as a Category 4 hurricane, or—using wind speed—as a Category 3 hurricane, it remained the same storm. A modeled storm, based as it is on the same interplay of meteorological parameters that create and drive real-world tropical cyclones, is similarly internally consistent—and continues to have the same characteristics regardless of how it might be classified.

The National Hurricane Center's new practice of using only wind speed to determine Saffir-Simpson categories has been anticipated in the latest version of the AIR U.S. Hurricane Model to be released later this spring. The AIR model has always assigned a Saffir-Simpson category to each modeled event, thus allowing users flexibility in classifying storm losses. In the updated version, the Saffir-Simpson category is based on the modeled hurricane's maximum wind speed at landfall—consistent with the NHC's new wind-only Saffir-Simpson Hurricane Wind Scale.

The loss results generated by the AIR model are not impacted by this change. The AIR U.S. Hurricane Model continues to determine a hurricane's wind field (the spatial distribution of winds) based on the full range of storm characteristics: minimum central pressure, radius of maximum wind, forward speed, and other defining parameters. The model generates damage estimates using these factors together with landfall location data.

Since earlier versions of the AIR Hurricane Model included Saffir-Simpson classifications based on central pressure, a comparison of the updated model's results to the output of earlier versions will show differences. These differences, however, are essentially artifacts of reporting. In addition, analyses of landfall frequency by Saffir-Simpson Category by coastal segment will also show some changes as a result of the change in reporting. As stated above, the assigned Saffir-Simpson category has no effect on modeled *losses*.

The Saffir-Simpson Hurricane Scale was not meant to have scientific precision. It has been and remains a very useful tool for communicating to stakeholders—among them, coastal residents and emergency responders—the threat represented by an approaching hurricane.

ABOUT AIR WORLDWIDE

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