Application of Surface-Adjusted GOES Low-Level Cloud-Drift Winds in the Environment of Atlantic Tropical Cyclones. Part II: Integration into Surface Wind Analyses

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ABSTRACT

The Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin—Madison recently (1997 season) began providing real-time Geostationary Operational Environmental Satellite (GOES) low-level cloud-drift winds in the vicinity of tropical cyclones on an experimental basis to the National Oceanic and Atmospheric Administration's (NOAA) Hurricane Research Division (HRD). The cloud-drift winds are derived from sequential high-resolution GOES visible channel imagery. These data were included in many of HRD's real-time tropical cyclone surface wind objective analyses, which were sent to NOAA's National Hurricane Center and the Central Pacific Hurricane Center on an experimental basis during the 1997–2001 hurricane seasons. These wind analyses were used to support the forecasters' tropical cyclone advisories and warnings. The satellite wind observations provide essential low-level coverage in the periphery of the tropical cyclone circulation where conventional in situ observations (e.g., ships, buoys, and Coastal-Marine Automated Network stations) are often widely spaced or nonexistent and reconnaissance aircraft do not normally fly. Though winds derived from microwave channels on polar orbiting satellites provide valuable surface wind data for HRD surface wind analyses, their swath coverage and orbital passes are limited spatially and temporally. GOES low-level visible (GLLV) winds offer nearly continuous spatial and temporal coverage in the western Atlantic and eastern Pacific basins. The GLLV winds were extrapolated to the surface using a planetary boundary layer model developed at HRD. These surface-adjusted satellite data were used in real-time surface wind analyses of 1998 Hurricane Georges, as well as in poststorm analyses of 1996 Hurricane Lili and 1997 Tropical Storm Claudette. The satellite observations often helped to define the spatial extent of the 17.5 m s^{-1} (34 kt) surface wind radii and also redefined the 25.7 m s^{-1} (50 kt) wind radius for one case. Examples of the impact of these data on real-time hurricane surface wind fields provided to the NHC will be discussed.

1. Introduction

*a. Overview of HRD's Surface Wind Analysis Product (H*Wind)*

The hurricane surface wind analysis system (H*Wind) developed at the National Oceanic and Atmospheric Administration's (NOAA) Hurricane Research Division (HRD) is useful for determining the location of the 17.5, 25.7, and 32.9 m s^{-1} (i.e., the 34, 50, and 64 kt) wind radii in Atlantic tropical cyclones (Powell et al. 1998). This information is critical in deciding the extent of tropical storm and hurricane watches, and warnings for coastal regions. Emergency management officials require that evacuation preparations be completed by the time that the 34-kt winds reach the local coastline. Since the estimated cost for warning each kilometer of U.S. coastline is $375,000 (OFCM 1997), the issuance of accurate tropical cyclone track and intensity forecasts are imperative. The current av-

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erage track forecast error after 24 h is 155.4 km (84n mi), with an average historical improvement of about 1% per year (McAdie and Lawrence 2000). Currently, forecasters at the National Hurricane Center (NHC) in Miami, Florida, utilize H*Wind analyses to assist them in determining the placement of significant wind radii around a tropical cyclone, particularly the 34-kt wind radius. Though it does not function directly to improve track forecasting, HRD's surface wind analysis system can impact significant wind radii information that NHC provides to the National Centers for Environmental Prediction, as well as offer an improved ability to delineate the extent of a tropical cyclone's surface wind field. This can potentially impact extended forecasts for tropical cyclones by global and mesoscale models that utilize this information. These analyses can also be useful in identifying interactions between tropical cyclones and synoptic-scale features. This promotes more accurate diagnoses and forecasts of tropical storm and hurricane force wind radii and can potentially reduce the uncertainty in warning coastal areas, as well as help protect offshore marine interests (e.g., naval vessels, shipping, and oil drilling platforms).

H*Wind is an objective analysis that uses in situ and remotely sensed wind data and storm position coordinates (based on fixes from reconnaissance aircraft and official advisories) for a tropical cyclone to create a surface wind field, which is displayed as isotachs and streamlines (Powell and Houston 1996). In situ data include observations from moored and drifting buoys, Coastal Marine Automated Network (C-MAN) stations, ships, meteorological aviation reports (METAR) stations, Global Positioning System (GPS) dropwindsondes (dropsondes), and aircraft flight-level data adjusted to the surface (10 m) based on Powell et al. (1996). Remotely sensed observations include the Step Frequency Microwave Radiometer (SFMR) aboard NOAA research aircraft and data from polar orbiting microwave satellites [the Special Sensor Microwave/Imager (SSM/I), the Quick Scatterometer (QuikScat), and the TRMM (Tropical Rainfall Measuring Mission) Microwave Imager (TMI)]. However, these microwave instruments currently available to the H*Wind database were not available at the time of this study. Detailed studies utilizing these platforms will be carried out in the future. Due to the location of moored buoys and C-MAN stations near the U.S. coast, H*Wind is usually able to incorporate relatively more data as tropical cyclones approach land. However, there are far fewer observing platforms available to measure winds around tropical cyclones that are located farther offshore in the Atlantic basin and Caribbean. The only data available in these remote locations is often flight-level data from U.S. Air Force and/or NOAA aircraft, SFMR data, GPS dropsondes, intermittent SSM/I, QuikScat, and TMI satellite passes, ship reports, and drifting buoy observations. The flight-level and SFMR data are generally collected near the storm's inner core region, and ship and drifting buoy data are often sparse. Additionally, the polar orbiting microwave satellites currently in use provide only 2 passes per day per satellite over a given storm, offer limited swath coverage, and only one sensor provides any wind directions (scatterometer). The poor distribution of the in situ and remotely sensed data can markedly diminish the quality of the surface wind analyses. Even in a coastal hurricane, there is often a bias of available data: landward storm quadrants usually contain far more observations (buoys, C-MANs, and METAR) than do seaward quadrants of a storm.

2. Methodology

a. Generating GLLV winds with the GOES *satellites*

NOAA's newest generation of Geostationary Operational Environmental Satellite (*GOES-8*) was launched in 1994 and positioned to provide coverage over the western Atlantic region (Menzel and Purdom 1994). GLLV winds are generated using both the *GOES-8* and *GOES-10* satellites, utilizing the imager's visible (0.52–0.72 μm) channel, which offers 1-km nadir spatial resolution. In recent years, the Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin–Madison (UW-CIMSS) has fully automated its wind extraction algorithm. Tracer selection and derivation procedures include an enhanced filtering capability to screen out undesirable cloud features, as well as the implementation of an objective quality control module (Velden et al. 1998).

To generate cloud-drift winds, low-level cloud features are typically tracked using a sequence of three 15-min interval images. Due to *GOES-8* imaging constraints, vector targeting with 15-min frequency imagery is limited to cumulus features west of 55°W longitude and north of 15°N latitude in the Atlantic basin. Targeted clouds are tracked for a 15-min period and if successful vector correlations are obtained, a wind vector is calculated. This same feature is again tracked using the next available 15-min imagery and another vector is determined. The cloud-tracking algorithm then averages the two vectors to obtain a more representative final vector. There is uncertainty regarding what averaging time to assign these cloud-drift winds. Since it is created by averaging two vectors obtained from 15-min imagery, a GLLV wind vector generated by this imagery could be considered to represent a time averaging of 15–30 min. However, through empirical tests Dunion and Velden (2002) found that the GLLV winds should be considered to have an averaging time of 15 min.

Individual vectors are then assigned a height in the atmospheric column, utilizing a recently implemented cloud-base height assignment algorithm. This new height assignment methodology utilizes an infrared (IR) image histogram to estimate the cloud-base temperature of tracked clouds and is applicable only to low-level cumulus (600–925 hPa) clouds (Spinoso 1997). Those

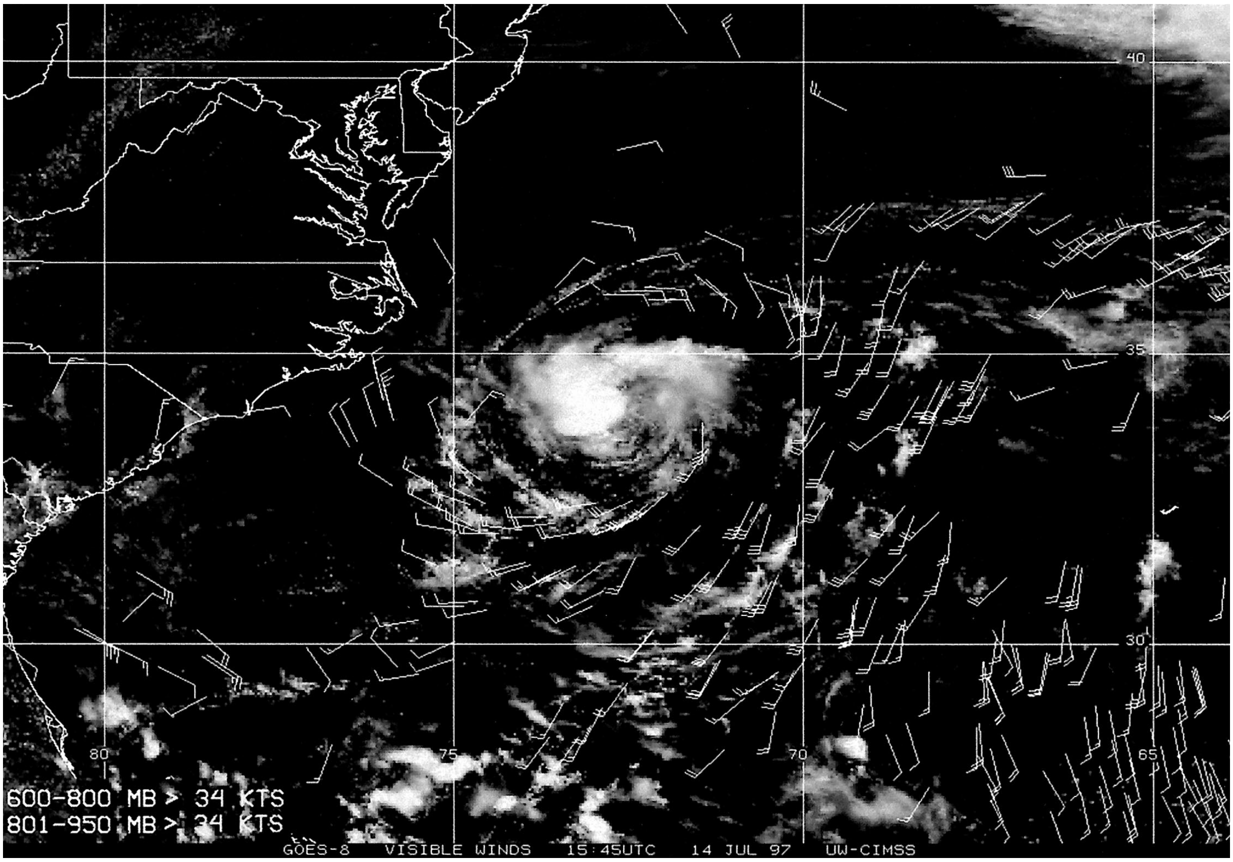

FIG. 1. *GOES-8* visible image of Tropical Storm Claudette (1545 UTC 14 Jul 1997) with overlaid GLLV winds.

vectors that are unable to be processed by the cloud base algorithm are assigned a height by the cloud-top method. This method takes the brightness temperatures in a specific target area and assigns the coldest 20% of the pixels to represent the temperature of the cloud top. The brightness temperature derived by either height assignment method is matched with collocated Navy Operational Global Atmospheric Prediction System (NOGAPS) model temperature data in order to obtain a final tracer altitude.

*b. GLLV winds: Potential to enhance H*Wind analyses*

By employing GOES satellites, cloud-drift winds are generated using image sequences from the visible channel of the GOES imager (Velden et al. 1998). This 1-km imagery (nadir) offers the advantage of producing high-resolution cloud-drift winds, but its use is restricted to daylight hours (usually 1300 to 0000 UTC in the western Atlantic Ocean, Caribbean Sea, and Gulf of Mexico). Enhanced imagery from the 3.9-μm shortwave IR channel (channel 2) on the GOES satellites has recently been tested regarding its ability to track low-level ($\geq$600 hPa) cumuliform clouds at night and shows promise as a potential source for generating wind vectors (Velden and Dunion 2001).

Figure 1 shows subsampled GLLV winds (600–925 hPa) generated in the environment of Tropical Storm Claudette (1545 UTC 14 July 1997) and clearly depicts the typical peripheral location of GLLV winds relative to the storm center. The peripheral bias of GLLV winds around tropical cyclones is caused by the presence of the central dense overcast (CDO) that is often associated with these storms. This upper-level cirrus shield over the storm often obscures effective detection of the low-level cumuliform features that are used to generate the cloud-drift winds. However, many western Atlantic tropical cyclones encounter strong upper-level ($\sim$200 hPa) westerlies that act to displace the CDO downshear of the upper-level flow. This shearing effect allows for the detection of GLLV winds closer to the storm center in a storm's western quadrants. For this reason, GLLV winds are usually more abundant in a storm's NW and SW quadrants and less so in the NE and SE quadrants. Figure 1 indicates this tendency for western quadrant biasing of the GLLV wind data around tropical cyclones. Conditions such as significant dry air entrainment into the core region can also create situations that allow for inner core GLLV wind detection in favored quadrants.

Though GLLV winds are biased in the periphery of tropical cyclones, they nonetheless offer an abundance of wind vector data to H*Wind analyses. Because of the high resolution of this image, subsampling of the GLLV wind vectors to ensure visual clarity was not necessary. Therefore, the wind vectors seen in Fig. 1 represent all available GLLV wind data. The cloud-drift winds are quality controlled before being put into the H*Wind analysis system. Wind vectors at or below 700 hPa are adjusted to the surface (maximum 1-min sustained winds at 10 m with a marine exposure) using the methods of Powell et al. (1996) and Dunion and Velden (2002).

GLLV winds offer the advantage of providing wind data in remote ocean regions and can potentially be useful in describing the wind field in a storm's periphery. Although the impact of GLLV winds on H*Wind analyses can be significant, it is critical that these winds be of comparable quality to the in situ data already being used in the product. Work by Dunion and Velden (2002) showed the high quality of surface-adjusted GLLV winds generated utilizing GOES satellite imagery. Adjustments to the surface will be discussed in greater detail in the next section. Dunion and Velden (2002) compared 300 surface-adjusted GLLV winds to collocated in situ observations (buoys, ships, and C-MAN stations) and showed the surface-adjusted GLLV winds to exhibit reasonably low rms errors in the tropical cyclone environment. Using GLLV wind data ranging from 2–22 m s^{-1}, the speed rms error was shown to be 2.81 m s^{-1} and the directional rms error was 23.7°. These values do not include recommended vector adjustments proposed by Dunion and Velden (2002) that account for initial height assignments of the GLLV winds. Subtle factors such as height assignment of the satellite wind were found to influence the final accuracy of the adjustment of GLLV winds to the surface and were included in their recommendations. By including these recommended adjustments, rms speed and direction errors were further reduced to 2.62 m s^{-1} and 18.7°, respectively. This fine-tuning of the GLLV winds promoted their use in the H*Wind surface wind analyses produced as guidance for real-time analysis and forecasting of tropical cyclone wind radii.

3. Impacts of surface-adjusted GLLV winds on H*Wind surface wind analyses

a. Impacts on the analysis of Tropical Storm Claudette

Because of their potential to provide important surface wind data in tropical cyclone environments, the incorporation of surface-adjusted GLLV winds into real-time H*Wind analyses began in 1997 and still continue to be an integral part of the analysis system. Within one year of their introduction in 1997, the GLLV winds were being utilized in over half of all H*Wind analyses per-

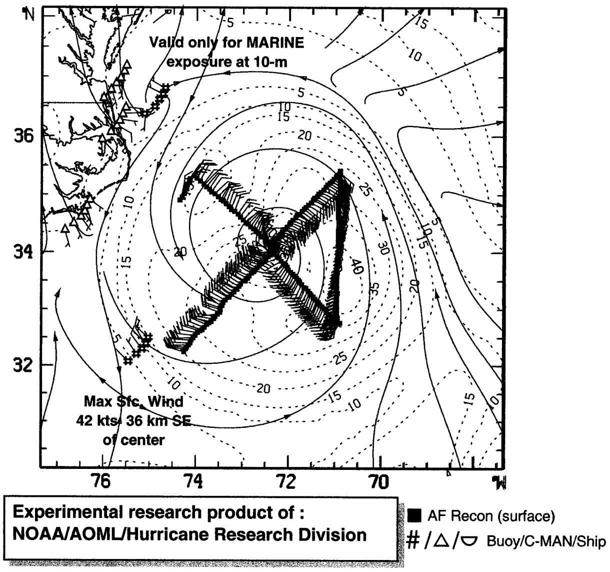

FIG. 2. Tropical Storm Claudette (1900 UTC 14 Jul 1997) H*Wind surface wind analysis (kt) without the inclusion of surface-adjusted GLLV winds. The analysis includes surface-adjusted AF reconnaissance, buoy, C-MAN, and ship observations and is valid for max 1-min sustained 10-m winds with marine exposure.

formed during the hurricane season and although these winds are limited to daylight hours, they were included in over 90% of the ''daylight'' analyses made during the 1998 and 1999 hurricane seasons.

The H*Wind composite showing a surface wind analysis of Tropical Storm Claudette at 1900 UTC 14 July 1997 (Fig. 2) is evidence that in situ data availability is sparse, particularly in the periphery of Claudette, where air force (AF) flight-level and coastal station data are absent. Though H*Wind is able to create a surface wind field with the available data, the absence of observations in Claudette's NE and SE quadrants would likely pose an analysis problem in those quadrants. The surface-adjusted GLLV winds (Fig. 3) provide substantial data in the storm's periphery and provide a rich data source in Claudette's previously data-void quadrants. It is important to note that GLLV winds were restricted to the tropical cyclone's periphery and no observations were generated in the inner core region. As discussed previously, this lack of inner core observations stems from the CDO, which hampered the detection of low-level cumuliform clouds by the *GOES-8* satellite.

Figure 4 is a difference field created by subtracting the analyses of Fig. 2 from Fig. 3 and shows the impact that the addition of GLLV winds had on the analysis of Tropical Storm Claudette. The greatest impact on the analysis occurred in Claudette's NE and SE quadrants where in situ and AF reconnaissance data were sparse. Claudette was classified as a tropical storm at this time and did not have a well-developed circulation and expansive CDO. As indicated by Fig. 4, the absence of a broad CDO allowed for the detection of GLLV winds

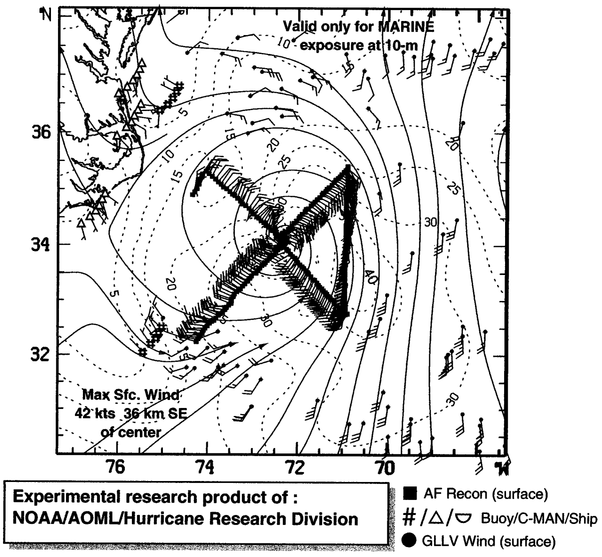

FIG. 3. As in Fig. 2 except H*Wind surface wind analysis (kt) includes surface-adjusted GLLV winds.

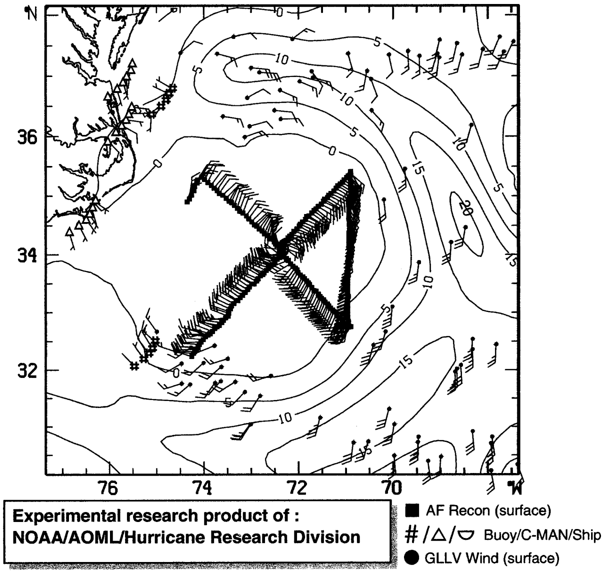

FIG. 4. Tropical Storm Claudette (1900 UTC 14 Jul 1997) H*Wind difference field (kt) generated by examining the impact on the H*Wind analyzed wind field by the surface-adjusted GLLV winds. Positive values indicate areas where the surface-adjusted GLLV winds increased the analyzed wind speed.

in all quadrants of the storm, including the typically shielded NE and SE quadrants. Although statistical analysis of H*Wind's output in cases when peripheral data is sparse has not yet been completed, preliminary results indicate that the analyses tend to decrease the winds excessively (radially outward from the inner core) in those situations. Figure 4 shows that the GLLV winds had the effect of increasing the winds by as much as 15–20 kt in the eastern half of the storm. In the inner core and western side of Claudette, there was little or no effect on the analysis, since there was already a high density of in situ and surface-reduced AF reconnaissance data in those regions. Table 1 indicates the impact made by the surface-adjusted GLLV winds on the analyzed radius of 34-kt winds.

In this case, the addition of GLLV winds into the analysis would have significantly affected a forecaster's determination of the radius of the 34-kt winds and may have affected the issuance of local marine advisories.

b. *Impacts on the analysis of Hurricane Georges*

Another example of an H*Wind analysis performed in a data-rich environment is shown in Fig. 5. This plot represents a surface wind anaylsis of Hurrican Georges at 1330 UTC 26 September 1998. At this time, Georges was a category 2 hurricane on the Saffir–Simpson scale (Saffir 1997; Simpson and Riehl 1981) with maximum sustained winds of 90 kt and was positioned in the relatively data-rich Gulf of Mexico. Surface-adjusted GLLV winds were, however, providing valuable vector information near the area of the tropical storm force winds (34 kt) in the NW quadrant of the storm. In this quadrant, very few in situ observations were available to assist in the H*Wind analysis of the 34-kt winds. In particular, there was little in situ data between the AF reconnaissance and the buoys and C-MANs along the coast, which could lead to a poor analysis of the 34-kt wind radius. Though not all reporting C-MAN stations were available for this analysis, the missing stations would not have changed the fact that there were a very limited number of wind vectors available in the region of 34-kt winds in the NW quadrant of Georges. The AF aircraft surface-adjusted data in question consisted of winds ranging from 50–55 kt, while the coastal platforms were generally recording winds of 20–25 kt. Since neither platform type was actually detecting the 34-kt wind radius in this case, H*Wind had to interpolate between the available data in order to define this specific wind radius. In this case, the interpolation distance was approximately 250 km, a vast distance that invites error. The surface-adjusted GLLV winds in the NW quadrant reduced this interpolation distance and in this case, actually detected the 34-kt winds. In this instance, the surface-adjusted GLLV winds were aiding in the placement of this wind radius by the analysis program.

Figure 6 is a difference field generated by examining the impact by surface-adjusted GLLV winds on the

TABLE 1. Impacts (per quadrant) of surface-adjusted GLLV winds on the H*Wind analyzed radius of 34-kt winds in Tropical Storm Claudette.

TS Claudette 1900 UTC 14 Jul 1997	NE	SE	SW	NW
34-kt wind radius (km)	−5	+71	+2	+1

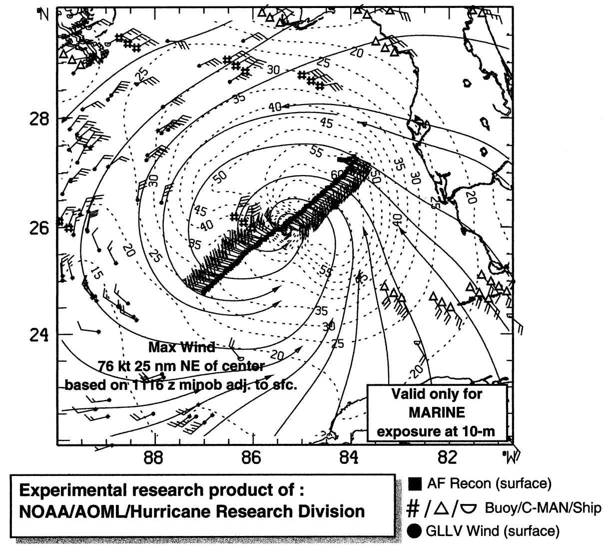

FIG. 5. Hurricane Georges (1330 UTC 26 Sep 1998) H*Wind surface wind analysis (kt) with the inclusion of surface-adjusted GLLV winds. The analysis also includes surface-adjusted AF reconnaissance, GPS dropsonde, buoy, C-MAN, and ship observations and is valid for max 1-min sustained 10-m winds with marine exposure.

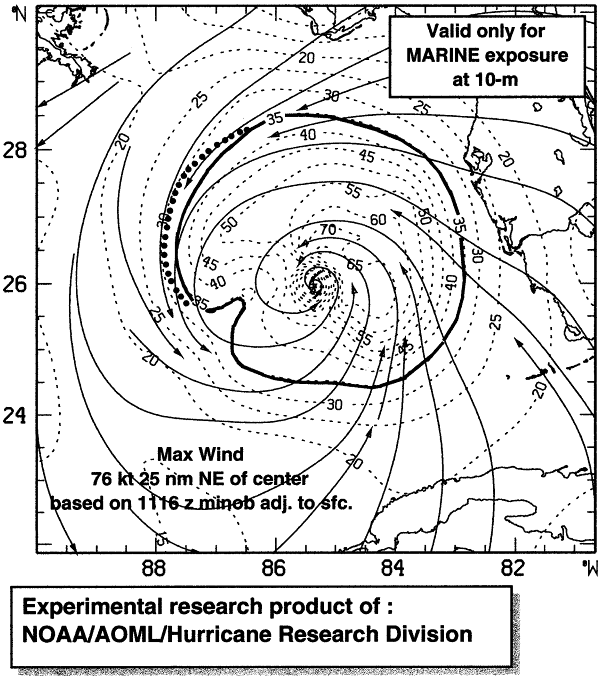

FIG. 7. As in Fig. 5. The solid bold line indicates the analyzed radius of 34-kt winds without the GLLV winds. The dotted bold line represents the analyzed radius of 34-kt winds when surface-adjusted GLLV winds were included in the H*Wind analysis.

H*Wind analyzed wind fields of Hurricane Georges. The field shows that impacts by the GLLV winds were less substantial than in the Claudette difference field (Fig. 4), but nonetheless affected the estimated winds in the NW quadrant of the storm by increasing the winds 5 or more knots. Given the motion of Georges at this time (WNW at 9 kt) and its close proximity to land, even small impacts of estimated winds such as this were relevant. Figure 7 exemplifies this point by showing the impact that the surface-adjusted GLLV winds had on the analysis of the radius of the tropical storm force winds (34 kt). This figure shows that with the addition of surface-adjusted GLLV winds, the 34-kt wind radius was expanded by as much as 32 km in the NW quadrant of Georges. Recall from Figs. 5 and 6 that the NW quadrant is most affected by the surface-adjusted GLLV winds, so changes in wind radius would likely occur in this quadrant. These impacts are quantified in Table 2.

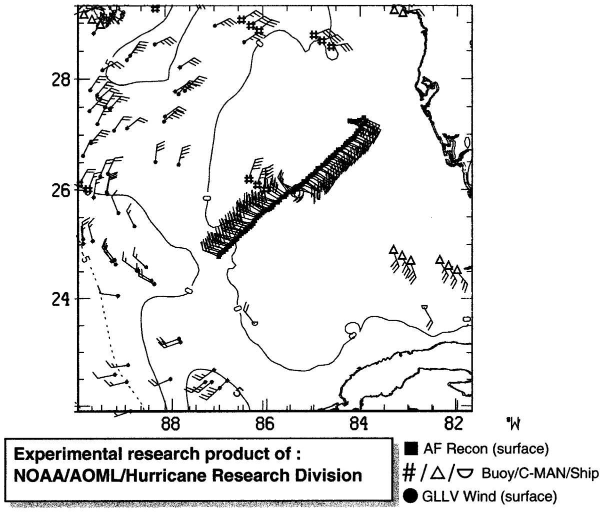

FIG. 6. Hurricane Georges H*Wind difference field (kt) generated by examining the impact on the H*Wind analyzed wind field by the surface-adjusted GLLV winds. Positive values indicate areas where the surface-adjusted GLLV winds increased the analyzed wind speed.

c. Impacts on the analysis of Hurricane Lili

Figure 8 depicts Hurricane Lili at 1200 UTC 20 October 1996 and is another example of an H*Wind surface wind analysis overlaid with the analysis input. The significant difference between Lili and the Claudette and Georges cases was that Lili was located far from the U.S. mainland and the dense network of in situ observing platforms around it. In such cases, the only data available for input into H*Wind are often aircraft surface-adjusted data, an occasional island observation, ship reports, and intermittent data from polar orbiting microwave satellites. Given the sparse data available for

TABLE 2. Impacts (per quadrant) of surface-adjusted GLLV winds on the H*Wind analyzed radius of 34-kt winds in Hurricane Georges.

Hurricane Georges 1330 UTC 26 Sep 1998	NE	SE	SW	NW
34-kt wind radius (km)	0	0	0	+32

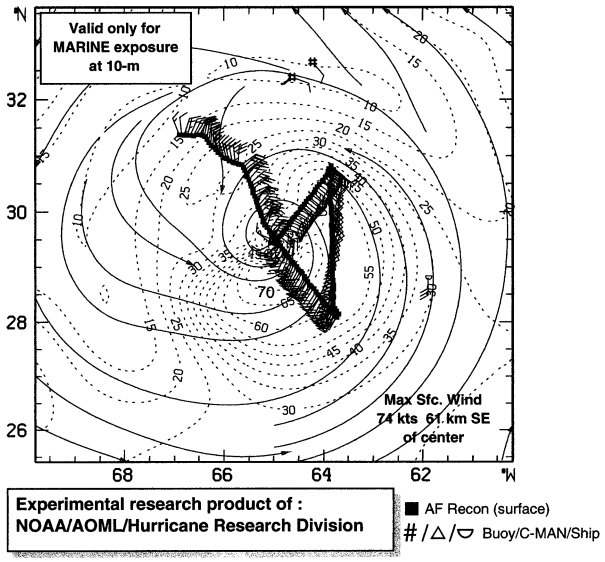

FIG. 8. Hurricane Lili (1200 UTC 20 Oct 1996) H*Wind surface wind analysis (kt) without the inclusion of surface-adjusted GLLV winds. The analysis includes surface-adjusted AF reconnaissance, buoy, and ship observations and is valid for maximum 1-min sustained 10-m winds with marine exposure.

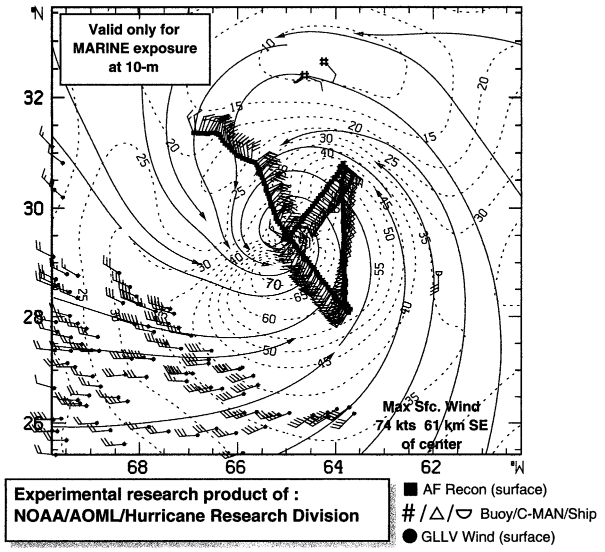

FIG. 9. As in Fig. 8 except H*Wind surface wind analysis (kt) includes surface-adjusted GLLV winds.

this analysis, H*Wind was able to produce a realistic wind field around Lili. Figure 9 is a surface wind analysis that includes surface-adjusted GLLV winds. The GLLV winds were particularly high in density in Lili's SW quadrant, which can be attributed to two factors. First, the conditions associated with Lili's CDO were likely limiting GLLV wind detection in the eastern quadrants. Second, Lili was positioned near the eastern extent of the operational coverage of *GOES-8* 15-min visible imagery (approximately 55°W) that was used to generate the GLLV winds. Anticipating the difference field that would result from these analyses, it is likely that the greatest impact would be evident in the SW quadrant of Lili, with much less significant GLLV impact being seen in the periphery of the other quadrants and in the inner core region of the storm.

Figure 10 depicts the resulting difference field created by subtracting the analyzed wind field of Fig. 8 from Fig. 9. Significant impacts (+15 to +20 kt) by the surface-adjusted GLLV winds can be seen in Lili's SW quadrant, which had the effect of wrapping some of the higher winds analyzed with the addition of the GLLV winds into the other quadrants. As in the Claudette case, the addition of the GLLV winds significantly increased the analyzed wind speeds in certain quadrants. This could have potentially impacted decisions regarding the issuance of watches and warnings, particularly for nearby Bermuda (32.5°N, 65°W) in this situation. Figure 11 shows a plot of analyzed wind radii by H*Wind with and without the inclusion of surface-adjusted GLLV winds. In this case, the absence of peripheral in situ data around Hurricane Lili allowed for even the 50-kt wind radius to be affected. The 50-kt wind radius shifted as much as 28 km when the GLLV winds were included in the analysis, while the 34-kt isotach radially expanded by as much as 120 km. This substantial increase in the radius of tropical storm force winds would certainly have a marked impact on a forecaster's determination of the radius of these winds.

As Figs. 9 and 10 suggest, the surface-adjusted GLLV winds had their greatest impact on the Lili analysis in the SW quadrant of the storm. Therefore, it is not surprising that the analyzed wind radii were impacted most in this region. Because of the absence of abundant data

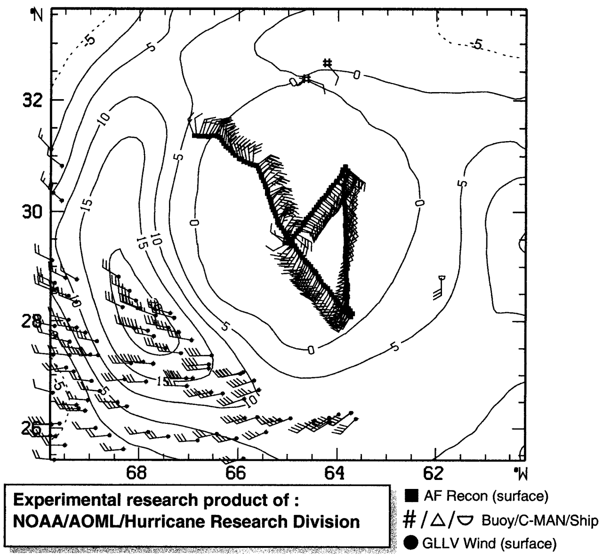

FIG. 10. Hurricane Lili H*Wind difference field (kt) generated by examining the impact on the H*Wind analyzed wind field by the surface-adjusted GLLV winds. Positive values indicate areas where the surface-adjusted GLLV winds increased the analyzed wind speed.

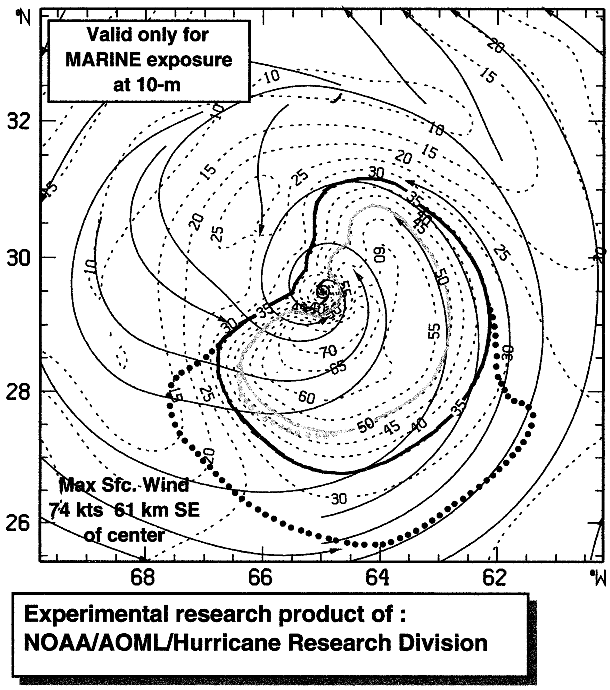

FIG. 11. As in Fig. 9. The solid black (gray) lines indicate the analyzed radius of 34 (50) kt winds without the GLLV winds. The dotted black (gray) lines represent the analyzed radius of 34 (50) kt winds when surface-adjusted GLLV winds were included in the H*Wind analysis.

around the other quadrants of Lili, surface-adjusted GLLV winds had a much greater influence on the final analyzed wind field relative to the improvements made to the Claudette and Georges analyses. Table 3 quantifies the impact made by the surface-adjusted GLLV winds on the analyzed radii of 34- and 50-kt winds in Hurricane Lili.

4. Discussion

Surface-adjusted GOES low-level visible (GLLV) winds offer a significant source of wind vector data in tropical cyclone environments. Given reasonable vector quality, it was recognized that these satellite-derived winds could become a vital addition to the NOAA/HRD surface wind analysis system, H*Wind. Controlled studies emphasizing the impact of surface-adjusted GLLV winds on H*Wind analyses of tropical cyclone environments were an outcome of this study. The analyses of Tropical Storm Claudette and Hurricanes Georges and Lili confirmed the suspected tendency for H*Wind to superfluously decrease the analyzed winds radially outward from the inner core of tropical cyclones in the absence of peripheral wind data. With the addition of surface-adjusted GLLV winds that are particularly effective at placing the 34-kt wind radius, more accurate H*Wind analyses are plausible. However, although the significant impact of GLLV winds on surface wind analyses is clear, confidence in the impacts is driven by the quality of the surface-adjusted GLLV winds. Dunion and Velden (2002) demonstrated the high quality of the GLLV winds, which merits confidence in the impacts they had on the H*Wind surface wind analyses shown here.

TABLE 3. Impacts (per quadrant) of surface-adjusted GLLV winds on the H*Wind analyzed radius of 34- and 50-kt winds in Hurricane Lili.

Hurricane Lili 1200 UTC 20 Oct 1996	NE	SE	SW	NW
34-kt wind radius (km)	0	+120	+95	0
50-kt wind radius (km)	0	0	+28	0

Surface-adjusted GLLV winds offer an opportunity to better describe the wind field distributions in tropical cyclone environments. These surface winds have been shown to exhibit low speed and directional rms errors (2.62 m s^{-1}, 18.7°) relative to collocated in situ data (Dunion and Velden 2002), making them a valuable tool when utilized in the HRD's H*Wind surface wind analysis product. Impact studies of three tropical cyclone environments indicated that the surface-adjusted GLLV winds significantly enhanced the analyses of the outer wind radii in two cases and even influenced the positioning of the analyzed 50-kt radius in one of these. Because of the availability of a significant amount of in situ wind data in the third case (Georges), a more modest impact by the GLLV winds was evident. Of particular importance is the ability of surface-adjusted GLLV winds to help improve the identification of the radius of 34-kt (tropical storm force) winds by the H*Wind analysis product. Accurate analysis of the extent of the 34-kt wind radius is critical to forecasters at the National Hurricane Center (NHC) and Central Pacific Hurricane Center (CPHC). Emergency management officials utilize NHC's and CPHC's advisories to plan the completion of their evacuation efforts prior to the onset of these 34-kt winds. Additionally, shipping vessels and other marine interests benefit from accurate diagnoses of the winds around tropical cyclones. Surface-adjusted GLLV winds offer an important means of better defining the scope of the wind fields in tropical cyclone environments and are a particularly effective source of wind information in traditionally data-void regions of the oceans.

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