2A.1 THE 2011 COLUMBUS DAY WEEKEND STORM: OVERCOMING CHALLENGES IN DIAGNOSING A RAPIDLY STRENGTHENING MARITIME LOW PRESSURE SYSTEM AND COMMUNICATING THE ASSOCIATED WARNING MESSAGE

Matthew Volkmer* , D. Scott Kelly, Anthony Cristaldi, Peter Blottman, Peggy Glitto, Randy Lascody, John Pendergrast, Arlena Moses, Timothy Sedlock, Robert Wimmer, Matthew Bragaw, Amanda Bowen, and David Sharp

NOAA/National Weather Service, Melbourne, FL

1. INTRODUCTION

On 9-10 October 2011 (the Columbus Day weekend), an area of low pressure developed near the northwest Bahamas and moved north and west across the East Central Florida Atlantic waters. The system intensified during the late afternoon on Sunday as it moved into the near shore waters of Brevard County. As the central pressure dropped below 1000 mb, sustained winds northwest of the circulation center, in the vicinity of the core convection, strengthened to tropical storm force accompanied by gusts to near hurricane force. The hybrid low moved onshore near Cape Canaveral, Florida, during the late evening hours and moved northwest during the overnight hours early Monday (10 October 2011). Impacts were significant to both marine and coastal communities. As the storm rapidly intensified, ships traveling in/out of Port Canaveral were exposed to increased peril and area marinas were forced to quickly take additional precautions for maritime storm conditions from gale conditions already being experienced. Along the northern Brevard and Volusia County coasts and barrier islands, residents and visitors experienced power outages and wind damage comparable to what typically occurs from landfalling (sub-)tropical storms. Dangerous wind and seas conditions were announced well ahead of the arrival of the low pressure system, culminating in the issuance of a local Storm Warning for mariners and a local High Wind Warning for coastal land areas – both rare product issuances relative to the geography and time of year.

Of particular interest was the band of significant convection which developed northwest of the center. Its evolving mesoscale character signaled the increasing wind, marine and flooding rain threats and subsequent impacts.

The band was well-sampled by traditional observation platforms (such as the KMLB WSR-88D radar, cloud-to-ground lightning sensors, offshore buoys, etc.) and enhanced observation platforms unique to NASA/Kennedy Space Center and United States Air Force (USAF)/45th Weather Squadron (such as the 50 and 915 MHz profilers, mesonet tower winds, and total lightning information sensors). The enhanced data sets were essential to diagnosing the strengthening system and supporting warning operations. Prior to landfall, the Lightning Detection and Ranging (LDAR) system showed increased (total) electrification of the core convection and inferred a rapid deepening of the low. Mesonet wind data across northern Brevard County and coastal Volusia County helped to gage the extent of downward mixing of strong winds.

This abstract will explore the utility of the enhanced data sets as the low deepened and made landfall. The challenges of communicating the warning message to describe the evolving threat and potential impact will also be presented.

2. EXTENDED AND SHORT RANGE FORECASTS

There was considerable forecast uncertainty in the extended range forecast models regarding the eventual development, placement, strength and evolution of the low pressure system that would impact the East Central Florida coast late Sunday evening. The Hydrometeorological Prediction Center (HPC) Extended Forecast Discussion on the afternoon of Tuesday, 4 October noted: “Across the East…the largest uncertainty exists with potential cyclone development along a stationary front draped across the Bahamas/Cuba. The 00Z EMWF/Canadian…and to a lesser extent the 00Z UKMET/GFS…depict gradual low development in the vicinity of Florida around Days

* *Corresponding author address*: Matthew Volkmer, NOAA/National Weather Service, 421 Croton Road, Melbourne, FL 32935. e-mail: matthew.volkmer@noaa.gov

5/6…with the ECMWF depicting development more in the Gulf and the GFS near the Bahamas." The early morning NWS Melbourne Area Forecast Discussion from Thursday, 6 October, 2011, also discussed the possibility of a sub-tropical low developing and bringing severe weather chances: "There may be some similarities to a May 2009 event in which there was a one-two punch from frontal convergence then a subtropical low. . . The exact timing for this event is still uncertain due to model inconsistencies, but generally think that the initial low development, about Sunday, will act to enhance the heavy rainfall chances ongoing from Saturday. As the low lifts closer to Florida later Sunday into Monday, low level shear would increase and bring the threat for isolated tornadoes."

The extended range model solutions for this event generally led to two potential scenarios with the ECMWF favoring surface cyclogenesis across the eastern Gulf of Mexico closer to the mid and upper layer trough while the GFS model tended to develop the surface low farther east, away from the mid to upper layer trough in an area of stronger upper divergence near the Bahamas or over the Atlantic near the Florida east coast. The divergent model solutions made for a challenging forecast with the longer range GFS forecasts generally outperforming the ECMWF in this case. The broad spectrum of solutions led to considerable uncertainty but did point to the potential for low pressure development near the Florida peninsula in the extended forecast range.

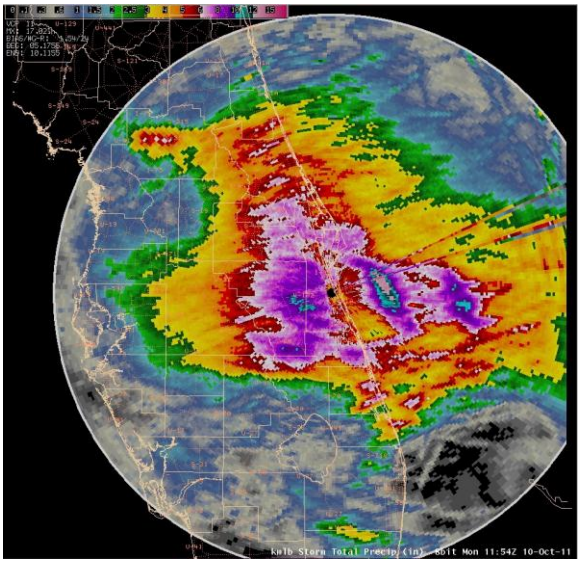

Fig 1. KMLB Storm Total Precipitation, 1755 UTC 5 Oct 2011 to 1155 UTC 10 Oct 2011.

The short range forecasts within three days of the low pressure development continued to show a wide range of uncertainty. A high pressure system built toward the Mid-Atlantic states during the days prior to the low pressure development, with strong low level easterly flow and an old frontal boundary lifting toward central Florida. This caused a multi-day heavy rainfall event with bands of showers continuing to stream onshore from the Atlantic. The heavy rainfall and flood event preceded the low pressure development with multiple Flood Warnings issued across East Central Florida. Four-day rainfall totals approached 17 inches across Osceola County and a widespread area of 10+ inch amounts were common across Indian River, Brevard, Volusia, Seminole, Orange and Osceola Counties (Figure 1). There was a concern for additional flooding from heavy rain from any low pressure system that might develop over the Atlantic.

The short range model performance even on the day of the event did not give forecasters much confidence in development or strength of the system. The Rapid Update Cycle (RUC) model continued to indicate a much weaker surface low developing and moving onshore much further south from the area where the system eventually made landfall.

3. STORM EVENT, OCTOBER 9-10, 2011

An initial band of moderate to heavy rain moved inland from the Atlantic during the morning hours of Sunday, 9 October. At the surface, a 1030 mb high pressure area was situated near the Mid-Atlantic region with an upper level trough at 250 mb extending from the southeast U.S. into the eastern Gulf of Mexico. A closed low at 500 mb developed across the southeast Gulf of Mexico and moved slowly northeast. Between 1400 UTC and 1500 UTC, a suspect area of circulation developed on the KMLB WSR-88D north of the west end of Grand Bahama Island. By 1700 UTC, a radar reflectivity hole and developing circulation center had formed across the offshore waters about 50 nautical miles offshore from Fort Pierce, Florida. The developing circulation moved northwest and was about 30 nautical miles offshore from Sebastian Inlet at 2100 UTC.

Between 2100 and 2359 UTC the system continued to intensify with a significant increase in both peak inbound and outbound radial velocities and total lightning activity. Peak inbound radial velocities were recorded at 52.9 m/s (102.9 knots)

at 2328 UTC at a distance of 37 nm, 73 degrees azimuth, from the KMLB WSR-88D, at approximately 882.4 m (2895 feet) and a second peak inbound radial velocity was recorded at 102.9 knots (52.9 m/s) at 2338 UTC at a distance of 35 nautical miles, 78 degrees azimuth, from the KMLB WSR-88D at approximately 820.5 m (2692 feet). The peak outbound radial velocity was 98.1 knots (50.5 m/s) at 2342 UTC at a distance of 37 nautical miles, 103 degrees azimuth, from the KMLB radar at approximately 895.2 m (2938 feet).

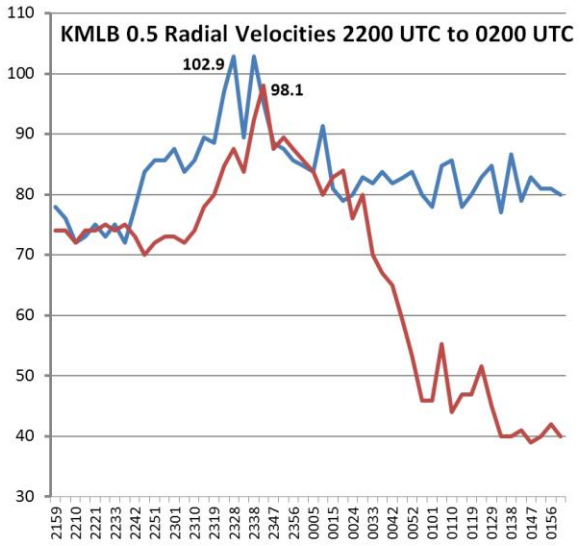

Fig 2. Peak Inbound (blue line) and Outbound (red line) KMLB 0.5 Radial Velocities in knots, 2200 UTC to 0200 UTC.

There was also a significant increase in lightning activity that accompanied the strengthening low level wind fields in the main convective banding feature west of the circulation center. National Lightning Detection Network (NLDN) cloud-to-ground lightning activity showed a steep increase from 2250 UTC to 2350 UTC with a peak 5-minute cloud-to-water flash rate of 68 lightning strikes from 2350 UTC to 2355 UTC.

Although not classified as a tropical or subtropical system by the National Hurricane Center, it did exhibit some of the defining characteristics. Beven (2012) includes a more complete discussion of cyclone type analysis for this system. Previous studies of lightning patterns and convective structure as they relate to both tropical and sub-tropical systems have similarities to the lightning patterns exhibited with this system. A study of 21 tropical systems in 2010 by Austin and Fuelberg noted that tropical storms and tropical depressions typically produce more lightning than hurricanes. Results from DeMaria, et al, (2012), confirmed previous studies indicating intensifying storms have greater lightning density than weakening systems, and that the lightning density for individual cyclones is very episodic. The lightning patterns with this Columbus Day weekend storm showed peak wind radial velocities sampled 15-30 minutes before the peak in 5-minute lightning strikes sampled by the NLDN network. A secondary peak in inbound radial velocities sampled at 0010 UTC occurred nearly coincident with a secondary peak in 5-minute CG flashes (61) from 0010 to 0015 UTC.

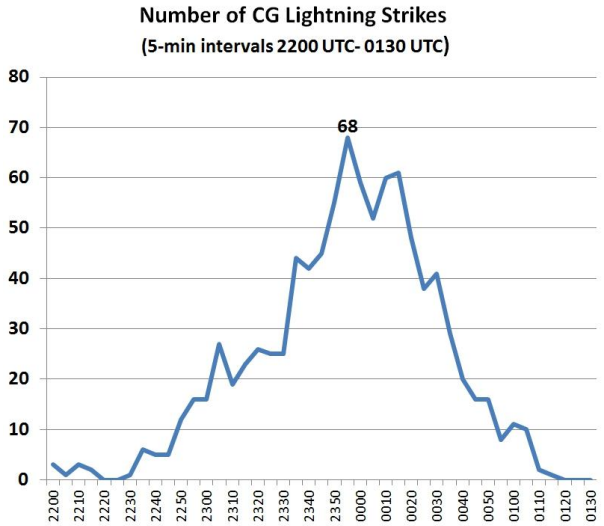

Fig 3. Number of NLDN Lightning Strikes in 5 minute intervals 2200 UTC to 0130 UTC.

Although surface wind measurements were not available under the core convection at the time of probable peak intensity due to a relatively sparse maritime observing network, the radial velocity radar data from the WSR-88D and lightning data from the NLDN networks confirm the increasing low level wind fields and organization with this system near or just prior to the time of observed peak lightning cloud-to-water flash rates.

The areal extent of the 1-minute LDAR lightning source density also was monitored to assess the organization of the strengthening system.

Highest intensity of the system and strongest winds speeds were likely realized between 2300 UTC and 2359 UTC on 9 October. Some of the strongest wind gusts on land occurred during the late evening hours as the circulation center was just offshore from Cape Canaveral. The strongest wind gust was recorded by a USAF 60 foot wind

tower at 39.2 m/s (81 mph) at 0220 UTC, 2 miles south-southeast of Playalinda Beach, near the coast north of Cape Canaveral. Another wind gust report from a nearby 60 foot wind tower recorded 34.9 m/s (78 mph), 3 miles southeast of Playalinda Beach. Other Cape wind towers recorded wind gusts between 30.8 m/s (69 mph) and 33.5 m/s (75 mph) between 0145 UTC and 0230 UTC on 10 October.

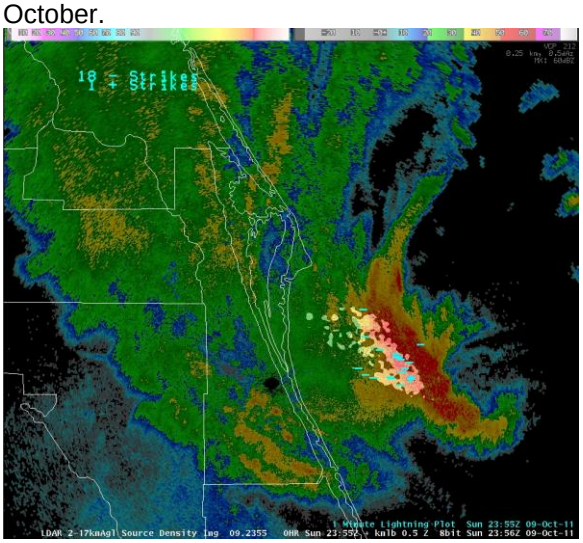

Fig 4. 2355 UTC KMLB 0.5 Reflectivity, 1-min NLDN data, and LDAR Source Densities 2-17km.

As the circulation center approached the coast near Port Canaveral between 0300 and 0400 UTC the main convective banding feature on the west side of the circulation center weakened considerably with minimal lightning activity noted and rapid decrease in radar reflectivity (not shown). Although the strength of the convection diminished, likely due to increasing shear, dry air aloft and lack of low level heat and moisture fluxes from the ocean surface, the surface pressure associated with the center began to rise. A pinched pressure gradient north of the system kept a strong onshore flow along the Volusia County coast from 0400 to 0630 UTC with some gusts over 58 mph from the Ormond Beach life guard mesonet station to coastal sections of New Smyrna Beach. The circulation center continued to move northwest through the night and exhibited another increase in convective organization during the late night hours over Marion County with a peak NLDN 5-minute flash rate of 82 cloud to ground lightning strikes ending at 0830 UTC.

4. ENHANCED DATA SETS

Real-time examination of total lightning data from the LDAR system at Kennedy Space Center (KSC) led to the confirmation of increasing electrical activity and extent that was nearly coincident with the increase in low level radial wind velocities seen in the base velocity data from the WSR-88D KMLB. The convection increased in organization and strength and the LDAR data were an important contributing component to verify the trends seen in the other data sets available to operational forecasters.

Mesonet data sets from the KSC and USAF wind tower network and other coastal mesonets were instrumental in receiving real-time assessments of the strongest winds that impacted the Brevard and Volusia County coastal areas. These mesonets led to real-time confirmation of winds gusting over 50 mph that were included in Special Weather Statements for the affected areas.

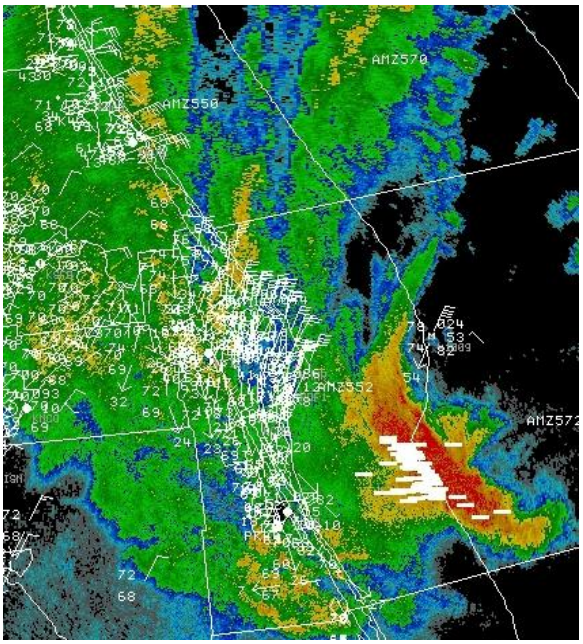

Fig 5. Coastal mesonet wind data instrumental in real-time wind analysis during the event.

5. WFO MELBOURNE OPERATIONS

During the afternoon hours on 9 October, the developing low pressure system showed increasing signs of organization with convective banding features and increasing low level radial velocities on the WSR-88D KMLB radar. At 1930 UTC (330 PM EDT) a Special Weather Statement was issued which described that “Doppler weather radar, satellite imagery and surface observations all showed a low pressure center which had formed offshore southeast Florida this morning, was moving northwest toward the East Central Florida coast. . . As the low continues to move

northwest toward the coast, these winds will continue through sunset, and perhaps a few hours after across Brevard and Volusia counties. Winds could occasionally gust to around 50 to 55 mph in absence of any showers or squalls, and could gust a little higher as squalls near the center of the low approach the coast."

Emergency management of Volusia, Brevard and Indian River counties were contacted to brief them on the approaching wind and water threat. Media and other partners were kept abreast of the latest information using NWSChat coordination software. The National Hurricane Center (NHC) was monitoring this system closely issuing Tropical Weather Outlooks and was in contact with Lead Forecasters at NWS Melbourne. Because the low pressure did not exhibit strong tropical or subtropical characteristics and meet the standard of having the required longevity of organized convection, NHC did not start advisories on this system. There was additional consideration for local forecast operations as the event was already ongoing across the East Central Florida near-shore waters and the system was approaching the coast. As a result, NWS Melbourne issued a High Wind Warning at 2127 UTC (527 PM EDT) for coastal Volusia, Brevard and Indian River counties. The warning included: "A High Wind Warning means a hazardous high wind event is expected or occurring. Sustained wind speeds of at least 40 mph or gusts of 58 mph or more can lead to property damage."

Through the evening hours, hourly strongly worded Special Weather Statements were disseminated with additional information on current observations, and the additional information on the strong winds that could be expected along the Brevard and Volusia County coasts. This included a statement at 0032 UTC (832 PM EDT) which stated: "Numerous reports of wind gusts between 50 and 60 mph have been reported along the Volusia, Brevard and Indian River County coasts over the past two hours. Sustained winds of 35 to 40 mph will continue through at least midnight...with gusts up to 70 mph possible along the Brevard and Volusia County coasts."

At 0034 UTC (834 PM EDT), the Gale Warning was upgraded to a Storm Warning for the Atlantic marine zones from Flagler Beach to Sebastian Inlet out to 60 nautical miles. The warning was issued for sustained wind speeds of 50 knots or greater. The issuance of a Storm Warning along the coast of Florida is a rare occurrence and was very unusual, especially for the time of year.

Hourly Impact Weather Updates and Graphicasts were also issued through the late evening hours to keep the public informed of the latest conditions through enhanced web services.

6. IMPACTS / WIND GUSTS AND PRESSURE

Significant impacts were experienced with this system ranging from marine interests across the Atlantic waters and in coastal marinas, to coastal structures that were damaged (shingles blown off older roofs, etc) across portions of Brevard and Volusia counties by the high winds. Most of the impacts were felt along the intracoastal and barrier islands from Melbourne north to Ormond Beach.

Other noted impacts were to vessels traversing the Atlantic waters near the storm. The Freedom of the Seas cruise ship departed Port Canaveral, Florida and traveled through convective bands on the west side of the low center during the evening hours. The ship experienced the increasing strength of the core convection near the low pressure center and its associated stronger low level wind fields. The anemometer of the ship (presumably at a height above 200 feet) measured winds gusts near 38.5 m/s (75 knots), with a peak gust of 46.3 m/s (90 knots). At one point, the ship was reported to have listed 12 degrees as it navigated through the high winds and seas. It was reported that 13 passengers experienced minor injuries due to the severe ship movement. The ship sustained some damage to public areas and guest staterooms, as well as experienced onboard fresh water flooding from the heavy rain, but the sea-worthiness of the ship was not affected.

The highest wind gusts were 33.5 m/s to 36.2 m/s (75 to 81 mph) at wind towers near the beaches north of Cape Canaveral at 60 ft elevation recorded between 0130 and 0230 UTC (930 and 1030 PM EDT). Peak wind gusts recorded along the Volusia County coast were between 25.9 m/s and 29.1 m/s (58 and 65 mph) between 0430 and 0630 UTC (1230 AM EDT and 230 AM EDT). The strongest wind gusts were recorded along the barrier islands from Ormond Beach to New Smyrna Beach after the system had moved onshore. Additional peak wind gusts from mesonet observation sites are available in Table 1. These peak wind gusts occurred from 0145 UTC (945 PM EDT) on 9 October 2011 to 0619 UTC (219 AM EDT) on 10 October 2011.

The lowest pressures included 999.5 mb at both Trident Pier (Figure 6) and Buoy 41009 (Figure 7) as the system moved near these maritime observing platforms.

Peak Wind Gusts from Mesonet Observations

Speed (MPH)	Location	Date/Time
81	2 mi SSE Playalinda Beach	09/1020PM
78	3 mi SE Playalinda Beach	09/1020PM
75	3 mi E Haulover Canal	09/1030PM
75	2 mi SSE Playalinda Beach	09/945PM
69	3 mi SSE Playalinda Beach	09/945PM
65	4 mi E Port Orange	10/141AM
63	3 mi NE New Smyrna Beach	10/1240AM
61	Volusia County Courthouse	10/213AM
59	New Smyrna Bch Lifeguard Stn	10/141AM
58	Ormond Beach Lifeguard Stn	10/219AM

Table 1. Peak Winds recorded from mesonet observations 9-10 October in local time (EDT).

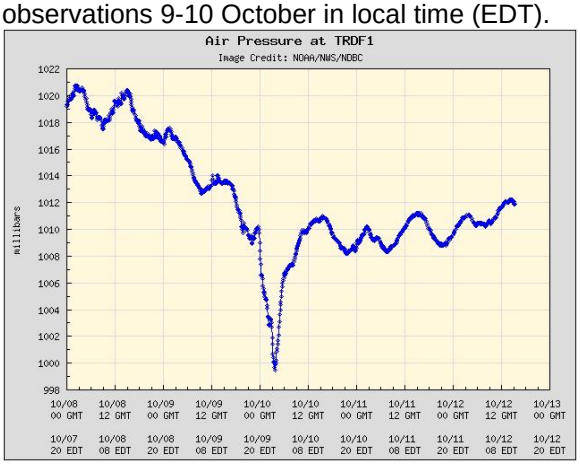

Fig. 6. Pressure Trace at Trident Pier (TRDF1). Minimum Pressure 999.5 mb at 0342 UTC on 10 Oct 2011. Image courtesy NOAA/NWS/NDBC.

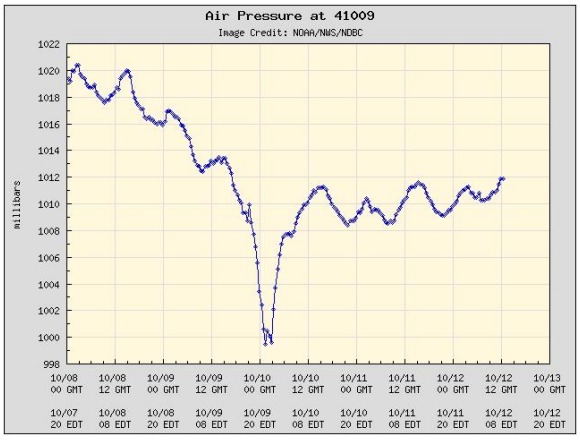

Fig. 7. Pressure Trace at Buoy 41009. Minimum Pressure 999.5 mb at 0120 UTC on 10 Oct 2011. Image courtesy NOAA/NWS/NDBC.

7. CHALLENGES AND BEST PRACTICES

The nature of this rapidly developing hybrid system posed some communications challenges but a consistent strategy was employed in coordination with NHC to ensure that the local warning message was articulated for East Central Florida users. This event affords the opportunity to promote some best practices for similar rapidly developing systems that move onshore, regardless of classification.

Some of the communications challenges include effectively articulating the impact potential similar to a landfalling Tropical Storm or Sub-tropical storm to describe the magnitude of event, but not add confusion to those who would employ typical tropical response plans. This event highlighted that some organizations may underestimate the profile of WFO forecast and warnings products within preparedness and response plans, even when directed to WFO local forecast and warning products from NHC.

A best practice from this event is Emergency Alert System (EAS) Activation for High Wind Warnings and Storm Warnings to heighten the desired response and bring attention to the warning message. Customer outreach can allow decision makers and the public to tune in to infrequently issued products (High Wind and Storm Warnings) in these types of events when traditional tropical or subtropical products are not being issued by the local NWS forecast office. Additional education in this regard will promote a heightened response from the public.

There is an importance in preserving the agency's "unified message" during an event with coordinated and collaborated forecasts, providing information consistency. This was accomplished through coordination with the NHC. During the event the real-time use of NWSChat with media partners was a best practice to keep the media informed and answer any questions about the evolving situation.

There is a need for balance between science and service when lives and property are threatened and the event is already underway, irrespective as to the classification of the system. The product suite should optimize mission delivery to ensure proper response to the warning message. It is incumbent on NWS local forecast and warning offices to ensure local warning products convey the threat from these systems and expected

impacts to the customer community and that their customers are familiar with products where they will find the warning information.

8. SUMMARY

This hybrid storm did not fit in a pre-defined box as being tropical or sub-tropical and the duration of a well-defined strong circulation lasted less than 18 hours as the system affected East Central Florida and the adjacent Atlantic waters. Beven (2012) also remarked the nature of this system is unclear even after extensive post-analysis.

The storm occurred following a multi-day heavy rainfall event and during a long holiday weekend which had societal implications relative to public awareness of the warning message. The long and short range models had difficulty with the forecast development, strength and track of the system, though extended range and short term briefings were valued services provided to the local emergency management community for this event.

NWS Melbourne issued local warnings (High Wind and Storm) for the mesoscale convective system and coordinated with the NHC. An analysis of NLDN cloud-to-ground lightning data and low level radial winds from the KMLB 88D indicated the increasing lightning trend supported increased convective organization with the system and stronger radial wind speeds (and thus low level wind fields) as the system was nearing the East Central Florida coast.

The system did produce sustained winds of tropical storm force and also a few reports of hurricane force gusts near the coast of northern Brevard County. Significant wind impacts were mainly confined to immediate coastal areas from Melbourne to Ormond Beach and over the adjacent Atlantic waters.

Proactive coordination with NHC before and during the event was undertaken to preserve the unified agency message of the storm's effects. This event has also furthered discussions toward maturing actions plans intended to guard against high wind impacts with proper consideration of the full suite of local Watch/Warning and Advisory with these types of low pressure systems.

EAS Activation is advocated for High Wind and Storm Warnings with strong maritime low pressure systems to increase dissemination and reception of the warning message. Other WFO products and services including Special Weather Statements, web-based Impact Weather Updates and Graphicasts, telephone and web briefings and chat coordination prior to and during the event were employed to convey the hazards and impacts from this system to the public, media and emergency management community.

9. REFERENCES

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