NOAA/PORTS® VISIBILITY SENSORS: TESTING TO OPERATIONS

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1. ABSTRACT

The National Oceanic and Atmospheric Administration(NOAA) National Ocean Service (NOS) Physical Oceanographic Real-Time System (PORTS®) provides real-time water level, currents and meteorological data for navigation aid in twenty major ports and harbors. In response to PORTS® user requests for visibility data, the National Ocean Service (NOS) began testing several varieties of visibility sensors for operations in a marine environment. Extensive testing culminated in the selection of the FS11 Vaisala visibility sensor. The FS11 sensor uses forward-scattering technology to measure the amount of scattering in a small volume of air between a transmitter and receiver, resulting in an extrapolated visibility at a set height out to 75 kilometers (km).

The first two visibility sensors were installed in the Mobile Bay PORTS® at a height of 3 meters (m) above ground approximately 15 miles apart along the western shore in areas susceptible to fog formation. Real-time data from these sensors are disseminated on NOAA's Center for Operational Oceanographic Products and Services PORTS® website every 6 minutes (min) and up to 10 km (5.4 nm), as any values greater than 10 km may not be reliably representative. The successful integration of this new data type will result in improved navigation safety and will facilitate decision-making for port pilots in the Mobile Bay, especially during the winter months when fog is more prevalent. The user requests for these data in certain ports prompted NOS to plan additional installations at other PORTS® sites.

2. BACKGROUND

Tragedy often precedes progress and accelerates the development and improvement of modern technology. For example, the freighter MV Summit Venture's devastating collision with the Sunshine Skyway Bridge over Florida's Tampa Bay in May 1980 was the impetus for the development of the National Oceanic and Atmospheric Administration's (NOAA) PORTS®, which is a suite of instruments that measure and disseminate real-time observations of water levels, currents, salinity, air gap, and meteorological parameters such as wind and water temperature. The PORTS® network consists of 57 stations located at 20 of the Nation's largest ports. The technology to help the Summit Venture's captain navigate in high winds, heavy rains and zero visibility was not well developed in the 1980s. If accurate air gap measurements and visibility sensors had been in place at the time, the MV Summit Venture may have been able to avoid areas with visibility so poor that the captain could barely see the ship's bow. Visibility sensors are widely used and essential for aviation and are becoming more critical for maritime applications as well; however, the requirements for maritime use are different than those for aviation. In many harbors marine pilots require a stated number of miles of visibility in order to proceed, and while the intent of the rule is clear, the specific requirements are vague.

In response to user requests for the inclusion of visibility sensors in the PORTS® network, the NOAA Center for Oceanographic Operational Products and Services (CO-OPS) signed a Memorandum of Understanding (MOU) with the National Weather Service (NWS) in 1999 to test visibility sensors at the Sterling Research and Development Center in Sterling, VA. Visibility sensors are used by the Federal Aviation Administration (FAA) for Runway Visual Range (RVR) and by the NWS for Automated Surface Observing Systems. These agencies selected the Belfort sensor for their programs and procured them in large quantities in the 1990s. After a request for PORTS® visibility data, OSTEP attempted to buy the identical model used by the NWS to conduct the requested tests; however, Belfort no longer supported that model, so OSTEP purchased the closest available model - the Belfort 6100. (The NWS Automated Weather Interactive Processing System or AWIPS uses the Belfort Model 6230b.) OSTEP also examined the Fidelity Technologies VM100, comparing it to NWS standards Belfort Model 6230b but concluded that it did not meet NWS standards.

OSTEP entered into a cooperative effort with the U.S. Coast Guard (USCG) C2CE Portsmouth, VA in March 2001 to test the Belfort visibility sensor models 6000 and 6100. Although the USCG was working with the Fidelity Technologies VM100 sensor, they were interested in the Belfort sensor and how well it and the VM100 met the NWS standards.

By late 2003, OSTEP had completed test and evaluation of Belfort sensors and had concluded that the tests did not demonstrate agreement with NWS standards for automated visibility sensors.

During late 2003 and early 2004, CO-OPS was

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involved in two visibility sensor tests. One was a January 2004 deployment and test of the Vaisala FD12 sensor (purchased before the FS11 became available) at Billy Mitchell Airport at Cape Hatteras.

Following that deployment, CO-OPS participated in a joint test with the FAA and the USCG at the John A. Volpe National Transportation Systems Center at the Otis Weather Test Facility at Cape Cod, MA. A six-month operational test of low-cost forward-scatter visibility sensors for the RVR system was conducted using beam transmissometers as a reference [FAA, 2006]. Sensors from several vendors were tested for FAA requirements, and CO-OPS was able to include Aanderaa and EnviroTech devices as well. This tri-agency group adopted the Vaisala FS11 sensor as their sensor of choice in the spring of 2005. Based on the findings at the Volpe Weather Test Facility, the FAA awarded a contract to Vaisala.

In August 2003, the Department of Commerce funded Phase I and part of a Phase II Small Business Innovation Research project for video-based visibility sensor system (V^2S^2) technology. International Electronic Machines Corporation (IEM) completed Phase I of the project and was awarded Phase II to continue work on a prototype. Even though Phase II did not receive the full appropriated funding, IEM developed a prototype V^2S^2.

OSTEP used FY 2005 year-end funds to procure two Vaisala FS11 sensors. The test of these sensors was outsourced to the U.S. Army Corps of Engineers (USACE) Field Research Facility (FRF) in Duck NC, but the MOU permitting the transfer of funds was not completed until FY 2007. This joint test, which began in March 2008, features six different forward scatter sensors being tested side by side, two sensors procured by CO-OPS and the rest by the USCG. USACE established a Web site for viewing and retrieving data sets (http://frf.usace.army.mil/airvis/av.shtml). To date, the CO-OPS intercomparison of the two FS11 sensors has yielded a satisfactory stability during long periods of neglect in near shore environment. Table 1 lists the sensors that are part of this joint test.

Test data from both the Volpe test and the FRF have also lead OSTEP to conclude that the Vaisala FS11 visibility sensor best meets maritime user requirements. These data, as well as a report prepared by John D. Crosby of EnviroTech, have also been major factors in the selection of this sensor. The EnvironTech report argues that unattainable standards will not result in better sensor performance, and may even encourage vendors to manipulate data to meet the accuracy requirements. It should be noted that OSTEP was unable to demonstrate successful performance for any of the sensors tested in accordance with Federal Meteorological Handbook #1 automated visibility standards.

Over eight years, OSTEP has tested eight different visibility sensors that represent four different technologies. These tests, conducted at five separate locations, include cooperative evaluations with five other agencies. Table 1 outlines OSTEP efforts to select the best technology and sensor for operational consideration.

3. THEORY OF OPERATION

The Vaisala FS11 is a forward scatter measuring instrument that utilizes a transmitter module and receiver module to determine the present visibility. This is accomplished by the transmitter making continuous infrared light pulses, which are focused into a narrow beam. The receiver lens collects the scattered light on the PIN photodiode for detection. This detected light is then converted and sampled by the instrument's internal CPU to determine the current visibility.

The visibility measuring sequence for the FS11 occurs at 15-second (s) intervals. Each interval consists of a 14-s signal measurement of the transmitter LED and activation of the receiver detector, followed by a 1-s diagnostic measurement used to determine sensor contamination. This measurement cycle is used to ascertain the signal and background values, which are then used to determine the offset corrected signal value. The FS11 software then calculates the extinction coefficient from samples by separating the signals coming from droplets and other scattering media. These samples are then used in a weighted sample for the determination of Meteorological Observable Range (MOR). This calculation is based on the known equation $MOR=-\ln 0.05/ext$.

The smart sensor utilizes a built-in 1-s diagnostic measurement to monitor the current status of the instrument and, in alternating sequences, determines the contamination level of both the transmitter and receiver lens. This measurement, which is used to apply a correction for the visibility calculation, will generate a warning message when the window contamination exceeds 10%. This warning is reported in the sample message. The next 1-s diagnostic measurement is used to determine backscatter and is made by the transmission of an independent LED inside the transmitter and receiver. The LED is transmitted through the light path to determine the amount of backscatter caused by foreign objects or debris. If this value also exceeds 10% (indicating that the backscatter is elevated or high) the sensor also generates the same warning message, since any contamination level exceeding 10% requires the same cleaning process to resolve the issue.

The system also monitors the power levels of the transmitter, hood heaters, and lens heaters and performs diagnostics that indicate current status and operation to help operators prevent failure.

4. MAINTENANCE

The manufacturer recommends that maintenance and cleaning be performed once per year or as needed, and that the instrument's calibration be checked annually or as needed, as well as when components are changed. The testing at the USACE FRF was done to help determine a minimum cleaning interval for sensors that are located in a near shore coastal environment, to replicate a worst case marine installation of the FS11 sensor, and to see how it performed in these conditions. In the first test, two Vaisala FS11 sensors were installed close to the surf zone to provide a high salt spray contamination. These sensors were then operated and monitored in tandem. One sensor was cleaned monthly, while the second sensor was monitored but not cleaned for a period of 10 months. The two systems were found to agree after the monthly cleaning was performed. Both systems were cleaned after 3 months due to an installation error by the technician, which required that both sensors be repositioned in place. Because of this position change, cleaning of sensors was performed so as not to introduce any biases. This phase of the test ended when one of the test sensors was removed and sent to the Chesapeake Instrument Lab for system integration to NOAA/NOS data collection platforms, data transmission and ingestion. The other FS11 remained at the FRF and was allowed to continue operation through its March 2009 annual calibration cleaning and check. The system operated within design parameters until the date of the cleaning, providing representative numbers.

The second phase of the testing started in March 2009. After initial cleaning and calibration, the instrument has been left to operate until failure or next annual service, whichever comes first. It is currently scheduled for cleaning and service in March 2010. Our testing has shown that the FS11 sensor is capable of providing a representative indication of the local visibility during long periods of neglect in harsh environments.

Contractors perform routine maintenance on sensor suites for the NOAA/PORTS® program. Our current recommendation is for a newly installed system to be checked and cleaned once a month for three months, after which the unit is to be serviced once every three months or as needed. The instrument calibration will be checked annually according to the manufacturer recommendations.

5. INSTALLATION

The Port of Mobile Bay, AL was selected for the integration of our first two operational visibility instruments in a port system. Site selection is critical to provide a representative sample of the visibility in Mobile Bay. Inputs from local users, NWS forecast office in Mobile, the Alabama State Ports Authority (ASPA), the Mobile Bay bar and tug pilots, and the harbormaster for the Port of Mobile provided input for site selection (figure 1). One critical requirement is access to 110-Vac power, which limits the instruments' deployment only to areas with access to locally provided power. This has been accomplished by locating one sensor on ASPA property on Pinto Island, AL. This location is about 100 m from the main shipping channel on the Mobile River and just north of the new turning basin at the northern end of Mobile Bay. The sensor was installed at this location in December 2009 prior to completion of construction at the site (figure 2).

The second sensor is located at the western end of Deer River on the ASPA, Mobile Middle Bay Port. This location was chosen due to its proximity to the developing port facility. It is also approximately 2 miles west of the main shipping channel and 10 miles south of the sensor located on Pinto Island. The sensor provides acceptable spatial coverage recommended by the NWS forecast offices both in Mobile, AL and Wakefield, VA. This installation is currently delayed awaiting the required site improvements prior to sensor installation.

6. PRODUCTS

Users have access to all PORTS® data through the CO-OPS website, which can be found at www.tidesandcurrents.noaa.gov/ports.html. The Mobile Bay PORTS® pages provide three-day water level and meteorological plots, composite pages displaying current meter data juxtaposed to water level, meteorological and physical oceanographic data, and an "all-met" page displaying all meteorological data. Visibility data are measured up to 75 km, but given the unrealistic nature of such a large range, CO-OPS limits the public data to 10 km (5.4 nm). Furthermore, there are limitations to measuring visibility in a marine environment. Mounted at approximately 3 m above the mounting surface at both Mobile locations, the instrument only captures the visibility at that single height and location. Small-scale differences in the air mass, such as patchy fog or low-lying fog, are not captured. The visibility data are 3-min averages of 1-s samples and are displayed every 6 min in a simple time-series plot, with the vertical axes capped at 5.4 nm. The visibility station pages also include plots from a nearby water level/meteorological station to allow easy comparison to water level and weather conditions in the immediate vicinity. The data are also updated in real-time on text screens and over a voice system.

The CO-OPS website includes a meteorological observations page, which can be accessed through the products menu, and contains meteorological data from all CO-OPS stations. Visibility data are also included on this page as a time-series plot in the same manner as the PORTS® plots, as are user options such as time frame and units. Additionally, a to-scale Google map with the visibility measurement overlaid is provided. The measurement is displayed as a circle, filled in to show the appropriate range to scale. Visibilities of less than 1 km are red, those less than 3 km are yellow, and those less than 10 km are green. This unofficial warning system allows users to quickly glean the severity of the conditions, as well as the spatial coverage of the meteorological observed range.

7. FUTURE

With the successful integration of two visibility sensors into the Port of Mobile PORTS® system, the NOAA/PORTS® program has now procured sensors for integration to the PORTS® systems for Narragansett Bay, Rhode Island, and the upper Chesapeake Bay to fulfill request of the Maryland pilots. Additional locations will be determined by user request in existing and future PORTS® installations and in the Great Lakes, if needed. Ahead of installation, the Port of Mobile has requested a third sensor to be installed in 2010 and located at the southern end of Mobile Bay near Dauphin Island, AL approximately 13 miles south of the middle bay site. Modifications will be made to include the data in Standard Hydrometeorological Exchange Format or SHEF bulletins.

8. REFERENCES

Crosby, John D. 2002: Visibility Accuracy: What's Realistic? EnviroTech Sensors, Inc. www.envirotechsensors.com

Federal Aviation Administration 6530.31, Maintenance of RVR Equipment, December 2006 http://www.faa.gov/documentLibrary/media/Order/ND/6560.311.pdf

Federal Aviation Administration, Points of Pride, FY 2006, RVR p.3 http://www.volpe.dot.gov/infosrc/docs/pop06.pdf

Federal Meteorological Handbook No. 1, September 2005 http://www.ofcm.gov/fmh-1/pdf/G-CH7.pdf

IEM, Video-based Visibility Sensor System http://www.iem.net/index80b7.html?products&imaging

USACE FRF Web site http://frf.usace.army.mil/airvis/av.shtml

Vaisala Users Manual

Table 1. OSTEP Efforts to Select the Best Visibility Technology

Sensors Evaluated	Testing Locations
Belfort 6100	Volpe National Transportation Systems Center
Belfort 6000	Sterling Research and Development Center
Envirotech	Cape Hatteras/Billy Mitchell Airport
Aanderaa	USACE/Field Research Facility
Cossanay/Fidelity Technologies	CO-OPS/Chesapeake Facility
IEM	
Vaisala FD-12	
Vaisala FS-11	

Cooperative Agencies	Technologies Evaluated
FAA	Forward Scatter
USCG	Back Scatter
NWS	Video-Based
USACE	Beam Transmissometer
NPS	

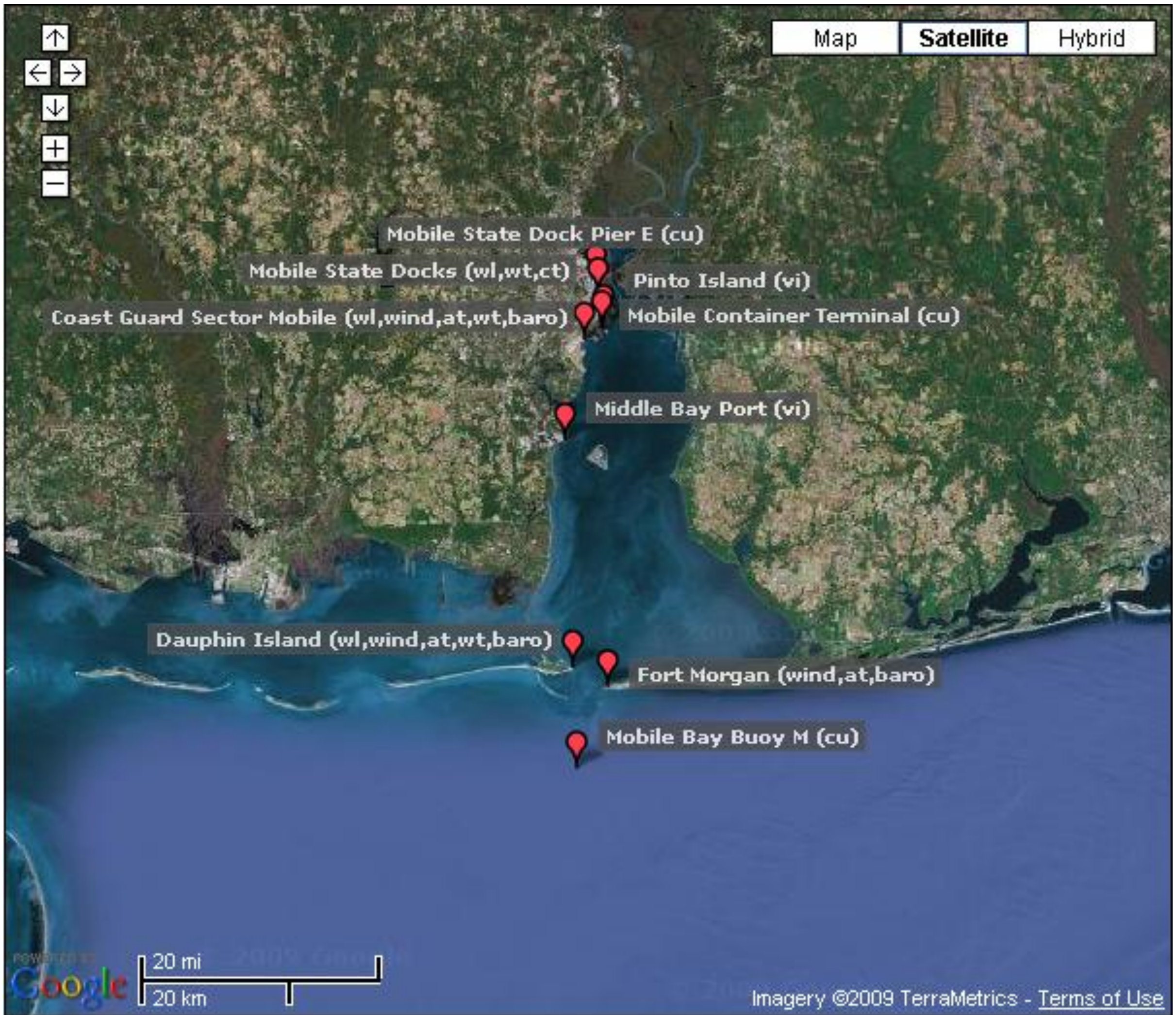

Figure 1. Mobile Bay PORTS® station locations

Figure 2. Vaisala FS11 visibility sensor installed at Pinto Island Terminal, Mobile AL