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PORTS IN A STORM

Windspeed data is critical for maintaining safety at seaports, especially during thunderstorms

← Leosphere's Windcube 400S at the entrance to the Port of Genoa

→ Windcube 400S and Windcube vertical profiler are part of the Port of Genoa wind hazards monitoring and forecasting solution

Shorelines are notably exposed to the elements, and so ports – particularly seaports – are susceptible to extreme weather conditions. What's more, ports are usually surrounded by urban development, which can cause or exacerbate wind turbulence, increasing risk to life and operations.

These factors can cause all kinds of problems. Gales and waves can of course make it difficult for ships and ferries to enter port and dock, and also to leave. High winds can compromise the integrity of port structures such as bridges and harborside cranes, and can also threaten the stability of containers that are stacked and empty. Wind is, in fact, nature's most destructive natural phenomenon, being responsible for 70% of the damage and death caused by nature.

In short, these and other risks constitute significant safety hazards to people working in ports and also on vessels, and mitigating those risks, for example by stopping work, can cost substantial sums of money.

ESTABLISHING A NEW MODEL

In Europe, the principal wind factors include extra-tropical cyclones and thunderstorms. Around 50 years ago a model was established to gauge the effects of cyclones on construction, and it's still in use today. But there is no corresponding model for thunderstorms, and no unified model for both phenomena. This is because thunderstorms are so complex, and their short duration and limited geography have made it difficult to measure them.

This gap in our knowledge has affected construction in ports. In some cases, safety concerns can lead to costly over-engineering, while in others, structures can be inadequate and therefore dangerous. Small and medium-height structures such as harbor cranes are often prone to damage and collapse, while the high cost of tall buildings in areas prone to thunderstorms is due to the need to withstand great wind speeds at ground level.

GENOESE EXPERTISE

For some years, a wind engineering group in Italy has been leading the way in seeking to address these shortcomings. The Department of Civil, Chemical and Environmental Engineering (DICCA) at the University of Genoa (UNIGE) led the Wind and Ports, and the Wind, Ports and Sea projects funded by the Italy-France Maritime 2007-2013 European program. Those projects ran between 2009 and 2015 and gathered data from ultrasonic anemometers at key points around each of the port areas it covered.

The information gathered was channeled into a central database for interpretation that included numerical simulations of wind fields, statistical analysis of long period records, and medium- and short-term wind velocity forecasts. As a result, the group decided that further work was needed, making use not just of the anemometer network but also of the meteorological radar, satellite antennae and wavemeter buoys of the region's meteorological agency, and of new measuring equipment, including Doppler lidar systems to improve the high-resolution monitoring of thunderstorms and extreme weather events.

PROJECT THUNDERR

With its agenda for further research defined, the group, led by Prof. Giovanni Solari of UNIGE, sought funding for a wide-reaching experiment coined Project Thunderr. An advanced grant was awarded to the group by the European Research Council in 2016.

UNIGE's fellow participants in the project include the Institute of Meteorology at the University of Berlin, Germany, which is involved in data analysis; the University of Eindhoven, Netherlands, which is performing a range of numerical calculations; and the University of Western Ontario, Canada, which is home to a wind tunnel capable of simulating tornadoes and downbursts.

Project Thunderr began in September 2017 and is scheduled to run until the end of August 2022. Its aims are to detect thunderstorms, to create a database of meteorological records and scenarios, to conduct laboratory tests and numerical simulations, to formulate a thunderstorm model appropriate for both atmospheric sciences and structural design, to improve engineering practice and the codification system it employs, and to make construction safer and more sustainable.

These aims may perhaps be summarized in two broad categories: thunderstorm research, and its implications for the design and building of structures.

THUNDERSTORM RESEARCH

In Project Thunderr, the wind monitoring network developed for previous UNIGE programs has been supplemented with a Leosphere Windcube 400S Doppler lidar system, installed at the port in Genoa. This enhanced network detects the position, diameter, structure, direction and translational speed of downbursts. A semi-automatic expert system separates wind events, and a wide range of information types are collected, including lidar data, radar Doppler images and lightning data, to classify the weather scenarios in which thunderstorms occur. The parameters of each event are cataloged.

"Thunderstorms are rare phenomena," says Massimiliano Burlando, associate professor at the University of Genoa. "There are perhaps only four or five strong events a year at Genoa's port and they are of short duration. A storm's vertical downdraft reaches the ground and spreads out. Lidar equipment helps us to capture fine detail from the inside, so we can gauge its geometric structure, distribution and evolution as the storm progresses. Some storms can be hard to measure, particularly when the cloud from which the downburst emanates is moving fast. But aside from these instances we can produce a mathematical model for structural analysis and other purposes."

Analysis of the lidar data also includes the calculation and evaluation of statistical averages, and the evolution of windspeed profiles over time and distance. With this information, large-scale downbursts can be simulated and wind tunnel tests can be conducted to evaluate scale effects. Also, the program aims to extrapolate weather scenarios from windspeed data, to improve downburst forecasts, and to separate and classify the various kinds and levels of damage caused by cyclones and thunderstorms.

The rich data the program yields is being used to generate detailed new wind field models and probability distributions to supplement classic synoptic representations of wind.

Nowcasts and forecasts

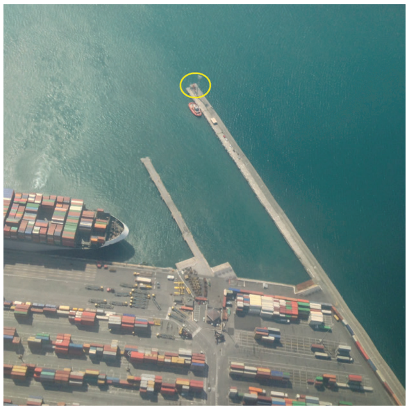
The Genoese wind projects have used two forecasting approaches: nowcast and forecast models, both of which make use of Doppler lidar systems in conjunction with other analysis methods.

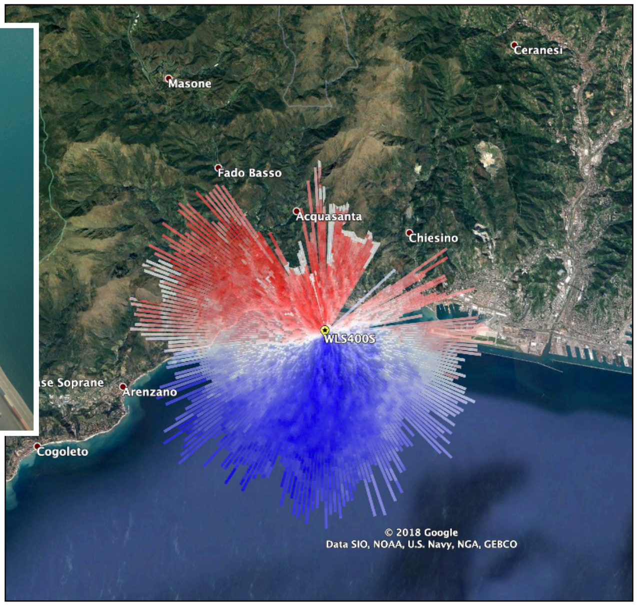
The nowcast model provides a detailed description of the current state of the weather. In addition to short-term forecasts of how the weather will change over a few hours, this approach has been developed to protect vessels and people against intense and imminent weather phenomena.

Real-time data obtained by lidar systems installed at and near ports will become even more important as autonomous shipping becomes a reality, because the information they gather can be provided simultaneously to ports and ships alike for immediate action.

The forecast model provides sea and weather forecasts over longer time horizons. It therefore provides an approach to planning any operations that are heavily influenced by sea and wind conditions a few days in advance: for example, ships entering and leaving the port, dockside mooring, loading and unloading of goods, and various terminal activities.

For example, port conditions in Genoa are such that advance notice of 36 hours is given when loading and unloading of certain cargoes, including potentially hazardous materials such as oil and petroleum, which can take several hours.





Aerial shot of Windcube 400S location

Radial wind speed map covering an area >100km^2 every two minutes

IMPLICATIONS FOR STRUCTURES

The data being derived and analyzed from this thunderstorm research is being used to create wind loading formats that will help to determine new approaches to the design and building of safer and more cost-efficient dock structures.

As part of this objective, Project Thunderr includes several structural analysis tests, including two towers equipped with monitoring equipment. At the same time, a database of structure test-cases in a variety of wind conditions is being gathered, and standard and new loading formats are being applied to gauge their viability. In the case of large structures, the lidar equipment can be used to complement the monitoring phase of the structures with real-scale wind measurements to validate their behavior in the wind and the models used during their design. These studies are enabling assessments to be made of design changes and their associated costs, resulting in safer and more economical structures.

Leosphere Windcube 400S

- Wind measurement range up to 10km (6 miles)
- Full 3D fast scan
- Automatic 3D cloud/aerosol detection
- Versatile and high-precision
- Reliable, unsupervised operation
- Fast deployment and setup

SAFETY IN NUMBERS

Project Thunderr has currently run only about a third of its course, and there is still much work to do. "By the time we complete the project we hope to have captured detailed data from up to 25 thunderstorm events," says Burlando.

Of course it is this detail that's important – detail that the lidar equipment is instrumental in bringing to the wind-monitoring network. The greater understanding it brings will not only streamline operations and lower overheads, but will also help make ports safer places. ∎