Interdependency of Port Clusters During Regional Disasters
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INTRODUCTION
Puerto Rico contains three major seaports. They are San Juan Port, the Port of Ponce, and the Port of Mayaguez. In 2017, these ports were disrupted by the wind and waves Hurricane Maria brought to the coast of Puerto Rico. Hurricane Maria devastated the island and its 3.4 million residents. This storm registered as a category 4 hurricane that brought 155 mph winds and 9 to 11 feet of rain. Flooding disrupted basic services and left the entire island without power. Hurricane Maria was said to be the most devastating storm to hit Puerto Rico in 80 years. The ports along the coasts of the island suffered severe damage from the rising sea-levels and strong winds making landfall over them.

The performance of maritime transportation systems struggle to remain reliable and resilient during times of disruption. Major disruptions at a port may result from external threats such as storms, labor disputes, and oil or hazardous material spills as well as multiple catastrophic events. The extent of the disruption and damage to a port, and the duration of the disruption depend on the severity of the threat, the degree to which the port is vulnerable to it, and the decisions that are made in responding to the disruption. Resiliency of a port is defined in terms of the severity of the disruption, the capacity of the disruption to reach a performance measure such as port capacity, as well as in terms of the duration of the impact on the performance measure.

PROJECT BACKGROUND
The ability of transportation systems to function when altered by a disruptive event is crucial for maintaining the national security and defense interests of the United States. Fluctuating oil and gas prices of recent years have increased the frequency and extent of external disruptions to ports. These disruptions can negatively impact the economic impact and the recovery process of the region will likely be affected by the devastating storm.

RESULTS
In general, the results of the research are expected showed the benefits of quantifying resiliency and how the information gained from such analysis can be beneficial when evaluating the impact of disruptive events on regional port clusters. The quantitative assessment of resiliency provides meaning, context, and relevance to port stakeholders which may not be readily apparent at face value. The independent nature of maritime transportation system requires redundancies and therefore the impact of disruptive events must be viewed from a holistic approach. It not possible to see the entire region of disruption by exploring the hindrance of one port. It is necessary to see the forest through the trees and develop methods and means to analyze these networks systematically.

This research will also show that Automatic Identification System (AIS) data can be utilized to create new metrics and methods for the assessment of resiliency in maritime systems. This research may show, in quantifiable terms, reductions in performance resulting from a simulated disruption. On a broad level, research may represent one of first steps toward the development of standardized metrics for quantifying resiliency in ports. The use of AIS data, which collects information from nearly all commercial vessels on a semi-continuous basis, is a rich data source with many applications in disaster science. The methods developed and applied here incorporate an all-hazards approach to quantifying resiliency in navigable waters and can be applied across a range of spatially and spatial scales.

ACKNOWLEDGEMENTS
Administrative Assistant Rosa Criado for assisting in layout of poster and final assessment of presentation.

Embry-Riddle Aeronautical University, Department of Civil Engineering for providing the necessary resources for the project.

REFERENCES

TIME-DEPENDENT RESILIENCY ANALYSIS
The time-dependent resiliency analysis plots will be made for systematic, objective means of measuring the resiliency of ports in a cluster.

Figure 1: (a) Arrival times, (b) Dwell times for Port Everglades displayed as a probability distribution function.

Table 1: Existing research data collected using AIS technology.

<table>
<thead>
<tr>
<th>Cargos Type</th>
<th>Year of Entrance</th>
<th>Port Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil/Chemical</td>
<td>2010</td>
<td>New Orleans</td>
</tr>
<tr>
<td>Timber/Concrete</td>
<td>2012</td>
<td>Long Beach</td>
</tr>
<tr>
<td>Paper</td>
<td>2015</td>
<td>Everglades</td>
</tr>
<tr>
<td>Pot/Ph-Val/Container</td>
<td>2016</td>
<td>Long Beach</td>
</tr>
<tr>
<td>Grains/Long-Load Container</td>
<td>2017</td>
<td>Everglades</td>
</tr>
<tr>
<td>Container/Bulk Carrier/Tanker</td>
<td>2022</td>
<td>Long Beach</td>
</tr>
</tbody>
</table>

For this study, vessel location information from onboard AIS transceivers will be used to generate average vessel dwell time within the port area of interest and net vessel transits into and out of the port areas of interest. Dwell time is the continuous length of time a vessel spends within the port area or associated regions such as offshore anchorages. This indicates the capability of the port to efficiently handle cargo flows at the terminals and beyond [5]. During a disruptive event, there is a decrease in port performance. Vessels are processed at a slower rate, causing an increase in overall dwell time in the area surrounding the port. The ability of ports to recover from a disruptive event determines their level of resiliency.

THEME-BASED RESILIENCY ANALYSIS
This research seeks to build upon the prior knowledge and expand the scientific understanding of regional disruptions to port clusters, areas of the country with multiple ports serving the same region.