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Unveiling of Maritime Networks from the Differentiated Analysis of Vessel Traffic in the Caribbean

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1 Introduction

The Caribbean region is a critical area of the global maritime traffic, acting as an interface between the Atlantic and the Pacific through the Panama Canal, for various types of vessels ranging from cargo ships to oil tankers and cruise liners. Local ports serve not only as infrastructure nodes for goods and passenger transit but also as complex hubs that see intricate networks of maritime routes, both global and local. These networks are useful for understanding global and local logistics, and environmental impact.

The presence of different types of vessels, each having distinct operational behaviours and routing protocols, suggests that multiple complex networks coexist within this maritime space, though data on port activity, and all the more so on maritime routes activity, lack, or are incomplete and hard to reach.

In this paper, we use a dataset of port calls in the Caribbean that we previously developed in order to provide a comprehensive analysis of the networks formed by different types of vessels in the Caribbean. Investigating how these distinct networks interact and coexist in the same geographical space can open up interesting perspectives for policy development in fields of maritime safety, environmental protection or regional logistics.

A visualisation dashboard has been developed to facilitate the geovisualisation of these ports calls as a proxy for port activity [1] and the resulting traffic networks, as well as personalised indicators on maritime traffic in the area.

2 Data

We have extracted a set of port calls with a method presented in [2], using three main data sources, AIS vessel position data, a set of ports and a vessel registry, described in the next three paragraphs. All the data will be catalogued and made available shortly, along with an information document.

The AIS dataset has been purchased from the firm exactEarth. Its timespan covers the whole of 2019, and its spatial extent spans from 3.86 degrees North to 34.05 degrees North in terms of latitude, and from 98.02 degrees West to 51.17 degrees West in terms of longitude. It covers the entire Caribbean, including the Gulf of Mexico. The whole

dataset encompasses a grand total of 641,709,724 data contacts, which represents a mean value of 1.76 million AIS messages per day. Figure 1 represents all data contacts for the sole month of January 2019 (46 million messages), that clearly shows the bounding box of our dataset.

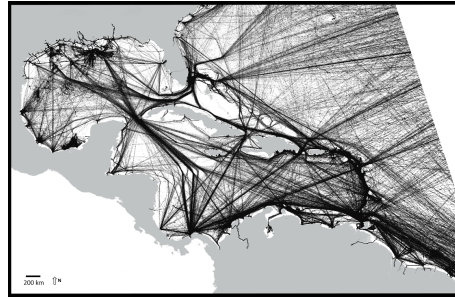


Fig. 1. AIS contacts of exactEarth dataset, for January 2019

In order to have a cartographic reference frame for calculating port calls, a dataset describing the infrastructure (quays and wharves) of all ports of interest in the Caribbean has been produced by the authors using GIS photo-interpretation. Digitalisation was carried out at a scale of 1:5000, using *Google Earth* and *Bing Map* satellite imagery, and the *OpenStreetMap* cartographic repository. A total of 528 ports, spanning across 41 territories (sovereign nations or dependencies) have been identified and labelled.

As we want to have a differentiated approach of the networks on the basis of the vessel type, it is important to label vessels. For this purpose, the IHS Markit database classification, otherwise purchased, has been used. Within all categories of vessels, the types we investigate are bulk carriers, container ships, cruise vessels, general cargo vessels, inter-island ships and tankers.

Once the port calls are computed using state-of-the-art parameters [3], the semantic trajectories of the vessels going from port to port are reconstructed, and networks of ports are built by putting together all trajectories. Therefore, a total of 298,804 directional journeys from one port to another have been computed, out of 9,969 individual pair of ports.

3 A dashboard for network analysis

In order to display information on port calls and local networks, a geovisualisation dashboard has been developed.

This dashboard enables the visualisation of the number of port calls at each port, characteristics such as the mean age and tonnage of vessels calling, and the exploration of data in an interactive way. More particularly, it is possible, as shown in Figure 2 to focus on a particular type of vessel, only showing edges with a cardinality within a

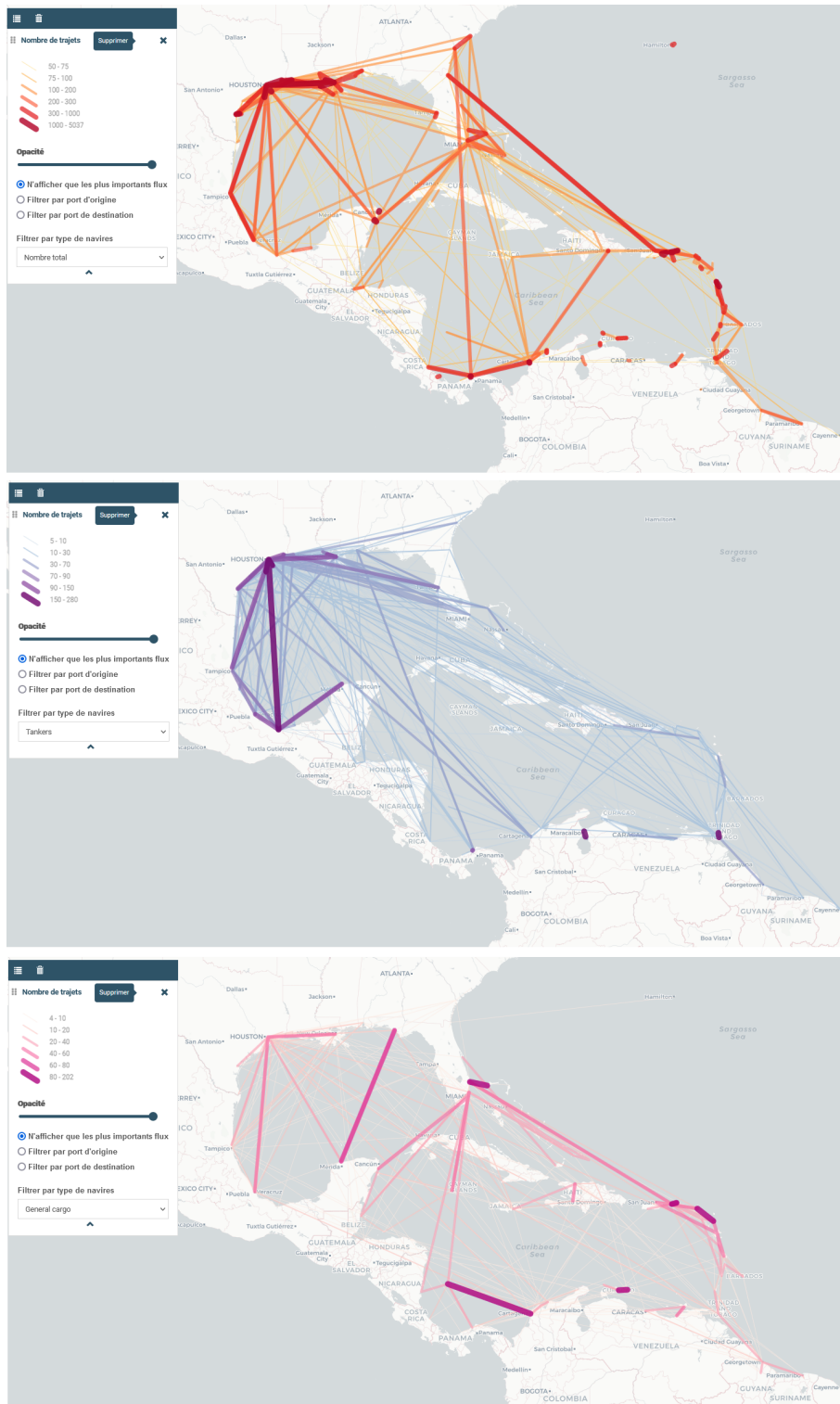


Fig. 2. Local networks for all vessels (top), tankers (middle) and general cargo vessels (bottom). Only edges with more than 50 journeys for all vessels, 5 journeys for tankers and 4 journeys for general cargo vessels are shown in this figure.

certain range, or visualise the ports from which originate the vessels calling at a given port, and inversely the destination ports of the vessels when leaving a given port, with the corresponding cardinalities of each link.

4 Perspectives

This dashboard enables to dig into data and perspectives are manifold. One promising direction involves understanding the spatiotemporal organisation of maritime traffic, taking into account the variability introduced by different types of traffic, particularly in an archipelago which undergoes a two-tier maritimisation system, propelled by domestic needs on the one hand and the needs of a globalised trade on the other hand [4]. This approach could offer critical insights for the effective deployment of maritime surveillance resources and logistical planning.

Another concern is the evaluation of the environmental pressures generated by this maritime traffic. Potential impacts on marine ecosystems and vulnerable coastal populations could be modeled by linking vessel types to pollutant emissions, which would be particularly useful for environmental regulation and policy implementation.

The identification of maritime traffic hotspots in terms of biodiversity also constitutes a research priority, particularly in the Caribbean where the proliferation of protected marine areas testify the will of neighbouring states to protect the environment. Overlaying shipping routes with ecologically significant areas could help identify high-risk regions where maritime traffic could have adverse effects on local biodiversity.

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