Questions in Virtuality:
Intelligent Interactions
with Data in Time and Space

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Memo on the opportunity for improved environmental management of ocean resources presented by intelligent use of the data in the Earth Data Store. The Oceans and Environment Application.

As work continues on the Earth Data Store, a project headed by UrtheCast as part of Canada's Digital SuperCluster (CDSC), the importance of a platform for earth observation data becomes more clear. It is difficult to work on a platform without a very clear idea of the applications which can rest on that platform, however. In the initial work, we are creating an Ocean-focused application that began with algae bloom data and has begun to morph towards ocean currents, fuel spill mitigation, and greenhouse gas emissions. This memo is a brief summary of some of the potentials for a longer term project that draws these and other foci together into an application that surfaces hydrology data, satellite observation data, shipping traffic data, and other sources of information into an easy-to-use analytics engine to plan, predict, and prevent commercial impacts on our coastal ecosystems.

Every analytics engine starts as disparate pieces of code accessible only to experts. Today, much of the information to make sensible decisions that protect our coastal habitats already exists in forms that are accessible to scientists. The satellite data are downloadable, the current predictions exist, sensors are widely deployed by Ocean Networks Canada, MEOPAR, and other research groups. But they are all in different formats and are accessible only to experts with a very solid idea of what they are looking for and a deep knowledge of the tools required to use the data. Even for experts, there are data sets that are difficult to find and hard to use. Both the Earth Data Store and the Canadian Integrated Ocean Observing System (CIOOS) are attempts to rectify this by providing detailed metadata stores that catalogue the data sources that are available and standardize the tools required to access that data. For expert users, this is enough. A combination of code and GIS tools will allow them to draw much more reliable conclusions given timely access to standardized sources of data. Not every project can afford to hire remote sensing scientists to draw data together for them, though.

The goal is to gather data and the tools to manipulate that data into a coherent suite of offerings that lower the bar to accessing and using this information. First moving from the need to write code and use separate tools down to a level where scripts in a display language can generate an application. But eventually moving to a graphical and language-driven environment to explore data sets. These explorations are planned on a number of computing platforms depending on the scenario – a field manager at an aquaculture facility may have only a cell phone, a team of project planners may have multiple augmented and virtual reality headsets to establish a collaborative decision making process. Touch tables are an alternative collaboration strategy currently being explored with our partners at Esri. In between these extremes are regular tablets, laptops, and desktop computers. The range of user interface presentations demands a separation between data processing and display functions of the

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application. The existence of cloud computing resources to process the vast amounts of data is also an integral part of the application.

So what is enabled in this future world where we can process data in near real-time in a computing cloud and drive environmentally sound decision making on such a wide variety of devices? Let's examine a few scenarios which we will then use to extract some system requirements:

1) A remote BC town, let's say Hartley Bay, is concerned about its exposure to a fuel spill from increased shipping traffic[i]. The town leaders want to model various scenarios to determine what their risk is and where it can be mitigated. By using the Oceans app to model out scenarios – wind and weather, waves, currents and tides, location of the incident – the town leaders are able to determine that most of the risk comes from an incident in Douglas Channel to the North of Hartley Bay, and it is during an outflow current in a South Easterly storm that the risks are highest. By modeling the flow of surface oil from such an incident, various responses can be considered which ultimately result in the town deciding to invest in a deployable boom fence on a reel and a set of smaller boat-deployed T fences that can be put out in the event of a spill. Placement of these fences is guided by the spill scenarios.
2) Carnival cruise lines is concerned about its carbon footprint. They make their money by carrying passengers through some of the most beautiful, unspoiled coastline in the world and customers want to make sure that what they are seeing is being protected. After protests in Europe over the realization that the 46 largest cruise ships release more pollutants than all the cars in Europe, Carnival has been taking steps to reduce its carbon footprint[ii]. They have achieved a 25% decrease by 2017 and are aiming for a 40% decrease by 2030. One part of that is route planning. By using the Oceans Application they have made use of the carbon footprint modeling tools to test scenarios where pausing in quiet bays for an hour or two during the most adverse tides could effect their overall carbon budget. Adding detailed current modeling to their route planning allows them to shave off a few more percent. The installation of sensors and cameras that feed back into the Oceans Application, and the public placement of a touch table running Ocean App visualizations in the Naturalist Lounge have been a hit with passengers and help to explain the natural environment through which they traverse. The high resolution satellite images can even spot whales!
3) The Oceans App is focused on the coastal waters of British Columbia, but this includes the liminal spaces on the edge of the coast. From low tide imagery to assess the health of traditional clam beds to monitoring construction and effluent outflow to tracking greenhouse gas emissions, the health of our marine ecosystems is integrally connected. Of course, concerns over invasion of privacy and protecting economic enterprise need to be balanced, but privatization of the commons does not erode a communal responsibility to protect our environment and without aerial and space-based remote sensing platforms access to many of these areas is impossible. Let's take the LNG industry as our example in this space. LNG is predominately methane which is supercooled to become a liquid. Methane is a greenhouse gas

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that is 70 times as potent as carbon dioxide when measured over a 20 year period. Methane seeps out of 85 percent of wells, but is also lost to the atmosphere during processing and transport. LNG facilities are inspected for methane leaks, but under BC regulations that will occur in only 7 percent of facilities per year. The newly launched Sentinel-5p mission by the European Space Agency has the capability to detect airborne pollutants, including methane. Although its spatial resolution is several kilometers per reading, the distribution of methane producing facilities is wide enough that space-based monitoring of large emissions is now possible. The ocean ecosystem both releases methane, through seeps in the seafloor and under ice in northern latitudes, and consumes methane through bacteria and even larger lifeforms such as crabs eating it! An understanding of our methane cycles, sources, and sinks is essential to controlling greenhouse gas emissions[iii].

A common denominator among these applications is that they are targeted at companies and individuals who may not have the technical and coding expertise of traditional geographers, remote sensing scientists and GIS professionals. Even in those cases where the technical expertise in remote sensing is there, the greenhouse gas emissions calculations and situational modeling capabilities are complex additions to a static satellite analysis. An interactive and flexible framework is required.

Our modeling facilities must get far better. The two ocean current modeling tools in the Salish Sea are FVCOM and NEMO, both of which perform adequately but hardly perfectly. Advanced machine learning approaches are underway to improve on these models with something that can be further trained by new data. A continually improving empirical model opens the door to using increasing computational power to take the place of hand-coded rule-based modeling systems for current prediction. This improves the ability to predict other dispersive phenomena such as oil spills and algae blooms.

The set of earth data is improving, our collaborators at Ocean Networks Canada, MEOPAR, the Hakai Institute, the emerging Canadian Integrated Ocean Observing System (CIOOS), and of course UrtheCast and the Earth Data Store project are all contributing vast amounts of data. With the metadata standards work underway this data is becoming easier to find and use. But the front end that can make locating the data, asking targeted questions, and visualizing the answers requires both hefty computing infrastructure and software investments to allow these capabilities to become broadly accessible.

The Oceans Application discussed in this whitepaper can be created. With the amount of economic activity dependent on our oceans and coastlines it must be, the threats to our environment are too extreme to be developing on our coastlines blindly. This software can open our eyes to the impacts of human activity on our natural world, and hopefully allow us to find new ways to appreciate the wonder of the coastal world we live in.

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[i] A discussion of boom types is available in the US study reported here: https://www.bsee.gov/sites/bsee.gov/files/osrr-oil-spill-response-research//330aa.pdf a BC company, https://www.harbo-technologies.com/, specializes in small, easily deployable oil booms. Hartley Bay is an area of specific concern given the proposed tanker traffic to the Northern Gateway project, https://ceaa.gc.ca/050/documents_staticpost/cearref_21799/2430/Marine_Physical_Environment.pdf

[ii] Cruise line carbon reduction goals: https://safety4sea.com/carnival-to-help-achieve-40-reduction-of-cruise-industrys-emissions-by-2030/ Carnival-specific commitments: https://carnivalsustainability.com/commitment/energy-emissions/ Carnival ships more polluting than all of Europe's cars: https://www.ft.com/content/8bceef94-86cd-11e9-a028-86cea8523dc2 Whales from space: https://www.smithsonianmag.com/smart-news/researchers-can-now-monitor-whales-satellite-180970703/

[iii] Liminal coastal spaces: https://www.hakaimagazine.com/features/who-controls-coast/ Methane emission rules: https://www.thestar.com/vancouver/2019/01/16/bcs-new-rules-to-cut-potent-methane-emissions-fall-short-environmental-groups-say.html Methane and LNG: https://thenarwhal.ca/6-awkward-realities-behind-b-c-s-big-lng-giveaway/ Sentinel-5p mission: https://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-5P/Facts_and_figures Methane eating crabs! https://vancouverisland.ctvnews.ca/methane-eating-crabs-may-be-adapting-to-climate-change-study-1.4313701