
Statistical Spills, Numerical Models, and Most Likely Outcomes from a Major Spill in the Salish Sea

Presented by:

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Genwest Systems, Inc.*



Photo Credit: Alan Niles

**Pacific States Oil Spill Task Force
2025 Annual Meeting**

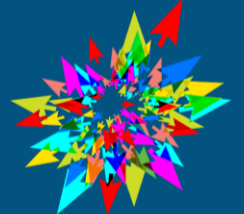
A collaborative effort



M
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Digital Alliance
Canada



Prof. Susan Allen

Dr. Rachael Mueller
Dr. Doug Latornell
Ben Moore-Maley
Vicky Do
Ashutosh Bhudia

Physical
Oceanography

Prof. Stephanie Chang

Krista Forsysinski
Leni Vespaziani
Ryah Rondolo
Dr. Casey Hilliard*
Cameron Power

Social
Science

Model of Impacts of
Dilbit and  il in the Salish Sea

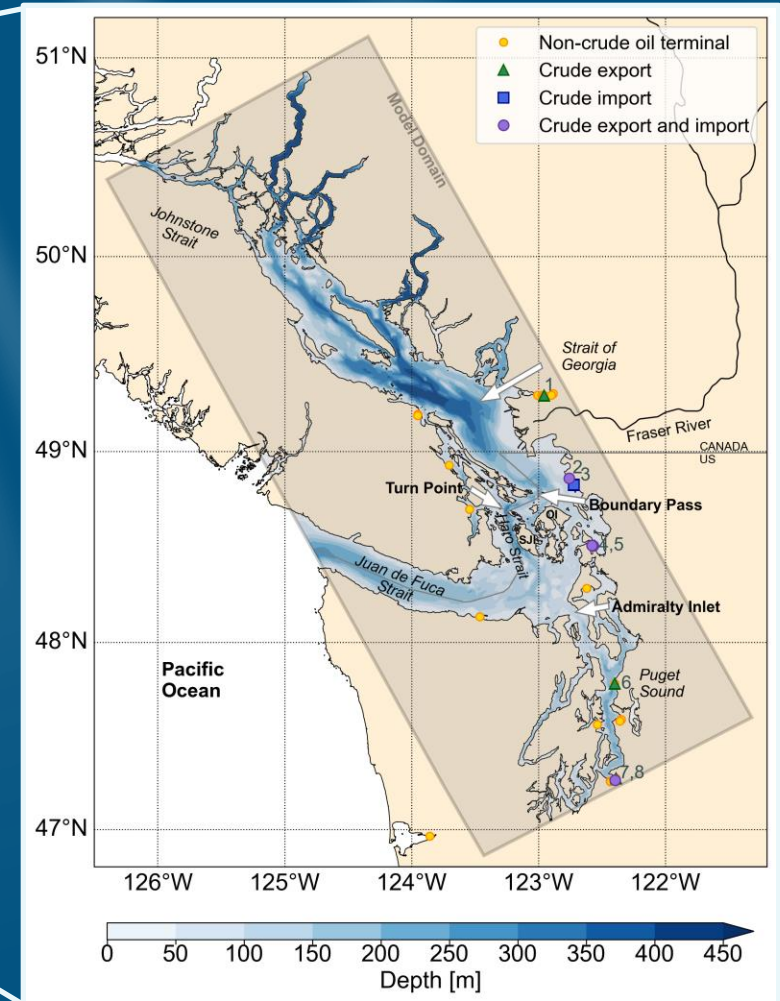
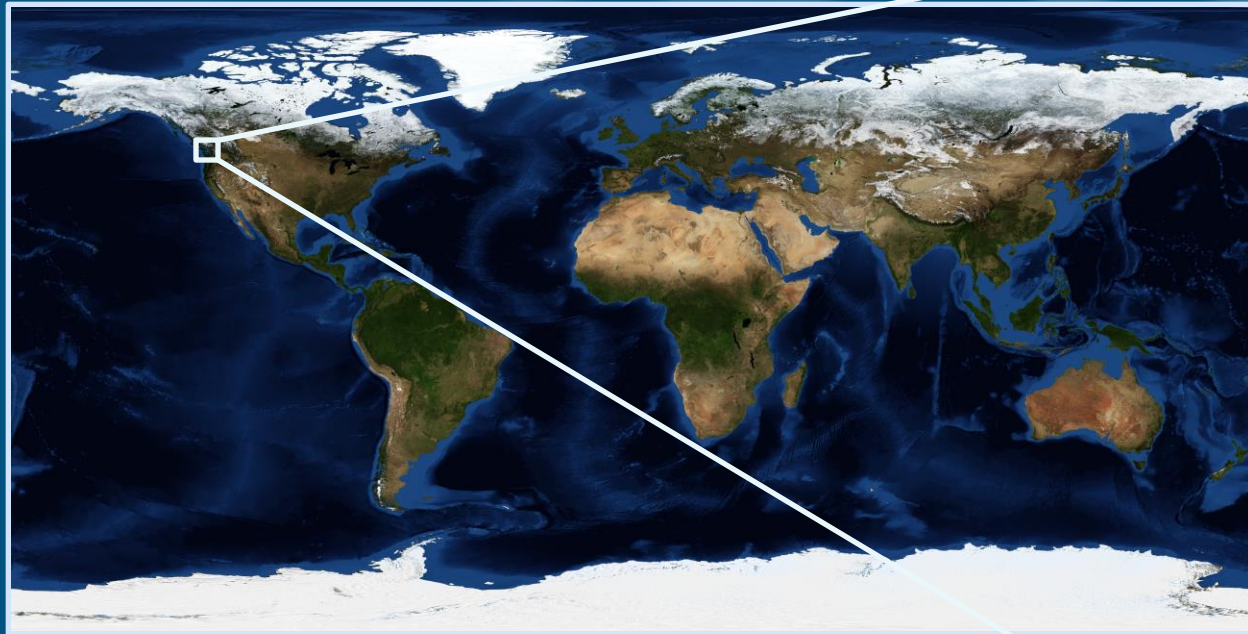
Oil Spill
Modeling

Shihan Li
Xiaomei Zhong

Prof. Haibo Niu

**Presented by:
Dr. Rachael
Mueller**

Planning and preparing for a major spill



A two-part process



[Part 1] Synthesize data into statistics and automate the process of determining major spill scenarios.



[Part 2] Use a suite of numerical models and 10,000 major-spill scenarios to predict most likely outcome(s) from a major spill.



A statistical representation of oil spill fate in the Salish Sea (Part 1)^{*}

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ABSTRACT

Transport of different oil types on land or water varies within the Salish Sea and over time. Although many studies have focused on the future health of Salish Sea ecosystems under a warming climate, we rarely have addressed how market-based dependencies on fossil fuels influence geographic and temporal variations in ecosystem vulnerabilities. This paper aims to help address this knowledge gap with details of oil transport and oil spill risk in the Salish Sea. Part 1 describes the method that we developed to statistically generate individual oil spill scenarios based on ship traffic data, meteorological data, and information on oil spill events. We estimate a set of 10,000 potential spill scenarios, referred to as "likely spill fate", and we compare this likely spill fate to other sets of 10,000 spills. The likely spill fate generated by the likely spill fate model is the most similar to the 10,000 potential spill scenarios. We present the results in a second paper in this special issue, Part 2 (Shihui Li et al., 2021). While Part 1 focuses on the methods and results from statistically generating 10,000 oil spill scenarios, Part 2 focuses on the likelihood of oil spill events in the Salish Sea based on the fate and transport of these 10,000, statistically generated oil scenarios. In this paper, we explore the development of our likely spill fate approach and show that the Salish Sea oil spill risk is regionally variable by oil type and spill volume.

1. Introduction

The Salish Sea is an extensive transport corridor from Vancouver Island and the mainland of the United States (Fig. 1). Despite handling 8,500 ship draft vessel tonnage (14,000,000 t) and around 45 billion liters of oil transport each year (Washington State Department of Ecology, 2015) has led to an expectation of a major oil spill. Most previous oil spill impacts since 1960 have occurred in the offshore oil fields that require public interest (Ulrich et al., 2019) focus on the circumstances of these spills. Given the lack of event in this region, a majority of oil spill risk assessment is documented in grey literature rather than peer-reviewed

^{*} This article is part of a special issue entitled "Oil spill fate and transport".

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A statistical representation of oil spill fate in the Salish Sea (Part 2)

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ABSTRACT

We use a novel approach that combines Automatic Identification System (AIS) ship traffic data, state regional oil spill data, and a suite of numerical models to statistically represent the risk of oil spill fate in the Salish Sea. We use a model of our location does not guarantee the same performance in a different location because the Salish Sea is a dynamically rich environment with distinct regional hydrodynamics that are not captured equivalently well amongst models. A model's performance in one region does not guarantee the same performance in a different region. Indeed, uncertainty in the model products used for wind, waves, and current forcing is a main source of biases uncertainty in oil spill fate predictions (Ulrich et al., 2019). One of the ways to address this uncertainty is by representing oil spill fate as a likelihood of impact based on the aggregated statistics from many runs rather than simply a single scenario.

1. Introduction

The Salish Sea is a semi-enclosed body of water located off the northeastern Pacific Ocean between Vancouver Island and the mainland of the United States and Canada, within the territories of many Indigenous Nations. It supports 8,500 ship draft vessel tonnage (14,000,000 t) and around 45 billion liters of oil transported each year (Washington State Department of Ecology, 2015), and distinct geographic regions with different driving forces of surface and vertical transport. Although the Salish Sea has not yet experienced impacts from a major oil spill, both endangered species as well as a 10 billion dollar revenue in commercial fisheries (Ulrich et al., 2019) are vulnerable to a major oil spill. This paper aims to address this vulnerability by providing information on the likelihood of fate and transport from a major oil spill event within this unique physical environment.

Peer-reviewed research of numerical simulations on oil spill fate in the Salish Sea is sparse and focuses on past oil spill events or spills in particular locations. One case study in Paper Sound showed that two oil spill models (MOCOSIM and COWI) produce similar results

when using the same forcing (Ulrich et al., 2019). The study highlights the importance of tidal currents, winds, and turbulent diffusion on oil spill fate and transport, which translates to missing that validating a model at one location does not guarantee the same performance in a different location because the Salish Sea is a dynamically rich environment with distinct regional hydrodynamics that are not captured equivalently well amongst models. A model's performance in one region does not guarantee the same performance in a different region. Indeed, uncertainty in the model products used for wind, waves, and current forcing is a main source of biases uncertainty in oil spill fate predictions (Ulrich et al., 2019). One of the ways to address this uncertainty is by representing oil spill fate as a likelihood of impact based on the aggregated statistics from many runs rather than simply a single scenario.

In previous studies, statistical representations of oil spill fate were used to determine the likelihood of impacts at a location as we near the locations of potential risk for oil spills by factors typically attributed to serving Canada's West Coast Marine Terminal (Niu et al., 2017) (Zhang et al., 2018), the Engineering Consortium, 2015, location

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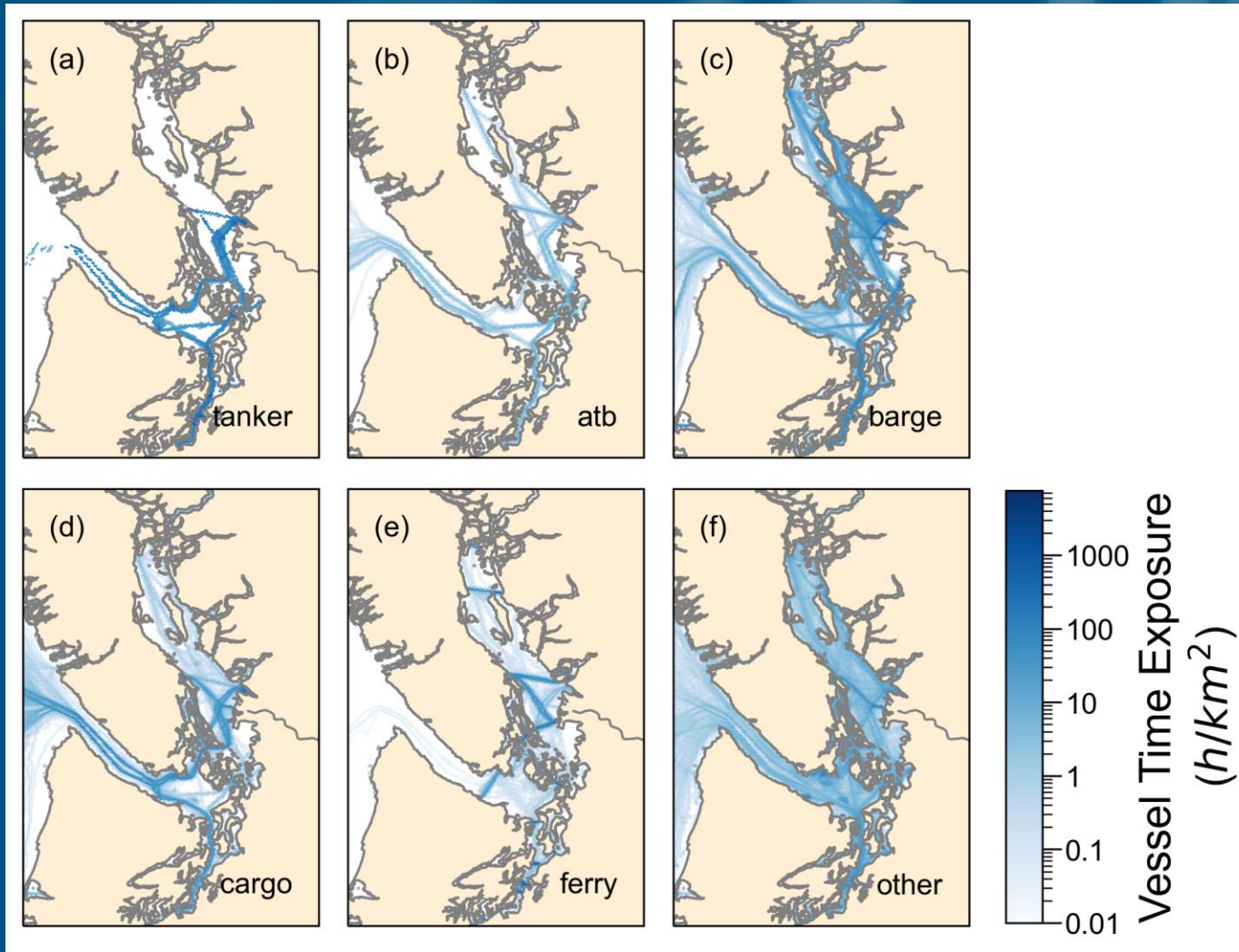
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Links to these manuscripts will be provided in the chat, at the end of the talk

Part 1: 2018 AIS ship tracks



- ❖ Vessel tracks were grouped into six categories and gridded by the vessel time (hrs) per 500x500 m (0.25 km²) cell → Vessel Time Exposure (VTE).
- ❖ These VTE maps were produced for each month and vessel type (plus aggregated).
- ❖ Vessel allowed to carry oil as cargo were: tankers, ATBs, and barges.

Cameron Power

Part 1: 2018 AIS ship tracks



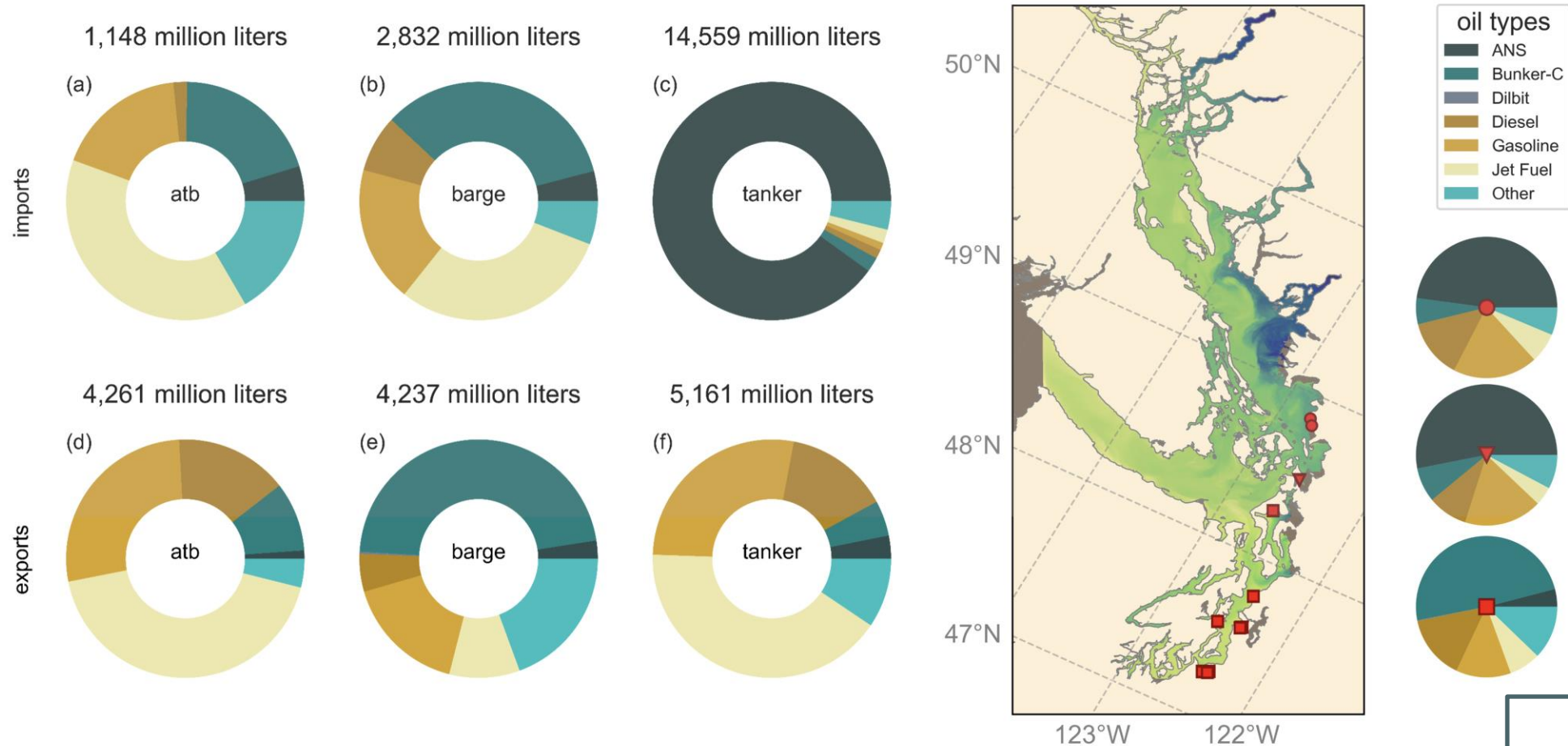
- Randomly select month weighted by Vessel Time Exposure (VTE). Randomly select year (2015-2018), day, and hour, uniformly.
- Weight the selection of spill lat/lon grid box using VTE for that month and choose the sub-grid lat/lon uniformly to get the spill location.
- Randomly select vessel type using the six vessel-type VTEs for that month (and the selected grid cell) to weight the likelihood of selection.
- Use VTE (for that month and vessel type in the selected grid) to weight the random selection of an individual, AIS vessel track → vessel type, vessel length.

- Time
- Location
- Type of vessel
- Maximum oil Capacity*



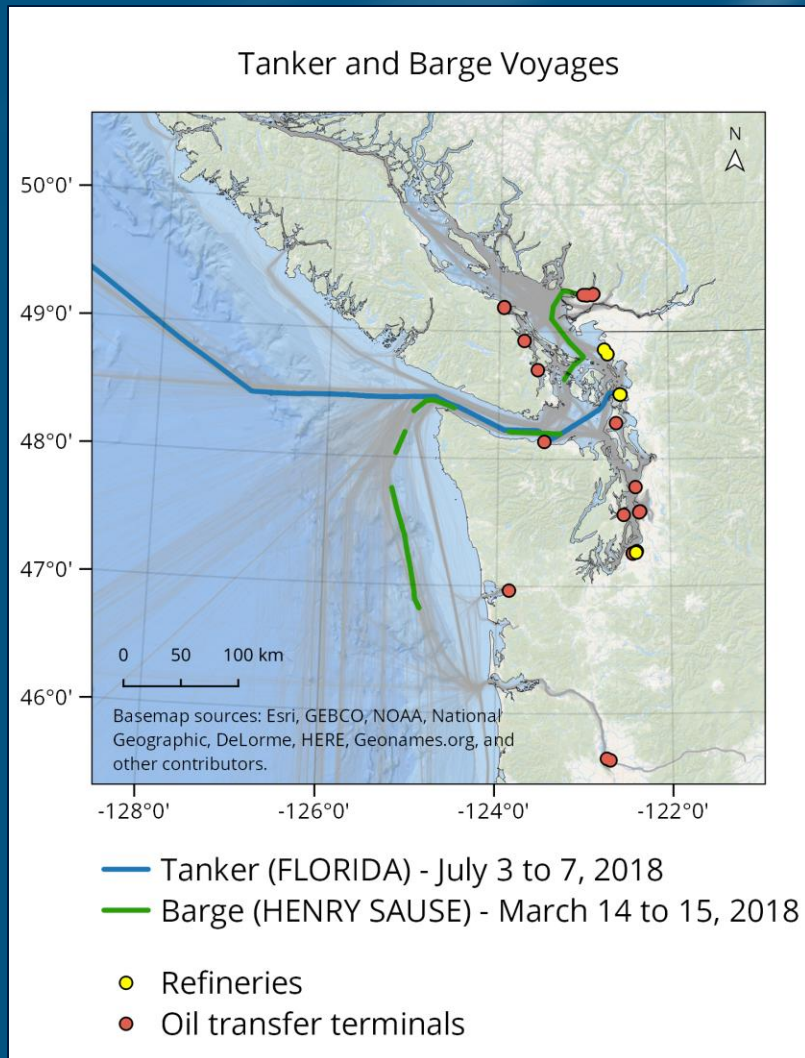
Oil type? Spill volume?

Part 1: Attributing oil types



Part 1: Technology wins and *gaps*

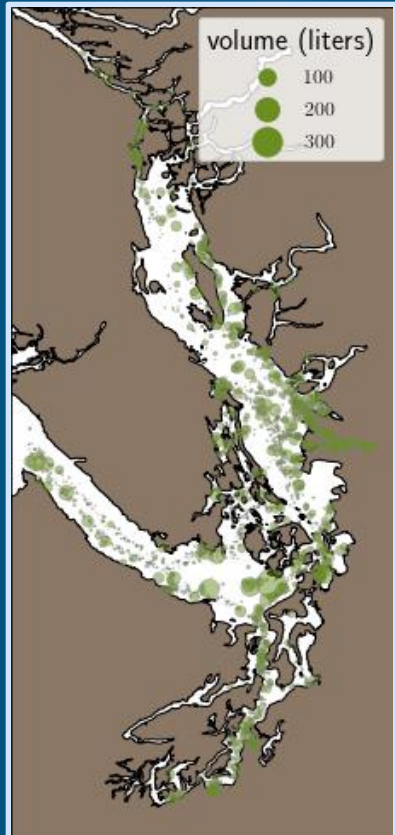
- ❖ AIS ship track data were joined (using a script provided by Casey Hilliard) to attribute “origin” and “destination” but *only ~50% of tank vessel voyages were “complete” (without data gaps).*
- ❖ *There is no public data source for British Columbia marine terminal oil transfers.*



Cameron Power

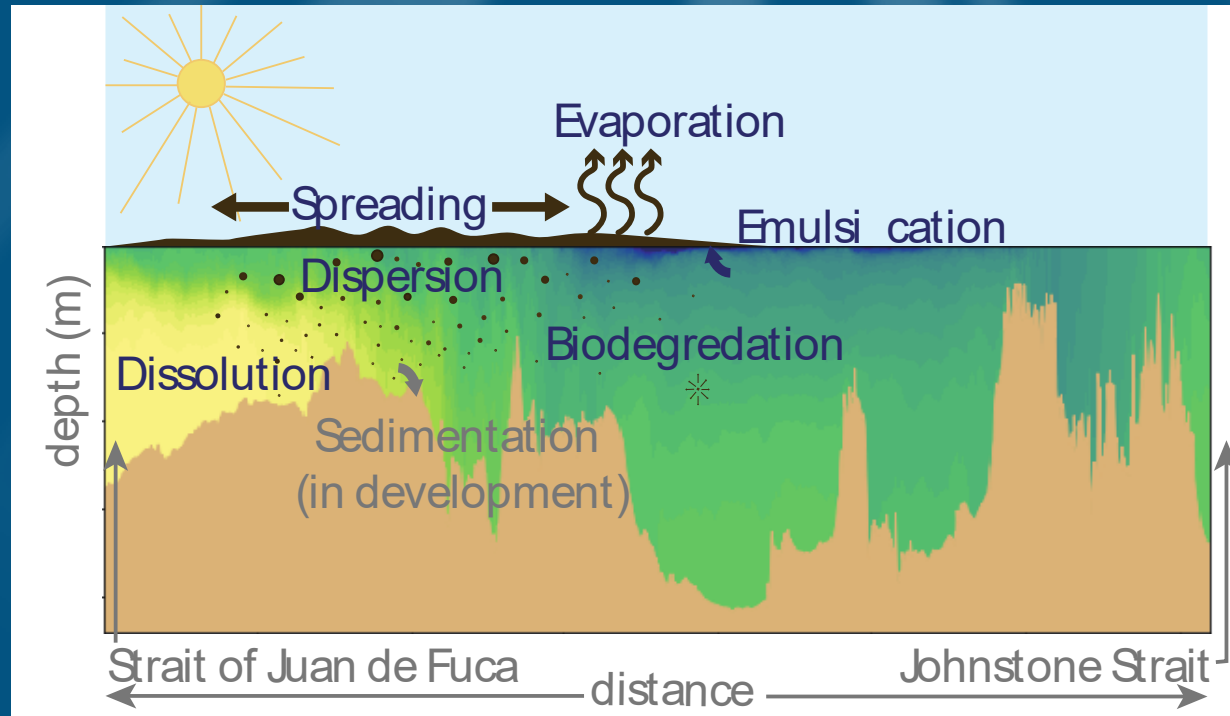
Part 2: 10,000 oil spill scenarios → models

Bunker
(example)



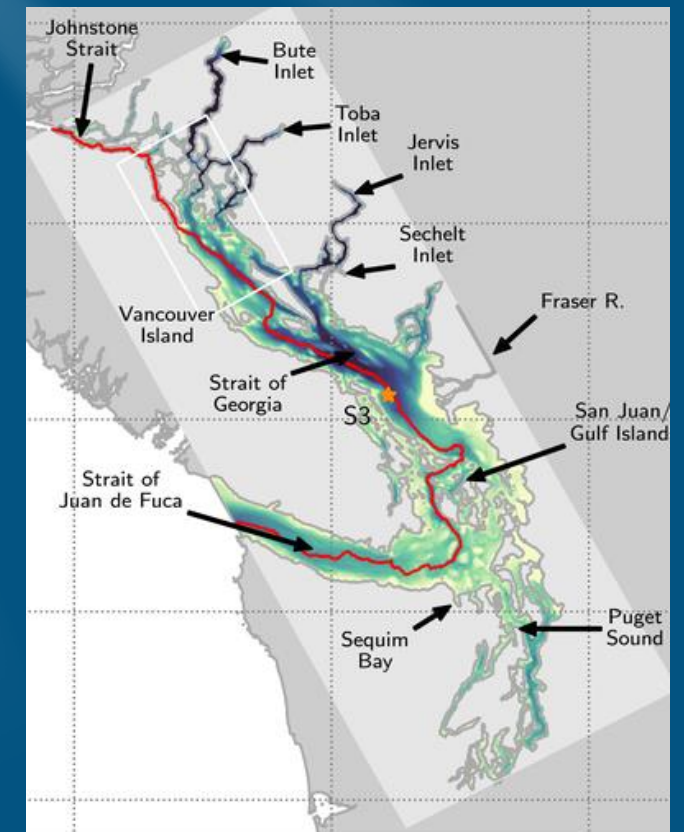
Oil spill scenarios

Salinity cross section
through Salish Sea



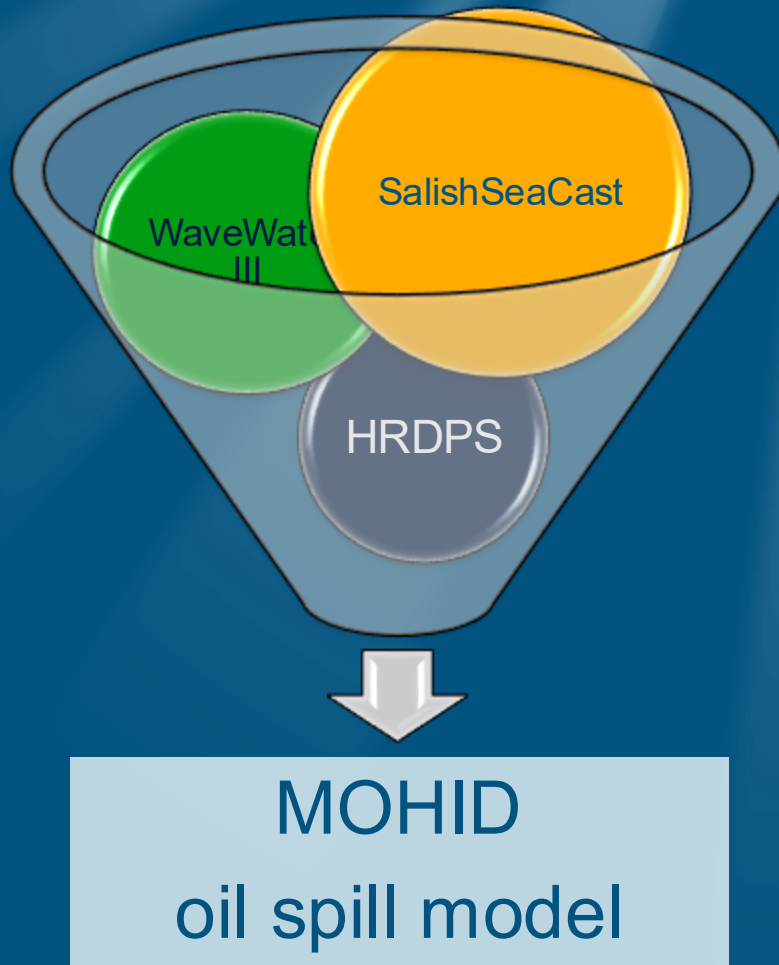
A suite of numerical models

Model domain



Thalweg line (salinity graphic to left)
map from Olson et al. (2020)

Part 2: A suite of models → impacts



❖ SalishSeaCast

- u-, v-, and w-current velocities
- Salinity
- Temperature
- Sea Surface Height

❖ WaveWatch III®

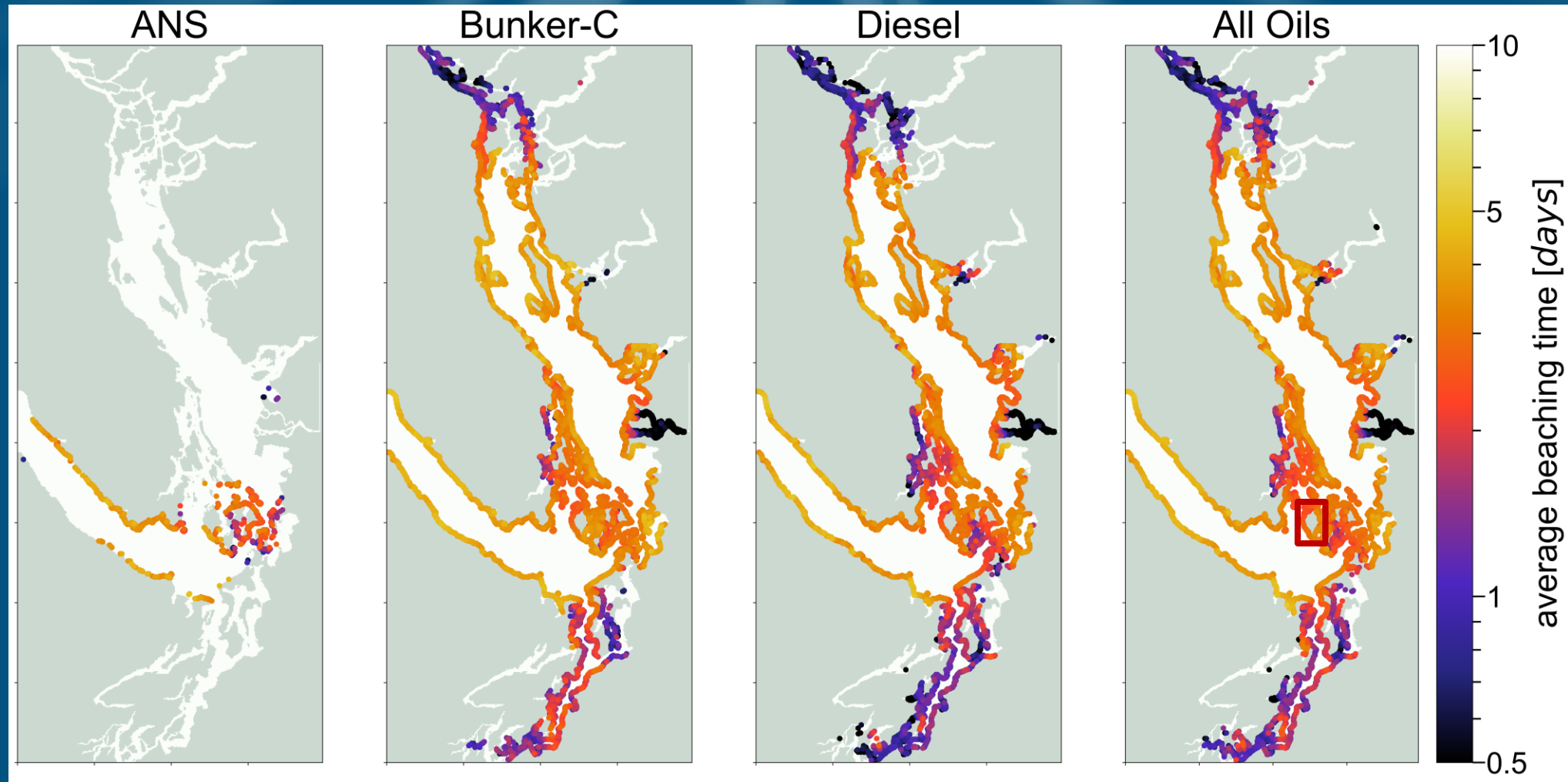
- Whitecap Coverage
- Significant Wave Height
- Mean Wave Period

❖ HRDPS

- u- and v-wind velocities

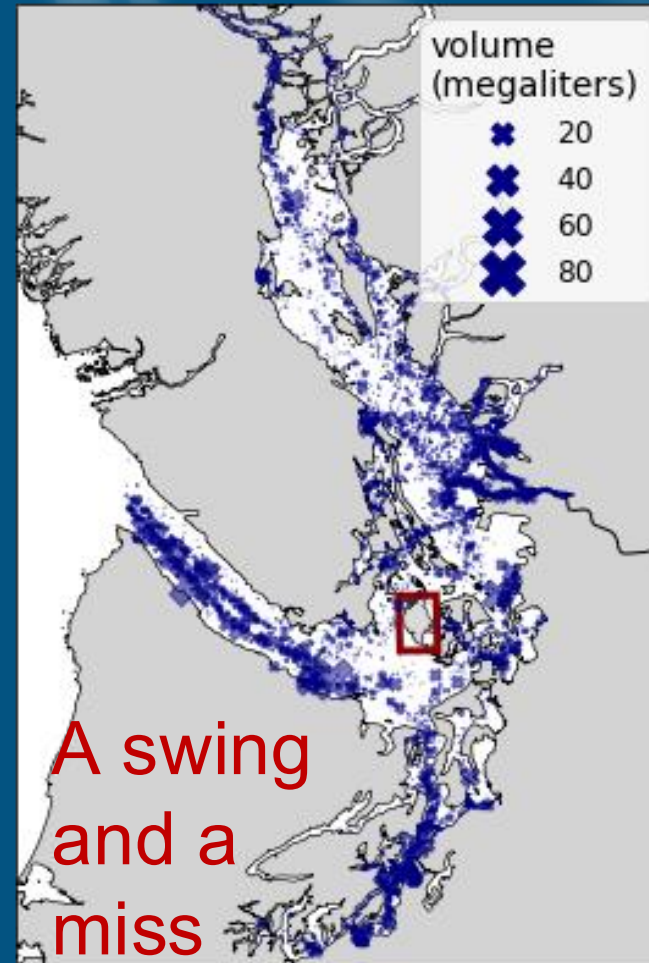
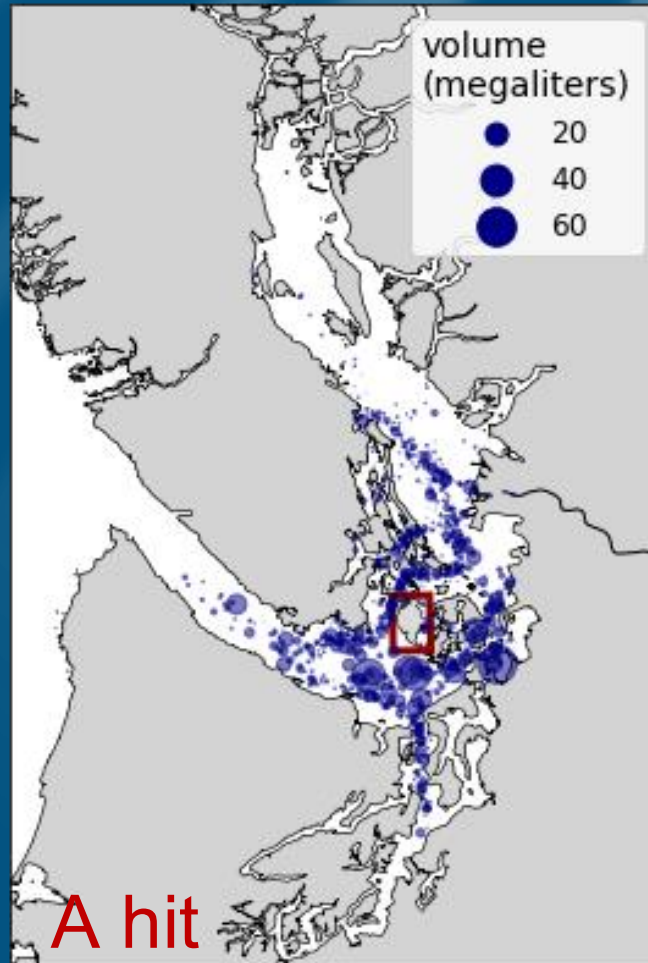
Susan Allen, Doug Latornell, Haibo Niu, Shihan Li, Ashutosh Bhudia, Vicky Do, Ben Moore-Maley, MOAD team

Part 2: Results (2018 traffic)



Susan Allen

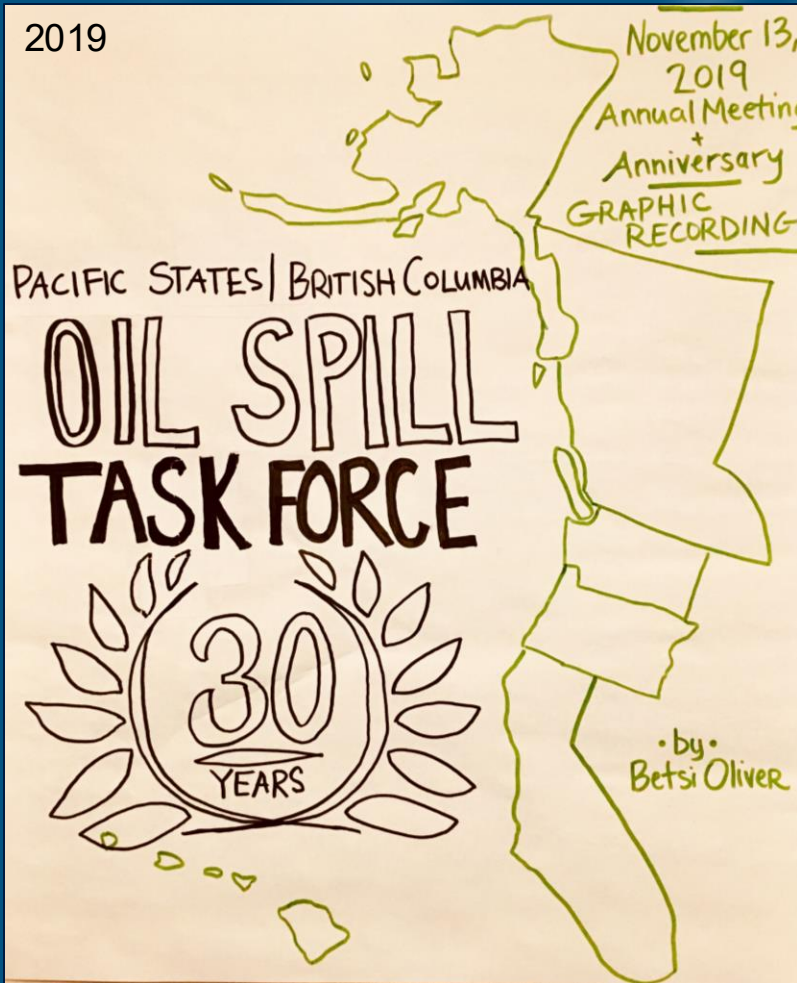
Part 2: Results (2018 traffic)



Part 2: Technology wins and *gap*

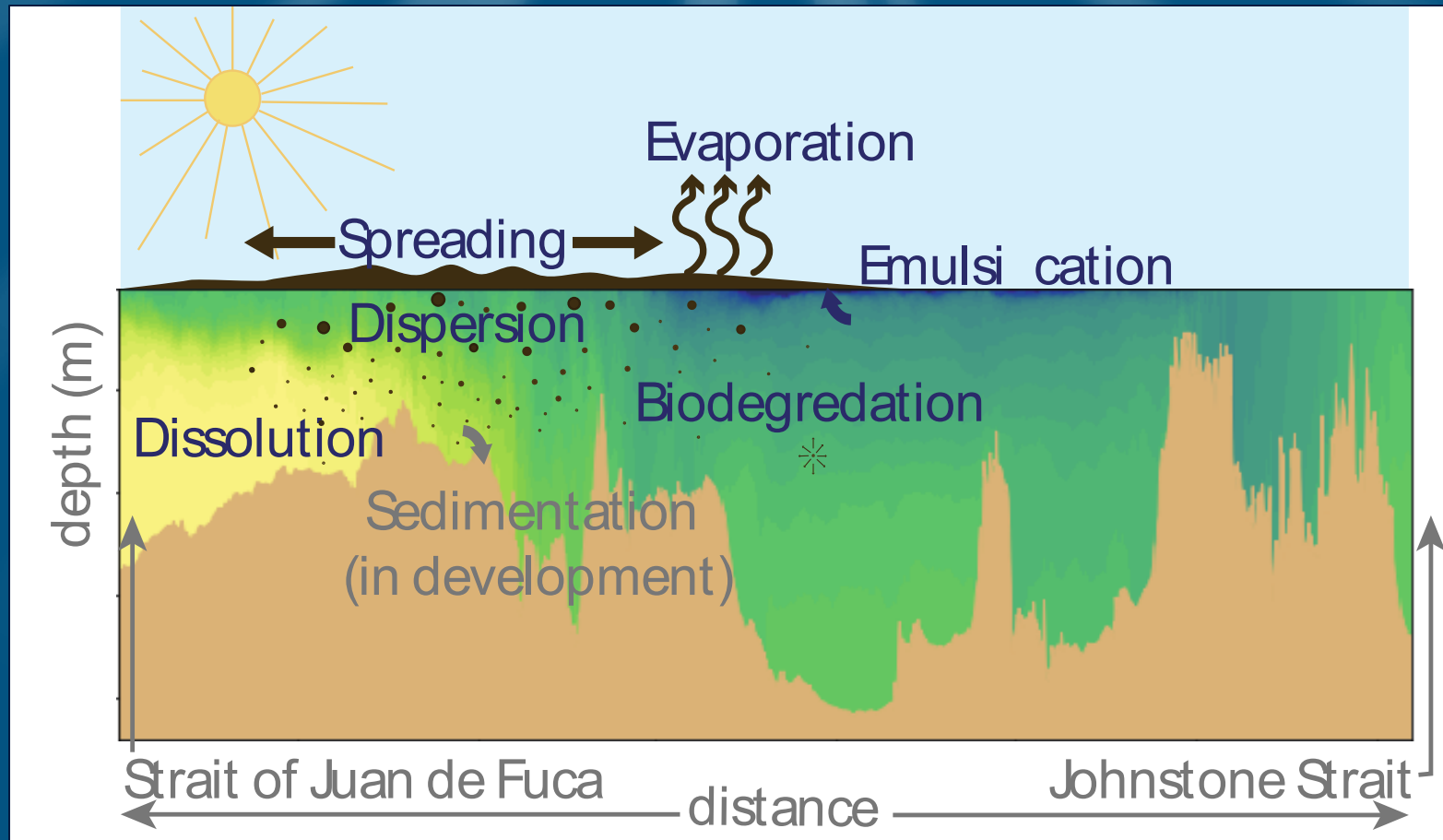
- ❖ First of its kind research study to incorporate both oil transfer and transport data in maps of likelihood.
- ❖ Comprehensive physical models with inter-annual variability in models of:
 - 3D hydrodynamics, wind, and waves.
- ❖ ***Response “ability” not factored into risk. What fraction of the time will wind, waves, tidal currents, and/or foggy conditions inhibit use of response equipment?***

A collaboratory win: You!



- ❖ Thank you Pacific States Oil Spill Task force for creating this resource for resource sharing, relationship-building, and collaboration!
- ❖ Thanks Charlie Constanzo, Ross McDonald, and Bikramjit Kanjilal for sharing knowledge and directing me to ECY for data.

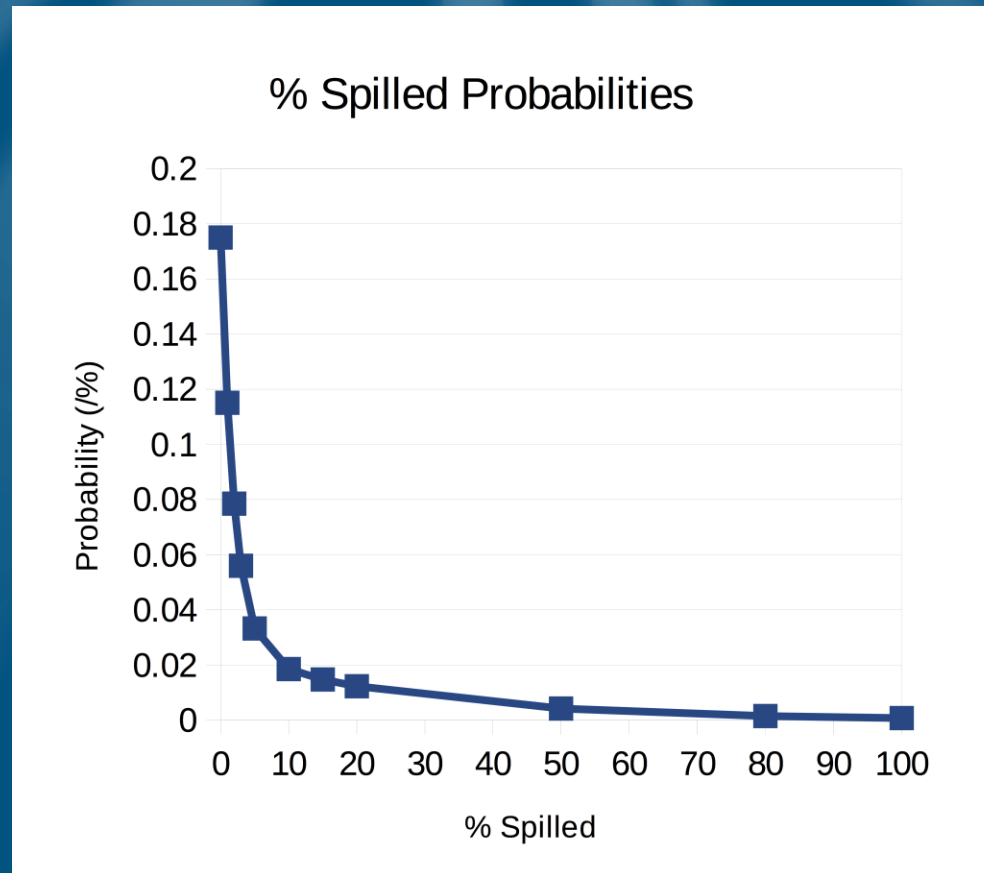
Questions?



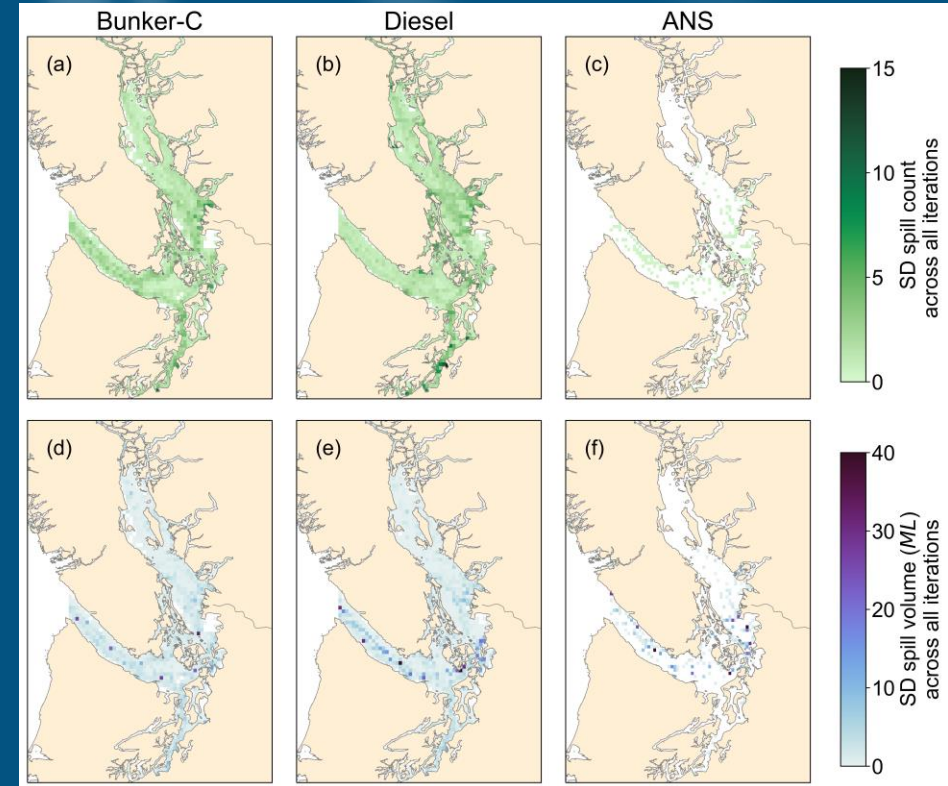
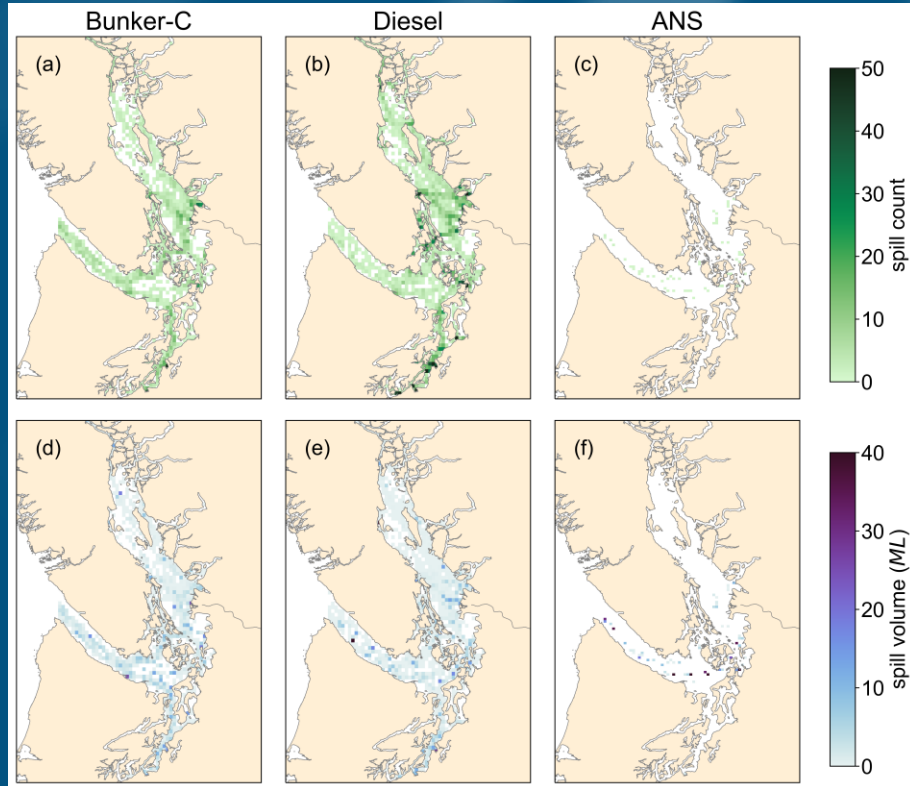
EXTRAS

- ❖ The following slides are extras to have on hand for Q&A

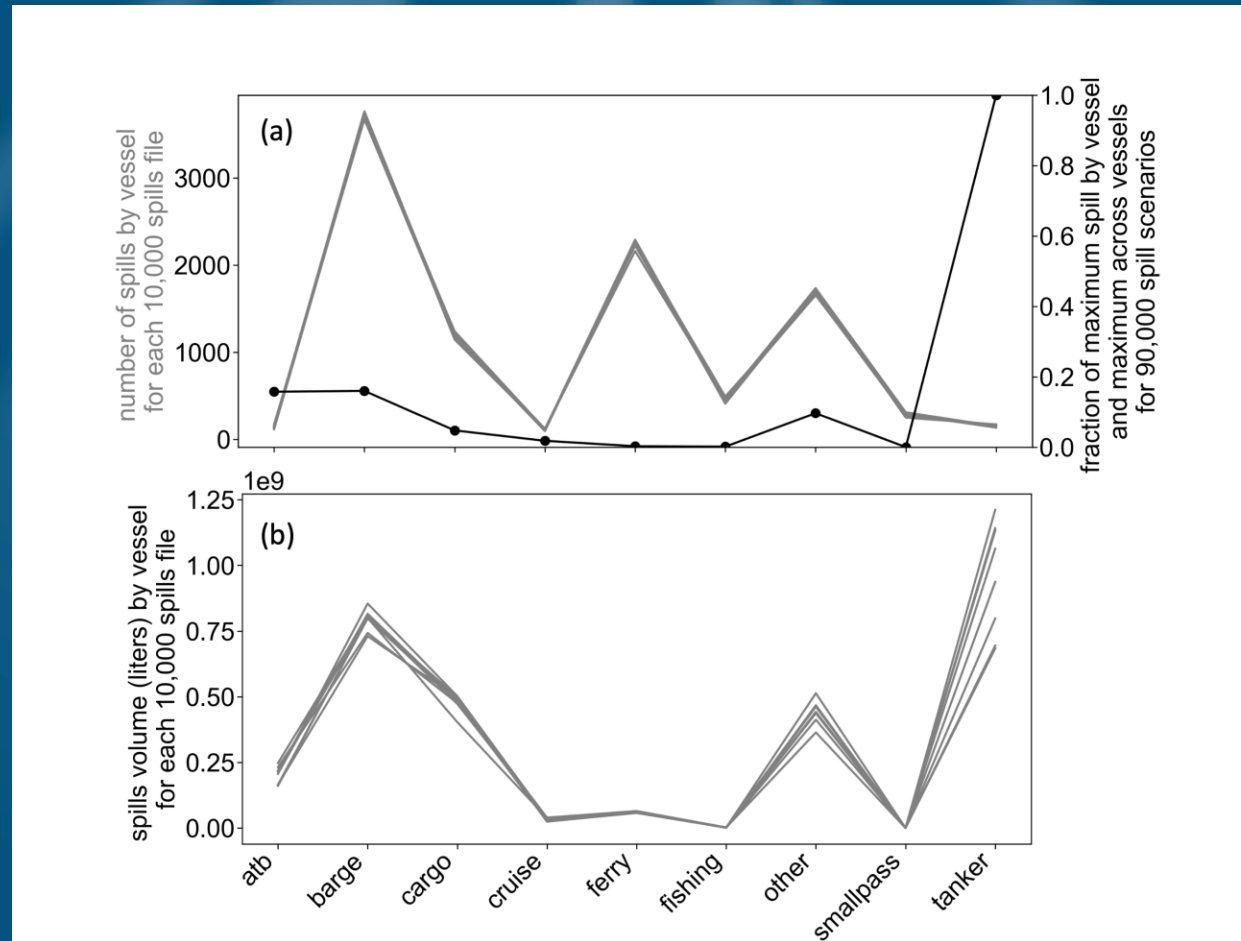
Spill probabilities



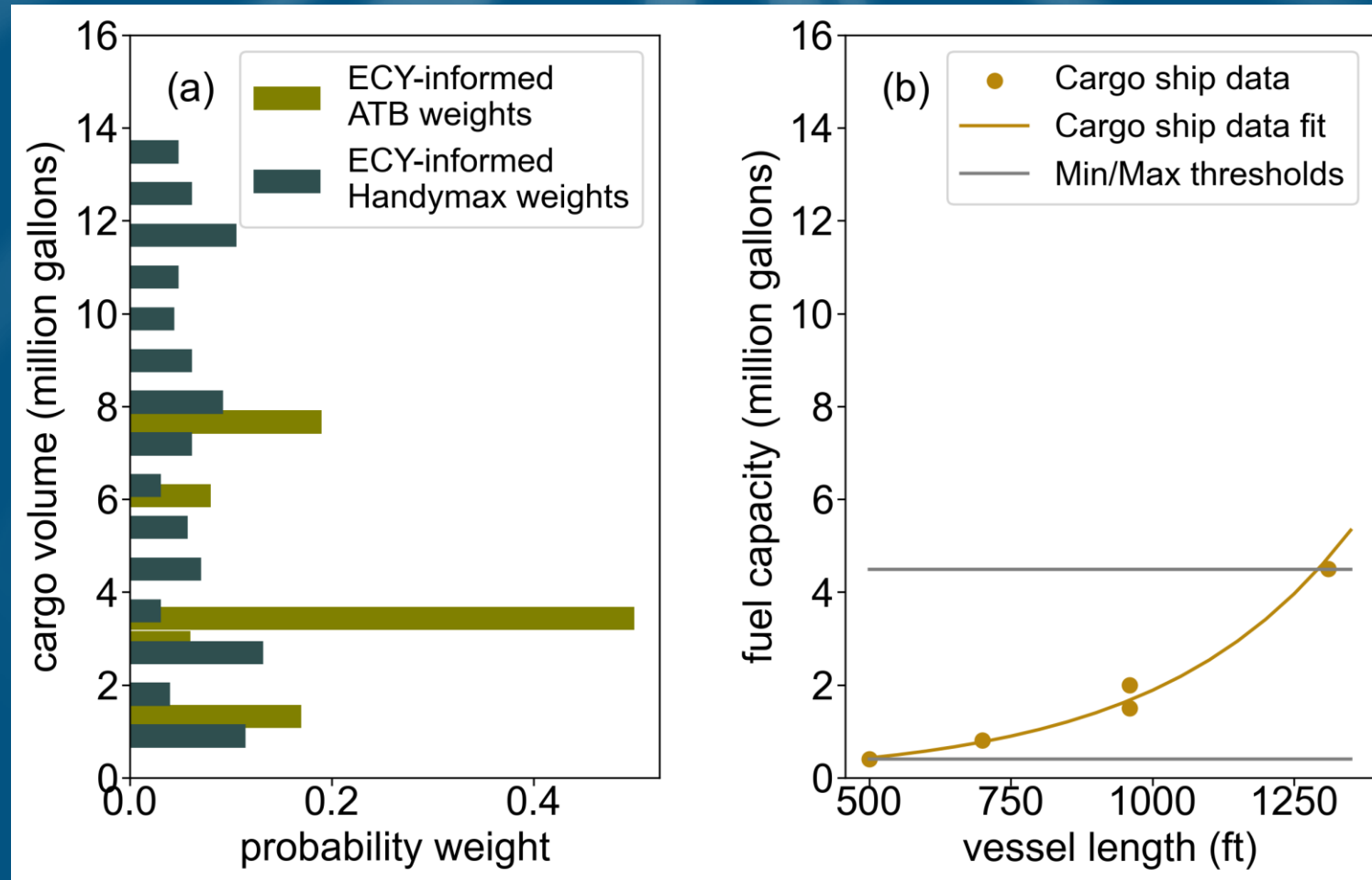
Spill Maps



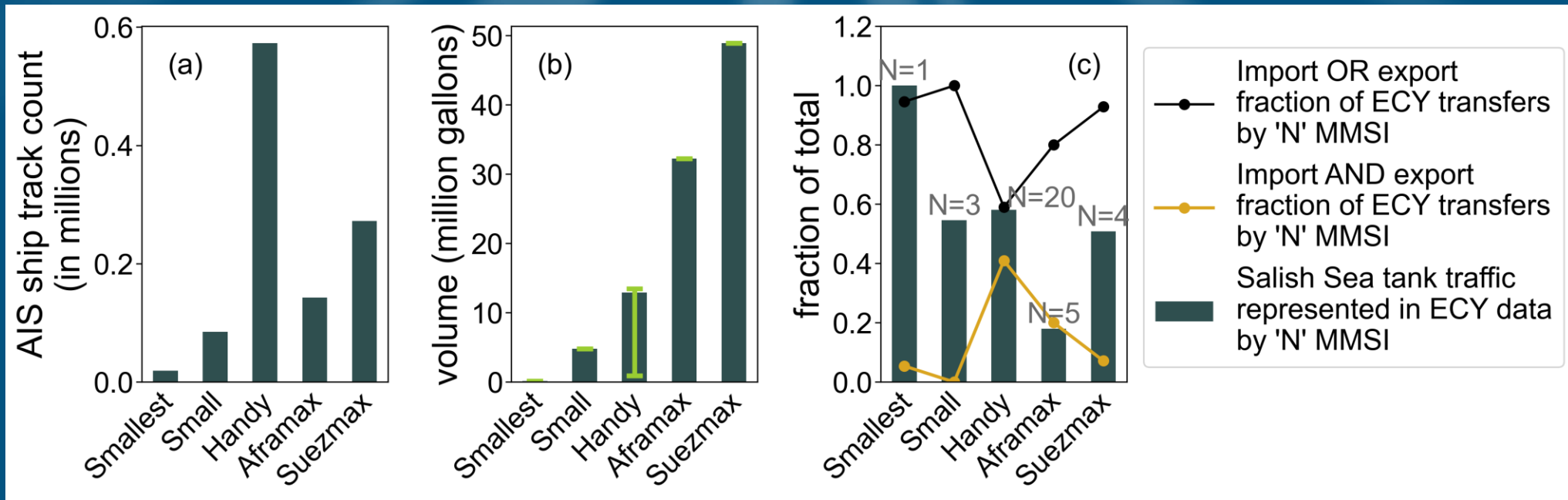
Comparison across nine aggregates of 10,000



Handymax tankers, ATB, and Cargo



Tanker traffic capacity assessment



Likelihood of oiling (Bunker v. ANS)

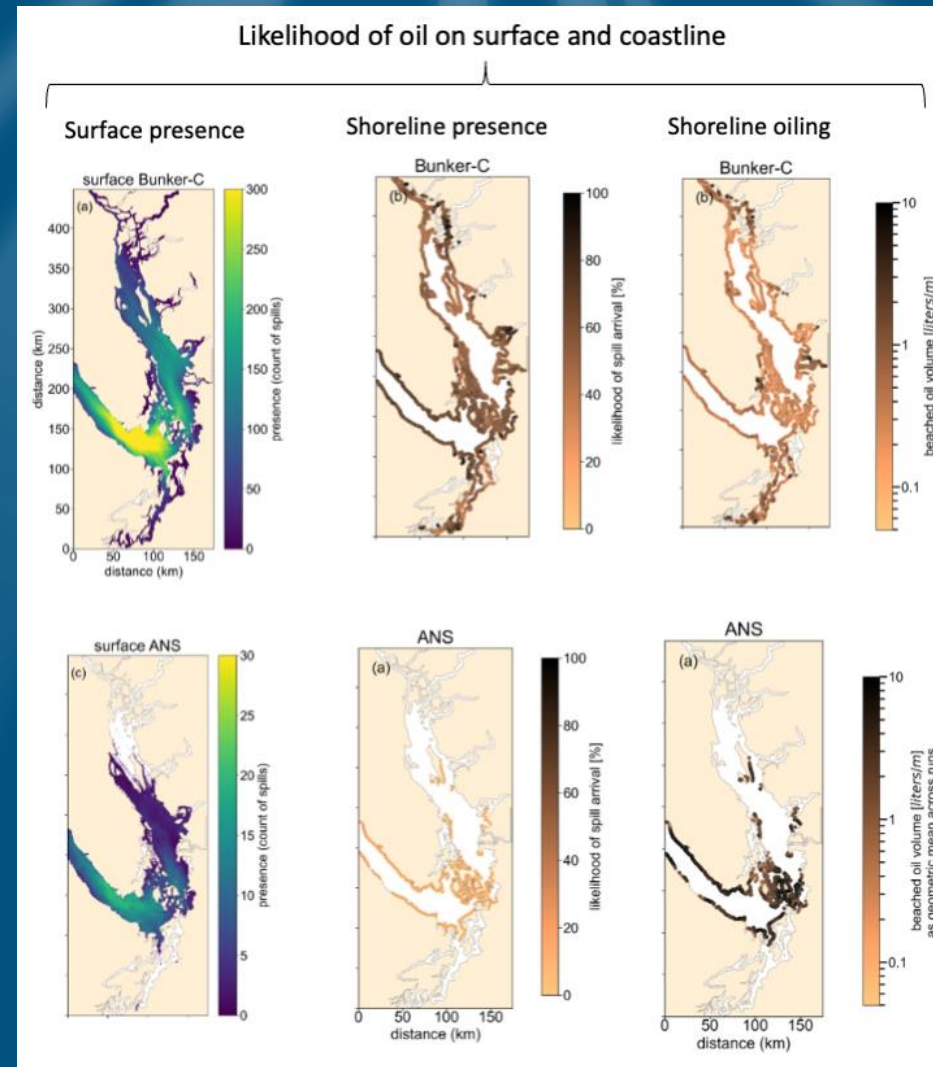


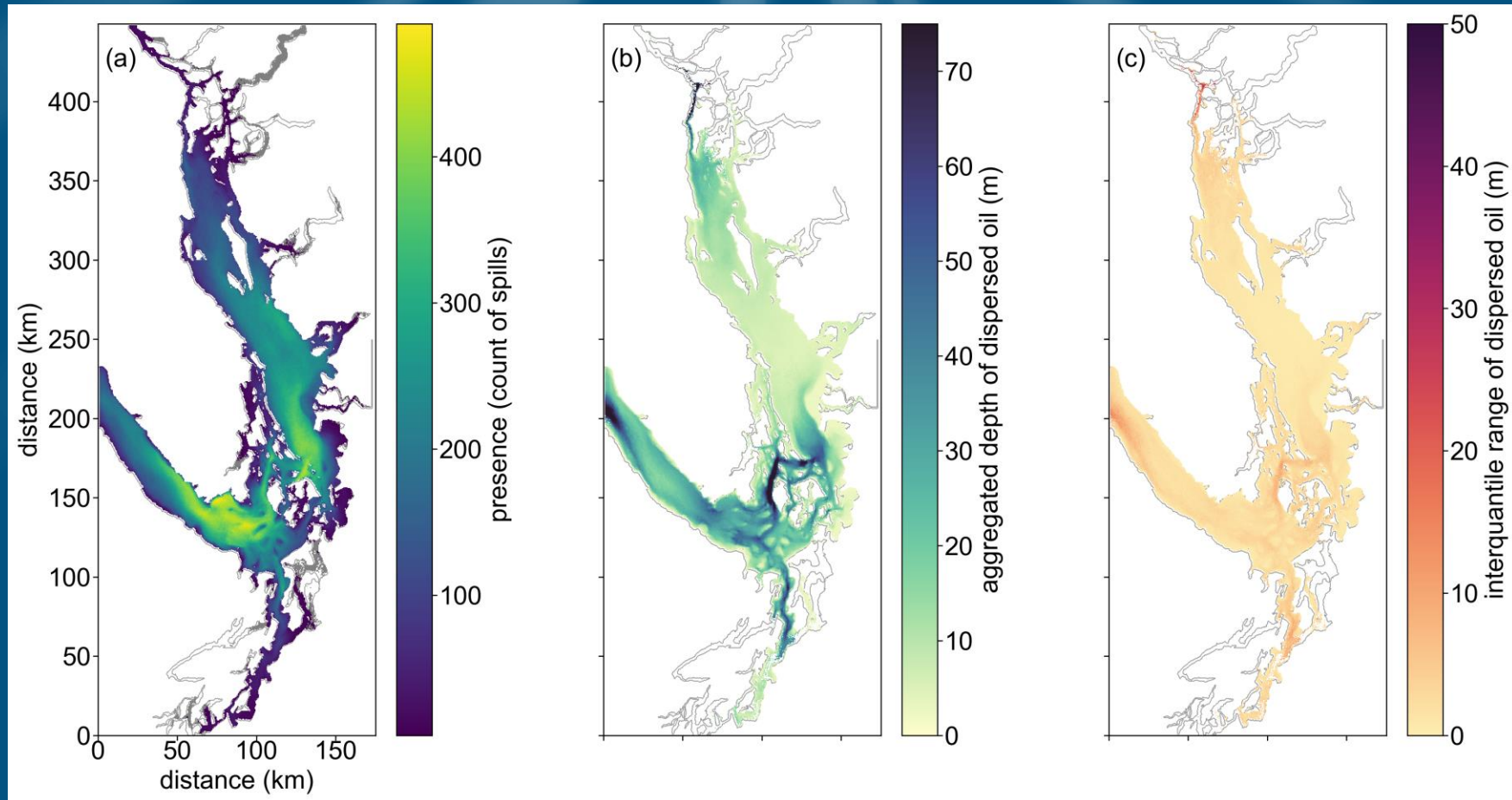
Figure 10 consists of two rows of four maps each, showing the results of oil spill simulations for four different oil types: ANS, Bunker-C, Diesel, and all oils. The maps are arranged in a 2x4 grid. The top row displays the 'likelihood of spill arrival [%]' on a color scale from 0 (light orange) to 100 (black). The bottom row displays the 'beached oil volume [liters/m] as geometric mean across runs' on a logarithmic color scale from 0.1 (light orange) to 10 (black). Each map has a vertical axis for 'distance (km)' from 0 to 400 and a horizontal axis for 'distance (km)' from 0 to 150. The maps show the coastline of the study area and the distribution of oil spill likelihood and beached oil volume. The 'all oils' map in the top row shows the highest likelihood of spill arrival, with large areas of black and dark brown. The 'all oils' map in the bottom row shows the highest beached oil volume, with large areas of black and dark brown. The 'ANS' map in the top row shows the lowest likelihood of spill arrival, with mostly light orange and yellow areas. The 'ANS' map in the bottom row shows the lowest beached oil volume, with mostly light orange and yellow areas.

Extra: Oil transfer data



G	P	Q	R	W
Deliverer	Product	TransferQtyInGallon	TransferType	DelivererTypeD
Maxum (Rainer Petroleum)	DIESEL/MARINE GAS OIL	2,500	Fueling	Facility
TLP Management Services LLC (TMS)	DIESEL/MARINE GAS OIL	546,000	Cargo	Facility
POLAR RESOLUTION	CRUDE OIL	12,390,000	Cargo	TANK SHIP
Phillips 66 Ferndale Refinery	BUNKER OIL/HFO	1,176,000	Cargo	Facility
SKS SEGURA	CRUDE OIL	8,820,000	Cargo	TANK SHIP
ITB ISLAND TRADER	GASOLINE	966,000	Cargo	TANK BARGE
ITB ISLAND TRADER	GASOLINE	1,680,000	Cargo	TANK BARGE
Shell Puget Sound Refinery	BUNKER OIL/HFO	3,150,000	Cargo	Facility
Shell Puget Sound Refinery	DIESEL/MARINE GAS OIL	3,360,000	Cargo	Facility

Oil at depth



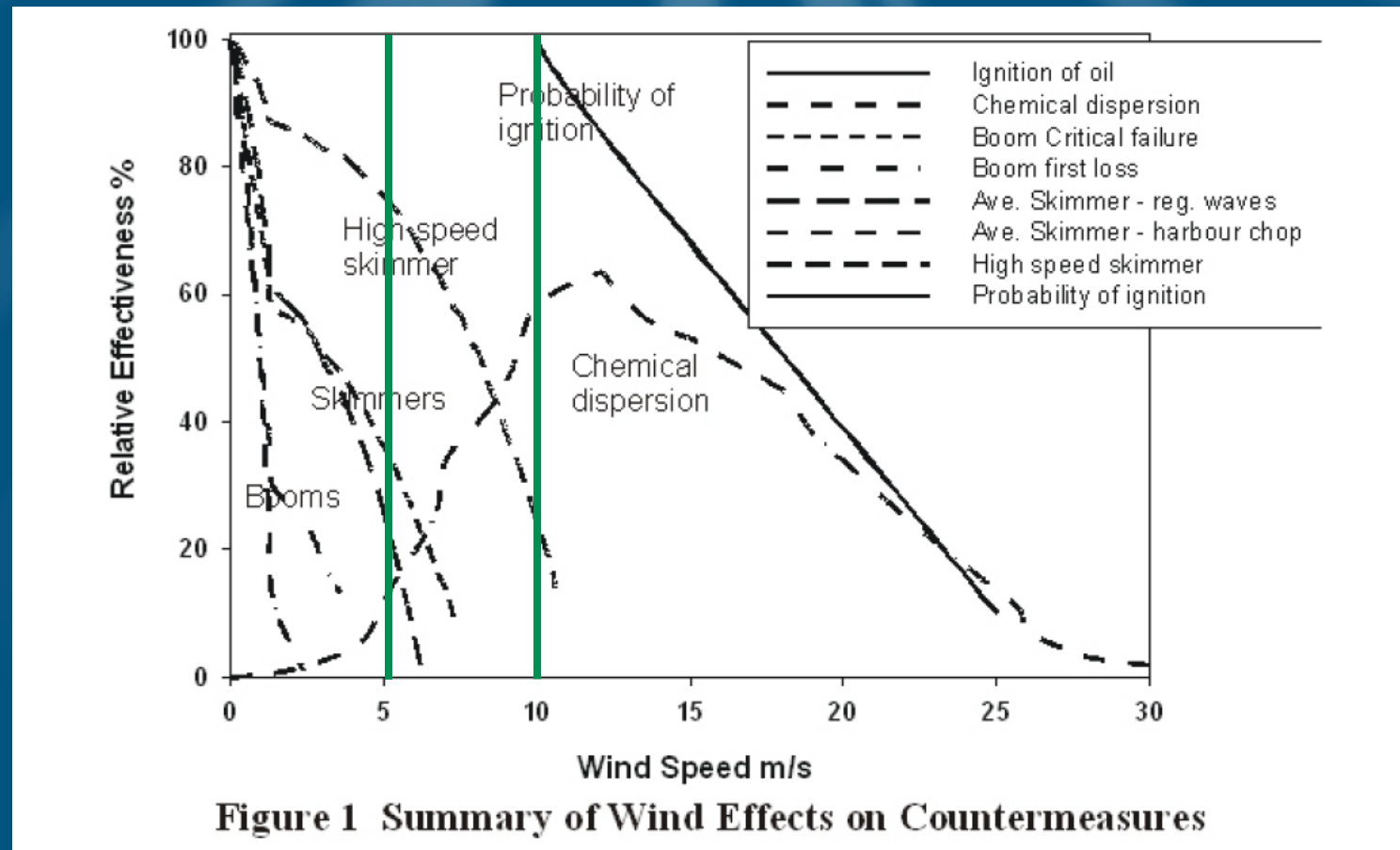
Extra: Oil transfer data

- ❖ **ANS:** CRUDE OIL, BAKKEN, Westridge Exported CAD Conventional
- ❖ **Bunker-C:** BUNKER OIL/HFO
- ❖ **Dilbit:** BITUMEN OIL (DIL OR SYN)
- ❖ **Jet Fuel [Diesel]:** JET FUEL/KEROSENE
- ❖ **Diesel:** DIESEL/MARINE GAS OIL, BIODIESEL, DIESEL LOW SULPHUR (ULSD)
- ❖ **Gasoline [Diesel]:** GASOLINE
- ❖ **Other [Bunker-C]:** ETHANOL, LUBE OIL/MOTOR OIL, Cat Feed/VGO, CUTTER STOCK, OILY WATER MIXTURE, WASTE OIL, Z-OTHER, HYDRAULIC OIL, OILY WASTE, USED OIL, NAPHTHA, EDIBLE/VEGETABLE OIL, DECANT OIL, NONENE, ASPHALT/CREOSEOTE

UPPER CASE: Indicates names used in the Department of Ecology Database

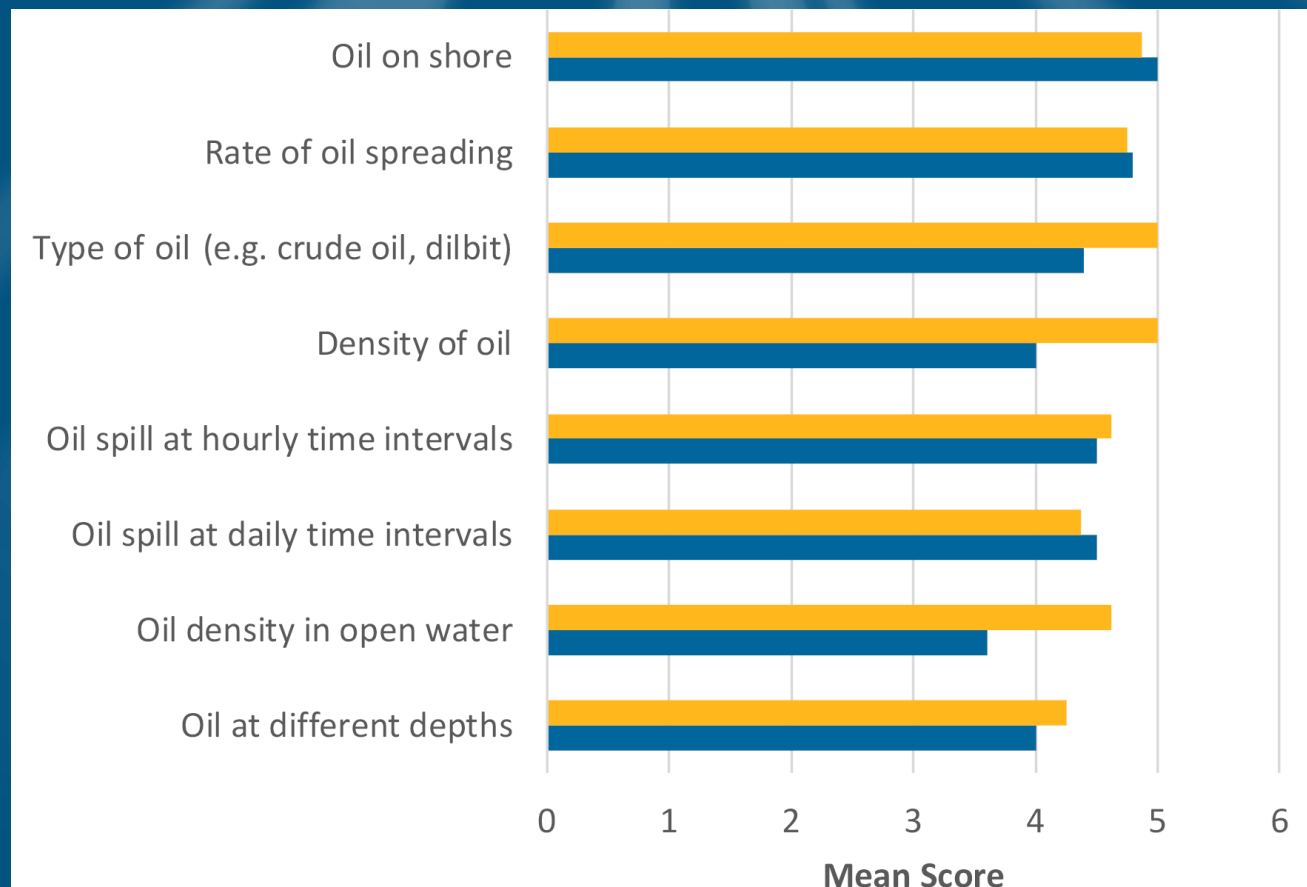
Blue: The category assigned in our monte-carlo

Extra: Wind vs. response ability



Environment Canada 2004 report by Merv Fingas

Survey results



Technical

Community