Ocean impacts on vessel and emergency response operations

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Contents

Part 1 vessel operations – Andy Keane

- Introduction
- Personal safety challenges and fatigue
- Vessel safety
- Weather routing
- Tanker and port operations

Image: Youtube

Image – Amoco Cadiz

Part 2 spill response – Maria Hartley

- Preparedness - oil fate and effects, modelling, seeps and slicks
- Response – trajectory modelling, response technology effectiveness
- Restoration – resources at risk, impact monitoring and restoration

Introduction

Around 80% of the volume of international trade in goods is carried by sea.

11 billion tonnes were transported by sea with a world fleet of 95,402 Ships

The largest sectors by vessel and tonnage were Bulk Carriers (Dry) & Oil Tankers (Wet)*

Extreme weather events and changes in sea levels can impact:

- Safety of vessels when navigation near extreme weather
- Safety of crew onboard vessels
- Cargo loss
- Functioning of shipping and port operations

*UNCTAD report 2019

Image: Shell Library

Image: Shell Library

Personal safety

Accidents to crew members can have grave consequences, there are limited medical facilities onboard and ships can be far from the nearest hospital. The ships movement can contribute to these in a number of ways;

- Slips trips and falls
- Cargo/stores shifting and the need to re-secure this and putting crew in danger
- Working on open deck vessels and the risk of being washed overboard

Image: Flickr.com

Images: Twitter

Fatigue

- Vessel's motion can impact on sleep and rest – seafarers adapt routines to take into account vessel movement.
- Could data be used to analyse the effect of the sea on the vessel to determine when weather induced crew fatigue will occur?

Vessel safety – factors to consider

- Weather and seas can directly impact the safety of the vessel through reduced visibility, reduced manoeuvrability and damage to navigational equipment.
  - Vessels carry limited spares
  - Weather forecasts and sea conditions can vary quickly
  - Automatic steering aids are not so reliant in heavy weather
  - Navigational marks can become damaged and obscured

- Weather can have an indirect impact on navigational safety
  - Fuel tanks can be compromised and the vessel can loose power and propulsion
  - High seas can impact manoeuvrability and sometimes 50% power is required just to stay in the same location
  - Ingress of water to cargo resulting in stability and capsize
  - In extreme conditions vessel can be lost due to hull failure

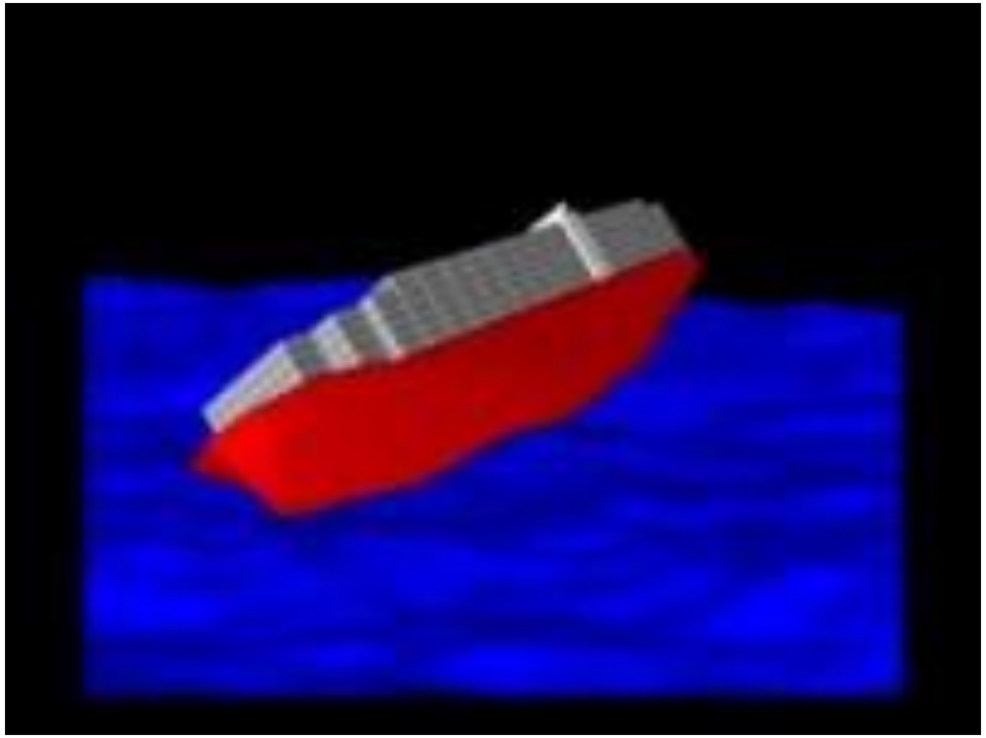
Image: Shell Library

Image: BBC.co.uk

Braer Spill - 1993

Vessel safety - rolling

- Vessel are designed to withstand extreme weather conditions however there are some aspects which can have significant impacts;
- Synchronous rolling
    - When the rolling period of the vessel is equal to the period of encounter of the waves, boosting the roll of the vessel with each wave, finally can result in capsize
    - The rolling period depends on the GM (metacentric height) of the vessel and the angle of contact with the wave, the worst being directly on the beam
- Synchronous pitching
    - When the pitching period of the vessel equals the period of encounter of the waves
    - Can result in breaking waves and 'scooping' of water on the bow, or propeller exiting water



Video: Youtube.com

Vessel safety

- Practical ways vessels prevent damage
  - Avoid seas on the beam or astern
  - Alter course to have the sea slightly off the bow
  - Reduce speed to adapt to wave length and also to reducing structural damage
  - Turn the vessel as quickly as possible during more moderate waves in the pattern
  - Keep all loose items secured and vent pipes closed
  - Be aware of water depth, wave and swell height and draft of the vessel as you could be getting near the seabed....

  - Stay away from the bad weather and be prepared for the unexpected like Rogue waves

Image: NZ Defence Force

Image: Google

Weather routing

Based on complex data and models that have been developed over a number of years

Weather routing will not only depend on the predicted weather but also the type of vessel and its available power.

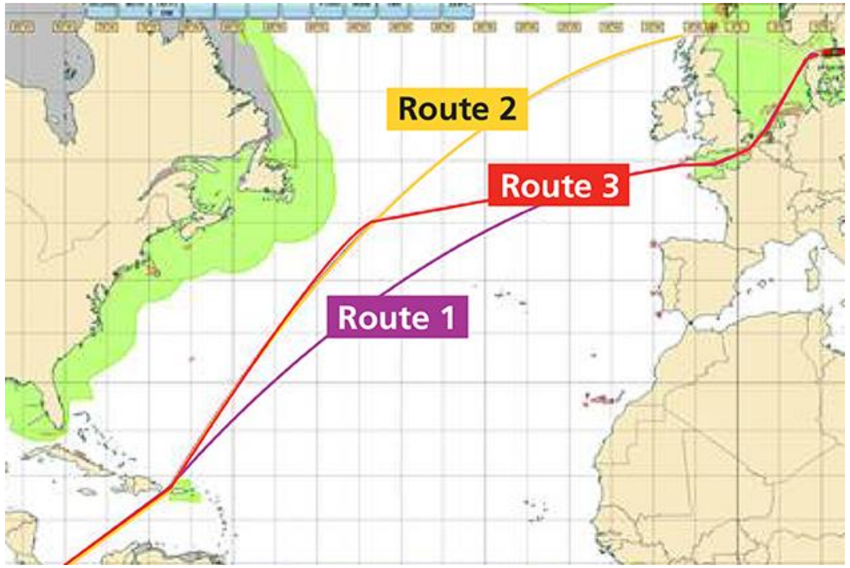


Image: StormGeo

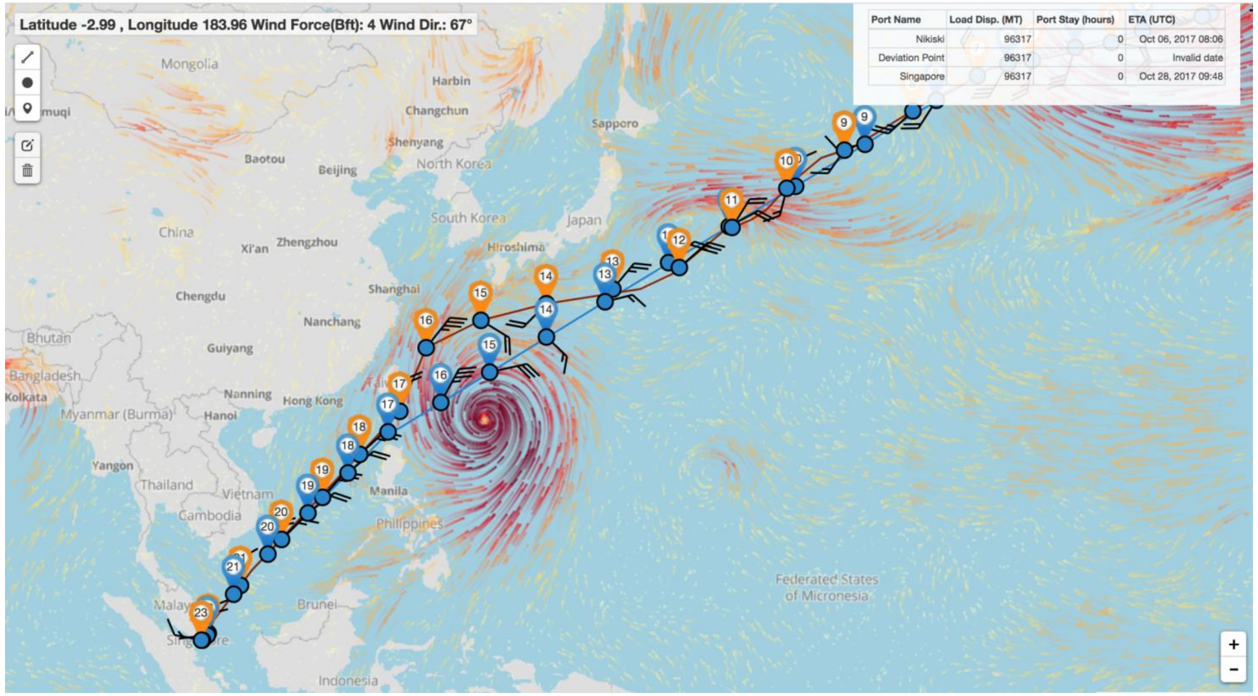


Image: Shell/Boss Training slides

Advantages for vessel operators of weather routing include; decreased delays, reduced fuel consumption, reduced emissions, reduced heavy weather damage risk, and increases the likelihood of all cargo arriving safely

Shell have achieved average fuel savings in a range of 6-8% for voyages over 4 days

Weather routing

Weather routing is a vital tool in avoiding heavy weather and can help reduce emissions.

The more accurate the sea information (swell height and length, wind waves) the more service providers routing suggestions can improve.

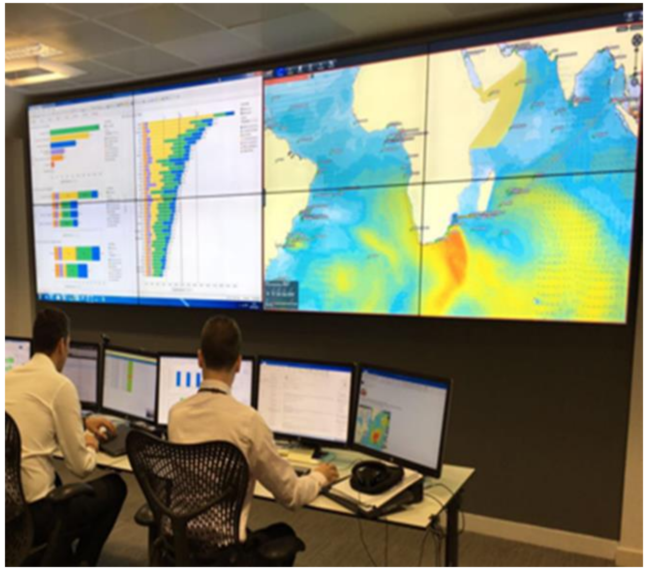


Image – Shell Your Road Shipping Data Centre

Image – Wallenius Marine

Wind assisted commercial vessels are being designed and constructed by a number of parties and weather routing will need to adapt to providing sail vessel friendly solutions that balance wind positive impact with sea state negative impact.

Tanker operations

- Ship to ship operations – two vessels moored together in open waters can be impacted by wave frequency and have a rolling period opposite to each other. Tank measurements and sampling can also be challenging in heavy seas

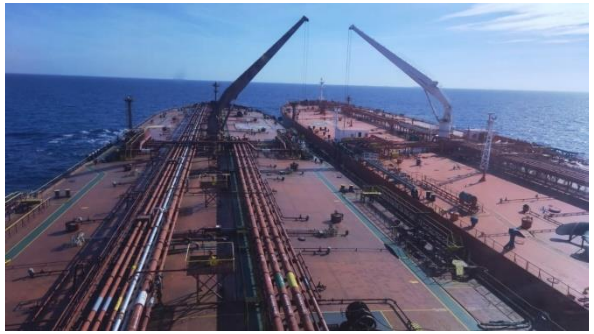


Image: Wikipedia

Image: Safety4sea

Image: Google

- Pilots - most ports rely on Pilots to navigate vessel safely in the harbour areas, they board outside port, if the Pilots cannot board the Port will have to operate in a restricted mode.

Video: Youtube – Marine online

Bulk cargo losses

- Container vessel losses
  - Average number of lost 1382 Per Annum*
  - Cases of 342 lost from one vessel in 1 storm
  - Catastrophic events account for half of all losses

- Water ingress to bulk cargo like grain or cement
  - Causes cargo to solidify and increases weight
  - Water can cause the cargo to act like liquid reducing stability

- Heating considerations in colder climates
  - Heavy seas and excessive motion will increase thermal loss to product
  - Warmer seas can cause expansion of products in tank and overflow

Image: oceannavigator.com

Cemfjord incident 01/2015

Image: UK P&I club

*Shipping World council report 2020

Impacts of climate on ports

Climatic Factor	Impacts
Mean Sea Level Storm Surges/Waves Changes in wave direction	Damage to port infrastructure. Impact on supporting infrastructure like railways/roads Increased maintenance/construction costs. Change in currents and flows resulting in shifting sand/channels requiring dredging and Navigational changes. Lack of water depth resulting in reduced capacity for vessels. Long Waves can have catastrophic effects on moored vessels
Higher Temperatures	Asset lifetime reduction. Potential for more worker health issues. More energy required for cooled warehouses, New sea routes available in artic areas. Less snow and melt reducing river levels and inland port connectivity
Rain and Fog	Increased levels of reduced visibility will reduce port efficiency. Excessive rain will result in more frequent flooding, more damage to equipment and damage to infrastructure.
Wind	More likelihood of port closure due to high winds reducing productivity. Increased safety risks during mooring and manoeuvring. Increased Tug capacity maybe required

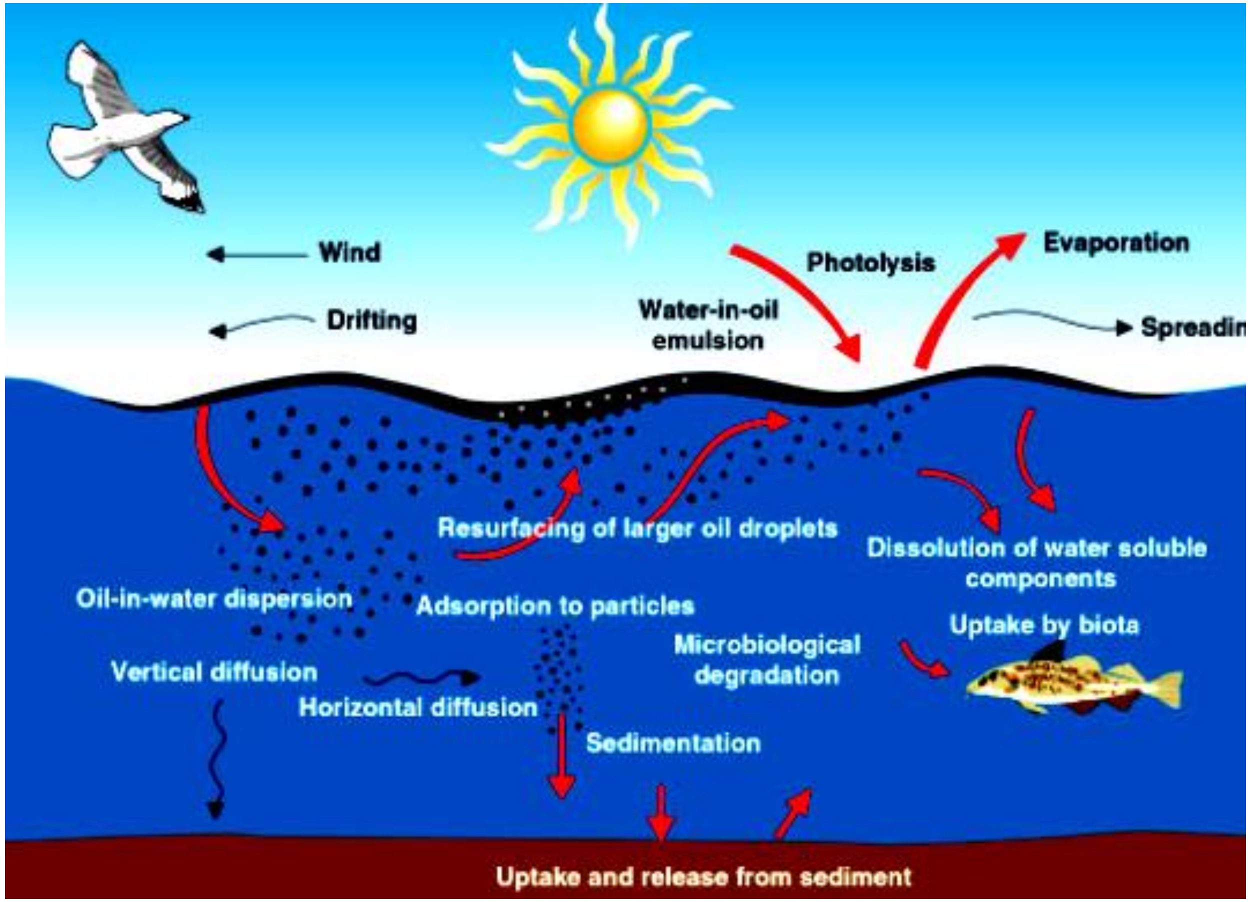
UNCTAD Research Paper No. 18

The impacts of the sea on Emergency Response

Dr. Maria Hartley
Technical Lead
Chevron Enterprise Emergency Management

Oil in water

- Oil: Highly complex mixture
- Different components have different environmental fates



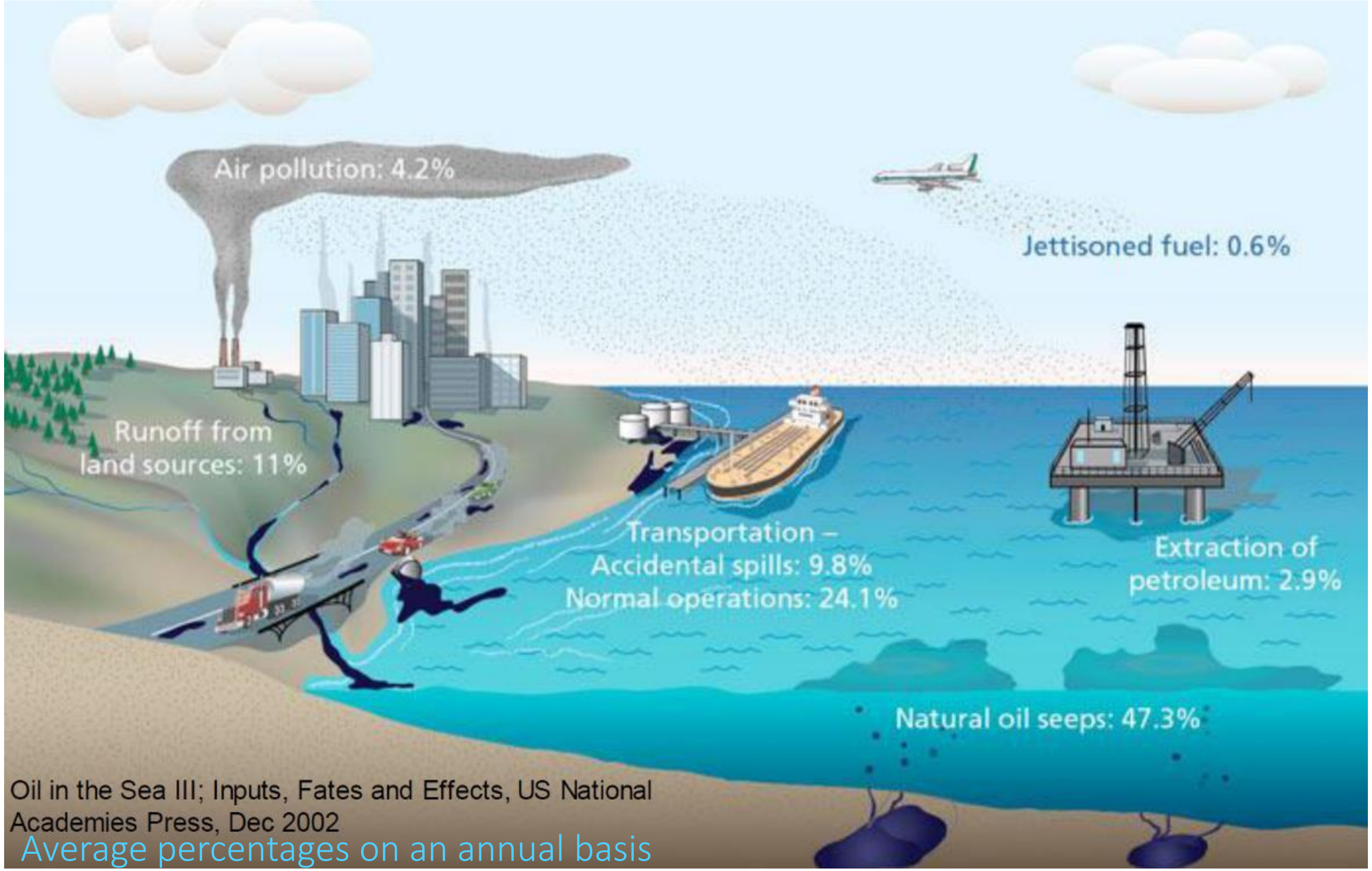
Oil changes physical character AND chemical composition

Consequences	Severity	**Response**

Key questions:

Oil type/ **Source**	Volume	**Location/ Trajectory**	Impact

Source: Where does oil in the oceans originate?



Average percentages on an annual basis

Natural oil seepage is the single largest contributor to oil in the Marine realm

- Actual percentage varies by geography

It is important to know where they occur

- Spill response preparedness
- Exploration for new resources
- Mystery spills

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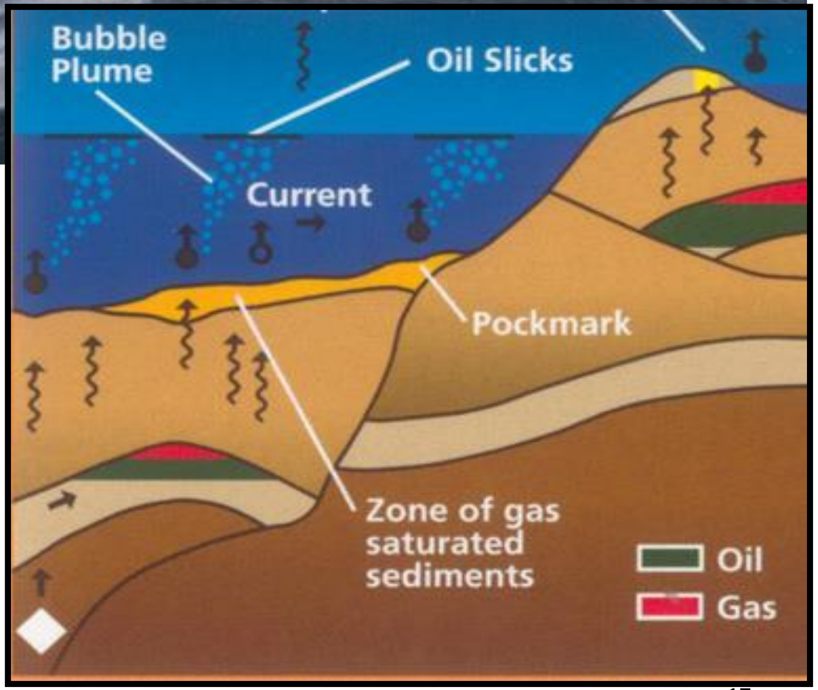
Source: Determination of cause - Slicks and Seepages

Natural Seepages are fleeting

- May only last a few hours or days, quantity varies
- Natural slicks dissipate after ~3 to 4 days
- May go weeks or more before seeping again

Detection Methods

- Physical sampling
  - Direct but costly, access can be an issue
- Optical photography, both aerial and satellite
  - Most common, but clouds and night will obstruct
- SAR Satellite radar
  - Non-Interventionist & low cost
  - Near global coverage & large imagery archives



Natural Seepage

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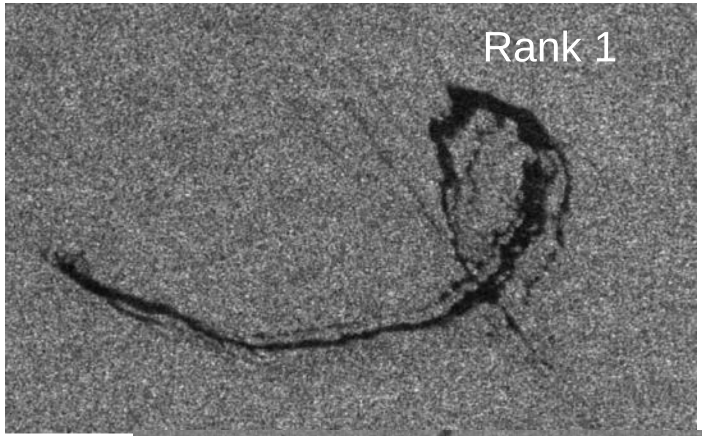
Source: Systematic Analysis of Slick categorization

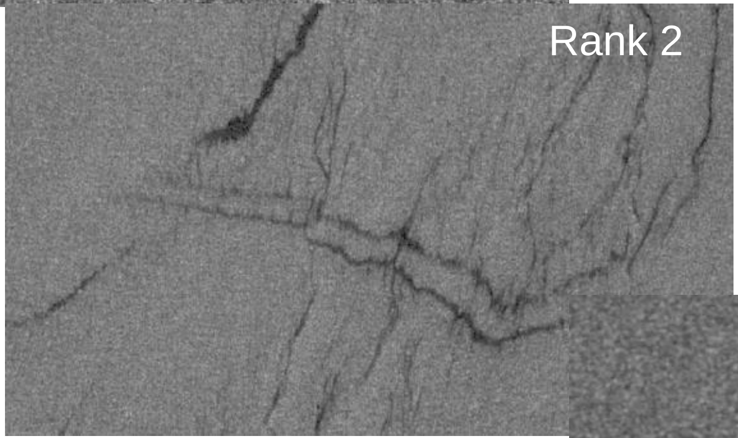
- Size, shape, aspect ratio, curvature
- Edge (sharp or gradational?)
- Assessment of freshness (dispersion, etc.)
- Nesting, clustering and, increasingly, repeatability
- Relation to industry installations & shipping lanes
- Geologic considerations (faulting at the sea floor, sediment inputs, known hydrocarbon accumulations & oil type, onshore seepage, etc.)

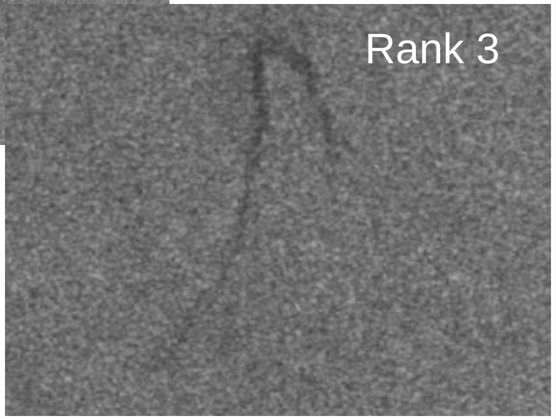
Source: SAR Seep Rankings – Natural and Pollution

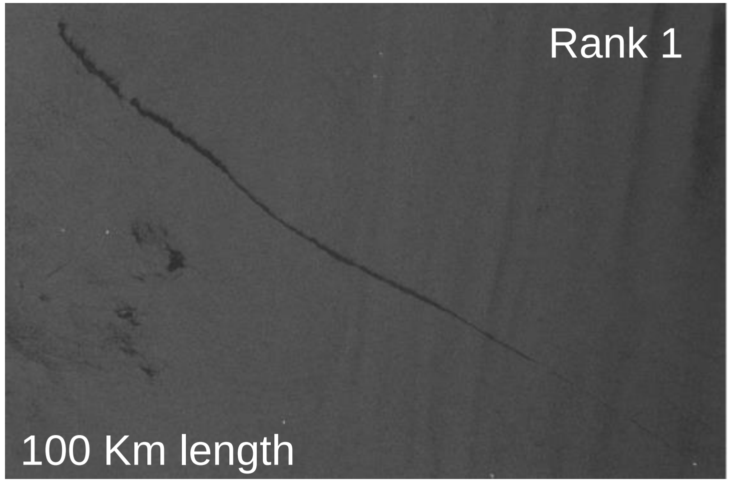


Natural Seeps

- Mostly affected by current
- Generally, 10 km length or less
- Often corkscrew shape





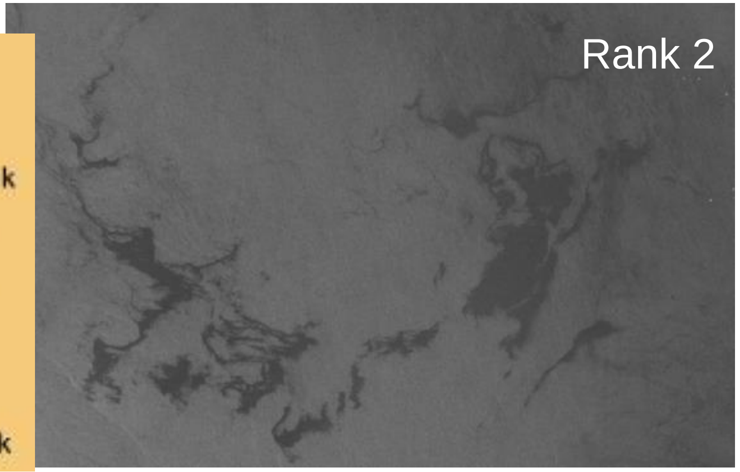


Pollution Slicks

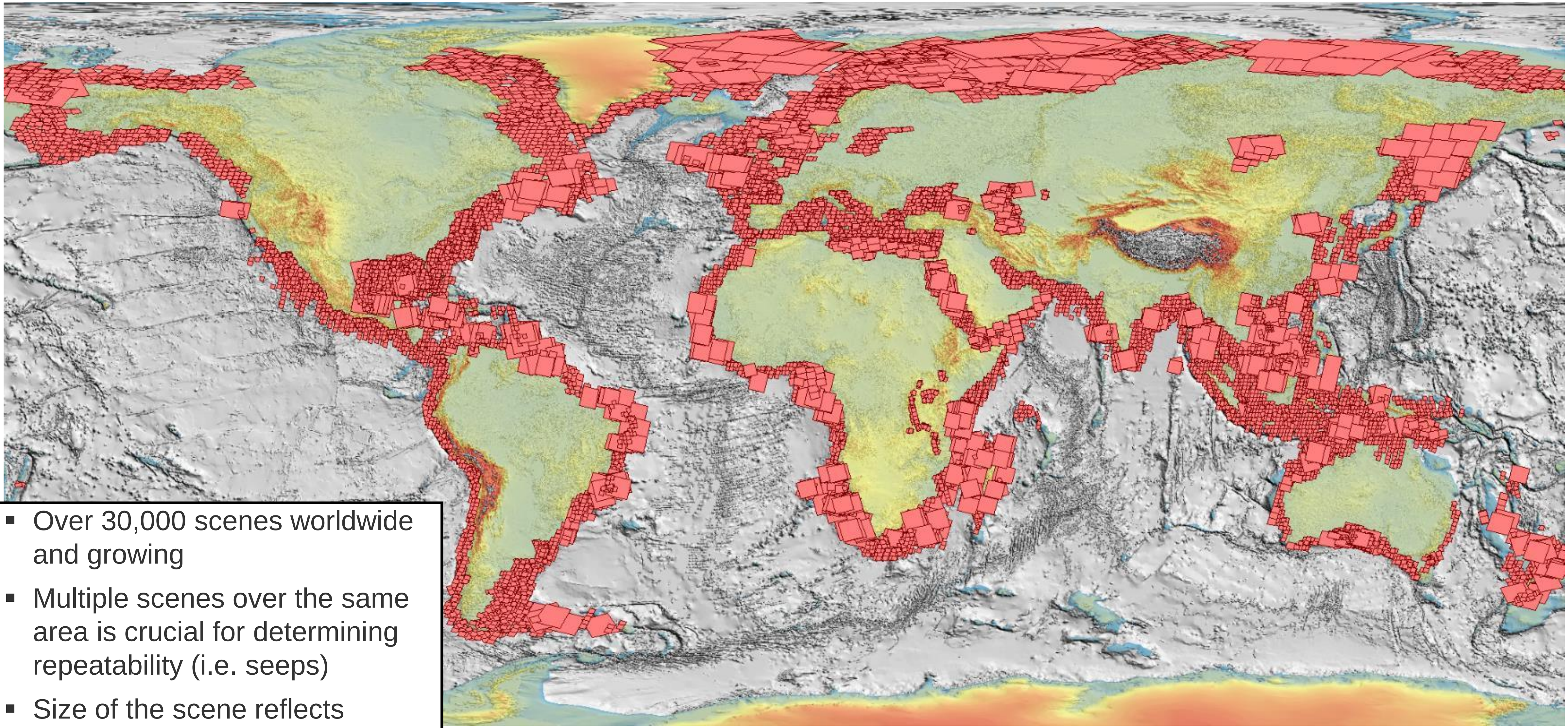
- Can be very long
- More persistent, more viscous because much thicker
- Tends to widen & “feather”

Legend

- Seepage Slick First Rank
- Seepage Slick Second Rank
- Seepage Slick Third Rank
- Priority Unassigned Slick
- Unassigned Slick
- Pollution Slick First Rank
- Pollution Slick Second Rank



Source: Chevron's Global Slicks Database – Radar Scenes



- Over 30,000 scenes worldwide and growing
- Multiple scenes over the same area is crucial for determining repeatability (i.e. seeps)
- Size of the scene reflects resolution of the picture

Since the mid 1990's, mostly since ~2005

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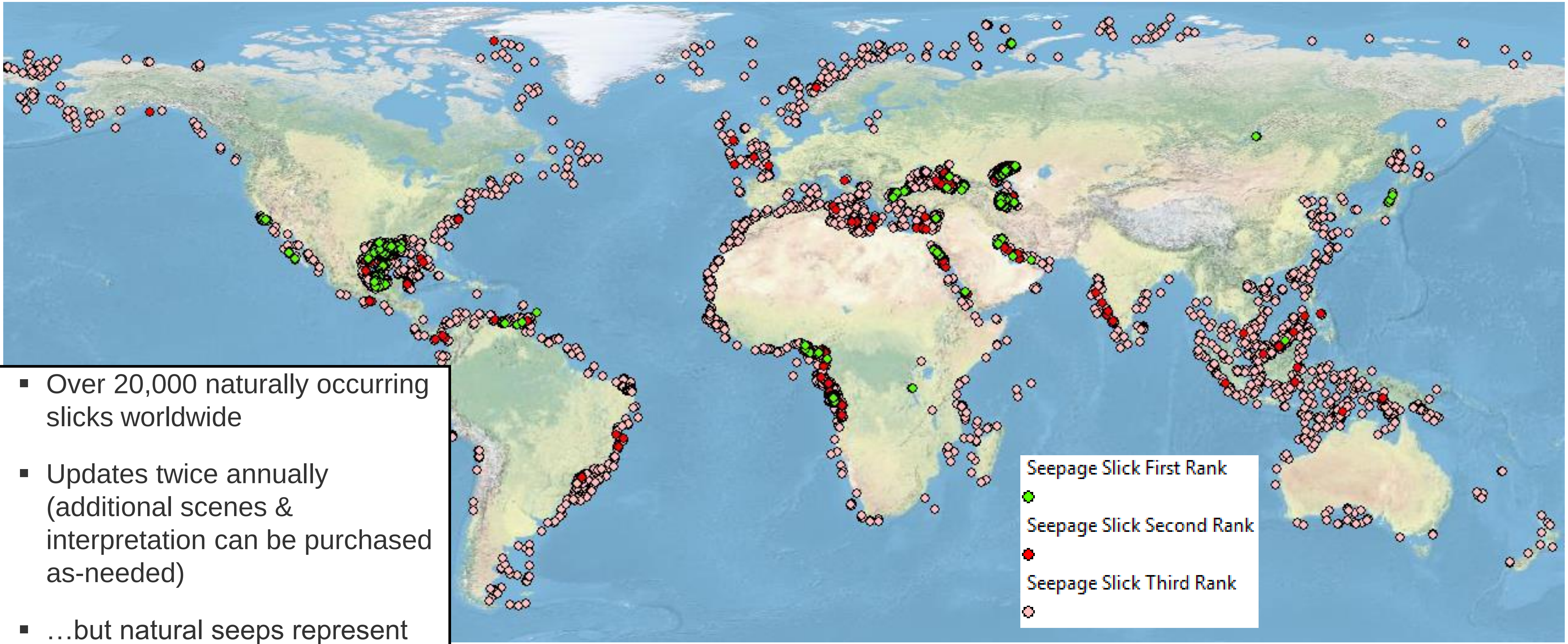
Source: Natural Seepage Slicks – Estimated Point of Emission



- Over 20,000 naturally occurring slicks worldwide
- Updates twice annually (additional scenes & interpretation can be purchased as-needed)
- …but natural seeps represent only a fraction of mapped slicks

Since the mid 1990’s, mostly since ~2005

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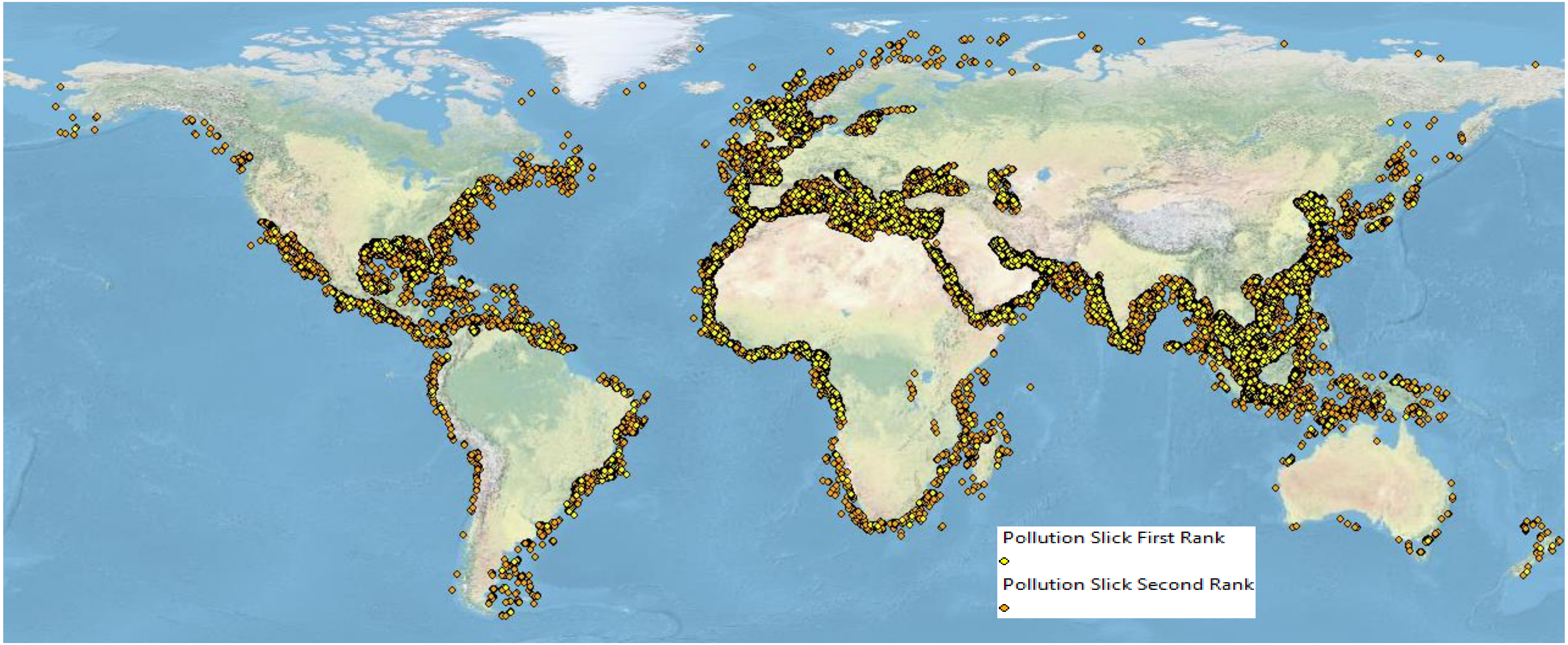
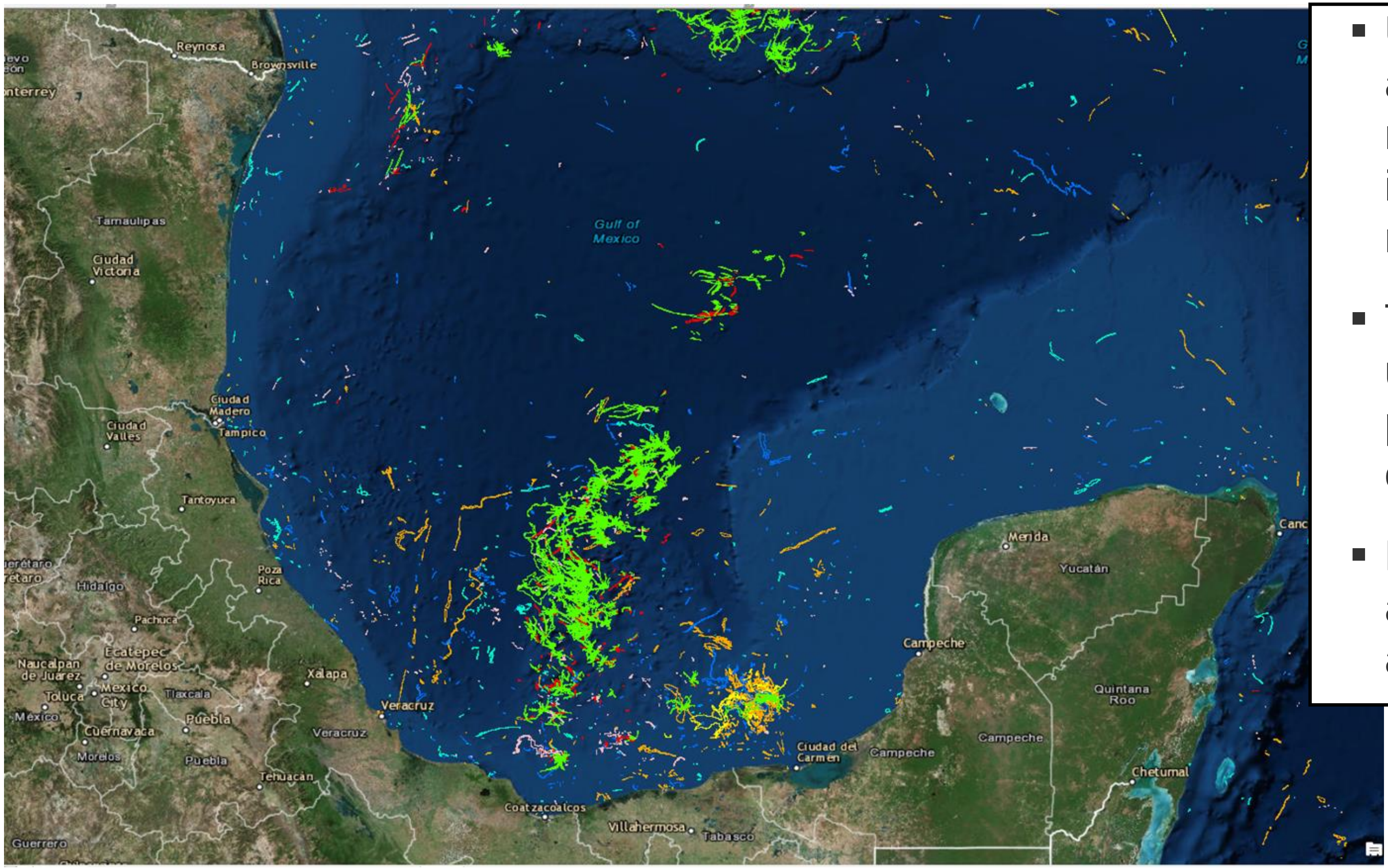
Source: Pollution Slicks Points – Estimated Point of Emission



Since the mid 1990's, mostly since ~2005

Source: Example Case Study: Mexico
New Country Entry - Baseline



- Understanding a baseline and general locations of natural seeps can be useful in determining origin of mystery slicks
- This can be monitored and updated as needed, particularly in areas we operate
- Real-time monitoring is just around the corner (optical and SAR)

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Source: Example Case Study: Mystery Spill

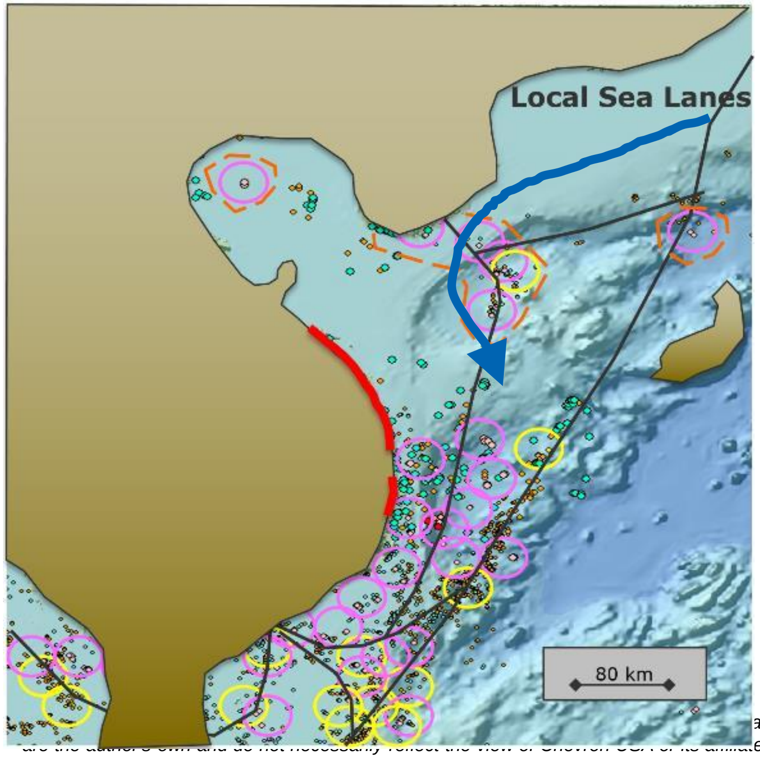
Geochemistry

- Crude oil and not refined product
- Spill sample oils characteristic of regional basin oils (except one near the sea traffic lane)
- Spill was either near emission point or very large due to minor biodegradation shown

Satellite imagery (SAR)

- No large natural seeps found
- Many pollution slicks found

Rank 1 Natural Seep
Rank 2 Natural Seep
Rank 3 Natural Seep
Unknown
Rank 1 Pollution Slick
Rank 2 Pollution Slick



Seeps Database aided in spill identification

- **Natural Seeps** are **sparse** and prevailing **currents** would tend to pull them away from the affected shoreline
- Rank 2, “unknown” and a few **rank 1 pollution slicks near platforms** were much more prevalent
- Observed slicks data was combined with other datasets to confirm the **source** of the spill

No Rank 1 Natural Seeps

Four Rank 2 Natural Seeps

Twenty-eight areas of Rank 3 Natural Seeps

Numerous Rank 4 Other Slicks

Sixteen areas of Rank 1 Pollution Slicks

Numerous Rank 2 Pollution Slicks

Very few natural seeps on north and northeast coast and most are far away

= Prevailing wind and water current direction

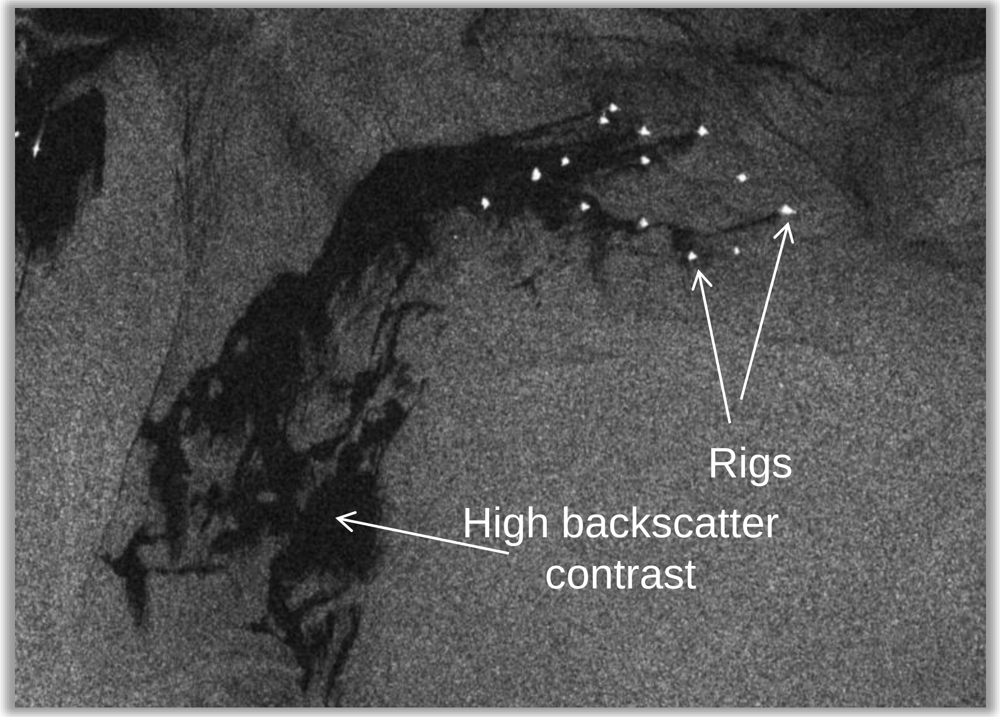
Source: What have we learned with SAR

Challenges

- Wind speeds of 0.5-2.5 m/s required for accurate measurement
  - Speed at which capillary waves occur
- Areas of high land **runoff** & **sediment** input can mask the signal
- Slicks **decay** with time due to:
  - Evaporation, bio-degradation, dispersion, photo-oxidation
- Strong tidal currents, high tidal ranges and biological communities can produce false positives in SAR images - misinterpreted as seeps.

Limitations

- Don't know Gas Oil Ratio (GOR) (gas or vapor adds buoyancy to hydrocarbon)
- Causes of the seep (moon, seismicity etc.)
- Amount of hydrocarbons in the basin
- Rate of release



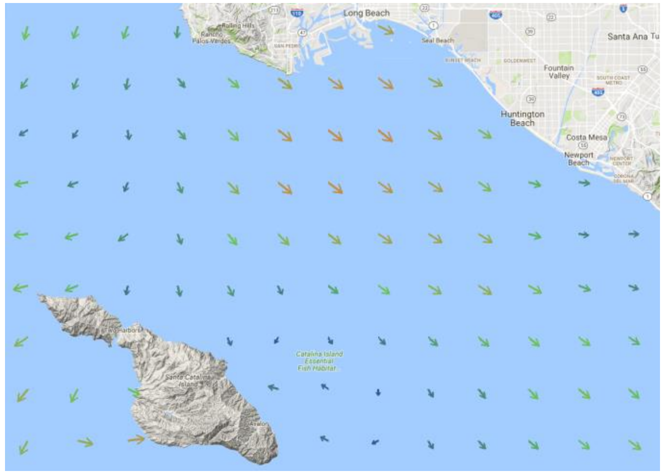
Location and Trajectory: Spill models

Model components generally fall into one of three categories

- **Spill scenario**
  – **volume**, duration and **location** of release
  – **type** of oil spilled

- **Mathematical model equations**
  – quantify transport & weathering processes
  – calculate hydrocarbon concentrations

- **Boundary & initial conditions**
  – chemistry and properties of oil
  – environmental parameters
  – shoreline position & type



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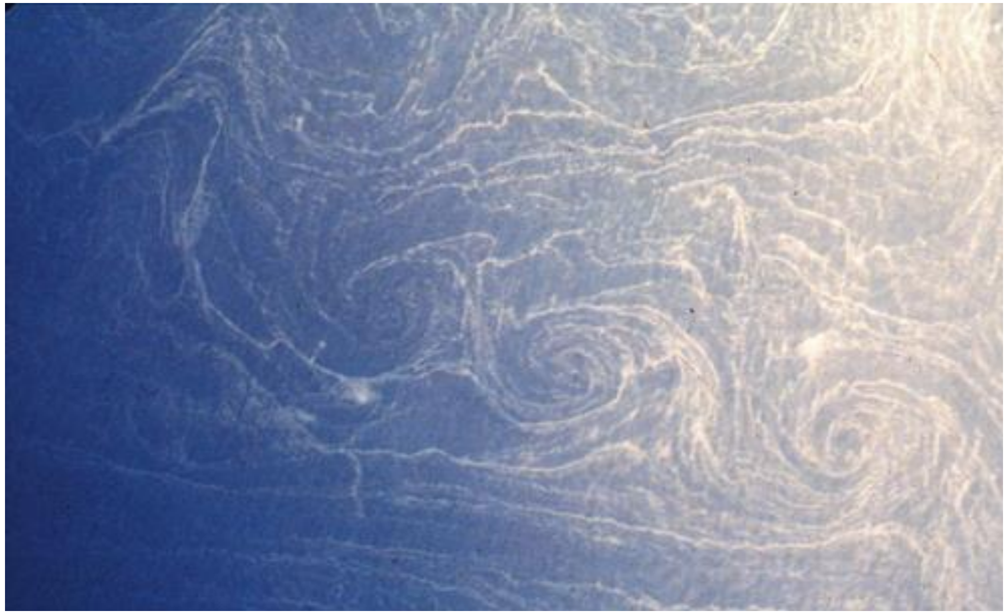
Location and Trajectory: Shortcomings of models – missing circulation features

Smaller eddies are not typically captured in ocean circulation models, but they influence transport

DHW “tiger tail’



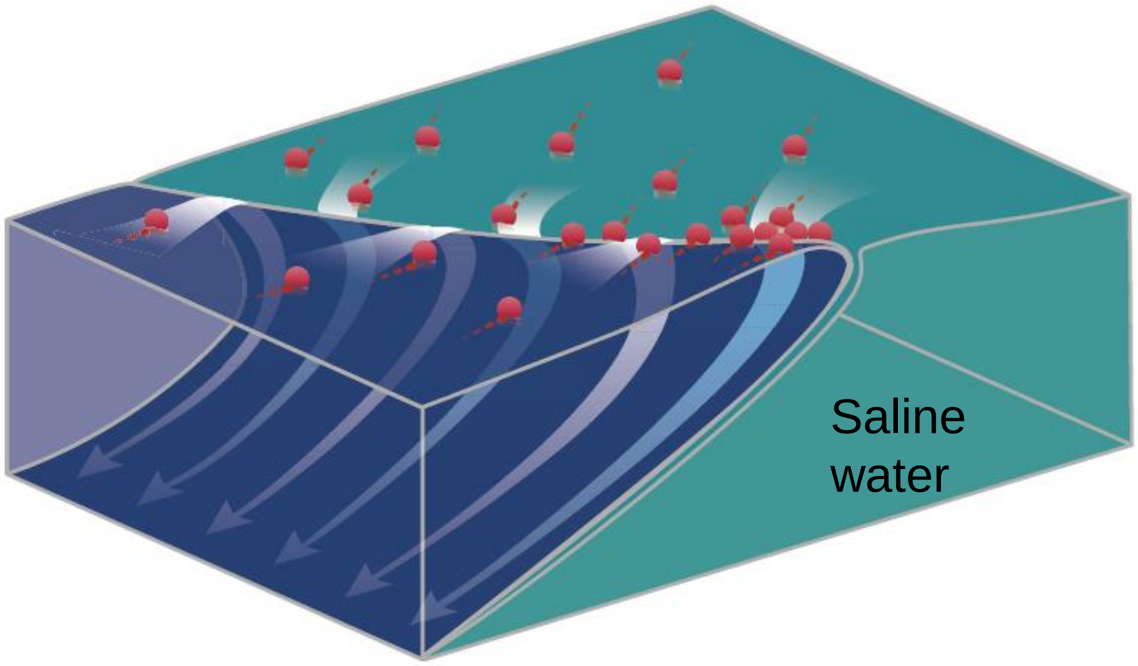
Eddies in Mediterranean Sea

Location and Trajectory: convergence and dispersion of flotsam

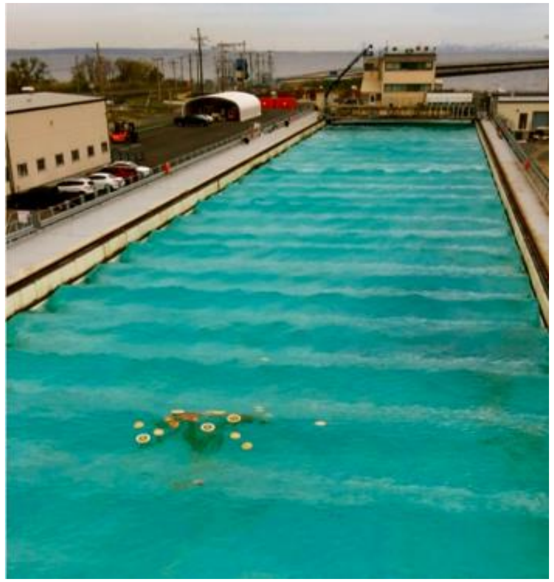
Anecdotal observations. Ocean currents often disperse floating oil over an increasingly large area, but we also sometimes see high concentrations of oil after significant spreading.

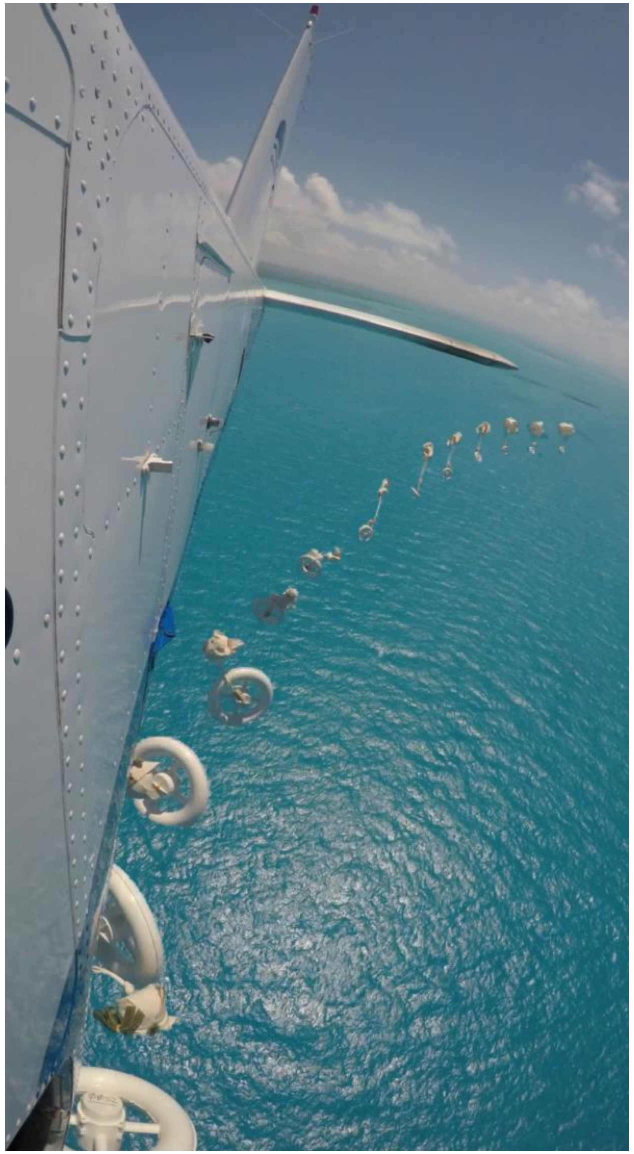
Possible mechanism: convergence and downwelling along of density fronts.

GOMRI funded experiment: Hundreds of satellite-tracked drifters released near DWH site initially dispersed but then a large number of the drifters gathered into a small cluster.



Location and Trajectory: CARTHE* drifters tested in lab, tank and ocean

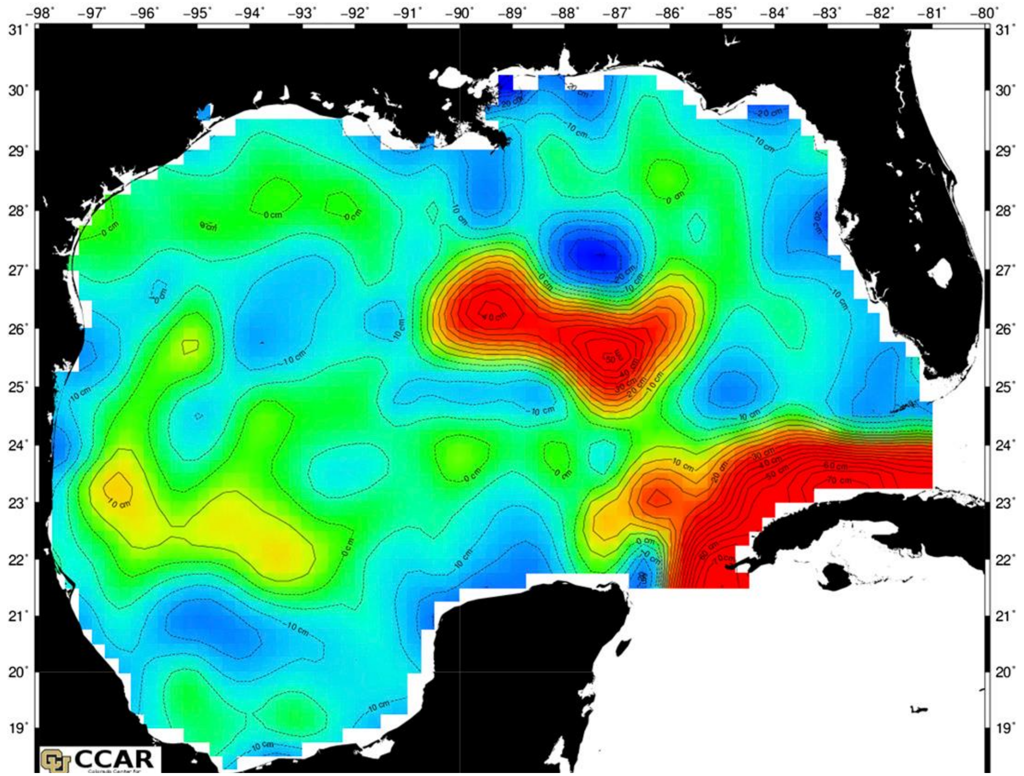




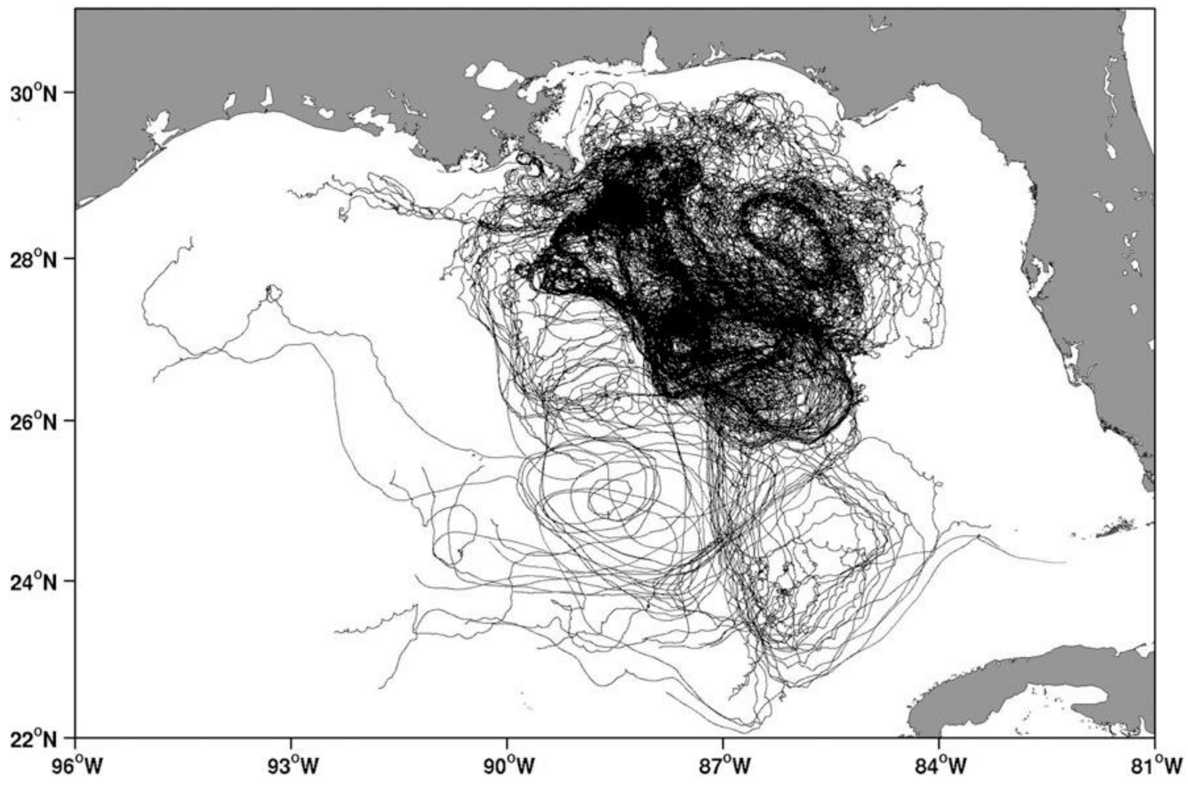
Consortium for Advanced Research on Transport of Hydrocarbon in the Environment (www.carthe.org). Funded by Gulf of Mexico Research Initiative (GOMRI)

Location and Trajectory: GOMRI experiments with data assimilation – observational data

Conventional assimilation from satellite-based measurements



~300 GOMRI drifter trajectories (1 Aug–30 Sep 2012)



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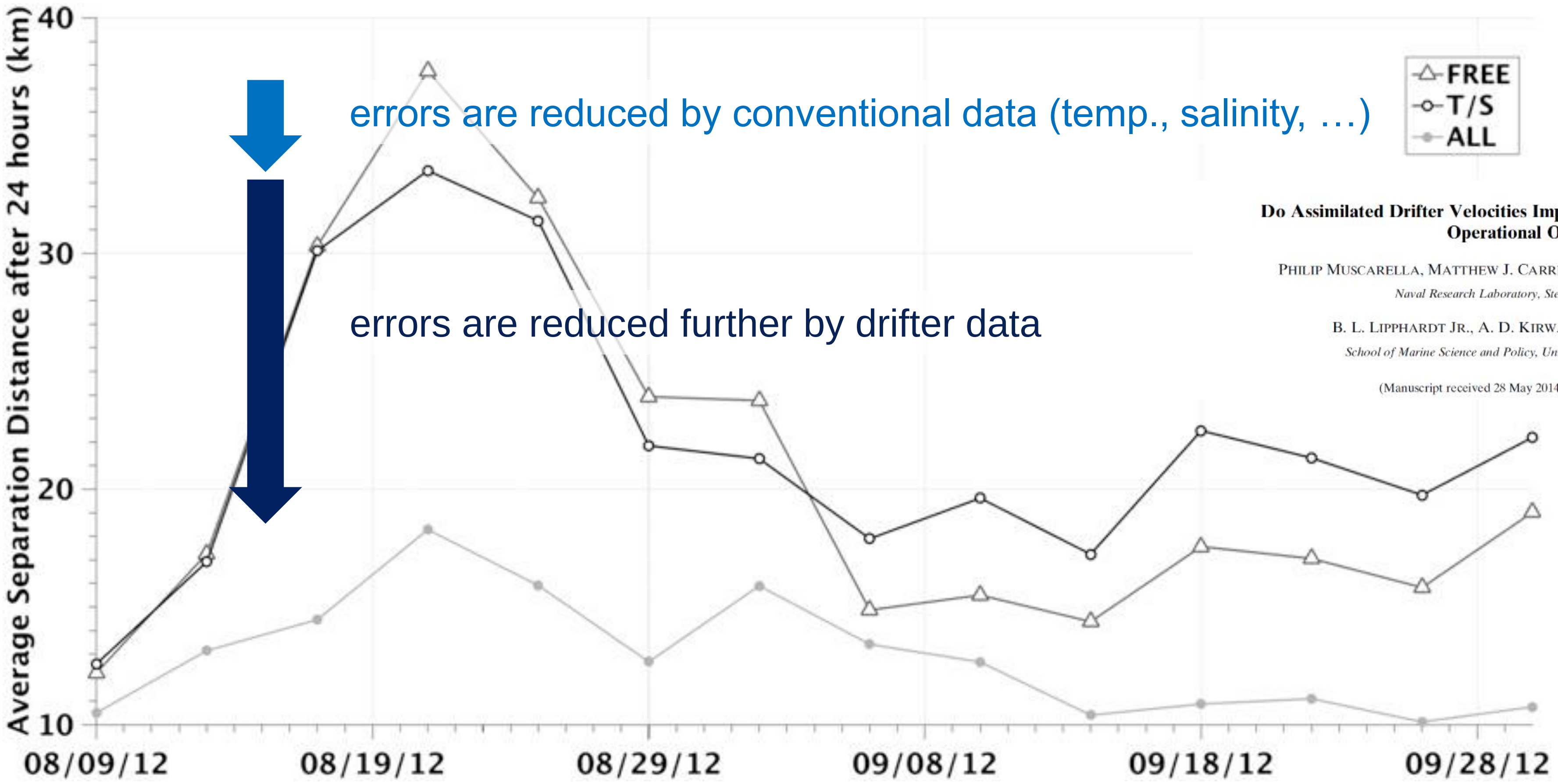
Location and Trajectory: GOMRI experiments with data assimilation – forecast errors



errors are reduced by conventional data (temp., salinity, …)

errors are reduced further by drifter data

Do Assimilated Drifter Velocities Improve Lagrangian Predictability in an Operational Ocean Model?

PHILIP MUSCARELLA, MATTHEW J. CARRIER, HANS NGODOCK, AND SCOTT SMITH

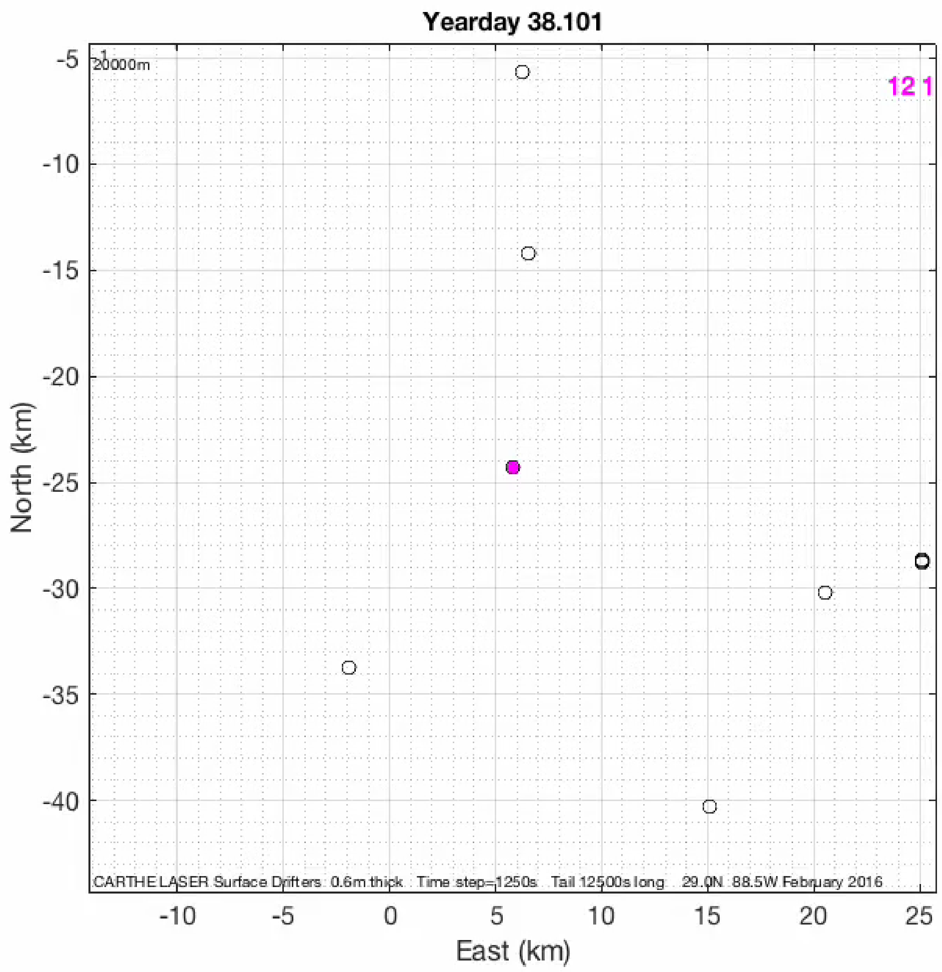
Naval Research Laboratory, Stennis Space Center, Mississippi

B. L. LIPPHARDT JR., A. D. KIRWAN JR., AND HELGA S. HUNTLEY

School of Marine Science and Policy, University of Delaware, Newark, Delaware

(Manuscript received 28 May 2014, in final form 8 December 2014)

Location and Trajectory: Ocean Black Hole



click to play movie

Collapse of 200 drifters from 30 km x 30 km into 100 m ocean sink! This is equivalent to reducing the size of a city to a conference room (1 million-fold decrease)!

This demonstrates how submesoscales connect the ocean surface to depth.

Ocean convergence and the dispersion of flotsam

Eric A. D'Asaro[a,b,1], Andrey Y. Shcherbina[b], Jody M. Klymak[c,d], Jeroen Molemaker[e], Guillaume Novelli[f], Cédric M. Guigand[f], Angelique C. Haza[f], Brian K. Haus[f], Edward H. Ryan[f], Gregg A. Jacobs[g], Helga S. Huntley[h], Nathan J. M. Laxague[i], Shuyi Chen[j], Falko Judt[k], James C. McWilliams[e], Roy Barkan[e], A. D. Kirwan Jr.[h], Andrew C. Poje[l], and Tamay M. Özgökmen[f]

Proceedings from the National Academy of Sciences (2018)

What we learned from CARTHE

- Advances in computing power have spread much faster than ocean observations, and this allowed for the number of mesh/grid points to be orders of magnitude greater than those constrained by data. Therefore, model initialization is only partial, and a large range of scales remained unconstrained in forecasts. *High-resolution modeling requires high-resolution observational data!*

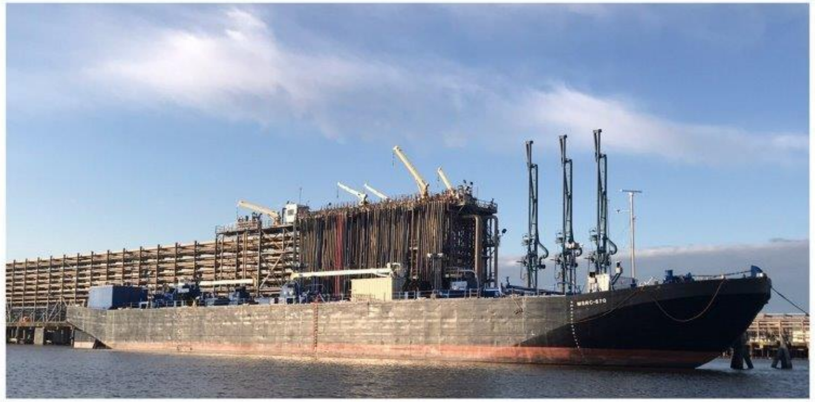
- The ocean surface is more energetic than previously understood, possibly due to *submesoscale* features (horizontal space scales 0.1 to 10 km and evolution time scales of hours to days). These features are too large for ship surveys and too small for satellite altimeter footprints. *Traditional instrumentation will not work for submesoscales.*

- CARTHE research has shown that large-scale releases of compact, inexpensive drifters are particularly useful for detecting submesoscale motions. *Data-intensive drifter releases can be coupled with state-of-the-art data assimilative models to improve forecast skill.*

Response

- Safe mobilization and deployment of response equipment
- Determination of the most effective response option based on the scenario.
- Weather and mass balance

Figure 9: A snapshot of commercially available capping stacks as at 2018 which gives a sense of where equipment is strategically located (NOROG NCS Wells Capping Status Report 2016)



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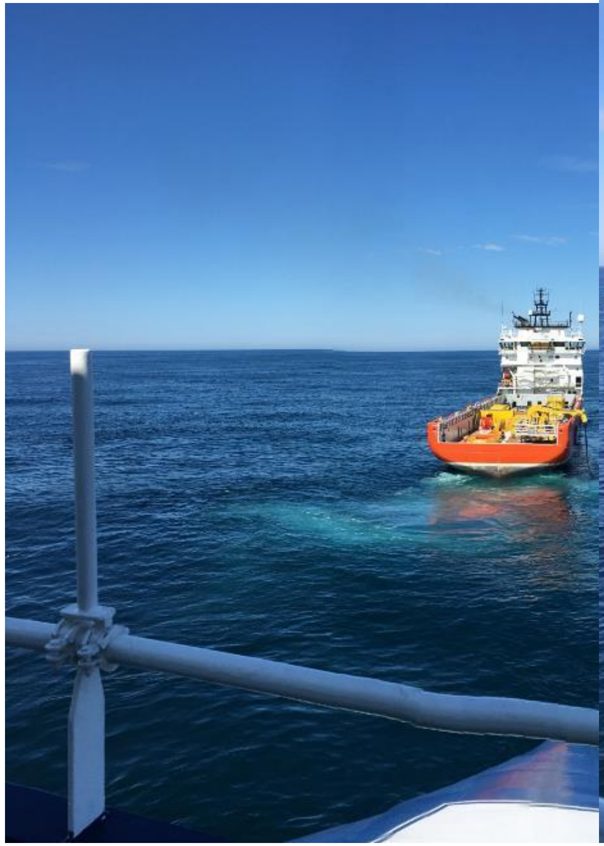
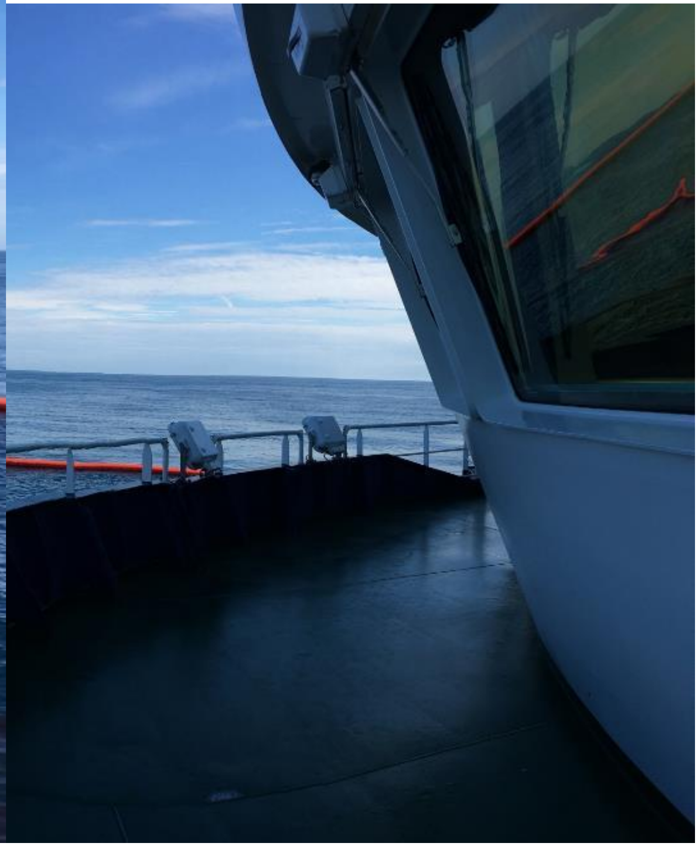
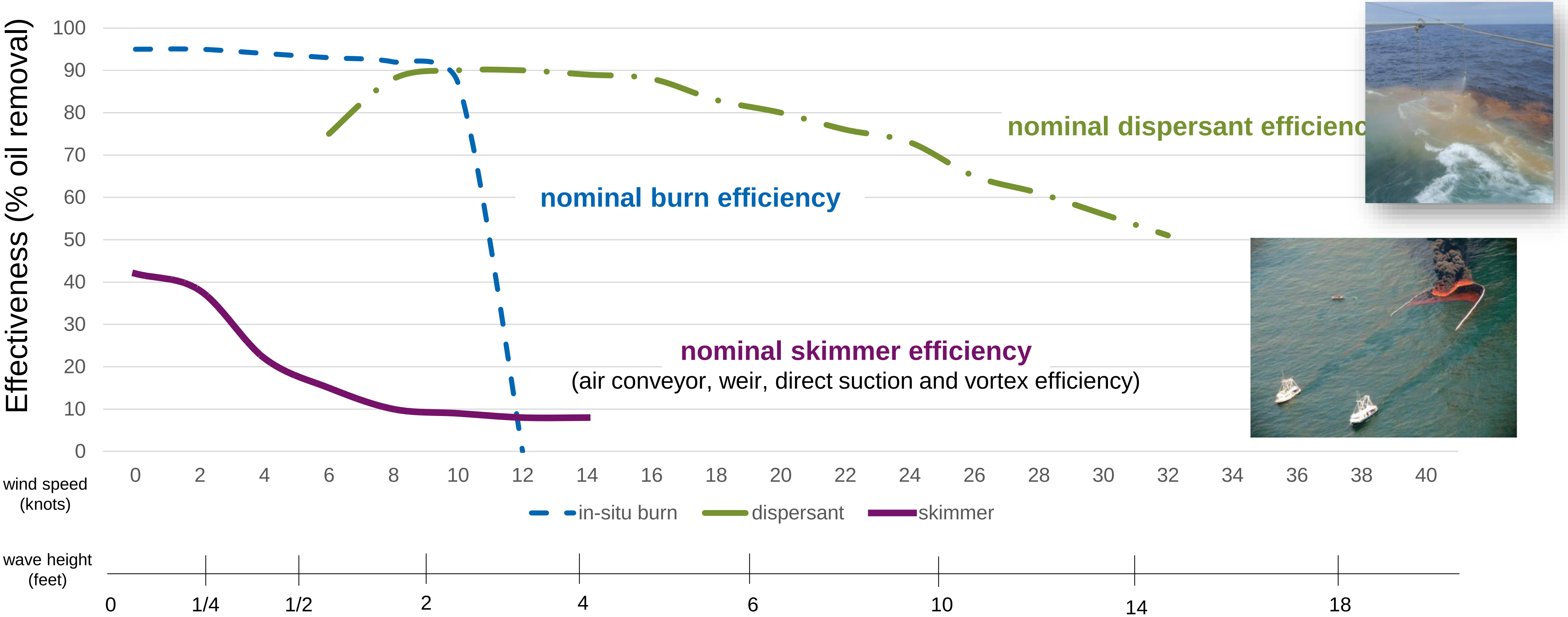
Response: You can’t respond effectively if you can’t see the oil





Estimated response efficiencies vs wind and wave

light – medium weight fresh crude oil DWH



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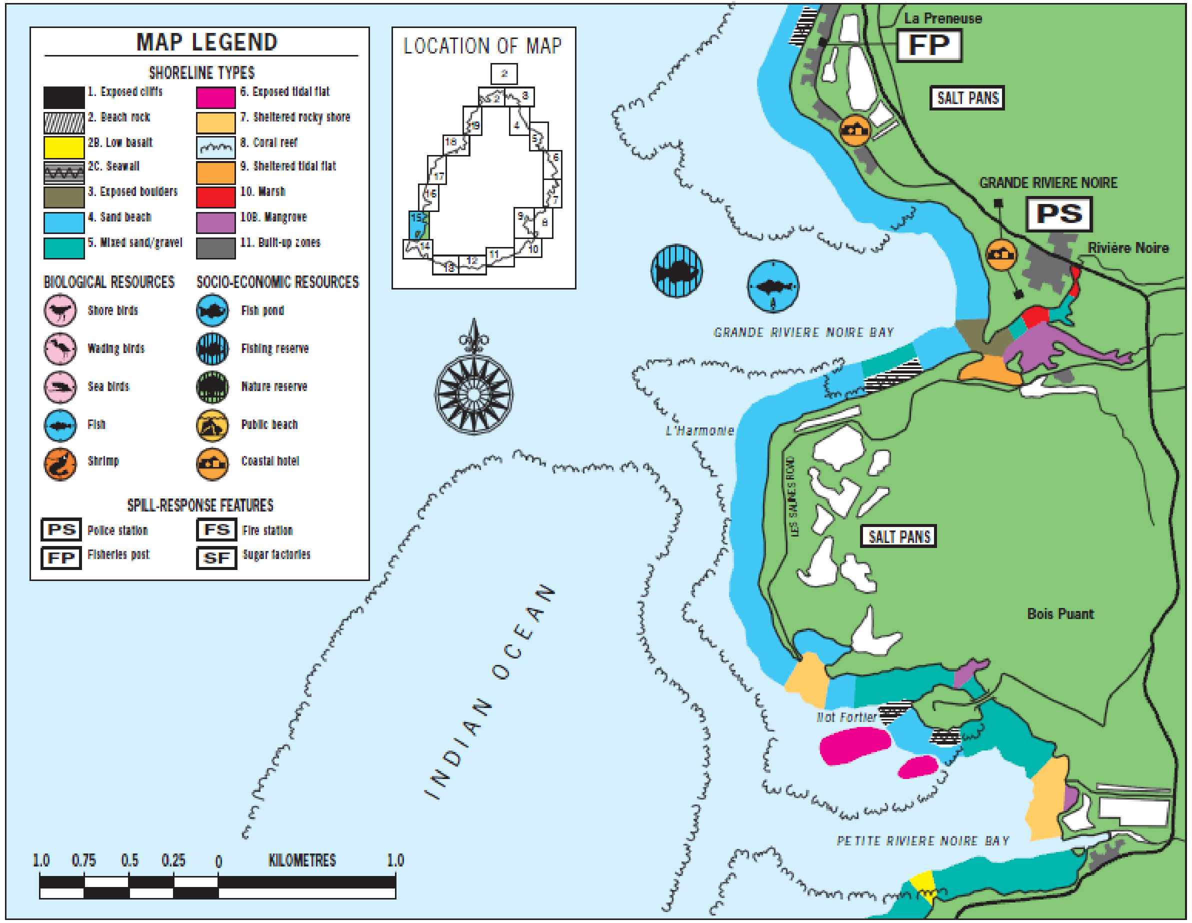
Response: Resources at Risk

1. Identify credible oil spill scenarios to understand potential spill risks: what are they, how large are they, and where will the oil likely go
2. Generate a map with identified resources (ecological & socioeconomic) that could potentially be impacted in the event of a spill
3. Create and exercise tactical plans for the protection and response to those resources



What we have learned

Ground-truthing, health of ecosystems (e.g., water quality, habitats, biodiversity), socio-economics, human use (e.g., water intakes, recreation, fishing, boat launches), change detection, staying up-to-date, access (e.g., max weight for bridges), staging areas (e.g., equipment lay down).

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Conclusions

- **Source**: Real time data and detection for seeps and slicks
- **Location and Trajectory**: The regular observations from satellite are a requirement. Readily available observations (mostly from satellite-based instruments) are sparse and limit predictability of ocean currents.
- **Location and Trajectory**: Local, dense, and persistent (over time), observations have been shown to increase predictability
  - Cheap expendable platforms (e.g., CARTHE drifters) can allow a rapid response to augment regular observations.
- **Response**: Change detection on shorelines for baseline and potential impact assessment
- **Response**: Safety for mobilization and deployment of response equipment
- **Response**: Determination of the effectiveness of response options

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Thank-you
Q&A?
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