Modern tools and methods, numerical models, and ocean science

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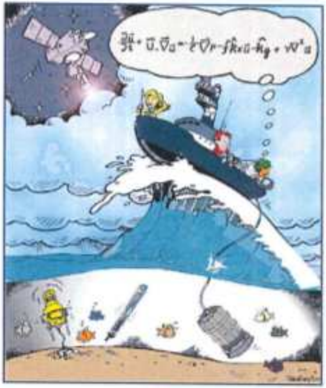
Outline

- What are we looking for?
- Scales
- Methods
- Examples
- Questions from the Symposium Science Committee

Can we see the light in the data jungle?

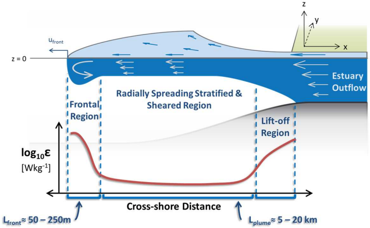
Cartoon from the Graduate School of Oceanography, University of Rhode Island, USA



What are we looking for?

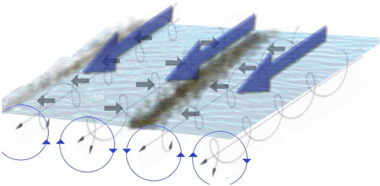
- Coastal plumes and fronts
- Transports of pollutants
- Plastic
- Hot Spots of pollutants
- Coastal erosion
- Waves - Extreme waves
- Currents - Extreme Currents
- Residence time
- Forecasting systems
- Human Impacts

River Plume Fronts

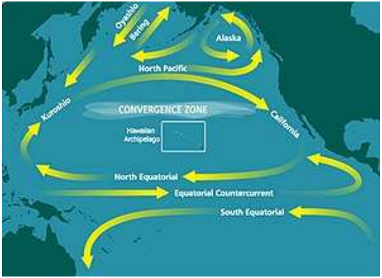


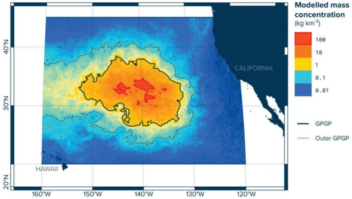
Plume of the Elwha River, Washington (John Felis, USGS) to the left. Schematic of a River Plume by Joe Jurisa to the right.

Langmuir Circulation and Slicks



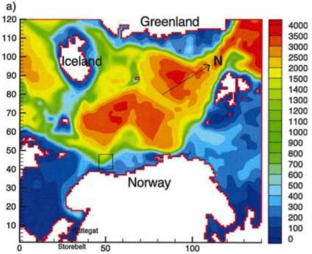
Langmuir Circulation (Wikipedia) to the left. Image of Marine Pollution, SEOS project, EU, to the right.

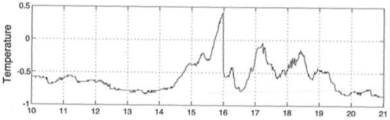




The Great Garbage Patch (Wikipedia) to the left. Mass Concentration (The Ocean Cleanup Project) to the right.

Events in the deep ocean - Ormen Lange I





Figures from Vikebø, Berntsen, and Furnes: Numerical studies of the response of currents at Ormen Lange to travelling storms, 2004.

Events in the deep ocean - Ormen Lange II

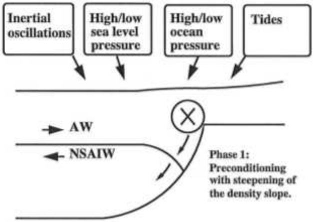
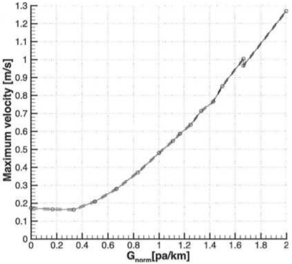


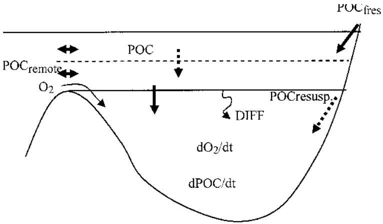
Fig. 1. A plausible model explaining the current response at OL to a passing low-pressure disturbances in the Nordic Seas.



Figures from Vikebø, Berntsen, and Furnes: Numerical studies of the response of currents at Ormen Lange to travelling storms, 2004.

Hypoxia, transports, residence times

From Erlandsson, Stigebrandt, and Arneborg (2006)



Often we 'only' need overall integrated values and transports. Residence times can be dominated by events rather than mean flow.

Coastal Ocean Observing Systems

From Blumberg and Bruno (2018) The Urban Ocean

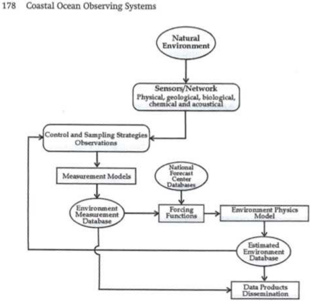


Figure 12.5 A flowchart of the NYHOPS system of systems.

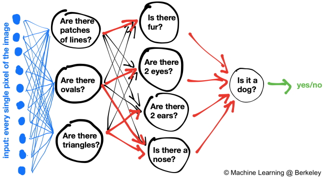
Schematic of the New York Harbor Observing and Prediction System.
Based on Bjerknes steps: Initial state, Laws of Motion + Prognostic step.

Scales

- Spatial scales: From 0.01 m to 10000 km
- Temporal scales: From seconds to many years
- The sampling theorem
- You need more than two measurements per important length/time-scale
- Impossible to satisfy this with models and observations
- Averaging, Filtering and parameterizations
- At best we obtain the mean state
- What about the fronts and the events and their effects on the means?
- Quantitative Skill Assessment?

Methods and Trends

- In with: Neural Networks, Machine Learning, Deep Learning, Big Data
- Out with: Equations and Numerical models based on versions of the Navier-Stokes equations



From MachineLearning at Berkeley

Pros and Cons Numerical Ocean Models

- Physical Laws of Motion
- From Navier-Stokes to RANS
- Established numerical methods
- Still problems with the sampling theorem
- Resolution
- Parameter tuning/Turbulence Closure
- Open Boundary Conditions
- Initial Values

Pros and Cons Neural Networks

- We do not need Physical Laws of Motion
- Train the systems to obtain fit with observations
- Growing number of deeper and deeper alternatives
- Still problems with the sampling theorem
- Enough data?
- Cost function
- The number of Parameters grows with the complexity
- Tuning
- Observing systems: Combination of Models and Data

Do we get lost in complicated tool-boxes?

- Parameter tuning in ocean models and machine learning
- Cost functions - what to tune against?
- Wide range of sub-grid scale models
- Wide range of algorithmic choices in machine learning
- Boundary values, initial values and forcing functions
- In the process of tuning and fitting, we loose focus on the underlying problems

Did we solve the problem at hand?

- Can we capture a possible plume of polluted water?
- Aggregation areas for plastic?
- Extreme current/wave events?
- Exchanges of water masses over sills in fjords?
- Mean transports and mean currents?
- We can answer some What if questions

Question 1

How does the hypothesis/idea/method(s) you are proposing aid in oceanographic observation?

- We must not loose sight of the physical, chemical, and biological problems at hand
- Where are the critical areas?
- Where are the hot-spots in space and time?
- We need to consider the relevant scales
- More than two points per essential length and time scale
- Effects of undersampling? Reflections are needed.

Question 2

Is there a methodological component of your idea(s) that can significantly impact the critical problem of under-sampling? If so how?

- We need to identify the phenomena that are undersampled
- Sampling where needed
- Increased costs
- When discussing results/measurements, we need to be aware of undersampled processes
- Effects of the under-sampled processes on the larger scales need to be understood

Question 3

How can your idea(s) be abstracted into ocean modeling in ways that can increase model skill?

- Blind tests show that N-models produce N-outputs
- Cost functions should reflect the objectives of the studies
- Insight in the physical processes, and the related scales, gives better planning of model grid and model resolution
- When balancing the model parameters, we know what to focus on
- Do we get the hydraulic jump, under the correct condition?

Question 3

How can your idea(s) be abstracted into ocean modeling in ways that can increase model skill?

- Do we get flow separation where it should be?
- Are the scales of the eddies correct?
- Is the internal wave realistically strong, or too strong because you do not allow overturning rolls?
- If the feedback to larger scales is important, effects need to be parameterized
- Grid adjustments/refinements where needed

Transfer of energy in Knight Inlet, British Columbia, Canada

- Map of Knight Inlet from Google map
- From Barotropic tide to Baroclinic tide, Internal waves, Hydraulic jumps, Overturning rolls, Horizontal eddies, whirlpools, and irreversible mixing
- Phenomena represented and/or aliased on the scales we have

Question 4

Or how can your idea(s) be used algorithmically to enable and/or augment control of marine autonomous vehicles either in the air, surface or underwater?

- We need to know what the AUV is searching for?
- Based on insight in the flow and mass fields near fronts, we may direct the AUV towards front.
- The same with hot spots and accumulation areas of for instance plastic.
- Follow gradients

Question 5

Is there a way in which your idea(s) can tie the three (Modeling/Sampling/Control) together in practical ways even for traditional ship-based observational methods?

- The same as above: We need to know what we are looking for?
- When observations are flowing in, one may use algorithms to search for specific features, and issue warnings if:
- Close to or crossing a front
- There are internal waves with aggregation of matter at a density interface
- An eddy with accumulation of mass inside

Communicating the State of Art

- Yes, we can do it!
- How do we communicate uncertainties, or limitations?
- Warming in the IPCC climate models
- Aquaculture zones based on simulations
- Jarle: Shut up, or we will never get funded
- Projects are given to those that deliver wanted or expected results?