Quantifying the Spatial Variation in Cross-shore Mixing in the Surf Zone

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Mixing Processes in Pipes, Sewers & the Natural Environment – from Theory to Practice

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IAHR AIRH International Association for Hydro-Environment Engineering and Research

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Background

- Pollutant loading
  - 10% of UK beaches do not pass the Bathing Water Directive standards

    (Abolfathi and Pearson, 2014)
  - ~20,000 tonnes of sunscreens wash into the northern Mediterranean each year

    (Saner, 2021)
- Limited understanding of solute mixing in the surf zone
  - Existing models for rivers
  - Variation in turbulence in on-offshore direction is visible
  - Turbulent mixing coefficient required for models
- What models can we use?

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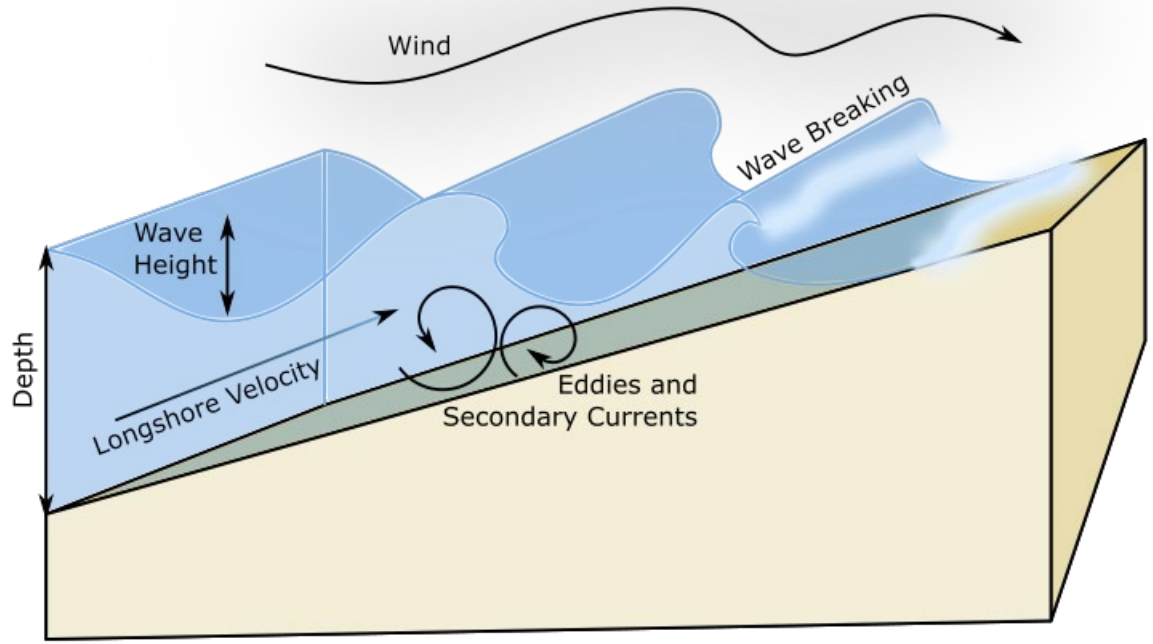
What causes mixing?

- Solute mixing is caused by diffusion and dispersion
  - Enhanced by turbulence in the surf zone
- Factors affecting mixing:
  - Velocity
  - Depth
  - Eddies and secondary currents
  - Wave breaking
  - Wave height
  - Wind



Methodology

- Three existing mixing models
  - Constant Coefficient (Rutherford, 1994)
  - Variable Velocity & Depth Coefficient (Kay, 1987)
  - FDM (West *et al.*, 2020) adapted to include Spatial Variability and Breaker-Induced Mixing
- DHI lab (Pearson *et al.*, 2005)
  - Injection points at 2 m , 3 m and 5 m offshore
  - Cross-shore dye concentration measured
  - At four location downstream of the injection point
- Data correction, Analysis and model Optimisation

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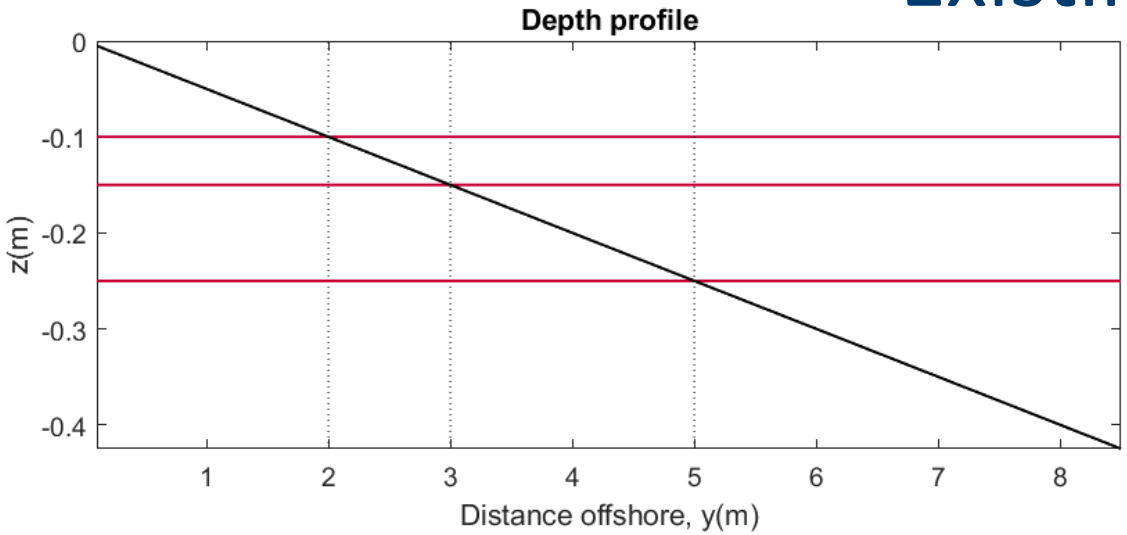
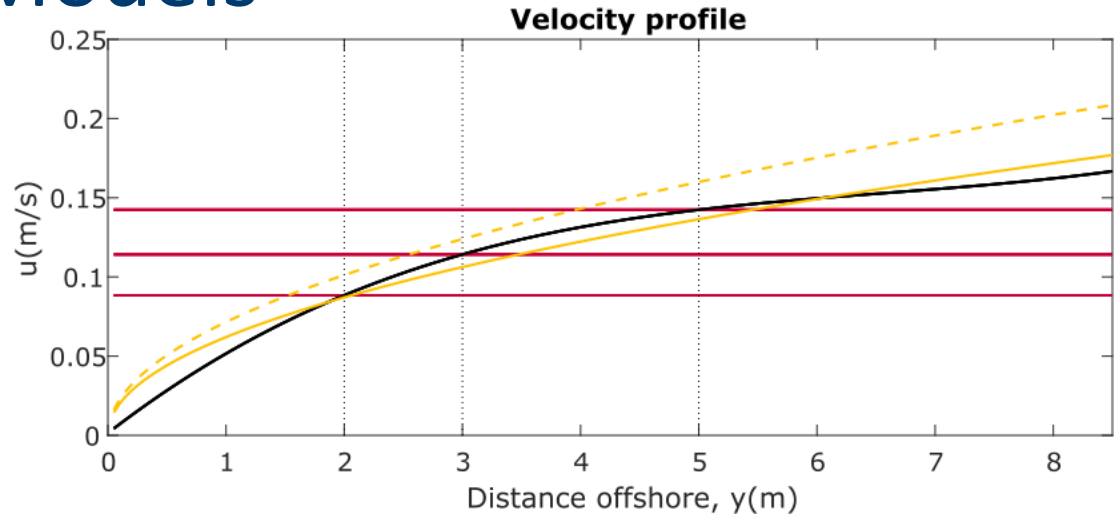
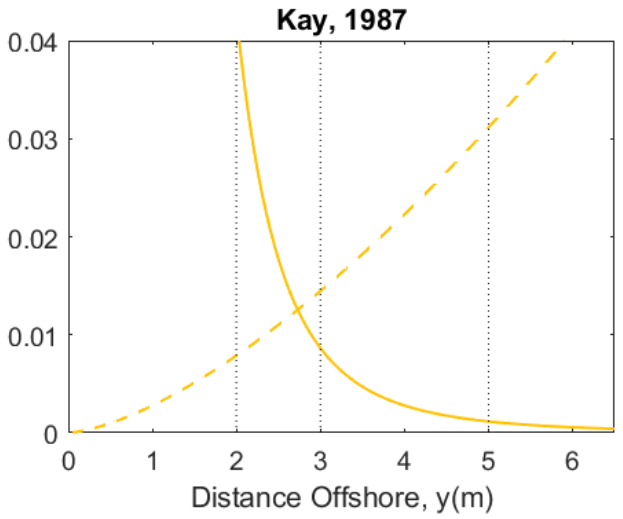
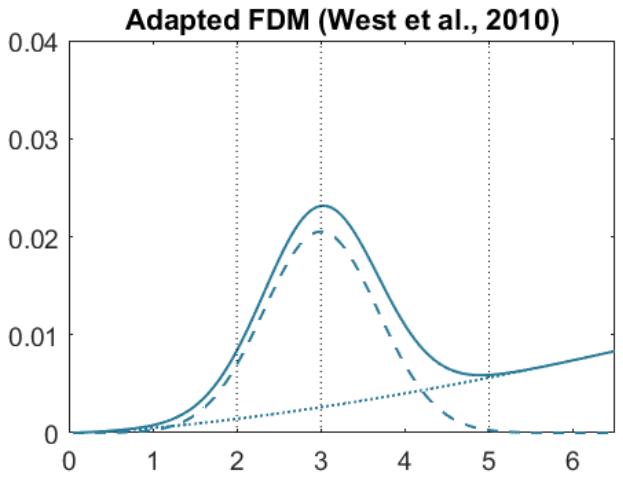
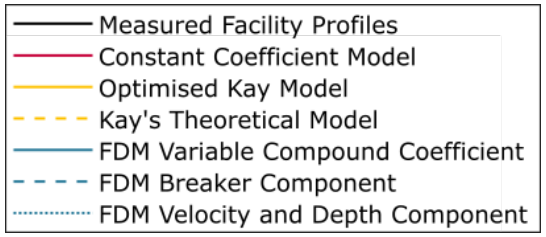
Existing Models











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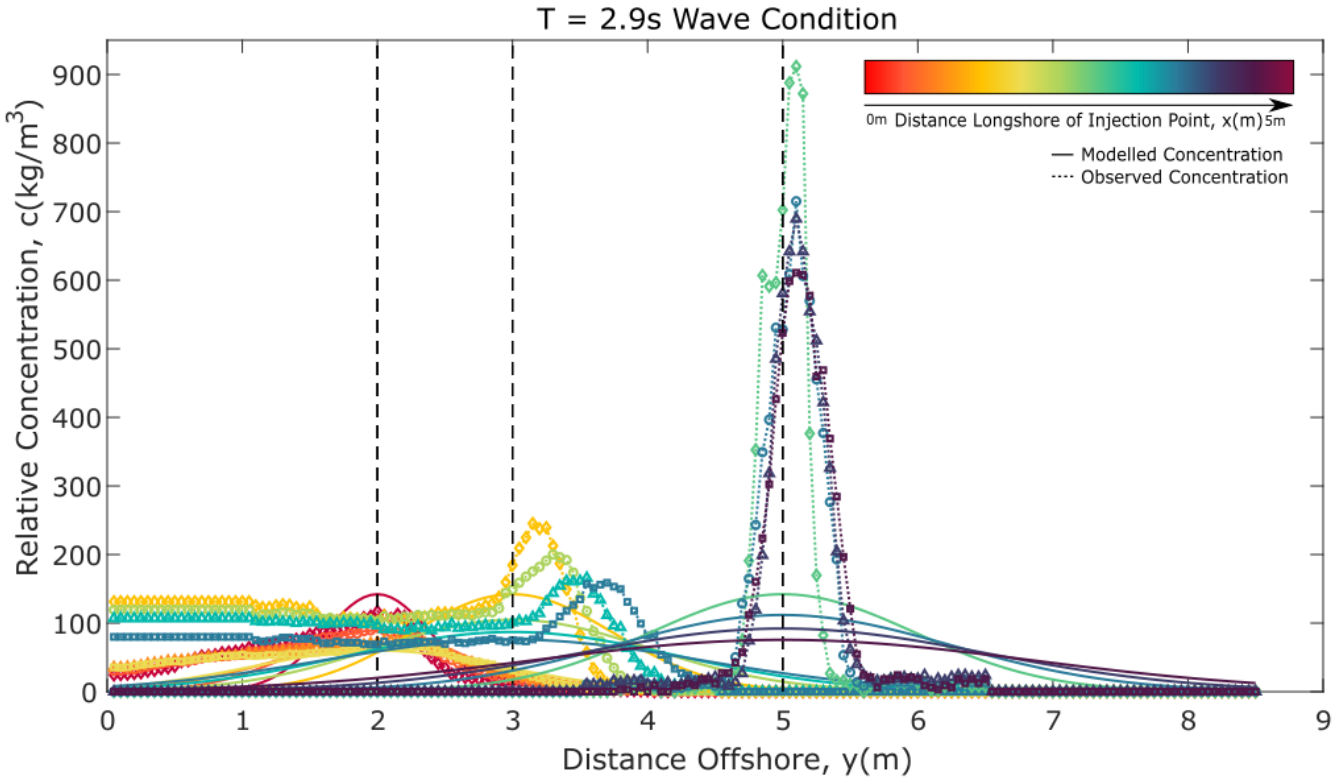
Results – constant coefficient

All parameters spatially uniform

- Normal distribution / symmetry of model does not fit observed data
- Mixing appears to be overestimated – peaks of observed data greater than modelled
- Offshore translation of peak – advection?
- ‘Tracer sink’ style dye trapping / recycling near shoreline



Wave Period	T = 1.2 s	T = 1.85 s	T = 2.9 s
R_t^2	0.5338	0.7615	0.6737

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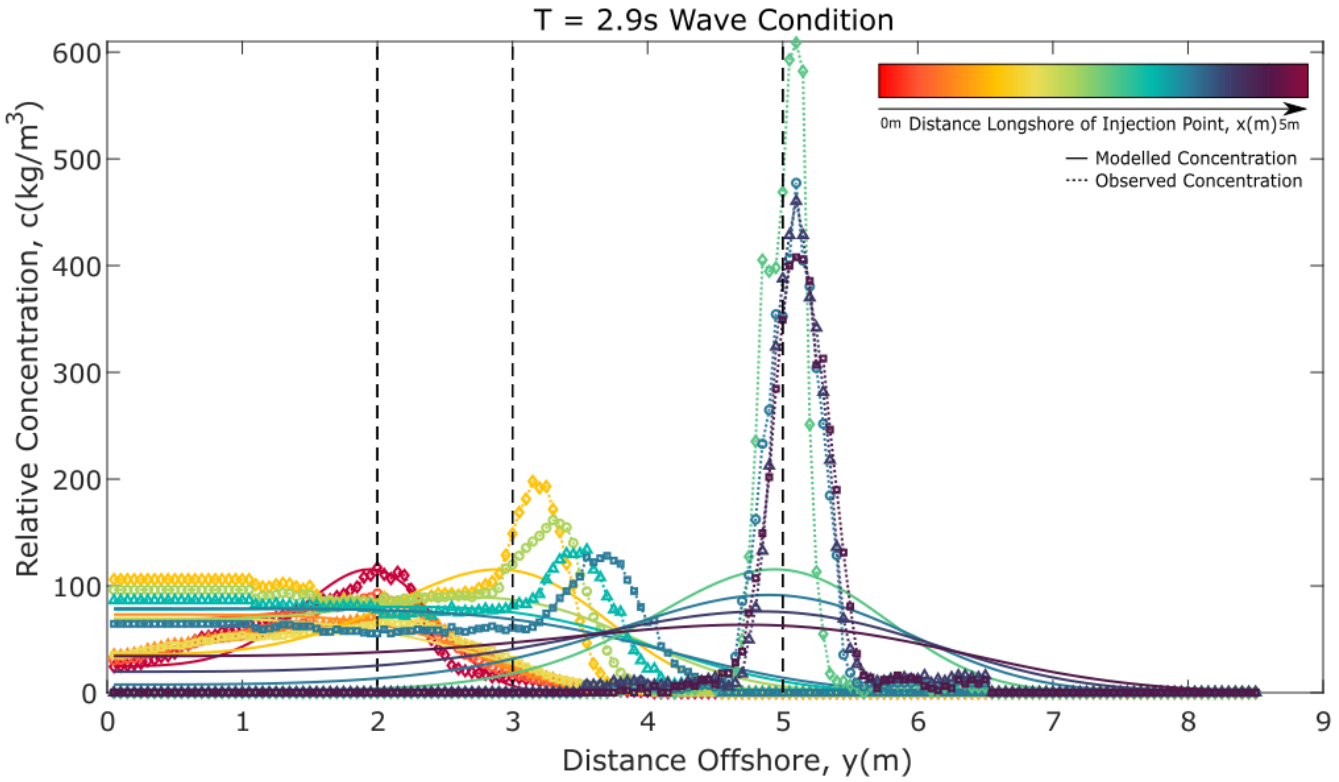
Results – Kay (1987)

Spatially variable velocity and mixing coefficient

- Improvement on previous model: predicts non-Gaussian behaviour
- Offshore mixing still overestimated and poor fit for peak concentrations
- Optimised input parameters for mixing profile are impossible in real life conditions – tends to infinity at shoreline



Wave Period	T = 1.2 s	T = 1.85 s	T = 2.9 s
R_t^2	0.7858	0.8017	0.9135

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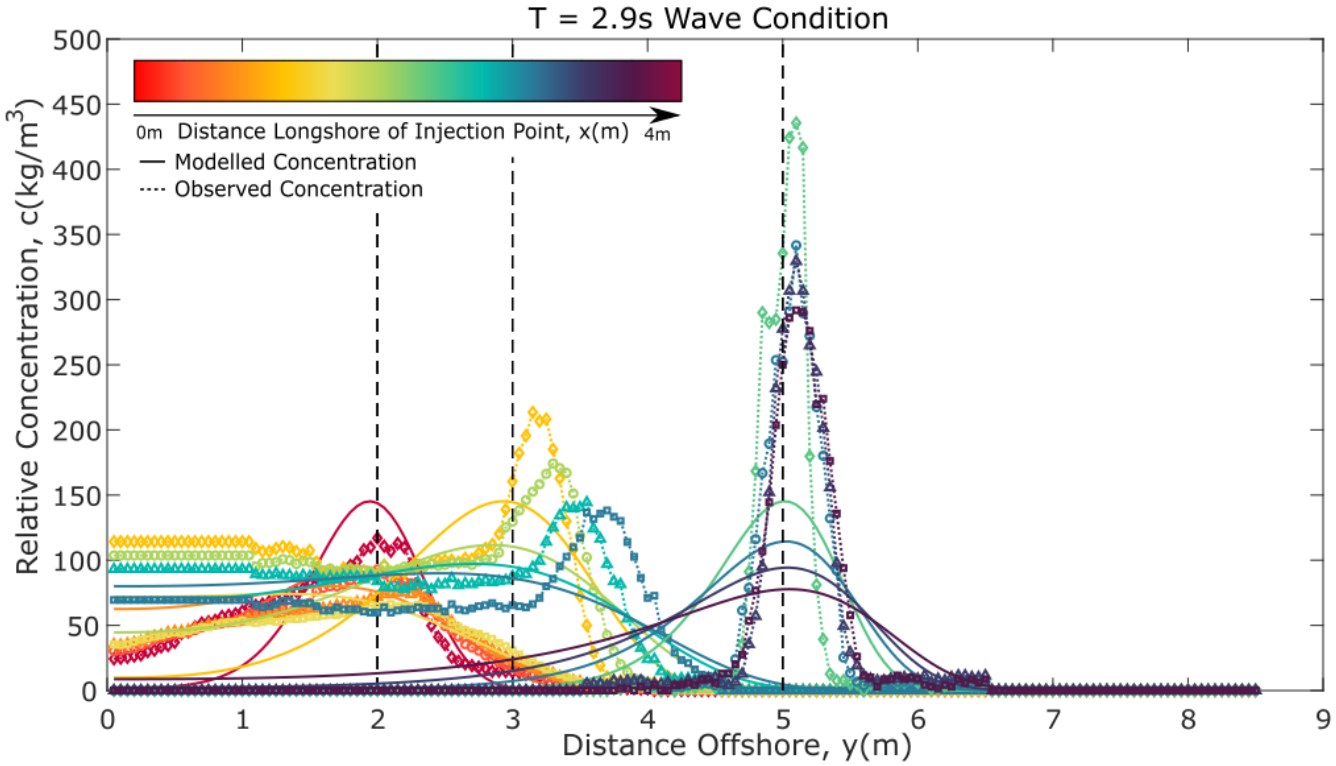
Results - FDM after West *et al.* (2020)

Spatially variable velocity & mixing, plus Breaker-Induced Mixing

- Allows for spatial variability in profiles
- Predicts non-Gaussian behaviour
- Shoreline concentrations not accurately described
- Overestimation of mixing
- Limitations in mixing coefficient profile:
  - Scale
  - Location of peak



Wave Period	T = 1.2 s	T = 1.85 s	T = 2.9 s
R_t^2	0.6660	0.8176	0.9023

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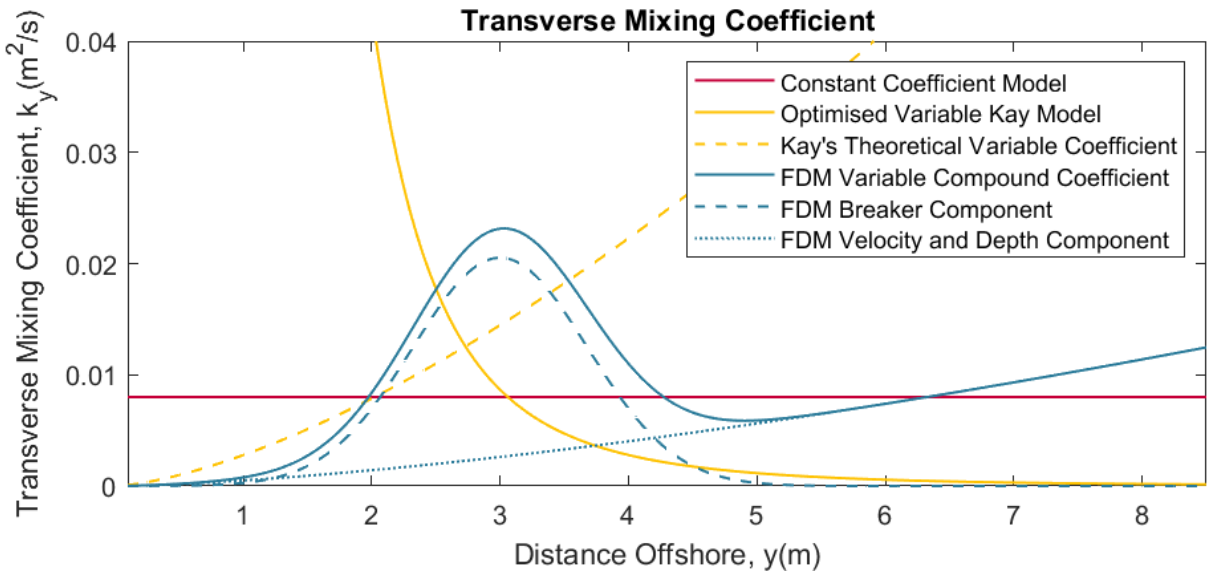
Discussion

- Points for discussion
  - Swash zone processes
  - Breaker induced turbulence
    - Magnitude, location of peak distribution
- Temporal variability
- Longshore spatial variation
- Vertical variation
- Non-neutral solutes



Wave Period	T = 1.2 s	T = 1.85 s	T = 2.9 s
Constant	0.5338	0.7615	0.6737
Kay	0.7858	0.8017	0.9135
FDM	0.6660	0.8176	0.9023

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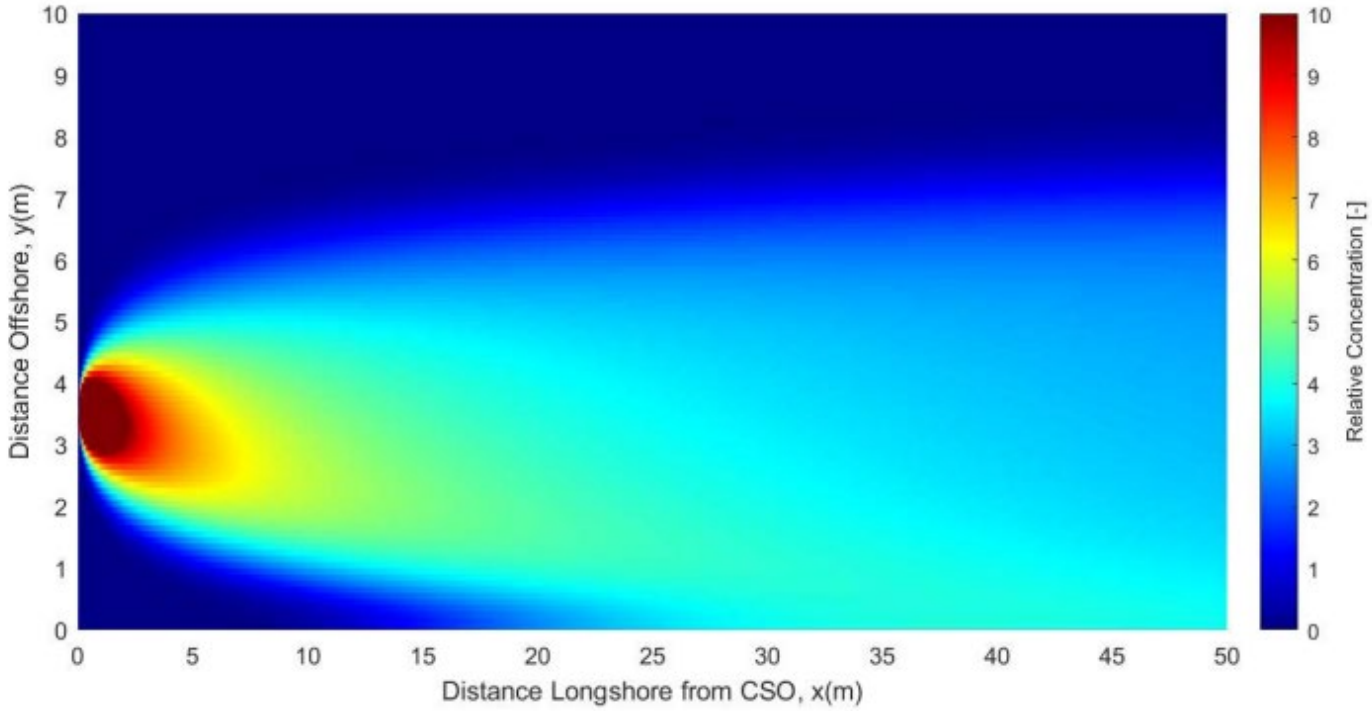
Conclusion

- Spatial variability of mixing coefficient is almost certain
- Mixing likely to peak within the surf zone and reduce offshore
- FDM best to use
- More research needed to quantify turbulence

Basic prediction of concentration distribution from a continuous point source, for example a sewer overflow:



Thank you to everyone involved in collecting and analysing this dataset.

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