

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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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?

A water pollution time bomb

Alarmed specialists say Durban's water security is not so much threatened by scarcity as by upstream pollution – much of it emanating from Pietermaritzburg's Msundusi River. **Fred Kocott and Siboniso Mngadi** report



No river safe for bathing

● Toxins at highest levels since testing began ● Watchdog 'leaves water companies free to pollute'

TIMES INVESTIGATION

Ryan Watts, Steve Biskley
George Greenwood, Dylan Lewis

Dangerous pollutants in England's waterways have reached their highest levels since modern testing began. The Times can reveal, with no river in the country now certified as safe for swimmers.

Wild swimming has surged in popularity, with tens of thousands of people heading to country rivers and ponds during this week's holidays.

However, an investigation by this newspaper has revealed that rivers in England are not tested enough to be

considered safe for swimming. Eighty-six per cent fall short of the EU's ecological standard – the minimum threshold for a healthy waterway – up from 75 per cent a decade ago.

In addition, half of all stretches of river monitored by the Environment Agency exceeded permitted limits of at least one hazardous pollutant last year, including toxic heavy metals and pesticides.

Despite serious pollution incidents frequently exceeding the limits, prosecutions by the agency against the regional monopolies that run Britain's waterways have declined – to three last year from thirty in 2014.

In some cases the agency is allowing the water companies to suggest their

own penalties, usually contributions to charity. Experts say that this leaves water companies feeling free to pollute rivers.

Kerry McCarthy, MP, a member of the environmental select committee, said that the companies were "treating fines as the cost of doing business, rather than seeing them as a serious deterrent", adding: "The Environment Agency needs to step up."

David Slater, a former director of the agency, said: "Cutting budgets absolutely has an effect: fewer policemen means less testing and less enforcement – and as we've seen with some of the water companies, people will take advantage of lax enforcement."

Last month Southern Water was fined

a record £127 million for "shocking" breaches that allowed raw sewage to be released into rivers and on to beaches. Environmental groups are now calling for reform of the Environment Agency. Stuart Singleton, White, of the Angling Trust, said: "We're going backwards – our rivers are getting worse."

Hundreds of wild-swimming clubs have formed across the country in the past two years, according to the Outdoor Swimming Society, whose membership has climbed to more than 70,000 from only a couple of hundred a decade ago.

Most people who enjoyed waterside beauty spots last week will have been unaware of how Britain's ageing sewer



Sewage hits nearly 50 beaches in England and Wales after heavy rain

By Claire Marshall
BBC Environment & Rural Affairs Correspondent

3 hours ago · 1 Comment



The Environment Agency (EA) has said that the report, which is the first of its kind, shows that the quality of water in rivers and ponds across England and Wales is poor. The report also shows that the quality of water in rivers and ponds is getting worse.

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Groundwater quality dips too

Study by Rain Centre examined water levels in core city areas

DANGEROUS SIGNS

One well per sq km was chosen in each ward of the city for the study.

The average water level in wells was 5.5 m and in July fell to 5.0 m.

The total dissolved solids, which is one of the important parameters to determine water quality, is 500-600 mg/l.

Urgent Further work is needed to detect water supply, drying, toxicology and lack of rainfall show some rivers have just closed presents on the groundwater table in some parts of the city. Many rivers, however, have been affected on groundwater for the past few months, which has led to depletion in the water table, says a study by Rain Centre, a city-based voluntary organisation.

In some areas, the water table has dropped below the level of the ground. This has also taken a toll on other quality, however, Chertsey, the study of 140 observation wells across the city with a different rate. The Metropolitan figure indicates a rise in the water table by 0.43 m in 1976 to 1977.

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High levels of faecal coliform in STPs: Report

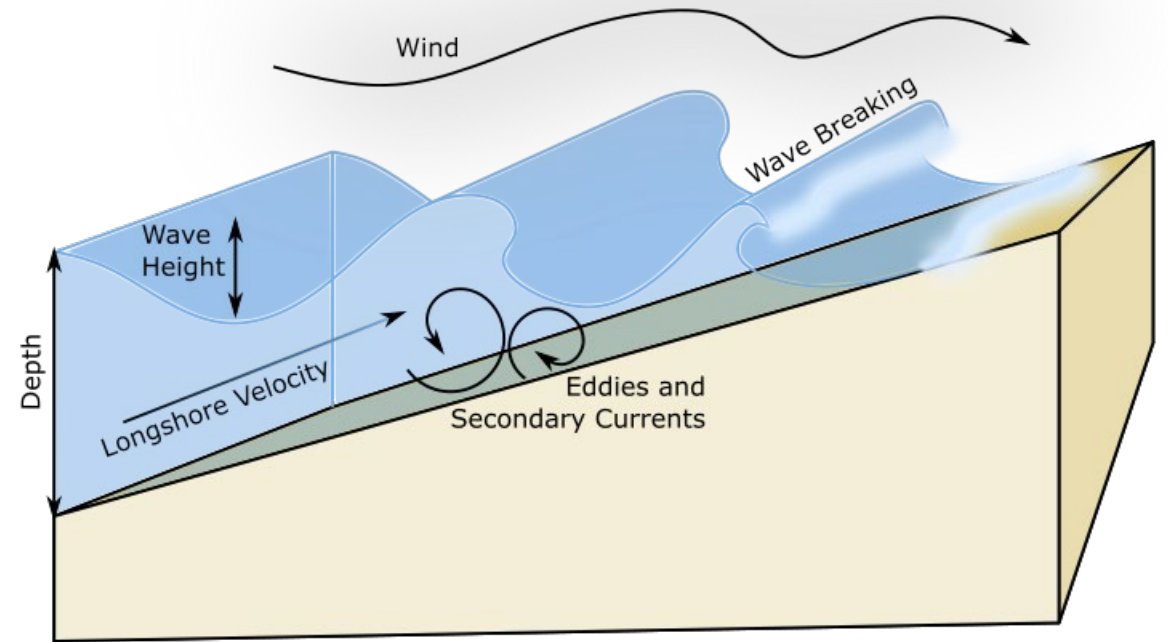
The Highest In Dhanas, Lowest In 3BRD

Indian Municipal Corporation (IMC) has reported that the highest levels of faecal coliform in STPs are in Dhanas, while the lowest are in 3BRD.

The report also shows that the quality of water in rivers and ponds is poor. The report also shows that the quality of water in rivers and ponds is getting worse.

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



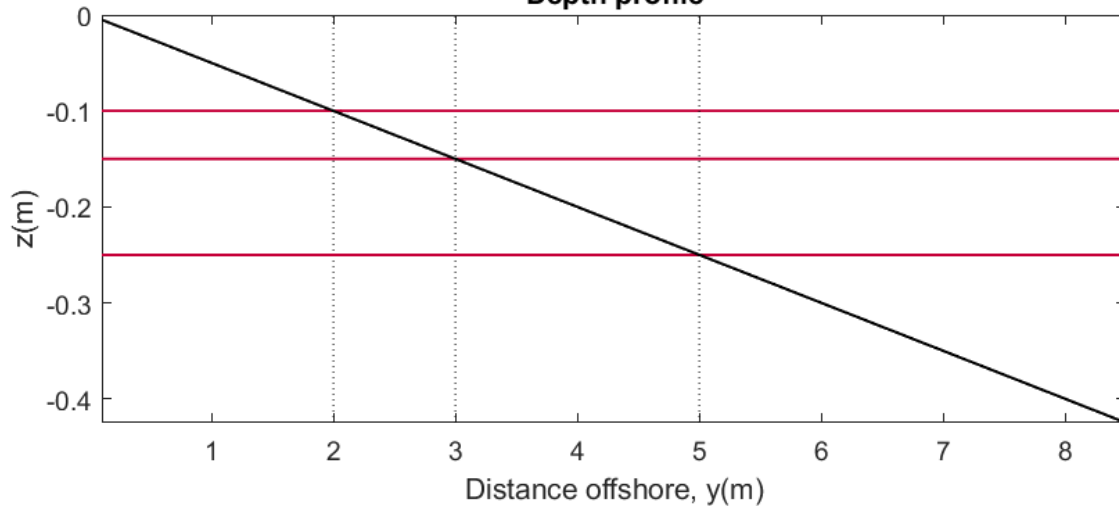
Methodology

- 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

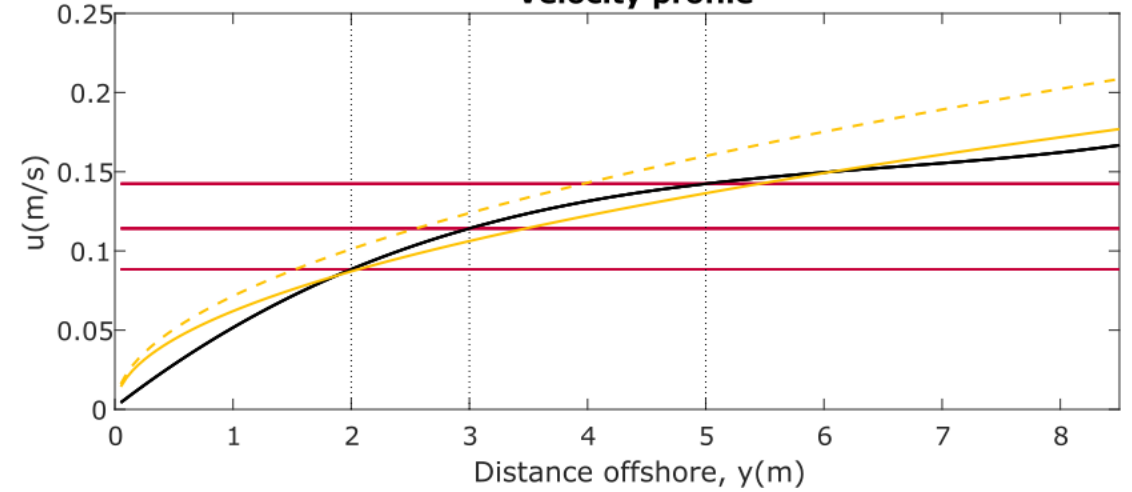


Existing Models

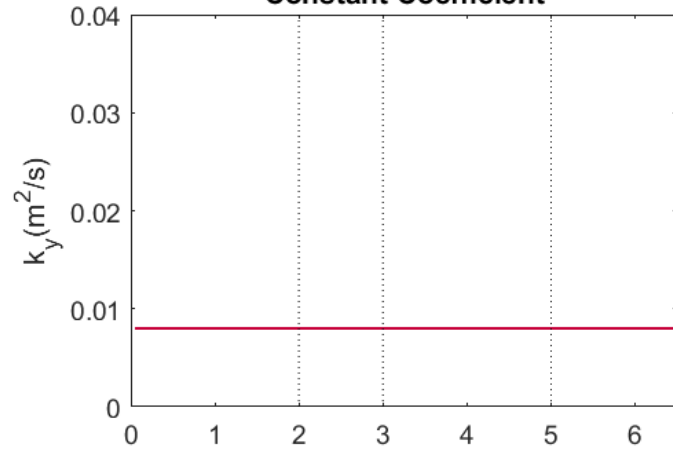
Depth profile



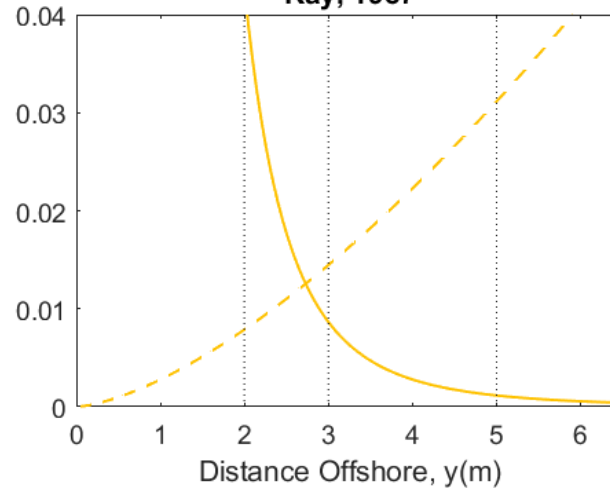
Velocity profile



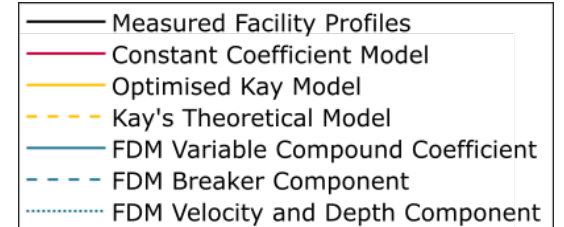
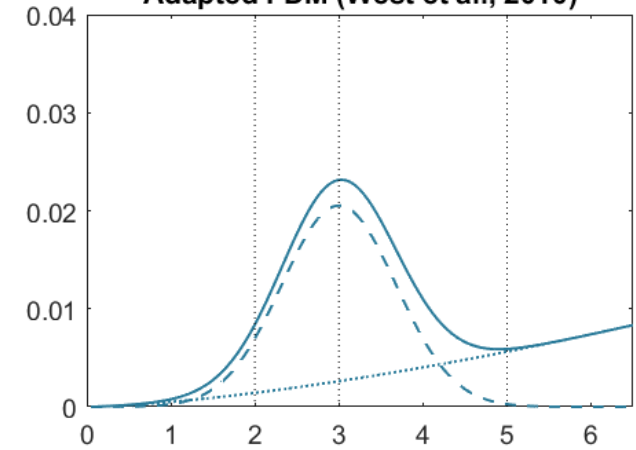
Constant Coefficient



Kay, 1987



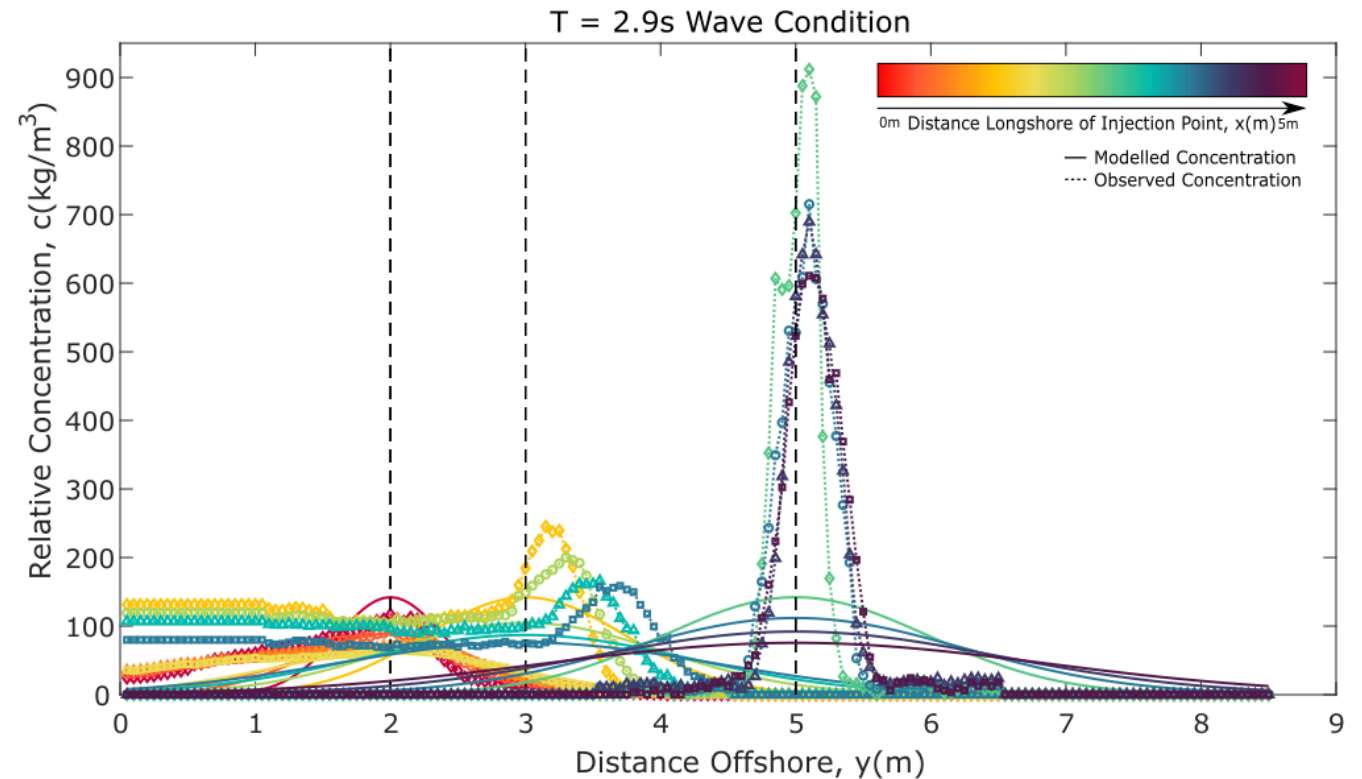
Adapted FDM (West et al., 2010)



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

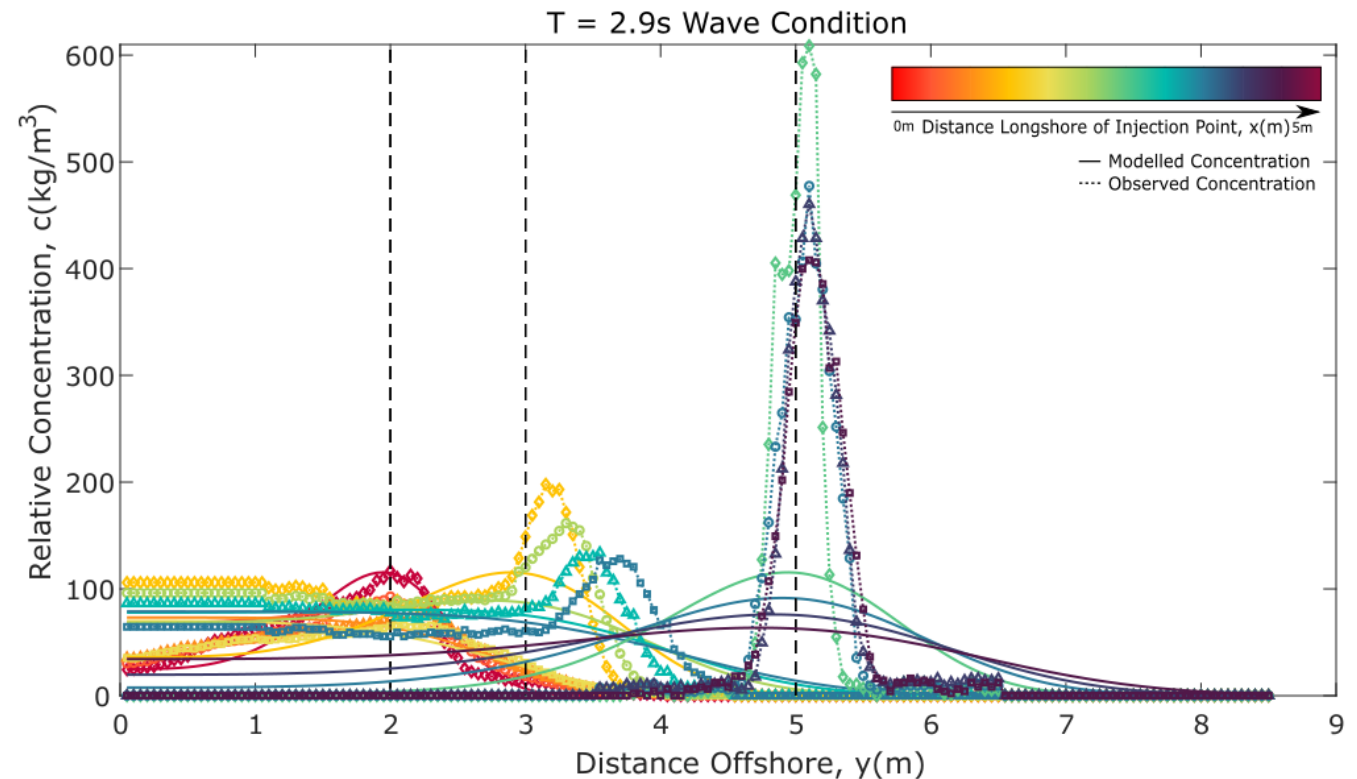


Wave Period	T = 1.2 s	T = 1.85 s	T = 2.9 s
R_t^2	0.5338	0.7615	0.6737

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

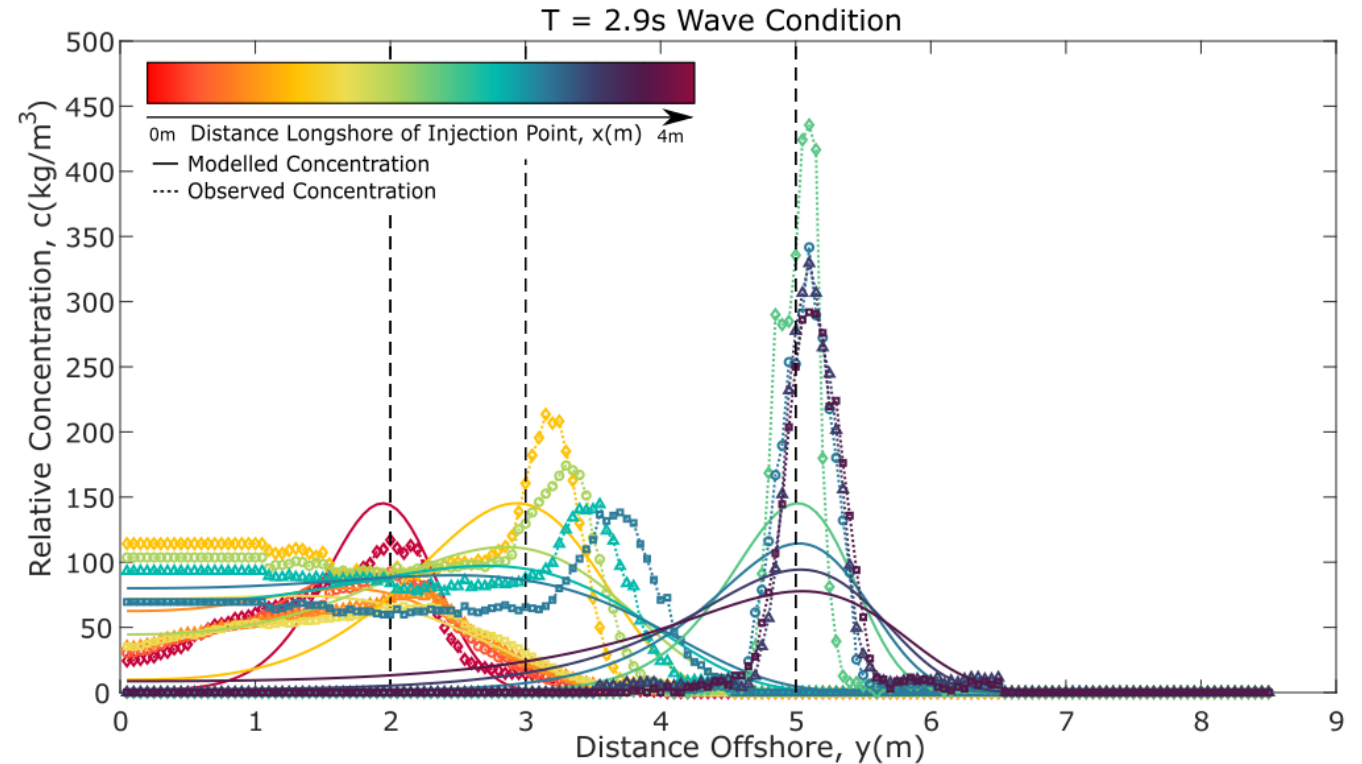


Wave Period	T = 1.2 s	T = 1.85 s	T = 2.9 s
R_t^2	0.7858	0.8017	0.9135

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

Spatially variable velocity & mixing, plus Breaker-Induced Mixing

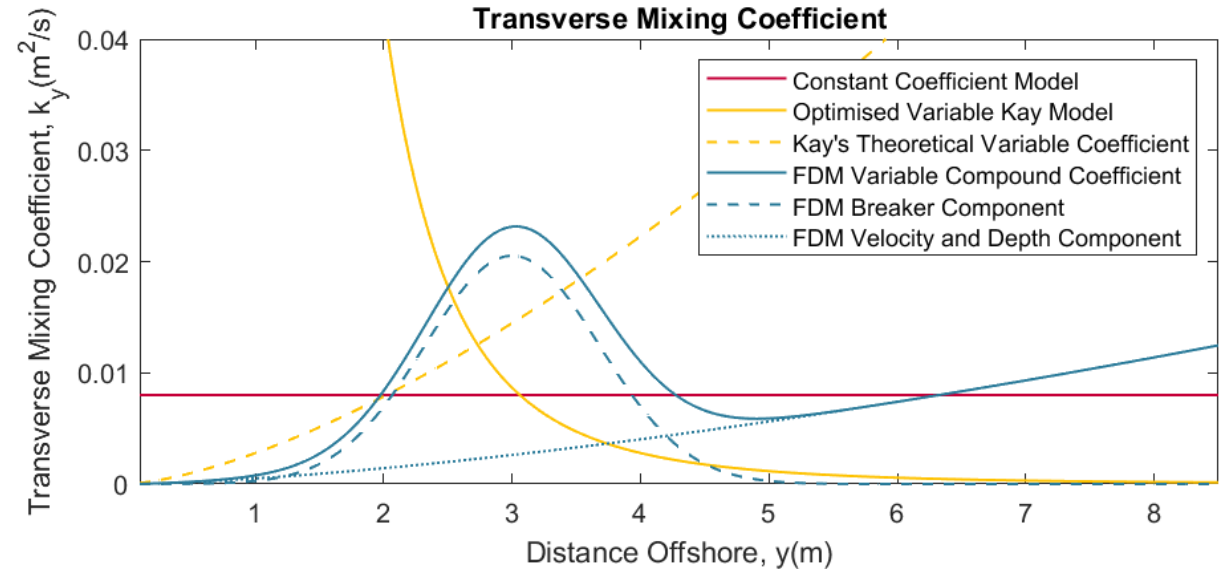
- Allows for spatial variability in profiles
- Predicts non-Gaussian behaviour
- Shoreline concentrations not accurately described
- Overestimation of mixing
- Limitations in mixing coefficient profile:
 - Scale
 - Location of peak



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

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

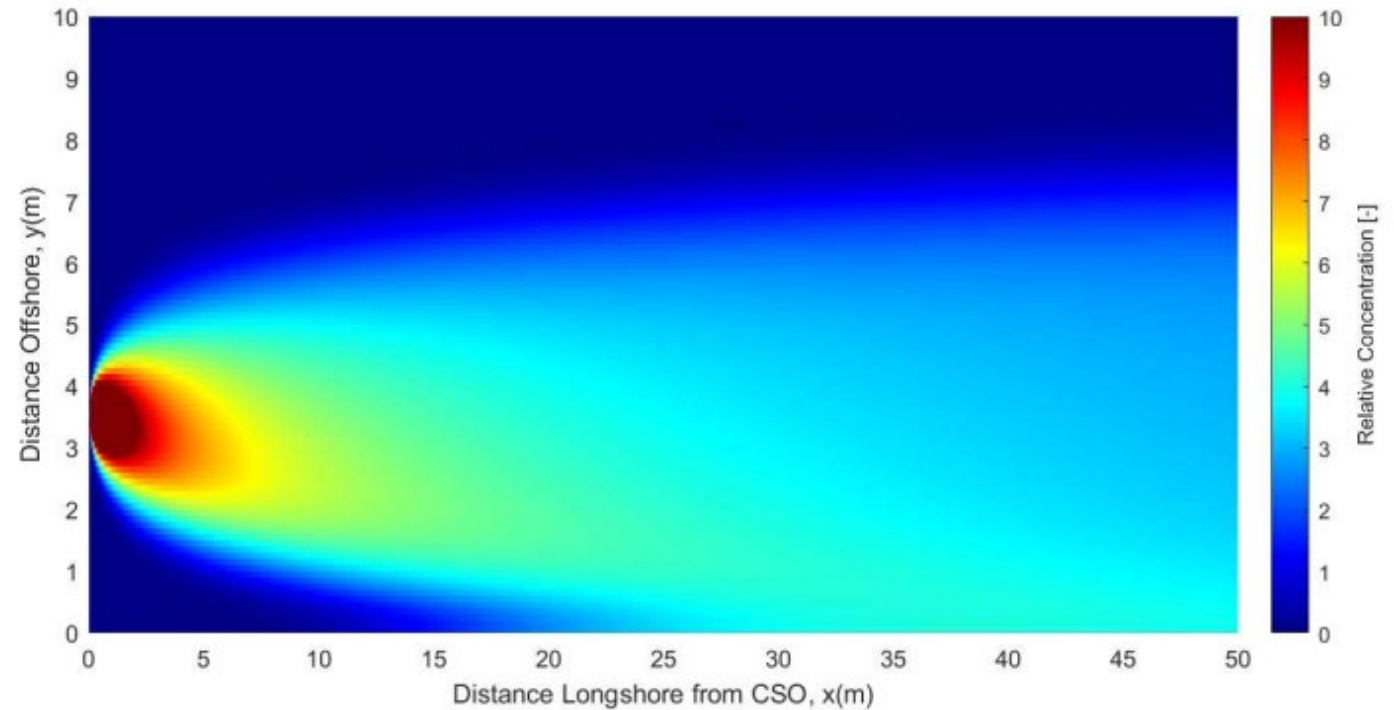


Wave Period	T = 1.2 s	T = 1.85 s	T = 2.9 s
Constant	0.5338	0.7615	0.6737
Kay	0.7858	0.8017	0.9135
FDM	0.6660	0.8176	0.9023

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.