THE CHANGING ROLE & APPLICATION OF MIKE MODELLING IN THE IRISH AQUACULTURE INDUSTRY

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A TETRA TECH COMPANY

OVERVIEW

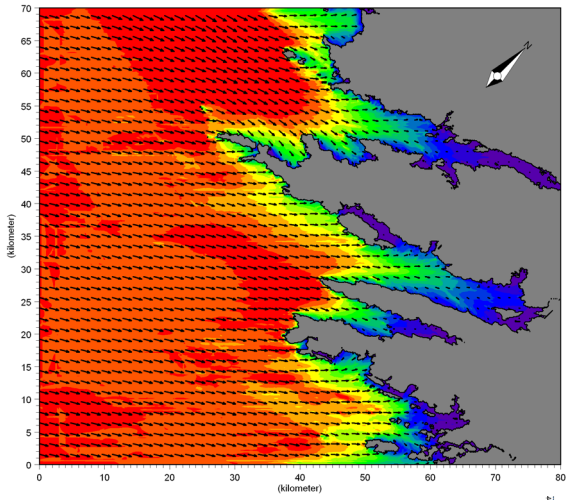
- Where it began for RPS
- Changing Legislation
- Supporting Licence Applications
- Supporting Research
- How things have changed
- Modelling now and into the future

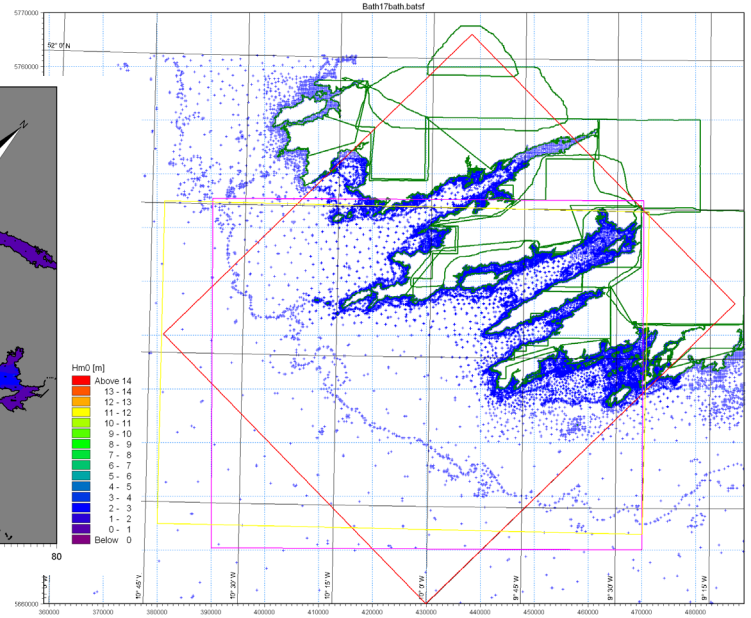
Small beginnings

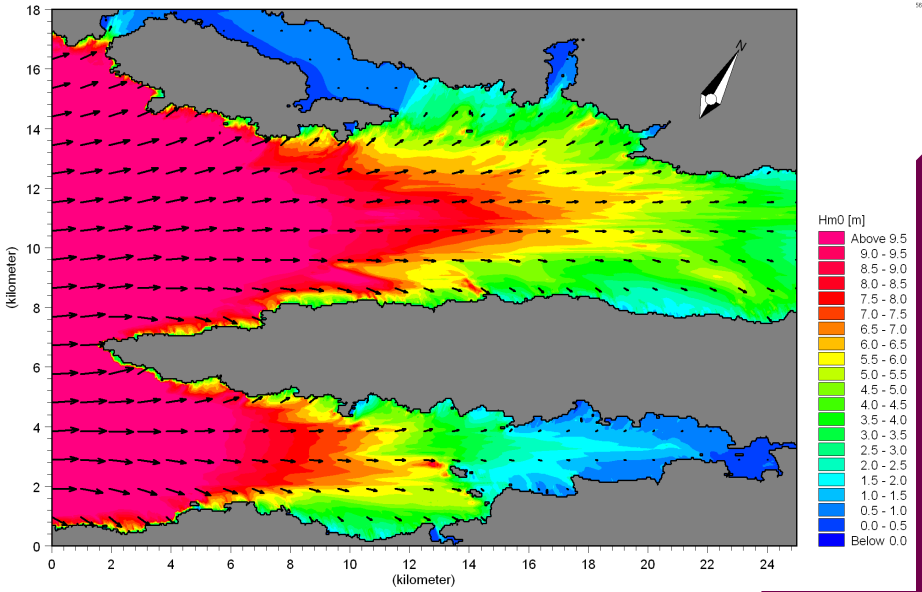
Supporting the Aquaculture Industry

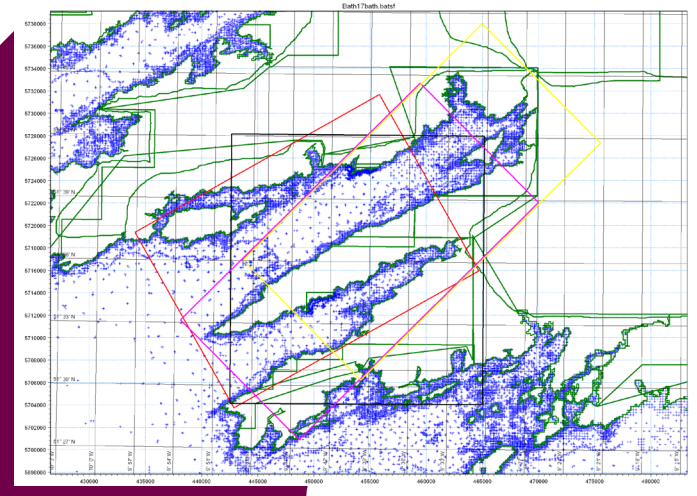
- What we were doing
  - Site selection
  - Site characterisation
    - Mooring design
    - Accessibility
- MIKE tools
  - MIKE classic for tidal flows
  - MIKE 21 NSW

Bantry & Dunmanus Bay
1:50 year waves from 240°









Then things began to change

European Water Framework Directive (WFD) adopted under SI 272 of 2009
European Communities (Control of Dangerous Substances in Aquaculture) Regs (SI 466 of 2008)

- Full EIA required for Aquaculture Licence
  - Assessment of EQS
    - Nitrogen & Phosphorus
    - Medication treatment residues
- What were others doing?
  - Scottish Practice
    - SAMS DEPOMOD
    - SEPA guidance
  - Netherlands
- Needed an Irish Approach

S.I. No. 77 of 2019 excerpt of Table 9: Physico-chemical conditions supporting the biological elements

Nutrient Conditions	Coastal Water Body (winter and summer)	
Dissolved Inorganic Nitrogen (mg N/l)	High status (0 psu (1)) ≤ 1.0	Good status (0 psu (1)) ≤ 2.6
	High status (34.5 psu(1)) ≤ 0.17	Good status (34.5 psu(1)) ≤ 0.25

(1) Linear interpolation to be used to establish the limit value for water bodies between these salinity levels based on the median salinity of the water body being assessed."

S.I. No. 466 of 2008 Emamectin benzoate (Slice) EQS

The following standards shall apply 24 hours post treatment at 100m from the site:	
Emamectin benzoate (Slice)	0.22ŋg/l*

* Note: concentration unit ŋg/l is equivalent to µg/m³

Our response

Develop modelling strategies

- What we were doing
  - Modelling waste streams
    - Feed & faeces
    - Medicinal discharges
    - Chemical discharges
    - Lice dispersion

- MIKE tools
  - MIKE classic
  - MIKE NPA –
    - decoupled & sub-grid
  - MIKE AD

Later
- MIKE FM
- MIKE PT
- MIKE AD

Month	Nitrogen discharge N Tonnes / month											
	Shot Head			Fastnet			Roancarrig			Waterfall		
	Total	Settleable	Soluble	Total	Settleable	Soluble	Total	Settleable	Soluble	Total	Settleable	Soluble
Sep	Fallow site			Fallow site			9.65	0.89	8.76	0.13	0.01	0.11
Oct							11.58	1.07	10.51	0.13	0.01	0.11
Nov	0.72	0.09	0.64	0.18	0.02	0.16	12.69	1.17	11.52	0.13	0.01	0.11
Dec	1.14	0.14	1	0.29	0.03	0.25	14.15	1.31	12.84	0.13	0.01	0.11
Jan	1.66	0.22	1.45	0.42	0.05	0.36	15.26	1.41	13.85	0.13	0.01	0.11
Feb	2.68	0.35	2.32	0.67	0.09	0.58	13.84	1.28	12.56	0.13	0.01	0.11
Mar	4	0.53	3.48	1	0.13	0.87	13.42	1.24	12.18	0.13	0.01	0.11
Apr	5.18	0.68	4.49	1.29	0.17	1.12	9.15	0.85	8.31	0.13	0.01	0.11
May	6.15	0.86	5.29	1.54	0.22	1.32	4.85	0.45	4.4	Fallow site		
Jun	7.91	1.11	6.8	1.98	0.28	1.7	1.98	0.18	1.79			
Jul	9.37	1.32	8.06	2.34	0.33	2.01	1.25	0.12	1.13	0.13	0.01	0.11
Aug	8.48	0.78	7.69	2.12	0.2	1.92	0.18	0.02	0.16	0.13	0.01	0.11
Sep	9.65	0.89	8.76	2.41	0.22	2.19	Fallow site			0.13	0.01	0.11
Oct	11.58	1.07	10.51	2.89	0.27	2.63				0.13	0.01	0.11
Nov	12.69	1.17	11.52	3.17	0.29	2.88	0.72	0.09	0.64	0.13	0.01	0.11
Dec	14.15	1.31	12.84	3.54	0.33	3.21	1.14	0.14	1	0.13	0.01	0.11
Jan	15.26	1.41	13.85	3.82	0.35	3.46	1.66	0.22	1.45	0.13	0.01	0.11
Feb	13.84	1.28	12.56	3.46	0.32	3.14	2.68	0.35	2.32	0.13	0.01	0.11
Mar	13.42	1.24	12.18	3.36	0.31	3.05	4	0.53	3.48	0.13	0.01	0.11
Apr	9.15	0.85	8.31	2.29	0.21	2.08	5.18	0.68	4.49	0.13	0.01	0.11
May	4.85	0.45	4.4	1.21	0.11	1.1	6.15	0.86	5.29	Fallow site		
Jun	1.98	0.18	1.79	0.49	0.05	0.45	7.91	1.11	6.8			
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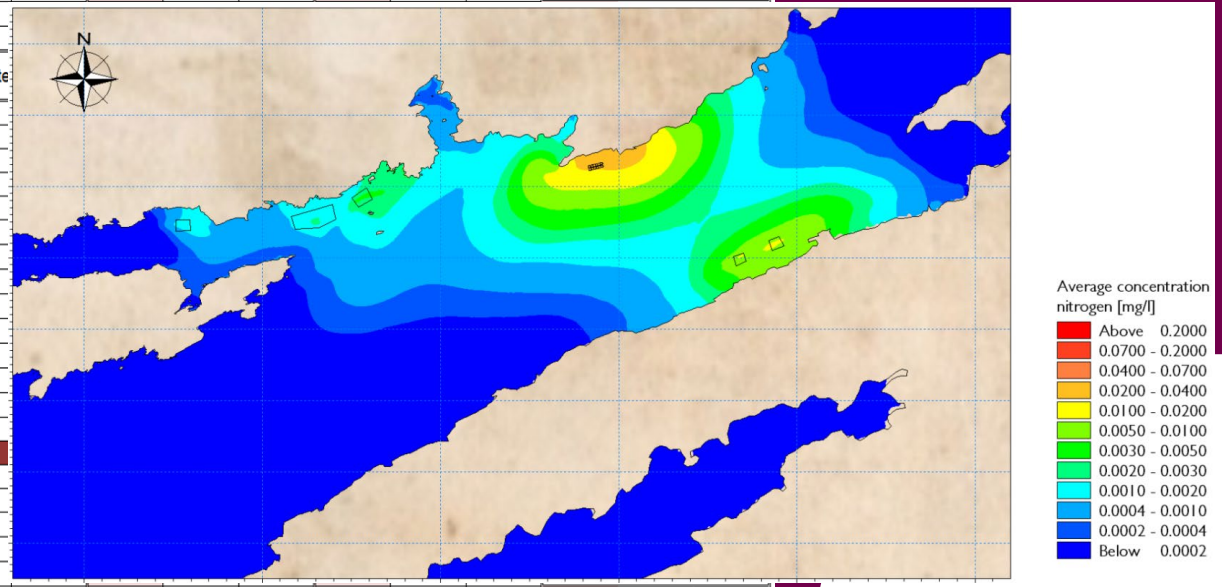
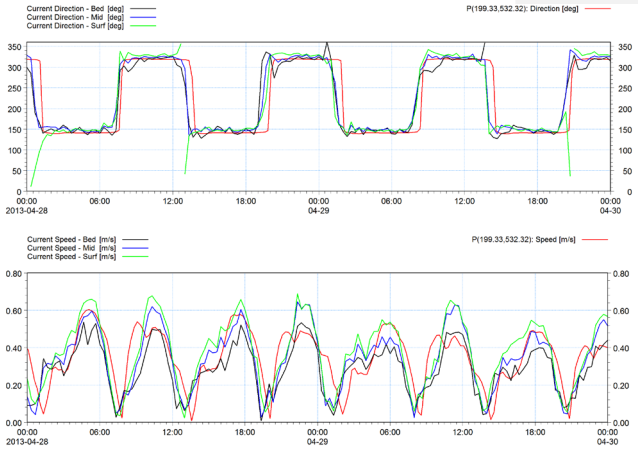
Average Nitrogen Concentration from all sites in Bantry Bay

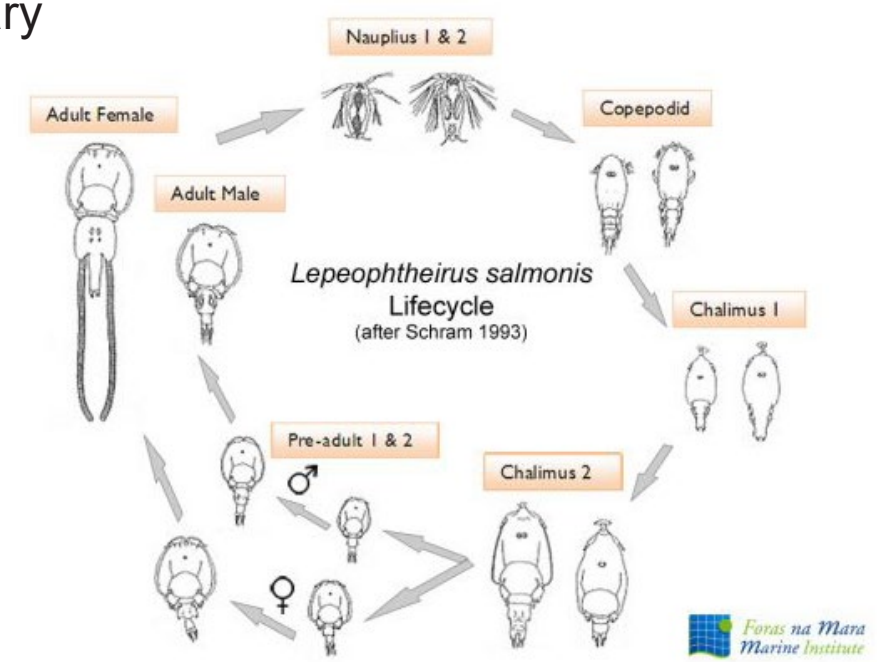


Supporting research

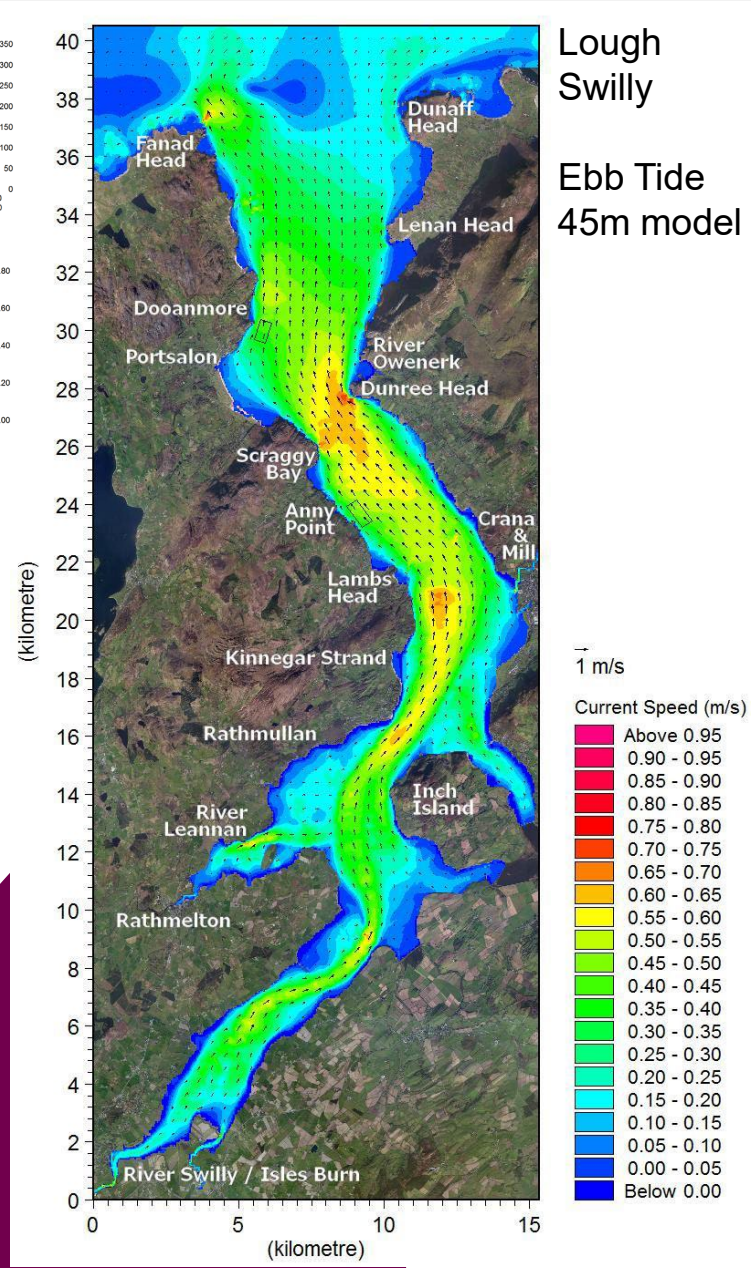
Sea Lice



- What we were doing
  - Examining potential for farm origin lice to infect wild salmon
    - Farm sites to estuary
    - Site to site
    - Infestive stage
      2-stage model
    - Theory of geotaxis
      Edit HPQ



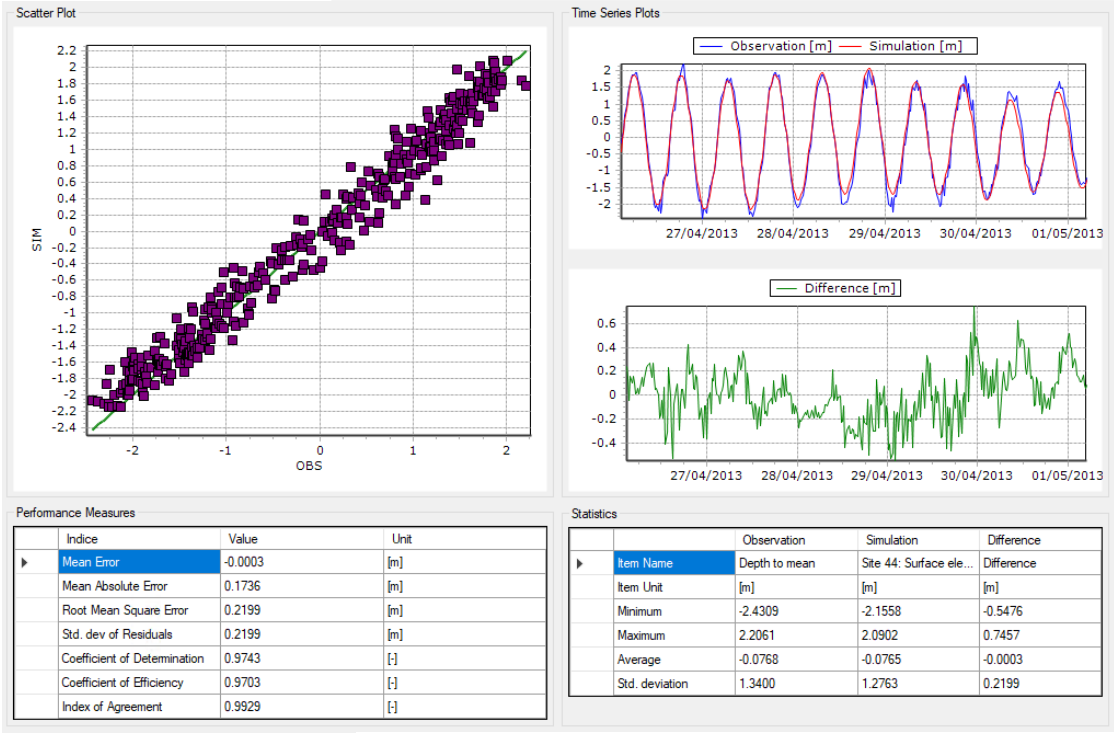
- MIKE tools
  - MIKE classic
  - MIKE NPA – (no ABM or EcoLab)



How things have changed

- Aquaculture practices
  - Organic farming with cleaner fish
  - Single Bay Management
  - Lice treatments
    - Targeted in feed or well boat
    - Freshwater

- Legislation & licencing
  - Very few licences have progressed
  - Public opinion is very strong
  - Irish Government Bodies are examining all licence applications
    - Model audits by Marine Institute
    - Prescribed model calibration standard
    - Developed a stepwise approach (e.g. 2D or 3D)
    - Standardise approach (Lice Track European funded research)



Time Series Comparator

Model validation performance metrics

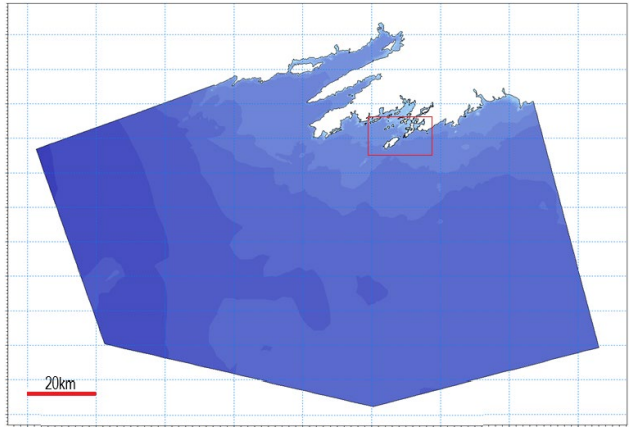
Metric	Statistic			Performance Measure			
Parameter	Average Absolute Value Observed AAV	Mean Absolute Error MAE	Root Mean Square Error RMSE	Coeff of Determination R^2	Coeff of Efficiency E	Index of Agreement d_2	Relative Mean Absolute Error* RMAE
Site 1							
Current Speed	0.326	0.057	0.069	0.83	0.81	0.95	0.18
Current Direction	222.0	11.664	29.244	0.89	0.89	0.97	
Easting Velocity	0.203	0.044	0.054	0.96	0.95	0.99	0.22
Northing Velocity	0.253	0.047	0.057	0.96	0.96	0.99	0.18
Surface Elevation	1.205	0.174	0.220	0.97	0.97	0.99	0.14

J. Sutherland *et al.* (2004), Evaluation of coastal area modelling systems at an estuary mouth.

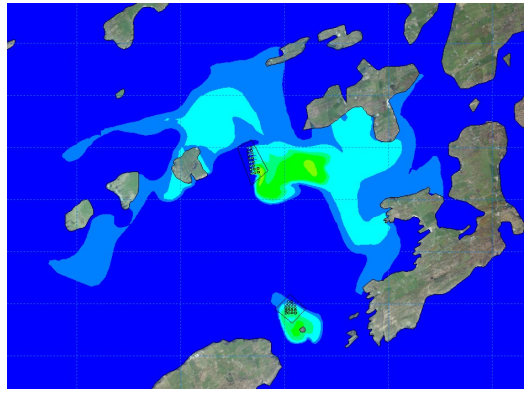
Coastal Engineering 51, 119– 142.

MIKE modelling now

Changes from those early models

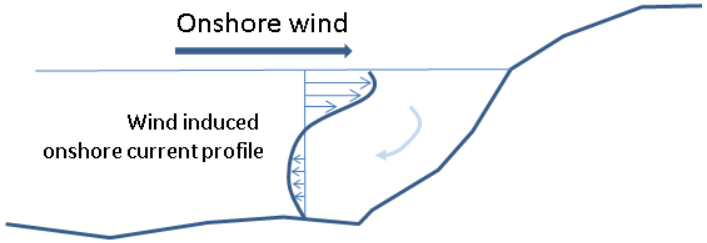


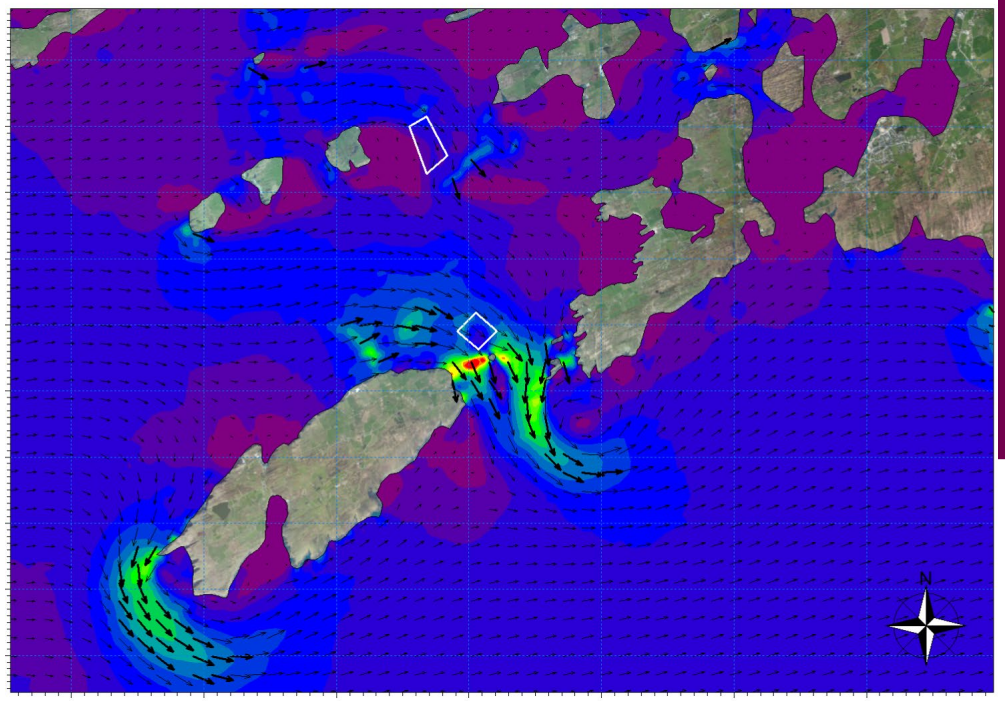
Roaringwater Bay SW Ireland



Flood tide current & dispersion

- Benefits of FM and modular execution (and decoupling)
- 2D model with 3D mechanisms
  - Many Irish sites are open, well flushed and mixed
  - No density stratification so depth averaged models may applied for solutes (AD)
  - Particle Tracking current profiles
    - Reduced currents due to bed shear - settled solids
    - Surface wind induced flow - lice dispersion

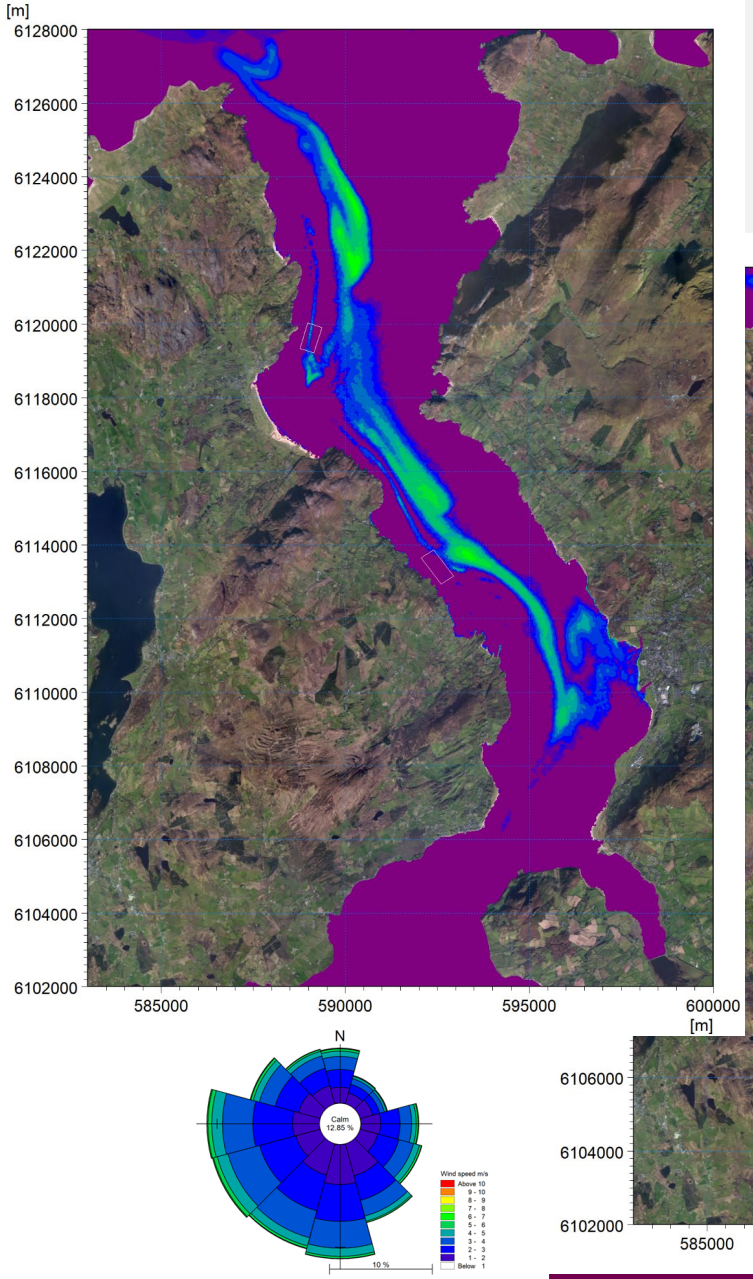




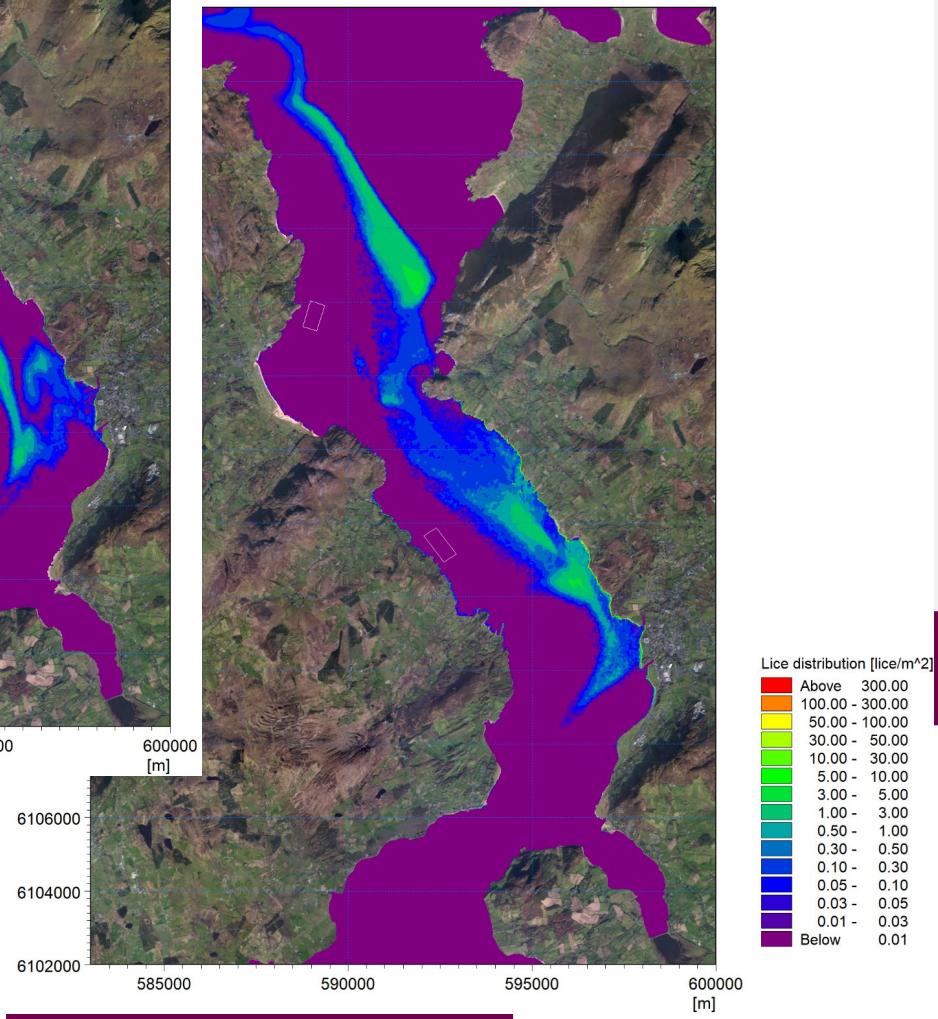
MIKE modelling now

Increased functionality

- Modelling of lice may be complex because of their behaviour and life cycle
  - ABM templates
    - Infestive stage only
    - ‘Lock in’ vertical position
    - Nearshore mechanisms
    - Standardised modelling output
- Going forward
  - More on lice behaviour – ABM rules
    - Light attraction
    - Freshwater avoidance where stratification does occur



Lice distribution in Lough Swilly with westerly wind



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