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A Numerical Model to Estimate Fish Exposure to Elevated Temperature in McNary Dam

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IIHR Hydroscience & Engineering

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Background

- Elevated river temperature increases fish metabolism and induce thermal stress in cold species fish population

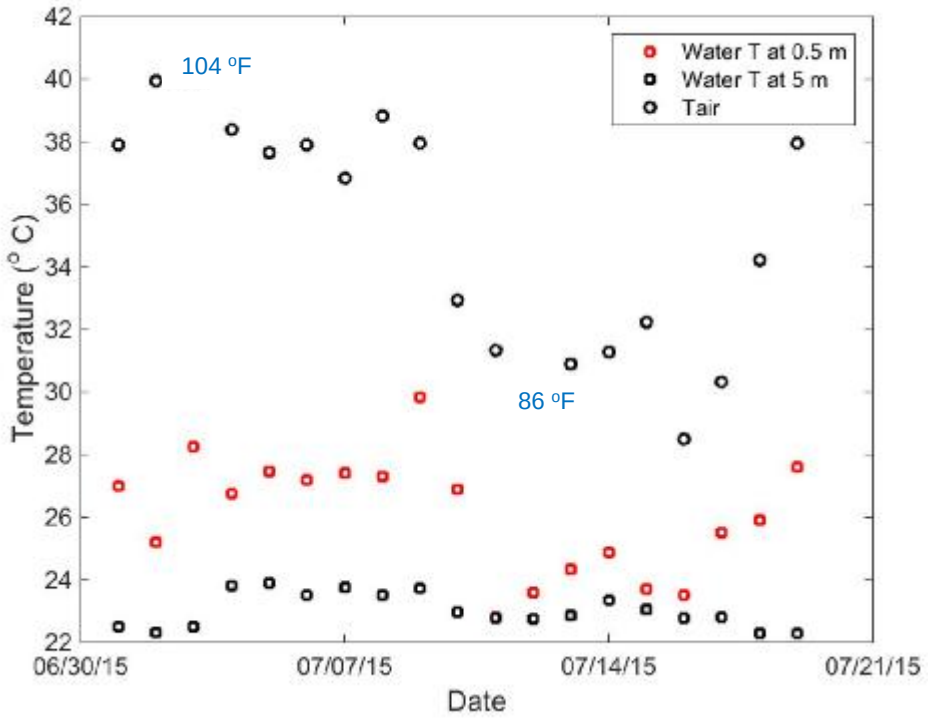
- The UILT for salmon ranges from 25 °C (77 °F) to 30 °C (86 °F)

- Zone of Tolerance: 23.6 °C (74.5 °F) or less

- Zone of Resistance: behavioral mechanisms permit fish to survive short-term extreme temperatures

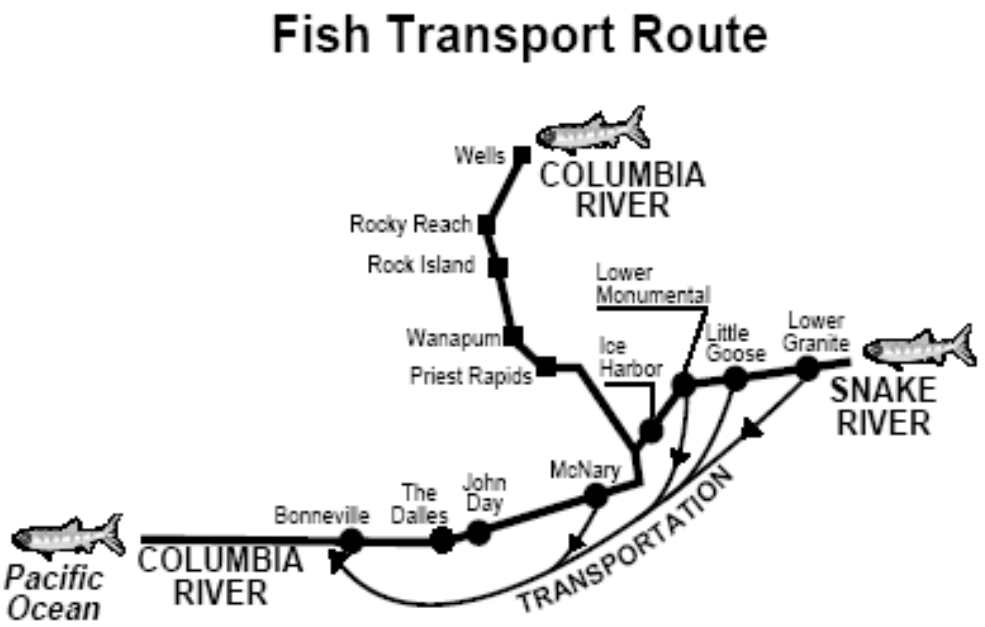
Seattle Times photo

Water Temperature and Fish Migration in 2015



- Record high water temperature in the Columbia and Snake Rivers during mid-June to the end of July.
- Snake River sockeye salmon, suffered losses exceeding 95% between Bonneville and Lower Granite dams

- Juveniles suffered delayed migration
- More than a quarter million Columbia River sockeye salmon have died in the river and its tributaries in the summer of 2015



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McNary Dam

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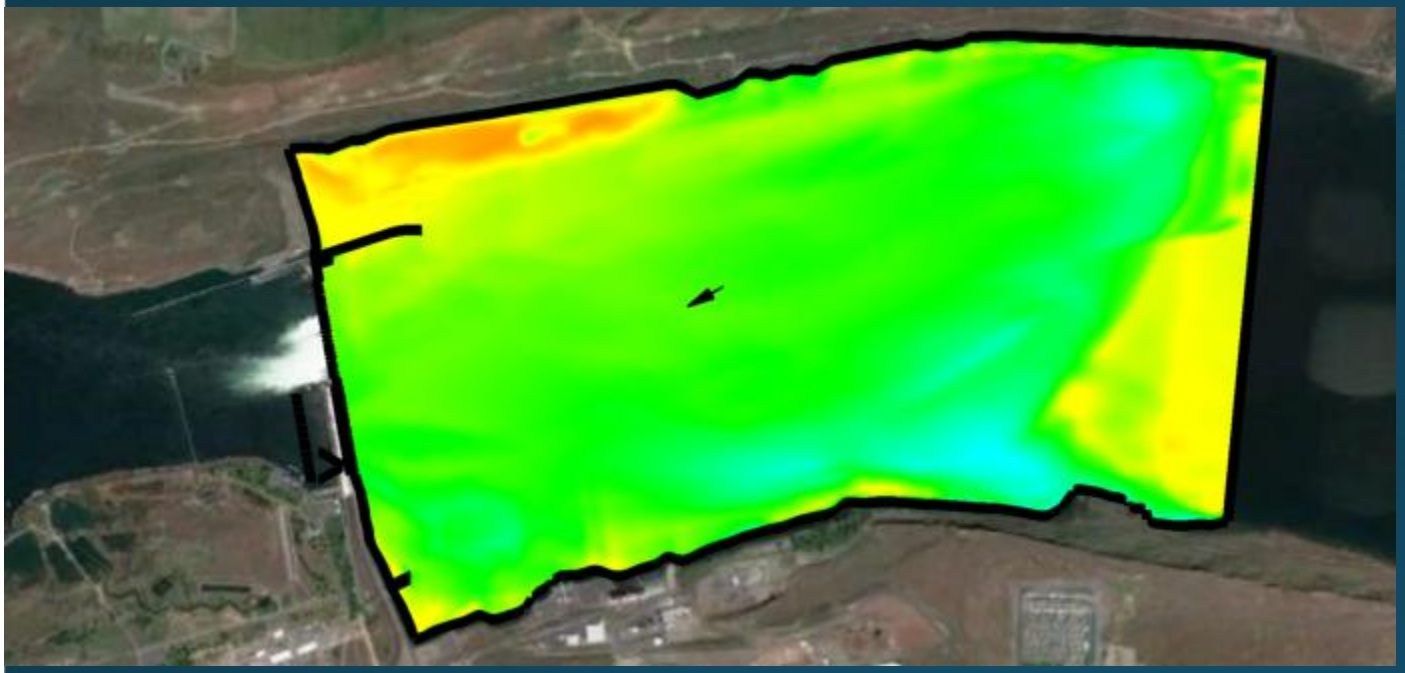
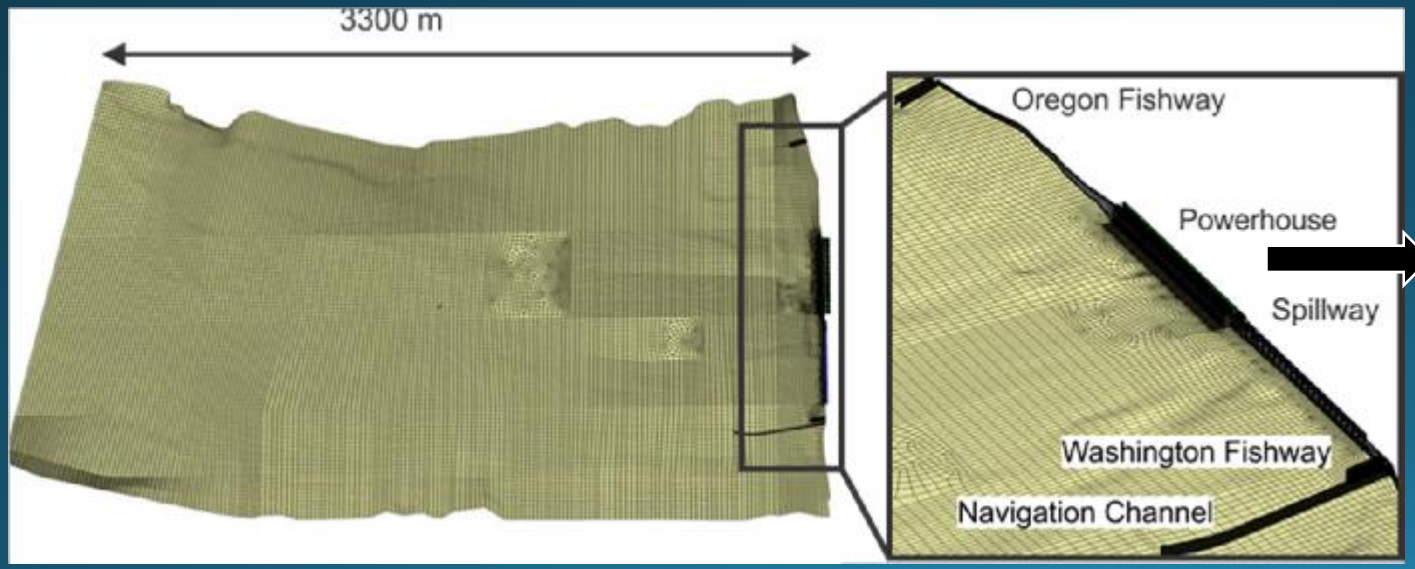
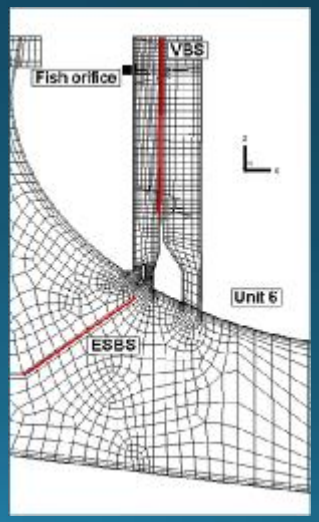


McNary Dam Model





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Model Overview

RANS Model + Energy Equation (Fluent, ANSYS)

Grid Generator

Implemented at IIHR

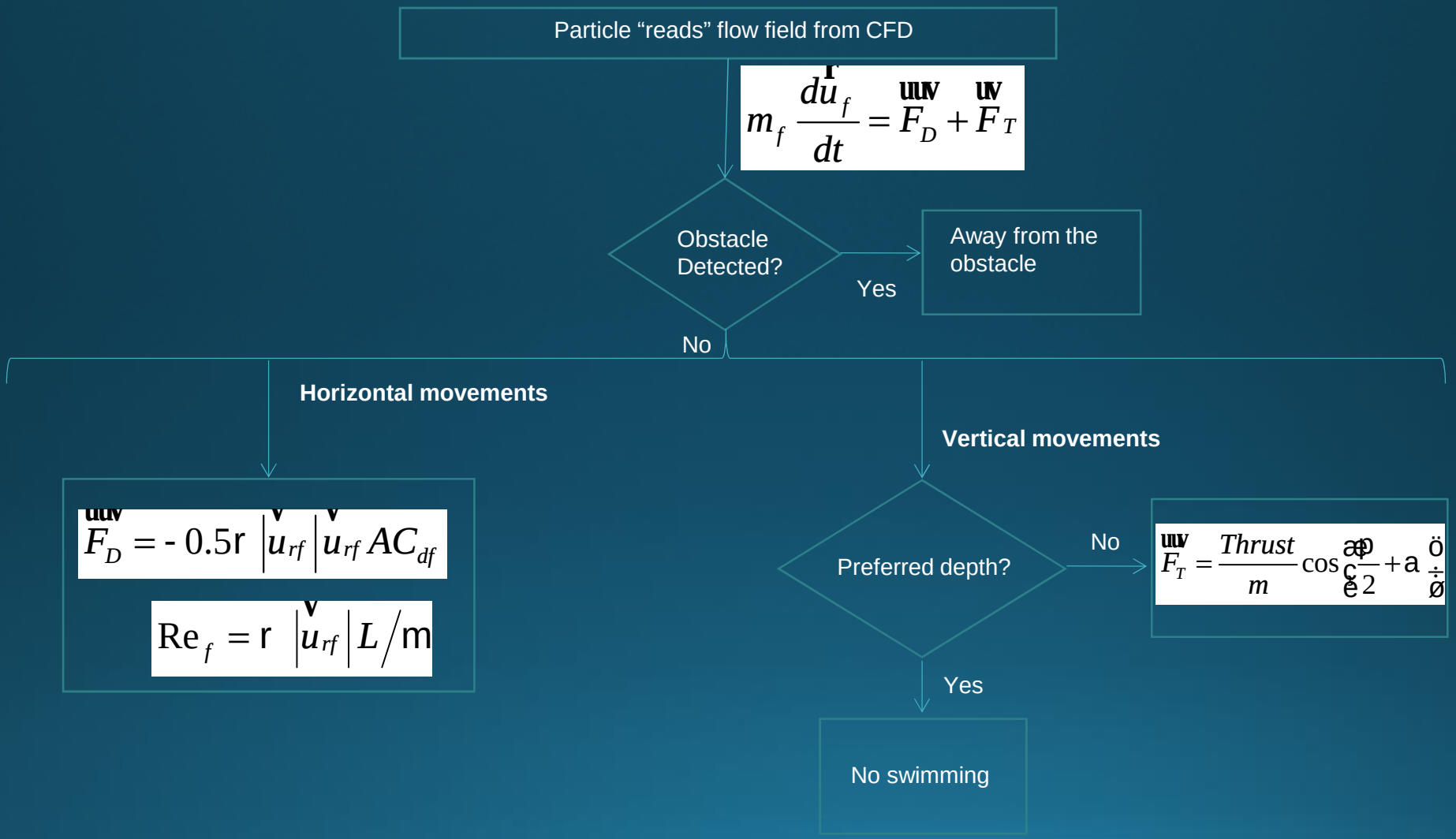
Net Radiation (incoming – reflected)
Long Wave Radiation
Conductive Heat Flux
Inlet Temperature Profiles

Temperature Model

Particle Model

Exposure to Elevated Temperature

Particle tracking - Surface swimming



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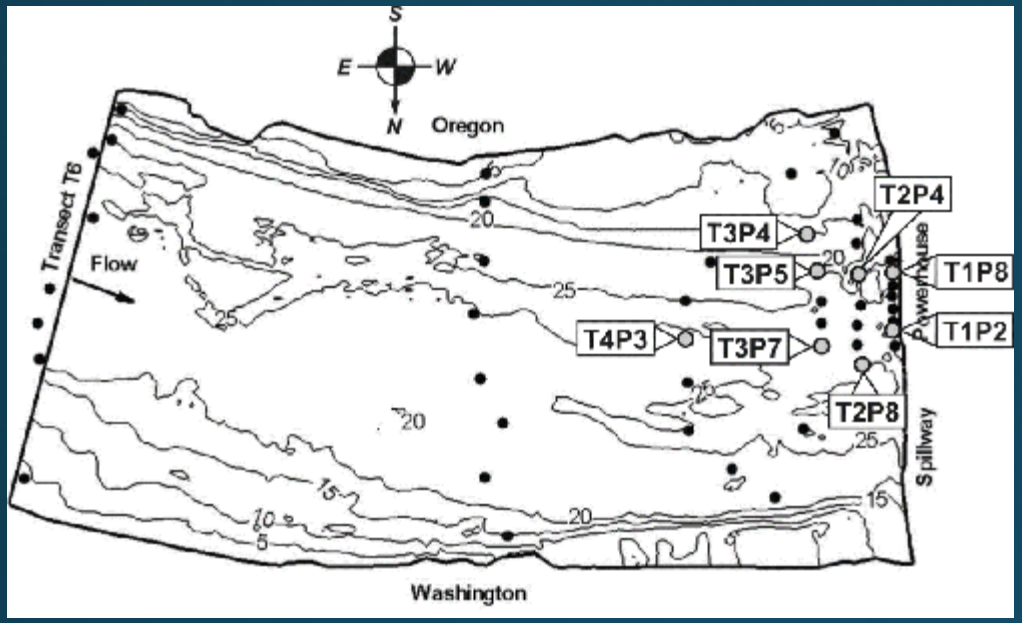
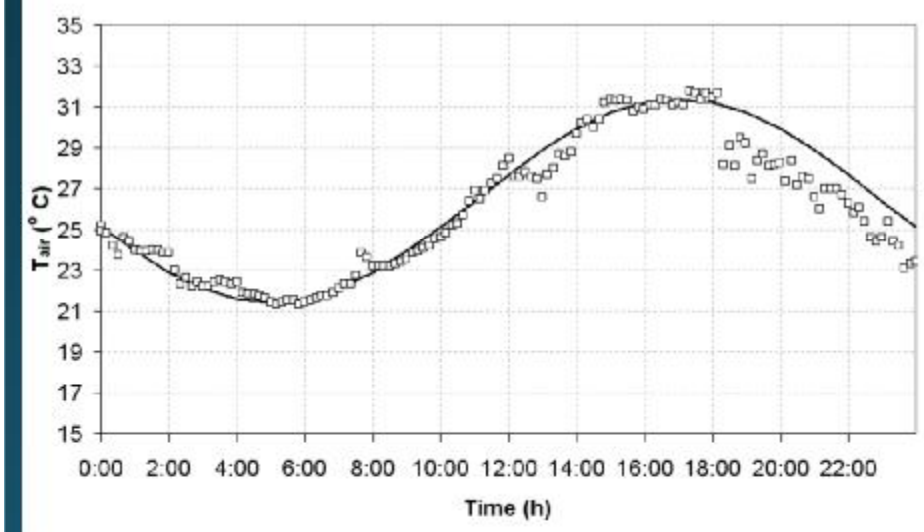
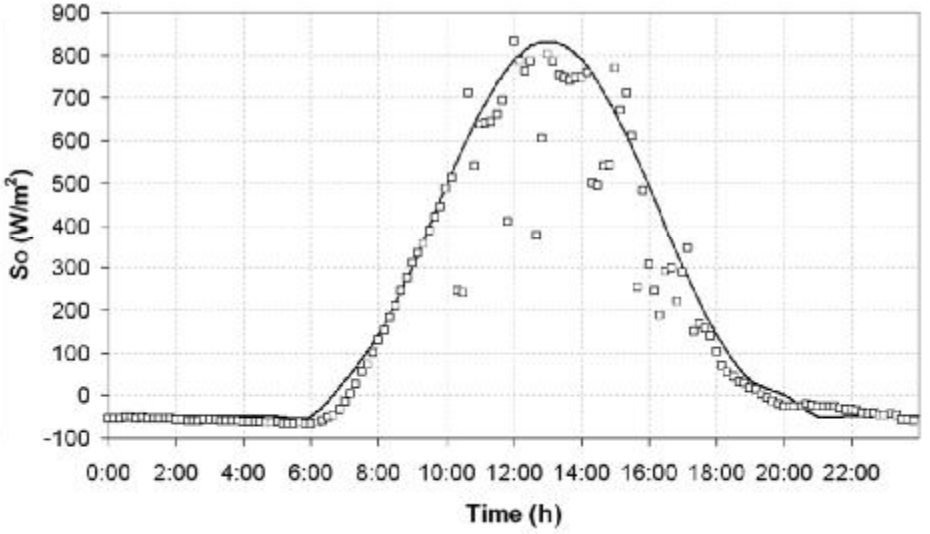


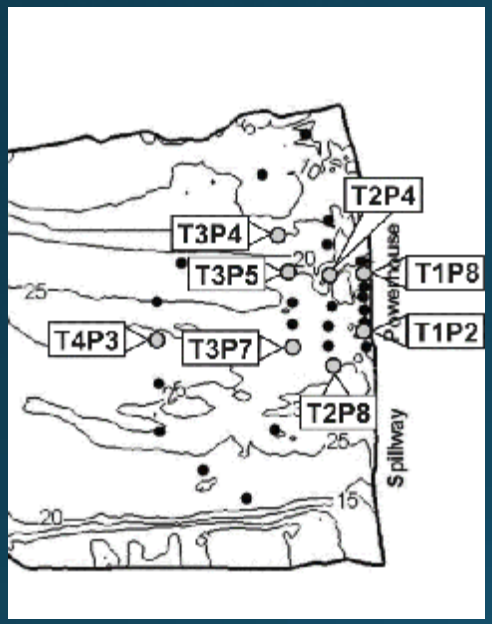
Field Study

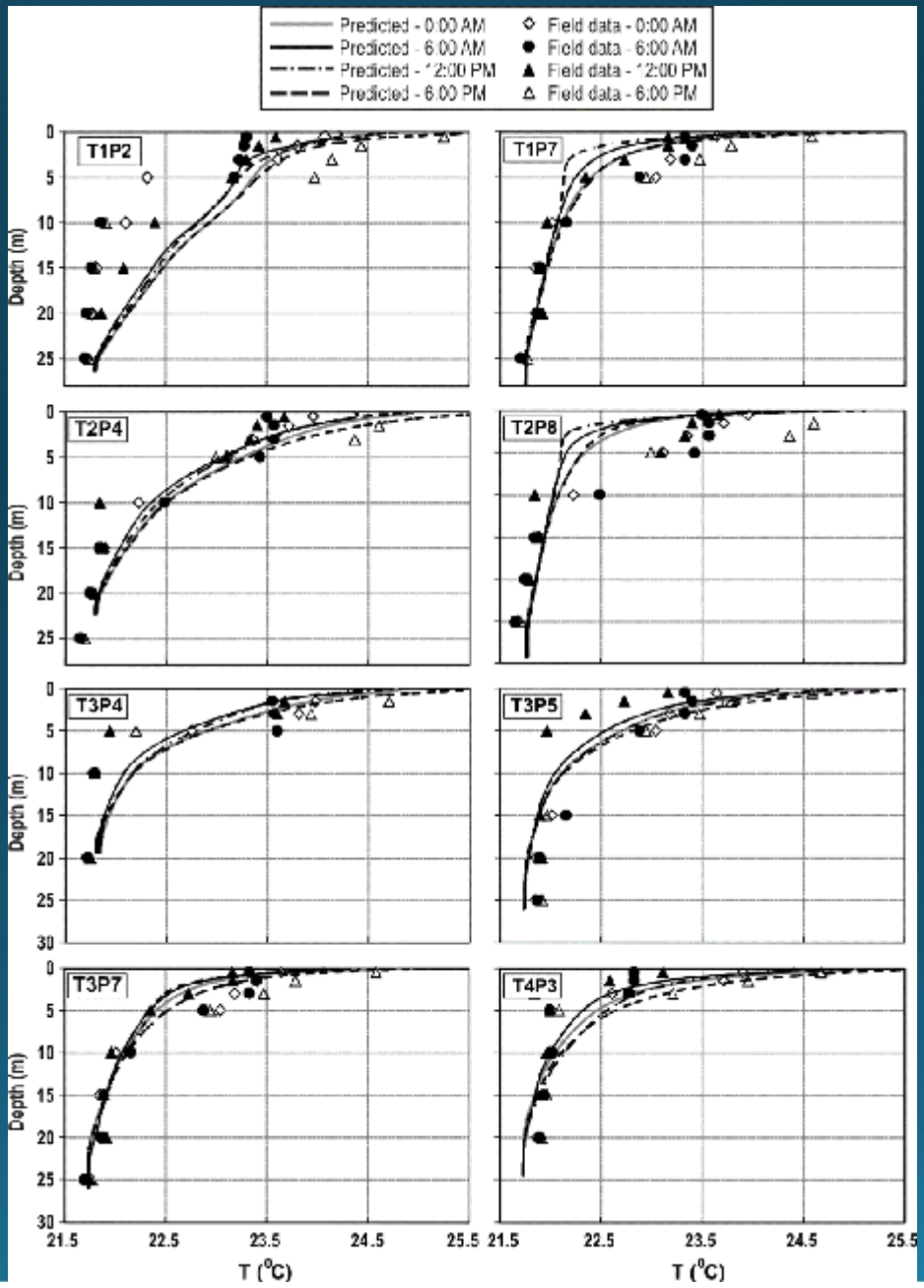
Aug. 18, 2004





Model Validation





Aug. 18, 2004

Model Validation

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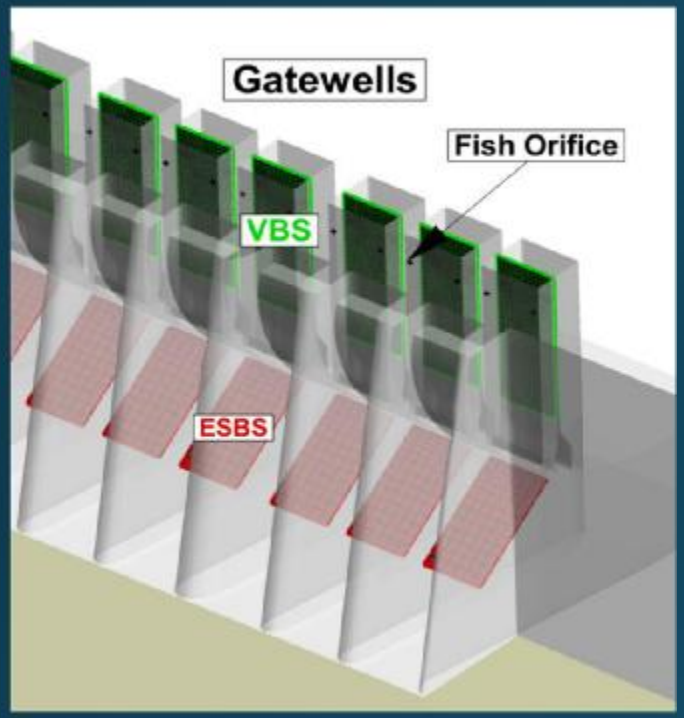

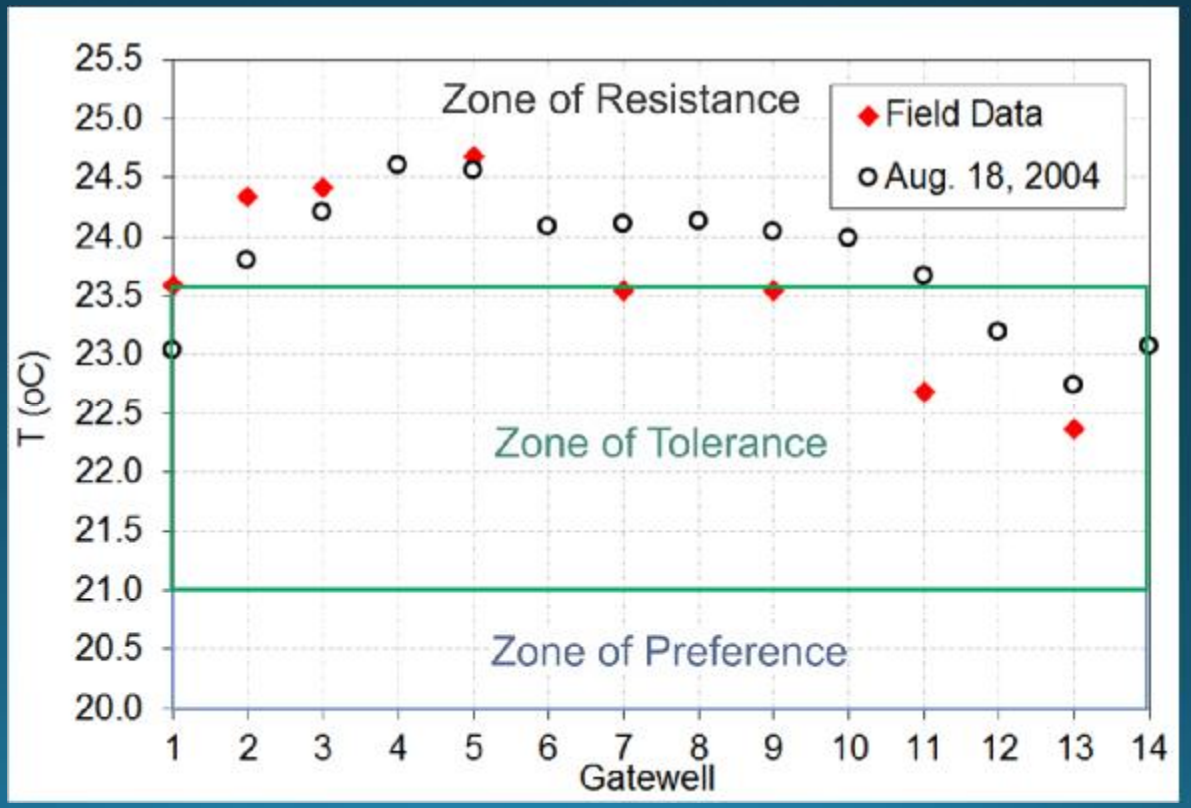

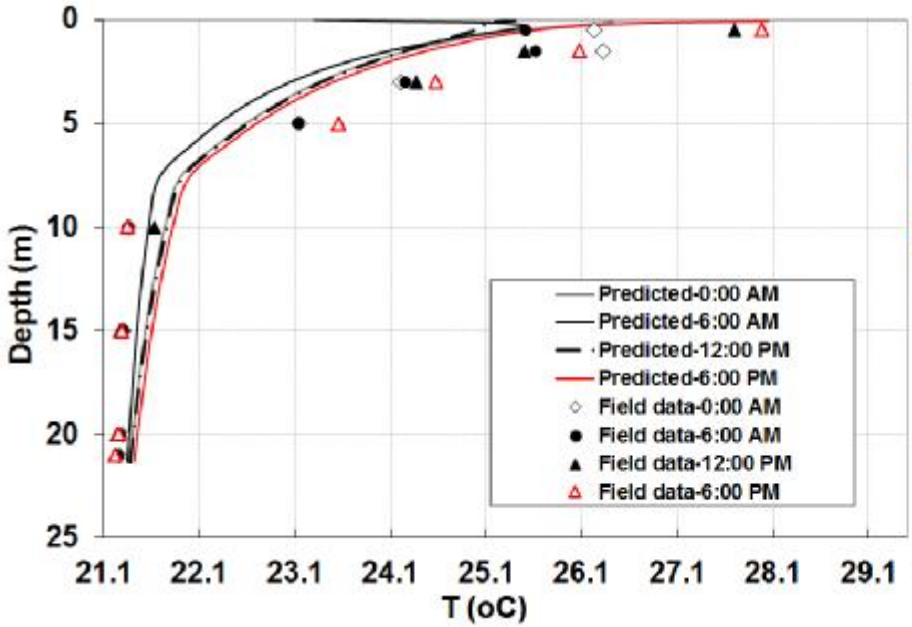

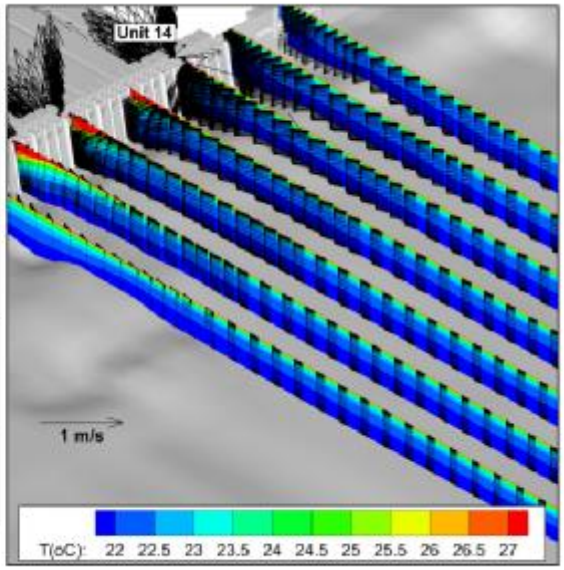

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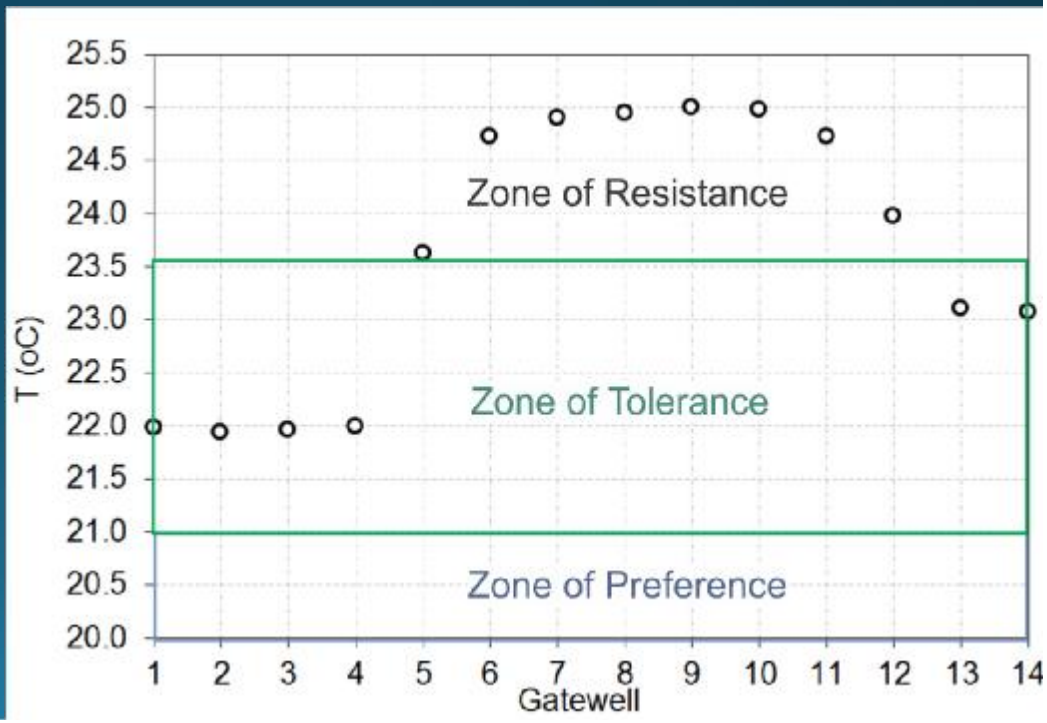
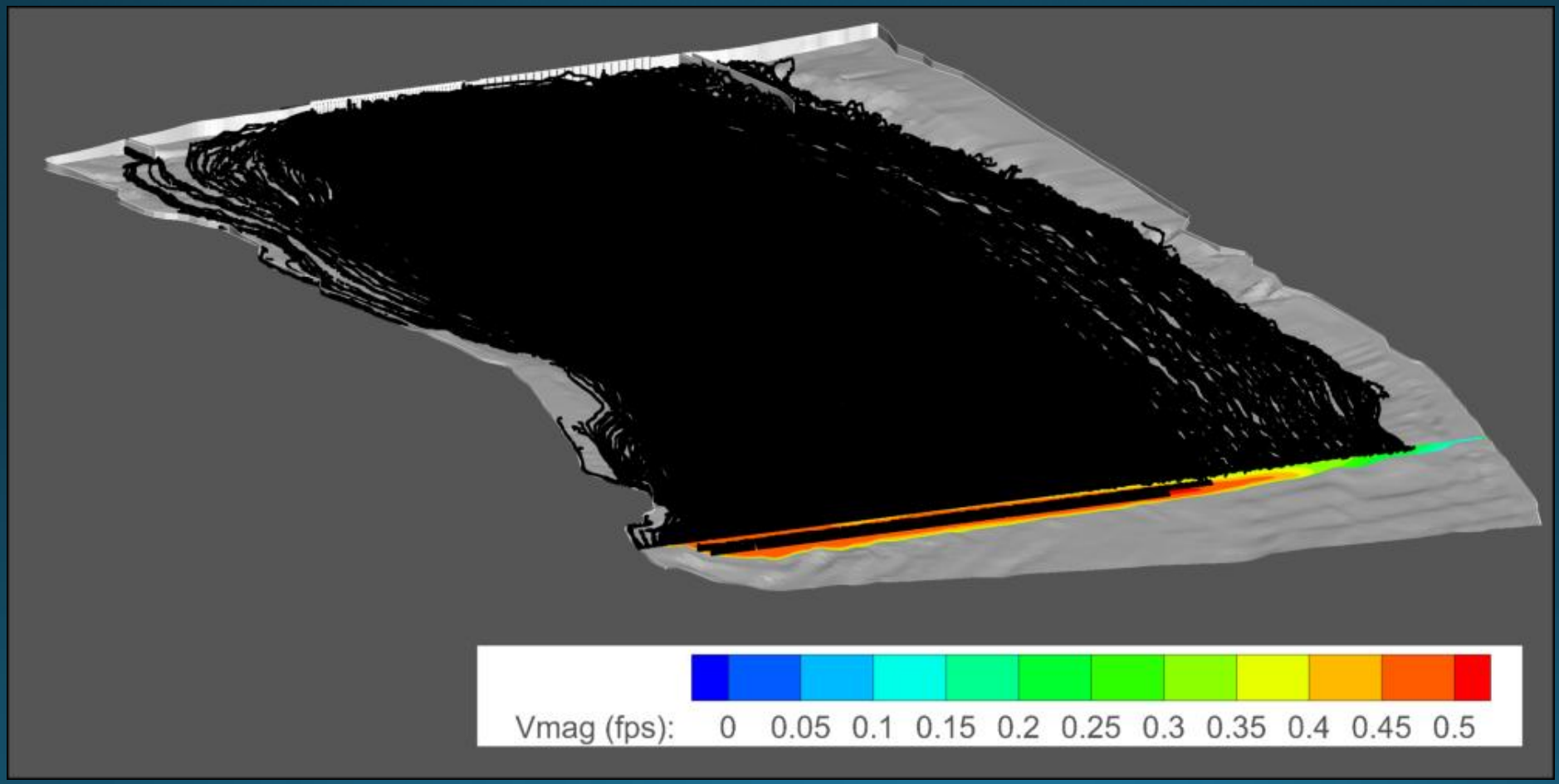
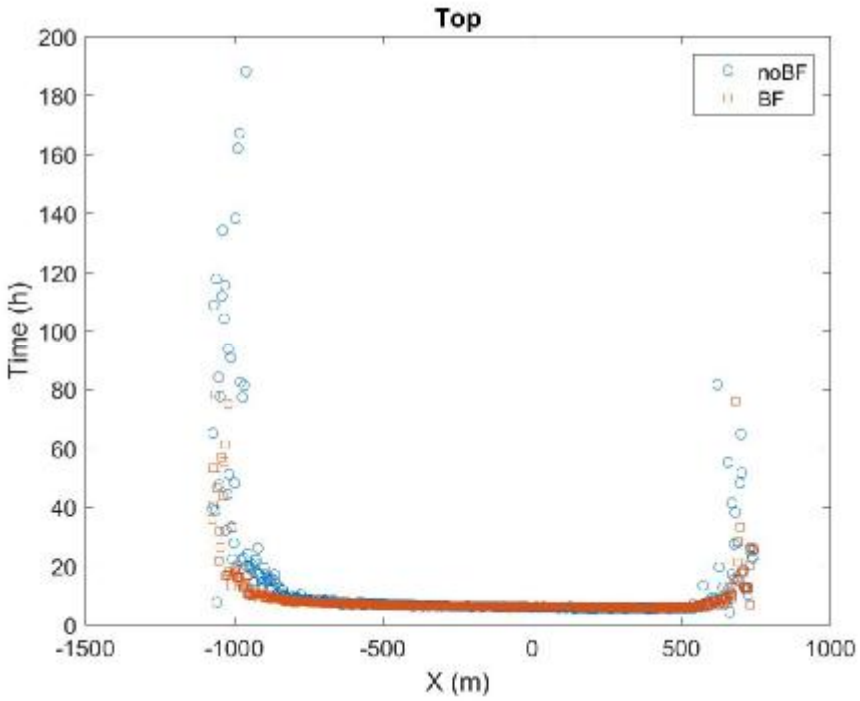
July 9, 2015

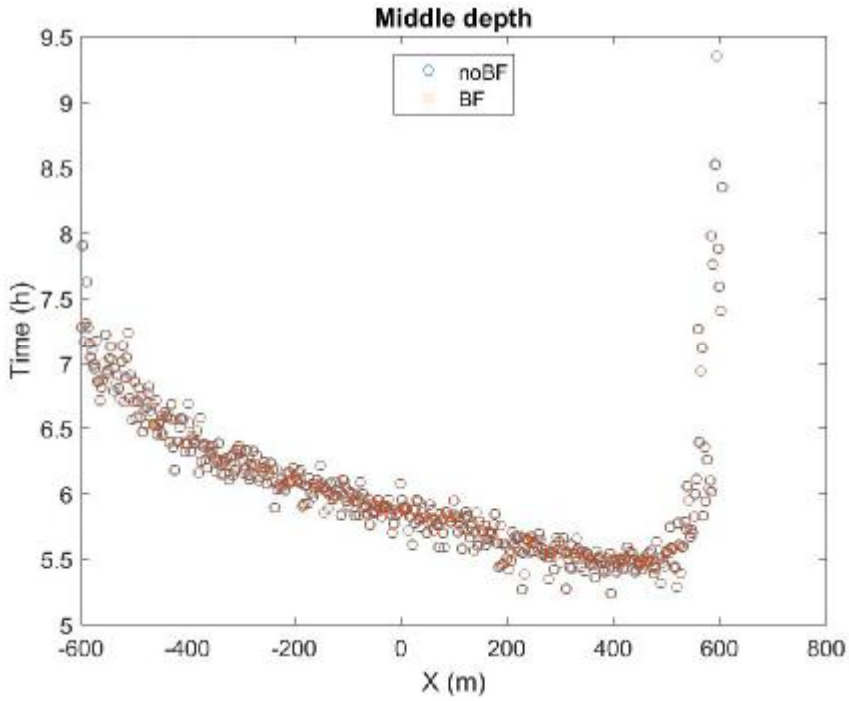
- The daily average water temperature was the highest of the season as a result of low river flow and high air temperature and solar radiation.
- Maximum air temperature 37.9 ^{o}C (100.2 ^{o}F)
- Maximum solar radiation 866 W/m^2

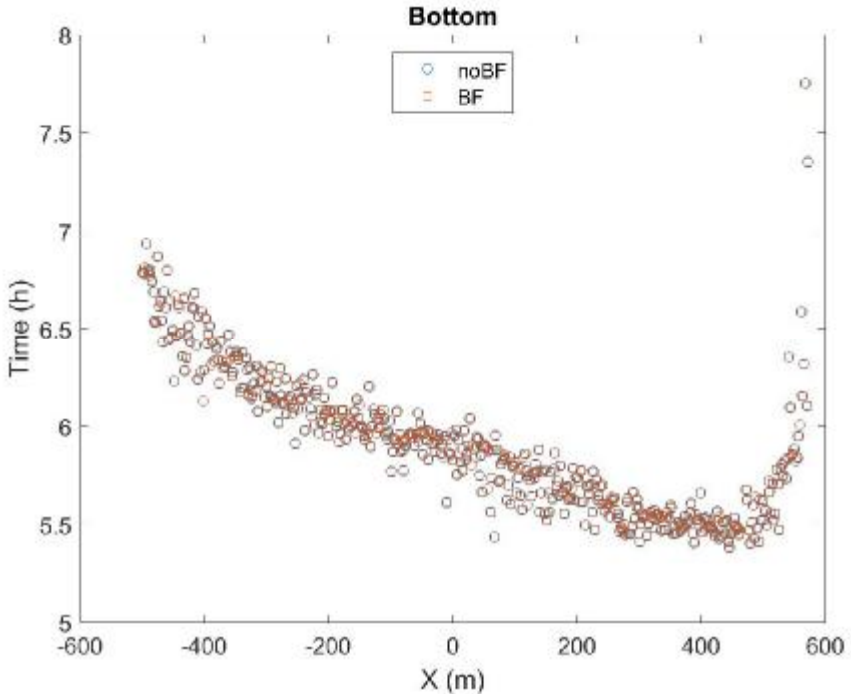


Injection Region

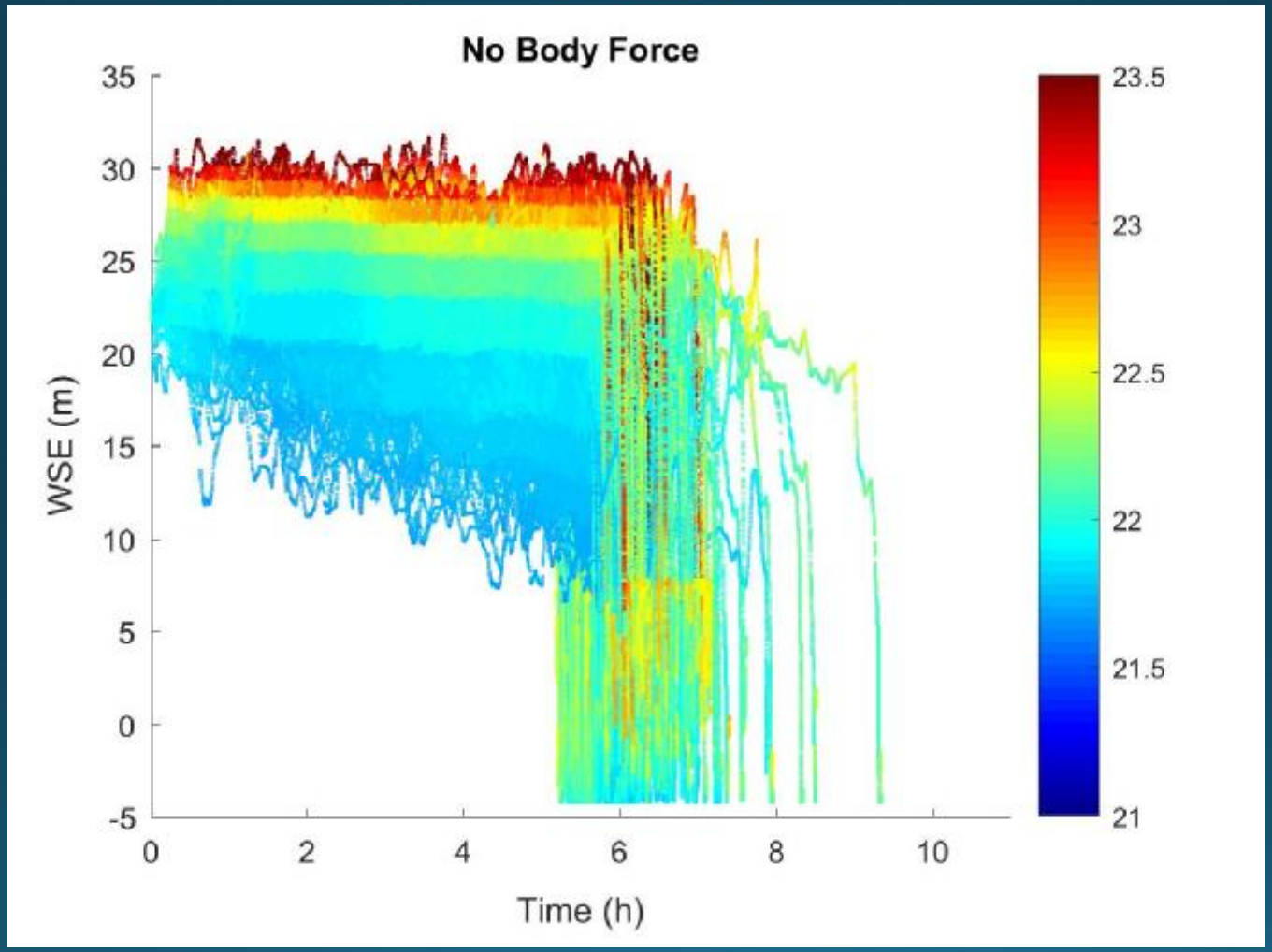




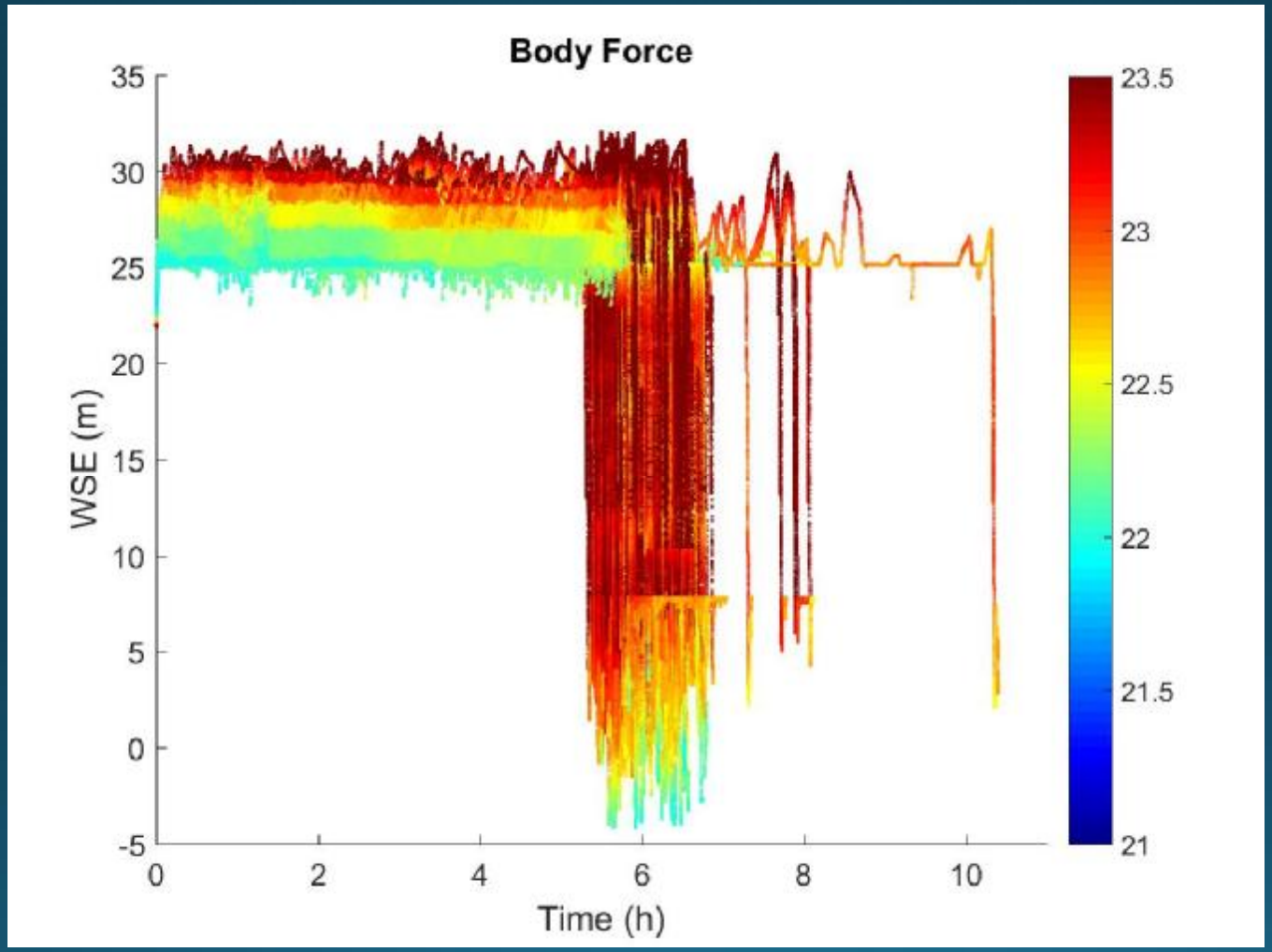




Residence Time



Particle Paths


Body Force
WSE (m)
Time (h)
35
30
25
20
15
10
5
0
-5
0
2
4
6
8
10
23.5
23
22.5
22
21.5
21

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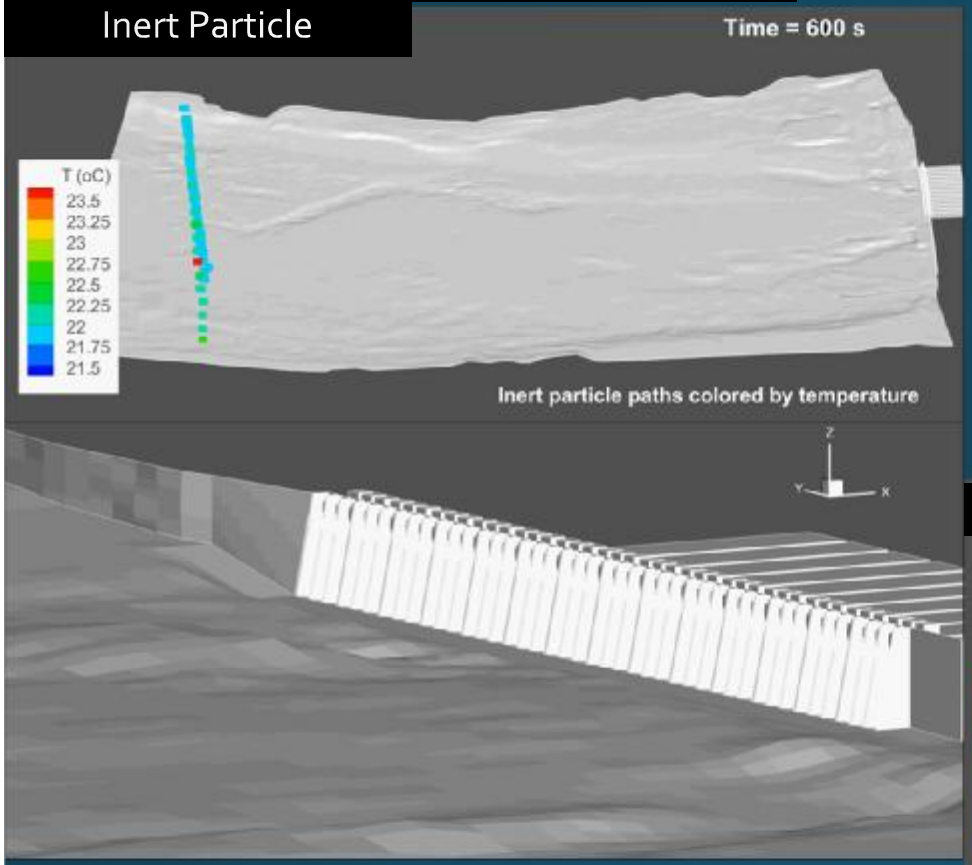
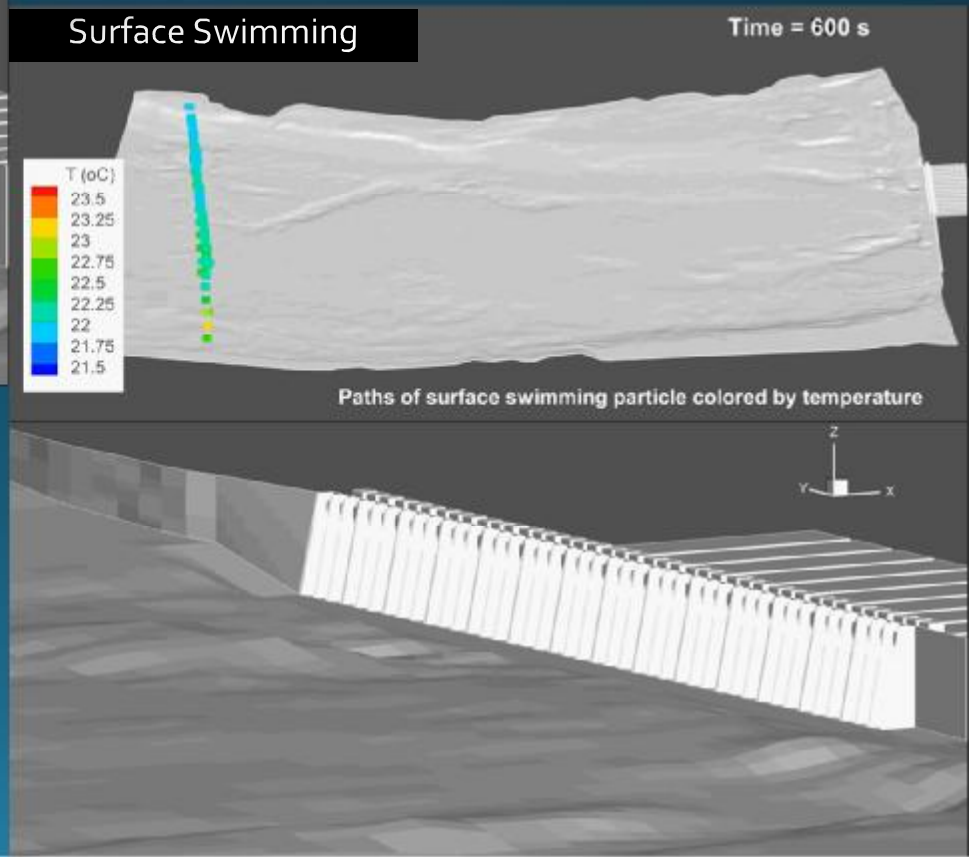
Inert Particle



99.3% in Tolerance Zone

99.8% in Tolerance Zone

Surface Swimming



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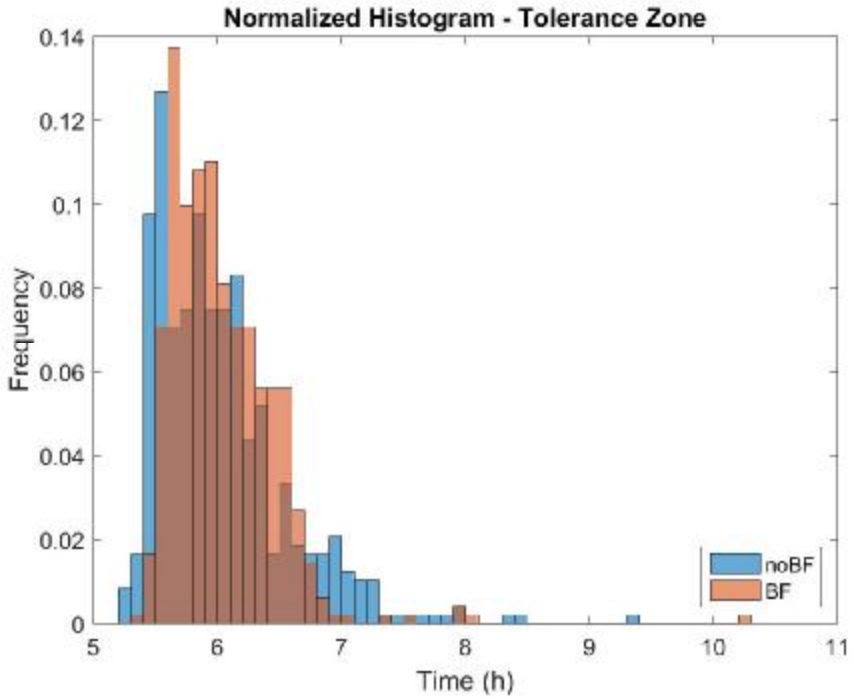
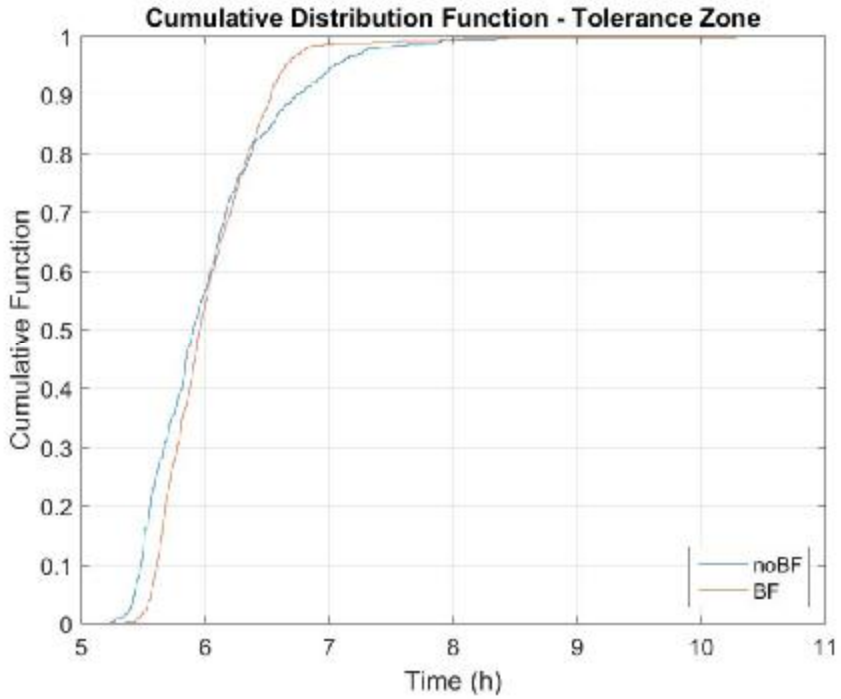
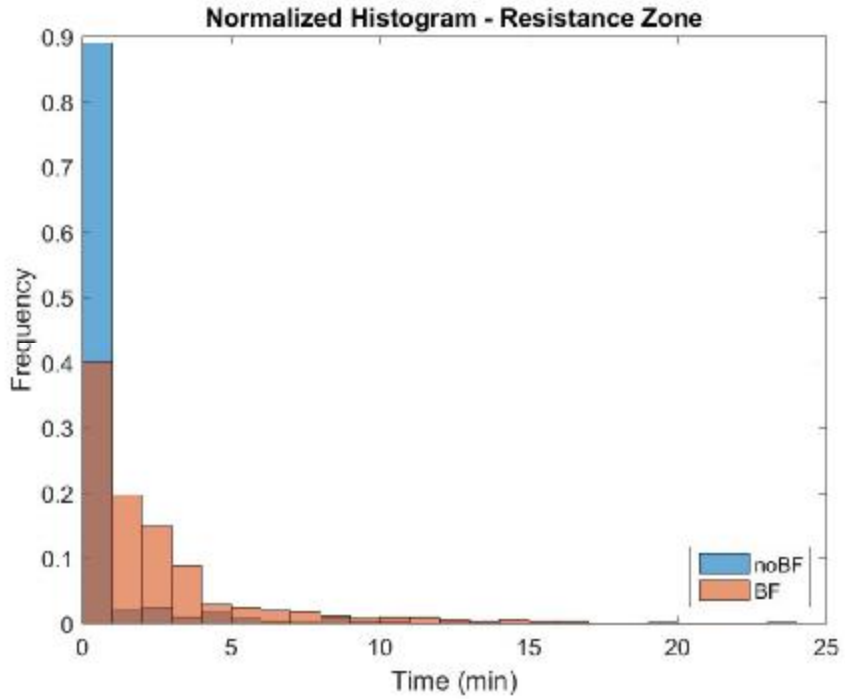
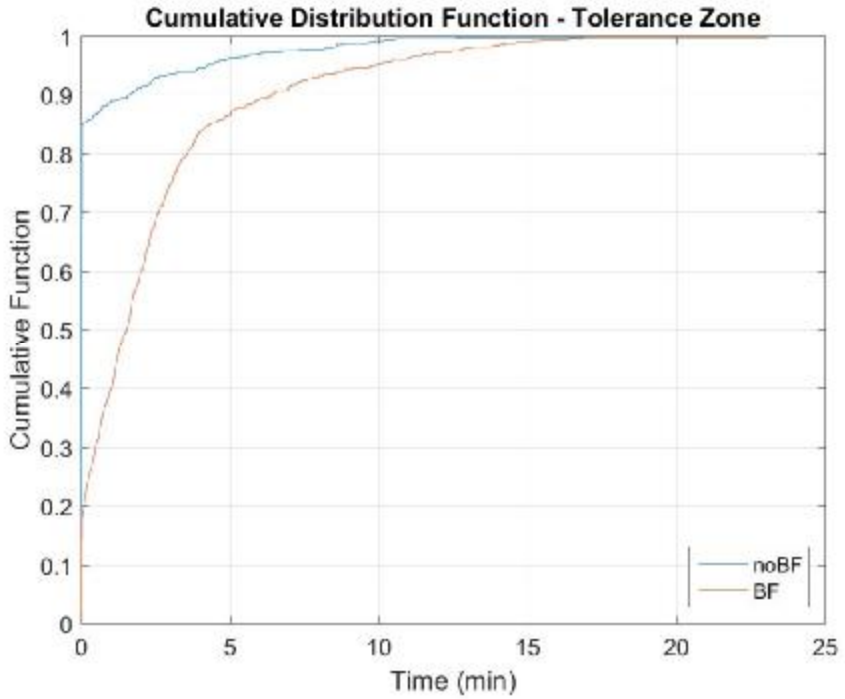
Exposure at Temperatures Tolerance Zone (21 °C to 23.6 °C)





Exposure at Temperatures Resistance Zone (T>23.6 °C)





Summary and Future Work

- A non-hydrostatic 3D model was developed to predict the hydraulics, temperature distribution and estimate thermal exposure. The model was able to capture the measured field temperature in the forebay and gatewells

- The present work is the **initial step towards the development of a more advanced tool** to estimate the stress or mortality rate due to high temperature. **A significant effort is needed to integrate biology and engineering**. Particularly, data and models on behavioral mechanisms, effect of acclimation and food availability, damage caused by thermal exposure, recovery time are needed

- The development of faster and accessible computers allows a complete model validation and the potential use of the model to evaluate mitigation measures based on thermal stress or mortality rate

Questions and Comments