Integration of routine and high-frequency data to improve 3-D water quality model predictions

Unravelling the metabolism black-box using a control-volume approach

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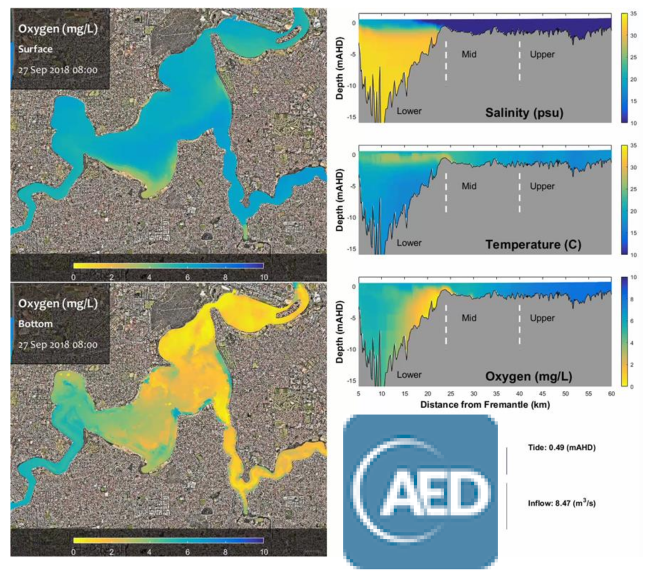
Objectives

- Supporting short- and long-term water quality management decisions in aquatic systems is a challenging task requiring a holistic view of the systems internal response to external stressors.
- Models have been developed to simulate the water quality of aquatic systems to assist with management decision making.
- Regular monitoring programs of water quality with weekly or longer time intervals helped track trends in water quality with understanding of how systems evolves over extended periods of time.
- However, to improve our knowledge of the finer-scale hydrodynamic and biogeochemical processes (e.g. mixing, diel metabolism) monitoring data collected at frequent intervals (10 mins) is essential.
- While high-resolution sensor data offer great potential to assist with the calibration and testing of water quality models, there remain challenges in the input of such high resolution sensor data into model prediction workflows.
- Therefore, our aim is to integrate a coupled state of art biogeochemical aquatic model and a 3 D hydrodynamic model – Swan Canning Estuarine Response Model (SCERM) with high frequency sensor data to validate its performance against observations, and to explore fine-scale dynamics underpinning observed variations in variables essential to understanding biogeochemical dynamics important to estuary metabolism.
- Due to the model sophistication and resolution both spatially and temporally resolution (secs and meters), and incorporation of complex hydrodynamics, physics, and material zones. It allows to resolve the components of biogeochemical processes affecting estuary metabolism changes over depth, time, and ecosystem environments.
- A **control volume approach** is implemented using 3D coupled hydrodynamics biogeochemical model to help unravel contributions of different processes making up the oxygen budget (to calculate metabolism).
- High frequency (10 mins) interval data of surface and bottom locations in the river are essential for the model calibration and validation, in addition to better estimation of metabolic processes for the future once model mechanistic processes are improved.

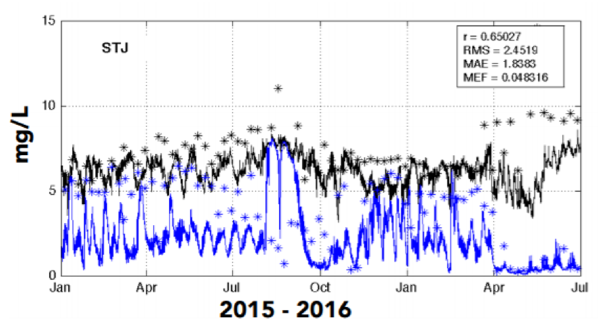
Swan Canning Estuarine Response Model (SCERM)

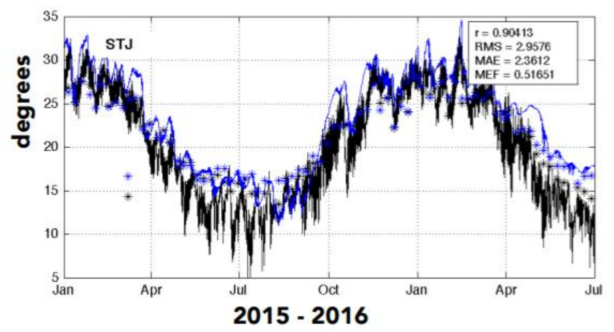
- Coupled 3D flexible-mesh (finite volume) hydrodynamic model (TUFLOW-FV) and Aquatic Ecodynamic model (AED2 - biogeochemical processes).
- AED modules cover most aquatic biogeochemical processes including nutrient cycling, oxygen dynamics, sediment/soil biogeochemistry, vegetation, etc.
- Due to the research focus on metabolism, dissolved oxygen dynamics are selected as the focus for improvement.

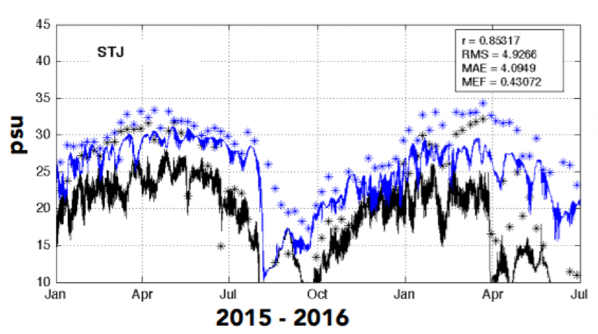


SCERM model validation and assessment 2015-2016

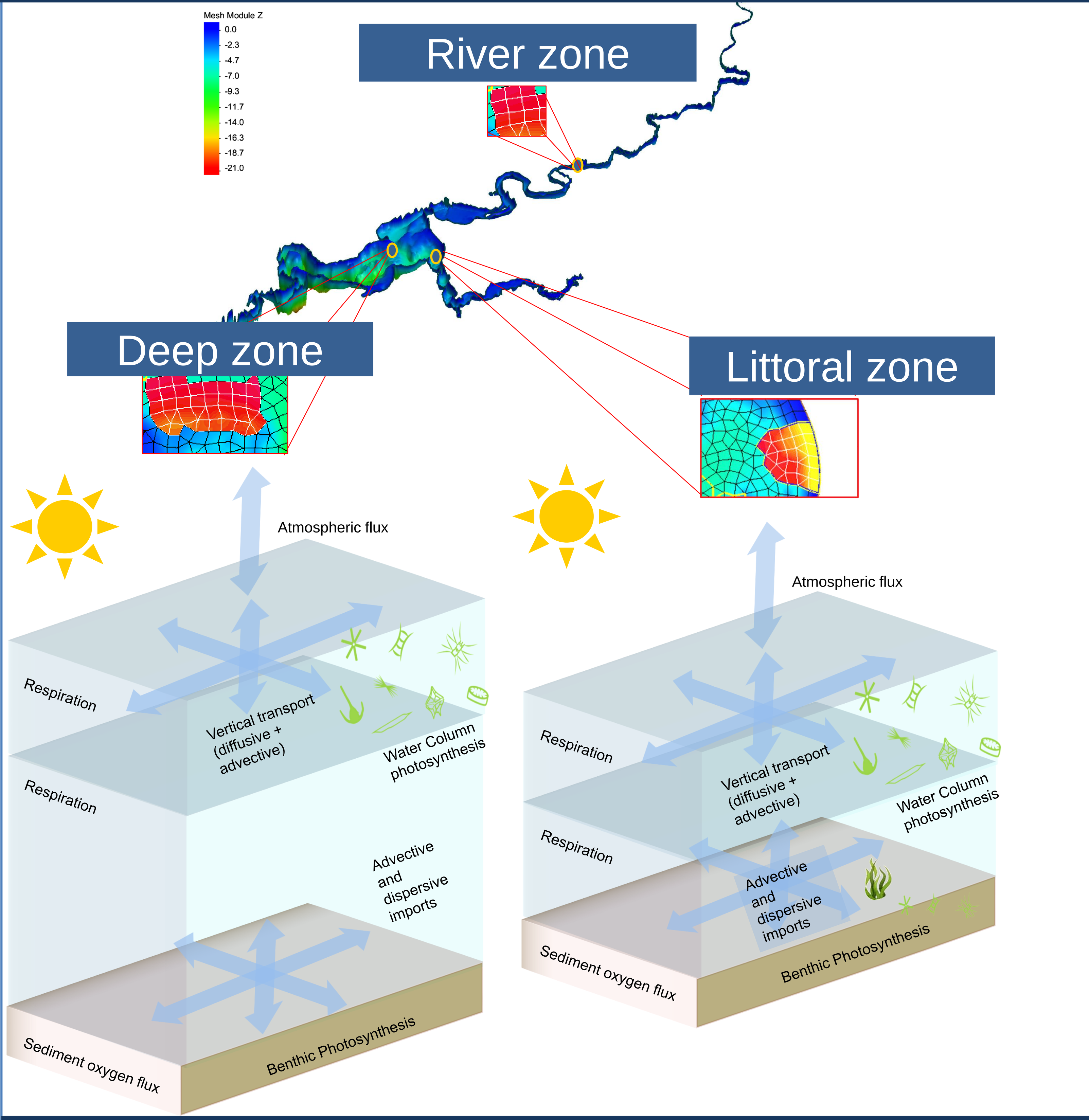
- SCERM model have been validated against fortnightly monitoring data at 6 monitoring sites evenly distributed along the estuary for high flow and low flow years.
- The model performance assessment showed its confidence in capturing both vertical and horizontal salinity, temperature, and dissolved oxygen averages seasonally and annually.







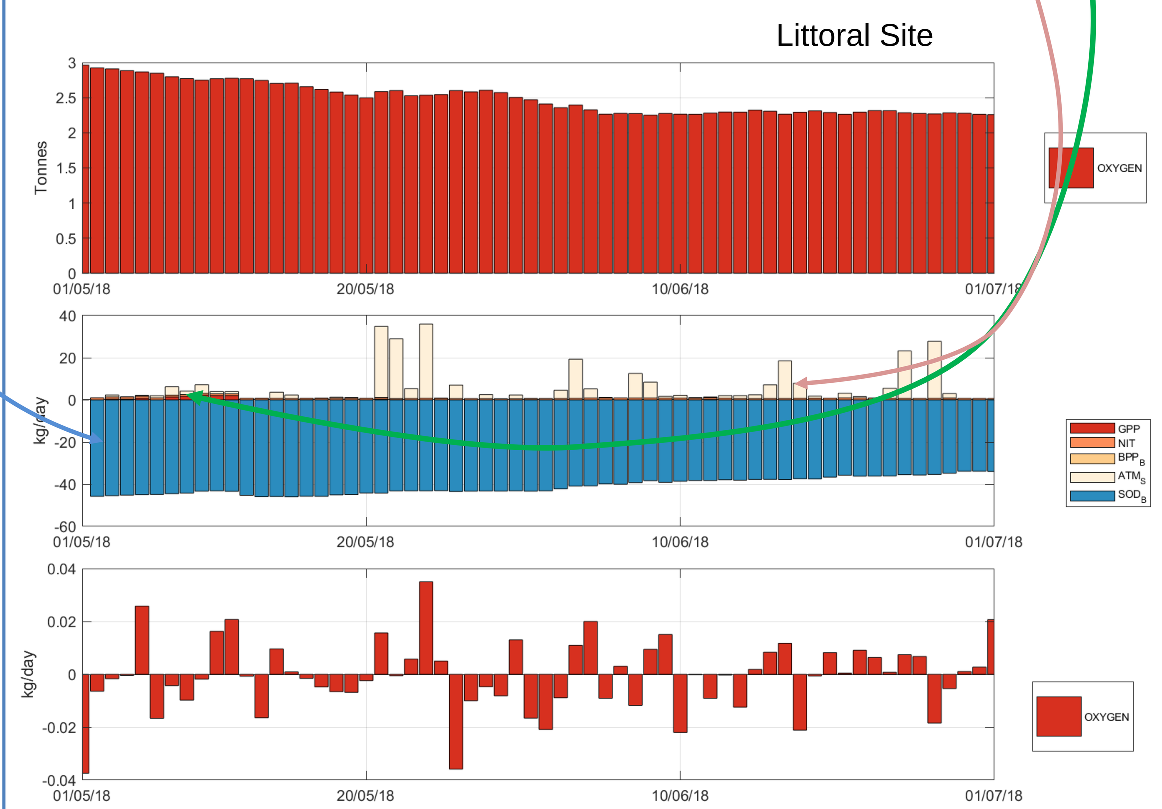
Control volume approach



Dissolved oxygen budget

$$\frac{dO_2}{dt} = \pm f_{atm}{}^{O_2} - f_{sed}{}^{O_2} - \frac{f_{miner}^{DOC}}{\chi_{C:O_2}^{miner}} - \frac{f_{nitrif}}{\chi_{N:O_2}^{nitrif}} + \sum_a^{N_{PHY}} \left(\frac{f_{uptake}^{PHY\_C_a}}{\chi_{C:O_2}^{PHY}} \right) - \sum_a^{N_{PHY}} \left(\frac{f_{resp}^{PHY\_C_a}}{\chi_{C:O_2}^{PHY}} \right) - \sum_z^{N_{ZOO}} \left(\frac{f_{uptake}^{ZOO_z}}{\chi_{C:O_2}^{ZOO}} \right)$$

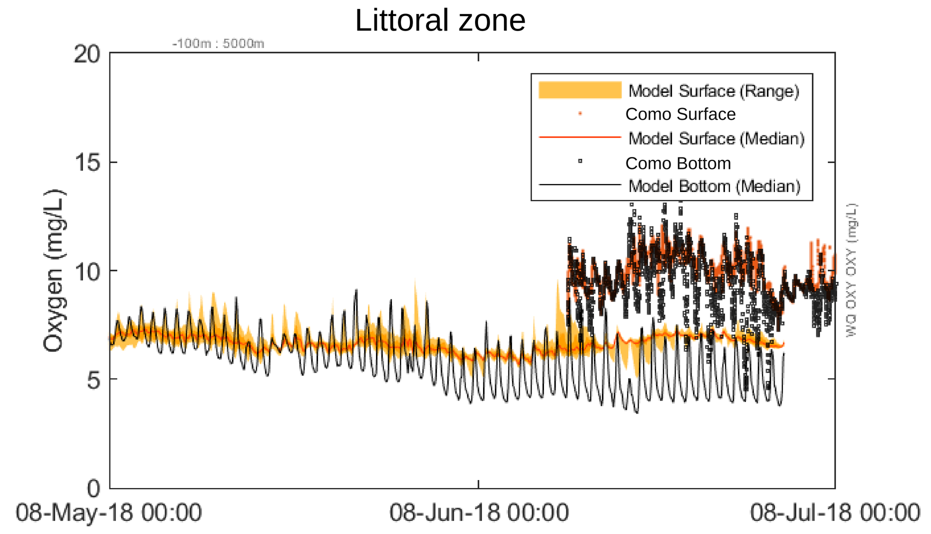
- Atmospheric oxygen exchange
- Sediment oxygen demand
- Oxygen consumption by mineralization of DOC (bacterial respiration)
- Oxygen consumption by nitrification
- Oxygen production by photosynthesis
- Oxygen consumption by phytoplankton respiration



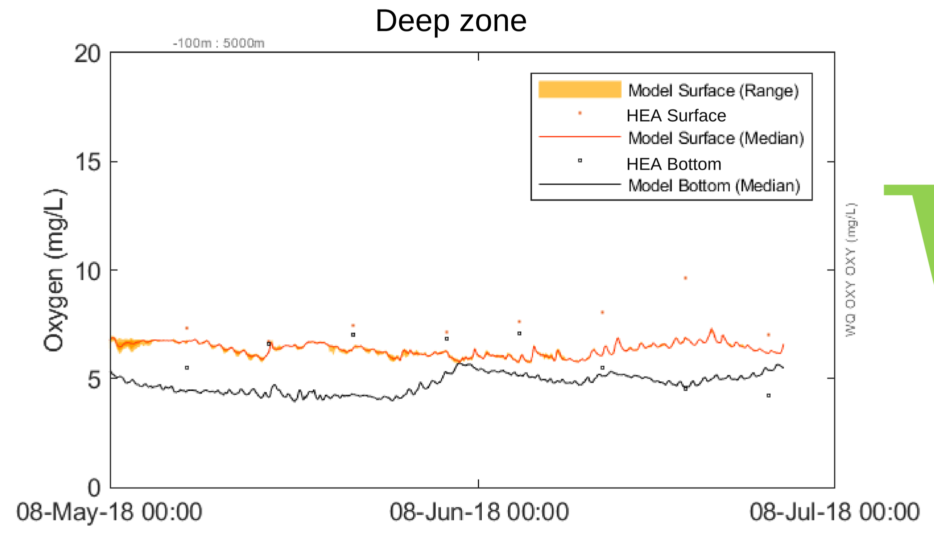
High frequency sensor data validation

Littoral zone

Opportunity for improvement in benthic photosynthesis ?



Deep zone



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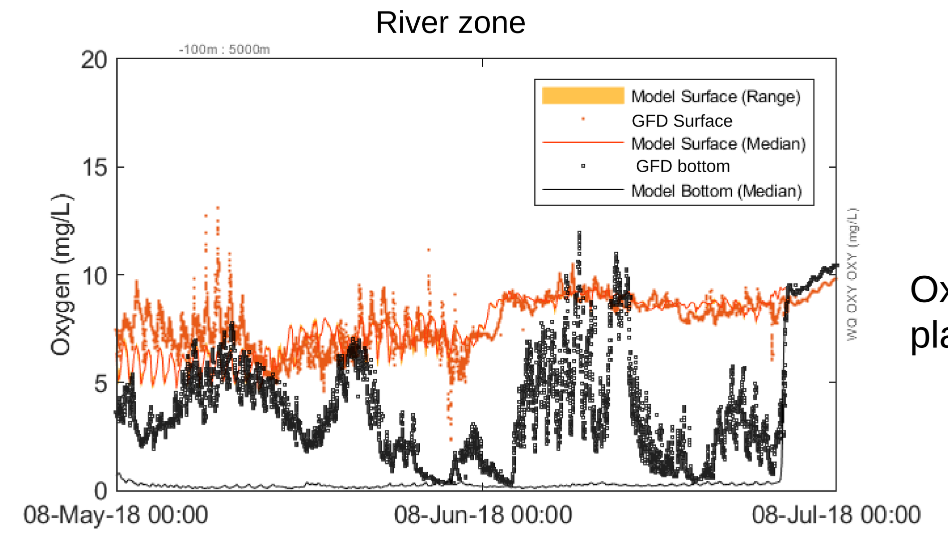
River zone

Opportunity for improvement– simulating the sediment oxygen demand ?



Oxygenation plant site

Ongoing and future work

Model captures diurnal dynamics of benthic oxygen in shallow areas, however, there is opportunity to improve it more, in particular at shallow areas with high benthic production. Future work will also include improving sediment oxygen demand estimation in the model.

Improving the model performance will help gain better insights into key drivers of estuarine processes and metabolism, at fine temporal and spatial scales. Key ongoing work includes:

1. Run the model for a comprehensive range of condition that span longer-term events observed in the field data (winter, summer, inflow episodic etc.).
2. Use the model to estimate a system-wide nutrient budget, and how it varies with time and space.
3. Analyse correlations between the processes captured by the nutrient budget and the metabolism parameters estimated from the field sensors.
4. Assess how the metabolism predicted at the mooring is related to the estuary scale biogeochemical flux pathways. Assess whether a field observation of high metabolism in the middle of the estuary is indicative of system-scale estuary health.

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