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Modelling the dynamics of a large-scale river plume and their effect on nutrient distribution

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Content

- Introduction to the Columbia River plume
- Model set up
- Near field plume dynamics
- Large-scale circulation and wind effects
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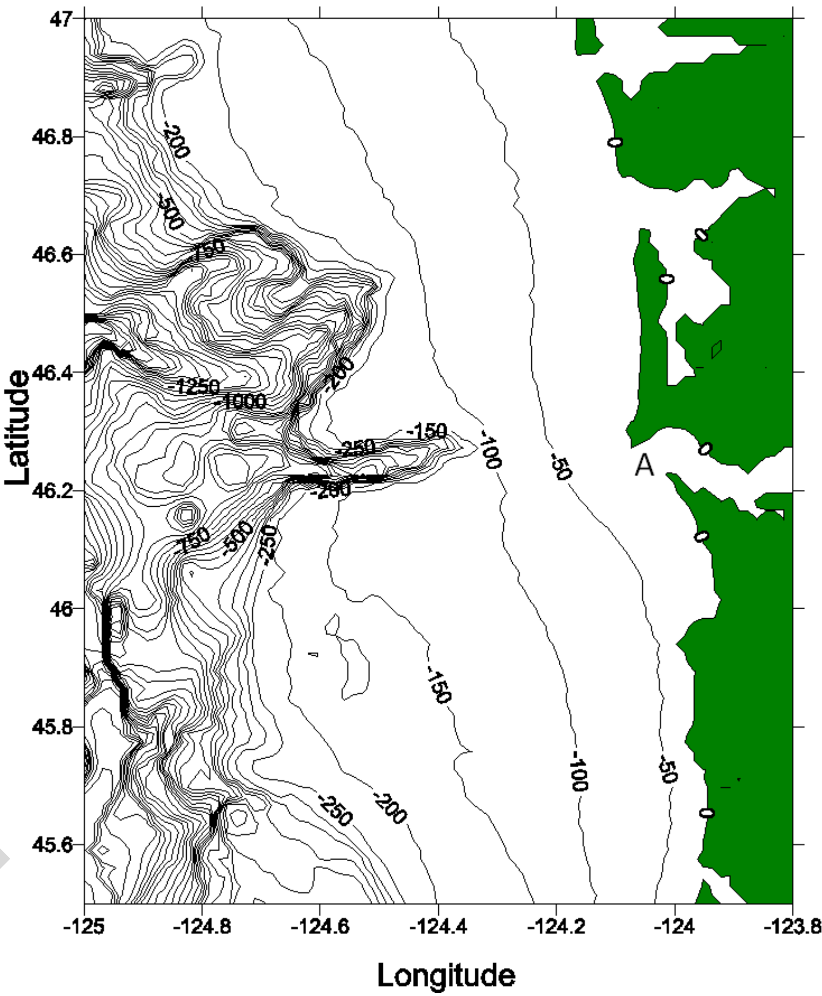
- Summary

The Columbia River

- Largest freshwater source to the N.E. Pacific
- Catchment area of 668,000 km^2
- Mean discharge of 7,300 m^{3}s^{-1}
- Large estuary >7km wide
- Mouth constrained to 3.5 km

Seasonal discharge

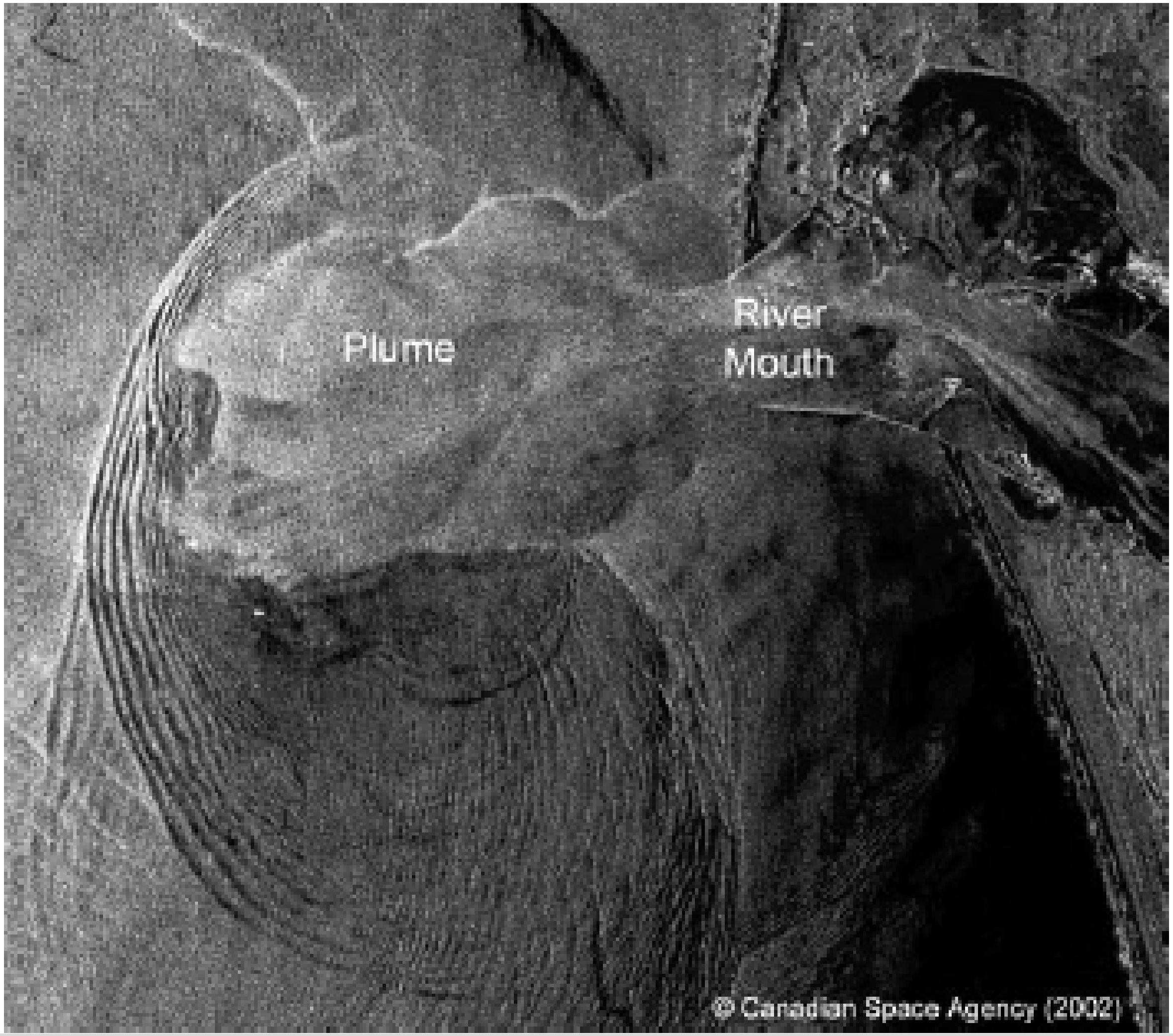
Narrow Shelf



Columbia river plume

- Low nitrate concentration (5μM) compared to other large estuarine systems
- High silicate concentration (150μM)
- Upwelling and entrainment of nitrate and iron rich waters
- Shown to be a region of increased productivity
- Tidally pulsed by a mixed semi-diurnal tide with a mean range at the mouth of 1.8m and peak velocities of 3 ms^{-1}

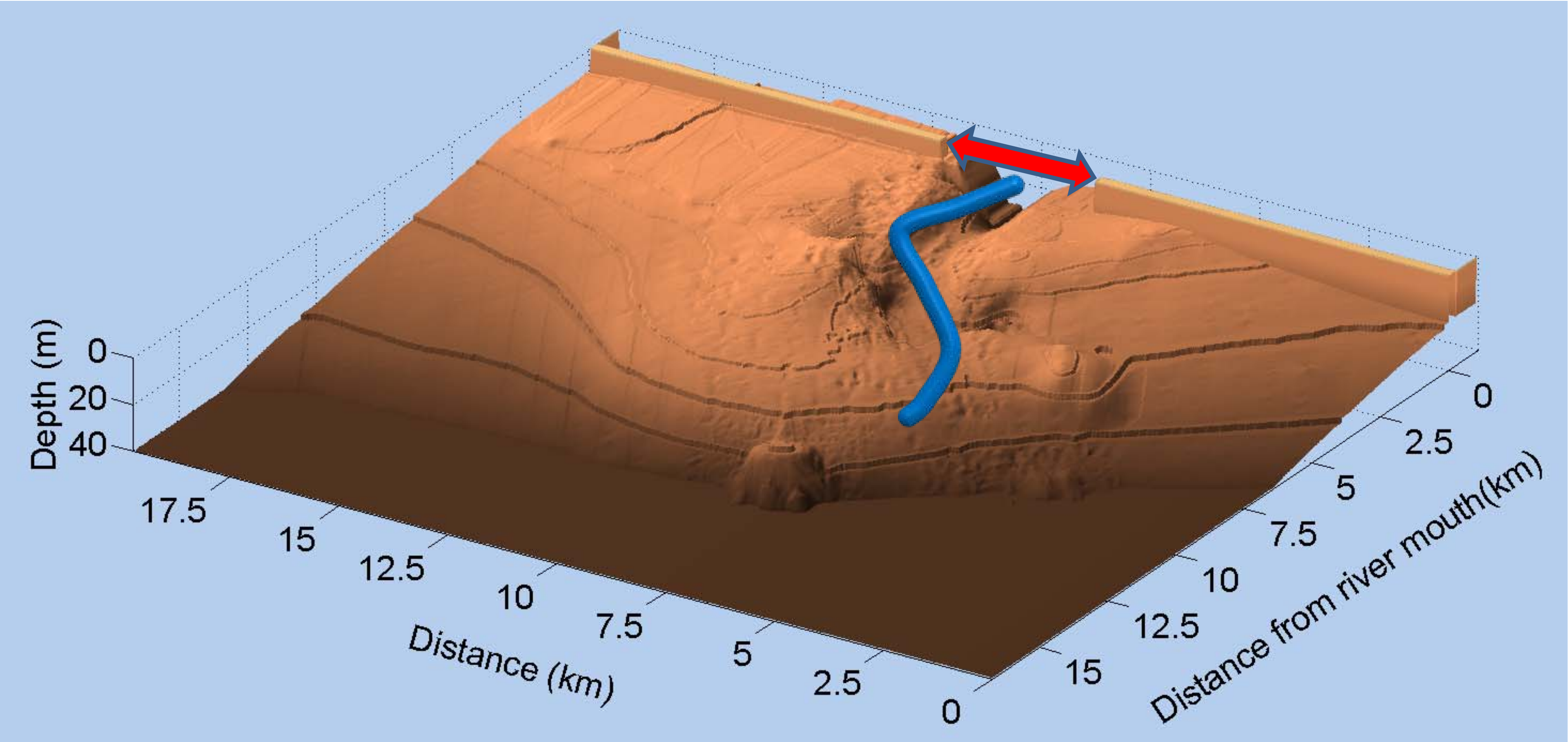
SAR image showing internal waves



MIT-gcm

- Non-hydrostatic and hydrostatic modes
- 3 Dimensional, vertical z coordinate system
- 25m horizontal resolution near field grid
- 500m horizontal resolution far field grid
- Pacanowski & Philander 1981, Richardson number dependant turbulence closure scheme
- Tracer package allows for inclusion of nutrients and Lagrangian drifters

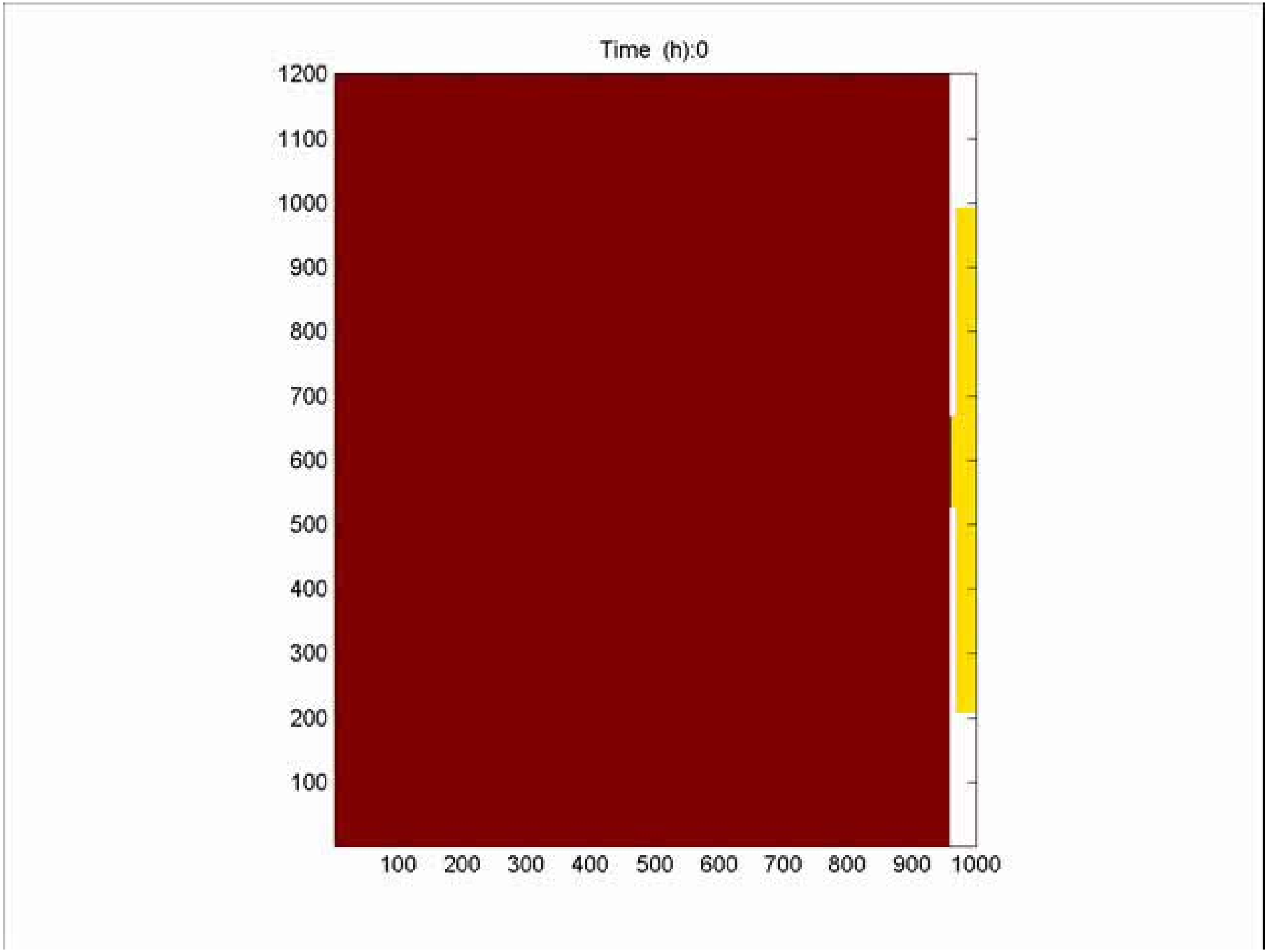
Near field grid bathymetry



Near field plume dynamics

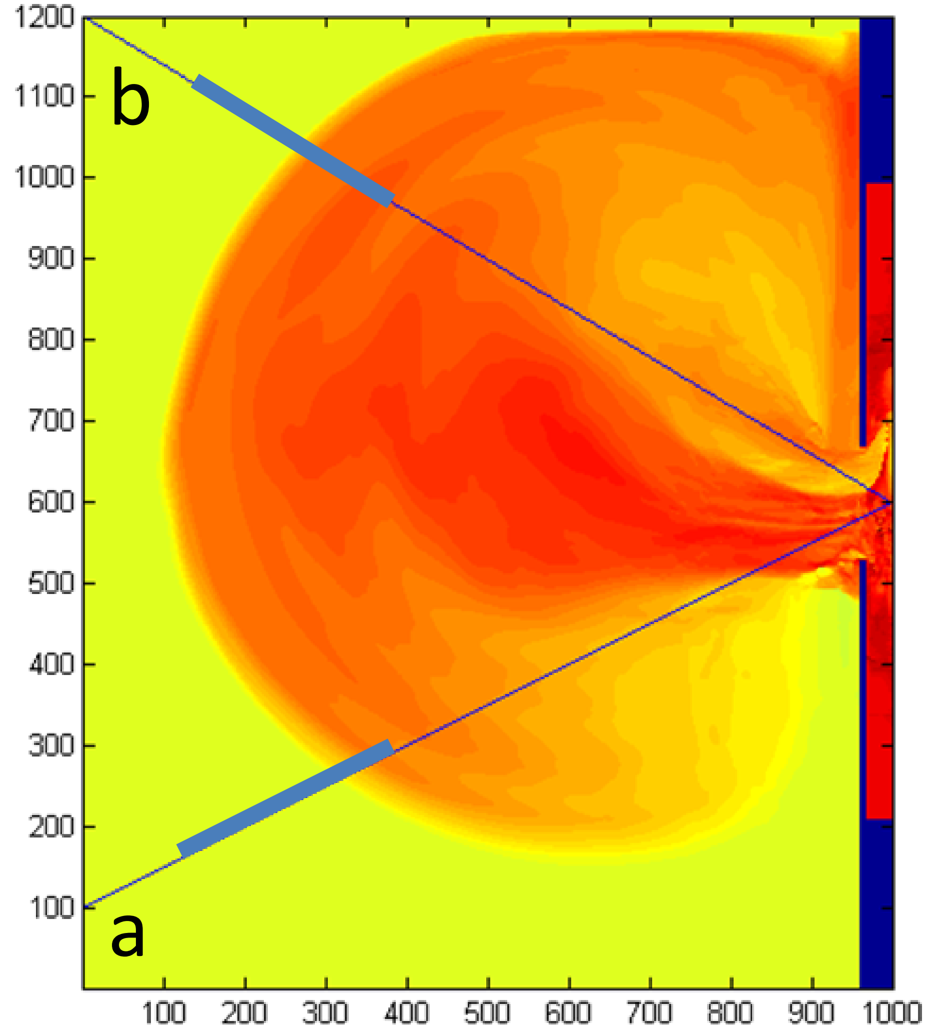
- 1 second time step for 9 hours
- 13 vertical levels (1, 1, 1, 1, 1, 1, 1.5, 2, 2.5, 3, 5, 10, 10 m)
- Forced with a horizontal velocity from the eastern estuarine boundary
- Open boundaries in North, South & West
- Telescopic grid at open boundaries to reduce wave reflection

Surface Density

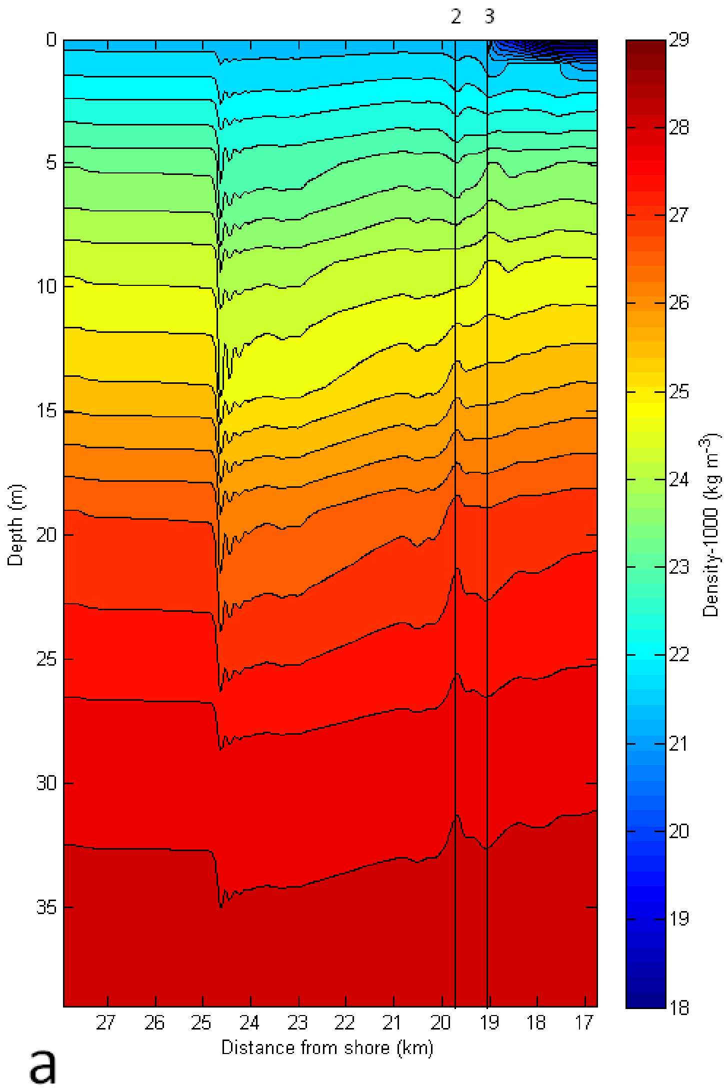


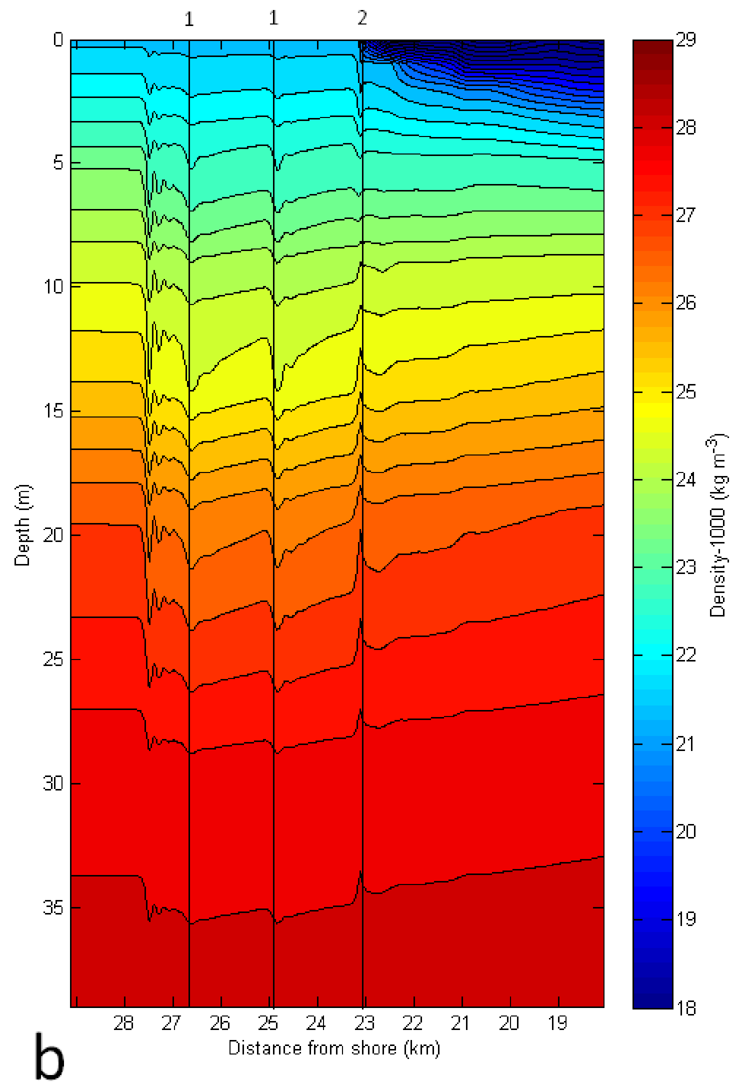
Surface density

- Surface plume after 8 hours 40 minutes
- Asymmetry due to Coriolis
- Northern lobe propagates faster than southern lobe
- 2nd mode IW phase velocity = 0.27 ms^{-1}



Internal wave fission

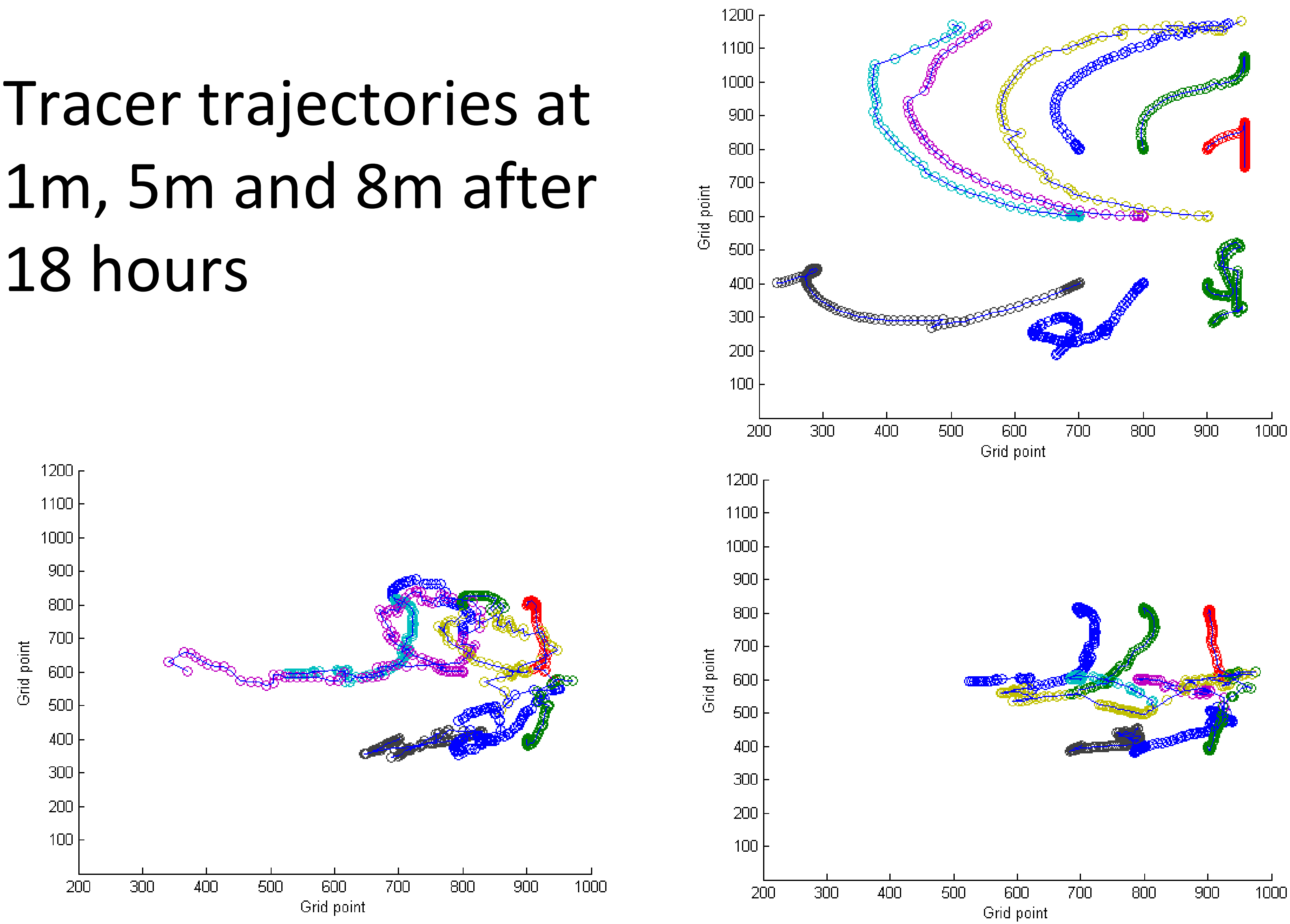




Recirculation of the plume

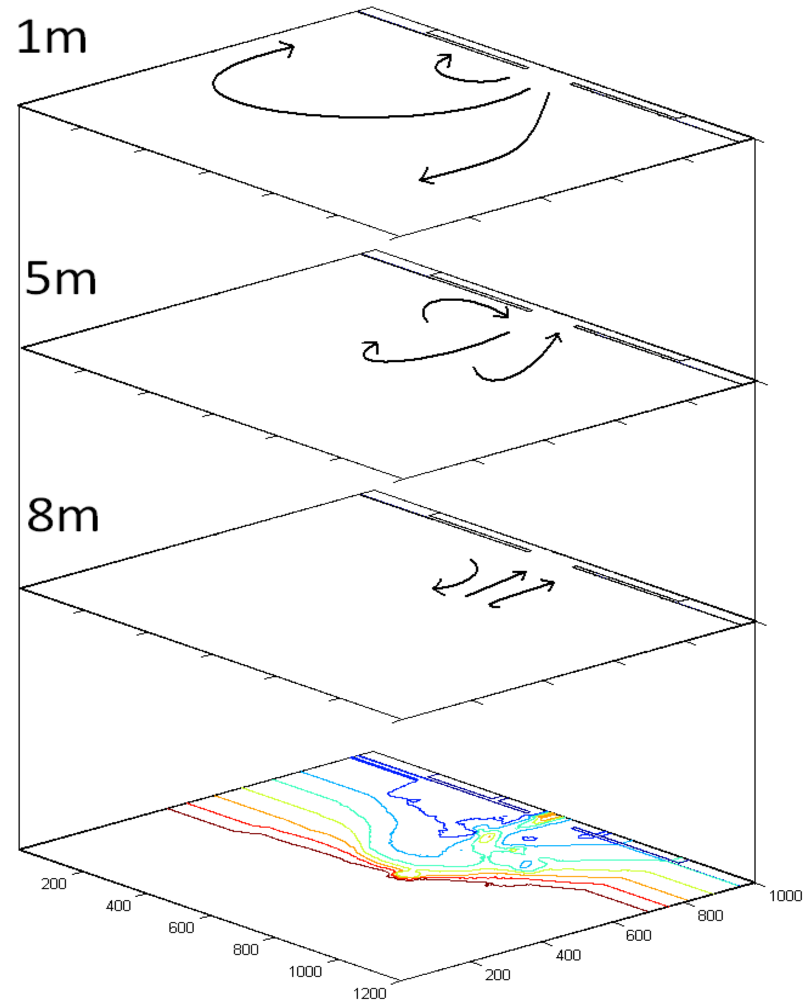
- Plume waters are high in silicates but low in nitrates
- Mixing with shelf water results in increased primary productivity
- Recirculation of plume waters sustains productivity in the area
- Tracers were used to record Lagrangian trajectories within and around the plume

Tracer trajectories at 1m, 5m and 8m after 18 hours



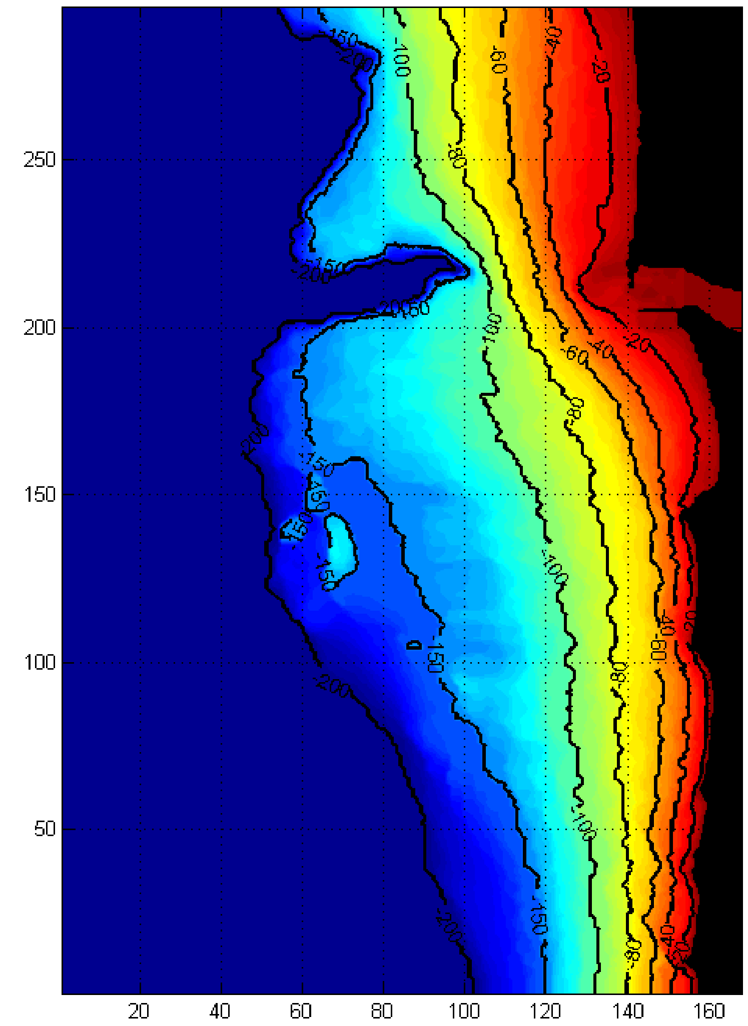
Summary of near-field dynamics

- Surface transport to North due to Coriolis
- At 5m Central jet still present, lateral recirculation of plume towards river mouth
- At 8m weaker flows opposing plume direction



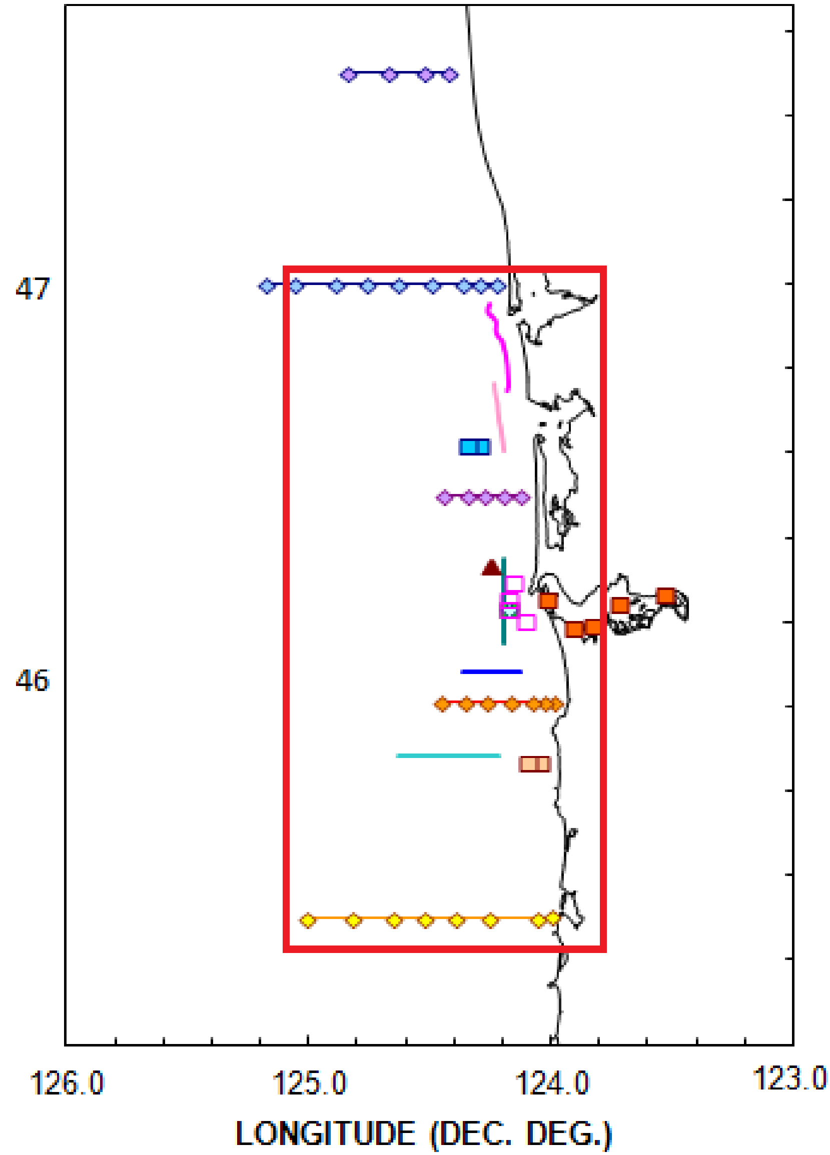
Far field simulations

- 500m horizontal resolution
- 1 min time step
- Period of one month
- Bathymetry to 200m and 1000m
- Area corresponding to RISE survey area

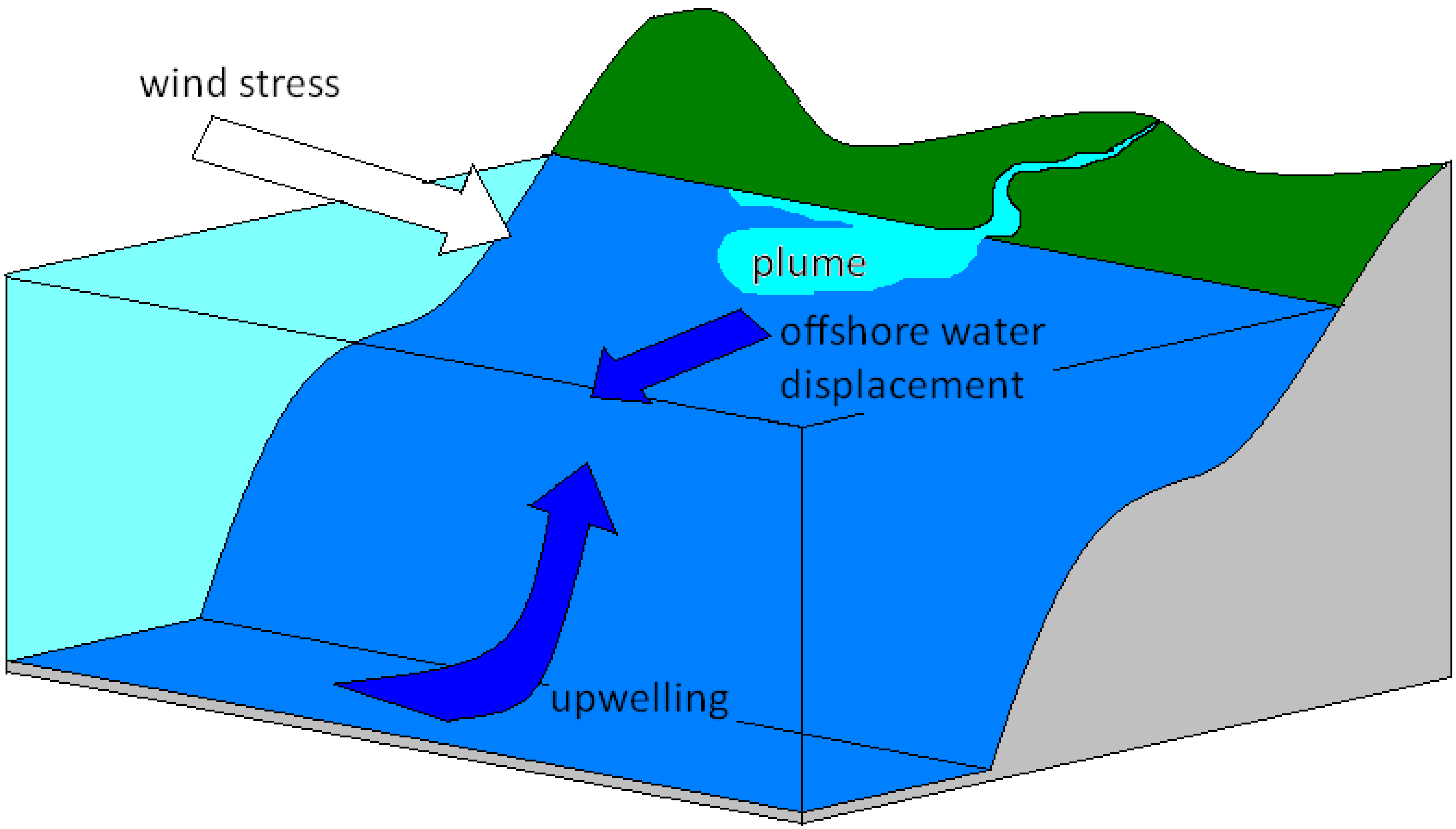


R.I.S.E

- River Influences on Shelf Ecosystems
- 4 x 3 week research cruises 2004-2006
- CTD, nutrient, phytoplankton
- Results focused on August 2005 cruise



Wind effects on plume waters



Large scale simulations

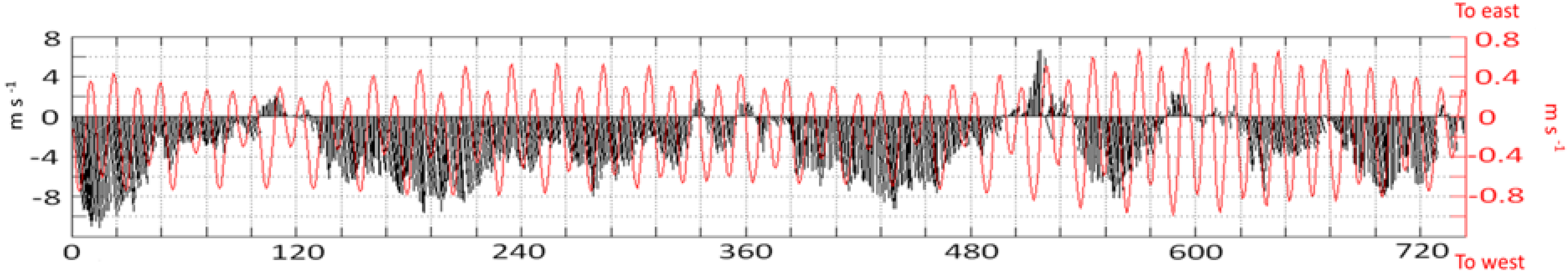
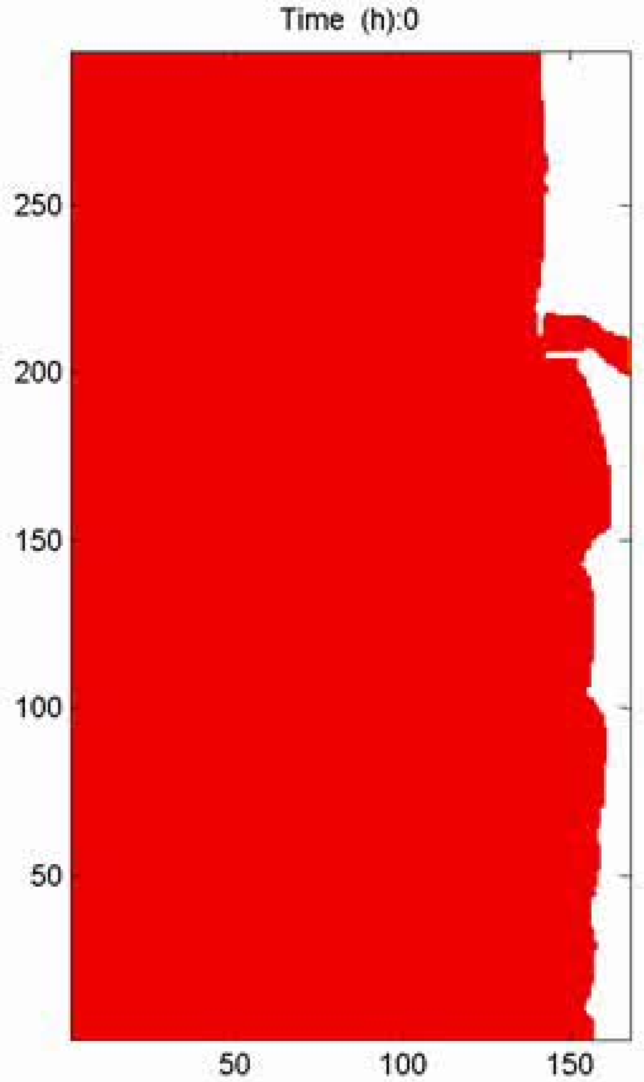
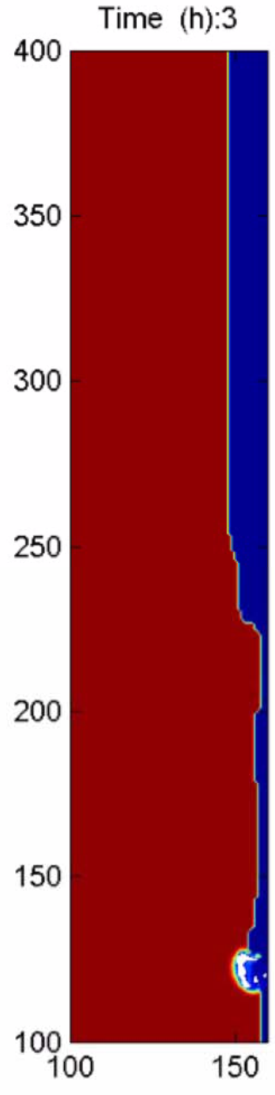


Figure 2. Wind velocity River discharge velocity

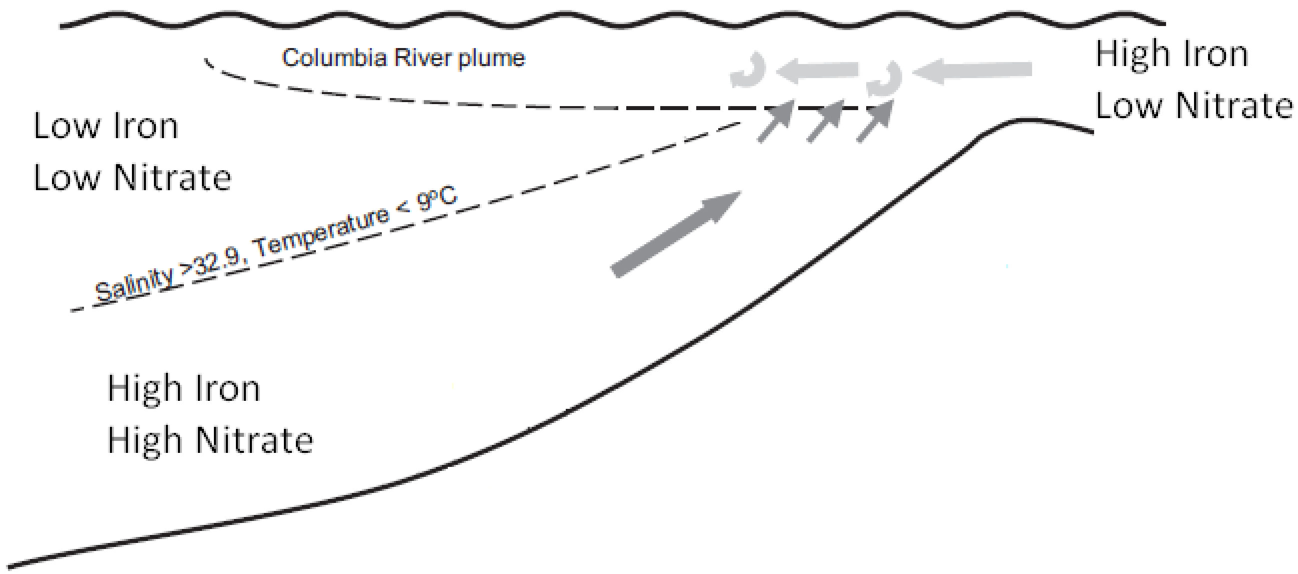
•Spatially uniform wind field from in situ measurements adjacent to river mouth
•Discharge velocities from in situ flow measurements and TPXO 7.1 tidal model


Time (h):0
250
200
150
100
50
50
100
150



Time (h):3
400
350
300
250
200
150
100
100
150

Nitrate transport



- Nitrate and Iron rich water entrained during flood tide
- Nitrate depleted water entrained during ebb

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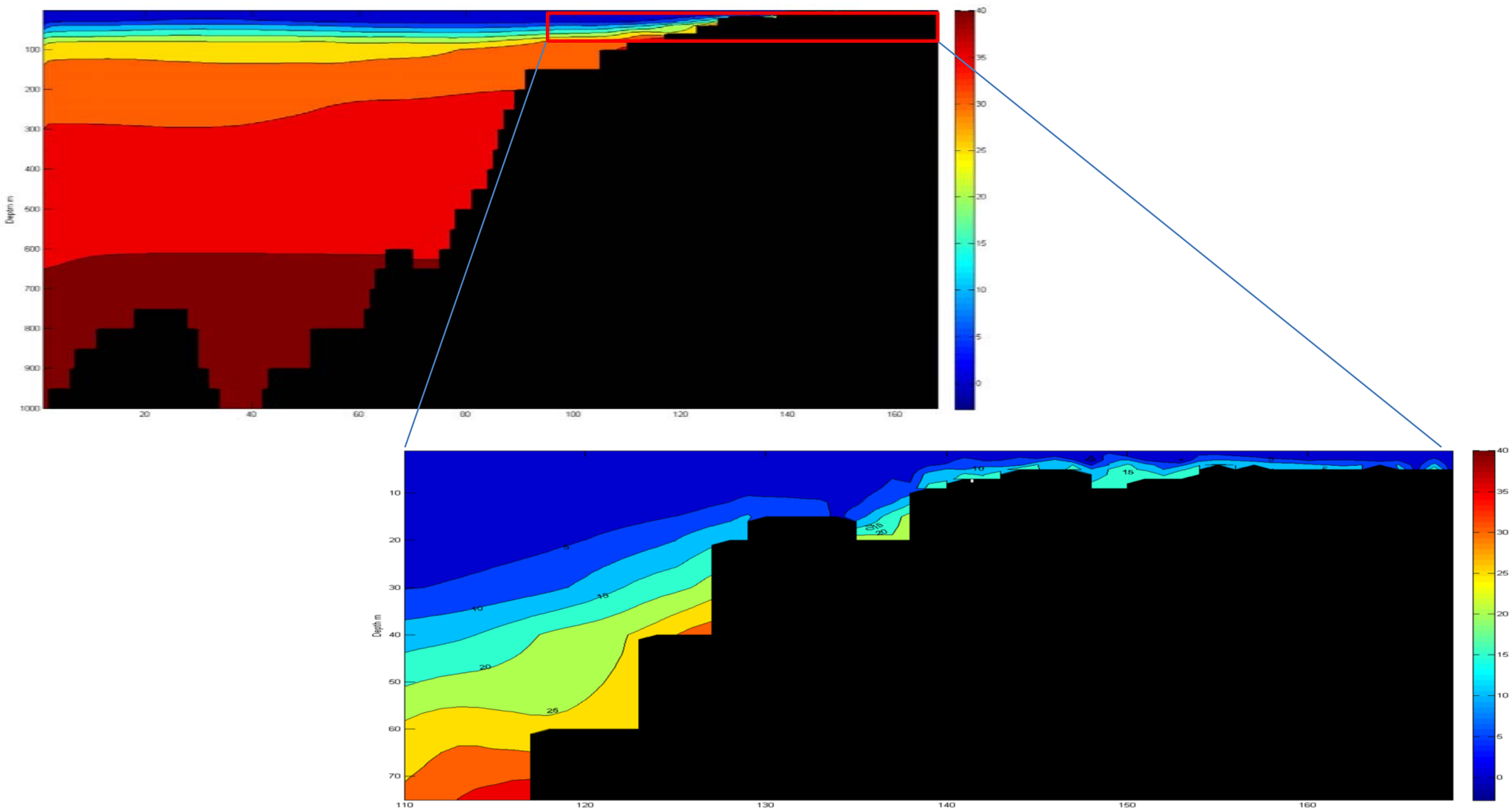
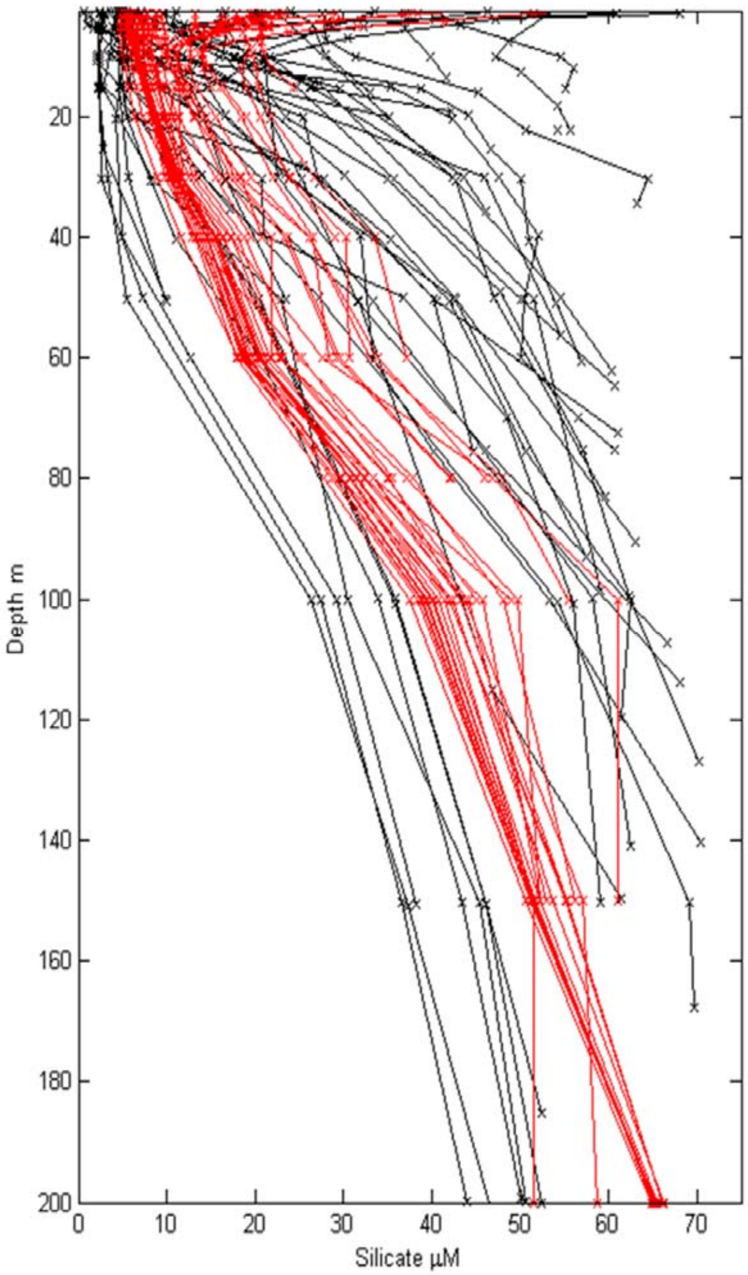
Nitrate concentrations across shelf





Profiles of silicate taken from RISE cruise (black) and from model output (red) show good agreement at depth

Summary

- Modelling results show a complex 3D interaction of near field plume and shelf water
- Second mode internal wave separation possible
- Near-field plume recirculation
- Large scale plume strongly dependant upon wind forcing
- Upwelling of Nitrate dependent on model depth
- Future inclusion of biological sinks for nutrients

Thank you for listening

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