

# Fate of Fresh Water in Tidally Stirred Seas

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## Background

Regions of freshwater influence (ROFIs) provide the critical interface between estuaries and continental shelf seas, across which freshwater and suspended particulate matter, and consequently terrestrial nutrients and anthropogenic contaminants are exchanged. On a local scale, the water quality in coastal and estuarine waters is fundamentally dependent on the mixing of water masses, residence times and particulate matter which mediate primary productivity, biogeochemical cycling, pollutant dispersal and ecosystem sustainability (Tett et al., 1993).

On a global scale the discharge of freshwater into the ocean plays a role in climate dynamics which is out of all proportion to its total volume flux. Although global freshwater discharge ( $0.6 \times 10^6 \text{m}^3/\text{s}$ ) is dwarfed by deep ocean fluxes (for example the North Atlantic subtropical gyre horizontal transport is approximately  $120 \times 10^6 \text{m}^3/\text{s}$ ) it nevertheless plays an important role in influencing the ocean stratification. Rahmstorf (1995) showed that a 10% increase in total freshwater flux into the ocean could substantially reduce, or even shut down, the North Atlantic 'thermohaline' circulation with potentially severe impacts on Western European climate.

The complex physical processes that control ROFI dynamics exhibit both estuarine and shelf sea characteristics. Understanding these complex dynamics is essential for understanding the fate of fresh water at this critical marine-terrestrial interface. This understanding is also a prerequisite for the effective management of coastal seas and is therefore of great importance to the UK government's Marine Management Organisation.

ROFIs tend to be characterised by strong lateral salinity (c.f. density) gradients. Whilst tidal currents dominate, it is the much weaker residual current that determines the fate of freshwater. However these weaker time-averaged currents are subtly controlled by stratification and bottom friction in a way that is not wholly understood (Heaps 1972; Verspecht 2009). Episodic processes associated with the tides have been conjectured to control the residual transport on a tidal time-scale (Simpson 1990, Palmer 2010) and also on a spring-neap time scale (Sharples 1995; Hopkins & Polton, 2010) but a definitive analysis using both numerical simulation and observational techniques remains to be done.

## Aims and Objectives

Our aim is to investigate the fate of fresh water in Liverpool Bay (see Figure) using a combination of state of the art computer simulations and leading edge observational techniques. The aim is to isolate and quantify the key processes that determine the mixing rates and lateral extent of the freshwater as it enters Liverpool Bay from the major estuaries.

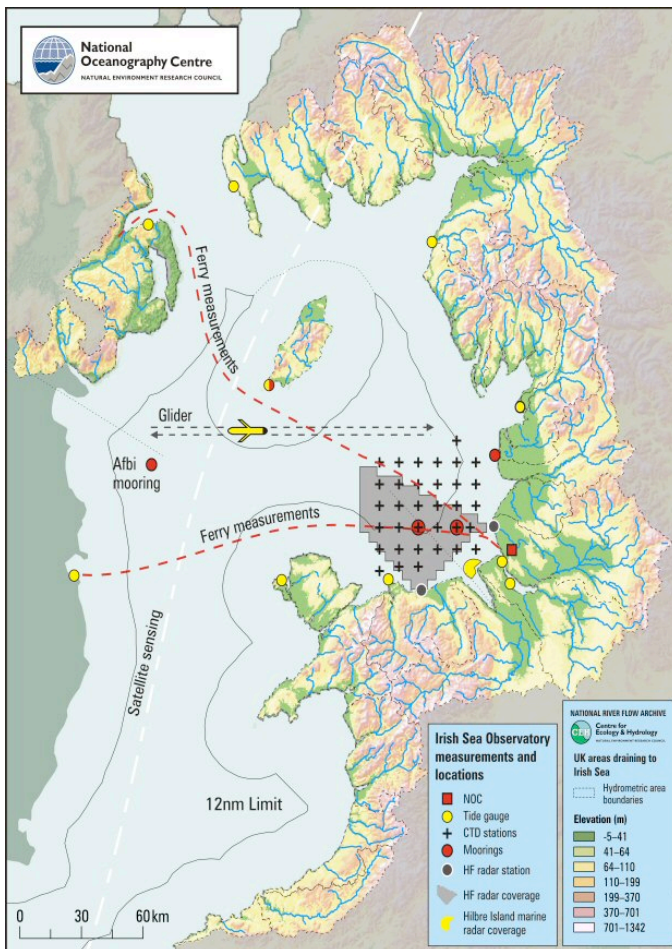
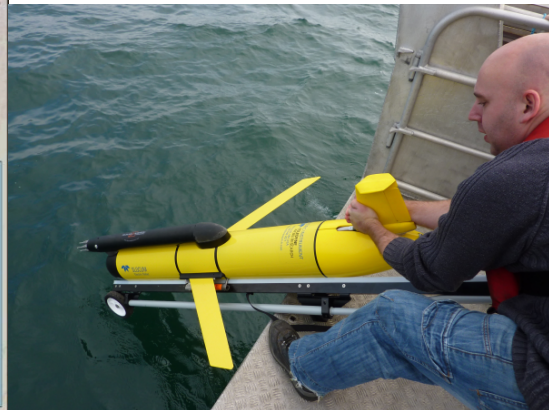


Figure: The NOC Irish Sea Observatory maintains instrumentation and infrastructure that supports monitoring and scientific research which is focussed in the complex coastal environment of Liverpool Bay. The project employs the latest technology including a small fleet of ocean gliders.



The project will take advantage of the UK National Oceanography Centre Irish Sea Observatory, (<http://cobs.pol.ac.uk/>) which has been in operation since 2002 (Proctor et al. 2003) in conjunction with numerical simulation data from the three-dimensional hydrodynamical model POLCOMS (Holt and James, 2001; Holt et al., 2005).

### Year 1

- Classes. Literature review. Become familiar with POLCOMS numerical model.
- Assess the skill of the model in reproducing the observational data.

### Year 2

- Become familiar with glider observational data transects across Liverpool Bay.
- Identify and quantify the physical processes responsible for transport of freshwater in ROFIs in numerical model. Contrast with (sparser) observational from Observatory.
- Identify temporal and spatial scales for the evolution of the horizontal density gradient in both model and observations.

### Year 3

- Investigate the sensitivity of the system to vertical mixing.
- Assess the predictive capabilities of the 3D numerical model (POLCOMS) for this process.

## **Training provided**

The student will participate in the training programme of Bangor University, as well as any appropriate courses offered at the National Oceanography Centre. The student will work

as part of the Observatory team. The project will provide experience in numerical modelling techniques (from coding to visualisation) and in observational techniques (from collection, through processing to visualisation). The observational component of the project will involve training with autonomous glider technologies (which is an up-and-coming UK Marine Science observational tool).

Applicants should possess, or expect to graduate with a first class or upper second degree in a numerate science, such as physics, mathematics, physical oceanography or meteorology, and have an enthusiasm to engage in numerical modelling. Previous knowledge of ocean sciences is not essential. At least some exposure to computer programming is essential. A successful candidate will display a willingness to engage with the observational aspects of the problem though no previous experience or training is expected.

Funding for this studentship is restricted to UK and EU nationals who fulfil NERC's eligibility requirements. More information is available from the NERC website at: <http://www.nerc.ac.uk/funding/available/postgrad/eligibility.asp>

## References

- Heaps, N. S. 1972. Estimation of density currents in the Liverpool Bay area of the Irish Sea. *Geophys. J. R. astr. Soc.* 30: 415–432.
- Holt, Jason, and I. D. James. 2001. An s-coordinate model of the northwest european continental shelf. Part I: Model description and density structure. *J. Geophys. Res.* 106 (C7): 14015–14034.
- Holt, Jason T., J. Icarus Allen, Roger Proctor, and Francis Gilbert. 2005. Error quantification of a high-resolution coupled hydrodynamic-ecosystem coastal-ocean model: Part 1 model overview and assessment of the hydrodynamics. *J. Mar. Syst.* 57: 167–188.
- Hopkins, Jo, and Jeff A. Polton. 2010. Spring neap scales of frontal adjustment and fresh water export in a region of freshwater influence. *Ocean Dynamics*. (Subm.).
- Palmer, Matthew Robert. 2010. The modification of current ellipses by stratification in the Liverpool Bay ROFI. *Ocean Dynamics* 60: 219–226. doi:10.1007/s10236-009-0246-x.
- Rahmstorf, S. 1995. Bifurcations of the Atlantic thermohaline circulation in response to changes in the hydrological cycle. *Nature*. 378: 145-149.
- Sharples, J. and J. H. Simpson. 1995. Semi-diurnal and longer period stability cycles in the Liverpool Bay-region of fresh-water influence. *Cont. Shelf Res.* 15: 295-313.
- Simpson, John H., J. Brown, J. Matthews, and G. Allen. 1990. Tidal straining, density currents, and stirring in the control of estuarine stratification. *Estuaries* 13: 125–132.
- Tett, P. B. et al. 1993. Biological consequences of tidal stirring gradients in the North Sea. *Philos. Trans. R. Soc. London A.* 343: 494-508.
- Verspecht, Florence, Tom P. Rippeth, John H. Simpson, Alejandro J. Souza, Hans Burchard, and M. John Howarth. 2009. Residual circulation and stratification in the Liverpool Bay region of freshwater influence. *Ocean Dynamics* 59: 765–779. doi:10.1007/s10236-009-0233-2.