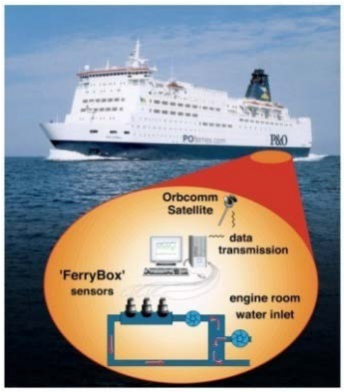
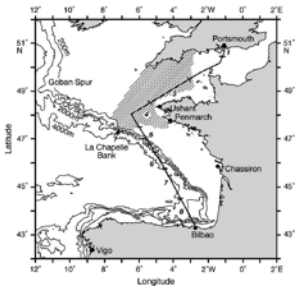
SEASONAL AND INTER-ANNUAL VARIABILITY IN PRODUCTIVITY IN RELATION TO WINTER NUTRIENT CONCENTRATIONS IN THE BAY OF BISCAY

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A key challenge in oceanography is to capture and quantify processes that happen on short time scales, seasonal changes and inter-annual variations. To address this problem the P&O European Ferries Ltd. Ship 'Pride of Bilbao' was fitted with a FerryBox from **2002 to 2010** and data returned to NOC in real time providing near continuous hydrographic measurements along the ferry track, between UK (Portsmouth) and Spain (Bilbao). Additional monthly samples were collected to provide calibration data.



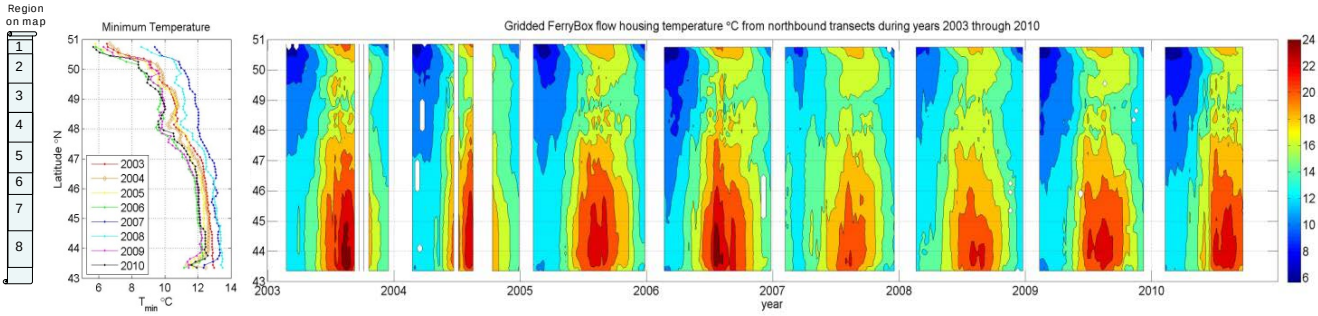
The Pride of Bilbao ferry route highlighting persistent regional features (see temperature plot)

Physical data

The ferry is used as a ship of opportunity (SOO) providing *in situ* sensor and discrete sample measurements. They include surface water (5m depth) measurements for salinity, temperature, oxygen and chlorophyll-fluorescence data. The figure below shows how temperature from 5 metres below the ocean surface vary over an eight year period that covers 0.8x10^{6}km of ship's track.

Variability

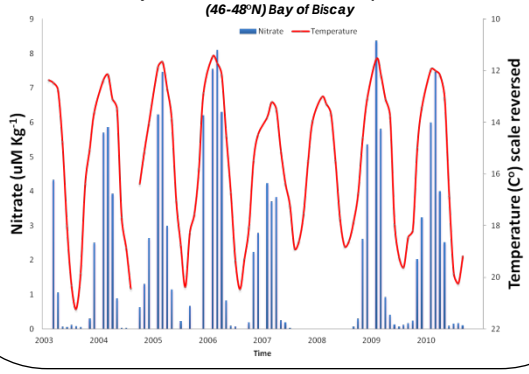
There is a large year to year variability in surface temperature in the shallow water (~60m) north of 50N (regions 1&2). In region 4 strong tides off Ushant mix heat into the 100m water column reducing the mean surface temperature and variability. In the Bay of Biscay, regions 5 & 6, there is less variability between years than in other regions. The winters of 2007 & 2008 are clearly warmer than in other years (see 'Minimum Temperature' figure).



Nutrient data

From 2003, monthly samples were taken on calibration crossings. In total over 6000 samples for the measurement of nutrients, including nitrate &nitrite, dissolved reactive phosphate and silicate concentrations. The data were used to resolve seasonal and inter-annual variation in nutrients and to relate this to variations in mixing and primary production. The monthly mean nitrate data from the Bay of Biscay (see Figure) shows relatively high values for the cold 2005/2006 winter and low values associated with the warm 2007 winter.

Monthly mean nitrate and sea surface temperature data (46-48°N) Bay of Biscay



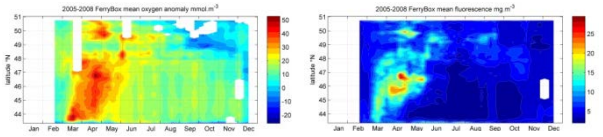
Mixing and productivity

In the Bay of Biscay the mixed layer depth (MLD), assessed using Argo floats (see table), was found to vary from <300m in relatively mild winters (such as 2006/2007) to nearly 500m in cold winters (2005/2006). Deeper mixing was associated with an increase in nitrate concentrations in the surface waters (~ 2.3 uM kg^{-1}). Increased vertical nutrient supply resulted in higher productivity (NCP_{mld}) the following spring. Net Community Production (NCP) was assessed using the month to month change in dissolved oxygen multiplied by the MLD and C:O Redfield ratio of 106:138 (Jiang *et al.,* 2012).

Inter annual variation in mixed layer depth (MLD) and Productivity (NCP) assessed using oxygen data

Year	MLD ARGO 0.5°C (m)	$NCP_{mld\ (DO)}$ (Mol C m^{-2})
2005/2006	469	20.91
2006/2007	**212**	**10.07**
2007/2008	**265**	**10.53**
2008/2009	439	19.91
2009/2010	476	16.91

The figure below shows the high resolution chlorophyll-fluorescence and dissolved oxygen data obtained. It shows comparable spring bloom timing between oxygen and chlorophyll-fluorescence data. The spring bloom was dominated by diatoms in the Bay of Biscay (Smythe-Wright, et al., 2012).



High resolution oxygen anomaly & chlorophyll-fluorescence data

Conclusions

The full dataset demonstrates that ships of opportunity, particularly ferries with consistently repeated routes, can deliver high quality *in situ* measurements over large time and space scales that currently cannot be delivered in any other way. Hydrographic data are available from the British Oceanographic Data Centre (www.bodc.ac.uk).

Acknowledgements: P&O officers & crew on the Pride of Bilbao and various students that have assisted in the calibration crossings over the 8 years of FerryBox operation. Work was supported by the European Commission under the 5th RTD Framework Programme, Contract n°: EVK2-CT-2002-00144.

References: Smythe-Wright *et al.* talk and Jiang *et al* poster, ISOBAY XIII

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