Spatiotemporal variations of fCO_2 in the North Sea

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1. Introduction

Shelf seas are thought to be substantially contributing to the global ocean's uptake of atmospheric CO_2 (Chen and Borges 2009 and references therein).

The North Sea (NS) is one of the best studied shelf seas and acts as "continental shelf pump"—local uptake of atmospheric carbon followed by formation and transport of subsurface water to the deep ocean (Thomas et al., 2004). Despite this, neither the seasonal fCO_2 cycle nor its year-to-year variability is well documented.

This work analyses the first high frequency fCO_2 dataset from the NS gathered along two transects (Fig. 1) by Voluntary Observing Ships (VOS). Here we focus on the spatiotemporal variations from seasonal to interannual time scales.

2. Summary of results

Throughout the North Sea, fCO_2 show clear seasonal changes (Fig 2, upper middle) driven by mixing plus biology, sea surface temperature (SST) changes, and air-sea CO_2 flux (Fig 3, upper far right).

Strongest gradients were observed along the meridional transect where fCO_2 decreased northwards (-12 µatm per degree latitude). This is maintained partly by northward decreasing solar radiation input (through SST). The rest is probably maintained by permanent mixing (which brings up remineralized carbon into the surface) in the southern North Sea.

Averaged over the whole basin, the NS is CO_2 undersaturated throughout the year and thus an annual sink of atmospheric CO_2. However, the southern parts become a source during summer and fall (Fig 2B) .

Year-to-year fCO_2 variations are large throughout the basin and driven mainly by changes in SST and spring bloom (Fig 4, lower middle). However, changes in alkalinity and eutrofication level may also be important in the south.

Data from Jan - Feb showed the least year-to-year differences (±10 *µ*atm, Fig 4A and 4D) suggesting that only observations from these months may be appropriate for the determination of any decadal fCO_2 trend due to increased atmospheric CO_2.

3. Data

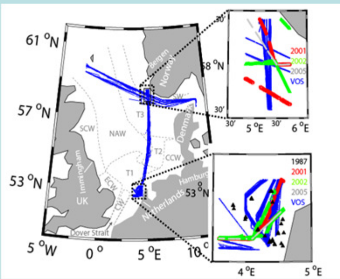

Figure 1: Map of the North Sea with tracks (blue) of the VOS ships (*Nuka Arctica* and *Trans Carrier*) during 2005 – 2007. Dashed rectangles indicate two sites at which the interannual variability is investigated using data from years and locations shown on the insets where blue indicates VOS tracks; red, green, and grey denote cruise tracks with underway fCO_2 measurements; black show cruise stations.

4. Seasonal/spatial variations

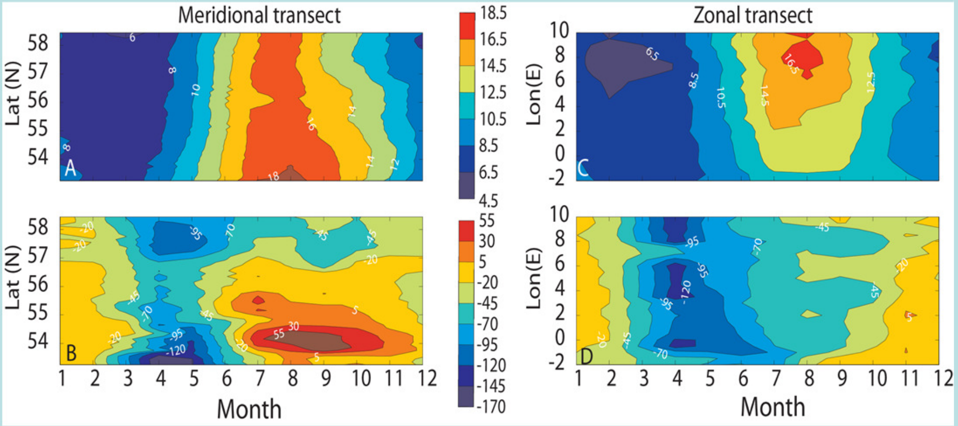

Figure 2: Hovmöller plots of SST (A and C) and fCO_2 difference (ΔfCO_2) (B and D) between the atmosphere and ocean along the meridional (A and B) and zonal (C and D) transects (see Fig 1). The seasonal cycles shown in the figure are for a composite year and comprise data acquired in 2005-2007. Negative ΔfCO_2 values indicate a CO_2 flux directed into the ocean and vice versa.

5. Seasonal forcing

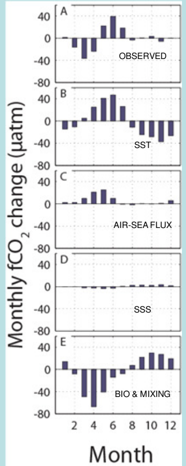

Figure 3: Monthly changes in fCO_2 as observed (A) and expected due to: SST changes (B), air-sea CO_2 exchange (C), SSS changes (D), and biology plus mixing (E). Negative values reflect a decrease in fCO_2 compared to the previous month and vice versa

6. Interannual variations

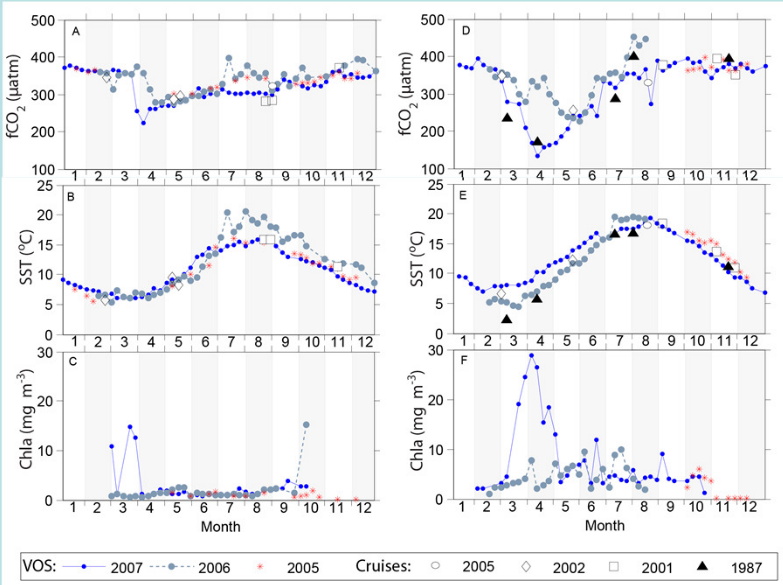

Figure 4: Seasonal cycles for fCO_2 (A and D), SST (B and E), and co-located SeaWiFS Chlorophyll-*a* (C and F) for different years. All data was averaged weekly. Panels A-C show data acquired from a 1.0°x1.0° site on the northern North Sea (Fig 1) for which underway fCO_2 and SST data from 2001, 2002, and 2005-2007 are available. Panels D-F show data acquired from a 0.6°x1.0° site in the southern North Sea (Fig 1) for which also station data from 1987 are available in addition to underway data from 2001, 2002, and 2005-2007.

7. References

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