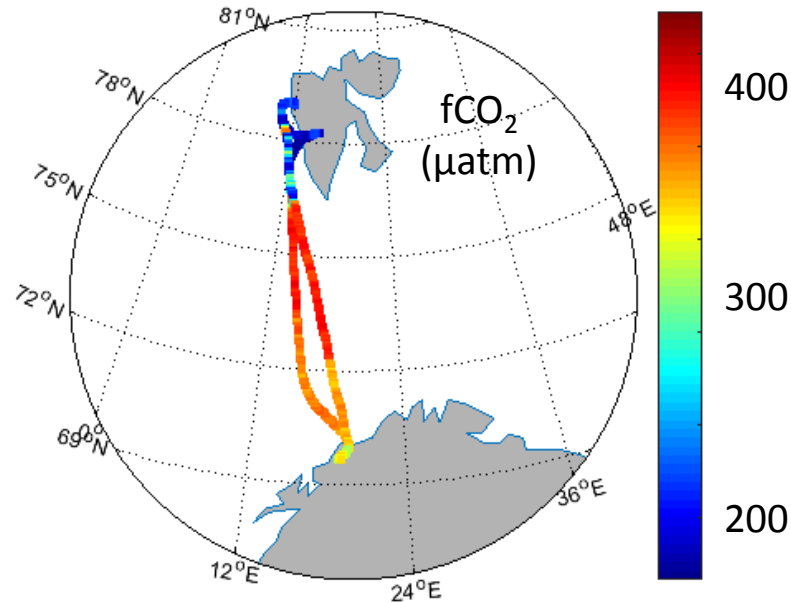


# FerryBox underway monitoring of pCO<sub>2</sub> and pH (in Arctic/subarctic Norway and the North Sea)



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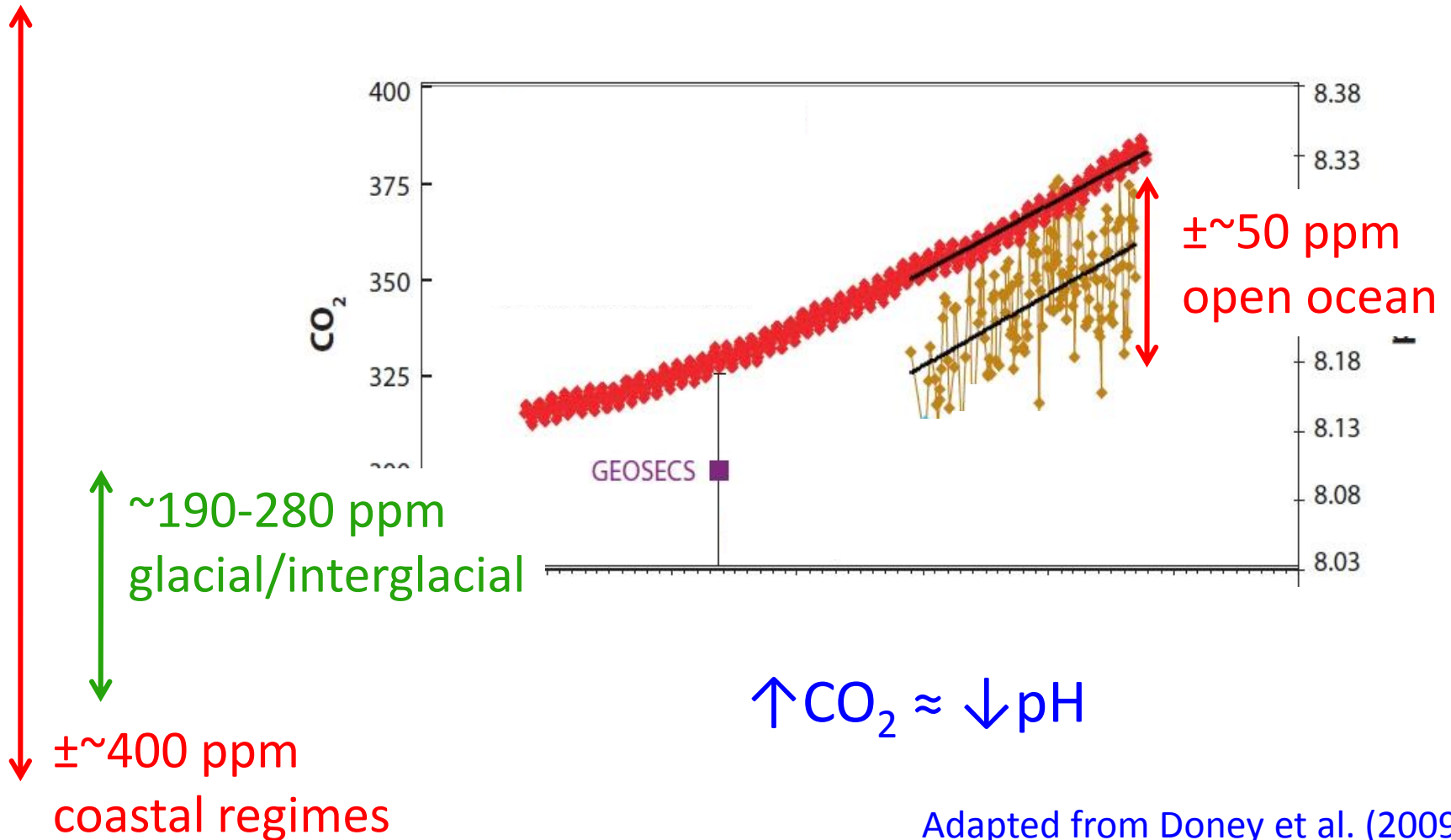
**Co-authors:** Kai Sørensen, Richard Bellerby, Phil Wallhead, Marit Norli, Emanuele Reggiani, Pierre Jacard (NIVA)

# Why are we interested in ocean carbonate chemistry?

- Global carbon cycling and climate variability are both linked to oceanic carbon (solubility and biological C pumps)
- Life in the ocean depends photosynthetic carbon fixation (which depends largely on  $\text{CO}_2$ ); hence the cycling of many other elements are linked to the C cycle
- $\text{CO}_2$  availability and pH can directly and indirectly affect foodweb structure and function
- Calcifying organisms and solubility of inorganic carbonates are linked to saturation state of  $\text{CaCO}_3$  ( $\Omega$ )
- $\text{CO}_2$  is projected to double within the next century due to fossil fuel emissions – ocean acidification

# CO<sub>2</sub> can vary on different temporal and spatial scales

~2000-4000 ppm  
100-200 million year max



Adapted from Doney et al. (2009)

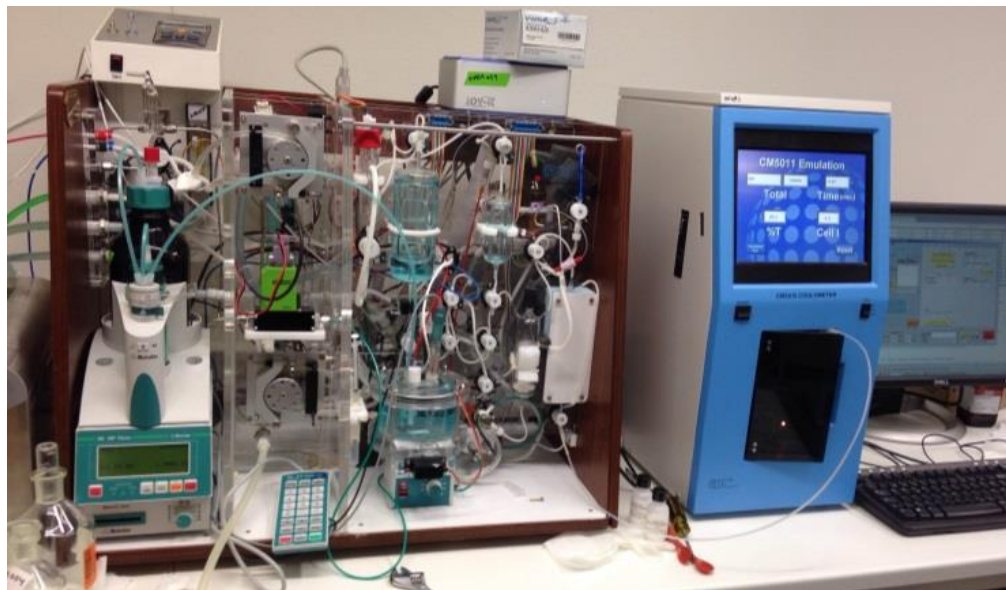


# Coastal and oceanic carbonate system observations

Membrane equilibration  $p\text{CO}_2$  sensor  
(NIVA/Franatech AS)



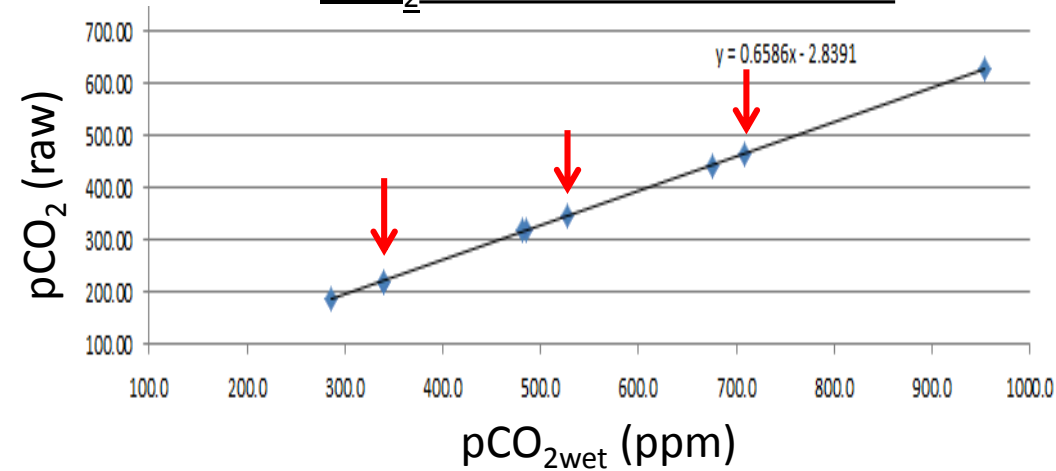
Spectrophotometric pH sensor  
(NIVA/Reggiani et al., 2014, 2016 in press)



VINDTA - total dissolved inorganic C /  
total alkalinity ( $\pm 1\text{-}3 \mu\text{mol kg}^{-1}$  precision)

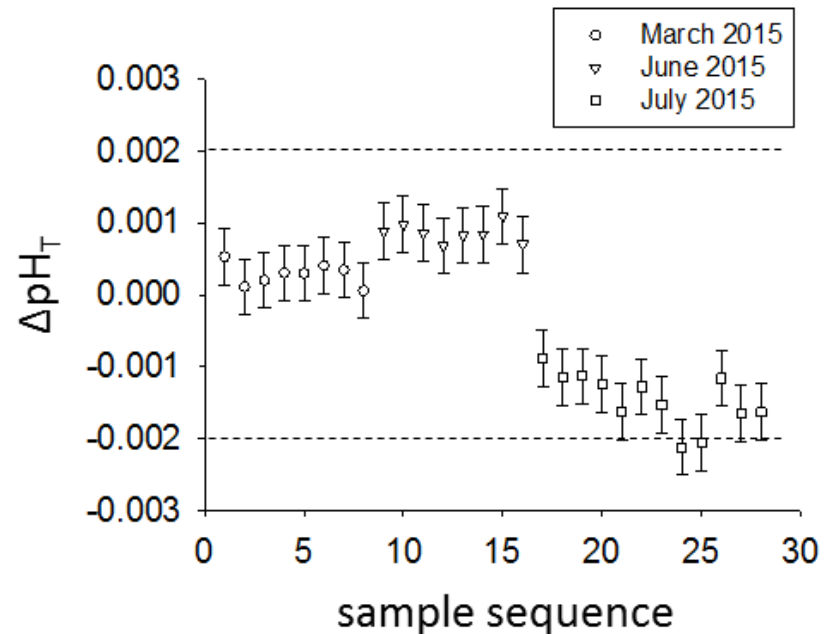
# Calibration and testing data

pCO<sub>2</sub> sensor calibration curve



**Lab-based calibrations are combined with field-collected “control” samples that are preserved and measured using VINDTA**

pH sensor testing data



# NIVA FerryBoxes with pH/pCO<sub>2</sub> observations

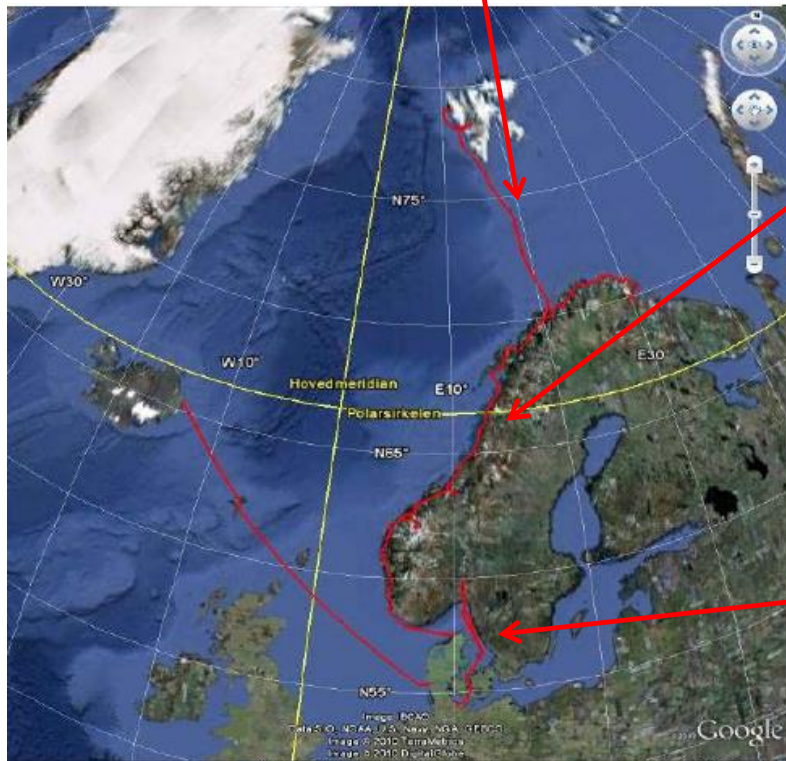
M/S Norbjørn



M/S Trollfjord



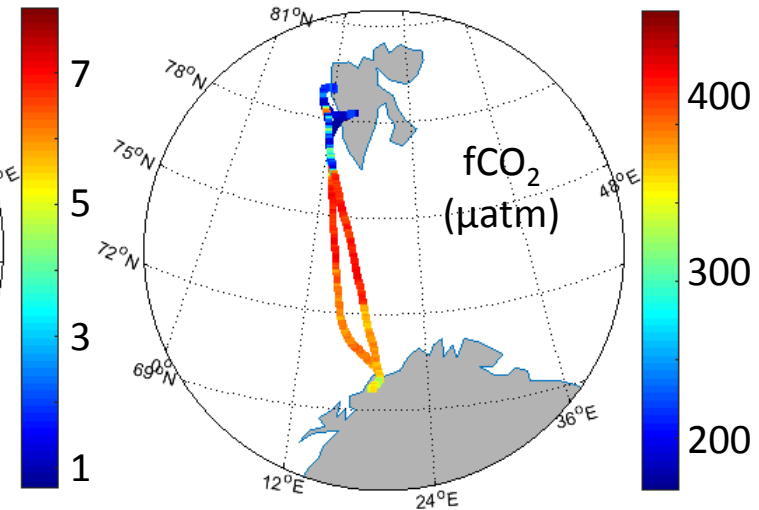
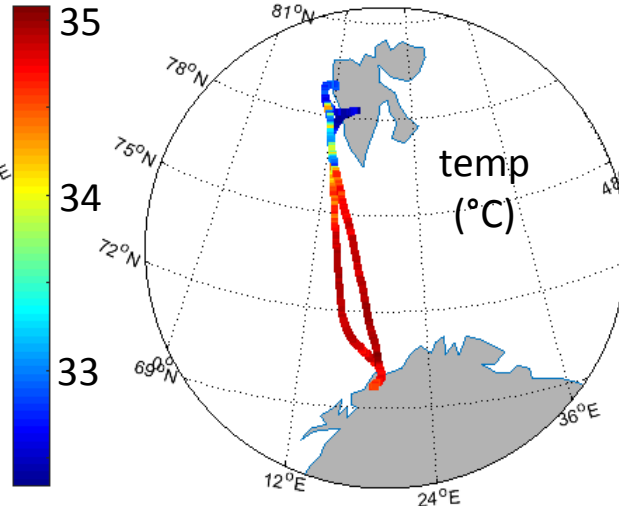
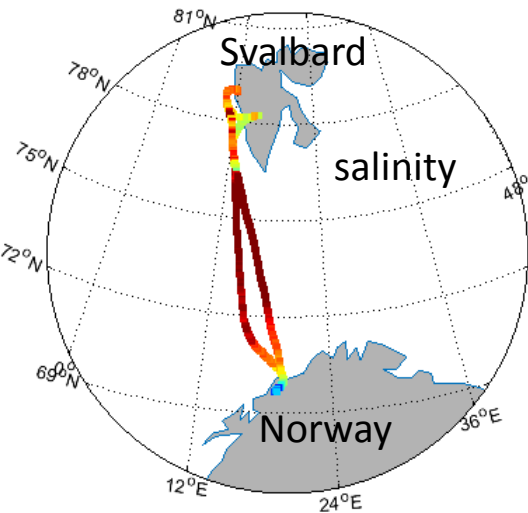
M/S Color Fantasy



# Regional and temporal variability in $f\text{CO}_2$ - Arctic

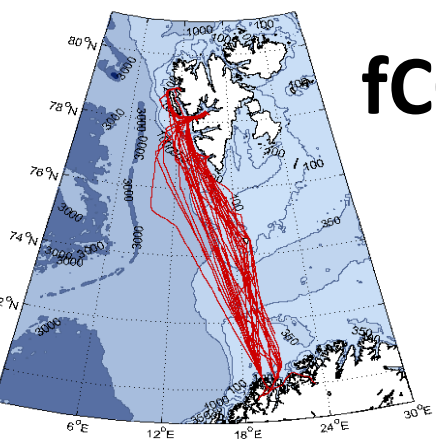


May 15 - May 21 2015





# fCO<sub>2</sub> - Barents Sea opening May 15-June 20 2015



May 15-17 2015  
TMS-LYR

May 18-21 2015  
LYR-TMS

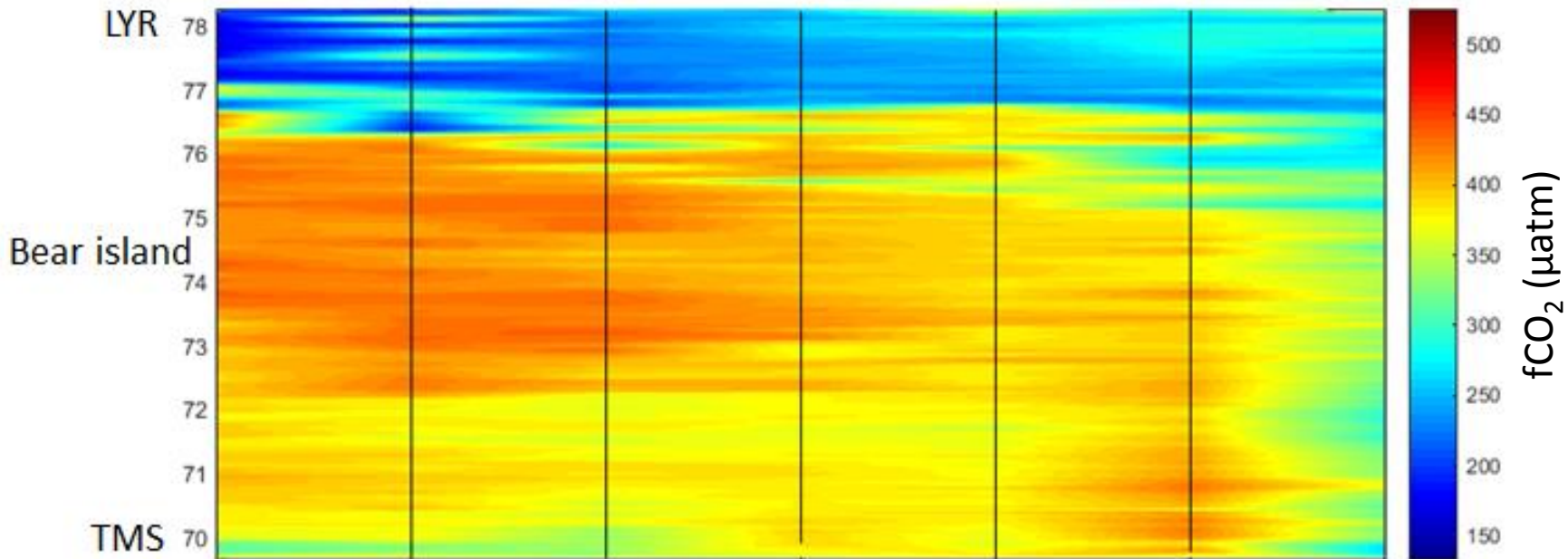
May 29-31 2015  
LYR-TMS

June 5-7 2015  
TMS-LYR

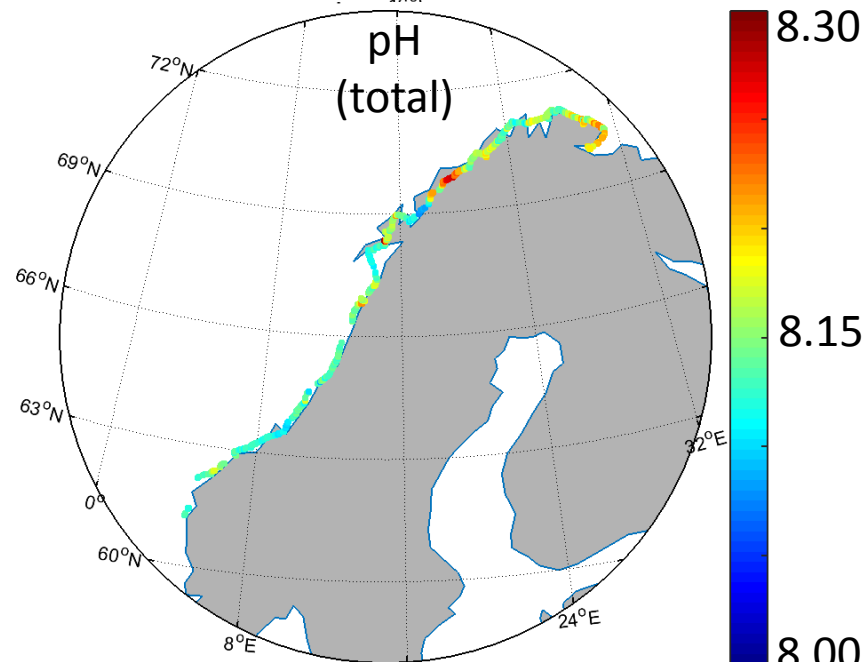
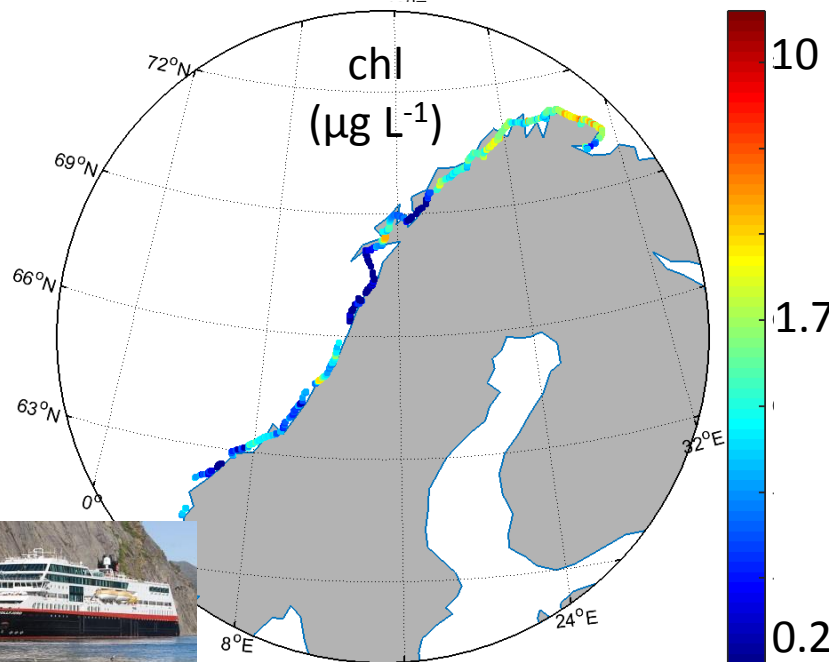
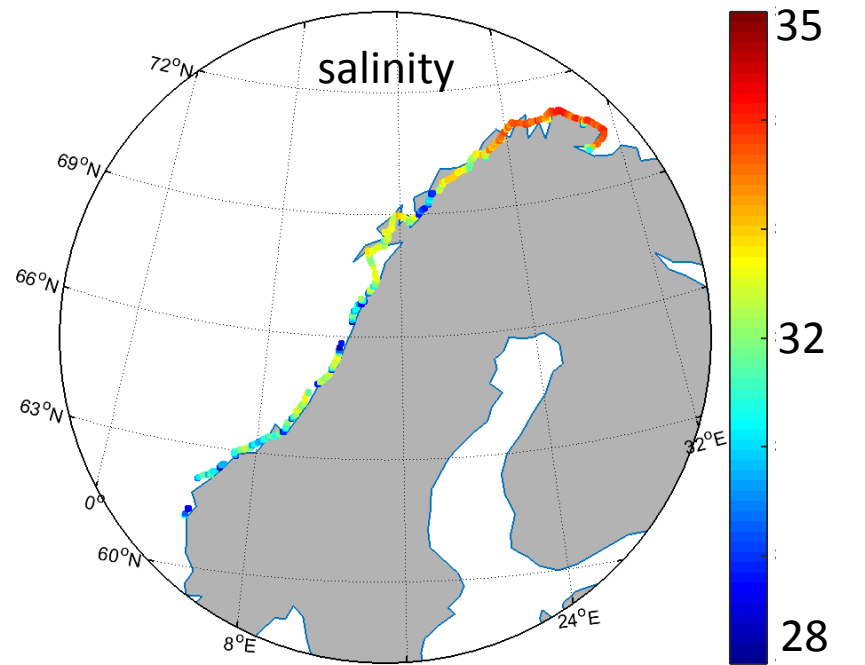
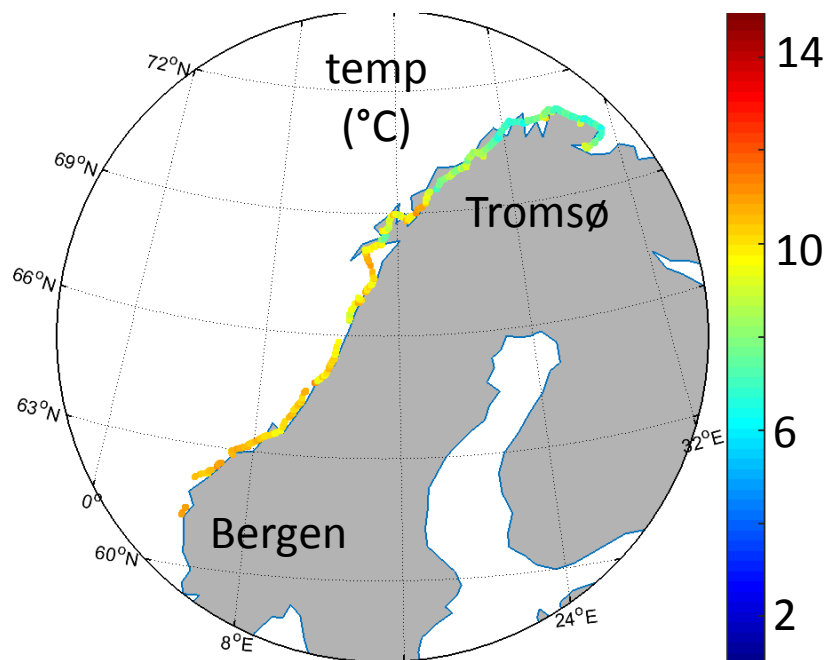
June 9-11 2015  
LYR-TMS

June 16-18 2015  
TMS-LYR

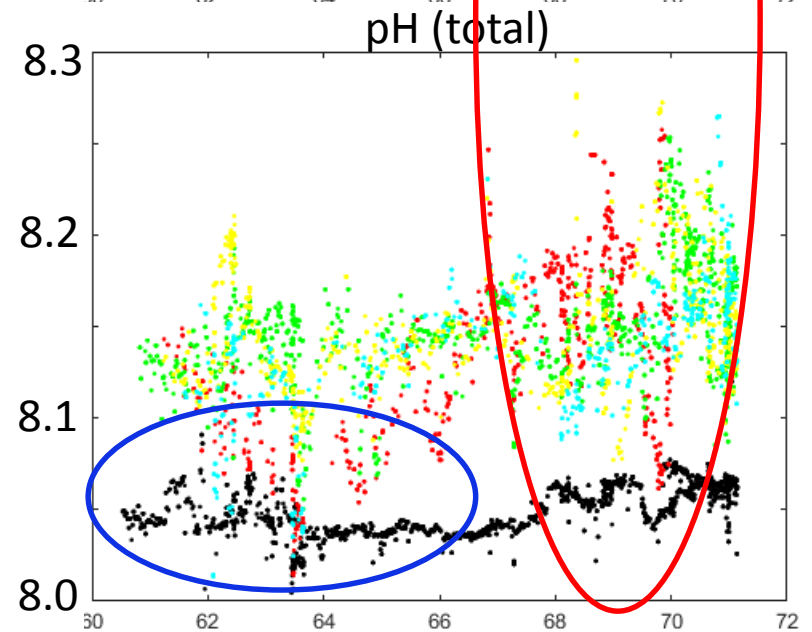
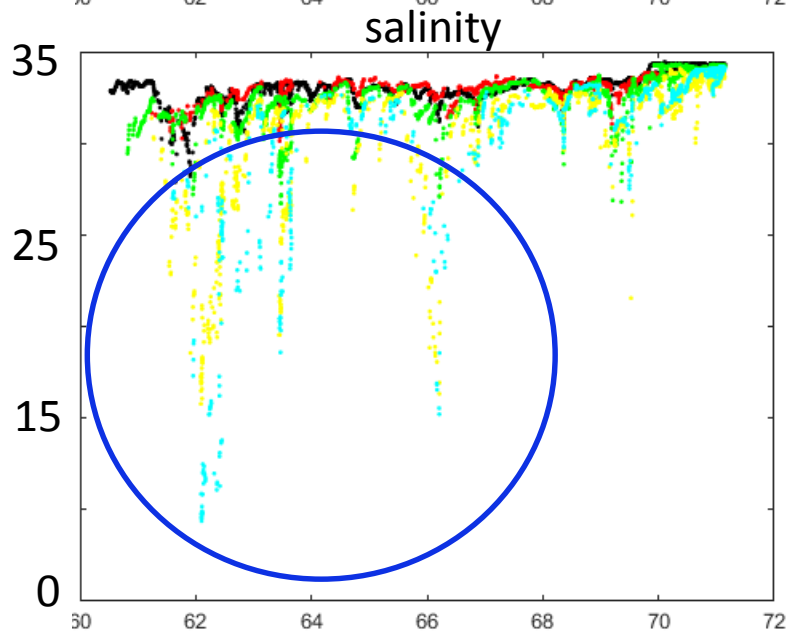
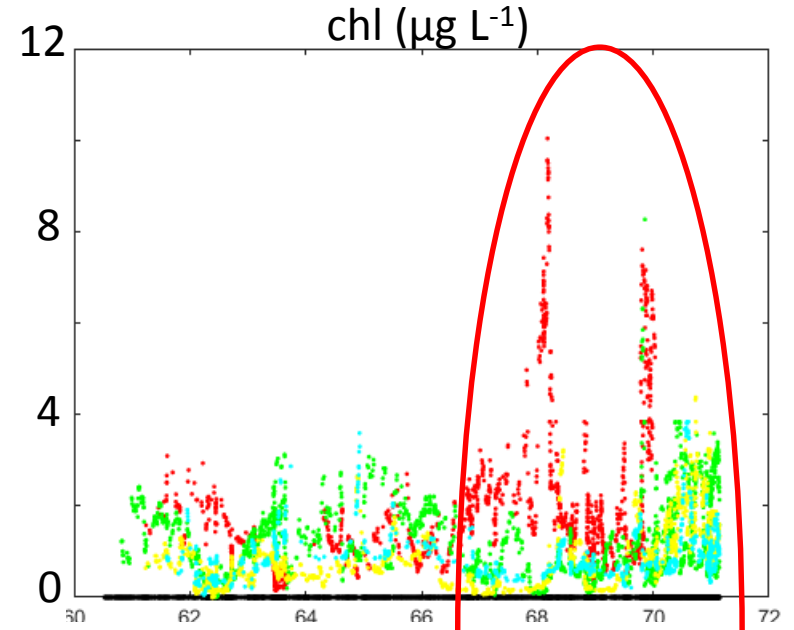
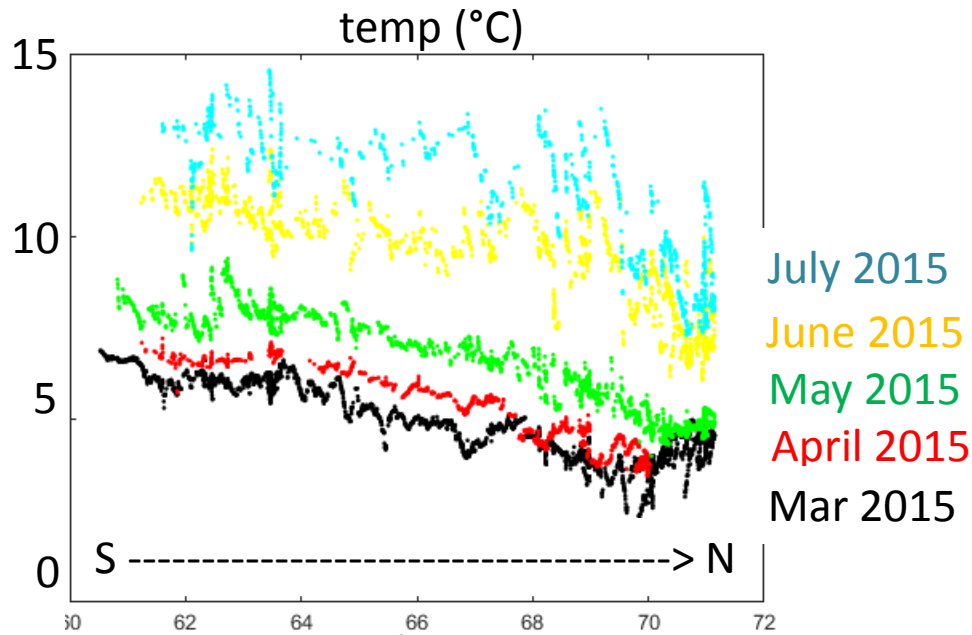
June 20-22 2015  
LYR-TMS



# pH – June 2015 coastal Norway

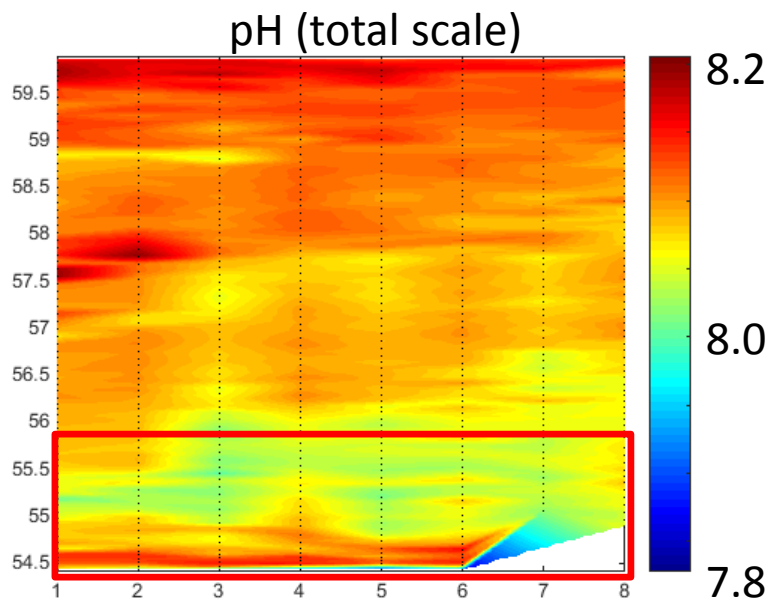
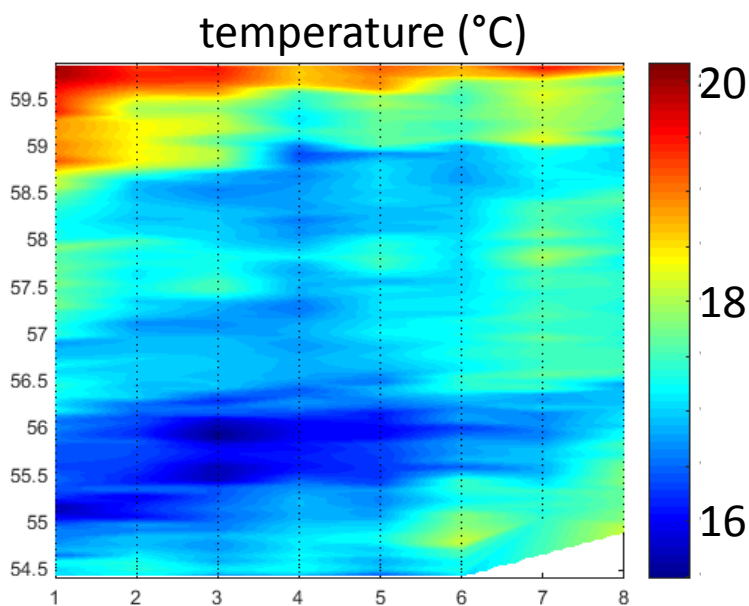
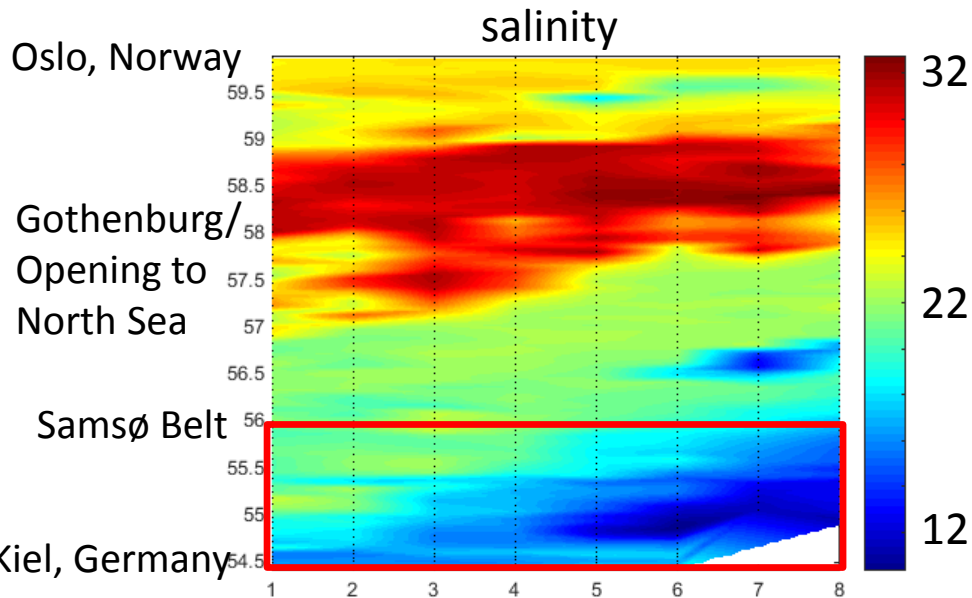
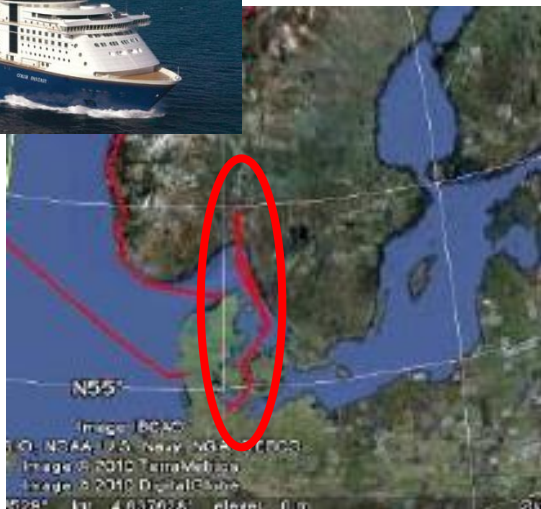


# pH – coastal Norway (Mar-July 2015)



# pH – inner North Sea

8 transects between August 28-Sept 6 2014



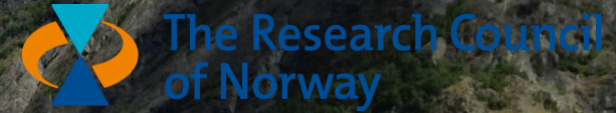
# Summary

- pCO<sub>2</sub> and pH sensors in operation on three NIVA FerryBox lines
- Precision and accuracy of sensors are suitable for examining seasonal/regional variability as well as long-term change
- Deploying the sensors and gathering/processing/validating the data is not trivial
- Large variability observed across all three lines: ~200 - 500+ ppm pCO<sub>2</sub> and pH between ~7.8 - 8.3
- Some general relationships with salinity and chl, but not significant

# Future work

- Complete the analysis of both  $\text{pCO}_2$  and pH on the same lines
- Re-process pH data using constants for salinity  $<30$  and  $T <5$
- Re-examine effects of photosynthesis on carbonate chemistry with help of discrete sample data, and possibly experimental data
- Have a closer look at the fjords and carbonate chemistry variability
- Continue observations for “weather” and “climate” purposes; work towards better understanding which processes are forcing changes in  $\text{CO}_2$  and pH

# Acknowledgements



Nærøysfjord; ~2.5 h by train/bus from Bergen