Cheap and cheerful BioGeoChemical (BGC) sensors: the current state of the art

Does the DBCP have a role to play?

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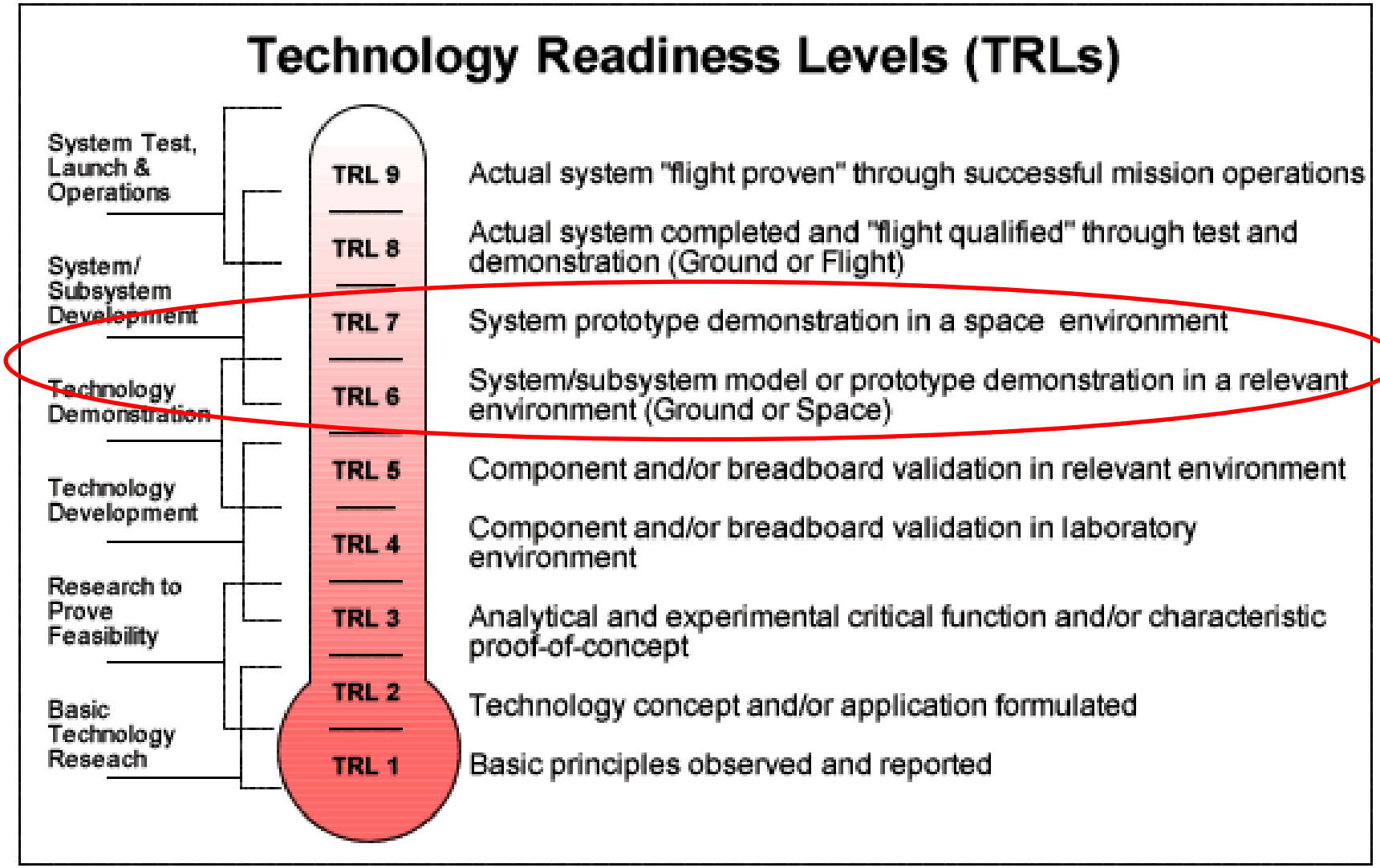
Rationale for a Pilot Project

- Timely: good low-cost BGC sensors now available
  - O_2 optodes well established
  - pCO_2 optode, pH and nutrients Lab-on-Chip 'nearly ready'
- Global drifter fleet could carry such sensors
  - Already rolling out with Argo and gliders
- DBCP has an action from OceanObs'09 to implement BGC obs
- DBCP has established Pilot Project methodology
  - Needs to be timely and at correct Technology Readiness Level (TRL)

Technology Readiness Levels (TRLs)



Rationale

- DBCP has funds to cover incremental costs
- Concept endorsed by GOOS and OOPC (April 2015)
- How to proceed? – strawman drafted for submission to DBCP-31
- Who will lead the initiative??
- To be discussed…

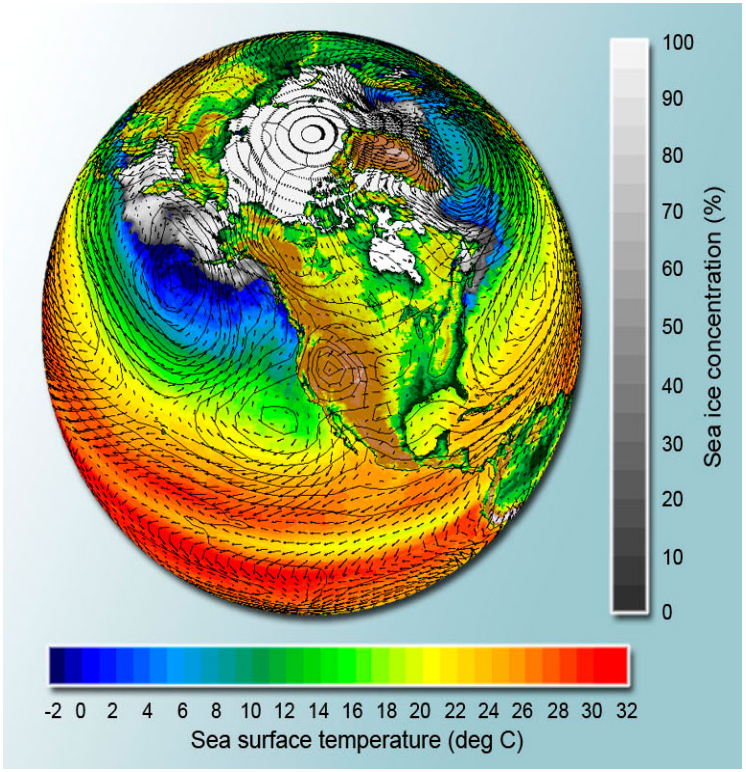
Pilot Project Objectives (draft)

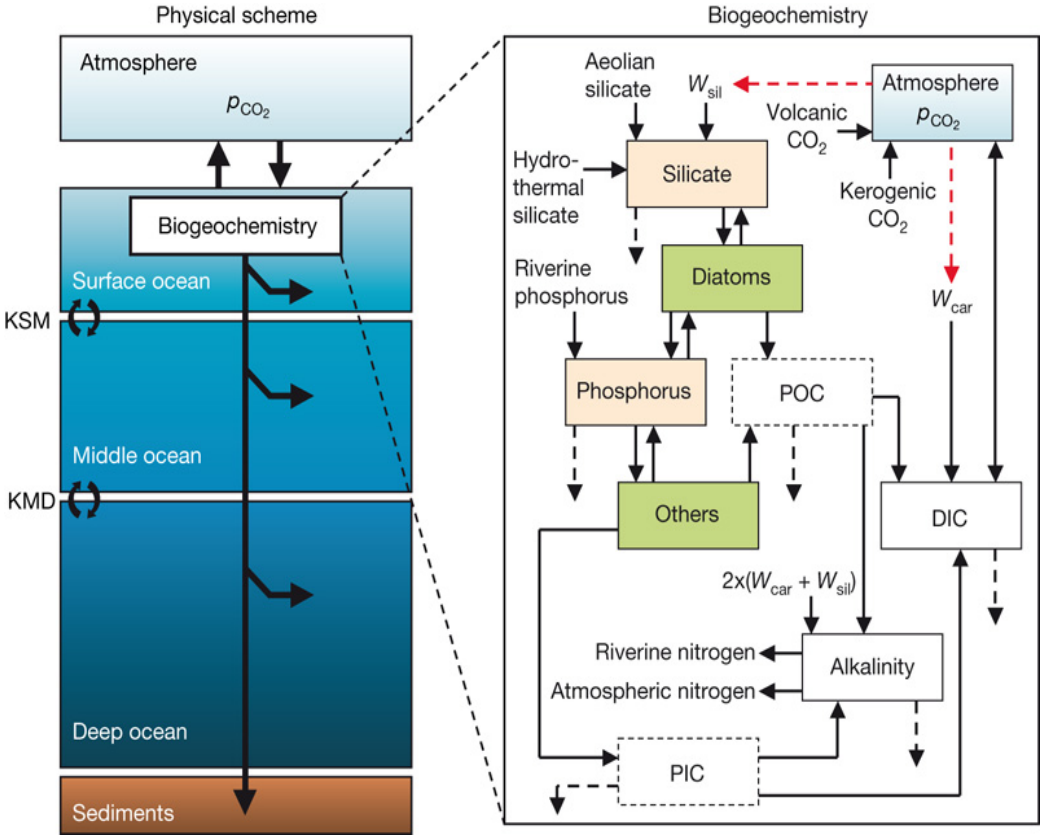
- To demonstrate the feasibility or otherwise of adding BGC sensors to standard SVP-B drifters already being procured by many agencies
- To evaluate the quality of the ensuing data and its usefulness in describing the state of the global oceans in BGC terms
- To elaborate a cost model for the financial implications of adding BGC sensors to drifters on a sustained basis
- To present the results on behalf of DBCP, GOOS and IOCCP to OceanObs'19 in 2019

Lab on chip technology (LOC) applied to in situ marine biogeochemical sensing

(Matt Mowlem, NOC)

Biogeochemistry: Global impact, hard to measure



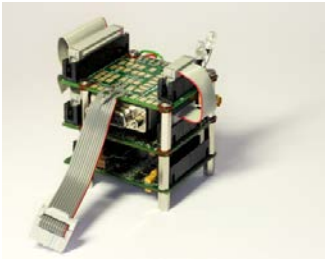


BGC Sensor Technologies and TRLs

- Microfabricated Solid State / Electrochemistry:
- Salinity 7
- Dissolved oxygen 7
- Optodes / optical sensors
- Gases 6
- pH, pCO_2 7
- Radionuclide 3
- Cytometer
- Whole cells (label free) 5
- Labelled cells 5
- Microplastics 4
- Bead assays 3

- Lab on Chip
- Inorganic Nutrients 8
- Organic Nutrients 5
- Trace metals 7
- pH 7, TA 4, DIC 3, pCO_2 4
- Small organics, e.g. PAH, PCBs (f-pM) 5
- Proteins and large organics (copies / L) 4
- Nucleic Acids (copies / L) 6
- Radionuclide 3

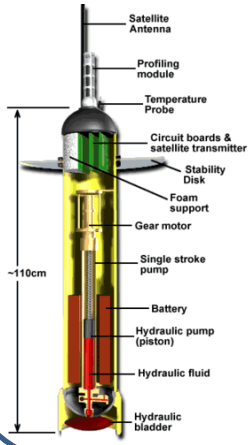
Integrated Analytical systems

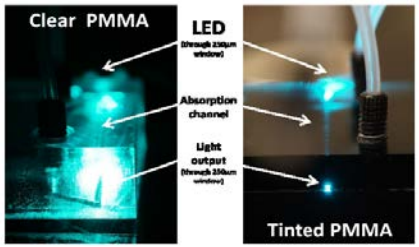


Pressure tolerant electronics

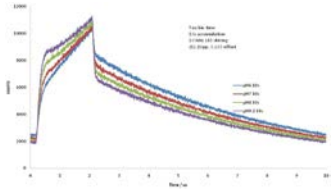
Microfluidics

Mass deployed platforms

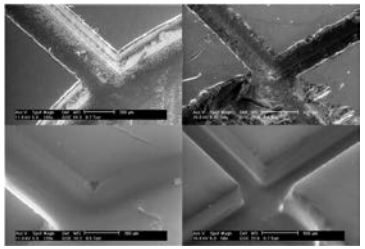




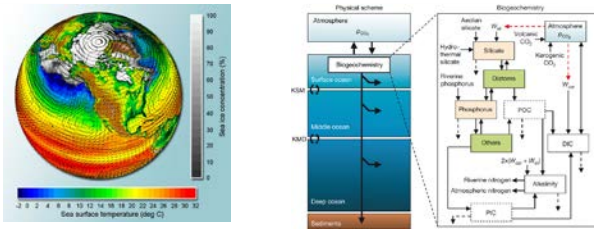
High performance low-cost optics



Assay optimisation



Low-cost manufacturing



Biogeochemical processes

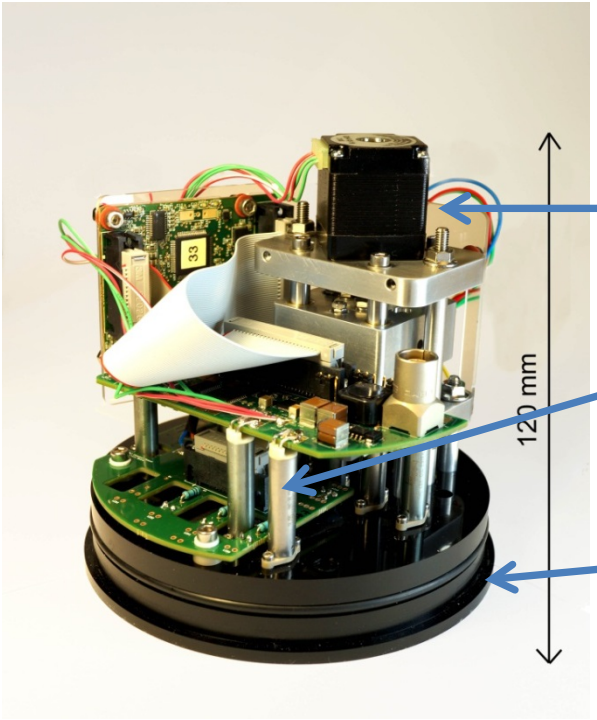
Lab on a chip

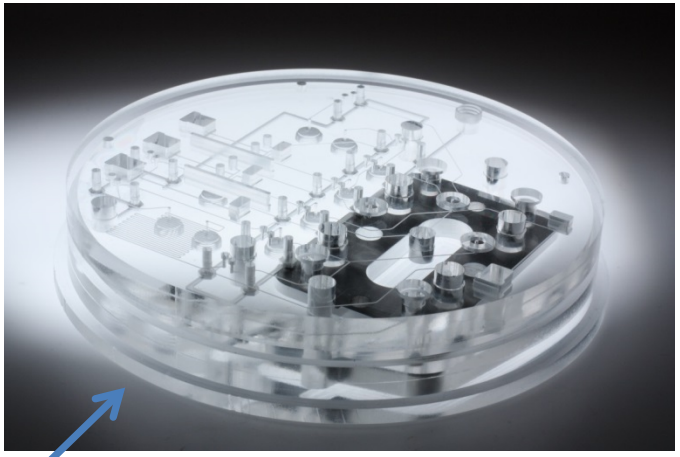
Platforms

- Profiling (Argo) floats
- AUVs
- Ocean Gliders
- UAVs
- Drop-sonde
- Moorings
- Ships of opportunity
- Offshore structures
- Coastal infrastructure
- Observatories
- DRIFTERS??

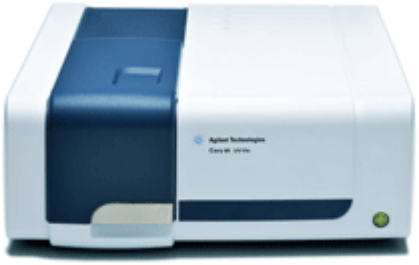
Example technology: Lab on chip

- Lab on chip: Nitrate, Nitrite, pH, Phosphate, Silicate, Iron, Manganese, Total Alkalinity, Ammonia, DOP, Dissolved Inorganic Carbon, DON…..





Spectrophotometric pH assay

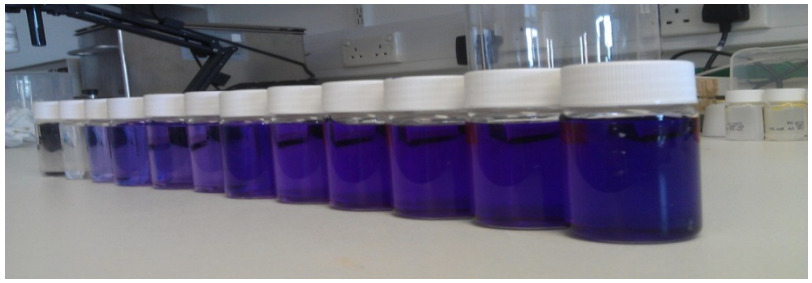


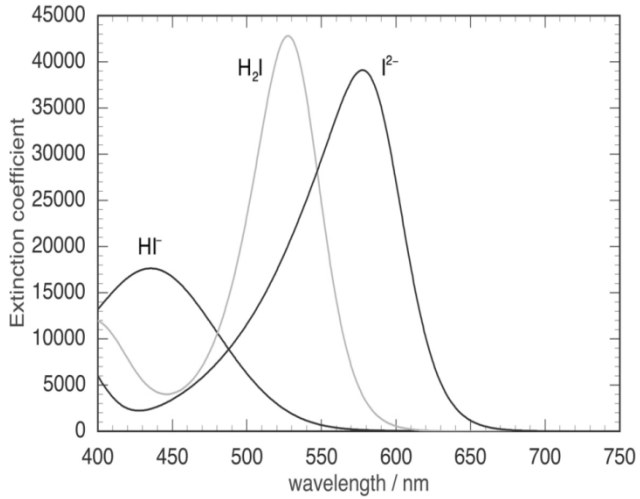
- Reference method
- High accuracy
- High precision
- Self calibrating
- Long term stability

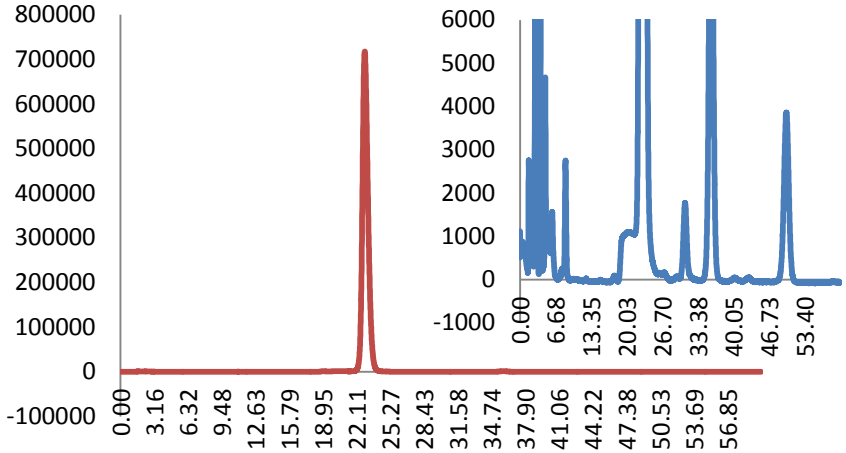
m-Cresol Purple

pH 4

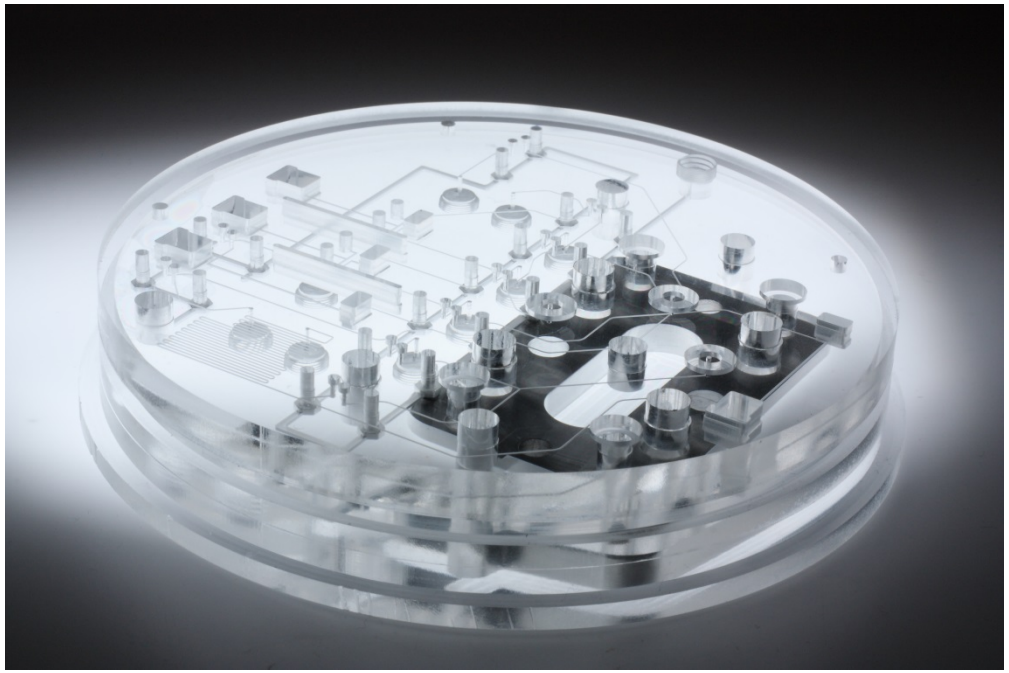
pH 12







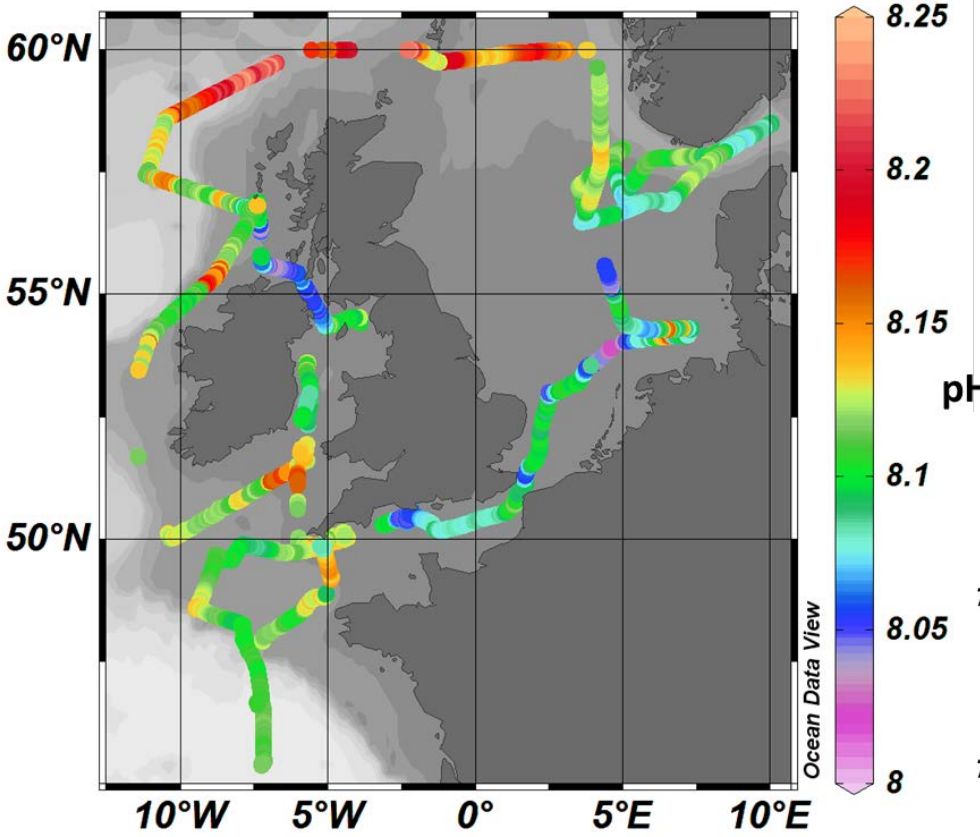
.....ON CHIP



100 mm

- Small footprint
- Low power
- Easy to build
- Low reagent consumption
- No waste emission

Cruise deployments

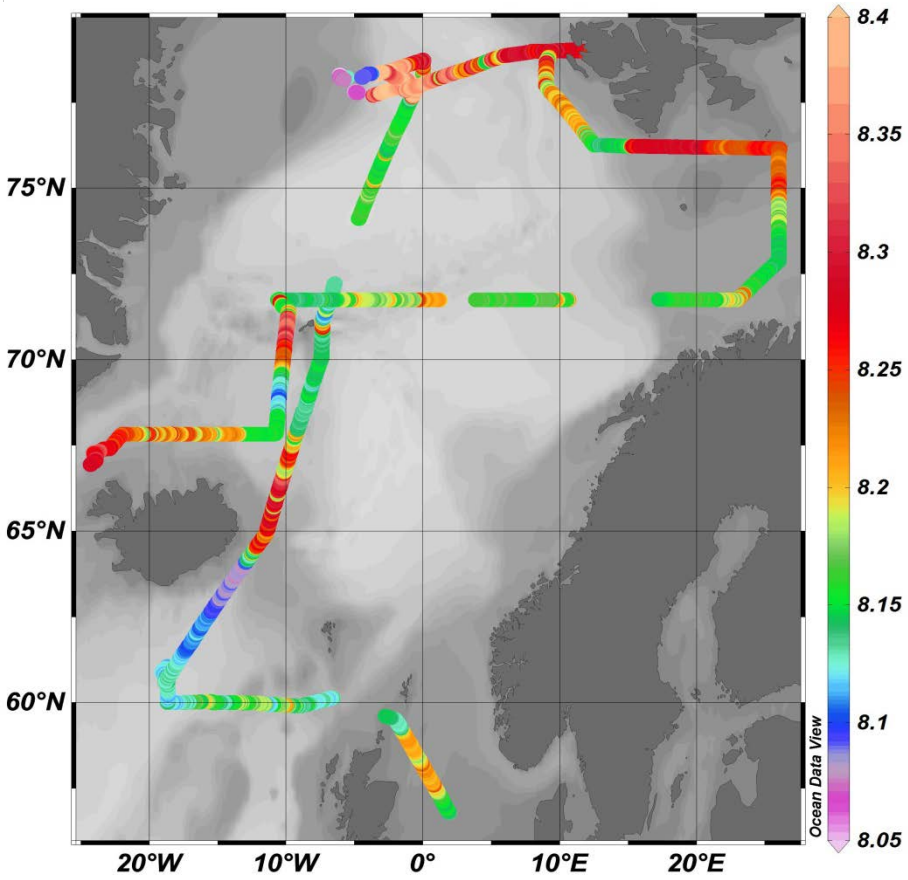


D366 June-July 2011

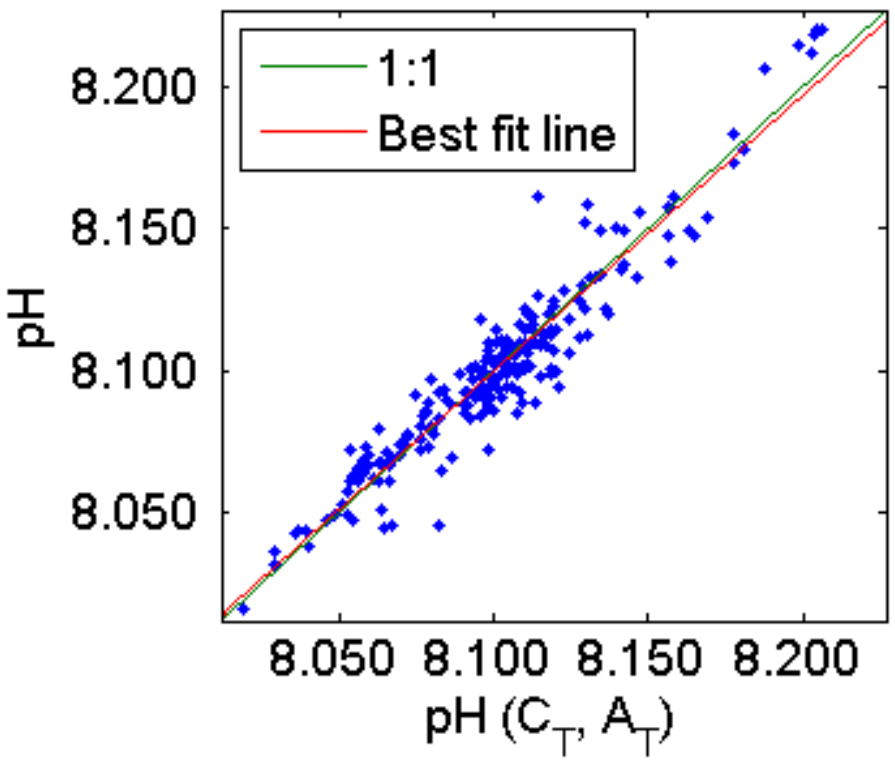
(Rerolle *et al*., 2013)

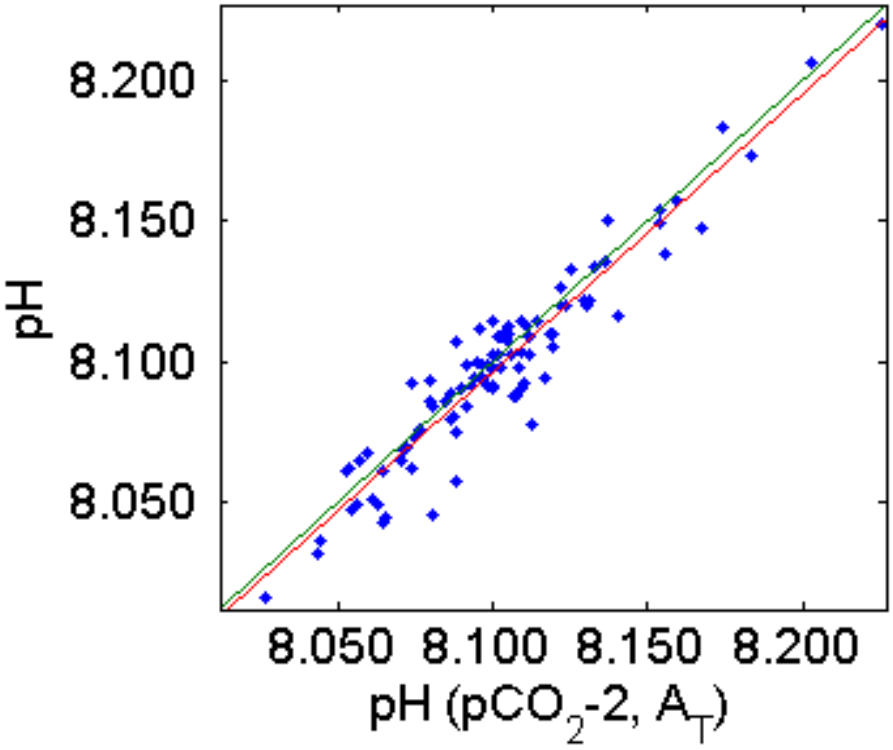
UK Ocean Acidification Research Programme

JR271 June-July 2012



D366 - CO_2 Data Inter-comparison

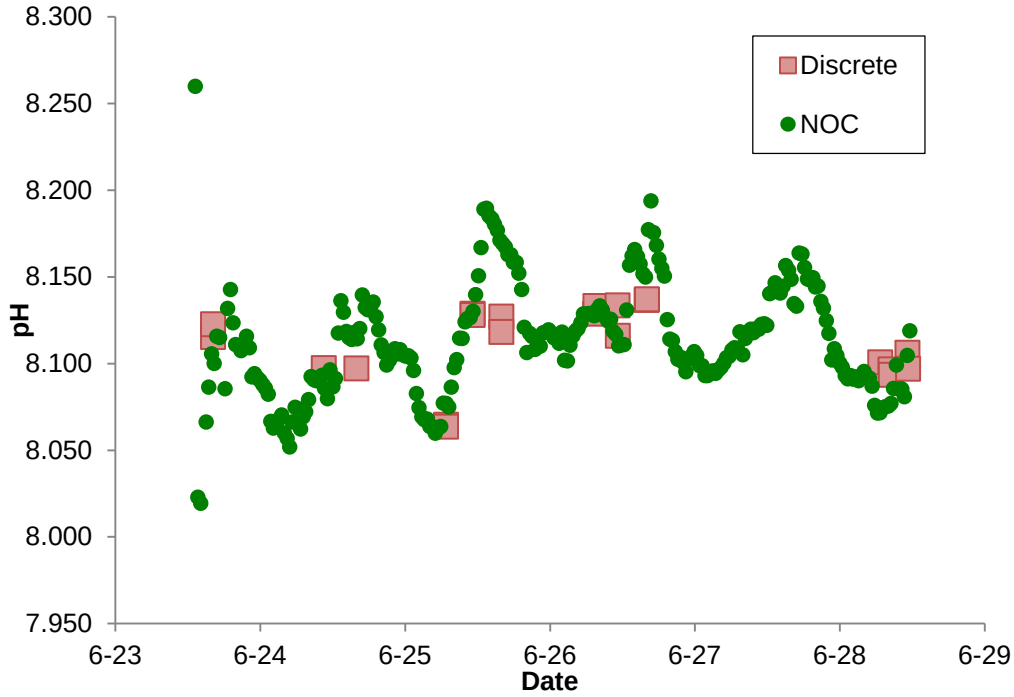




Comparison of measured pH with pH calculated from a pair of the carbonate variables DIC, TA and pCO_2 (e.g. $pH_{DICpCO2}$) showed an RMSE between 0.006 and 0.008 pH units (MR=0.001-0.004).

(Ribas Ribas et al., 2014 BGD)

pH deployment in Gullmar fjord in Sweeden (June, 2015)
5-Day deployment at 30 min sampling frequency



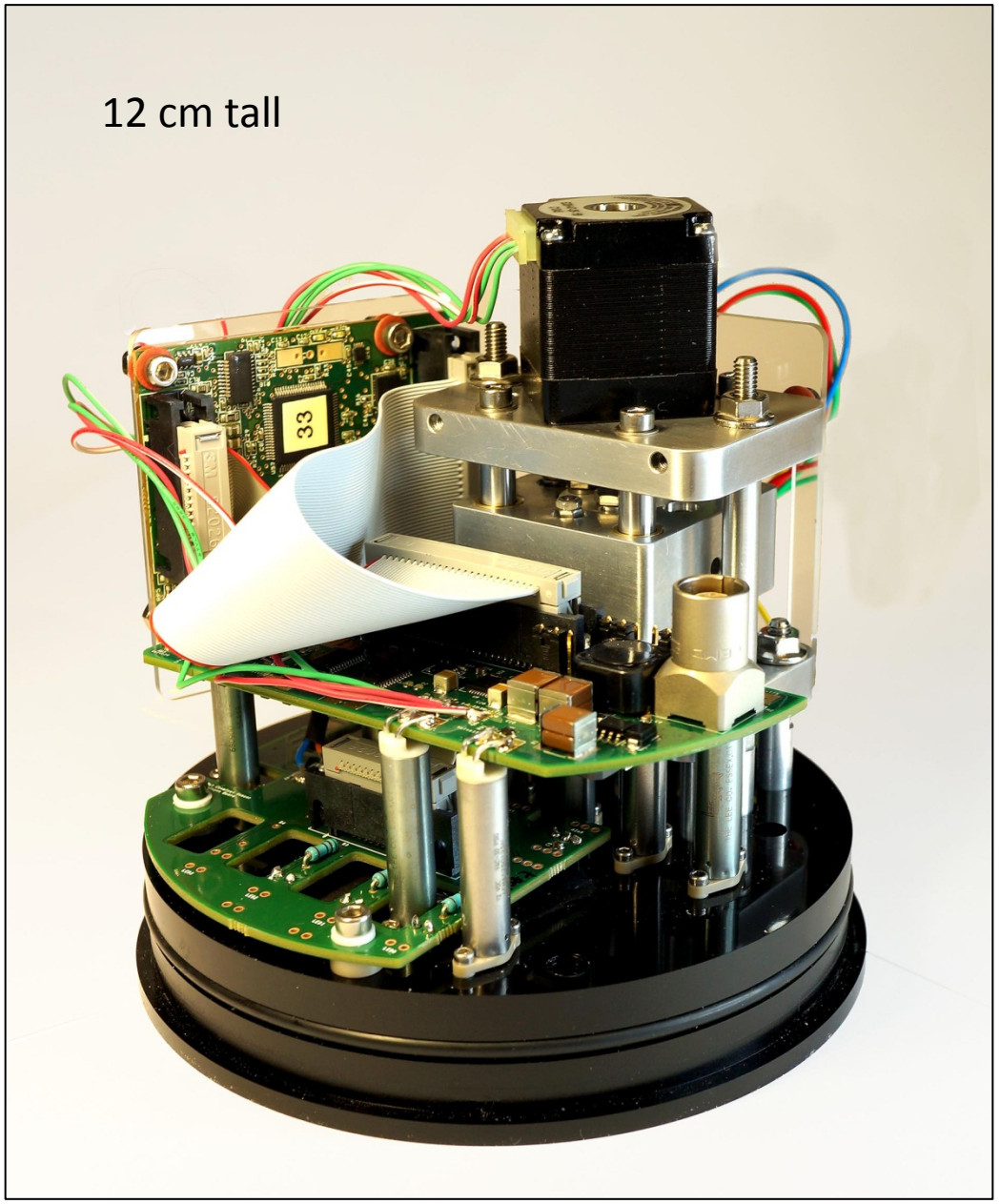
V3 nitrate sensor

Limit of detection: 0.025 µM

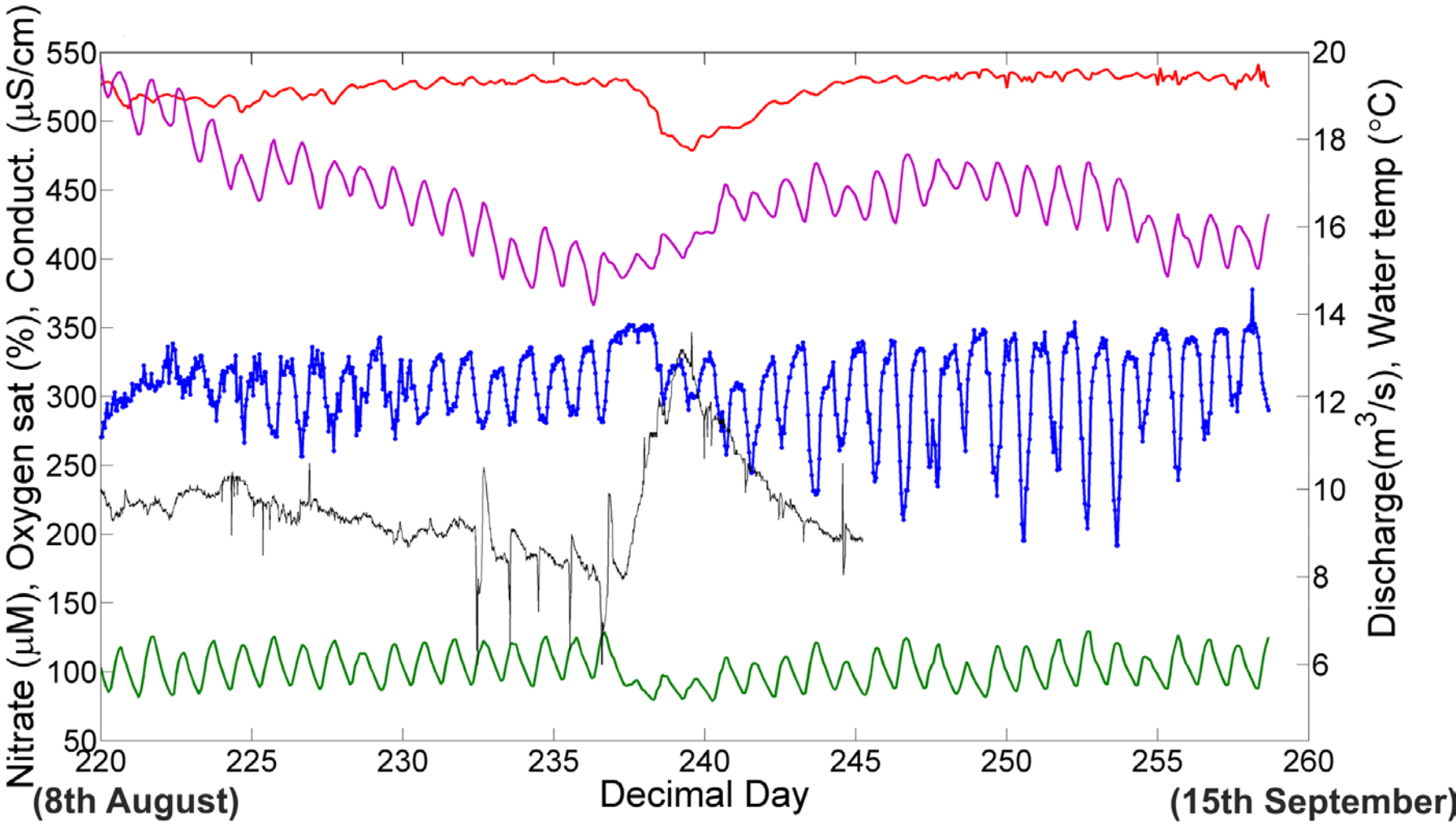
Range: up to 1000 µM

Power consumption: 1W, or
300 Joules per measurement

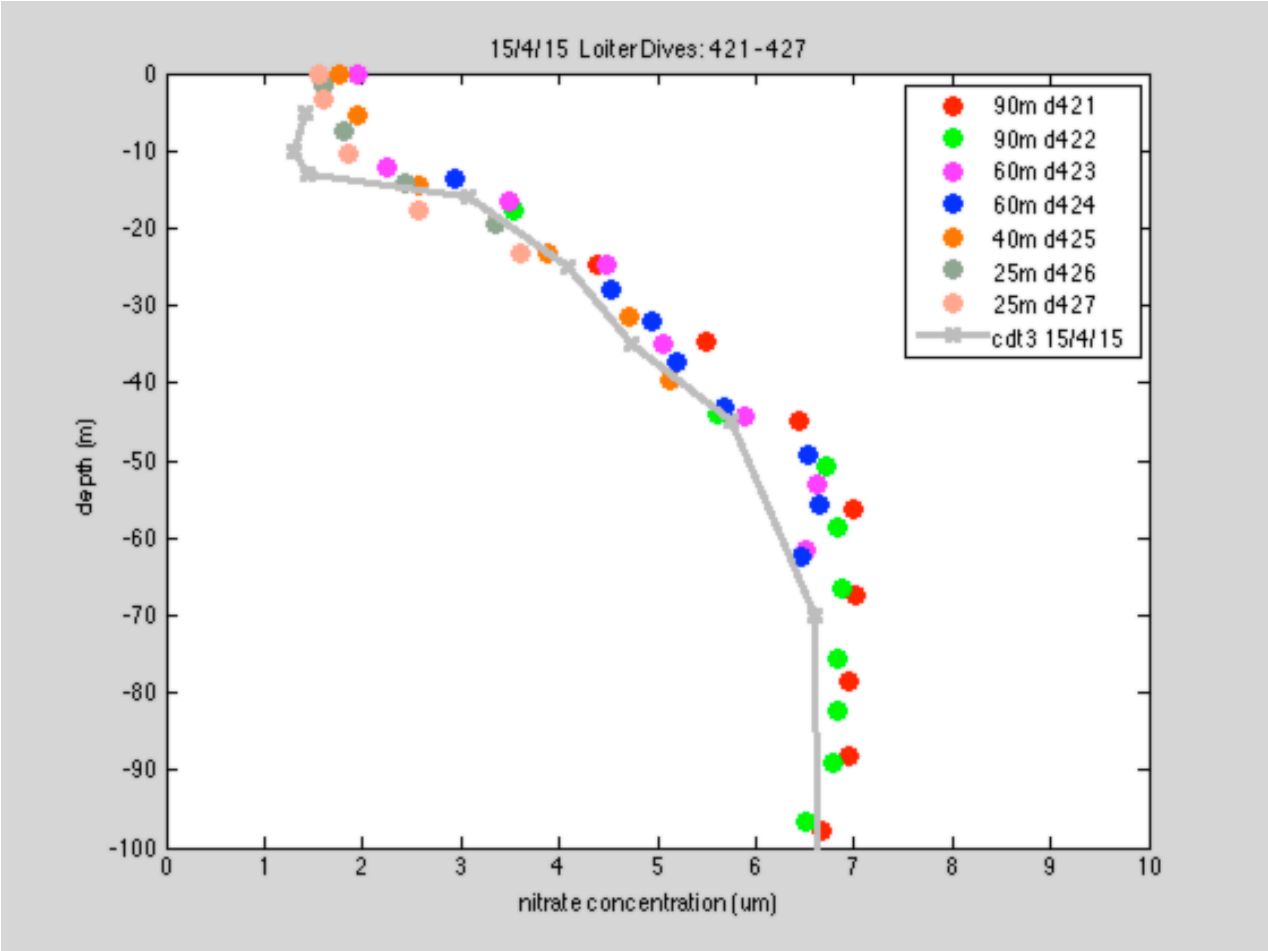
Size allows installation inside
underwater glider



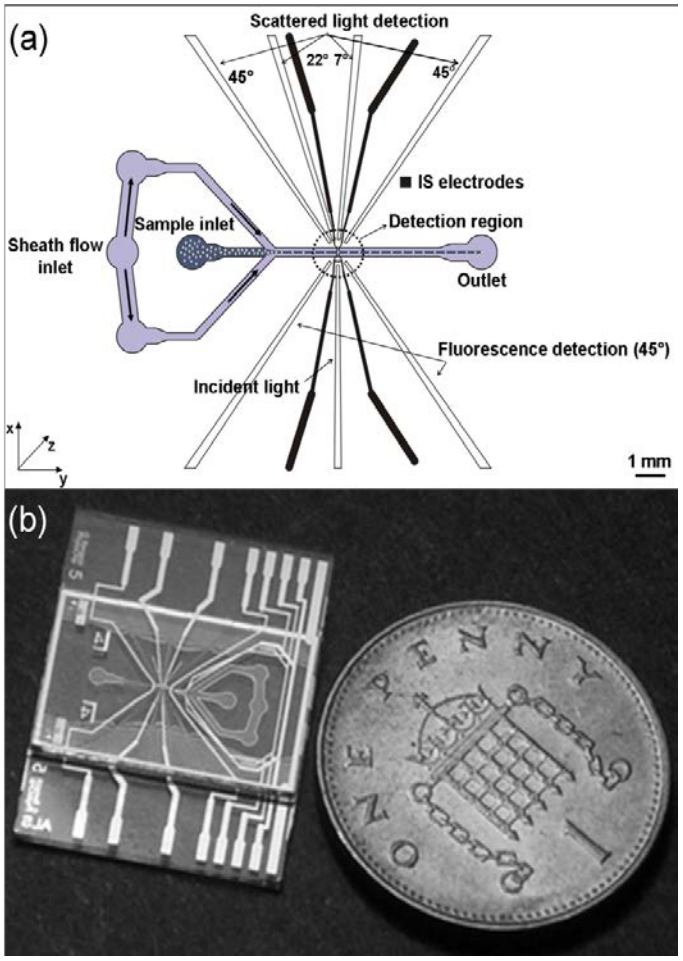
Data from nitrate sensor deployed in Hampshire Avon, UK (blue line)



Nitrate Lab on Chip on an Ocean Glider



Cytometer



- Simultaneous measurement of electrical (impedance) and optical properties of individual cells
- In-lab prototype
- No air required for optics or operation (suitable for deep sea)
- Challenges include sample concentration, and optical detection limits (power in chip)

Summary

- BGC sensors are coming of age – some at TRL 6/7
- Some (but not all) are appropriate for DBCP evaluation via a pilot project
- Size, energy consumption and cost are all falling
- Accuracy, stability and robustness still to be fully evaluated
- OceanObs'09 called for BGC rollout
- What will we say at OceanObs'19?
- Will we collect Brownie Points?