OCB summer workshop, Woods Hole, 2014

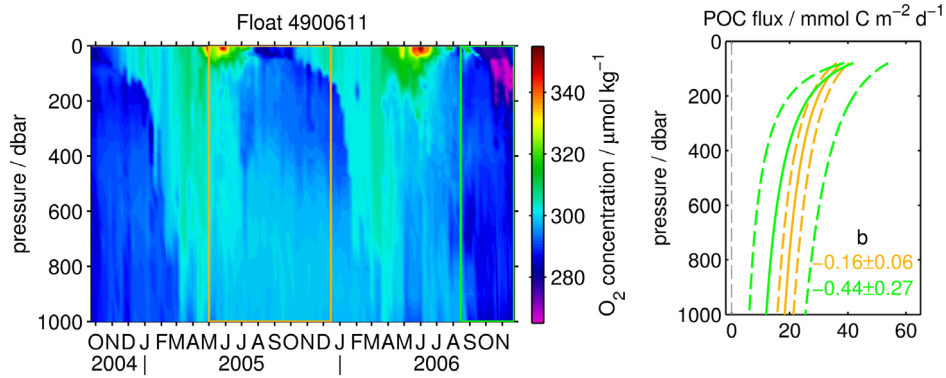
Autonomous sensors to quantify remineralization rates and the mesopelagic C flux

Henry Bittig, Björn Fiedler, Arne Körtzinger (GEOMAR)
Antoine Poteau, Catherine Schmechtig,
Hervé Claustre (OAO–LOV)
Ken Johnson (MBARI)

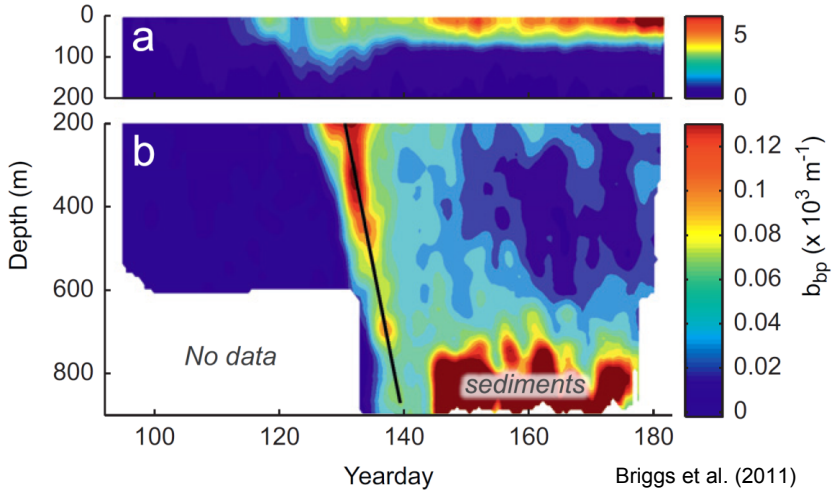
GEOMAR

Remineralization & C Flux

- **Chemical approach**

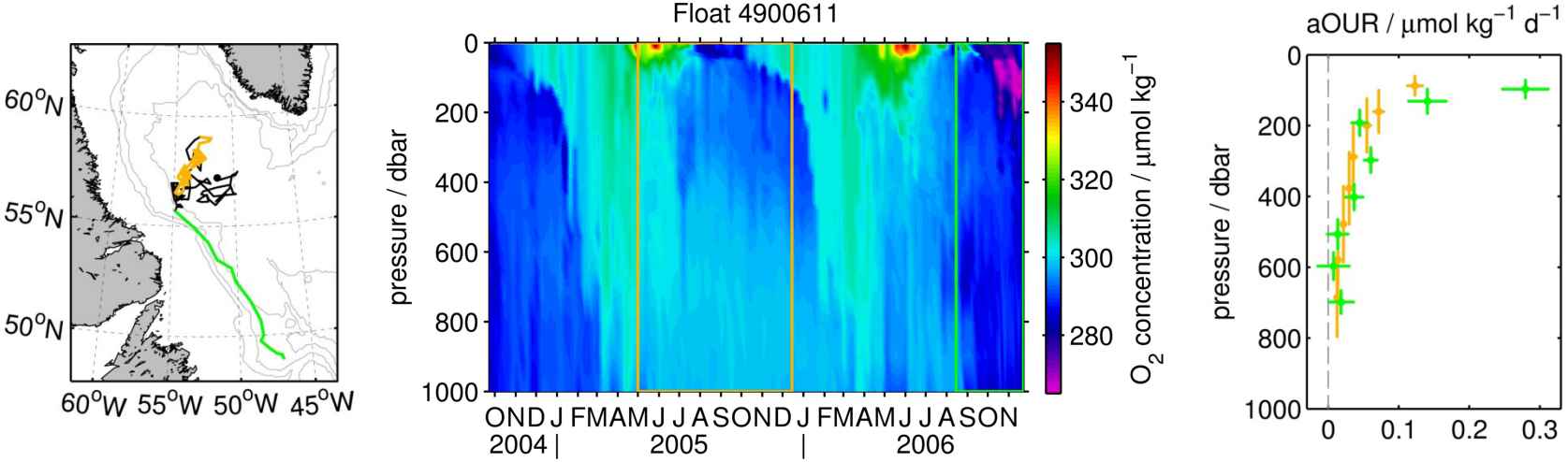


- **Optical approach**



Chemical Approach: General Concept
Showcase 1: Labrador Sea Argo-O_2

Evolution of Tracer vs. Time → Respiration Signal



- Central Labrador Sea (April – December 2005)
- Boundary current (July – November 2006)
- Deeply mixed water column after deep convection (vertically homogenized)

- AADI optode 3830 calibrated against deployment CTD-O_2 cast

after C. Kihm, PhD thesis

Chemical Approach: General Concept
Showcase 1: Labrador Sea Argo-O_2

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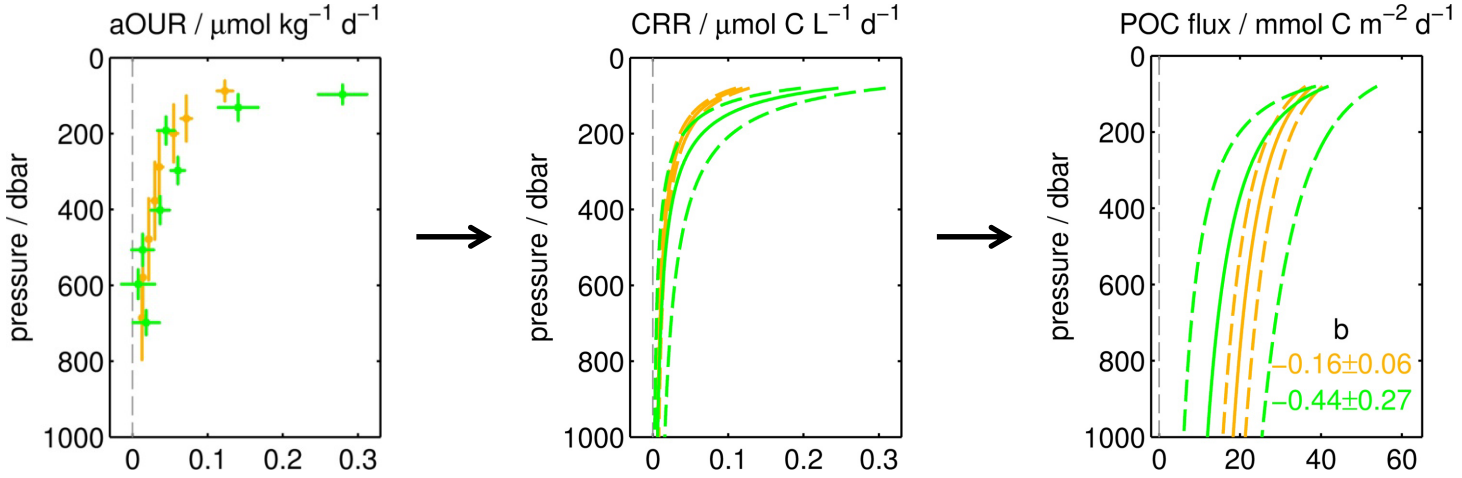
Respiration Signal → C Flux

- O_2 utilization along isopycnals
- Assumed O_2:C ratio (e.g., –1.34:1, Körtzinger et al., 2001)
- fit to (differentiated) Martin curve
- Integration of C respir. rate → C flux



- b exponent higher using OUR than other techniques (Martz et al. 2008)

after C. Kihm, PhD thesis

HELMHOLTZ ASSOCIATION

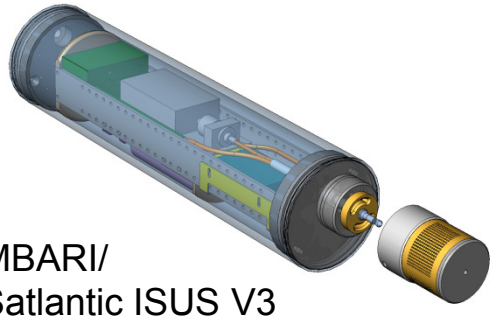
GEOMAR

Available Sensors

- Oxygen — O_2 sensors most mature, air sea gas exchange
- Nitrogen — ISUS/SUNA nitrate sensor
- Carbon — pH, pCO_2, indirectly: local A_T – S relationship

Aanderaa (AADI)
Optode 4330

Sea-Bird
Optode SBE 63



MBARI/
Satlantic ISUS V3

CONTROS
HydroC

MBARI Deep-Sea DuraFET

Satlantic SUNA V2

HELMHOLTZ ASSOCIATION

Chemical Approach: Utility

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Available Sensors

- Oxygen — O_2 sensors most mature, air sea gas exchange
- Nitrogen — ISUS/SUNA nitrate sensor
- Carbon — pH, pCO_2, indirectly: local A_T – S relationship

Caveat

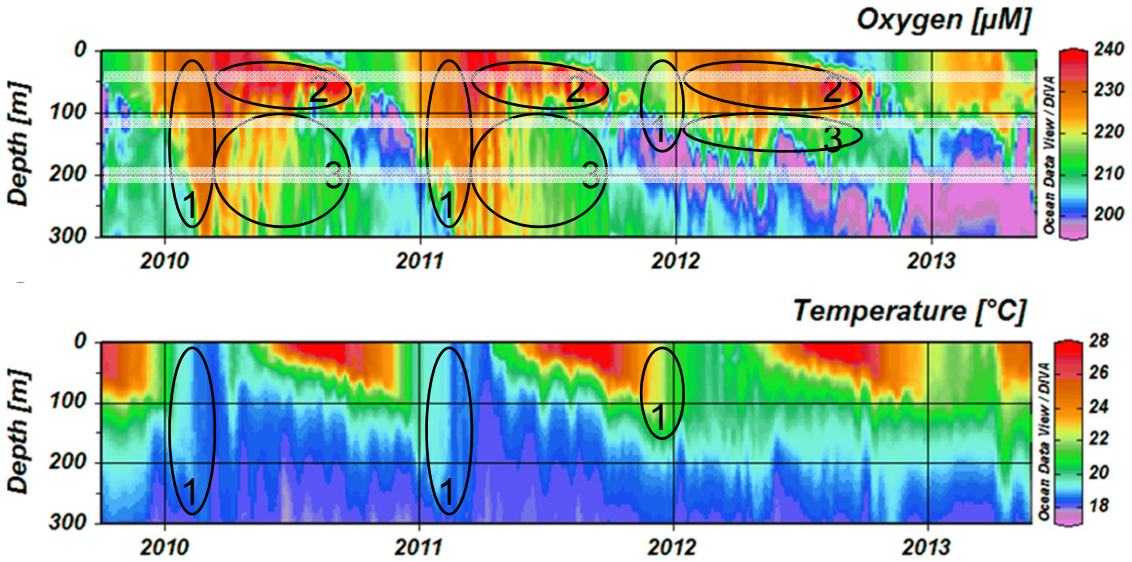
- Give only net biological signal → sum of production & respiration
- Affected by biology and ocean physics (advection, mixing, entrainment) !

Requirement: separate Ocean Physics

- Seasonal reset (deep mixing)
- „Simple“ hydrographic setting

Showcase 2a: Temporal Aspect
North Atlantic Subtropical Gyre

- Bio-Argo Floats (MBARI/UW) @ 31°40’ N / 064°10’ W (BATS)



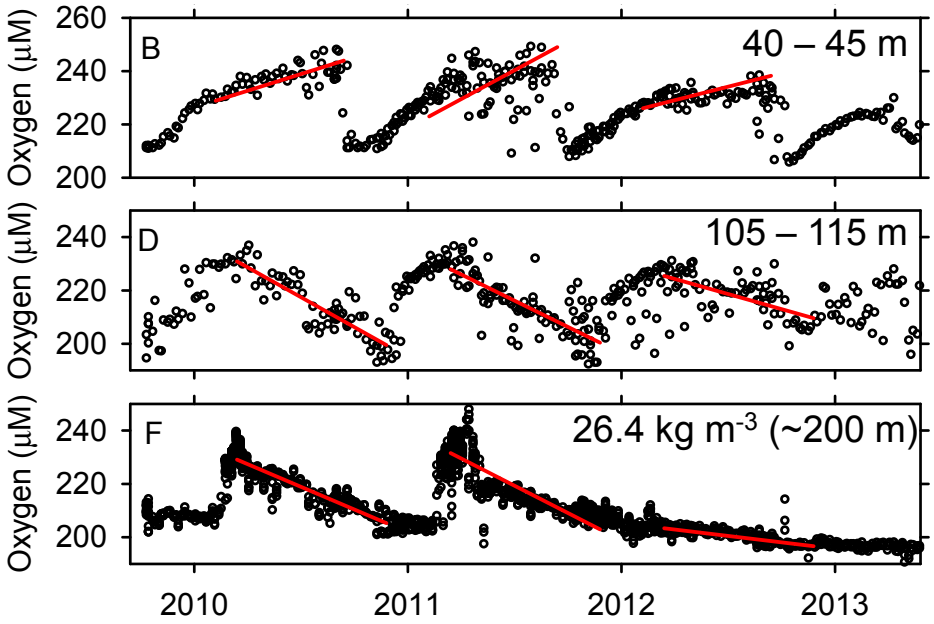
← Productive zone
← Respiration zone

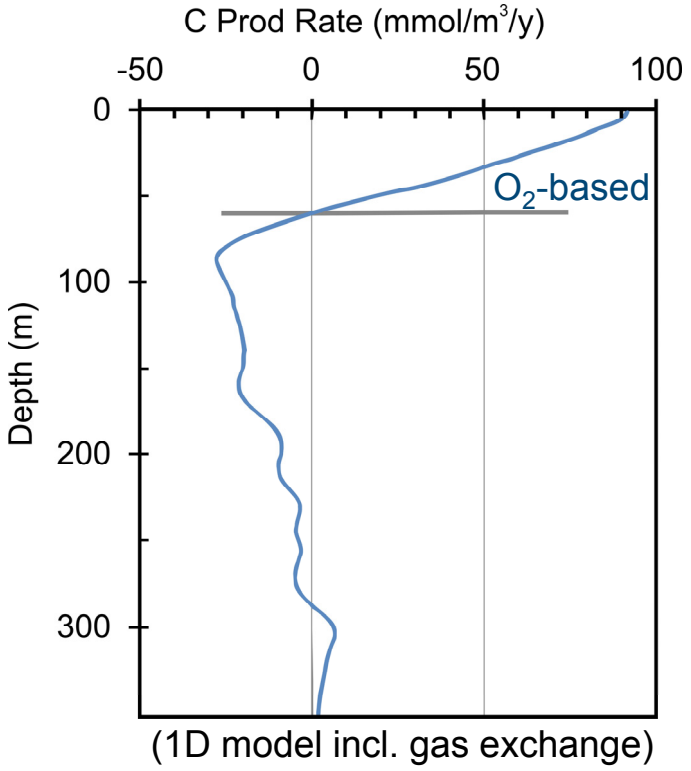
1 Convective overturn homogenizes water column
2 Seasonal net O_2 increase (SOM)
3 Seasonal net O_2 decrease

Johnson & Riser (2014), submitted.

Showcase 2a: Temporal Aspect
North Atlantic Subtropical Gyre

- Bio-Argo Floats (MBARI/UW) @ 31°40’ N / 064°10’ W (BATS)
- Quantify both production & respiration

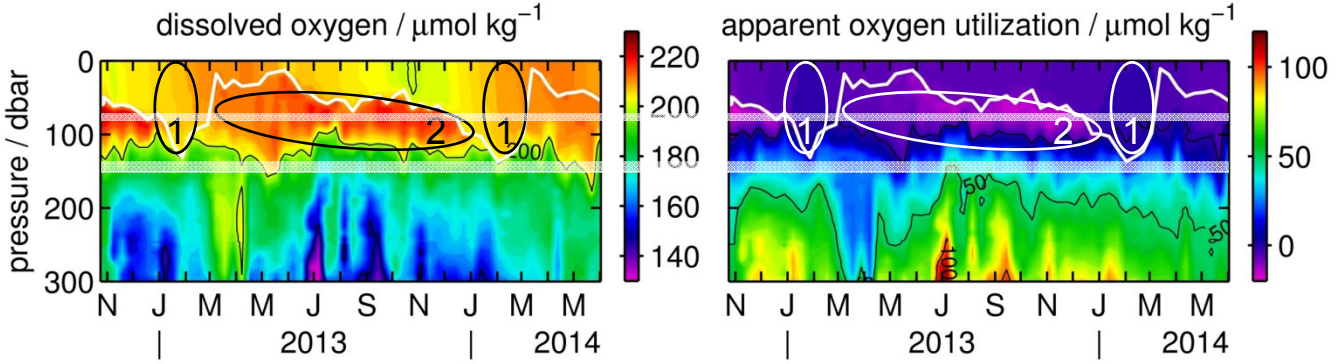




Johnson & Riser (2014), submitted.

Showcase 2b: Temporal Aspect
North Atlantic Subtropical Gyre

- Bio-Argo Floats (remOcean) @ 20° N / 040° W
- Shallower mixing, deeper nitracline/productive zone



← Productive zone
← Respiration zone

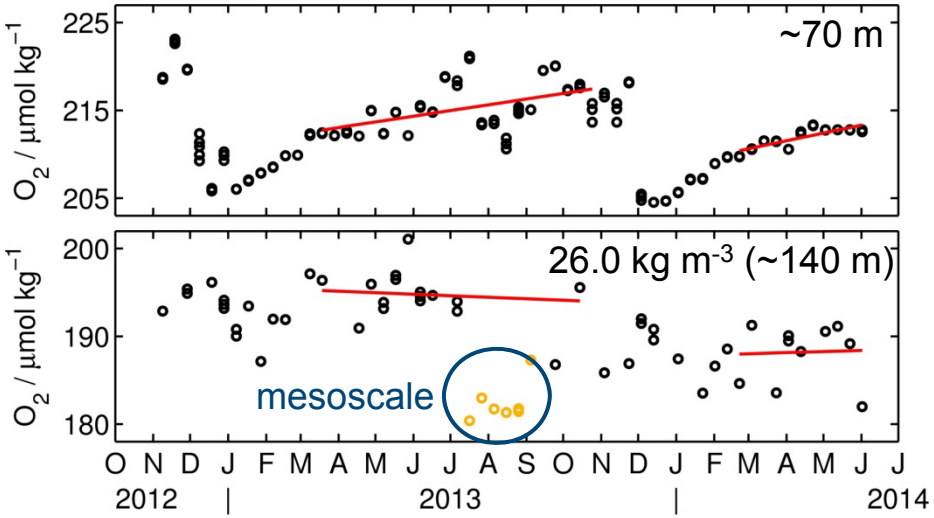
1 Convective overturn
2 Seasonal net O_2 increase (SOM)

No seasonal net O_2 decrease

"steady-state"
biological respiration
vs.
physical diffusion/mixing

Showcase 2b: Temporal Aspect
North Atlantic Subtropical Gyre

- Bio-Argo Floats (remOcean) @ 20° N / 040° W
- Shallower mixing, deeper nitracline/productive zone



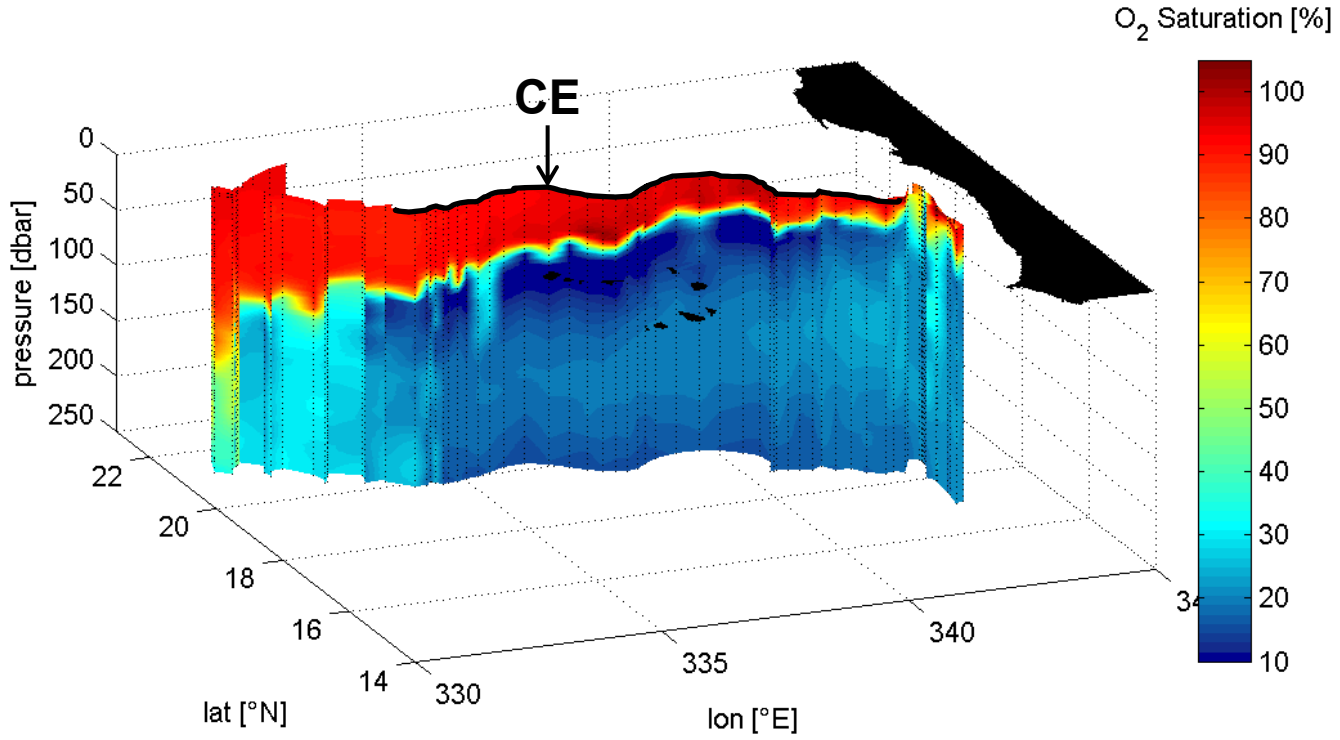
← Productive zone

← Respiration zone !

- Ocean physics superimposed to biological signal (continuously mixed)

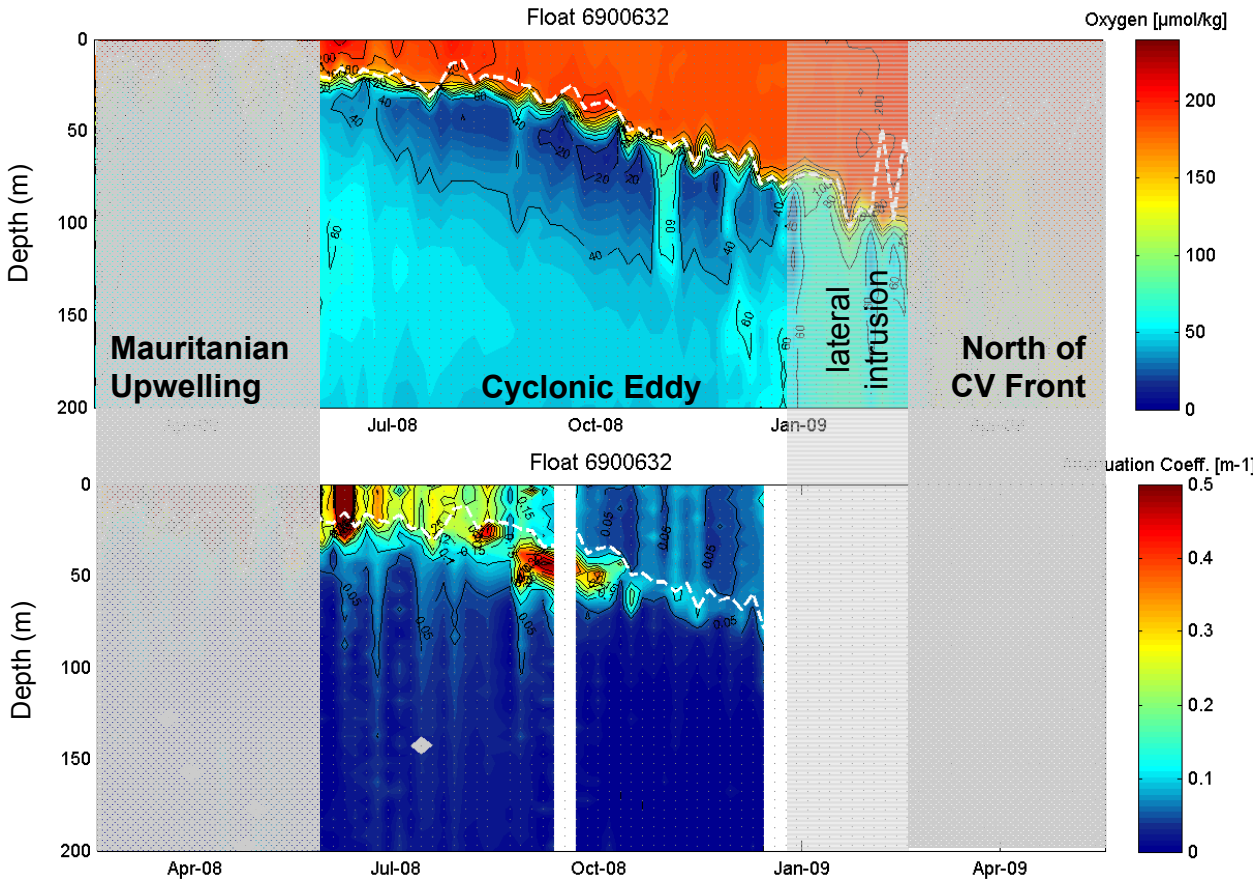
Showcase 3: Spatial Aspect
Cyclonic Eddy (CE) off Mauritania

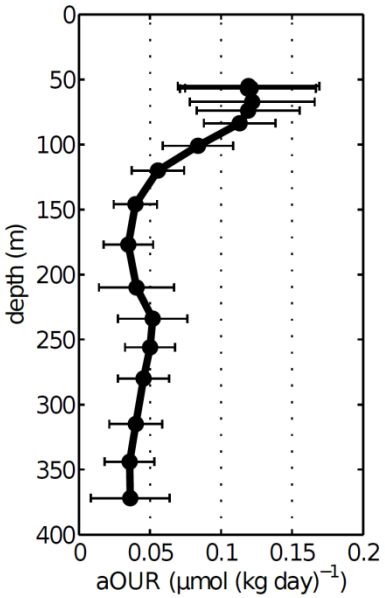
- Bio-Argo float (WMO ID 6900632; O_2, c_p) trapped inside Cyclonic Eddy
- Isolated water body → simplified ocean physics



Fiedler, unpublished.

Showcase 3: Spatial Aspect
Cyclonic Eddy (CE) off Mauritania



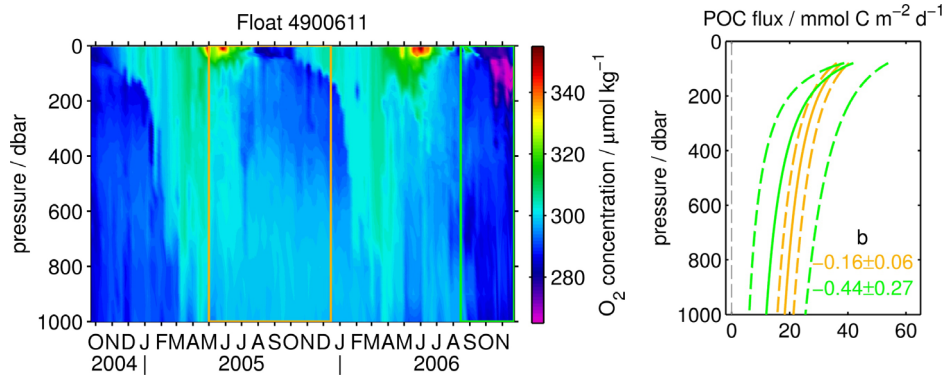


Export production:
20 mmol C m^{-2} d^{-1}

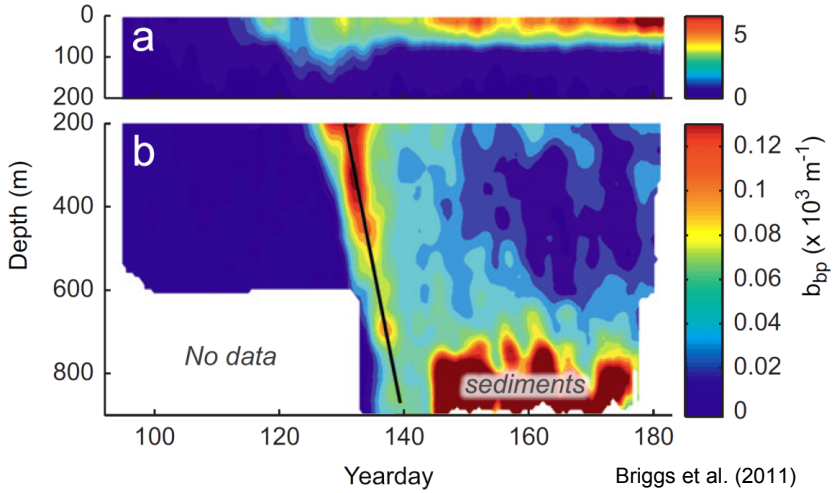
Karstensen et al., in prep.

Remineralization & C Flux

- **Chemical approach**



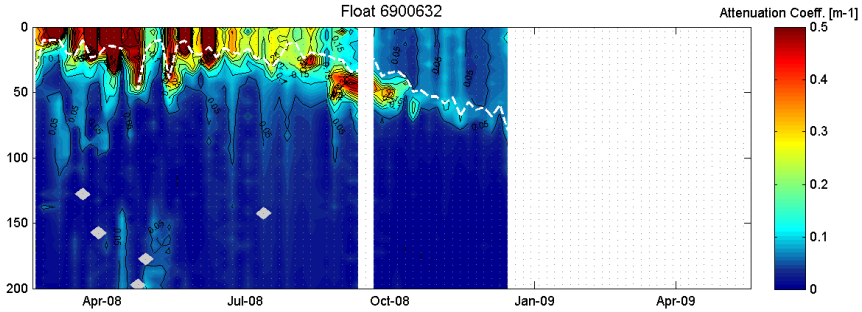
- **Optical approach**



Optical Approach

General Concept

- Establish proxy for POC
  → Follow C directly



Available Sensors

- Beam attenuation $c_p(650)$
- Particle backscatter $b_{bp}(700)$

Requirements

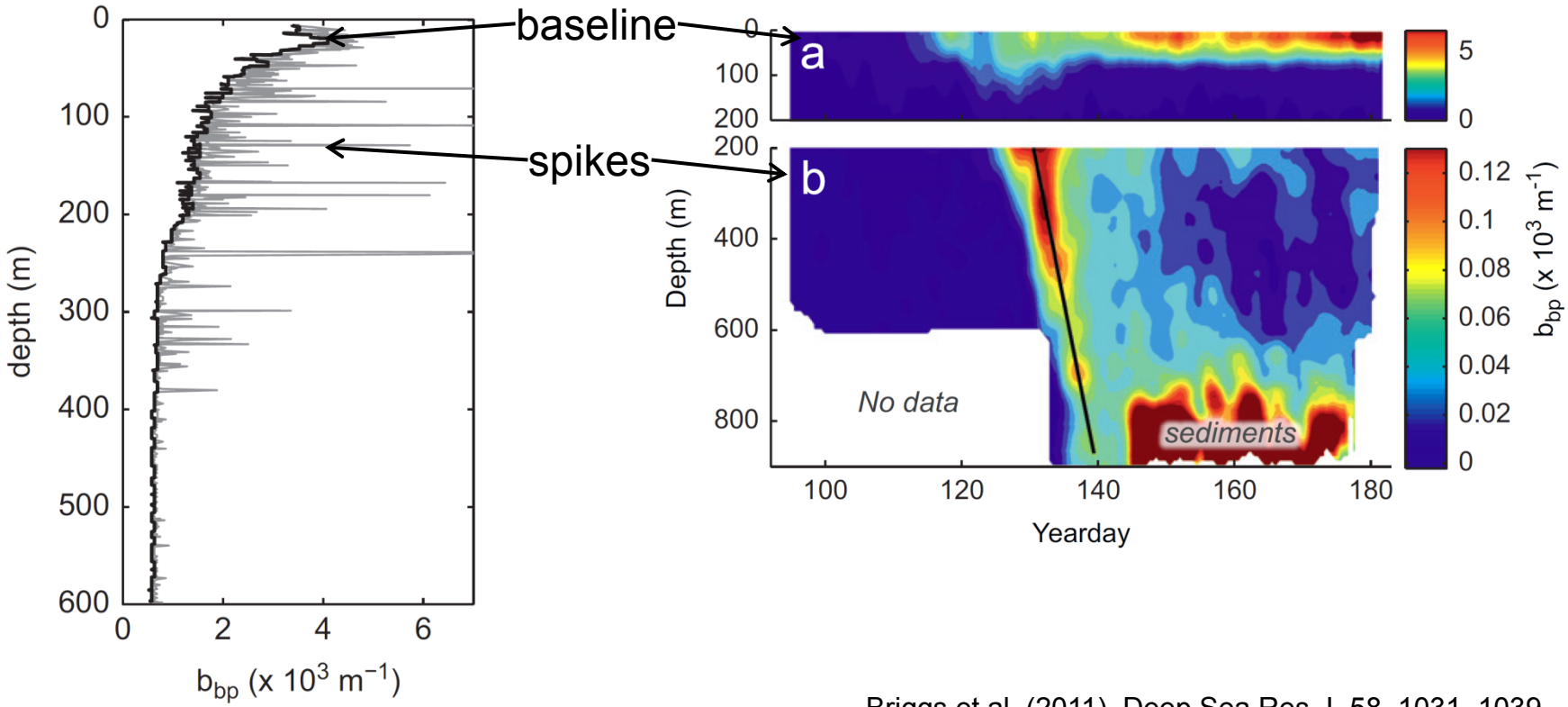
- No seasonal system required
- *Sensitivity*

WET Labs
C-Rover

WET Labs
ECO triplet

Showcase 1: Profile Focus
Trace POC Export (NAB08 experiment)

- Separate profile data into baseline & spikes (Briggs et al., 2011)
- “Direct” POC observation



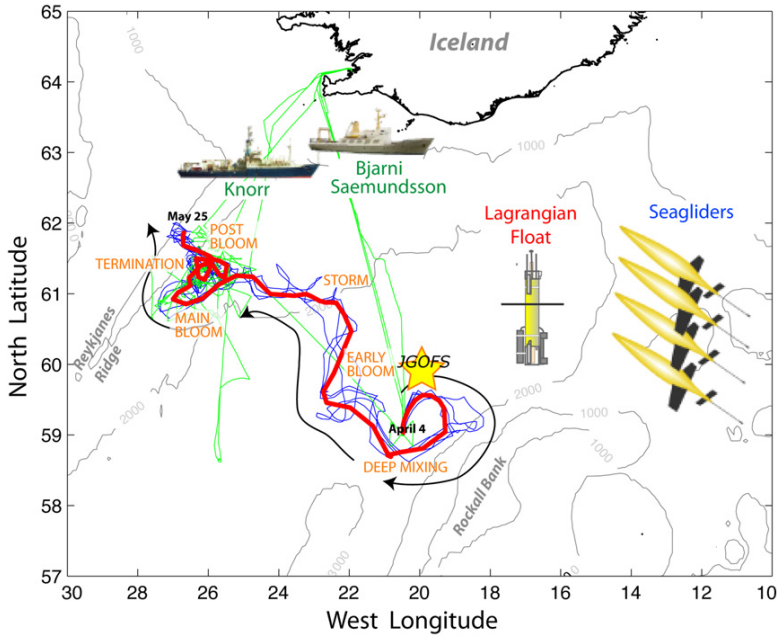
Briggs et al. (2011), Deep Sea Res. I, 58, 1031–1039.

Showcase 2: Mixed Layer Focus
Use Budget Imbalance (NAB08 experiment)

- Use mixed layer C inventory changes (Alkire et al., 2012):
  - TOC (POC & DOC) ~ POC proxy
  - Production ~ O_2 budget / O_2-NCP

- Difference between production and POC accumulation (in mixed layer) = Export (out of mixed layer)

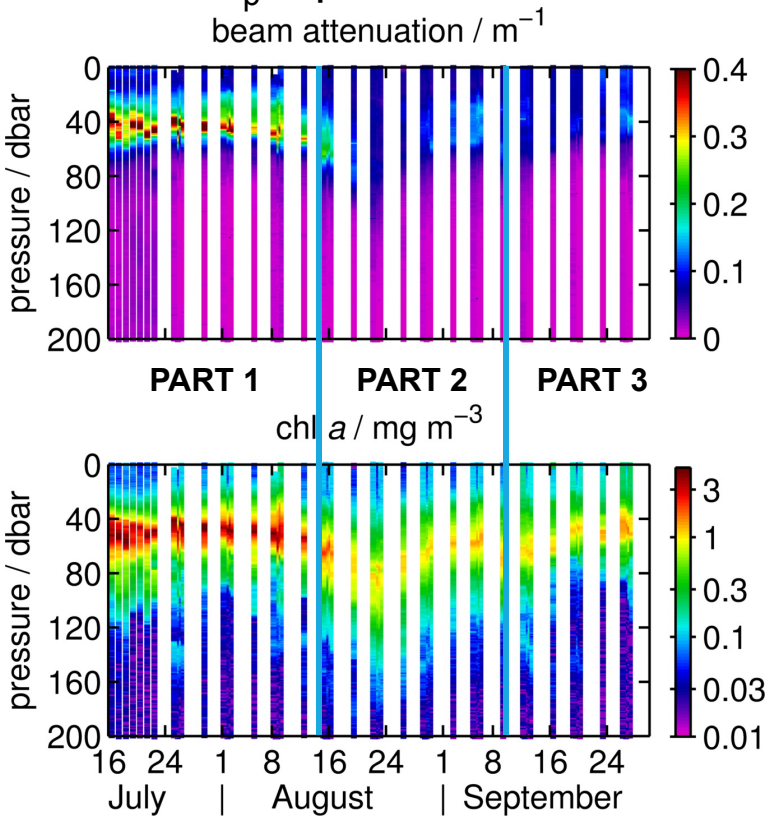
$$F_{sink} = F_{NCP} - dPOC/dt - dDOC/dt$$
$$O_2 \qquad b_{bp} \qquad ./.$$

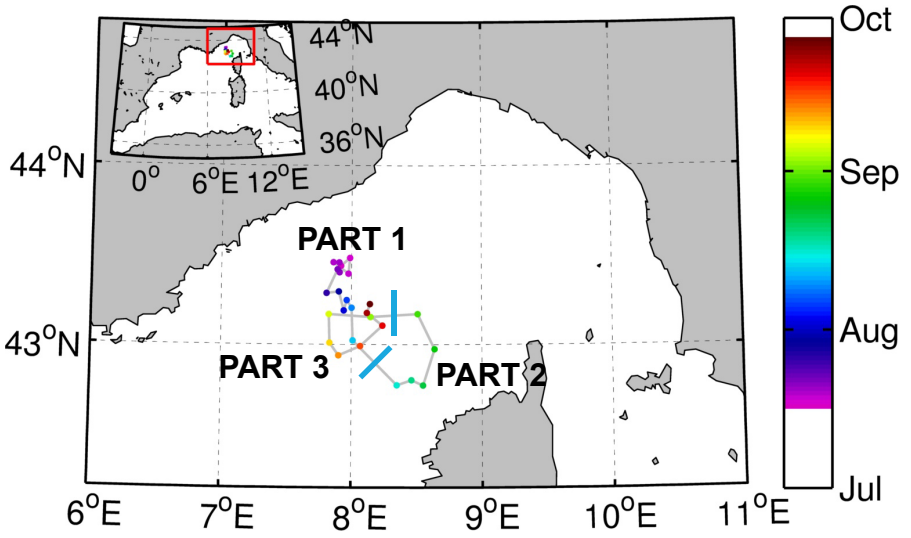


Alkire et al. (2012), Deep Sea Res. I, 64, 157–174.

Showcase 3: Float Drift Focus
Sediment Accumulation during Drift

- Med Sea deep bloom → oligotrophic system
- Particles settle on transmissiometer: „in-situ sediment trap“
- Drift in c_p ~ particle flux





Claustre et al., in prep.

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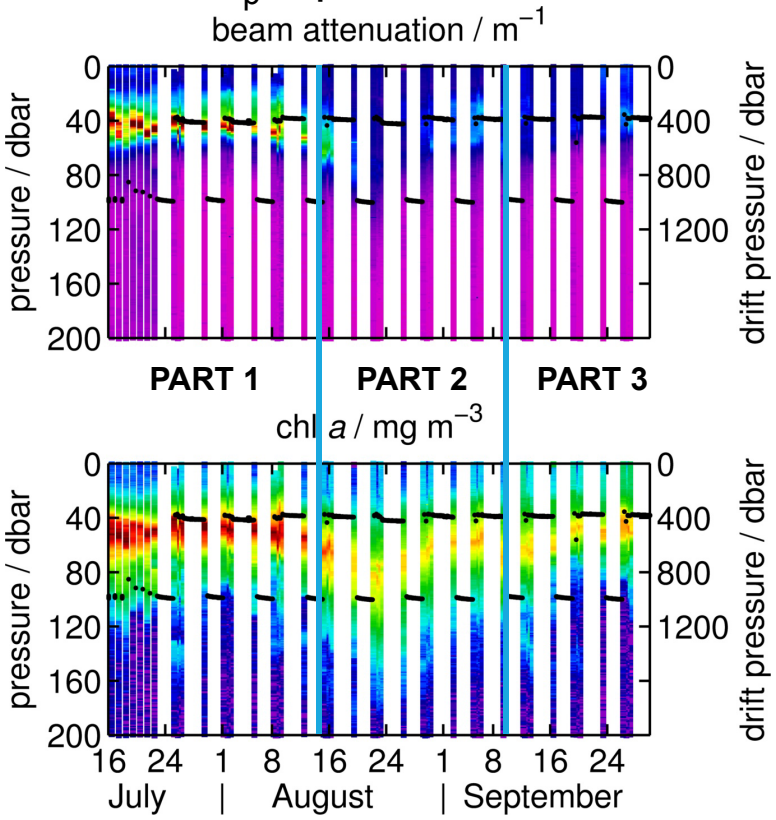

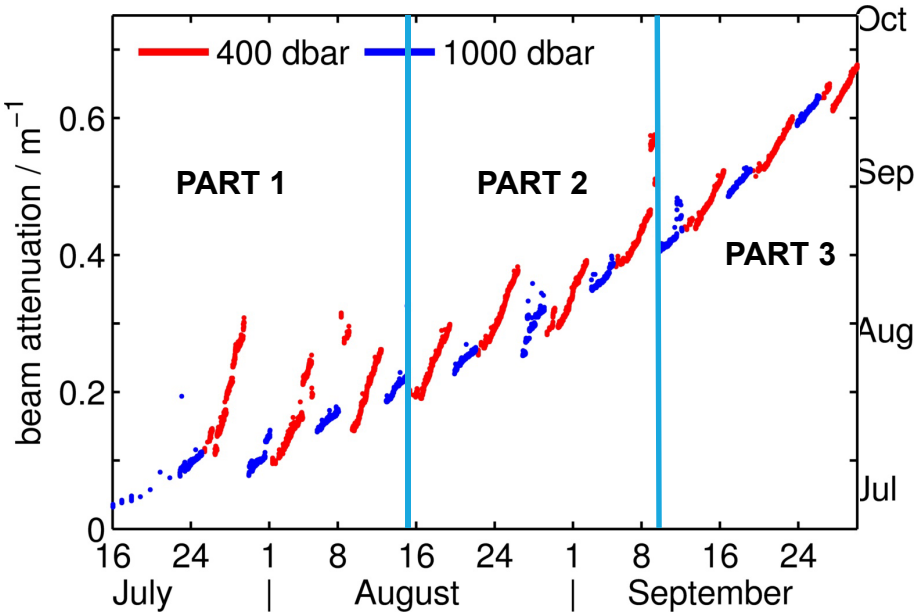

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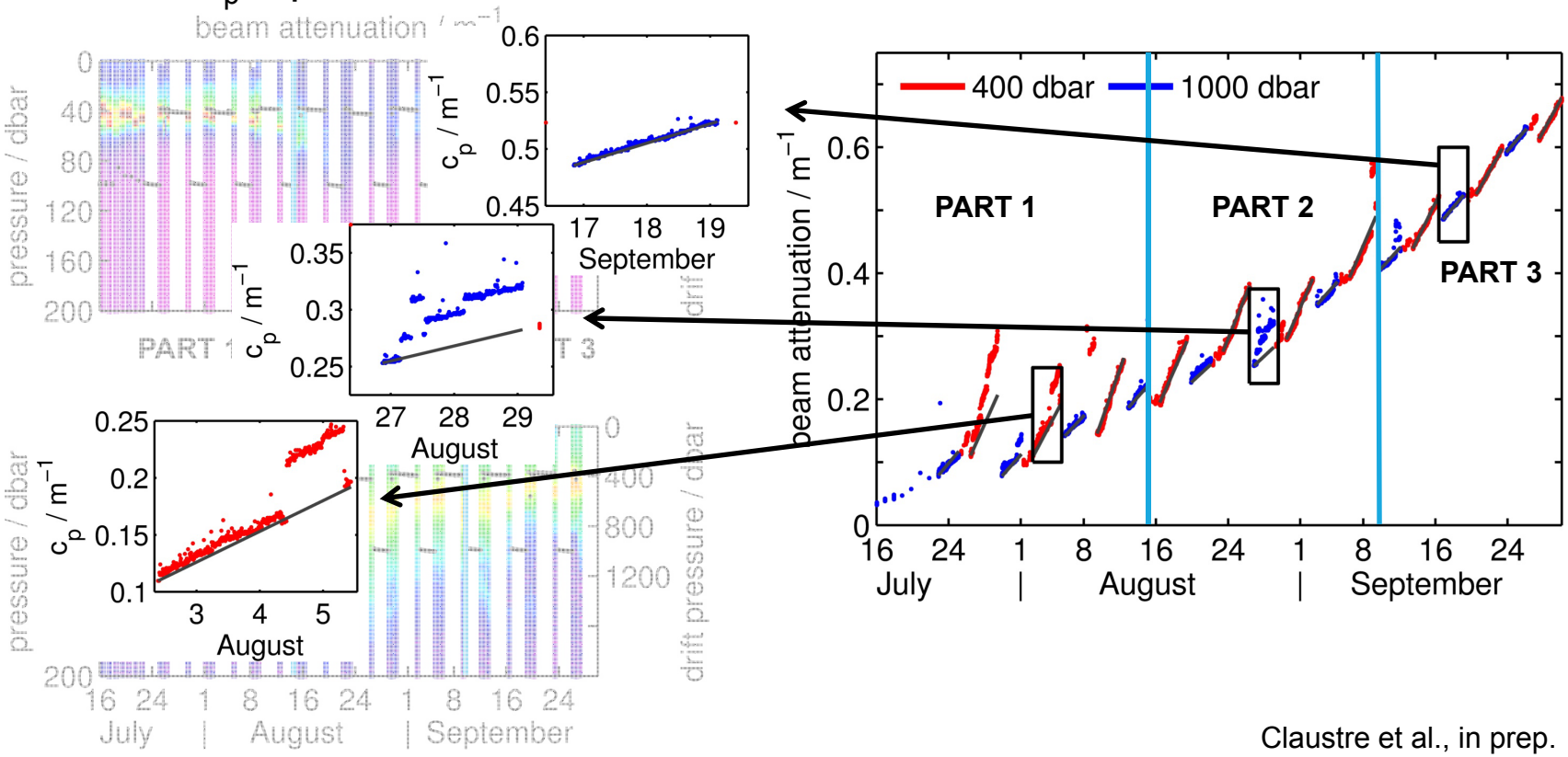

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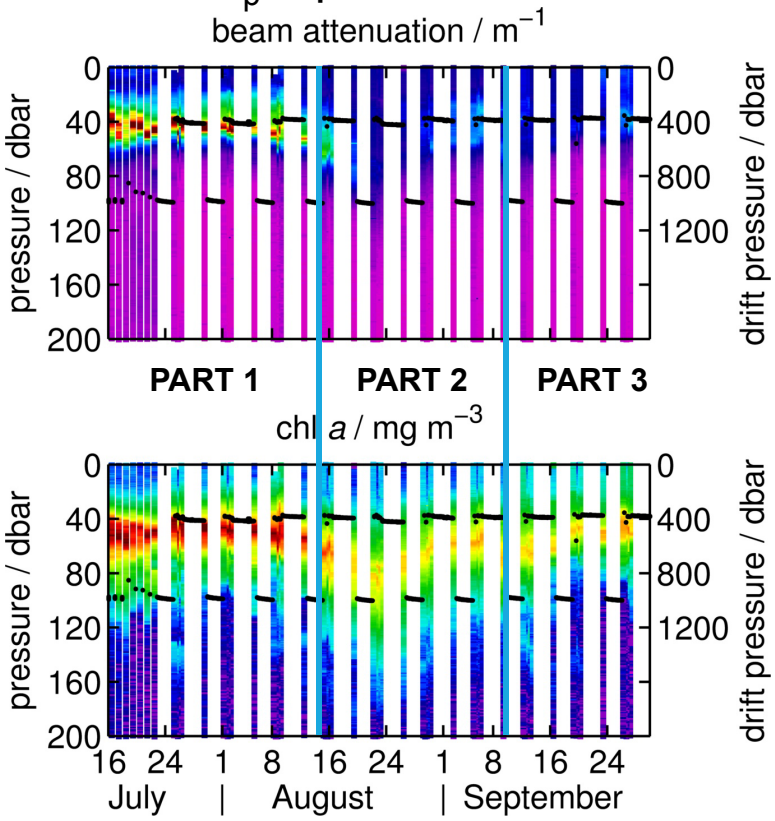
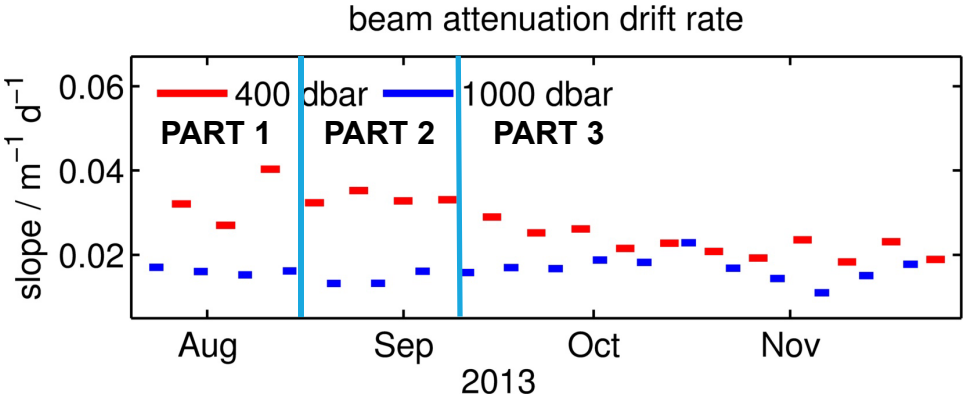
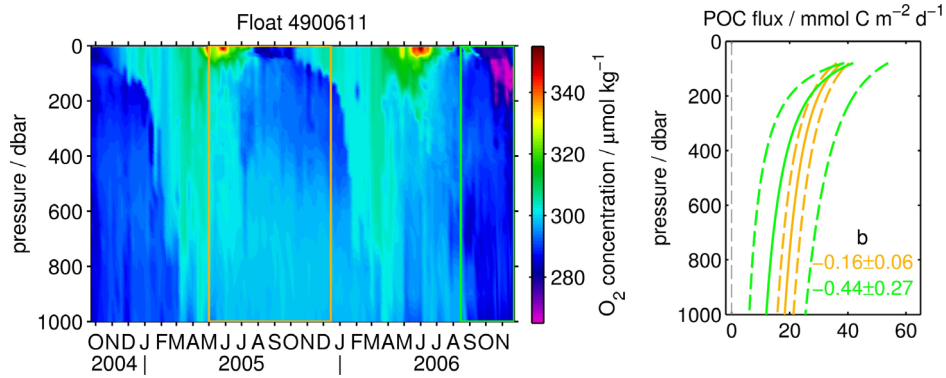




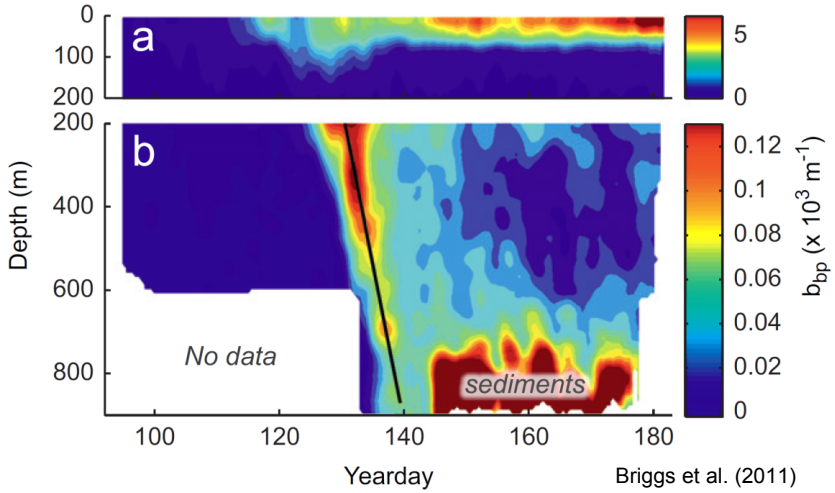
Claustre et al., in prep.

Trends

- **Chemical approach**

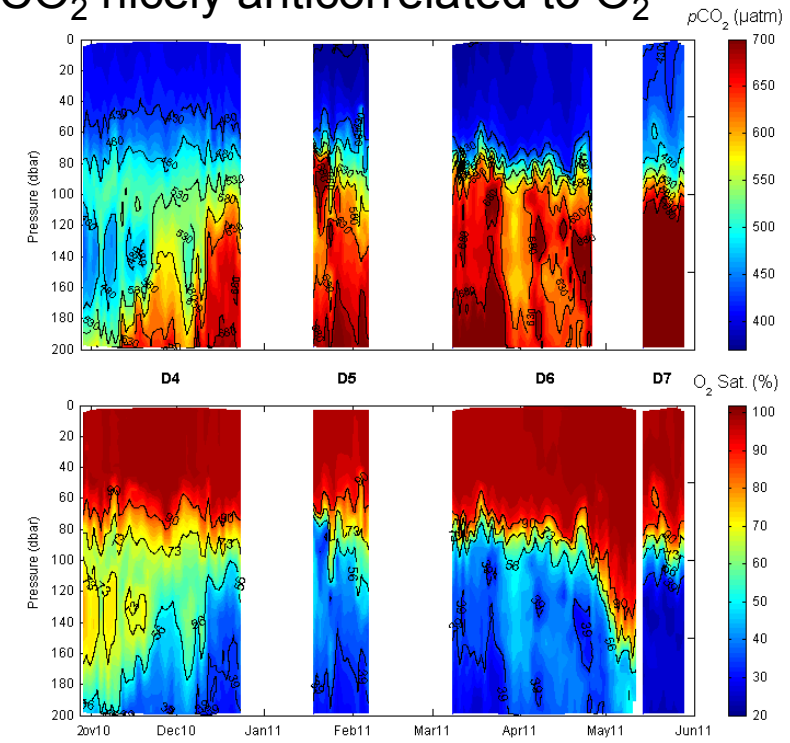


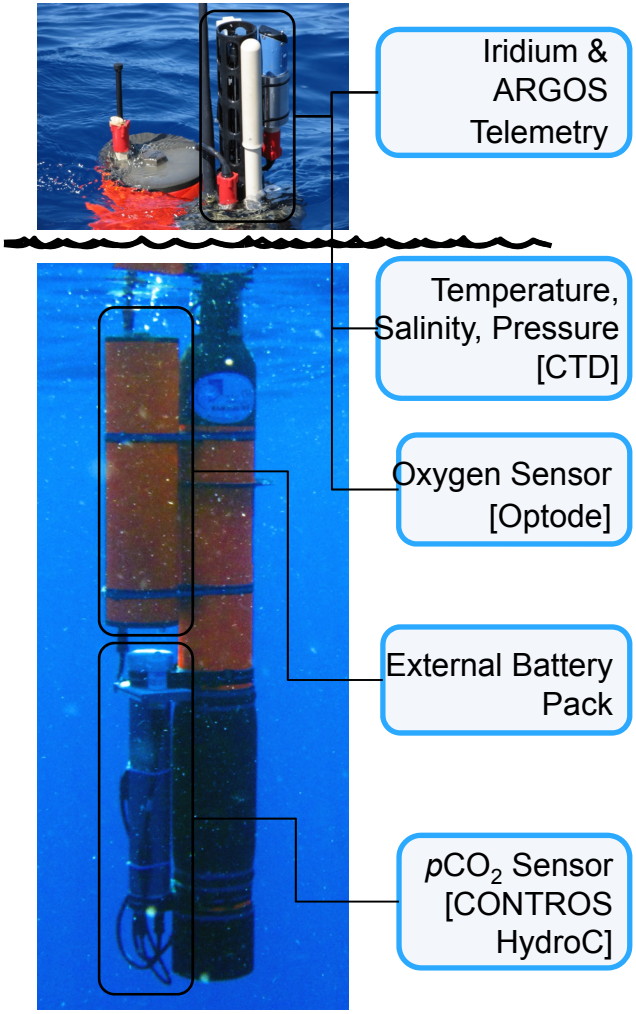
- **Optical approach**



Trends: Extended Chemical Capabilities: Inorganic C Float

- CO_2-system sensors (pCO_2, pH)
- Potential to reduce uncertainty in stoichiometric ratios (→ C-overconsumption)
- pCO_2 nicely anticorrelated to O_2

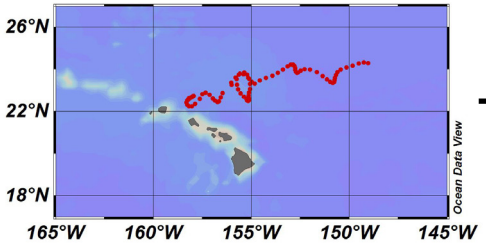


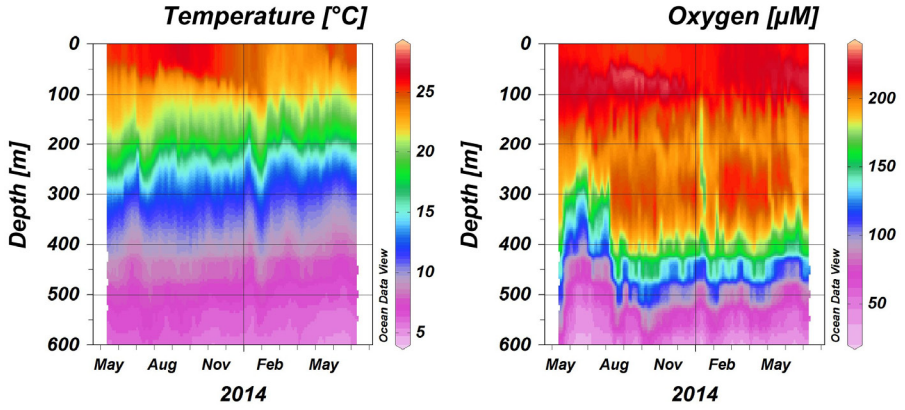


Fiedler et al. (2013), J. Atmos. Oceanic Technol., 30, 112–126.

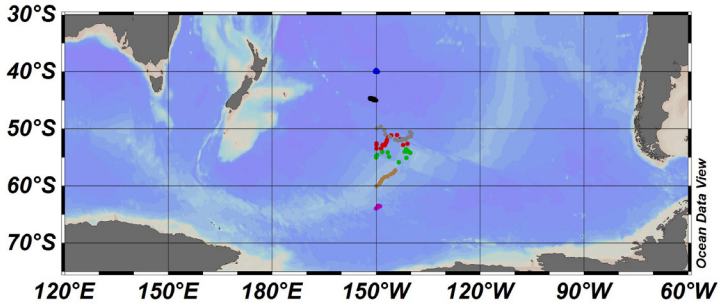
Trends: Extended Chemical Capabilities: C:N:O Float

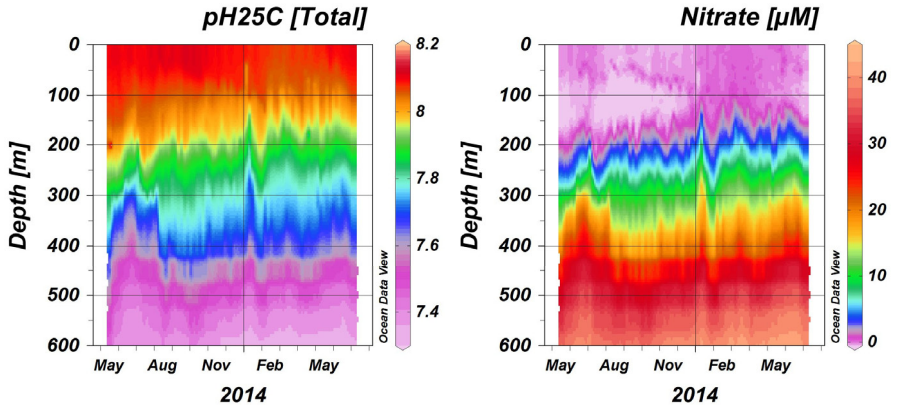
- Technological potential for C:N:O Float: simultaneous C, N, and O measurements
- e.g., MBARI @ HOT:





- pre-SOCCOM:

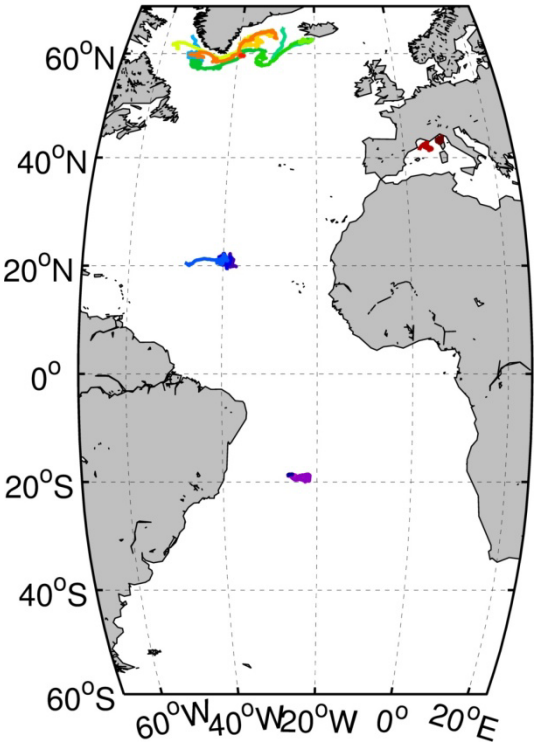


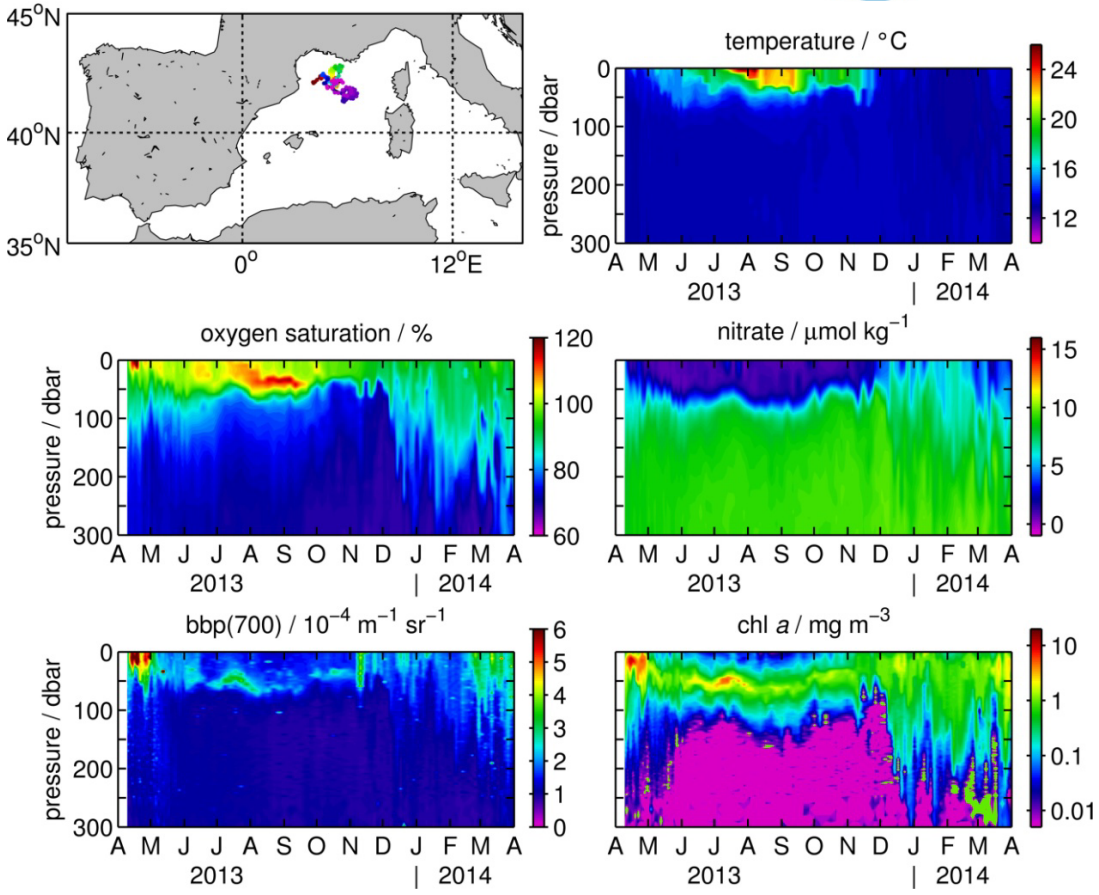


Johnson et al., http://www.mbari.org/chemsensor/floatviz.htm

Trends: Chemical & Optical Approaches combined

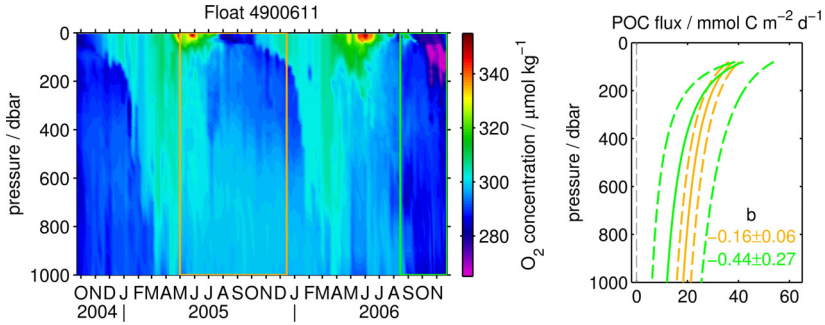
- e.g., lovbio floats (capable to carry heavy load of sensors)
- Multitude of information from autonomous platforms



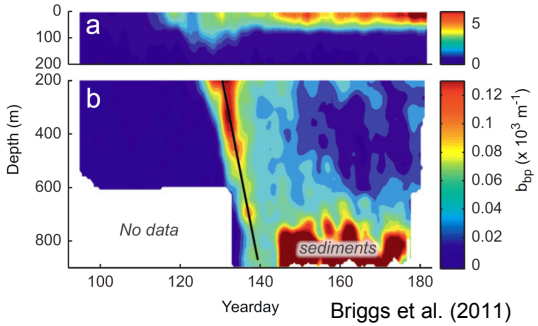


Summary

- Chemistry:
  - sum of production & respiration
  - if physics can be separated
  - feasible with deep winter mixing / otherwise simplified system (CE)



- Optics:
  - complementary approach
  - requires in-situ data for calibration



Briggs et al. (2011)

- advent of new / more mature technology to extend capabilities
- possibly smart way to separate physics in complex systems (modeling complement)