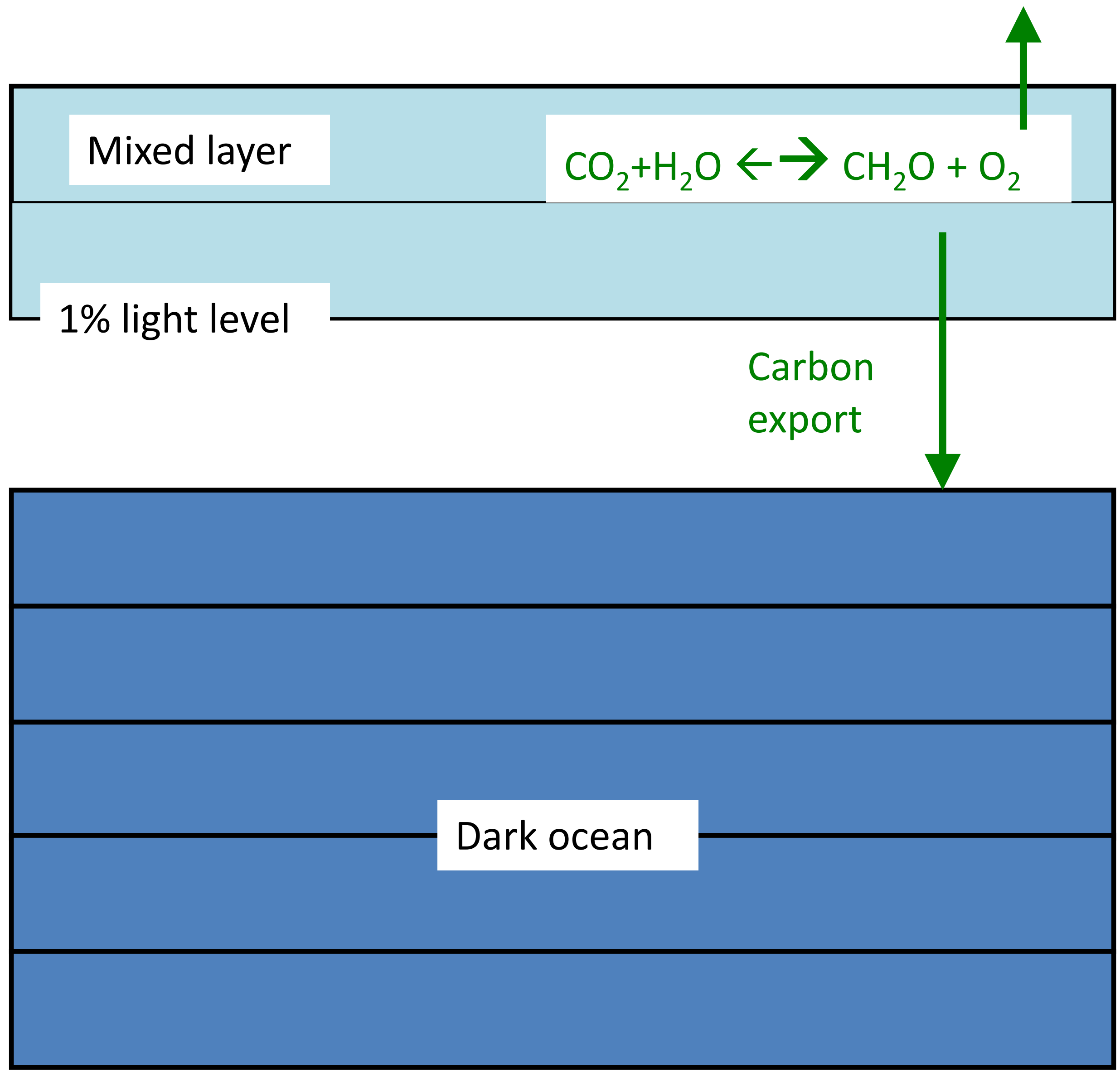
Keck meeting

Caveat!!!

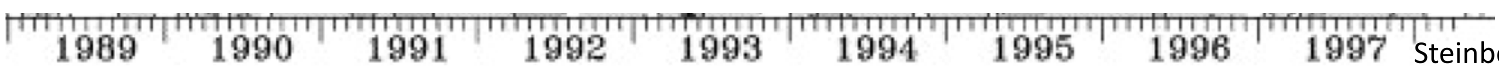
Background: biological and chemical cycles in the world's oceans



Significant puzzles about ocean carbon fluxes

North Atlantic subtropical gyre at Bermuda: what enables DIC drawdown in the upper 50 m?

Annual cycle of dissolved inorganic carbon (mmol m^{-3}) at Bermuda; upper 250 m



Steinberg et al., 2004

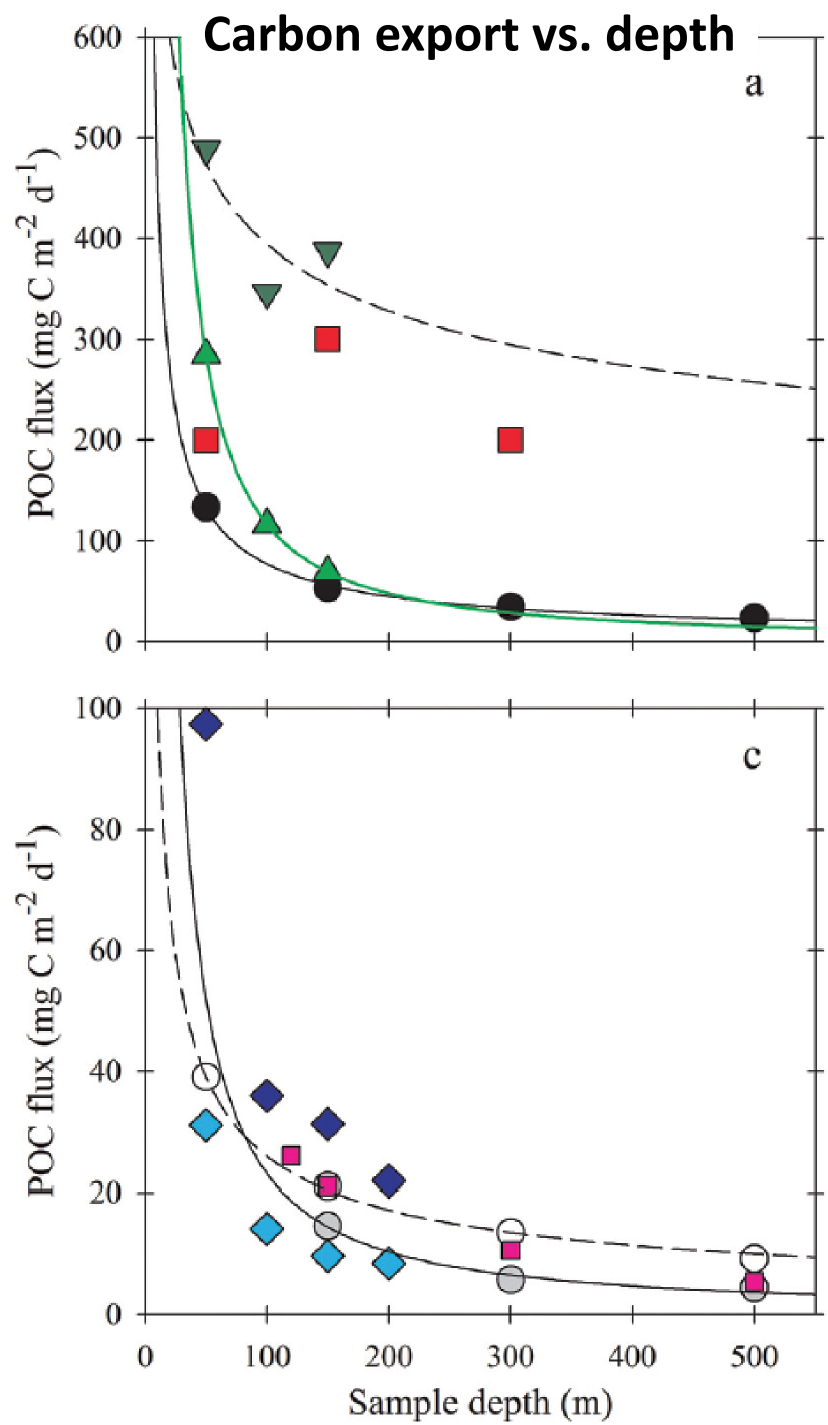
- 7 mmol m^{-3} NO_3^- required for observed DIC drawdown
- Throughout growing season, $[NO_3^-] << 1$
- Where does N come from?
  - Nitrogen fixation
  - NO_3^- mining by vertically migrating phytoplankton
  - Vertical mixing? But this introduces dissolved inorganic carbon
- AUV’s could examine the footprint of this process…

Influence of synoptic meteorological events on ocean carbon fluxes

- Calm weather
  - Shallow, well-lit mixed layer
  - Mature ecosystem develops
  - Grazing ~ production; low export
- Storm comes through
  - Mixed layer deepens, light and productivity fall
- Calm weather ensues
  - Mixed layer shoals
  - Productivity rises in high-light environment
  - Period of high export
  - Mature community develops…
- *Is there any validity to this scenario?*
  - AUV's could monitor physical forcing and the biogeochemical response
- Alternative
  - Iron deposition as remote continental airmass passes over ocean region
  - Primary productivity and export production spike

Fate of carbon exported from the mixed layer or euphotic zone - 1

- Fluxes of sinking particles decrease very rapidly with depth



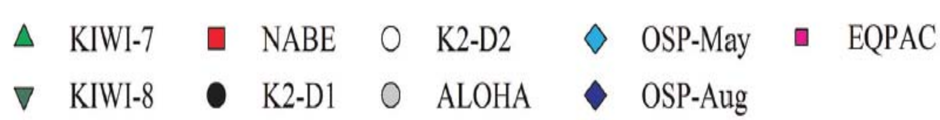


Fig. 3. Plot of POC flux vs. depth and representative fits to the Martin curve (a, c) (Eq. 1; data plotted vs. sample depth) or exponential fit (b, d) (Eq. 2; data plotted vs. depth below euphotic zone). Data are from Table 1. The four high-flux sites are plotted in (a) and (b) on a POC flux scale of 0-600 mg C m^{-2} d^{-1}, while the five lower-flux sites are plotted in (c) and (d) on a flux scale of 0-100 mg C m^{-2} d^{-1}. In the upper panels, the best fit is drawn for KIWI-8 (dashed line), KIWI-7 (solid green line), and K2-D1 (solid black line). In the lower panels, the best fit is drawn for K2-D2 (dashed line) and ALOHA (solid black line). The mathematical fits and associated uncertainties for each site are provided in Table 6.

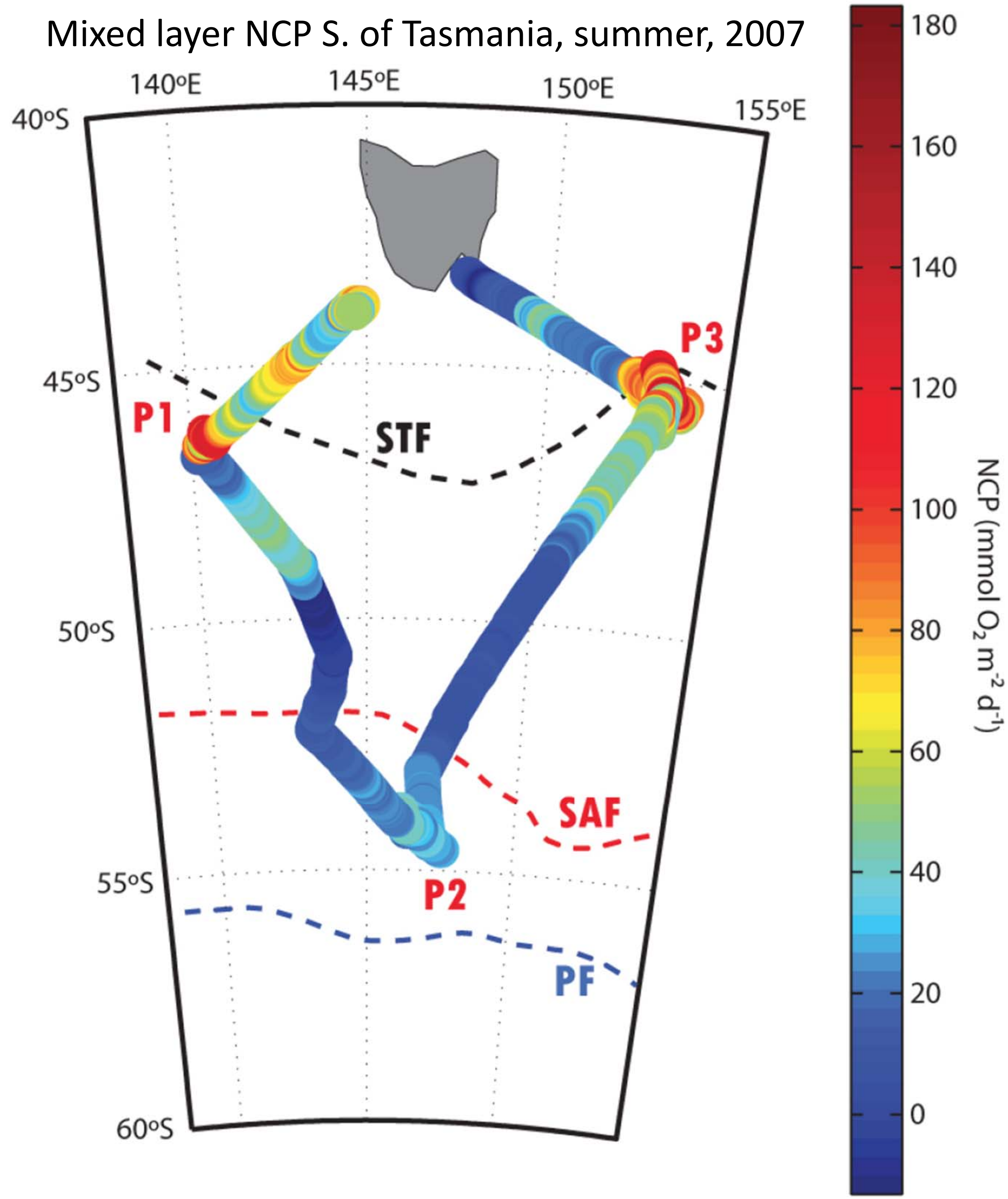
Buesseler and Boyd, 2009

Fate of carbon exported from the mixed layer or euphotic zone - 2

- P1 and P3 occupied for ~5 days; productivity is very high (50-150 mmol m^{-2} day^{-1}) (Cassar et al., 2011)
- And sediment trap fluxes:

Site i.d.	Depth m	Total POC flux $\mu mol\ m^{-2}\ d^{-1}$	
P1	140	6141.9	
	190	10,280.9	(10)
	240	10,567.2	
	290	8103.2	
P2	140	9508.2	
	190	5928.5	
	240	5578.3	(6)
	290	5196.5	
P3	140	752.3	
	190	988.9	
	240	568.0	(0.8)
	290	549.1	

Mixed layer NCP S. of Tasmania, summer, 2007



AUV studies of shallow remineralization of sinking organic matter

- Optical studies of individual particles
  - Composition
  - Sinking rate
  - Vertical flux
  - Lateral advection
  - Change in properties with depth to characterize breakdown

Patch experiments

Objective: track an upper ocean ecosystem for 1-2 weeks and observe its biogeochemical evolution in response to physical forcing

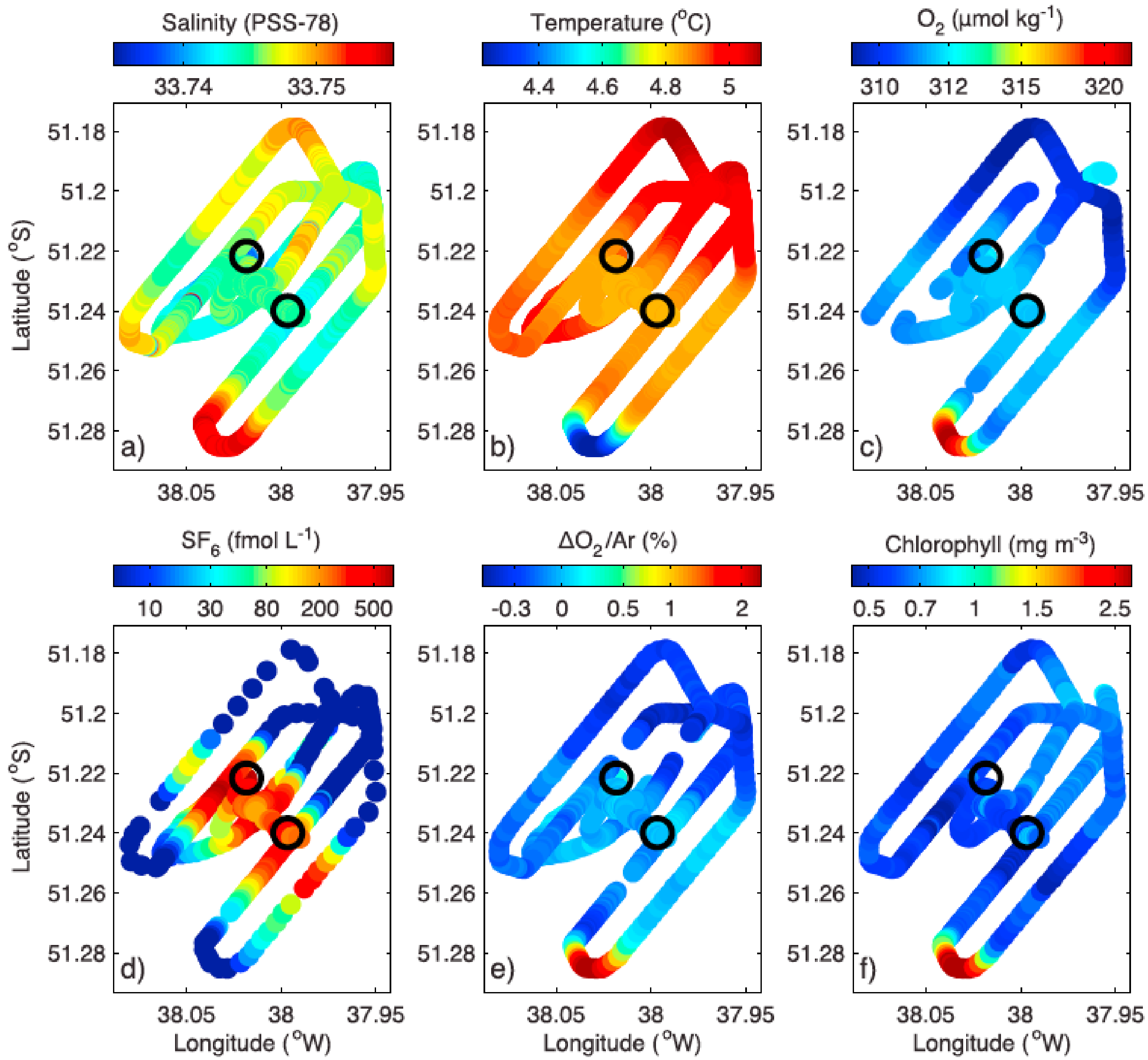
Standard shipboard mode

- Inject a patch of SF_6
- Inject iron or not, depending on objectives
- Continuously measure SF_6 to identify THE patch
- Make physical and biogeochemical observations: O_2, DIC, nutrients, optical properties, flux terms (gross photosynthesis, net community production, respiration)
- Characterize evolution of ecosystem in response to physics and biogeochemical dynamics

Possible AUV modes

- Ultra mode: AUV's inject tracer, measure tracer to track patch
- Dynamics mode:
  - Team of AUV's identify dynamical feature (ring), tracks feature
- Minimalist mode: AUV's identify surface feature from heterogeneity

GasEx III patch experiment, Atlantic Subantarctic



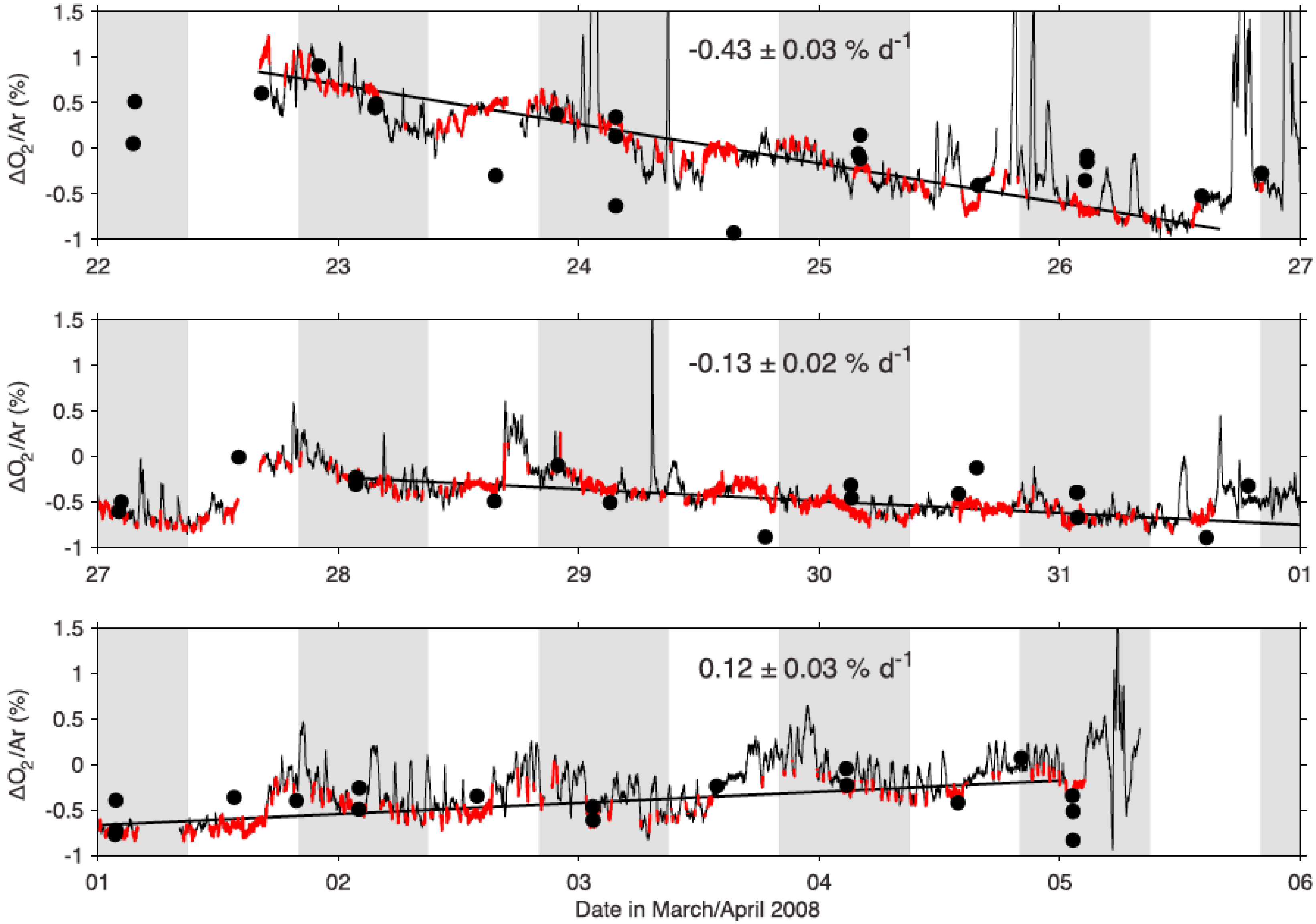


Figure 6. Time series of surface, underway ΔO_2/Ar measurements during patch 2 from 22 March to 6 April 2008. Gray bars indicate local night. Red line segments indicate measurements inside the patch when underway SF_6 concentrations were greater than 75 fmol L^{-1} during 22–27 March, greater than 25 fmol L^{-1} during 27 March to 1 April, or greater than 10 fmol L^{-1} during 1–6 April. Black points show discrete, mixed layer ΔO_2/Ar measurements. Straight lines show linear regressions of 1 h binned averages of in-patch data with slopes and errors indicated.

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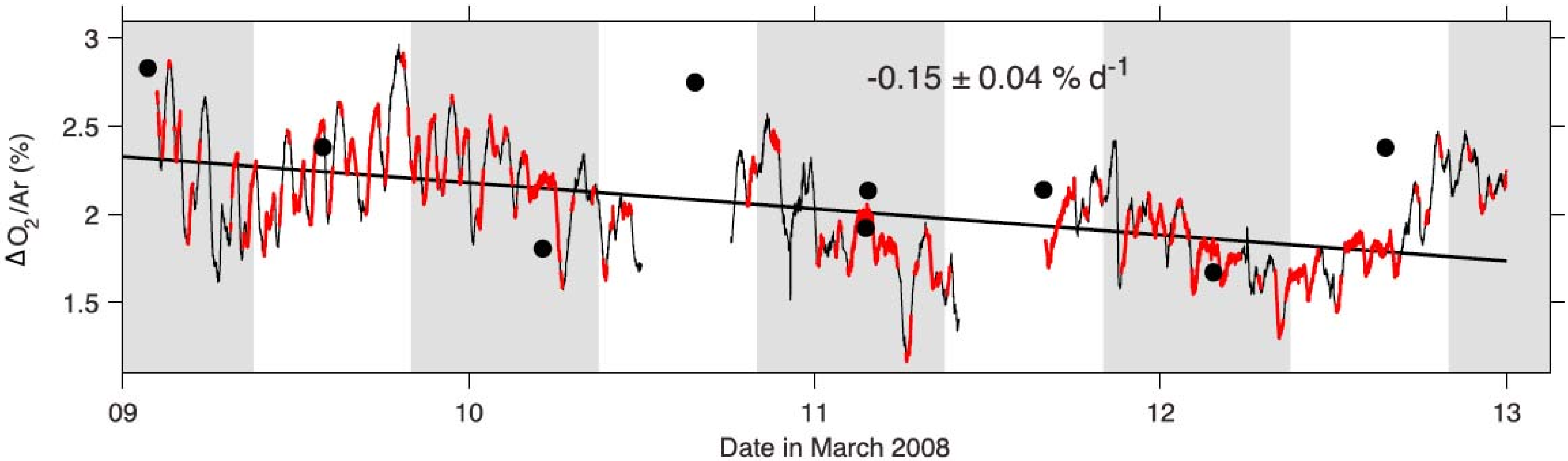


Figure 2. Time series of surface, underway $\Delta O_2/Ar$ measurements during patch 1. Gray bars indicate local night. Red line segments indicate measurements inside the patch when underway SF_6 concentrations were greater than 30 fmol L^{-1}. Black points show discrete $\Delta O_2/Ar$ measurements. Straight line shows linear regression of 1 h binned averages of in-patch data with slope and error indicated. Underway $\Delta O_2/Ar$ measurements of patch 1 ended on 13 March to repair a fault in the system.

Summary of questions

- Sources of nutrients in the subtropical gyre?
- Evolution of local ecosystems in response to synoptic forcing
- Evolution of local ecosystems in response to other physical forcing and biogeochemical variability
- Seasonal net carbon production in the mixed layer and euphotic zone
- Biology and dynamics of sinking particles

Minority view: for ocean biogeochemistry, new sensors can be more important than command and control, depending on experiment

- High precision DIC, NO_3^-, O_2, total gas content
- Optical sensors for flow cytometry, fast repetition rate fluorometry…

Background: biological and chemical cycles in the world's oceans

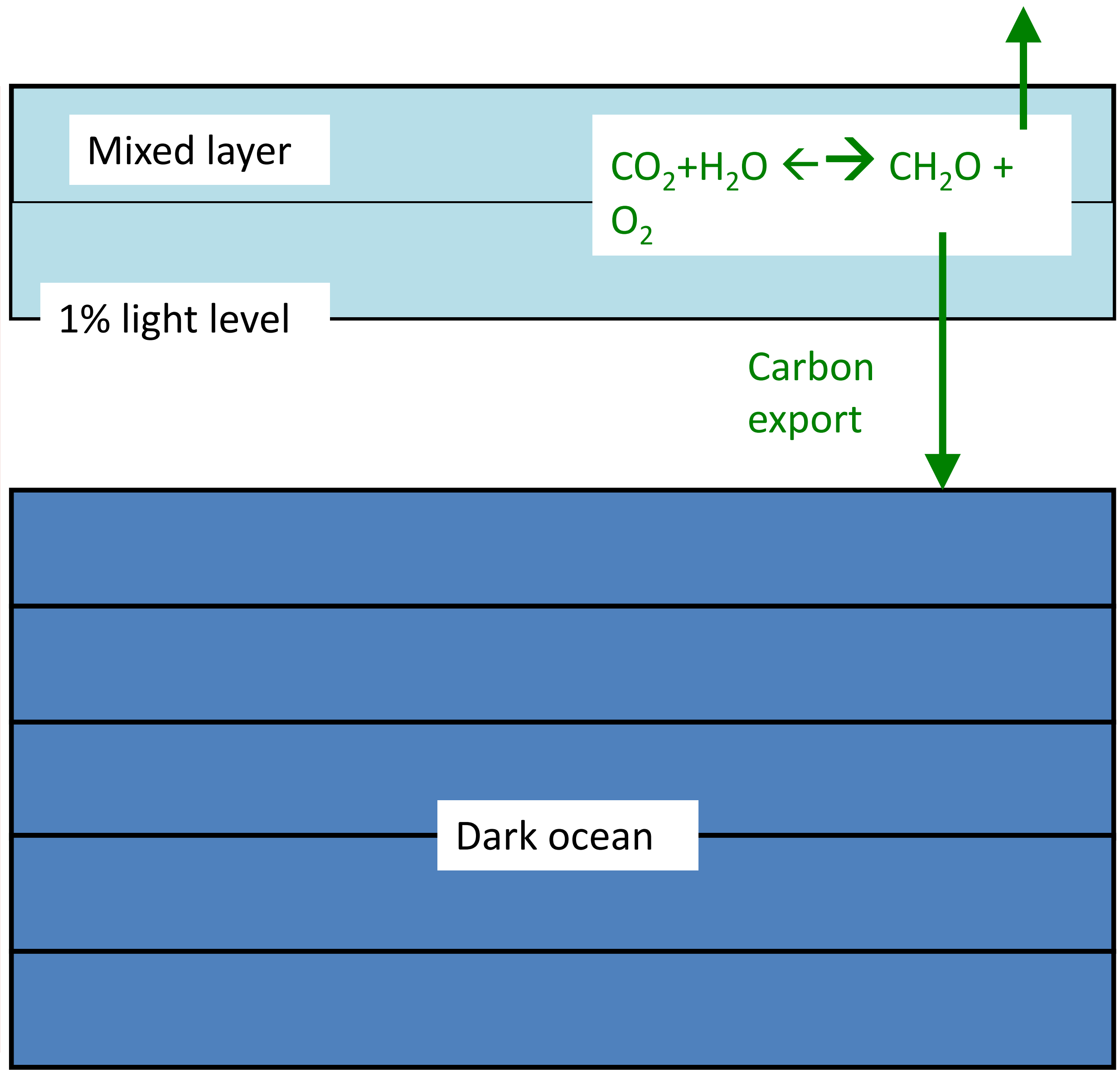
NCP = photosynthesis-respiration

C_{org} is not stored in euphotic zone; NCP ~ export

O_2 flux to the atmosphere = O_2supersat * gas transfer velocity

Correct for physical supersaturation based on Ar supersat

Sea-air O_2 flux = carbon NCP and export



Time period accessed by O_2 balance ~ 1 week

Some details regarding the calculation of net community production

- O_2 in the mixed layer is supersaturated as because of physical processes
  - Measure Ar supersaturation and correct O_2 supersaturation accordingly
- Some assumptions:
  - Steady state
  - No mixing with water below the mixed layer
- Estimate gas transfer velocity and calculate O_2 efflux to atmosphere

Other sources of information about rates of NCP and carbon export

- Seasonal drawdown of dissolved inorganic carbon or nutrients (seasonal timescale)
- Sediment traps
- $^{234}Th/C$ ratios and fluxes
- $^{15}NO_3^-$ assimilation