Carbon Cycle Feedbacks from the Seafloor

Session introduction and overview

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2019 OCB Workshop Session 4

OCB 2019 Summer Workshop

This Introductory Presentation

1. Big picture perspectives on the role of seafloor sediments in ocean carbon and biogeochemical cycles
2. How global fluxes of organic carbon to & from the seafloor are have been assessed (recap of OCB advances over 40 years)
3. Introduction to eddy covariance as a new method to evaluate the dynamics of seafloor fluxes under natural flow and light conditions.

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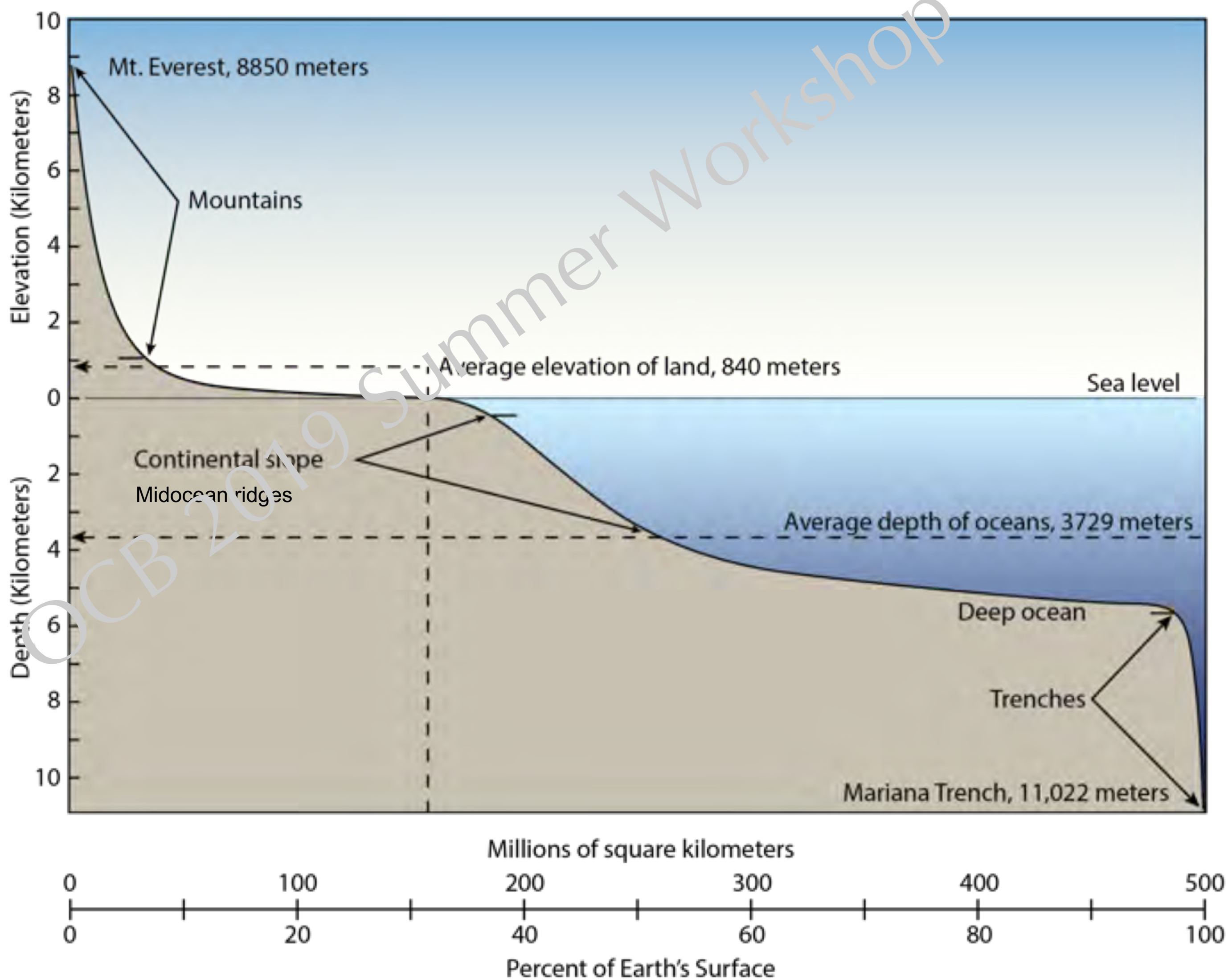
Earth's Surfaces- hypsographic curve

~70% of the geological surface of the Earth is seafloor.

Average ocean depth = 3729 m (2.3 miles)



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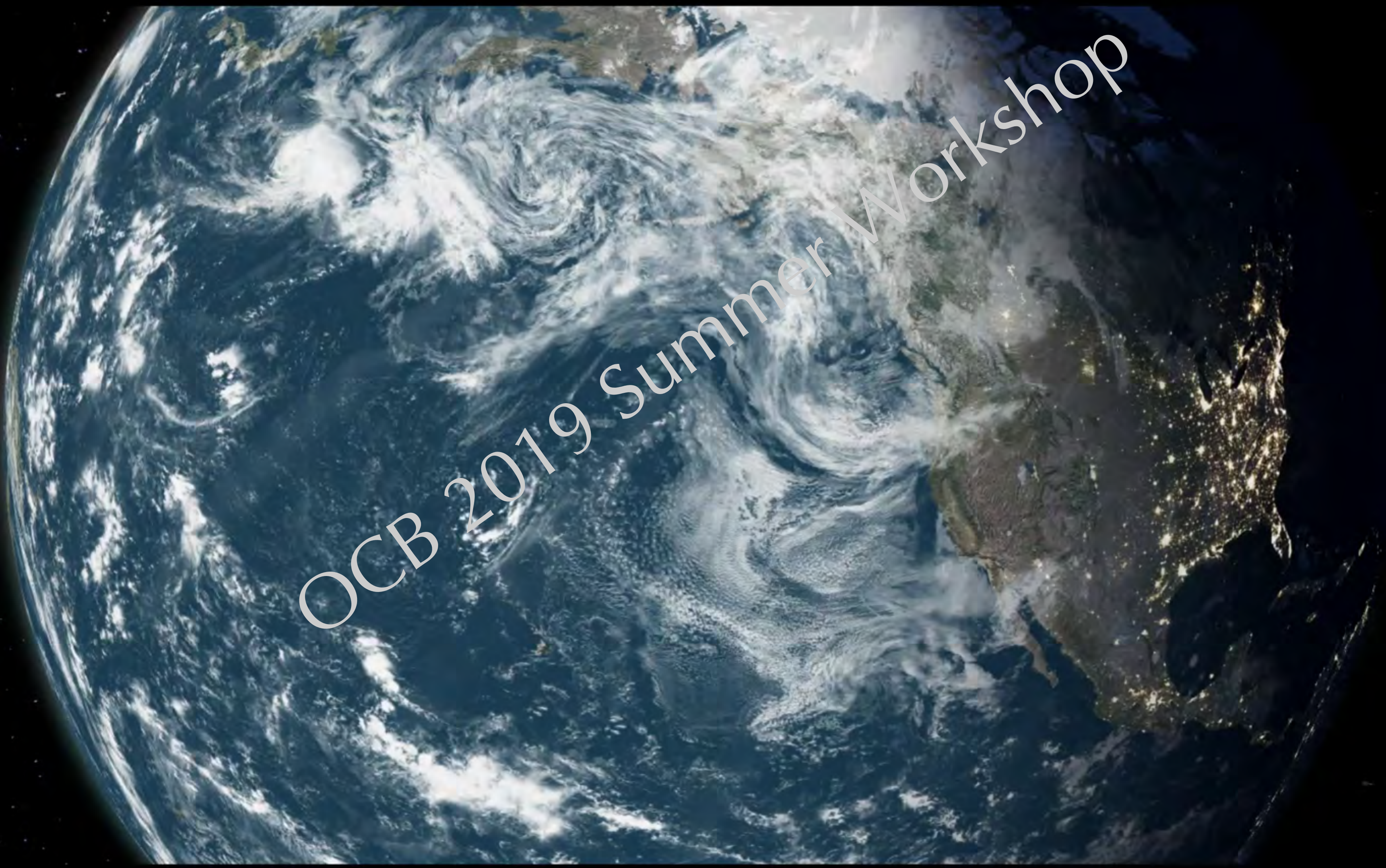
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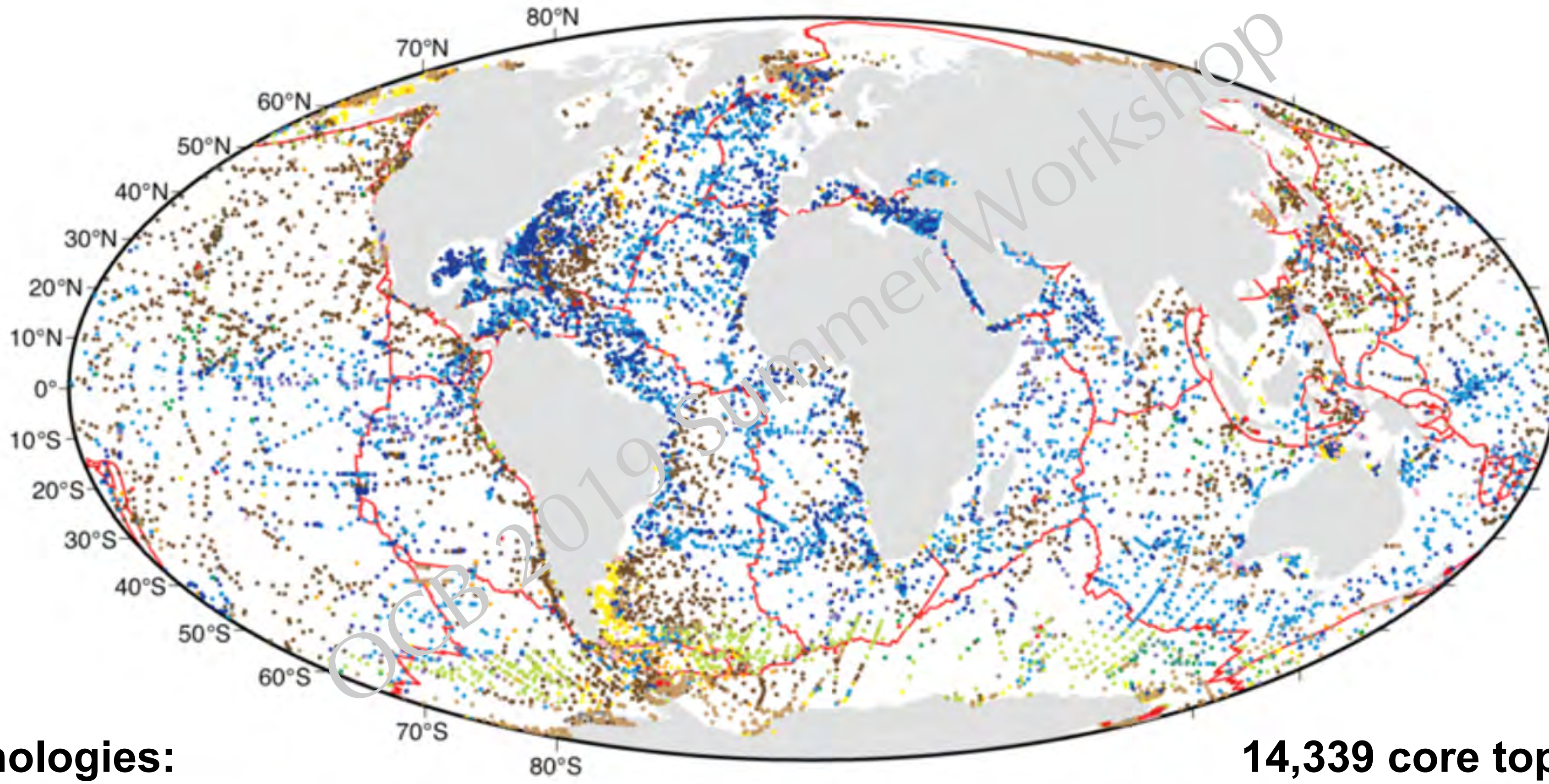
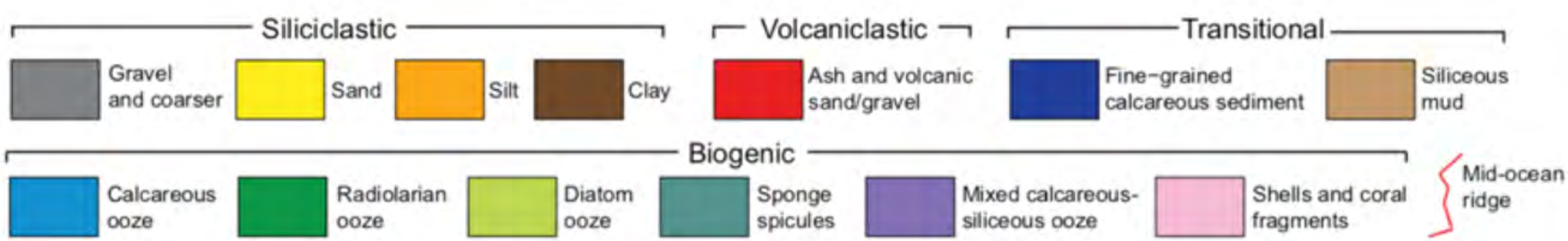
Oceanic Sediment Composition
(*Dutkiewicz et al. 2015 Geology*)



Lithologies:

14,339 core tops



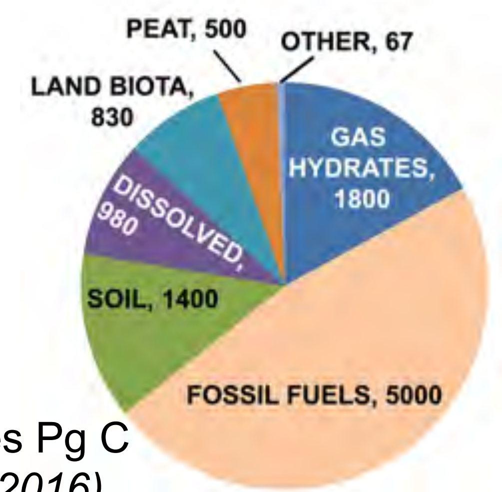
Key Roles of Seafloor Sediments in Ocean Carbon and Biogeochemical Cycles

1. Interface between geosphere and hydrosphere and reservoir central to the mitigation of ocean acidification (anthropogenic and geological) through:
- Carbon sequestration and storage (including ‘blue carbon’ sea grasses, mangroves and salt marshes)
- Dissolution of sedimentary $CaCO_3$ (neutralization of excess CO_2)

2. Mixing zone of terrestrial and marine organic carbon leading to:
- High rates of aerobic and anaerobic respiration (especially on deltas, open shelves) and DIC export to open ocean water column
- Hypoxia, inorganic nitrogen losses by denitrification, trace element redox speciation changes & fluxes, scavenging and authigenic mineral formation

3. Zone of gas hydrate formation and dissociation leading to release of methane from ancient C sources; subject to ocean warming

4. Habitats for life and metabolism from the shallowest to the deepest end of the ocean continuum



Carbon reservoir sizes Pg C
Ruppel and Kessler (2016)

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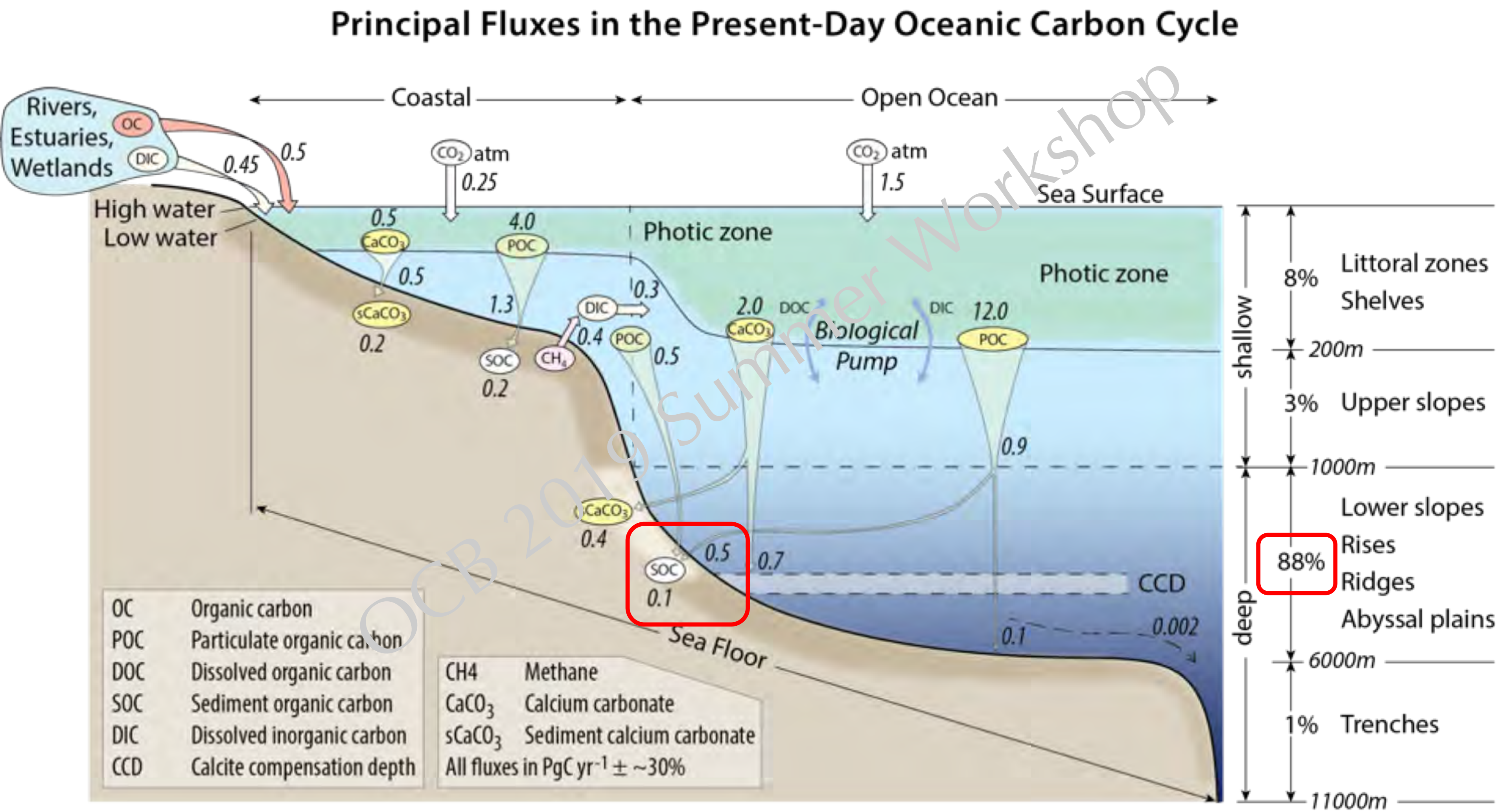
A Changing Oceanic Carbon Cycle



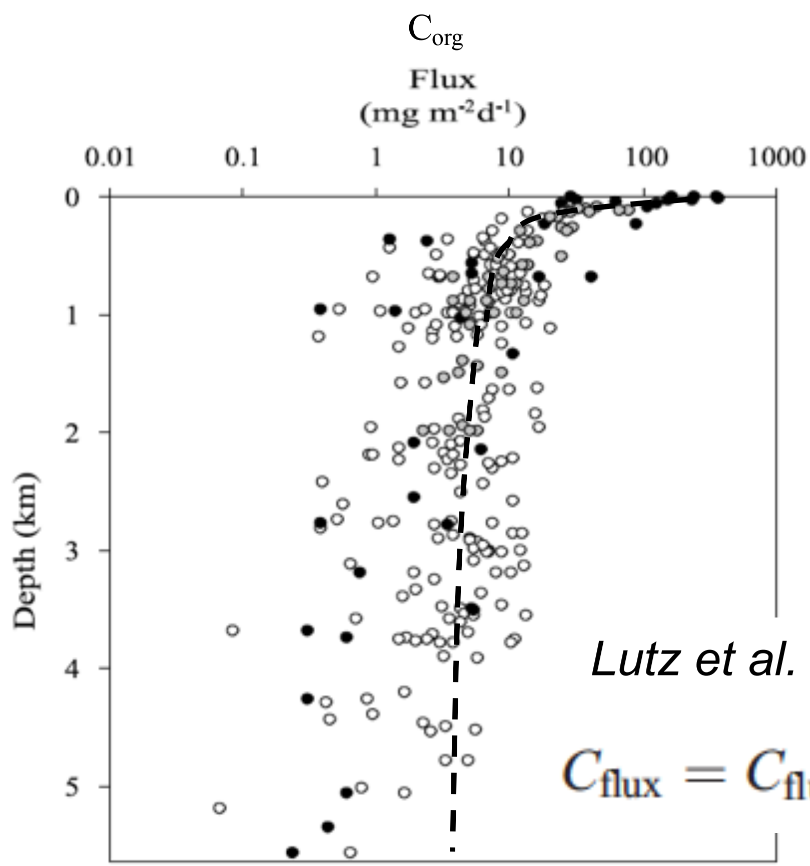
Fluxes in PgC yr^{-1} *(1 Petagram = 10^{15} g)*

Sources: *Bauer et al. 2013; Chen 2010; Lutz et al. 2007; Ruppel and Kessler 2016; Seiter et al. 2005; Smith & MacKenzie 2016; Sulpis et al. 2018.*

The Export of Organic Carbon to the Deep Ocean

Starting with ***Suess (1980)***
composite models of sediment trap fluxes indicated organic carbon fluxes to the deep ocean decrease exponentially.

$$C_{flux(z)} = {C_{NPP}}/{(0.0238z+0.212)}$$

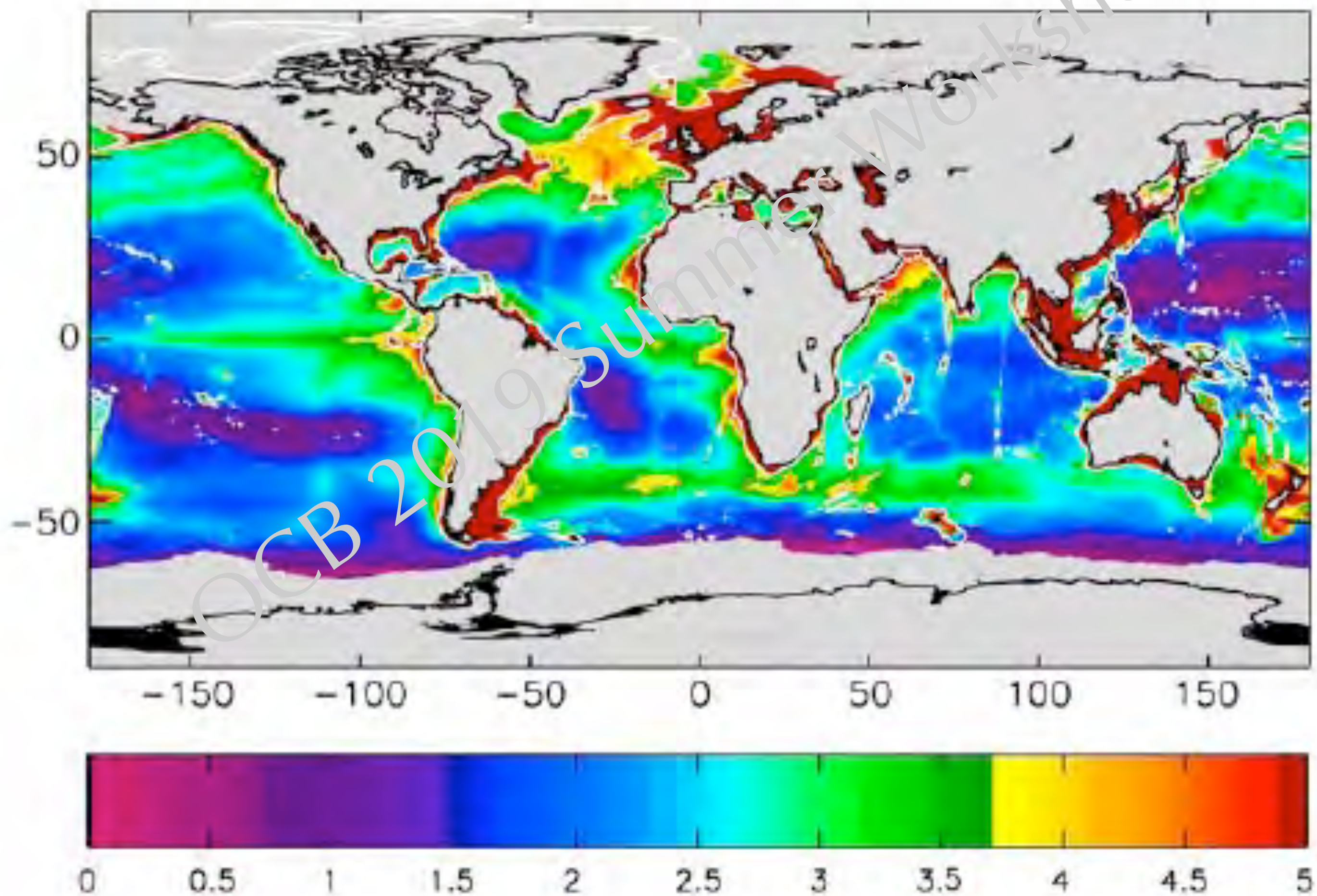


Lutz et al. (2002)

$$C_{flux} = C_{flux(z_0)} e^{-\left(\frac{D}{W}\right)z}$$

Global POC Flux assessment based on satellite data, monthly mean NPP derived from Chl, PAR, STT; exponential decay model for sinking flux (*Muller-Karger et al. 2005 GRL)*

POC flux ocean > 1000m ~ 0.31 Pg C yr^{-1}



POC Flux gC m^{-2} yr^{-1}

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Benthic Approach to Fluxes

"What comes down
is remineralized or buried"

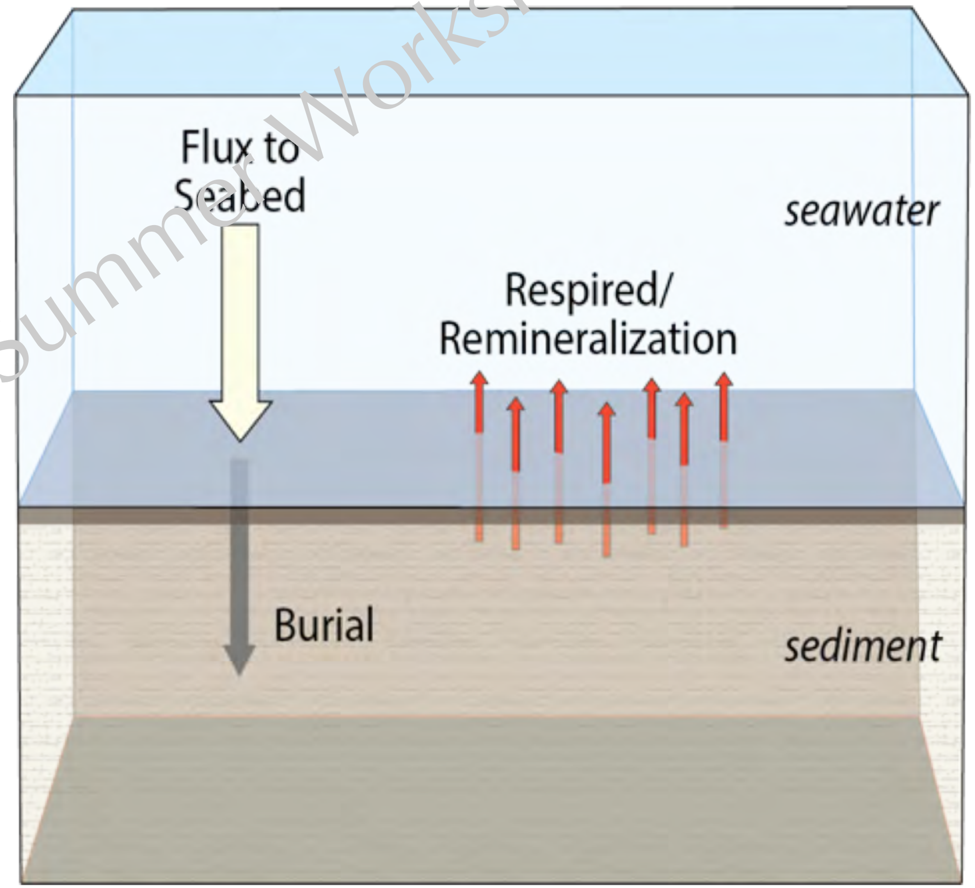
Organic Matter Remineralization (Respiration)

$$(CH_2O) + O_2 \rightarrow CO_2 + H_2O$$

$$C{:}O_2 \sim 1.0$$

$$Burial = [SOC]_{at\ depth} * Sed.Rate$$

Where anaerobic microbial respiration occurs,
reduced products also consume O_2 maintaining this overall balance



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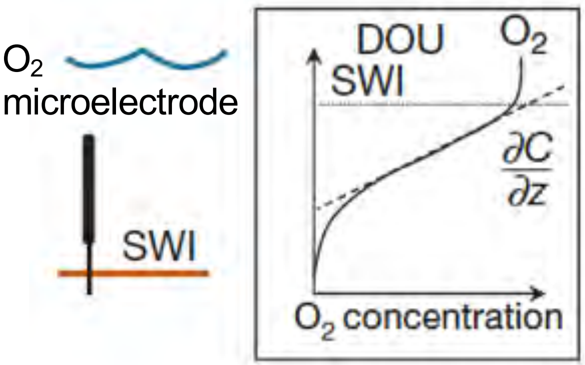
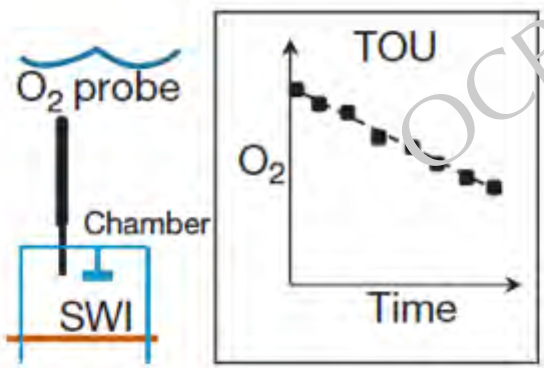
Approaches for Deriving Seafloor Fluxes

Pore water gradient and benthic chamber incubations



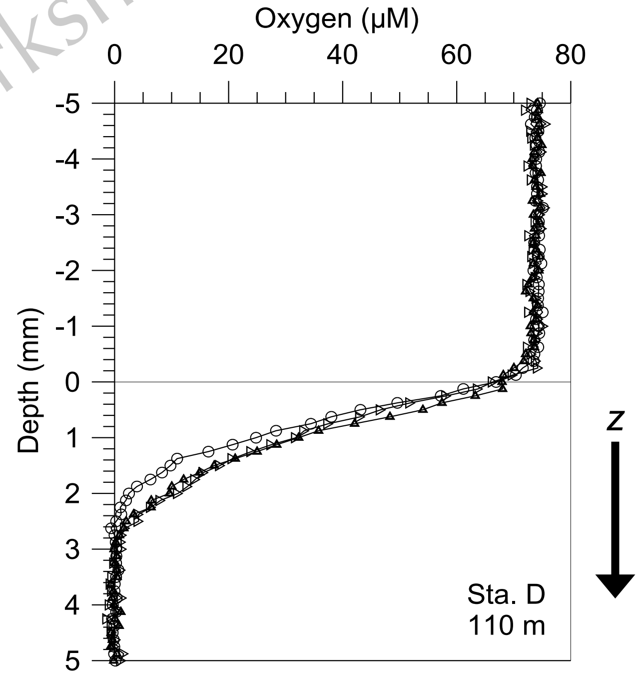


Diffusive Oxygen Utilization

$$\mathrm{DOU} = -\phi D_s \frac{d[O_2]}{dz}$$

Total Oxygen Utilization

$$\mathrm{TOU} = \frac{d[O_2]}{dt} \times \frac{V_{\mathrm{Chamber}}}{A_{\mathrm{Chamber}}}$$



DOU = 3.7 ±0.7 mmol m^{-2} d^{-1}
10/05/2004, Oregon Shelf

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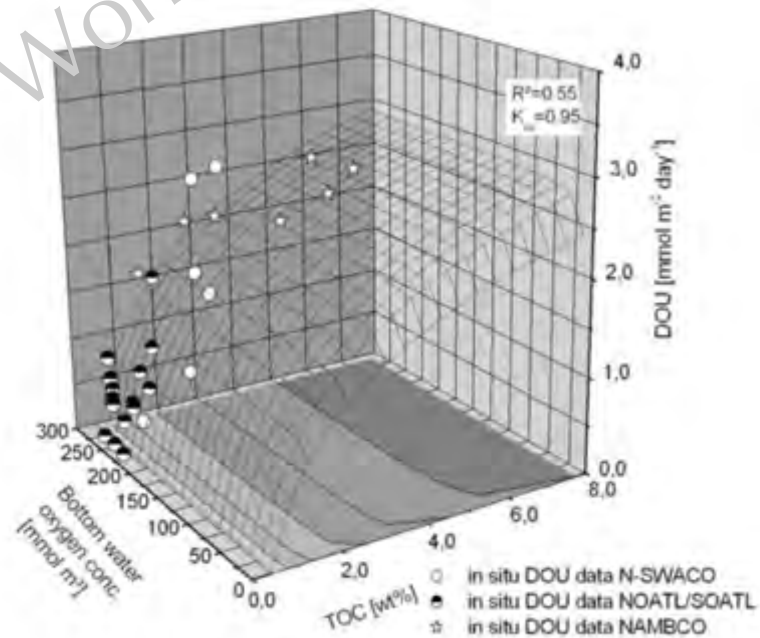
Steps to a Global Assessment of Organic C reaching seafloor >1000 m

1. *Cai and Reimers (1995)* developed a general correlation between benthic oxygen flux (DOU or TOU), bottom water oxygen concentration [Ox] and core top organic C content (SOC) based on data from the NE Pacific.

   a. The form of this relationship reflected first-order kinetics for the the degradation of SOC and a hyperbolic dependence on [Ox].

$$\frac{-\partial[Ox]}{\partial t} \approx DOU = -k \times \left([SOC] \times \frac{[Ox]}{(K_{ox} + [Ox])}\right)$$

2. Seiter, Hansen and Zabel (2005) developed similar functional relationships (multiple regressions) for <u>11 regions</u> and applied these using input data grids of SOC and [Ox] projected over the globe.



Inputs used in multiple regression analysis of three Atlantic provinces

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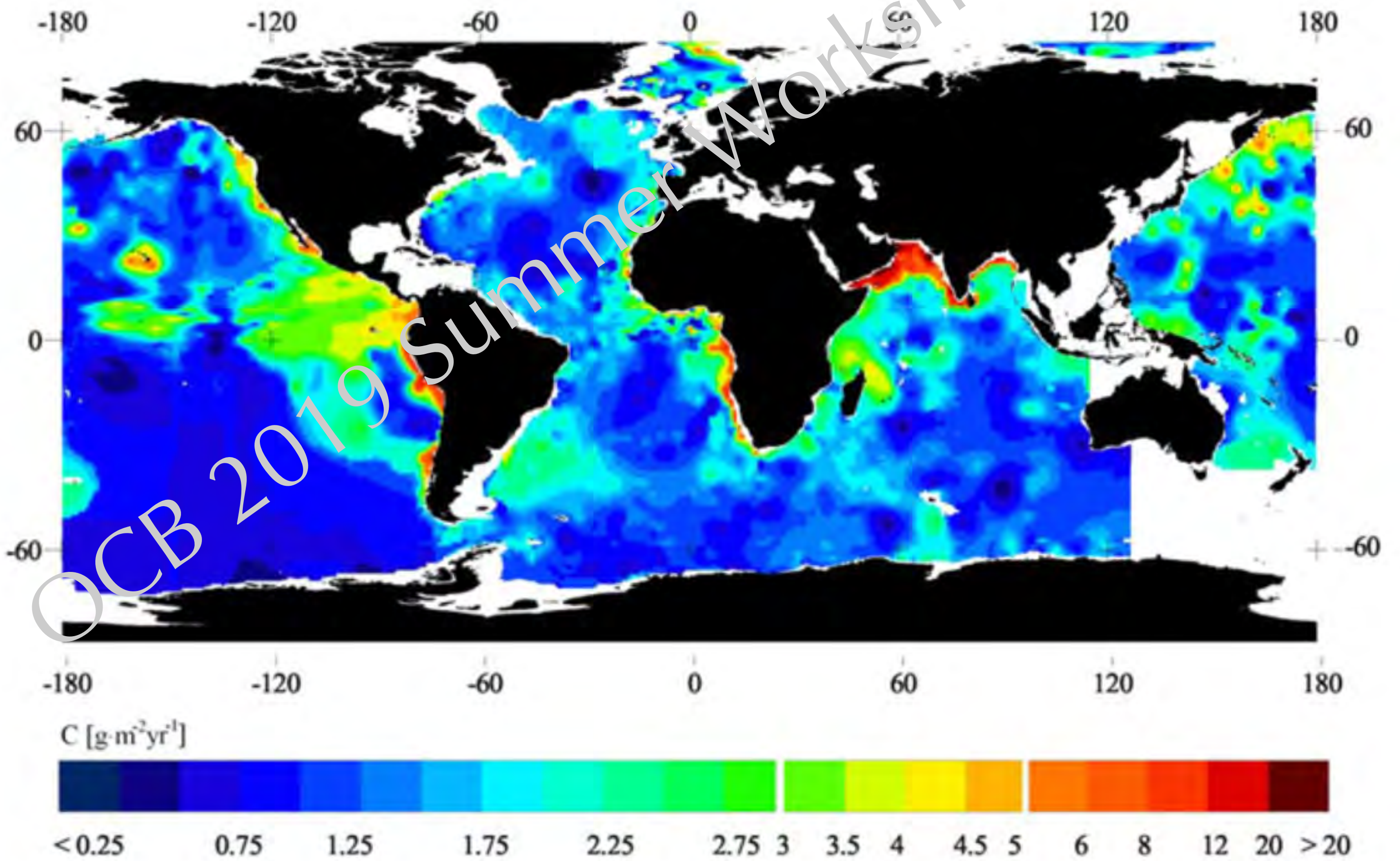
Pattern of POC flux to deep seafloor based on DOU predictions *(Seiter et al. 2005)*

>1000 m water depth; Integrated global flux = **0.5 PgC yr^{-1}**

Data Inputs still sparse. More needed. Time to reassess. 😃



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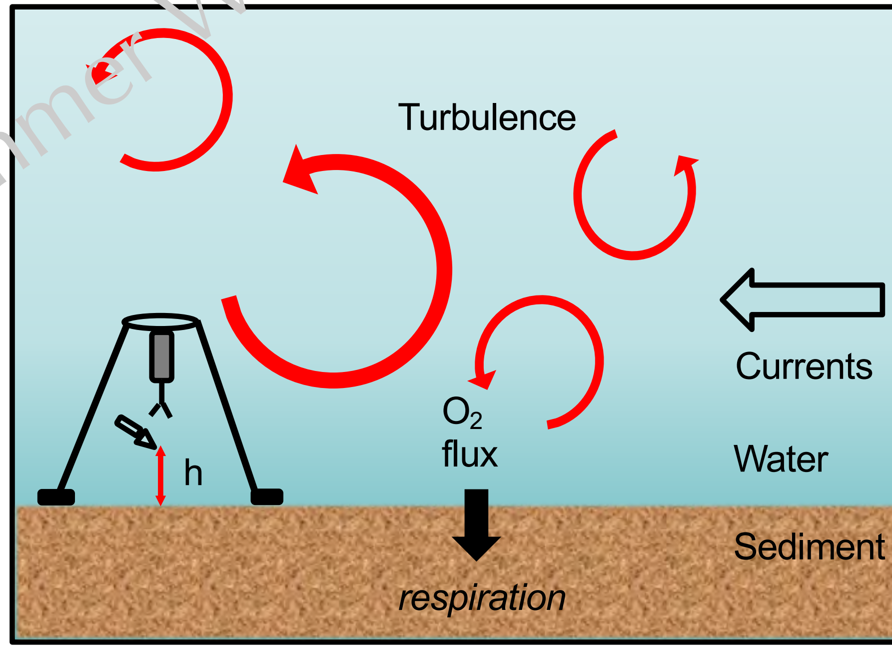
Aquatic Eddy Covariance:
Dynamic flux measurements

Acoustic Doppler Velocimeter
Fiber optic O_2 sensor & thermistor

Reynolds Decomposition:

$$w(t) = \bar{w} + w'$$
$$C(t) = \bar{C} + C'$$
$$T(t) = \bar{T} + T'$$

A water-side approach to flux measurements



$$Flux = \overline{w'C'}$$

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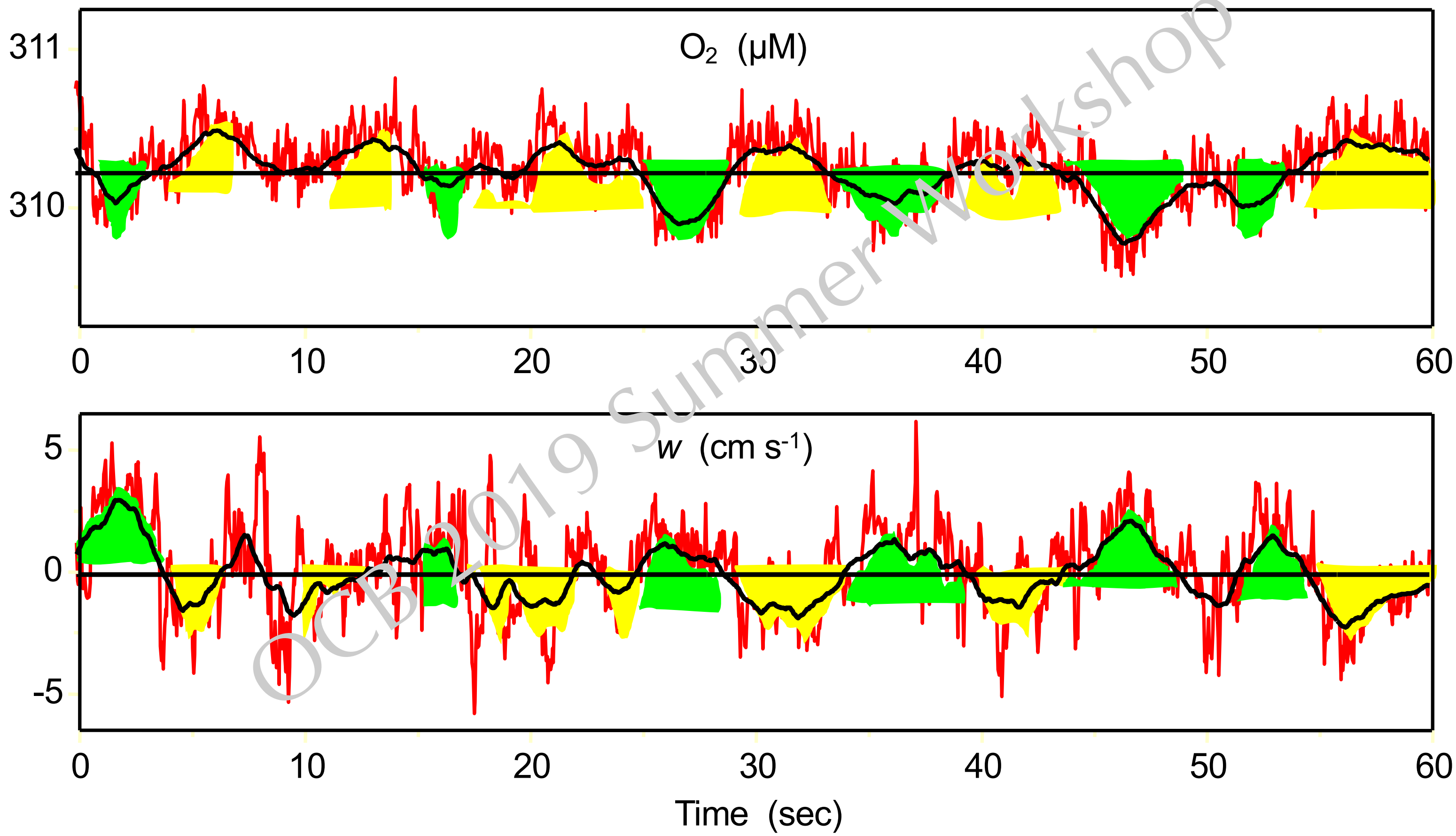
Eddy covariance – real example of 64 Hz data



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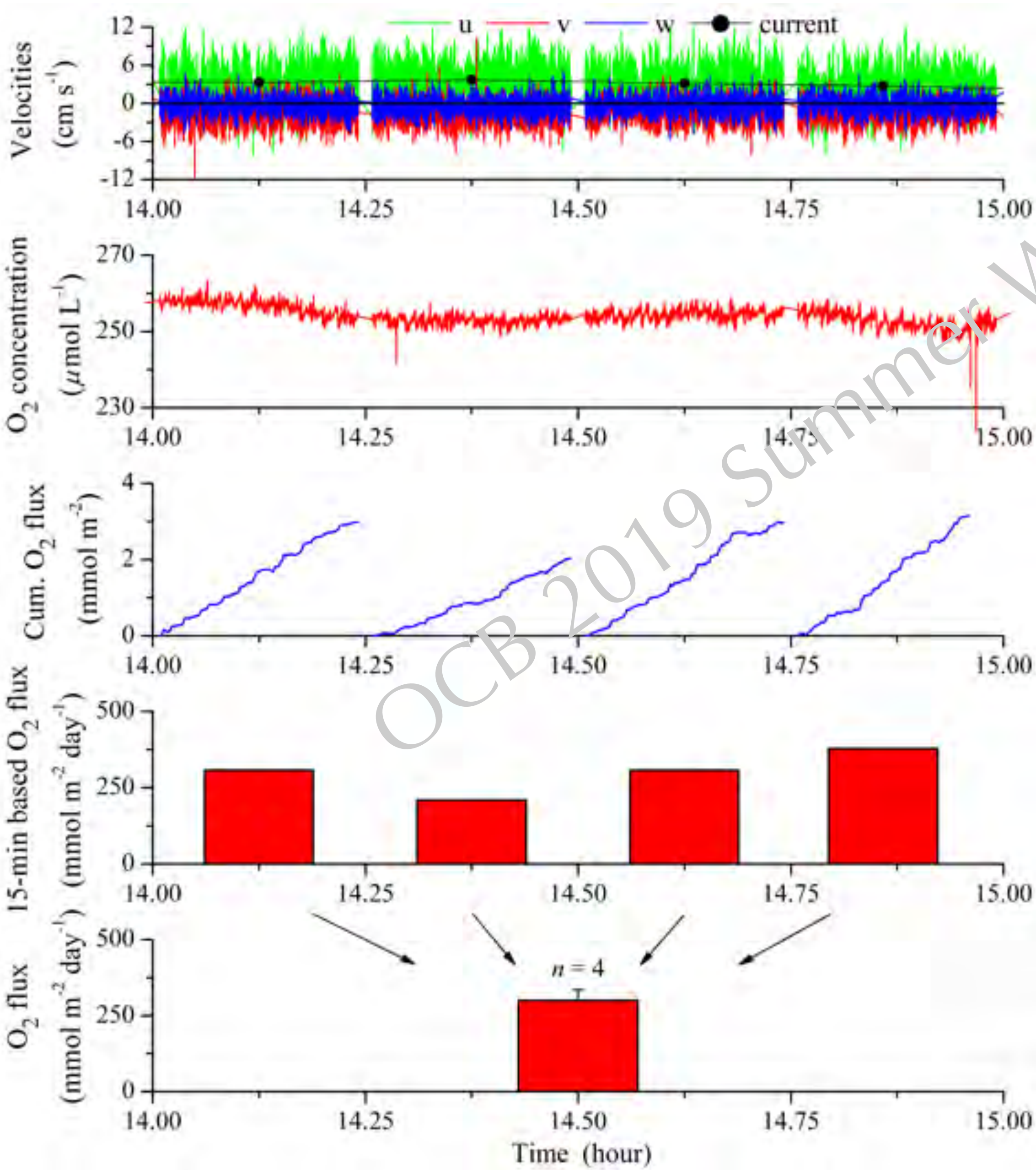
Instantaneous vertical advective $Flux = w(t_i)C(t_i)$

Time averaged $Flux \;=\; \overline{w'C'}$

Units: [cm s^{-1}][nmol cm^{-3}]=[nmol cm^{-2} s^{-1}]

Source: Peter Berg

EC Measurements to Fluxes



15 min time series segments

Hume et al. (2011) L&O

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Talks to Follow:

Temperate seagrass bed metabolism and carbon sequestration
Amelie Berger, Univ. Virginia

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Seasonal benthic metabolism on the shelf of the northern California Current System
Kristen Fogaren, OSU

Talks to Follow:

The fate of sediment storehouses of ancient methane in a warming Arctic Ocean
Katy Sparrow, FSU

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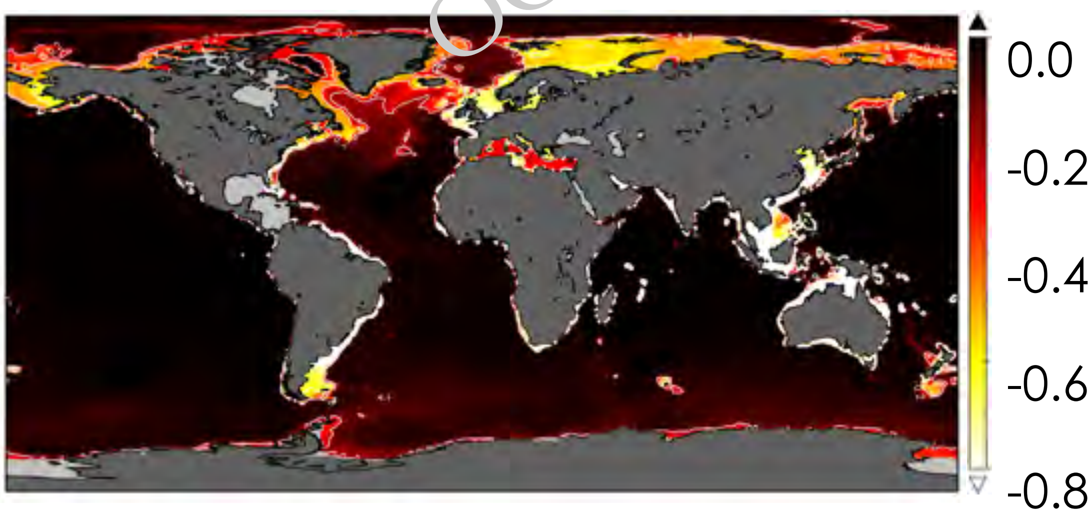
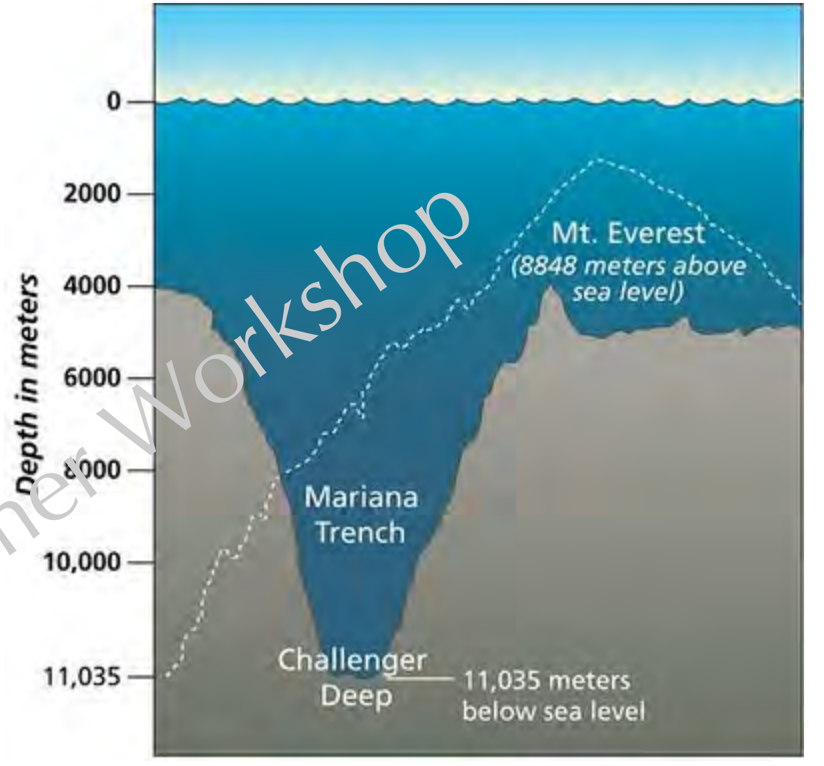
Anthropogenic changes in bottom-water $\Omega_{calcite}$



Current $CaCO_3$ dissolution at the seafloor caused by anthropogenic CO_2
Olivier Sulpis, McGill Univ.

Talks to Follow:

Hadal trenches hot spots for organic carbon cycling in the deep ocean
Ronnie N Glud, SDU, Denmark



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