Coastal Synthesis Workshop Agenda

Sediment Processes and Fluxes

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Many Collaborators:
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Themes of the talk:

Theme I: Global/regional estimates of carbon burial in sediments

How reliable are they?

Can they be compared to other flux measurements (e.g. atm/oce)?

What are key variables and processes?

Need observations and models of key processes controlling carbon sequestration

Theme II: Issue of timescales

Carbon-centric benthic processes in coastal ocean range from hours to centuries

Challenge in reconciling measurements at different timescales

Role of events at all timescales (days to decades/centuries)

Theme III: Spatial heterogeneity

Importance of sediment supply (burial/mineral surface area)

Importance of OM flux (magnitude/composition)

Importance of exposure to oxidants ([O2], mixing)

Challenges for estimating fluxes at whole-margin, continent-wide scales

Theme I: Global/regional estimates of carbon burial in sediments

How reliable are they?

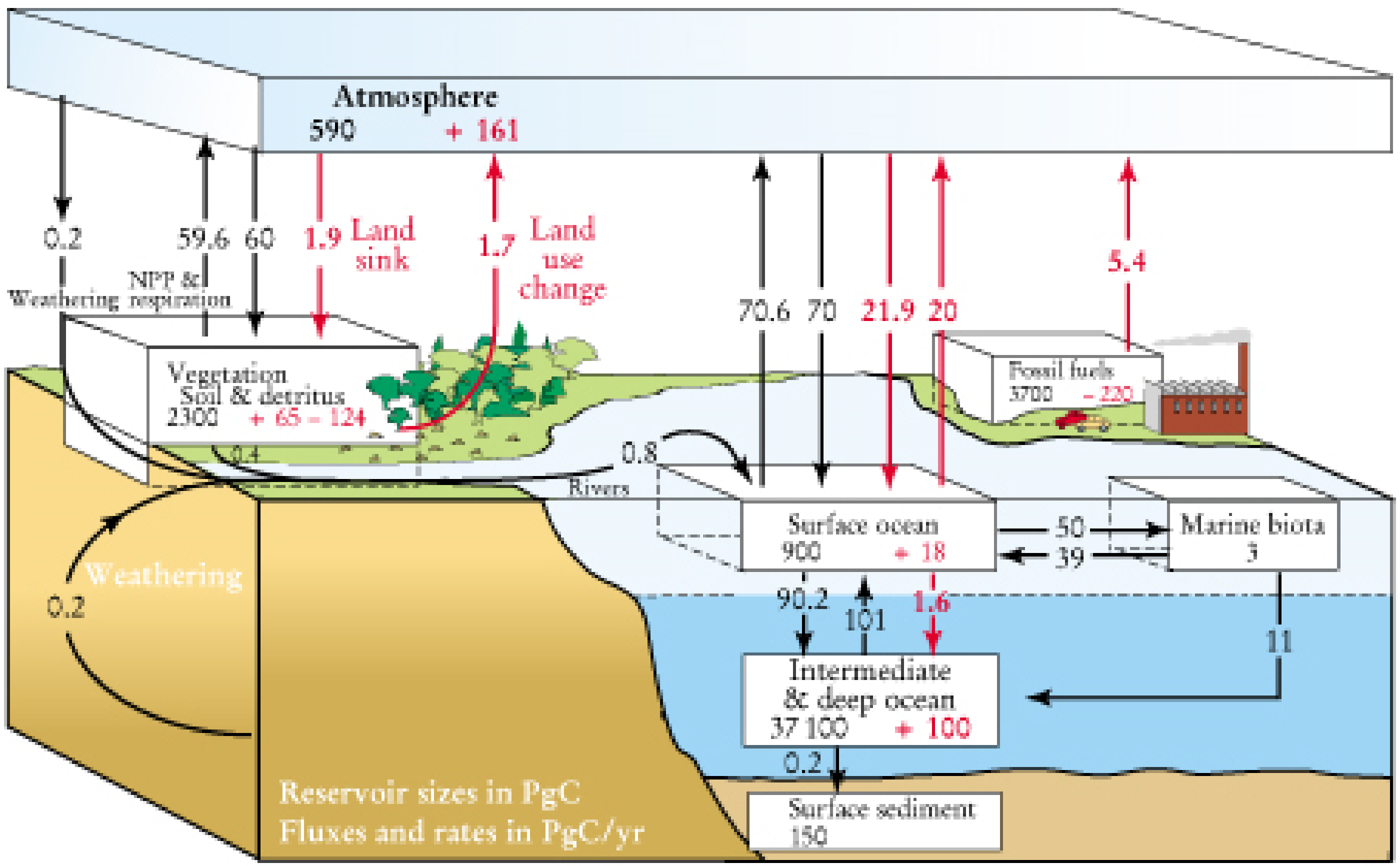
Global/Regional Carbon Budgets (Several Compilations)

Estimates of Carbon Burial ➔ 0.2 PgC/y

Relatively small term

Importance of coastal margins/deltas

Can we compare them to other flux estimates?



Sarmiento & Gruber 2002

Theme I: Global/regional estimates of carbon burial in sediments

Can they be compared to other flux measurements (e.g. atm/oce)?

Approach to Calculate Carbon Accumulation/Burial in continental sediments:

OC Sediment Sink = OC content x **Accumulation Rate** x **Area**

Extremely crude approach that is likely not directly comparable to other estimates of carbon fluxes

Reasons:

1) Poor spatial coverage of OC distributions
2) Poor spatial coverage of accumulation rates
3) Accumulation rates calculated primarily with radio-isotopes
   Time span of these measurements is highly variable
   Most often used Pb-210 has a time span of decades
4) Most recent fluxes rates are not reflected in longer records (such as sediments)

➔ ***The scales of the burial flux estimates used in most global/regional studies are not comparable with other flux measurements (daily/monthly/seasonal/annual)***

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C 1999 Trans Tech Publications, Switzerland

The Influence of Hiatuses on Sediment Accumulation Rates

P. M. Sadler

Department of Earth Sciences, University of California, Riverside CA 92521, USA

Hiatuses pervade the stratigraphic record at all scales ... Every attempt to measure a rate of accumulation must average together sediment increments and surfaces of hiatus. As the time span of measurement lengthens, longer hiatuses tend to be incorporated into the estimated rate. ***Consequently, short term rates are systematically faster than longer term rates.***

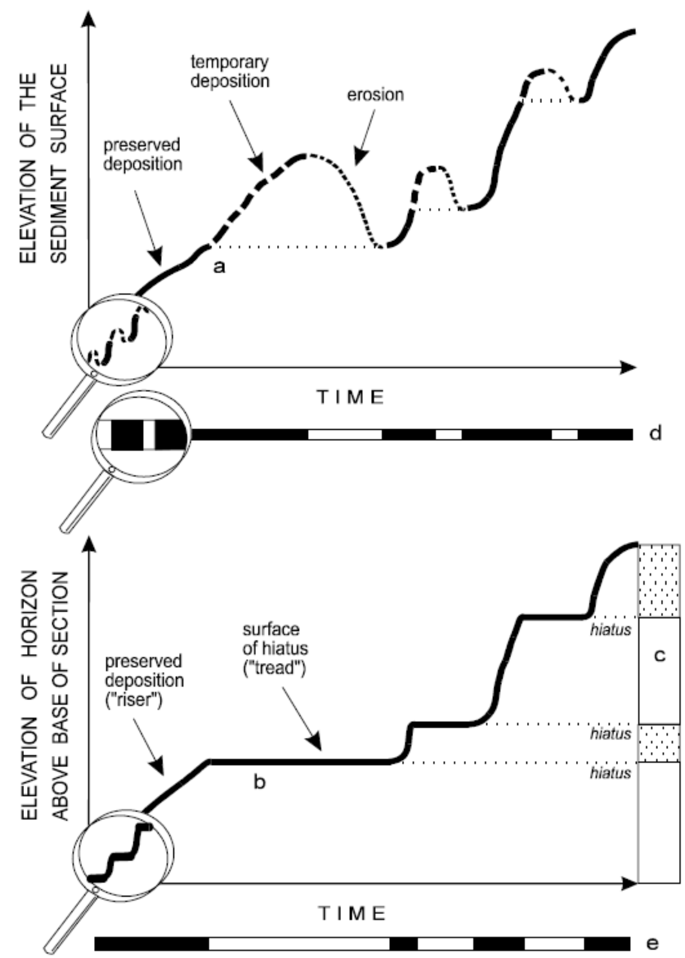


Figure 1. The distinction between the accumulation history (a), staircase plot (b)

Short term rates are systematically faster than longer term rates.

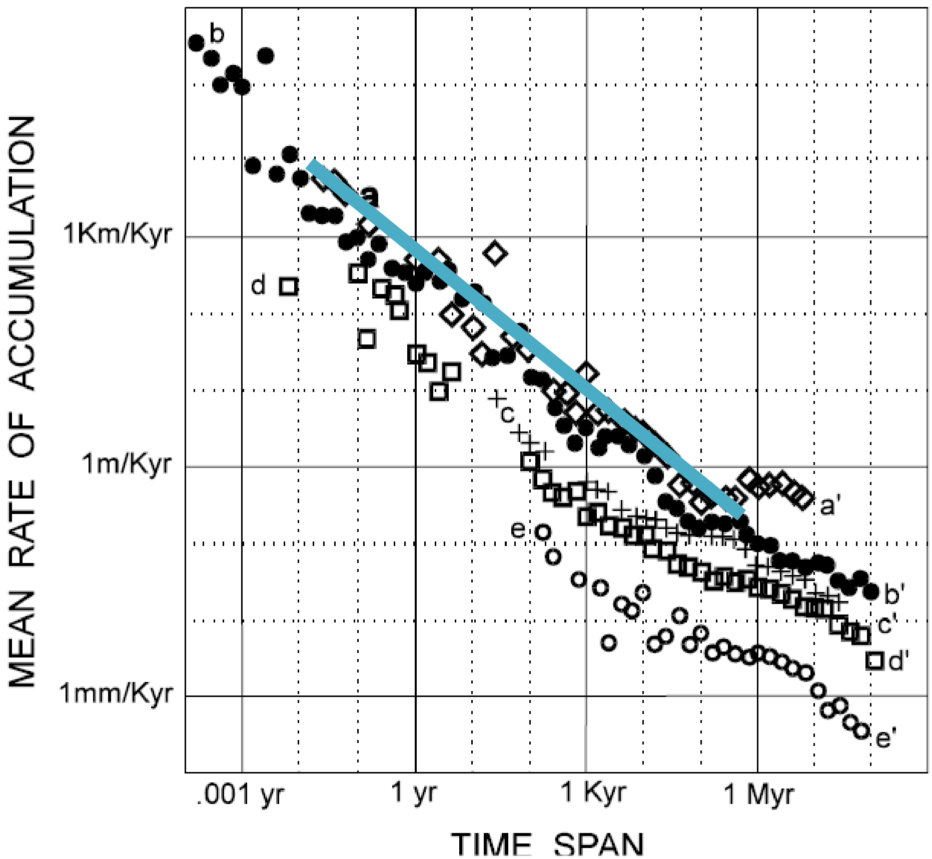


Figure 4. Mean accumulation rates for terrigenous sediments on passive continental margins. a-a': deltas (diamonds; 2,988 empirical rate determinations); b-b': shelf seas (filled circles; 22,636); c-c': continental slopes (crosses; 6,421); d-d': continental rises and abyssal plains (squares: 10,821); e-e': abyssal red clays (open circles; 2,215). Rates are averaged for logarithmically scaled windows of time span; there are five, non-overlapping windows for each order of magnitude.

Accumulation Rates in Deltas

Time span of measurements:

Isotope	**Half-life**
Be-7	53.3 d (0.15 y)
Pb-210	22.2 y
C-14	5,730 y

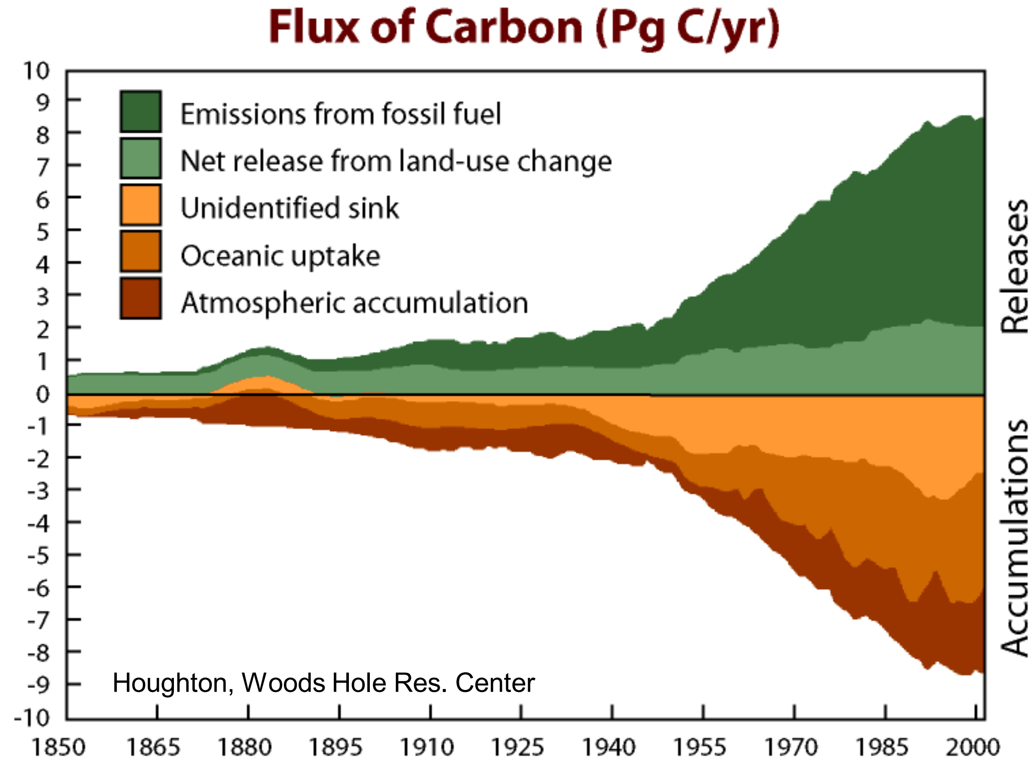
Expected Delta Accumulation Rates:

Isotope Used	**Sed. Rate**
Be-7	~10 cm/y
Pb-210	~1 cm/y
C-14	~0.1 cm/y

Magnitude of Net Fluxes 'Felt' by Sediments accumulating at multiple decade timescales

➔Net Fluxes over the Anthropocene range from 1 Pg C/y in 1900 to 10 Pg C/y in 2000

➔These historically-varying fluxes result in very different flux rates at different time spans



Time Span Years AD	Total C Added (Pg)	% of Total Increase	Calculated Flux (Pg C/y)
1850-2000	440	100	2.2
1900-2000	398	90.5	4.0
1950-2000	290	66	5.8
1990-2000	88	20	8.8

➔***Sediment accumulating carbon at longer time spans would reflect lower flux rates than those measured in last 10 years***

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Challenge in reconciling measurements at different timescales

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Theme III: Spatial heterogeneity

Importance of sediment supply (burial/mineral surface area)

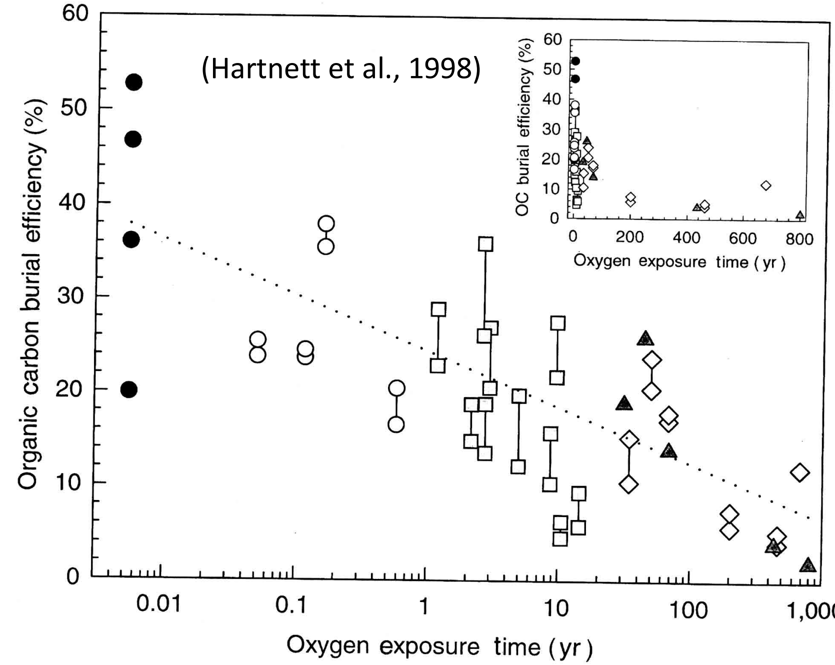
Importance of OM flux (magnitude/composition)

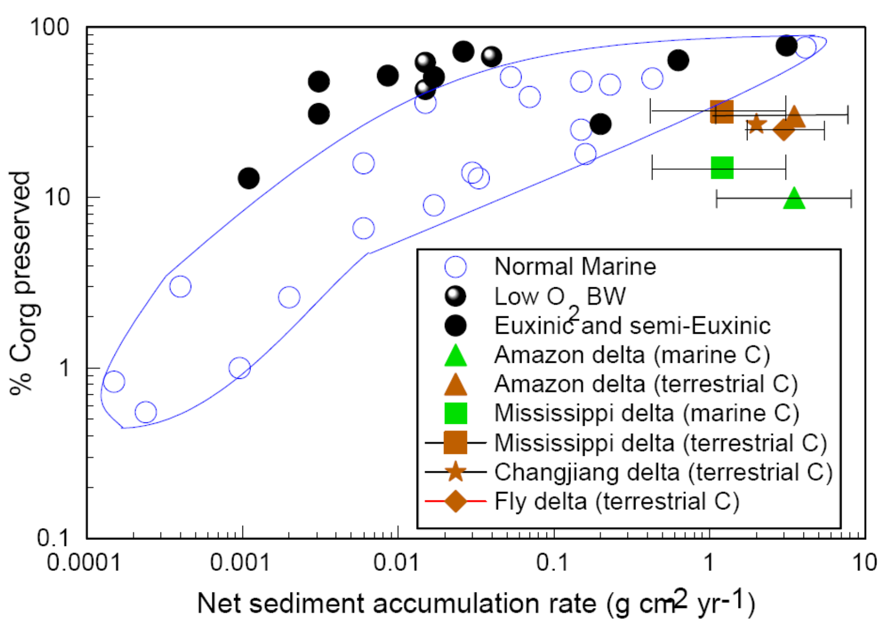
Importance of exposure to oxidants ([O2], mixing)

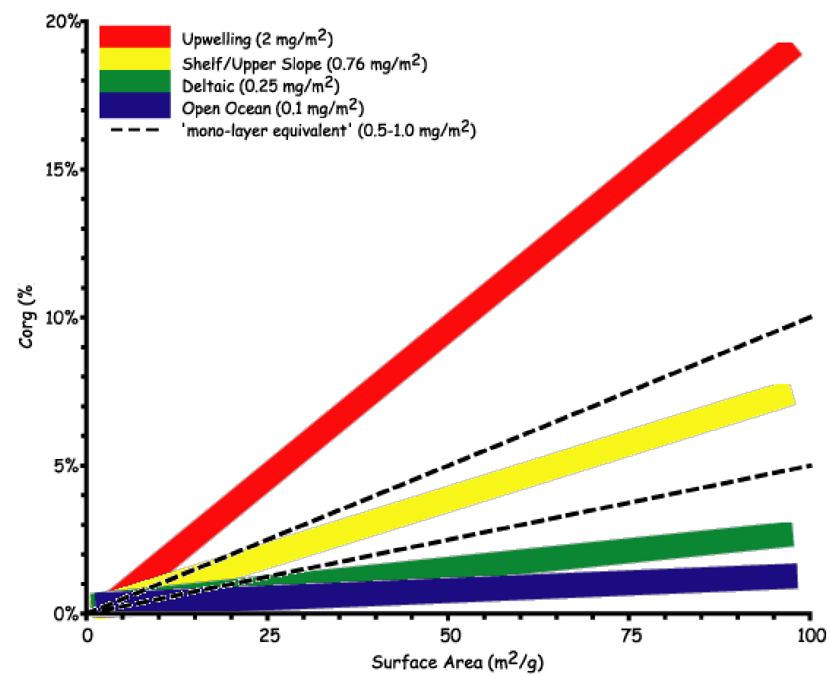
Challenges for estimating fluxes at whole-margin, continent-wide scales

Theme I: Carbon burial in sediments – Key Variables

- Sediment supply
  (burial/mineral surface area)
- OM flux
  (magnitude/composition)
- Exposure to oxidants
  (O2, metal-oxides, etc.)
- Time scale!







Theme I: Global/regional estimates of carbon burial in sediments

Environmental processes controlling key variables

Benthic processes controlling/affecting carbon sequestration

Physical

Transport, deposition, resuspension, biological mixing of carbon-relevant materials (organic matter, sediment, dissolved oxygen)

Biogeochemical

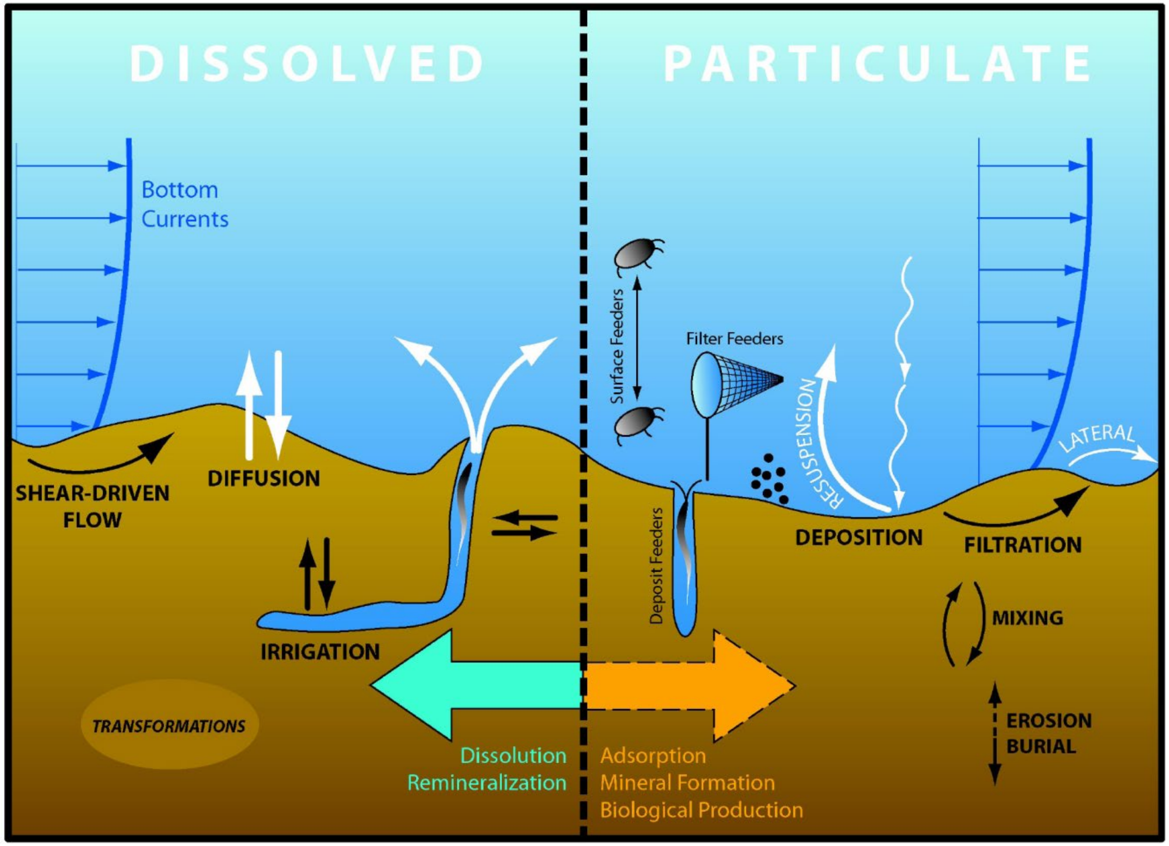
Biological production, degradation, sorption/desorption of organic materials

Observations and models for each type of process exist

i.e., Sediment transport

i.e., Sediment diagenesis

Observations and models that link Physical – Biogeochemical processes specifically are needed.

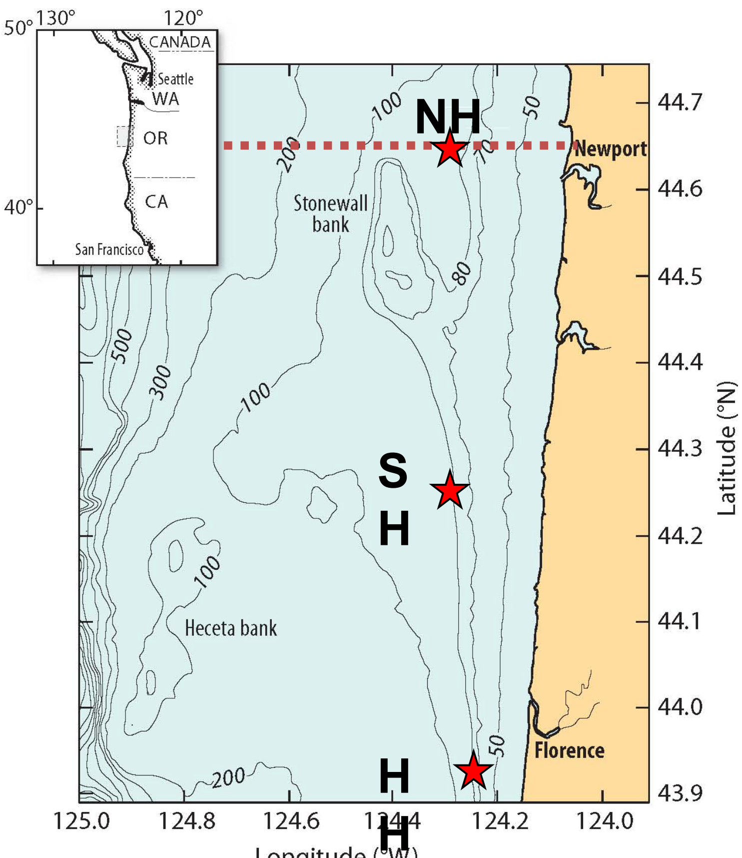


Theme II: Issue of timescales

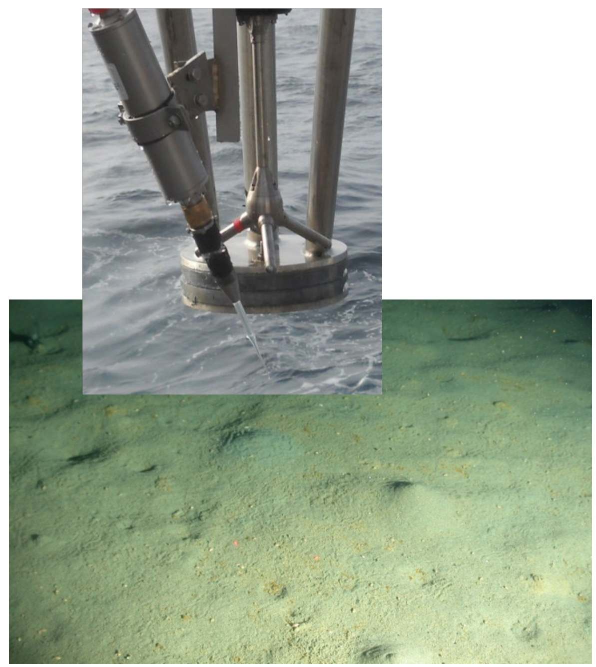
Forcings affecting benthic carbon processes in coastal ocean range from hours to decades

Wave event (hours) to Upwelling (weeks) to El Nino/La Nina (years)

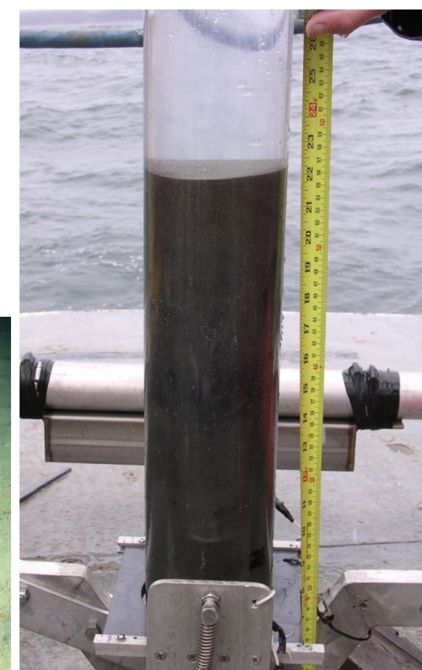
Example: Benthic O2 Consumption (Clare Reimers)



Oxygen Flux by Eddy Correlation Method (after Berg et al. 2003)

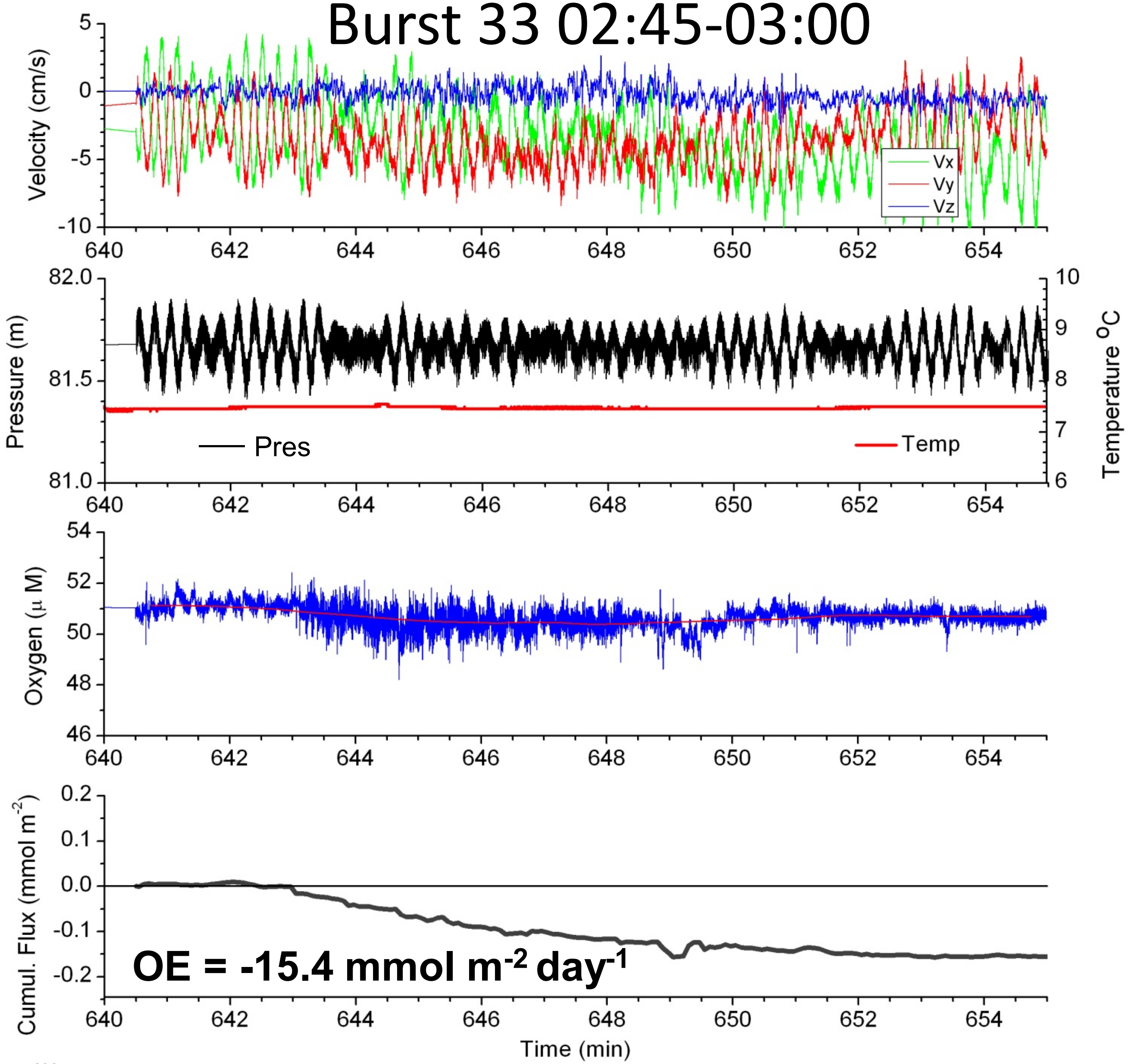


Traditional Porewater Diffusion Method



Example of Time series data (currents, waves, oxygen and flux)

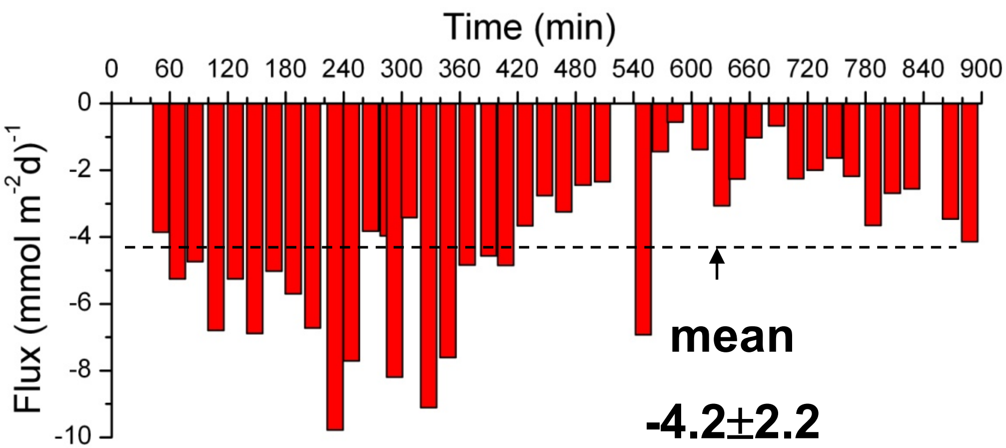
Burst 33 02:45-03:00



$\Sigma(V_z'C'dt)$

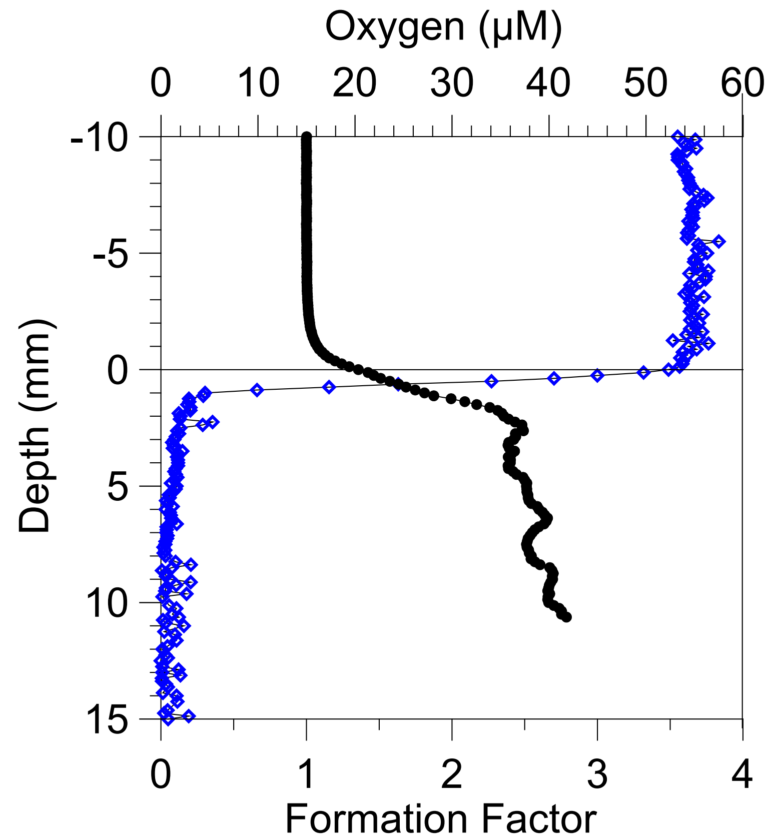
Eddy Flux vs. Diffusive

EC Fluxes



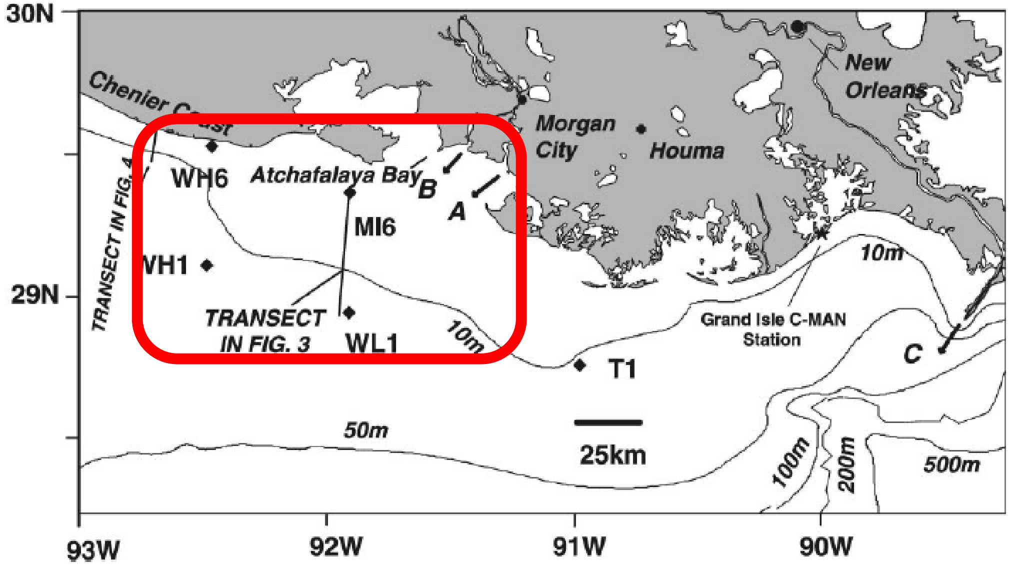
Using Fick's Law

DOU = -3.2 mmol m^{-2} day^{-1}

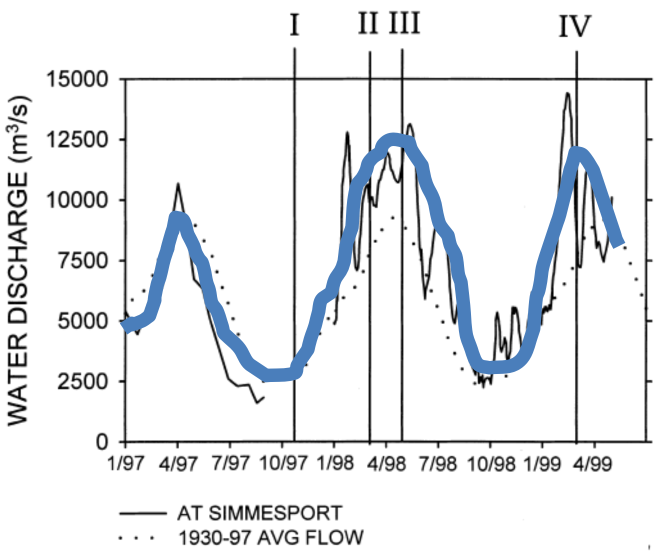


Example of seasonal vs. decadal accumulation rates off Atchafalaya River (Allison et al. 2000; Gordon et al., 2001)

➔ **Seasonal vs. long-term (100 yr time span) accumulations vary by an order of magnitude**



Seasonally Contrasting Discharge

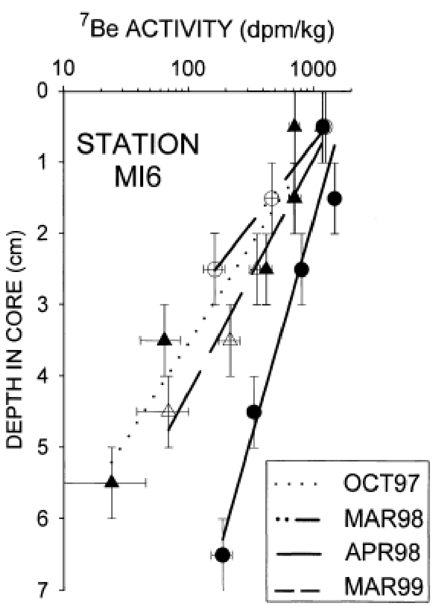


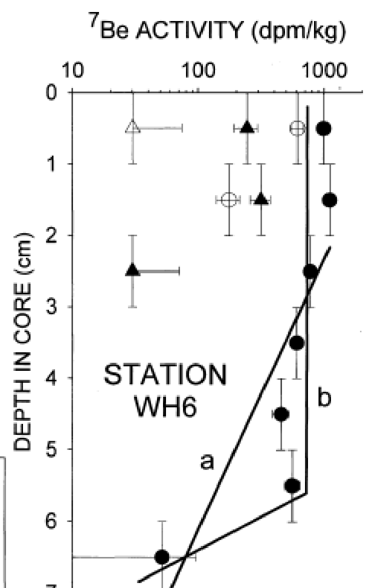
Approach:

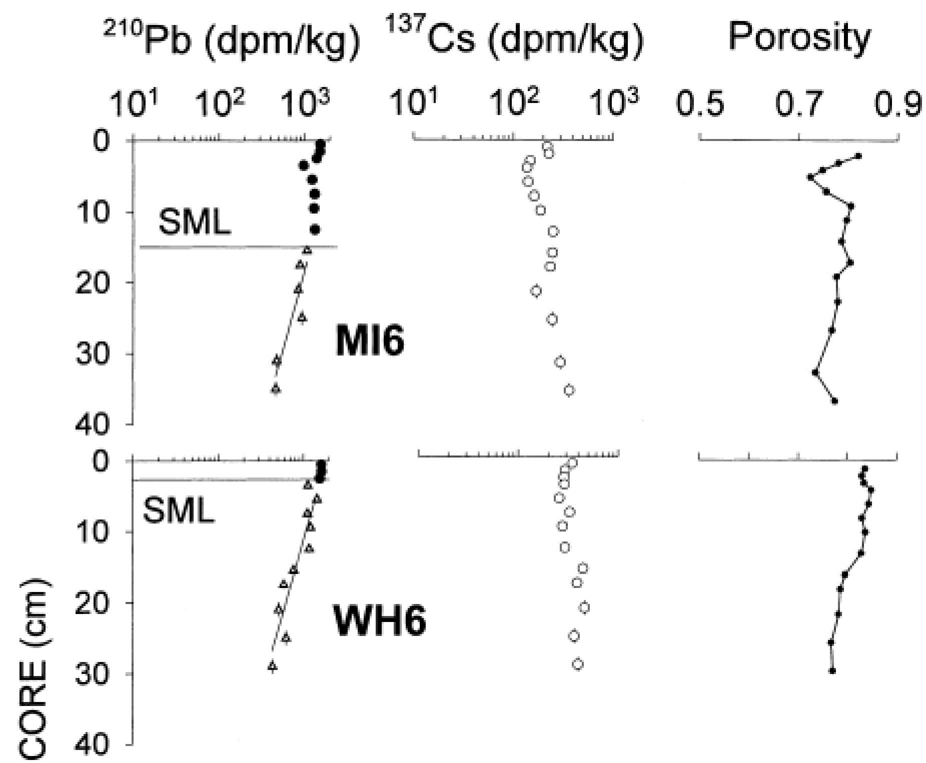
- *Collected cores at different locations during different cruises (I-IV) of contrasting oceanographic and discharge conditions*
- *Measured accumulation rates using radionuclides of contrasting half-lifes (i.e. different time spans; Be-7 vs. Pb-210)*

Ranges in seasonal vs. decadal accumulation rates

Location	Seasonal Sed. Rate High Q	Seasonal Sed. Rate Low Q	Long-Term Sed. Rate (~100 y timescale)
Inshore	10 – 14 cm/y	4 – 6 cm/y	0.5 – 0.7 cm/y
Offshore	2 -4 cm/y	1 – 4 cm/y	0.1 – 0.4 cm/y

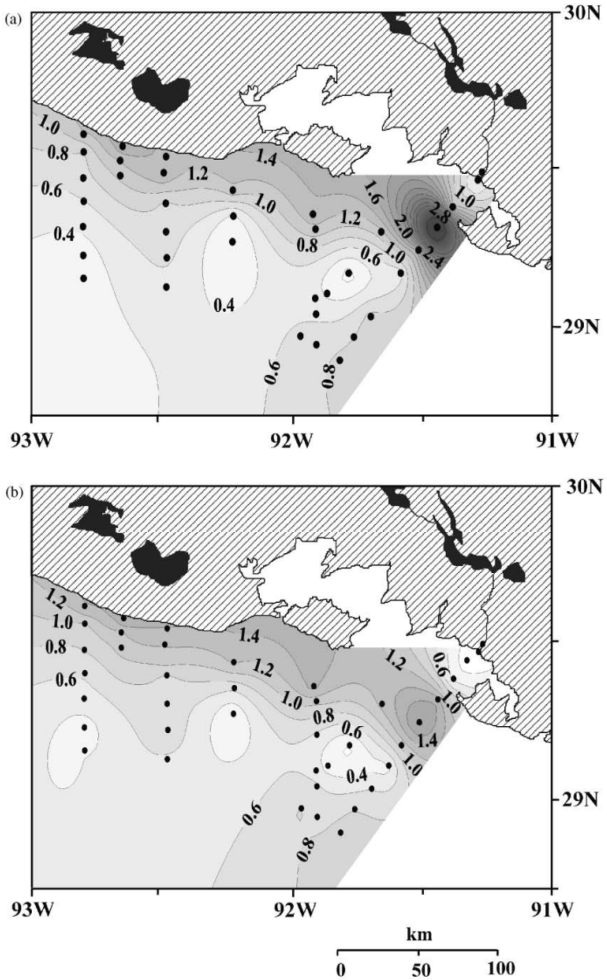




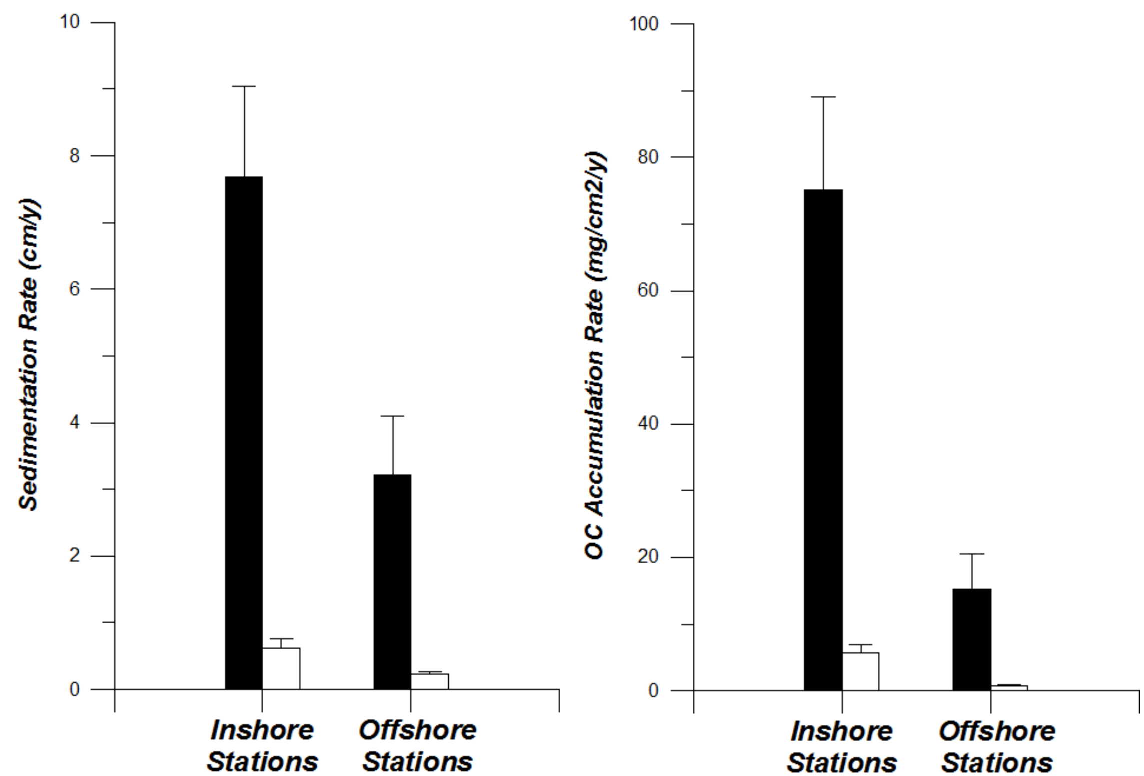


By combining measured sedimentation rates with measured organic carbon distributions ***at different spatial/temporal timescales***, we can estimate ***short- and long-term carbon burial*** rates (Gordon et al., 2001)

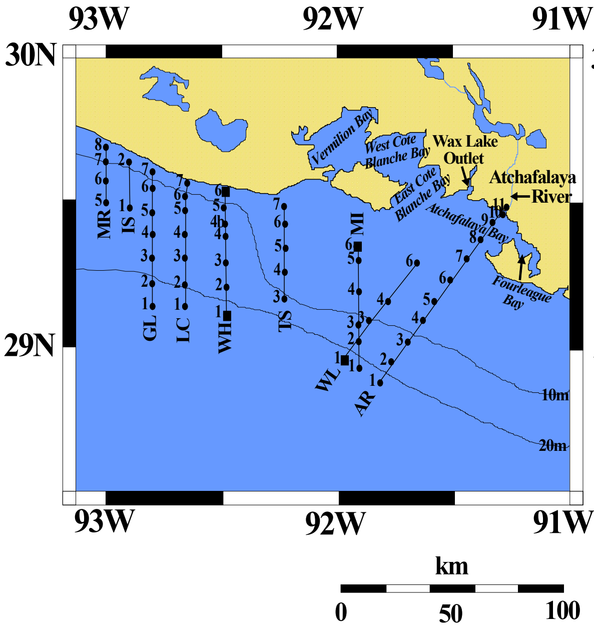
Seasonal OC Concentrations

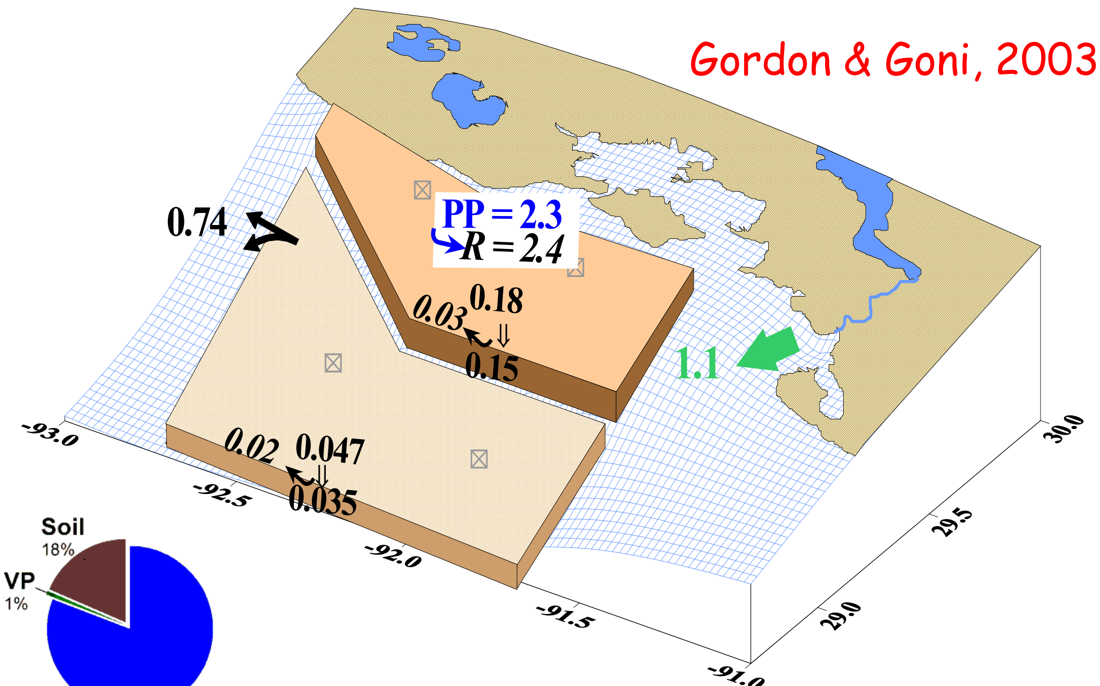


Order of Magnitude Differences in Seasonal (months) vs. Long-term (decades) Sedimentation and OC Accumulation Rates

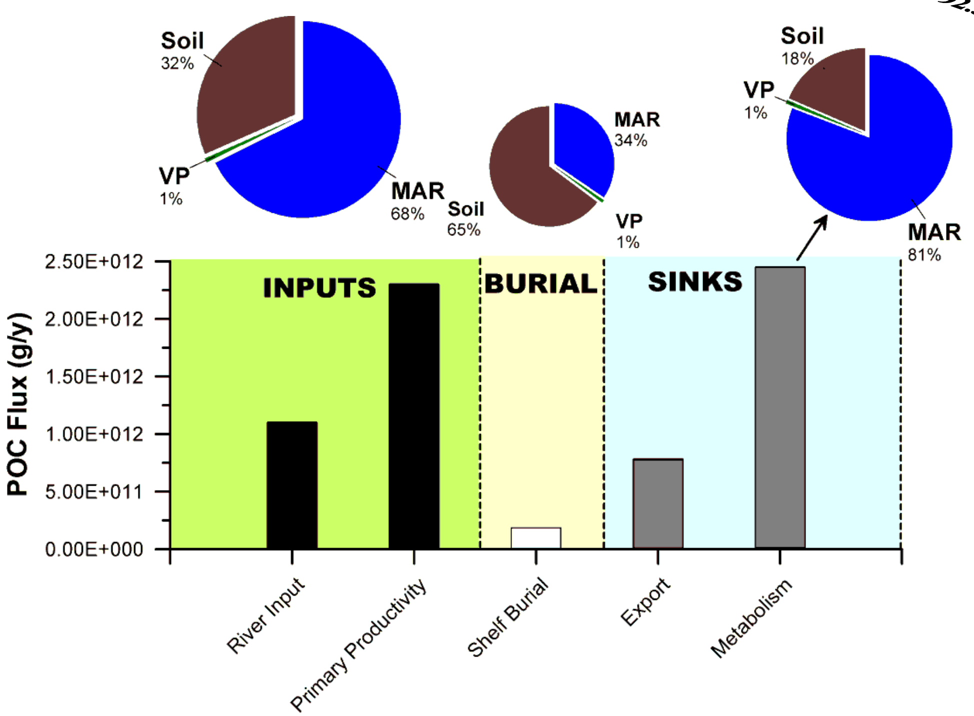


Published Regional Fluxes are Long-Term Estimates!





Gordon & Goni, 2003



Burial – dominated by terrestrial soil OC

Mineralization – dominated by respiration of marine

Export –composed of soil OC

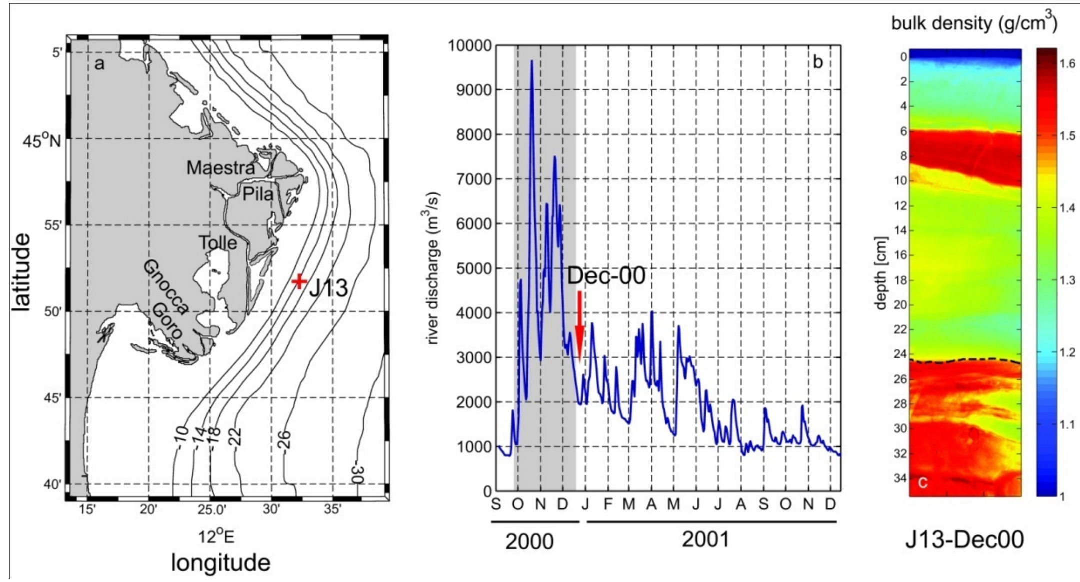
Theme II: Issue of timescales

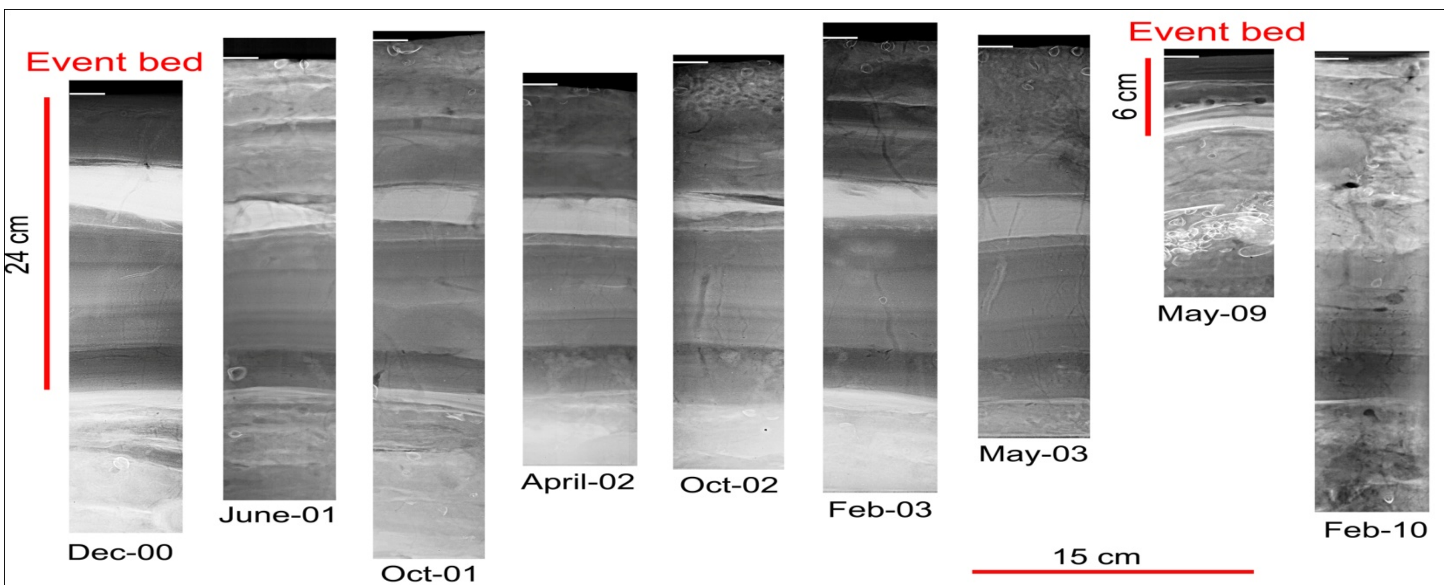
Challenge in reconciling measurements at different timescales

Is the carbon sediment sink at steady state?

Example of Po River Delta core evolution and ultimate fate of Carbon in sediment sink (Tesi et al., submitted)

100-year flood in Po River Produced a 24-cm thick deposit that was studied over a 10 year period

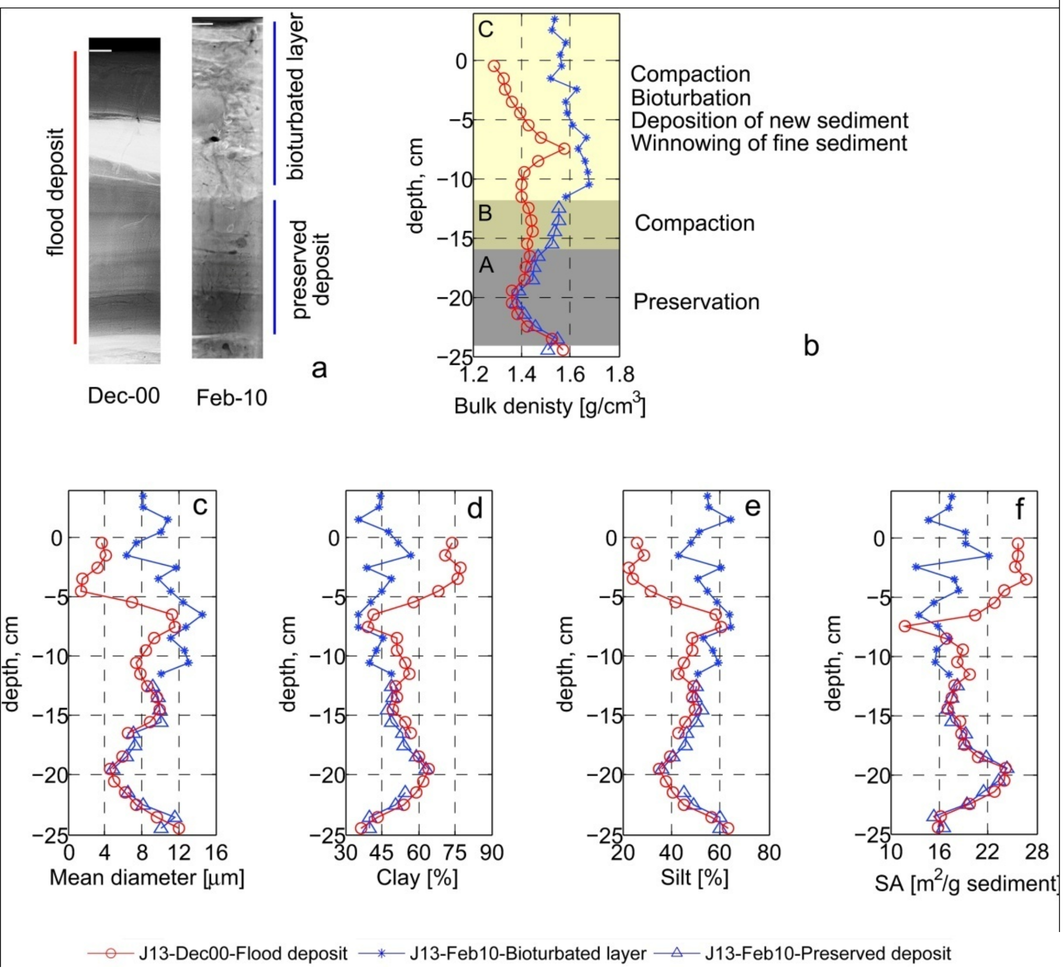


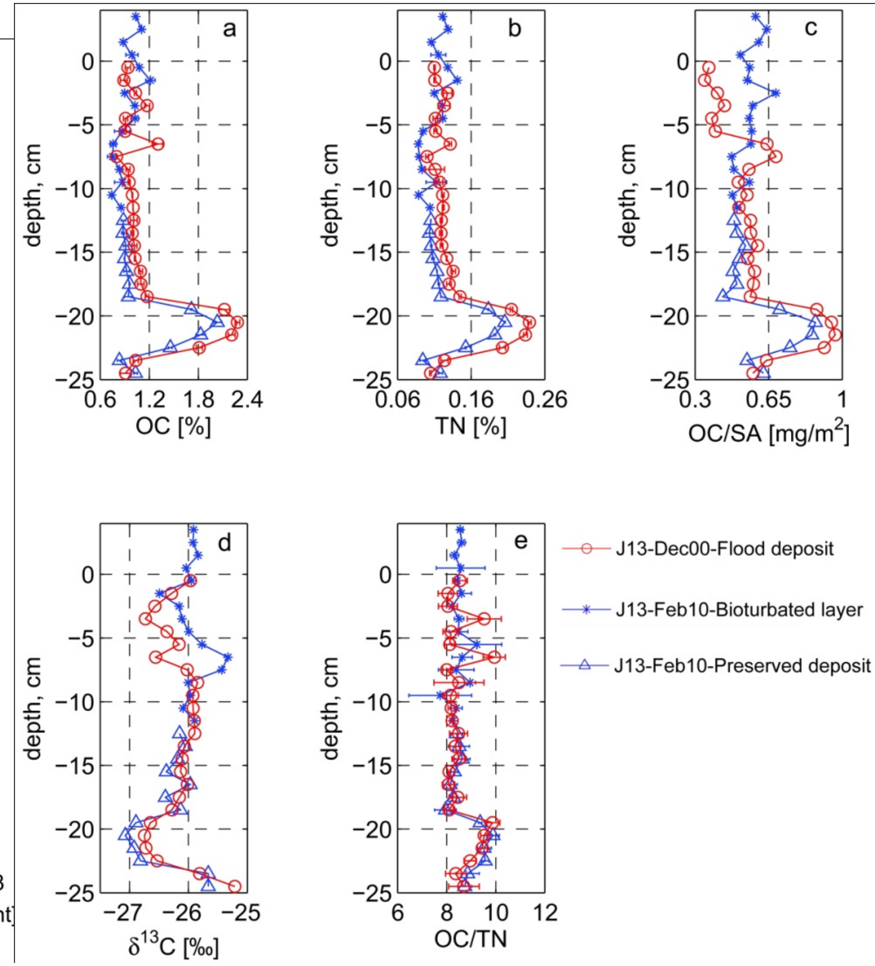


Physical processes and biological activity changed texture and carbon content/composition of surface horizons of deposit

➔ ***Mixing, winnowing, degradation***

Microbial biological activity changed the carbon content/composition of deeper horizons ➔ ***Preferential degradation of labile materials***





Theme II: Issue of timescales

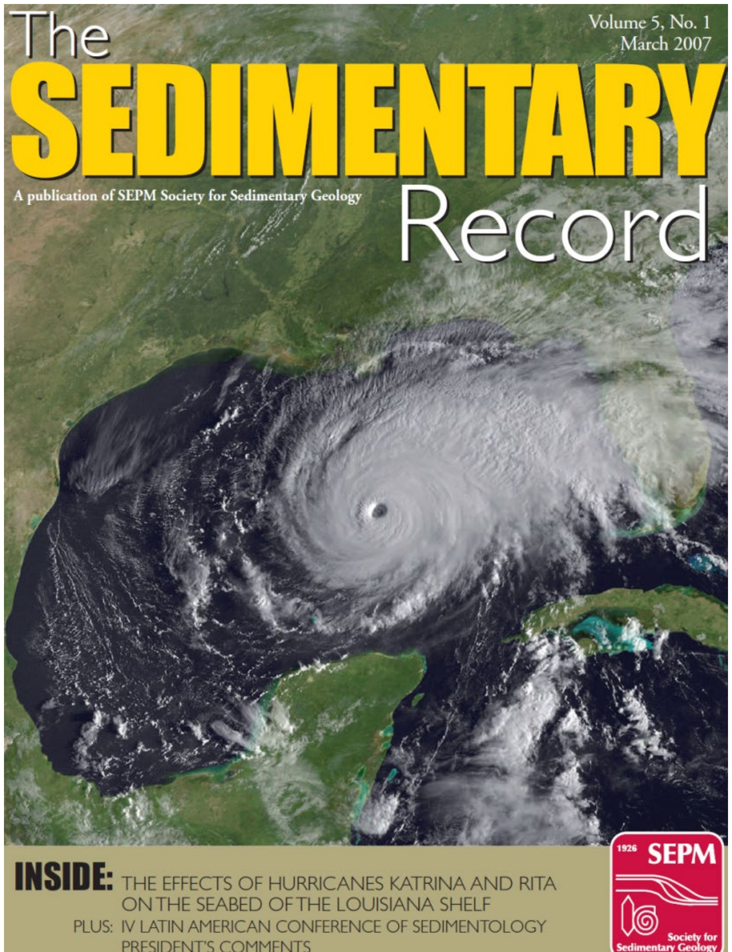
Role of events at all timescales (days to decades/centuries) in Carbon Burial

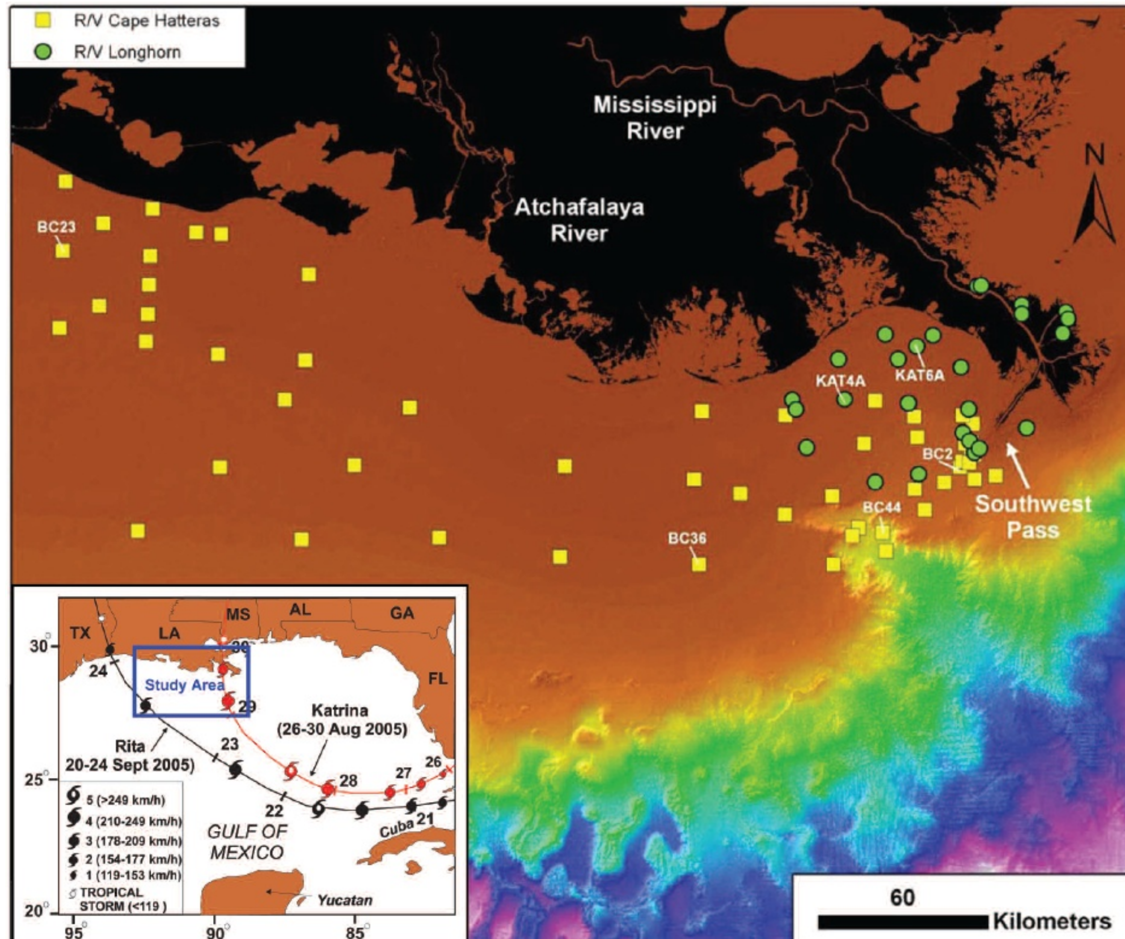
Examples: wind-driven upwelling, storms, floods, earthquakes

The carbon sediment sink is not at steady state at these scales!

Example of Hurricanes (Katrina/Rita accumulations)

Goni et al., 2007; Dail et al., 2007; Corbett et al. unpub.





Effect of hurricanes were order of magnitude higher than ‘steady-state’

Storm Deposit Thicknesses

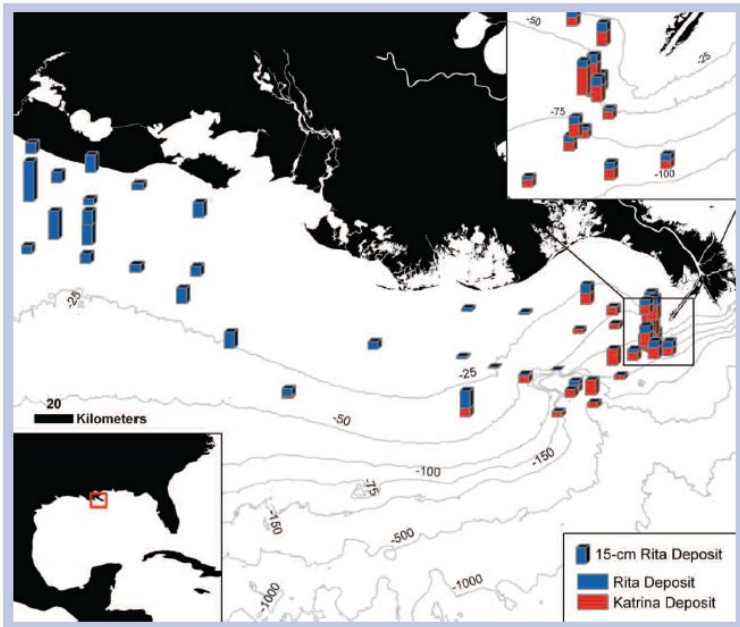


Figure 2. Map illustrating the thickness of sediment deposits associated with Hurricanes Katrina and Rita.

Rates of Storm-induced Accumulations

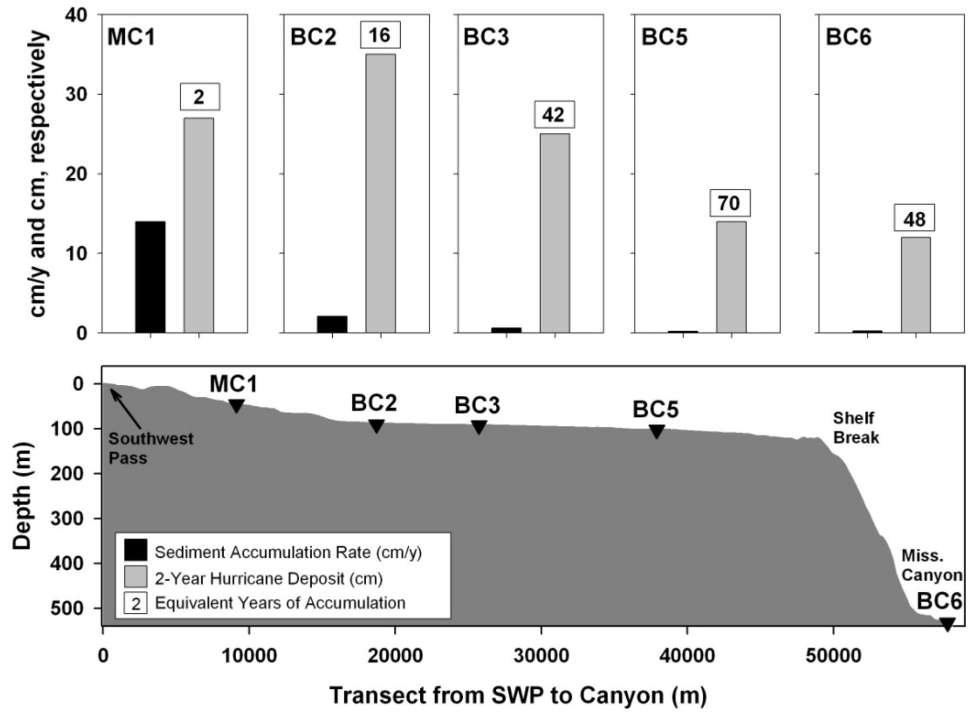


Table 1. Estimates of total mass accumulation of sediment, organic carbon and nitrogen on the seabed due to the combined Rita and Katrina events in contrast to annual inputs by rivers and regional primary production.

	Sediment	Organic Carbon	Nitrogen
Rita/Katrina Accumulations (g)	$1.16x10^{15} \pm 1.56x10^{14}$	$1.36x10^{13} \pm 2.46x10^{12}$	$1.56x10^{12} \pm 2.5x10^{11}$
Annual Inputs (g/y)			
Combined Mississpi/Atchafalaya Rivers	$2.16x10^{14}$	$3.62x10^{12}$	$3.96x10^{11}$
Regional Net Primary Production		$1.05x10^{13} \pm 3.82x10^{12}$	$1.74x10^{12} \pm 6.36x10^{11}$
Non-Hurricane Accumulations (g/y)	$1.18x10^{14}$	$1.17x10^{12}$	$1.40x10^{11}$

Seabed accumulation rates account for the porosity values measured in storm and non-storm deposits.
Estimates of annual inputs (river discharge and primary productivity) and of non-hurricane accumulations are from Gordon and Goni, 2004.

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Challenges for estimating fluxes at whole-margin, continent-wide scales

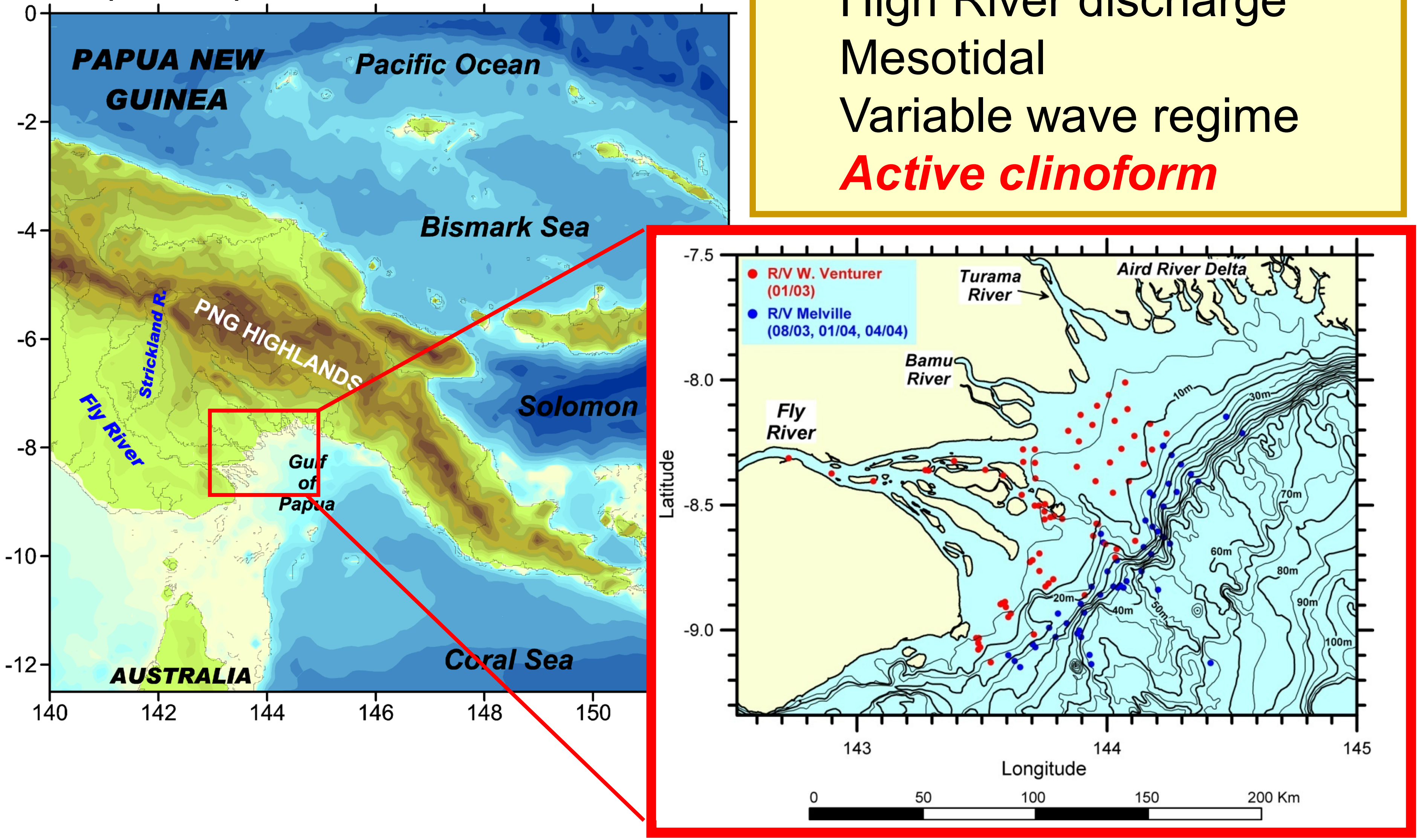
Theme III: Spatial heterogeneity

Carbon contents, compositions and burial rates not evenly distributed along/across margins

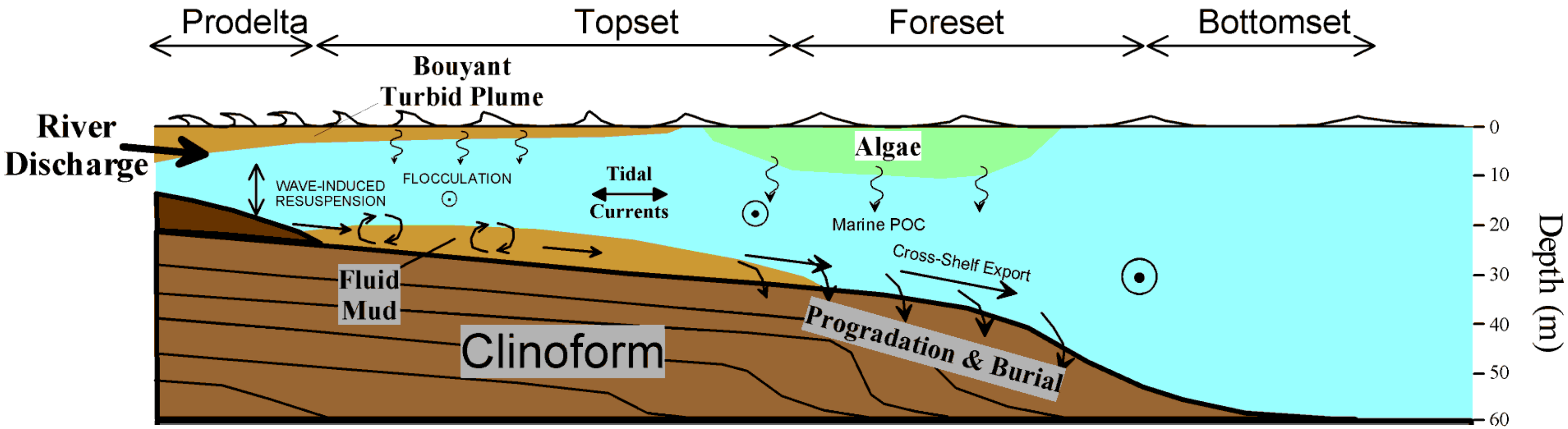
NW Gulf of Papua

- High River discharge
- Mesotidal
- Variable wave regime
- *Active clinoform*

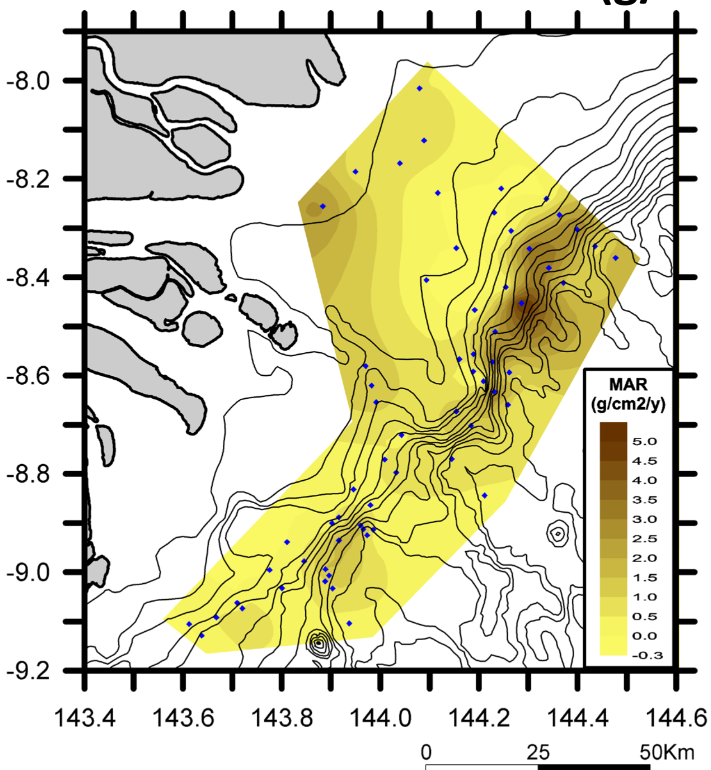
Examples: Papua New Guinea



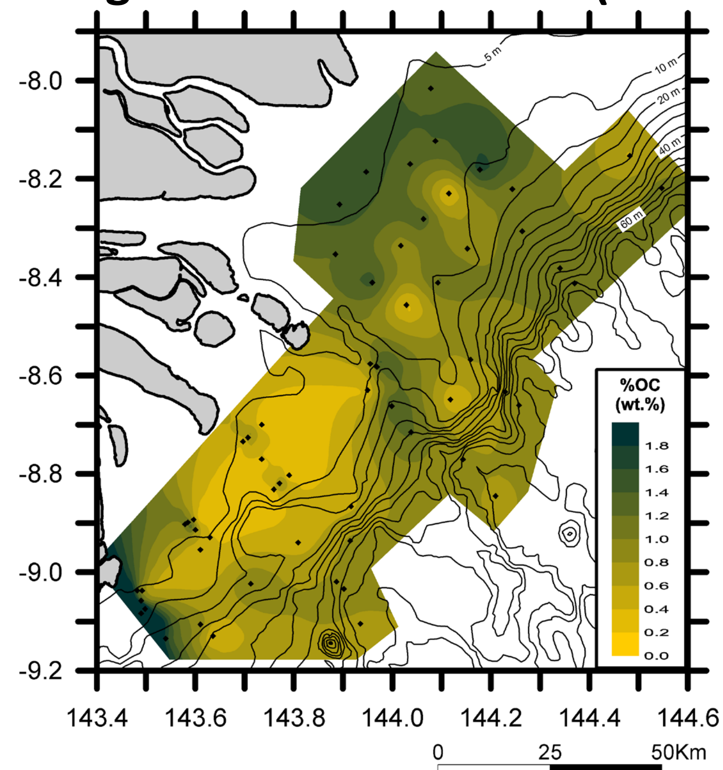
Particle Transport Processes



Mass Accumulation Rates (g/cm²/y)



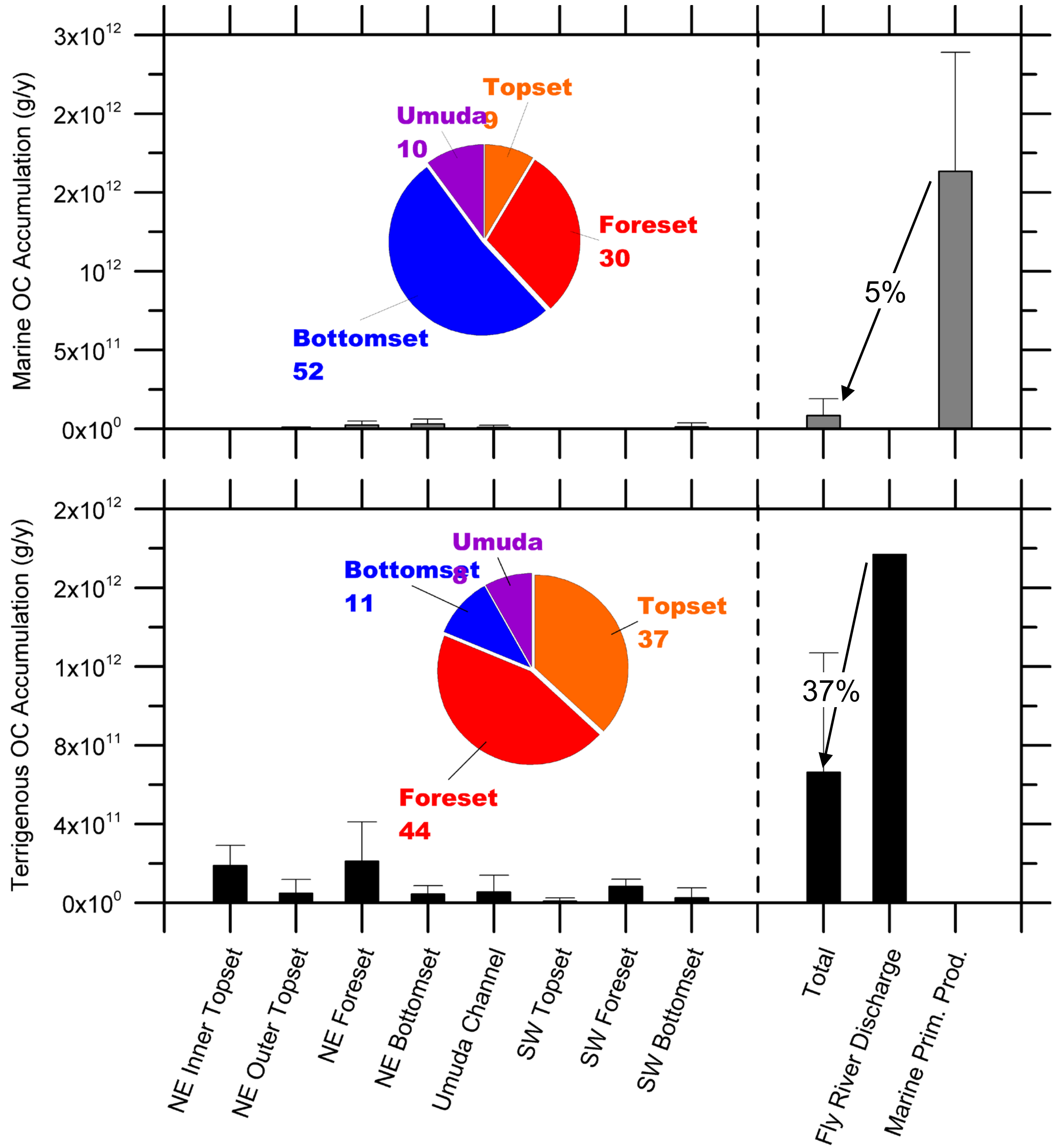
Organic Carbon Content (wt.%)



Terrigenous & Marine OC Accumulation Fluxes

Marine OC Fluxes

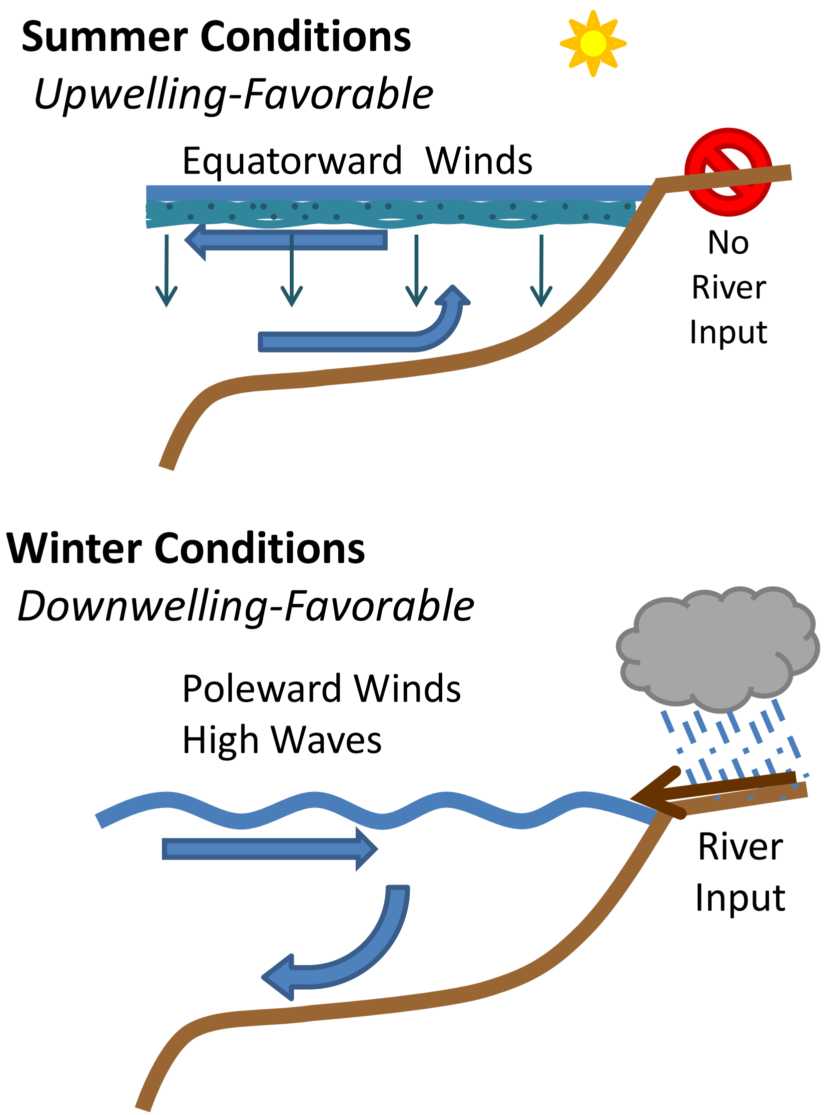
Terrigenous OC Fluxes

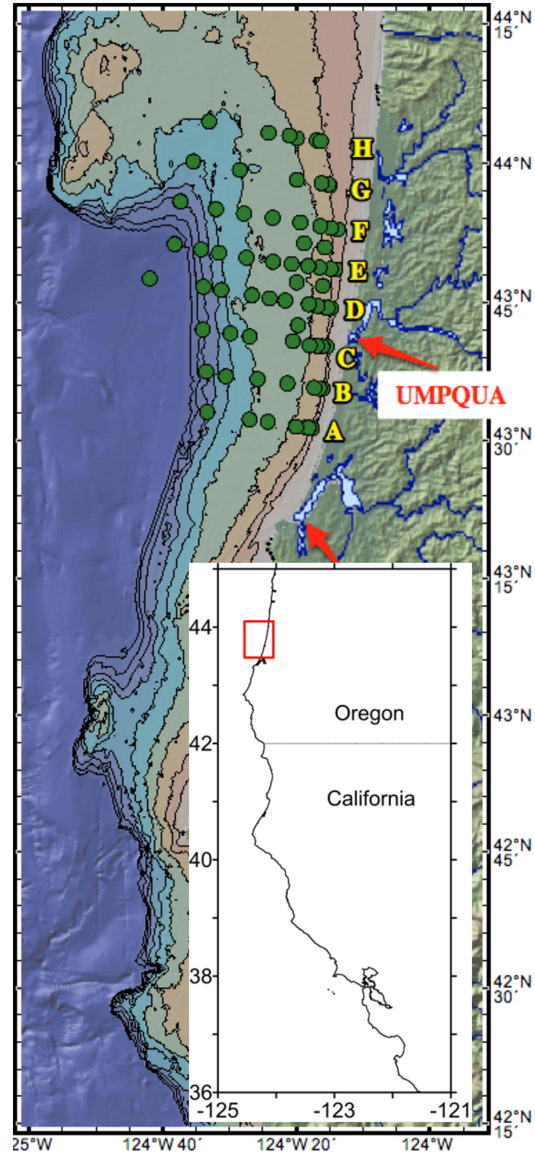


Theme III: Spatial heterogeneity

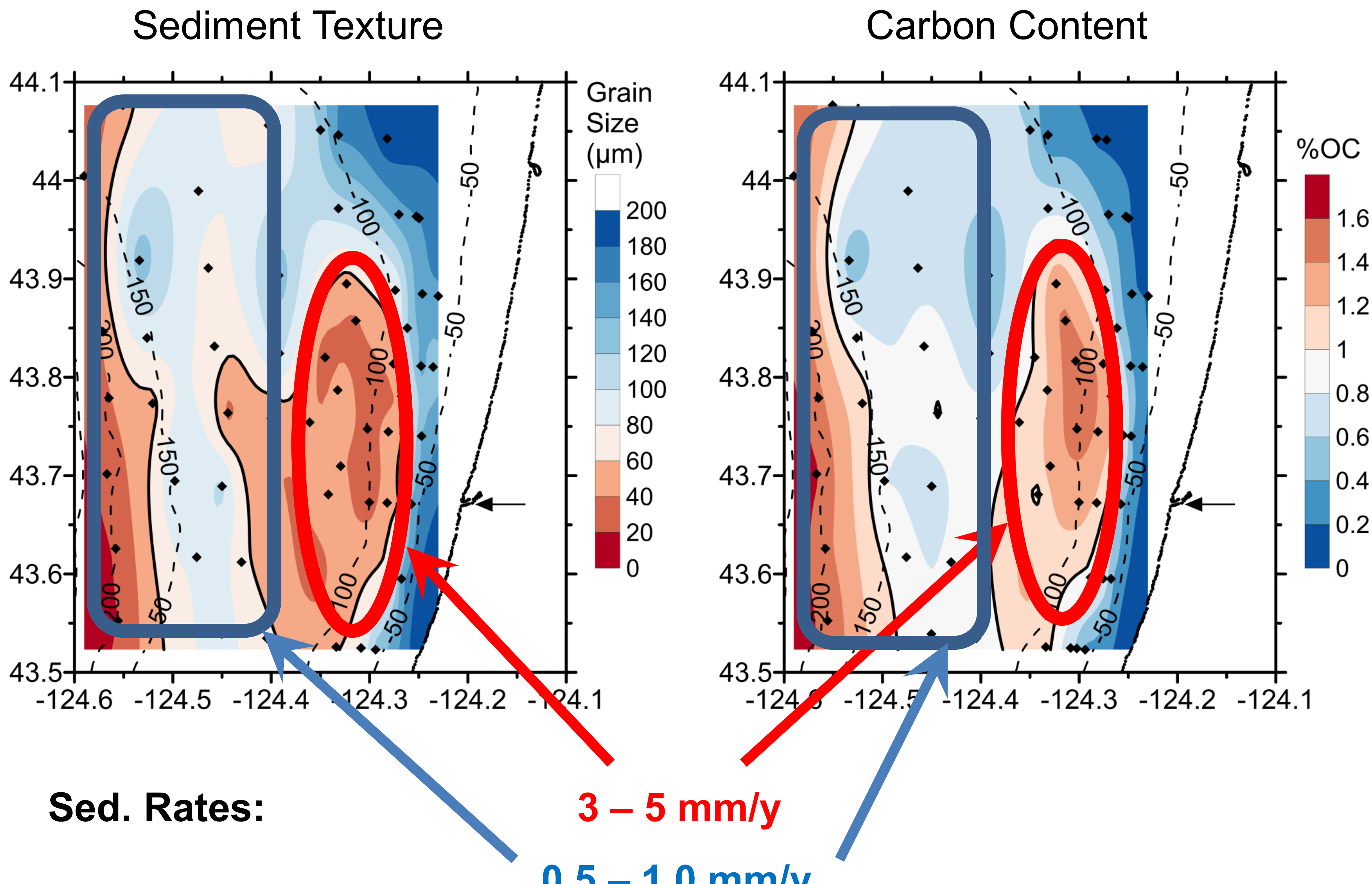
Importance of magnitude and composition of sediment and OM supply

-- Role of rivers in supplying fine sediments to enhance allochthonous and autochthonous OM accumulations. Umpqua shelf.



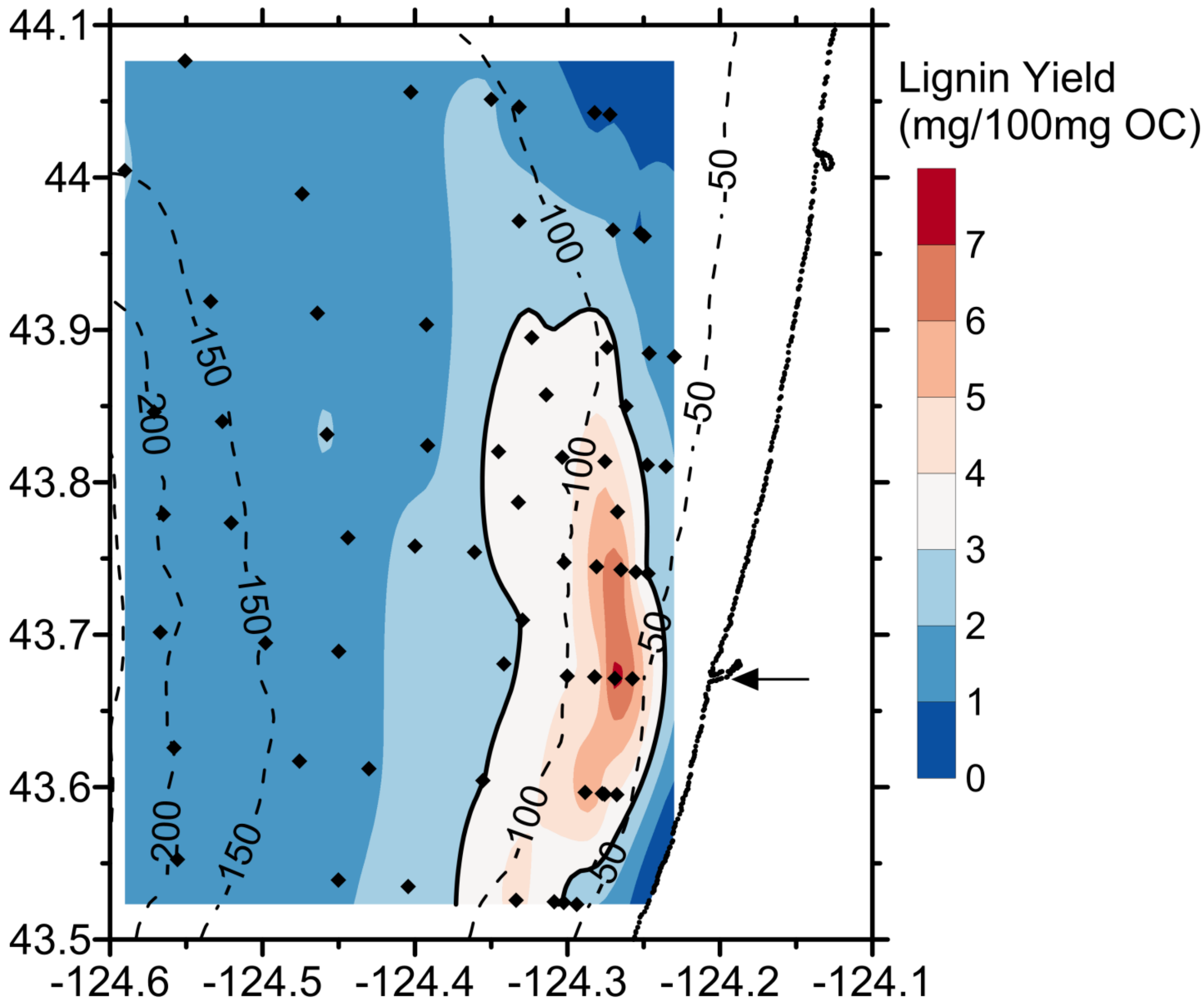


Sediment & Carbon Distributions
➔ River Depocenter



Shape of Carbon Depocenter Regulated by:

Fluvial Inputs (High Terrigenous Character) AND
Physical processes (coherence between discharge and waves/currents)



Future Needs to Integrate Benthic Processes/Fluxes with rest of NACM Efforts

Observations at appropriate (i.e., multiple) temporal scales

Seasonal, event –scale measures of carbon sediment sink

Observations at appropriate (i.e. multiple) spatial scales

Integration of chemical and geological variability (i.e. sediment types, accumulation rates)

Model-Data Integration

Combine observations and models of sediment dynamics with observations and models of biogeochemical cycling

Integrate observations and models at different time scales

- Upscale short-term observations to annual, multi-annual scales
- Decipher the relationships between decadal scale sediment records with shorter time scale processes in the water column

Theme III: Spatial heterogeneity

Importance of O2 exposure time
Keil/Harnett

Challenges for estimating fluxes at whole-margin, continent-wide scales