

Presentations

11-3-2013

**Reworking of flood deposits on the Waipaoa Shelf, New Zealand:
buoyant and gravity-driven fluxes**

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Moriarty, J. M.; Harris, C. K.; Friedrichs, C. T.; and Hadfield, M. G.. "Reworking of flood deposits on the Waipaoa Shelf, New Zealand: buoyant and gravity-driven fluxes". 11-3-2013. 22nd Biennial Conference of the Coastal & Estuarine Research Federation, San Diego, CA.

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Gravity-Driven Transport on the Waipaoa River Continental Shelf, NZ

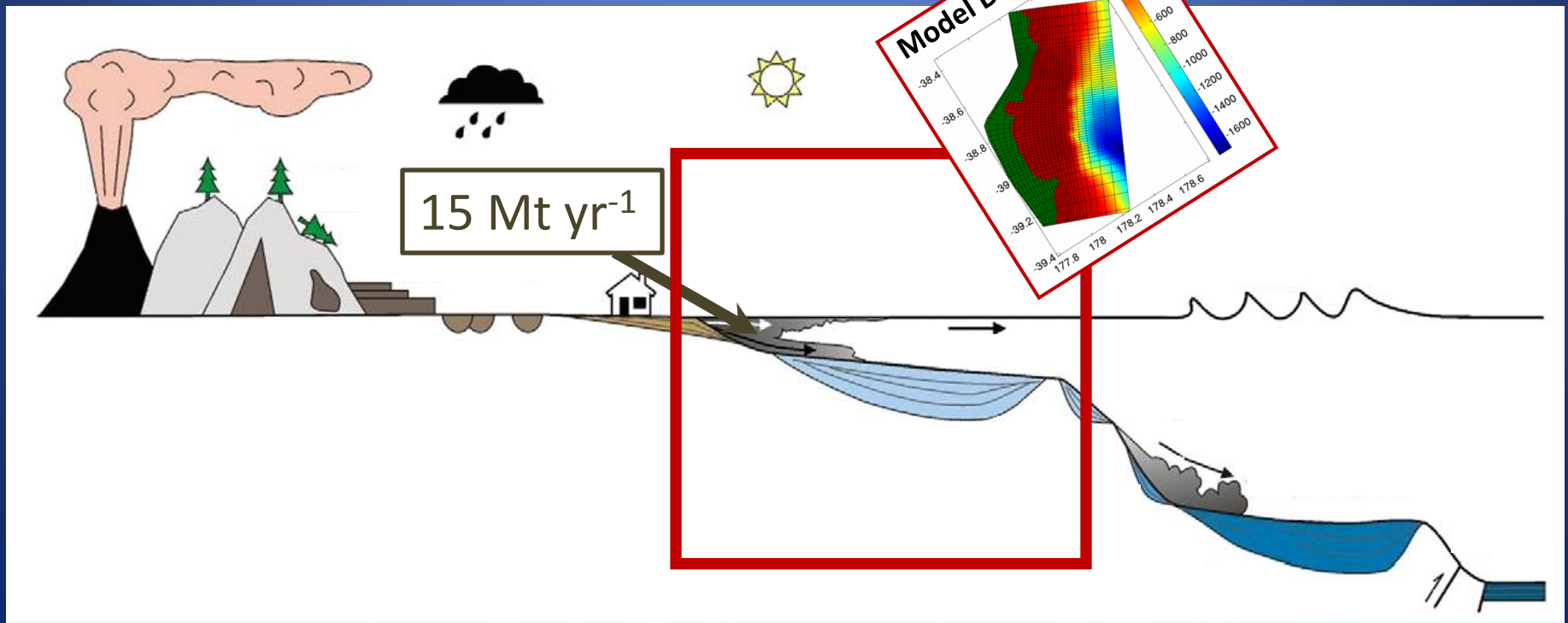
Julia Moriarty
Courtney Harris
Carl Friedrichs
Mark Hadfield

6 November 2013 --- Coastal & Estuarine Research Federation Biennial Meeting

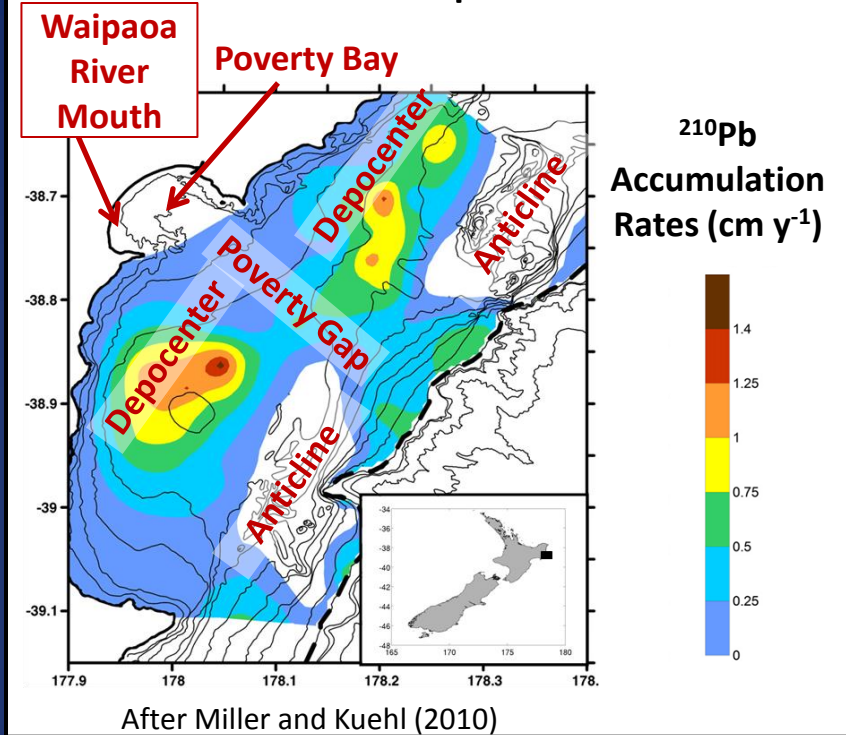


A Source-to-Sink Study: the Waipaoa River

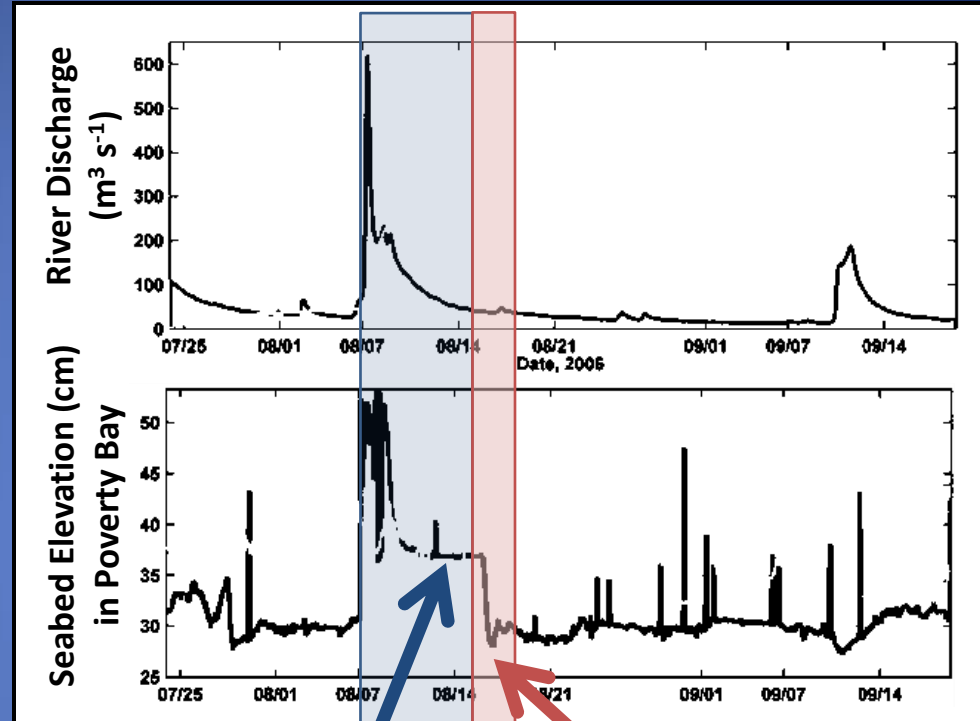
- NSF MARGINS program
 - How are flood deposits formed and reworked on the Waipaoa continental shelf over thirteen months?



Long-term accumulation in two shelf depocenters



How is sediment transported to shelf depocenters?

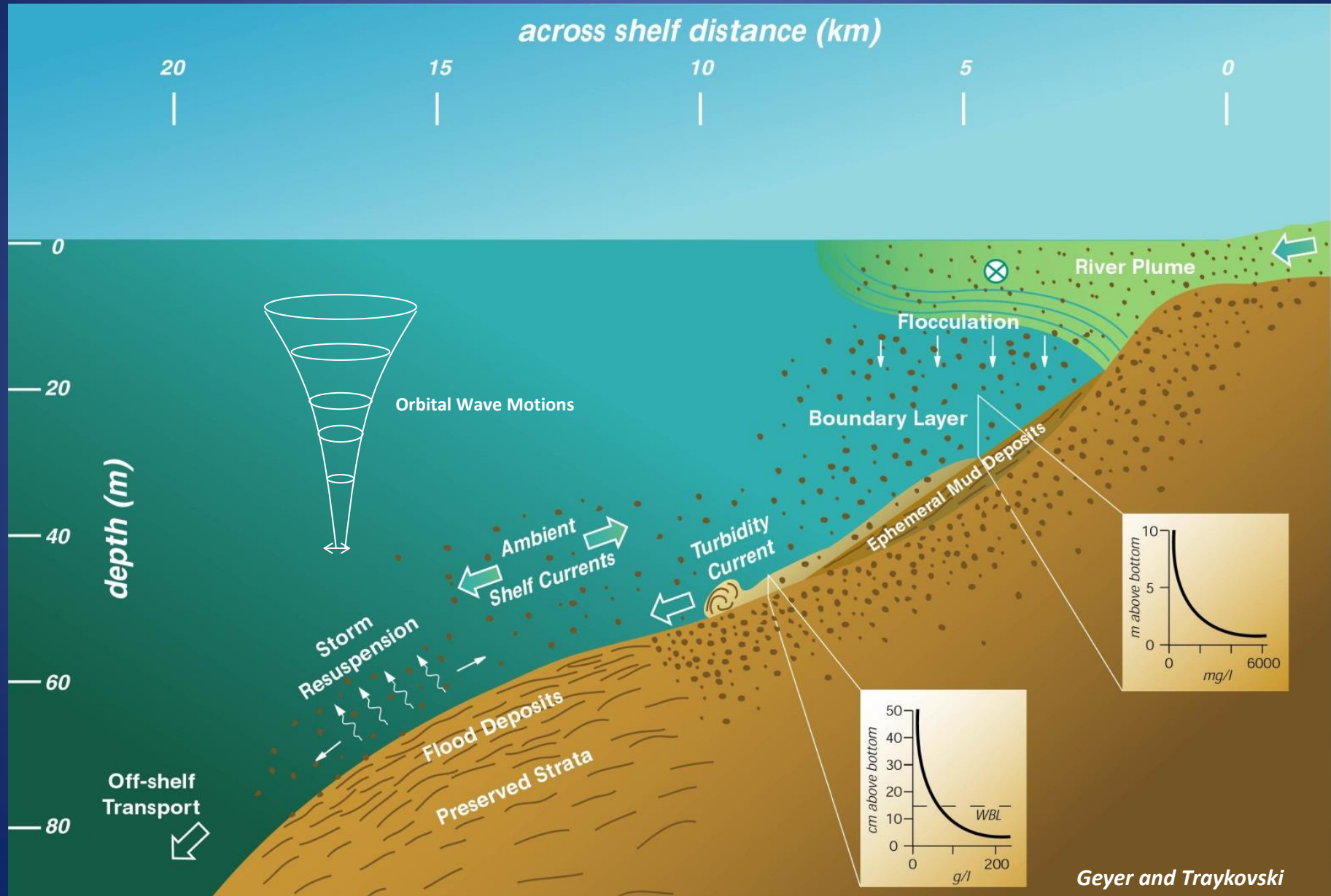


After Bever et al. (2011)

Temporary deposition following floods.

Sediment exported from Poverty Bay during wave event.

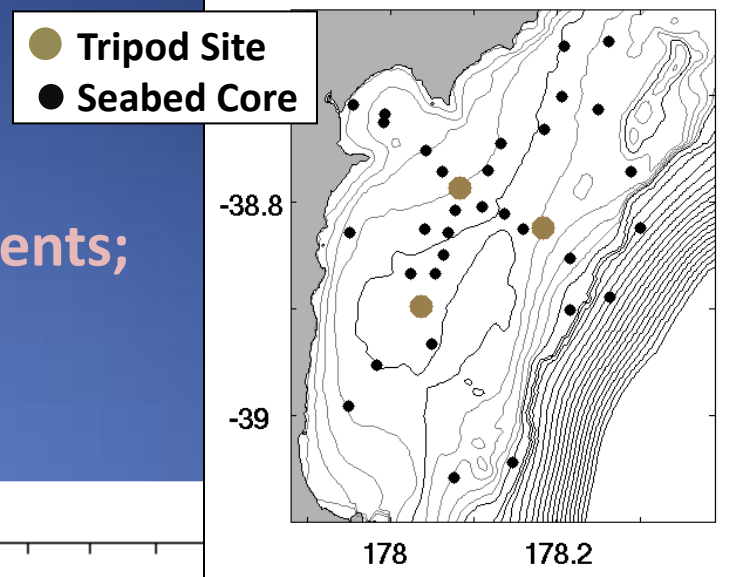
Continental shelf processes include gravitational forcing, in addition to plume delivery and wave/current resuspension



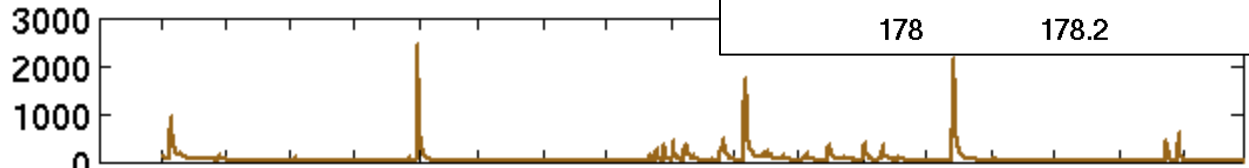
Waipaoa Shelf Initiative:

Jan. 2010 – Feb. 2011

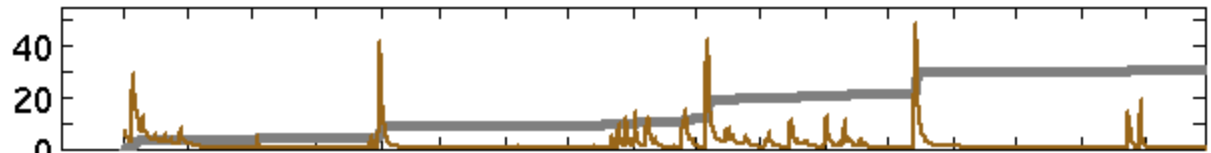
- Seabed and hydrodynamic measurements;
Numerical modeling effort
- Two 8-year floods, wave events



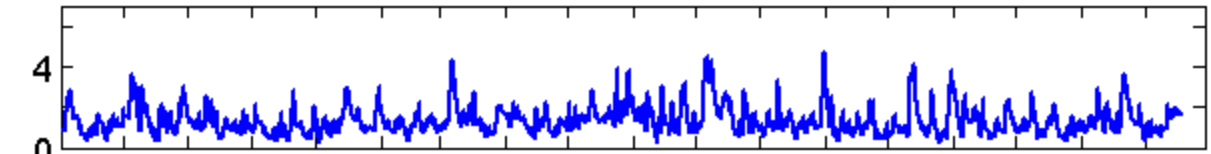
Water Discharge ($\text{m}^3 \text{s}^{-1}$)



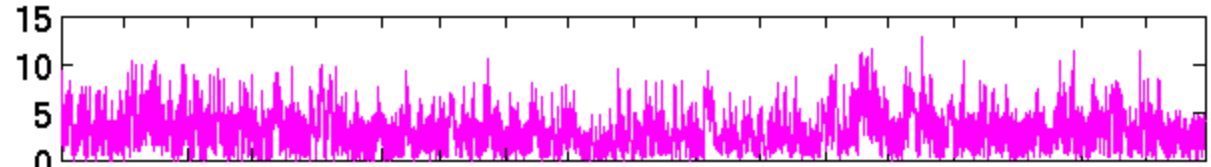
**Sediment Concentration
(g L^{-1})**



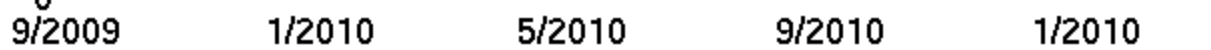
**Cumulative Sediment Input
(million metric tons)**



Sig. Wave Height (m)



Wind Speed (m s^{-1})

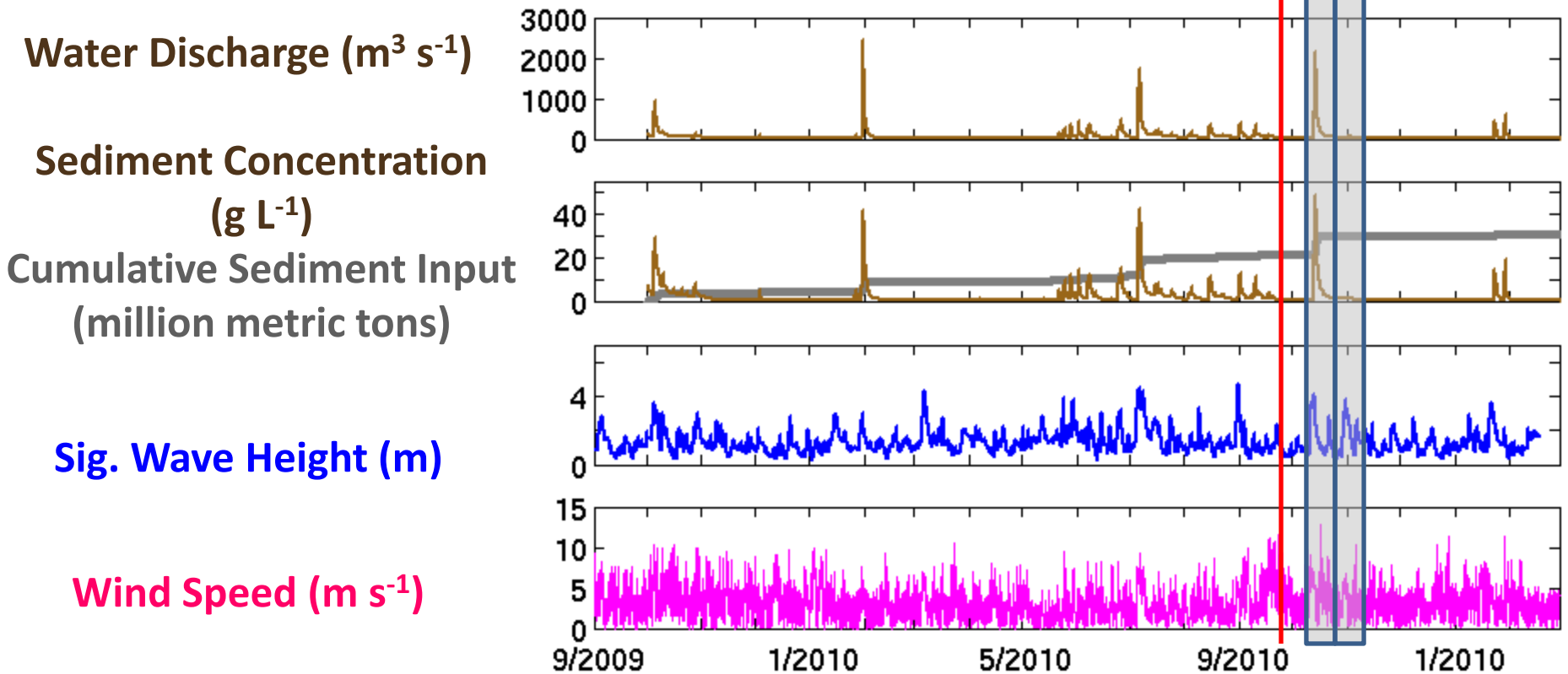


Waipaoa Shelf Initiative:

Jan. 2010 – Feb. 2011

- Seabed and hydrodynamic measurements;
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September Observations
Flood
High Wave Event

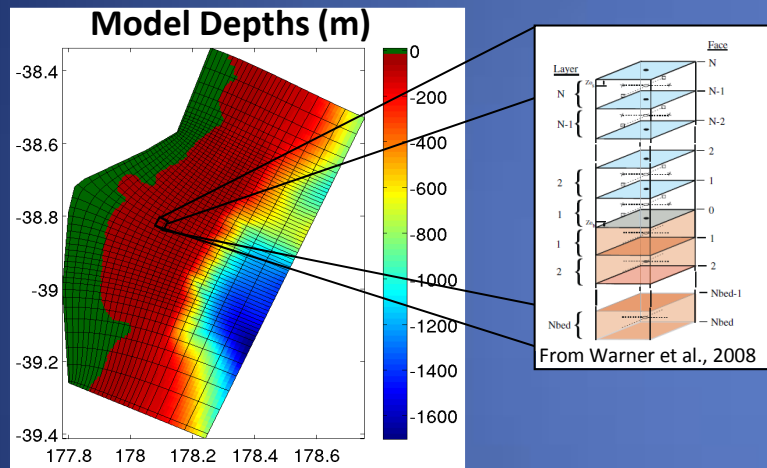


Approach: Two Models

ROMS-CSTMS

CSTMS: Warner et al., 2008

ROMS: Haidvogel et al., 2000; 2008;
Shchepetkin and McWilliams, 2005, 2009;

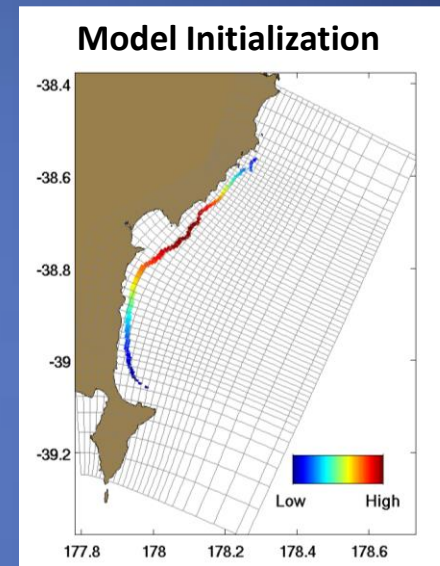


PROS: Includes water column processes, including river plume behavior, wave resuspension

CONS: Insufficient vertical resolution for wave-current boundary layer

Gravity-Flow Model

Scully et al., 2003; Ma et al., 2010



PROS: Accounts for near-bed turbid layer; computationally efficient

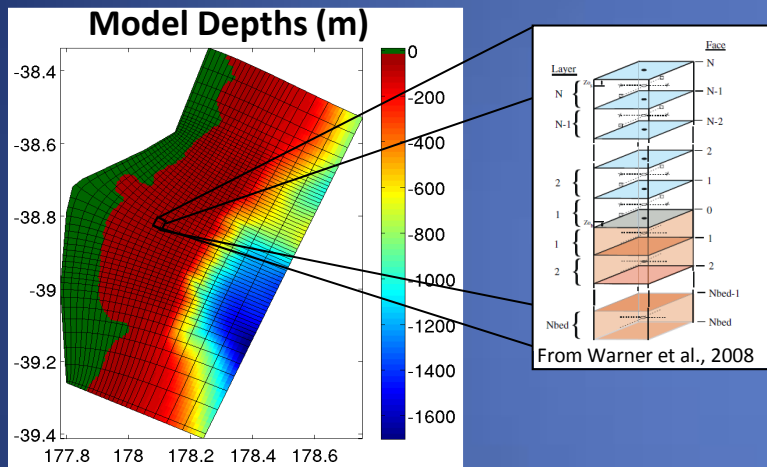
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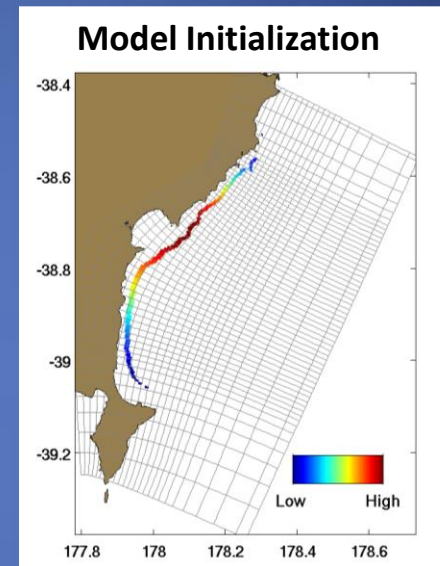
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ROMS-CSTMS Model

Regional Ocean Modeling System (ROMS) - Community Sediment Transport Modeling System (CSTMS)

- Community-developed, primitive equation, finite volume numerical model with model nesting capabilities
- Accounted for waves, wind, tides, river input, larger scale currents
- Accounted for multiple sediment classes and seabed layers, erosion, and deposition.
- Vertical resolution cannot resolve the wave-current boundary layer for larger applications

Momentum Conservation:
$$\frac{\partial \phi}{\partial z} = -\frac{\rho(T, S, P)g}{\rho_0}$$

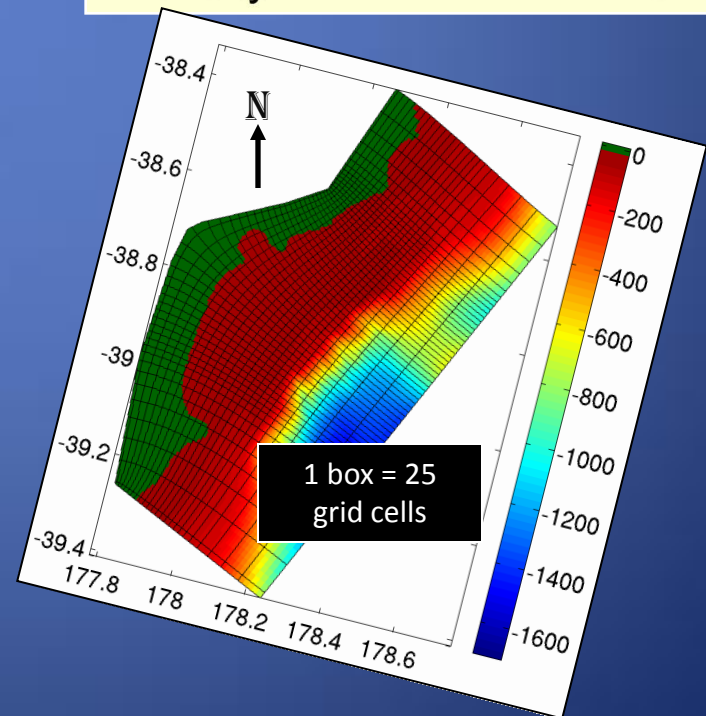
$$\frac{\partial u}{\partial t} + \bar{u} \cdot \nabla u - fv = -\frac{\partial \phi}{\partial x} - \frac{\partial}{\partial z} \left(\overline{u'w'} - \nu \frac{\partial u}{\partial z} \right) + F_u + D_u$$

$$\frac{\partial v}{\partial t} + \bar{u} \cdot \nabla v + fu = -\frac{\partial \phi}{\partial y} - \frac{\partial}{\partial z} \left(\overline{v'w'} - \nu \frac{\partial v}{\partial z} \right) + F_v + D_v$$

Mass Conservation:
$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

Tracer Concentration Conservation:
$$\frac{\partial C}{\partial t} + \bar{u} \cdot \nabla C = -\frac{\partial}{\partial z} \left(\overline{C'w'} - \nu \frac{\partial C}{\partial z} \right) + F_c + D_c$$

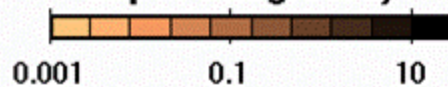
Density
$$\rho = \rho(T, S, C_s)$$



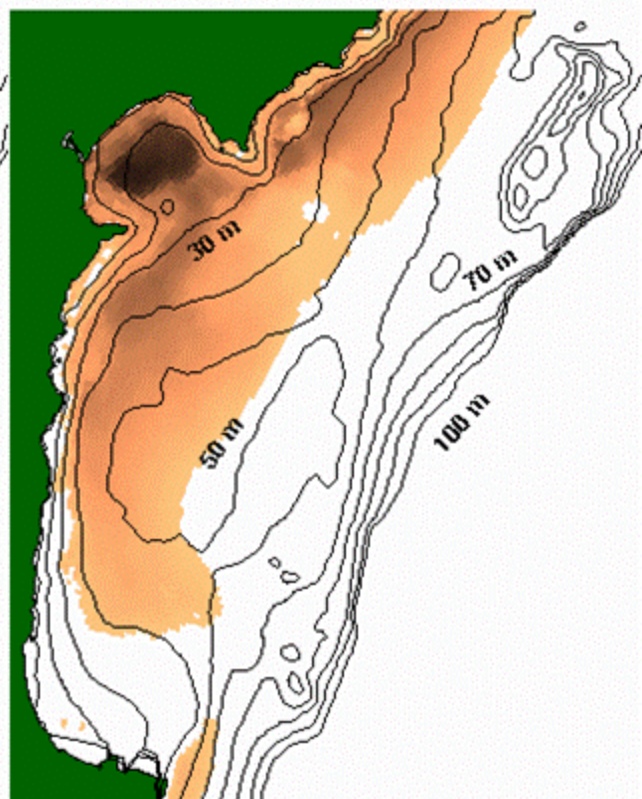
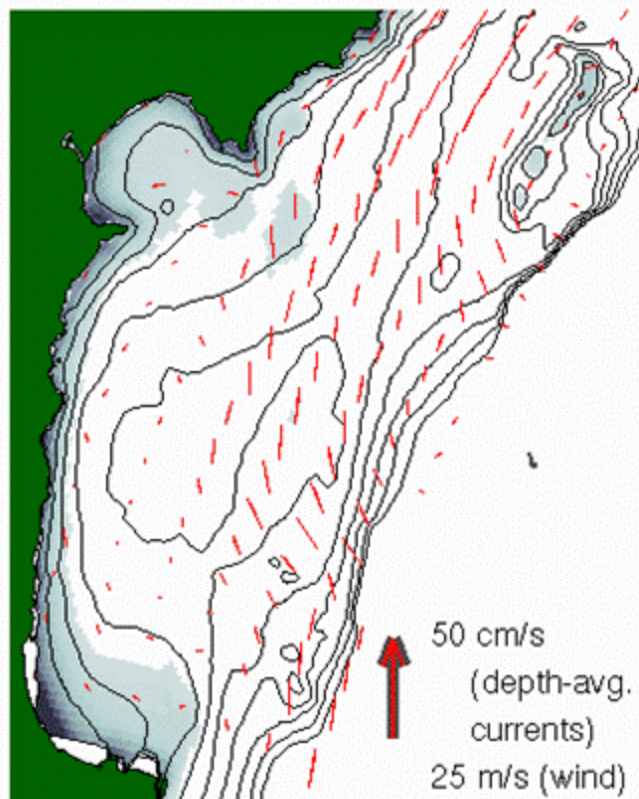
Bed Shear Stress (Pa)



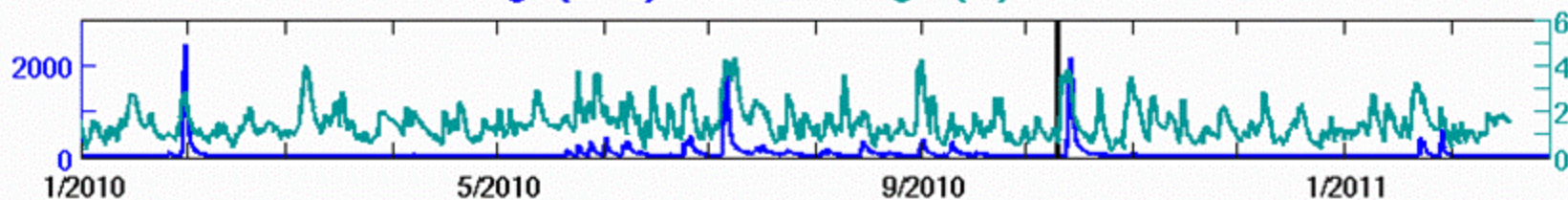
SSC (kg m^{-2} ; depth-integrated)



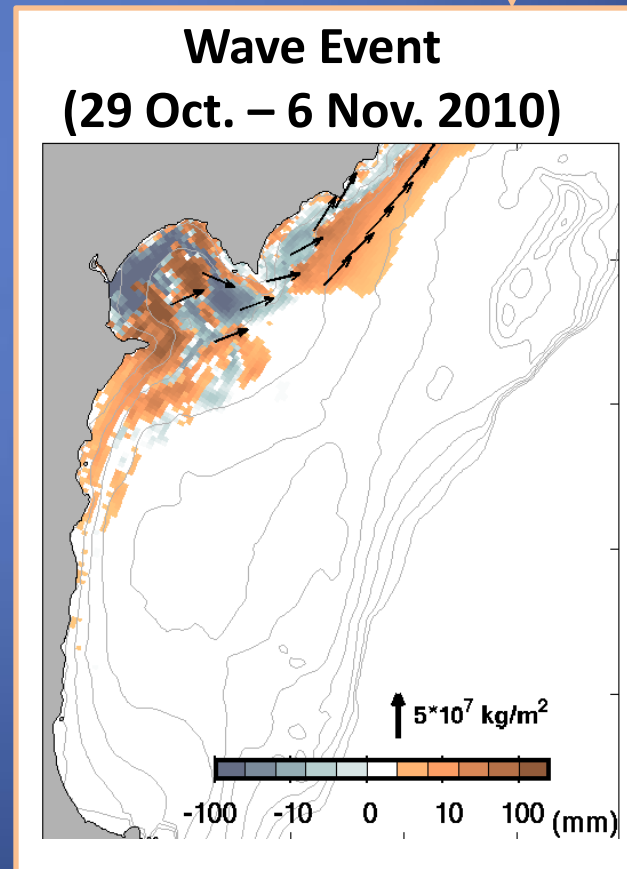
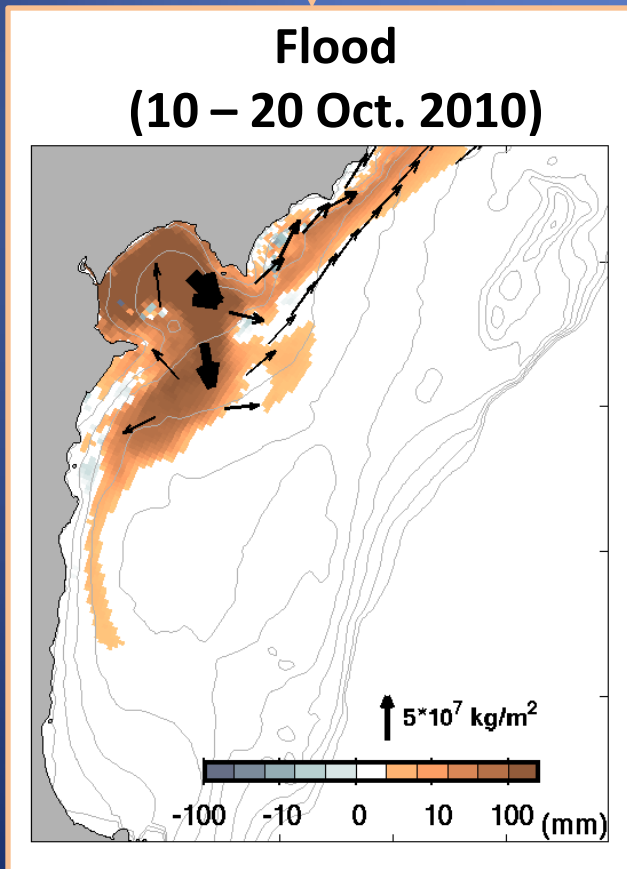
Deposit (mm)



River Discharge (m^3/s) and Wave Height (m): 10-Oct-2010



Floods: Deposition near river mouth
Wave events: Sediment transported offshore



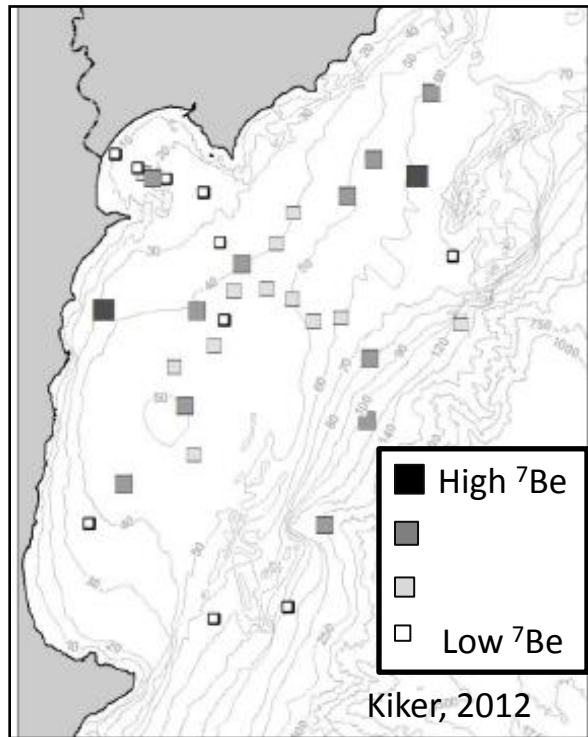
Model captures:

- Increased deposition on shelf relative to Poverty Bay
- Along-shelf Dispersal

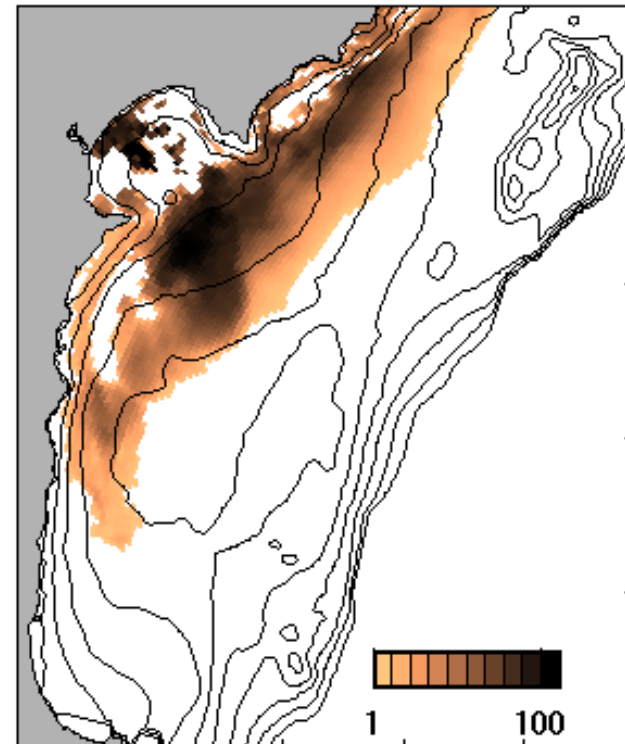
Model misses:

- Estimated deposition landward of long-term depocenters

Recent Deposition, Sept. 2010:
 ^7Be Inventories

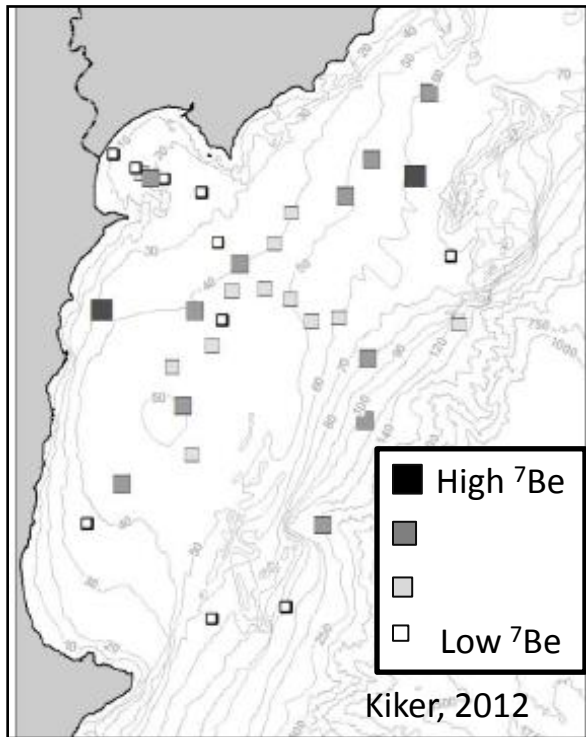


Estimated Deposition (mm):
July 16 – Sept. 7, 2010

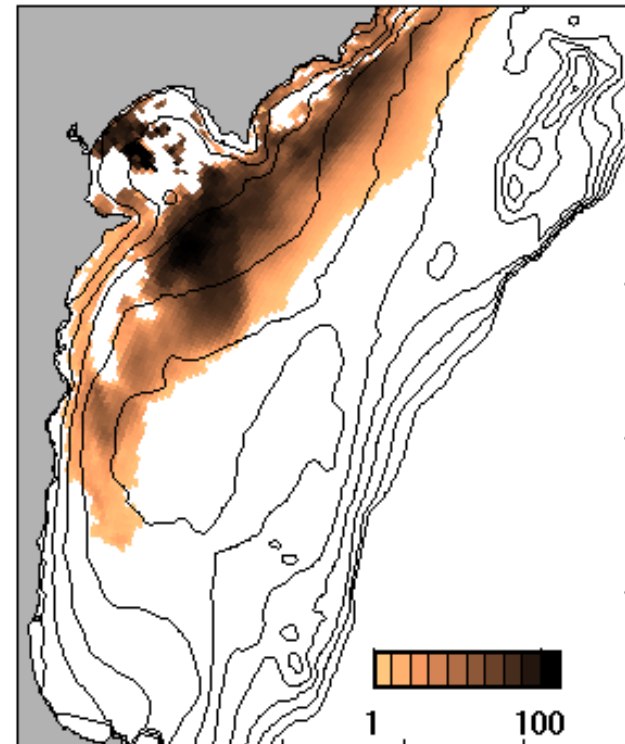


Can gravity flows transport sediment to deeper water?

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 ^7Be Inventories



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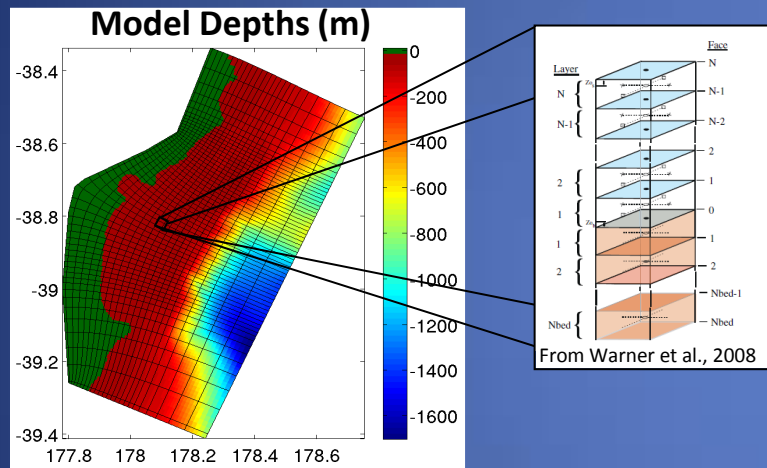


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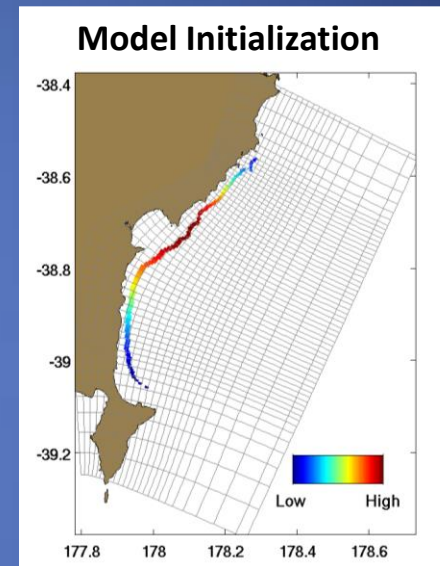


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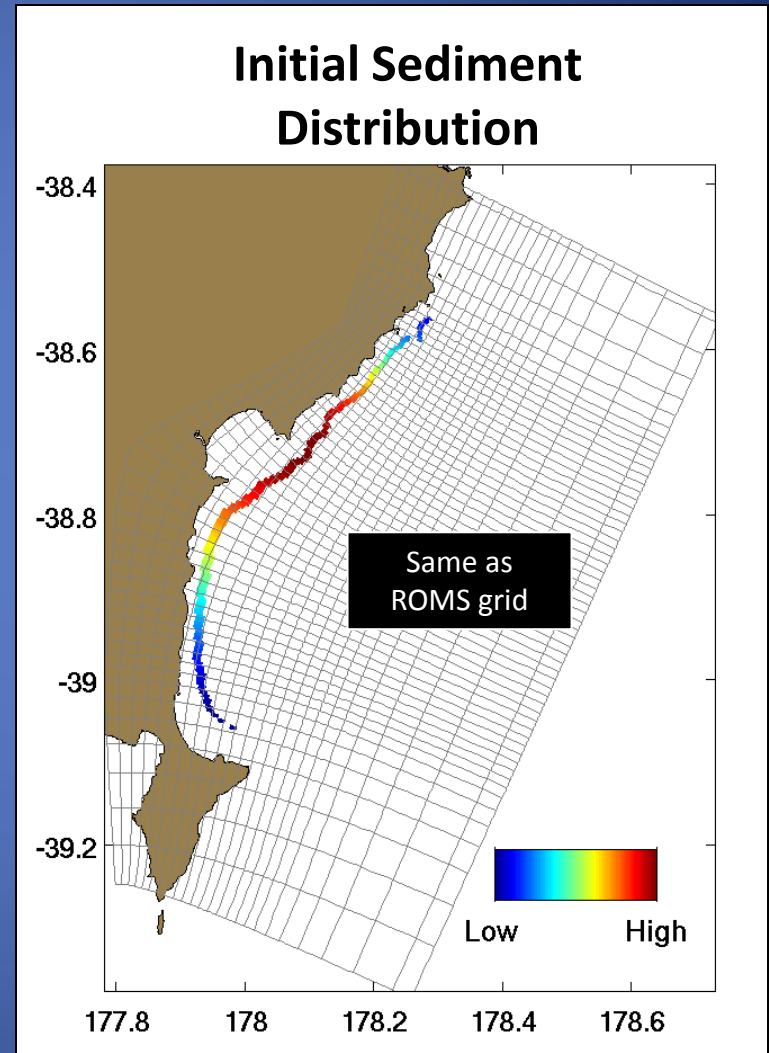
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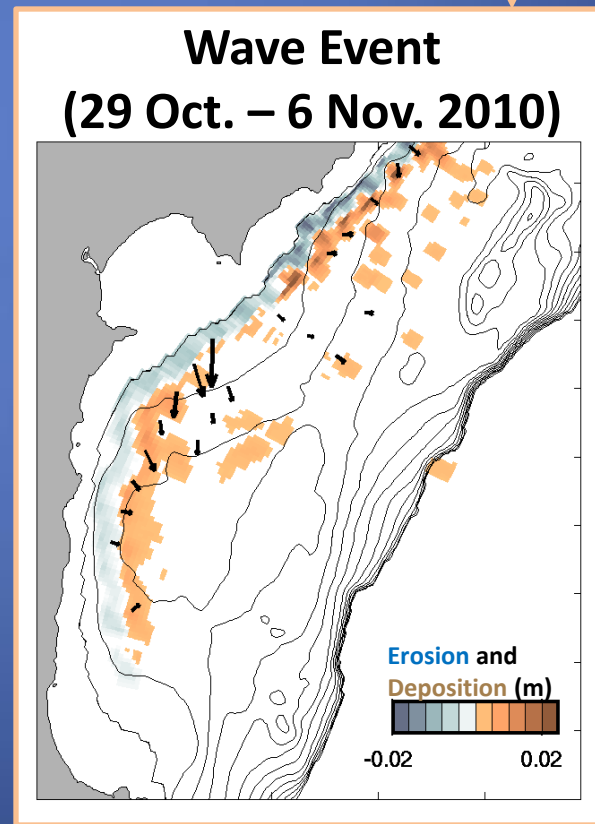
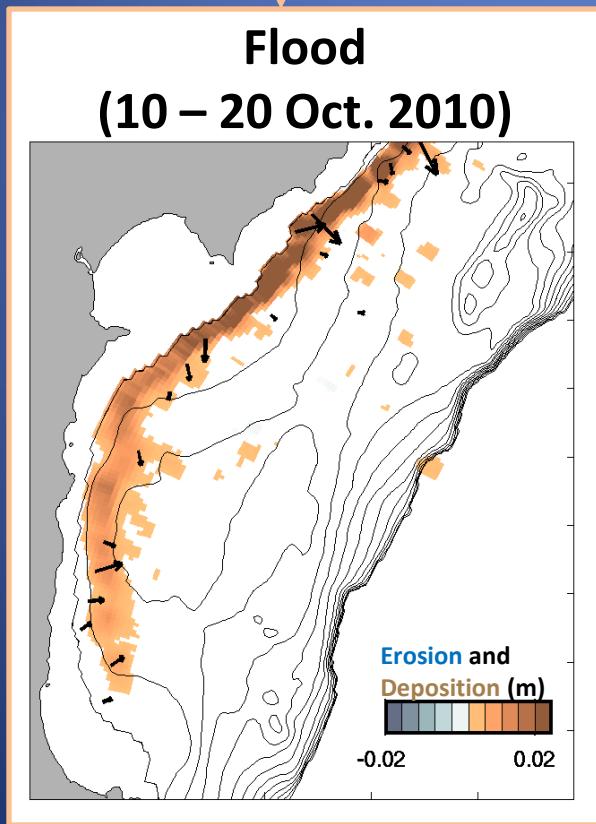
2D Wave- and Current Gravity Flow Model

- Chezy equation balances gravity and friction
- Critical Richardson number of 0.25 limits sediment resuspension
- Spatially-varying waves and currents
 - Inputs from ROMS model

$$\delta_{wbl} g' \sin \theta = C_d u_{grav} |u_{max}|$$
$$g' = g \left(\frac{\rho_s - \rho_w}{\rho_s \rho_w} \right) C_{s,wbl,mean}$$
$$Ri = \frac{-g(\rho_s - \rho_w)}{\rho_w} \frac{\partial C_s / \partial z}{(\partial U / \partial z)^2}$$



Wave- and current- induced gravity flows transport material downslope



Wave- and current- induced gravity flows transport material downslope

Jan. 2010

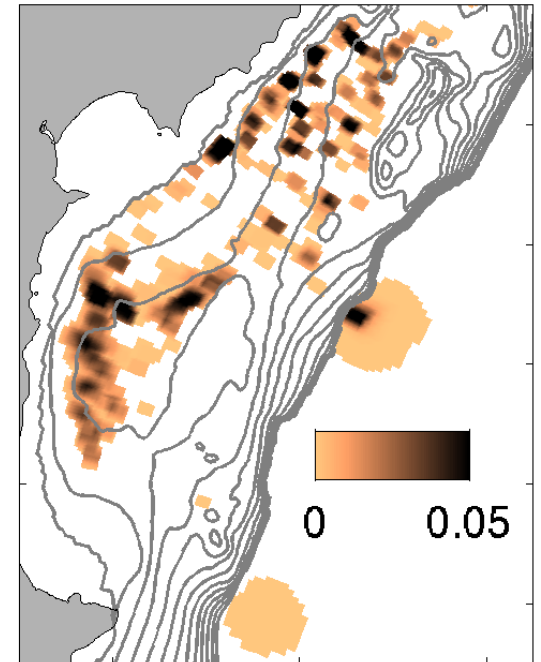
Oct. Flood

High Waves

Feb. 2011

- Lower wave energy and flatter seabed → Deposition

Deposition over 13 Months (m)

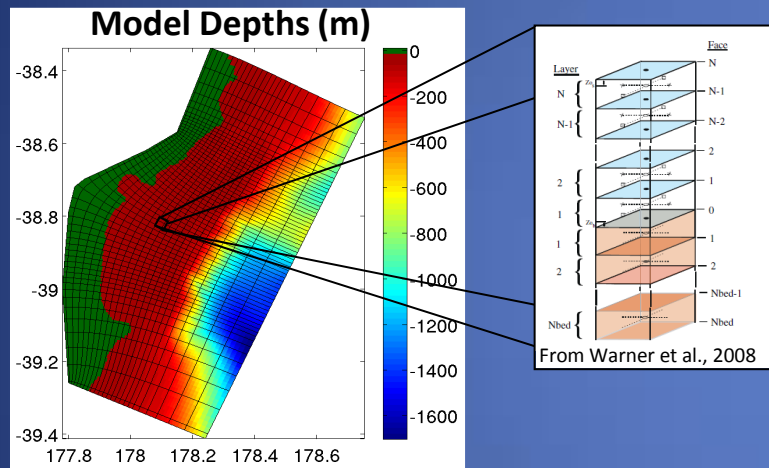


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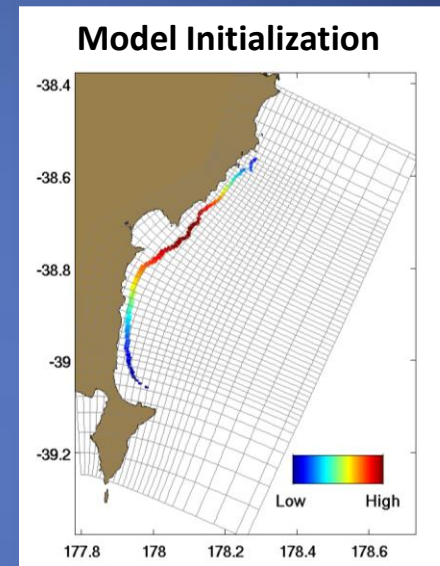
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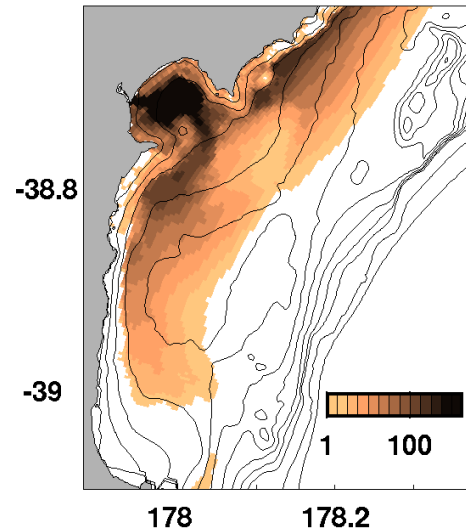
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Conclusions

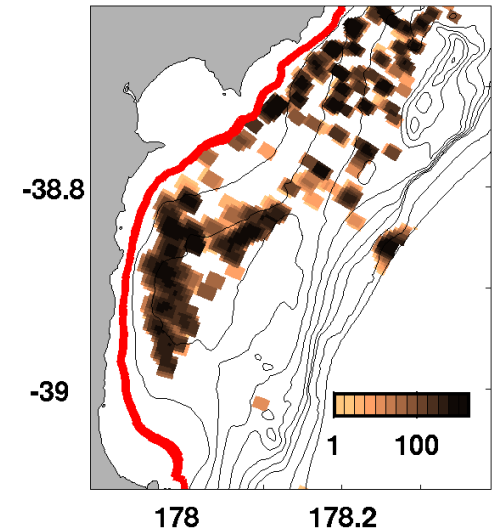
- Water column processes distribute sediment along-shore
- Waves resuspend sediment from Poverty Gap
- Gravity-flows contribute to accumulation near long-term depocenters, shelf break

Estimated Deposition (mm): Jan 2010 – Feb 2011

ROMS Standard Model

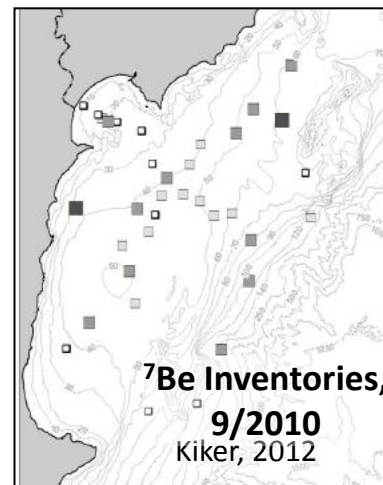


Gravity Flow Model

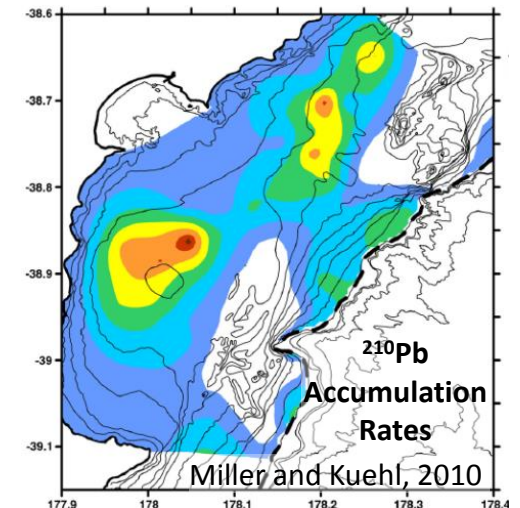


Observed Radioisotope Signatures:

Recent Deposition



Long-term Accumulation

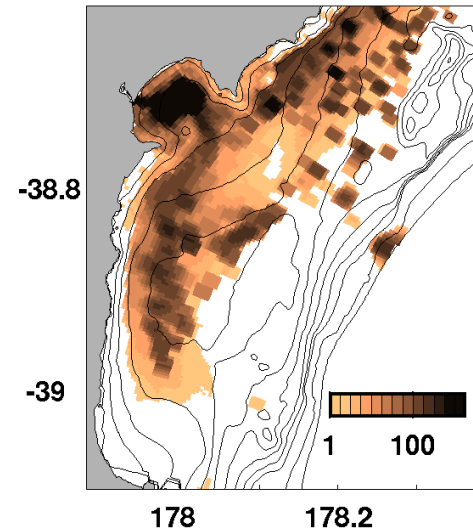


Conclusions

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- Waves resuspend sediment from Poverty Gap
- Gravity-flows contribute to accumulation near long-term depocenters, shelf break

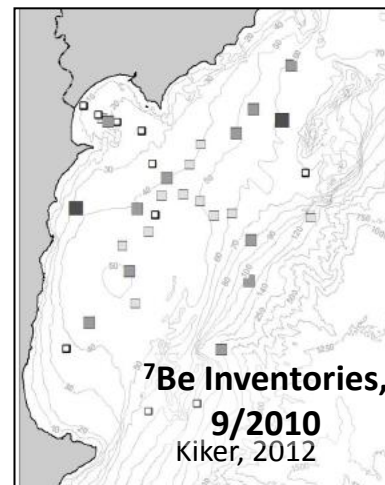
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Buoyant Transport + Gravity Flows

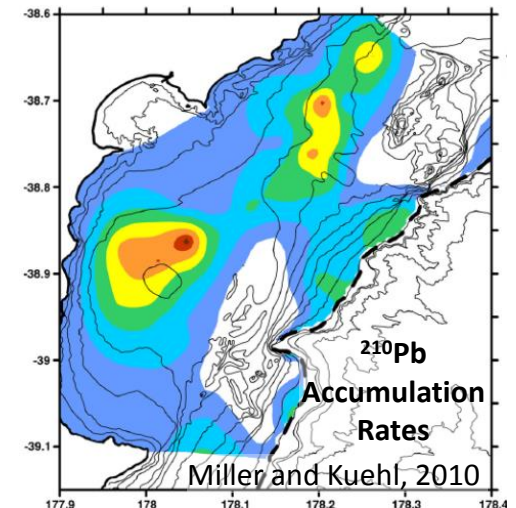


Observed Radioisotope Signatures:

Recent Deposition



Long-term Accumulation



Acknowledgements

J.P. Walsh (ECU)

Reide Corbett (ECU)

Andrea Ogston (UW)

Alan Orpin (NIWA)

Joey Kiker (ECU)

Rip Hale (UW)

Tara Kniskern

Aaron Bever

Steve Kuehl

Linda Schaffner

Justin Birchler

Adam Miller

David Weiss

Mary Ann Bynum

Tom Crockett

Albert Kettner (U Colorado)

Data was generously provided by M. Hadfield, S. Stephens, M. Uddstrom and Meteorological and Wave Science Staff (NIWA), G. Hall and D. Peacock (Gisborne District Council), S. Kuehl (VIMS), J. McNinch (USACoE) and NOAA.

Funding provided by: National Science Foundation, VIMS, NIWA

