Modeling Seabed Geologic & Geoacoustic Variability

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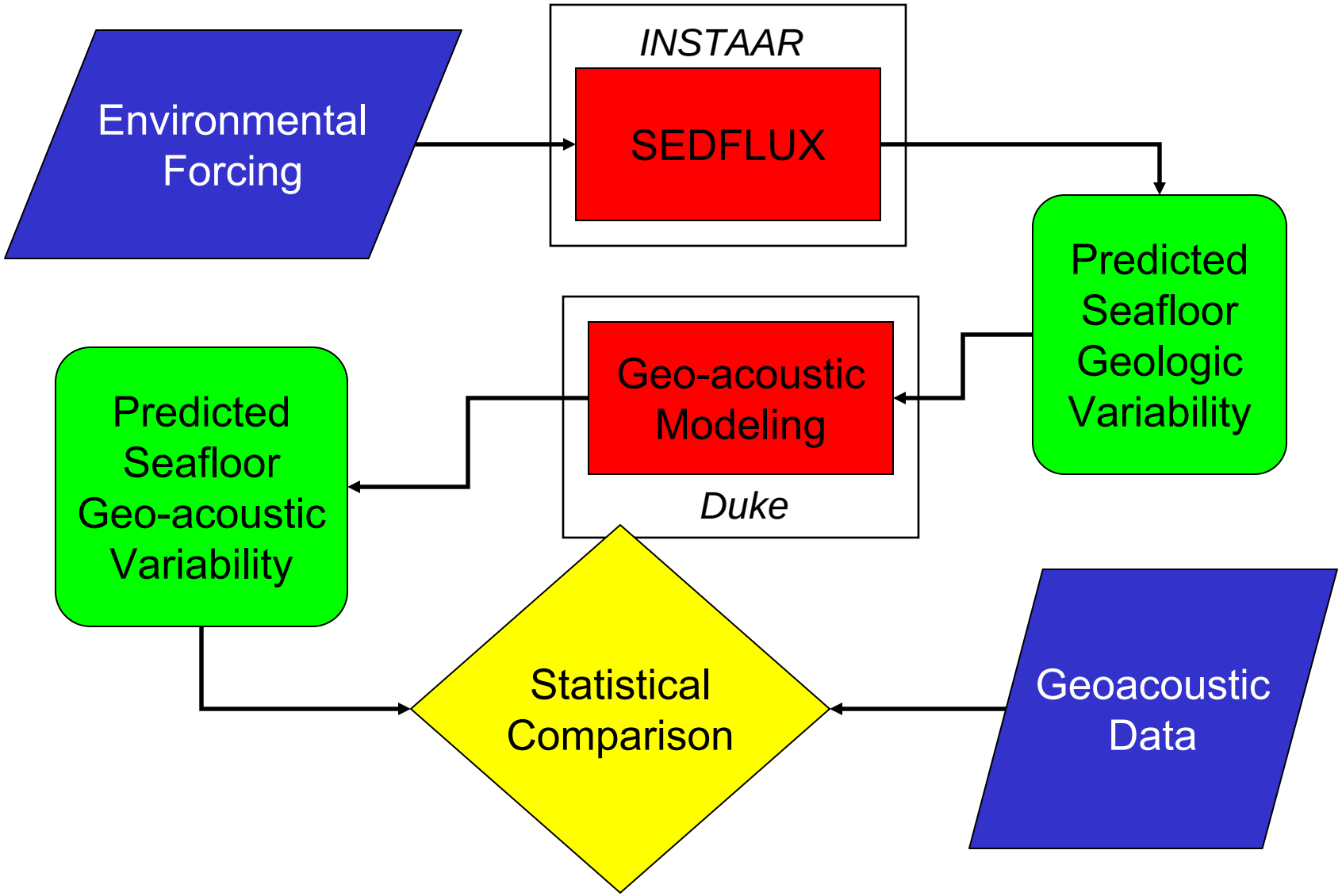
Methods for Characterizing Seabed Geoacoustic Variability

APPROACH	ACCURACY	COVERAGE	EFFICIENCY
Direct Sampling *e.g., Mayer et al.* Acoustic Methods *e.g., Holland et al.*			
Interpolation/ Extrapolation *e.g., Goff* Geologic/Geo-acoustic Modeling *INSTAAR-Duke*			

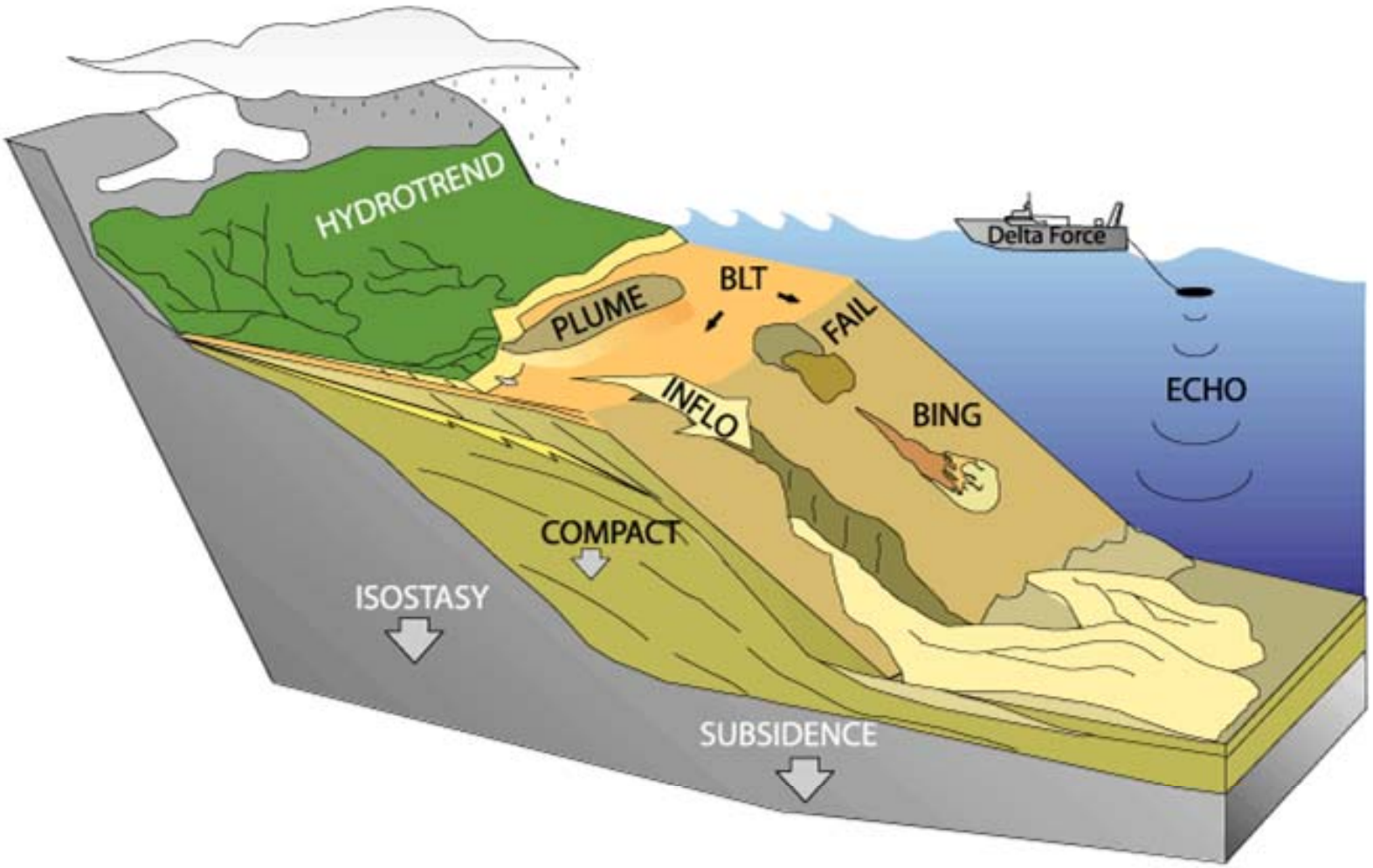
INSTAAR-Duke Collaboration with in Seabed Team



Objectives

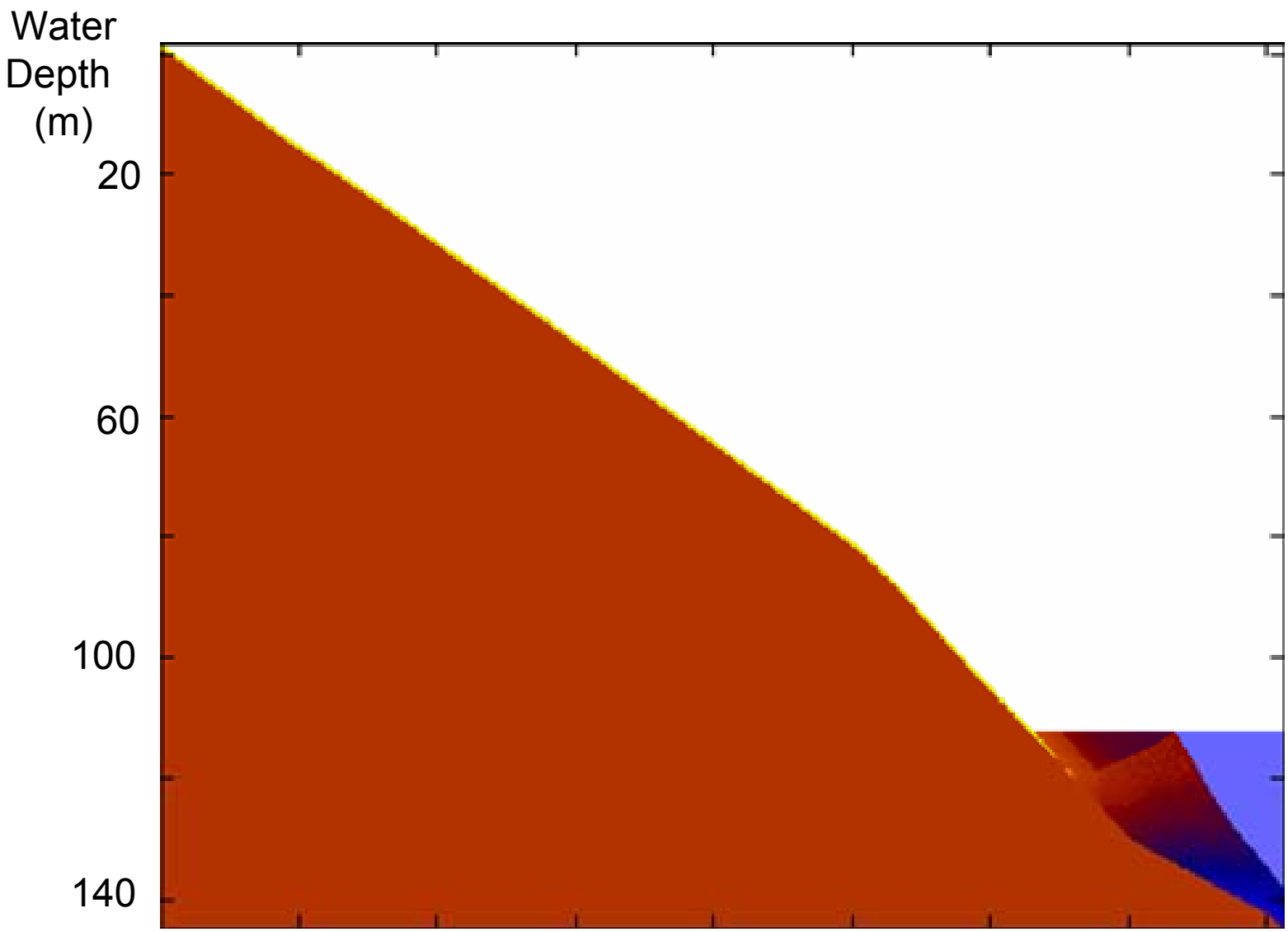
INSTAAR	Duke
Simulate seabed in selected study areas	Simulate corresponding geo-acoustic properties
Conduct sensitivity runs of potential seabed variability	Simulate seismic reflection data of seabed predictions

SEDFLUX Overview



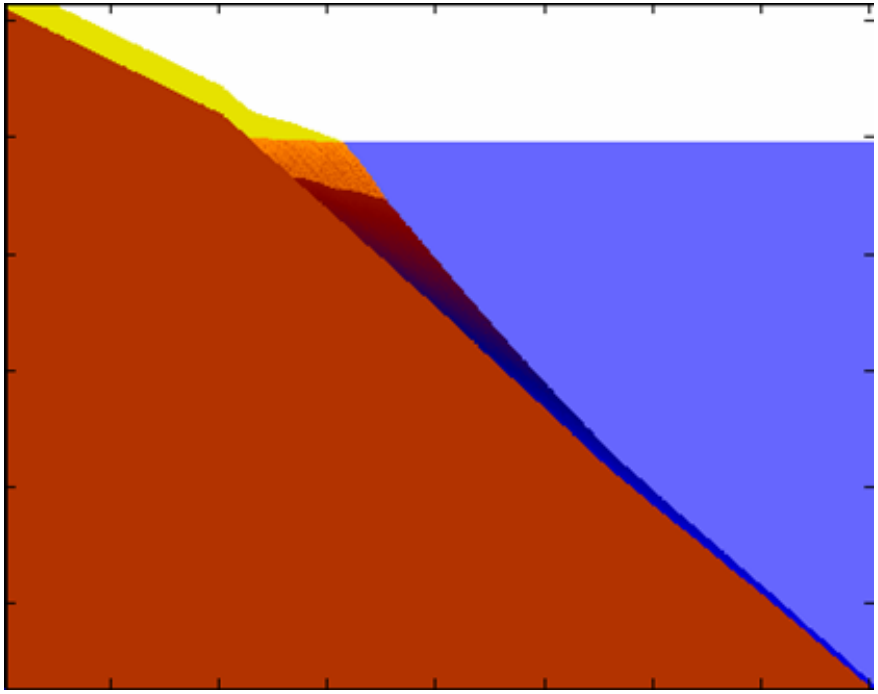
SEDFLUX Example

21,000 year run, 170 km profile

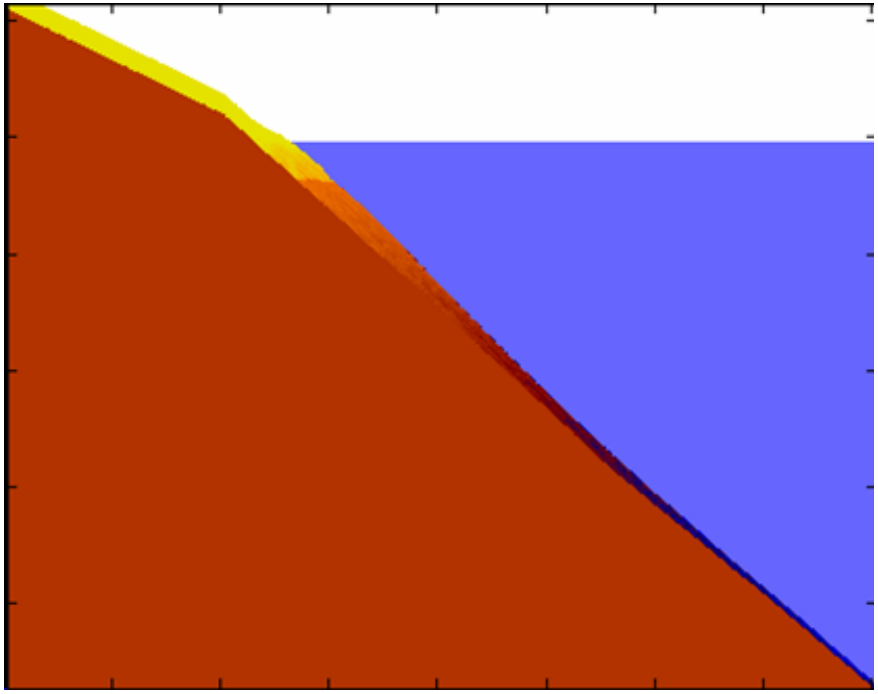


SEDFLUX Sensitivity Test

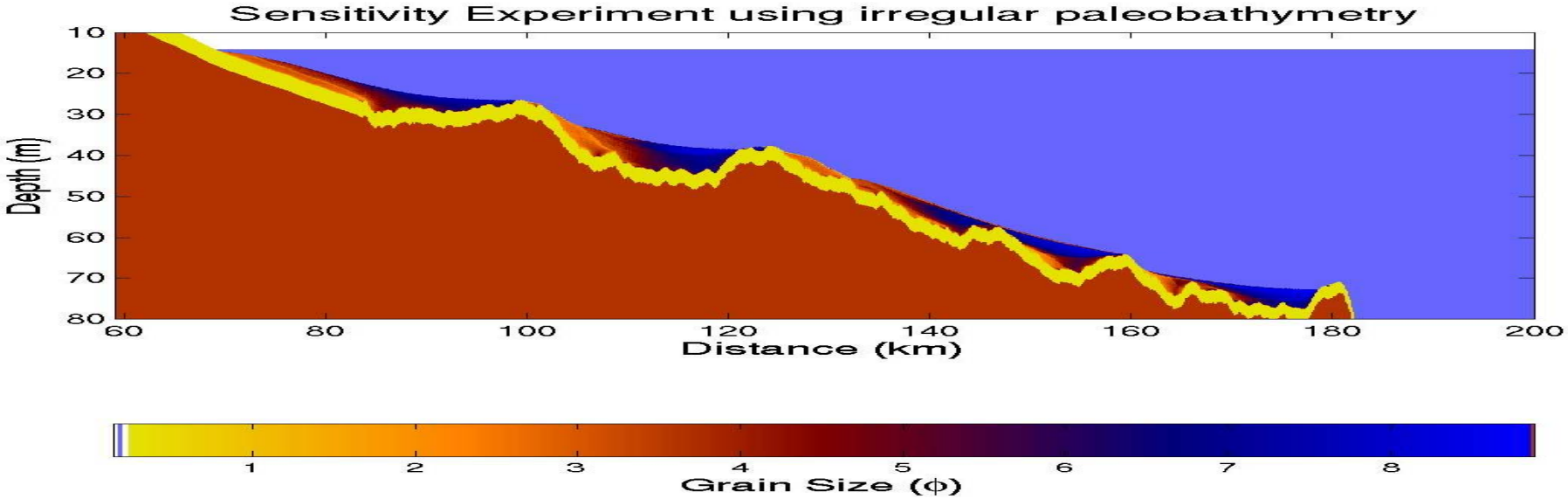
No Storms

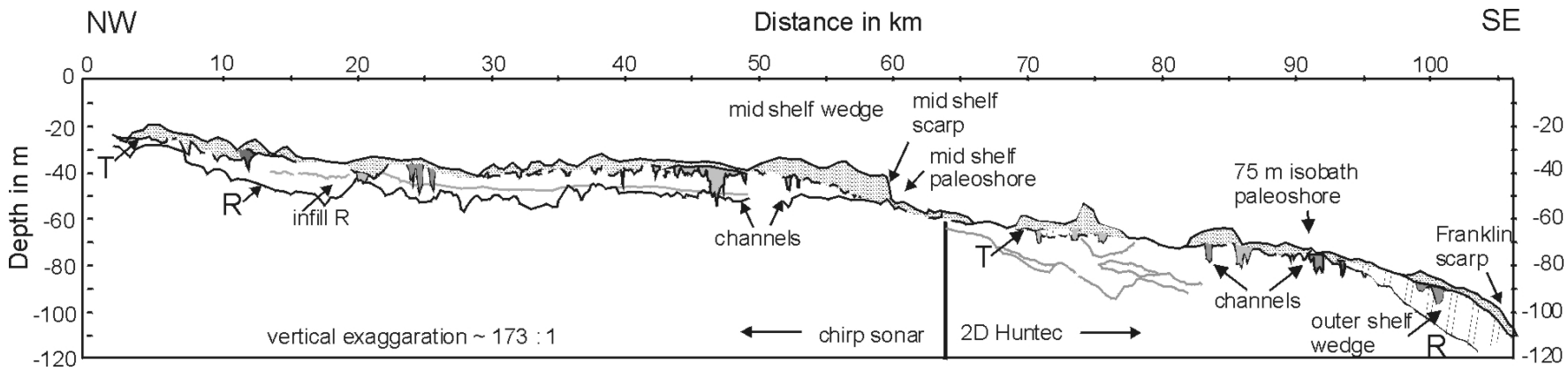


Storms



SEDFLUX Simulation of New Jersey STRATAFORM/Geo-Clutter Study Area





after Duncan et al, 2000

SEDFLUX Sensitivity Runs

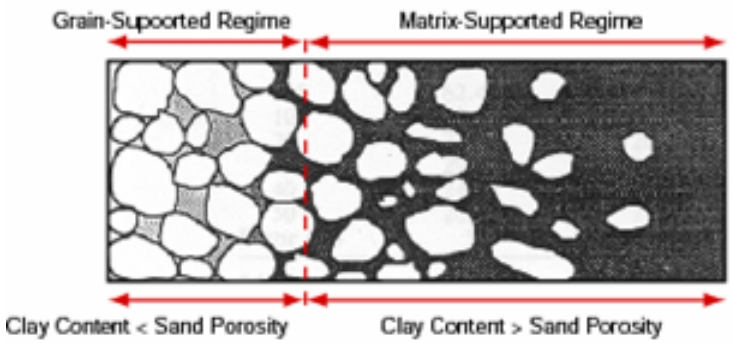
CLIMATIC BOUNDARY CONDITION	Input Range	Sediment Discharge (Qs)	SEDFLUX Variability Σ GSD(t)
Subaerial Drainage Area	35k +/- 5k	14%	< 5%
	140k +/- 50k	18%	10-20%
Temperature	10 ° C	Q = 8% Qs = 45%	-15% - 22%
Precipitation	0.5 m	Q = 210% Qs = -15%	22%
Ocean storms	0-1200	----------	180-460%

SEDFLUX Output – Geo-Acoustic Modeling Input

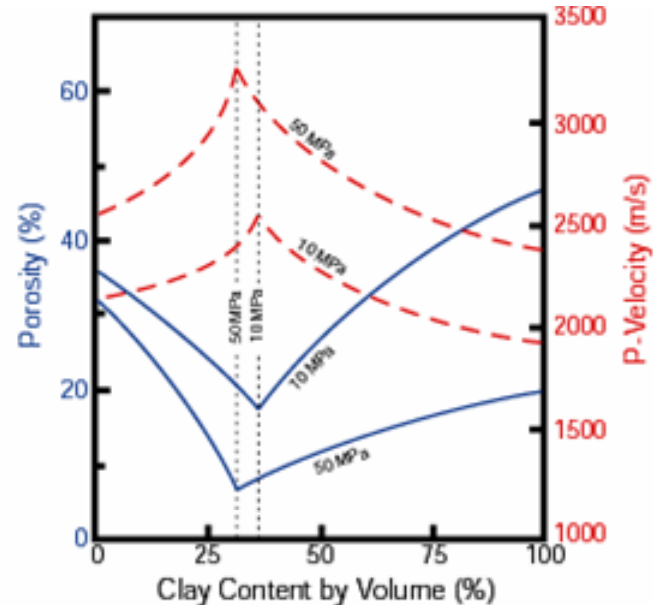
Property	SEDFLUX
Grain Size/Clay Content	Predicts
Porosity	*Derives*
Bulk Density	*Derives*
Permeability	*Derives*
Shear Modulus	Must be Modeled
Dry Bulk Modulus	Must be Modeled
Saturated Bulk Modulus	Must be Modeled
Velocity	Must be Modeled
Attenuation	Must be Modeled

Modeling of Bulk Elastic Moduli

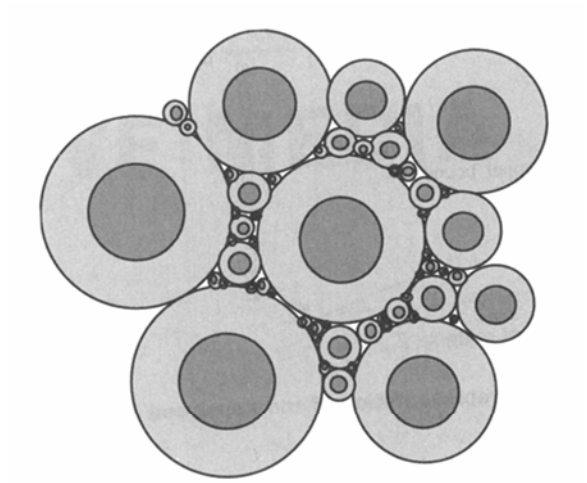
Porosity Model for Fine-Coarse Sediment Mixtures



Marion et al., 1992



Kuster-Toksöv Formulation for Effective Moduli



Mavko et al., 1998

$$\left(K_{KT}^{*}-K_{m}\right)\frac{\left(K_{m}+\frac{4}{3}\mu_{m}\right)}{\left(K_{KT}^{*}+\frac{4}{3}\mu_{m}\right)}=\sum_{i=1}^{N}x_{i}\left(K_{i}-K_{m}\right)P$$

$$\left(\mu_{KT}^{*}-\mu_{m}\right)\frac{\left(\mu_{m}+\frac{4}{3}\zeta_{m}\right)}{\left(\mu_{KT}^{*}+\frac{4}{3}\zeta_{m}\right)}=\sum_{i=1}^{N}x_{i}\left(\mu_{i}-\mu_{m}\right)Q$$

Poro-Elastic Modeling of Frequency-Dependent Velocity and Attenuation

Biot Model

e.g., P-waves

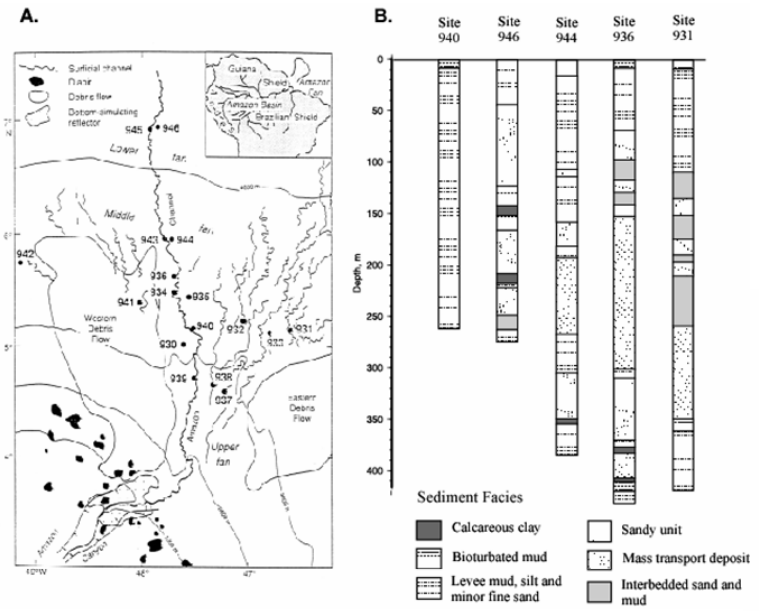
$$\begin{pmatrix} V_{p1} \\ V_{p2} \end{pmatrix} = \left| \frac{2\left(HM - C^2\right)}{\rho_b M + mH - 2\rho_f C \mp A^{1/2}} \right|^{1/2}$$

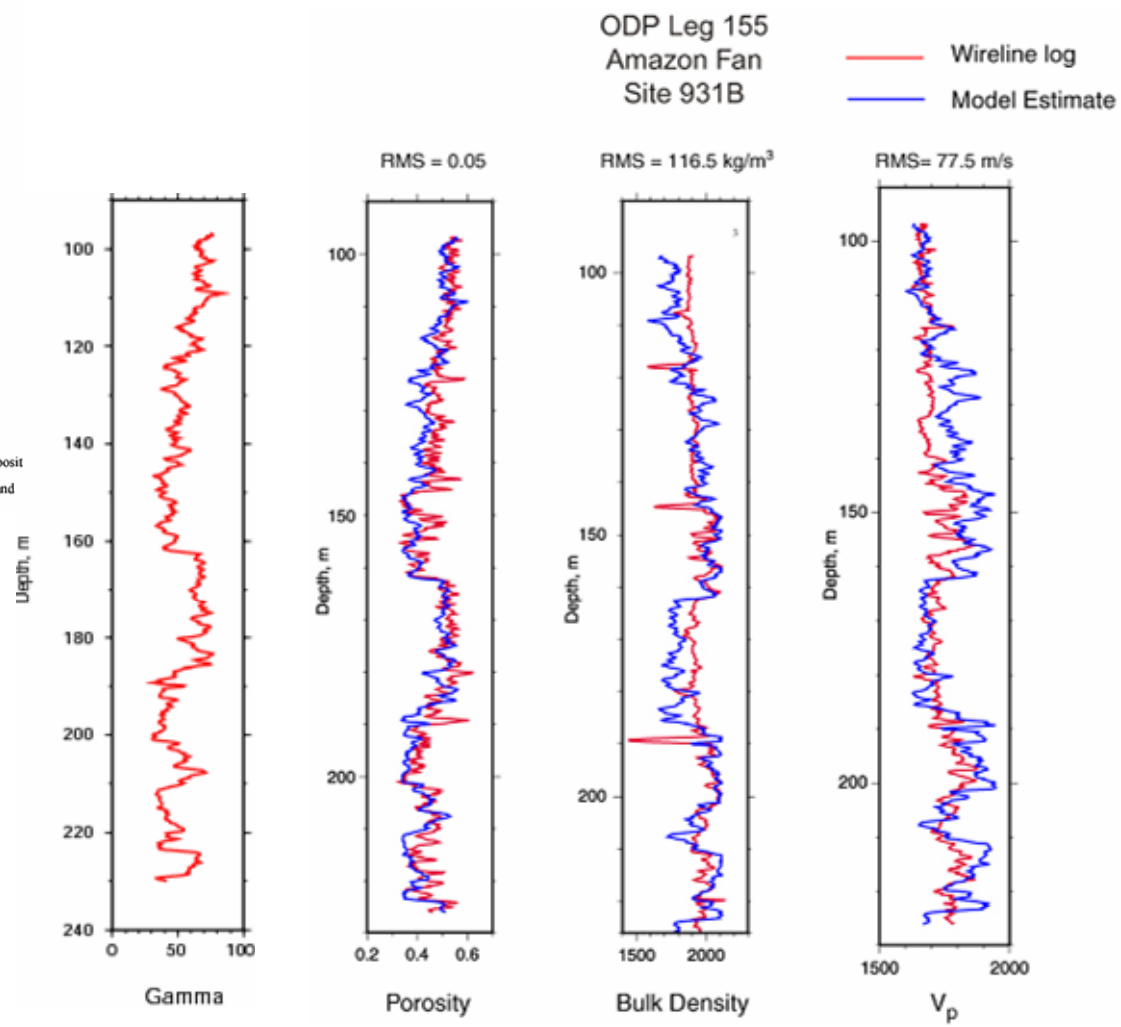
$$V = \omega / \mathrm{Re}\left(V_p\right)$$

$$\alpha = \mathrm{Im}\left(V_p\right)$$

$$\frac{1}{Q} = \frac{\alpha V}{\pi f}$$

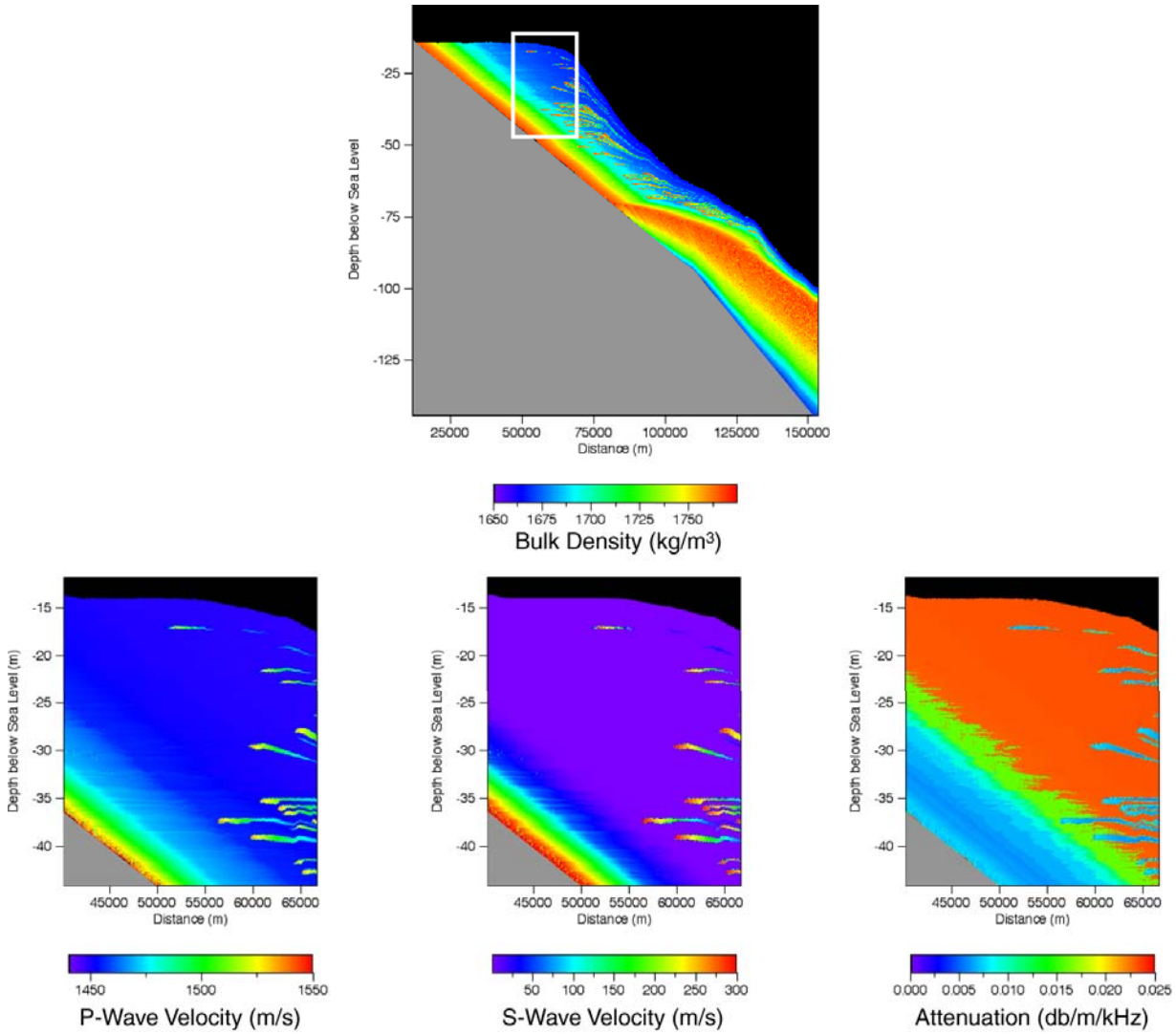
Geo-Acoustic Modeling Validation





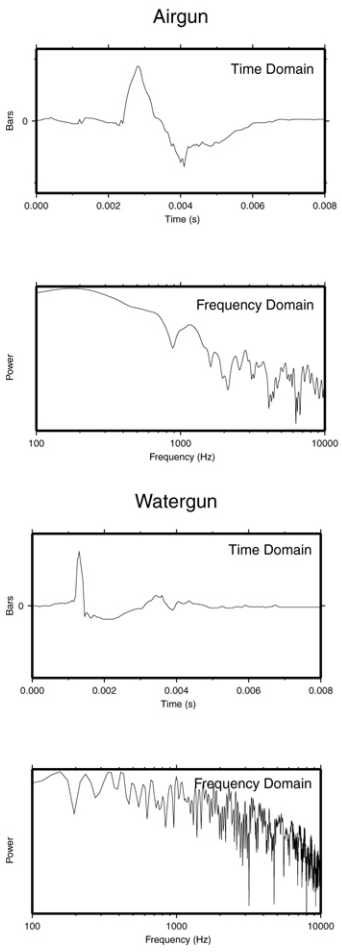
Pratson et al., in press (Geophysics)

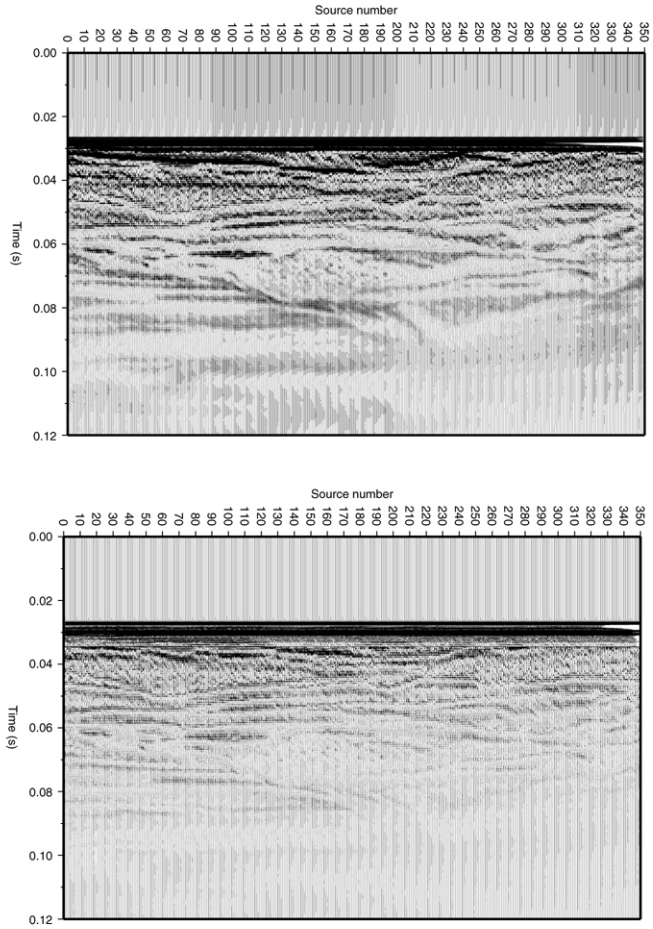
Geoacoustic Simulations of SEDFLUX Realizations



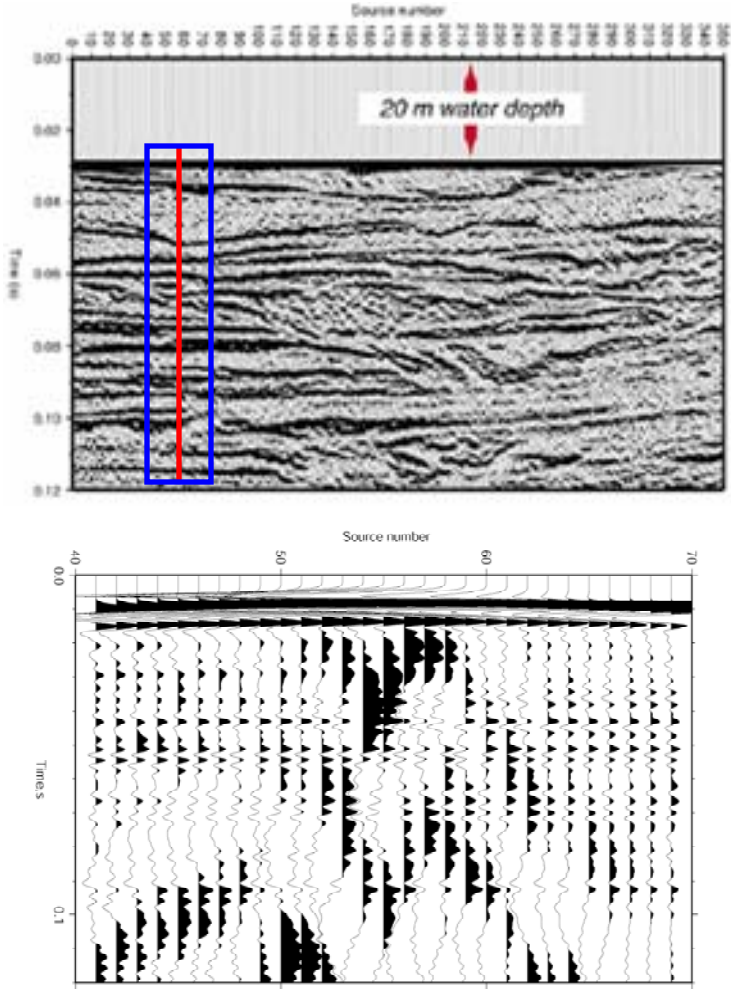
Seismic Reflection Simulations - 1D → 2D

1-D Poro-Elastic Model





2-D Poro-Elastic Model

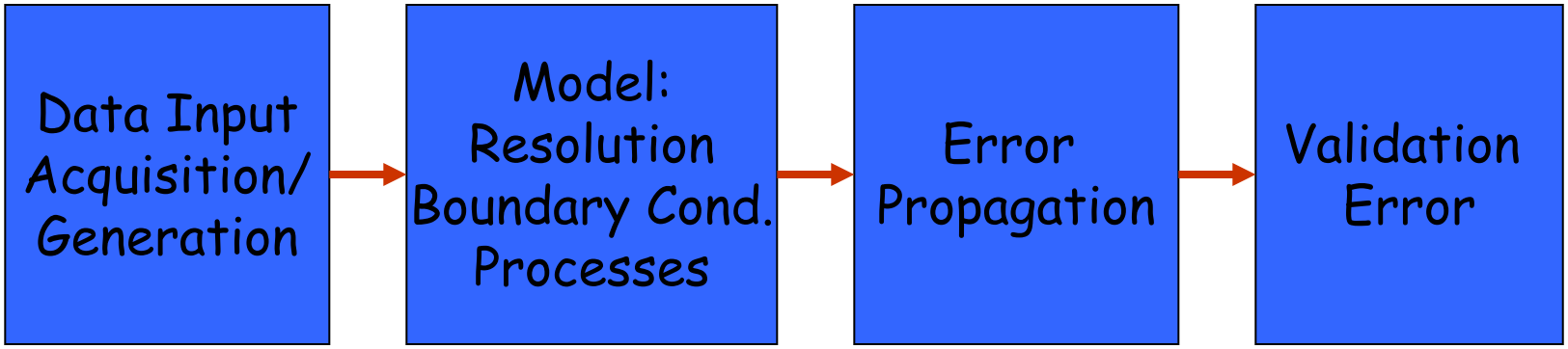


Next Steps

- **Implement Buckingham Model**
- **Complete Sensitivity Studies**
- **Conduct Model – Data Comparison**
- **Model Additional Areas of Interest**

  e.g., Straits of Sicily

There are Challenges in Capturing "Uncertainty" in Process Modeling of Natural Seabed Variability…



- Environmental disconnect

  seabed composite result of past environments
- Simplifications in process modeling

  process models = first-order approximation of natural processes
- Uncertain/unknown and thus un-quantifiable errors

  environmental forcing often based on geologic proxies
- Incompleteness of the geologic record

  validation complicated by gaps in geo-history

…But Also Significant Potential

Process-based Predictions:

- Can efficiently be made for large, potentially inaccessible areas.
- Require little a priori knowledge of the seabed.

  need initial bathymetric surface
- Can guide interpolation/extrapolation of existing seabed data.
- Can predict seabed change due to environmental events.

  e.g., storms and floods