Modular Whole Margin Model: *SedFlux*

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Photo - JPEG decompressor
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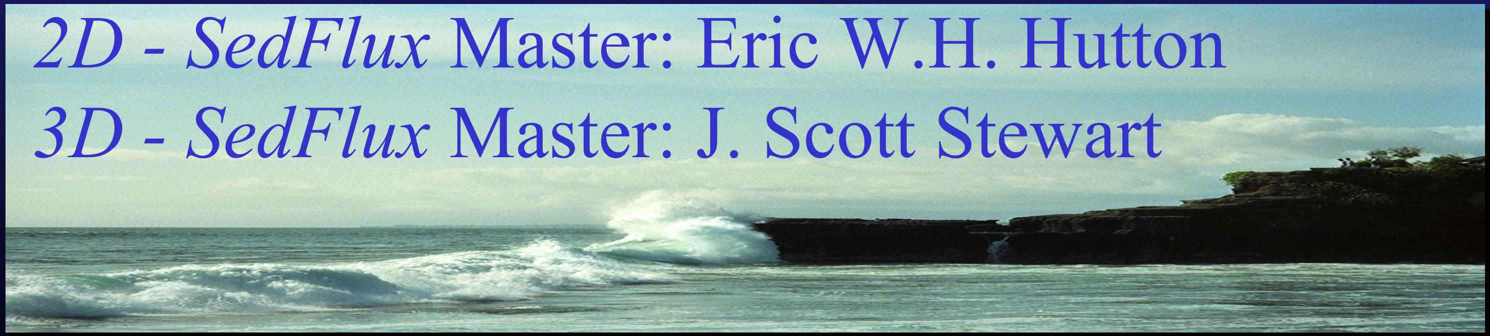
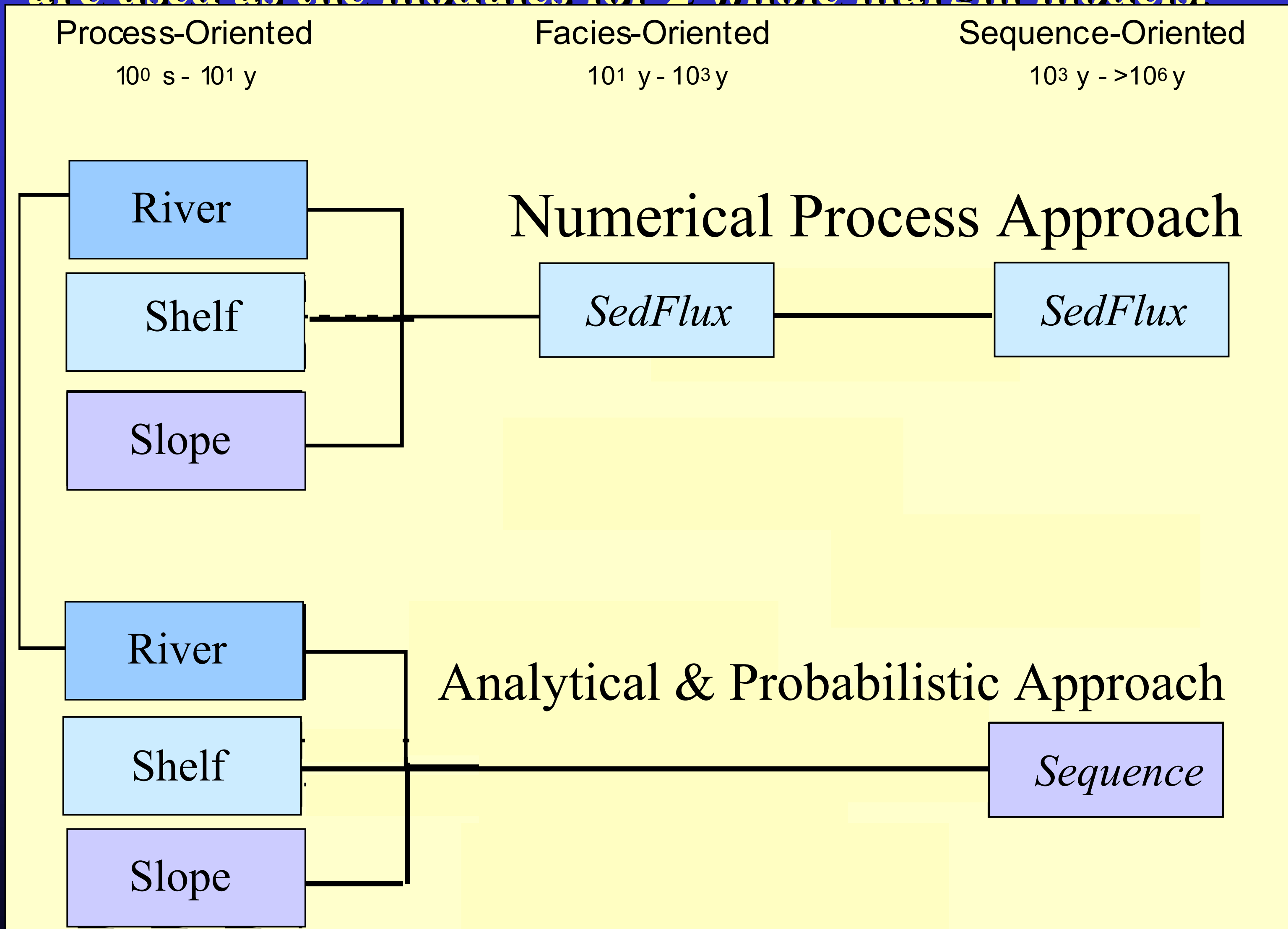
SedFlux Modelers 1985-2002

- **Bernie Boudreau – Oceanography**
- **Carl Friedrichs - Oceanography**
- **Chris Reed - Aerospace Engineering**
- **Damian O'Grady – Geological Sciences**
- **Dave Bahr - Geophysics**
- **Elizabeth Calabrese – Computer Science**
- **Eric Hutton - Engineering Physics**
- **Gary Parker - Civil Engineering**
- **Homa Lee - Geotechnical Engineering**
- **Irina Overeem – Geological Sciences**
- **Jacques Locat - Geological Engineering**
- **James Syvitski - Oceanography**
- **Jane Alcott - Geological Engineering**
- **Jasim Imran - Civil Engineering**
- **Jeff Wong – Geotechnical Engineering**
- **John Smith – Chemistry**
- **Ken Skene – Oceanography**
- **Lincoln Pratson - Geophysics**
- **Mark Morehead - Geophysics**
- **Mike Steckler - Geophysics**
- **Patricia Wiberg - Sedimentology**
- **Rick Sarg – Geological Sciences**
- **Scott Peckham -Geophysics**
- **Scott Stewart - Aerospace Engineering**
- **Steve Daughney – Chemical Engineering**
- **Thierry Mulder – Geotech. Engineering**



18 process models produced during STRATAFORM are used as the modules for 2 whole margin models.



STRATAFORM MODELING EFFORT

Discharge
HYDROTREND-INSTAAR

Plume & Coastal Ocean
PLUME-INSTAAR
ECOM-3D -WHOI
TFLOC-Dal U
TRANSPORT & **SLICE -URS**

Bottom Boundary Layer
CORE-URS
2D BBL-UVA
EVENT-ODU

Turbidity Current
LAMTURC-UI HYPER-USC
INFLO-INSTAAR BANG-Duke

Debris Flow
MUDFLOW-UI
SKRED-INSTAAR & NGI
BING-UMinn

Sediment Failure
FAIL-INSTAAR
2-D STRESS-Duke
GISFAIL-USGS

Seascape Architecture
WHOLEMARGIN-UMinn
CLINOFORM-Duke
SEASCAPE-Duke
2D & 3D SEDFLUX-INSTAAR
SEQUENCE-LDEO & URS & ODU
FACIES-ODU

Other Useful Models
CorAl-Duke
ECHO-INSTAAR
RIGIDEET-LDEO
SIMSTRAT-UTex

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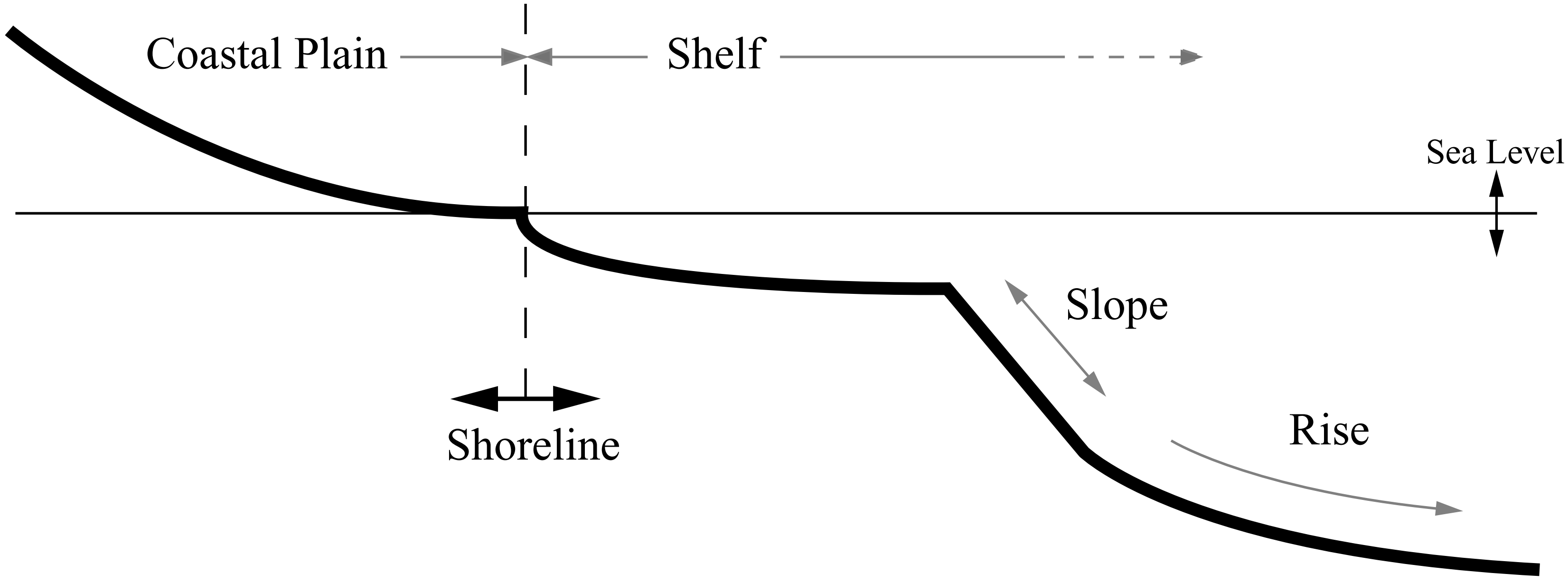
Sequence Whole Margin Model Concept a la Steckler et al.



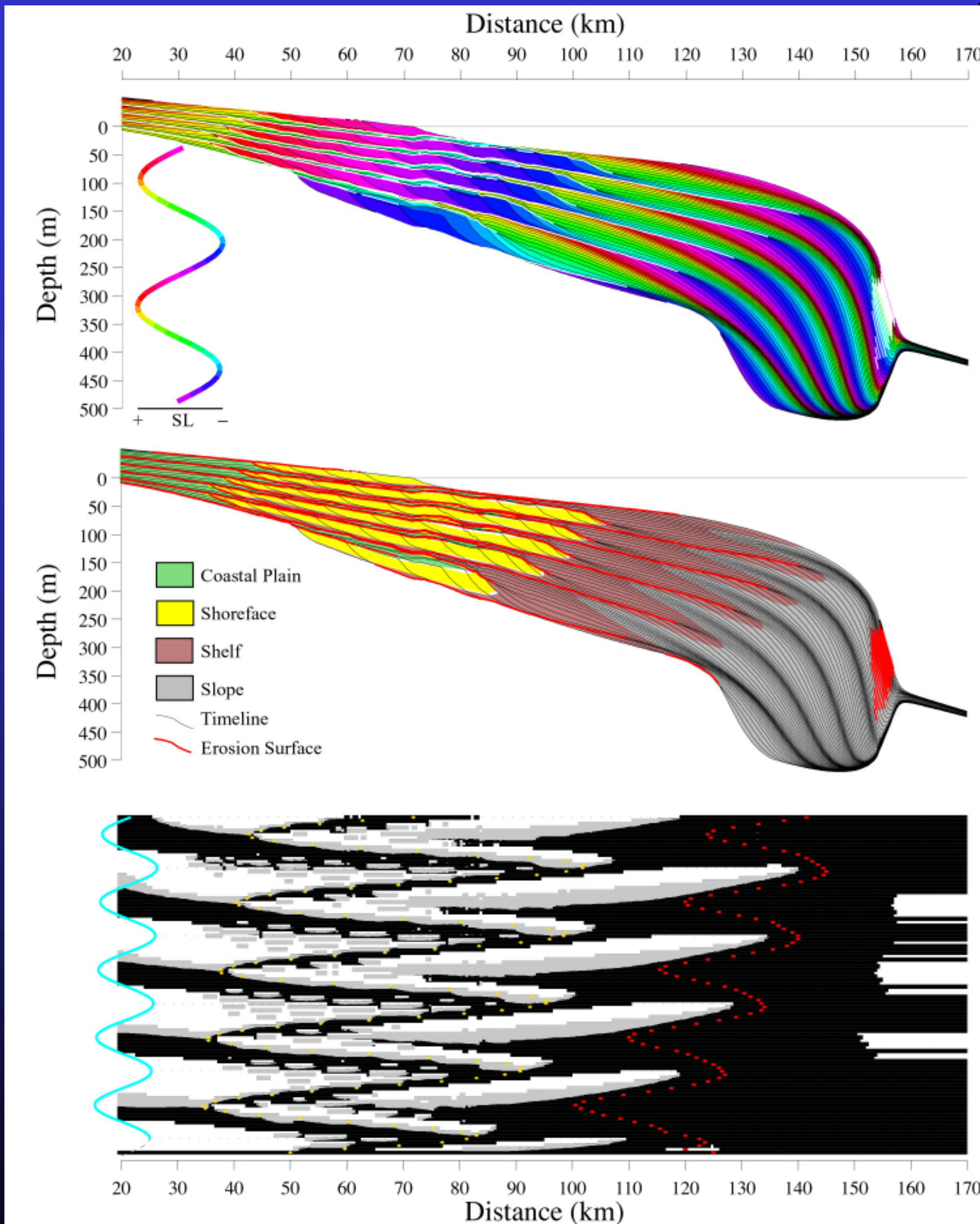
Conceptual Diagram of Components of *SEQUENCE4*.

Shoreline is a moving boundary.

Deposition decreases with water depth.

Gravitational slope processes invoked with threshold criteria.

Turbidites deposition on rise.



Stratigraphic sections

Colored by age/sea level

Colored by environment

Wheeler Diagram

deposition

deposited and eroded

non-deposition

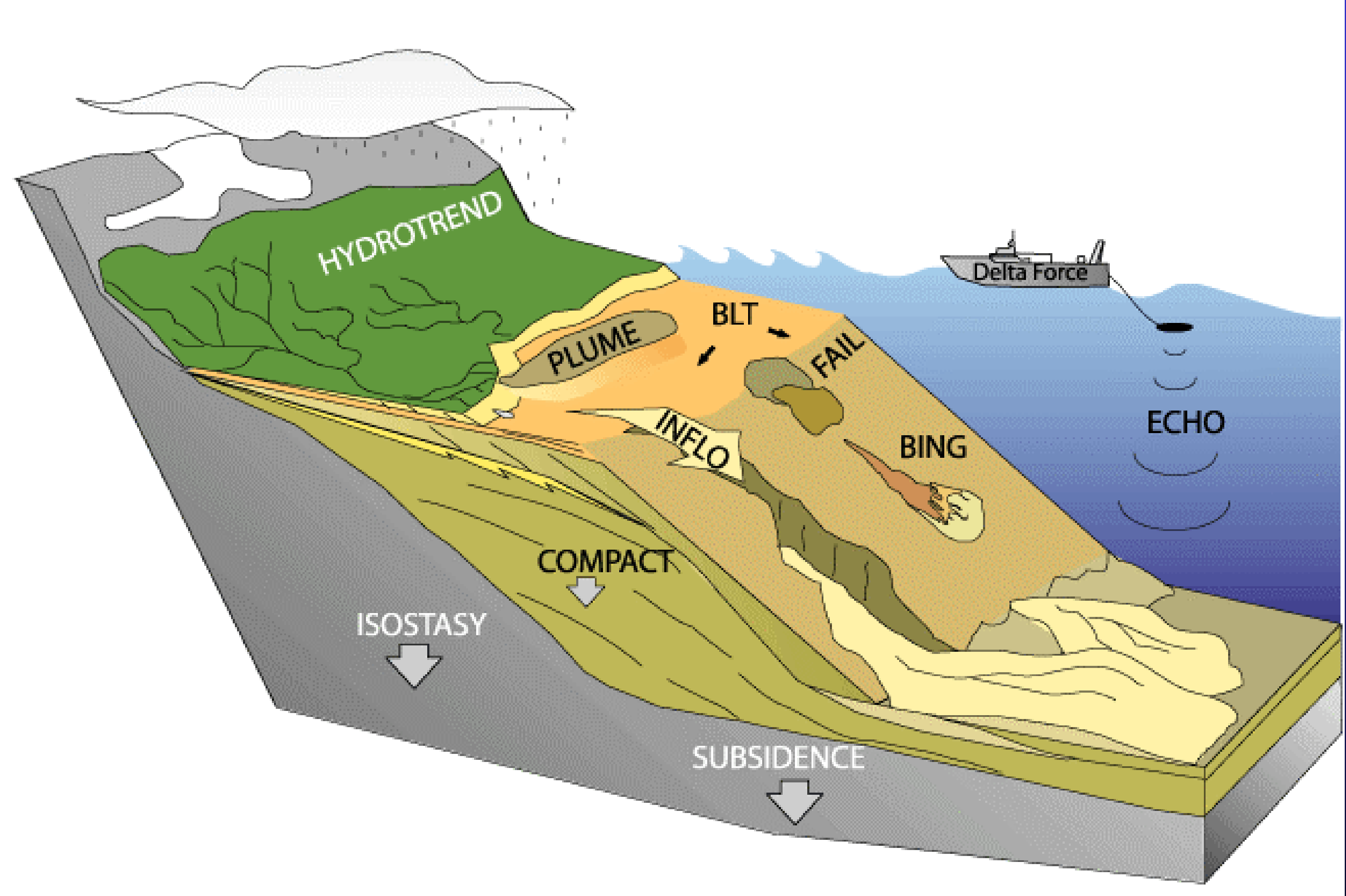
3 Erosion surfaces developed

regressive subaerial

regressive submarine

transgressive ravinement

SedFlux Component Modeling Scheme



Advection-Diffusion

$$\frac{\partial C}{\partial t}+u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=\frac{1}{h}\frac{\partial}{\partial x}\left(hK_x\frac{\partial C}{\partial x}\right)+\frac{1}{h}\frac{\partial}{\partial y}\left(hK_y\frac{\partial C}{\partial y}\right)+\frac{S}{h}$$

Navier-Stokes Momentum

$$\frac{\partial}{\partial t^*}\left(\rho^* u^*\right)+\frac{\partial}{\partial x^*}\left(\rho^* u^{*2}+p^*\right)+\frac{\partial}{\partial y^*}\left(\rho^* u^* v^*\right)+\frac{\partial}{\partial z^*}\left(\rho^* u^* w^*\right)=\frac{\partial \tau^*_{xx}}{\partial x^*}+\frac{\partial \tau^*_{xy}}{\partial y^*}+\frac{\partial \tau^*_{zz}}{\partial z^*}$$

Navier-Stokes Energy

$$\frac{\partial}{\partial t^*}\left(\rho^* e^*_t\right)+\frac{\partial}{\partial x^*}\left(\rho^* u^* e^*_t+p^* u^*\right)+\frac{\partial}{\partial y^*}\left(\rho^* v^* e^*_t+p^* v^*\right)+\frac{\partial}{\partial z^*}\left(\rho^* w^* e^*_t+p^* w^*\right)=$$

$$\frac{\partial}{\partial x^*}\left(u^*\tau^*_{xx}+v^*\tau^*_{xy}+w^*\tau^*_{xz}-q^*_x\right)+\frac{\partial}{\partial y^*}\left(u^*\tau^*_{yx}+v^*\tau^*_{yy}+w^*\tau^*_{yz}-q^*_y\right)+\frac{\partial}{\partial z^*}\left(u^*\tau^*_{zx}+v^*\tau^*_{zy}+w^*\tau^*_{zz}-q^*_z\right)$$

Parker & Imran et al., Formulation of Debris Flow Momentum

$$\frac{2}{3}\frac{\partial}{\partial t}\left(U_p D_s\right)-U_p\frac{\partial D_s}{\partial t}+\frac{8}{15}\frac{\partial}{\partial x}\left(U_p^2 D_s\right)-\frac{2}{3}U_p\frac{\partial}{\partial x}\left(U_p D_s\right)=D_s g\left(1-\frac{\rho_w}{\rho_m}\right)S-D_s g\frac{\partial D}{\partial x}-2\frac{\mu U_p}{\rho_m D_s}$$

$$\frac{\partial}{\partial t}\left(U_p D_s\right)+\frac{\partial}{\partial x}\left(U_p^2 D_p\right)+U_p\frac{\partial D_s}{\partial t}+\frac{2}{3}U_p\frac{\partial}{\partial x}\left(U_p D_s\right)=D_p g\left(1-\frac{\rho_w}{\rho_m}\right)S-D_p g\frac{\partial D}{\partial x}-\frac{\tau_y}{\rho_m}$$

SedFlux MODELING SCHEME

Precip. & Temp. Data: GCM predictions, air or ground info
Drainage Basin Relief and Area, Glacier Distribution: satellite info

↓

Hydrological Model

=

daily Q, Qs, Cs, grain size, river velocity, channel size

\+

Seafloor Bathymetry: GEOSAT
Ocean Climate (wind & waves): Sat & Buoy Data

↓

River Plume Models

Nepheloid Layer Model **(mid water column)** ↔ **Shelf Transport Model** **(bottom boundary dynamics)**

=

Sediment Flux, Accumulation Rate, Seafloor Properties (ρ_{bulk}, grain size) on continental margin (shelf and slope)

↓

Slope Stability Models

=

Compaction, excess pore pressure, sediment strength potential failure planes, volume of failure

↓

Sediment Gravity Flow Models

=

Seafloor Stratigraphy, Bedding Geometry & Coherency, Erosion Surfaces, Seafloor Properties (ρ_{bulk}, grain size, porosity)

\+

Acoustic Source Signatures (calibrated)

↓

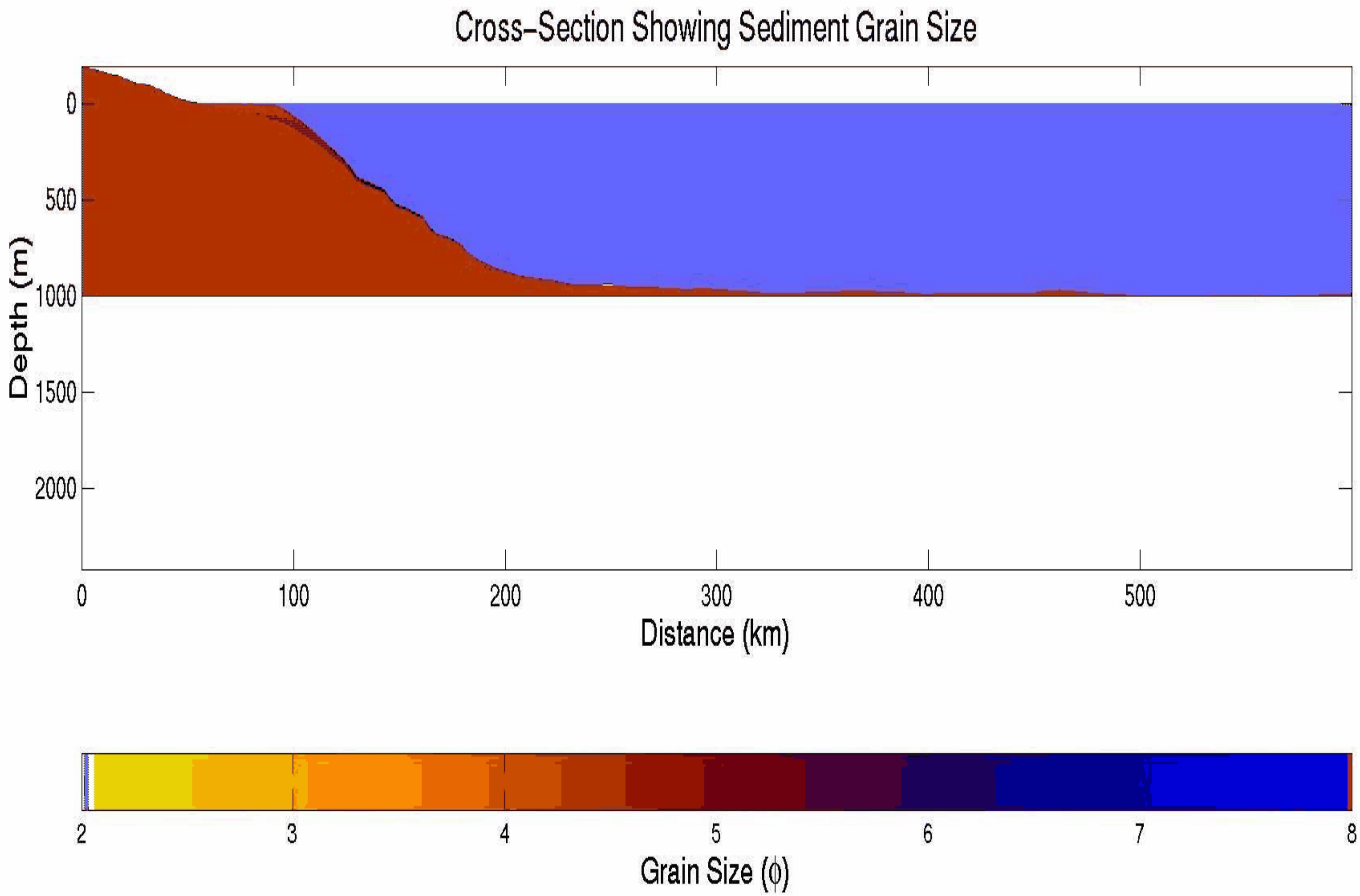
Acoustic Models

=

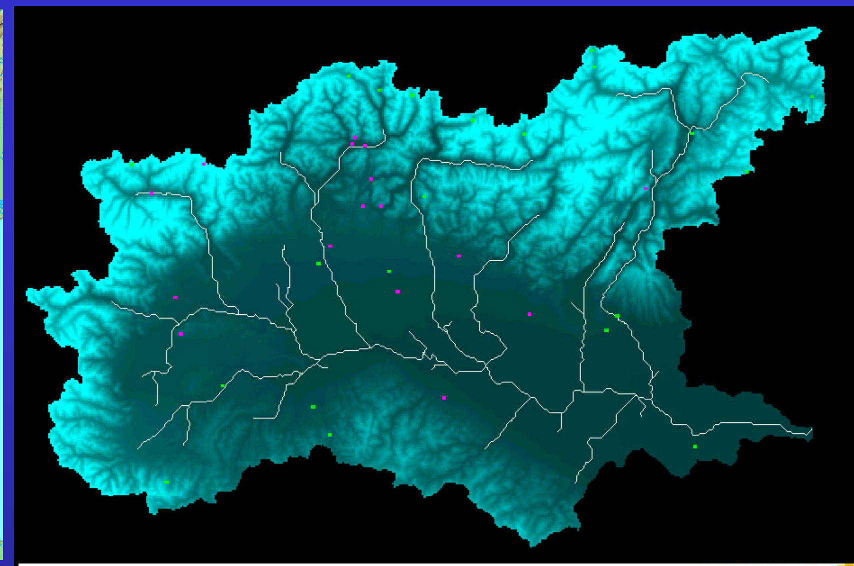
Reflecting Surfaces, Acoustic Absorbtion & Attenuation
Acoustic Geoclutter

QuickTime™ and a GIF decompressor are needed to see this picture.

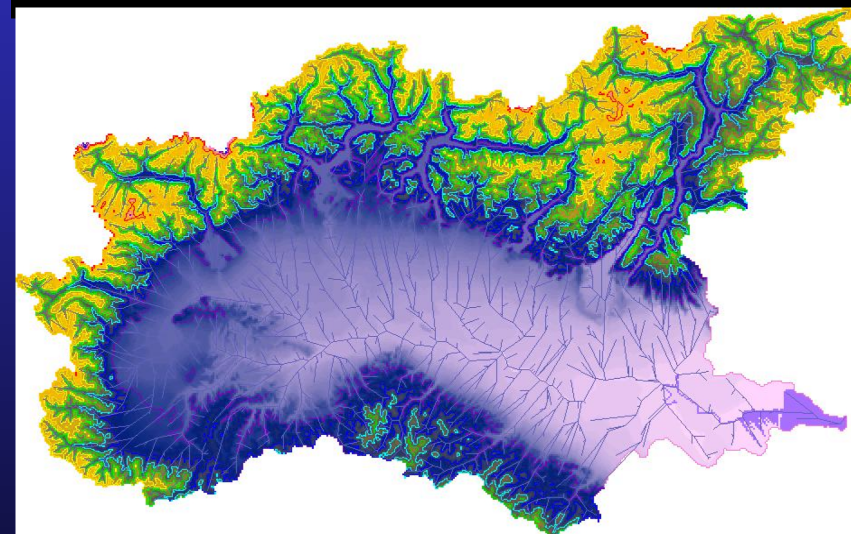
MODULE	INPUTS	OUTPUTS	COMMENTS
HYDROTREND	Climate (T, P, L, E) Basin (hypso., ELA, lakes, soil): 2D	Q, Uo, Ho, Bo, Cs, Di, 1D- River mouth	Eulerian Steady-state; T= daily
PLUME	HYDROTREND Wind Scalar	Vertical Flux, 1 to 10 m in XY	Eulerian Steady-state; T= daily
LITTORAL	Tidal Range, HYDROTREND Significant Wave H	$\partial\eta/\partial x$, $\partial D/\partial x$, $\partial\rho/\partial x$ 1 m in X	Eulerian Steady-state; T= daily
INFLO	HYDROTREND Internal: $\partial z/\partial x$, $\partial D/\partial x$, $\partial\rho/\partial xz$	$\partial\eta/\partial x$, $\partial D/\partial x$, $\partial\rho/\partial x$ 1 m in X	Eulerian Steady-state; T= 1 s
SHELF BLT (UVA, VIMS, URS, INSTAAR)	Uw pdf; Uc-x; Internal: $\partial z/\partial x$ $\partial D/\partial x$, $\partial\rho/\partial x$	$\partial\eta/\partial x$, $\partial D/\partial x$, $\partial\rho/\partial x$ < 10 m in X	Eulerian Steady-state; T= < daily
FAIL	Earthquake E pdf Internal: $\partial z/\partial x$, $\partial D/\partial x$, $\partial\rho/\partial x$, $\partial Pe/\partial x$, $\partial W/\partial x$	ΣDi, 10 to 100 m in X	Eulerian Steady-state; T= > yr
INFLO or BANG	Internal: $\partial D/\partial x$, $\partial\rho/\partial x$, $\partial z/\partial x$, $\partial\rho/\partial x$	$\partial\eta/\partial x$, $\partial D/\partial x$, $\partial\rho/\partial x$ 1 m in X	Eulerian or Lagrangian, T= 1 s
BING (SKRED)	Internal: $\partial D/\partial x$, $\partial\nu/\partial x$, $\partial Y/\partial x$, $\partial z/\partial x$	$\partial\eta/\partial x$, $\partial D/\partial x$, $\partial\rho/\partial x$ < 10 m in X	Lagrangian, T= < 0.1 s
COMPACT	Internal: $\partial D/\partial z$, $\partial Pe/\partial z$, $\partial\rho/\partial z$	$\partial z/\partial x$, $\partial\rho/\partial x$ < 0.1 to 1 m in Z	Eulerian Steady-state; T= > yr
BOUNDARY	sea level/∂t, tectonics/$\partial t\partial x$ mantle viscosity	$\partial z/\partial x$	Eulerian Steady-state; T= > daily



2D-SedFlux Run: 2Myr



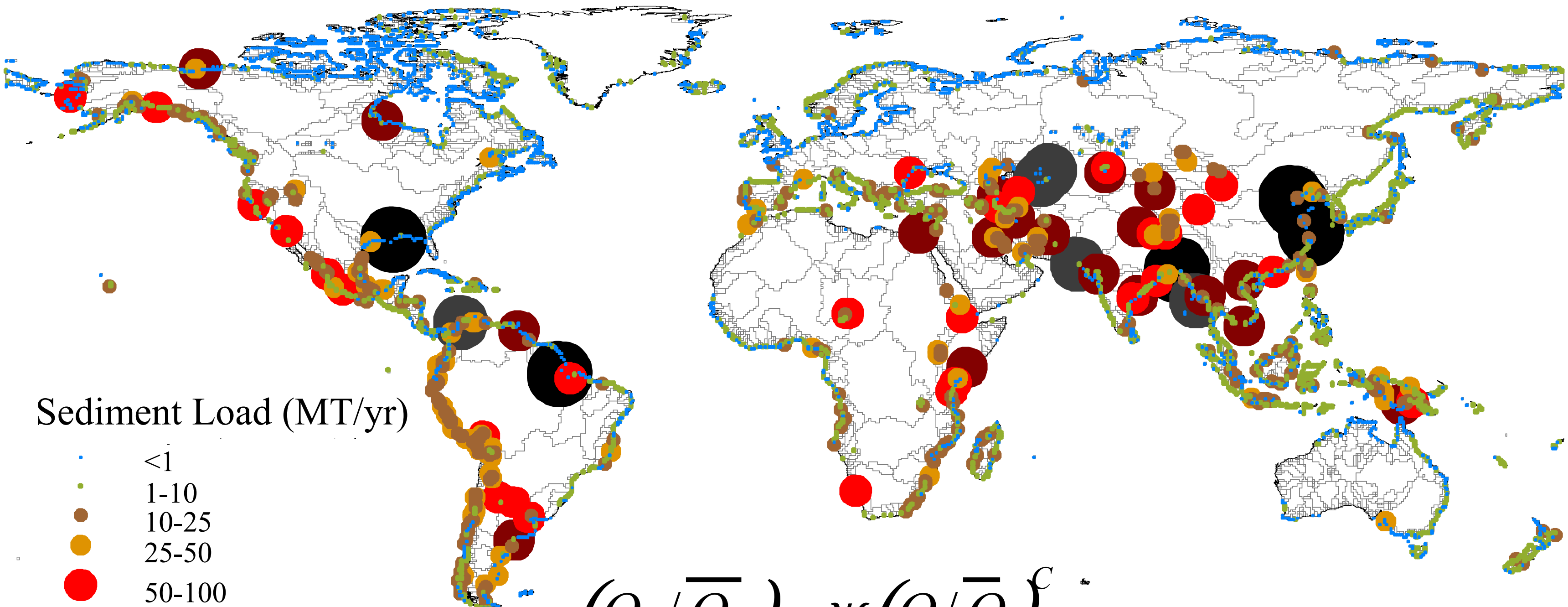
HydroTrend produces daily variability in water and sediment discharge for both paleo and modern river basins and uses other spatial models i.e. *Hydro1k* and *RiverTools* and global databases (e.g. *DODS)*.



Sediment Load at River Mouth (MT/yr)

Syvitski and Morehead, 1999 (Natural)

$$\overline{Q_s} = 2\times10^{-6} R^{3/2} A^{1/2} e^{kT}$$



Sediment Load (MT/yr)

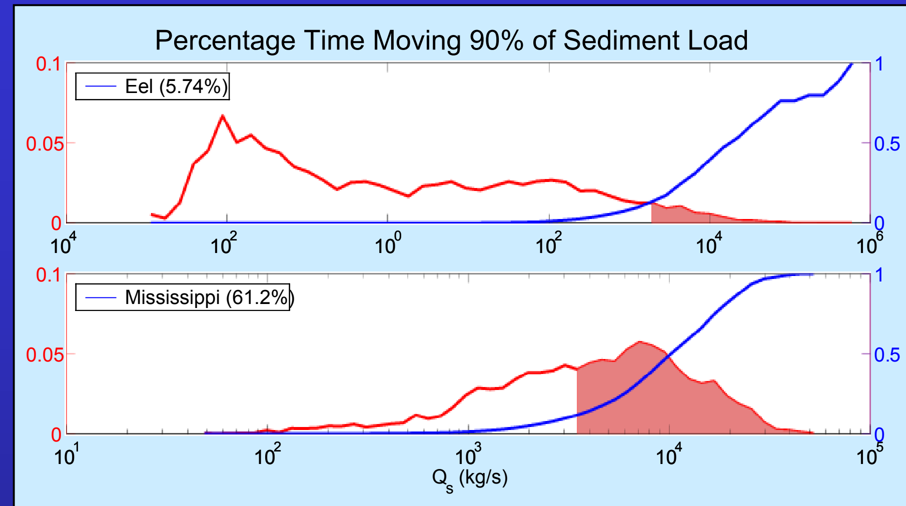
- <1
- 1-10
- 10-25
- 25-50
- 50-100
- 100-200
- 200-400
- >400

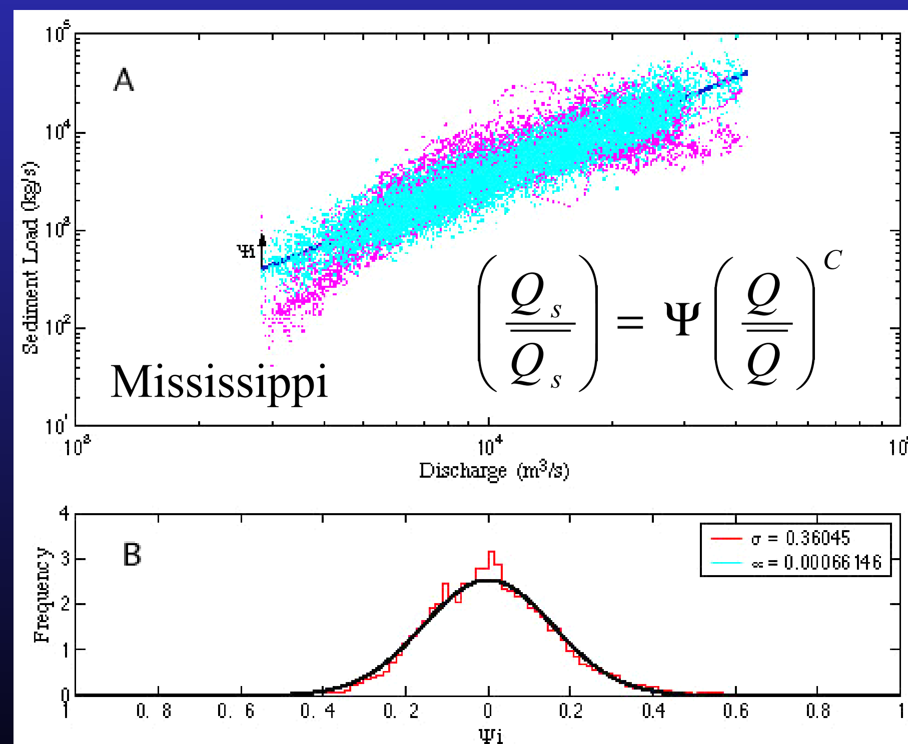
$$\left(Q_s / \overline{Q_s}\right) = \psi \left(Q / \overline{Q}\right)^C$$

$$\sigma(\psi) = 0.763\times10^{-0.00003\overline{Q}}$$

$$E(C) = 1.76 - 0.025T + 0.00013R + 0.145\ln(\overline{Qs})$$

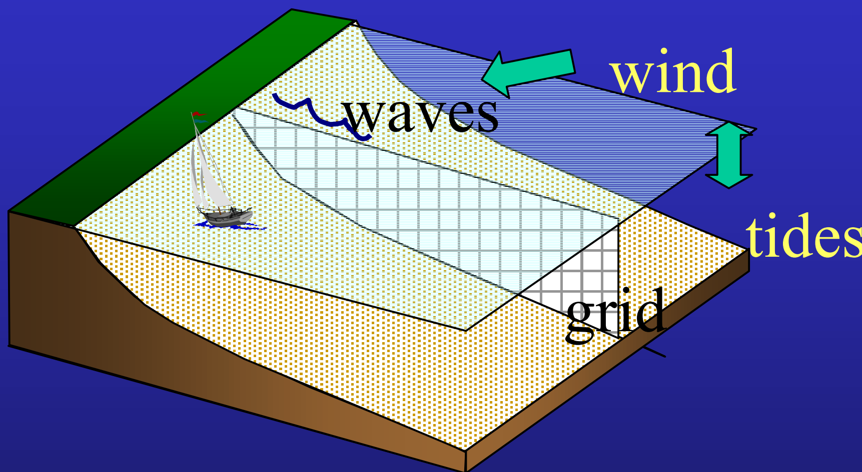
$$\sigma(C) = 0.17 + 0.0000183\overline{Q}$$



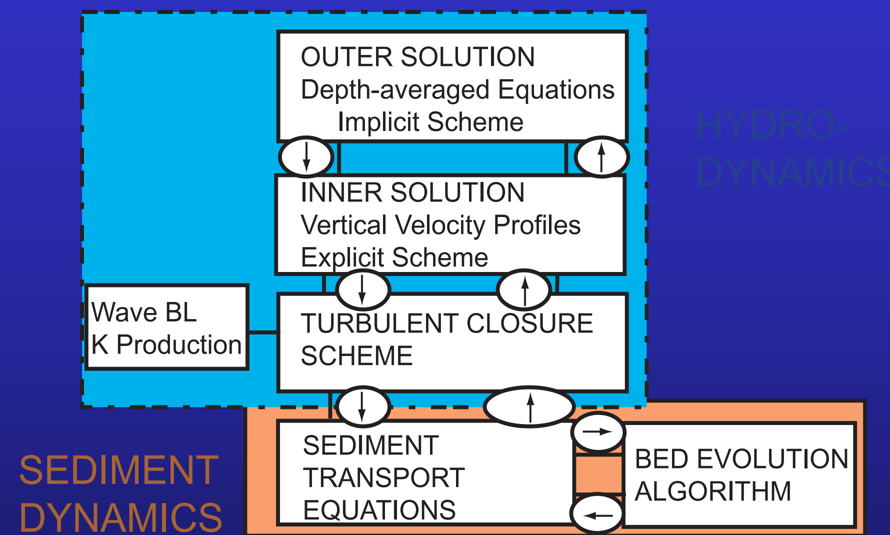


SedFlux **employs** ***pdf*****s to track only the high Qs events, yet conserve mass, and thereby save computation time**

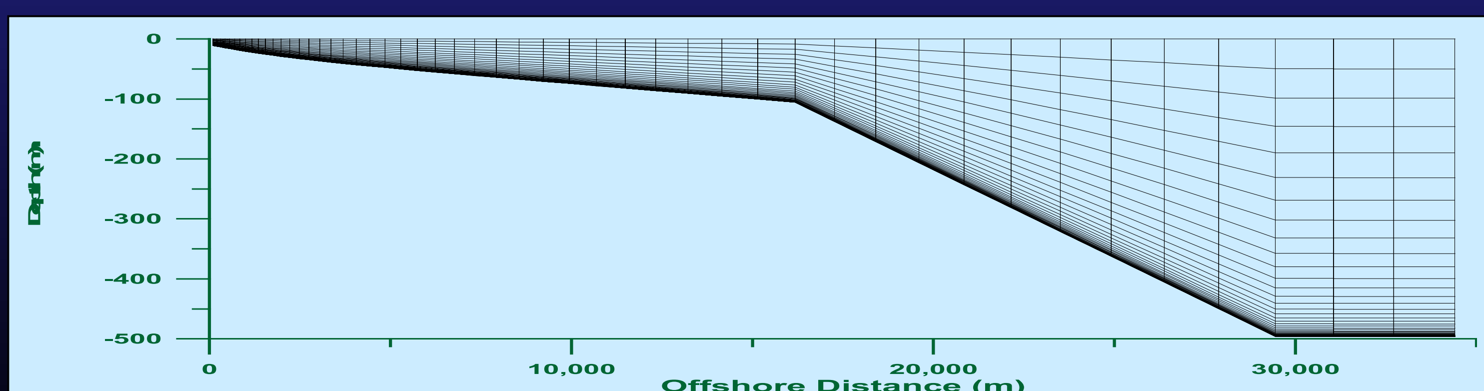
Each module has its own computational grid and boundary closure scheme



SLICE (2d) MODEL

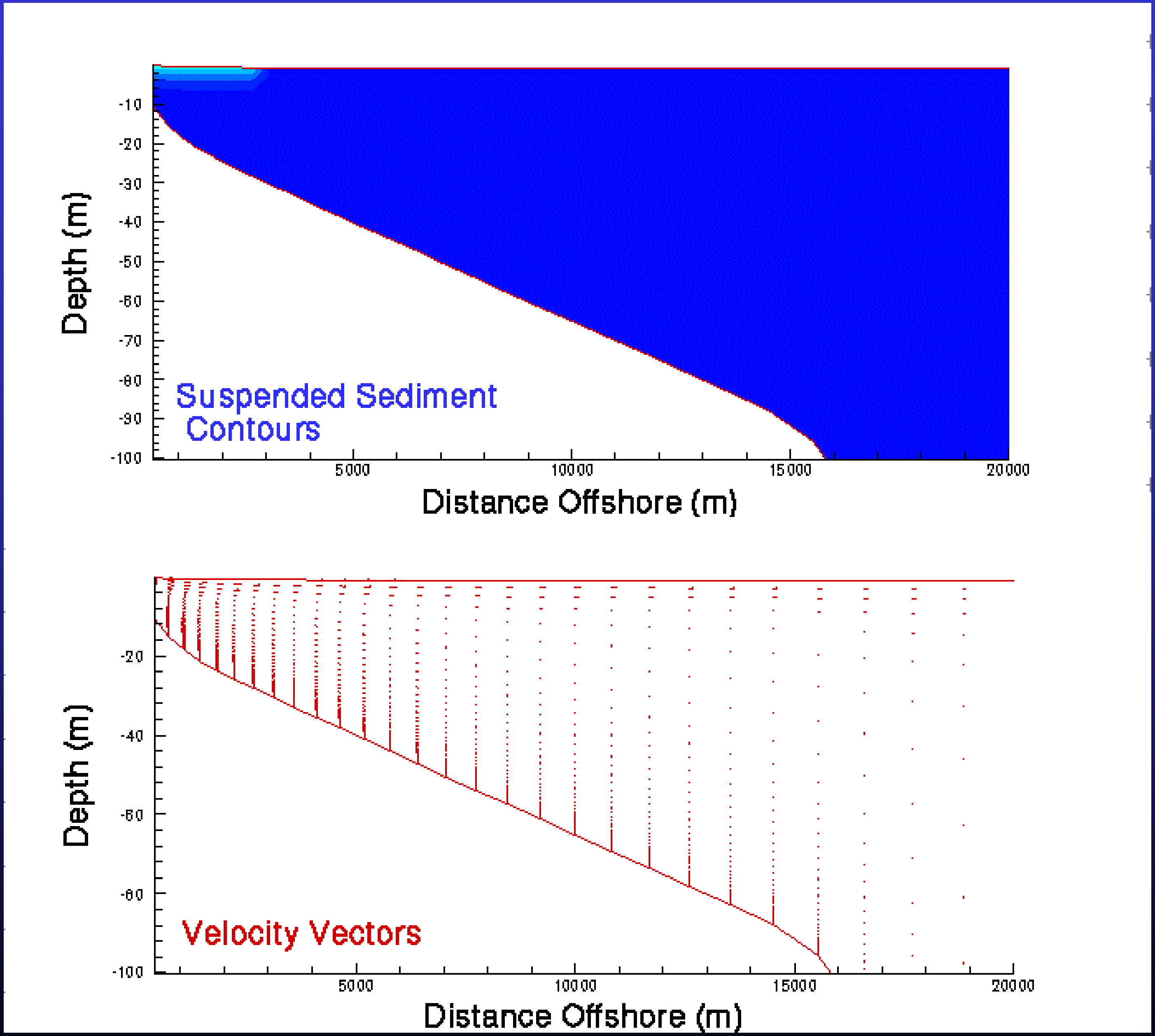


k-ε turbulent closure scheme

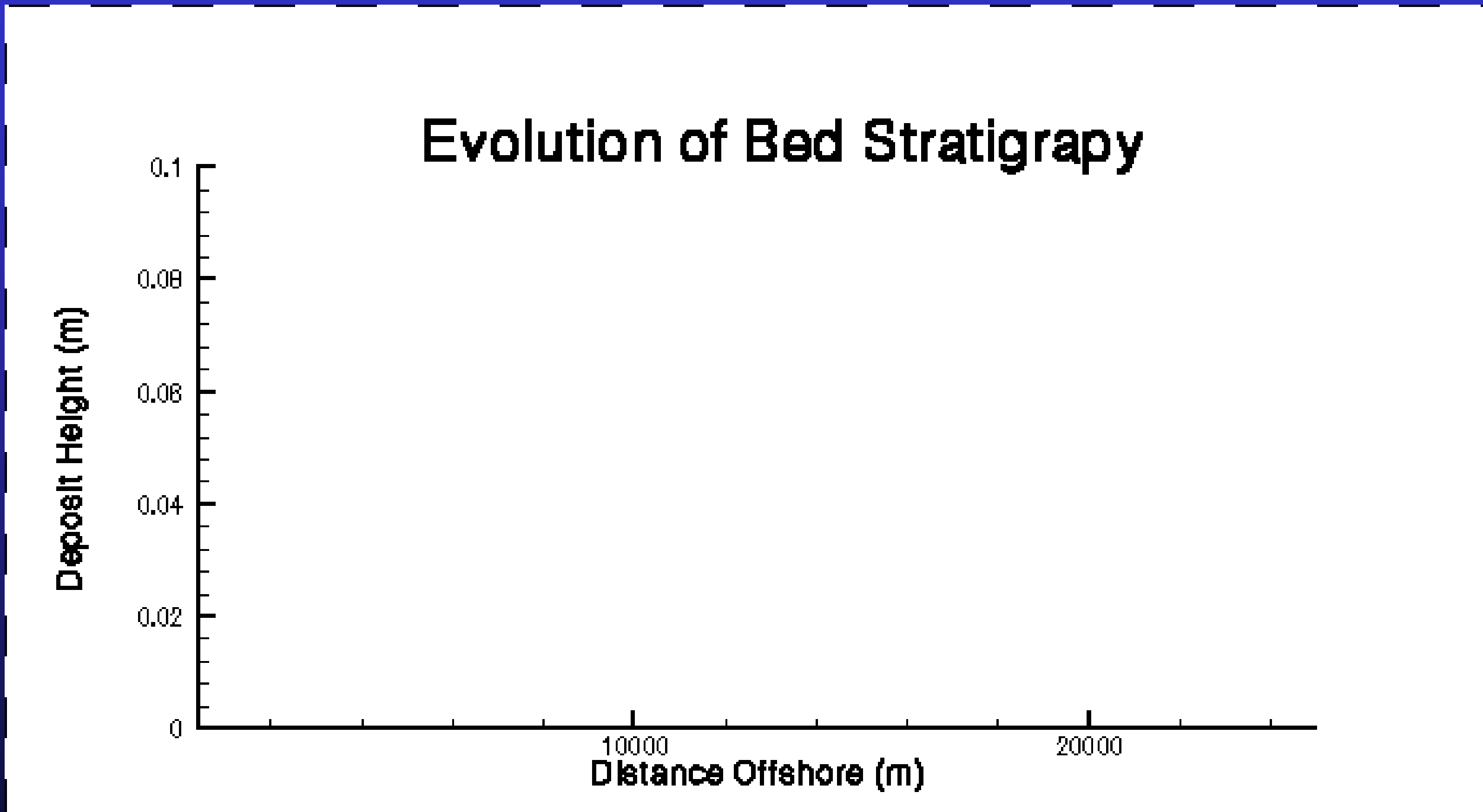


Modules to be first tested in stand alone mode

URS: Slice Model



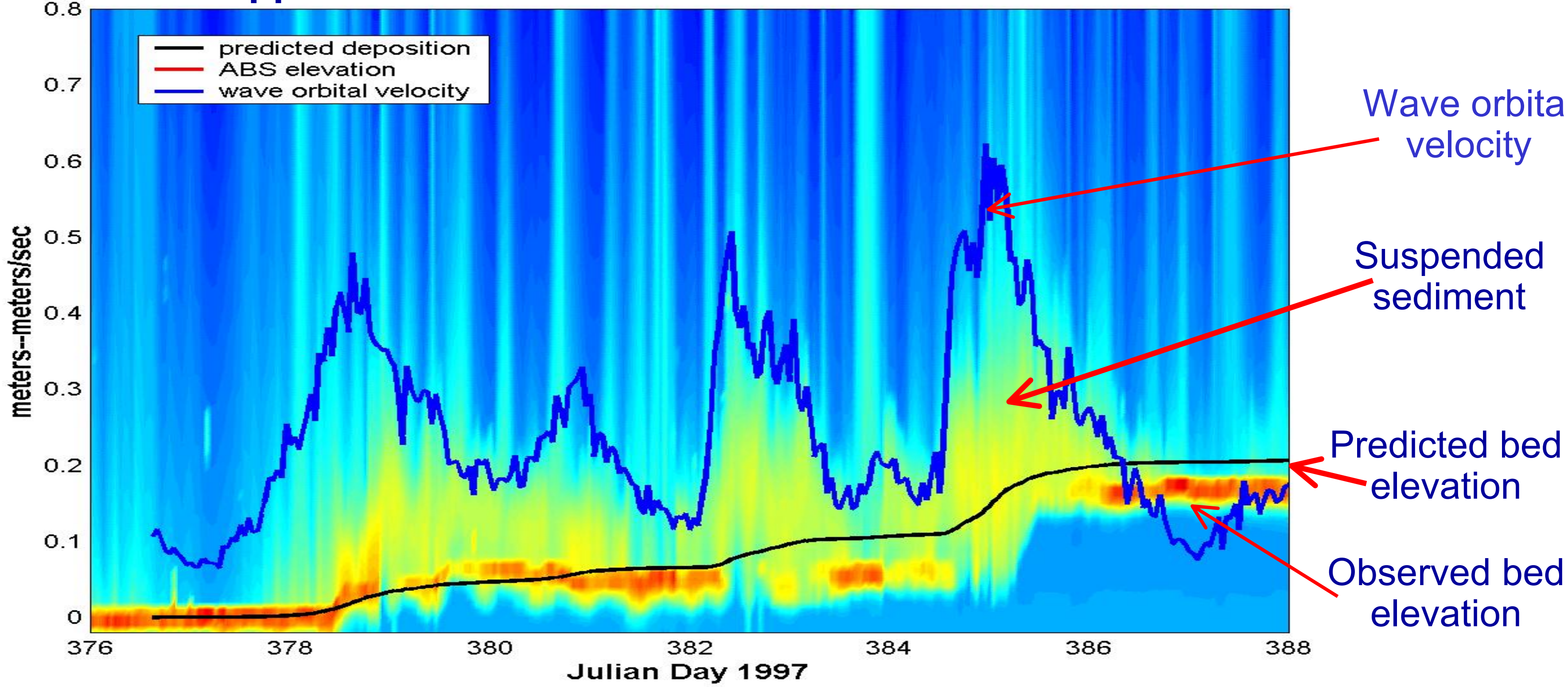
URS: Slice Model



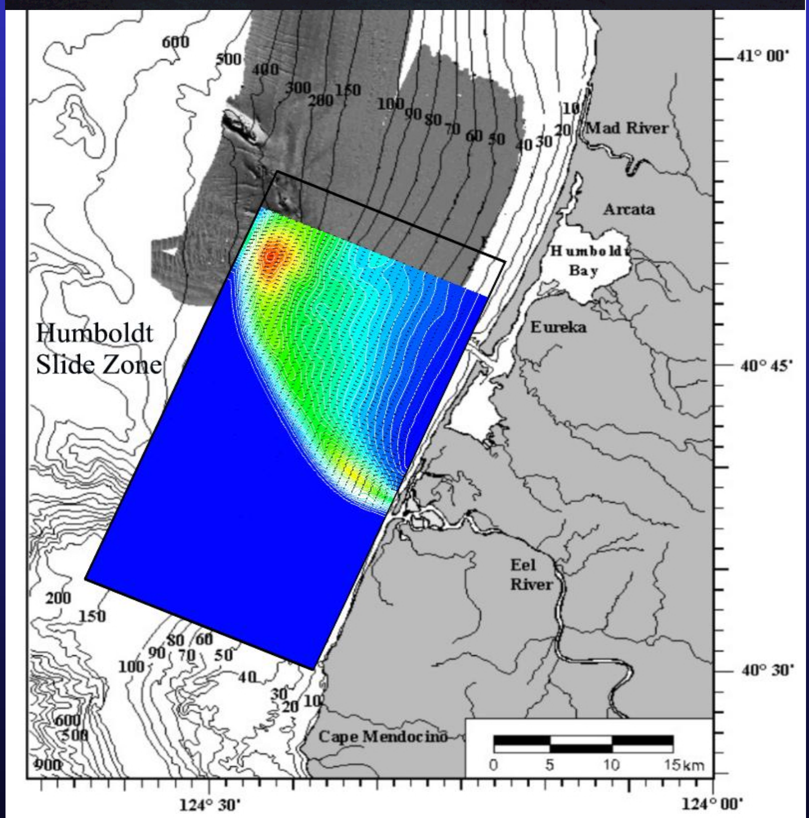
Modules to be first tested in stand alone mode

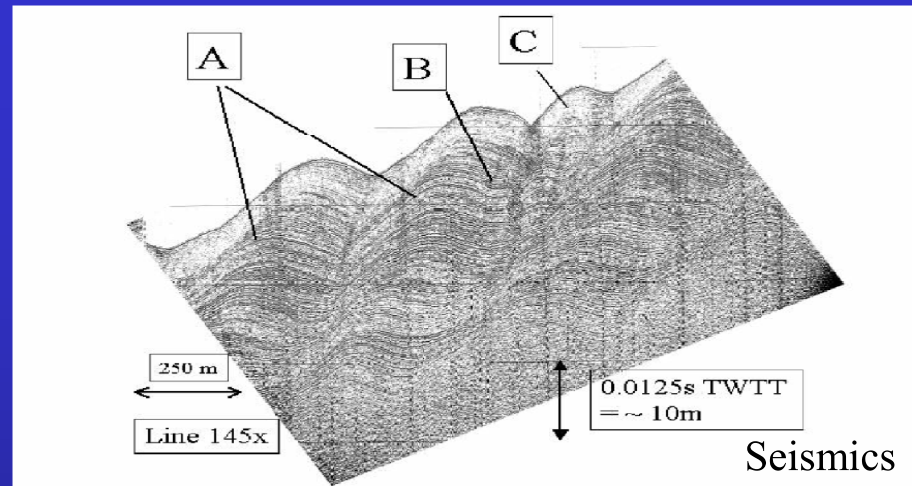
Each *SedFlux* module needs some form of verification (lab or field) before incorporation in master architecture.

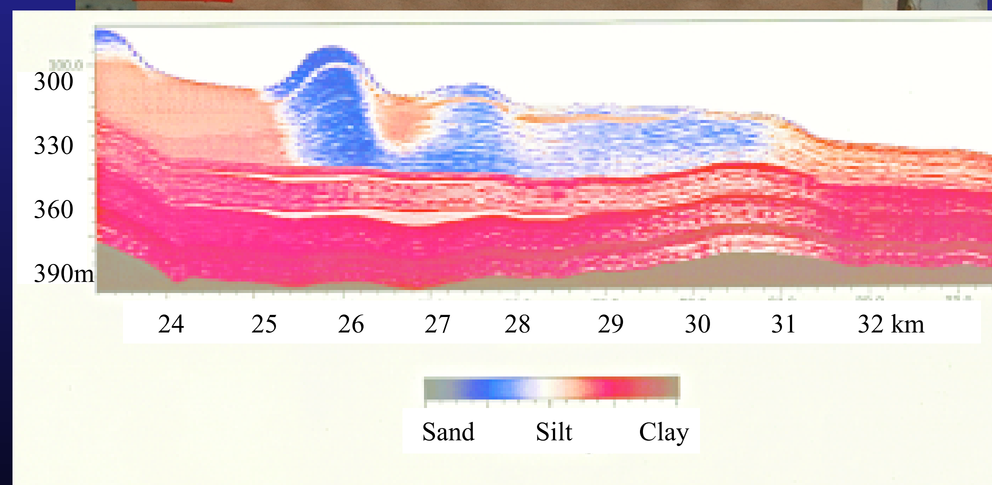
Application to 1996-97 Eel River Flood at 60-meter Site



(Observations from Traykovski et al., CSR 2000)

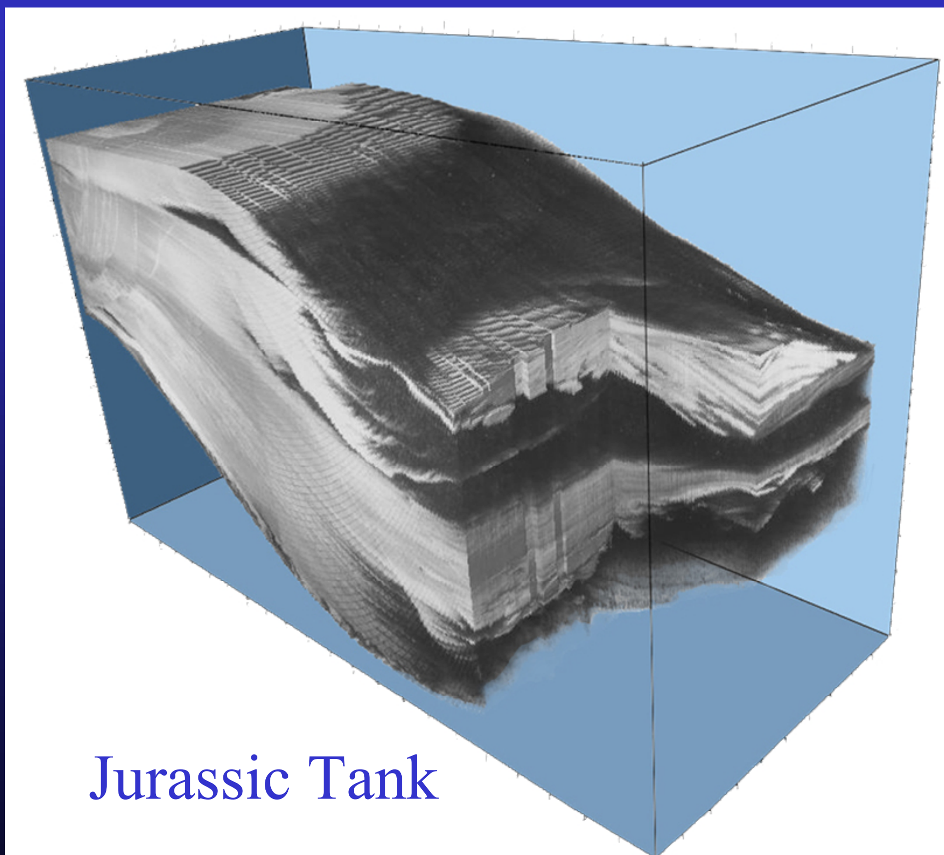


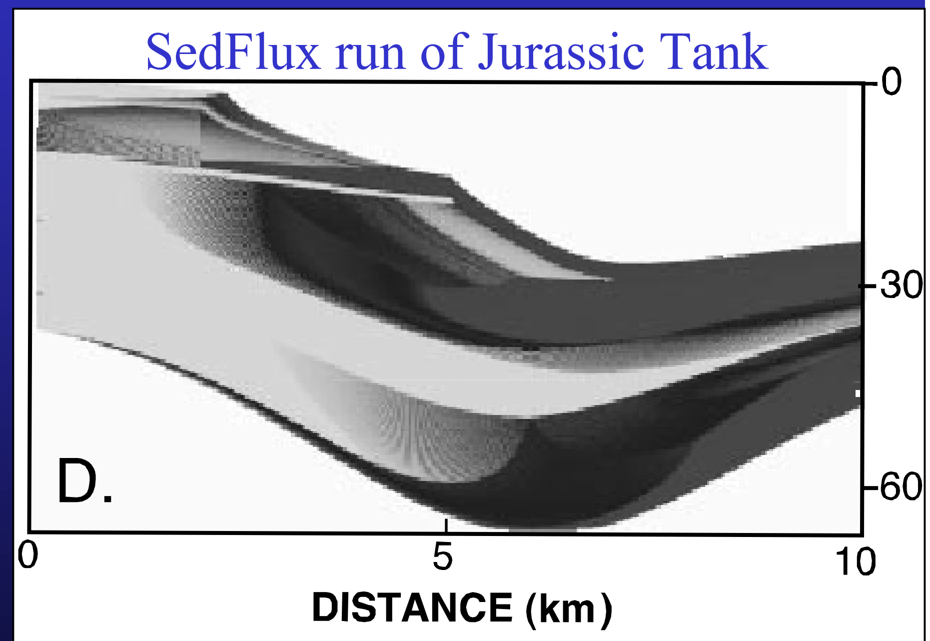




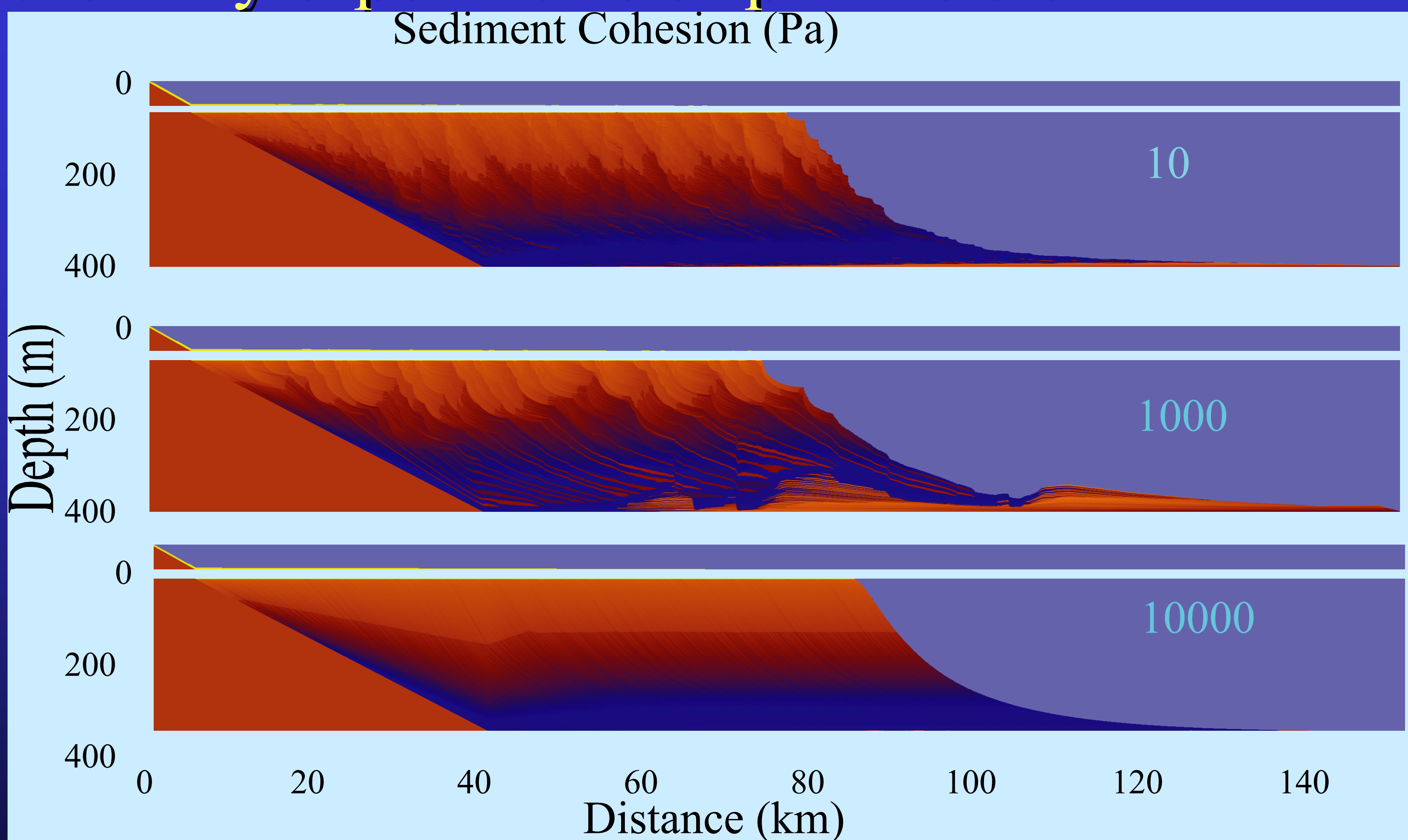
Community Sediment Model Workshop, Boulder, Feb. 20-22, 2002

The *SedFlux* goal is an integrative modeling system that simulates the formation of stratigraphic *sequences* populated by *facies* created by sedimentary *processes*.

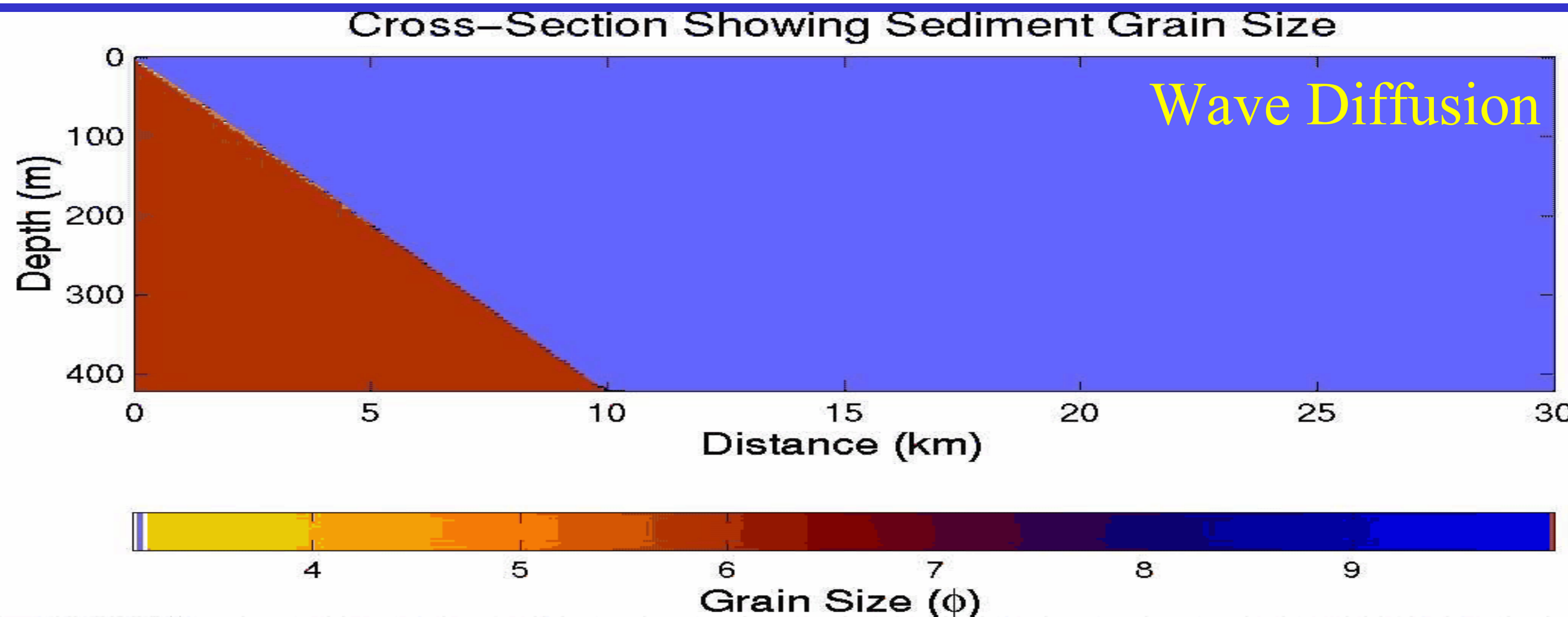


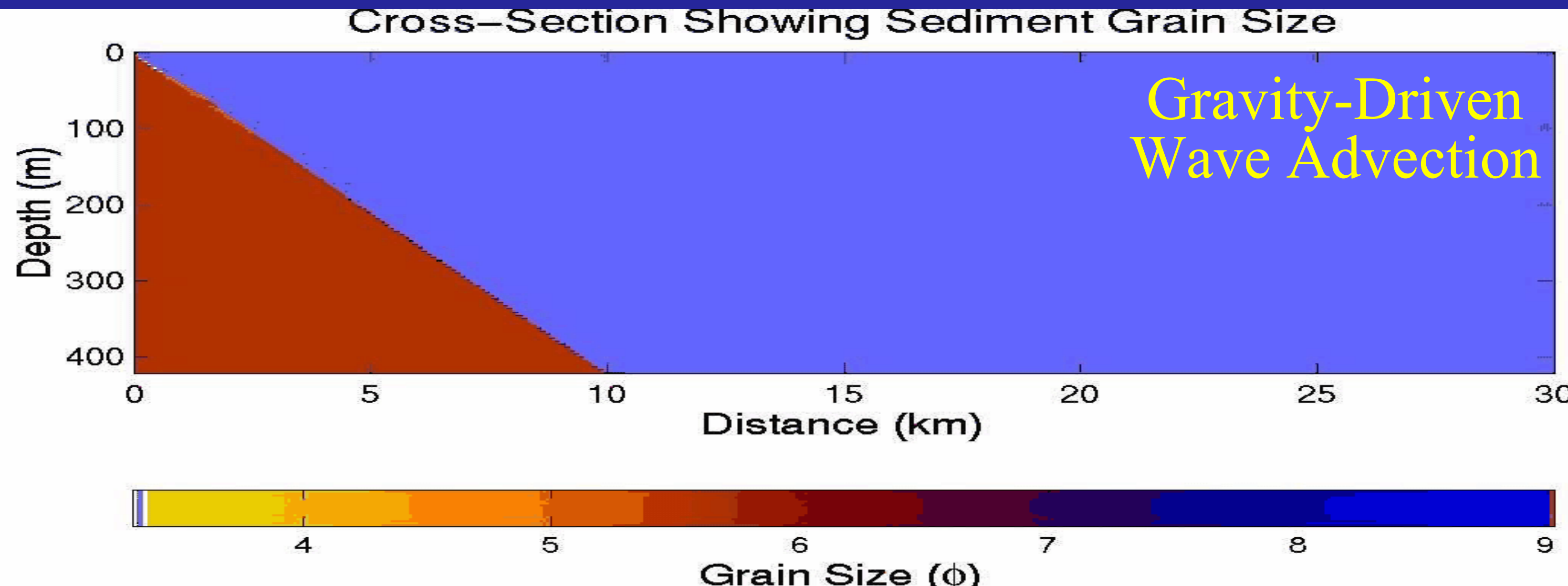


Sensitivity experiments on parameters



As sediment cohesion is increased, from 1 to 1000 Pa, failure size increases but the number of seafloor failure decreases.



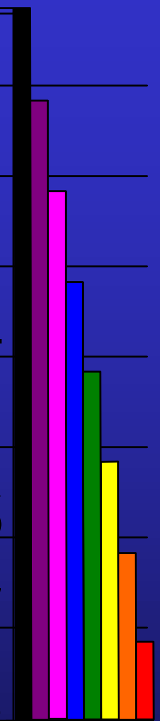


Sensitivity Experiments through Visualization

Community Sediment Model Workshop, Boulder, Feb. 20-22, 2002

Model Runs

River Influx	Run 1
Waves	Run2
Debris Flows	Run 3
Turbidity Currents	Run 4
Both	Run 5
Sea Level	Run 6
Isostasy	Run 7
Basin Geometry	Run 8

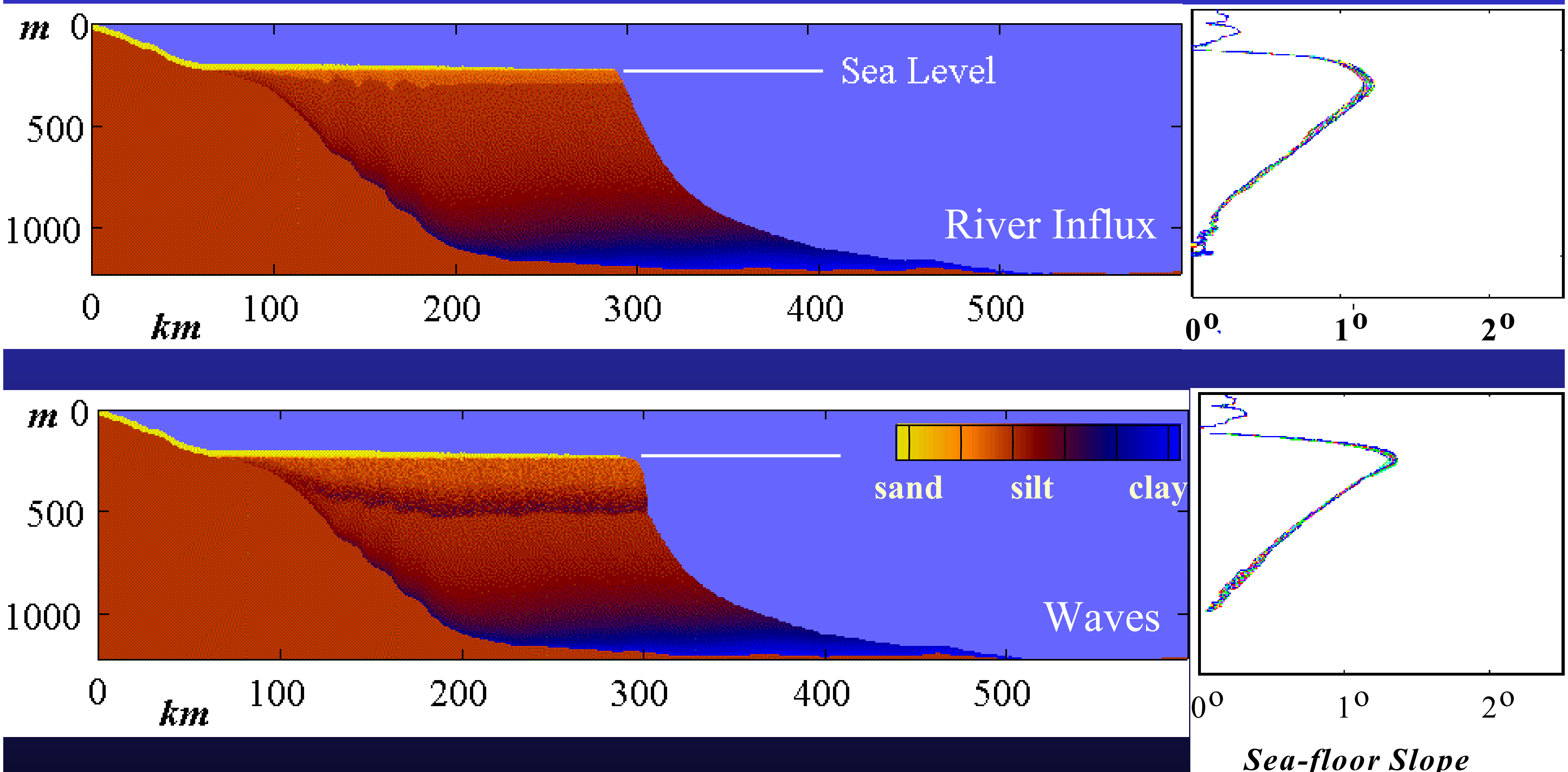


Simple

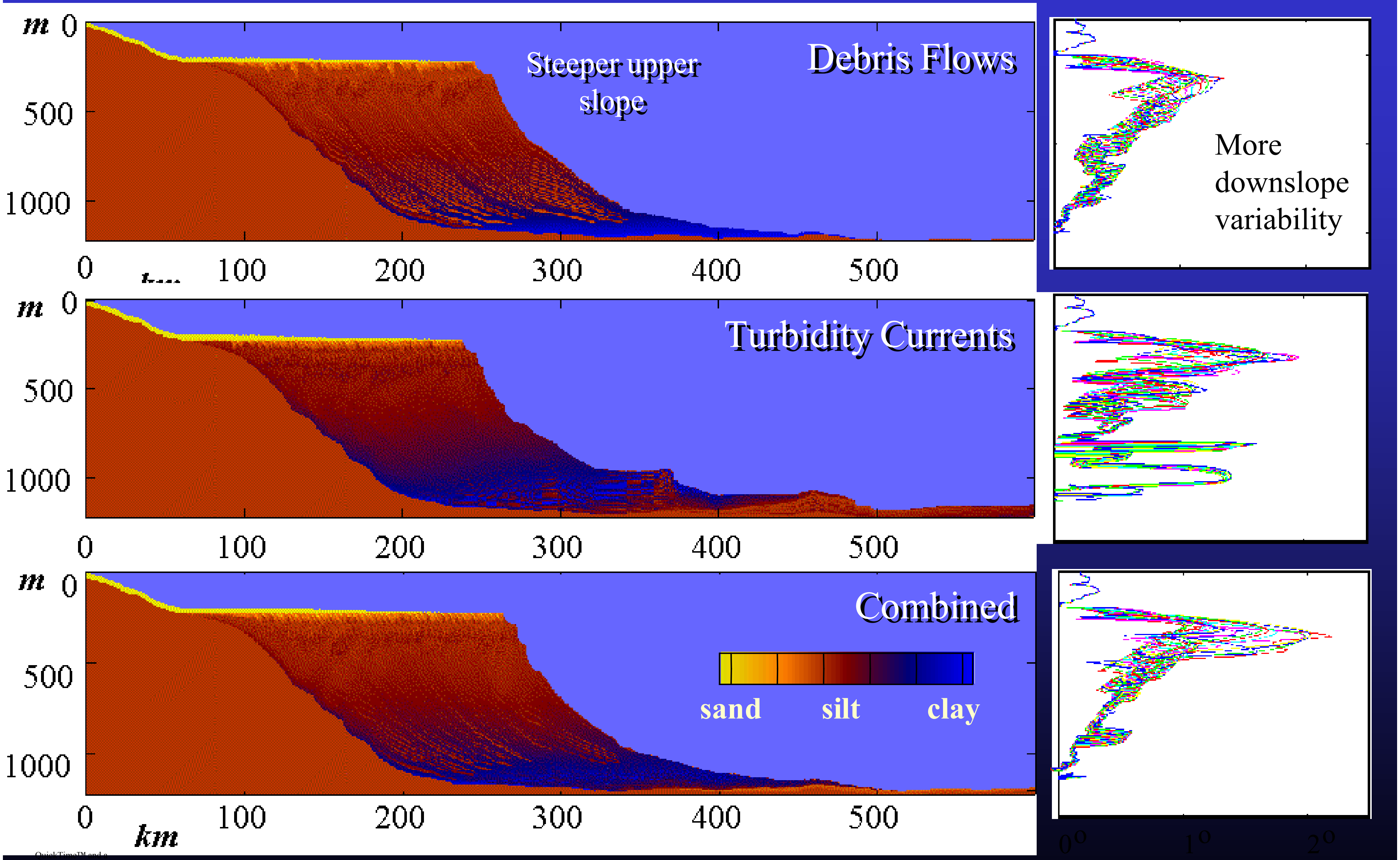
Complex

Whole Margin Sensitivity Experiment

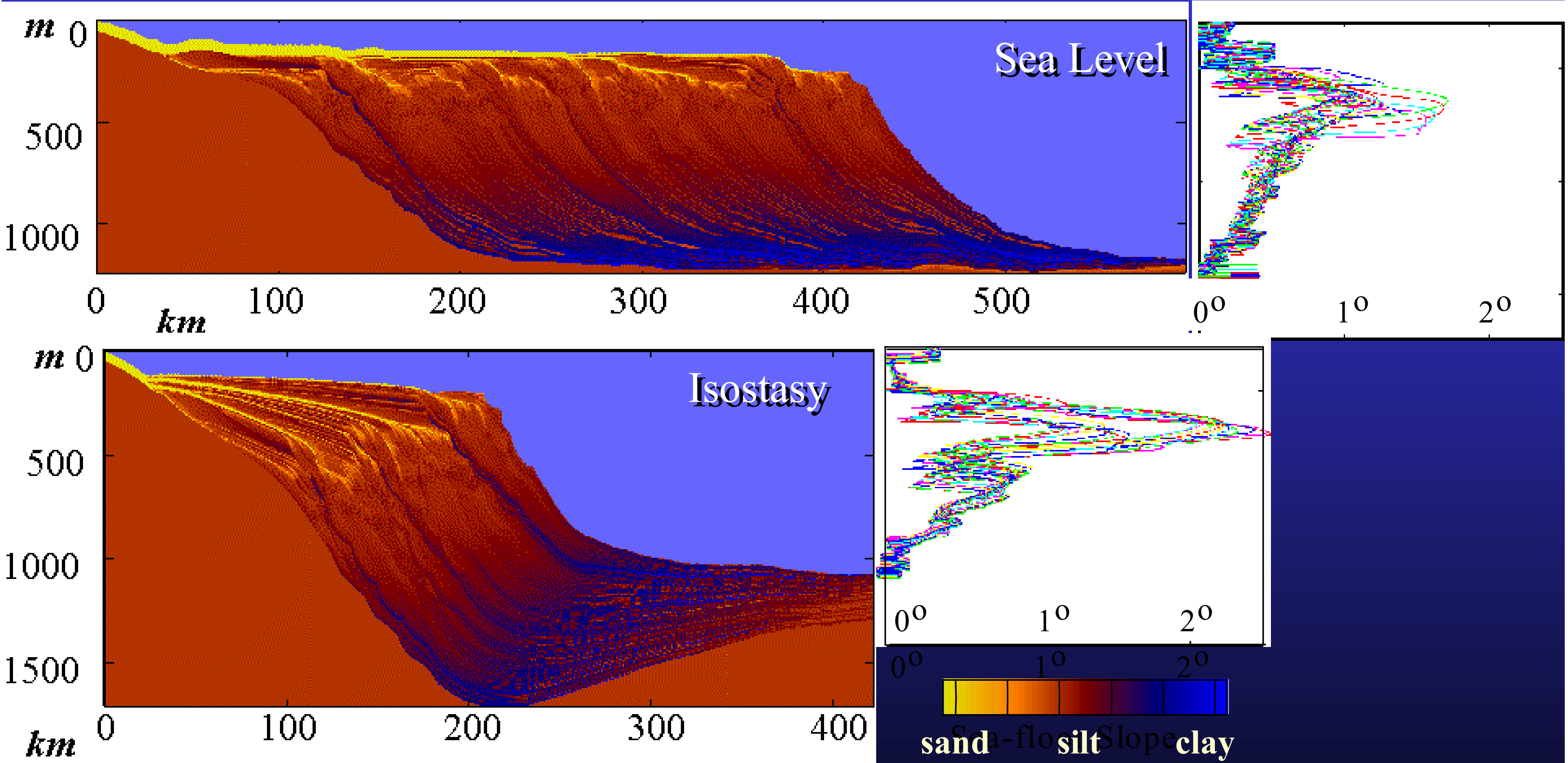
Hemipelagic sedimentation + shelf storms ⇒ simple clinoforms



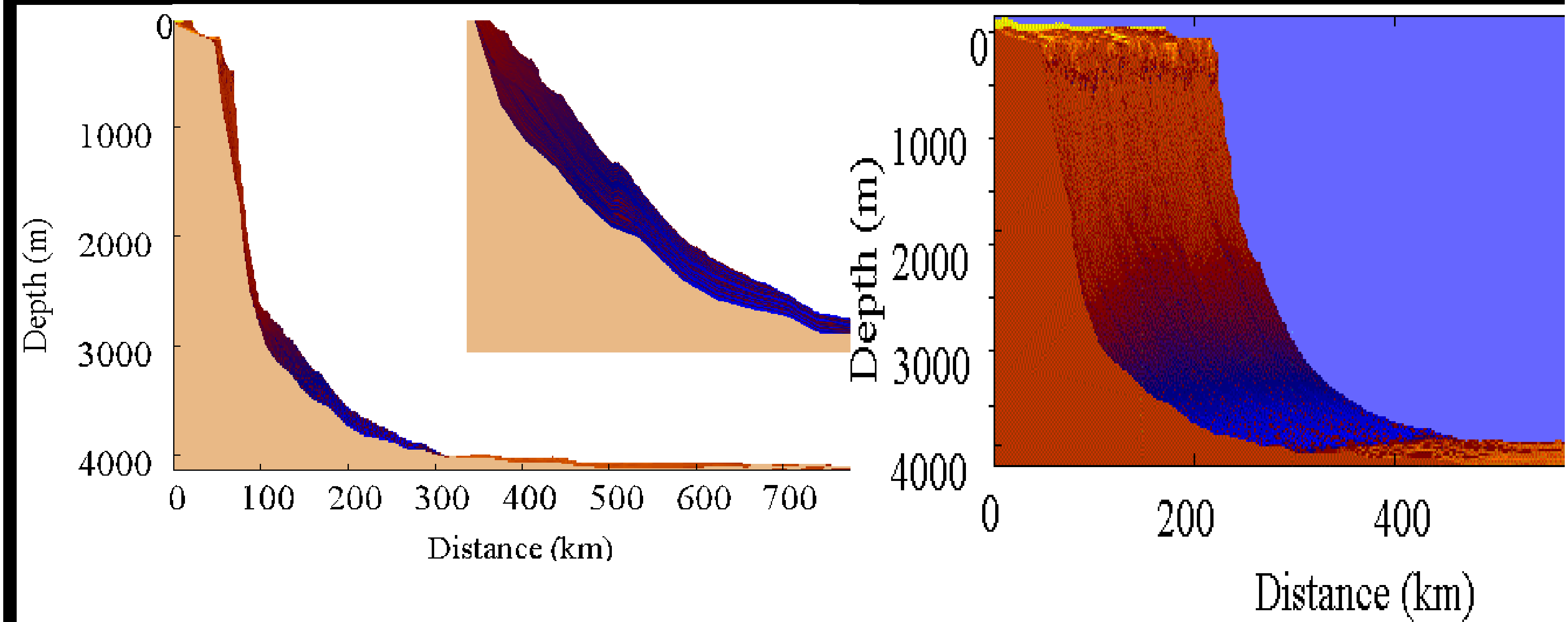
Slope Failure and Mass Wasting

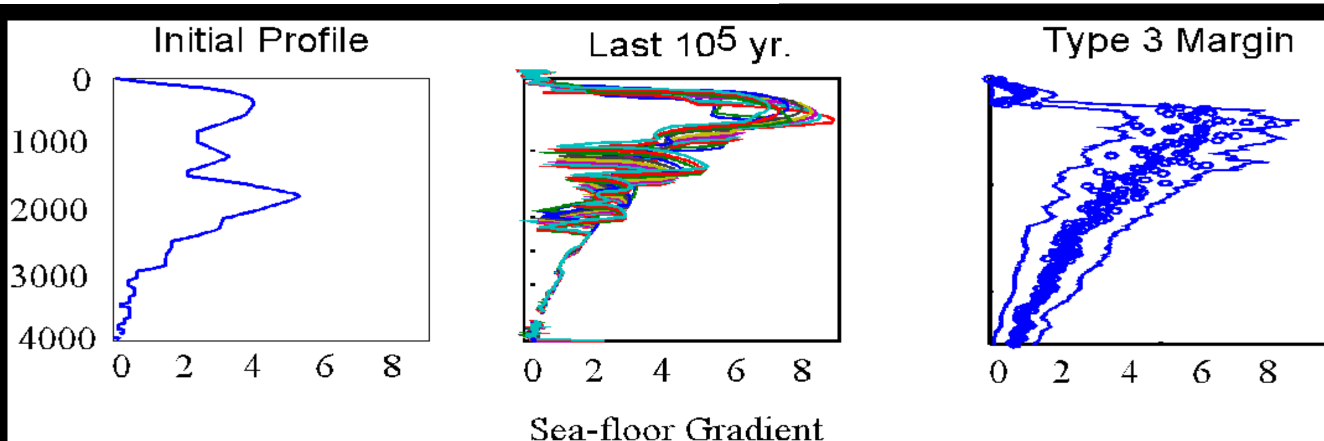


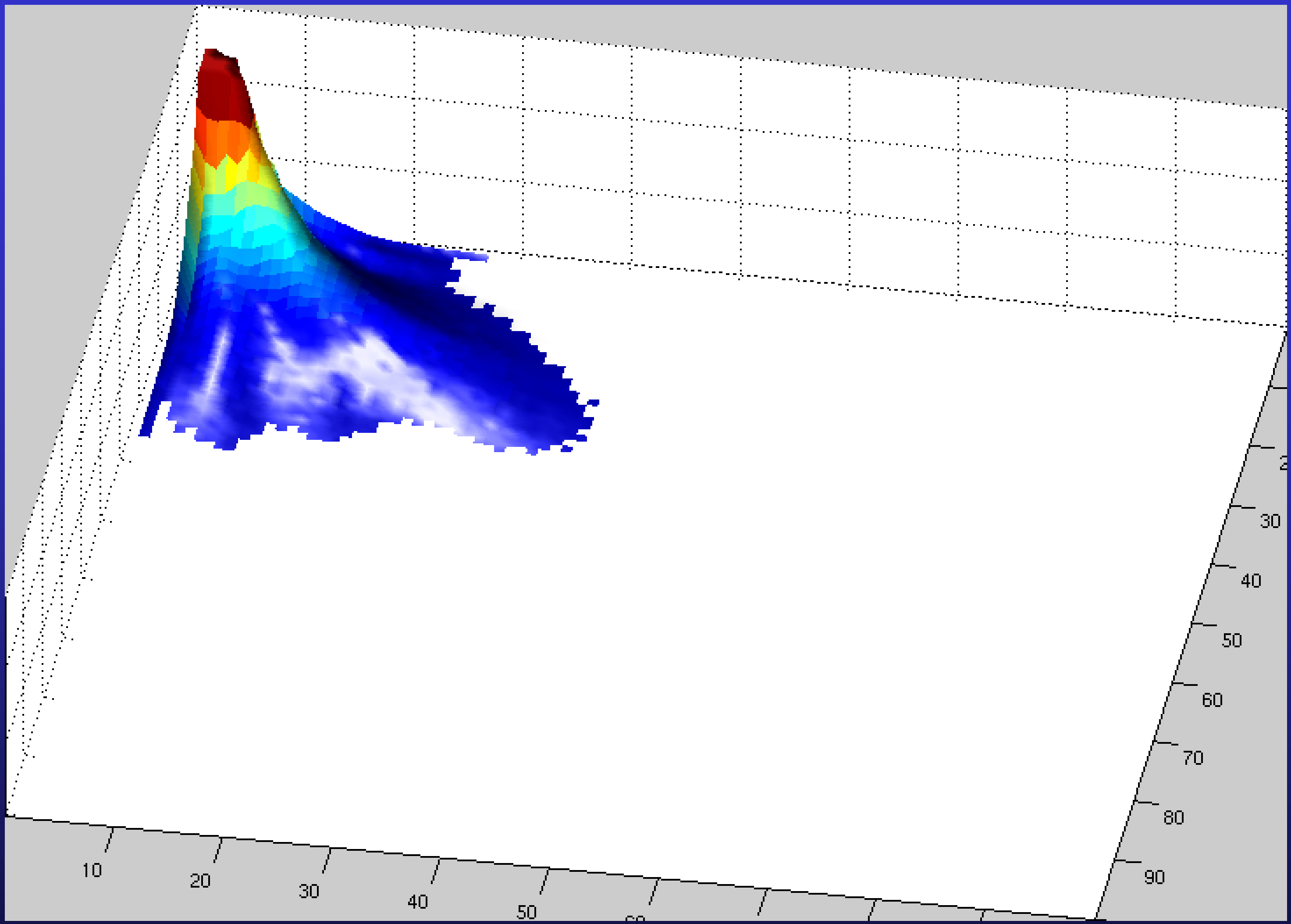
Accommodation space ⇒ small impact on slope profiles



Slope "adjustment"







First Run of 3D-SedFlux
Delta-lobe Switching Module

Sources of Model Uncertainty

Input: Acquisition/ Generation → **Model:** Resolution Boundary Cond. Process → Module Error Propagation → Field/Lab Validation Error