Linking Models: new componentized versions of CSDMS models

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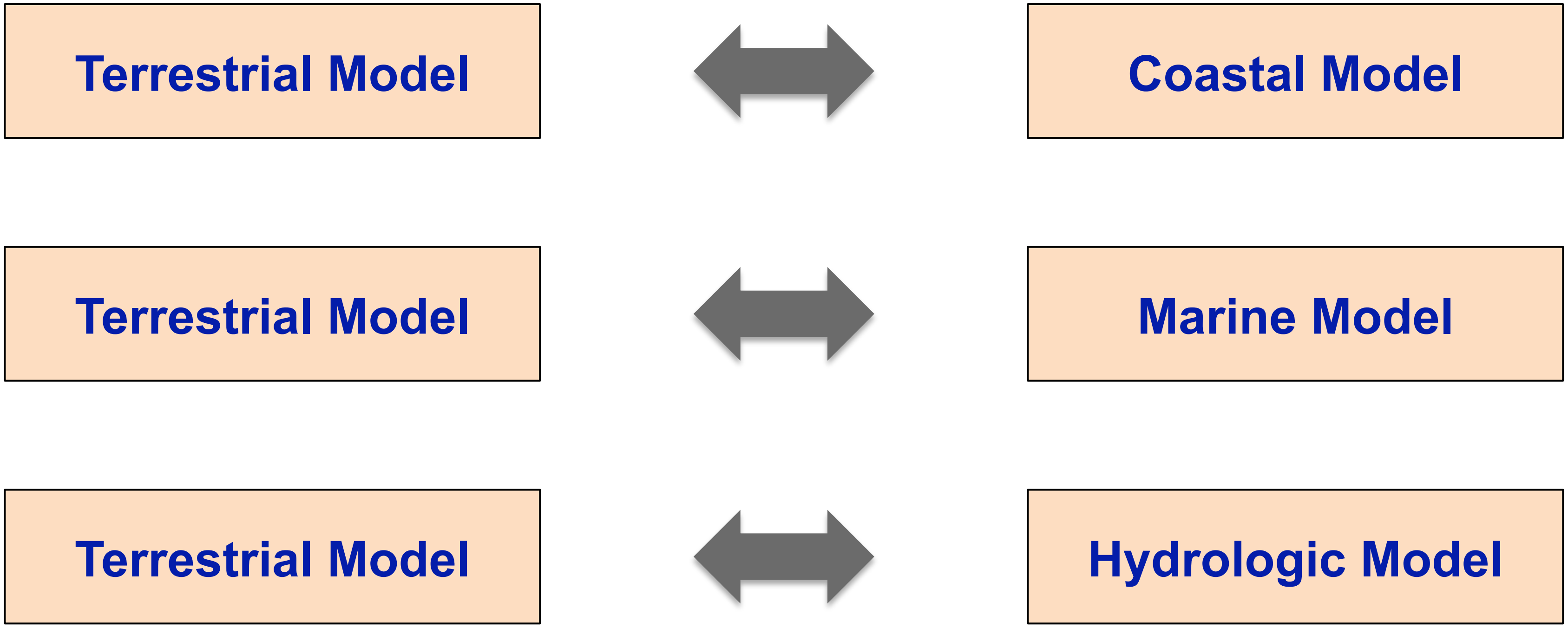
CSDMS is the *Community Surface Dynamics Modeling System*

(pronounced ˈsɪstəms)

Some proof of concept projects that are underway



Terrestrial Model ↔ Coastal Model

Terrestrial Model ↔ Marine Model

Terrestrial Model ↔ Hydrologic Model

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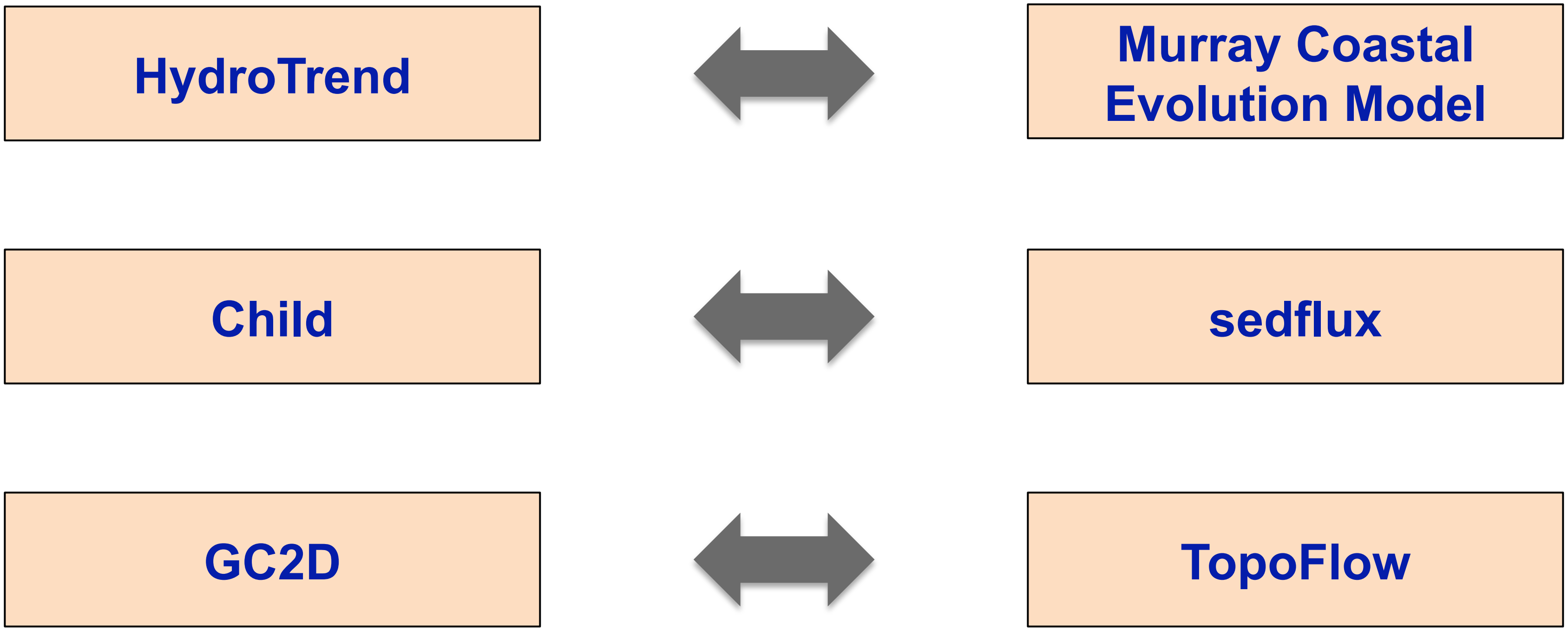
Some proof of concept projects that are underway



HydroTrend ↔ Murray Coastal Evolution Model

Child ↔ sedflux

GC2D ↔ TopoFlow

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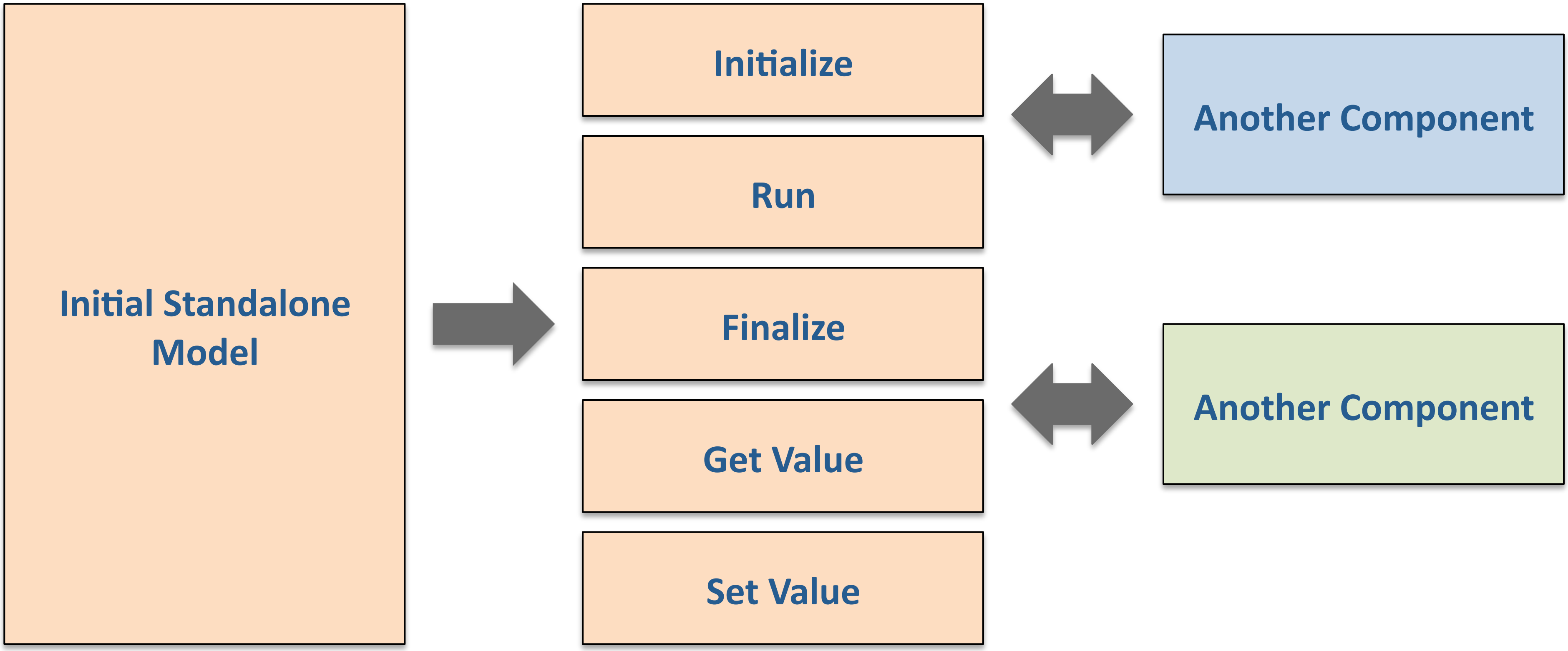
These models reflect the wide range of models in our community

These 6 models represent:

- 6 authors
- 4 languages
- 4 domains
- 140,000 lines of source code
    - of a total of 215,000 in our repository
- 3 different grids
    - raster, non-uniform mesh, spatially averaged
- 2 different levels of model granularity
    - process and model

A standalone model is componentized by dividing it into bits that perform tasks that other components can use



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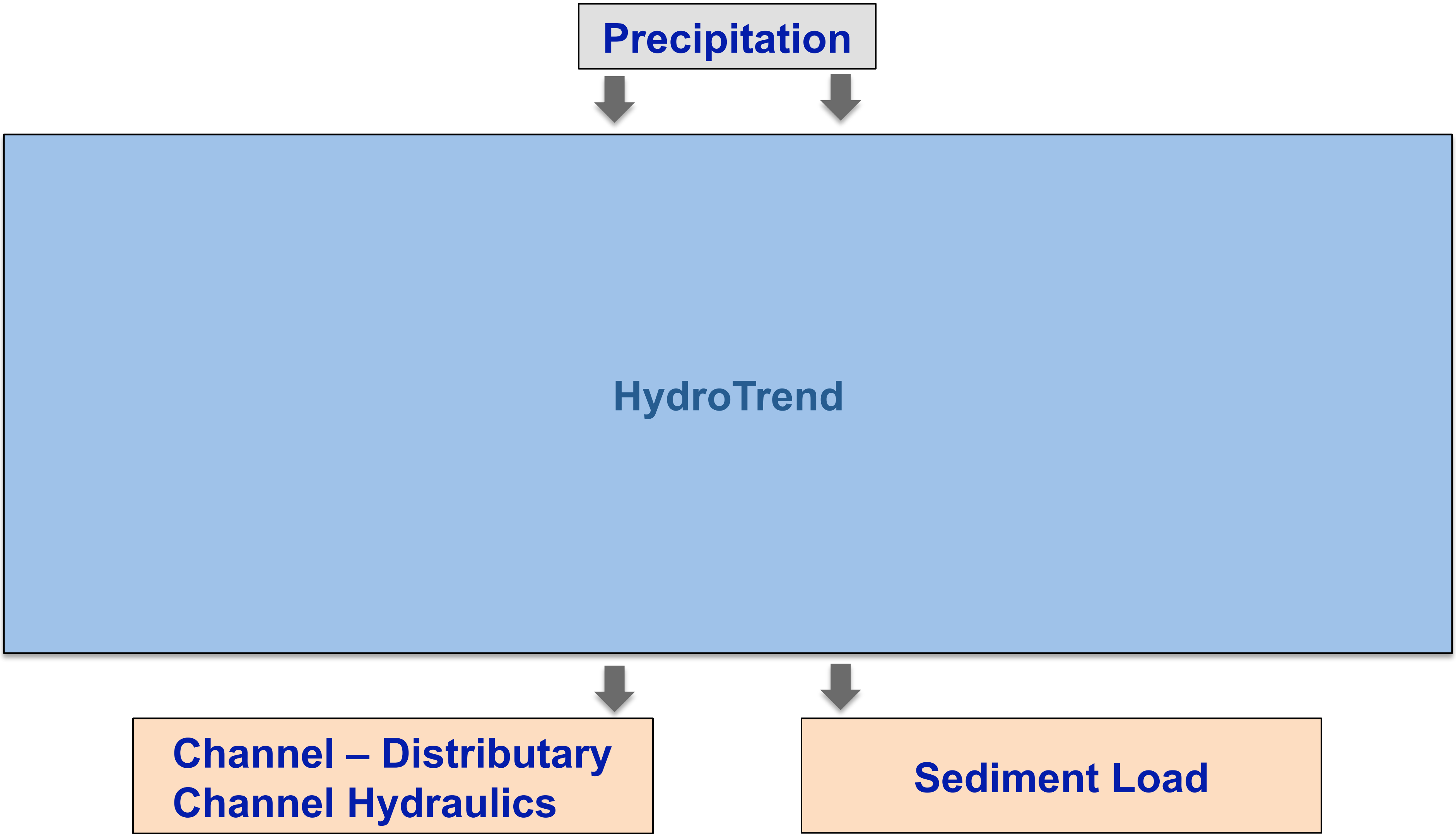
HydroTrend predicts the flux of water and sediment at a river mouth



Precipitation

HydroTrend

Channel – Distributary Channel Hydraulics

Sediment Load

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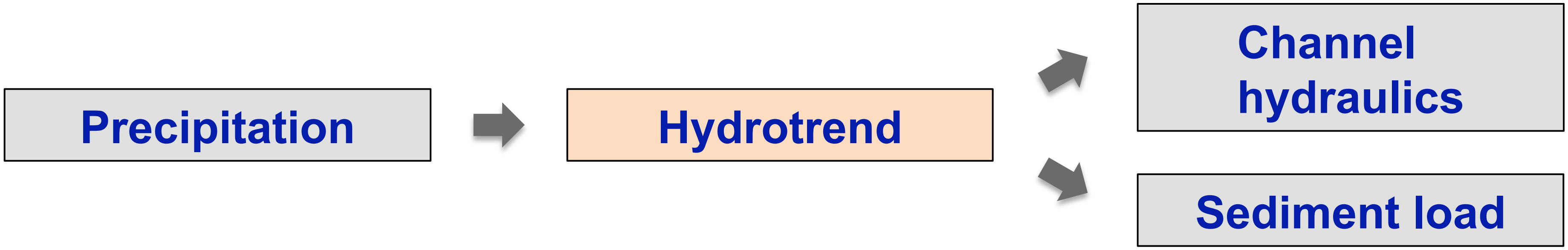
HydroTrend predicts the flux of water and sediment at a river mouth



Precipitation

Hydrotrend

Channel hydraulics

Sediment load

HydroTrend:

- 10,500 lines of C code
- Minimal command line interface
- Input precipitation statistics
- Output river discharge as binary hydrotrend file

HydroTrend still predicts the flux of water and sediment at a river mouth

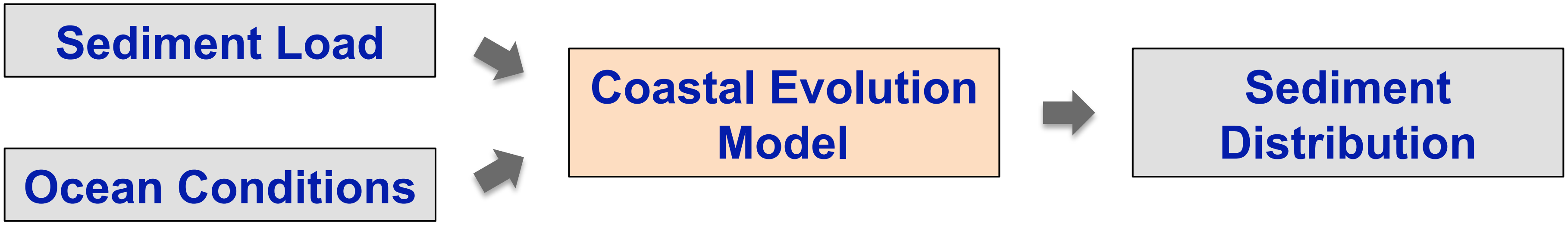
HydroTrend:

- 11,300 lines of C code (8% increase – mostly new files)
- API (IRF, and getters and setters)
- Expanded CLI
- GUI (within CCA)
- CCA component

Checkout a version from our model repository:

```
> svn checkout https://csdms.colorado.edu/svn/hydrotrend
```

CEM predicts the distribution of sediment after it enters the ocean

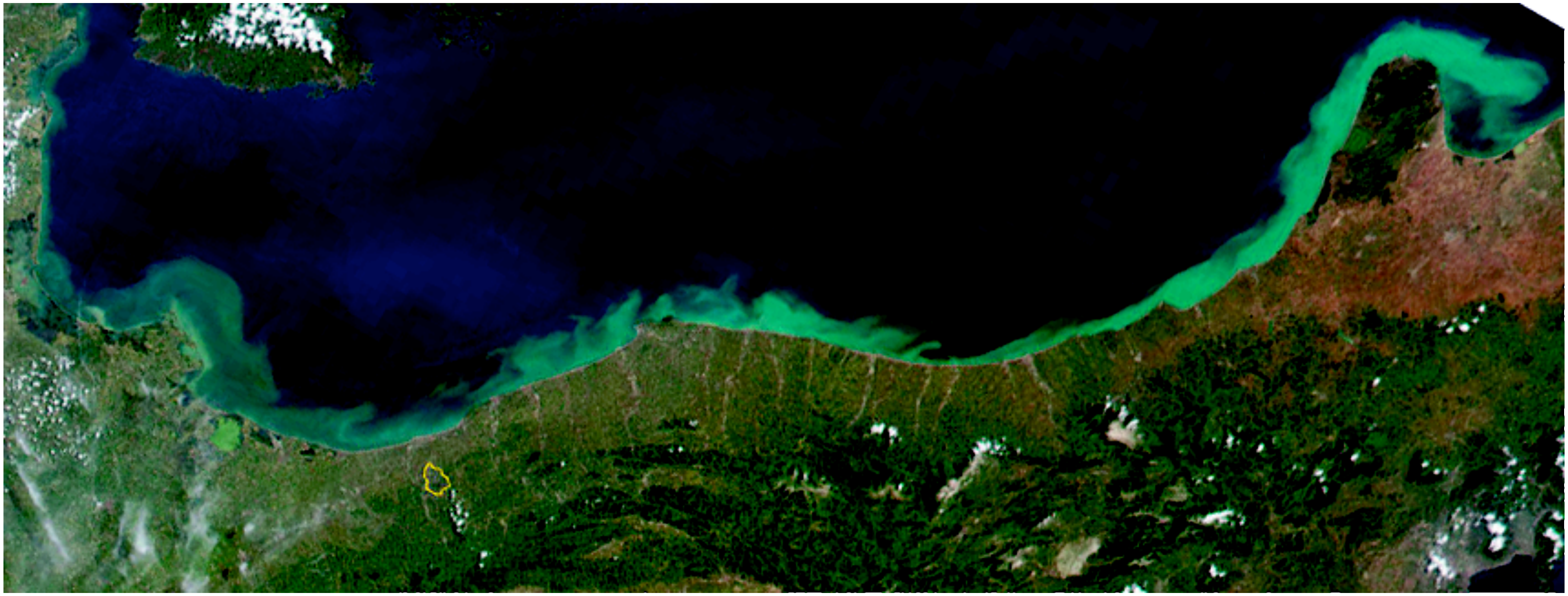


Sediment Load

Ocean Conditions

Coastal Evolution Model

Sediment Distribution



CEM predicts the distribution of sediment after it enters the ocean

CEM:

- 4,300 lines of C code
- No command line interface
- No input files (hardcoded variables)
- Constant sediment supply, wave angle characteristics
- Output bathymetry as text file

CEM still predicts the distribution of sediment after it enters the ocean

CEM after:

- 4,500 lines of C code (8% increase – mostly new files)
- API (IRF, and getters/setters) – C, and Python
- Library
- Command line interface
- GUI (within CCA)
- CCA component
- Output format CSV, BOV, netcdf

Checkout a version from our model repository:

```
> svn checkout https://csdms.colorado.edu/svn/deltas
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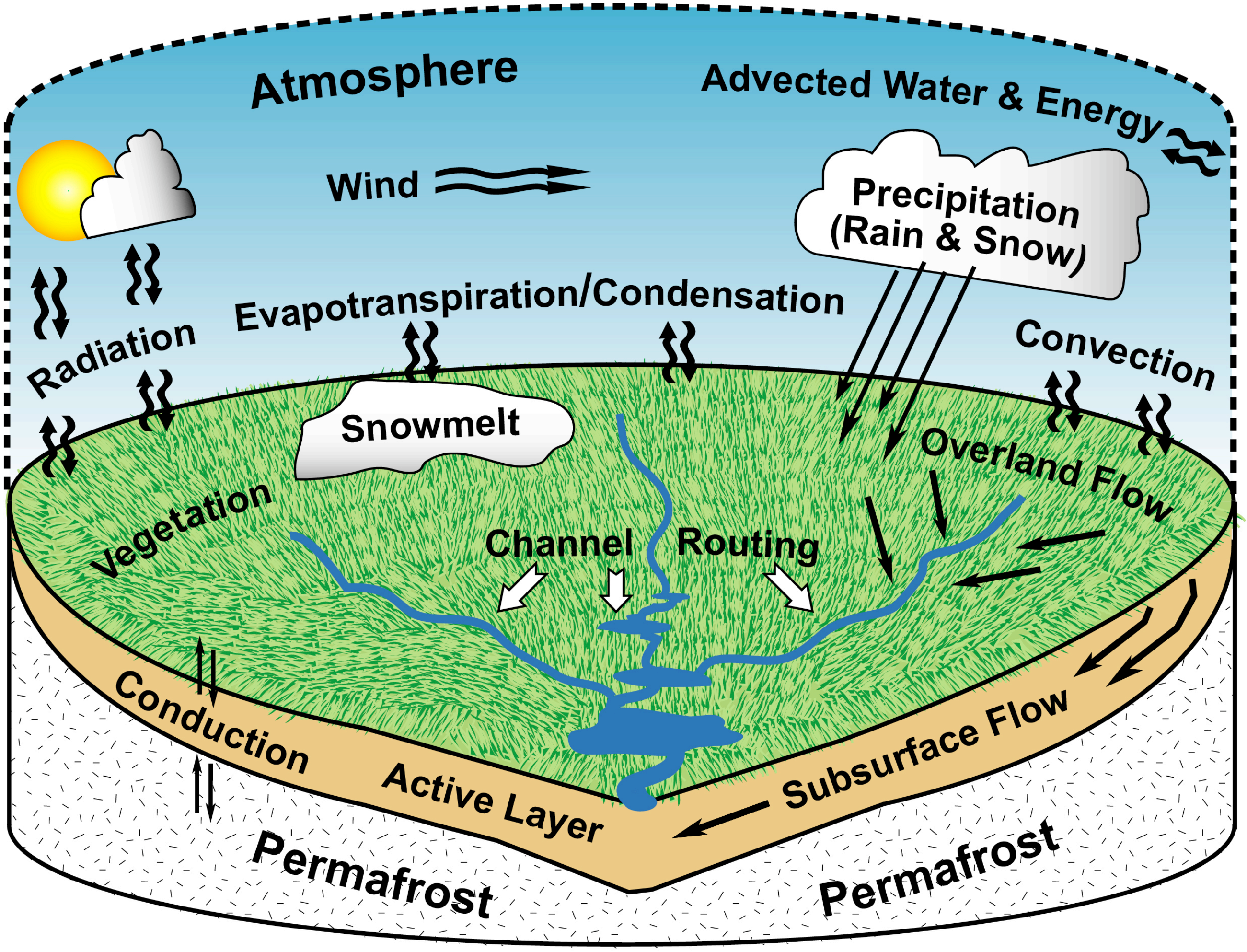
A fully spatial hydrologic model with multiple methods for modeling physical processes in watersheds



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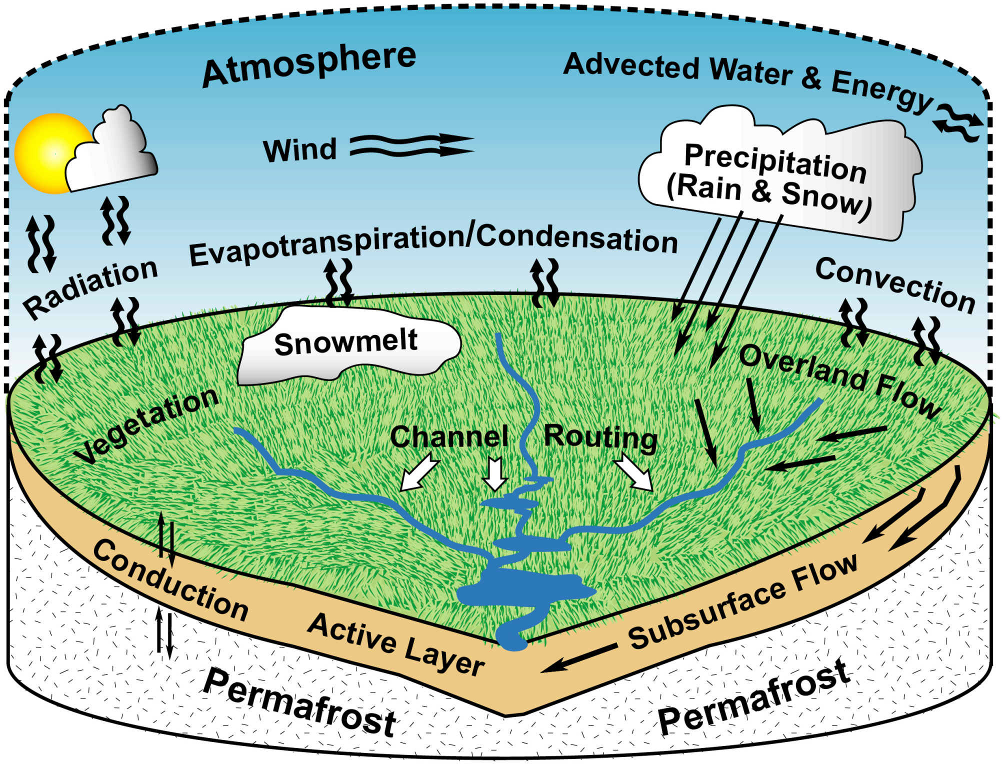
A fully spatial hydrologic model with multiple methods for modeling physical processes in watersheds

TopoFlow is:

- 28,500 lines of IDL code
- Component model
- GUI
- Input variables can be scalar, time series, grid, grid series
- Output any variable as an RTG binary file
- Components are linked within the topoflow framework



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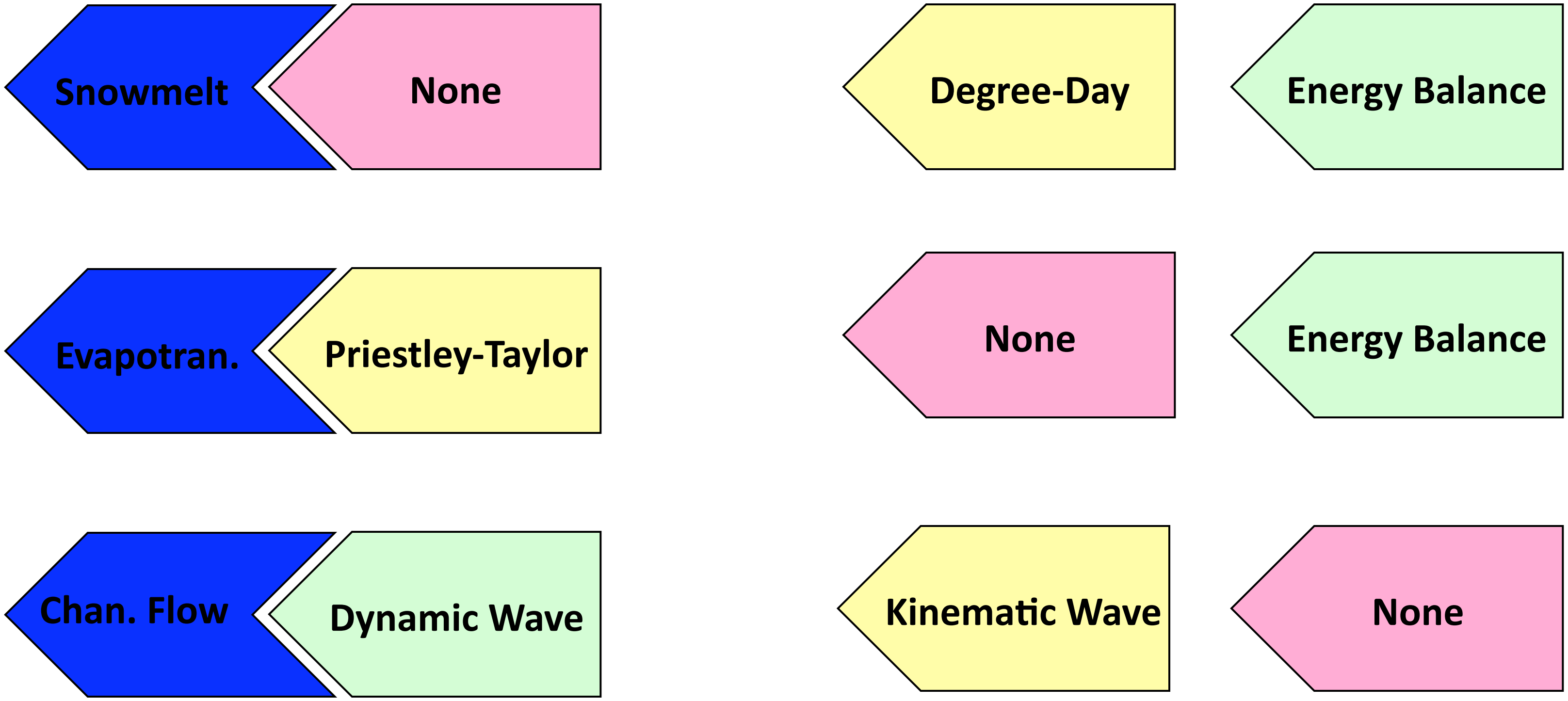
TopoFlow was already a component based model in the spirit of a plug-and-play framework



Snowmelt | None | Degree-Day | Energy Balance

Evapotran. | Priestley-Taylor | None | Energy Balance

Chan. Flow | Dynamic Wave | Kinematic Wave | None

Each method has a similar set of dialogs to specify or collect input and output variables. Any process can be turned off.

TopoFlow still is a fully spatial hydrologic model with multiple methods for modeling…

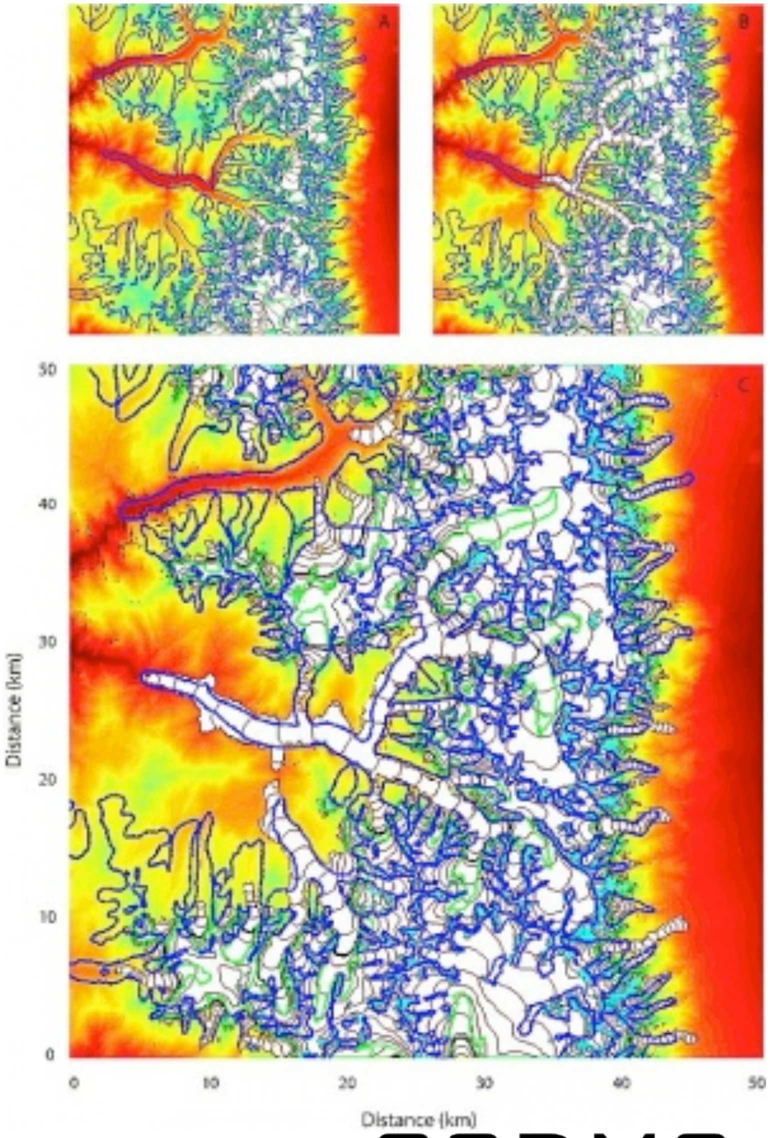
TopoFlow after:

- 33,058 lines of code (14% increase)
- Component model
- Python
- Same output but saved as CSV, BOV, netcdf
- No preprocessing tools yet

GC2D is a 2D valley glacier and ice sheet model

GC2D Before:

- 1500 lines of MATLAB code
- No user interface
- Input parameters hard wired in code
- Limited output variables/format



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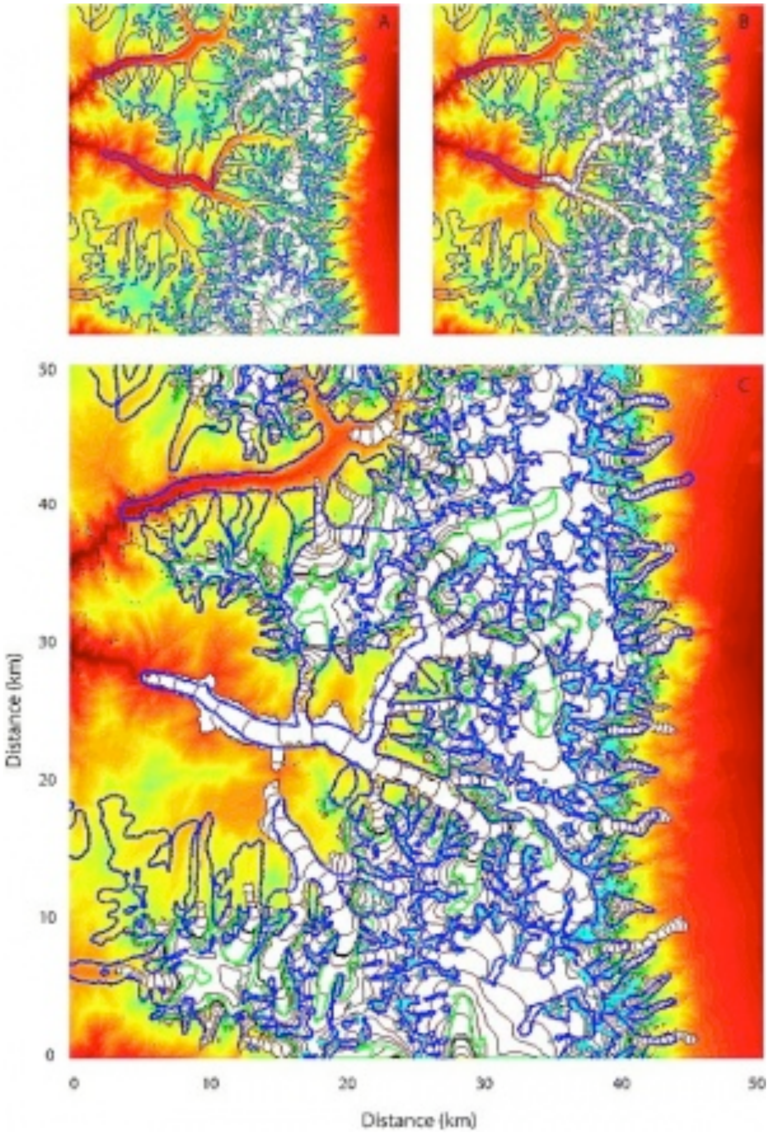
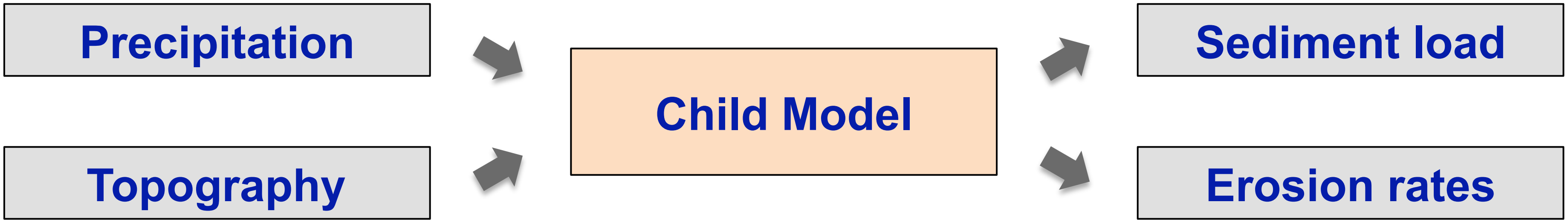
GC2D still is a 2D valley glacier and ice sheet model

GC2D After:

- 1900 lines of Python code (25%)
- Python process component
- CCA Component
- Input from config files
- Output as BOV, netCDF, etc.
- Added functionality: calculate melt rates



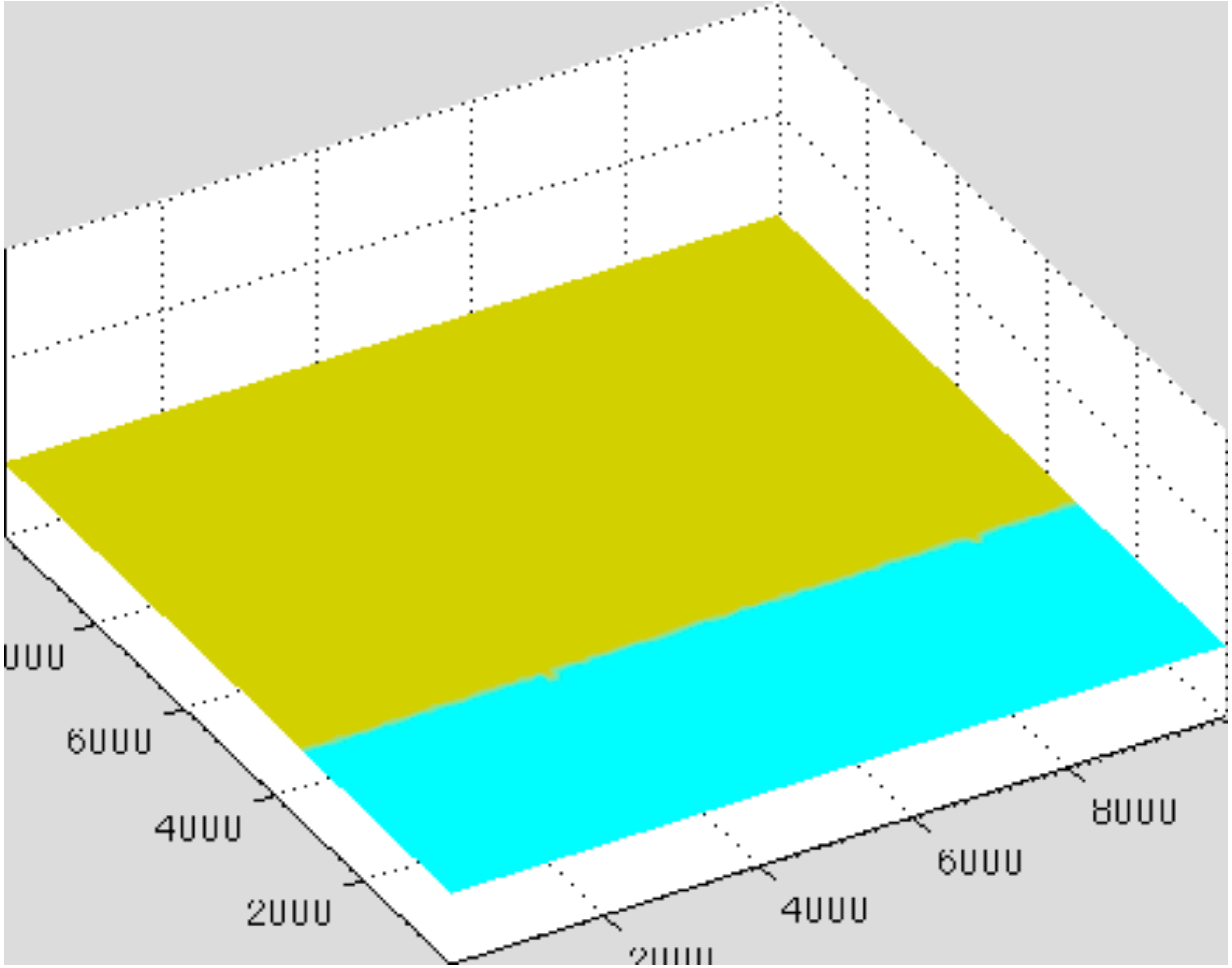
Child is a landscape evolution model that delivers sediment to the ocean



Child details:

- 39,000 lines of C++ code
- Component model
- User interface through input file
- Lots of output variables as ASCII files
- Calculations done on a non-uniform mesh

As the land rises, water erodes the landscape and carries sediment to the ocean where it's dumped



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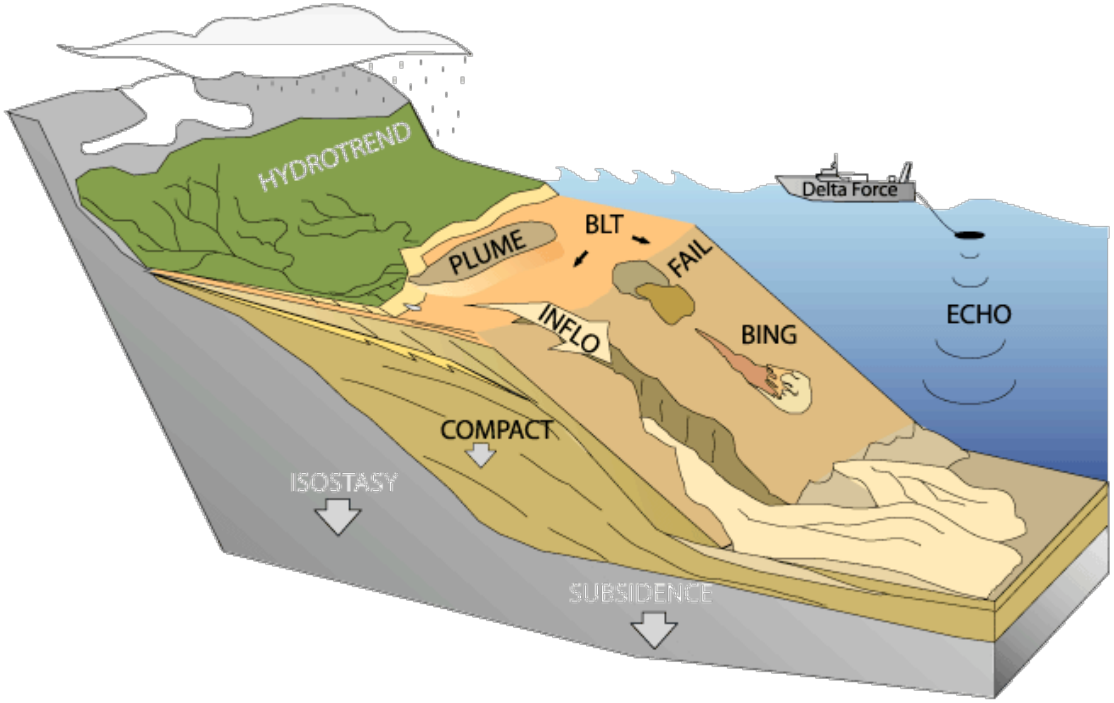
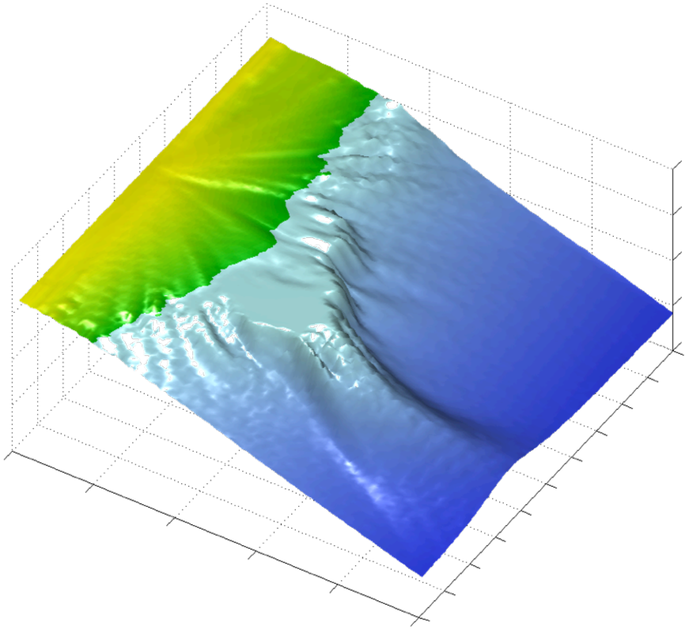
sedflux links component models to simulate the growth of a continental margin.





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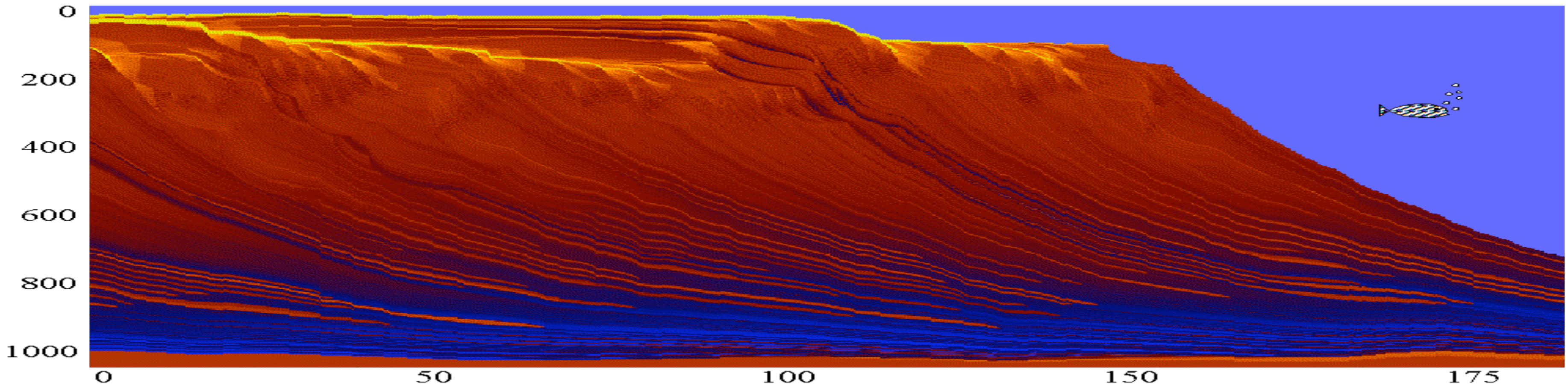
sedflux provides a framework that keeps track of stratigraphy



sedflux details:

- 70,000 lines of C code
- Component model
- User interface through input file, and command line
- Lots of output variables as confusing binary data
- Calculations done on a uniform mesh

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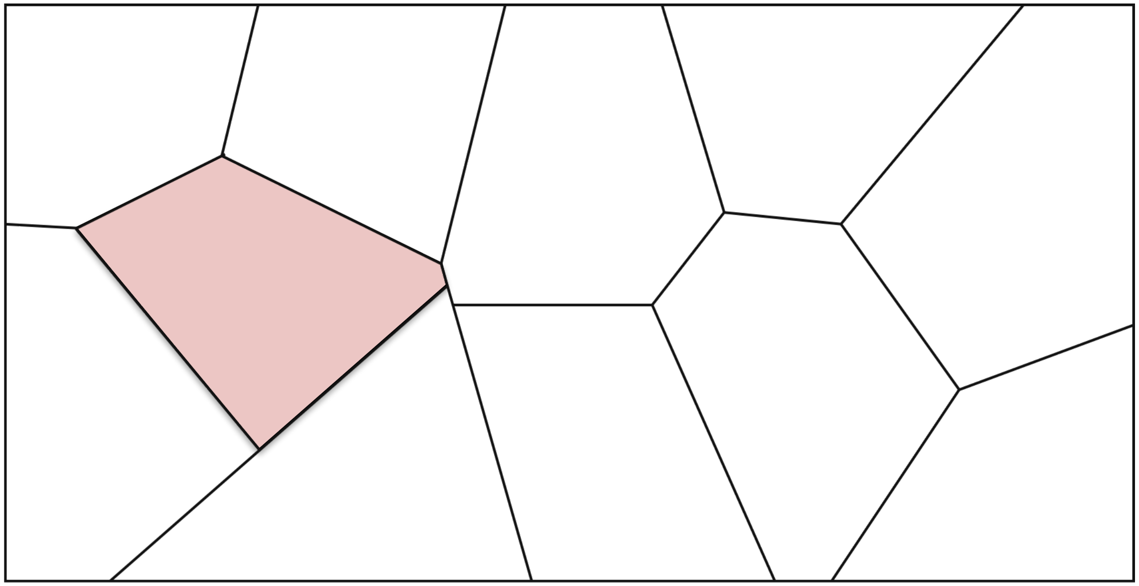
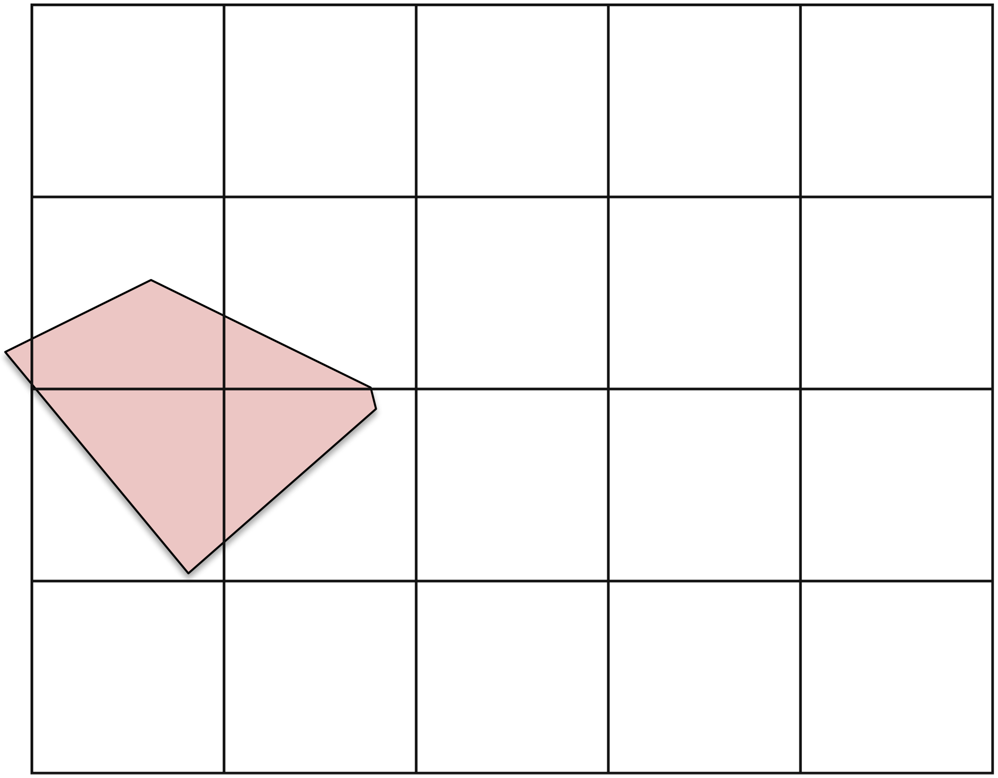
Child does its calculations on an unstructured mesh



Sedflux, like most of our models, uses a uniform mesh



Perhaps the biggest challenge in this particular coupling will be grid mapping.

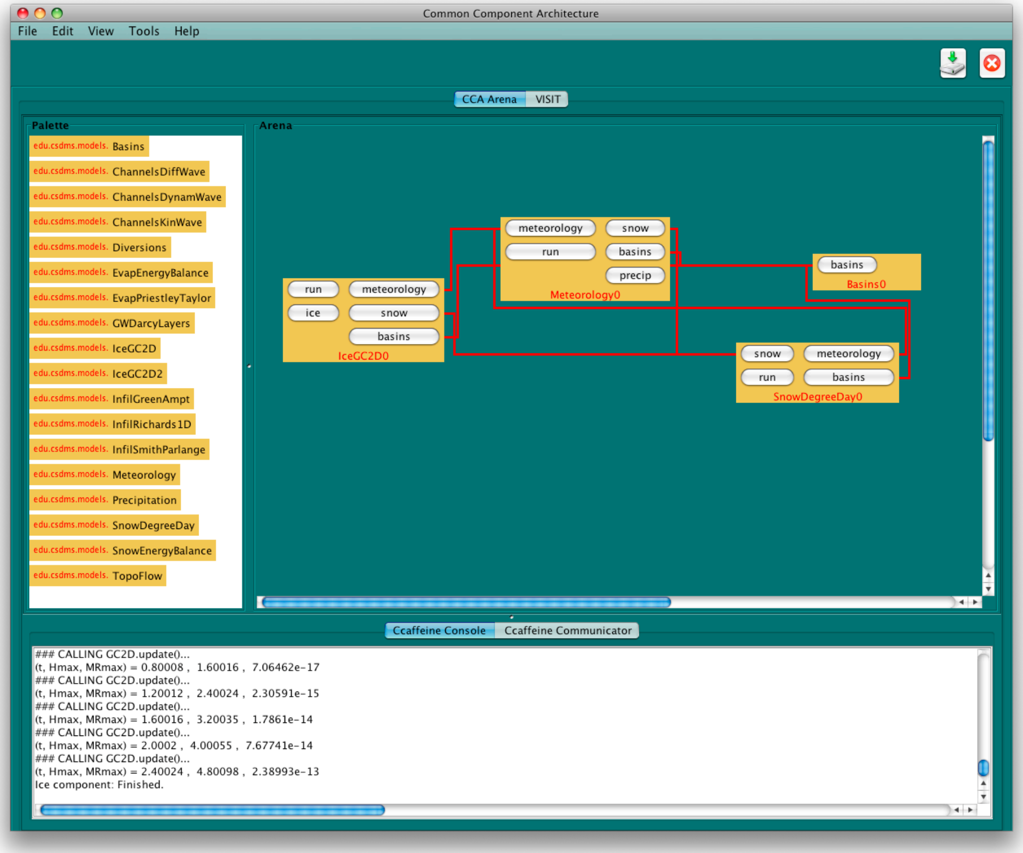
Both Child and sedflux are components but they have not been linked quite yet

As with our other components, both models:

- Have an API (and so a library)
- Can be run by CSDMS members remotely on beach
- Can be run as a standalone model or as a component
- Can be linked to other components (in other languages)

The CSDMS Modeling tool allows users to link models through a graphical interface

Using this GUI, they can choose components from available palettes to create their own, customized applications, and then run them on our cluster. We have linked our GUI with VisIt to provide run-time visualization.


Common Component Architecture
File
Edit
View
Tools
Help
CCA Arena
VISIT
Palette
edu.csdms.models. Basins
edu.csdms.models. ChannelsDiffWave
edu.csdms.models. ChannelsDynamWave
edu.csdms.models. ChannelsKinWave
edu.csdms.models. Diversions
edu.csdms.models. EvapEnergyBalance
edu.csdms.models. EvapPriestleyTaylor
edu.csdms.models. GWDarcyLayers
edu.csdms.models. IceGC2D
edu.csdms.models. IceGC2D2
edu.csdms.models. InfilGreenAmpt
edu.csdms.models. InfilRichards1D
edu.csdms.models. InfilSmithParlange
edu.csdms.models. Meteorology
edu.csdms.models. Precipitation
edu.csdms.models. SnowDegreeDay
edu.csdms.models. SnowEnergyBalance
edu.csdms.models. TopoFlow
Arena
meteorology
snow
run
basins
precip
Meteorology0
basins
Basins0
run
meteorology
ice
snow
basins
IceGC2D0
snow
meteorology
run
basins
SnowDegreeDay0
Ccaffeine Console
Ccaffeine Communicator

```
### CALLING GC2D.update()...
(t, Hmax, MRmax) = 0.80008 ,  1.60016 ,  7.06462e-17
### CALLING GC2D.update()...
(t, Hmax, MRmax) = 1.20012 ,  2.40024 ,  2.30591e-15
### CALLING GC2D.update()...
(t, Hmax, MRmax) = 1.60016 ,  3.20035 ,  1.7861e-14
### CALLING GC2D.update()...
(t, Hmax, MRmax) = 2.0002 ,  4.00055 ,  7.67741e-14
### CALLING GC2D.update()...
(t, Hmax, MRmax) = 2.40024 ,  4.80098 ,  2.38993e-13
Ice component: Finished.
```

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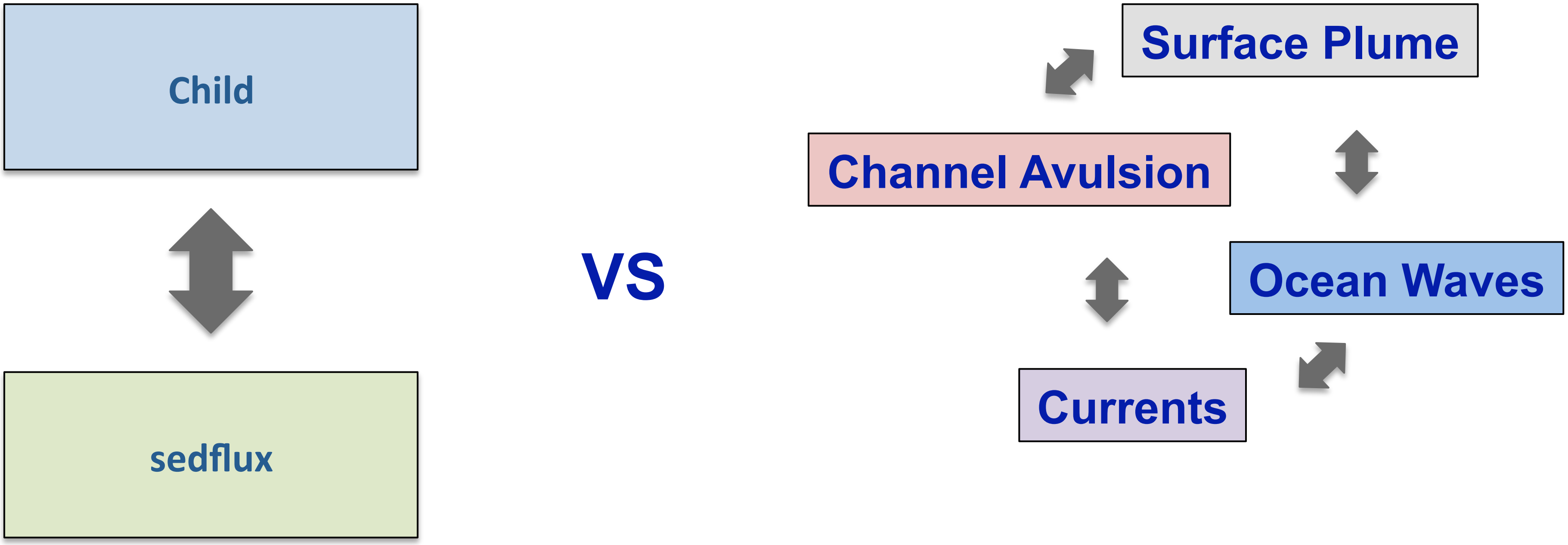
Process components seem to be the most natural level of granularity for model componentization.

Processes (such as infiltration) represent the “scale” at which modelers are most likely to want to replace one approach with another. For example, modelers very often want to compare different approaches and algorithms with respect to speed, accuracy, scalability or realism.



Child

sedflux

VS

Surface Plume

Channel Avulsion

Ocean Waves

Currents

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Lost in translation…

Converting models from one language to another is a complex task that should be avoided whenever possible. Conversion tools usually cannot fully automate the conversion process.

In conclusion,

Questions?