Exploring Surface Processes: How to Build Coupled Models

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password:fallmeeting2019

Irina Overeem, Mark Piper, Nicole Gasparini, Andrew Ashton, Nate Lyons

AGU Workshop 2019

Exploring Surface Processes: How to Build Coupled Models

Introduction

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AGU Workshop 2019

Agenda

8:00 - 8:30	Welcome, intros, setup
8:30 - 9:30	Intro to *landlab*
9:30 - 9:45	Break
9:45 - 11:00	Building coupled models with *landlab*
11:00 - 12:00	Intro to *pymt*
12:00 - 13:15	Lunch
13:15 - 14:30	Building coupled models with *pymt*
14:30 - 14:45	Break
14:45 - 15:15	Breakouts and brainstorms
15:15 - 16:00	Future research directions
15:45 – 16:00	Wrap-up, opportunities for more

Instructors

Nicole Gasparini,
CSDMS Terrestrial working group chair
Landlab lead developer

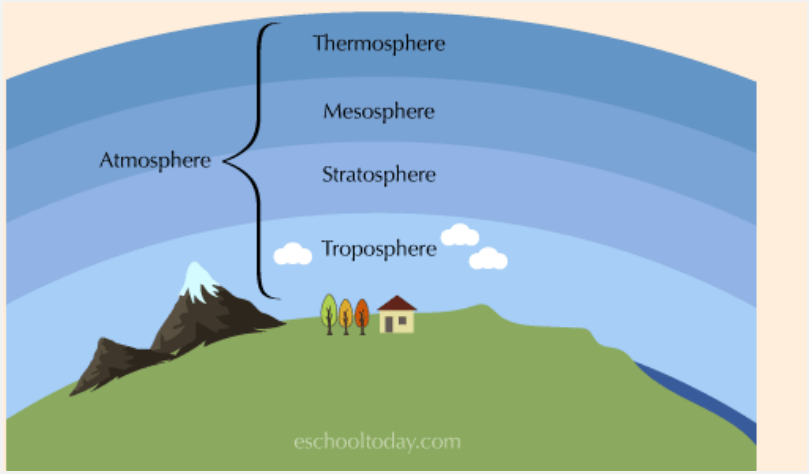
Mark Piper,
CSDMS Software Engineer

Nate Lyons
Landlab developer

Andrew Ashton
CSDMS coastal working group chair
Coastline Evolution Model developer

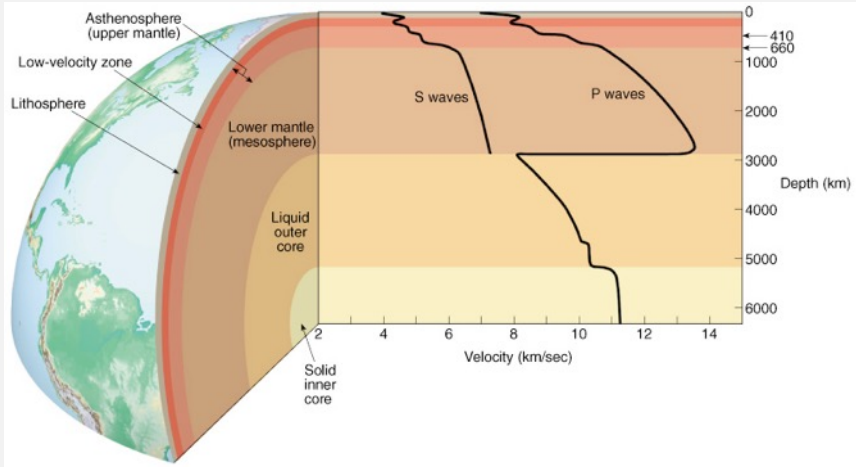
Irina Overeem, CSDMS Deputy Director

US Geoscience Modeling Facilities



CESM
Community Earth System Model
(NCAR)
1983

CSDMS
Community Surface Dynamics
Modeling System
2007

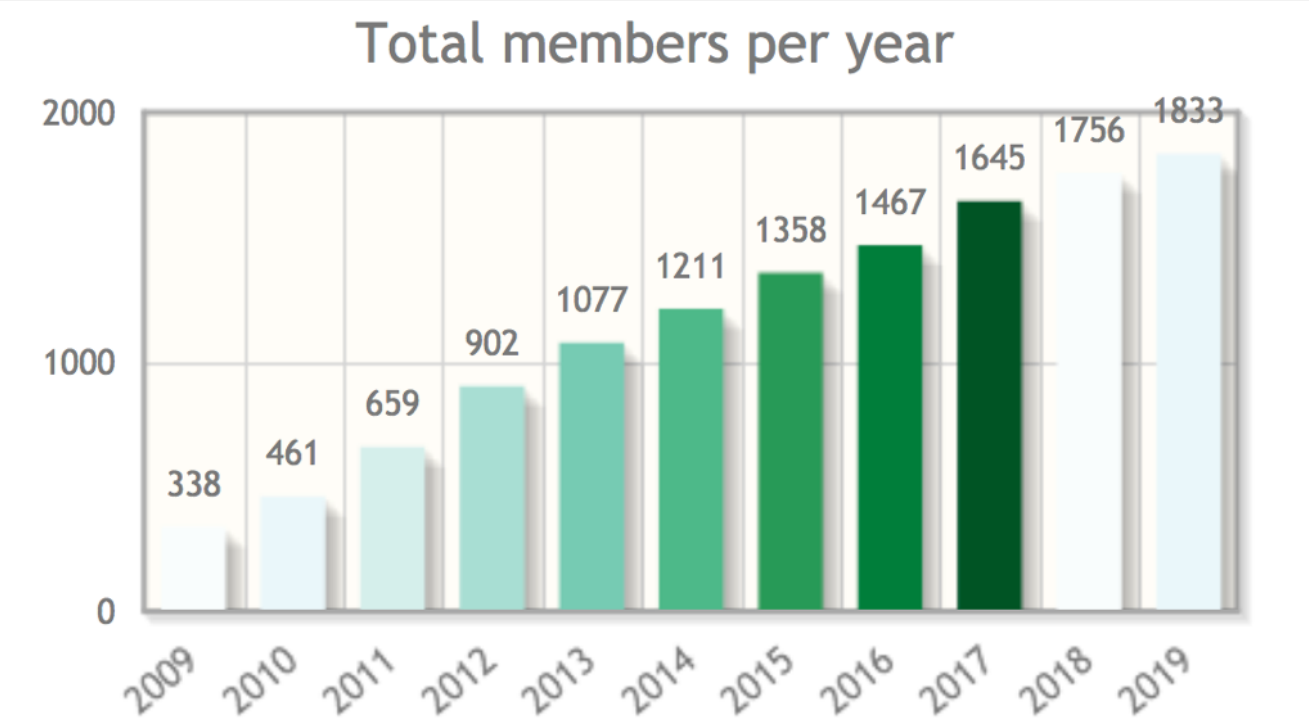


CIG
Computational Infrastructure
for Geodynamics
2005

"CSDMS is envisioned as a modeling environment containing a community-built, freely available suite of integrated, ever-improving software modules aimed at predicting the erosion, transport, and accumulation of sediment and solutes in landscapes and sedimentary basins over a broad range of time and space scales."

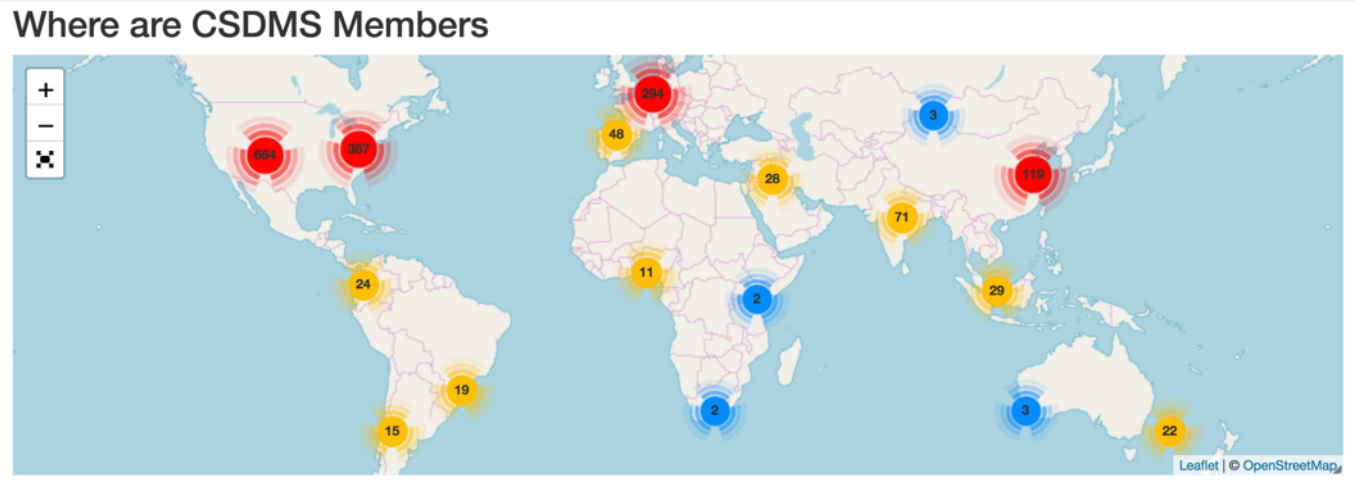
- Science Plan vision document, 2004

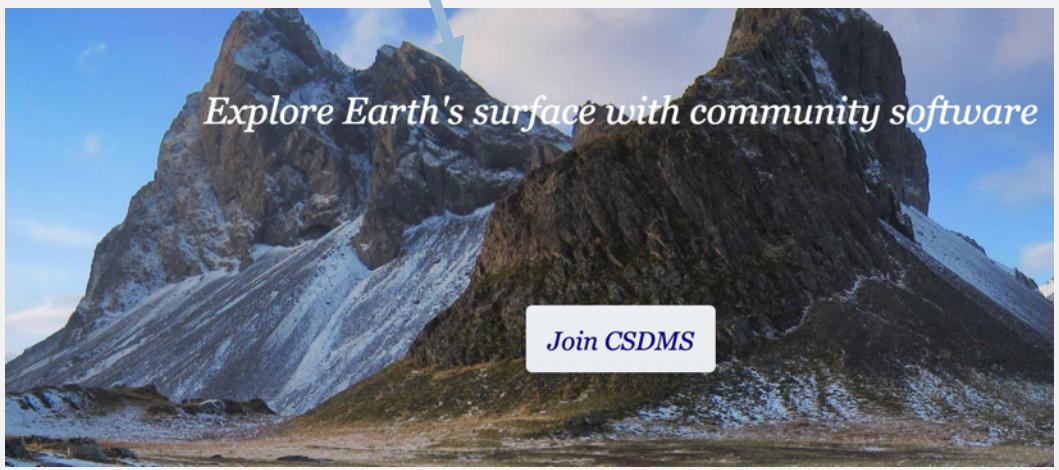
CSDMS Community



If you are not yet a member,
be part of the community, join as a member

https://csdms.colorado.edu/wiki/Main_Page



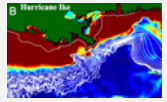


70 countries
641 institutions (222 US academic, 38 US government/NGO)

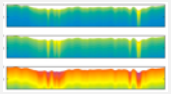
Examples of community research questions*

How do drainage networks form after glaciation?

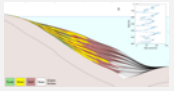
Can we better predict flood inundation?



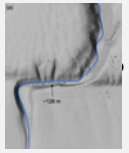
How do hurricanes trigger deep-sea turbidity currents?



How do Arctic rivers affect permafrost melt?

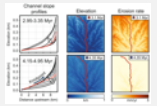


How are climate and sea level cycles reflected in marine stratigraphy?

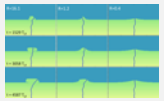


When does stream offset accurately record fault slip?

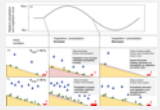
How can we efficiently predict debris-flow timing?



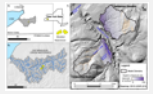
Can sediment provenance reveal environmental signals in stratigraphy?



How will sea-level rise impact coastal deltas?



How do cycles in climate and vegetation influence landscape evolution?



Can we forecast erosion at hazardous waste sites?

Can changes in grazing and wildfire regime trigger woody plant encroachment?

** addressed using CSDMS technology*

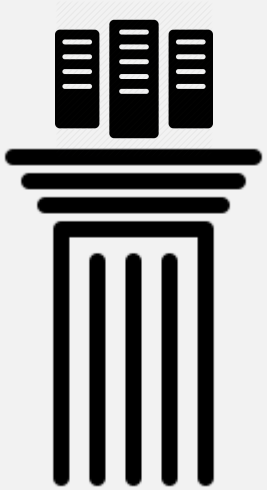
CSDMS
community surface dynamics modeling system

CSDMS supports computational modeling in earth-surface science by engaging ***community***, providing ***computing*** resources, and promoting ***education***

share resources, collaborate

COMMUNITY
SUPPORT

create, run, test, analyze, and apply models

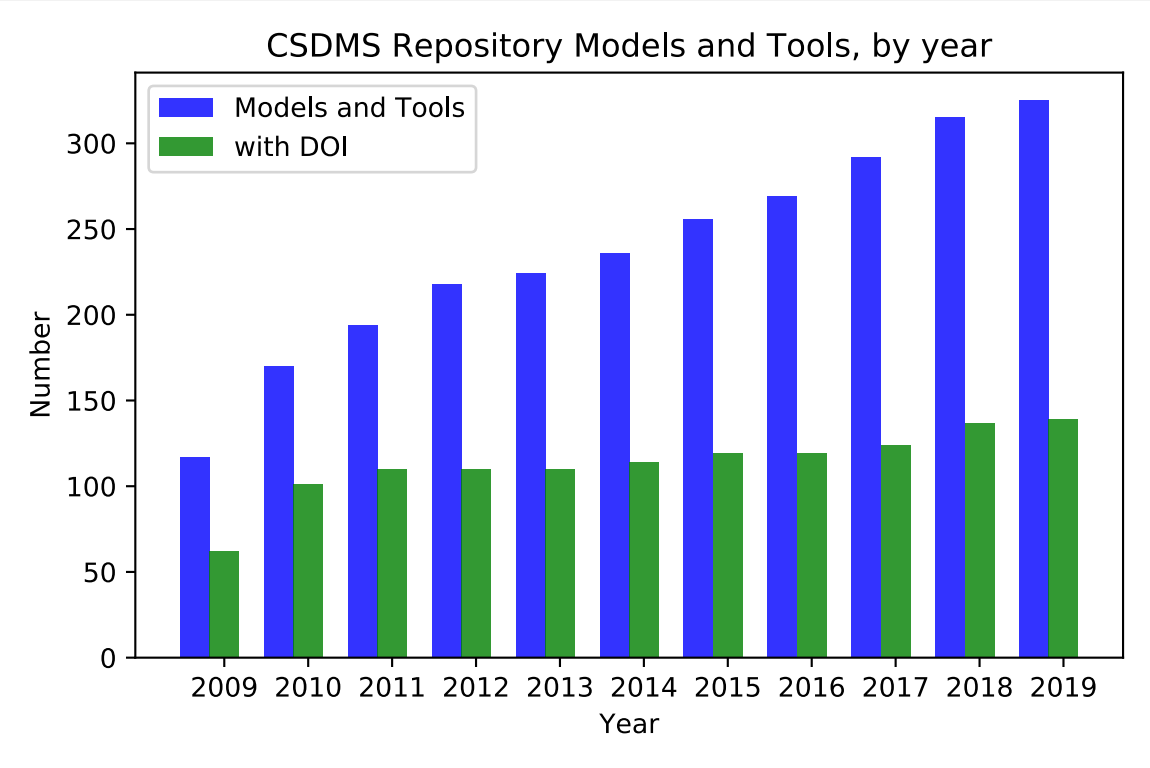


COMPUTING
RESOURCES

learn and teach

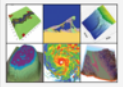
EDUCATION
OPPORTUNITIES

CSDMS Model Repository



- Community **open catalog & archive** for modeling software and tools
- Full **metadata** for each program
- Contributors can obtain Digital Object Identifier (DOI) to make product citable
- CSDMS tracks h-index for programs based on bibliography

All models

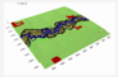


Number of models: *229*, Number of tools: *89*, WMT compliant: *35*, PyMT compliant: *8*

Type: All of the models mentioned below

235 Models
90 Tools

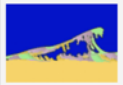
Terrestrial models



Number of models: *105*, Number of tools: *78*, WMT compliant: *10*, PyMT compliant: *5*

Type: Landscape evolution models, avulsion models, sediment transport models, advection diffusion models, ice sheet evolution models, lithospheric flexure models, groundwater models, surface water-quality models, water balance models, etc.

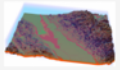
Coastal models



Number of models: *70*, Number of tools: *9*, WMT compliant: *10*, PyMT compliant: *2*

Type: Coastline evolution models, delta sedimentation models, tidal flat models, storm surge models, plume models, tubidity current models, stratigraphic models, wave refraction models, etc.

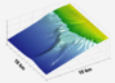
Hydrological models



Number of models: *76*, Number of tools: *51*, WMT compliant: *25*, PyMT compliant: *3*

Type: Hydrologic models, stream avulsion models, flow routing models, groundwater models, fluvial sediment transport models, etc.

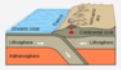
Marine models



Number of models: *53*, Number of tools: *8*, WMT compliant: *4*, PyMT compliant: *1*

Type: Basin circulation models, gravity flow models, wave models, stratigraphy models, etc.

Geodynamic models



Number of models: *16*, Number of tools: *1*, WMT compliant: *1*, PyMT compliant: *1*

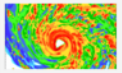
Type: Fault, lithospheric flexure, lithosphere deflection, Mantle Evolution Model, etc.

Ecosystem models

Number of models: *1*, Number of tools: *1*, WMT compliant: *1*, PyMT compliant: *0*

Type: Ecosystem models

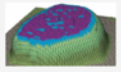
Climate models



Number of models: *14*, Number of tools: *6*, WMT compliant: *4*, PyMT compliant: *1*

Type: Climate models, weather models

Carbonates and Biogenics models



Number of models: *1*, Number of tools: *0*, WMT compliant: *0*, PyMT compliant: *0*

Type: Carbonate cyclicity model

Landlab components and models

Number of models: *8*, Number of tools: *1*, WMT compliant: *2*, PyMT compliant: *0*

Type: Earth surface processes models

Annual Meeting, May 19-21st, 2020

A number of stipends for students, and scientists in need of support, to promote diversity and inclusivity.

COMMUNITY

Software Cyberinfrastructure: CSDMS Modeling Framework

> ***"CSDMS is envisioned as a modeling environment containing a community-built, freely available suite of integrated, ever-improving software modules aimed at predicting the erosion, transport, and accumulation of sediment and solutes in landscapes and sedimentary basins over a broad range of time and space scales."***
>
> ***- Science Plan, 2004***

1. Interface standard (BMI)

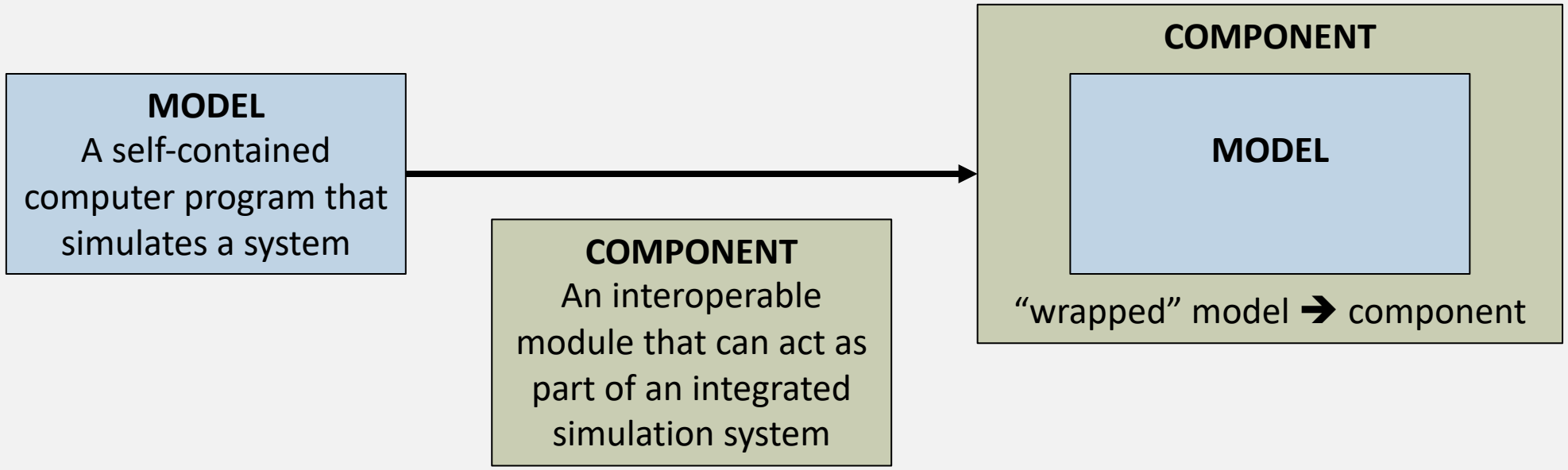
2. Language interoperability (Babelizer)

3. Model-building toolkits (Landlab and Permafrost toolbox)

4. Execution and coupling framework (PyMT)

COMPUTING

Software Cyberinfrastructure: CSDMS Modeling Framework



BMI specifies a common set of functions, such as:

`initialize()`

`get_value()`

`update()`

`set_value()`

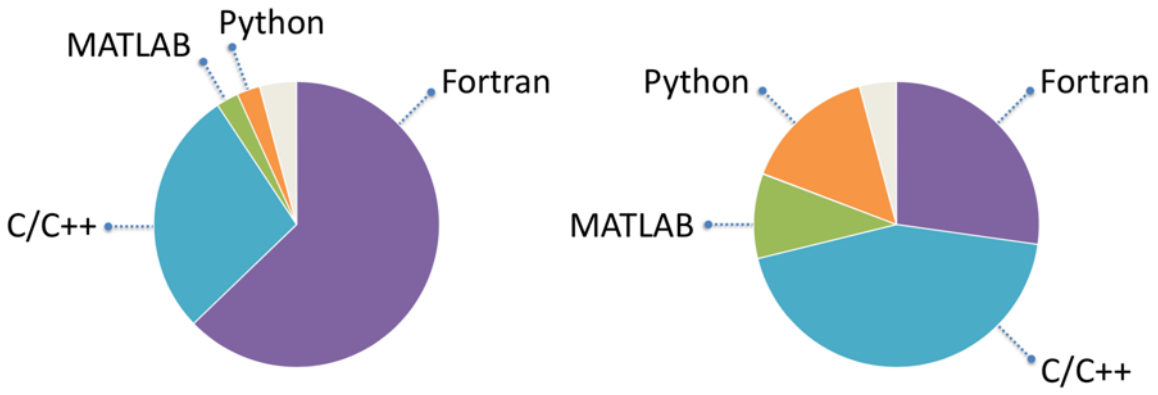
`finalize()`

COMPUTING

Language interoperability

The CSDMS Model Repository

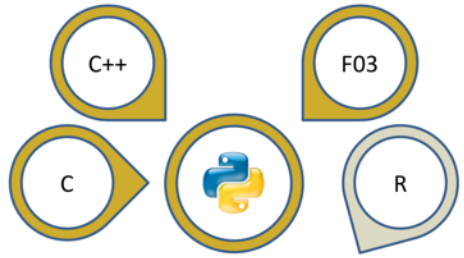
Over 300 community-contributed Earth-system models.



Fraction of Earth-system models as contributed to the CSDMS model repository as measured by lines of code (left) and number of models (right).

Language Interoperability: *The Babelizer*

Inter-language communication between models.

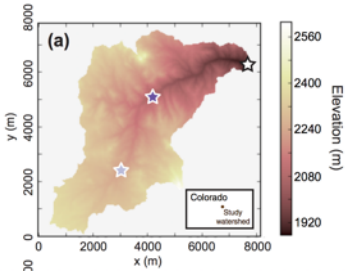


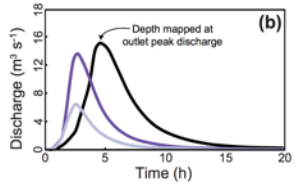
The CSDMS *Babelizer* automatically generates the necessary code to wrap shared libraries that expose a Basic Model Interface so that they can be imported into a Python environment. Currently, the Babelizer supports libraries written in *C*, *C++*, *FORTRAN* (and *Python*, obvs). We will look to add addition languages (like *R*) as needs arise.

LANDLAB

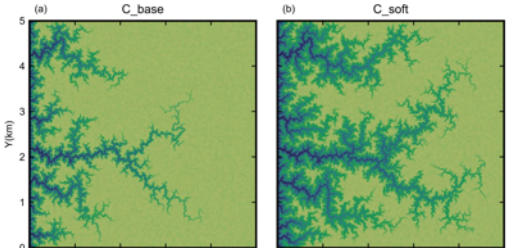
a python toolkit for modeling earth surface processes

Install | User Guide | Tutorials | Reference Manual | Support | FAQs | More

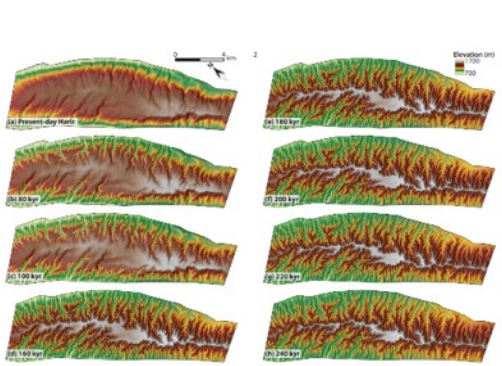




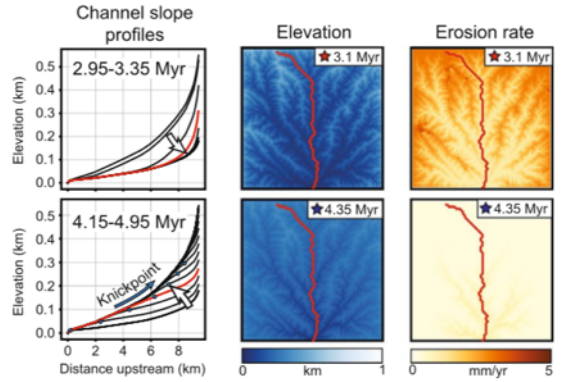
Rainfall-runoff (Adams et al., 2017)



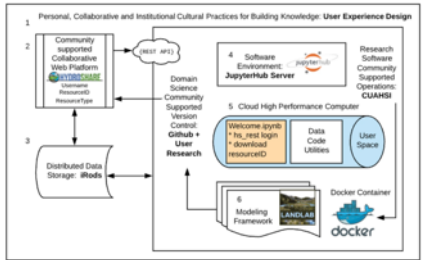
Post-glacial drainage nets (Lai & Anders, 2017)



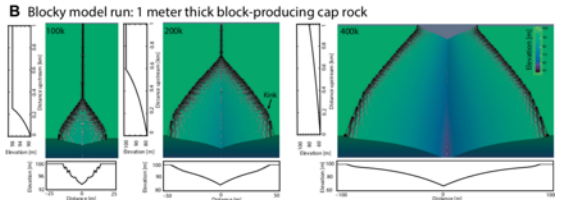
Evolution of anticlines (Zebari et al., 2019)



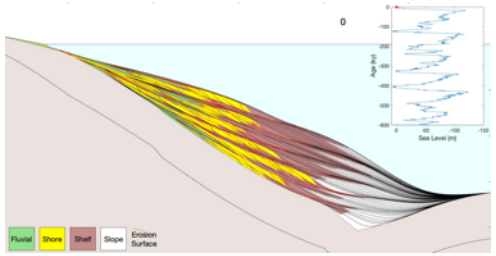
Sediment provenance as a signal of climate and tectonics in sedimentary basins (Sharman et al., 2019)



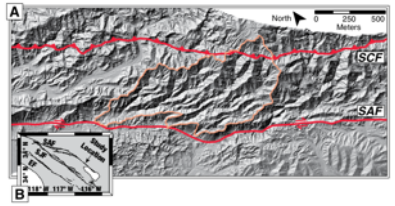
Hydrology education (Bandaragoda et al., 2019)



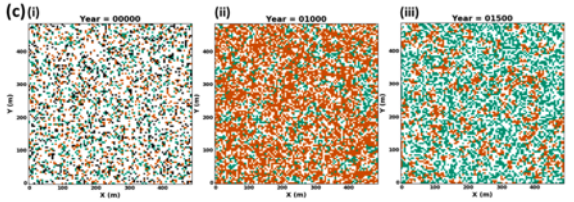
Influence of boulders on hillslope and channel evolution (Glade et al., 2019)



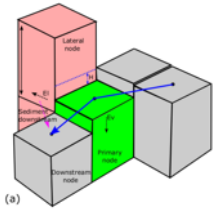
Basin stratigraphy (Steckler et al., in prep)



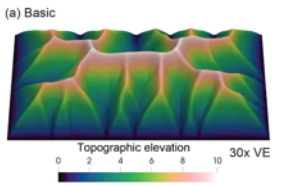
Tectonic shear (Gray et al., 2017)

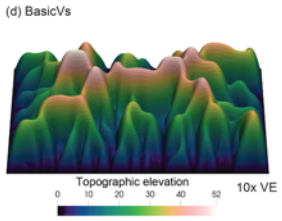


Vegetation dynamics (Nudurupati et al., in prep.)

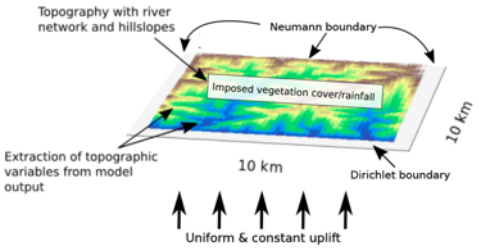


Valley widening (Langston et al., 2018)

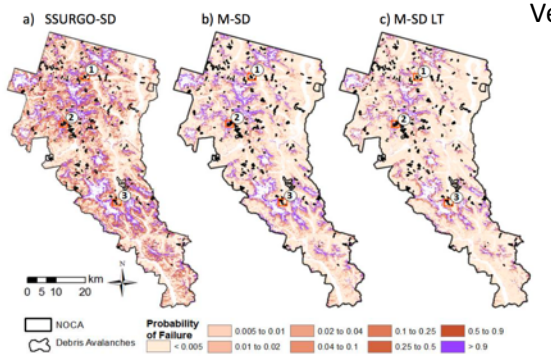




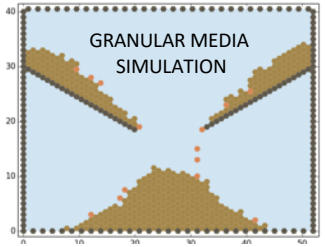
Landform evolution (Barnhart et al., 2019)



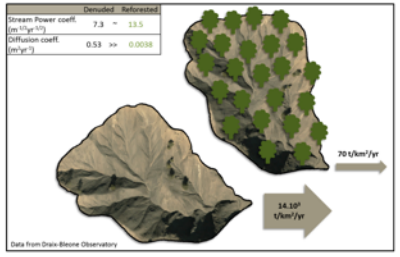
Vegetation & erosion (Schmid et al., 2018)



Landslide probability (Strauch et al., 2018)



Cellular automata (Tucker et al., 2016)



Sediment yield (Carriere et al., 2019)

pymt

a Python toolkit for coupling and running Earth surface models

Install Quickstart User Guide Examples Reference Manual Source

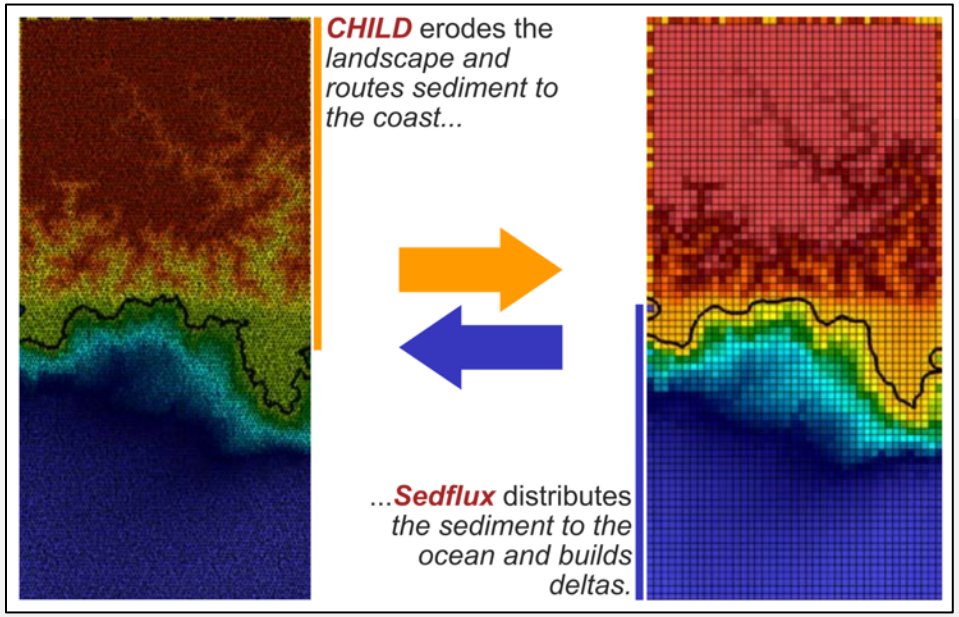
current
pymt components:

Avulsion
CEM
Child
ECSimpleSnow
FaSTMECH
FrostNumber
GIPL
Hydrotrend
Ku
Plume
Sedflux3D
Subside
Waves

```
[8]: model.initialize(config_file, dir=initdir)

[9]: model.set_value("channel_exit_water_flow__speed", 1.2)
     model.set_value("channel_exit_x-section__mean_of_width", 400.)
     model.set_value("channel_exit_x-section__mean_of_depth", 4.)
     model.set_value("channel_exit_water_sediment~suspended__mass_conc

[9]: array([ 0.01])
```

Here we update the model for 10 time steps, printing the model time after each step.

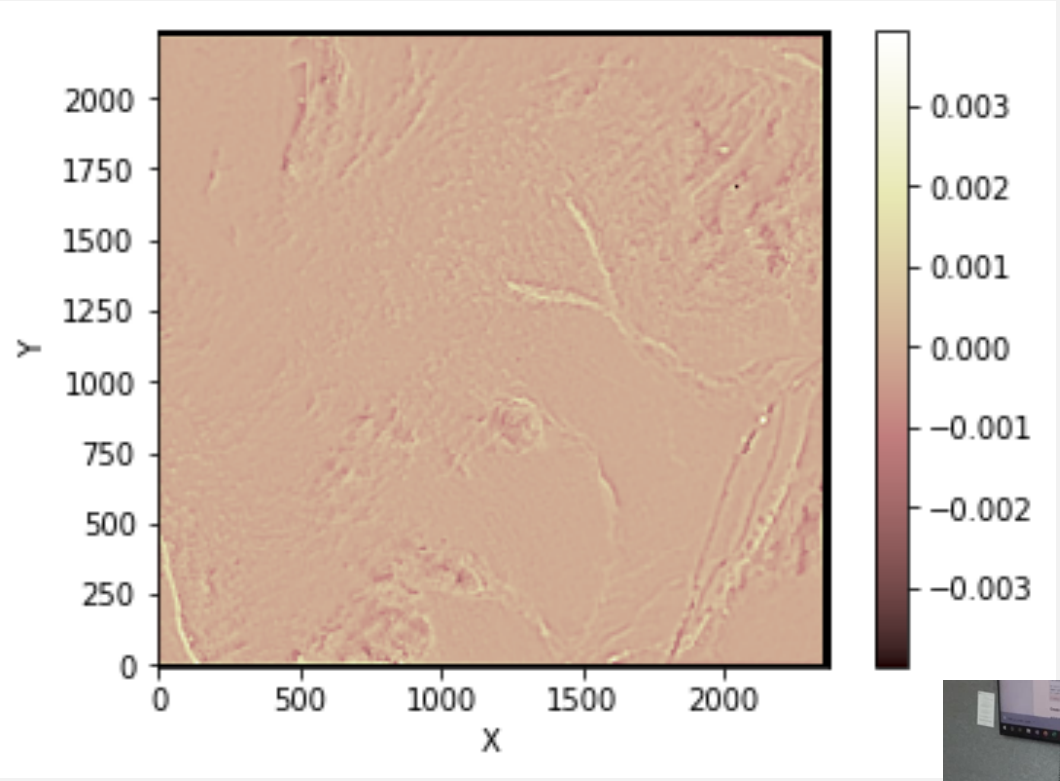
```
[10]: for t in range(10):
          model.update()
          print(model.get_current_time())

      365.00000000036493
      730.0000000010949
      1095.00000000219
      1460.00000000365
      1825.000000005475
      2190.000000007665
      2555.00000001022
      2920.00000001314
      3285.0000000164246
      3650.0000000200744
```



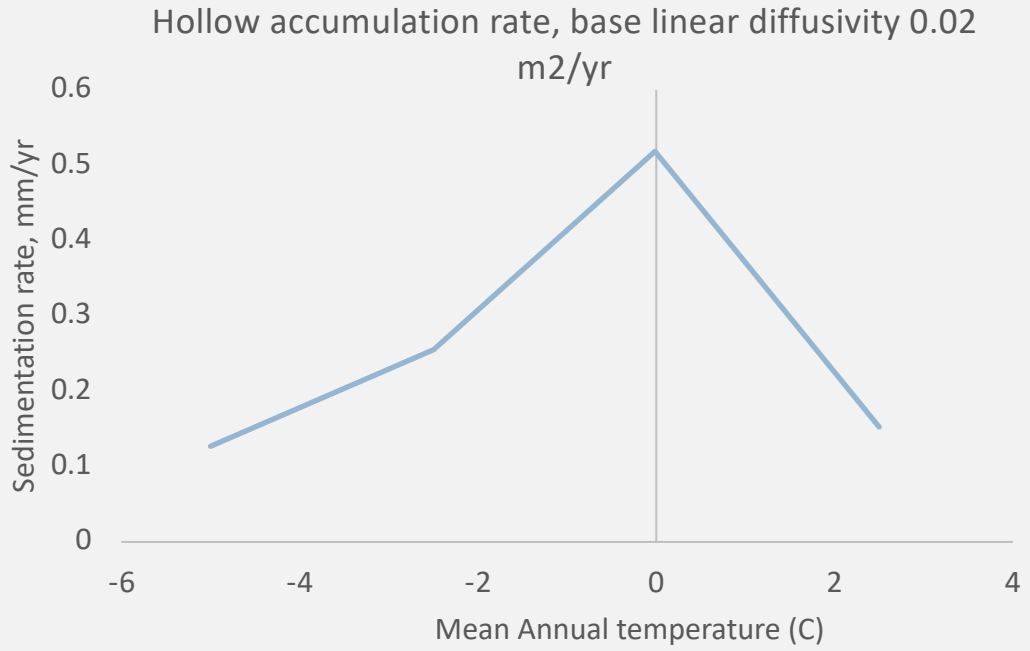
Landlab process components can act as **pymt** components:

DepthDependentDiffuser
ErosionDeposition
Flexure
FlowDirector
FlowAccumulator
LandslideProbablity
LinearDiffuser
NormalFault
OverlandFlow
PotentialET
PrecipitationDistribution
Radiation
SoilMoisture
StreamPowerEroder
SPACE
TaylorNonLinearDiffuser
TransportLengthDiffuser
VegetationDynamics

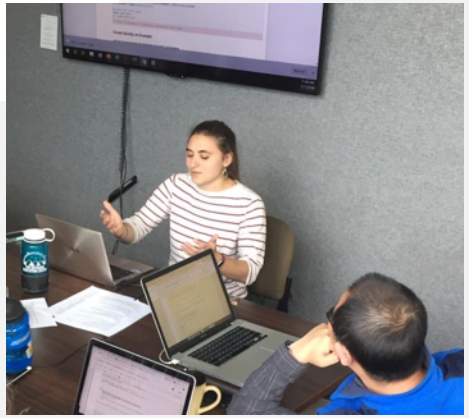
Why modular, standardized, shared software?



Coupled and adapted landlab and pymt components:
Depth-limited diffuser (for landscape evolution)
Kudryatsev model, ECsimplesnow (for permafrost)
Future: couple in radiation (landlab), soil moisture (landlab)



Steward peninsula, AK,
How does permafrost affect hillslope dynamics and sedimentation rates in landscape?
(Delvecchio, AGU poster EP43E-2405)



Agenda

8:00 - 8:30	Welcome, intros, setup
8:30 - 9:30	Intro to *landlab*
9:30 - 9:45	Break
9:45 - 11:00	Building coupled models with *landlab*
11:00 - 12:00	Intro to *pymt*
12:00 - 13:15	Lunch
13:15 - 14:30	Building coupled models with *pymt*
14:30 - 14:45	Break
14:45 - 15:15	Breakouts and brainstorms
15:15 - 16:00	Future research directions

https://github.com/csdms/agu-2019