Earth Surface Dynamics Models

James (Jai) Syvitski, CSDMS Executive Director

Daily updated SSC along river networks (model WBMsed)
Modelers checklist

- Define goals of the modeling effort
- Outline processes to be simulated
- Define assumptions (modules, model)
- Describe boundary conditions
- Describe data requirements;
- Select computational strategy & governing equations
- Calibrate or verify modules
- Conduct numerical experiments
Properties of a good numerical scheme

(1) **Precision**  Numerical solutions should approach analytical solutions. For waves, precision refers to both phase and amplitude.

(2) **Consistency**  Equations should be well discretized ---if the time step and mesh size tend to zero we are back to continuous equations.

(3) **Stability**  Solutions should converge to the correct solution.

(4) **Uniqueness**  Systems should not gain or lose energy without stimulus.

(5) **Conservation**  Equations should conserve mass/volume, (momentum, energy) for the system being modeled: e.g. Exner (erosion – deposition).

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What Resolution?

30 m horizontal resolution

90 m horizontal resolution

50km horizontal resolution

10km horizontal resolution

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Boundary Conditions

Data Integration in Modeling

Initializations

Observations

\[ Q_{ss} = \int_{z=\delta wbl}^{h} c_s Udz \]

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Anthropogenic: Organic & Black Carbon aerosols (green) & industrial sulfates (white)
### Increasing Complexity

- **Diffusive** ➟ **ADM** ➟ **SWE** ➟ **RANS** ➟ **LES** ➟ **DNS**
- **Boussinesq** ➟ **non-hydrostatic** ➟ **non-Boussinesq**
- **FDM** ➟ **FVM** ➟ **FEM**
- **Explicit** ➟ **implicit**
- **1D** ➟ **2D** ➟ **3D**
- **Eulerian** ➟ **Lagrangian** ➟ **PIC**
- **Steady-state** ➟ **non-steady state**
- **Newtonian** ➟ **non-Newtonian**
- **Depositional** ➟ **Post-depositional**
- **Time marching** ➟ **compute & drift** ➟ **event-based**
- **Local** ➟ **regional** ➟ **global**
- **Siliciclastic** ➟ **carbonate**
- **Abiotic** ➟ **biotic**
Nutrient Sources

**Natural**
- N\(_2\)-Fixation
- P Weathering

**Anthropogenic**
- **Non-Point**
  - Fertilizer (by crop type)
  - N\(_2\)-fixation - crops
  - Manure (by animal species)
  - Atmos. Dep. N
- **Point**
  - Sewage (pop.; treatment level)

Hydrology & Physical Factors
- Global Watersheds
- Water Runoff
- Precip. Intensity
- Land-use
- Slope

In-River N, P, Si, C Removal
- Rivers & Reservoir
- Consumptive Water Use

Seitzinger et al. 2005, Mayorga et al. 2010
Seitzinger et al. 2010

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Future scenarios

- Policy Options & Costs
- Nutrient Sources from Food and Energy
- Nutrient Export at River Mouth
- Coastal Effects (algae blooms; anoxia; fisheries; etc.)

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Sources of Model Workflow uncertainty:

1) Data for model initialization and model boundary conditions—uncertainties associated with input data must be involved in model simulations;
2) Algorithms & numerical schema — these internal model uncertainties must be understood and expressed independent of the input uncertainties;
3) Test data used to judge model skill – all verification data come with uncertainties