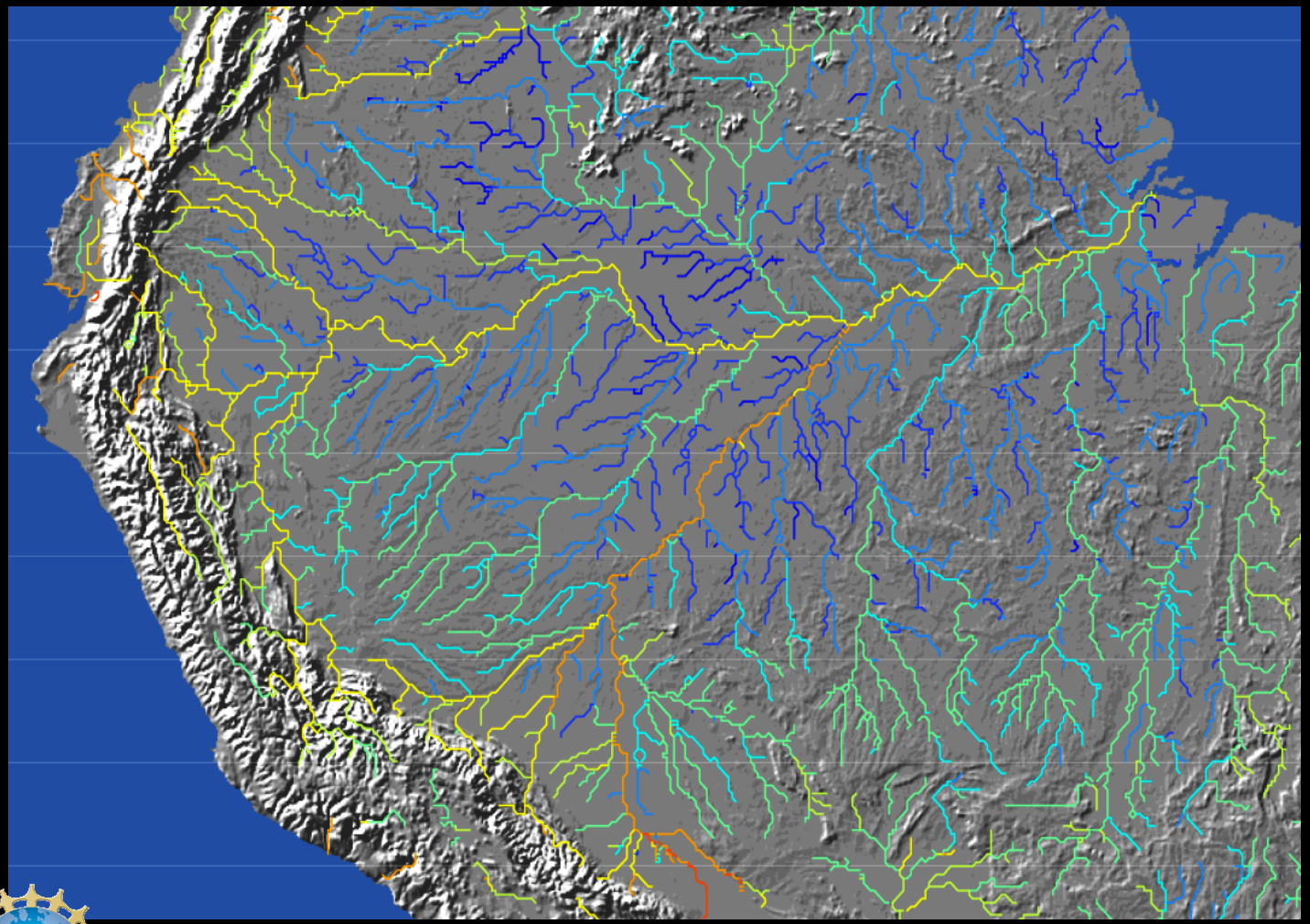
Earth Surface Dynamics Models

James (Jai) Syvitski, CSDMS Executive Director



Daily updated SSC along river networks (model WBMsed)

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COMMUNITY SURFACE DYNAMICS MODELING SYSTEM

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.

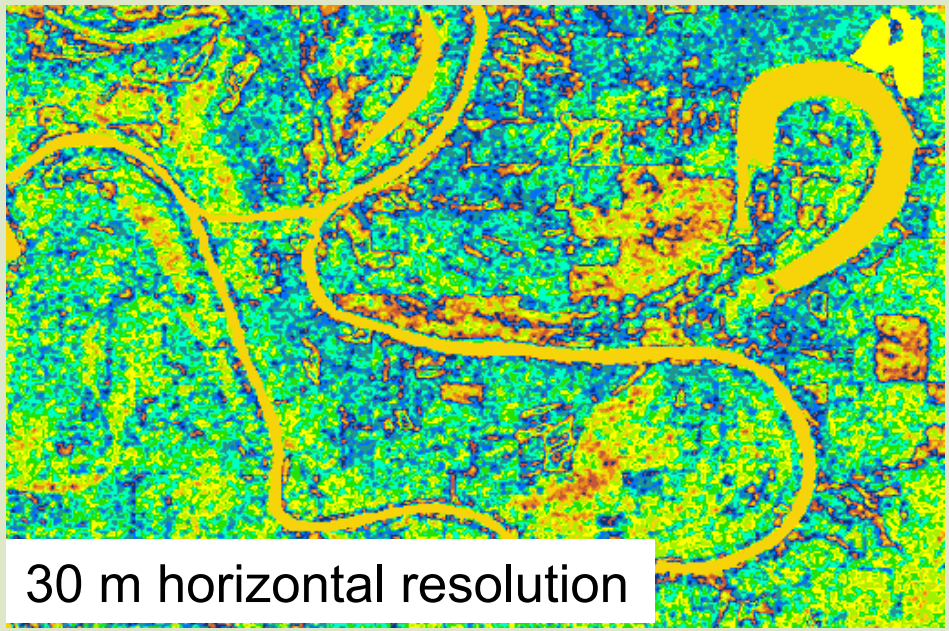
(2) Consistency Equations should be well discretized ---if the time step and mesh size tend to zero we are back to continuous equations

(3) Stability Solutions should converge to the correct solution

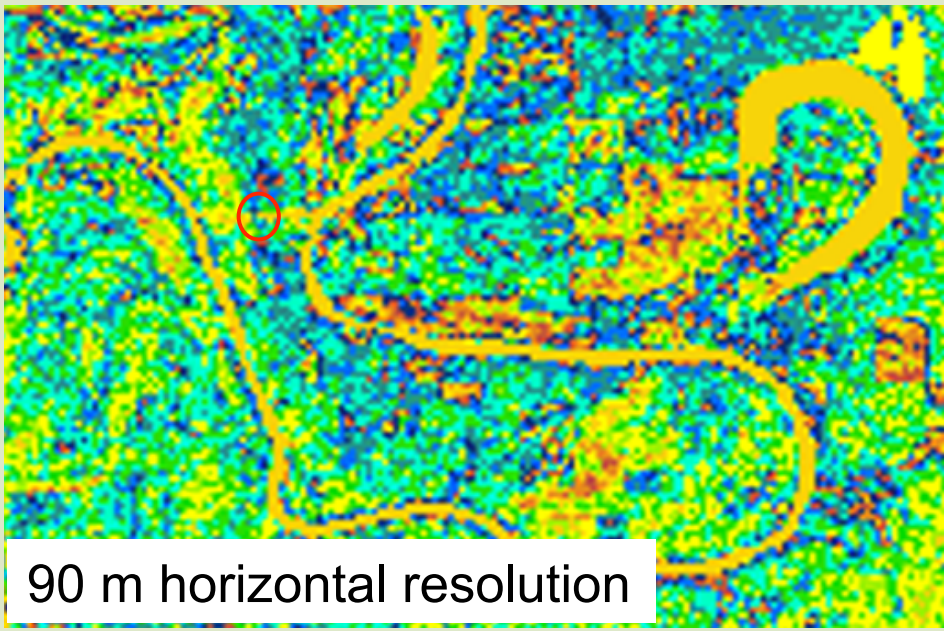
(4) Uniqueness Systems should not gain or lose energy without stimulus

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

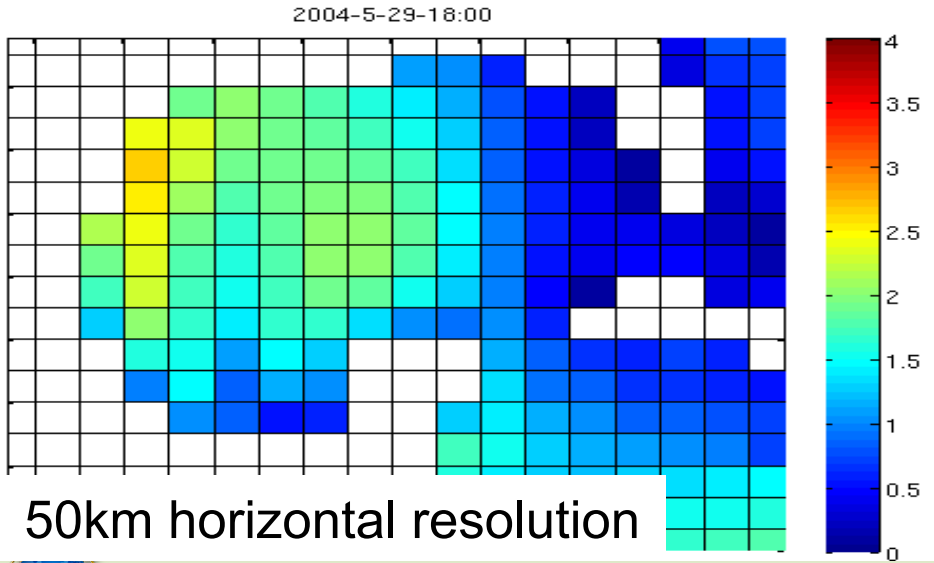
What Resolution?



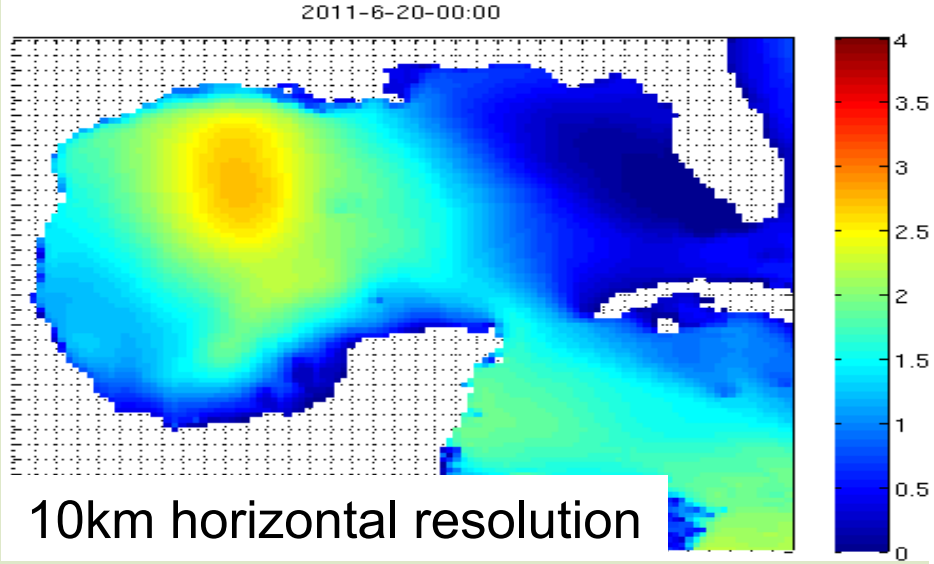
30 m horizontal resolution



90 m horizontal resolution

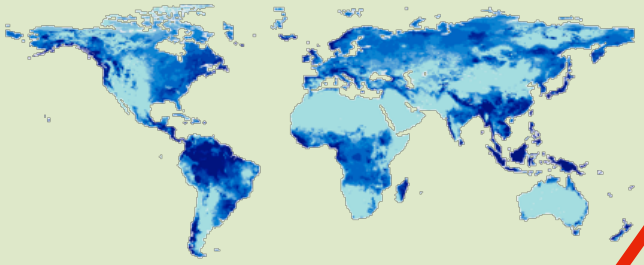


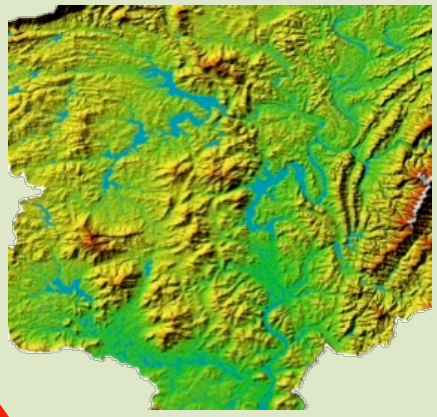
50km horizontal resolution



10km horizontal resolution

Boundary Conditions



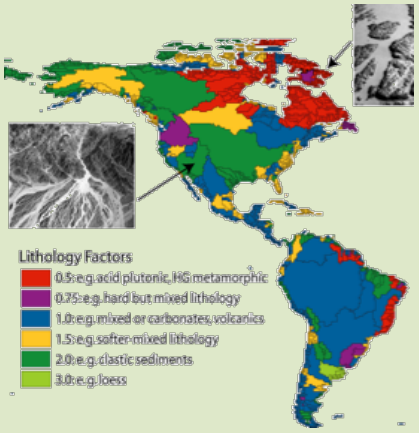


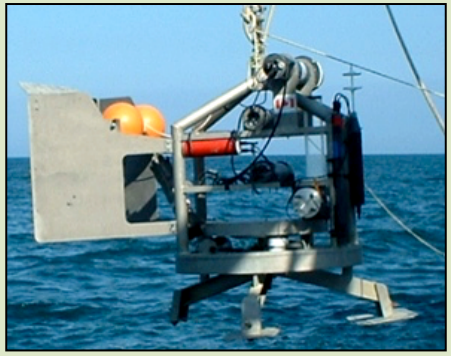
Data Integration in Modeling

Initializations

$$Q^{x}_{s,s} = \int_{z=\delta wbl}^{h} c_s U dz$$

Observations





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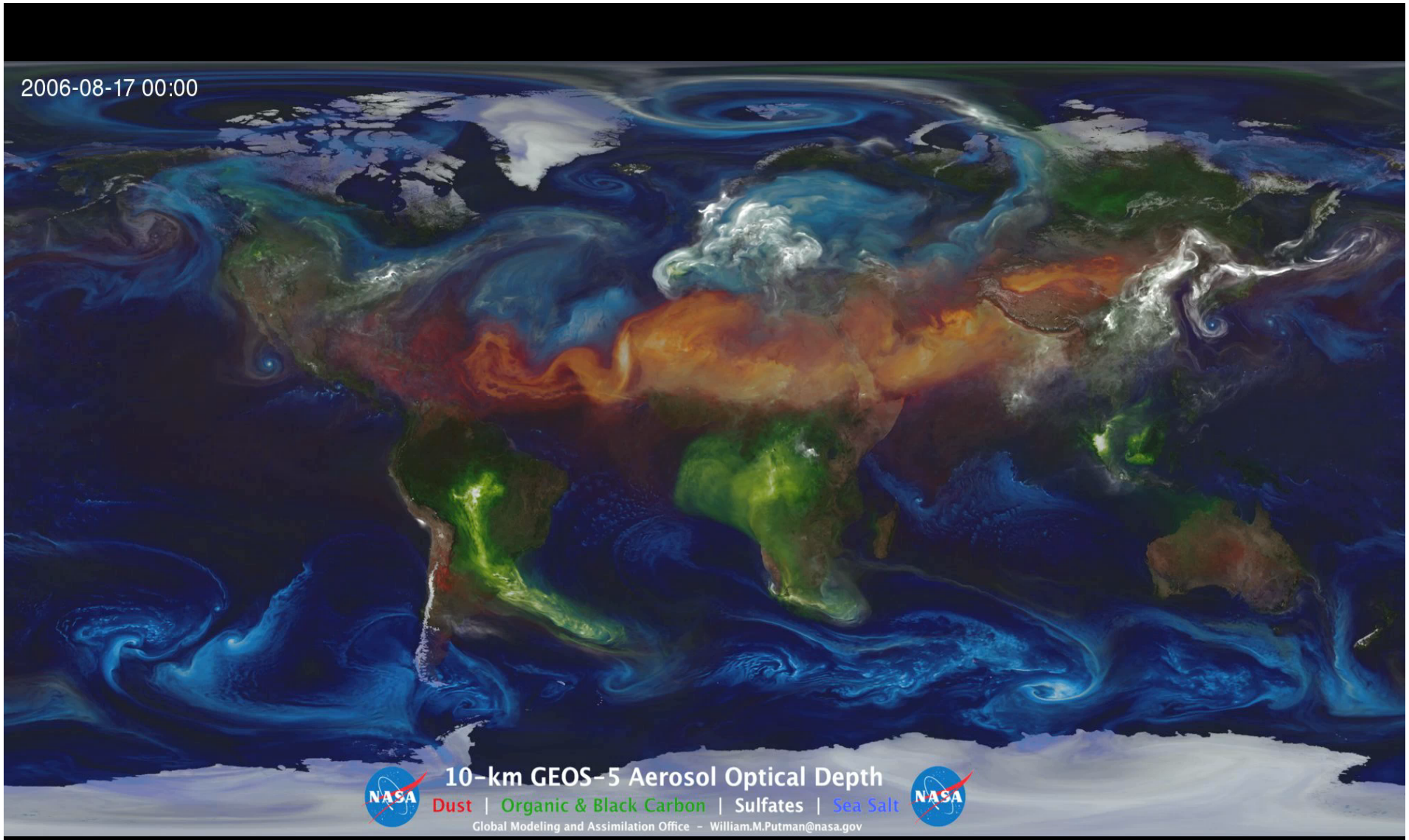

Anthropogenic: Organic & Black Carbon aerosols (green) & industrial sulfates (white)

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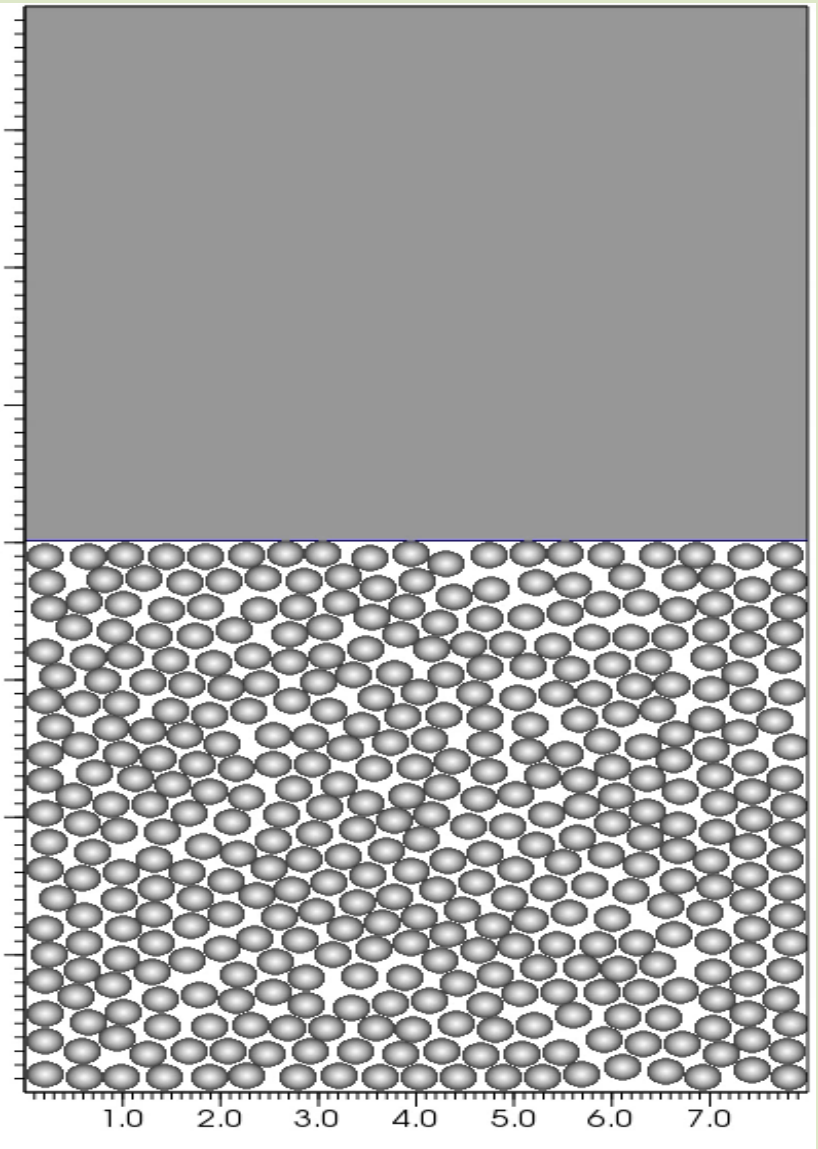
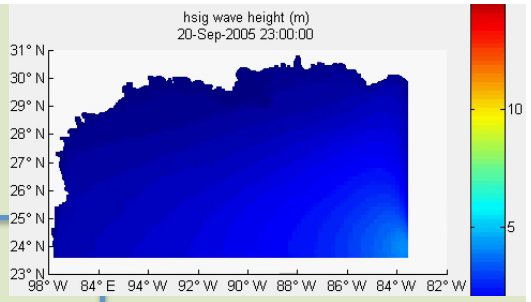
Increasing Complexity ➟

- 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



Gulf of Mexico Model/Data Workflow



GPCC-NCEP
Weather (P, T, …)

WBMsed
Discharge & Sediment Flux

ROMS N. Atlantic
Outer Boundary Oceanography

ECMWF ERA
Winds

ROMS GoM
Circulation, bottom stresses

WaveWatch III
Wave Characteristics

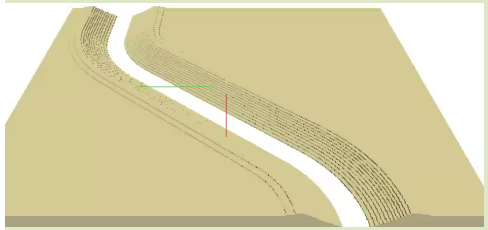
GFDL/GFS
Winds

ETOPO2+ &
Bathymetry

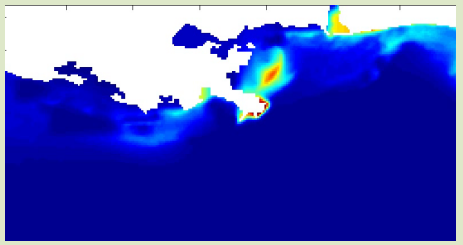
CSTM
Sediment Transport

dbSEABED
Seafloor Properties

HurriSlip
Location and Sediment Volume for TC



RANS-TURBINS
Turbidity Current Dynamics

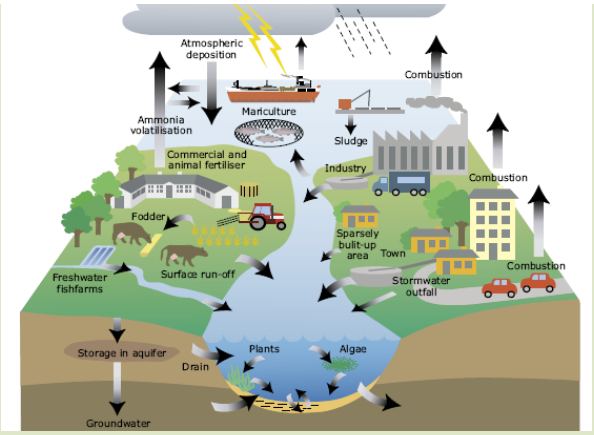


Global data | GoM Input | GoM dynamics | Model Chain End

BOEM
Bureau of Ocean Energy Management

Syvitski, 2016

Global **NEWS** Model



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

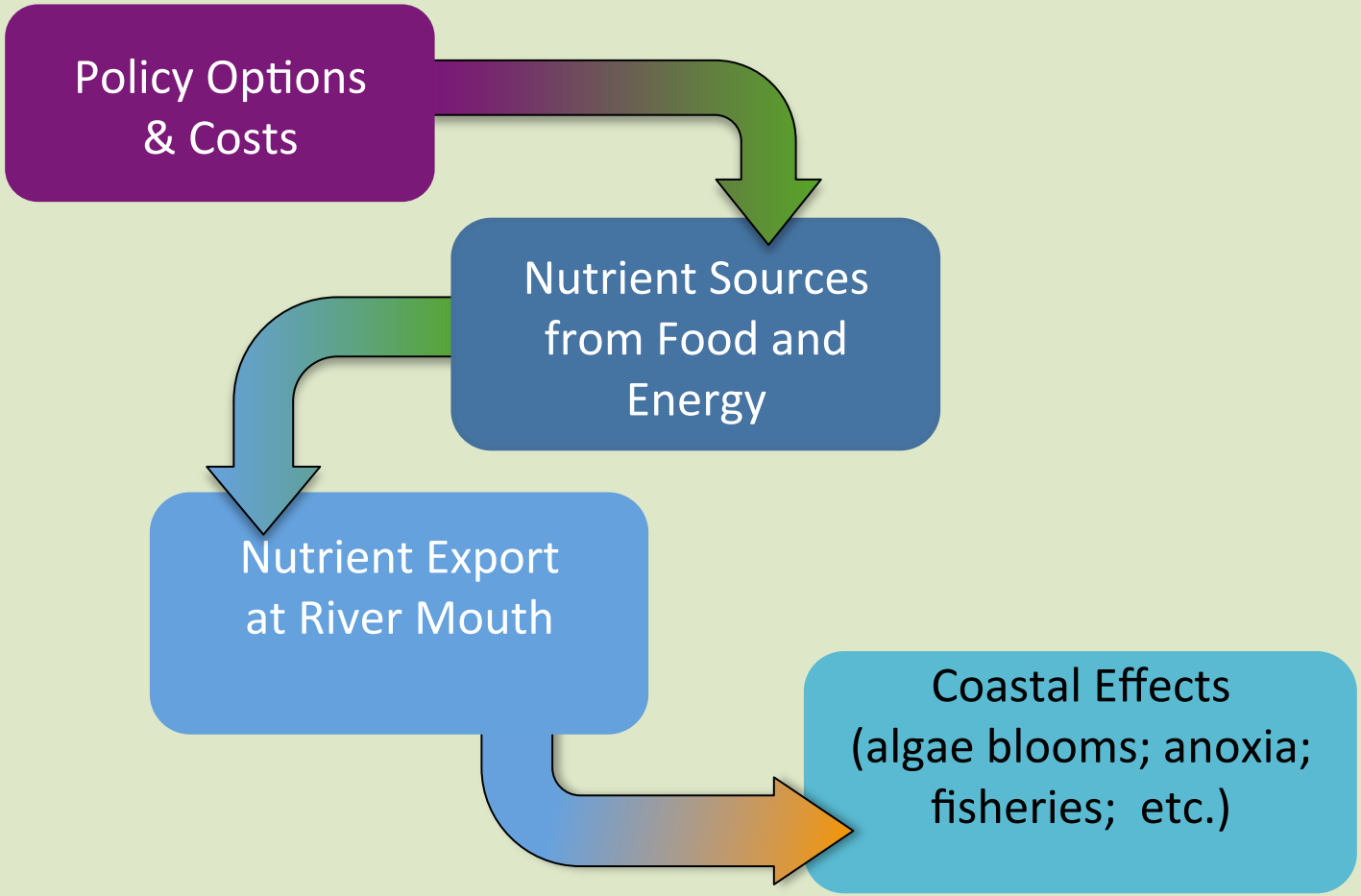
In-River N, P, Si, C Removal

Rivers & Reservoir
Consumptive
Water Use

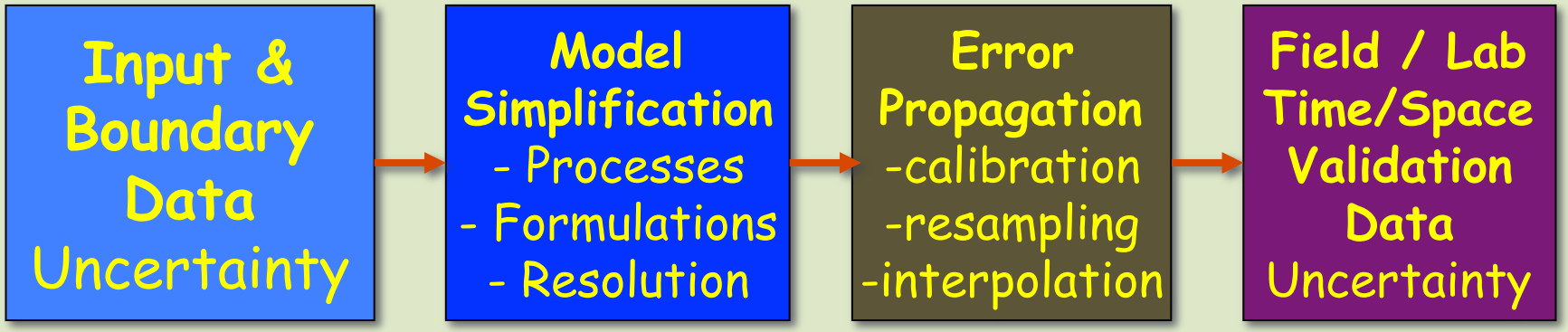
Nutrient Loading to Castal Waters

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

Future scenarios



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