2.5D TO 4D: INITIAL AND BOUNDARY CONDITIONS AND TESTING NUMERICAL MODELS WITH HIGH RESOLUTION TOPOGRAPHY

Ramón Arrowsmith

• Numerical models—some examples with HRT ($^{\text{CSDMS}}$ complement)

• HPC lessons from OpenTopography

• Concluding thoughts

OpenTopography is supported by the U.S. National Science Foundation under Award #s: 1226353 & 1225810
Finite difference solution to mass conservation and geomorphic transport laws (GTL) run for 500 kyr.

No fluvial or debris flow processes.

HRT = initial conditions and character of morphologic relationships for testing appropriate GTL.

Hydrologic modeling using high-resolution terrain and vegetation maps allows unprecedented details on spatial patterns of runoff, soil moisture, ET.

Sensitivity analysis of the simulated ratio of infiltration-excess ($Q_{\text{inf}}$) runoff to total runoff ($Q_{\text{tot}}$) for different levels of hillslope hydraulic conductivity ($K_{\text{hill}}$) show the transitions in runoff generation mechanisms of 6 year run.

(a) $0.33K_{\text{hill}}$

(b) Base Case

(c) $5K_{\text{hill}}$

(d) $10K_{\text{hill}}$

From Schreiner-McGraw and Vivoni (2018)
Computational fluid dynamics (Reynolds-Averaged Navier-Stokes (RANS) & Large Eddy Simulation (LES)):
Increasingly used to model flow over aeolian landscapes including 3D over natural landscapes
Extend empirical observations from spatially limited (often 2d) arrays
Simulate a range of incident flows; Validate with differencing
Gaps:
- roughness parameterization limits shear stress accuracy (e.g., vegetation, bedforms)
- availability of temporal resolution for events and broader freq-magnitude regime assessments

Quantifying flow resistance in mountain streams using computational fluid dynamics modeling over structure-from-motion derived microtopography

Connect scales of flow resistance with surface roughness and water depth

Chen, DiBiase, McCarroll, Liu, in review
Computational fluid dynamics (Detached Eddy Simulation):
Turbulence modeling in the Grand Canyon using LIDAR and bathymetric/total station topography: ties to field experiment (2008 controlled flood) with advanced numerical approach
Hydrodynamics to assess flood hazard in complex urban topography
Quantitative assessment of natural hazards uses predictive models to estimate the extent and dynamics
Requires computations which are forced by the surface topography (Example: Chosica, Peru)
Uses these tools for community outreach for direct engagement and preventative actions
Jeremy Phillips, University of Bristol, project funded by EPSRC in UK

Drone photo of houses upper part of Chosica (right)

SfM model (below)
Hydrodynamics for ecological applications

Enables exploration of relevant parameters such as *Net Rate of Energy Intake*. Model the net energy balance from an individual fish’s perspective if it were to maintain position within every computational node of the wetted channel (uses Delft3D) $10^4$ simulations in a fully automated cloud computing workflow

Mesh preparation from HRT is time consuming but critical

HIGH PERFORMANCE COMPUTING

SOL / EEMT (Effective Energy & Mass Transfer)

Algorithms run on OSG and Comet

7. SOL and EEMT Models

Calculate monthly global (beam + diffuse + indirect) solar irradiation and hours of sunlight

Swetnam, T., et. al, (2016). Scaling GIS analysis tasks from the desktop to the cloud utilizing contemporary distributed computing and data management approaches: A case study of project-based learning and cyberinfrastructure concepts, paper 138, XSEDE ’16

Image: Monthly solar irradiation
TauDEM – Hydrologic analysis of terrain data (17k jobs):

Dedicated Gordon supercomputer node:
I/O Node 48 GB Memory/4.8TB Flash memory + 16 Compute nodes, 64GB memory + InfiniBand

Democratization of supercomputing resources

NEED STAFF SUPPORT: something that works on your desktop may not easily port to this environment

Youn et al., 2014. Leveraging XSEDE HPC resources to address computational challenges with high-resolution topography data
What realism do we really need from our data and models?

HRT?

Plate 1. Paintings as metaphors for different approaches to landscape evolution modeling.
C) Statistical realism: Mondrian 1917, Composition in Blue B (Kroller-Muller Museum, Netherlands).
Concluding thoughts

What good are models? (e.g., Oreskes, et al., 1994)
Build intuition upon quantitative, physical basis
Corroborate hypotheses
Elucidate discrepancies
Sensitivity analyses/parameter sweep
Explore what if questions

High resolution issues
Is the resolution necessary for the question?
Are we losing the power of the abstraction by adapting powerful engineering tools to complex and specific conditions?

Needs and gaps
Multiscale approaches
Meshing—geometric representation for initial and boundary conditions for numerical models
Address uncertainty—is it noise or is it real (roughness)
Training, tool curation, common interfaces and standards, HPC access and integration (e.g., CSDMS, OT, etc.), desktops<->cloud<->HPC
Technical staff support
Validation sites and datasets (“establishment of legitimacy”)
Opportunity and challenge to go beyond steady in time and homogeneous in space (but increasing ambiguity!)