The Role of Geocomputation in the Hydrological Sciences

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International Symposium on Geocomputation and Analysis

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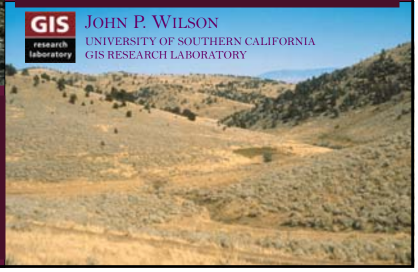
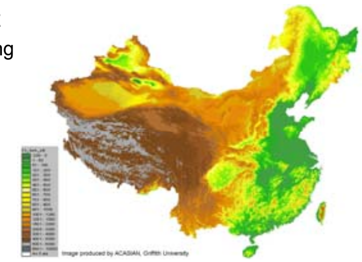


Outline

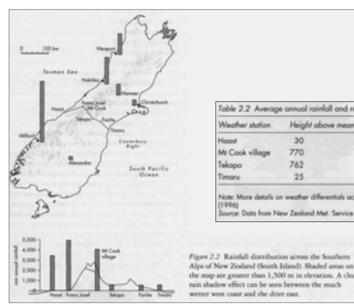
- Background
- State-of-the-Art
  - Terrain Modeling
  - Hydrological Modeling
- Enduring Challenges
- Conclusions



Background (Terrain Modeling)

Slide Courtesy of Graeme Aggett

Terrain Modeling (2)



Source: Davie (2002)

Scale / Processes / Regimes

Global	Cloud cover and CO2 levels control primary energy inputs to climate and weather patterns
Meso	Prevailing weather systems control long-term mean conditions; elevation-driven lapse rates control monthly climate; and geological substrate exerts control on soil chemistry
Topo	Surface morphology controls catchment hydrology; slope, aspect, horizon, and topographic shading control surface insolation
Micro	Vegetation canopy controls light, heat, and water for under-story plants; vegetation structure and plant physiognomy controls nutrient use
Nano	Soil microorganisms control nutrient recycling

Source: Hutchinson (2000)

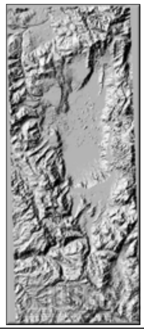
The National Map

- A seamless, continually maintained, nationally consistent set of base geographic data
- Data steward partnerships
- Links the topographic map with underlying base geographic data
- Underpins Federal activities and those of other public and private organizations
- Consistent with NSDI principles

Slide Courtesy of Mark DeMulder

National Elevation Dataset (NED)

- Seamless national coverage of "best available" raster elevation data
  - Geographic "projection" with 1-arc-second (30-m) and 1/3-arc-second (10-m) grid spacing
  - Alaska: 2-arc-second grid spacing
  - Datum: NAD 83 horizontal; NAVD 88 vertical
  - Elevation units: decimal meters
  - Updated bi-monthly to incorporate new USGS DEM production
- The NED is the elevation layer of *The National Map*



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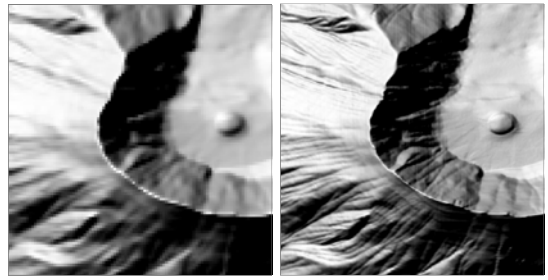
Multi-Resolution NED



1 arc-second
1/3 arc-second

Slide Courtesy of Dean Gusch

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Elevation Derivatives (EDNA)

- Collaborative effort to create common topographically-derived data layers in systematic and consistent manner for U.S.
- Multi-layer data set (raster & vector)
- National Albers projection
- 30 m resolution

Slide Courtesy of Kris Verdin

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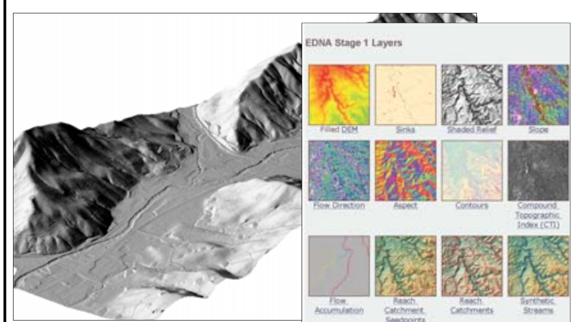
EDNA Stage 1 Layers



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National Hydrography Dataset

- Rich cartographic feature content for making maps
- Stream addressing system for linking water-related information to the national drainage network
- Upstream/downstream modeling along the drainage network
- Infrastructure for maintenance and enhancement

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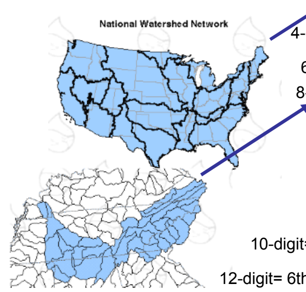
Hydrologic Units



2-digit= 1st level = 22 regions
4-digit= 2nd level = 222 subregions
6-digit= 3rd level = 789 accounting
8-digit= 4th level = 2223 cataloging

new!

10-digit= 5th level = ~22,000 watersheds
12-digit= 6th level = ~160,000 subwatersheds

Slide Courtesy of Bob Pierce

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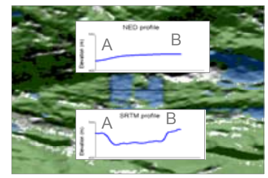
SRTM Datasets

- 11-day mission aboard Space Shuttle Endeavor in February 2000
- Collected interferometric SAR data for 80% of Earth's land surface (60º N to 56º S latitude)
- JPL processed SAR data into DEMs
- Provides 1-arc-sec data over U.S. and 3-arc-sec (90-m) data other places

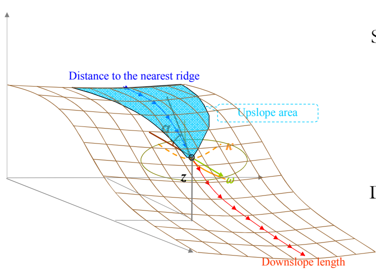
Slide Courtesy of Dean Gusch

Land Cover Effects

- SRTM data collected with a "first return" system, so measured elevations in forested and built-up areas often will not represent ground level elevations
- National Land Cover Dataset used to stratify assessment by land cover class to help characterize how surface features affect accuracy …l



Topographic Attributes



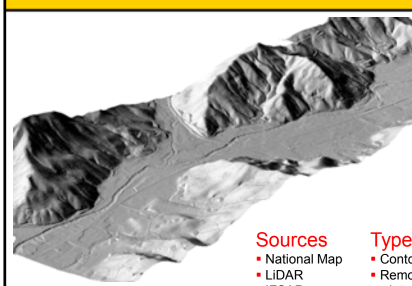
Elevation (z)
Slope gradient (α)
Slope aspect (ω)
Curvatures (κ)
Distance to the nearest ridge
Downslope length
Upslope area

Slide Courtesy of Bard Romstad

Some Outstanding Issues …

- Source and granularity of DEM used
- Presence and handling of spurious pits (interpolation)
- Choice of drainage enforcement option (if any)
- Choice of flow routing algorithm
- Dynamic character of key variables and processes
- **It is the topographic shape that matters most!**

DEM Source and Data Type

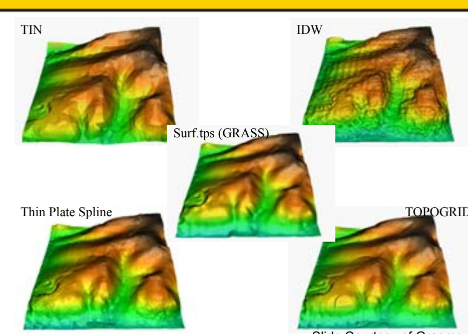


Picture courtesy of David Maune

Sources
- National Map
- LiDAR
- IFSAR
- GPS

Types
- Contour and stream line data
- Remotely sensed elevation data
- Surface specific point elevation data

Surface Interpolation



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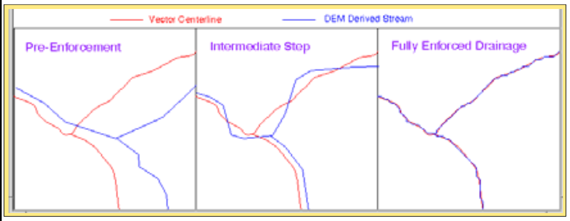
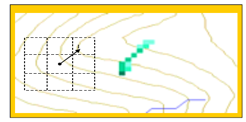
Drainage Enforcement



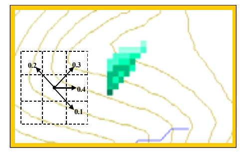
Slide Courtesy of Pete Steeves

Single vs. Multiple Flow Directions

Single Flow Direction Grid — A numerical representation of the flow direction field in which each cell takes on one of eight values depending on which of its eight neighboring cells is in the direction of steepest descent



Multiple Flow Direction Grid — A numerical representation of the flow direction field in which flow is partitioned between one or more or the eight neighboring cells such that proportions add up to one



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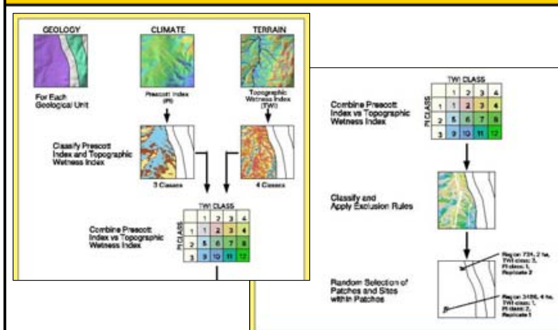
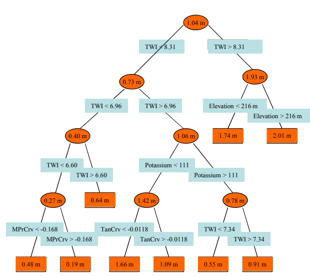
SSURGO Soil Survey Data

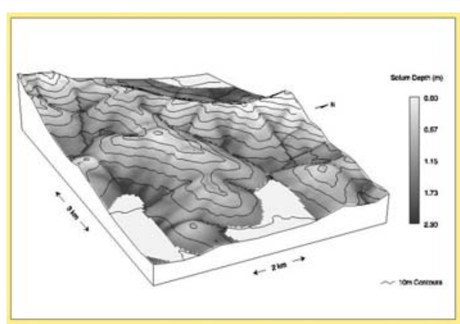
Soil Sampling / Landscapes



Solum Depth Regression Tree



Predicted Solum Depth Map



Soil Water / Vegetation Links

Spruce Forest at Tree Line

Piercy Creek Clearcut
Tanoak replaces
redwoods and douglas fir

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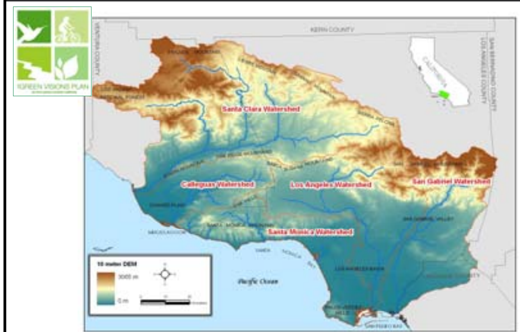
Green Visions Project



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Los Angeles Basin …

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GVP Watershed Modeling

- Determined quantities of contaminants entering stream network
- Simulated transport of contaminants in reservoirs, rivers, and groundwater
- Predicted water quality by stream catchment
- Used Danish Hydraulic Institute's MIKE BASIN modeling tools

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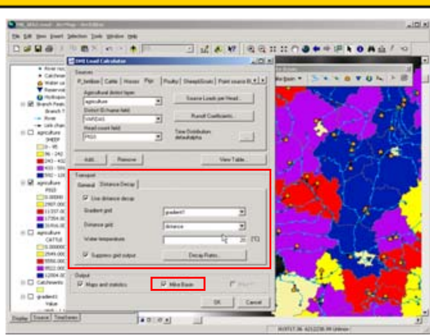
User Interface – WQ Module



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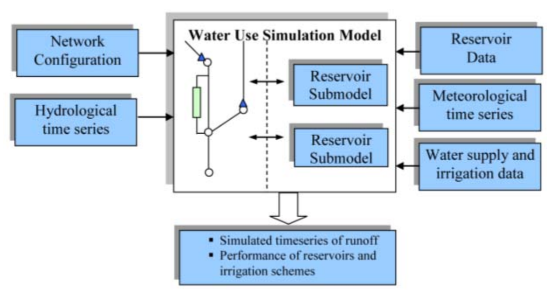
MIKE BASIN



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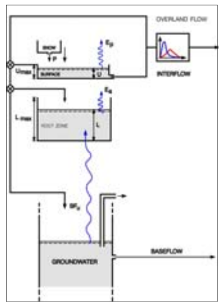
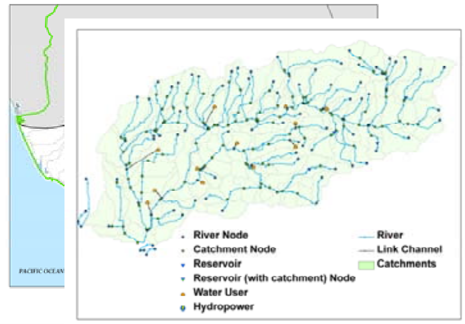
Model Implementation

- Prepare model and data
- Calibrate rainfall-runoff relationships
- Calibrate delivery and transport of contaminants
  - NO3-N, NH3-N
  - Total P
- Validate rainfall-runoff and water quality predictions



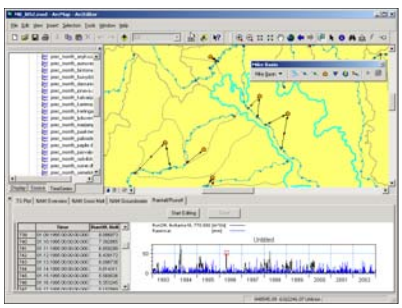
Subwatershed Delineation



Rainfall-Runoff Analysis

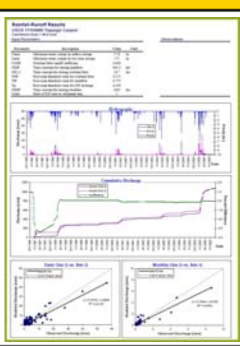
Basic Inputs

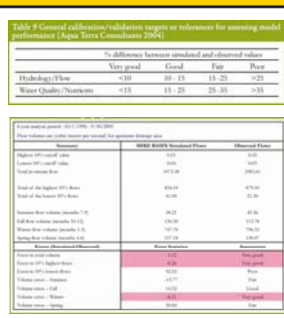
- Initial conditions
- Rainfall, potential evaporation, & temperature time series
- Stream flow data for model calibration and validation



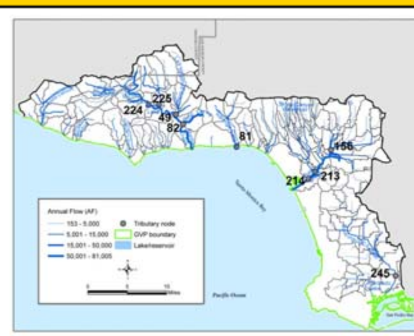
Monitoring Data

Rainfall-Runoff Results





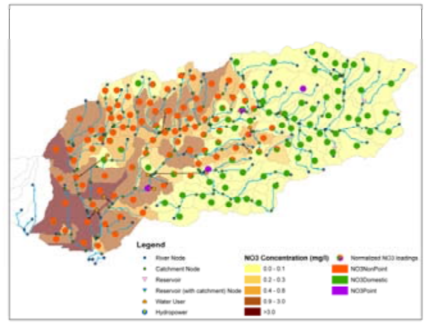
Santa Monica Bay Flows



Contaminant Sources

- Fertilizer Sources
  - Crop data
  - Fertilizer application rates
  - Distance decay factor (calibration)
- Livestock Sources
  - Very few
- Domestic Sources
  - Population estimates
  - Sewage treatment data
  - Distance decay factor (calibration)
- Point Sources
  - Five major NPDES

NO3-N Predictions



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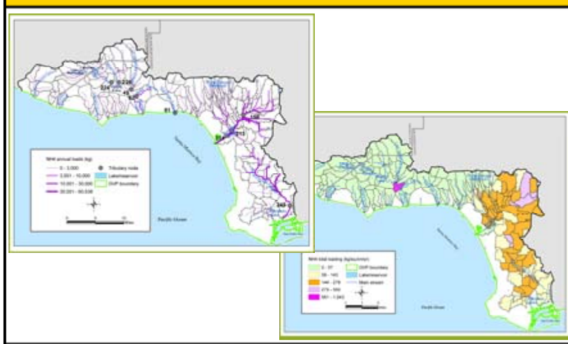
Santa Monica Bay Loads …



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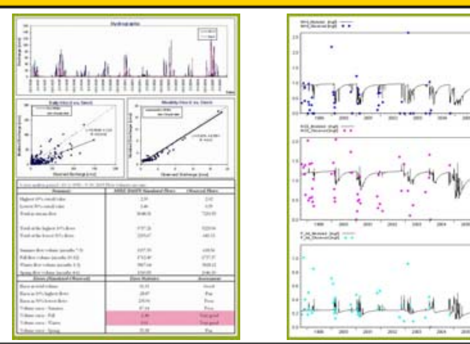
Water Quality Results



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Spatial Granularity – LA River

- Drains 2,002 km^2
- 1,783 unique stream segments (links) in NHD Plus
- 171 tributaries and subcatchments used for MIKE BASIN model runs
- 11.7 km^2 (1,171 ha) minimum map unit

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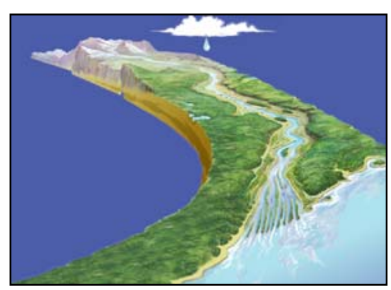
What is the Ultimate Goal?

Goal is to follow a drop of water from where it falls on the land, to the stream, and all the way to the ocean



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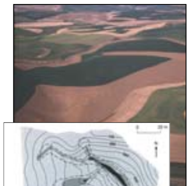
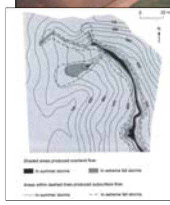
Enduring Challenges

- Role of scale & landscape hierarchies
- Complex process feedbacks
  - Sensitivity of MIKE BASIN to model design decisions and inputs
- Dynamic character of key processes
  - Inclusion of cloud cover in solar radiation models
  - Quasi-dynamic topographic wetness index
- Role of measurement, calibration, validation, and uncertainty
  - Difficulty of handling scale mismatches and possibility that process regimes change with time





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Runoff Generation

Table 5.2 A summary of the ideas on how stormflow is generated in a catchment

	Horton	*Betson*	*Hewlett and Hibbert*
Infiltration	Controls overland flow	Controls overland flow	All rainfall infiltrates
Overland flow mechanism	Infiltration excess	Infiltration excess	Saturated overland flow
Contributing area	Uniform throughout the catchment	Restricted to certain areas of the catchment	Contributing area is variable in time and space

Source: Davie (2000)

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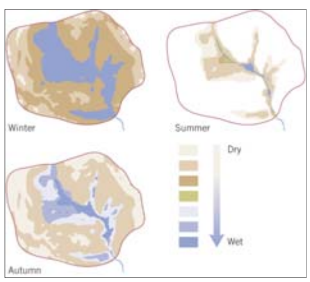
Preferred View …

- Saturated overland flow is dominant overland flow mechanism in humid, mid-latitude areas
- Variable source areas concept is most valid description of stormflow processes
- Infiltration excess overland flow occurs where infiltration capacity of a soil is low or rainfall rates are high



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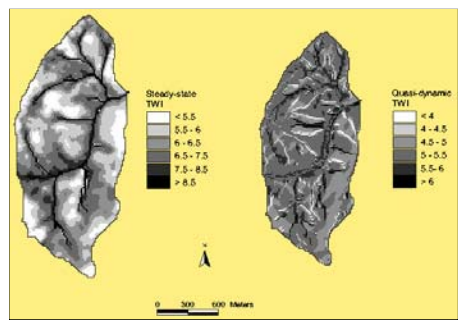
The Immediate Challenge



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Final Thoughts

- Need to rethink our research paradigms
  - Think of new ways to represent, measure and interpolate variables of interest, build and apply models, & inform decisions
- Geocomputation has major role to play here
  - Computing, modeling, sensor networks, etc.
- And with that, I will stop and take questions …

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