GIS, Spatial Analysis & Spatial Thinking: Essential Tools for the Modern Geoscientist's Toolbox

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26 April 2010

Spatial Science

Outline

- My work
  - Mapping & classification
  - Digital terrain analysis
  - Fuzzy logic & classification
  - Hydrologic modeling
  - Spatial analysis
  - Geocomputation
- Interdisciplinary spatial science
- Overlap w/ earth science
- Final comments

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Mapping & classification

- USDA Soil Taxonomy
  - Hierarchical classification consisting of soil orders, sub-orders, great soil groups, families & series
  - Lower levels described by soil moisture & temperature regimes as well as characteristic horizons
- Spatial structure
  - Soil map units

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Mapping & classification (2)

- Paucity of measurements
- Reliance on proxy variables & crisp logic
- Multiple sources of error & uncertainty
- Scale dependent map products with multiple one-to-many linkages embedded in them

Cf. SSURGO & STATSGO datasets

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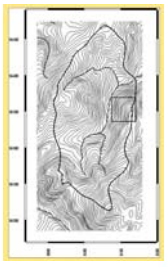
Digital terrain analysis

- Terrain plays key role in modulating atmospheric & earth surface processes
- Digital elevation models play key role
- Calculate first & second derivatives plus variety of primary & secondary topographic attributes



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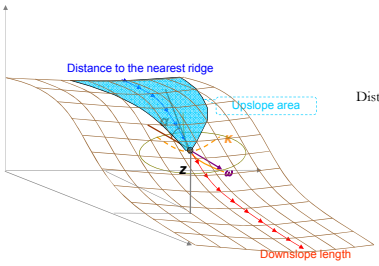
Topographic attributes



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

Slide Courtesy of Bard Romstad

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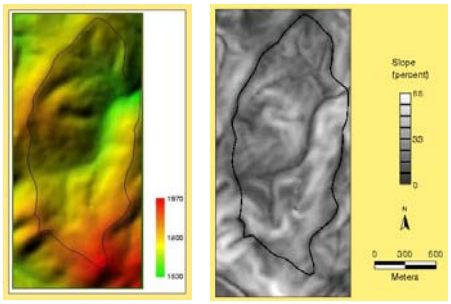
Elevation & slope



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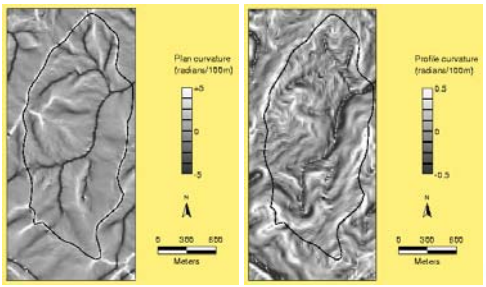
Plan & profile curvatures



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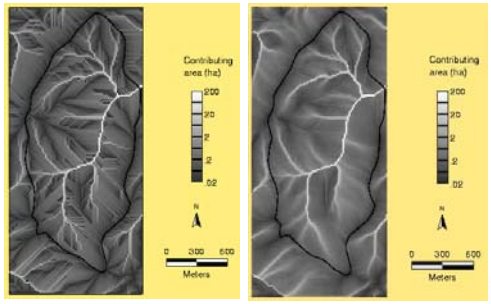
Upslope contributing areas



D8 flow routing algorithm

DEMON flow routing algorithm

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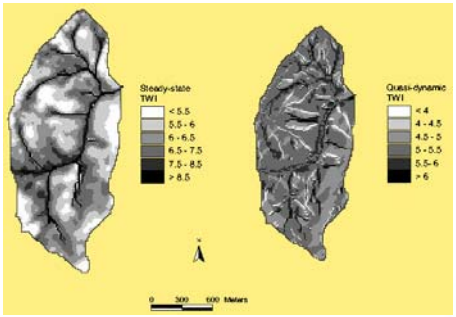
Topographic wetness indices



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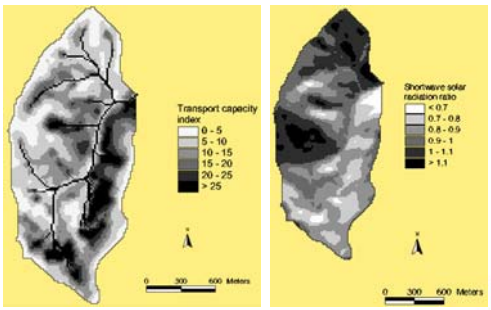
Energy inputs



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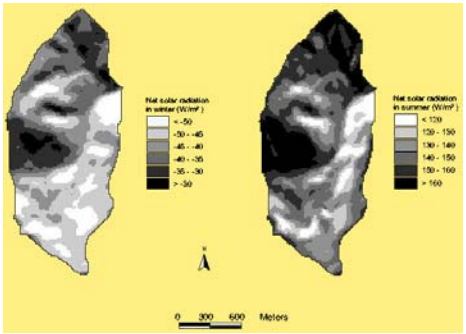
Net solar radiation



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Geomorphometry

- Science of digital terrain analysis
- Rapidly evolving field – LiDAR & related RS technologies
- Focuses on extraction of land surface parameters & land surface objects from digital topography
- Provides valuable model support …

Slide Courtesy of Dean Gusch

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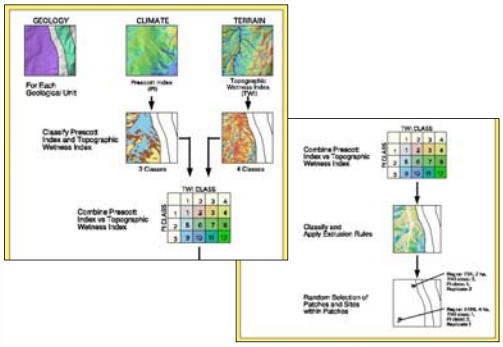
Stratified random sampling



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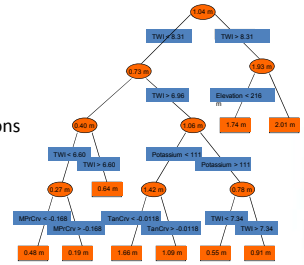
Modeling solum depth

- Regression trees
  - Used five inputs & described 90% of variation
  - Based on 73 observations
- Generalized linear models
  - 3 inputs (TWI, STI, & potassium content)
  - Described 75% of variation



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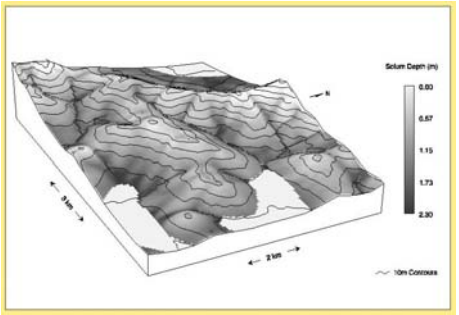
Predicted solum depth map



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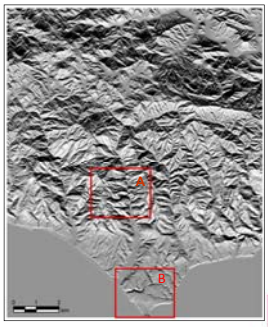
Fuzzy logic & classification

- Two basic approaches
  - Semantic import models
  - Fuzzy k-means
- Fuzzy classification of landscapes
  - Point Dume 1:24K USGS map quadrangle



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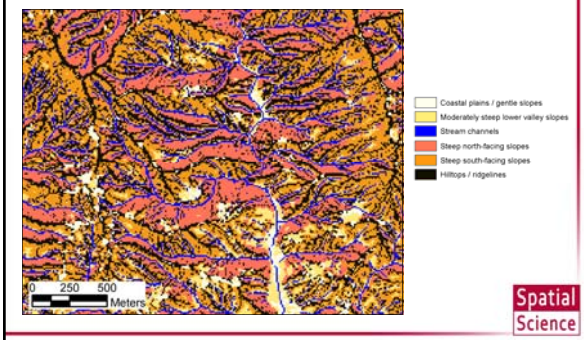
Fuzzy classification of landforms



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Fuzzy landform classes


Coastal plain


Footslopes


Stream channels


North-facing steep slopes


South-facing steep slopes


Hilltops / ridgelines

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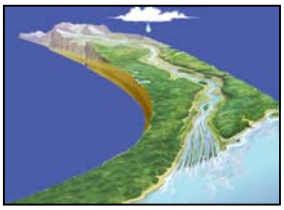
Hydrologic modeling

- Determine quantities of contaminants entering stream network
- Simulate transport of contaminants in reservoirs, rivers & groundwater
- Predict water quality by stream catchment



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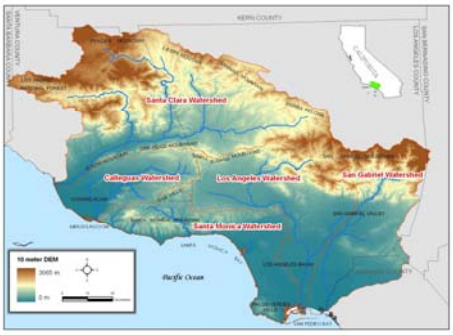
Study area



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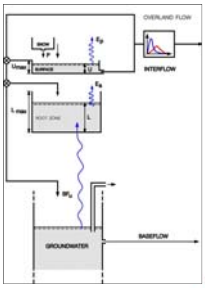
MIKE BASIN

- Simple rainfall-runoff & pollution loading model authored by Danish Hydraulic Institute
- Runs on top of ArcGIS toolbox
- Incorporates easy-to-use model calibration & validation tools



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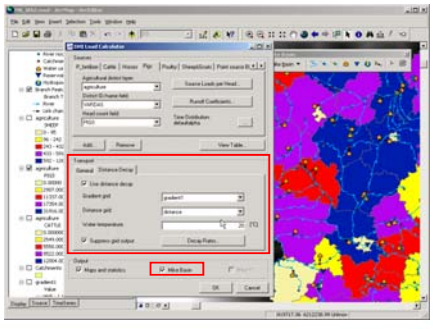
WQ module user interface



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National Hydrography Dataset

- Stream address system for linking water-related information to national drainage network
- Supports upstream / downstream modeling along drainage network
- Provides rich cartographic feature content for making maps

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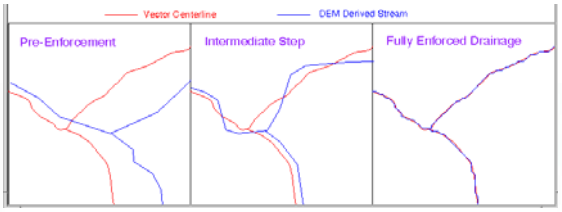
Drainage enforcement



Slide Courtesy of Pete Steeves

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Model discretization

- Drains 2,200 km^2
- 1,783 unique stream segments (links) in NHD Plus
- 171 tributaries and sub-catchments used for MIKE BASIN model runs
- 11.73 km^2 (1,173 ha) minimum map unit

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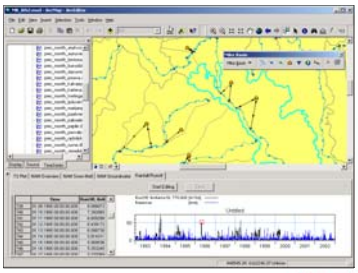
Rainfall-runoff model analysis

- Key inputs
  - NHD Plus
  - Rainfall, ET & temperature time series
  - Stream flow data for model calibration & validation



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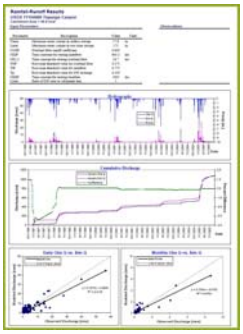
Rainfall-runoff model results



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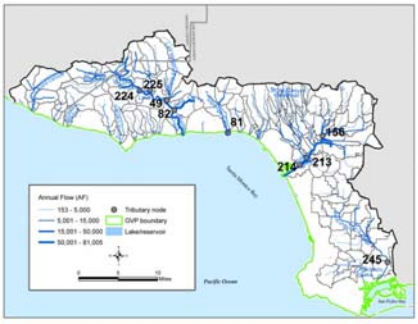
Santa Monica Bay flows



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Contaminant sources

- Point sources
  - Five major NPDES polluters
- Domestic sources
  - Population data
  - Sewage treatment plants
  - Distance decay calibration factor
- Fertilizer sources
  - Crop data
  - Fertilizer application rates
  - Distance decay calibration factor
- Livestock sources

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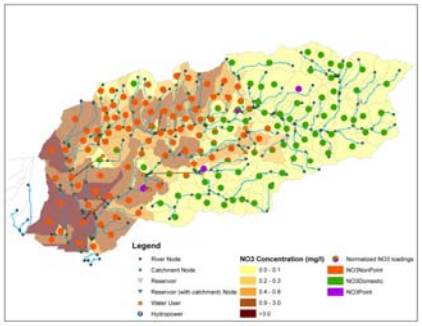
MIKE BASIN NO_3-N predictions



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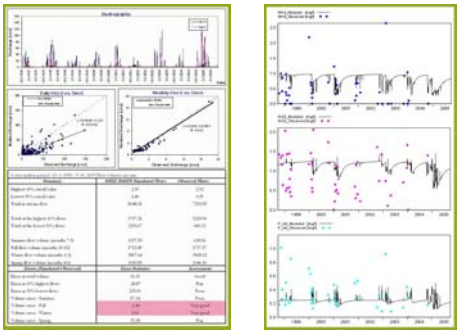
Water quality modeling results



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Spatial analysis

- Melanoma is one of most rapidly increasing cancers among white population in U.S.
- Studies consistently point to UV exposure as most important risk factor
- Individual sun exposure has proved difficult to quantify
- How well can we model spatial variations in UV radiation given measurement network & interpolation techniques available (in 2005)?

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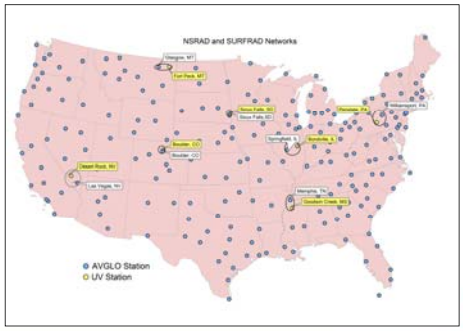
Measurement network



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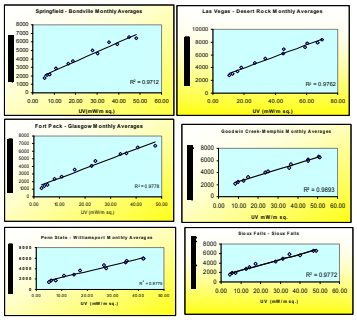
Radiation data correlations



Springfield – Bondville, IL
Las Vegas – Desert Rock, NV
Boulder – Boulder, CO
Fort Peck – Glasgow, MT
Goldwin Creek – Memphis, TN
Penn State – Williamsport, PA
Sioux Falls – Sioux Falls, SD

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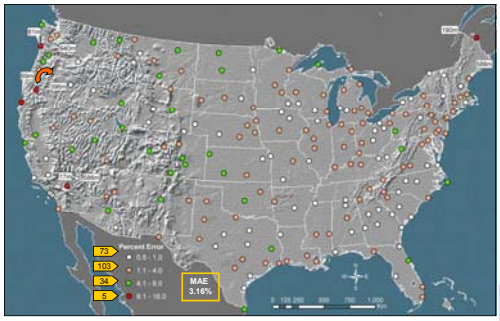
Thiessen polygon error map



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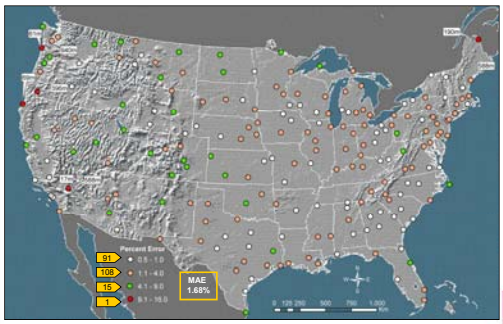
Kriged error map



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Splined error map

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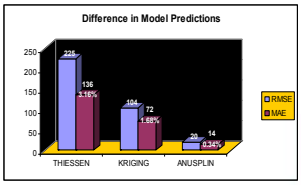
Model differences

- Spline predictions 11 & 2.2 times better than Thiessen polygon & kriged predictions
- ANUSPLIN …
  - Smallest RMSE, MAE & VE
  - Highest R (observed / predicted)
  - Smallest R (observed / error)



	RMSE	MAE	VE	Correlation OBS/PRED	Correlation OBS/ERR
THIESSEN	225	136 (3.16%)	50906	0.90	0.40
KRIGING	104	72 (1.68%)	10885	0.98	0.31
ANUSPLIN	**20**	**14 (0.34%)**	**384**	**0.99**	**0.15**

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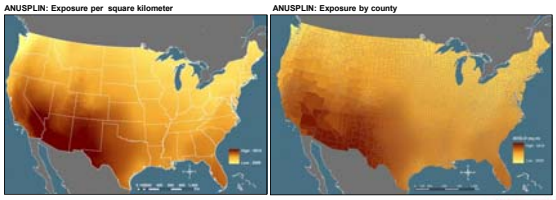
ANSPLIN UV exposure model

- Used Arc/Info GRID tools to calculate zonal means
- Generated map of UV exposures by county



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Geocomputation

- Collaborative work w/ JC Chen & Rhonda Spencer, Keck School of Medicine
- National study tracing health of 7,500 women spread across 22 states
- Subjects undergo cognitive function testing annually (40 clinical centers)
- We would need to calculate mean solar light exposures for 0.5, 1, 3, 6 & 12 month intervals preceding each annual test

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Interdisciplinary spatial science

- Start w/ Geography Department UCAR review (04/09)
- Spatial Science Faculty Advisory Committee established 08/09
  - College of Letters, Arts & Sciences (4)
  - Keck School of Medicine (2)
  - School of Architecture (1)
  - School of Policy, Planning & Development (2)
  - School of Social Work (1)
  - Viterbi School of Engineering (2)
- Proposal submitted to Provost on 12/09

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Motivation

- Systematic development of computational tools for handling spatial data began in 1960s
- Geographic information systems & software for image processing, pattern recognition, & scientific visualization are now in widespread use throughout academy
- Functions for manipulation, analysis, & modeling of spatial data available in standard statistical & mathematical packages
  - ArcGIS, for example, has 750 such functions

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Motivation (2)

"The development of relevant theory and concepts, and the cultivating of spatial intelligence through education, has lagged far behind, however, and it is clear that a wide gap exists between the power and accessibility of tools on the one hand and the ability of researchers, students, and the general public to make effective use of them on the other."

(Geography Department UCAR Committee Report, 2009)

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Interdisciplinary Spatial Science B.A.

- Small core (22 units)
  - Fundamentals of design communication
  - Introduction to geographic information systems
  - Principles of geographic information science
  - Principles of remote sensing
  - GIS design & applications
  - Geographic information systems & planning applications
- Plus Computing, Planning & Design, & Quantitative Analysis tracks (12 units)

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Interdisciplinary Spatial Science Ph.D.

- Spatial science doctoral certificate program
- Five core courses
  - Fundamentals of spatial thinking
  - Principles of spatial analysis
  - Geospatial information management
  - Geocomputation
  - Current topics in spatial science
- New spatial science doctoral program sponsored by College & Keck School of Medicine?
- NSF IGERT proposal submitted in 03/10

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GIST Online Programs

- M.S. & Graduate Certificate programs
- Nine semester courses
  - Concepts for spatial thinking
  - Spatial databases
  - Spatial analysis & modeling
  - Geospatial project management
  - GIS programming & customization
  - GPS/GIS field techniques
  - Remote sensing for GIS
  - Cartography & visualization
  - Web GIS
- Embanet partnership

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GIS Research Laboratory

- Designated ESRI Development Center
- Build & support geospatial web services
- Manage campus site licenses & support variety of geospatial software tools

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Overlap w/ earth sciences

- The earth sciences cover wide array of challenges facing society in 21st century ranging from energy to environmental concerns
- Students require new types of training & additional skills to address complex interactions between physical, chemical, & biological systems operating across multiple spatial scales
- New spatial science courses can help to provide this training

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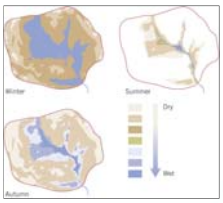
Final Comments

- Spent my career modeling space-time variability of patterns & processes operating on Earth's surface
- Our theories, models & observations now immersed in rich new computational settings
- We can all work at finer granularities than we have up to this time



Slide courtesy of Tim Davie

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