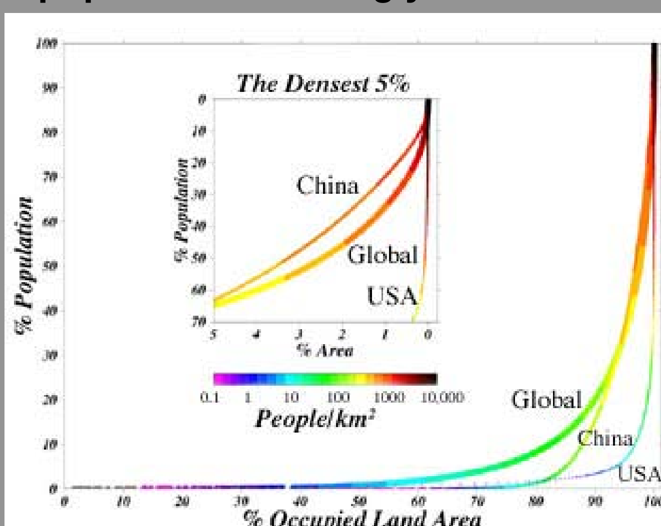
LCLUC Impacts in the Urban Environment

Urban LC accounts for small % of global land area - but has disproportionate impacts - both on surrounding areas and on % of human population.

Urban cores coupled with their surrounding spheres of influence account for significantly more area than the cores alone - and have much greater influence

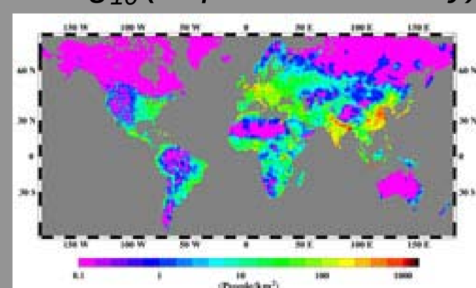
Definition of ***Urban*** areas varies considerably with discipline, investigator & question

At all spatial scales, population is strongly clustered…



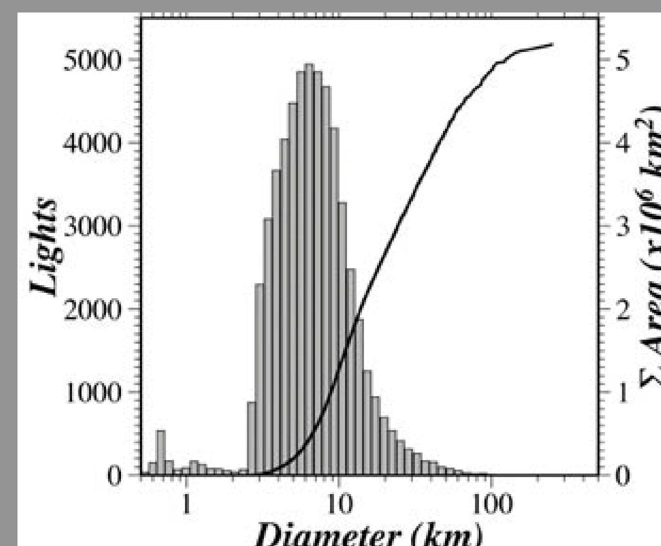
Small & Cohen, 2002

Log$_{10}$ (Population Density)



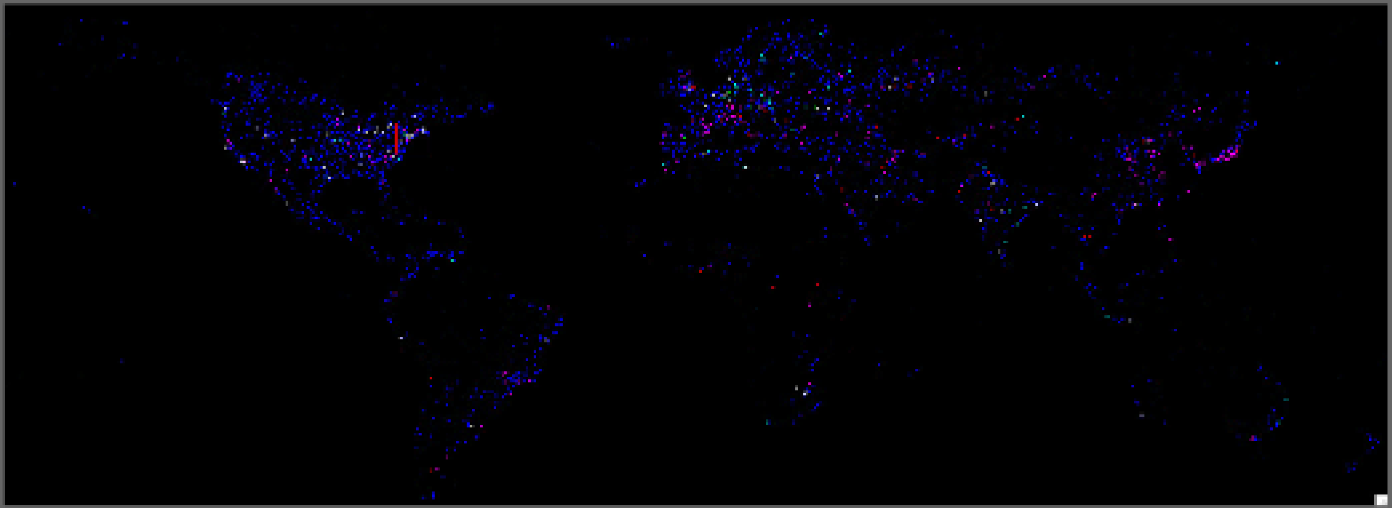
Stable Lights

But urban clusters often aggregate Into much larger conurbations



Small et al, 2005

Multiscale Influence of Urban Development

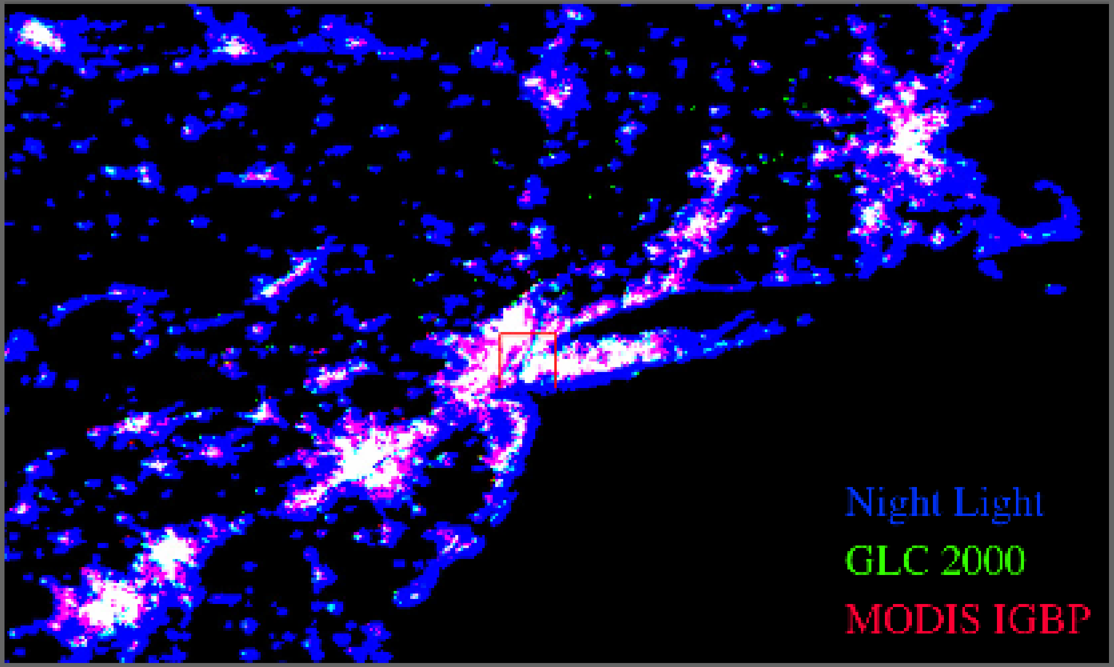


Global Scale

~3% of land area
strongly clustered

Regional Scale (meso-β)

some connurbations 30-50%
of land area at regional scales.



Local Scale (< meso-γ)

100% of land area

Urban LCLUC projects span Atmosphere, Hydrosphere & Biosphere Systems

Multiple spatial & temporal scales and resolutions

Focus on dynamics of coupled urban-rural systems

Regional hydro-meteorology impacts of urban growth - ***Bowling et al***

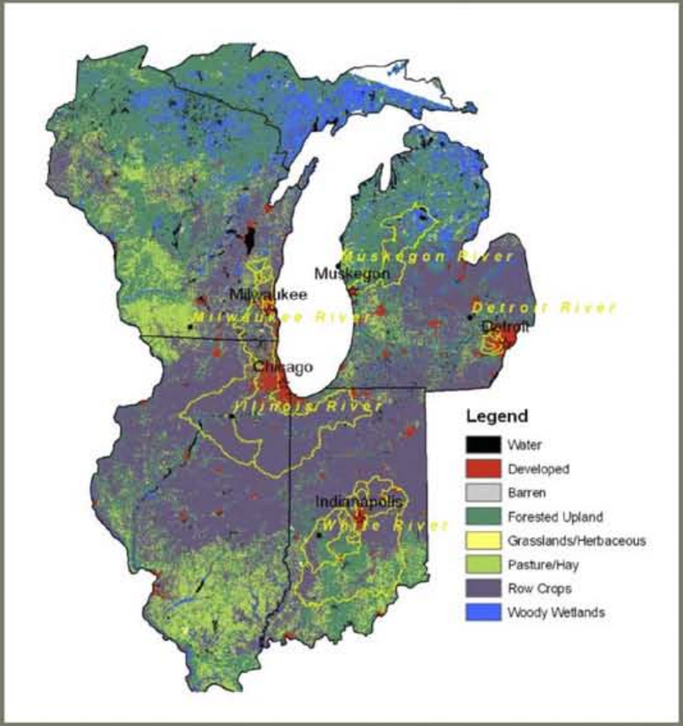
Global comparisons using multiple sensors & datasets - ***Christensen et al***

Coastal & estuarine biogeochemical impact of urban growth - ***Fisher & Gitelson et al***

Fluvial hydrologic impacts of impervious cover - ***Goetz et al***

Multi-scale impacts of land cover dynamics on urban climate - ***Small, Avissar & Walko***^{2}

Urbanization impacts on the hydrometeorology of the Upper Great Lakes Region



L. Bowling (Agronomy),
K. Cherkauer (ABE),
B. Pijanowski (FNR), D. Niyogi (EAS)
Purdue University

- How is urban land use projected to change in the next 20 years?
- How are precipitation and temperature affected during summer thunderstorms?
- What is the relative impact of precipitation changes versus infiltration changes on streamflow?

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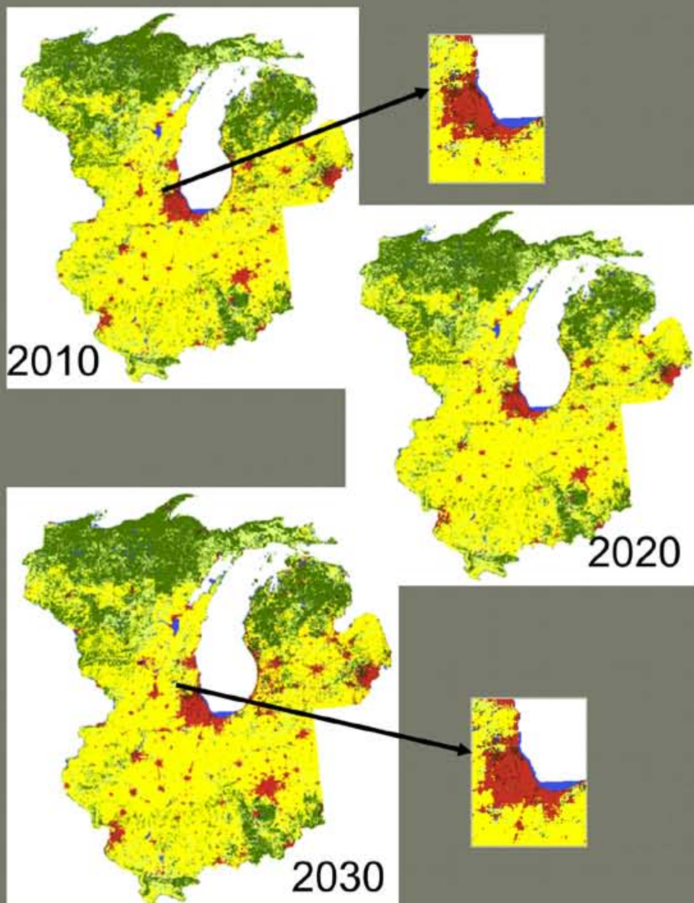
Land Use Forecasts



- Land Transformation Model (LTM):
  - Neural networks trained on historic census and forest cover data
- Projections:
  - 100 m resolution
  - 2010 – 2030, every 5 years
- Residential and commercial growth:
  - Greatest in MI (91, 49%)
  - Lowest in WI (32, 30%)
- Agriculture and wetlands decrease in all states
- Forest regrowth in MI and WI

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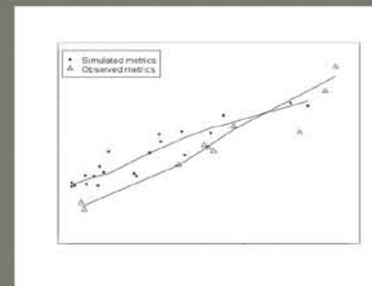
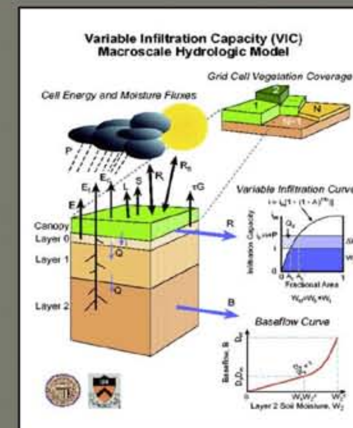
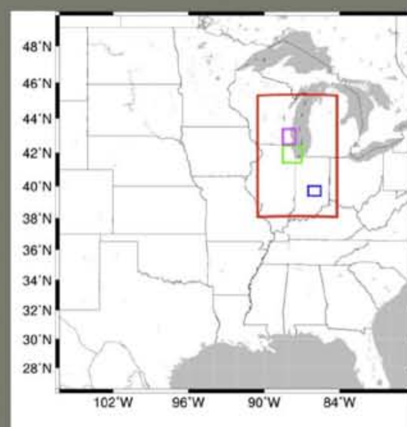
Meteorology & Hydrology Simulations

- **RAMS 4.3 with LEAF2 land scheme**
  - Initial and boundary conditions from NCEP Final Analyses (FNL)
  - June 21-23, 2006 storm event
  - Fractional land cover from LTM projections
  - 3 nested domains



Yang et al. (2009), J. Hydromet.





- Variable Infiltration Capacity (VIC) hydrology model
  - Adapted to represent hydrologic impacts of impervious surfaces
  - Weather inputs modified based on the ratio of RAMS simulations

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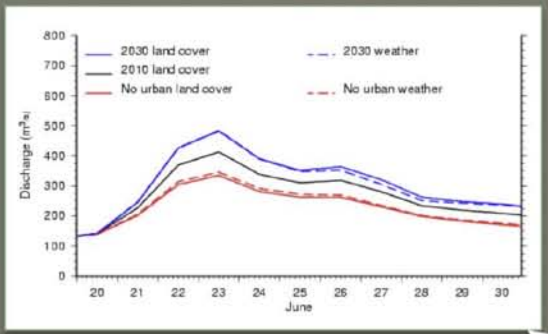
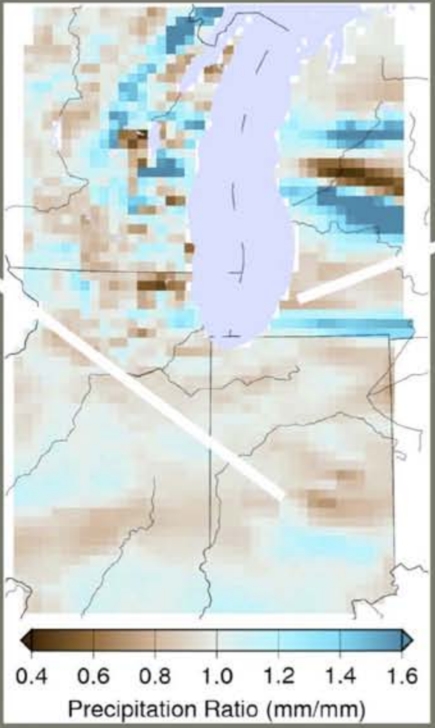
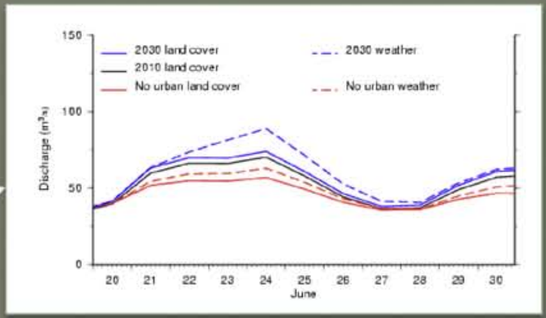
Precipitation & Streamflow Changes

RAMS results:
2030 land cover simulation /
2010 land cover simulation





Muskegon River, MI



White River, IN

- Changes in convective precipitation are minor relative to runoff increases from ISA
- Projected 2030 changes as large as urban impact already experienced

- Projected changes in convective precipitation much more substantial

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UNIVERSITY.

100 CITIES PROJECT

Sensing for Solutions — Bridging Cities and Science

JEarth | Analytical Remote Sensing Imagery Application for Researchers and Practitioners

Phil Christensen, Lela Prashad, Saadat Anwar, Betim Deva, Scott Dickenshied, Eric Engle, Dale Noss

School of Earth and Space Exploration, Arizona State University

lprashad@asu.edu - 100cities.asu.edu

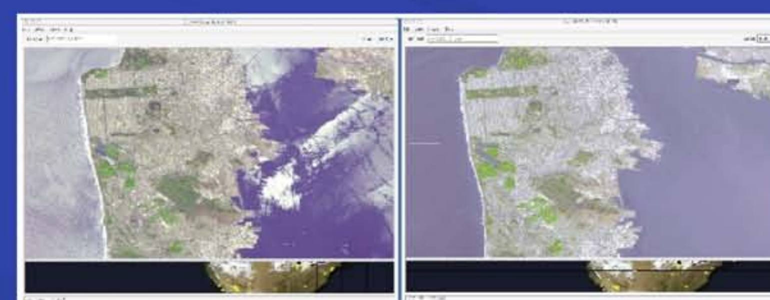
JEarth is set of analytical GIS tools for viewing and analyzing remote sensing imagery and vectors (shapefiles) including ASTER, Landsat, MODIS, and hyperspectral imagery such as TIMS.

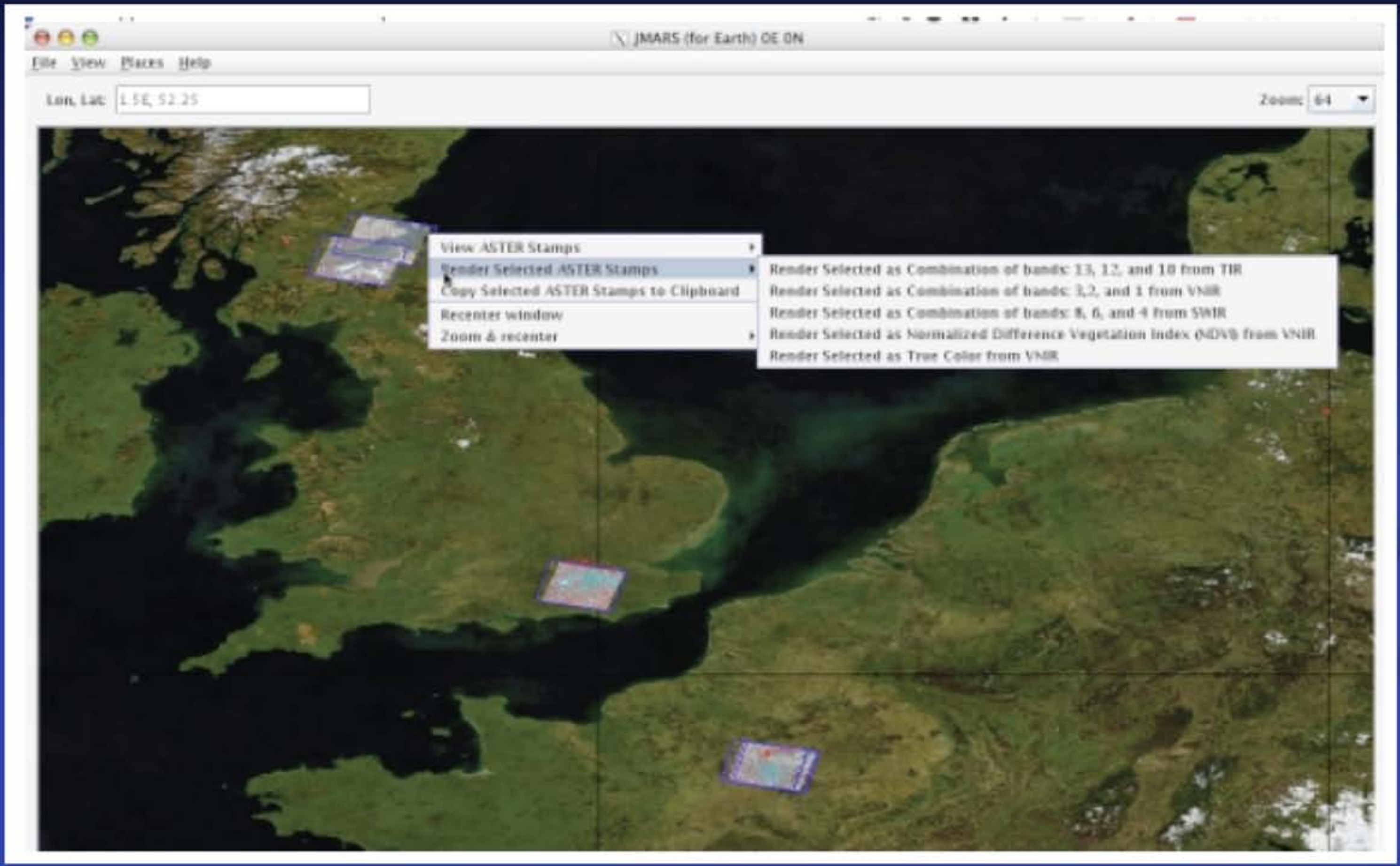
JEarth is being created from existing applications:

- **JMars (Java Mission-planning and Analysis for Remote Sensing jmars.asu.edu/)**
- **THMPROC (themis.asu.edu/thmproc), a web-based, interactive tool for processing imagery**

JEarth will include **(in addition to imagery):**

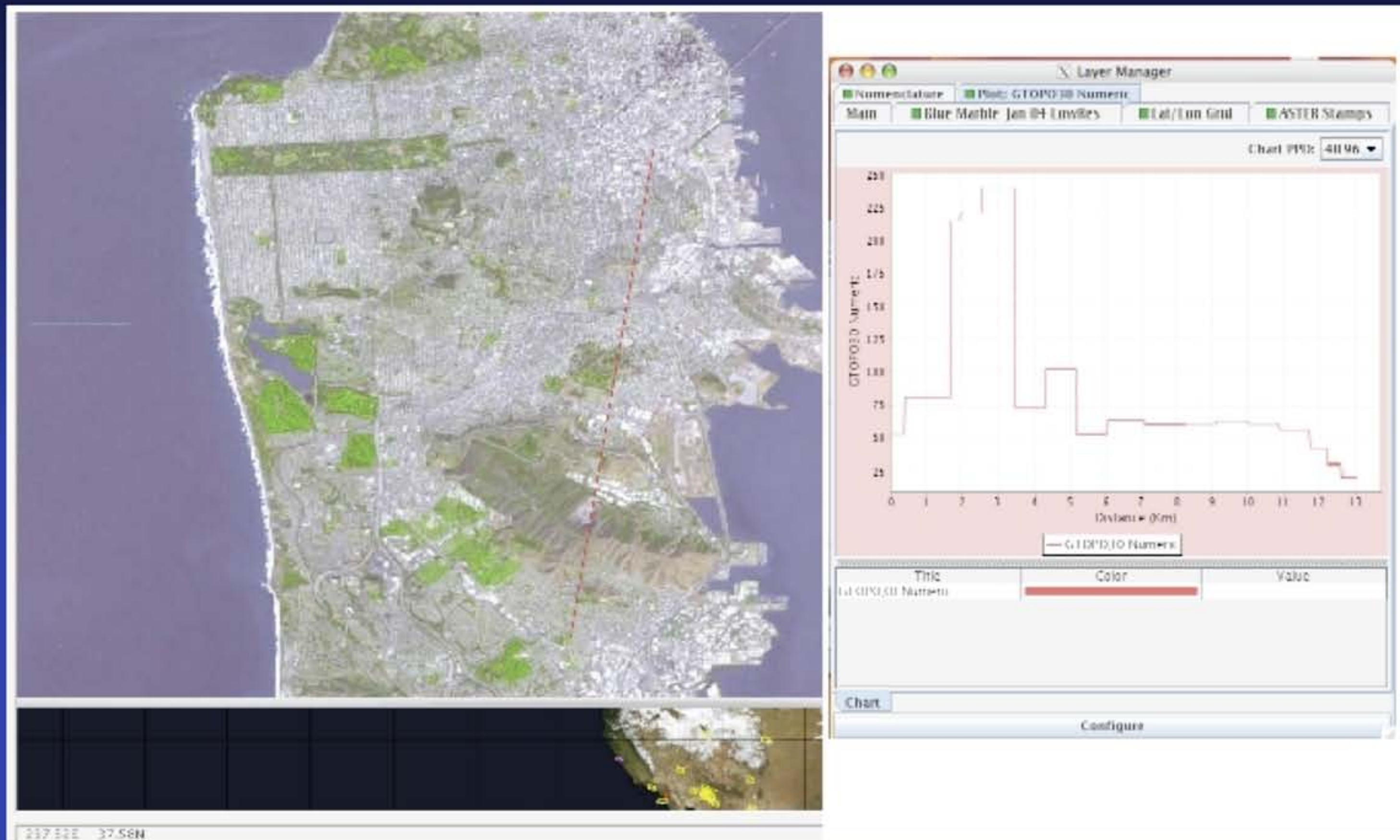
- Social, ecological, climate, geologic, political, and population-related datasets
  - Integration of datasets on global, country, and city scales
- **LULC Datasets:**
  - Partnering with NSF Long Term Ecological Research to provide high-resolution object oriented ecology LULC classification
  - Global landcover, ecological regions, biodiversity





JEarth Example 1

ASTER imagery for cities shown as "stamps" within a global true color MODIS image. The stamps can be selected to display different imagery products, such as vegetation maps, surface temperature, or basic true color.



JEarth Example 2

Profiles can be drawn to assess change across an image. In this example elevation is shown. Other examples include temperature, vegetation abundance, and reflectance of urban materials.

Responses of coastal waters to terrestrial inputs of elemental CNP in urbanizing coastal regions

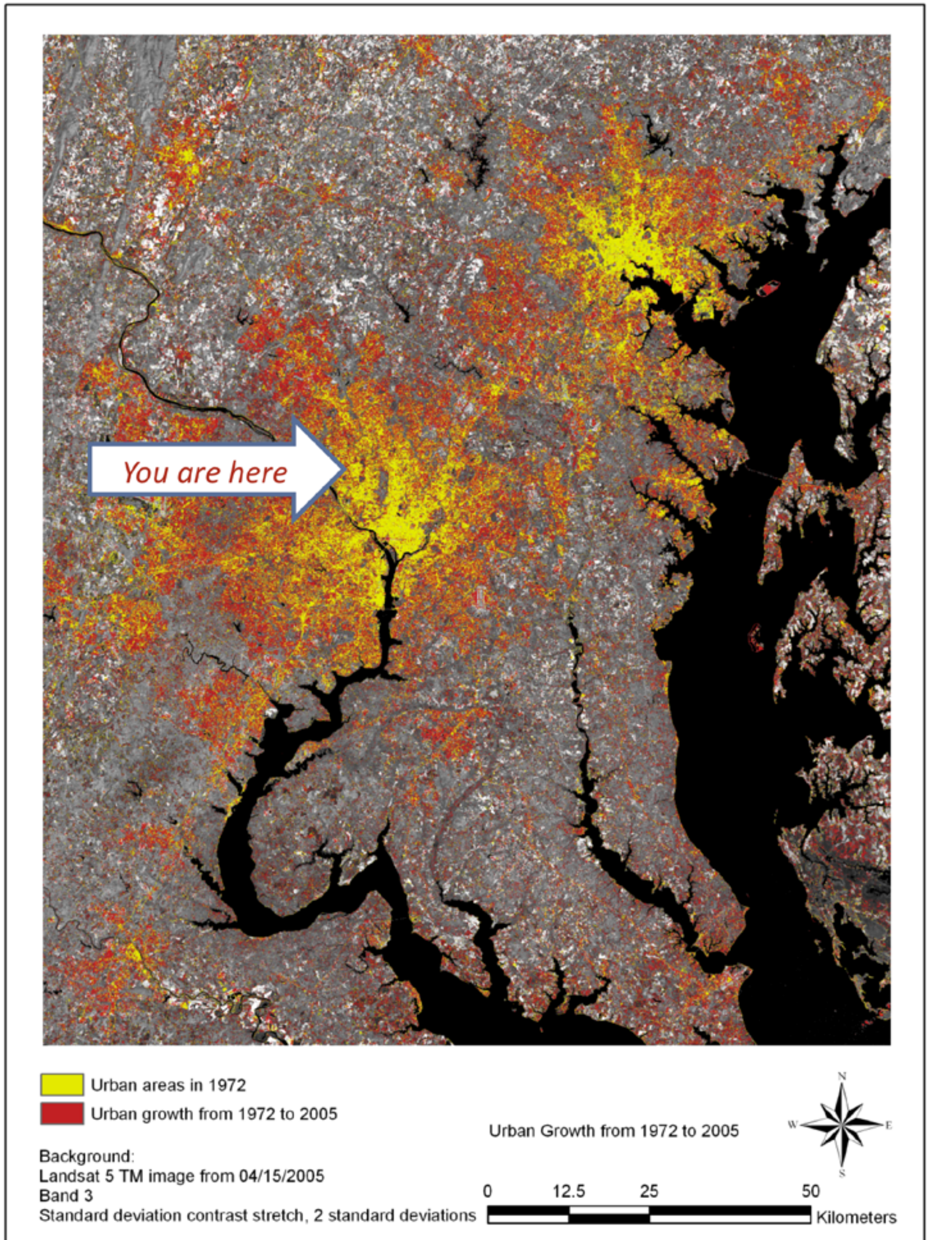
Thomas Fisher, Gregory Radcliffe, Kuang Lee

Horn Point Laboratory, Center for Environmental Science, Univ. Maryland

Anatoly Gitelson, Daniela Gurlin, Wesley Moses

CALMIT, School of Natural Resources,

Univ. Nebraska-Lincoln



Urbanization in the Chesapeake Bay Basin:

Rt 95 Corridor:

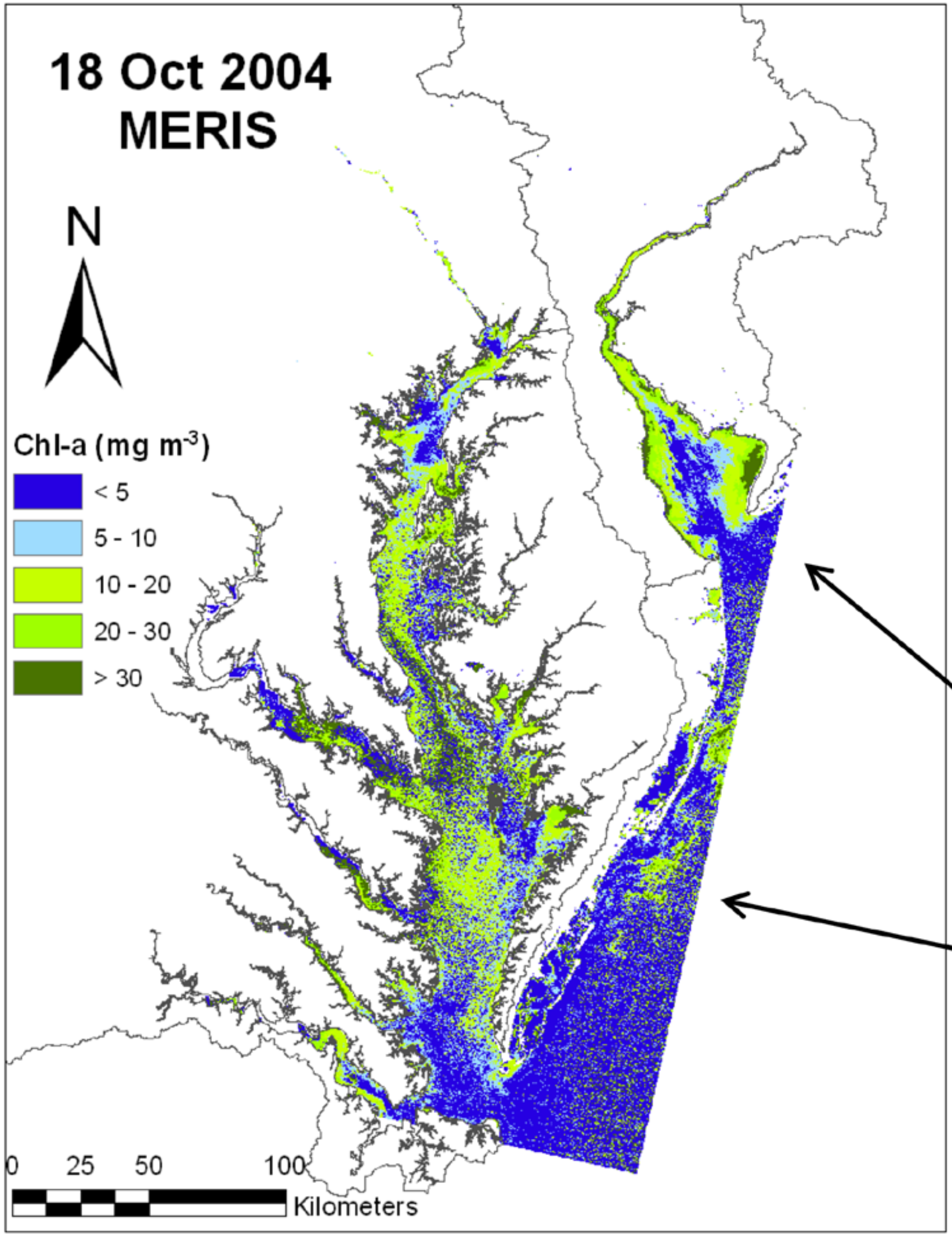
Baltimore MD, Washington DC, and Fredericksburg VA:

Yellow: urban in 1972

Red: urban growth from 1972 to 2005

Method

unsupervised classification (ISODATA) with 150 initial classes reclassified to non-urban/urban land use/cover classes



Chlorophyll-a:

Application of 3 band algorithm of Gitelson et al. (2008) for estimation of chl-a in turbid and productive coastal waters.

This image shows tidal flushing of the central part of Delaware Bay with high production on the flanks as well as a broad central chl-a maximum in Chesapeake Bay.

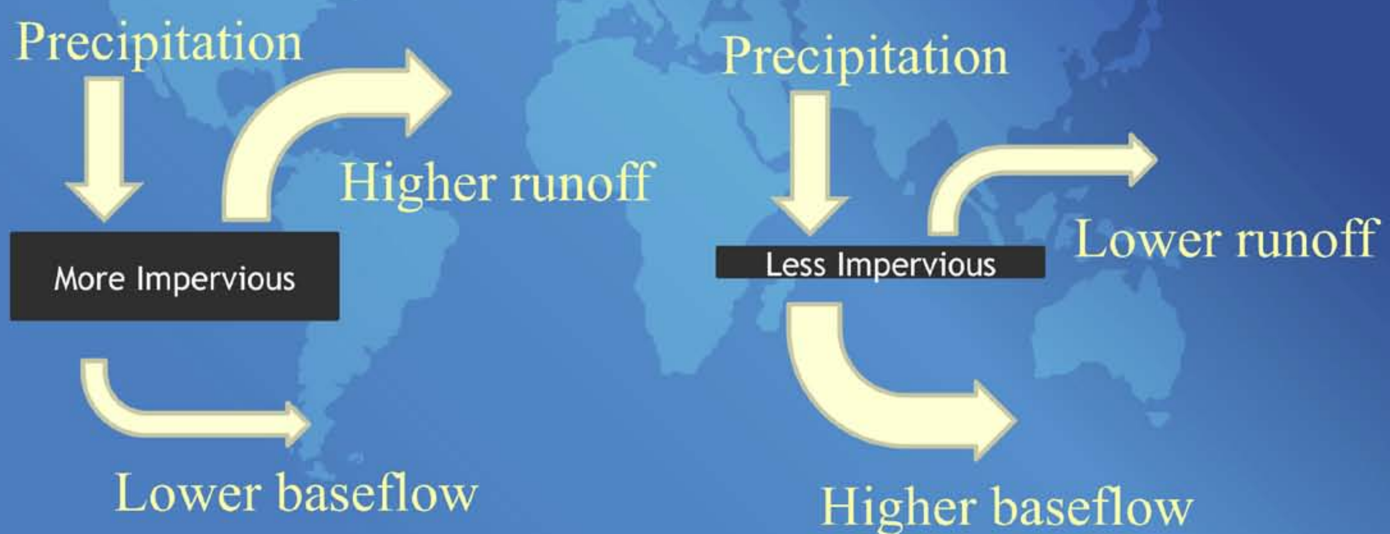
Conclusions (Fisher and Gitelson)

1. Urbanization in each basin increases total basin population and population density.
2. Human population density is a primary driver of N, P, and TSS fluxes from the gauged portions of terrestrial basins into their respective estuaries.
3. The model GWLF was successfully calibrated in gauged basins and is being used to estimate N, P, TSS fluxes from ungauged portions of the terrestrial watersheds to their estuaries.
4. The algorithm of Gitelson et al. (2008) has been successfully applied to estimate chl-a in the turbid, productive waters of these three estuaries and adjacent coastal areas.

Scott Goetz , Mindy Sun, Greg Fiske
The Woods Hole Research Center

Modeling Impacts of Impervious Cover on Streams

Impervious cover affects both the hydraulic conductivity (how much) and flow routing (where to).

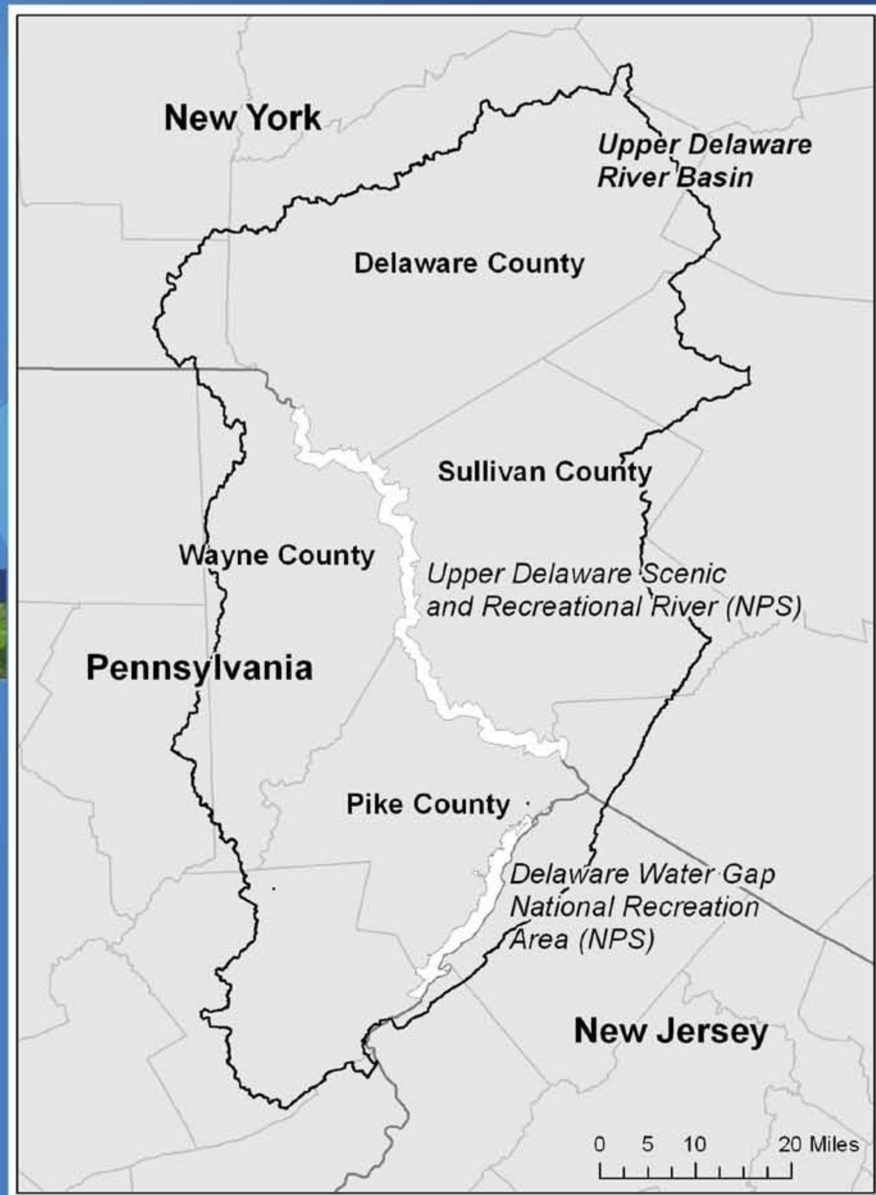


NASA

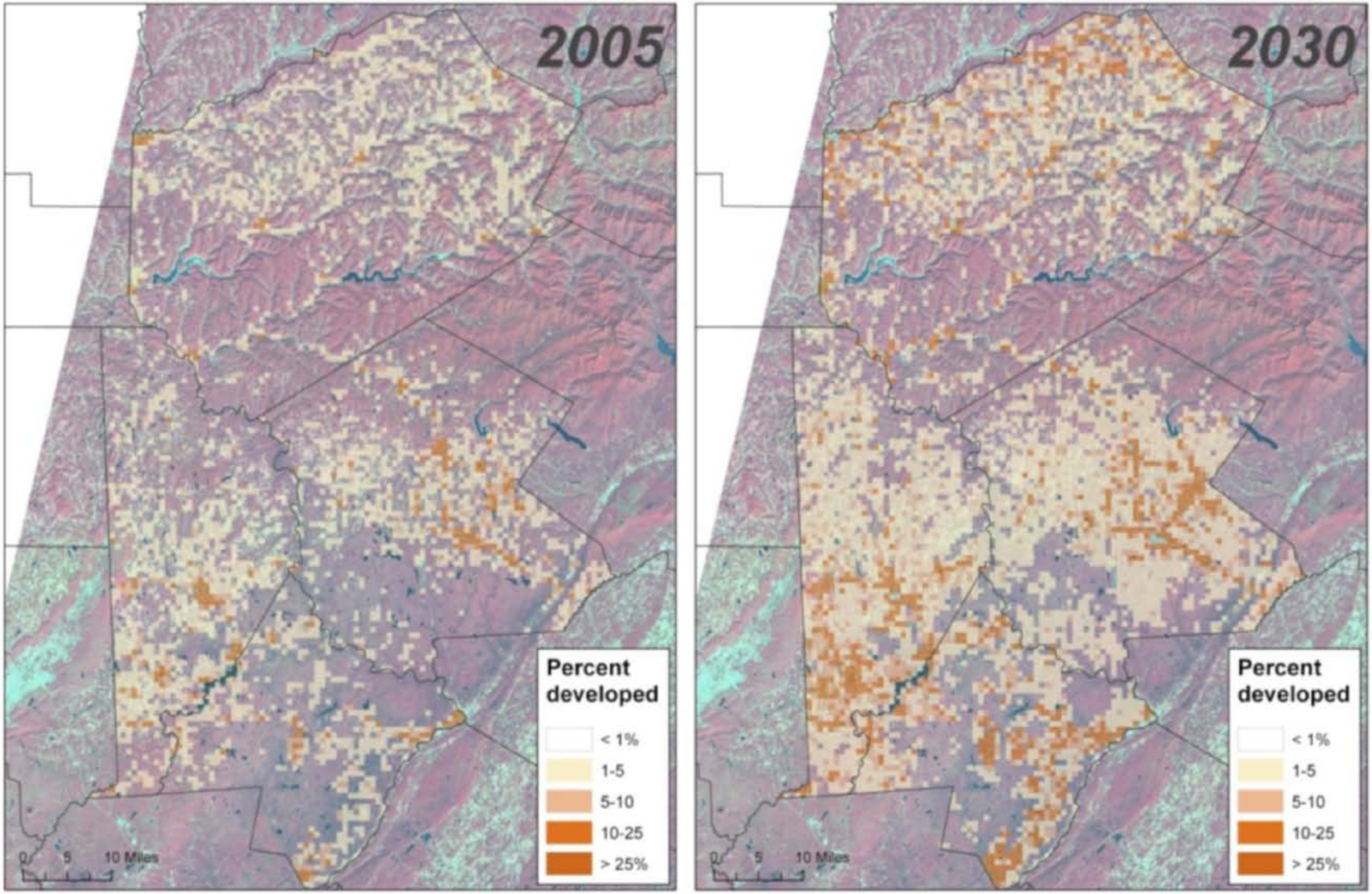
NATIONAL PARK SERVICE

pennsylvania PA DCNR

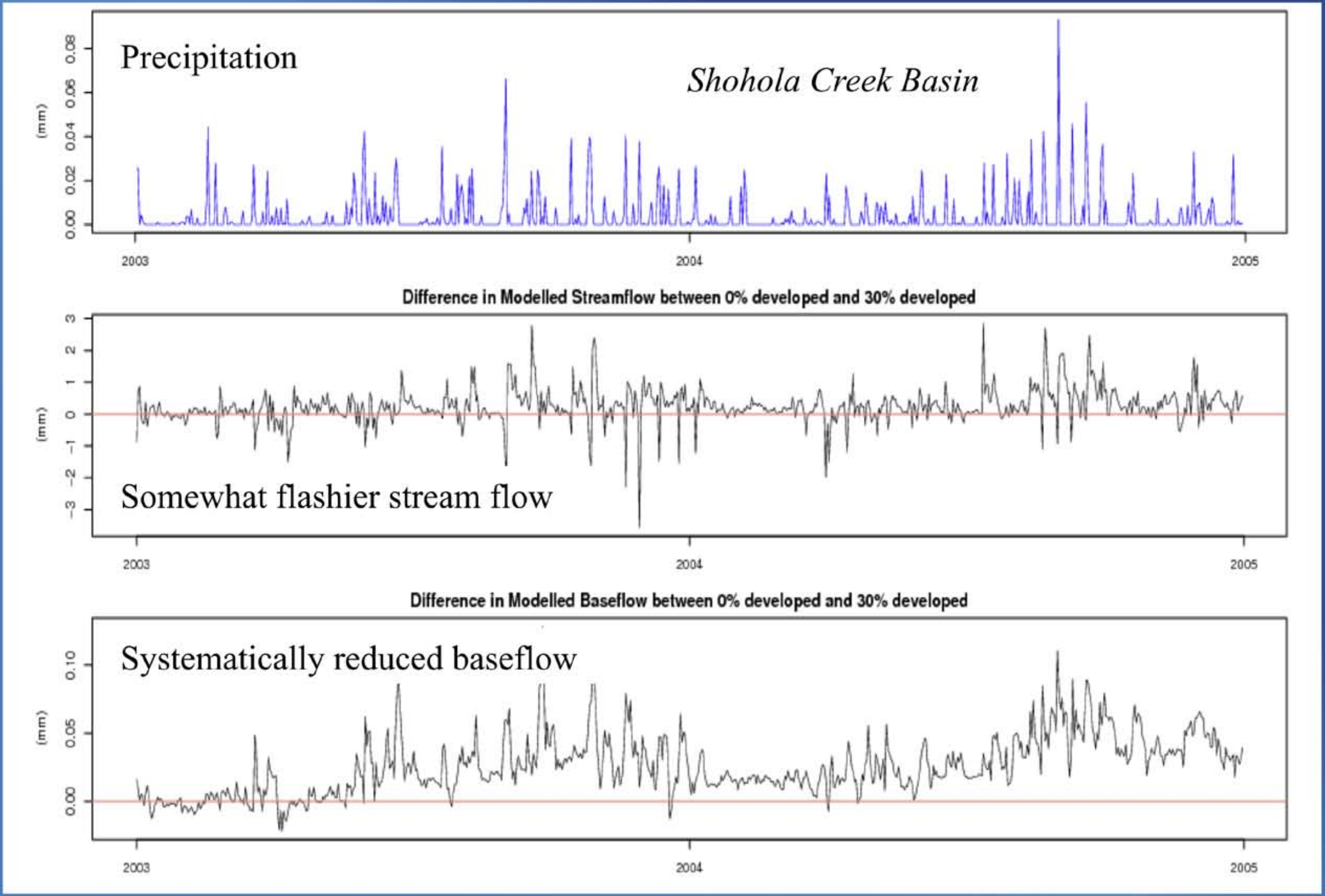
THE WOODS HOLE RESEARCH CENTER



Sleuth Model Predictions of Probability of Conversion to Impervious Cover



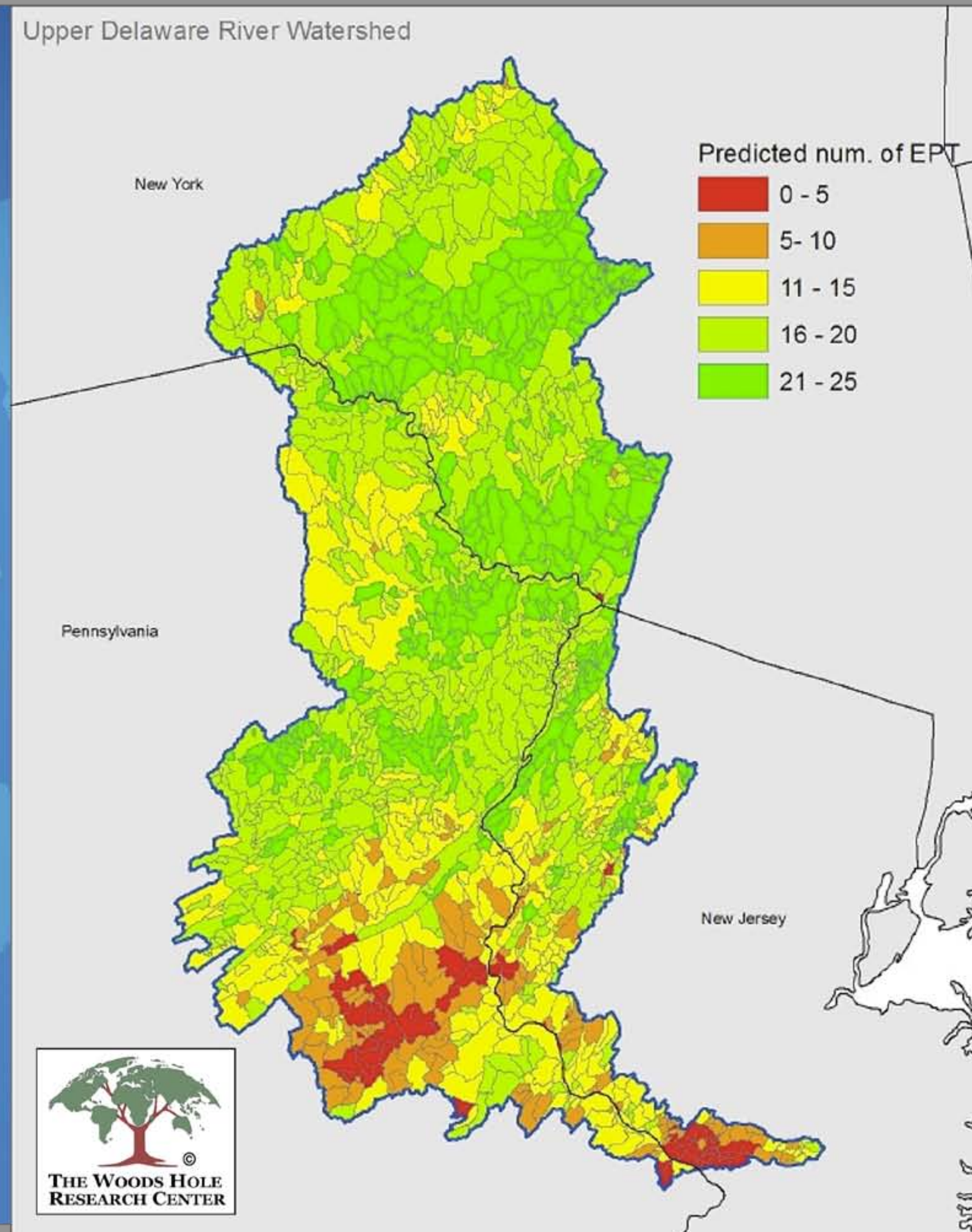
RHESSys Simulated Hydrologic Changes with Increased Impervious Cover



Predicted Richness of Sensitive Taxa (benthic) for small watersheds encompassing the Upper Delaware & Delaware Water Gap Parks

Red = low / bad

Green = high / good



Publications:

2008 Special issue on Freshwater Remote Sensing

- Goetz, S.J., Gardiner, T., & Viers, J. *Recent advances in monitoring freshwater and estuarine ecosystems with remote sensing: an introduction to the special issue.* **Remote Sensing of Environment** 112:3993-3995
- Goetz, S. J., and G. Fiske, *Linking the diversity and abundance of stream biota to landscapes in the mid-Atlantic USA*. **Remote Sensing of Environment** 112:4075-4085

Development and Sensitivity Analysis of High Resolution Land Surface Parameter from Satellite Data for use in Mesoscale Land Surface & Climate Models.

Christopher Small[1], Roni Avissar[2], Robert Walko[2], Kathy Walko[2]

[1] Lamont-Doherty Earth Observatory, Columbia University
[2] Dept. of Civil & Environmental Engineering, Duke University

Objectives

Understand scale dependence of anthropogenic land cover modification on regional climate

Improve mesoscale climate model predictive power by incorporating decameter-scale land surface properties - derived directly from remotely sensed observations

Strategy

Use Spectral Mixture Models to derive land surface physical parameters directly from Spectral endmember fractions. ***Advantages***: *Physical, Quantitative, Verifiable, Scaleable*

Test model sensitivity to spatial resolution of land surface inputs and compare 2 different Land Surface Model (LSM) schemes for contrasting climatic/land cover environments.

Funding provided by USDA National Research Initiative, and CSREES grant #USDA 2006-35615-16716

Deriving Land Surface Parameters from Multi-Temporal Optical Imagery

Spectral Mixture Analysis (SMA) derives areal abundance of fundamental land cover components (water, vegetation, rock/soil substrates, NPV) and shadow. *Quantitative, Physical, Verifiable, Scaleable*

Deriving physical properties from physical measurements eliminates discretization errors and can represent continuous gradations in surface properties through time.

Multi-Temporal SMA uses the additional information provided by temporal changes in reflected radiance.

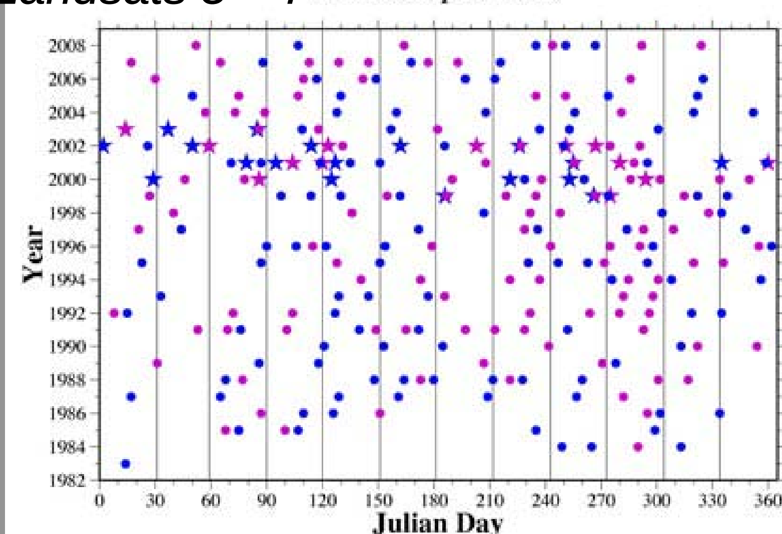
$$\text{Change } \Delta = \partial E + \partial A + \partial VI + \partial XY$$

Earth Surface, *Atmosphere*, *Viewing & Illumination Geometry*, *Geospatial Uncertainty*

Distinguish Δ Land Cover from Δ Illumination & Δ Atmosphere

Quantify Seasonal & Inter-annual Changes

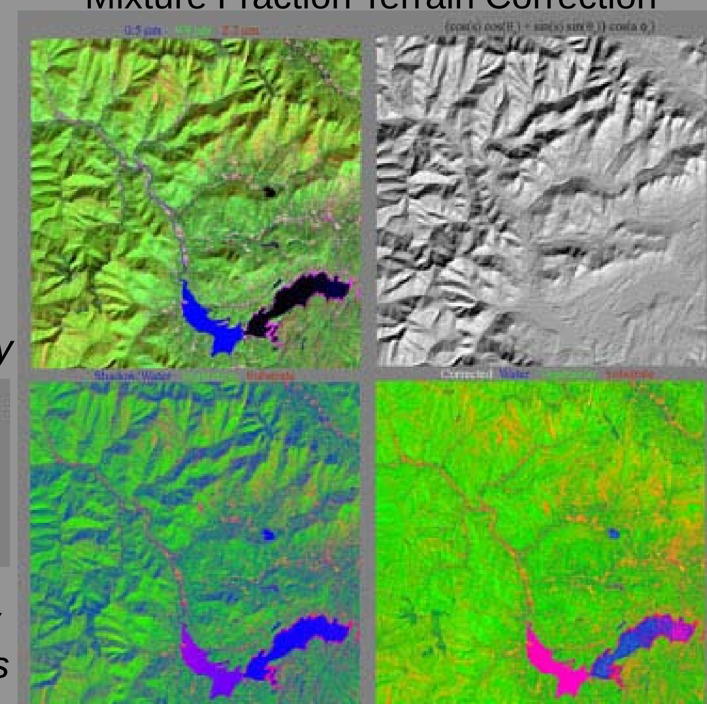
Landsats 5 + 7



Derive Physical Quantities Directly

Avoid Unnecessary Error & Assumptions

Mixture Fraction Terrain Correction



Modeling Land Surface Processes

Land surface models (LSMs) are an essential component of weather and climate models.

The most important function of a LSM is to correctly partition downward incident radiation into reflected radiation, emitted radiation, and turbulent fluxes of sensible and latent heat.

In nature, this partitioning of energy depends on many factors, including:

Atmosphere	Vegetation	Soil	Urban
Temperature Humidity Surface wind speed Amount of sunlight	Height Density Albedo Surface area Root depth and density Stomatal conductance Growing season	Albedo Porosity Hydraulic conductivity Thermal conductivity Moisture profile Temperature	Albedos, thermal conductivity, and heat storage properties of buildings, streets, and sidewalks Building height and areal coverage Engineered drainage systems

Some of these factors are generally well known, but others are not and must usually be estimated,- sometimes with little information to go on.

Our study is aimed at improving estimates of some of these factors and testing how the improvement impacts the behavior of the LSMs in diverse urban & rural settings.

Land Surface Model Comparison

We are using two very different LSMs for this study: LEAF3 and HiSVAT

LEAF3 represents vegetation, buildings, soil, and canopy air space as separate entities, and further subdivides soil and the vegetation canopy into multiple layers. Energy and water transfers between all components and with the atmosphere are represented explicitly. **LEAF3** requires physical parameters to describe each of its components.

HiSVAT combines vegetation, buildings, and soil into a single “surface” entity that has an albedo and can store heat and moisture. It requires very few physical parameters, most of which can be determined by remote sensing. However, it requires statistical tuning of a few remaining parameters.

Both models use parameters derived directly from multi-temporal Landsat validated with meter-scale Quickbird and Ikonos imagery.

Currently refining estimation of seasonal albedo, vegetation phenology & surface roughness from Landsat time series and integrating parameters into LSMs.

For both models, we need to quantify the difference between single-surface albedo, bulk vegetation or building albedo, and bulk vegetation/soil albedo, and their dependence on solar zenith angle.

Current efforts focused on estimation & incorporation of multitemporal albedo, roughness, and fractional soil, impervioiu & vegetation cover into LSMs for sensitivity analysis.