“Improving BASINS/HSPF predictions of nitrogen export to improve TMDL accuracy using NASA imagery”

Estimating nitrate export from Chesapeake Bay watersheds using MODIS and climate data

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Background

- Nitrogen: chief nutrient generated from landscapes that leads to eutrophication of receiving waters
- TMDL (total maximum daily load): maximum amount of a pollutant that a water body can receive and still meet water quality standards
  - TMDLs are used as a basis to establish plans designed to meet water quality standards and/or restore impaired water bodies
- HSPF, BASINS, Chesapeake Bay Model: varieties of a particular model (HSPF) that simulates watershed hydrology and water quality
  - effects of land use, point and nonpoint sources, etc.
  - EPA and the Chesapeake Bay program use to develop TMDLs

Background

- Most models assume no spatial or temporal variations in N export from forests
- Mixed land use and fertilizer application are major drivers of diminished water quality,
  - *realism in the modeling of export from forest land* is required to properly identify land use contributions
- Current assumption of Chesapeake Bay Model is "an acre of 'forests, woodlots, and wooded' land contributes 3.1 lb/year of nitrogen to the watershed." (modified by N deposition, other factors; documentation needed)
- The Chesapeake Bay watershed is 60% forested
  - Leads to biased estimates that are highly problematic

Objective

- Better characterize seasonal and inter-annual variability of nitrogen loads from forests
- Use remote sensing imagery to estimate variability in N export from forests
  - Disturbance
  - Logging
  - Drought
- Implement these inputs within HSPF (Chesapeake Bay Model) to improve overall estimates of nutrient loads based on more realistic parameterization of forests

Partners

- EPA
- Chesapeake Bay Program
- BASINS, HSPF community

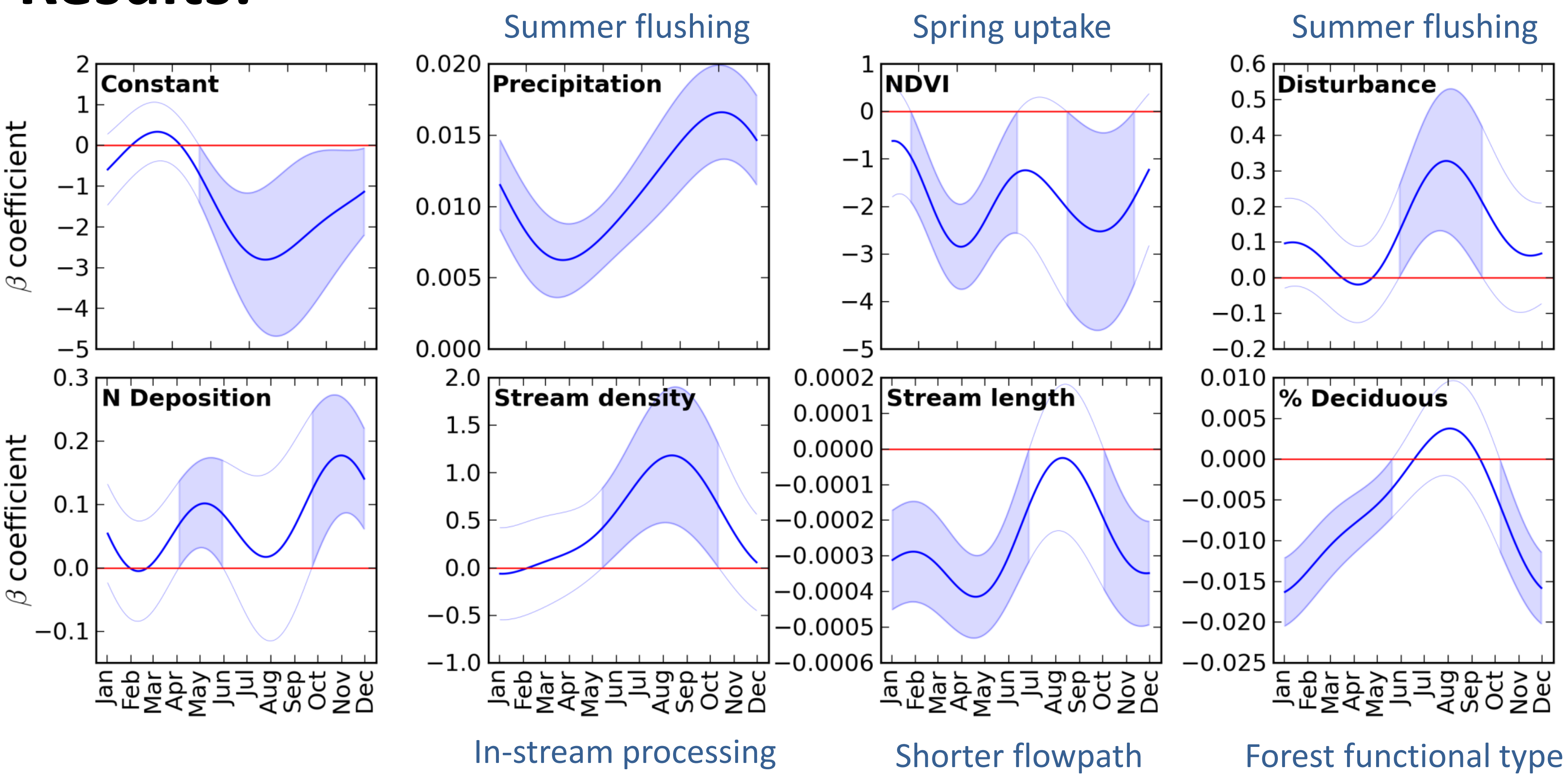
Key Datasets

- Widely available imagery: MODIS
  - MOD09A1: 16-day reflectance used to derive Tasseled cap indices, a disturbance index and NDVI
  - Tested other products, e.g. GPP (gross primary productivity) and PSN (photosynthesis), but:
    - MOD13A1 and MOD17A2 had too much missing data
- Climate data (PRISM monthly)
- Landscape data about watersheds
  - Stream density, stream length, latitude

Approach

- 2001-2009 water quality measurements from streams draining forested watersheds to calculate N loads
- MODIS imagery summarized by watershed to characterize variation in forest condition
- Functional concurrent linear models (FCLMs) to predict N loads from forests as a function of imagery
  - FLCMs can use time series for predictors and responses and therefore allow continuous-time predictions
  - similar to regression: uses multiple predictors
  - we incorporate lag effects

Results:



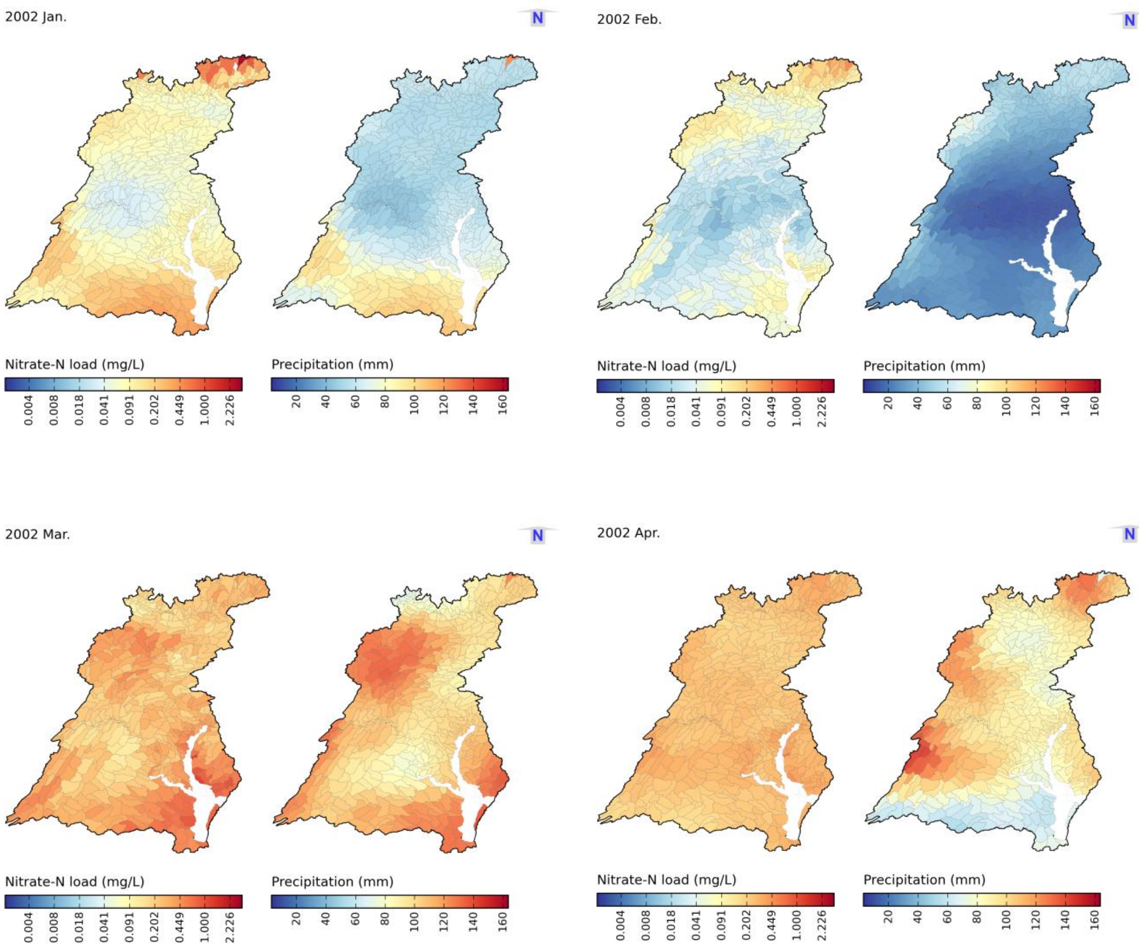
Model $R^2 = 0.80$

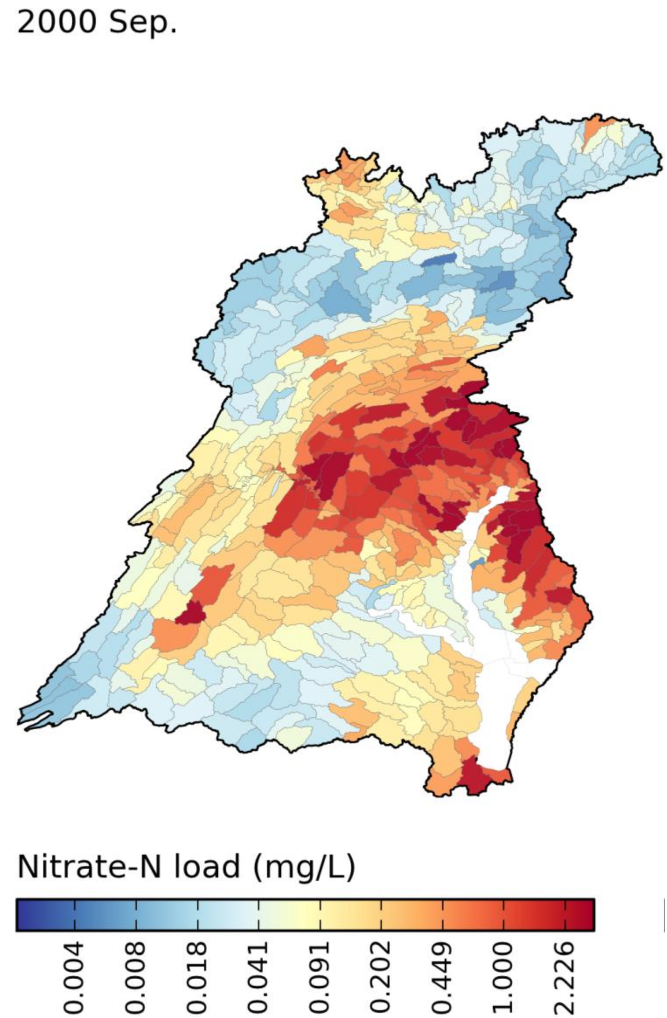
Cross-validation R^2 by year ranged from 0.55 – 0.88

- with 2003 having poorest prediction

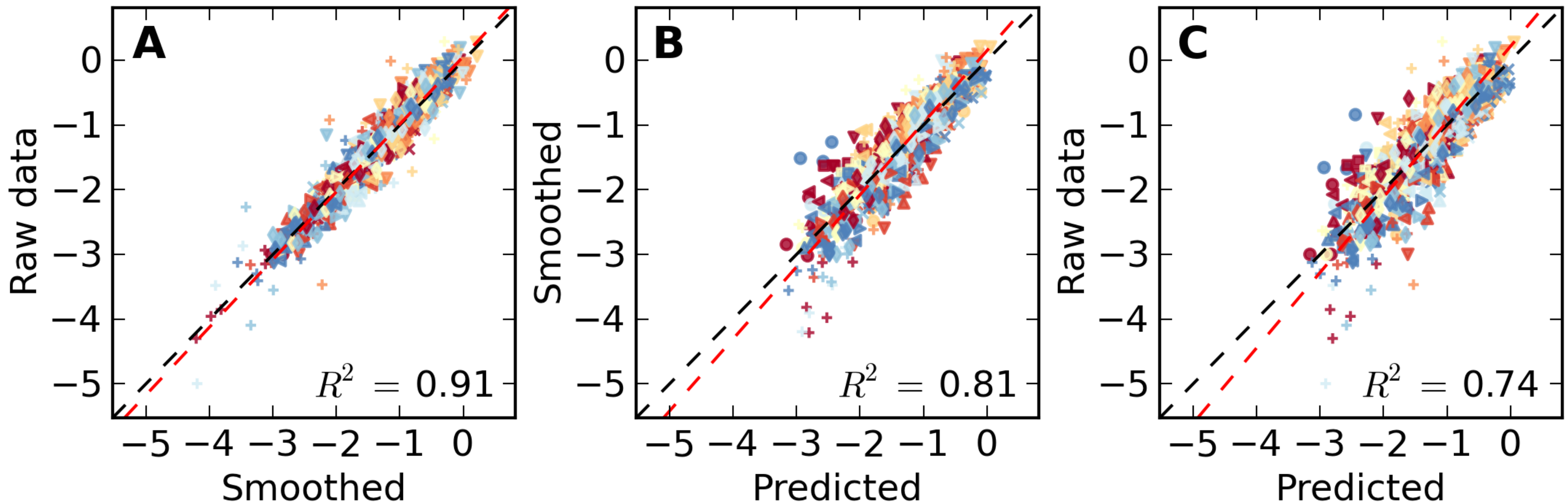
Cross-validation R^2 by watershed ranged from 0.47 – 0.87

Image-Derived Nitrate-N Loads from Forests





Better model fits with fewer (remote sensing) predictors:

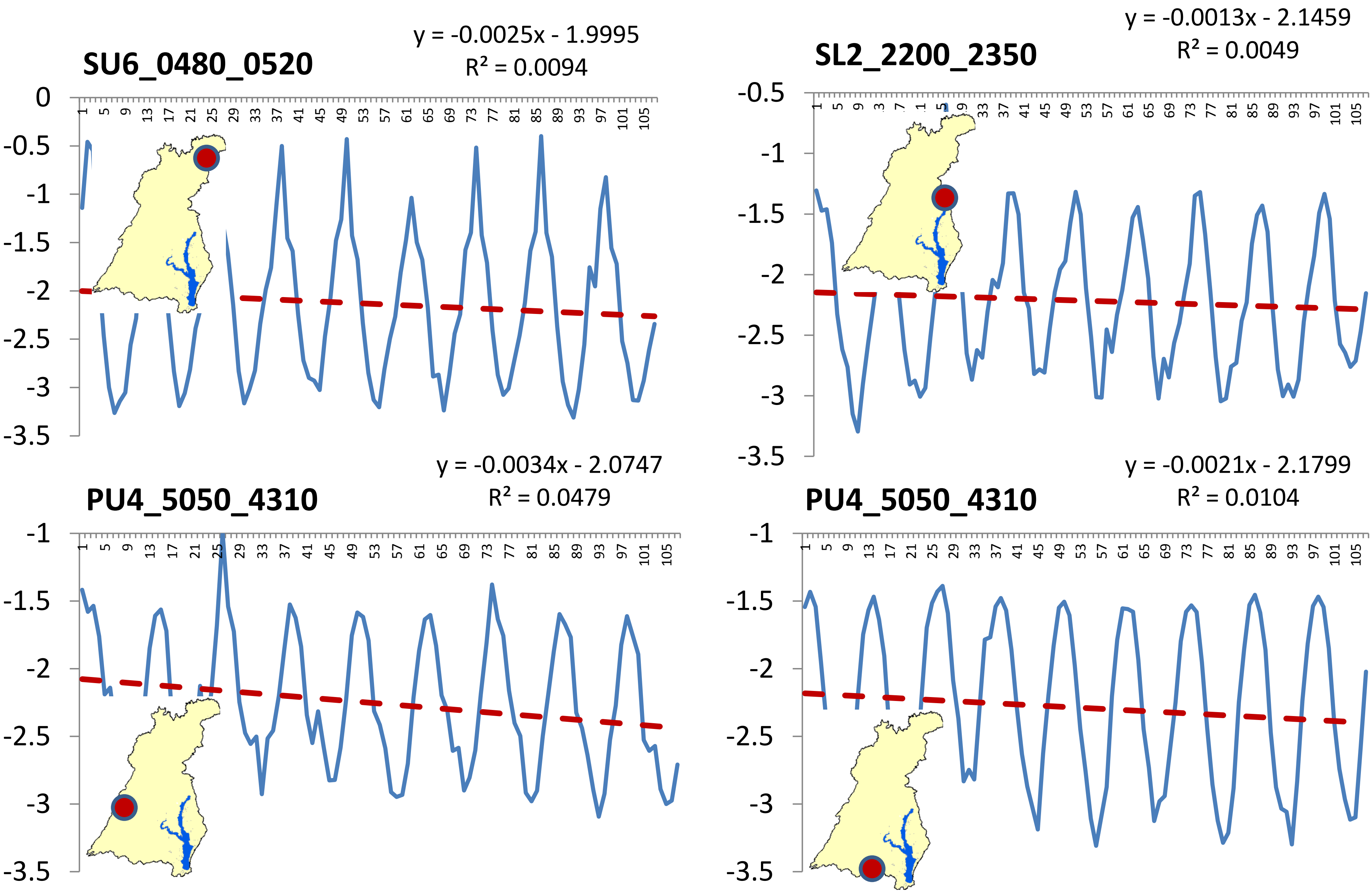


YEAR	R^2model	R^2valid	Bias
2001	0.828	0.677	-0.057
2002	0.813	0.790	0.095
2003	0.807	0.622	-0.088
2004	0.823	0.597	-0.141
2005	0.807	0.874	-0.168
2006	0.817	0.704	0.017
2007	0.810	0.797	0.195
2008	0.812	0.781	0.134

WID	R^2model	R^2valid	Bias
Upper Big Run	0.829	0.798	-0.399
Blacklick Run	0.810	0.677	-0.101
Cedar Creek	0.826	0.688	-0.133
Cowpasture river	0.825	0.721	0.263
Deep Run	0.837	0.728	0.214
Sinnemahoning Creek	0.806	0.849	0.180
Jackson River	0.819	0.589	-0.163
Kettle Creek	0.802	0.858	-0.019
Pine Creek	0.821	0.501	-0.262

Predictions for MODIS period of record

Predictions from the FLCM: Temporal trends

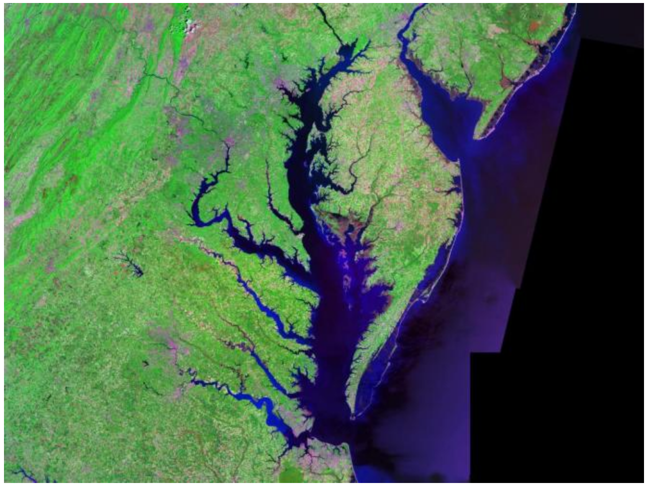


Impacts

- We have finalized our algorithms
- Angélica Gutiérrez-Magness at UM-College Park has worked with our output and the CBP-HSPF to compare forest loads generated by our FCLM model against the current implementation of CBP-HSPF
- Early 2013: demonstration with Chesapeake Bay Program (and EPA), with the goal:
- Determine an approach to implement these data within the Bay Model!

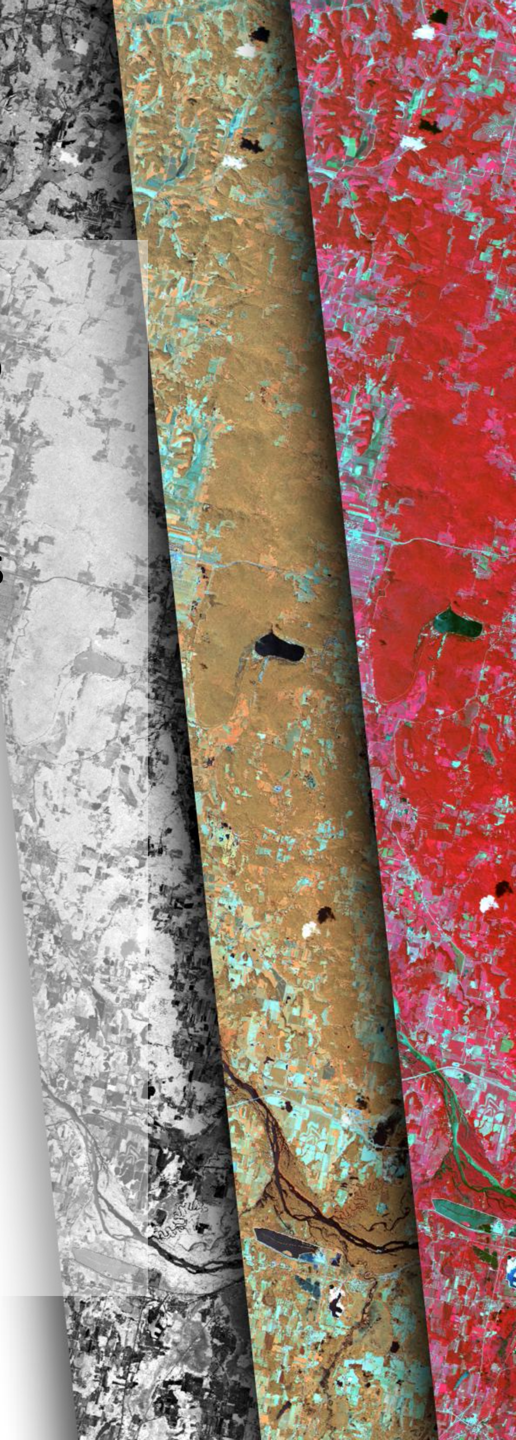
Strategy for Quantifying Impacts

- More accurate model predictions and better data will facilitate better goal-setting for watershed loading management.
- Ultimately: adoption by modeling community

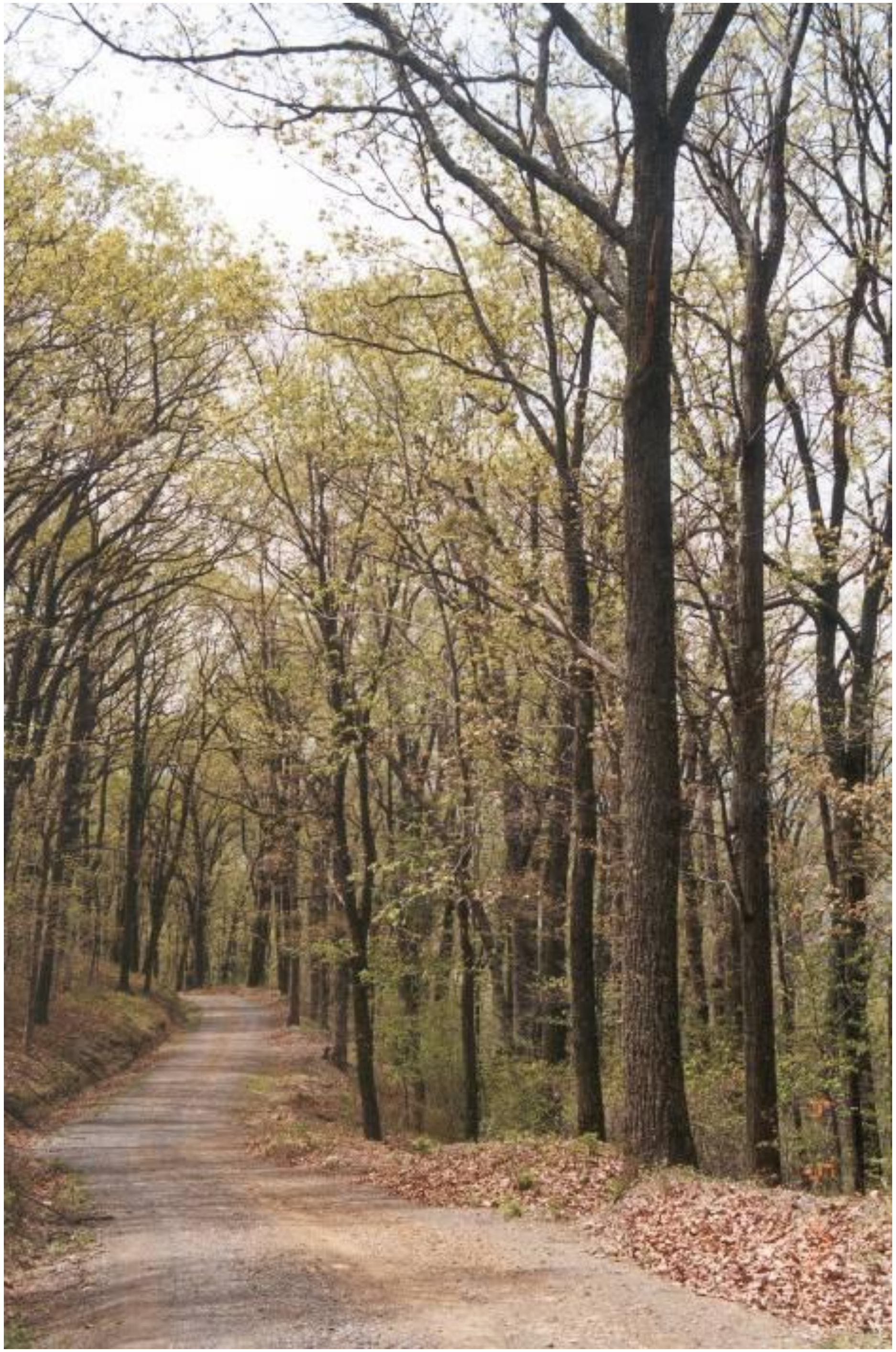


Key Considerations

- **Will be addressed as we progress:**
- What is current representation of forests?
- We have modeled NO_3-N (not TN)
  - NO_3-N is the dominant form of N that varies (Eshleman)
- Extend the record before 2000
  - AVHRR less accurate, should capture trends
- Use data in scenario/simulation mode
  - Current effort was oriented towards observations
- Disturbance "type" assessment
  - Lindsay Deel, others




Questions and discussion



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Lindsay Deel

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Clayton Kingdon

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Too many people to list….

Lew Linker comments (11/30/12):

- We’ll need to move to a TN basis of loads including ammonia and organic N forest loads as well as nitrate.
- Any adjustments to account for groundwater TN loads from forest need to be resolved.
- The description of wooded land in the Watershed Model (WSM) is “Forests, Woodlots and Wooded Land” and there’s lots of this land use in the middle of cities (12% in DC and 20% in Newport News for example). We’ll need to reconcile the differences in land use between the 2 models.
- Most important, we’ll need to “scenarioize” the approach so that management actions can be reflected in the forest response at least in regards of atmo, dep and forest harvesting. It’s not enough to represent forest as it is, but the dynamic range of forest response from pristine to high-load 1985 conditions needs to be simulated. Forest should be represented from 1985 to present, at least annually, along with a pristine forest with atmo dep. loads an order of magnitude less than present.
- Instances of double potential double counting need to be resolved as when a State representing logging as 1% of their forest area but that effect may have been already accounted for in the MODIS imagery.
- Going forward the WSM will be updated on a regular basis (annually?) and a way to regularly update the MODIS approach needs to be resolved.