"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 a uniform load: "an acre of 'forests, woodlots, and wooded' land contributes 3.1 lb/year of nitrogen to the watershed."
- 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

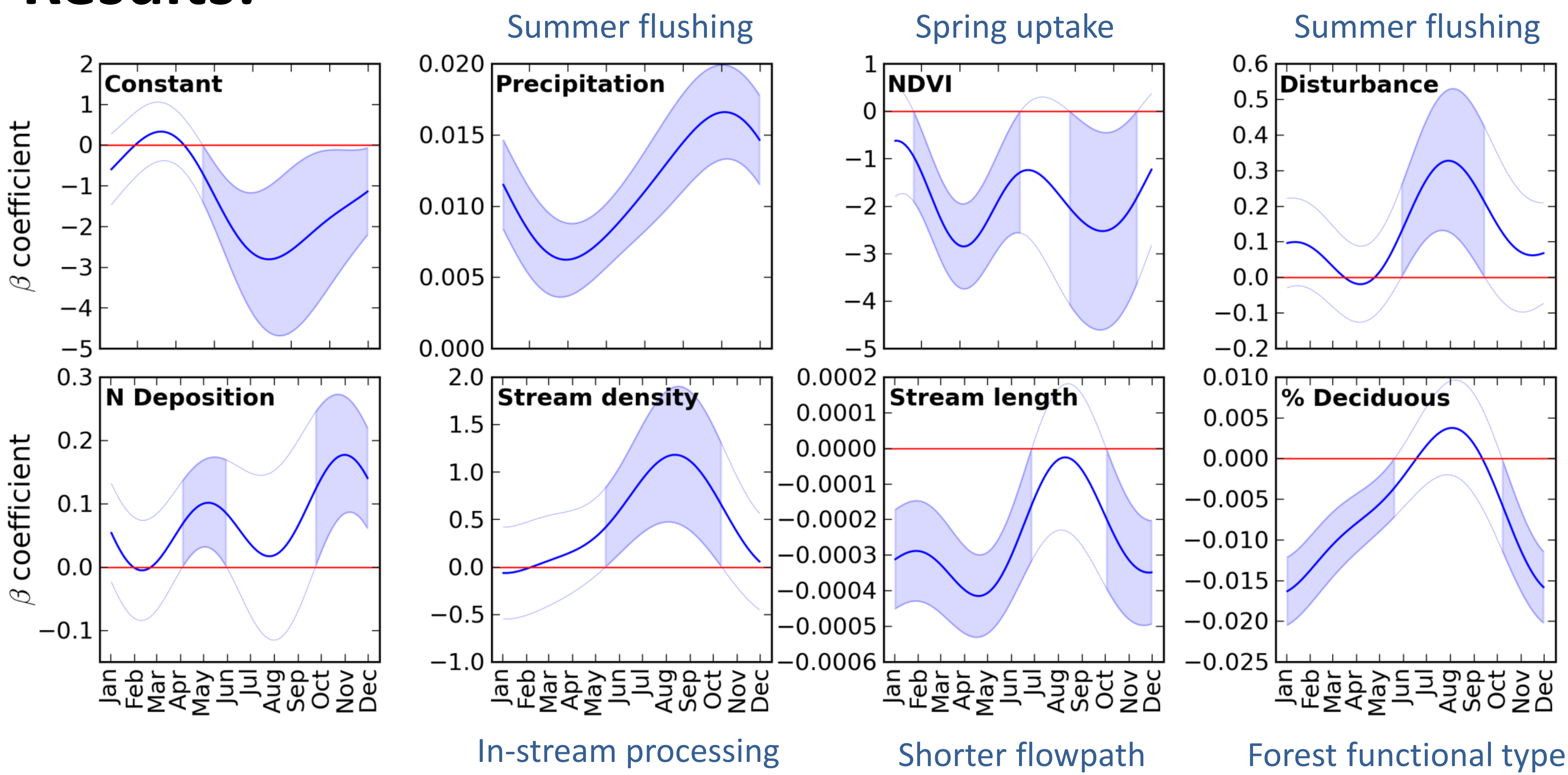
Key Datasets

- 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 <u>calculate N loads</u>
- MODIS imagery summarized by watershed to characterize variation in <u>forest condition</u>
- 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:



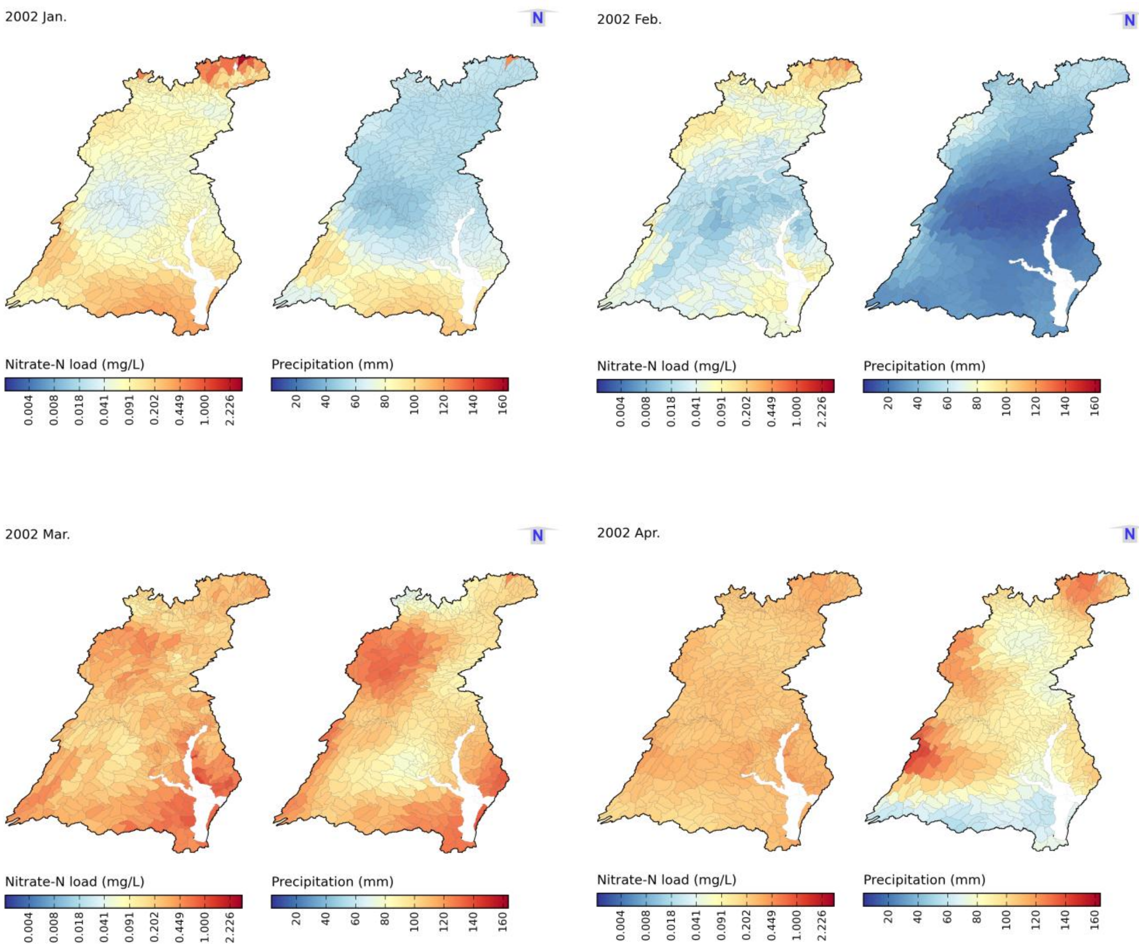
Model $R^2 = 0.80$

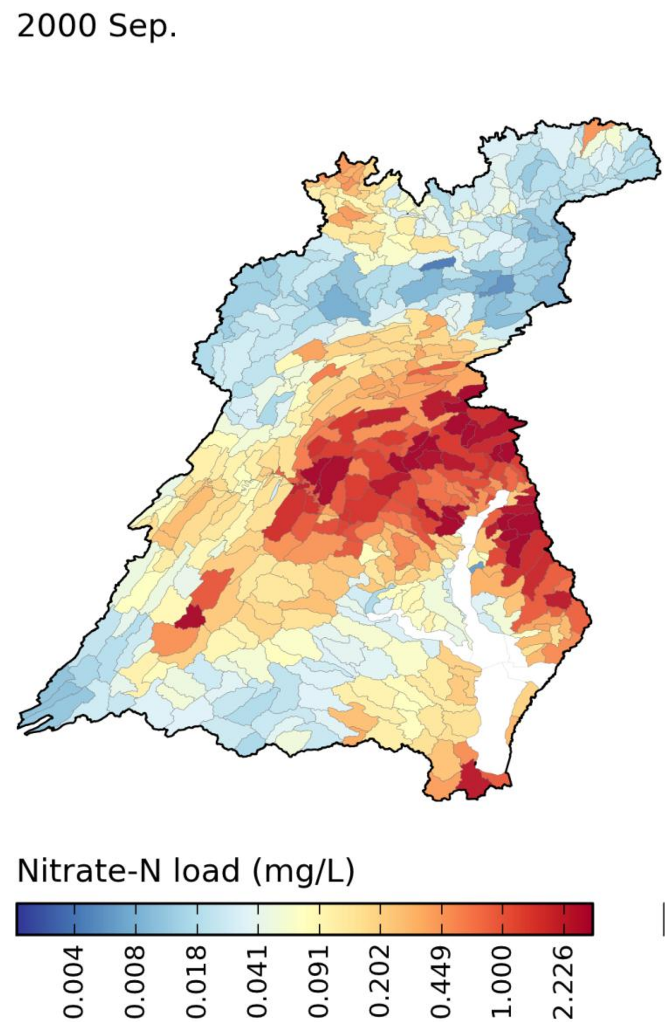
Cross-validation R^2 by year ranged from 0.55 – 0.88

- with 2003 having poorest prediction

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

Image-Derived Nitrate-N Loads from Forests



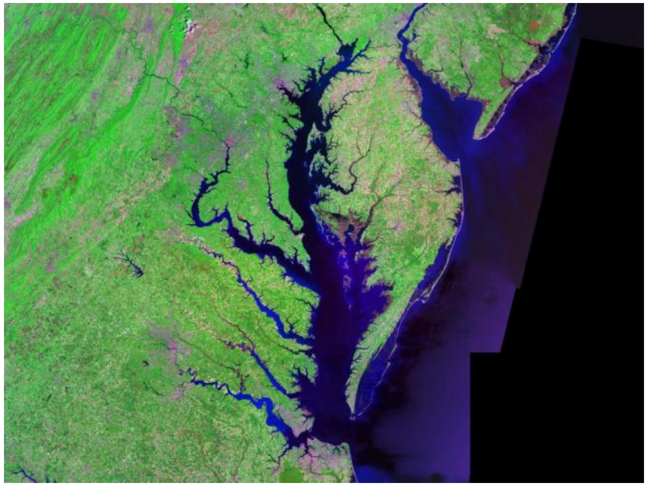


Impacts

- We have finalized our algorithms
- Angélica Gutiérrez-Magness at UM-College Park is recalibrating CBP-HSPF to use the forest loads generated by our FCLM model
- We then will test model performance against the current implementation of CBP-HSPF
- Early 2013: demonstration with EPA and Chesapeake Bay Program
  - Goal: implementation into 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



Discussion