Preparing for a simulation of forest using remote sensing data

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Outline

- Overview of the functional linear concurrent modeling (FLCM) approach (continuous-time modeling) of stream nutrient loading from forest in the CBW using MODIS and met data.
- Analyses of FLCM, HSPF (EOS and delivered) load predictions
- Why forest predictions will benefit from remote sensing information.

What prompted this research…

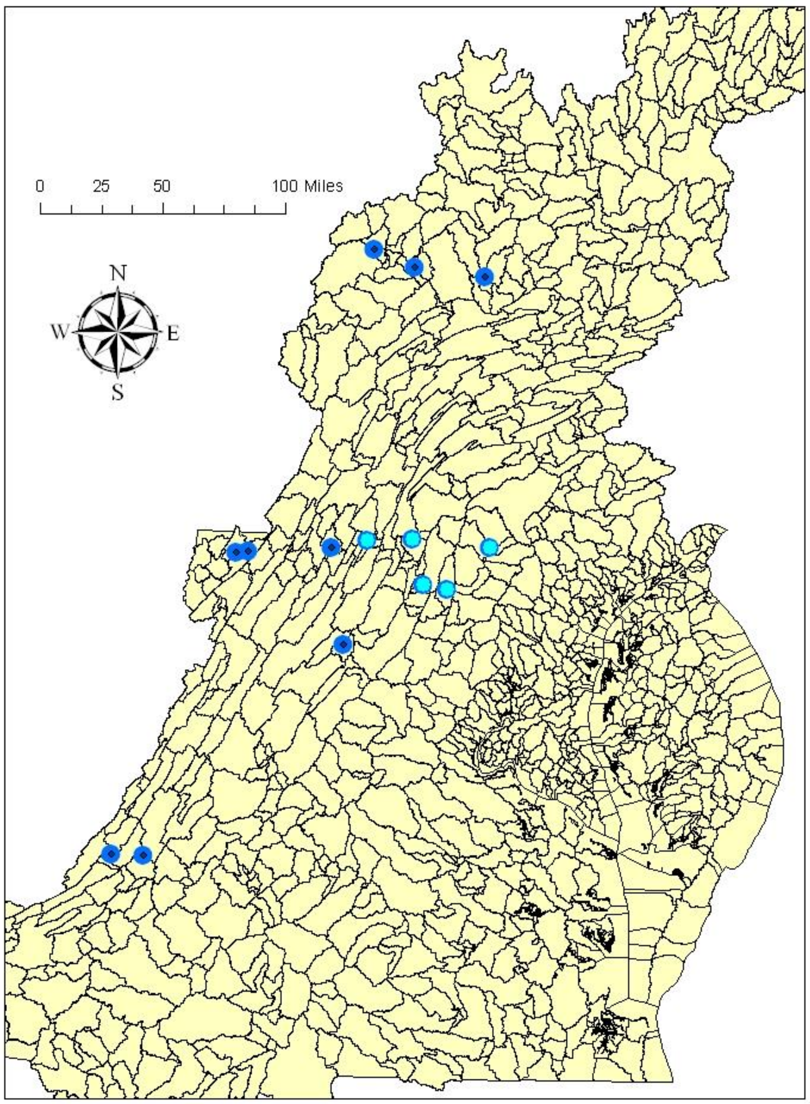
- **Assumed**:
  - The CB model 5.3 model assumes only atmospheric deposition (AD) as an input load, with a median total Nitrogen load to be 3.1 kg/ha/yr .
  - Linear response to an increase in Atm. Deposition.
- **Issues:**
  - the rate of N export can increase at a rate higher than the rate of deposition increase
  - The rate of N export increases during disturbances events

Model Overview

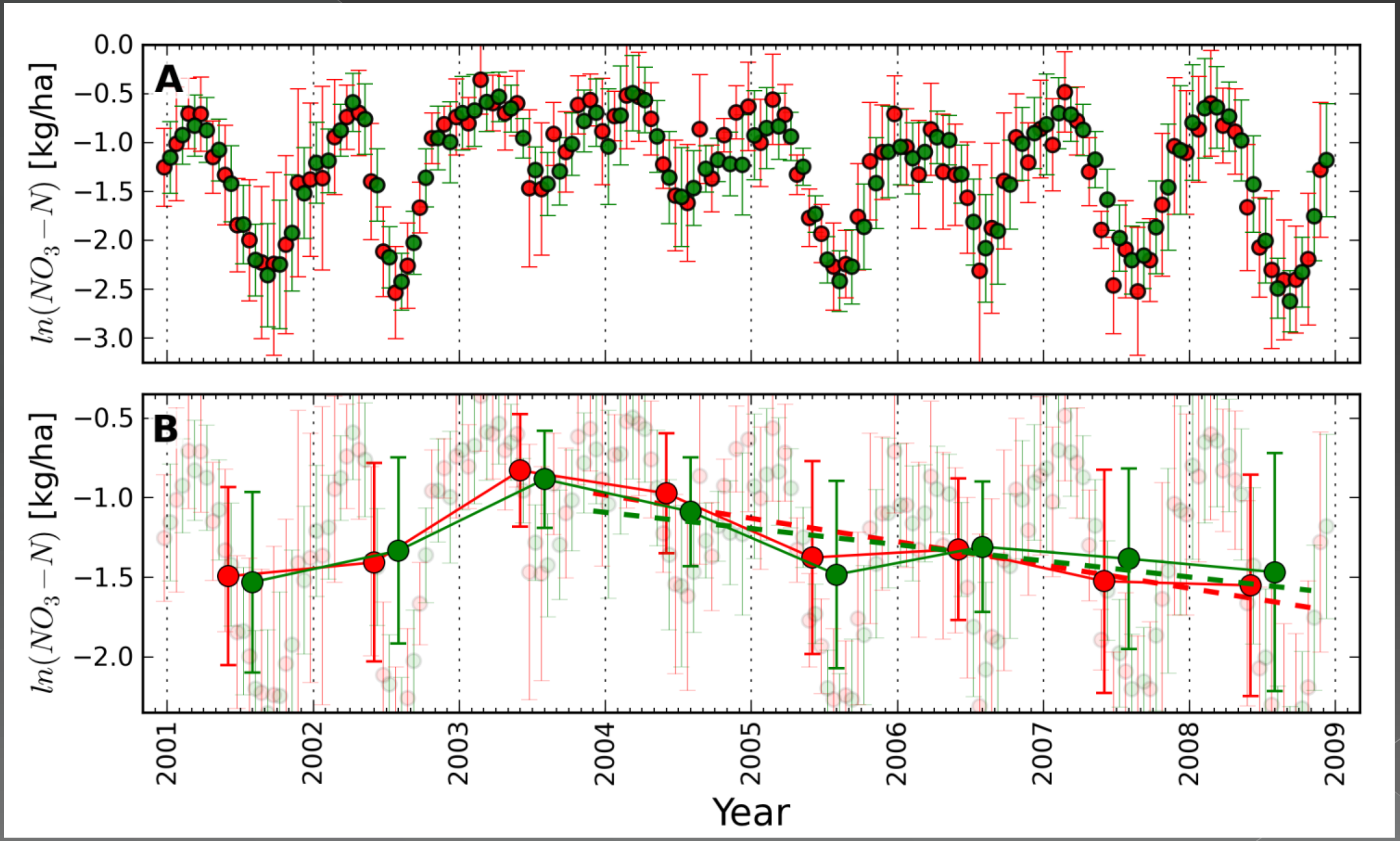
- Objective: To develop ecological meaningful, landscapes-scale and near-continuous (monthly) time models to predict Nitrate loads from forest using remote sensing, meteorological, and GIS data.
- Forested Watersheds > 80% and WQ available
- MODIS and In-Situ Nitrate data : 2001-Present.
- LOADEST: daily Nitrate-N loads (Q, concentration).
- MODIS : reflectance
- NDVI and NDII (Basic vegetation Index) estimated for each image.

FLCM Development Watersheds		
Watershed	% FOREST	Area (sq-mi)
Deep Run (MD)*	93.9	6.3
Kettle Creek (PA)	91.03	668.75
Sinnemahoning Creek – Drifwood (PA)	89.34	813.75
Cowpasture River (VA)	87.93	1242.75
Blacklick Run (MD)*	87.5	2.5
Cedar Creek (VA)	87.45	292.75
Jackson River (VA)	87.19	1678.25
Upper Big Run (MD)*	85.71	0.6
Pine Creek (PA)	83.38	2536.75
Verification Watersheds		
Potomac River at Hancock (MD)	75.4	4073
Catoctin Creek (MD)	52.44	184.5
Conococheague Creek (MD)	42.17	1383.75
Antietam Creek (MD)	31.08	751.25
Monocacy River (MD)	22.27	478.25

Watersheds Location - Remote Sensing Forest Analysis



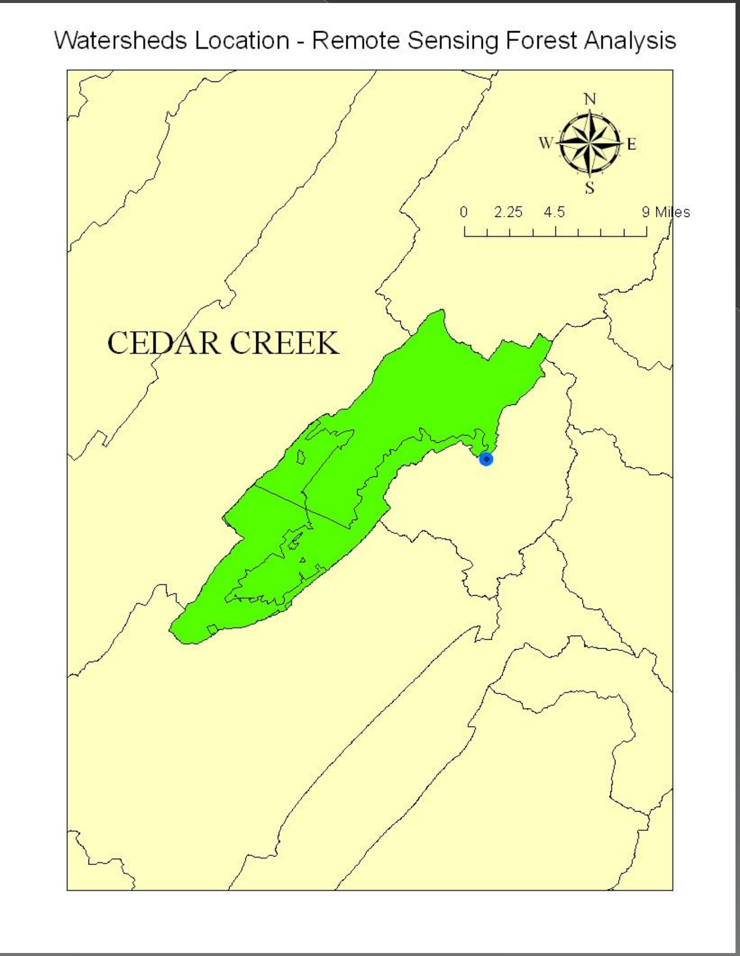
Model fits obtained from the functional linear concurrent model aggregated across watersheds through time



FLCM accuracy and Long-term Continuity….

- Explained 81% of the variation in monthly stream water nitrate loads for nine mostly forested watersheds over eight years of monitoring data.
- Our modeling approach used MODIS data as a major input, data from sensors with similar measurements strategies such as the VIIRS aboard the Suomi-NPP mission ensures long-term continuity.

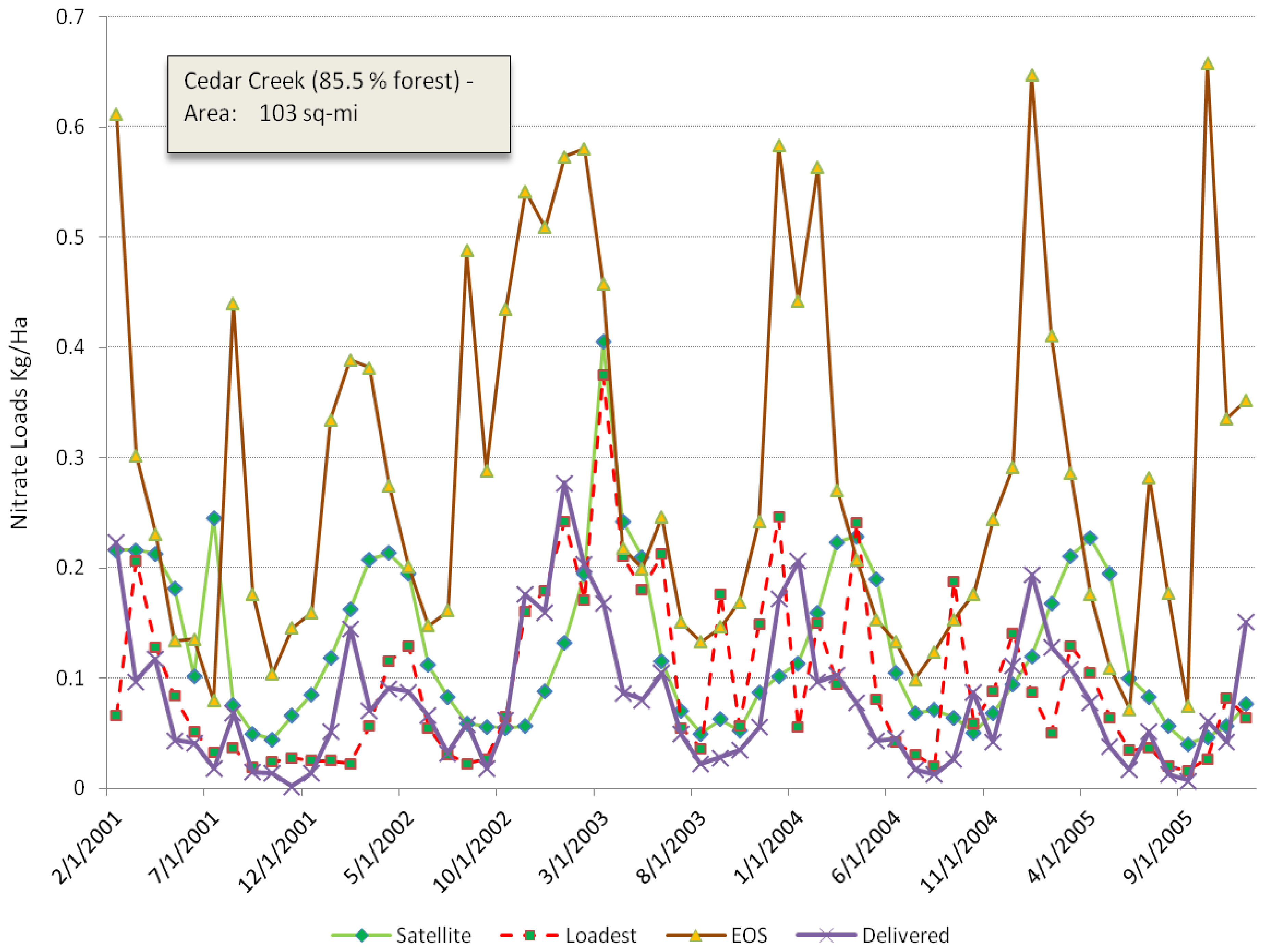
How we did the comparison…



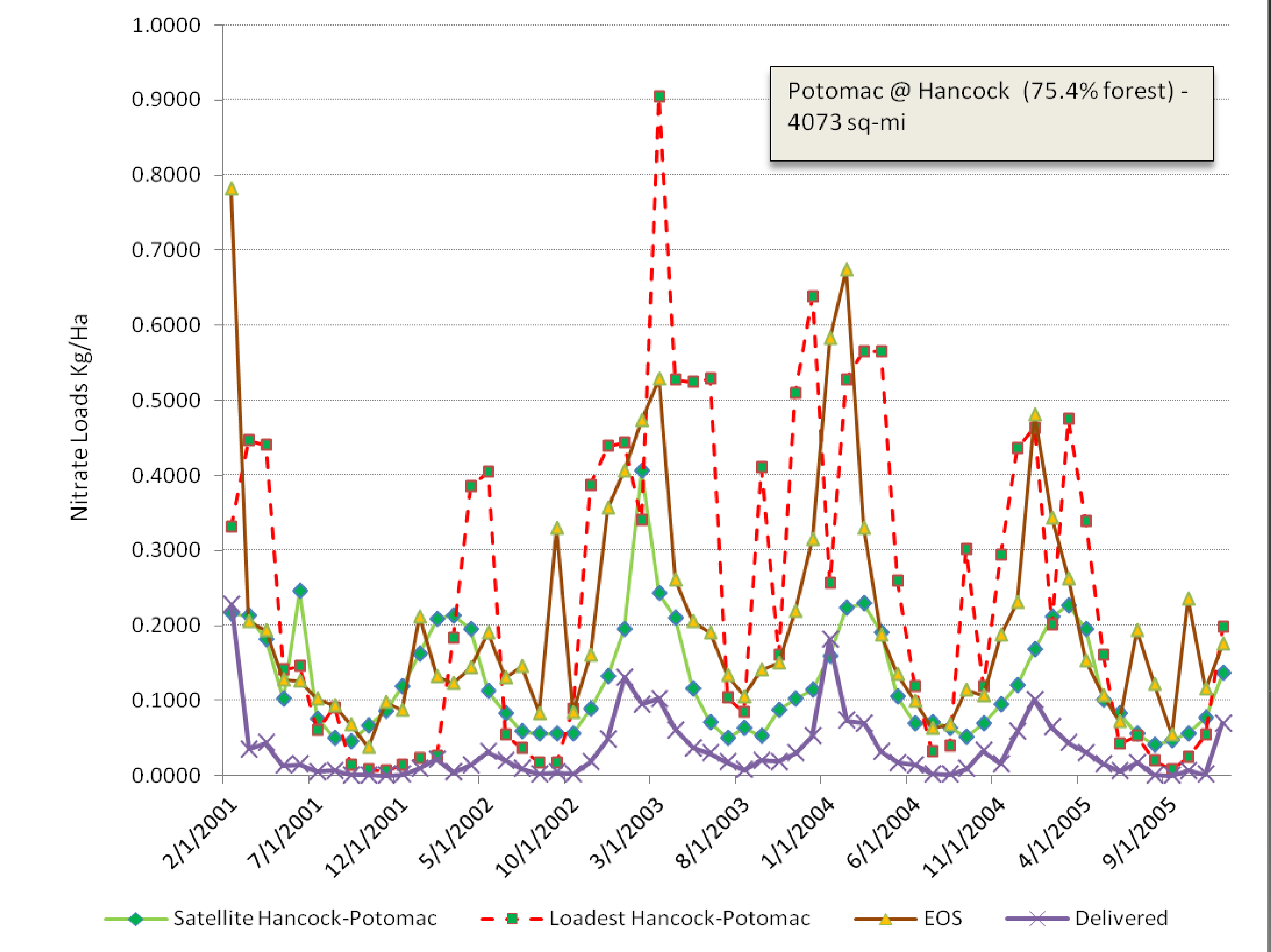
- For each watershed, we added the nitrate loads (e.g., EOS) from all the land segments draining to the watershed’s outlet.
- GIS methodologies were used to extract data from satellite imagery using the watershed’s boundary.
- LOADEST loads assumed to be the target (justification to include EOS and Delivered loads in the analyses)

How we did the comparison…

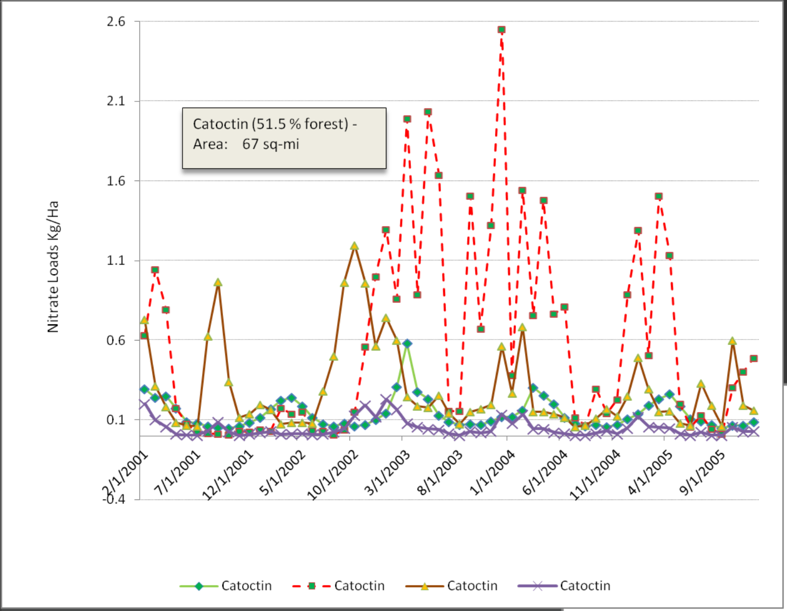
- Used watersheds with various % forested LU.
- Watersheds areas varying from 0.6 to 4000 sq-mi
- Evaluation period 2001-2005. (HSPF calibration scenario; MODIS 2001 – present)
- Visual assessment and sample statistics.



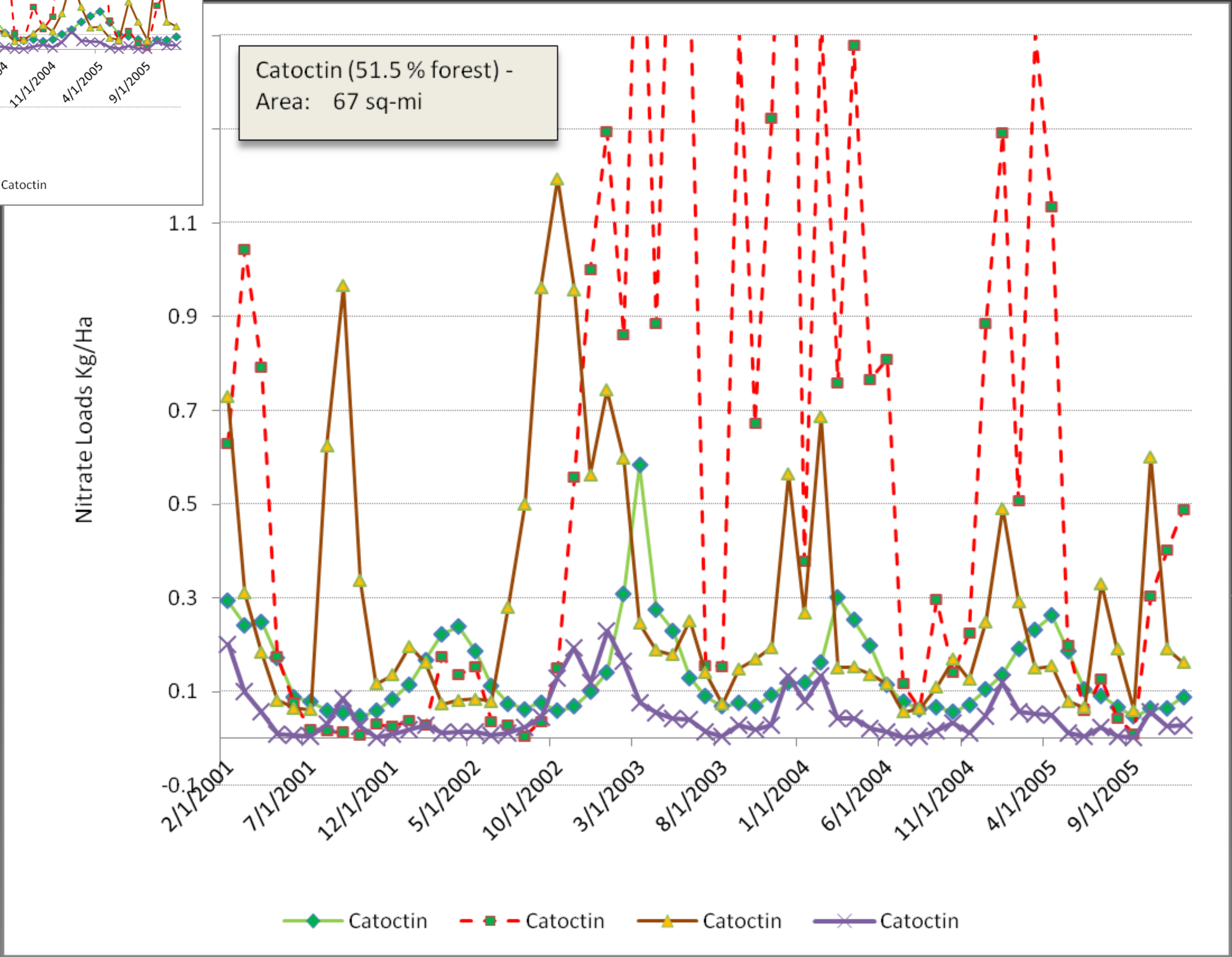
Cedar Creek (85.5 % forest) -
Area: 103 sq-mi
Nitrate Loads Kg/Ha
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2/1/2001
7/1/2001
12/1/2001
5/1/2002
10/1/2002
3/1/2003
8/1/2003
1/1/2004
6/1/2004
11/1/2004
4/1/2005
9/1/2005
Satellite
Loadest
EOS
Delivered



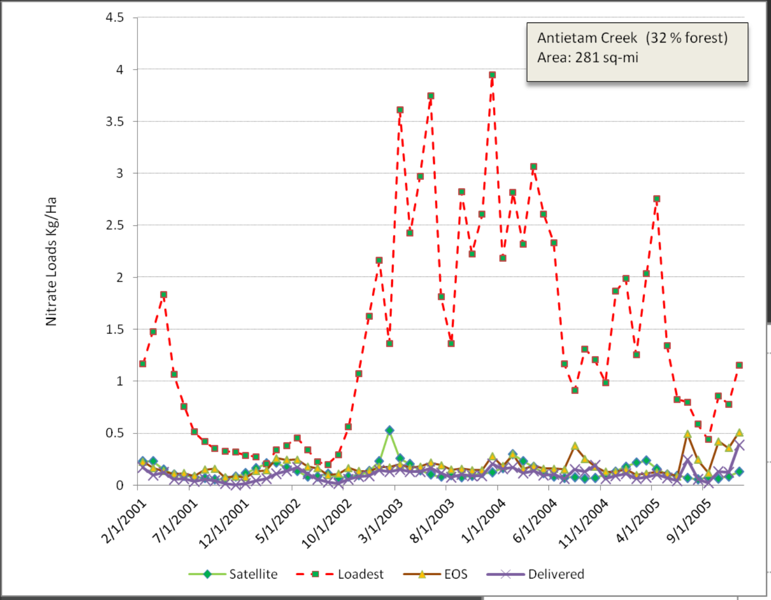
Potomac @ Hancock (75.4% forest) - 4073 sq-mi
Nitrate Loads Kg/Ha
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
2/1/2001
7/1/2001
12/1/2001
5/1/2002
10/1/2002
3/1/2003
8/1/2003
1/1/2004
6/1/2004
11/1/2004
4/1/2005
9/1/2005
Satellite Hancock-Potomac
Loadest Hancock-Potomac
EOS
Delivered

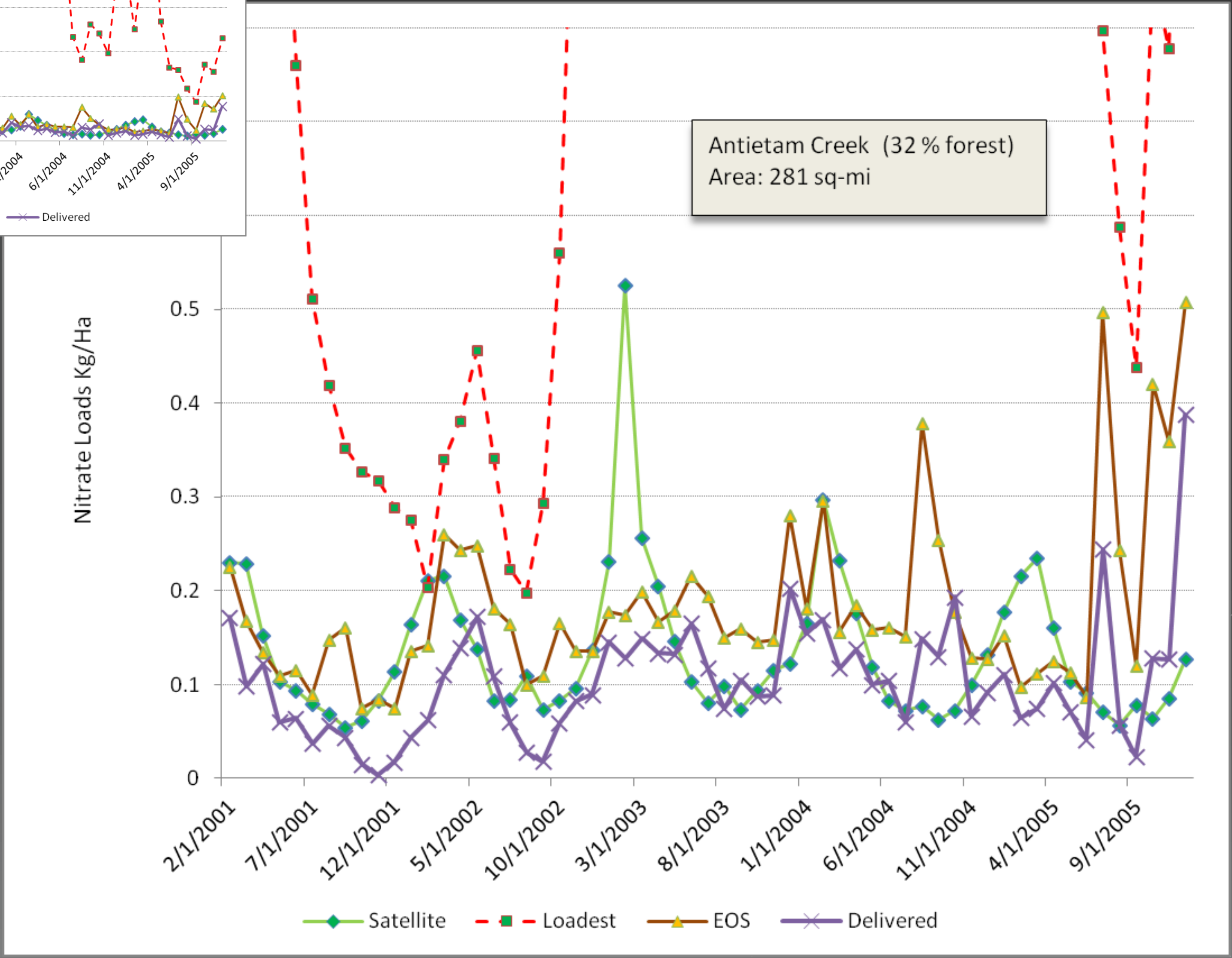


Catoctin (51.5 % forest) -
Area: 67 sq-mi
Nitrate Loads Kg/Ha
2.6
2.1
1.6
1.1
0.6
0.1
-0.4
2/1/2001
7/1/2001
12/1/2001
5/1/2002
10/1/2002
3/1/2003
8/1/2003
1/1/2004
6/1/2004
11/1/2004
4/1/2005
9/1/2005
Catoctin
Catoctin
Catoctin
Catoctin



Catoctin (51.5 % forest) -
Area: 67 sq-mi
Nitrate Loads Kg/Ha
1.1
0.9
0.7
0.5
0.3
0.1
-0.1
2/1/2001
7/1/2001
12/1/2001
5/1/2002
10/1/2002
3/1/2003
8/1/2003
1/1/2004
6/1/2004
11/1/2004
4/1/2005
9/1/2005
Catoctin
Catoctin
Catoctin
Catoctin


Antietam Creek (32 % forest)
Area: 281 sq-mi
Nitrate Loads Kg/Ha
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
2/1/2001
7/1/2001
12/1/2001
5/1/2002
10/1/2002
3/1/2003
8/1/2003
1/1/2004
6/1/2004
11/1/2004
4/1/2005
9/1/2005
Satellite
Loadest
EOS
Delivered


Antietam Creek (32 % forest)
Area: 281 sq-mi
Nitrate Loads Kg/Ha
0
0.1
0.2
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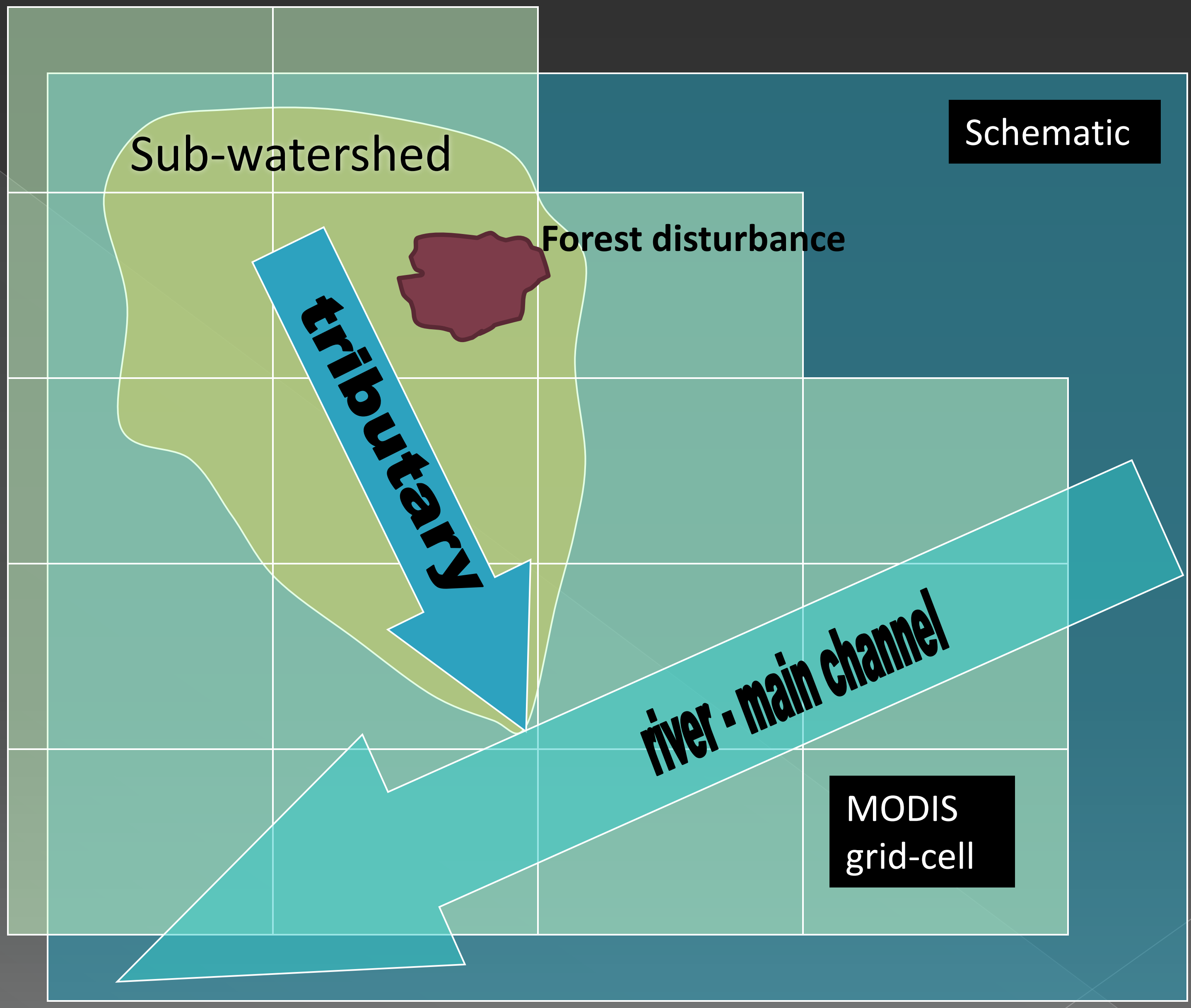
2/1/2001
7/1/2001
12/1/2001
5/1/2002
10/1/2002
3/1/2003
8/1/2003
1/1/2004
6/1/2004
11/1/2004
4/1/2005
9/1/2005
Satellite
Loadest
EOS
Delivered

Interpretation of Statistical Analyses

- Kendal Analysis indicated that there was no trend in the data.
- Autocorrelation Analyses:
  - negative correlation for a 6-month lag and positive correlation for a 12-month lag.
- Bias relative to Loadest: Increased as the % forested area decreased.
- Cross-correlation : To determine the relative performance of the models with respect to LOADEST.

Why forest predictions will benefit from remote sensing information?

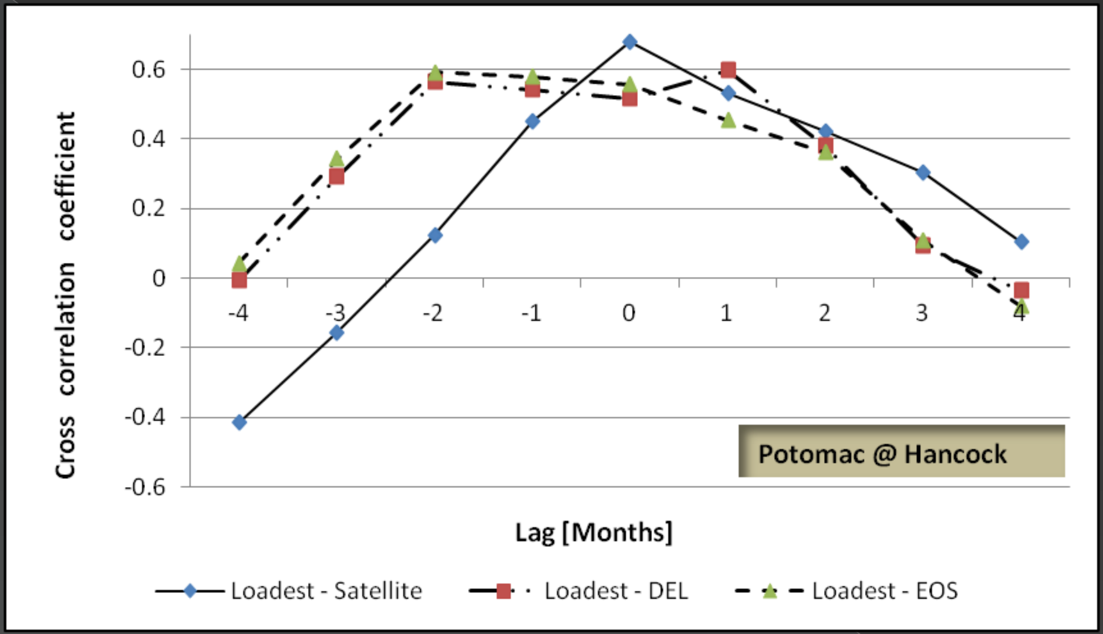
- Atmospheric deposition is not the only input load driving the release of nitrates in forested areas.
- Remote sensing will provide the signal of forested loads (which at the moment is unknown) providing a better base line for management.
- Information on disturbances will be embedded in the satellite data guiding the calibration of EOS.
- Implementation is simple and sensors with similar measurements strategies such as the VIIRS aboard the Suomi-NPP mission will ensure long-term continuity.



MODIS grid-cell = 500x500 mts

QUESTIONS?

- "Continuous-time modeling of streamwater nutrient loading from forests in the Chesapeake Bay watershed using MODIS and meteorological data“ – Environmental Science and Technology. (Sing. A., et al).



CORRELOGRAM

Lag (months)	1	6	12
Loadest	0.637	-0.219	0.306
Satellite	0.723	-0.152	0.371
EOS	0.541	-0.146	0.261
DEL	0.471	-0.128	0.211

	Mean	StDev
Loadest	0.1250	0.074
Satellite	0.2456	0.2142
EOS	0.2075	0.1559
DEL	0.0341	0.0439