Developing a Dynamic SPARROW Water Quality Decision Support System Using NASA Remotely-Sensed Products

Presented by

Richard A. Smith (USGS), PI

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Challenge: Develop a dynamic decision support system (DSS) for the USGS SPARROW water quality model through the use of remotely-sensed data and other NASA Land Information System (LIS) products. Apply the DSS to the Southeastern United States, and train water quality managers in five high-profile coastal watersheds.

Need: SPARROW is widely used throughout the United States for long term, steady state water quality analysis. However, users are increasingly asking for a dynamic version of the model that can provide seasonal estimates of nutrients and suspended sediment to receiving waters. Time varying SPARROW forecasts would aid water managers in decision making regarding allocation of resources in protecting aquatic habitats, planning for harmful algal blooms, and restoration of degraded habitats in stream segments and estuaries.

Opportunity: The spatial and temporal scale of satellite remote sensing products and LIS modeling data make these sources ideal for the purposes of development and operation of the dynamic SPARROW model. Remote sensing products can potentially contribute several critical independent variables in a SPARROW calibration (a non-linear regression) in which the dependent variables are the water quality constituents total nitrogen, total phosphorus, and suspended sediment.

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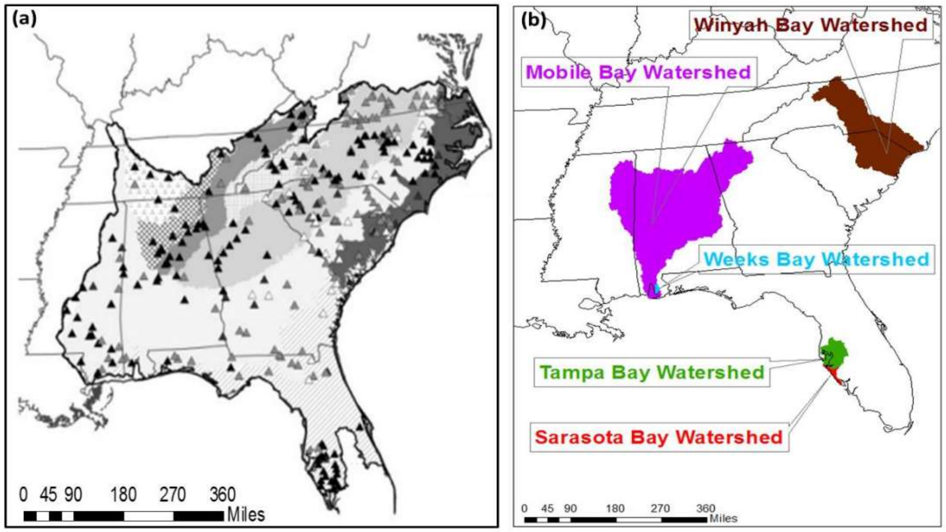
Brief Overview of Approach

- Started March 1, 2017 (3-yr project)
- 28 participating scientists and officials from 9 institutions (USGS, NASA, two universities, five EPA and NOAA estuarine management programs)
- Objective is support of water quality management through development of short and long-term forecasting system.



- Online system will integrate NASA and NOAA remote sensing with dynamic SPARROW and MODFLOW (groundwater) models.
- Forecast of total nitrogen, total, phosphorus, and suspended sediment to five southeastern estuaries (see map) using local models nested in (and informed by) a regional model.
- Probabilistic short-term forecasts (< 1-year) will provide ecologically relevant information to a broad audience.
- Long-term forecasts (10 – 30 years) will be scenario-based and assist with local land-use planning under uncertain climatic conditions.

Anticipated Impacts

User Groups:

1. ***Mobile Bay NEP (Turbidity/sediment loads primary stressors to shallow water habitats.***)
   - Supports MBNEP 5-year plan for maintaining/improving SAV
   - Establish seasonal baseline conditions for suspended sediment loads to estuary
   - Track progress towards 5-year plan goals after restoration efforts
2. ***Weeks Bay NERR (Long term climate risk)***
   - Predict and track phenological changes
   - Support development of long term management plan
3. ***Tampa Bay NEP (Eutrophication from nitrogen and phosphorus loading)***
   - Forecast short- and long-term effects of urban stormwater, septic system, agriculture, pt. sources
   - Enhance current retroactive assessments of seagrass risk with short-term forecasting
   - Assist USGS/Tampa Bay ocean acidification program assess photosynthetic potential
4. ***Sarasota Bay NEP (Eutrophication from nitrogen and phosphorus loading)***
   - Forecast short- and long-term effects of urban stormwater, septic system, agriculture, pt. sources
   - Enhance current retroactive assessments of seagrass risk with short-term forecasting
5. ***Winyah Bay, SC NERR (Nutrient/sediment loads; long term climate risk)***
   - Predict and track phenological changes
   - Support development of long term management plan

USGS:

1. Contribute to development of new (dynamic) SPARROW DSS system
2. Increase use of remote sensing in USGS water quality program
3. Supports development of water quality forecasting capability
4. Supports development of national-scale groundwater model

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Project Partners and User community

United States Geological Survey	**Mobile Bay National Estuary Program**
* Dr. Richard Smith, PI	Roberta Swann, Co-I/Institutional PI
Dr. Anne Hoos, Co-I	Tom Herder, Co-I
Dr. Gregory Schwarz, Co-I	**Tampa Bay Estuary Program**
Dr. Richard Alexander, Co-I	Ed Sherwood, Co-I/Institutional PI
* Dr. Matt Miller, Co-I	Holly Greening, Collaborator
Dr. Wes Zell, Co-I	**Winyah Bay National Estuarine Research Reserve**
Dr. Ward Sanford, Co-I	Dr. Erik Smith
Dr. Meredith Reitz, Co-I	**Sarasota Bay Estuary Program**
Dr. Journey , Celeste, Co-I	Dr. Jay Leverone, Co-I/Institutional PI
Universities Space Research Association	**Weeks Bay National Estuarine Research Reserve**
*Dr. Mohammad Al-Hamdan, Co-I/Institutional PI	Mike Shelton, Co-I/Institutional PI
Dr. William Crosson, Co-I	**Southwest Florida Water Management District**
Jayanthi Srikishen, Co-I	Dr. Chris Anastasiou, Collaborator
University of Alabama in Huntsville	Jennette Seachrist, Collaborator
Dr. Maurice Estes, Jr., Co-I/Institutional PI	
Dr. Ashraf Al-Hamdan, Co-I	
Dr. James Cruise, Co-I	
Dr. W. Lee Ellenburg, Co-I	
Africa Flores, Co-I	
University of Wyoming	
Dr. Kevin Befus	

Partner communities our project hopes to engage in the future:

- **Similar coastal watershed management organizations nationwide**
  - **National Estuary Program (EPA) and Research Reserve (NOAA)**
  - **Other non-federal coastal organizations**

- **Inland watershed management/protection organizations**

- **State health and natural resources departments**
  - **e.g. *South Carolina Department of Health and Environmental Control**

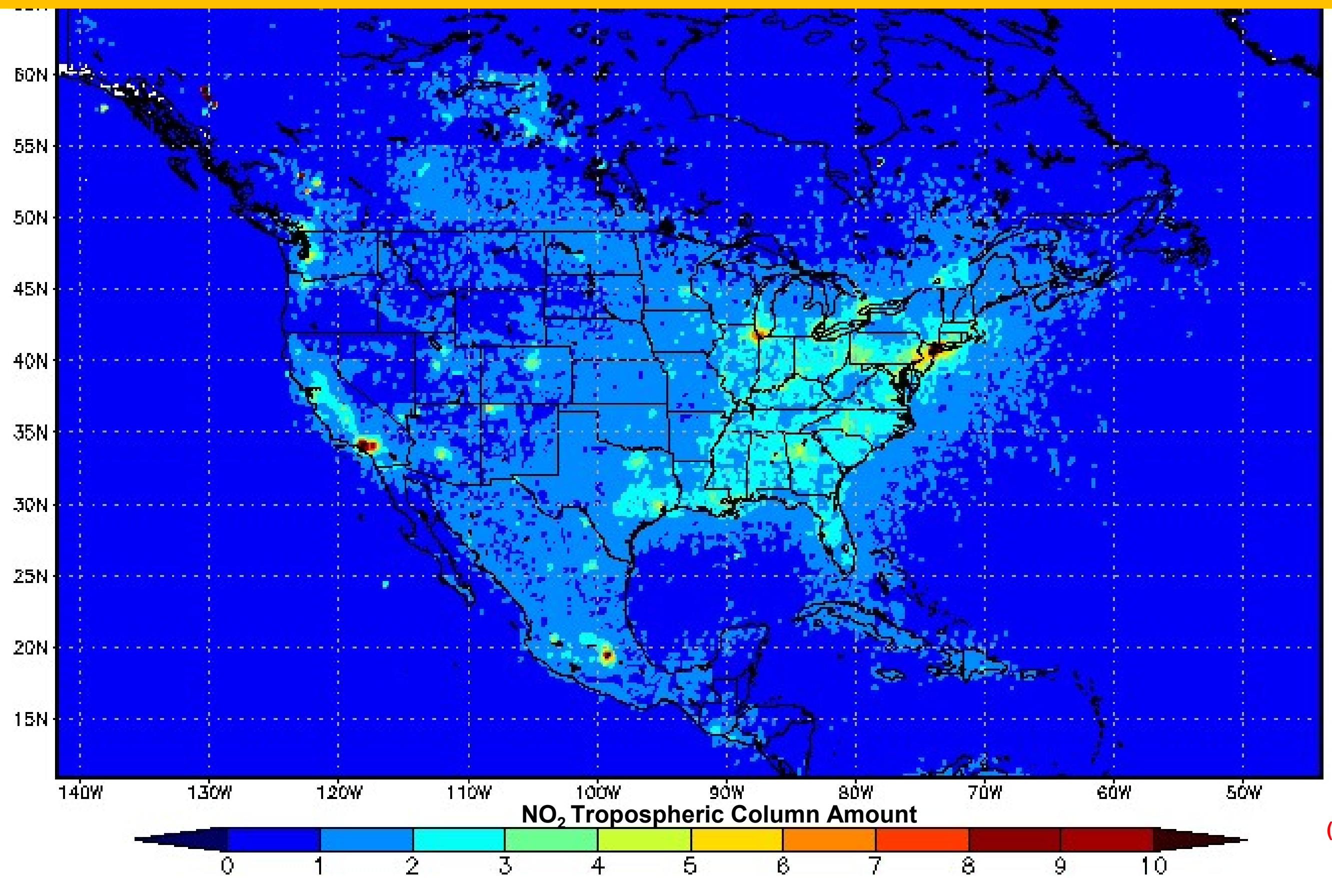
*** Has requested informal participation in this project.**

Key Datasets:

Remotely-sensed / Modeled Product	Source	Spatial Resolution	Temporal Resolution	SPARROW Use
LAI	MODIS/VIIRS	1 km/500 m	8-day	N, P sources
NDVI, EVI	MODIS/VIIRS	250 m/375 m	16-day	Vegetation Index, N,P sources/Disturbed land
LAI, FPAR	MODIS/VIIRS	1 km/500 m	Daily	Vegetation health
NO_2	OMI	13x25 km	Daily	Nitrogen Deposition
ET	LIS	3 km	Daily	Plant Uptake of N, P
Disturbed Land	MODIS/Landsat/Sentinel	1km/30 m/10 m	Daily/16 day/10 day	TSS, nutrient Source
Soil Moisture	SMAP	Downscaled to 9 km	Daily	Denitrification Proxy
Soil Temperature	LIS	3 km	Daily	Denitrification Proxy
Groundwater Anomalies	GRACE	400 km	Monthly	Groundwater Modeling
Meteorological Data	NLDAS	12 km	Hourly	Meteorological Forcing Inputs
LCLU	NLCD-2011	30 m	Every 5 years	Land Cover Characterization

Remotely-sensed Atmospheric Deposition of Nitrogen
(NASA OMI/Aura Tropospheric Column NO_2 will be used as a proxy for dry deposition

Spatial Resolution: 13 x 24 km. **Temporal Resolution:** Once Daily at ~1:30 PM Local Time. **Availability:** Oct 1, 2004-Present. **Latency:** 1 day. **Format:** HDF-5



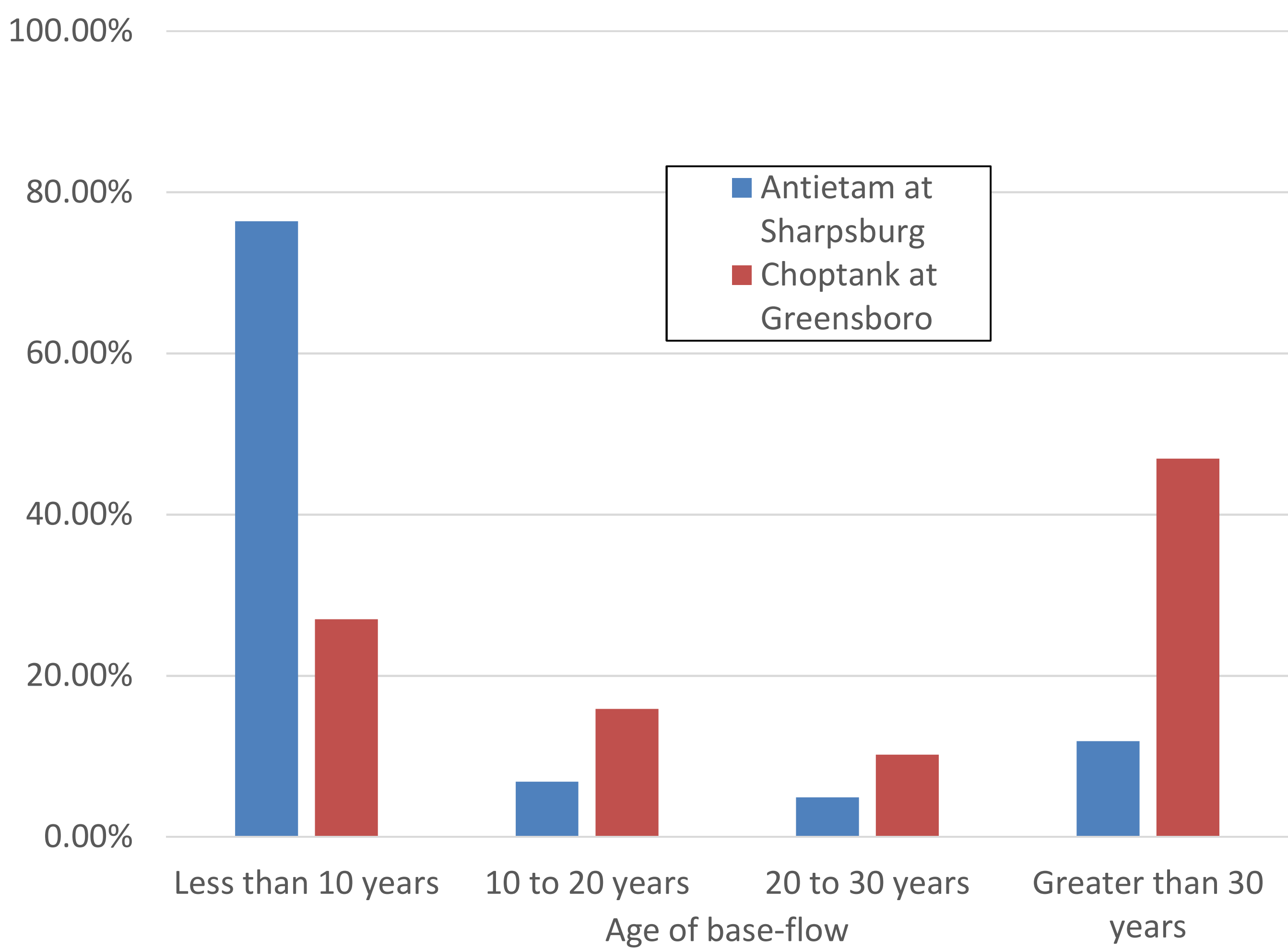
(June 1, 2008 - July 30, 200

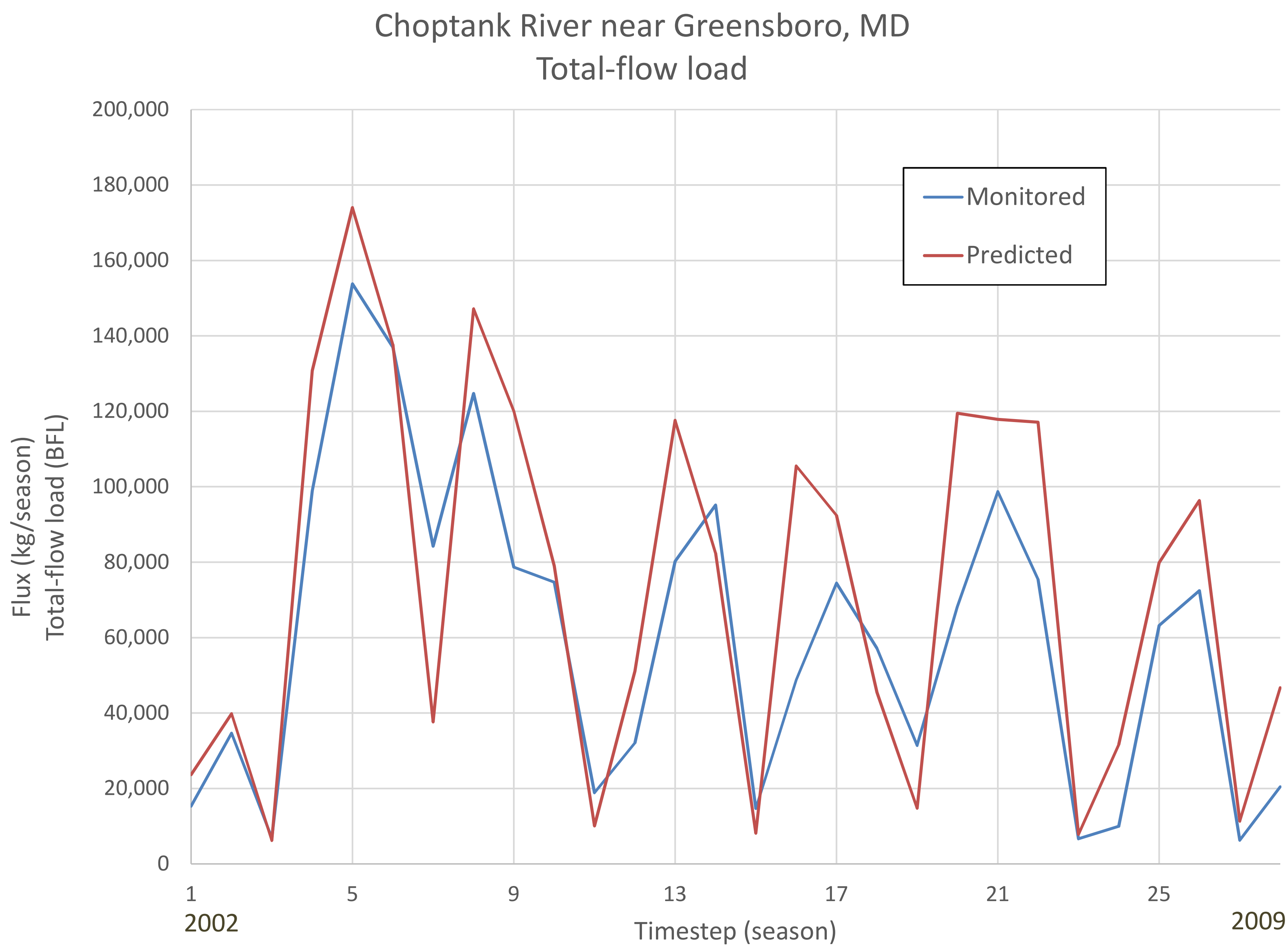
(10^{15} molecule/cm^2)

Model Integration

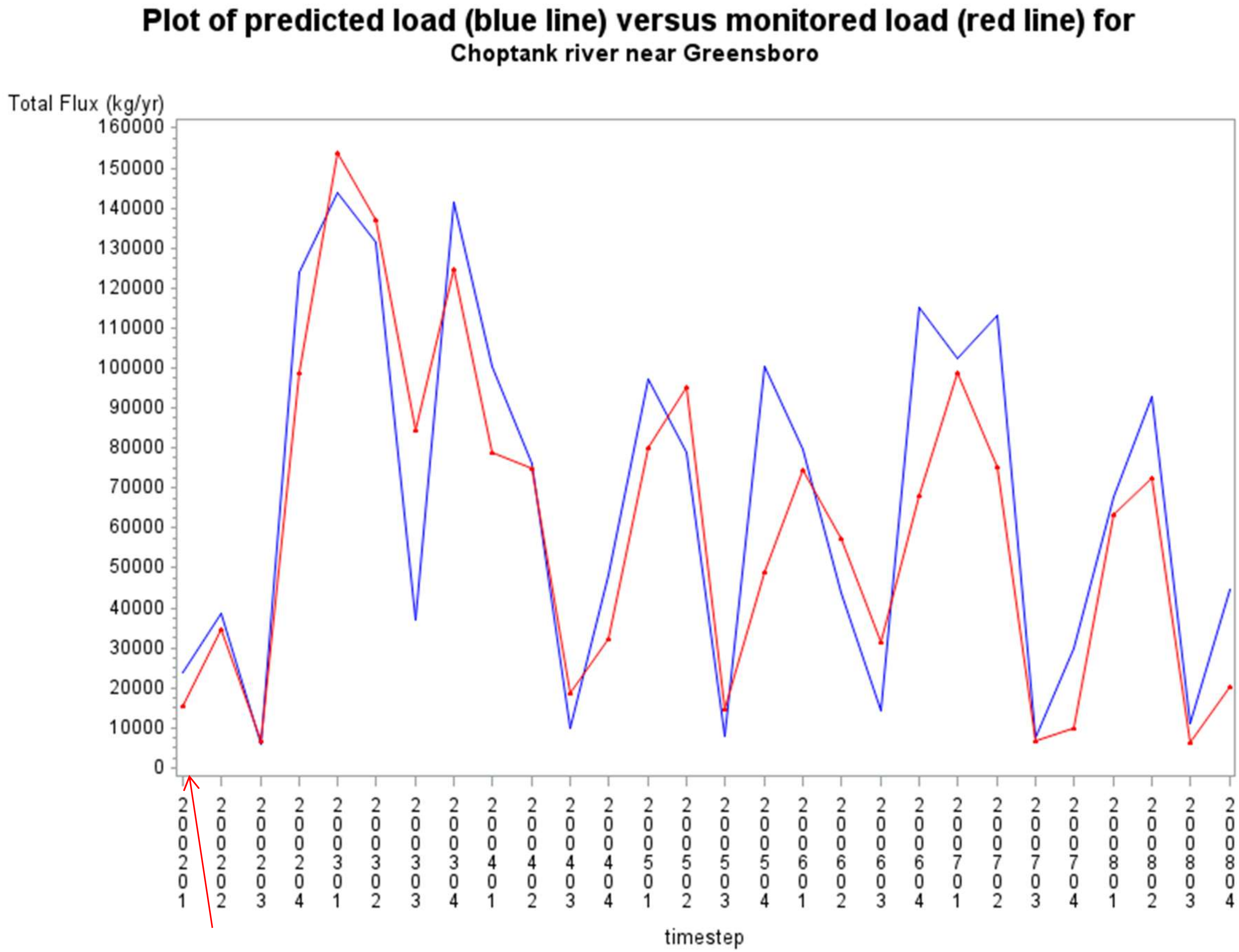
1. Dynamic SPARROW model of Southeastern US
2. National-scale MODFLOW groundwater model
4. DSSAT Agricultural model of Southeastern US
5. Nested SPARROW forecasting models for five coastal watersheds (user-group partners) presented through "R Shiny" web interface.

Large Differences in Ground Water Residence Time Between Coastal Plain and Most Non-CP Watersheds





Choptank River near Greensboro, MD
Total-flow load
Monitored
Predicted
Flux (kg/season)
Total-flow load (BFL)
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1
5
9
13
17
21
25
2002
2009
Timestep (season)



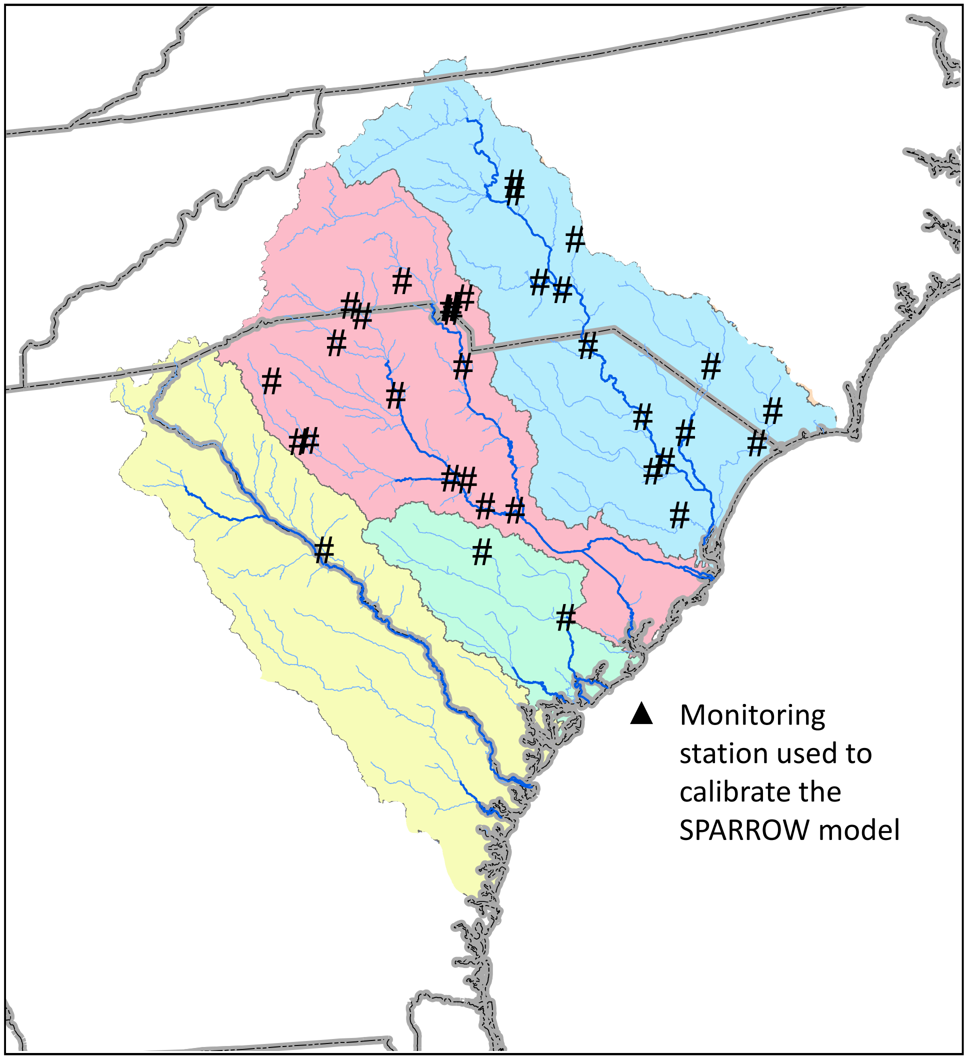
Surface fertilizer zero after March, 2002

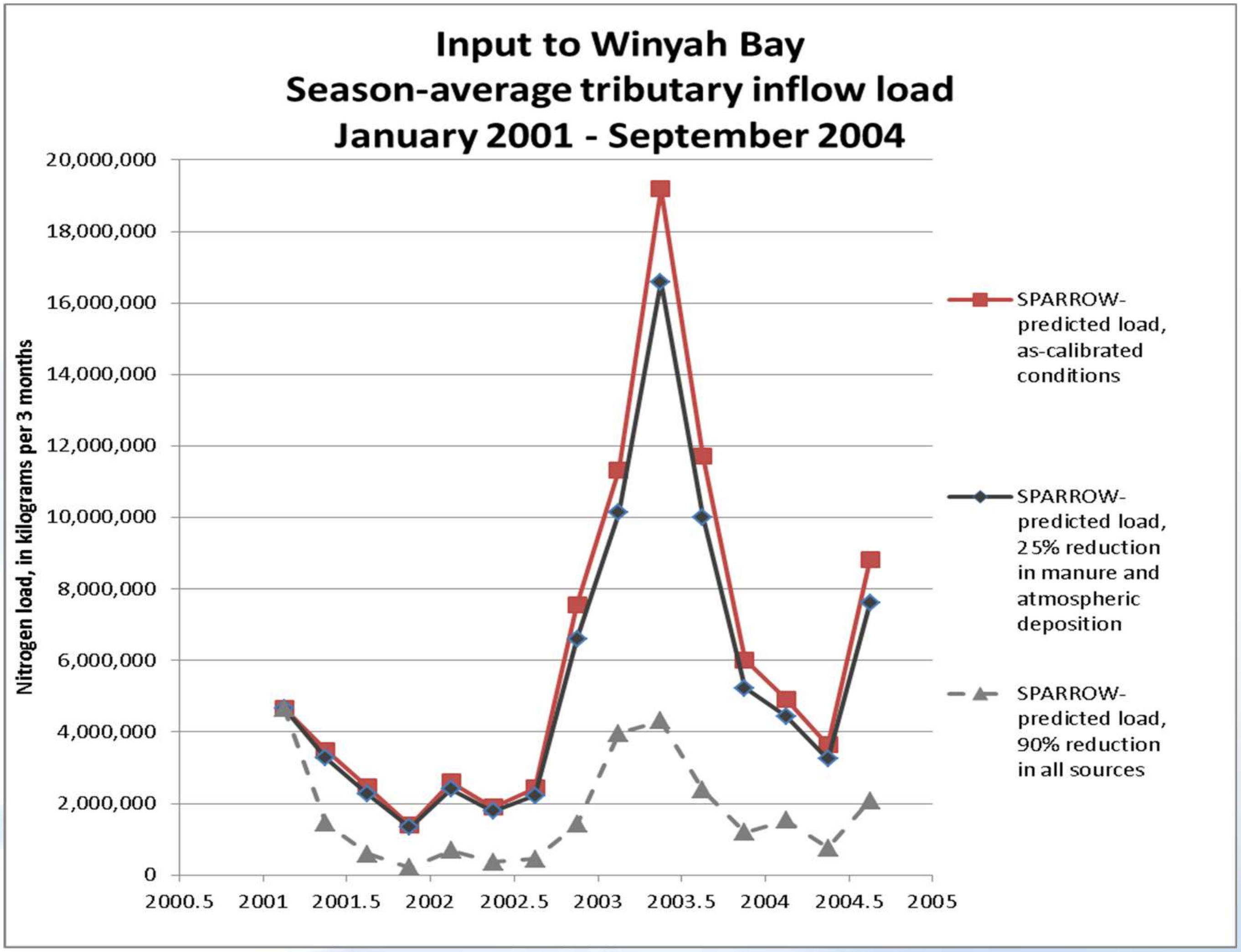
Transition Strategy

- The current USGS SPARROW Decision Support System will be replaced, potentially expanding the dynamic system developed in this project. We will use the open-source R software "Shiny", which supports the development of interactive web-based applications that provide user access and visualization of model results.
- The Shiny software offers considerable flexibility for customization of the design, such that the visualization of the output from the SPARROW dynamic models can be tailored to the particular needs of specific end users and coastal areas.
- R scripts will also be developed to acquire, process and integrate the remotely-sensed data and products into the dynamic SPARROW tools. These scripts, which will be part of the SPARROW-R package, will allow for an automated process of acquiring the data from the NASA ftp servers, reformat and subset them into different domains for running the dynamic SPARROW models for the various regions of our study.
- USGS and partners will lead online interactive webinars and make site visits as required for additional technical support to ensure end users have the training and documentation needed to operate the dynamic SPARROW model for their area.
- End users have the staff capability and infrastructure to operate the dynamic SPARROW models. Our end users will have the training, documentation, and in-house capability to sustain dynamic SPARROW model operations and benefits post project.
- Our end users have well-established Coastal Training Programs that regularly organize and run training events for local/regional decision-makers and are available to support transfer of model output to local target audiences.

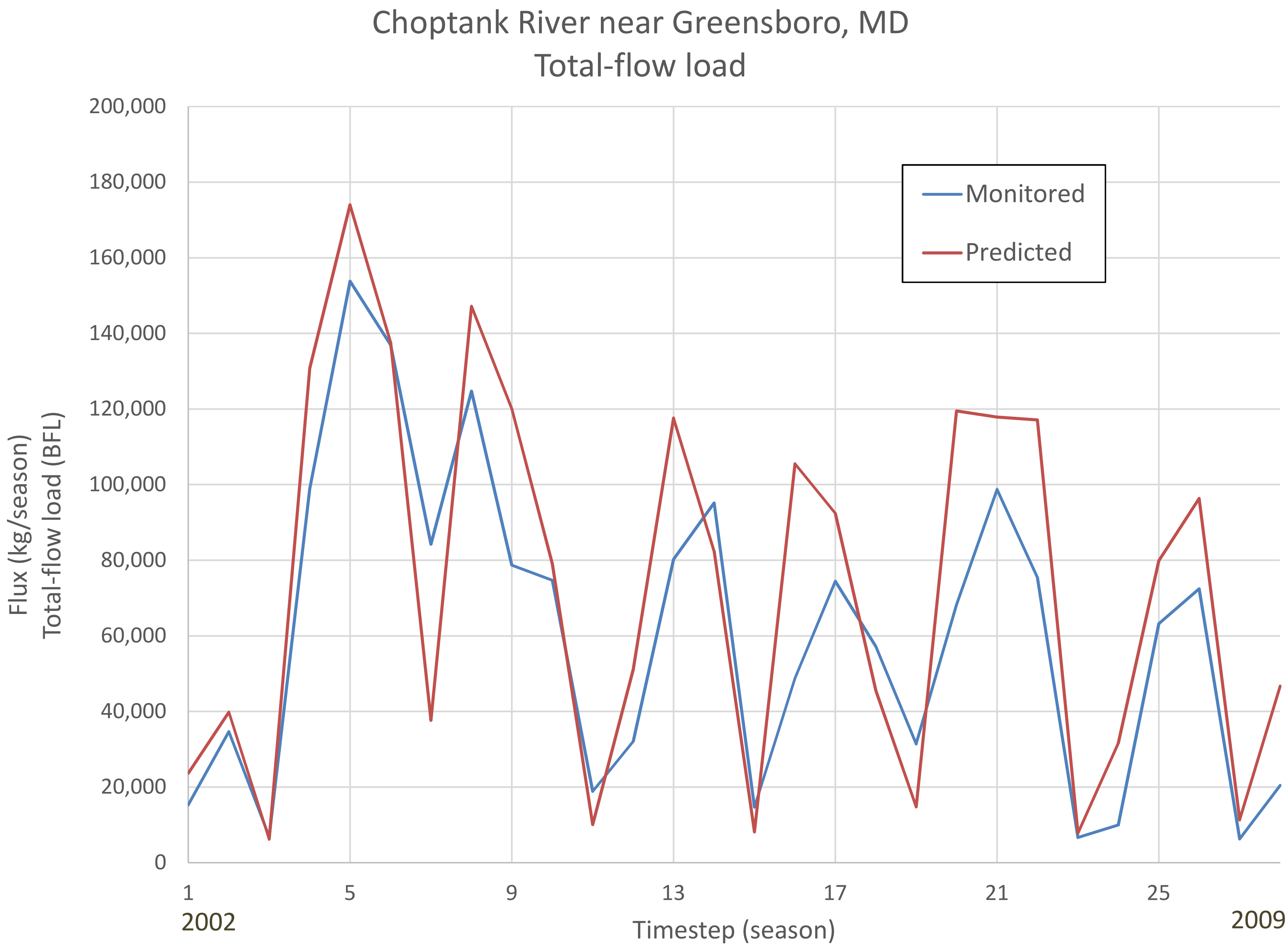
Example of Recent Modeling Progress

Areal extent of recently-calibrated dynamic SPARROW model for river basins in South Carolina



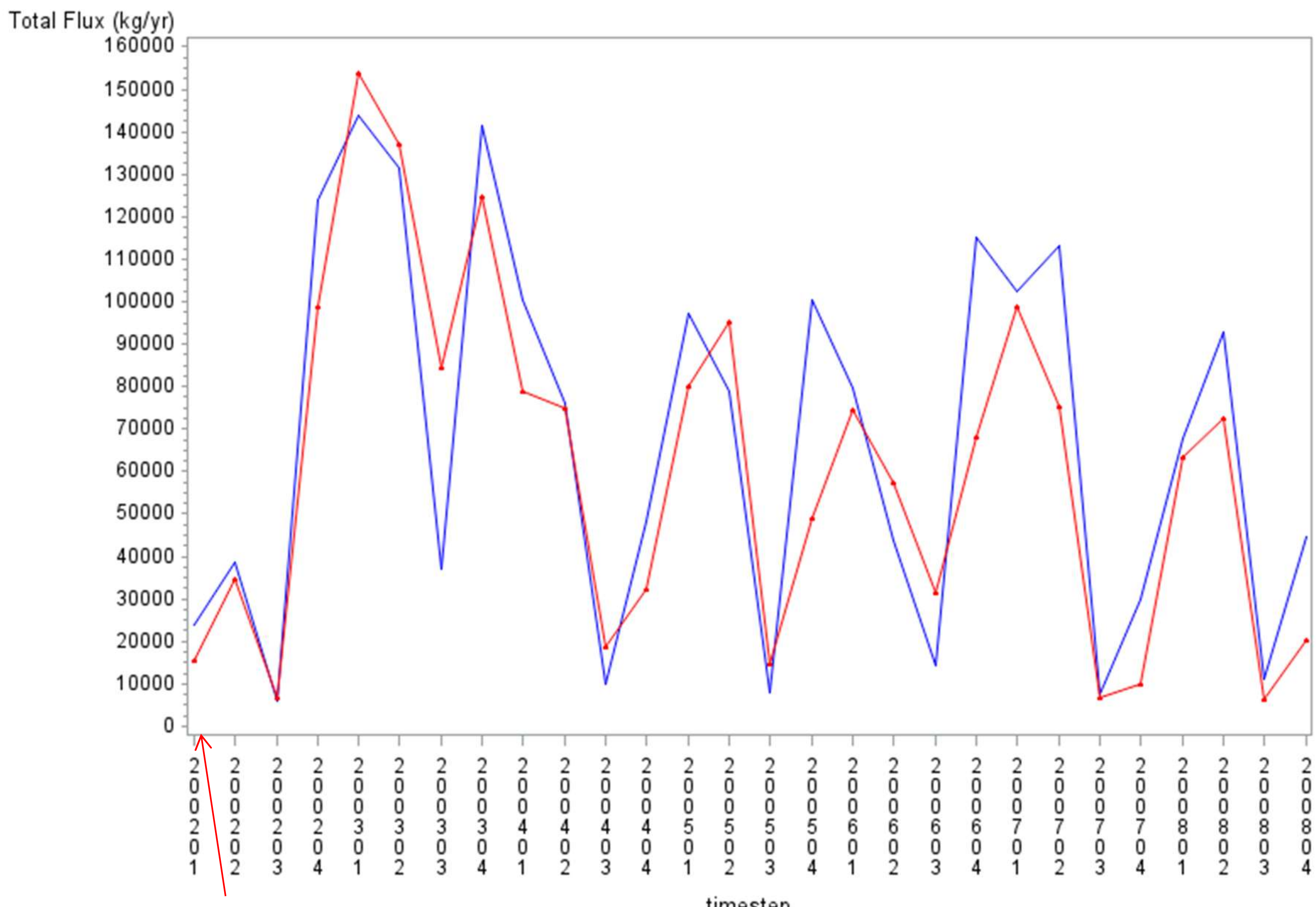


Input to Winyah Bay
Season-average tributary inflow load
January 2001 - September 2004
Nitrogen load, in kilograms per 3 months
20,000,000
18,000,000
16,000,000
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
2000.5
2001
2001.5
2002
2002.5
2003
2003.5
2004
2004.5
2005
SPARROW-predicted load, as-calibrated conditions
SPARROW-predicted load, 25% reduction in manure and atmospheric deposition
SPARROW-predicted load, 90% reduction in all sources



Choptank River near Greensboro, MD
Total-flow load
Monitored
Predicted
Flux (kg/season)
Total-flow load (BFL)
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1
5
9
13
17
21
25
2002
2009
Timestep (season)

Plot of predicted load (blue line) versus monitored load (red line) for
Choptank river near Greensboro



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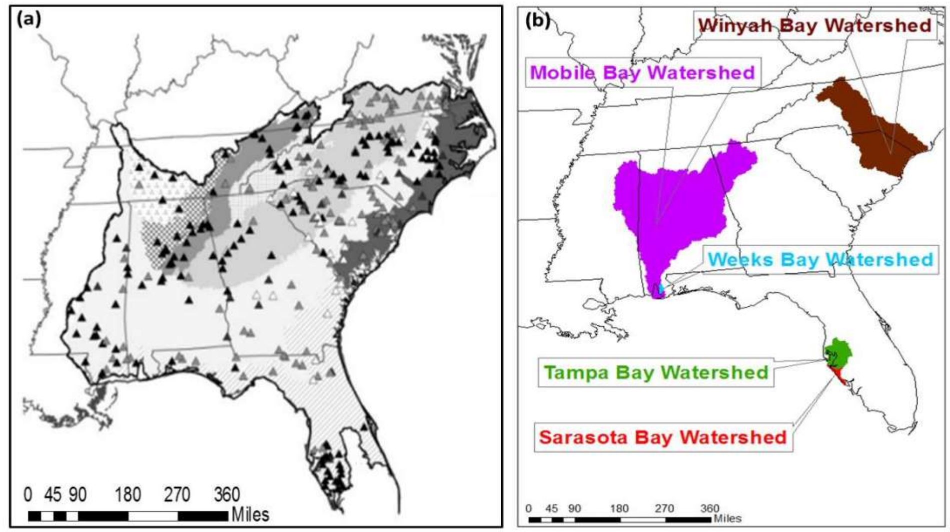

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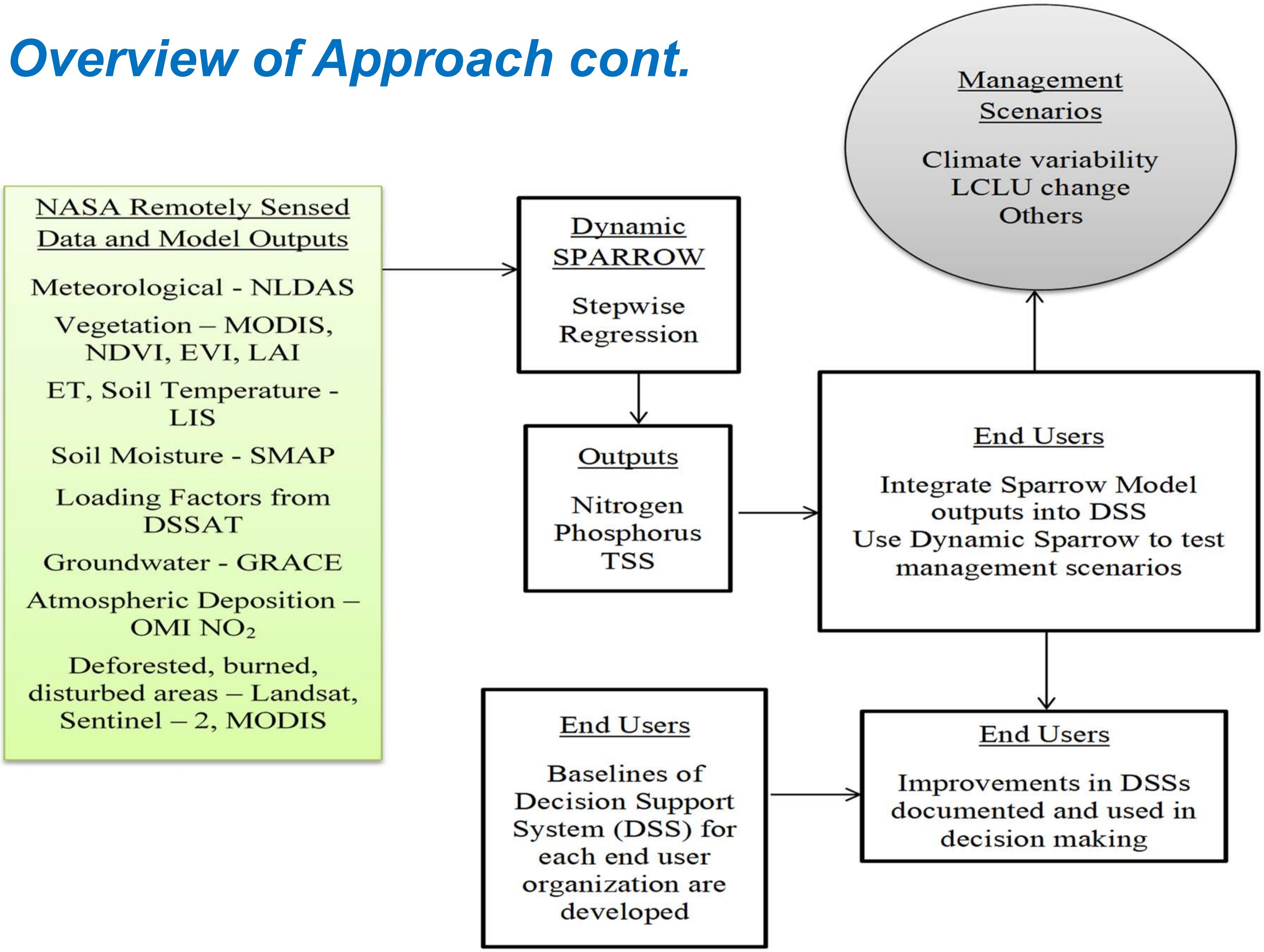
Overview of Approach cont.



Publications

Reitz, M., W.E. Sanford, G. Senay, and J. Cazenas (2017), Annual estimates of recharge, quick-flow runoff, and ET for the contiguous US using empirical regression equations, 2000-2013: U.S. Geological Survey data release, https://doi.org/10.5066/F7PN93P0.

Reitz, M., W.E. Sanford, G. Senay, and J. Cazenas (2017), Annual estimates of ET, recharge and quick-flow runoff for the contiguous US using empirical regression equations. (In Press, JAWRA)

Presentations/abstracts this quarter:

Reitz, M., W. Sanford, G. Senay, and W.H. Kress (2017, April). Estimating water budget components of evapotranspiration, recharge, and runoff for Mississippi and the Mississippi Alluvial Plain. Talk presented at the Mississippi Water Resources Conference, Jackson, MS.

Al-Hamdan, M., R. Smith, A. Hoos, G. Schwarz, R. Alexander , W. Crosson, J. Srikishen, M. Estes, J. Cruise, A. Al-Hamdan, W. Ellenburg, A. Flores, W. Sanford, W. Zell, M. Reitz, M. Miller, C. Journey, K. Befus, R. Swann, T. Herder , E. Sherwood, J. Leverone, M. Shelton, E. Smith, C. Anastasiou, J. Seachrist, K. Kaufman, A. Hughes, D. Graves. *Developing a Dynamic SPARROW Water Quality Decision Support System Using NASA Remotely-Sensed Products. Will be presented at Alabama Water Resources Conference.* September 6-8, 2017*, Orange Beach, AL. (Submitted Abstract).*