An Integrated Framework for Flow and Transport Modeling at Regional Scales

Ahmad A. Tavakoly

EWN, April 15, 2019

Main goal

This research explores the development of water flow and transport computation on large scale river networks

vector-based models more correctly follow the stream and watershed structure of the real landscape

Related Work

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A GIS FRAMEWORK FOR REGIONAL MODELING TRANSPORT: CASE STUDY, SAN ANTONIO AN

Ahmad A. Tavakoly, David R. Maidment, James W. McClellan Claire Griffin, Cédric H. David, and

ABSTRACT: This article presents a framework for integrating a regi based nitrogen dataset (Texas Anthropogenic Nitrogen Dataset, TX- (Routing Application for Parallel computation of Discharge) to simula transport in river networks containing thousands of reaches. A two- Antonio and Guadalupe basins during dry and wet years (2008 and 2 TN export in urbanized (San Antonio) *vs.* rural (Guadalupe) drainag voirs on TN transport. Simulated TN export values are within 10 per stations in 2008 and 2009. Results show that in both years the San A than the Guadalupe basin of delivered TN to the coastal ocean. Th activities including point sources, associated with the city of San A activities. The Guadalupe basin lacks major metropolitan areas and i tilized agricultural fields. Both basins delivered more TN to coastal TN removal in the San Antonio and Guadalupe basins is inversely rel the more TN delivery (or the less TN removal).

(KEY TERMS: total nitrogen; geographic information system; river n water hydrology; NHDPlus; Routing Application for Parallel computa

Tavakoly, Ahmad A., David R. Maidment, James W. McClelland, Tim fin, Cédric H. David, and Lisa Meyer, 2016. A GIS Framework fo Transport: Case Study, San Antonio and Guadalupe Basins. *Journal tion* (JAWRA) 52(1): 1-15. DOI: 10.1111/1752-1688.12355

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CONTINENTAL-SCALE RIVER FLOW MODELING USING HIGH-RESOLUTION NHD

Ahmad A. Tavakoly, Alan D. Snow, Cédric H. David, M and Zong-Liang Yan

ABSTRACT: As a key component of the National Flood Interopera the continental scale river flow modeling of the Mississippi River from NHD*Plus*. The Routing Application for Parallel computat MRB with more than 1.2 million river reaches for a 10-year stu Infiltration Capacity (VIC) model was used as input to RAPID. T on RAPID performance, the differences between the VIC-RAPID of the MRB, and the impact of major dams on the streamflow when initial parameter values, especially the Muskingum K par into account. The statistical summary indicates the RAPID mod Regions and the Upper and Lower Mississippi River Regions in co to the better performance of the VIC model. The model accuracy considered in the modeling framework. In general, results show t factory at the continental scale of the MRB.

(KEY TERMS: surface water hydrology; Continental River Trans NHD*Plus* Dataset; rivers/streams; runoff.)

Ahmad A. Tavakoly, Alan D. Snow, Cédric H. David, Michael L. Yang, 2016. Continental-Scale River Flow Modeling of the Mi NHD*Plus* Dataset. *Journal of the American Water Resources A* 1688.12456

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Research papers

An integrated framework to model nitrate contaminants with interactions of agriculture, groundwater, and surface water at regional scales: The STICS–EauDyssée coupled models applied over the Seine River Basin

Ahmad A. Tavakoly[a,b,*], Florence Habets[c], Firas Saleh[d], Zong-Liang Yang[e], Cyril Bourgeois[f], David R. Maidment[g]

[a] U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, United States
[b] University of Maryland, Earth System Science Interdisciplinary Center
[c] Sorbonne Universités, UPMC, Univ Paris 06, CNRS, EPHE, UMR 7619 METIS, Paris, France
[d] Jupiter, 251 30th Street, New York City 10001, United States
[e] Department of Geological Sciences, Jackson School of Geosciences, The University of Texas at Austin, United States
[f] Centre International de Recherche sur l'Environnement et le Développement, Nogent-sur-Marne, France
[g] Department of Civil, Architectural, and Environmental Engineering, The University of Texas at Austin, United States

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Surface-aquifer interactions
Regional scale modeling
Distributed hydrologic modeling
Seine River Basin

ABSTRACT

Nutrient enrichment from natural and anthropogenic activities is one of the major environmental pollution stressors. This study presents an integrated framework that couples a mesoscale atmospheric analysis system (SAFRAN), an agronomic model (STICS) and a distributed hydro(geo)logic model (EauDyssée) to estimate nitrogen flux at the regional scale. The EauDyssée modeling framework was developed to include nitrate transport from soils to rivers via surface runoff and stream-aquifer interactions. Further, an in-stream nitrate model was developed based on the large-scale river routing of the framework. The utility of the integrated framework was demonstrated on the Seine River Basin (SRB), which has an area of 88,000 square kilometers. The SRB is one of the most productive agricultural areas in France and encompasses the megalopolis of Paris. This basin is a complex hydrosystem with multiple aquifers. The STICS-EauDyssée integrated framework was implemented for a long-term simulation covering 39 years (1971–2010) at a daily time step. Comparison of groundwater nitrate concentrations with observations showed an overall absolute bias of less than 10 mg/L. Model results showed that simulated nitrate flux to rivers highly depend on the inflow produced by surface and subsurface waters. Results also demonstrated that approximately 10% of leaching nitrate flux is delivered to the river network from stream-aquifer interactions. The statistical analysis indicates the modeling system performs better in the eastern region of the SRB in comparison to the western part of the basin, due to the hydrological complexity of the western part of the basin. Comparison of maximum nitrate concentration between dry and wet years (1990 and 2001) showed an increase of 60%, largely driven by more annual water yield in the wet year compared to the dry year.

1. Introduction

environmental effects such as harmful algal blooms (growth of phyto- plankton in a water body), hypoxia (oxygen depletion), and reduction

Research scope

#1
Steady-state flow and transport modeling

#2
Dynamic flow and transport modeling in large scale

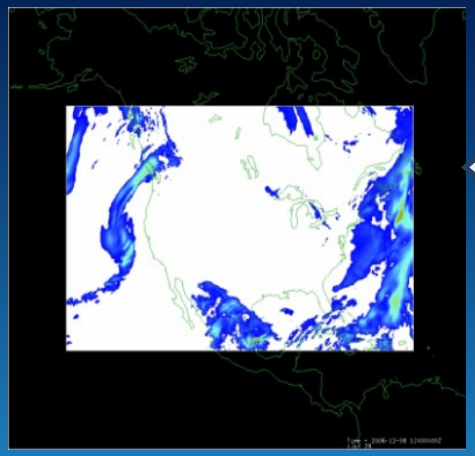
Modeling **mean annual** nitrogen loading

Improve modeling of **nitrate transport at large river networks**

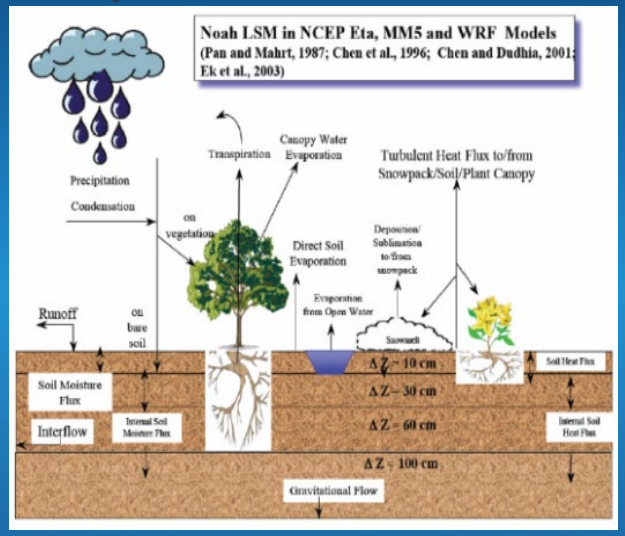
Texas: Sponsored study region

Seine basin: Collaboration with MINES Paris Tech

Framework of Continental water dynamic modeling

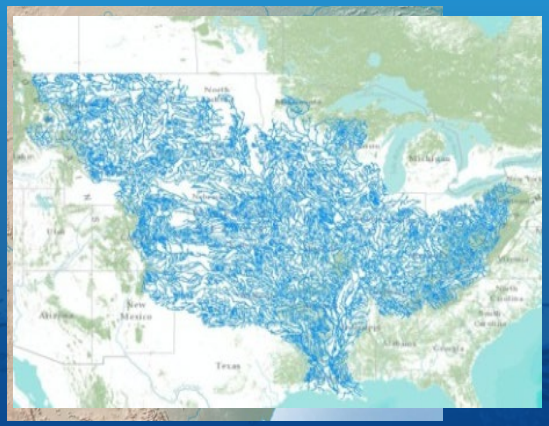


Atmospheric model or dataset



Land surface model

Moving forward from regional scale river modeling to continental scale river modeling



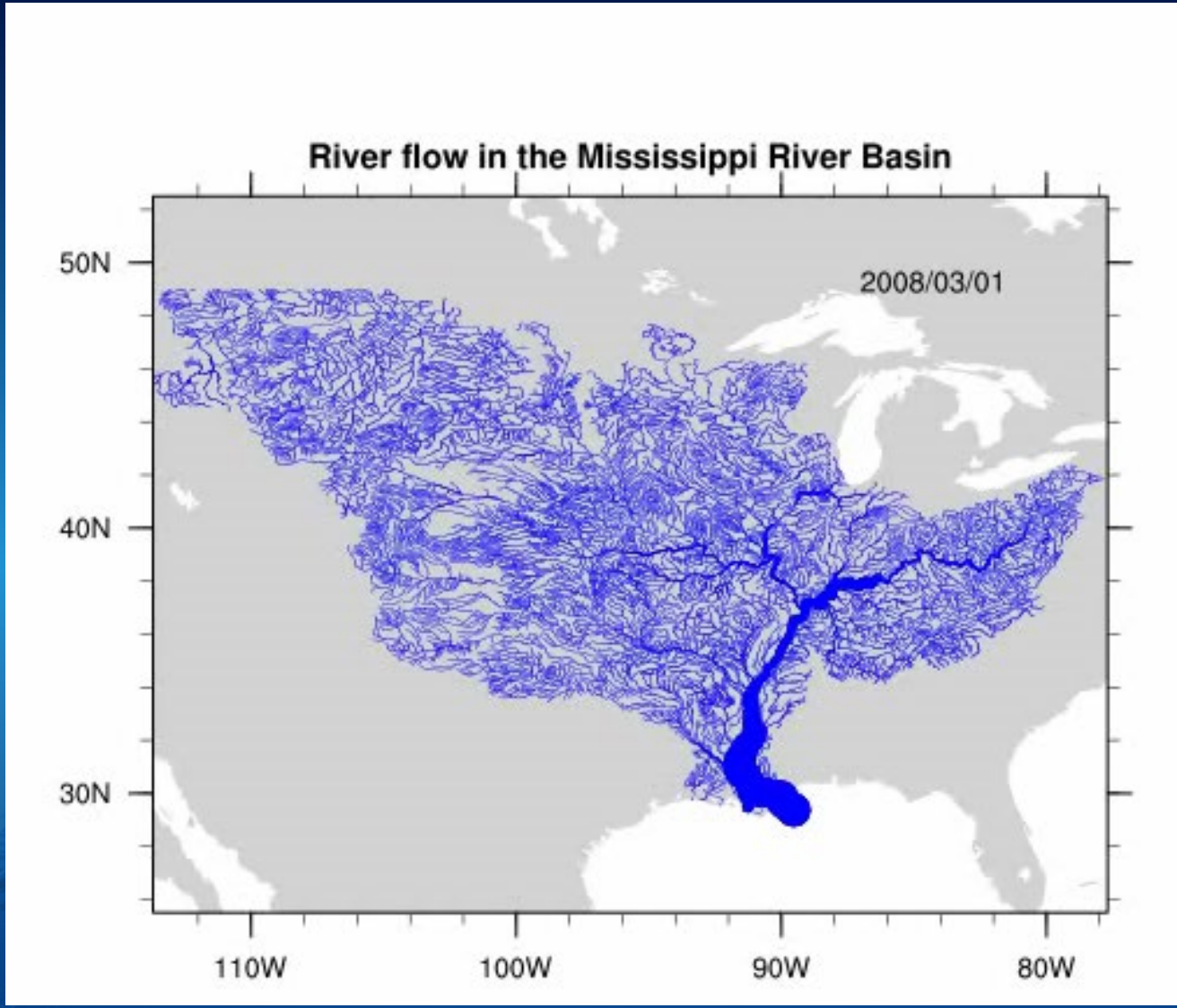
Regional scale river modeling
David et al. (2013)

Continental scale : 1,200,000 river reaches

Regional scale: 65,000 river reaches

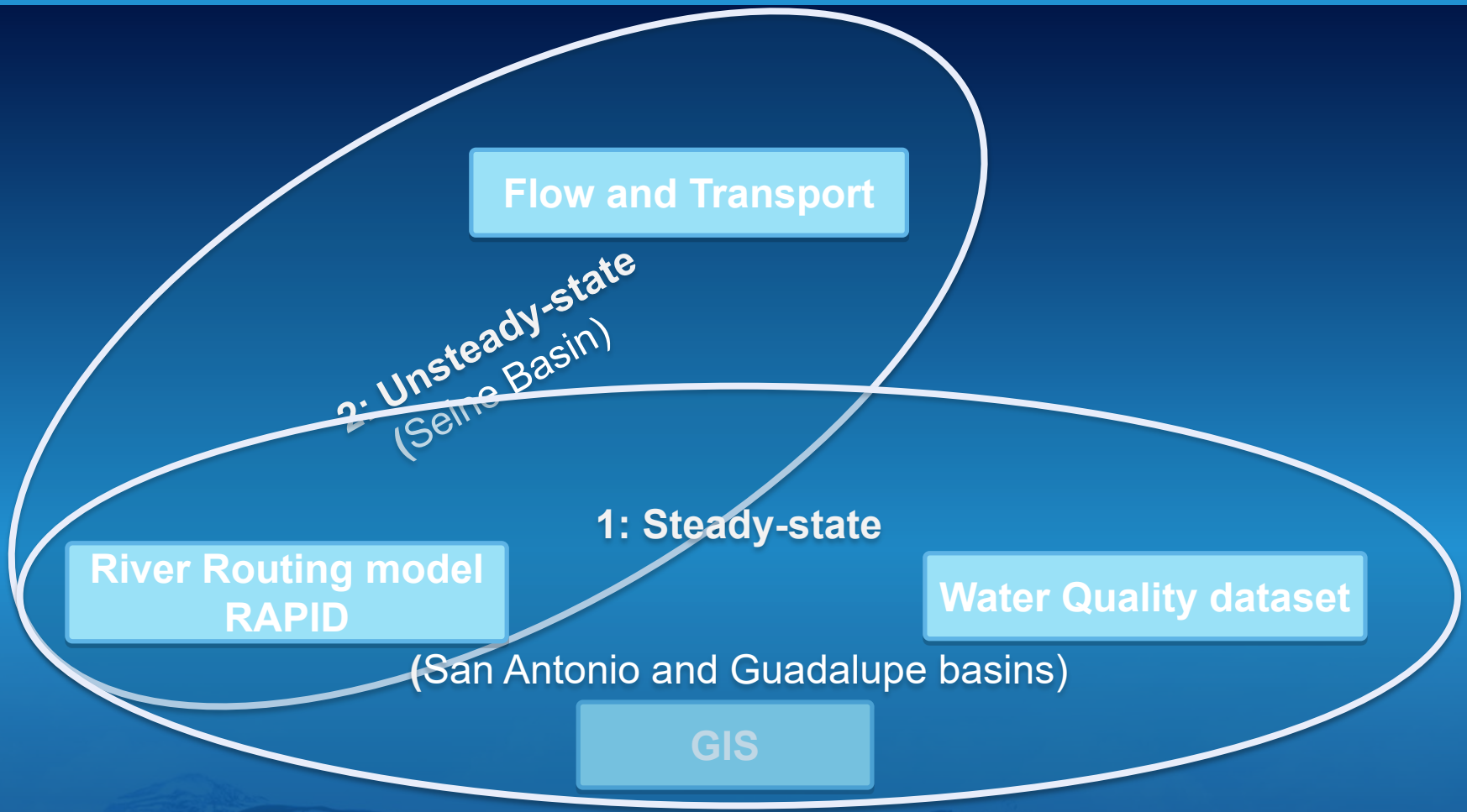
Flow in the Mississippi River Basin

March to May 2008

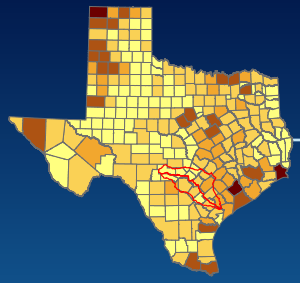


Tavakoly et al. (2012, 2017)

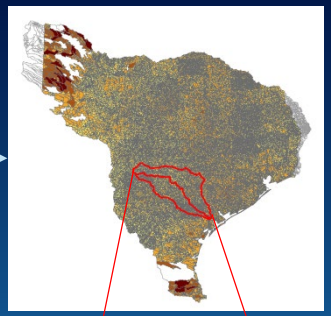
Steady-state flow and transport modeling



GIS-based steady-state modeling framework



Texas Anthropogenic Nitrogen Budget

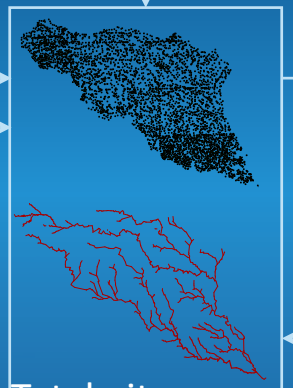


Schematic network

RAPID

Reservoirs

Waste water treatment plants

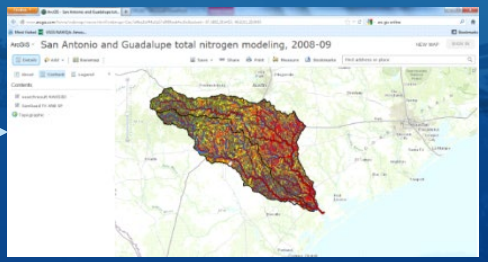


Observation

Calibration

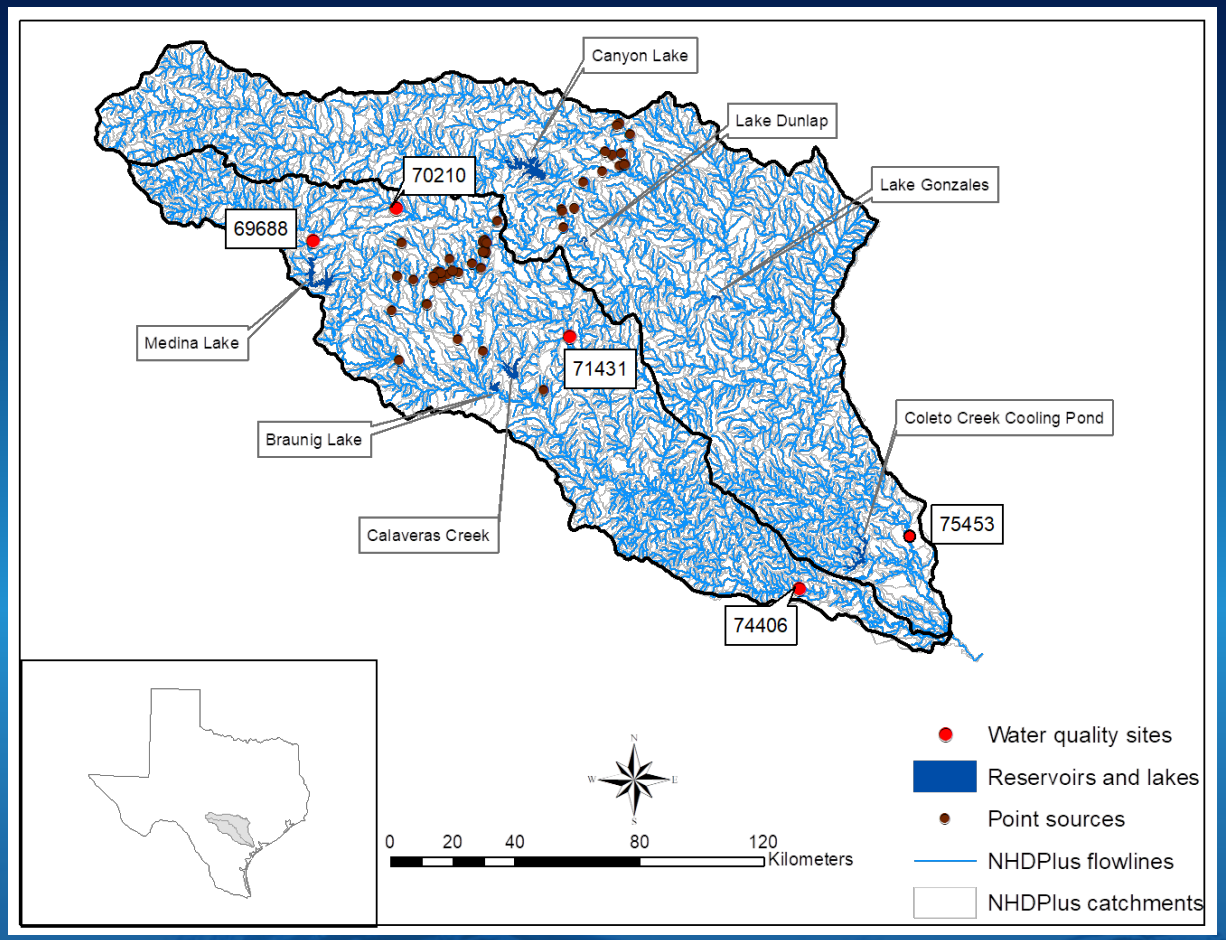
Total nitrogen load estimation

Share as a service on ArcGIS server



Web map

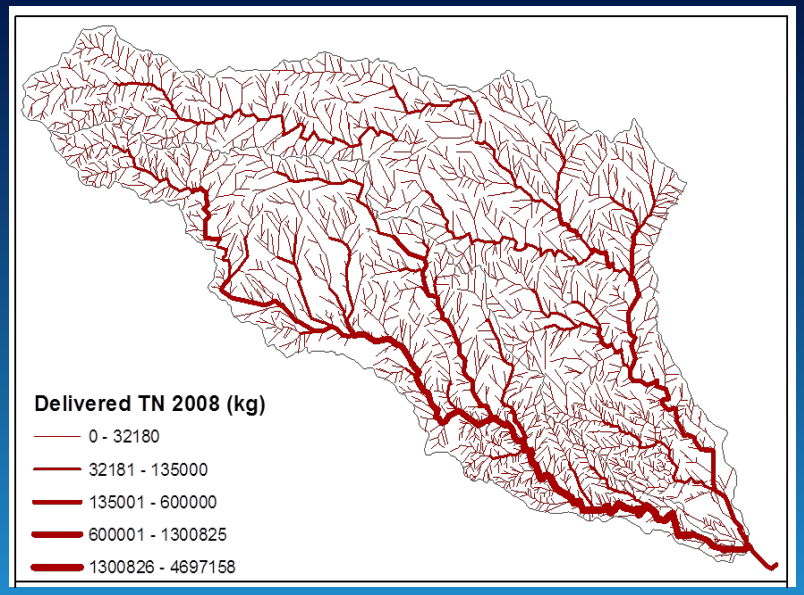
Point sources, Reservoirs and lakes

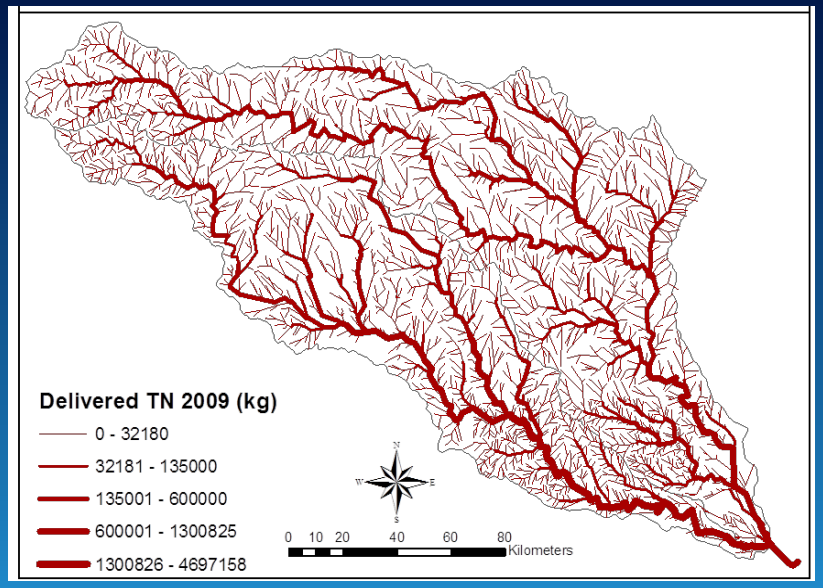


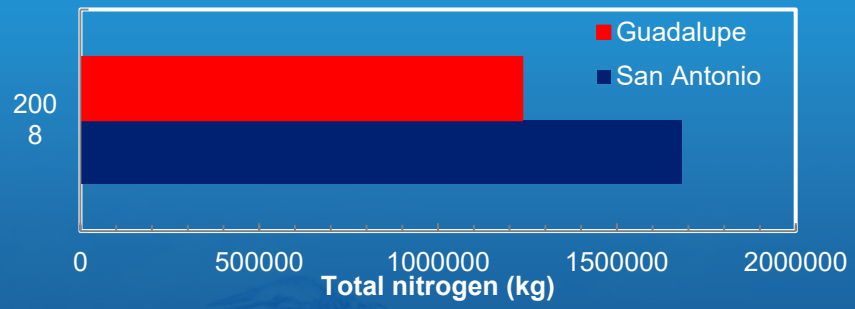
Seven lakes and reservoirs

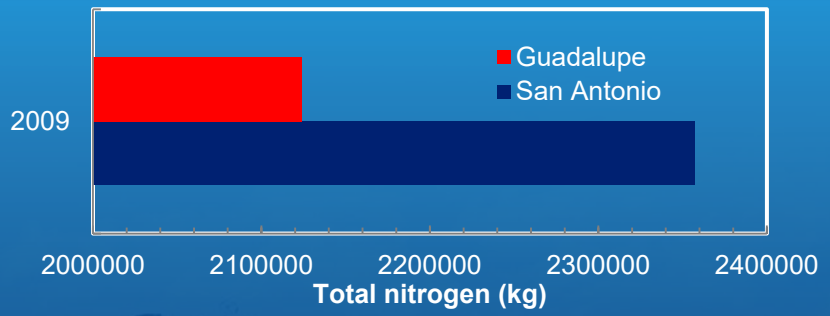
53 point sources: 37 in the San Antonio basin and 16 in the Guadalupe basin

Spatial variation of in-stream TN









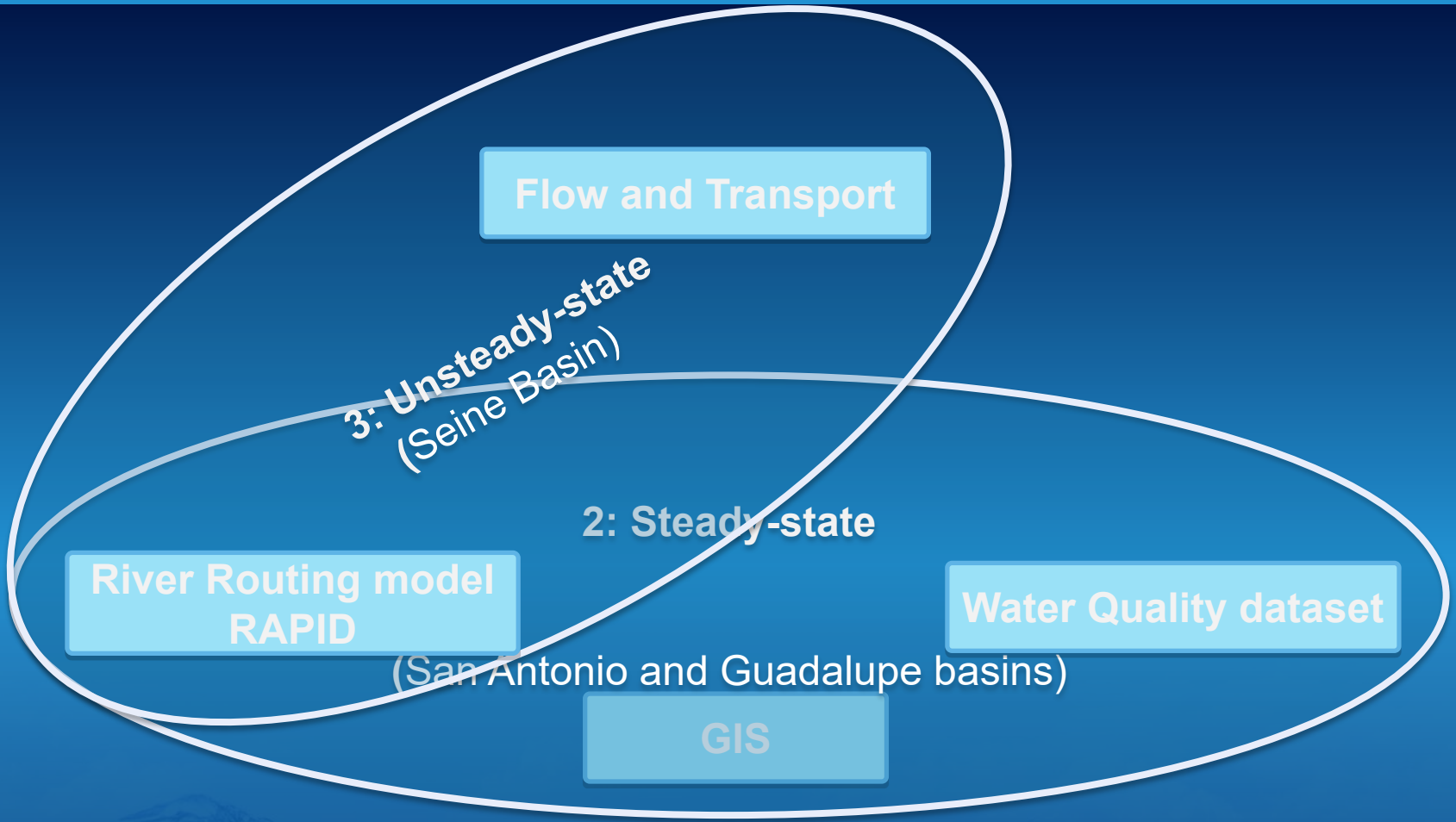
The San Antonio basin delivers 26% more TN load than the Guadalupe basin in a 2008
The San Antonio basin delivers 10% more than the Guadalupe basin's contribution in 2009

The San Antonio basin is affected more substantially by urban activities

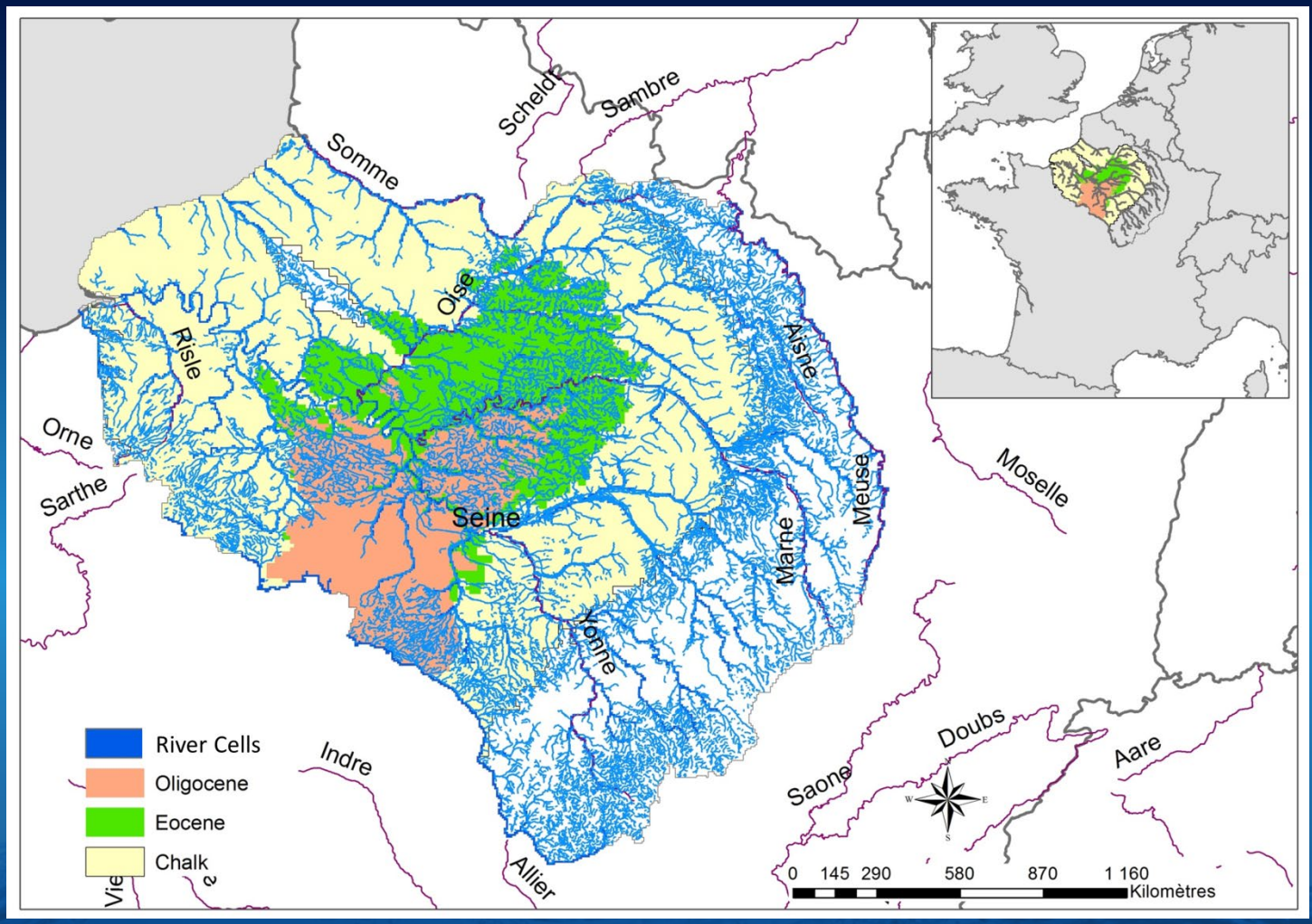
Results

- ✓GIS framework can be applied to represent a spatial distribution of flow and water quality factors in a large river network with *thousands of river segment*
- ✓Spatially intense pollutant modeling *can be implemented* within GIS, but it is hard to make it fully dynamic
  - The San Antonio basin contributed more TN than the Guadalupe basin
  - Both basins delivered more TN to the Gulf of Mexico in 2009 than in 2008

Dynamic flow and transport modeling

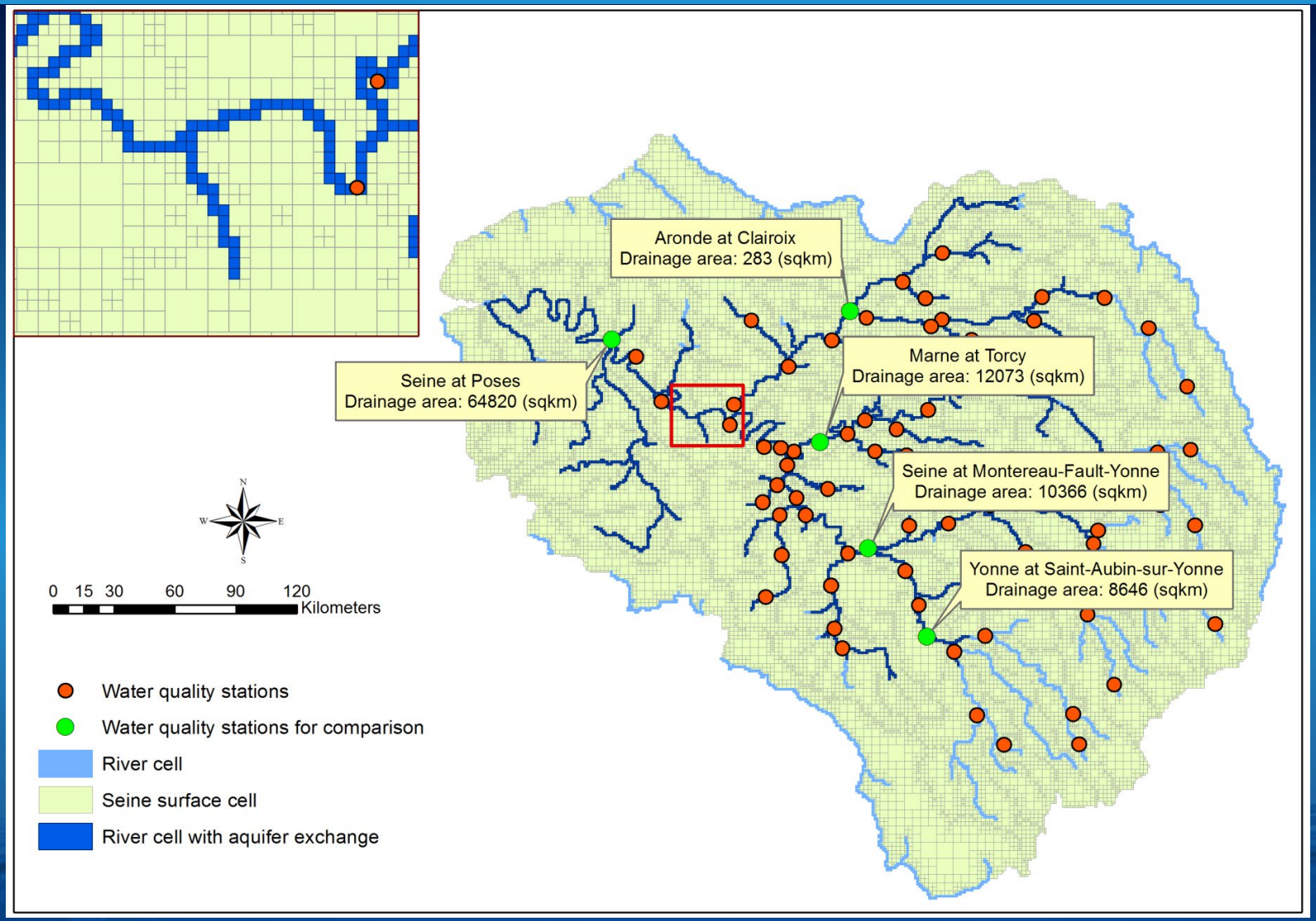


Seine River Basin



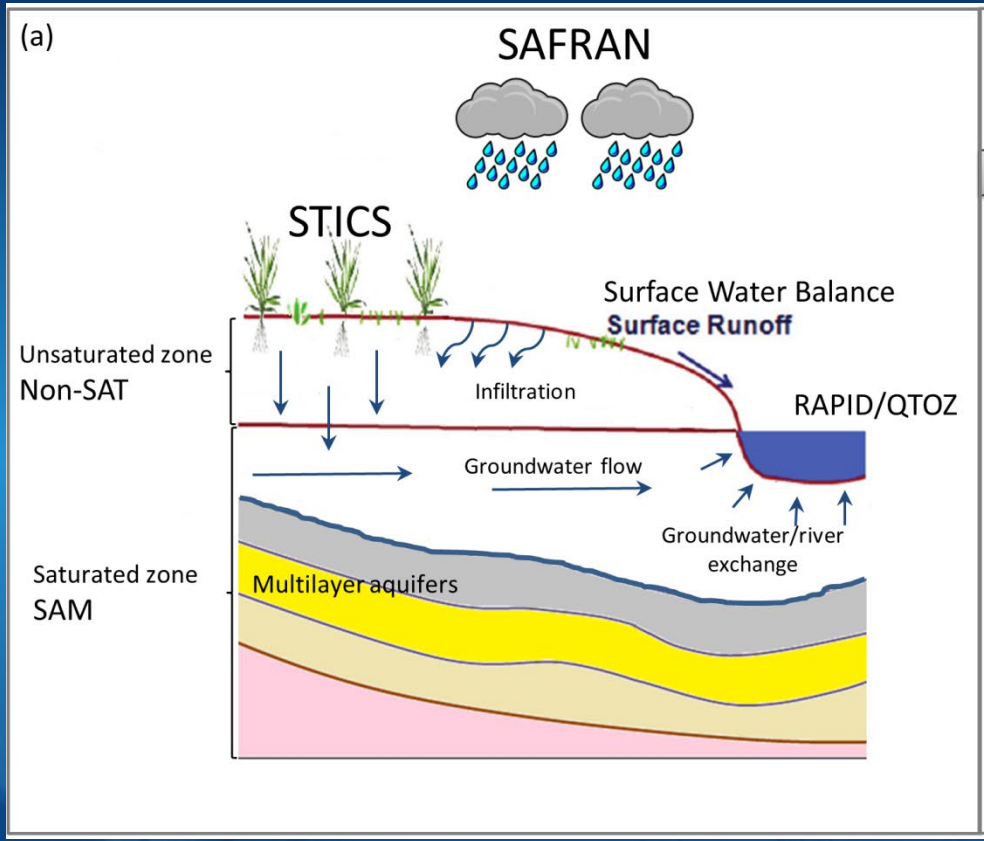
Simulation time period: 39 years (1979-2010) with daily time step for nitrate modeling
Total area: 80,500 km^2

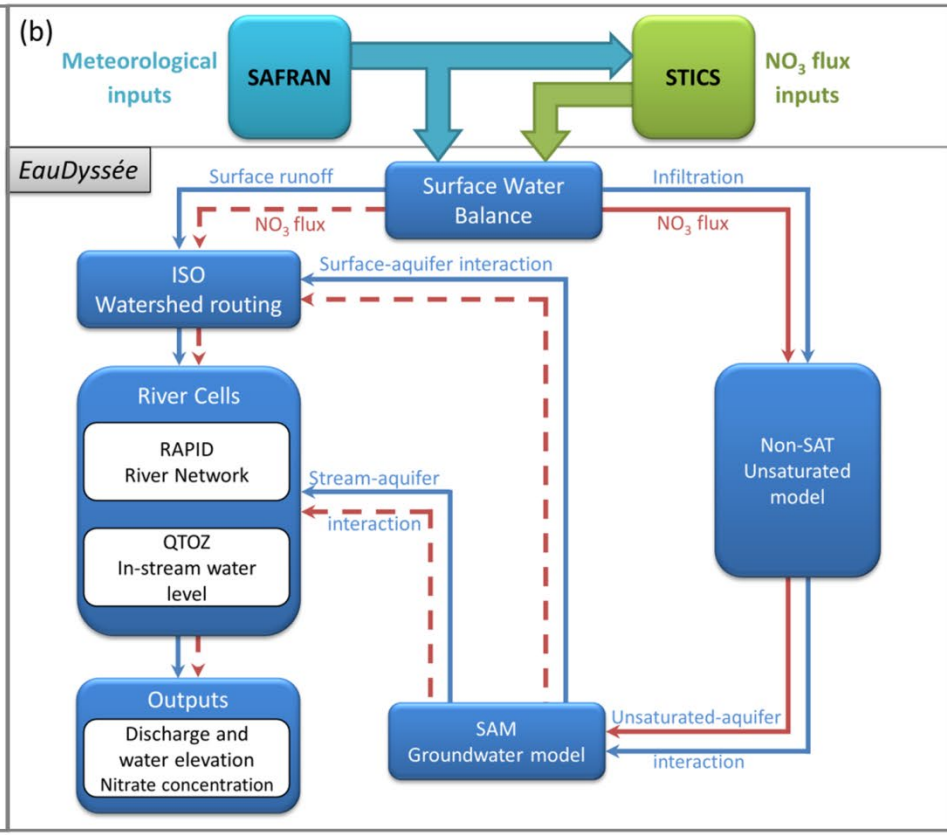
Seine River network and water quality stations



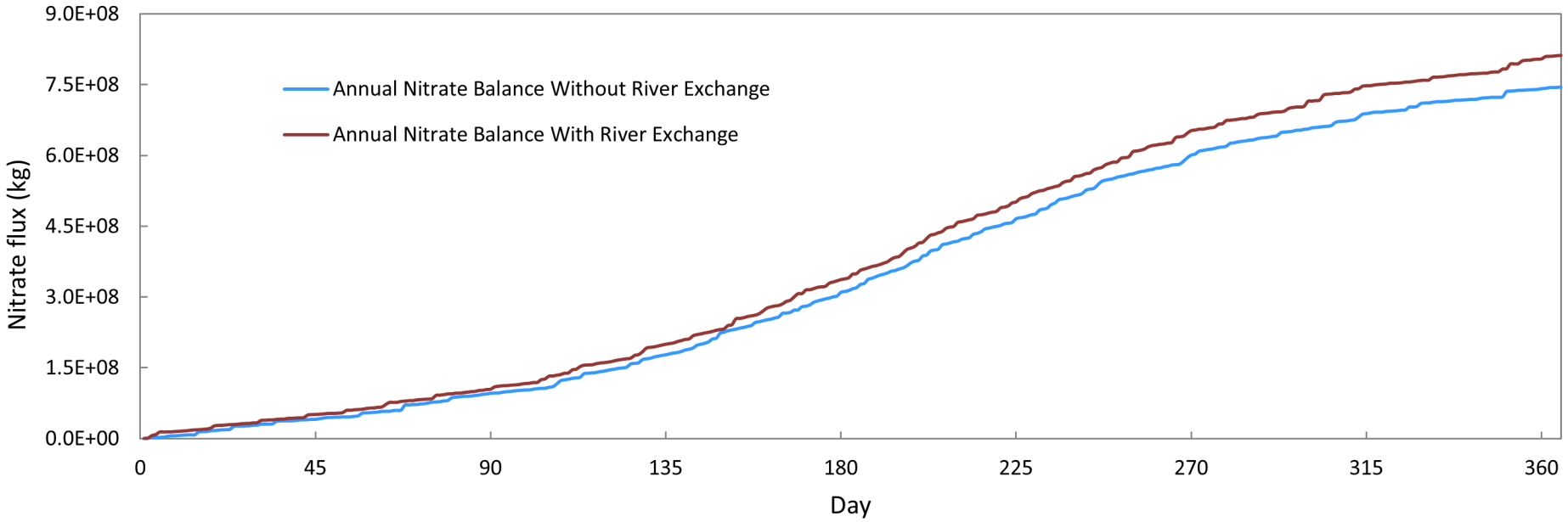
6481 river grid-cells, 72 stations with more than 150 water quality sampling dates

Eau-Dyssée modeling platform



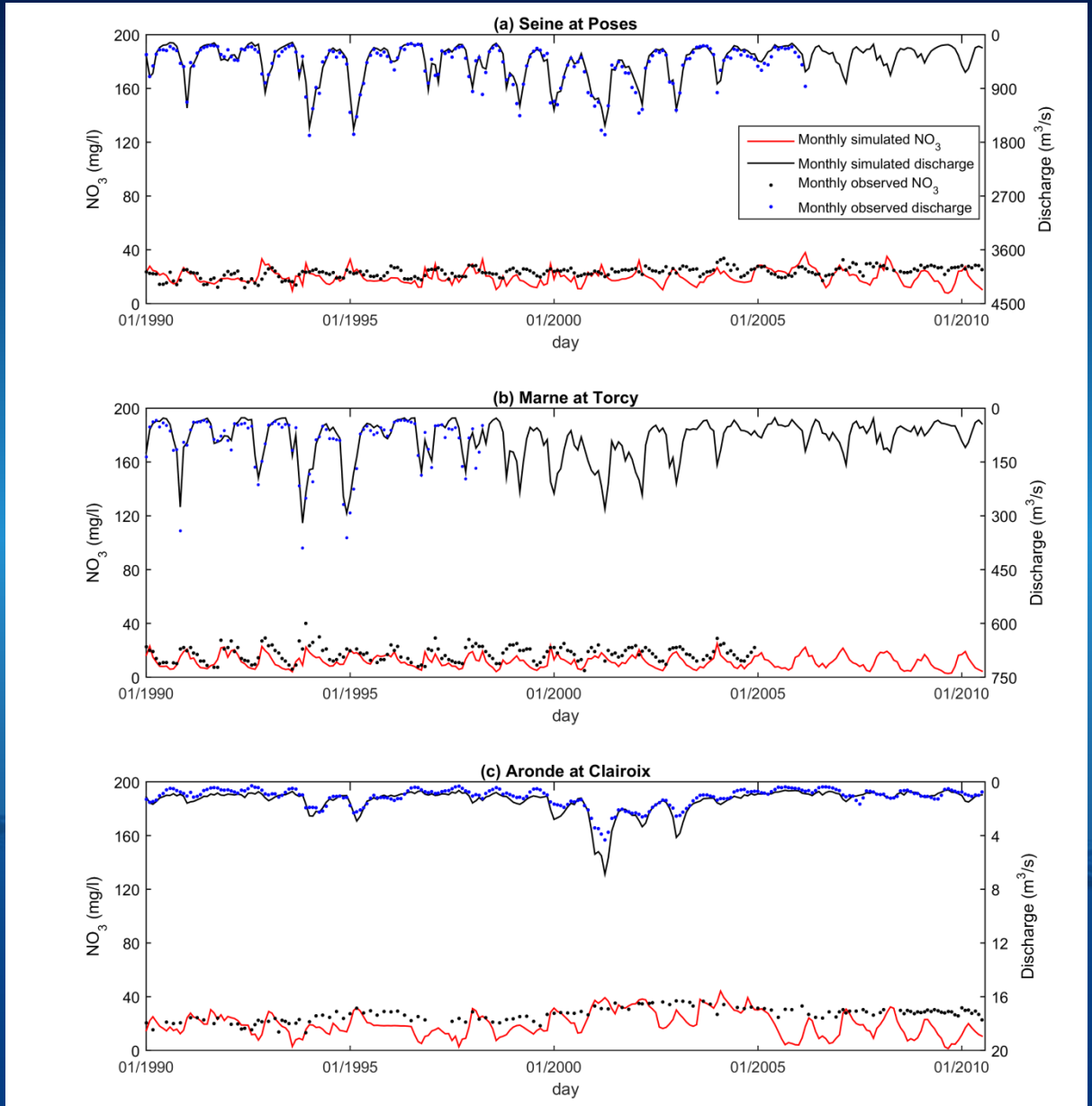


Annual average nitrate balance

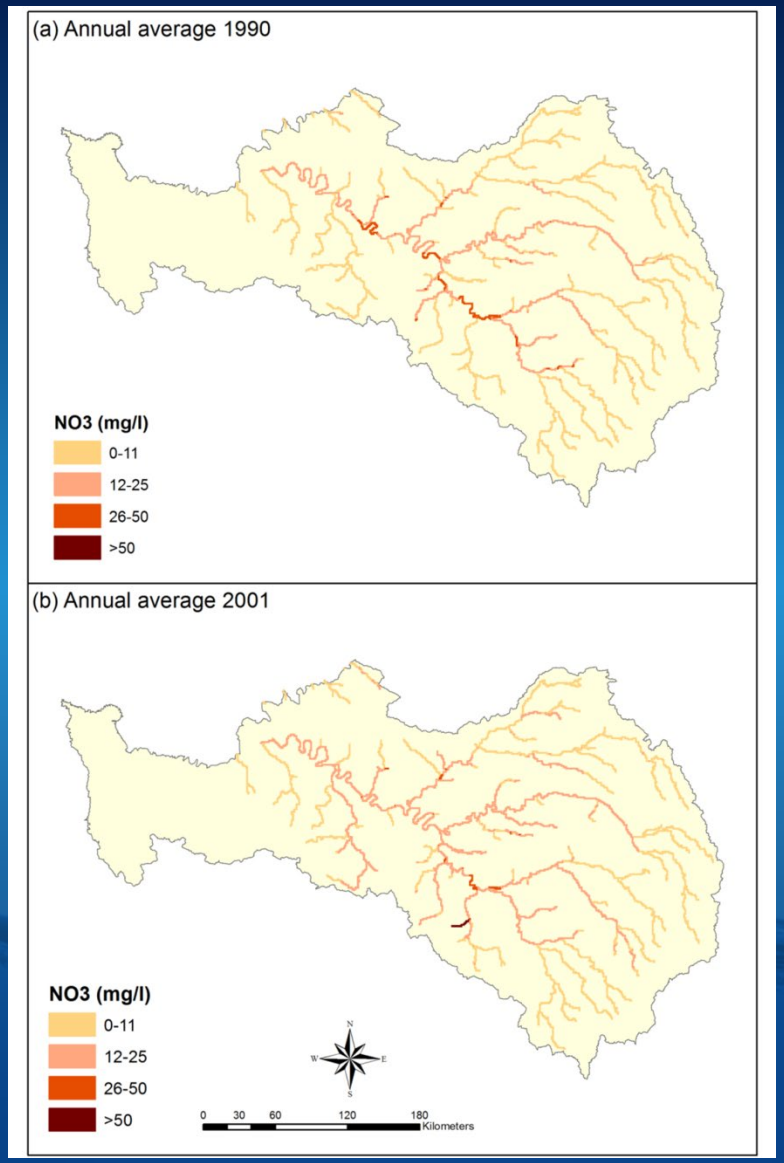


Approximately 10% of nitrate flux is delivered to the river network from aquifers

Seasonal comparison of simulated and observed nitrate



Annual Spatial Variation of Nitrate Concentration



Results

- The simulated results compared favorably to the measured data on an mean annual basis
- Model results showed that simulated nitrate highly depends on the inflow produced by surface and subsurface waters
- Variation of mean annual nitrate from year to year can be explained by the hydrologic regime of that year

Questions

Ahmad A. Tavakoly, PhD
ERDC-Coastal and Hydraulics Laboratory (CHL)
UMD-Earth System Science Interdisciplinary Center (ESSIC)
Ahmad.A.Tavakoly@erdc.dren.mil
Office: 301-405-9180