The Dynamic Land Ecosystem Model (DLEM): Overview

Hanqin Tian
Auburn University

Chesapeake Hypoxia Analysis and Modeling Program (CHAMP)

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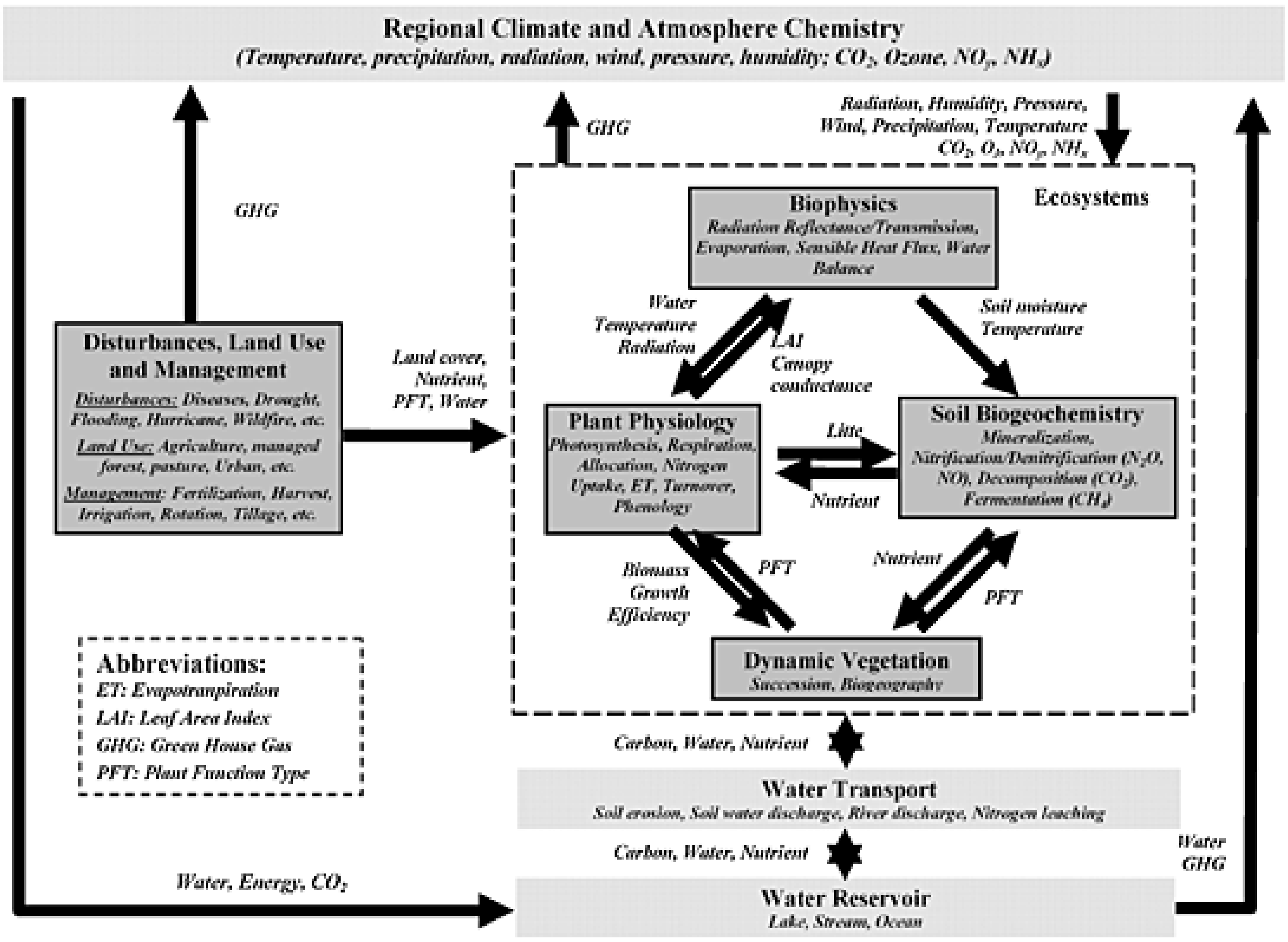
CBPO 410 Severn Avenue, Annapolis, MD

Outline

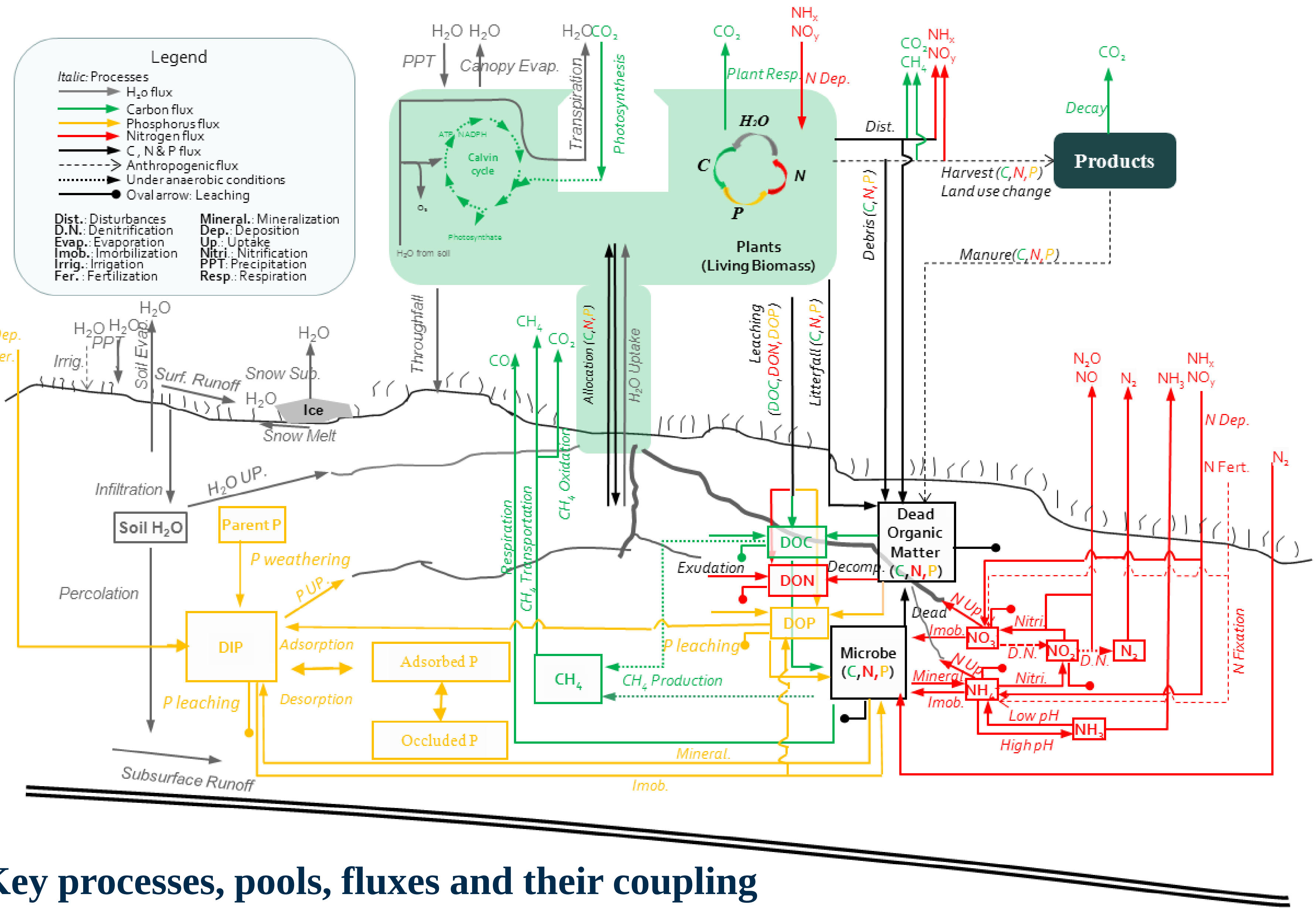
- **DLEM – Dynamic Land Ecosystem Model**
- **DLEM applications:**
  - **NASA IDS project – US Eastern Coast**
  - **NASA IDS project - Chesapeake and Delaware Watershed**
- **DLEM for NOAA CHAMP**
- **Future plan**

The DLEM Framework



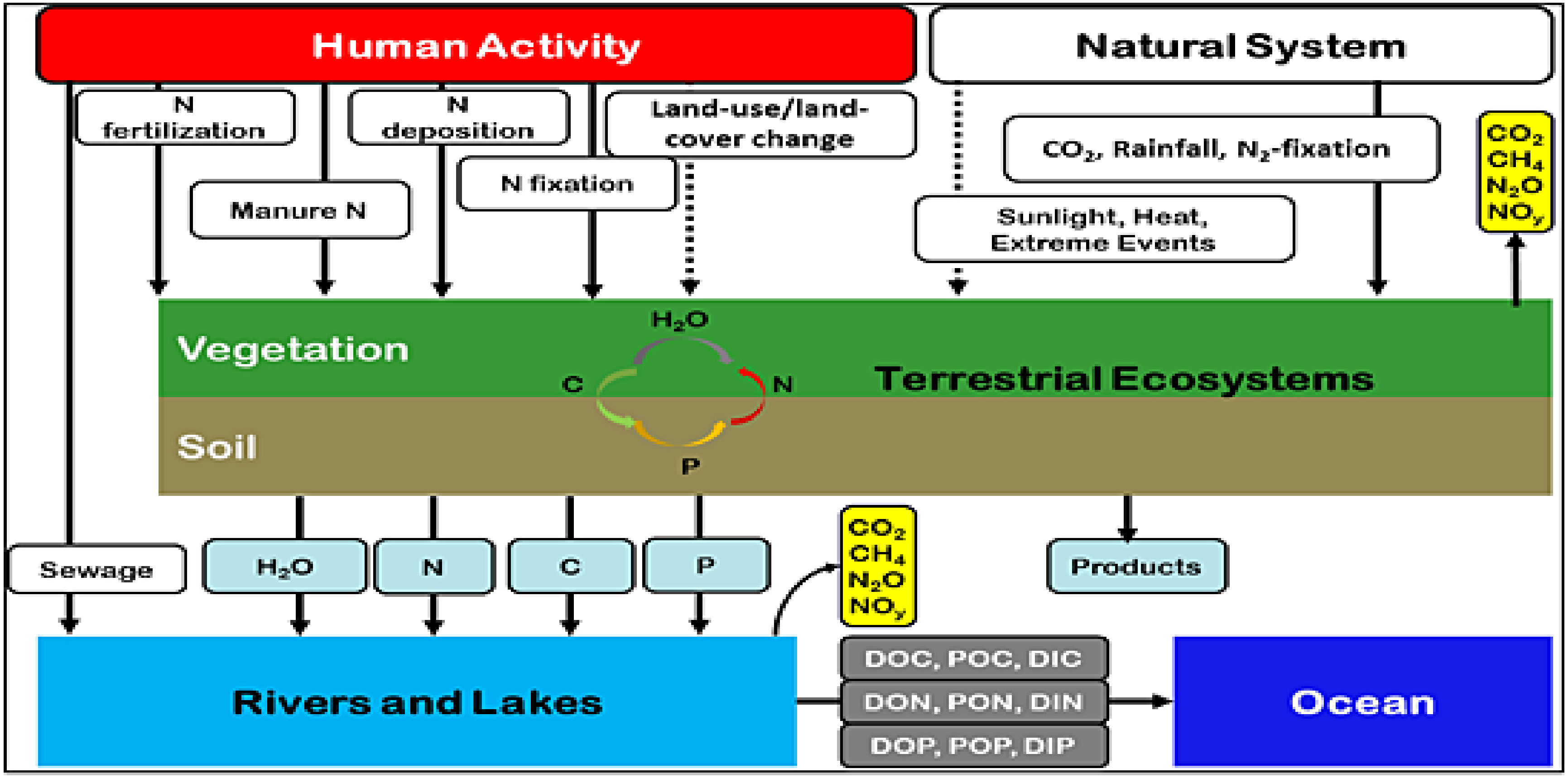
Tian et al., 2015-JGR-Biogeoscience

DLEM - A coupled biogeochemical model



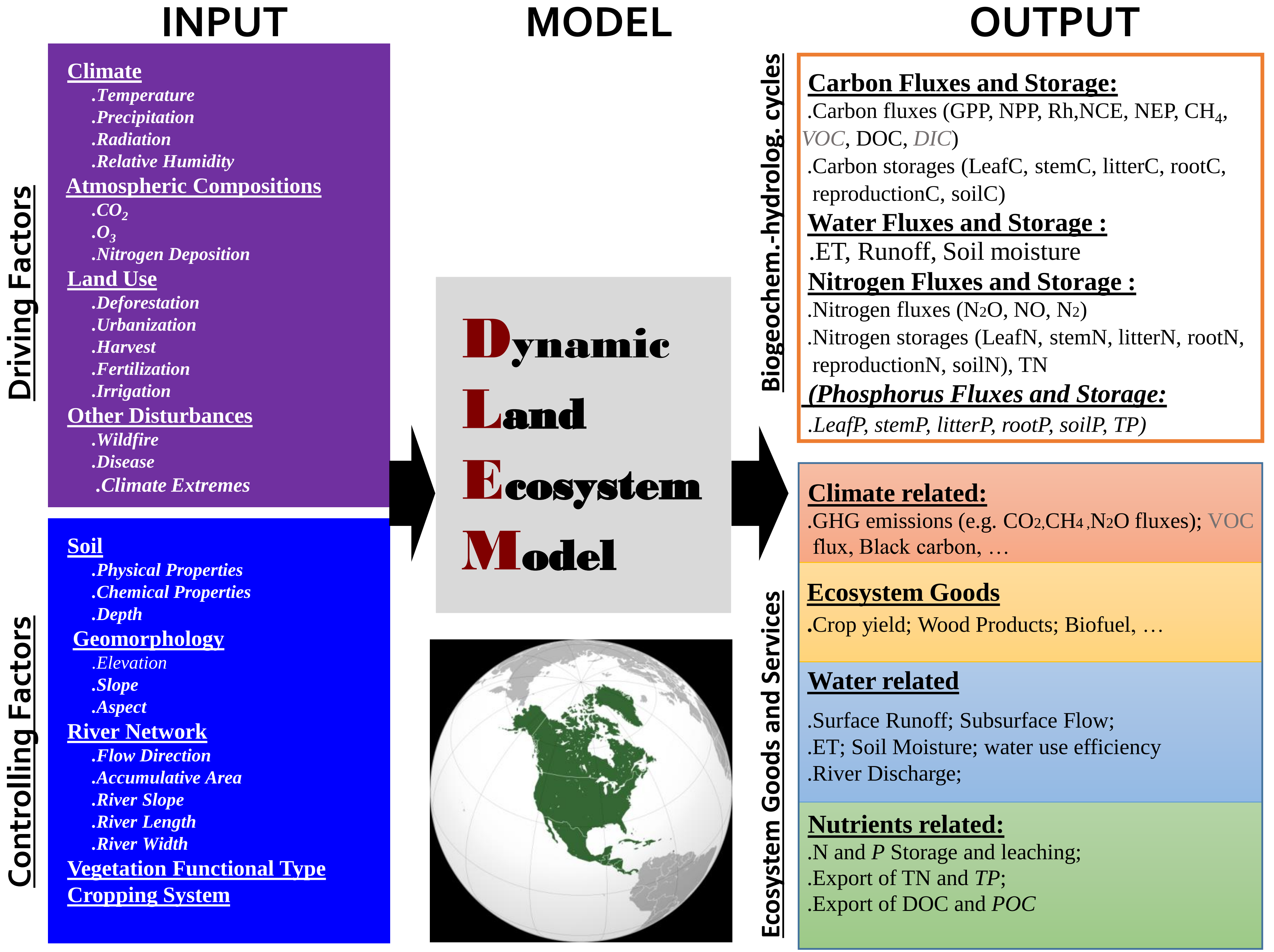
Key processes, pools, fluxes and their coupling

DLEM module: the terrestrial-aquatic interfaces



Major natural and human driving forces and key biogeochemical fluxes (C: Carbon; N: Nitrogen; and P: phosphorus) along the terrestrial-aquatic interfaces.

Tian et al., 2015-JGR-Biogeoscience



INPUT
MODEL
OUTPUT
Driving Factors
Climate
.Temperature
.Precipitation
.Radiation
.Relative Humidity
Atmospheric Compositions
.CO_2
.O_3
.Nitrogen Deposition
Land Use
.Deforestation
.Urbanization
.Harvest
.Fertilization
.Irrigation
Other Disturbances
.Wildfire
.Disease
.Climate Extremes
Controlling Factors
Soil
.Physical Properties
.Chemical Properties
.Depth
Geomorphology
.Elevation
.Slope
.Aspect
River Network
.Flow Direction
.Accumulative Area
.River Slope
.River Length
.River Width
Vegetation Functional Type
Cropping System
Dynamic
Land
Ecosystem
Model
Biogeochem.-hydrolog. cycles
Carbon Fluxes and Storage:
.Carbon fluxes (GPP, NPP, Rh,NCE, NEP, CH_4, VOC, DOC, DIC)
.Carbon storages (LeafC, stemC, litterC, rootC, reproductionC, soilC)
Water Fluxes and Storage :
.ET, Runoff, Soil moisture
Nitrogen Fluxes and Storage :
.Nitrogen fluxes (N_2O, NO, N_2)
.Nitrogen storages (LeafN, stemN, litterN, rootN, reproductionN, soilN), TN
(Phosphorus Fluxes and Storage:
.LeafP, stemP, litterP, rootP, soilP, TP)
Ecosystem Goods and Services
Climate related:
.GHG emissions (e.g. CO_2,CH_4,N_2O fluxes); VOC flux, Black carbon, …
Ecosystem Goods
.Crop yield; Wood Products; Biofuel, …
Water related
.Surface Runoff; Subsurface Flow;
.ET; Soil Moisture; water use efficiency
.River Discharge;
Nutrients related:
.N and P Storage and leaching;
.Export of TN and TP;
.Export of DOC and POC

Key Features of the DLEM

- ❑ Coupled cycles of C, N, P and water at multiple temporal and spatial scales

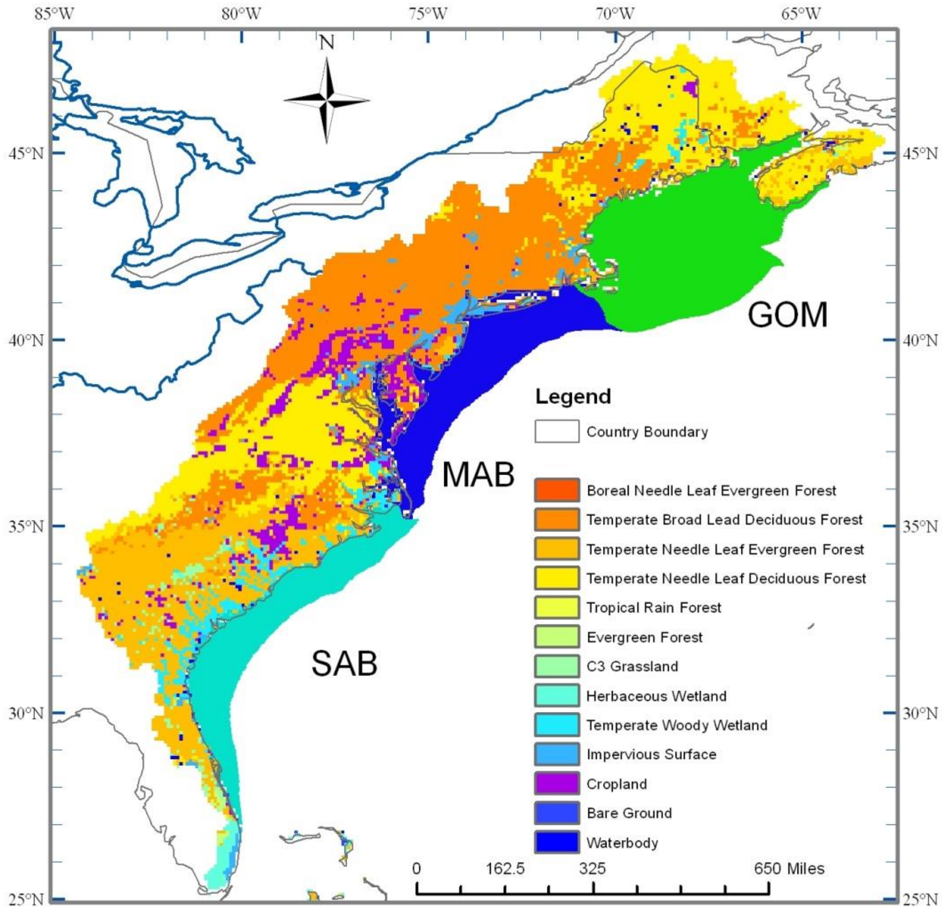
- ❑ Simultaneous consideration of three major GHGs (CO_2, CH_4 and N_2O)

- ❑ Multiple stresses including climate, CO_2, O_3, N deposition, land use/cover change, natural disturbance (fire, insect/disease, hurricane, etc.), and land management practices (e.g. irrigation, fertilization, cropping system)

- ❑ Surface-groundwater coupling

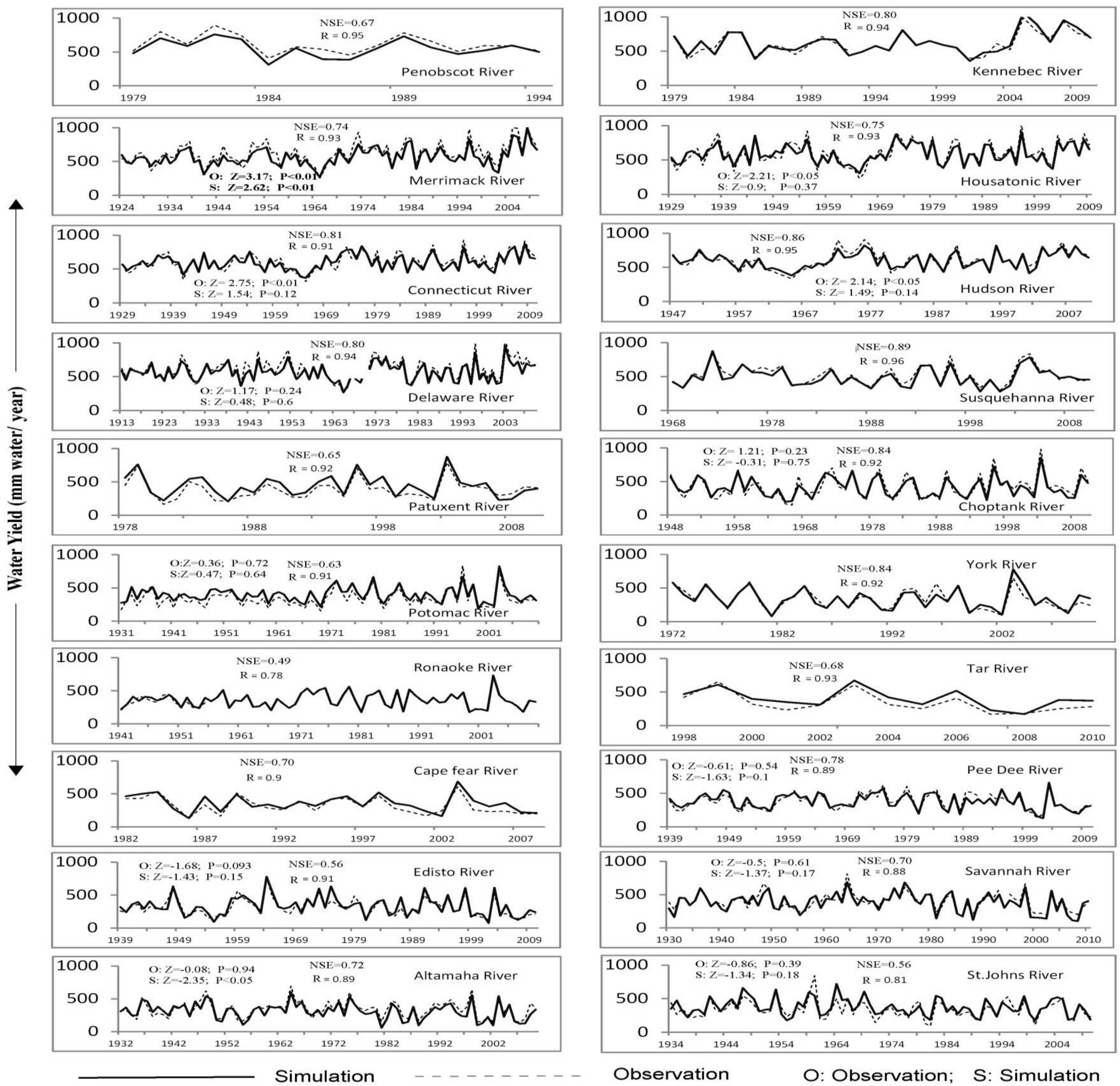
- ❑ Water and material movement over space

The study domain along the US eastern coast

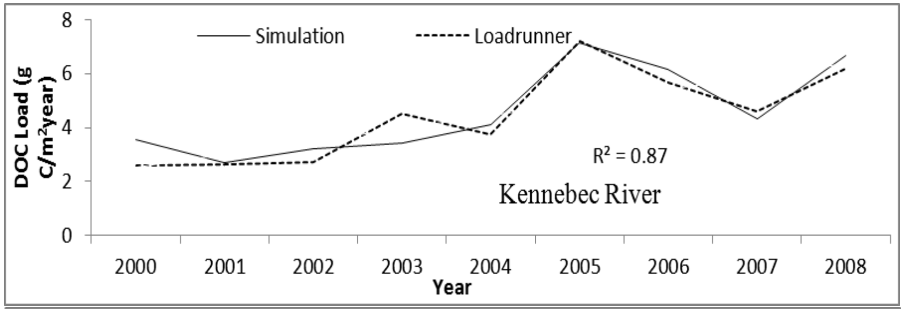


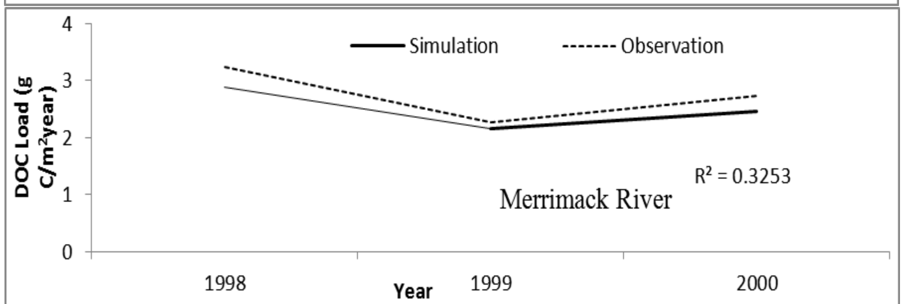
NASA IDS Project: Impacts of Changing Climate and Land Use on Carbon Cycling and Budgets of the Coastal Ocean Margin: Observations, Analysis, and Modeling

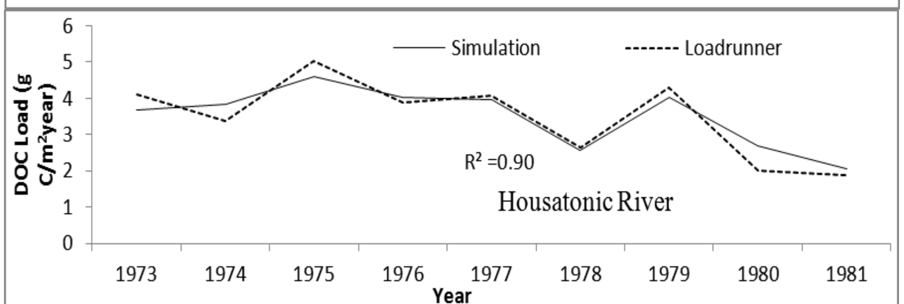
Model Evaluation: River discharge in the US Eastern Coast

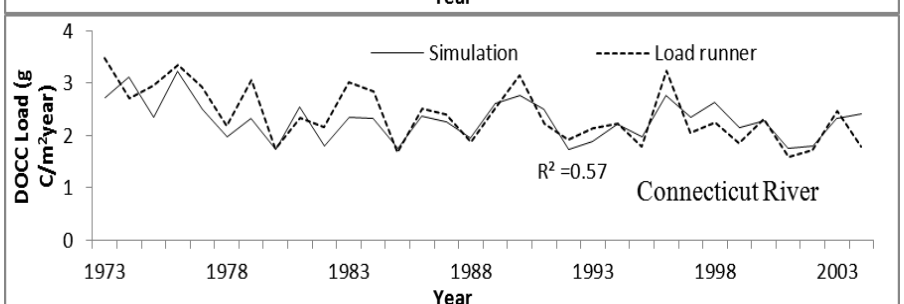


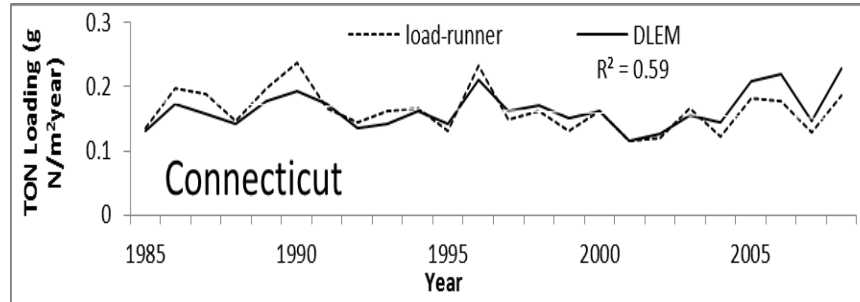
Model Evaluation: C and N in the US EC

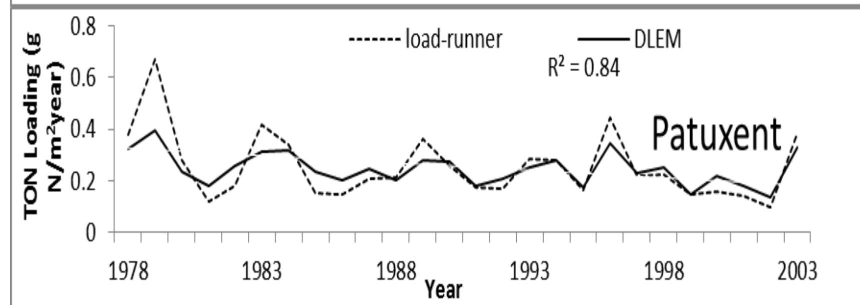


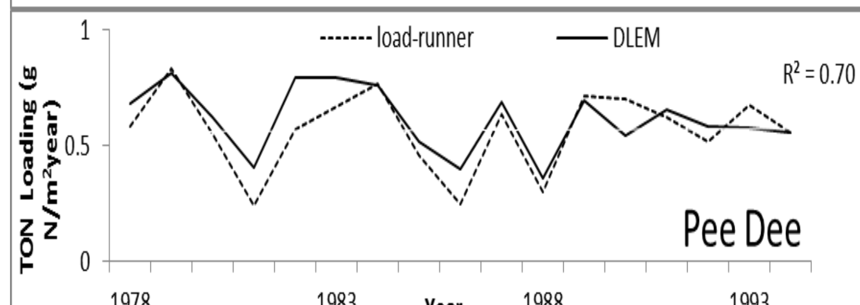


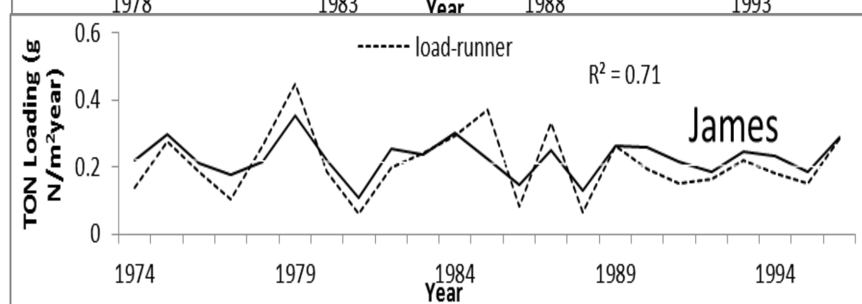




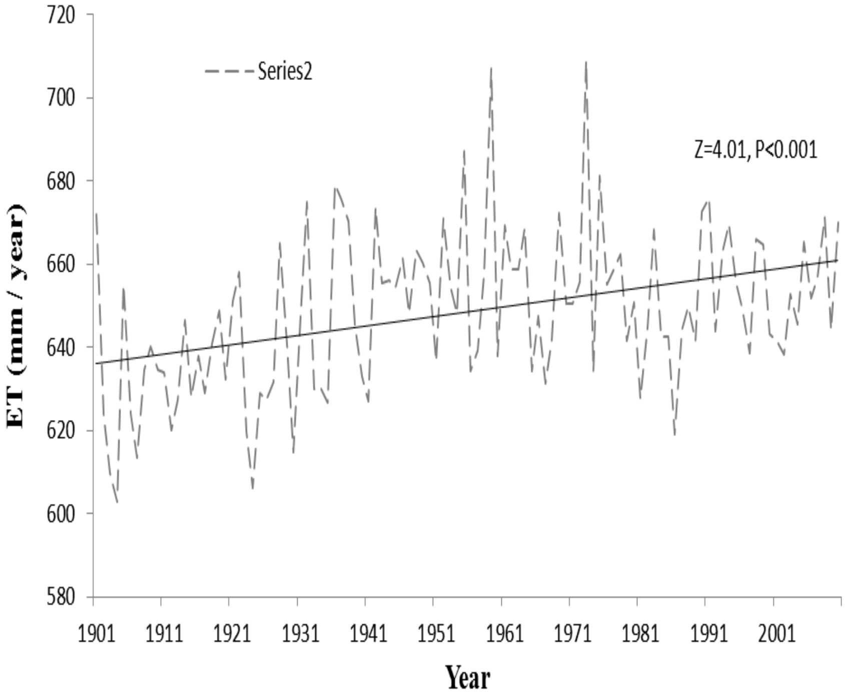


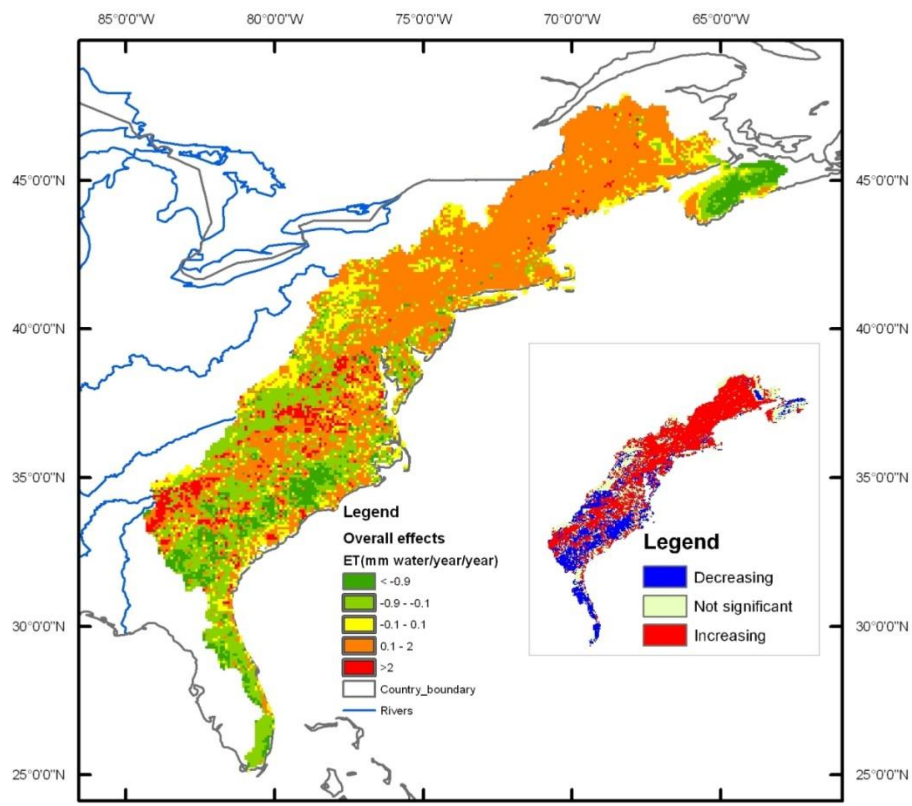






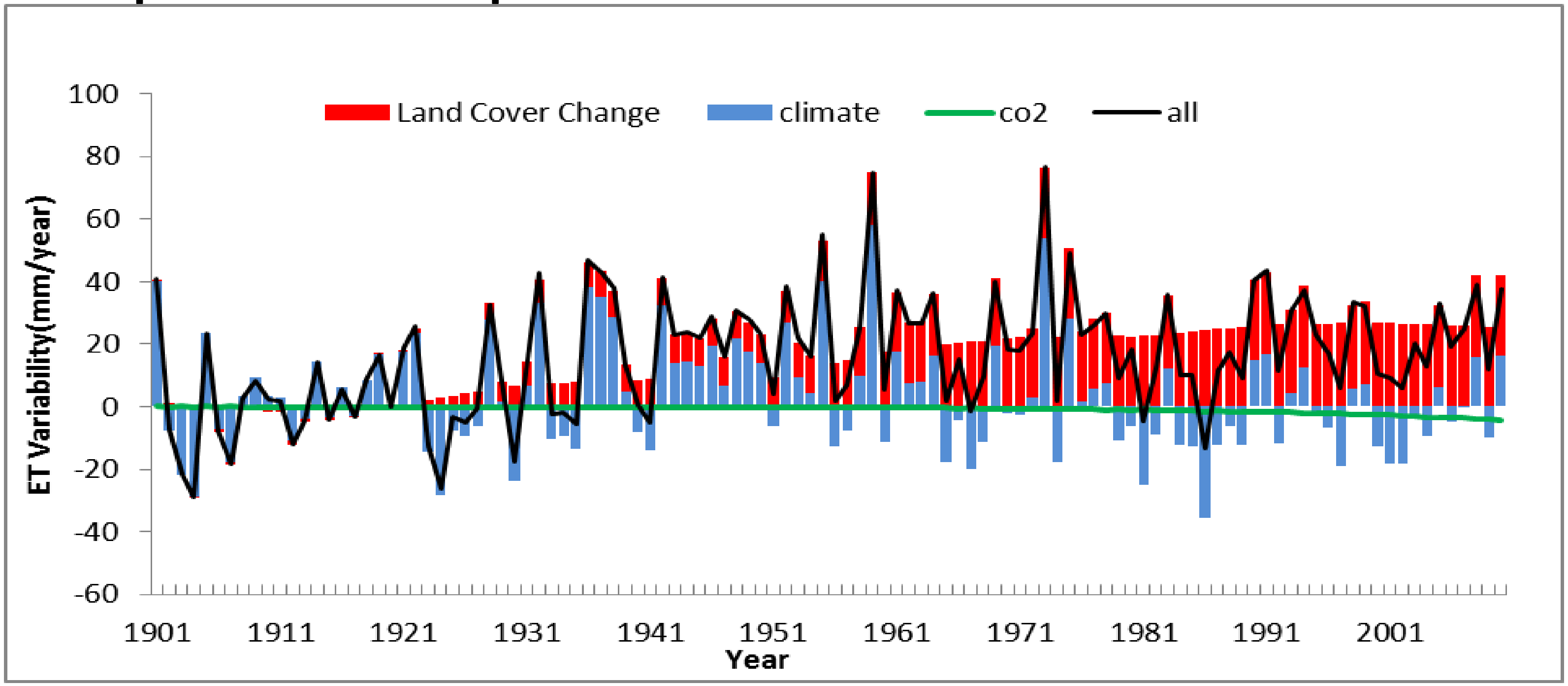
Evapotranspiration





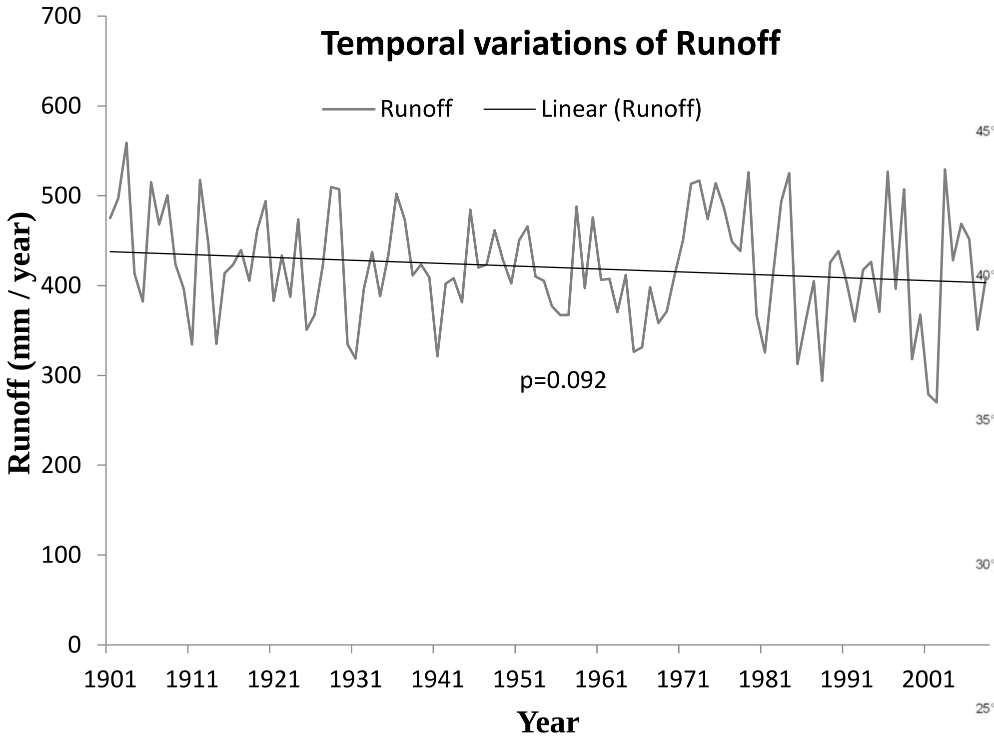
Average ET of NAECoS was 648.3±38.6 mm ET exhibited significant inter-annual variability with the maximum ET of 708 mm occurred in 1973 and the minimum ET of 603 mm in 1904.

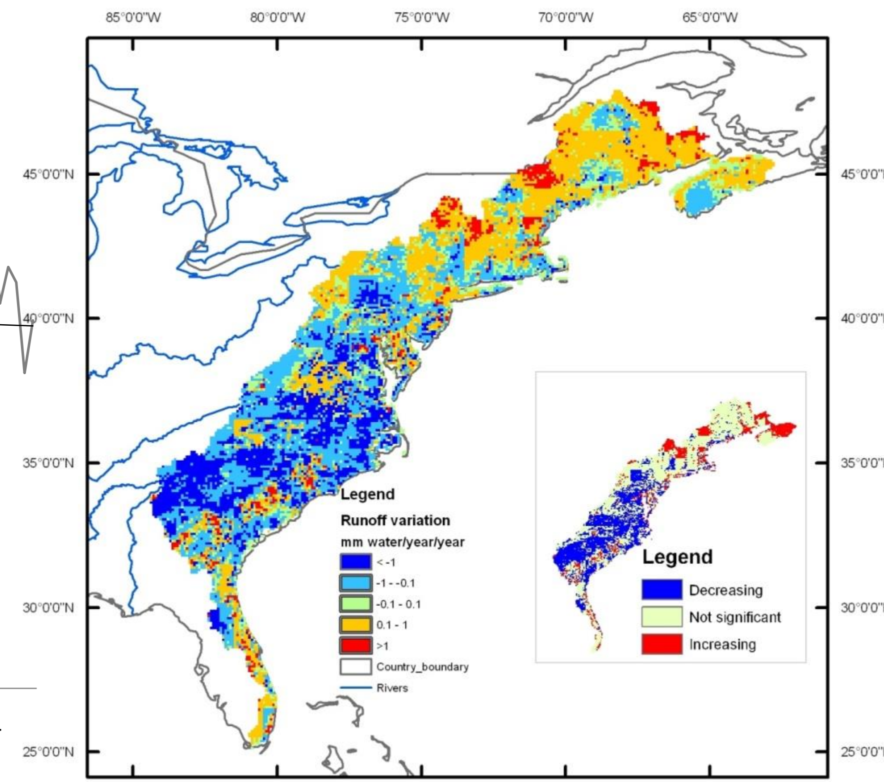
Evapotranspiration



Climate change was responsible for the interannual variability in ET; Land use Change increased ET; CO2 elevation reduced ET but not comparable with that of Land use change

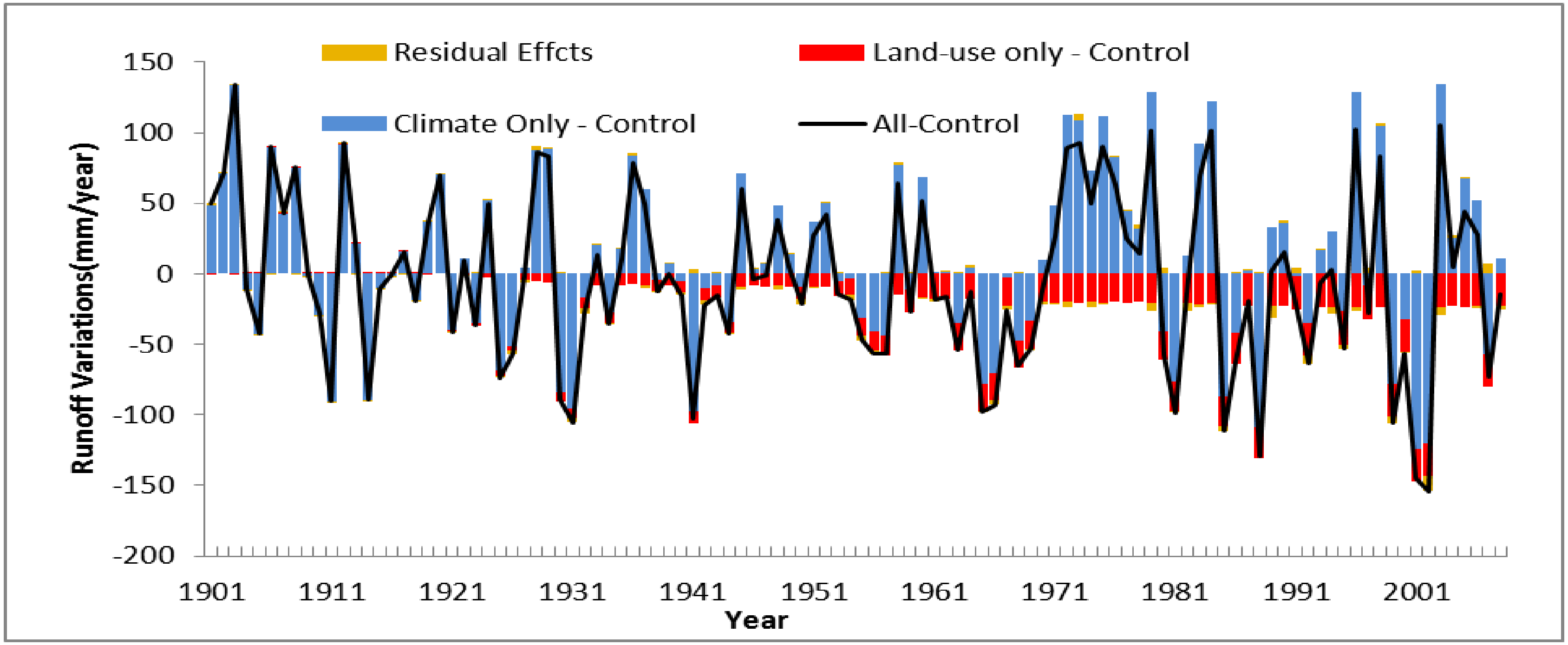
Runoff





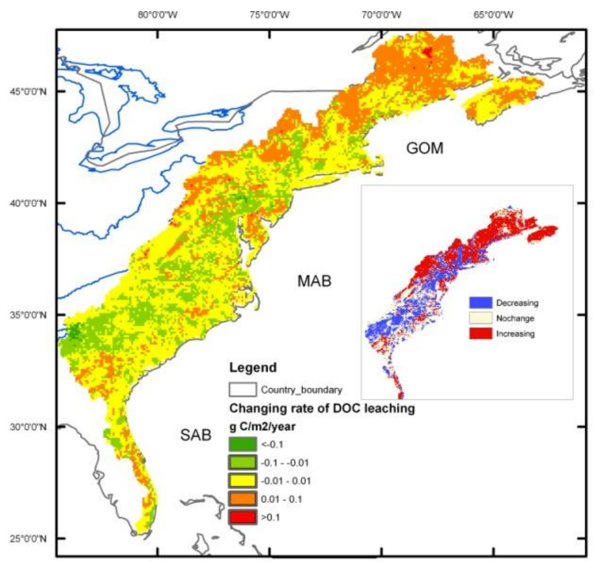
mean annual runoff was 420.5±122.2 mm (95% confidence interval) during 1901-2008.
Increased runoff generation occurred in norther NAECOS, whereas
In most part of the southern NAECoS, runoff was reduced.

Runoff

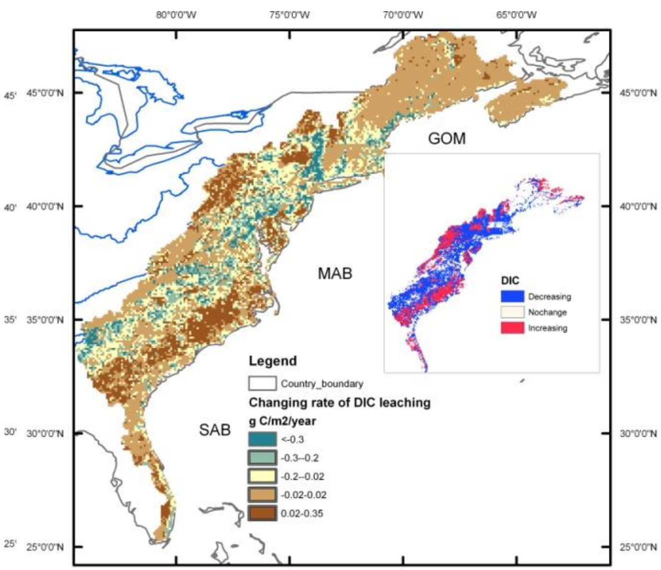


Climate change was responsible for the interannual variability in runoff; Land use Change decreased runoff and reduction in runoff by land use change increased With time.

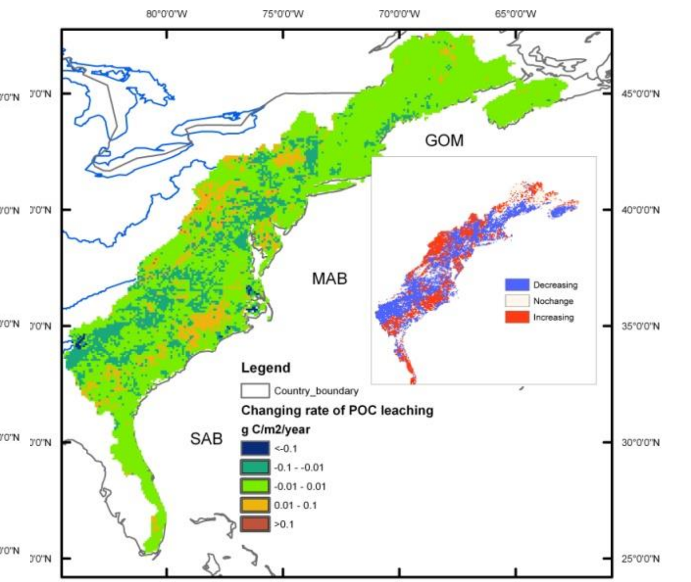
Carbon export



DOC

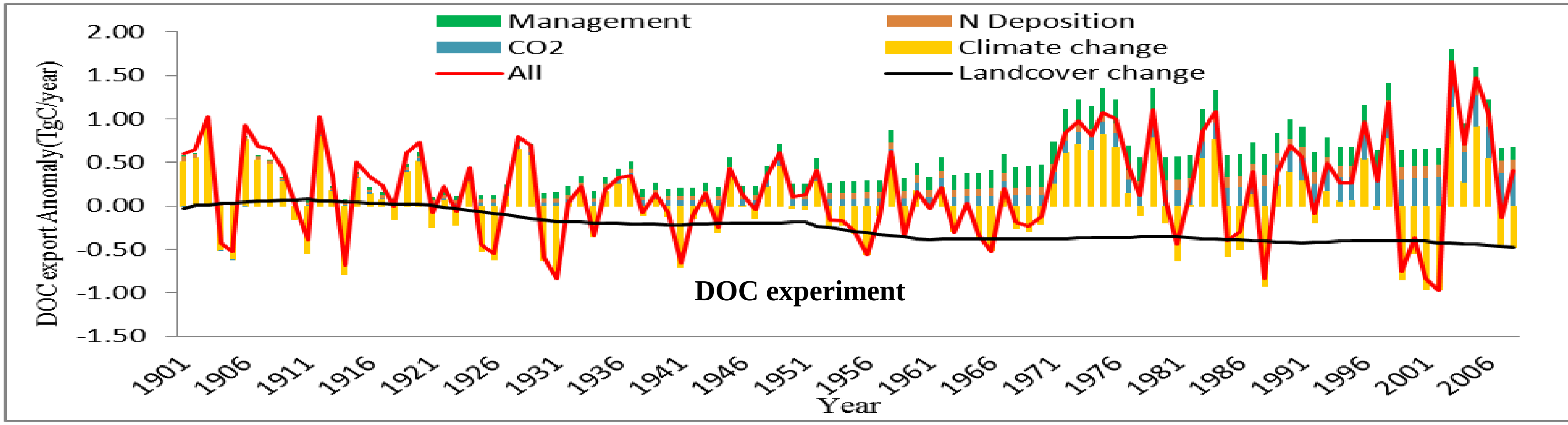


DIC

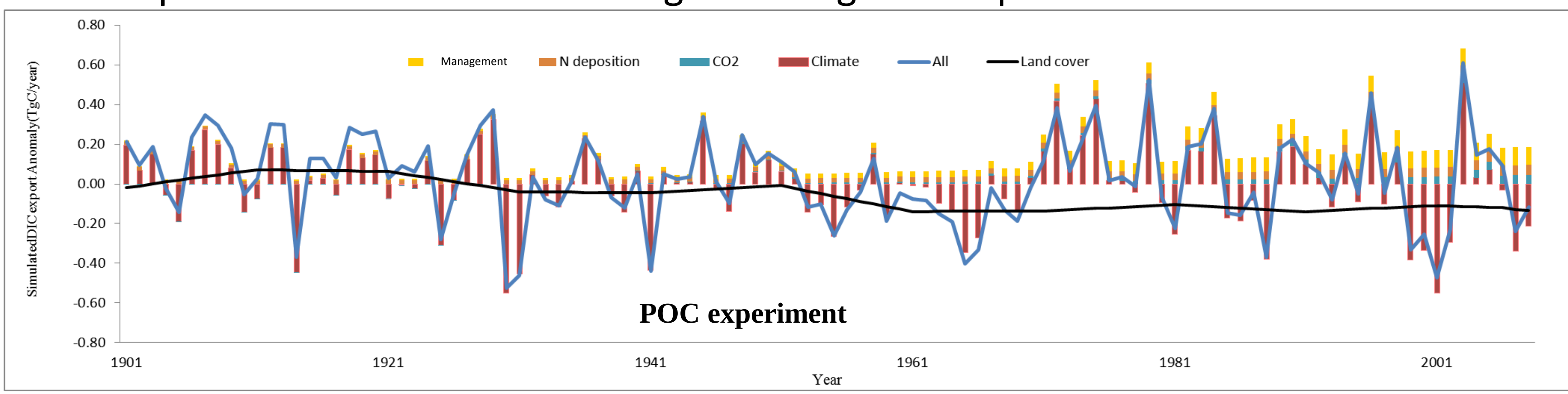


POC

Carbon export

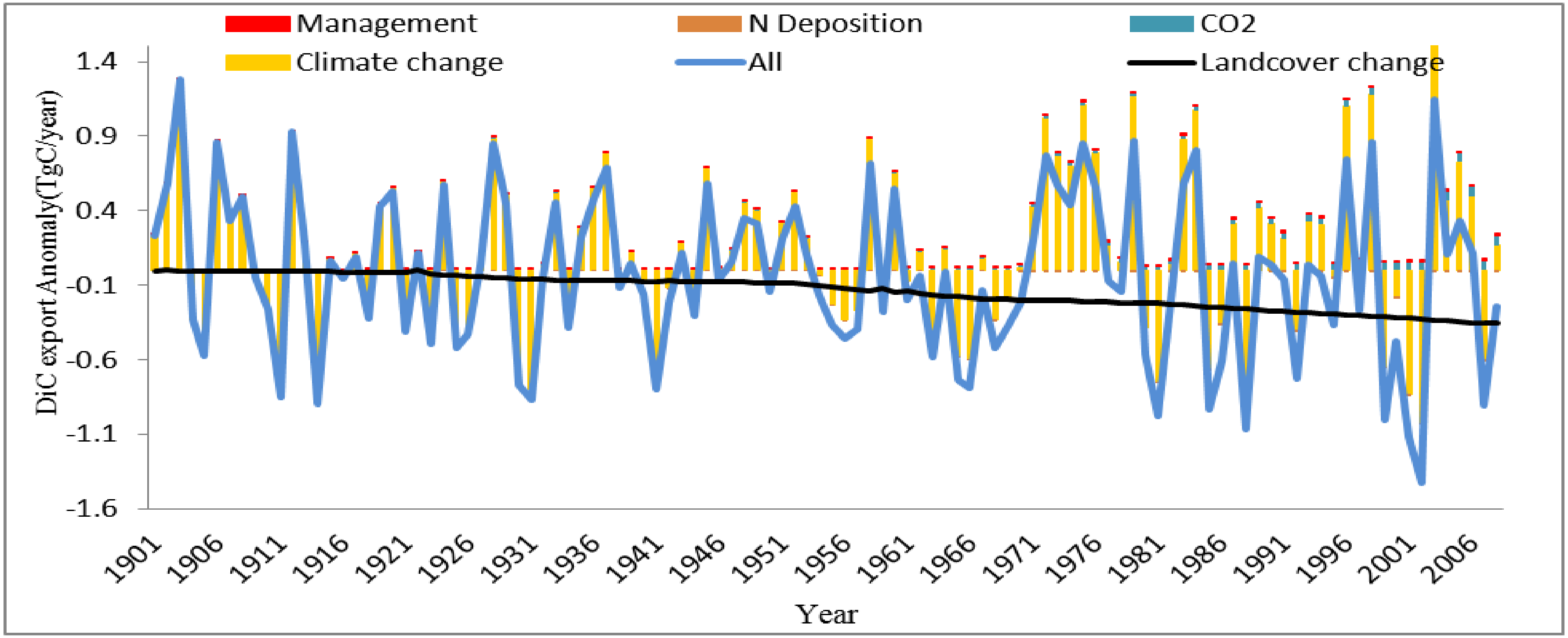


DOC export fluctuated with climate change. N disposition, CO2 elevation, N fertilizer use had positive impacts whereas land use change had negative impacts.



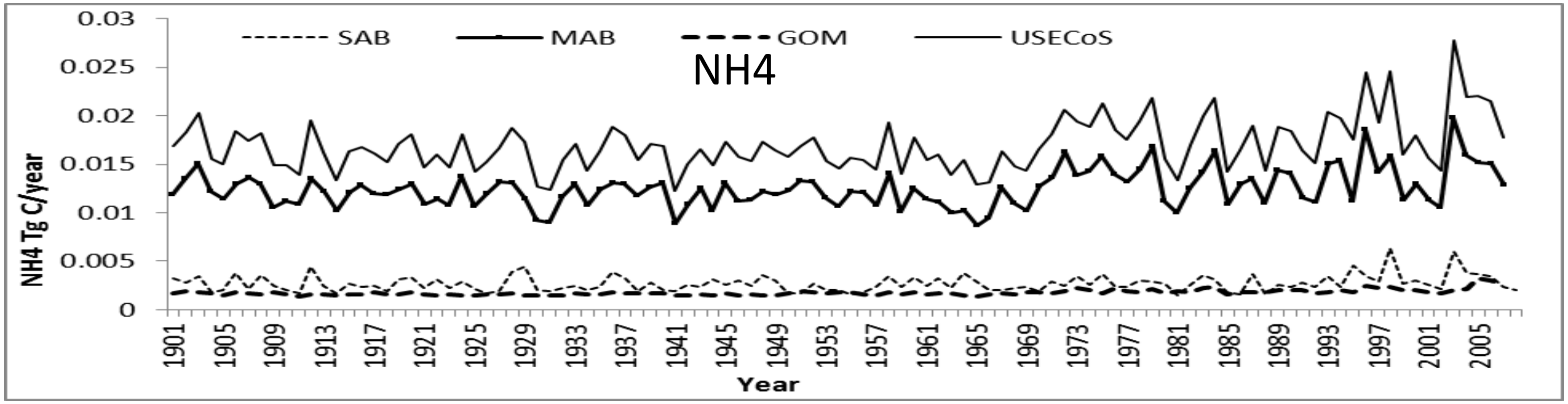
POC export varied with climate change in different years. N disposition, CO2 elevation, N fertilizer use had positive impacts whereas land use change had negative impacts.

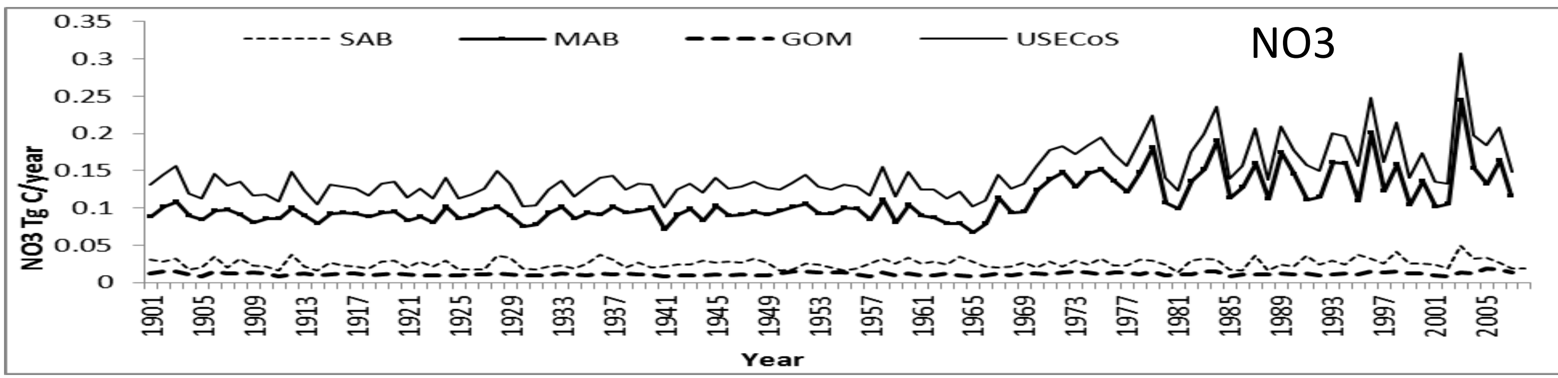
Carbon export



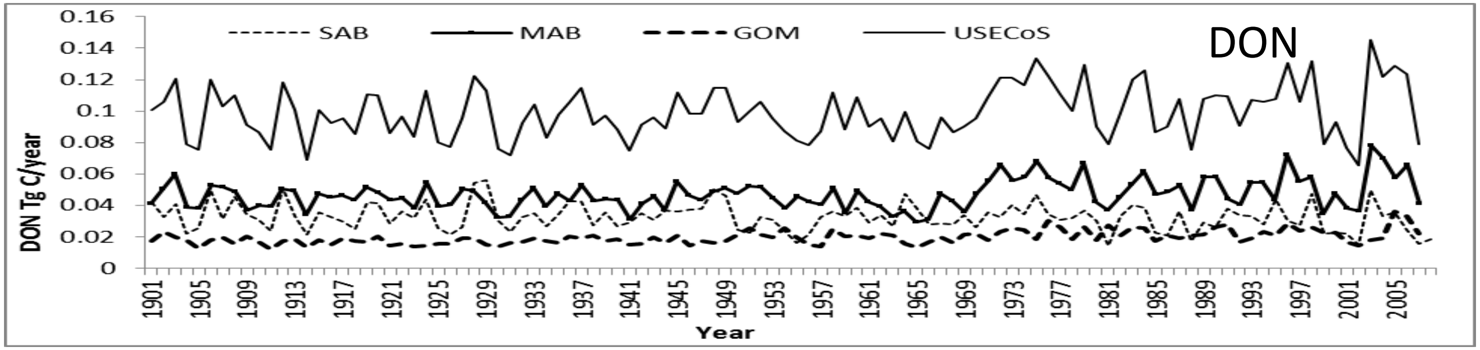
DIC experiment

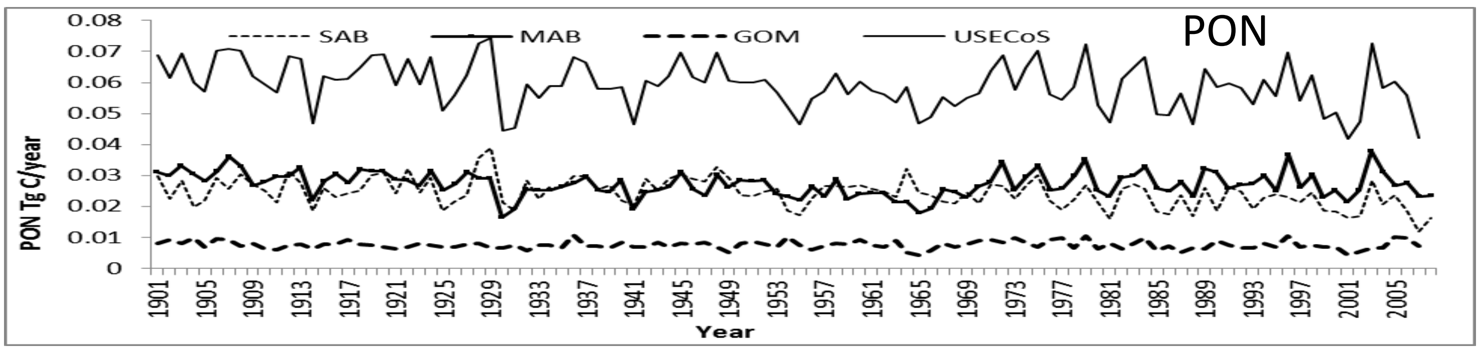
Nitrogen Export



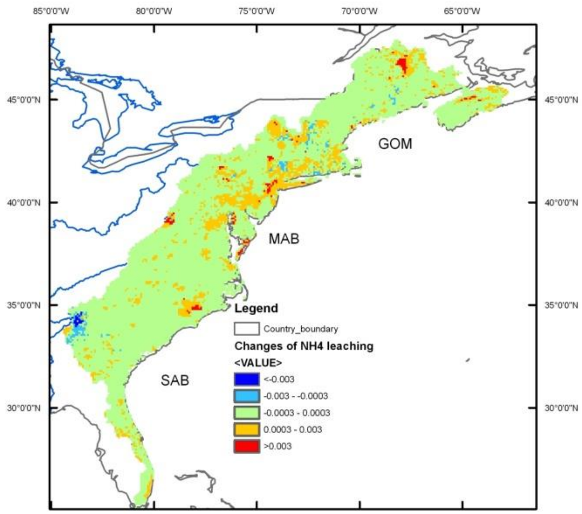


Nitrogen Export

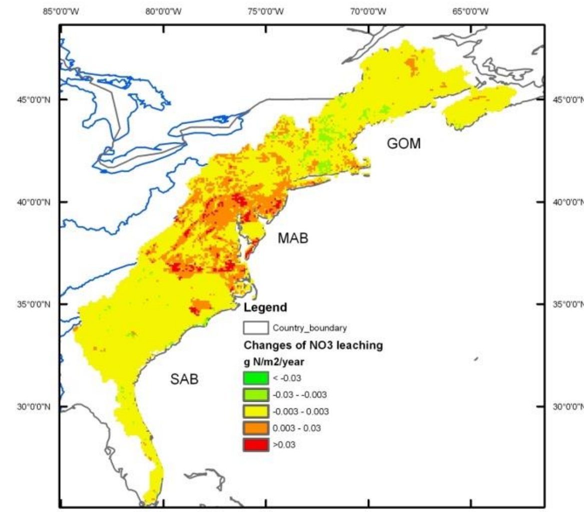




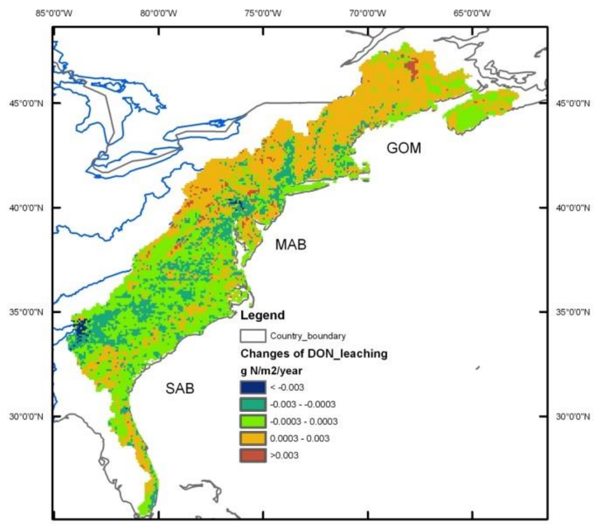
Nitrogen Export



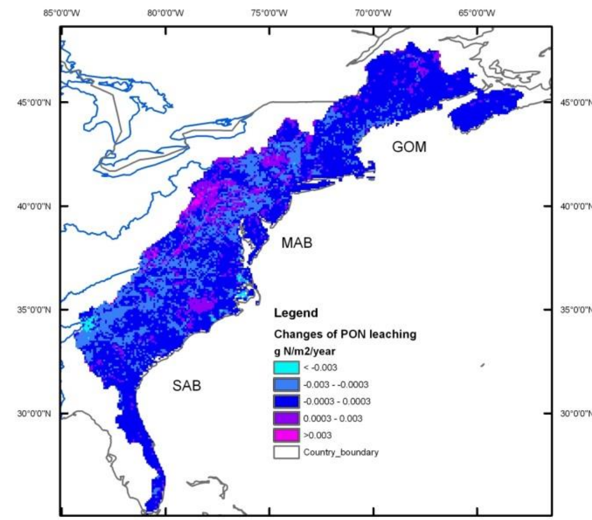
NH4



NO3

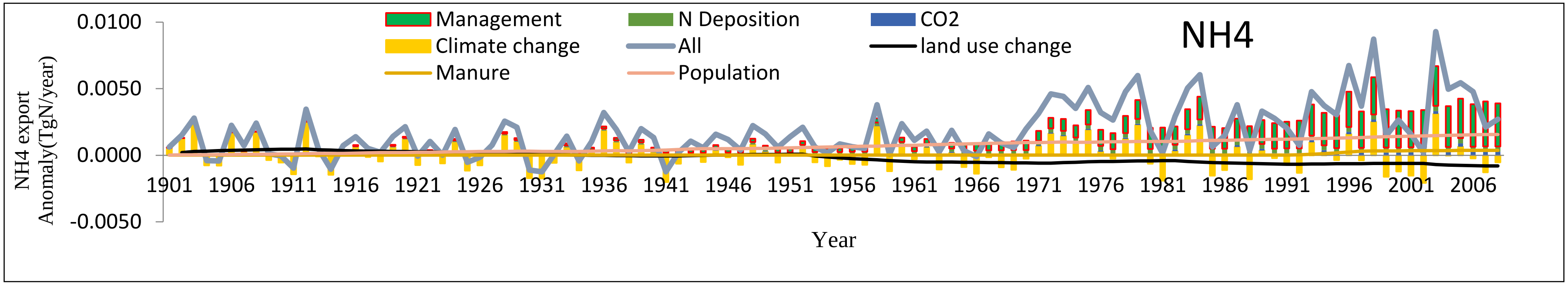


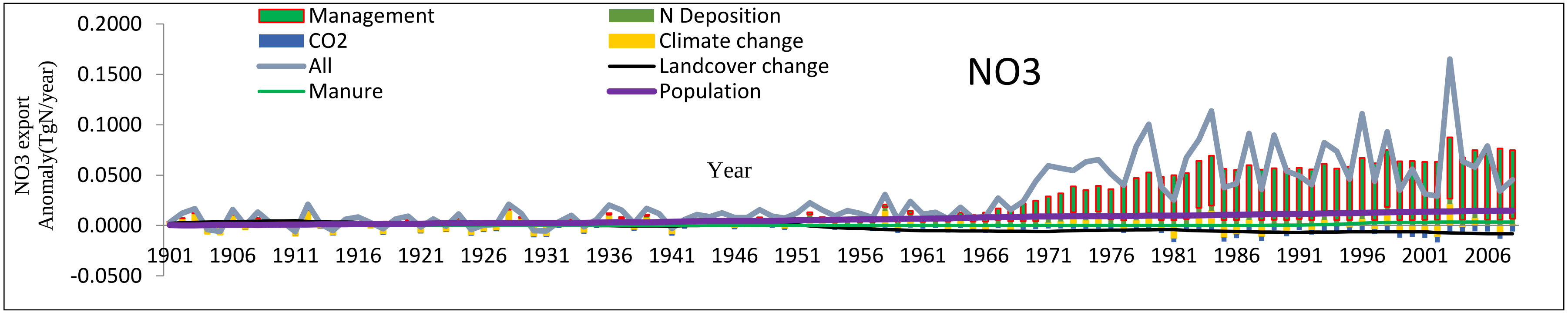
DON



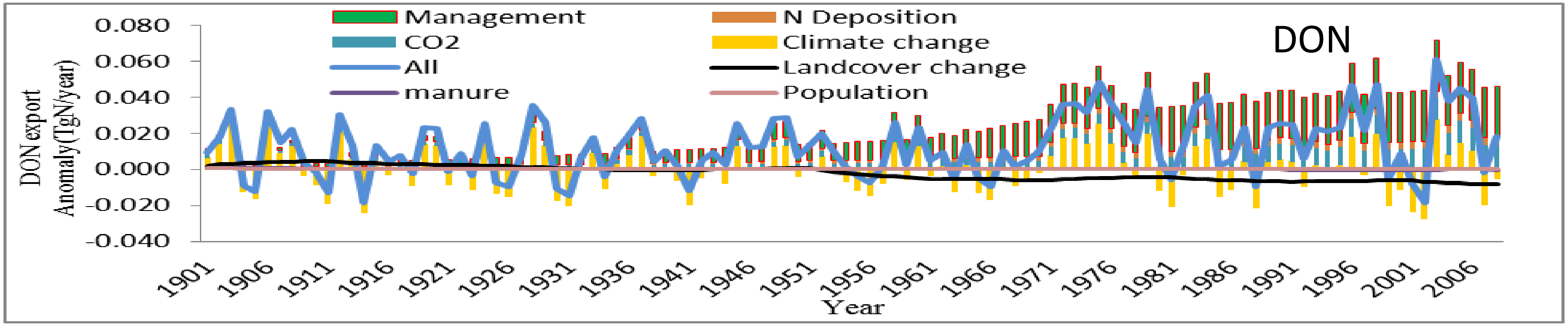
PON

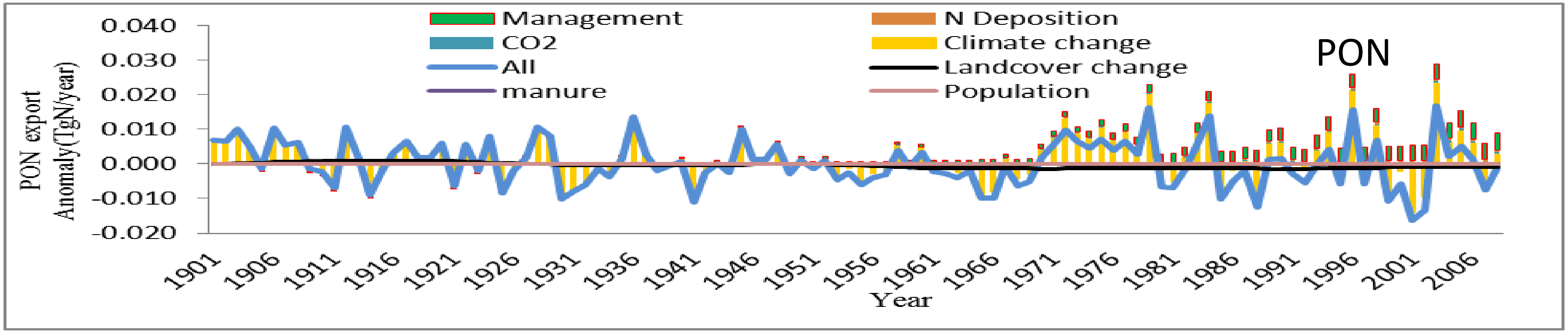
Nitrogen Export



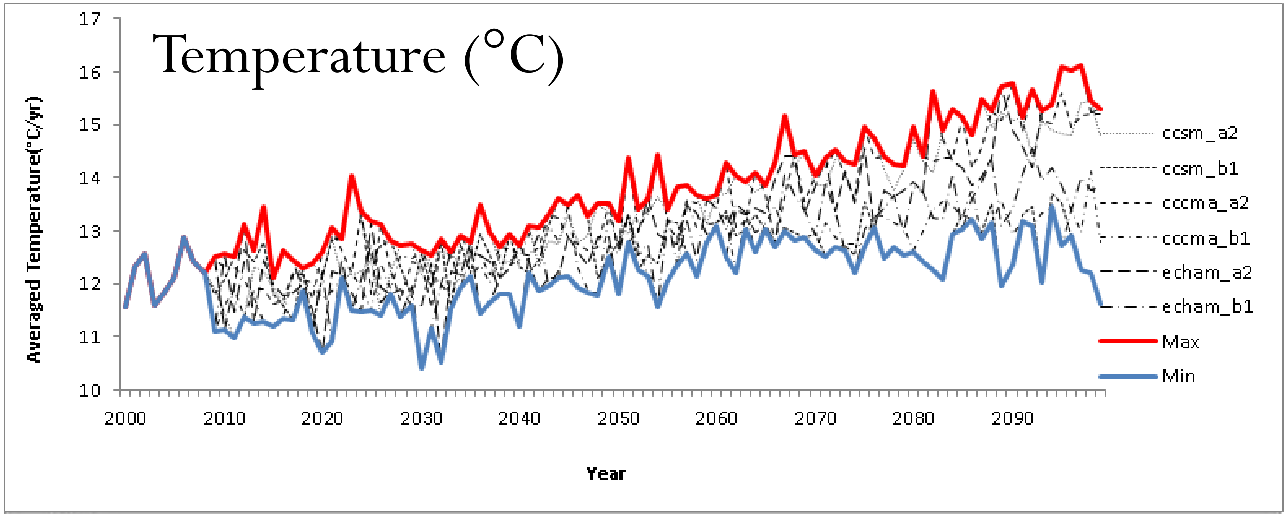


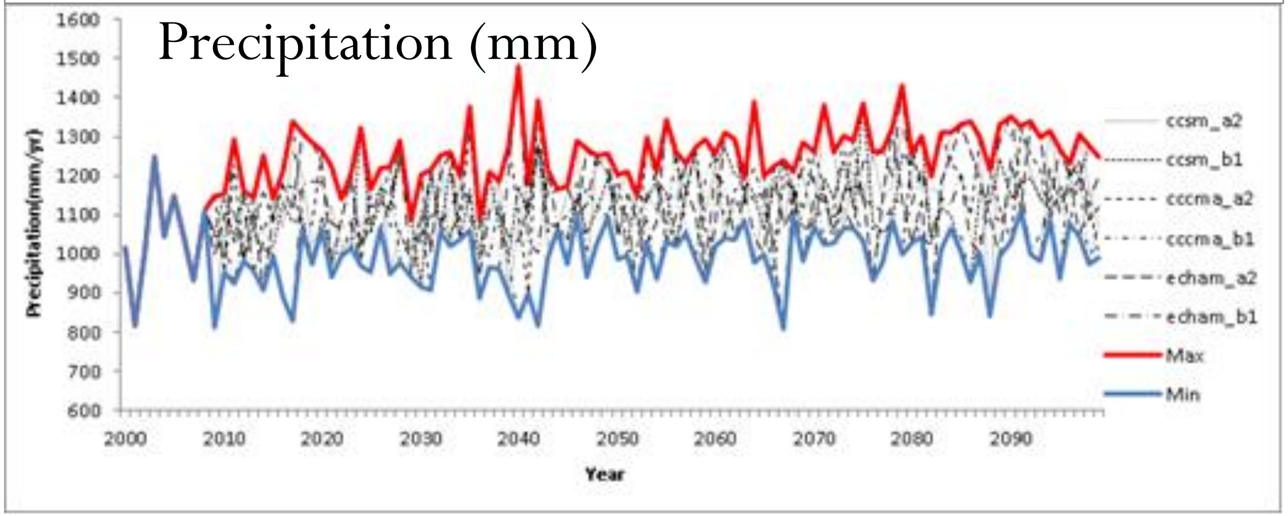
Nitrogen Export



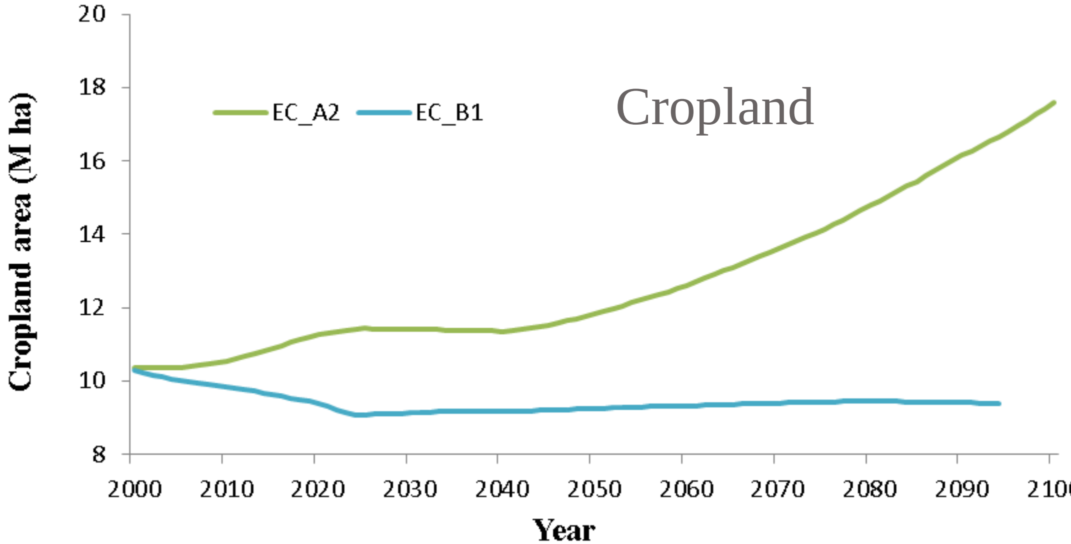


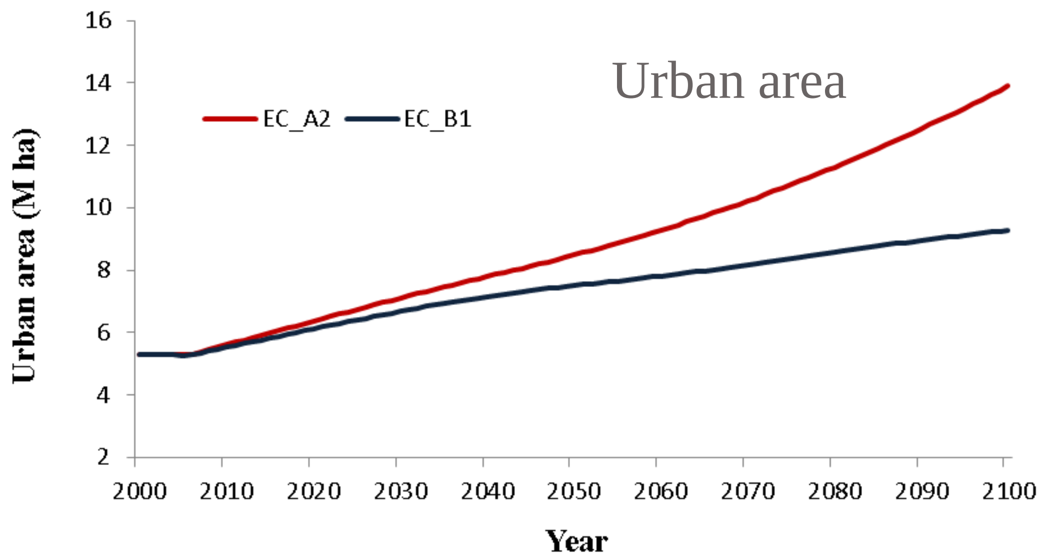
Projected climate change across the US EC



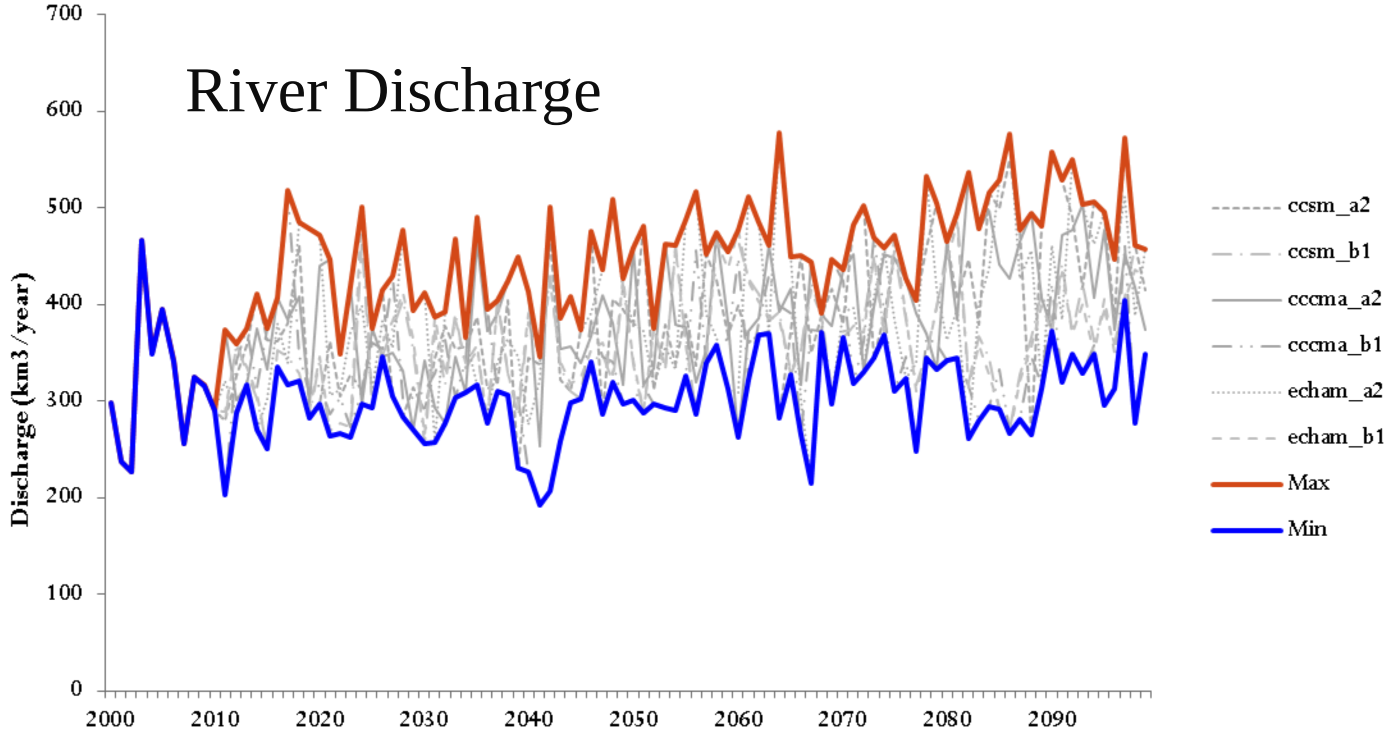


Future Land use change

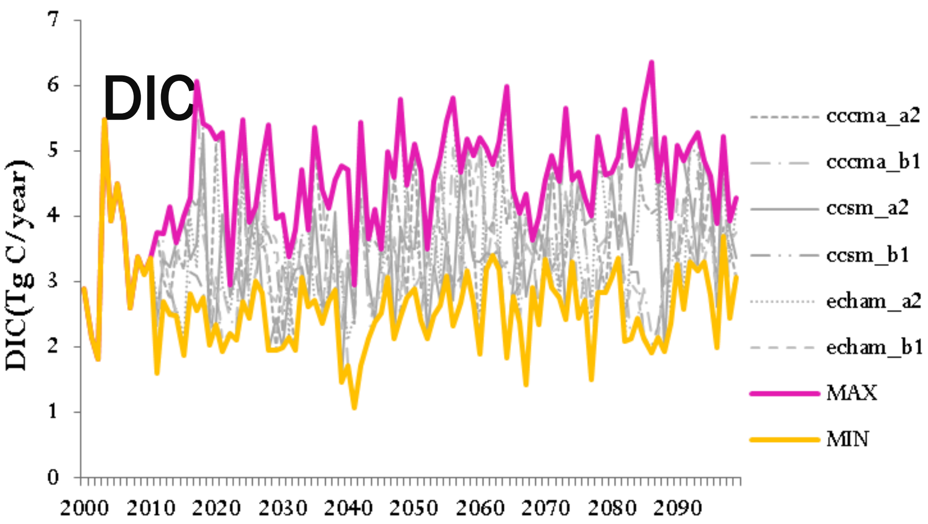


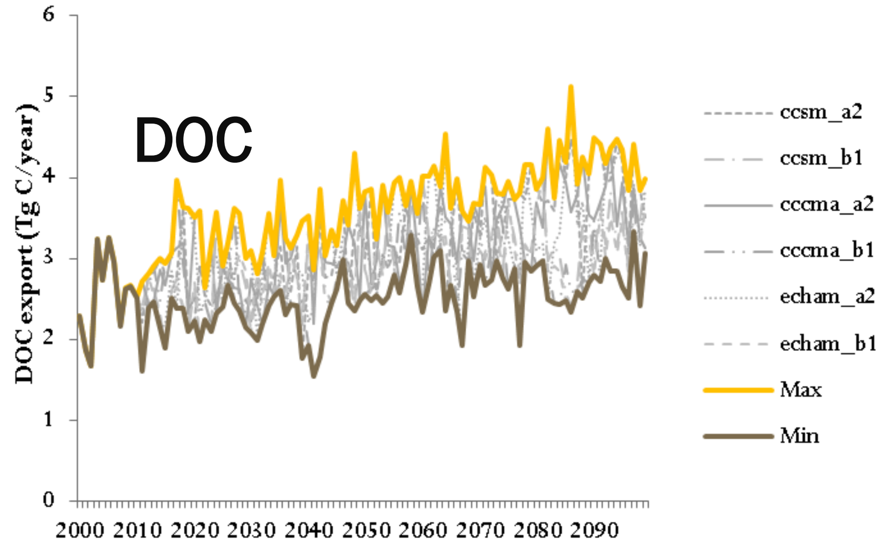


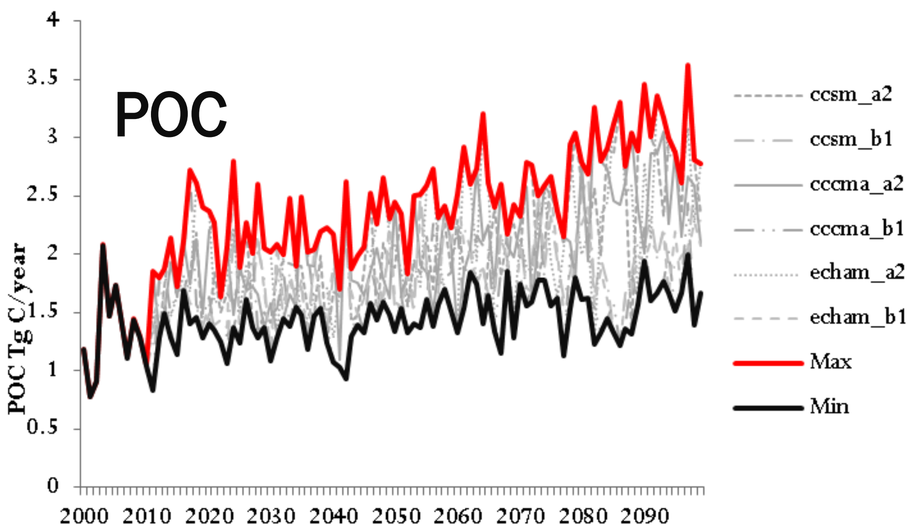
River discharge

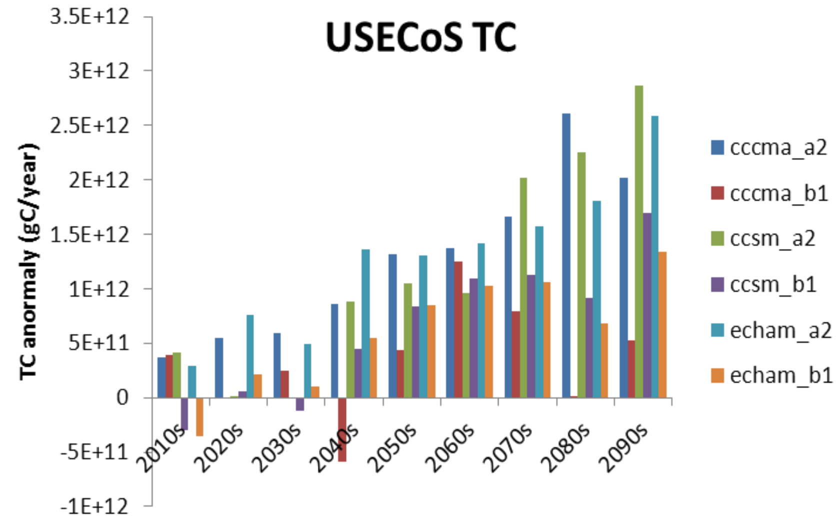


Carbon export

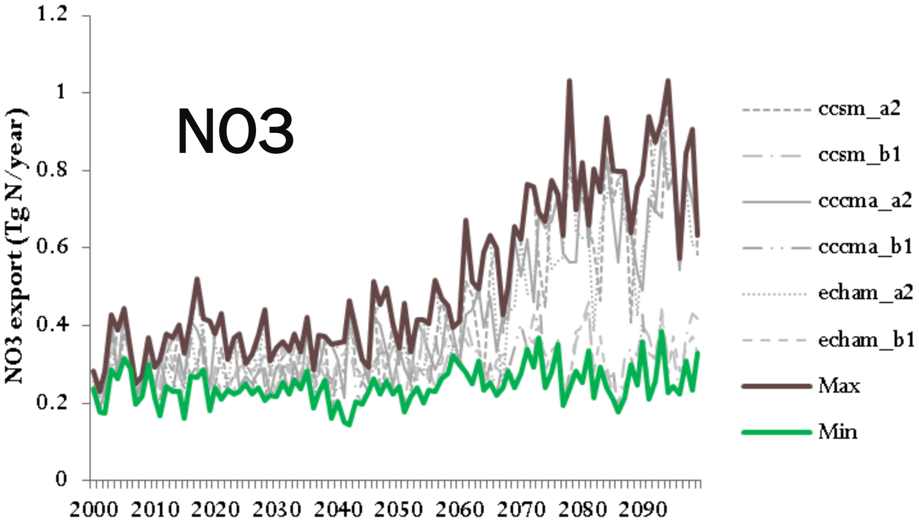


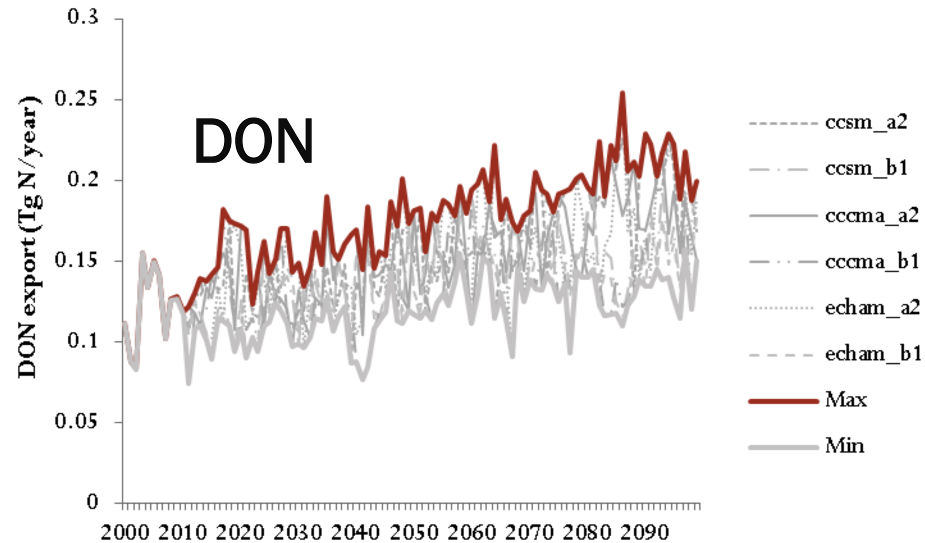


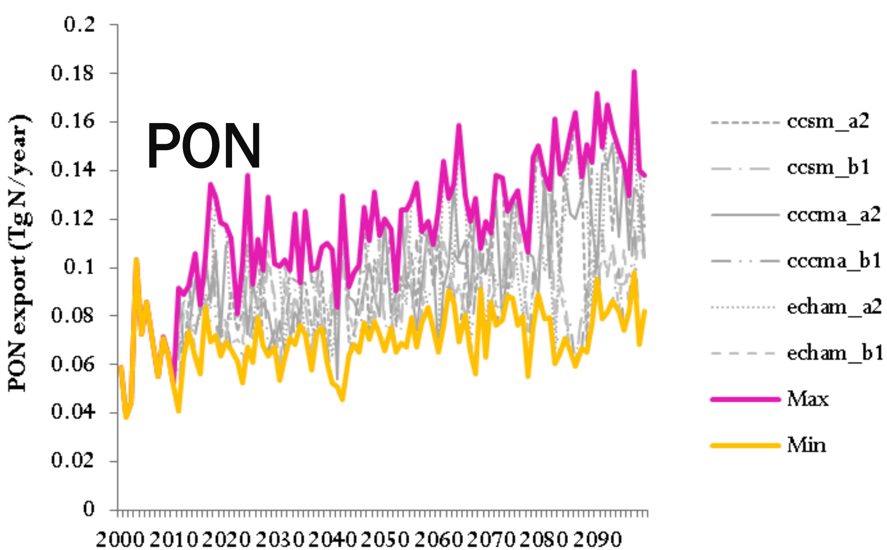


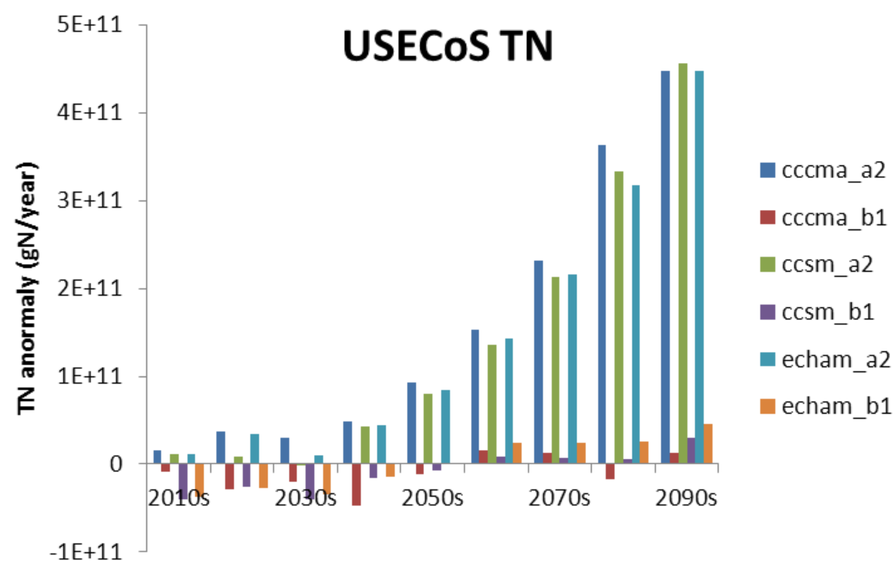


Nitrogen export

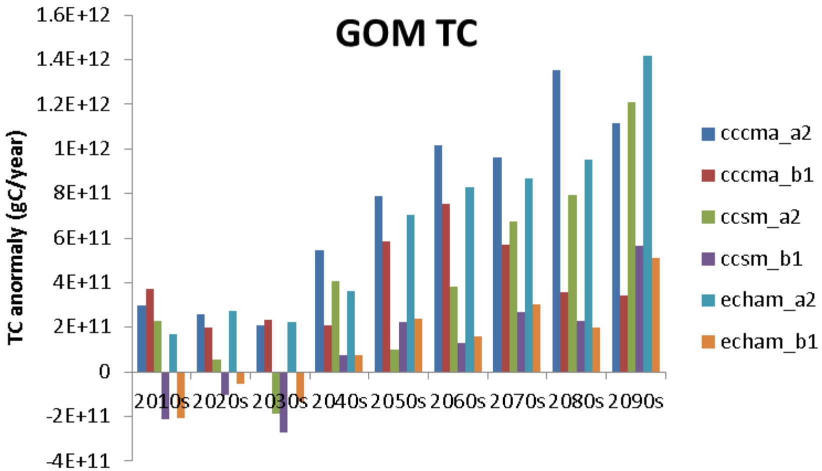


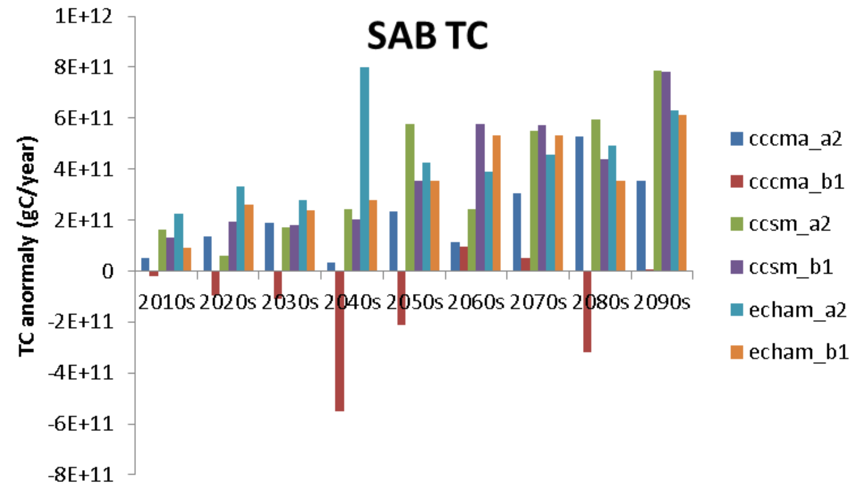


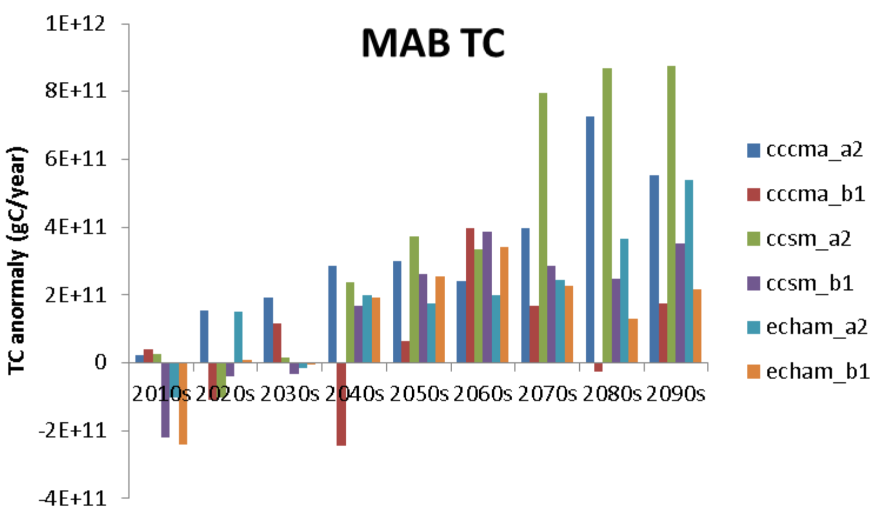


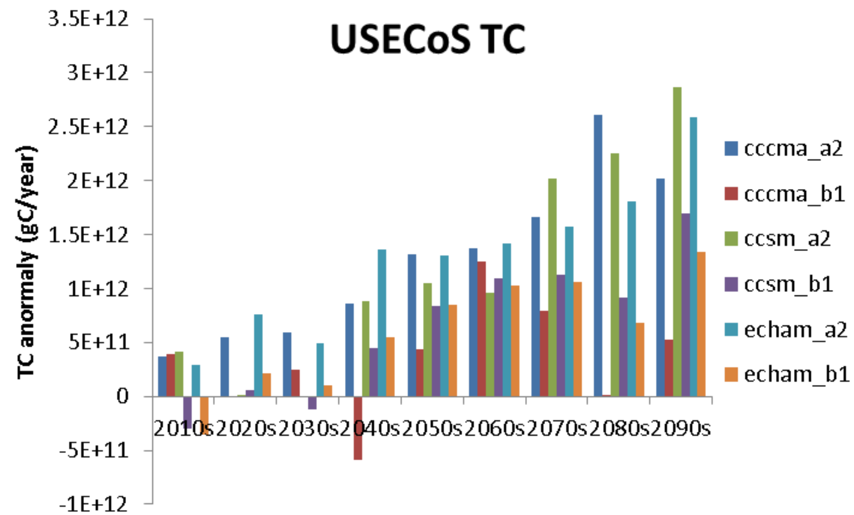


Future total carbon export from GOM, MAB and SAB Sub Basins

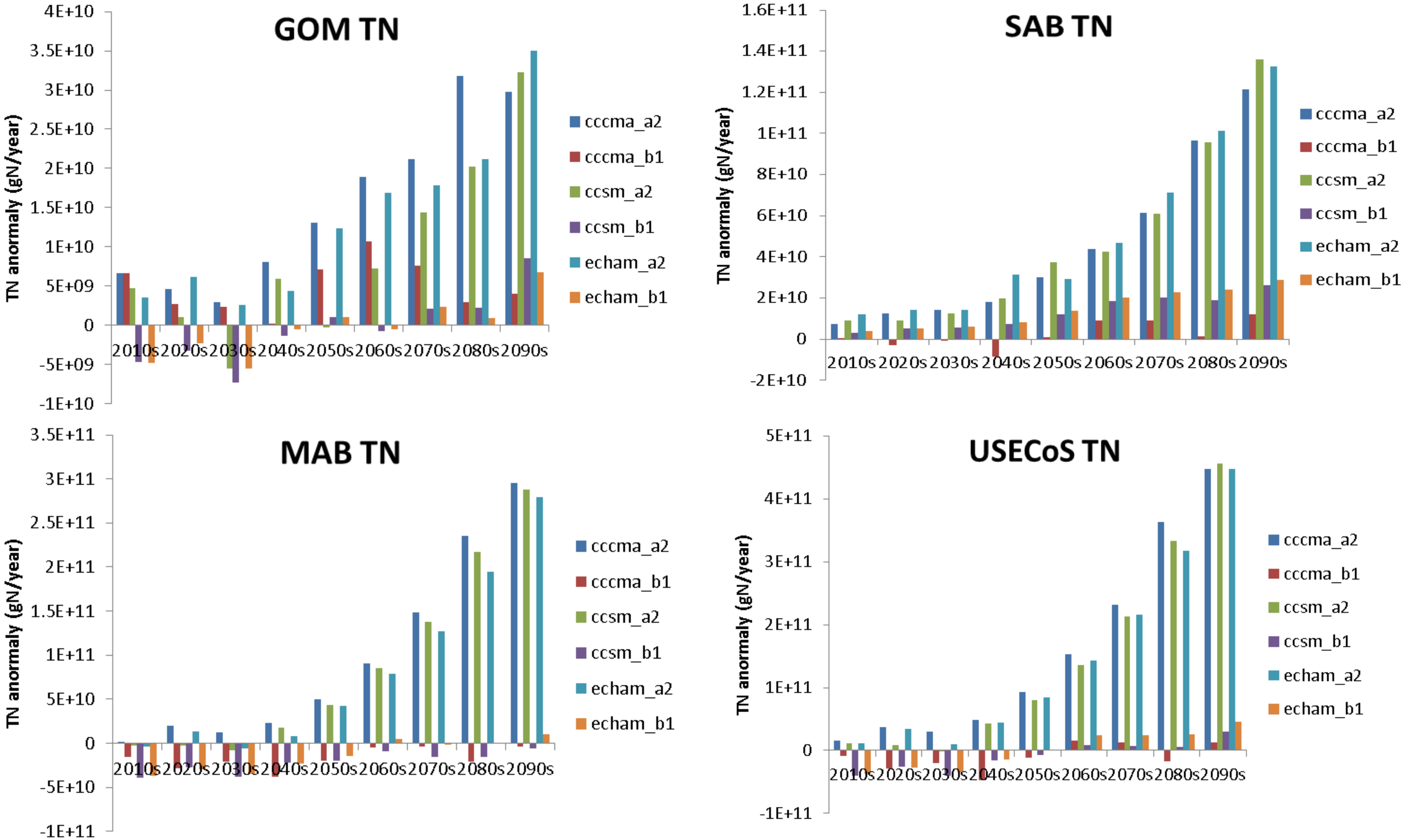




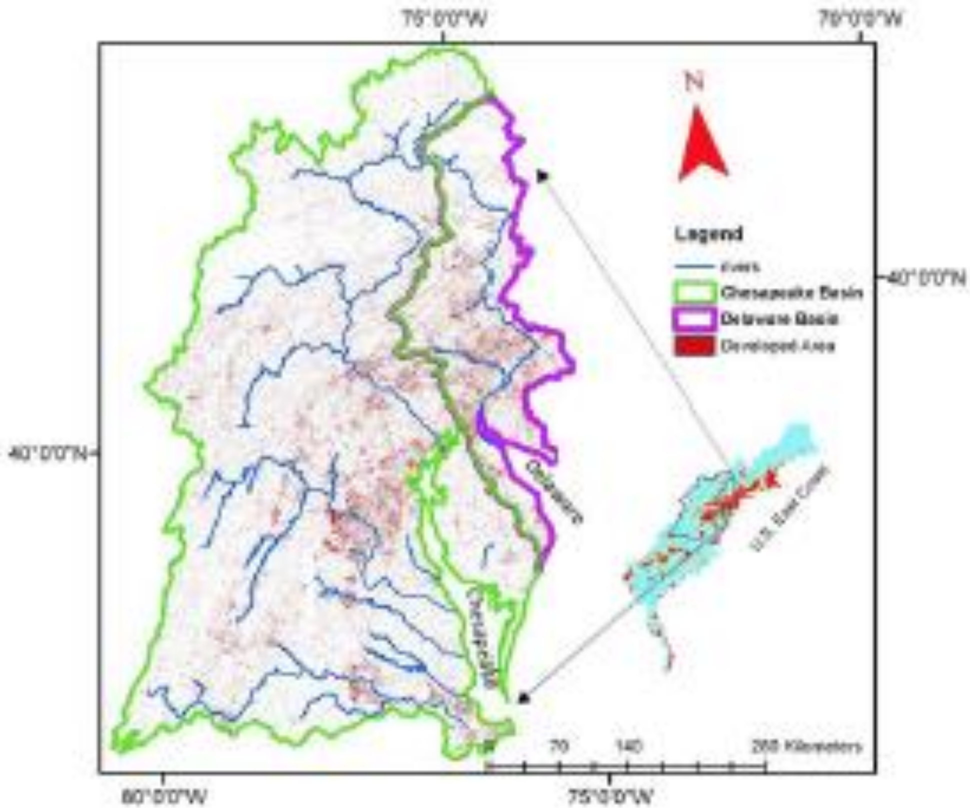




Future total nitrogen export from GOM, MAB and SAB Sub Basins



The study domain of the New IDS project



NASA IDS Project: Synergistic impacts of population growth, urbanization, and climate change on watersheds and coastal ecology of the northeastern United States

Development of input datasets

Climate Data (**PRISM Climate Data**)

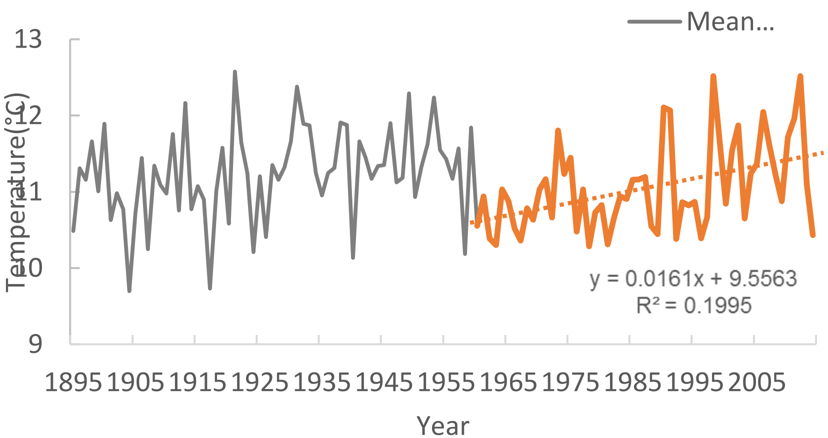
- Covering the period of **1895 – present**
- Spatial resolution: **4km**
- Daily or monthly weather parameter: **tmax, tair, tmin, precipitation**

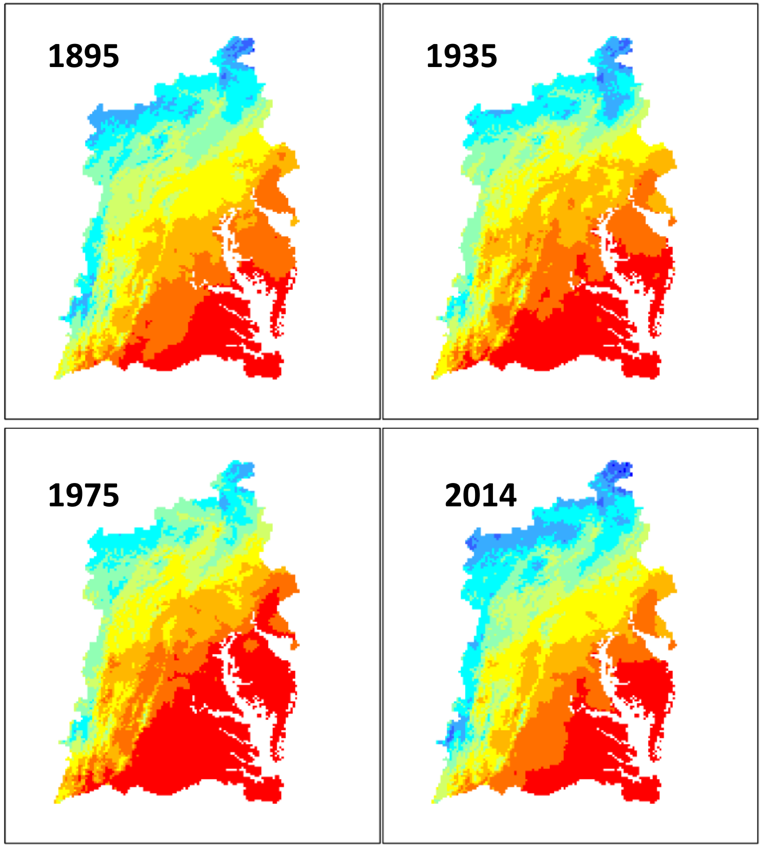
Daily:1981-2016

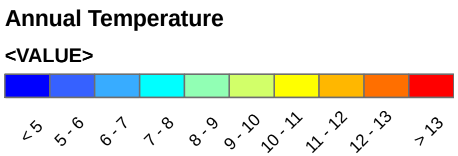
Monthly:1895-1980 (Reconstruct the daily pattern by randomly selected the daily pattern of climate data from 1981-2016)

Development of input datasets

Temperature

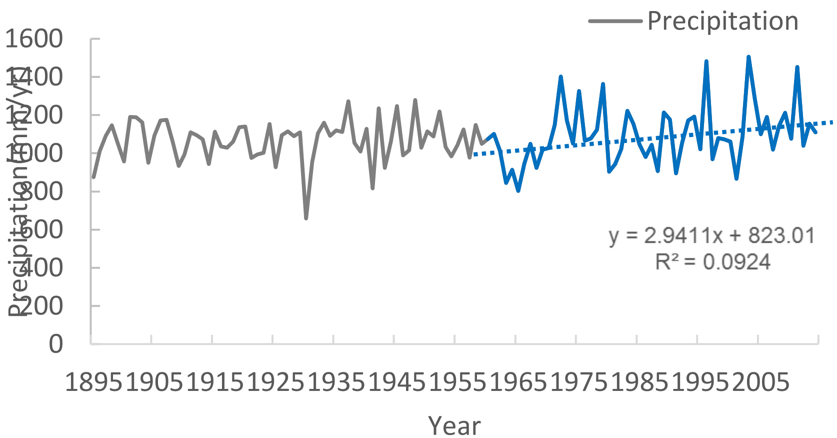


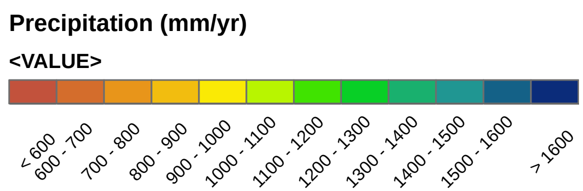


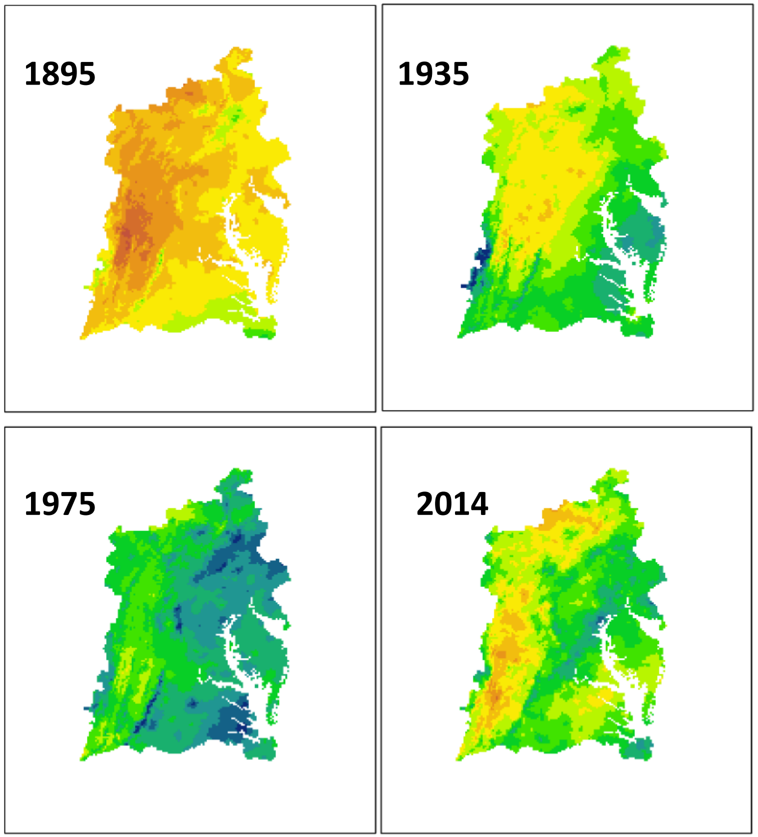


Development of input datasets

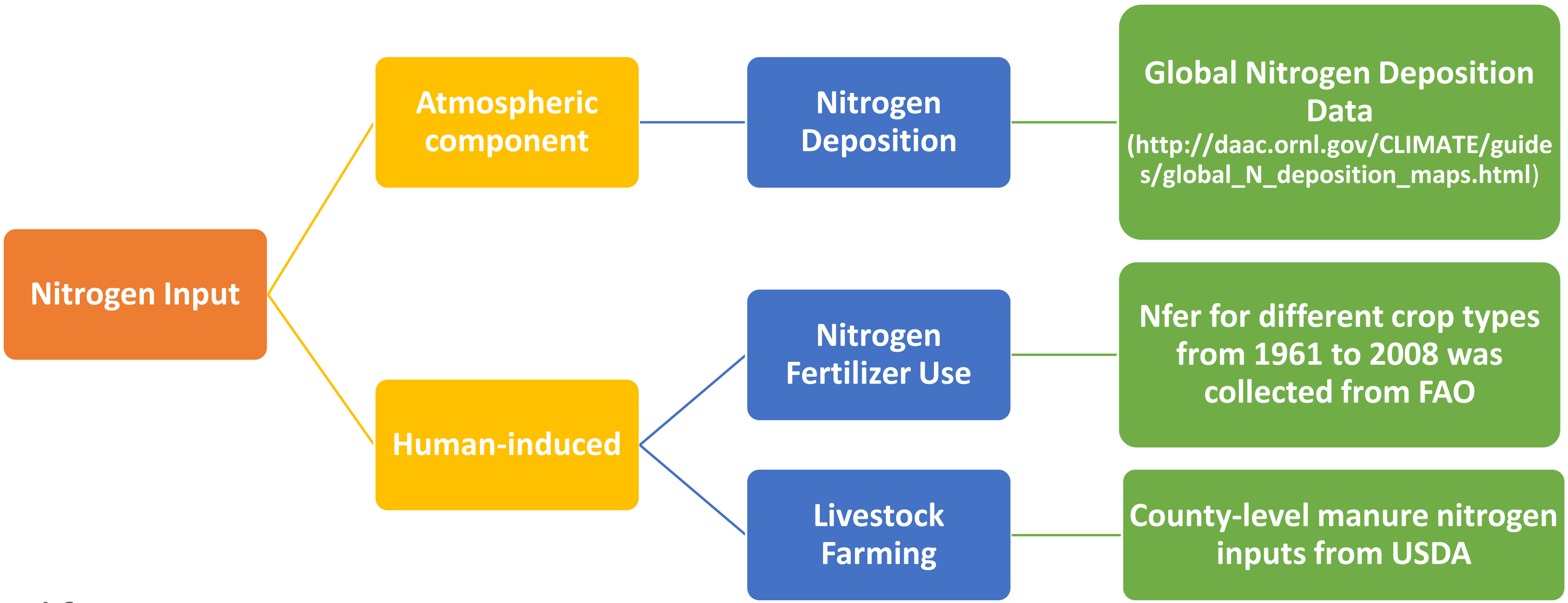
Precipitation

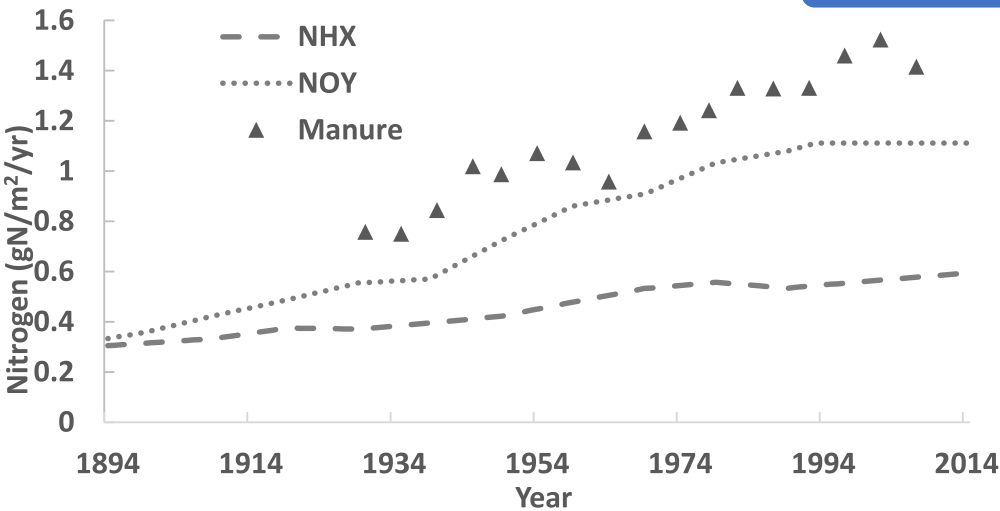


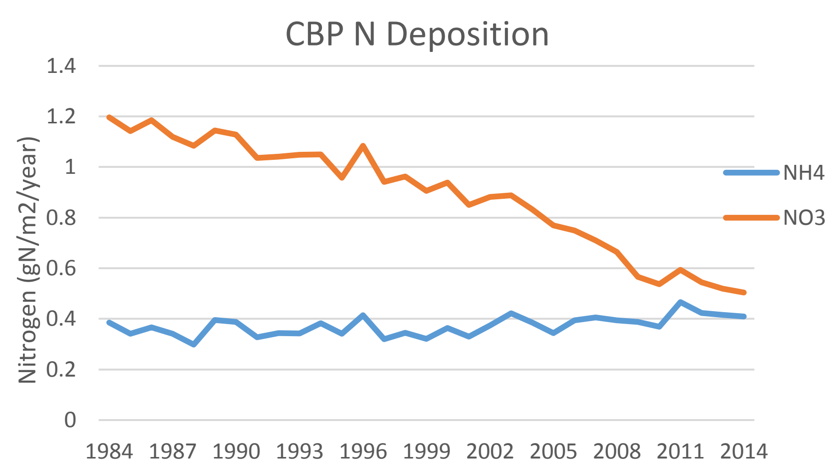




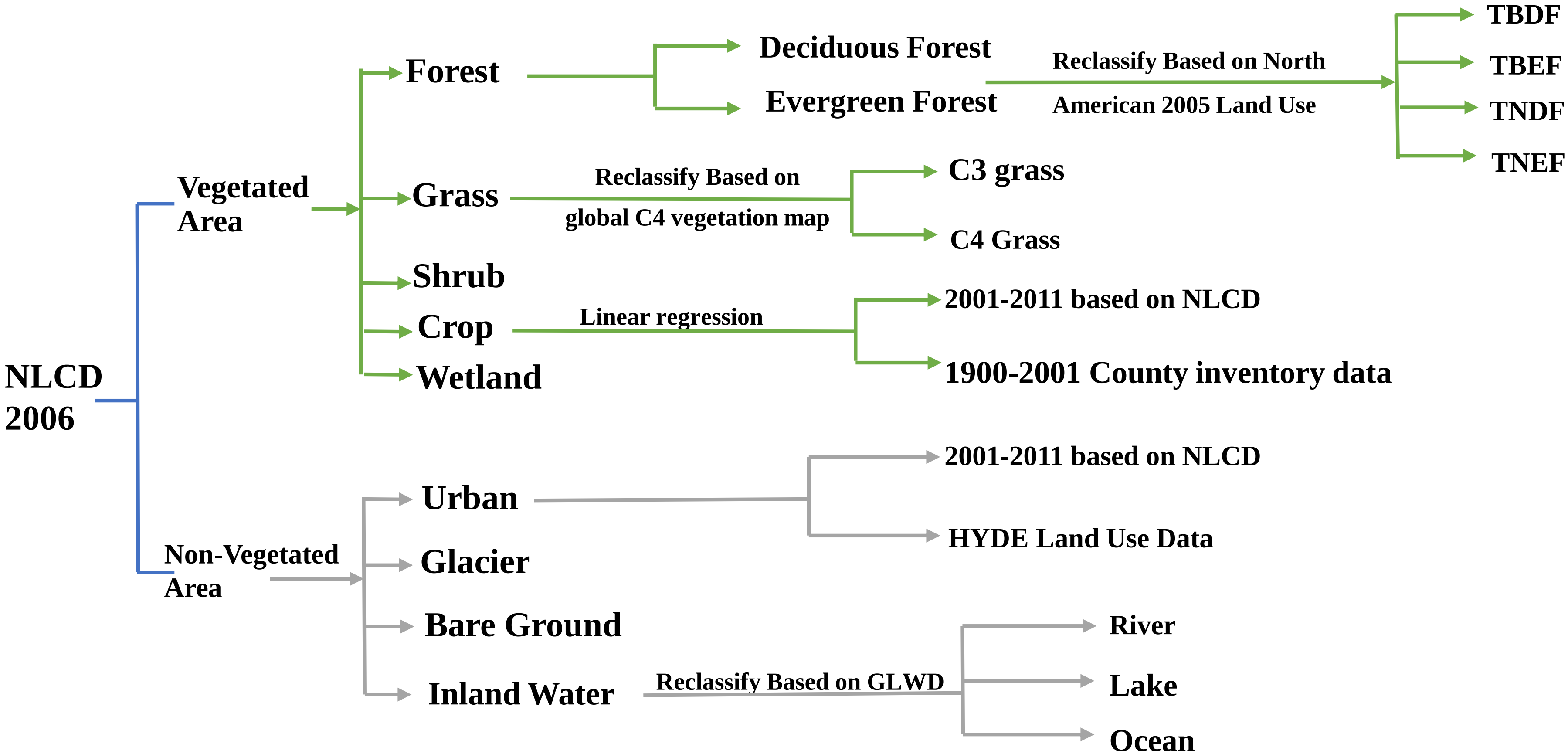
Development of input datasets





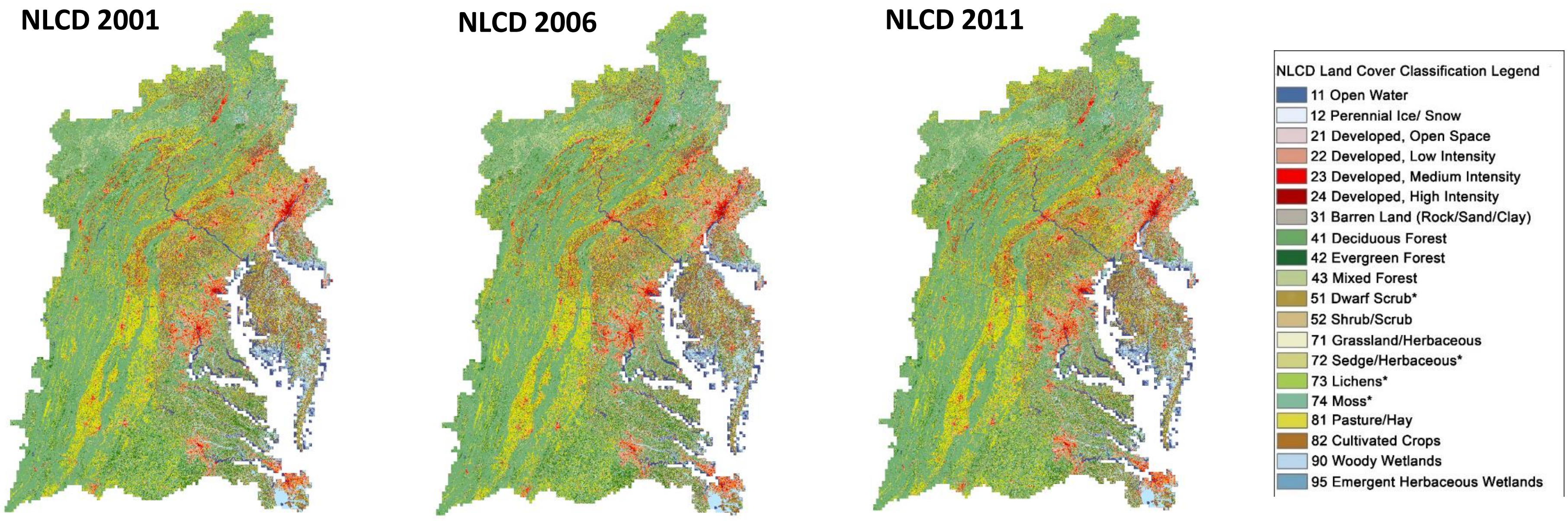


Development of input datasets- Land use data



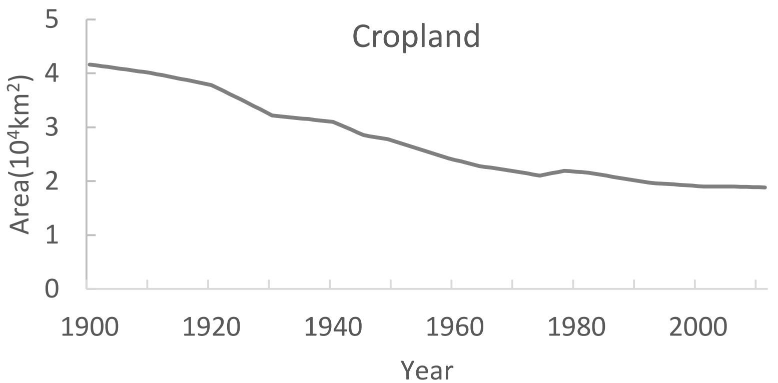
Development of input datasets- Land use data

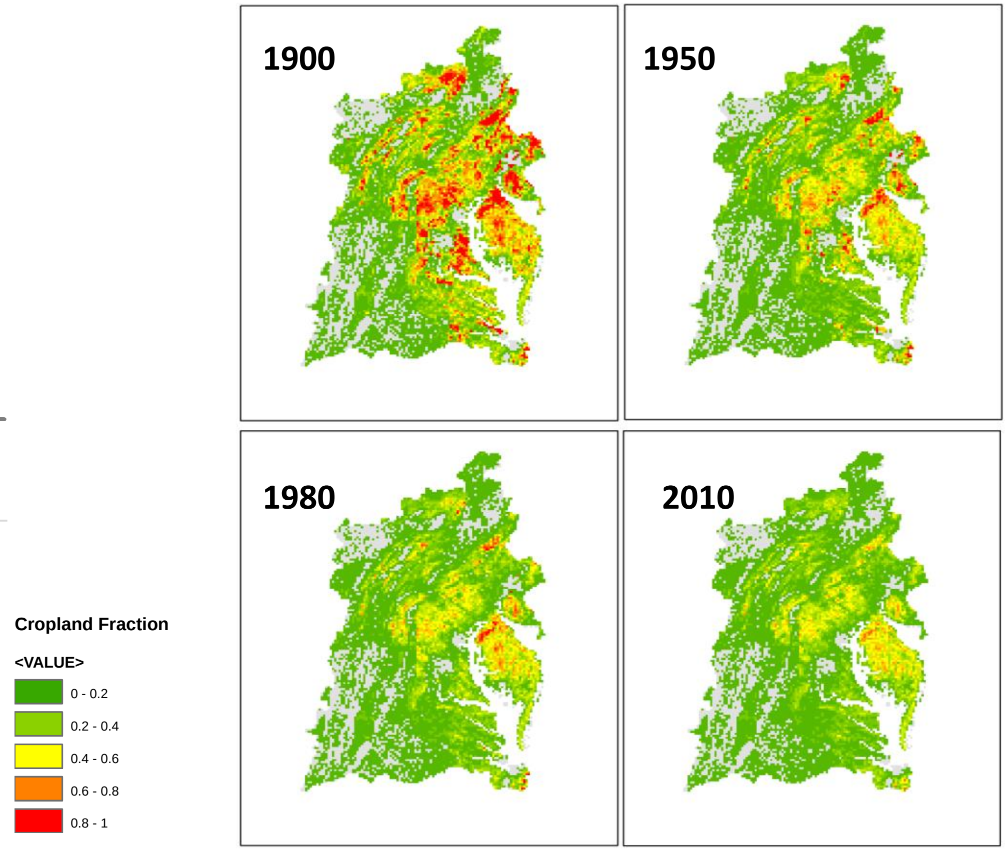
- Land use and land cover data
  - National Land Cover Dataset (NLCD) – (Spatial Resolution 30 m)



Development of input datasets

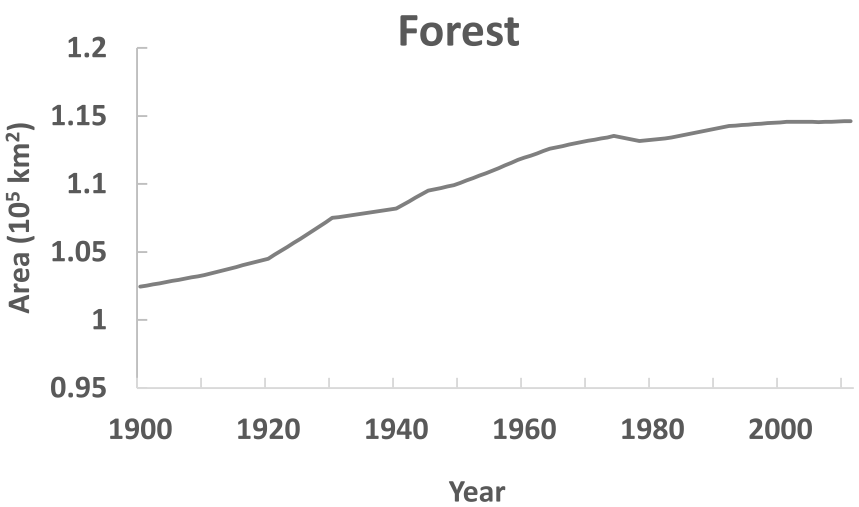
- Cropland

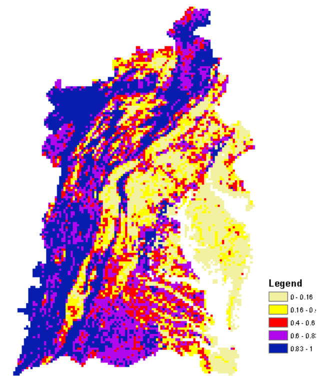




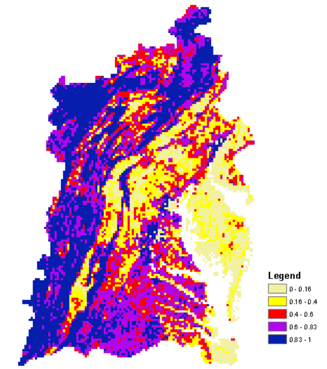
Development of input datasets

- Forest

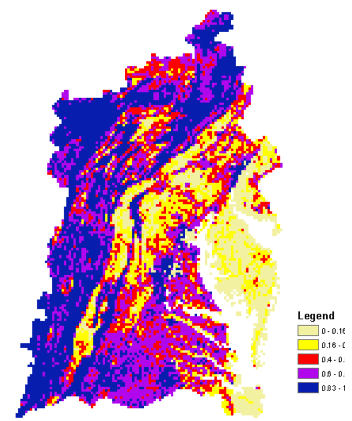




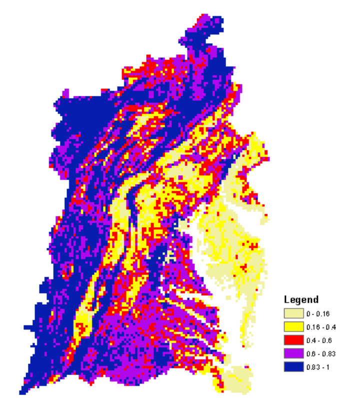
1900



1950



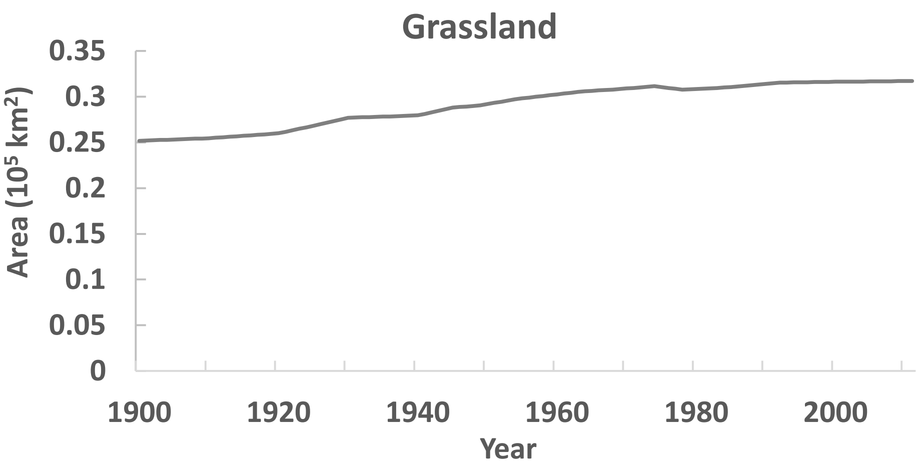
1980

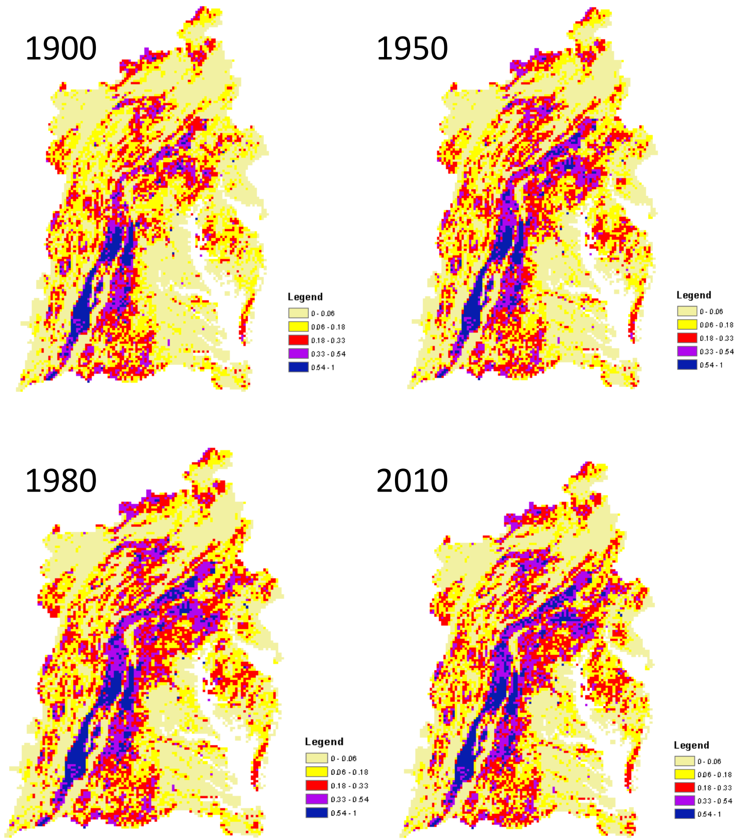


2010

Development of input datasets

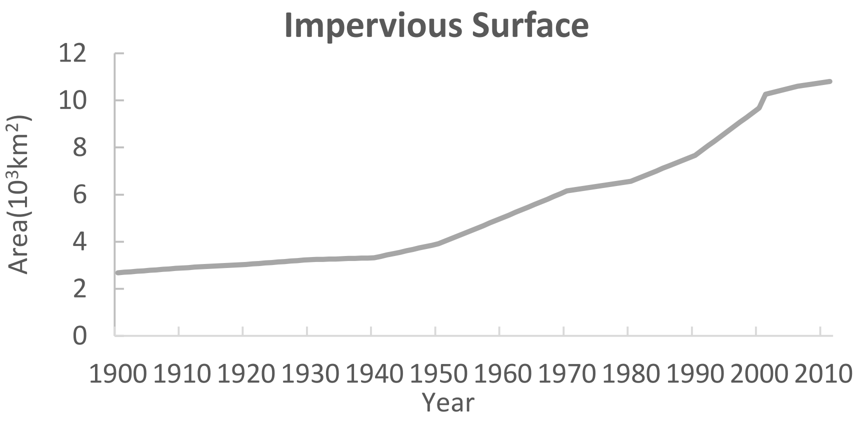
- Grassland

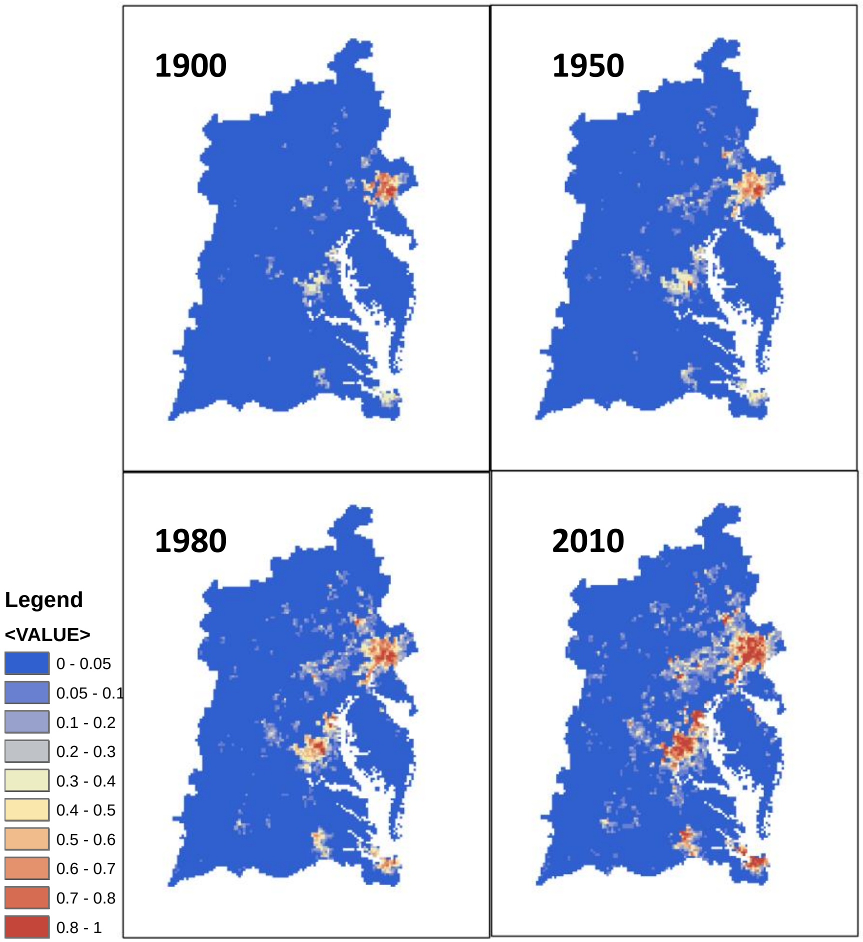




Development of input datasets

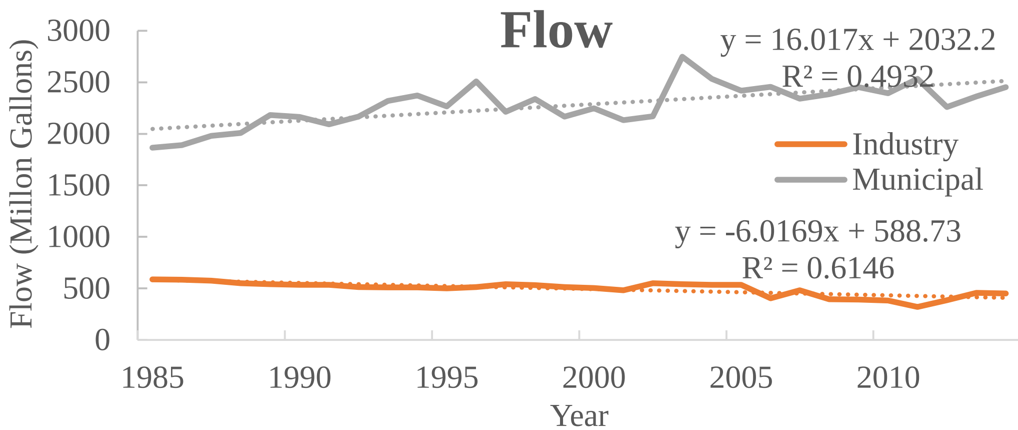
- Impervious surface

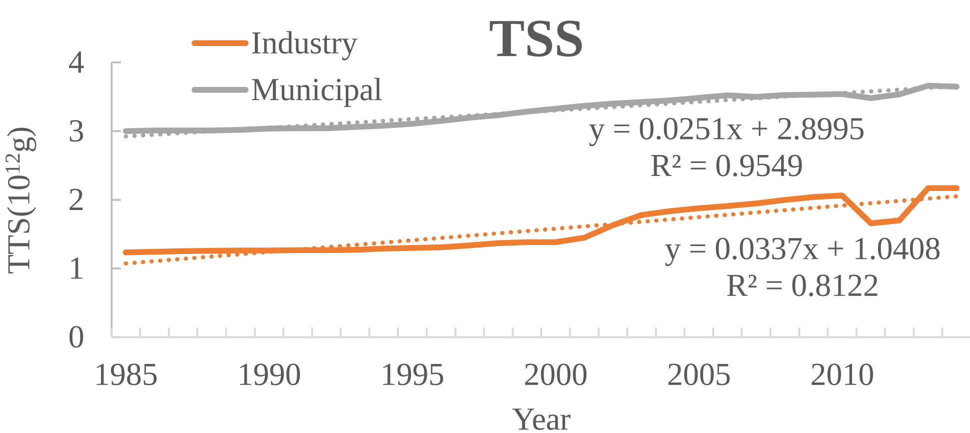


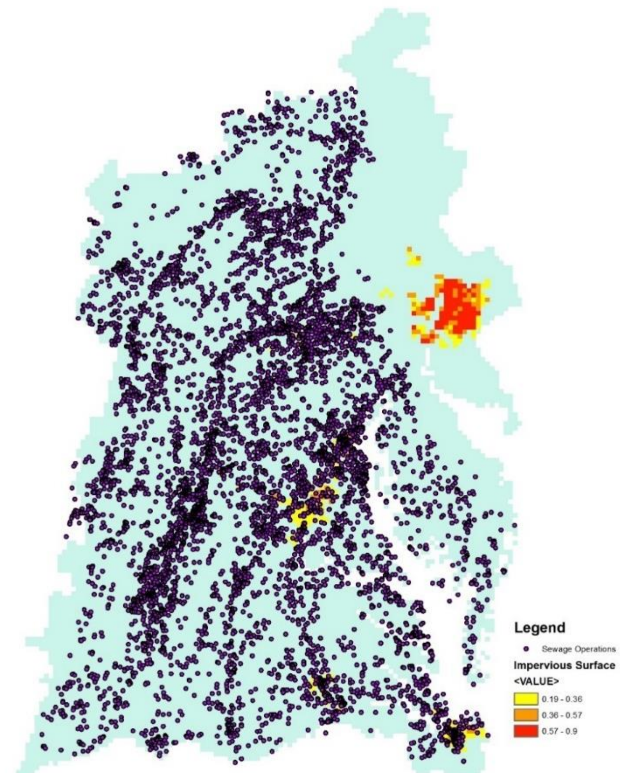


Development of input datasets

Urban Sewage



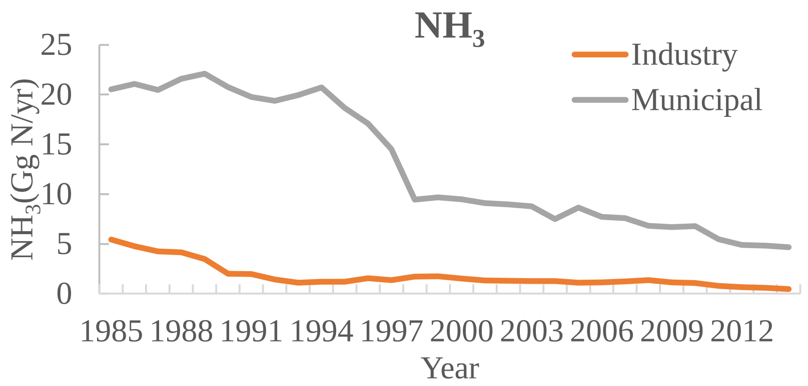


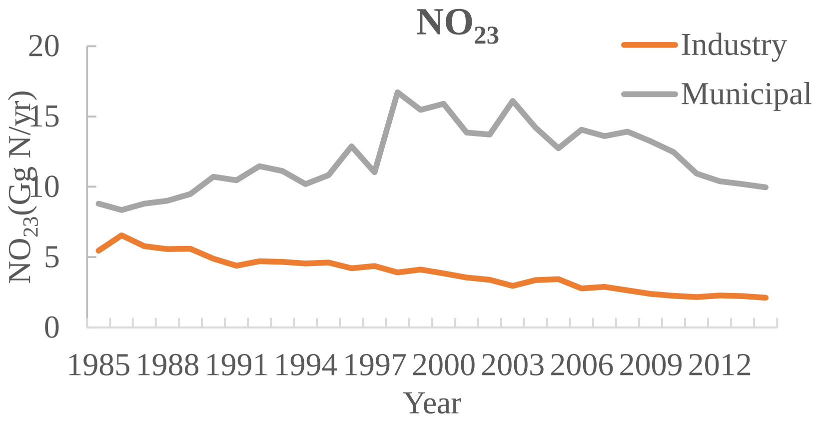


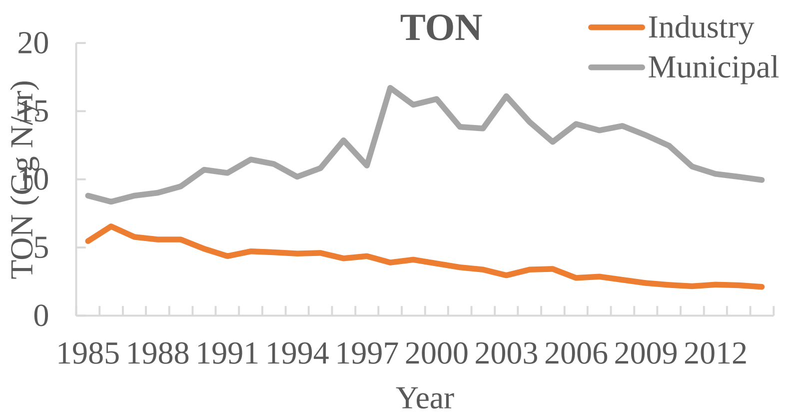
Point source sewage operation distribution map

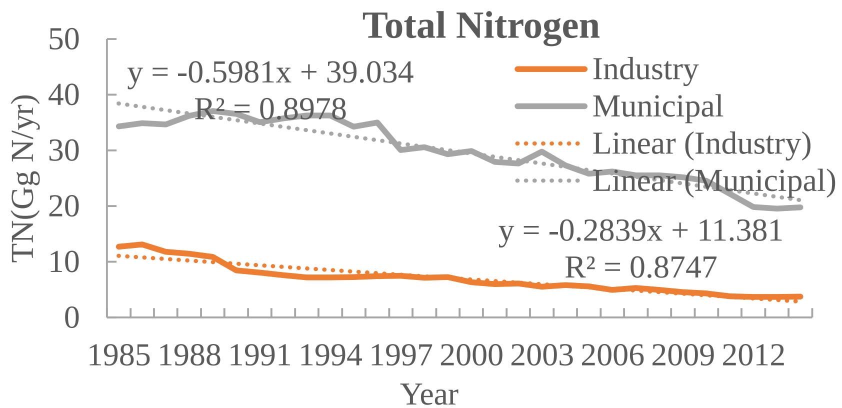
Development of input datasets

- Urban Sewage Nitrogen



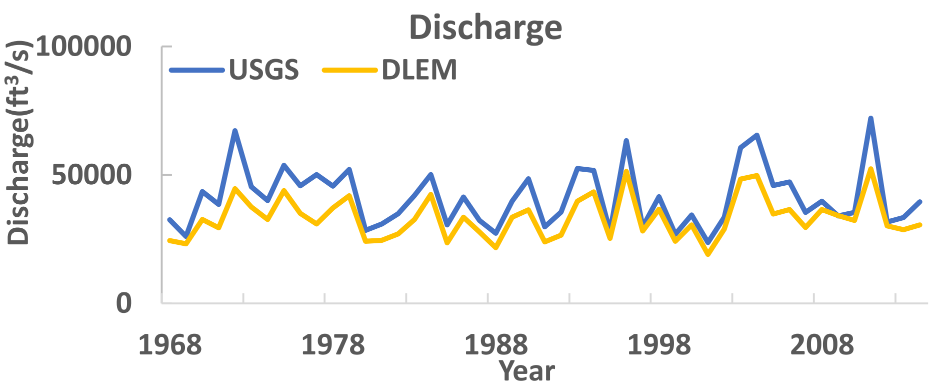


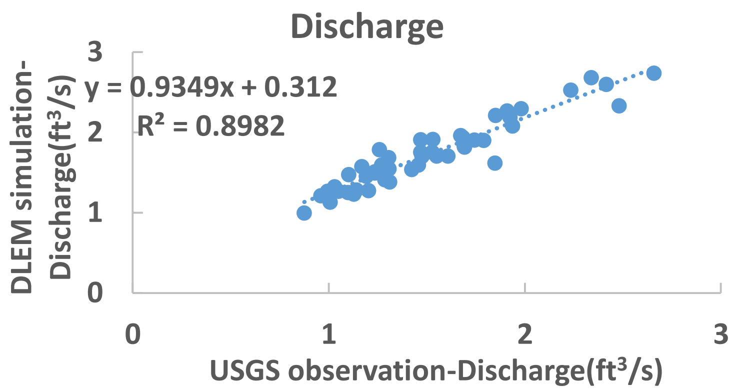




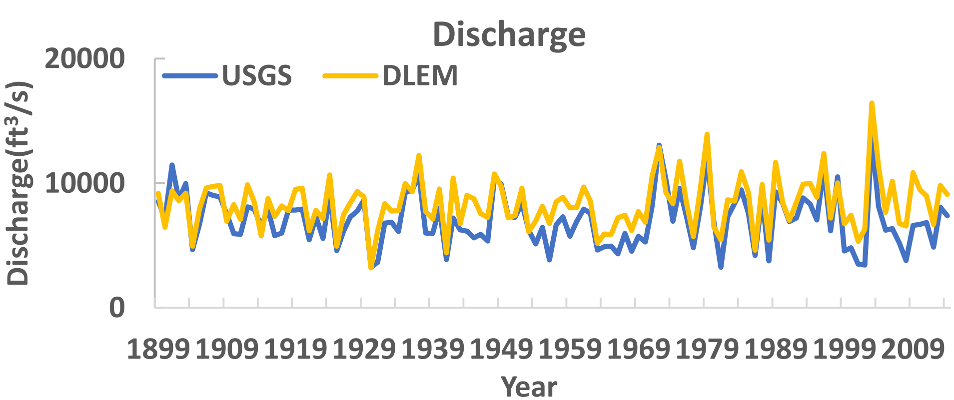
DLEM validation

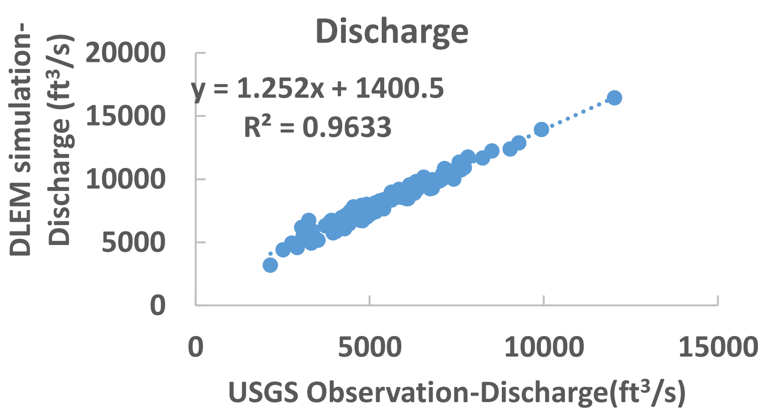
- Susquehanna River





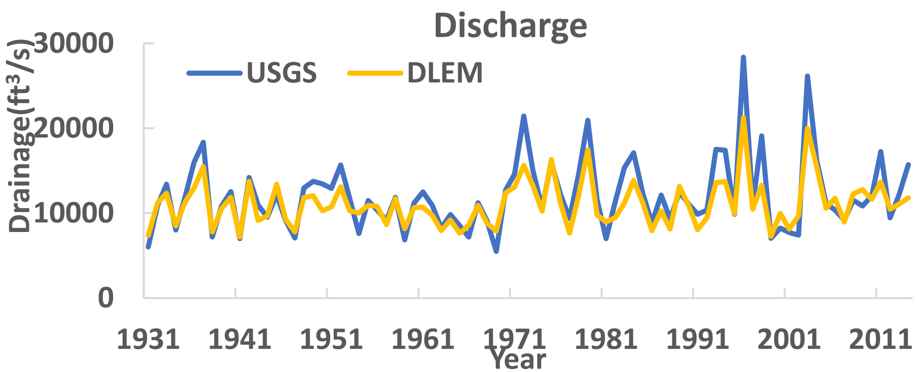
- James River

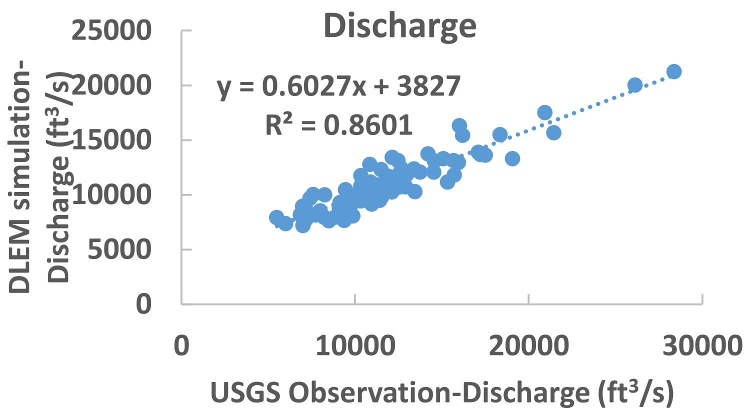




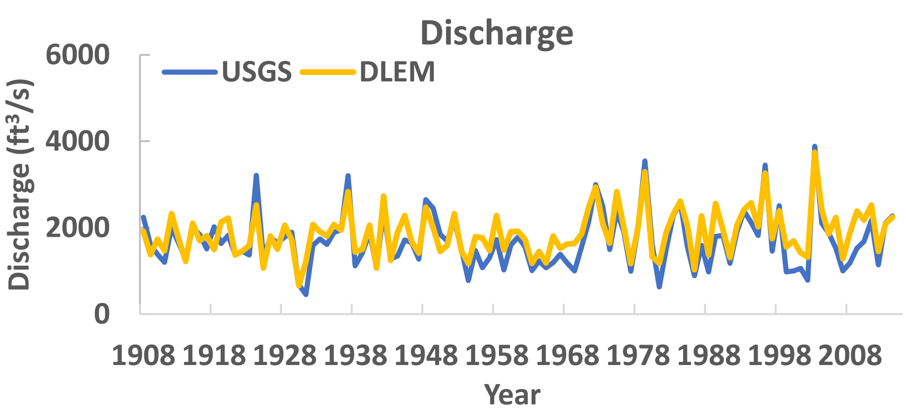
DLEM validation

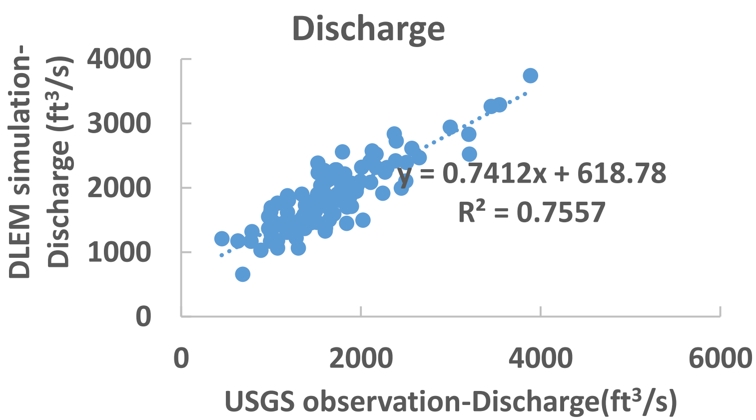
- Potomac River





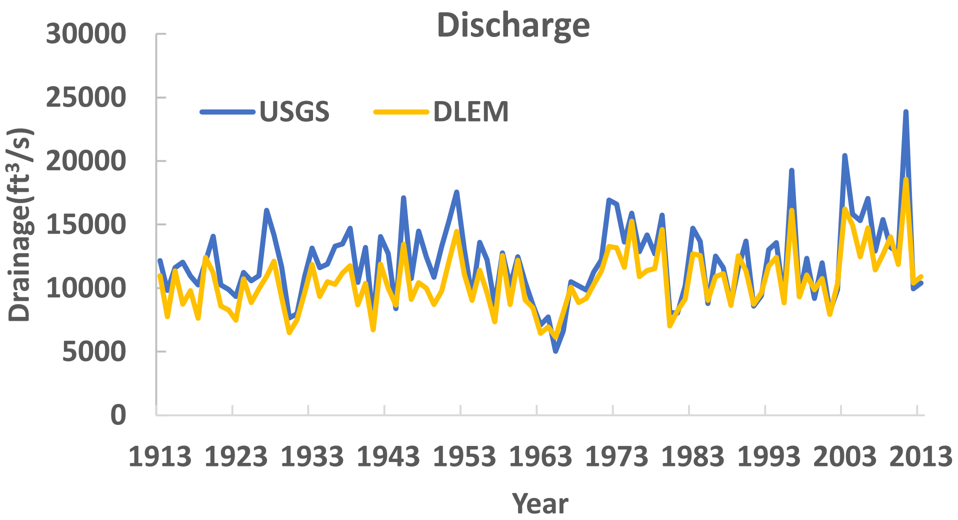
- Rappahannock River

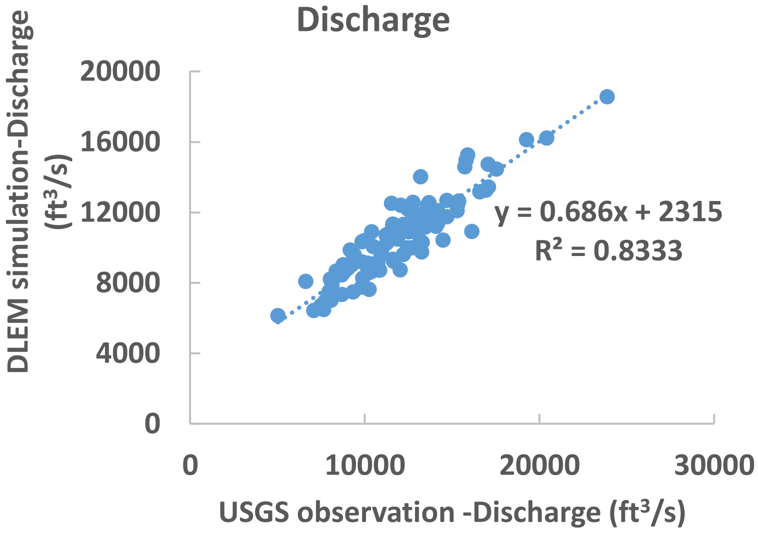




DLEM validation

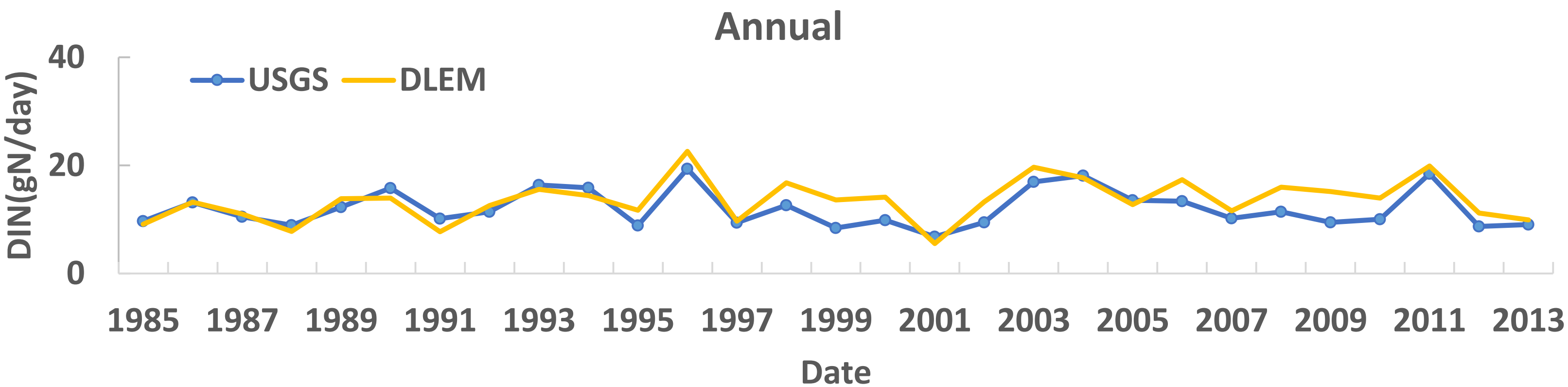
- Delaware River

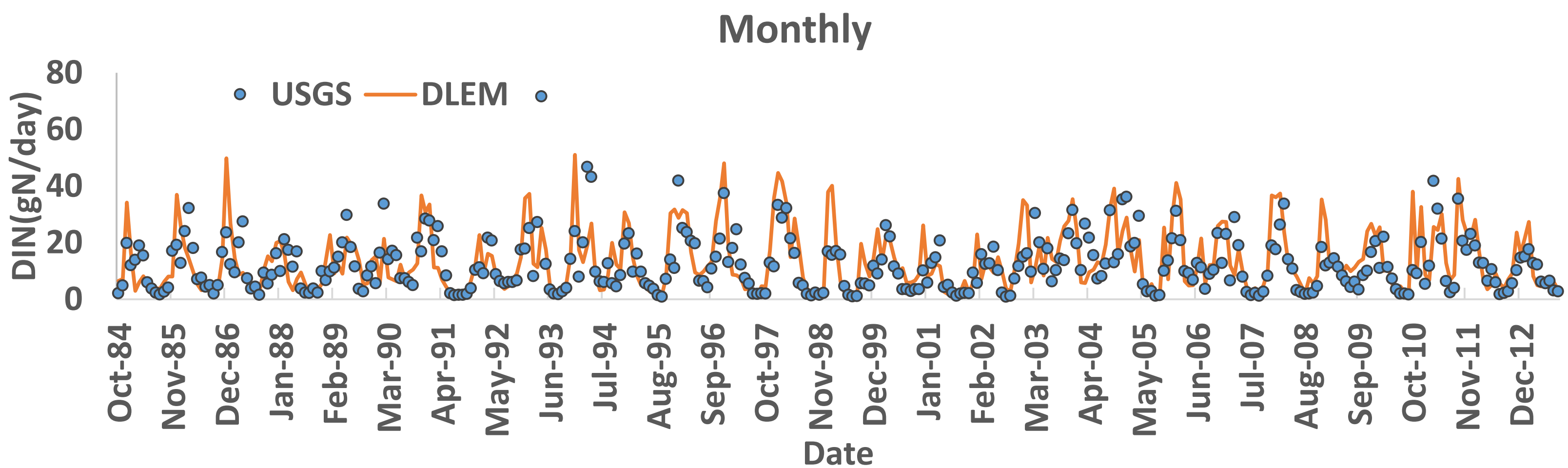




DLEM validation

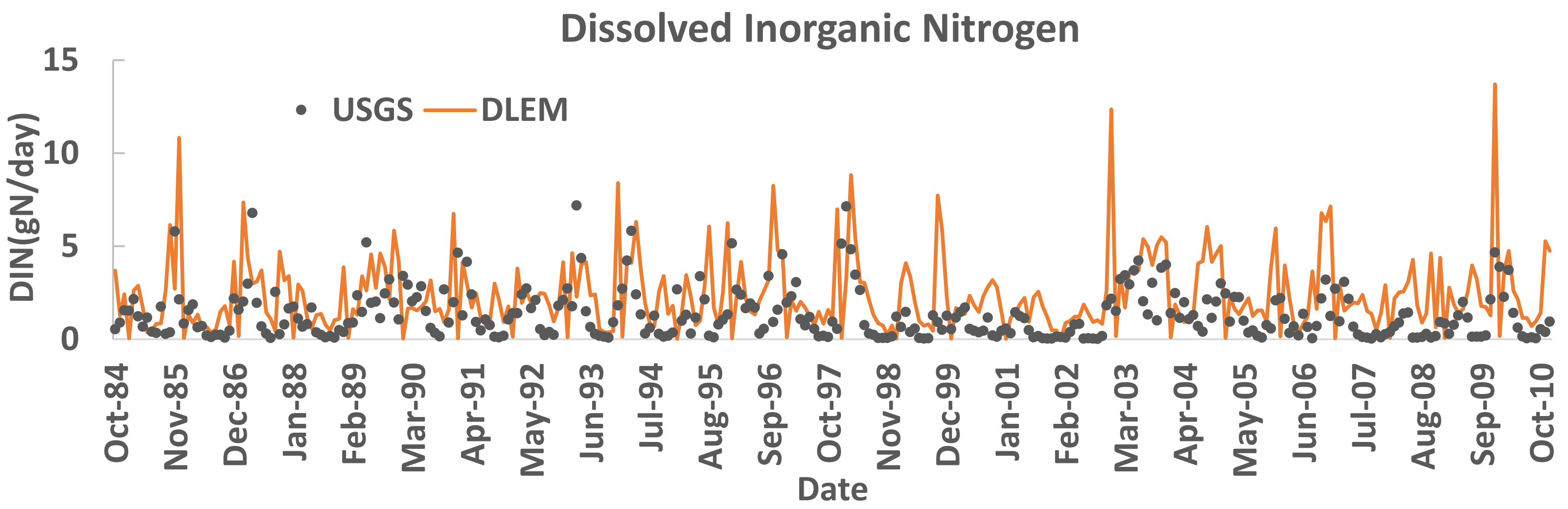
- Susquehanna River-DIN





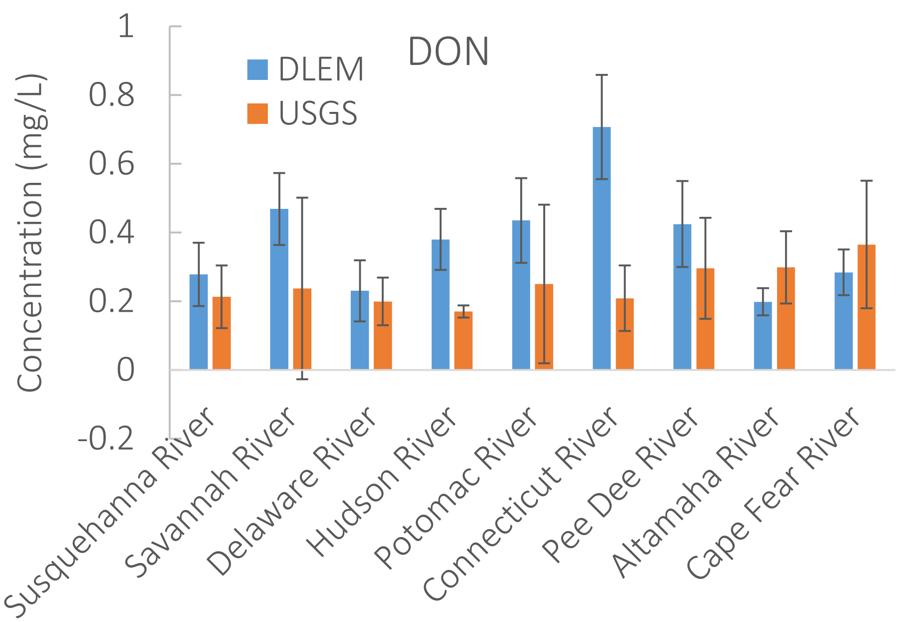
DLEM validation

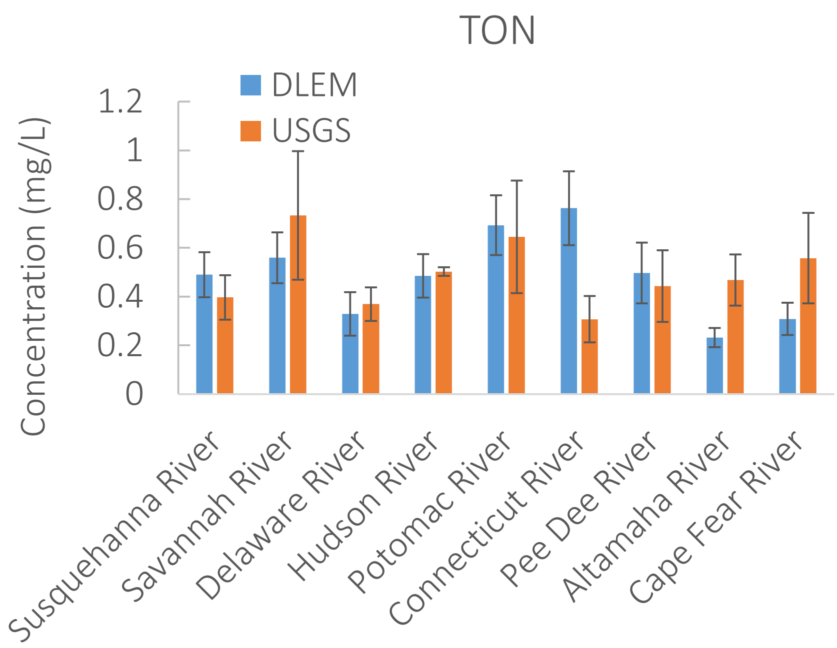
- James River



DLEM validation

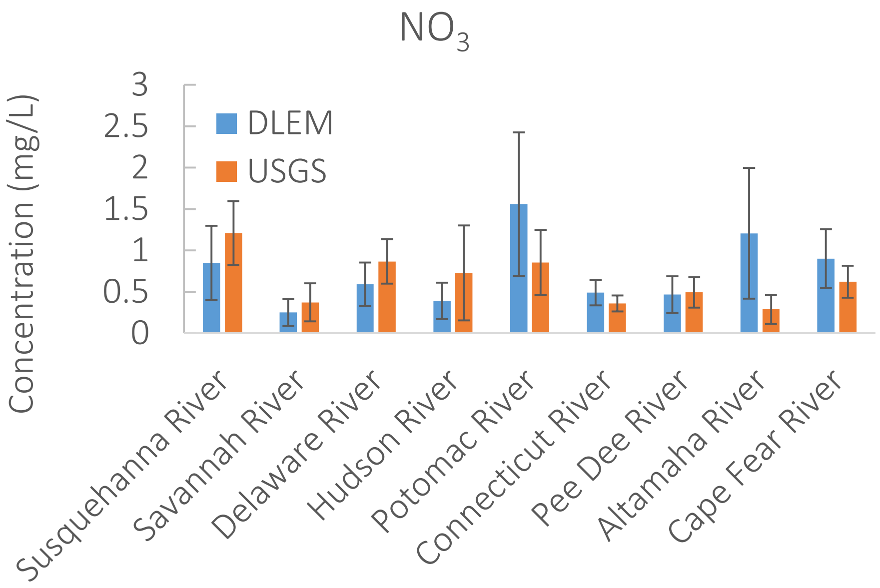
- Organic Nitrogen Export

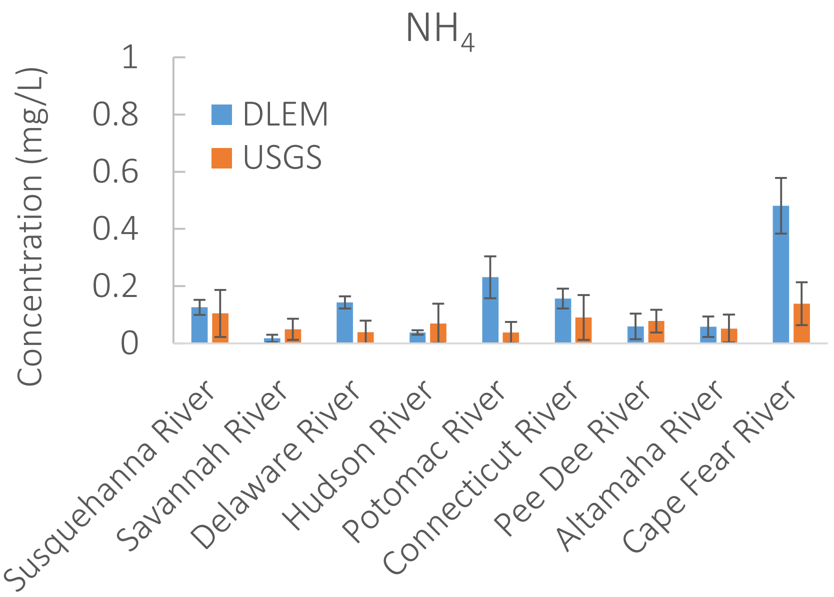




DLEM validation

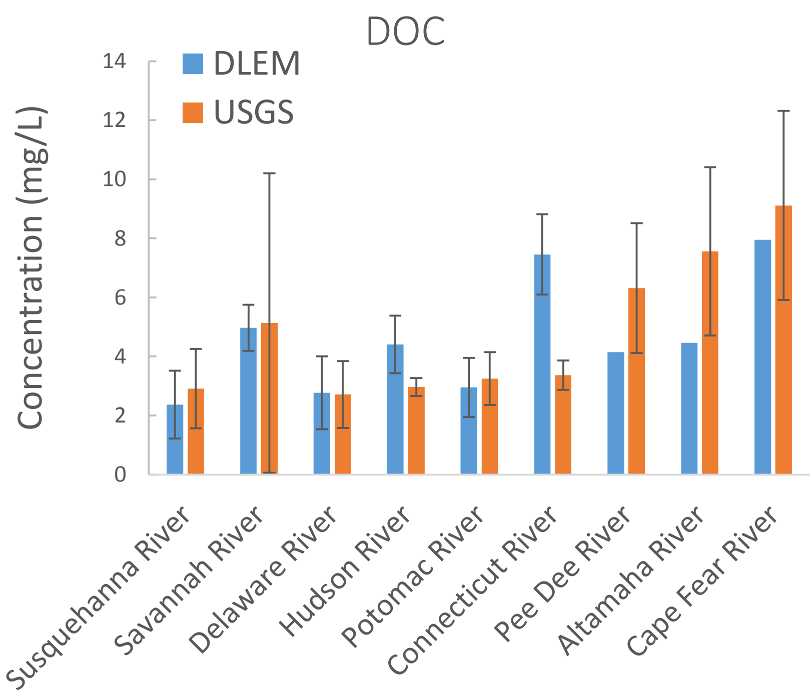
- Inorganic Nitrogen Export

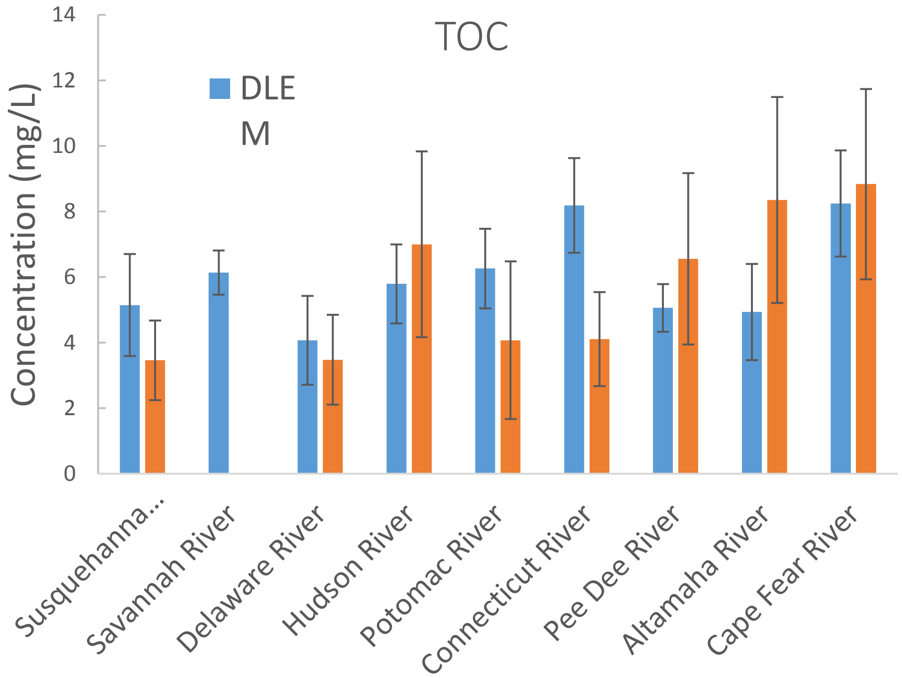




DLEM validation

- Carbon Export

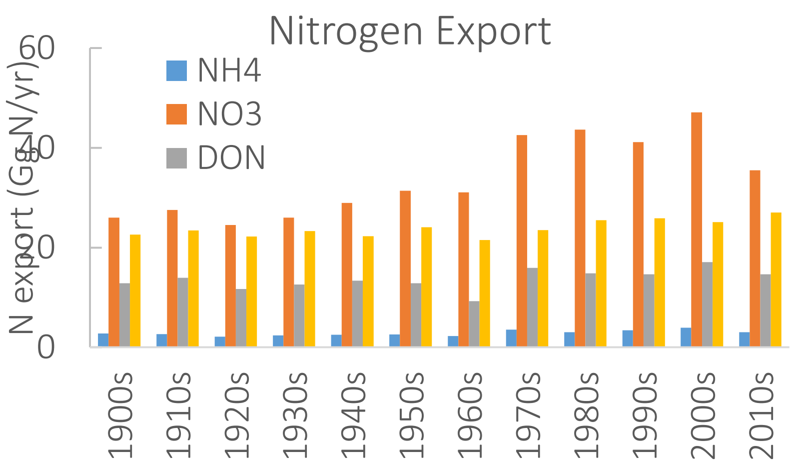


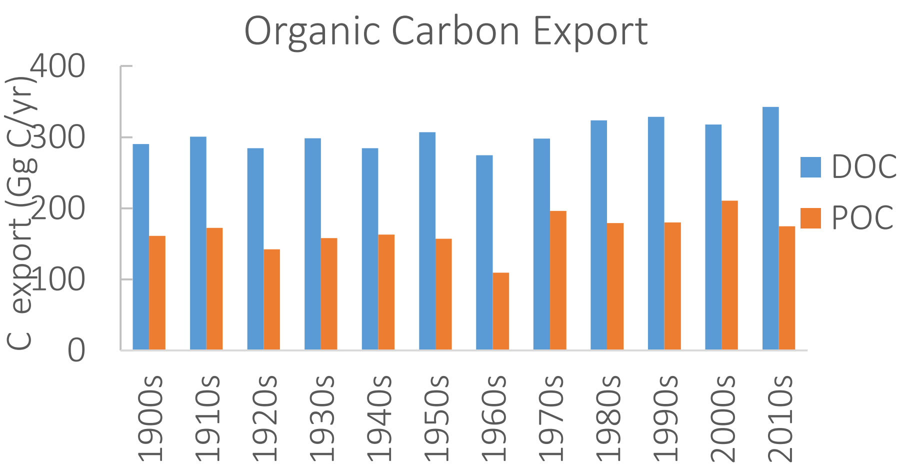


DLEM Simulation and Analysis: an update

- Total Export into the Chesapeake Bay

Decades	Total Export (Gg)					
	DOC	POC	NH_4	NO_3	DON	PON
1900s	160.95	290.28	2.79	25.99	12.86	22.62
1950s	157.07	307.20	2.55	31.38	12.81	24.08
1980s	178.94	323.68	3.05	43.65	14.82	25.46
2000s	210.52	317.99	3.89	47.13	17.08	25.11
2011-2015	174.81	342.54	3.03	35.50	14.64	27.04





Comparison with other study

Year	CBP WM* Shenk and Linker[2013]	DLEM May 2016
Discharge		
2001	55	47
2002	57	52
2003	138	136
2004	106	108
2005	81	79
mean 2001-2005	87 ± 35	84±37
DIN		
2001	65	51
2002	73	94
2003	120	186
2004	88	124
2005	84	104
mean 2001-2005	86 ± 21	112±49
TON		
2001	32	31
2002	33	31
2003	84	67
2004	67	55
2005	49	45
mean 2001-2005	53 ± 21	46±16

Needs to improve the DLEM representation of biogeochemical processes within the water body

Future Work Plan in the NOAA Project

- **Extend the new high-resolution gridded datasets to 2015.**

We are currently developing a consistent 1-km gridded database for 1950-2010, which includes land use, climate forcing, sewage water information, and river networks, to drive DLEM simulations of carbon and nutrient biogeochemistry in human-dominated regions.

- **Improve model representation of phosphorus (P) cycling.**

In the proposed task, we will further calibrate and evaluate this P submodel and apply it to simulate and predict the P export from land to the Chesapeake Bay as influenced by climate and land use changes.

DLEM simulation implementation for the NOAA Project

Theme 1 – Diagnosis: Realistic hindcasts (1985-2015)
(DLEM forced by multiple factors)

Theme 2 – Prediction: Realistic future simulations (2015-2050)
(DLEM forced by projected climate and land use scenarios)

Theme 3 – Attribution: Factorial (natural/climate vs. anthropogenic) simulations
(DLEM Factorial simulation experiments forced by individual or combined factors)

Theme 4 – Decision Support: Alternative management scenario simulations
(DLEM forced by alternative management scenario)

Other ongoing relevant work

Scale adaptive gas emission model

The new water transport model extend the biogeochemical processes within the grid cell, it could be used to reduce the scale effect of the large scale gas emission simulations such as NH3 or N2O emission.

Decision support model

Develop a sub-model with LID and BMP controls (methods generalized from SWMM or SUSTAIN model) and incorporate into DLEM.

We plan to use swarm intelligence algorithms (such as genetic algorithm or ant-colony algorithm) to balance the benefit gain from BMP/LID facilities and the cost by calculating the local optimization.