Estimating the Basin Extent and Persistence of Legacy Nutrient Sources with Dynamic SPARROW

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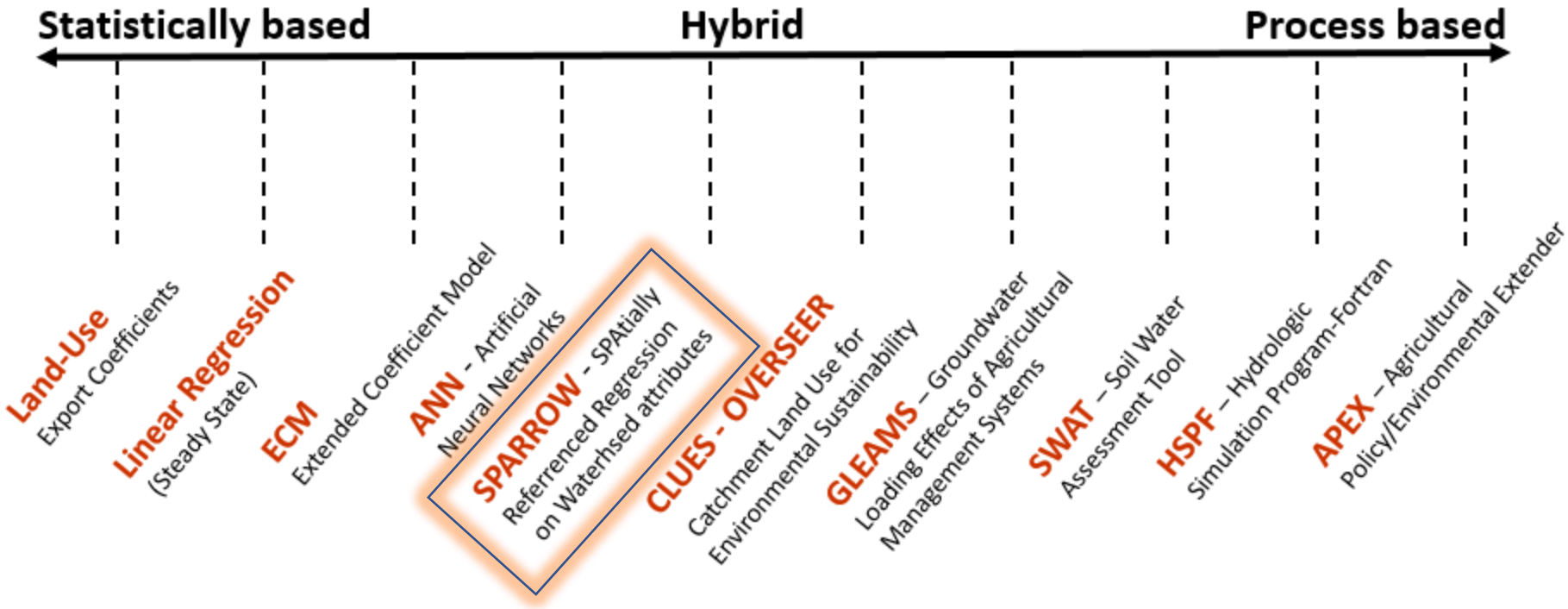
Watershed Modelling Continuum



SPARROW Water-Quality Model

SPAtially Referenced Regression on Watershed Attributes

Monitored Loads

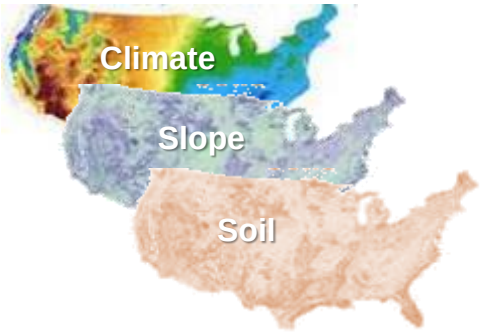
(100s to 1000s of sites)

(Y variable)

Spatial Data

Sources

Land-to-Water Delivery

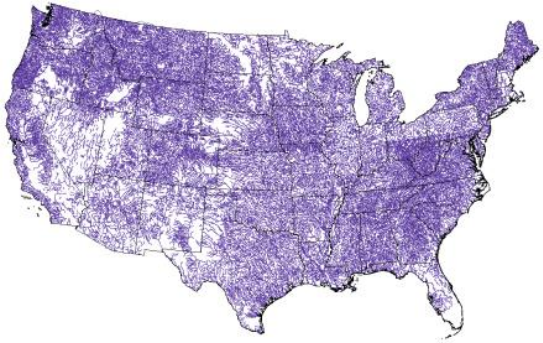


Stream & Reservoir Decay

(X variables)

Index to network

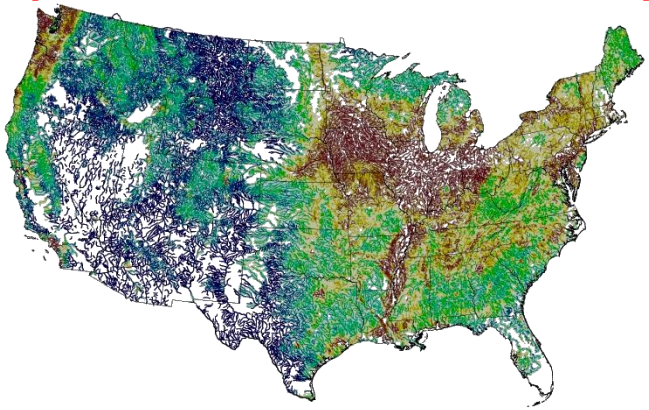
Routed Stream Network



Build and calibrate model

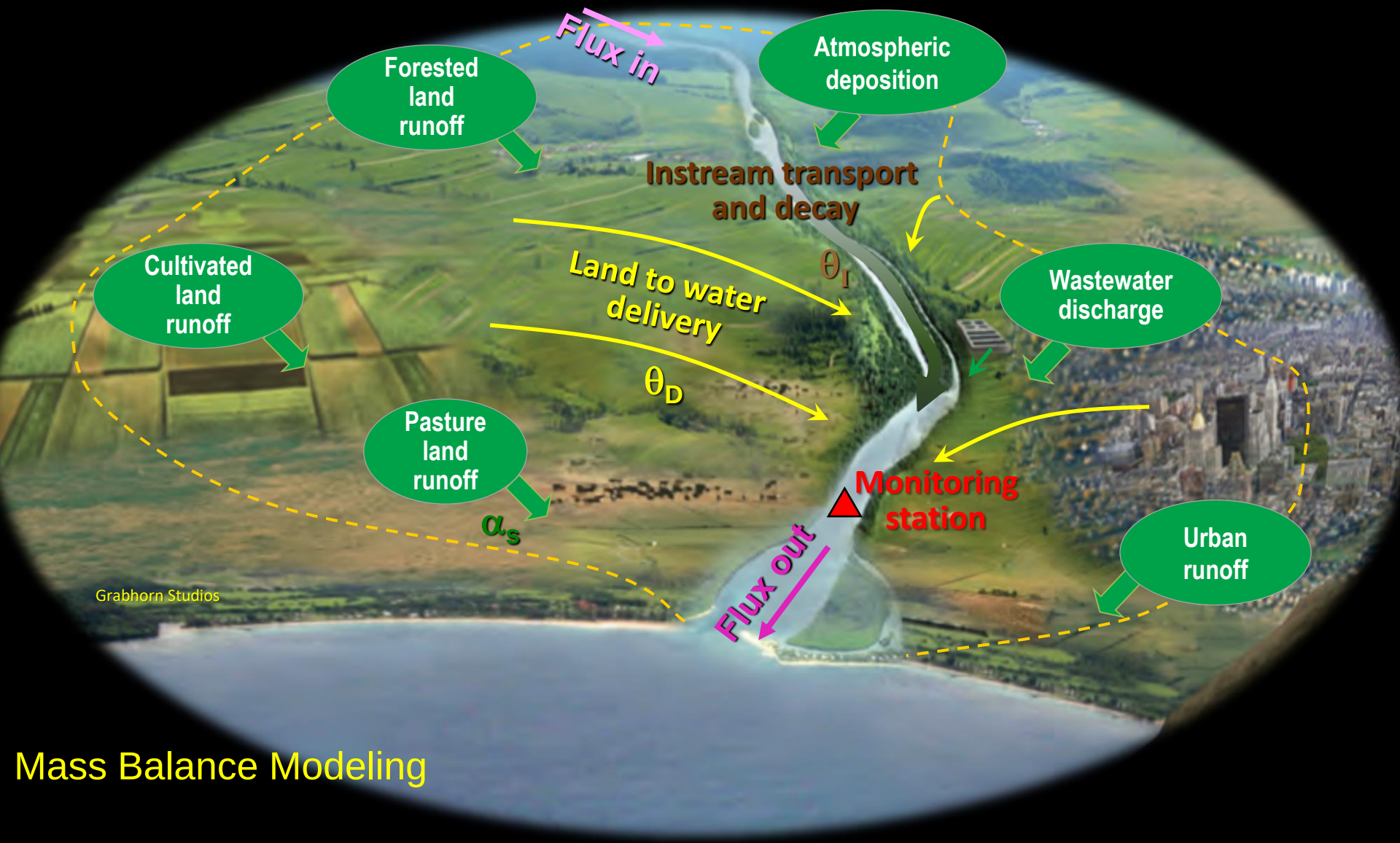
Model Predictions at all Stream Reaches

(10,000s to 1,000,000s reaches)



https://www.usgs.gov/mission-areas/water-resources/science/everything-you-need-know-about-sparrow

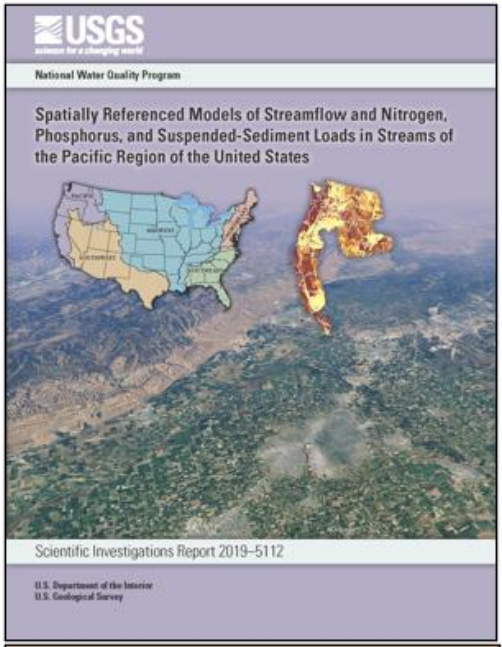
SPARROW: SPAtially Referenced Regression on Watershed attributes
Watershed Model

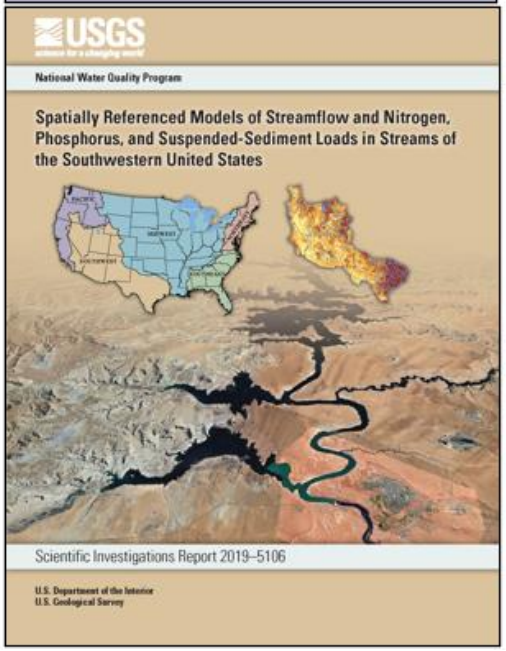


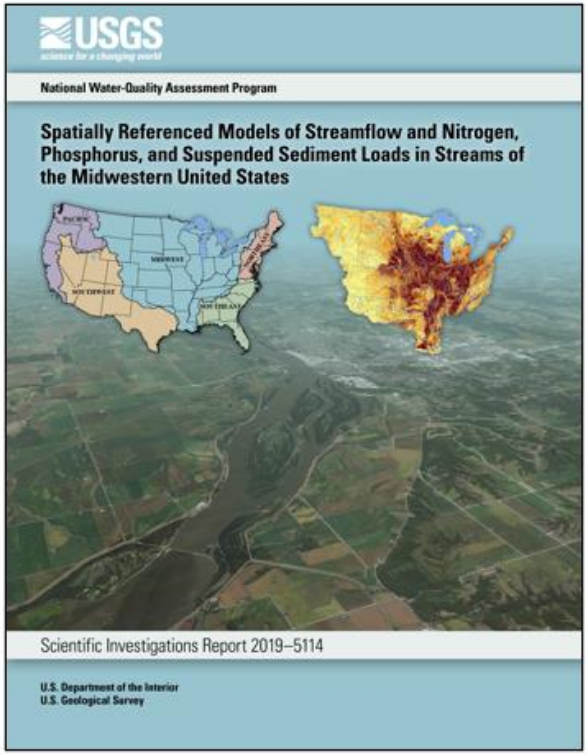
Mass Balance Modeling

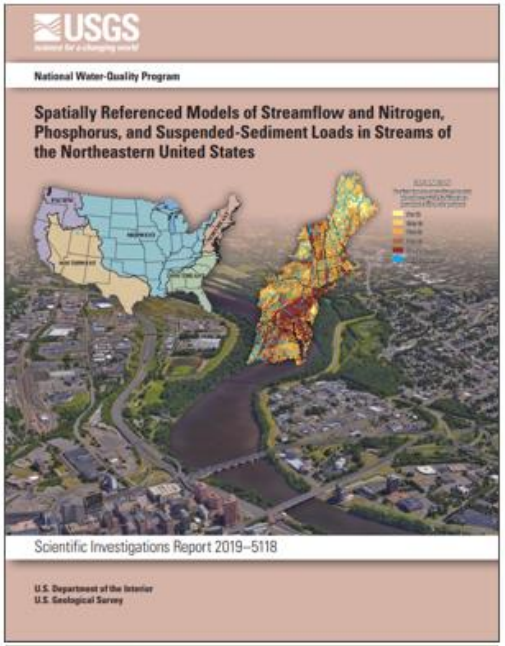
Target = Flux out = Flux in + (α_s Sources x θ_D Delivery) – θ_I Instream Decay

USGS Regional SPARROW Models



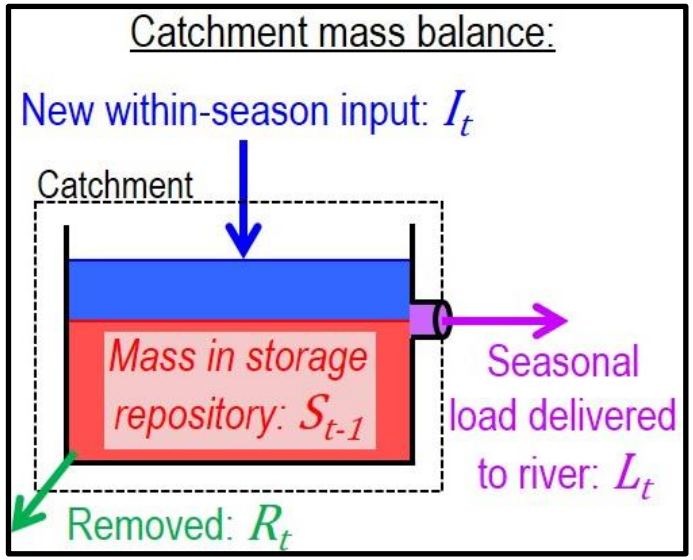






Making SPARROW dynamic unlocks predictive capabilities

Assume some mass is already in storage (**old**) before **new** inputs



Smith 2012; Schmadel et al. (2021) ERL

But we want to keep SPARROW usages

- Simple physics-guided statistical model
- Draws on nationally consistent datasets
- Multiscale: Spatially referenced
- Delivery from headwaters to estuaries

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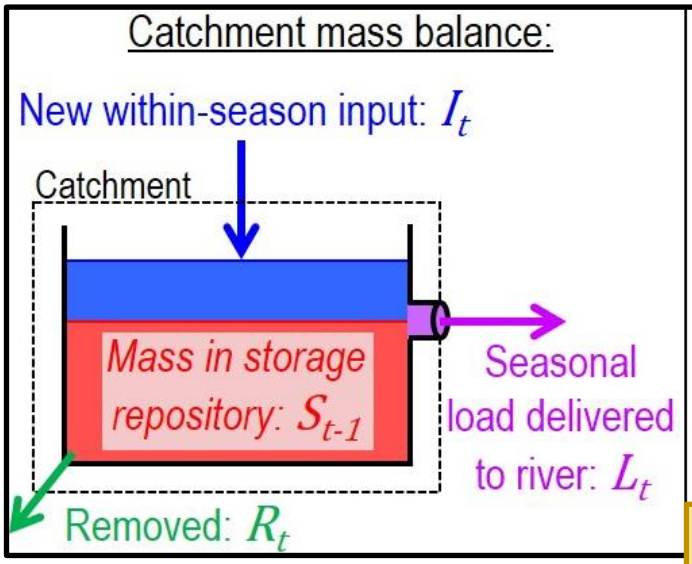

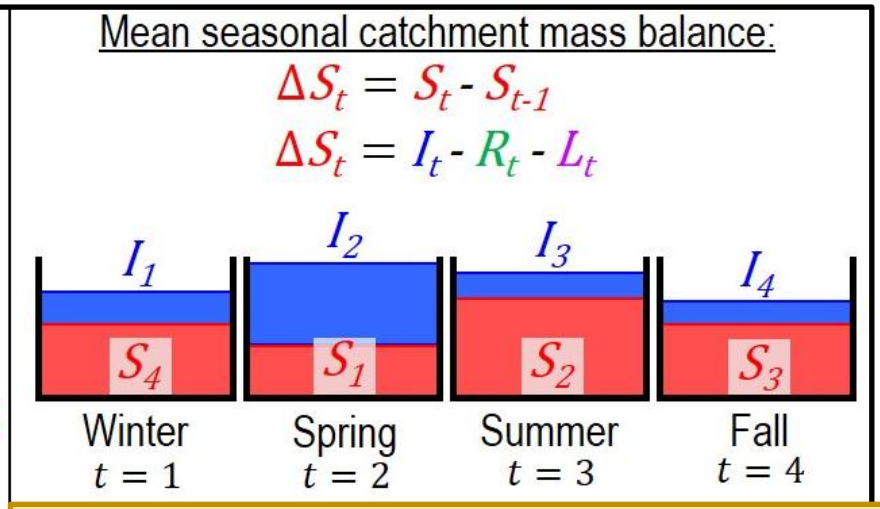

Smith 2012; Schmadel et al. (2021) ERL

Dynamic allows for quantification of **new** versus **old**:

$$L_t = \sum_{n=1}^{N} \alpha_n I_{t,n} f_{I,t,n} + \alpha_S L_{t-1} f_{S,t}$$

One-period lag (first-order storage process) rate of release: $\alpha_S f_{S,t}$

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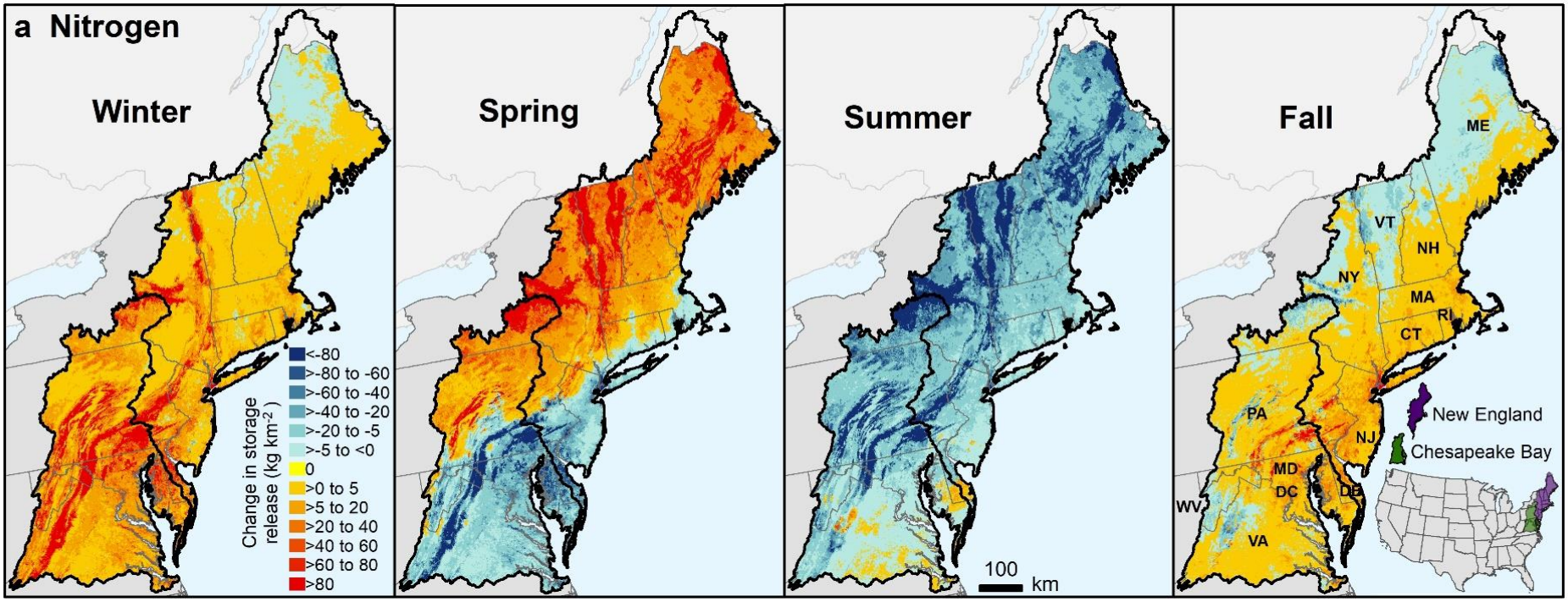
Seasonal shifts in drivers cause storage accumulation and release



Schmadel et al. (2021) ERL

Drivers

Runoff ↑ = **Storage release** ↑

Vegetation ↓ = **Storage release** ↑

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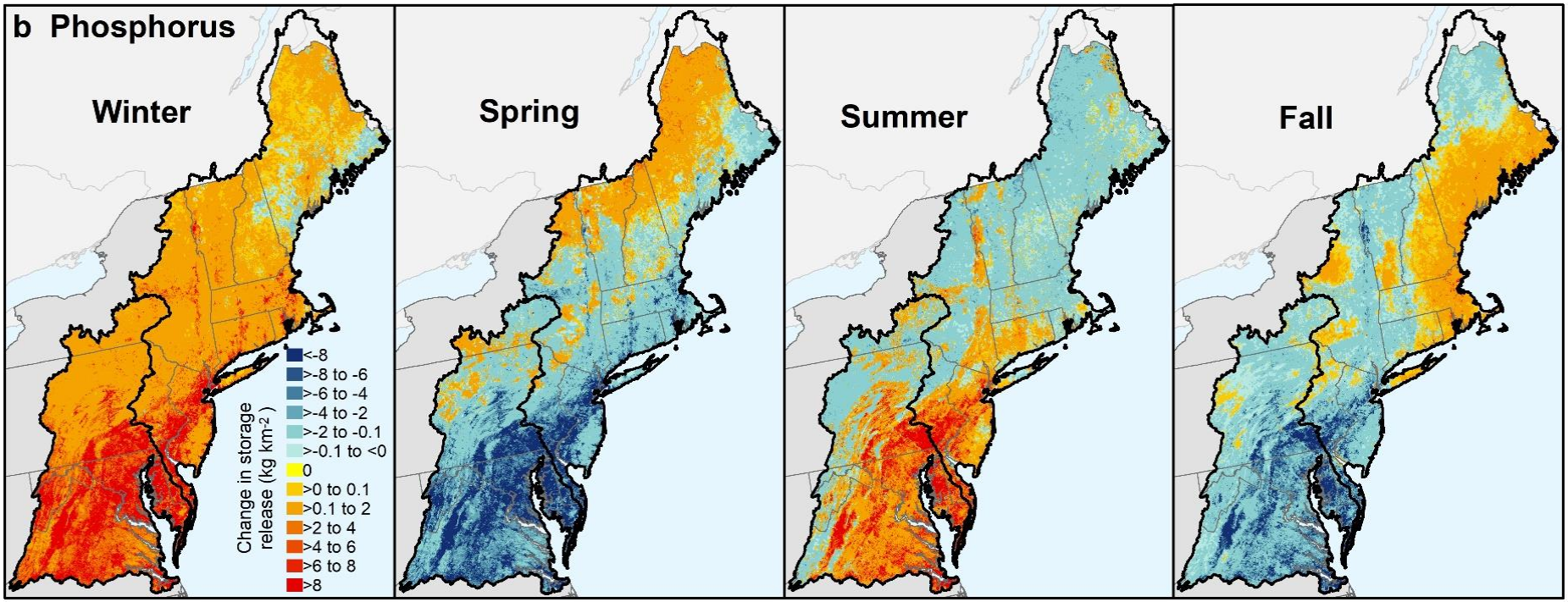
Seasonal shifts in drivers cause storage accumulation and release



Schmadel et al. (2021) ERL

Drivers

Precipitation ↑ = **Storage release** ↑

Vegetation ↓ = **Storage release** ↑

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Dynamic calibration helps identify key data and drivers

$$L_t = \sum_{n=1}^{N} \alpha_n I_{t,n} f_{I,t,n} + \alpha_S L_{t-1} f_{S,t}$$

New mass

Old mass

Nitrogen	Phosphorus
Explanatory variables	Explanatory variables
Sources	**Sources**
Wastewater point sources	Wastewater point sources
Fertilizer applications	Small streams
Fixation from soybean, alfalfa	Small ponds
Manure applications	Fertilizer applications
Atmospheric wet deposition	Manure applications
Urban land cover	Geology (siliciclastic, crystalline)
Catchment storage	Urban land cover
	Catchment storage
Input land-to-water delivery	**Land-to-water delivery**
Quickflow runoff	Quickflow runoff
NDVI	NDVI
Ratio nitrate to total inorganic N	Small upland ponds
Small ponds	Average overland flow distance
Average overland flow distance	
Storage land-to-water delivery	**Storage land-to-water delivery**
Change in runoff +	NDVI, previous period
Change in NDVI -	Change in precipitation +
NDVI, previous period	Change in NDVI -
Carbonate geology	Soil erodibility (K factor)
River corridor	**Aquatic decay**
Lakes, reservoirs, impoundments	Lakes, reservoirs, impoundments
Rivers, mean	Rivers, mean
Temperature, mean centered	Temperature, mean centered

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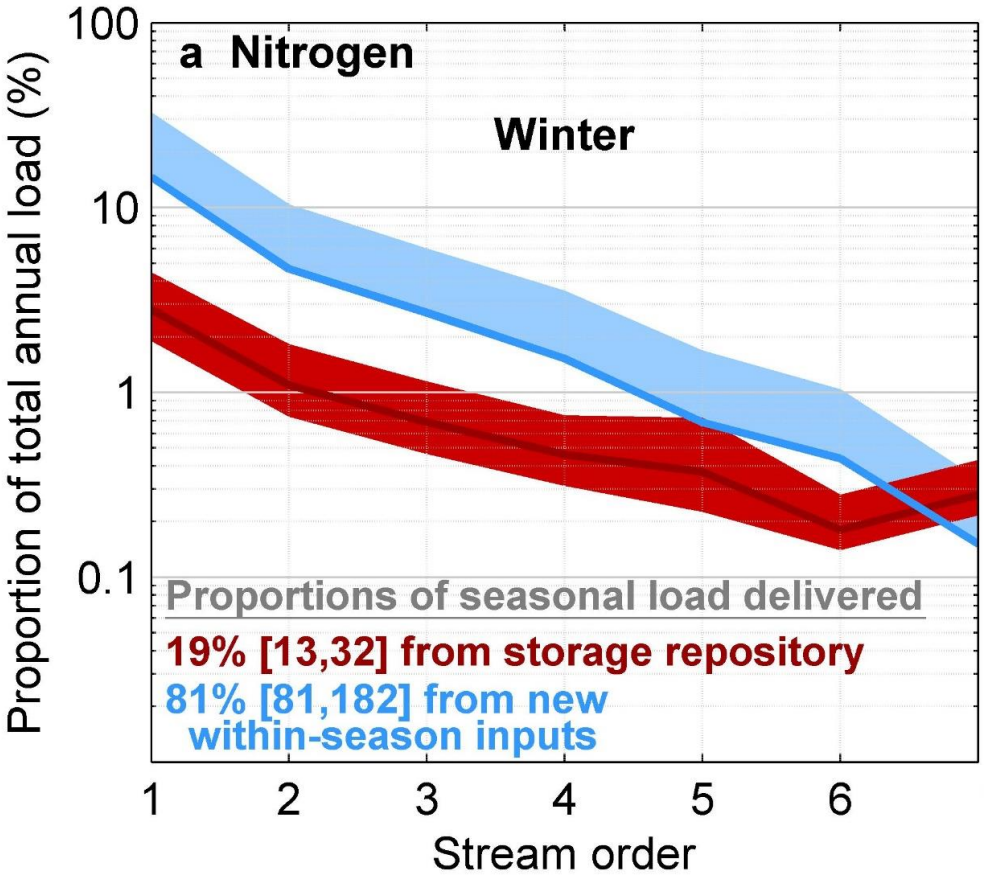
The contribution of storage to downstream nutrient load is significant



New mass

Old mass

Uncertainty shown =
Timing of fertilizer and manure applications

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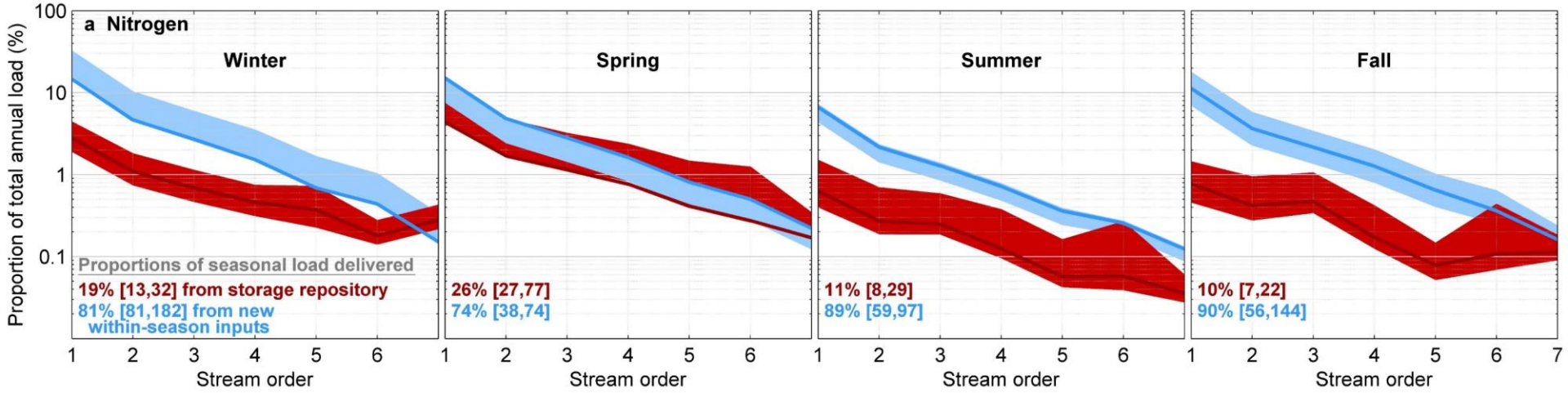

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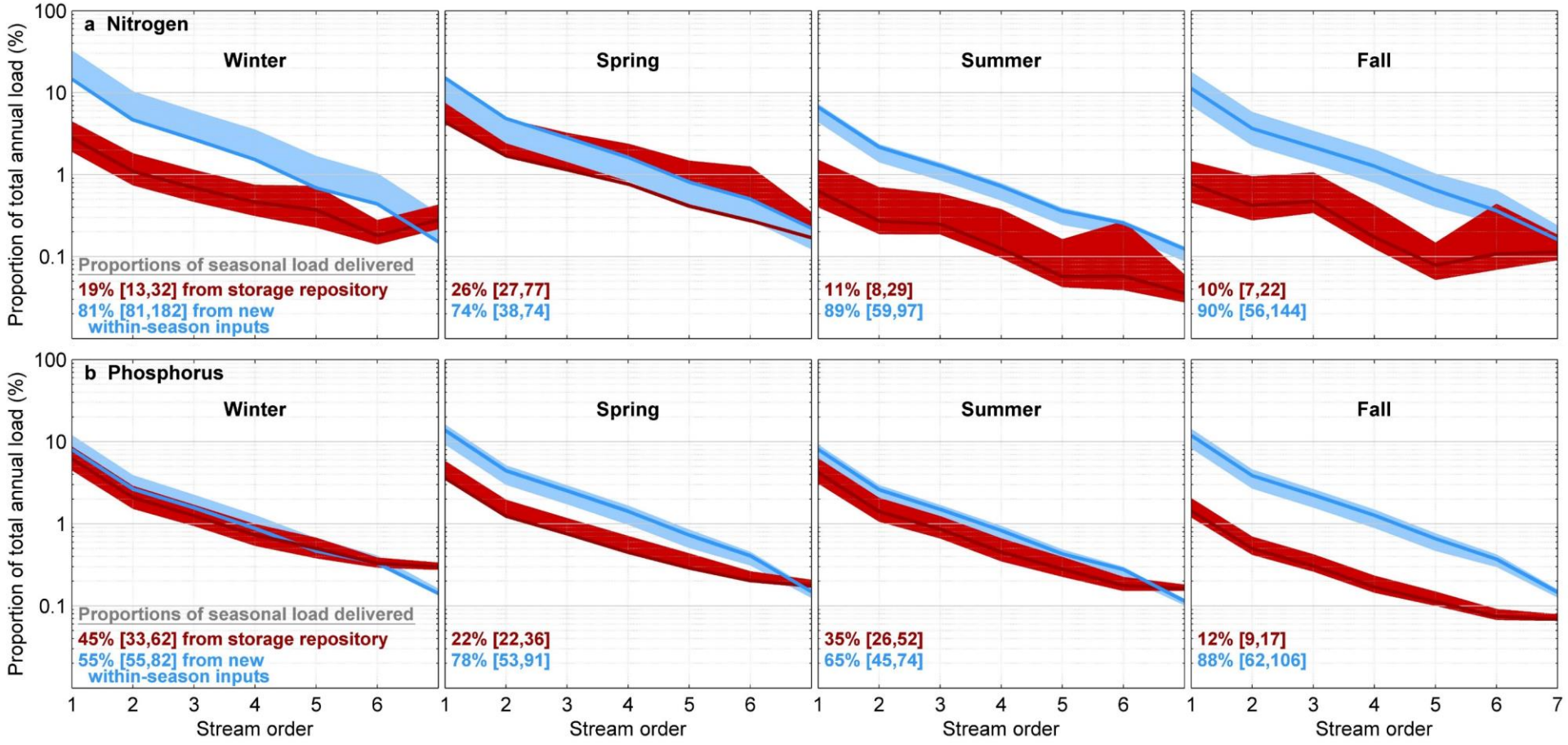

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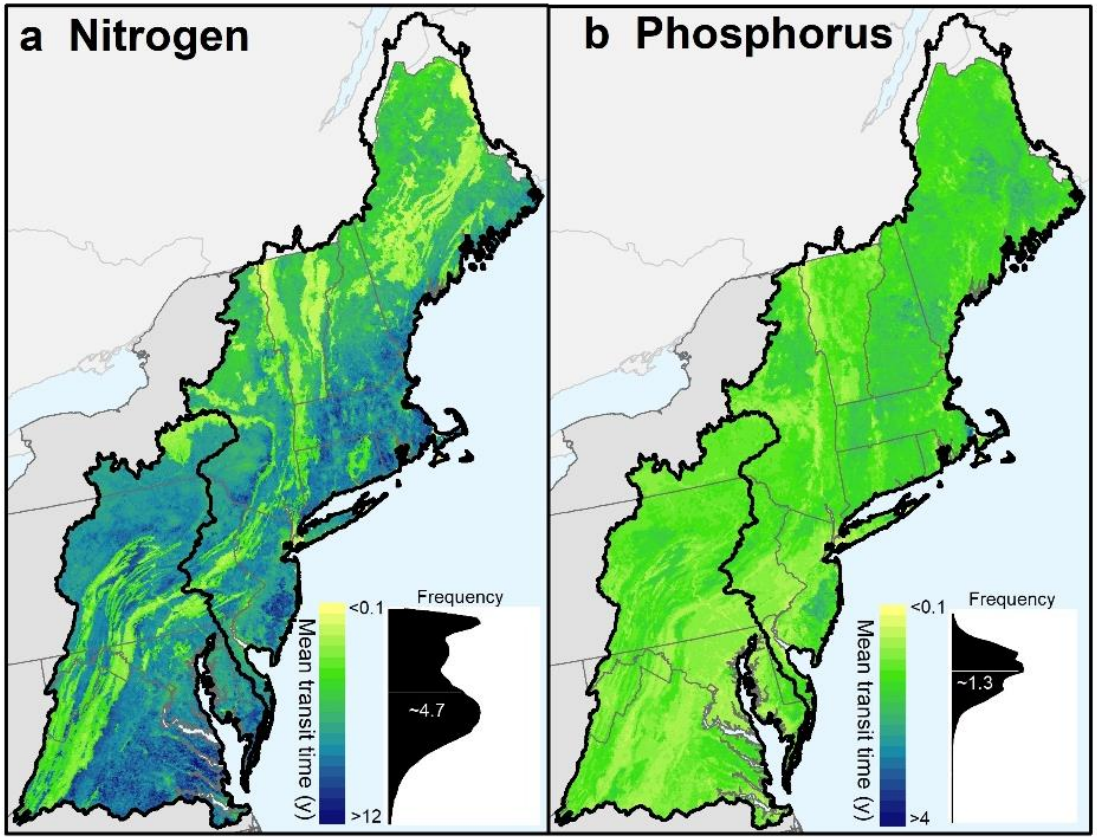
Catchment mean transit times indicate different N and P storage processes



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- Nitrogen: Regional mean of 4.7 years, highest density around 2 years
- Phosphorus: Regional mean around 1.3 years
- Delay in the downstream response to management practices should be expected.

Dynamic allows for quantification of **new** versus **old**:

$$L_t = \sum_{n=1}^{N} \alpha_n I_{t,n} f_{I,t,n} + \alpha_S L_{t-1} f_{S,t}$$

Mean transit time $\approx 1/\alpha_s \Sigma f_{S,t}$

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Improved dynamic accounting unlocks predictive capabilities

(1) What is the role of nutrient legacies from headwaters to estuaries and from **season-to-season** and **year-to-year**?

- Developing longer period models of priority basins (Illinois River Basin, Puget Sound, Upper Colorado) but the vision is CONUS
- Stakeholders: USGS Water Mission Area Integrated Water Availability National Project & Washington State Department of Ecology

(2) The eventual goal is next-season forecasts of nutrient loads.

- Improved parsing of N and P storage processes, but which processes?
- New ways of accounting for dynamic river corridor processes

Thank you!