SWAT Conference & Workshop 2024 – Lima, Perú

Hydrological Modeling with the Soil and Water Assessment Tool (SWAT+) Using the Alternative POLARIS Soil Dataset

Efrain Noa-Yarasca, Javier Osorio Leyton, Mike White, Jeff Arnold

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Agenda

Introduction

Methodology

Results

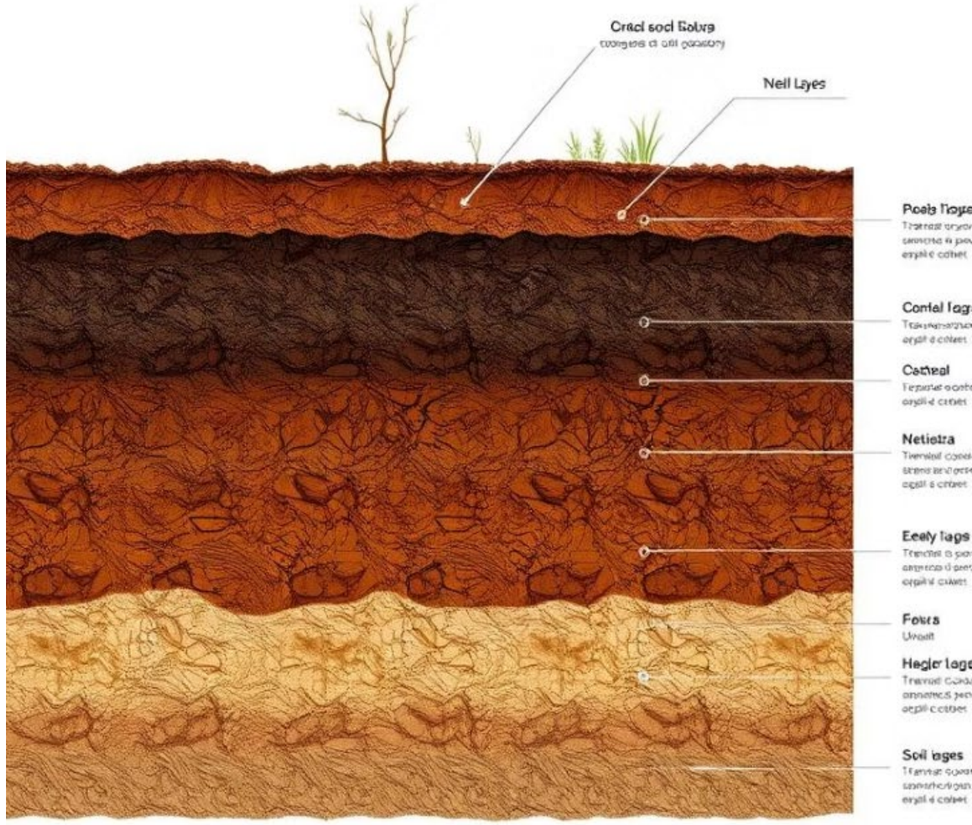
Conclusion

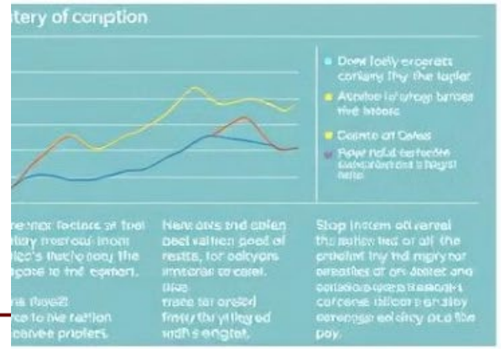
Questions

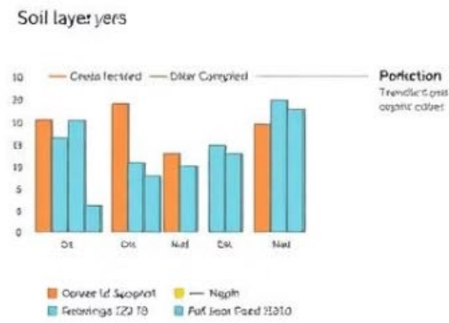
Introduction: Importance of Soil

Databases in Hydrological Modeling

- Soil databases are essential for hydrological modeling and environmental science.
- Having extensive and detailed soil data makes hydrological models more accurate and reliable.
- Soil properties like texture, water content, bulk density, and organic matter impact key processes such as infiltration, runoff, and evapotranspiration.
- Accurate soil data lead to better model predictions of streamflow, sediment yield, and more.





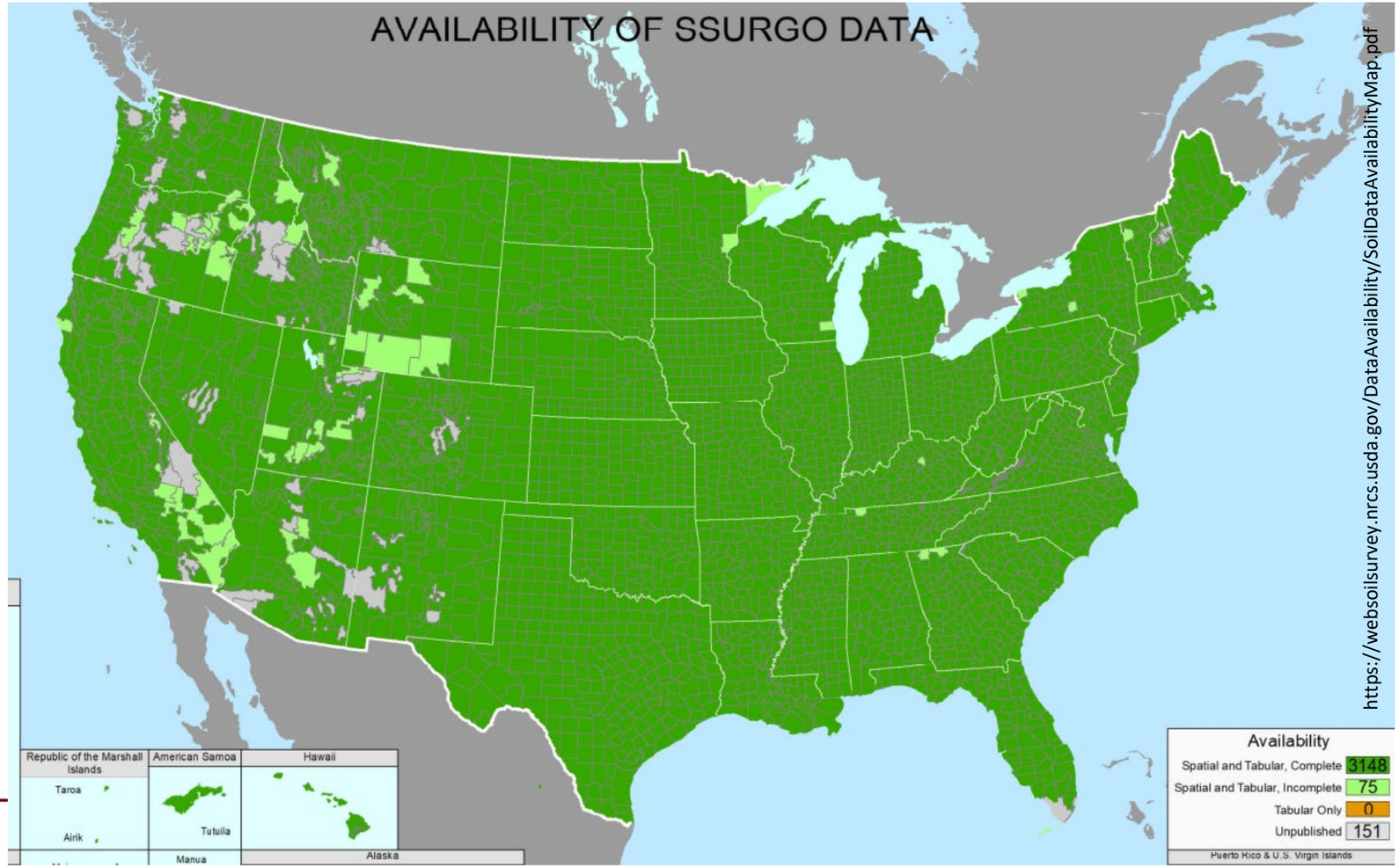


SSURGO Database: Strengths and Limitations

The SSURGO database, a key resource for hydrological modeling with detailed century-old soil data, is valuable but has known limitations.

"Note 2: While SSURGO data packages are available for all areas of the United States and Island territories, the soil survey has not been completed for some remote areas of the Western United States. When you download SSURGO data for these areas, you will see a single map unit with the map unit symbol of NOTCOM and the map unit name of **Not Completed *Areas***. *Additionally, some SSURGO data packages contain a mixture of soil survey data and NOTCOM".*

Natural Resources Conservation Service (2024)



SSURGO Database: Strengths and Limitations

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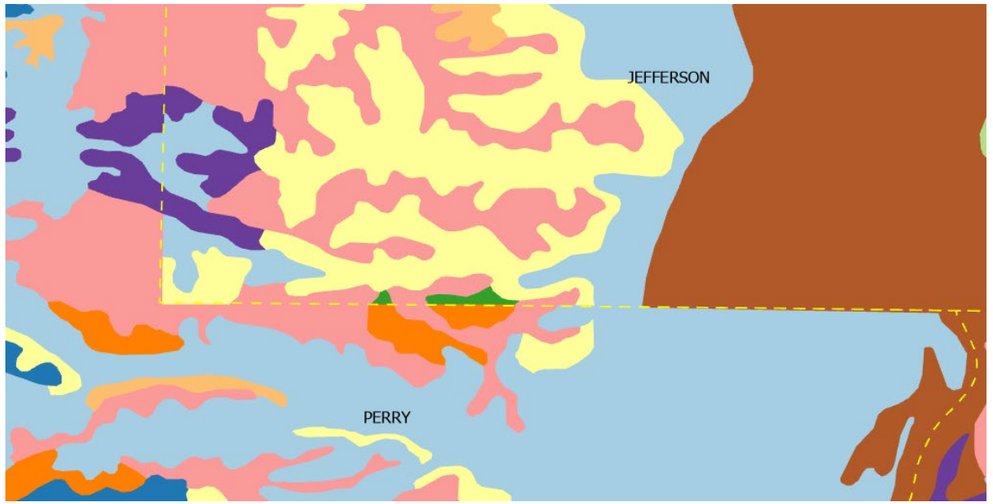
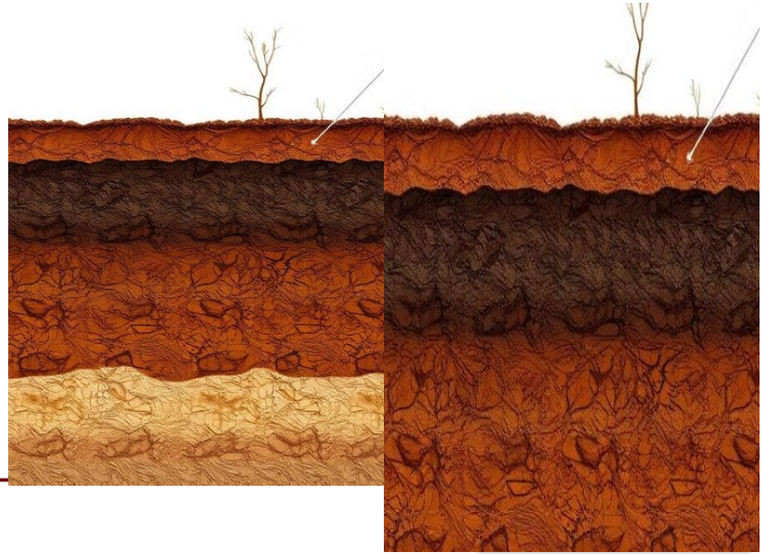
- Artificial discontinuities at governmental borders



- Non-uniform soil layers in contiguous areas
- Lack uniform depth.



POLARIS Database: Advancements in Soil Mapping

The Probabilistic Remapping of SSURGO (POLARIS) database addresses several limitations of SSURGO through **Digital Soil Mapping** and **machine learning** techniques (Chaney et al., 2016, 2019)

1 **Continuity**

Spatially continuous soil data across USA

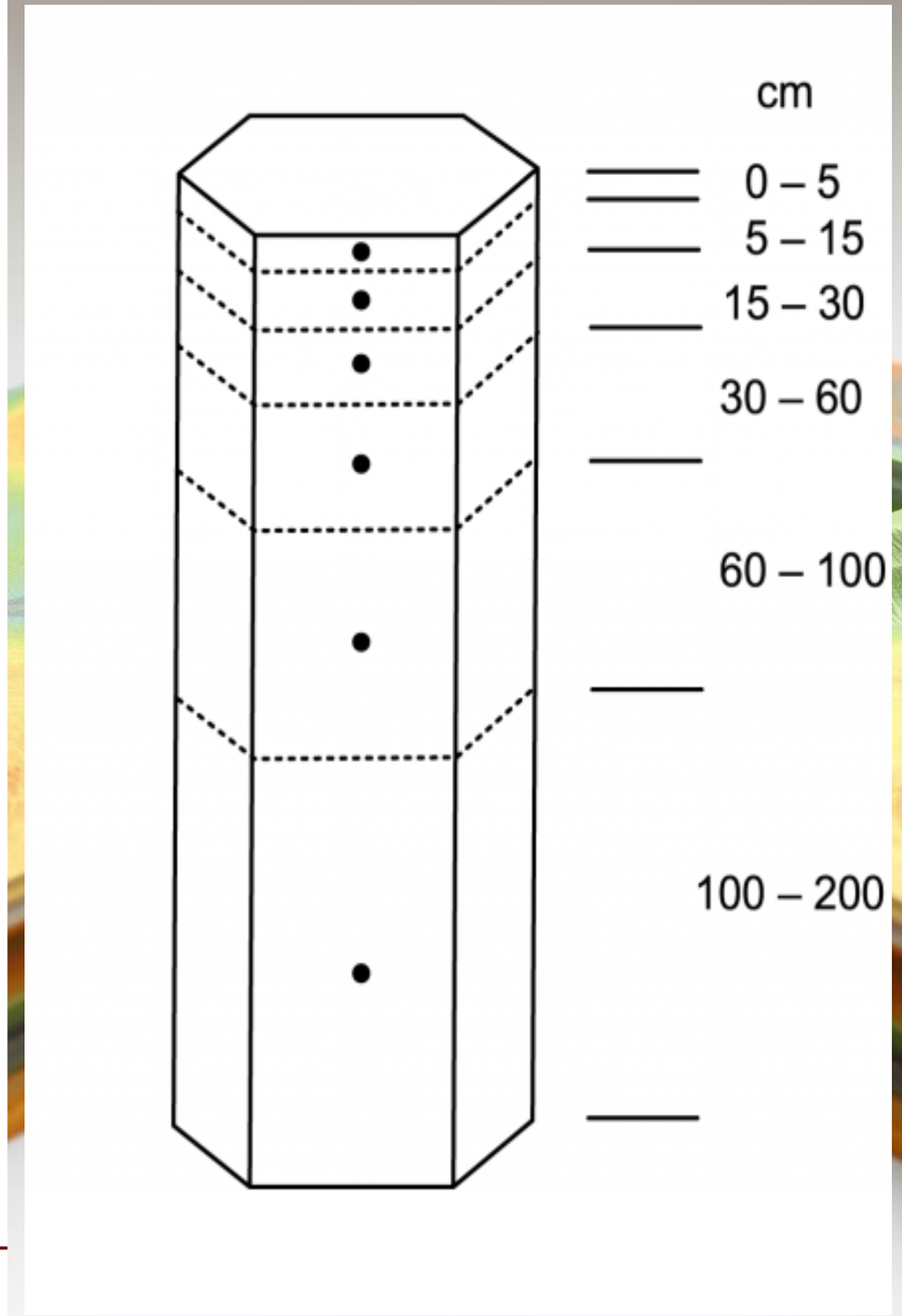
2 **Consistence**

Consistent soil data in number of layers and layer depth (2.0 m)

3 **Uncertainty**

Inclusion of associated uncertainties in soil properties (bulk density, organic matter content, soil texture (clay, silt, and sand), and available water capacity).

P5, P50, P95, mean, and mode



POLARIS Database: Advancements in Soil Mapping

http://hydrology.cee.duke.edu/POLARIS/

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lat2425_lon-98-97.tif	2019-05-03 23:21	211K	
lat2526_lon-80-79.tif	2019-05-03 23:21	211K	
lat2526_lon-81-80.tif	2019-05-03 23:20	3.5M	
lat2526_lon-82-81.tif	2019-05-03 23:20	2.5M	
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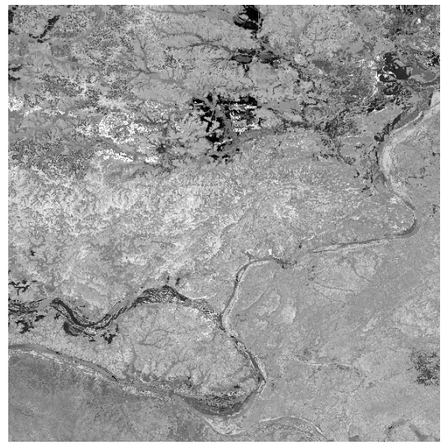
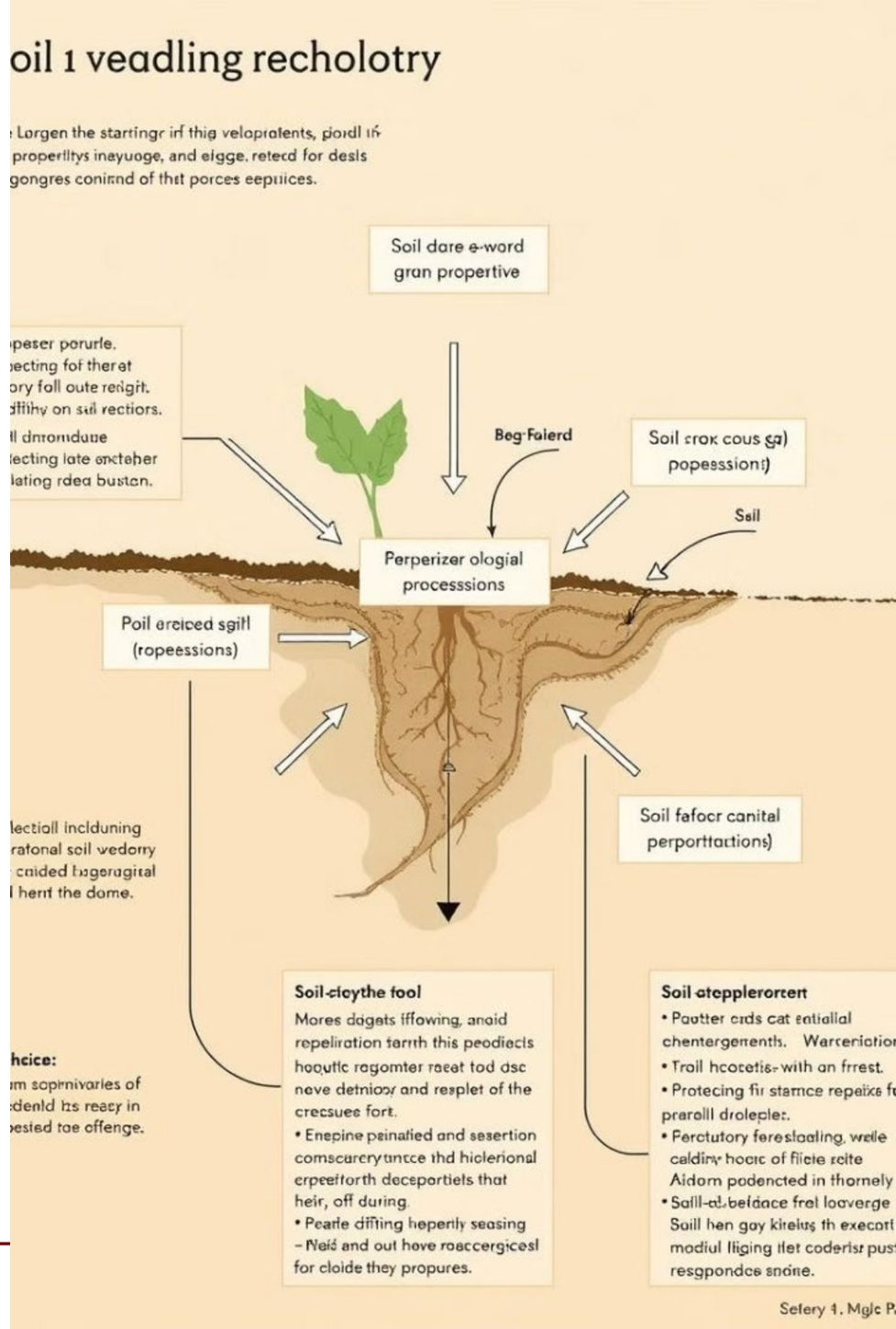


Objectives:

- The study examines how the POLARIS soil dataset performs in streamflow and sediment yield modeling using SWAT+.
- POLARIS soil data results are compared to SSURGO data results



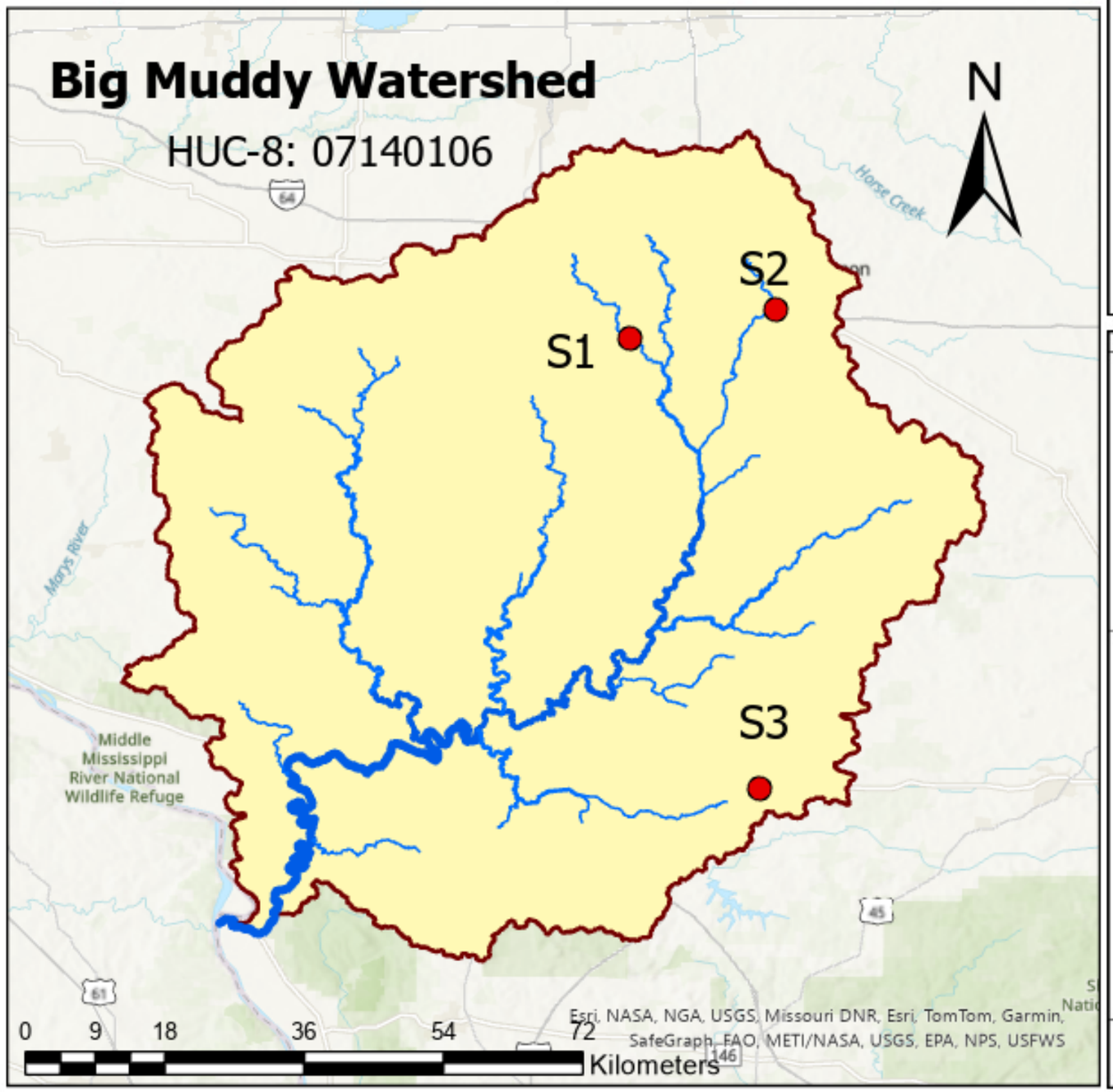
Study Area: Big Muddy River Watershed

Area: 6086 km^2

Land-use:
Agriculture and forests (upper & central areas)

Natural vegetation & wetlands for flood and water quality control (lower areas)

Soil:
Silt over clay with slow drainage and high water-holding capacity



Methodology

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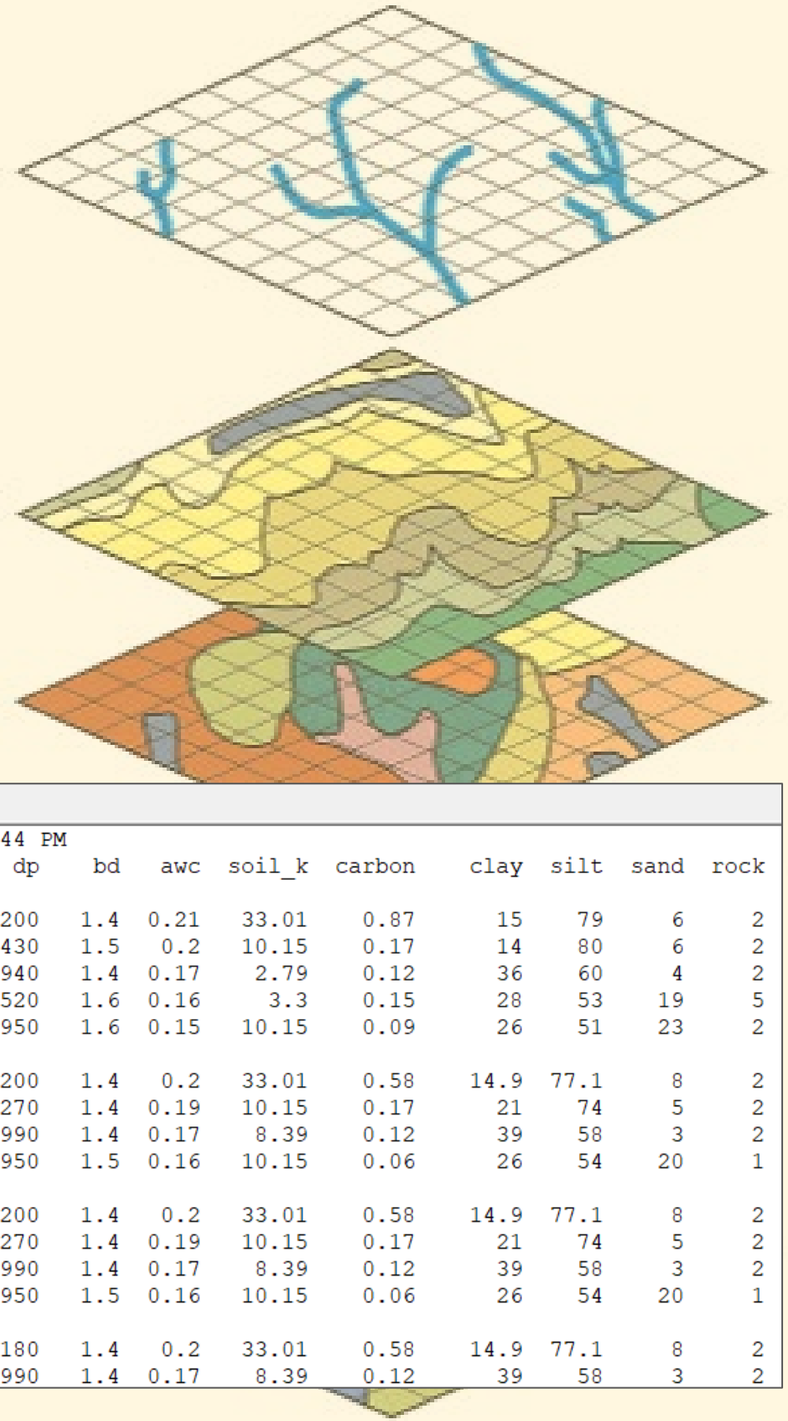

soils.sol

soils.sol

```
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 1403668          5       C   1950      0.365    3.402                             Fine
                                                                                    200   1.4  0.21   33.01   0.87     15    79     6     2
                                                                                    430   1.5   0.2   10.15   0.17     14    80     6     2
                                                                                    940   1.4  0.17    2.79   0.12     36    60     4     2
                                                                                   1520   1.6  0.16     3.3   0.15     28    53    19     5
                                                                                   1950   1.6  0.15   10.15   0.09     26    51    23     2
 1403670          4       C   1950      0.381    4.255                             Fine
                                                                                    200   1.4   0.2   33.01   0.58   14.9  77.1     8     2
                                                                                    270   1.4  0.19   10.15   0.17     21    74     5     2
                                                                                    990   1.4  0.17    8.39   0.12     39    58     3     2
                                                                                   1950   1.5  0.16   10.15   0.06     26    54    20     1
 1403671          4       C   1950      0.381    4.255                             Fine
                                                                                    200   1.4   0.2   33.01   0.58   14.9  77.1     8     2
                                                                                    270   1.4  0.19   10.15   0.17     21    74     5     2
                                                                                    990   1.4  0.17    8.39   0.12     39    58     3     2
                                                                                   1950   1.5  0.16   10.15   0.06     26    54    20     1
 1403674          3       C   1950      0.377    4.514                             Fine
                                                                                    180   1.4   0.2   33.01   0.58   14.9  77.1     8     2
                                                                                    990   1.4  0.17    8.39   0.12     39    58     3     2
```

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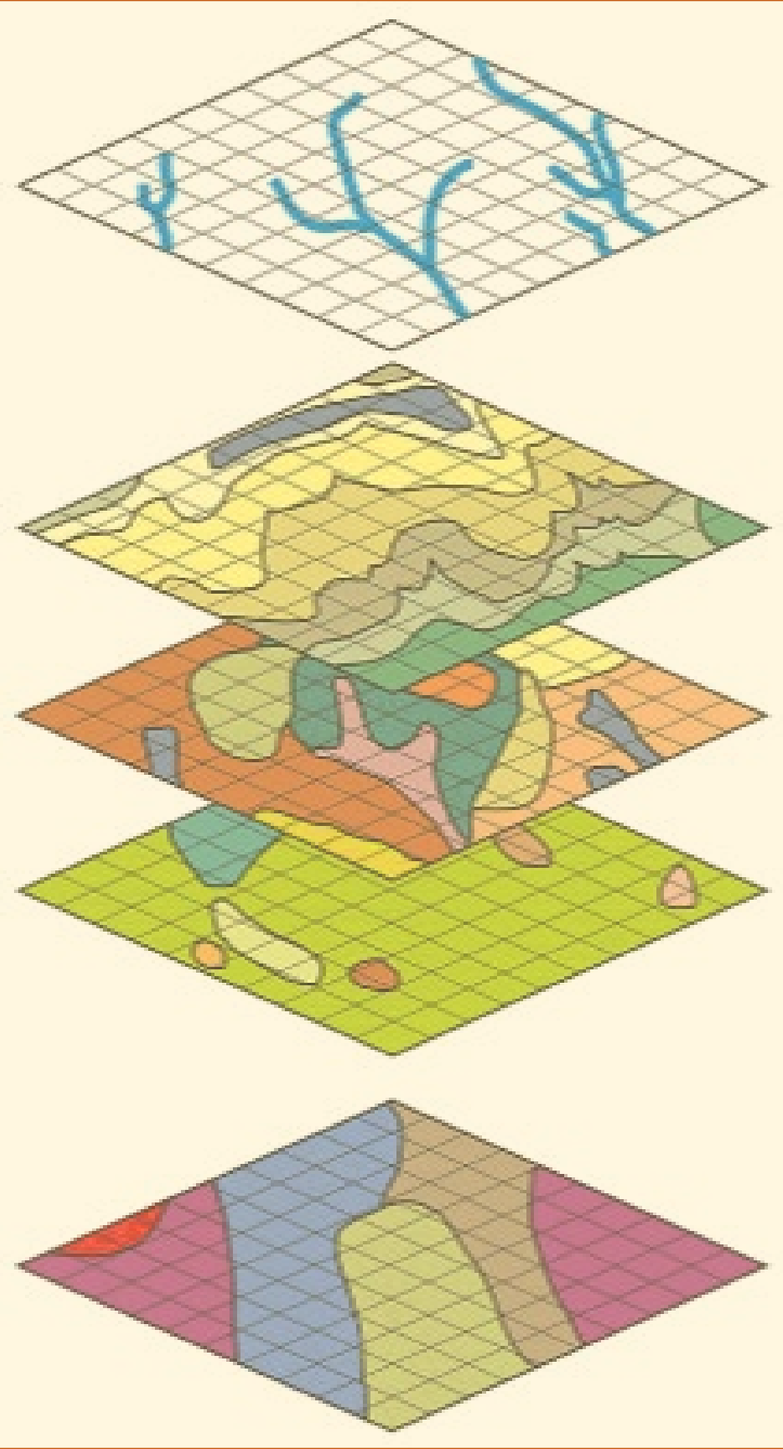
Run the SWAT model with the prepared soil data	SWAT+	SWAT+
Compare SSURGO and POLARIS Model Outputs		

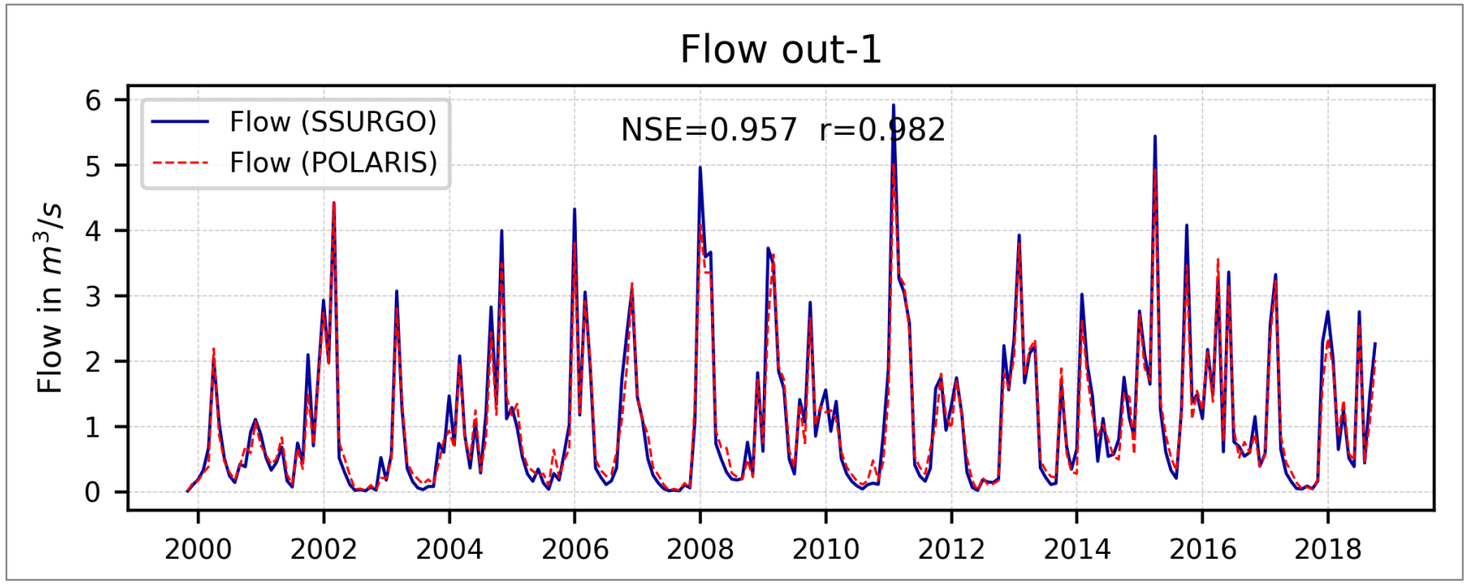


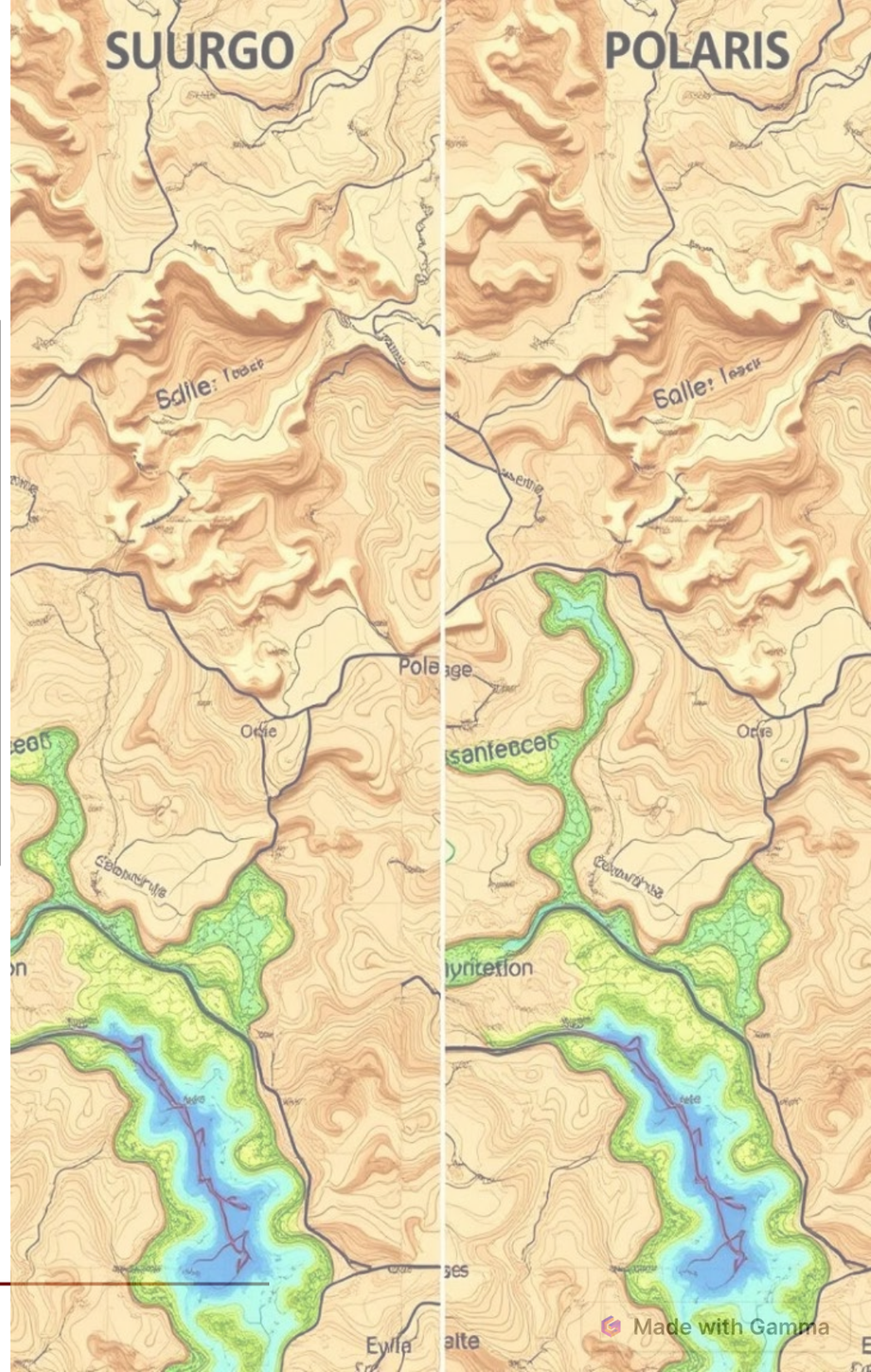
Modeling settings

- Land use data: National Land Cover Database (NLCD) (Raster: 30x30 m)
- Soil data: SSURGO and POLARIS (USDA, 2023).
- Slope: three ranges: 0 - 5, 5 - 20, > 20 %.
- sub basins: 93
- HRUs: 14794
- Modeling period: 2000 – 2018 (19 years)
- Soft calibration

Results: Streamflow

- SWAT model simulations for streamflow were visually similar





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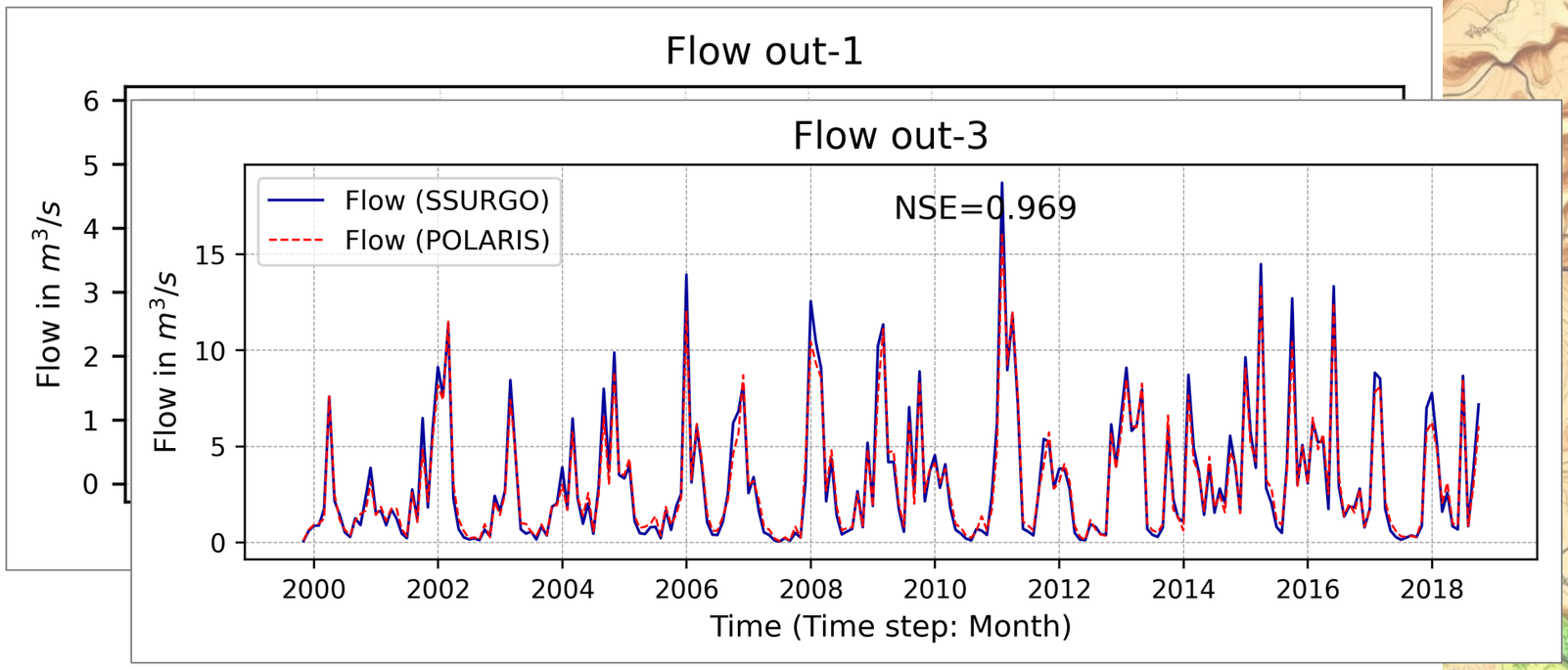
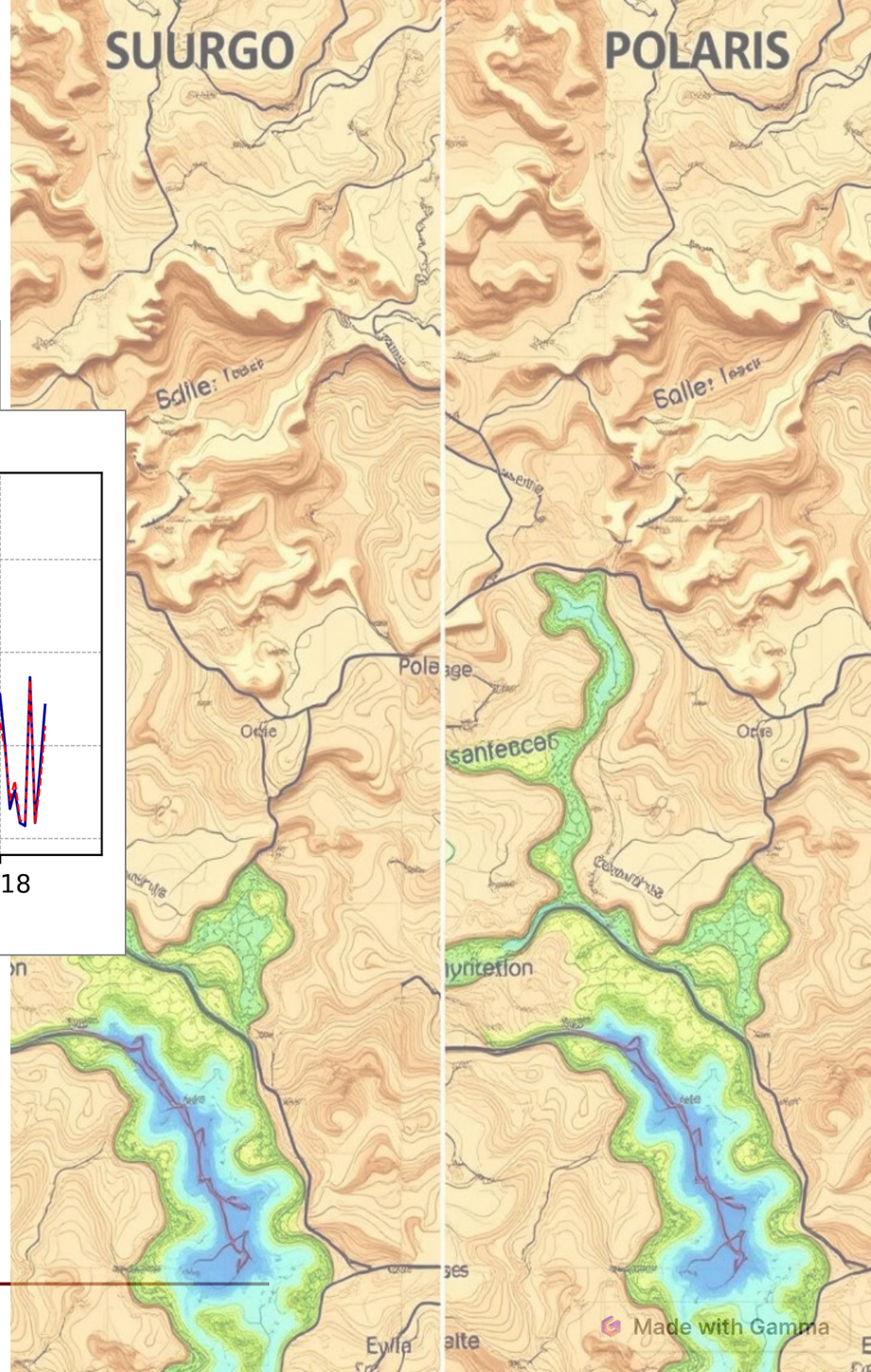




Results: Streamflow

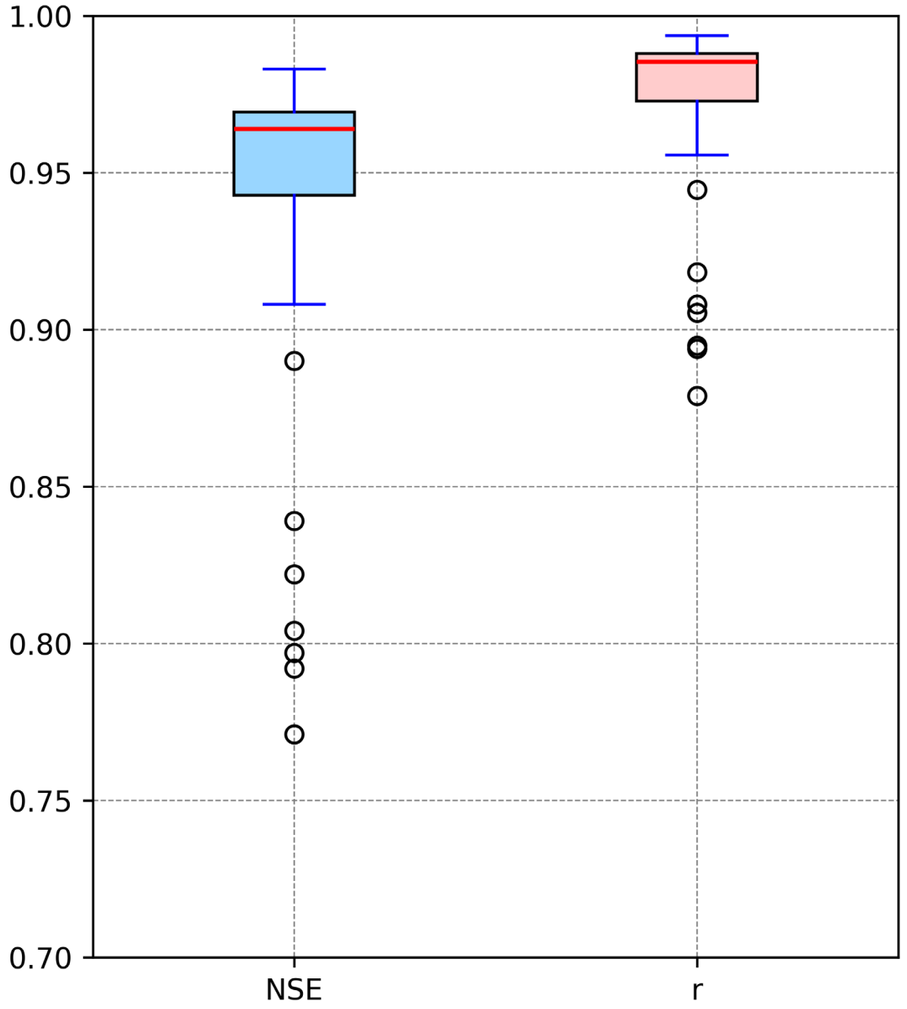
For the 93 sub-basins:

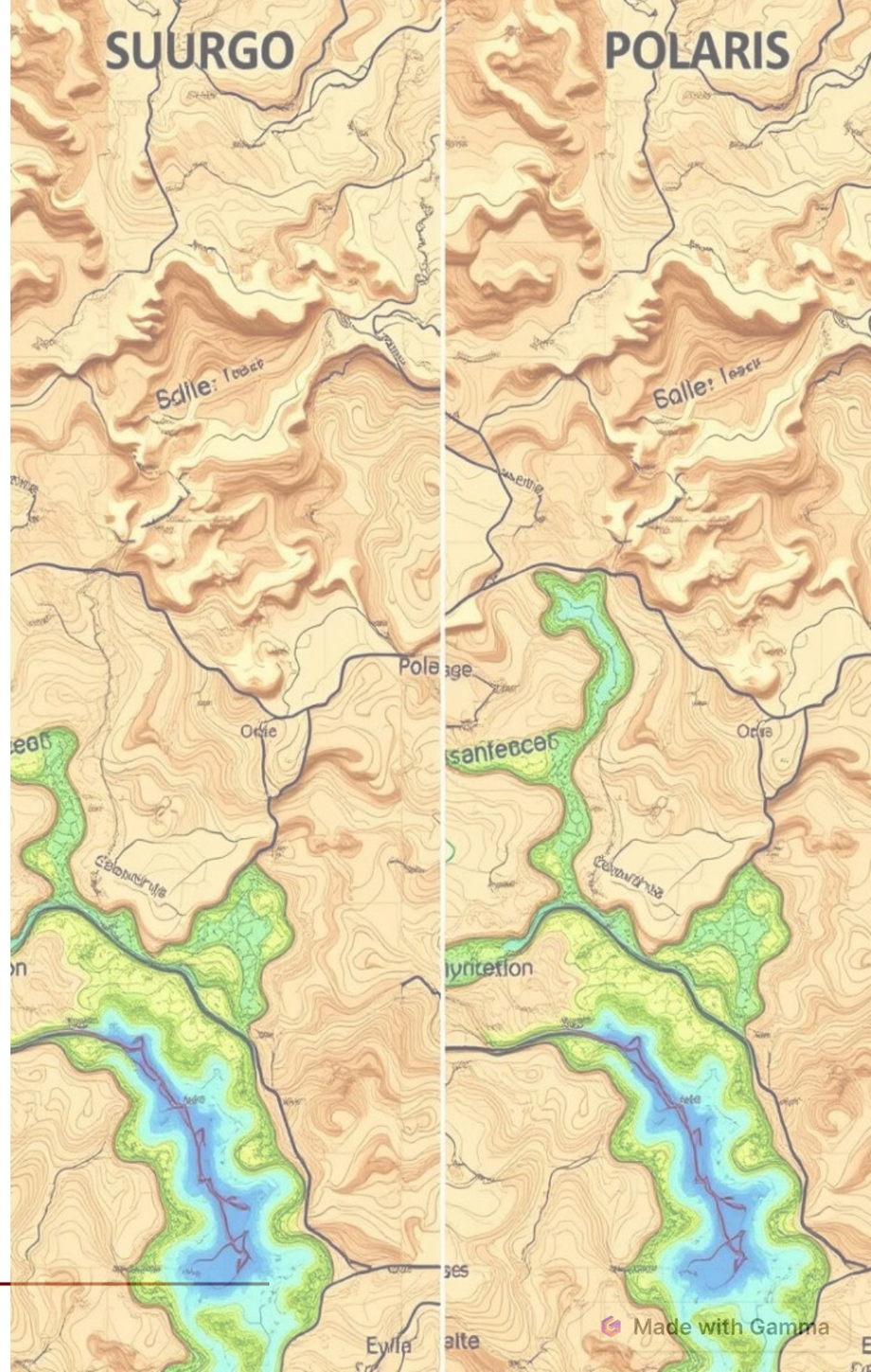
NSE = 0.771 to 0.983

(M = 0.96, SD = 0.043),

r = 0.879 to 0.994

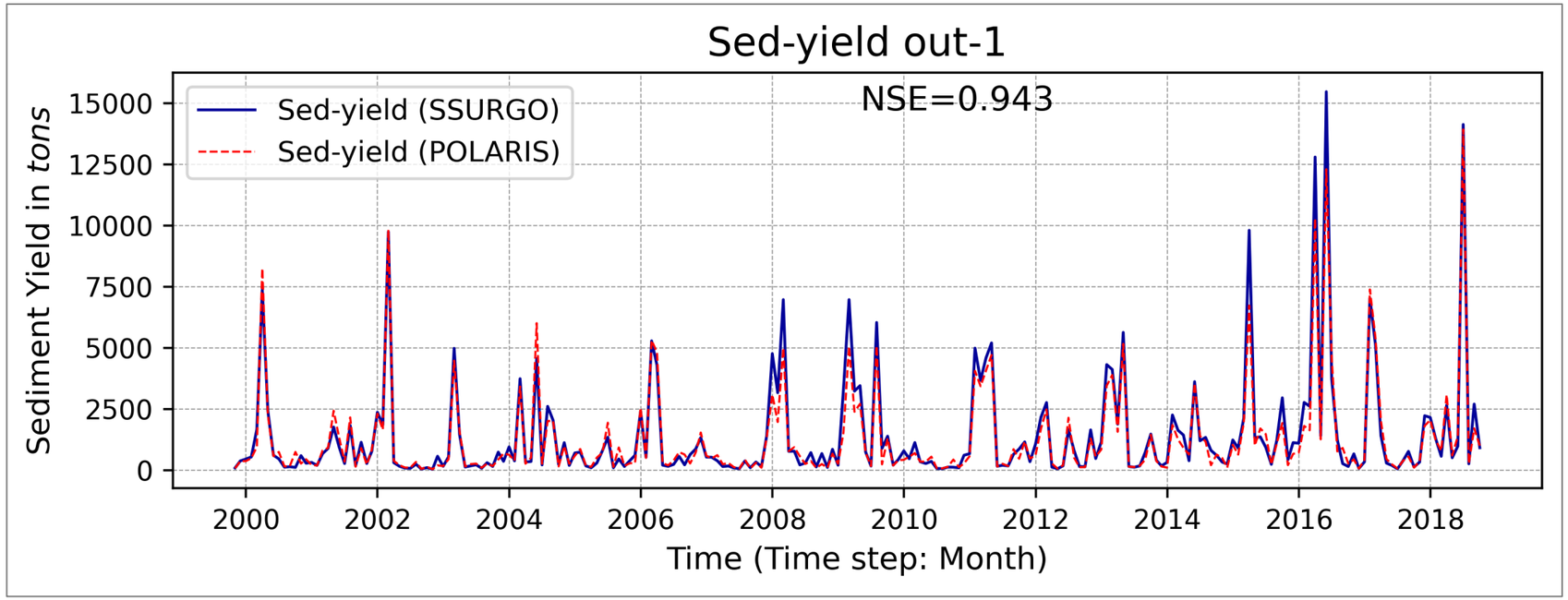
(M = 0.98, SD = 0.023)

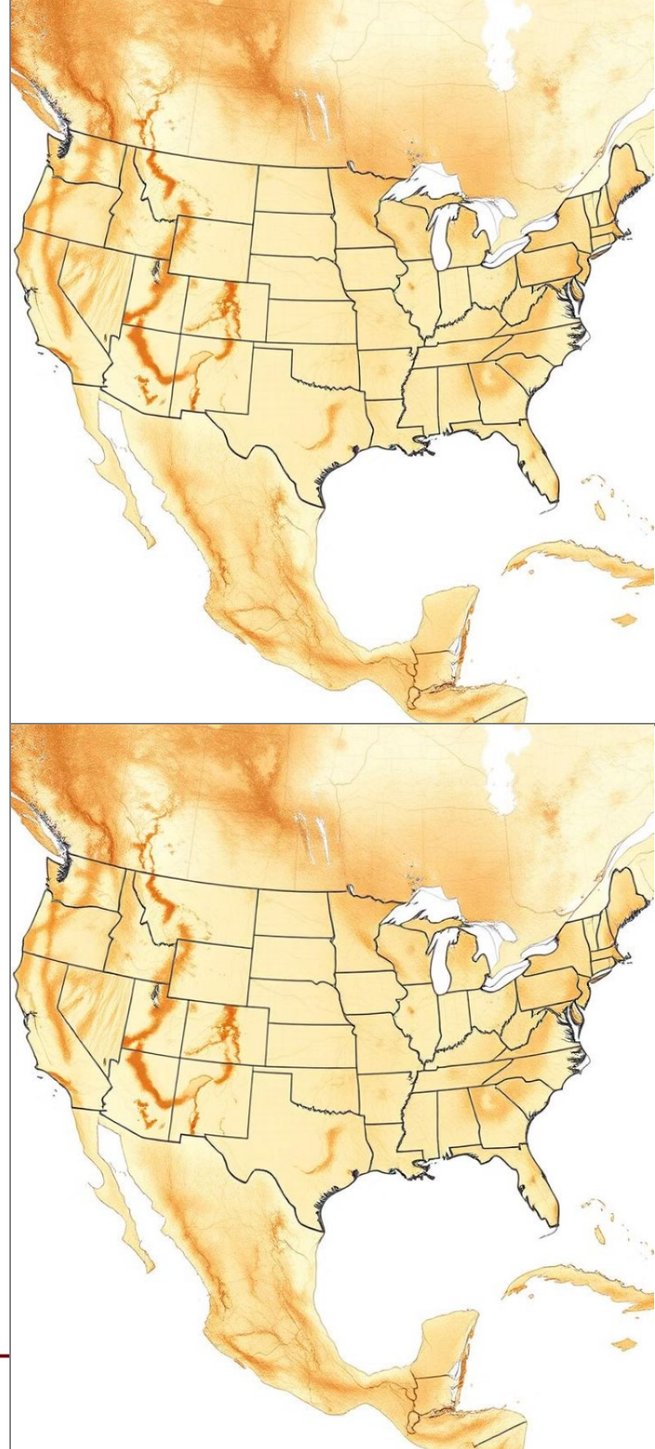




Results: Sediment yield

- SWAT model simulations for sediment yield were visually similar





Results: Sediment yield

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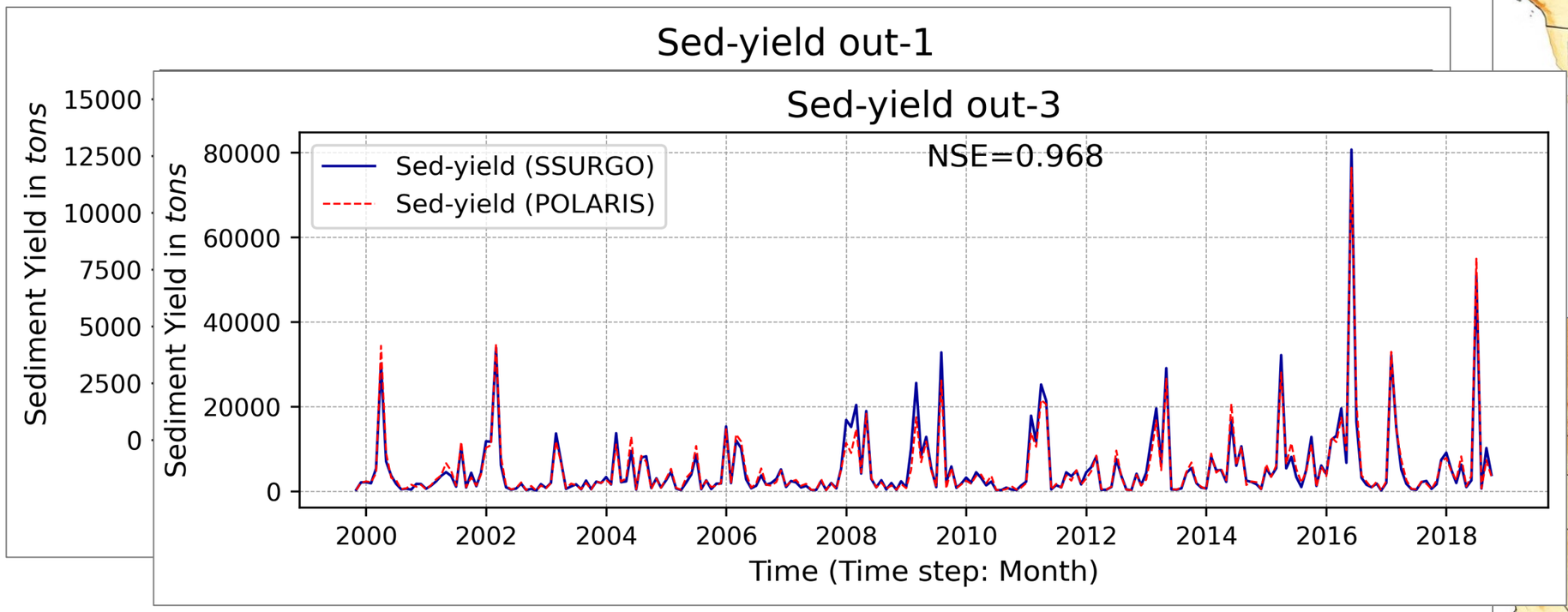
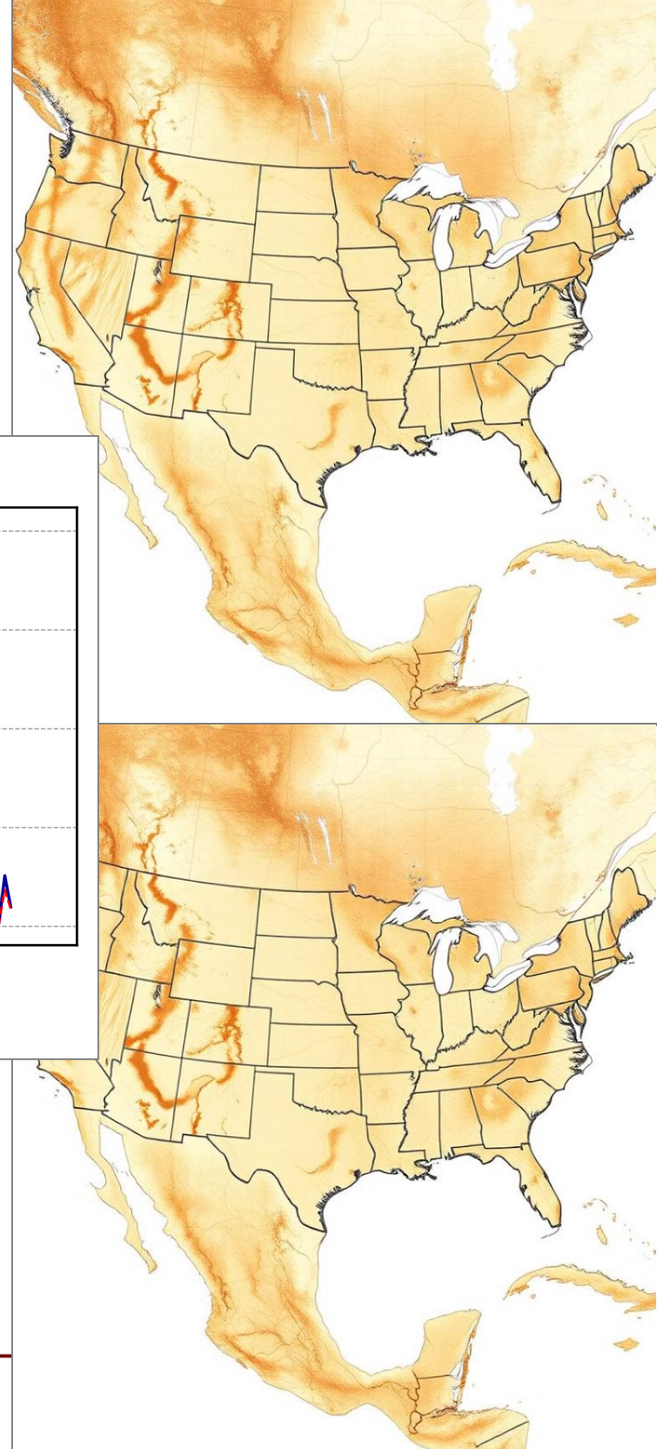




Results: Sediment yield

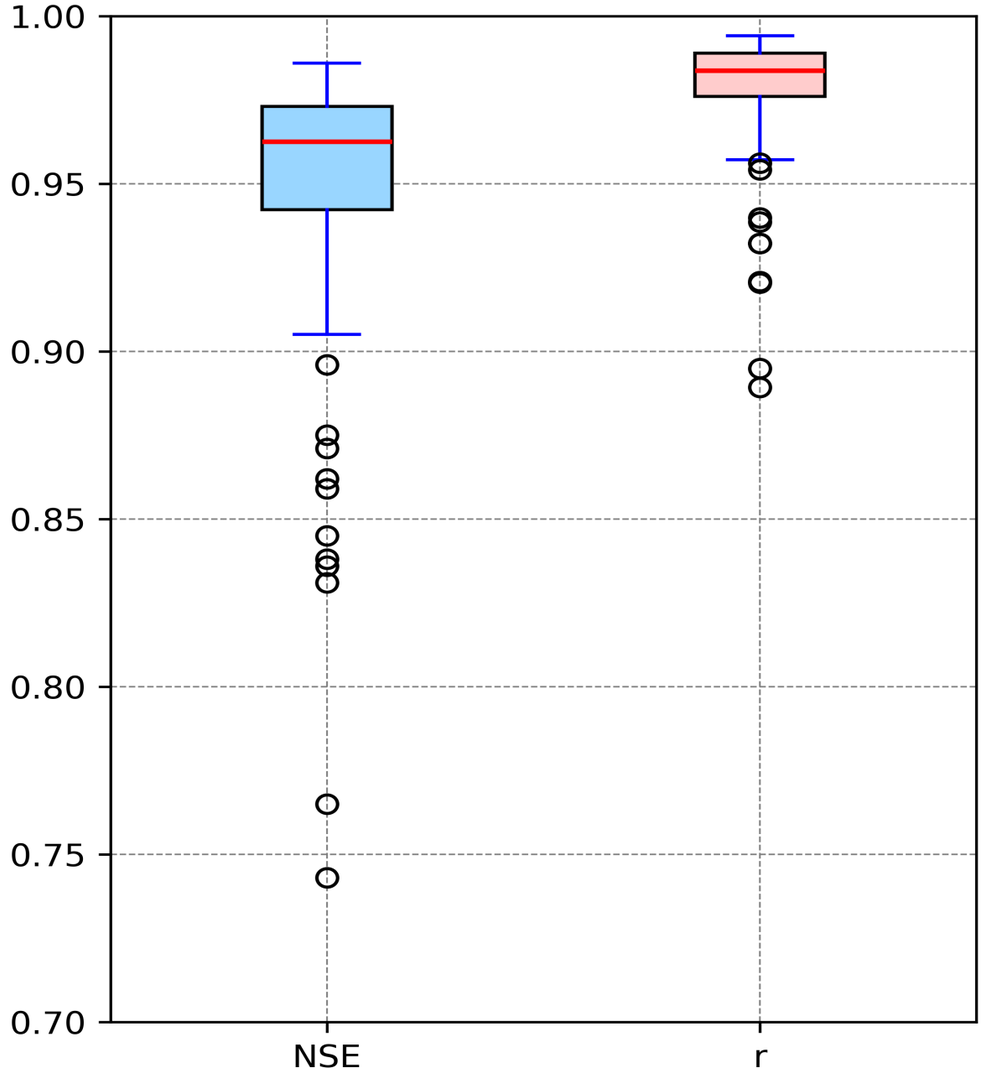
For the 93 sub-basins:

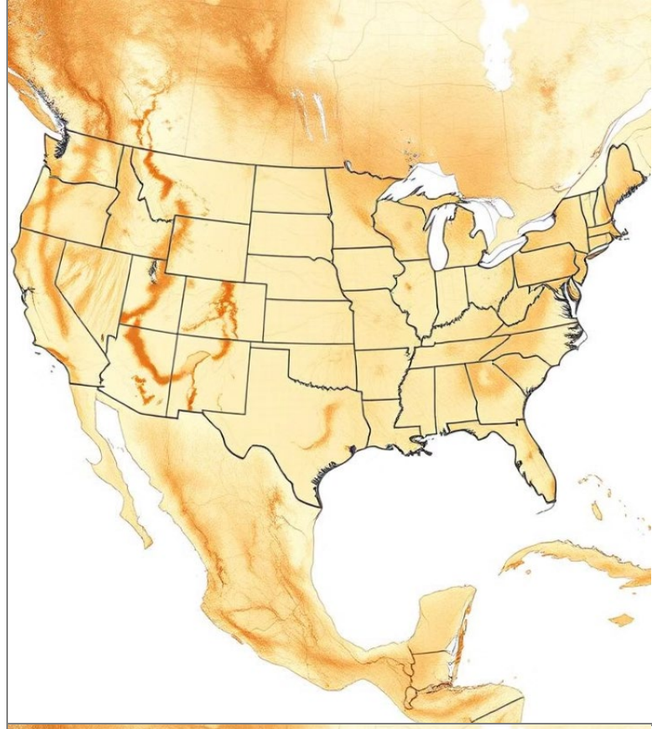
NSE = 0.733 – 0.986

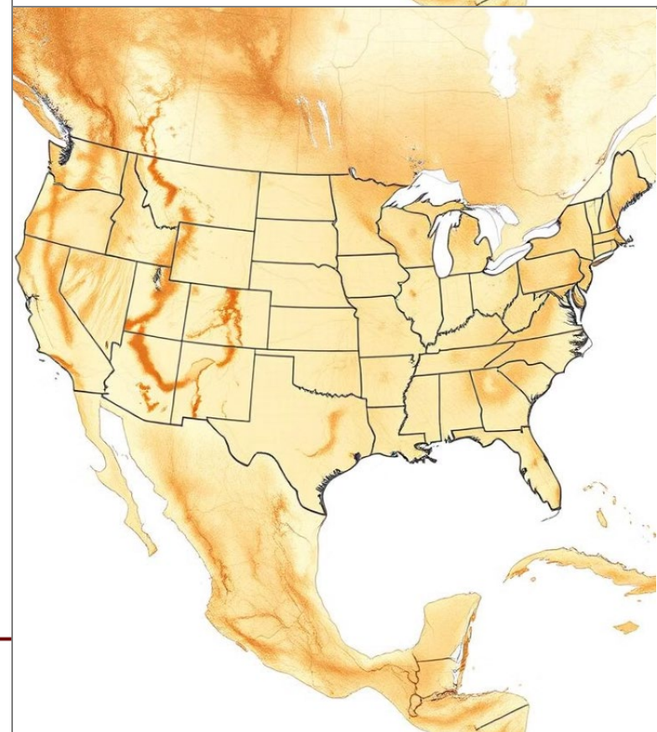
(M = 0.94, SD = 0.051),

r = 0.866 – 0.994

(M = 0.98, SD = 0.023)

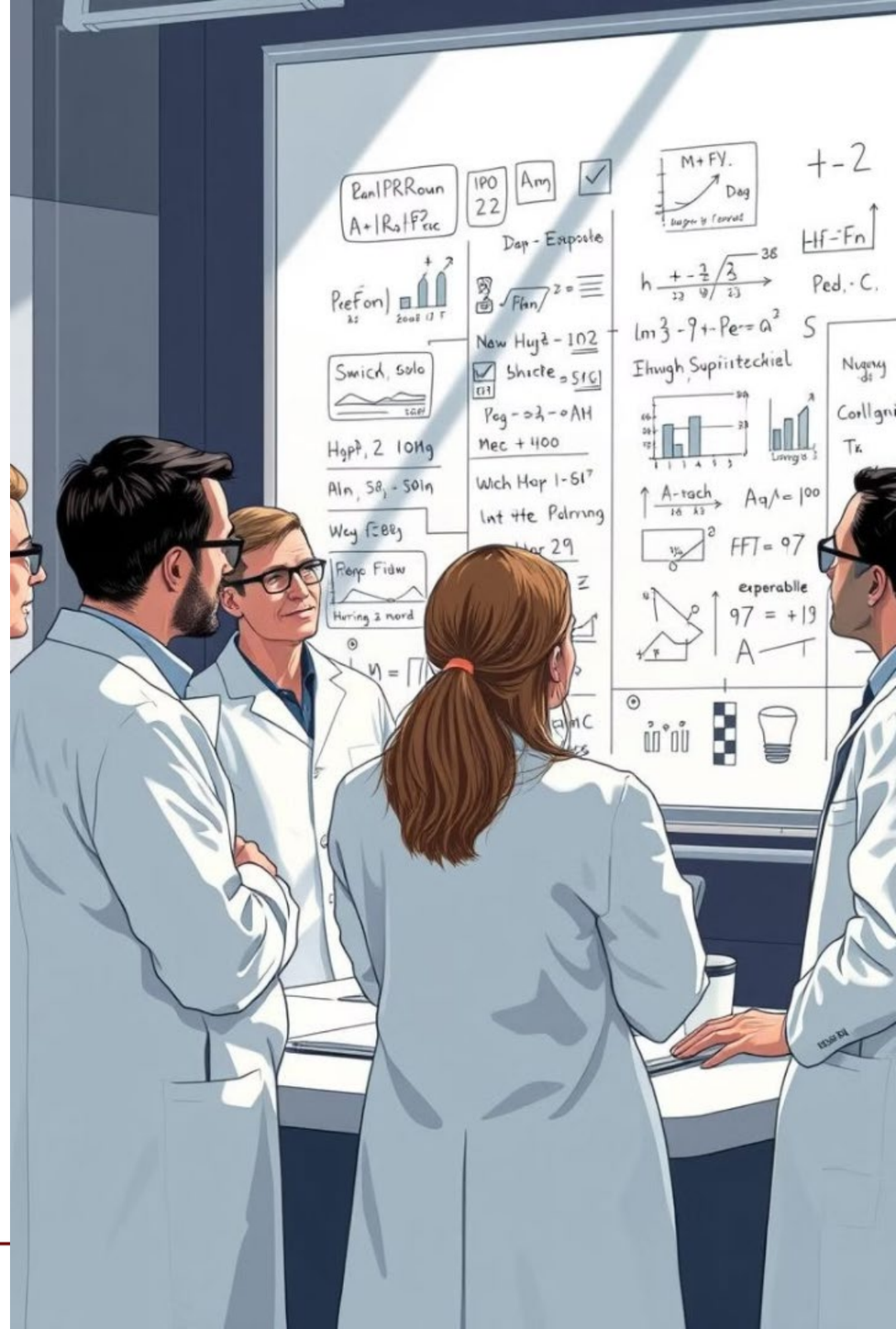






Conclusion

- Both datasets (SSURGO & POLARIS) provided similar results with high Nash-Sutcliffe Efficiency (NSE) and strong correlation coefficients (r).
- POLARIS, with its continuous coverage and consistent soil layers, is promising soil data for hydrological modeling, especially in complex areas where SSURGO have limitations.
- **Future research** should explore POLARIS in different land uses and climates to fully utilize its potential in advancing hydrological science.



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efrain.noa-Yarasca@ag.tamu.edu

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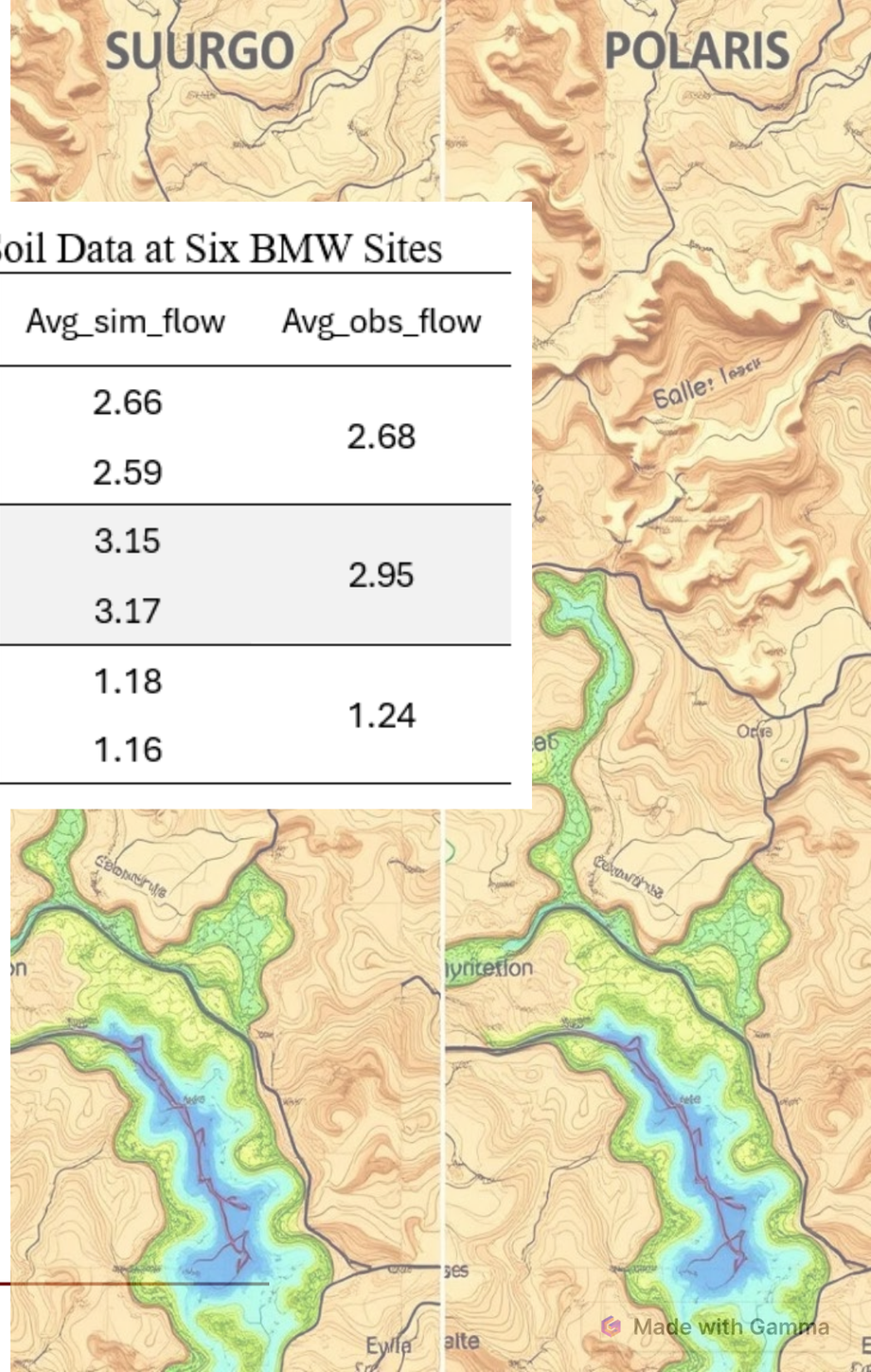
Results: Streamflow

Table 1. Streamflow Simulation Performance Using SSURGO and POLARIS Soil Data at Six BMW Sites

File	Stream-name	Soil data	NSE	PBIAS	RMSE	Avg_sim_flow	Avg_obs_flow
Site S1	m_4_116	SSURGO	0.762	0.815	4.501	2.66	2.68
		POLARIS	0.707	3.382	5.001	2.59	
Site S2	m_4_355	SSURGO	0.751	-14.962	5.609	3.15	2.95
		POLARIS	0.703	-15.475	6.125	3.17	
Site S3	m_4_1700	SSURGO	0.541	0.779	3.998	1.18	1.24
		POLARIS	0.523	2.347	4.076	1.16	



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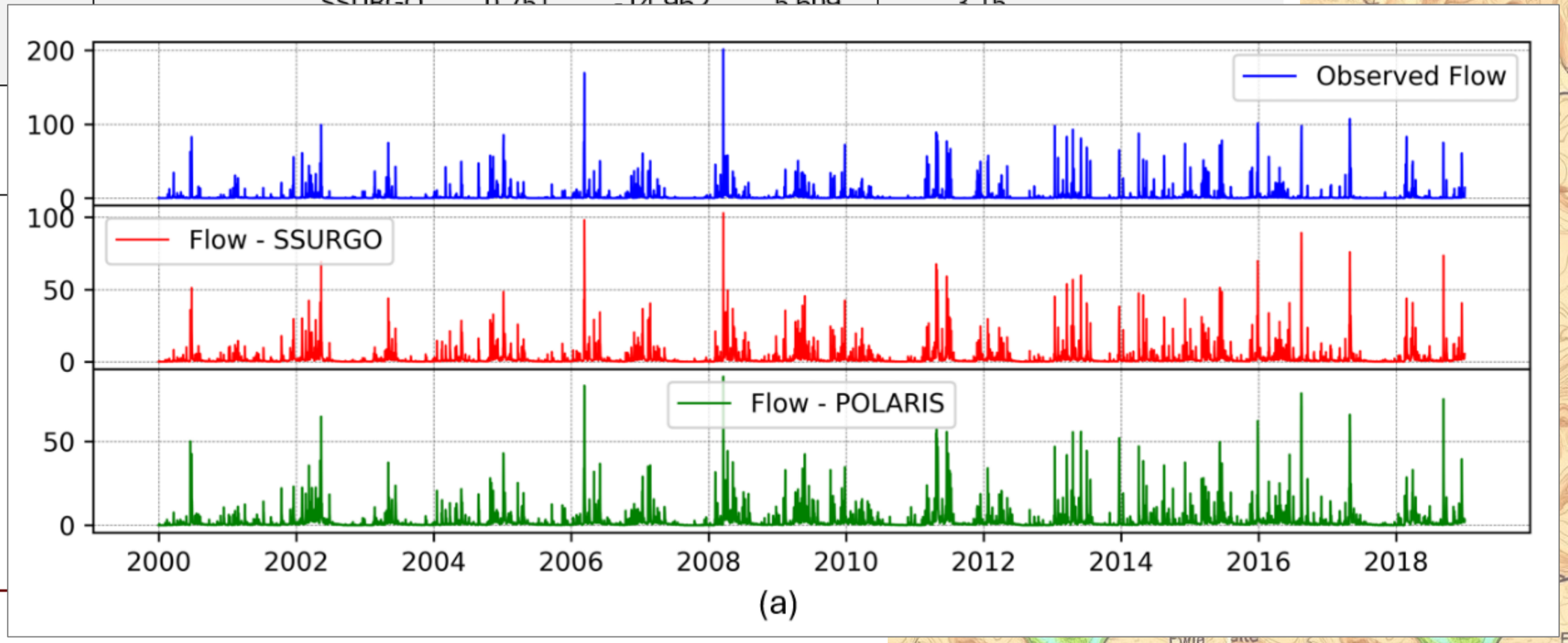
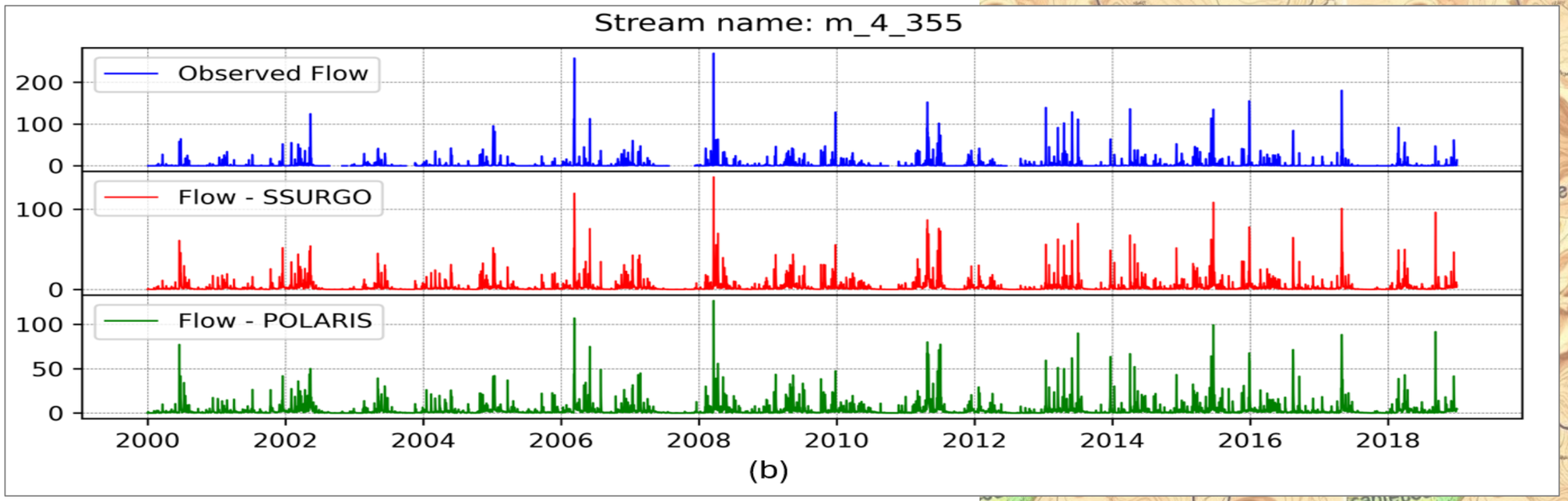
Site S3							

Site S1



Results: Streamflow

Site S2



Site S3