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How Spatially Distributed Precipitation Data Improve Hydrological Modeling: A SWAT+ Analysis in Mountainous Areas

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Introduction

Introduction

- Hydrological modeling challenges in mountainous regions
- Importance of accurate precipitation inputs
- Goal: Evaluate how spatially distributed precipitation data improve SWAT+ model performance in complex terrain
- We evaluated: 1) Daymet, 2) Gauge, 3) Bias-corrected Daymet (Qmap), and (4) Bias-corrected Daymet (MFBC)
- Previous assessment in northwest Mexico (de la Fraga et al., 2024): AORC, CHIRPS, Daymet, and ERA5
- Now, in this study we investigate its hydrological implications: streamflow simulation, water balance components, and spatial representation of hydrological processes
- Hypothesis: high-resolution gridded precipitation data improve hydrological simulations
- Research questions:

(i) SWAT+ performance
(ii) Gridded precipitation inputs → streamflow simulation
(iii) Bias correction → model performance
(iv) Implications on water balance components
(v) Spatial distribution of hydrological processes

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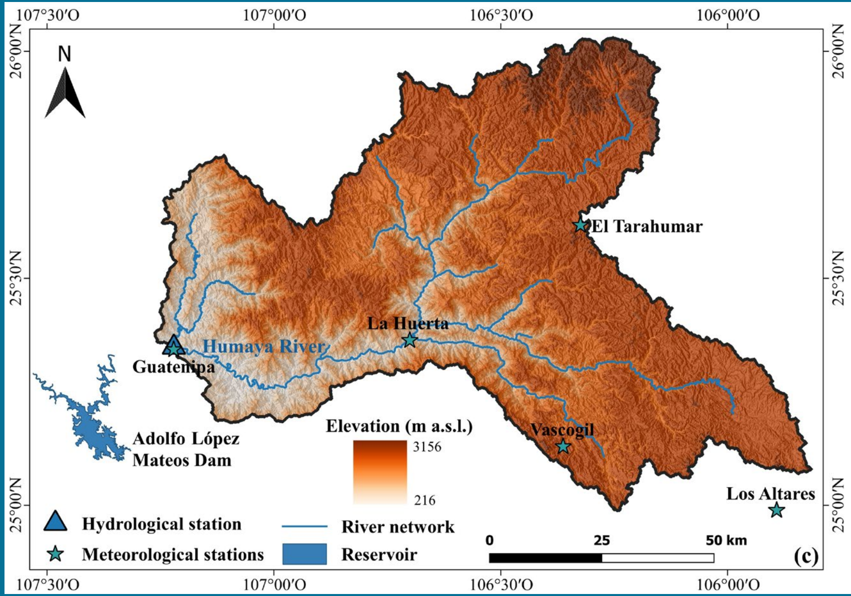
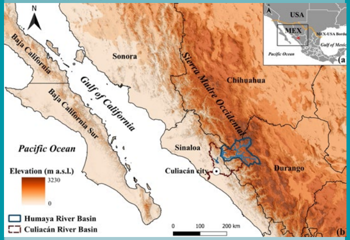
Study Area

Study Area

- Humaya River Basin, NW Mexico
- 8,261 km², monsoon-driven climate
- Topography, geology, and data limitations
- Culiacán Valley, one of Mexico's most productive agricultural regions (CONAGUA, 2024)






Fotografía Río Humaya
Cortesía: sierrarios.org

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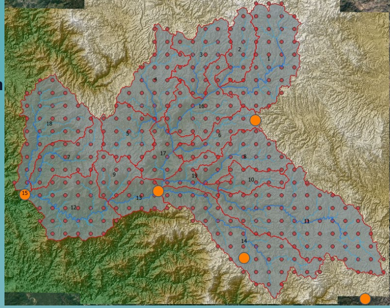
Methods

5 rain gauge stations
(orange points)

Daymet 358 locations 5km
(red points)



Methods

- **SWAT+** (Bieger et al., 2017) **model setup**
- **Four precipitation inputs: Gauge** (SMN, 2025)**, Daymet** (Thornton et al., 2021)**, Daymet (Qmap-corrected)** (Gudmundsson, 2025; Gudmundsson et al., 2012)**, Daymet (MFBC-corrected)** (Kimsal, 2023; Yoo et al., 2014)
- **Simulation period (1980–2001):**
- **warm-up (1980–1982), calibration (1983–1992), and validation (1993–2001)**
- **Automatic calibration DDS** (Tolson & Shoemaker, 2007)**, SWAT+ Toolbox** (Chawanda, 2021)
- **Objective function: NSE** (Nash & Sutcliffe, 1970)
- **Model performance: Evaluation metrics NSE & PBias**
- **Water balance components and streamflow partitioning**
- **Spatial distributions of hydrological processes**

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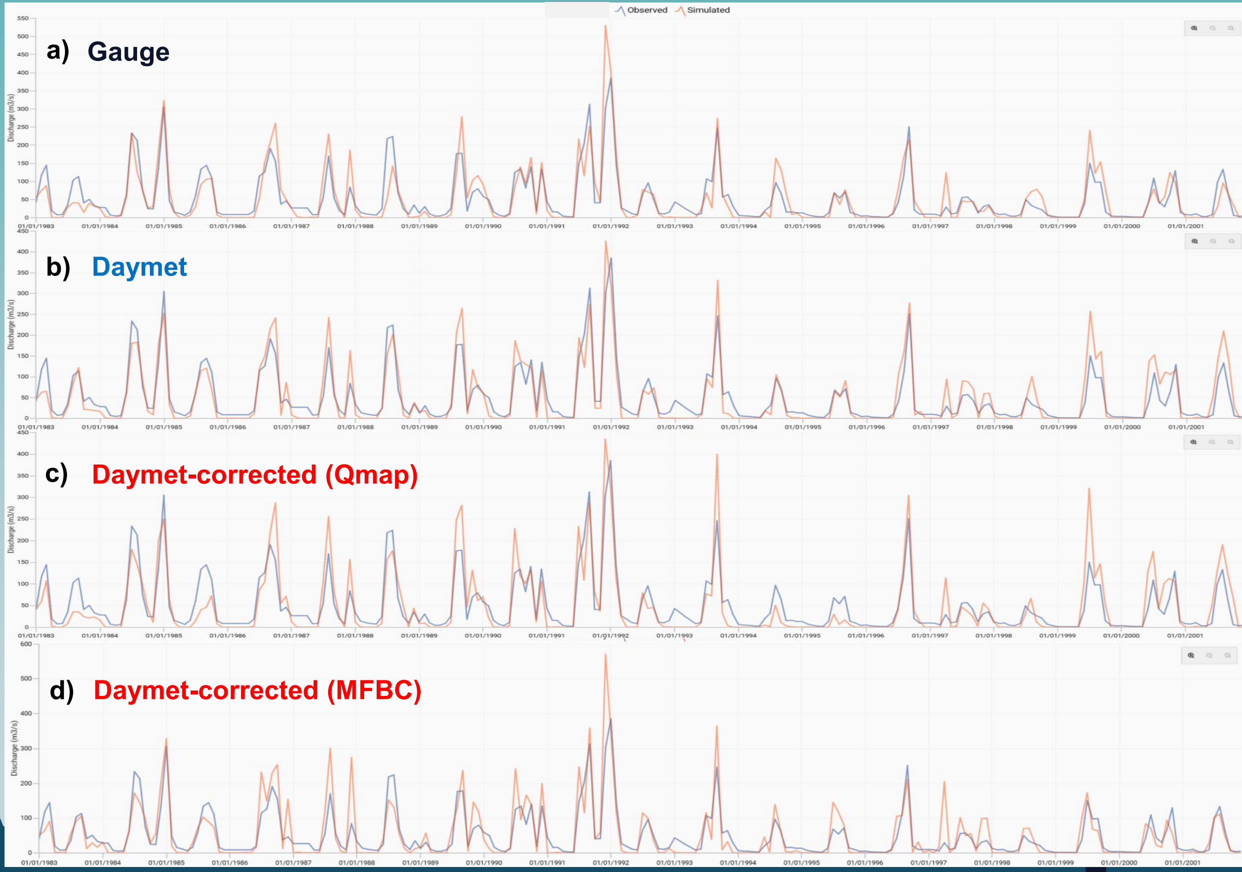
Results and Discussion

Streamflow Simulation Results

- Raw Daymet: Best performance (NSE = 0.78, PBias = -0.08%)
- Bias correction reduced accuracy
- Gauge: Decent but less spatially consistent

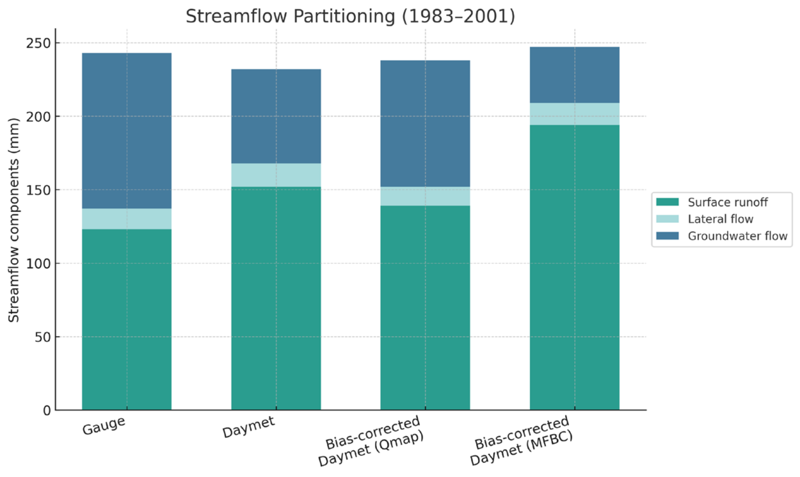
Model performance metrics. According to Moriasi et al. (2015) criteria. Best-performing values are highlighted.

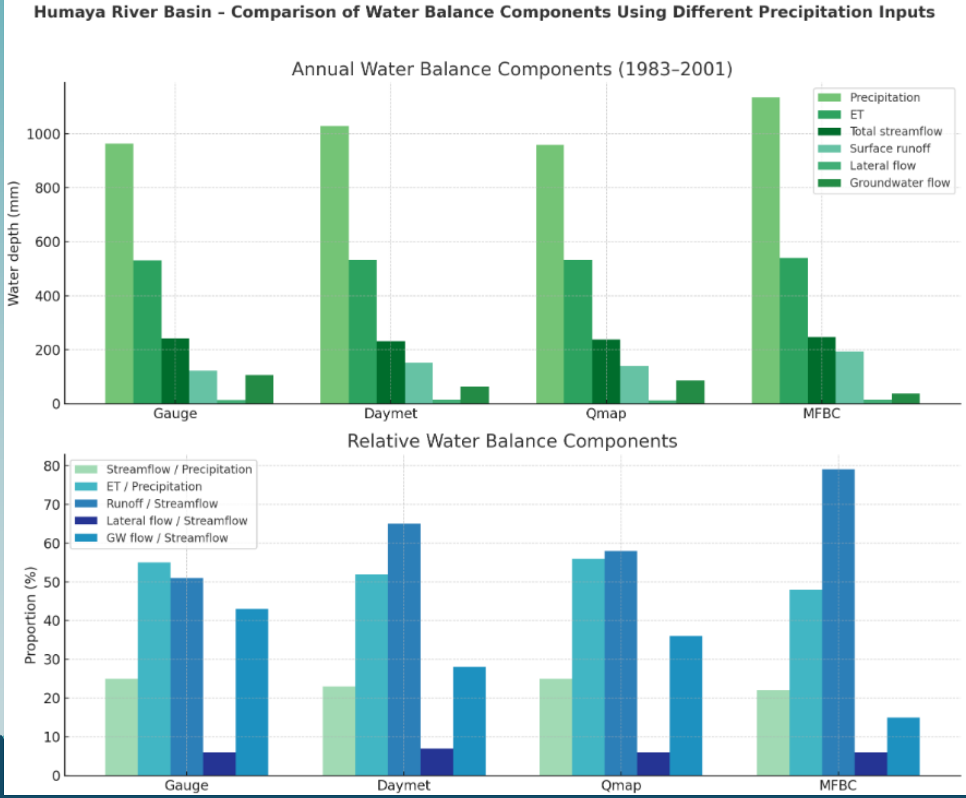
Precipitation source Metrics		
	NSE	PBIAS (%)
Gauge	0.71 (good)	2.2 (very good)
Daymet	**0.78 (good)**	**-0.08 (very good)**
(Qmap)	0.67 (satisfactory)	3.7 (very good)
(MFBC)	0.59 (satisfactory)	-3.8 (very good)



Water Balance

- Precipitation higher in MFBC
- ET dominant flux (48 - 56% of precipitation)
- Total streamflow across models remained relatively consistent
- Discrepancies in streamflow partitioning
- Surface runoff higher in MFBC
- GW flow lower in MFBC



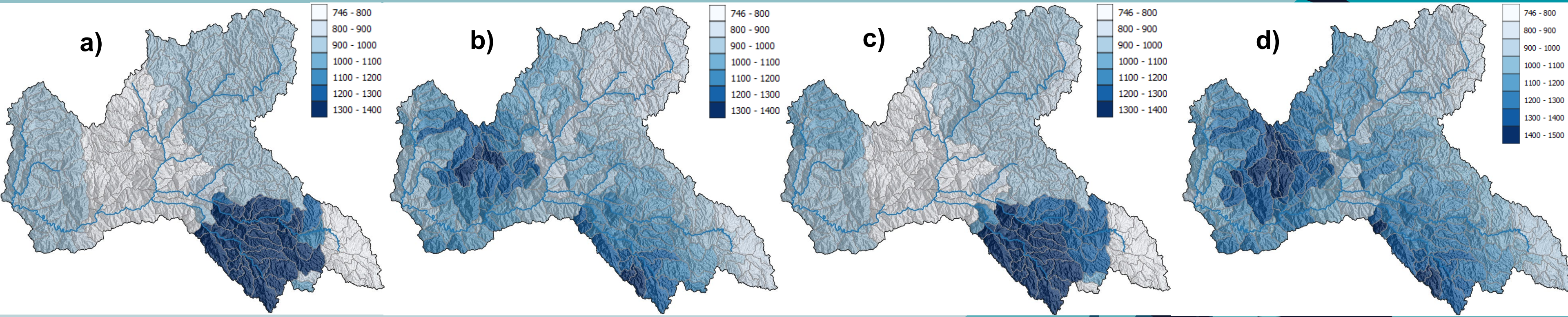


Spatial Analysis

Precipitation (mm)

- Daymet captured spatial patterns better
- MFBC exaggerated precipitation magnitudes

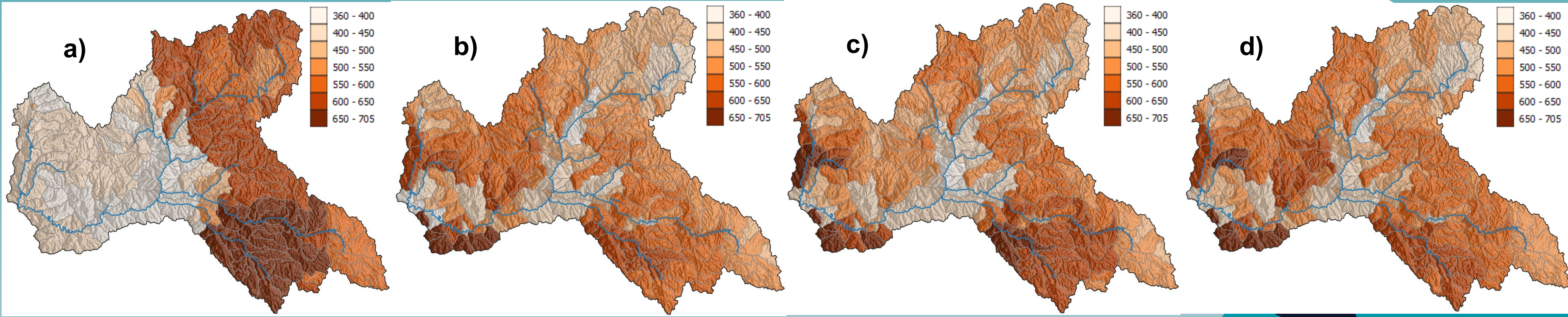
Gauge **Daymet** **Daymet-corrected (Qmap)** **Daymet-corrected (MFBC)**



Actual Evapotranspiration (mm)

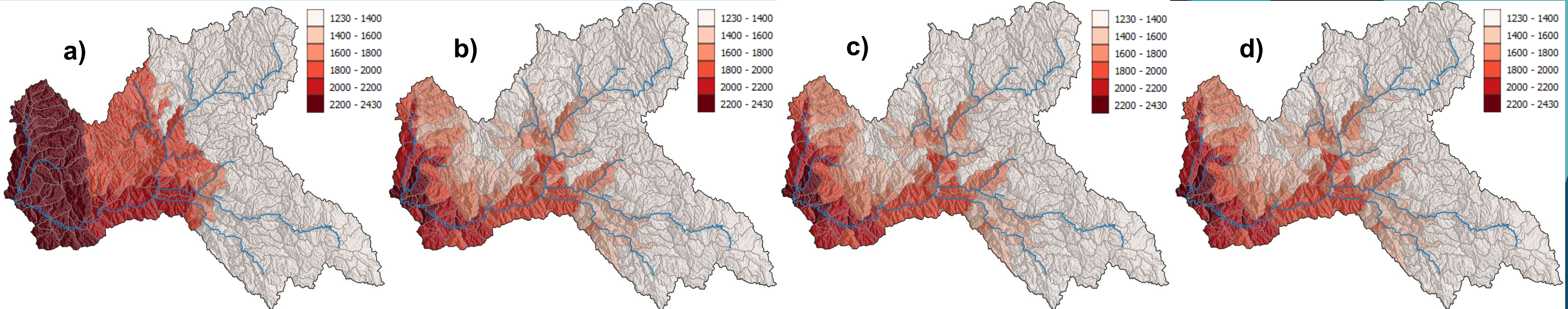
- Daymet-based models captured spatial variability in ET and PET

Gauge | **Daymet** | **Daymet-corrected (Qmap)** | **Daymet-corrected (MFBC)**



Potential Evapotranspiration (mm)

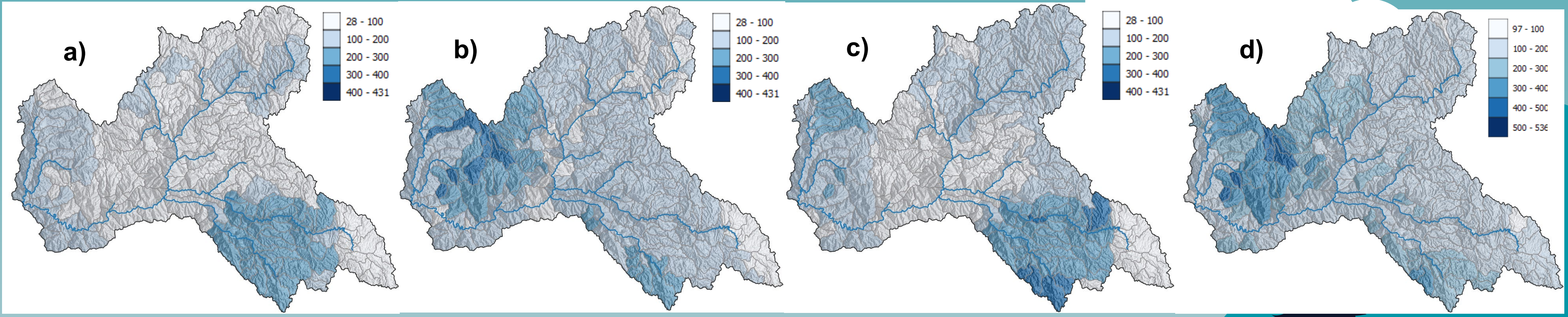
Gauge | **Daymet** | **Daymet-corrected (Qmap)** | **Daymet-corrected (MFBC)**



- Daymet identified surface runoff and groundwater flow better
- MFBC showed unrealistically low groundwater flow
- High - resolution inputs improve representation of hydrological processes

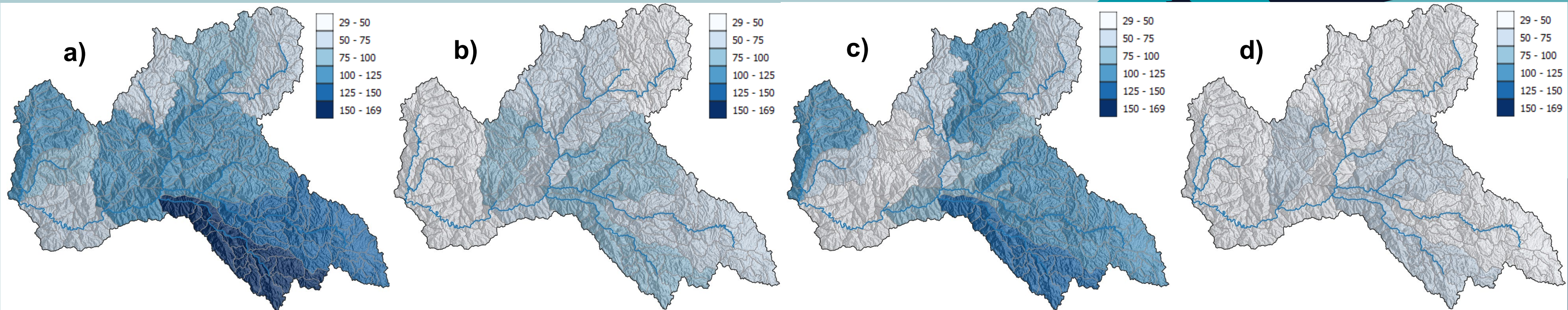
Surface Runoff (mm)

Gauge **Daymet** **Daymet-corrected (Qmap)** **Daymet-corrected (MFBC)**



Groundwater Flow (mm)

Gauge **Daymet** **Daymet-corrected (Qmap)** **Daymet-corrected (MFBC)**



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Conclusions

Conclusions

- SWAT+ performed well, demonstrating its applicability in this mountainous basin.
- Raw Daymet outperformed gauge and bias-corrected inputs.
- Bias correction, when based on sparse reference data, may degrade model performance.
- Internal flow components are highly sensitive to input choice.
- High-resolution datasets like Daymet improve spatial realism and process representation.

Thus, gridded precipitation products are valuable tools in data-scarce mountainous regions, but correction strategies must be applied with caution.

Thank you for your attention !

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