Snowmelt runoff in global hydrological models

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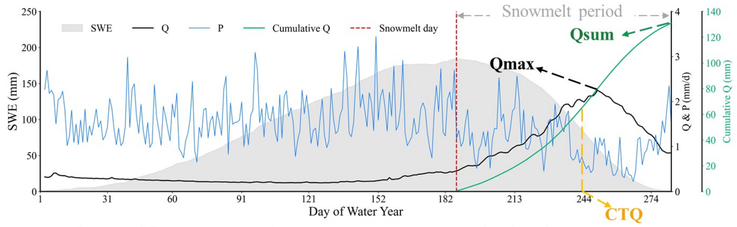
1 Background



- **Qsum/Qmax** : total/maximum snowmelt discharge
- **CTQ**: centroid timing of snowmelt discharge

Importance

Snowmelt runoff (SMR) is a key indicator of **water resource availability** and snowmelt-induced **flood risks**.

Gap

Limited insight into SMR process representation and model performance differences

Research questions

How well do current models and datasets simulate SMR and does increased **model complexity** lead to better SMR performance?

Models & Data products

PCR-GLOBWB	DBH	VIC	MATSIRO	CLM40
LPJML	CWATM	H08	HYDROPY	JULES-W2
MIROC-INTEG-LAND	ORCHIDEE-MICT	WATERGAP2-2E	GRADES	GRDR

- **6 ISIMIP2a models** + **7 ISIMIP3a models** + **2 data products**
- **3,834 mid-high latitude, snow-covered catchments**

Reference: Lei X, Lin H, Lin P*. (2025). Process diagnostics of snowmelt runoff in global hydrological models. (in review)

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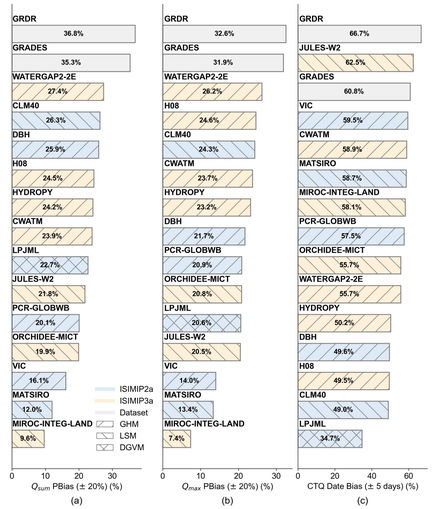
2 Results

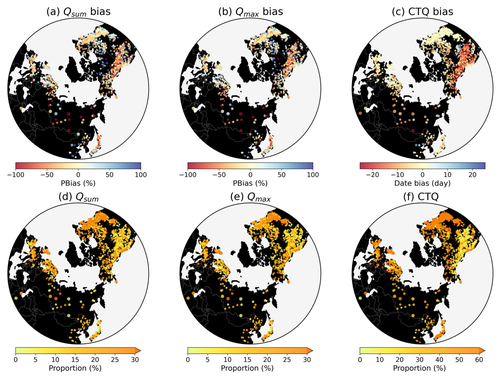
How well do models and datasets perform?



- **GRDR & GRADES** performed best over Qsum, Qmax, and CTQ.
- Best vs. worst models show up to **28% difference**, affecting ~1,000+ basins.
- **ISIMIP3a** generally outperform ISIMIP2a.
- **GHMs** generally outperform LSMs in Qsum and Qmax; unclear for CTQ.

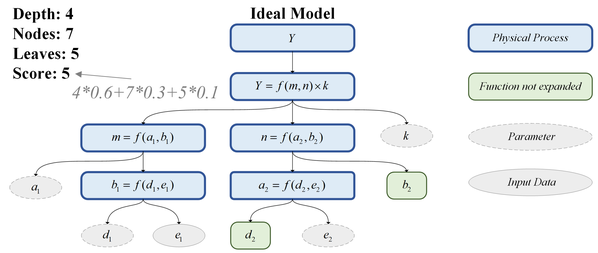
Where do models struggle most?

- Ensemble means show systematic **underestimation** and **early** melt timing in the western United States, Northern Europe, and Siberian plains.
- Less than 10% of models perform well in **mountainous** and **northern** basins.



Well: PBias ≤ ±20% or ±5 days

Why do models perform differently?

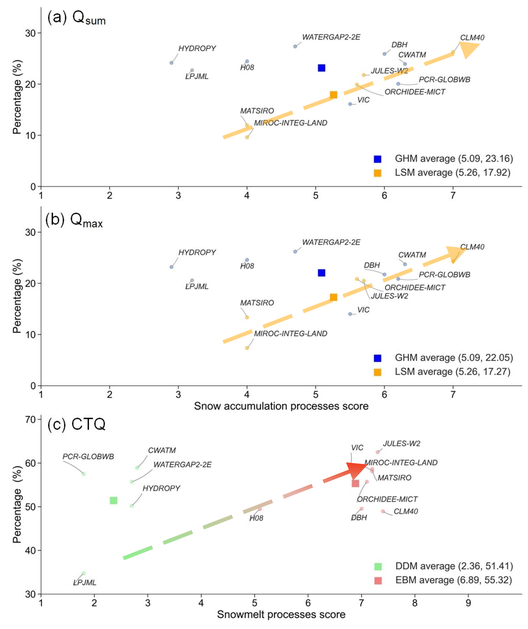


TBMCS: Tree-Based Model Complexity Scoring

Model complexity is captured through:

- Tree **depth**
- Number of **nodes** (equations)
- Number of **leaves** (inputs & parameters)

Higher complexity means more detailed representations



- For Qsum and Qmax, model complexity doesn't always improve performance, except in **LSMs**, where dynamic treatments of snowfall partitioning, sublimation, and snow density lead to gains.
- For CTQ, **EBMs** outperform DDMs by incorporating detailed energy transfer processes and dynamic snow albedo, improving surface energy estimation.

Linkage between model complexity and model performances

3 Conclusions

- Better simulation of **CTQ** than Qsum/Qmax. **Data products** (GRADES, GRDR) outperform models.
- Most models **underestimate** Qsum/Qmax and simulate **earlier** CTQ, especially in: Western U.S. mountains, Northern Europe, Siberian plains. Fewer than 10% of models fall within target bias ranges.
- Qsum/Qmax show no clear trend, except in **LSMs**. CTQ improves with higher model complexity.

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