Signatures-based appraisal of global rainfall datasets to capture hydrological trends in a meso-scale catchment

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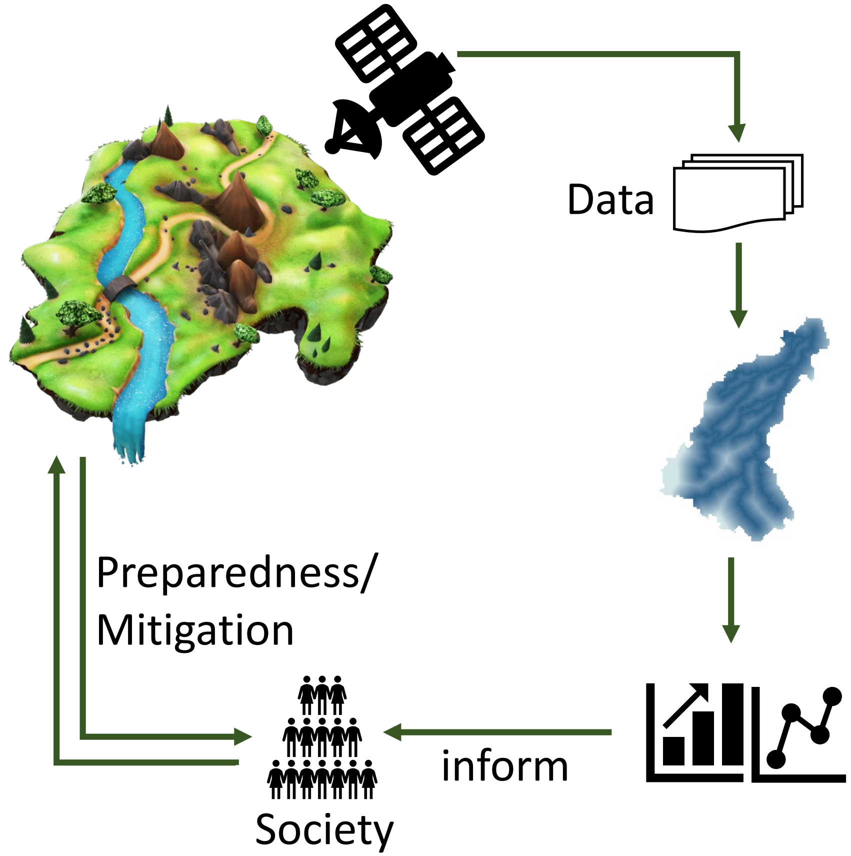
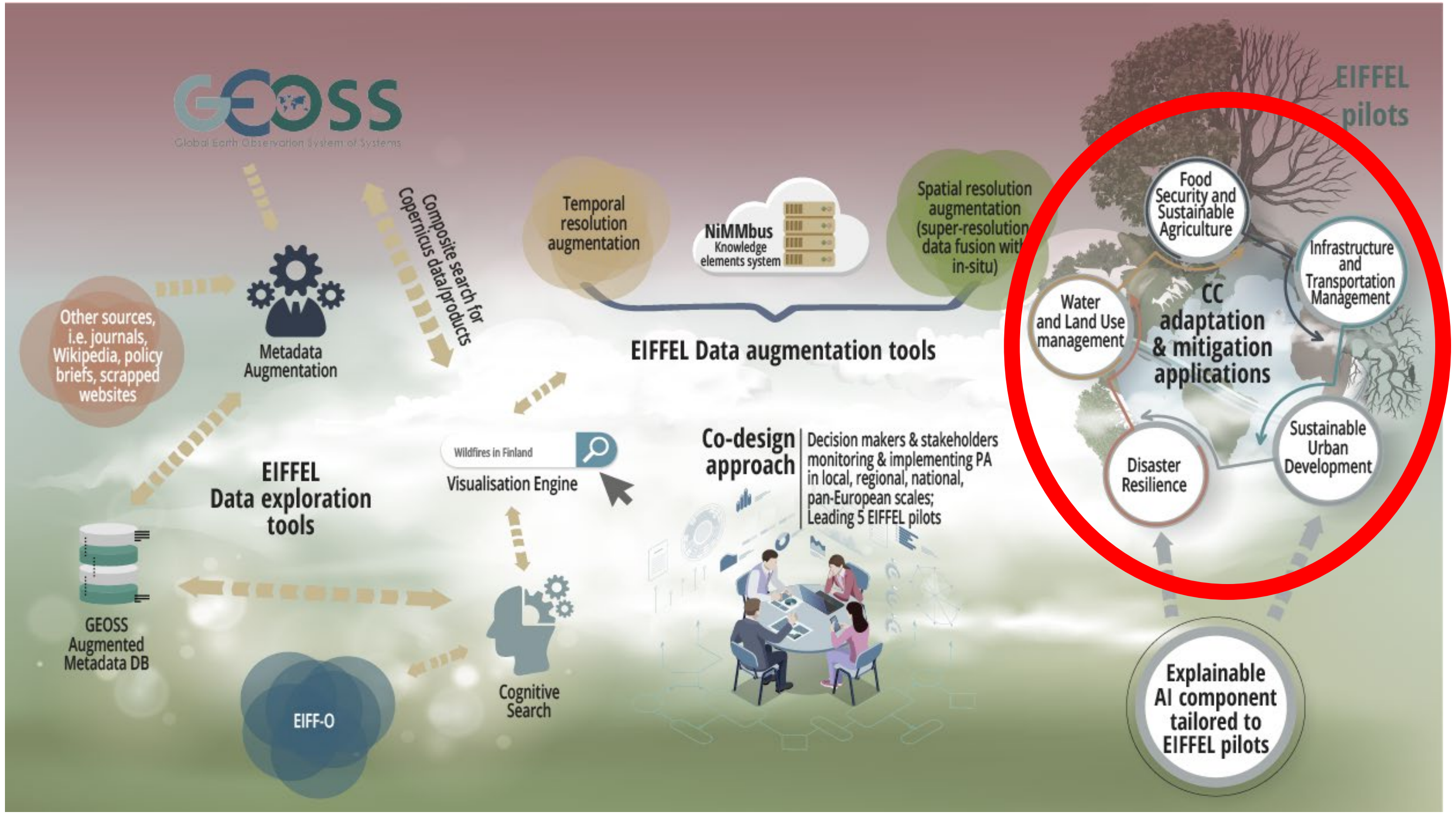
Introduction and background





Eiffel GEOSS APPLICATIONS FOR CLIMATE CHANGE

Revealing the role of GEOSS for building climate change adaptation & mitigation applications.

Global dataset

Hydrological Model

Climate change

Nature based solutions

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Hydrological model

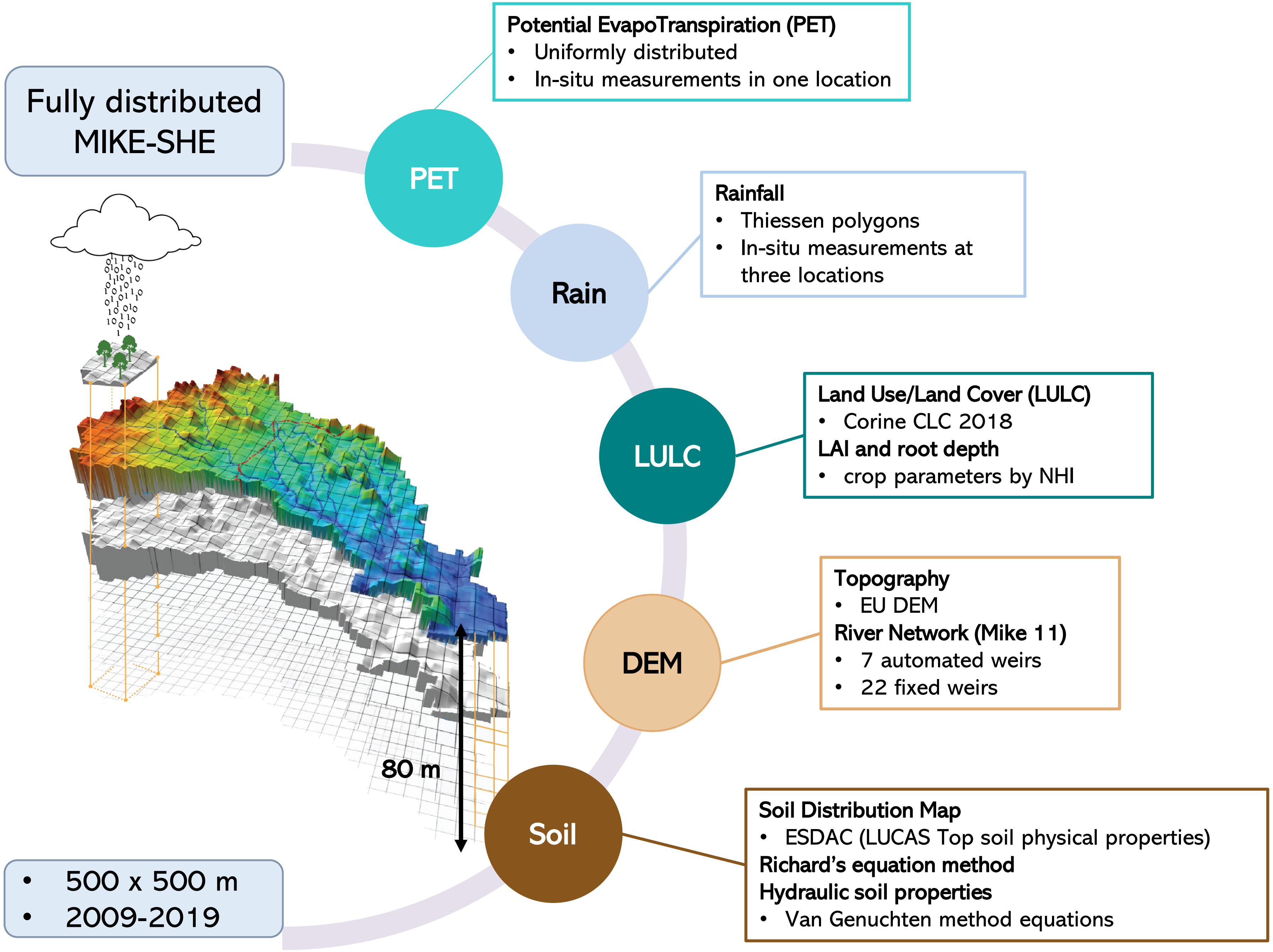
Study area:

Aa of Weerijs Catchment

- **Source:** Brecht, Belgium
- **Outlet:** Breda, Netherlands
- **Total Area**: 346 km^2

  Netherlands: 147 km^2

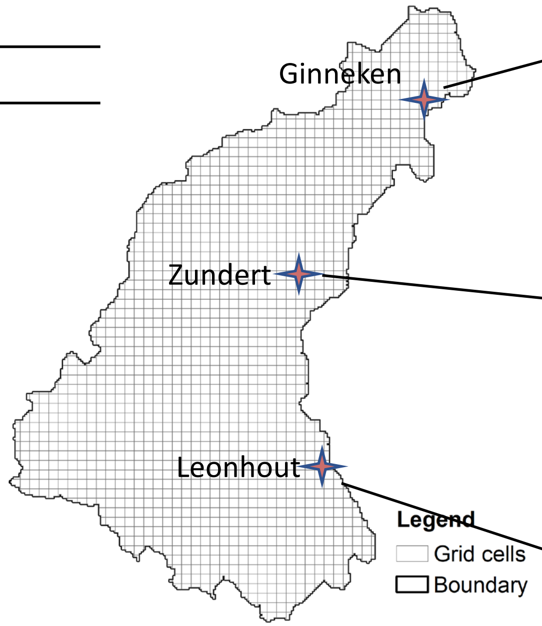
  Belgium: 199 km^2



Precipitation		Datatype	Hz. Coverage	Hz. Resolution	Temporal Coverage	Temporal Resolution
1	MSWEP	Gridded	Global	0.1° x 0.1°	1979 - present	Daily
2	IMERG Final	Gridded	Global	0.1° x 0.1°	2000 – present	Daily
3	ERA5 land	Gridded	Global	0.1° x 0.1°	1996 – present	Hourly
4	E-OBS	Gridded	Europe	0.1° x 0.1°	1950 - present	Daily

Comparison with gauge data

- Probability of detection (POD)
- False alarm ratio (FAR)
- Equitable threat score (ETS)
- Frequency bias (FB)



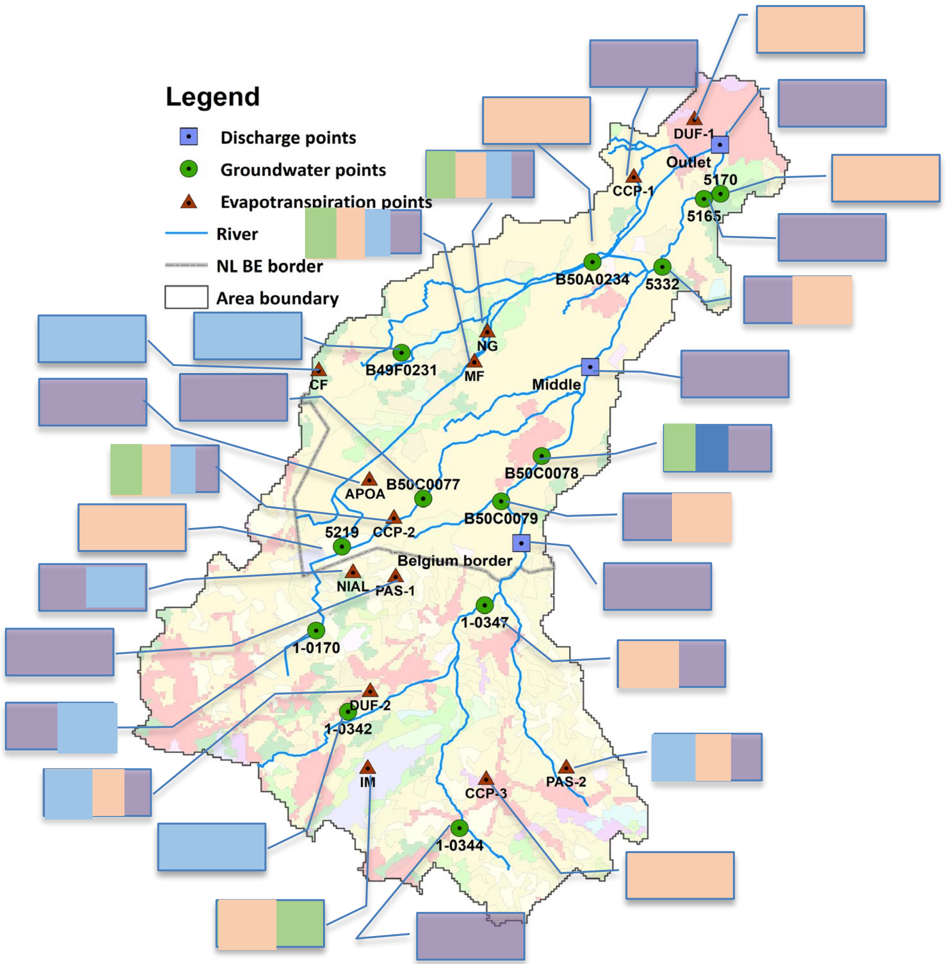
	ERA5 Final	MSwep	Imerg Final	E-OBS
POD	0.82	0.82	0.68	0.76
FAR	0.19	0.17	0.18	0.03
ETS	0.45	0.47	0.35	0.58
FB	1.02	1	0.83	0.79

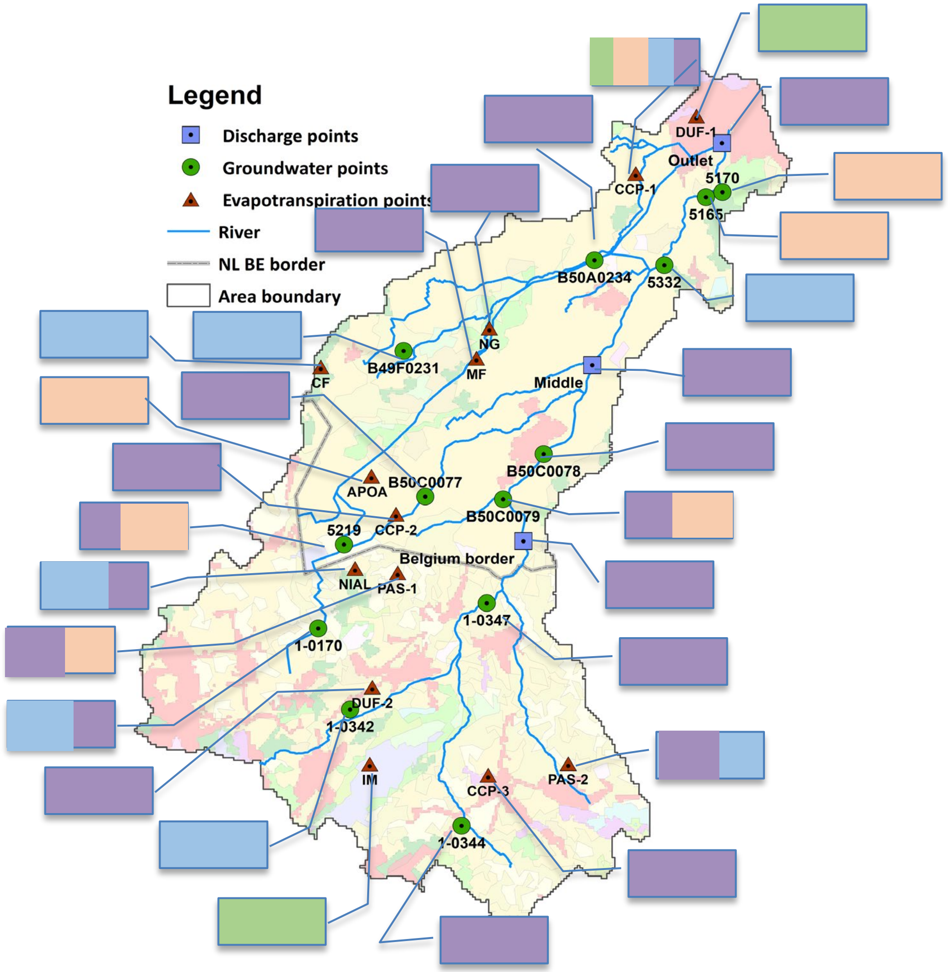
	ERA5 Final	Mswep	Imerg Final	E-OBS
POD	0.82	0.81	0.66	0.75
FAR	0.17	0.15	0.16	0.02
ETS	0.46	0.48	0.34	0.57
FB	0.99	0.96	0.78	0.77

	ERA5 Final	MSwep	Imerg Final	E-OBS
POD	0.94	0.93	0.74	0.88
FAR	0.28	0.25	0.26	0.12
ETS	0.49	0.53	0.4	0.66
FB	1.3	1.24	1	1

Model simulation performance based on R

Model simulation performance based on NSE





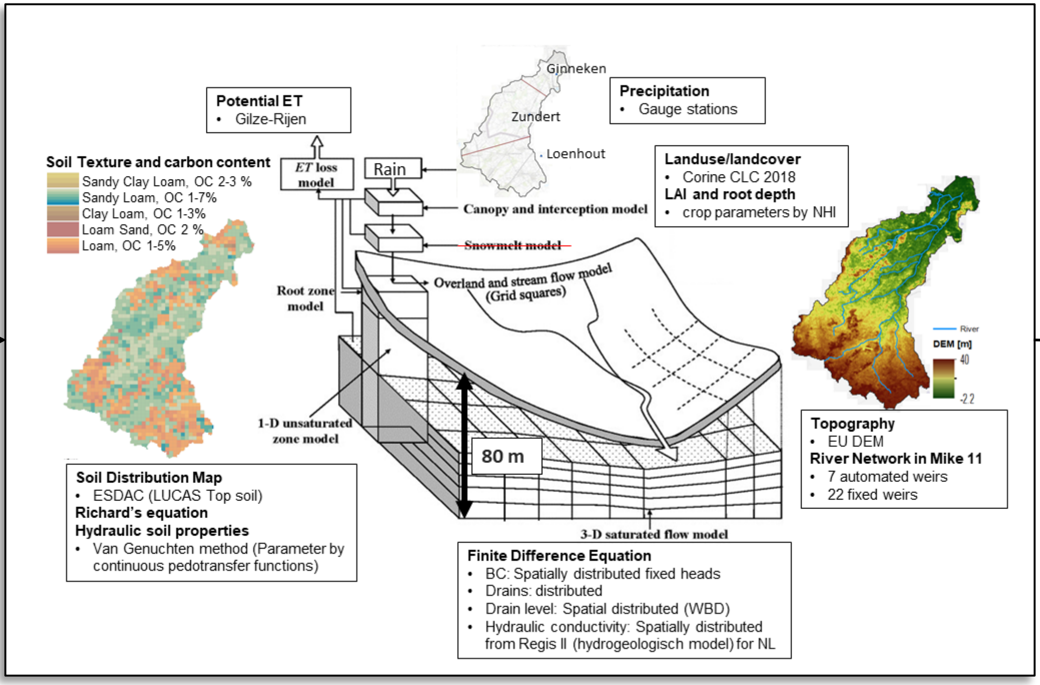
ERA 5 LAND | MSwep | IMERG Final | E-OBS

Research Questions:

- Does the performance of rainfall datasets, as evaluated by rain gauge data, correlate with their accuracy in simulating hydrological variables (discharge and groundwater)?
- How does the variation in evaluation criteria/metrics influence perceptions regarding the performance quality of rainfall datasets.

Methodology:

Direct rainfall datasets comparison with gauge data



Evaluation of outputs
1. Time series metrics only
2. **Hydrological signatures** only
3. Combine TS metrics and hydrological signatures

Metrics for direct evaluation of rainfall datasets with gauge data (16)

Rainfall time series (R)	
Probability of detection	M_{POD}
False alarm ratio	M_{FAR}
Equitable threat score	M_{ETS}
Frequency bias	M_{FB}
Nash and Sutcliffe (NSE)	$M_{NS,R}$
Log NSE	$M_{NS,log(R)}$
Mean absolute error (MAE)	$M_{MAE, R}$
Correlation coefficient (R)	$M_{R, R}$
Total rainfall on very wet days R95pt0t	$M_{R95pt0t}$
Total rainfall on slightly wet days R05pt0t	$M_{R05pt0t}$
Longest consecutive dry days	M_{CDD}
Longest consecutive wet days	M_{CWD}

Rainfall duration curve (RDC)	
Nash and Sutcliffe (NSE)	$M_{NS,RDC}$
Log NSE	$M_{NS,LOG(RDC)}$
Mean absolute error (MAE)	$M_{MAE,RDC}$
Correlation coefficient (R)	$M_{R,RDC}$

For the metrics which are represented by single values:

$$M = \left|1 - \frac{X_{sim}}{X_{obs}}\right|$$

(Euser et al., 2013)

Metrics for evaluation of time series of output variables (10)

Discharge time series (Q)	
Kling Gupta efficiency	$M_{KGE,Q}$
Nash Sutcliffe (NSE)	$M_{NS,Q}$
Log NSE	$M_{NS,log(Q)}$
Mean absolute error (MAE)	$M_{MAE,Q}$
Correlation coefficient (R)	$M_{R,Q}$
Groundwater levels time series (G)	
Kling Gupta efficiency (KGE)	$M_{KGE,G}$
Nash Sutcliffe (NSE)	$M_{NS,G}$
Log NSE	$M_{NS,log(G)}$
Mean absolute error (MAE)	$M_{MAE,G}$
Correlation coefficient (R)	$M_{R,G}$

Hydrological signatures with corresponding metrics for evaluation of output variables (25)

Flow duration curve (FDC)	
Nash and Sutcliffe (NSE)	$M_{NS,FDC}$
Log NSE	$M_{NS,log(FDC)}$
Mean absolute error (MAE)	$M_{MAE,FDC}$
Correlation coefficient (R)	$M_{R,FDC}$
FDC high flow segment volume (hfv)	$M_{FDC,hfv}$
FDC mid flow segment slope (mfs)	$M_{FDC,mfs}$
Base flow index (BFI)	M_{BFI}
Runoff ratio (RR)	M_{RR}
Streamflow elasticity (SE)	M_{SE}
Autocorrelation lag by 1 day(1-lag)	$M_{1\text{-}lag}$
Rising limb density (month^{-1}, RLD)	M_{RLD}

*Base flow index (BFI) and Runoff ratio (RR) are only calculated for discharge at outlet.

15-day RR NSE	$M_{NS,15\text{-}RR}$
15-day RR Log NSE	$M_{NS,\ log(15\text{-}RR)}$
15-day RR MAE	$M_{MAE,\ 15\text{-}RR}$
15-day RR R	$M_{R,\ 15\text{-}RR}$

Groundwater duration curve (GDC)	
Nash and Sutcliffe (NSE)	$M_{NS,GDC}$
Log NSE	$M_{NS,log(GDC)}$
Mean absolute error (MAE)	$M_{MAE,\ GDC}$
Correlation coefficient (R)	$M_{R,GDC}$

Discharge statistics	
Mean discharge	$M_{Q,mean}$
Mean log-transformed discharge	$M_{mean,log(Q)}$
Median discharge	$M_{Q,mdn}$
Discharge variance	$M_{Q,v}$
Variance of log-transformed discharge	$M_{v,log(Q)}$
Peak discharge	$M_{Q,peak}$

Overall performance

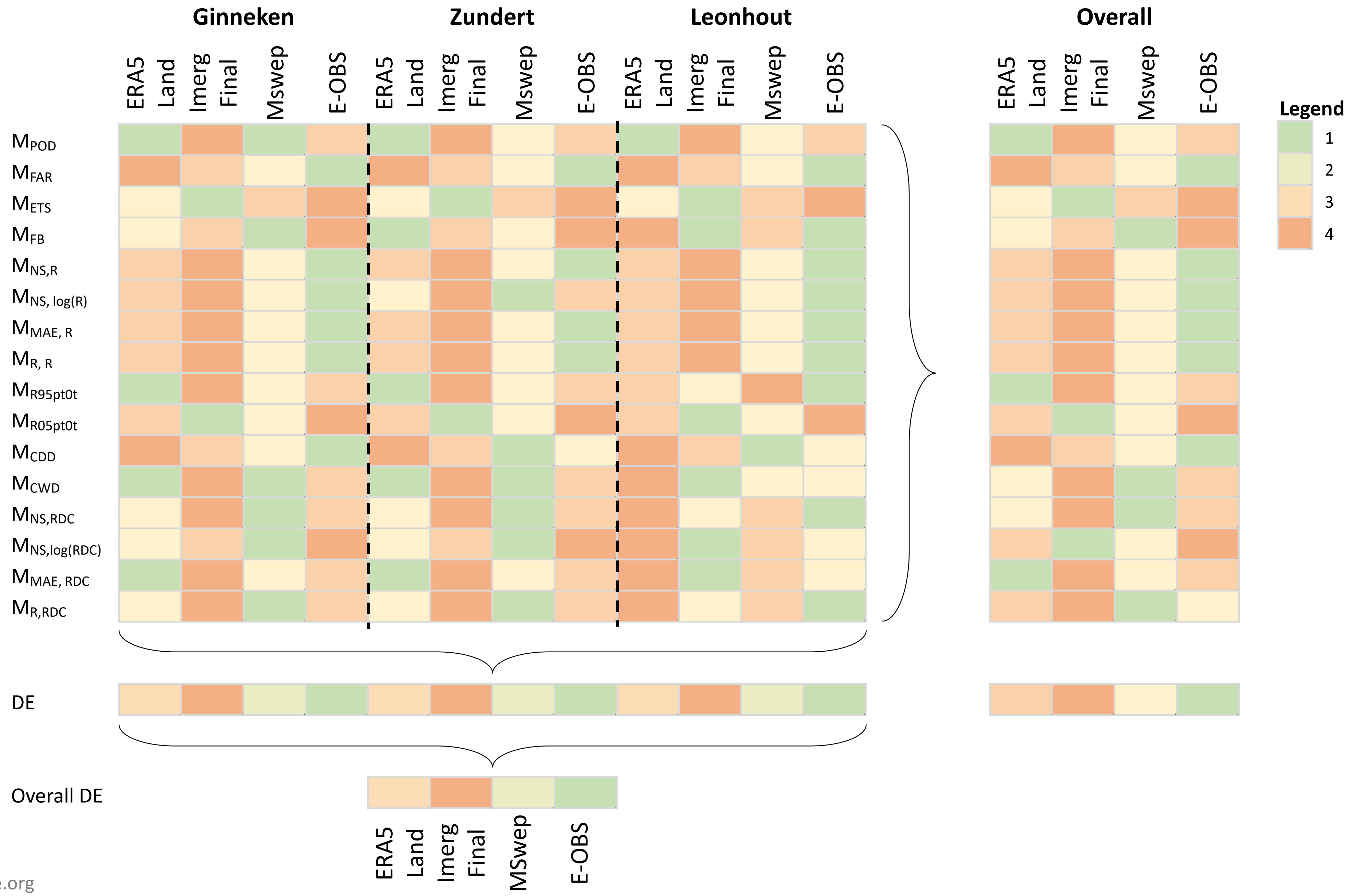
$$DE = \sqrt{\frac{\sum_{i=1}^{N}(P - Mi)^2}{N}}$$

P: Value for perfect model; N: total no. of metrics

(Hrachowitz et al., 2014)

Results:

Metrics for direct evaluation of rainfall datasets with gauge data



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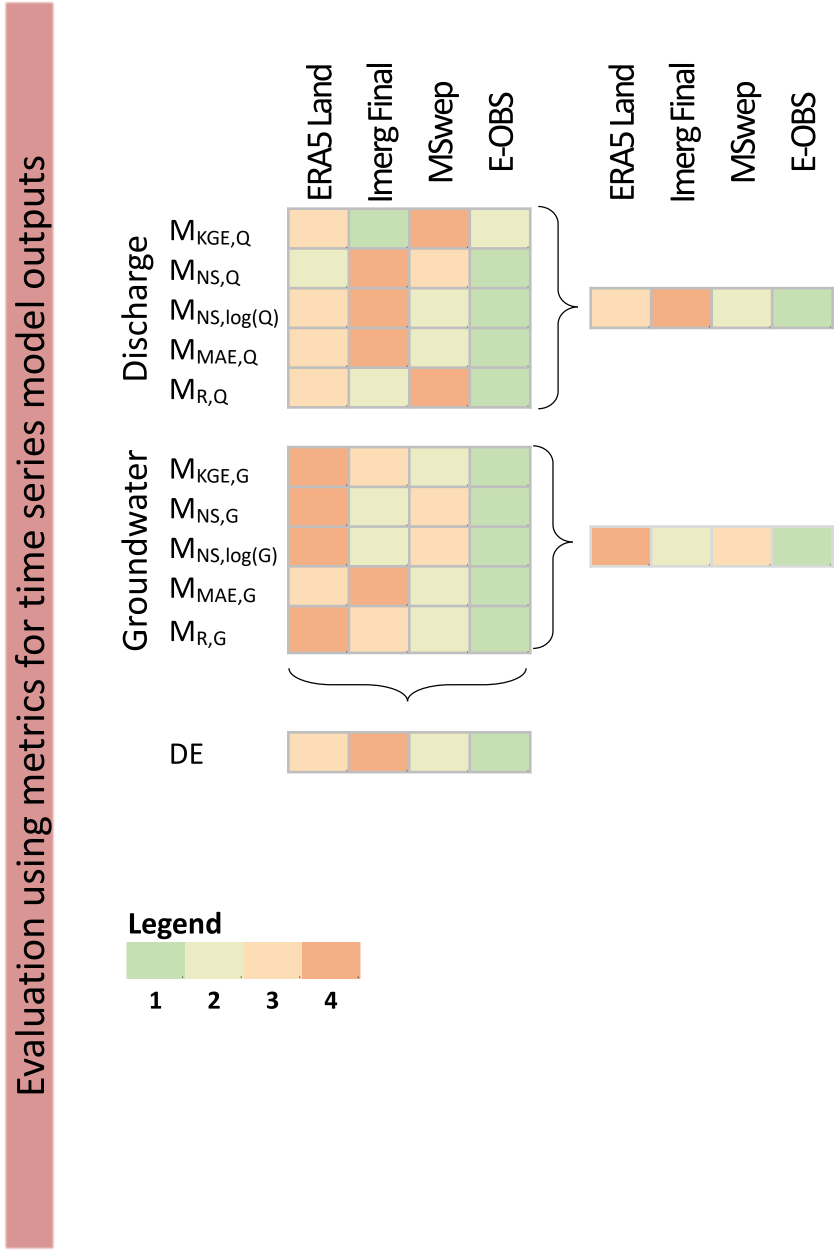
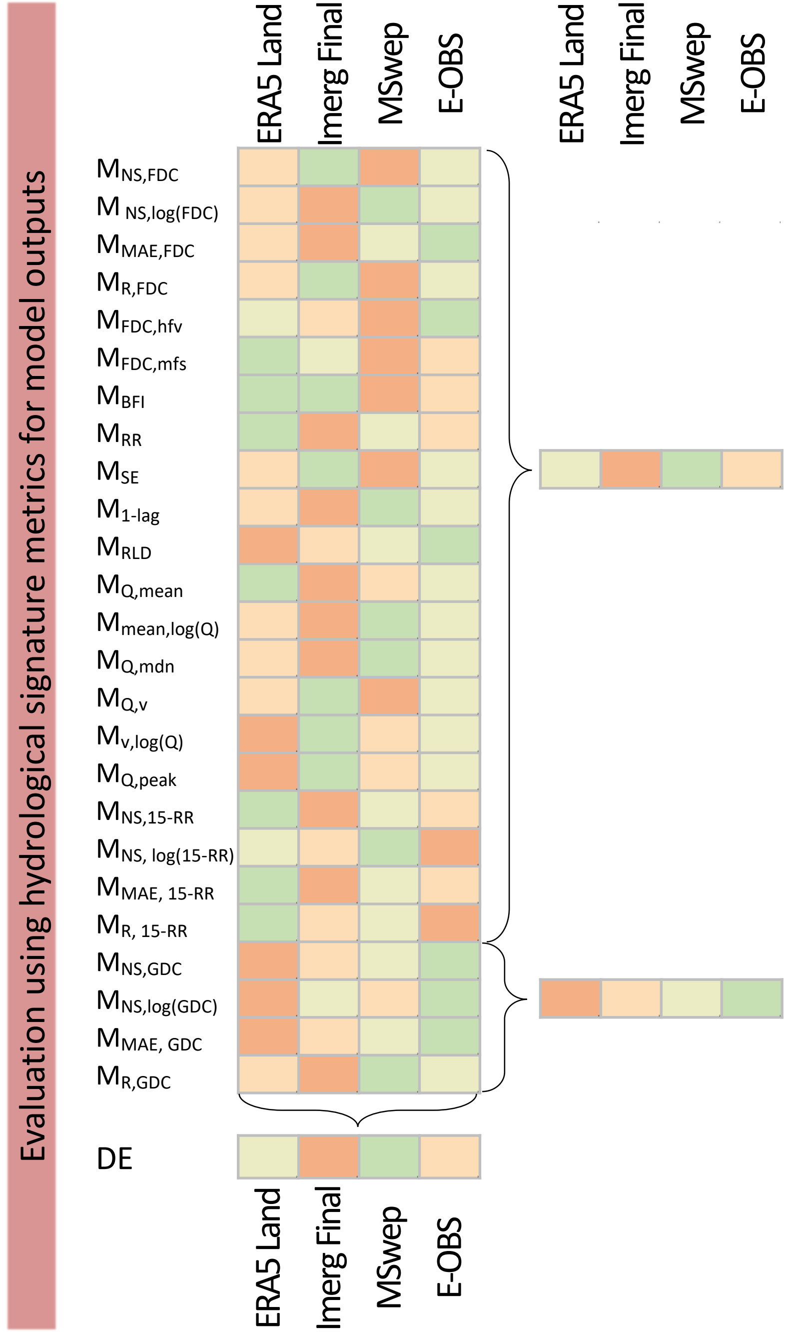
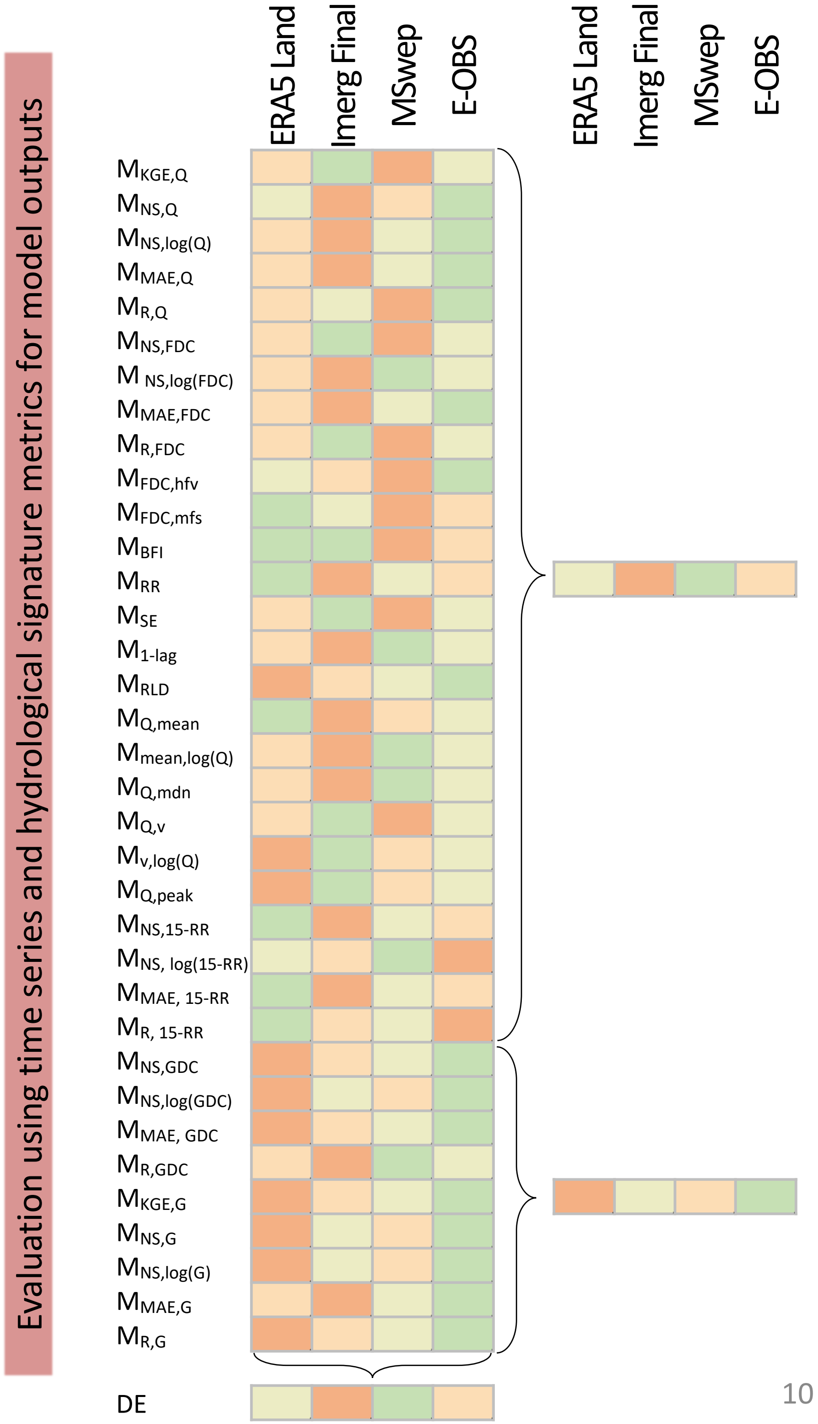
Results:



Evaluation using metrics for time series model outputs
ERA5 Land
Imerg Final
MSwep
E-OBS
Discharge
$M_{KGE,Q}$
$M_{NS,Q}$
$M_{NS,log(Q)}$
$M_{MAE,Q}$
$M_{R,Q}$
Groundwater
$M_{KGE,G}$
$M_{NS,G}$
$M_{NS,log(G)}$
$M_{MAE,G}$
$M_{R,G}$
DE
Legend
1
2
3
4



Evaluation using hydrological signature metrics for model outputs
ERA5 Land
Imerg Final
MSwep
E-OBS
$M_{NS,FDC}$
$M_{NS,log(FDC)}$
$M_{MAE,FDC}$
$M_{R,FDC}$
$M_{FDC,hfv}$
$M_{FDC,mfs}$
M_{BFI}
M_{RR}
M_{SE}
M_{1-lag}
M_{RLD}
$M_{Q,mean}$
$M_{mean,log(Q)}$
$M_{Q,mdn}$
$M_{Q,v}$
$M_{v,log(Q)}$
$M_{Q,peak}$
$M_{NS,15-RR}$
$M_{NS, log(15-RR)}$
$M_{MAE, 15-RR}$
$M_{R, 15-RR}$
$M_{NS,GDC}$
$M_{NS,log(GDC)}$
$M_{MAE, GDC}$
$M_{R,GDC}$
DE

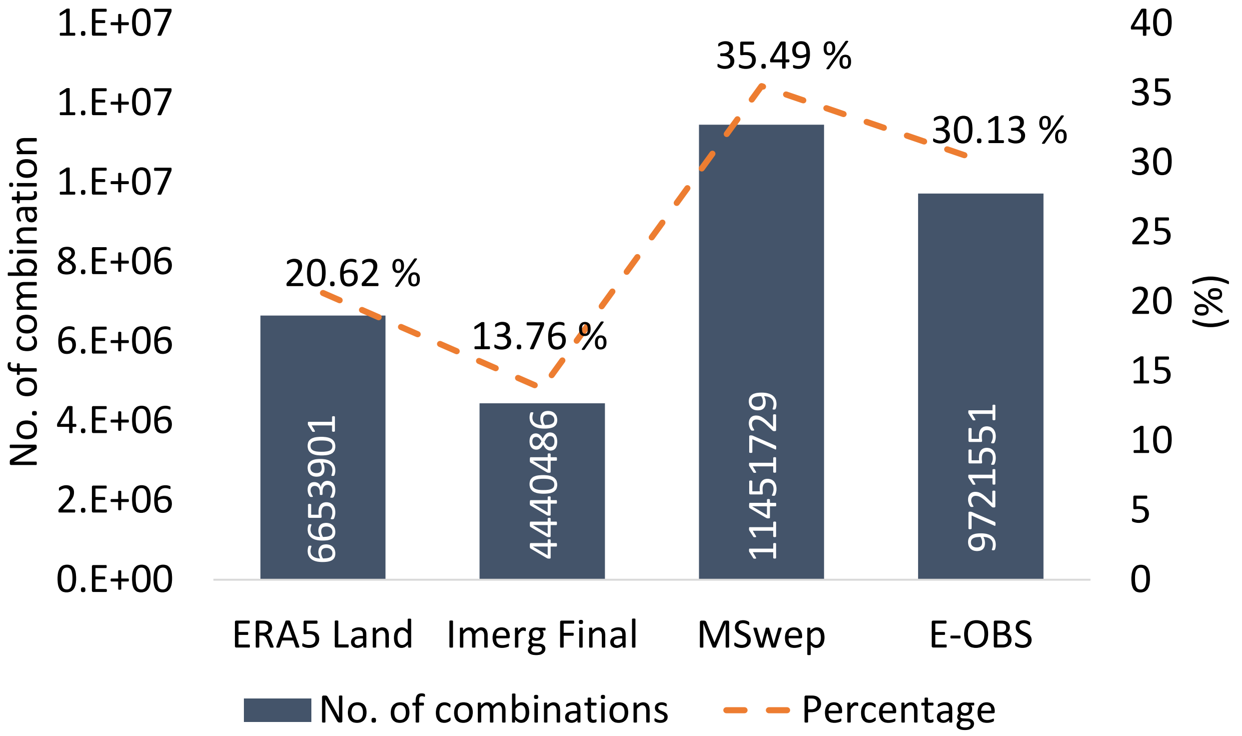


Evaluation using time series and hydrological signature metrics for model outputs
ERA5 Land
Imerg Final
MSwep
E-OBS
$M_{KGE,Q}$
$M_{NS,Q}$
$M_{NS,log(Q)}$
$M_{MAE,Q}$
$M_{R,Q}$
$M_{NS,FDC}$
$M_{NS,log(FDC)}$
$M_{MAE,FDC}$
$M_{R,FDC}$
$M_{FDC,hfv}$
$M_{FDC,mfs}$
M_{BFI}
M_{RR}
M_{SE}
M_{1-lag}
M_{RLD}
$M_{Q,mean}$
$M_{mean,log(Q)}$
$M_{Q,mdn}$
$M_{Q,v}$
$M_{v,log(Q)}$
$M_{Q,peak}$
$M_{NS,15-RR}$
$M_{NS, log(15-RR)}$
$M_{MAE, 15-RR}$
$M_{R, 15-RR}$
$M_{NS,GDC}$
$M_{NS,log(GDC)}$
$M_{MAE, GDC}$
$M_{R,GDC}$
$M_{KGE,G}$
$M_{NS,G}$
$M_{NS,log(G)}$
$M_{MAE,G}$
$M_{R,G}$
DE

Results:

Rainfall		Model output	Time series only		Hydrological signature only		Time series plus hydrological signatures	
1st	2nd		1st	2nd	1st	2nd	1st	2nd
		Discharge	E-OBS	MSWEP	MSWEP	ERA5-Land	MSWEP	ERA5-Land
		Ground water	E-OBS	IMERG Final	E-OBS	MSWEP	E-OBS	IMERG Final
E-OBS	MSWEP	Overall	E-OBS	MSWEP	MSWEP	ERA5-Land	MSWEP	ERA5-Land

- There can be **34.36 billion** unique combinations considering all 35 metrics
- Yet, considering 1 to 8 metrics in the group of 35, we have tested **32.27 million** unique combinations



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Conclusions:

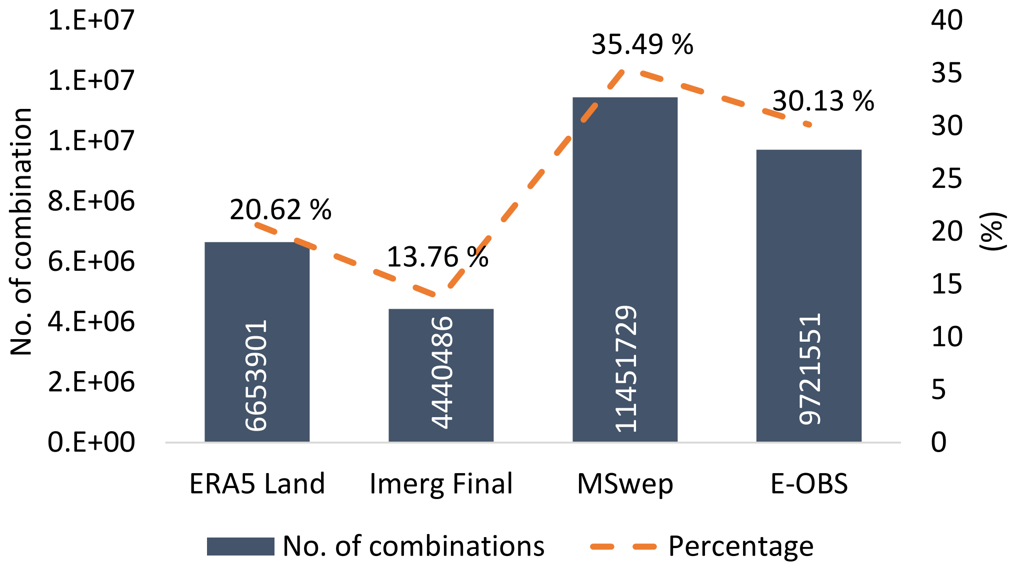
- **Does the performance of rainfall datasets, as evaluated by rain gauge data, correlate with their accuracy in simulating hydrological variables (discharge and groundwater)?**

  - ➢ Rainfall dataset evaluation with rain gauge do not necessarily correlate with its performance in simulating variables.

Rainfall 1st	Rainfall 2nd	Model output	Rank 1st	Rank 2nd
E-OBS	MSWEP	Discharge	MSWEP	ERA5-Land
		Ground water	E-OBS	IMERG Final
		Overall	MSWEP	ERA5-Land

- **How does the variation in evaluation criteria and metrics influence perceptions regarding the performance quality of rainfall datasets.**

  - ➢ Dataset performance assessment varies based on evaluation criteria.
  - ➢ Careful evaluation metrics selection is crucial, considering specific research needs and geographical context of study area.



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