EUMETSAT H SAF

High resolution satellite Earth observations improve hydrological modeling in the Po River Basin, Italy

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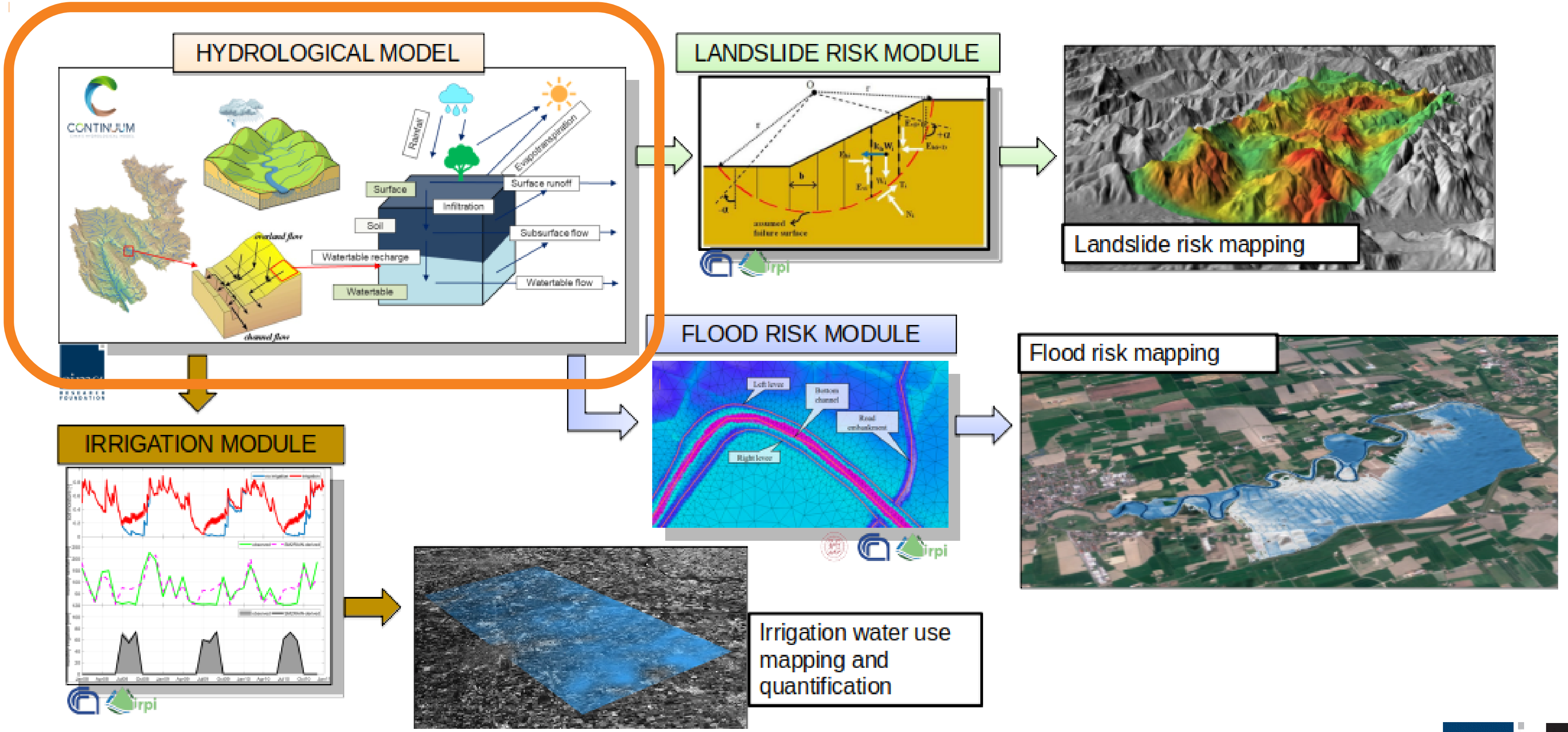
Outline

In the framework of the Destination Earth program, this work contributes to the development of a Digital Twin Earth, to highlight the potential of high-resolution satellite products in monitoring the water cycle and the hydrological extremes through high resolution modeling.

- Modeling framework
- Case study description
- Model calibration
- Model simulation driven by ground observations (baseline)
- Model simulation driven by satellite products
- Model calibration with satellite products
- Conclusions

Biophysical modeling in DTE-Hydrology



Snow modeling in DTE:

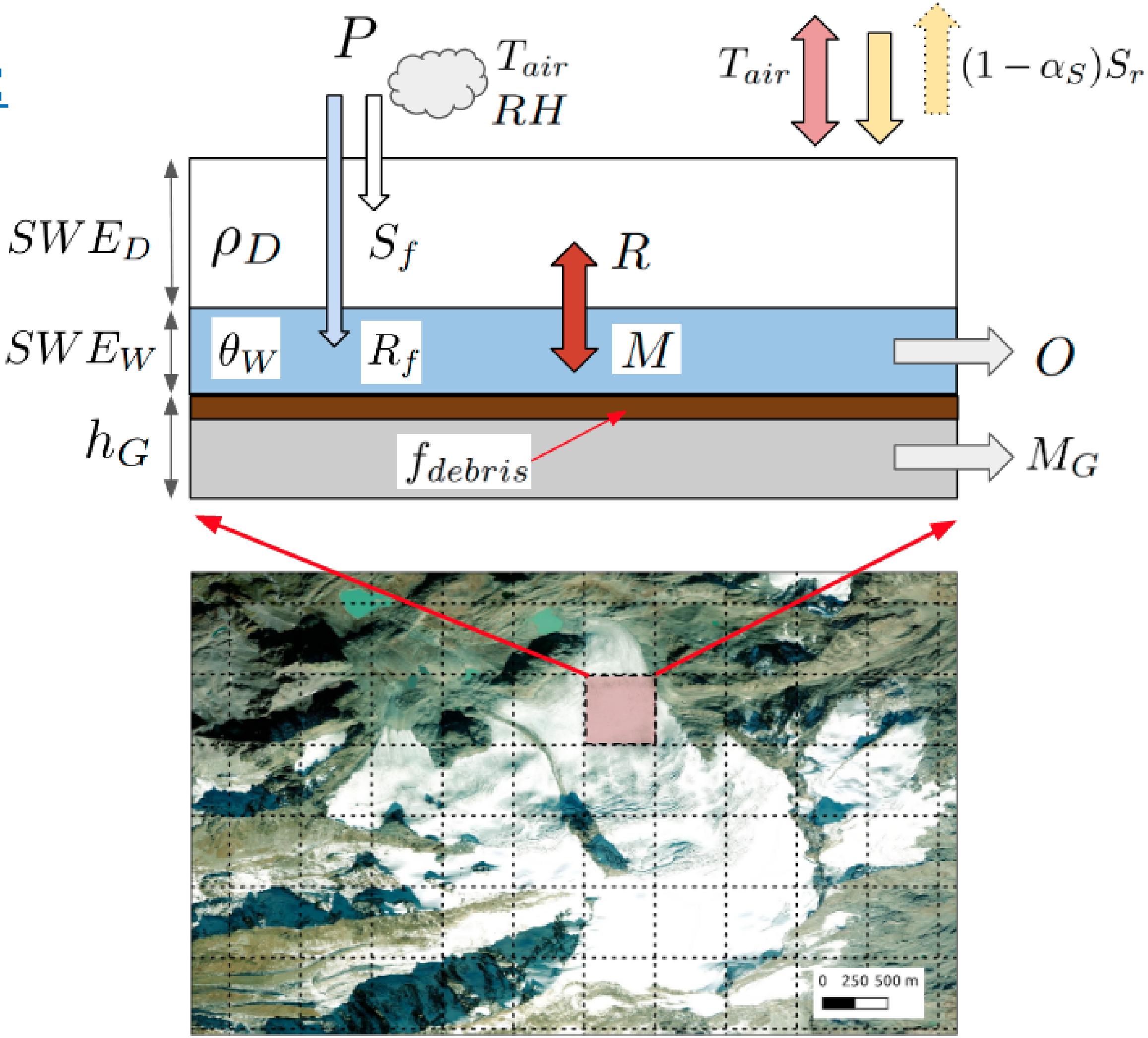
The S3M snow model

- ***Dry and wet snow***
- *Melt-freeze cycles*
- *Parsimonious snowmelt approach*
- *Explicit simulation of albedo*
- *Ideal for multi-source, EO-based data assimilation*
- *Glaciers*

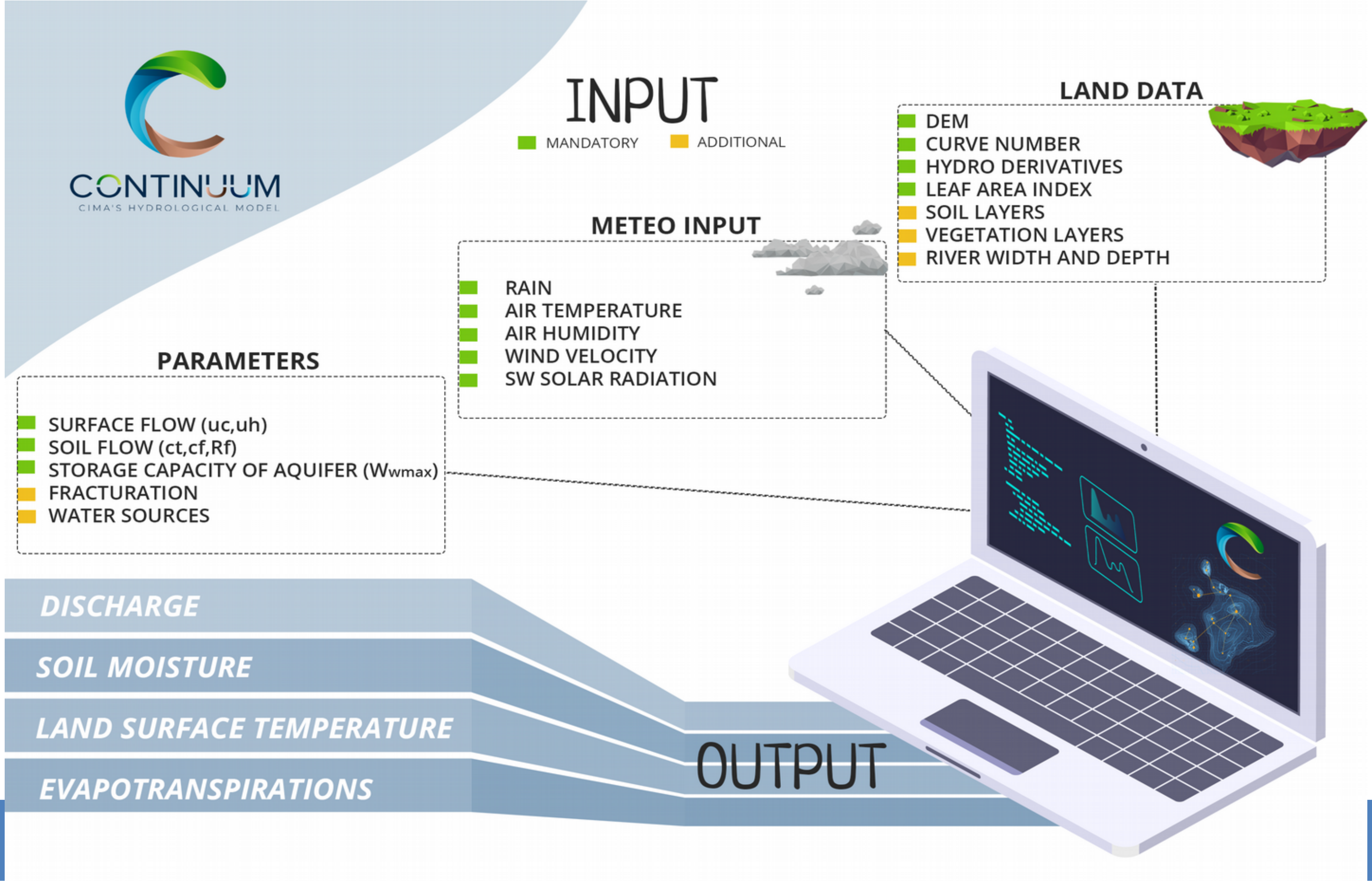
Avanzi et al. (2021)

Geoscientific Model Development

GitHub



The hydrological model Continuum



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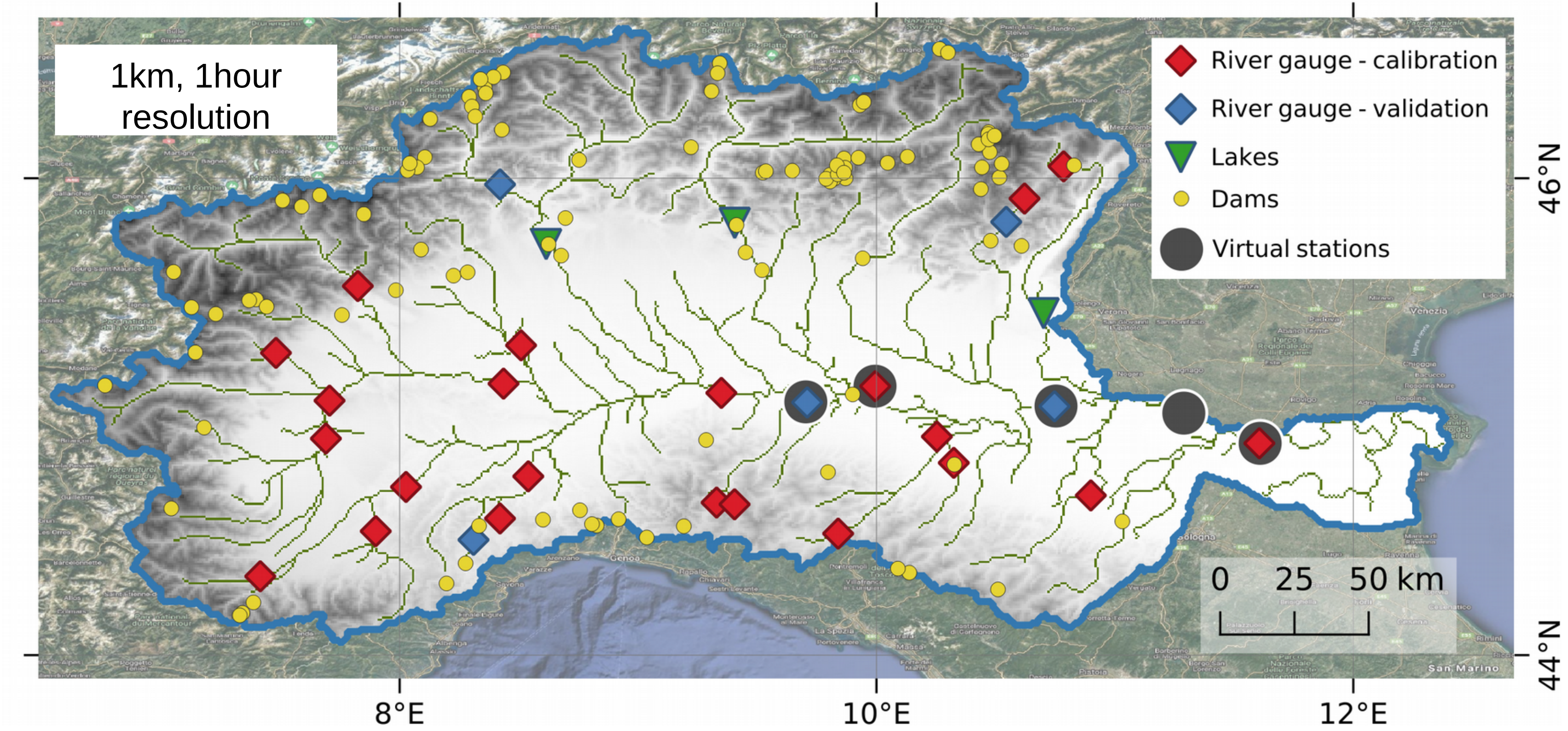
Model setup



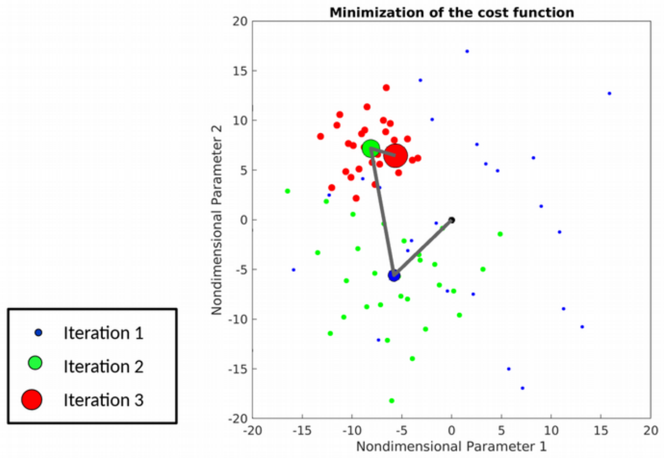
1km, 1hour resolution
River gauge - calibration
River gauge - validation
Lakes
Dams
Virtual stations
0 25 50 km
8°E
10°E
12°E
46°N
44°N

Model calibration

- In the calibration we perturbed 6 model parameters related to 4 physical hydrologic features:

1) *infiltration velocity at saturation (ct)*
2) *field capacity (cf)*
3) *Curve Number (CN)*
4) *water sources (ws)*

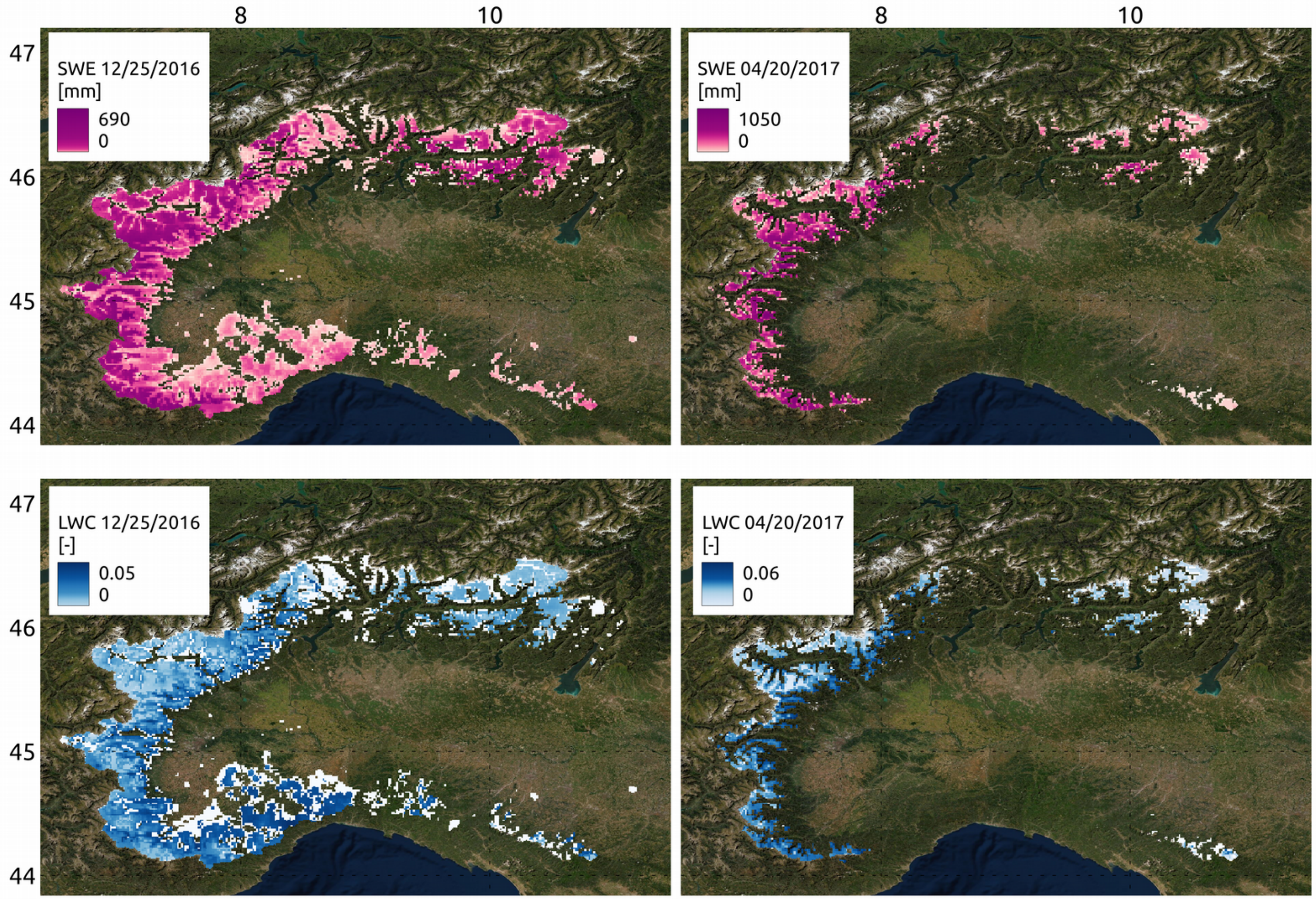
- 22 discharge stations
- Calibration period:
  1/7/2018 – 31/12/2019
  (+ 6 months for model warm-up)
- Gaussian Latin Hypercube Sampling
- 20 simulations per iteration



Cost function J to minimize:

$$J = \frac{\sum_{i=1}^{N_{flow}} \log(A_i) f\left(1 - KGE\left(Q_{\mathrm{mod},i}, Q_{obs,i}\right)\right)}{\sum_{i=1}^{N_{flow}} \log(A_i)}$$

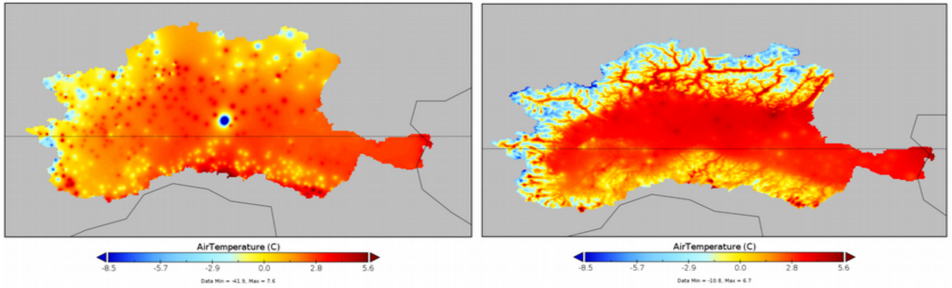
Representation of the search algorithm in a 2-dimension space



Snow modeling in DTE

Baseline run

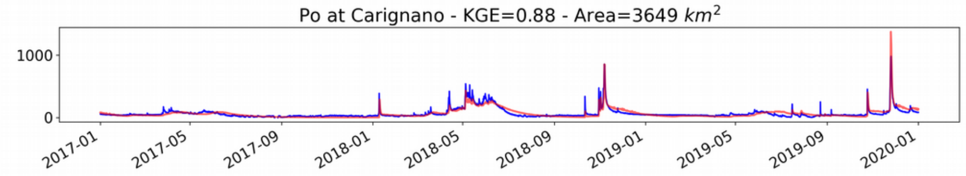
	Station	Area [km²]	KGE	r	Bias rate	CV rate	RMSE [m³/s]	ME [m³/s]
CALIBRATION	Salsominore	171	0.06	0.61	1.85	1.10	12	4
	Cartosio	180	0.69	0.78	1.05	0.78	11	0
	Valsigiara	192	0.20	0.77	1.71	0.71	10	3
	Cimego	233	-0.03	0.00	1.00	0.75	4	0
	Ostia_Parmense	387	0.62	0.65	0.96	0.86	26	-1
	Ponte_Verdi	485	0.31	0.71	0.43	0.74	41	-14
	Ragoli	504	0.19	0.27	0.95	0.67	11	0
	Gaiola	515	0.61	0.89	0.71	1.23	9	-5
	Lanzo	541	0.74	0.83	0.81	1.02	16	-4
	Ponte_Alto	1077	0.60	0.82	1.12	0.67	24	3
	Cassine	1364	-0.12	0.82	1.88	0.34	59	16
	Farigliano	1379	0.80	0.84	0.95	0.88	23	-2
	S_Secondo	1422	0.46	0.71	0.94	0.55	74	-2
	Palestro	2168	0.67	0.88	0.81	0.76	93	-15
	Tavagnasco	3096	0.59	0.90	0.61	0.94	64	-39
	Alba_Q_A	3180	0.75	0.81	1.12	0.90	45	8
	Carignano	3649	0.88	0.89	0.97	1.05	38	-2
	Torino_Murazzi	6134	0.73	0.88	1.24	1.03	61	19
	Casale_Monferrato	12882	0.55	0.83	1.33	0.75	156	60
	Spessa	35976	0.80	0.90	0.87	1.11	333	-99
	Cremona	47616	0.69	0.89	0.83	1.23	427	-171
	Pontelagoscuro	67487	0.69	0.88	0.91	1.28	565	-123
VALIDATION	Piana_Crixia	229	0.17	0.66	0.76	0.28	18	-1
	Ponte_dei_Tedeschi	361	0.15	0.41	0.41	0.82	14	-7
	Candoglia	1480	0.56	0.86	0.60	1.14	47	-29
	Piacenza	39195	0.76	0.89	0.83	1.13	384	-139
	Borgoforte	59169	0.68	0.88	0.85	1.26	521	-192
	min	171	-0.12	0.00	0.41	0.28	4	-192
	25%	436	0.25	0.71	0.81	0.74	15	-22
	median	1379	0.61	0.83	0.94	0.88	41	-2
	75%	4891	0.71	0.88	1.09	1.11	84	1
	max	67487	0.88	0.90	1.88	1.28	565	60
	mean	10781	0.51	0.75	0.98	0.89	114	-27



Input parameters

- Precipitation → Radar-gauge merging (MCM)
- Air temperature → Altitude correction + outlier filtering
- Relative humidity
- Wind speed
- Solar radiation

(Air temperature, Relative humidity, Wind speed, Solar radiation:) Inverse distance interpolation of ground measurements



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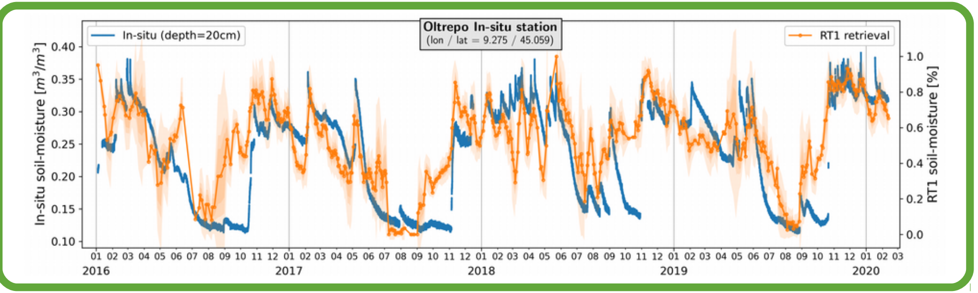
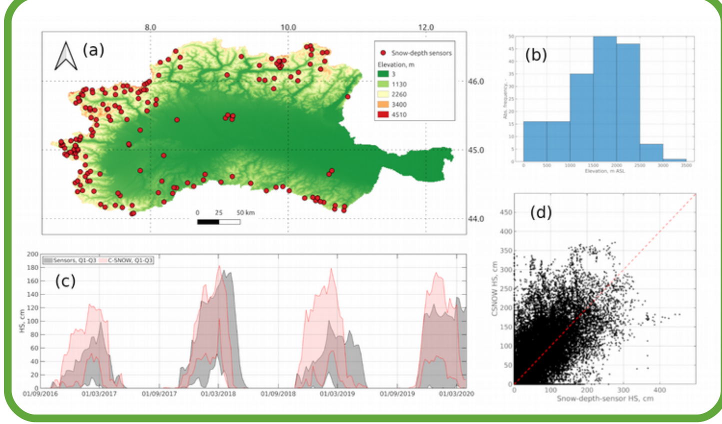
Satellite-based products

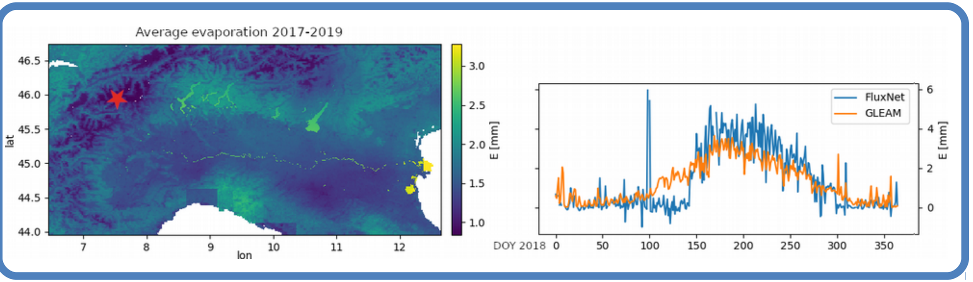
RT1



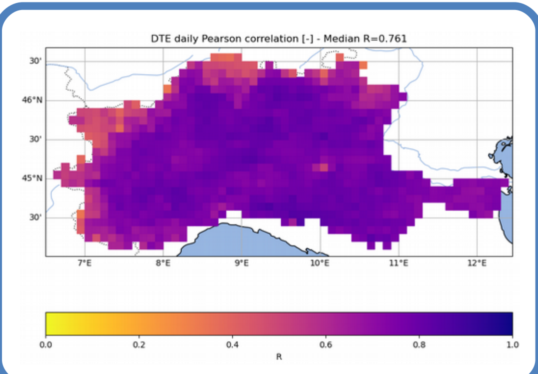
C-SNOW



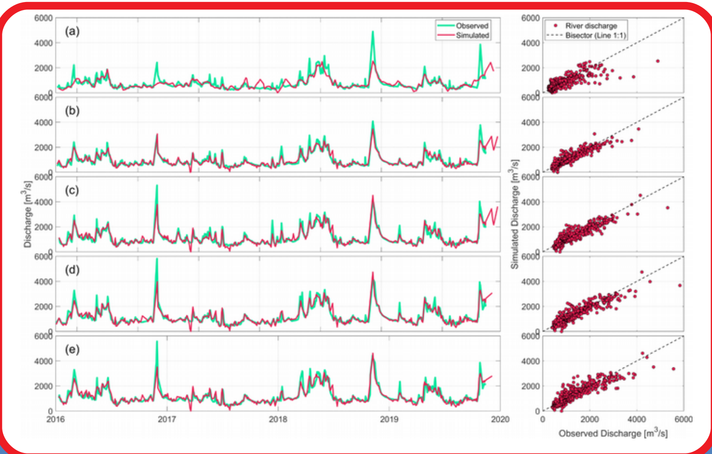
GLEAM



SM2RAIN



Discharge



Input

Assimilation

Benchmark data

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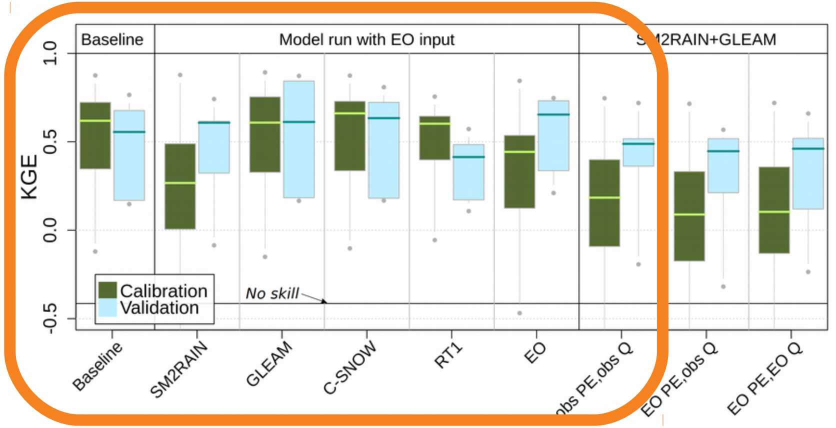
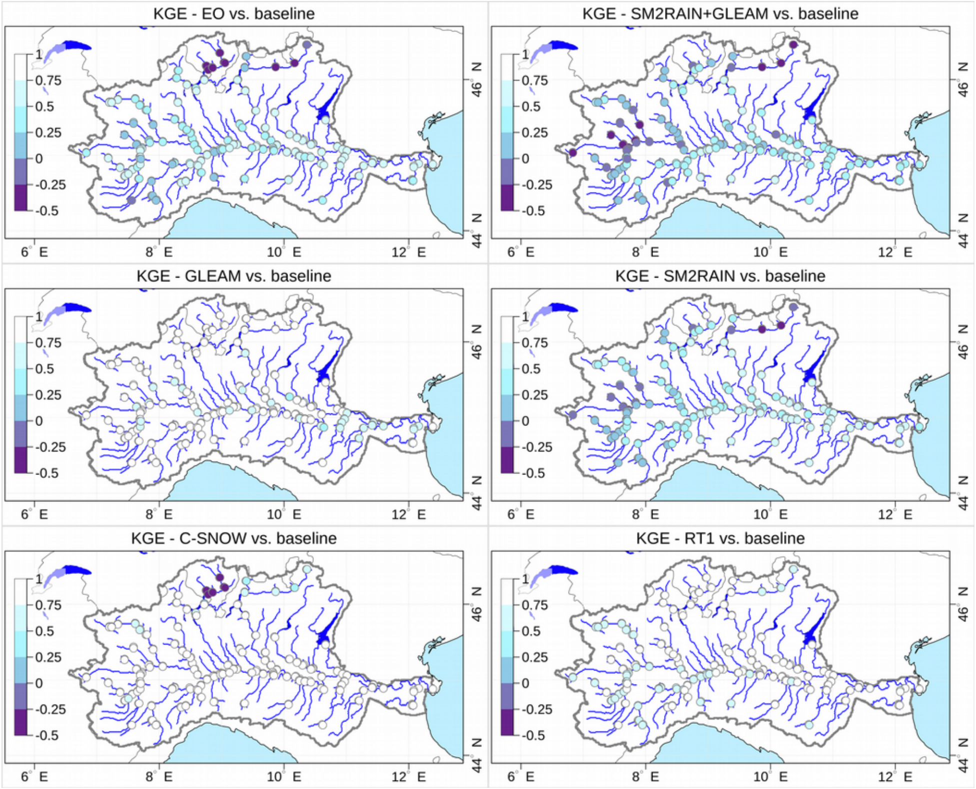
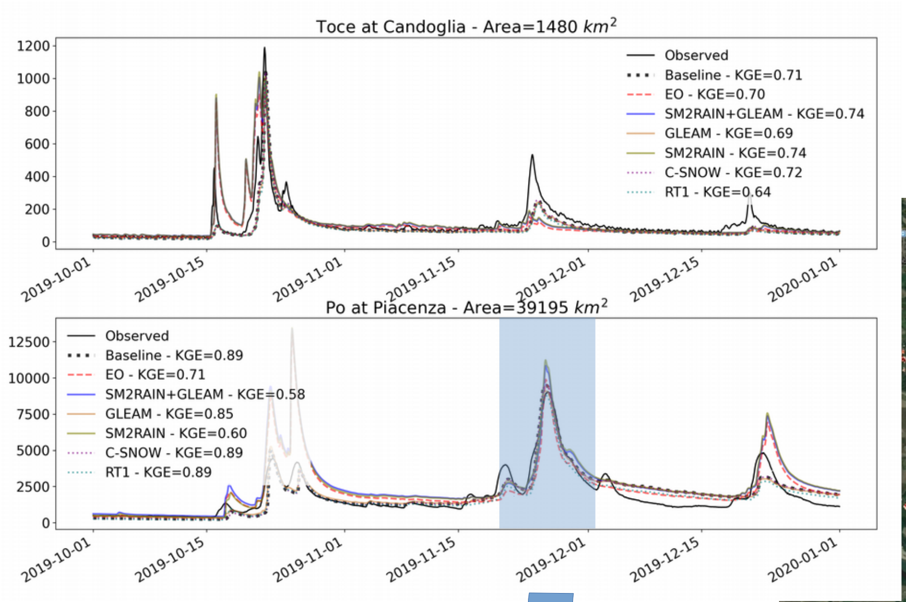
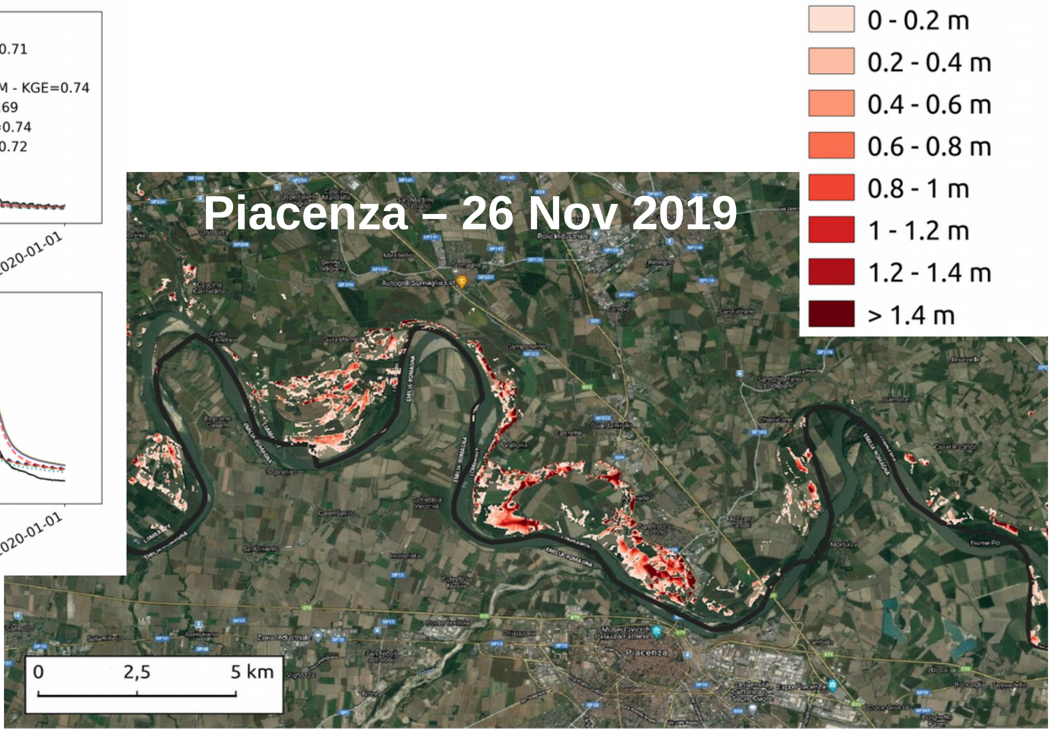
Model runs with satellite input





Floods in October-December 2019

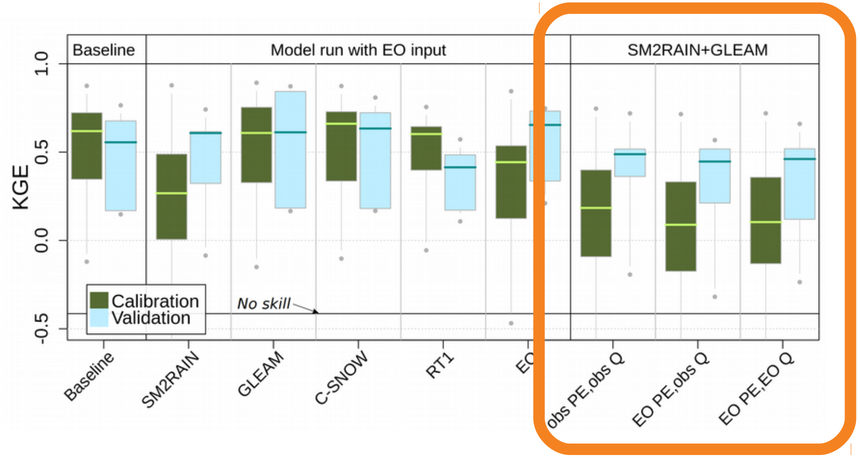


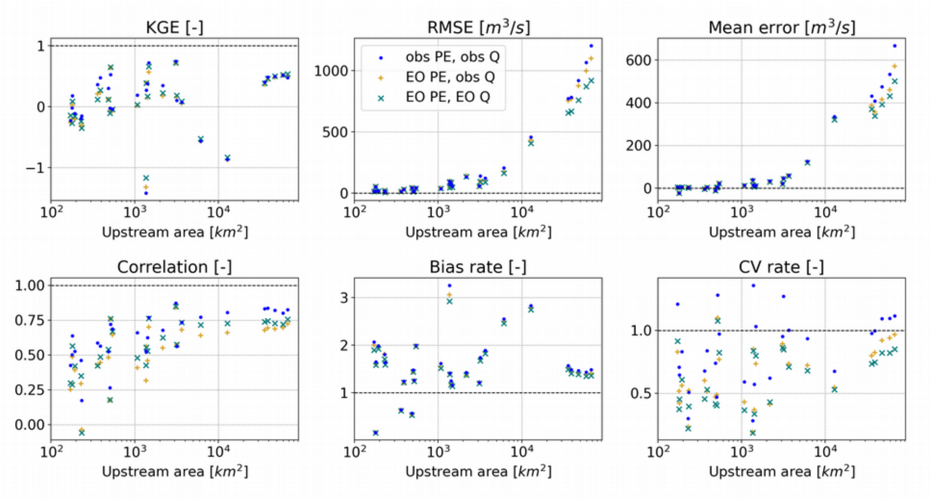


ESA Sentinel 1A / 1B

Results at two validation stations

Satellite products for model calibration





- Surprisingly high skills of hydrological simulations at the 5 validation stations

Conclusions

- Hydrological simulations driven by satellite datasets produced encouraging results, with 95% of KGE of discharges above the no-skill threshold (versus 100% for the baseline run)

- Satellite precipitation (SM2RAIN) has the largest weight on the model performance.

- GLEAM evaporation and C-SNOW snow product yielding an average 2% and 4% improvements over a baseline run driven by high-quality ground-based datasets

- Skillful results in a model calibration heavily relying on satellite products both with regard to forcing input and to benchmark discharge

Check out our discussion paper in HESS:

“High resolution satellite products improve hydrological modeling in northern Italy”

https://hess.copernicus.org/preprints/hess-2021-632/

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