International Conference Energy & Meteorology (ICEM)

Towards climate-resilient energy systems

Galzignano (PD), June 27-29th 2023

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International Conference Energy & Meteorology (ICEM 2023)

Hydrological Seasonal Forecast as a Resources Assessment Tool for the Upper Adige Catchment

Zaramella M[1,2], Dinale R[3], Ghetta S[3], Lusito L[1], Cordeddu S[1], Aldrigo G[1], Campostrini S[1], Restivo E[1], Shrestha S[2], Troccoli A[1], Borga M[2]

1 University of Padova – TESAF
2 Inside Climate Service s.r.l.
3 Office for Hydrology and Dam- Autonomous province of Bozen

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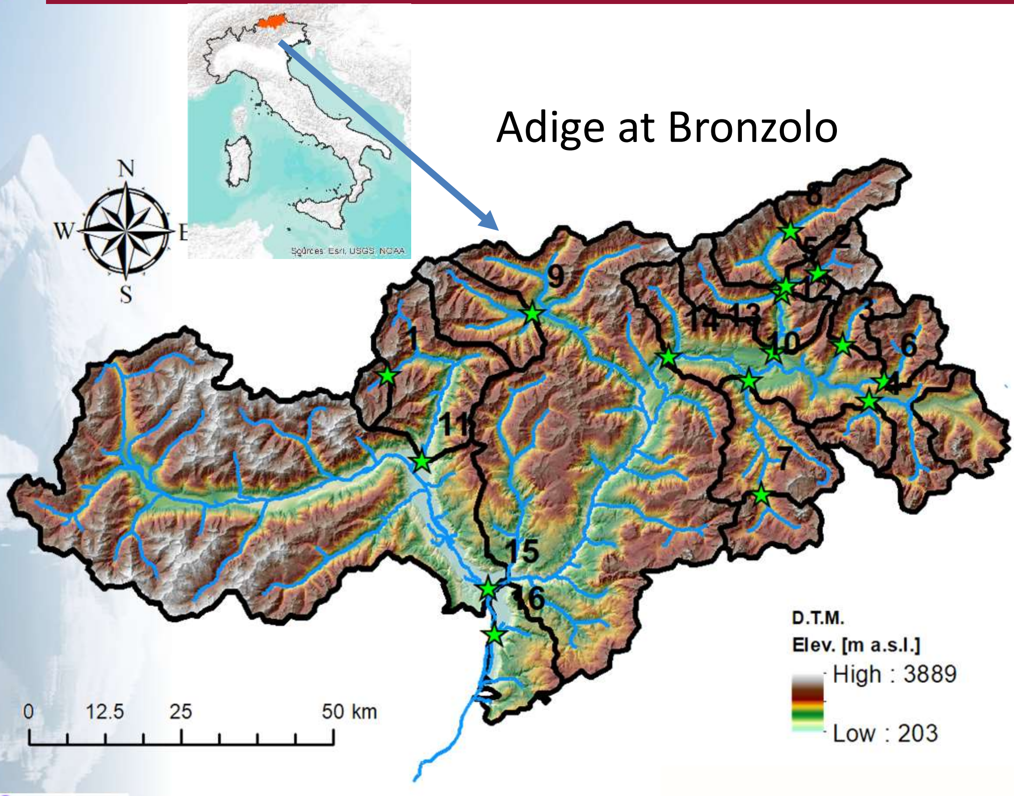
STUDY AREA: THE UPPER ADIGE CATCHMENT

Adige at Bronzolo



17 sub-basins with area ranging from 77 to 6900 km².

Basin ID	Name	Ele. (m asl)	Area (Km²)
0	Rio Plima at the Gioveretto Dam	2922	77
1	Rio Plan at Plan	2163	49
2	Rio Riva at Seghe	1831	76
3	Rio Anterselva at Bagni	2072	82
4	Rio Braies at Braies	2188	93
5	Rio Riva at Caminata	1829	115
6	Rio Casies at Colle	2162	117
7	Gadera at Pedraces	1911	125
8	Aurino at Cadipietra	1796	150
9	Ridanna at Vipiteno	1700	210
10	Gadera at Mantana	1915	397
11	Passirio at Merano	1533	414
12	Aurino at Caminata	1887	420
13	Aurino at S.Giorgio	1847	608
14	Rienza at Vandoies	1916	1919
15	Adige at PonteAdige	1878	2732
16	Adige at Bronzolo	1885	6924

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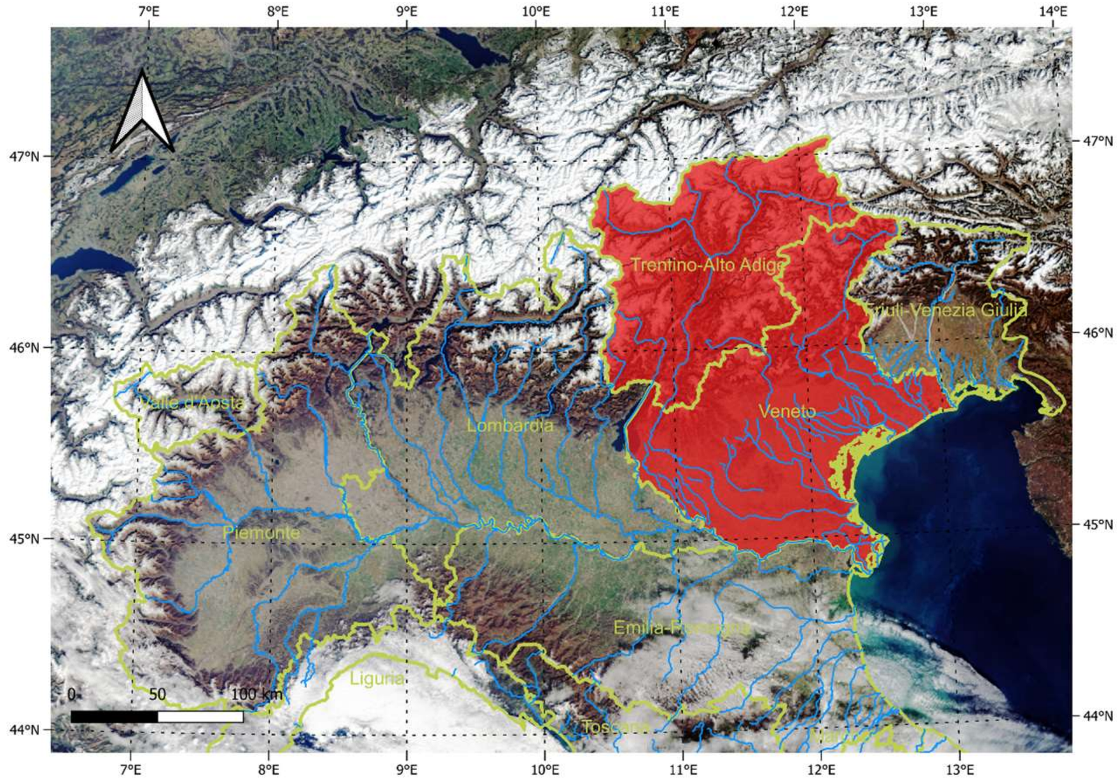

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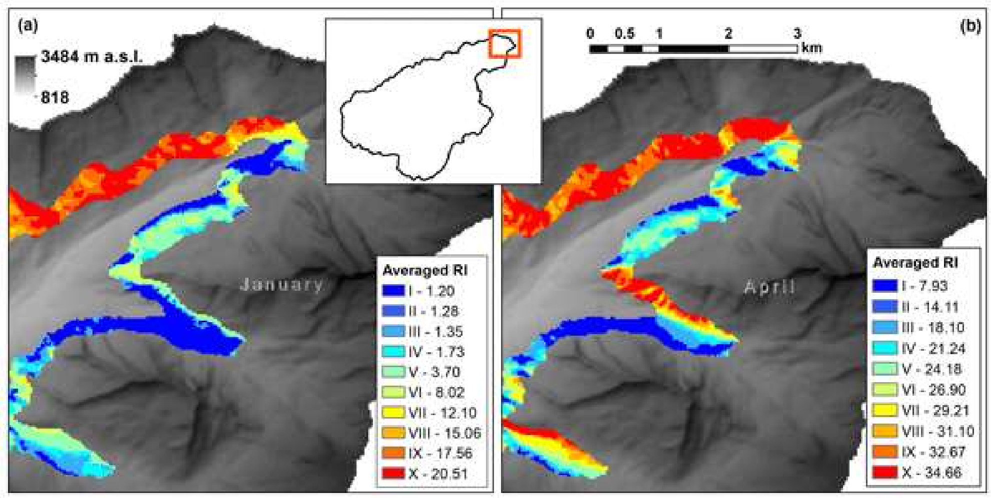
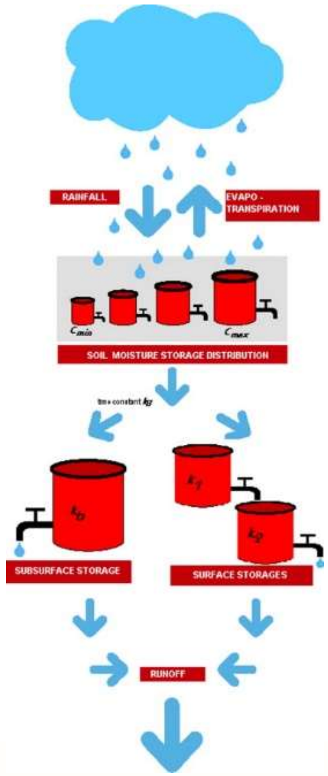
METHODOLOGY: HYDROLOGICAL MODEL AND SNOWPACK MODEL



TOPMELT
(SNOW DYNAMICS)
+
PDM-ICHYMOD (RUNOFF GENERATION)
=
HIGH COMPUTATIONAL PERFORMANCE



TOPMELT (Zaramella et al. 2019):

- Enhanced Temperature Index snowpack model;
- clear Sky Solar radiation;
- frequency distribution function approach;
- monthly averaged incident solar Energy Index (EI [Wm^2]) accounting for the visible horizon/shading.

Probability Distributed Moisture Model PDM and ICHYMOD (Moore, 2007; Norbiato et al., 2004):

- Pareto function distribution of the soil retention capacity;
- lumped runoff generation;
- maximum capacity linked to surface lithology.
- input fed by TOPMELT.

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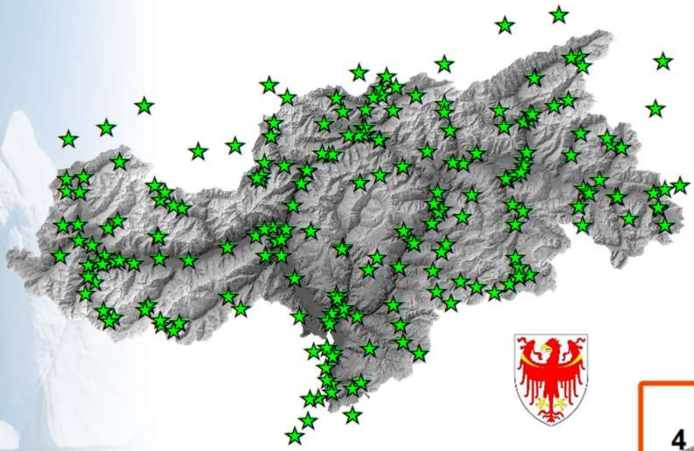
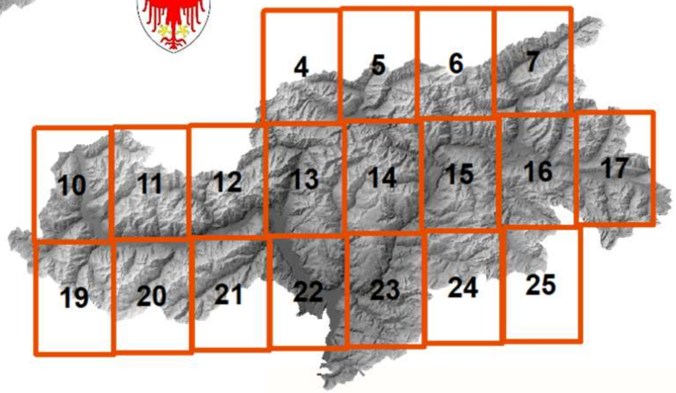
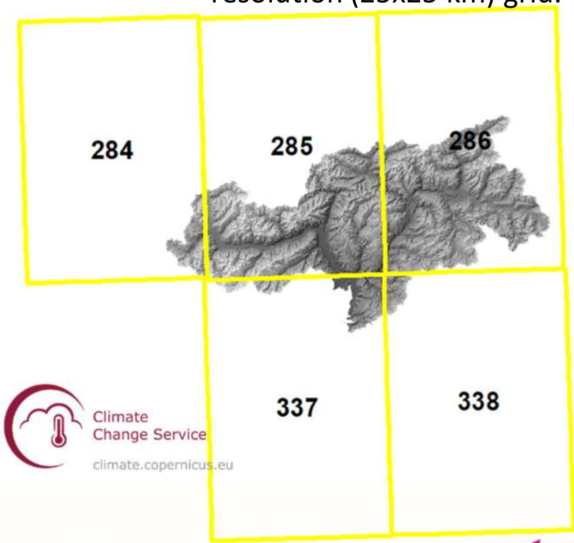
METHODOLOGY: HISTORICAL AND SEASONAL DATASET



ECMWF, DWD, ECCC, CMCC and… ESP

- Hindcast step from 1993 to 2016 (23 years);
- Precipitation at daily time step and temperature at 6h time step
- 1° spatial resolution (100x100 km);
- Monthly ensembles to 80 days lead time;
- QM Bias adjustement on measured data transferred onto a 0.25° resolution (25x25 km) grid.





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climate.copernicus.eu

Meteo stations

- 16 discharge stations;
- More than 100 meteo stations;
- hourly aggregation from the 80's;
- hourly time step from 1991;

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OBJECTIVES OF THE APPLICATION DEVELOPMENT

- Assessment of hydrological seasonal forecast skills from 1993 to 2016 (hindcast, 4 models: ECMWF, DWD, ECCC, CMCC (currently under computation).
- Analysis of the performance for major past drought events (2005 and 2022 currently under evaluation, preliminary results presented here).
- Inclusion of hydropower production seasonal forecast by means of random forest approach.
- Inclusion of a crop model.

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METHODOLOGY: SKILL ASSESSMENT

Y = number of years (1993-2016)
M = number of ensemble member

FOR = Forecast
REF = Perfect simulation

LT = Lead time [days]
BEN = Benchmark

$Q^{FOR}_{mean-m,y}(LT) =$
Mean of runoff over the M members for month y

Bias

$$Bias(LT) = \frac{1}{Y}\sum_{y=1}^{Y}\frac{Q^{FOR}_{mean-m,y}(LT) - Q^{REF}_{y}(LT)}{Q^{REF}_{y}(LT)}$$

Nash Sutcliffe Efficiency

$$NSE(LT) = 1 - \frac{\sum_{y=1}^{Y}\left(Q^{REF}_{y}(LT) - Q^{FOR}_{mean-m,y}(LT)\right)^2}{\sum_{y=1}^{Y}\left(Q^{REF}_{y}(LT) - Q^{REF}_{mean}(LT)\right)^2}$$

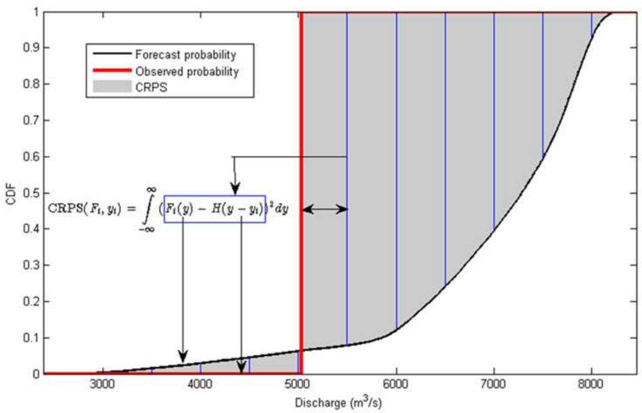
Spread Error Ratio

$$SprER(LT) = \frac{1}{Y}\sum_{y=1}^{Y}\frac{\sum_{m=1}^{M}\left(Q^{FOR}_{y,m}(LT) - Q^{FOR}_{mean-m,y}(LT)\right)^2}{\sum_{m=1}^{M}\left(Q^{FOR}_{y,m}(LT) - Q^{REF}_{y}(LT)\right)^2}$$

Continuous Ranking Probability Skill Score

$$CRPS(F_t - y_t) = \int_{-\infty}^{+\infty}(F_t(y) - H(y - y_t))^2 dy$$

$$CRPSS(LT) = 1 - \frac{\sum_{y=1}^{Y} CRPS^{FOR}_{y}(LT)}{\sum_{y=1}^{Y} CRPS^{BEN}_{y}(LT)}$$



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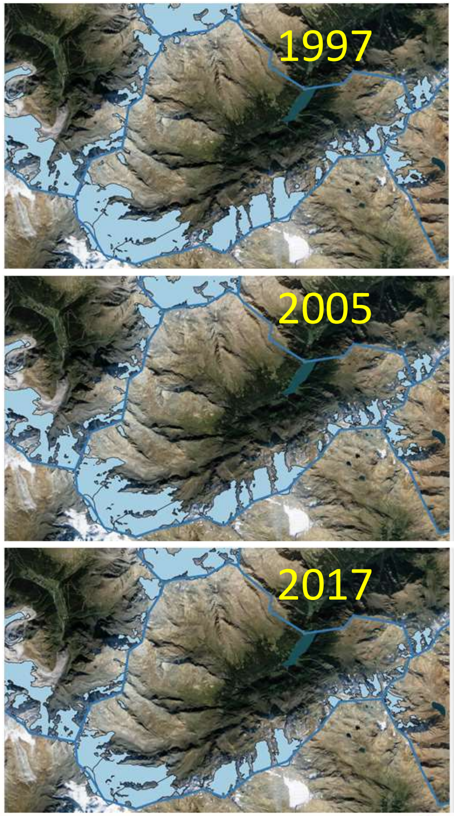
EVALUATION OF GLACIER MELT IMPACT ON STREAMFLOW – IMPLEMENTATION OF HYDROPOWER



Stephan P. Galos, Christoph Klug & Roberto Dinale "20 Years of Glacier Change: The homoge-nized glacier inventories for South 3 Tyrol 1997-2005-2017", Geografia Fisica e Dinamica Quaternaria.

- 14 major hydropower plant;
- Glacier flow validation: reconstructed inflow at the Gioveretto dam from 2005 to 2015

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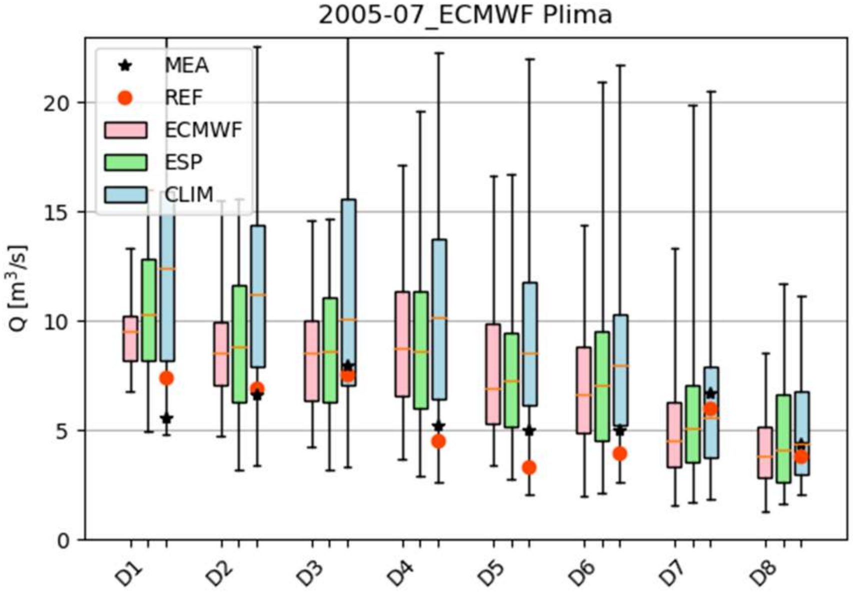
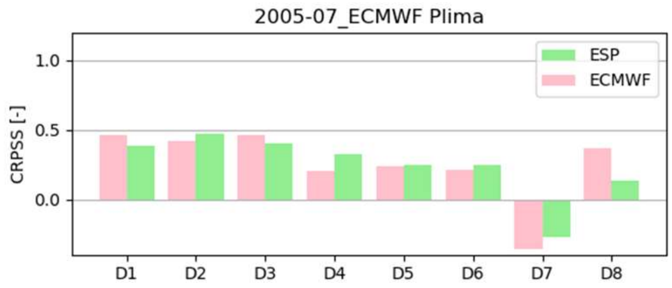
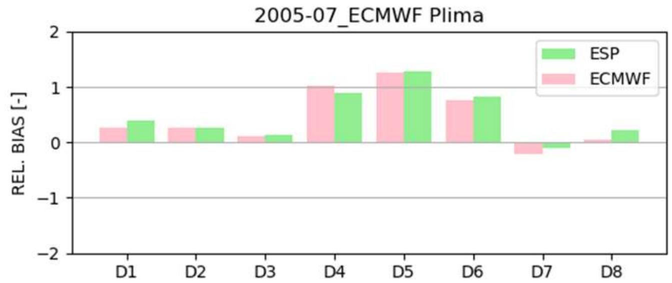
2005 DROUGHT EVENT – RIO PLIMA AT THE GIOVERETTO DAM







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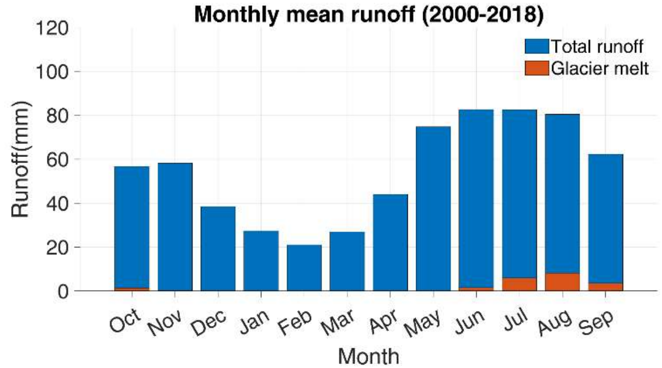
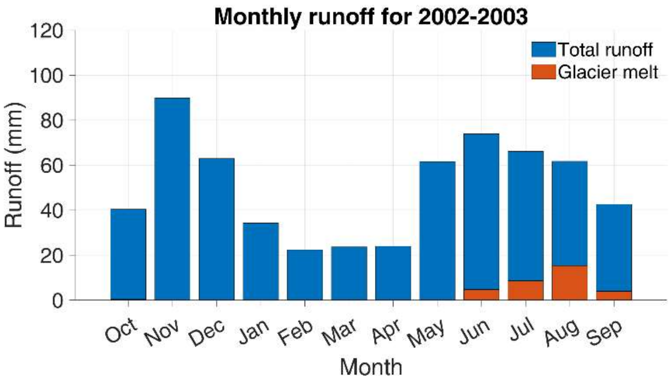
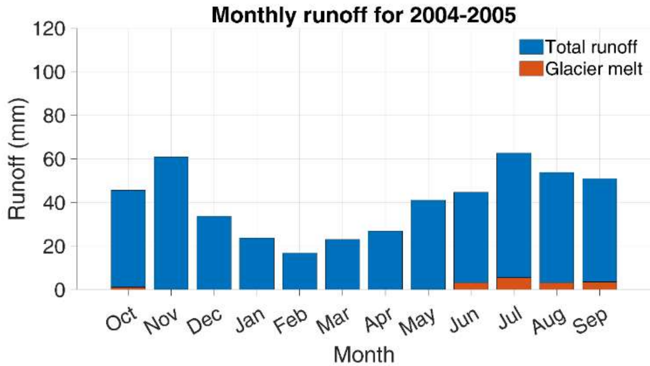
EVALUATION OF GLACIER MELT IMPACT ON STREAMFLOW

Major glacier contribution: Jun-July-Aug-Sep

Months	% Glacier contribution to total runoff		
	Mean	2005	2003
June-Sept	6.3	8.3	**13.3**
August	10.1	2.2	**24.8**







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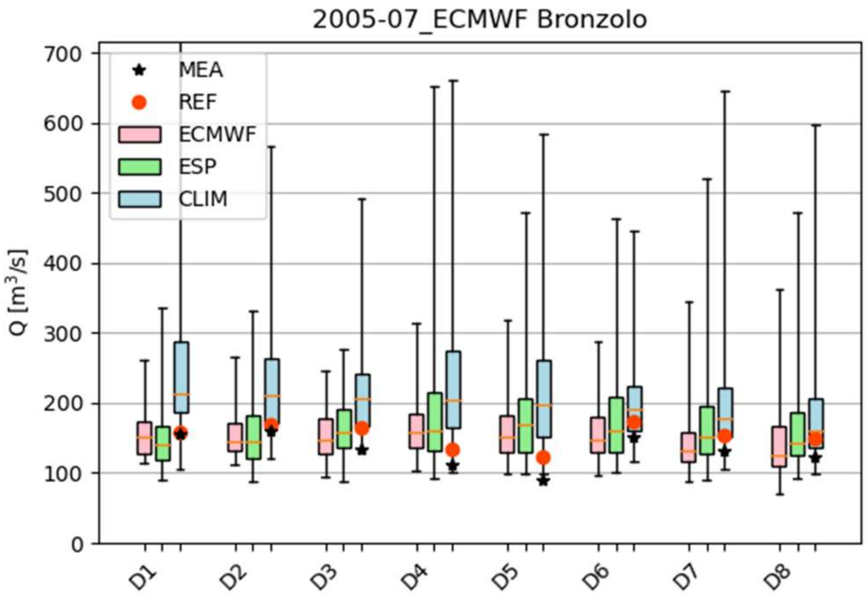
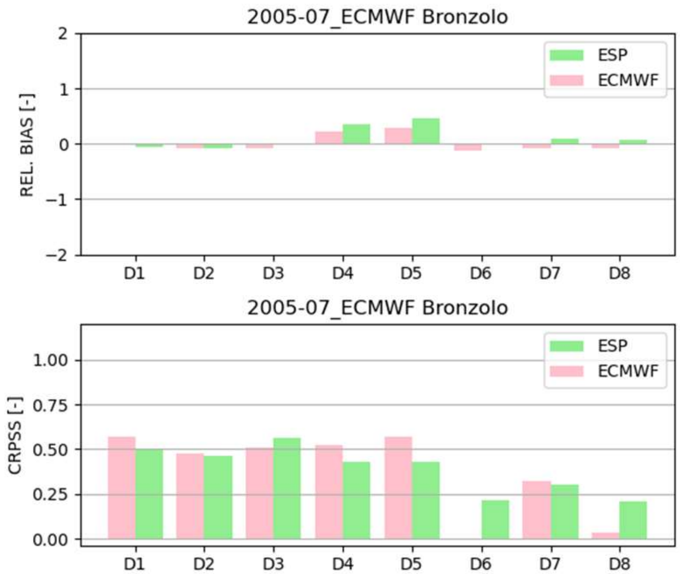
2005 DROUGHT EVENT – ADIGE AT BRONZOLO ECMWF





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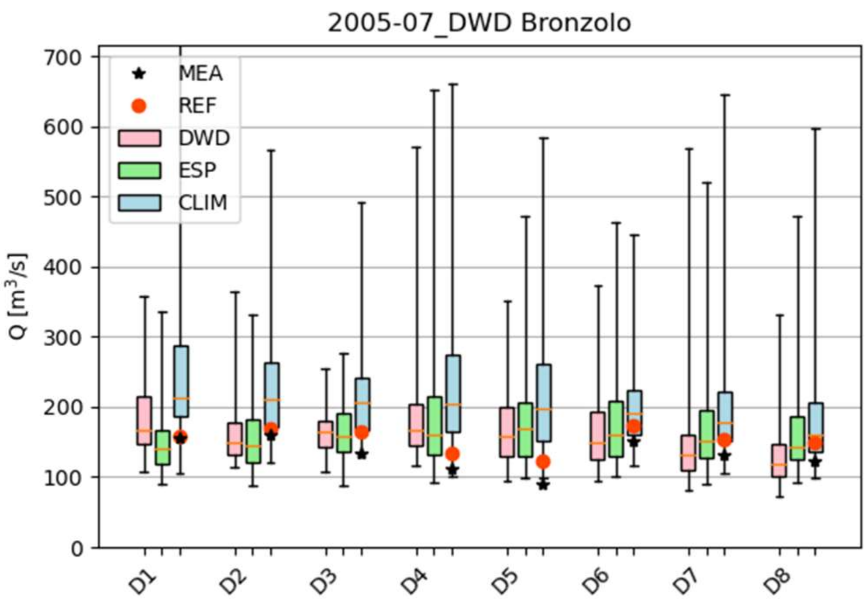
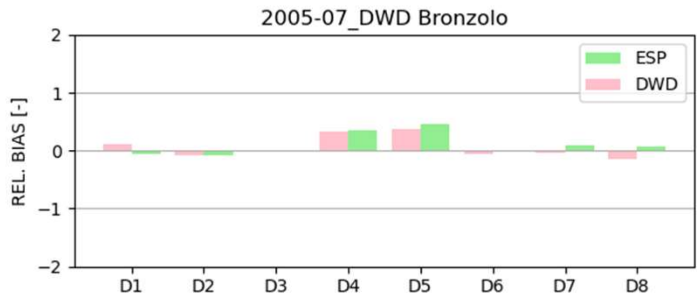
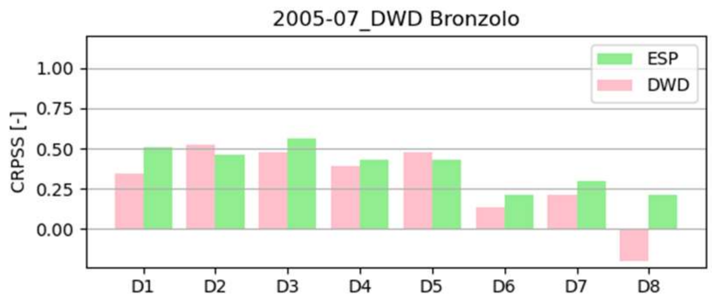
2005 DROUGHT EVENT – ADIGE AT BRONZOLO DWD







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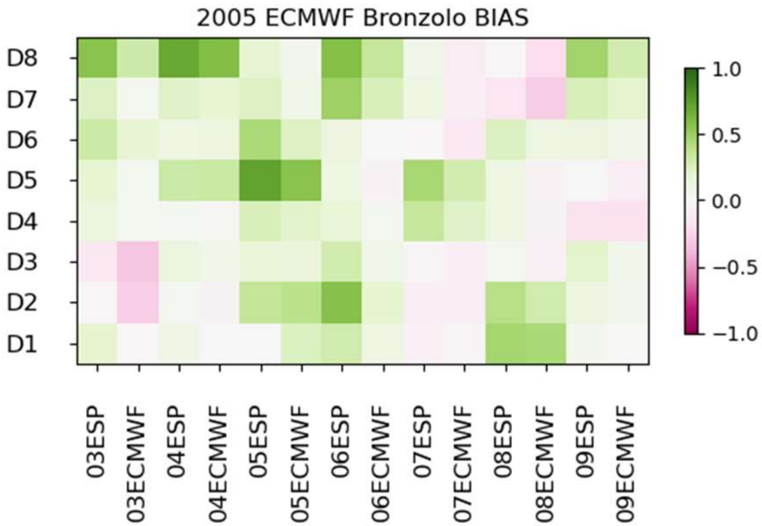

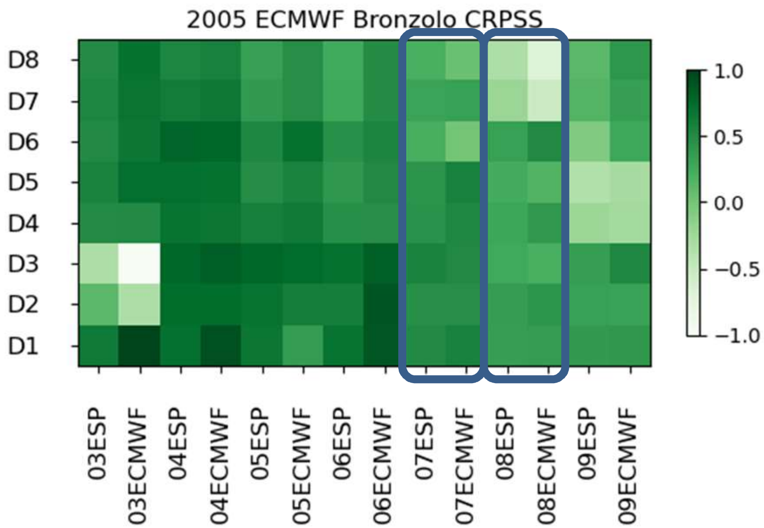

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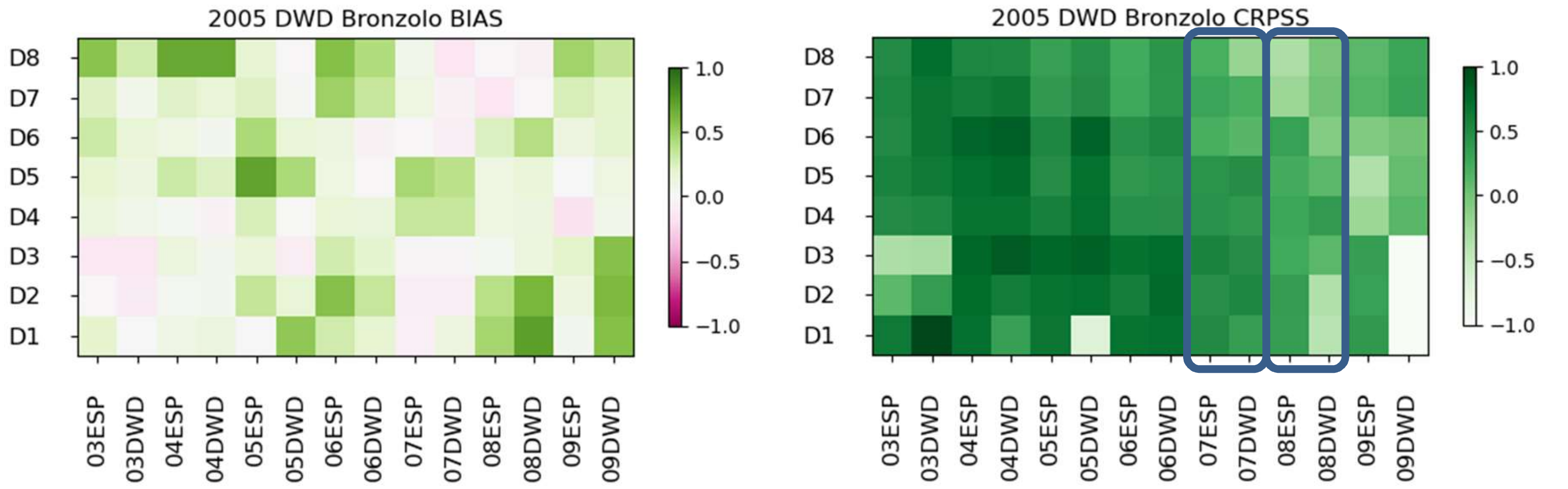

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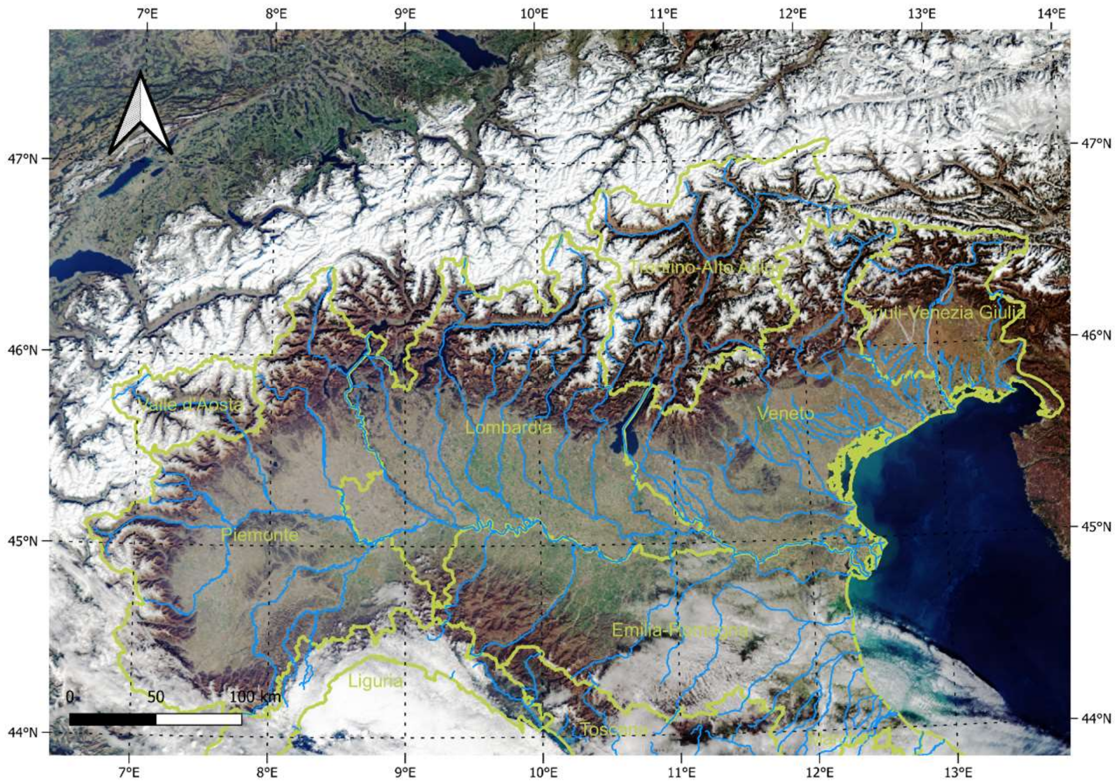
2022 DROUGHT EVENT

- First drought event assisted by the seasonal forecast system.
- Snow drought, satellite image March 5th 2022.
- The snow drought hit the north-eastern alps.
- Water scarcity on the plains of the Veneto region.
- Drought observatory created by regional water resources authorities.



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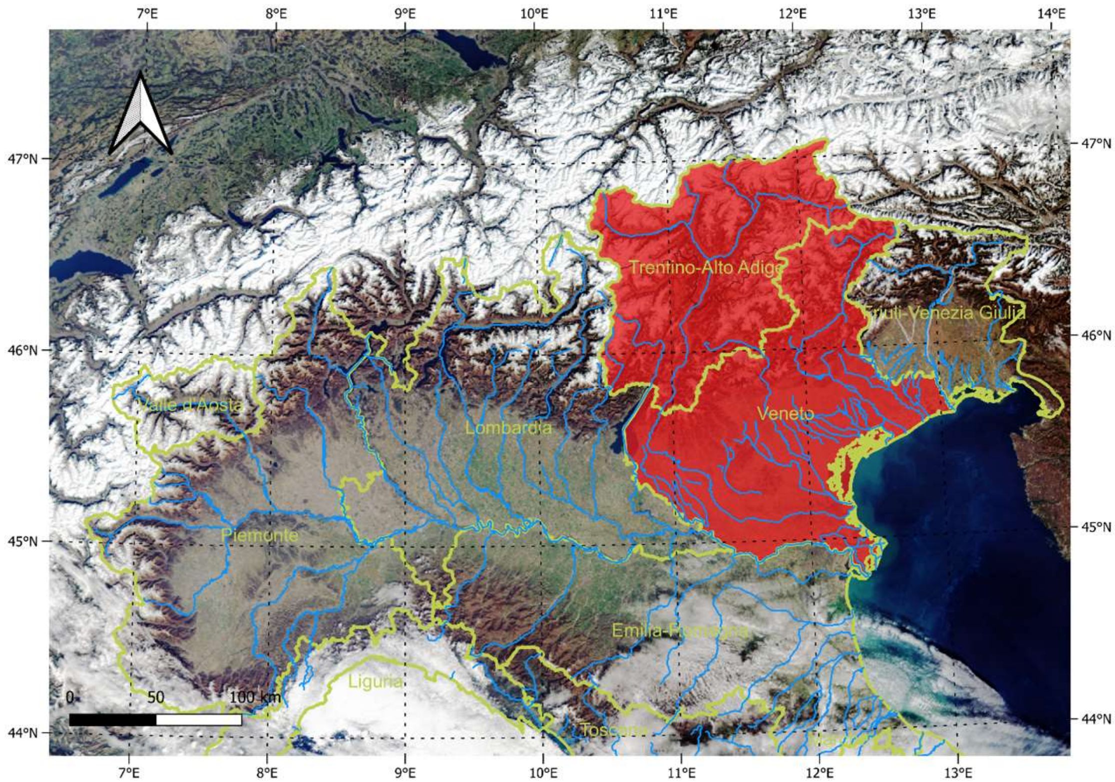

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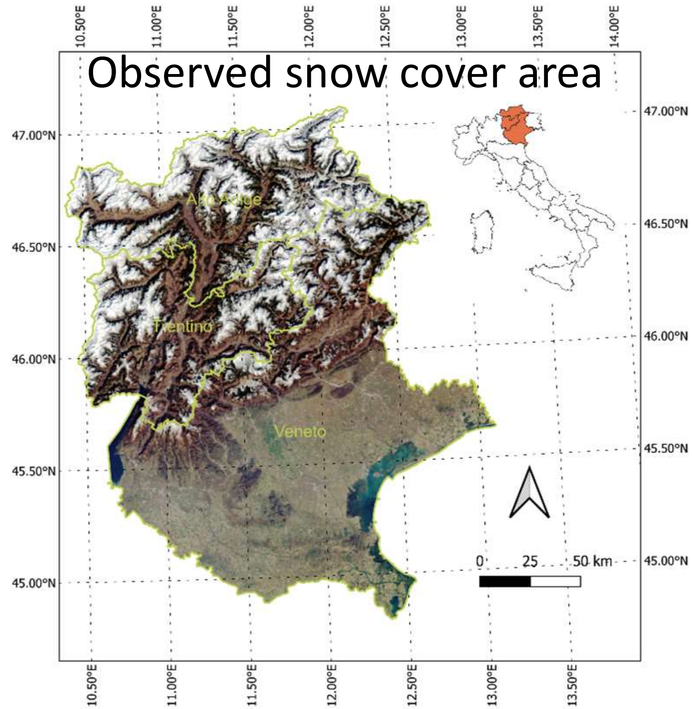

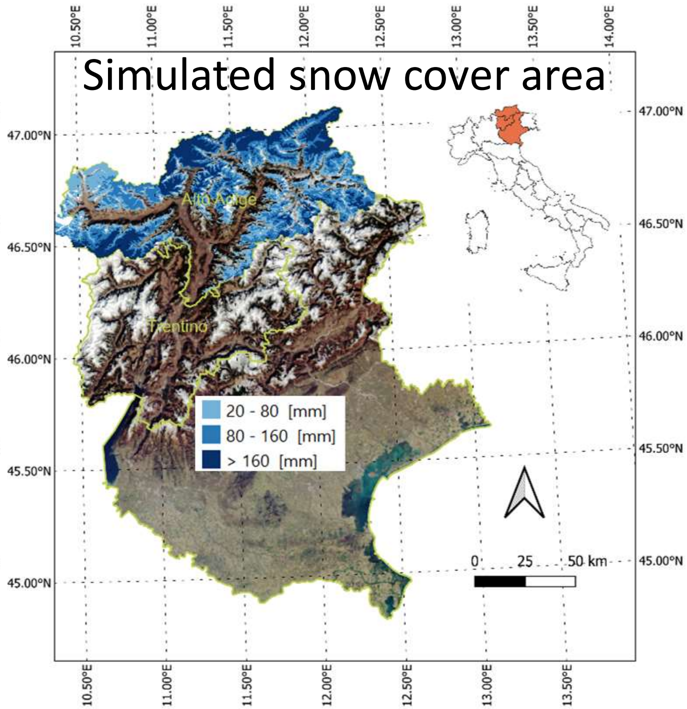

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2022 DROUGHT EVENT

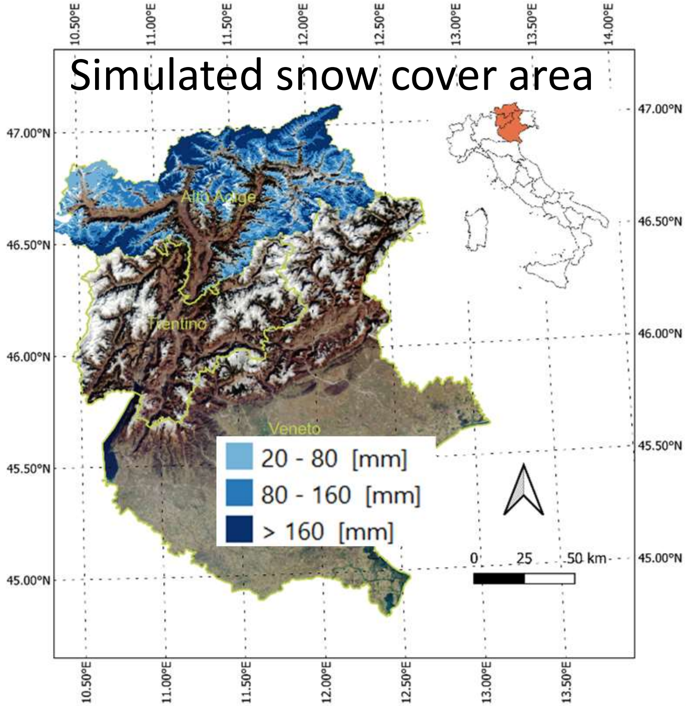
March 1° 2022, minimum snow water equivalent since 1991

$WE \cong 80\ mm$
$SCA \cong 65\%$

https://climate.copernicus.eu/precipitation-relative-humidity-and-soil-moisture-march-2022

https://www.copernicus.eu/en/media/image-day-gallery/snow-defic-alps-winter-2022

Di Marco, N., Avesani, D., Righetti, M., Zaramella, M., Majone, B., & Borga, M. (2021). Reducing hydrological modelling uncertainty by using MODIS snow cover data and a topography-based distribution function snowmelt model. *Journal of Hydrology*, *599*, 126020.



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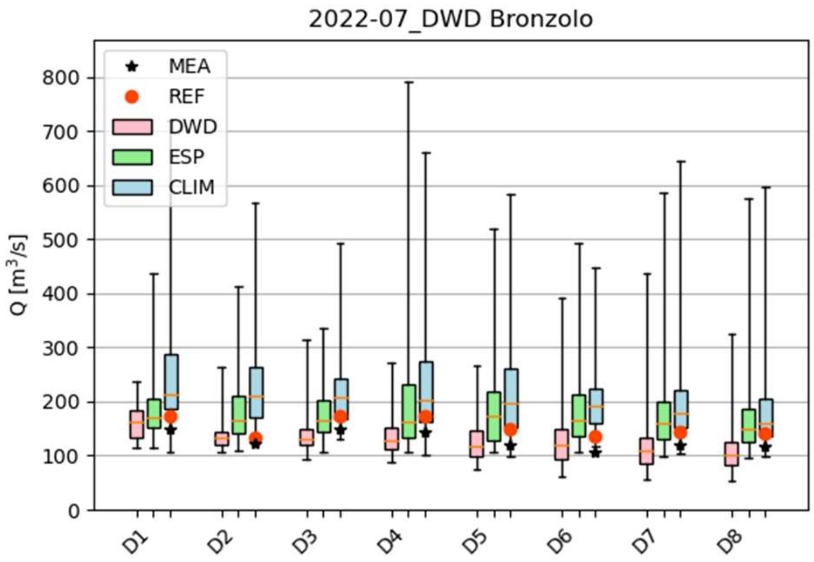
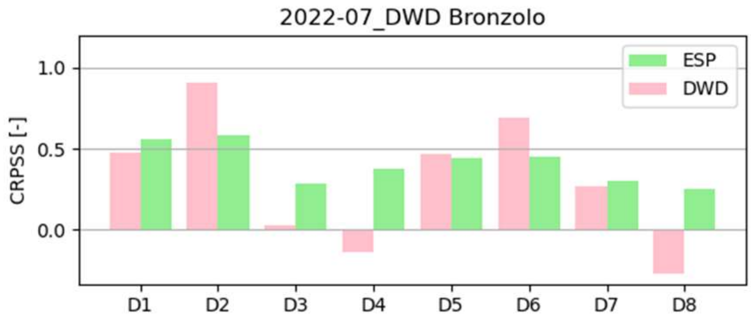
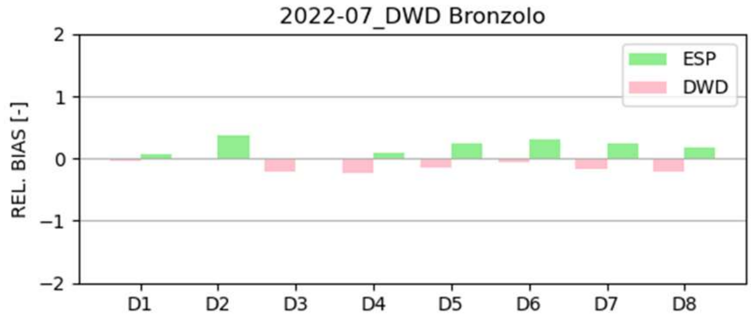
2022 DROUGHT EVENT - DWD







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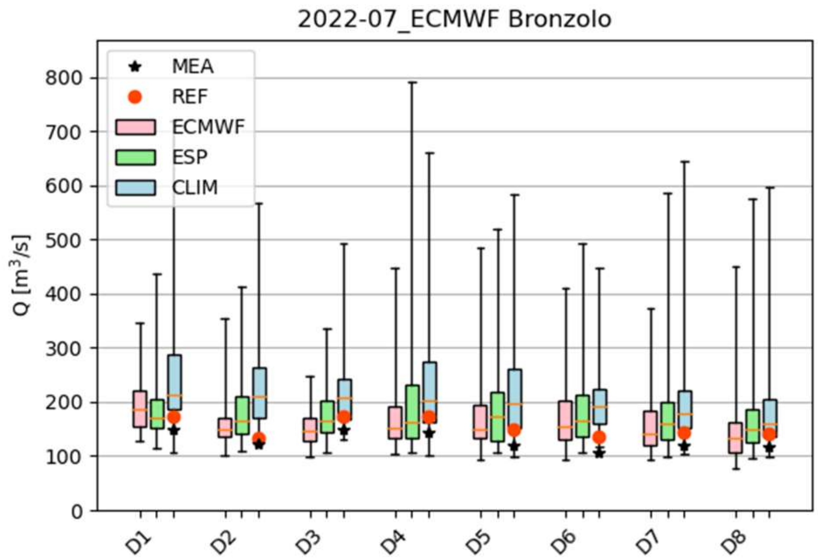

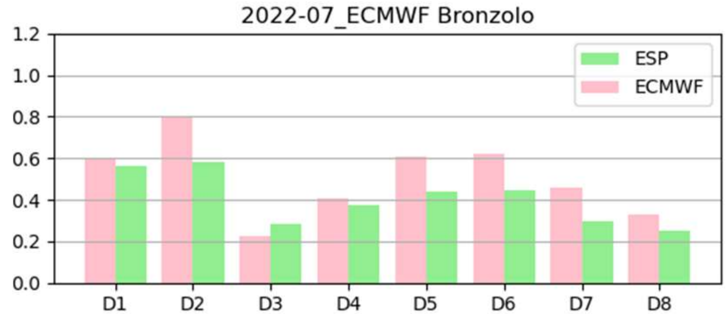

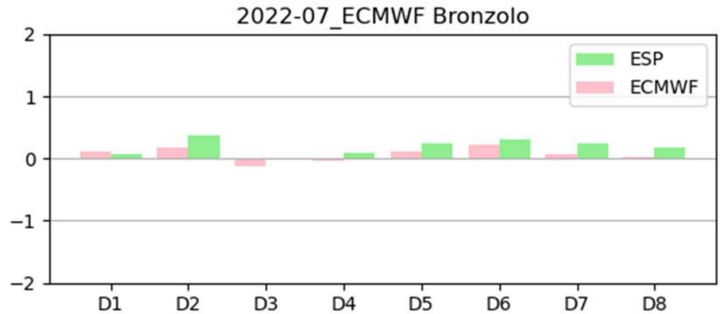

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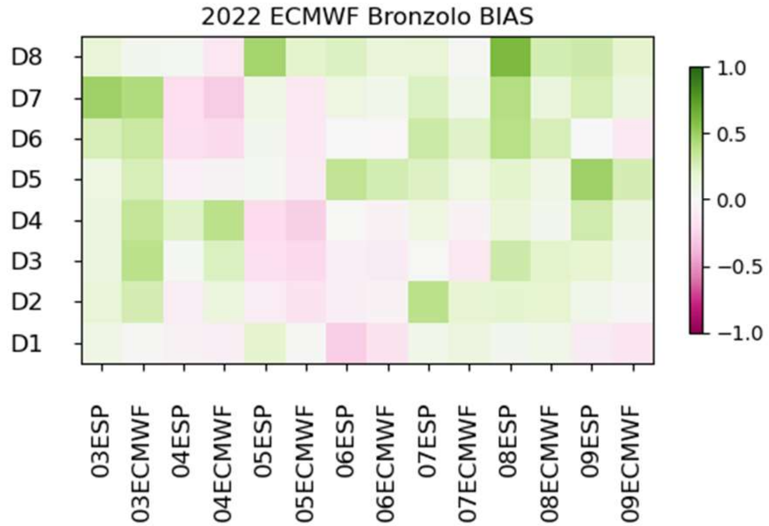

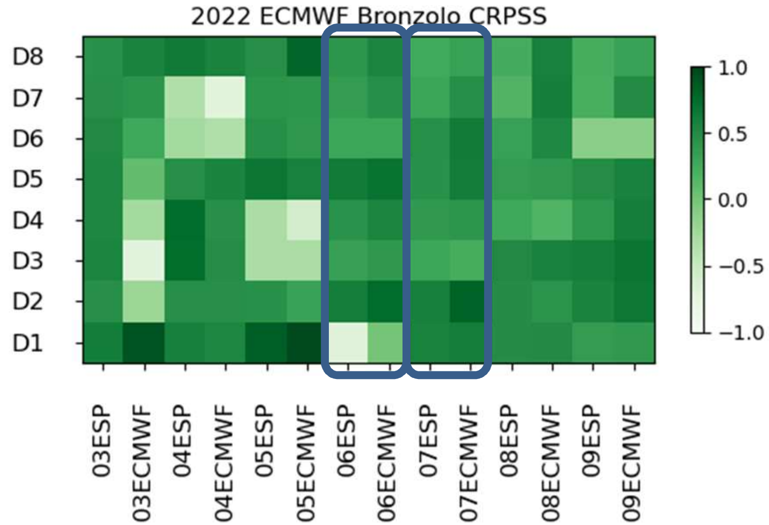

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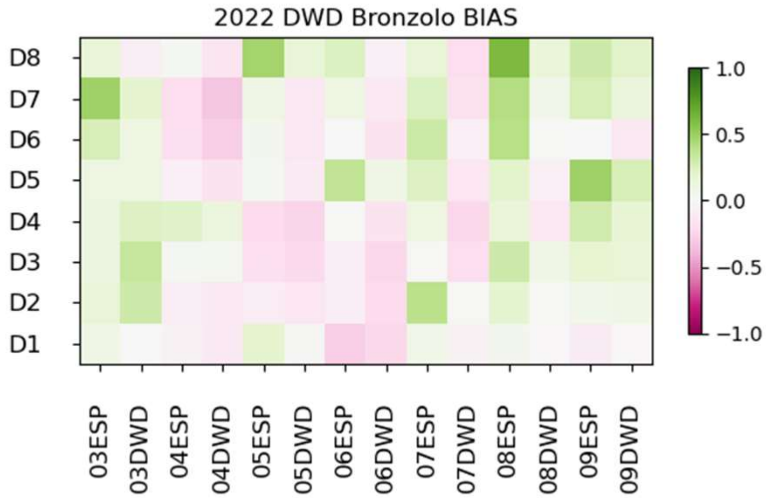

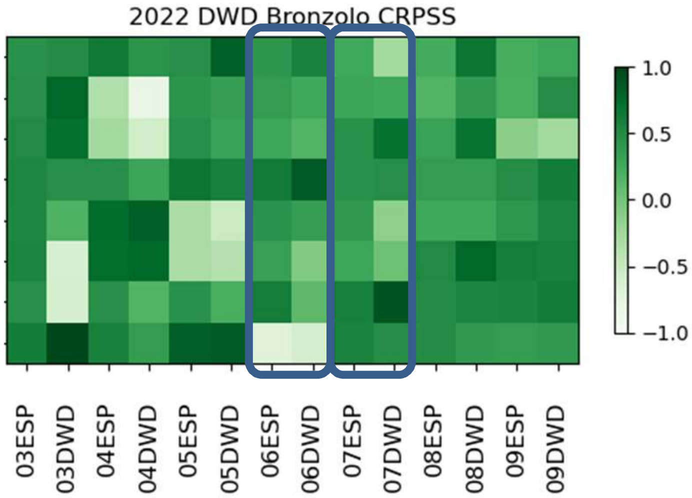

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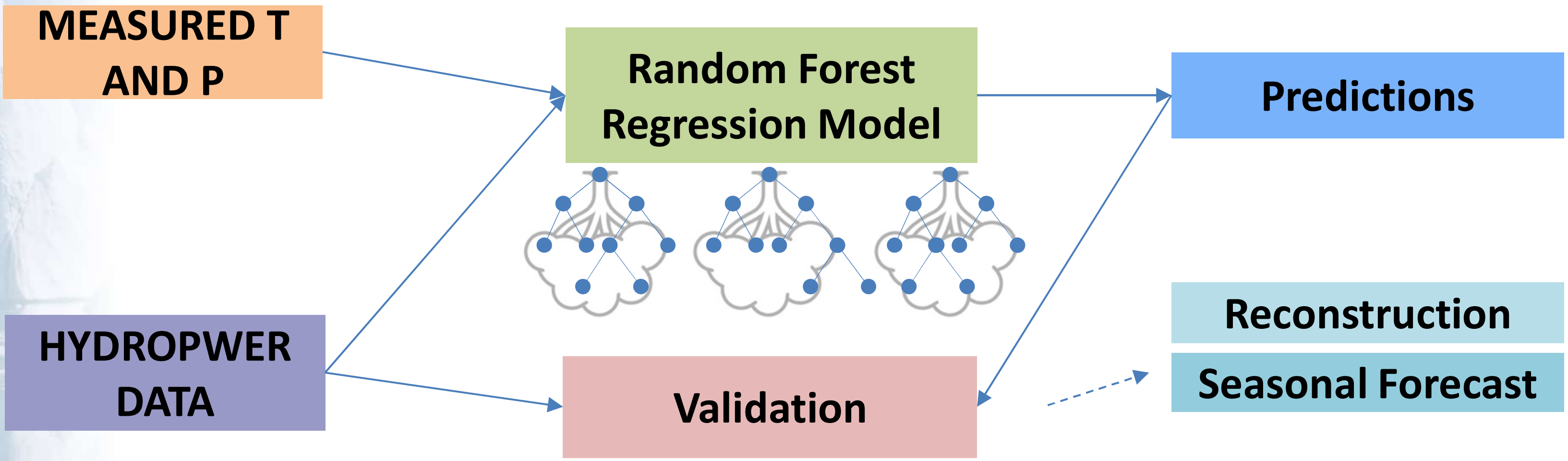
HYDROPOWER PRODUCTION MODELLING – RANDOM FOREST



- Leave-One-Year-Out (LOYO)

$*Ho\ et\ al.\ (2020)$

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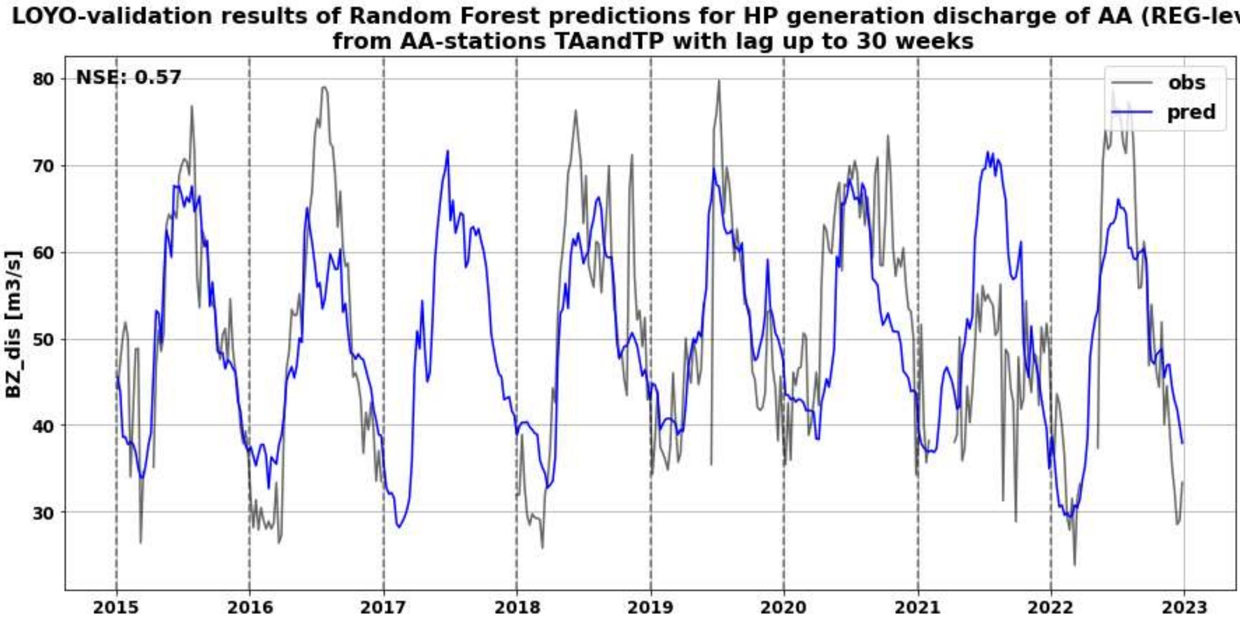
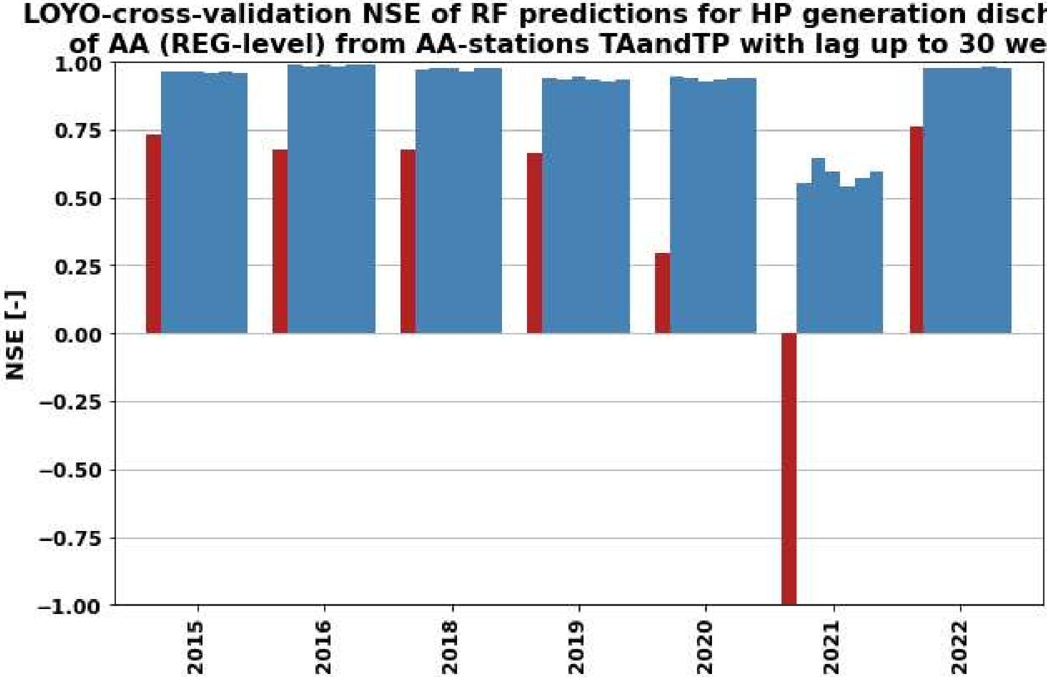
HYDROPOWER PRODUCTION MODELLING – RANDOM FOREST



Climate Change

HYDROPOWER PRODUCTION MODELLING – RANDOM FOREST



Climate Change

CONCLUSION and DEVELOPMENT

- Complete skill computation on hindcast: ECMWF, DWD, ECCC, CMCC
- Inclusion of a crop model
- Implementation of a coupled hydrological-RF model, including the SF of HP generation
- Optimization of the RF-HP model for the prediction of extremes.
- Include more metrics