FORECASTING DISCHARGE AND WATER LEVELS OF RIVERS AND DAMS USING EARTH OBSERVATION AND AI

Mozaika, Ltd.

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http://www.mozajka.co

THE PROBLEM

- The exploitation of rivers and hydropower reservoirs involves daily monitoring of the water resources, the meteorological conditions, the status of the river banks, the flood areas, etc.
- As maximum river discharge often results in flooding, it is of importance to provide with timely and reliable forecasts of discharge and water levels.
- Predicting river discharge and water levels has been a subject of hydrological modelling and a topic of serious research.
- However, only in recent years scholars and practitioners have turned to consider earth observation data for their studies, mainly to compare evidence of flood mapping.

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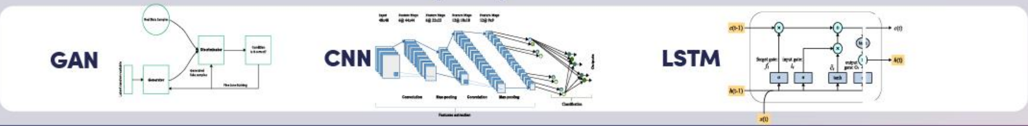
FORECASTING METHOD – EO4AI


Satellite data


Geospatial position


In-situ measurements



METEOROLOGICAL AND ENVIRONMENTAL FACTORS


Precipitation


Snow cover


Soil moisture


Vegetation index

IN-SITU MEASUREMENTS

- Discharge
- Water level
- Turbidity

GENERATE FORECASTS FOR

Rivers
Discharge
Water level
Turbidity

Dams
Available volume
Water level
Inflow
Water equivalent of Snow Stock

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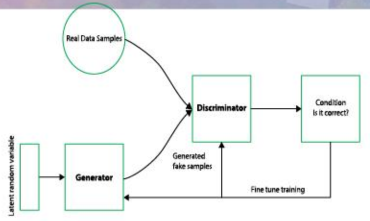
FORECASTING METHOD – EO4AI

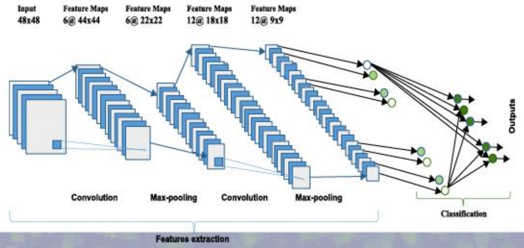
Satellite data

Geospatial position

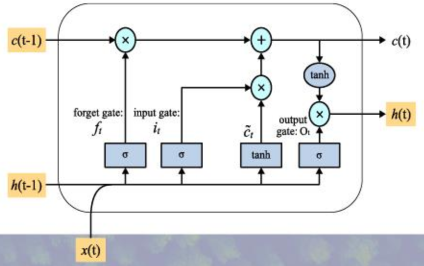
In-situ measurements



GAN

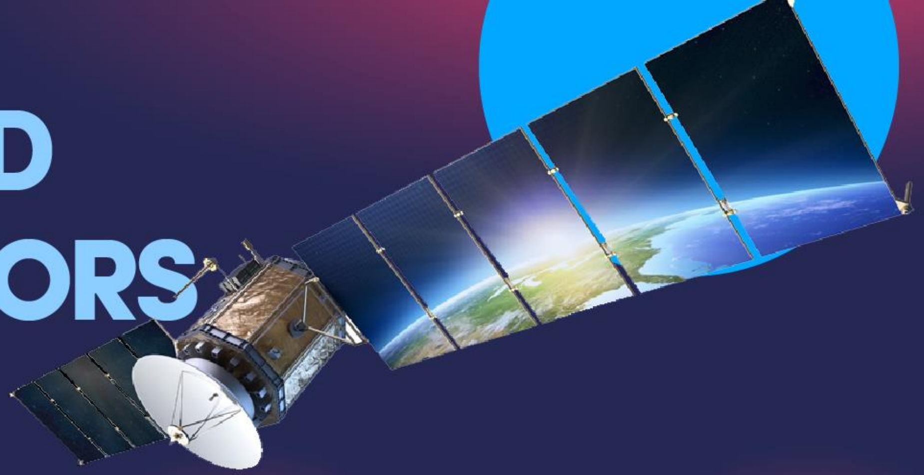


CNN



LSTM

METEOROLOGICAL AND ENVIRONMENTAL FACTORS



Turbidity

Surface reflection

Precipitation

Snow cover

Soil moisture

Wind

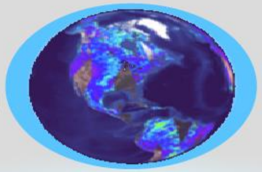
Vegetation index

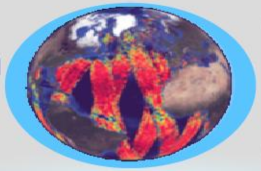
Solar radiance

Velocity

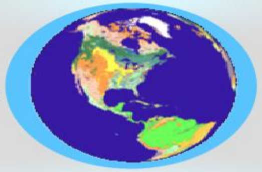
EARTH OBSERVATION DATA

ADAM (former eodataservice) is an interdisciplinary / cross domain platform

climate health


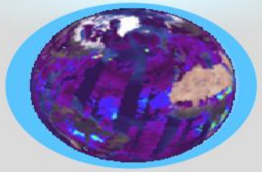
ocean


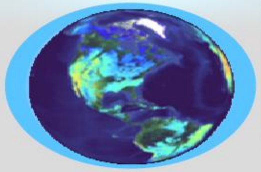
makes global environmental geospatial data Findable, Accessible, Interoperable and Reusable (FAIR

land cover


agriculture


provides an effective subsetting functionality that accesses the data only when requested and serves to the client only the data amount that is really needed

pollution


weather


- exposes OGC-standardised discovery (openSearch) and access (WCS 2.0) interfaces

Discovery

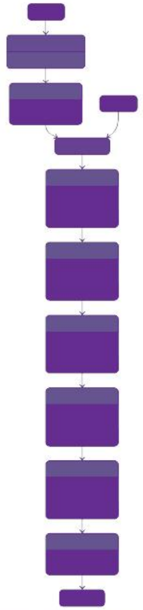
Exploration

Visualization

Processing

MISSING DATA GENERATION – GAN

GAN Architecture



Results missing data generation

Arda river

Meteorologial feature	Satellite dataset name	MinMae of generated values with the average formula	MinMae of generated with GAN missing values
Soil moisture	ESACCI-SOILMOISTURE-L3S-SSMV-COMBINED_4326_025	0.22	-0.44
Liquid precipitations	IMERG_DAY_LIQUID_SCALED_4326_01	0.00	-1.62
Snow cover	MODIS_SNOW_4326_001	0.00	-0.16
NDVI	MOD13_NDVI_4326_005	0.00	0.06
Solid precipitations	IMERG_DAY_ICE_SCALED_4326_01	0.00	3.83

Danube river

Meteorologial feature	Satellite dataset name	MinMae of generated values with the average formula	MinMae of generated with GAN missing values
Soil moisture	ESACCI-SOILMOISTURE-L3S-SSMV-COMBINED_4326_025	0.01	0.01
Liquid precipitations	IMERG_DAY_LIQUID_SCALED_4326_01	2.17	3.24
Snow cover	MODIS_SNOW_4326_001	0.08	0.15
NDVI	MOD13_NDVI_4326_005	0.00	0.03
Solid precipitations	IMERG_DAY_ICE_SCALED_4326_01	0.20	0.60

Satellite data from ADAM

Harmonized spatial resolution 1.1 km
Harmonized temporal resolution 1 day
Training data
2014 - 2019
Testing data
2020

IN-SITU MEASUREMENTS

Discharge

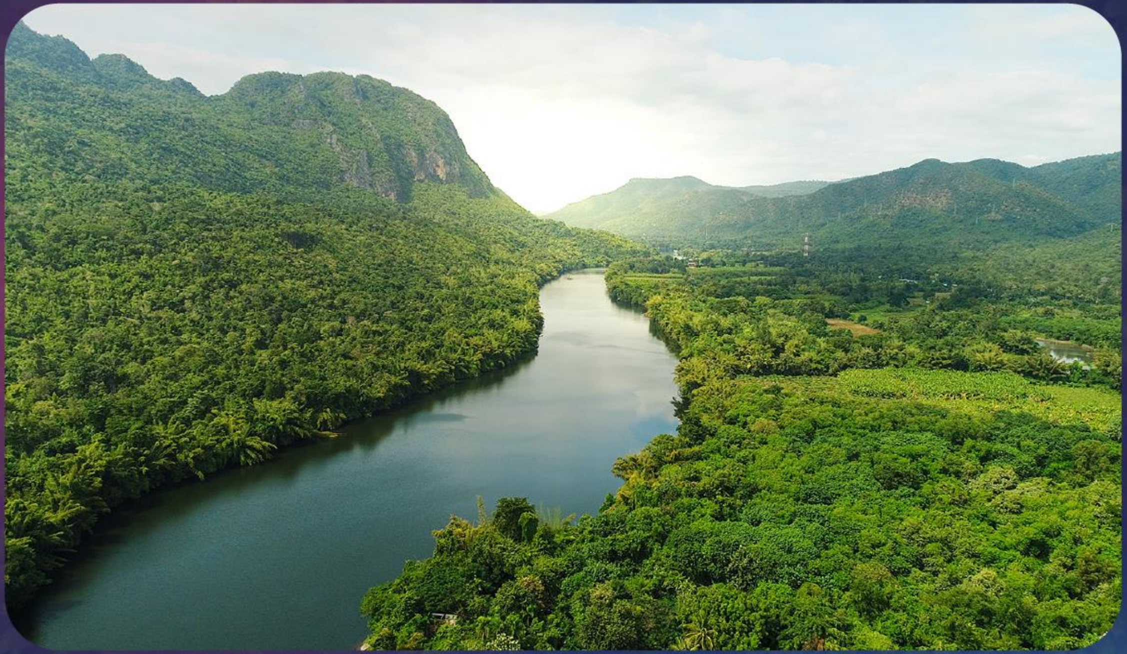
Water level

Turbidity

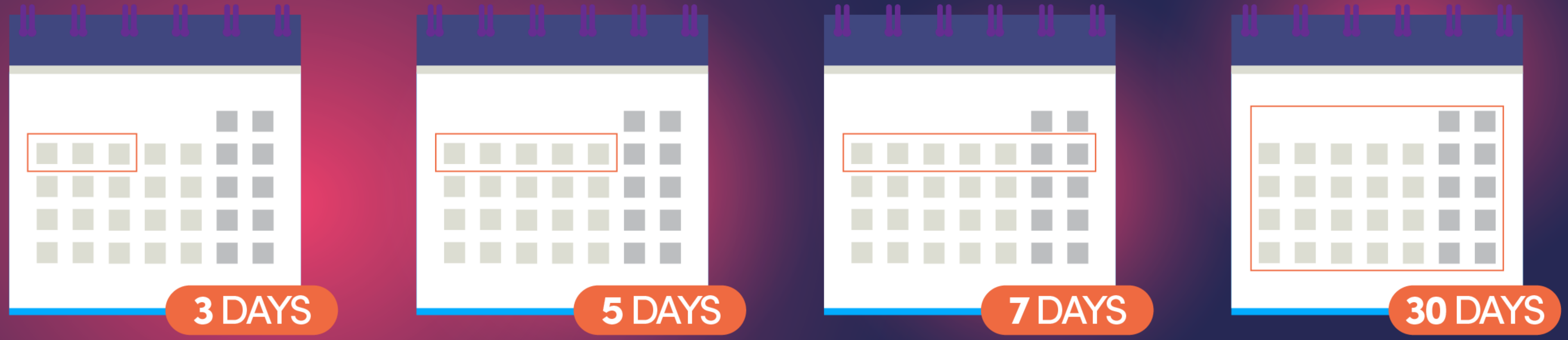
GENERATE FORECASTS FOR

Rivers
Discharge
Water level
Turbidity

Dams
Available volume
Water level
Inflow
Water equivalent of Snow Stock



FORECAST MODELS



TRAINING WITH HISTORIC DATA

5 years back for rivers

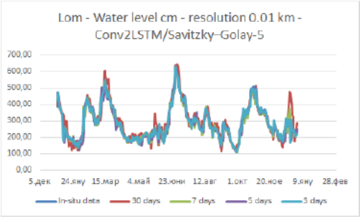
10 years back for dams

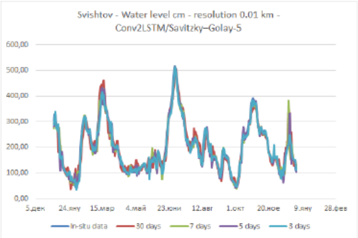
- meteorological factors from satellites
- liquid precipitation, solid precipitation and snow cover
- in-situ measurements

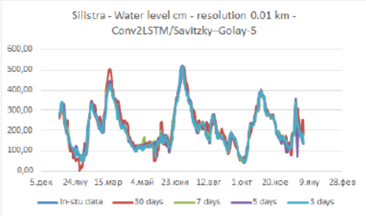
Experiments with results for one year ahead with each model

Performance estimated comparing forecast data with in-situ measurements

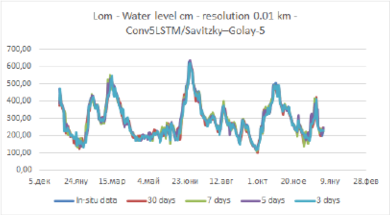
EXPERIMENTS RESULTS FOR WATER LEVEL ON THE DANUBE

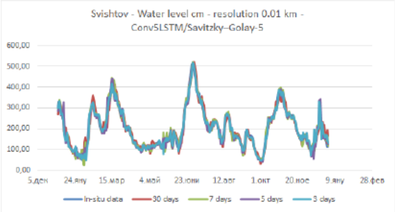


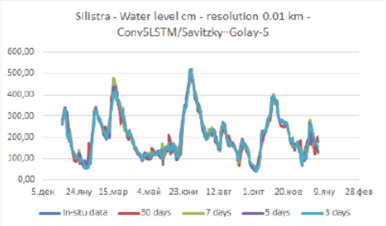




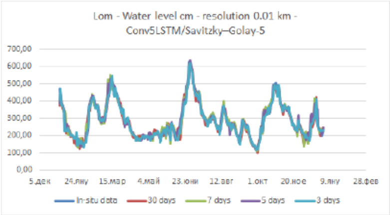
Lom (cm)				
	3 days	5 days	7 days	30 days
Conv2LSTM/SG5	4,06	6,74	6,5	-4,86
Conv2LSTM/SG11	16,78	19,13	17,82	27,72
Conv5LSTM/SG5	6,57	2,23	1,11	6,41
Conv5LSTM/SG11	5,87	3,83	6,1	2,84
Conv5LSTM/RL	16,19	19,81	19,62	20,41

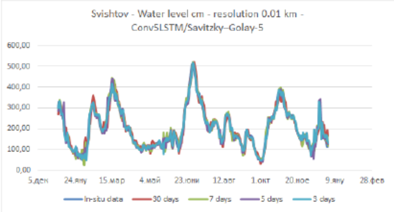


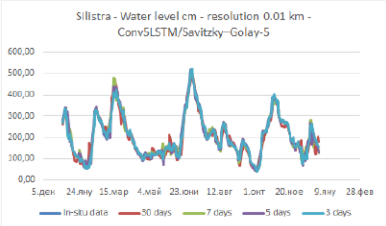




Svishtov (cm)				
	3 days	5 days	7 days	30 days
Conv2LSTM/SG5	2,83	3,24	2,86	-0,61
Conv2LSTM/SG11	3,07	2,06	3,53	4,67
Conv5LSTM/SG5	0,74	3,26	1,36	-1,61
Conv5LSTM/SG11	2,78	5,39	2,71	-0,7
Conv5LSTM/RL	12,78	13,86	15,78	16,71

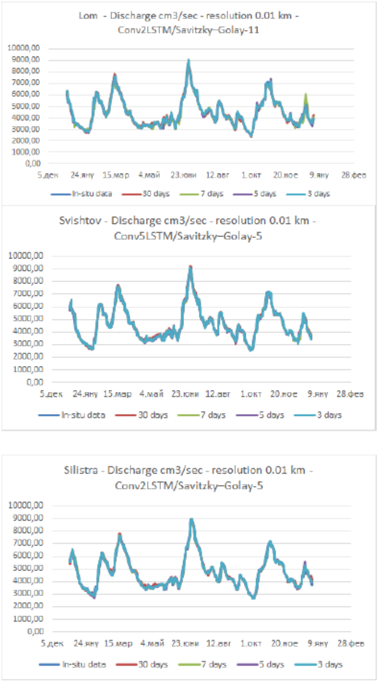


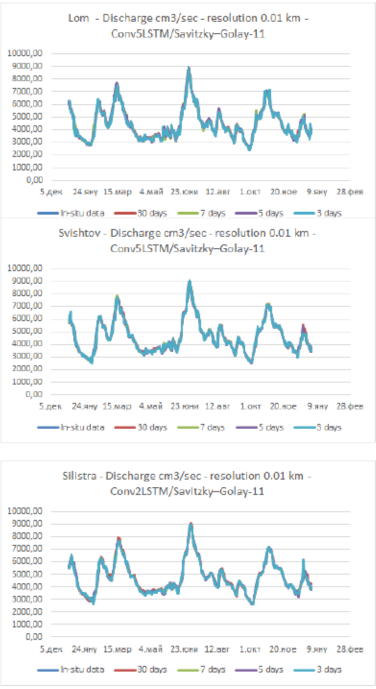


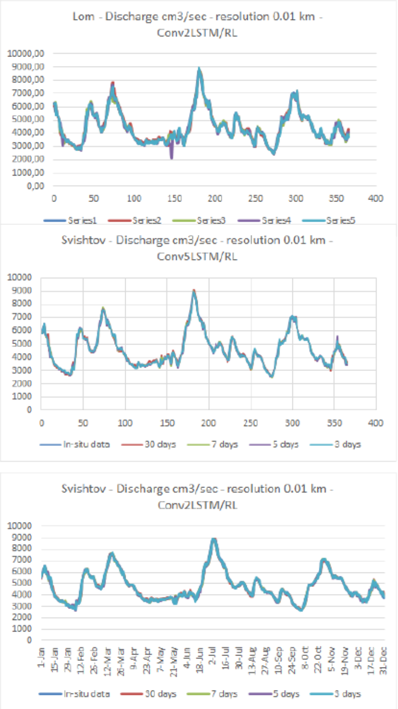


Silistra (cm)				
	3 days	5 days	7 days	30 days
Conv2LSTM/SG5	2,69	1,93	0,06	-5,8
Conv2LSTM/SG11	1,48	3,2	3,31	-3,09
Conv5LSTM/SG5	3,93	4,09	2,58	6,23
Conv5LSTM/SG11	2,95	2,31	2,22	-3,88
Conv5LSTM/RL	9,83	12,12	11,58	18,68

EXPERIMENTS RESULTS DISCHARGE FOR THE DANUBE







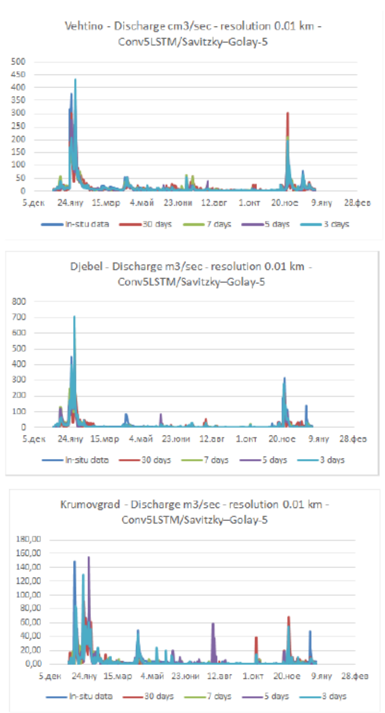
Lom Discharge				
	30 days	7 days	5 days	3 days
Conv5LSTM/RL	0,97	0,97	0,97	0,97
Conv2LSTM/RL	0,97	0,97	0,96	0,98
Conv5LSTM/SG5	0,97	0,96	0,96	0,96
Conv2LSTM/SG5	0,97	0,96	0,97	0,98
Conv5LSTM/SG11	0,97	0,97	0,97	0,97
Conv2LSTM/SG11	0,97	0,96	0,97	0,98

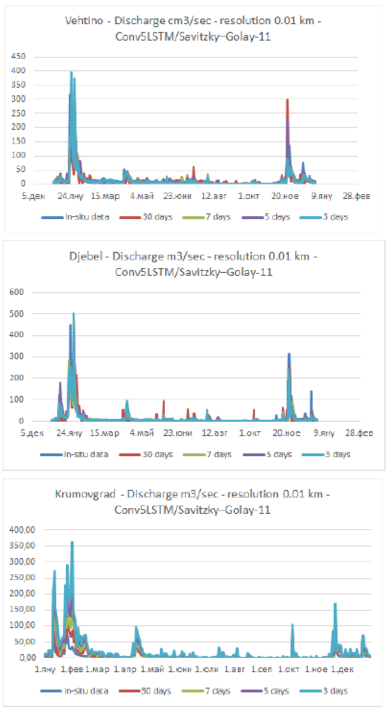
Svishtov Discharge				
	30 days	7 days	5 days	3 days
Conv5LSTM/RL	0,98	0,99	0,99	0,99
Conv2LSTM/RL	0,98	0,98	0,98	0,99
Conv5LSTM/SG5	0,99	0,99	0,99	0,99
Conv2LSTM/SG5	0,98	0,99	0,99	0,99
Conv5LSTM/SG11	0,99	0,99	0,99	0,99
Conv2LSTM/SG11	0,98	0,99	0,98	0,99

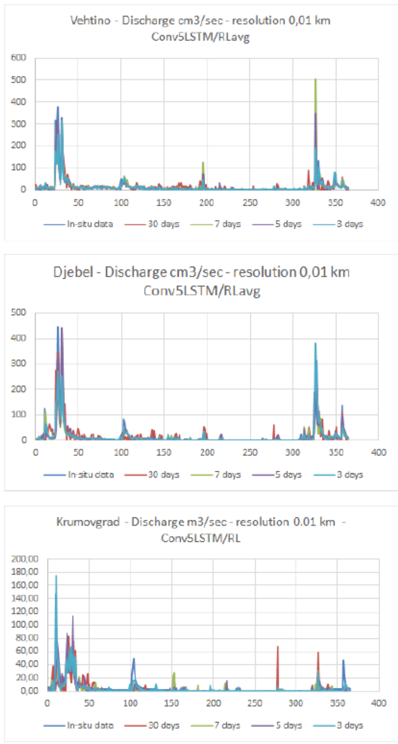
Silistra Discharge				
	30 days	7 days	5 days	3 days
Conv5LSTM/RL	0,99	0,99	0,99	0,99
Conv2LSTM/RL	0,99	0,99	0,99	0,99
Conv5LSTM/SG5	0,99	0,99	0,99	0,99
Conv2LSTM/SG5	0,99	0,99	0,99	0,99
Conv5LSTM/SG11	0,98	0,99	0,99	0,99
Conv2LSTM/SG11	0,98	0,99	0,99	0,99

Nash–Sutcliffe Efficiency equals 1 (NSE=1): 1 - SUMPRODUCT((Real measurement - Forecast)^2) / SUMPRODUCT((Real measurement - Avg of Real measurement)^2)

EXPERIMENTS RESULTS FOR DISCHARGE FOR ARDA







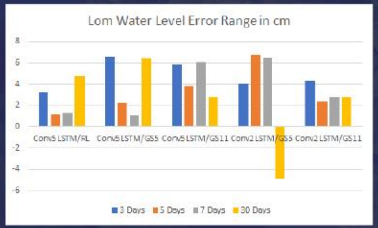
Vehtino Discharge	30 days	7 days	5 days	3 days
Conv5LSTM/RL	0,64	0,74	0,73	0,63
Conv5LSTM/SG5	0,67	0,63	0,69	0,66
Conv5LSTM/SG11	0,54	0,69	0,7	0,75
Conv5LSTM/SG11avg	0,34	0,44	0,55	0,61
Conv5LSTM/Rlavg	0,63	0,36	0,64	0,71

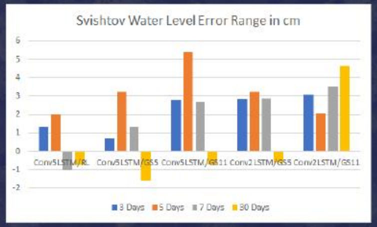
Djebel Discharge	30 days	7 days	5 days	3 days
Conv5LSTM/RL	0,57	0,71	0,48	0,56
Conv5LSTM/SG5	0,62	0,6	0,52	0,51
Conv5LSTM/SG11	0,59	0,61	0,67	0,7
Conv5LSTM/SG11avg	0,55	0,49	0,48	0,55
Conv5LSTM/RLavg	0,74	0,69	0,71	0,71

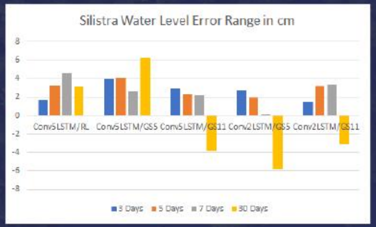
Krumovgrad Discharge	30 days	7 days	5 days	3 days
Conv5LSTM/RL	0,04	0,45	0,16	0,45
Conv5LSTM/SG5	0,18	0,23	-0,03	0,28
Conv5LSTM/SG11	0,22	0,19	0,17	0,15
Conv5LSTM/SG11avg	-0,09	0,25	0,28	0,32
Conv5LSTM/RLavg	-0,03	0,33	0,07	-0,07

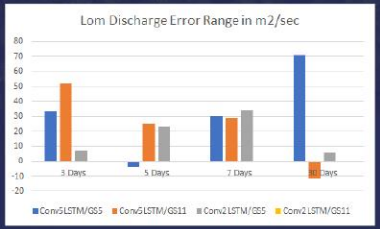
Nash–Sutcliffe Efficiency equals 1 (NSE=1): 1 - SUMPRODUCT((Real measurement - Forecast)^2) / SUMPRODUCT((Real measurement - Avg of Real measurement)^2)

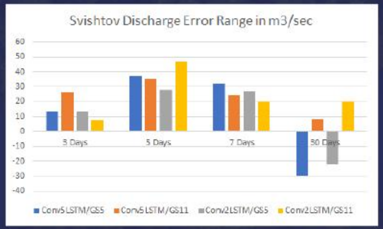
COMPARISON OF THE PRECISION OF THE DIFFERENT MODELS

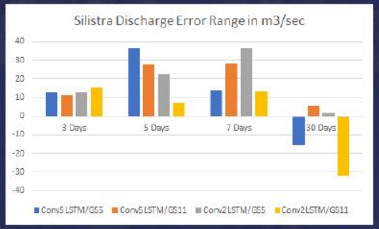


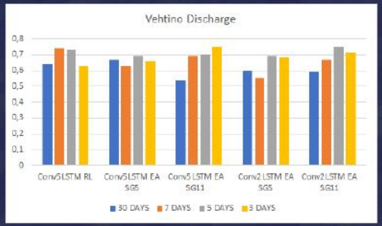


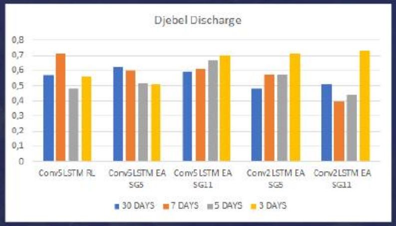


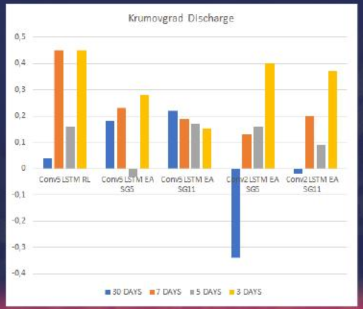


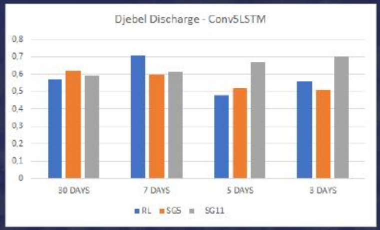


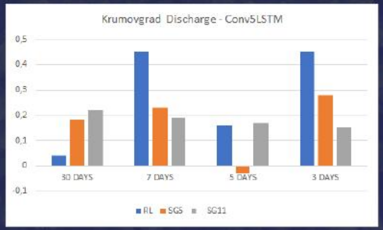


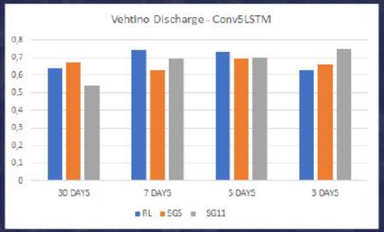




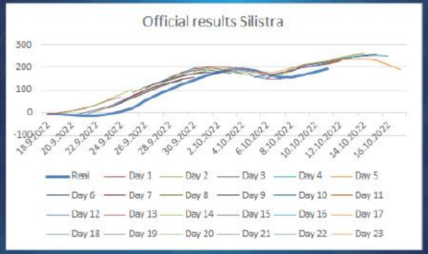


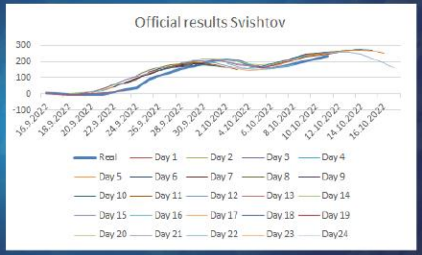




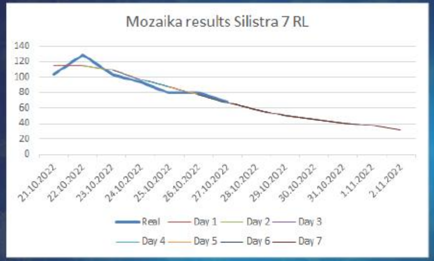


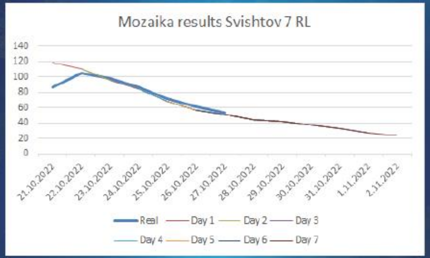
COMPARISON OF THE RESULTS FROM OUR MODELS WITH THE OFFICIAL RESULTS FOR WATER LEVEL ON THE DANUBE

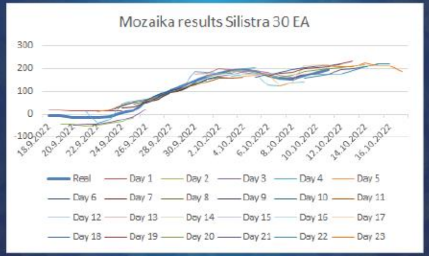


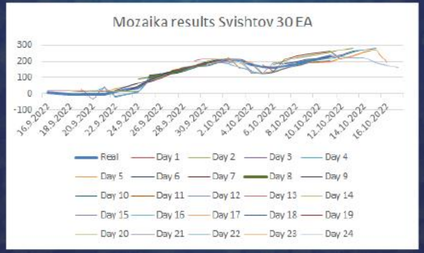


Official forecast

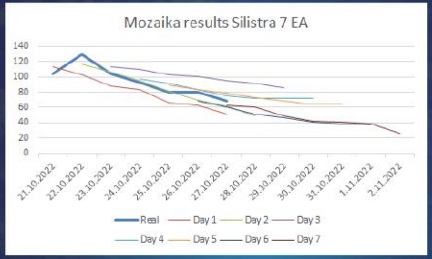


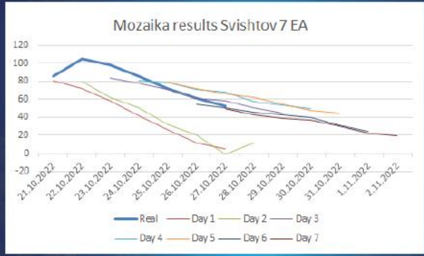


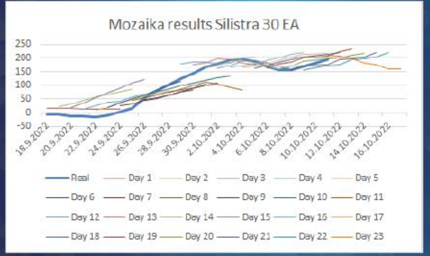


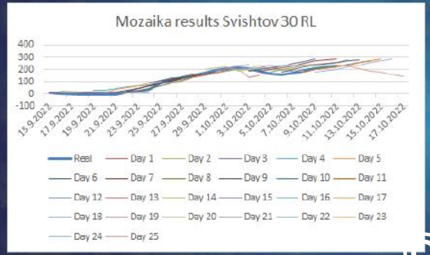


Training with 9 years of daily data





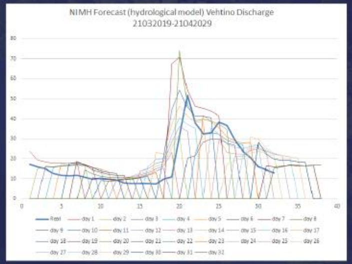


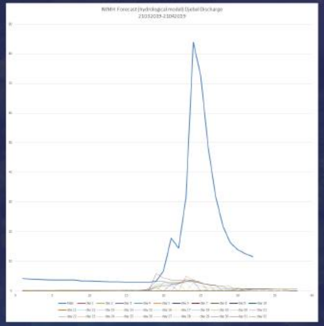


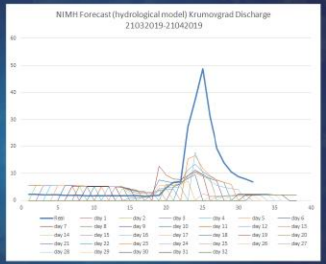
Training with 5 years of daily data

COMPARISON OF THE RESULTS FROM OUR MODELS WITH THE OFFICIAL RESULTS FOR DISCHARGE ON ARDA

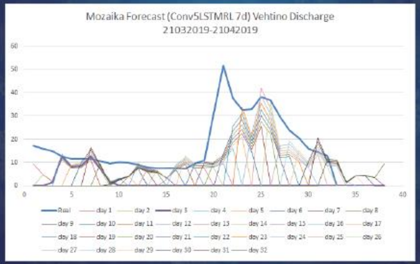
Traditional hydrological model

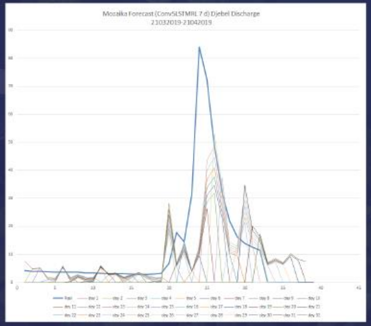


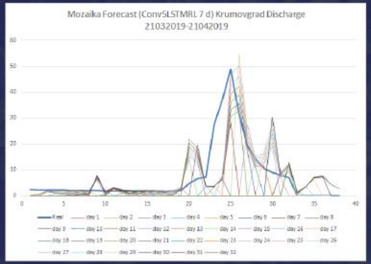




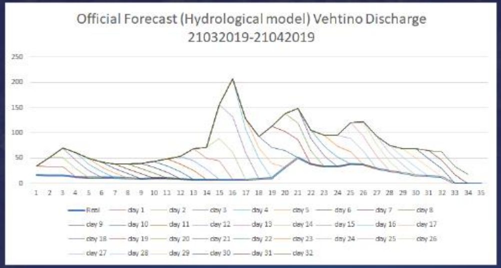
7 days model, training with 5 years daily data

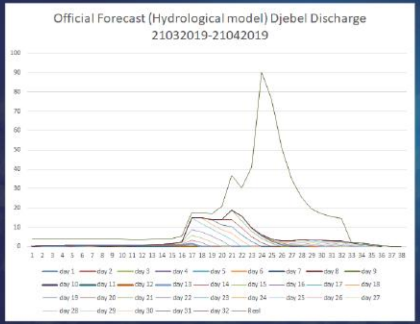


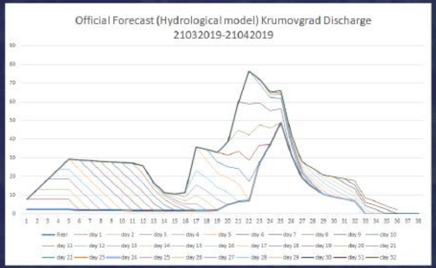




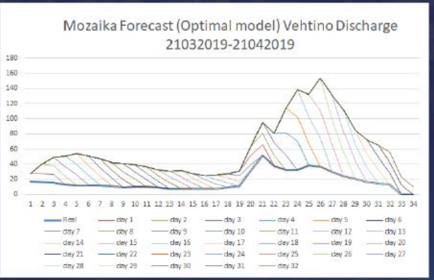
Traditional hydrological model

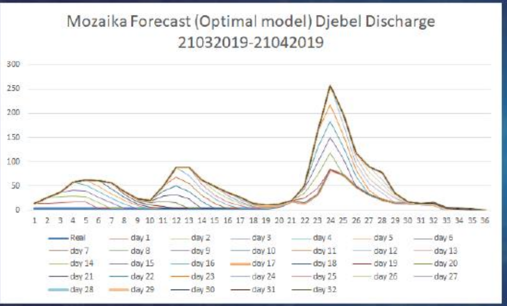


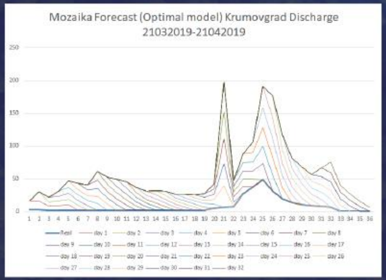




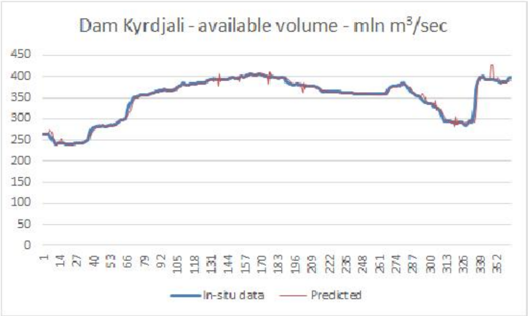
Best model, training with 5 years daily data

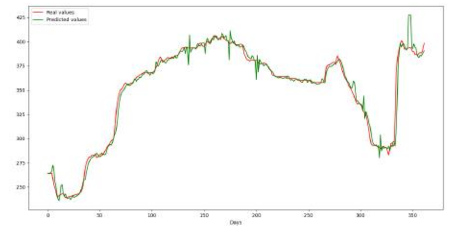






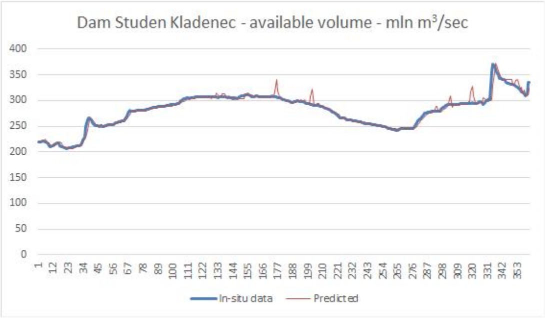
EXPERIMENTS RESULTS FOR AVAILABLE VOLUME OF THE DAMS OF CASCADE ARDA

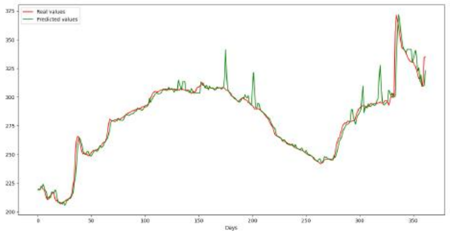




Kurdjali	
Months	Error ratio in mln m3
January	3,17
February	3,24
March	4,39
April	2,02
May	2,78
June	2,87
July	3,32
August	1,28
September	1,92
October	3,92
November	5,27
December	

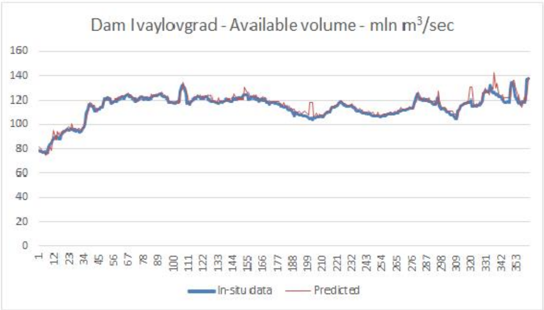
Total volume mln m^3	Useful volume mln m^3
497,2	390,0

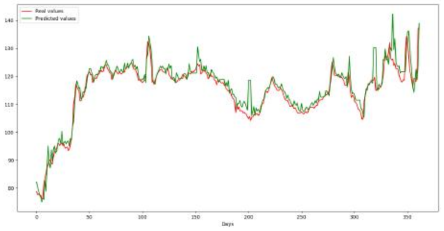




Studen kladenec	
Months	Error ratio in mln m3
January	1,86
February	3,97
March	2,13
April	1,72
May	2,46
June	2,91
July	3,14
August	1,21
September	0,98
October	4,53
November	6,26
December	

Total volume mln m^3	Useful volume mln m^3
387,8	297,1

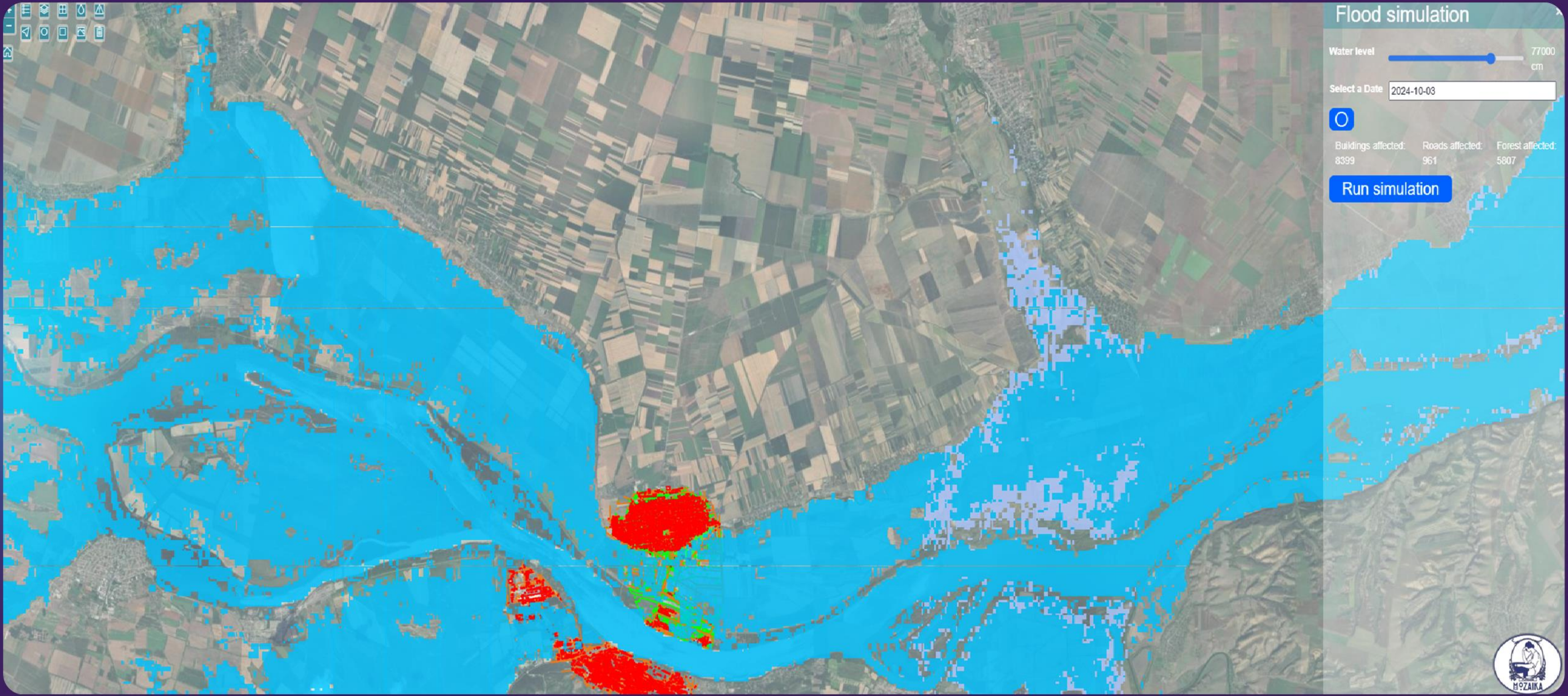




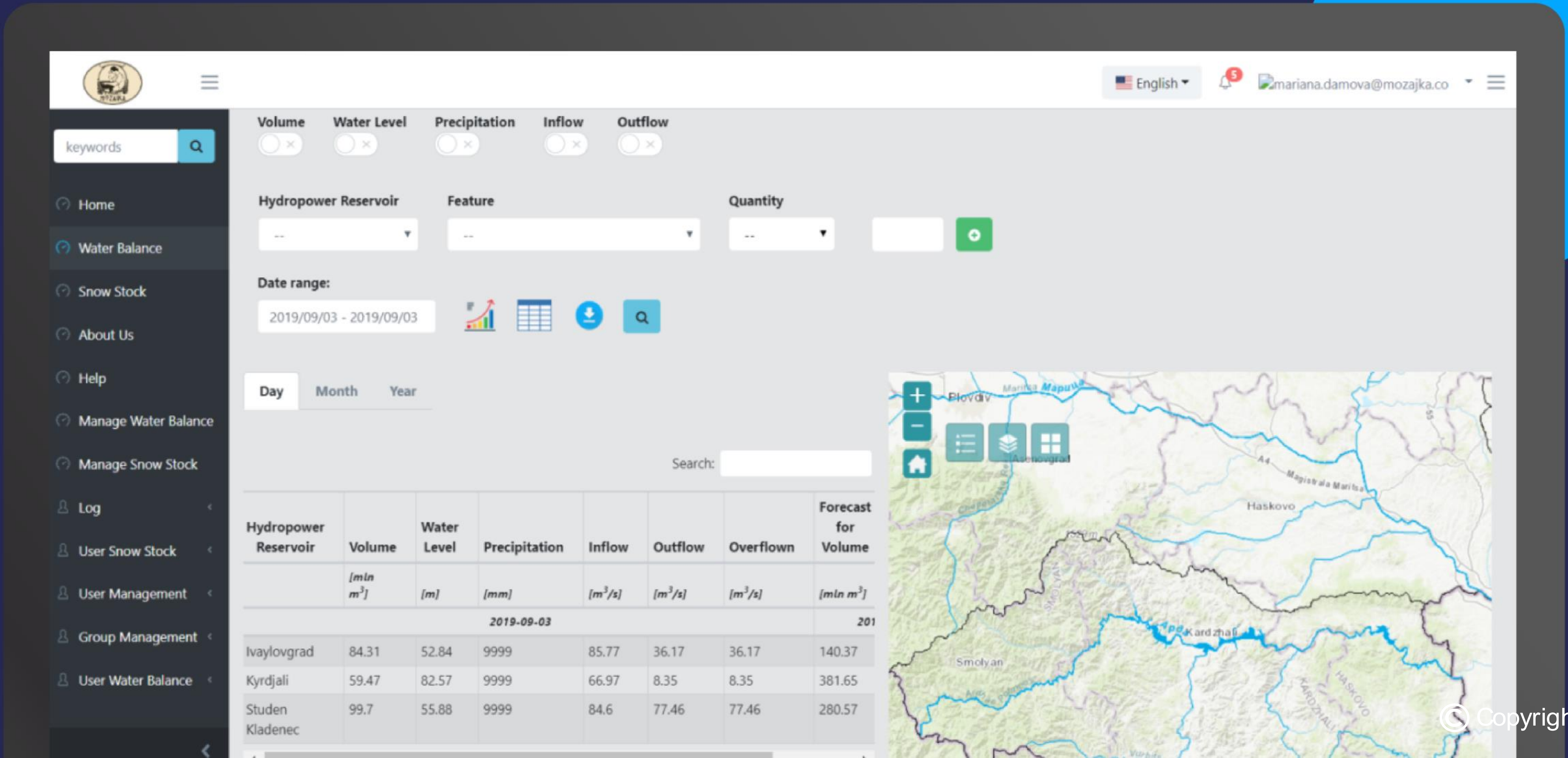
Ivailovgrad	
Months	Error ratio in mln m3
January	2,09
February	1,63
March	0,98
April	1,61
May	1,24
June	1,68
July	3,25
August	1,16
September	1,33
October	1,90
November	2,85
December	

Total volume mln m^3	Useful volume mln m^3
156,7	97,2

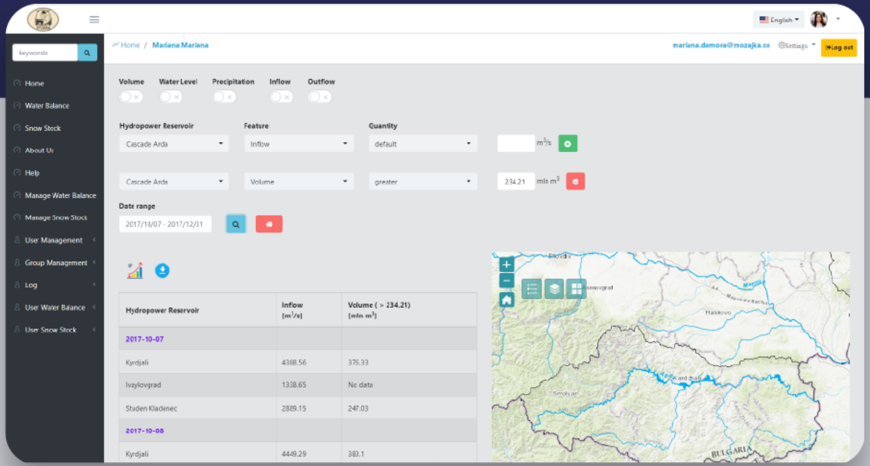
FLOOD SIMULATION AND FORECASTING

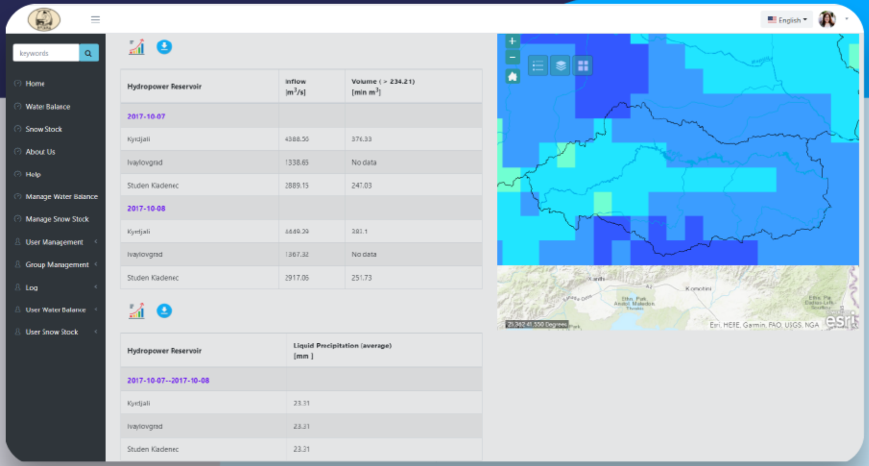


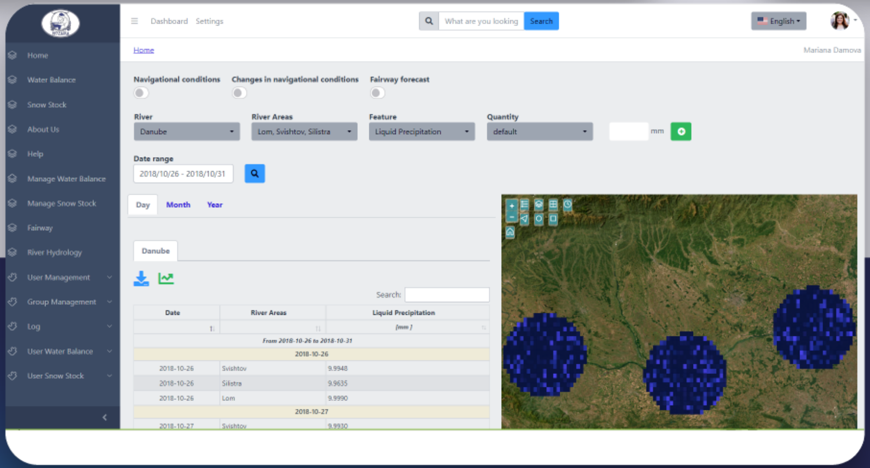
THE APPLICATION – ISME-HYDRO

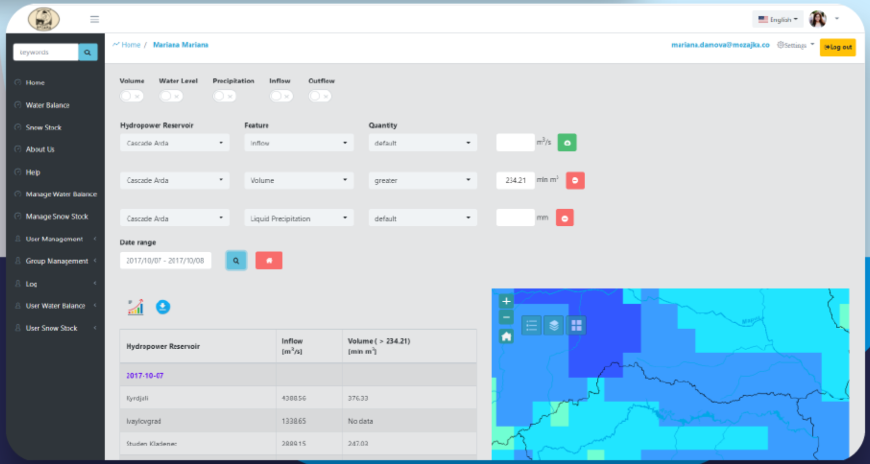


THE APPLICATION – ISME-HYDRO

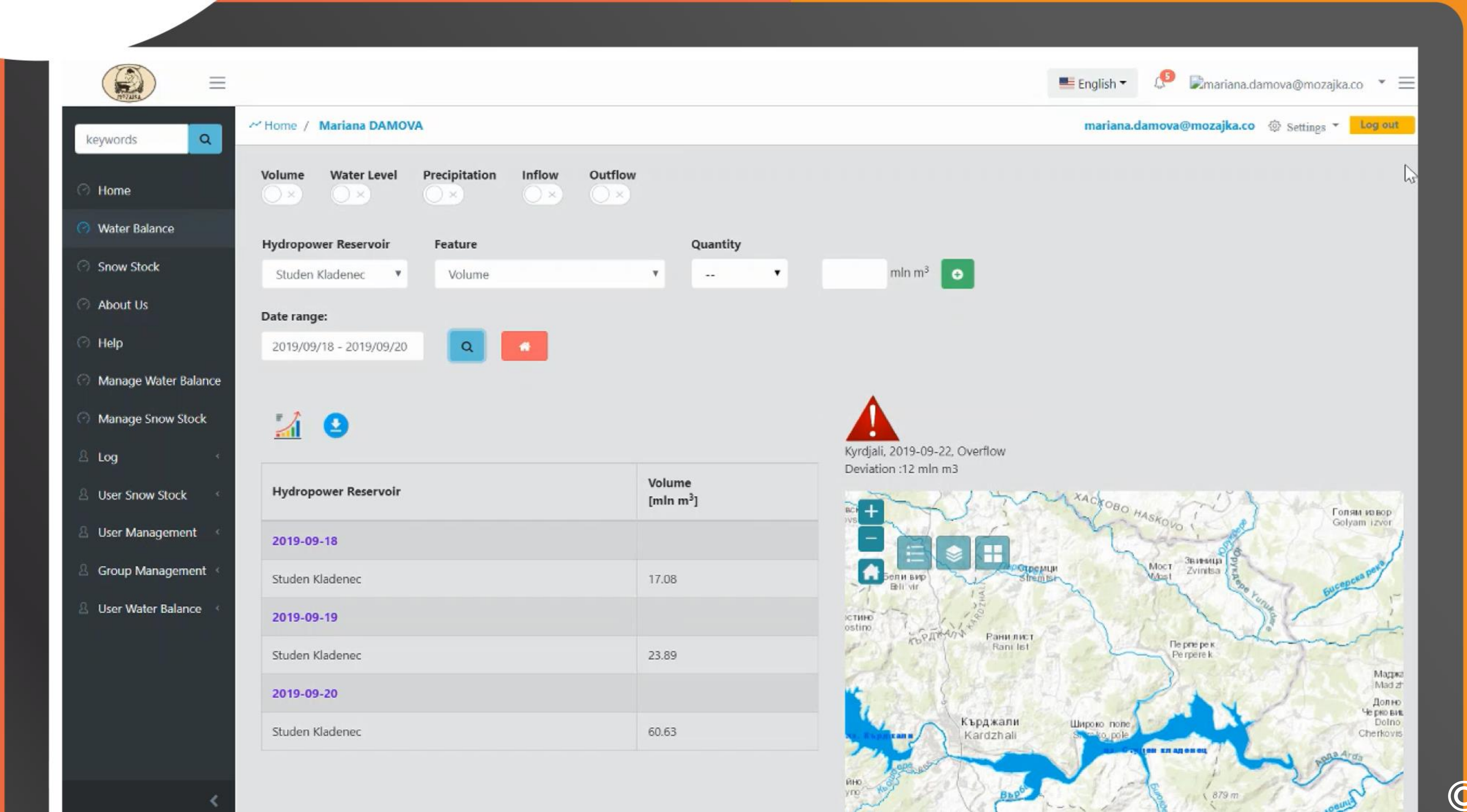








ALERTING



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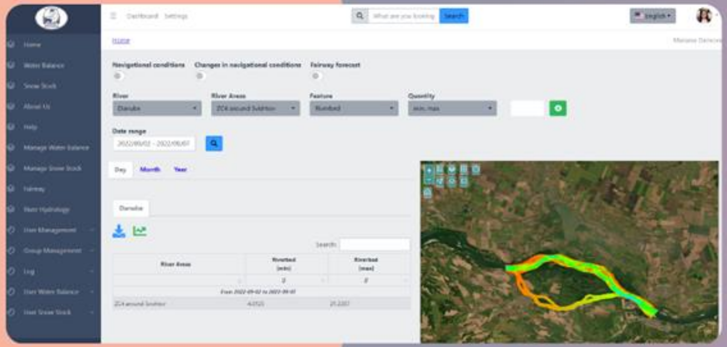
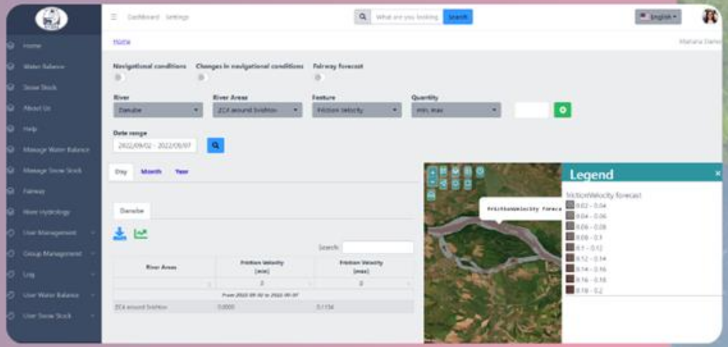
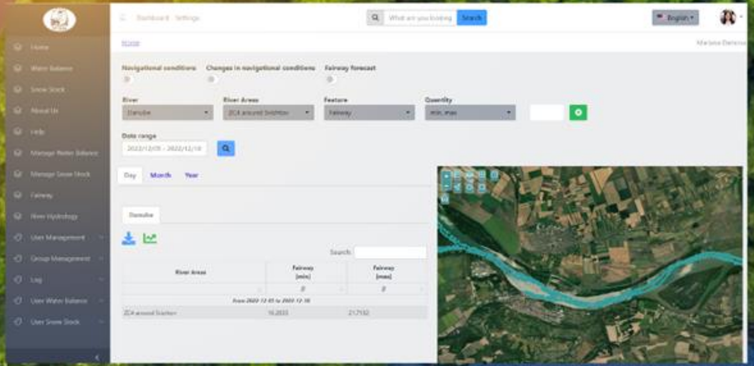
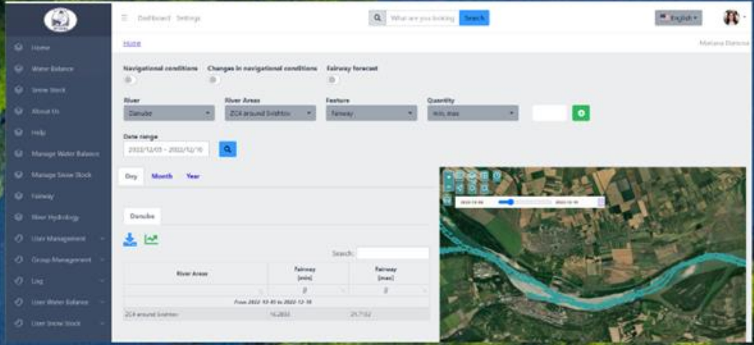
Manage Snow Stock
Log
User Snow Stock
User Management
Group Management
User Water Balance
Volume
Water Level
Precipitation
Inflow
Outflow
Hydropower Reservoir
Feature
Quantity
Studen Kladenec
Volume
mln m3
Date range:
2019/09/18 - 2019/09/20
Kyrdjali, 2019-09-22, Overflow
Deviation :12 mln m3
Hydropower Reservoir
Volume [mln m3]
2019-09-18
Studen Kladenec
17.08
2019-09-19
Studen Kladenec
23.89
2019-09-20
Studen Kladenec
60.63
Кърджали
Kardzhali

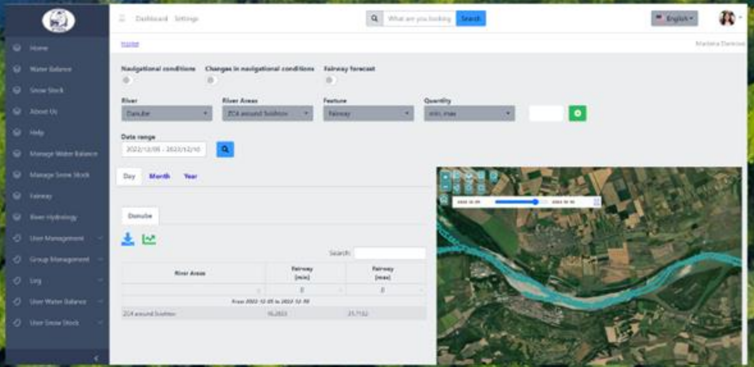
FAIRWAY MODIFICATION VISUALIZATION











ISME-HYDRO – AN INTEGRATED INFORMATION SYSTEM FOR THE BENEFIT OF WATER RESOURCES MANAGERS

a disruptive web-based workflow

that makes use of a combination of AI methods

and delivers a viable and hands-on solution

WE ARE READY TO ASSESS & DEPLOY ALL AROUND THE WORLD.
WATER RESOURCES MANAGEMENT AND MORE

ACKNOWLEDGEMENT

- This work has been carried out within ESA Contracts No. 4000122783/17/NL/SC and No. 4000133836/21/NL/SC and 4000141832/23/NL/MH/rp and Destination Earth contract with Murmuration No. MURM-ESA-SUB-2023-02

THANK YOU

Mozaika

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