INTERNATIONAL SAVA RIVER BASIN COMMISSION

Hydrological Information System of the Sava River Basin – Sava HIS

Capacity Building Workshop on Hydrological Data Exchange, standardization, and Interoperability in WMO‘s Region VI

25-26 January 2024, Online

29–30 January 2024, Zagreb, Croatia

Mirza Sarač
Secretariat of the International Sava River Basin Commission

INTERNATIONAL SAVA RIVER BASIN COMMISSION

Sava HIS within the Agenda

Online Session, 25th January 2024

13:20–13:50	SAVA HIS	Mirza Sarač, ISRBC
13:50–14:15	WHOS and SAVA HIS (data protocols and tools, data, metadata)	Mirza Sarač, ISRBC Silvano Pecora, WMO INFCOM Vice-President and Chair JET-HYDMON

Physical Session, 29th January 2024

9:30–10:40	SAVA HIS (data interoperability and Tools)	Mirza Sarač, ISRBC

Physical Session, 30th January 2024

15:00–15:30	Open Discussion: Improvement of SAVA HIS	Mirza Sarač, ISRBC

Workshop output

Among others, to set-up background for **further developments of Sava HIS and its interconnectivity with the WMO systems and tools**

INTERNATIONAL SAVA RIVER BASIN COMMISSION

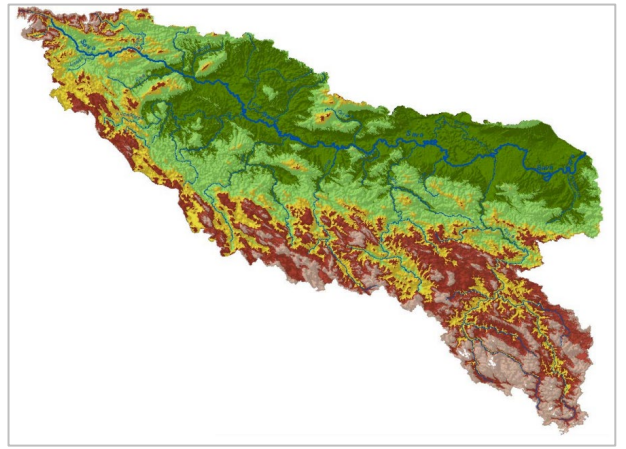
Sava River Basin

Key facts

- **Area:** 97 713 km^2 (the second largest Danube sub-basin; share: 12%)
- **River length:** 940 km (594 km of which is the waterway)
- **Population:** approx. 9 million

Country	Share of the basin (%)	Share of the territory (%)
Bosnia and Herzegovina	39.2	75.8
Croatia	26.0	45.2
Serbia	15.5	17.4
Slovenia	12.0	52.8
Montenegro	7.1	49.6
Albania	0.2	0.6

- **Average annual air temperature**: approx. 9.5°C
- **Mean monthly water temperature**: lowest January: -1.5°C / highest July: 20°C
- **Average annual rainfall:** approx. 1,100 mm
- **Long-term average annual precipitation**: 600 mm up to 2,300 mm
- **Average flow of the Sava at the mouth:** approx. 1700 m^3/s (the largest Danube tributary)
- **Spatial distribution of runoff**: 150 mm/year (under 5 l/s/km^2) up to 1,200 mm/year (almost 40 l/s/km^2)
- **Long-term average unit-area-runoff**:
  - Complete catchment area: 18 l/s/km^2
  - Tributaries:
    - Una River - 23 l/s/km^2
    - Vrbas River - 19 l/s/km^2
    - Bosna River - 19 l/s/km^2
    - Ukrina River - 12 l/s/km^2
    - Tinja Rivers - 12 l/s/km^2
    - Drina River - 40 and 50 l/s/km^2

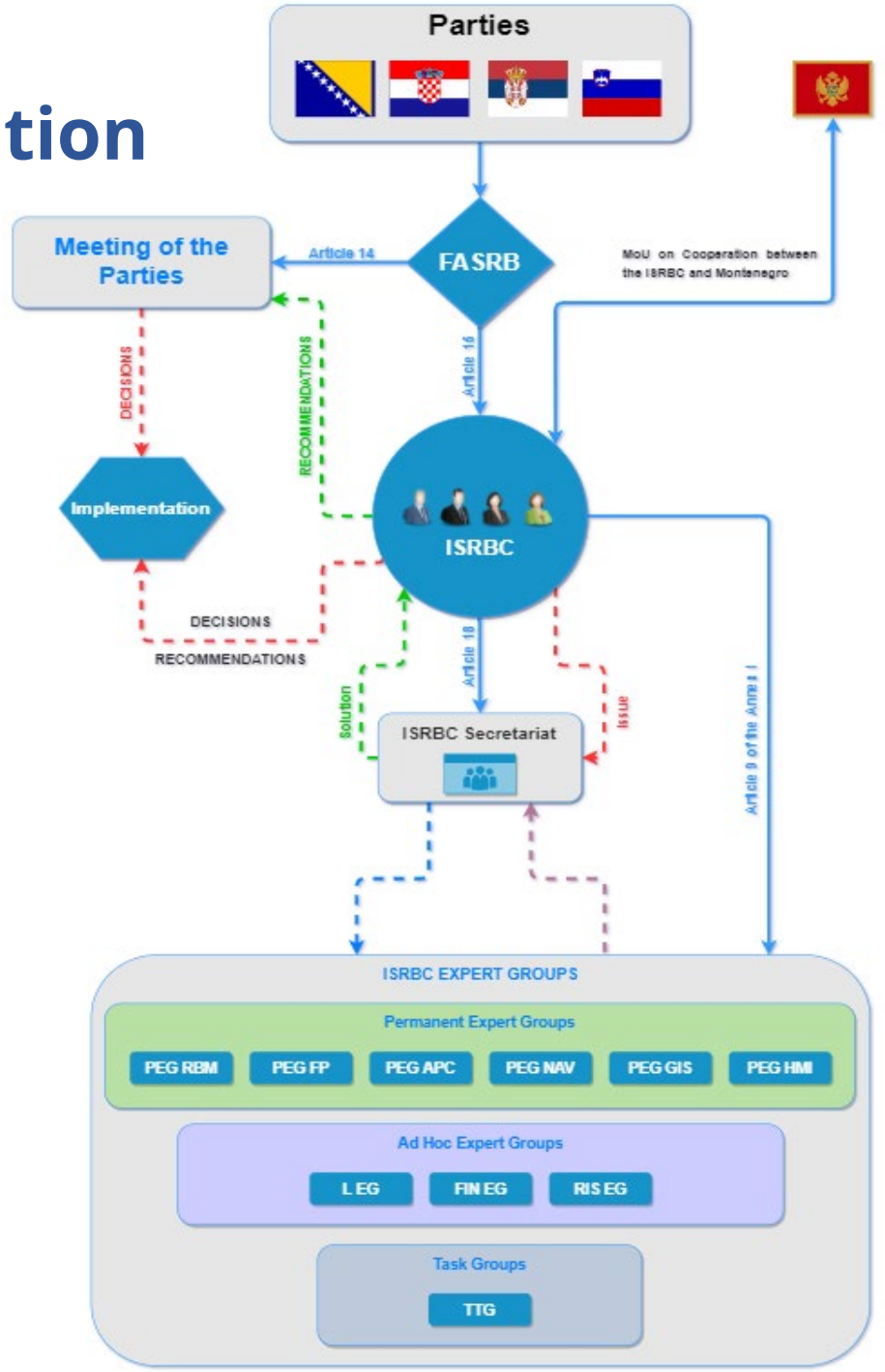


INTERNATIONAL SAVA RIVER BASIN COMMISSION

Background of cooperation

- **FASRB**: Framework Agreement on the Sava River Basin
- **Parties**:
  - Bosnia and Herzegovina
  - Croatia
  - Serbia
  - Slovenia

  (Montenegro – cooperation on technical level until full membership)
- **Implementation coordinated by:**
  the International Sava River Basin Commission
- **Key objective**: Sustainable development of the region through transboundary water cooperation
- **Particular objectives** – to establish:
  - International regime of navigation
  - Sustainable water management
  - Sustainable management of hazards (floods, droughts, accidents involving water pollution, etc.)



INTERNATIONAL SAVA RIVER BASIN COMMISSION

ISRBC Scope of cooperation

Management plans (river basin, flood risk, sediment, climate change adaptation)

Integrated systems (information, modelling, forecasting)

Economic activities (navigation, river tourism)

Harmonization of **regulation** (national → EU)

Protocols to the FASRB:

Issue	Signed	Ratified / in force
Navigation Regime	3 Dec. 2002	29 Dec. 2004
Prevention of Water Pollution caused by Navigation	1 June 2009	8 Oct. 2017
Flood Protection	1 June 2010	27 Nov. 2015
Sediment Management	6 July 2015	8 Oct. 2017
Emergency Situations	Final harmonization expected	
Transboundary Impact	Draft under reconsideration	

INTERNATIONAL SAVA RIVER BASIN COMMISSION

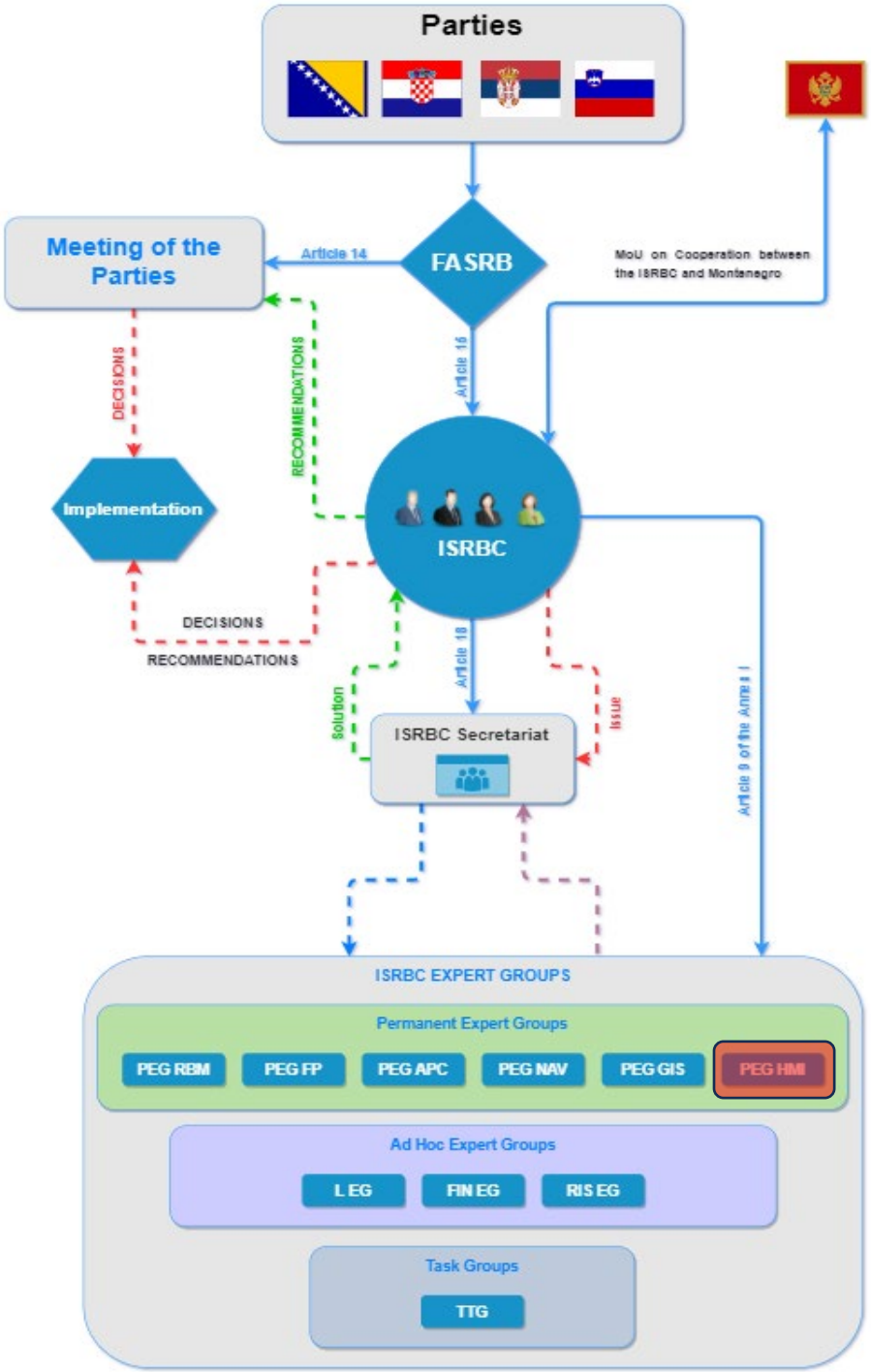
Exchange of data and information

The FASRB stipulates:

- „...the Parties shall, **on a regular basis, exchange information on the water regime** of the Sava River Basin...“

The Protocol on Flood Protection to the FASRB stipulates:

- „The Parties shall, **through the hydro-meteorological services and institutions responsible for flood protection, ensure timely exchange of meteorological and hydrological data**, analyses and information important for flood protection, especially the timely forecast of high waters, in line with the agreed procedure.“



Coordination of the HM Data Exchange

PEG HMI - Permanent Expert Group for Hydrological and Meteorological Issues

- Providing support to exchange of HM data within the Sava River Basin, especially in relation to:
  - creation of a HM database for the whole Sava River Basin
  - preparation of hydrological yearbooks of the Sava River Basin
- Development of strategy and action plans of the ISRBC and providing support and assistance in performing the specified activities

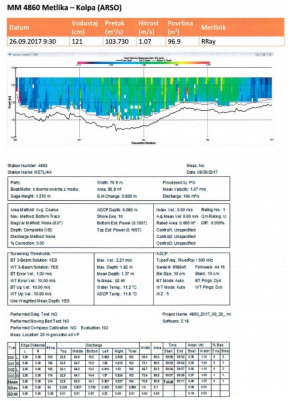
Meeting of Directors of the NHMSs from the Sava River Basin countries

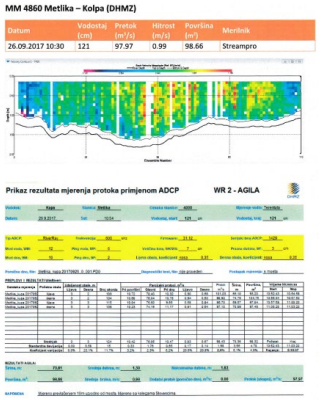
INTERNATIONAL SAVA RIVER BASIN COMMISSION

Initial HM Data Exchange

- **Hydrological Yearbooks**
  - Water levels (daily values, min, aver, max, frequency and duration)
  - Water discharges (daily values, min, aver, max, duration)
  - Water temperatures (daily values, min, aver, max)
  - Suspended sediment discharge/turbidity (daily values, min, aver, max)
  - Overview of the characteristical water levels and discharges

  - Precipitations (monthly values, totals)
  - Overview of the characteristical air temperatures and precipitations
- **A web portal for the real-time data exchange**
- **Joint measurements at border sections**

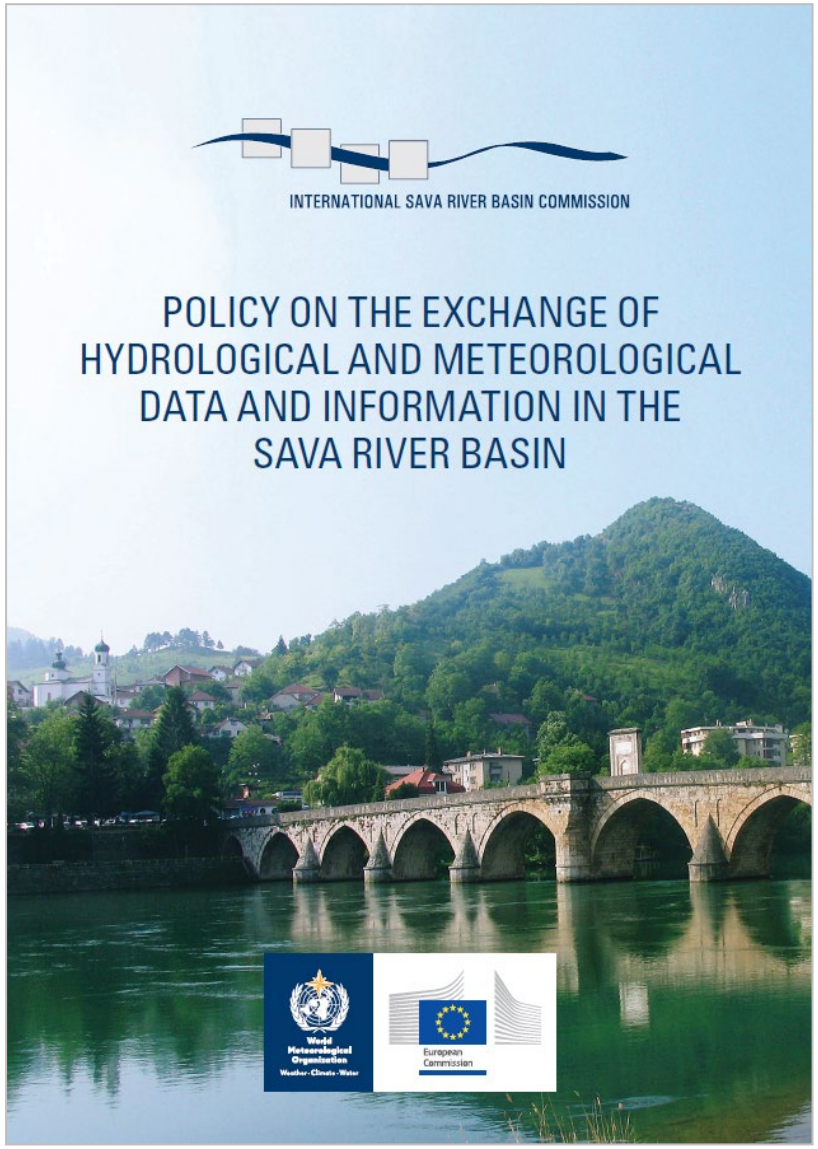




INTERNATIONAL SAVA RIVER BASIN COMMISSION

Policy on the HM Data Exchange

A legal background for establishement of Sava HIS



- Signed by the NHMSs directors in 2014
- WMO resolutions transposed
  - Resolution 25 (Cg-XIII) - Exchange of Hydrological Data and Products
  - Resolution 40 (Cg-XII) - Policy and Practice for the Exchange of Meteorological and Related Data and Product
- Principles (organizations, monitoring locations, data to be exchanged)
- Routes (procedures, timetable, quality standards, use and redistribution, ownership, charging, future harmonization)
- Organizations (data providers/receivers)
  - Hydro-meteorological services
  - Water / environment agencies
  - Hydropower companies (still pending)
- International legal framework
- National legal framework

INTERNATIONAL SAVA RIVER BASIN COMMISSION

Policy on the HM Data Exchange

Annex A: Organisations covered by the Policy

A.1 International Sava River Basin Commission (ISRBC)

A.2 *Signatory* organisations:

State	Name of organisation	Abbreviation
Bosnia and Herzegovina	Federal Hydrometeorological Service	FHMZFBIH
	Sava River Watershed Agency	AVPSAVA
	Republic Hydro-Meteorological Service of Republic of Srpska	RHMZRS
Montenegro	Institute of Hydrometeorology and Seismology	IHMS
Republic of Croatia	Meteorological and Hydrological Service	DHMZ
Republic of Serbia	Republic Hydrometeorological Service of Serbia	RHMZ
	Agency for Environmental Protection	
Republic of Slovenia	Slovenian Environment Agency	ARSO

A.3 Other organisations:

State	Name of organisation	Abbreviation

- The Signatories to this Policy should normally include, but are not limited to, the States' national hydrometeorological institutions - or equivalent organisation responsible for the collection and/or management and distribution of a States' national hydrological (and meteorological) data or information.

Additional organisations which operate in one (or more) of the States, **in connection with the management of the Sava River Basin, may become a Signatory** to the Policy at the invitation of the Commission.

INTERNATIONAL SAVA RIVER BASIN COMMISSION

Policy on the HM Data Exchange

Annex B: Data types covered by the Policy

B.1 List of data and information types covered by the Policy:

Parameter	Temporal Resolution (Statistic[3])	Units
River, Lake or Reservoir Level/Stage	Daily (Mean) Hourly	cm
River Discharge	Daily (Mean) Hourly	$m^3 s^{-1}$
Water Temperature	Daily (Mean)	°C
Suspended Sediment Discharge	Daily (Mean)	$kg s^{-1}$
Groundwater Level	Daily Every 5/10th Day	cm
Ice Condition	Daily	% of river cross section or text description
Precipitation	Annual (Total) Monthly (Total) Daily (Total) 6/12 Hourly (Total) Hourly (Total)	mm
Air Temperature	Daily (Mean) Hourly	°C
Relative Humidity	Daily Hourly	%
Wind (Speed and Direction)	Daily Hourly	m/s
Snow Depth	Daily	cm
Evaporation	Daily (Total)	mm
Solar Radiation	Daily	$J m^{-2}$
Sunshine	Daily (Total)	Hours
Atmospheric Pressure	Daily	hPa

INTERNATIONAL SAVA RIVER BASIN COMMISSION

Policy on the HM Data Exchange

Annex D: Minimum level of agreed data exchange

C.1 Purpose

C.1.1 This Annex outlines a minimum level of agreed data and information exchange to be concluded under this Policy.

C.2 General

C.2.1 *Signatories* will make the data and information outlined in this Annex available without charge to all other organisations covered by the Policy for the management of the Sava River Basin.

C.2.2 Unless otherwise specified, data and information exchanged under this Annex is done so in line with the principles and procedures outlined in the Policy.

C.2.3 All data and information listed in this Annex shall be in compliance with Clause 5.1.

C.2.4 The data and information detailed in Section C.3 of this Annex includes, but is not limited to, all data published by the Commission in the Hydrological Yearbooks of the Sava River Basin.

C.3 Data to be exchanged

C.3.1 All data and information outlined in the following table, which are currently collected or held by the *Signatories* for the monitoring locations specified in C.4, will be exchanged:

Parameter		Temporal Resolution (Statistic)	Units
P1	Water Stage	Daily (Mean)	cm
P2	River Discharge	Daily (Mean)	$m^3 s^{-1}$
P3	Water Temperature	Daily (Mean)	°C
P4	Suspended Sediment Discharge	Daily (Mean)	$kg s^{-1}$
P5	Precipitation	Daily (Total)	mm
P6	Air Temperature	Daily (Mean)	°C
P7	Water Stage	Current Stage	cm
P8	River Discharge	Current Discharge	$m^3 s^{-1}$
P9	Water Temperature	Current Temperature	°C

C.4 Monitoring stations included

C.4.1 Full period of record, data and information from the monitoring stations in the following table will be exchanged:

Hydrological Stations	BA	HR	ME	RS	SI	Total
	34	22	2	18	17	**93**

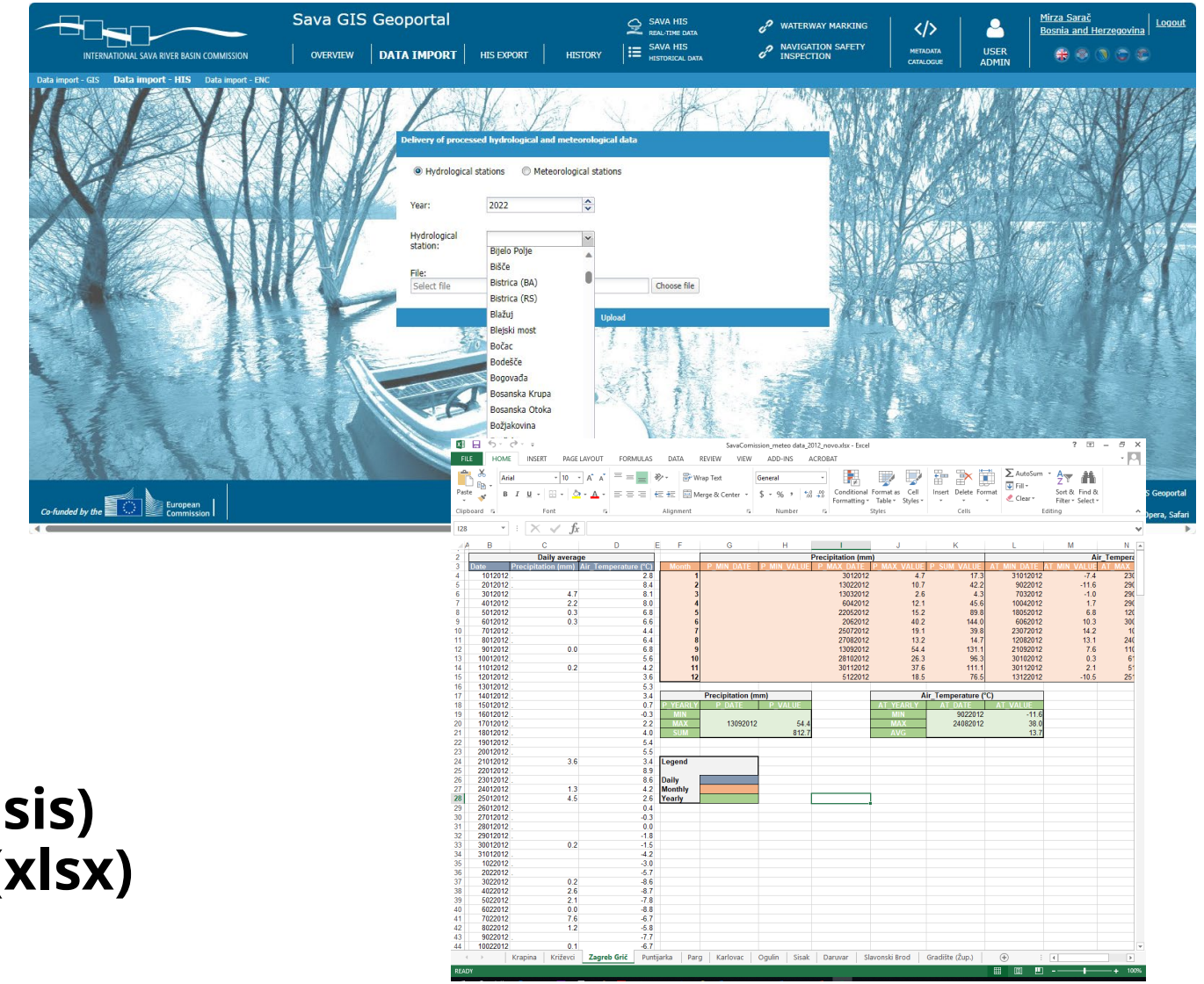
Meteorological Stations	BA	HR	ME	RS	SI	Total
	28	11	3	6	5	**53**

INTERNATIONAL SAVA RIVER BASIN COMMISSION

Sava HIS data providers and exchange format

Daily (processed data)

- Slovenia:
  - Slovenian Environment Agency
- Croatia:
  - Croatian Meteorological and Hydrological Service
- Bosnia and Herzegovina:
  - Federal Hydrometeorological Service
  - Republic Hydro-Meteorological Service of RoS
- Serbia:
  - Republic Hydrometeorological Service
- Montenegro:
  - Institute of Hydrometeorology and Seismology



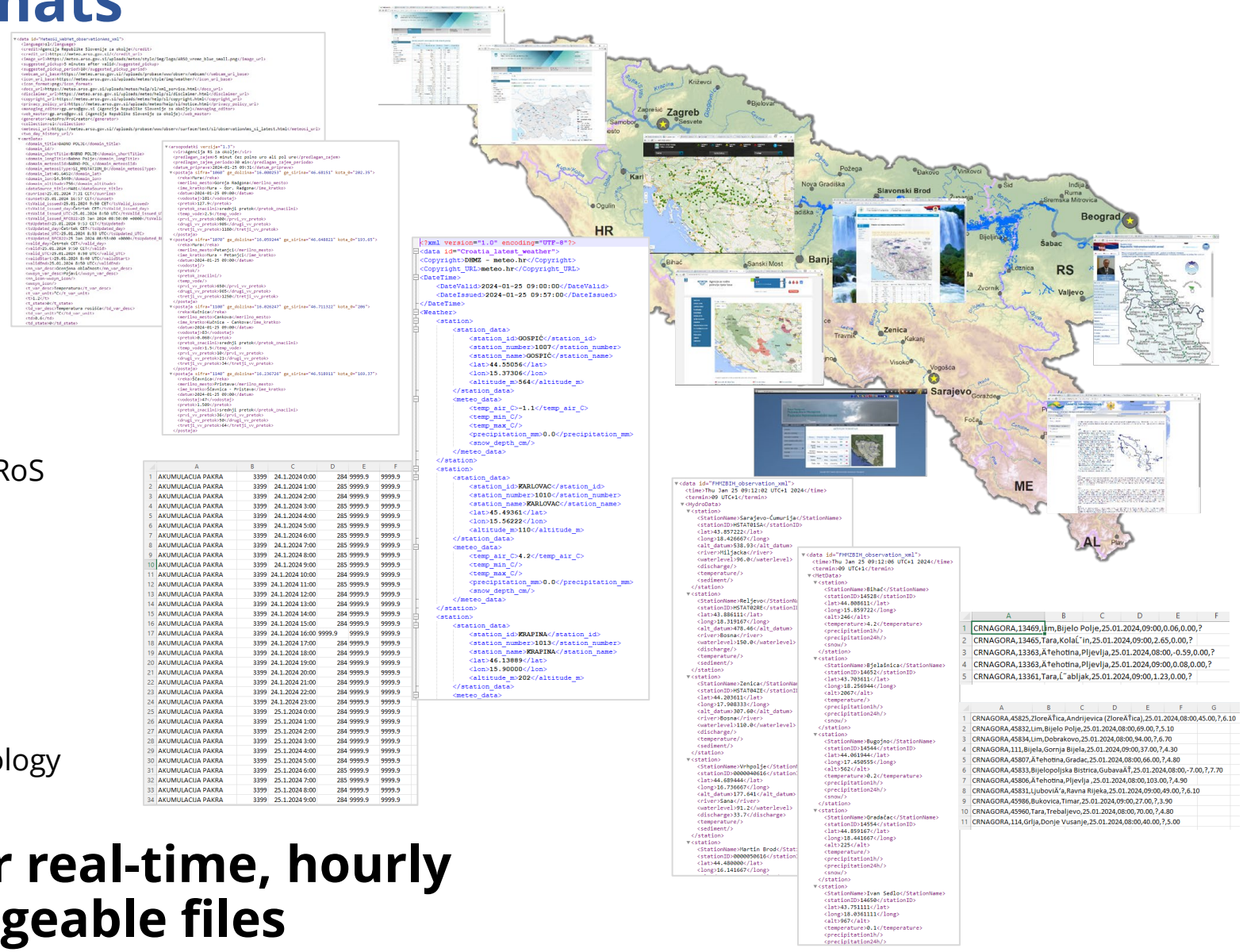
Data delivery (import at yearly basis) using a unique exchangeable file (xlsx)

INTERNATIONAL SAVA RIVER BASIN COMMISSION

Sava HIS data providers and exchange formats

Hourly (real-time raw data)

- Slovenia:
  - Slovenian Environment Agency
    - xml / web service
- Croatia:
  - Croatian Meteorological and Hydrological Service
    - xlsx&xml / ftp (initially: csv&xml / ftp)
- Bosnia and Herzegovina:
  - Federal Hydrometeorological Service
    - xml / ftp (initially: csv&xml / ftp)
  - Republic Hydro-Meteorological Service of RoS
    - zrx / ftp (initially: json / web service)
  - Sava River Watershed Agency
    - zrx / ftp (initially: csv / ftp)
- Serbia:
  - Republic Hydrometeorological Service
    - zrx / ftp (initially: csv / web service)
- Montenegro:
  - Institute of Hydrometeorology and Seismology
    - csv / ftp



Data delivery (import at near real-time, hourly basis) using different exchangeable files

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www.savahis.org

Sava HIS

Hub for observed data

1. Standards

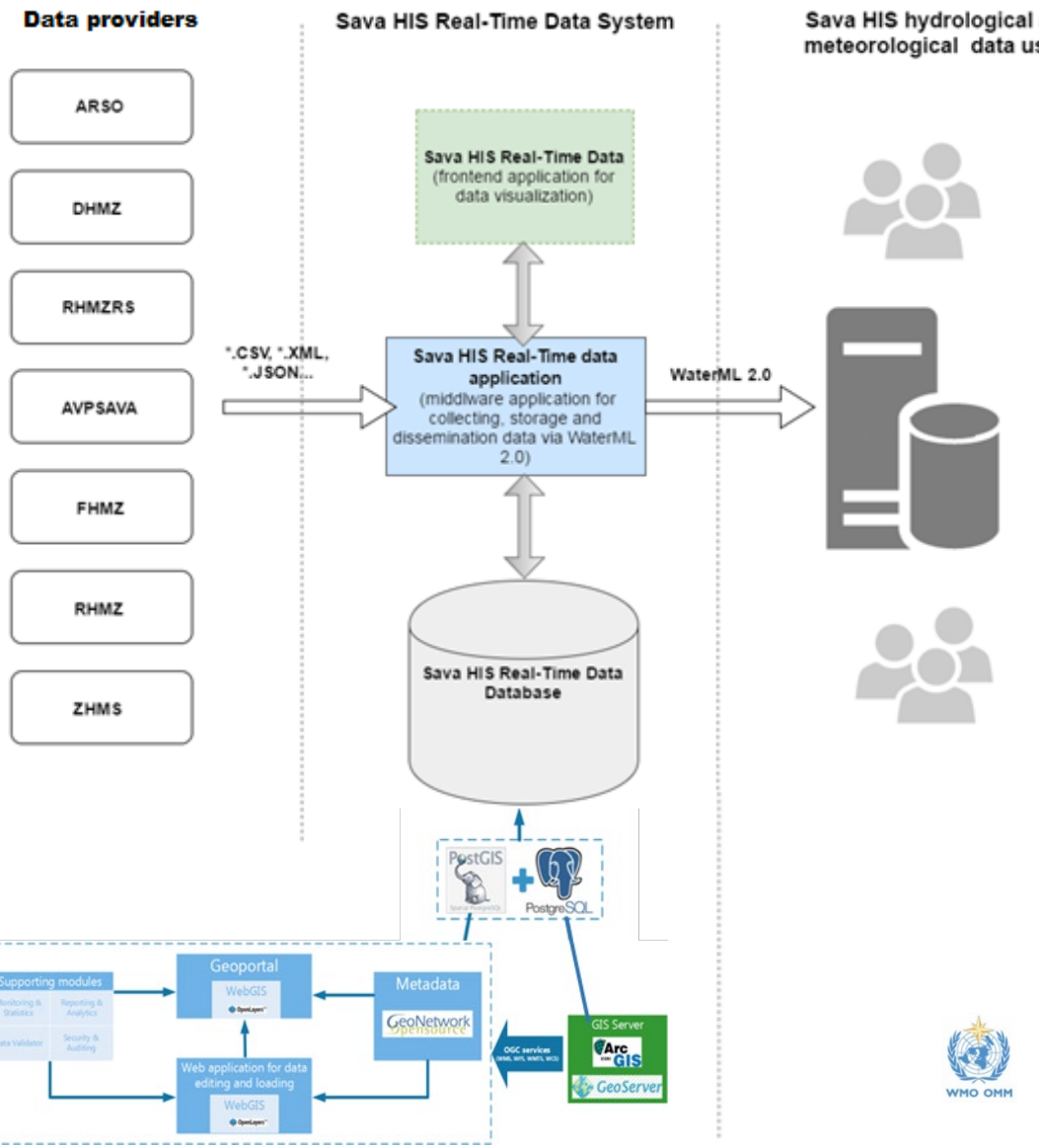
WaterML 2.0 language for describing water data

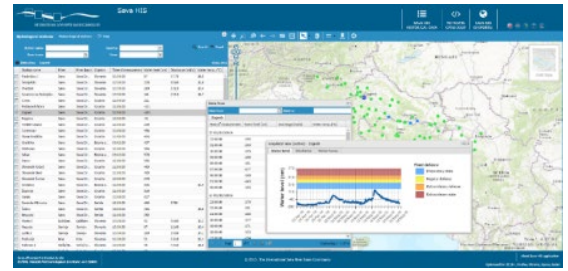
2. Services

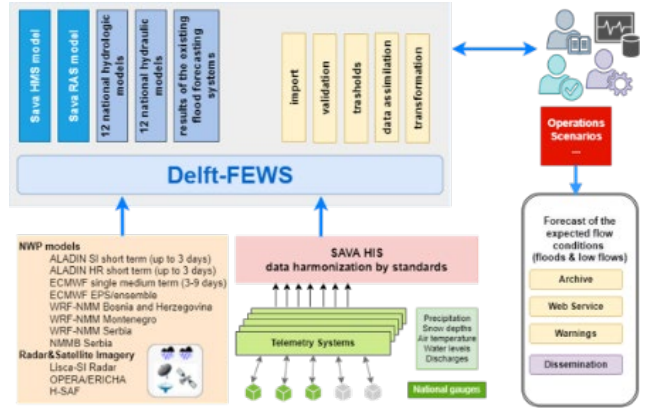
Catalog of water data sources – web services

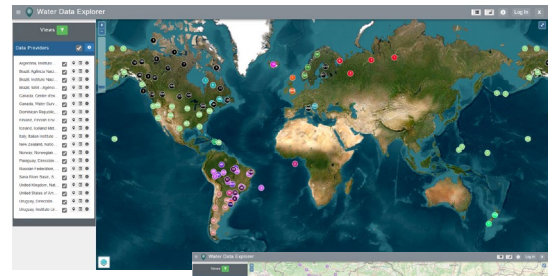
3. End user applications

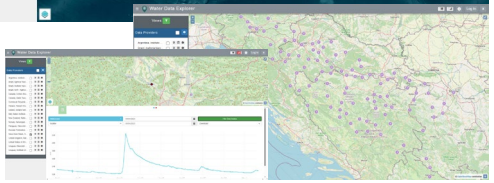
Web apps and desktop software for data access











Sava GIS

WMO OMM WHOS

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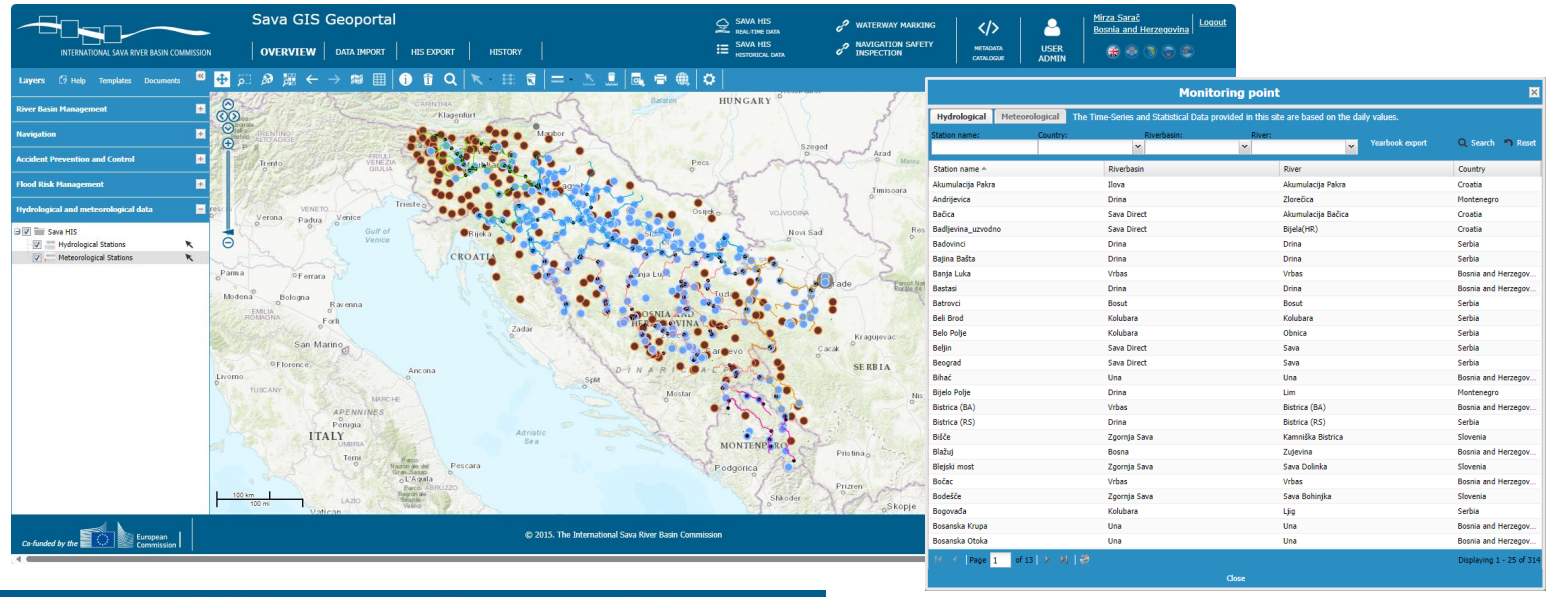
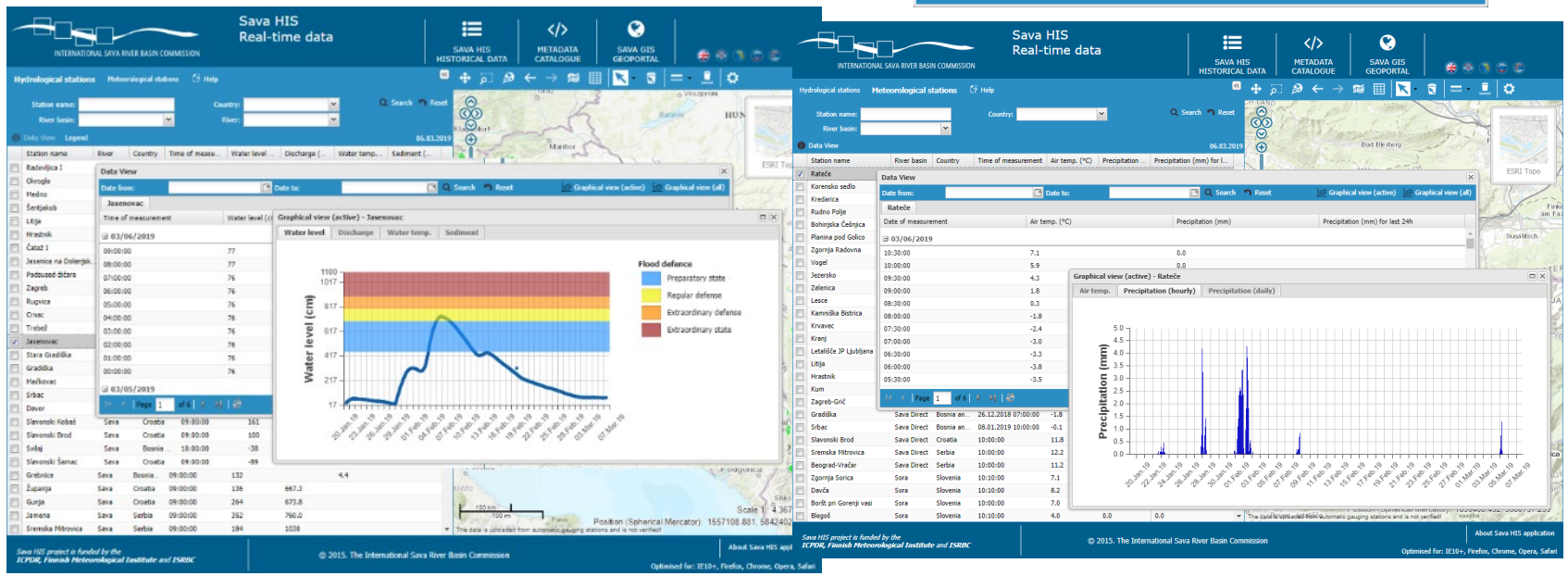
Sava HIS visualization

Sava GIS Geoportal



Sava HIS
Real-time data



INTERNATIONAL SAVA RIVER BASIN COMMISSION

Available stations and data in Sava HIS

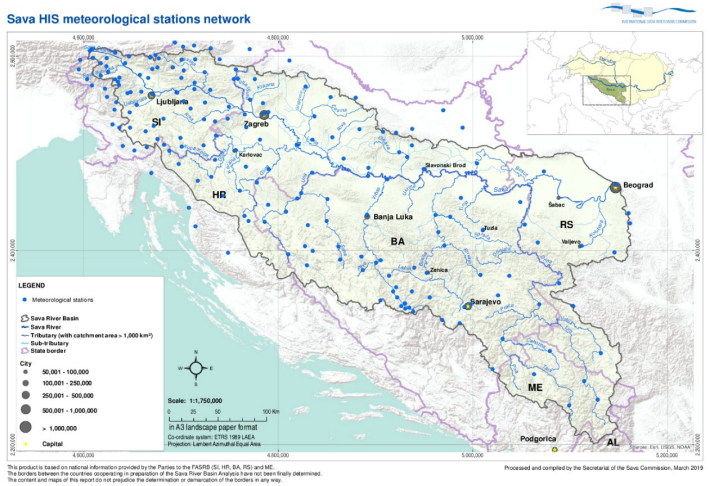
By Data Policy (2014)

- 93 **hydrological** stations

Sava HIS (2024)

Hydrological Stations	BA	HR	ME	RS	SI	Total
	104	125	13	31	26	**299**

Parameter	Temporal Resolution
River, Lake or Reservoir Level/Stage	Daily (Mean)
	Hourly
River Discharge	Daily (Mean)
	Hourly
Water Temperature	Daily (Mean)
Suspended Sediment Discharge	Daily (Mean)
	Hourly (Turbidity)
Ice Condition	Daily



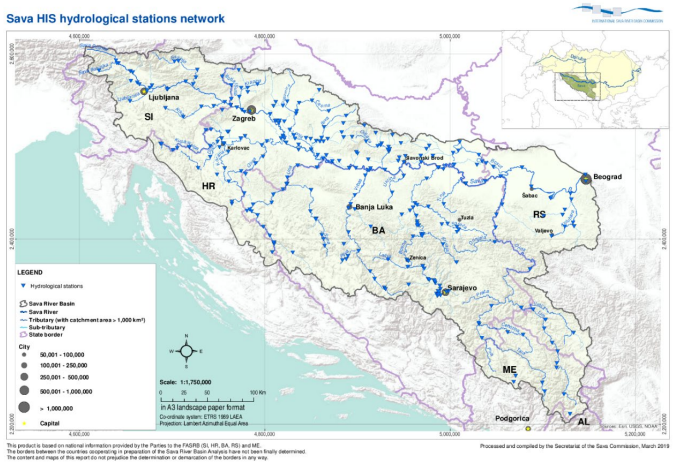
By Data Policy (2014)

- 53 **meteorological** stations

Sava HIS (2024)

Meteorological Stations	BA	HR	ME	RS	SI	Total
	66	49	5	14	78	**212**

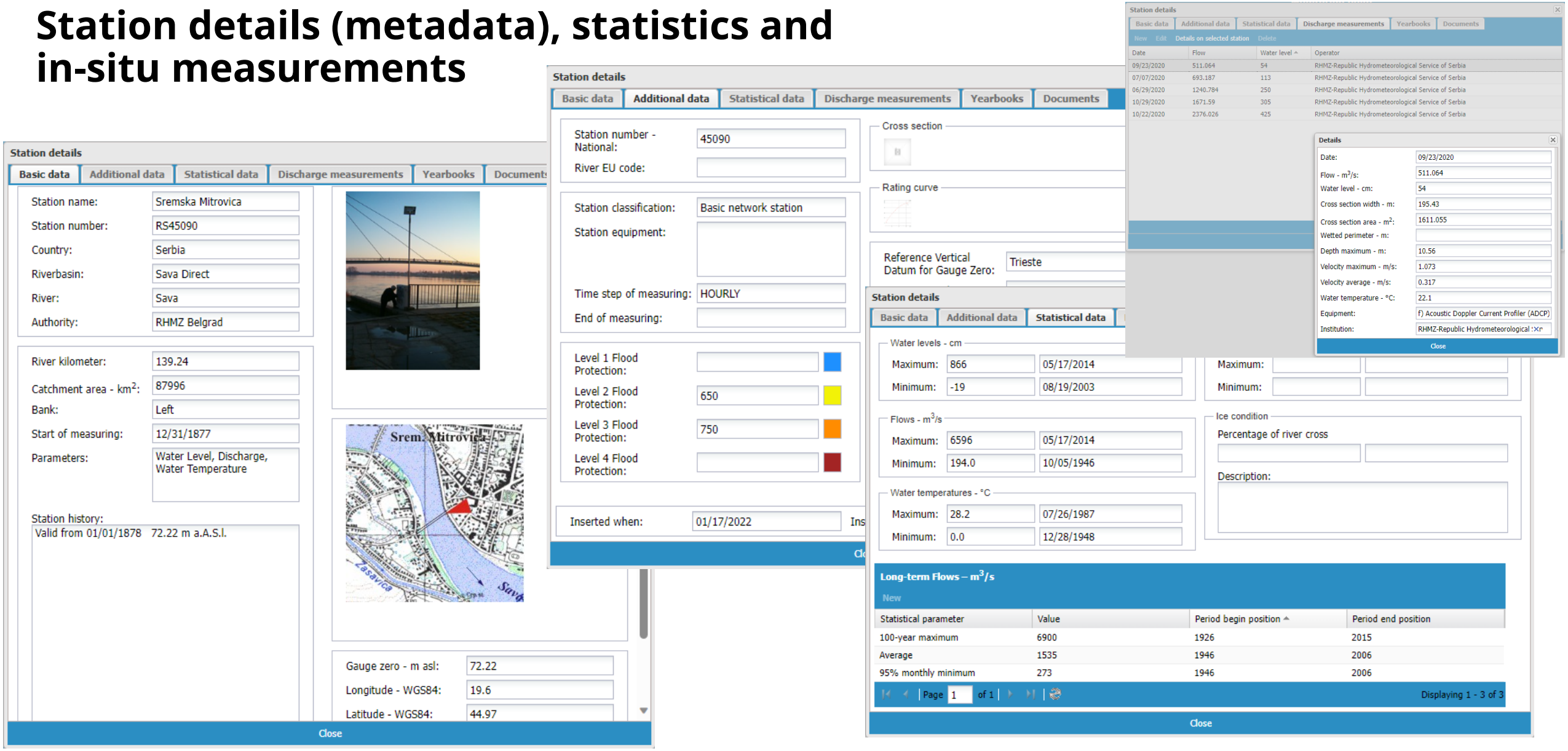
Parameter	Temposal Resolution
Precipitation	Annual (Total)
	Monthly (Total)
	Daily (Total)
	6/12 Hourly (Total)
	Hourly (Total)
Air Temperature	Daily (Mean)
	Hourly
Relative Humidity	Daily
	Hourly
Wind (Speed and Direction)	Daily
	Hourly
Snow Depth	Daily
Evaporation	Daily (Total)
Solar Radiation	Daily
Sunshine	Daily (Total)
Atmospheric Pressure	Daily



INTERNATIONAL SAVA RIVER BASIN COMMISSION

Available stations and data in Sava HIS

Station details (metadata), statistics and in-situ measurements



INTERNATIONAL SAVA RIVER BASIN COMMISSION

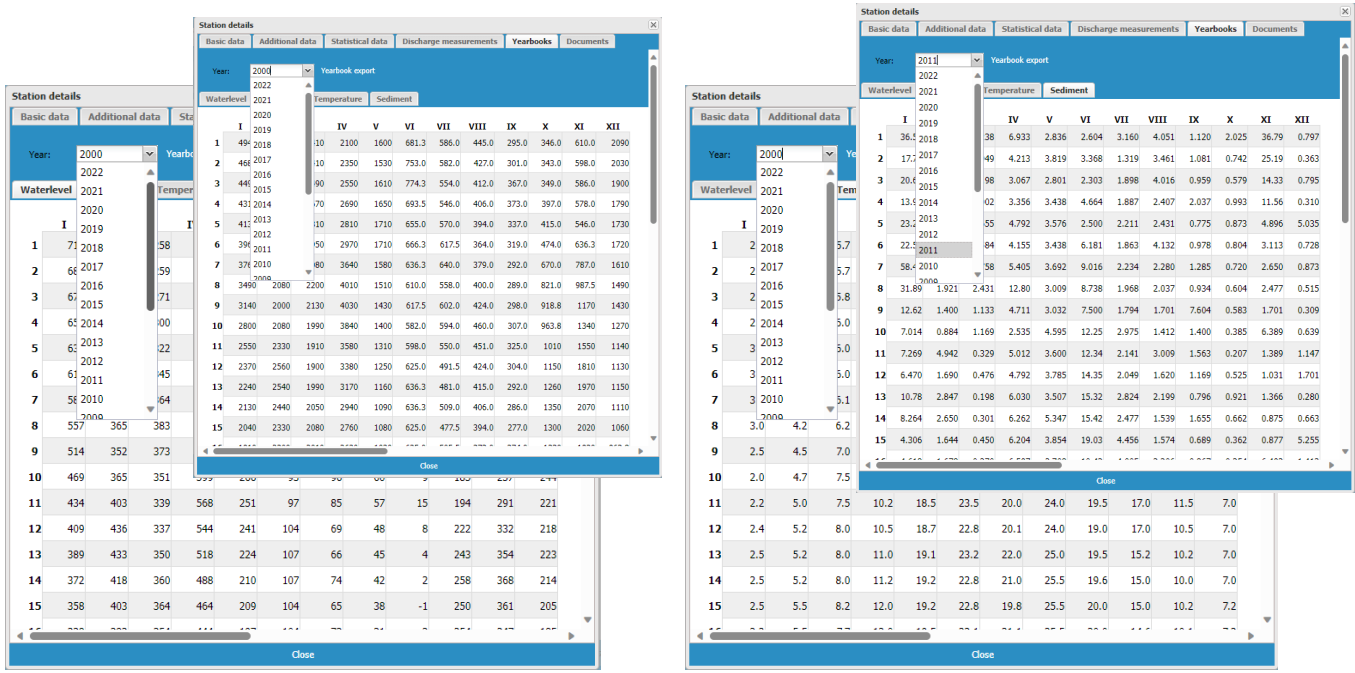
Available stations and data in Sava HIS

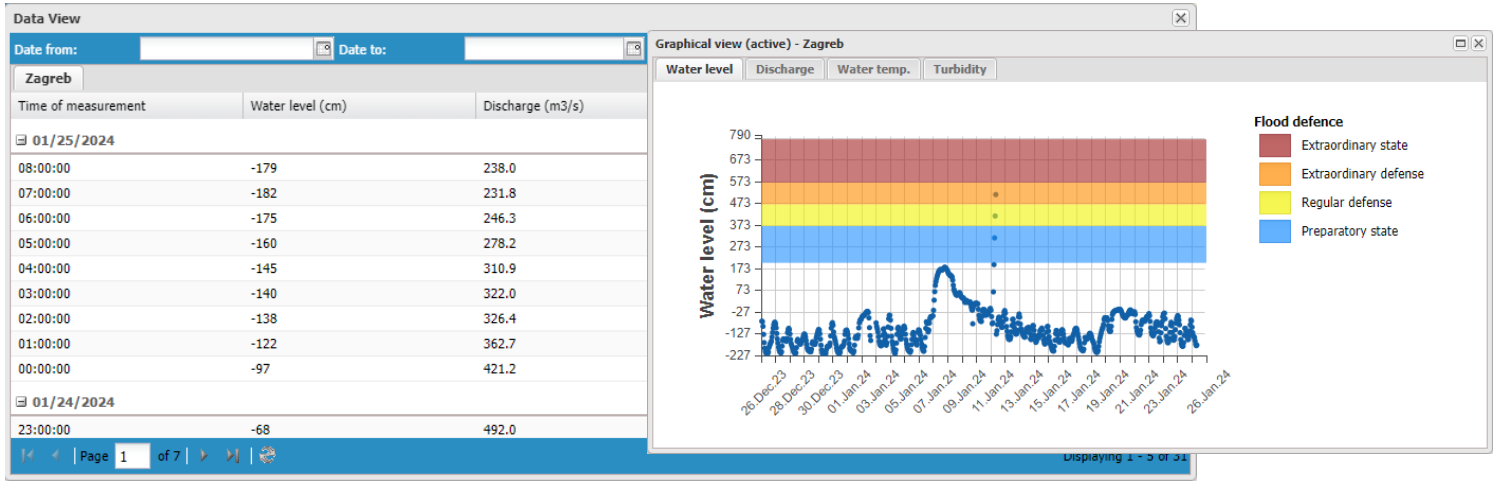
Time-series data

Daily processed data (2000-2022)

- Water discharge
- Water level
- Water temperature
- Sediment discharge
- Precipitation
- Air temperature

Hourly raw data (last 30days)





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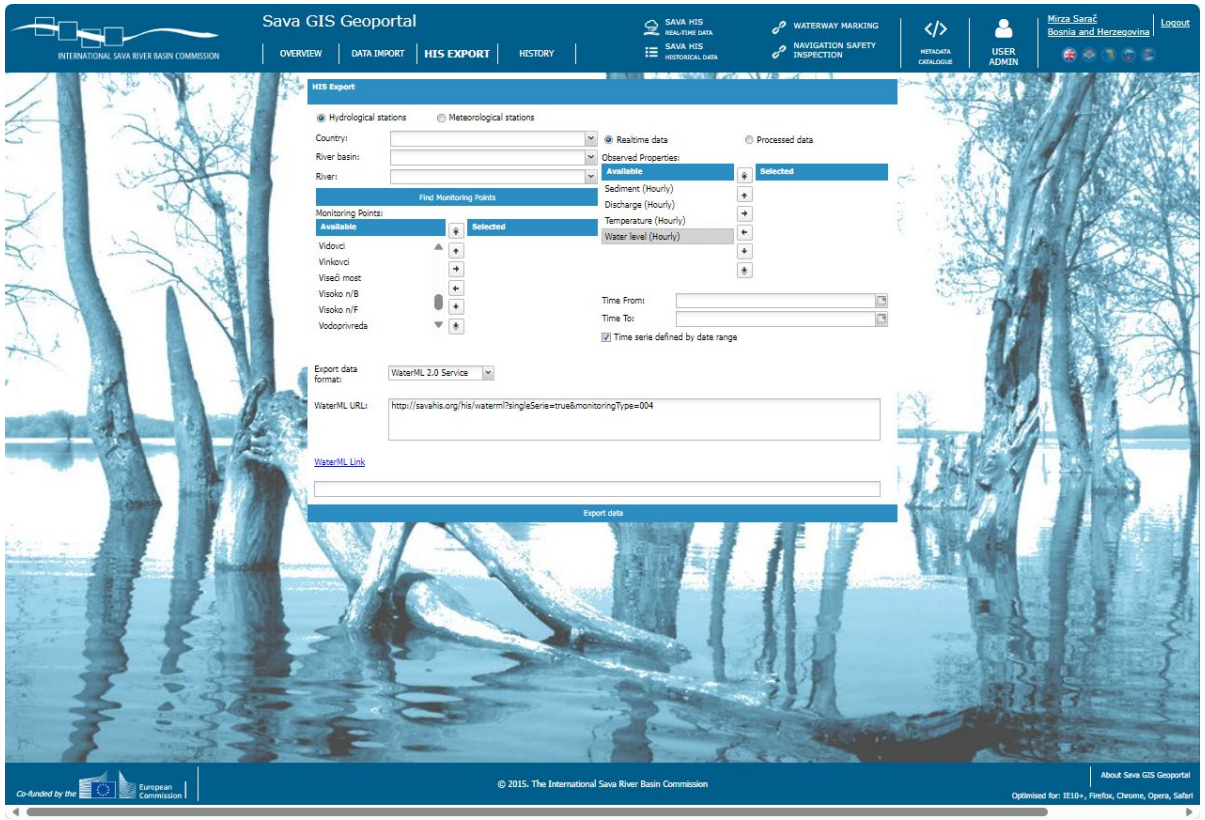
Sava HIS interoperability

WML 2.0 Webservice

Example timeseries call

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variable

period

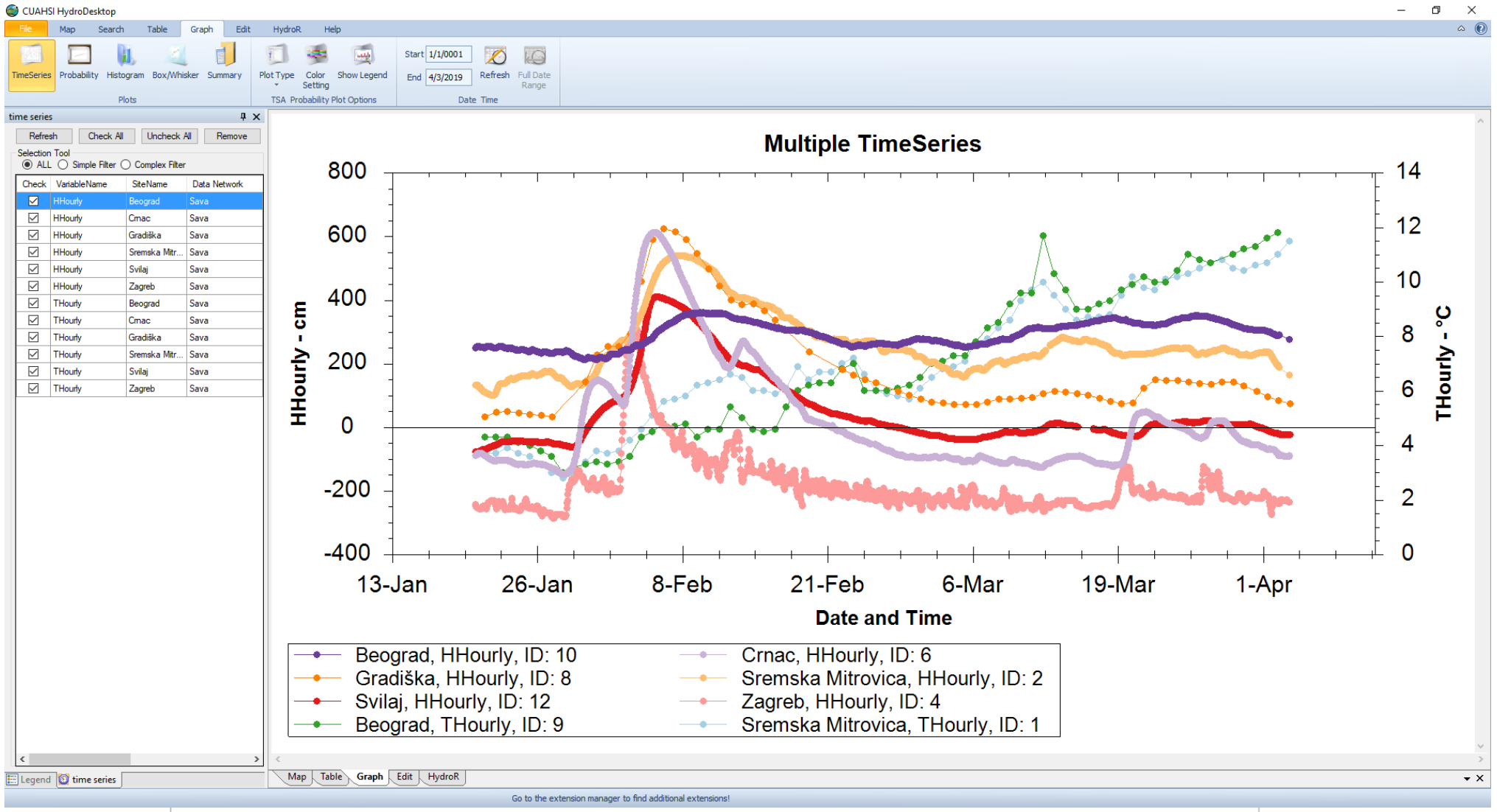
location

time series

INTERNATIONAL SAVA RIVER BASIN COMMISSION

Sava HIS interoperability

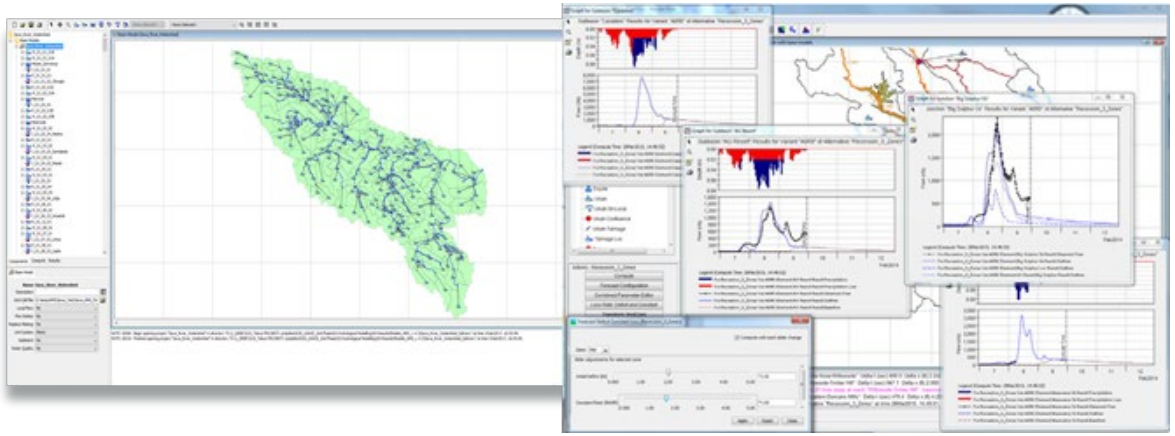
It will be demonstrated as a hands-on exercise (Jan 29th)

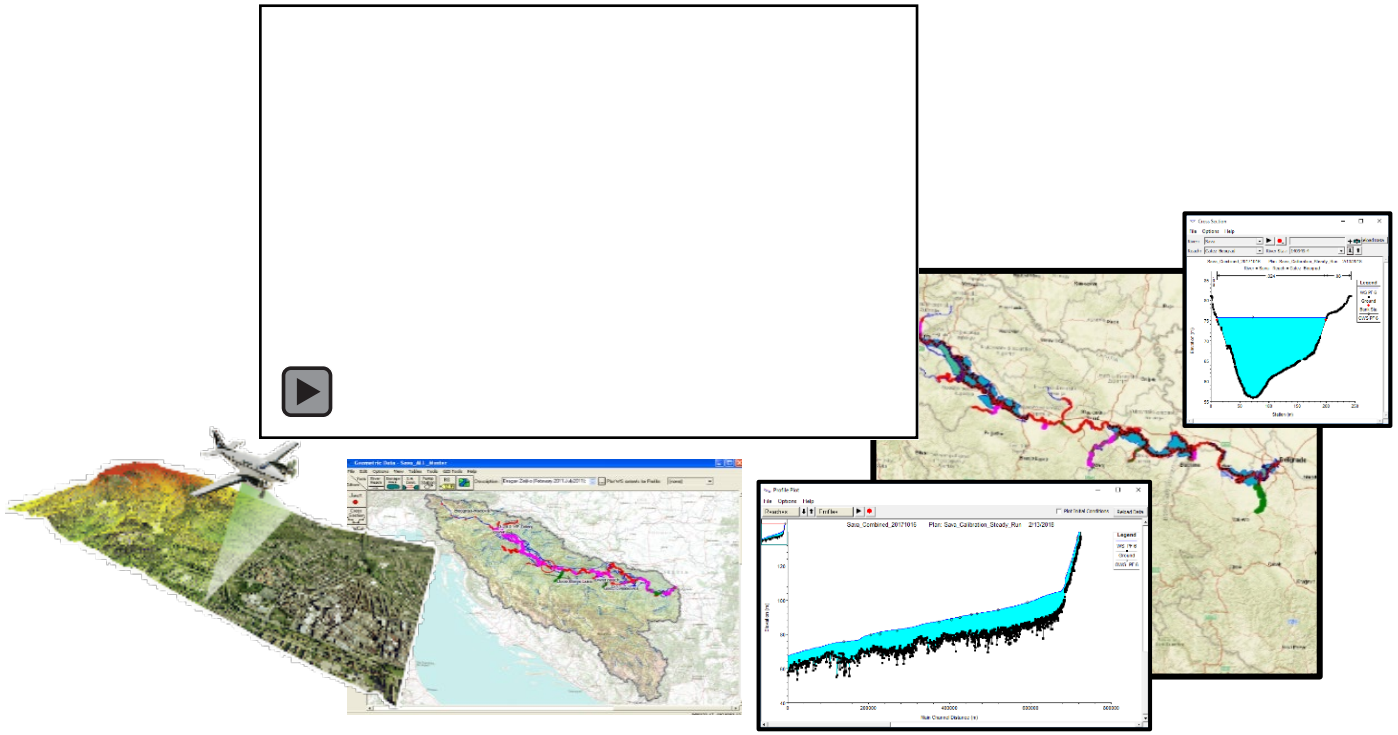


Export data

INTERNATIONAL SAVA RIVER BASIN COMMISSION

Sava HIS as input to the modelling





Simulation models operational under the forecasting system

Hydrologic model (HEC-HMS)

of the Sava River Basin (2010, 2014, 2016, **2021**)

- 19 integrated models
- 235 subbasins
- 174 junctions
- 22 dams locations for the reservoirs analysis
- calibrated (as event-based) and re-calibrated (for long-term simulations)

Hydraulic model (HEC-RAS)

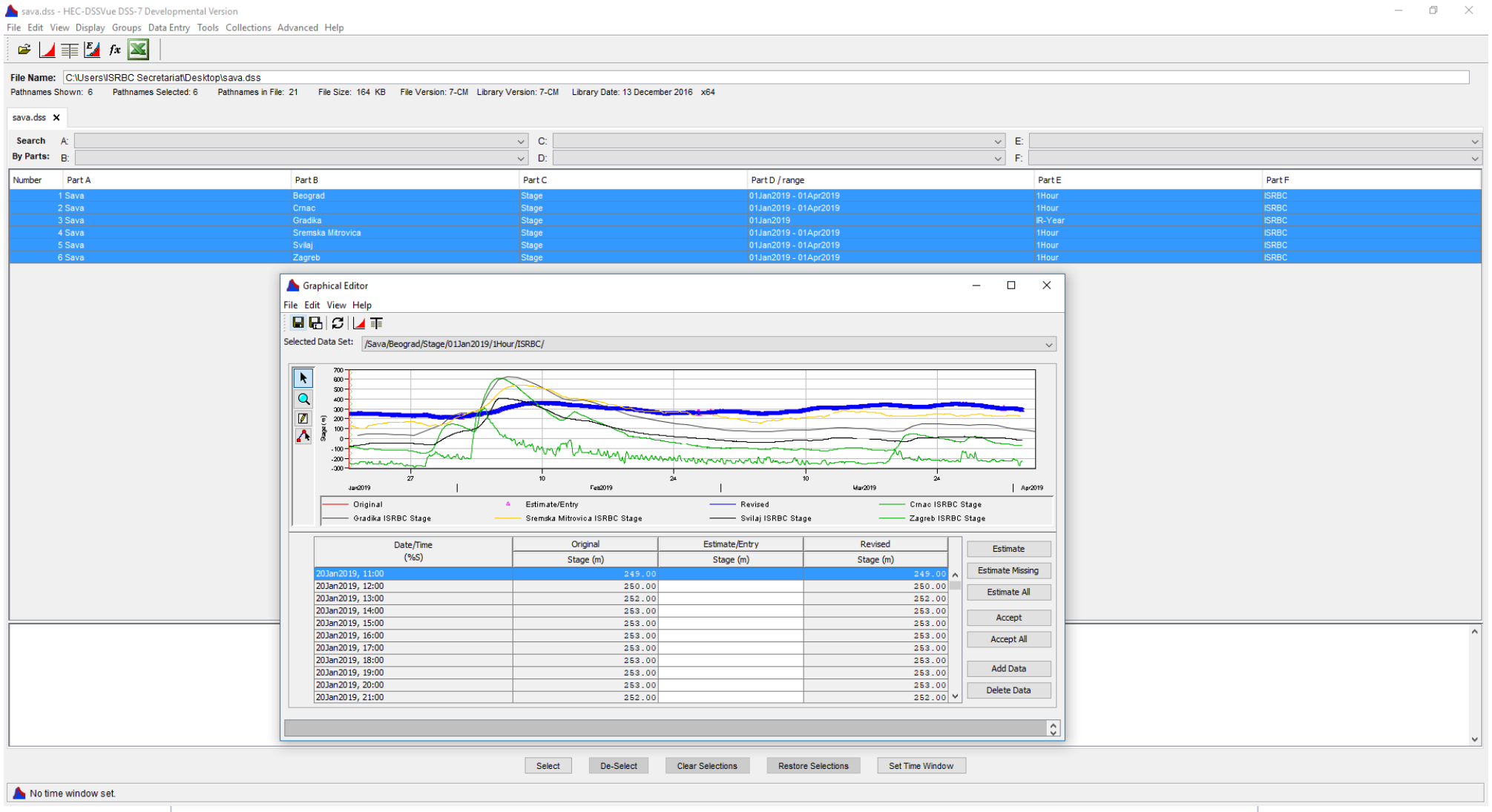
of the Sava River (2012, 2018, **2022**)

- accurate terrain model (LiDAR)
- 1D/2D simulation possibilities
- levee breach analysis
- calibrated (as event-based) and re-calibrated (for long-term simulations)

INTERNATIONAL SAVA RIVER BASIN COMMISSION

Sava HIS interoperability

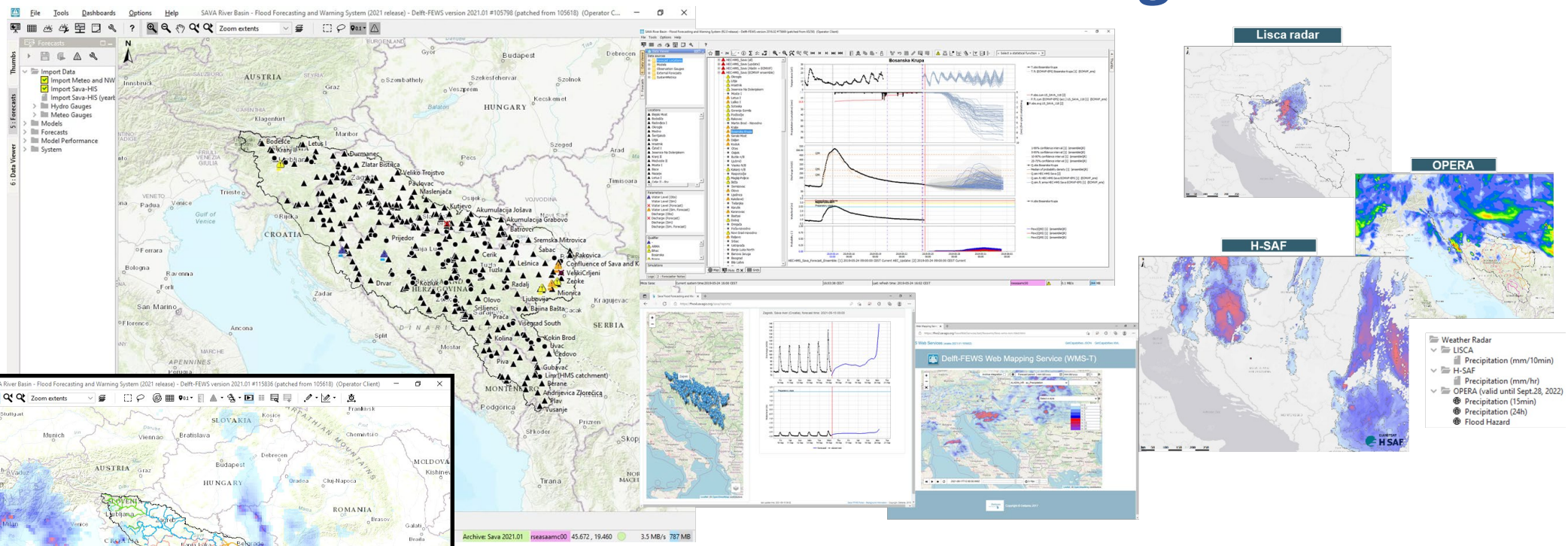
It will be demonstrated as a hands-on exercise (Jan 29th)

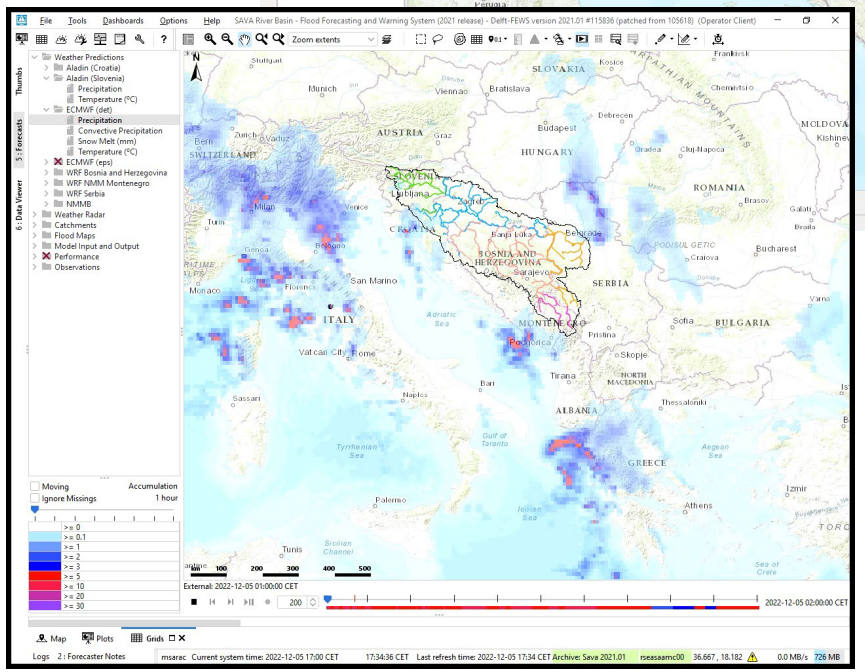


Export data

INTERNATIONAL SAVA RIVER BASIN COMMISSION

Sava HIS as a hub of the observed real-time data in the forecasting





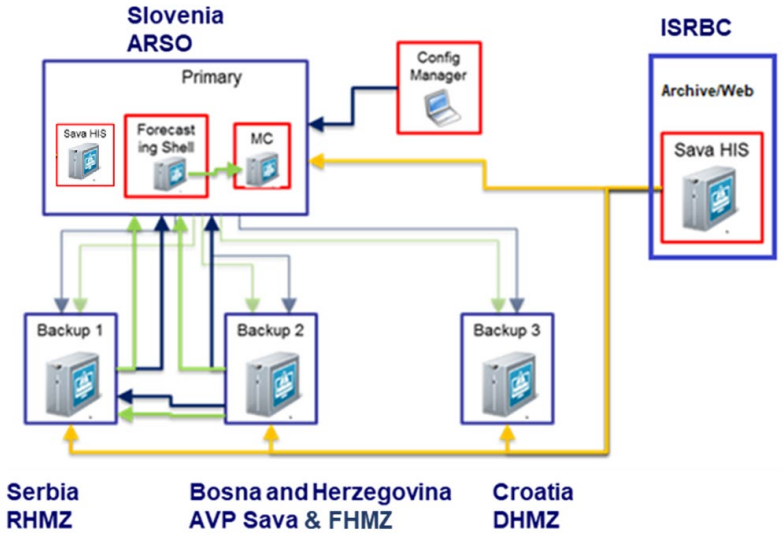
System operational since 2018

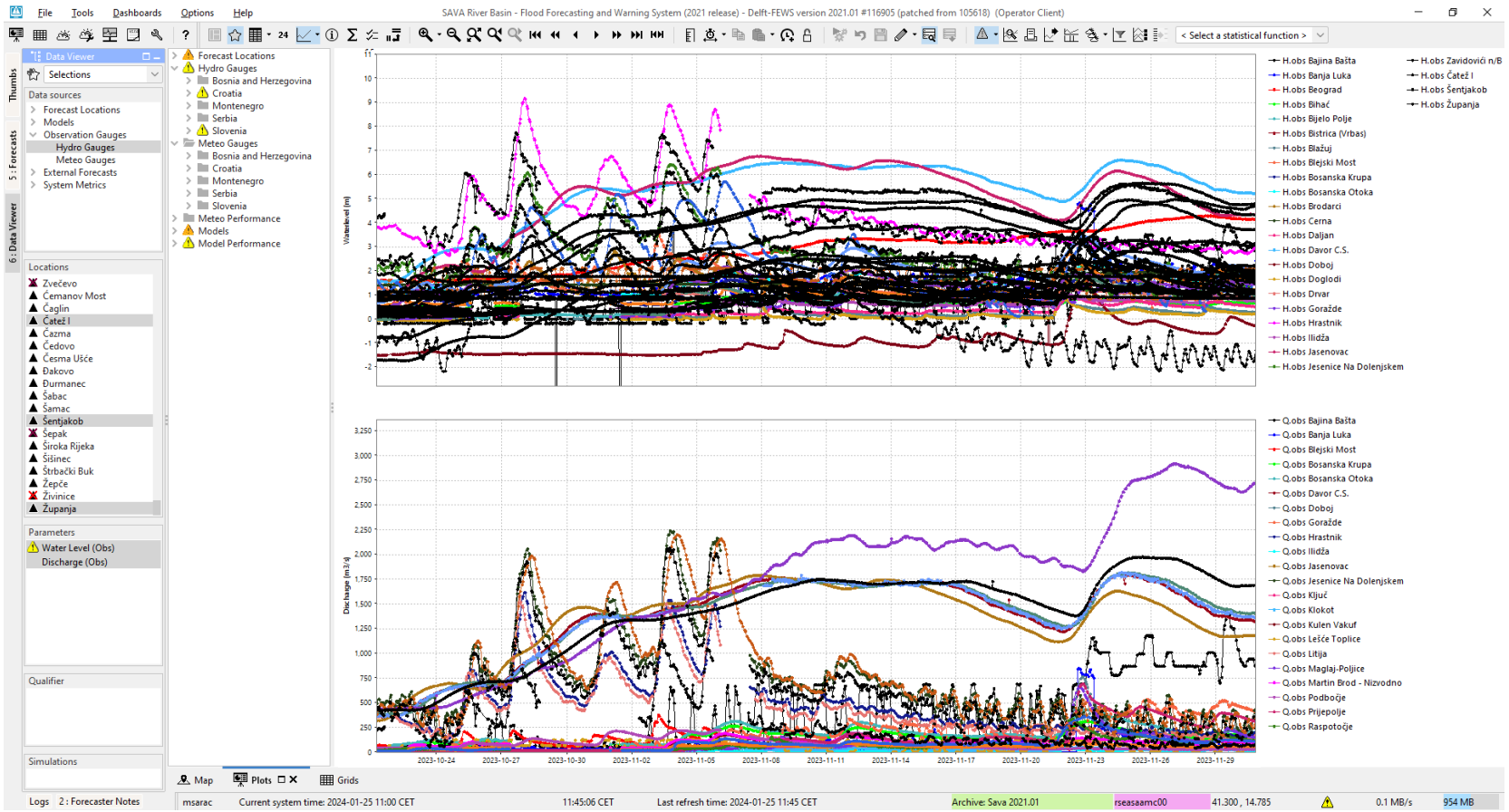
- 10 users – responsible national forecasting organizations
- the system assessed as a versatile forecasting system and unique in the region and example for the rest of the world
- mature base for possible future extensions (low flow forecasting and warning)

INTERNATIONAL SAVA RIVER BASIN COMMISSION

Sava HIS as a hub of the observed real-time data in the forecasting

Hourly raw data (from 2010)

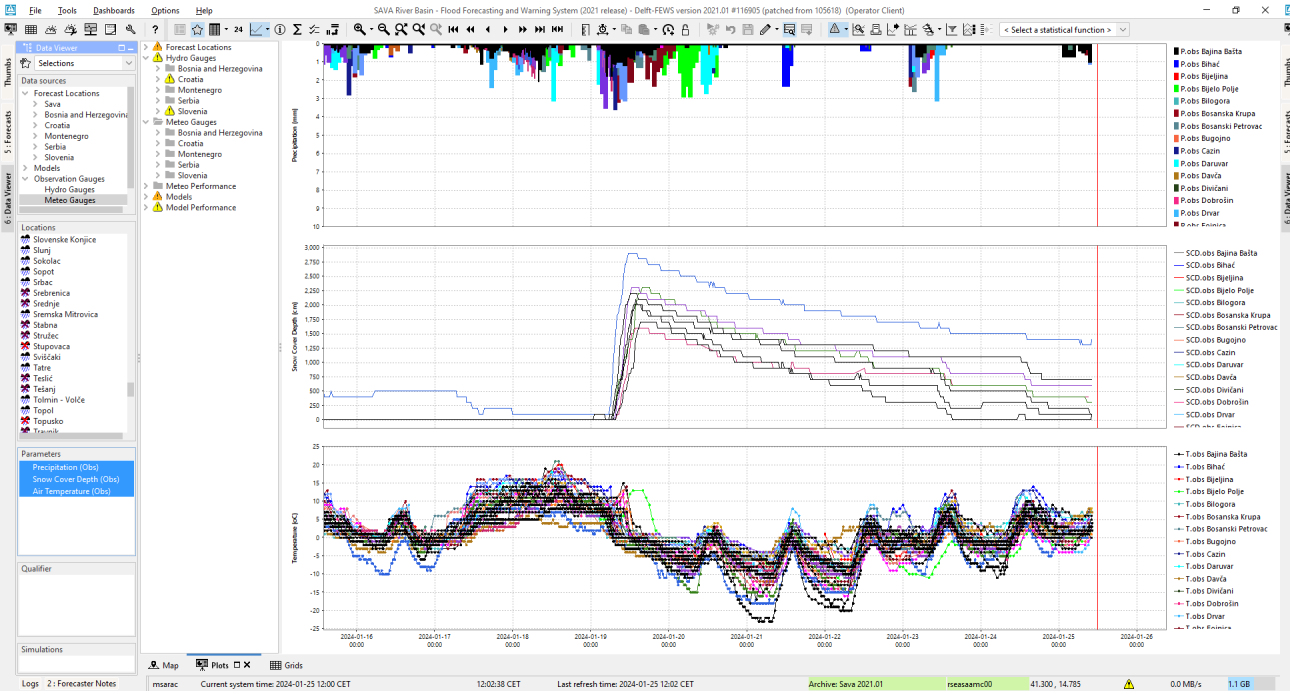




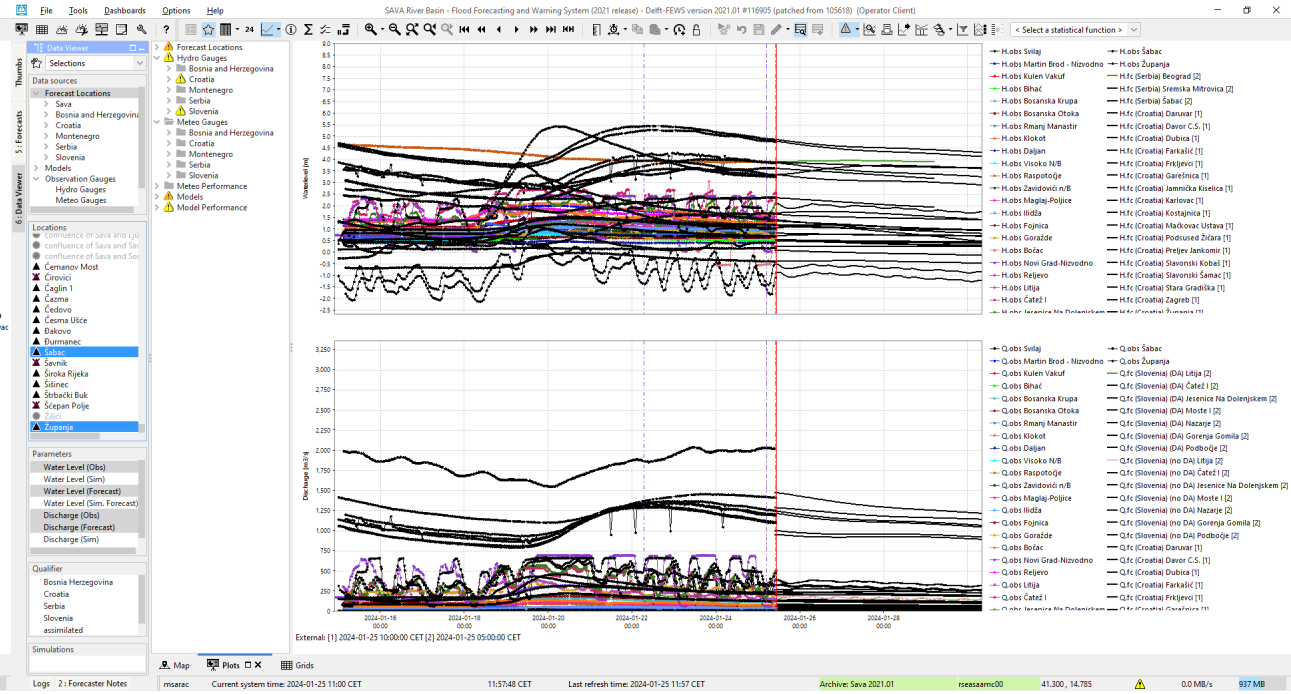
INTERNATIONAL SAVA RIVER BASIN COMMISSION

Sava HIS as a hub of the observed real-time data in the forecasting

Latest meteo data



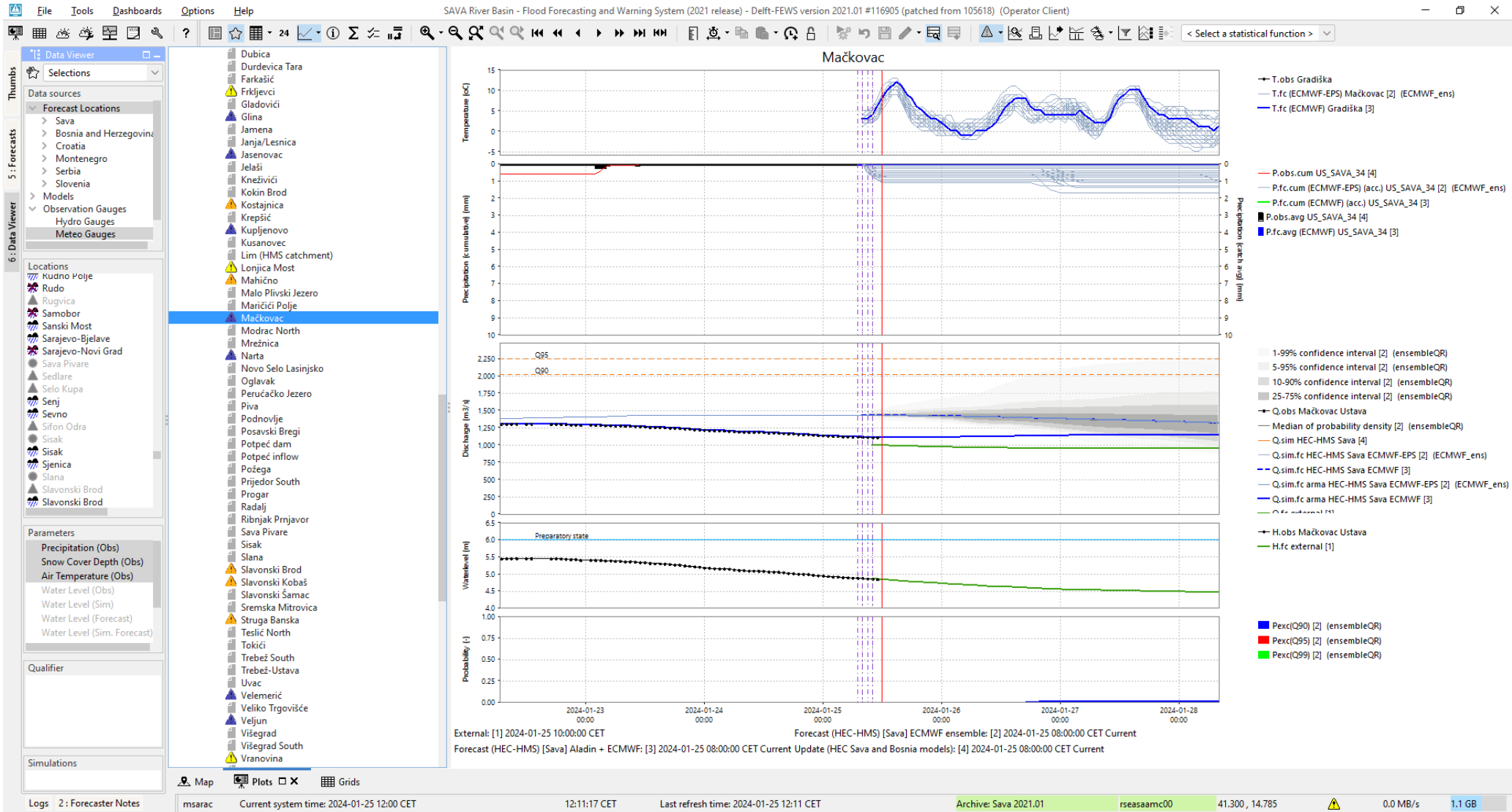
Latest hydro data and forecasts



INTERNATIONAL SAVA RIVER BASIN COMMISSION

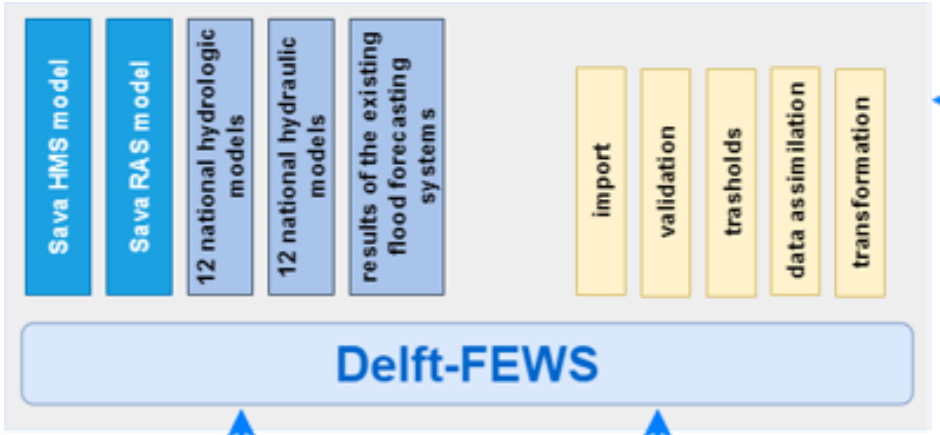
Sava HIS as a hub of the observed real-time data in the forecasting

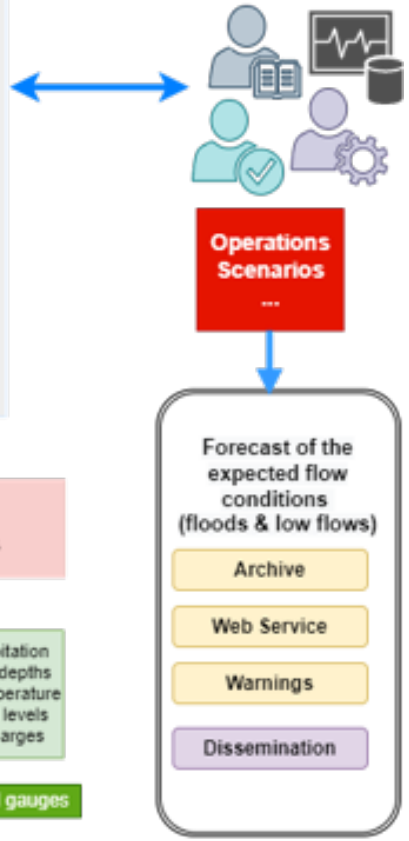
Contribution of the observed data

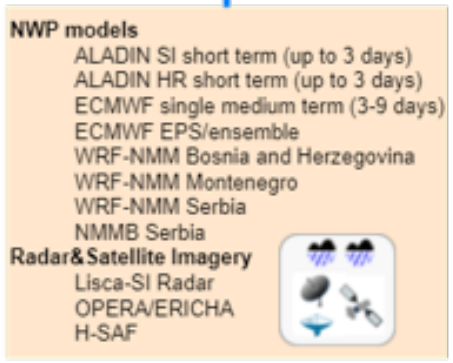


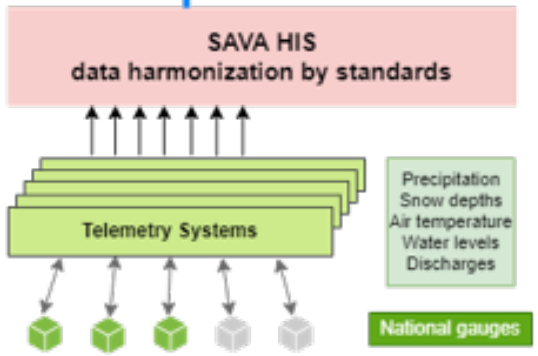
INTERNATIONAL SAVA RIVER BASIN COMMISSION

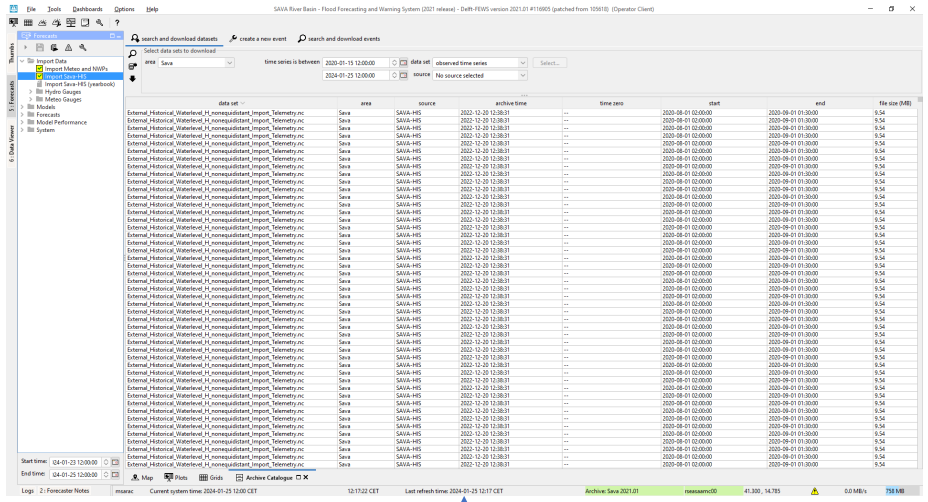
Sava HIS as a hub of the observed real-time data in the forecasting

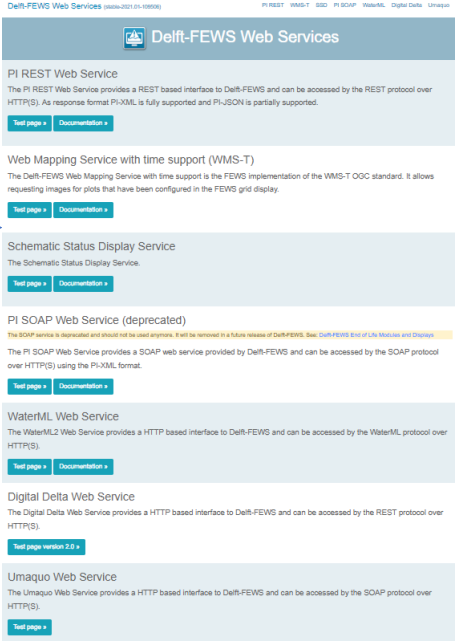












INTERNATIONAL SAVA RIVER BASIN COMMISSION

Sava HIS as a hub of the observed real-time data in the forecasting

PI REST Webservice

Example timeseries call

https://ffws2.savagis.org/FewsWebServices/rest/fewspiservice/v1/timeseries?locationIds=SAVA_5

Delft-FEWS Web Services (stable-2021.01-109506)

Delft-FEWS PI REST Web Service

Get timeseries that are part of the default filter, filtered by the query parameters.

GET https://ffws2.savagis.org/FewsWebServices/rest/fewspiservice/v1/timeseries?locationIds=SAVA_20&parameterIds=Q.obs

Method parameters	GET timeseries	Description
filterId		An existing subfilter of the default filter id
locationIds	SAVA_20	One or more location ids
parameterIds	Q.obs	One or more parameter ids
moduleInstanceIds	moduleinstanceid1[;moduleinstanceid2;...;moduleinstanceidn]	One or more module instance ids
qualifierIds	qualifierId1[;qualifierId2;...;qualifierIdn]	One or more qualifier ids
taskRunIds	taskRunId1[;taskRunId2;...;taskRunIdn]	One or more taskRunIds
startTime	yyyy-MM-dd HH:mm:ss	Start time. Format: yyyy-MM-ddTHH:mm:ssZ
endTime	yyyy-MM-dd HH:mm:ss	End time. Format: yyyy-MM-ddTHH:mm:ssZ

```
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  ▼<header>
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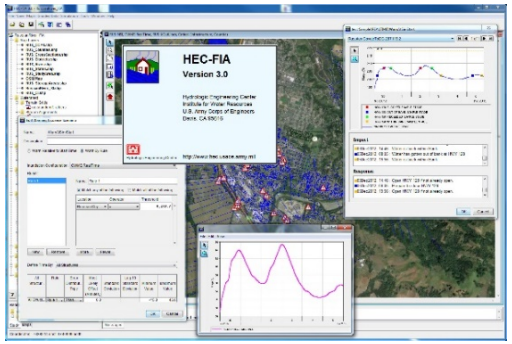
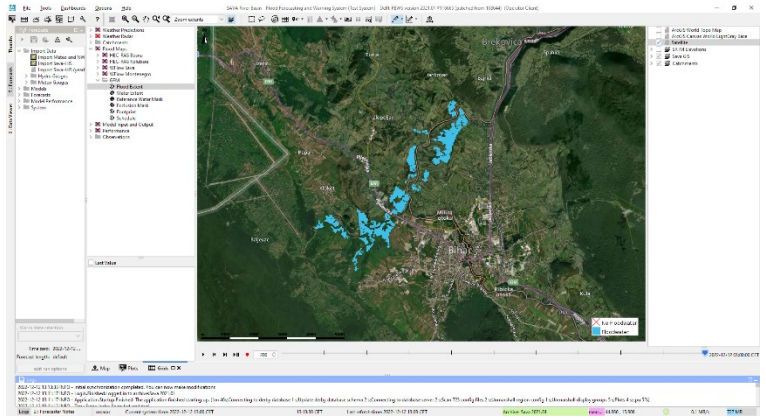
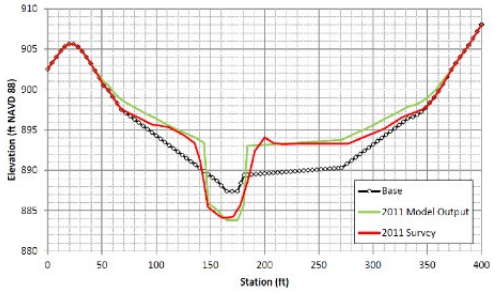
INTERNATIONAL SAVA RIVER BASIN COMMISSION

Awareness and looking for future products and users







ONGOING Sava and Drina River Corridors Integrated Development Program (GEF / World Bank)

- 2 phases ~ 10 years
  - phase 1: 2022-2026 in implementation
  - phase 2: 2026-2030 in preparation
- Sava HIS data providers actively involved as one of the main beneficiaries

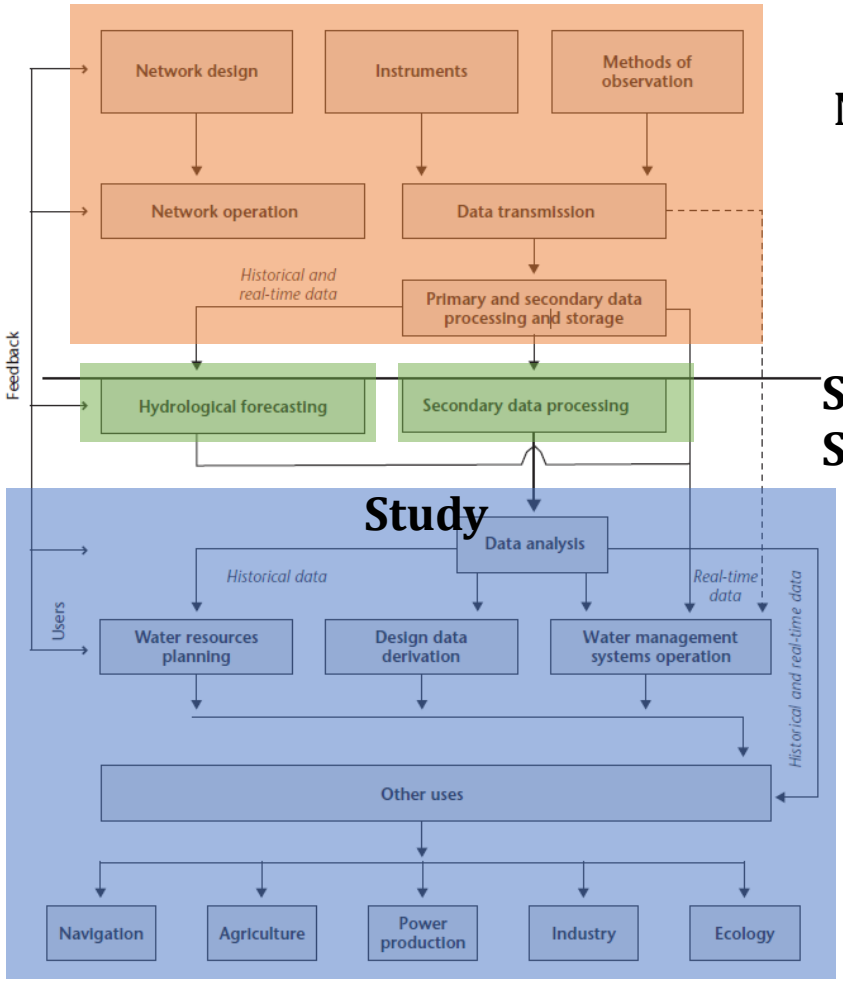
- **Hydrological Study development**
- **Sava HIS upgrade** and improvement including innovative data exchange and interoperability

- Flood forecasting improvements
- Low flow forecasting establishement (navigation purposes and drought analysis)
- Warnings
- Sediment transport modeling
- Climate change analysis

INTERNATIONAL SAVA RIVER BASIN COMMISSION

Sava HIS as the basis for the basin-wide Hydrological Study

Different purposes



NHMSs

Sava HIS
Sava FFWS

WMO Guide to Hydrological Practices, Volume II
Management of Water Resources and Application of Hydrological Practices

…and analysis

- Precipitation distribution (in space and time)
- Temperature distribution
- Evaporation distribution
- Wind distribution
- Snowpack distribution
- Series of monthly and annual volume of stream flow
- Mean daily discharge series
- Low flow frequency distribution
- Depth–discharge relationship for important points
- Frequency distribution of high discharges
- Rates of high water rise
- Time lag between rises at different points along the streams
- Frequency distribution of large-volume floods
- Shapes of typical flood hydrographs
- Travel times of floods
- Time lag between precipitation and runoff
- Flood synchronization at different tributaries
- Ice cover information
- Sediment transport and deposition
- Aquifer extent and characteristics
- Series of water levels of relevant aquifers

INTERNATIONAL SAVA RIVER BASIN COMMISSION

Sava HIS as the basis for the basin-wide Hydrological Study

History

Hydrological Study of the Sava River Catchment (1969)

- period: 1926-1965
- stations: 38 hydro and 20 meteo

Hydrological Study of the Sava River (1976)

- period: 1926-1974
- stations: 65 hydro and 61 meteo

Hydrology Balance of the Danube River (1977)

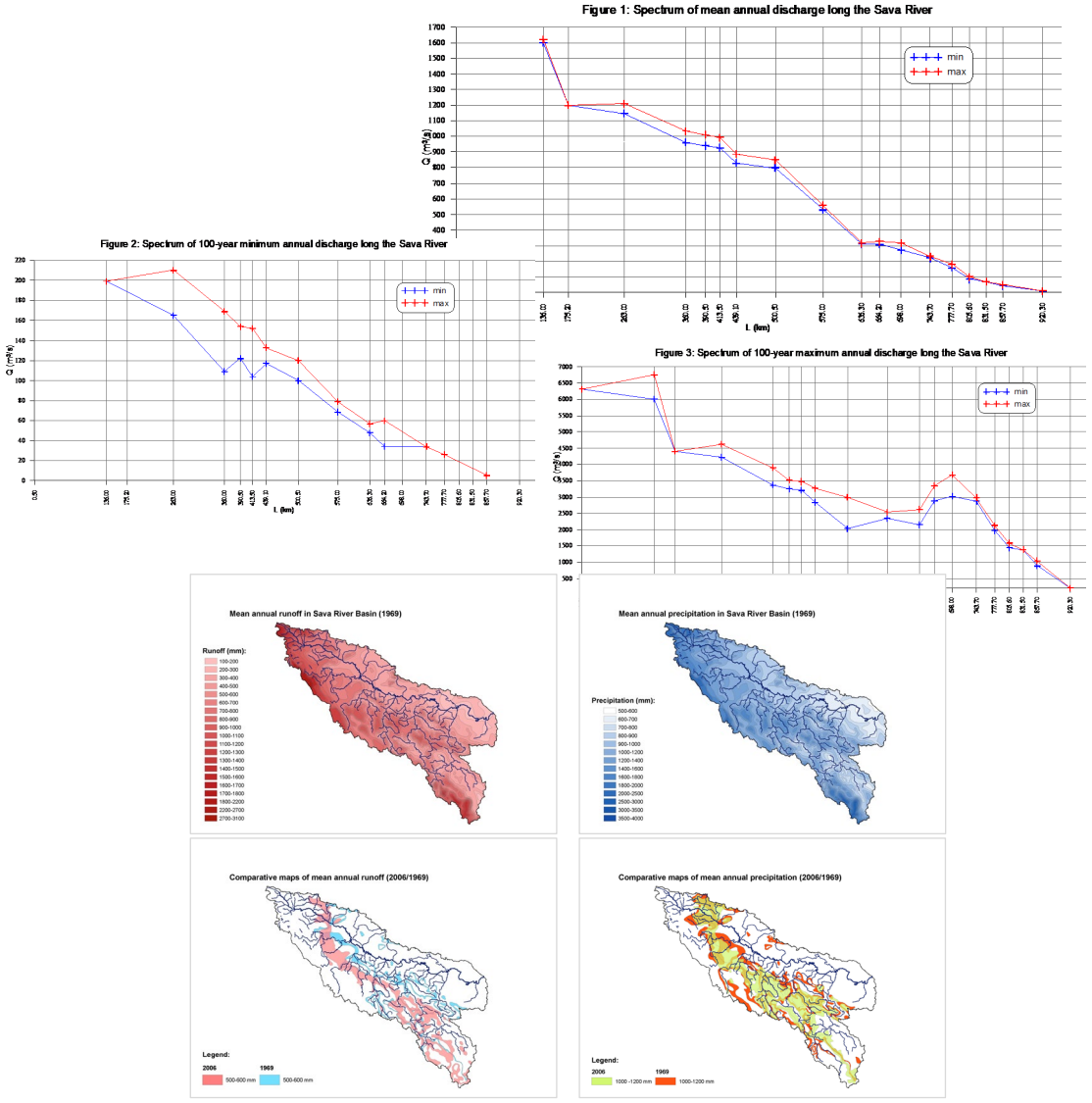
Hydrology of the Danube River (1988)

INTERNATIONAL SAVA RIVER BASIN COMMISSION

Sava HIS as the basis for the basin-wide Hydrological Study

Main objective: to enhance knowledge of the water cycle components and their spatial and temporal distribution in the Sava River basin through a synopsis of different hydrological topics of special importance for a better assessment of development activities

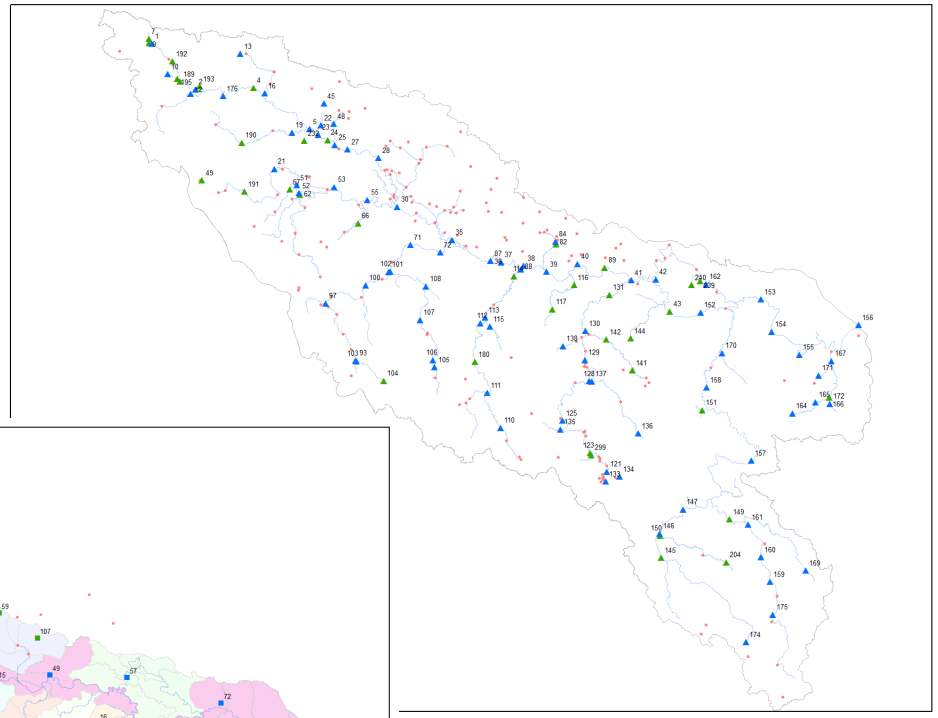
- Development of the methodology for preparation of the Hydrological Study
- Preparation of the Study
- Establishment of the web-based application for presentation and use of the Study
- Knowledge transfer and capacity building
- Recommendations for future studies and developments

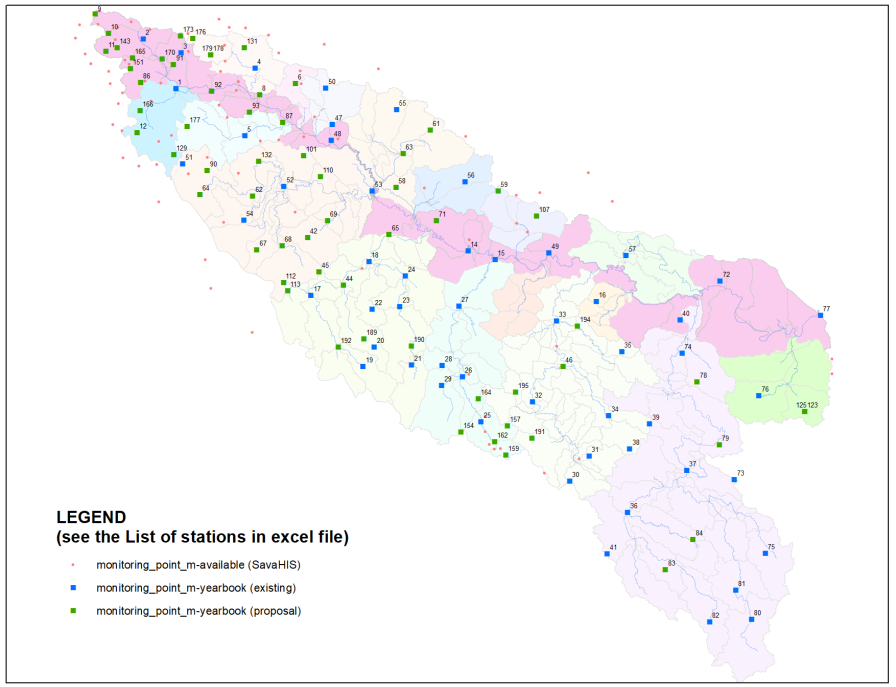


INTERNATIONAL SAVA RIVER BASIN COMMISSION

Sava HIS as the basis for the basin-wide Hydrological Study

Sava HIS – stations relevant for the Study (agreed through the PEG HMI)





- **Hydro: 120**
  - Sava: 26
  - tributaries: 94
- **Meteo: 115**

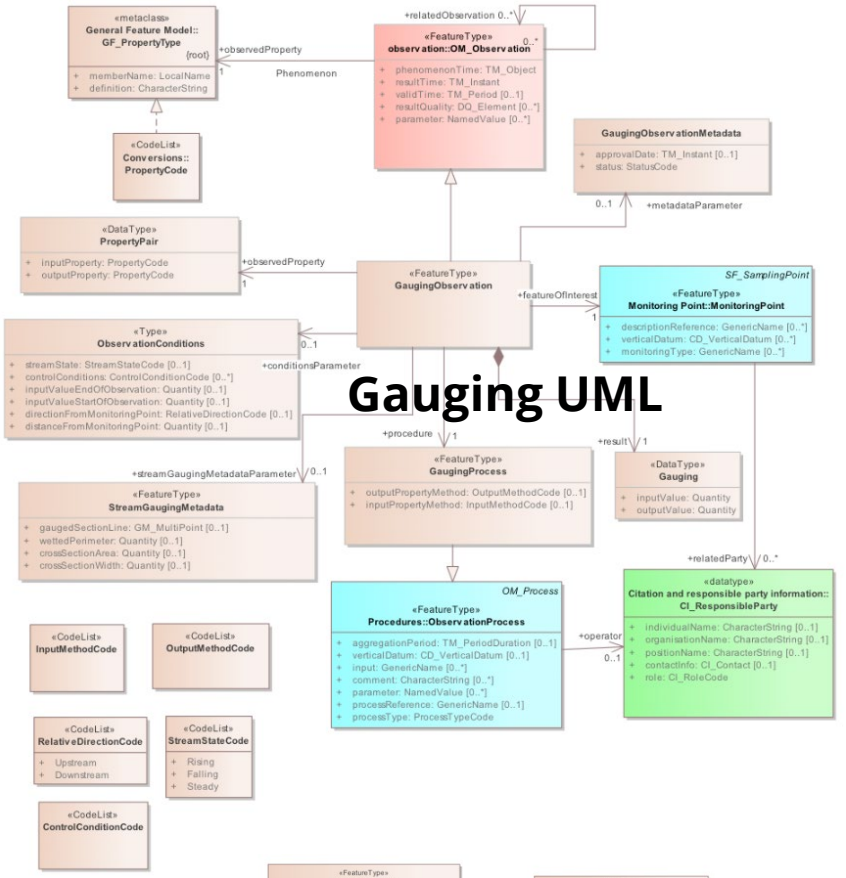
INTERNATIONAL SAVA RIVER BASIN COMMISSION

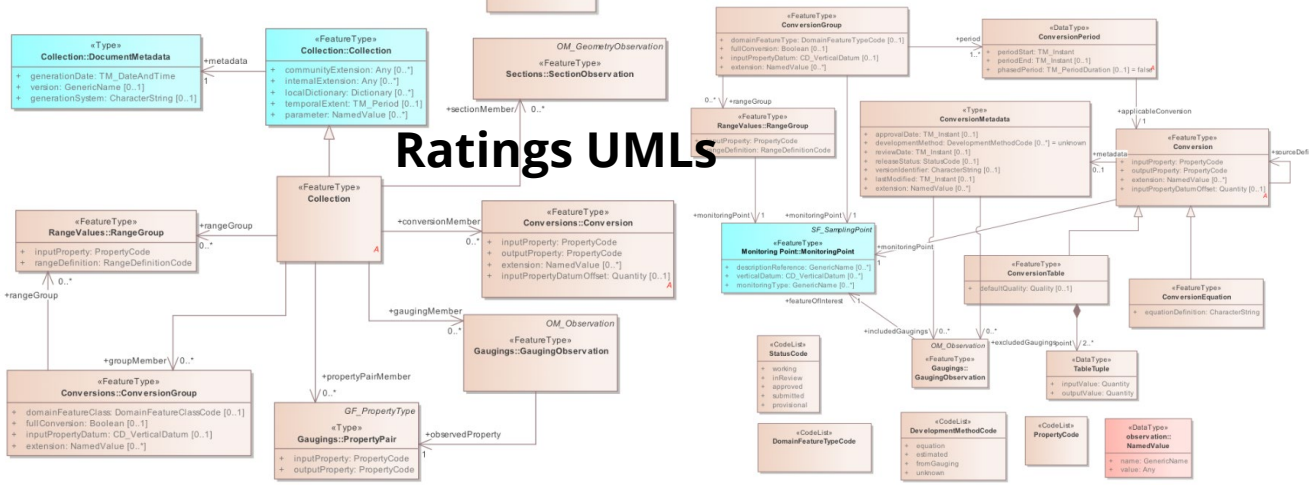
Sava HIS as the basis Hydrological Study

Statistical data standardization

Data models: WaterML 2 & OGC/ISO19156 Observation, Measurements and Samples
Web services: OGC SensorThings API

WaterML 2: Part 1 – Timeseries
WaterML 2: Part 2 – Ratings, Gaugings and Sections





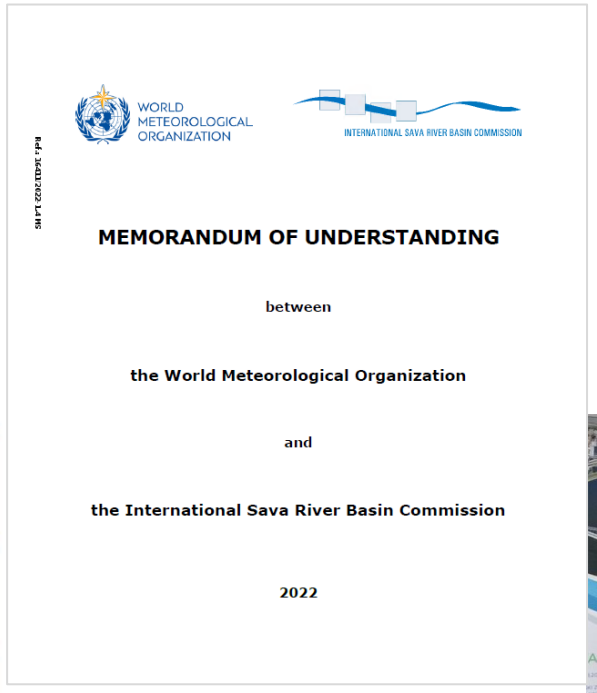
INTERNATIONAL SAVA RIVER BASIN COMMISSION

Sava HIS and WHOS

WMO OMM

INTERNATIONAL SAVA RIVER BASIN COMMISSION

WMO-ISRBC cooperation


WORLD METEOROLOGICAL ORGANIZATION

INTERNATIONAL SAVA RIVER BASIN COMMISSION

MEMORANDUM OF UNDERSTANDING

between

the World Meteorological Organization

and

the International Sava River Basin Commission

2022

- The MoU between the WMO and the ISRBC signed on September 15th, 2022
  - activities related to cooperation in joint projects and initiatives' planning and implementation
  - exchange of knowledge, experiences, good practices and results of scientific, research and development projects and
  - joint work to promote the exchange of data and information at the regional and global level

WMO OMM

Sava HIS as the WHOS pilot

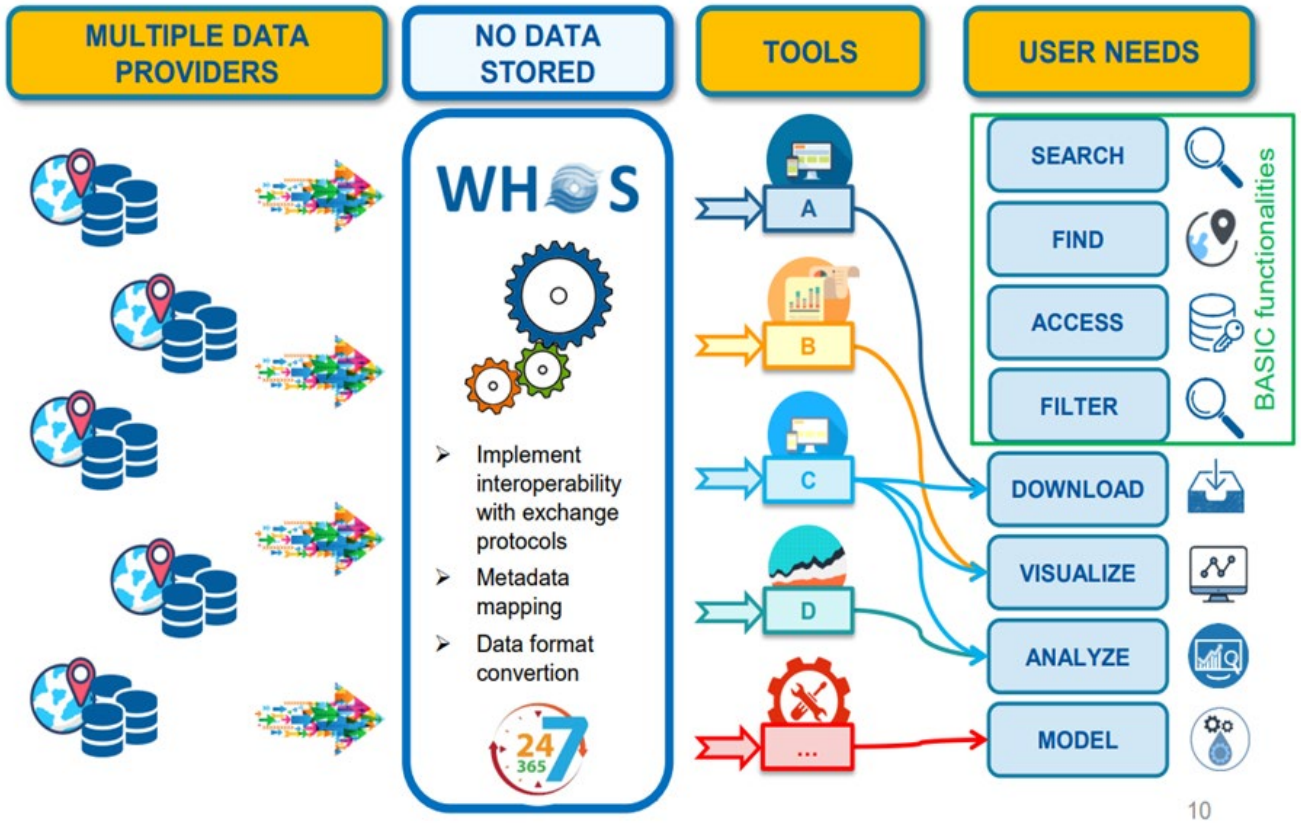
INTERNATIONAL SAVA RIVER BASIN COMMISSION

WMO OMM

- Initiative earlier presented at the 15th meeting of ISRBC's PEG HMI, January 24th, 2019, by the WMO Commission for Hydrology (CHy)
- The ISRBC at its 60th Session, June 30th – July 01st, 2022, expressed interest to collaborate in a pilot of WMO Hydrological Observing System
- The WMO informed the NMHS Directors on the WHOS initiative, September 20th, 2022

INTERNATIONAL SAVA RIVER BASIN COMMISSION

WMO Hydrological Observing System (WHOS)

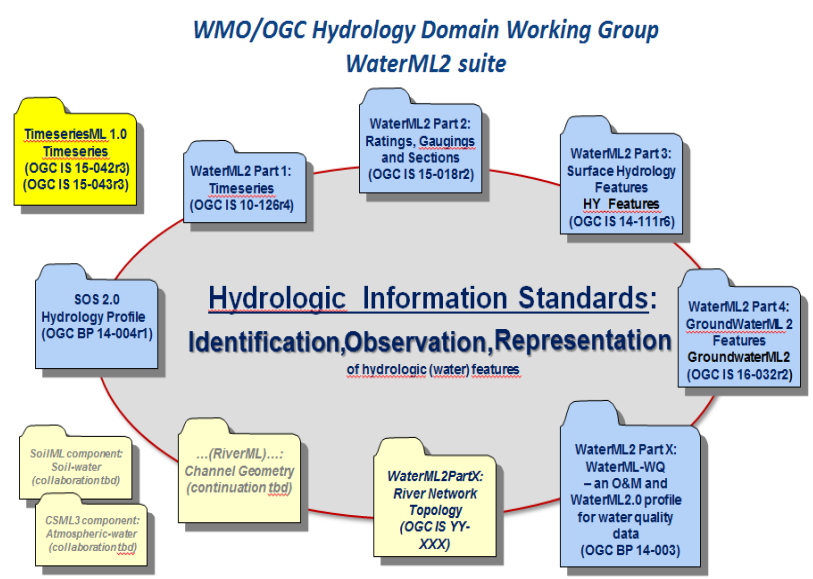


WMO OMM

- WHOS is the hydrological component of the WMO Integrated Global Observing System (WIGOS) and World Information System (WIS)
  - the main aim is to ensure the quality and comparability of observations within WIGOS and facilitate hydrological data sharing
  - the WHOS shall comprise hydrological observations, initially focusing on water level and discharge
- WHOS is a solution supporting reliable hydrological data exchange using open standards and web services by linking hydrological data providers (heterogeneous sources) and users (multiple uses) making the data discoverable, interoperable, accessible and retrievable

INTERNATIONAL SAVA RIVER BASIN COMMISSION

WMO Hydrological Observing System (WHOS)



WHOS Standardization Approach

1. Data Providers implement standards
2. WHOS brokering approach (Discovery and Access Broker, DAB) builds on standardization

WMO OMM

INTERNATIONAL SAVA RIVER BASIN COMMISSION

WMO Hydrological Observing System (WHOS)

WHOS-Plata

WHOS-Arctic

(Argentina, Bolivia, Brazil, Canada, Denmark, Finland, Iceland, Norway, Paraguay, Russia, Sweden, Uruguay, the United States, and United Kingdom)

ONGOING

- WHOS-PROHMSAT
- WHOS-FEWS
- WHOS Dominican Republic
- ISRBC's SAVA HIS
- New Zealand
- Cambodia and Lao
- NIGER Basin
- Togo
- Global Runoff Data Centre (GRDC)
- Groundwater (IGRAC)

WMO OMM

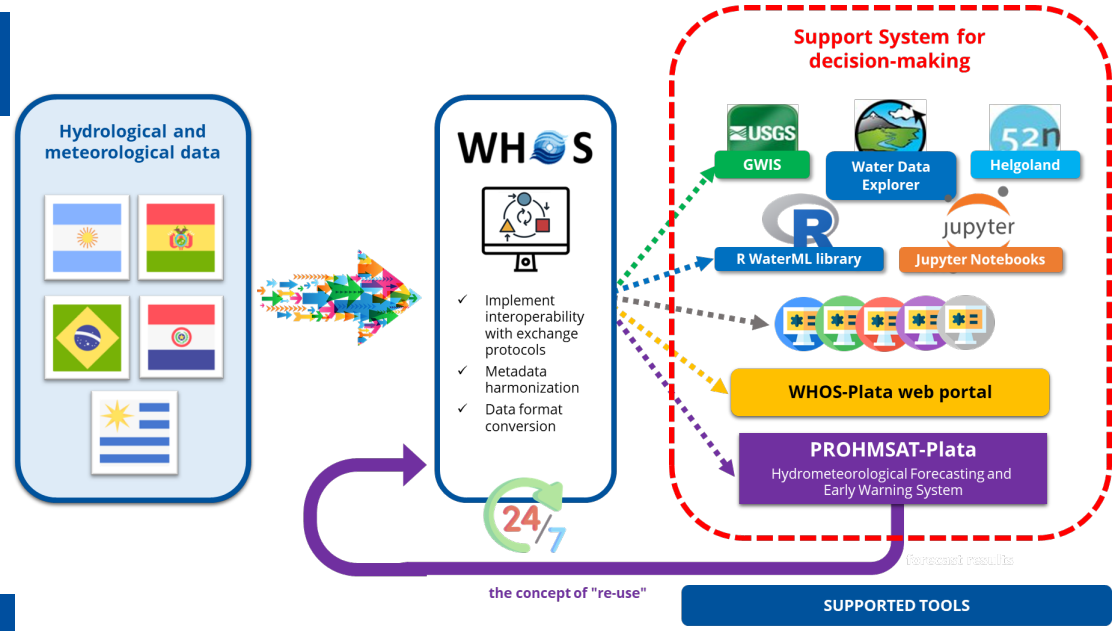
freely exchanging and reusing hydrometeorological data in an interoperable way

INTERNATIONAL SAVA RIVER BASIN COMMISSION

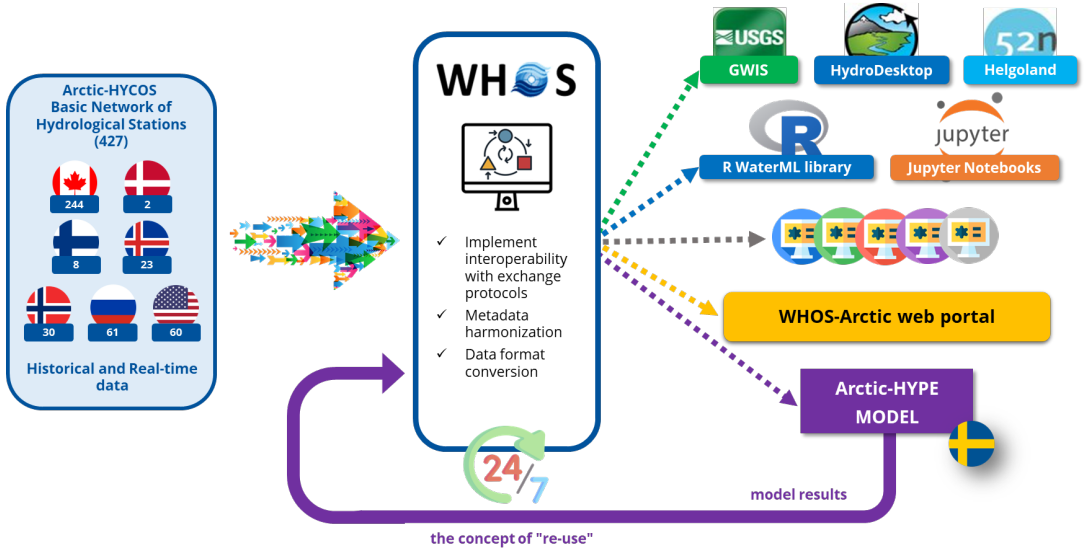
WMO Hydrological Observing System (WHOS)

WHOS-Plata

WHOS implementation: Interoperability with some applications



WHOS-Arctic

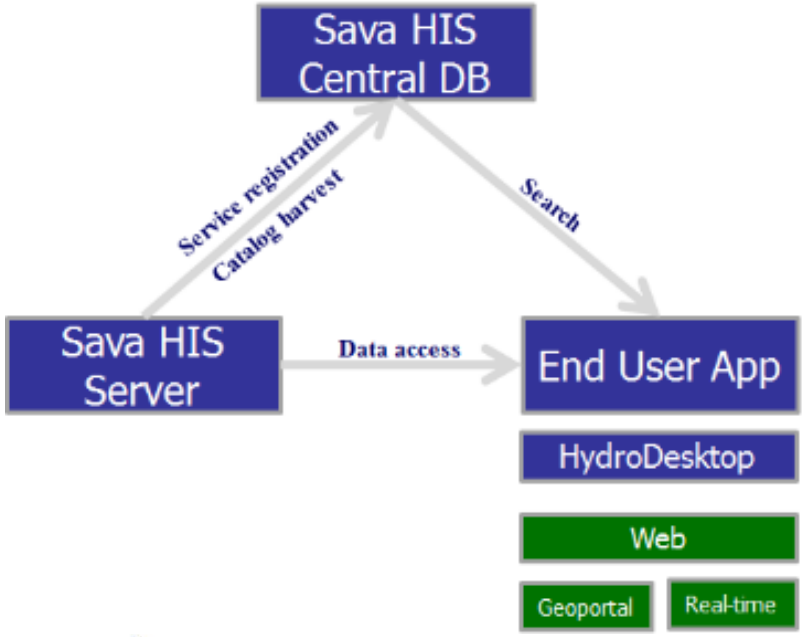


WMO OMM

INTERNATIONAL SAVA RIVER BASIN COMMISSION

Sava HIS as the WHOS pilot

WHOS-Sava implementation
Interoperability under the testing



WMO OMM

WaterML 2.0

WHOS

- ✓ Implement interoperability with exchange protocols
- ✓ Metadata harmonization
- ✓ Data format conversion

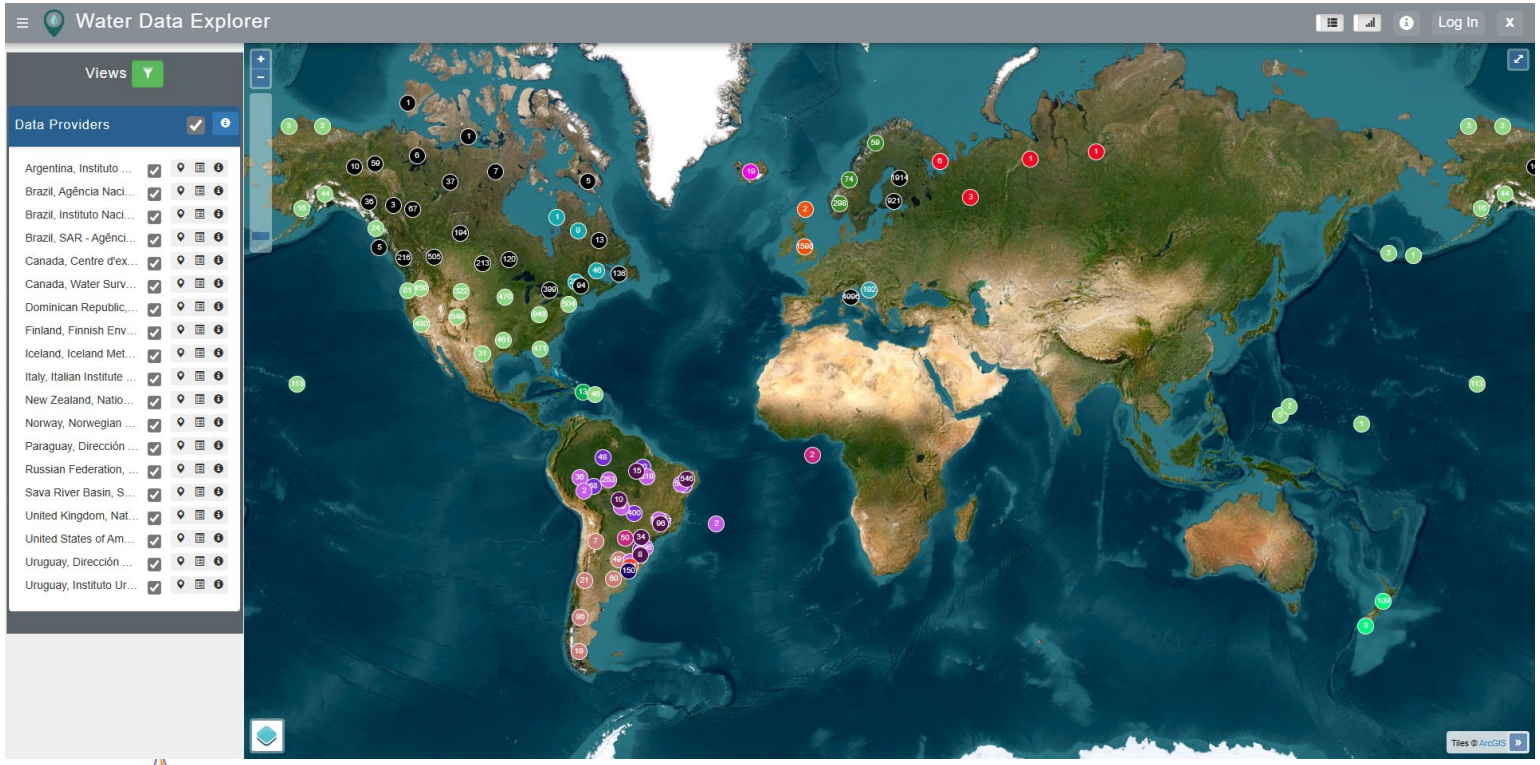
SUPPORTED TOOLS

- APPs ?
- R WaterML library
- Jupyter Notebooks
- WHOS-Global web portal
- MODELS ?

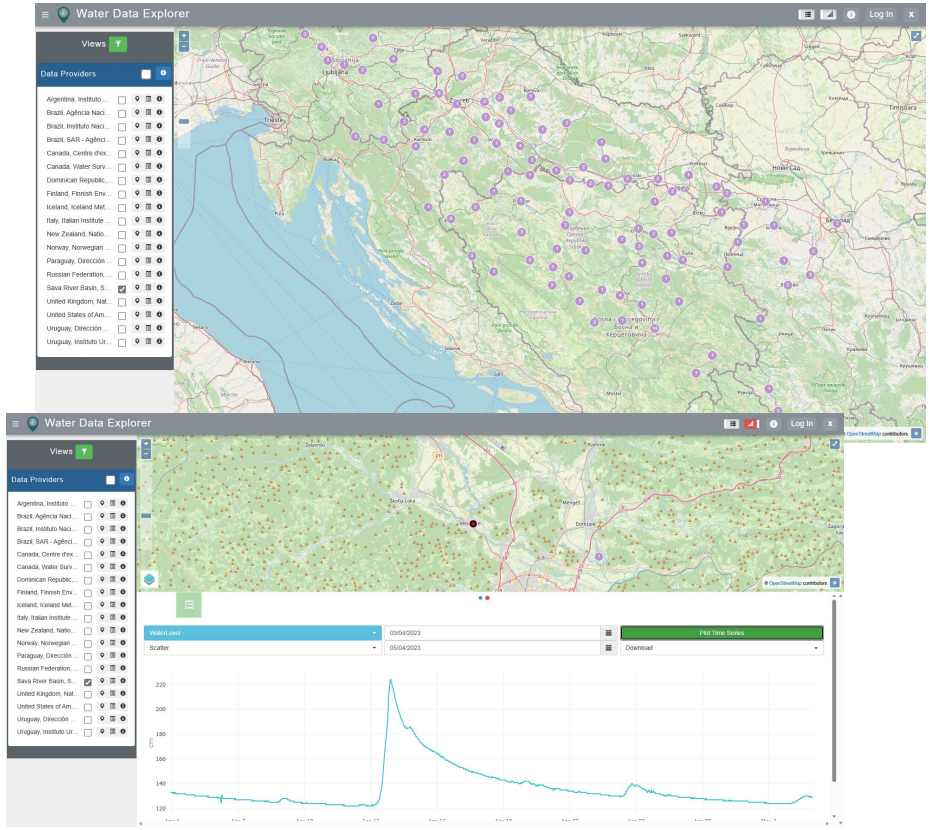
INTERNATIONAL SAVA RIVER BASIN COMMISSION

Sava HIS as the WHOS pilot

WHOS-Sava implementation



- Functionalities tested by the ISRBC's PEG HMI



WMO OMM

INTERNATIONAL SAVA RIVER BASIN COMMISSION

THANK YOU FOR YOUR ATTENTION

Mirza Sarač
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International Sava River Basin Commission

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