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Democratization of hydrological modeling and forecasting tools – Hydrological Models as a Service

PAVICS

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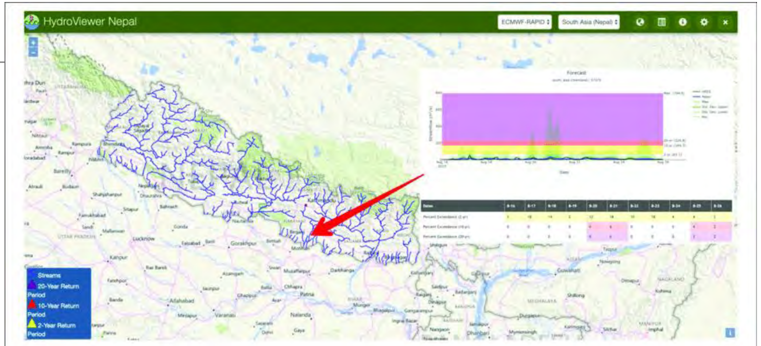
HydroDS

GEO GLOWS
GLOBAL WATER SUSTAINABILITY



(Souffront Alcantara et al. 2019)

What is HMaaS?

- Automatic hydrological model building
- Integrated provision of required data (bridges)
- Seamless integration of processes (model calibration, validation, simulation, forecasting, etc.)
- Return results in a format that is understandable and useful to users
- Centralize the computations on powerful remote clusters

What is HMaaS? - Examples

HydroDS: Distributed hydrological model including data preparation for global streamflow forecasting (Gichamo et al. 2020)

UEB-Hydroshare: A model that can be run using the HydroShare repository and frameworks for the hydrological sciences community (Gan et al. 2020)

HydroViewer: App to visualize streamflow anywhere on the globe from a hydrological model run with forecast weather data (Nelson et al. 2019)

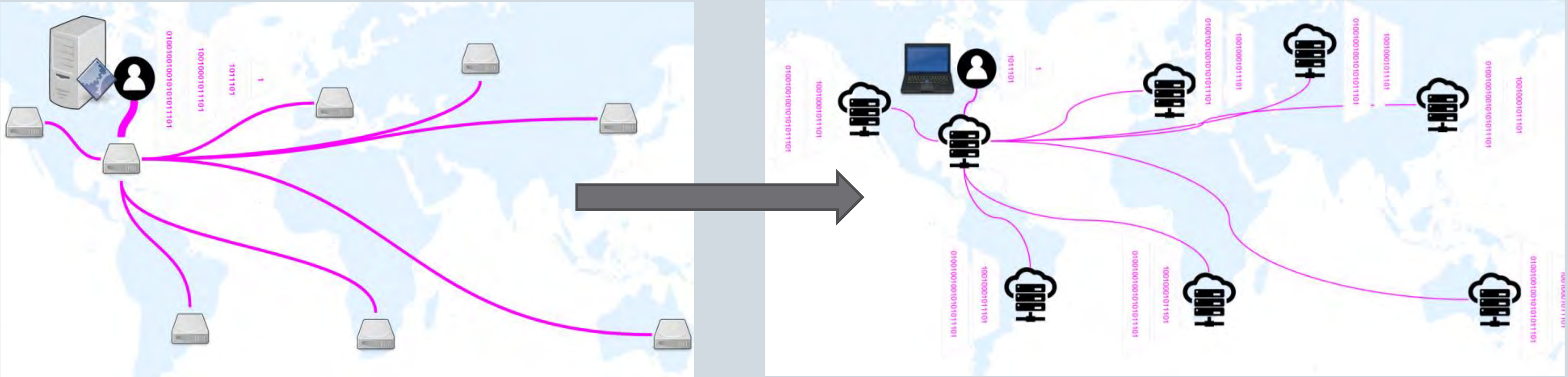
PAVICS-Hydro: Flexible hydrological modelling framework for general-use hydrology (climate change impact studies to streamflow forecasting)

Why do we want/need HMaaS?

Reduce	the local computation resources required
Increase	efficiency by spending less time on clerical tasks such as data preparation and focus on science
Train	users (students and knowledge users) more efficiently using on-line tutorials and exercises
Provide	repeatable methodologies that can be shared with others to replicate studies

Why do we want HMaaS?

Ex: Climate change impact studies - Access to, and processing of, climate model data



A 2D variable on a regional North American grid @ 22 km resolution for a daily simulation from 1950-2100 is roughly 20 Gb

ESGF Earth System Grid Federation

CMIP6 is ~10x CMIP5 which is 50x CMIP3. Processing this for hydrological modelling requires lots of computing power and storage!

Why do we want HMaaS?

Ex: Some tasks require lots of steps and manipulations, such as basin delineation

Before

How To: Create a watershed model using the Hydrology toolset

Summary
A watershed is an upslope area that contributes water flow as concentrated drainage.
This area can be delineated from a digital elevation model (DEM) using the Hydrology toolset from the Spatial Analyst toolbox.
Procedure
The following instructions provide a workflow to create a watershed model using the
Hydrology toolset from the Spatial Analyst toolbox and convert the model to watershed bounding polygons.
1.Run the Fill tool.
a. In ArcCatalog, navigate to Toolboxes > System Toolboxes > Spatial Analyst Tools > Hydrology > Fill.
b. Use a digital elevation model (DEM) as the 'Input surface raster'.
c. Verify the path name for the 'Output surface raster'.
d. Input the Z-limit, if necessary.
e. Click OK.
2.Run the Flow Direction tool.
a. In ArcCatalog, navigate to Toolboxes > S em Toolb s > Spatial Analyst Tools ydrology > Flow Direction.
b. Use the DEM output from Step 1 as the put surfac ster'.
c. Verify the path name for the 'Output fl ter'.
d. Click OK.
Run the Flow Accumulation tool.
a. In ArcCatalog, navigate to Toolboxes > S em Toolb > Sp al Analy ools ydro > Flow umu on.
b. Use the output raster from Step 2 as th ection
c. Verify the path name for the 'Output accumulation raster'.
d. Click OK.
Run the Snap Pour Point tool to locate the pour points to cells of high accumulated flow.
a. In ArcCatalog, navigate to Toolboxes > System Toolboxes > Spatial Analyst Tools > Hydrology > Snap Pour Points.
b. Either input a point feature class or a raster as the 'Input raster or feature pour point data'.
Note:
Cells that are not NoData (cells with values) are considered pour points and are snapped if a raster input is used, while a point feature input specifies the locati
c. Use the output raster from Step 3 as the 'Input accumulation raster'.
d. Verify the path name for the 'Output raster'.
e. Click OK.
Note:
Pour points are points at which water flows out of an area, usually the outlet or re-entrant locations from the flow accumulation. The Snap Pour Point tool snaps
Run the Watershed tool.
a. In ArcCatalog, navigate to Toolboxes > System Toolboxes > Spatial Analyst Tools > Hydrology > Watershed.
b. Use the output raster from Step 2 as the 'Input flow direction raster'.
c. Use the output from Step 4 as the 'Input raster or feature pour point data'.
d. Verify the path name for the 'Output raster'.
e. Click OK.
5.Run the 'Raster to Polygon' tool to create polygon features from the watershed raster.
a. In ArcCatalog, navigate to Toolboxes > System Toolboxes > Conversion Tools > From Raster > Raster to Polygon.
b. Use the output from Step 5 as the 'Input raster'.
c. Verify the path name for the 'Output polygon features'.
d. Click OK.

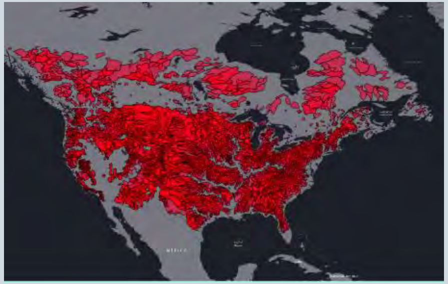
After: Click and done

PAVICS-Hydro – Our contribution to HMaaS

Integrate hydrological modelling and prediction tools in PAVICS to better understand the impacts of climate change on water resources availability in Canada and in the United States, and eventually on a global scale.

- Implements the RAVEN hydrological model (U.Waterloo)
- Prediction in ungauged basins
- Calibration algorithms
- Stream flow time series analysis and frequency analysis
- Hydrological forecasting research
- Automated distributed hydrological model building

Raven



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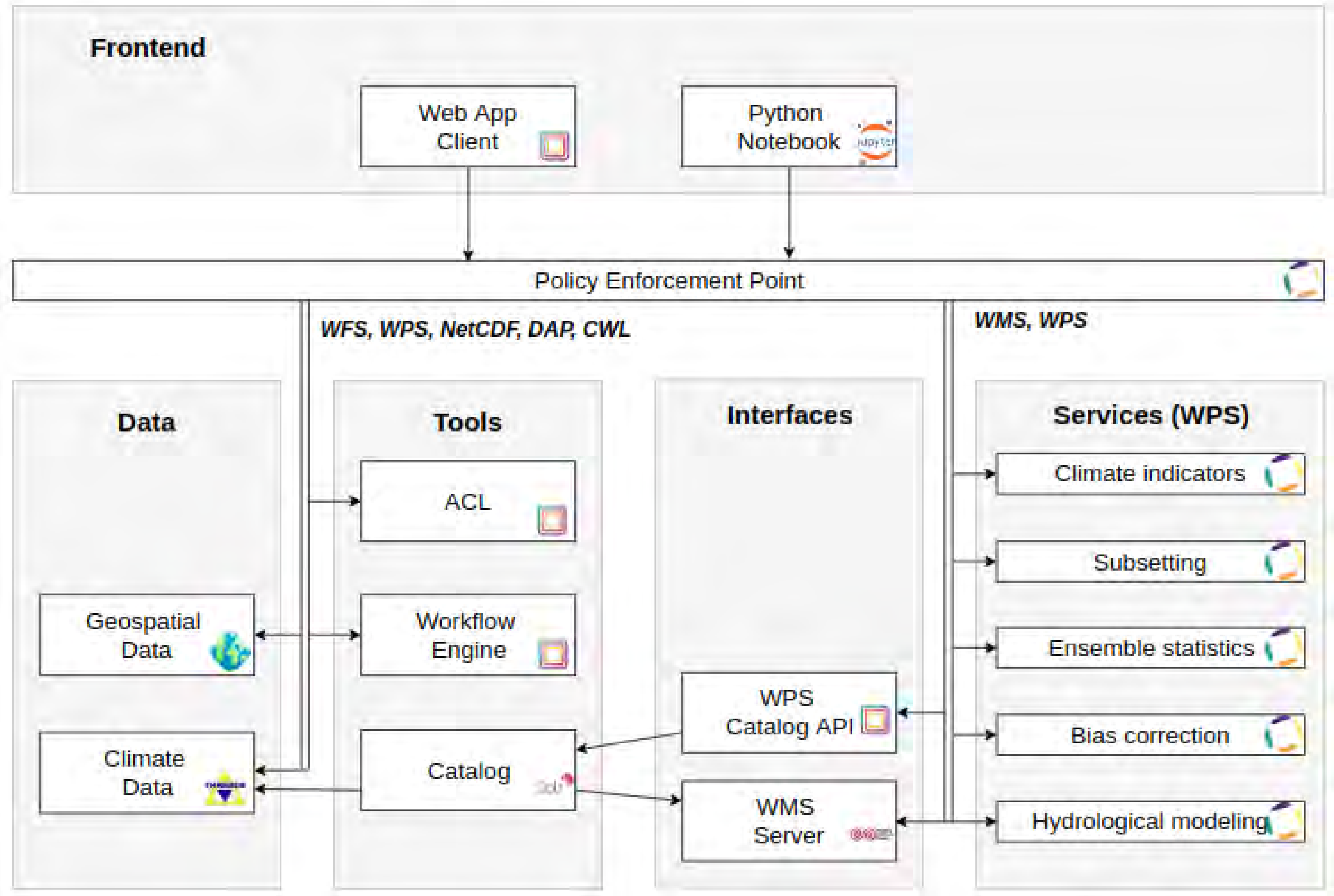
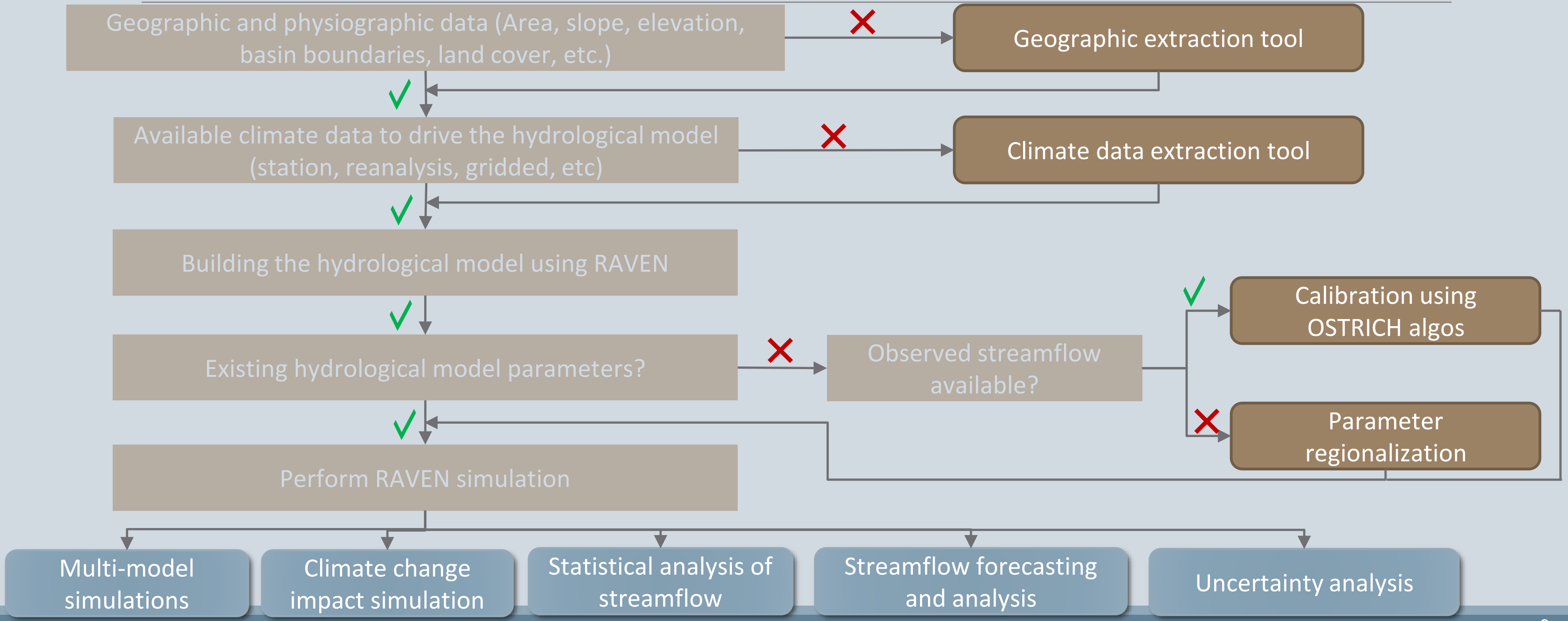

Frontend
Web App Client
Python Notebook
Policy Enforcement Point
WFS, WPS, NetCDF, DAP, CWL
WMS, WPS
Data
Geospatial Data
Climate Data
Tools
ACL
Workflow Engine
Catalog
Interfaces
WPS Catalog API
WMS Server
Services (WPS)
Climate indicators
Subsetting
Ensemble statistics
Bias correction
Hydrological modeling

PAVICS-Hydro – Component chart



PAVICS-Hydro - Components

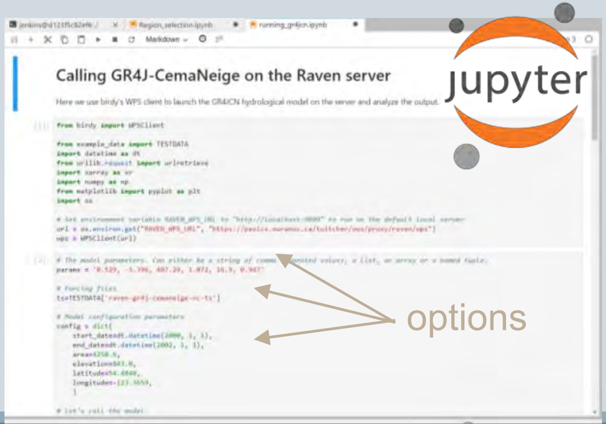
- Watershed modeling

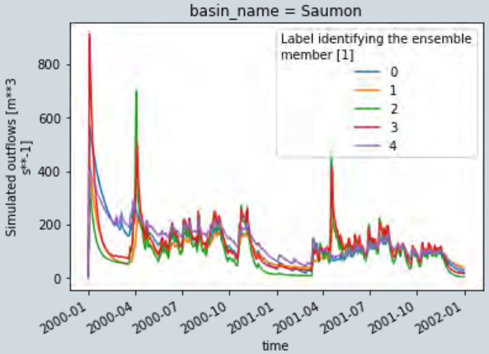
1- Uses the RAVEN framework

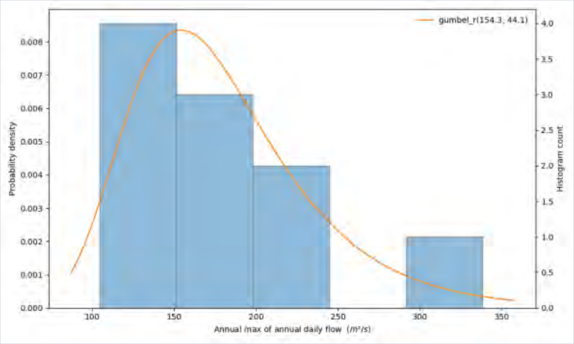
2- As of now, 4 hydrological models are emulated: HMETS, MOHYSE, HBV and GR4J

3- All you need is a RAVEN input file (built by PAVICS-Hydro!) to setup the model

4- Uses a Jupyter Notebook to launch simulations and collect results (including RAVEN config files for local analysis. Returns figures and simulation NetCDF files.







OUTPUT: https://pavics.ouranos.ca/wpsoutputs/881192e6-1af5-11ea-8db8-0242ac120002/raven-gr4j-cemaneige-sim-0_Hydrographs.nc

PAVICS-Hydro – Userbase

- Research groups in hydrology and hydroclimatology
  - Possible to test ideas quickly with little resource allocation
  - Capacity to share workflows and methodology with colleagues and/or in publications
  - Accelerated student training
  - Calculations are performed on our servers, so fewer resources required
- Research groups in other related fields
  - Environment, Ecology, Biology, hydrogeology, etc.
  - Simple tool to obtain streamflow timeseries to drive domain-specific models = faster research
- RAVEN users: Hydropower utilities, consultants, independent researchers
  - Fast and efficient RAVEN model building for specific applications
  - Ability to quickly change model configurations

Modular and Open-source framework

- Completely open-source code, available to all
- Custom workflows that are repeatable, sharable and publishable
- All codes and datasets respect ESGF and OGC conventions, for maintenance and compatibility
- Free to use, just need to register for an account!

Conclusion

HMaaS has started the democratization of using hydrological modelling tools

Users with limited background can start exploring the modelling chain and improve their understanding of processes through tutorials

Researchers can use HMaaS to improve their workflow and efficiency

The hydrological community as a whole can benefit from this type of collaboration and integration

Links

Platform: pavics.ouranos.ca/jupyter

Documentation @ ouranosinc.github.io/pavics-sdi/

Code @ github.com/Ouranosinc

Docker images @ hub.docker.com/u/pavics/

Contact: pavics@ouranos.ca

References

Gan, T., Tarboton, D.G., Dash, P., Gichamo, T.Z. and Horsburgh, J.S., 2020. Integrating hydrologic modeling web services with online data sharing to prepare, store, and execute hydrologic models. *Environmental Modelling & Software*, p.104731.

Gichamo, T.Z., Sazib, N.S., Tarboton, D.G. and Dash, P., 2020. HydroDS: Data services in support of physically based, distributed hydrological models. *Environmental Modelling & Software*, *125*, p.104623.

Souffront, M.A., Nelson, J., Shakya, K., Edwards, C., Roberts, W., Krewson, C., Ames, D.P., Jones, N.L. and Gutierrez, A., 2019. Hydrologic Modeling as a Service (HMaaS): A New Approach to Address Hydroinformatic Challenges in Developing Countries. *Frontiers in Environmental Science*, *7*, p.158.