PAVICS-Hydro Kick-off Meeting

– RAVEN I/O, implementation and use –

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ÉTS Montreal

October 10, 2018

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Outline

1. RAVEN code and compilation
2. RAVEN setup files
3. RAVEN data formats
   - inputs: forcing & calibration data
   - outputs
4. RAVEN template setups for GR4J, MOHYSE, and HMETS

5. OSTRICH introduction
6. OSTRICH template setups for GR4J, MOHYSE, and HMETS

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RAVEN code and compilation

RAVEN in ASCII mode:

- download source code from `http://raven.uwaterloo.ca/Downloads.html`
- compile via `make`

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RAVEN with NetCDF support:

- install NetCDF library
- check path of NetCDF library in Makefile
- make sure `CXXFLAGS += -Dnetcdf` is set in Makefile
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open SVN code on CHyMS portal
↷ `https://chyms.nrc.gc.ca`

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RAVEN setup files

Five setup files:

1. `modelname.rvi` – the primary model input file
   - numerical algorithm options (start time, time step, duration, etc.)
   - model structure

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RAVEN setup files

Five setup files:

1. `modelname.rvi` – the primary model input file
   - numerical algorithm options (start time, time step, duration, etc.)
   - model structure
2. `modelname.rvh` – the HRU/ basin definition file
   - number and properties of subbasins and HRUs and their connection
   - land use/type, vegetation class, aquifer class, and soil classes specified for each HRU

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RAVEN setup files

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   - specifies most of model parameters (grouped into classes)

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4. `modelname.rvt` – the time series/ forcing function file
   - specifies temperature, precipitation, and other environmental forcings

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2. `modelname.rvh` – the HRU/ basin definition file
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3. `modelname.rvp` – the class parameters file
   - specifies most of model parameters (grouped into classes)
4. `modelname.rvt` – the time series/ forcing function file
   - specifies temperature, precipitation, and other environmental forcings
5. `modelname.rvc` – the initial conditions file
   - specifies initial conditions for all state variables in all HRUs and subbasins

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RAVEN data formats
– forcing data (ASCII) –

*.rvt

ASCII mode:

```
# meteorological forcings
:Gauge
   :Latitude    54.4848
   :Longitude -123.3659
   :Elevation  843.0
   :MultiData
      <YYYY-MM-DD> <HH:MM:SS> <time step in days> <# data points>
      :Parameters  RAINFALL    SNOWFALL    TEMP_DAILY_AVE
      :Units       mm/d        mm/d        C
                   0.000000    0.000000    -12.991528
                   ...
   :EndMultiData
:EndGauge
```


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RAVEN data formats
– forcing data (ASCII) –

*.rvt

ASCII mode:

`:MultiData-:EndMultiData` block usually moved to separate file and linked in `modelname.rvt` as:

```
# meteorological forcings
:Gauge
   :Latitude    54.4848
   :Longitude -123.3659
   :Elevation  843.0
   :RedirectToFile data_obs/meteo_daily.rvt
:EndGauge
```


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RAVEN data formats
– forcing data (NetCDF) –

*.rvt

NetCDF mode (NetCDF file contains time series per gauge):

```
:Gauge meteorological forcings
   :Latitude    54.4848
   :Longitude -123.3659
   :Elevation  843.0
   :Data RAINFALL mm/d
      :ReadFromNetCDF
         :FileNameNC      data_obs/meteo_daily.nc
         :VarNameNC       rain
         :DimNamesNC      [nstations] time
         :StationIdx      [ID of station of interest (starts with 1)]
         :TimeShift       0.0
         :LinearTransform 1.0 0.0
      :EndReadFromNetCDF
   :EndData
   ...
:EndGauge
```


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RAVEN data formats
– forcing data (NetCDF) –

*.rvt

NetCDF mode (NetCDF file contains forcings at multiple stations):

```
:StationForcing maximum_temperature
   :ForcingType      TEMP_MAX
   :FileNameNC       data_obs/meteo_daily_gridded_2d.nc
   :VarNameNC        temp_max
   :DimNamesNC       nstations ntime
   :TimeShift        0.0
   :LinearTransform  1.0 0.0
   :RedirectToFile   GriddedForcings_2D.txt
:EndStationForcing
```


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RAVEN data formats
– forcing data (NetCDF) –

*.rvt

NetCDF mode (NetCDF file contains gridded forcings):

```
:GriddedForcing maximum_temperature
   :ForcingType      TEMP_MAX
   :FileNameNC       data_obs/meteo_daily_gridded_3d.nc
   :VarNameNC        temp_max
   :DimNamesNC       nlon nlat ntime   # must be in the order of (x,y,t)
   :TimeShift        0.0
   :LinearTransform  1.0 0.0
   :RedirectToFile   GriddedForcings_3D.txt
:EndGriddedForcing
```


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RAVEN data formats
– calibration data (ASCII) –

*.rvt

ASCII mode:

```
:ObservationData HYDROGRAPH <subbasin-id> m3/s
   <YYYY-MM-DD> <HH:MM:SS> <time step in days> <# data points>
   5.78
   5.66
   -1.2345   # nodata value
   ...
:EndObservationData
```

usually moved to separate file and linked in `modelname.rvt` as:

```
:RedirectToFile data_obs/Qobs_daily.rvt
```


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RAVEN data formats
– calibration data (NetCDF) –

*.rvt

NetCDF mode:

```
:ObservationData HYDROGRAPH <subbasin-id> m3/s
   :ReadFromNetCDF
      :FileNameNC      data_obs/meteo_daily.nc
      :VarNameNC       qobs
      :DimNamesNC      [nstations] time
      :StationIdx      [ID of station of interest (starts with 1)]
   :EndReadFromNetCDF
:EndObservationData
```


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RAVEN data formats
– outputs (ASCII) –

*.rvi

default outputs:

- `Hydrographs.csv`
- `WatershedStorage.csv`
- `solution.rvc`
- `RavenErrors.txt`

custom outputs: (set in *.rvi)

- set `:EvaluationMetrics <list of metrics>`
  ↷ `Diagnostics.csv`
- set `:WriteForcingFunctions`
  ↷ `ForcingFunctions.csv`
- set `:WriteMassBalanceFile`
  ↷ `WatershedMassEnergyBalance.csv`

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RAVEN data formats
– outputs (ASCII) –

*.rvi

some helpful output flags:

- `:SilentMode`
  minimizes terminal output (good for calibration mode)
- `:NoisyMode`
  maximizes terminal output (good for debugging)
- `:SuppressOutput`
  nothing but `Diagnostics.csv` is written to file
  (good for calibration mode)
- `:WriteNetcdfFormat yes`
  default outputs `Hydrographs.nc` and `WatershedStorage.nc` are written in NetCDF format

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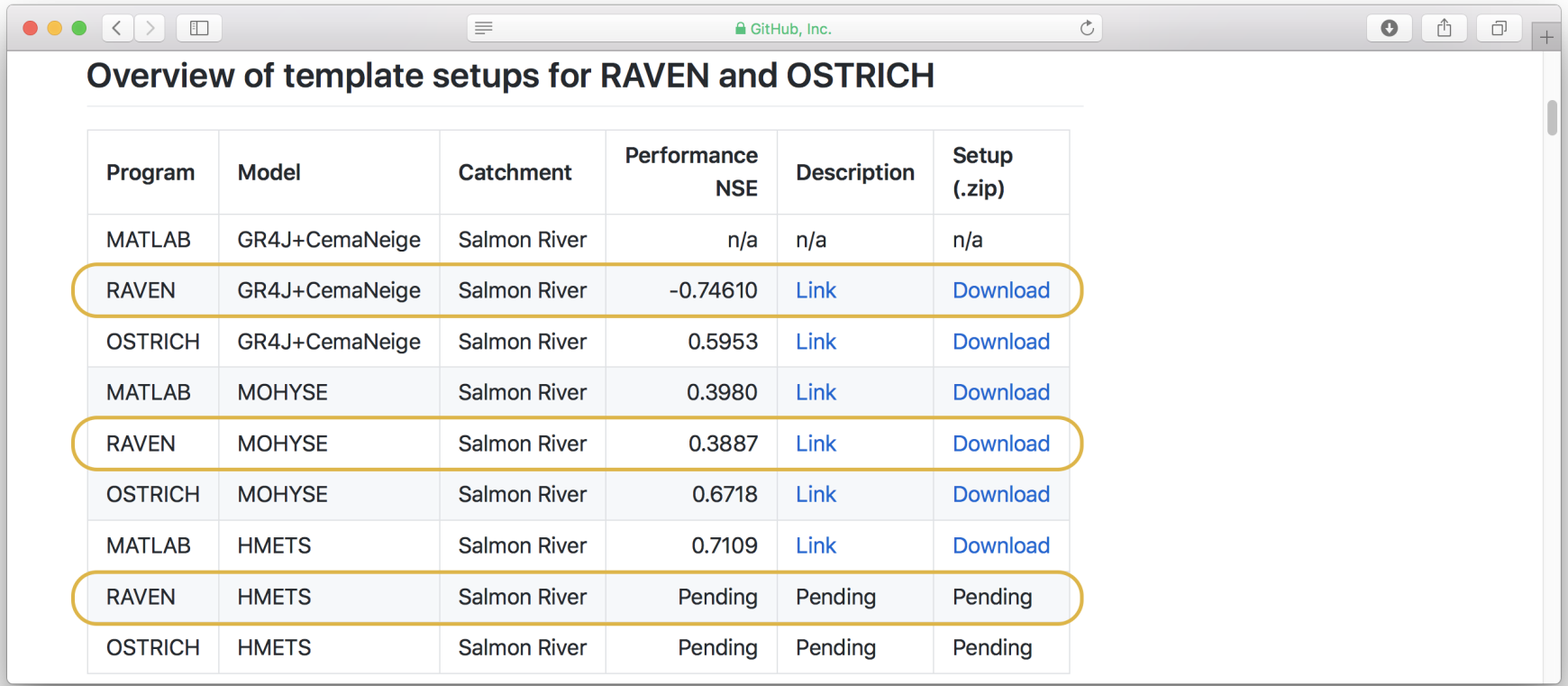
Run RAVEN

– GR4J, MOHYSE, and HMETS model –

template RAVEN setups can be found here

↷ https://github.com/Ouranosinc/raven/wiki/Technical-Notes



Overview of template setups for RAVEN and OSTRICH

Program	Model	Catchment	Performance NSE	Description	Setup (.zip)
MATLAB	GR4J+CemaNeige	Salmon River	n/a	n/a	n/a
RAVEN	GR4J+CemaNeige	Salmon River	-0.74610	Link	Download
OSTRICH	GR4J+CemaNeige	Salmon River	0.5953	Link	Download
MATLAB	MOHYSE	Salmon River	0.3980	Link	Download
RAVEN	MOHYSE	Salmon River	0.3887	Link	Download
OSTRICH	MOHYSE	Salmon River	0.6718	Link	Download
MATLAB	HMETS	Salmon River	0.7109	Link	Download
RAVEN	HMETS	Salmon River	Pending	Pending	Pending
OSTRICH	HMETS	Salmon River	Pending	Pending	Pending

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Run RAVEN

– GR4J, MOHYSE, and HMETS model –

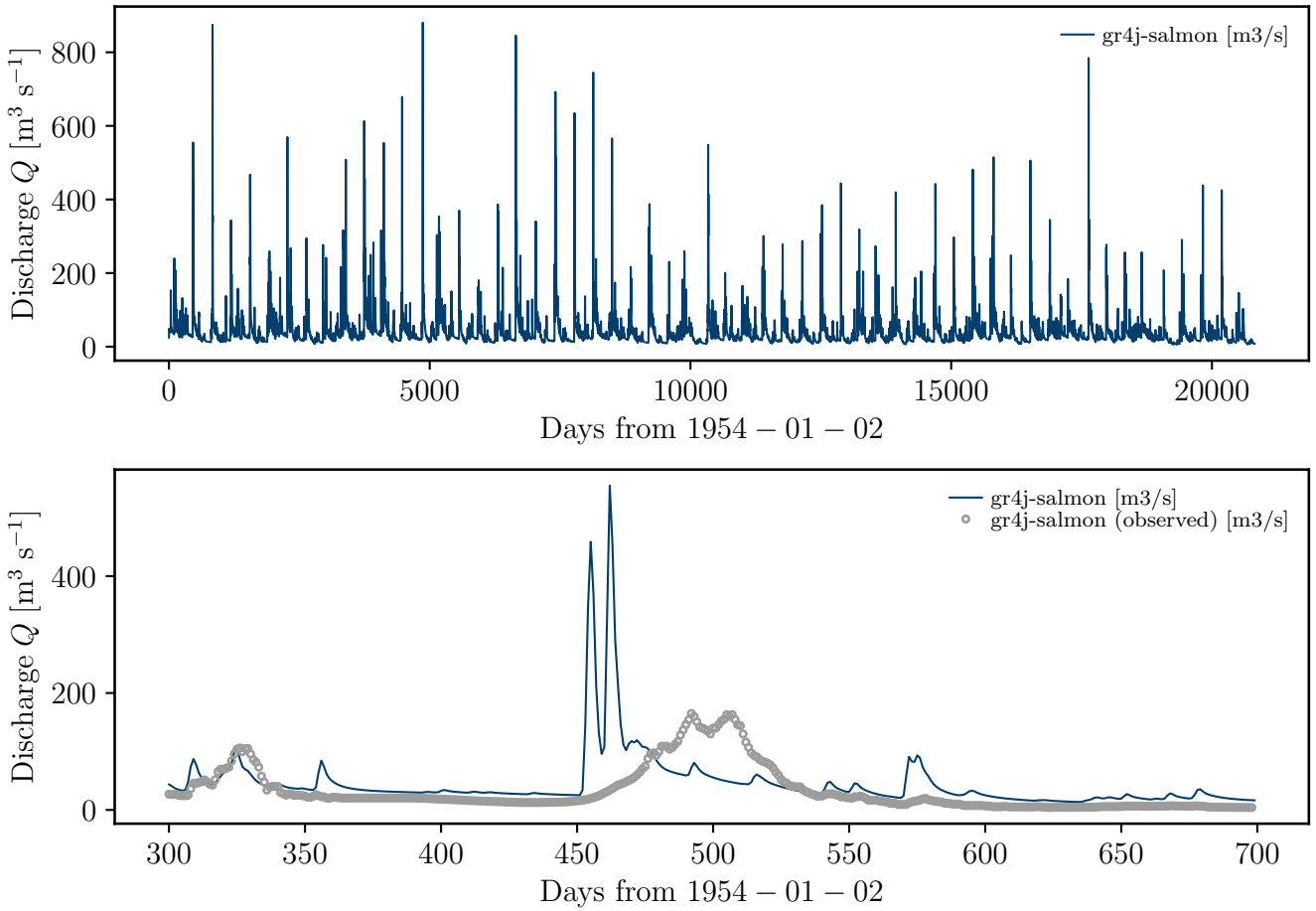

Figure: GR4J+CemaNeige run for Salmon River watershed using RAVEN

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Run RAVEN

– GR4J, MOHYSE, and HMETS model –

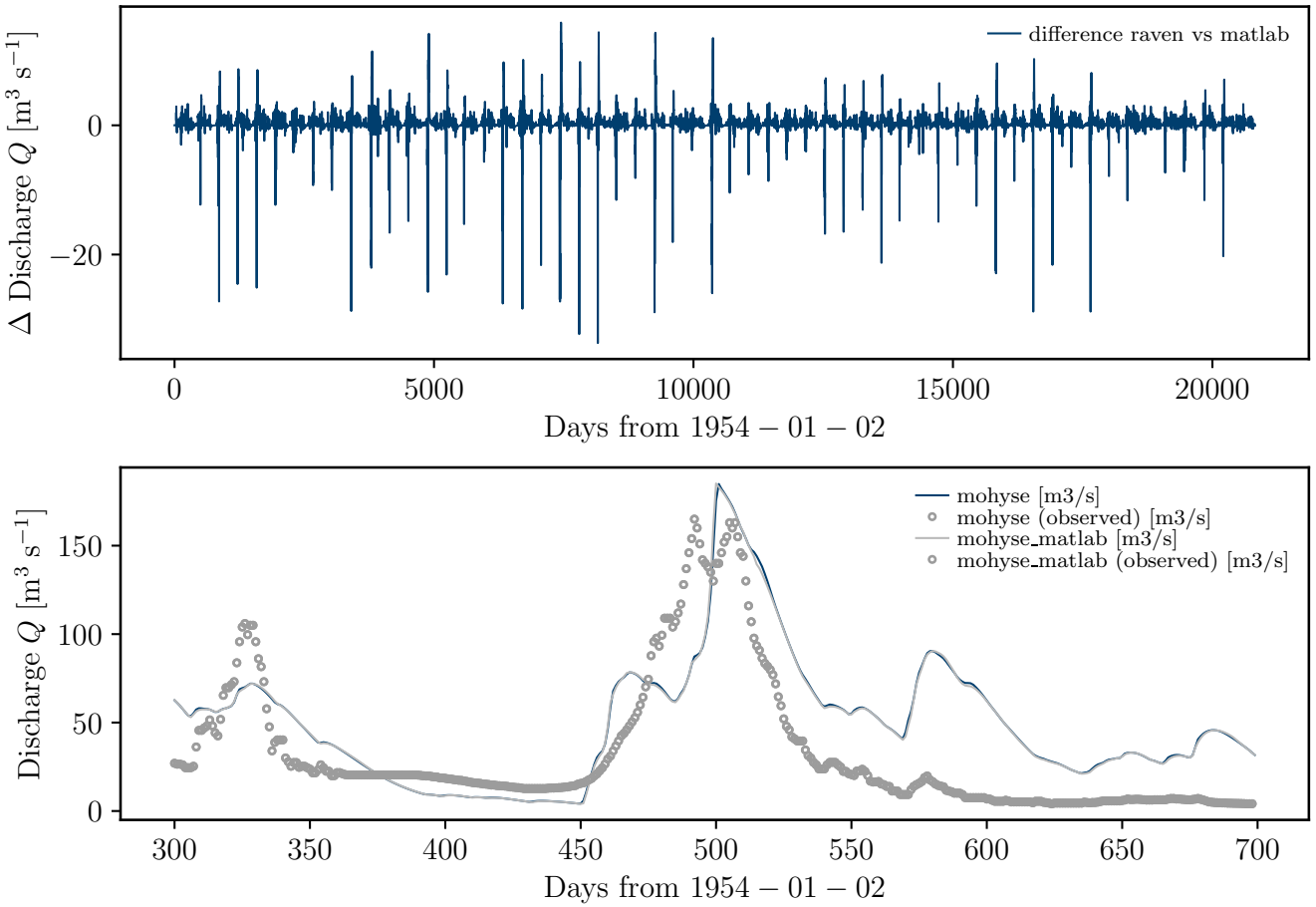

Figure: MOHYSE run for Salmon River watershed comparing MATLAB and RAVEN

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Run RAVEN

– GR4J, MOHYSE, and HMETS model –

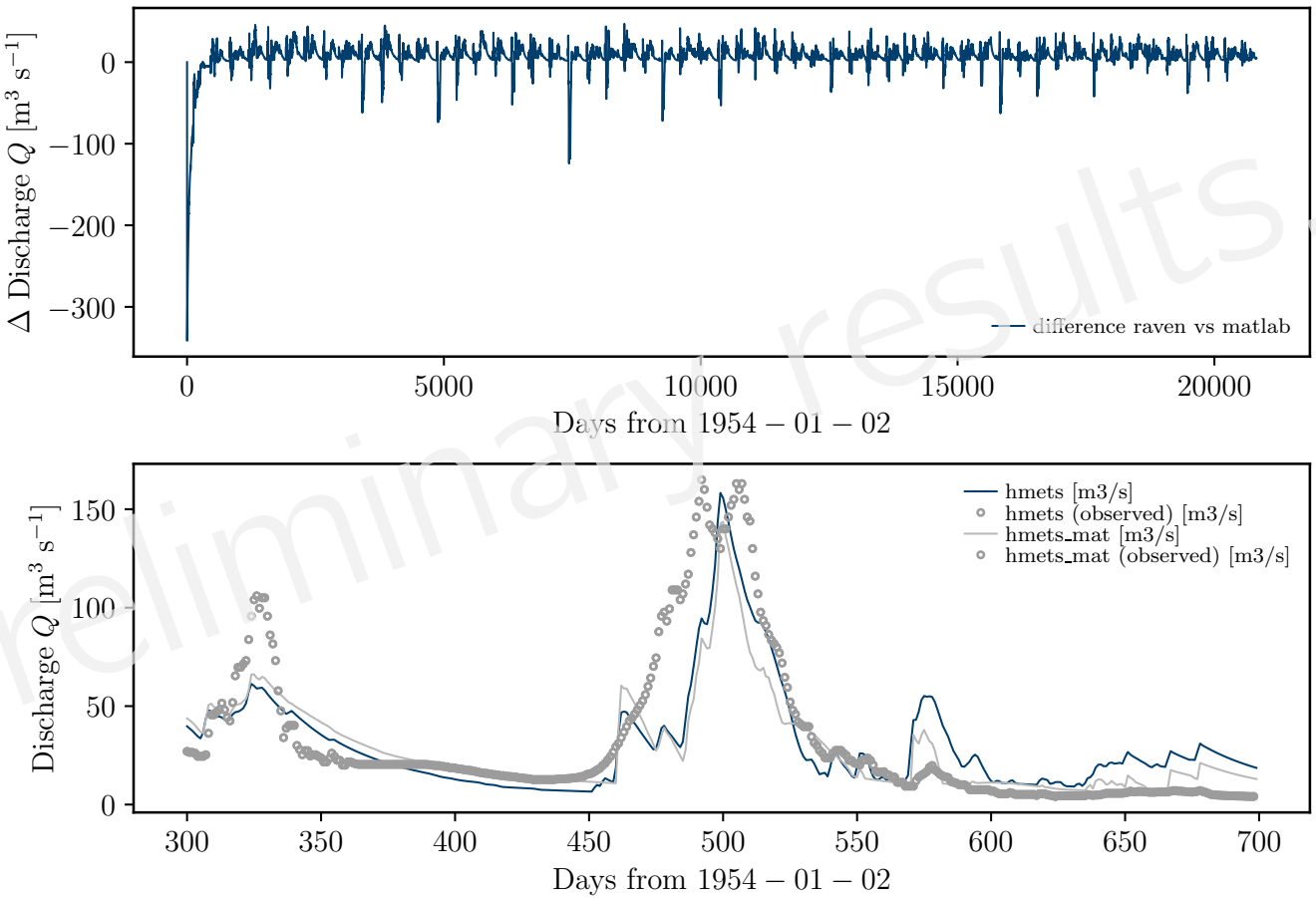

Figure: HMETS run for Salmon River watershed comparing MATLAB and RAVEN

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Run RAVEN

– GR4J, MOHYSE, and HMETS model –

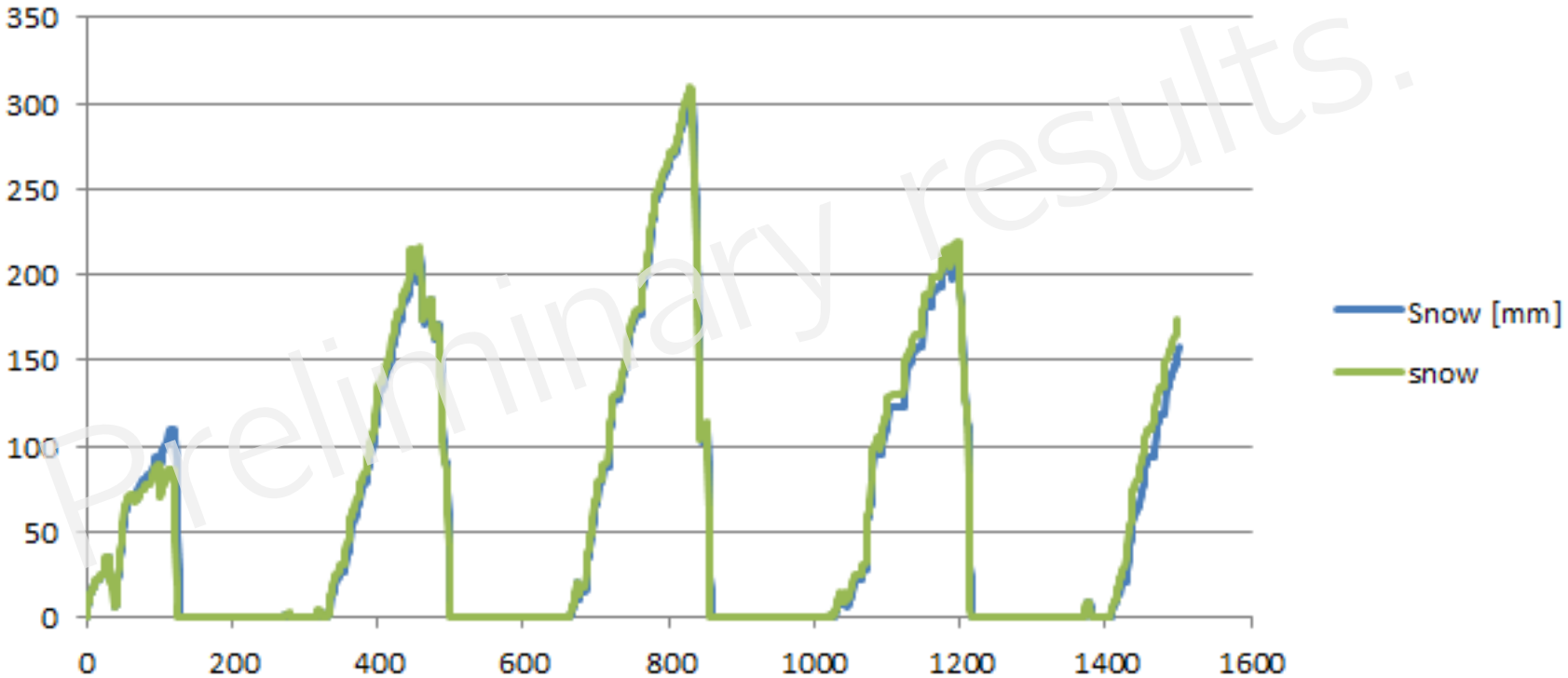

Figure: HMETS run for Salmon River watershed comparing MATLAB and RAVEN

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Run RAVEN

– GR4J, MOHYSE, and HMETS model –

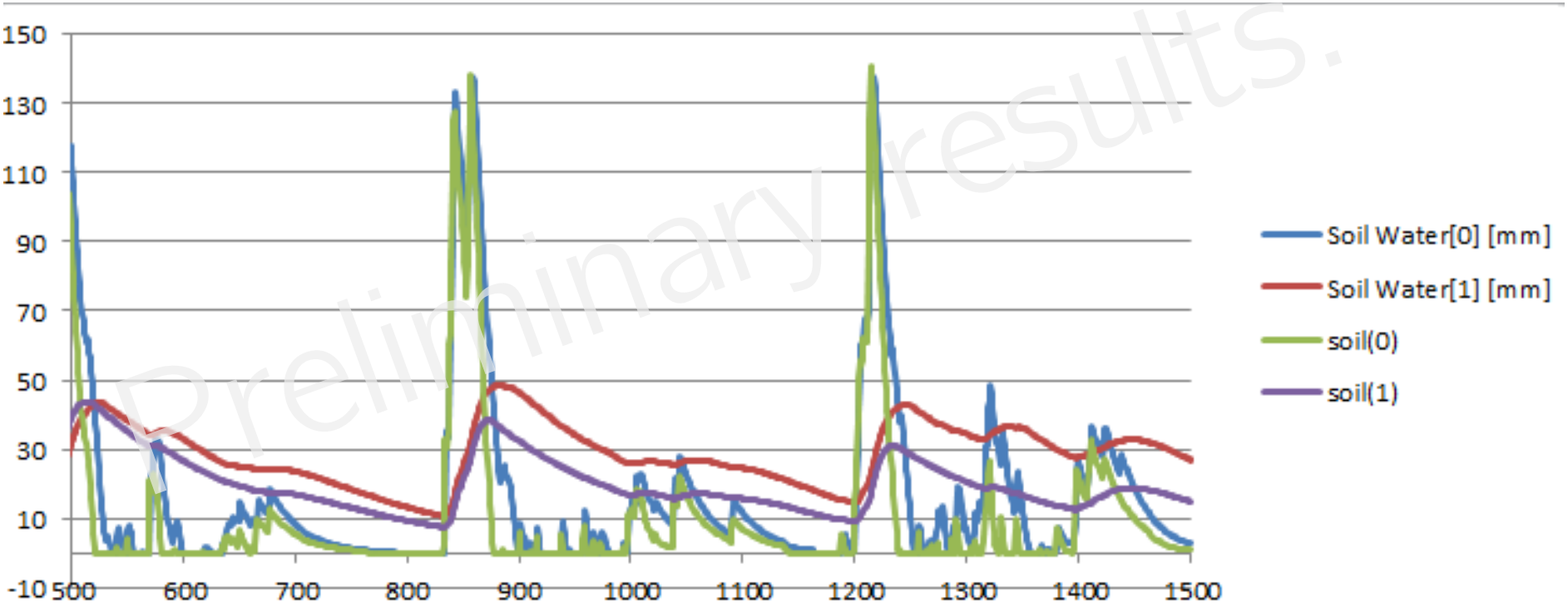

Figure: HMETS run for Salmon River watershed comparing MATLAB and RAVEN

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OSTRICH

(Hydrologic) Model

RAVEN
GR4J
MOHYSE
CEQUEAU
...

Optimizer

DDS
PA-DDS
Nelmin
SCE
...

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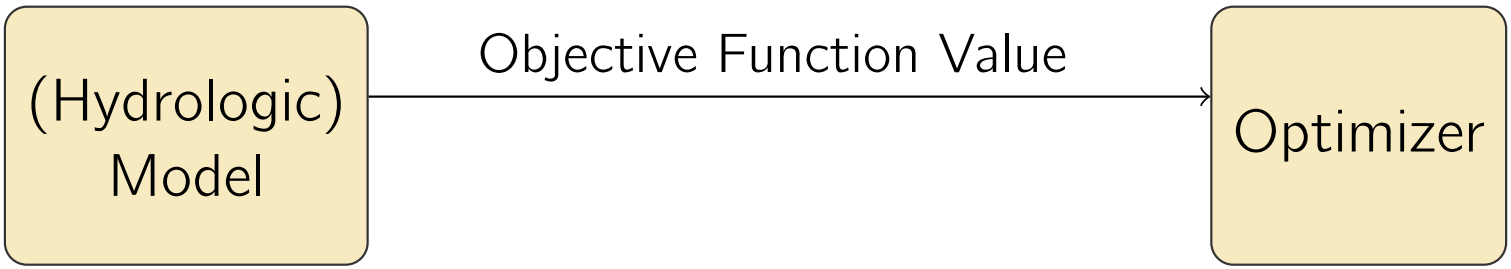
OSTRICH



RAVEN
GR4J
MOHYSE
CEQUEAU
...

DDS
PA-DDS
Nelmin
SCE
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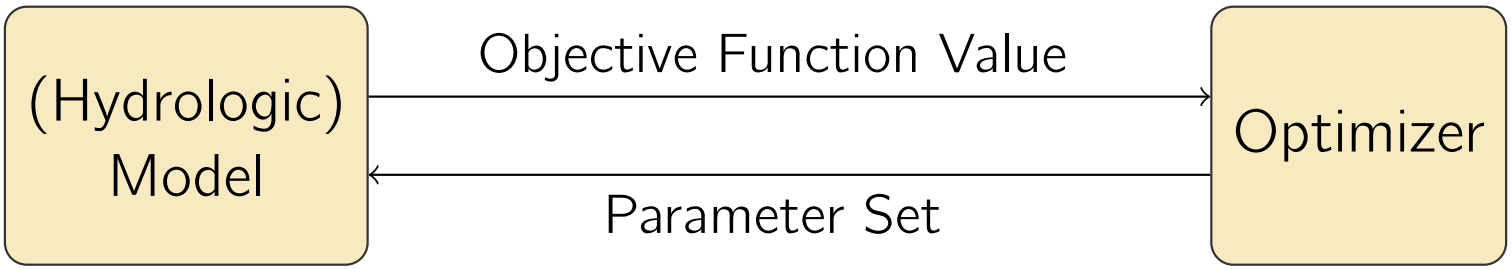
OSTRICH



RAVEN
GR4J
MOHYSE
CEQUEAU
...

DDS
PA-DDS
Nelmin
SCE
...

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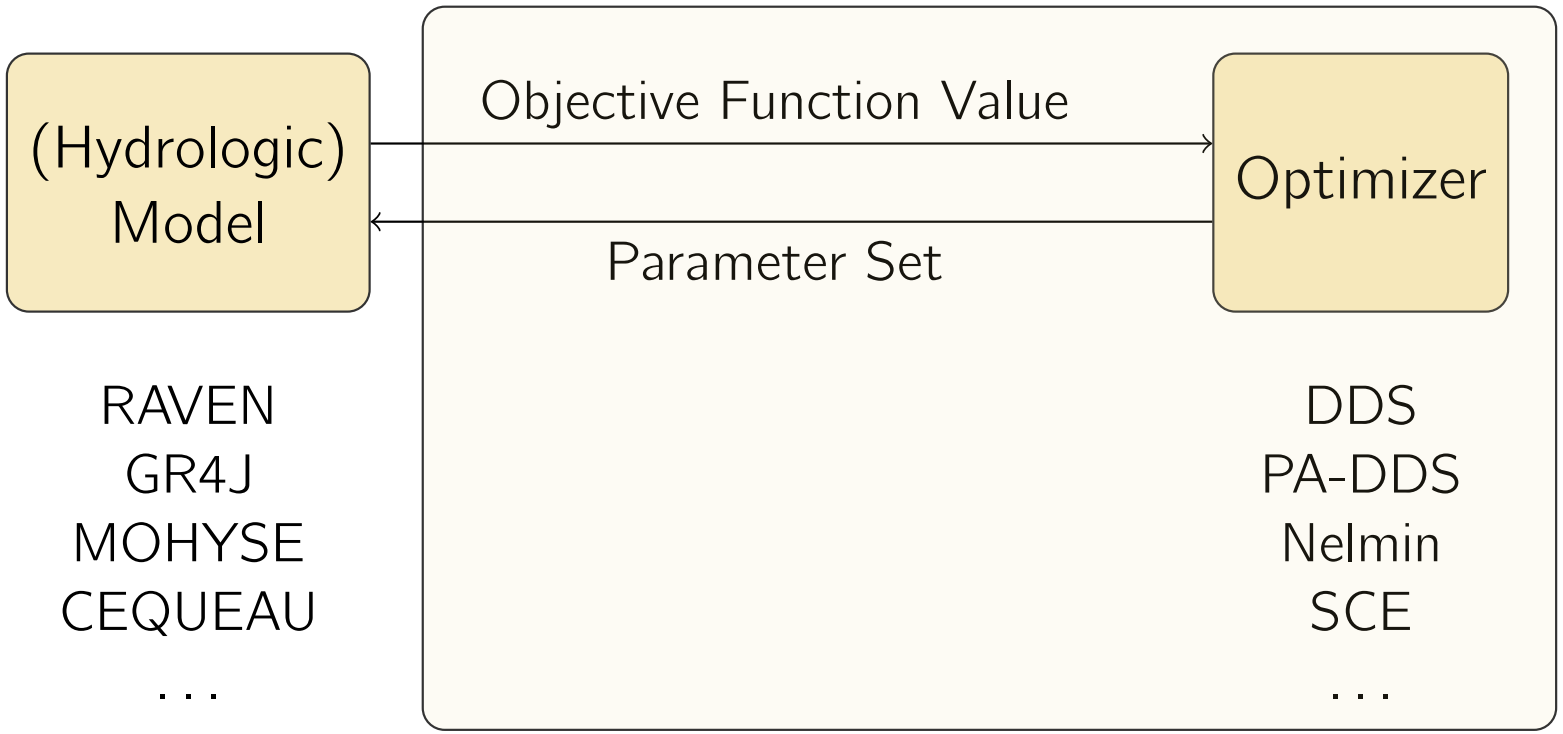
OSTRICH



Framework provided by OSTRICH toolbox

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OSTRICH

OSTRICH - Optimization Software Toolkit
developed by L. Shawn Matott (University of Buffalo)
includes various optimization, sensitivity and uncert. analysis algorithms

webpage: `http://www.eng.buffalo.edu/~lsmatott/Ostrich/OstrichMain.html`
citation: Matott, LS. 2017. OSTRICH: an Optimization Software Tool, Documentation and User's Guide, Version 17.12.19. 79 pages, University at Buffalo Center for Computational Research.

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OSTRICH

– Example: Setup for GR4J –

ostIn.txt

```
# Optimization algorithm
ProgramType           [ DDS | PADDS | SCE | ... ]

# Objective function type
ObjectiveFunction     [ GCOP | WSSE ]

# Script that runs model
ModelExecutable       ./Ost-RAVEN.sh | Ost-RAVEN.bat

# Optional: Script that conserves model runs with
#           currently best parameter set
PreserveBestModel     ./save_best.sh | save_best.bat
```


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OSTRICH

– Example: Setup for GR4J –

ostIn.txt

```
# calibration will work in seq. and parallel mode
ModelSubdir processor_

# list all directories that contain information
# required to run model
BeginExtraDirs
   model
EndExtraDirs

# name of template files and their proper final
# name required by model
BeginFilePairs
   raven-gr4j-salmon.rvp.tpl; raven-gr4j-salmon.rvp
EndFilePairs
```


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OSTRICH

– Example: Setup for GR4J –

ostIn.txt

```
# parameter/ decision variable specification
BeginParams
  # param.  init.    low   high    tx_in   tx_ost   tx_out
  par_x1    random   0.01  2.5     none    none     none
  par_x2    random   -15    10     none    none     none
  par_x3    random    10   700     none    none     none
  par_x4    random     0     7     none    none     none
  par_x5    random     1    30     none    none     none
  par_x6    random     0     1     none    none     none
EndParams
```


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OSTRICH

– Example: Setup for GR4J –

ostIn.txt

```
# Specify the response variables in model output
BeginResponseVars
  # name filename                    keyword  line col token
  NSE    ./model/Diagnostics.csv  OST_NULL 1    4   ','
EndResponseVars

# (Optional) Modify response variables
BeginTiedRespVars
  NegNS 1 NS wsum -1.00
EndTiedRespVars

# Specify objective function
BeginGCOP
  CostFunction    NegNS
  PenaltyFunction APM
EndGCOP
```


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OSTRICH

– Example: Setup for GR4J –

ostIn.txt

```
# (Optional) Random seed control
RandomSeed 123

# Algorithm should be last in this file
# --> Look up algorithm specific settings in manual
BeginDDSAlg
   PerturbationValue 0.20
   MaxIterations     50
   UseRandomParamValues
   # (optional) intialize DDS to parameter
   # values in initial model input files:
   # UseInitialParamValues
EndDDSAlg
```


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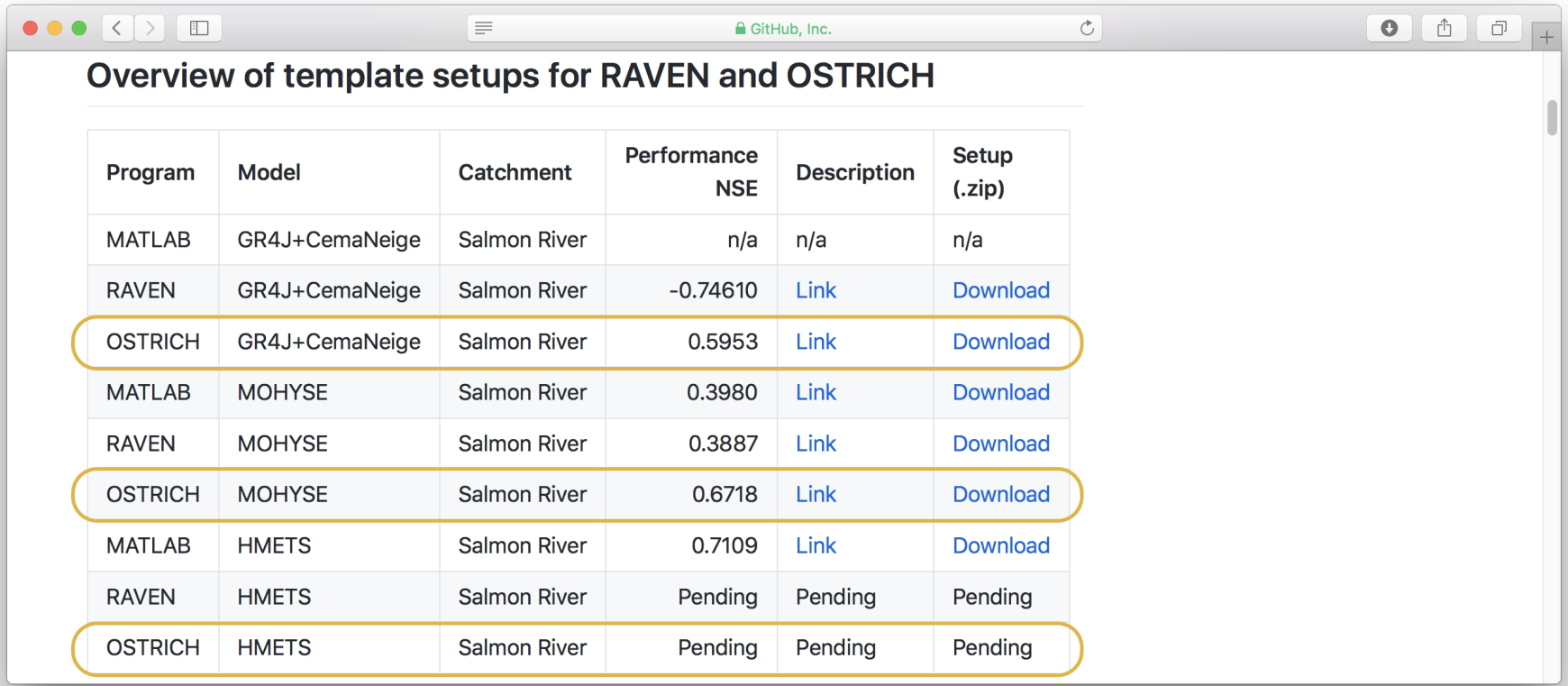

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