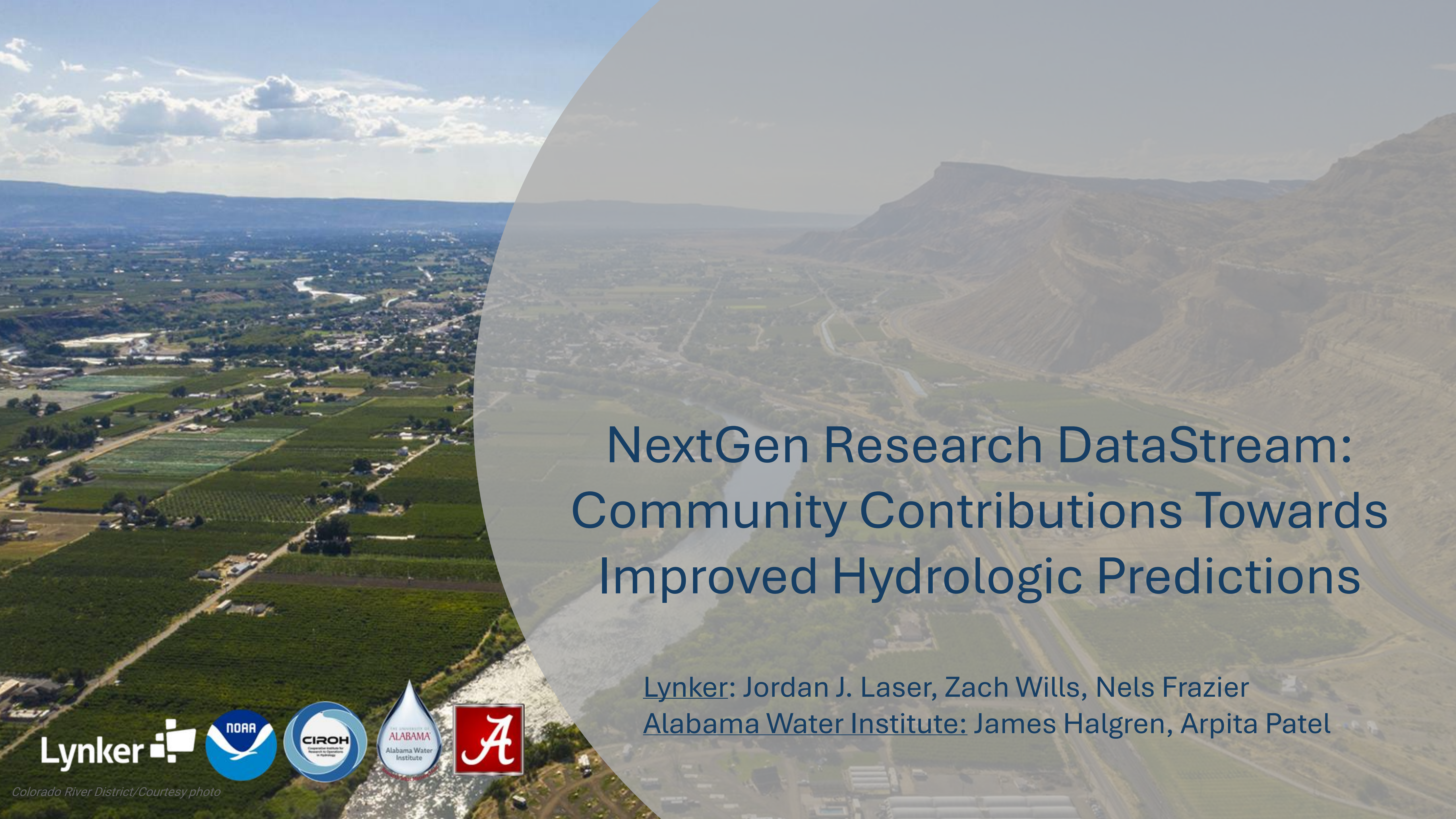


Colorado River District/Courtesy photo

NextGen Research DataStream: Community Contributions Towards Improved Hydrologic Predictions

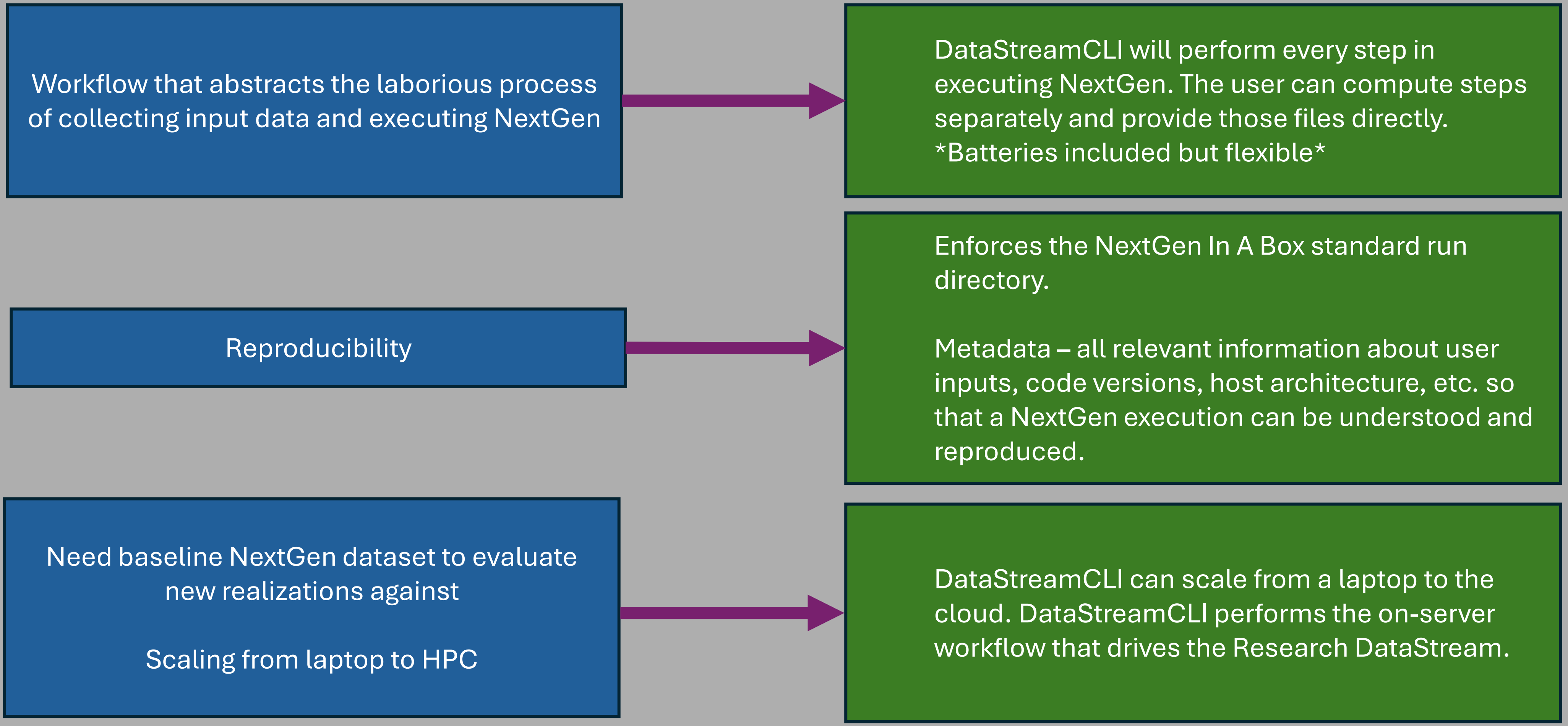
Lynker: Jordan J. Laser, Zach Wills, Nels Frazier
Alabama Water Institute: James Halgren, Arpita Patel

Colorado River District/Courtesy photo

Road Map

1. DataStreamCLI Motivation
2. DataStreamCLI Design
3. Research DataStream Motivation
4. Research DataStream Design
5. Research DataStream State
6. Hands-on workshop

DataStreamCLI Motivation



Workflow that abstracts the laborious process of collecting input data and executing NextGen

DataStreamCLI will perform every step in executing NextGen. The user can compute steps separately and provide those files directly. *Batteries included but flexible*

Reproducibility

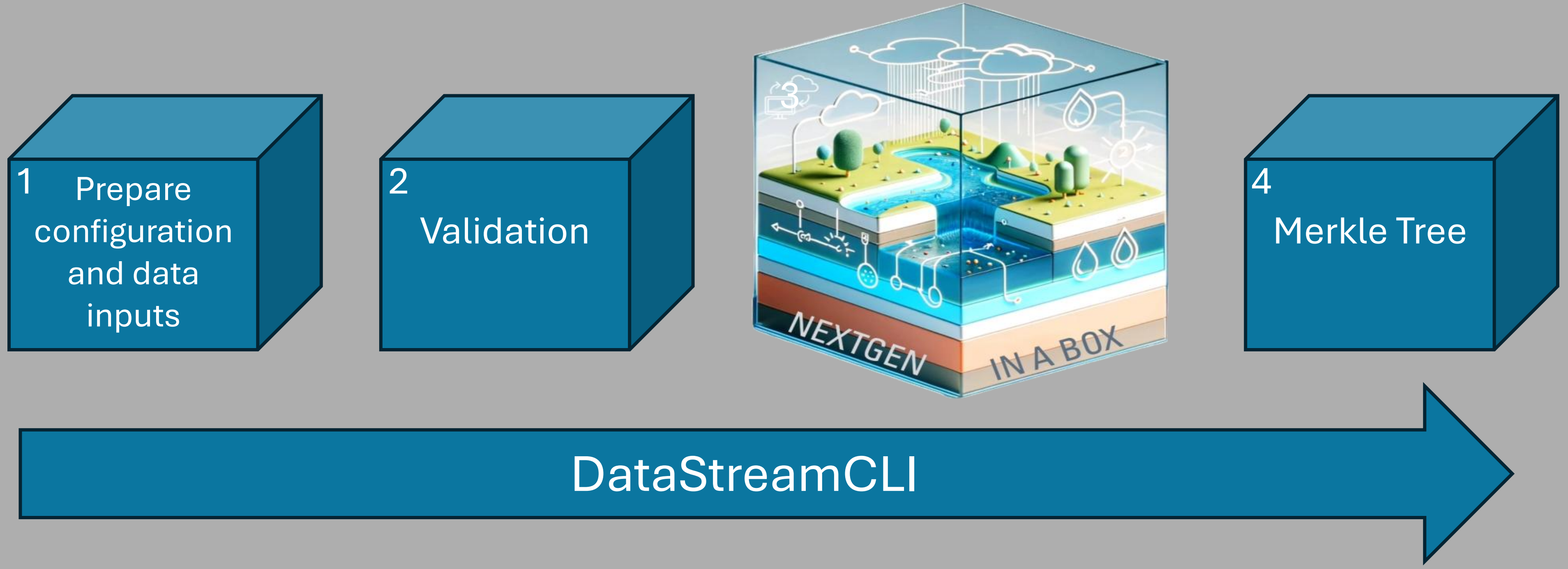
Enforces the NextGen In A Box standard run directory.

Metadata – all relevant information about user inputs, code versions, host architecture, etc. so that a NextGen execution can be understood and reproduced.

Need baseline NextGen dataset to evaluate new realizations against

Scaling from laptop to HPC

DataStreamCLI can scale from a laptop to the cloud. DataStreamCLI performs the on-server workflow that drives the Research DataStream.



1 Prepare configuration and data inputs

2 Validation

3

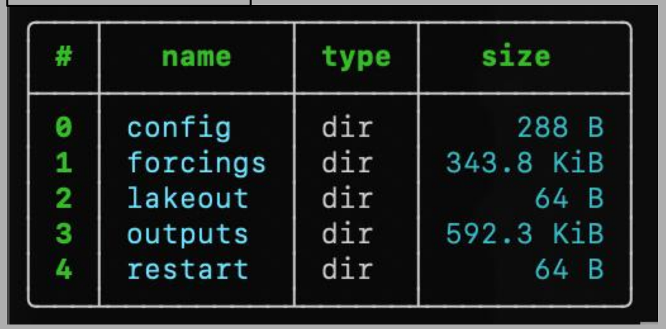
4 Merkle Tree

DataStreamCLI

DataStreamCLI refers to the software chain that builds and validates NextGen input packages (ngen-run/), executes NextGen through NextGen In A Box (NGIAB), and versions the entire run for reproducibility.

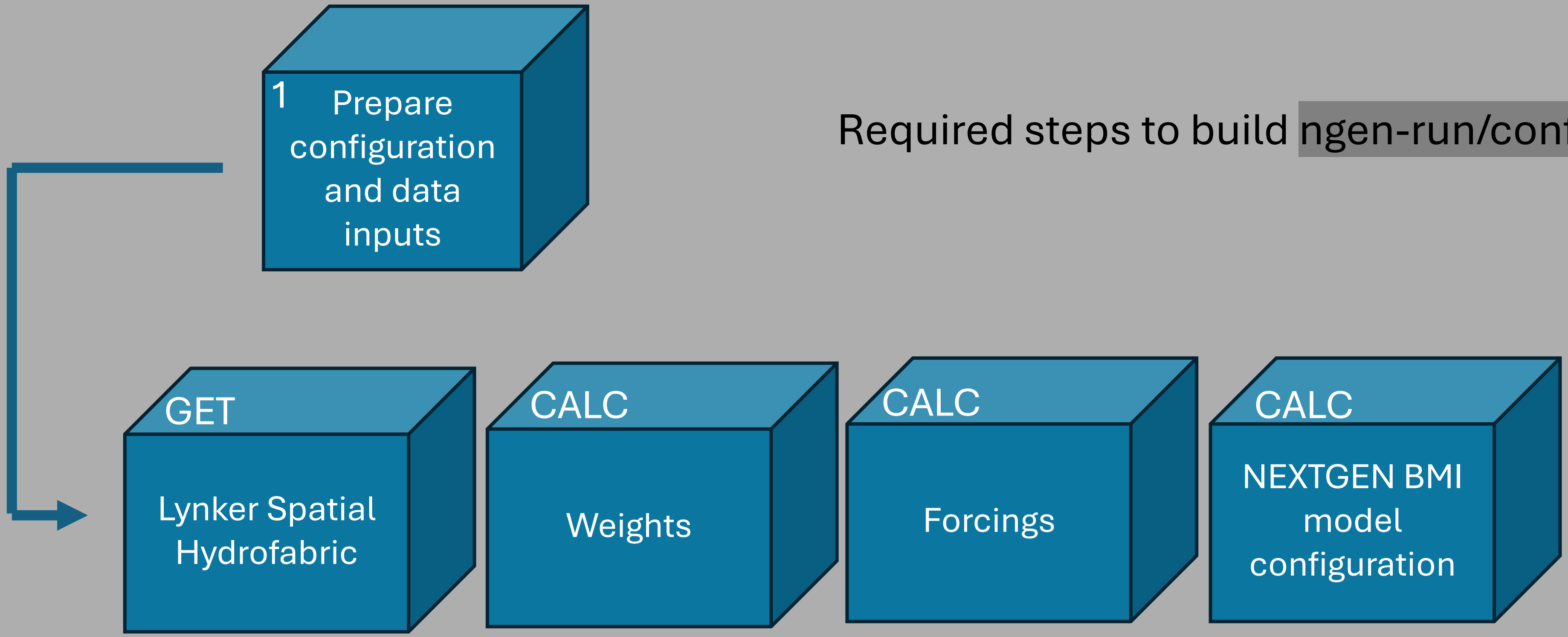
This enforces a standard folder (ngen-run/), which enables interoperability and reproducibility.

ngen-run/



```
 #    name        type    size
 0    config      dir        288 B
 1    forcings    dir    343.8 KiB
 2    lakeout     dir         64 B
 3    outputs     dir    592.3 KiB
 4    restart     dir         64 B
```

Required steps to build ngen-run/config and ngen-run/forcings


1
Prepare configuration and data inputs
GET
Lynker Spatial Hydrofabric
CALC
Weights
CALC
Forcings
CALC
NEXTGEN BMI model configuration

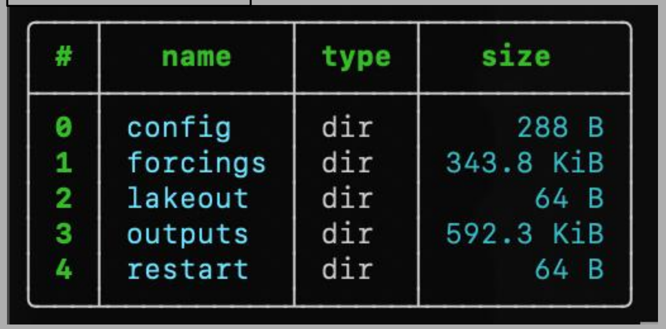
Defines spatial domain

Indices and coverage used to extract catchment averaged forcings. Calculated by exactextract.

Performs conversion between National Water Model and NextGen forcings formats

Required files for NextGen BMI modules

ngen-run/



```
 #     name      type      size
 0   config      dir      288 B
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```
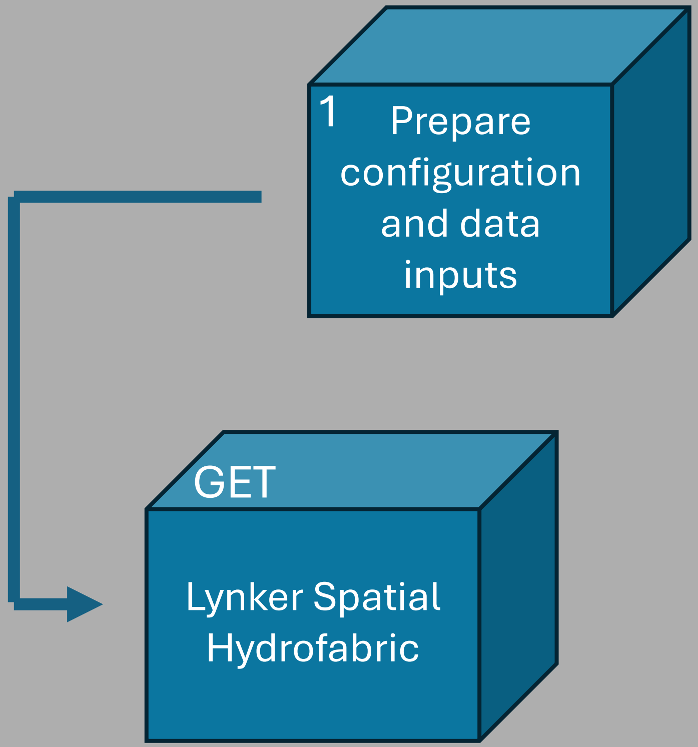
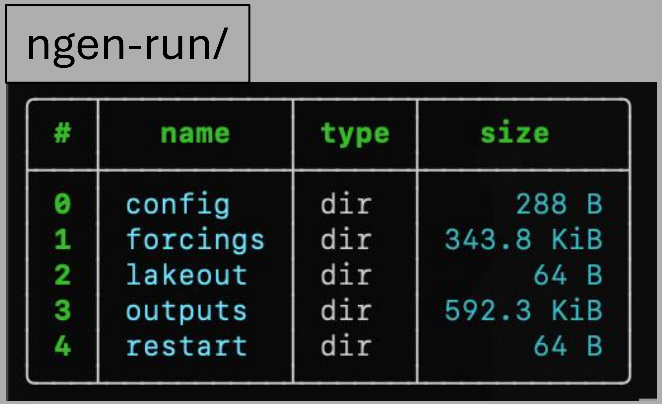


1
Prepare configuration and data inputs
GET
Lynker Spatial Hydrofabric

Defines spatial domain

LynkerSpatial

Open Data, Open Science



```
ngen-run/

 #    name        type    size
 0    config      dir       288 B
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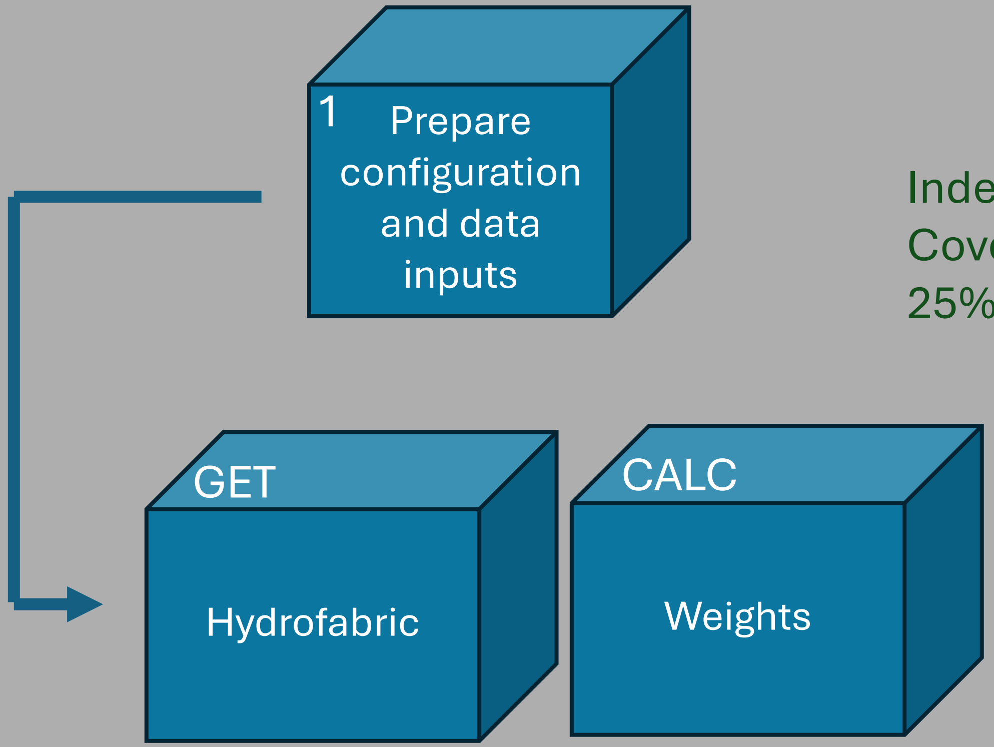


1 Prepare configuration and data inputs

GET

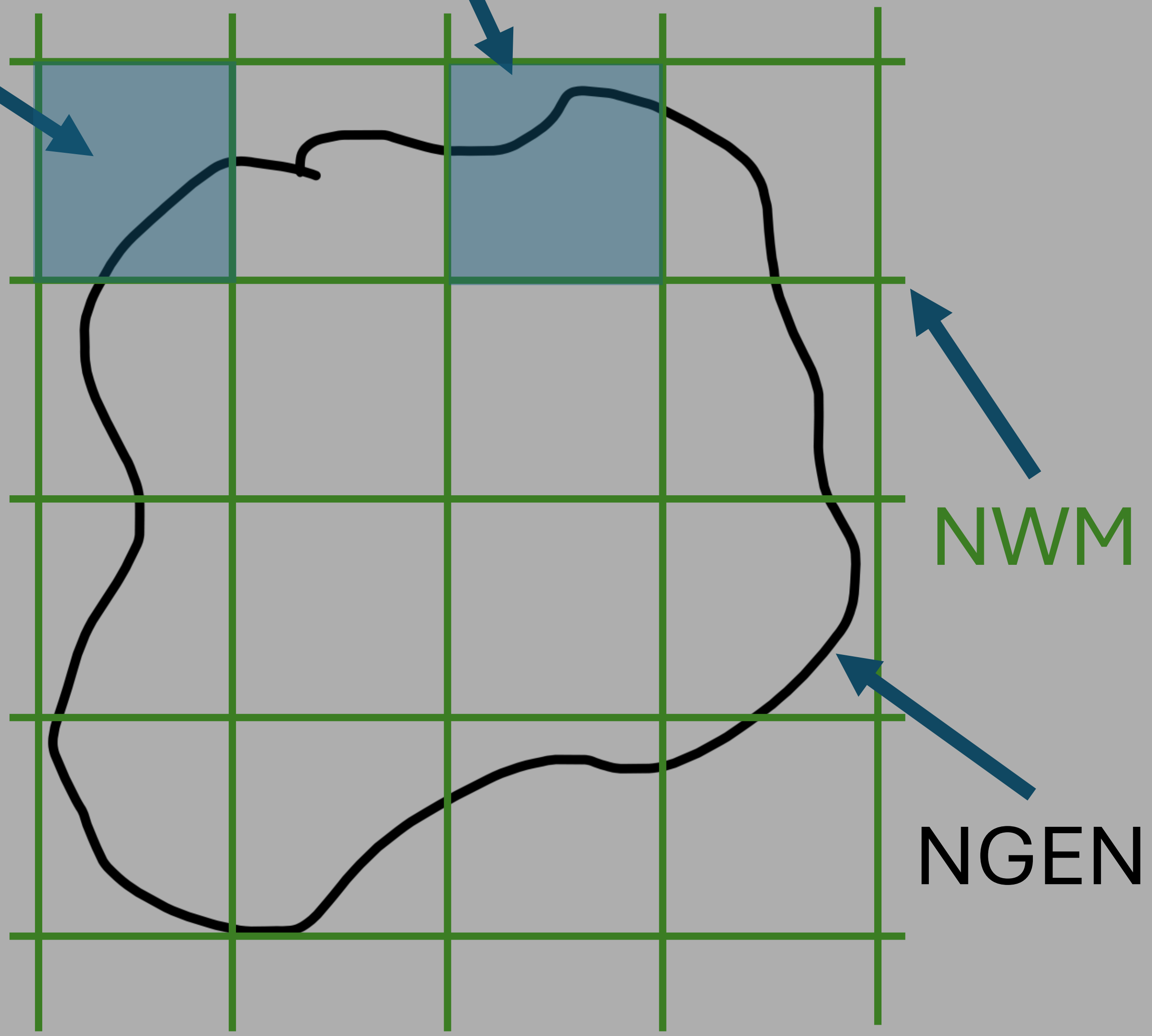
Hydrofabric

CALC

Weights

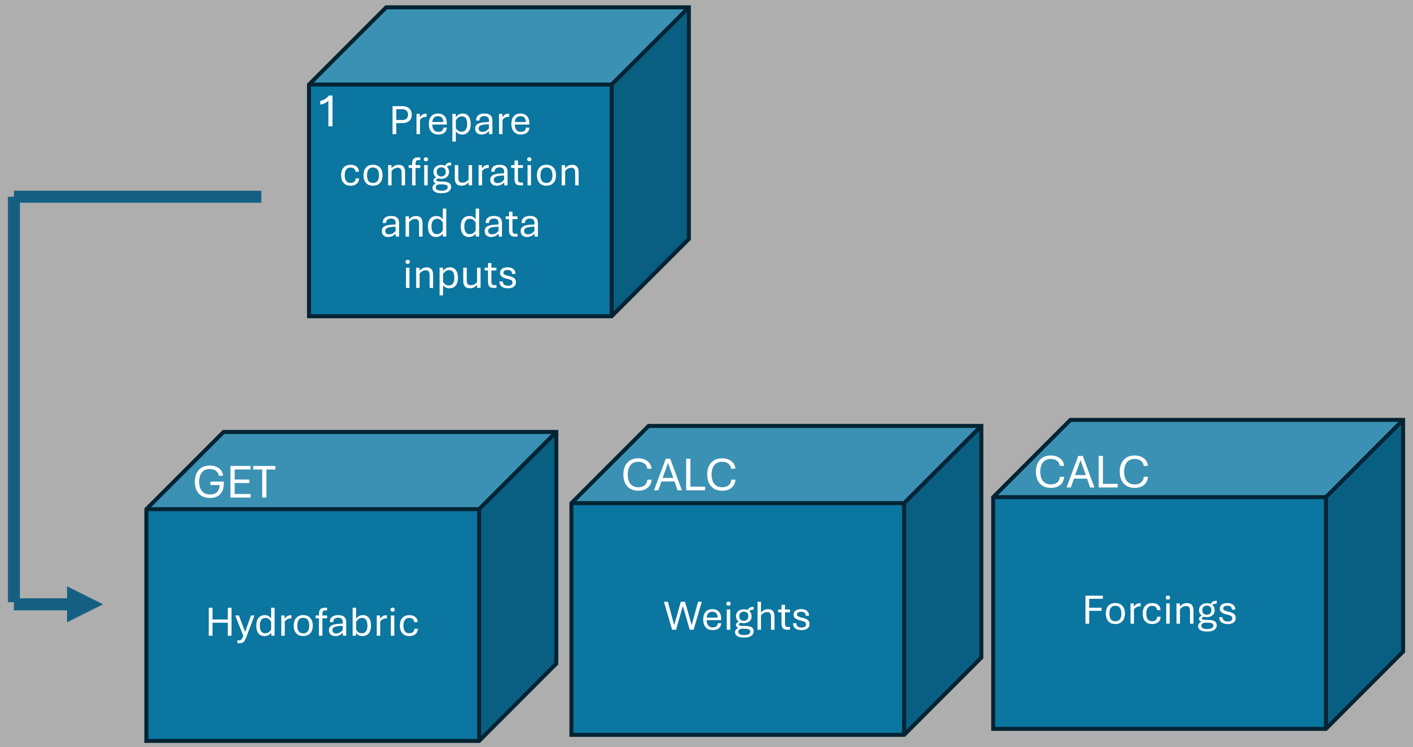
Defines spatial domain

Indices and coverage used to extract catchment averaged forcings



Index: 27463
Coverage:
75%

Index: 27461
Coverage:
25%



1 Prepare configuration and data inputs

GET Hydrofabric

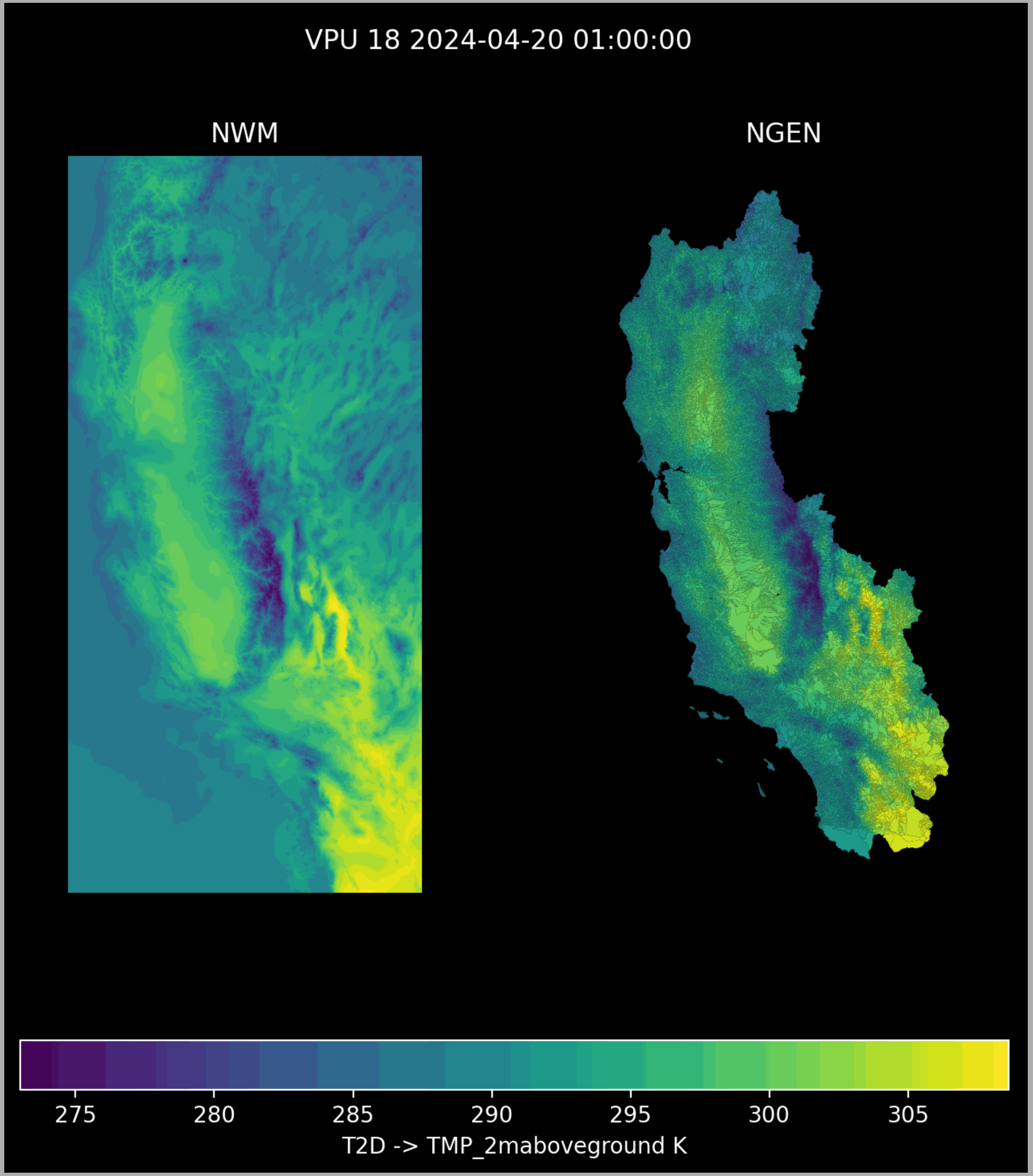
CALC Weights

CALC Forcings

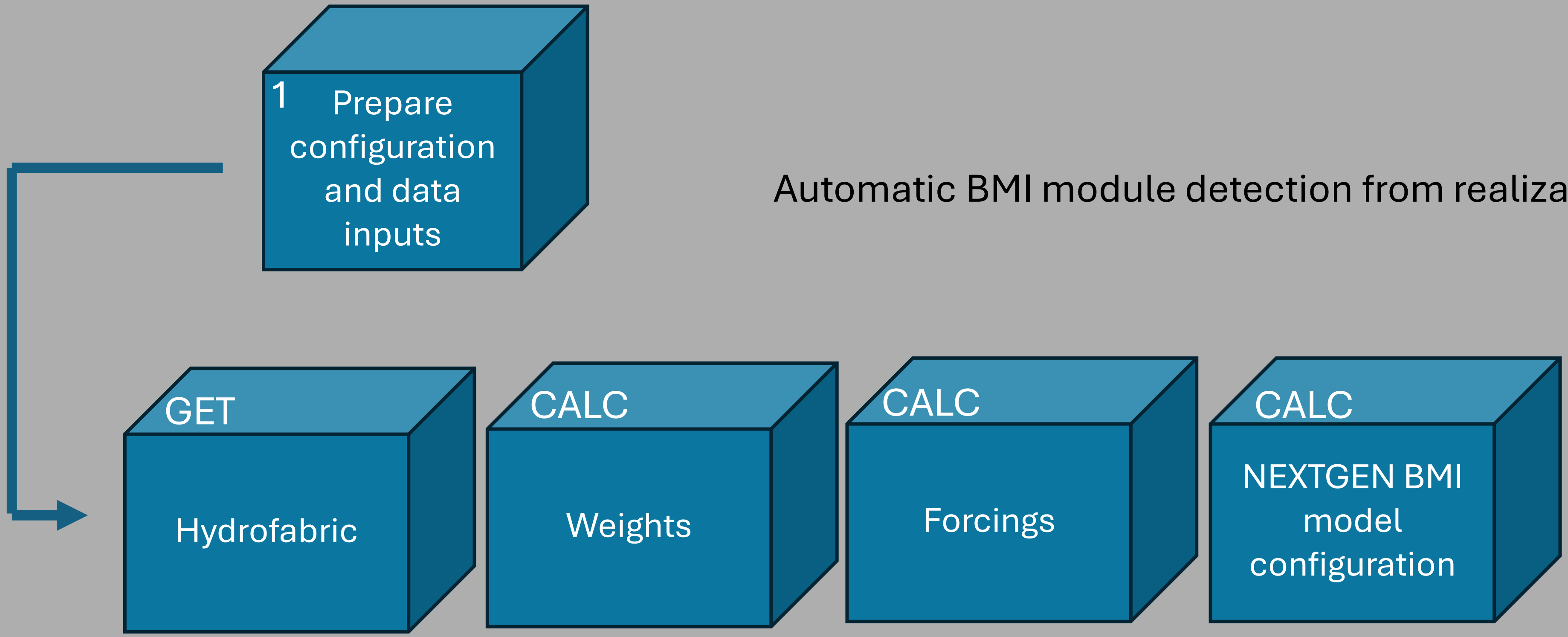
Defines spatial domain

Indices and coverage used to extract catchment averaged forcings

Performs conversion between National Water Model and NextGen forcings formats



Automatic BMI module detection from realization file



1 Prepare configuration and data inputs

GET

Hydrofabric

Defines spatial domain

CALC

Weights

Indices and coverage used to extract catchment averaged forcings

CALC

Forcings

Performs conversion between National Water Model and NextGen forcings formats

CALC

NEXTGEN BMI model configuration

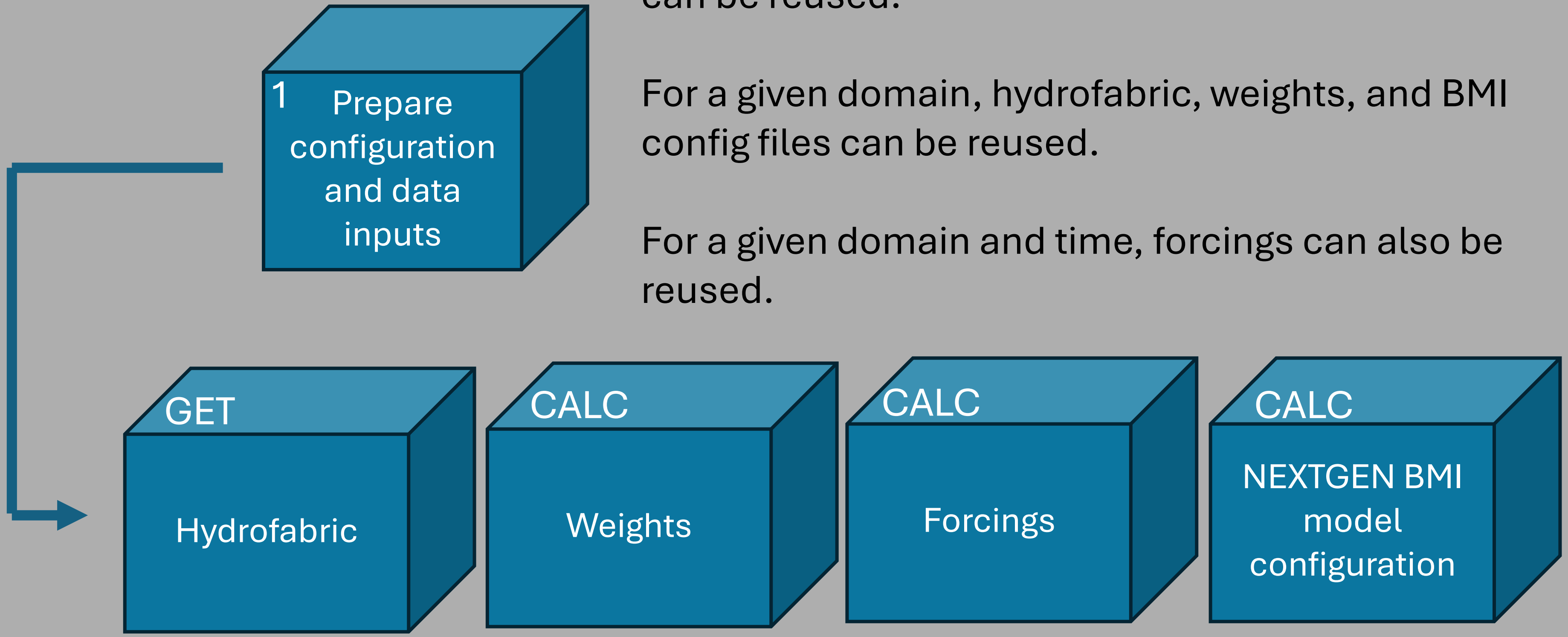
Required files for NextGen BMI modules

- Supported BMI module config generation
  - PET, CFE, Noah-OWP-Modular, t-route
- Coming soon
  - SoilFreezeThaw, TopModel, LSTM, others

The resource directory is used as a cache for files that can be reused.

For a given domain, hydrofabric, weights, and BMI config files can be reused.

For a given domain and time, forcings can also be reused.


1 Prepare configuration and data inputs
GET
Hydrofabric
CALC
Weights
CALC
Forcings
CALC
NEXTGEN BMI model configuration

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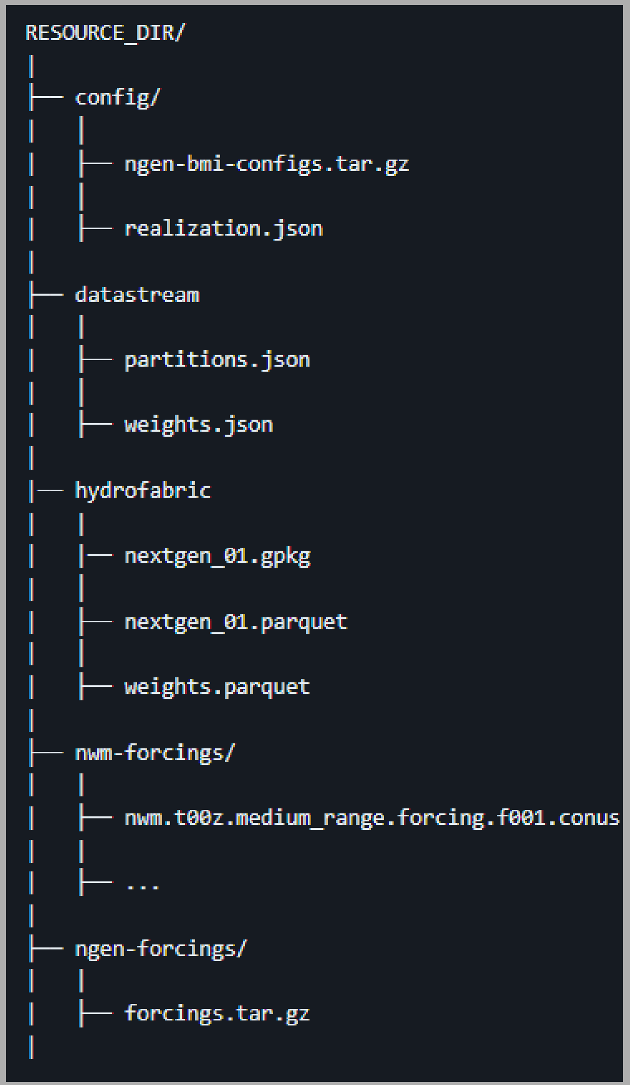
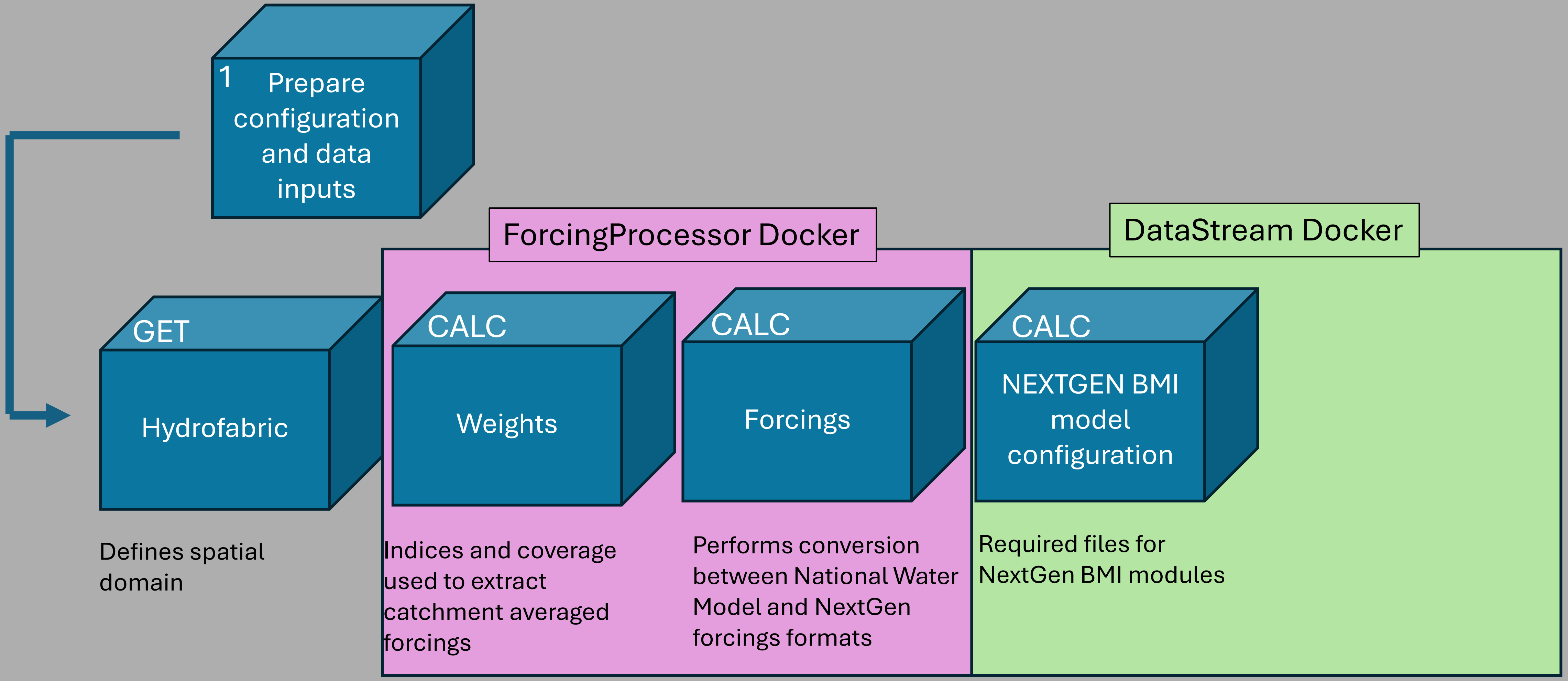
Performs conversion between National Water Model and NextGen forcings formats

Required files for NextGen BMI modules



```
RESOURCE_DIR/
|
├── config/
|   |
|   ├── ngen-bmi-configs.tar.gz
|   |
|   ├── realization.json
|
├── datastream
|   |
|   ├── partitions.json
|   |
|   ├── weights.json
|
|── hydrofabric
|   |
|   |── nextgen_01.gpkg
|   |
|   ├── nextgen_01.parquet
|   |
|   ├── weights.parquet
|
├── nwm-forcings/
|   |
|   ├── nwm.t00z.medium_range.forcing.f001.conus
|   |
|   ├── ...
|
├── ngen-forcings/
|   |
|   ├── forcings.tar.gz
|
```

https://github.com/CIROH-UA/ngen-datastream/tree/main?tab=readme-ov-file#resource_dir-datastream-resour



1 Prepare configuration and data inputs

GET Hydrofabric

Defines spatial domain

ForcingProcessor Docker

CALC Weights

Indices and coverage used to extract catchment averaged forcings

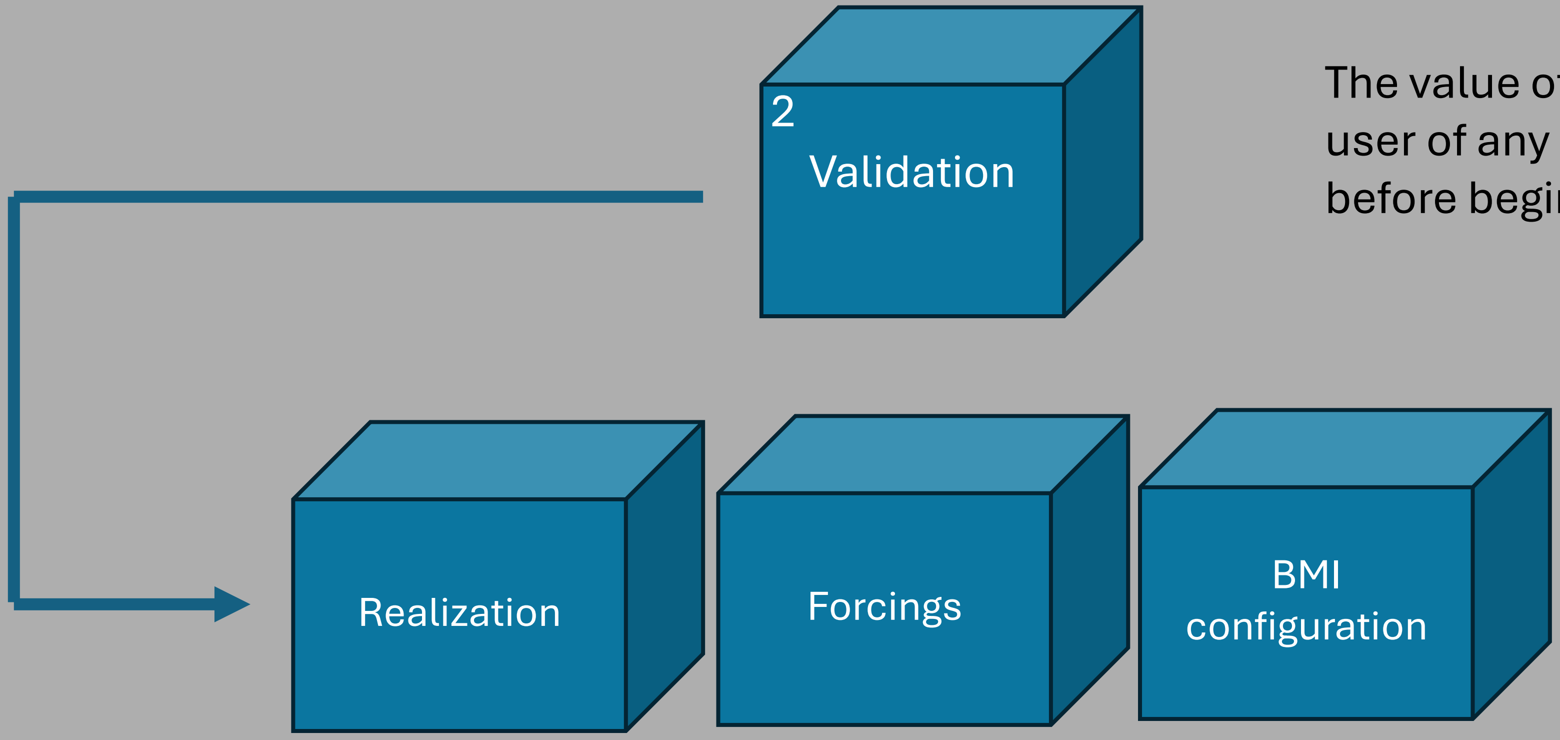
CALC Forcings

Performs conversion between National Water Model and NextGen forcings formats

DataStream Docker

CALC NEXTGEN BMI model configuration

Required files for NextGen BMI modules



2

Validation

Realization

Forcings

BMI configuration

The value of the validation step is to notify the user of any errors in the NEXTGEN run package before beginning the execution

Coming soon -> BMI module variable mapping validation

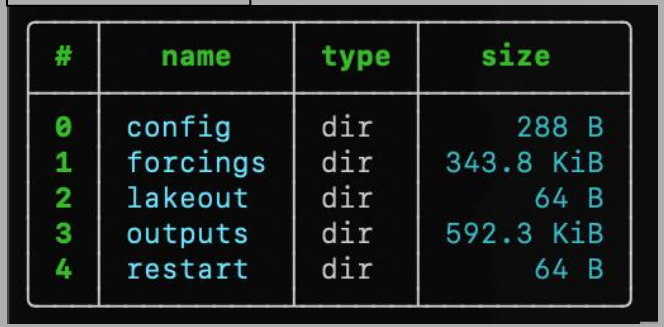
Required for

Ensures the user has supplied a valid realization file to configure NEXTGEN

Ensures a forcing file exists for each catchment in the hydrofabric and for each time step specified in the realization

Ensures all BMI model configuration files exist.

ngen-run/



```
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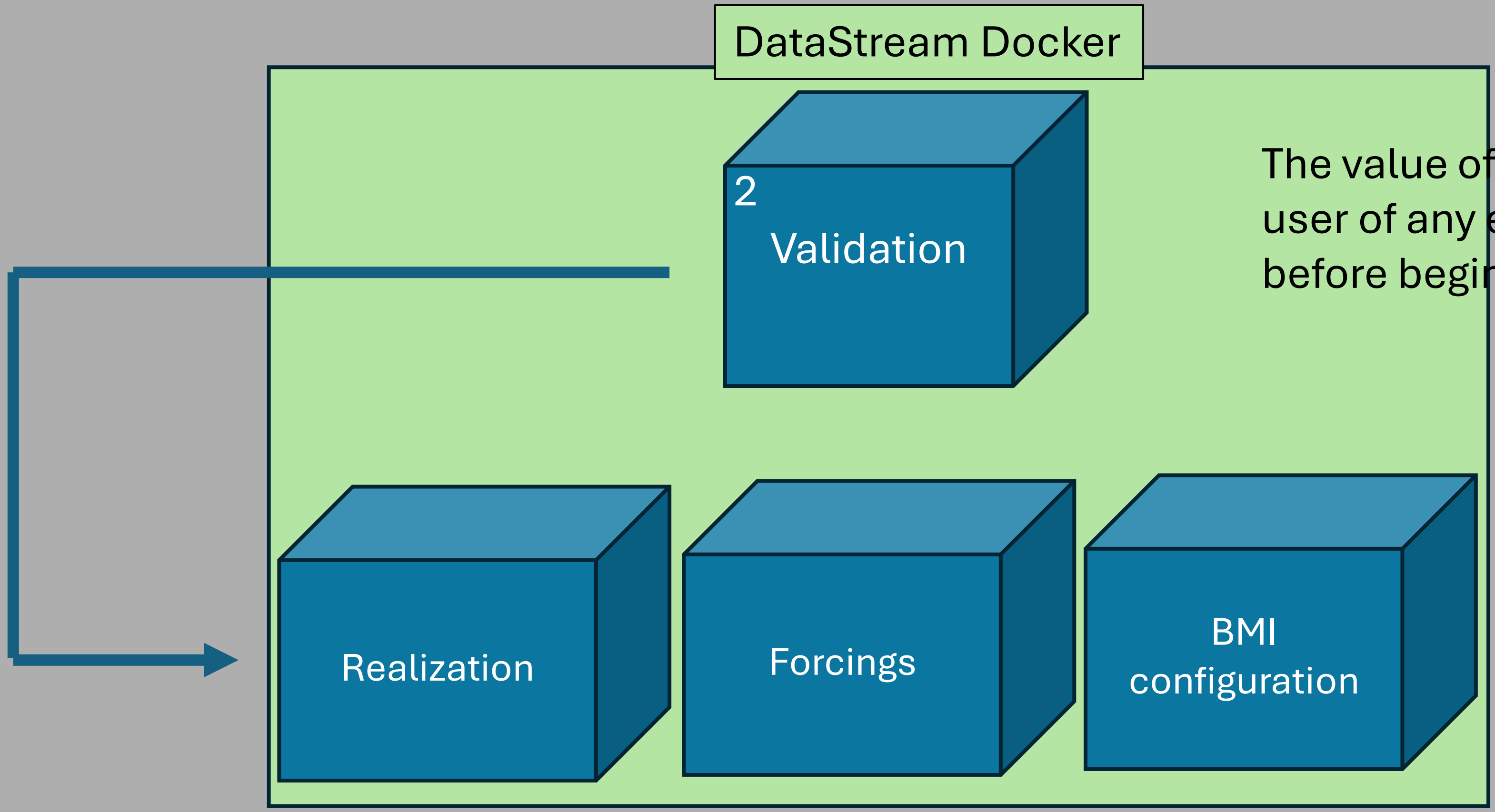
```



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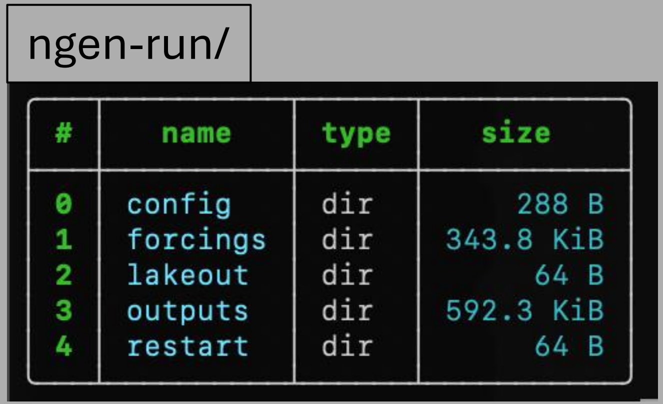

ngen-run/

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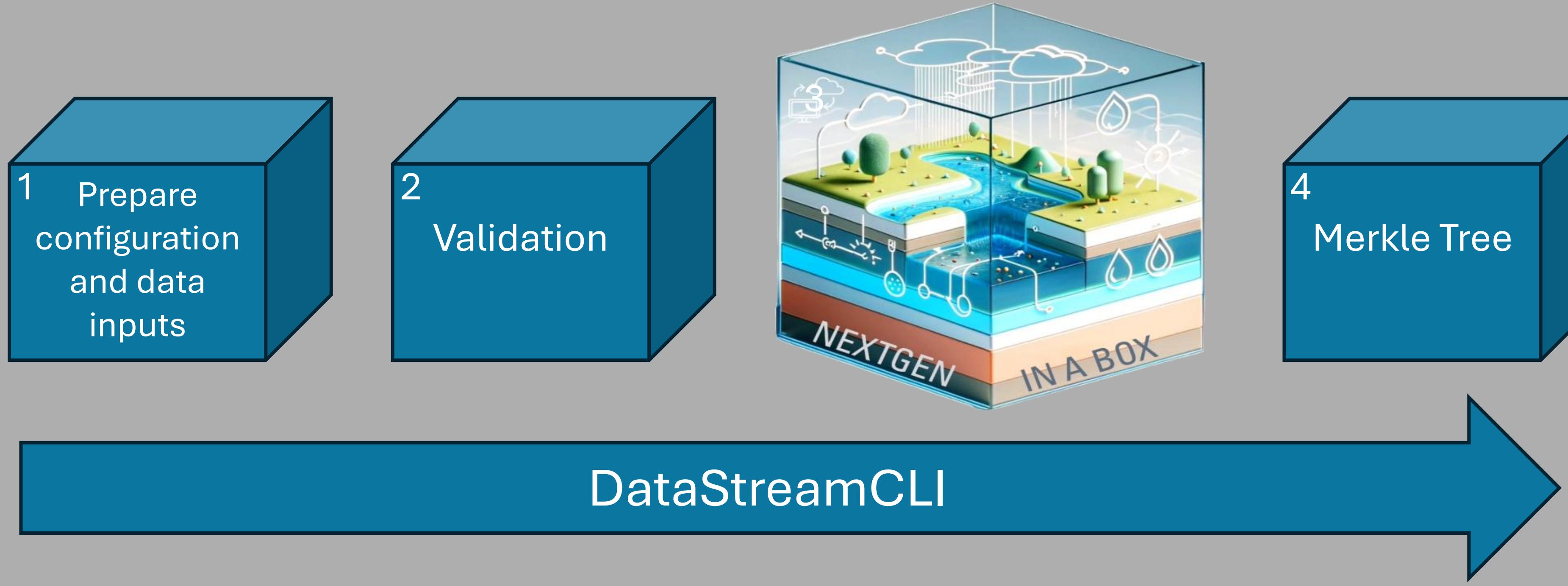

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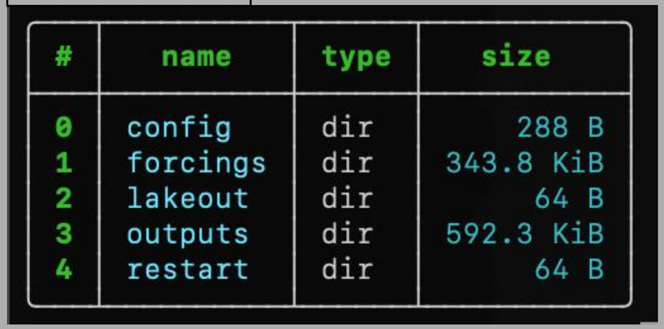

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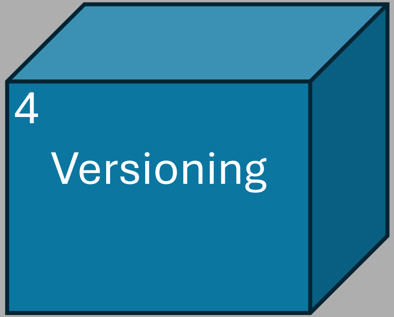
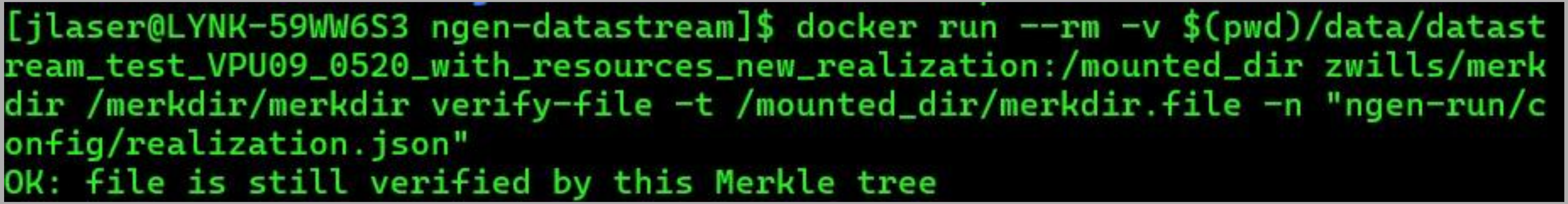


4

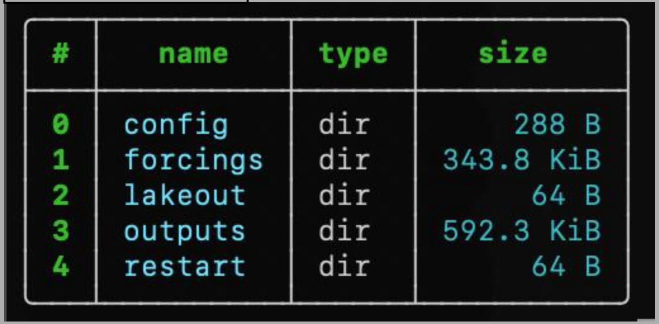
Versioning

- Merkle Tree based hashing algorithm
  - “Root” hash allows for quickly identifying if two ngen-run directories are different.
  - Ability to query whether some file is a part of the tree represented by the root hash
  - Ability to compare files without opening them



```
[jlaser@LYNK-59WW6S3 ngen-datastream]$ docker run --rm -v $(pwd)/data/datast
ream_test_VPU09_0520_with_resources_new_realization:/mounted_dir zwills/merk
dir /merkdir/merkdir verify-file -t /mounted_dir/merkdir.file -n "ngen-run/c
onfig/realization.json"
OK: file is still verified by this Merkle tree
```

ngen-run/



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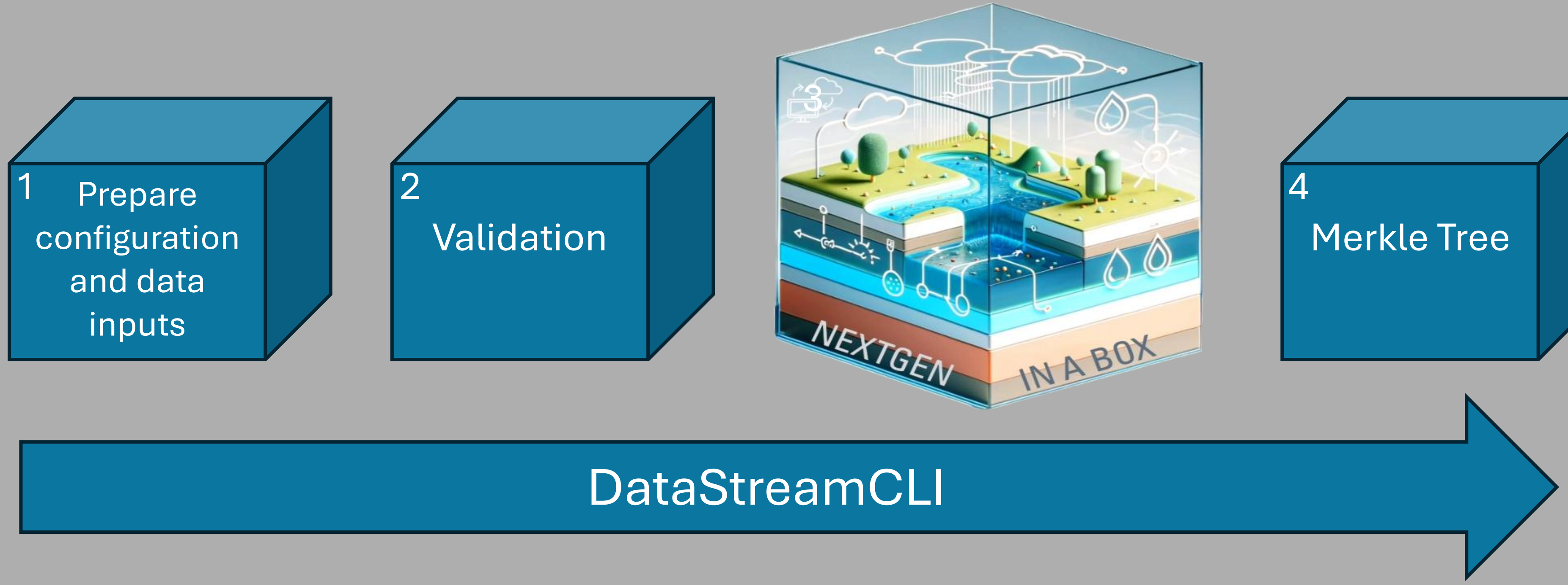

1 Prepare configuration and data inputs

2 Validation

4 Merkle Tree

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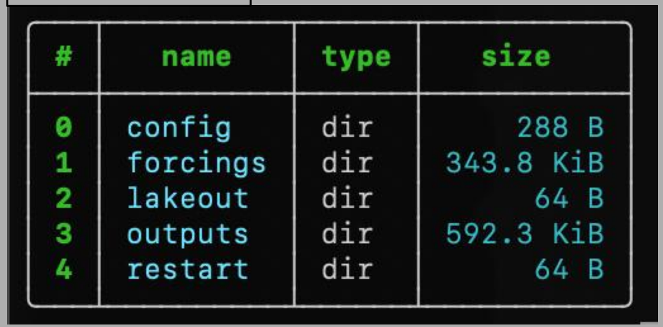

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 0   config        dir       288 B
 1   forcings      dir   343.8 KiB
 2   lakeout       dir        64 B
 3   outputs       dir   592.3 KiB
 4   restart       dir        64 B
```

3. Research DataStream Motivation

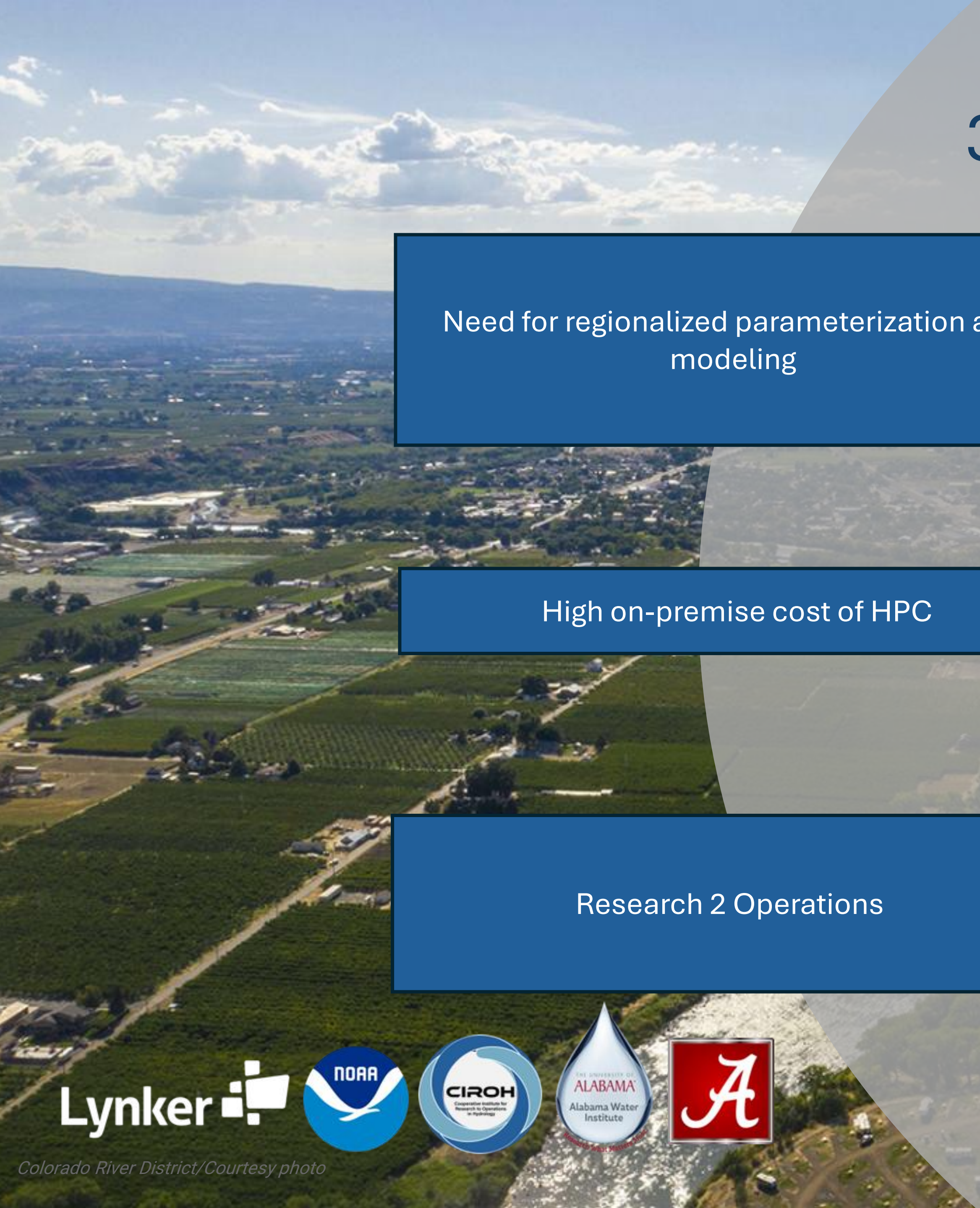
Need for regionalized parameterization and modeling → Within the NextGen Framework, models and parameters can be configured individually for each catchment

High on-premise cost of HPC → Cloud providers offer a cost-effective alternative to purchasing and maintaining expensive on-premise hardware.

The Research DataStream is written in Terraform and made publicly available.

Research 2 Operations → The Research DataStream is open to community contributions.

An evaluation workflow is under development to ensure continued improvement of the system.



Colorado River District/Courtesy photo

4. Research DataStream Design

- CONUS wide
  - Distributed processing by Vector Processing Unit (VPU)
  - Regional hydrologic processes map to compute resources
  - Outputs are delineated by VPU

- Mimic NWM forecast cycles
  - Short range (18 hourly time steps) 24 times per day
  - Medium range (240 hourly time steps) 4 times per day
  - Analysis assim extend (28 hourly time steps) 1 per day

- Publicly available and editable NextGen configuration files
  - Automated evaluation drives improvement.

- AWS Step Functions state machine
  - Manages infrastructure workflow

- DataStreamCLI
  - Manages on-server workflow

Colorado River District/Courtesy photo

4. Research DataStream State

- VPUs available : 02, 03N, 03S, 03W, 04, 05, 06, 08, 09, 10L, 10U, 11, 12, 13, 14, 15, 16, 18
  - (05, 10L, 10U, 11 not available for medium range)

- Run Types –
  - short range (all initialization cycles),
  - medium range (all cycles, 1st member),
  - analysis assim extend

- Cold start

- NextGen configuration - NOAH-OWP, PET, CFE, and troute.
  - Dynamically read on each execution from publicly available realizations that now hold mutable community parameters.

Colorado River District/Courtesy photo

Research DataStream: Workshop

- https://github.com/CIROH-UA/ngen-datastream/blob/main/docs/CIROH_devcon_2025/workshop.md

- Ask at least 1 anonymous question.

Colorado River District/Courtesy photo

Future Work

- Implement community contribution workflow
  - Evaluation
  - Validation
- GUI for DataStreamCLI
- Stay up-to-date with hydrofabric
- Academic article

Colorado River District/Courtesy photo