Jupyter application in weather forecasting DeeepRain project

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DeepRain

Project

Features

Modern methods of machine learning (ML) to improve precipitation forecasts in Germany

Collaborative project

Partners

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JACOBS UNIVERSITY

UNIVERSITÄT BONN

Deutscher Wetterdienst
Wetter und Klima aus einer Hand
DWD

UNIVERSITÄT OSNABRÜCK

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DeepRain

Project

Objectives

Innovative Fusion of Earth System data

Ground-breaking application of deep learning for weather forecasting

24-hour predictions of precipitation on a 1 km grid (super-resolution)

Knowledge transfer among scientific disciplines and to end users

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DeepRain

Data & Resources

Data

1.8 PB DWD data products

Some available online, and some only locally on two HPC systems

Machine – Learning (**ML**)

Mostly using NN utilizing well–known python libraries (scikit–learn, PyTorch, Tensorflow,. .)

HPC

JUWELS Cluster/ Booster hosted by FZJ

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Challenges

Data

- Access
- Quality Assurance
- Provenance

ML

- Pre-processing
- Reproducibility

HPC

- Deployment & Environment
- Visualization

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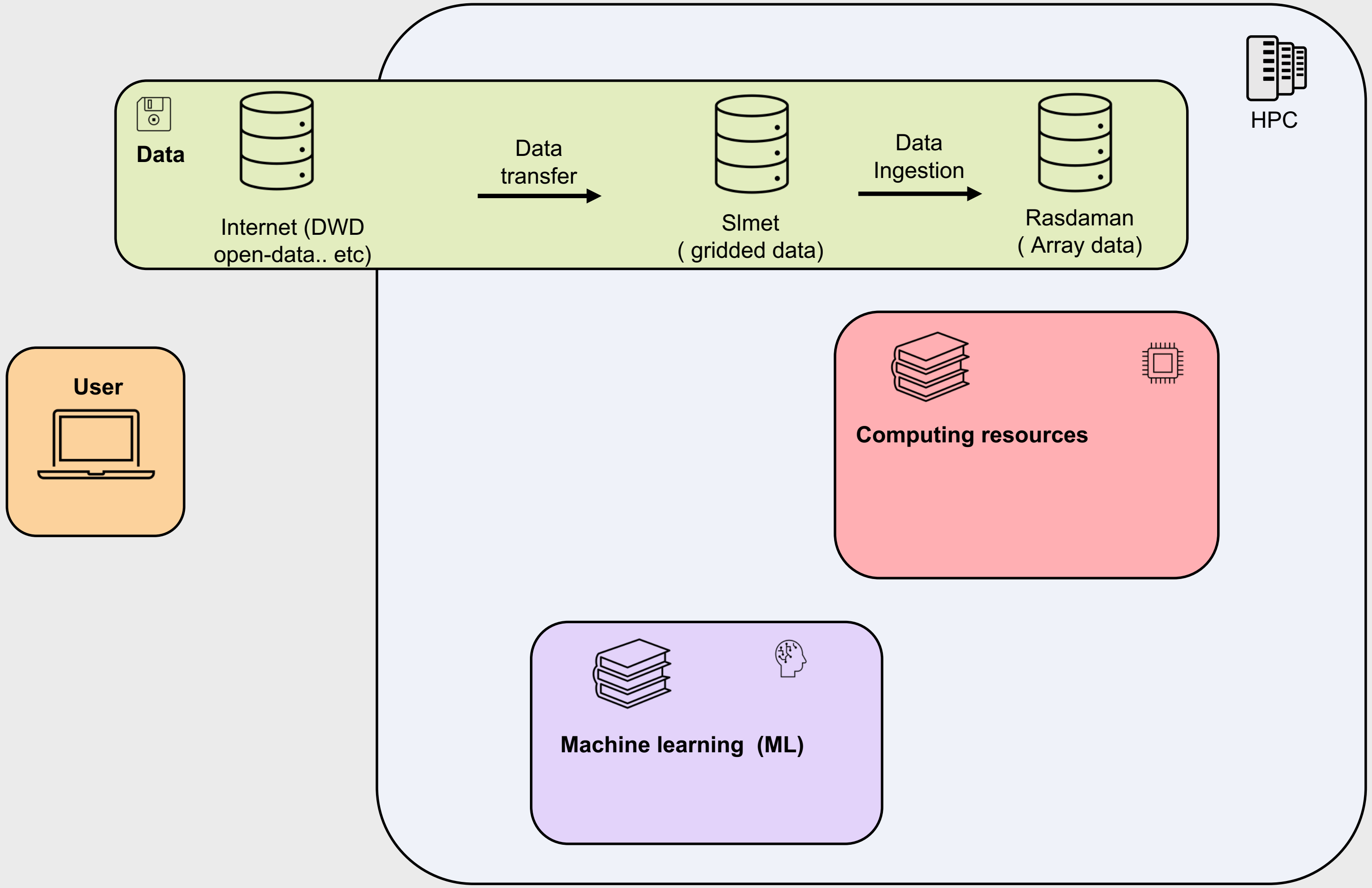
4 interfaces

- User
- Data
- ML
- Computing resources



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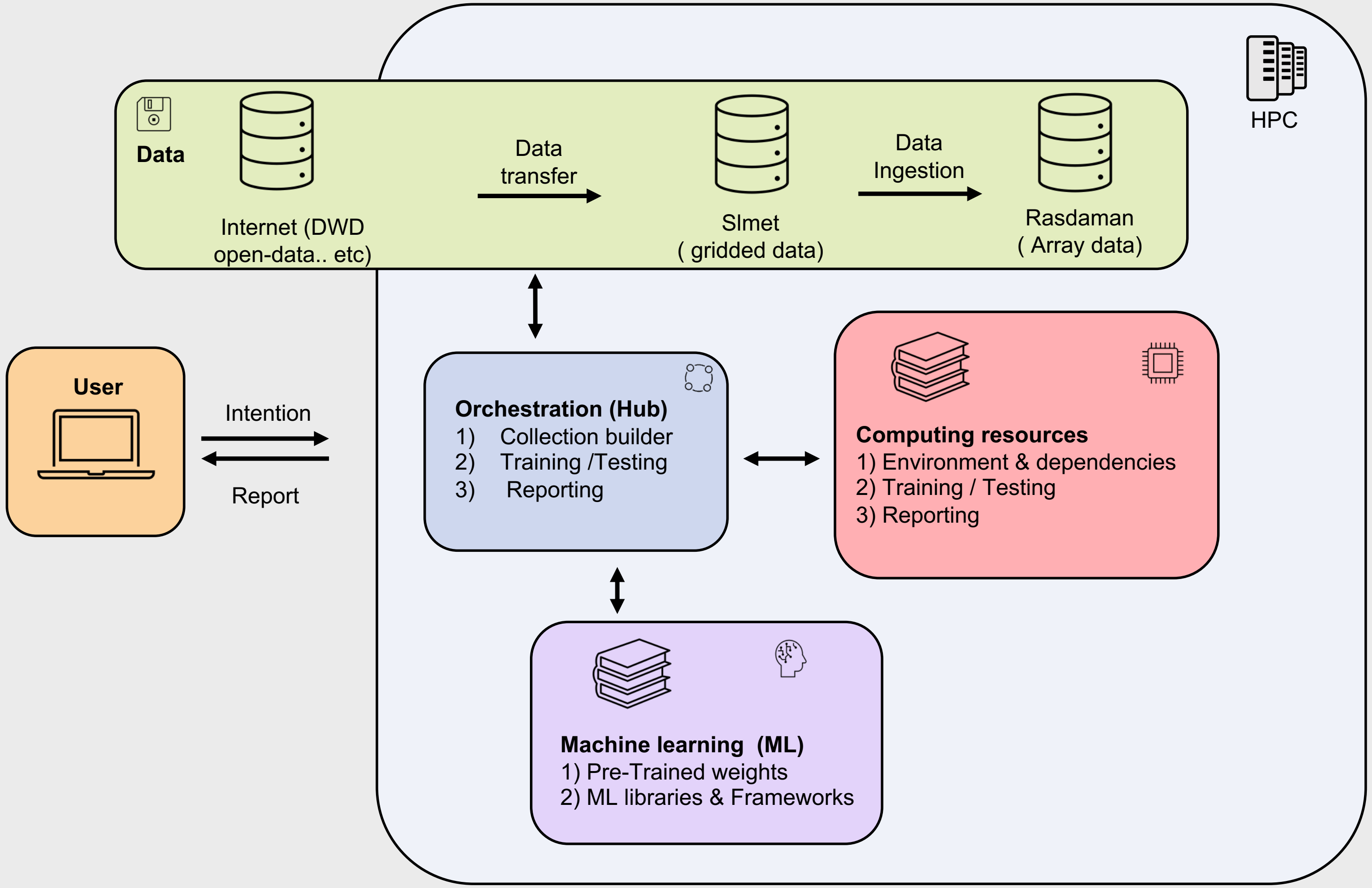
CWFR in HPC

- Orchestration HUB



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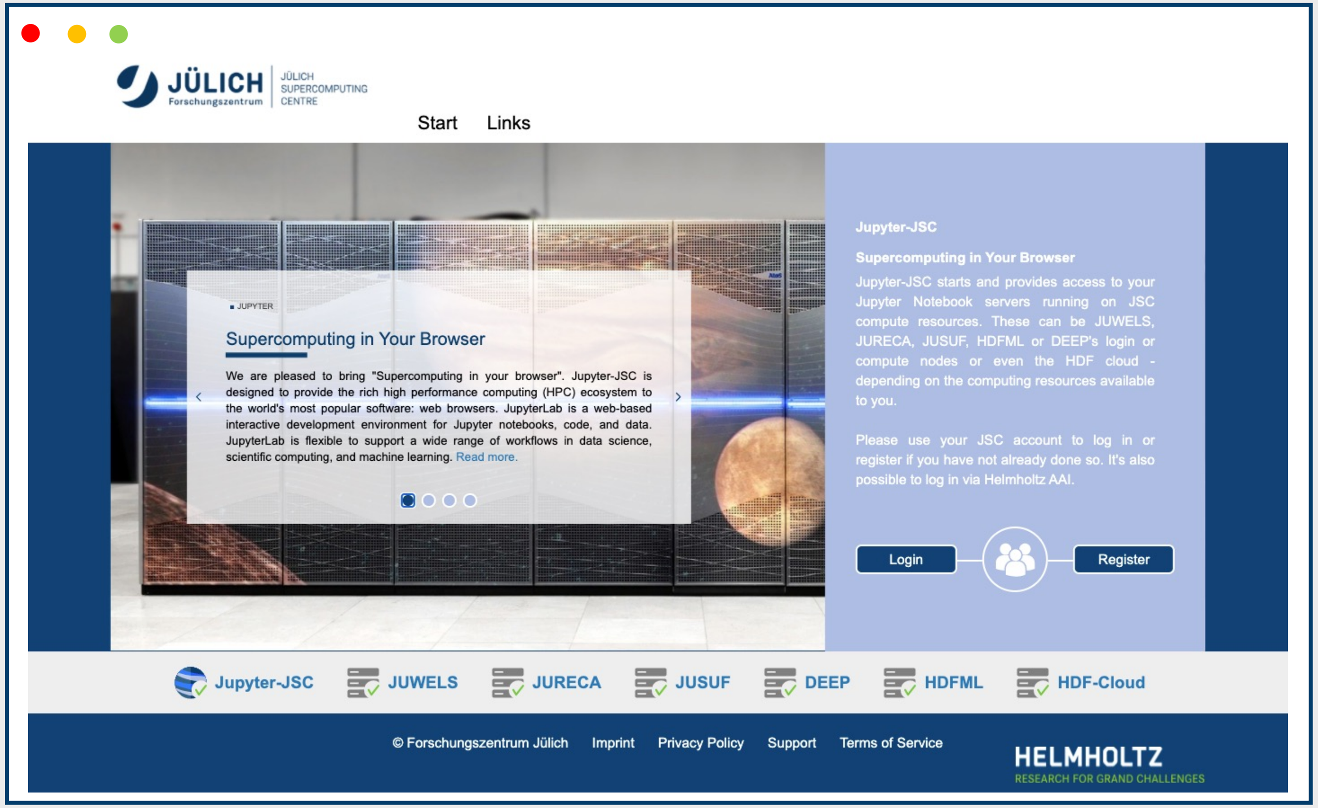
CWFR in HPC

-> Jupyter-JSC

- Accessibility
- Lower technological barrier
- Better UI



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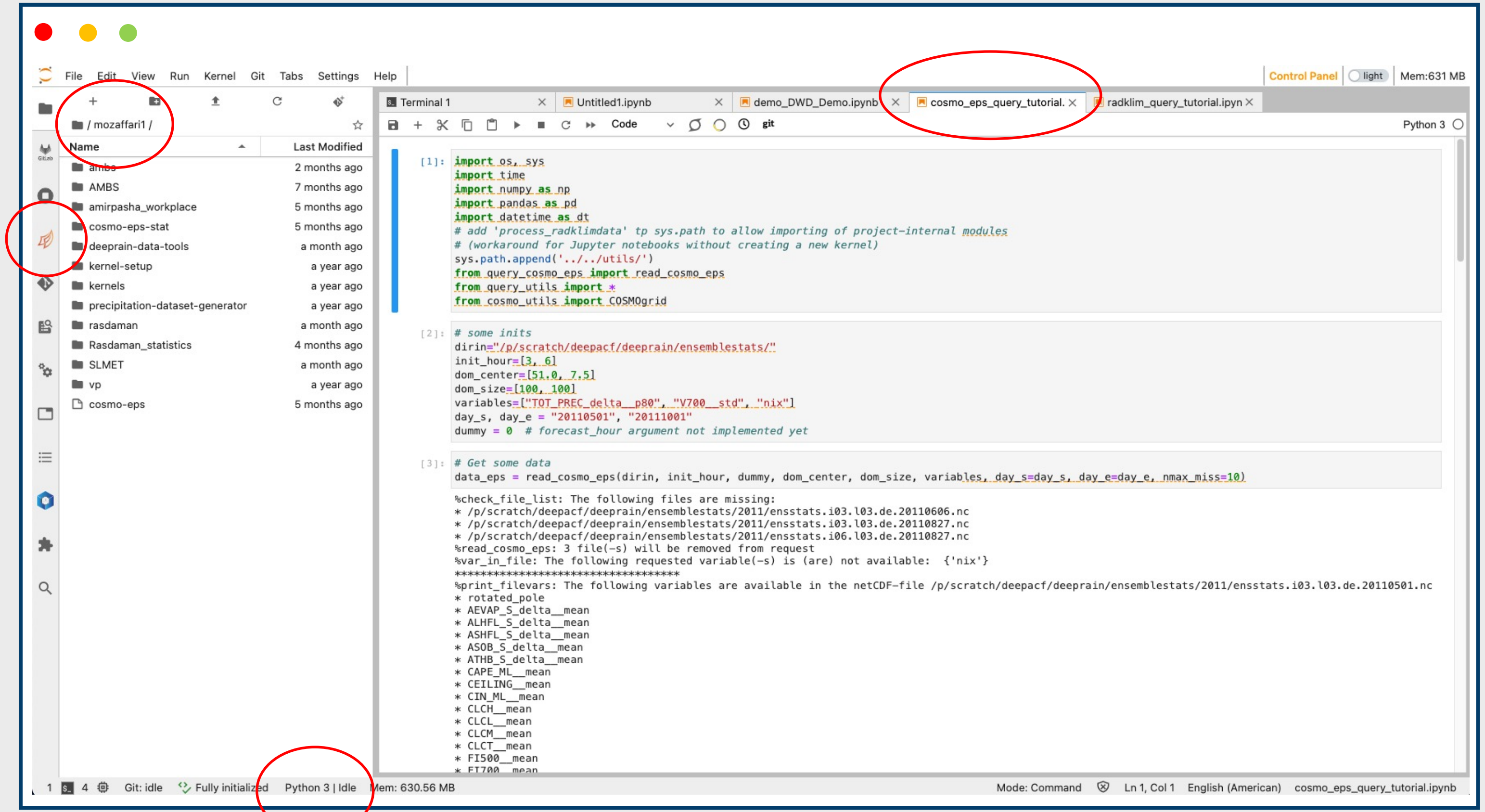
CWFR in HPC

-> Jupyter-JSC

- Familiar UI
- Customizable kernel
- Access to HPC



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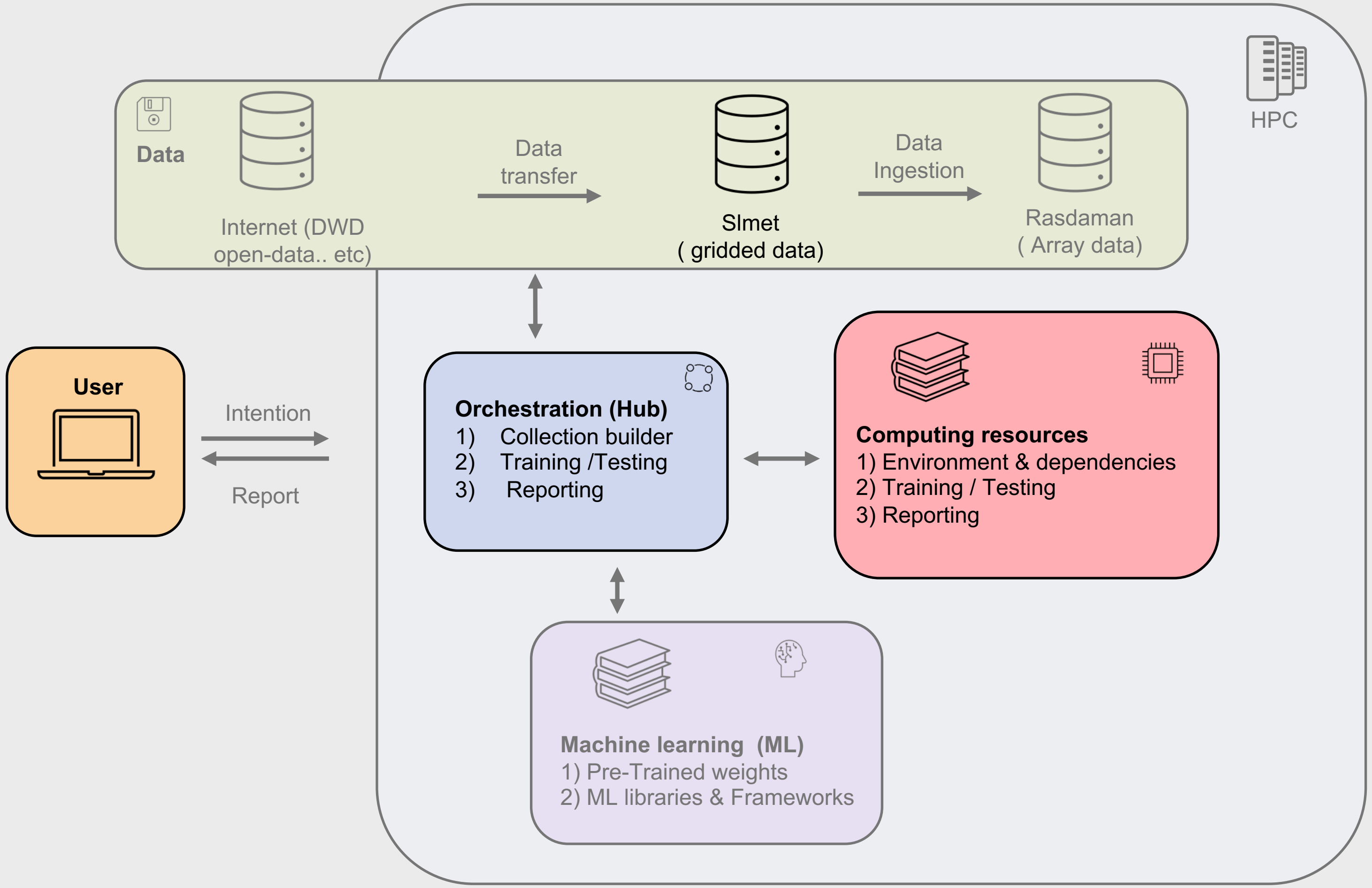
Example 1:

- **Data retrieval from multiple file-base system and cross validation**



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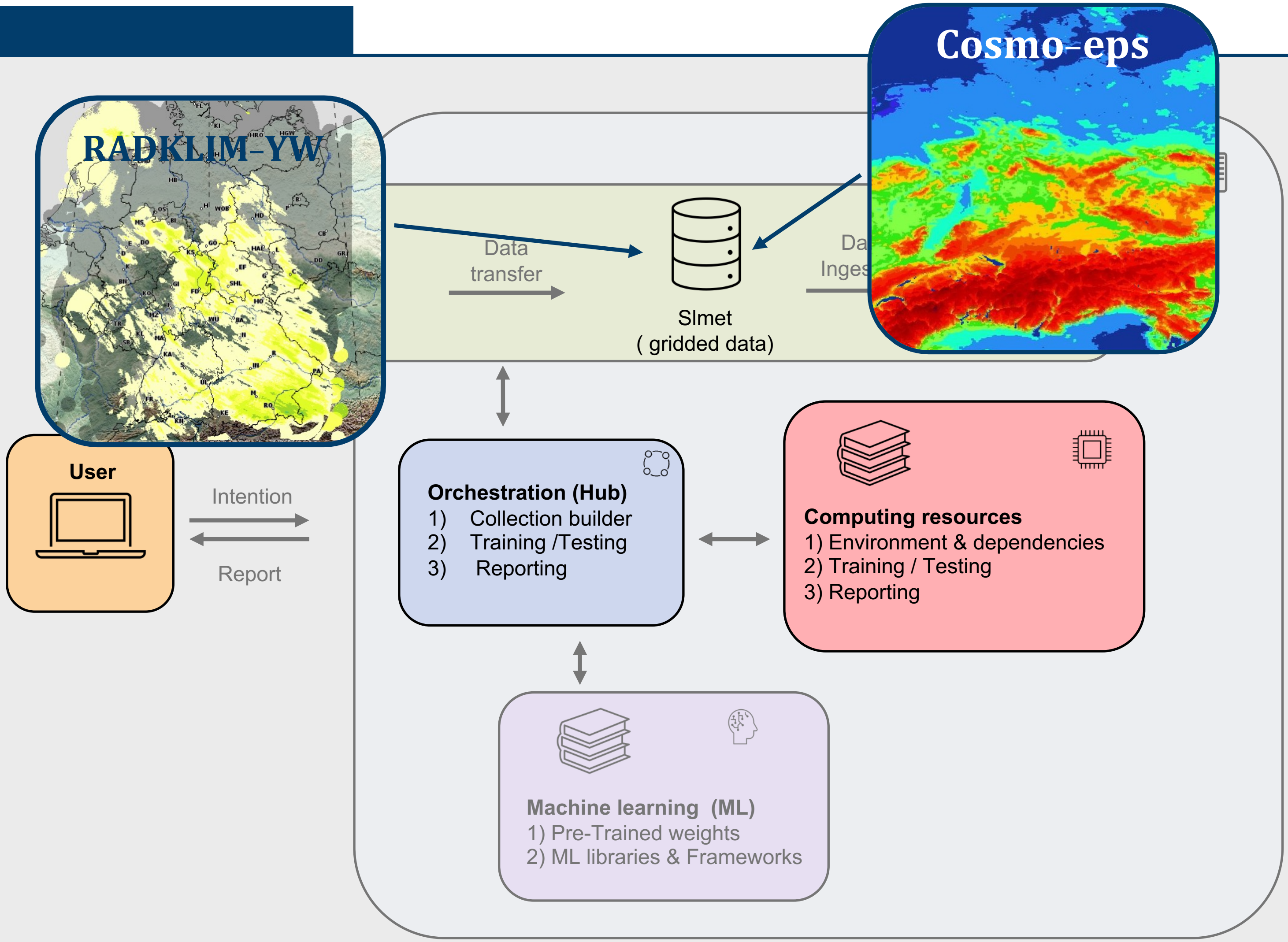
Example 1:

- Data retrieval from multiple file-base system and cross validation



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Example 1:

- **Data retrieval from multiple file-base system and cross validation**

```
# specify the top-level directory where the remapped data is stored in the Juelicher file system
# (!!! note the directory structure described at the end of the README.md !!!)
data_dir = "/p/scratch/deepacf/deeprain/radklim_process/netcdf/remapped/"

# specify the target domain in terms of dentral coordinate and domain size
dom_center = [51.0, 7.5]            # (unrotated) geogarphical coordinate (lat,lon) in degrees
                                    # a nearest neighbor approach is used to find the corresponding point on the COSM grid
dom_size = [100, 100]               # number of gridpoints in meridional (y) and zonal (x) direction of the target domain
date_start = "2016010100"           # start date of time period, format: YYYY
date_end   = "2017010100"           # end date of time period
freq       = "3H"                   # retrieve hourly precipitation every 3 hour (between date_start and date_end)
                                    # see https://pandas.pydata.org/pandas-docs/stable/user_guide/timeseries.html#timeseries-offset
                                    # for valid frequency aliases
```

```
[1]: import os, sys
     import time
     import numpy as np
     import pandas as pd
     import datetime as dt
     # add 'process_radklimdata' tp sys.path to allow importing of project-internal modules
     # (workaround for Jupyter notebooks without creating a new kernel)
     sys.path.append('../../utils/')
     from query_cosmo_eps import read_cosmo_eps
     from query_utils import *
     from cosmo_utils import COSMOgrid

[2]: # some inits
     dirin="/p/scratch/deepacf/deeprain/ensemblestats/"
     init_hour=[3, 6]
     dom_center=[51.0, 7.5]
     dom_size=[100, 100]
     variables=["TOT_PREC_delta__p80", "V700__std", "nix"]
     day_s, day_e = "20110501", "20111001"
     dummy = 0  # forecast_hour argument not implemented yet

[3]: # Get some data
     data_eps = read_cosmo_eps(dirin, init_hour, dummy, dom_center, dom_size, variables, day_s=day_s, day_e=day_e, nmax_miss=10)
```


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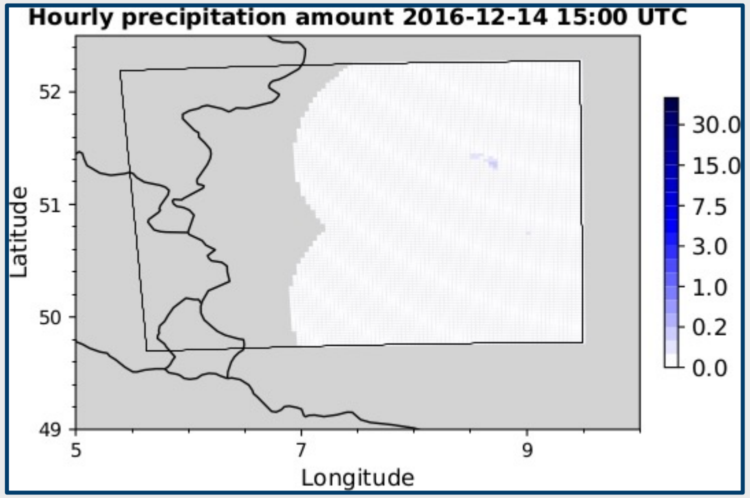
Example 1:

- **Data retrieval from multiple file-base system and cross validation**

```
%check_file_list: The following files are missing:
* /p/scratch/deepacf/deeprain/ensemblestats/2011/ensstats.i03.l03.de.20110606.nc
* /p/scratch/deepacf/deeprain/ensemblestats/2011/ensstats.i03.l03.de.20110827.nc
* /p/scratch/deepacf/deeprain/ensemblestats/2011/ensstats.i06.l03.de.20110827.nc
%read_cosmo_eps: 3 file(-s) will be removed from request
%var_in_file: The following requested variable(-s) is (are) not available:  {'nix'}
***********************************
%print_filevars: The following variables are available in the netCDF-file /p/scratch/deepacf/deeprain/ensemblestats/2011/ensstats.i03.l03.de.20110501.nc
* rotated_pole
* AEVAP_S_delta__mean
* ALHFL_S_delta__mean
* ASHFL_S_delta__mean
* ASOB_S_delta__mean
* ATHB_S_delta__mean
* CAPE_ML__mean
* CEILING__mean
* CIN_ML__mean
* CLCH__mean
* CLCL__mean
* CLCM__mean
* CLCT__mean
```



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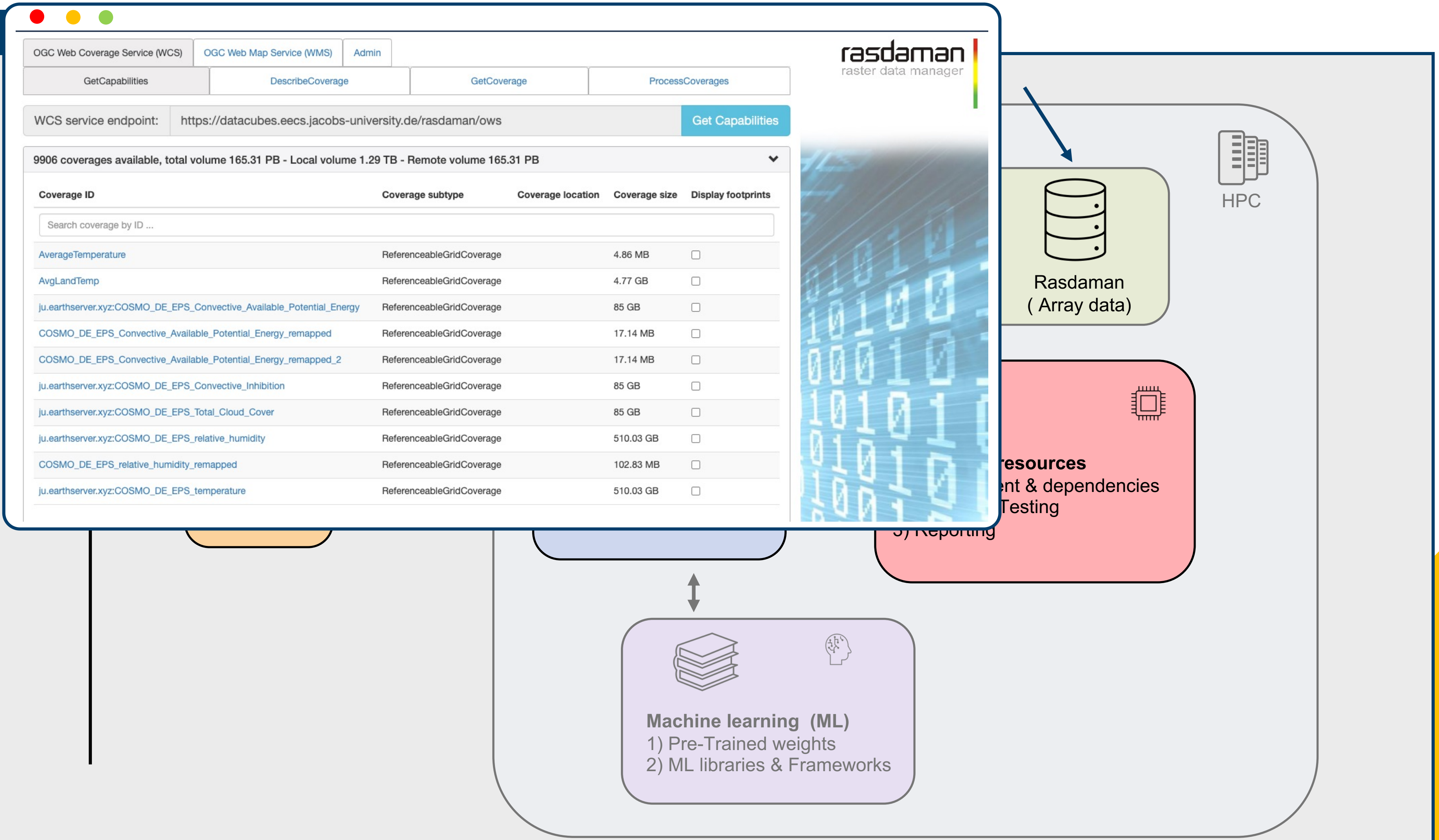
Example 2:

- **Data retrieval from an online array database and data visualization**



Coverage ID	Coverage subtype	Coverage location	Coverage size	Display footprints
AverageTemperature	ReferenceableGridCoverage		4.86 MB	☐
AvgLandTemp	ReferenceableGridCoverage		4.77 GB	☐
ju.earthserver.xyz:COSMO_DE_EPS_Convective_Available_Potential_Energy	ReferenceableGridCoverage		85 GB	☐
COSMO_DE_EPS_Convective_Available_Potential_Energy_remapped	ReferenceableGridCoverage		17.14 MB	☐
COSMO_DE_EPS_Convective_Available_Potential_Energy_remapped_2	ReferenceableGridCoverage		17.14 MB	☐
ju.earthserver.xyz:COSMO_DE_EPS_Convective_Inhibition	ReferenceableGridCoverage		85 GB	☐
ju.earthserver.xyz:COSMO_DE_EPS_Total_Cloud_Cover	ReferenceableGridCoverage		85 GB	☐
ju.earthserver.xyz:COSMO_DE_EPS_relative_humidity	ReferenceableGridCoverage		510.03 GB	☐
COSMO_DE_EPS_relative_humidity_remapped	ReferenceableGridCoverage		102.83 MB	☐
ju.earthserver.xyz:COSMO_DE_EPS_temperature	ReferenceableGridCoverage		510.03 GB	☐

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Example 2:

- **Data retrieval from an online array database and data visualization**

Service endpoint URL.

```
[3]: service_endpoint = "https://datacubes.eecs.jacobs-university.de/rasdaman/ows"
```

Function that retrieves the response of the query as an xarray dataset.

```
[4]: def get_query_response(query):
         '''
             Function returns a query as a netcdf byte-encoded response.

             Parameters: None

             Returns xarray.Dataset
         '''

         time0 = time.time()
         query_response = requests.post(service_endpoint, data={'query': query})

         # Convert bytes to file-like object
         netcdf_file = io.BytesIO(query_response.content)

         # Convert the netcdf_file like object to a xarray dataset.
         ds = xr.open_dataset(netcdf_file)

         print("Data query took {0:5.2f}s...".format(time.time() - time0))

         # Retun the xarray dataset.
         return ds
```


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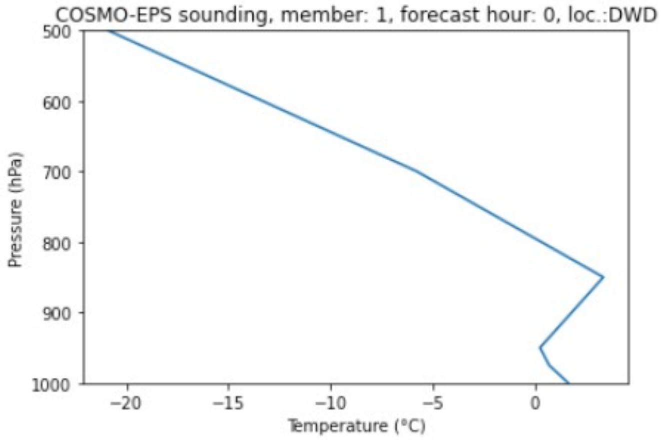
Example 2:

- **Data retrieval from an online array database and data visualization**

```
[10]: fig, ax = plt.subplots()

      plt.plot(ds['temperature'], ds['pressure_level']*.01)
      plt.ylim(1000., 500.)
      plt.ylabel('Pressure (hPa)')
      plt.xlabel('Temperature (°C)')
      plt.title("COSMO-EPS sounding, member: 1, forecast hour: 0, loc.:DWD")
```

```
[10]: Text(0.5, 1.0, 'COSMO-EPS sounding, member: 1, forecast hour: 0, loc.:DWD')
```



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Example 2:

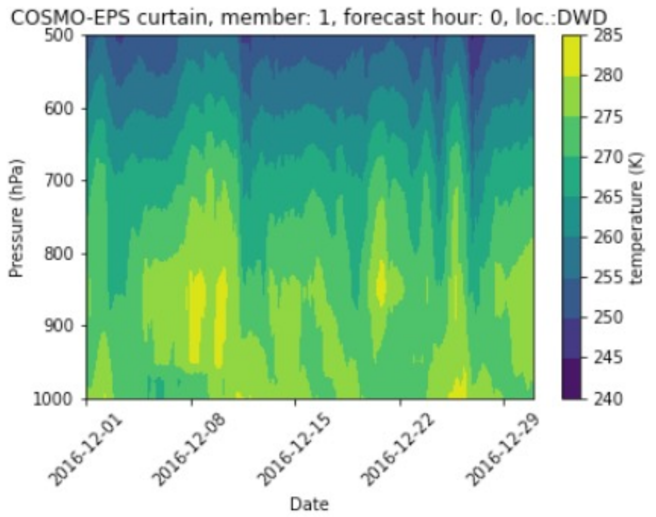
- **Data retrieval from an online array database and data visualization**

```
[12]: times = ds["ansi"].values

fig, ax = plt.subplots()

c = plt.contourf(times, ds['pressure_level']*0.01, ds['temperature'].T)
cb = plt.colorbar(c, label='temperature (K)')
plt.title("COSMO-EPS curtain, member: 1, forecast hour: 0, loc.:DWD")
plt.ylim(1000., 500.)
plt.xlabel('Date')
plt.ylabel('Pressure (hPa)')

add_date_label(ax, times)
```



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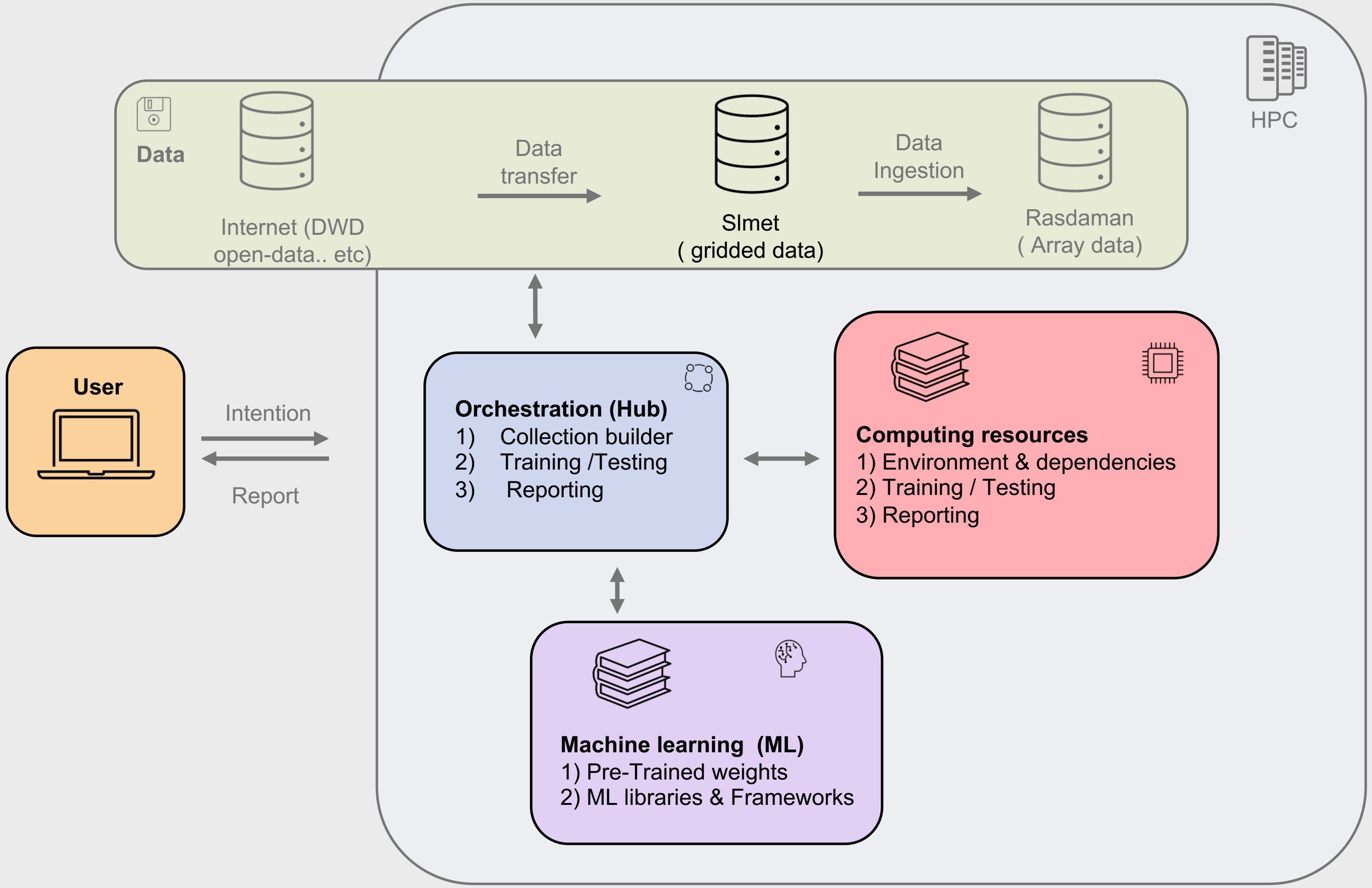
Example 3:

- **ML results retrieval and visualization of forecast and skill score**



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Example 3:

- **ML results retrieval and visualization of forecast and skill score**

Histograms of rain data

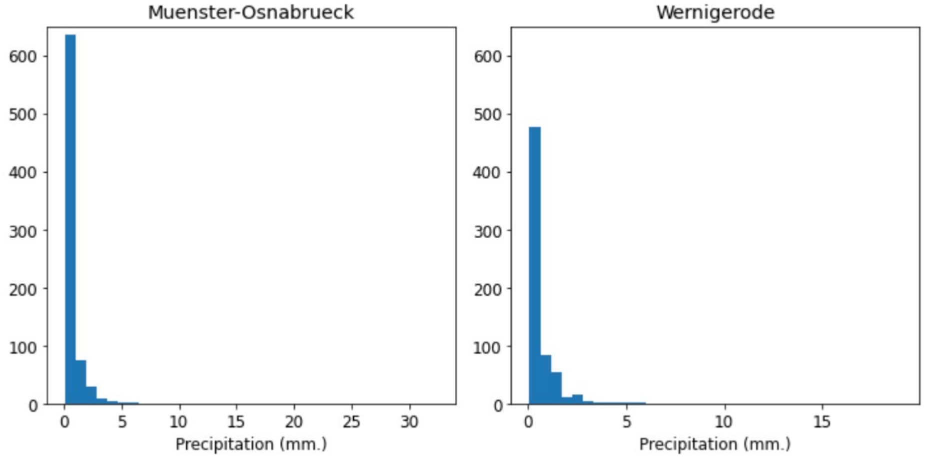
```
rain_histogram = []

for i, station in enumerate(stations):
    train_y = np.loadtxt('data/'+ station +'_0_4_5x5_allFeatures_created_2020-10-23/train_y.csv', delimiter=',')
    test_y  = np.loadtxt('data/'+ station +'_0_4_5x5_allFeatures_created_2020-10-23/test_y.csv', delimiter=',')
    y = np.concatenate((train_y, test_y))
    y = np.exp(y)
    print(station, y.shape)
    rain_histogram.append(y)

bins = 35

def format_hist_rain(ax, data, station):
    ax.hist(data, bins)
    ax.set_title(station)
    ax.set_xlabel('Precipitation (mm.)')
    ax.set_ylim([0,650])
```

```
np.mean(precipitation) for Muenster-Osnabrueck = 0.6601049868766404
np.mean(precipitation) for Wernigerode = 0.6971684053651266
np.mean(precipitation) for Braunlage = 0.7928571428571428
np.mean(precipitation) for Redlendorf = 0.7919494869771113
```



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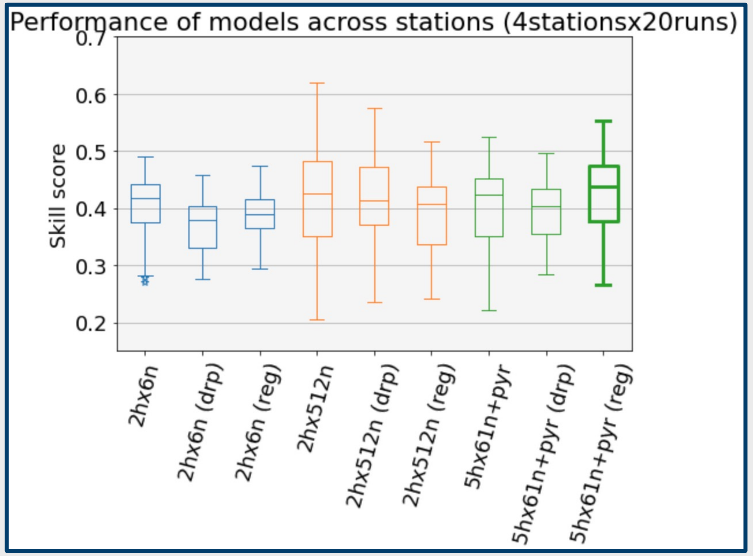
Example 3:

- **ML results retrieval and visualization of forecast and skill score**

Model comparation across stations

```
model_comp = data = np.empty([9, 80])

for j, model in enumerate(names):

    skill_model = []
    for i, station in enumerate(stations):

        skill_model_in_station = np.loadtxt(path_all+'/'+model+'/'+station+'/'+metric+'.txt', dtype=np.float64, delimiter=',')
        skill_model.append(skill_model_in_station)

    model_comp[j] = np.concatenate(skill_model)

print(model_comp.shape)


print('Median of skill score for models =', np.median(model_comp, axis=1))
print('Model with the highest median =', names_for_ticks[np.argmax(np.median(model_comp, axis=1))])
```

```
(9, 80)
Median of skill score for models = [0.41711134 0.37980181 0.38917765 0.42484066 0.41382593 0.40783788
 0.42309215 0.40392879 0.4383606 ]
Model with the highest median = 5hx61n+pyr (reg)
```



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Summary

- •Jupyter (deployed on HPC system) provides an easy–to–use framework for complicated workflows
- • User–friendly interface helps the user to easily interact with extensive data and HPC system
- •Ease of porting a workflow from a local machine to an HPC system with minimal adjustment

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Thank you

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