Make sure you have read the "exercise_calibration_preparation.pdf" before getting started here.

*This exercise is basically the same as exercise C$_2$ but the parallel version. It is again a calibration of the more **complex hydrologic model** of the Lake of the Woods reservoir with 21 subbasins (9 of which are explicit lakes) and 103 hydrologic response units (HRUs) over a 6 year calibration period. The example has **128 parameters** that need to be calibrated. We will use a multi-objective calibration to optimize the streamflow at one station (Vermillion) and the inflows to a lake (Lac La Croix). We will use the **OSTRICH toolbox** for calibration and the **hydrologic framework RAVEN** as our hydrologic model. The calibration algorithm will be the parallel version of the **Pareto Archived Dynamically Dimensioned Search (parallel PA-DDS)**.*

Task 1: Getting started

We will first make sure that all the settings are correct! This is similar steps as in exercise C$_2$.

1. Go to the exercise folder `Demo_C4`.
2. Depending on your operating system (Windows, Linux, or MacOS), you might have to make a few adjustments:
    a. Identify the OSTRICH executable in the main folder `Demo_C4` matching your operating system. Write it down:

       Ostrich_____.exe
    b. Identify in the subfolder `model` the name of the Raven executable matching your operating system. Write it down:

       Raven_____.exe
    c. Go to the subfolder `model`. You will find a script `run_RAVEN.sh` (Unix/MacOS) and `run_RAVEN.bat` (Windows). Open it and make sure that the correct Raven executable is used here (see 2b above).
    d. You will find two files named `ostIn_Windows.txt` and `ostIn_Unix.txt` in the main folder. Take the one matching your operating system, copy it and save it under the new name `ostIn.txt`. The two files are basically the same, only some "/" and "\" conversions are necessary between the Unix (=Linux or MacOS) and Windows systems.

Task 2: Run Raven only

We will only run Raven- no calibration yet. This is to make sure that Raven is running without any problem.

3. Go to the `model` subfolder.
4. Make sure that you find a subfolder `output` there. If not, please create this folder. It will later contain all Raven specific output files such as discharge time series etc.
5. Execute the Raven executable matching your system (see 2b. above). This is done by opening a terminal/ command line.
   Under Windows:
       Open Command Prompt, navigate to the model subfolder, type and execute (use the right executable name):
       `Raven_____.exe LOWRL -o output\`
   Under Linux/ MacOS:
       Open terminal, type and execute (use the right executable name):
       `./Raven_____.exe LOWRL -o output/`
6. The simulation should finish with
       `Exiting Gracefully: Successful Simulation`
   Model results can be found in the `output` subfolder.

Task 3: Calibration

We will now start a calibration of the model we have just run with one parameter set in Task 2.
Keep in mind that the WHOLE setup is exactly the same as in C_2. We are only using the parallel version of OSTRICH.

7. Go to the main folder `Demo_C4`.
8. Execute the Ostrich executable matching you operating system (see 2a. above) on TWO cores by running the following command in the terminal/ command line:
   Under Windows:
   ```
   mpiexec -n 2 Ostrich_____.exe
   ```
   Under Linux/ MacOS:
   ```
   mpirun -np 2 Ostrich_____.exe
   ```
9. The calibration starts and will finish with some `Algorithm Metrics`.
10. The OSTRICH results and information will be stored in the main folder in several files.
    Browse all of them and write down what they contain:
    a. OstErrors[0,1].txt   _____

    b. OstModel[0,1].txt   _____

    c. OstNonDomSolutions[0,1].txt   _____

    d. OstOutput[0,1].txt   _____

    e. OstPADDSPn.txt   _____

    f. OstStatus0.txt   _____

11. We calibrated NSE as you can see in the `BeginResponseVars` and `BeginTiedRespVars` block in the ostIn.txt file.
    How many iterations were used?
    a. # iterations: _____
    What is the final (best) calibration result?
    b. # non-dominated solutions found: _____
    What is the best NSE found for streamflow at Vermillion station (first objective)?
    c. NSE of streamflow: _____
    What is the NSE for the inflows to *Lac La Croix for this parameter set (solution)?*
    d. NSE of inflow: _____
12. Plot the non-dominated solutions in Excel/Matlab/Python etc.
13. Move all `Ost*.txt` files to the subfolder `processor_0` and rename the folder to `results_nse_nse_budget_XXX` (replace XXX by the budget under 11a) to safe the results for later. Otherwise they get overwritten when you initiate the next calibration.
14. Repeat the calibration with higher budgets and add the non-dominated solutions to the plot you have created in the previous task! How does results compare to the sequential results? Compare runtime, number of dominated solutions and the pareto fronts!

Budget	Plotted	# non-dominated solutions	Runtime [m]
50			
200			
500			

Note: In MO calibration like this, when looking for best overall tradeoff across multiple trials, you can put all non-dominated solutions from multiple trials together and then do another non-dominated sort to retain the overall set of non-dominated solutions.

Good luck!