



**Universität Stuttgart**

Institute for Modelling Hydraulic and Environmental Systems  
Department of Hydromechanics and Modelling of Hydrosystems

# FluidFlow Benchmark: Reporting and Interaction

Bernd Flemisch

FFIBS Initiation Meeting, 16.09.2021



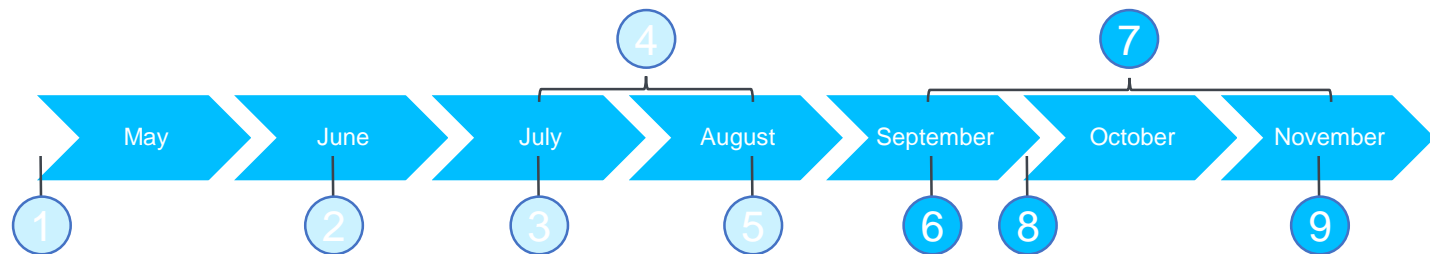
## ToDoS (NOW)

- Log in to the Discord server at <https://discord.gg/8Q5fZS3T47>
- In your profile, provide a user name "FirstName LastName (organization)", e.g. "Bernd Flemisch (Stuttgart)"
- You will be added to your private channel
  
- If you don't have a github.com account, create one at <https://github.com/signup>
- Communicate your github.com username to Bernd
- You will be added to your private repository

# Who?

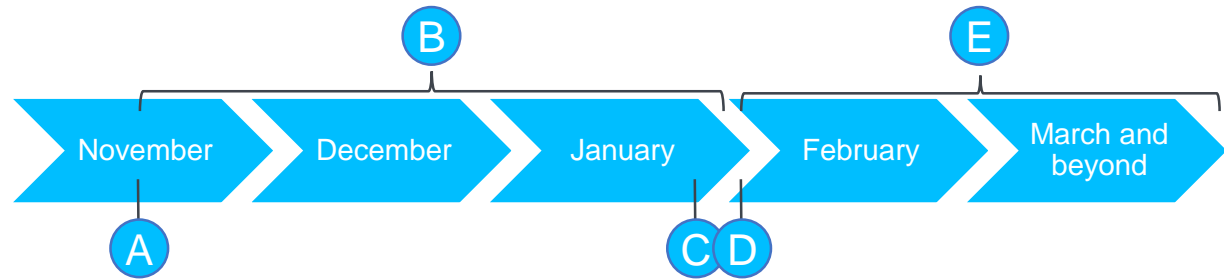
Institution	Person(s)
<b>Participants</b>	
Austin	Nick Espinosa, Mary Wheeler
CSIRO	Jonathan Ennis-King, Samuel Jackson, Andy Wilkins
Delft	Denis Voskov, Hadi Hajibeygi
Herriot-Watt	Florian Doster, Sebastian Geiger
Imperial	Matthew Jackson
LANL	Satish Karra, Hari Viswanathan, Bill Carey
Melbourne	Stephan Matthai, AbdAllah Youssef
MIT	Lluís Saló
Stanford	Hamdi Tchelepi
Stuttgart	Holger Class, Dennis Gläser, Fabian Jobst
<b>Experimental Group</b>	
Bergen	Martin Fernø + team members
<b>Organizers</b>	
Bergen	Jan Nordbotten, Martin Fernø, Magne Jørgensen
MIT	Ruben Juanes
Stuttgart	Bernd Flemisch

## When?



1. 30. April, 2021: Closed call for participation opens.
2. 15. June, 2021: Call closes.
3. 15. July, 2021: Preliminary benchmark description supplied to participants.
4. 16. July – 19. August, 2021: Preparation phase, discussion possible among all participants and the experimental team.
5. 20. August, 2021: Deadline for feedback on preliminary benchmark description.
6. 16. September, 2021: Kick-off Zoom meeting, second iteration of description distributed.
7. 17. September – 16. November, 2021: **Blind phase**, no direct communication between different participants or with the experimental group or uninvolved persons.
8. 1. October, 2021: Final benchmark description circulated to participants.
9. 14. November, 2021: **Deadline for submitting blind benchmark data.**

## When?



- A. 17. November, 2021: Virtual workshop and comparison of “fully blind” simulation forecasts.
- B. 17. November 2021 – 31. January 2022: **Synchronization phase**, communication between all participants enabled, but not with the experimental group.
- C. 27. January, 2022: **Deadline for submitting final benchmark data.**
- D. 1.-2. February, 2022: Real workshop in Norway (location to be determined) with presentation of final simulation forecasts, experimental results, model calibration study, and synthesis of results.
- E. Spring 2022: Writing and submitting papers based on the findings of the study.

## What?

### Dense Data Time Series

*All measurables* identified in section 2.7 shall be reported at *10-minute intervals* starting at the initial injection and lasting *120 hours*. The data is expected in csv format in a file `time_series.csv` of the form

```
# t, p_1, p_2, mob_A, imm_A, diss_A, seal_A, <same for B>, M_C
0.000e+00, 1.234e+56, 1.234e+56, <...>
6.000e+02, 1.234e+56, 1.234e+56, <...>
...
```

according to the measurables defined in section 2.7.

# What?

## Map of Phase Compositions

To be reported *for each 24 hours* after injection starts on a uniform *Cartesian grid of 284 by 165 cells*. For each temporal snapshot indicated by X hours, X = 24, 48, ..., cell values should be provided in csv format in a file `spatial_map_<X>h.csv` of the form

```
# x, y, saturation, concentration
5.000e-03, 5.000e-03, 1.234e+56, 1.234e+56
1.500e-02, 5.000e-03, 1.234e+56, 1.234e+56
...
2.835e+00, 5.000e-03, 1.234e+56, 1.234e+56
5.000e-03, 1.500e-02, 1.234e+56, 1.234e+56
1.500e-02, 1.500e-02, 1.234e+56, 1.234e+56
... ..
2.825e+00, 1.645e+00, 1.234e+56, 1.234e+56
2.835e+00, 1.645e+00, 1.234e+56, 1.234e+56
```

The origin of the coordinate system should be located in the lower left corner with the x-axis positively oriented towards the right and the y-axis positively oriented towards the top.

# What?

## Requested Sparse Data

1. *As a proxy for assessing risk of mechanical disturbance of the overburden:* Maximum pressure at sensor number 1 and 2.
2. *As a proxy for when leakage risk starts declining:* Time of maximum mobile free phase in Box A.
3. *As a proxy for our ability to accurately predict near well phase partitioning:* All quantities defined in Section 2.7.2 in Box A at 72 hours after injection starts.
4. *As a proxy for our ability to handle uncertain geological features:* All quantities defined in Section 2.7.2 in Box B at 72 hours after injection starts.
5. *As a proxy for our ability to capture onset of convective mixing:* Time for which the quantity M defined in Section 2.7.3 first exceeds 110% of the width of Box C.
6. *As a proxy for our ability to capture migration into low-permeable seals:* Total mass of CO<sub>2</sub> in the top seal facies (areas marked yellow in the sketch) at final time.



# What?

## Sparse Data Determination

- Each of the sparse data shall be reported as six numbers:
  - Prediction of the mean quantity as obtained by the experiments
  - Prediction in the standard deviation of the quantity over the ensemble of experiments
  - Stated in terms of P10, P50 and P90 values
- Mean values assess the capability of predicting the various measurables
- Standard deviations address the extent to which these quantities are deterministic
- Any preferred methodology may be chosen:
  - ensemble runs
  - methods from uncertainty quantification
  - human intuition from experience

# What?

## Sparse Data Format

The quantities are expected to be uploaded to the repository in form of a csv file `sparse_data.csv` of the form

```
# idx, p10_mean, p50_mean, p90_mean, p10_dev, p50_dev, p90_dev
1a, 1.234e+56, <...>, # pressure at sensor 1 [N/m2]
1b, 1.234e+56, <...>, # pressure at sensor 2 [N/m2]
2, 1.234e+56, <...>, # time of max mobile free phase in Box A [s]
3a, 1.234e+56, <...>, # mobile free phase in Box A at 72h [kg/m2]
3b, 1.234e+56, <...>, # immobile free phase in Box A at 72h [kg/m2]
3c, 1.234e+56, <...>, # dissolved in water in Box A at 72h [kg/m2]
3d, 1.234e+56, <...>, # seal in Box A at 72h [kg/m2]
4a-d <same for Box B>
5, 1.234e+56, <...>, # time when M exceeds 110% of Box C's width [s]
6, 1.234e+56, <...>, # total mass of CO2 in the top seal facies [kg]
```

# What?

## Qualitative Data

- Questionnaires to gather contextual information
- In particular during the workshops
- Address issues of
  - numerical modeling and simulation
  - choices and judgements made for assessing the confidence intervals

# How?

## Data Reporting

- GitHub organization <https://github.com/fluidflower>
- One repository for each participating group, e.g. [fluidflower/csiro](#)
- Result files should be uploaded there
- Participant repositories will be
  - *private* during the *blind phase*
  - open to *all participants* (read-only) during the *synchronization phase*
  - turned *public* (read-only) with acceptance of the *first paper*
- General repository [fluidflower/general](#) accessible to all participants during the whole process: accompanying material such as parameter values, pictures, ...
- Repository [fluidflower/experiment](#) for the experimental data:
  - *private* during the blind and synchronization phase
  - opened to *all participants* (read-only) at the workshop in February
  - turned *public* (read-only) with acceptance of the *first paper*

# How?

## Communication

- Discord server "FluidFlower benchmark" at <https://discord.gg/8Q5fZS3T47>
- One channel for each participating group, e.g. "csiro"
- Participant channels will be
  - *restricted* to the respective participating group + Bernd during the *blind phase*
  - open to *all participants* during the *synchronization phase*
  - turned *public* (read-only) with acceptance of the *first paper*
- Channel "general" accessible to all participants during the whole process, set to read-only during the blind phase
- Channel "experiment" for communication with the experimental group:
  - *restricted* to the experimental group + Bernd during the blind and synchronization phase
  - opened to *all participants* at the workshop in February
  - turned *public* (read-only) with acceptance of the *first paper*

## How?

### Communication during the blind phase

- **Only communicate sensitive information within your participating group**
- Includes *avoiding possible around-the-corner communication* by talking to uninvolved persons
- **Ok / Careful / Don't:**
  - "They only gave us a picture of the experimental rig. It's really hard to extract a computational geometry from this."
  - "We even have to estimate the width of a fracture."
  - "The picture gave me no clue, so I simply set it to 123 mm."
- *Communication with Bernd* is allowed via the Discord participant channel
- This communication should be *reserved for*
  - *technical issues*: "I can't access my Git repo"
  - *organizational issues*: "I won't meet the deadline"
  - *suspected errors* in the data: "This unit can't be  $\text{mm}^2$ , it has to be mD."
- **Don't expect help on getting more data**: "I really need to know the exact width of the rig at this particular position." **Make an assumption and write it up.**

## ToDoS (NOW)

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  - Communicate your github.com username to Bernd
  - You will be added to your private repository

## ToDo (Later)

- Download the participation agreement at [https://github.com/fluidflower/general/blob/main/participation\\_agreement.pdf](https://github.com/fluidflower/general/blob/main/participation_agreement.pdf).
- Sign one agreement per participating institution and send it to [bernd@iws.uni-stuttgart.de](mailto:bernd@iws.uni-stuttgart.de).
- Do so **before 30. September**.





**Universität Stuttgart**

Institut für Wasser- und Umweltsystemmodellierung  
Lehrstuhl für Hydromechanik und Hydrosystemmodellierung

**Vielen Dank!**



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