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NTNU-UiO Porous Media Laboratory

Senter for fremragende forskning
Norges forskningsråd

NTNU
Norwegian University of Science and Technology

UiO : University of Oslo

Experiences with OPM use in education

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TPG4160 - Reservoir Simulation

- Course in reservoir simulation given at NTNU
- Combine theory, coding and simulations
- Given by Jon Kleppe before 2019
- Popular around the world
  - Due to accessibility?
  - Open notes and codes
- I took over the course in 2019
  - Increased use of open source software

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Why open source?

- All students have access to the software
  - Also when they leave the university
- Openness needed for research
  - Research supposed to the rigorous - not obtained by *black box* software
  - Possible to build on software to test out new ideas, methods and methodology

Software

Pre-2019

- FORTRAN77
- ECLIPSE 100
- GRAF
- Excel

Post-2019

- Python
- OPM-Flow
- ResInsight
- ecl+Python

Lecture Notes

Pre-2019

- Word

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Lecture note 1

INTRODUCTION TO RESERVOIR SIMULATION

Analytical and numerical solutions of simple one-dimensional, one-phase flow equations

As an introduction to reservoir simulation, we will review the simplest one-dimensional flow equations for horizontal flow of one fluid, and look at analytical and numerical solutions of pressure as function of position and time. These equations are derived using the continuity equation, Darcy's equation, and compressibility definitions for rock and fluid, assuming constant permeability and viscosity. They are the simplest equations we can have, which involve transient fluid flow inside the reservoir.

Linear flow

Consider a simple horizontal slab of porous material, where initially the pressure everywhere is P_0, and then at time zero, the left side pressure (at $x = 0$) is raised to P_L while the right side pressure (at $x = L$) is kept at $P_R = P_0$. The system is shown on the next figure:

Post-2019

- Latex

GRIDS IN RESERVOIR SIMULATION 107

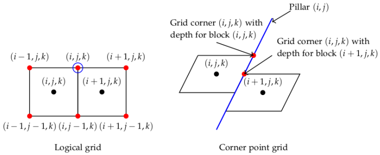


Figure 7.6: A constant j-slice through a corner point grid (right), and its corresponding logical grid seen from above (left). Black circles are cell centers, and red circles are grid corners. The (i,j)-pillar is shown in blue. The corner point grid have cells which are logical neighbors, but have different depths for the same logical corners.

for different grid cells, as illustrated in the right figure in Fig. 7.6. Each logical corner in the regular i, j, k grid is shared by 8 grid cells. Different depths for the same logical corner can be used for representing faults and non-reservoir gaps.

It would seem straight forward to represent 2D fault patterns by defining pillars along the fault planes. However, the resulting grids will not be **K**-orthogonal, so zig-zag faults (see Fig. 7.5) is actually preferred. Compartment volumes may be severely affected by this approximation. Well paths close to faults may also need to be moved in the model so that they penetrate the correct compartments. Complex fault patterns in 3D is impossible to represent without an additional zig-zag representation in the vertical. Un-

Lecture notes

- Lecture notes
  - *Reservoir Simulation Through Open Source Software*
  - Not online - yet…
- Content:
  - Theory
  - Example scripts (1D simulations)
  - How to run OPM-Flow
  - How to use ResInsight
  - Exercises
- Simple instruction videos on YouTube

6

Reservoir simulation of single-phase flow

Rocket engines burning fuel so fast
Up into the night sky they blast
Through the universe the engines whine
Could it be the end of man and time?

Black Sabbath - Into The Void

In this chapter we will continue with the one-dimensional single phase case considered in Chap. 3 and Chap. 5. In this chapter we will solve the diffusivity equation, Eq. (3.48), using the reservoir simulator OPM-Flow. OPM-Flow is a reservoir simulator with up to three phases (oil, water and gas). It is not created for single phase flow, so even though we will use it for single phase flow, the simulator itself will solve multi-phase equations with only one non-zero phase. This also means that we need to define a two-phase model (e.g. oil and water), but we will only have water in the model.

OPM-Flow is based on providing an input file, by some called an input deck[1], which contain all reservoir data, fluid data and the initial and boundary conditions (e.g. well control). The input file will be described in the following.

[1] The term deck for a computer file goes back to the ancient (pre 1980) times of punched cards. Each card represented a line in a text file.

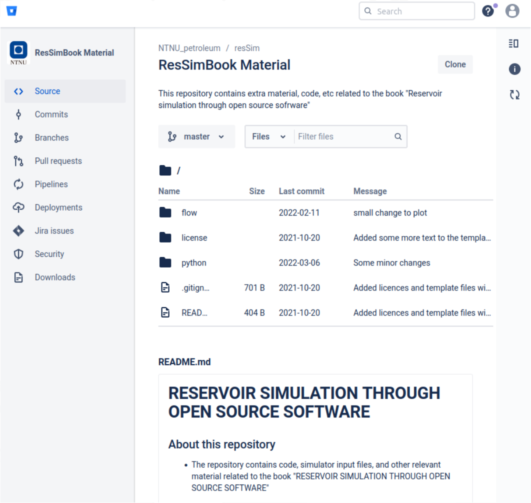
Picture by Arnold Reinhold (Wikipedia)

6.1 OPM-Flow input files (.DATA-files)*

The name of the main input file to OPM-Flow is commonly written with capital letters, and with the file extension *.DATA. These files

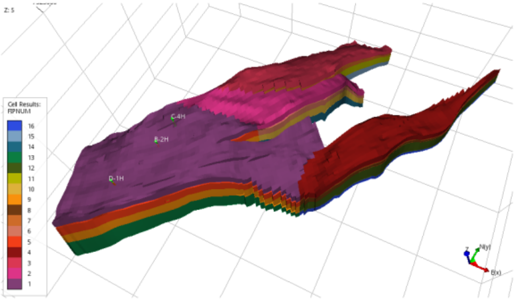
Exercises

- Coding simple simulators (1D)
- Comparing results with
  - Theory
  - OPM-Flow
- Complex (>1D) examples run with OPM-Flow
- Project on full-field models
  - Optimization on SPE10 layer
  - CO2 injection on Norne-model



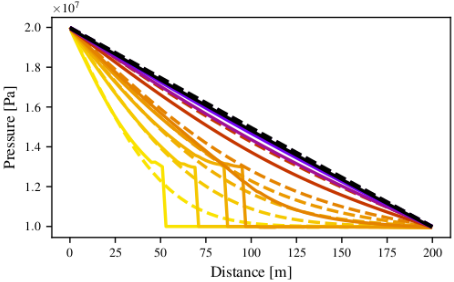
Experience

- Command-line environment is challenging
  - Steep learning curve
- Compatibility
  - Most students run Windows or use Mac
  - Increasingly popular to run Flow locally rather than on cluster
- ResInsight is popular
  - Available for Windows
  - Easy to use



Experience

- Rapid development of OPM-Flow
  - Year-to-year changes of example cases
- Continuous improvements
  - Increasing compatibility with Eclipse models
  - Better performance
- Avoiding license call important for optimization



Experience

- Code complex for students
  - Master and PhD studies have a limited time horizon
  - Lower barrier with Python scripts and MRST
  - Support from industry would be appreciated
- Limited success in getting student to work on the code base
  - Support from industry would be appreciated
  - Topics with limited scope needed