

pycopm: An open-source tool to tailor OPM Flow geological models

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Summary

Reservoir simulations help the energy industry make better decisions by predicting how fluids like oil, gas, water, hydrogen, and carbon dioxide will flow underground. To keep these predictions accurate, engineers often need to update geological models quickly as new information becomes available. pycopm is a tool designed to make this process faster and easier. It allows users to adjust geological models in several ways, such as simplifying complex grids, focusing on specific parts of a reservoir, or changing the shape and position of the model (Figure 1). These capabilities help engineers test different scenarios efficiently. Although pycopm was first used on two well-known public datasets, it has since become useful in many other situations because of its easy-to-use features and recent extensions. Today, it supports studies involving model refinement, comparing coarse and detailed models, analyzing interactions between nearby sites, and speeding up troubleshooting in large simulations.

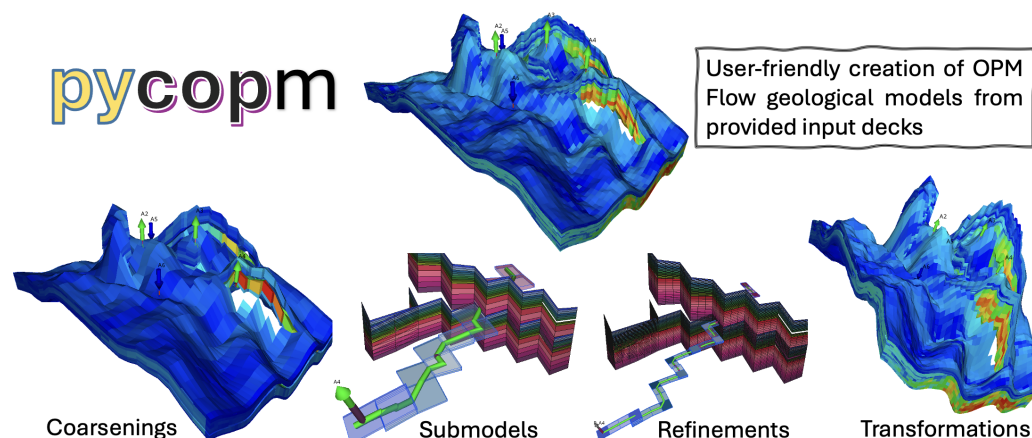


Figure 1: Graphical representation of pycopm's functionality ([here](#) are details to reproduce this).

Statement of need

The first step in reservoir simulations is to choose a simulation model, which serves as the computational representation of a geological model, incorporating properties such as heterogeneity, physics, fluid properties, boundary conditions, and wells. Once the spatial model is designed, it is discretized into cells containing average properties of the continuous reservoir model. All this information is then communicated to the simulator, which internally solves conservation equations (mass, momentum, and energy) and constitutive equations (e.g., saturation functions, well models) to perform the predictions. OPM Flow is an open-source simulator for subsurface applications such as hydrocarbon recovery, CO₂ storage, and H₂

storage ([Rasmussen et al., 2021](#)). The input files of OPM Flow follow the industry-standard Eclipse format. The different functionalities are defined using keywords in a main input deck with the .DATA extension, while additional information is typically provided in supplementary .INC files, including tables for saturation functions and PVT (pressure-volume-temperature) properties, as well as the grid discretization. We refer to the [OPM Flow manual](#) for an introduction to OPM Flow and all supported keywords.

Simulation models can be substantial, typically encompassing millions of cells, and can be quite complex due to the number of wells and faults, defined by cell indices in the x, y, and z direction (i, j, and k nomenclature). While manually modifying small input decks is feasible, it becomes impractical for large models. In addition, these models commonly rely on corner-point grids defined through pillars and horizons, and they may include further geometric modifications specified through deck keywords. Such representations are not intuitive to manipulate, particularly for users who are not familiar with the internal structure of simulation decks.

These challenges inspired the development of pycopm, a user-friendly Python tool designed to tailor geological models from provided input decks. pycopm is intended for researchers, engineers, and students who need to apply model transformations such as coarsening, refinement, submodel extraction, and structural adjustments. The coarsening and refinement capabilities are especially relevant in current workflows, since multi-fidelity modeling has become an active and widely adopted research direction that requires the flexibility to generate models with different levels of complexity.

State of the field

Two key properties in a reservoir model are its storage capacity, measured by pore volume, and the ability of fluids to flow between cells, known as transmissibilities. Therefore, these properties must be properly handled when generating a new model. While grid refinements and transformations do not pose a significant issue, submodels and grid coarsening present challenges due to the lack of unique methods for addressing these properties. In other words, the approach depends on the specific model, and while there are a few methods in the literature, this remains an active area of research.

Two of the most widely used commercial software suites in reservoir modeling are [Petrel](#) and [Aspen RMS](#). Petrel provides an integrated, end-to-end environment that spans workflows from seismic interpretation to reservoir simulation, enabling users to construct simulation-ready models with customized gridding strategies. Aspen RMS, while also capable of handling 3D and 4D seismic data and integrating these into reservoir models, is more strongly focused on geological modeling and reservoir characterization. Despite their extensive capabilities, both platforms are highly complex and demand significant user expertise, often involving steep learning curves. Additionally, their use is constrained by proprietary licensing models, which can limit accessibility and reproducibility, particularly in academic and open research contexts.

[opm-upscaling](#) is part of the [OPM initiative](#), and provides a set of C++ tools focused on single-phase and steady-state upscaling of capillary pressure and relative permeability. However, it does not include functionality for grid refinement or affine transformations, and its upscaling routines operate mainly on the grid structure. As a result, users must manually adjust the remaining components of the deck to match the new i, j, and k indices. Examples include updating the locations of wells, numerical aquifers, and other model elements.

[ResInsight](#) is an open-source C++ tool designed for postprocessing reservoir models and simulations. It can export modified simulation grids and supports operations such as grid refinement and submodel extraction. Nevertheless, it does not generate an updated input deck reflecting the modified i, j, and k coordinates. It also lacks built-in capabilities for model coarsening or for applying general affine transformations. Users on macOS may encounter

installation challenges, and the software has difficulty handling models with very small cell dimensions (below 1 mm) or with very large cell counts (greater than 100 million).

To the author's knowledge, prior to the development of pycopm there was no integrated Python-based solution that combined coarsening, refinement, submodel extraction, and geometric transformations for modifying geological models compatible with OPM Flow. Python offers a significantly more accessible environment than C++, which lowers the entry barrier for researchers, engineers, and students who need flexible model manipulation tools. pycopm offers flexibility in selecting different approaches, allowing end-users to compare methods and choose the one that best fits their needs. For additional information about the different approaches implemented in pycopm for coarsenings, refinements, submodels, and transformations, see the section on [theory](#) in pycopm's documentation.

Software design

pycopm leverages well-established and excellent Python libraries. The Python package numpy ([Harris et al., 2020](#)) forms the basis for performing array operations. The Shapely package ([Gillies et al., 2025](#)), particularly the `contains_xy` method, is fundamental for submodel implementation used to locate grid cells within a given polygon. To parse the output binary files of OPM Flow, the [opm](#) Python libraries are utilized. The primary methods developed in pycopm include handling of corner-point grids, upscaling transmissibilities in complex models with faults (non-neighboring connections) and inactive cells, projecting pore volumes on submodel boundaries, interpolating to extend the definition of i, j, and k dependent properties (e.g., wells, faults) in grid refinement, and parsing and writing input decks.

While graphical user interfaces (GUIs) are generally more intuitive for beginners, command-line interfaces (CLIs) offer advantages in speed and efficiency, enable powerful automation and scripting, provide fine-grained control, require minimal computational resources, and integrate naturally with modern AI-driven workflows. Therefore, interaction with the tool is performed through a terminal executable named pycopm, which provides a set of command-line flags (29 at the time of writing; see the online documentation for the [current list](#)). These flags control the desired functionality, such as specifying the input deck, defining how the model should be modified, and selecting the output file name. This design enables users to chain multiple operations by further editing the generated decks. For example, a user may refine a model first and subsequently extract a submodel. An illustrative example is provided in [test_4_submodel.py](#) in the project repository. Advanced users who are familiar with Python can access the underlying functionality directly through Python scripts. This provides greater flexibility for integrating the tool into more sophisticated workflows and for customizing model transformations to meet specific research or engineering needs.

Internally, pycopm is structured as a modular Python package with clearly defined subpackages, each responsible for a specific aspect of the workflow. These include:

- input parsing and deck processing,
- grid construction and transformations,
- property mapping and upscaling,
- file generation and output writing, and
- execution and workflow control.

This separation of concerns enhances maintainability and extensibility, allowing developers to modify or extend individual components without affecting the overall system. The primary design goal of pycopm is to provide flexibility for handling and modifying reservoir models, rather than focusing on support for multiple data deck formats or maximizing raw computational performance. This flexibility is enabled by its Python-based implementation and modular architecture.

Research impact statement

pycorm is already being adopted across several projects at NORCE Research AS and Equinor ASA. The user base is growing, with increased activity observed across multiple locations. GitHub traffic insights also show a steady rise in repository clones, indicating expanding interest and usage.

The software has supported several research publications, including:

- Sandve et al. (2024), where it was used to coarsen the Drogon model for history matching,
- Nilsen et al. (2025), which applied coarsening of the same model to optimize operations using wind energy,
- Sandve et al. (2025), where submodel extraction and coarsening were applied to the Troll aquifer model to analyze pressure interference, and
- Landa-Marbán et al. (2026), which used coarsening of the Troll aquifer model to optimize well placement in CO₂ storage simulations.

pycorm is part of the software suite developed within the [Centre for Sustainable Subsurface Resources](#) and maintained under the [cssr-tools](#) GitHub organization. A key objective of these tools is to support research outputs that adhere to the FAIR principles (Findable, Accessible, Interoperable, Reusable) originally formalized in Wilkinson et al. (2016). These principles have not been consistently implemented in subsurface research in recent years (Liu et al., 2026), limiting the long-term impact and reproducibility of published results. To address this, significant effort has been dedicated to building comprehensive online documentation that enables users to reproduce figures, tables, and computational workflows from recent publications. For example, the [TCCS-13](#) documentation includes step-by-step terminal commands required to generate the results presented in Landa-Marbán et al. (2026). This ensures that published work is not only transparent but also directly reusable by other researchers, enhancing scientific rigor and accelerating future developments.

Looking ahead to increase the research impact, the plan for pycorm's future development includes extending its functionality to support additional keywords from input decks beyond those in geological models, on which pycorm has been successfully tested ([Drogon](#), [Norne](#), [Smeaheia](#), [SPE10](#), [Troll aquifer model](#)). This support will be added as pycorm is applied in further models, and external contributions to the tool are welcomed. Additionally, extending pycorm's capabilities includes implementing a feature to generate a single input deck by combining geological models from different input decks.

AI usage disclosure

No generative AI tools were used in the original development of the software submitted to JOSS. Microsoft M365 Copilot, based on a GPT-5 reasoning model, was used to review and improve the writing of the manuscript. During the JOSS review, Copilot was also used to assist with expanding the API documentation, modernizing the code, optimizing performance, extending the test suite, and increasing test coverage of command-line argument validation. All AI-assisted suggestions and changes were reviewed, edited, and validated by the author, who takes full responsibility for the resulting manuscript and software.

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