# LUNDIsim: open-data multiresolution model meshes with porosity and permeability properties inspired from SPE10 challenge for geoscience, reservoir simulation, and data science applications

Laurent Duval[*], Frédéric Payan[†], Christophe Preux[‡], Lauriane Bouard[§]

January 16, 2025

**Abstract**

This note describes the content of LUNDIsim dataset. It consists in five main meshes in GRDECL format: one common hexaedral (Corner Point Grid) mesh model, plus four meshes filled with permeability and porosity values, corresponding to distinct subsurface environments. The latter four meshes are provided with lower-resolution versions, meant for geoscience, reversoir engineering, and data science applications (rendering, simulation, upscaling, compression, learning). It is available at 10.5281/zenodo.14641959.

***Keywords***— geoscience, reservoir simulation, model mesh, scientific data

## 1 General description and associated references

LUNDIsim consists in an open dataset, composed of four distinct subsurface environments sharing a common faulted polygonal model mesh, inspired by Model 2 of the 10th SPE Comparative Solution Project [CB01] (`https://www.spe.org/web/csp/datasets/set02.htm`). It is associated with one published journal paper [HexaShrink2019] and one to-be-submitted companion preprint [LUNDIsim2025]:

**HexaShrink2019** HexaShrink, an exact scalable framework for hexahedral meshes with attributes and discontinuities: multiresolution rendering and storage of geoscience models, Computational Geosciences, August 2019 (doi) [PDP$^+$19],

**LUNDIsim2025** LUNDIsim: model meshes for flow simulation and compression benchmarks, to be submitted to *Geoscience Data Journal*, January 2025 (pdf) [DPPB25].

LUNDIsim was mainly conceived to conduct benchmarks on the compression of reservoir geoscience models with respect to flow simulation. We describe in this document the essential information required to seize the different components of this dataset.

## 2 LUNDIsim dataset description and filenames

Hereafter is the necessary information required to visualize and use the LUNDIsim dataset. We refer to preprint [LUNDIsim2025] for more details.

Each component in LUNDIsim consists in a composite mesh in ASCII "GRDECL" (Grid Eclipse) format with one (in "PNG" format) or two additional images (in "JPG" or JPEG format). The latter images are represented in Table 1 hereafter. The common full-scale (at resolution 0) mesh is an hexahedral mesh representing a geological reservoir, designed with three non-parallel faults. It is stored in file 'LUNDIsim-Base-Grid-res0-mesh.grdecl' and depicted by image 'LUNDIsim-Base-Grid-res0-view-3D.png'. Its size is $128 \times 128 \times 32$ cells. The mesh geometry is described as a "Corner Point Grid" ("CPG" format), a data structure frequent in geoscience. It allows the description of non-conformal meshes, for instance containing subsurface faults. Each "GRDECL" file is made of ASCII-readable characters[1]:

- A header (SPECGRID 128 128 32 1 F) specifies the grid dimensions and numerical format.
- Geometry is described by keywords ZCORN and COORD. Keyword ZCORN specifies the depth of each cell node in the grid. Keyword COORD combined with ZCORN, allows a grid with dip and displacement faults to be entered.

*IFP Energies nouvelles, France. Corresponding author: laurent.duval@ifpen.fr
†Université Côte d'Azur, CNRS, IS3, France
‡IFP Energies nouvelles, France
§IFP Energies nouvelles, France and Université Côte d'Azur, CNRS, IS3, France

[1] "GRDECL" conventions and the supported keywords for composite model meshes are described here: `https://docs.opengosim.com/manual/input_deck/grid/grdecl/`.

- Categorical property ACTNUM specifies the active cell status for each cell and can be used for visualization, simulation, etc. ACTNUM is set to value 1 for all meshes in LUNDIsim.

The common full-scale mesh is used to define four different composite model meshes, each specific of one of four subsurface environments called Fluvial, Nearshore0, Nearshore1 and NearshoreA, respectively. Random simulations with different parameters were performed to fill each hexahedral cell with two geological properties: permeability (keyword PERMX, specifying the permeability for each cell in the grid in the x-direction) and porosity (keyword PORO, specifying the rock porosities as fractions). Such properties are required to run flow simulations on reservoir grids. For instance, Nearshore0 mesh model at resolution 0 is stored in file 'LUNDIsim-Nearshore0-res0-mesh.grdecl', and its permeability and porosity are depicted in image files 'LUNDIsim-Nearshore0-res0-porosity.jpg' and 'LUNDIsim-Nearshore0-res0-permeability.jpg', respectively.

Finally, each of the four above model meshes has been decomposed into lower resolutions (from 1 to 4) using the multiscale decomposition HexaShrink described in paper [HexaSkrink2019] [PDP+19]. In short, geometry (ZCORN, COORD) and properties (ACTNUM, PERMX, PORO) are iteratively approximated using specific dyadic linear/nonlinear wavelet decompositions, reducing sizes in each dimension by a factor of two. Such operations are termed "upscaling" in reservoir science or "down-sampling" in data analysis. Namely, model meshes at resolution 1 have $64 \times 64 \times 16$ cells, down to resolution 4 with $8 \times 8 \times 2$ cells. For instance, Fluvial model mesh at resolution 3 is stored in GRDECL file 'LUNDIsim-Fluvial-res3-mesh.grdecl', with upscaled permeability and porosity depicted in 'LUNDIsim-Fluvial-res3-permeability.jpg' and 'LUNDIsim-Fluvial-res3-porosity.jpg' respectively.

Overall, LUNDIsim consists of a total of 62 data files:

- $1 + 4 \times 5 = 21$ GRDECL files (5 of which being full-size model meshes),
- $1 + 4 \times 5 \times 2 = 41$ images in PNG or JPG format,

plus the present data description note.

# 3 Free and open-source LUNDIsim mesh visualization software

LUNDIsim illustrations were made with ResInsight (`https://resinsight.org`) (version v.2023.06, `https://github.com/OPM/ResInsight`), an open source cross-platform 3D visualization and post-processing tool for reservoir models and simulations (developed in Python, available for Windows and Linux). Other Python libraries support GRDECL format, for instance PyGRDECL (`https://github.com/BinWang0213/PyGRDECL`) or XTGeo (`https://pypi.org/project/xtgeo`), and can be also used for visualization or other processing.

# 4 LUNDIsim dataset overview

The following Table 1 gathers all 41 images, corresponding to 21 GRDECL files: common mesh, and four model mesh environments, at all 5 available resolutions.

# References

[CB01] M. A. Christie and M. J. Blunt. Tenth SPE comparative solution project: A comparison of upscaling techniques. In *SPE Reservoir Simulation Symposium*. Society of Petroleum Engineers, 2001.

[DPPB25] Laurent Duval, Frédéric Payan, Christophe Preux, and Lauriane Bouard. $\text{LUNDI}_{\text{sim}}$: model meshes for flow simulation and compression benchmarks. *PREPRINT*, 2025.

[PDP+19] Jean-Luc Peyrot, Laurent Duval, Frédéric Payan, Lauriane Bouard, Lénaïc Chizat, Sébastien Schneider, and Marc Antonini. HexaShrink, an exact scalable framework for hexahedral meshes with attributes and discontinuities: multiresolution rendering and storage of geoscience models. *Computat. Geosci.*, 23:723–743, Aug. 2019.

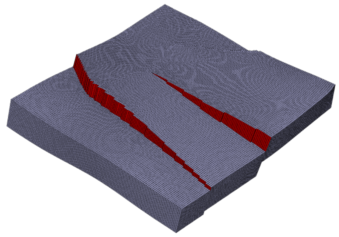
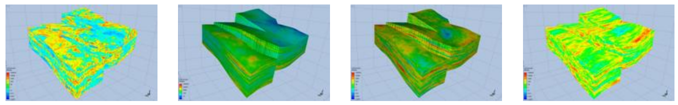
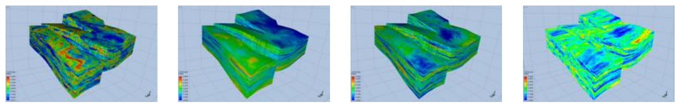
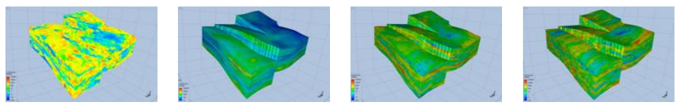
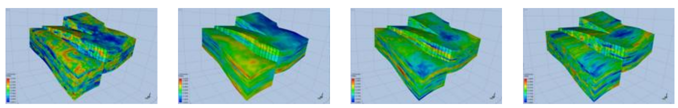
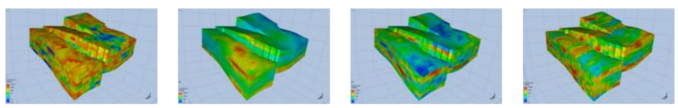
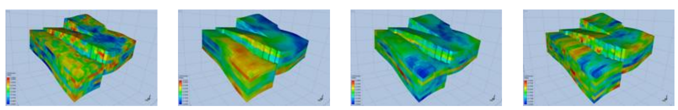
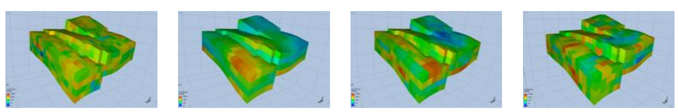
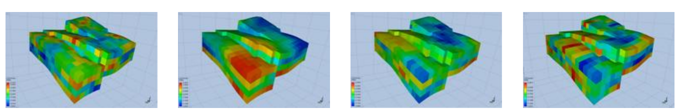
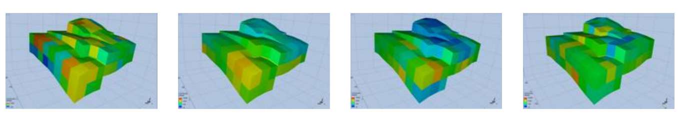
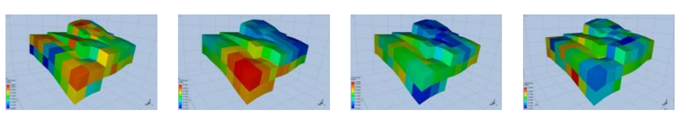
| Res. [size] | Data type | Environment name: Fluvial | Nearshore0 | Nearshore1 | NearshoreA |
|---|---|---|---|---|---|
| 0 [128 128 32] | Common mesh |  | | | |
| 0 | Perm. |  | | | |
| [128 128 32] | Poro. |  | | | |
| 1 | Perm. |  | | | |
| [64 64 16] | Poro. |  | | | |
| 2 | Perm. |  | | | |
| [32 32 8] | Poro. |  | | | |
| 3 | Perm. |  | | | |
| [16 16 4] | Poro. |  | | | |
| 4 | Perm. |  | | | |
| [8 8 2] | Poro. |  | | | |

Table 1: Visualization of LUNDIsim meshes and associated properties. Top: common model mesh with three faults. Bottom: permeability and porosity properties for all four environments (right-most columns: Fluvial, Nearshore0, Nearshore1, NearshoreA), for each of five available resolutions (bottom-most rows). Data type, resolution and size are given as row headers.