# Waiwera标准算例测试

在/test/benckmark路径包含很多测试算例，可用于验证代码可以正常运行，也可帮助用户熟悉Waiwera如何设置模拟。算例包括：

• MINC: benchmark tests with fractured rocks represented using the Multiple INTeracting Continua (MINC) approach (see Modelling fractured media using MINC)—一种反映岩石裂隙的网格处理方法。

• Model Intercomparison Study: a selection of test problems from the 1980 “Geothermal Model Intercomparison Study”

• NCG: tests for non-condensable gas equations of state (see Water / NCG EOS modules)—气体状态方程。

• sources: tests for verifying correct behavior of various source controls (see Source controls)—各种源项控制。

使用CREDO库管理Waiwera标准算例测试： pip install waiwera-credo

运行Waiwera标准算例测试还需要PyTOUGH，控制TOUGH2模拟的Python库，用来提取TOUGH2结果，与Waiwera结果比对。

## 运行测试算例

串行方式运行： python benchmark\_tests.py

并行方式运行： python benchmark\_tests.py -np 4

注意：建议在非su身份下并行运行，否则mpirun会出现错误。

测试结果保存在：/test/benchmark/test\_summary.html

## 运行单个测试

例如，进入/test/benchmark/minc/column，然后运行：

python test\_minc\_column.py -np 2

运行结果信息保存在：/output/TESTNAME/TESTNAME-report.html

# Waiwera输入

输入文件是JSON格式，一种轻量级的数据交换格式，可读性强，例如：

{"dimensions": {"length": 20.5, "width": 14.8, "depth": 17.2},

"position": [161.2, -12.5, 405.1],

"colour": "blue",

"checked": true

}

Python脚本处理JSON文件：

import json

data = json.load(file('input.json', 'r'))

data["dimensions"]["depth"] = 17.3

data["age"] = 3.5

json.dump(data, file('edited.json', 'w'))

## Waiwera JSON文件结构



# 设置一个Waiwera模拟

## 5.1模拟名称

{"title": "Wairakei reservoir model, version 12.4"}

## 5.2模拟网格

## 5.3模拟坐标系统

## 5.4网格单元排序

## 5.5网格正交性

## 5.6网格区域分解

## 5.7网格荷载平衡

## 5.8网格分区

## 5.9水的热动力学

5.9.1热动力学计算

5.9.2外插液态水热动力学

## 5.10状态方程

5.10.1主要变量参数

5.10.2渗透率修正

水的EOS模块

水/NCG (non-condensible gases) EOS模块

水/盐 EOS模块

Water / salt / NCG EOS模块

## 5.11重力

## 5.12岩石参数

岩石类型

岩石渗透率

渗透方向

随时间变化的岩石属性

岩石类型单元和区域

相对渗透率曲线

毛细孔压力函数

## 5.13使用MINC模拟裂隙介质

MINC几何

MINC岩石属性

示例

{"mesh": {"filename": "my\_mesh.msh",

"zones": {"production": {"x": [-500, 500],

"y": [-500, 500],

"z": [-1000, -200]},

"outer": {"-": "production"}},

"minc": {"geometry": {"fracture": {"spacing": 45},

"matrix": {"volume": [0.15, 0.3, 0.5]}},

"rock": {"fracture": {"type": "fracture"},

"matrix": {"type": "matrix"},

"zones": "production"

}}

},

"rock": {"types": [{"name": "formation",

"permeability": [1e-14, 1e-14, 1e-15],

"zones": ["outer"]},

{"name": "fracture",

"permeability": 1e-12, "porosity": 0.5},

{"name": "matrix",

"permeability": 1e-16, "porosity": 0.05}]}

}

MINC初始条件

MINC输出

## 6.8边界条件

6.8.1无通量边界条件

6.8.2Dirichlet边界条件

6.8.3Neumann边界条件

## 6.9源汇项

6.9.1源汇项名称

6.9.2源汇项单元和区域

6.9.3注射

6.9.4产出

6.9.5混合流体

6.9.6示踪剂注入

6.9.7分离器

6.9.8源汇项控制

6.9.10源项的交互作用

## 6.10源项网络

有些源项不独立，存在相互作用的情况，包括：multi-feed wells, borefields, reinjection

6.10.1分组

6.10.2 Reinjectors

## 6.11插值表

## 6.12初始条件

## 6.13时间推进计算

6.13.1 时间步进计算方法

At each time step, the time-stepping method results in a system of non-linear equations to be solved, using the PETSc “SNES” iterative non-linear solver (see Solution of equations at each time step). This in turn leads to a sequence of systems of linear equations to be solved at each non-linear solver iteration, using the PETSc “KSP”linear solvers.

6.13.2 指定计算时间步长

6.13.3 自适应时间步长

6.13.4 减小时间步长

6.13.5 时间步进终止

6.13.6 恒定态模拟

6.13.7 求解非线性方程组

6.13.8示例

{"time": {"step": {"size": 1e6,

"adapt": {"on": true,

"method": "iteration",

"minimum": 5, "maximum": 8},

"maximum": {"number": 500},

"stop": {"size": {"maximum": 1e15}},

"method": "beuler",

"solver": {

"nonlinear": {"maximum": {"iterations": 10},

"tolerance": {"function": {"relative": 1e-6}},

"jacobian": {"differencing": {"increment": 1e-9}}}

}},

"stop": null}}

6.13.8 求解线性方程组

6.13.9 求解物质输移方程

## 6.14 物质输移

## 6.15 Log output

6.15.1 YAML format

6.15.2 Log message structure

6.15.3 Log message format

## 6.16 模拟输出

Waiwera outputs the simulation results (not log messages, which are written to the Log output) to an output file in the HDF5 file format. HDF5 is a binary file format and data model designed for efficiently storing and handling large, complex datasets. A variety of software tools are available for managing, viewing and analyzing HDF5 files. Waiwera simulation results consist mainly of:

* selected fluid properties (e.g. pressures, temperatures) in each cell
* selected flux properties (e.g. mass fluxes) through each face
* selected source properties (e.g. flow rates, enthalpies) at each source (see Source terms)
* selected source group and reinjector properties (e.g. flow rates, enthalpies) if a source network is defined (see Source networks)
* selected mesh geometry properties (e.g. cell centroids and volumes, and face areas) which are written to the HDF5 file at specified times.

6.16.1 Regular output

6.16.2 Initial and final output

6.16.3 Output at specified times

6.16.4 Output fields

6.16.5 Jacobian matrix output

## 6.17 使用脚本设置模拟

# 导入Waiwera的输入文件

## 7.1从TOUGH2输入数据文件导入

## 7.2 导入过程的限制

## 7.3 导入网格

## 7.4 示例

# 运行Waiwera

## 8.2运行

waiwera model.json

mpiexec -np 16 waiwera model.json

## 8.3 选择并行计算进程数目

## 8.4 PETSc命令行参数

mpiexec -np 16 waiwera model.json -log\_view

## 8.5 Run-time console output

# 后处理Waiwera的输出

## 9.1可视化模拟输出

使用HDFView工具

## 9.2 模拟输出文件是什么结构?

9.2.1 Output at cells

9.2.2 Output at sources

9.2.3 Output at faces

9.2.4 Output time dataset

9.2.5 Index datasets and data ordering

9.2.6 MINC cell indexing

## 9.3 模拟输出和处理脚本

使用h5py：



将生成如下图片：



Fig. 9.4: Steady-state temperature and vapour saturation results for demo simulation

## 9.4 Log output

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Fig. 9.5: Time step size history plot from Waiwera YAML log file, for a steady-state simulation