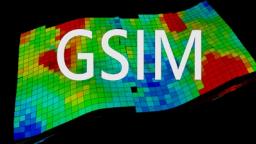




Federal University of Ceará  
Multiscale Integrated Simulation Group



# ITERATIVE COUPLING OF SINGLE-PHASE RESERVOIR FLOW AND GEOMECHANICS



Y.N. Saraiva, H.A.V. Haro & L.G. Rodrigues

# INTRODUCTION

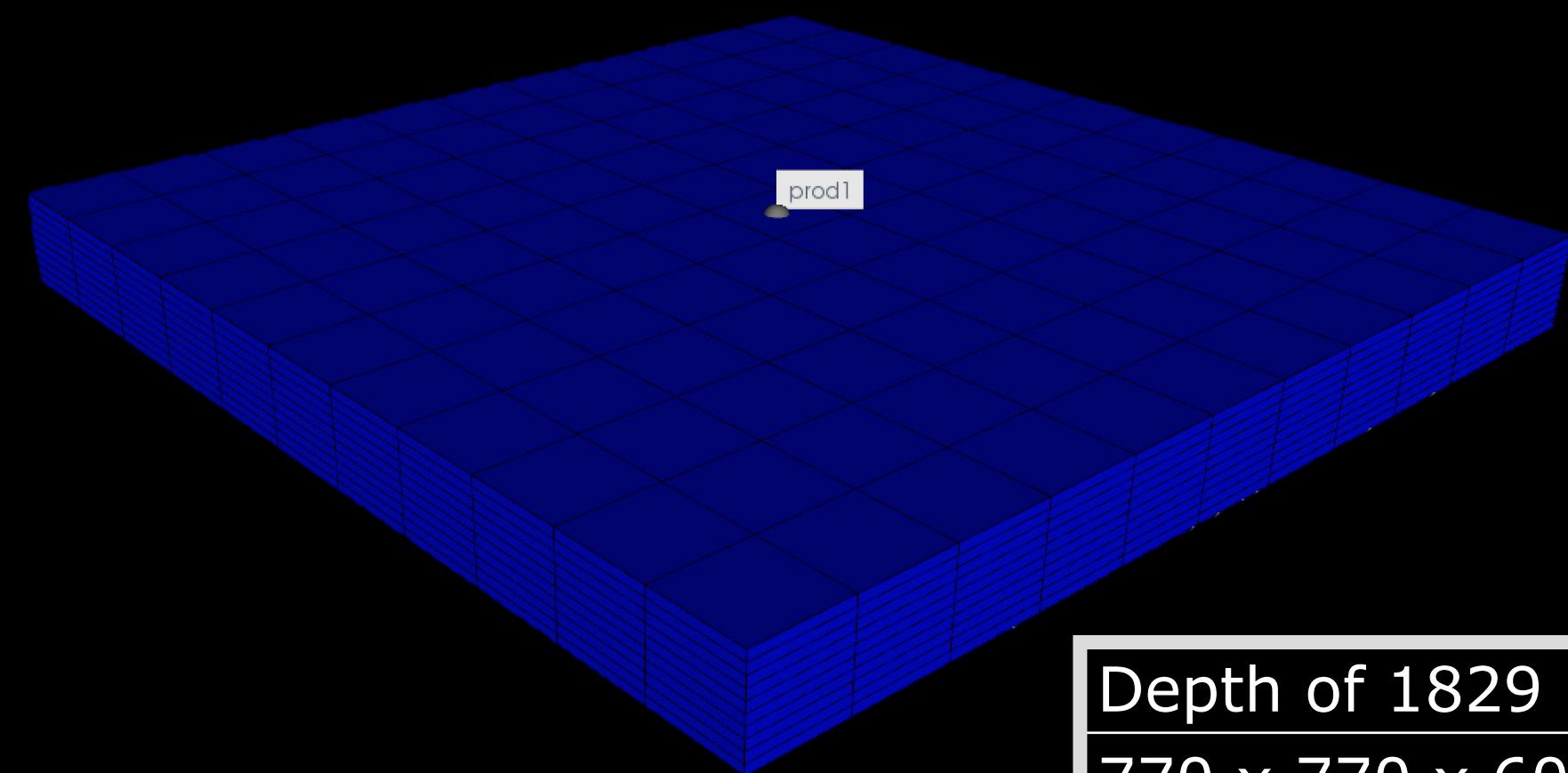
Simulation analysis

Explicit and iterative coupling

Simulation performance

Objective

# INTRODUCTION



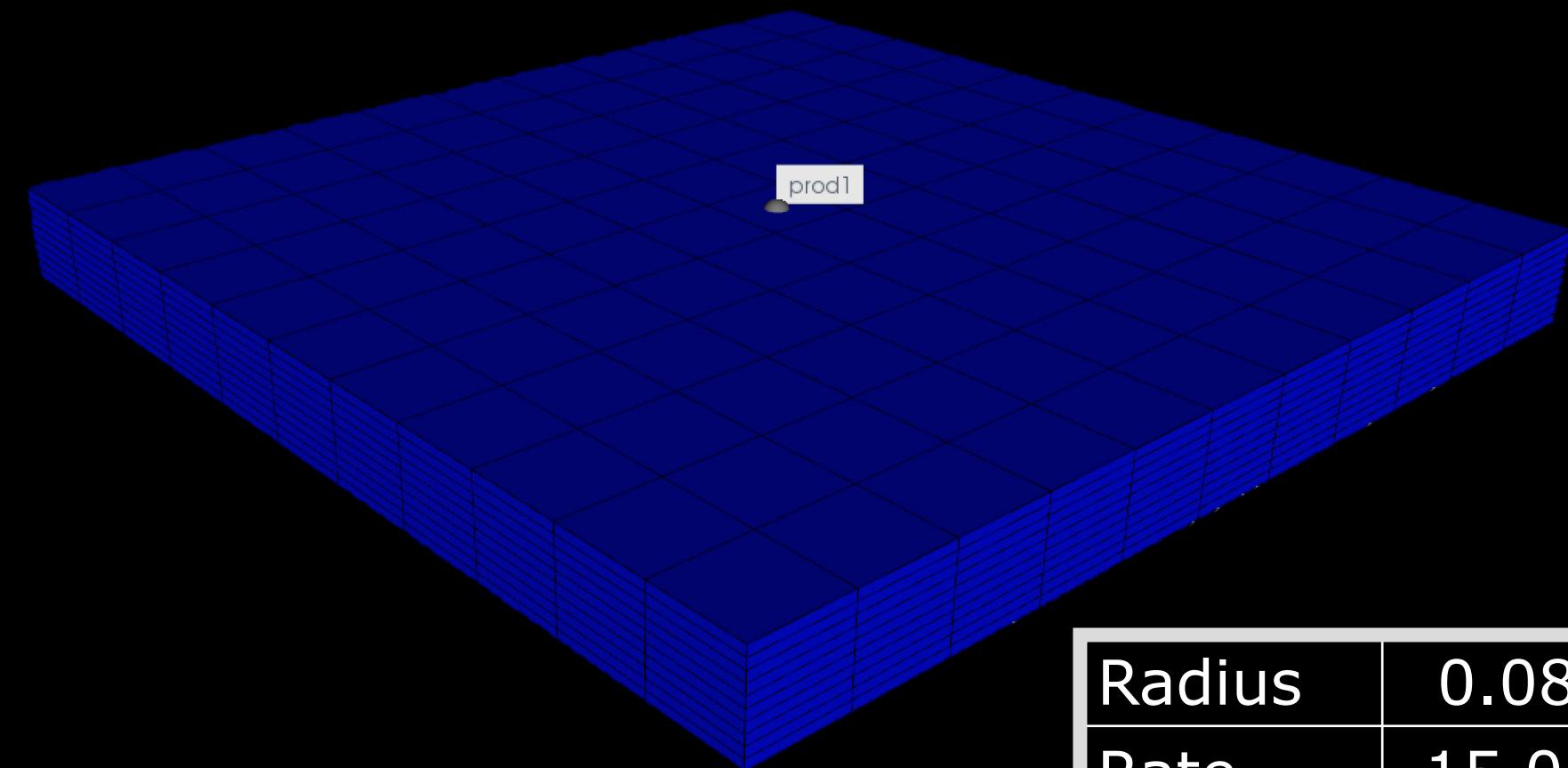
Depth of 1829 m

770 x 770 x 60 (m)

Single-phase water depletion

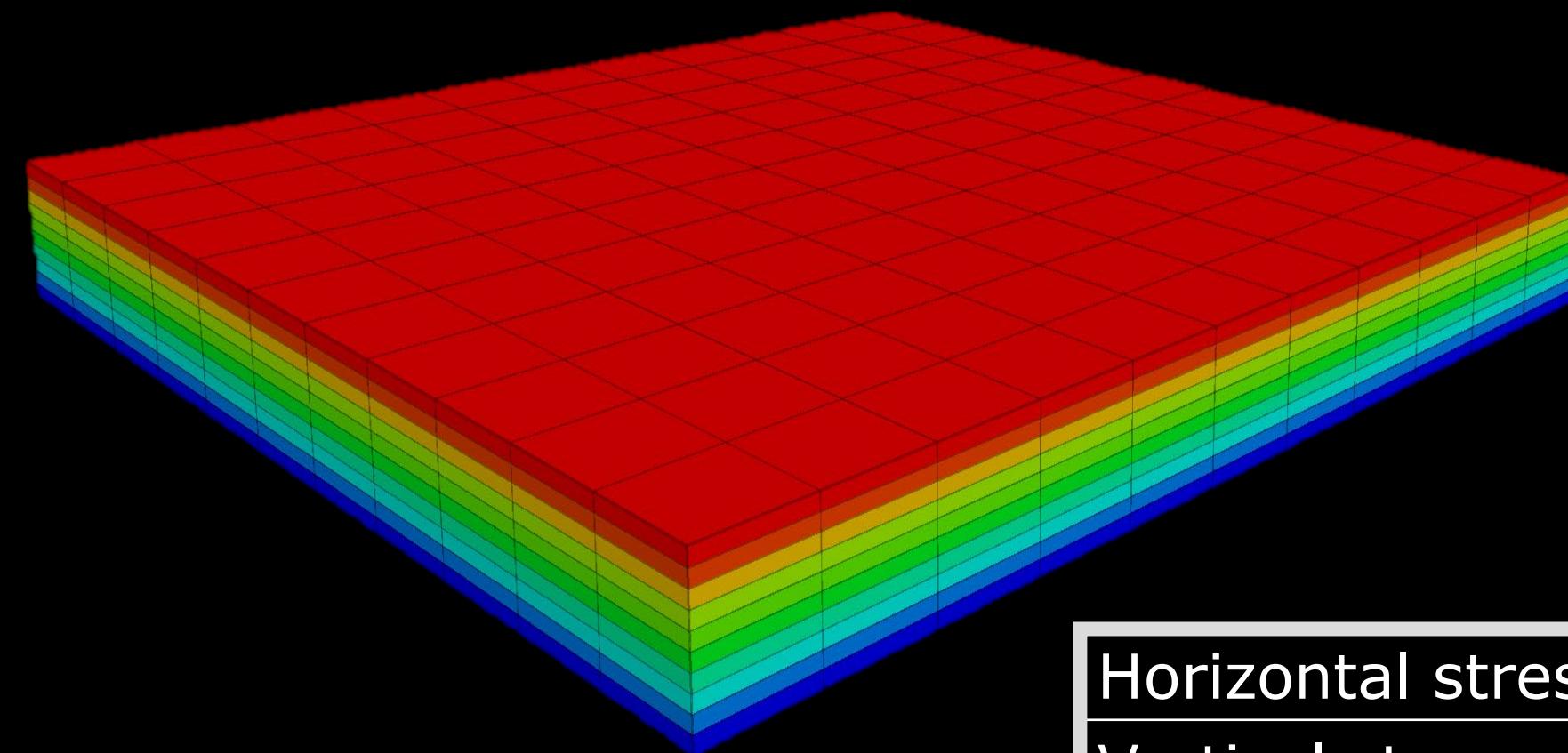
Displacement boundary conditions

# INTRODUCTION



|        |        |         |
|--------|--------|---------|
| Radius | 0.08   | m       |
| Rate   | 15,000 | bbl/day |

# INTRODUCTION



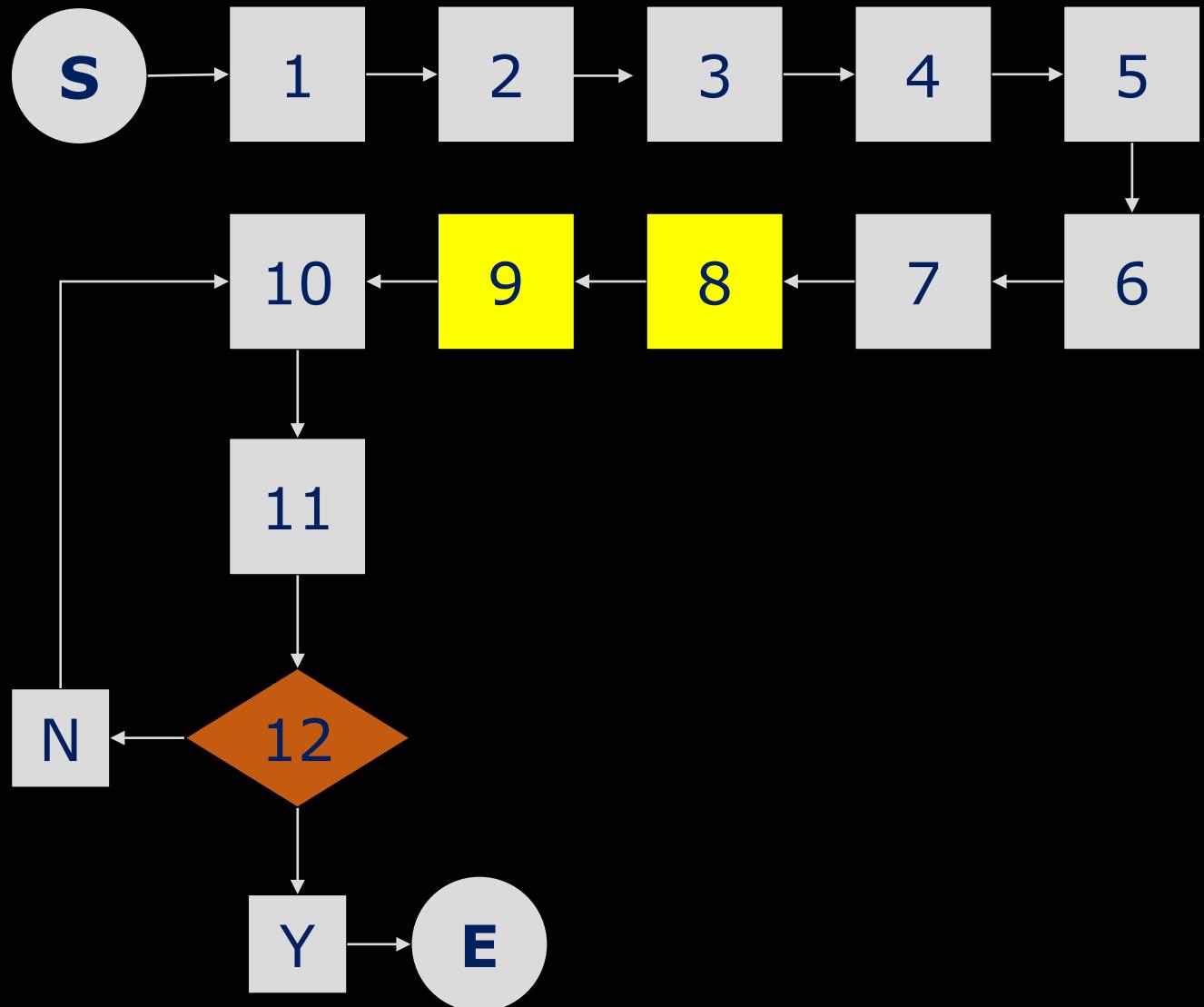
|                     |           |
|---------------------|-----------|
| Horizontal stresses | 27.58 MPa |
| Vertical stress     | 41.37 MPa |
| Young modulus       | 68.94 MPa |
| Poisson ratio       | 0.30      |

# METHODOLOGY



1. Pore pressure in each block
2. Pore pressure in each gridpoint of blocks
3. Volumetric Strain by volumetric average
4. Update the porosity, permeability and compressibility

# METHODOLOGY



1. Model brick size.
2. Constitutive model.
3. Fix velocity in all gridpoints.
4. Apply initial stress conditions.
5. Apply reaction forces.
6. Free velocity in all gridpoints.
7. Apply constraints conditions.
8. First pore pressure of problem.
9. Apply zero initial displacement.
10. Apply next pore pressure.
11. Fish and Python commands.
12. Are the timesteps finished?

# METHODOLOGY

$$\emptyset^{n+1} = \frac{\emptyset^n + \varepsilon v^{n+1} - (1 - \emptyset^n) \alpha t (T^{n+1} - T^n)}{1 + \varepsilon v^{n+1}}$$

Tortike and Farouq Ali (1993)

$$Cr = \frac{\varepsilon v^{n+1} - \varepsilon v^n}{\emptyset^n (P^{n+1} - P^n)}$$

Inoue and Fontoura (2009)

$$K^{n+1} = K^n \frac{\left(1 + \frac{\varepsilon v^{n+1}}{\emptyset^n}\right)^3}{1 + \varepsilon v^{n+1}}$$

Tortike and Farouq Ali (1993)

# METHODOLOGY

$$\emptyset^{n+1} = \frac{\emptyset^{n+1} + \varepsilon v^{n+1}}{1 + \varepsilon v^{n+1}}$$

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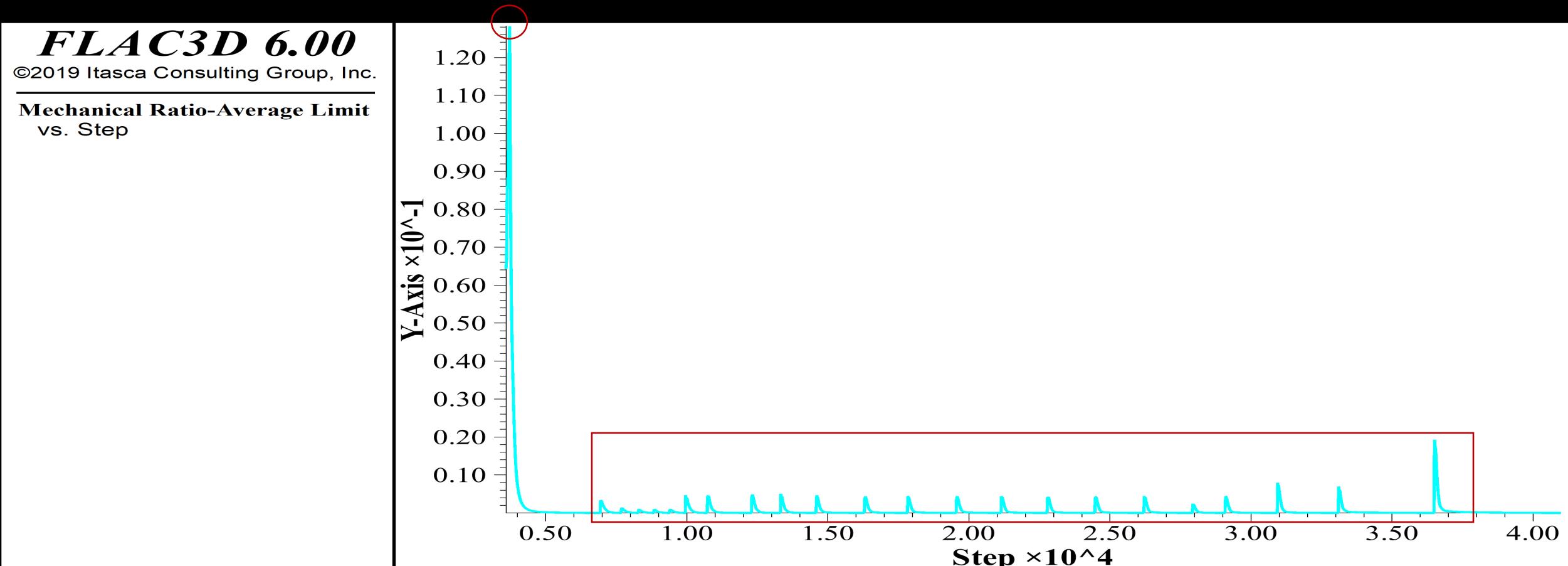
Inoue and Fontoura (2009)

$$K^{n+1} = K^n \frac{\left(1 + \frac{\varepsilon v^{n+1}}{\emptyset^n}\right)^3}{1 + \varepsilon v^{n+1}}$$

Tortike and Farouq Ali (1993)

# RESULTS

## ➤ Mechanical ratio-average limit



Until 250 days.

# RESULTS

## ➤ Displacement vectors and compression behavior

**FLAC3D 6.00**

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### Zone Displacement Vectors

Maximum: 0.243316

Scale: 97.6377

### Zone Volumetric Strain Increment

Calculated by: Volumetric Averaging

2.0852E-04

0.0000E+00

-5.0000E-04

-1.0000E-03

-1.5000E-03

-2.0000E-03

-2.5000E-03

-3.0000E-03

-3.5000E-03

-4.0000E-03

-4.5000E-03

-5.0000E-03

-5.5000E-03

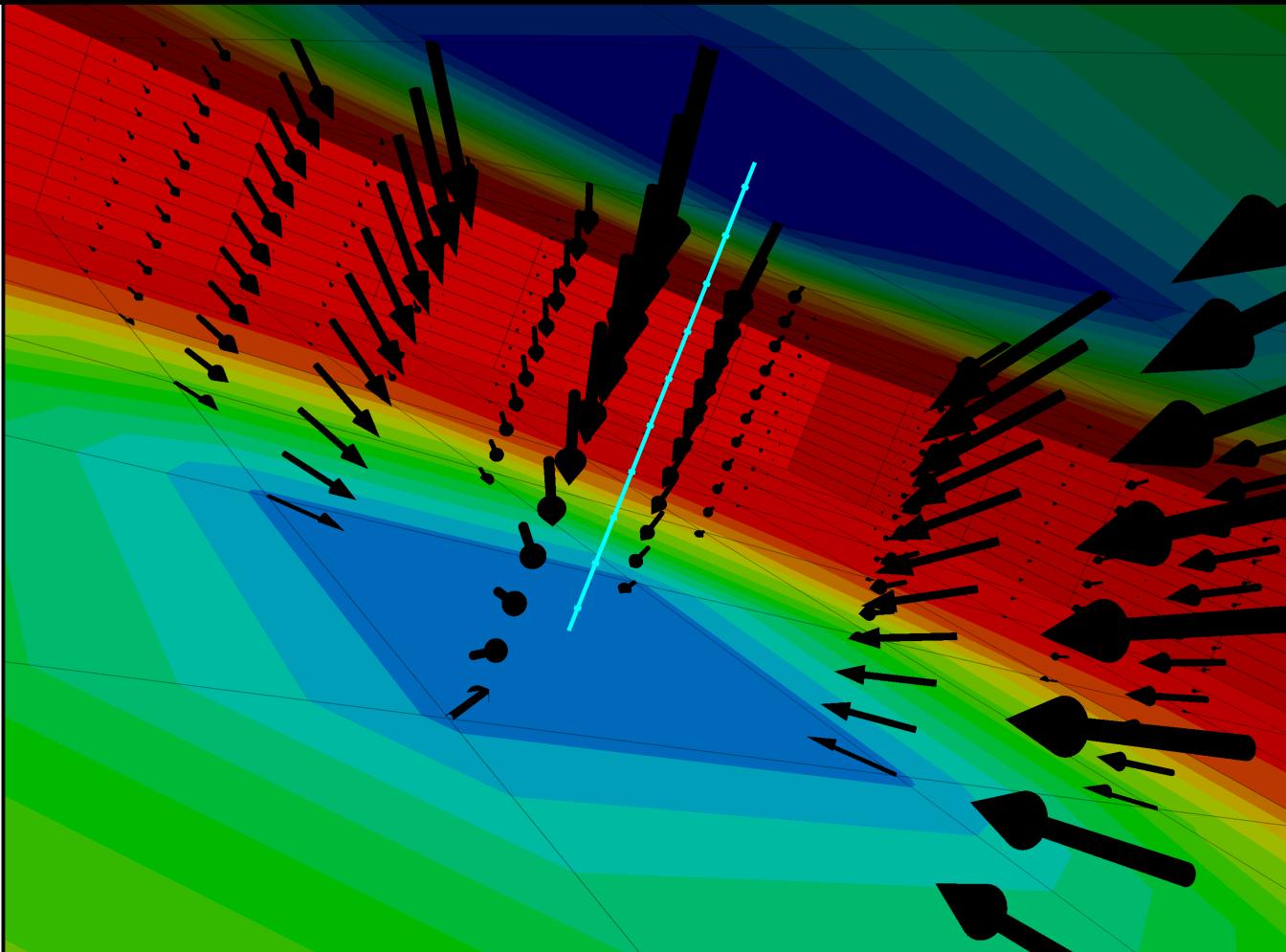
-6.0000E-03

-6.5000E-03

-6.6324E-03

### Cable Group of Element Slot Skin

Well



# RESULTS

## ➤ Subsidence 3D view

**FLAC3D 6.00**

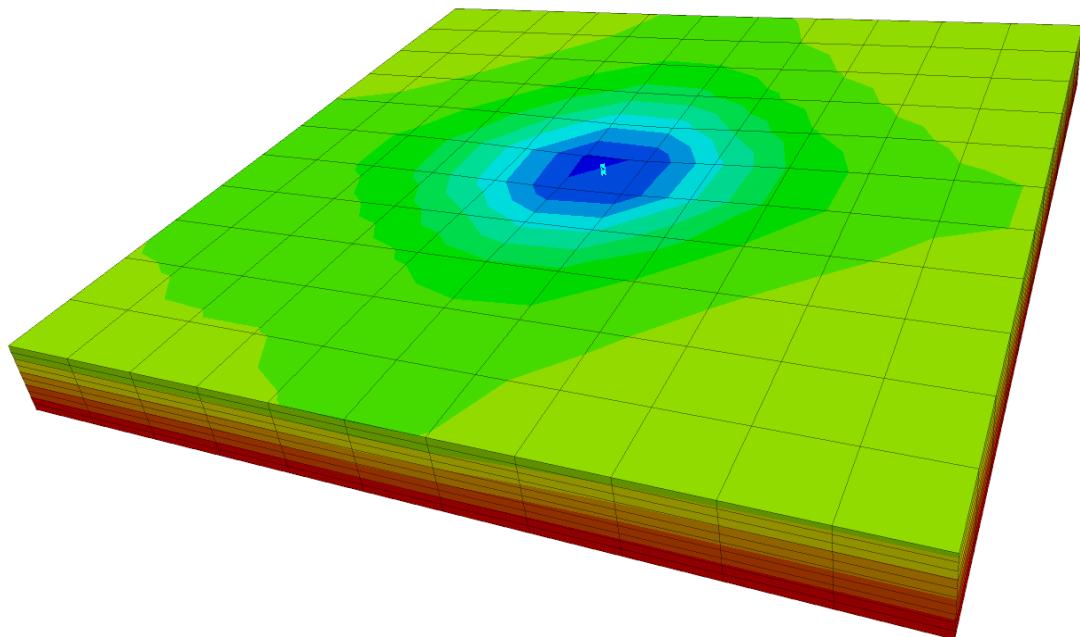
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### Zone Z Displacement

Deformed Factor: 5

0.0000E+00  
-2.0000E-01  
-4.0000E-01  
-6.0000E-01  
-8.0000E-01  
-1.0000E+00  
-1.2000E+00  
-1.4000E+00  
-1.6000E+00  
-1.8000E+00  
-2.0000E+00  
-2.2000E+00  
-2.4000E+00  
-2.4250E+00

### Cable Group of Element



**FLAC3D 6.00**

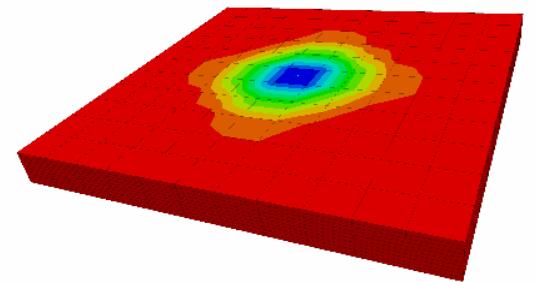
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### Zone Z Displacement

Deformed Factor: 5

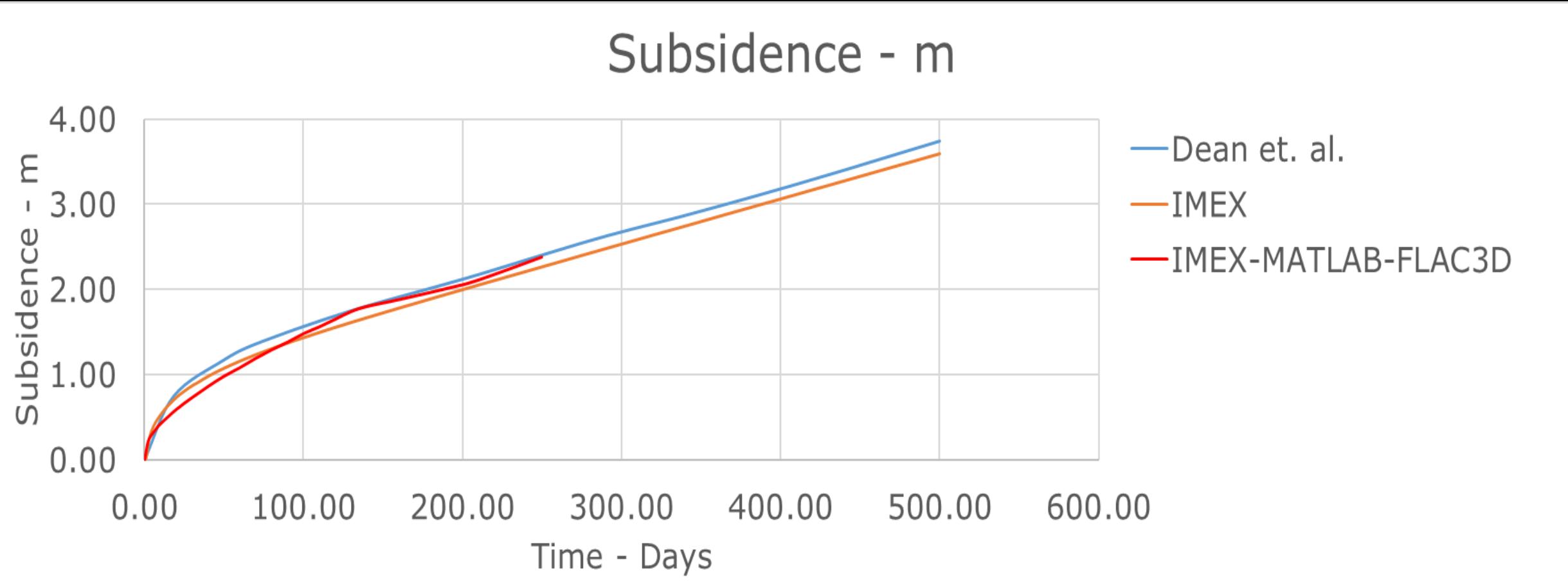
0.0000E-00  
-2.0000E-02  
-4.0000E-02  
-6.0000E-02  
-8.0000E-02  
-1.0000E-01  
-1.2000E-01  
-1.4000E-01  
-1.6000E-01  
-1.8000E-01  
-2.0000E-01  
-2.0132E-01

### Cable Group of Element



# RESULTS

## ➤ Subsidence effect



# CONCLUSION

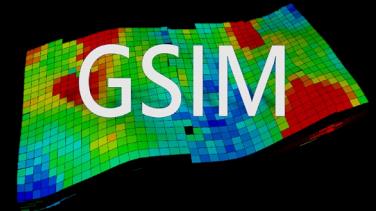
- The explicit and iterative coupling proposed in this paper obtained similar results as the one proposed in Dean's article.
- However, the coupling developed in this work ensures better control of the properties and behavior of the simulation, due to the adjustment and analysis of geomechanical parameters behavior.
- This work also shows how the reservoir behaves and how it deforms during exploitation, ensuring its safe monitoring, updating key reservoir parameters as porosity, permeability, and compressibility.

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+55 85 99934 4056



yurinunessaraiva@gmail.com



Yuri Saraiva