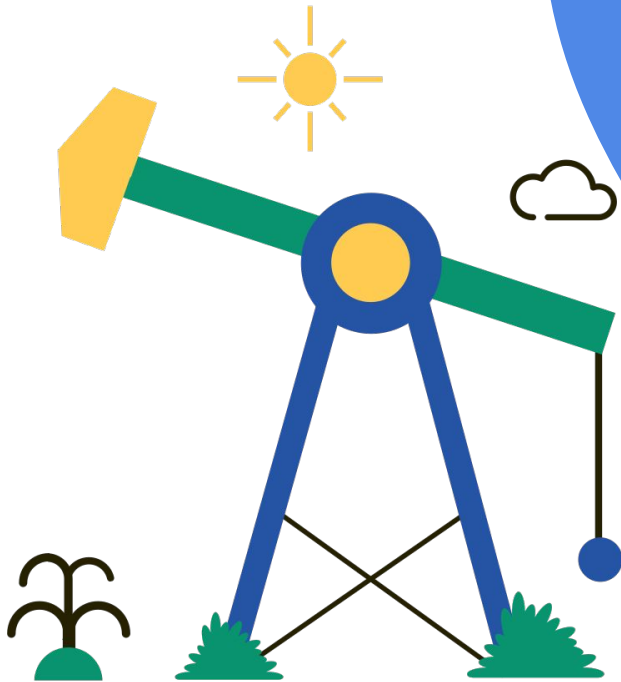


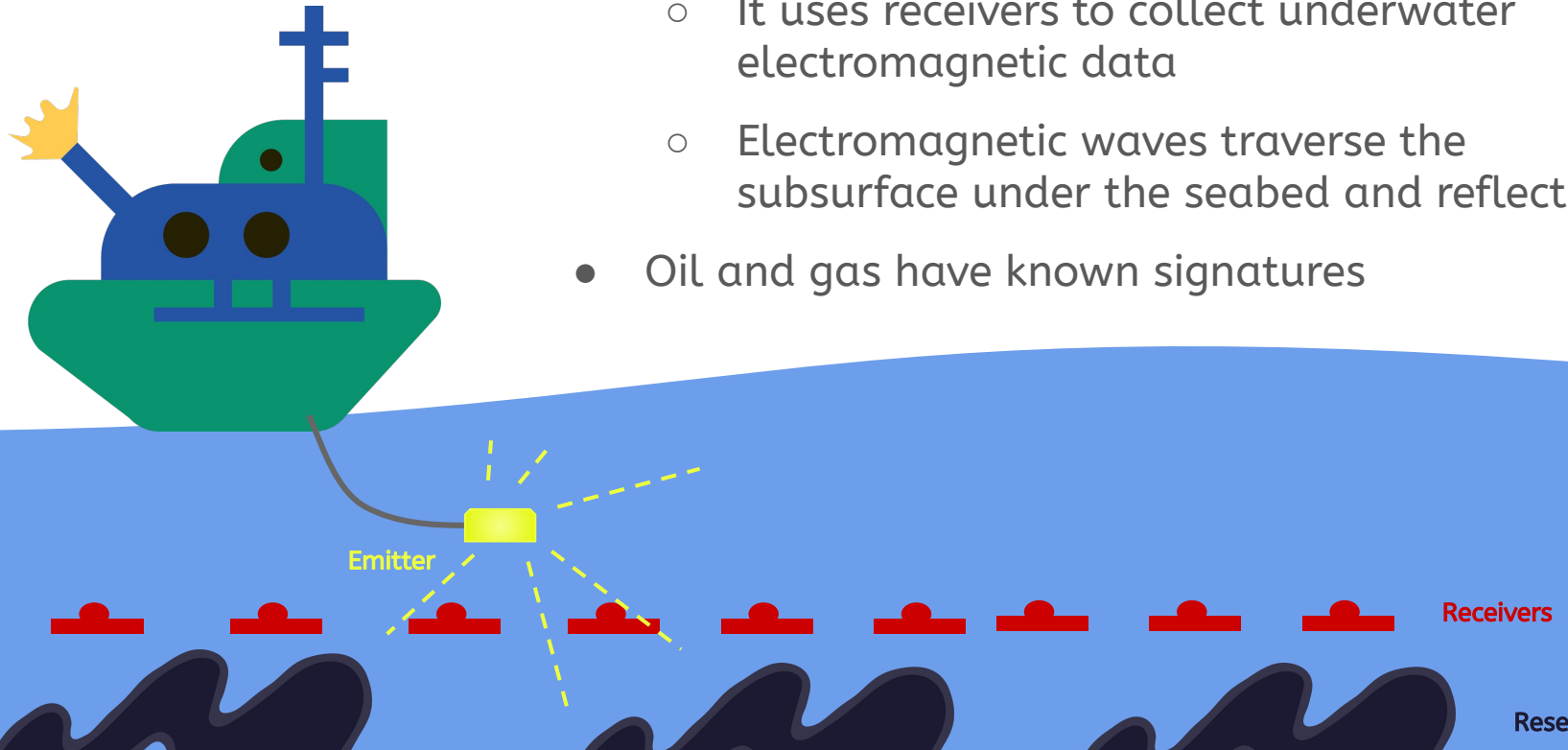
# Performance Improvements Applied in an Electromagnetic Inversion Application Focused on Homogeneous and Heterogeneous Computational Environments

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# Introduction

- Marine Controlled-Source Electromagnetic Method (mCSEM)
  - It uses receivers to collect underwater electromagnetic data
  - Electromagnetic waves traverse the subsurface under the seabed and reflect
- Oil and gas have known signatures

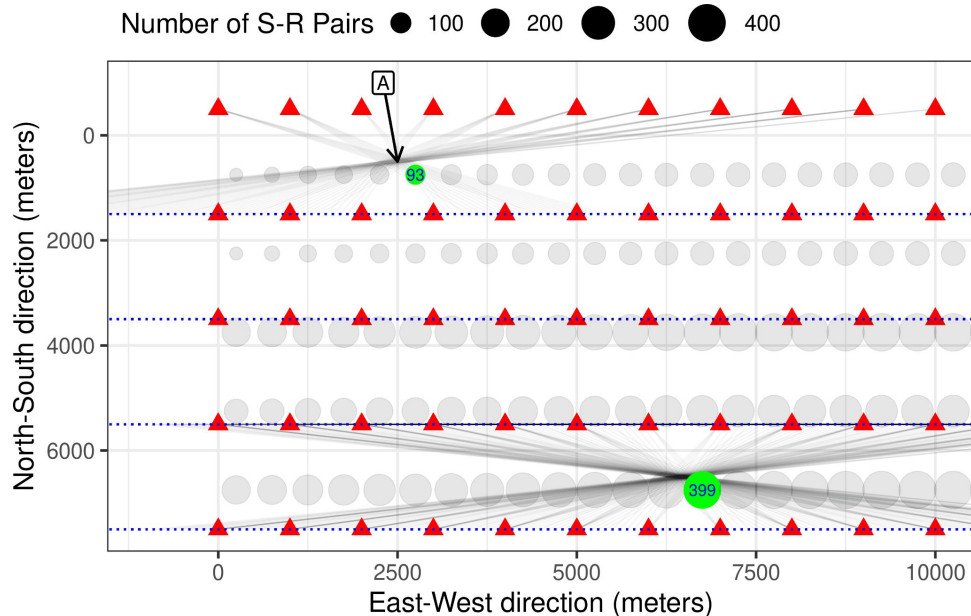


# Introduction



- The data collected from receivers is not “understandable”
- Needs numerical methods to recover data
- Big quantity of data
- Inversion process is computationally expensive
- Run inversion in parallel
- High Performance Cluster

# The mCSEM Inversion Application

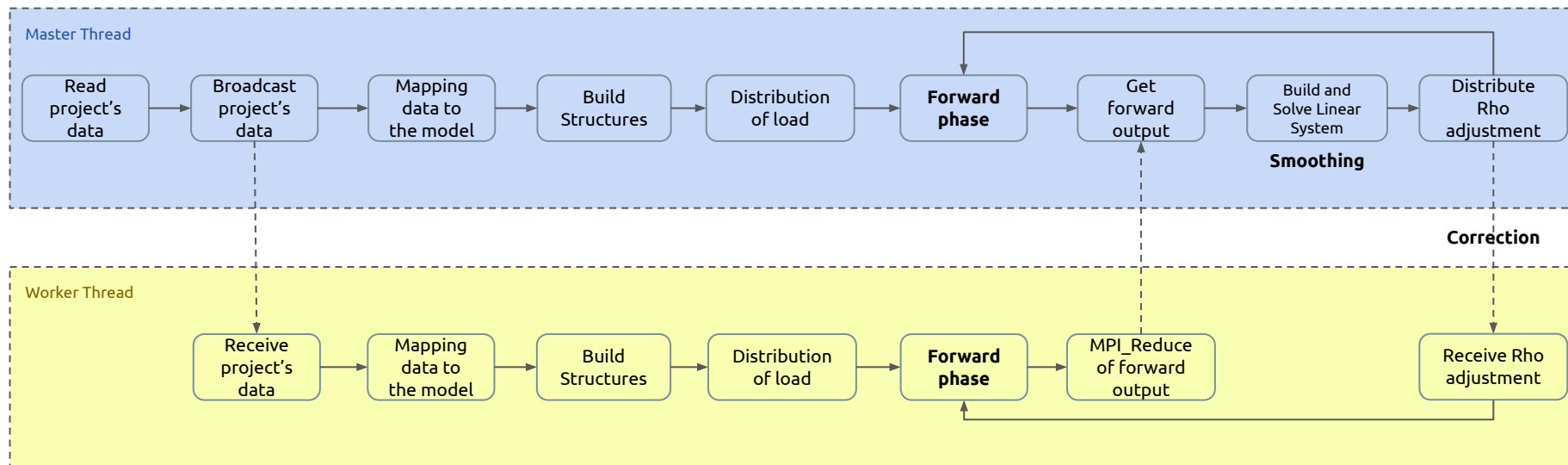


Survey data (red triangles are receivers, small blue squares are emitters), combined with the 2D grid of CMPs (circles).

- Application uses the **Common Midpoint Technique**
  - Map the collected data to the model
- It uses **geographical midpoint** between the **receiver** and the **emitter**
- Mapping will assign **different quantities** of **Source-Receiver pairs** to each CMP cell
- The CMP cell can or cannot match a receiver position

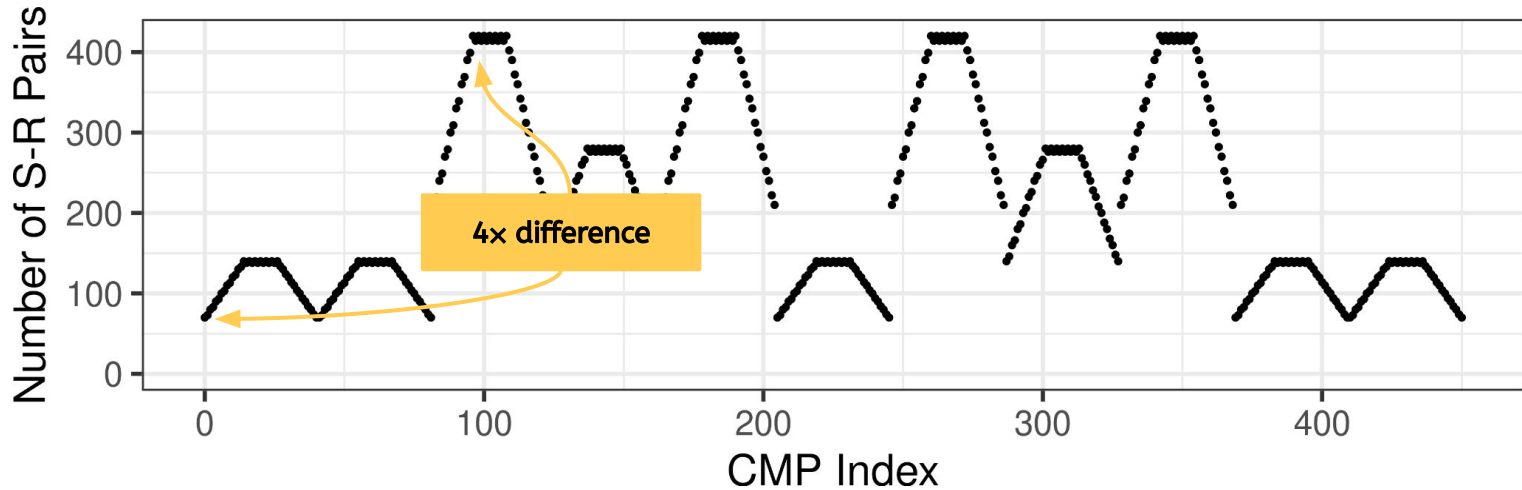
# The mCSEM Inversion Application

- Based on the numerical inversion process
- 1D inversion using the CMP domain for 3D data
- Application parallelize two phases: the **forward** and **smoothing**



# Finding the Imbalance

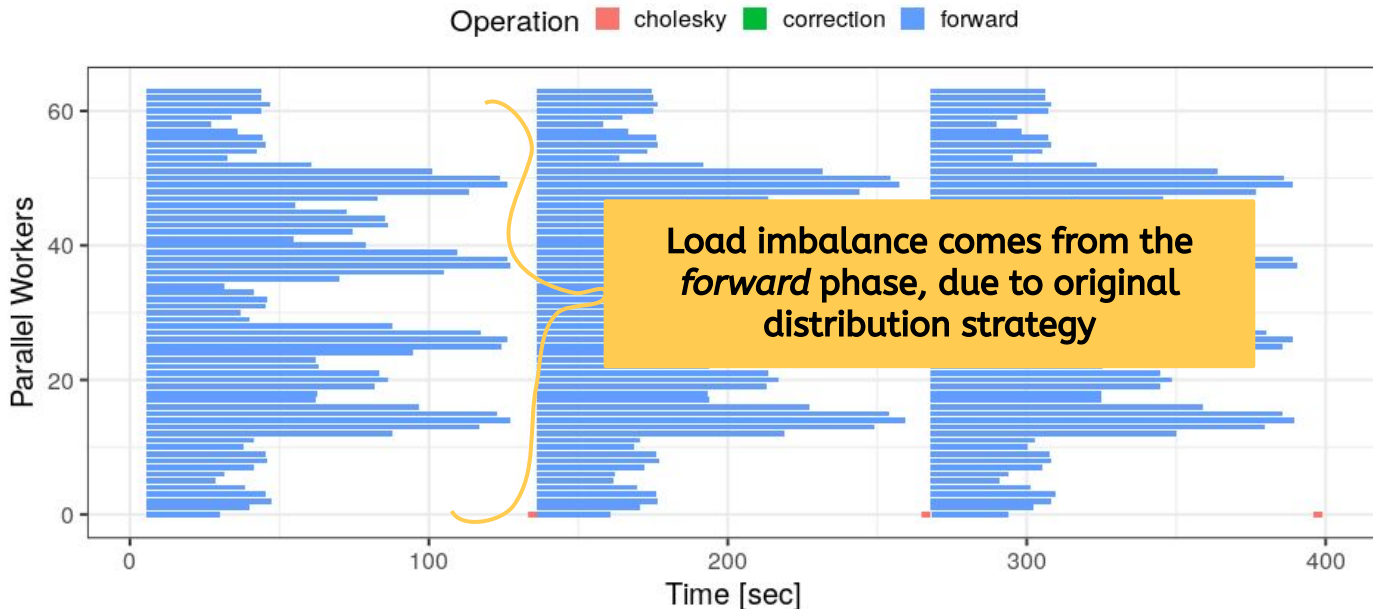
- First instrumentations results give us the organization of the cells
- Outputs with quantity of S-R pairs per CMP



Number of S-R pairs associated for each CMP of the studied model.

# Finding the Imbalance

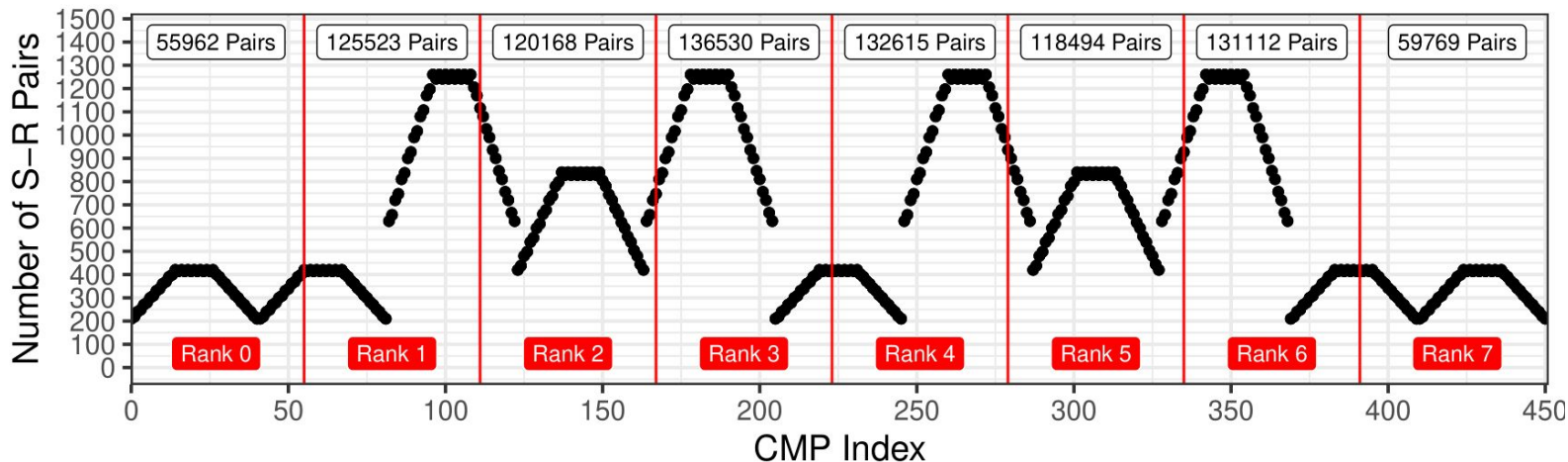
We ran the application with 64 MPI workers, disabling OpenMP threads



Execution behavior of the application executing only with MPI, presenting the timespace of the three main regions of the inversion algorithm.

# Finding the Imbalance

- Original distribution:
  - Considers the total quantity of **CMP** cells
  - **Disregards** the **heterogeneous** load of them

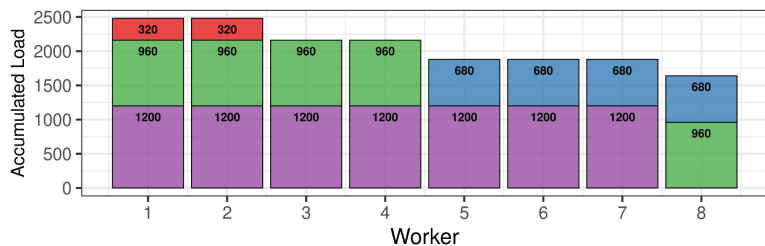


Behavior of the original distribution – it divide the cells among workers, disregarding its own heterogeneous weight.

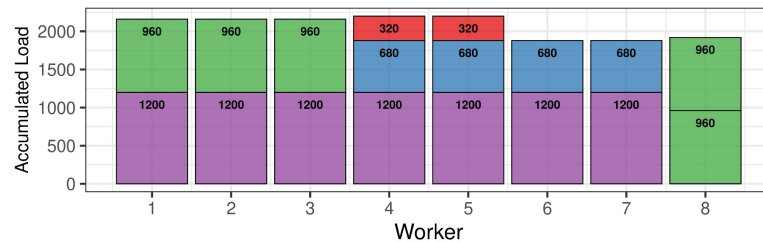


# Load Balancing Heuristics

## Round Robin



## Sorted-Greedy



## ABE-guided

minimize:

$makespan$

subject to:

$$\forall c \in C : \sum_r n_{c,r} = N_c$$

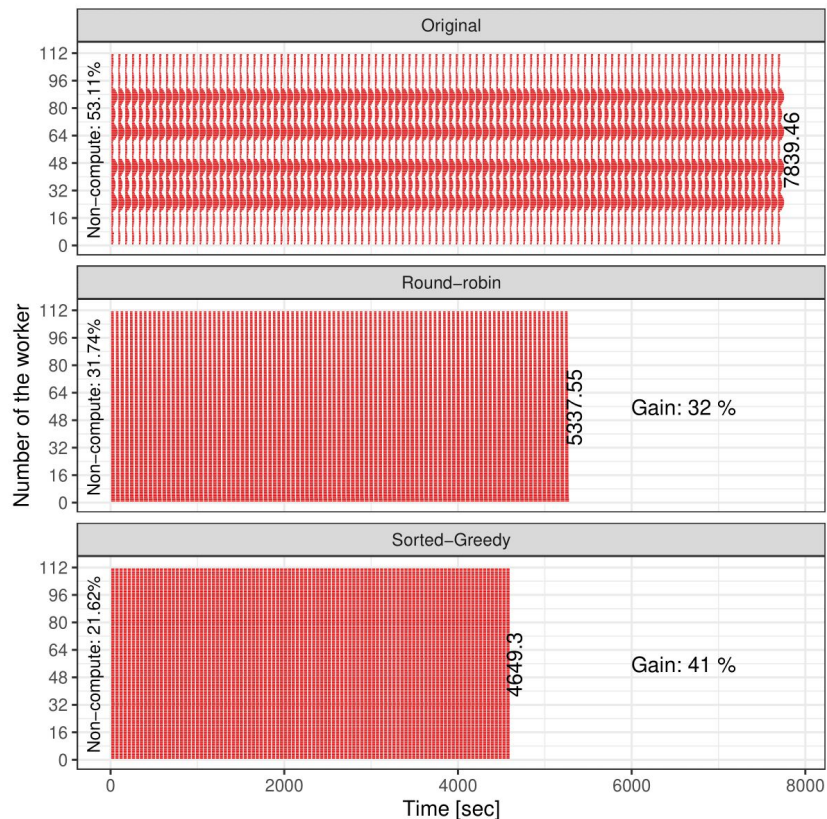
$$\forall r \in R : \sum_c n_{c,r} * w_{c,r} \leq makespan * N_r$$

$$\forall c \in C, r \in R : n_{c,r} \geq 0$$

## HEFT



# Improvements on the Application



Space/time view of the forward step of 100 iterations for the Original, Round-robin, and Greedy allocation policies.

- **Makespan**
- 3 homogeneous heuristics
- 100 iterations
- Local cluster Draco
- 7 nodes, 16 cores per node
- Total of 112 MPI ranks
- Improvements up to 41%

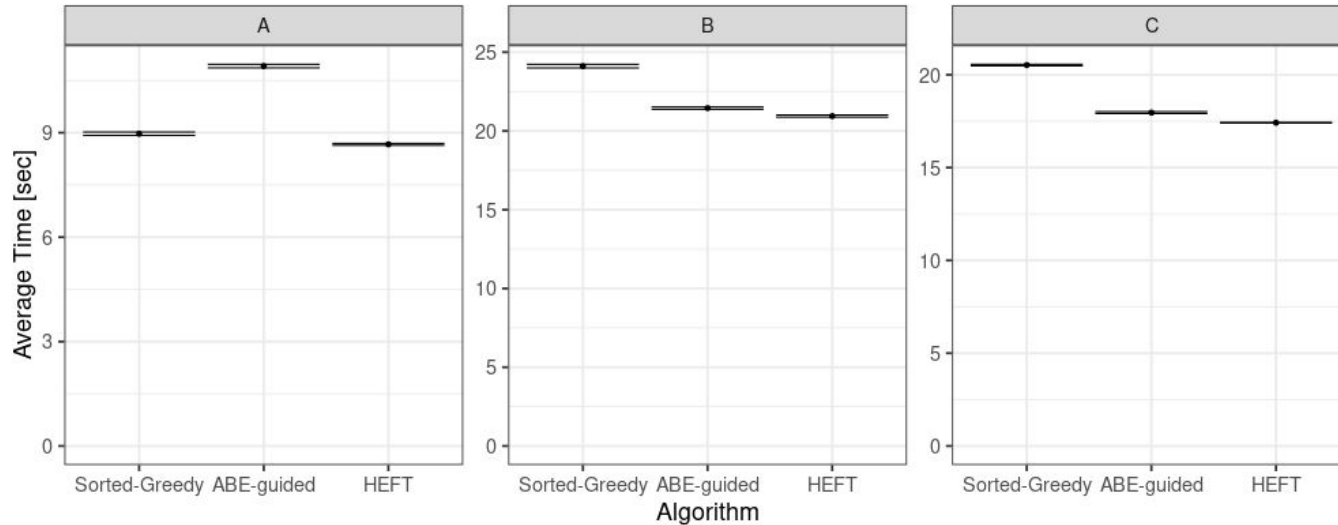
# Improvements on the Application

- Previous experiment motivates to **extend** solutions
- Load balancing using **heterogeneous** machines
- **No** changes on processor's frequency
- Two heuristics: **ABE-guided** and **HEFT**
- We selected three different machine combinations scenarios

Study case	draco	hype	cei	blaise	Total Cores
<b>A</b>	7	5	2	1	304
<b>B</b>	3	2	1	0	112
<b>C</b>	0	1	2	1	112

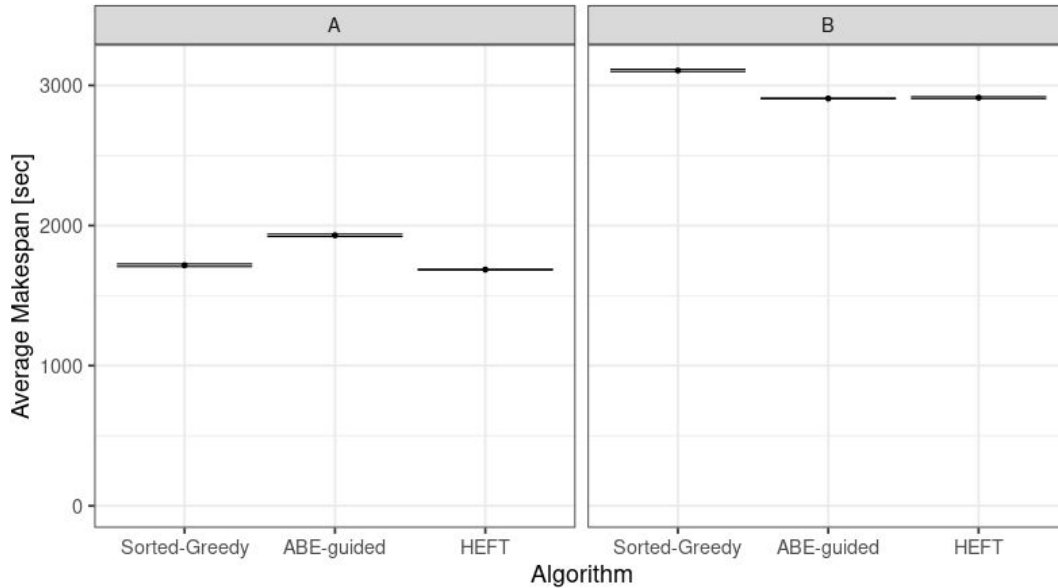
# Improvements on the Application

- Compare **iteration time** in each scenario with each heuristic
- 10 repetitions with 10 iterations each



Average time of execution of one iteration in each scheduler running on different heterogeneous configurations.

# Improvements on the Application



Average makespan with execution of 100 iterations for each scheduler in two different heterogeneous scenarios.

- **Makespan** reduction with **heterogeneous** solutions
- 100 iterations
- Achieved a performance gain of **78%** against the Original scheduler

- We investigate the computing performance of an MPI-based **inversion application of mCSEM**
- Identified issue regarding **load balancing** and solved it
- Performance improvement
  - **41%** on homogeneous scenarios
  - **78%** on heterogeneous scenarios
- **Capacity planning tool** to further predict best execution scenario
  - Available at [bit.ly/interactive-capacity-plan](https://bit.ly/interactive-capacity-plan)

# ACKNOWLEDGMENTS

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