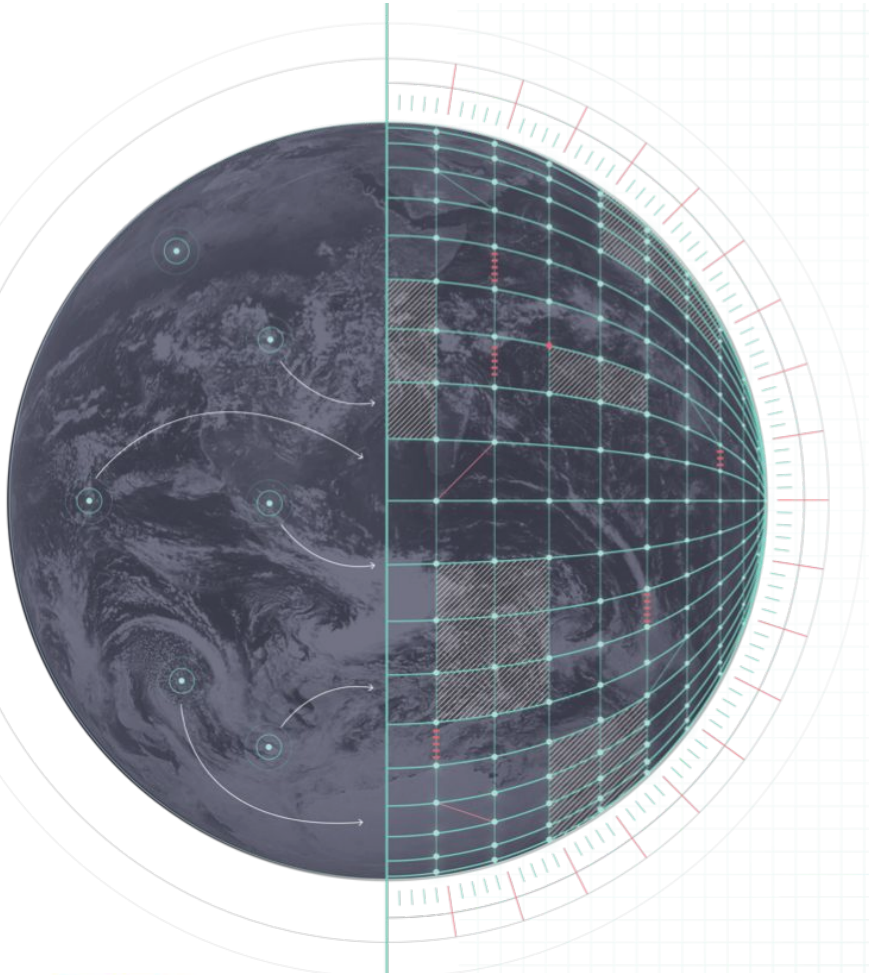

Earth Sciences Department

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SNIC PRESENTS:
SUSTAINABILIT

Destination Earth

Pioneering the Future with Digital Twins

Okke van Eck
GPU Research Engineer
Barcelona Supercomputing Center

okke.vaneck@bsc.es

27th of November 2024, Bussum

Funded by the European Union

Destination Earth implemented by ECMWF esa EUMETSAT

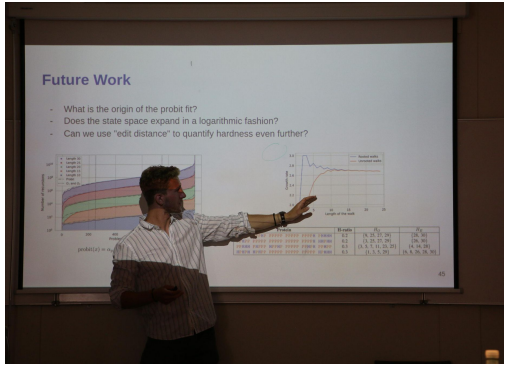
Who's Okke?

Universiteit van Amsterdam

via

VU VRIJE UNIVERSITEIT AMSTERDAM

Barcelona Supercomputing Center
Centro Nacional de Supercomputación



Climate is changing..

Climate is changing..

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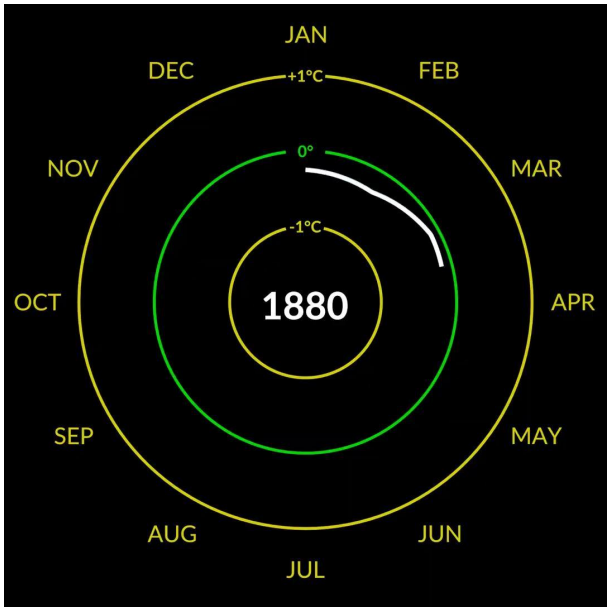
Climate is changing..



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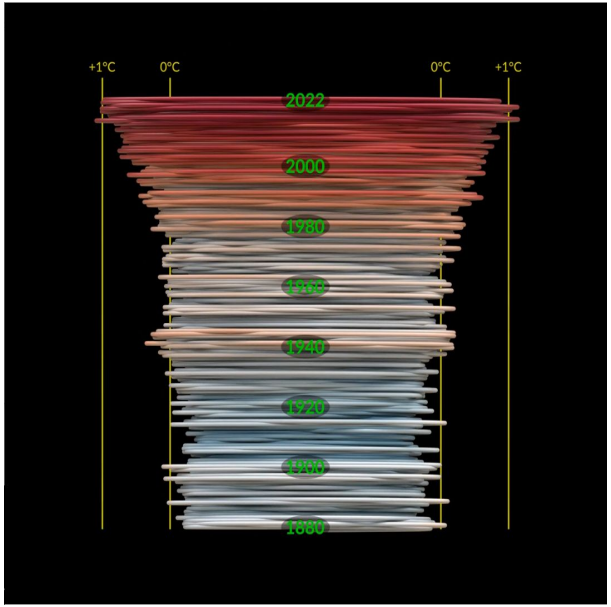

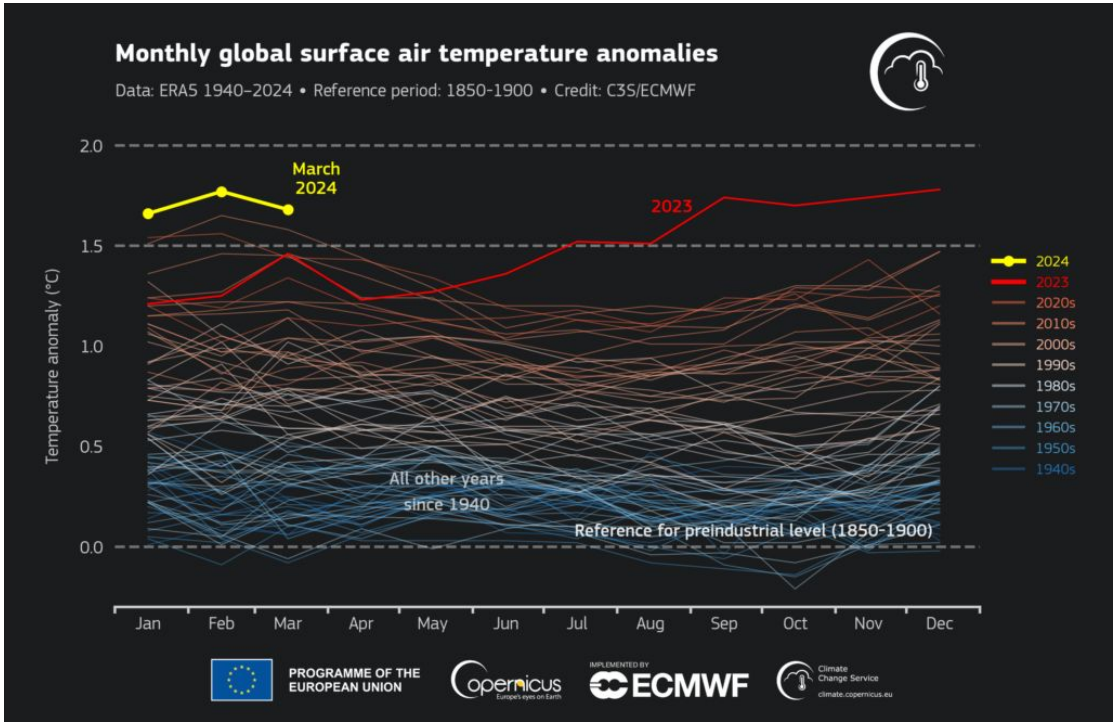

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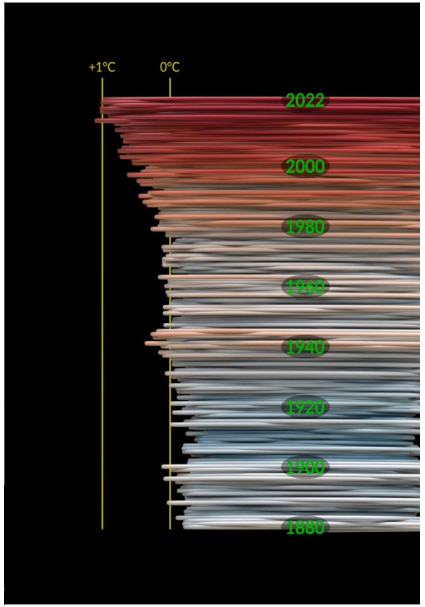

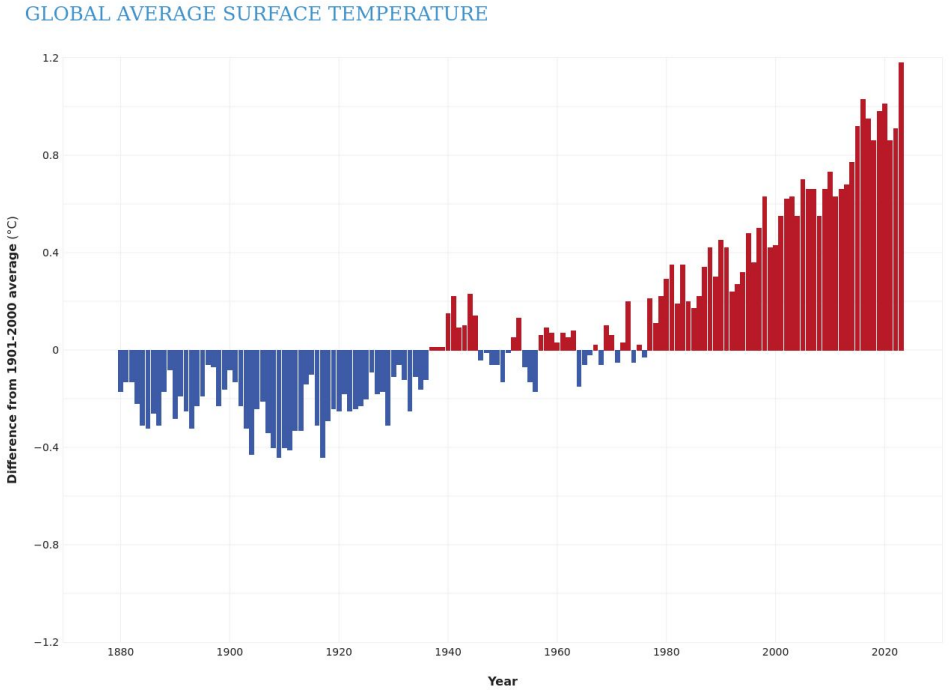

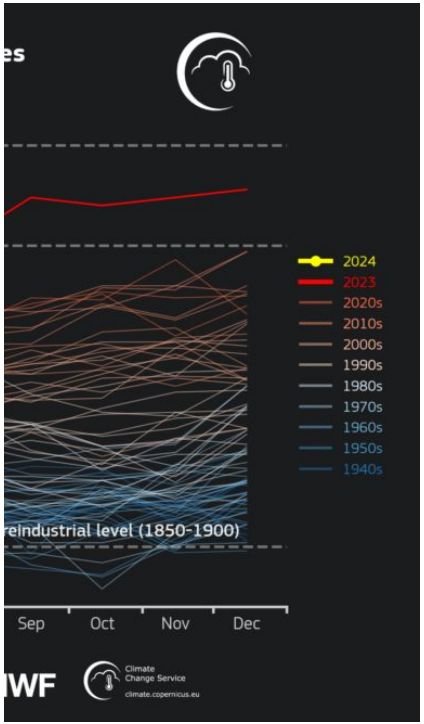

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Destination Earth: Digital Twins

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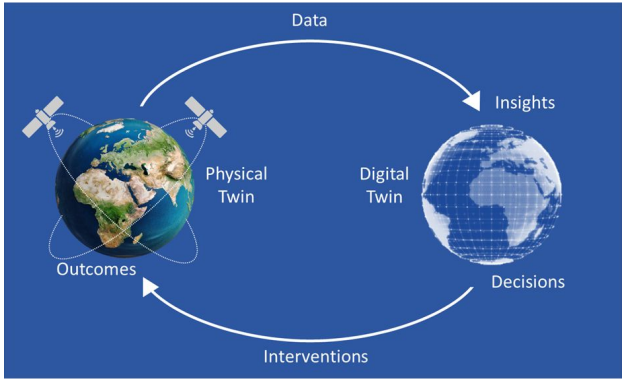
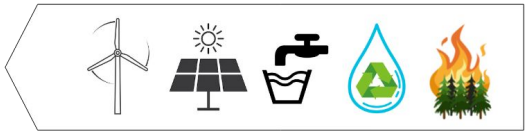
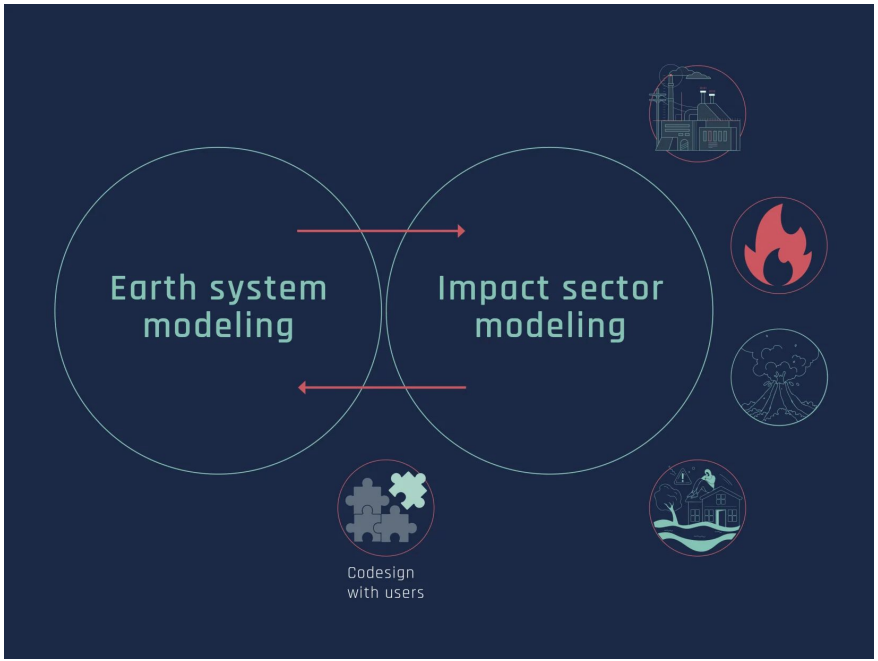
Why digital twins?





Impact sector applications



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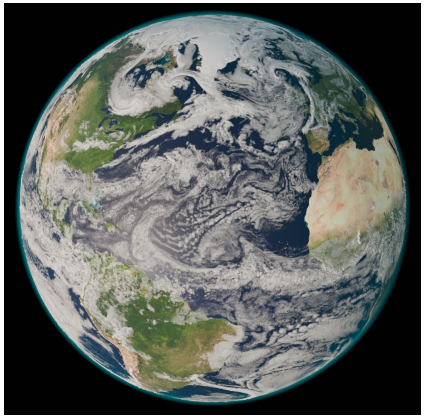
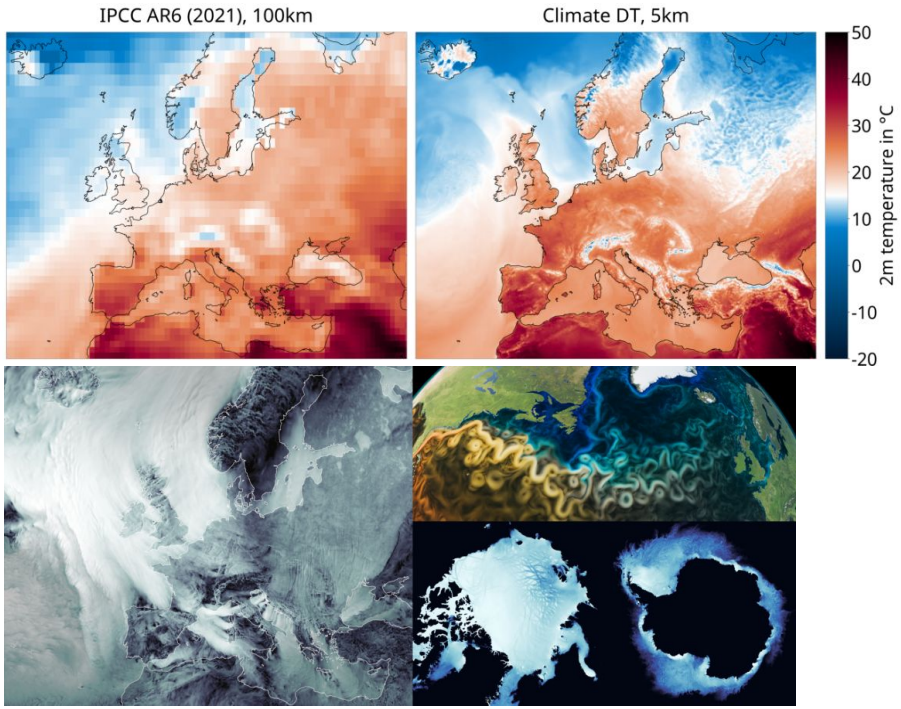
Destination Earth: Digital Twins

- Phase 1 ran from 2022-2024
- 3 different models
- One simulation takes months
- 300+ supercomputer nodes
- Multiple EuroHPC supercomputers

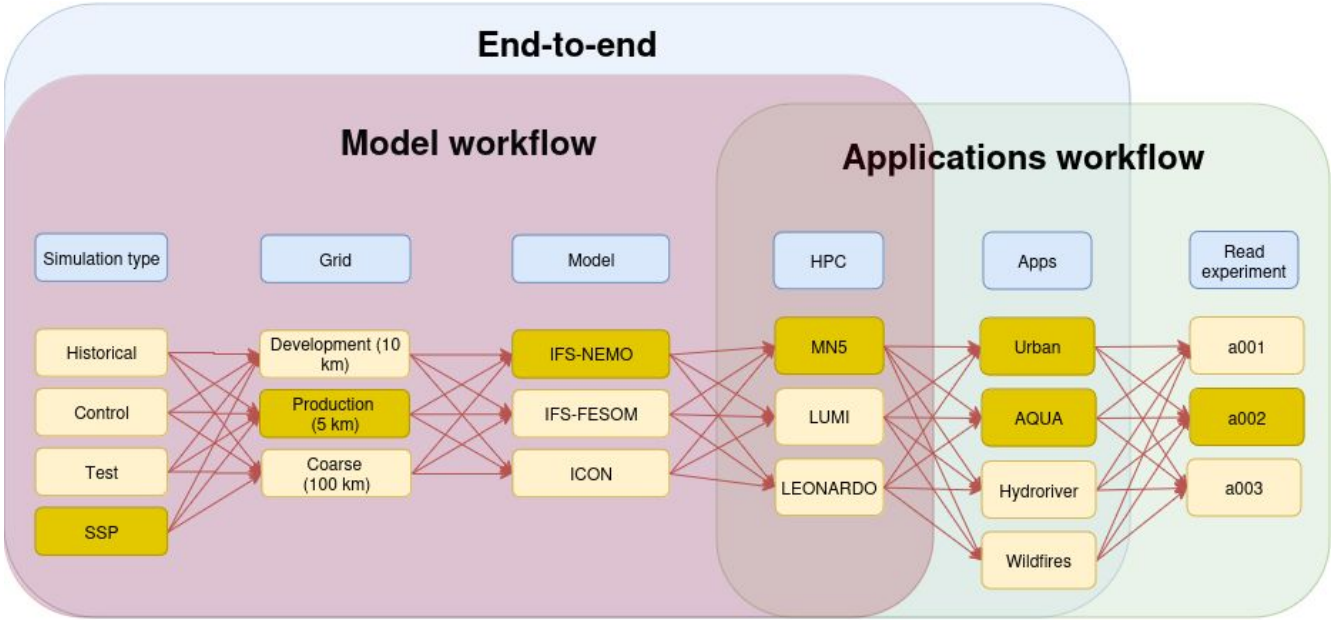




Funded by the European Union
Destination Earth
implemented by
ECMWF
esa
EUMETSAT

What does it take to run a model?

- AUTOSUBMIT



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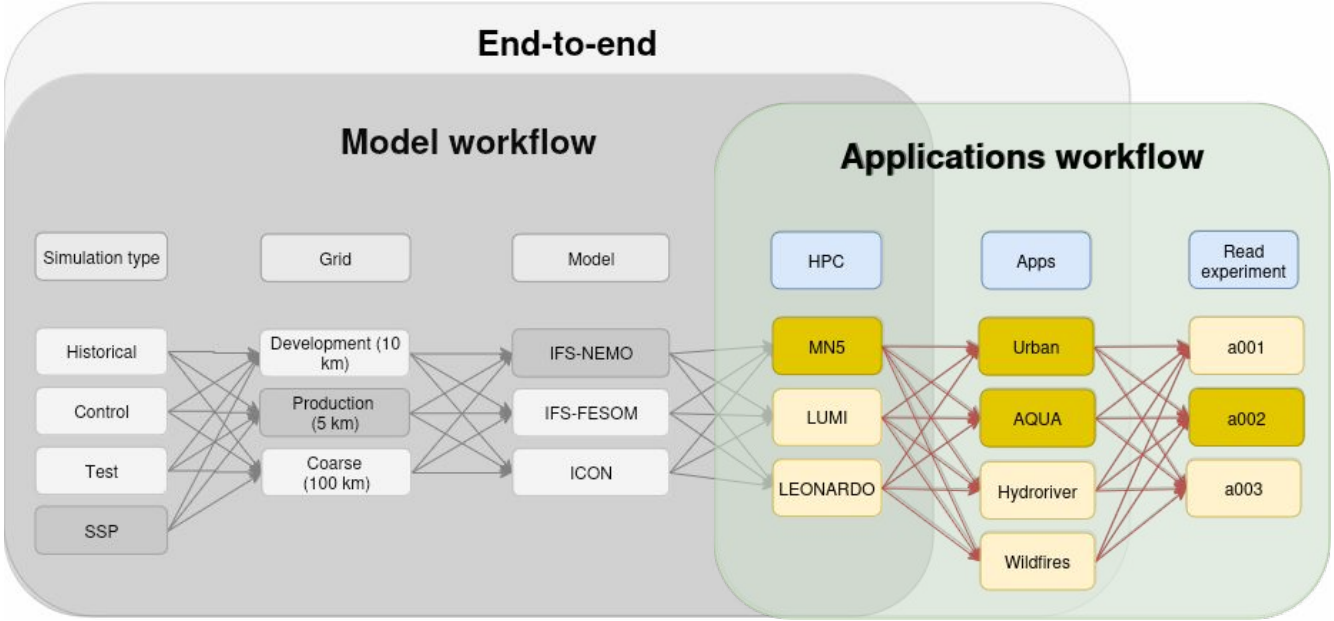
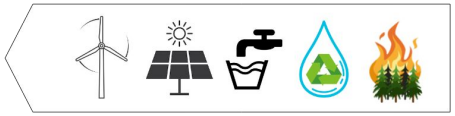


esa



Impact sector applications

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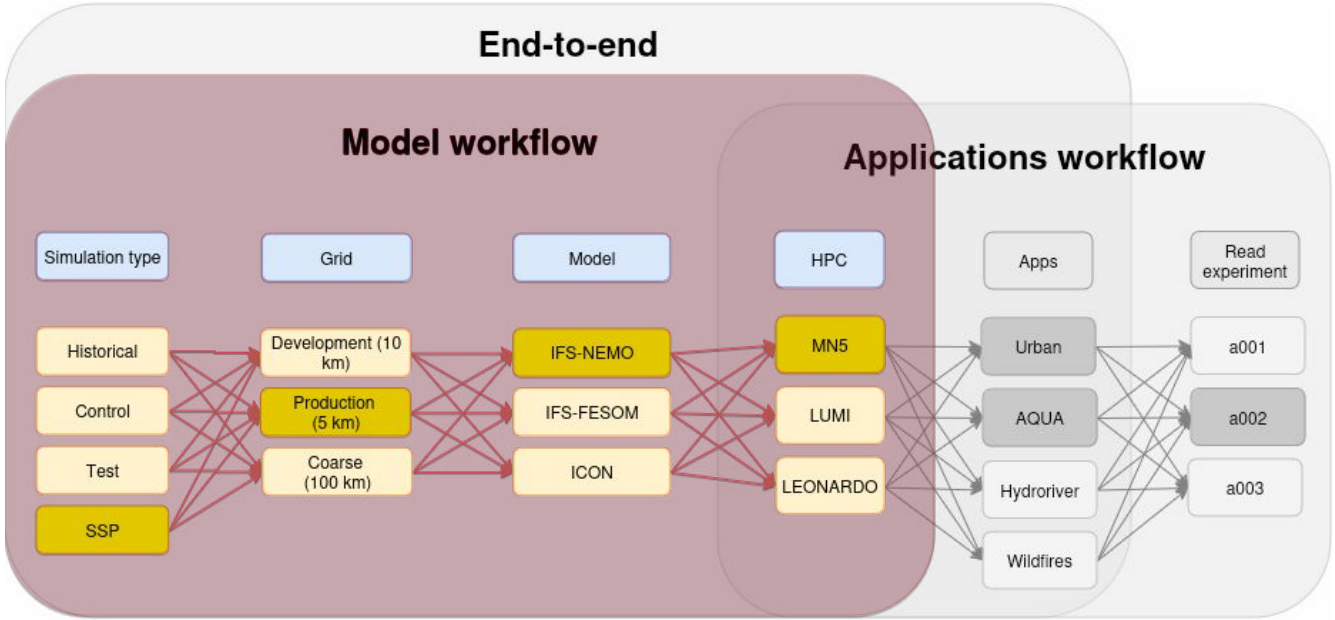

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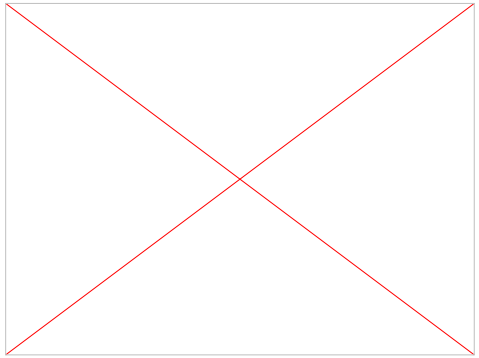

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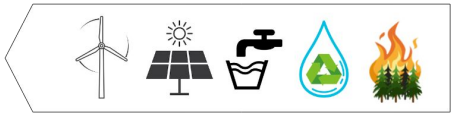

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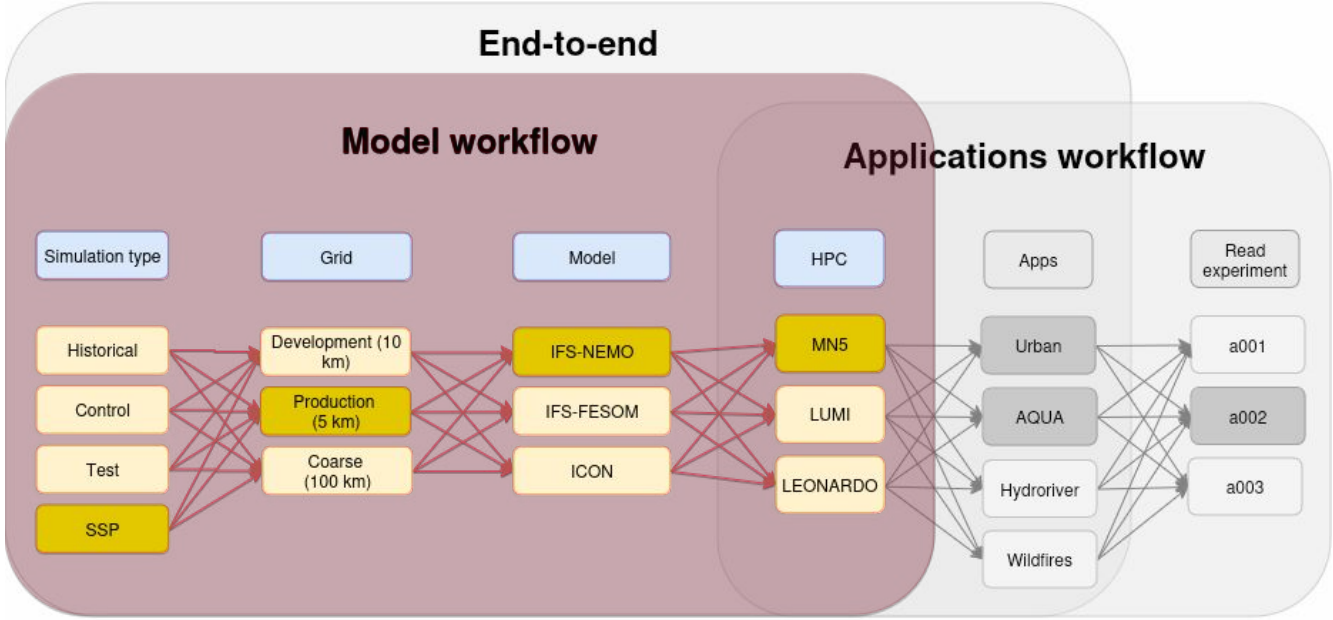

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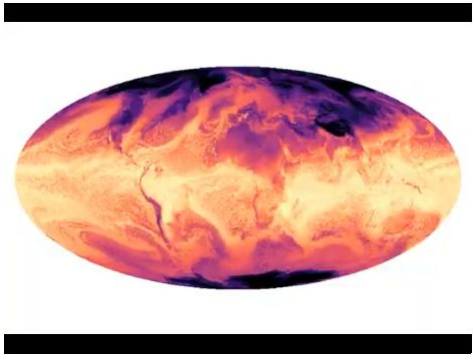

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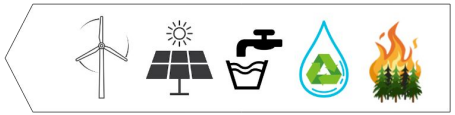

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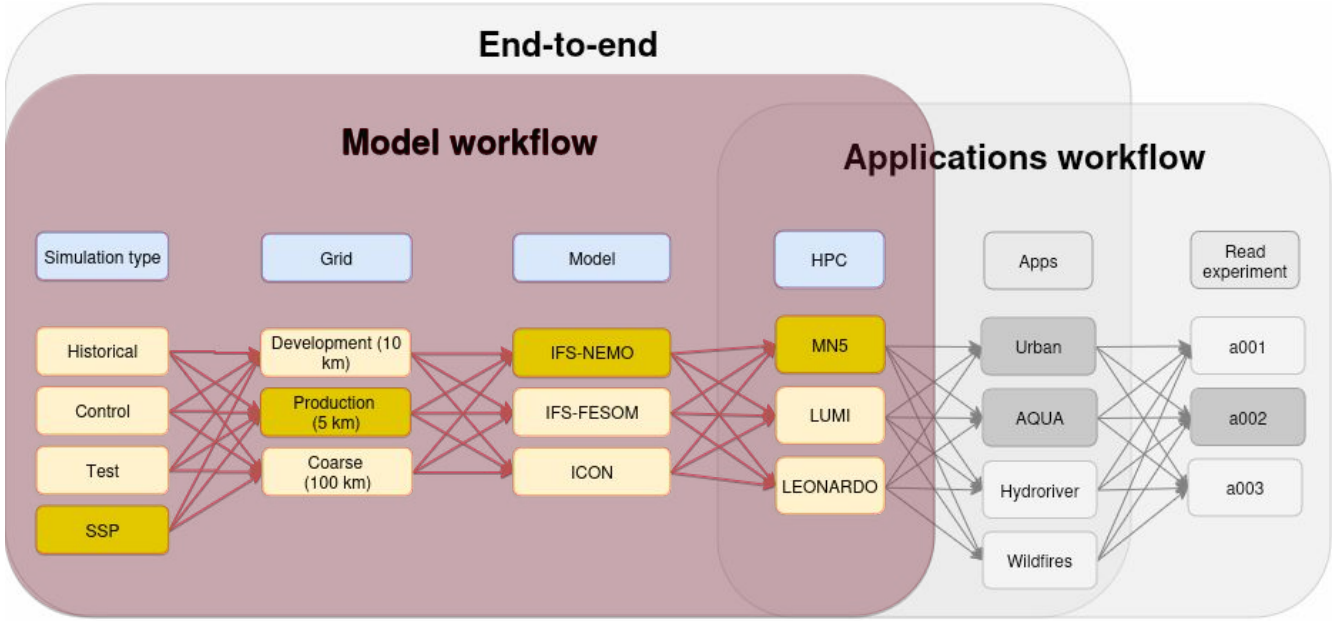

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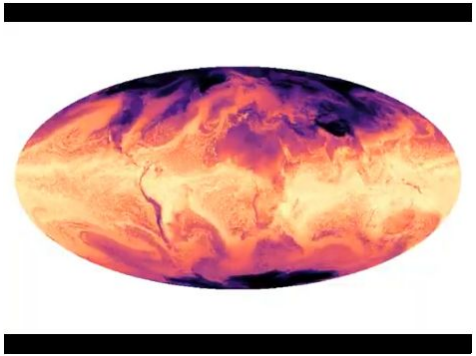

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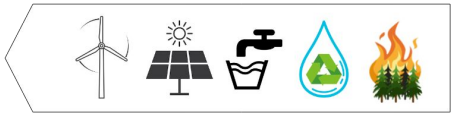

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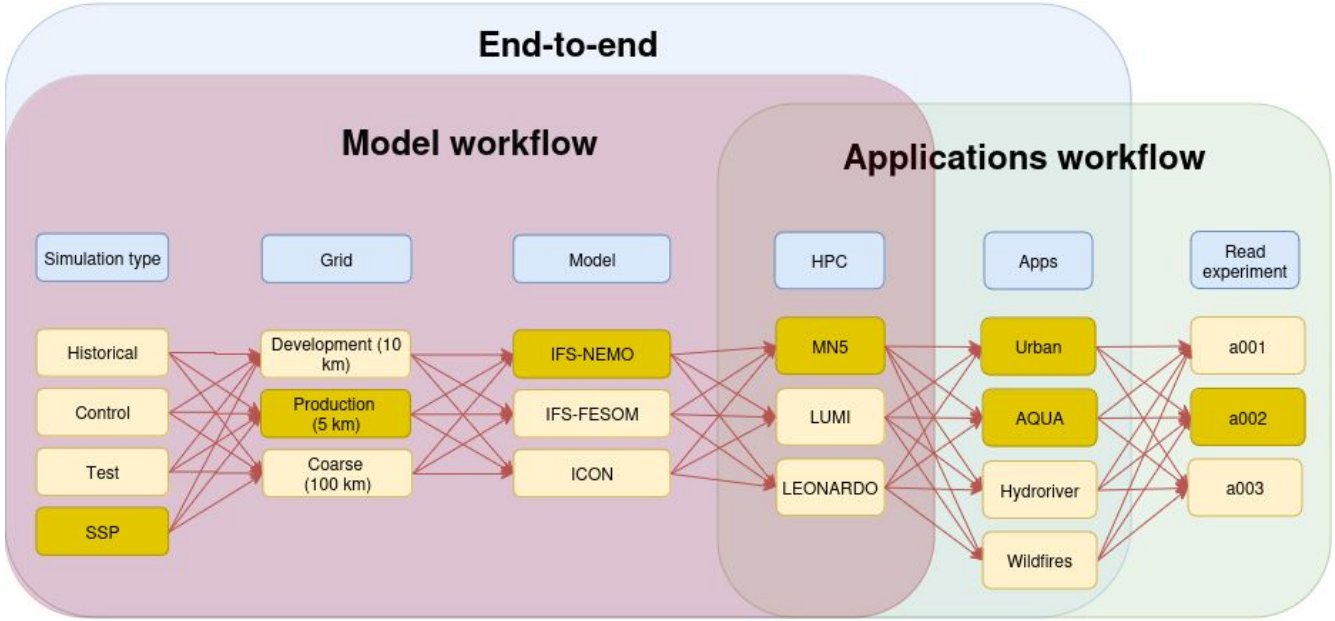

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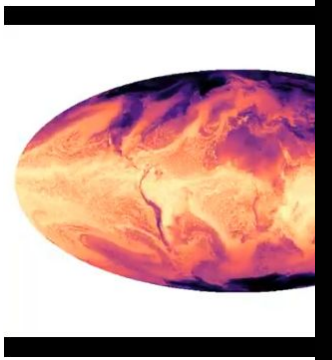

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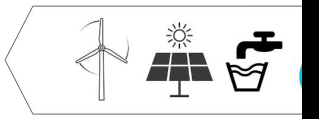

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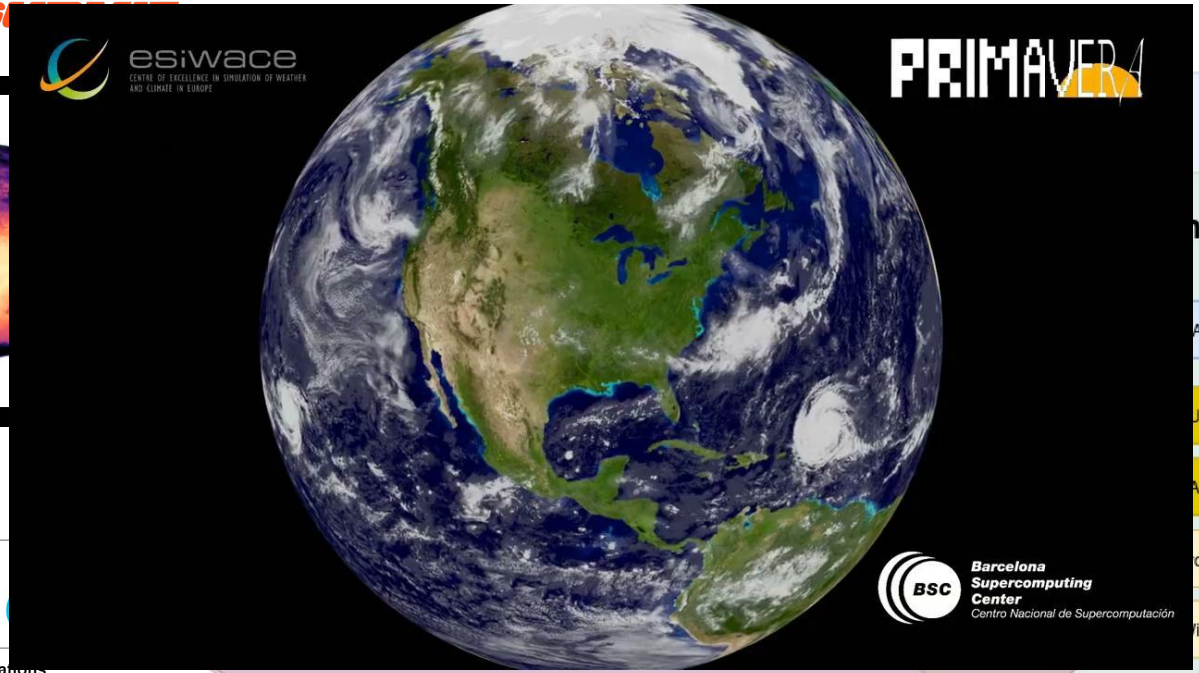
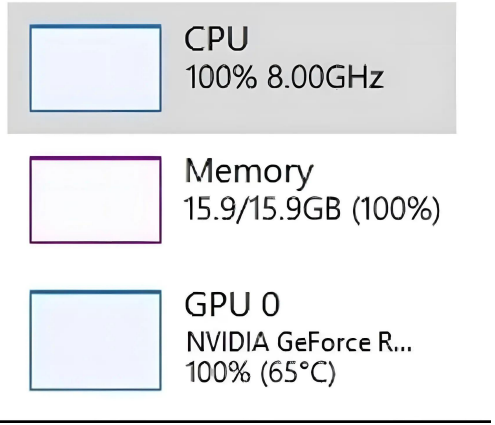
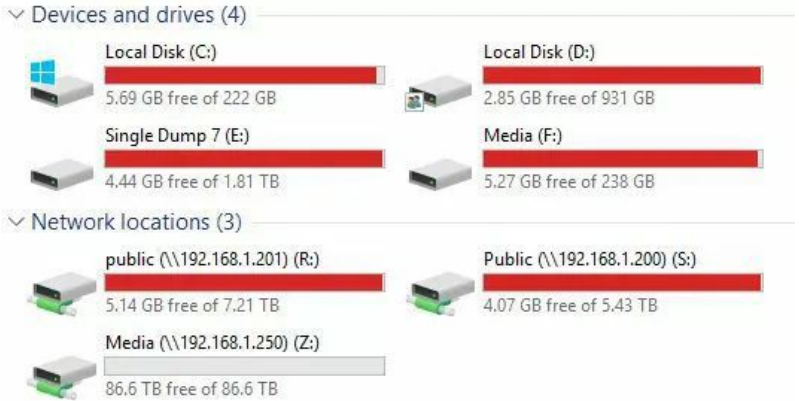


Performance Engineering

Performance Engineering

"I paid for the whole PC, I'm gonna use the whole PC"





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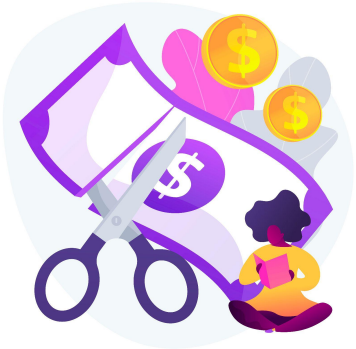


Performance Engineering

Follow these simple steps:

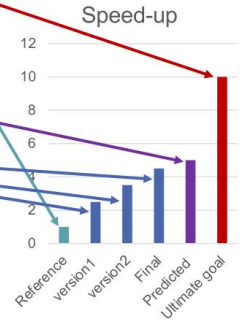
Systematic approach

Given an application …

1. Understand (user) **requirements**
2. Understand **current performance**
3. **Can** it be done?
4. **How** can it be done?
5. **Tuning**

   Not there yet? => back to 2

6. Analyze & document the result



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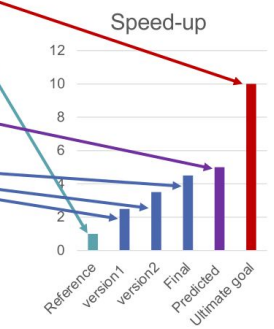


Thank you Ana Varbanescu!

Performance Engineering

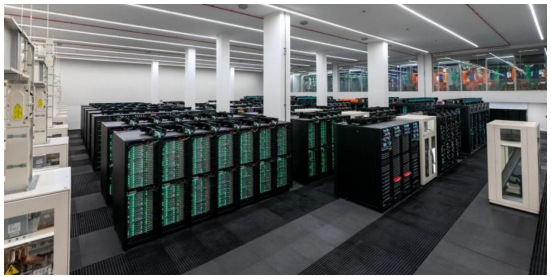
Always optimize your application for a specific system!

Performance Engineering

Always optimize your application for a specific system!

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

MN5 MARENOSTRUM



Performance Engineering

Always optimize your application for a specific system!

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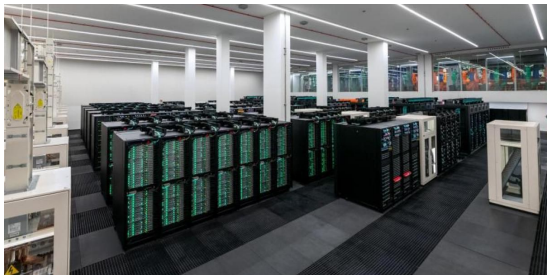
Centro Nacional de Supercomputación

MN5 MARENOSTRUM

CSC

LUMI



Performance Engineering

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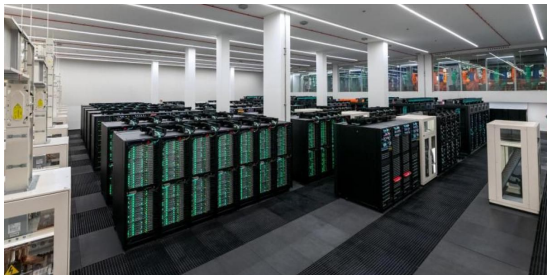
Centro Nacional de Supercomputación

MN5 MARENOSTRUM

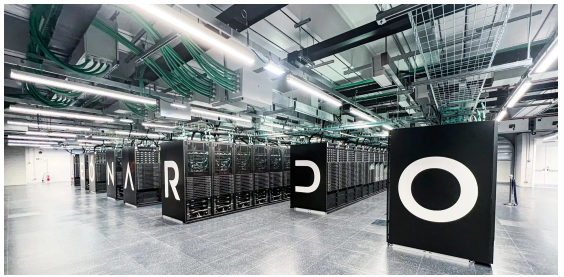


CSC

LUMI

CINECA

LEONARDO



Performance Engineering

Rank	TOP500 Rank	System	Cores	Rmax (PFlop/s)	Power (kW)	Energy Efficiency (GFlops/watts)
12	5	**LUMI** - HPE Cray EX235a, AMD Optimized 3rd Generation EPYC 64C 2GHz, AMD Instinct MI250X, Slingshot-11, HPE EuroHPC/CSC Finland	2,752,704	379.70	7,107	53.428
15	8	**MareNostrum 5 ACC** - BullSequana XH3000, Xeon Platinum 8460Y+ 32C 2.3GHz, NVIDIA H100 64GB, Infiniband NDR, EVIDEN EuroHPC/BSC Spain	663,040	175.30	4,159	48.320
28	7	**Leonardo** - BullSequana XH2000, Xeon Platinum 8358 32C 2.6GHz, NVIDIA A100 SXM4 64 GB, Quad-rail NVIDIA HDR100 Infiniband, EVIDEN EuroHPC/CINECA Italy	1,824,768	241.20	7,494	32.187

Performance Engineering

Performed optimizations:

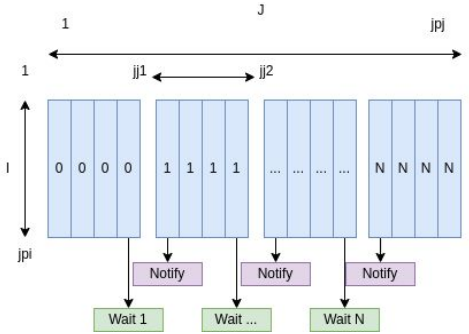
- CPU 

- GPU 

Performance Engineering

Performed optimizations:

- CPU
  - OpenMP regions (1.2x - 2.8x depending on the region)
- GPU

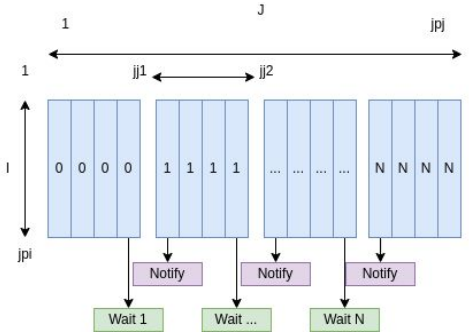


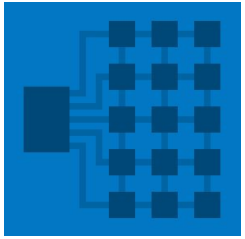
Performance Engineering

Performed optimizations:

- CPU
  - OpenMP regions (1.2x - 2.8x depending on the region)
  - MultIO improvement (1.03x)

- GPU





Performance Engineering

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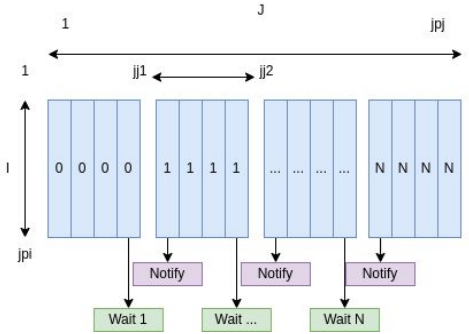
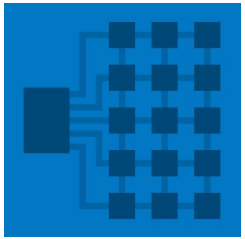
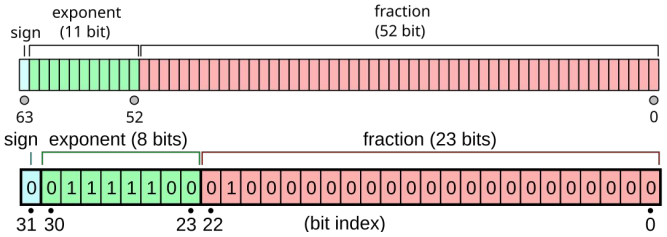
  - MultIO improvement (1.03x)
  - Mixed Precision (1.2x)
- GPU



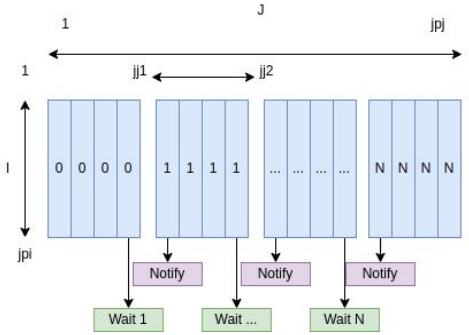


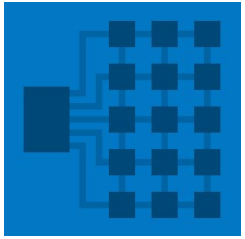


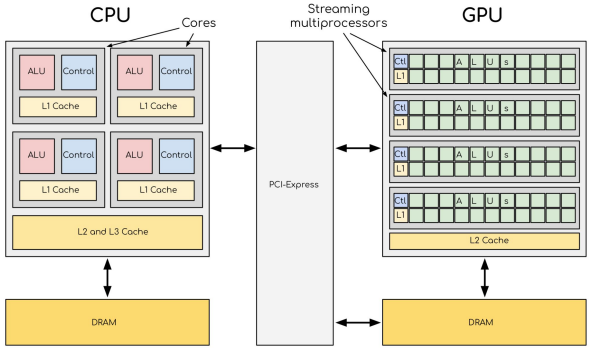
Performance Engineering

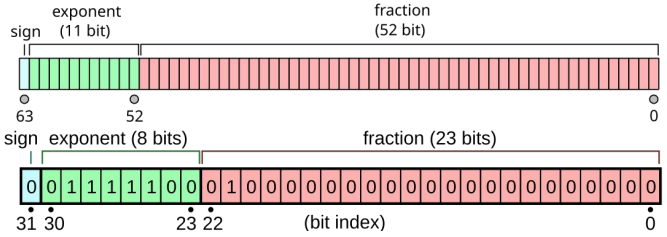
Performed optimizations:

- CPU
  - OpenMP regions (1.2x - 2.8x depending on the region)
  - MultIO improvement (1.03x)
  - Mixed Precision (1.2x)
- GPU
  - Porting pilot-regions of Sea-Ice module to GPUs (5.9x)





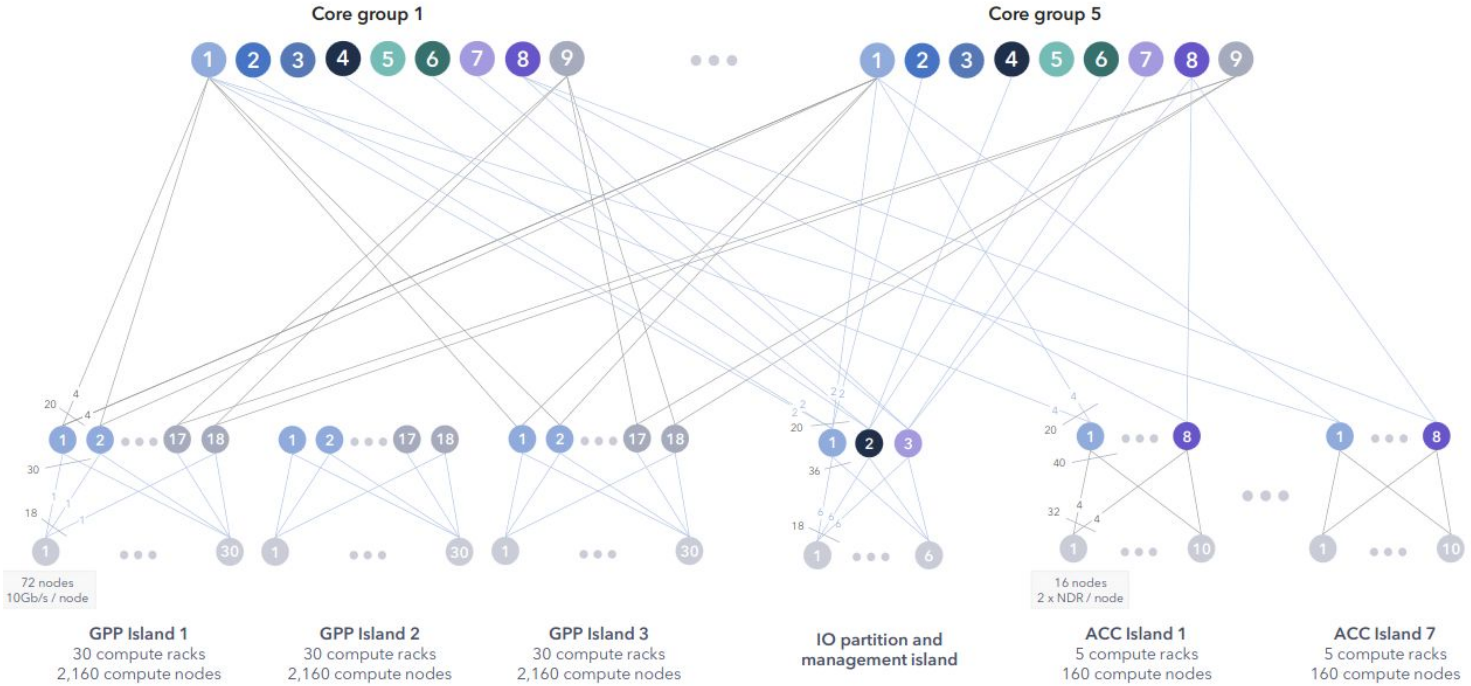




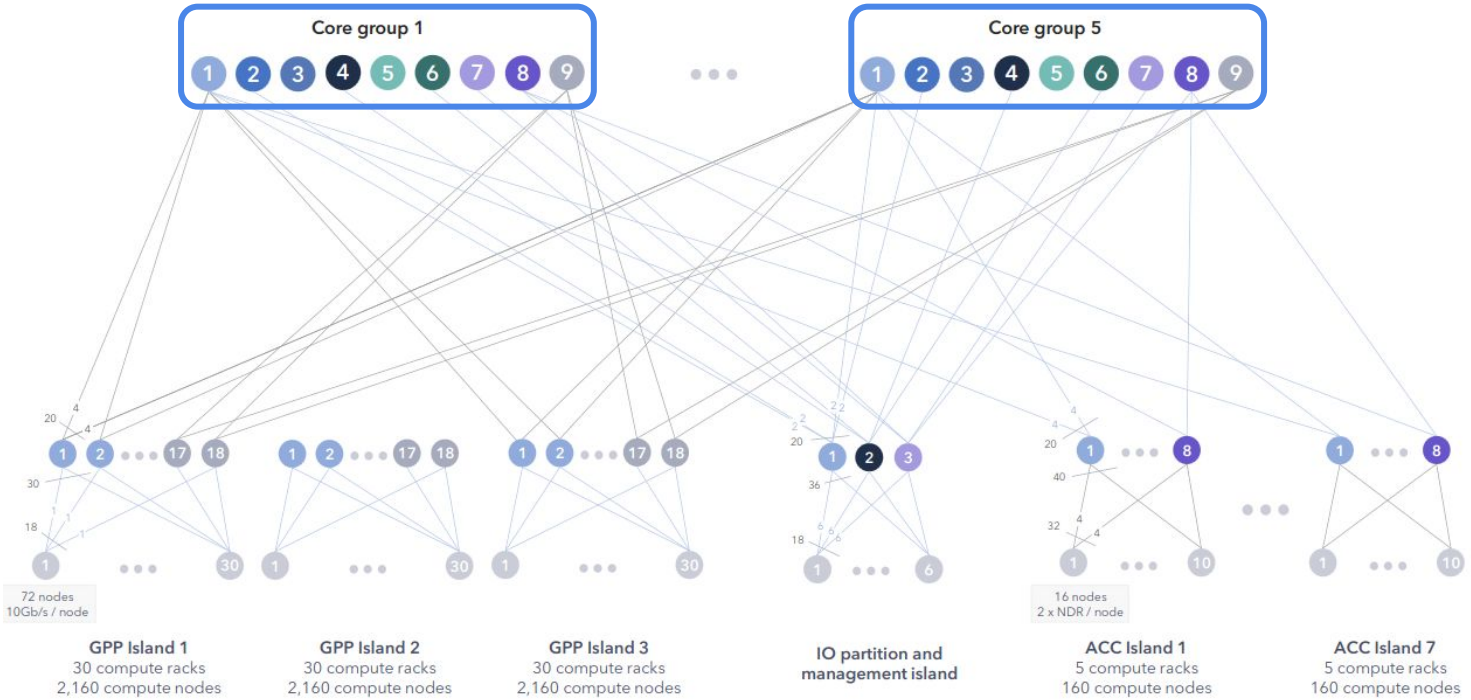
Performance Profiling

HPC 101

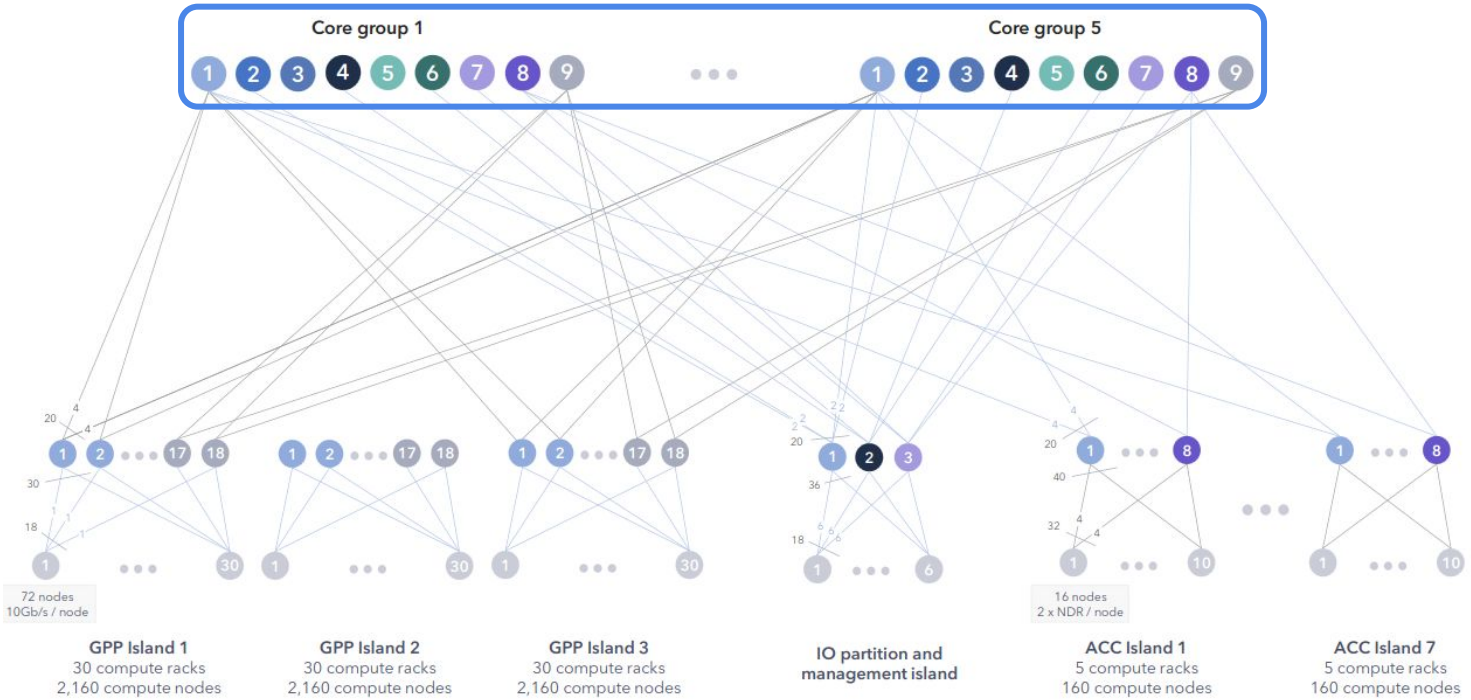
HPC 101


Core group 1
Core group 5
72 nodes
10Gb/s / node
16 nodes
2 x NDR / node
GPP Island 1
30 compute racks
2,160 compute nodes
GPP Island 2
30 compute racks
2,160 compute nodes
GPP Island 3
30 compute racks
2,160 compute nodes
IO partition and management island
ACC Island 1
5 compute racks
160 compute nodes
ACC Island 7
5 compute racks
160 compute nodes

HPC 101


Core group 1
1 2 3 4 5 6 7 8 9
Core group 5
1 2 3 4 5 6 7 8 9
72 nodes
10Gb/s / node
GPP Island 1
30 compute racks
2,160 compute nodes
GPP Island 2
30 compute racks
2,160 compute nodes
GPP Island 3
30 compute racks
2,160 compute nodes
IO partition and management island
16 nodes
2 x NDR / node
ACC Island 1
5 compute racks
160 compute nodes
ACC Island 7
5 compute racks
160 compute nodes

HPC 101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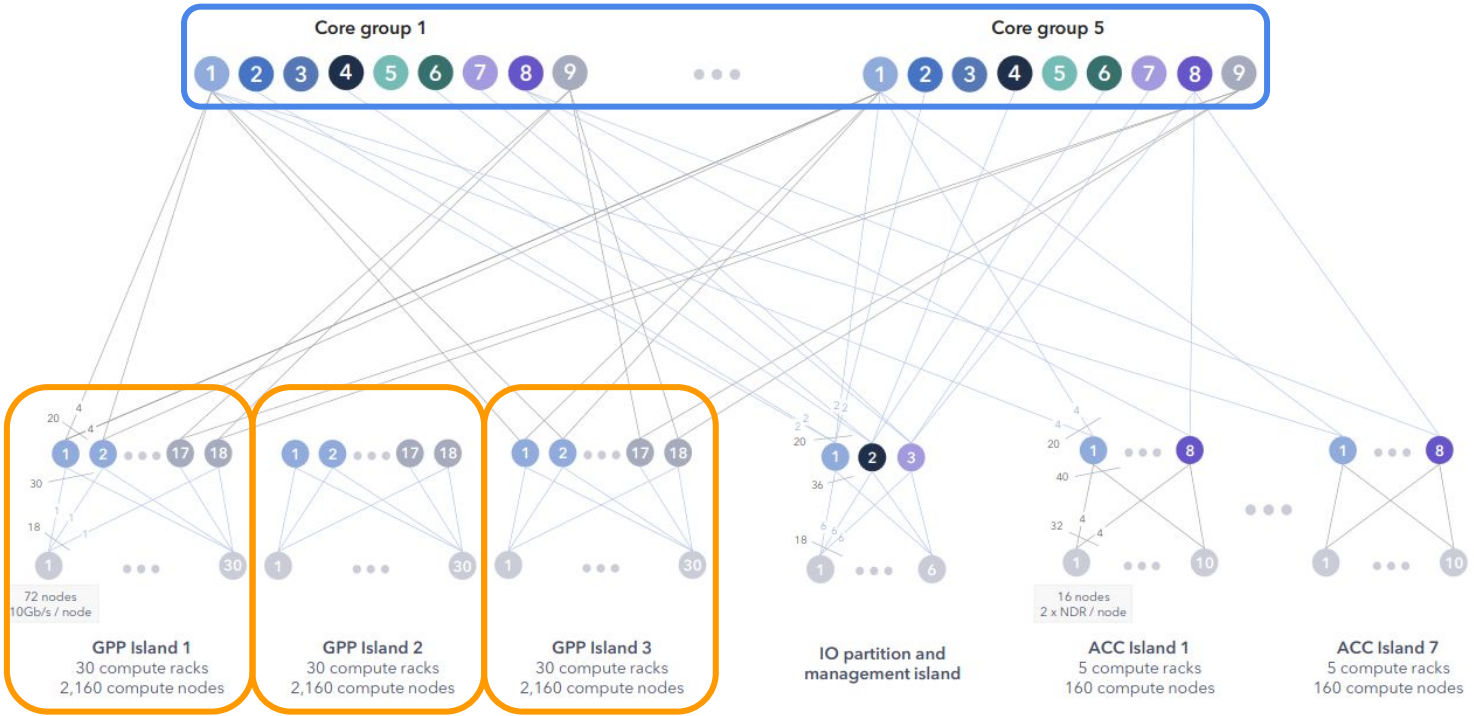
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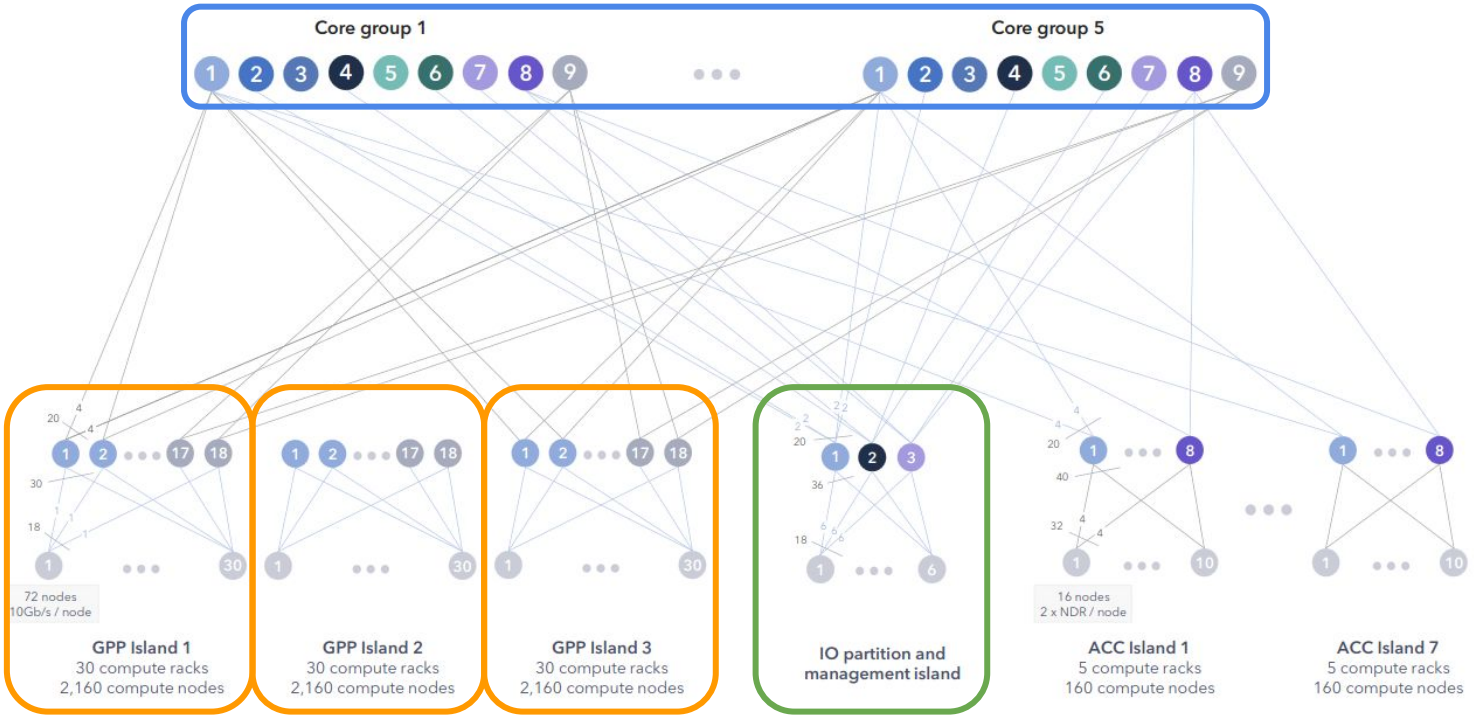
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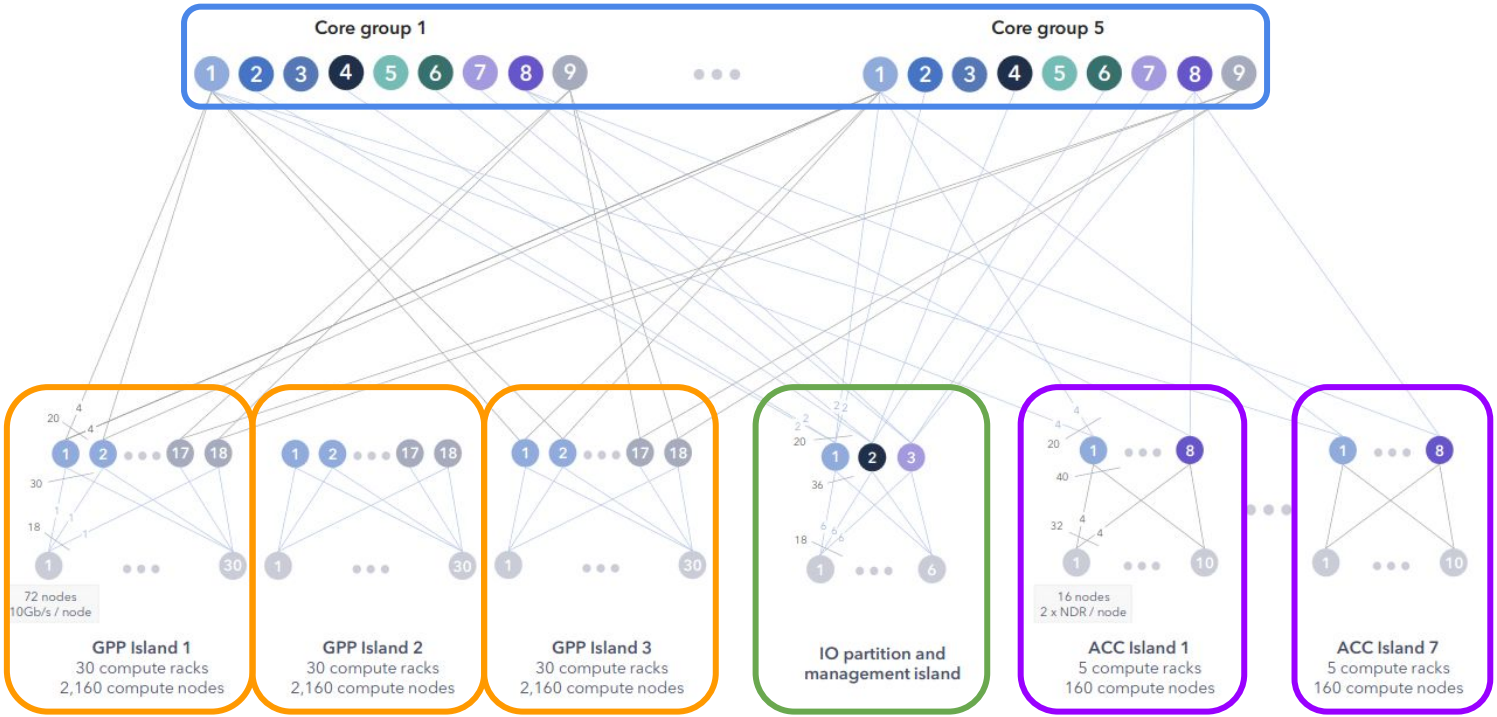
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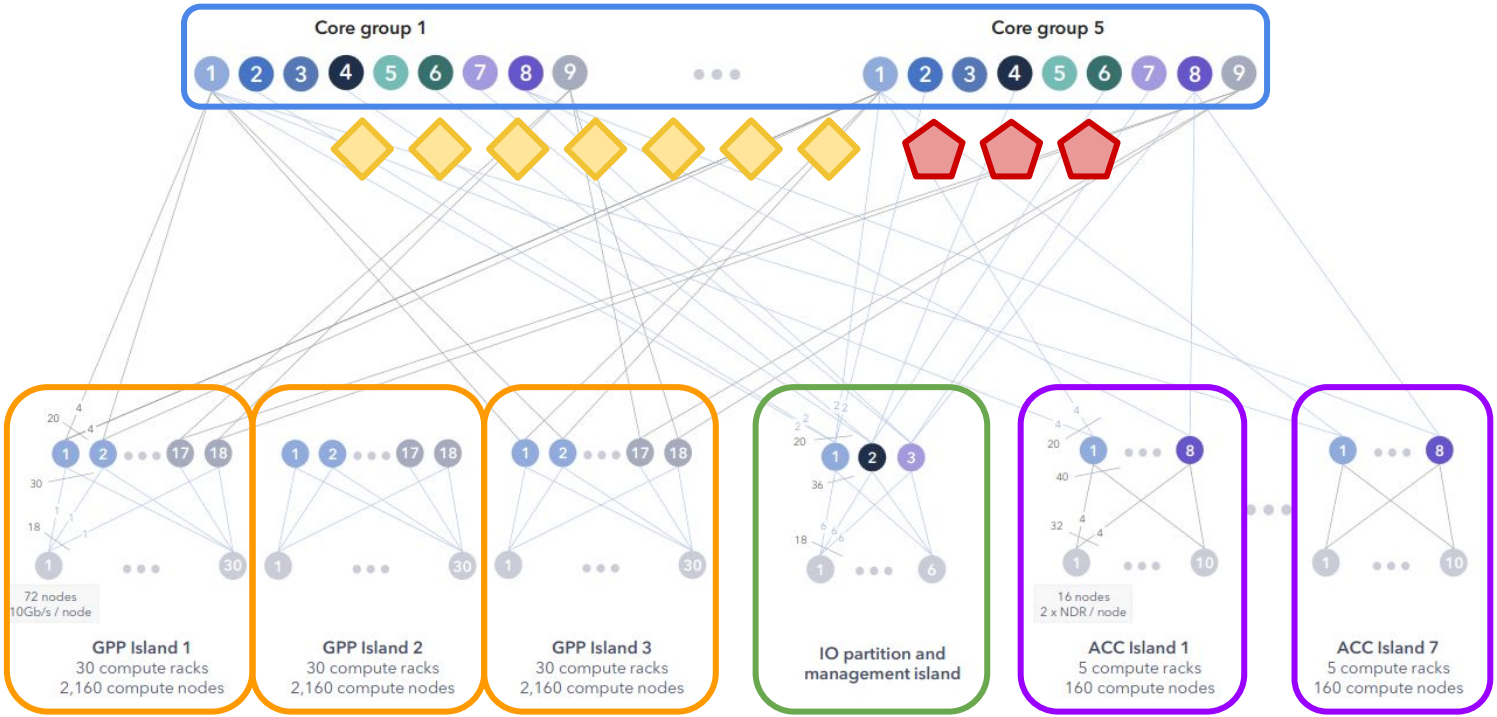
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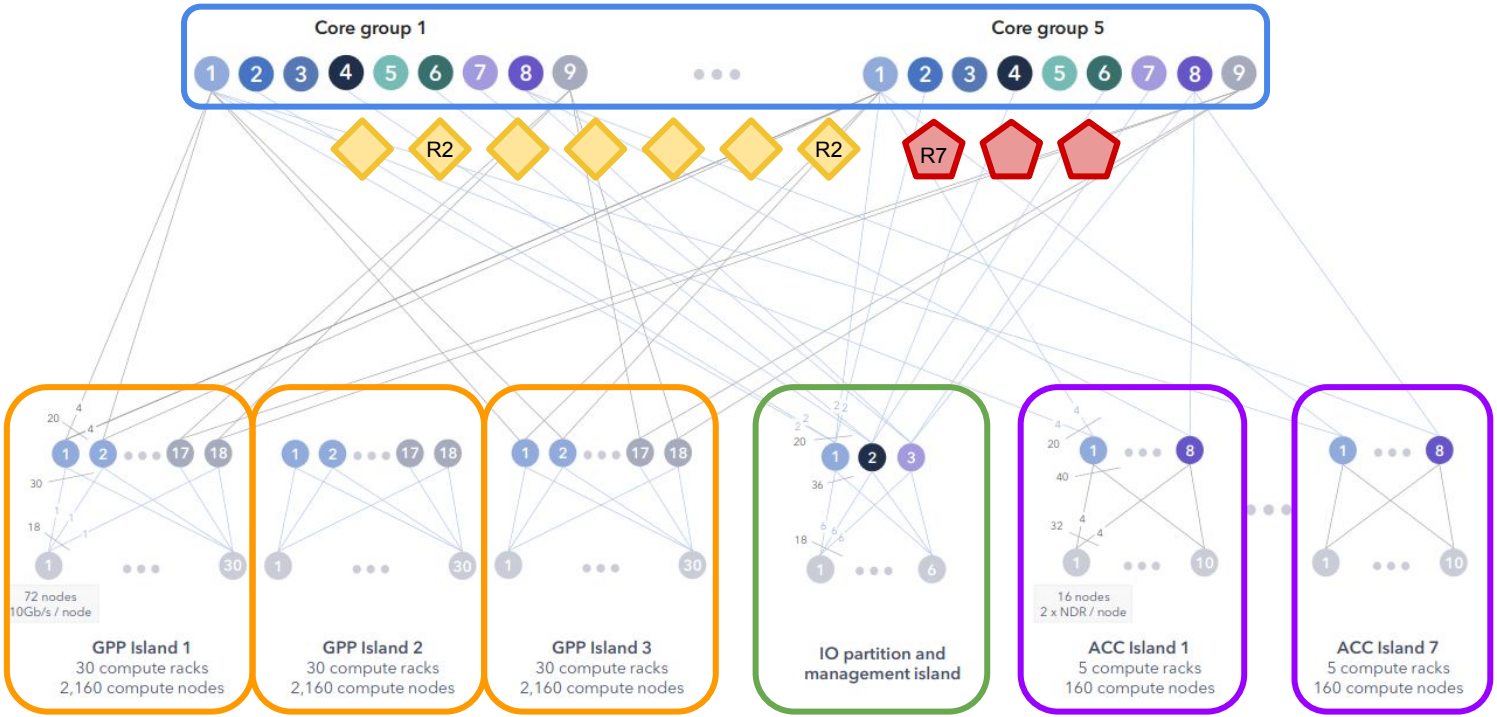
Core group 1
Core group 5
R2
R2
R7
72 nodes
10Gb/s / node
GPP Island 1
30 compute racks
2,160 compute nodes
GPP Island 2
30 compute racks
2,160 compute nodes
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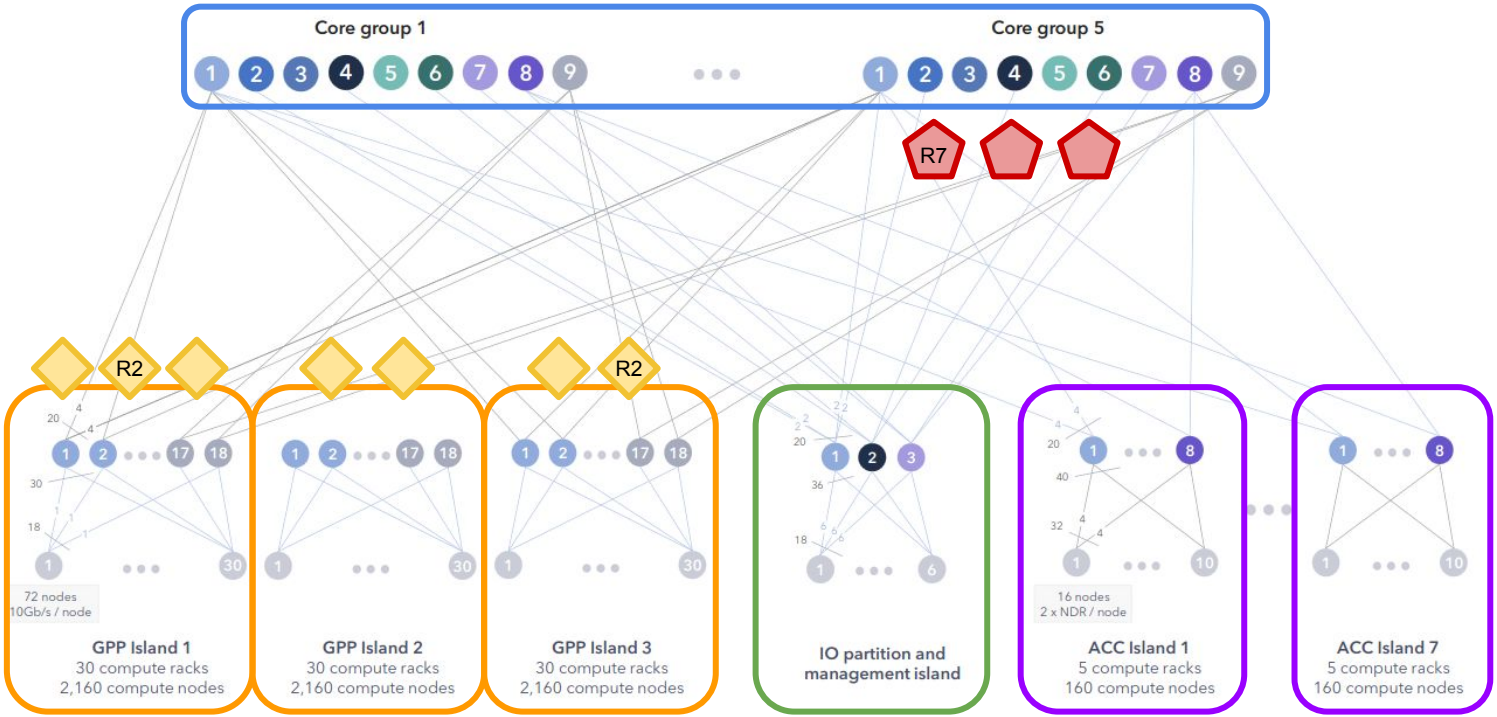
Core group 1
Core group 5
R7
R2
R2
72 nodes
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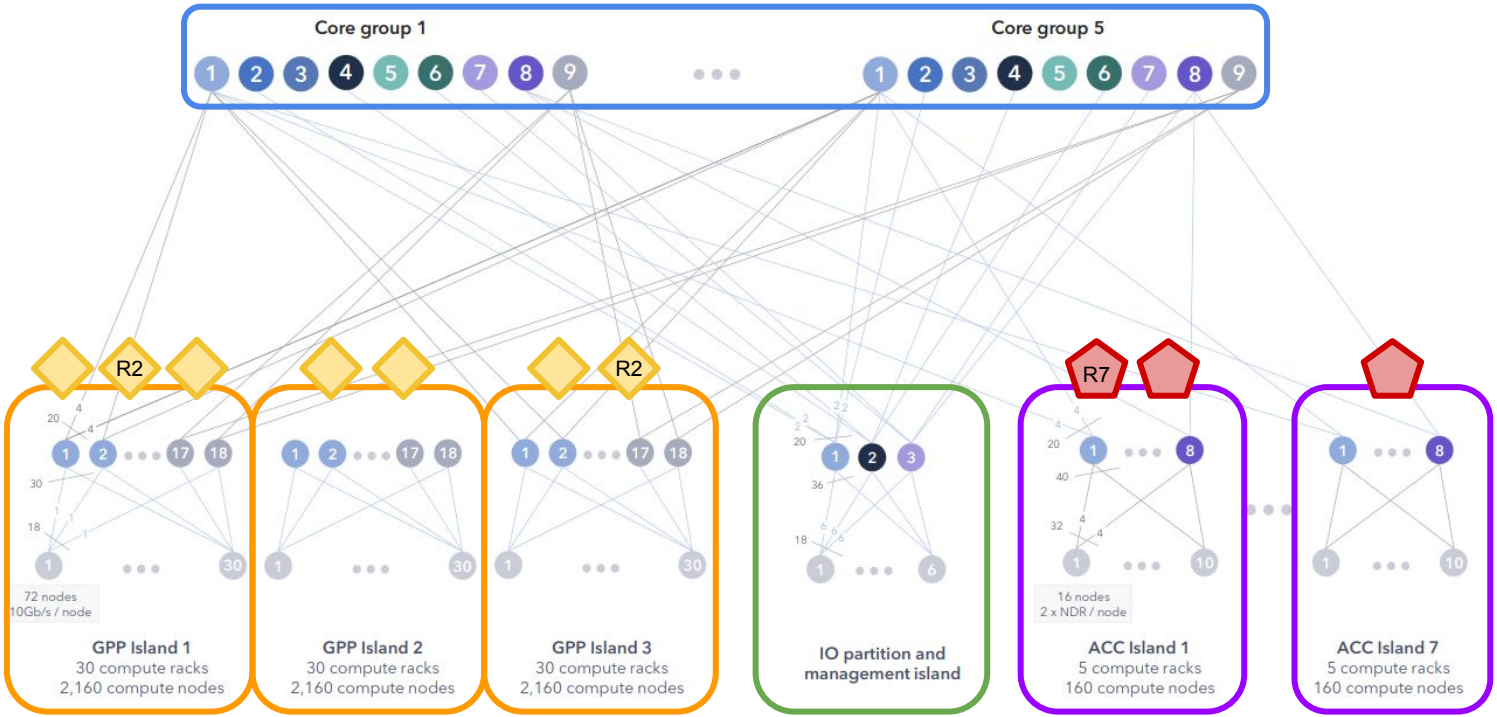
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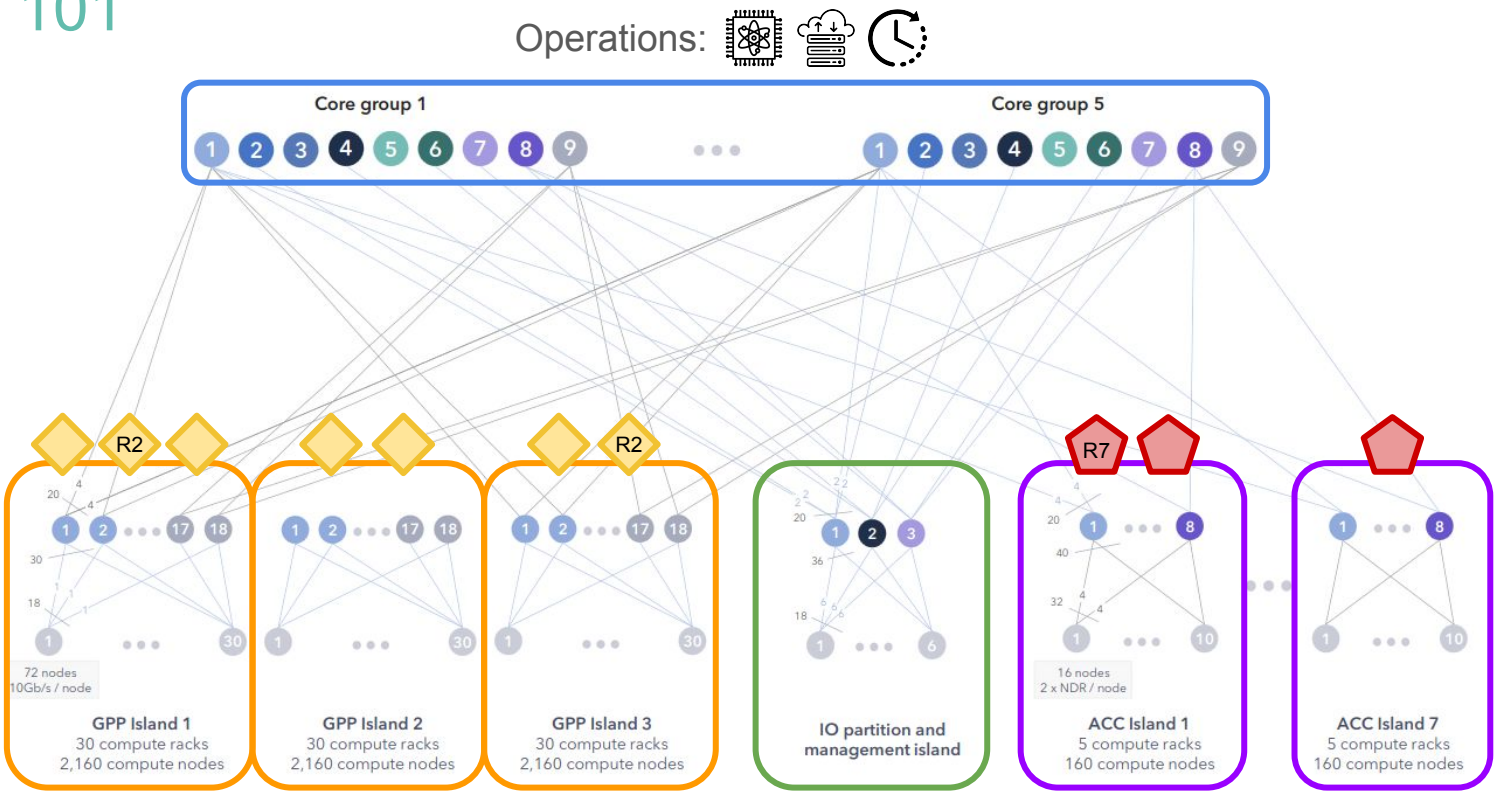
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Core group 1
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R2
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R7
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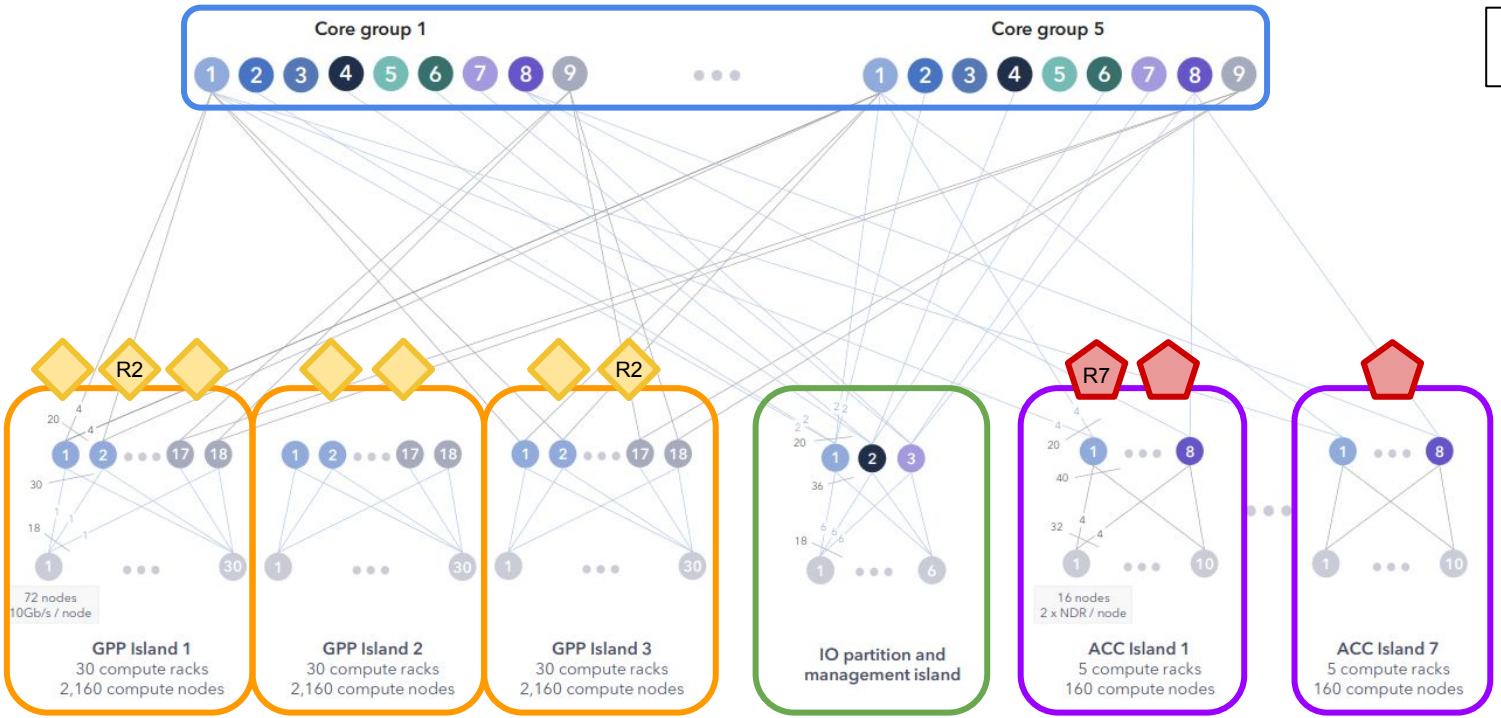
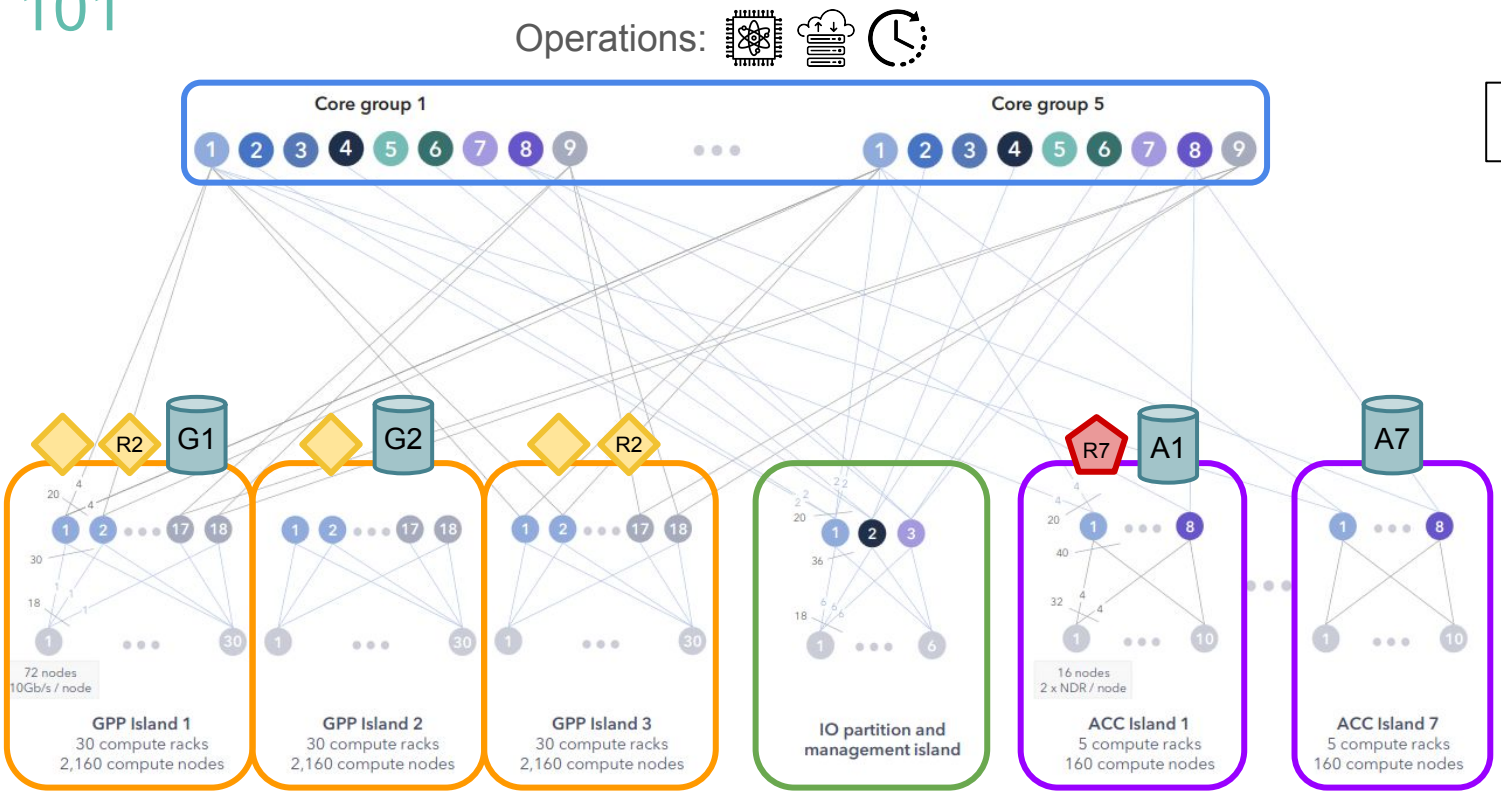
HPC 101

Operations:

Cycle 0



HPC 101


Operations:
Core group 1
Core group 5
Cycle 1
R2
G1
G2
R2
R7
A1
A7
72 nodes
10Gb/s / node
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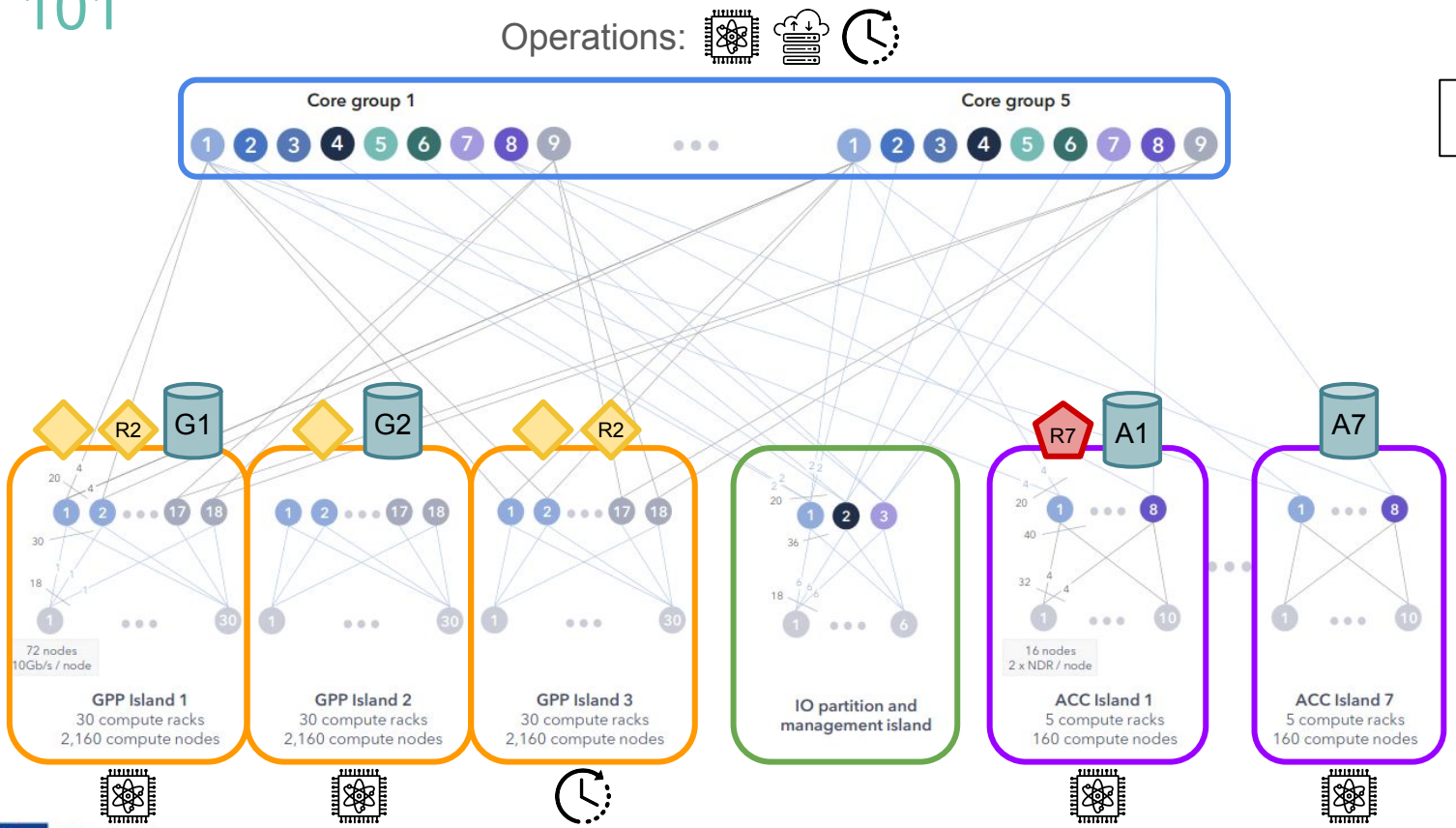
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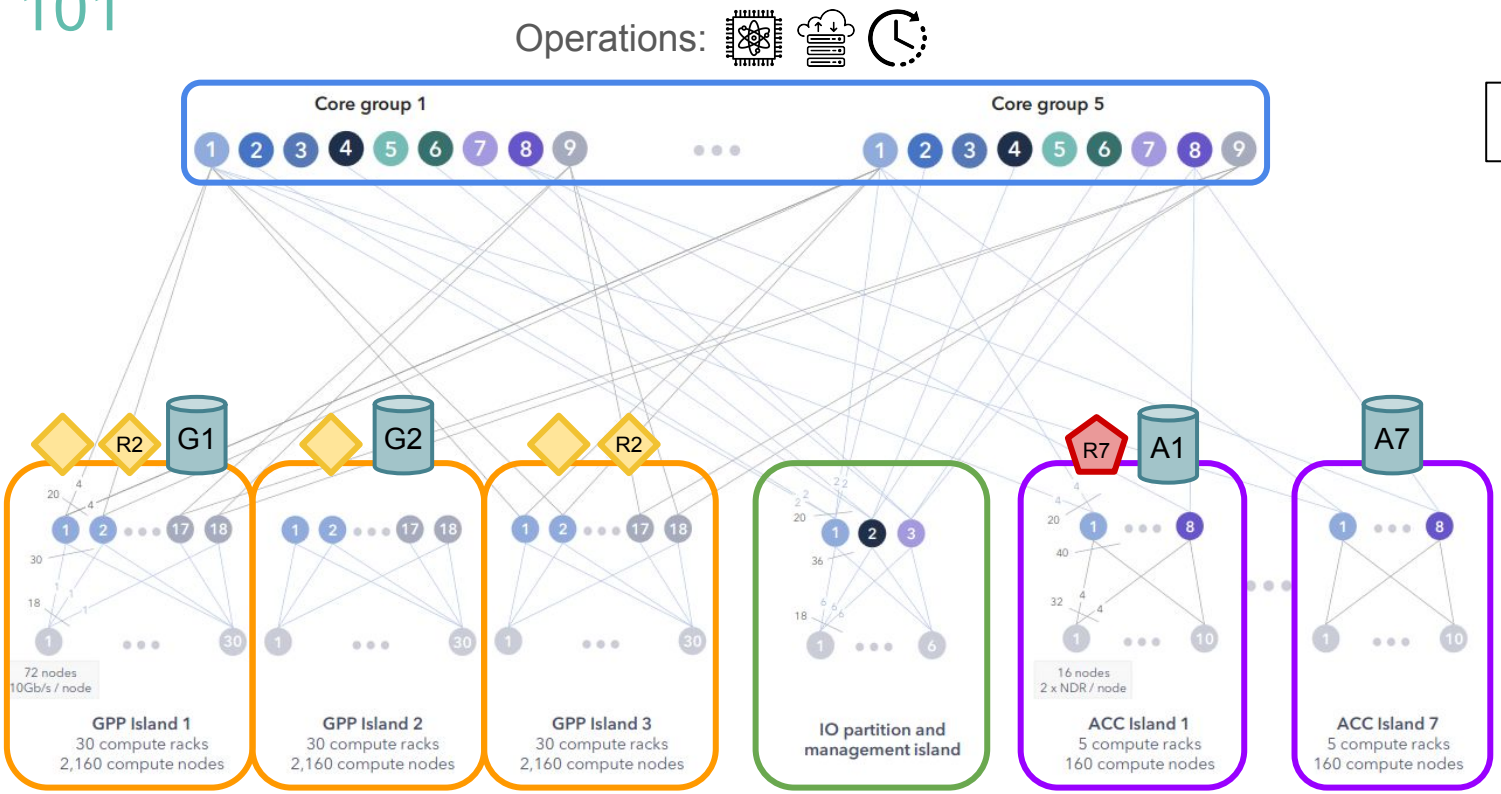
Operations:
Core group 1
Core group 5
Cycle 2
R2
G1
G2
R2
R7
A1
A7
72 nodes
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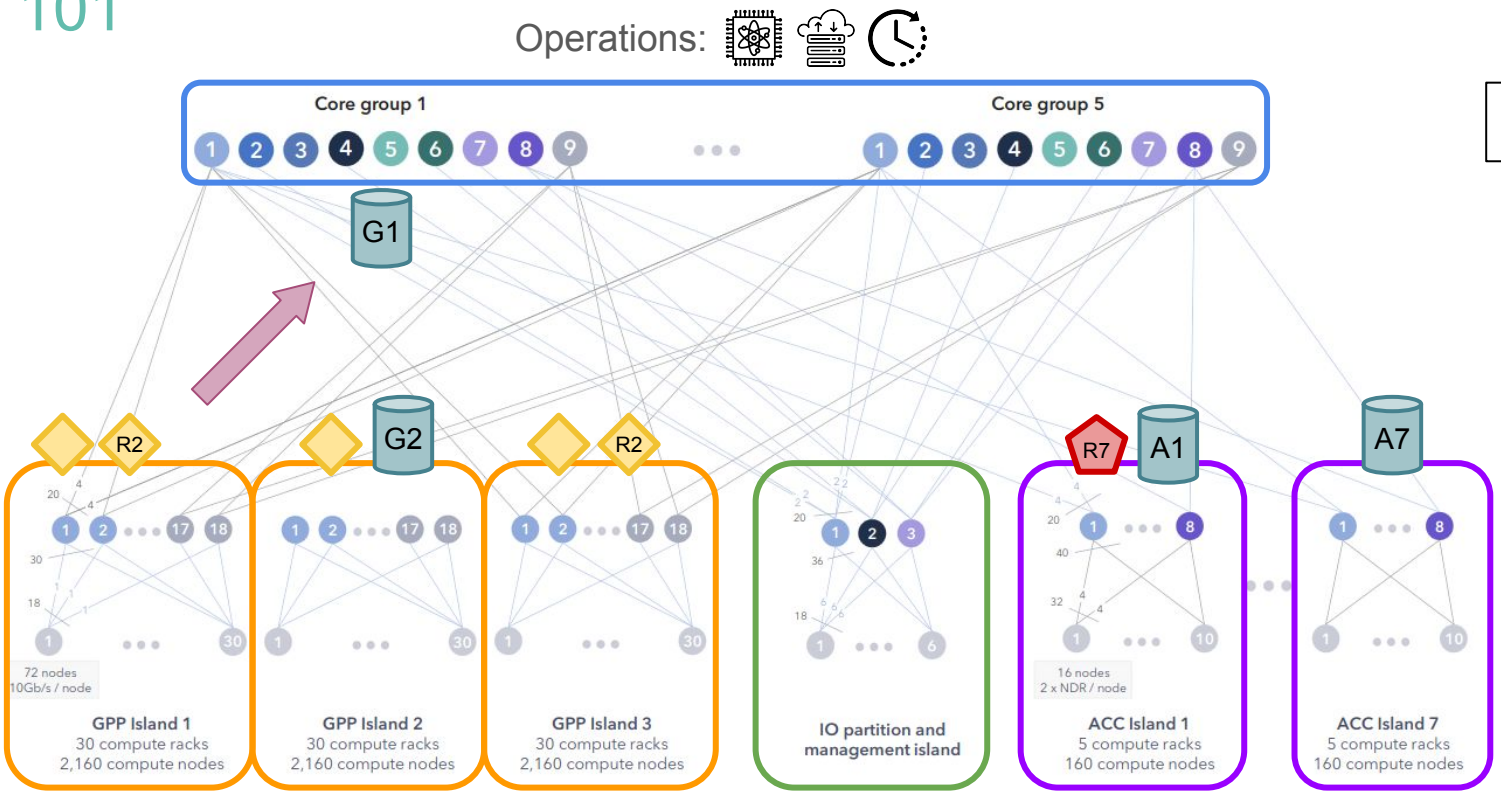
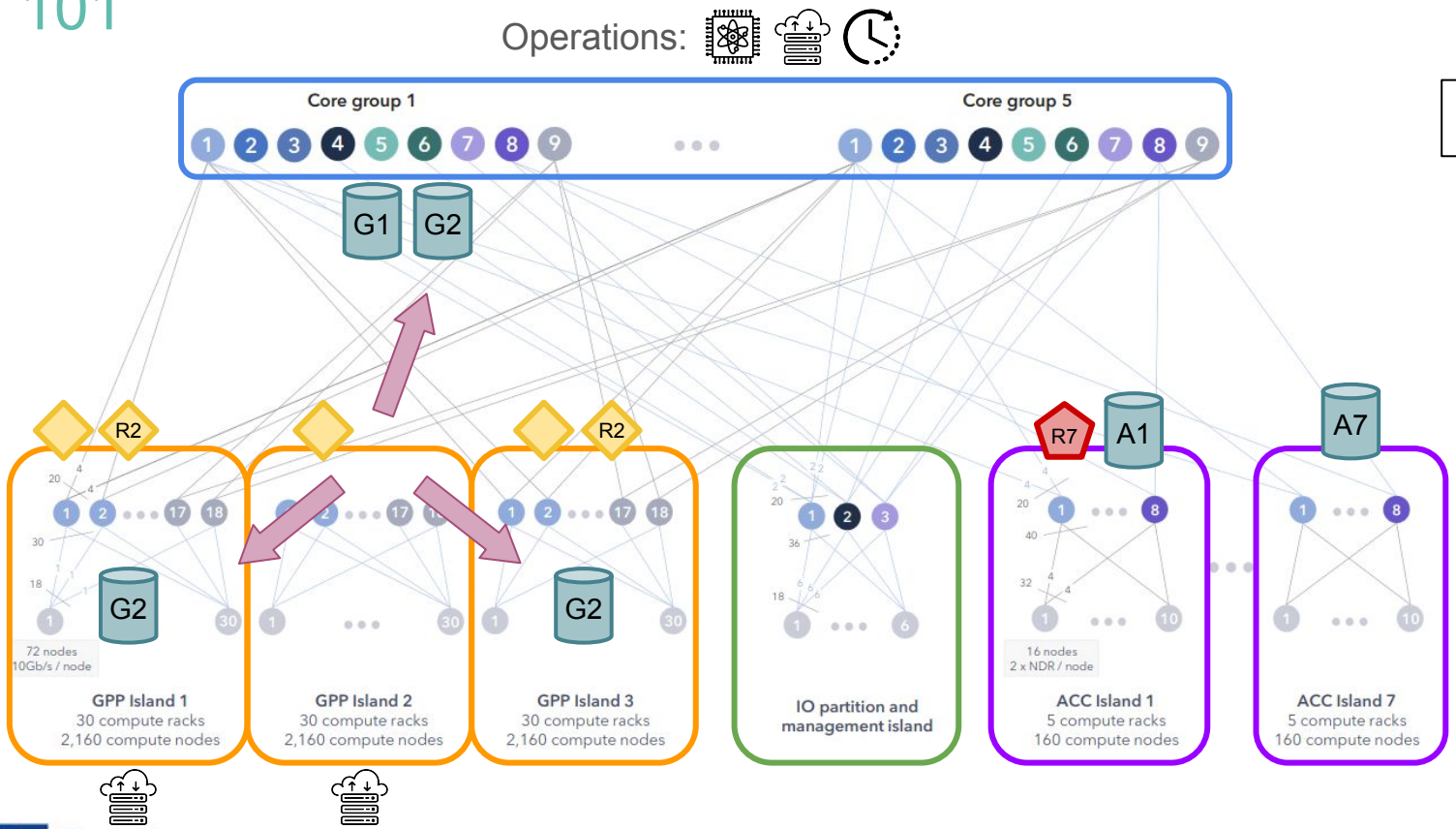


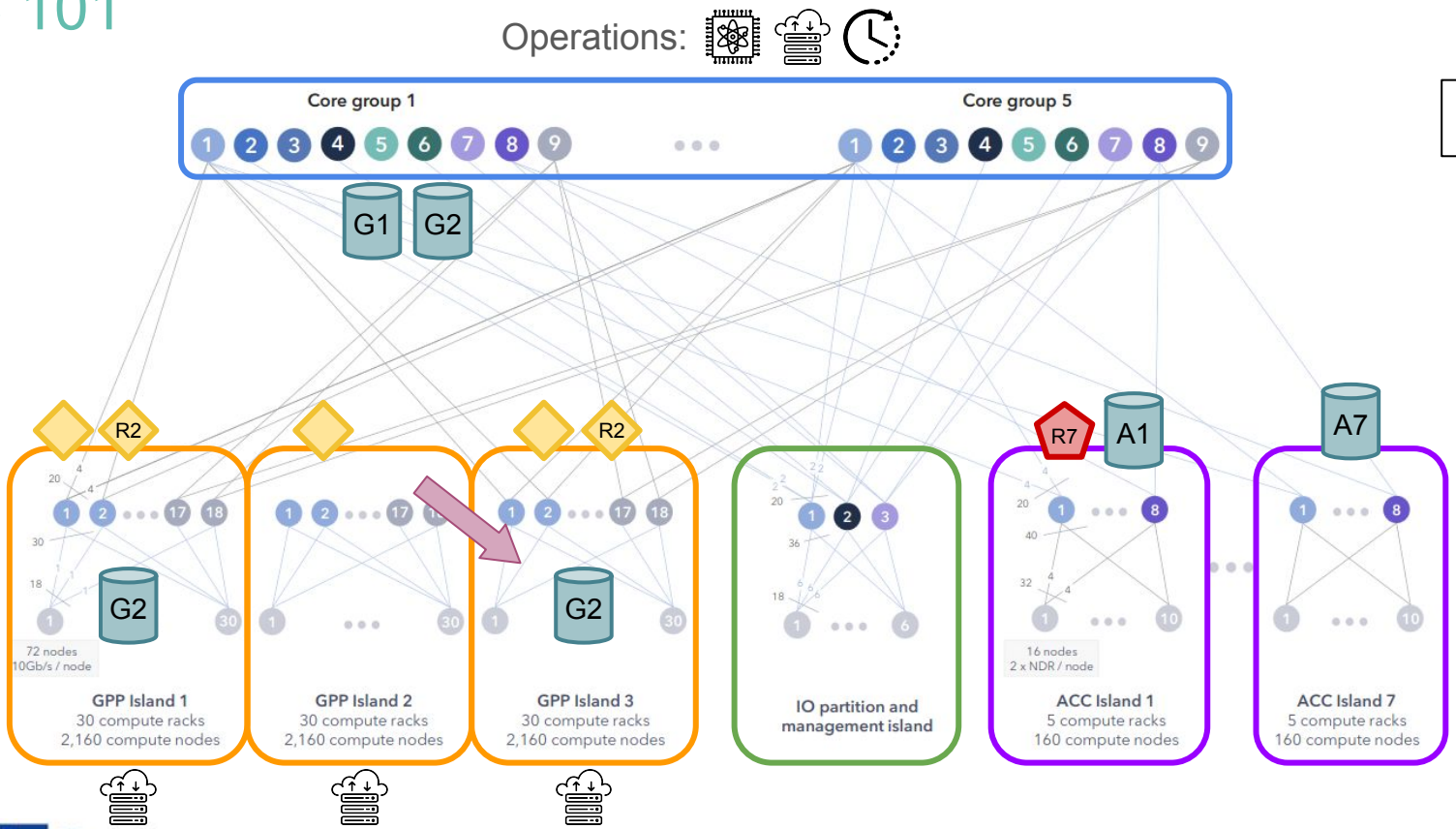
Cycle 2

HPC 101



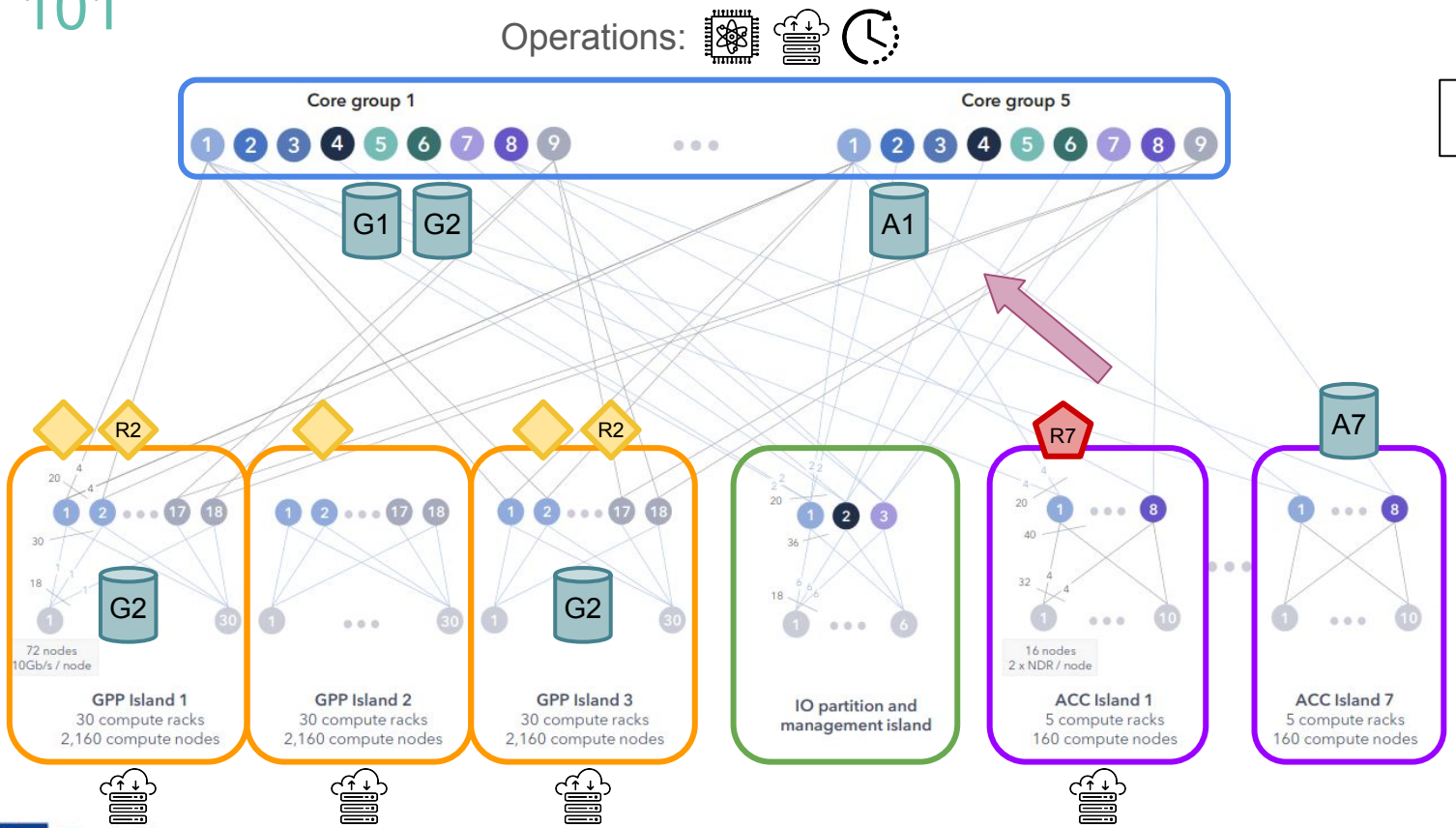
Cycle 2

HPC 101



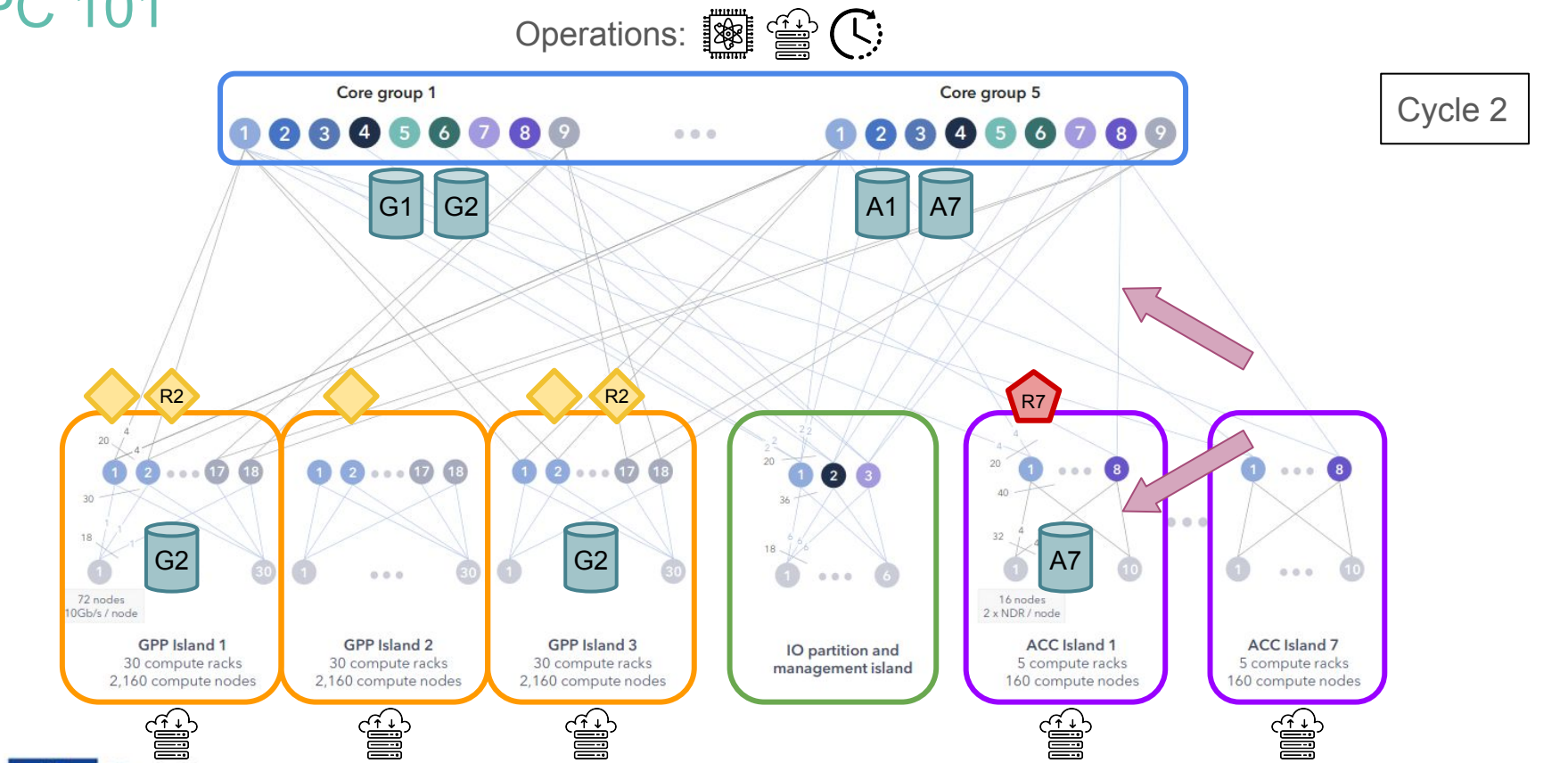
Cycle 2

HPC 101



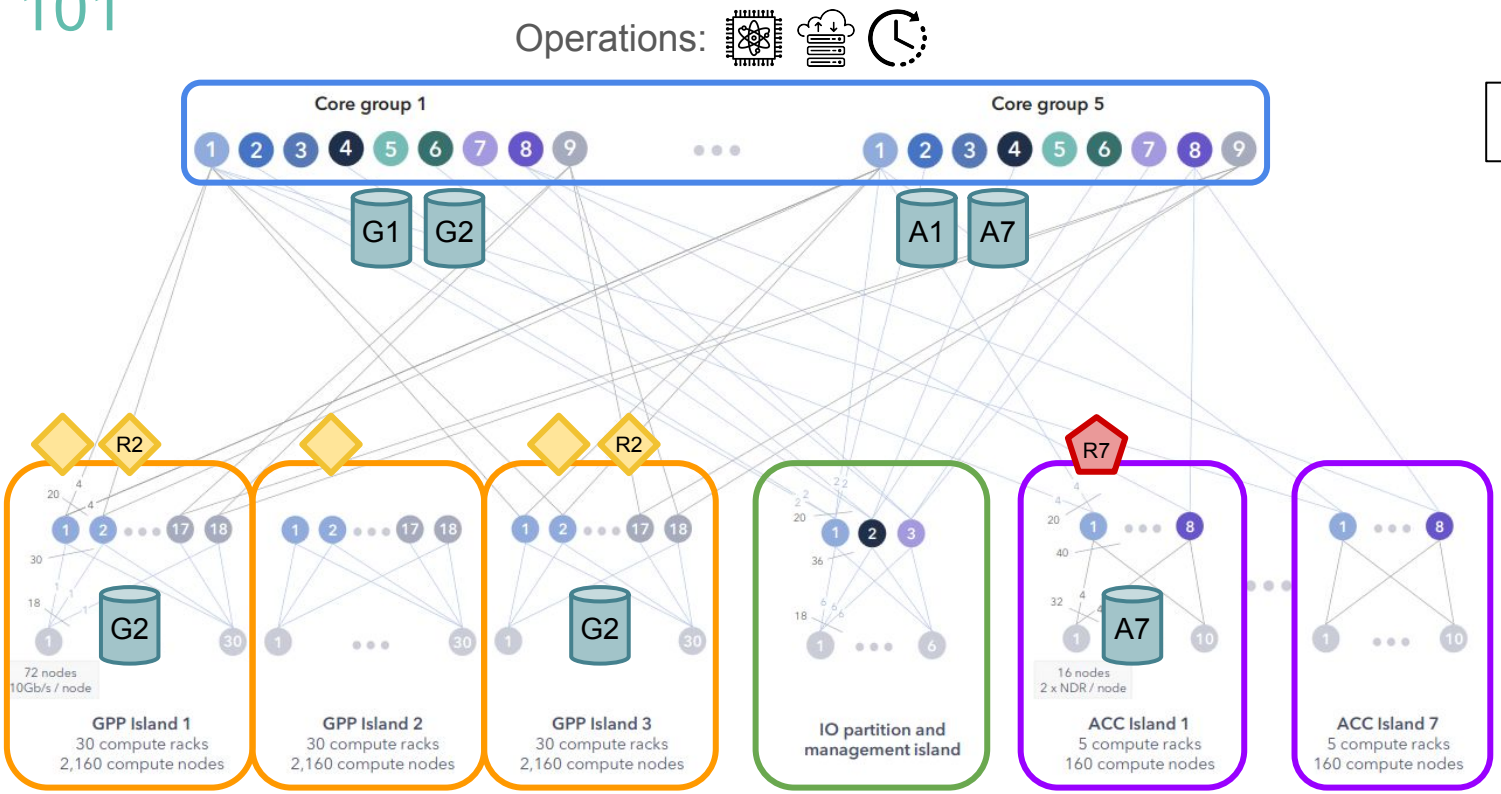
Cycle 2

HPC 101



Cycle 2

HPC 101

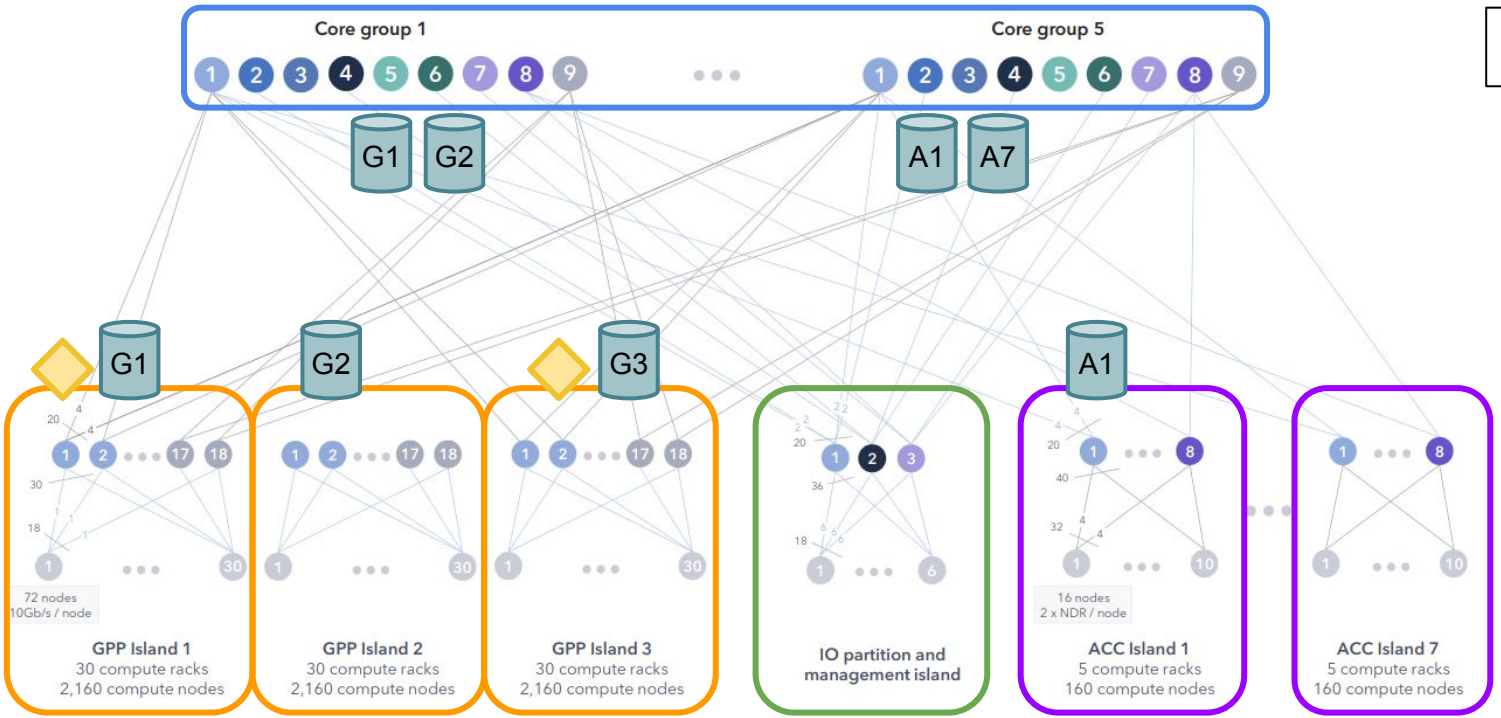


Cycle **3**

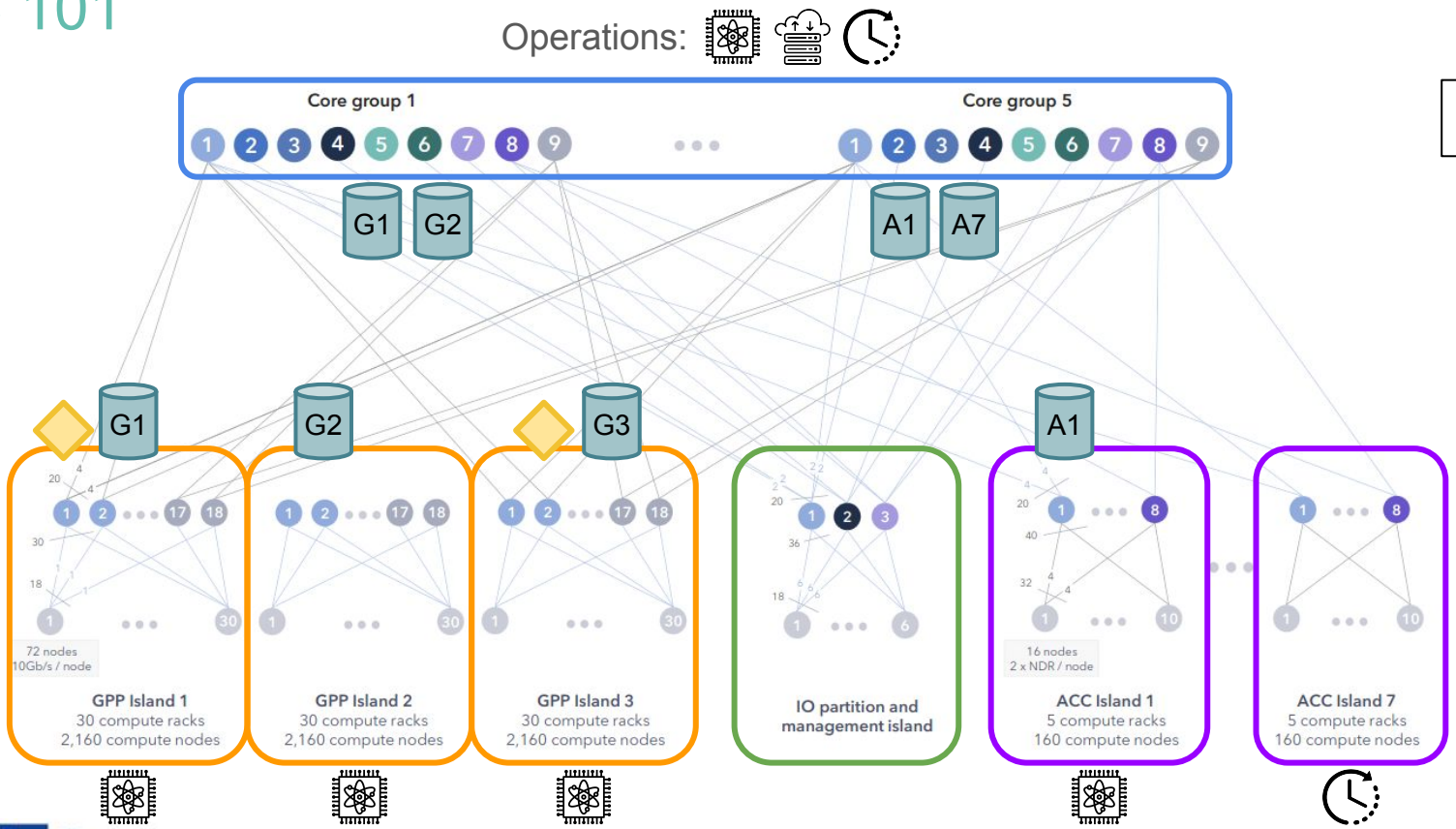
HPC 101

Operations:

Cycle 3



HPC 101

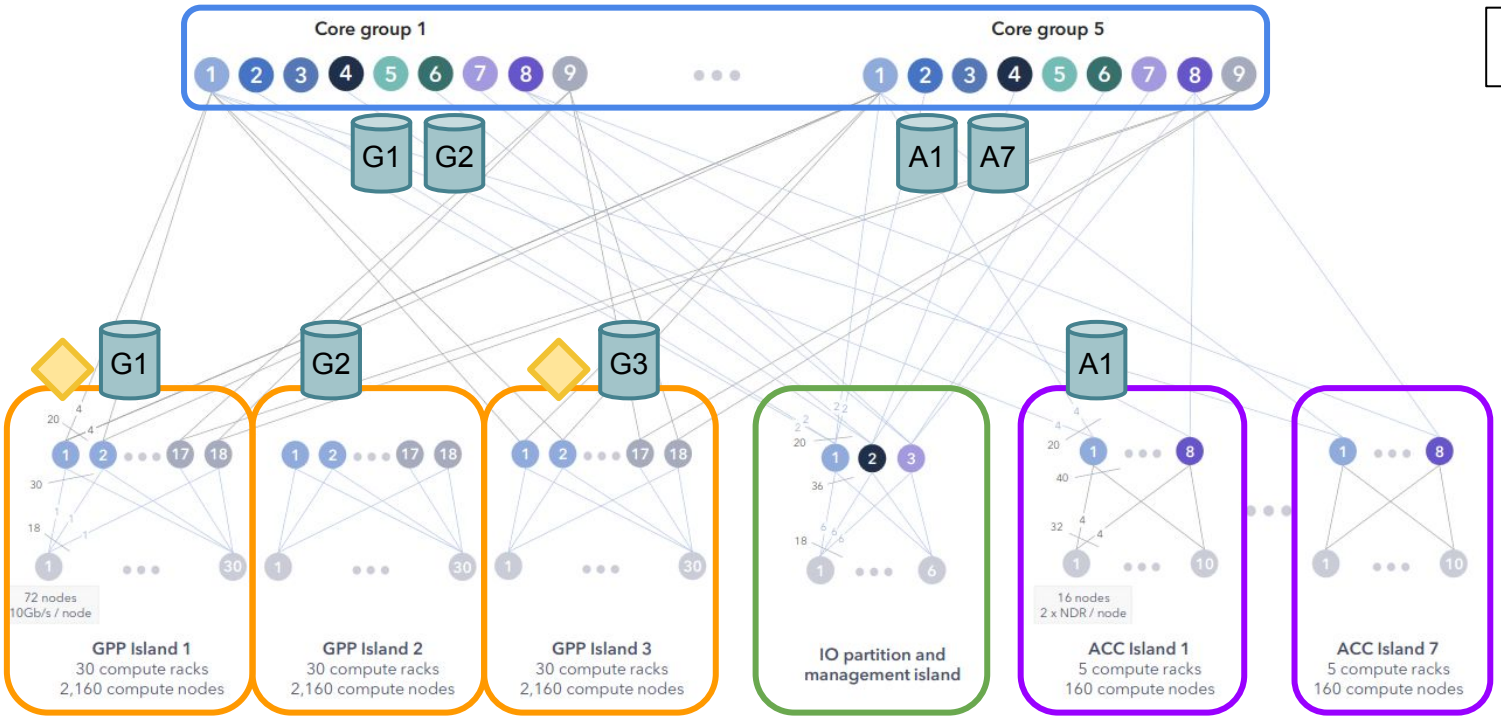


Cycle 3

HPC 101

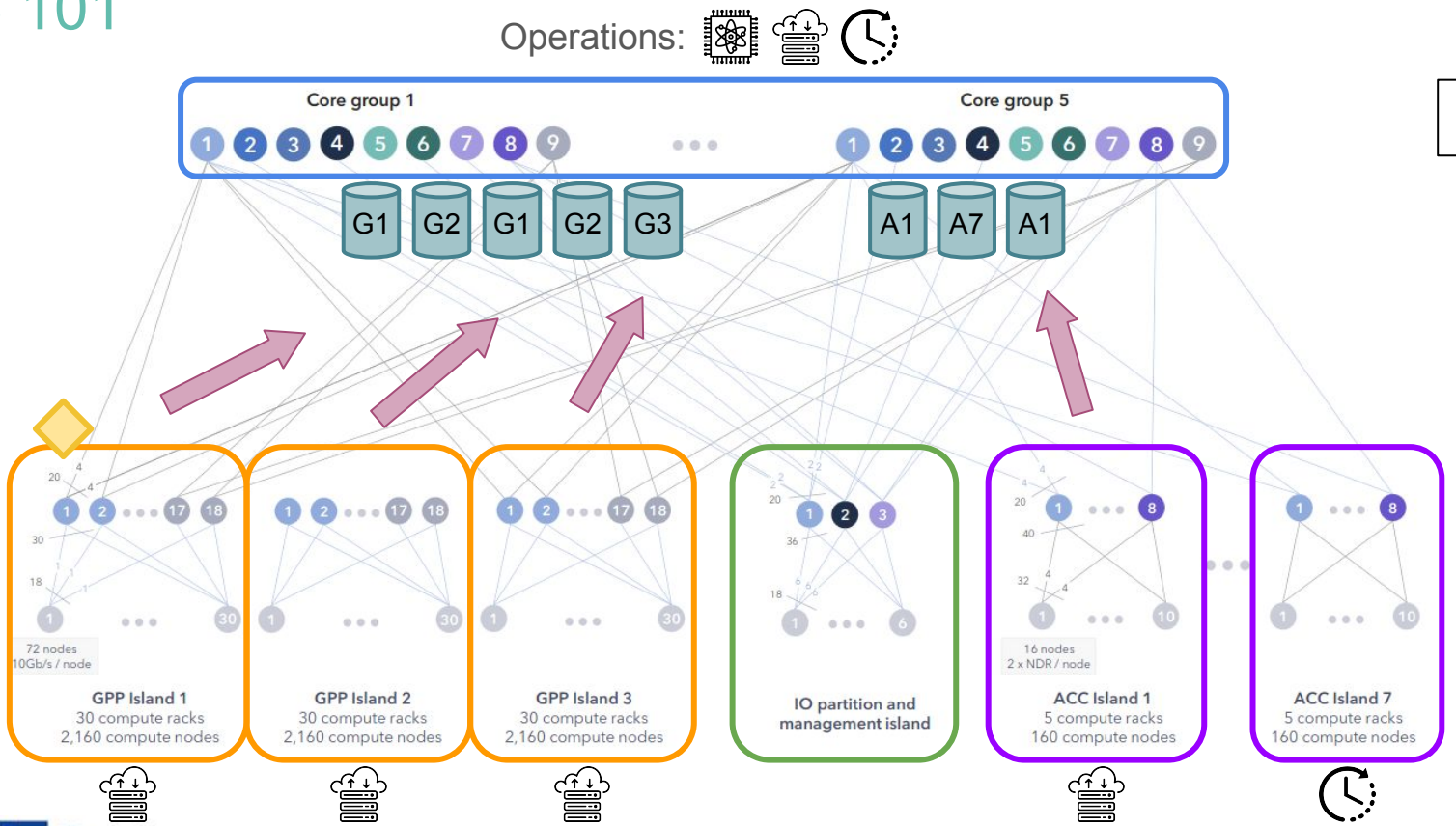
Operations:

Cycle **4**

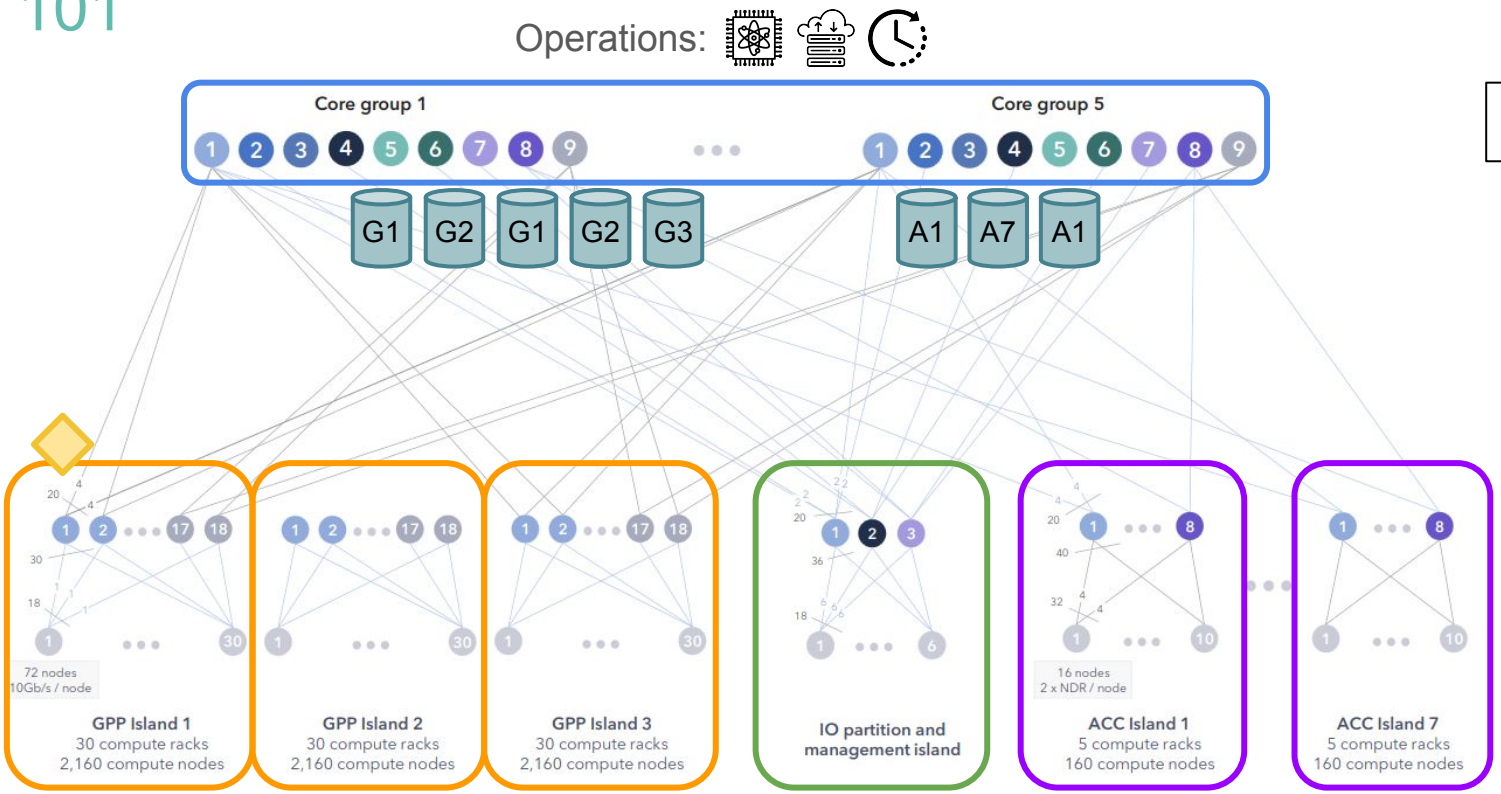


HPC 101

Cycle 4



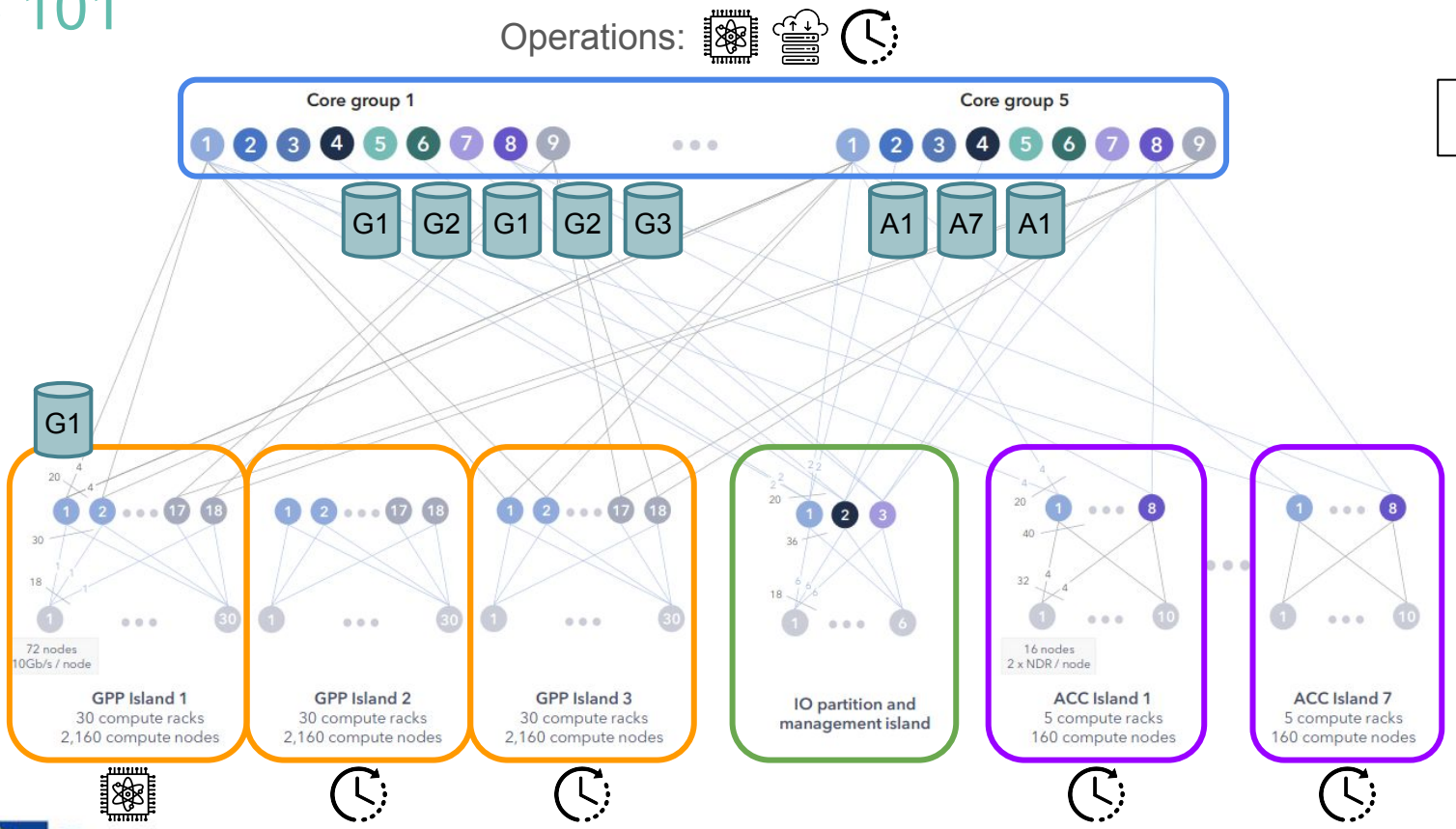
HPC 101



Cycle **5**

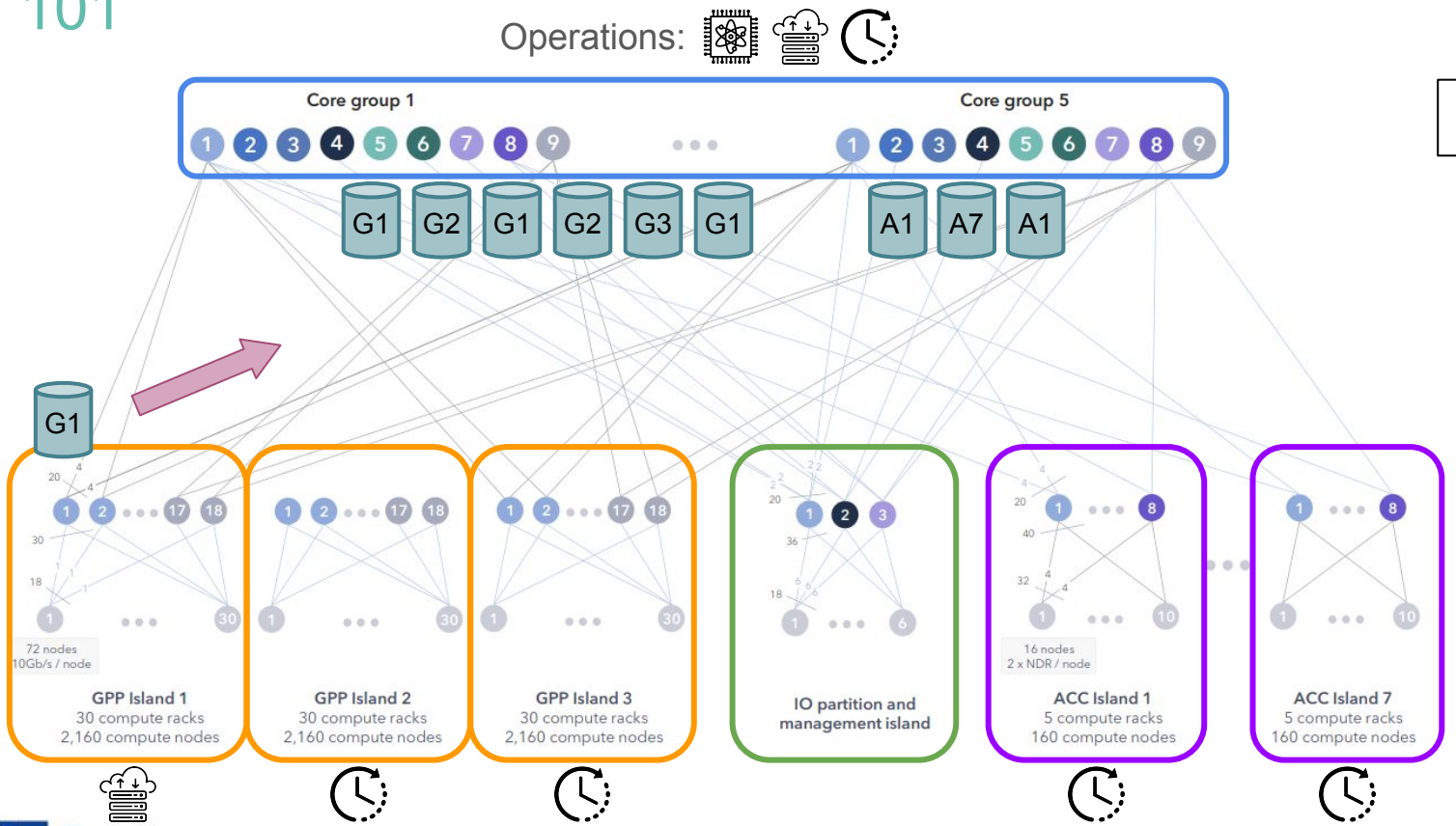
HPC 101

Cycle 5



HPC 101

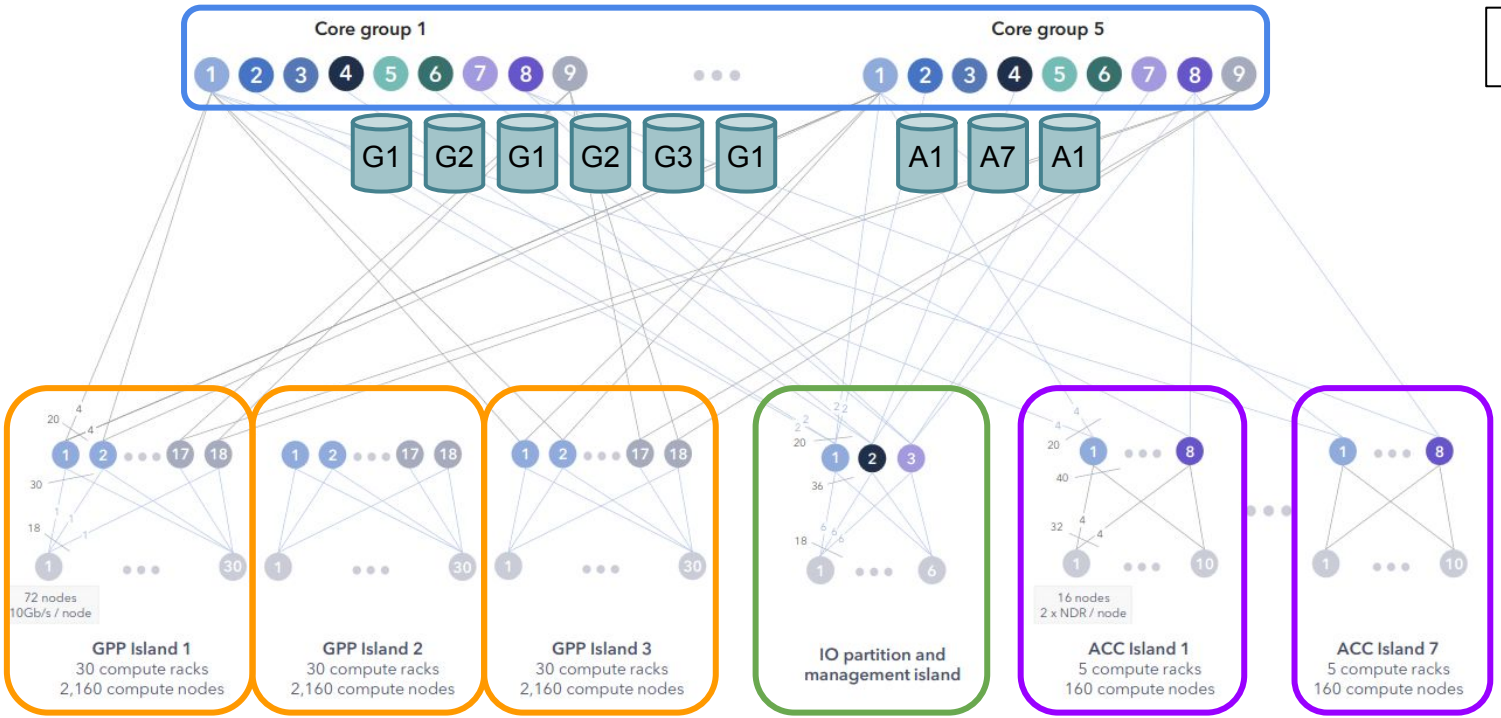
Cycle **6**



HPC 101

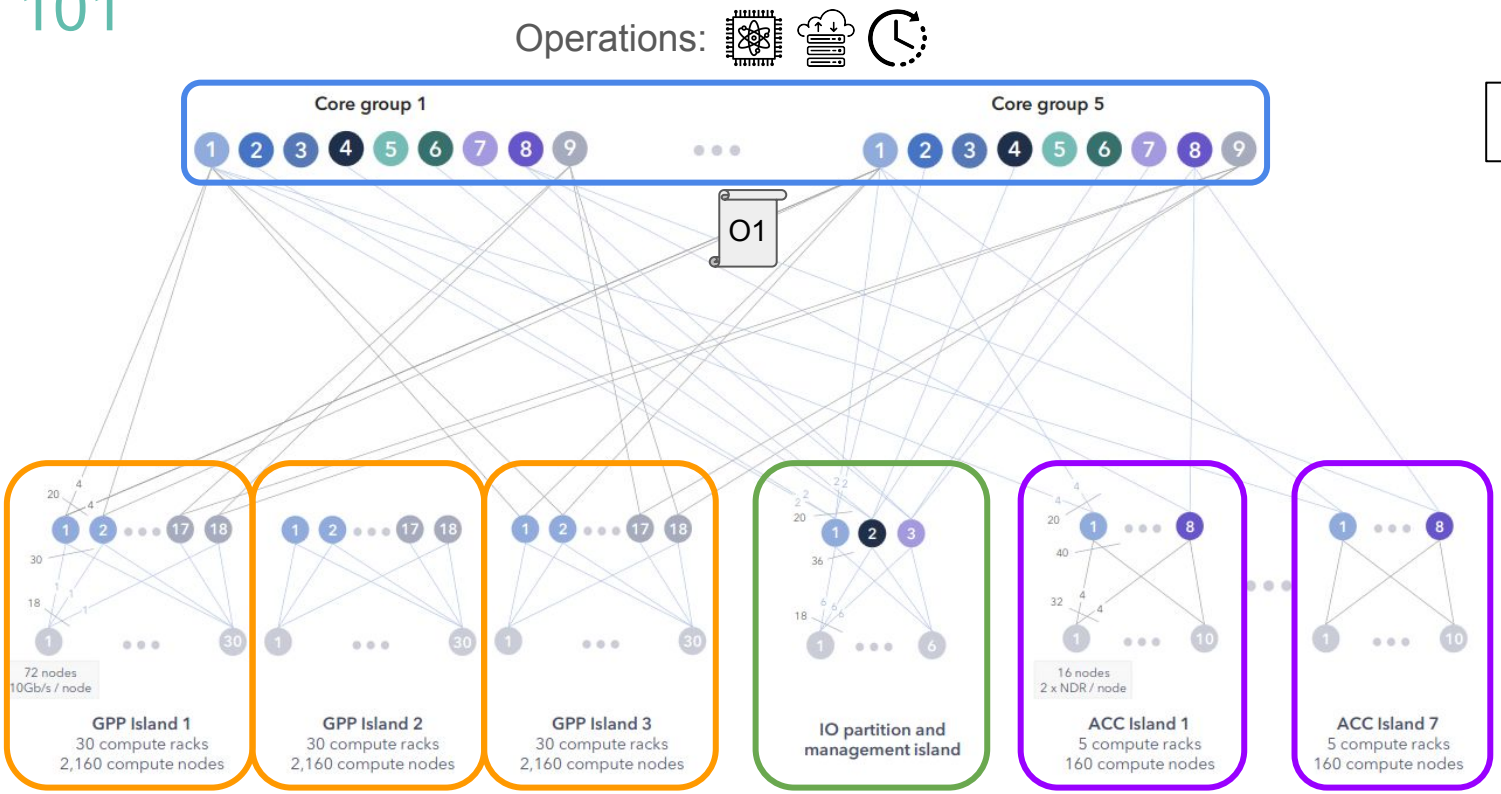
Operations:

Cycle 6

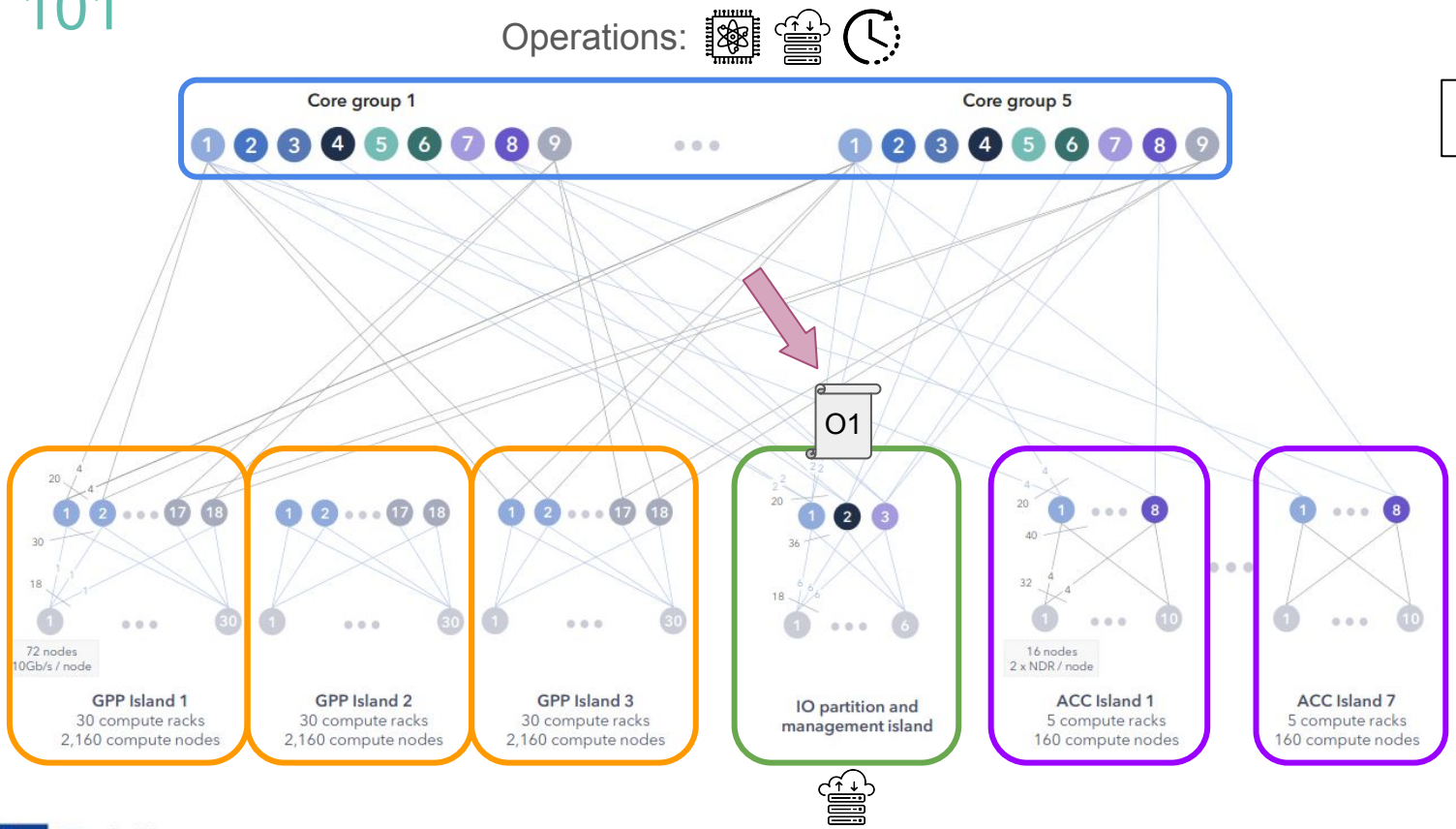


HPC 101

Cycle **7**



HPC 101

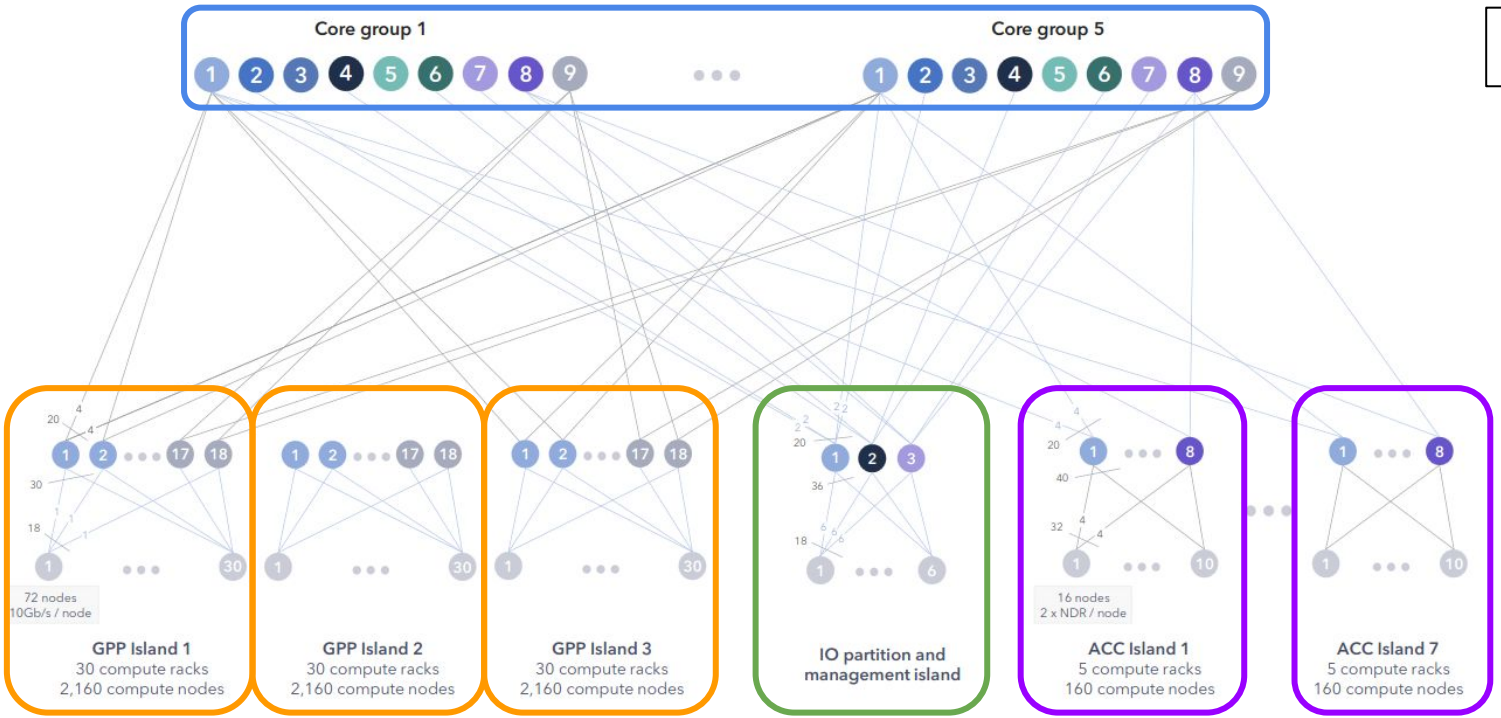


Cycle **8**

HPC 101

Operations:

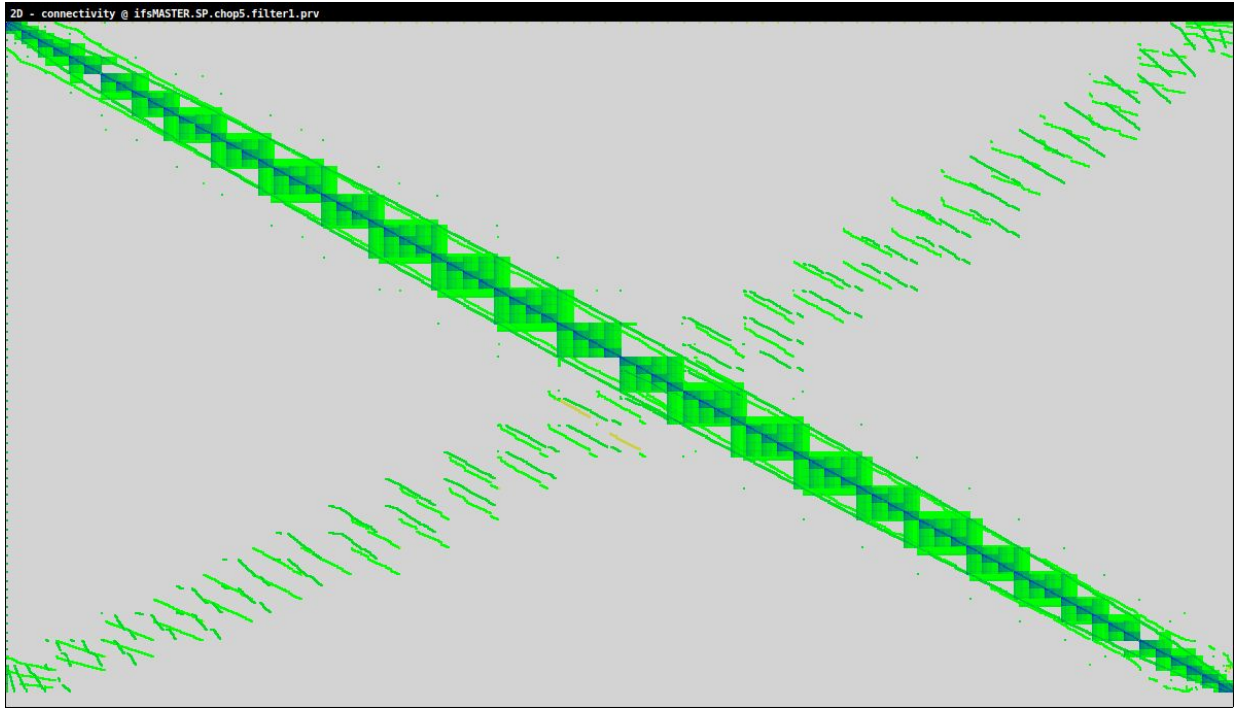
Cycle **9**



Performance Profiling

Earth Sciences Department
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Performance profiling



Earth Sciences Department
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Performance profiling

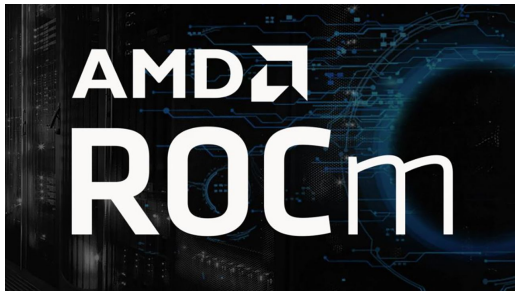
Tools to use:

Funded by the European Union
Destination Earth implemented by ECMWF esa EUMETSAT

Performance profiling

Tools to use:

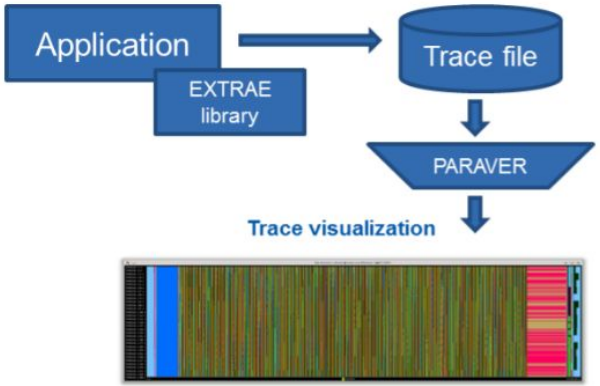
- GPU → Depends on platform!



Performance profiling

Tools to use:

- GPU → Depends on platform!
- CPU → Extrae & Paraver



CPU Profiling

- CPU Modelfactors

	10240(1280x8)[1]	20480(2560x8)[2]
Global efficiency	60.99	43.63
-- Parallel efficiency	60.99	48.09
-- Load balance	84.62	84.07
-- Communication efficiency	72.07	57.20
-- Computation scalability	100.00	90.74
-- IPC scalability	100.00	90.46
-- Instruction scalability	100.00	98.44
-- Frequency scalability	100.00	101.89

Percentage(%) 100 80 60 40 20 0

	10240(1280x8)[1]	20480(2560x8)[2]
-- Hybrid Parallel efficiency	60.99	48.09
-- MPI Parallel efficiency	68.40	55.96
-- MPI Load balance	86.62	85.99
-- MPI Communication efficiency	78.97	65.08
-- Serialization efficiency		
-- Transfer efficiency		
-- OpenMP Parallel efficiency	89.16	85.93
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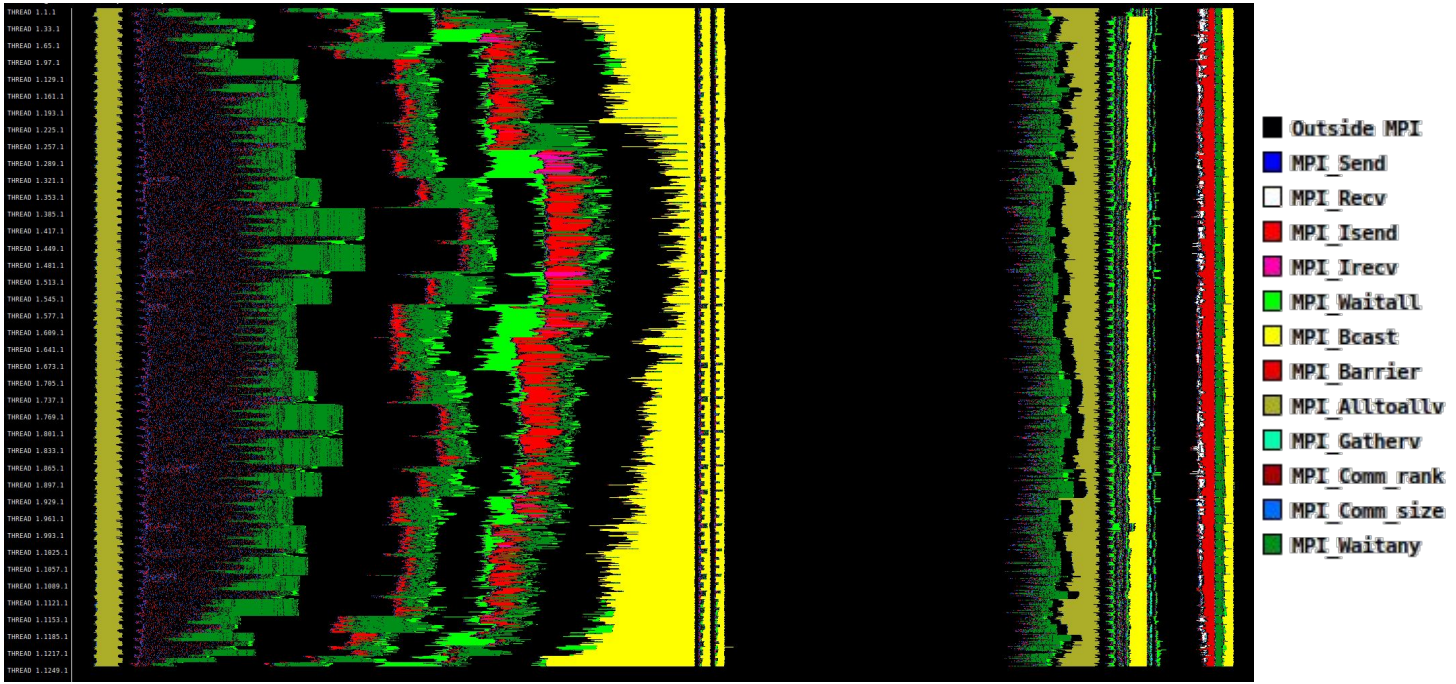
Percentage(%) 100 80 60 40 20 0

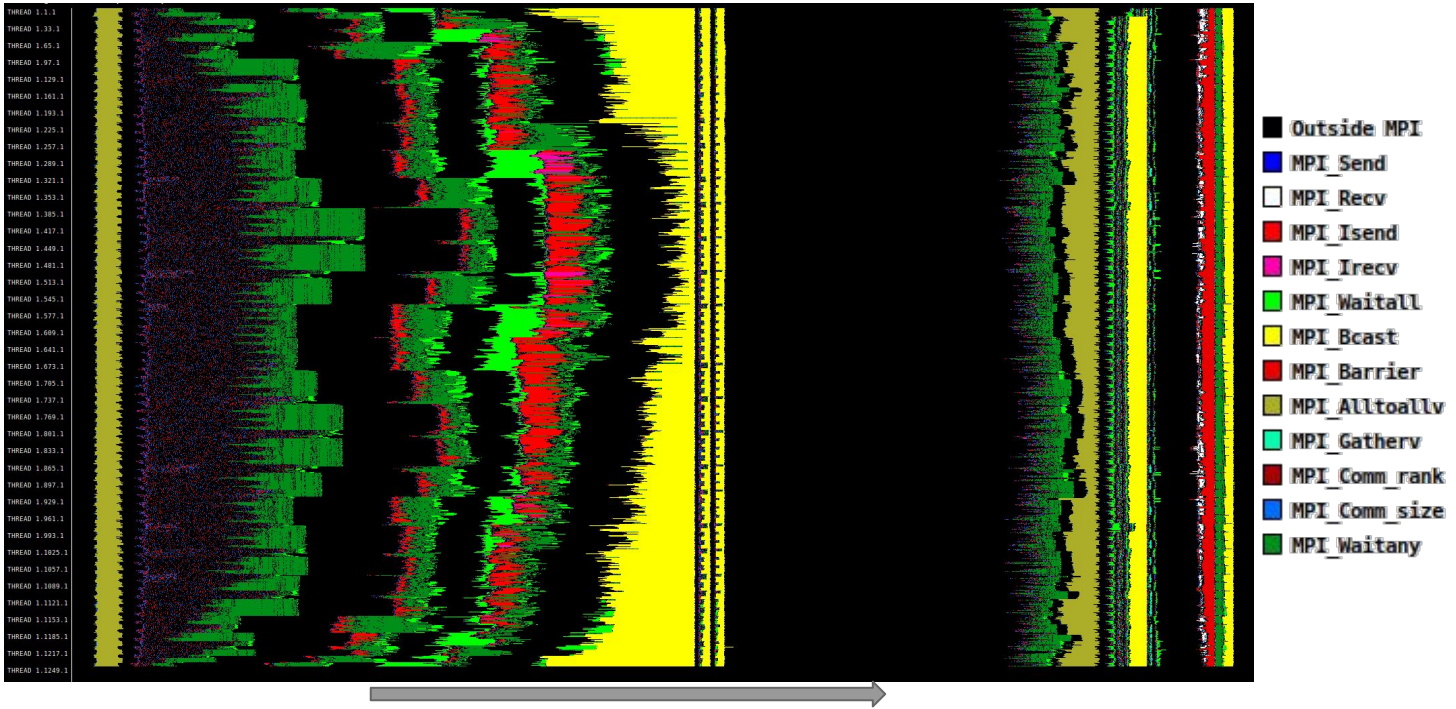
CPU Profiling

- Extrae
- Paraver



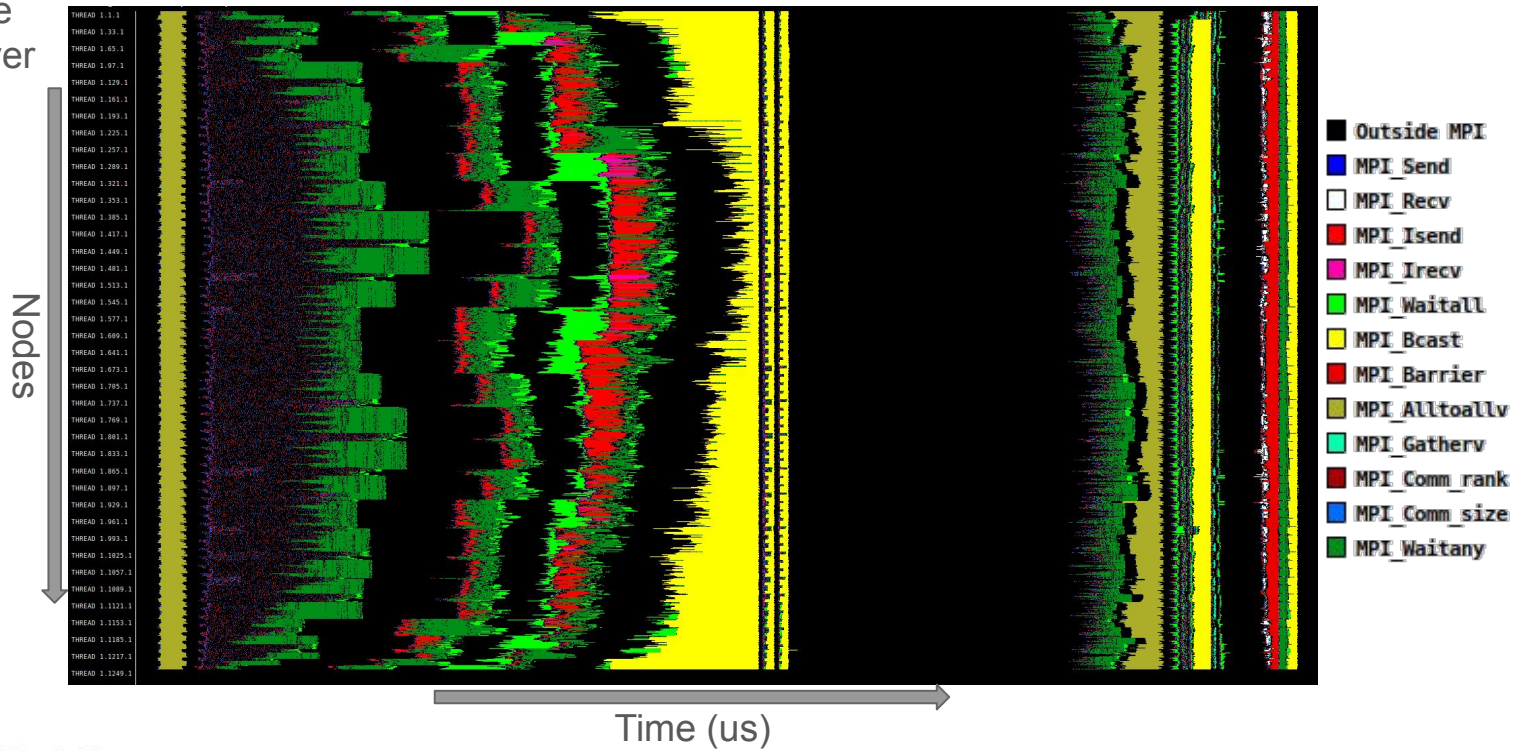
CPU Profiling

- Extrae
- Paraver



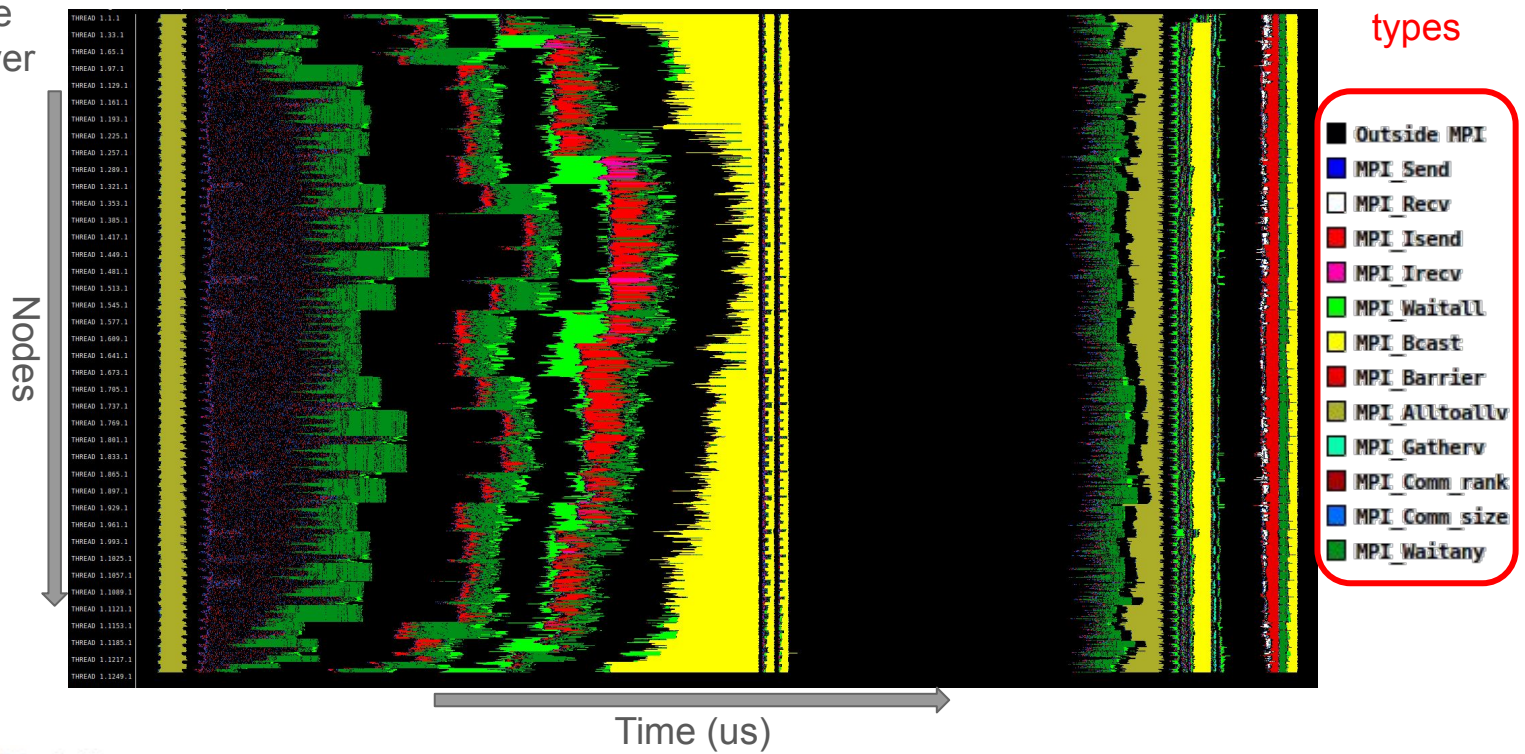
CPU Profiling

- Extrae
- Paraver



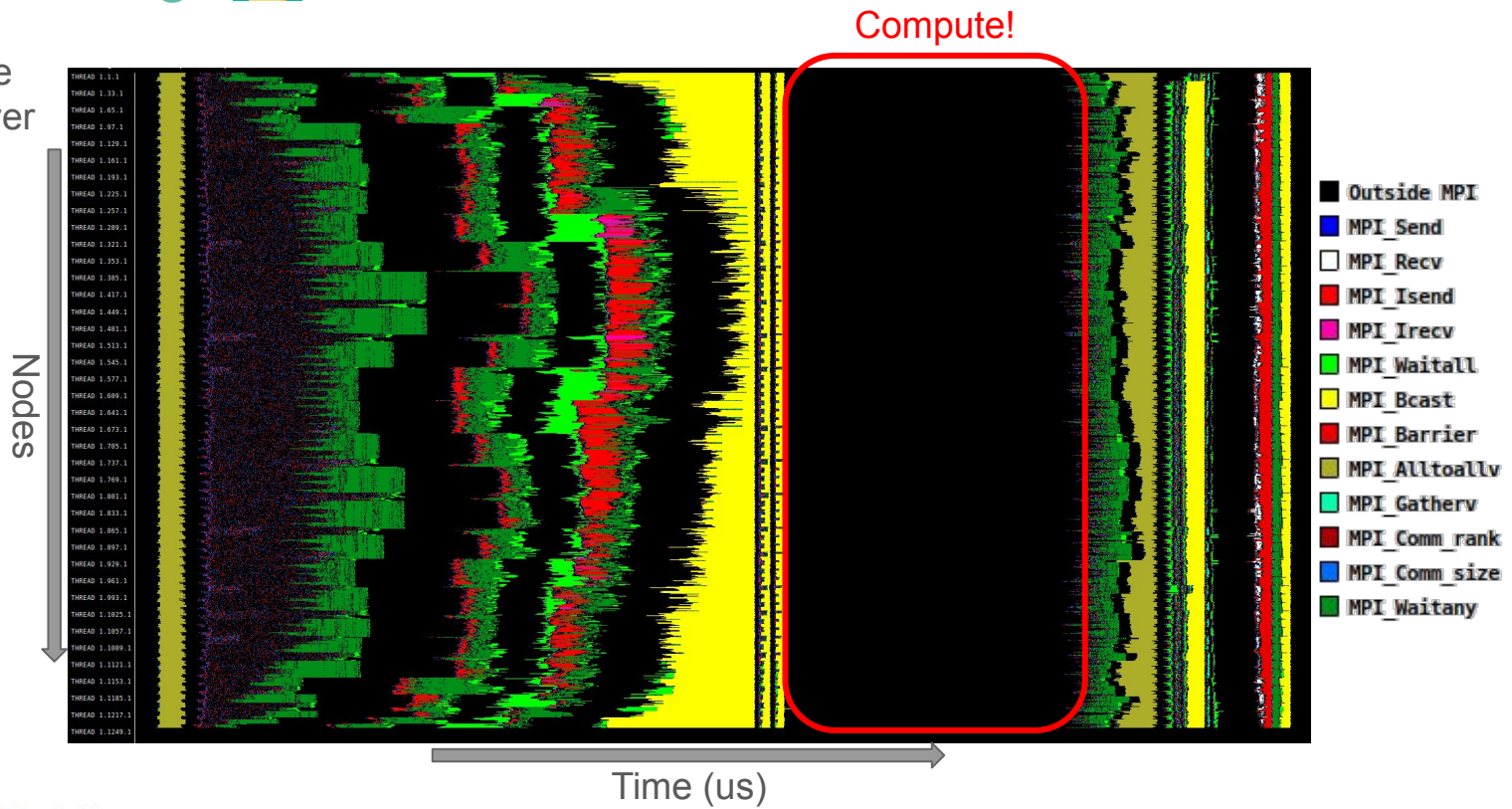
CPU Profiling

- Extrae
- Paraver



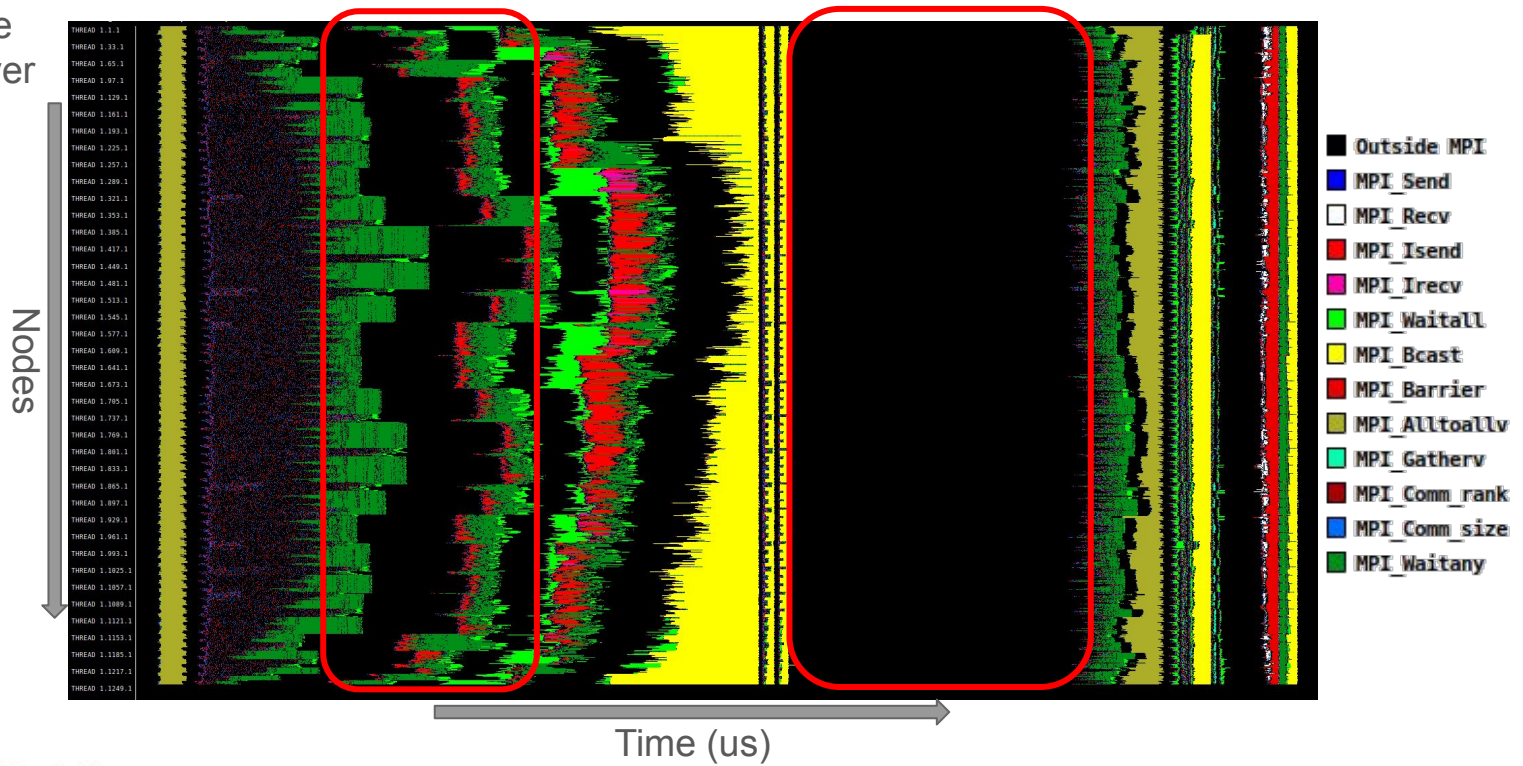
CPU Profiling

- Extrae
- Paraver



CPU Profiling

- Extrae
- Paraver



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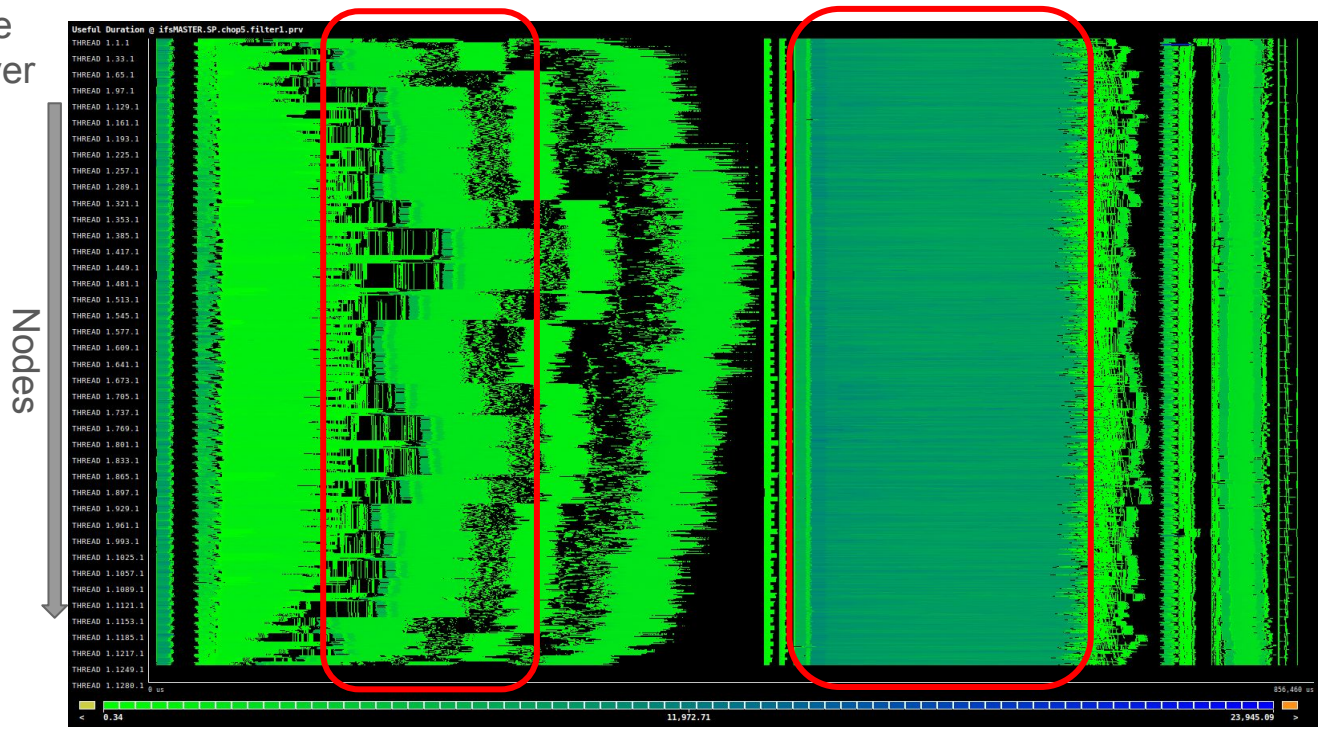
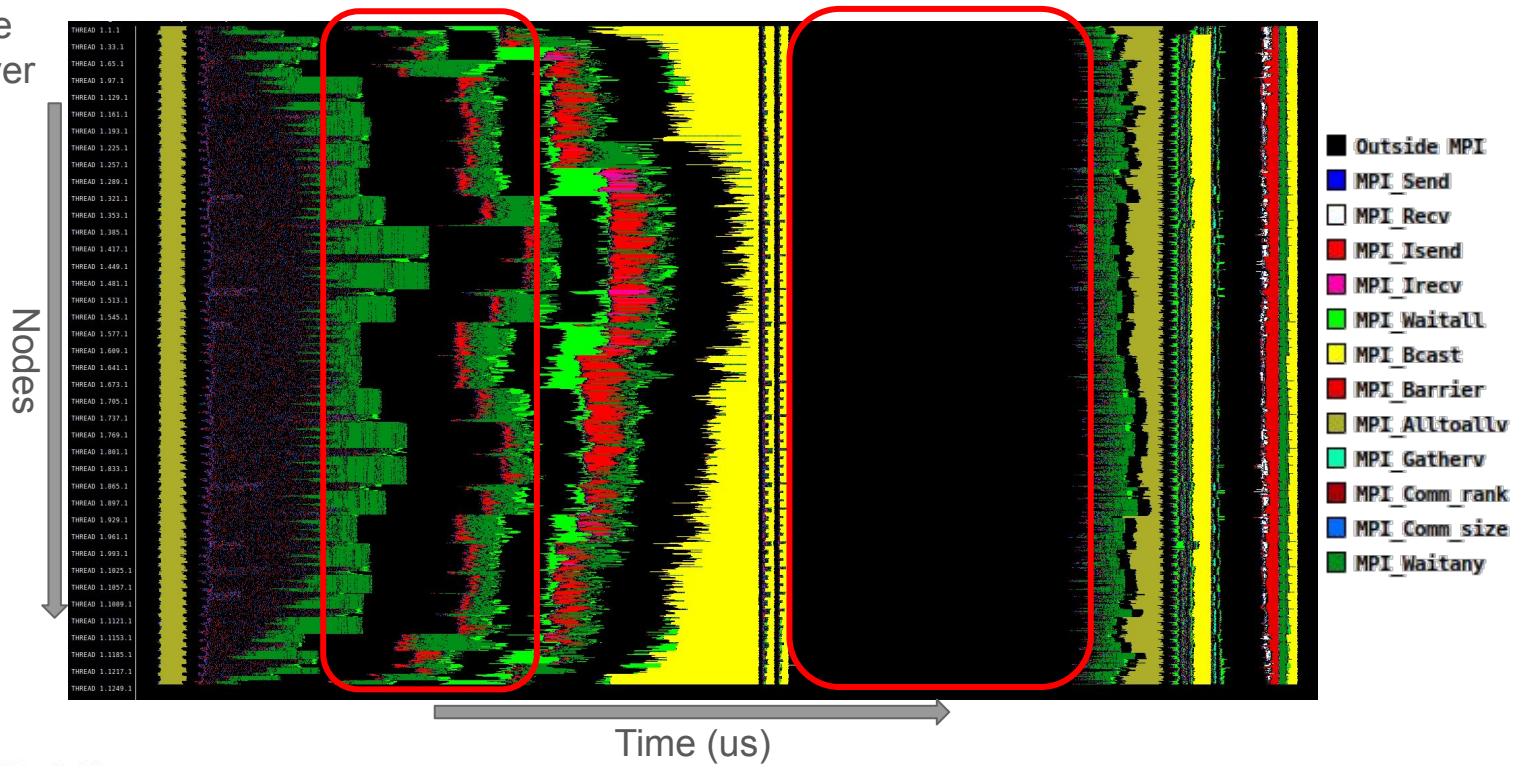
CPU Profiling

- Extrae
- Paraver



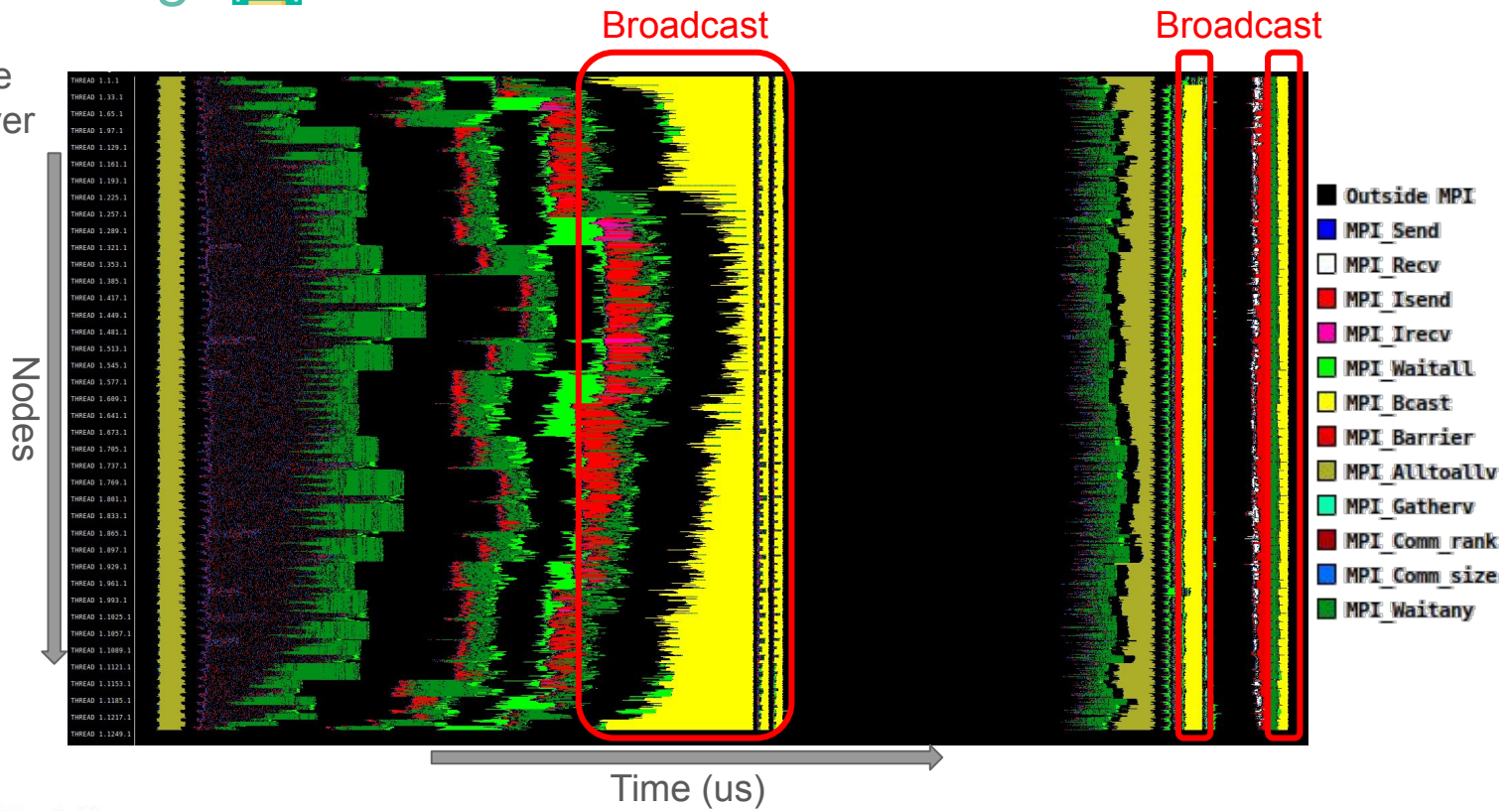
CPU Profiling

- Extrae
- Paraver



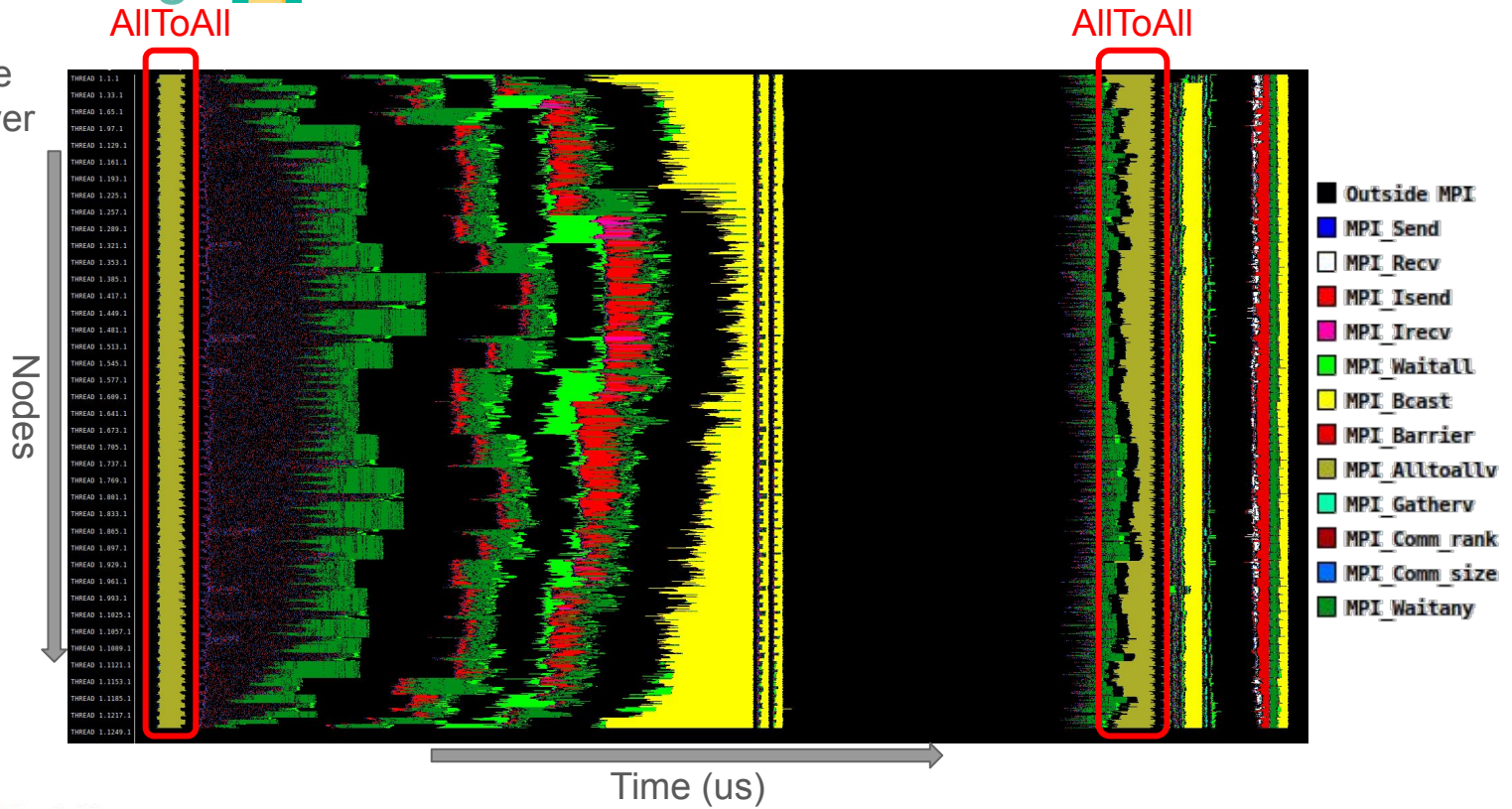
CPU Profiling

- Extrae
- Paraver



CPU Profiling

- Extrae
- Paraver



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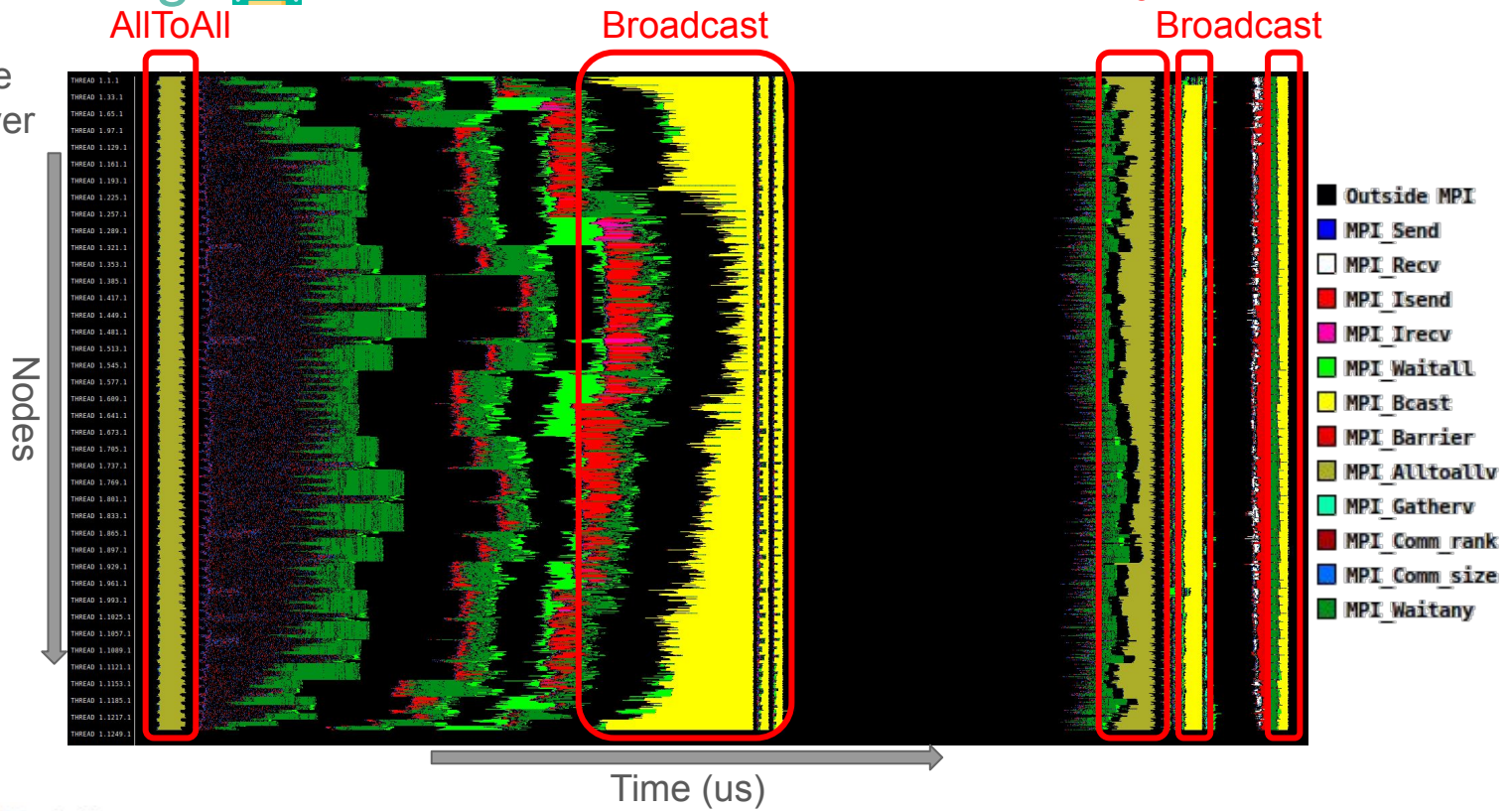
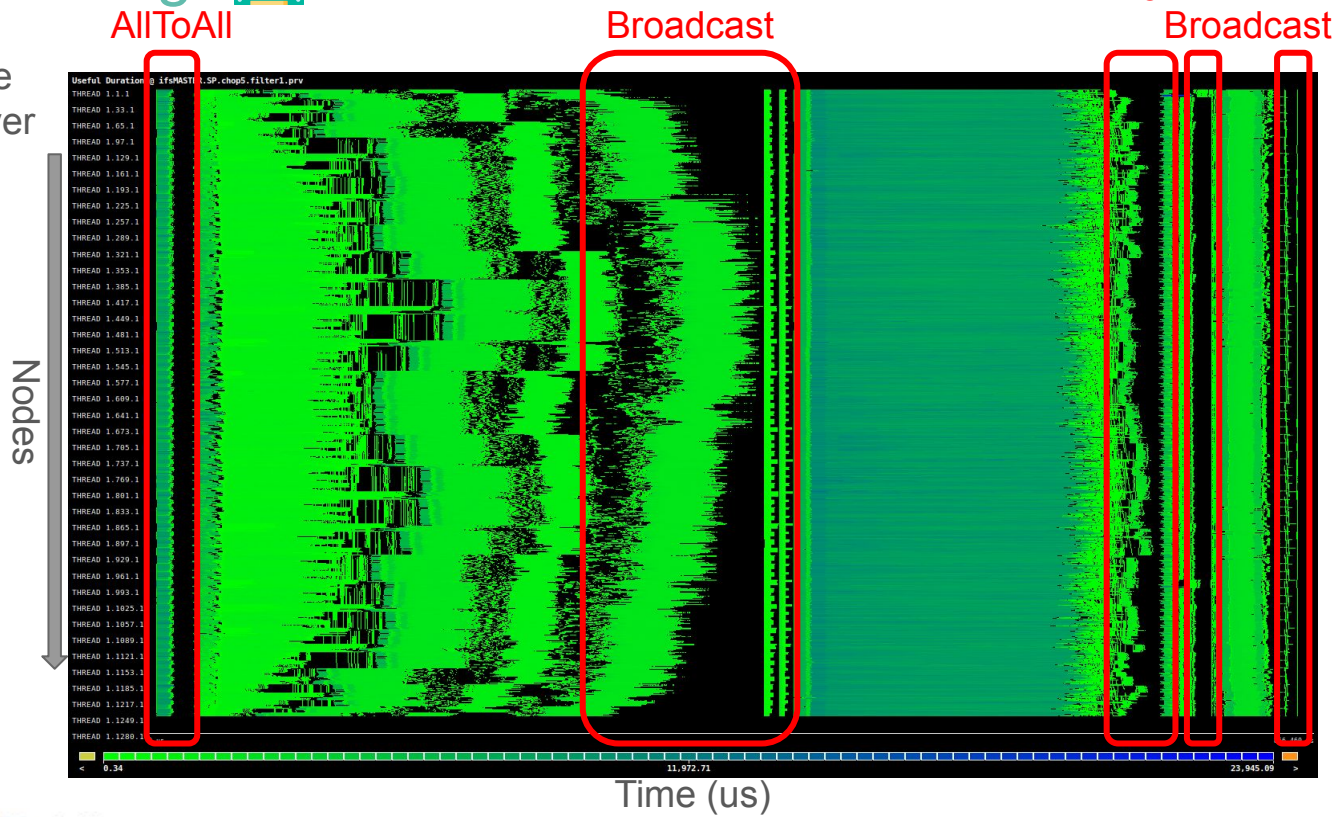
CPU Profiling

- Extrae
- Paraver



CPU Profiling

- Extrae
- Paraver



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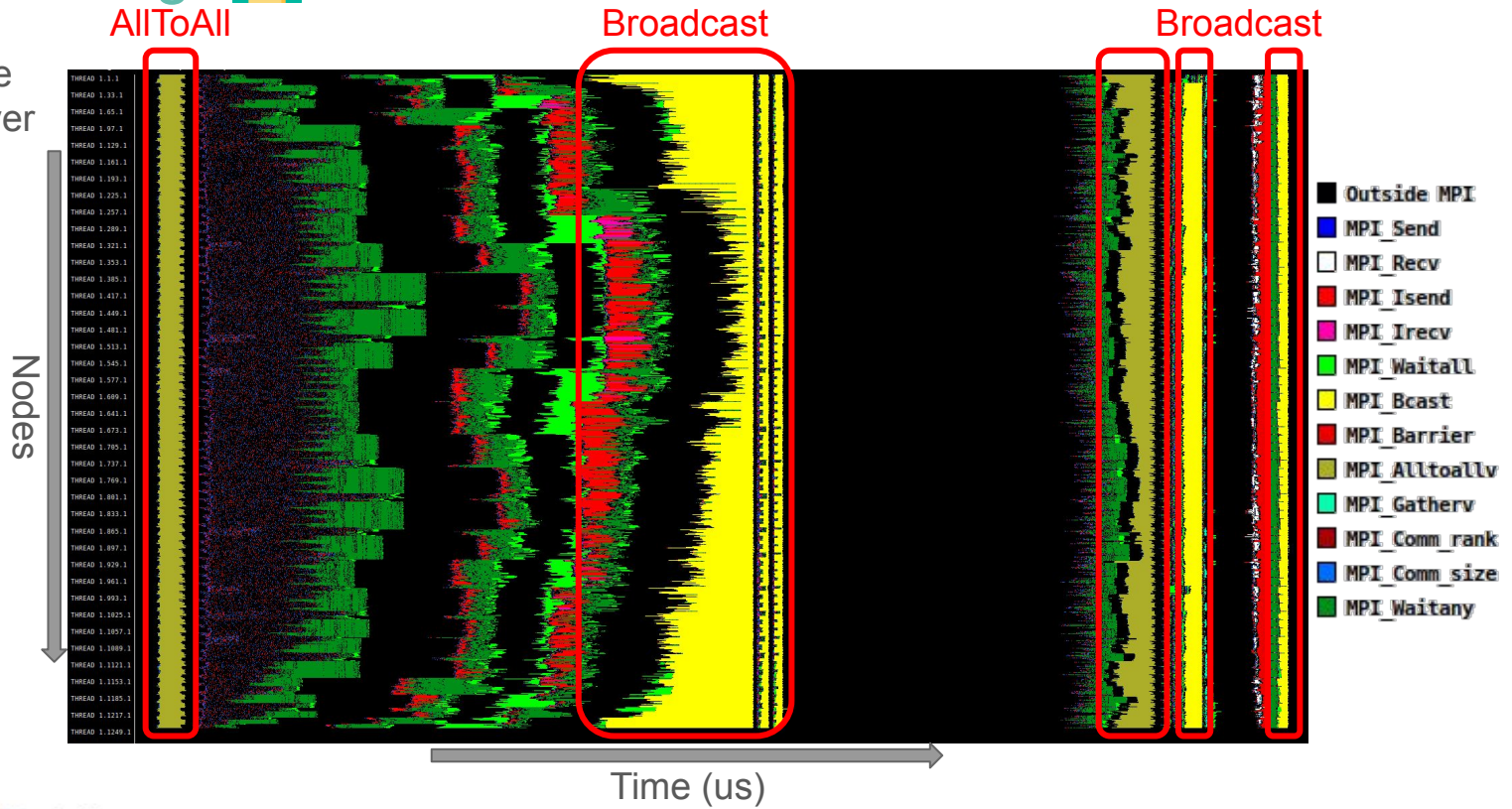
CPU Profiling

- Extrae
- Paraver

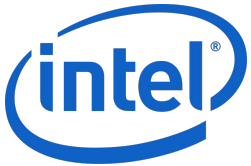


GPU Profiling 

Platform matters!

GPU Profiling

Platform matters!



GPU

GPU Profiling

Platform matters!

GPU

Compiler

GPU Profiling

Platform matters!

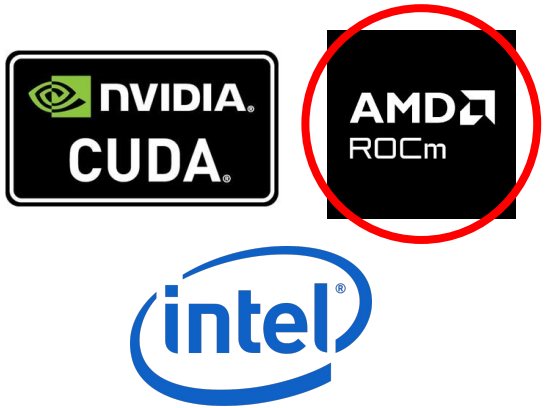
GPU

Compiler

Language

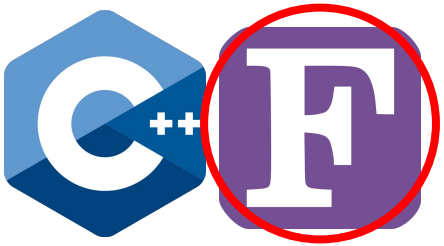
GPU Profiling

Platform matters!



GPU

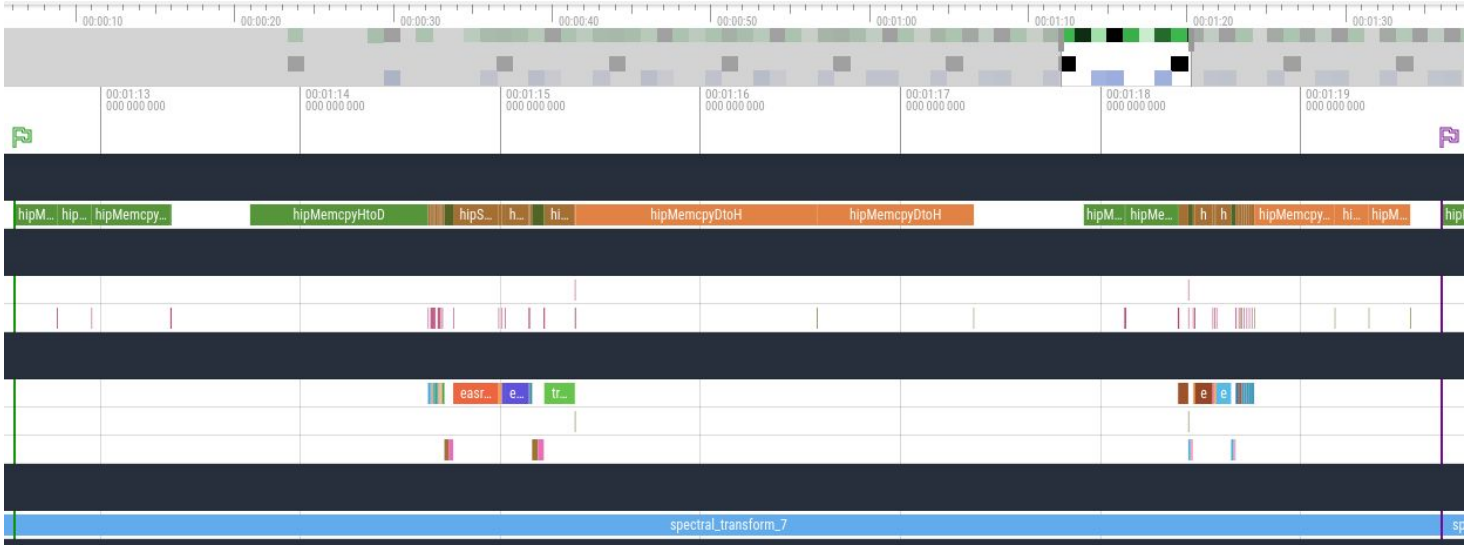
Compiler



Language

GPU Profiling

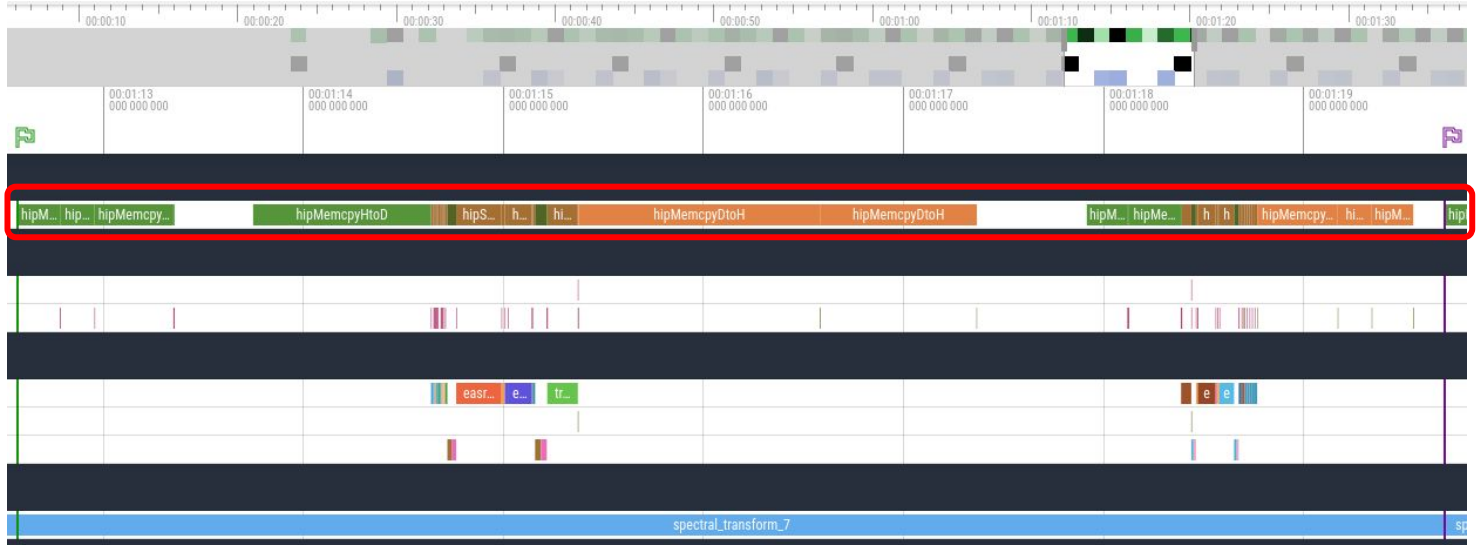
```
rocprof --hip-trace --roctx-trace -o ./rocprof/rocprof.csv $BIN
```



Perfetto visualization

GPU Profiling

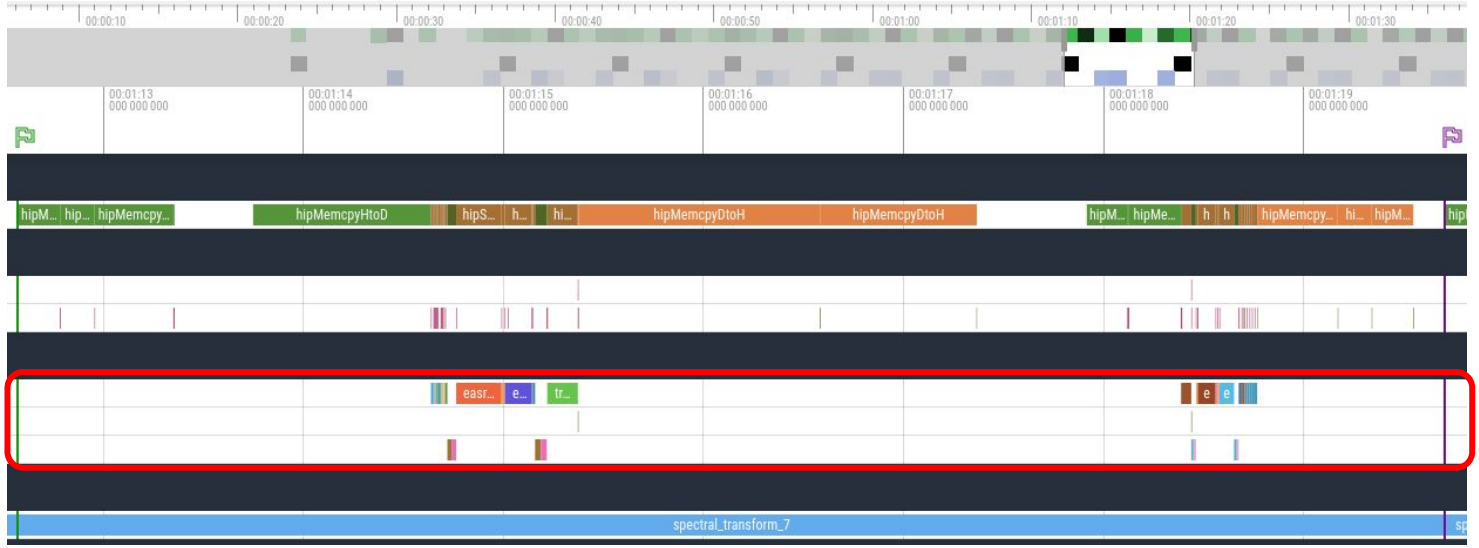
```
rocprof --hip-trace --roctx-trace -o ./rocprof/rocprof.csv $BIN
```



Perfetto visualization

GPU Profiling

```
rocprof --hip-trace --roctx-trace -o ./rocprof/rocprof.csv $BIN
```



Perfetto visualization

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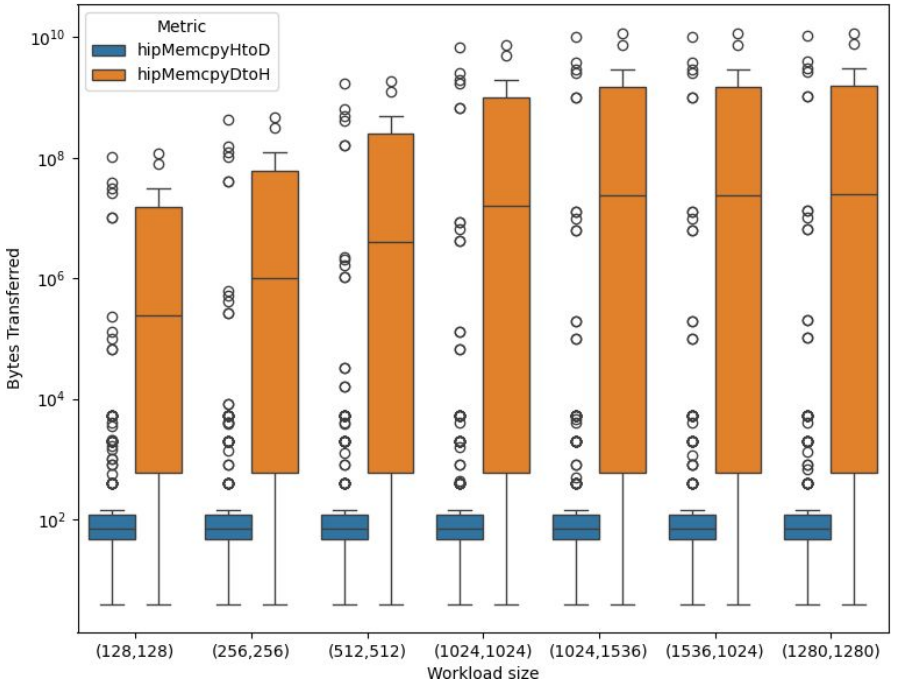
GPU Profiling

GPU Profiling

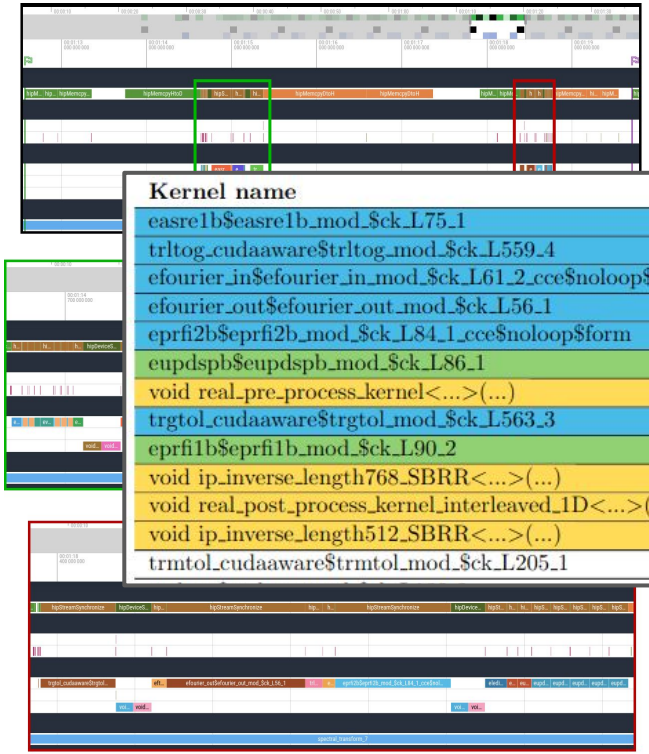


GPU Profiling

Kernel name	Calls	TotalDurationNs	AverageNs	Percentage
easre1b$easre1b_mod_$ck_L75_1	10	2 164 195 747	216 419 574	19,8255
trltog_cudaaware$trltog_mod_$ck_L559_4	10	1 531 345 585	153 134 558	14,0282
efourier_in$efourier_in_mod_$ck_L61_2_cce$noloop$form	10	1 198 170 052	119 817 005	10,9760
efourier_out$efourier_out_mod_$ck_L56_1	10	875 120 791	87 512 079	8,0167
eprfi2b$eprfi2b_mod_$ck_L84_1_cce$noloop$form	10	740 841 358	74 084 135	6,7866
eupdspb$eupdspb_mod_$ck_L86_1	60	612 827 387	10 213 789	5,6139
void real_pre_process_kernel<...>(...)	20	513 296 858	25 664 842	4,7021
trgtol_cudaaware$trgtol_mod_$ck_L563_3	10	479 085 073	47 908 507	4,3887
eprfi1b$eprfi1b_mod_$ck_L90_2	60	299 659 753	4 994 329	2,7451
void ip_inverse_length768_SBRR<...>(...)	10	282 009 617	28 200 961	2,5834
void real_post_process_kernel_interleaved_1D<...>(...)	20	226 225 138	11 311 256	2,0724
void ip_inverse_length512_SBRR<...>(...)	10	216 095 188	21 609 518	1,9796
trmtol_cudaaware$trmtol_mod_$ck_L205_1	10	178 045 797	17 804 579	1,6310
evdtuv$evdtuv_mod_$ck_L132_2	10	149 741 079	14 974 107	1,3717
efourier_in$efourier_in_mod_$ck_L58_3_cce$noloop$form	10	148 382 992	14 838 299	1,3593
eledir$eledir_mod_$ck_L98_1	10	139 369 528	13 936 952	1,2767
espnsde$espnsde_mod_$ck_L87_1	10	115 237 936	11 523 793	1,0557
eltinv$eltinv_mod_$ck_L136_2_cce$noloop$form	10	113 872 491	11 387 249	1,0431
trltom_cudaaware$trltom_mod_$ck_L218_1	10	110 770 720	11 077 072	1,0147
void ip_forward_length768_SBRR<...>(...)	10	110 712 645	11 071 264	1,0142
void ip_forward_length512_SBRR<...>(...)	10	110 086 079	11 008 607	1,0085
eftdir$eftdir_mod_$ck_L89_2_cce$noloop$form	10	94 305 395	9 430 539	0,8639
efsc$efsc_mod_$ck_L97_2	10	89 873 545	8 987 354	0,8233
euvtvd$euvtvd_mod_$ck_L108_2	10	85 680 570	8 568 057	0,7849
euvtvd$euvtvd_mod_$ck_L89_1	10	68 517 640	6 851 764	0,6277
evdtuv$evdtuv_mod_$ck_L113_1	10	66 336 511	6 633 651	0,6077
efsc$efsc_mod_$ck_L75_1	10	58 245 610	5 824 561	0,5336
eprfi1b$eprfi1b_mod_$ck_L85_3_cce$noloop$form	60	57 399 205	956 653	0,5258
eltdir$eltdir_mod_$ck_L157_3_cce$noloop$form	10	57 060 646	5 706 064	0,5227
eltdir$eltdir_mod_$ck_L156_2_cce$noloop$form	10	22 749 187	2 274 918	0,2084
<barrier packet>	20	753 461	37 673	0,0070
evdtuv$evdtuv_mod_$ck_L170_4	10	97 760	9776	0,009
euvtvd_comm$euvtvd_comm_mod_$ck_L106_2_cce$noloop$form	10	63 681	6368	0,0006
trgtol_cudaaware$trgtol_mod_$ck_L456_8	10	32 960	3296	0,0003
trgtol_cudaaware$trgtol_mod_$ck_L457_9	10	23 040	2304	0,0002

Table 8: Global overview of the ecTrans kernels for 10 iterations. The blue highlighted rows are the 6 user kernels which are analysed. The green highlighted rows have a smaller kernel granularity. The yellow highlighted rows are library calls.

GPU Profiling



Kernel name	Calls	TotalDurationNs	AverageNs	Percentage
easre1b$easre1b_mod_$ck_L75_1	10	2 164 195 747	216 419 574	19,8255
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efourier_in$efourier_in_mod_$ck_L61_2_cce$noloop$form	10	1 198 170 052	119 817 005	10,9760
efourier_out$efourier_out_mod_$ck_L56_1	10	875 120 791	87 512 079	8,0167
eprfi2b$eprfi2b_mod_$ck_L84_1_cce$noloop$form	10	740 841 358	74 084 135	6,7866
eupdspb$eupdspb_mod_$ck_L86_1	60	612 827 387	10 213 789	5,6139
void real_pre_process_kernel<...>(...)	20	513 296 858	25 664 842	4,7021
trgtol_cudaaware$trgtol_mod_$ck_L563_3	10	479 085 073	47 908 507	4,3887
eprfi1b$eprfi1b_mod_$ck_L90_2	60	299 659 753	4 994 329	2,7451
void ip_inverse_length768_SBRR<...>(...)	10	282 009 617	28 200 961	2,5834
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trmtol_cudaaware$trmtol_mod_$ck_L205_1	10	178 045 797	17 804 579	1,6310
1 994 329				2,7451
8 200 961				2,5834
1 311 256				2,0724
1 609 518				1,9796
7 804 579				1,6310
4 974 107				1,3717
4 838 299				1,3593
3 936 952				1,2767
1 523 793				1,0557
1 387 249				1,0431
1 077 072				1,0147
1 071 264				1,0142
1 008 607				1,0085
430 539				0,8639
987 354				0,8233
568 057				0,7849
851 764				0,6277
633 651				0,6077
824 561				0,5336
956 653				0,5258
706 064				0,5227
274 918				0,2084
<barrier packet>	20	753 461	37 673	0,0070
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euvtvd_comm$euvtvd_comm_mod_$ck_L106_2_cce$noloop$form	10	63 681	6368	0,0006
trgtol_cudaaware$trgtol_mod_$ck_L456_8	10	32 960	3296	0,0003
trgtol_cudaaware$trgtol_mod_$ck_L457_9	10	23 040	2304	0,0002

Table 8: Global overview of the ecTrans kernels for 10 iterations. The blue highlighted rows are the 6 user kernels which are analysed. The green highlighted rows have a smaller kernel granularity. The yellow highlighted rows are library calls.

GPU Profiling

```
rocprof -i rocprof_counters.txt -o ./rocprof/rocprof.csv $BIN
```

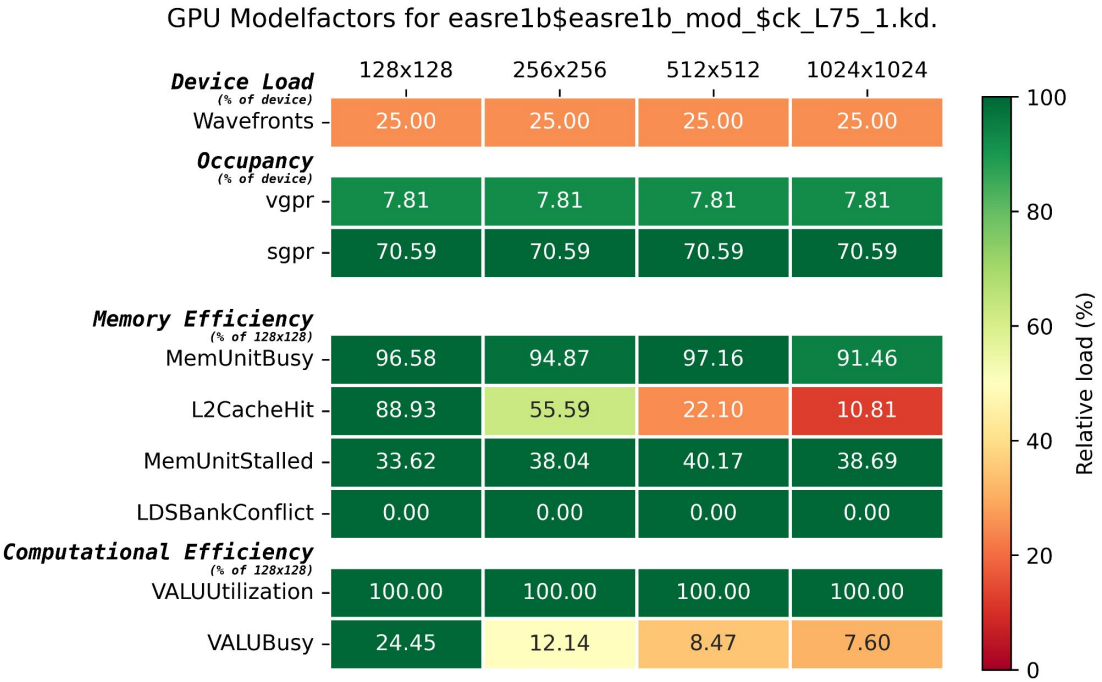
```
Index,KernelName,gpu-id,queue-id,queue-index,pid,tid,grd,wgr,lds,scr,vgpr,sgpr,fbar,sig,obj,GPUBusy,Wavefronts,VALUInsts,VFetchInsts,VWriteInsts,VALUUtilization,VALUBusy,WriteSize,L2CacheHit,MemUnitBusy,MemUnitStalled,LDSBankConflict
0,"eltinv$eltinv_mod_$ck_L136_2_cce$noloop$form.kd"0,0,0,26071,26071,1579087872,256,0,0,4,48,33664,0x0,0x14b05013c040,100.0000000000,24673248.0000000000,17.0000000000,0.0000000000,0.0000000000,100.0000000000,20.7725185968,12332528.0000000000,49.9978626693,77.1977044758,55.9370012636,0.0000000000
1,"eprfi1b$eprfi1b_mod_$ck_L85_3_cce$noloop$form.kd"0,0,2,26071,26071,157593600,256,0,0,4,72,38592,0x0,0x14b05013c100,100.0000000000,2462400.0000000000,20.0000000000,0.0000000000,0.0000000000,100.0000000000,24.2834884261,1227104.0000000000,49.9996649935,71.7003018579,49.2693704348,0.0000000000
2,"eprfi1b$eprfi1b_mod_$ck_L90_2.kd"0,0,4,26071,26071,56320,256,0,0,24,80,37696,0x0,0x14b05013c080,100.0000000000,880.0000000000,111907.6136363636,0.0000000000,0.0000000000,96.8019501699,9.6155911525,1008455.6562500000,81.3899031130,60.5181117611,43.6472872603,0.0000000000
3,"eprfi1b$eprfi1b_mod_$ck_L85_3_cce$noloop$form.kd"0,0,6,26071,26071,157593600,256,0,0,4,72,38592,0x0,0x14b0
...
```

GPU Profiling

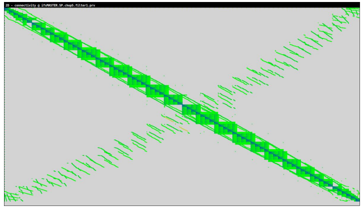
```
rocprof -i rocprof_counters.txt -o ./rocprof/rocprof.csv $BIN
```

```
Index,KernelName,gpu-id,queue-id,queue-index,pid,tid,grd,wgr,lds,scr,vgpr,sgpr,fbar,sig,obj,GPUBusy,Wavefronts,VALUInsts,VFetchInsts,VWriteInsts,VALUUtilization,VALUBusy,WriteSize,L2CacheHit,MemUnitBusy,MemUnitStalled,LDSBankConflict
0,"eltinv$eltinv_mod_$ck_L136_2_cce$noloop$form.kd"0,0,0,26071,26071,1579087872,256,0,0,4,48,33664,0x0,0x14b05013c040,100.0000000000,24673248.0000000000,17.0000000000,0.0000000000,0.0000000000,100.0000000000,20.7725185968,12332528.0000000000,49.9978626693,77.1977044758,55.9370012636,0.0000000000
1,"eprfi1b$eprfi1b_mod_$ck_L85_3_cce$noloop$form.kd"0,0,2,26071,26071,157593600,256,0,0,4,72,38592,0x0,0x14b05013c100,100.0000000000,2462400.0000000000,20.0000000000,0.0000000000,0.0000000000,100.0000000000,24.2834884261,1227104.0000000000,49.9996649935,71.7003018579,49.2693704348,0.0000000000
2,"eprfi1b$eprfi1b_mod_$ck_L90_2.kd"0,0,4,26071,26071,56320,256,0,0,24,80,37696,0x0,0x14b05013c080,100.0000000000,880.0000000000,111907.6136363636,0.0000000000,0.0000000000,96.8019501699,9.6155911525,1008455.6562500000,81.3899031130,60.5181117611,43.6472872603,0.0000000000
3,"eprfi1b$eprfi1b_mod_$ck_L85_3_cce$noloop$form.kd"0,0,6,26071,26071,157593600,256,0,0,4,72,38592,0x0,0x14b0
...
```

GPU Profiling

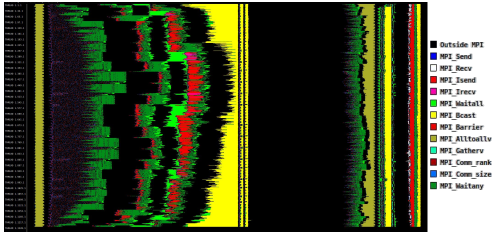


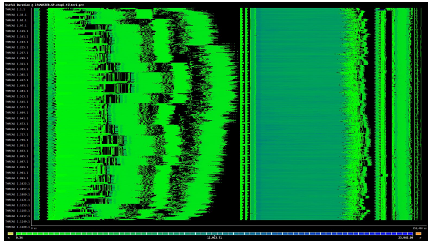
Performance profiling

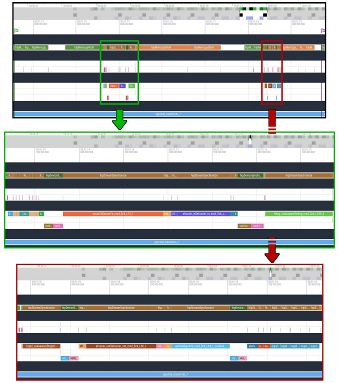


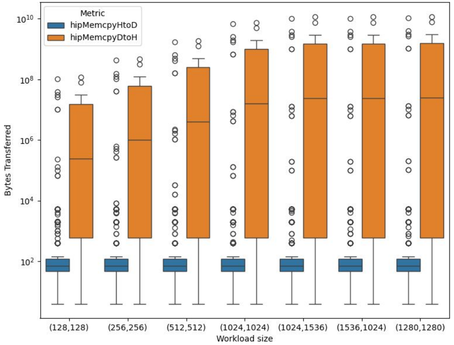
	10240(1280x8)[1]	20480(2560x8)[2]
Global efficiency	60.99	43.63
-- Parallel efficiency	60.99	48.09
-- Load balance	84.62	84.07
-- Communication efficiency	72.07	57.20
-- Computation scalability	100.00	90.74
-- IPC scalability	100.00	90.46
-- Instruction scalability	100.00	98.44
-- Frequency scalability	100.00	101.89

Percentage(%)









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efourier_in$efourier_in_mod_$ck_L61_2_cce$noloop$form	10	1 198 170 052	119 817 005	10,9760
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eupdspb$eupdspb_mod_$ck_L86_1	60	612 827 387	10 213 789	5,6139
void real_pre_process_kernel<...>(...)	20	513 296 858	25 664 842	4,7021
trgtol_cudaaware$trgtol_mod_$ck_L563_3	10	479 085 073	47 908 507	4,3887
eprfi1b$eprfi1b_mod_$ck_L90_2	60	299 659 753	4 994 329	2,7451
void ip_inverse_length768_SBRR<...>(...)	10	282 009 617	28 200 961	2,5834
void real_post_process_kernel_interleaved_1D<...>(...)	20	226 225 138	11 311 256	2,0724
void ip_inverse_length512_SBRR<...>(...)	10	216 095 188	21 609 518	1,9796
trmtol_cudaaware$trmtol_mod_$ck_L205_1	10	178 045 797	17 804 579	1,6310
evdtuv$evdtuv_mod_$ck_L132_2	10	149 741 079	14 974 107	1,3717
efourier_in$efourier_in_mod_$ck_L58_3_cce$noloop$form	10	148 382 992	14 838 299	1,3593
eledir$eledir_mod_$ck_L98_1	10	139 369 528	13 936 952	1,2767
espnsde$espnsde_mod_$ck_L87_1	10	115 237 936	11 523 793	1,0557
eltinv$eltinv_mod_$ck_L136_2_cce$noloop$form	10	113 872 491	11 387 249	1,0431
trltom_cudaaware$trltom_mod_$ck_L218_1	10	110 770 720	11 077 072	1,0147
void ip_forward_length768_SBRR<...>(...)	10	110 712 645	11 071 264	1,0142
void ip_forward_length512_SBRR<...>(...)	10	110 086 079	11 008 607	1,0085
eftdir$eftdir_mod_$ck_L89_2_cce$noloop$form	10	94 305 395	9 430 539	0,8639
efsc$efsc_mod_$ck_L97_2	10	89 873 545	8 987 354	0,8233
euvtvd$euvtvd_mod_$ck_L108_2	10	85 680 570	8 568 057	0,7849
euvtvd$euvtvd_mod_$ck_L89_1	10	68 517 640	6 851 764	0,6277
evdtuv$evdtuv_mod_$ck_L113_1	10	66 336 511	6 633 651	0,6077
efsc$efsc_mod_$ck_L75_1	10	58 245 610	5 824 561	0,5336
eprfi1b$eprfi1b_mod_$ck_L85_3_cce$noloop$form	60	57 399 205	956 653	0,5258
eltdir$eltdir_mod_$ck_L157_3_cce$noloop$form	10	57 060 646	5 706 064	0,5227
eltdir$eltdir_mod_$ck_L156_2_cce$noloop$form	10	22 749 187	2 274 918	0,2084
<barrier packet>	20	753 461	37 673	0,0070
evdtuv$evdtuv_mod_$ck_L170_4	10	97 760	9776	0,009
euvtvd_comm$euvtvd_comm_mod_$ck_L106_2_cce$noloop$form	10	63 681	6368	0,0006
trgtol_cudaaware$trgtol_mod_$ck_L456_8	10	32 960	3296	0,0003
trgtol_cudaaware$trgtol_mod_$ck_L457_9	10	23 040	2304	0,0002

Table 8: Global overview of the ecTrans kernels for 10 iterations. The blue highlighted rows are the 6 user kernels which are analysed. The green highlighted rows have a smaller kernel granularity. The yellow highlighted rows are library calls.

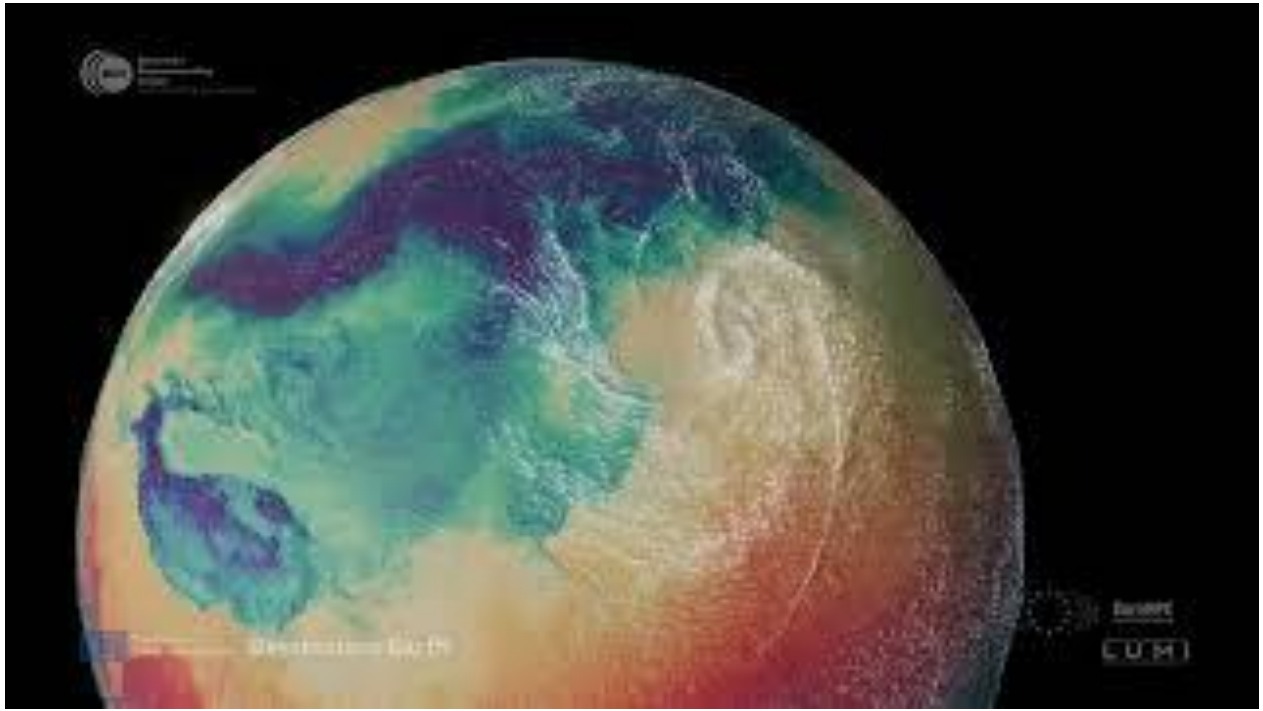
GPU Modelfactors for easre1b$easre1b_mod_$ck_L75_1.kd.

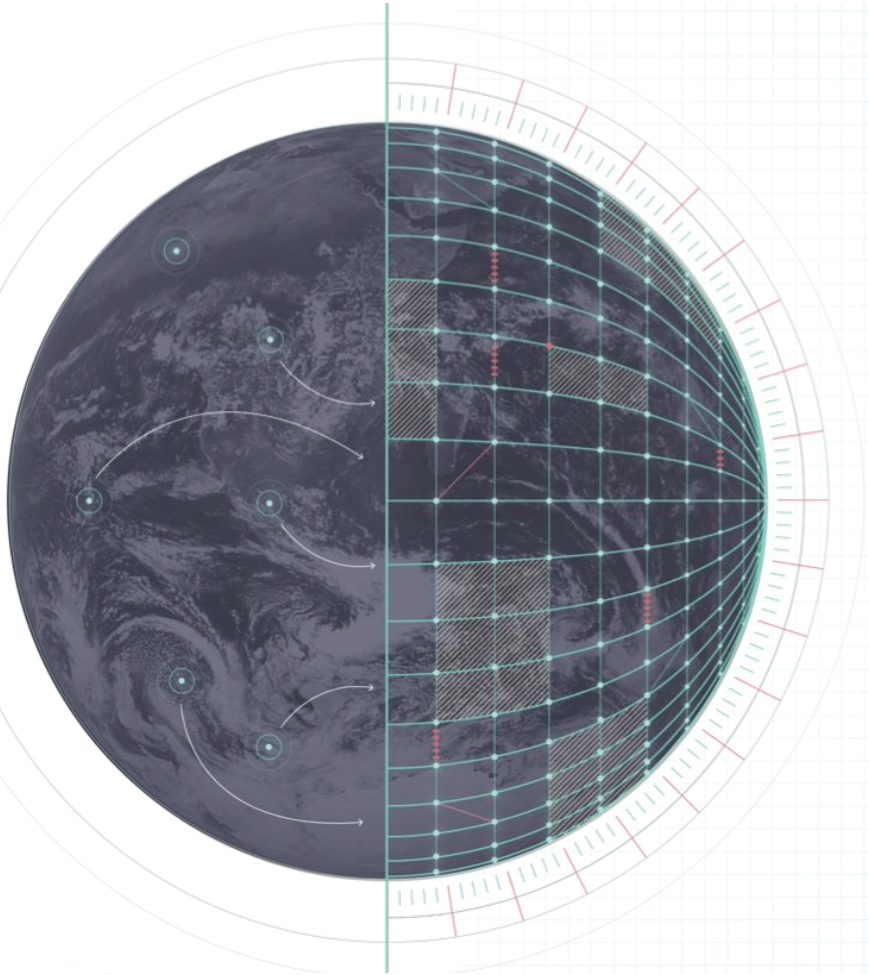
	128x128	256x256	512x512	1024x1024
Device Load (% of device)				
Wavefronts	25.00	25.00	25.00	25.00
Occupancy (% of device)				
vgpr	7.81	7.81	7.81	7.81
sgpr	70.59	70.59	70.59	70.59
Memory Efficiency (% of 128x128)				
MemUnitBusy	96.58	94.87	97.16	91.46
L2CacheHit	88.93	55.59	22.10	10.81
MemUnitStalled	33.62	38.04	40.17	38.69
LDSBankConflict	0.00	0.00	0.00	0.00
Computational Efficiency (% of 128x128)				
VALUUtilization	100.00	100.00	100.00	100.00
VALUBusy	24.45	12.14	8.47	7.60

Relative load (%)

The earth is still alive..

The earth is still alive..





Earth Sciences Department

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

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Destination Earth

Pioneering the Future with Digital Twins

Okke van Eck
GPU Research Engineer
Barcelona Supercomputing Center

okke.vaneck@bsc.es

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