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### Outline

• Introduction to Scalasca

• How to compile (using Score-P)

• Explaining functionalities of Scalasca/CUBE4 on two applications

• Testing a case with a large trace



### Scalasca

- Scalasca is a software tool that supports the performance analysis of parallel applications
- The analysis identifies potential performance bottlenecks in particular those concerning communication and synchronization and offers guidance in exploring their causes.
- Installed version on Summit: v2.25
- Module: scalasca
- For instrumentation is used Score-P
- Web site: <a href="https://www.scalasca.org">https://www.scalasca.org</a>
- Email: <u>scalasca@fz-juelich.de</u>



# Capability Matrix - Scalasca

Capability	Profiling	Tracing	Notes/Limitations
MPI, MPI-IO	Yes	Yes	
OpenMP CPU	Yes	Yes	
OpenMP GPU	No	No	
OpenACC	No	No	Score-P does instrument but CUBE does not provide information
CUDA	No	No	Score-P does instrument but CUBE does not provide information
POSIX I/O	Yes	Yes	
POSIX threads	Yes	Yes	
Memory – app-level	Yes	Yes	
Memory – func-level	Yes	Yes	
Hotspot Detection	Yes	Yes	
Variance Detection	Yes	Yes	
Hardware Counters	Yes	Yes	

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# Techniques

- Profile analysis:
  - Summary of aggregated metrics
    - Per function/call-path and/or per process/thread
  - mpiP, TAU, PerfSuite, Vampir
- Time-line analysis
- Pattern analysis



# Automatic trace analysis



- Apply tracing
- Automatic search for patterns on inefficient behavior
- Classification of behavior
- Much faster than manual trace analysis
- Scalability



### Workflow





### CUBE4

- Parallel program analysis report exploration tools
  - Libraries for XML report
  - Algebra utilities for report processing
  - GUI for interactive analysis exploration
- Three coupled tree browsers
  - Performance property
  - Call-tree path
  - System location
- CUBE4 displays severities
  - Value for precise comparison
  - Colour for easy identification of hostpots
  - Inclusive value when closed and exclusive when expanded



### Scalasca on Summit

module load scalasca

scalasca

Scalasca 2.5

Toolset for scalable performance analysis of large-scale parallel applications usage: scalasca [OPTION]... ACTION <argument>...

1. prepare application objects and executable for measurement:

scalasca -instrument < compile-or-link-command> # skin (using scorep)

2. run application under control of measurement system: scalasca -analyze <application-launch-command> # scan

3. interactively explore measurement analysis report: scalasca -examine <experiment-archive | report> # square

Options:

- -c, --show-config show configuration summary and exit -h, --help show this help and exit -n, --dry-run show actions without taking them --quickref show quick reference guide and exit --remap-specfile show path to remapper specification file and exit -v, --verbose enable verbose commentary -V, --version show version information and exit



### Scalasca Workflow

- Compilation: use Score-P
- Execution of the binary for profiling (it will create an output folder):

scalasca -analyze jsrun ...

• Examine of the data (GUI is loaded)

scalasca -examine output\_folder



### MiniWeather – MPI – Tools parameters

• Parameters for Scalasca/Score-P

module load scorep/6.0\_r14595 module load scalasca/2.5

export SCOREP\_METRIC\_PAPI=PAPI\_TOT\_INS,PAPI\_TOT\_CYC,PAPI\_FP\_OPS export SCOREP\_MPI\_ENABLE\_GROUPS=ALL export SCAN\_MPI\_LAUNCHER=jsrun



### Instrumentation

Type of	Instrumenter	Default value	Instrumented	Runtime
instrumentation	switch		routines	measurement
				control
MPI	mpp=mpi/	(auto)	configured by	'Selection of MPI
	mpp=none		install	Groups'
SHMEM	mpp=shmem/	(auto)	configured by	—
	mpp=none		install	
CUDA	[no]cuda	enabled	all	'CUDA
				Performance
				Measurement'
OpenCL	[no]opencl	enabled	configured by	'OpenCL
			install	Performance
				Measurement'
OpenACC	[no]openacc	enabled	configured by	'OpenACC
			install	Performance
				Measurement'
OpenMP	thread=omp /	(auto)	all parallel	—
	[no]openmp		constructs, see	
			Note below	
Pthread	thread=pthread	(auto)	Basic Pthread	—
			library calls	
'Automatic	[no]compiler	enabled	all	'Filtering'
Compiler				
Instrumentation'				
'Recording of I/O	[no]io[=]	disabled	configured by	'Recording of I/O
activities'			install	activities'
'Source-Code	[no]pdt	disabled	all	'Filtering'
Instrumentation				
Using PDT'				
'Semi-Automatic	[no]pomp	disabled	manually annotated	'Filtering'
Instrumentation of				
POMP2 User				
Regions'				
'Manual Region	[no]user	disabled	manually annotated	'Filtering' and
Instrumentation'				'Selective
				Recording'
'Score-P User	libwrap=[]	disabled	all by library	'Filtering'
Library Wrapping'			wrapper	



### MiniWeather - MPI

- Edit the Makefile and add the \$PREP before the compiler name
- Compile:

MPI: make PREP="scorep --mpp=mpi --pdt" mpi

• Execution (submission script):

scalasca -analyze jsrun -n 64 -r 8 ./miniWeather\_mpi

• Visualize:

scalasca -examine /gpfs/.../scorep\_miniWeather\_mpi\_8p64\_sum



### CUBE4 – Central View

		X CubeGUI-4.4.3: scorep	_miniWeather_mpi_8p64_sum/s	ummary.cubex						
File Display Plugins Help										
Absolute		Absolute		•	Absolute			•		
		Call tree			System tree	Statistics 🚺 Sur	nburst 🛛 🗲 P	rocess x Thread	Syste	
Metric tree          2093.48 Time (sec)         2.62e7 Visits (occ)         4.93e10 Bytes transferred (bytes)         1.26e5 MPI file operations (occ)         3.617 Computational imbalance (sec)         0.00 Minimum Inclusive Time (sec)         4.2.21 Maximum Inclusive Time (sec)         4.2.21 Maximum Inclusive Time (sec)         3.91e7 io_bytes_read (bytes)         0 ALLOCATION_SIZE (bytes)         0 DEALLOCATION_SIZE (bytes)         0 DO maximum heap memory_allocated (bytes)         1.08e13 PAPI_TOT_INS (#)         6.16e12 PAPI_TOT_CYC (#)		Can tree Fiat view			2693.48 ma	chine summit.ccs.ornl.go	V		am View Other	3 Windows: Metric tree Call tree System tree
0.00 2693.48 (100.00%)	2693.48	0.00 2	593.48 (100.00%)	2693.48	0.00	2693.48 (100.00	0%)	2693.48		
Check for new version is disabled.										

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# Exploring the menus

000	CubeGUI-4.4.3: scorep_miniWeather_mpi_8p64_sum/summary.cubex	
<u>File D</u> isplay <u>P</u> lugins <u>H</u> elp		
Restore Setting   Save Settings		
Absolute	Absolute	Absolute 👻 🦉
Own root percent	Call tree Flat view	System tree 🚺 Statistics 🚺 Sunburst 📝 Process x Thread
External percent	► 2693.48 miniWeather mpi	▶ ■ 2693.48 machine summit.ccs.ornl.gov
<ul> <li>2.62e7 Visits (occ)</li> <li>4.93e10 Bytes transferred (bytes)</li> <li>1.26e5 MPI file operations (occ)</li> <li>0.00 Minimum Inclusive Time (sec)</li> <li>42.21 Maximum Inclusive Time (sec)</li> <li>3.84e8 io bytes_read (bytes)</li> <li>0 ALLOCATION_SIZE (bytes)</li> <li>0 DEALLOCATION_SIZE (bytes)</li> <li>0 bytes_leaked (bytes)</li> <li>0.00 maximum_heap_memory_allocated (bytes)</li> <li>1.08e13 PAPI_TOT_INS (#)</li> <li>6.16e12 PAPI_TOT_CYC (#)</li> </ul>		
4		All (64 elements)
0.00 2693.48 (100.00%) 2693.48	0.00 2693.48 (100.00%) 2693.48	0.00 2693.48 (100.00%) 2693.48

Check for new version is disabled.



### How to expand the trees

			🔀 CubeG	UI-4.4.3: scorep_miniWea	ather_mpi_8p64_sum/summ	ary.cubex					
<u>F</u> ile <u>D</u> isplay <u>P</u> lugins	<u>H</u> elp										
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Expand all nodes



### Computation – System tre

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Absolute	Absolute	•	Absolute				*	ų
Metric tree	Call tree		🔚 System tree	I Statistics	🖸 Sunburst	🕖 Process x Thre	ead	stell
<ul> <li>□ 0.00 Time (sec)</li> <li>□ 0.00 Execution</li> <li>□ 714.00 Computation</li> <li>□ 3.87 MPI</li> <li>□ 0.00 Management</li> <li>□ 27.35 Init/Finalize</li> <li>□ 118.94 Communicator</li> <li>□ 831.51 File</li> <li>□ 0.00 Synchronization</li> <li>□ 0.00 Collective</li> <li>□ 0.00 Collective</li> <li>□ 0.00 Communication</li> <li>□ 0.00 Communication</li> <li>□ 0.00 Communication</li> <li>□ 0.00 Communication</li> <li>□ 25.10 Point-to-point</li> <li>□ 829.39 Collective</li> <li>□ 0.00 Genesided</li> <li>□ 0.00 Communication</li> <li>□ 25.10 Point-to-point</li> <li>□ 829.39 Collective</li> <li>□ 0.00 Genesided</li> <li>■ 0.00 File I/O</li> <li>□ 0.41 Individual</li> <li>□ 4.0.41 Collective</li> <li>□ 0.00 Request Start</li> <li>□ 102.49 Request Completion</li> <li>□ 0.00 Overhead</li> <li>□ 2.62e7 Visits (occ)</li> <li>□ 0 Bytes transferred (bytes)</li> <li>□ 0 Received</li> <li>□ 0 Collective</li> <li>□ 0 Received</li> <li>□ 0 Collective</li> <li>□ 0 Collective</li> <li>□ 0 Received</li> <li>□ 0 Collective</li> <li>□ 0 Sent</li> <li>□ 0 Received</li> <li>□ 0 Received</li></ul>	<ul> <li> <ul> <li>0.00 double dmin(double, double)</li> <li>0.00 MPI Barrier</li> <li>5.04 void injection(double, double, double &amp;, double &amp;, double &amp;</li> <li>2.60 void output(double *, double)</li> <li>0.00 MPI Bcast</li> <li>0.00 MPI Comm_rank</li> <li>0.00 MPI_File_get info</li> <li>0.30 void numarQint, int)</li> <li>0.00 MPI_file_create_subarray</li> <li>0.00 MPI_Type_create_subarray</li> <li>0.00 MPI_Type_create_invector</li> <li>0.00 MPI_file_write_at_all</li> <li>0.00 MPI_file_set view</li> <li>0.00 MPI_file_write_at_all</li> <li>0.00 MPI_file_daddress</li> <li>0.00 MPI_file_cose</li> <li>0.00 MPI_file_cose</li> <li>0.00 MPI_file_read_at</li> <li>0.00 MPI_recv</li> <li>0.00 MPI_recv</li></ul></li></ul>		●         0.00 machin           ▼         0.00 nod           ●         4.81           ●         5.49           ●         4.79           ●         4.80           ●         4.80           ●         4.79	e summit.ccs.or le f01n10 MPI Rank 0 MPI Rank 1 MPI Rank 1 MPI Rank 2 MPI Rank 3 MPI Rank 4 MPI Rank 4 MPI Rank 6 MPI Rank 6 MPI Rank 7 le f01n11 MPI Rank 10 MPI Rank 10 MPI Rank 11 MPI Rank 11 MPI Rank 12 MPI Rank 13 MPI Rank 14 MPI Rank 15 le f01n12 MPI Rank 15 MPI Rank 15 MPI Rank 16 MPI Rank 17 MPI Rank 17 MPI Rank 18 MPI Rank 19 MPI Rank 20 MPI Rank 21 MPI Rank 21 MPI Rank 22 MPI Rank 23 le f01n13 MPI Rank 24 MPI Rank 25 MPI Rank 26 MPI Rank 27 MPI Rank 28 MPI Rank 29 MPI Rank 20 MPI Rank 29 MPI Rank 29 MPI Rank 20	nl.gov			n view Other
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Selected "void compute\_tendencies\_x(double \*, double \*, double \*)"



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### Computation – Blox plot

X CubeGUI-4.4.3: scorep\_miniWeather\_mpi\_8p64\_sum/summary.cubex

File Display Plugins Help

Restore Setting 🔻 Save Settings



Selected "void compute\_tendencies\_x(double \*, double \*, double \*)"



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### **Computation Sunburst**



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### Computation – Process x Thread

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keric tree	Call tree 📘 Flat view	System tree 🚺 Statistics 🚺 Sunburst 🖉 Process x Thread
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Selected "4.79 MPI Rank 14



### Score-P configuration parameters

#### 

X CubeGUI-4.4.3: scorep\_miniWeather\_mpi\_8p64\_sum/summary.cubex

#### File Display Plugins Help

### Restore Setting 🔻 Save Settings

Absolute	*	Absolute	Score-P Configuration 🛛 🖉 Sour	ce 🤍 Info 🖉
E Metric tree		Call tree Flat view	Variable	Value A
💌 🗖 0.00 Time (sec)	*	0.00 double dmin(double, double)	1 SCOREP ENABLE PROFILING	true Sector
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714.00 Computation		5.04 void injection(double, double, double &, double &, double &	2 SCOREP_ENABLE_TRACING	false
<ul> <li>✓ □ 0.00 Management</li> <li>□ 27 35 Init/Finalize</li> </ul>		<ul> <li>If a construction of a construction</li></ul>	3 SCOREP_ENABLE_UNWINDING	false
■ 27.55 mit/minize		0.00 MP_Comm_rank	4 SCOREP_VERBOSE	false
0.00 Window			5 SCOREP_TOTAL_MEMORY	20M
0.00 Synchronization     0.00 Collective		<ul> <li>0.00 MPI_FIle_get_into</li> <li>0.30 void ncwrap(int, int)</li> </ul>	6 SCOREP PAGE SIZE	8К
♥ L) 0.00 One-sided □ 0.00 Active Target		□ 0.00 MPI_Info_get □ 0.00 MPI_Info_set	7 SCOREP EXPERIMENT DIRECT	'./scorep miniWeather mpi 8p
<ul> <li>0.00 Passive Target</li> <li>0.00 Communication</li> </ul>		0.00 MPI_File_write_at     0.00 MPI_Comm_size	8 SCOREP OVERWRITE EXPERIM	true
<ul><li>25.10 Point-to-point</li><li>829.39 Collective</li></ul>		0.00 MPI_Type_size     0.00 MPI_Type_create_subarray		'summit ccs ornl gov'
□ 0.00 One-sided □ 0.00 File I/O		0.00 MPI_Type_commit     0.00 MPI_Type_create hvector		"
<ul> <li>0.41 Individual</li> <li>40.41 Collective</li> </ul>		0.00 MPI Type free		
<ul> <li>0.00 Request Handling</li> <li>0.00 Request Start</li> </ul>		□ 0.00 MPI_File_set_view	11 SCOREP_ENABLE_STSTEM_TRE	Taise
■ 102.49 Request Completion			12 SCOREP_FORCE_CFG_FILES	true
2.62e7 Visits (occ)		0.00 MPI_FIIe_close	13 SCOREP_TIMER	'tsc'
<ul> <li>O Bytes transferred (bytes)</li> <li>O Point-to-point</li> </ul>		0.00 MPI_Comm_free     0.00 MPI_Get_address	14 SCOREP_PROFILING_TASK_EXC	1К
<ul> <li>4.42e10 Sent</li> <li>0 Received</li> </ul>		□ 0.00 MPI_File_read_at □ 0.00 MPI Get count	15 SCOREP_PROFILING_MAX_CAL	30
<ul> <li>O Collective</li> <li>2.52e9 Outgoing</li> </ul>		<ul> <li>B 8.66 void perform timestep(double *, double *, doub</li></ul>	16 SCOREP_PROFILING_BASE_NAME	'profile'
2.52e9 Incoming     0 Remote Memory Access		30.27 void set_halo_values_x(double *) 0.00 MPL/recv	17 SCOREP_PROFILING_FORMAT	'cube4'
			18 SCOREP_PROFILING_ENABLE_C	true
<ul> <li>□ 0 MPI file operations (occ)</li> <li>□ 0 coop to dividual</li> </ul>	+	317.99 void compute_tendencies x(double *, double *, double /, double //	19 SCOREP_PROFILING_CLUSTER	64
	•	A / Void set halo values zidouble*		'subtree'
0.00 714.00 (26.51%) 2	2693.48	0.00 317.99 (44.54%) 714.00	4	Subtree v v



### CUBE – Flat view

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0.00 714.00 (26.51%)	2693.48	0.00 317.99 (44.54%) 714.0	00	0.00	4.79	9 (1.51%)	317	.99
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Ready

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Open slide master to edit

### Initialization variation

#### X CubeGUI-4.4.3: scorep\_miniWeather\_mpi\_8p64\_sum/summary.cubex

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### <u>File Display Plugins H</u>elp

#### Restore Setting 🔻 Save Settings

Absolute	Absolute	Absolute		* Sy
Metric tree	Call tree Flat view	🔚 System tree	🚺 Statistics 🚺 Sunburst	Process x Thread
▼ □ 0.00 Time (sec)	O.00 miniWeather_mpi			
•	✓ □ 0.00 int main(int, char **)	0.65		ž.
714.00 Computation	0.00 void init(int *, char ***)			
3.87 MPI	27.33 MPI_Init			0
<ul> <li>0.00 Management</li> </ul>	0.00 MPI_Comm_size			Ť.
27.35 Init/Finalize	0.00 MPI_Comm_rank			9
118.94 Communicator	0.00 double dmin(double, double)	0.58		- 0.55
831.51 File	0.00 MPI_Barrier	0.00		
O.00 Window	•			
🔻 🗖 0.00 Synchronization	0.00 void hydro_const_theta(double, double &, double &)			
0.00 Collective	<ul> <li>0.00 void output(double *, double)</li> </ul>			
•	0.00 MPI_Bcast			- 0.49
0.00 Active Target	0.00 MPI_Comm_rank	0.50		
0.00 Passive Target	0.00 MPI_File_open			
👻 🗖 0.00 Communication	0.00 MPI_Comm_dup			
25.10 Point-to-point	0.00 MPI_File_get_info			
829.39 Collective	0.00 void ncwrap(int, int)			
0.00 One-sided	0.00 MPI_Info_get	0.43		- 0.43
▼ □ 0.00 File I/O	0.00 MPI_Info_set	0.15		
0.41 Individual	0.00 MPI_File_write_at			
40.41 Collective	0.00 MPI_Comm_size			
🔻 🗖 0.00 Request Handling	0.00 MPI_Type_size			
0.00 Request Start	0.00 MPI_Type_create_subarray	0.00		
102.49 Request Completion	0.00 MPI_Type_commit	0.36		
0.00 Overhead	0.00 MPI_Type_create_hvector			
2.62e7 Visits (occ)	0.00 MPI_Type_free			
<ul> <li>D Bytes transferred (bytes)</li> </ul>	0.00 MPI_Type_create_struct			
🔻 🗖 0 Point-to-point	0.00 MPI_File_set_view			
4.42e10 Sent	0.00 MPI_File_write_at_all	0.29		
0 Received	0.00 MPI_Allreduce			
	0.00 MPI_File_close			- 0.28
2.52e9 Outgoing	0.00 MPI_Info_free			
2.52e9 Incoming	0.00 MPI_Comm_free			- 0.26
•	0.00 MPI_Get_address	0.00		
🗆 0 Sent	0.00 MPI_File_read_at	0.22		
O Received	0.00 MPI_Get_count			
O MPI file operations (occ)	0.00 void perform_timestep(double *, double	Box Plot	🔾 Violin P	Plot
Vertical Ver	O 00 void semi discrete step(double * double	Box Hoc	VIOINT	
0.00 27.35 (1.02%) 2693.4	48         0.00         27.33 (99.93%)         27.35	0.26	0.43 (56.98%)	0.56



# MPI\_Comm\_dup variation

Dipply Pugnes Belp           Absolute              Absolute		X CubeGUI-4.4.3: scorep_miniWeather_mpi_8p64_sum/summary.cubex	
<pre>stare Setting • Save Settings</pre> <pre> http://with tec: </pre> <pre> Absolute / Absolute /</pre>	<u>File D</u> isplay <u>P</u> lugins <u>H</u> elp		
hete Absolute     Metric tree     Metric tree     1000 Tree isel     1000 Tree	Restore Setting 🔻 Save Settings		
Metric tree       Call tree       Flat view       System tree       Statistics       Submit submit is and interval in the statistics       Process x Thread         1000 Three (sec)       0.000 Mein submit is and interval in the statistics       0.000 Mein submit is and interval in the statistics       Image: Statistics <th>Absolute</th> <th>Absolute</th> <th>Absolute</th>	Absolute	Absolute	Absolute
10.00 Time (sec) <ul> <li> <ul> <li>             0.00 Execution             </li>             0.00 Int mainfine, that "*)             </ul></li>             0.00 Int mainfine, that "*)             "             0.00 ONP   Int !=             0.00 Int mainfine, that "*)             "             0.00 ONP   Int !=             0.00 ONP   Int</ul>	Netric tree	Call tree	📘 System tree 🔳 Statistics 🔯 Sunburst 🖉 Process x Thread
0 MPI file operations (occ) <ul> <li></li></ul>		• 0.00 miniWeather_mpi • 0.00 int mani(int, char **) • 0.00 ovid init(int *, char ***) • 0.00 MPI_Comm_size • 0.00 MPI_Comm_rank 0.00 MPI_Comm_rank 0.00 woid injection(double, double) 0.00 void injection(double, double, double &, double &, double & • 0.00 void output(double *, double) 0.00 MPI_Bcast 0.00 MPI_Comm_rank 0.00 MPI_File open 116.13 MPI_Comm_dup 0.00 MPI_rile get_info 0.00 MPI_rile_get_info 0.00 MPI_rile_get 0.00 MPI_rile_get 0.00 MPI_rile_get 0.00 MPI_rile_get 0.00 MPI_rile_write_at 0.00 MPI_rype_create_subarray 0.00 MPI_rype_create_subarray 0.00 MPI_rype_create_struct 0.00 MPI_rile_set_view 0.00 MPI_rile_write_at all 0.00 MPI_rile_close 0.00 MPI_rile_close 0.00 MPI_rile_close 0.00 MPI_rile_close 0.00 MPI_rile_close 0.00 MPI_rile_read_at 0.00 MPI_rile_read_at	
118.94 (4.42%)       2693.48       0.00       116.13 (97.64%)       118.94       0.14       1.81 (12.54%)       13.53	O MPI file operations (occ)     I 9600 Individual	<ul> <li>0.00 void perform_timestep(double *, double *, double *, double *, double *, double *, double * double * double * double * double *</li> </ul>	Box Plot     O Violin Plot
	0.00 118.94 (4.42%) 2693.48	0.00 116.13 (97.64%) 118.94	0.14 1.81 (12.54%) 13.53



# MPI\_Comm\_dup variation II

Televi Teline Tele						
Restore Setting 🔻 Save Settings						
bsolute	•	Absolute	<ul> <li>Absolute</li> </ul>			
🔚 Metric tree		Call tree	🚺 System tree	I Statistics	🖸 Sunburst	🕖 Process x Thread
Metric tree           0.00 Time (sec)           7 14.00 Computation           7 714.00 Computation           27.35 Init/Finalize           118.94 Communicator           831.51 File           0.00 Owindow           831.51 File           0.00 Collective           0.00 One-sided           0.00 Communication           25.10 Point-to-point           829.39 Collective           0.00 One-sided           0.00 Communication           25.10 Point-to-point           829.39 Collective           0.00 One-sided           *           0.00 Communication           25.10 Point-to-point           829.39 Collective           0.00 One-sided           *           0.00 One-sided           *           0.00 Request Handling           0.00 Request Start           102.49 Request Completion           0.00 Overhead           2.62e7 Visits (occ)           *           0 Received           •           0 Received           •           0 Received           •           0 Sent           0 Received		<ul> <li>Can dee Plat view</li> <li>Colo miniWeather mpi</li> <li>0.00 init main(int, char **)</li> <li>0.00 wid init(int *, char ***)</li> <li>0.00 MPI_comm_size</li> <li>0.00 MPI_Comm_rank</li> <li>0.00 double dmin(double, double)</li> <li>0.00 double dmin(double, double, double &amp;, double &amp;, double &amp;</li> <li>0.00 void injection(double, double, double &amp;, double &amp;, double &amp;</li> <li>0.00 void output(double *, double)</li> <li>0.00 MPI_Brast</li> <li>0.00 MPI_Comm_rank</li> <li>0.00 MPI_File get_info</li> <li>0.00 MPI_File get_info</li> <li>0.00 MPI_file_get</li> <li>0.00 MPI_file_write_at</li> <li>0.00 MPI_file_write_at</li> <li>0.00 MPI_Type_create_subarray</li> <li>0.00 MPI_Type_create_subarray</li> <li>0.00 MPI_Type_free</li> <li>0.00 MPI_Type_free</li> <li>0.00 MPI_file_write_at_all</li> <li>0.00 MPI_file_vrite_at_all</li> <li>0.00 MPI_file_cose</li> <li>0.00 MPI_file_cost</li> <li>0.00 MPI_file_cost</li> <li>0.00 MPI_file_cost</li> <li>0.00 MPI_file_vrite_at_all</li> <li>0.00 MPI_file_cost</li> <l< td=""><td>O ,00 matchesister (Construction)     O ,00 matchesister (Cons</td><td>ine summit.ccs.or ode f01n10 53 MPI Rank 0 53 MPI Rank 1 53 MPI Rank 2 53 MPI Rank 3 53 MPI Rank 4 53 MPI Rank 4 53 MPI Rank 5 53 MPI Rank 5 53 MPI Rank 5 53 MPI Rank 6 53 MPI Rank 7 54 MPI Rank 9 54 MPI Rank 9 55 MPI Rank 10 56 MPI Rank 10 57 MPI Rank 11 50 MPI Rank 11 50 MPI Rank 12 50 MPI Rank 13 50 MPI Rank 14 51 MPI Rank 15 50 MPI Rank 16 51 MPI Rank 16 51 MPI Rank 17 52 MPI Rank 18 53 MPI Rank 21 54 MPI Rank 21 55 MPI Rank 22 55 MPI Rank 24 55 MPI Rank 25 55 MPI Rank 25 55 MPI Rank 27 55 MPI Rank 27 55 MPI Rank 28 56 MPI Rank 29 56 MPI Rank 29 57 MPI Rank 29 57 MPI Rank 29 58 MPI Rank 29 59 MPI Rank 29 50 MPI Rank 29 51 MPI Rank 29 51 MPI Rank 29 51 MPI Rank 29 51 MPI Rank 20 52 MPI Rank 29 53 MPI Rank 20 54 MPI Rank 29 54 MPI Rank 29 55 MPI Rank 20 55 MPI Rank 20 55 MPI Rank 20 55 MPI Rank 20 56 MPI Rank 20 56 MPI Rank 20 57 MPI Rank 20 57 MPI Rank 20 57 MPI Rank 20 58 MPI Rank 20 59 MPI Rank 20 50 MPI Rank 20 51 MPI Rank 20 51 MPI Rank 20 51 MPI Rank 20 52 MPI Rank 20 53 MPI Rank 20 54 MPI Rank 20 55 MPI Rank 20 55 MPI Rank 20 56 MPI Rank 20 57 MP</td><td>nl.gov</td><td></td></l<></ul>	O ,00 matchesister (Construction)     O ,00 matchesister (Cons	ine summit.ccs.or ode f01n10 53 MPI Rank 0 53 MPI Rank 1 53 MPI Rank 2 53 MPI Rank 3 53 MPI Rank 4 53 MPI Rank 4 53 MPI Rank 5 53 MPI Rank 5 53 MPI Rank 5 53 MPI Rank 6 53 MPI Rank 7 54 MPI Rank 9 54 MPI Rank 9 55 MPI Rank 10 56 MPI Rank 10 57 MPI Rank 11 50 MPI Rank 11 50 MPI Rank 12 50 MPI Rank 13 50 MPI Rank 14 51 MPI Rank 15 50 MPI Rank 16 51 MPI Rank 16 51 MPI Rank 17 52 MPI Rank 18 53 MPI Rank 21 54 MPI Rank 21 55 MPI Rank 22 55 MPI Rank 24 55 MPI Rank 25 55 MPI Rank 25 55 MPI Rank 27 55 MPI Rank 27 55 MPI Rank 28 56 MPI Rank 29 56 MPI Rank 29 57 MPI Rank 29 57 MPI Rank 29 58 MPI Rank 29 59 MPI Rank 29 50 MPI Rank 29 51 MPI Rank 29 51 MPI Rank 29 51 MPI Rank 29 51 MPI Rank 20 52 MPI Rank 29 53 MPI Rank 20 54 MPI Rank 29 54 MPI Rank 29 55 MPI Rank 20 55 MPI Rank 20 55 MPI Rank 20 55 MPI Rank 20 56 MPI Rank 20 56 MPI Rank 20 57 MPI Rank 20 57 MPI Rank 20 57 MPI Rank 20 58 MPI Rank 20 59 MPI Rank 20 50 MPI Rank 20 51 MPI Rank 20 51 MPI Rank 20 51 MPI Rank 20 52 MPI Rank 20 53 MPI Rank 20 54 MPI Rank 20 55 MPI Rank 20 55 MPI Rank 20 56 MPI Rank 20 57 MP	nl.gov	
9600 Individual	▼	▼ □ 0.00 void semi discrete sten(double * double * do	All (64 elements	)		
0 118.94 (4.42%)	2693.48	0 00 116 13 (97 64%) 118	94 0 00	0.1	4 (0 12%)	11



### Getting information about metrics

X CubeGUI-4.4.3: scorep miniWeather mpi 8p64 sum/summarv.cubex File Display Plugins Help Restore Setting 
 Save Settings Absolute Absolute 🔱 Info 🔇 Score-P Configuration Source ystem Metric : Time spent in MPI file Region name: MPI File open Metric tree Call tree Flat view management calls Mangled name: MPI File open View 0.00 Time (sec) 0.00 miniWeather mpi Display name : File 0.00 Execution 0.00 int main(int, char \*\*) Unique name : mpi mgmt file Region description: 714.00 Computation 0.00 void init(int \*, char \*\*\*) Data type : DOUBLE Call path ID: 13 0.00 MPI Init 3.87 MPI Other Unit of measurement : sec Beginning line: undefined 0.00 MPI Comm size 0.00 Management Value : Ending line: undefined 27.35 Init/Finalize 0.00 MPI Comm rank URL : Paradigm: mpi 118.94 Communicator 0.00 double dmin(double, double) @mirror@scorep\_metrics-6.0-Role: file io metadata مان<u>ا</u> 831.51 Eila 0.00 MPI Barrier trunk.html#mpi mgmt file Source file: MPI 🗆 0.00 Wi • 0.00 void injection(double, double, double &, double &, double & Kind of values : INCLUSIVE Url: 0.00 Synch 0.00 void hydro const theta(double, double &, double &) Caller info: not available Documentation 0.00 Co 0.00 void output(double \*, double) Convertible to data 0.00 MPI Bcast ▼ □ 0.00 On Expand/collapse Cacheable Path: 0.00 MPI Comm rank 0.00 Normal metric 0.00 miniWeather mpi Find items 0.00 815.72 MPI File open + 0.00 int main(int, char \*\*) - 🗆 0.00 Comm 0.00 MPI Comm dup Clear found items Path: + 0.00 void output(double \*, 25.10 P 0.10 MPI File get info 0.00 Time (sec) double) Sort tree items ... 829.39 0.00 void ncwrap(int, int) + 0.00 Execution + 815.72 MPI File open 0.00 On 0.00 MPI Info get + 3.87 MPI Copy to clipboard - 🗆 0.00 File I/ 0.00 MPI Info set + 0.00 Management 0.41 Inc 0.00 MPI File write at Edit metric... 🖬 40.41 C 0.00 MPI Comm size Metric Documentation Call path/Region Documentation Identify metrics... • 
□ 
0.00 Regue 0.00 MPI Type size Score-P metrics 0.00 Re Remove identification markers 0.00 MPI Type create subarray 102.49 0.00 MPI Type commit Show metric statistics 0.00 Overhead 0.00 MPI Type create hypector Time 2.62e7 Visits (occ) 0.00 MPI Type free Show max severity information D 0 Bytes transferred ( 0.00 MPI Type create struct Description: Mark this item ■ 5.40 MPI File set view D Point-to-point Total time spent for program execution including the idle times of 4.42e10 Sent 0.00 MPI File write at all CPUs reserved for slave threads during OpenMP sequential execution. 0 Received 0.00 MPI Allreduce This pattern assumes that every thread of a process allocated a 10.29 MPI File close separate CPU during the entire runtime of the process. 2.52e9 Outgoing 0.00 MPI Info free Unit: 2.52e9 Incoming 0.00 MPI Comm free Seconds O Remote Memory Access 0.00 MPI Get address Diagnosis: 0.00 MPI File read at 0 Sent Expand the call tree to identify important callpaths and routines 0 Received 0.00 MPI Get count where most time is spent, and examine the times for each process or D MPI file operations (occ) 0.00 void perform timestep(double \*, double thread to locate load imbalance. 9600 Individual • □ 0.00 void semi\_discrete\_step(double \*\_double \*\_dou **b** 4 2693.48 0.00 0.00 831.51 (30.87%) 815.72 (98.10%) 831.51 Visits

Shows a short description of the clicked item

### MPI\_Allreduce variation

	🔀 CubeGUI-4.4.3: scorep_miniWeather_mpi_8p64_sum/summary.cubex	
<u>F</u> ile <u>D</u> isplay <u>P</u> lugins <u>H</u> elp		
Restore Setting 🔻 Save Settings		
Absolute	Absolute	Absolute 👻 y
Metric tree	Eall tree Flat view	📓 System tree 🚺 Statistics 🚺 Sunburst 🖉 Process x Thread
	<ul> <li>0.00 void hydro_const_theta(double, double &amp;, double &amp;)</li> <li>0.00 void output(double *, double)</li> <li>14.81 MPI Bcast</li> <li>0.00 MPI Comm_rank</li> <li>0.00 MPI File open</li> </ul>	15.36
<ul> <li>27.35 Init/Finalize</li> <li>118.94 Communicator</li> <li>831.51 File</li> <li>0.00 Window</li> <li>0.00 Synchronization</li> <li>0.00 Collective</li> </ul>	<ul> <li>0.00 MPI_Comm_dup</li> <li>0.00 MPI_File_get_info</li> <li>0.00 void ncwrap(int, int)</li> <li>0.00 MPI_Info_get</li> <li>0.00 MPI_info_set</li> <li>0.00 MPI_evrito_at</li> </ul>	12.28
<ul> <li>0.00 One-sided</li> <li>0.00 Active Target</li> <li>0.00 Communication</li> <li>25.10 Point-to-point</li> <li>829.39 Collective</li> </ul>	<ul> <li>0.00 MPI_Comm_size</li> <li>0.00 MPI_Type_size</li> <li>0.00 MPI_Type_create_subarray</li> <li>0.00 MPI_Type_commit</li> <li>0.00 MPI_Type_create_hvector</li> <li>0.00 MPI_Type_free</li> </ul>	9.21
□ 0.00 One-sided ■ 0.00 File I/O ■ 0.41 Individual ■ 40.41 Collective ■ 0.00 Request Handling □ 0.00 Request Start ■ 102.49 Request Completion	<ul> <li>0.00 MPI_Type_create_struct</li> <li>0.00 MPI_File_set_view</li> <li>0.00 MPI_File_write_at_all</li> <li>814.58 MPI_Allreduce</li> <li>0.00 MPI_File_close</li> <li>0.00 MPI_Info_free</li> <li>0.00 MPI_Comm_free</li> </ul>	6.14
□ 0.00 Overhead ■ 2.62e7 Visits (occ) ■ 0 Bytes transferred (bytes) ■ 0 Point-to-point ■ 4.42e10 Sent □ 0 Received ■ 0 Collective ■ 2.62e0 Outbrainer	<ul> <li>0.00 MPI_Get_address</li> <li>0.00 MPI_File_read_at</li> <li>0.00 MPI_Get_count</li> <li>0.00 void perform_timestep(double *, double *, doubl</li></ul>	3.07
<ul> <li>2.52e9 Oncoming</li> <li>O Remote Memory Access</li> <li>O Sent</li> <li>O Received</li> </ul>	<ul> <li>0.00 MPI_Vaitall</li> <li>0.00 void compute_tendencies_x(double *, double *, double *</li> <li>0.00 void set_halo_values_z(double *)</li> <li>0.00 void compute_tendencies_z(double *, double *, double *</li></ul>	0.00 0.51
O MPI file operations (occ)      O MPI file operations (occ)      O Individual	O.00 void finalize()     O.00 MPL Finalize	Box Plot     Violin Plot
0.00 829.39 (30.79%) 2693.	8.48 0.00 814.58 (98.21%) 829.39	0.51 12.73 (95.47%) 13.31

Selected "MPI\_Allreduce"



### Collective I/O

#### X CubeGUI-4.4.3: scorep\_miniWeather\_mpi\_8p64\_sum/summary.cubex

#### •••

#### <u>File D</u>isplay <u>P</u>lugins <u>H</u>elp

#### Restore Setting 🔻 Save Settings

Metric tree      Metric tree   I 000 Time (sc)      I 000 Time (sc)   0 000 Time (sc)      I 000 Management   0 000 Management   I 000 Management   0 000 Management   I 000 Visio functionable   0 000 Visio functionable   000 Visio functionable <	Absolute *	Absolute	▼ Absolute
D 000 Time (sed)     T 14.00 Computation     T 1	Metric tree	Eall tree 🗐 Flat view	🛐 System tree 🛛 🚺 Statistics 🛛 💆 Sunburst 🖉 Process x Thread
<ul> <li>Defer strains (occ)</li> <li>O Point-to-point</li> <li>O Point-to-point</li> <li>O Point-to-point</li> <li>O Received</li> <li>O Collective</li> <li>O Collective</li></ul>	Metric tree          • 0.00 Time (sec)       •         • 0.00 Execution       •         • 714.00 Computation       •         • 118.94 Communicator       •         • 118.94 Communicator       •         • 0.00 Synchronization       •         • 0.00 Collective       •         • 0.00 Communication       •         • 0.00 Communication       •         • 0.00 Collective       •         • 0.00 One-sided       •         • 0.00 Request Handling       •         • 0.00 Request Start       •         • 102.49 Request Completion       •         • 0.00 Overhead       •	Call tree       Flat view         0.00 void hydro_const_theta(double, double &, double &)         0.00 void output(double *, double)         0.00 NPI_Bcast         0.00 MPI_Comm_rank         0.00 MPI_Comm_rank         0.00 MPI_comm_dup         0.00 MPI_comm_dup         0.00 MPI_comm_dup         0.00 MPI_comm_dup         0.00 MPI_comm_size         0.00 MPI_rije_gize         0.00 MPI_rype_create_subarray         0.00 MPI_rype_create_subarray         0.00 MPI_rype_create_struct         0.00 MPI_File_write_at_all         0.00 MPI_rype_free         0.00 MPI_rile_set_view         40.41 MPI_File_write_at_all         0.00 MPI_rise_close         0.00 MPI_rise_close         0.00 MPI_rise_close         0.00 MPI_rise_ise         0.00 MPI_rise_comm_free         0.00 MPI_rise_comm_free         0.00 MPI_File_dose	■ System tree       ■ Statistics       ■ Subburst       ■ Process x Inread         ■ 0.00 machine summit.ccs.ornl.gov       ■ 0.00 node f01n10       ■ 12.92 MPI Rank 0         ■ 0.43 MPI Rank 1       ■ 0.43 MPI Rank 2       ■ 0.43 MPI Rank 3         ■ 0.43 MPI Rank 5       ■ 0.43 MPI Rank 6       ■ 0.43 MPI Rank 7         ■ 0.43 MPI Rank 8       ■ 0.43 MPI Rank 8       ■ 0.43 MPI Rank 8         ■ 0.43 MPI Rank 8       ■ 0.43 MPI Rank 8       ■ 0.43 MPI Rank 10         ■ 0.43 MPI Rank 11       ■ 0.43 MPI Rank 12       ■ 0.43 MPI Rank 13         ■ 0.43 MPI Rank 14       ■ 0.43 MPI Rank 15       ■ 0.43 MPI Rank 14         ■ 0.43 MPI Rank 15       ■ 0.043 MPI Rank 14       ■ 0.43 MPI Rank 15         ■ 0.043 MPI Rank 14       ■ 0.43 MPI Rank 15       ■ 0.043 MPI Rank 16         ■ 0.43 MPI Rank 14       ■ 0.43 MPI Rank 16       ■ 0.43 MPI Rank 17         ■ 0.43 MPI Rank 18       ■ 0.43 MPI Rank 18       ■ 0.43 MPI Rank 12         ■ 0.43 MPI Rank 18       ■ 0.43 MPI Rank 12       ■ 0.43 MPI Rank 17         ■ 0.43 MPI Rank 12       ■ 0.43 MPI Rank 12       ■ 0.43 MPI Rank 12         ■ 0.43 MPI Rank 17       ■ 0.43 MPI Rank 17       ■ 0.43 MPI Rank 12         ■ 0.43 MPI Rank 20       ■ 0.43 MPI Rank 21       ■ 0.43 MPI Rank 21
	<ul> <li>Loco Bytes transferred (bytes)</li> <li>O Bytes transferred (bytes)</li> <li>4.42e10 Sent</li> <li>0 Received</li> <li>O Collective</li> <li>2.52e9 Outgoing</li> <li>2.52e9 Incoming</li> <li>O Sent</li> <li>O Sent</li> <li>O Received</li> <li>O Received</li> <li>MPI file operations (occ)</li> <li>9600 Individual</li> </ul>	<ul> <li>0.00 MPI_Get_count</li> <li>0.00 void perform_timestep(double *, double *, doub</li></ul>	<ul> <li>□ 0.43 MPI Rank 22</li> <li>□ 0.43 MPI Rank 23</li> <li>□ 0.00 node f01n13</li> <li>□ 0.43 MPI Rank 24</li> <li>□ 0.43 MPI Rank 25</li> <li>□ 0.43 MPI Rank 25</li> <li>□ 0.43 MPI Rank 26</li> <li>□ 0.43 MPI Rank 27</li> <li>□ 0.43 MPI Rank 28</li> <li>□ 0.43 MPI Rank 29</li> <li>□ 0.43 MPI Rank 29</li> <li>□ 0.43 MPI Rank 30</li> <li>■</li> </ul>



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### MPI\_Waitall variation

#### CubeGUI-4.4.3: scorep\_miniWeather\_mpi\_8p64\_sum/summary.cubex

### <u>File Display Plugins Help</u>

#### Restore Setting 🔻 Save Settin

osolute	<ul> <li>Absol</li> </ul>	lute	•	Absolute			
Metric tree	bi i i	Call tree 📋 Flat view		🚺 System tree 🚺 Statis	tics 🚺 Sunburst	🕖 Process x Thre	ead
0.00 Time (sec)	*	0.00 void hydro_const_theta(double, double &, double &)	-				
0.00 Execution		0.00 void output(double *, double)		2.24			٦
714.00 Computation		0.00 MPI Bcast					
👻 🗖 3.87 MPI		0.00 MPI Comm rank					- 2.0
🔻 🗖 0.00 Management		0.00 MPI File open		-			
27.35 Init/Finalize		0.00 MPI Comm dup					- 1.96
118.94 Communicator		0.00 MPI File get info		1.96			
831.51 File		0.00 void ncwrap(int, int)		1.80			
0.00 Window		0.00 MPI Info get					
0.00 Synchronization		0.00 MPI Info set					
0.00 Collective		0.00 MPI File write at					- 1.6
▼ □ 0.00 One-sided		0.00 MPL Comm size		-			- 1.6
0.00 Active Target				1.49			
0 00 Passive Target		0.00 MPL Type create subarray					
		$\Box 0.00 \text{ MPL Type commit}$					
25 10 Point-to-noint							
R29 39 Collective							
				1.12			-
0.41 Individual 40.41 Collective							
- 0.00 Request Landling							
O 00 Request Flanding							
0.00 Request Start				0.75			
102.49 Request Completion				0.75			
D 0.00 Overnead							
2.62e7 VISITS (OCC)							
0 Bytes transferred (bytes)		U 0.00 MPI_Get_count					
V D Point-to-point		U 0.00 void perform_timestep(double *, double *, doub	C				
4.42e10 Sent		U 0.00 void semi_discrete_step(double *, double *, double *, double	20	0.37			-
		U 0.00 void set_halo_values_x(double *)					
▼ □ 0 Collective		U 0.00 MPI_Irecv					- 0.5
2.52e9 Outgoing		U 0.00 MPI_Isend					
2.52e9 Incoming		102.49 MPI_Waitall					
<ul> <li>U 0 Remote Memory Access</li> </ul>		0.00 void compute_tendencies_x(double *, double *, double *	*	0.00			
L 0 Sent		0.00 void set_halo_values_z(double *)		0.00			
□ 0 Received		0.00 void compute_tendencies_z(double *, double *, double *	*				
O MPI file operations (occ)		🔻 🗆 0.00 void finalize()		Box Plot	O Violin Pl	nt	
9600 Individual		O 00 MPL Finalize	•	O Box Hot			
00 102.49 (3.81%) 2693	3.48 0.00	102.49 (100.00%) 102	2.49	0.50	1.60 (70.91%)		2.
· · · · · · · · · · · · · · · · · · ·							

### Information about transferred data

		X CubeGUI-4.4.3: scorep_miniWeather_mpi_8p64_sum/summary.cubex		
<u>F</u> ile <u>D</u> isplay <u>P</u> lugins <u>H</u> elp				
Restore Setting 🔻 Save Settings				
Absolute	•	Absolute	Absolute	S
Metric tree		Call tree Flat view	💽 System tree 🚺 Statistics 🚺 Sunburst 🖉 Process x Th 🕩	/sten
▼       0.00 Time (sec)         ▼       0.00 Execution         ■ 645.23 Computation         ▼       0.00 Management         ■ 84.20 Init/Finalize         ■ 119.66 Communicator         ■ 853.78 File         □ 0.00 Window         ▼       0.00 Oelective         ▼       0.00 One-sided         □ 0.00 Communication         ■ 0.00 Communication         ■ 0.00 Communication         ■ 13.26 Point-to-point         ■ 843.52 Collective         □ 0.00 One-sided         ▼       0.00 Communication         ■ 13.26 Point-to-point         ■ 843.52 Collective         □ 0.00 Collective         □ 0.00 File I/O         ■ 0.74 Individual         ■ 40.29 Collective         ■ 0.00 Request Start         ■ 112.29 Request Completion         □ 0.00 Overhead         ■ 2.43e7 Visits (occ)         ▼       □ 0 Point-to-point         ■ 4.42e10 Sent         □ 0 Received         ▼       □ 0 Collective         ■ 2.52e9 Outgoing         ■ 2.52e9 Outgoing         ■ 2.52e9 Outgoing         ■ 2.52e9 Incoming         □ 0 Received	4.93e10	<pre>     O miniWeather_mpi     O int main(int, char **)     O ovid init(int *, char **)     O MPI_Init     O MPI_Comm_size     O MPI_Comm_size     O MPI_Comm_rank     O double dmin(double, double, double &amp;, double &amp;, double &amp;     O void injection(double, double, double &amp;, double &amp;, double &amp;     O void output(double *, double)     O MPI_Barst     O MPI_Comm_rank     O MPI_Comm_rank     O MPI_Comm_dup     O MPI_File_get_info     O void nowrap(int, int)     O MPI_File_get_info     O void nowrap(int, int)     O MPI_File_set_view     O MPI_File_set_view     O MPI_File_set_view     O MPI_File_set_view     O MPI_File_close     O MPI_File_close     O MPI_File_close     O MPI_File_read_at     * O void set_halo_values_x(double *, double *, double *, dout     * O void set_halo_values_x(double *, double *, double *, dout     * O void set_halo_values_z(double *, double *, double *, double     O void compute_tendencies_z(double *, double *, double     * O void finalize()     O MPI_Finalize     Veid (100.00%)     4.42e10 (100.00%)     Attent </pre>	■ 0 machine summit.ccs.ornl.gov           *         0 node g07n09           ■ 6.91e8 MPI Rank 1           ■ 6.91e8 MPI Rank 2           ■ 6.91e8 MPI Rank 3           ■ 6.91e8 MPI Rank 4           ■ 6.91e8 MPI Rank 5           ■ 6.91e8 MPI Rank 5           ■ 6.91e8 MPI Rank 5           ■ 6.91e8 MPI Rank 6           ■ 6.91e8 MPI Rank 7           *         0 node g07n10           ■ 6.91e8 MPI Rank 10           ■ 6.91e8 MPI Rank 11           ■ 6.91e8 MPI Rank 12           ■ 6.91e8 MPI Rank 13           ■ 6.91e8 MPI Rank 14           ■ 6.91e8 MPI Rank 15           *         0 node g07n11           ■ 6.91e8 MPI Rank 16           ■ 6.91e8 MPI Rank 17           ■ 6.91e8 MPI Rank 18           ■ 6.91e8 MPI Rank 12           ■ 6.91e8 MPI Rank 21           ■ 6.91e8 MPI Rank 22           ■ 6.91e8 MPI Rank 23           *         0 node g07n12           ■ 6.91e8 MPI Rank 23           *         0 node g07n12           ■ 6.91e8 MPI Rank 23           *         0 node g07n12           ■ 6.91e8 MPI Rank 25           ■ 6.91e8 MPI Rank 26           ■ 6.91e8 MPI Rank 27           ■ 6.91e8 M	1 View Other
4.42210 (89.7070)	4.55810	4.4201	5 (5.5570) 4.42210	

Selected "MPI\_Isend"

### Read-Individual operations

#### X CubeGUI-4.4.3: scorep\_miniWeather\_mpi\_8p64\_sum/summary.cubex

File Display Plugins F	leib
------------------------	------

#### Restore Setting 🔻 Save Settings

Absolute	Absolute		•	Absolute				پ پ
Metric tree	🔚 Call tree	Flat view		🚺 System tree	🚺 Statistics	🖸 Sunburst	🕖 Process x Threa	ad
<ul> <li> <ul> <li></li></ul></li></ul>		<pre>&gt;</pre>		<ul> <li> <ul></ul></li></ul>	summit.ccs.ornl.g 01n10 MPI Rank 0 I Rank 1 I Rank 2 I Rank 2 I Rank 3 I Rank 4 I Rank 5 I Rank 6 I Rank 6 I Rank 6 I Rank 6 I Rank 7 01n11 I Rank 8 I Rank 8 I Rank 10 I Rank 10 I Rank 11 I Rank 12 I Rank 12 I Rank 12 I Rank 12 I Rank 13 I Rank 14 I Rank 15 01n12 I Rank 15 01n12 I Rank 16 I Rank 17 I Rank 18 I Rank 19 I Rank 20 I Rank 21 I Rank 21 I Rank 21 I Rank 21 I Rank 22 I Rank 23 01n13 I Rank 24 I Rank 24 I Rank 25 I Rank 25 I Rank 27 I Rank 28 I Rank 29 I Rank 30	0		
0 149 (0.12%) 1.26e	0	149 (100.00%) 14	19	0	0	(0.00%)		149
				L				

### Write-Collective operations

#### X CubeGUI-4.4.3: scorep\_miniWeather\_mpi\_8p64\_sum/summary.cubex

#### 

#### <u>File Display Plugins Help</u>

#### Restore Setting 🔻 Save Settings

Absolute	Absolute	Absolute 👻 🦿
Metric tree	Call tree II Flat view	📕 System tree 🚺 Statistics 🚺 Sunburst 📕 Process x Thread
✓ □ 0.00 Request Handling	0 void hydro_const_theta(double, double &, double &)	▼ □ 0 machine summit.ccs.ornl.gov
0.00 Request Start	O void output(double *, double)	↓ U 0 hode 101110     ↓
102.49 Request Completion	□ 0 MPI_Bcast	600 MPI Rank 1
0.00 Overnead		600 MPI Bank 2
Z.0227 VISILS (OCC) D.0 Putes transferred (butes)		600 MPI Rank 3
T O Byles transferred (byles)		■ 600 MPI Rank 4
<ul> <li>■ 4 42o10 Sont</li> </ul>	O woid newrop(int_int)	600 MPI Rank 5
		600 MPI Rank 6
		600 MPI Rank 7
2.52e9 Outgoing		• 0 node f01n11
2.52e9 Incoming	0 MPL Comm size	600 MPI Rank 8
O Remote Memory Access     O		600 MPI Rank 9
□ 0 Sent	O MPI Type create subarray	600 MPI Rank 10
O Received	0 MPI Type commit	600 MPI Rank 11
▼ □ 0 MPI file operations (occ)	0 MPI Type create hvector	600 MPI Rank 12
🔻 🗖 9600 Individual	0 MPI Type free	600 MPI Rank 13
149 Reads	0 MPI_Type_create_struct	600 MPI Rank 14
451 Writes	O MPI_File_set_view	■ 600 MPI Rank 15
7.70e4 Collective	3.84e4 MPI_File_write_at_all	▼ □ 0 node f01n12
O Reads	O MPI_Allreduce	
3.84e4 Writes	O MPI_File_close	600 MPI Rank 1/
<ul> <li>0.00 Computational imbalance (sec)</li> </ul>	0 MPI_Info_free	
18.09 Overload	0 MPI_Comm_free	600 MPI Rank 19
0.00 Single participant	0 MPI_Get_address	600 MPI Rank 20
Isogo Underload	0 MPI_File_read_at	600 MPI Rank 21
U 0.00 Non-participation		600 MPI Rank 22
	U voia perform_timestep(aouble *, aouble *,	$\sim$ 0 node f01n13
0.00 Minimum Inclusive Time (sec)	U 0 void semi_discrete_step(double *, double *, double *, double, ii	600 MPI Rank 24
■ 42.21 Maximum inclusive time (sec)		600 MPI Rank 25
		600 MPI Rank 26
		600 MPI Rank 27
3 84e8 MPLIO	$\Box$ 0 void compute tendencies x(double * double * double *)	600 MPI Rank 28
O ALLOCATION SIZE (bytes)	$\square$ 0 void set halo values z(double *)	600 MPI Rank 29
$\square$ 0 DEALLOCATION SIZE (bytes)	$\Box$ 0 void compute tendencies z(double *, double *, double *)	600 MPI Rank 30
0 bytes leaked (bytes)	▼ □ 0 void finalize()	
0.00 maximum bean memory allocated (bytes)	O MPL Finalize	All (64 elements)
0 3.84e4 (30.59%) 1.26e	5 0 3.84e4 (100.00%) 3.84e4	0 600 (1.56%) 3.84e4



### Computational imbalance - Overload

#### X CubeGUI-4.4.3: scorep\_miniWeather\_mpi\_8p64\_sum/summary.cubex

#### 

<u>File D</u>isplay <u>P</u>lugins <u>H</u>elp

#### Restore Setting 🔻 Save Settings

Metric tree       Call tree       Flat view       Statistical       Statistical       Process x Thread	Absolute 👻	Absolute	•	Absolute				▼ y
<ul> <li> <ul> <li>                  0.00 Request Handling                  102.49 Request Completion                  102.49 Request Completion                  102.49 Request Completion                  0.00 WH Reads                  0.00 WH Reads                  0.00 WH Reads                  0.00 WH Reads                      0.00 WH Reads                      0.00 WH Reads                      0.00 WH Reads                        0.00 WH Reads                          0.00 WH Reads                          0.00 WH Reads                          0.00 WH Reads                          0.00 WH Reads                               0.00 WH Reads                           0.00 WH Reads                               0.00 WH Reads</li></ul></li></ul>	Metric tree	Call tree II Flat view		🔚 System tree	🚺 Statistics	🚺 Sunburst	🕖 Process x Thread	sten
Image: Contract of the second seco	Metric tree          •       0.00 Request Handling       •         0.00 Request Start       •       102.49 Request Completion         0.00 Overhead       2.62e7 Visits (occ)       •         •       0 Point-to-point       •         •       0 Point-to-point       •         •       0 Collective       •         •       0 Received       •         •       0 Reds       •         •       149 Reads       •         •       149 Reads       •         •       0.00 Computational imbalance (sec)         •	Call tree Flat view  Call tree		<ul> <li>System tree</li> <li>0.00 machine</li> <li>0.00 node</li> <li>0.00 M</li> <li< td=""><td>Statistics     Statistics     Summit.ccs.or     f01n10     IPI Rank 0     IPI Rank 1     IPI Rank 1     IPI Rank 3     IPI Rank 4     IPI Rank 5     IPI Rank 5     IPI Rank 6     IPI Rank 7     f01n11     IPI Rank 8     IPI Rank 10     IPI Rank 10     IPI Rank 11     IPI Rank 11     IPI Rank 11     IPI Rank 13     IPI Rank 14     IPI Rank 14     IPI Rank 15     f01n12     IPI Rank 16     IPI Rank 18     IPI Rank 19     IPI Rank 12     IPI Rank 14     IPI Rank 14     IPI Rank 12     IPI Rank 21     IPI Rank 21     IPI Rank 22     IPI Rank 22     IPI Rank 23     f01n13     IPI Rank 26     IPI Rank 26     IPI Rank 27     IPI Rank 28     IPI Rank 29     IPI Rank 30</td><td>Sunburst nl.gov</td><td>Process x Thread</td><td>tem View Other</td></li<></ul>	Statistics     Statistics     Summit.ccs.or     f01n10     IPI Rank 0     IPI Rank 1     IPI Rank 1     IPI Rank 3     IPI Rank 4     IPI Rank 5     IPI Rank 5     IPI Rank 6     IPI Rank 7     f01n11     IPI Rank 8     IPI Rank 10     IPI Rank 10     IPI Rank 11     IPI Rank 11     IPI Rank 11     IPI Rank 13     IPI Rank 14     IPI Rank 14     IPI Rank 15     f01n12     IPI Rank 16     IPI Rank 18     IPI Rank 19     IPI Rank 12     IPI Rank 14     IPI Rank 14     IPI Rank 12     IPI Rank 21     IPI Rank 21     IPI Rank 22     IPI Rank 22     IPI Rank 23     f01n13     IPI Rank 26     IPI Rank 26     IPI Rank 27     IPI Rank 28     IPI Rank 29     IPI Rank 30	Sunburst nl.gov	Process x Thread	tem View Other
0.00         18.09 (50.00%)         36.17         0.00         8.55 (47.27%)         18.09         0.00         0.00 (0.00%)         8.55	0.00 maximum heap memory allocated (bytes)	O 00 MPL Finalize	•	All (64 elements)				-
	0.00 18.09 (50.00%) 36.17	0.00 8.55 (47.27%) 18.0	.09	0.00	0.	.00 (0.00%)	8	.55

### Computational imbalance - Underload

#### CubeGUI-4.4.3: scorep\_miniWeather\_mpi\_8p64\_sum/summary.cubex

#### • • •

<u>File D</u>isplay <u>P</u>lugins <u>H</u>elp

#### Restore Setting 🔻 Save Settings

Absolute 👻	Absolute	-	Absolute				• v
Netric tree	Call tree		🔚 System tree	🚺 Statistics	🚺 Sunburst	🕖 Process x Thread	stem
✓ □ 0.00 Request Handling	0.05 void hydro_const_theta(double, double &, double &)	•	<ul> <li>0.00 machine</li> </ul>	e summit.ccs.or	nl.gov		
0.00 Request Start	<ul> <li></li></ul>						×
102.49 Request Completion	0.00 MPI_Bcast		0.16 M	IPI Rank U			
0.00 Overhead	0.00 MPI_Comm_rank			IPI Rank I			0
2.62e7 Visits (occ)	0.00 MPI_File_open		■ 0.18 №	IPI Rank 2			Ť
<ul> <li>D Bytes transferred (bytes)</li> </ul>	O.00 MPI_Comm_dup		■ 0.18 M	IPI Rank 3			er,
🔻 🗆 0 Point-to-point	0.00 MPI_File_get_info		0.17 M	1PI Rank 4			
4.42e10 Sent	0.00 void ncwrap(int, int)		L 0.00 M	IPI Rank 5			
0 Received	0.00 MPI_Info_get		0.18 M	IPI Rank 6			
▼ □ 0 Collective	0.00 MPI_Info_set		0.18 M	IPI Rank 7			
2.52e9 Outgoing	0.00 MPI_File_write_at		▼ □ 0.00 node	e f01n11			
2.52e9 Incoming	0.00 MPI_Comm_size		■ 0.16 M	IPI Rank 8			
O Remote Memory Access	0.00 MPI_Type_size		□ 0.00 M	IPI Rank 9			
0 Sent	0.00 MPI_Type_create_subarray		■ 0.18 M	IPI Rank 10			
0 Received	0.00 MPI_Type_commit		■ 0.18 M	1PI Rank 11			
✓ □ 0 MPI file operations (occ)	0.00 MPI Type create hvector		■ 0.18 M	1PI Rank 12			
🔻 🗖 9600 Individual	0.00 MPI Type free		0.00 M	1PI Rank 13			
149 Reads	0.00 MPI Type create struct		□ 0.18 M	1PI Rank 14			
451 Writes	0.00 MPI File set view		■ 0.18 M	1PI Rank 15			
7.70e4 Collective	0.00 MPI File write at all	1	🔻 🗆 0.00 node	e f01n12			
0 Reads	0.00 MPI Allreduce		🖬 0.16 M	1PI Rank 16			
3.84e4 Writes	0.00 MPI File close		□ 0.00 M	1PI Rank 17			
<ul> <li>0.00 Computational imbalance (sec)</li> </ul>	0.00 MPI Info free		🖬 0.18 M	1PI Rank 18			
18.09 Overload	0.00 MPI Comm free		🗖 0.18 M	1PI Rank 19			
0.00 Single participant	0.00 MPI Get address		🖬 0.18 M	1PI Rank 20			
18.09 Underload	0.00 MPI File read at		🗆 0.00 M	1PI Rank 21			
0.00 Non-participation	0.00 MPI Get count		0.18 M	1PI Rank 22			
0.00 Singularity	0.07 void perform timestep(double *, double		0.18 M	1PI Rank 23			
0.00 Minimum Inclusive Time (sec)	0.69 void semi discrete step(double *, double *, double *, double		👻 🗆 0.00 node	e f01n13			
42.21 Maximum Inclusive Time (sec)	0.13 void set halo values x(double *)		🗖 0.17 M	1PI Rank 24			
▼ □ 0 io bytes read (bytes)	0.00 MPL Irecv		□ 0.00 M	1PI Rank 25			
3.91e7 MPI-IO	0.00 MPL Isend		🗖 0.18 M	1PI Rank 26			
▼ □ 0 io bytes written (bytes)	0.00 MPI Waitall		🗖 0.18 M	1PI Rank 27			
3.84e8 MPI-IO	8.36 void compute tendencies x(double *, double *, double *		🗖 0.18 M	1PI Rank 28			
O ALLOCATION SIZE (bytes)	0.01 void set halo values z(double *)		□ 0.00 M	1PI Rank 29			
O DEALLOCATION SIZE (bytes)	8.55 void compute tendencies z(double * double * double *		🗖 0.18 M	1PI Rank 30			-
0 bytes leaked (bytes)	<ul> <li>0.00 void finalize()</li> </ul>		4			•	
□ 0.00 maximum heap memory allocated (bytes)		•	All (64 alamasta)				
•			All (64 elements)				Ť.
0.00 18.09 (50.00%) 36.17	0.00 8.55 (47.27%) 18.09	9	0.00	0.	18 (2.14%)	8.	.55
			-				

### Computational imbalace

### **Computational load imbalance heuristic**

**Description:** 

This simple heuristic allows to identify computational load imbalances and is calculated for each (call-path, process/thread) pair. Its value represents the absolute difference to the average exclusive execution time. This average value is the aggregated exclusive time spent by all processes/threads in this call-path, divided by the number of processes/threads visiting it.





### Bytes read

X CubeGUI-4.4.3: scorep\_miniWeather\_mpi\_8p64\_sum/summary.cubex

#### <u>File Display Plugins H</u>elp

Restore Setting 🔻 Save Settings

Absolute	Absolute	Absolute 🔹 🦉
Metric tree	Call tree	💽 System tree 🚺 Statistics 🙋 Sunburst 💆 Process x Thread
Absolute  Metric tree  Metric tree   Metric tree    Description  Descr	Absolute  Call tree Flat view  Flat view  Call tree Flat view  Call tree Flat view  Flat view  Call tree Flat view  Call tree Flat view  Flat Flat view  Call tree Flat view  Flat Flat view  Flat Flat view  Flat Flat view  Flat Flat Flat Flat Flat Flat Flat Fla	Absolute System tree Statistics Suburst Process x Thread
0 DEALLOCATION_SIZE (bytes)     0 bytes_leaked (bytes)	□ 0 void compute_tendencies_z(double *, double *, double *)     ▼ □ 0 void finalize()	
L 0.00 maximum hean memory allocated (bytes)	4	All (64 elements)
0 3.91e7 (100.00%) 3.91e7	0 3.91e7 (100.00%) 3.91e	0 3.91e7 (100.00%) 3.91e7

Selected "MPI Rank 0"


### Instructions

solute	*	Absolute	- 1	Absolute				
Metric tree		Call tree Flat view		🔚 System tree	Statistics	Sunburst	🕖 Process x Th	nread
0.00 Overhead		T.97e9 void output(double *. double)	-	- ,				
2.62e7 Visits (occ)		1.09e11 MPI Bcast		1.89e10				
0 Bytes transferred (bytes)		2.96e8 MPL_Comm_rank						
O Point-to-point		1.89e11 MPI_File_open						
4.42e10 Sent		7.44e11 MPI_Comm_dup					ŀ	1.86e10
O Received		2.63e8 MPI_File_get_info						
✓ □ 0 Collective		3.70e8 void ncwrap(int, int)						
2.52e9 Outgoing		5.41e5 MPI_Info_get		1.83e10				
2.52e9 Incoming		1.01e6 MPI_Info_set		1.05010				
O Remote Memory Access		3.1/e6 MPI_File_write_at						
		I.9365 MPI_Comm_size						
U Received		9.620/ MPI_Type_size						
O MPI file operations (occ)     O MPI file operations (occ)		2.9668 MPI_Type_create_subarray						
<ul> <li>Ide Boods</li> </ul>		I 5000 MPL Type_continut		1 77010				
A51 Writes		I 73e8 MPL Type free		1.77010				
7 70e4 Collective		2 56e6 MPL Type_reate_struct						
0 Reads		3.36e10 MPL File set view						
3.84e4 Writes		1.80e11 MPI File write at all						
0.00 Computational imbalance (sec)		6.53e12 MPI Allreduce	8					
I8.09 Overload		2.63e10 MPI File close						
0.00 Single participant		7.38e7 MPI Info free		1.70e10				
🔻 🖬 18.09 Underload		6.60e8 MPI_Comm_free						
🔻 🗖 0.00 Non-participation		2.67e9 MPI_Get_address						
0.00 Singularity		8.10e5 MPI_File_read_at					Ļ	1 67e10
0.00 Minimum Inclusive Time (sec)		2.55e5 MPI_Get_count						1.07010
42.21 Maximum Inclusive Time (sec)		8.45e9 void perform_timestep(double *, double *, double *, double *, double	1					
0 io_bytes_read (bytes)		2.76e11 void semi_discrete_step(double *, double *, d	ic	1.64e10				
■ 3.91e7 MPI-IO		5.41e10 void set_halo_values_x(double *)						
0 io_bytes_written (bytes)		1.94e10 MPI_Irecv						
■ 3.8468 MPI-IO		2.34e10 MPI_Isend						
O DEALLOCATION_SIZE (bytes)		5.57611 MPI_Wallall 9.95611 yoid compute tendencies y(double * double * do	ık		<u> </u>		-	1.60e10
O bytes leaked (bytes)		5.03e9 void set halo values z(double *)	11.					
0.00 maximum hean memory allocated (bytes)		1.07e12 void compute tendencies z(double * double * do	1	1.58e10				
		8.84e5 void finalize()	-					
6.16e12 PAPI TOT CYC (#)		1.32e8 MPL Finalize						
	<b>T</b>		-	<ul> <li>Box Plot</li> </ul>		O Violin Plot		



## CUBE4 – Derived metrics – Instructions per Cycle

Ok

 Right click on any metric of the metric tree, and select "Edit metric" -> Create derived metric -> "as a root"

		🔀 Create new metric a	s a child of metric		
Select metric from	collection :	please select	• + -		
Derived metric typ	e: Postderived	metric			•
Display name :	Instructions	per cycle			
Unique name :	derived_ipc				
Data type :	DOUBLE				
Unit of measureme	ent : instructions	per cycle			
URL:					
Description :					
		Addression "+"	Accordation " "	Agaroaption "page"	
metric::PAPI_TOT_I	NS()/ <b>metric::</b> PAPI	I_TOT_CYC()	,		



# Instructions per cycle (IPC) – Useful computational workload



There is no specific rule but codes with IPC less than 1.5, can be improved



### Floating operations NOT per second

tore Setting 🔻 Save Settings									
ute	•	Absolute			•	Absolute			
Metric tree		🔚 Call tree	Flat view			🚺 System tree	🚺 Statistics	🚺 Sunburst	🕖 Process x Threa
2801.73 Time (sec) 2.62e7 Visits (occ) 4.93e10 Bytes transferred (bytes) 1.26e5 MPI file operations (occ) 36.36 Computational imbalance (sec) 0.00 Minimum Inclusive Time (sec) 3.91e7 io_bytes_read (bytes) 3.84e8 io_bytes_written (bytes) 0 ALLOCATION_SIZE (bytes) 0 DEALLOCATION_SIZE (bytes) 0 DEALLOCATION_SIZE (bytes) 0 bytes_leaked (bytes) 0.00 maximum_heap_memory_allocated (bytes) 1.12e13 PAPI_TOT_INS (#) 6.34e12 PAPI_TOT_INS (#) 6.34e12 PAPI_TOT_INS (#) 2.47e9 PAPI_L2_DCM (#)		- I - I - I	1.08e8 void output(double *, c 0 MPI_Bcast 0 MPI_Comm_rank 1.0246 MPI_File_open 1.09e6 MPI_Comm_dup 0 MPI_File_get_info 0 void ncwrap(int, int) 0 MPI_Info_get 0 MPI_Info_set 1804 MPI_File_write_at 0 MPI_Type_create_subarra 0 MPI_Type_create_subarra 0 MPI_Type_create_subarra 0 MPI_Type_create_struct 0 MPI_Type_create_struct 0 MPI_Type_create_struct 0 MPI_File_set_view 3.96e6 MPI_File_write_at_a 0 MPI_File_create_struct 0 MPI_File_create_struct 0 MPI_File_create_struct 0 MPI_File_create_struct 0 MPI_File_create_struct 0 MPI_File_set_view 3.96e6 MPI_File_write_at_a 0 MPI_File_create_struct 0 MPI_Get_address 596 MPI_File_read_at 596 MPI_File_read_at 0 MPI_Get_count 8.06e6 void perform_timestep 1.73e10 void set_halo_vi 0 MPI_Isend 0 MPI_Send 0 MPI_Finalize	double) ay r II (double *, double *, doutle e_step(double *, double *) alues_x(double *) tendencies_x(double *) tendencies_z(double *, d	ble *, double * c, double *, double	<ul> <li>         1         All (64 elements)     </li> </ul>	chine summit.cc	s.orhl.gov	
4 89e11 (100 00%)	/ 89611	0	2 50e11 (51 0	9%)	4 89e11	0	2 50e11	(100.00%)	2



# Derived metric of Floating operations to create the metric Flops

		X Cube	GUI-4.4.3: scorep_mir	iWeather_mpi_8p64_sum/	summary.cubex				
File <u>D</u> isplay <u>P</u> lugins <u>H</u> elp									
Restore Setting 🔻 Save Settings									
bsolute	Ŧ	Absolute			•	Absolute			
Ketric tree		🔚 Call tree	Flat view			🔚 Syste	em tree 🚺 Statistics	🖸 Sunburst	롣 Process x Thread
<ul> <li>2801.73 Time (sec)</li> <li>2.62e7 Visits (occ)</li> <li>4.93e10 Bytes transferred (bytes)</li> <li>1.26e5 MPI file operations (occ)</li> <li>3.6.36 Computational imbalance (sec)</li> <li>0.00 Minimum Inclusive Time (sec)</li> <li>3.91e7 io bytes read (bytes)</li> <li>3.84e8 io bytes_written (bytes)</li> <li>0 ALLOCATION SIZE (bytes)</li> <li>0 DEALLOCATION SIZE (bytes)</li> <li>0.00 maximum_heap_memory_allocated (bytes)</li> <li>1.12e13 PAPI_TOT_INS (#)</li> <li>2.47e9 PAPI_L2_DCK (#)</li> <li>1.74e8 Flops</li> </ul>			61e7 void output(doi         0.00 MPI_Coast         0.00 MPI_Comm_rai         146.80 MPI_File_or         9063.10 MPI_comm_rai         10.00 MPI_file_get, if         0.00 MPI_info_get         0.00 MPI_info_set         10.00 MPI_file_get, if         0.00 MPI_file_get, if         0.00 MPI_info_set         10.00 MPI_info_set         0.00 MPI_rope_creat         0.00 MPI_type_creat         0.00 MPI_Type_creat         0.00 MPI_rope_creat         0.00 MPI_rope_creat <td>ble *, double) ik en _dup fo t, int) ite_at e te_subarray mit te_hvector te_struct ew :e_at_all e ess d_at mestep(double *, double * screte_step(double *, double *) v id tall pute_tendencies_x(double *) pute_tendencies_z(double *) pute_tendencies_z(double</td> <td>, double *, double * ble *, double *, double **, double *, double **, double *, double</td> <td>7.87e8 7.86e8 7.85e8 7.83e8 7.83e8 7.82e8 7.81e8 0 Box</td> <td>Plot</td> <td></td> <td>- 7.86e8 - 7.85e8 - 7.85e8 - 7.85e8 - 7.85e8 - 7.85e8</td>	ble *, double) ik en _dup fo t, int) ite_at e te_subarray mit te_hvector te_struct ew :e_at_all e ess d_at mestep(double *, double * screte_step(double *, double *) v id tall pute_tendencies_x(double *) pute_tendencies_z(double *) pute_tendencies_z(double	, double *, double * ble *, double *, double **, double *, double **, double *, double	7.87e8 7.86e8 7.85e8 7.83e8 7.83e8 7.82e8 7.81e8 0 Box	Plot		- 7.86e8 - 7.85e8 - 7.85e8 - 7.85e8 - 7.85e8 - 7.85e8



### Difference between two executions

cube\_diff scorep\_miniWeather\_mpi\_4p64\_sum1/profile.cubex scorep\_miniWeather\_mpi\_8p64\_sum2/profile.cubex -c -o result.cubex

	C					
ile Display Plugins Help		X CubeGOI-4.4.3: C/result.cubex				
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Ketric tree		Call tree	🔚 System tree	I Statistics	🚺 Sunburst	🕖 Process x Thr 🔇
<ul> <li>2.62e7 Visits (occ)</li> <li>-16.94 Time (sec)</li> <li>-43.99 Minimum Inclusive Time (sec)</li> <li>43.86 Maximum Inclusive Time (sec)</li> </ul>		<ul> <li>-0.00 MPI_Barrier</li> <li>-0.27 void injection(double, double, double &amp;, double &amp;, dou</li> <li>-0.13 void hydro_const_theta(double, double &amp;, double &amp;</li> <li>-0.37 void output(double *, double)</li> </ul>	19.70		· · · · ·	
<ul> <li>O bytes_put (bytes)</li> <li>O bytes_get (bytes)</li> <li>3.91e7 io_bytes_read (bytes)</li> <li>3.84e8 io_bytes_written (bytes)</li> </ul>		<ul> <li>4.06 MPI_Bcast</li> <li>-0.01 MPI_Comm_rank</li> <li>19.31 MPI_File_open</li> <li>-57.67 MPI_Comm_dup</li> </ul>	13.13			
<ul> <li>0 ALLOCATION_SIZE (bytes)</li> <li>0 DEALLOCATION_SIZE (bytes)</li> <li>0 bytes_leaked (bytes)</li> <li>0.00 maximum_heap_memory_allocated (bytes)</li> <li>1.08e13 PAPI_TOT_INS (#)</li> </ul>		<ul> <li>-0.00 MPI_File_get_info</li> <li>-0.02 void ncwrap(int, int)</li> <li>-0.00 MPI_Info_get</li> <li>-0.00 MPI_Info_set</li> <li>0.26 MPI_File_write_at</li> </ul>	6.57			
<ul> <li>6.16e12 PAPI_TOT_CYC (#)</li> <li>4.89e11 PAPI_FP_OPS (#)</li> <li>4.68e10 bytes_sent (bytes)</li> <li>4.68e10 bytes_received (bytes)</li> <li>0 PAPI_L2_DCM (#)</li> </ul>		<ul> <li>-0.00 MPI_Comm_size</li> <li>-0.01 MPI_Type_size</li> <li>-0.01 MPI_Type_create_subarray</li> <li>-0.01 MPI_Type_commit</li> <li>-0.01 MPI_Type_create_hvector</li> </ul>	0.00			0.67
		<ul> <li>-0.01 MPI_Type_free</li> <li>-0.00 MPI_Type_create_struct</li> <li>1.35 MPI_File_set_view</li> <li>-0.01 MPI_File_write_at_all</li> </ul>	-6.57			
		<ul> <li>-8.58 MPLAIreduce</li> <li>0.55 MPLFile_close</li> <li>-0.00 MPLInfo_free</li> <li>-0.46 MPL_Comm_free</li> <li>-0.15 MPL_Get_address</li> <li>0.07 MPL File read at</li> </ul>	-13.13		<u></u>	13.17
4	-	<ul> <li>0.00 MPI_Get_count</li> <li>0.02 void perform_timestep(double *, double *, end set_halo_values_x(double *)</li> <li>0.51 MPI_Irecv</li> </ul>	-19.70		O Violin Plot	
-16 94 (100 00%)	-16.94	0.00 -8.58 (14.87%) -57.67	7 0.00	0.00 ((	0.00%)	-105 3





# Tracing with Scalasca



# Tracing with Scalasca

- Tracing can/will cause bigger overhead during the execution of the application
- More information are recorded including timeline
- Scalasca will analyze the trace according to various patterns and it will identify the bottlenecks



# How much memory buffer to use for tracing?

• Examine the profiling data

scalasca -examine **-s** /gpfs/alpine/.../scorep\_miniWeather\_mpi\_8p64\_sum INFO: Score report written to /gpfs/alpine/.../scorep\_miniWeather\_mpi\_8p64\_sum/**scorep.score** 

head /gpfs/alpine/.../scorep\_miniWeather\_mpi\_8p64\_sum/scorep.score

Estimated aggregate size of event trace: 978MB

Estimated requirements for largest trace buffer (max\_buf): 16MB

Estimated memory requirements (SCOREP\_TOTAL\_MEMORY): 18MB

• Add in your submission script (include ~10% extra):

export SCOREP\_TOTAL\_MEMORY=20MB



### Overhead

- You need to declare enough size of SCOREP\_TOTAL\_MEMORY to avoid flushing of the performance files.
- For our application, non instrumented execution on 1 node takes ~30 seconds, while for profiling and tracing is 45 and 53 seconds respectively, so 50% and 76% overhead.
- The overhead always depends on the application and what you instrument, OpenMP etc.
- We have choice of selective instrumentation or manually profiling filter



### How to use Scalasca/Score-P with tracing?

• In your submission script, replace:

scalasca -analyze jsrun ...

with

scalasca -analyze -q -t jsrun

• The -q disables the profiling.



# Initial view with tracing

•••			X CubeGUI-4.4.3: scorep_miniWeather_mpi_8p64_trace/trace.cubex						
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<ul> <li>2762.50</li> <li>2.62e7 V</li> <li>64 MPI s</li> <li>0 MPI pa</li> <li>6.98e6 T</li> <li>9.35e10</li> <li>83.45 M</li> <li>83.45 M</li> <li>2749.88</li> <li>36.72 Co</li> </ul>	Time (sec) Visits (occ) synchronizations (occ) iri-wise one-sided synchronizations (occ) MPI communications (occ) MPI file operations (occ) MPI bytes transferred (bytes) Delay costs (sec) PI point-to-point wait states (propagating vs. terminal) (sec) PI point-to-point wait states (direct vs. indirect) (sec) ritical path (sec) Performance impact (sec) omputational imbalance (sec) MPI bytes transferred (sec)		2762.50 miniWeather_mpi		<ul> <li>▶ ■ 2762.50 machi</li> <li>▲</li> <li>▲</li> <li>▲</li> <li>▲</li> <li>▲</li> <li>↓</li> <li>↓</li></ul>	ne summit.ccs.ornl.ç	<u>ov</u>	▲ ▼ ▼	1 View Other
0.00	2762.50 (100.00%) 2762.5	0	0.00 2762.50 (100.00%) 2762.50	0	0.00	2762.50 (100.00	%)	2762.50	D
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## Computation with tracing and expand trees

•••	X CubeGUI-4.4.3: scorep_miniWeather_mpi_8p64_trace/trace.cubex	
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▼ □ 0.00 Time (sec)	0.00 MPI_Type_create_hvector	<ul> <li>■ 0.00 machine summit.ccs.ornl.gov</li> <li>■ 0.00 node e04n15</li> </ul>
729 82 Computation		■ 4.82 MPI Rank 0
▼ 4.51 MPI	0.00 MPL File set view	5.50 MPI Rank 1
✓ □ 0.00 Management	0.00 MPI File write at all	■ 4.80 MPI Rank 2
94.12 Init/Finalize	0.00 MPI Allreduce	🖬 4.80 MPI Rank 3 역
0.00 Initialization Completion	0.00 MPI File close	4.80 MPI Rank 4
0.01 Wait at Finalize	0.00 MPI_Info_free	5.50 MPI Rank 5
118.16 Communicator	0.00 MPI_Comm_free	4.80 MPI Rank 6
828.23 File	0.00 MPI_Get_address	4.80 MPI Rank 7
	0.00 MPI_File_read_at	▼ ∐ 0.00 node e04n16
0.00 Wait at Create	0.00 MPI_Get_count	4.82 MPI Rank 8
0.00 Wait at Free	0.00 TRACE BUFFER FLUSH	5.50 MPI Rank 9
•	I0.44 void perform_timestep(double *, double *, double *, dou	4.80 MPI Rank 10
<ul> <li>0.00 Collective</li> </ul>	48.95 void semi_discrete_step(double *, double *, double *,	4.80 MPI Rank 11
0.00 Wait at Barrier	34.87 void set_halo_values_x(double *)	4.80 MPI Rank 12
0.00 Barrier Completion	↓ 0.00 MPI_Irecv	A 90 MPI Rank 13
▼ □ 0.00 One-sided	LI 0.00 TRACE BUFFER FLUSH	4.80 MPI Rank 14
✓ □ 0.00 Active Target		
		■ 4.82 MPI Bank 16
V L 0.00 Early Walt		5 50 MPI Bank 17
= 0.00 Late Complete		4 79 MPI Bank 18
	□ 0.00 TRACE BOFFER FLOSH	4.80 MPI Bank 19
T 0.00 Passive Target		4.80 MPI Rank 20
	4 07 void set halo values z(double *)	5.50 MPI Rank 21
0.00 Wait for Progress	291.87 void compute tendencies z(double *. double *. d	4.80 MPI Rank 22
▼ □ 0.00 Communication	0.00 TRACE BUFFER FLUSH	4.80 MPI Rank 23
55.18 Point-to-point	0.00 TRACE BUFFER FLUSH	▼ □ 0.00 node e04n18
70.27 Late Sender	0.00 TRACE BUFFER FLUSH	4.82 MPI Rank 24
0.00 Messages in Wrong Order	<ul> <li></li></ul>	5.51 MPI Rank 25
13.19 From different sources	0.00 MPI_Finalize	4
0.00 From same source		All (64 elements)
0.00 729.82 (26.42%) 2762.50	0.00 318.57 (43.65%) 729.82	0.00 0.00 (0.00%) 318.57

Selected "void compute\_tendencies\_x(double \*, double \*, double \*)"



C

### Late Sender for Point-to-Point communication



CAK RIDG

### Late Sender - Time

#### Late Sender Time

#### **Description:**

Refers to the time lost waiting caused by a blocking receive operation (e.g., MPI\_Recv or MPI\_Wait) that is posted earlier than the corresponding send operation.



If the receiving process is waiting for multiple messages to arrive (e.g., in an call to MPI\_Waitall), the maximum waiting time is accounted, i.e., the waiting time due to the latest sender.

Unit:

#### Seconds

#### **Diagnosis:**

Try to replace MPI\_Recv with a non-blocking receive MPI\_Irecv that can be posted earlier, proceed concurrently with computation, and complete with a wait operation after the message is expected to have been sent. Try to post sends earlier, such that they are available when receivers need them. Note that outstanding messages (i.e., sent before the receiver is ready) will occupy internal message buffers, and that large numbers of posted receive buffers will also introduce message management overhead, therefore moderation is advisable.

### Documentation: https://apps.fz-juelich.de/scalasca/releases/scalasca/2.5/help/scalasca\_patterns.html



### Late Sender – Wrong Order Time/Different Sources

Late Sender, Wrong Order Time / Different Sources

#### **Description:**

This specialization of the Late Sender, Wrong Order pattern refers to wrong order situations due to messages received from different source locations.



#### Unit:

Seconds

#### Diagnosis:

Check the proportion of <u>Point-to-point Receive Communications</u> that are <u>Late Sender</u>, <u>Wrong Order Instances (Communications</u>)</u>. Swap the order of receiving from different sources to match the most common ordering. Consider using the wildcard MPI\_ANY\_SOURCE to receive (and process) messages as they arrive from any source rank.



### Late Sender – Wrong Order Time/Same source

#### Late Sender, Wrong Order Time / Same Source

#### **Description:**

This specialization of the Late Sender, Wrong Order pattern refers to wrong order situations due to messages received from the same source location.



#### Unit:

Seconds

#### **Diagnosis:**

Swap the order of receiving to match the order messages are sent, or swap the order of sending to match the order they are expected to be received. Consider using the wildcard MPI\_ANY\_TAG to receive (and process) messages in the order they arrive from the source.



### MPI Wait at N x N Time

	🗙 CubeGUI-4.4.3: scorep_miniWeather_mpi_8p64_trace/trace.cubex	
<u>F</u> ile <u>D</u> isplay <u>P</u> lugins <u>H</u> elp		
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<ul> <li>0.00 Passive Target</li> <li>0.00 Uock Contention</li> <li>0.00 Wait for Progress</li> <li>0.00 Communication</li> <li>55.18 Point-to-point</li> <li>70.27 Late Sender</li> <li>13.19 From different sources</li> <li>0.00 From same source</li> <li>0.00 Late Receiver</li> <li>0.00 Early Reduce</li> <li>0.00 Early Reduce</li> <li>0.00 Early Reduce</li> <li>0.00 Early Scan</li> <li>4.23 Late Broadcast</li> <li>797.80 Wait at N x N</li> <li>0.00 Late Post</li> <li>0.00 Lock Contention</li> <li>0.00 Lock Contention</li> <li>0.00 Low Kontention</li> <li>0.00 Loce Post</li> <li>0 Distro Post</li> <li>0 Lote Post</li> <li>0 Late Senders</li> <li>0 Messages in Wrong Order</li> <li>4</li> </ul>	□ 0.00 MPI_Info_set □ 0.00 MPI_File_write_at □ 0.00 MPI_Comm_size □ 0.00 MPI_Type_size □ 0.00 MPI_Type_create_subarray □ 0.00 MPI_Type_create_hvector □ 0.00 MPI_Type_create_struct □ 0.00 MPI_Type_create_struct □ 0.00 MPI_File_set_view □ 0.00 MPI_File_write_at all <b>797.80 MPI_Allreduce</b> □ 0.00 MPI_File_close □ 0.00 MPI_File_close □ 0.00 MPI_File_count □ 0.00 MPI_File_read_at □ 0.00 MPI_Get_address □ 0.00 void perform_timestep(double *, double *, double *, double *, c × □ 0.00 void set_halo_values_x(double *) * □ 0.00 TRACE BUFFER FLUSH * □ 0.00 MPI_Isend □ 0.00 TRACE BUFFER FLUSH * □ 0.00 void compute_tendencies_x(double *, double *, dou * □ 0.00 void compute_tendencies_x(double *, double *, dou ■ 0.00 void set_halo_values_z(double *) * □ 0.00 void compute_tendencies_x(double *, double *, dou ■ 0.	• 0.00 machine summit.ccs.ornl.gov         • 0.00 node e04n15         • 0.33 MPI Rank 0         • 13.09 MPI Rank 1         • 13.09 MPI Rank 2         • 13.09 MPI Rank 3         • 13.09 MPI Rank 4         • 13.09 MPI Rank 5         • 13.09 MPI Rank 7         • 0.00 node e04n16         • 12.13 MPI Rank 7         • 0.00 node e04n16         • 12.50 MPI Rank 7         • 0.00 node e04n16         • 12.50 MPI Rank 10         • 12.50 MPI Rank 11         • 12.50 MPI Rank 12         • 12.50 MPI Rank 13         • 12.61 MPI Rank 14         • 12.73 MPI Rank 15         • 0.00 node e04n17         • 12.73 MPI Rank 15         • 0.00 node e04n17         • 12.73 MPI Rank 16         • 12.73 MPI Rank 17         • 12.73 MPI Rank 12         • 12.73 MPI Rank 21         • 12.73 MPI Rank 22         • 12.73 MPI Rank 23         • 0.00 node e04n18         • 12.55 MPI Rank 24         • 12.60 MPI Rank 25         • 12.60 MPI Rank 25
0.00 797.80 (28.88%) 2762.50	0.00 797.80 (100.00%) 797.80	0.00 0.00 (0.00%) 797.80
elected "MPL Allreduce"		

elected "MPI Allreduce"



### MPI Wait at N x N Time - Explanation

#### MPI Wait at N x N Time

#### **Description:**

Collective communication operations that send data from all processes to all processes (i.e., n-to-n) exhibit an inherent synchronization among all participants, that is, no process can finish the operation until the last process has started it. This pattern covers the time spent in n-to-n operations until all processes have reached it. It applies to the MPI calls MPI\_Reduce\_scatter, MPI\_Reduce\_scatter\_block, MPI\_Allgather, MPI\_Allgatherv, MPI\_Allreduce and MPI\_Alltoall.



Note that the time reported by this pattern is not necessarily completely waiting time since some processes could – at least theoretically – already communicate with each other while others have not yet entered the operation.

Also note that Scalasca does not yet analyze non-blocking and neighborhood collectives introduced with MPI v3.0.



### Number of MPI communications

		X CubeGUI-4.4.3: scorep_miniWeather_mpi_8p64_trace/trace.cubex			
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Keric tree		Call tree 📘 Flat view	🔙 System tree	🚺 Statistics 🛛 🚺 Sunburst	📕 Process x Thr 💷
<ul> <li>O MPI pair-wise one-sided synchronizations (occ) <ul> <li>0 Unneeded synchronizations</li> <li>0 MPI communications (occ)</li> <li>0 Point-to-point</li> <li>3.46e6 Sends <ul> <li>0 Late Receivers</li> </ul> </li> <li>2.15e6 Receives</li> <li>2.15e6 Receives</li> <li>3.40e6 Late Senders <ul> <li>0 Collective</li> <li>4.83e4 Exchange</li> <li>0 As source</li> <li>1.89e4 As destination</li> <li>0 One-sided</li> <li>0 Puts</li> <li>0 Gets</li> <li>0 Atomics</li> </ul> </li> <li>O MPI file operations (occ)</li> <li>9600 Individual <ul> <li>149 Reads</li> <li>451 Writes</li> <li>7.70e4 Collective</li> <li>0 Reads</li> <li>3.84e4 Writes</li> </ul> </li> </ul></li></ul>		<pre>     O MPI_Info_set     O MPI_comm_size     O MPI_Type_commit     O MPI_Type_commit     O MPI_Type_create_subarray     O MPI_Type_create_hvector     O MPI_Type_create_truct     O MPI_Type_create_struct     O MPI_Type_create_struct     O MPI_File_set_view     O MPI_File_set_view     O MPI_File_write_at_all     O MPI_file_close     O MPI_comm_free     O MPI_file_close     O MPI_Get_address     O MPI_Get_address     O MPI_Get_count     O TRACE BUFFER FLUSH     * 0 void set_halo_values_x(double *, double *, double *, double *     * 0 0 void Set_halo_values_x(double *)     * 0 0 MPI_Isend </pre>	6.45e4 5.81e4 5.16e4 4.52e4 3.87e4 3.23e4		- 5.39e4 - 5.12e4 - 3.36e4
<ul> <li>O Point-to-point</li> <li>4.42e10 Sent</li> <li>4.42e10 Received</li> <li>O Collective</li> <li>2.52e9 Outgoing</li> <li>2.52e9 Incoming</li> <li>O One-sided</li> <li>0 Sent</li> </ul>	•	<ul> <li>O TRACE BUFFER FLUSH</li> <li>2.15e6 MPI_Waitall</li> <li>O TRACE BUFFER FLUSH</li> <li>O TRACE BUFFER FLUSH</li> <li>Void compute_tendencies_x(double *, double *, double</li> <li>O TRACE BUFFER FLUSH</li> <li>O TRACE BUFFER FLUSH</li> <li>O void set_halo_values_z(double *)</li> <li>Void compute_tendencies z(double *, double *, double *</li> </ul>	3.23e4     2.58e4     Box Plot	Violin Plot	<sup>2.71e4</sup>
2.15 6 (20.020)	6 00 06	0 2 1566 (100 00%) 2 1566	2 70 04	3 36e4 (24 60%)	5 30 04

selected "MPI\_Waitall"



### Short and Long-term delay

#### Short-term MPI Late Sender Delay Costs

#### **Description:**

Short-term delay costs reflect the direct effect of load or communication imbalance on MPI Late Sender wait states.

#### Unit:

Seconds

#### Diagnosis:

High short-term delay costs indicate a computation or communication overload in/on the affected call paths and processes/threads. Because of this overload, the affected processes/threads arrive late at subsequent MPI send operations, thus causing Late Sender wait states on the remote processes.

Compare with <u>MPI Late Sender Time</u> to identify an imbalance pattern. Try to reduce workload in the affected call paths. Alternatively, shift workload in the affected call paths from processes/threads with delay costs to processes/threads that exhibit late-sender wait states.

#### Long-term MPI Late Sender Delay Costs

#### **Description:**

Long-term delay costs reflect indirect effects of load or communication imbalance on wait states. That is, they cover waiting time that was caused indirectly by wait states which themselves delay subsequent communication operations.

#### Unit:

Seconds

#### **Diagnosis:**

High long-term delay costs indicate that computation or communication overload in/on the affected call paths and processes/threads has far-reaching effects. That is, the wait states caused by the original computational overload spread along the communication chain to remote locations.

Try to reduce workload in the affected call paths, or shift workload from processes/threads with delay costs to processes/threads that exhibit Late Sender wait states. Try to implement a more asynchronous communication pattern that can compensate for small imbalances, e.g., by using non-blocking instead of blocking communication.



### Long-term delay sender



Selected "void compute\_tendencies\_x(double \*, double \*, double \*)"



## Long-term delay sender

hestore setting a save settings		Abaabata			Abaabaa				
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**CAK RIDGE** National Laboratory

# Propagating wait states





### Tracing start

### **Propagating MPI Point-to-point Wait States**

(only available after <u>remapping</u>)

### **Description:**

Waiting time in MPI point-to-point operations that propagates further and causes additional waiting time on other processes. **Unit:** 

Seconds

### **Terminal MPI Point-to-point Wait States**

(only available after <u>remapping</u>)

### **Description:**

Waiting time in MPI point-to-point operations that does not propagate further.



### Terminal wait states

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O.00 Inter-partition imbalance		
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selected "Late Sender"



C

### Direct wait stats

X CubeGUI-4.4.3: scorep\_miniWeather\_mpi\_8p64\_trace/trace.cubex

#### File Display Plugins Help

#### Restore Setting 🔻 Save Settings



Selected "Late Sende



### Wait States

### MPI Point-to-point Wait State Classification: Direct vs. Indirect

(only available after <u>remapping</u>)

### **Description:**

Partitions MPI point-to-point wait states into waiting time directly caused by delays and waiting time caused by propagation. Unit:

Seconds

### **Direct MPI Point-to-point Wait States**

(only available after <u>remapping</u>)

**Description:** 

Waiting time in MPI point-to-point operations that results from direct delay, i.e., is directly caused by a load- or communication imbalance. Unit: Seconds

### Indirect MPI Point-to-point Wait States

(only available after <u>remapping</u>)

#### **Description:**

Waiting time in MPI point-to-point operations that results from indirect delay, i.e., is caused indirectly by wait-state propagation. Unit:

Seconds



# Imbalance in the critical path

• •		X	CubeGUI-4.4.3: scorep_miniWeather_mpi_8p64_trace/trace.cubex		
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🔻 🗆 0.00 Inc	direct wait states		11.92 MPI_File_write_at_all	0.00 MPI Rank 18	
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🗖 25.20 lr	mbalance		0.00 MPI_Comm_free	0.00 MPI Rank 22	
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□ 0	.00 Inter-partition imbalance		Image:	All (64 elements)	•
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### Critical Path Profile

#### **Critical Path Profile**

#### **Description:**

This metric provides a profile of the application's critical path. Following the causality chain from the last active program process/thread back to the program start, the critical path shows the call paths and processes/threads that are responsible for the program's wall-clock runtime.



Note that Scalasca does not yet consider POSIX threads when determining the critical path. Thus, the critical-path profile is currently incorrect if POSIX threads are being used, as only the master thread of each process is taken into account. However, it may still provide useful insights across processes for hybrid MPI+Pthreads applications.

#### Unit:

#### Seconds

#### **Diagnosis:**

Call paths that occupy a lot of time on the critical path are good optimization candidates. In contrast, optimizing call paths that do not appear on the critical path will not improve program runtime.

Call paths that spend a disproportionately large amount of time on the critical path with respect to their total execution time indicate parallel bottlenecks, such as load imbalance or serial execution. Use the percentage view modes and compare execution time and critical path profiles to identify such call paths.

The system tree pane shows the contribution of individual processes/threads to the critical path. However, note that the critical path runs only on one process at a time. In a well-balanced program, the critical path follows a more-or-less random course across processes and may not visit many processes at all. Therefore, a high critical-path time on individual processes does not necessarily indicate a performance problem. Exceptions are significant load imbalances or serial execution on single processes. Use the critical-path imbalance metric or compare with the distribution of execution time across processes to identify such cases.



### Critical Path Imbalance

#### **Description:**

This metric highlights parallel performance bottlenecks.

In essence, the critical-path imbalance is the positive difference of the time a call path occupies on the critical path and the call path's average runtime across all CPU locations. Thus, a high critical-path imbalance identifies call paths which spend a disproportionate amount of time on the critical path.



The image above illustrates the critical-path profile and the critical-path imbalance for the example in the <u>Critical Path Profile</u> metric description. Note that the excess time of regions foo and baz on the critical path compared to their average execution time is marked as imbalance. While also on the critical path, region bar is perfectly balanced between the processes and therefore has no contribution to critical-path imbalance.

#### Unit:

Seconds

#### **Diagnosis:**

A high critical-path imbalance indicates a parallel bottleneck, such as load imbalance or serial execution. Cross-analyze with other metrics, such as the distribution of execution time across CPU locations, to identify the type and causes of the parallel bottleneck.



### Intra-partition Imbalance

CubeGUI-4.4.3: scorep_miniWeather_mpi_8p64_trace/trace.cubex			
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Absolute	Absolute	Absolute	
Metric tree	Call tree	📗 System tree 🚺 Statistics 🔯 Sunburst 📝 Process x Thr 🕩	
<ul> <li>796.45 Short-term</li> <li>1.35 Long-term</li> <li>2.86 Short-term</li> <li>2.86 Short-term</li> <li>1.35 Long-term</li> <li>2.86 Short-term</li> <li>1.35 Long-term</li> <li>0.00 MPI point-to-point wait states (propagating vs. terminal) (sec)</li> <li>0.00 Propagating wait states</li> <li>39.16 Late Sender</li> <li>0.00 Late Receiver</li> <li>0.00 Late Receiver</li> <li>0.00 Late Receiver</li> <li>0.00 Direct wait states (direct vs. indirect) (sec)</li> <li>0.00 Late Receiver</li> <li>0.00 Late Receiver</li> <li>0.00 Late Receiver</li> <li>0.00 Direct wait states</li> <li>44.30 Late Sender</li> <li>0.00 Direct wait states</li> <li>39.16 Late Sender</li> <li>0.00 Late Receiver</li> <li>0.00 Indirect wait states</li> <li>39.16 Late Sender</li> <li>0.00 Late Receiver</li> <li>17.77 Critical path (sec)</li> <li>25.20 Imbalance</li> <li>0.00 Performance impact (sec)</li> <li>0.00 Critical-path activities</li> <li>113.380 Activity impact</li> <li>0.00 Imbalance impact</li> <li>0.00 Imbalance impact</li> <li>0.00 Computational imbalance</li> <li>731.13 Non-critical-path activities</li> <li>18.36 Overload</li> <li>0.00 Single participant</li> <li>18.36 Underload</li> <li>0.00 Non-participation</li> </ul>	<ul> <li>0.00 double dmin(double, double)</li> <li>0.00 MPI_Barrier</li> <li>0.03 void injection(double, double, double &amp;, double &amp;, double &amp;</li> <li>0.03 void output(double *, double)</li> <li>0.26 MPI_Bcast</li> <li>0.00 MPI_Comm_rank</li> <li>5.68 MPI_File_open</li> <li>382.17 MPI_Comm_dup</li> <li>0.00 MPI_Info_get</li> <li>0.00 MPI_Info_get</li> <li>0.00 MPI_File_write_at</li> <li>0.00 MPI_Type_create_subarray</li> <li>0.05 MPI_Type_create_subarray</li> <li>0.05 MPI_Type_free</li> <li>0.07 MPI_Type_free</li> <li>0.07 MPI_Type_free</li> <li>0.00 MPI_Allreduce</li> <li>6.54 MPI_File_close</li> <li>0.00 MPI_Info_free</li> <li>0.00 MPI_Info_free</li> <li>0.00 MPI_Allreduce</li> <li>6.54 MPI_File_close</li> <li>0.00 MPI_Comm_free</li> <li>0.00 MPI_Comm_free</li> <li>0.00 MPI_Comm_free</li> <li>0.00 MPI_Comm_free</li> <li>0.01 MPI_Get_count</li> <li>0.00 MPI_Comm_free</li> <li>0.01 MPI_Get_count</li> <li>0.00 MPI_FILE_read_at</li> <li>0.01 MPI_Get_count</li> <li>0.00 MPI_FILE_read_at</li> <li>0.11 void perform_timestep(double *, double *, d</li></ul>	• 0.00 machine summit.ccs.ornl.gov         • 0.00 node e04n15         • 425.74 MPI Rank 0         0.00 MPI Rank 1         0.00 MPI Rank 3         0.00 MPI Rank 4         0.00 MPI Rank 5         0.00 MPI Rank 6         0.00 MPI Rank 7         • 0.00 MPI Rank 8         0.00 MPI Rank 8         0.00 MPI Rank 8         0.00 MPI Rank 8         0.00 MPI Rank 10         0.00 MPI Rank 11         0.00 MPI Rank 12         0.00 MPI Rank 13         0.00 MPI Rank 14         0.00 MPI Rank 15         * 0.00 MPI Rank 16         0.00 MPI Rank 12         0.00 MPI Rank 13         0.00 MPI Rank 14         0.00 MPI Rank 15         * 0.00 node e04n17         0.00 MPI Rank 18         0.00 MPI Rank 16         0.00 MPI Rank 18         0.00 MPI Rank 21         0.00 MPI Rank 23         * 0.00 MPI Rank 23         * 0.00 MPI Rank 23         * 0.00 MPI Rank 25         •	
0.00 884.94 (32.18%) 2749.8	8 0.00 434.77 (49.13%) 884.94	0.00 0.00 (0.00%) 434.77	

Selected "MPI\_File\_write\_at\_all"



Open slide master to edit

### Non Critical Path Activities

	🔀 CubeGUI-4.4.3: scorep_miniWeather_mpi_8p64_trace/trace.cubex	
<u>F</u> ile <u>D</u> isplay <u>P</u> lugins <u>H</u> elp		
Restore Setting 🔻 Save Settings		
Absolute	Absolute	Absolute ۲ پ
Metric tree	Call tree Flat view	💽 System tree 🚺 Statistics 🔯 Sunburst 🖉 Process x Thr 🕩 🛱
796.45 Short-term	0.00 double dmin(double, double)	🔹 🗖 0.00 machine summit.ccs.ornl.gov
1.35 Long-term	0.00 MPI_Barrier	▼ □ 0.00 node e04n15
👻 🗆 0.00 Late Broadcast	🔻 🔲 0.15 void injection(double, double, double &, double &, dou	0.00 MPI Rank 0
2.86 Short-term	0.06 void hydro_const_theta(double, double &, double &	0.00 MPI Rank 1
1.35 Long-term	0.00 void output(double *, double)	0.00 MPI Rank 2
💌 🗆 0.00 MPI point-to-point wait states (propagating vs. terminal) (sec)	0.52 MPI_Bcast	0.00 MPI Rank 3 약
🔻 🗆 0.00 Propagating wait states	0.00 MPI_Comm_rank	0.00 MPI Rank 4
39.16 Late Sender	725.01 MPI_File_open	0.00 MPI Rank 5
0.00 Late Receiver	0.00 MPI_Comm_dup	0.00 MPI Rank 6
👻 🗆 0.00 Terminal wait states	0.00 MPI_File_get_info	0.00 MPI Rank 7
44.30 Late Sender	0.00 void ncwrap(int, int)	▼ □ 0.00 node e04n16
0.00 Late Receiver	0.00 MPI_Info_get	13.00 MPI Rank 8
<ul> <li>0.00 MPI point-to-point wait states (direct vs. indirect) (sec)</li> </ul>	0.00 MPI_Info_set	12.97 MPI Rank 9
•	0.45 MPI_File_write_at	12.97 MPI Rank 10
44.30 Late Sender	0.00 MPI_Comm_size	12.98 MPI Rank 11
0.00 Late Receiver	0.00 MPI_Type_size	
<ul> <li>0.00 Indirect wait states</li> </ul>	0.00 MPI_Type_create_subarray	12.99 MPI Rank 13
39.16 Late Sender	0.00 MPI_Type_commit	■ 12.95 MPI Rank 14
0.00 Late Receiver	0.00 MPI_Type_create_hvector	
I7.77 Critical path (sec)	0.00 MPI_Type_free	▼ □ 0.00 node e04n17
25.20 Imbalance	0.00 MPI_Type_create_struct	12.83 MPI Rank 16
<ul> <li>0.00 Performance impact (sec)</li> </ul>	0.28 MPI_File_set_view	12.82 MPI Rank 17
<ul> <li>0.00 Critical-path activities</li> </ul>	0.00 MPI_File_write_at_all	12.79 MPI Rank 18
1133.80 Activity impact	0.07 MPI_Allreduce	12.83 MPI Rank 19
<ul> <li>0.00 Imbalance impact</li> </ul>	0.00 MPI_File_close	12.83 MPI Rank 20
884.94 Intra-partition imbalance	0.00 MPI_Into_free	12.82 MPI Kalik 21
0.00 Inter-partition imbalance	0.38 MPI_Comm_free	12.82 MPI Rank 22
731.13 Non-critical-path activities	0.02 MPI_Get_address	
<ul> <li>0.00 Computational imbalance (sec)</li> </ul>	0.00 MPI_File_read_at	• 10.00 Hode e04118
▼ ■ 18.36 Overload	□ 0.00 MPI_Get_count	12.99 MFI Kalik 24
D 0.00 Single participant		
V II 18.36 Underload	♥ ■ 0.01 Voia perform_timestep(double *, double *, d	
U 0.00 Non-participation		All (64 elements)
0.00 731.13 (26.59%) 2749.8	B 0.00 725.01 (99.16%) 731.13	0.00 0.00 (0.00%) 725.01

Selected "MPI\_File\_open"





### Scalasca with MPI+OpenMP



### MiniWeather – MPI+OMP

• Compile:

MPI: make PREP="scorep --mpp=mpi -openmp --pdt" openmp

Execution (submission script):

scalasca -analyze -q -t jsrun -n 16 -r 2 -a 1 -c 8 "-b packed:8" ./miniWeather\_mpi\_openmp

• Visualize:

# scalasca -examine /gpfs/.../ scorep\_miniWeather\_mpi\_openmp\_2p16x8\_trace



### **OpenMP** Views

#### X CubeGUI-4.4.3: scorep\_miniWeather\_mpi\_openmp\_2p16x8\_trace/trace.cubex

#### File Display Plugins Help Restore Setting Save Settings Absolute Absolute Absolute $\mathbf{w}$ w. System View Flat view 🔚 Call tree 🔚 System tree Statistics Ounburst 🕖 Process x Thr Metric tree 0.00 machine summit.ccs.ornl.gov 0.00 Time (sec) D 0.00 !\$omp for @miniWeather mpi openmp.cpp:505 0.00 node a03n07 0.00 Execution 0.00 MPI Rank 0 0.00 void hydro const theta(double, double &, dou 958.21 Computation 0.11 Master thread 495.11 MPI 0.00 !\$omp implicit barrier @miniWeather mpi open Other 0.13 OMP thread 1 0.00 OpenMP Image: Some parallel @miniWeather mpi openmp.cpp:546 0.13 OMP thread 2 💌 🗖 141.63 Management 0.00 !\$omp for @miniWeather mpi openmp.cpp:546 0.13 OMP thread 3 115.08 Fork 0.00 void injection(double, double, double &, double 0.12 OMP thread 4 ISPACE 159.39 Synchronization 0.00 void hydro const theta(double, double &, double 0.12 OMP thread 5 0.00 Flush 0.00 !\$omp implicit barrier @miniWeather mpi open 0.12 OMP thread 6 2.63 Overhead • 0.00 !\$omp parallel @miniWeather mpi openmp.cpp:564 0.11 OMP thread 7 3642.54 Idle threads 0.00 MPI Rank 1 1.02e8 Visits (occ) 0.00 void injection(double, double, double &, double & 0.11 Master thread If MPI synchronizations (occ) 0.00 void hydro const theta(double, double &, double 0.13 OMP thread 1 I 0 MPI pair-wise one-sided synchronizations (occ) 0.00 !\$omp implicit barrier @miniWeather mpi open 0.12 OMP thread 2 I.74e6 MPI communications (occ) Image: 0.12 OMP thread 3 3.20e4 MPI file operations (occ) 0.00 void perform timestep(double \*, double 0.12 OMP thread 4 2.34e10 MPI bytes transferred (bytes) 0.00 void semi discrete step(double \*, double \*, doub 0.12 OMP thread 5 2959.85 Delay costs (sec) 0.00 void set halo values x(double \*) 0.11 OMP thread 6 E 26.39 MPI point-to-point wait states (propagating vs. terminal) (sec) 0.11 OMP thread 7 E 26.39 MPI point-to-point wait states (direct vs. indirect) (sec) 0.00 TRACE BUFFER FLUSH 0.00 node b16n15 42.64 Critical path (sec) I5.25 !\$omp parallel @miniWeather mpi openmp.cp 0.00 MPI Rank 2 5466.59 Performance impact (sec) 0.11 Master thread E 22.72 Computational imbalance (sec) • 0.00 !\$omp implicit barrier @miniWeather mpi 0.13 OMP thread 1 0.00 TRACE BUFFER FLUSH 0.13 OMP thread 2 0.00 TRACE BUFFER FLUSH 0.12 OMP thread 3 0.00 TRACE BUFFER FLUSH 0.12 OMP thread 4 0.00 MPI Isend 0.12 OMP thread 5 0.00 TRACE BUFFER FLUSH 0.11 OMP thread 6 0.00 MPI Waitall 0.11 OMP thread 7 0.00 TRACE BUFFER FLUSH I5.48 !\$omp parallel @miniWeather mpi openmp.cp Þ D.00 !\$omp implicit barrier @miniWeather mpi All (128 elements) Ŧ • 4 5514.58 0.00 15.25 (10.77%) 141.63 0.00 0.00 141.63 (2.57%) 0.00 (0.00%) 15.25

Selected "!\$omp parallel @miniWeather mpi openmp.cpp:351"



C
# **OpenMP** Thread Management Time

#### **OpenMP Thread Management Time**

#### **Description:**

Time spent managing teams of threads, creating and initializing them when forking a new parallel region and clearing up afterwards when joining.



#### Unit:

Seconds

#### **Diagnosis:**

Management overhead for an OpenMP parallel region depends on the number of threads to be employed and the number of variables to be initialized and saved for each thread, each time the parallel region is executed. Typically a pool of threads is used by the OpenMP runtime system to avoid forking and joining threads in each parallel region, however, threads from the pool still need to be added to the team and assigned tasks to perform according to the specified schedule. When the overhead is a significant proportion of the time for executing the parallel region, it is worth investigating whether several parallel regions can be combined to amortize thread management overheads. Alternatively, it may be appropriate to reduce the number of threads either for the entire execution or only for this parallel region (e.g., via num\_threads or if clauses).



### Duration of Fork

X CubeGUI-4.4.3: scorep\_miniWeather\_mpi\_openmp\_2p16x8\_trace/trace.cubex

#### File Display Plugins Help Restore Setting Save Settings Absolute Absolute Absolute Ŧ Ŧ System 🔚 System tree 🚺 Statistics 🛛 🚺 Sunburst 🛛 🕖 Process x Thr 📜 Metric tree 🔚 Call tree Flat view 0.00 machine summit.ccs.ornl.gov View 0.00 Time (sec) - 0.00 node a03n07 0.00 Execution 0.00 void injection(double, double, double &, double & 0.00 MPI Rank 0 0.00 void hydro const theta(double, double &, dou 958.21 Computation 0.10 Master thread 495.11 MPI 0.00 !\$omp implicit barrier @miniWeather mpi openi Other 0.09 OMP thread 1 0.00 OpenMP • 0.00 !\$omp parallel @miniWeather mpi openmp.cpp:546 0.10 OMP thread 2 I41.63 Management ▼ □ 0.00 !\$omp for @miniWeather mpi openmp.cpp:546 0.10 OMP thread 3 115.08 Fork 0.00 void injection(double, double, double &, double 0.10 OMP thread 4 I59.39 Synchronization 0.00 void hydro const theta(double, double &, dou 0.00 Flush 0.00 !\$omp implicit barrier @miniWeather mpi open 0.10 OMP thread 5 0.11 OMP thread 6 2.63 Overhead • 0.00 !\$omp parallel @miniWeather mpi openmp.cpp:564 0.11 OMP thread 7 3642.54 Idle threads ▼ □ 0.00 !\$omp for @miniWeather mpi openmp.cpp:564 0.00 MPI Rank 1 0.00 void injection(double, double, double &, double & 1.02e8 Visits (occ) 0.10 Master thread If MPI synchronizations (occ) 0.00 void hydro const theta(double, double &, double 0.09 OMP thread 1 I 0 MPI pair-wise one-sided synchronizations (occ) 0.00 !\$omp implicit barrier @miniWeather mpi open 0.10 OMP thread 2 I.74e6 MPI communications (occ) Image: 3.20e4 MPI file operations (occ) 0.00 void perform timestep(double \*, double 0.10 OMP thread 3 0.10 OMP thread 4 2.34e10 MPI bytes transferred (bytes) 0.00 void semi discrete step(double \*, double \*, doub 0.10 OMP thread 5 2959.85 Delay costs (sec) 0.00 void set halo values x(double \*) 0.11 OMP thread 6 E 26.39 MPI point-to-point wait states (propagating vs. terminal) (sec) 0.11 OMP thread 7 26.39 MPI point-to-point wait states (direct vs. indirect) (sec) 0.00 TRACE BUFFER FLUSH 0.00 node b16n15 42.64 Critical path (sec) 🝷 🗖 13.06 !\$omp parallel @miniWeather\_mpi\_openmp.cp 5466.59 Performance impact (sec) 0.00 !\$omp for @miniWeather mpi openmp.cpp:3 0.11 Master thread 22.72 Computational imbalance (sec) 0.00 !\$omp implicit barrier @miniWeather mpi 0.09 OMP thread 1 0.00 TRACE BUFFER FLUSH 0.10 OMP thread 2 0.00 TRACE BUFFER FLUSH 0.10 OMP thread 3 0.00 TRACE BUFFER FLUSH 0.10 OMP thread 4 👻 🗌 0.00 MPI Isend 0.10 OMP thread 5 0.00 TRACE BUFFER FLUSH 0.11 OMP thread 6 0.00 MPI Waitall 0.11 OMP thread 7 0.00 TRACE BUFFER FLUSH 0.00 MPI Rank 3 I3.92 !\$omp parallel @miniWeather mpi openmp.cp • 0.00 !\$omp for @miniWeather mpi openmp.cpp:3 🝷 🗌 0.00 !\$omp implicit barrier @miniWeather\_mpi All (128 elements) Ŧ • 5514.58 0.00 0.00 0.00 115.08 115.08 (2.09%) 13.06 (11.35%) 0.00 (0.00%) 13.06

Selected "Fork"

**CAK RIDGE** National Laboratory

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# Source code of corresponding OpenMP call

	X CubeGUI-4.4.3: scorep_miniWeather_mpi_openmp_2p16x8_trace/trace.cubex		
<u>F</u> ile <u>D</u> isplay <u>P</u> lugins <u>H</u> elp			
Restore Setting 🝷 Save Settings			
Absolute	Absolute 🔹	Score-P Configuration	sy
<ul> <li>Metric tree</li> <li>Metric tree</li> <li>0.00 Time (sec) <ul> <li>0.00 Execution</li> <li>958.21 Computation</li> <li>495.11 MPI</li> <li>0.00 OpenMP</li> <li>141.63 Management</li> </ul> </li> <li>150.98 Fork</li> <li>159.39 Synchronization <ul> <li>0.00 Flush</li> <li>2.63 Overhead</li> <li>3642.54 Idle threads</li> <li>1.02e8 Visits (occ)</li> </ul> </li> <li>16 MPI synchronizations (occ)</li> <li>174e6 MPI communications (occ)</li> <li>3.20e4 MPI file operations (occ)</li> <li>2.34e10 MPI bytes transferred (bytes)</li> <li>2959.85 Delay costs (sec)</li> <li>26.39 MPI point-to-point wait states (propagating vs. terminal) (sec)</li> <li>26.39 MPI point-to-point wait states (direct vs. indirect) (sec)</li> <li>42.64 Critical path (sec)</li> <li>5466.59 Performance impact (sec)</li> <li>22.72 Computational imbalance (sec)</li> </ul>	<pre>Call tree Flat view Call tree Flat view Call tree Flat view Call tree Flat view Call tree Flush Call tree Call tr</pre>	<pre>334 } 334 } 334 } 335 } 336 } 337 } 338 339 340 //Set this MPI task's halo values in the x-direction. This routine 341 void set_halo_values_x( double *state ) { 342 int k, ll, ind_r, ind_u, ind_t, i, s, ierr; 343 double z; 344 MPI_Request req_r[2], req_s[2]; 345 346 //Prepost receives 347 ierr = MPI_Irecv(recvbuf_I,hs*nz*NUM_VARS,MPI_DOUBLE, left 348 ierr = MPI_Irecv(recvbuf_r,hs*nz*NUM_VARS,MPI_DOUBLE, righ 349 350 //Pack the send buffers 351 #pragma omp parallel for private(s) collapse(2) 352 for (ll=0; ll<num_vars; (k="0;" (s="0;" +="" 353="" 354="" 355="" 356="" 357="" 358="" 359="" 360="" 361="" 362="" 363="" 364="" 365="" 366="" 367="" 367<="" 368="" 369="" finish="" fire="" for="" ierr="MPI_Waitall(2,req_r,MPI_STATUSES_IGNORE);" k*hs="" k++)="" k<nz;="" lef="" ll++)="" off="" receives="" s++)="" s<hs;="" s]="state[ll*(nz+2*hs)*(nx+2" sendbuf_[[ll*nz*hs="" sendbuf_r[ll*nz*hs="" sends="" td="" the="" to="" wait="" {="" }=""><td>system View Other</td></num_vars;></pre>	system View Other
0.00 115.08 (2.09%) 5514.58	0.00 13.06 (11.35%) 115.08	369 #pragma omp parallel for private(s) collapse(2)	
Selected "Fork"			

Selected "Fork'



### OpenMP Thread Team Fork

### **OpenMP** Thread Team Fork Time

#### **Description:**

Time spent creating and initializing teams of threads.





### Implicit Synchronization

#### X CubeGUI-4.4.3: scorep\_miniWeather\_mpi\_openmp\_2p16x8\_trace/trace.cubex File Display Plugins Help Restore Setting Save Settings Absolute w. Absolute Ŧ Absolute System 🚺 Statistics 🚺 Sunburst Metric tree Call tree Flat view 🔚 System tree 🕖 Process x Thr 0.00 void perform timestep(double \*, double \*, double \*, double \* View 0.00 Execution 0.00 void semi discrete step(double \*, double \*, doub 0.10 0.10 958.21 Computation 0.00 void set halo values x(double \*) 495.11 MPI Other 0.00 OpenMP 0.00 TRACE BUFFER FLUSH I41.63 Management 🝷 🗖 0.00 !\$omp parallel @miniWeather mpi openmp.cpp 0.10 115.08 Fork 0.00 !\$omp for @miniWeather mpi openmp.cpp:3 I1.39 !somp implicit barrier @miniWeather mi 0.00 Synchronization 0.00 TRACE BUFFER FLUSH 0.00 Barrier 0.09 0.00 Explicit 0.00 TRACE BUFFER FLUSH 104.97 Implicit 0.00 TRACE BUFFER FLUSH 0.09 54.42 Wait at Barrier 🝷 🗌 0.00 MPI Isend 0.00 TRACE BUFFER FLUSH D 0.00 Critical 0.09 0.00 MPI Waitall 0.00 TRACE BUFFER FLUSH 0.00 Ordered 0.00 Task Wait 0.09 0.00 Flush • 0.00 !\$omp for @miniWeather mpi openmp.cpp:3 2.63 Overhead I1.42 !\$omp implicit barrier @miniWeather mp 3642.54 Idle threads 0.00 TRACE BUFFER FLUSH 0.08 1.02e8 Visits (occ) 0.00 TRACE BUFFER FLUSH 0.08 0.00 TRACE BUFFER FLUSH If MPI synchronizations (occ) I 0 MPI pair-wise one-sided synchronizations (occ) 0.00 !\$omp parallel @miniWeather mpi openmp.cpp I.74e6 MPI communications (occ) 3.20e4 MPI file operations (occ) 0.71 !\$omp implicit barrier @miniWeather mpi 2.34e10 MPI bytes transferred (bytes) 0.00 TRACE BUFFER FLUSH 0.08 0.08 2959.85 Delay costs (sec) 0.00 TRACE BUFFER FLUSH E 26.39 MPI point-to-point wait states (propagating vs. terminal) (sec) 0.00 TRACE BUFFER FLUSH E 26.39 MPI point-to-point wait states (direct vs. indirect) (sec) ▼ □ 0.00 void compute tendencies x(double \*, double 42.64 Critical path (sec) 0.00 !\$omp parallel @miniWeather mpi openmp.cpp 5466.59 Performance impact (sec) 0.07 E 22.72 Computational imbalance (sec) I1.74 !somp implicit barrier @miniWeather mr 0.00 TRACE BUFFER FLUSH O Violin Plot Box Plot 0.00 TRACE BUFFER FLUSH • F 4 104.97 0.08 5514.58 0.00 0.09 (48.09%) 0.00 104.97 (1.90%) 11.39 (10.85%) 0.10

Selected "!\$omp implicit barrier @miniWeather\_mpi\_openmp.cpp:359"

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# Implicit Synchronization - Explanation

#### **OpenMP Implicit Barrier Synchronization Time**

(only available after <u>remapping</u>)

#### **Description:**

Time spent in implicit (i.e., compiler-generated) OpenMP barrier synchronization, both waiting for other threads <u>Wait at Implicit OpenMP Barrier Time</u> and inherent barrier processing overhead. **Unit:** 

Seconds

#### **Diagnosis:**

Examine the time that each thread spends waiting at each implicit barrier, and if there is a significant imbalance then investigate whether a schedule clause is appropriate. Note that dynamic and guided schedules may require more <u>OpenMP Thread Management Time</u> than static schedules. Consider whether it is possible to employ the nowait clause to reduce the number of implicit barrier synchronizations.



### Idle threads

File       Display       Plugins       Help         Restore Setting       ✓ Save Settings         Absolute       ✓       Absolu         Metric tree       ✓       Absolut         ✓       0.00 Time (sec)       ✓         ✓       0.00 Execution       ✓         Ø 958.21 Computation       ✓       958.21 Computation         ✓       0.00 OpenMP       ✓         ✓       141.63 Management       ✓         ✓       115.08 Fork       ✓         ✓       0.00 Barrier       ✓         ✓       0.00 Barrier       ✓	Iute <ul> <li>Call tree</li> <li>Flat view</li> </ul> <ul> <li>0.00 MPI_Info_get</li> <li>0.00 MPI_Info_set</li> <li>3.07 MPI_File_write_at</li> <li>0.00 MPI_Comm_size</li> <li>0.00 !\$omp parallel @miniWeather_mpi_openmp.cpp:761</li> <li>□ 0.00 !\$omp for @miniWeather_mpi_openmp.cpp:761</li> <li>□ 0.00 !\$omp implicit barrier @miniWeather mpi open</li> </ul>	Absolute          System tree       Statistics       Sunburst       Process x T         • 0.00 machine summit.ccs.ornl.gov         • 0.00 node a03n07         • 0.00 MPI Rank 0         0.00 Master thread         • 11.49 OMP thread 1	v II ( )		
Restore Setting   Absolute  Absolute  Metric tree  Output	Iute <ul> <li>Call tree</li> <li>Flat view</li> </ul> <ul> <li>O.00 MPI_Info_get</li> <li>O.00 MPI_Info_set</li> <li>O.00 MPI_Comm_size</li> <li>O.00 MPI_Comm_size</li> <li>O.00 !\$omp parallel @miniWeather_mpi_openmp.cpp:761</li> <li>O.00 !\$omp for @miniWeather_mpi_openmp.cpp:761</li> <li>O.00 !\$omp implicit barrier @miniWeather_mpi open</li> <li>Implicit barrier @miniWeather_mpi open</li></ul>	Absolute          System tree       Statistics       Sunburst       Process x T         0.00 machine summit.ccs.ornl.gov         0.00 node a03n07         0.00 MPI Rank 0         0.00 Master thread         11.49 OMP thread 1	<b>v</b> 1 <b>r</b> < ▶		
Absolute  Absolute  Absolute  Absolute  Absolute  Absolute  Absolute  Absolute  Absolut  Absolut Ab	Iute <ul> <li>Call tree</li> <li>Flat view</li> <li>0.00 MPI_info_get</li> <li>0.00 MPI_info_set</li> <li>3.07 MPI_File_write_at</li> <li>0.00 MPI_comm_size</li> <li>I 0.00 !\$omp parallel @miniWeather_mpi_openmp.cpp:761</li> <li>I 0.00 !\$omp for @miniWeather_mpi_openmp.cpp:761</li> <li>I 0.00 !\$omp implicit barrier @miniWeather_mpi_openmp.cpp:761</li> </ul>	Absolute          System tree       Statistics       Sunburst       Process x T         • 0.00 machine summit.ccs.ornl.gov         • 0.00 node a03n07         • 0.00 MPI Rank 0         0.000 Master thread         • 11.49 OMP thread 1	• 11 • •		
Metric tree          Metric tree       C         • 0.00 Time (sec)       •         • 0.00 Execution       •         • 958.21 Computation       •         • 495.11 MPI       •         • 0.00 OpenMP       •         • 141.63 Management       •         • 115.08 Fork       •         • 0.00 Synchronization       •         • 0.00 Barrier       •         • 0.00 Synchronization       •	Call tree Flat view 0.00 MPI_Info_get 0.00 MPI_Info_set 3.07 MPI_File_write_at 0.00 MPI_Comm_size 0.00 !\$omp parallel @miniWeather_mpi_openmp.cpp:761 - 0.00 !\$omp for @miniWeather_mpi_openmp.cpp:761 0.00 !\$omp implicit barrier @miniWeather_mpi_openmp.cpp:761 - 0.00 !\$omp implicit barrier @miniWeather_mpi_openmp.cppi_openmp.cppi_openmp.cppi_openmp.cppi_openmp.cppi	System tree       Image: Statistics       Sunburst       Image: Process x T         ■ 0.00 machine summit.ccs.ornl.gov         ■ 0.00 node a03n07         ■ 0.00 MPI Rank 0         □ 0.00 Master thread         □ 11.49 OMP thread 1	1r < ▶ ▲		
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Selected "MPI File write at all"



### Idle threads - Explanation

#### **OpenMP Idle Threads Time**

#### (only available after <u>remapping</u>)

#### **Description:**

Idle time on CPUs that may be reserved for teams of threads when the process is executing sequentially before and after OpenMP parallel regions, or with less than the full team within OpenMP parallel regions.





### Limited Parallelism – Process x Thread





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## Limited Parallelism - Explanation

### **OpenMP Limited Parallelism Time**

(only available after <u>remapping</u>)

#### **Description:**

Idle time on CPUs that may be reserved for threads within OpenMP parallel regions where not all of the thread team participates.





### Long-term delay costs

X CubeGUI-4.4.3: scorep\_miniWeather\_mpi\_openmp\_2p16x8\_trace/trace.cubex

#### File Display Plugins Help

Restore Setting 🔻 Save Settings





# Long/Short-term OpenMP Thread Idleness delay costs

### Long-term OpenMP Thread Idleness Delay Costs

**Description:** 

Long-term delay costs reflect indirect effects of load or communication imbalance on wait states. That is, they cover waiting time that was caused indirectly by wait states which themselves delay subsequent communication operations. Here, they identify costs and locations of delays that indirectly leave OpenMP worker threads idle due to wait-state propagation. In particular, long-term idle thread delay costs indicate call paths and processes/threads that increase the time worker threads are idling because of MPI wait states outside of OpenMP parallel regions.

Unit:

Seconds

#### **Diagnosis:**

High long-term delay costs indicate that computation or communication overload in/on the affected call paths and processes/threads has far-reaching effects. That is, the wait states caused by the original computational overload spread along the communication chain to remote locations.

### Short-term OpenMP Thread Idleness Delay Costs

### **Description:**

Short-term costs reflect the direct effect of sections outside of OpenMP parallel regions on thread idleness.

### Unit:

Seconds

### **Diagnosis:**

High short-term delay costs for thread idleness indicates that much time is spent outside of OpenMP parallel regions in the affected call paths.

Try to reduce workload in the affected call paths. Alternatively, apply OpenMP parallelism to more sections of the code.



# Computational Imbalance overload

•••	X CubeGUI-4.4.3: scorep_miniWeather_mpi_openmp_2p16x8_trace/trace.cubex	
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<ul> <li>iii 20.39 MPI point-to-point wait states (propagating vs. terminal) (sec)</li> <li>iiii 26.39 MPI point-to-point wait states (direct vs. indirect) (sec)</li> <li>iiiiiiiiiiiiiiiiiiiiiiiiiiiiiiii</li></ul>	0.00 TRACE BUFFER FLUSH     0.00 void finalize()     0.00 MPI_Finalize	
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Selected "!\$omp for @miniWeather\_mpi\_openmp.cpp:322"

# Computational Imbalance overload – Process x Thread

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