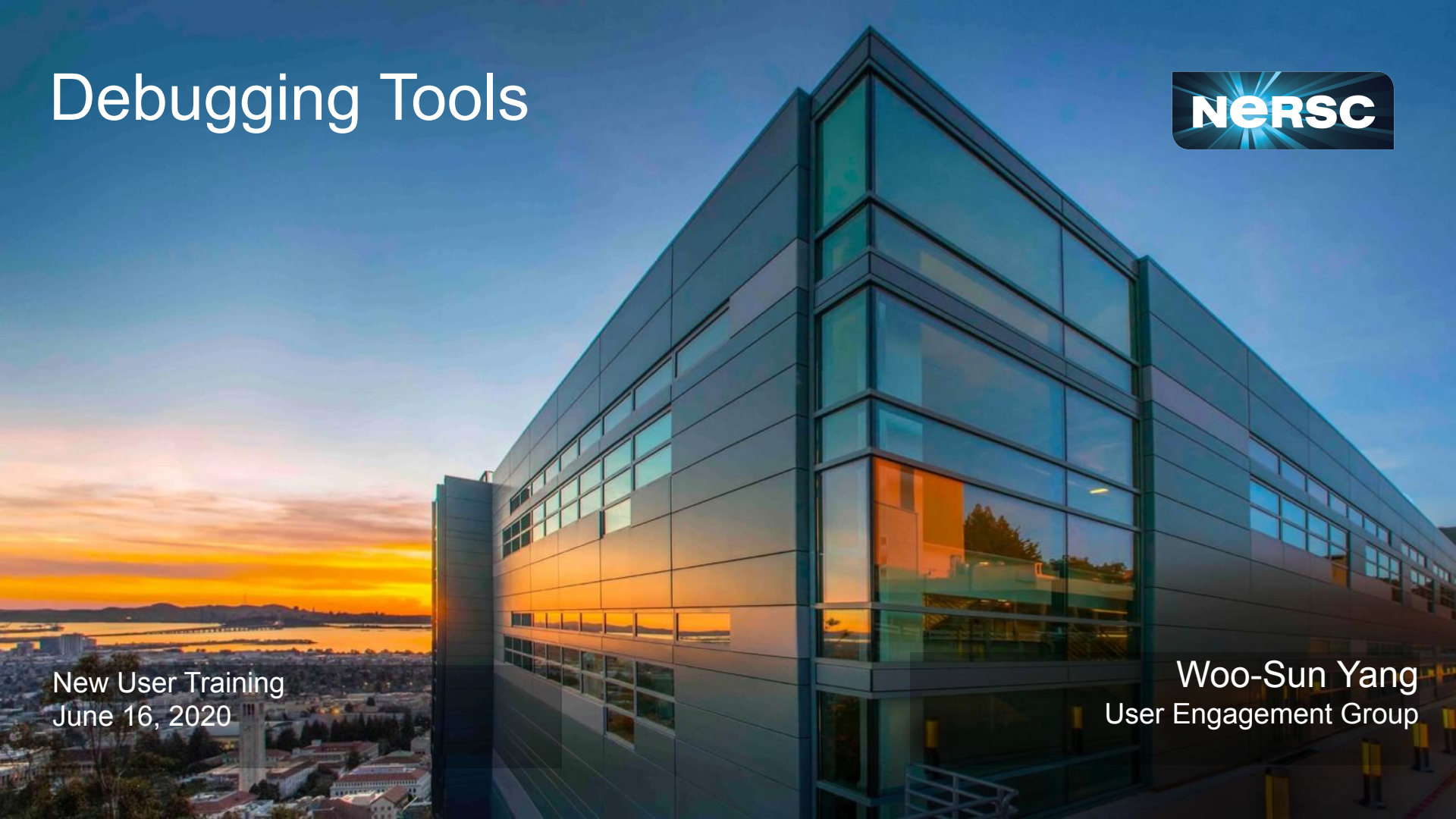
Debugging Tools



New User Training
June 16, 2020

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User Engagement Group

Debuggers

- Program errors:
  - Program crashes, program hangs, program generates incorrect results, …
- How to find and fix them?

	Using print statements	Using debuggers
Typical workflow	• Add print statements around suspicious or strategic locations in the source code • Compile the code • Run the program and examine the printed values to get a hint about what or where the problem may be • If no hint is obtained, add different print statements • Repeat	• Start your program under a debugger • Set breakpoints in your program • Run • When the program stops at the breakpoints, check variables • Can add more breakpoints and continue

Pro and con	• "Easy" – no need to learn about a debugging tool
	• Difficult to guess where and what to print
	• Time consuming and tedious
	  • Rebuild the code each time the code is modified
	  • Will likely use multiple batch jobs – inefficient use of allocations
	• Not easy to understand what is wrong from the potentially long printed values (e.g., multi-dim arrays)
		• Compile only once (in general)
		• Control program execution (stop, continue, …)
		• Tools and features available to aid to spot problem areas (e.g., visually check for abnormality in variable values by plotting them with the debugger's visualization tool)

Parallel Debuggers Available on Cori

- Parallel debuggers with a graphical user interface (GUI)
  - DDT (Distributed Debugging Tool) – part of the Arm Forge tool
  - TotalView
- Specialized debuggers
  - STAT (Stack Trace Analysis Tool)
    - Collect stack backtraces from all (MPI) tasks
  - ATP (Abnormal Termination Processing)
    - STAT invoked when an application fails
  - Valgrind
    - Suite of debugging and profiling tools
    - Best known for its detailed memory debugging tool, ‘memcheck’
    - https://docs.nersc.gov/development/performance-debugging-tools/valgrind/
  - Intel Inspector
    - Threading and memory debugging
    - https://docs.nersc.gov/programming/performance-debugging-tools/inspector/

DDT and TotalView

- GUI-based traditional parallel debuggers
- C, C++, Fortran codes with MPI, OpenMP, pthreads
- Licenses
  - DDT: up to 4,096 processes
  - TotalView: up to 512 processes
  - Shared among users and machines
- For info:
  - https://developer.arm.com/docs/101136/latest/arm-forge
  - https://docs.nersc.gov/development/performance-debugging-tools/ddt/
  - https://docs.roguewave.com/en/totalview/current/html/
  - https://docs.nersc.gov/development/performance-debugging-tools/totalview/

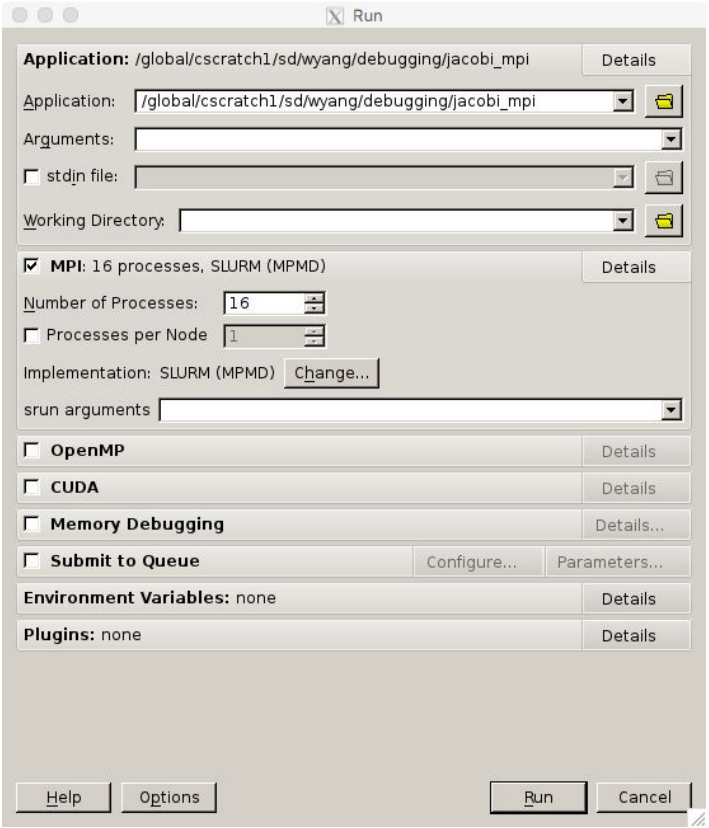
How to Build and Run with DDT

- Compile with `-g` for debugging symbols and `-O0` for no optimization (Intel compiler)

```
$ ftn -g -O0 -o jacobi_mpi jacobi_mpi.f90
```

- Start an interactive batch job and run DDT:

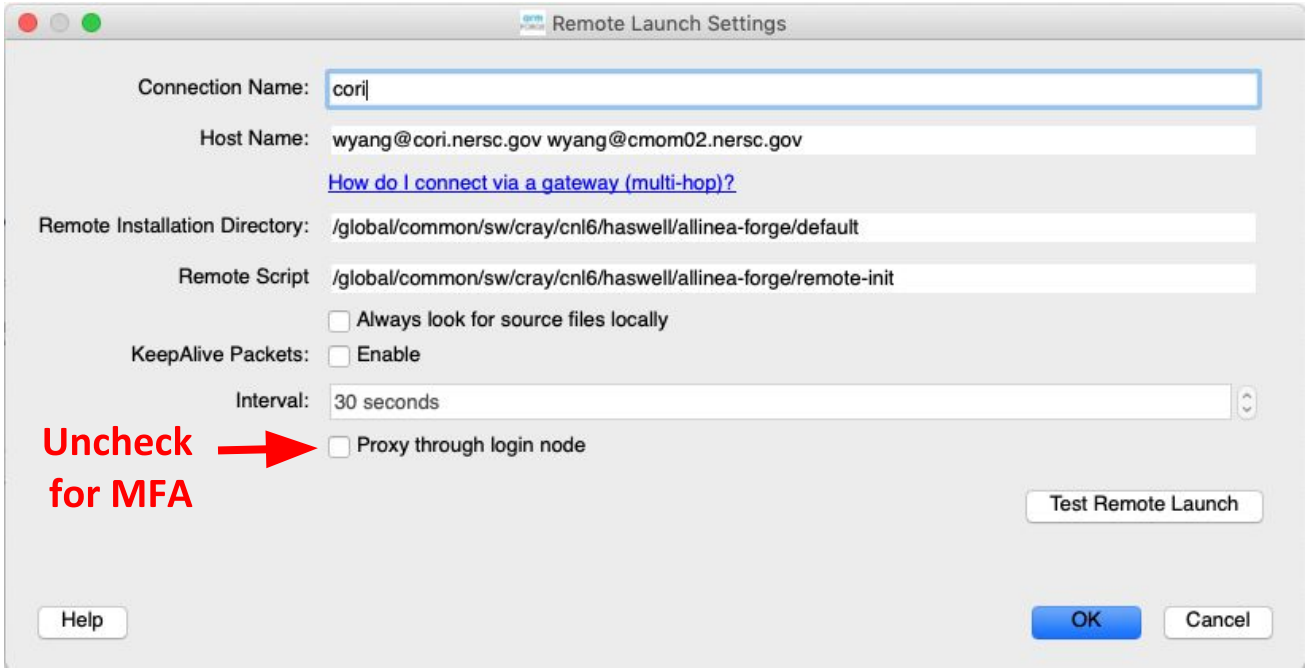
```
$ salloc -N 1 -t 30:00 -q debug -C knl
$ module load allinea-forge
$ ddt ./jacobi_mpi
```



If You Work Far Away From NERSC

- Running X11 GUIs over network: it responses painfully slowly due to intrinsically high latency and inefficient bandwidth between X11 client and server
- Two solutions
  - Use NoMachine (NX) to improve the speed
    - Works for X11 window applications
    - https://docs.nersc.gov/connect/nx/
  - Use Arm Forge remote client
    - Run on your desktop/laptop
    - Submit a debugging batch job on a NERSC machine and make the job connect to the client ("**reverse connect**")
    - Display results in real time
    - https://developer.arm.com/tools-and-software/server-and-hpc/downloads/arm-forge (for downloading remote clients)
    - https://docs.nersc.gov/programming/performance-debugging-tools/ddt/#reverse-connect-using-remote-client (for setup)

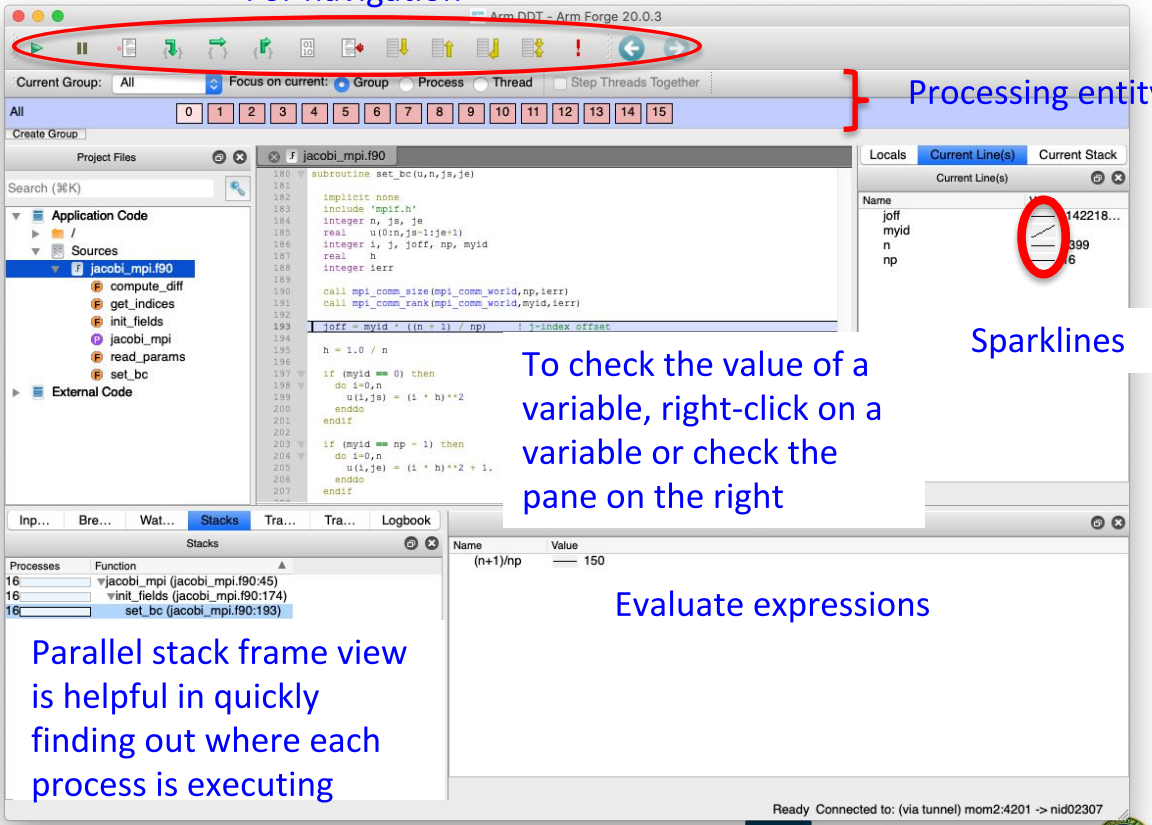
Arm Forge Remote Client Settings



- See https://docs.nersc.gov/development/performance-debugging-tools/ddt/

DDT Window

For navigation



Processing entity to control

Sparklines

To check the value of a variable, right-click on a variable or check the pane on the right

Evaluate expressions

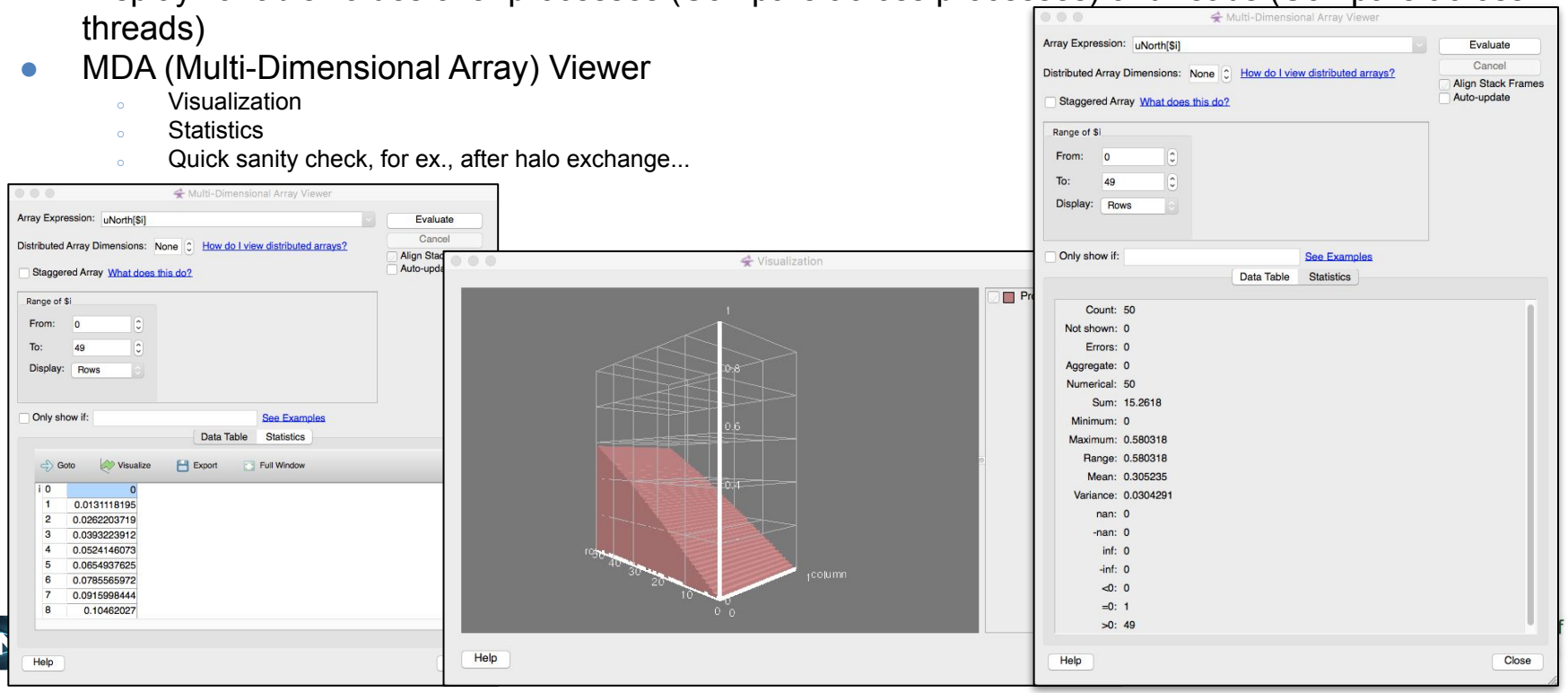
Parallel stack frame view is helpful in quickly finding out where each process is executing

Breakpoints, Watchpoints and Tracepoints

- Breakpoint
  - Stops execution when a selected line (breakpoint) is reached
  - Double click on a line to create one; there are other ways, too
- Watchpoints for variables or expressions
  - Stops when a variable or an expression changes its value
- Tracepoints
  - When reached, prints what lines of codes is being executed and the listed variables
- Can add a condition for an action point
  - Useful inside a loop
- Can be made active or inactive

Check Variables

- Right click on a variable for a quick summary
- Variable pane
- Evaluate pane
- Display variable values over processes (Compare across processes) or threads (Compare across threads)
- MDA (Multi-Dimensional Array) Viewer
  - Visualization
  - Statistics
  - Quick sanity check, for ex., after halo exchange...

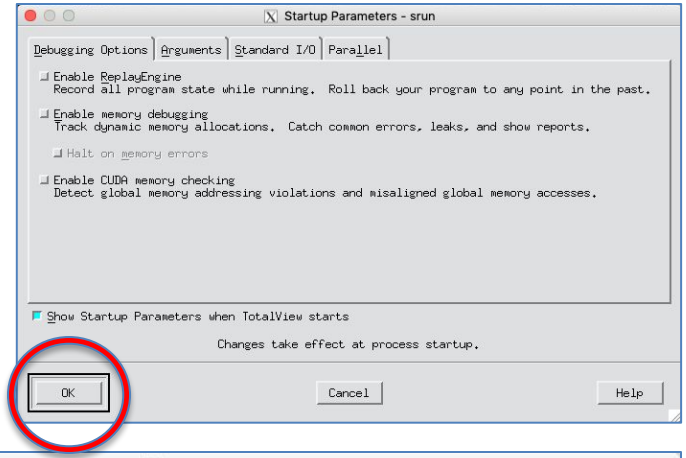


TotalView

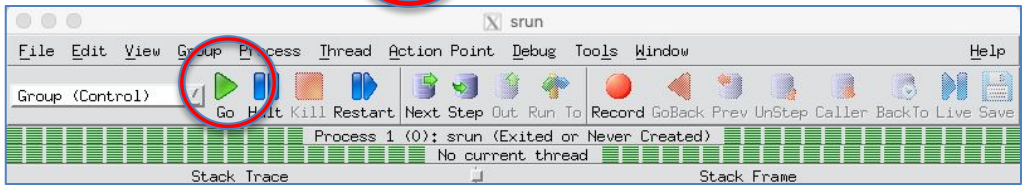
- Start a batch job interactively and run your code with TotalView

```
$ salloc -N 1 -C knl -t 30:00 -q debug
$ module load totalview
$ export OMP_NUM_THREADS=4
$ totalview srun -a \
   -n 8 -c 32 --cpu-bind=cores ./jacobi_mpiomp
```

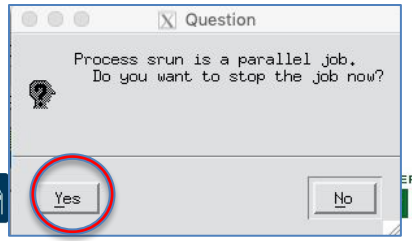
- Click ‘OK’ in the ‘Startup Parameters - srun’ window



- Click ‘Go’ in the main window

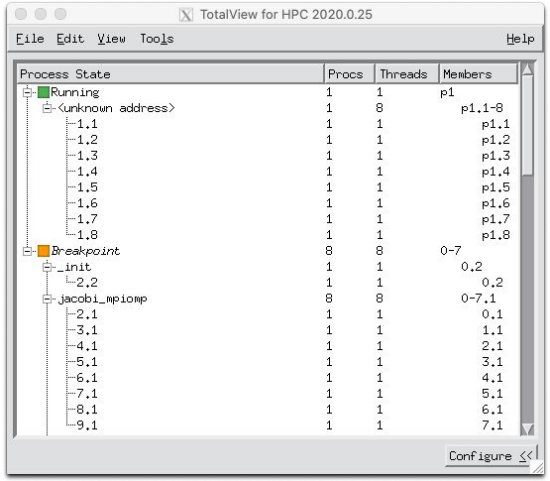


- Click ‘Yes’ to the question ‘Process srun is a parallel job. Do you want to stop the job now?’



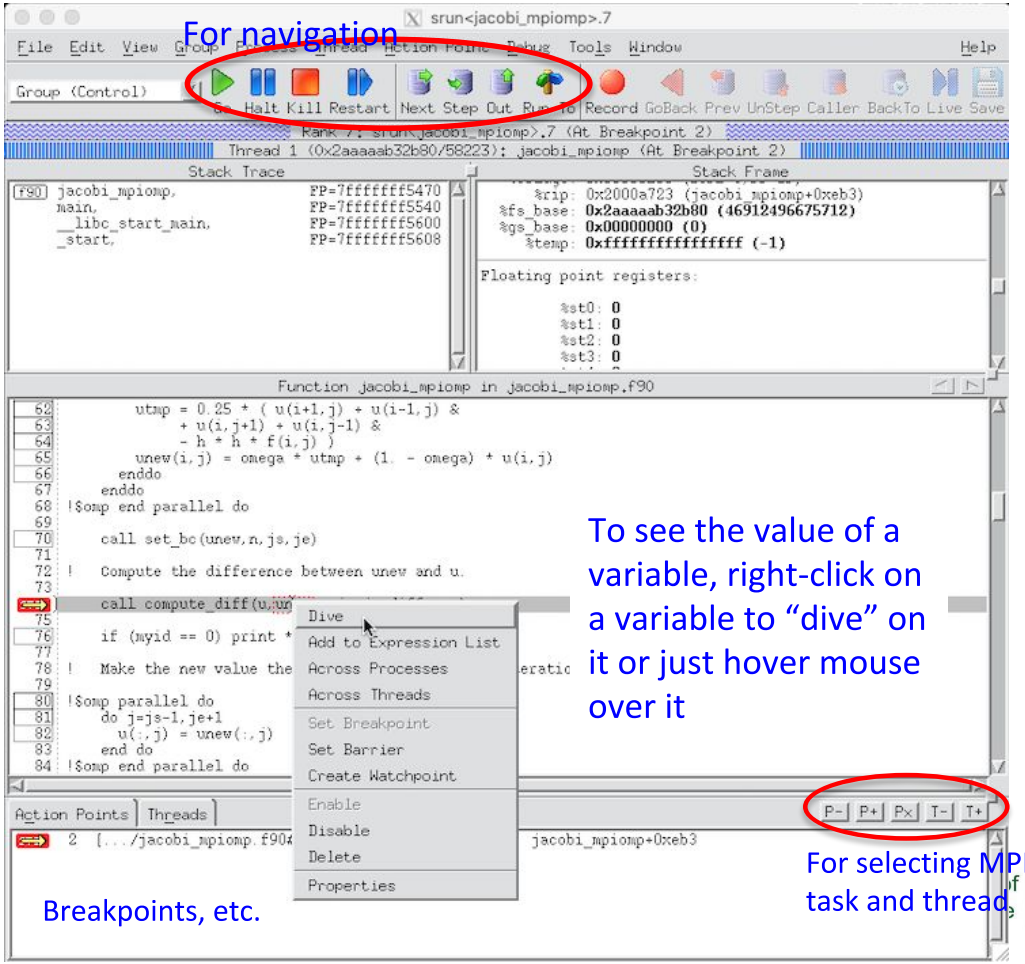
TotalView (cont'd)

Root window



State of MPI tasks and threads; members denoted roughly as '*rank.thread*'

Process window



For navigation

To see the value of a variable, right-click on a variable to "dive" on it or just hover mouse over it

For selecting MPI task and thread

Breakpoints, etc.

NERSC

STAT (Stack Trace Analysis Tool)

- Gathers stack backtraces (sequence of function calls leading up to the current function) from all (MPI) processes
  - Merge them into a single file (*.dot)
  - Results displayed as a single call tree for all processes
  - Can be useful for debugging a hanging application
  - With the info learned from STAT, can investigate further with DDT or TotalView
- Works for MPI, CAF, UPC, and OpenMP

STAT (Stack Trace Analysis Tool) (cont'd)

- STAT commands (after loading the 'stat' module)
  - stat-cl: invokes STAT to gather stack backtraces
  - STATview: A GUI to view the results
  - STATGUI: a GUI to run STAT or view results
- For more info:
  - 'intro_stat', 'STAT', 'STATview' and 'STATGUI' man pages
  - /opt/cray/pe/stat/default/doc/stat_userguide.pdf
  - –https://docs.nersc.gov/development/performance-debugging-tools/stat_atp/

Debug a Hanging App with STAT

- If your code hangs consistently, use STAT to examine whether MPI processes get stuck.

With usual optimization flags, if any

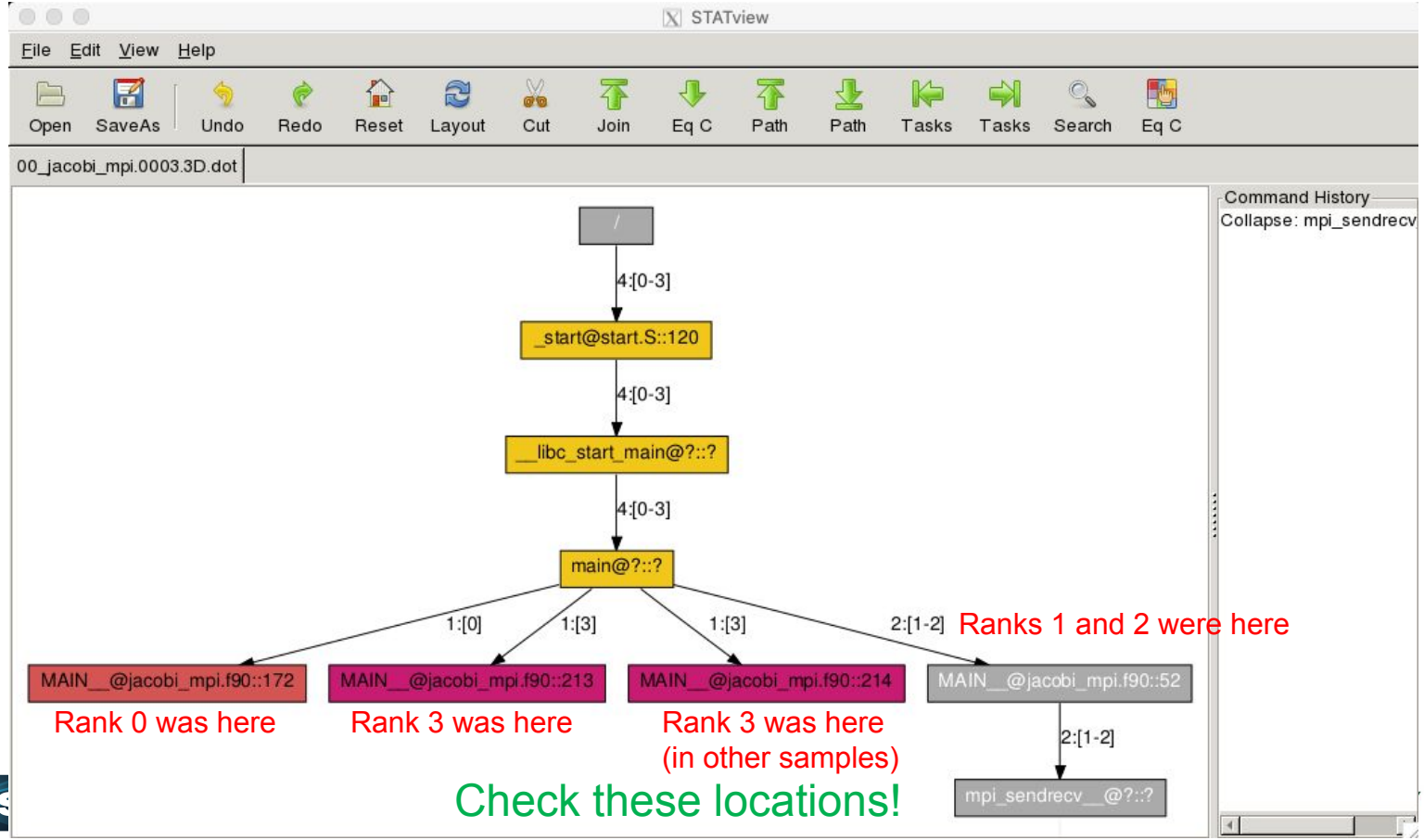
```
$ ftn -g -o jacobi_mpi jacobi_mpi.f90
$ salloc -N 1 -t 30:00 -q debug -C knl
...
$ srun -n 4 -c 64 --cpu-bind=cores ./jacobi_mpi &
[1] 135543
$ module load stat
$ stat-cl -i 135543
...
Attaching to application...
Attached!
Application already paused... ignoring request to pause
Sampling traces...
Traces sampled!
...
Resuming the application...
Resumed!
Merging traces...
Traces merged!
Detaching from application...
Detached!

Results written to /global/cscratch1/sd/wyang/debugging/stat/stat_results/jacobi_mpi.0003
$ ls -l stat_results/jacobi_mpi.0003/*.dot
-rw-rw---- 1 wyang wyang 5201 Jun  7 14:55 stat_results/jacobi_mpi.0003/00_jacobi_mpi.0003.3D.dot
$ STATview stat_results/jacobi_mpi.0003/00_jacobi_mpi.0003.3D.dot
```

-i to get source line numbers

STAT samples stack backtraces 10 times

Debug a Hanging App with STAT (cont'd)



ATP (Abnormal Termination Processing)

- ATP invokes STAT wgeb the application fails
  - Output in atpMergedBT.dot and atpMergedBT_line.dot (showing source line numbers), which are to be viewed with STATview
- The atp module is loaded on Cori by default, but ATP is *not* enabled; to enable:

```
$ export ATP_ENABLED=1 # sh/bash/ksh
% setenv ATP_ENABLED 1 # csh/tcsh
```

- For more info
  - 'intro_atp' man page
  - –https://docs.nersc.gov/development/performance-debugging-tools/stat_atp/

Debug a Hanging App with ATP

- Submit a hanging job with ATP enabled

```
$ ftn -g -o jacobi_mpi jacobi_mpi.f90
$ cat runit
#!/bin/bash
#SBATCH -N 1
#SBATCH -C knl
...
export ATP_ENABLED=1
export FOR_IGNORE_EXCEPTIONS=true
srun -n 4 -c 64 --cpu-bind=cores ./jacobi_mpi
```

Enable ATP
Code built with Intel fortran compiler

```
$ sbatch runit
Submitted batch job 31445729
```

Debug a Hanging App with ATP (cont'd)

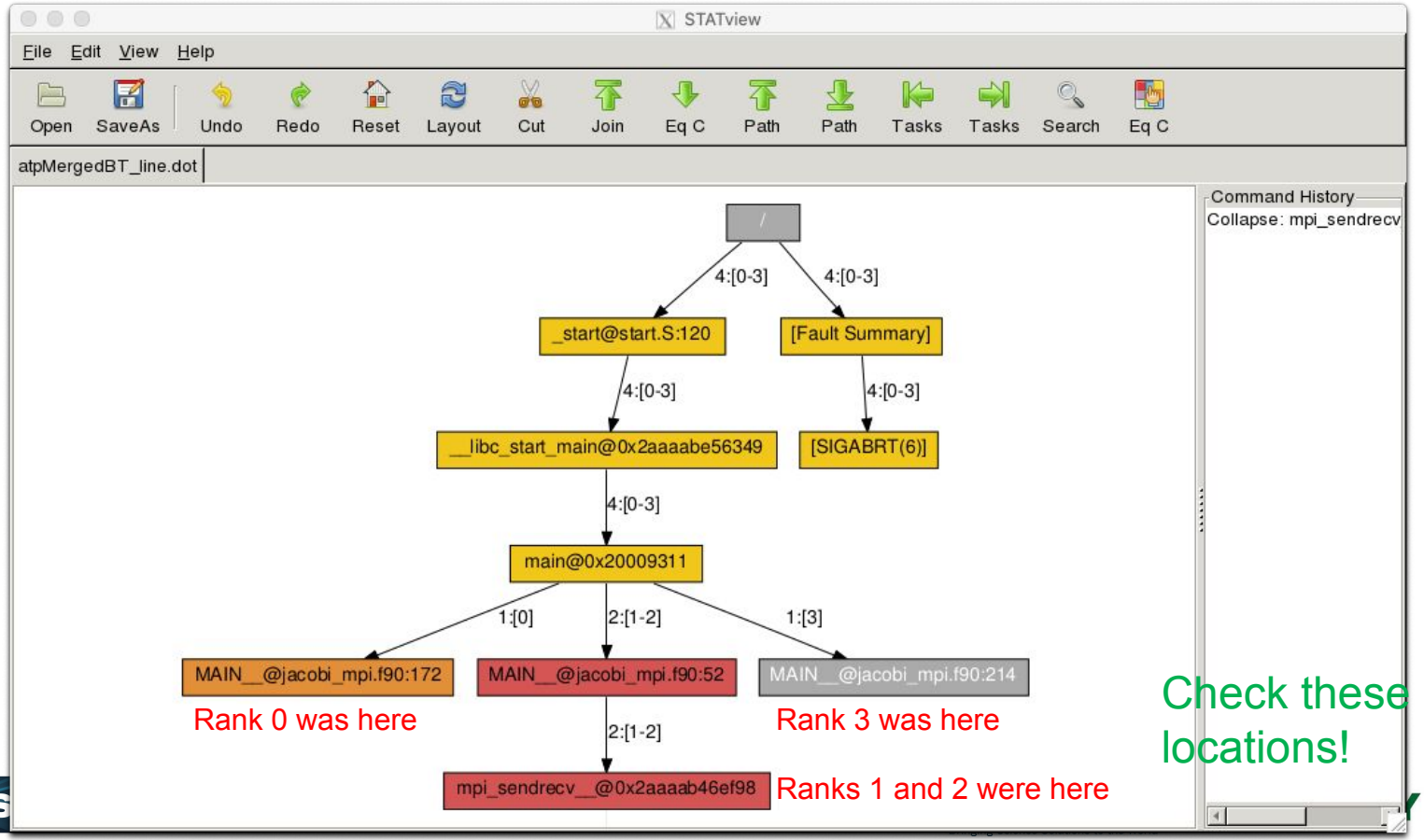
- From a login node, ssh to a MOM node and cancel the srun job

```
$ ssh cmom02
...
$ sacct -j 31445729
       JobID    JobName  Partition    Account  AllocCPUS      State ExitCode
------------ ---------- ---------- ---------- ---------- ---------- --------
31445729           runit  debug_knl     nstaff        272    RUNNING      0:0
...
31445729.0   jacobi_mpi                nstaff        256    RUNNING      0:0
31445729.1   cti_dlaun+                nstaff          1    RUNNING      0:0
$ scancel -s ABRT 31445729.0
$ logout
```

- Dot files are generated; view them with STATview

```
$ ls -l *.dot
-rw-rw----  1 wyang wyang    1287 Jun  7 15:31 atpMergedBT.dot
-rw-rw----  1 wyang wyang    1837 Jun  7 15:31 atpMergedBT_line.dot
$ module load stat
$ STATview atpMergedBT_line.dot
```

Debug a Hanging App with ATP (cont'd)



Arm Tools Tutorial on July 16, 2020!

- ½-day tutorial for Arm tools
  - Arm Forge
    - DDT - debugger
    - MAP – performance profiling
  - Performance Reports: performance summary
- Beginning/Intermediate level
- Will teach how to profile Python apps, too
- By Arm engineer
- Info and registration:
  - https://www.nersc.gov/users/training/events/arm-debugging-and-profiling-tools-tutorial-june-25-2020/


Thank You and
Welcome to
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