Deep Learning and GPU programming using OpenACC

14 – 17 July 2020

MODULE TWO: PROFILING

Dr. Volker Weinberg | LRZ | 16.07.2020

OpenACC
More Science, Less Programming

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MODULE OVERVIEW

Topics to be covered

- Compiling and profiling sequential code
- Explanation of multicore programming
- Compiling and profiling multicore code

COMPILING SEQUENTIAL CODE

PGI COMPILER BASICS

pgcc, pgc++ and pgfortran

- The command to compile C code is ‘pgcc’
- The command to compile C++ code is ‘pgc++’
- The command to compile Fortran code is ‘pgfortran’
- The -fast flag instructs the compiler to optimize the code to the best of its abilities

```
$ pgcc –fast main.c
$ pgc++ -fast main.cpp
$ pgfortran –fast main.F90
```

PGI COMPILER BASICS

-Minfo flag

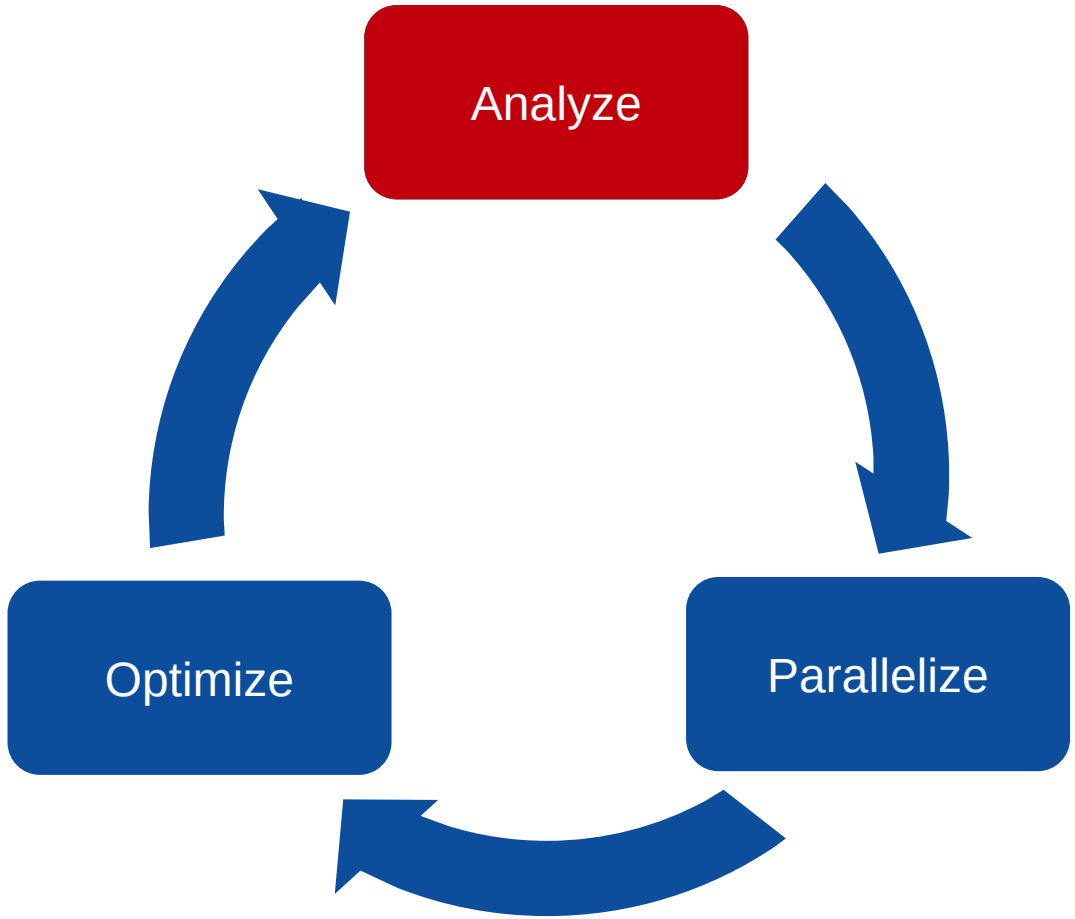
- The Minfo flag will instruct the compiler to print feedback about the compiled code
- -Minfo=accel will give us information about what parts of the code were accelerated via OpenACC
- -Minfo=opt will give information about all code optimizations
- -Minfo=all will give all code feedback, whether positive or negative

```
$ pgcc –fast –Minfo=all main.c
$ pgc++ -fast -Minfo=all main.cpp
$ pgfortran –fast –Minfo=all main.f90
```

PROFILING SEQUENTIAL CODE

OPENACC DEVELOPMENT CYCLE

- **Analyze** your code to determine most likely places needing parallelization or optimization.
- **Parallelize** your code by starting with the most time consuming parts, check for correctness and then analyze it again.
- **Optimize** your code to improve observed speed-up from parallelization.



PROFILING SEQUENTIAL CODE

Step 1: Run Your Code

Record the time it takes for your sequential program to run.

Note the final results to verify correctness later.

Always run a problem that is representative of your real jobs.

Terminal Window

```
$ pgcc –fast jacobi.c laplace2d.c
$ ./a.out
    0, 0.250000
  100, 0.002397
  200, 0.001204
  300, 0.000804
  400, 0.000603
  500, 0.000483
  600, 0.000403
  700, 0.000345
  800, 0.000302
  900, 0.000269
  total: 39.432648 s
```

PROFILING SEQUENTIAL CODE

Step 2: Profile Your Code

Obtain detailed information about how the code ran.

This can include information such as:

- Total runtime
- Runtime of individual routines
- Hardware counters

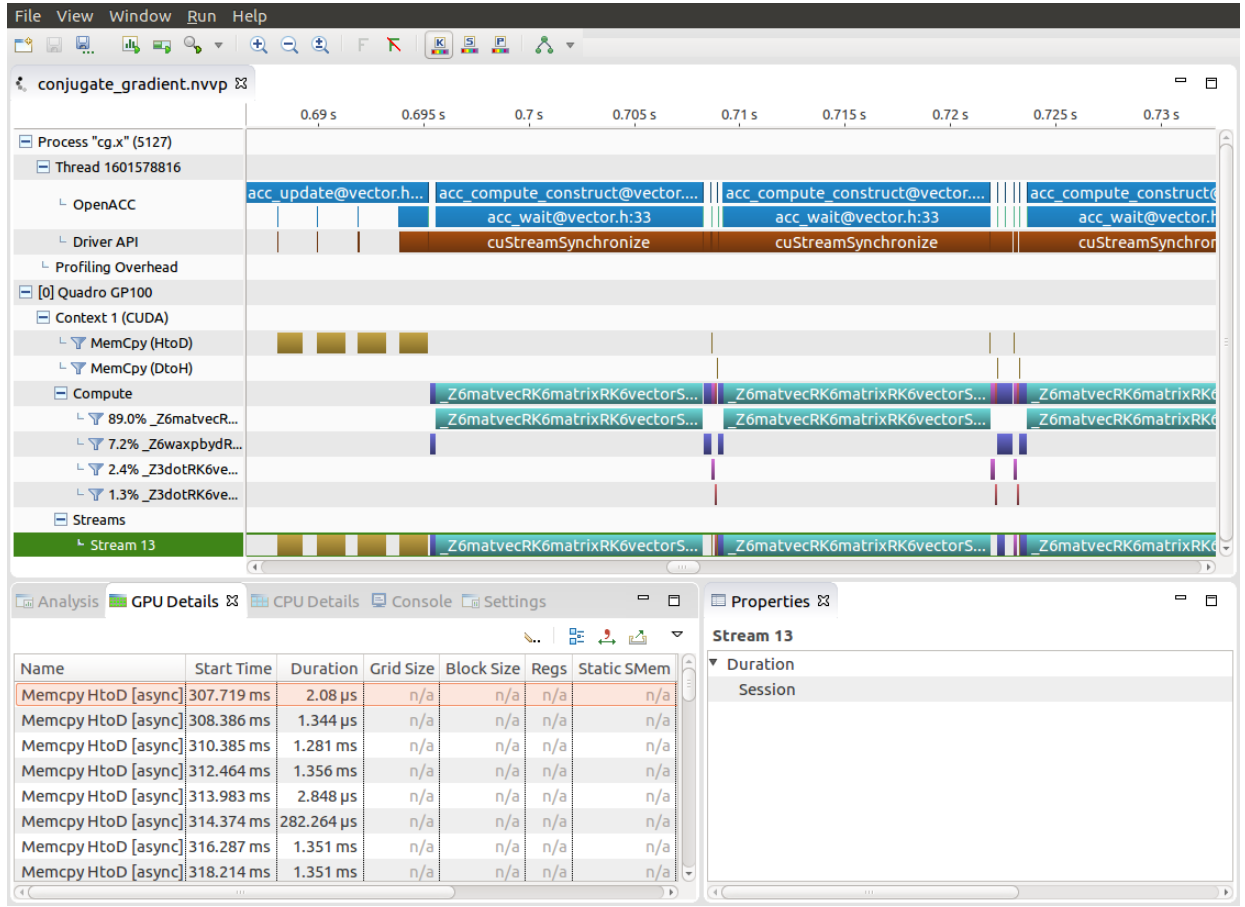
Identify the portions of code that took the longest to run. We want to focus on these “hotspots” when parallelizing.

```
! pgprof ./laplace

Jacobi relaxation Calculation: 4096 x 4096 mesh
    0, 0.250000
  100, 0.002397
  200, 0.001204
  300, 0.000804
  400, 0.000603
  500, 0.000483
  600, 0.000403
  700, 0.000345
  800, 0.000302
  900, 0.000269
 total: 60.611229 s

======== CPU profiling result (bottom up):
Time(%)      Time  Name
 54.51%    32.43s  calcNext
 54.51%    32.43s  | main
 45.40%    27.01s  __c_mcopy8_avx
  0.05%     30ms  swap
  0.05%     30ms  | main
  0.03%     20ms  __c_mcopy8

======== Data collected at 100Hz frequency
```

PROFILING SEQUENTIAL CODE

Introduction to PGProf

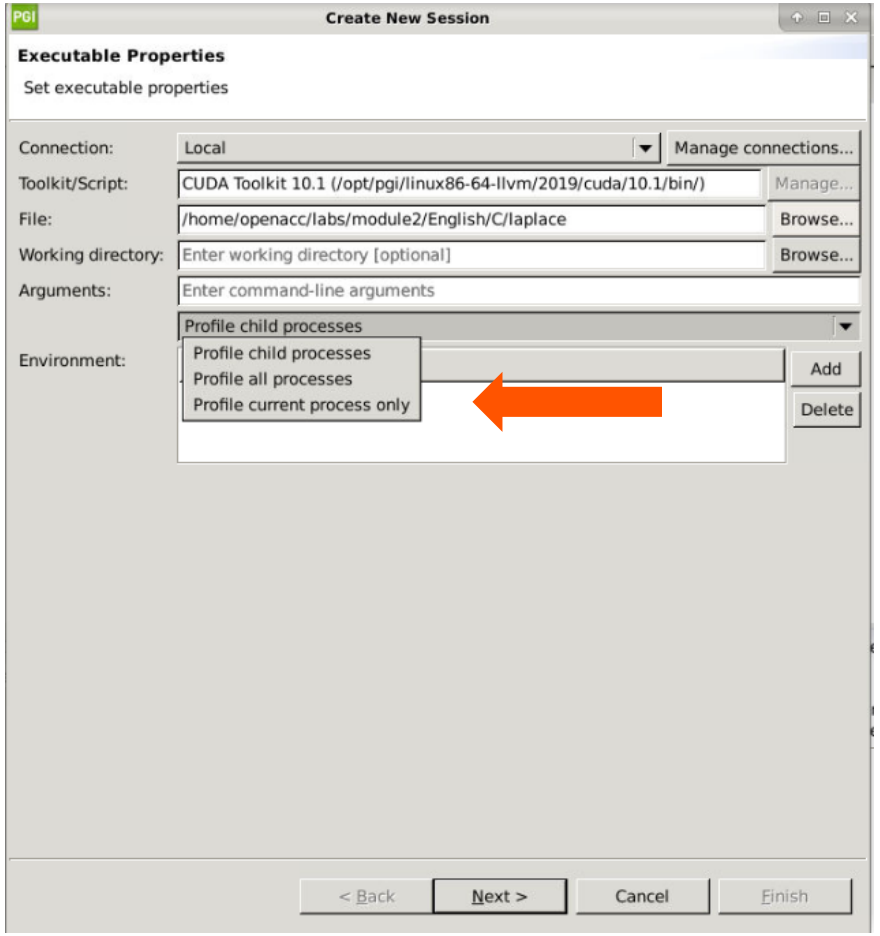
- Gives visual feedback of how the code ran
- Gives numbers and statistics, such as program runtime
- Also gives runtime information for individual functions/loops within the code
- Includes many extra features for profiling parallel code



PROFILING SEQUENTIAL CODE

CPU Details

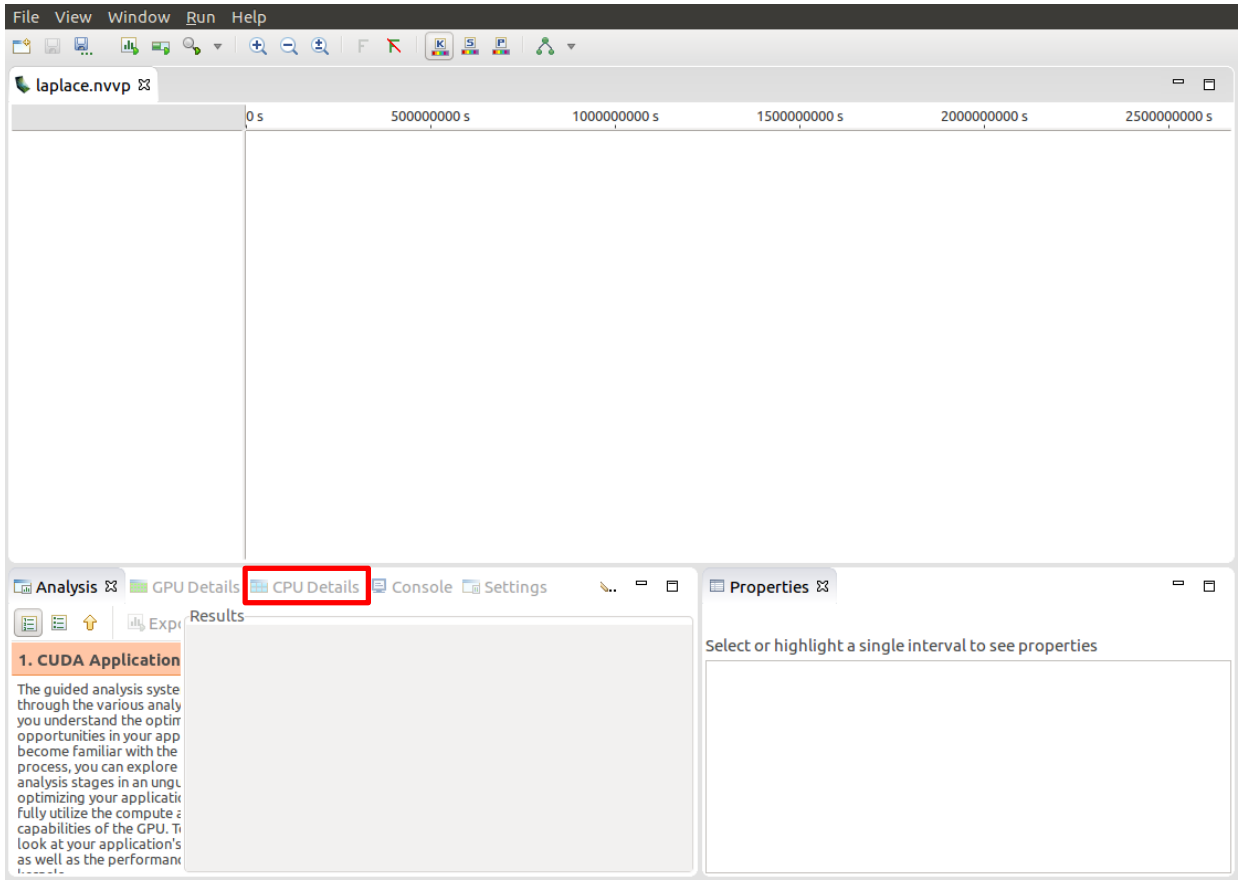
- **Please make sure to choose "Profile current process only" from the dropdown instead of "Profile child process"**. The CPU details will not be displayed in the profiler otherwise.



PROFILING SEQUENTIAL CODE

First sight when using PGPROF

- Profiling a simple, sequential code
- Our sequential program will run on the CPU
- To view information about how our code ran, we should select the “CPU Details” tab



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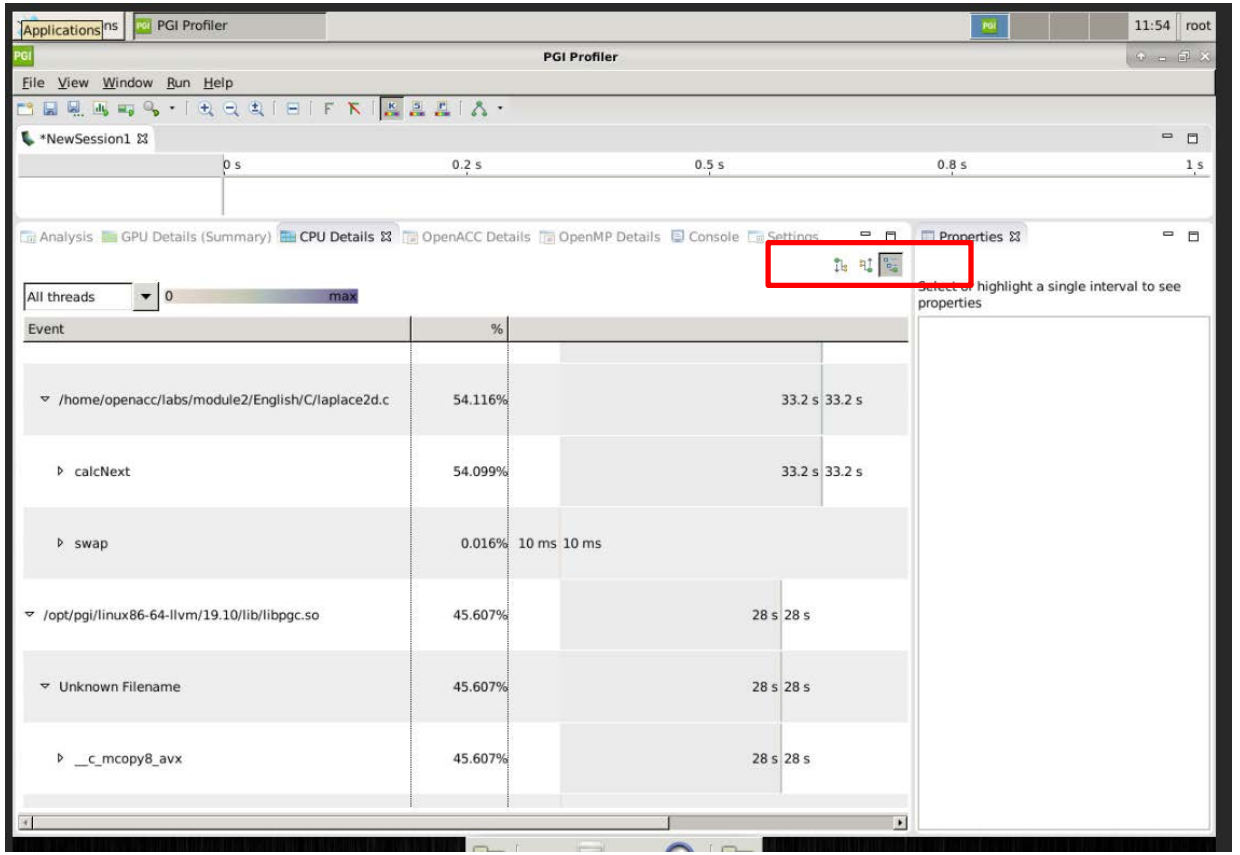
PROFILING SEQUENTIAL CODE

CPU Details

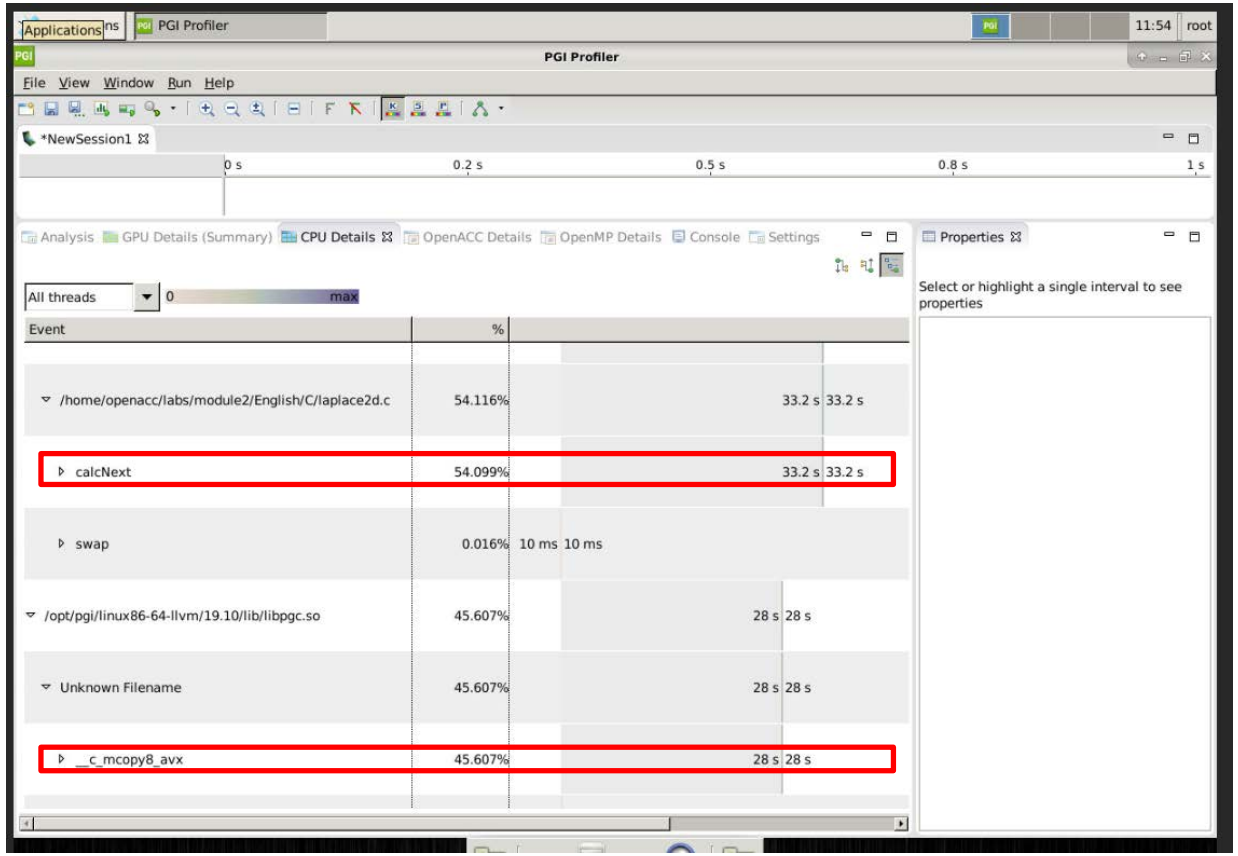
- Within the “CPU Details” tab, we can see the various parts of our code, and how long they took to run
- We can reorganize this info using the three options in the top-right portion of the tab
- We will expand this information, and see more details about our code



PROFILING SEQUENTIAL CODE

CPU Details

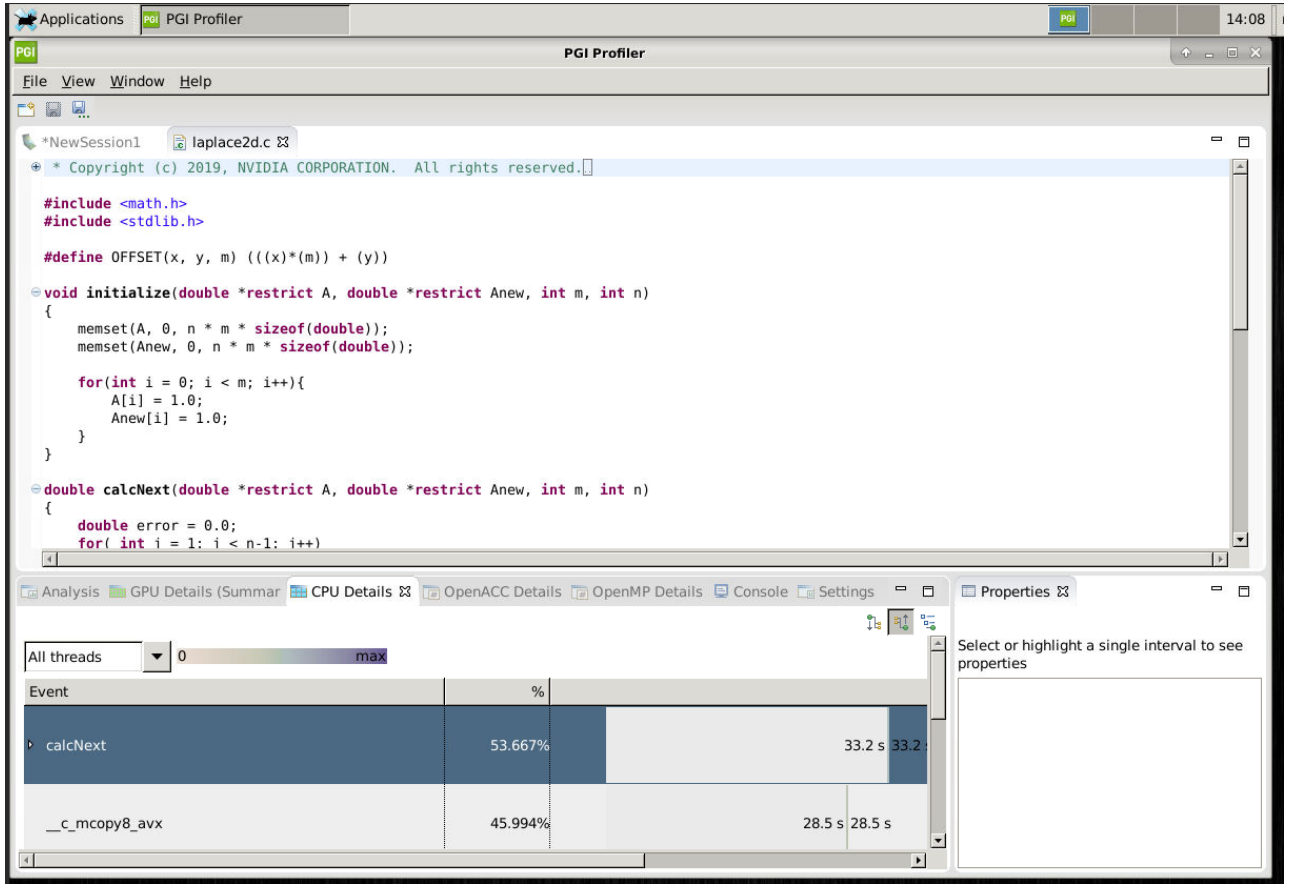
- We can see that there are two places that our code is spending most of its time
- 33.2 seconds in the “calcNext” function
- 28 seconds in a memcpy function
- The c_mcopy8_avx that we see is actually a compiler optimization that is being applied to our “swap” function



PROFILING SEQUENTIAL CODE

PGPROF

- We are also able to select the different elements in the CPU Details by double-clicking to open the associated source code
- Here we have selected the “calcNext” element, which opened up the source file in the top part of the windo



PROFILING SEQUENTIAL CODE

Step 2: Profile Your Code

Obtain detailed information about how the code ran.

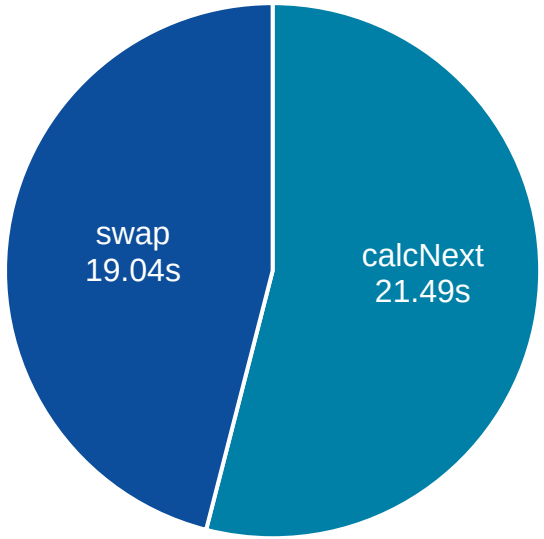
This can include information such as:

- Total runtime
- Runtime of individual routines
- Hardware counters

Identify the portions of code that took the longest to run. We want to focus on these “hotspots” when parallelizing.

Lab Code: Laplace Heat Transfer

Total Runtime: 39.43 seconds



PROFILING SEQUENTIAL CODE

Step 3: Identify Parallelism

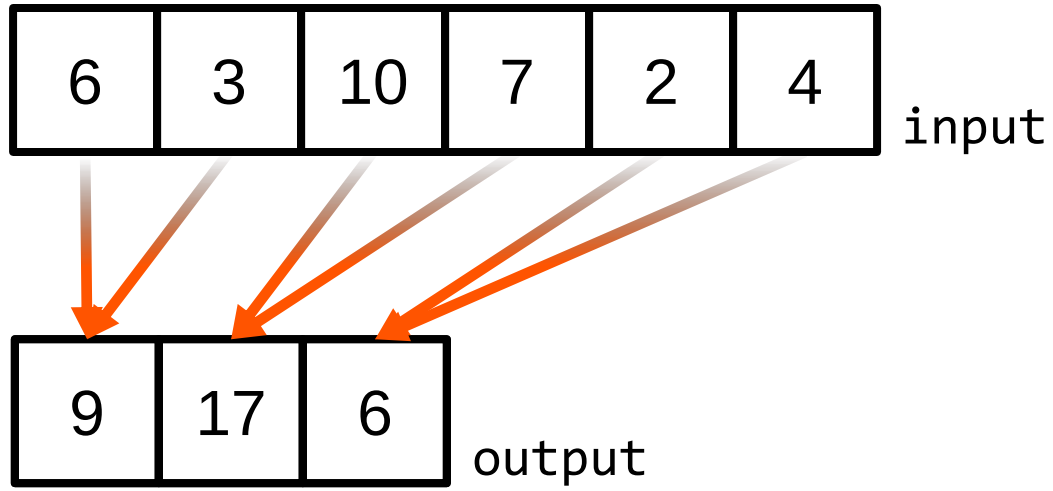
Observe the loops contained within the identified hotspots

Are these loops parallelizable?
Can the loop iterations execute independently of each other?
Are the loops multi-dimensional, and does that make them very large?

Loops that are good to parallelize tend to have a lot of iterations to map to parallel hardware.

```
void pairing(int *input, int *output, int N){

  for(int i = 0; i < N; i++)
    output[i] = input[i*2] + input[i*2+1];
}
```



PLEASE START LAB NOW!

TRAINING SETUP

- To get started, follow these steps:
- Create an NVIDIA Developer account at http://courses.nvidia.com/join Select "Log in with my NVIDIA Account" and then "'Create Account“ (done yesterday)
- Visit http://courses.nvidia.com/dli-event and enter the event code

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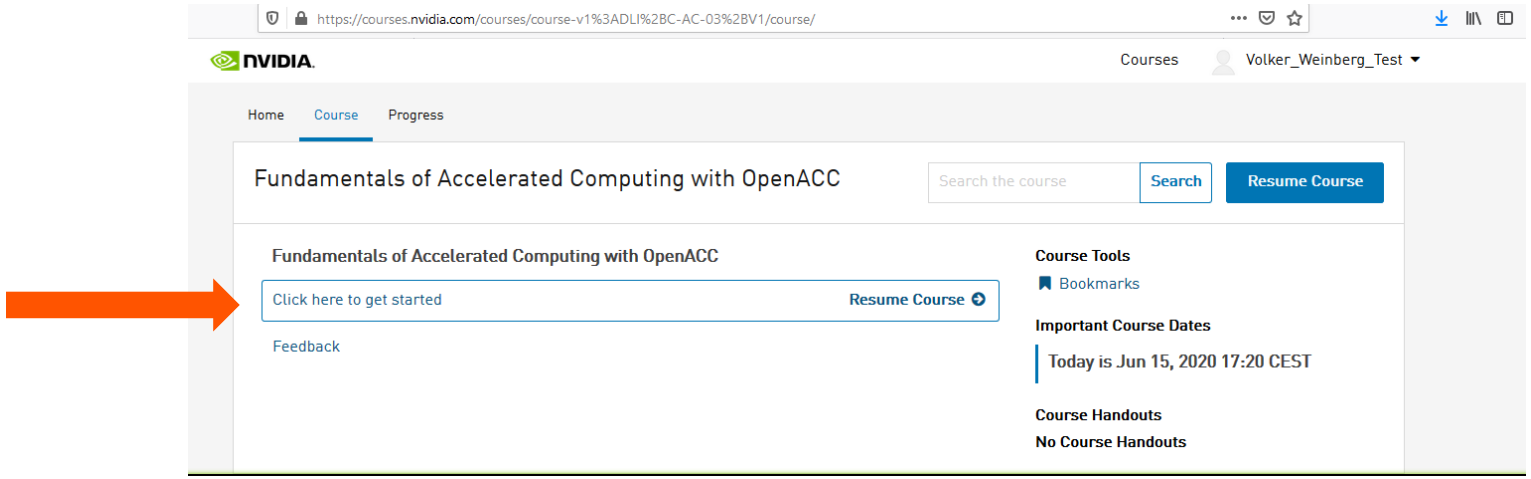
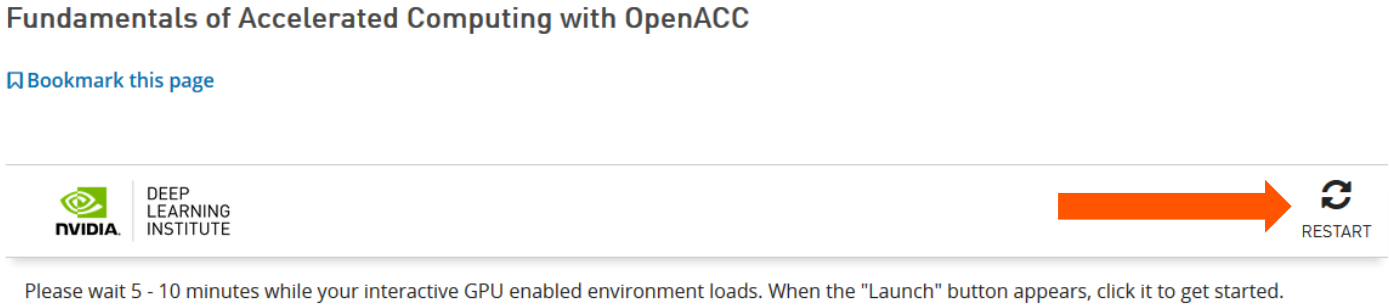
TRAINING SETUP





PROFILING MULTICORE CODE

PROFILING MULTICORE CODE

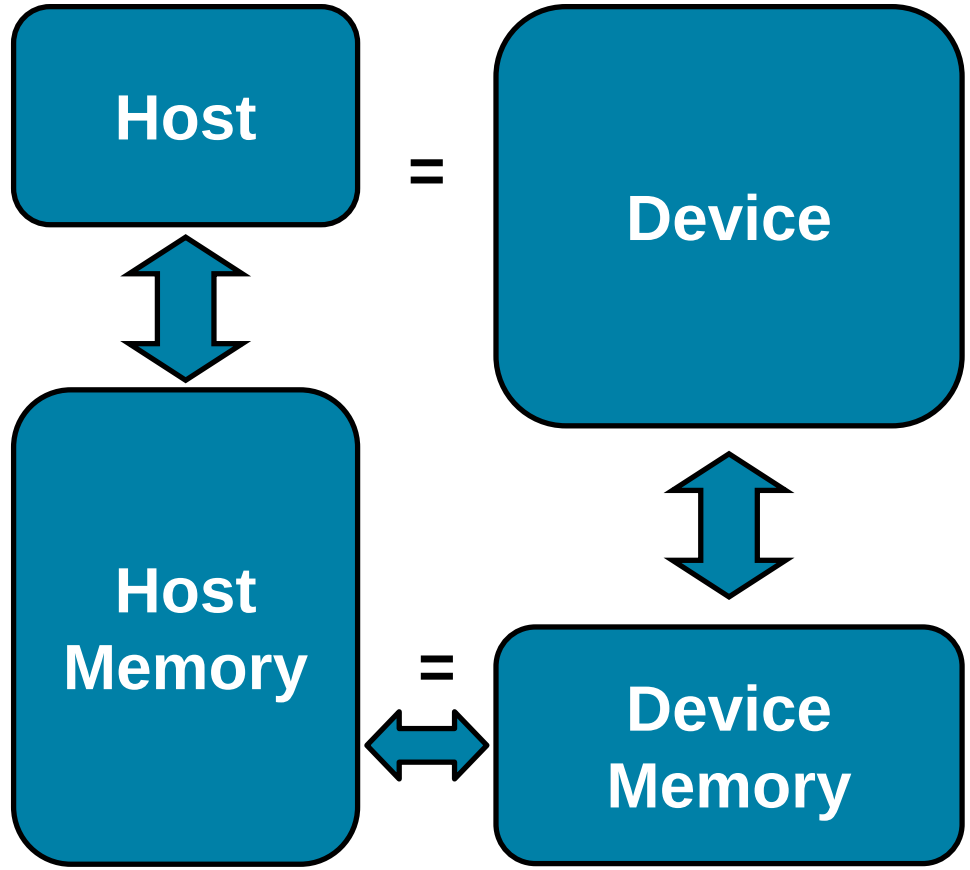
What is multicore?

- *Multicore* refers to using a CPU with multiple computational cores as our parallel device
- These cores can run independently of each other, but have shared access to memory
- Loop iterations can be spread across CPU threads and can utilize SIMD/vector instructions (SSE, AVX, etc.)
- Parallelizing on a multicore CPU is a good starting place, since data management is unnecessary

PROFILING MULTICORE CODE

Using a multicore CPU with OpenACC

- OpenACC's generic model involves a combination of a host and a device
- Host generally means a CPU, and the device is some parallel hardware
- When running with a multicore CPU as our device, typically this means that our host/device will be the same
- This also means that their memories will be the same



PROFILING MULTICORE CODE

Compiling code for a specific parallel hardware

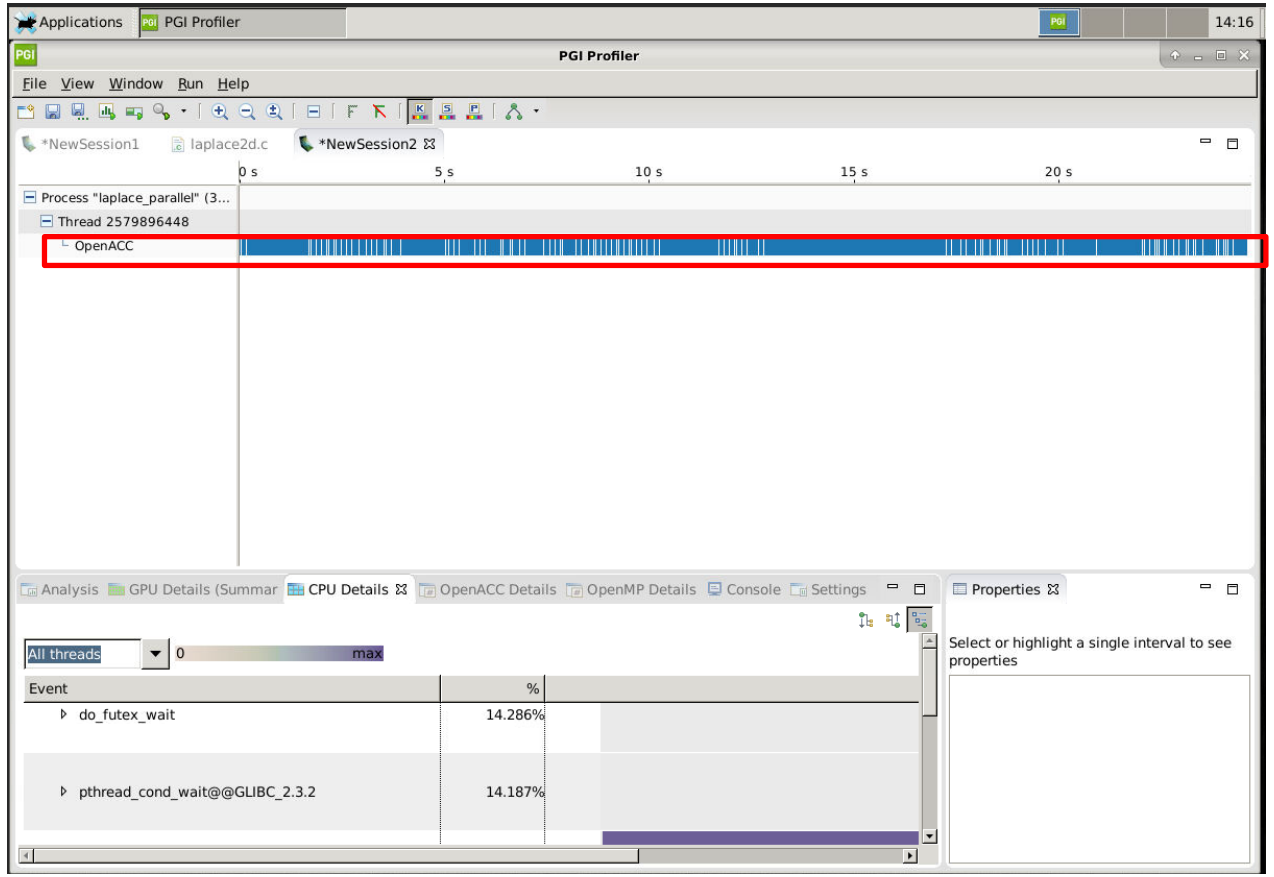
- The '-ta' flag will allow us to compile our code for a specific, target parallel hardware
- 'ta' stands for "Target Accelerator," an accelerator being another way to refer to a parallel hardware
- Our OpenACC code can be compiled for many different kinds of parallel hardware without having to change the code

```
$ pgcc -fast -Minfo=accel -ta=multicore laplace2d.c
  calcNext:
       35, Generating Multicore code
           36, #pragma acc loop gang
```

PROFILING MULTICORE CODE

PGPROF

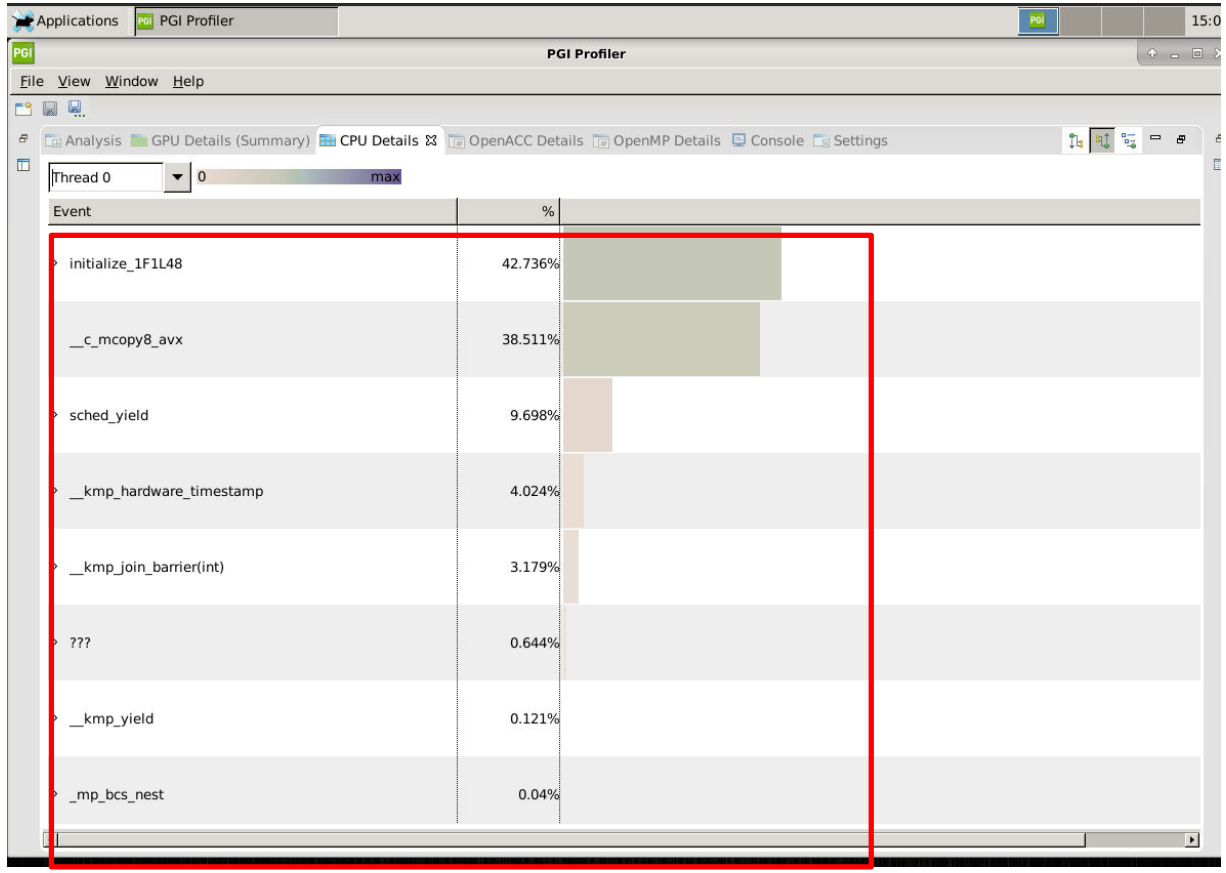
- The first difference we see in this multicore profile is that there is now a “timeline”
- This timeline will show when our parallel hardware is being used, and how it is being used
- Each of the blue bars represent a portion of our program that was run on the multicore CPU



PROFILING MULTICORE CODE

CPU Details

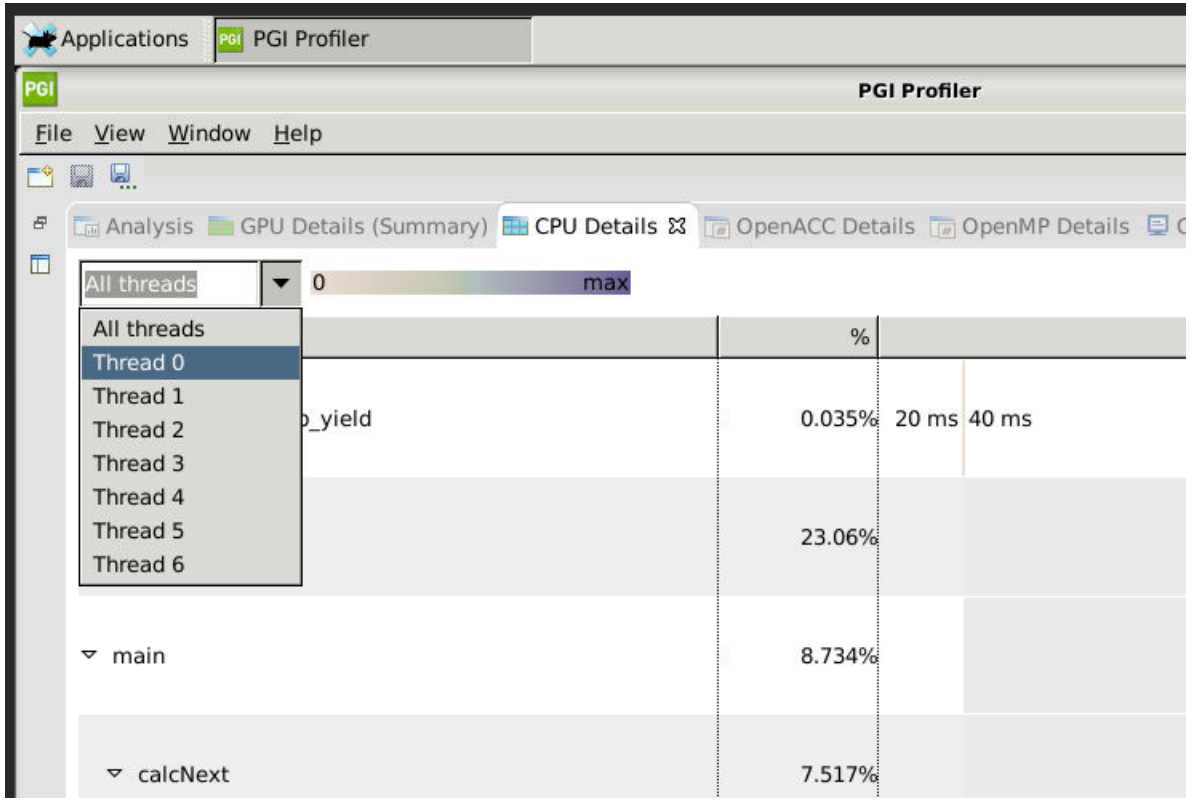
- Looking at our CPU Details, we can see that there is a lot more happening compared to our sequential program
- For the most part, these extra details revolve around the need for the CPU cores to communicate with each other



PROFILING MULTICORE CODE

View of computational threads

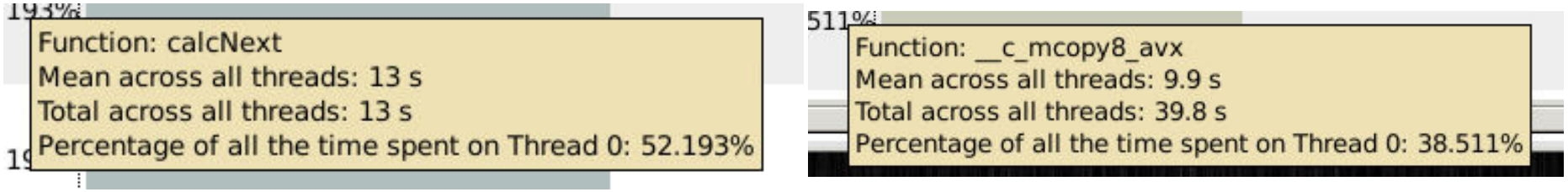
- You can see statistics for all threads or select a specific thread in the box on the top left of the CPU Details tab.



PROFILING MULTICORE CODE

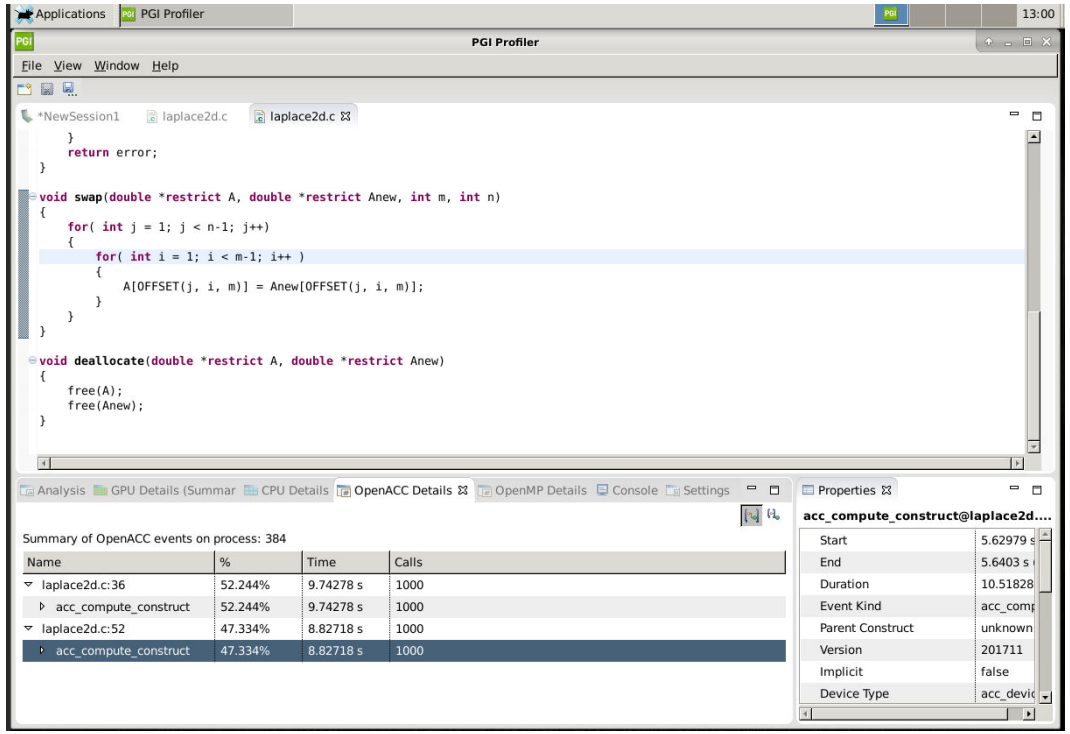
View of all computational threads

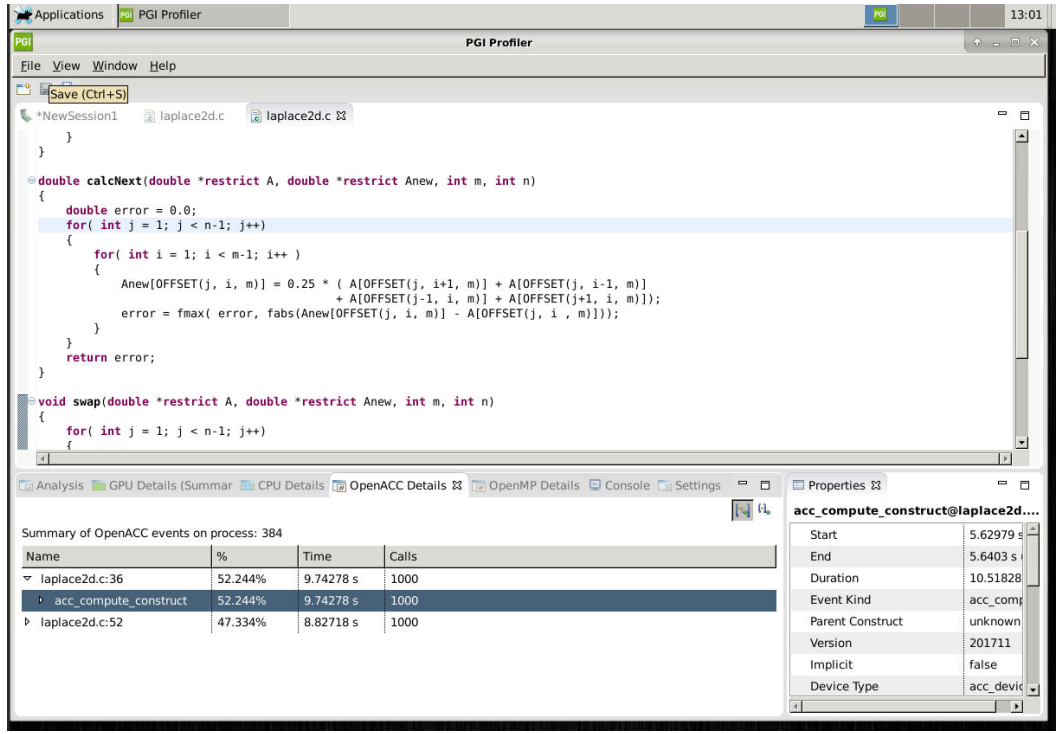
- When moving the mouse on the % value, one can see
  - Mean across all threads
  - Total across all threads
  - Total as a percentage of all the time spent on one / all threads.



PROFILING MULTICORE CODE

OpenACC Details





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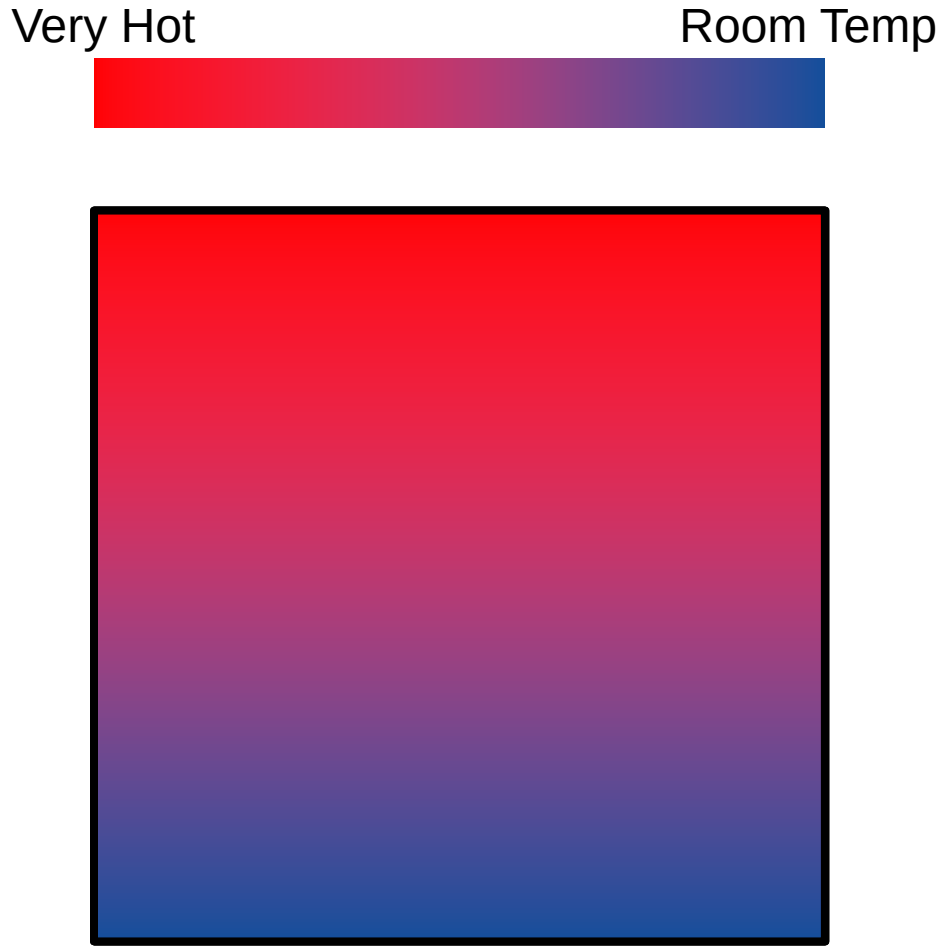
LAPLACE HEAT TRANSFER

Introduction to lab code - visual

We will observe a simple simulation of heat distributing across a metal plate.

We will apply a consistent heat to the top of the plate.

Then, we will simulate the heat distributing across the plate.



LAPLACE HEAT TRANSFER

Introduction to lab code - technical

The lab simulates a very basic 2-dimensional heat transfer problem. We have two 2-dimensional arrays, **A** and **Anew**.

The arrays represent a 2-dimensional, metal plate. Each element in the array is a **double** value that represents temperature.

We will simulate the distribution of heat until a **minimum change value** is achieved, or until we exceed a **maximum number of iterations.**

A

0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0

Anew

0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0

LAPLACE HEAT TRANSFER

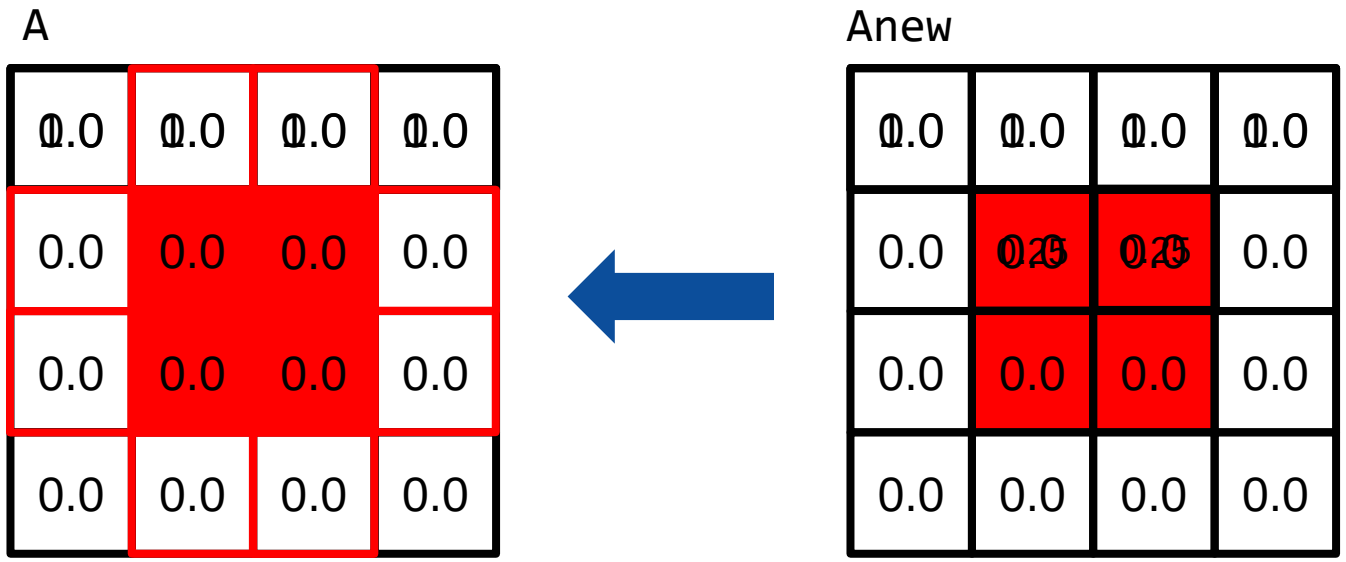
Introduction to lab code - technical

We initialize the top row to be a temperature of 1.0

The **calcNext** function will iterate through all of the inner elements of array A, and update the corresponding elements in Anew

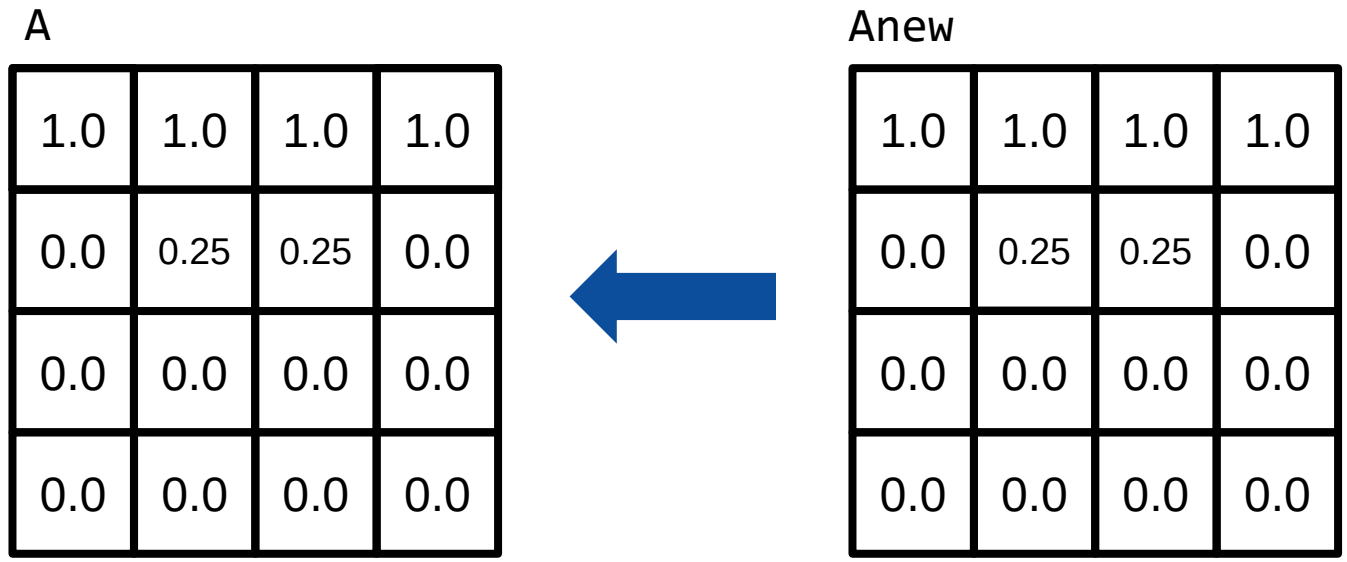
We will take the average of the neighboring cells, and record it in **Anew.**

The **swap** function will copy the contents of Anew to A



LAPLACE HEAT TRANSFER

Introduction to lab code



The **swap** function will copy the contents of Anew to A

KEY CONCEPTS

In this module we discussed…

- Compiling sequential and parallel code
- CPU profiling for sequential and parallel execution
- Specifics of our Laplace Heat Transfer lab code

LAB GOALS

In this lab you will do the following…

- Build and run the example code using the PGI compiler
- Use PGProf to understand where the program spends its time

THANK YOU

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TRAINING SETUP

- To get started, follow these steps:
- Create an NVIDIA Developer account at http://courses.nvidia.com/join Select "Log in with my NVIDIA Account" and then "'Create Account“ (done yesterday)
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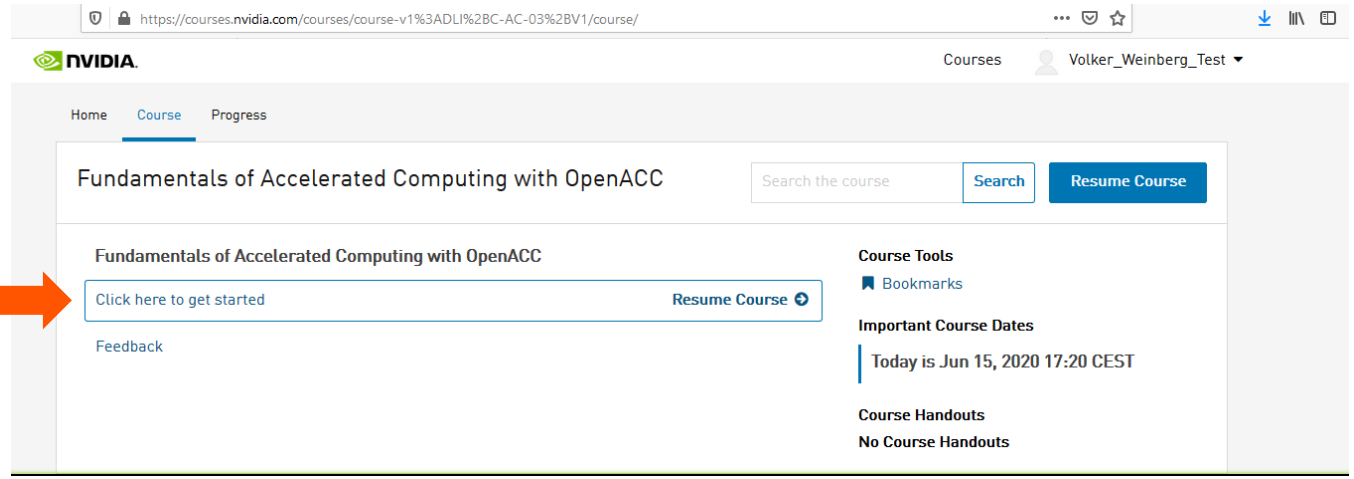
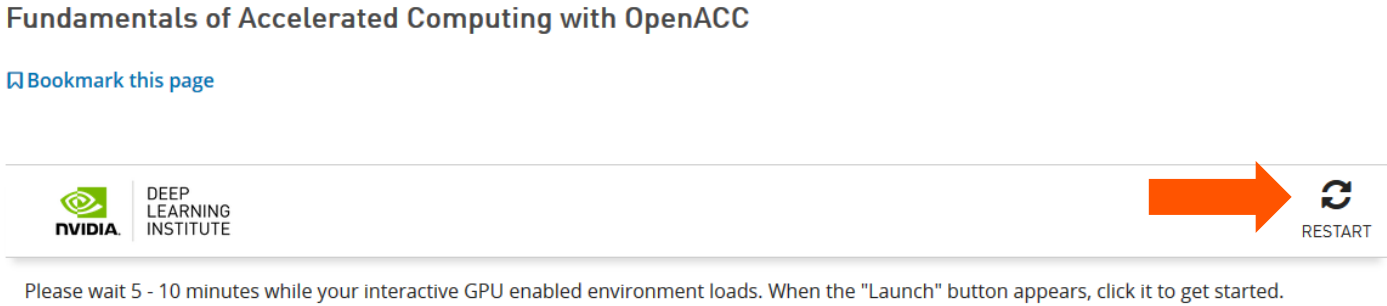
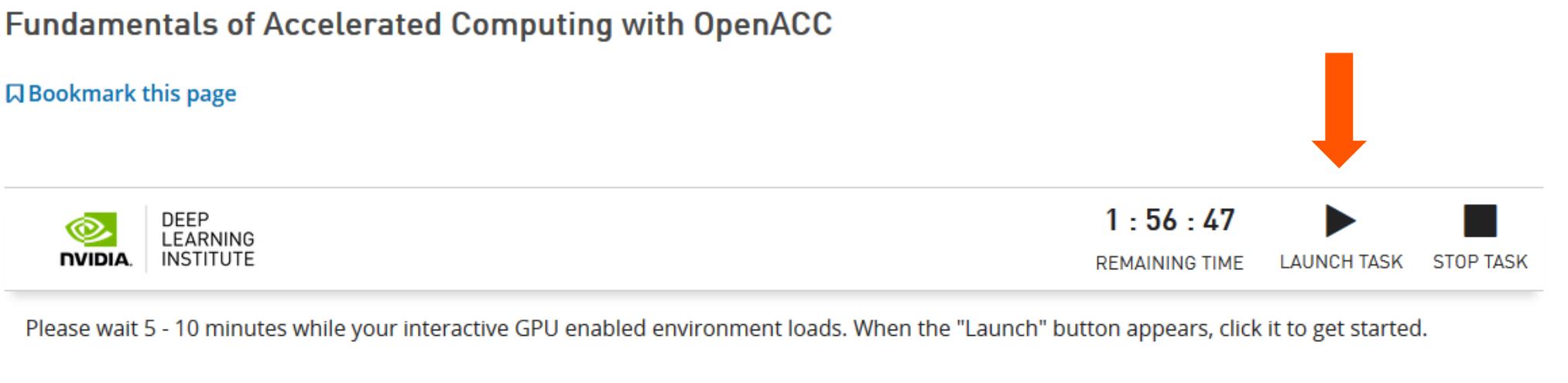
TRAINING SETUP





TRAINING SETUP



TRAINING SETUP

TRAINING SETUP

Welcome to the OpenACC labs

Please select the appropriate lab below.

- Module 2 - Application Profiling with PGProf Lab - This lab introduces students to application profiling using the PGProf profiler.
- Module 3 - OpenACC Directives Basics - This lab introduces OpenACC directives.
- Module 4 - GPU Programming with OpenACC - This lab introduces GPU programming with OpenACC.
- Module 5 - Data Management with OpenACC - This lab introduces OpenACC data management directives.
- Module 6 - OpenACC Loop Optimizations - This lab introduces students to loop optimizations in OpenACC.

Application Profiling with PGProf Lab

This lab is meant to accompany Module 2 of the OpenACC.org teaching materials. The purpose of this lab is to introduce students to application profiling using the PGProf profiler. Lab instructions and source code is available for C/C++ and Fortran.

Please see the following files to begin the lab:

- C/C++
- Fortran

PROFILING SEQUENTIAL CODE

CPU Details

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