For my summer research project at the University of Wisconsin - River Falls, I worked with Tareq AbuZayyad to create a comparison between two implementations of photon propagation simulations for the IceCube Project. The GPU program, called i3mcml (stands for Ice Monte Carlo Multi-Layer version 3), achieved a 65x speed up. The comparison between i3mcml and PPC (stands for Photon Propagation Code), its CPU-run counterpart, was done to be sure the much faster GPU version is useful and produces accurate simulated photon propagation data.

Tareq wrote the GPU program, which was based on PPC and CUDAMCML, a simulation program for how light moves through various tissues in the body that is run on a GPU. In application to IceCube, the multiple layers are those of Antarctic ice, that is comprised of various layers of dust, debris, and other obstructions that affect how light propagates. CUDA is the name of the coding architecture that developers use to make programs run on GPUs. CUDA was made by nVidia, a leader in GPUs. When a time comparison was made, the following results were observed:

Simulation Program	Processor	Type of Cores	Time
PPC	CPU (Intel Q6600)	Quad-core	1 hour, 19 minutes
i3MCML	GPU (9800GT)	112 stream	1 minute, 13 seconds
i3MCML	GPU (laptop 9600M)	32 stream	3 minutes, 40 seconds

In addition to running the simulation programs, my main job was to compare the output from each simulation. We ran PPC once and used this set of four output files, titled 111111.ppc.out, 333333.ppc.out, 555555.ppc.out, 777777.ppc.out, as the basis of comparison for six sets of four output files from i3mcml, similarly titled 111111.mcml.out, etc. Each of the raw ".out" files contained a lot of information I did not need, so I used the shell command "cat 111111.mcml.out | grep HIT > 1m.out" to grab all the lines with data regarding a triggered DOM reading. All of these lines start with the word "HIT," hence the shell command. A sample line looks like this:

HIT 111111 194 30 46 9048.7412 0.135966

"HIT" is just an identifier. "111111" is the set number. "194" is the event number. "30" is the string number hit. "46" is the DOM number hit. "9048.7412" is the time, in nanoseconds, it took the photon to travel from the surface of the ice to the location it was recorded. "0.135966" is the photon's direction, expressed as the cosine of the angle that it entered the ice at. The zero degree direction is straight up (positive z-direction) at the South Pole.

I used several scripts (i3Event_event.C, theory.C, and Event_dom.C) to put this information into ROOT files. ROOT files allow us to make histograms of the data so we can compare the output of the two simulations in a visual and numerical way. First, I examined all hits for triggered events using the ascii2root() function in i3Event_event.C. Then, I grouped the hits into events by common event number using the process_trees() function in i3Event_event.C. An event-by-event comparison was possible because the same 10^5 muons generated by MMC were input into both i3mcml and PPC. For the event grouping comparison, number of hits per event, number of strings and DOMs hit per event, and center of gravity (a weighted average of where in IceCube hits were recorded for the event) were investigated. I used theory.C to put the data from PPC and i3mcml together into a single ROOT file. I used Event_dom.C to calculate the center of gravity of each event using icecube_geometry.nt, a file that has the location of each DOM in the ice.

Histograms for both the comparison of all hits and the comparison by event grouping showed that i3mcml and PPC are in good agreement. Many of the histograms I created for comparison are posted on the IceCube Wiki within the IceCube Internal Website under "Comparison of GPU and CPU Photon Transport Simulations for IceCube" by Mary Murphy and "GPU based implementation of Photon Transport" by Tareq AbuZayyad.