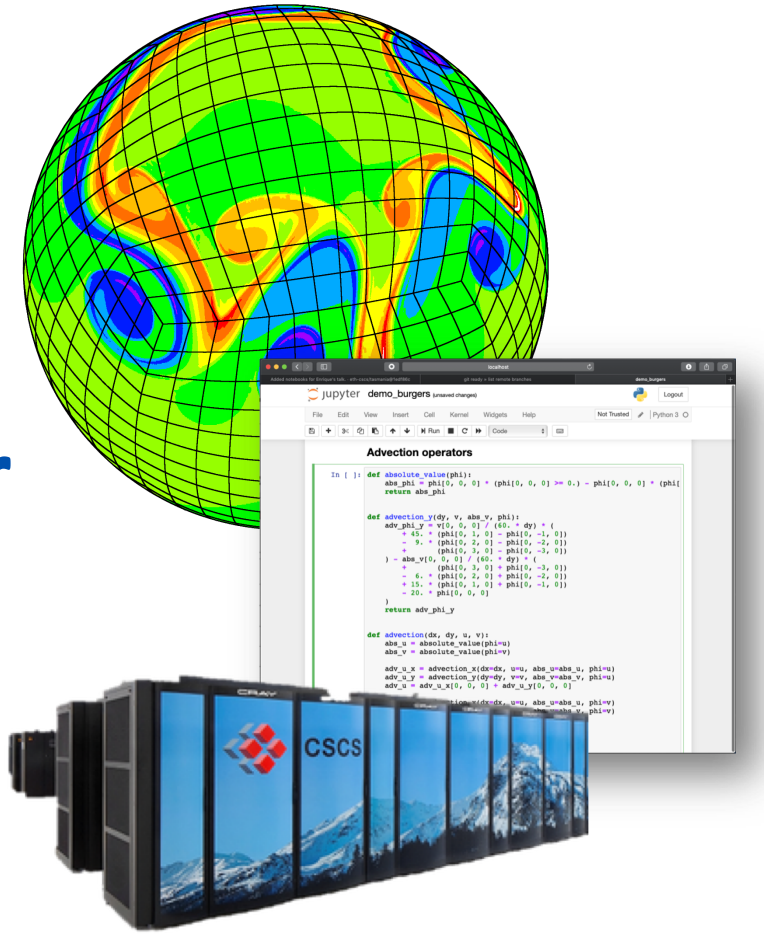
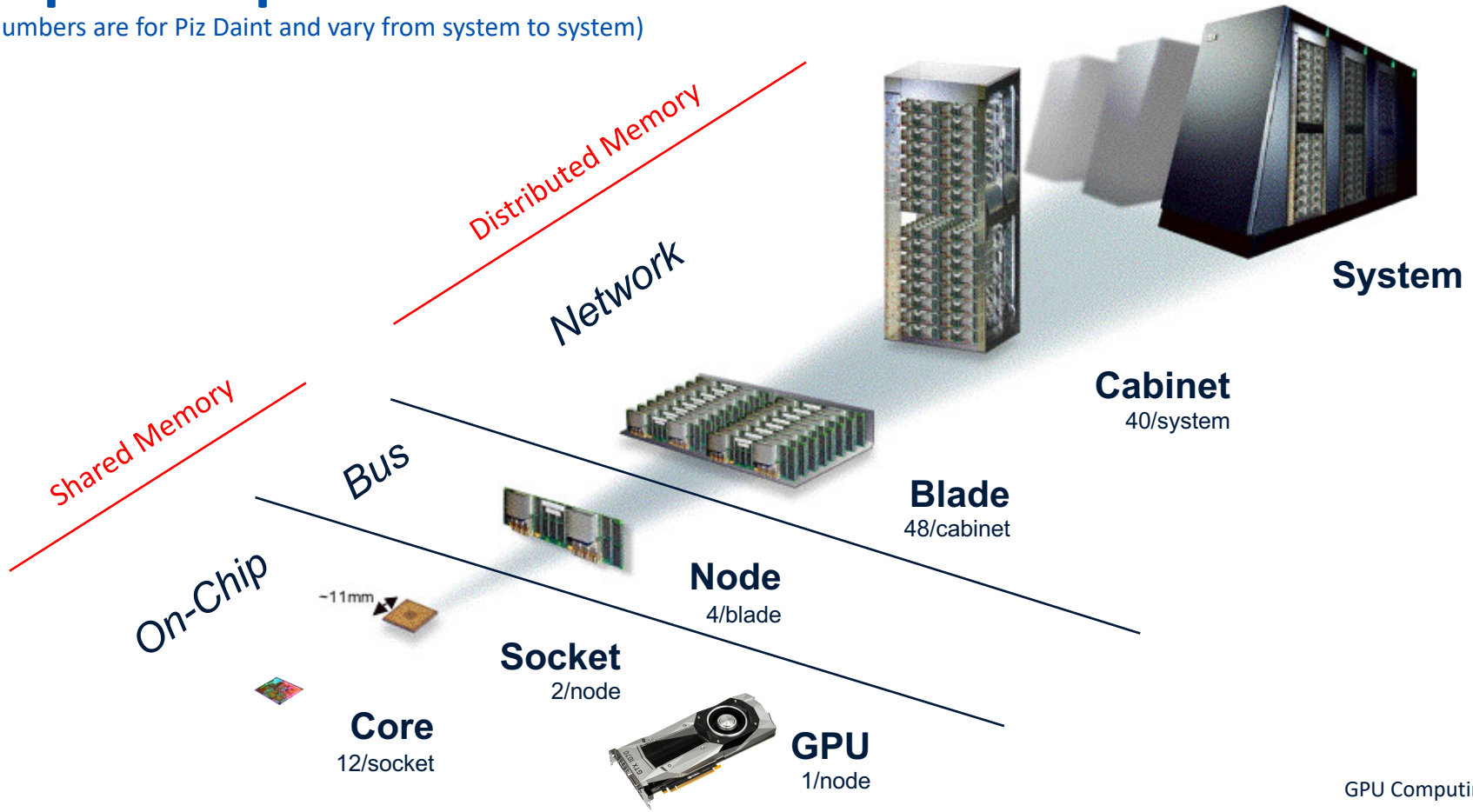
High Performance Computing for Weather and Climate (HPC4WC)

Content: Graphics Processing Units
Lecturers: Stefano Ubbiali
Block course 701-1270-00L
Summer 2021



Supercomputer Architecture

(Numbers are for Piz Daint and vary from system to system)



Learning goals

- Understand why specialized hardware such as GPUs is become the new “normal”
- Learn how to program a GPU using a high-level programming language
- Understand potential and difficulties of GPU-computing

Who has experience with programming GPUs?

Source: www.eia.gov

Power, power, power!

250x shortfall compared to target 1km global simulations at 1 SYPD! (Schulthess et al., 2019)

Scalability tests with IFS on Piz Daint for simulations with 1.45km grid spacing (Düben et al., 2020)

Dycore option	#tasks and threads	Energy consumption per year	Throughput
Hydrostatic	4880 tasks; 12 threads per task	85.21 MWh/SY	0.190 SYPD
Non-hydrostatic	9776 tasks; 6 threads per task	191.74 MWh/SY	0.088 SYPD
Non-hydrostatic	4880 tasks; 12 threads per task	195.30 MWh/SY	0.085 SYPD

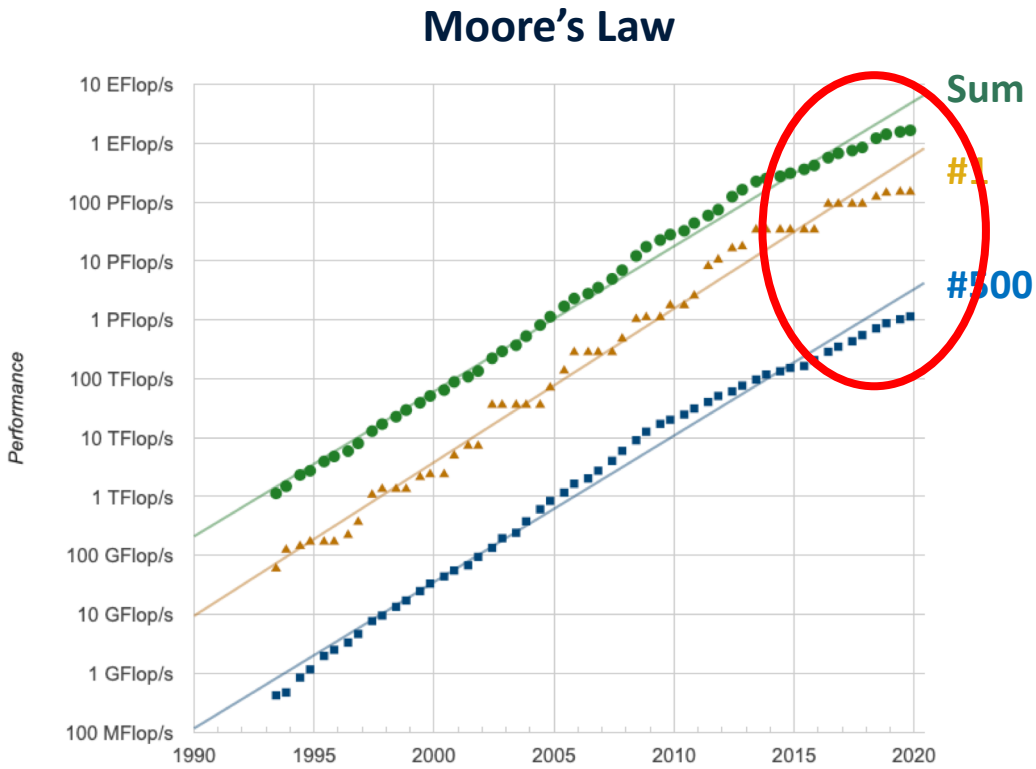
191.74 MWh/SY $*$ 0.088 SYPD = 16873 kWh/day

Average electricity consumption of U.S. residential utility: ≈29 kWh/day

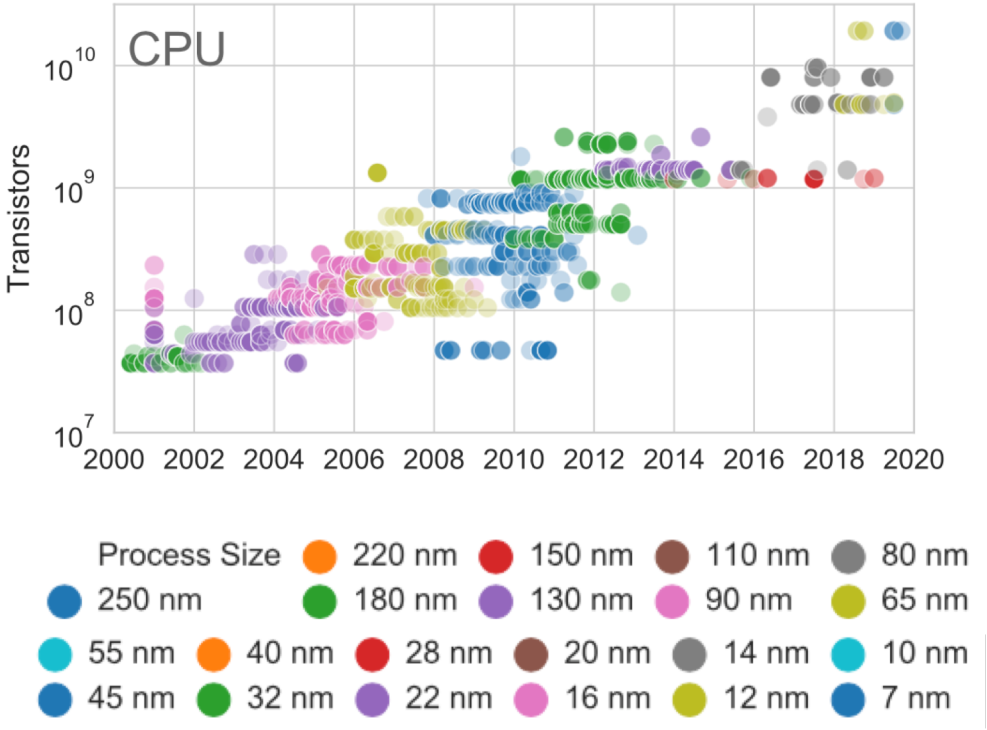
Source: top500.org

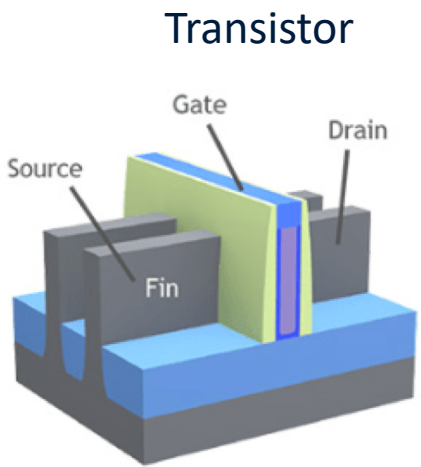
Where do the Watt's go?

- CPUs are very complex and built for general purpose
- For weather and climate modeling, we often don't use all of the capabilities of a general purpose computer chips
- Historically, chips were custom-built for scientific computing
- Moore's law and the economics of developing and manufacturing chips ($30 - $80 M) changed that
- Era of "General Purpose Computing"



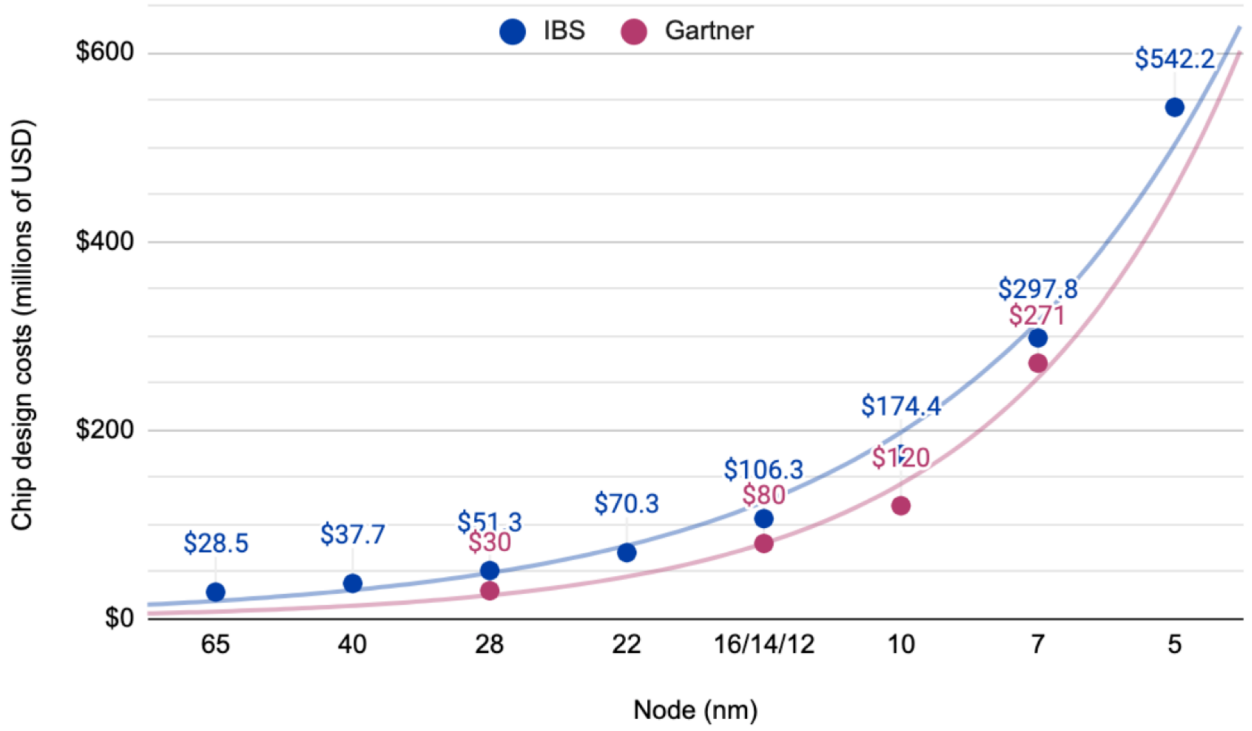
The End of General Purpose Computing



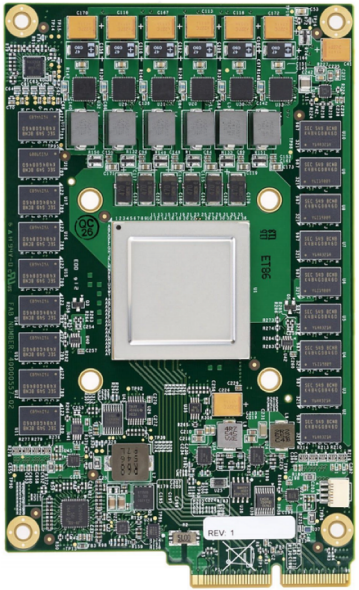


Distance between Si-atoms is 0.5 nm!

Chip Design Costs

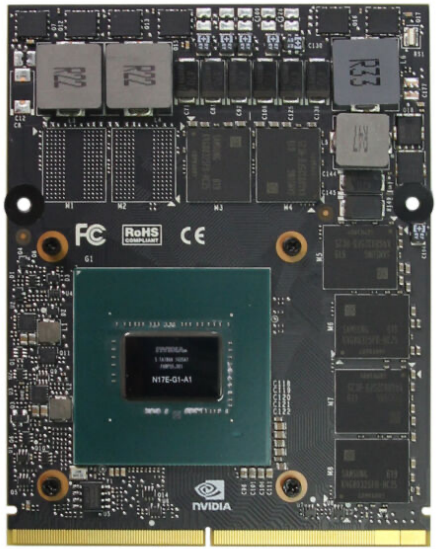


Specialized Chips are on the Rise!



Google's TPU
(e.g. machine learning)

FPGA
(e.g. bitcoin mining)

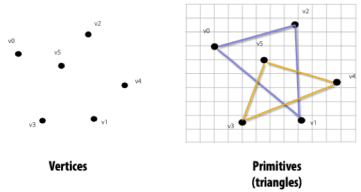


GPU
(e.g. gaming)

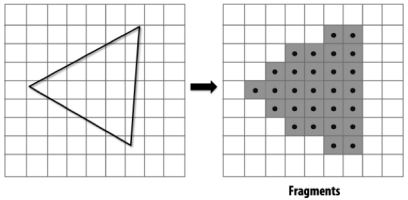
GPU's are for gaming, right?

GPU Computing

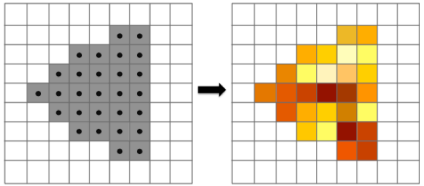
Primitive computation



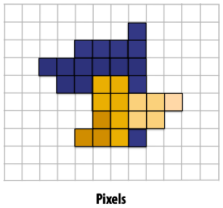
Rasterization



Fragment processing



Pixel operations



Parallel operations!

As video games became more complex, the hardware and software environment evolved to be more flexible.

With *OpenGL*, *OpenCL*, *CUDA*, … programming languages started to appear that made general purpose computing on GPUs possible.

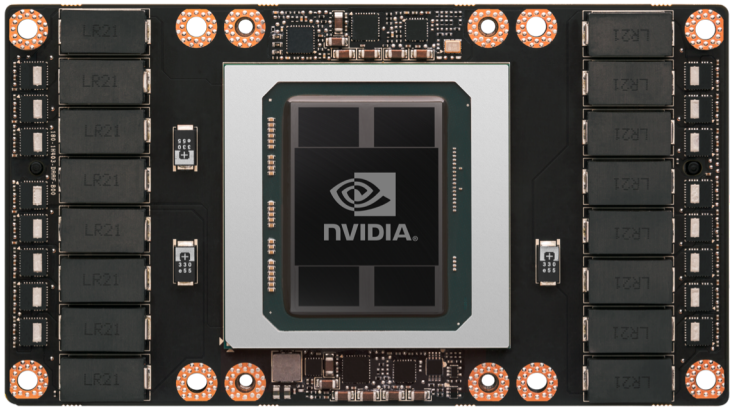
GPUs are great for some workloads / algorithms, but not so great for others!

Performance / Watt

Intel Xeon E5-2690 v3 + DRAM

~ 200 W 0.5 TFLOP/s 70 GB/s

NVIDIA Tesla P100

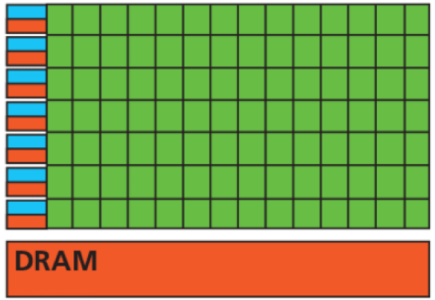


~ 300 W 5.3 TFLOP/s 720 GB/s

CPU vs. GPU

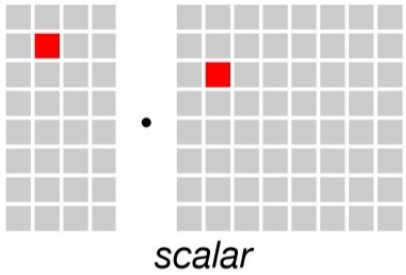
Architecture

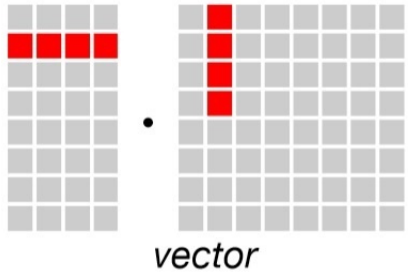
Few complex cores
Few fast threads
Complex ILP
Little die surface for FLOPs



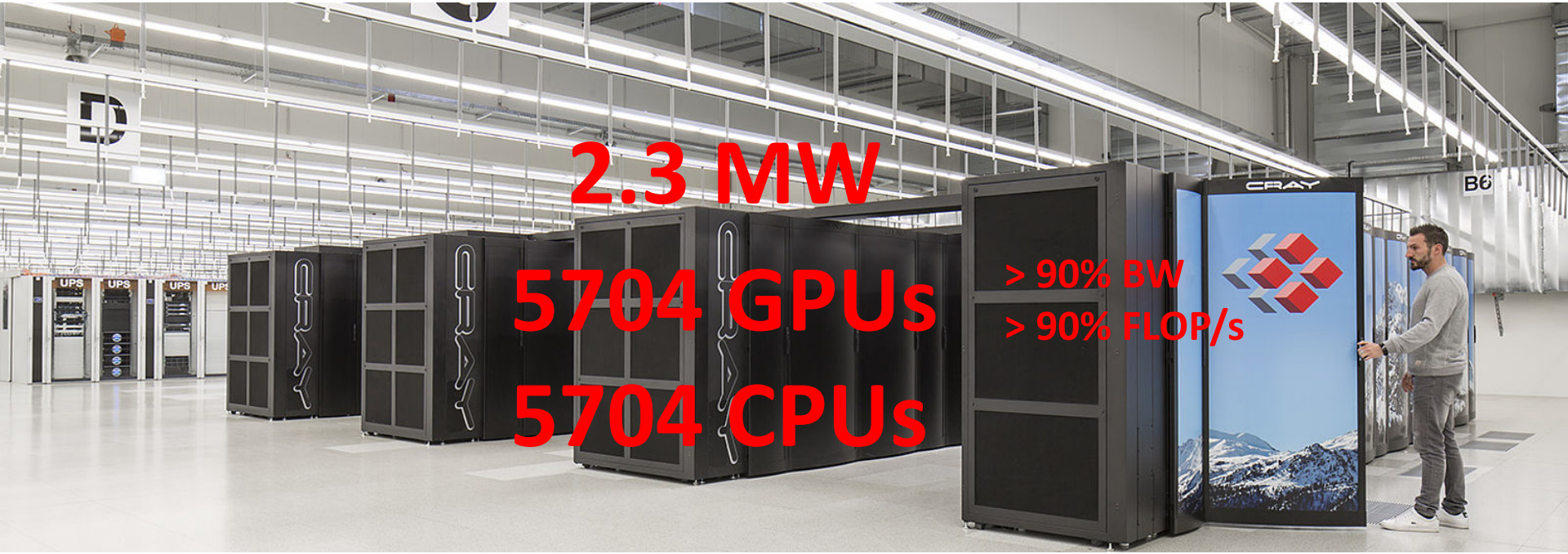
Many simple cores
Many concurrent threads
Maximize FLOP-throughput

Compute primitive

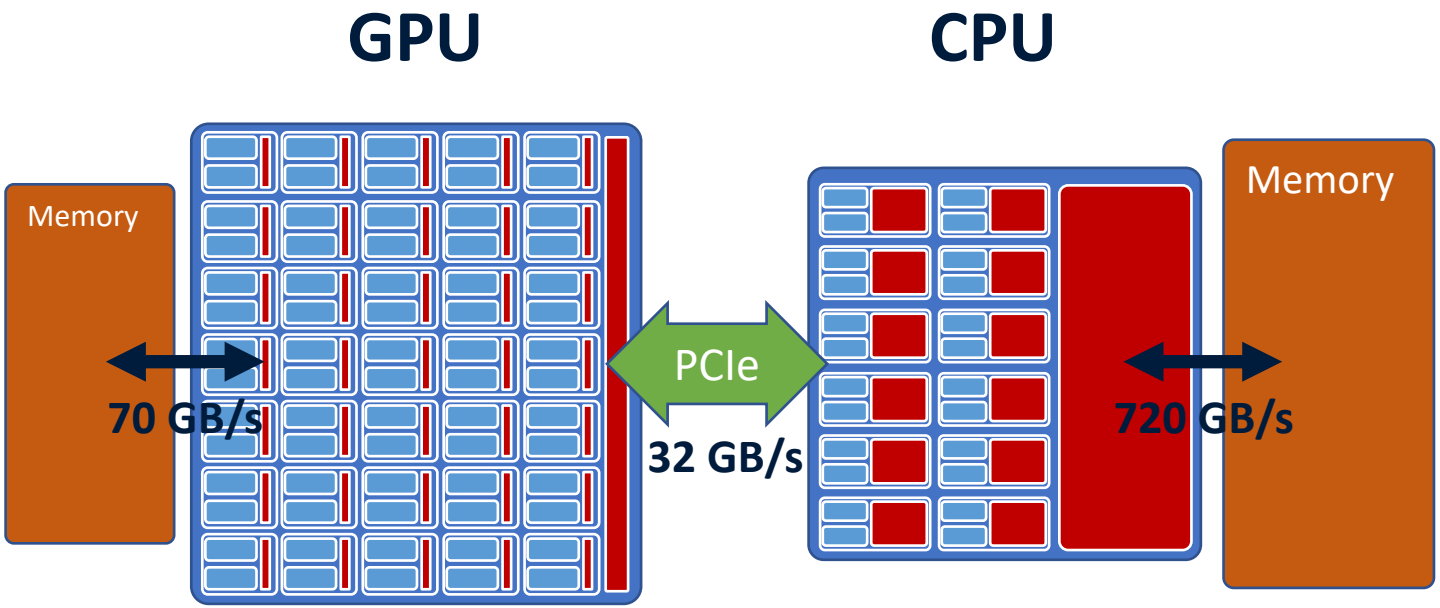




Hybrid Supercomputer

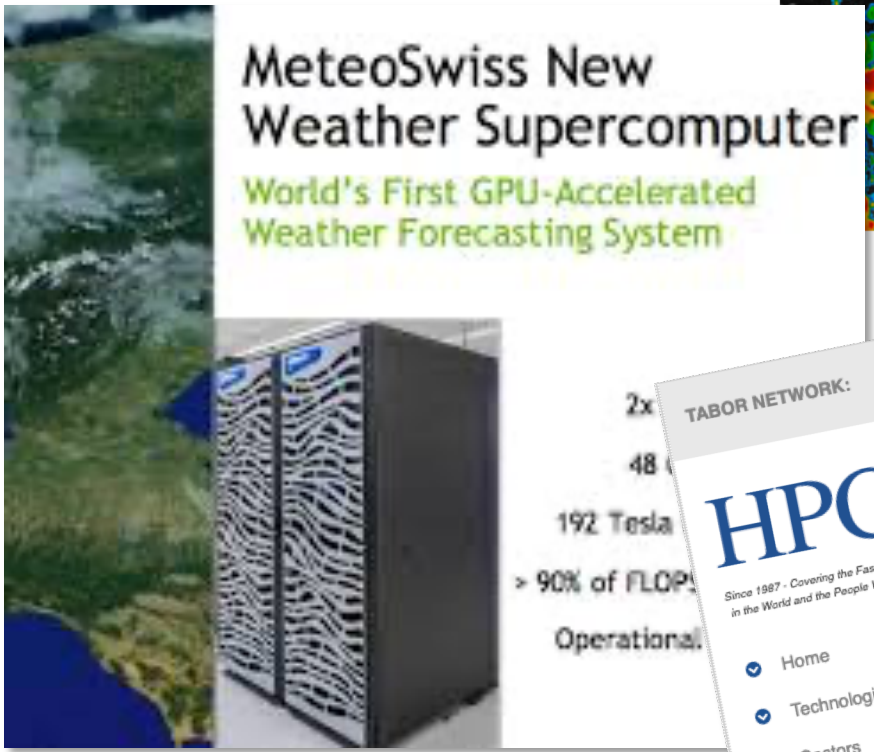


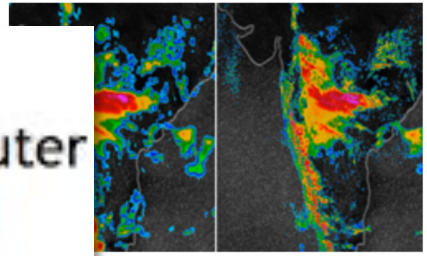
Node Architecture



Crucial to minimize memory transfers between CPU and GPU!

Weather and Climate on GPUs





HPC | TOP STORIES

Jan 10, 2019

New GPU-accelerated Weather Forecasting System Dramatically Improves Accuracy

By Nefi Alarcon

Tags: News, OpenACC, Tesla

Discuss

TABOR NETWORK: DATANAMI ENTERPRISEAI HPCWIRE JAPAN ADVANCED SCALE FORUM HPC ON WALL ST

HPC wire

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GPUs to Power the Exascale Era

U.S. Department of Energy and Cray Deliver Record-Setting Frontier Supercomputer at ORNL

- Custom AMD EPYC™ CPUs optimized for HPC and AI
- Purpose-built HBM-enabled Radeon Instinct™ GPUs

Home > CPUs

El Capitan Supercomputer Detailed: AMD CPUs & GPUs To Drive 2 Exaflops of Compute

by Ryan Smith on March 4, 2020 1:00 PM EST

Intel Xe-HP GPU Deployed for Aurora Exascale Development

By Tiffany Trader

Questions?

Lab Exercises

01-GPU-programming-cupy.ipynb

- Introduction to GPU programming using a high-level programming language

Note. You will be asked to write a GPU version of `stencil2d.py`. To be able to use Matplotlib to plot the results, please issue this command from a terminal:

```
export PYTHONPATH=/users/classXXX/HPC4WC_venv/lib/python3.8/site-packages:$PYTHONPATH
```

Let’s go!

(see you on Slack)