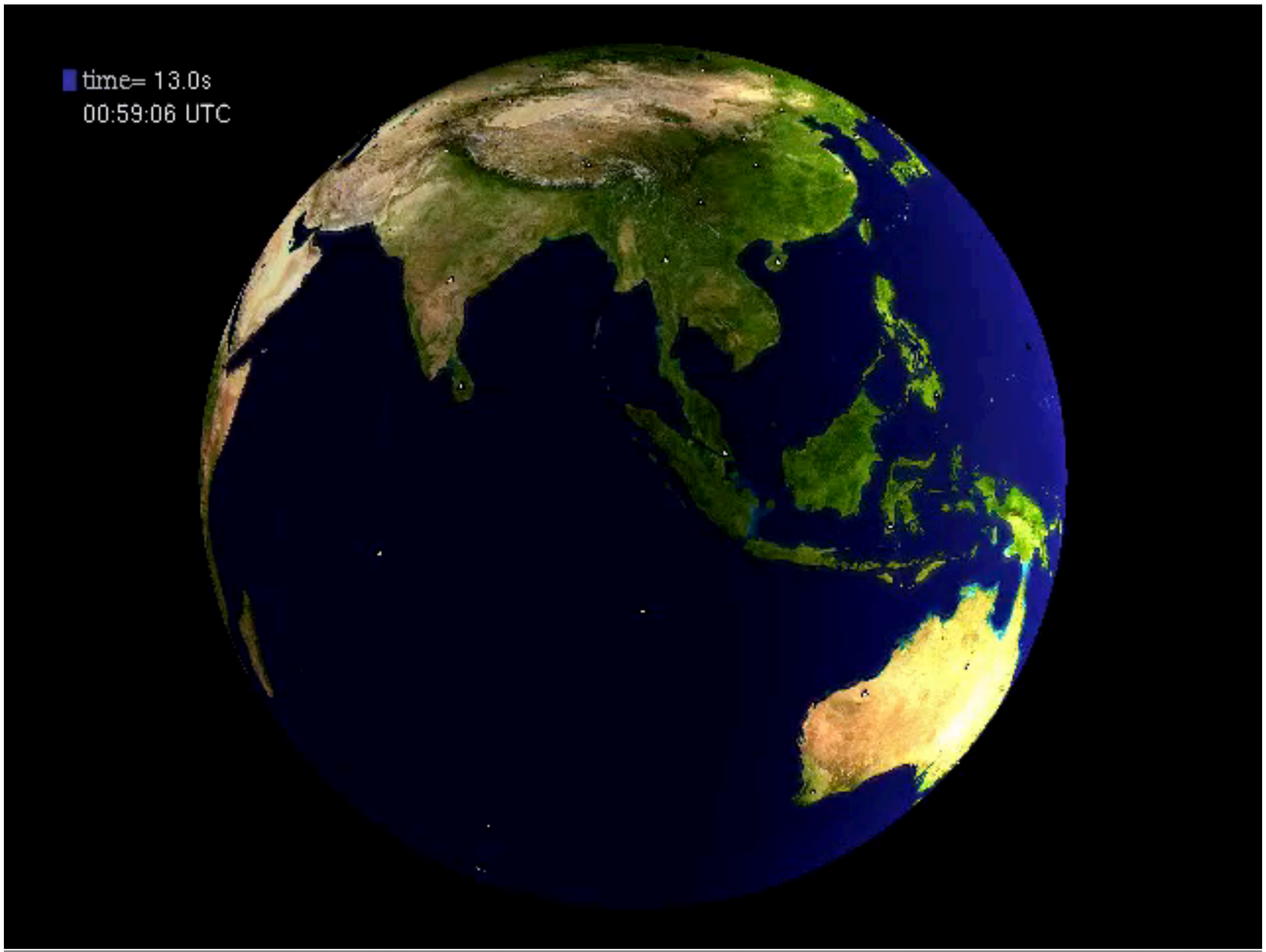
Computational Geophysics
ErSE 326



Introduction:

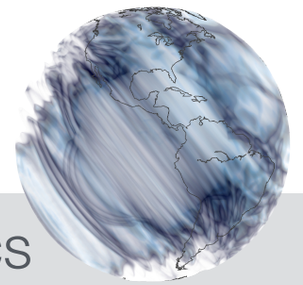
- computational trends

Geophysics:

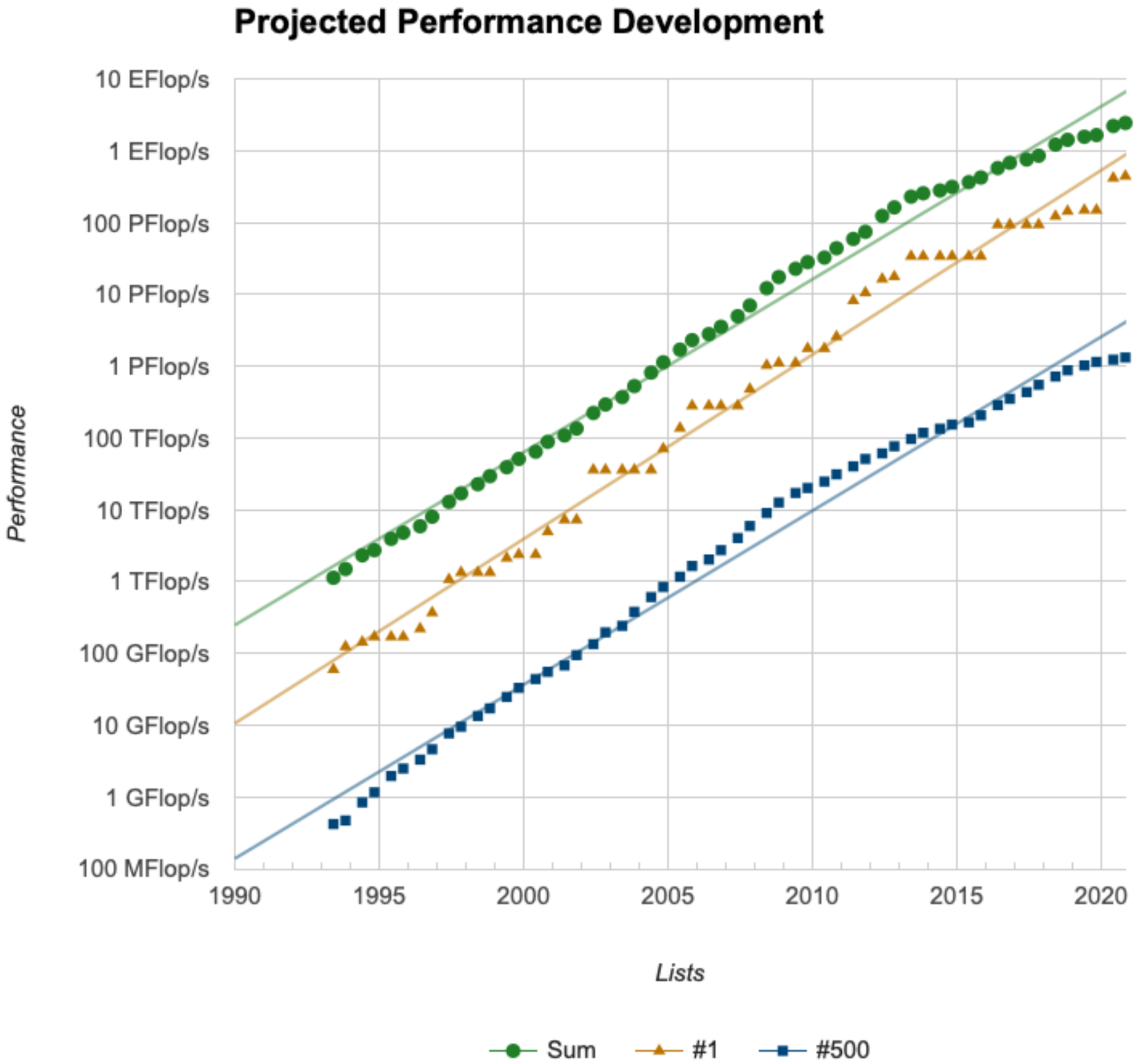
- Heat Flow
- Wave propagation

Numerical methods:

- finite-differences (FD)
- pseudo-spectral (PS)
- finite-element method (FEM)
- spectral-element method (SEM)

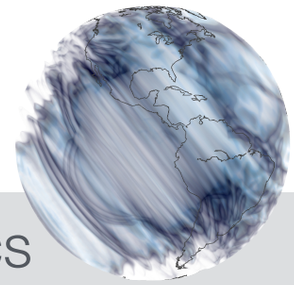


Trends - fastest supercomputers



Fugaku

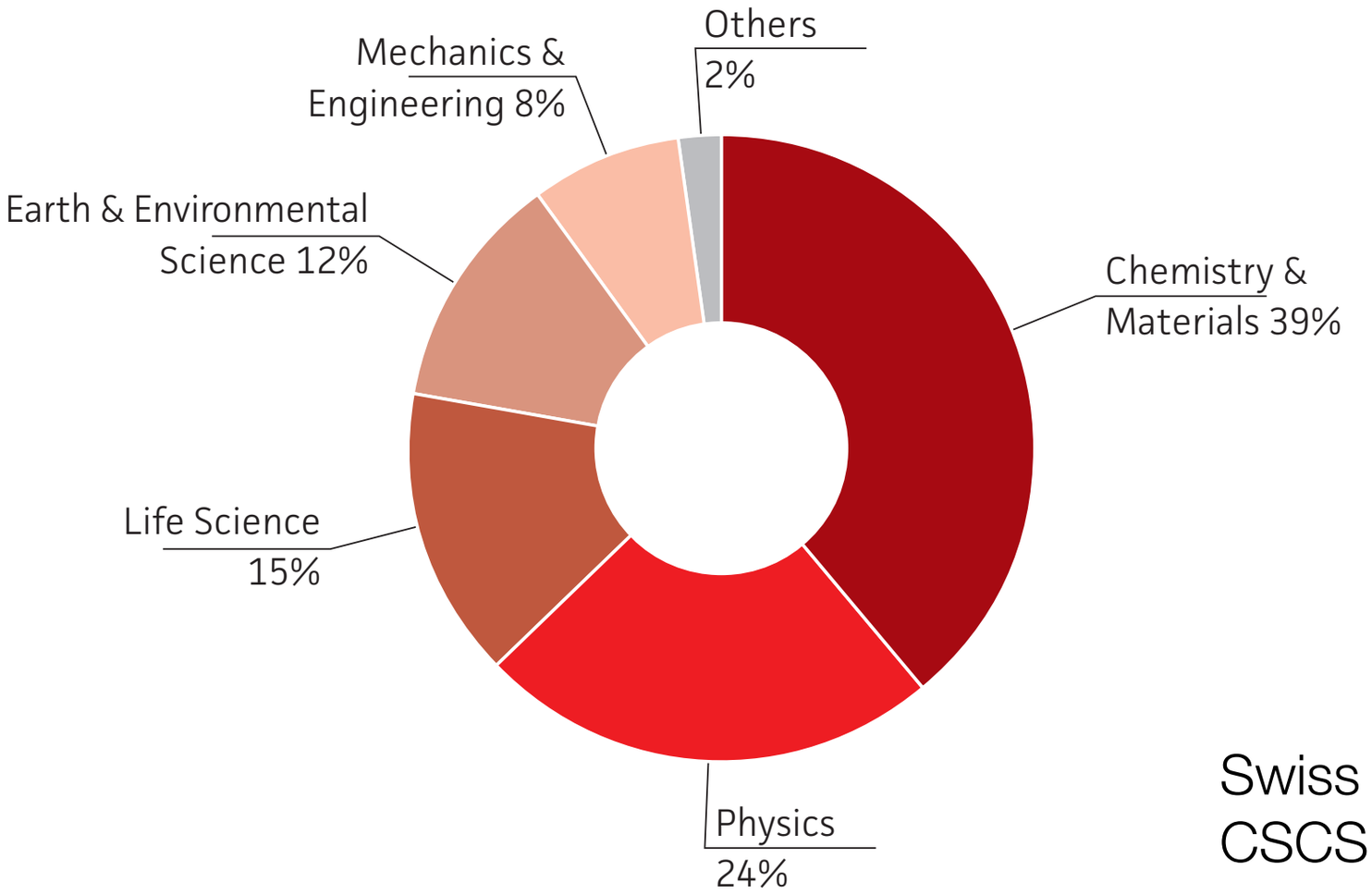
1. exa-scale (half-precision) system since year 2020



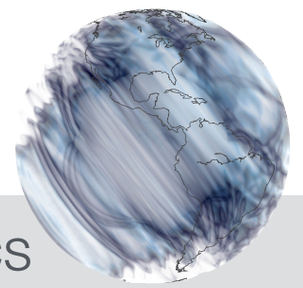
hysics

Trends - Usage by Research Field

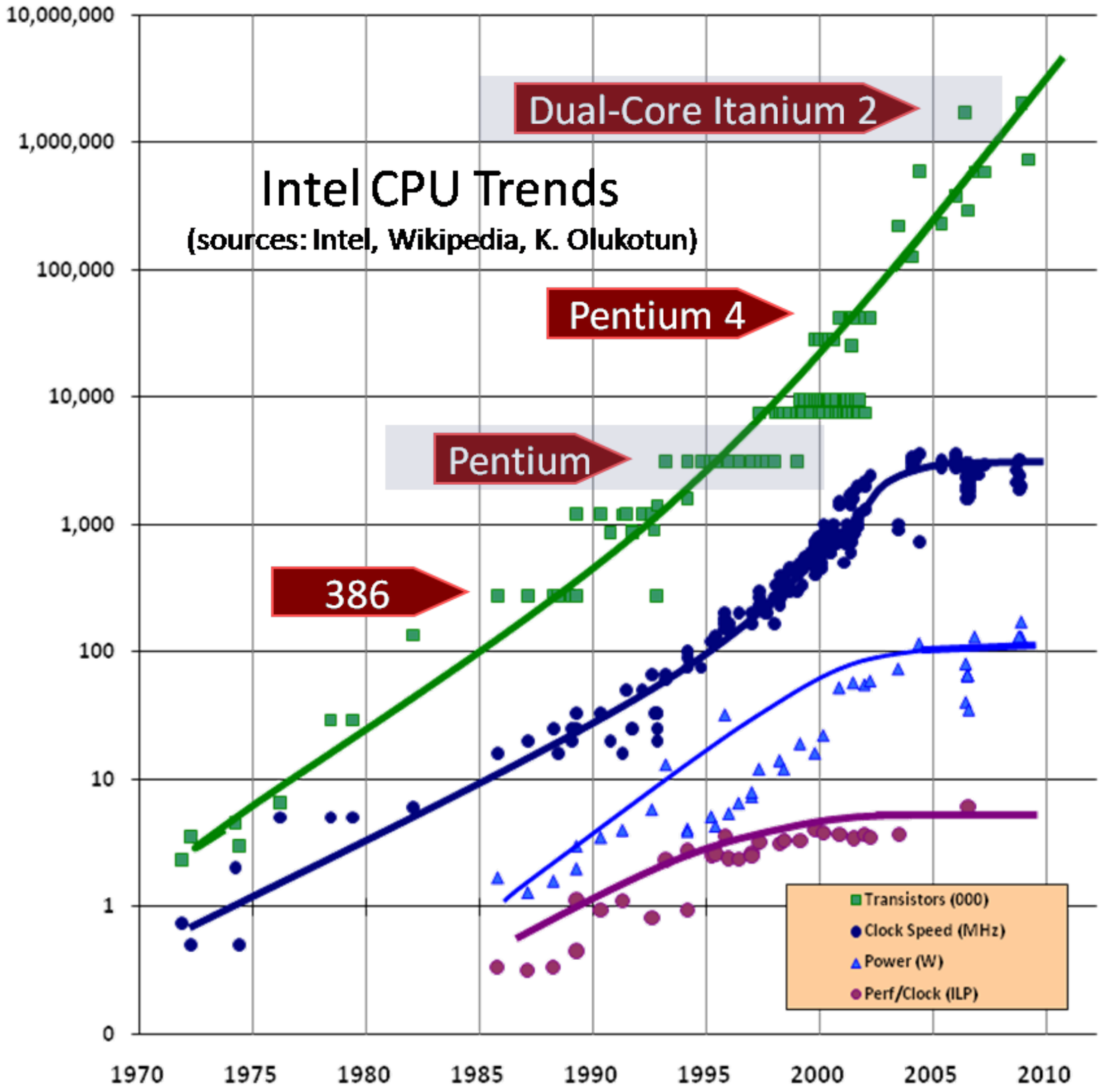
User Lab Usage by Research Field



Swiss National Supercomputing Center
CSCS (2020)

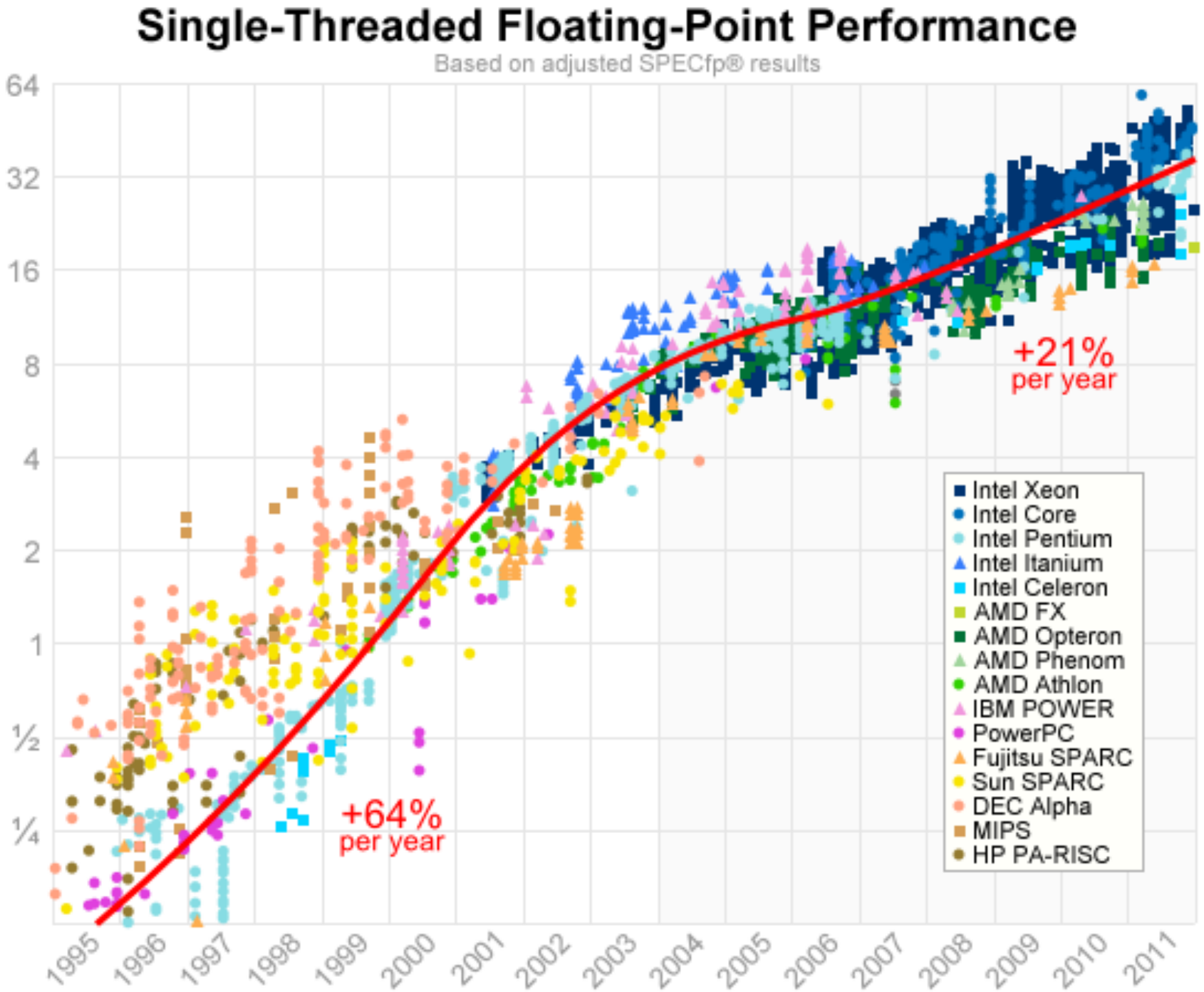


Trends - CPU

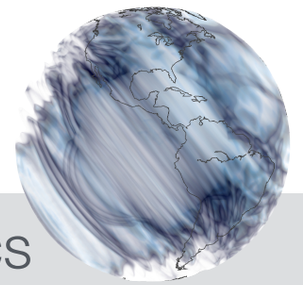


multi-core CPUs
since ~2006

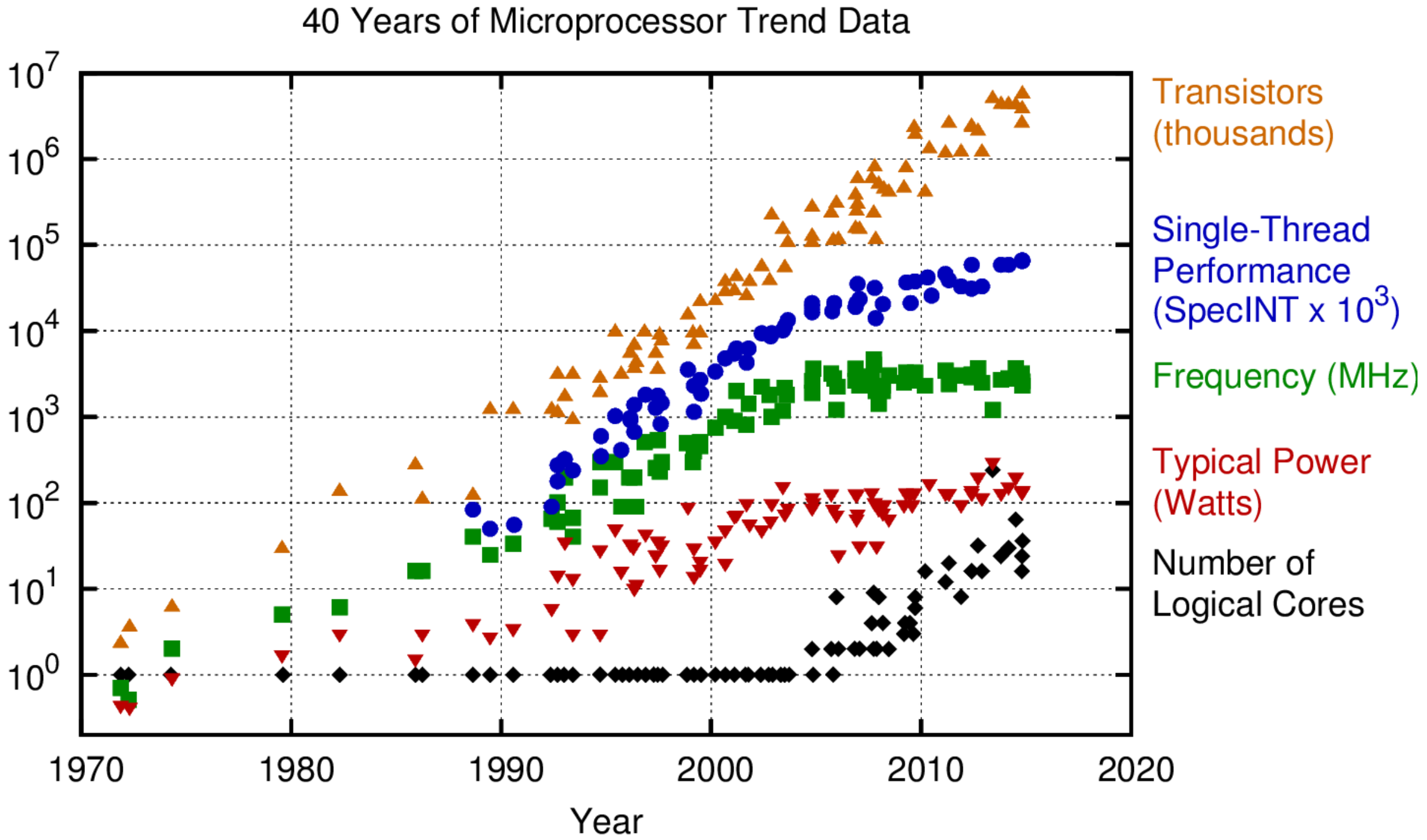
Trends - CPU



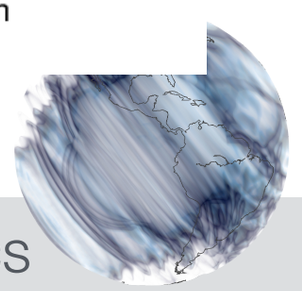
slow-down
since ~2003



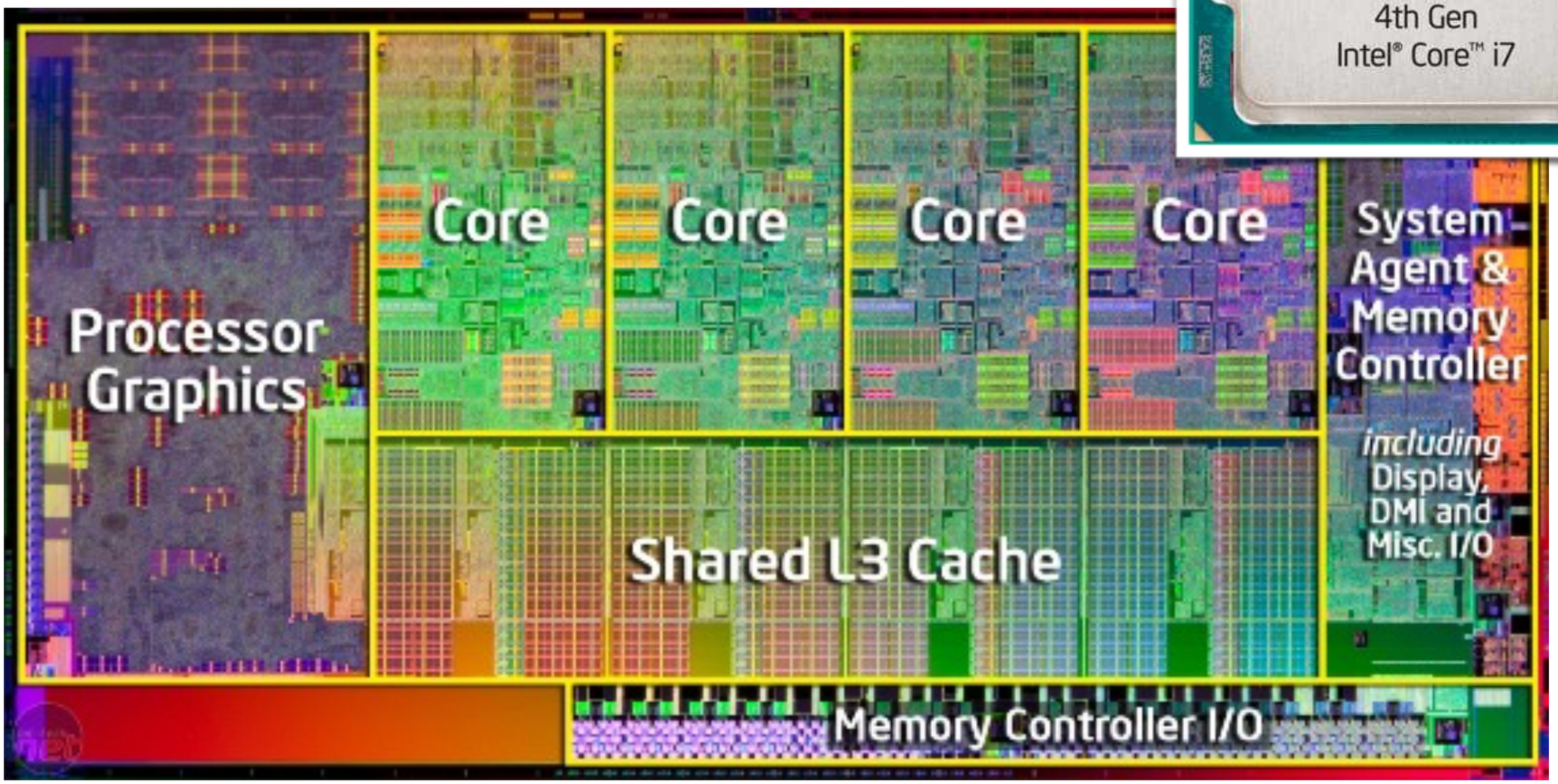
Trends - CPU



Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten
New plot and data collected for 2010-2015 by K. Rupp



Trends - CPU


Core
Core
Core
Core
System Agent & Memory Controller
including Display, DMI and Misc. I/O
Processor Graphics
Shared L3 Cache
Memory Controller I/O


intel
4th Gen
Intel® Core™ i7

Trends - CPU

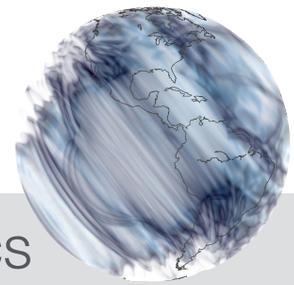
6 cores
12 threads (hyperthreading)
base frequency 2.9 GHz
lithography 14nm
average power **45 W**

(2018)

Trends - CPU

8 cores
16 threads (hyperthreading)
base frequency 2.4 GHz
lithography 14nm
average power **45 W**

(2020)



Trends - CPU

8 cores
16 threads (hyperthreading)
base frequency 3.3 GHz
lithography 10nm
average power **65 W**

(2021)

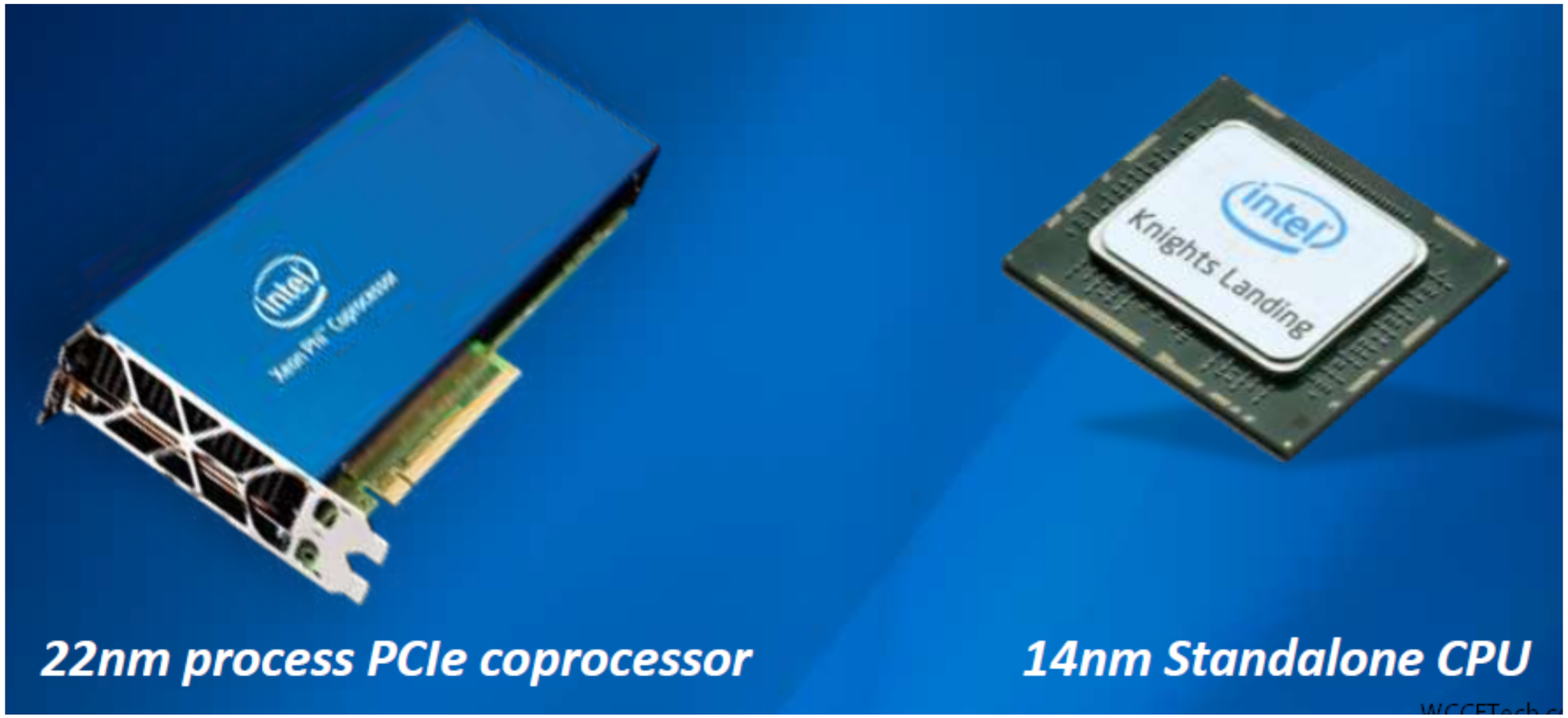
Trends - CPU

Arm v8-architecture
48+4 cores
512-bit SIMD
base frequency 2.2 GHz
lithography 7nm

average power ~160 W
-> 16 GF/W

(2020)

Trends - Intel Phi

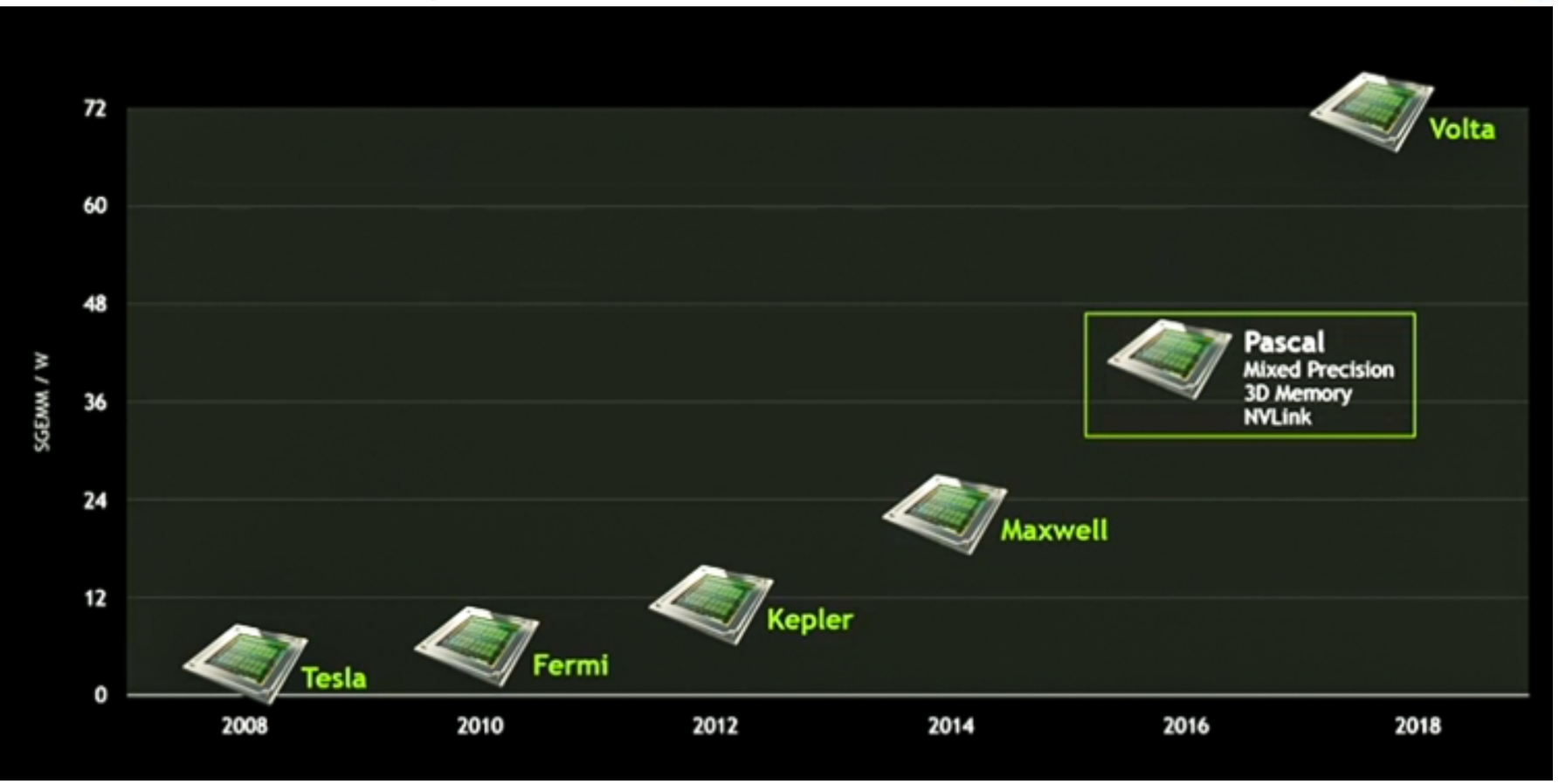


hardware accelerators
(discontinued 2020)

Trends - GPU

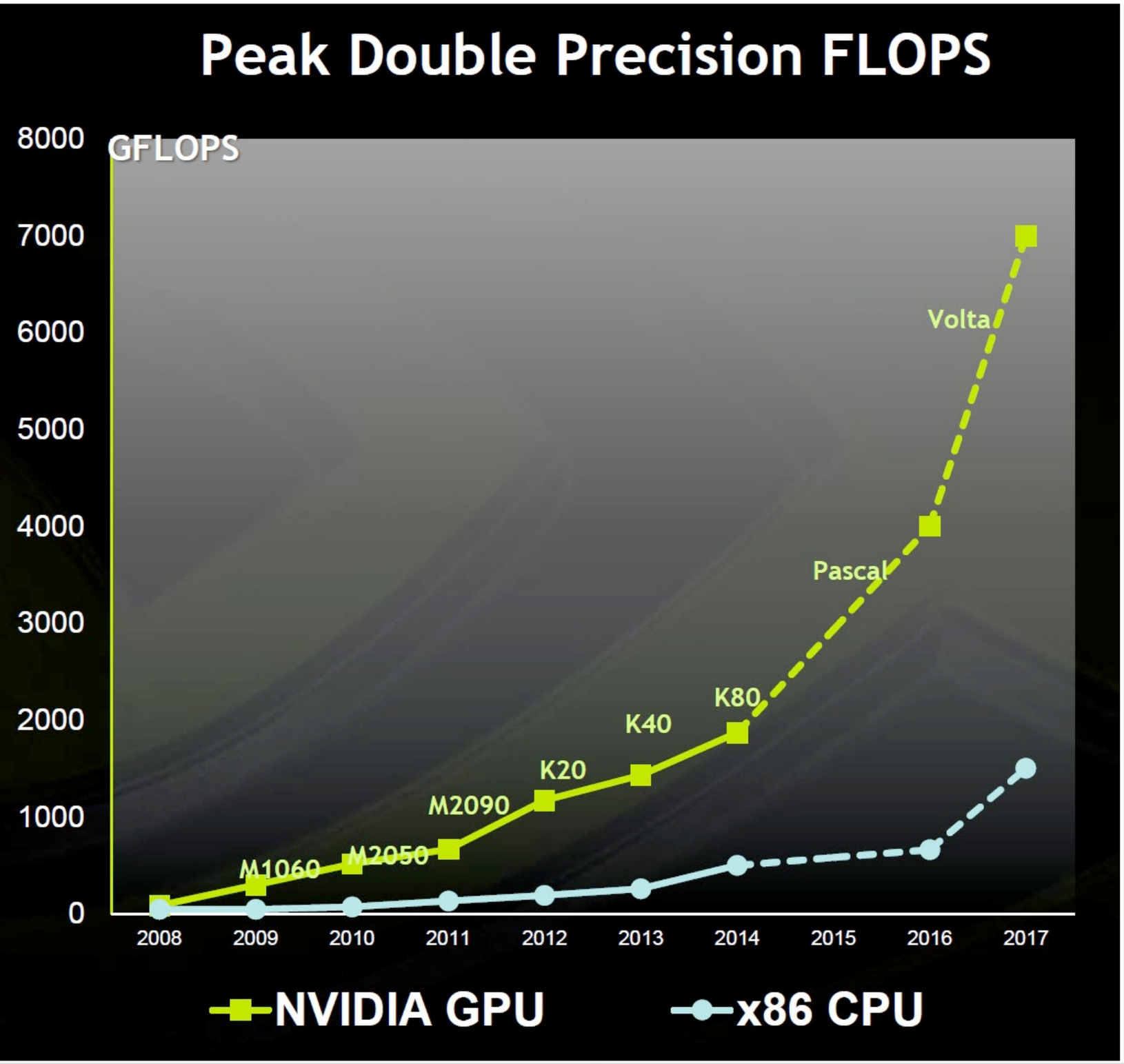
Trends - GPU

Nvidia - graphic cards

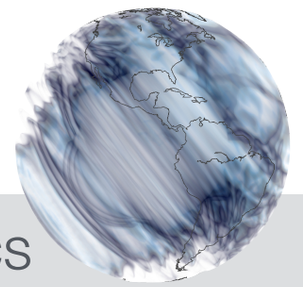


hardware accelerators

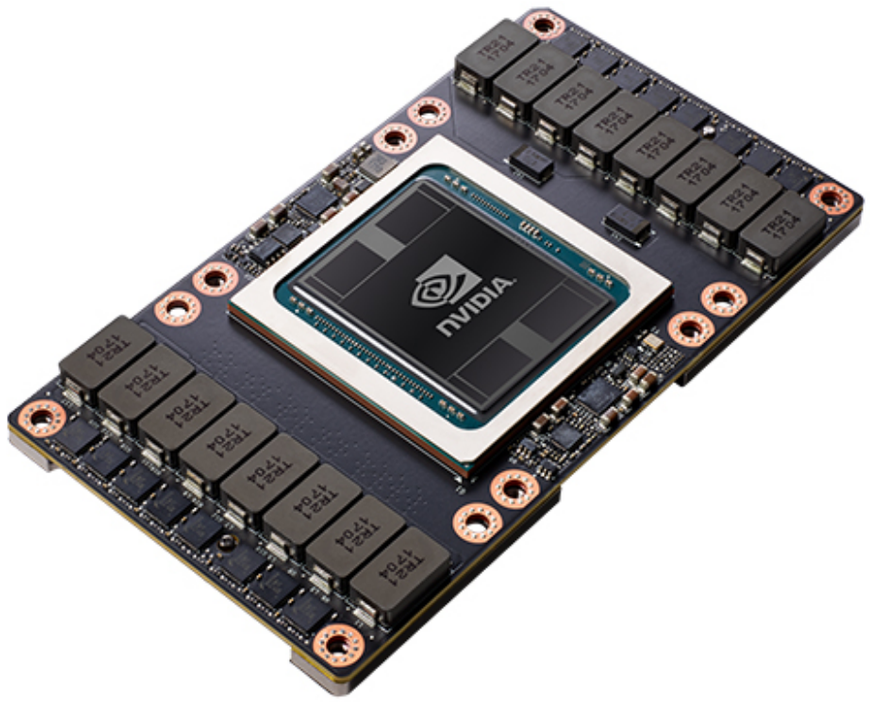
Trends - GPU



hardware accelerators



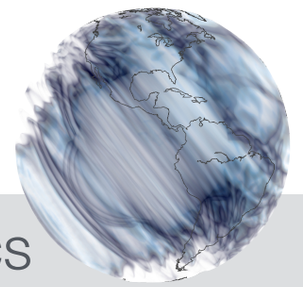
Trends - GPU



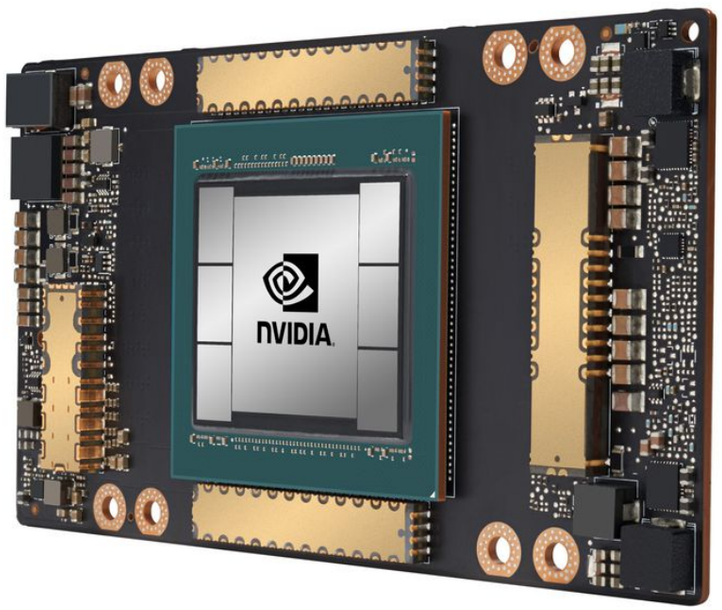
Nvidia Volta V100
32 * 80 double-precision cores

base frequency 1.5 GHz
lithography 12nm

power ~300 W
-> peak 26 GF/W (FP64)
(2018)



Trends - GPU



Nvidia Ampere A100
32 * 108 double-precision cores

base frequency 1.4 GHz
lithography 7nm

power ~400 W
-> peak 24 GF/W (FP64)
(2020)

Trends - Supercomputers w/ hardware accelerators


Fugaku


Summit


Sierra


Sunway

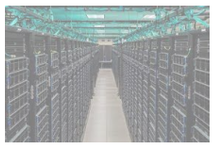
Perlmutter

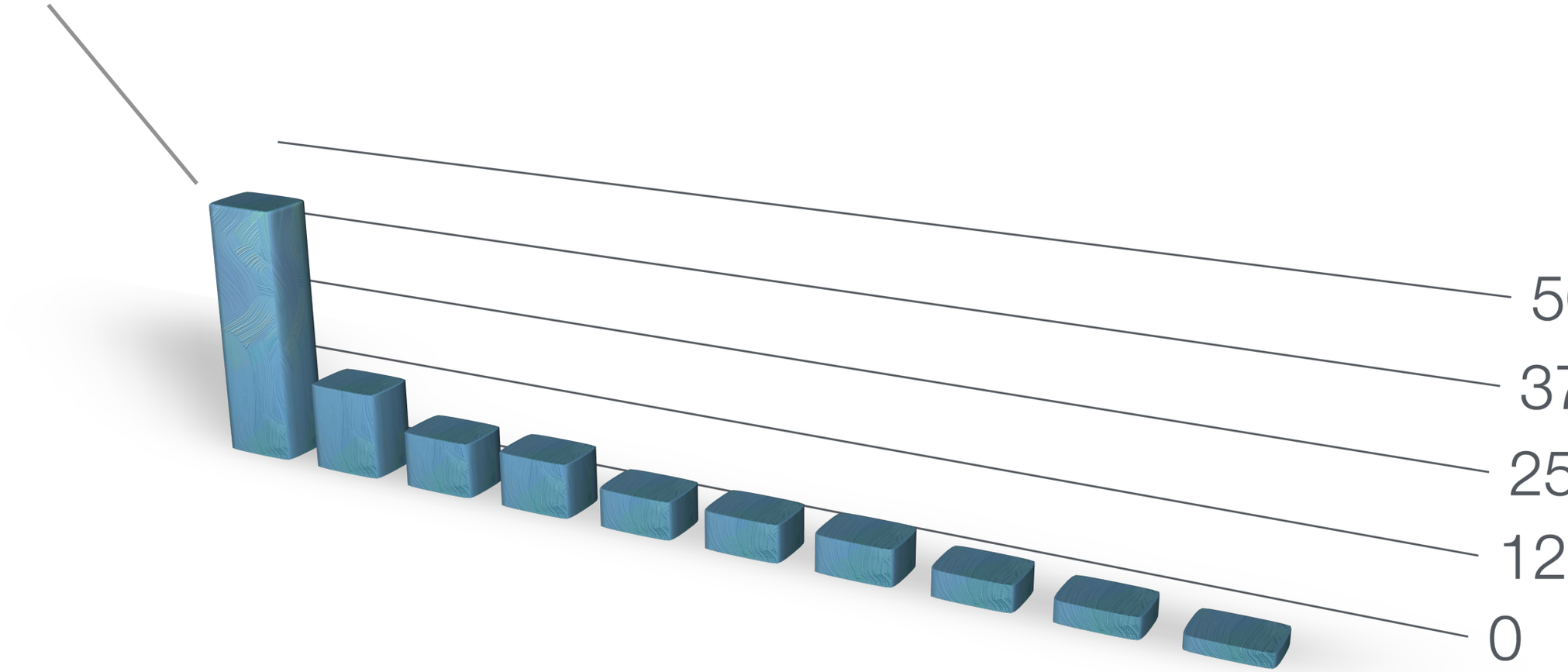

Selene


Tianhe-2

JUWELS


HPC5


Frontera



(Top500.org - June 2021)

Introduction:

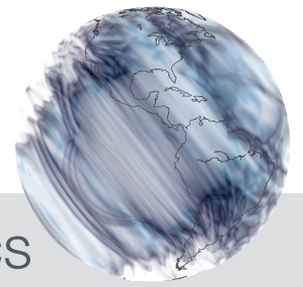
- computational trends

Geophysics:

- Heat Flow
- Wave propagation

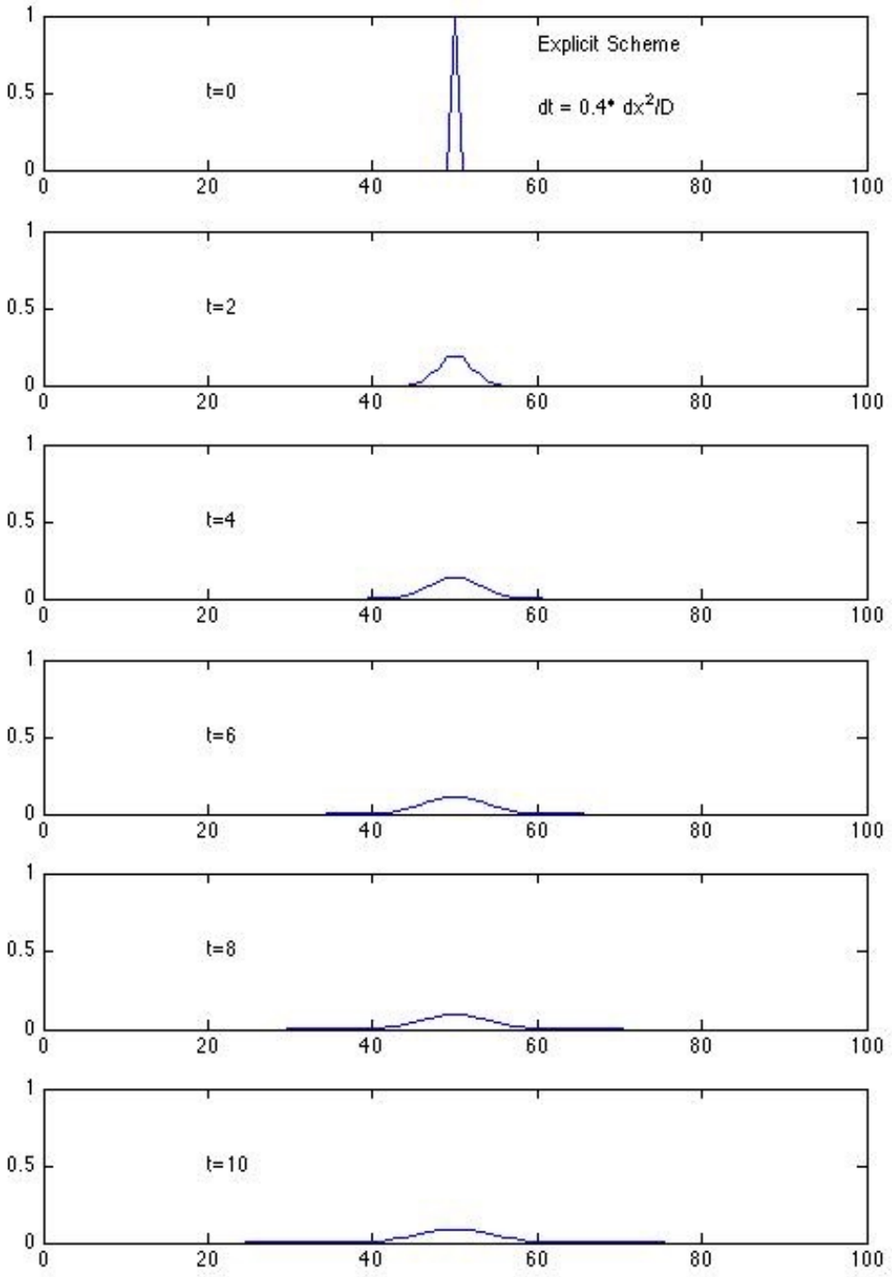
Numerical methods:

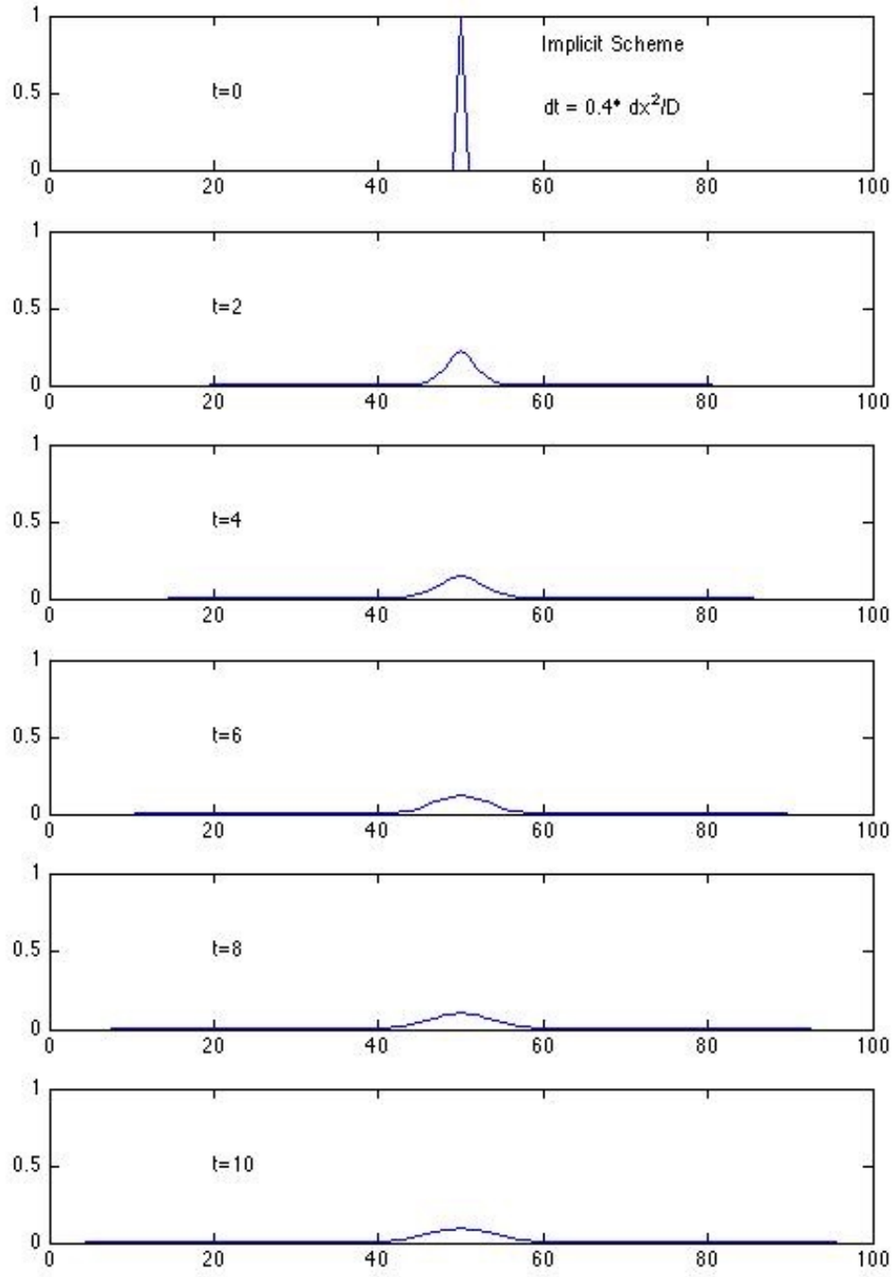
- finite-differences (FD)
- pseudo-spectral (PS)
- finite-element method (FEM)
- spectral-element method (SEM)

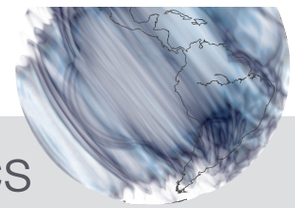


Numerical methods - **Finite-Differences**

heat flow

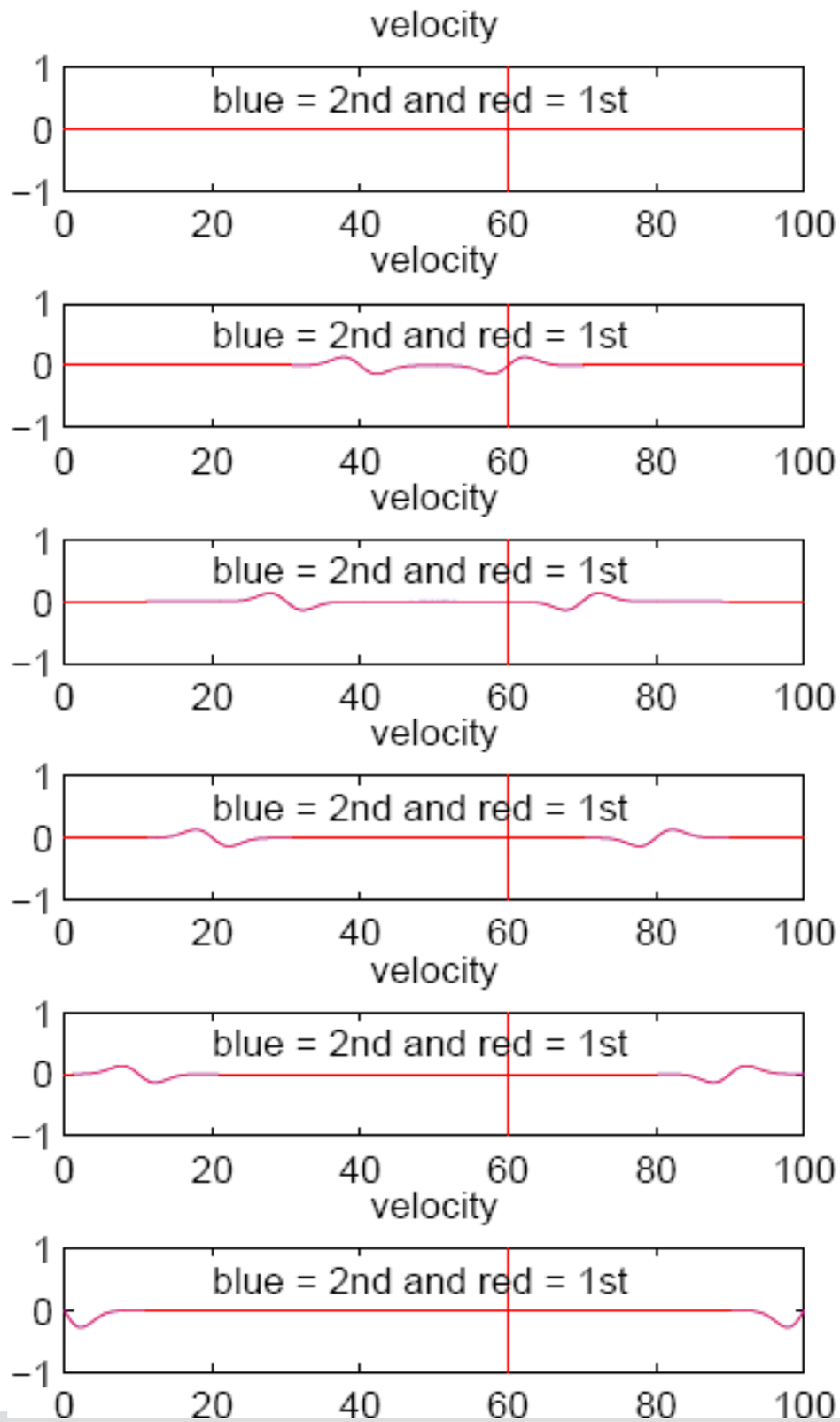






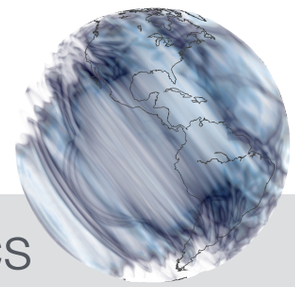
Numerical methods - **Finite-Differences**

wave propagation



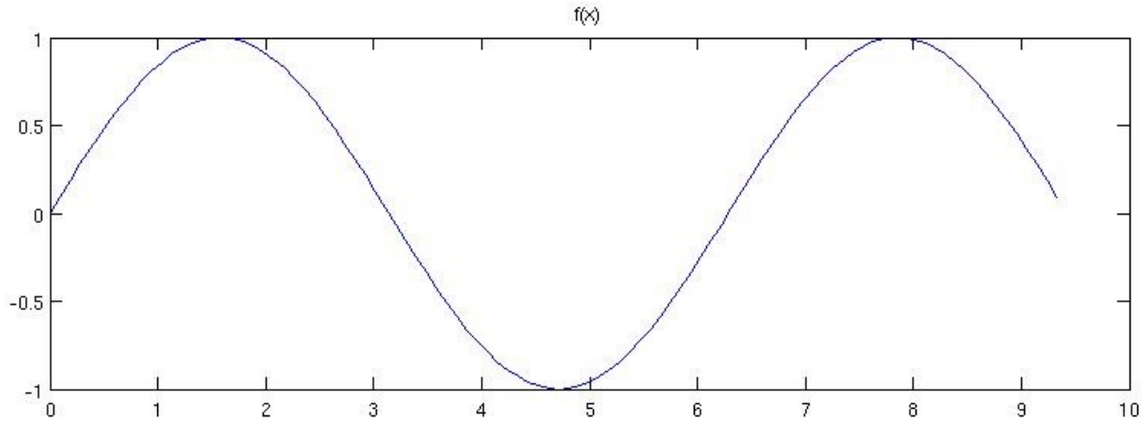
Numerical methods - **Finite-Differences**

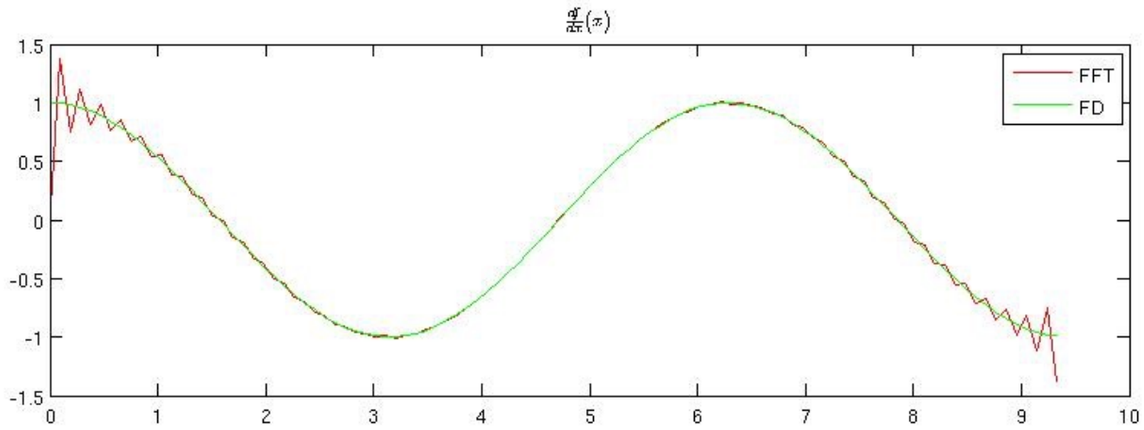
tsunami waves

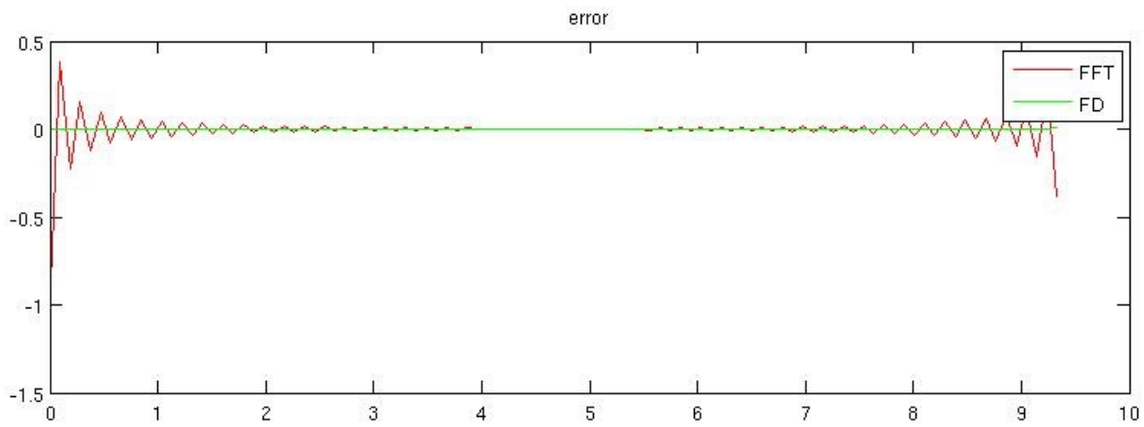


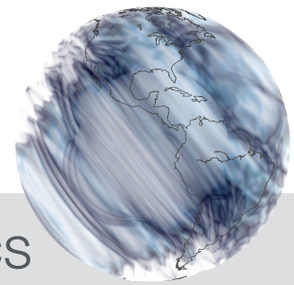
Numerical methods - **Pseudo-Spectral**

wave propagation



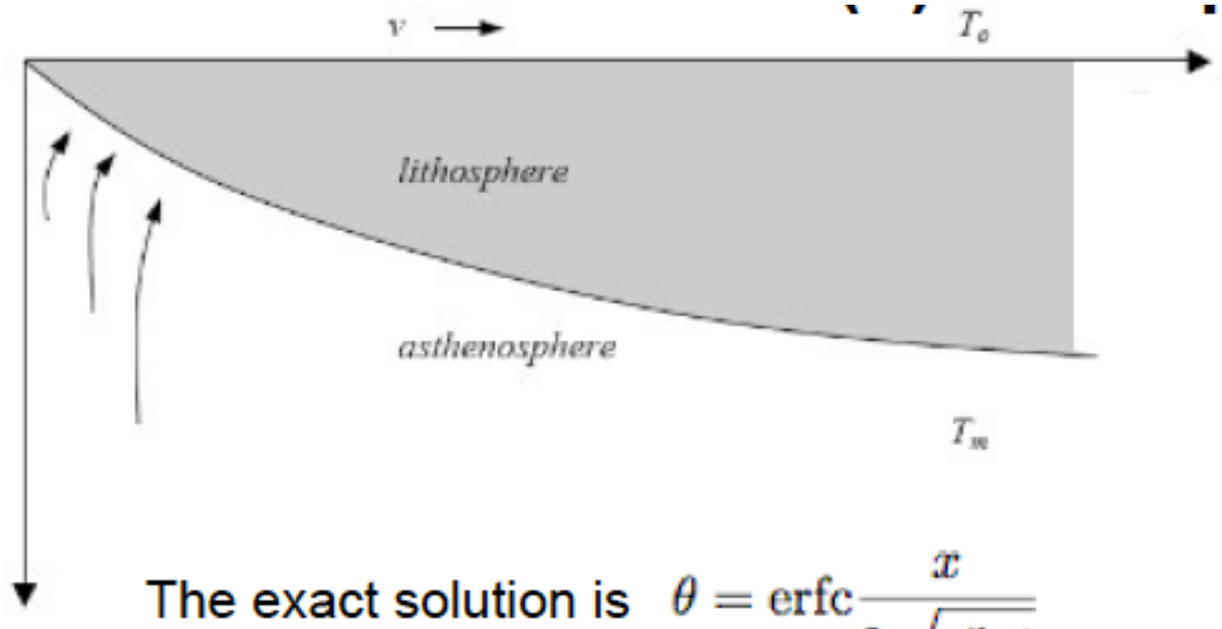




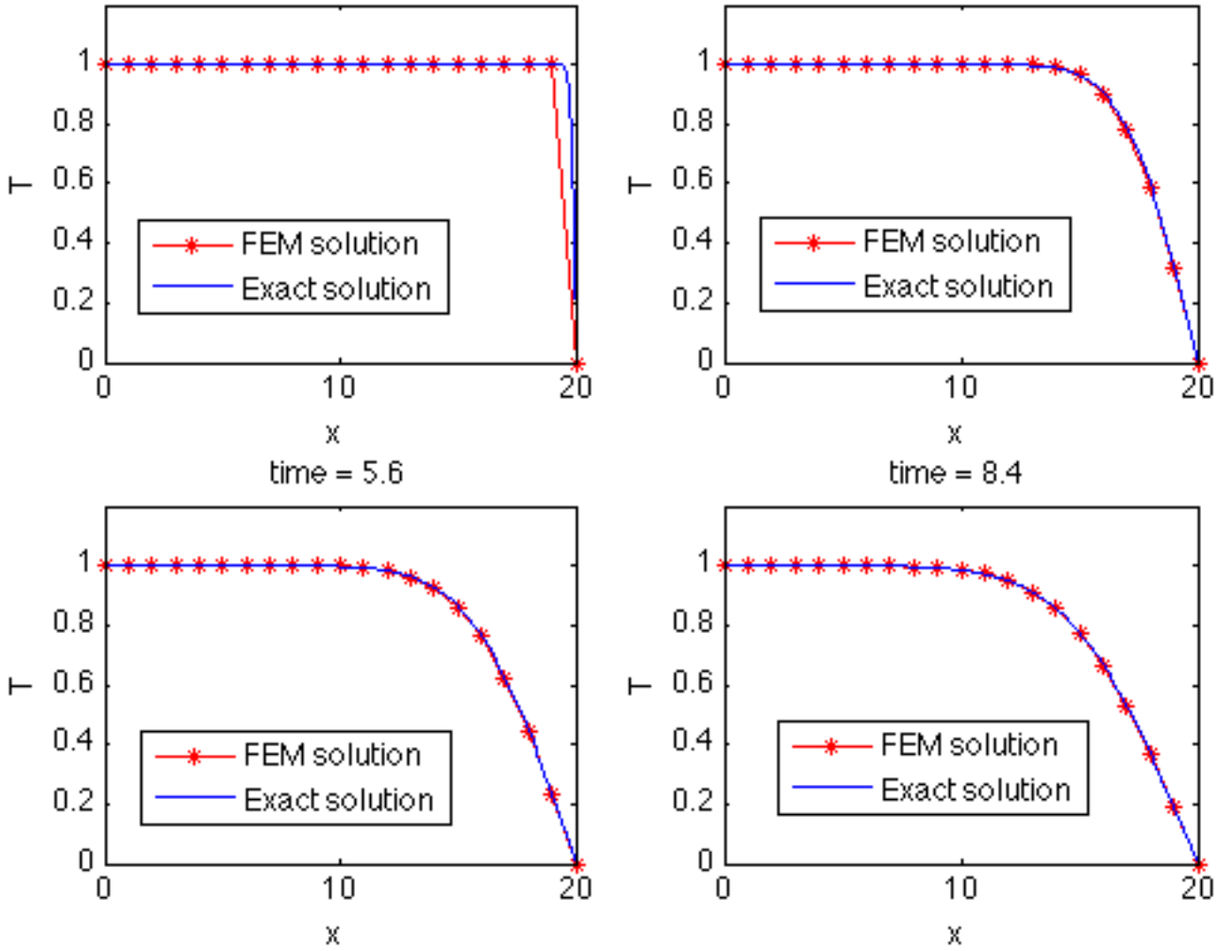


Numerical methods - **Finite-element method**

half-space cooling



The exact solution is $\theta = \mathrm{erfc}\dfrac{x}{2\sqrt{\frac{\kappa}{\rho c_p}t}}$



Numerical methods - **Spectral-element method**

wave propagation - anywhere

Computational Geophysics
-> in a nutshell