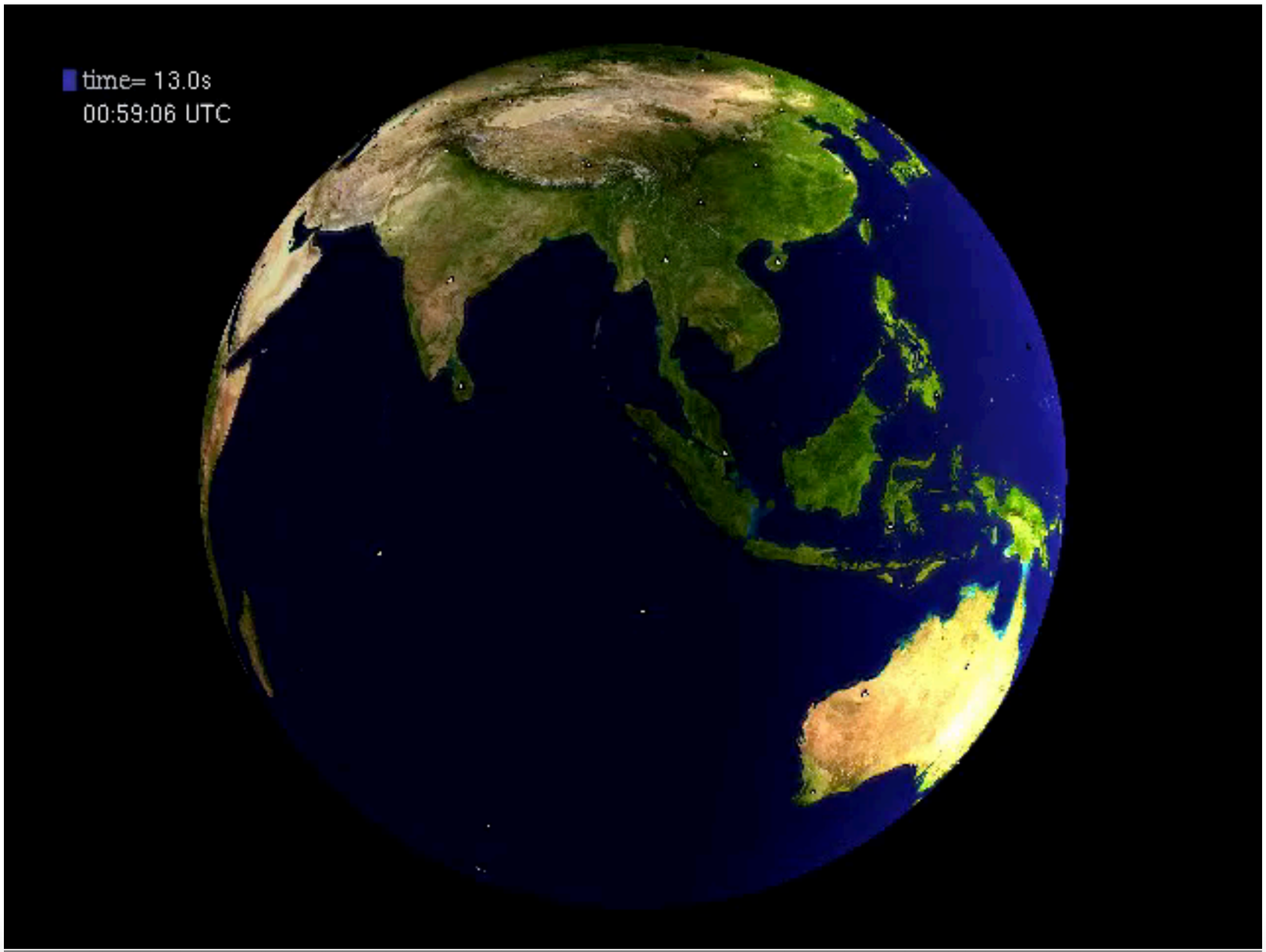
# Computational Geophysics
# ErSE 326



Introduction:

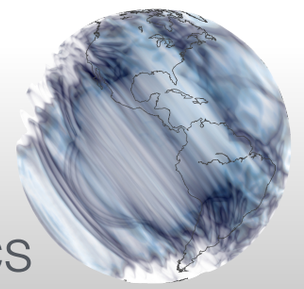
- computational trends

Geophysics:

- Heat Flow
- Wave propagation

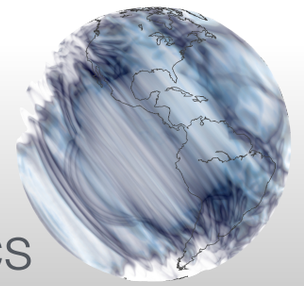
Numerical methods:

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

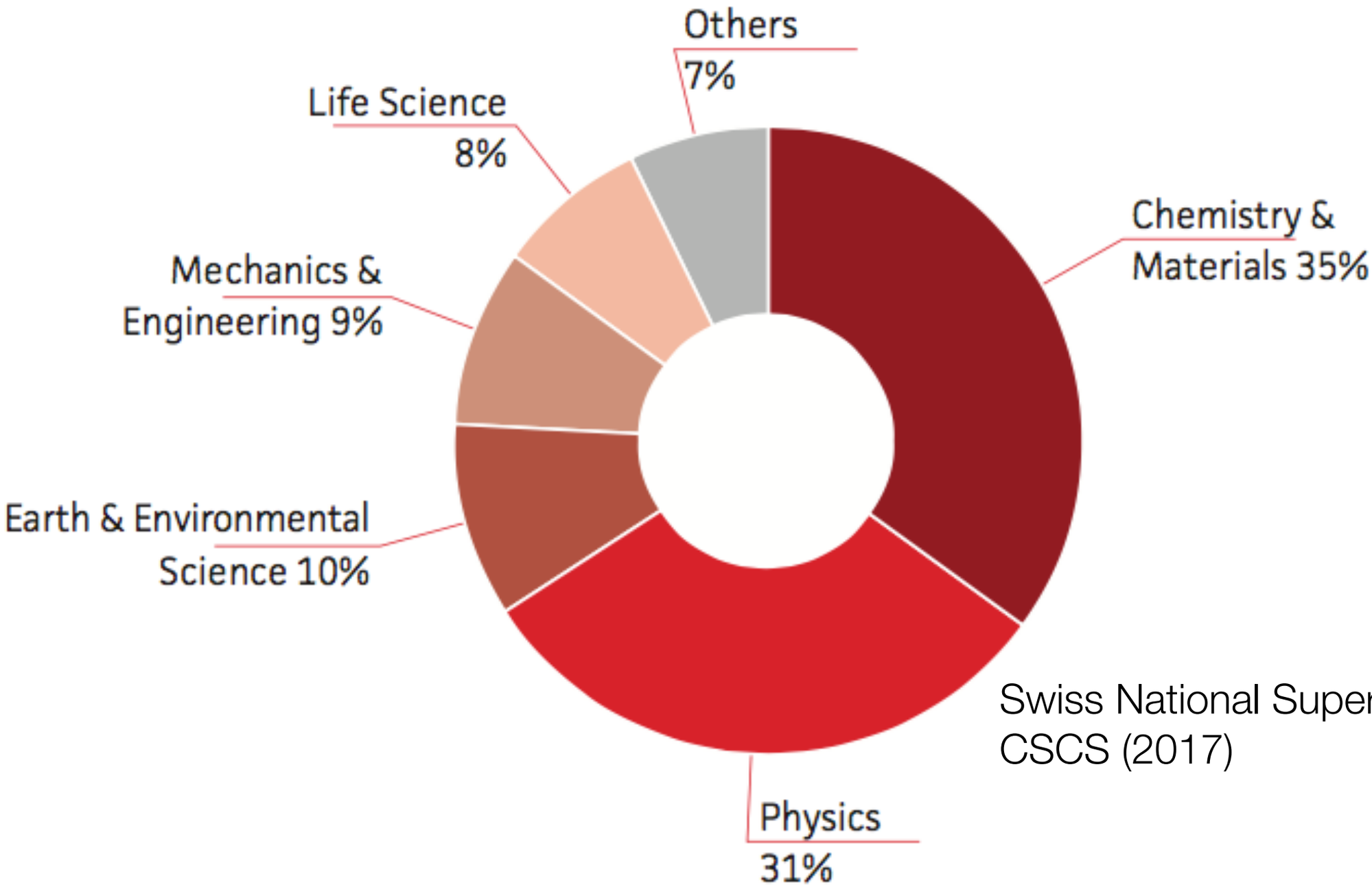


# Trends - fastest supercomputers

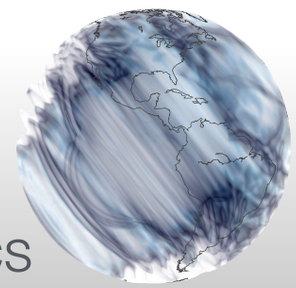

exa-scale system
year ~2020



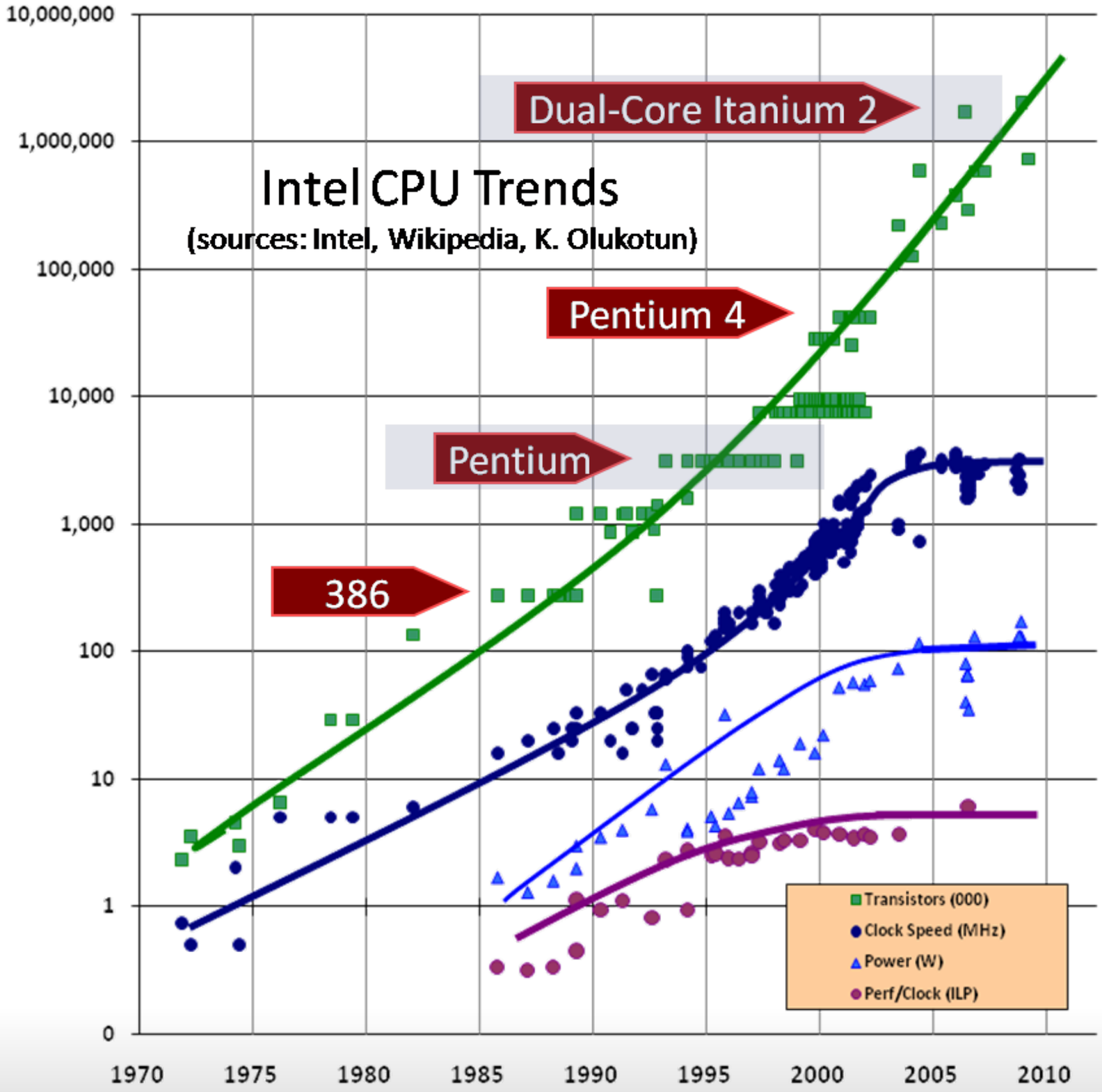
# Trends - Usage by Research Field



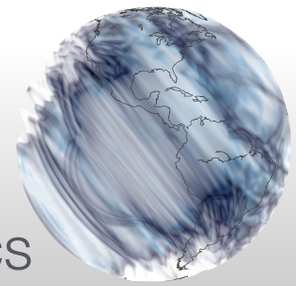

Swiss National Supercomputing Center
CSCS (2017)



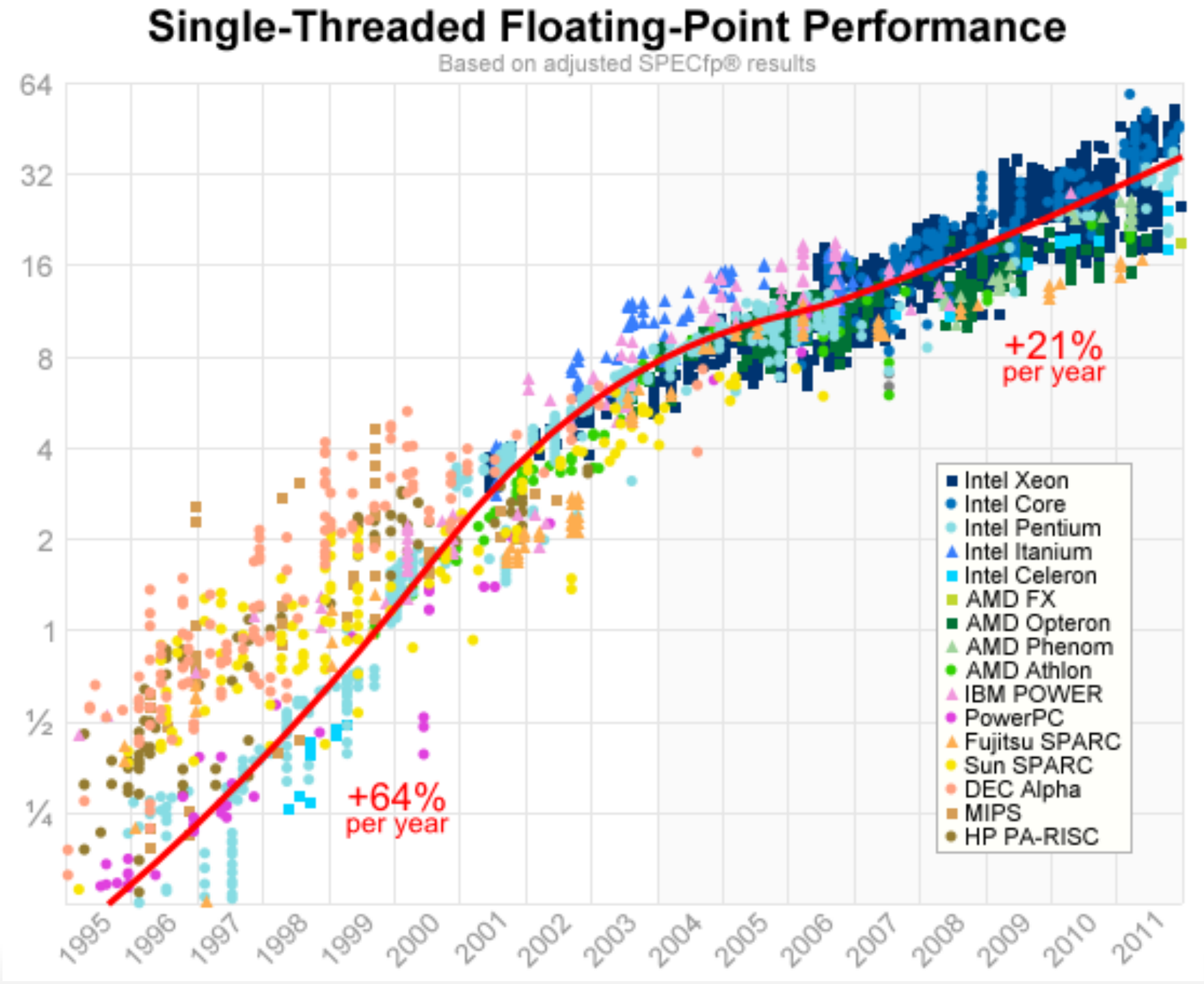
# Trends - CPU




multi-core CPUs
since ~2006

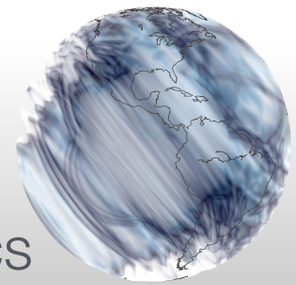


# Trends - CPU

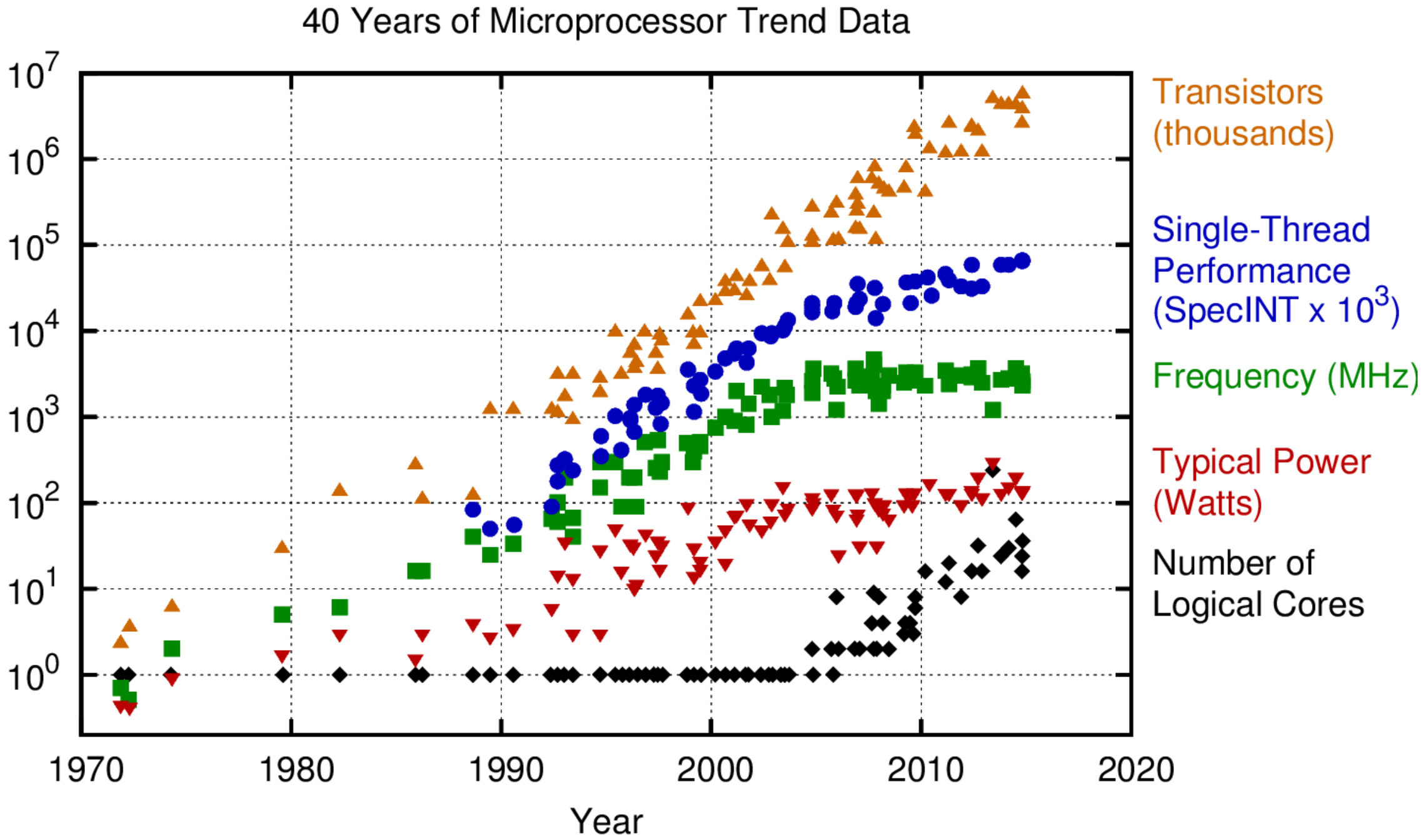



slow-down
since ~2003

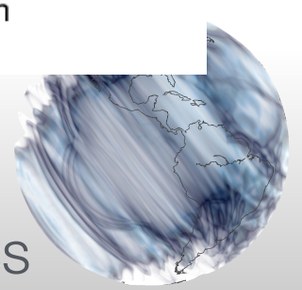




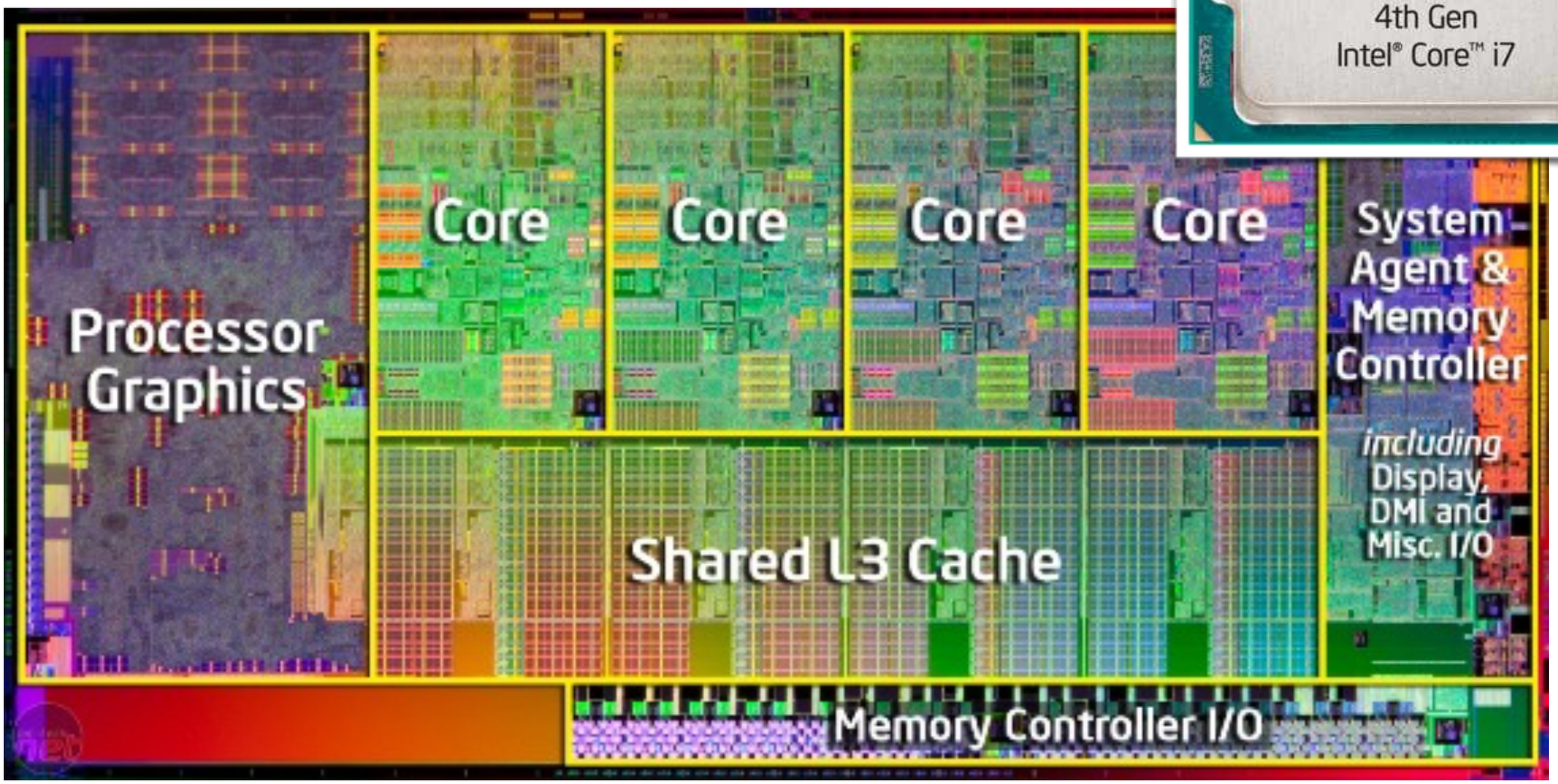
# Trends - CPU




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

(2018)

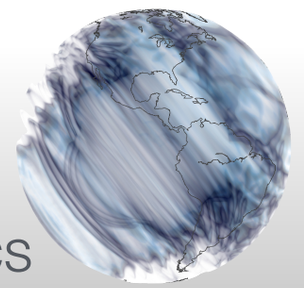
# Trends - CPU


16 cores
32 threads (hyperthreading)
base frequency 2.8 GHz
lithography 14nm

(2018)

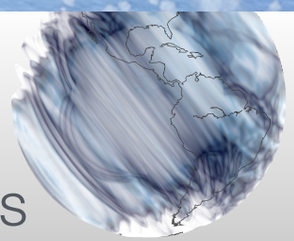
# Trends - CPU


(Intel 2018)



Computational Geophysics

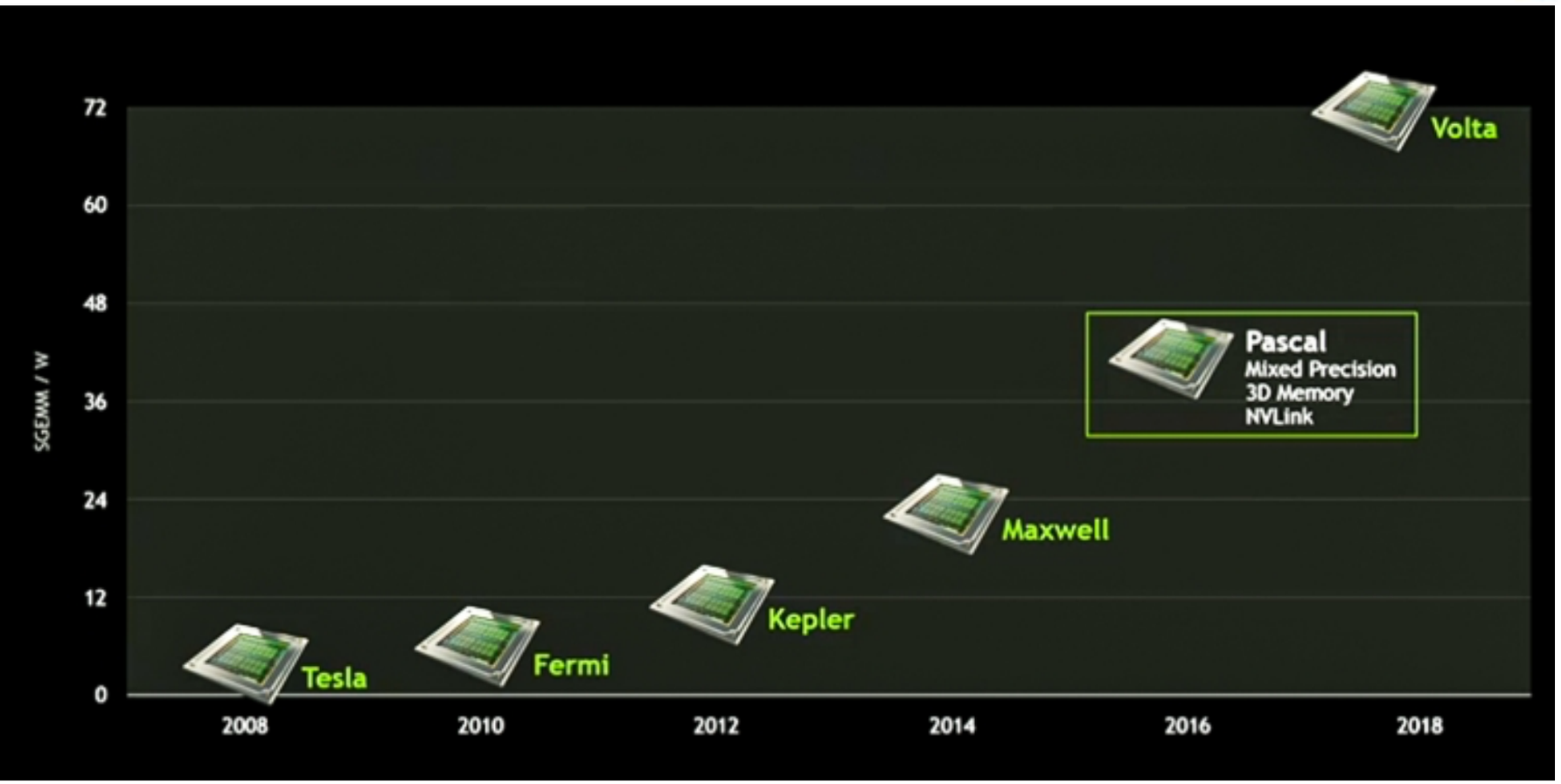
# Trends - GPU

Computational Geophysics

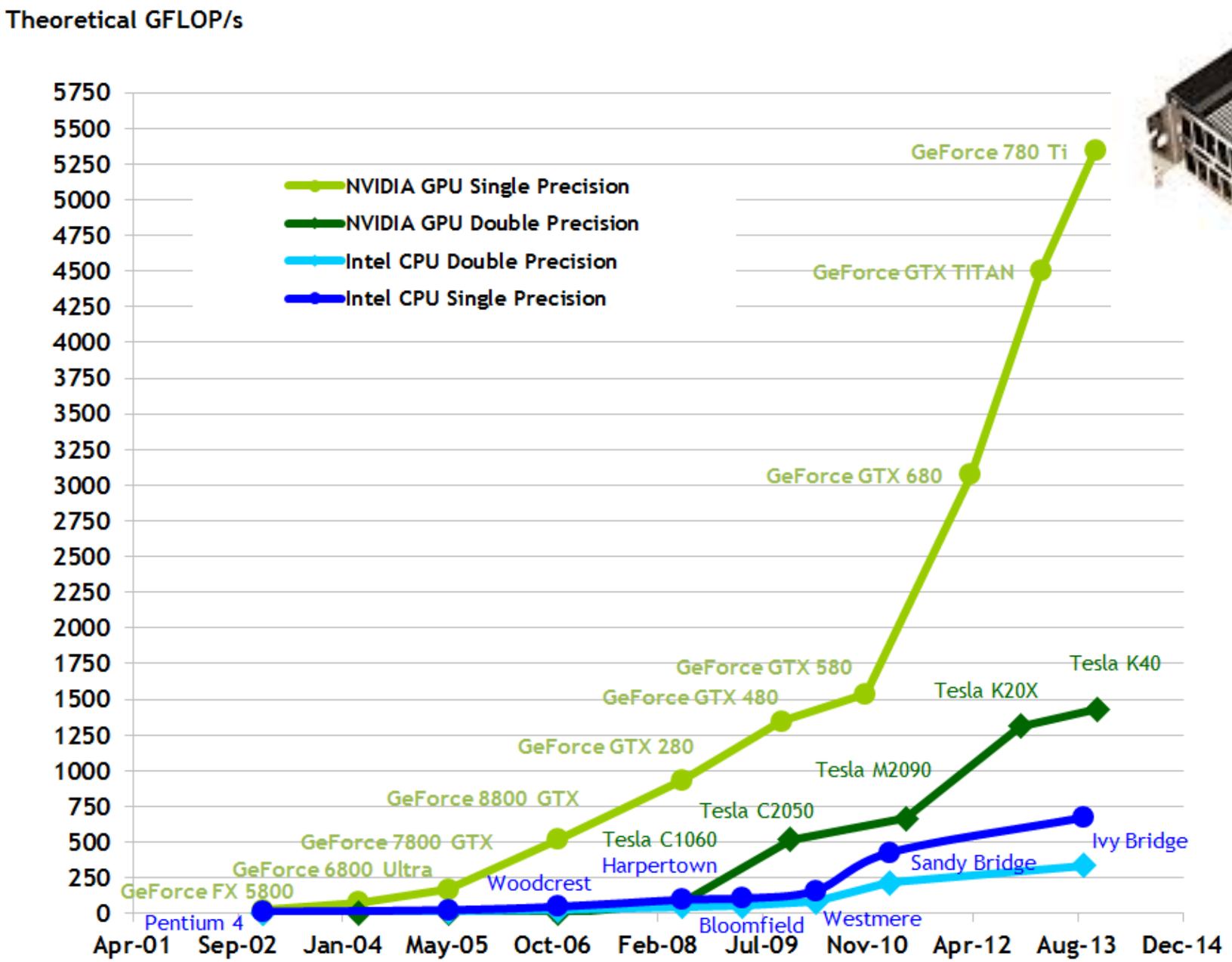
# Trends - GPU


Nvidia - graphic cards



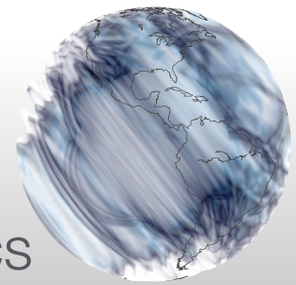

hardware accelerators

# Trends - GPU

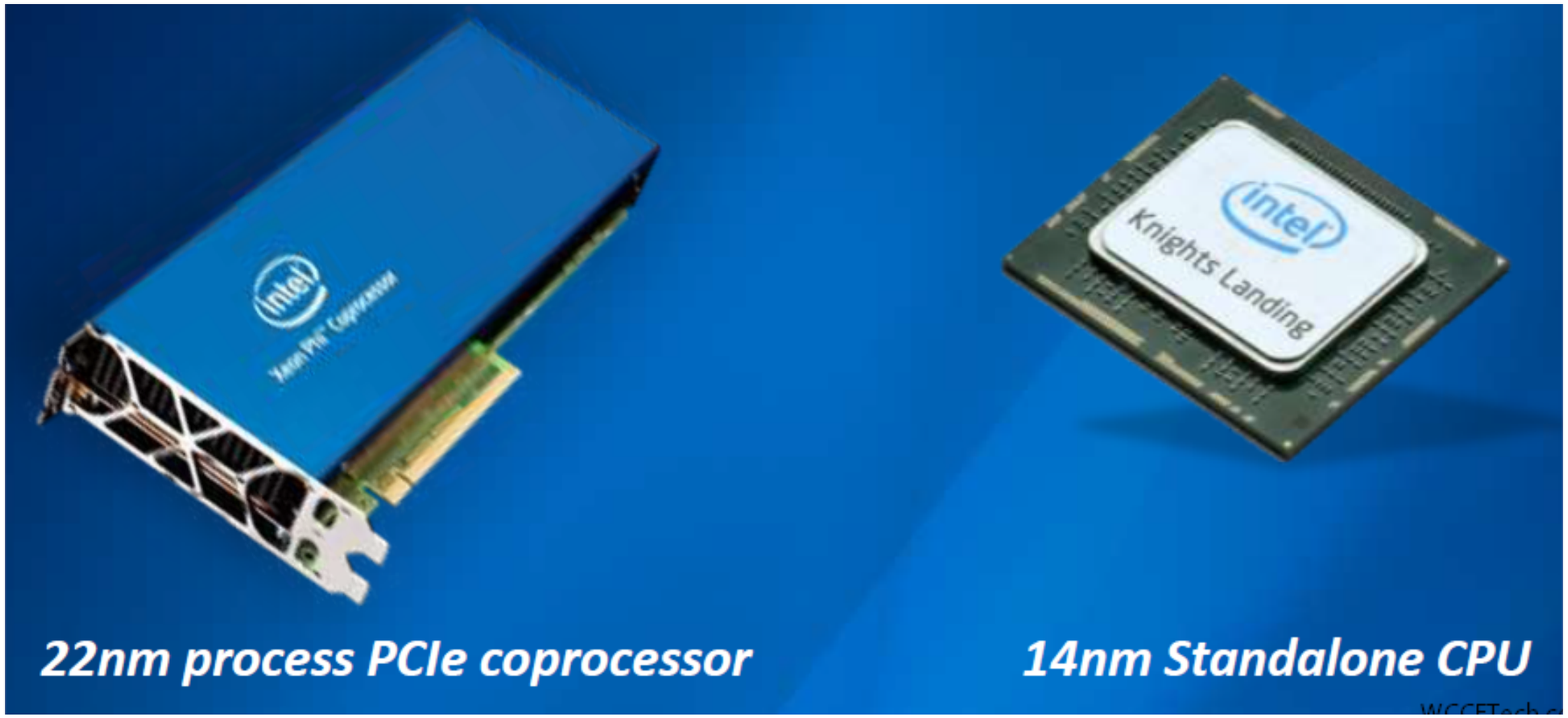



Floating-Point Operations per Second - Nvidia CUDA C Programming Guide
Version 6.5 - 24/9/2014 - copyright Nvidia Corporation 2014


hardware accelerators



# Trends - Intel Phi




hardware accelerators

# Trends - Supercomputers w/ hardware accelerators


Summit


Sierra


Sunway


Tianhe-2

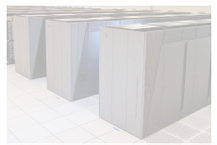

Piz Daint

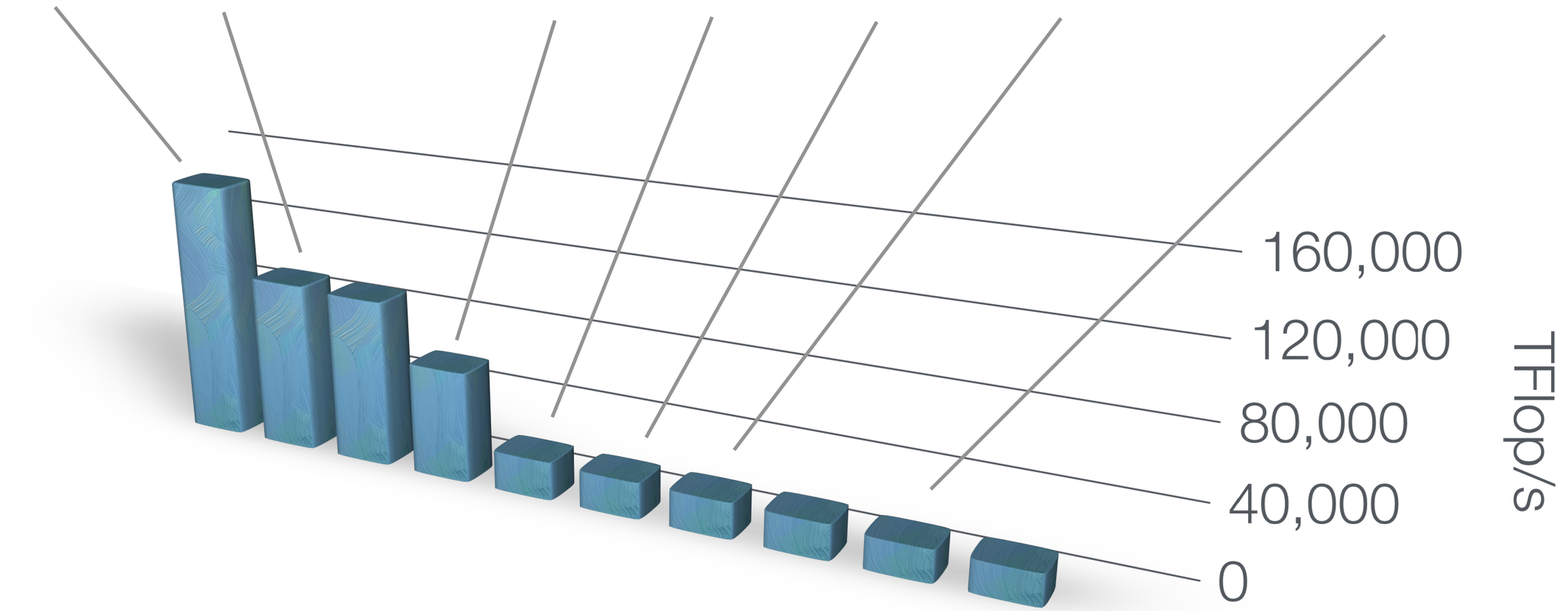

Trinity


ABCI

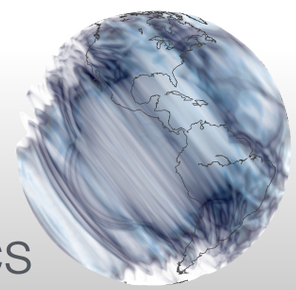

SuperMUC


Titan


Sequoia




(Top500.org - Nov 2018)



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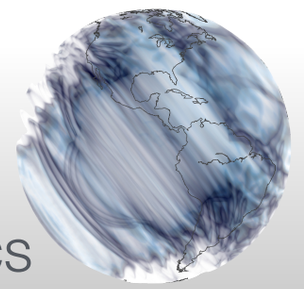
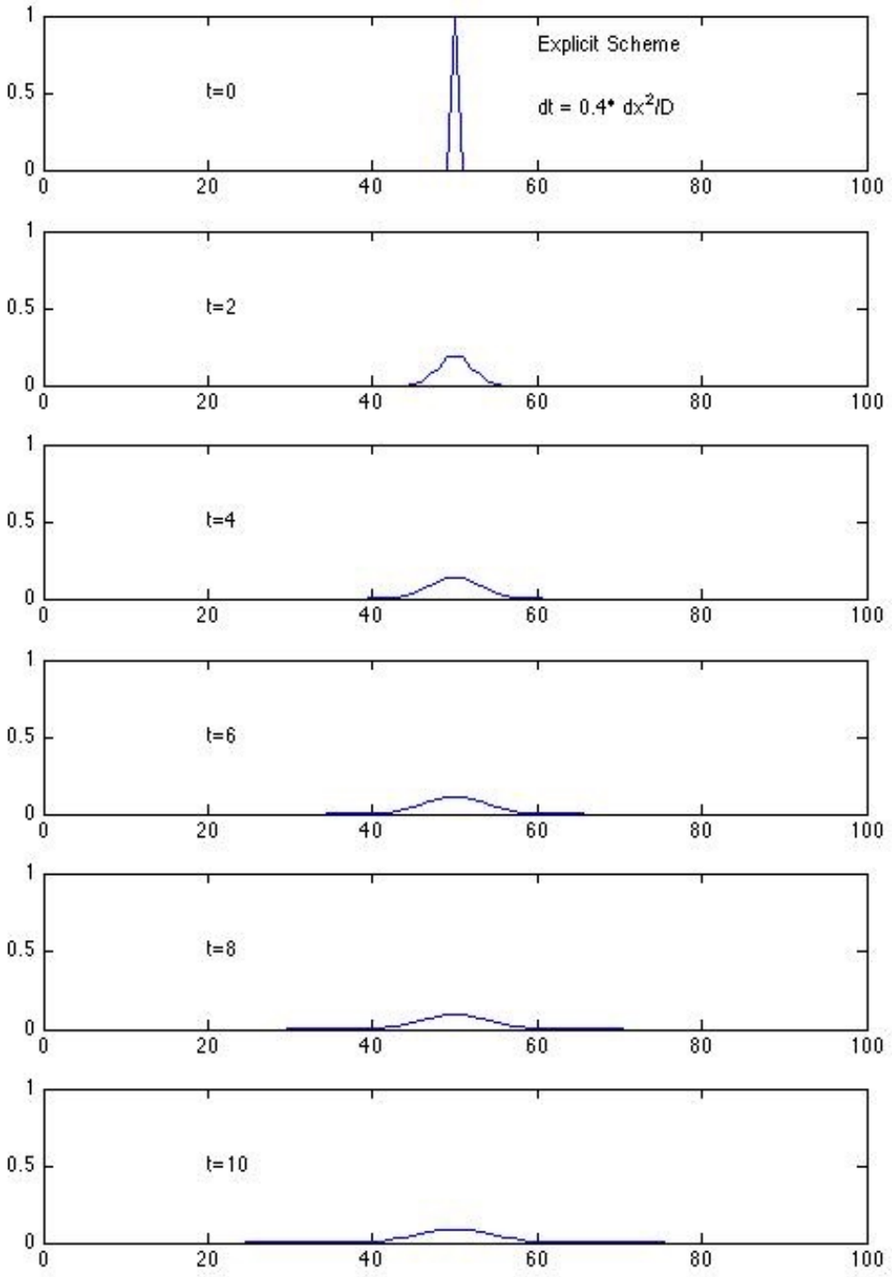
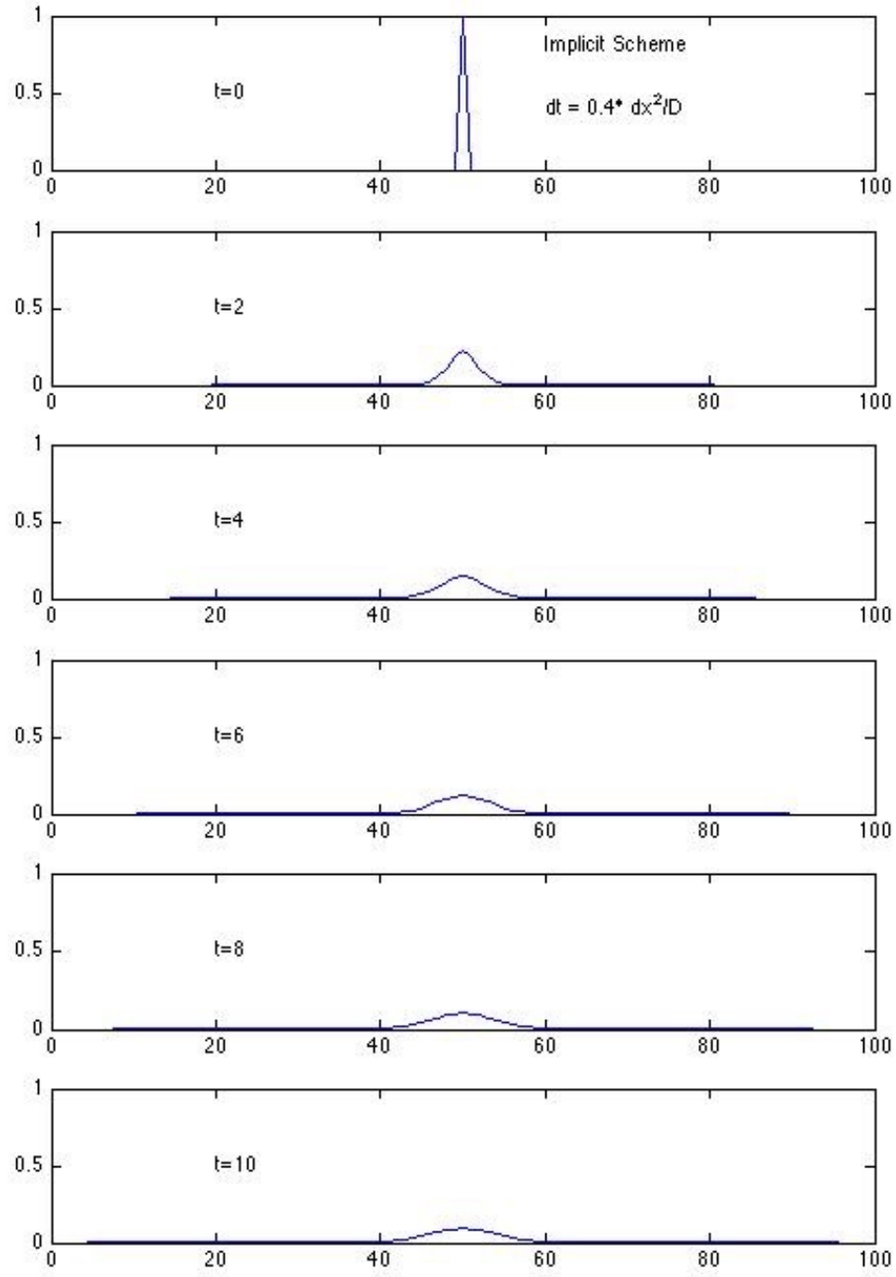


# Numerical methods - **Finite-Differences**

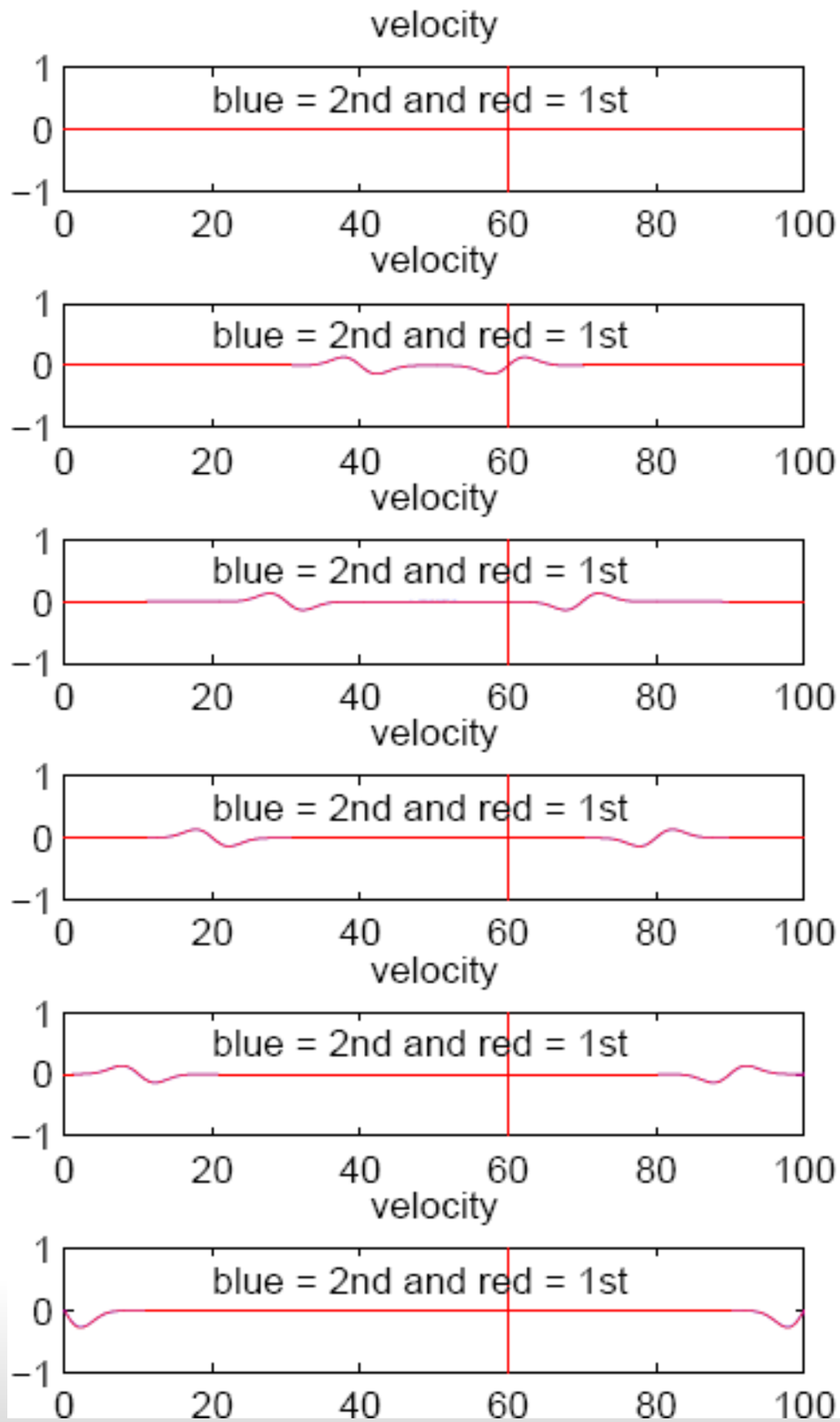
heat flow



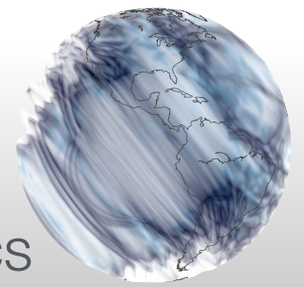
# Numerical methods - **Finite-Differences**

wave propagation



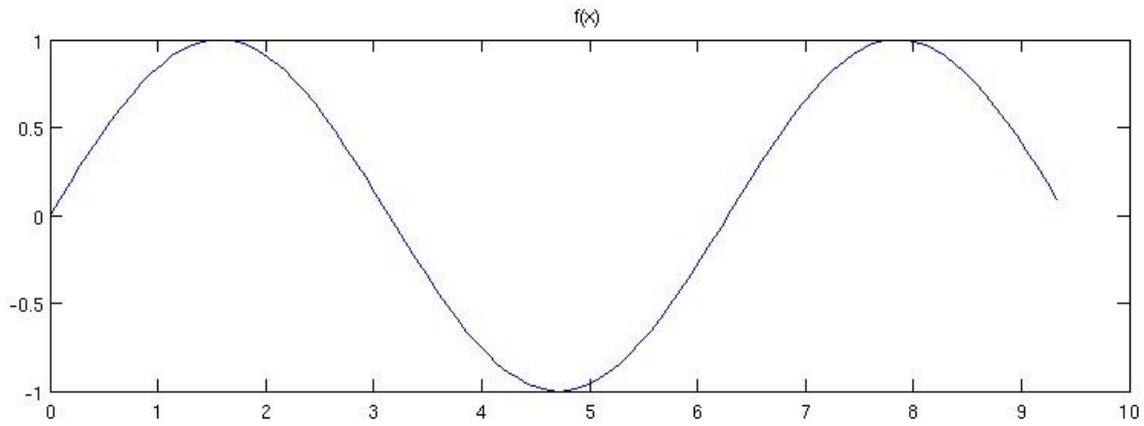
# Numerical methods - **Finite-Differences**

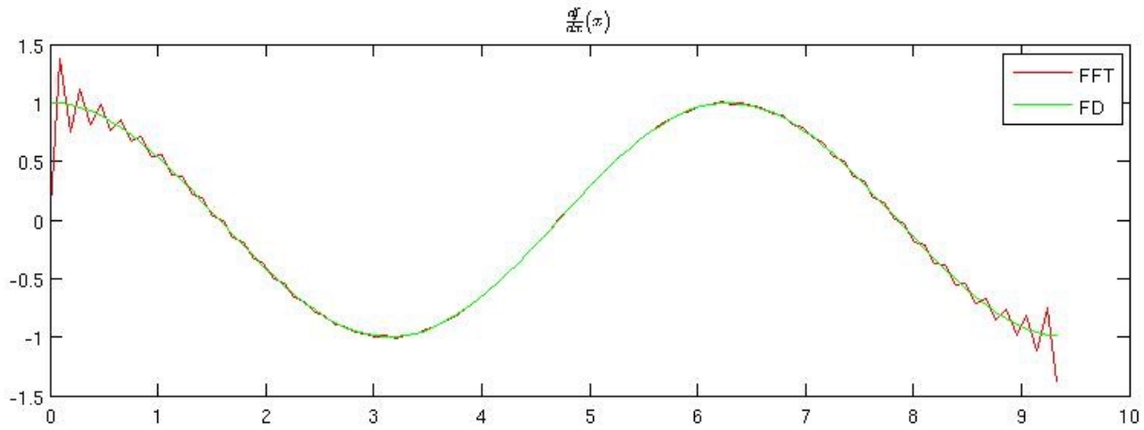
tsunami waves

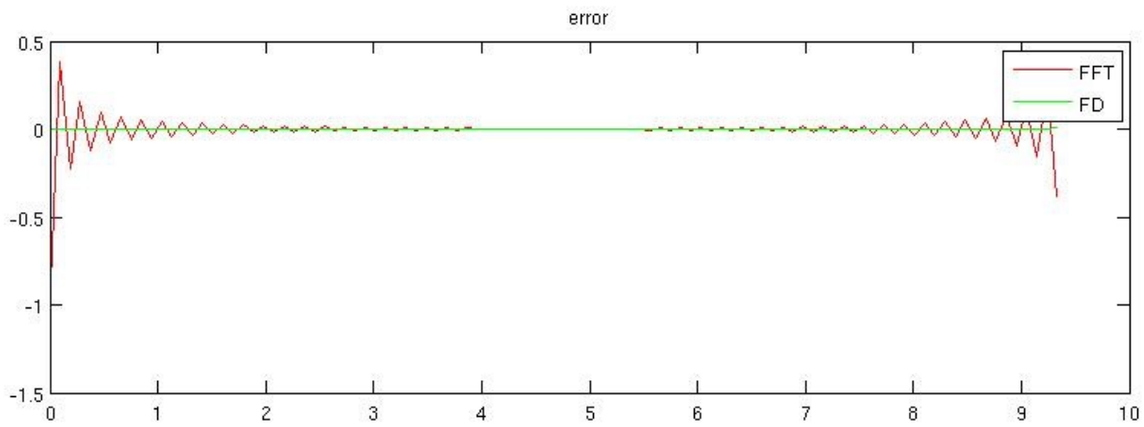



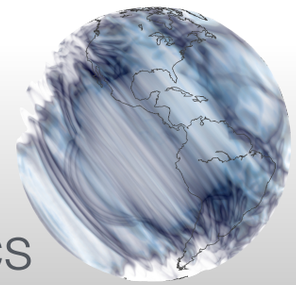
# Numerical methods - **Pseudo-Spectral**

wave propagation



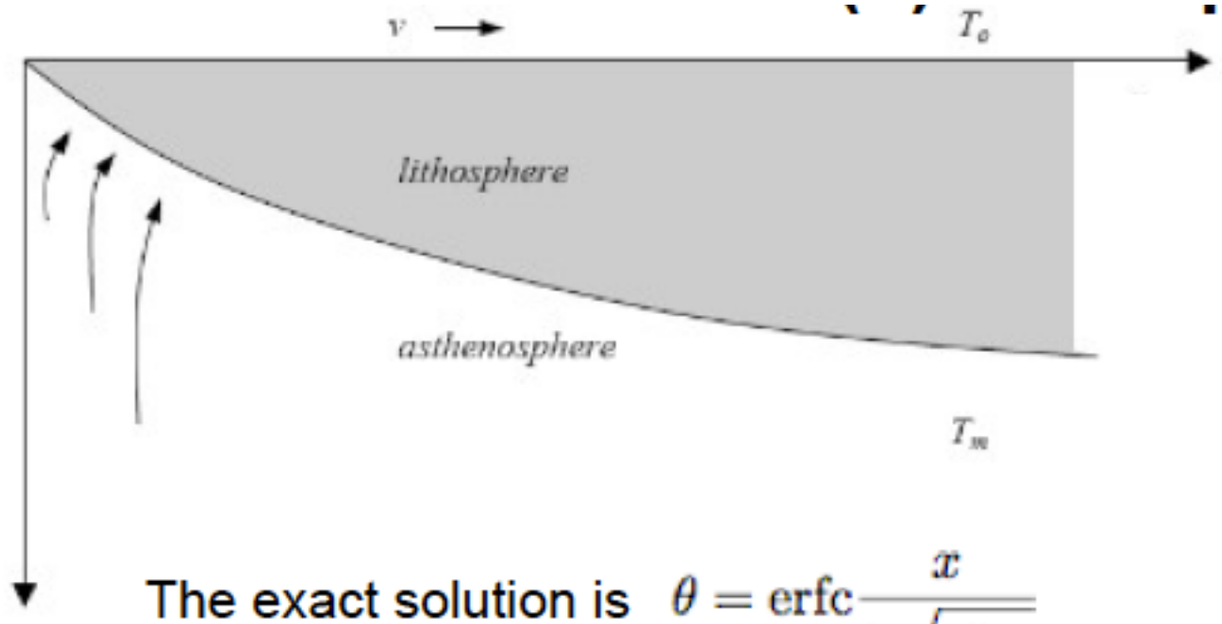



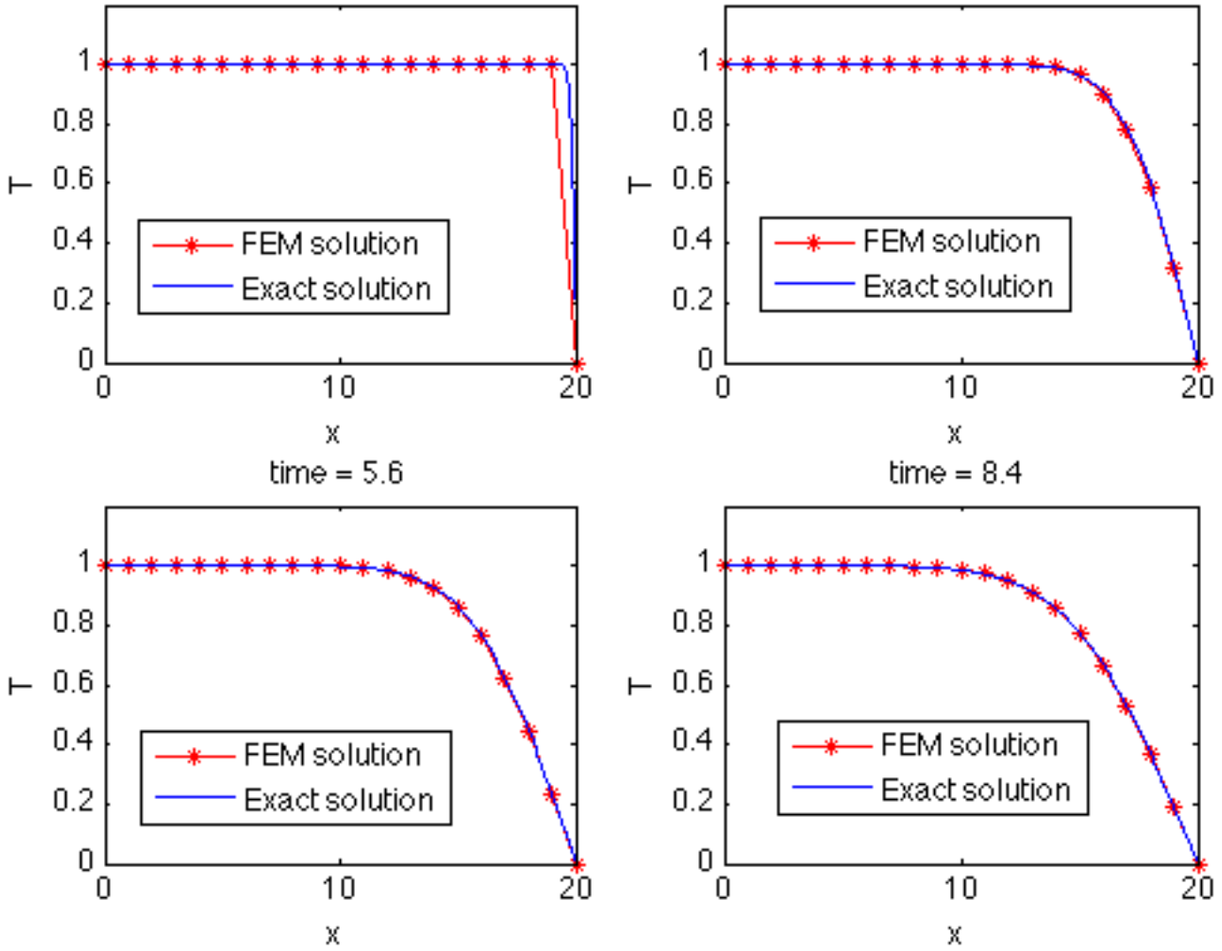



# Numerical methods - **Finite-element method**

half-space cooling




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



# Numerical methods - **Spectral-element method**

wave propagation

# Computational Geophysics
## -> in a nutshell