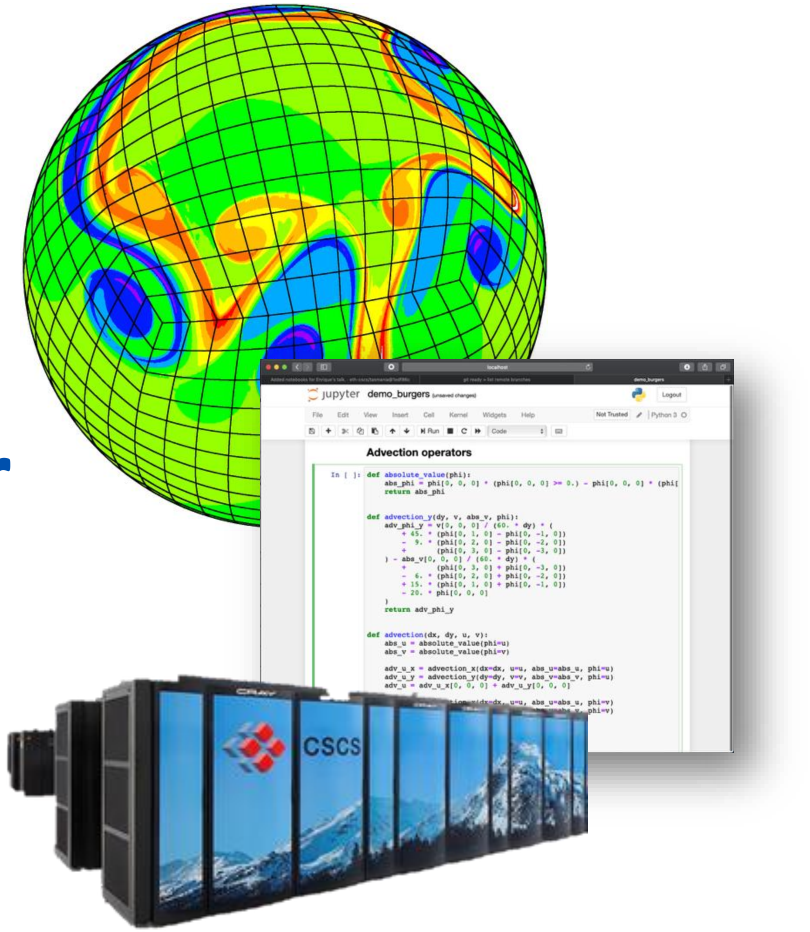
High Performance Computing for Weather and Climate (HPC4WC)

Content: Administrative

Lecturers: Oliver Fuhrer, Simon Adamov, Tobias Wicky

Block course 701-1270-00L

Summer 2025



Nice to meet you!

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Simon Adamov
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Victoria Bauer
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July 13, 2021 2am in the morning...

Tages-Anzeiger

Mujinga Kambundji
Alles ausser Sport – die Sprinterin antwortet auf persönliche Fragen. 25

Zeit zum Lesen
Bücher für die Ferien: Neun Empfehlungen der Kulturredaktion. 29

Auf den ersten Blick
Psychologinnen sagen, warum die Liebe meist mehr Zeit braucht. 36

Nach dem Sturm droht Zürich jetzt Hochwasser

Komplementärpraktiker warnen vor Zweiklassenmedizin

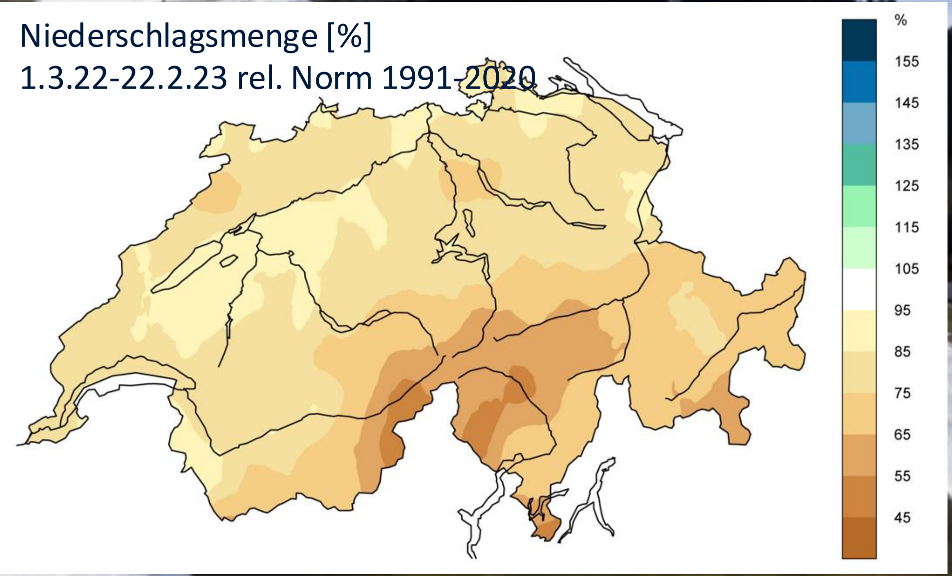
«Die Szenen vom Sonntag widersprechen allem, was ich an England liebe.»

Pflegende, Touristen und Lehrerinnen: Wo die Impfpflicht gilt und für wen

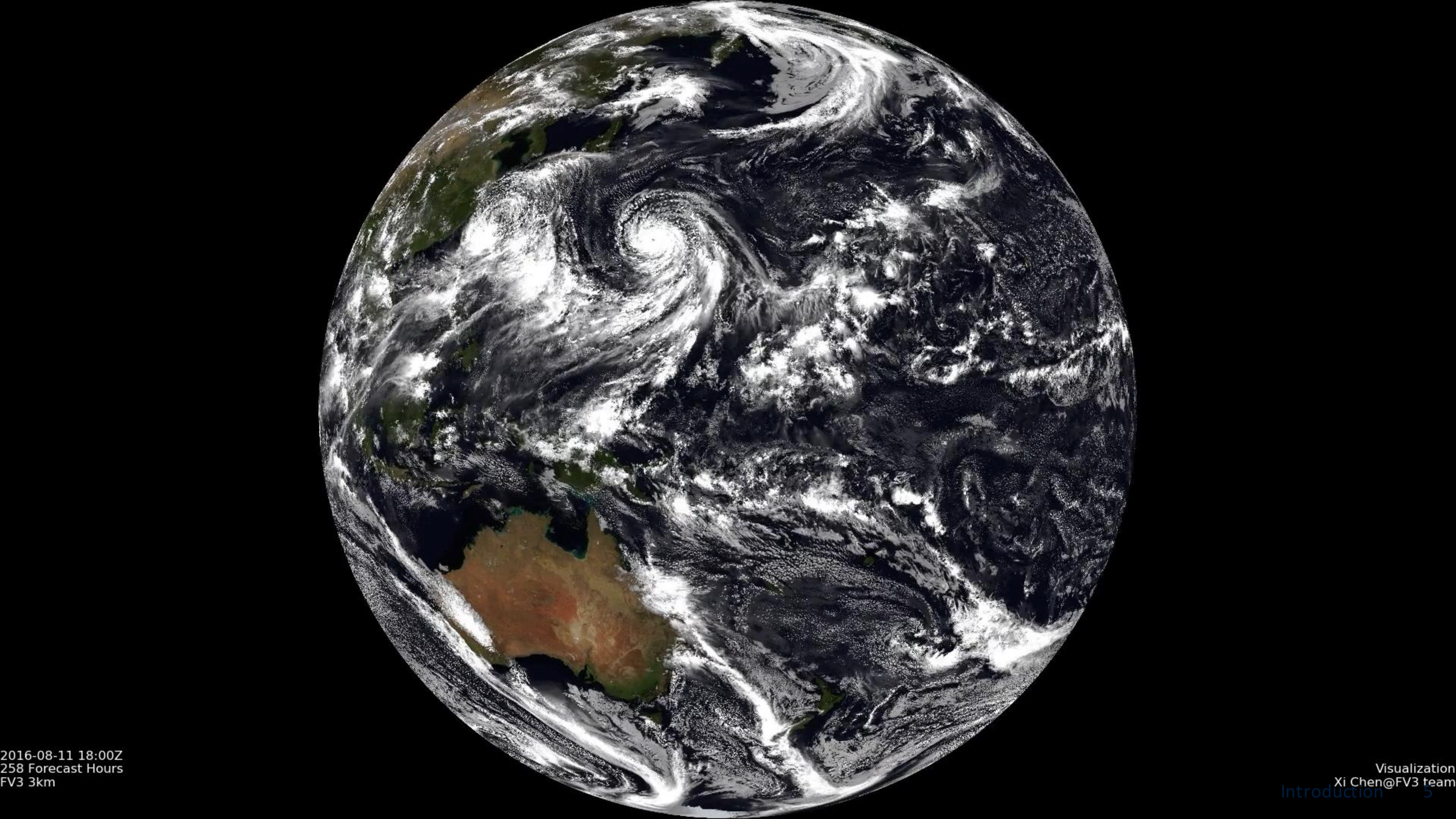
Leutenegger steht in der Kritik

What’s behind the warnings for such extreme events?

Winter 2022/2023



How do we know if this will be the «norm» in the future?


2016-08-11 18:00Z
258 Forecast Hours
FV3 3km
Visualization
Xi Chen@FV3 team

Weather and climate models run on supercomputers

Goals of Course

- Understand high performance computing concepts relevant for weather and climate simulations
- Able to work with weather and climate simulation codes that run on large supercomputers

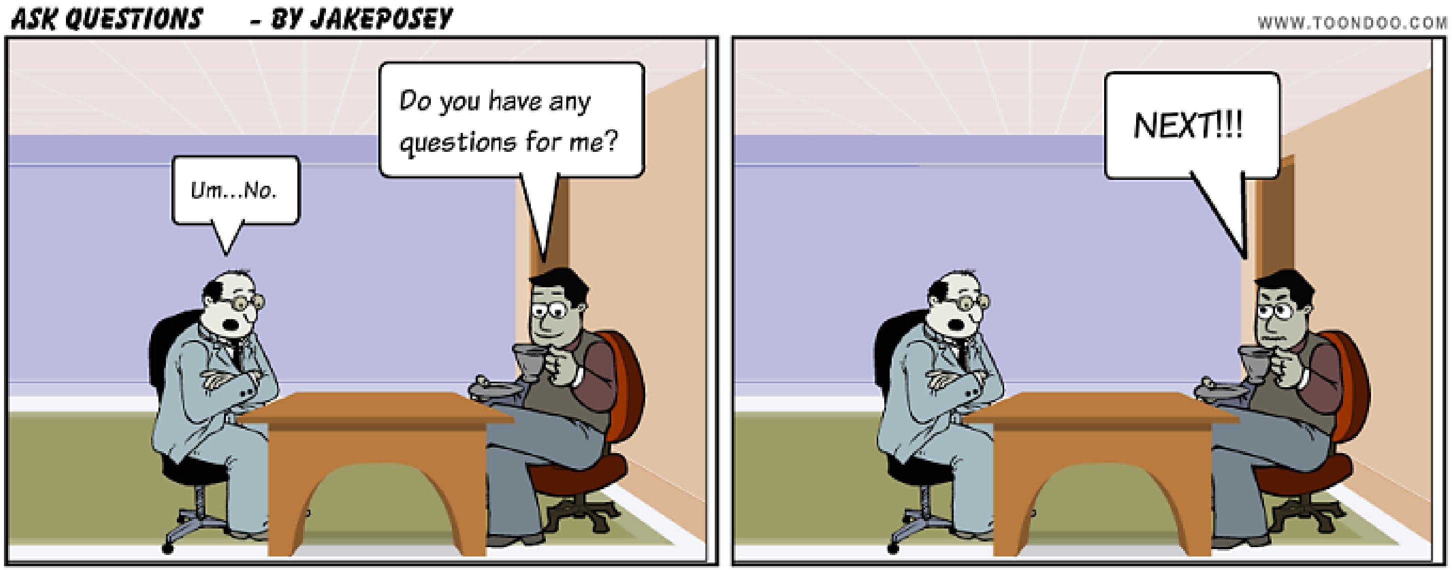
Approach

“ I ***hear***, and I forget.
I ***see***, and I remember.
I ***do***, and I understand. ”

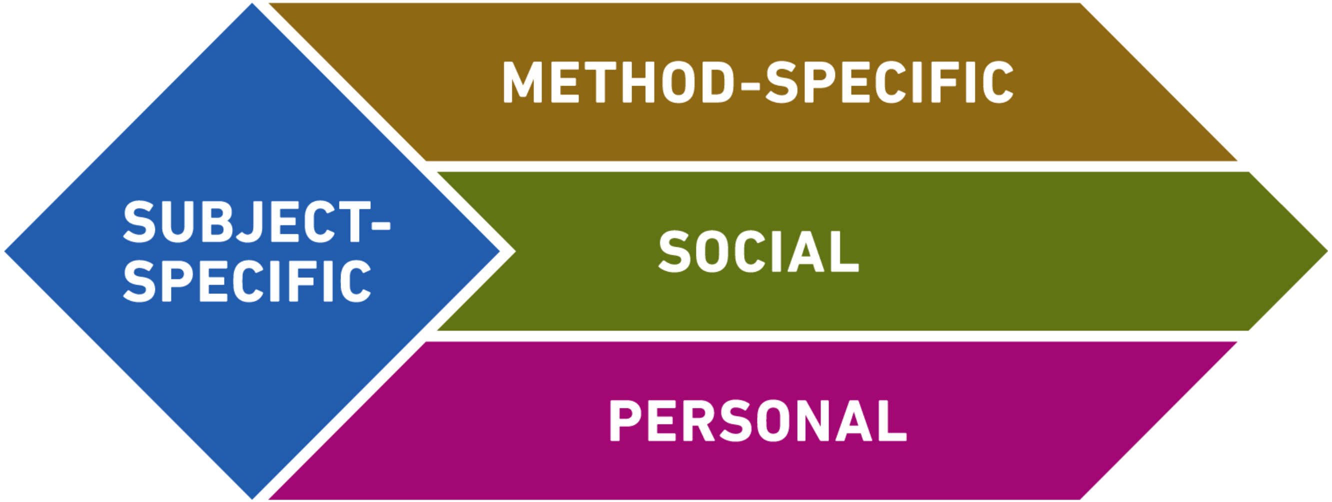
(Chinese proverb)

- Lectures that explain concepts and give context (***hear***).
- Demonstrations of the concepts being applied (***see***).
- Practical exercises and a work project (***do***).

Questions, please!



Competencies



Schedule

Monday	Motivation, stencil computations, memory hierarchy, lab environment
Tuesday	Shared memory parallelism, OpenMP, performance metrics
Wednesday	Distributed memory parallelism, domain-decomposition and halo-updates
Thursday	Hardware trends in supercomputing, GPU computing
Friday	High-level programming, domain-specific languages, wrapup

08:15 – 12:00	Morning session
12:00 – 13:30	***Lunch break***
13:30 – 17:00	Afternoon session

Currently registered students (eDoz)

We are currently
38 registered participants.

At the upper limit for this course.

Departement	
D-EAPS	8
D-MATH	8
D-USYS	8
D-PHYS	6
D-INFK	5
D-CHAB	1
D-MAVT	1
REKT	1

Studiengang	
Rechg.Wiss. MSc	8
Atmos+Clima MSc	7
Umw.natw. MSc	7
Physik MSc	6
Data Sc. MSc	3
Dokt. D-INFK	1
Dokt. D-MAVT	1
Dokt. D-USYS	1
Fachstud. Uni	1
Informatik MSc	1
LD Chemie	1
Mob ERDW	1

Prerequisites

- **Fundamentals of numerical analysis and atmospheric modeling**
  - Basic partial differential calculus and finite difference methods.
  - e.g. ETH course "Numerical methods in environmental physics" or "Weather and climate models"
- **Experience in a programming language (C/C++, Fortran, Python, …)**
  - We will read and write Fortran, C++ and Python in this course.
- **Experience using command line interfaces in *nix environments (e.g., Unix, Linux)**
  - Familiar with work in the command line shell and the most commonly used shell commands.
  - Can logon to Linux system via ssh and can work remotely on that system.
  - We will work on the Piz Daint supercomputer at the Swiss National Supercomputing Center (CSCS) in Lugano in this course.

If you think this course might not be suitable for you, talk to us!

Quick Poll

- Linux / Unix, Terminal
- Programming (Python, Fortran, C/C++, ...), Compilation, Debugger
- Jupyter Notebooks
- PDE, Stencil, Weather Model
- Numpy, OpenMP, MPI, CUDA

Practicalities

- **All course material on GitHub repository** (slides, notebooks, codes, …)
  https://github.com/ofuhrer/HPC4WC/

- **Questions related to course and projects in dedicated Slack workspace**
  https://join.slack.com/t/hpc4wc2025/shared_invite/zt-37p7avedd-fKWDtQAVTwS2briR90DV4Q

  Generally, try to use public channels for questions since others probably have the same questions.

- **Lectures are not recorded**

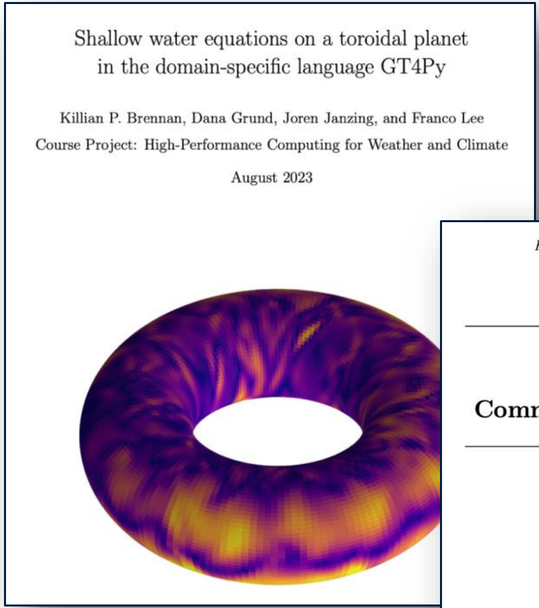
How to earn credits (3 ECTS)

- **Attend the block course** (and participate actively!)
- **Work project**
  - Choose group and topic
  - Hand in working source code and report (max. 10 pages)
  - Projects will be graded
  - **Deadline: 31. August 2025**
- Credits are awarded if course attended and grade of work project ≥ 4.0
- Same rules apply for BSc, MSc, and PhD students

Work project

- **Work in groups of 3-4** (no individual projects)
  - Programming is not a solitary art!
- **Topics Google Docs**
  - Have an idea of your own? Cool, discuss with us to shape it into a project!
  - Each project must have a software development and performance evaluation part and has to be related to course material
- **Grading**
  - 25% correctness (compiles & runs, results correct, no bugs)
  - 25% quality (structure, clean code, comments, naming, tests, error handling)
  - 25% performance (depending on work project)
  - 25% report (maximum 10 pages)
- **See last year's projects for examples**

Examples

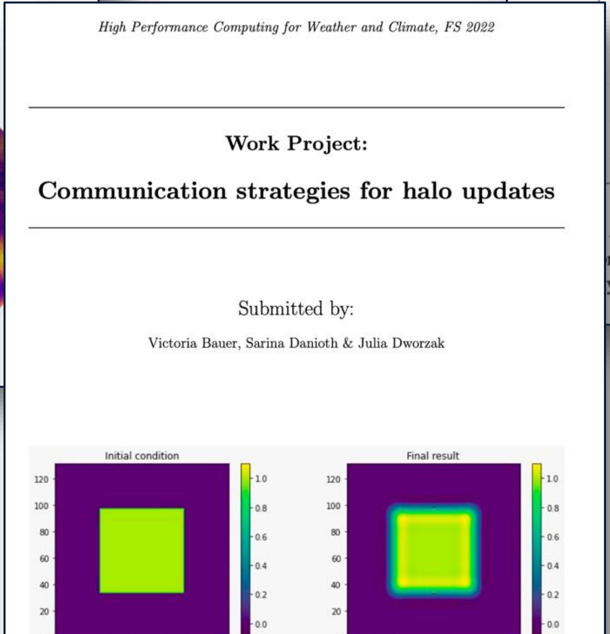


Shallow water equations on a toroidal planet
in the domain-specific language GT4Py

Killian P. Brennan, Dana Grund, Joren Janzing, and Franco Lee

Course Project: High-Performance Computing for Weather and Climate

August 2023



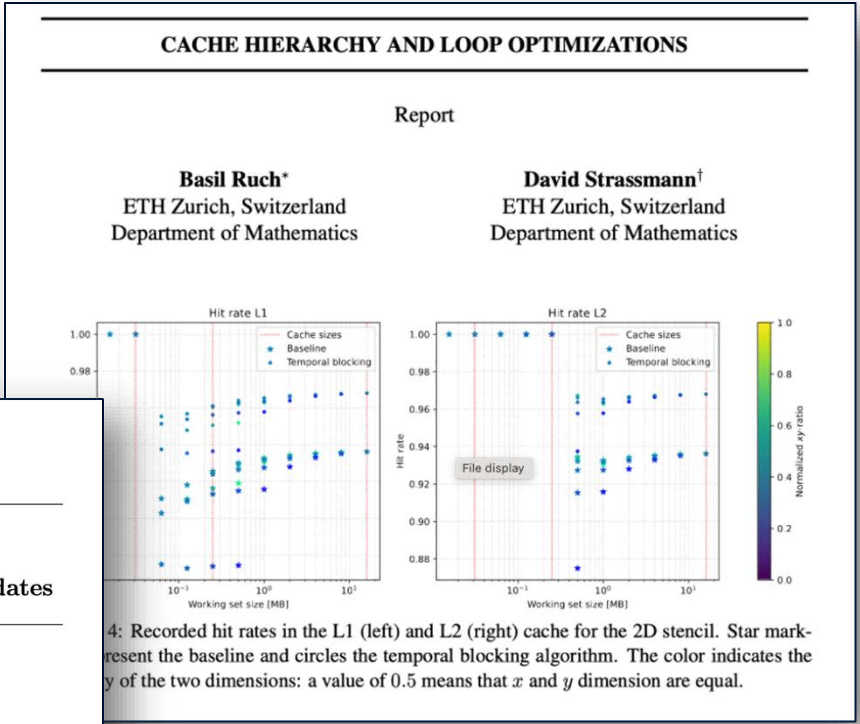
High Performance Computing for Weather and Climate, FS 2022

Work Project:

Communication strategies for halo updates

Submitted by:

Victoria Bauer, Sarina Danioth & Julia Dworzak



CACHE HIERARCHY AND LOOP OPTIMIZATIONS

Report

Basil Ruch*
ETH Zurich, Switzerland
Department of Mathematics

David Strassmann†
ETH Zurich, Switzerland
Department of Mathematics

4: Recorded hit rates in the L1 (left) and L2 (right) cache for the 2D stencil. Star mark-
resent the baseline and circles the temporal blocking algorithm. The color indicates the
y of the two dimensions: a value of 0.5 means that x and y dimension are equal.

Lab exercises

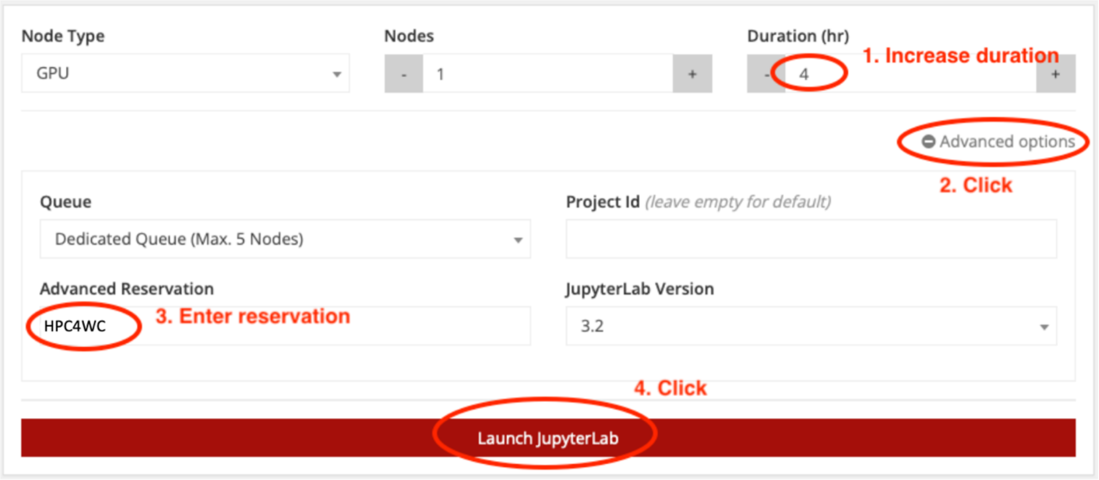
- Swiss National Supercomputing Centre https://www.cscs.ch/
- Alps supercomputer (#8 on list of 500 largest supercomputers worldwide)

CSCS Accounts

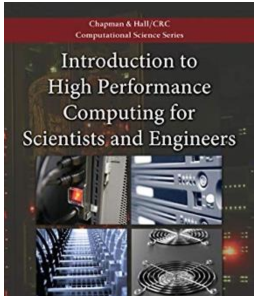
- Everybody has a unique user name (classXXX) and password.
- **Do not share you login / pwd with anybody else.** Accounts with suspicious activities will be closed down by CSCS immediately.
- **Change your password** immediately upon your first login to CSCS using the `passwd` command in a Terminal (see instructions).
- We have a shared quota of 4000 node hours for using the CSCS supercomputers for this block course.
  - Do not launch jobs with more than 1 node without checking with us first.
  - Do not leave your JupyterHub Server running if you don't need it.
- **Do not contact CSCS first** if you have trouble. Ask us or use the Slack workspace to get your issues resolved.
- Take a look at the [CSCS Code of Conduct]()

JupyterHub

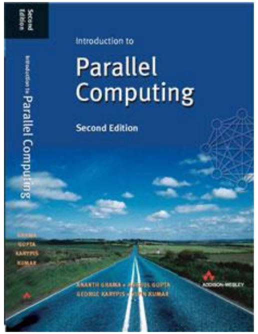
- Lab exercises will all be conducted on https://jupyter-santis.cscs.ch/, the JupyterHub portal of CSCS.
- Interactive development and computing environment.
- If things get stuck or go wrong, it's always possible to "Stop Server" and "Lauch Server" again.
- Jupyter notebooks auto-save and *almost* certainly no work will be lost.



Literature & Links

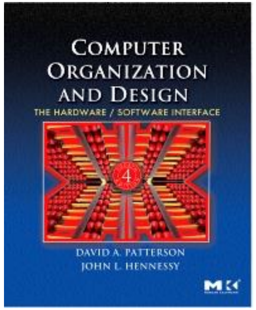


Introduction to High Performance Computing for Scientists and Engineers, G. Hager and G. Wellein, CRC Press, 2011 (available online at ETH)



Parallel Computing, A. Grama, A. Gupta, G. Karypis, V. Kumar (available free online)

Parallel Programming in MPI and OpenMP, V. Eijkhout (Link to course)



Computer Organization and Design, D.H. Patterson and J.L. Hennessy (available online at ETH)