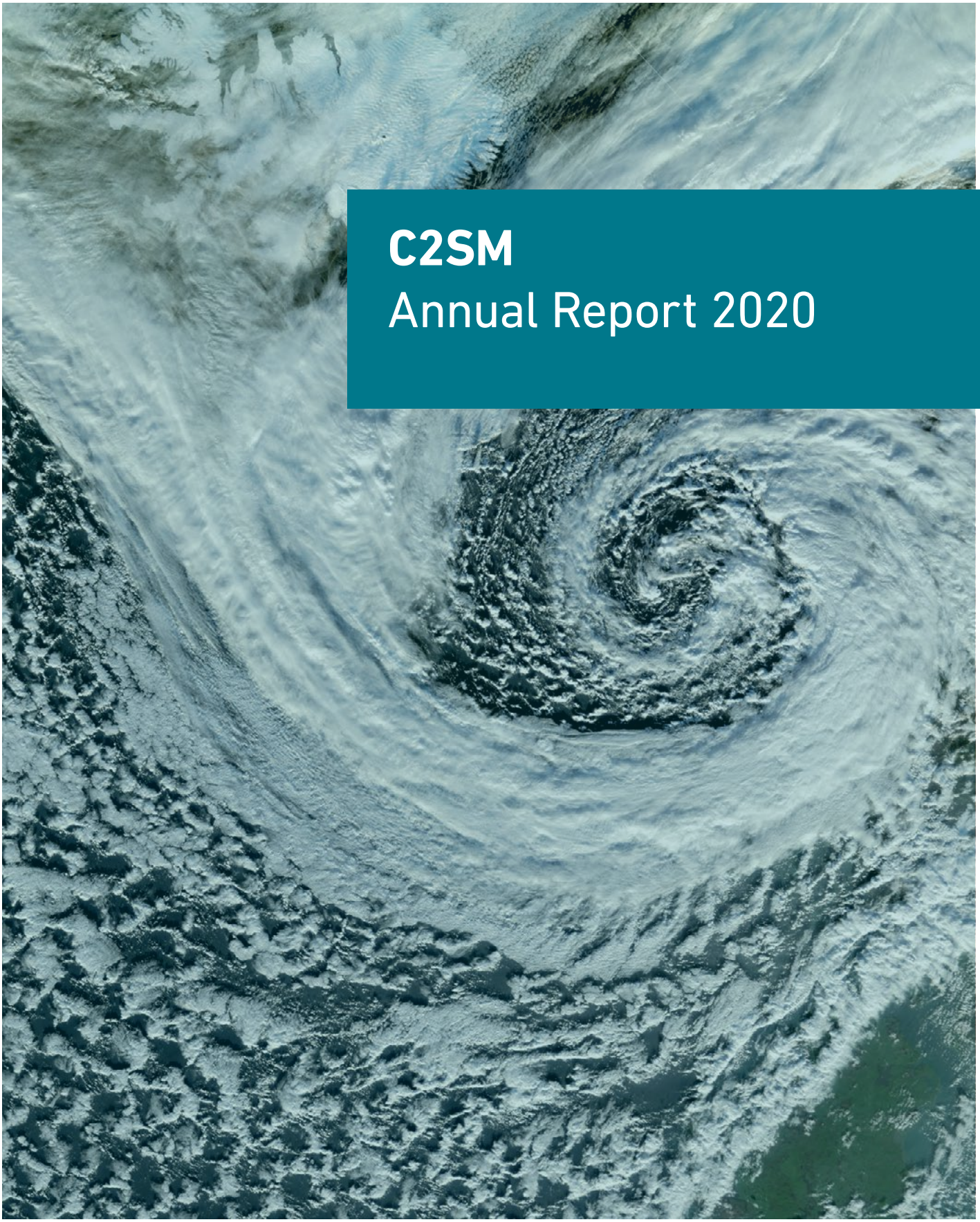
ETH zürich

Center for Climate Systems Modelling



C2SM
Annual Report 2020

C2SM Center for Climate Systems Modeling

The Center for Climate Systems Modeling (C2SM) is a competence center based at ETH Zurich and a joint initiative between ETH Zurich, MeteoSwiss, Empa, WSL, and Agroscope with the main objective to improve the understanding of the climate system and to strengthen the predictive skill of climate models on time scales from months to millennia. The center was established in 2008 and has now completed its third phase (January 2017 – December 2020). This document highlights the main achievements in 2020.

The C2SM Steering Committee, December 2021

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About C2SM

The Climate Modeling Challenge

Climate change is a challenging scientific issue that involves a multitude of complex, non-linear processes operating over a wide range of spatio-temporal scales in all sub-components of the Earth system. Over the last decades, numerical models have increasingly been used in research and service activities related to climate change. They now form the backbone for many applications including short-term weather forecast, climate data assimilation, seasonal climate prediction, climate predictions and projections (from decades to centuries), process and attribution studies, and the testing of strategies to mitigate and adapt to climate change. Thus, numerical modeling has developed into the third pillar of science, without which much of the research in climate science would no longer be possible.
At the same time, the continuing development of the numerical codes and supporting infrastructure is becoming an insurmountable challenge for individual research groups, making it hugely beneficial for participating groups to share models and the tasks to maintain, upgrade, develop, optimize, and run them. The emergence of new supercomputing architectures also implies a rapidly growing new challenge for climate model development and maintenance. In addition, coordinated efforts are required to store and analyze the increasing amount of climate data currently generated, including observations and model outputs.

Vision

A premier institution for climate modeling and data provision

The core aim of C2SM is to provide expertise, know-how, and infrastructure to enable and enhance the partners' research portfolios and to foster synergies between the partners in the areas of weather and climate sciences, atmospheric transport, chemistry, and aerosol research, climate risks and impact, as well as agricultural applications. In particular, we aim to exploit the favorable constellation with ETH Zurich, MeteoSwiss, and CSCS to push forward in high-performance computing in the area of weather and climate modeling, which has been identified as one of the grand challenges not only in high performance computing, but also in the area of environmental sciences. The plan is to build on the success stories of previous HPC projects and strengthen these links, building a world-leading center for climate modeling.

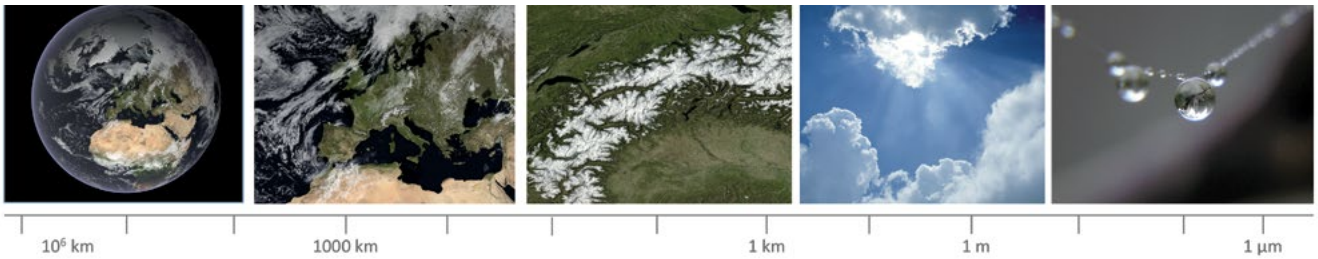
Mission

The C2SM network

The center's mission is to provide a technical and scientific platform and a network for its partners institutions

- to support the development and application of complex models of the weather and climate system and the analysis and visualization of climate data,
- to enable and facilitate collaborations within the C2SM's community and beyond,
- to exploit synergies among the partner institutions,
- to engage in a dialogue with the general public and other stakeholders about climate-relevant issues.

C2SM also acts as the primary entry and interaction point for ETH, for national and international institutions, and for society at large on issues related to climate and climate change.



Research Theme

Scientific strategy

In C2SM's third phase (2017 through 2020), we focus on building ICON as the common model platform for the C2SM community. We further work in the area of high performance computing taking advantage of the opportunities that arise from current developments in climate modeling and from the unique setting of partners that are brought together by C2SM. Specifically, we propose to strongly enhance the collaboration with CSCS and MeteoSwiss and to focus our technology/research efforts on (i) model consolidation around the ICON model, (ii) the development of the next generation of modeling platform for weather and climate, (iii) the development of methods and tools to analyze massive amounts of data, particularly in the context of the Swiss Climate Scenarios, and (iv) to integrate nearby science fields such as climate impact and atmospheric chemistry research into the core weather and climate activities exploiting the already existing close collaborations and the locational advantage of the ETH domain institutions. In addition, we continue providing specific services, training and outreach, building on the competences, products, and successes that were acquired and developed since 2008.

Activities

C2SM coordinates a world-leading network of research institutions and experts. It strongly relies on its affiliated research groups to provide the respective disciplinary expertise and capabilities to advance the frontiers of knowledge in their research fields. C2SM sees its primary role in bringing together the climate research community and integrating this knowledge base, as well as providing central technical, educational, and outreach services to the benefit of the whole community.

A key set of activities aims to foster interdisciplinary research and interactions across disciplinary boundaries. A second set of activities centers around establishing a common and coherent modeling framework that allows the community i) to bridge the gap between different spatio-temporal scales and between the different atmospheric, hydrological, oceanographic, and terrestrial components of the climate system and ii) expand on new research themes. These enable the partner groups and institutions to undertake the challenging model development and applications studies that would otherwise not be possible.

Research coordination

To foster the collaboration between research groups by facilitating scientific discussions and exchanges.
To coordinate the development of large, collaborative research projects and to further manage them.
To develop a common modeling strategy that enables the development of new and original research avenues. Of particular importance is the planned consolidation of the supported model families through adopting the ICON weather and climate model.

Support for research activities

- To continue to maintain, improve, and provide to the center's community a hierarchy of state-of-the-art climate and climate-related models. In particular, the center is responsible for maintaining and refining both a global and a regional climate model, as well as the associated modules e.g., for aerosols, atmospheric composition, (biogeo)chemistry, oceans, land surfaces, and clouds.
- To pro-actively gain expertise in the ICON model and support the members to transition to this model.
- To exploit and disseminate key national and international data sets by providing a repository for them and by developing analysis and data management tools.
- To support the ETH members in organizing funding for data storage and computing nodes.
- To prepare for the exploitation of the next generation of high-performance computers.

Education and training

- To contribute towards an improved training of PhD students through the establishment of projects across research groups, institutions, and disciplines.
- To train scientists (PhD students, post docs, etc.) in the areas of data visualization, data analysis, use and interpretation of climate data, programming, and data management.
- To continue organizing the Swiss Climate Summer Schools jointly with the Oeschger Center for Climate Research at the University of Bern.

Outreach and events

- To continue raising public awareness related to climate and weather through various channels while focusing on linking with other relevant themes, for which climate change has implications. The primary avenues will be the well-established "Klimarunde" and public outreach events such as Scientifica.

Governance

Structure, Organization, and Personnel of C2SM

The center was established in 2008 by the funding partners ETH, MeteoSwiss, Empa, and Agroscope, and became operational in March 2009. WSL joined the center in 2013 to enhance the collaborations and respective expertise in the area of climate change and climate change impact. In January 2017, C2SM entered its third phase, which covers the four-year period 2017 through 2020.
As of 31 December 2020, the center includes 40 members, who are professors or senior scientists at the partner institutions (see Annex for a detailed list) and form the center's Plenary.
The C2SM community includes all students, postdoctoral fellows, technical and scientific staff from the research groups of each member and thus represents a group of over 400 people. Seven members out of 40 form the Steering Committee (SC) who defines the overall strategy and oversees its implementation. The SC elects a chair and co-chair from its members. The Scientific Advisory Board (SAB) consists of recognized individuals from different Swiss and European institutions and advises and supports the center in its strategic planning (see Annex).
Operationally, the center is run by an executive director, who oversees an administrative office composed of scientific programmers, a PR and communication specialist, and an administrative assistant. The scientific programmers are active in two main focus areas: Global Climate Modeling (GCM) and Regional Climate Modeling (RCM). Two working groups, composed of 6 to 8 C2SM members or researchers, meet on a regular basis to discuss and propose the strategy to be developed and the tasks to be performed in each of the areas. The center also supports six software developers through specific research projects acquired by C2SM and its members (see page 26 for more details on the current projects). The structure and organization of C2SM is described in greater detail in the Terms of Reference, that can be downloaded from the C2SM website.

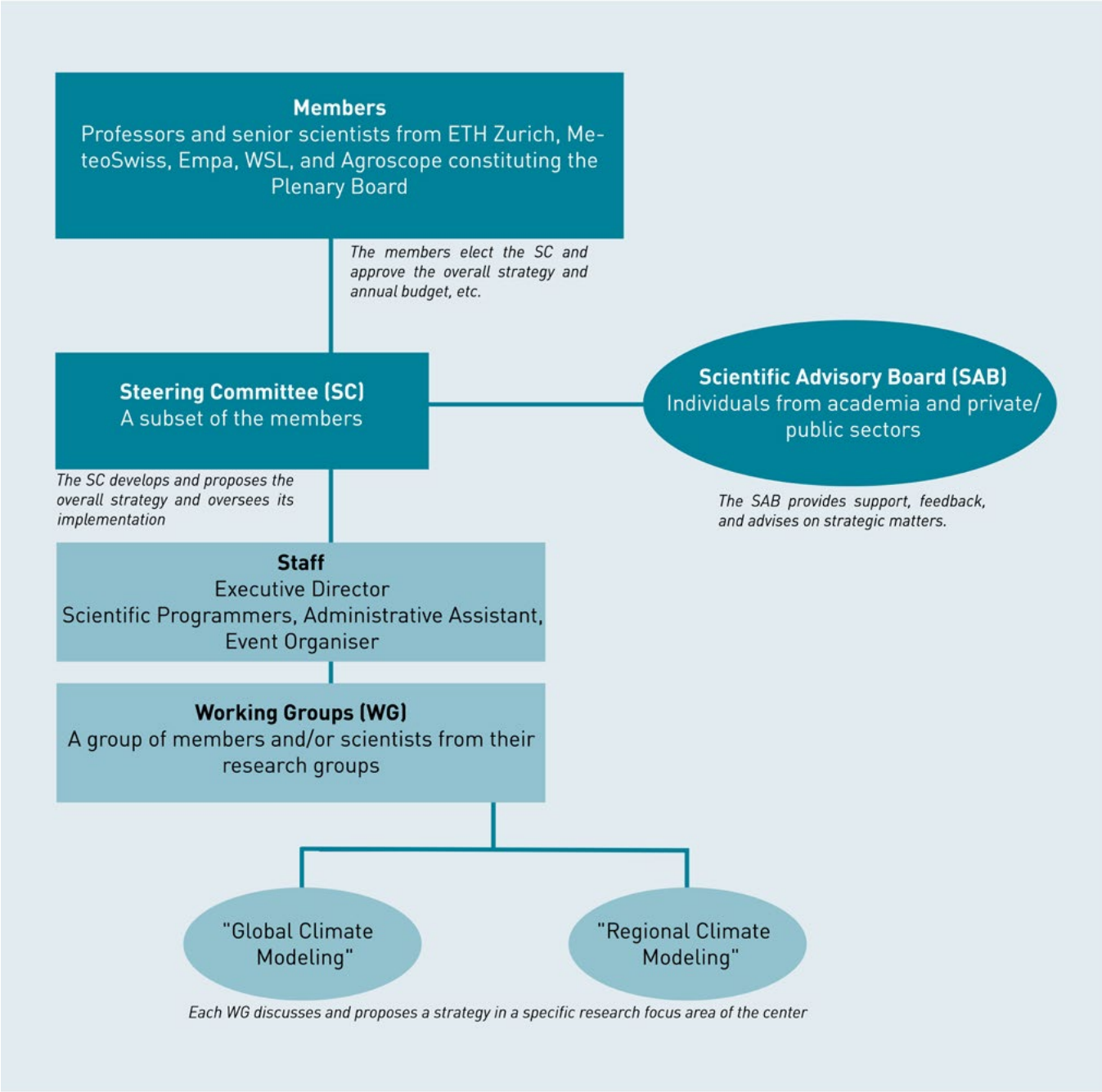
www.c2sm.ethz.ch/the-center/documents.html

Core staff

Role	Name
Executive Director	Christina Schnadt Poberaj
Scientific Programmer	Urs Beyerle
Administrative Assistant	Rahel Buri
Scientific Programmer	Jonas Jucker
Scientific Programmer	Matthieu Leclair
PR and Communication	Tanja Meier
Scientific Programmer	Katherine Osterried

* As of 31 December 2020, the core staff corresponds to a total of 3.25 FTE. The administrative assistant is directly supported by the Institute for Atmospheric and Climate Science, and only paid by C2SM to a small fraction. In addition to the core staff, project fellows and research assistants are supported through funding from different projects.

www.c2sm.ethz.ch/the-center/people.html



Structure C2SM

Main Achievements

C2SM and its community have contributed to the successful acquisition and subsequent implementation of several large collaborative projects addressing a range of topics, particular in the area of high-performance computing.

Research Coordination

Highlight: Transition from competence to extradepartmental center

After several years of preparations C2SM was approved as an extra-departmental science center of ETH in November 2020, to be effective January 2021. C2SM will be assigned to the domain of ETH's Vice President for Research, and as such will directly report to him.

C2SM will transition into this new organizational form together with renewed commitments from its long-term partners Swiss Federal Office for Meteorology and Climatology (MeteoSwiss), Swiss Federal Laboratories for Materials Science and Technology (Empa), and Swiss Federal Research Institute for Forest, Snow and Landscape Research (WSL). With the transition, C2SM is ensured a long-term perspective allowing its vision to solve tomorrow's challenges in the analysis and modeling of weather and climate to come true.

For the next five years, C2SM'S activities will be organized around the four major themes "High Performance Computing (HPC)", "Weather and Climate Model Development, Usage, and Support", "Climate Scenarios", and "Impact Research". With the two latter themes, it will expand its contributions to the generation of climate scenarios and also newly include impact sciences in its portfolio. This way C2SM will offer added value to a broader group of members. The four themes are built on the premise that the optimal way to bring together the members is to work jointly on common objectives and to share resources. C2SM provides the expertise, know-how, and infrastructure to enable and enhance its members' research portfolios and to foster synergies between the members, building upon the respective strengths of the member institutions.

Much of C2SM's coding work revolves around tasks defined and discussed in member working groups. Specifically, the annual work schedule of the C2SM scientific programmers is determined by tasks and / or short-term projects that are collected from individual C2SM member groups or bigger projects in the community. The scientific programmers together with the Executive Director prioritize the tasks according their strategic importance and urgency of the requests and present and discuss them at regular working groups meetings. The major part of this work is base funded, but some additional fraction may be financed by third-party projects of individual members or bigger projects in the community. We have now restructured our previous working groups and created four new ones aligned with the four strategic themes. We will introduce a bi-annual "C2SM Working Group Day", during which all working groups will meet in successive meetings. The first such C2SM Working Group Day is scheduled for March 2021.

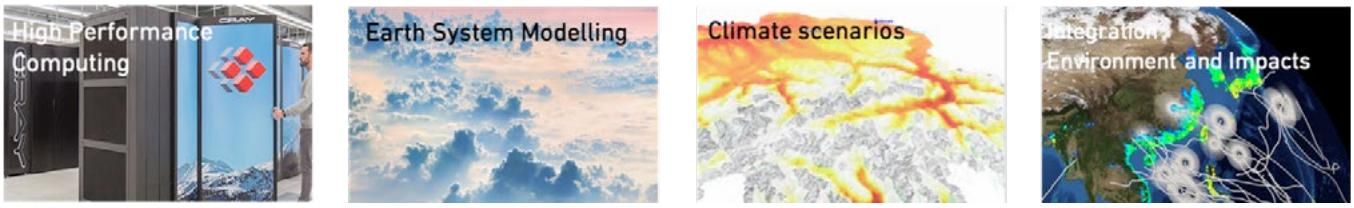
The transition and associated expansion of strategic foci and tasks requires a stronger workforce. Negotiations were successful in making the case for two new positions in the areas of HPC and climate scenarios/impact modeling. In addition, one position became open after one scientific programmer left C2SM. Hiring is now completed, and in addition to offering a temporary employee a long-term employment contract, C2SM will welcome two new scientific programmers in the Executive Office in spring 2021.

One of the most prominent reasons for transitioning C2SM to an institution with a long-term perspective is the ambition to take forward the development of the next generation of modeling systems for weather and climate. Here, C2SM achieved a major milestone this year: in November 2020, ETH school board approved the open ETH project proposal EXCLAIM led by Prof. Nicolas Gruber and involving many C2SM members (see article on EXCLAIM on page 9).

Last but not least, ETH School Board appointed Prof. Reto Knutti as C2SM's new chair and Prof. Heini Wernli as his

deputy. Both Profs. Knutti and Wernli will start their two-year term in January 2021.

Prof. Reto Knutti replaces Prof. Nicolas Gruber who was deputy Chair of C2SM from its start in 2008 to 2012, and has been chairing C2SM since then. We thank Prof. Gruber for his genuine, outstanding and never subsiding engagement for C2SM: he reached numerous achievements during his time as Chair. Amongst others, he established ETH-Klimarunde in 2013, which is meanwhile considered the ETH flagship outreach event in the area of climate change. However, his greatest accomplishment undoubtedly consists of taking the lead in transitioning the competence center C2SM to an extra-departmental science center in the past four years. C2SM is also sincerely grateful to Dr. Mischa Croci-Maspoli who has been Deputy Chair of C2SM since 2016. His exceptional and continuous engagement for C2SM is largely valued.



Four strategic themes C2SM

High Perfomance Computing

Recent years have seen immense progress in our capacity to predict weather and climate evolution using numerical models. An important driver for this development has been the rapid progress in high-performance computing (HPC). It is expected that with the further increase of high-performance computing capacity, the computational resolution of such models will continue to be refined in the next decades. From a computer science perspective, this strategy poses major challenges. First, harvesting the computational capacity of emerging HPC architectures increasingly involves the use of heterogeneous many-core architectures consisting of both CPUs and accelerators (e.g., GPUs). The efficient exploitation of such architectures requires a paradigm shift and has only just started. Second, continuously adapting state-of-the art weather and climate models to emerging and new hardware and the associated programming models poses a formidable challenge, as these models typically entail huge code bases maintained by a large community of domain-scientists.

For almost a decade, C2SM has actively been contributing to this development preparing climate codes for the next generations of high-performance computers to exploit emerging computing capabilities. C2SM has been strongly collaborating with MeteoSwiss, ETH groups, and CSCS, and has been involved in several consecutive projects of the Swiss initiative for High Performance and High Productivity Computing (HP2C) (e.g., HP2C-COSMO, HP2C-OPCODE, and HP2C-POMPA) and since then has been contributing to the follow-up initiative, the Platform for Advanced Scientific Computing (PASC), where it was previously involved in the projects CLAW and GridTools. Until recently, C2SM was involved in two PASC projects, ENIAC and PASCHA, which were finished in summer 2020.

https://c2sm.ethz.ch/research.html

PASC ENIAC

The aim of the ENIAC project (July 2017 – June 2021) was to adapt the numerical weather prediction and climate model ICON to new hardware technologies such as GPUs and investigate the question of performance portability. ENIAC was a collaboration between ETH Zurich, C2SM at ETH Zurich, CSCS, and MPI of Meteorology in Hamburg, Germany (MPI-M). The port to GPU was based on OpenACC compiler directives for most components, except for the soil model JSBACH which was automatically ported using the CLAW compiler developed as part of the project. In the past year major progress has been made to port the code for global climate application to GPU and a first set of physical parameterizations has been completed. First test simulations for the “Quasi-Biennial Os-

cillation in a Changing Climate" (QUBICC) project lead by MPI-M have been carried out, running the code on up to 2000 GPU nodes at 2.8 km horizontal resolution. Single socket comparison shows a speed up factor of about 5 on GPU as compared to CPU. Thanks to the achievement reached, the project was granted an extension until June 2021. C2SM employed the software developers Valentin Clément and Philippe Marti on this project until summer 2019.

https://www.pasc-ch.org/projects/2017-2020/eniac-enabling-the-icon-model-on-heterogeneous-architectures/

PASC PASCHA

The aim of the PASCHA project (July 2017 – Jun 2021) coordinated by Prof. Hoefler (D-INF, ETH), was to provide portability for the COSMO model (avoiding the GPU vendor lock), increase the productivity of programming models like domain specific languages (DSLs) adopted in production and enhance the performance on accelerators by integrating a new functional parallelism (in addition to data parallelism) into the COSMO model. In the last year an implementation using asynchronous directives of OpenACC and the use of OpenMP tasking for the parameterizations was investigated.

The high-level DSL toolchain dawn was developed as part of the project. The language provides a Matlab-like high level syntax that increases the productivity of model development. Further extensions were developed, in particular to support non-structured grid, which could be applied to the ICON model.
The project was granted an extension until June 2021. C2SM core staff K. Osterried contributed to this project.

www.pasc-ch.org/projects/2017-2020/pascha/

WEW-COSMO

WEW-COSMO (Weiterentwicklungen COSMO) is a research and technical development collaborative project hosted at C2SM, funded by MeteoSwiss and partly by the consortium COSMO, which focuses on improving the COSMO and ICON weather forecast and climate models for the application in the Alpine region. One focus is on improving parameterisations such as fog, hail, and heavy precipitation. In addition, an ensemble dispersion system is developed and the numerical weather forecast is further developed in the nowcasting range. A second focus of the project is on adapting and testing the COSMO and ICON models to be used on hybrid high-performance architectures. The project is a collaboration between ETH Zurich, C2SM at ETH Zurich, and the Federal Office for Meteorology and Climatology MeteoSwiss. The project started in 2017 and will continue until the end of 2022.

As part of the high-performance component IMPACT (ICON on Massively Parallel ArchiteCTures) of WEW-COSMO, first steps were taken to run ICON-LAM on GPU. Since code executed on GPU cannot produce bit-identical output to the CPU, the testing infrastructure in ICON had to be extended. While simple bit-reproducibility tests already existed prior to this work package, more elaborate, probabilistic testing needed for GPU development did not. Therefore a new testing software was written that computes the spread of a perturbed model ensemble to estimate the expected growth of errors due to numerical differences arising from different hardware. This test has been operational in ICON's continuous integration system since summer 2019 and has already detected several bugs in the GPU implementation. Based on this solid testing environment, GPU-capable code for the microphysics (graupel), turbulence (tiedke) and land (terra) parameterizations could be implemented and is now continuously tested and maintained. C2SM employs software developer R. Dietlicher on this part of the project.

Visualization of Ensemble Dispersion Simulations at MeteoSwiss

The emergency response to atmospheric release of radioactivity strongly relies on particle dispersion simulations. These are driven by numerical weather prediction models, which are increasingly run as ensembles to estimate meteorological uncertainty. In the framework of the project EMER-Met, MeteoSwiss is developing an ensemble dispersion simulation tool chain comprised of multiple FLEXPART dispersion simulations driven by one of the new COSMO ensembles. Visualizing this new ensemble information is the main task of C2SM postdoc Stefan Rüdisühli. Starting in May 2019, he developed a new software to visualize both deterministic and ensemble dispersion simulations, and created first prototype ensemble products. In addition, he has contributed to the single precision implementation of COSMO required to run the operational COSMO ensemble that will drive the new ensemble dispersion simulations.

www.c2sm.ethz.ch/research/wew-cosmo.html

New projects

EXCLAIM

The newly funded open ETH project EXCLAIM, which will start in spring 2021, aims at developing an exascale computing and data platform for weather and climate modelling that is capable of simulating the regional to global ocean-sea-ice-atmosphere-land system at much higher resolution than hitherto possible. Such a step change in resolution will permit the explicit modeling of many critical processes of weather and climate, in particular clouds and convection, thus reducing uncertainties in weather prediction and climate projections.

EXCLAIM will be run under the umbrella of C2SM and will centrally contribute to the implementation of C2SM's first two research themes, High-Performance Computing and Earth System Modeling. Over the next six years, a team of about 10 software engineers and postdocs, guided by to be appointed directors of science and of software will develop this platform in collaboration with CSCS, the Swiss Data Science Center (SDSC), MeteoSwiss, and Empa.

www.c2sm.ethz.ch/research/exclaim.html

Support for Research Activities

C2SM provides community support in the area of global and regional climate modeling.

www.c2sm.ethz.ch/services.html

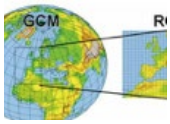
Global climate modeling

The global climate modellng activities at C2SM focused on further establishing the next generation weather and climate model ICON (ICOsahedral Nonhydrostatic Model). Therefore the testing capability with the Jenkins Continuous Integration Framework has been extended to ICON and ICON-ART. It is now possible to run weekly tests on all C2SM supported HPC machines. To test the correctness of climate model results of ECHAM-HAMMOZ and ICON simulations, the development of a sanity-checker at C2SM continued. This tool is based on the work of David Neubauer from the group of C2SM member Ulrike Lohmann and statistically compares results from a 10-year simulation in question against respective data of a reference pool. It is publicly available through the C2SM-ICON GitHub organization.
With prospect on the replacement of COSMO with ICON as the operational weather model at MeteoSwiss in 2022, a new set of external parameters was implemented for the unstructured ICON grid in EXTPAR. The so-called 'Topographic Radiation Correction Parameters" are essential for accurate radiation forecasts in mountainous areas.

Furthermore C2SM organized three-monthly ICON meetings, a place to exchange with the community about topics related to ICON.

wiki.c2sm.ethz.ch/GCM/WebHome

Regional climate modeling



The regional climate modeling (RCM) activities at C2SM have traditionally focused on the COSMO model, a limited-area atmospheric model developed by the Consortium for Small-Scale Modeling (COSMO) including MeteoSwiss and other European meteorological services. Beginning in 2019, some activities in the RCM modeling group have also involved the ICON atmospheric model, because C2SM members are now beginning to use ICON for regional climate modeling. Activities in 2019 included porting of the M7 addition to the ART aerosol model, which was developed during the PhD work of Franziska Glassmeier in the group of Ulrike Lohmann, into the official ART code. The ART-M7 code is now regularly maintained and fully compatible with the latest version of the COSMO model. Additionally, a tolerance testsuite was adapted from the COSMO model for the ICON modeling framework to facilitate the porting of the ICON model to GPUs.

wiki.c2sm.ethz.ch/COSMO/WebHome

Education and Training

C2SM organized and carried out several workshops.

Swiss COSMO User Workshop

The Swiss COSMO User Workshop is an informal one day event whose goal is to bring together COSMO users and developers from Switzerland, share experience and knowledge about the models, and to get insights into some projects involving this model. Presentations could provide an overview of activities revolving around the COSMO model, the description of a technical problem, the presentation of results from a specific project, or the demonstration of a tool that can be useful for other model users. 40 people registered for the COSMO User Workshop co-organized by C2SM, MeteoSwiss, and EMPA and held at Empa Akademie on 21 January 2020. Thirteen presentations were given highlighting the varied uses of COSMO within the Swiss user community. The program and presentations can be found at the C2SM wiki at:

https://wiki.c2sm.ethz.ch/MODELS/COSMOCuW2020

Scientific Visualization using Python 2020

In October 2020, C2SM in collaboration with ETH Scientific IT Services (SIS) again carried out its two python workshops for their community. Due to the pandemic, both courses were conducted online. The first course, carried out in the mornings of 1and 2 October 2020, introduced the participants to the basic elements of python. The second course, a four mornings workshop on 20-23 October 2020, focused on the visualization in the Python programming language. Both workshops were fully booked and again very well received by the C2SM community. Based on the popularity and the very positive feedback from the attendees, the workshops are going to be repeated in autumn 2021.

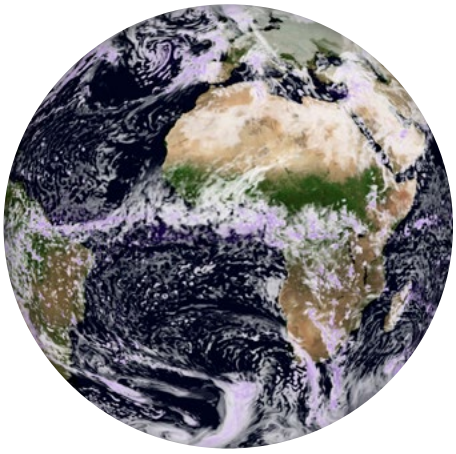
Outreach and Events

C2SM organized the first online edition of ETH-Klimarunde in 2020.

ETH-Klimarunde 2020: Klima- und andere Krisen: Was lernen wir daraus?

For more than a year now, the Corona pandemic has dominated our world. The most devastating epidemic of the 21st century to date has had consequences that were previously unimaginable. The crisis has also been accompanied by extreme political measures. Stores and restaurants were temporarily forced to close in spring and summer 2020, many people have been working from home for months and have reduced their commuting and business as well as private travels. But the first lockdown also led to measurable relief for the atmosphere: For the first time since World War World War II, the global CO_2 emissions fell significantly.

What is the long-term impact of the Corona pandemic on air quality and mobility? What are the implications of the Corona crisis for climate policy? Can we derive from the crisis approaches for a more consistent approach to the climate problem? These and more questions were discussed at "Klimarunde 2020".



Due to the Corona crisis we conducted ETH-Klimarunde online for the very first time. We were very pleased with

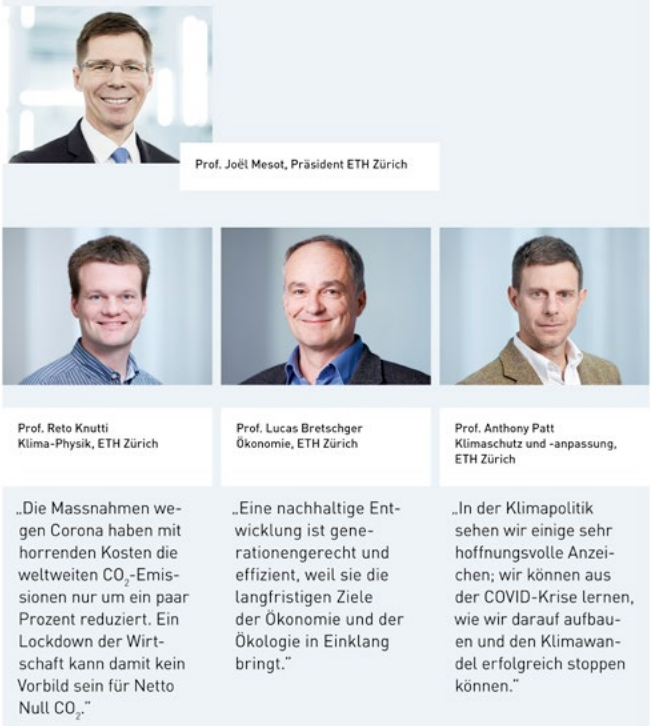
the great participation in this online event: More than 450 people joined us for the live-webinar with an introduction by ETH President, Prof. Joël Mesot, and the keynote speakers Prof. Reto Knutti, Prof. Lucas Bretschger, and Prof. Anthony Patt.

The second part was no less interesting. We organized 14 parallel zoom sessions that replaced the traditional format of the "Tischgespräche" in the great hall of the ETH main building. This year the participants were able to interact with 29 experts directly via chat or by using their microphone.

We received very positive feedback regarding the quality of the event. Overall, the event was rated "excellent" or "very good" by the majority, i.e. more than 80 % of respondents. It was a very exciting event for us as we faced a lot of new challenges with the novel online format. We would like to thank all our volunteers and our-co-organizer, the Energy Science Center, who supported us and without whom the quality of the event would not have been reached.

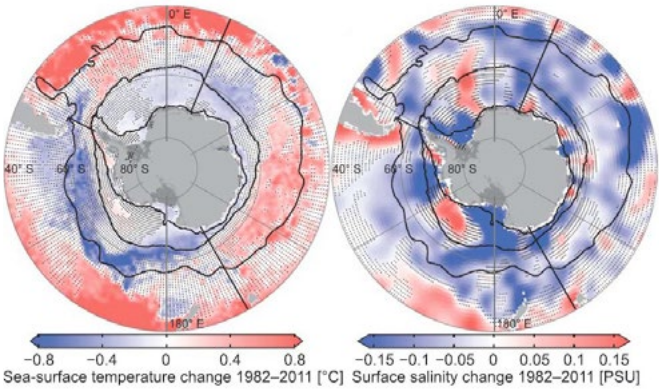
The video-recording of the full webinar as well as pictures and posters of the experts can be found on our website:

https://c2sm.ethz.ch/events/eth-klimarunde-2020.html



Scientific Highlights

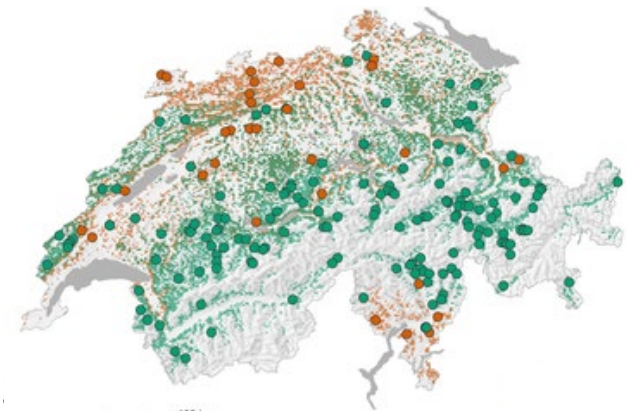
Paper: Sea-Ice Induced Southern Ocean Subsurface Warming and Surface Cooling in a Warming Climate



Much of the Southern Ocean surface south of 55° S cooled and freshened between at least the early 1980s and the early 2010s. Many processes have been proposed to explain the unexpected cooling, including increased winds or freshwater fluxes. However, these mechanisms so far failed to fully explain the surface trends and the concurrent subsurface warming (100 to 500 m). Here, we argue that these trends are predominantly caused by an increased wind-driven northward sea-ice transport, enhancing the extraction of freshwater near Antarctica and releasing it in the open ocean. This conclusion is based on factorial experiments with a regional ocean model. In all experiments with an enhanced northward sea-ice transport, a strengthened salinity-dominated stratification cools the open-ocean surface waters between the Subantarctic Front and the sea-ice edge. The strengthened stratification reduces the downward mixing of cold surface water and the upward heat loss of the warmer waters below, thus warming the subsurface. This sea-ice induced subsurface warming mostly occurs around West Antarctica, where it likely enhances ice-shelf melting. Moreover, the subsurface warming could account for about 8 ± 2% of the global ocean heat content increase between 1982 and 2011. Antarctic sea-ice changes thereby may have contributed to the slowdown of global surface warming over this period. Our conclusions are robust across all considered sensitivity cases, although the trend magnitude is sensitive to forcing uncertainties and the model's mean state. It remains unclear whether these sea-ice induced changes are associated with natural variability or reflect a response to anthropogenic forcing.

Haumann FA, Gruber N, Münnich M: Sea-ice induced Southern Ocean subsurface warming and surface cooling in a warming climate. AGU Advances 2020, 1: e2019AV000132, doi: 10.1029/2019AV000132

Paper: Assessing the response of forest productivity to climate extremes in Switzerland using model-data fusion

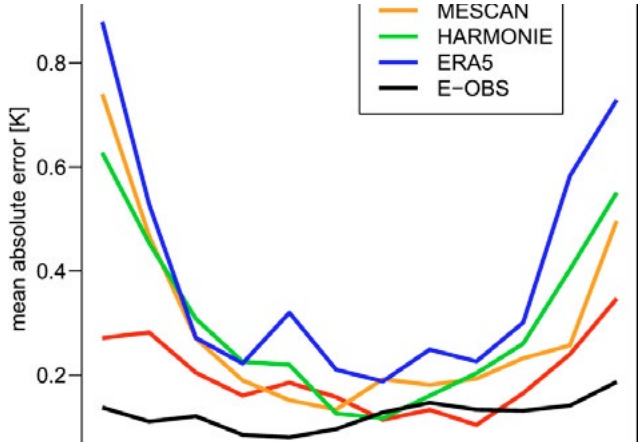


The response of forest productivity to climate extremes strongly depends on ambient environmental and site conditions. To better understand these relationships at a regional scale, we used nearly 800 observation years from 271 permanent long-term forest monitoring plots across Switzerland, obtained between 1980 and 2017. We assimilated these data into the 3-PG forest ecosystem model using Bayesian inference, reducing the bias of model predictions from 14% to 5% for forest stem carbon stocks and from 45% to 9% for stem carbon stock changes. We then estimated the productivity of forests dominated by Norway spruce and European beech for the period of 1960–2018, and tested for productivity shifts in response to climate along elevational gradients and in extreme years. Simulated net primary productivity (NPP) decreased with elevation (2 .86 ± 0.006 Mg C ha^{-1} $year^{-1}$ km^{-1} for spruce and 0.93 ± 0.010 Mg C ha^{-1} $year^{-1}$ km^{-1} for beech). During warm–dry extremes, simulated NPP for both species increased at higher elevations, but decreased at lower elevations. About 21% of the potential species distribution range in Switzerland showed reductions in NPP of more than 25%. Reduced plant water

availability had a stronger effect on NPP than temperature during warm-dry extremes. Importantly, cold–dry extremes had negative impacts on regional forest NPP comparable to warm–dry extremes. Overall, our calibrated model suggests that the response of forest productivity to climate extremes is more complex than a simple shift toward higher elevations. Such robust estimates of NPP are key for increasing our understanding of forests ecosystems carbon dynamics under climate extremes.

Trotsiuk V, Hartig F, Cailleret M, Babst F, Forrester DI, Baltensweiler A, Buchmann N, et al. (2020) Assessing the response of forest productivity to climate extremes in Switzerland using model-data fusion. Global Change Biology 26: 2463–2476, doi.org/10.1111/gcb.15011

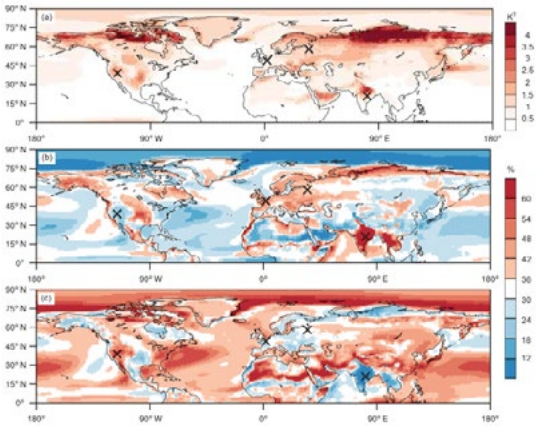
Paper: New ERL paper on temperature monitoring in the Alpine region: How well do modern reanalyses perform?



A recently published paper by Simon Scherrer (MeteoSwiss) assesses the monitoring capabilities of modern reanalyses in the Swiss Alps during the last 20 to 60 years. Monthly and seasonal 2 m air temperature (T2m) anomalies of the global ERA5 and three regional reanalyses are evaluated against high quality in-situ observational data. All reanalyses show a good year-round performance for the foothills with ERA5 showing the best overall performance. The high-resolution regional reanalysis COSMO-REA6 clearly performs best at high elevations, especially in winter. Most reanalyses show deficiencies at high elevations in winter and considerably overestimate recent T2m trends in winter. Hence, utmost care is required when using reanalyses for T2m trend assessments in the Alps, even in the most recent decades. A high-resolution model topography is an important prerequisite for an adequate monitoring of winter T2m at high elevations and assimilating T2m remains challenging. The remaining shortcomings highlight the continued need for a reliable and dense in-situ observational monitoring network in mountain regions.

Scherrer, S. C., 2020. Temperature monitoring in mountain regions using reanalyses: Lessons from the Alps. Environ. Res. Lett., 15, 044005. doi.org/10.1088/1748-9326/ab702d

Paper: New ERL paper on temperature monitoring in the Alpine region: How well do modern reanalyses perform?



In this study we quantify how much the coldest, middle and hottest third of all days during extremely hot summers contribute to their respective seasonal mean anomaly. This extreme-summer substructure varies substantially across the Northern Hemisphere and is directly related to the local physical drivers of extreme summers. For example, in eastern India the hottest 30 d of an extreme summer contribute more than 65% to the total extreme-summer T2m anomaly, while the colder days are close to climatology. In the high Arctic, however, extreme summers occur when the coldest 30 d are substantially warmer than they are climatologically. Furthermore, in roughly half of the Northern Hemisphere land area, the coldest third of summer days contributes more to extreme summers than the hottest third, which highlights that milder- than-normal coldest summer days are a key ingredient of many extreme summers. Comparing extreme-summer substructures in ERA-Interim and CESM present day climate simulations reveals a remarkable level of agreement.

Röthlisberger, M., M. Sprenger, E. Flaounas, U. Beyerle, and H. Wernli, 2020. The substructure of extremely hot summers in the Northern Hemisphere. Weather Clim. Dynam., 1, 45–62. doi:10.5194/wcd-1-45-2020

Key Publications of C2SM Members

*For all publications with more than ten authors we cite the first author together with the author(s) from the C2SM community

*Allen, R. J., U. Lohmann, et al., 2020: Climate and air quality impacts due to mitigation of non-methane near-term climate forcers, Atmos. Chem. Phys., 20, 9641–9663, https://doi.org/10.5194/acp-20-9641-2020, 2020.

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Trotsiuk V, Hartig F, Cailleret M, Babst F, Forrester DI, Baltensweiler A, Buchmann N, et al. (2020) Assessing the response of forest productivity to climate extremes in Switzerland using model-data fusion. Global Change Biology 26: 2463–2476, doi.org/10.1111/gcb.15011

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Annex

As of 31 December 2020

Plenary Members

Steering Committee members (7)

Prof. Nicolas Gruber, Chairman	ETH D-USYS	Environmental Physics
Dr. Dominik Brunner	Empa	Atmospheric Modeling
Dr. Mischa Croci-Maspoli	MeteoSwiss	Climate Change, Climate Services
Prof. Daniela Domeisen	ETH D-USYS	Atmospheric Predictability
Prof. Reto Knutti	ETH D-USYS	Climate Physics
Dr. Gian-Kasper Plattner	WSL	Climate, Environmental ORD
Prof. Heini Wernli	ETH D-USYS	Atmospheric Dynamics

Regular members (33)

Prof. Christof Appenzeller	MeteoSwiss	Analysis and Forecasting
Dr. Marco Arpagaus	MeteoSwiss	Numerical Predictions
Prof. David Bresch	ETH D-USYS, MeteoSwiss	Environmental Decisions
Dr. Brigitte Buchmann	Empa	Mobility, Energy and Environment
Prof. Nina Buchmann	ETH D-USYS	Grassland Sciences
Prof. Harald Bugmann	ETH D-USYS	Forest Ecology
Prof. Paolo Burlando	ETH D-BAUG	Hydrology and Water Resources
Prof. Tom Crowther	ETH D-USYS	Integrative Biology
Dr. Lukas Emmenegger	Empa	Air Pollution/Environmental Technology
Prof. Daniel Farinotti	ETH D-BAUG, WSL	Glaciology
Prof. Andreas Fischlin	ETH D-USYS	Terrestrial Systems Ecology
Dr. Sven Kotlarski	MeteoSwiss	Climate Evolution
Dr. Xavier Lapillonne	MeteoSwiss	Computing
Prof. Michael Lehning	WSL	Snow and Permafrost
Dr. Jens Leifeld	Agroscope	Air Quality and Climate
Dr. Mark Liniger	MeteoSwiss	Climate Prediction
Prof. Ulrike Lohmann	ETH D-USYS	Atmospheric Physics
Prof. Nicolai Meinshausen	ETH D-MATH	Statistics
Dr. Carlos Osuna	MeteoSwiss	Computing
Prof. Anthony Patt	ETH D-USYS	Human-Environment Systems
Prof. Thomas Peter	ETH D-USYS	Atmospheric Chemistry
Prof. Christoph Schär	ETH D-USYS	Climate and Water Cycle
Prof. Sebastian Schemm	ETH D-USYS	Circulation of the Atmosphere
Prof. Thomas Schulthess	ETH D-PHYS	Theoretical Physics
Dr. Cornelia Schwierz	MeteoSwiss	Climate Monitoring

Prof. Sonia Seneviratne	ETH D-USYS	Land-Climate Dynamics
Dr. Philippe Steiner	MeteoSwiss	Numerical Prediction
Dr. Reto Stöckli	MeteoSwiss	Climate Fundamentals
Prof. Benjamin Stocker	ETH D-USYS	Computational ecosystems science
Prof. Heather Stoll	ETH D-ERDW	Climate Geology
Prof. Martin Wild	ETH D-USYS	Climate and Radiation
Prof. Lenny Winkel	ETH D-USYS	Environmental Geochemistry
Prof. Niklaus Zimmermann	WSL	Landscape Dynamics

As of 31 December 2020

Scientific Advisory Board (SAB) Members

Scientific Advisory Board (SAB) members	
Dr. Karin Ammon	SCNAT, Bern, CH
Dr. Albert Klein Tank	Met Office, Exeter, UK
Prof. John Mitchell	University of Reading, Reading, UK
Dr. Jürg Füssler	INFRAS, CH
Prof. Bjorn Stevens	MPI-Meteorology, Hamburg, DE

The SAB has the mandate to advise the Center on strategic matters and to provide feedback regarding the achievements, as well as the planned developments.

Within the C2SM community

Research Projects Related to C2SM

A number of projects were initiated within the C2SM community, with some of the projects contributing to the core budget (see below).

Project name*	Lead PI	Funding mechanism	Duration
PASC ENIAC	U. Lohmann (ETH)	PASC	01/07/2017 - 30/06/2020
PASC PASCHA	T. Hoefler (ETH)	PASC	01/07/2017 - 30/06/2020
WEW-COSMO	P. Steiner (MeteoSwiss)	MeteoSwiss	01/01/2017 - 31/10/2021

Reporting period (1 January 2020 - 31 December 2020)

Budget

Saldo (CHF) 01/01/2020	301'666

Income (CHF) 01/01/2020-31/12/2020	
ETH School Board	160'000
USYS Department	100'000
Surcharges core staff	26'916
ETH members	53'000
MeteoSwiss	50'000
Empa	70'000
WSL	50'000
Agroscope	10'000
SciViz fees	5'482
Third-party and project contributions *	27'199
C2SM reserve fonds	17'281
Total income	**527'367**

Expenses (CHF) 01/01/2020-31/12/2020	
Salaries core staff	52'7488
Events	2'774
Running costs	5'175
Training	12'150
Travel	78
Hardware	7'823
Data storage	16'952
Total expenses	**563'431**

Saldo (CHF) 31/12/2020	302'944

* The PASC PASCHA, WEW-COSMO, and SDSC Carbosense4D projects have contributed to the core C2SM budget.

C2SM Partners

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement des Innern EDI
Bundesamt für Meteorologie und Klimatologie MeteoSchweiz

MeteoSchweiz

Empa
Materials Science and Technology

WSL

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement für
Wirtschaft, Bildung und Forschung WBF
Agroscope

Contact
Dr. Christina Schnadt Poberaj - Executive Director
Center for Climate Systems Modeling (C2SM)
ETH Zürich
Universitätstrasse 16
8092 Zürich, Switzerland

info@c2sm.ethz.ch
www.c2sm.ethz.ch
@C2SM_ETH

+41 44 633 8458

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