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HPC activities at the Austrian Weather Service

IKT - HPC
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Review, current status and open future

- The Austrian Weather Service
- Begin of HPC activities
- The HPC systems and their use at the Austrian Weather service
- The zoo of modelling systems at the Austrian Weather Service
- Additional HPC resources
- Final considerations

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- GeoSphere Austria is the Federal Institute for Geology, Geophysics, Climatology and Meteorology since January 1, 2023.
- GeoSphere Austria is based on the merger of the Central Institute for Meteorology and Geodynamics (**ZAMG**), founded in 1851, as the National weather and earthquake service, and the Federal Geological Survey (GBA), founded in 1849, as the geological service. GeoSphere Austria employs about 500 people.
- According to the GeoSphere Austria Act (Federal Law Gazette I, No.60/2022) of 14 April 2022, GeoSphere Austria, as the national geological, geophysical, climatological and meteorological service, is responsible for advising the Federal Government and warning the public on geological, geophysical, climatological and meteorological matters.
- By contributing to a prevention-oriented approach to climate change, Geosphere Austria aims to secure a sustainable development of Austria.

Other national weather services in Austria:

- Austro Control Aviation Weather Service
- Military Weather Service

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- In the area of the atmosphere, the main service and and research activities are related to the topics **weather**, **climate** and **environment** (air pollution).
- Today for a modern weather service dealing with these topics, it is common to work with numerical atmospheric models on powerful HPC systems.
- Until the 1990s, ZAMG weather forecasts were mainly based on products of global weather models (with coarse resolution) provided by other NWP centres (ECMWF, DWD, and other). The horizontal resolution (100-150km) was too coarse to take complex topography (alps) and mesoscale processes into account
- In the past only few NWP centres worked on mesoscale limited-area-models (horizontal resolution 10-20 km). Global NWP models today can operate at a resolution of 10 km or less (ECMWF).
- Challenges working with model data from external NWP centers:

  Are the required data available for the geographical region of interest ?

  How can the required data be obtained, and when will the data be available?

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Trigger event: The Chernobyl reactor accident in April 1986

- Austria was severely affected by the radioactive fallout; the alpine regions received the highest fallout contamination, showing a very inhomogeneous spatial distribution of the surface deposition.
- It was obvious that the forecasting tools based on rough data were not sufficient to more detailed advise to the national authorities (radiation protection, etc.). Better tools were needed for nuclear emergency response, especially in the case of an accident at one of the many nuclear power plants near Austria's borders.
- To improve the treatment of mesoscale processes, ZAMG started to push efforts in the field of Limited Area modeling (incl.HPC) and became a member of RC-**LACE** (Regional Cooperation for Limited Area modeling in Central Europe, 1994) for working with the **ALADIN** model (MeteoFrance).
- The Czech Hydrometeorological Institute (CHMI) became the regional center of NWP operations to provide a daily dissemination of NWP products to LACE member institutes; the Prague centre started the ALADIN operations on a **NEC** computer in 1998.
- In 2001, ZAMG received funding for the ITT of the first HPC capable of running mesoscale models operationally („Krisenrechner“).
- As part of the national critical infrastructure, ZAMG must operate its own highly available, robust HPC system.
- This is not only necessary in case of technical accidents, but also in case of weather-related natural disasters (storm, heavy rain, etc.).

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Operational HPC systems at ZAMG

	year of ITT	budget w/o taxes	loss of purch.power (since last ITT)	system	peak perf.	el. power	cooling
I)	2001	454.205 €		SGI ORIGIN 3400 28 R14000 CPUs	8 GFlops	< 10 kW	Air
II)	2006	916.660 €	- 8 %	NEC SX8R (+1 AMD-opteron) 2 nodes , 16 SX8R CPUs	560 GFlops	19 kW	Air
III)	2011	1.416.660 €	- 7,5 %	SGI ICEx cluster (SNB) 256 nodes, 4032 cores	82 TFlops	107 kW	Air/Liquid
IV)	2017	1750.000 €	- 7,2 %	HPE ICExa cluster (SKL) 192 nodes, 6912 cores	550 TFlops	95 kW	DLC
V)	2023	2.083.333 €	-14.6 %	? ? ?	? ? ?	? ? ?	DLC
VI)	? ? ?	? ? ?	? ? ?	? ? ?	? ? ?	? ? ?	? ? ?

Models used on the HPC

HPC system	Weather forecast	Environment/Air Pollution Models	Climate research
I) SGI ORIGIN	ALADIN (12km)	MM5, preproc.	---
II) NEC SX8 (+)	ALARO	MM5, preproc. (SX8) CAMX (opteron)	COSMO-CLM (reg.)
III) SGI ICEx	AROME	WRF-chem	COSMO-CLM (reg.)
IV) HPE ICExa	AROME (2.5km)	WRF-chem	PALM-4U (urban)
V) ? ? ?	AROME (<1km)	WRF-chem	PALM-4U (urban)

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The Zoo of Modeling systems

- Tasks on (normal) weather forecasting: The main model was **ALADIN** and is now its successor **AROME** (from MeteoFrance).
- Tasks on air pollution: The ZAMG/GeoSphere must operationally provide forecasts of ozone, particulate matter, etc. to the regional authorities. For some years the **CAMx**-Modell (Comprehensive Air Quality Model with Extensions) was used at ZAMG, coupled with output from ALADIN (or MM5); CAMx is a multi-scale photochemical modeling system for gas and particulate air pollution. A few years ago, CAMx was replaced by the **WRF-chem** (NCAR) model with online chemistry fully embedded in WRF. The required functions in WRF-chem for air pollution/air chemistry are not available in AROME.
- Tasks on Climate research: For studies and advice on the impacts of projected global climate change on alpine regions the regional climate model **COSMO-CLM** (DWD/DKRZ) was used. The required functions were not available in ALADIN/AROME. Further regional climate modelling activities were discontinued by a management decision in 2019. For studies and advice on heat stress in urban environments the local/urban scale model **PALM-4u** (Univ.Hannover) is used. Climate simulations that run over a long period of time (days) are separated from the real-time model runs.
- Will there be a uniform modelling system at GeoSphere for all weather, climate and air pollution/air chemistry tasks?

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Recent real time model runs

Model	domain	Forecast time	Runs per day	Compute resources	Wall clock time
AROME	600x540x90, dx=2.5km	+60h	8	34 nodes, 1224 tasks	25 min.
AROME-RUC	900x576x90, dx=1.2km	+12h	24	30 nodes, 1080 tasks	30 min.
WRF-chem/ 2domains	D01) 512x512x48, dx=12km D02) 256x223x48, dx=4km	+72h	2	18 nodes, 612 tasks	~4 hrs.

Research and development

At GeoSphere, there is only one HPC system for time-critical production tasks and for all research and testing activities, that require HPC resources: Climate simulations, pre-operational runs, model testing, scenario simulations

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External HPC resources

- Use of HPC resources at **ECMWF** for operational tasks:

  Ensemble forecasts with C-LAEF (Convection-permitting Limited-Area Ensemble Forecasting system, based on AROME). 16+1 Ensemble members;

  grid: 600x540x90 @2.5km; 2 runs per day +60h, 6 runs per day +3h
- Use of HPC resources at LUMI (EuroHPC) for research projects:

  Participation in pilot studies on **DestinationEarth**. Destination Earth is an initiative of the European Commission to develop a highly-accurate digital model of the Earth (a digital twin of the Earth).

  GeoSphere participates with AROME model runs in different horizontal resolutions (<1km) and with WRF-chem simulations, based on results from different weather models as input to WRF-chem.

Small local HPC test systems at GeoSphere:

- NEC A300-2, Aurora: Testing the urban climate model palm an the vector platform.
- CRAY CS500 DeepLearning machine: Testing the use of artificial intelligence (AI) in wind turbine forecasting.

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Where will our scientists do their HPC work in the future?

- With the availability of own HPC resources at ZAMG, our scientists were able to work on new topics, applications and products, such as climate simulations, chemical weather forecasts, etc.
- But the increasing demand for more computing power and new technologies requires larger HPC systems with higher costs, more power consumption and more waste heat.
- Our major challenges are now:
  - Funding (with appropriate development) for the HPC life cycle and for new technologies.
  - Electrical power and cooling: limited capacities, increasing costs, sustainable use of electricity.
  - Human resources: we need more and well qualified staff for the maintenance of the system and for application support
  - Side effects: the increasing storage volume for the output of the HPC applications (or the input for AI/ML applications)

Final questions :

- Is it necessary to own and operate a dedicated HPC?
- Are shared HPC resources (such as a United Weather Center) a way to overcome limitations and improve HPC services and their efficiency ?

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THANKS

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