Regional Cooperation for Limited Area Modeling in Central Europe

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Implementation of ALARO climate simulations on 2.3 km (RCM for beginners by beginners)

Ján Mašek, Radmila Brožková, Alena Trojáková (CHMI)

ZAMG DHMZ Czech Hydrometeorological Institute OMSZ IMGW METEO ROMANIA SHMU ARSO METEO Slovenia

Presentation outline

- Regional climate modeling at CHMI
- Strategy
  - choice of model domain and configuration
  - driving models and types of simulations
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- Technicalities
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Regional climate modeling at CHMI

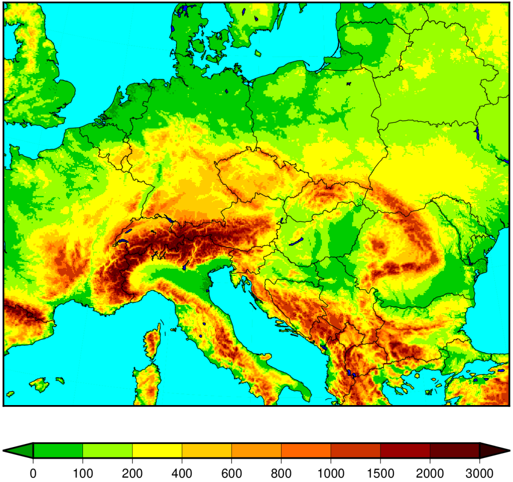
- CHMI climate simulations with model ALADIN stopped 10 years ago.
- New impulse came in 2020 with start of project PERUN (Prediction, Evaluation and Research for Understanding National sensitivity and impacts of drought and climate change for Czechia).
- To facilitate high resolution regional climate modeling, CHMI procured a new supercomputer NEC SX Aurora TSUBASA.
- Logical choice was to perform climate simulations with ALARO, still the expertise in climate mode must be built.

Strategy

- The idea is to capitalize on know-how gathered from NWP version of ALARO-1, operated at CHMI:
  - identical model domain and resolution ($\Delta x = 2.3\,\text{km}$, linear grid, 87 levels)
  - same ALARO-1 configuration, with only minimal changes necessary for the meaningful climate simulations
- The hope—to be verified—is that high resolution NWP model tuning will perform well also in the climate mode.

Strategy: model domain

- $\Delta x = 2.3\,\mathrm{km}$, 87 levels, total 1080×864 points, 11-point extension zone, 16-point coupling zone
- To avoid climate drift from the driving model, domain should **not** be **too big.**
- To enable development of fine scales, domain should **not** be **too small.**



Strategy: model domain

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- By lucky coincidence, size of the operational CHMI domain seems to be a **reasonable compromise:**
  - LBC control sufficient to **prevent climate drift** from the driving scenario $\Rightarrow$ no need of spectral nudging
  - domain large enough for generation of **correct small-scale variance** by spatial spinup
- Use of a **tiny domain** coupled directly to coarse GCM like ESM2-1 is not recommended, because the solution would underestimate fine-scale variance (Matte et al. 2017).
  - here the way is to use **double nesting,** with a sufficiently large intermediate domain

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Strategy: model configuration

- **NH dynamical kernel:**
  - 2TL SL scheme with $\Delta t = 90\,\mathrm{s}$
  - PC scheme with 1 iteration
  - SLHD nonlinear diffusion
- **ALARO-1 physics:**
  - ISBA surface scheme with **4 soil levels for the heat transfer** $\Rightarrow$ correct response to a range of **diurnal to annual forcings**
  - TOUCANS turbulence with cured two-energy option
  - ACRANEB2 radiation with 1h/3h intermittency
  - 3MT scheme still on
  - family of GWD parameterizations off
  - prognostic graupel not yet activated

Strategy: driving models

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- **ERA5** – used for reanalysis and evaluation runs:
  - truncation TL639 ($\Delta x \approx 31$ km), 137 atmospheric levels
  - 3-h output frequency
  - reanalysis $\Rightarrow$ **reproduces weather of the day**
- **CNRM ESM2-1** – used for historical and scenario runs:
  - truncation TL127 ($\Delta x \approx 156$ km), 91 atmospheric levels
  - involves complex atmospheric chemistry and aerosol model
  - coupled to CTRIP runoff model, NEMO ocean model, and GELATO sea-ice model
  - 6-h output frequency
  - no data assimilation $\Rightarrow$ **does not reproduce weather of the day**

Strategy: types of simulations

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- **Reanalysis run** – past weather, driven by ERA5:
  - 6-h cycle with CANARI surface analysis and upper air blending
  - 30-h integrations launched at 00 UTC
  - **2-level ISBA scheme** (as in operations)
- **Evaluation run** – past weather, driven by ERA5:
  - no data assimilation/blending, **4-level ISBA scheme**
  - chain of 10-day integrations with cycled prognostic variables
- **Historical run** – past climate, driven by CNRM ESM2-1:
  - same as evaluation run, but with different driving model
  - reference for determining the climate impact
- **Scenario run** – future climate, driven by CNRM ESM2-1:
  - same as historical run, but for chosen climate scenario

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Important advice from Météo-France:

- It is not a good idea to determine the climate impact of GCM driven scenario run with respect to ERA5 driven evaluation run.
- To prevent a headache, use historical run from the same GCM as a reference.
- Like this, you will not have to care about different biases of GCM and ERA5, affecting your RCM simulations.

Strategy: physiography

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- For the time being, climate simulations use the **same physiography as NWP configuration:**
  - **GMTED2010 7.5” topography** used to derive gridbox mean orography, land-sea mask and orographic roughness
  - vegetation roughness taken from **ECOCLIMAP II dataset,** with the tree height scaled by factor 1.5
  - other physiography fields still taken from **coarse e923 datasets**
  - climate scenarios run with **present day physiography, ozone and aerosols**
- **ECOCLIMAP II** dataset will be fully used only **after switch to SURFEX.**

Strategy: radiative forcing

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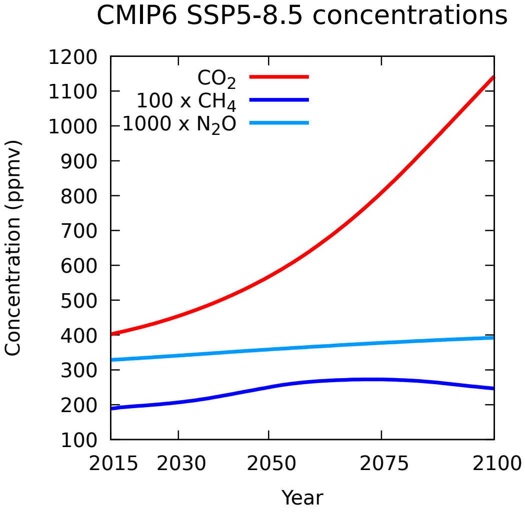
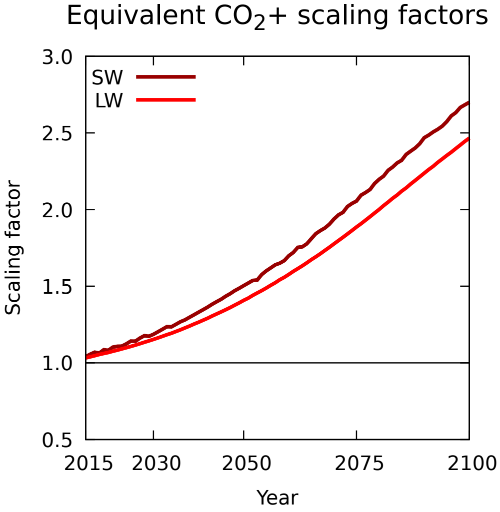
- For better consistency with driving scenario, ACRANEB2 scheme uses **evolving greenhouse gas concentrations**.
- Refitting of CO_2+ transmissions (mixture of CO_2, CH_4, N_2O, O_2) on yearly basis would be too laborious.
- Simpler option is to **rescale CO_2+ concentration,** so that the same radiative forcing in the tropopause is obtained:

$$F^{\text{net}}_{\text{200hPa}}(CO_2, CH_4, \ldots) = F^{\text{net}}_{\text{200hPa}}(k \cdot CO_2^{\text{ref}}, k \cdot CH_4^{\text{ref}}, \ldots)$$

- **Separate scaling factors** k_{SW}, k_{LW} are determined for each year, using the narrowband model on a reference profile.

Strategy: radiative forcing





Strategy: radiative forcing

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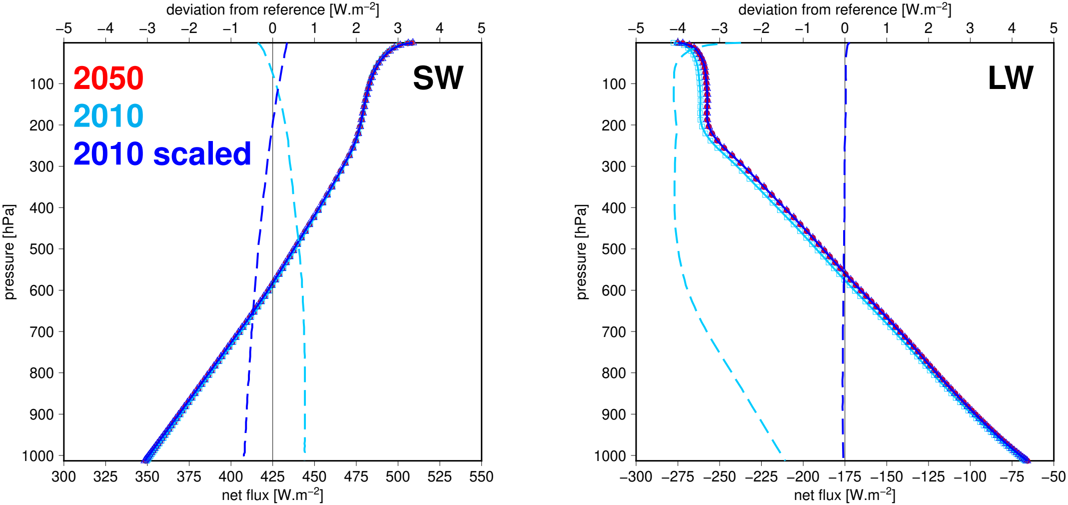

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Technicalities: LBC preparation

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- To reduce size of LBC files downloaded to CHMI, **telecom domain** with $\Delta x = 15.4\,\mathrm{km}$ is used.
- **ERA5** data for period 1979–2020 were transformed by **configuration 903** at ECMWF.
- **CNRM ESM2-1** data for periods 1989–2014 (historical run) and 2015–2100 (SSP5-8.5 scenario) were transformed by **configuration E927** at MF.
- Due to incompatibility of global and telecom clim files, **E927 had to be run with option NFPCLI=2,** not NFPCLI=3!

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Technicalities: LBC preparation

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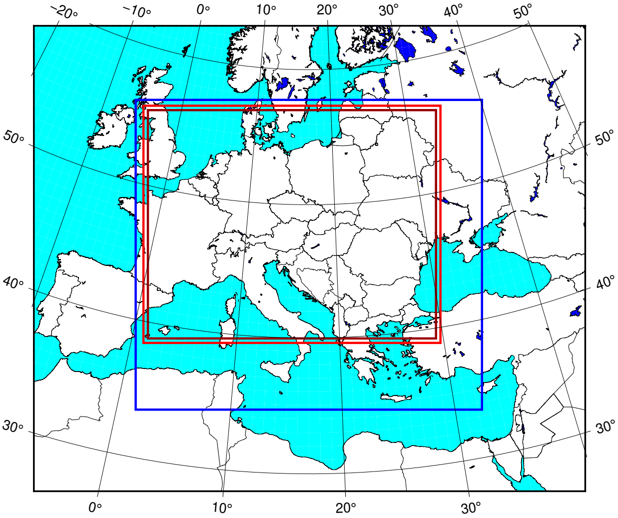
— telecom domain
— integration domain C+I
— integration domain C



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Technicalities: LBC preparation

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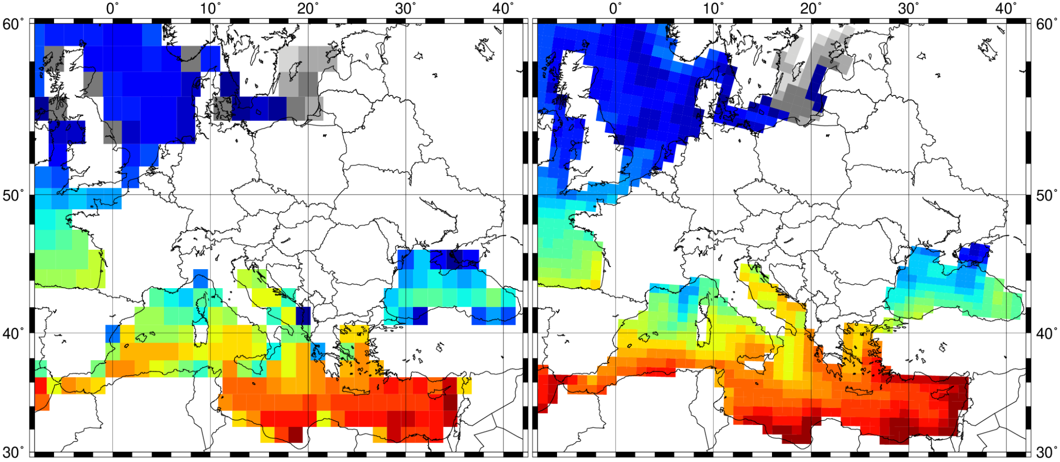
- RCM run uses **prescribed SST** from driving model.
- Along the coastlines, SST from the model ESM2-1 is **contaminated by SURFEX tiling.**
- Gridbox averaged surface temperature can be a mixture of land and sea values.
- Solution is to replace SST in telecom files, coming from E927, by **SST interpolated directly from NEMO** model.
- Utility **updsst** was created, changing geometry from NEMO grid to ALADIN grid (and converting NetCDF to FA).

Technicalities: LBC preparation



SST in ARPEGE **SST in NEMO**

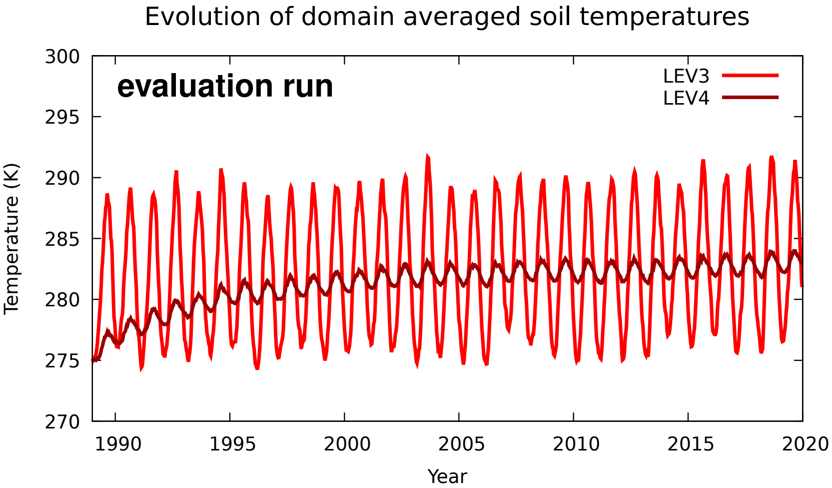
Technicalities: LBC preparation

- ERA5 telecom files are available on CHMI archiv:
  `/sam/sx4.lace/mma101/era5cpl/`
- ESM2-1 telecom files are available on MF hendrix:
  `/home/masekj/cmip6/cplesm2-1/histo/`
  `/home/masekj/cmip6/cplesm2-1/ssp585/`
- Telecom files are finally transformed to integration domain with $\Delta x = 2.3\,\mathrm{km}$ by **configuration EE927,** run at CHMI.
- Telecom and integration clim files are both created from e923 climatology $\Rightarrow$ **option NFPCLI=3 can be used.**

Technicalities: cycling

- Simulations are run as the series of 10-day integrations.
- Final values of prognostic variables are written to restart file.
- Some fields in restart file are updated by **updcli** utility:
  - climatological fields interpolated between two nearest months
  - sea-ice determined according to SST from the driving model
  - modification of land-sea mask (sea-ice treated as land)
  - lake temperature determined from actual SST of the surrounding seas, not from climatology
- Updated restart file is used as init file for the next 10-day integration.

Technicalities: spinup



Technicalities: performance on SX Aurora

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- **A bottleneck** for model performance **is I/O speed.**
- Volume of integration I/O is reduced by:
  - historical file written only at integration start/end
  - hourly inline fullpos with selection namelists
- Computations are done on vector engines, while I/O is done on vector host where it is faster $\Rightarrow$ **I/O server is used.**
- **One year simulation** on 8 full SX Aurora nodes with I/O server **takes 2.25 days** of wall clock time.
- FA to GRIB conversion and data storing are done in parallel on scalar front-ends.

Technicalities: data volumes

ESM2-1 global atmospheric file:	**493 MB**
Telecom LBC file:	**12.4 MB**
High resolution LBC file:	**897 MB**
1 year of telecom LBC files:	**17.7 GB**
1 year of high resolution LBC files:	**1.20 TB**
1 year of fullpos and GRIB files:	**3.79 TB**

Preliminary conclusions and future plans

- Designed ALARO climate simulations work technically.
- Detailed validation is a subject of ongoing work, performed by other PERUN partners.
- The next set of climate simulations will use improved ALARO-1 configuration, hopefully including:
    - SURFEX scheme with ECOCLIMAP II, TEB, FLAKE (perhaps with 3L soil and EBA snow scheme)
    - prognostic graupel
    - TKE based mixing length formulation
    - small fixes in the physics
    - inclusion of CFC-11, CFC-12 in ACRANEB2 radiation

Strengths & weaknesses of ALARO climate simulations:

- \+ RCM provides detailed, physically consistent description of local climate.
- \+ Convection permitting resolution allows for more realistic climatology of extreme precipitation events.
- \+ Orographic drag is well resolved by model dynamics.
- \+ Hourly high resolution outputs are available in-house.
- – Most of physiography comes from coarse e923 datasets.
- – Present day ozone/aerosols not consistent with ESM2-1.

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Thank you for your attention.

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