Climate modelling using the Aurora HPC platform

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About Czech Hydrometeorological Institute (CHMI)

- **Mission** – to provide high level professional data, information and services in the fields of:
  - Meteorology;
  - Climatology;
  - Hydrology and water quality;
  - Air quality.
- **CHMI** is part of the critical infrastructure of the state.

CHMI headquarters at Prague

Background

Project **PERUN**: **P**rediction, **E**valuation and **R**esearch for **U**nderstanding **N**ational sensitivity and impacts of drought and climate change for Czechia.

8 institutions are involved:

– Czech Hydrometeorological Institute is the principal leader and contractor of the project;

– There are academic, research and service institutions covering meteorology, climate, hydrology and geology.

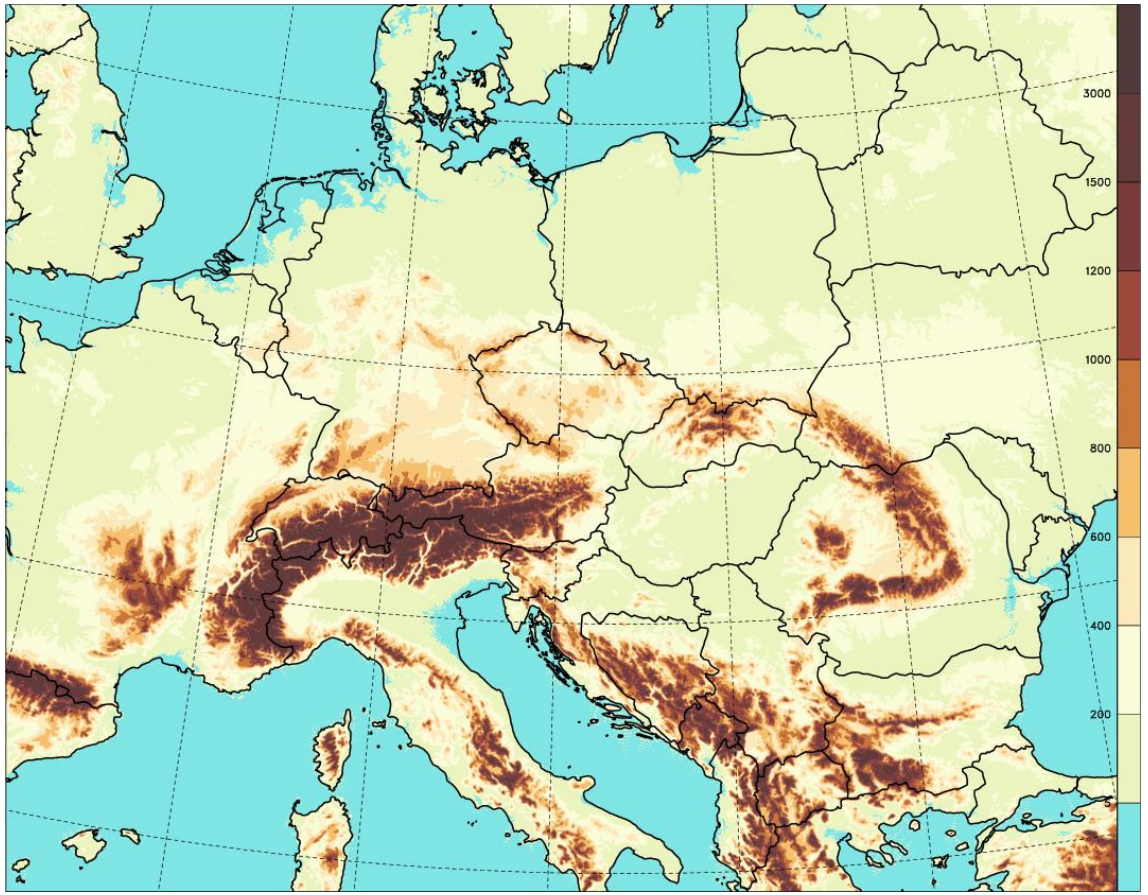
Our role:

– Prepare the configuration of **ALADIN-CLIMATE/CZ** model;

– Perform climate experiments including the preparation of climate scenarios.

Meteorological choices

- Large enough domain to ***preserve variability of small convection permitting scales*** in the domain of interest, also despite coarse resolution of the driving Global Circulation Model;
- Convection permitting high resolution ***2.3 km***, 87 vertical levels, non-hydrostatic core;
- Scale aware physics.



HPC equipment at CHMI for the PERUN Project

Climate experiments, Scenarios &Weather Forecast back-up

- The NEC-SX Aurora Tsubasa
- 48 compute nodes
- 384 vector engines
- 2Pb shared storage

Climate experiments

Model assessment in the climate mode:

- **Reanalysis experiment** 1989-2019;
  - 6h assimilation cycle, coupling with ERA5 reanalysis, each day 30 h forecast starting from 0 h UTC.
- **Evaluation experiment** 1989-2019;
  - Continuous simulation coupled to ERA5 reanalysis;

Model verification over the past period

- **Domain and data**:

  Central Europe: the so-called EOBS dataset;

  Czech Republic: the so-called **GriSt** dataset, obtained by the interpolation of stations (268 for temperature and 787 for precipitation) to the model grid of 2.3 km;

  For precipitations we also get the **Merge product** of radars and stations starting from 2002.

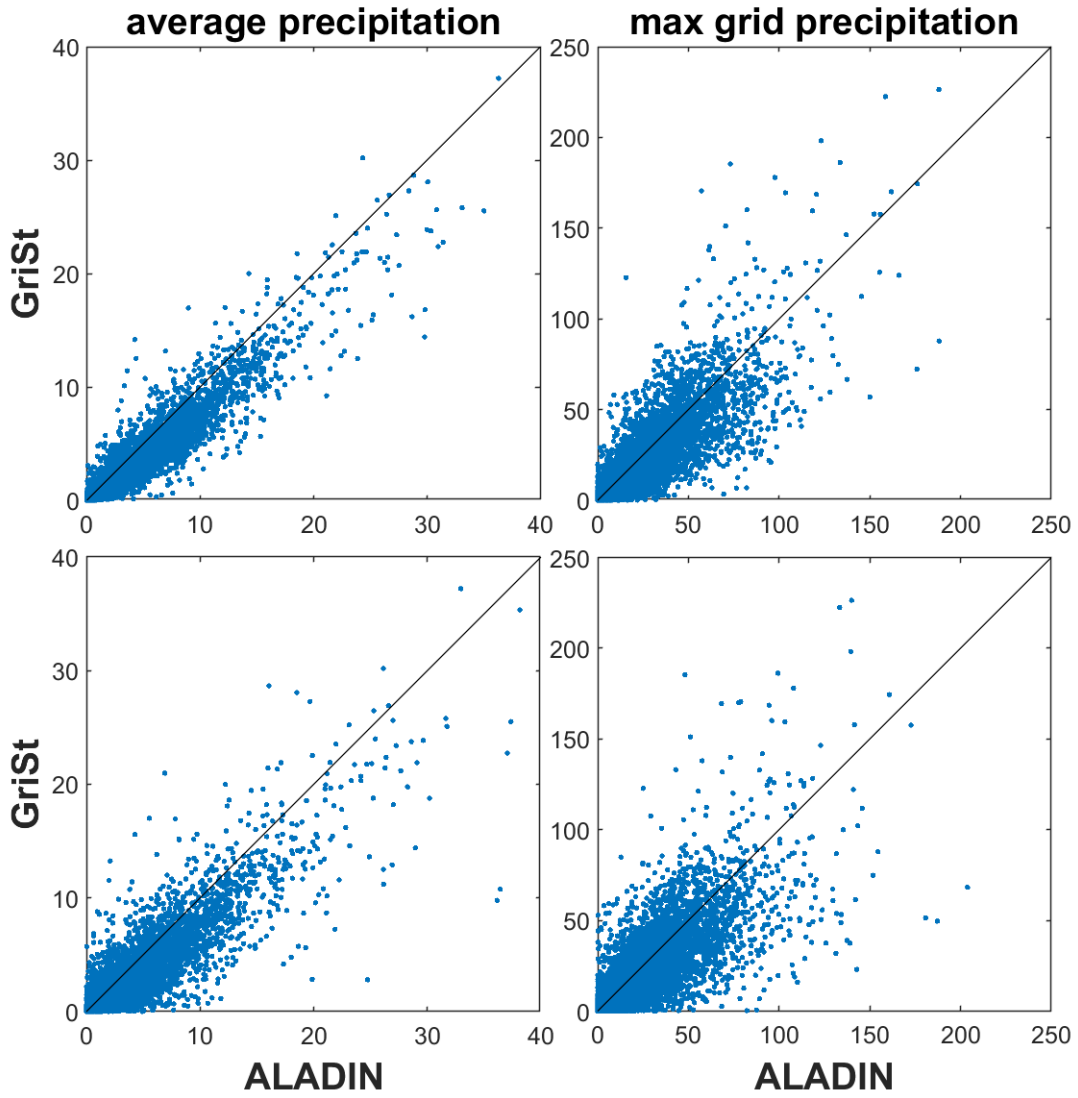
- **Evaluated screen level parameters:**

  Tmean, Tmin, Tmax, RH, Wspeed, RR

Precipitation results

Daily precipitation sums correlation for experiments "reanalysis - aaa" and "evaluation - aab"

avg aaa = 0,95
max aaa = 0,85
avg aab = 0,90
max aab = 0,79



aaa

aab

Courtesy of Petr Zacharov

Preparing for scenario: “historical climate” experiment

The goal: climate type of run using a ***coupling with the same GCM as used to prepare future scenarios,*** i.e. to prepare for de-biasing.

- **Set up:**

  coupling with the **ESM2-1 CMIP6** system of Météo-France/CNRM.

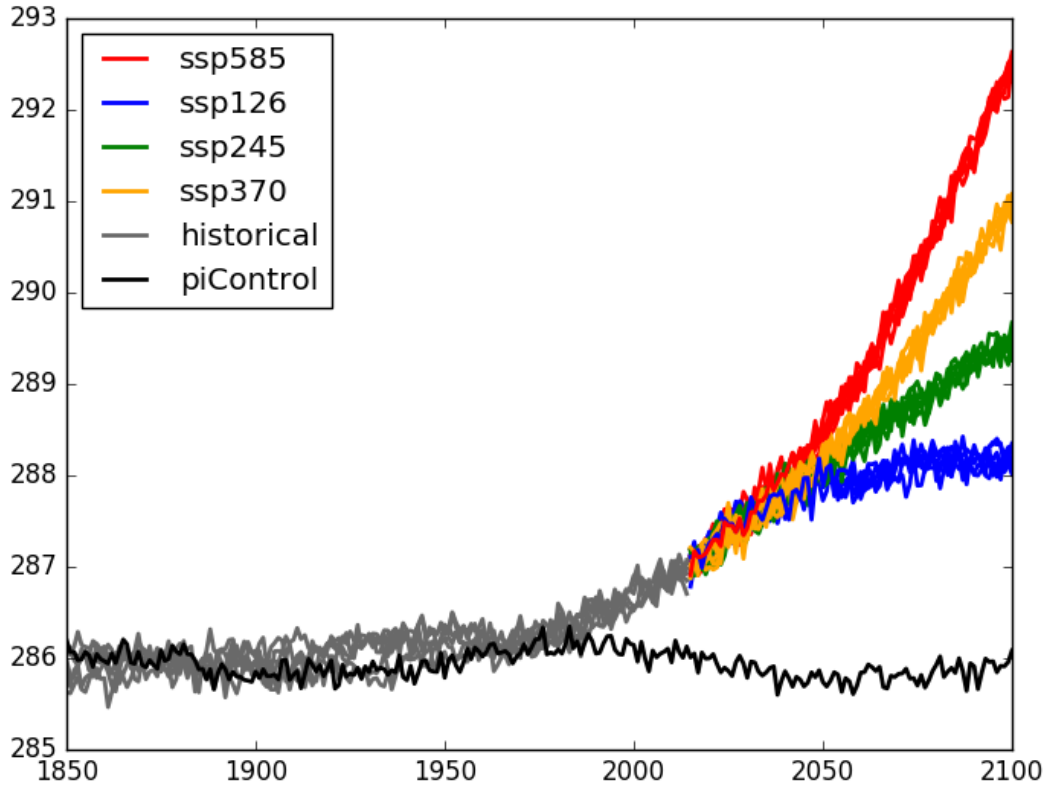
  decadal update of required surface parameters, SST taken from NEMO.

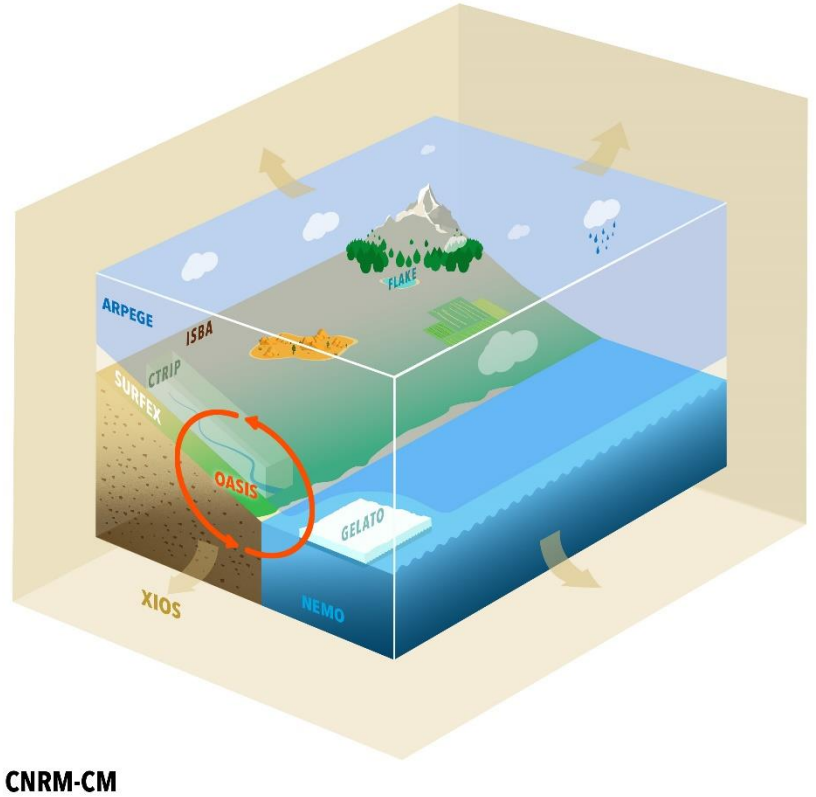
- **Covered period:**

  from 1975 to 2014 to cover the 30-year normal period 1981-2010.

  The scenario begins from 2015.

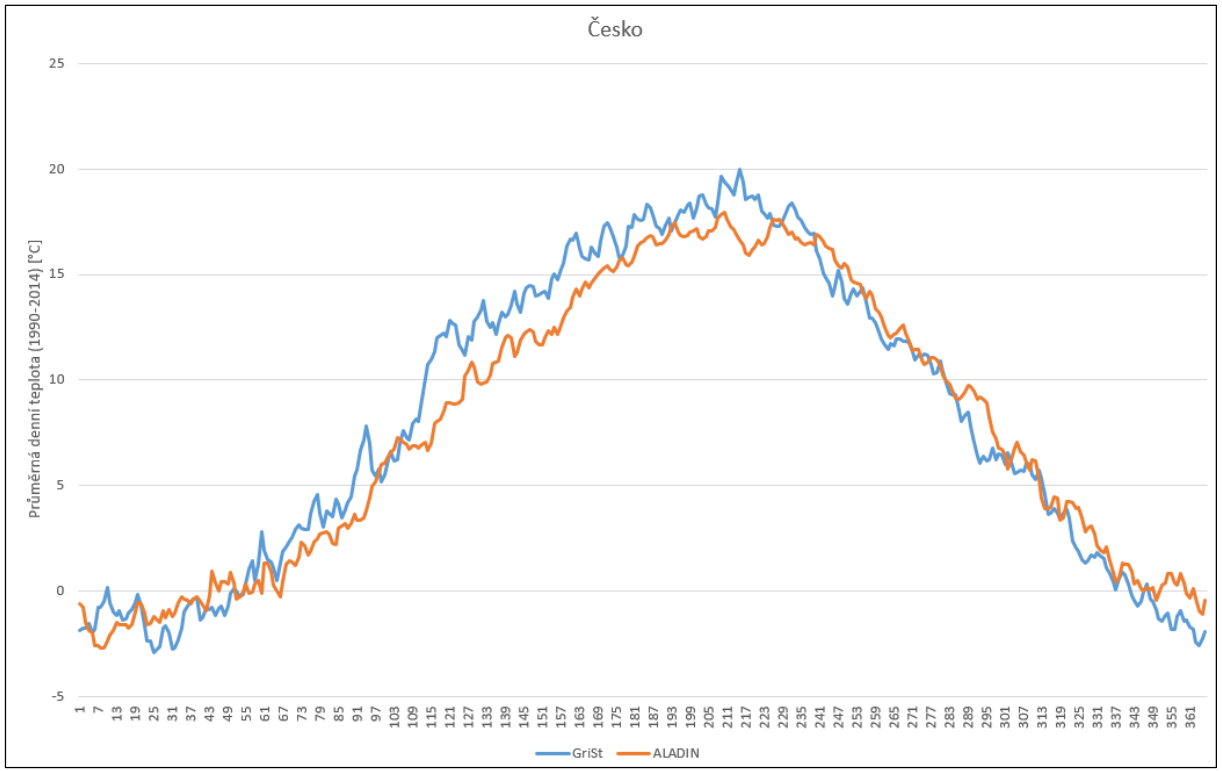
CMIP6 scenario by the CNRM system ESM2-1

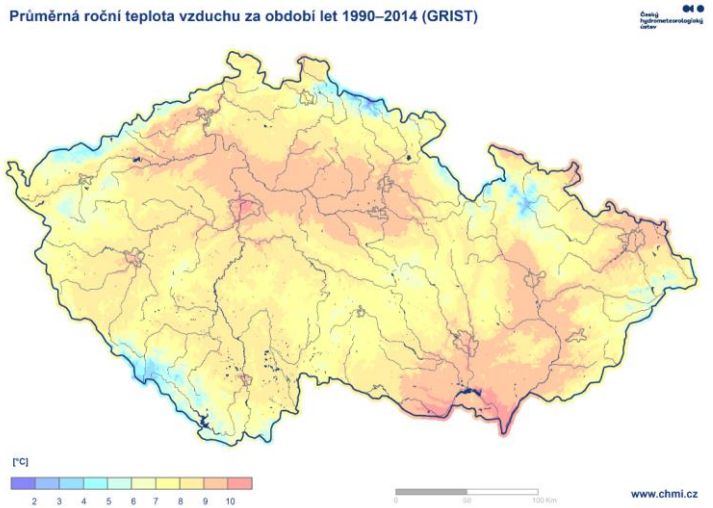




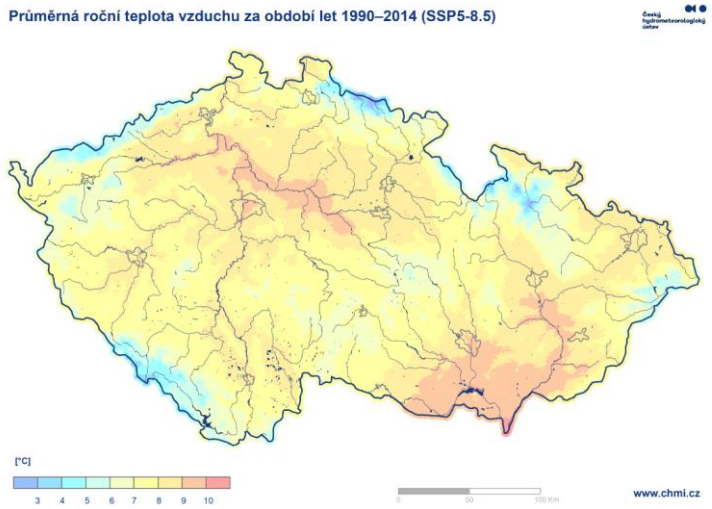
CMIP6: Coupled Model Intercomparison Project Phase 6, World Climate Research Program

Temperature – coupling with ESM2-1





GriST



model

Mean annual temperature. ***Period: 1990-2014.***

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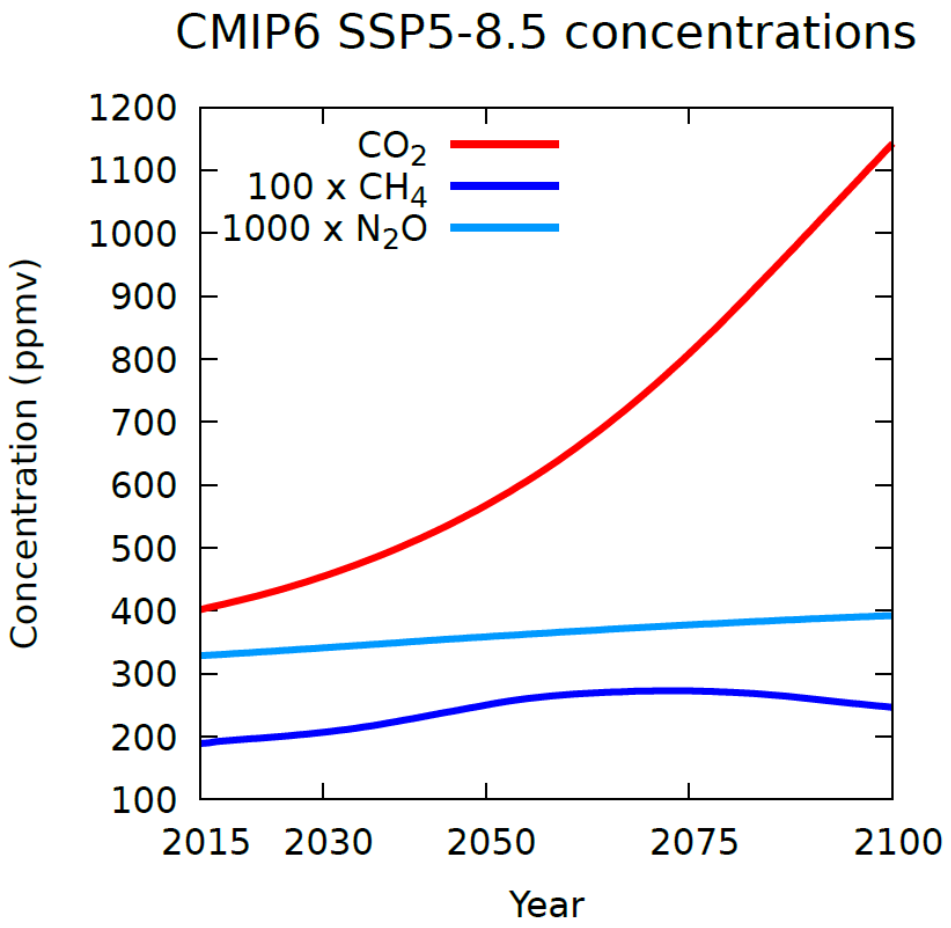
Prescribed green house gas concentrations SSP5-85



SSP5-8.5 greenhouse gas concentrations (ppmv)					
gas \ year	2015	2030	2050	2075	2100
CO_2	401.7	454.3	567.2	808.5	1142.3
CH_4	1.890	2.067	2.499	2.725	2.465
N_2O	0.328	0.341	0.358	0.377	0.392

Optical properties for ACRANEB2 are scaled so that the radiative balance for the Earth-troposphere system is kept. It is cheap and precise.

Computing scenarios up to 2100

Computer resources optimizations and issues

- **Model code optimization and vectorization:**

  rather OK, forecast model taken from NWP operations;

- **Model IO footprint:**

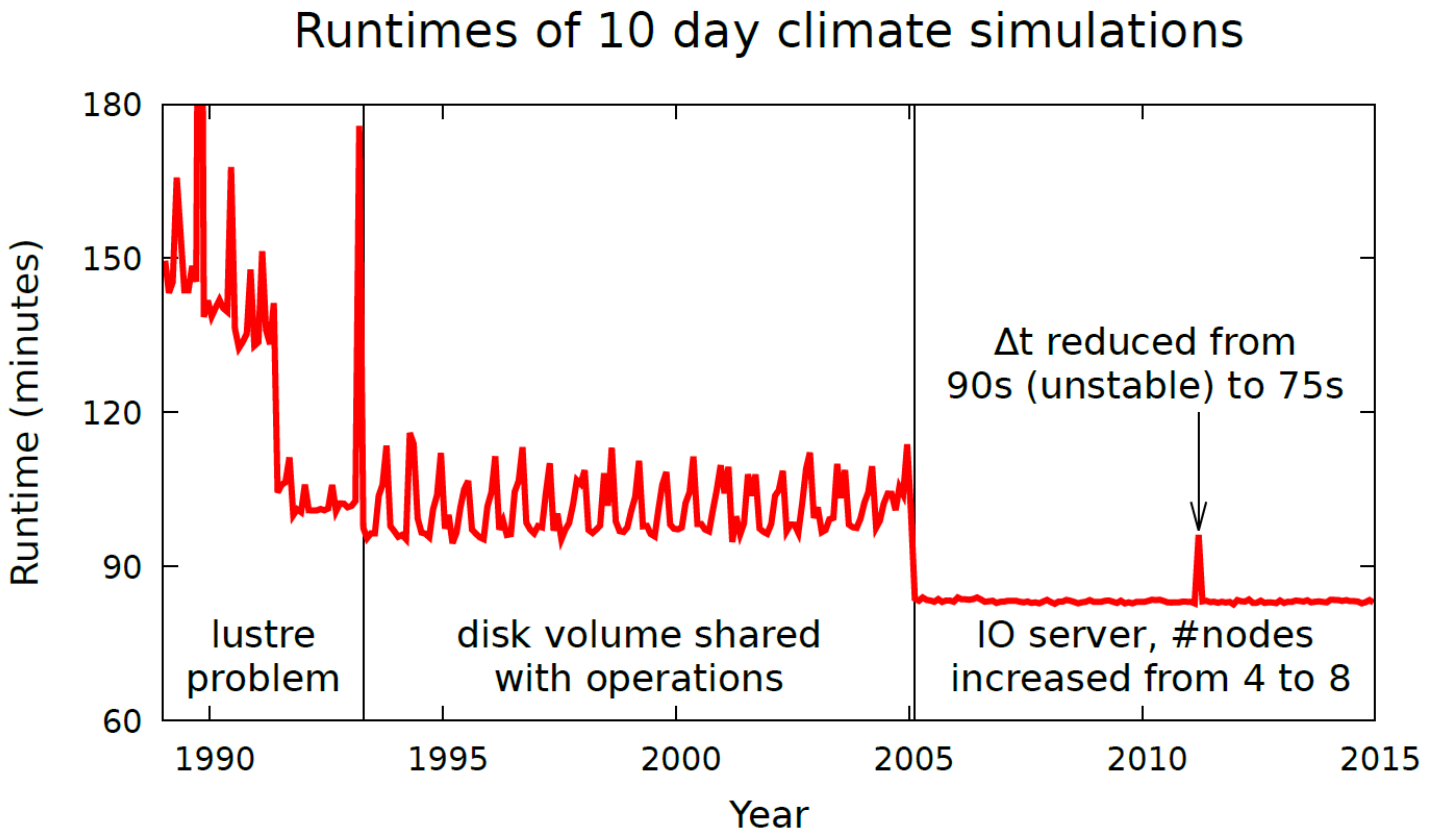
  to short every time-step printout (file ifs.stat) to keep this file write on MDT;

  to select fields output to the necessary list (CORDEX);

  to activate the IO server on Vector Host to make Vector Engines not waiting for IO operations to complete;

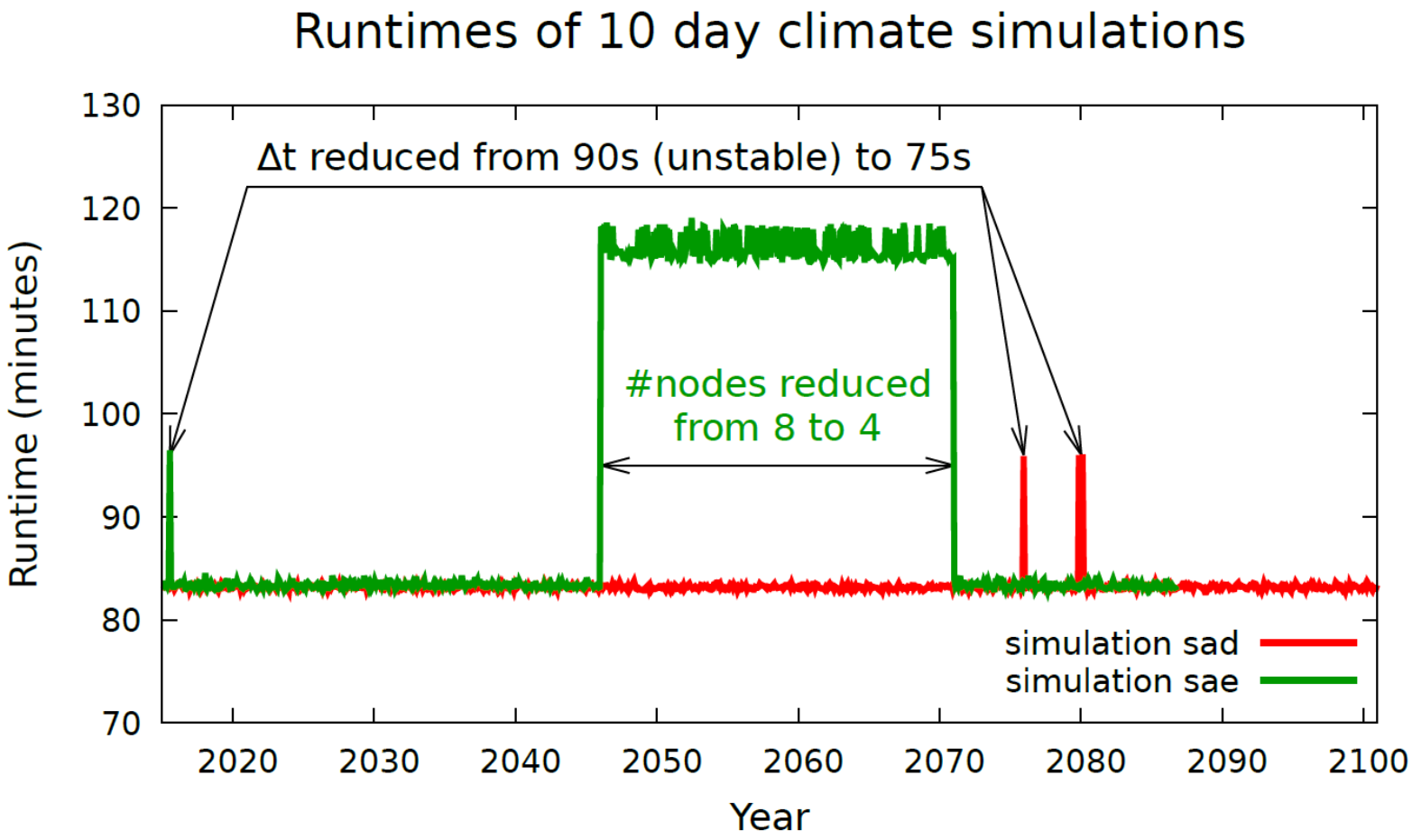
- **Healthy and optimally configured file system.**

Compute performance evolution – historical experiment



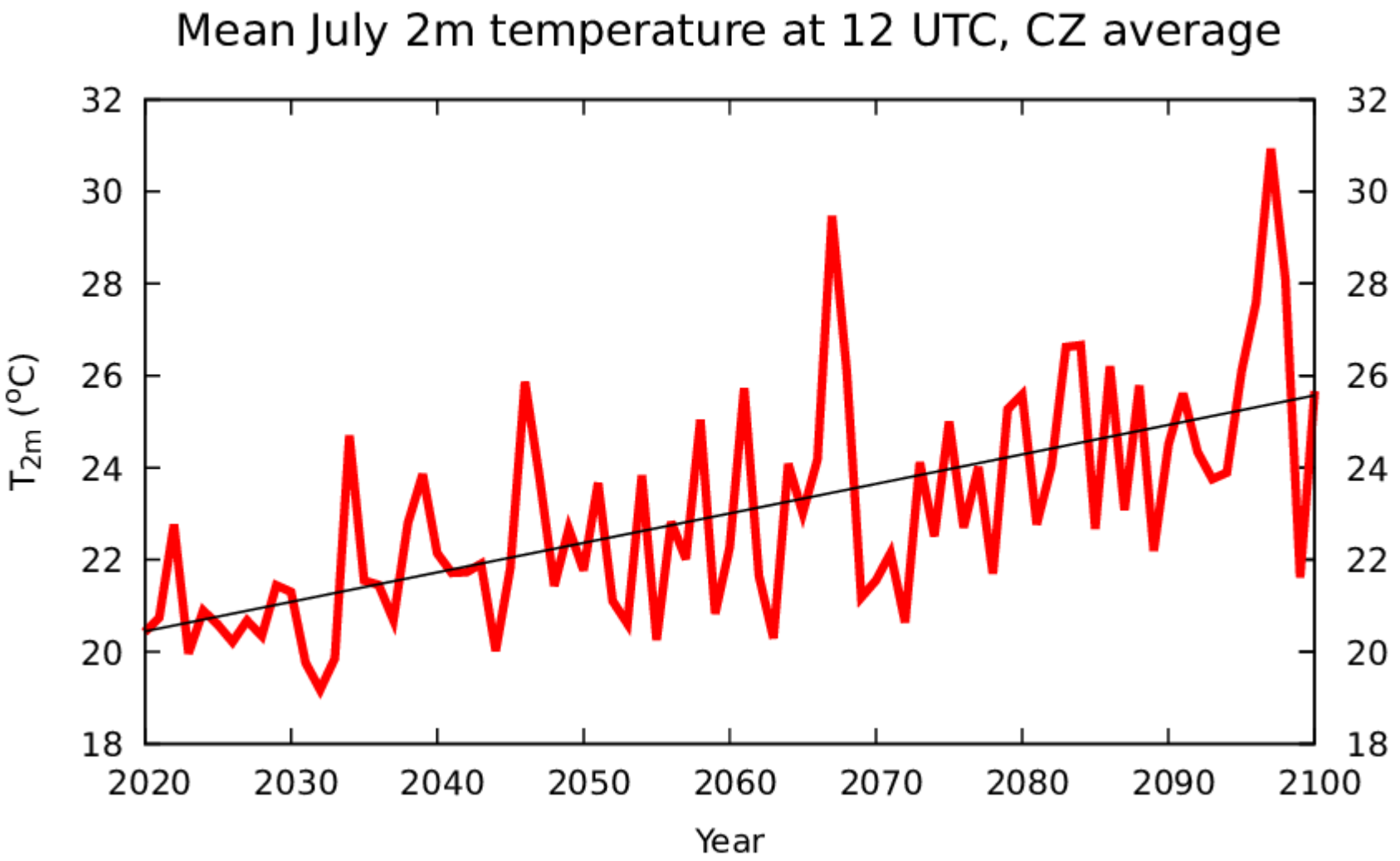
Removing file system troubles and introducing the IO server led to quite improved performance and stability.

Compute performance evolution – scenarios



For the climate run we get a great compute stability.

Temperature evolution in scenario SSP5-8.5

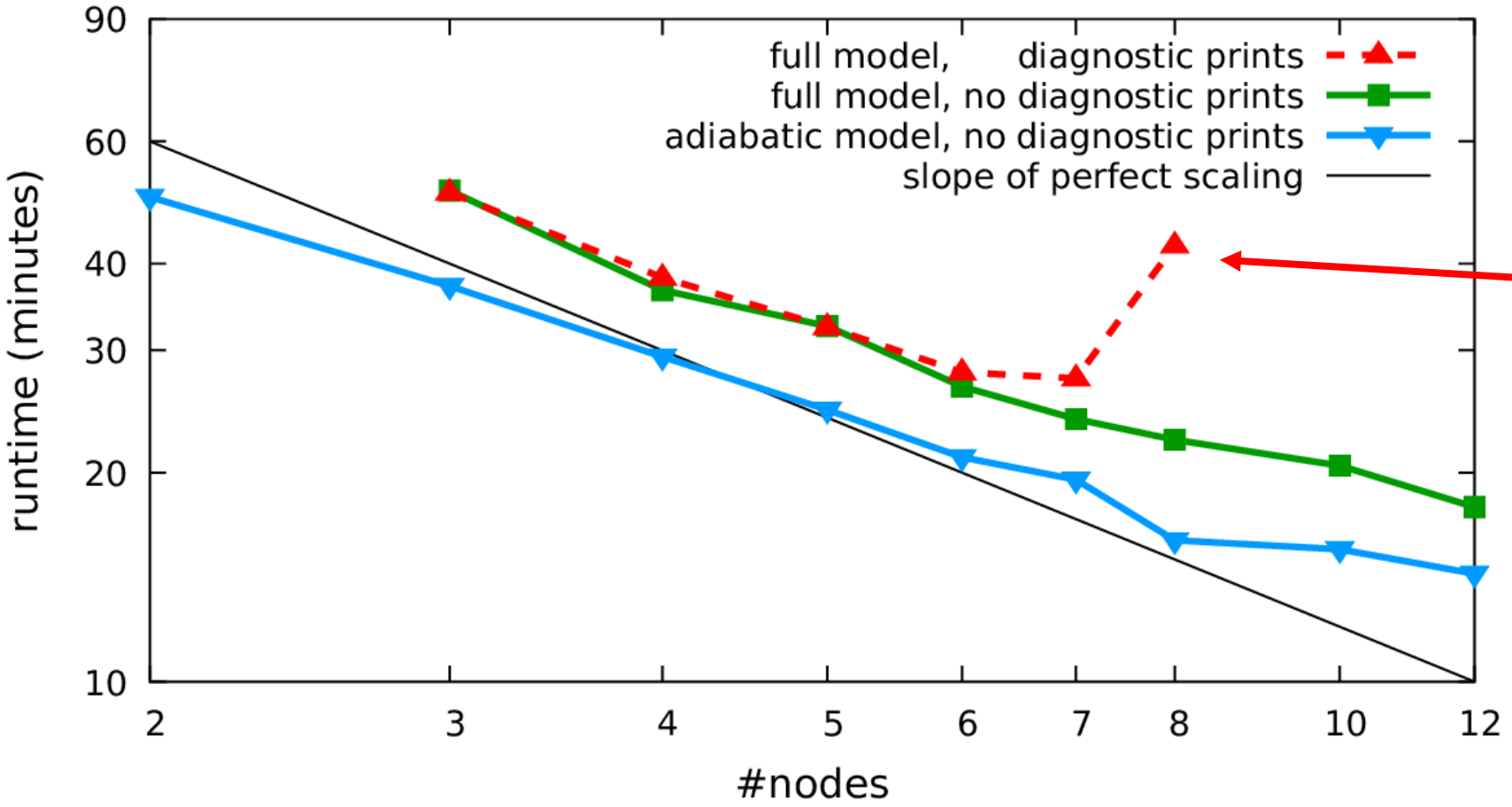


ALADIN performance tests using a bigger domain

More grid-points: more memory, more communications => scalability issue

- **New testing domain:**
  1536 x 1250 points in horizontal (a double), 87L, dx=890 m, dt=30 s; linear grid, double precision;
- **Test on CHMI system (Aurora 2):**
  Memory issue – solved by also using OpenMP (2 threads OK);
- **A small scalability test done for number of nodes from 2 to 12.**

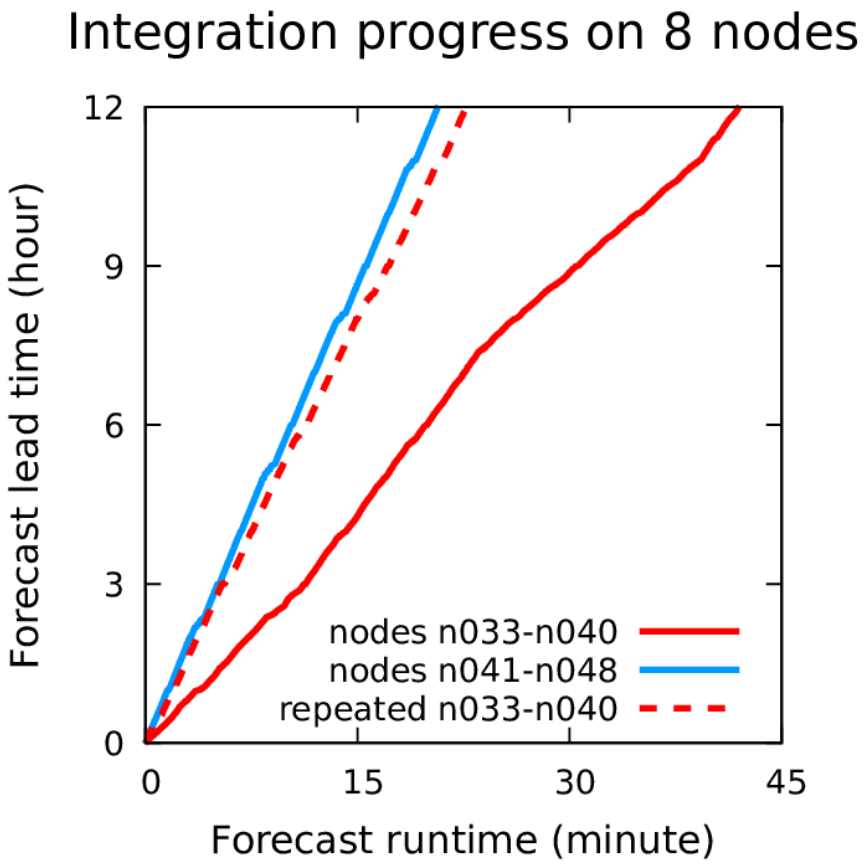
ALADIN Scalability test results



strange reason
of the slow down.
Non reproducible.

The scalability of the full model follows the one of the dynamical core of the model.

Timing difference cause?



The two runs (red and blue) have identical configuration. One has a double of elapse time.

- *Repeating the test on the same nodes;*
- *Time step run times sum is the same!*
- *? Difference … print of time stepping diagnostics. Perhaps but not reproducible.*

ALADIN performance on Vector Engine 3

	Vector Engine 1	Vector Engine 2	Vector Engine 3 compatibility mode	Vector Engine 3 native mode	Vector Engine 3 native mode
VE SKU	10AE	20B	30A	30A	30A
Host CPU	Intel E5-2630	AMD 7742	AMD 7713P	AMD 7713P	AMD 7713P
Interconnect	HDR-100	HDR-200	HDR-200	HDR-200	HDR-200
Number of nodes	4	4	**2**	**2**	**4**
Sum of time steps times [s]	835	770	806	803	416
Total elapsed time [s]	910	824	907	904	514

Speedup vs VE 1: 2.0x
Speedup vs VE 2: 1.9x

Run information: 24h forecast runs using CHMI's benchmark setup for procurement in 2019
ALADIN version: CY43T2
Each node is equipped with 8 Vector Engines
The same executable has been used for VE 1, VE 2 and VE 3 (compatibility mode) runs

VE 3 compatibility mode: Binaries can be executed on VE 1 and VE 2 without recompilation
VE 3 native mode: Binaries are incompatible with VE 1 and VE 2 due to new ISA features

Short summary

- Aurora offers a very stable and reliable compute environment;
- Problems encountered are mostly linked to the file system (Lustre);
- There is a very advantageous ratio of the compute performance and power consumption (we are at about half of expected figures for the project).

Thank you for your attention

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