COSMO-crCLIM: a joint effort in developing a GPU/CPU version of COSMO-CLM

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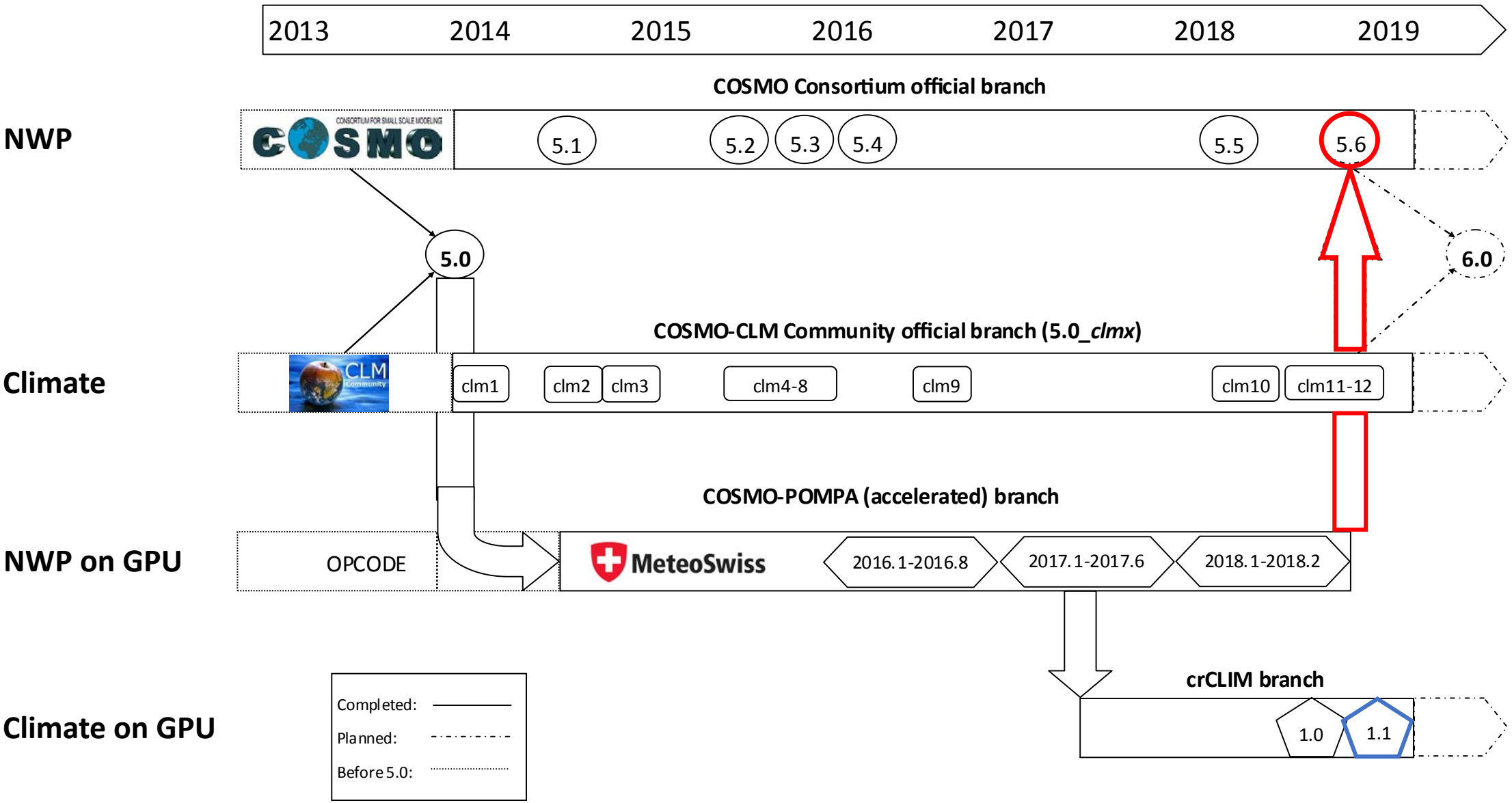
From COSMO to COSMO-crCLIM

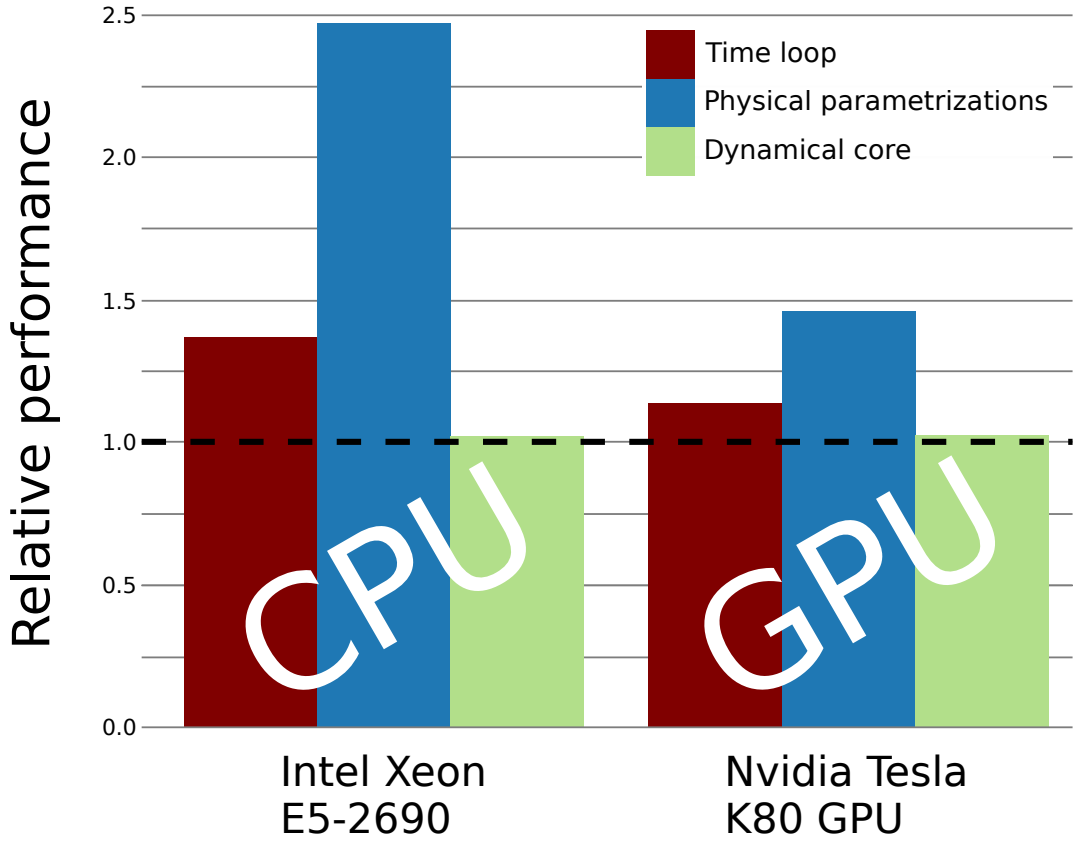


Credit: K. Osterried

How does COSMO-crCLIM differ from COSMO?

Technical development:

- Adapted from COSMO-POMPA (Fuhrer et al, 2014) used at MeteoSwiss for NWP:
  - Runs both on CPU and GPU
  - Uses the C++ dycore
- Runs in climate mode
- Explored bit-reproducibility between CPU and GPU versions

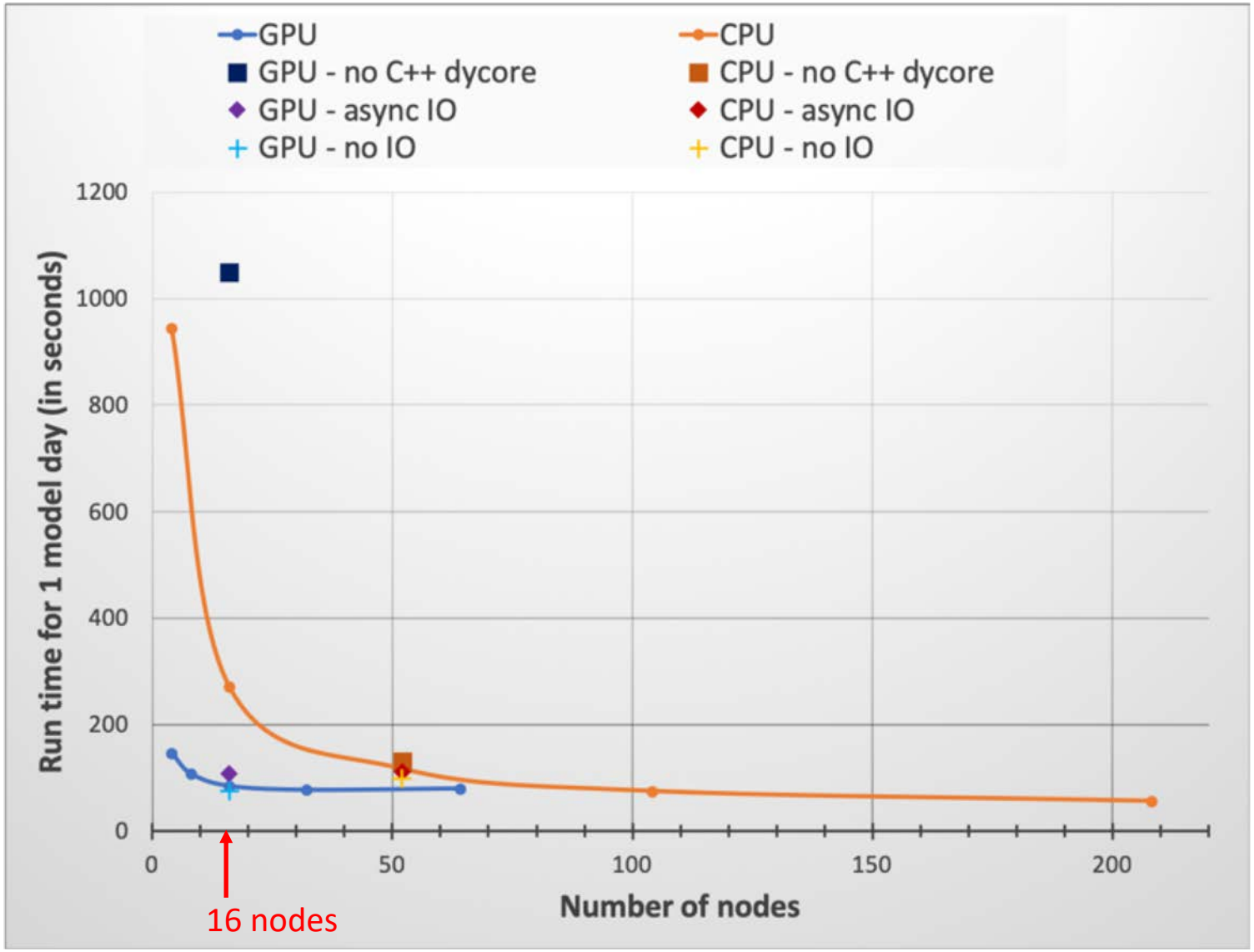


Performance of bit-reproducible relative to non-reproducible model

Schär et al, BAMS, submitted

COSMO-crCLIM: faster - cheaper

- 4x faster on 16 GPU nodes than on 16 CPU nodes
- Use of C++ dynamical core on GPU => huge gain in speed



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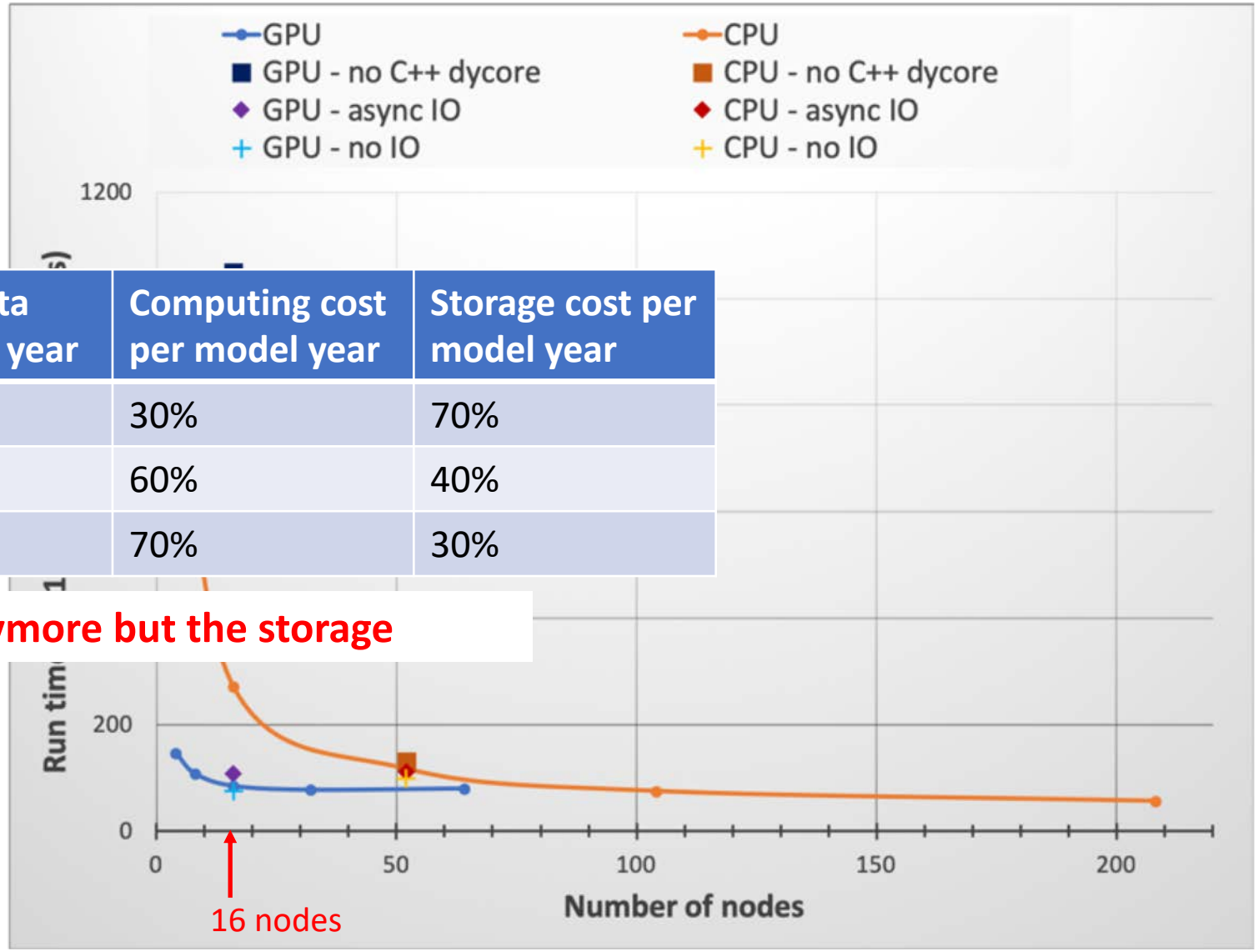
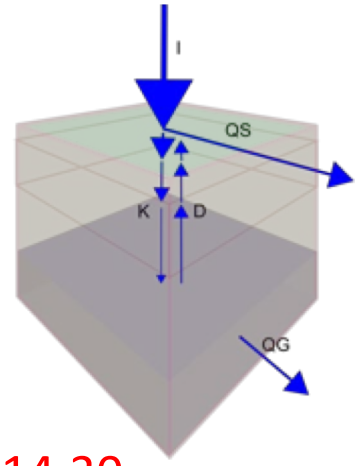
	Running time per model year	Output data per model year	Computing cost per model year	Storage cost per model year
16 GPU nodes	9 hours	1TB	30%	70%
16 CPU nodes	28 hours	1TB	60%	40%
52 CPU nodes	12 hours	1TB	70%	30%

The issue is not the computing cost anymore but the storage



How does COSMO-crCLIM differ from COSMO-CLM?

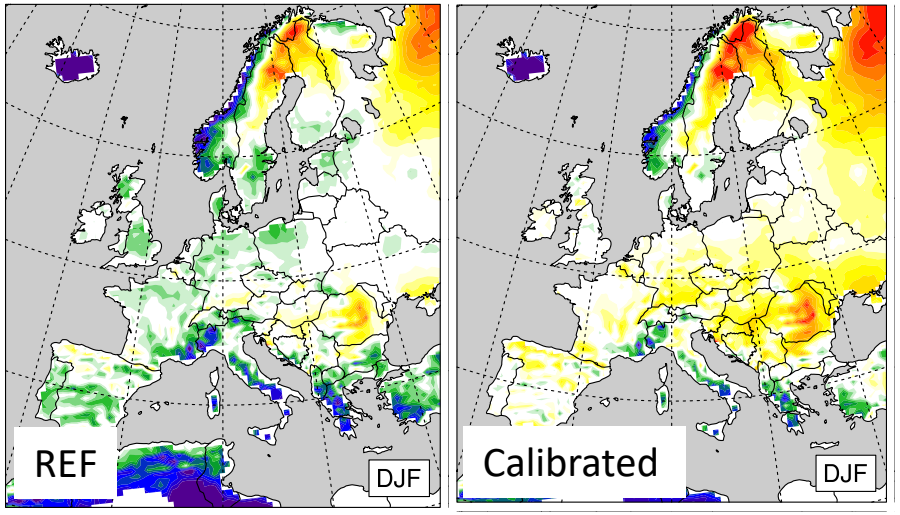
New development for science:



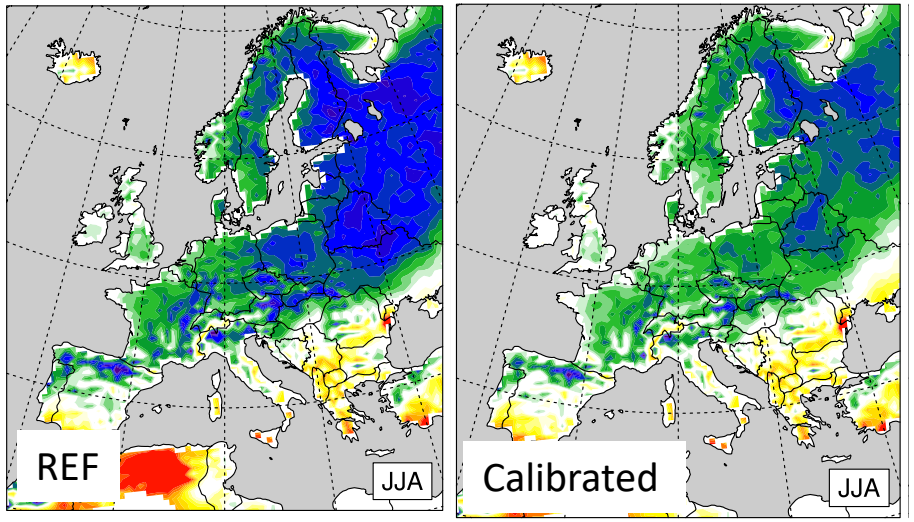
- Implementation of a new soil hydrology scheme (Schlemmer et al, 2018):
  - a zero flux at lower boundary (no free drainage)
  - a diagnostic water table
  - a groundwater discharge dependent on subgrid-scale orography
  - a flux correction of water transport (to conserve mass)

=> now implemented in COSMO-POMPA, being validated at high resolution - D. Regenass's talk at 14:30

- Switch to the AeroCom aerosol climatology to replace the Tanré-climatology
- A new calibration based on Bellprat et al, 2012, 2016



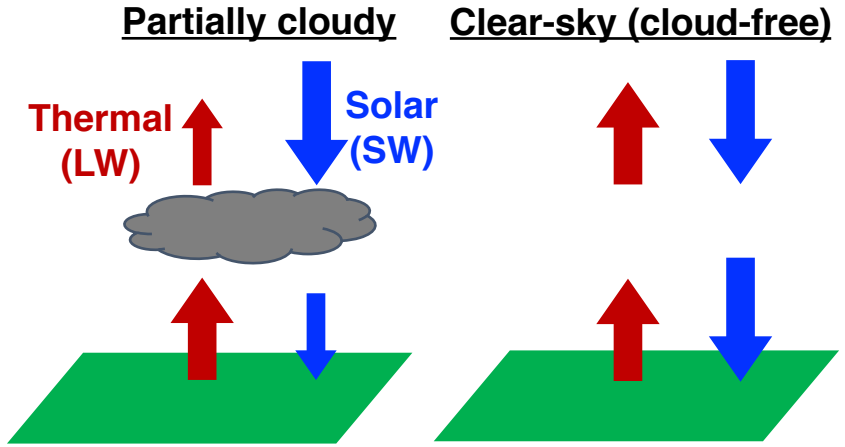
Temperature biases (K)



Credit: S. Sørland

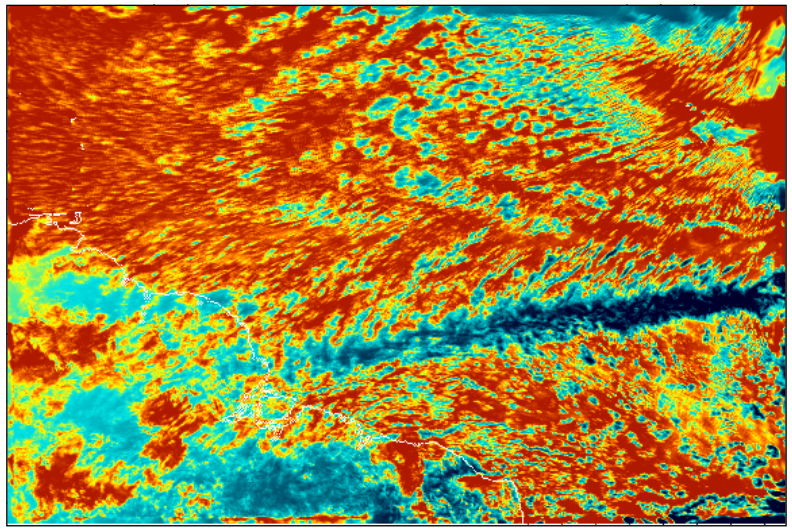
- Implementation of clear-sky SW/LW radiation fields – to evaluate effect of clouds on energy budget

	Cloudy (standard)	Clear-sky (new)
Time-ave net SW at surface / TOA	ASOB_S / ASOB_T	ASOB**C**_S / ASOB**C**_T
Net SW at surface / TOA	SOBS / SOBT	SOB**C**S / SOB**C**T
Time-ave net LW at surface / TOA	ATHB_S / ATHB_T	ATHB**C**_S / ATHB**C**_T
Net LW at surface / TOA	THBS / THBT	THB**C**S / THB**C**T

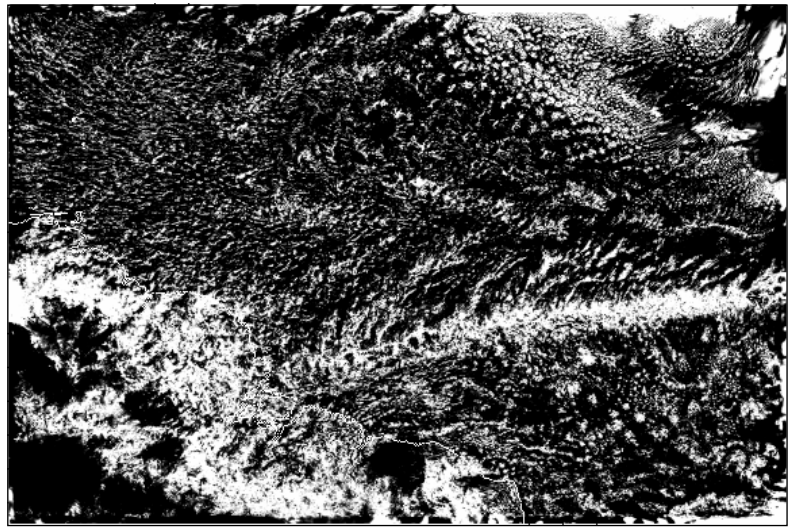


SW Cloud Radiative Effect (ASOBC_S – ASOB_S)

Over Tropical Atlantic, 2km resolution



Low-level cloud cover fraction (CLCL)



Credit: L. Hentgen

Advantages of COSMO-crCLIM

- Runs in climate mode on GPU => faster/cheaper
- Updated physics and enhanced output

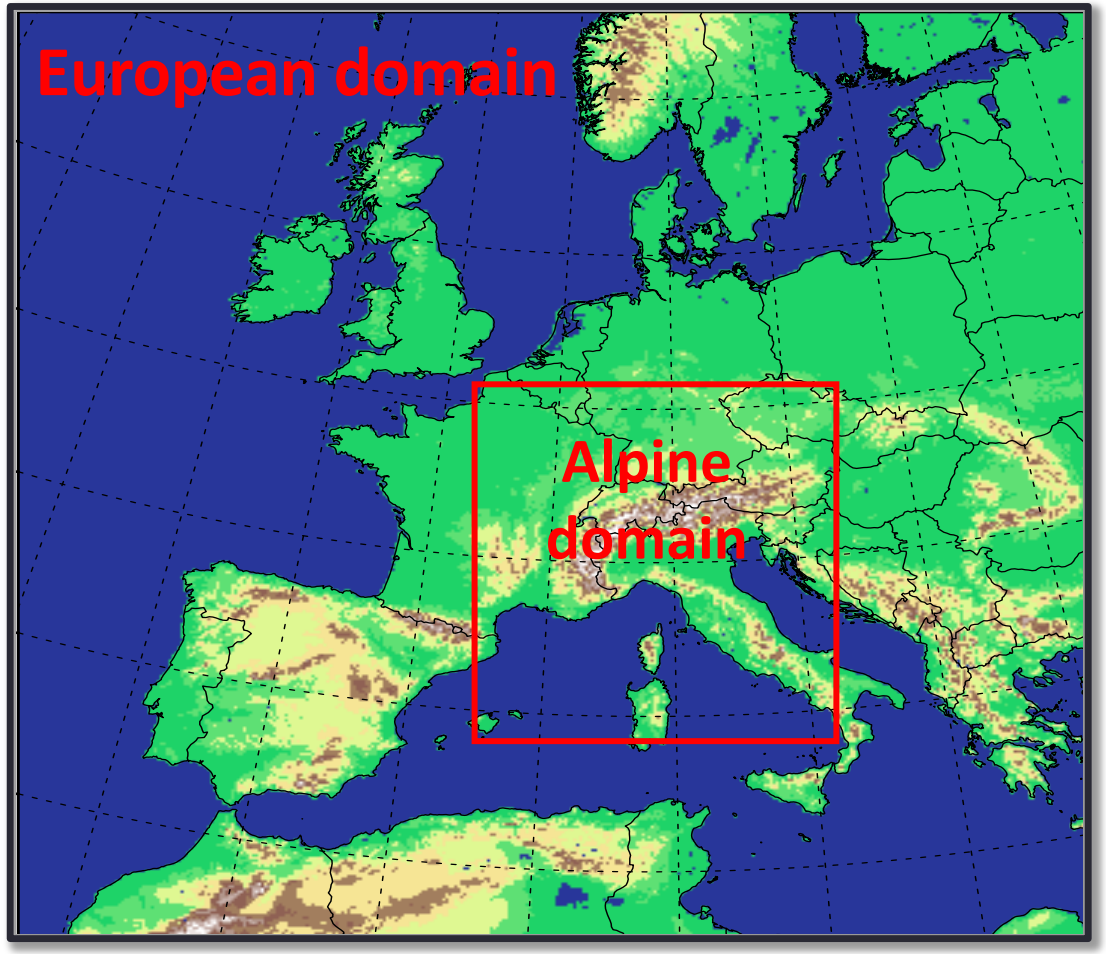
$\Rightarrow$ can increase the horizontal resolution to convection-resolving scales **at continental scale** at reasonable cost

$\Rightarrow$creates a seamless climate prediction model able to perform **climate change simulations** at hydrostatic scales at 50-12 km (CORDEX project) and non-hydrostatic scales down to 2 km (crCLIM project)

crCLIM project: Convection-resolving climate simulations at continental scale

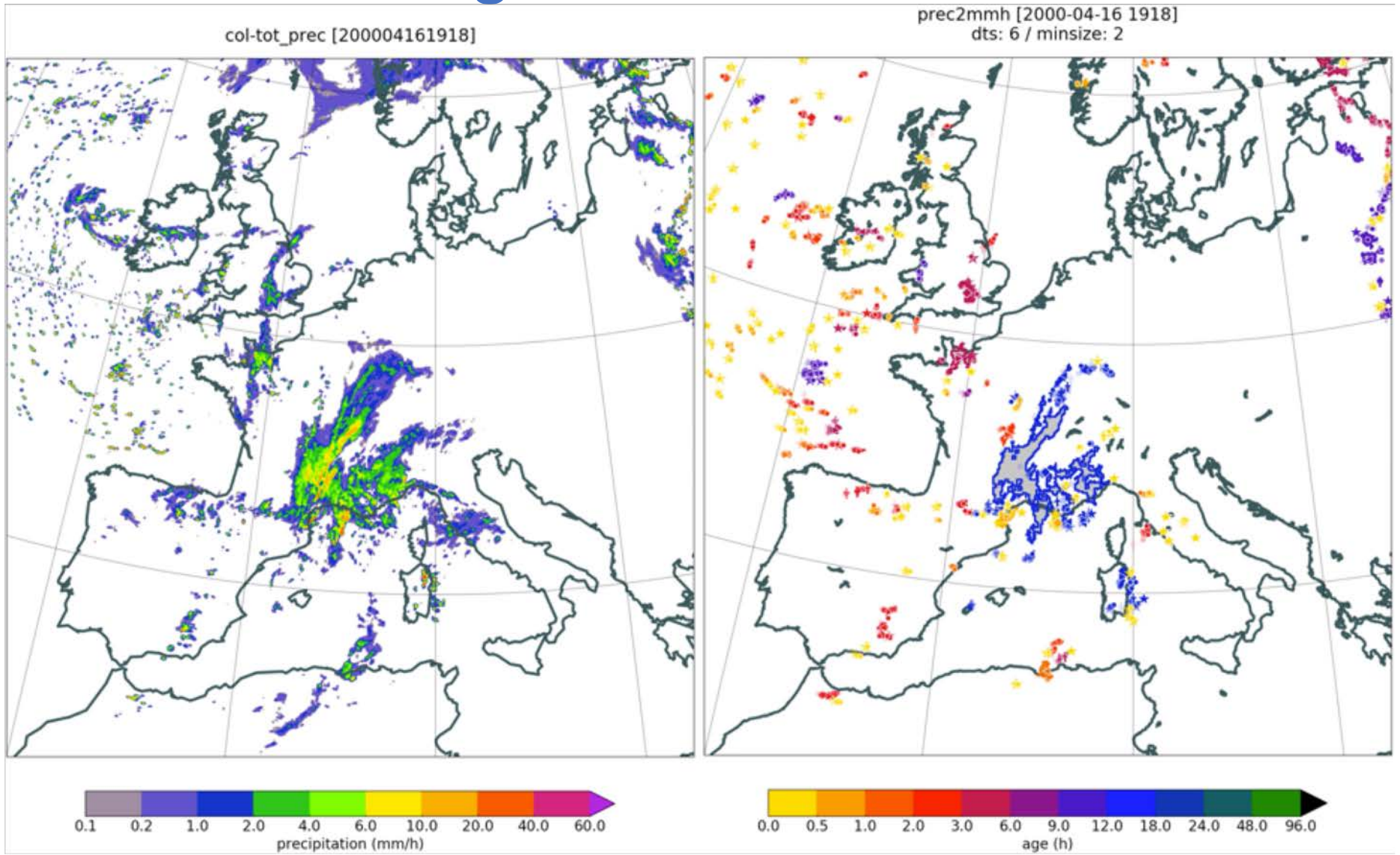
- Two-step one-way nesting:
  ERA-Interim ⇒ 12 km ⇒ 2.2 km
- Run over two domains:
  - Decade simulations over large European domain (e.g. Leutwyler et al, 2017)
  - Alpine domain (FPS simulations)
- Challenge: large output volume, can only save small set of variables, cannot save at higher frequency than hourly

=>higher temporal output (e.g. minutes) diagnosed *on-the-fly* using file system interface (SimFS) to generate statistics of high-impact events and their changes under global warming



Credit: N. Ban

Precipitation cell tracking



Six-minute precipitation (mm/h) at 2.2 km resolution

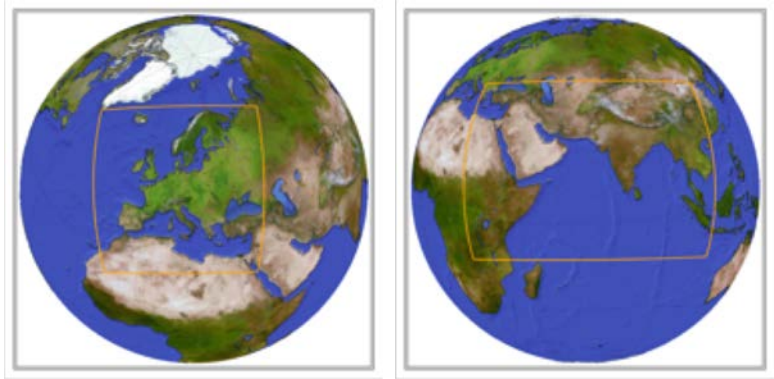
Precipitation cells from 10 April 2000 0006UTC to 18 April 0000UTC

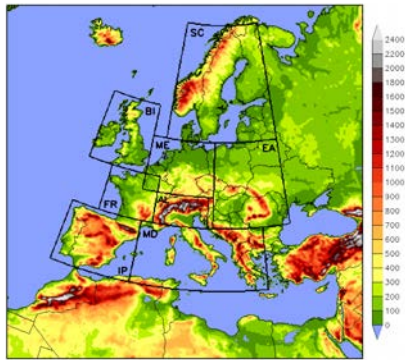
Credit: S. Rüdisühli; http://crclim.ch

CORDEX at 12-25 km resolutions

COSMO-crCLIM involved in:

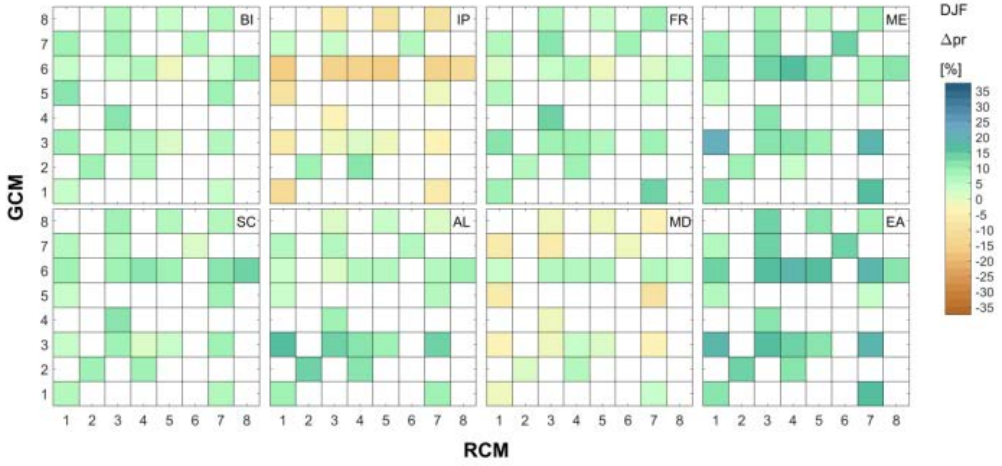
- EU-PRINCIPLES (EURO-CORDEX domain)
- CORDEX-CORE (South Asian domain) together with CLM community for other domains



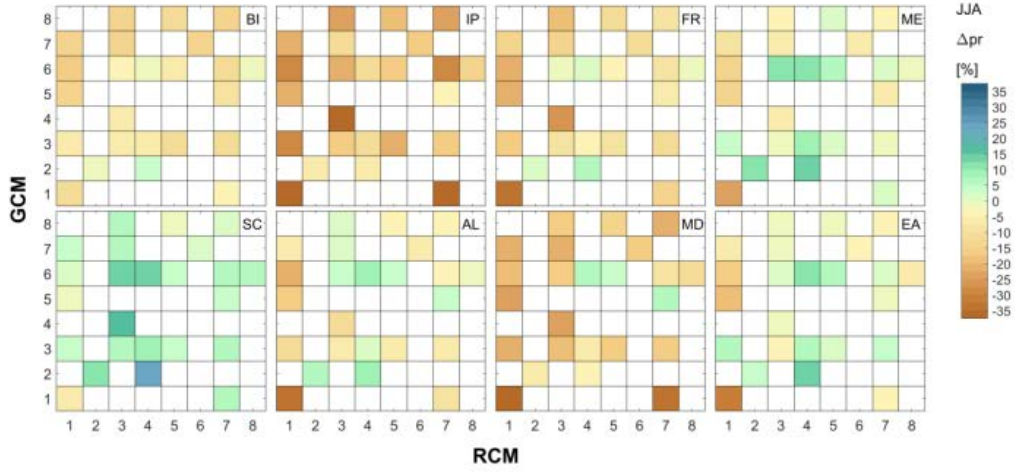


Sørland and Demory

DJF precipitation changes (RCP8.5)



JJA precipitation changes (RCP8.5)



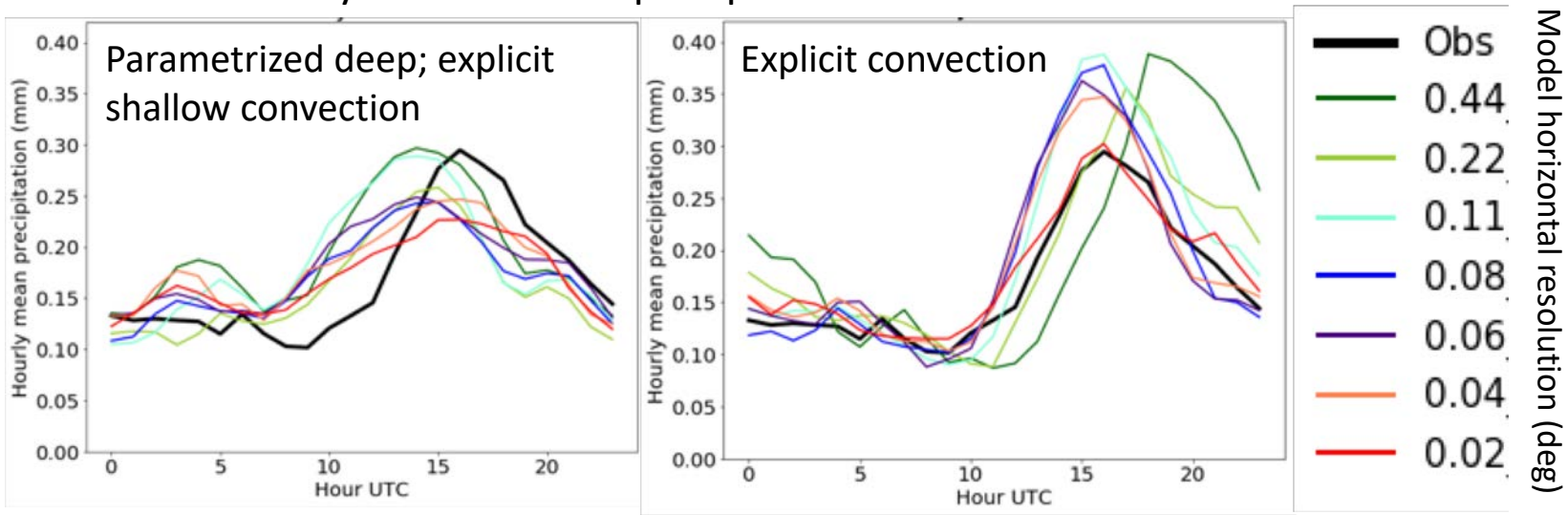
Vautard et al, 2019, PRINCIPLES

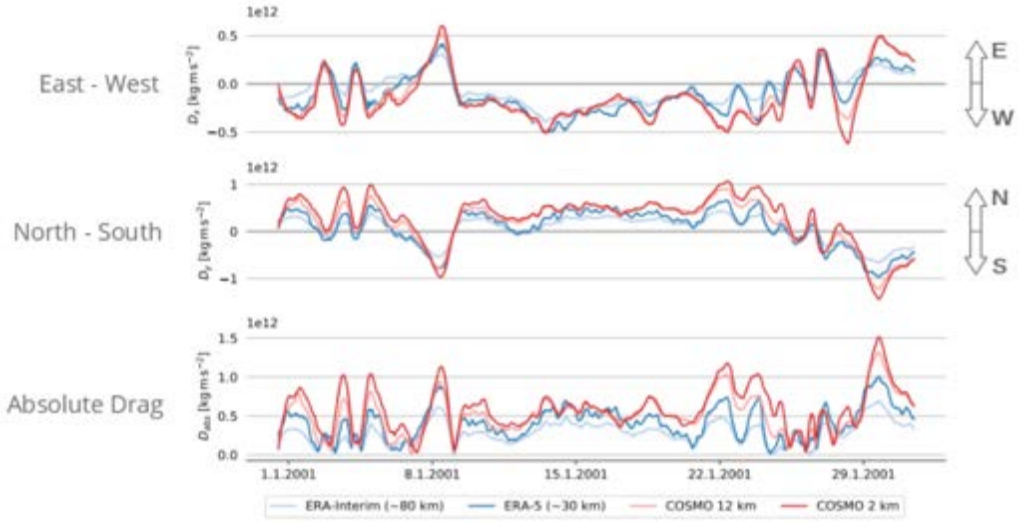
Ongoing work enabled by COSMO-crCLIM at various resolutions

- Understand when to switch off convection parametrization
  - Diurnal cycle improved from 25-12km resolution with explicit convection

Credit: J. Vergara-Temprado

Diurnal cycle of summer precipitation over Switzerland





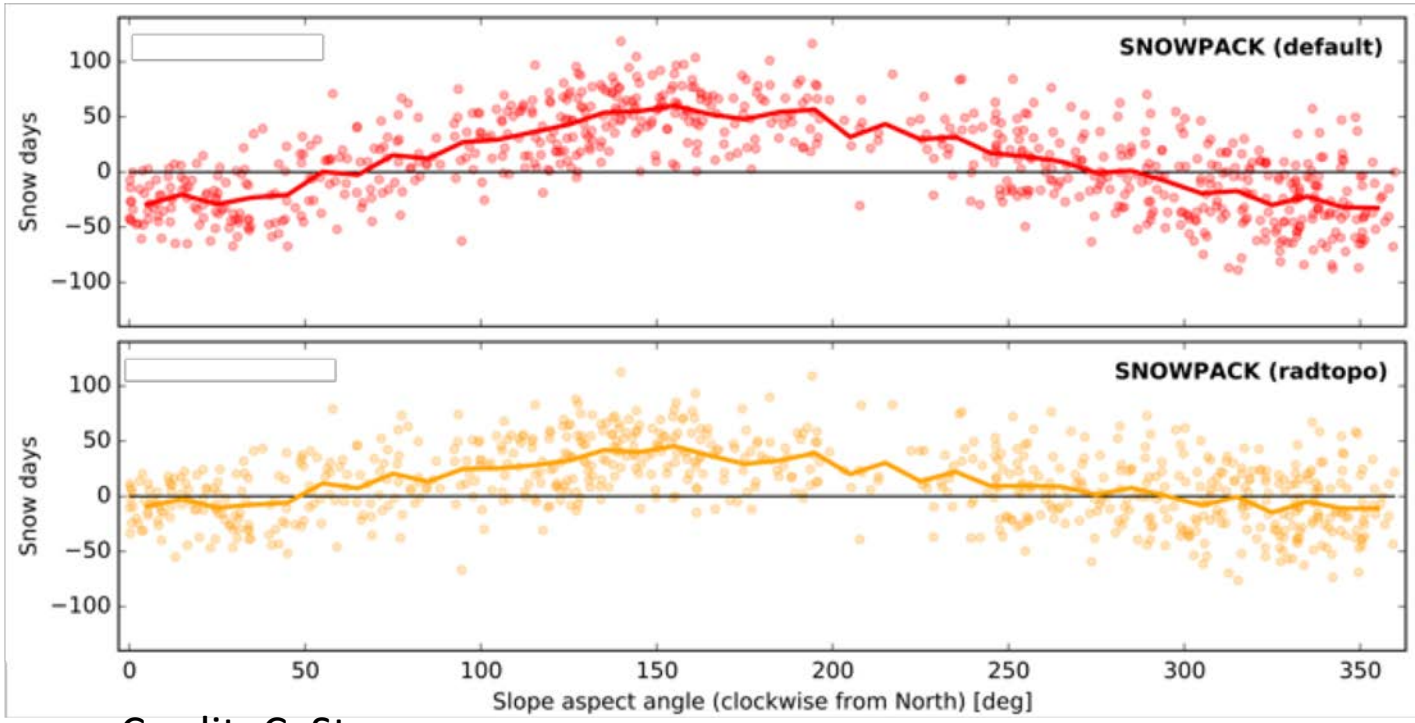
- Understand orographic drag and improve parametrization
  - Higher resolution => more resolved drag
  - Different behaviors between North/South and East/West directions

Credit: C. Zeman

Ongoing work enabled by COSMO-crCLIM at Δx=2km

- Improve simulation of snow cover over orography depending on slope aspect and angle, using COSMO's 'radiation-topography' scheme
  - Default scheme: too many days covered by snow on South-facing slope; not enough on North-facing slope
  - Radiation-topography scheme: reduces biases everywhere

=> will be run over domain covering Alps and Pyrenees; Δx=2km



Credit: C. Steger

- Effect of climate change on clouds over Tropical Atlantic; Δx=2km (Hentgen et al, in press)
- Changes in heavy precipitation events with global warming over Europe; Δx=2km (Ban et al, 2019)
- Changes in snow cover under global warming (Lüthi et al, 2019)

Summary

- A lot of effort has been put into the development of COSMO-crCLIM
  - Collaborative work between ETH, MeteoSwiss, C2SM, CSCS
  - Started from COSMO-POMPA (NWP)
  - Runs on both CPU and GPU => faster, cheaper
  - Adapted to run in climate mode
- Able to perform climate change simulations at continental scales at various resolutions
  - 50-12km resolutions (PRINCIPLES, CORDEX-CORE)
  - 2km resolution (crCLIM, FPS)
- A lot of potential for further research

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