Validation and climate projections of the ALARO-0 model on the EURO-CORDEX domain

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1 ALARO-0 climate runs at RMIB: status

2 Validation of ALARO-0 for climate

3 Climate projections

4 Subdaily precipitation

O. Giot et al. (RMIB)

ALARO-0 EURO-CORDEX climate runs

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ALARO-0 EURO-CORDEX climate runs

A little bit of history

Extended downscaling experiment by De Troch et al., JoC, 2013:

- Evaluation of ALADIN and ALARO-0 cy36t1 at 40, 10 and 4 km.
- Initial and lateral boundary conditions: ERA-40 or model at 40km resolution (one-way nesting)
- 40-year run with daily reinitializations
- Reference: to station observations 1961-1990

Thanks to the 3MT physics parameterization scheme, ALARO-0 generates **consistent results across scales** and correctly represents **extreme daily precipitation**, even at high resolutions.

Results indicate that ALARO-0 is a good candidate for regional climate modelling.

ALARO-0 climate runs at RMIB

Participation in the Coordinated Regional Climate Downscaling Experiment (CORDEX):

- Runs are performed with ALARO-0 cy36t1
- Boundary conditions: ERA-Interim (evaluation) or CMIP5 GCM: CNRM-CM5 (historical and future)
- Run continuously (one month at a time) for a 31-year period.
- Domain and resolutions: EUR-44 ($0.44^{\circ} \approx 50$ km) and EUR-11 ($0.11^{\circ} \approx 12.5$ km)



Validation

Validated using state-of-the-art performance metrics.

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Validation of the ALARO-0 model within the EURO-CORDEX framework

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Current status

Runs are ongoing on the Tier-1 supercomputer at Ghent University. The checked runs are finished or ongoing, green ones are next.

	Analysis	Historical	RCP 2.6	RCP 4.5	RCP8.5
1976- 2005	~	~	-	-	-
2005- 2040	-	-	×	*	*
2040-	-	_	~	√	<u> </u>
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2070- 2100	-	-	~	√	√

National project



- Dynamical downscaling of EURO-CORDEX 12.5km or 50km runs on a high-resolution $\mathcal{O}(4\text{km})$ domain over Belgium
- In addition to our contribution with ALARO-0, partner institutes use e.g. COSMO-CLM, MAR
- This provides an ensemble of high-resolution climate runs for local impact modellers.

National project: CORDEX.be



- Creating netCDF files that conform to the CORDEX archive specifications
- Processing 100s of TBs of historical files to extract TBs of data

... in R: new R package CordextractR (flexibility required!)

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 - Specify your in/output variables of choice, including functions such as sum, modulus, mask, threshold, max... in a declarative way
 - Set-up of a data conversion pipeline using producer-filter-consumer pattern (avoids (computation-intensive) logic/branches during the conversion)
 - **Fast** conversion (in spite of R): the bottleneck is mainly IO
 - Unit tests for all functions

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- Submitting data to the ESGF nodes (many of which have been down for a while...)

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ALARO-0 EURO-CORDEX climate runs

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Validation of ALARO-0 for climate

Evaluation run:

- Lateral boundary conditions from the ERA-Interim reanalysis
- Continuous 31-year run (1979-2010)
- Reference: E-OBS 7 data set

Can ALARO-0 represent the most important features of the European climate?

In practice:

- I Is ALARO-0 competitive with other EURO-CORDEX ensemble members, using the standardized performance metrics as in Kotlarski *et al.*, 2014?
- 2 Are these metrics **robust**?

Performance metrics

Scores are based on seasonal mean values of near-surface air temperature and precipitation.

- BIAS: mean bias
- 95%-P: 95th percentile of the absolute grid point differences
- RSV: ratio of spatial variability
- PACO: pattern correlation
- RIAV: ratio of interannual variability
- TCOIAV: temporal correlation of interannual variability

All scores except TCOIAV should be similar for reanalysis- and GCM-driven runs (if GCMs represent the climate well)

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Robustness

Are the scores **robust**, i.e. independent of the period used? \Rightarrow Jackknife procedure:

- Calculate all scores for 1000 random 20-year samples out of the 32-year period
- Construct 95% confidence intervals
- Compare interval width to the ensemble spread.

Temperature

optimal score jackknife 9 K14 models RMIB-UGer

jackknife 95% confidence interval RMIB-UGent (top=.11; bottom=.44)

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Temperature

optimal score ja

jackknife 95% confidence interval

RMIB-UGent (top=.11; bottom=.44)

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Precipitation

optimal score ja

jackknife 95% confidence interval

RMIB-UGent (top=.11; bottom=.44)

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Temperature bias patterns



Precipitation bias patterns



Conclusions

A state-of-the-art validation was performed of the ALARO-0 evaluation run of RMIB-UGent, following standardized metrics.

- ALARO-0 performs well, despite not being tuned for climate: cfr. white/green backgrounds
- Temperature biases persist in Scandinavia / Eastern Europe (same spatial pattern as ARPEGE)
- For precipitation, ALARO-0 often outperforms all other models! Robustness test: all scores except RIAV and TCOIAV are robust

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ALARO-0 EURO-CORDEX climate runs

RCP 8.5 vs historical T2m (Uccle, Belgium)



Change in temperature: RCP 8.5 (2070-2100) vs historical (1976-2005)





Winter



Change in precipitation: RCP 8.5 (2070-2100) vs historical (1976-2005)



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Subdaily precipitation



OBS: "centennial" 10-minute precipitation observation series in Uccle

References

- De Troch, R., et al.: Multiscale performance of the ALARO-0 model for simulating extreme summer precipitation climatology in Belgium, Journal of Climate, 26(22), 8895-8915, doi:10.1175/JCLI-D-12-00844.1, 2013.
- Kotlarski, S., et al.: Regional climate modeling on European scales: a joint standard evaluation of the EURO-CORDEX RCM ensemble, Geosci. Model Dev., 7, 1297-1333, doi:10.5194/gmd-7-1297-2014, 2014.
- Giot, O., et al.: Validation of the ALARO-0 model within the EURO-CORDEX framework, Geosci. Model Dev., 9, 1143-1152, doi:10.5194/gmd-9-1143-2016, 2016.
- I De Troch, R., The application of the ALARO-0 model for regional climate modeling in Belgium: extreme precipitation and unfavorable conditions for the dispersion of air pollutants under present and future climate conditions, PhD dissertation, 2016.

Backup slides

Climate scenarios



- Finished: RCP 8.5 2040-2100
- Ongoing: RCP 4.5 2040-2100
- Ongoing: RCP 2.6 2040-2100
- Planned: * 2005-2040

Relative change in yearly precipitation: RCP 8.5 (2070-2100) vs hist (1976-2005)

