Project: **802**

Project title: **COSMO-CLM simulations with 2-way nesting**

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The current status of the project

In 2013-2016 the coupled system CCLM+MPIESM using a 50km CCLM horizontal resolution was developed and tested on interannual to decadal time scales. Its interpolation accuracy was shown to be smaller than the COSMO tendency. For surface pressure it was found to be 1 Pa on average. The application of the system in North Atlantic showed a significant upscaling effect. In particular a substantial improvement of the cyclone and blocking frequency in MPIESM was found. The climatology of the two-way coupled MPIESM was within the range of an MPIESM stand alone ensemble. TWC of CCLM+MPIESM over Europe with 18km COSMO-CLM horizontal resolution didn't show a significant upscaling effect. However, it reduced the boundary effect of one-way coupled simulations significantly and reduced slightly the temperature and precipitation biases, in particular close to the inflow and the outflow boundaries (see Figure 2). Similar results are found for the coupling in the CANA region (See Figure 1). As intended, the surface pressure of MPIESM and COSMO-CLM exhibit deviations much smaller than 1 hPa on large scales (upper row, second column, Figure 1-3) which is not the case in one way coupled simulations (column 3).

In 2017 we investigated the question, to what extent the results depend on the ESM chosen. The TWC coupling was implemented in ARPEGE and applied over Europe. Figure 3 shows the same differences as in Figure 2 but for CCLM+ARPEGE coupling. Again, the pressure difference between CCLM and ARPEGE and the overall boundary effect of the TWC simulation (column 2) is significantly smaller than in OWC simulations (column 3 and 4). However, the reduction of the boundary effect in the TWC simulation is smaller than in the CCLM+MPIESM simulation since the horizontal resolution of ARPEGE (80km) is only slightly coarser than in CCLM (50km).

A reinvestigation of the interpolation accuracy of the TWC showed that the surface pressure interpolation bias is smaller than the COSMO-CLM tendency (on average) but not the error at individual times in mountaineous regions. It was found that the error is not dominated by the vertical but by the horizontal interpolation (Figure 4, left column). The introduction of horizontal interpolation of the pressure deviation from the standard atmosphere reduced the bias by one to two orders of magnitude (Figure 4, right column). Now the interpolation error is order of magnitude 1 Pa at every grid point and much smaller than the COSMO-CLM tendency. This, however, affects not only the TWC but also all OWC simulations. Thus, the interpolation of pressure deviation has been introduced in the program for preparation of initial and boundary conditions (int2lm) as well. Furthermore, the accuracy of the vertical interpolation has been improved by a factor of 2 by introduction of an iteration of computation of pressure and temperature on the target grid.

The results obtained are promising. The analysis of the impact of the improvement of the horizontal and of the vertical interpolation on the climatology in OWC and TWC simulations is ongoing. Up to the knowledge of the author, there is no other two-way coupling between atmospheres, which has this level of accuracy and allows for a local increase of vertical resolution. I

The performance of the CCLM+MPI-ESM coupling (see Will et al. (2017)) is much smaller than possible due to lack of parallelization of the computation of horizontal derivatives in MPI-ESM and usage of an expensive vertical interpolation method (spline interpolation) in CCLM. This has been investigated in the second half of 2017. The CCLM+ARPEGE TWC exhibits additional cost of 100% (which is much less than CCLM+MPIESM). In MPIESM+CCLM the work is ongoing of replacement of the horizontal derivative in MPIESM by sending the derivatives to MPIESM. The remaining issue is the replacement of the vertical spline interpolation by an explicite differencing. This remains for future work.

Climatology over Europe in MPIESM+CCLM and ARPEGE+CCLM

It could be shown that this TWC modeling approach can be easily applied between different Earth System Models and the COSMO-CLM. This allows to follow the multi-model ensemble approach. First results with both model system allow to identify common features, which can be attributed to the method rather than the properties of the particular models coupled. A more detailed analysis is planned for 2018.

Figure 1 shows the result for MPIESM+CCLM T63L47/dlon=50km,k=45 for PMSL, T_2M, CLCT (total cloud cover) and TOT_PREC. In particular the surface pressure difference is much smaller in MPIESM and CCLM in TWC mode. Furthermore, the CLCT difference between COSMO-CLM and MPIESM is more homogeneous. The precipitation differences are less extreme and T_2m exhibits a smaller large scale amplitude than in OWC mode. All together, the boundary effect seems to be strong in wave number 1 and 2 in PMSL, CLCT and T_2m and a substantially increased precipitation at the inflow and outflow boundary occurs in OWC simulations. In particular, if ERAINT is used as IBC.

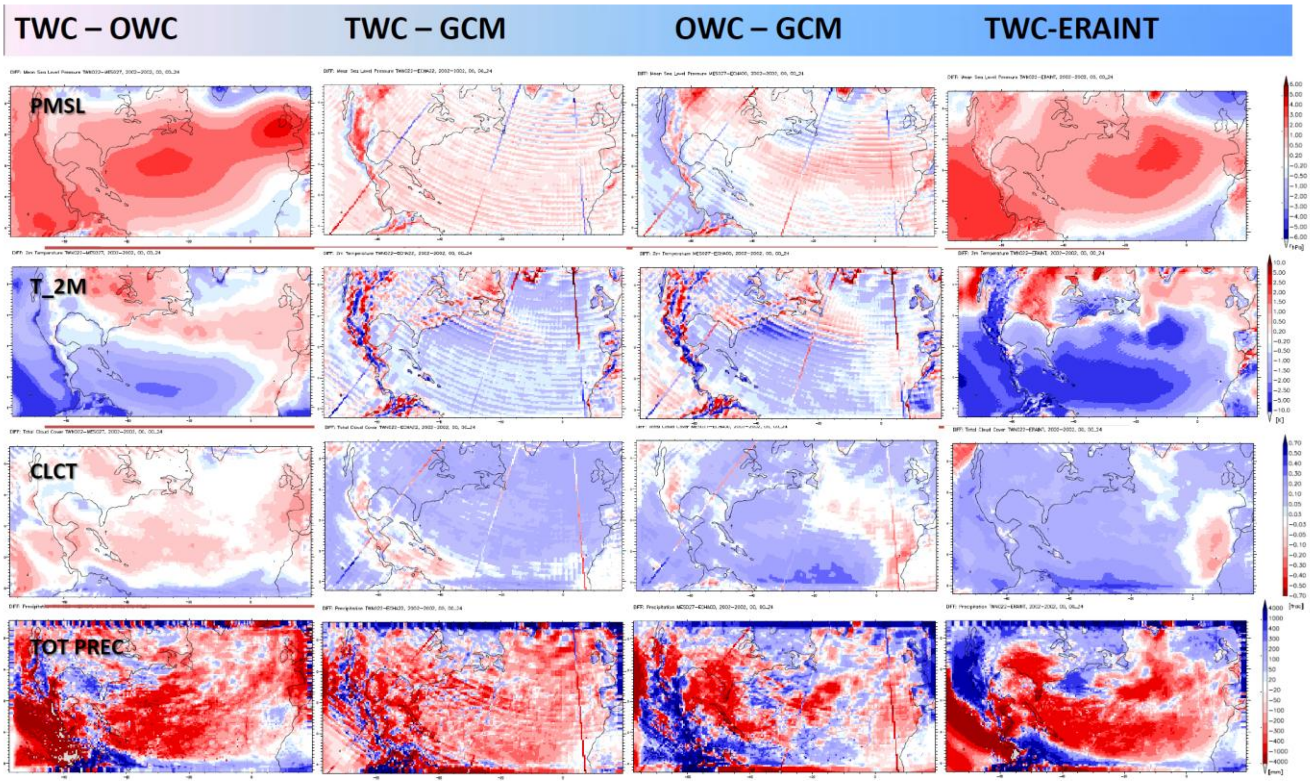

Figure 1: ***Mean 2000-2001 differences of One and Two-ay Coupled simulation results CCLM-MPIESM in domain CANA*** for the quantities PMSL, T_2M, CLCT and TOT_PREC. TWC-OWC: Difference of two- and one way coupled simulation on COSMO-CLM grid. TWC-GCM: Difference between COSMO-CLM and ARPEGE for two-way coupled simulation. OWC-GCM: Difference between COSMO-CLM and ARPEGE for one-way coupled simulation with ARPEGE IBCs.TWC-OBS: Difference between COSMO-CLM in TWC mode and ERAINT data.

In Figure 2 the same quantities are shown for MPIESM+CCLM over Europe. However, the CCLM resolution is now dlon=18km. The boundary effect is stronger than for the coupling over CANA region, probably due to a much larger impact of the land surface in Europe domain and higher COSMO-CLM resolution. Interestingly the precipitation difference in the boundary zone have opposite signs in the EVAL (ERAINT IBCs) and OWC (MPIESM IBCs) simulation. Figure 3 shows the same quantities as in Figure 2 but for ARPEGE+CCLM. However, the ARPEGE resolution is now T127L95. The boundary effect found is thus weaker. Interestingly the sign of the boundary effect in precipitation in OWC with ARPEGE is similar to ERAINT and opposite to MPIESM.

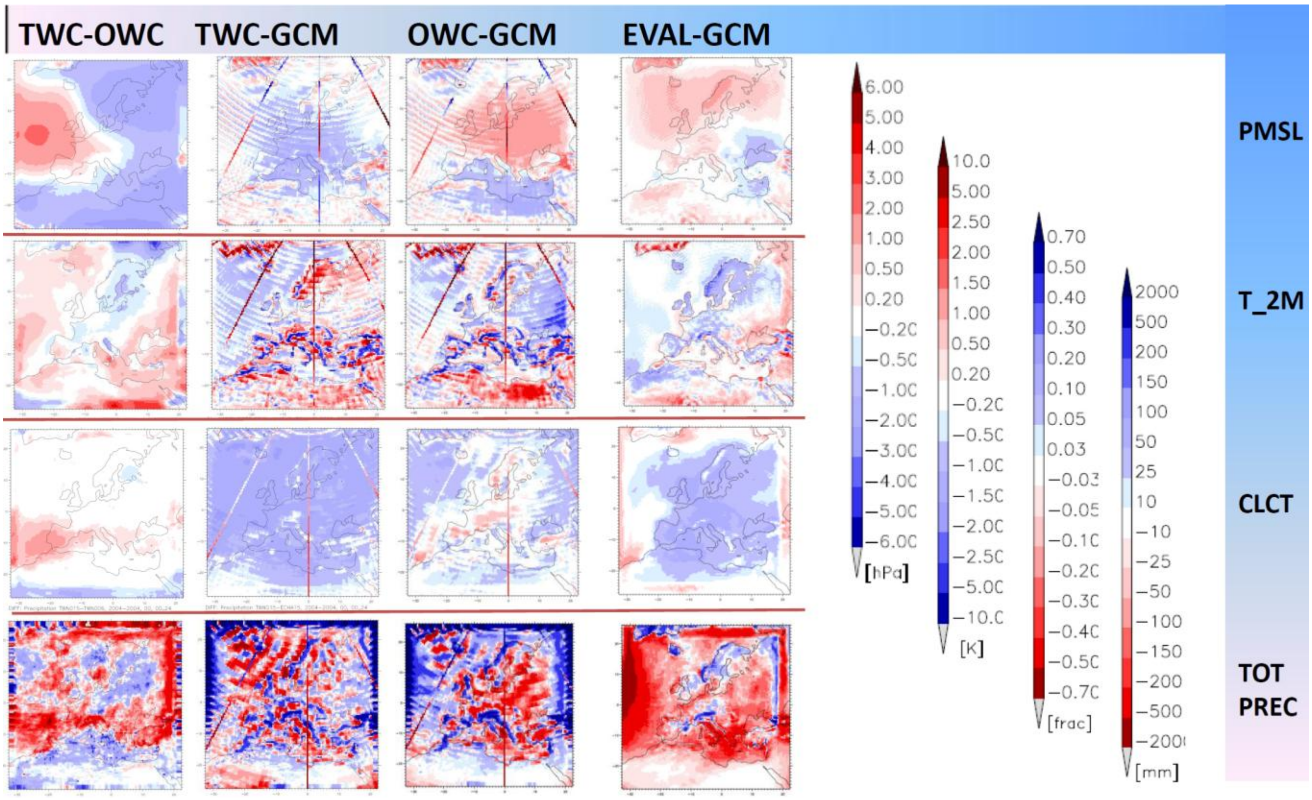

Figure 2: **Mean 2000-2004 differences of One and Two-ay Coupled simulation results CCLM-MPIESM in domain Europe** *for the quantities PMSL, T_2M, CLCT and TOT_PREC. TWC-OWC: Difference of two- and one way coupled simulation on COSMO-CLM grid. TWC-GCM: Difference between COSMO-CLM and ARPEGE for two-way coupled simulation. OWC-GCM: Difference between COSMO-CLM and ARPEGE for one-way coupled simulation with ARPEGE IBCs.TWC-OBS: Difference between COSMO-CLM in TWC mode and ERAINT data.*

Figure 4 shows the impact of the horizontal interpolation of pressure deviation instead of absolution pressure on the interpolation accuracy. The error is reduced by more than one order of magnitude.

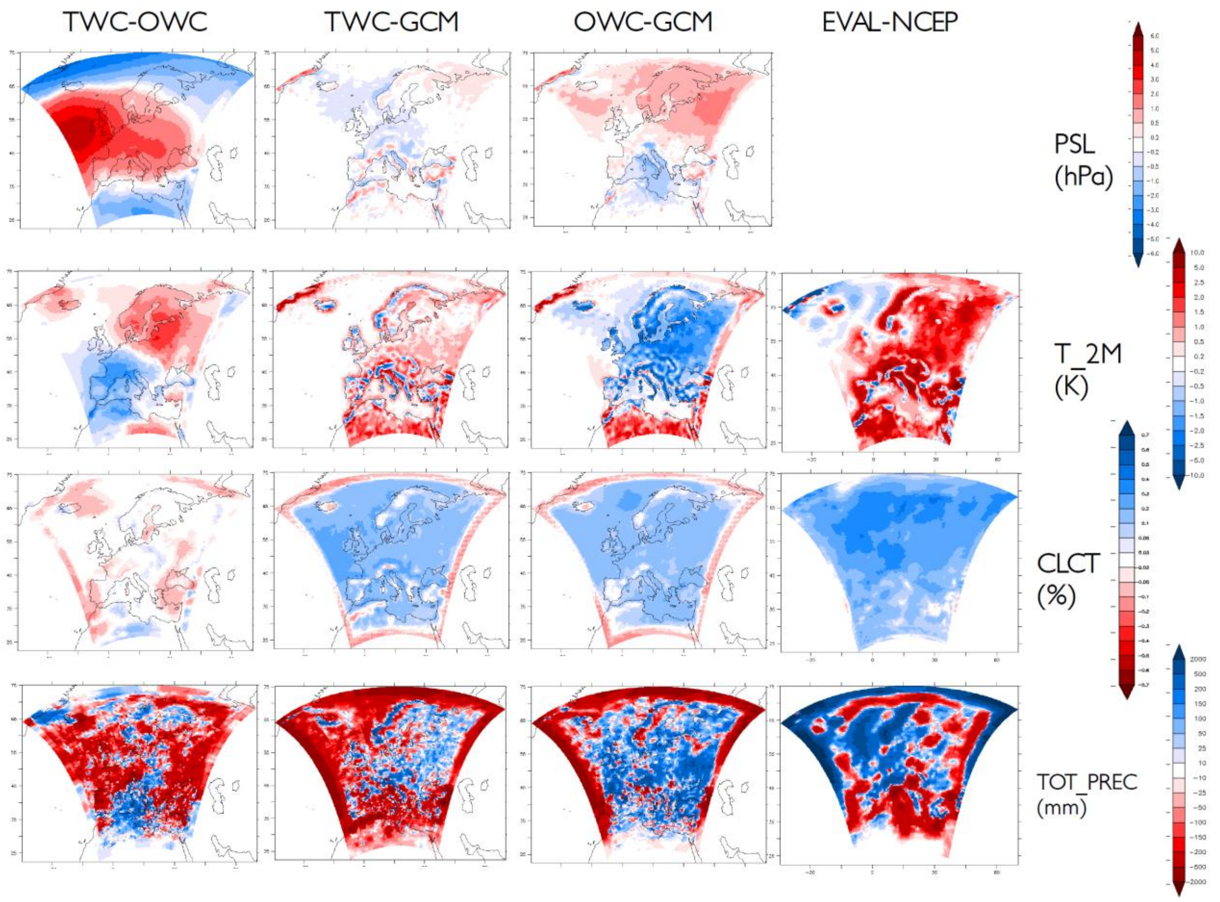

Figure 3: Mean 2000-2001 differences of One and Two-ay Coupled simulation results CCLM-ARPEGE in domain Europe *for the quantities PMSL, T_2M, CLCT and TOT_PREC. TWC-OWC: Difference of two- and one way coupled simulation on COSMO-CLM grid. TWC-GCM: Difference between COSMO-CLM and ARPEGE for two-way coupled simulation. OWC-GCM: Difference between COSMO-CLM and ARPEGE for one-way coupled simulation with ARPEGE IBCs..EVAL-NCEP: Difference between COSMO-CLM and NCEP for the one way coupled simulation with NCEP IBCs.*

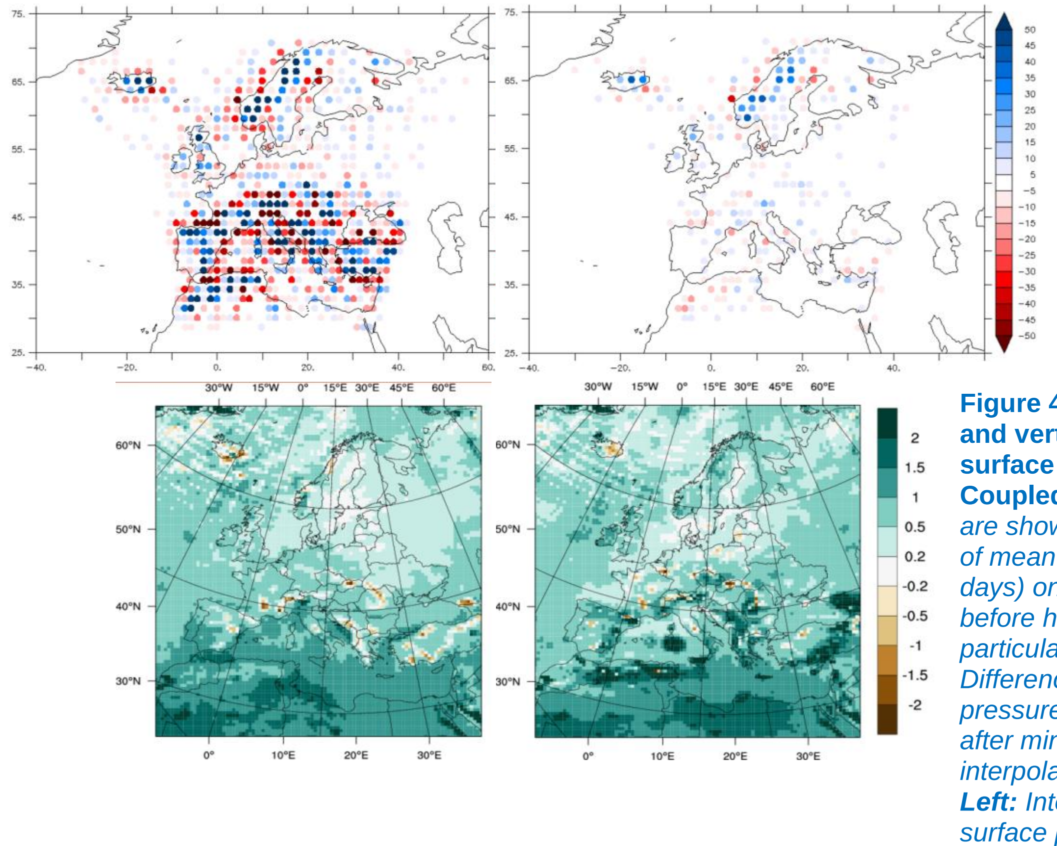

Figure 4: Accuracy of horizontal and vertical interpolation of surface pressure in Two-Way-Coupled simulations*. The results are shown in Pa.* ***Top:*** *Difference of mean surface pressure (14 days) on ARPEGE grid after minus before horizontal interpolation for a particular time.* ***Bottom:*** *Difference of mean surface pressure on COSMO-CLM grid after minus before vertical interpolation for a particular time.* ***Left:*** *Interpolation of absolute surface pressure (PS).* ***Right:*** *Interpolation of pressure deviation from standard atmosphere (PP).*