Project No. 037005

CECILIA

Central and Eastern Europe Climate Change Impact and Vulnerability Assessment

Specific targeted research project

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D 2.7: Report on possible improvements in very high resolution climate simulation

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Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

General introduction

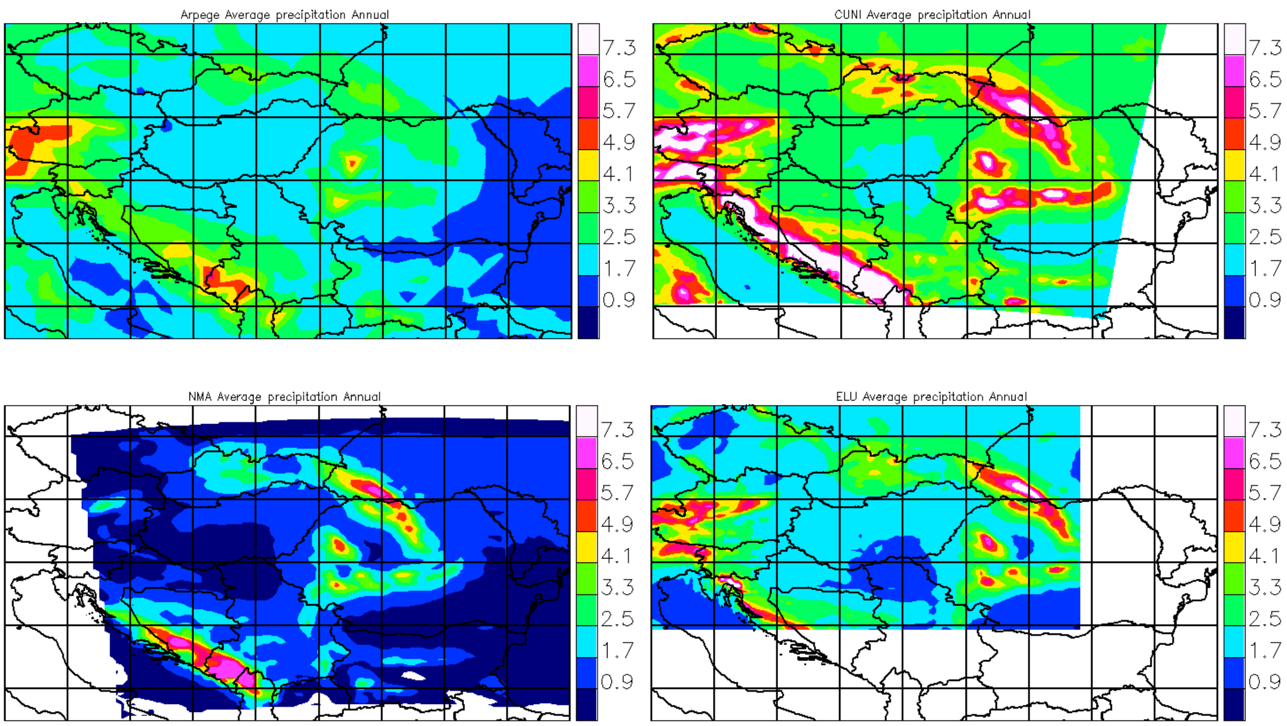
This deliverable has been assembled from independent contributions from the involved institutes according to the CECILIA description of work.

Effects of resolution on the precipitation intensity spectrum in Central Europe (Contribution by DMI)

A high spatial resolution of a regional climate model will give a higher degree of realism to the description of orographic effects. In previous studies there have been indications that a higher resolution of a regional climate model will lead to a better quality of the extreme tail of the precipitation intensity spectrum. This improvement is not just due to the decreased aggregation, but is probably also due to the more explicit description of precipitation, i.e., that a smaller fraction of the precipitation needs to be parameterised as sub-grid convective precipitation.

In the CECILIA project we have access to data from two driving models: The CNRM ARPEGE stretched-grid global simulation with around 50km grid distance over Europe, and the ICTP RegCM RCM simulation in 25km resolution from the ENSEMBLES project. High-resolution simulations in about 10km grid distance have been performed by the OMSz with ALADIN for the ARPEGE driving simulation and by CUNI, NMA and ELU with RegCM for the ICTP RegCM driving simulation. In Fig. 1 we show the average annual precipitation for the control period 1961-1990 for these simulations and compare to two sets of observations. This comparison would have been better using reanalysis-driven data; however, there are currently only high-resolution reanalysis-driven data from two of the four models (CUNI and NMA). This analysis employs data from the CECILIA extremes database created under WP4.

It is clear that orographic effects are larger for the high-resolution simulations than for the lower-resolution driving simulations. However, when comparing to observations, as depicted in Figs 1e and 1f from the ENSEMBLES E-OBS 25km data set and from the CECILIA station data, respectively, there seems to be too much precipitation in the CUNI and OMSz high-resolution simulations.



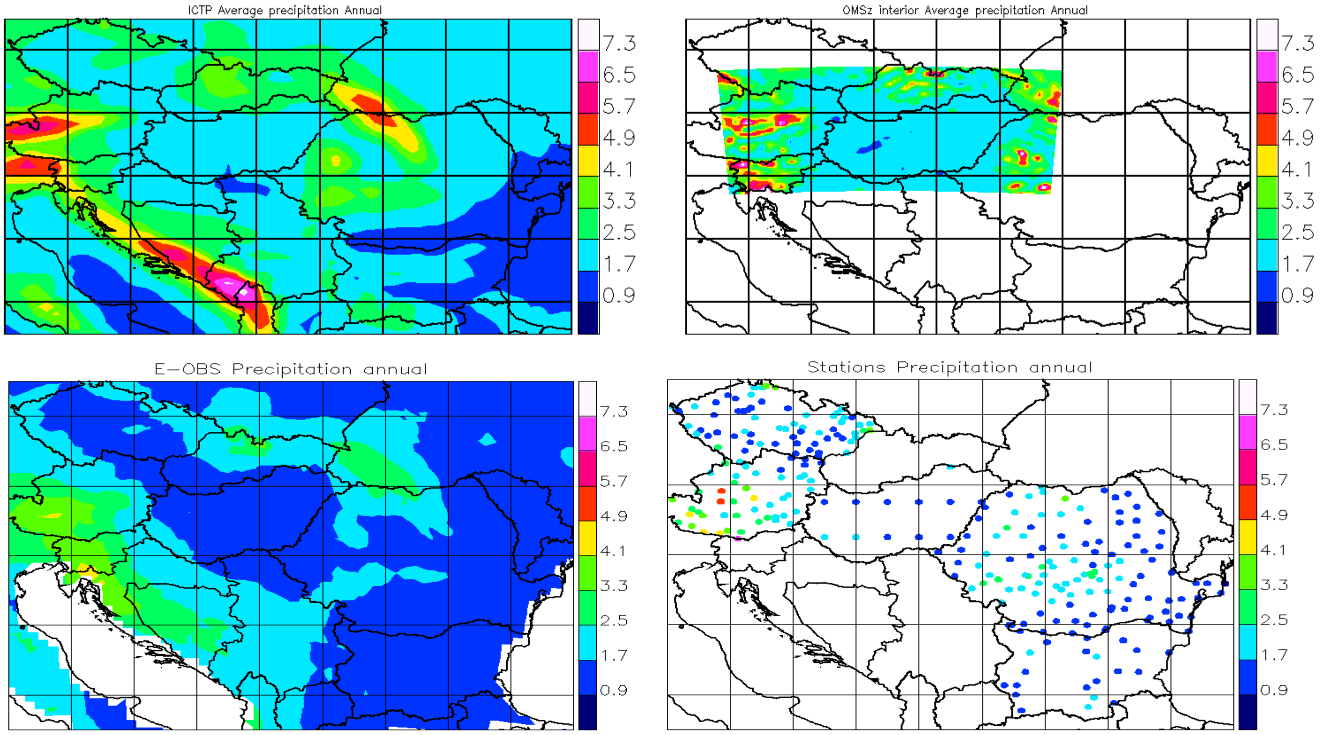


Figure 1 Average annual precipitation (mm/day) from the CECILIA driving simulations (panels a and e), high-resolution simulations (panels b,c,d,f) and from observations (panels g and h).

A problem with absolute magnitudes of precipitation can be dealt with through scaling, provided that the intensity spectrum is realistic. This is being checked in Fig. 2, where the ratio between the wet-day 99th percentile, corresponding to a 1-2 year return time, and the median (50th percentile) wet-day intensity is shown for the summer season. First of all, a comparison of the two observation-based panels illustrates that the E-OBS data at 25km grid distance shows a much weaker tail of the intensity distribution than the individual CECILIA stations, in particular in heavy-tail areas like eastern Romania. The gridding of daily observations is known to cause a weakening of the intensity tail (ENSEMBLES deliverable D5.18), and the density of stations forming the basis of E-OBS is particularly low in the area under investigation here. The documentation in ENSEMBLES D5.18 suggests that a 99th percentile in E-OBS in general would be roughly 70% of what it should be; this reduction might be even larger because of the low station density in the study area. It is therefore probable that the high-resolution simulations actually are more realistic than the lower-resolution ones regarding the tail of the precipitation intensity spectrum.

The ICTP 25km simulation exhibits very high values over large areas, not confined to mountains; hence, this simulation probably exaggerates the intense precipitation in summer. The high-resolution simulations have high values in mountainous areas, roughly corresponding to the CECILIA station data.

In Fig. 3 we document that the models under investigation all suffer severely from the drizzling problem: It rains very frequently. Exceptions are NMA and possibly ELU. Percentages of wet days, i.e. days with over 1mm of precipitation are frequently twice what observations indicate. For annual frequencies (not shown) the problem is less pronounced but still serious. This means that the high-resolution models are probably in need of further parameter optimization. The wet-day precipitation (mean intensity) is quite realistic (not shown). Note that this will further enhance tendencies to exaggerated extremes observed in Fig. 2, if all-day return periods are compared instead of wet-day percentiles.

Further investigations are planned with a more thorough study of the individual seasons and of the intensity spectrum details. When reanalysis-based simulations become available for the remaining simulations, it will be possible to investigate the properties of the regional models without the uncertainty from the difference between reality and GCM control climate.

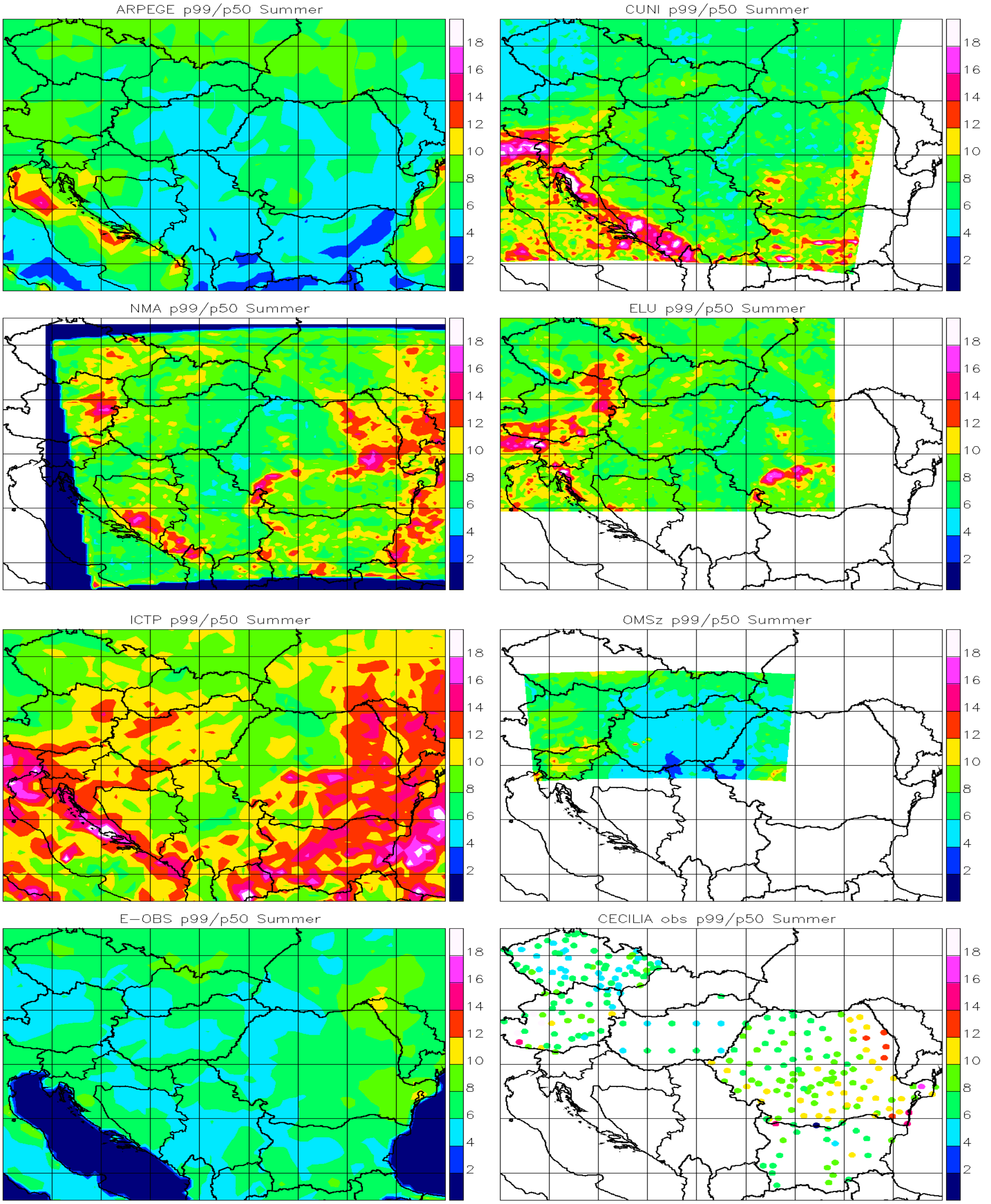


Figure 2 Ratio between 99th percentile and median for summer, calculated from wet days, from the CECILIA driving simulations (panels a and e), high-resolution simulations (panels b,c,d,f) and from observations (panels g and h).

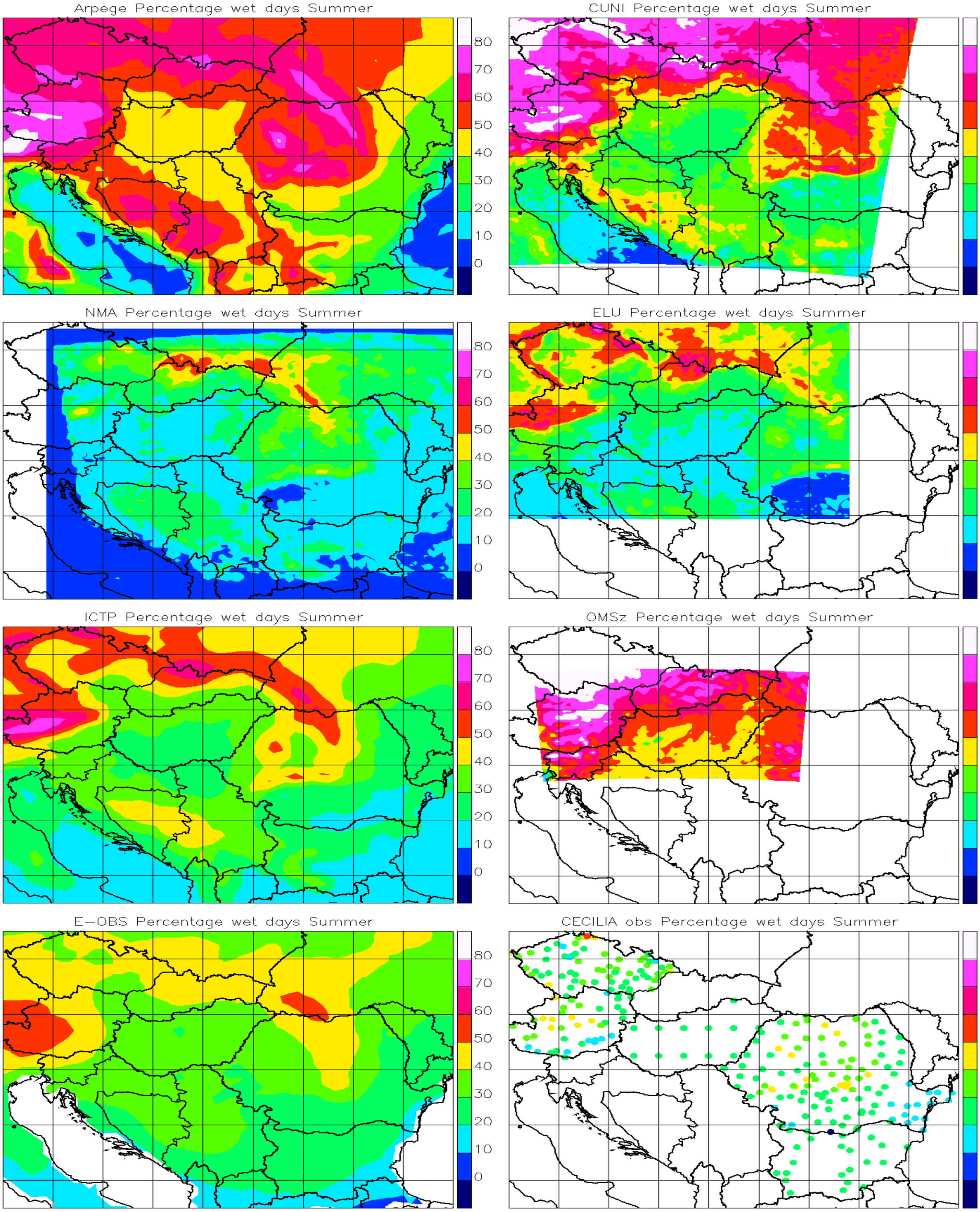


Figure 3 Percentage of days with precipitation > 1 mm in summer from the CECILIA driving simulations (panels a and e), high-resolution simulations (panels b,c,d,f) and from observations (panels g and h).

HIGH RESOLUTION CLIMATE MODELING IN COMPLEX TERRAIN USING A SUB-SCALE SURFACE SCHEME (Contribution by BOKU)

Motivation

Regional Climate Models (RCM's) with a spatial resolution of even 10 km are not able to resolve big European mountain valleys (e.g. Inn valley) in a realistic way. The RCM surface fields in mountainous regions represent the situation at the average altitude within the grid box. But especially snow accumulation and snow melt highly depends on temperature and hence on the surface altitude. Even the sensitivity of snow accumulation to temperature changes is influenced by the altitude. As snow cover significantly influences the surface energy fluxes, a realistic snow modelling is essential within mountainous regions.

Aim

The goal of this contribution is to quantify the effect of a very high resolution (1 km) sub-scale land surface and topography scheme on the RCM-modelled snow accumulation and snow melt and the consequential changes in the surface energy and water fluxes. A direct run at 1 km with non-hydrostatic model (like PSU/NCAR mesoscale model known as MM5) would take lot of computational time and hence it is not possible to run the model at such a high resolution for more than few days or months. Therefore an intermediate approach is used to attain such a high resolution. The basic idea of this approach is to run the land-surface model at higher resolution than the atmospheric model interactively.

Methodology

For our study we use ICTP Regional Climate Model (RegCM3). In RegCM3, the surface physics are performed using Biosphere-Atmosphere Transfer Scheme version 1e (BATS1e). A mosaic type parameterization of subgrid-scale topography and land-use has been developed and implemented in the framework of ICTP Regional Climate Model (RegCM3). In this parameterization scheme (called Sub-BATS) regular fine scale sub-grid is defined for each coarse scale model grid-box. Each sub-grid is characterized by its own height and land-use type. Meteorological fields are disaggregated from the coarse grid to the fine grid (e.g. temperature, water vapour) using the standard lapse rate for temperature and mass consistency for water vapour. Disaggregation is based on the elevation differences between the coarse grid and the fine grid. BATS surface physics computations are performed on the fine grid. Surface fields from the fine grid are re-aggregated to the coarse grid for input to the Atmospheric model.

Test of model set-up

An investigation of an improved snow accumulation and snow melt within the Alpine region requires a good representation of the precipitation. As the first results of the standard CECILIA RegCM3 version (alpha) showed too much precipitation within the Alpine region, systematic tests of different domains and lateral boundary conditions have been applied, to find the most appropriate set-up for this application. All different tests are listed in table 1.

Simulation 2(a) showed lot of precipitation over Alps and some grid points with enoromous snow accumulation. To overcome this problem simualtion 2(b) and 2(c) are done and these three simualtions (a,b,c) were compared with Lateral boundary conidtions(ICTP-25km simulaitons), RegCM3 ouput from CUNI, Prague and MM5 output from Reclip-More Project. It was suspected that there might be a problem in the quality of boundary conditions. This conclusion led to drive the model with high resolution recently released ERA-Interim data. Interface for RegCM3 ERA-Interim was written and first 1 year test simulation was done and compared with the above mentioned 6 other simulations. Results was highly encourging showing significant improvemnet of precipitation simuatlion in ERA-Interim driven runs. These results set the basis of new study of comparing different lateral boundary conditions and nesting strategies. The simulation 3 are a set of simulations done with 3 different lateral bondary conditions (ERA-Interim, ERA40, NCEP) with 3 different spatial resolutions (0.75,1.125,2.5 degree) and different Domain Resultions (90km,30km,10km). Results from 8 simulations at finest domain (10km) were compared and presented in EGU2009. The simulations driven directly (without intermediate Nests) with ERA-Interim 0.75 degree and ERA40-1.125 degree showed more realistic results than any other simualtion. It was suspected that this improvement of directly driven ERA-Interim and ERA40 simulations could be merely because of the effect of domain size. To verify this hypothesis, a 10km simulation is done for the big domain used for intermediate 30km simulations (covering almost whole Europe) and compared the results with previous simulations. The hypothesis that high resultion ERA-Interim/ERA40 10km simlatuions without intermediate domain produced better results becuase of small domain size was verified. The results for precipitation bias and temporal correlation are shown in Fig. 1 and Fig. 2.

As best performing set up for our sub-scale investigations we choose RegCM CECILIA alpha version forced with 0.75 degree ERA-Interim lateral boundary contititions and the small domain. This set-up was used for a six year integradion usine the standard and a sub-scale version of RegCM3.

Table 1: List of RegCM3 test runs

	Simulation Type	Period of Simualtion	Lateral Boundary Conditions
1.	1 yr. BATS/SubBATS	Sep98 – Aug99	ICTP 25km Run
2. (a)	10 yrs. BATS/SubBATS	Dec79 – Dec90	ICTP 25km Run
(b)	10 yrs. BATS with Beta RegCM3	Dec79 – Dec90	ICTP 25km Run
(c)	10 yrs. BATS with Emanual Conv.	Dec79 – Dec90	ICTP 25km Run
3	1 yr. BATS with Default/Beta RegCM3	Jan -Dec 1989	0.75 ERA-Interim
4	16 one year Simulations with different Nesting Strategies and different types and resolutions of Lateral Boundary Conditions	Oct98 - Dec99	0.75 ERA-Interm, 1.125/2.5 ERA40, 2.5 NCEP Rean. II
5	1 year simulation at 10km for full European Domain to check the domain size effect	Dec79 – Dec90	0.75 ERA-Interm
6	6 years BATS Vs SubBATS Runs	Oct 98-Jan05	0.75 ERA-Interm

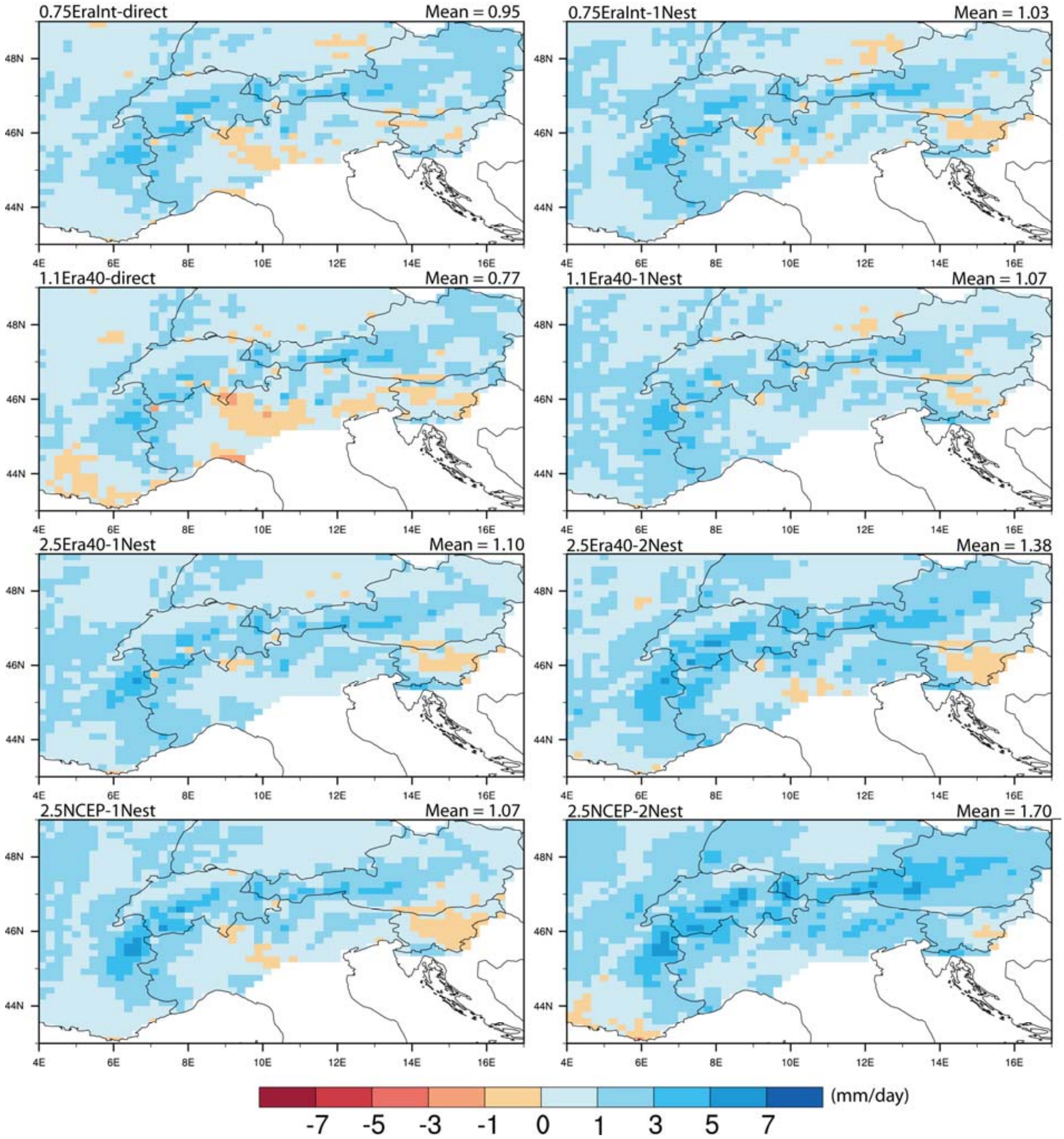


Figure 1: Precipitation bias of RegCM3 forced with different lateral boundary conditions for the year 1999.

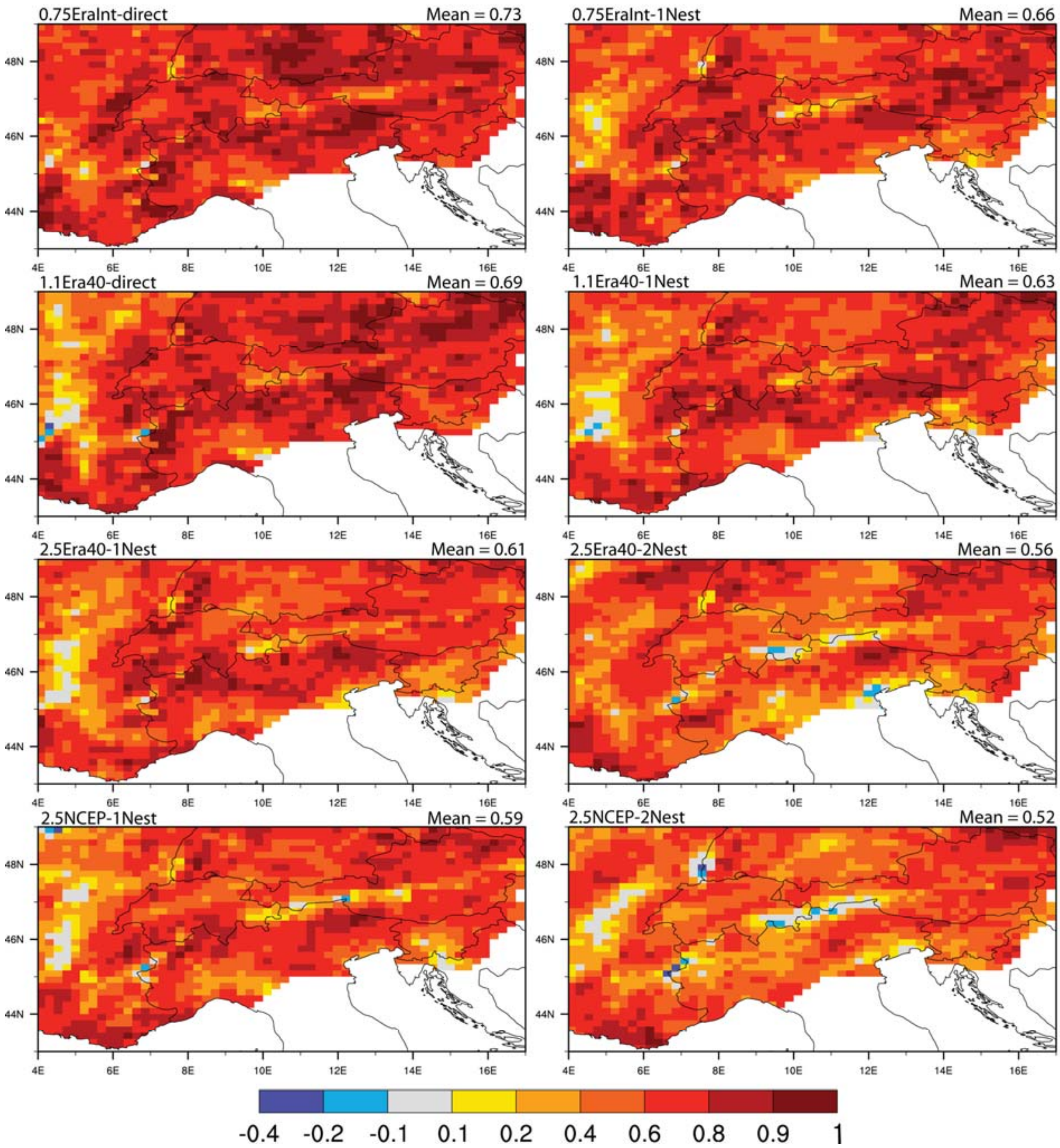


Figure 2: Temporal correlation of the monthly mean precipitation of RegCM3 forced with different lateral boundary conditions for the year 1999.

IMPROVEMENTS OF THE SUB-SCALE SCHEME

The main effect of the used sub-scale scheme is a better resolving of the topography within complex terrain and a more realistic representation of land-use. For this study we compare the results of a high resolution RCM with 10 km grid spacing and a sub-scale version with a grid spacing in the surface scheme of 1 km. Fig. 3 shows the different resolutions for the Alpine region and the differences area height. With 1 km resolution it is possible to resolve the major Alpine valleys more realistically. The higher resolution gives a better representation of the altitudes and thus the temperatures and snow accumulation and melt. With 10 km spacing an underestimation of low altitudes below 600m and also an underestimation of very high elevations above 2400 m is observed.

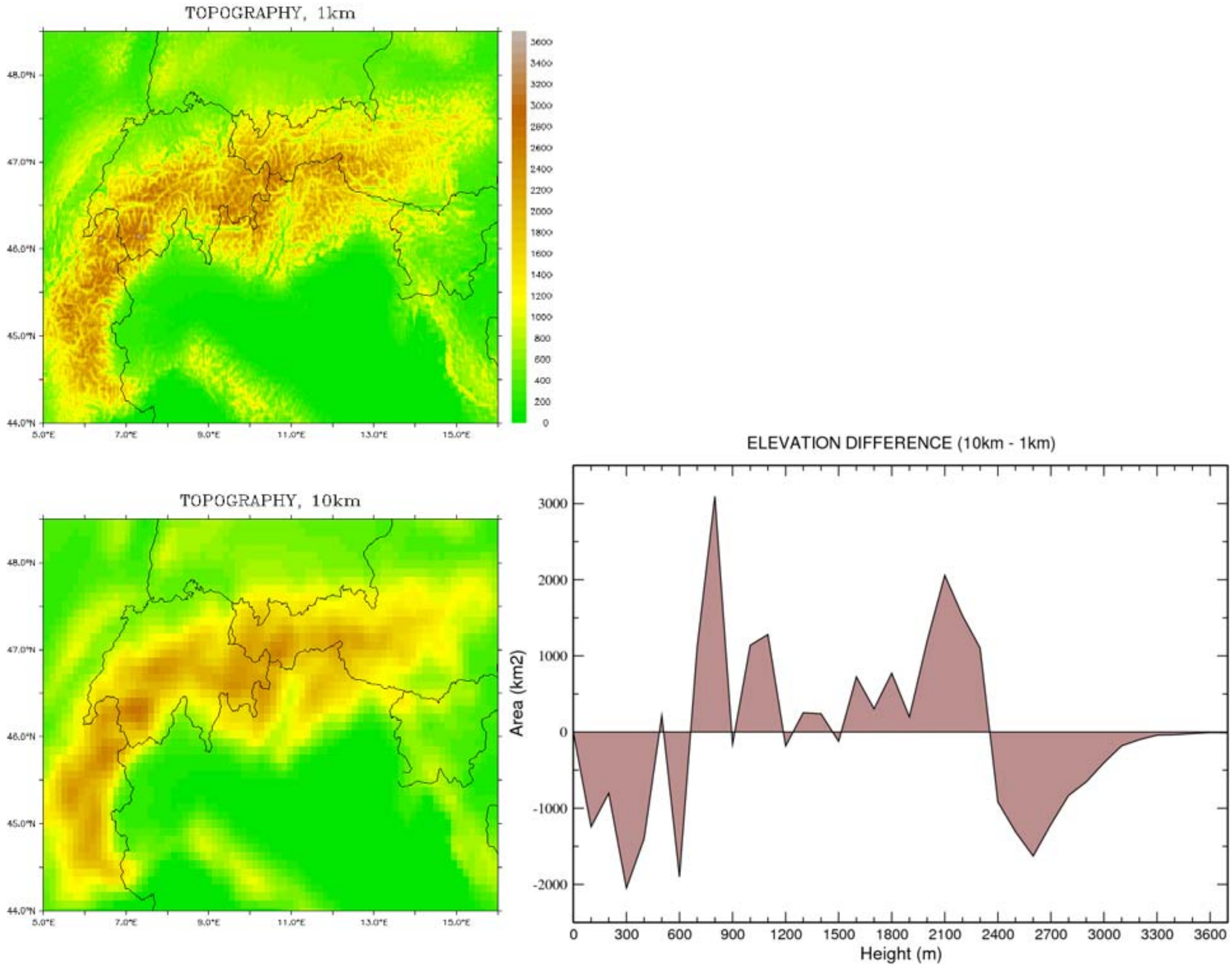


Figure 3: The Alpine region as seen by the model with 10 km and 1 km resolution. Area/elevation differences between the two resolutions.

The effects induced using the sub-scale scheme are a mixed signal from the elevation – and hence snow cover - and a better representation of the land use. As in the used surface scheme BATS only one land use category is used and not a fractional mixture as in other land surface models, the effect of land use can be quite high within mountainous regions. On single grid points, a realistic representation of land use can alter the energy fluxes more than the elevation effects, as the land categories in mountainous regions like forest, grassland, tundra or glacier have totally different characteristics. Especially at grid cells where the land category glacier exists (on the coarse scale or only in the fine scale) the differences between energy fluxes can be very high. The different representation of land use in the coarse and fine resolution is shown in Fig. 4 for a region on the Alpine main ridge. The white colour represents glaciers, grey is tundra and dark green is forest.

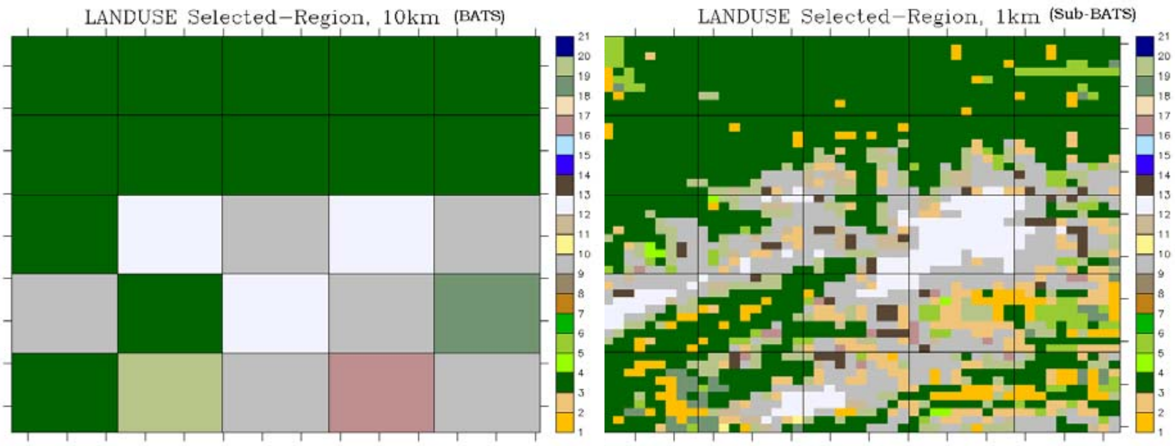


Figure 4: Different representation of the land use types in the coarse (left) and fine (right) resolution for a region on the Alpine main ridge.

ANALYSES AND FINDINGS

The sub-scale scheme elevation disaggregation mainly affects the temperature. In Fig. 5 the 2 m air temperature (left side) and the ground temperature (right side) are shown. The resolving of the Alpine topography can be readily seen in the temperature fields.

The use of a sub-scale surface scheme clearly improves the snow accumulation within the Alpine region. In Fig. 6 the results of the six year integrations are shown. On the left side the average of days with snow cover (snow water equivalent higher than 2 mm) is plotted. In the 1 km resolution the valley are captured quite well. For the whole Alpine domain the better representation of the topography leads to a decrease in snow covered area. This could also be seen on the right side of Fig. 6. Here the percentage of snow covered days is shown, but the values of the sub-scale scheme have been re-aggregated to the coarse grid. This value is directly linked to the albedo, as the snow covered area is modifying the albedo and in the sub-scale scheme the albedo for the coarse grid is averaged from the sub-scale grids. In the sub-scale run the fraction of snow covered area is approximately reduced by 10 percent. This has to have effects of the energy fluxes.

The effect of the sub-scale scheme on the energy fluxes within the Alpine region is quite complex. Due to locally different temperature distributions the convection is slightly modified, leading to changed cloudiness and even on (convective) precipitation. In Fig. 7 of the sub-scale scheme on the precipitation within the Salzach catchment is shown. There is no accumulative effect on the precipitation but a change in the convective precipitation, as the differences between the runs are highest in May and August and negligible during fall and winter.

For the Salzach catchment the subscale run increases the absorbed solar radiation up to 4 W/m². 'The increase show a clear annual cycle, which increases sharply in March, has a maximum in June and decreases roughly to zero in middle August. This highly corresponds with the differences in the snow covered area in the both runs. The strong reduction in August also indicates that this increase in absorption mainly depend on different snow cover and does not stand from the different land-use.

The non linear effects induced by the sub-scale scheme are shown in Fig. 9. Here the incident solar radiation is plotted. With the start of thermal induced convection in April the incident solar radiation is reduced in the sub-scale simulation. The highest difference of approximately 4 W/m² is found in May and June with a sharp decrease in July and August, but a relevant reduction is found till the middle of September. This can be explained by the modified temperature structures in the sub-scale run, increasing the convective induced clouds, which decreases the incoming solar radiation. This radiation reduction has the same magnitude and timing as the increased absorbed solar radiation due to a more realistic snow representation within the Salzach valley.

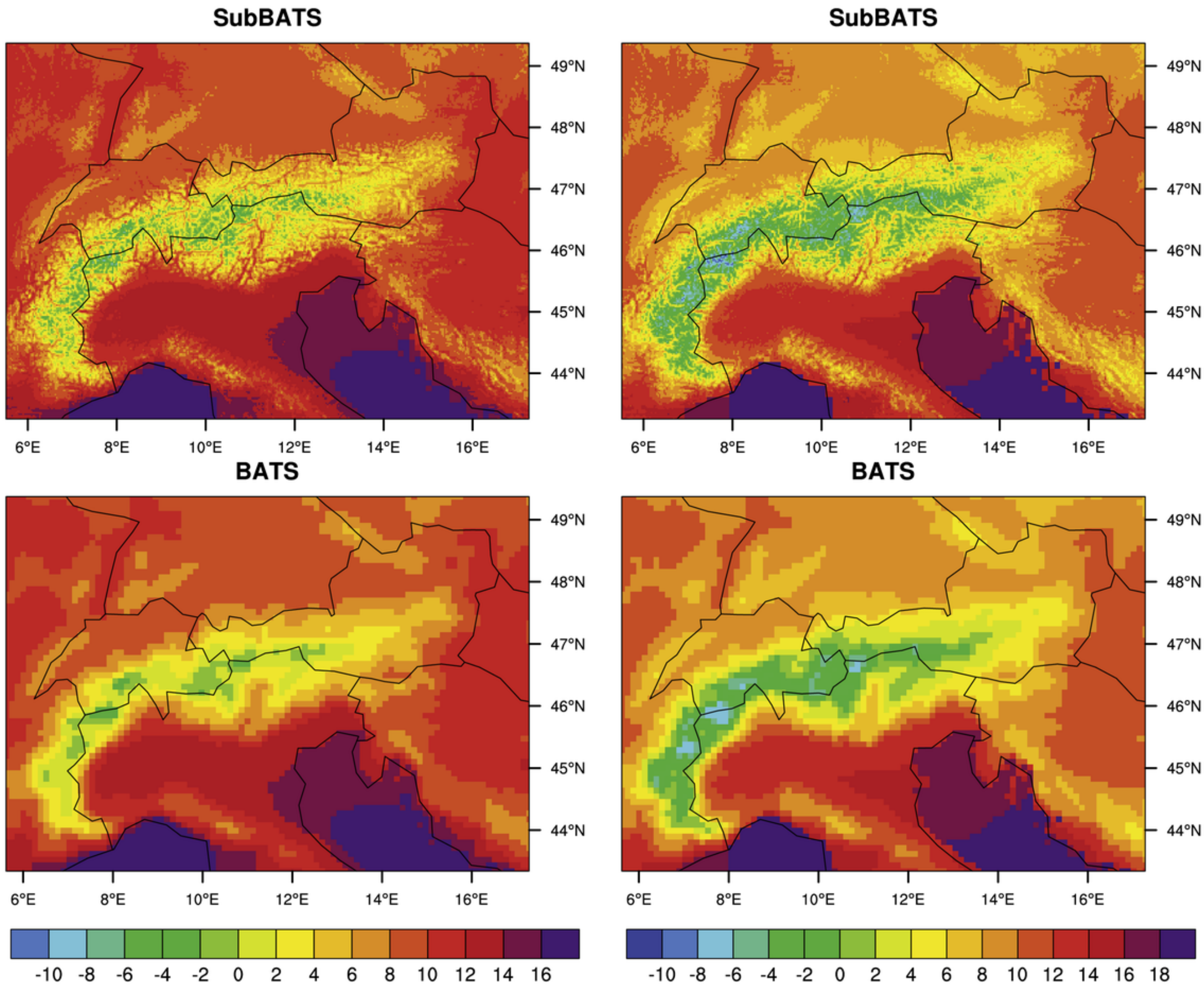


Figure 5: Average 2 m Temperature (left) and ground temperature (right).

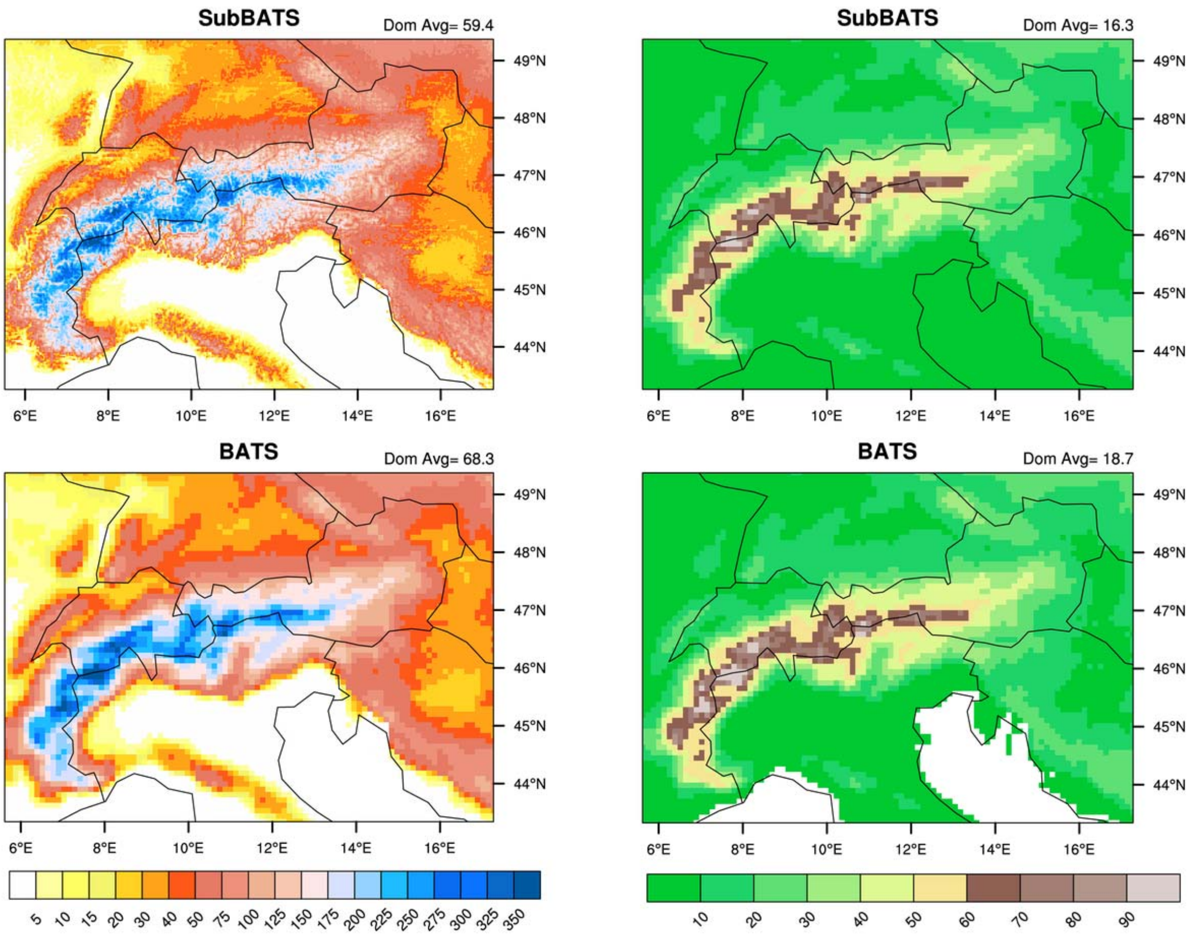


Figure 6: Average number of snow days (snow water equivalent > 2 mm) left and average fraction of snow cover. Lower panel is coarse (10 km) and upper panel fine (1 km) resolution. For the right side the fine scale is re-aggregated on the coarse grid.

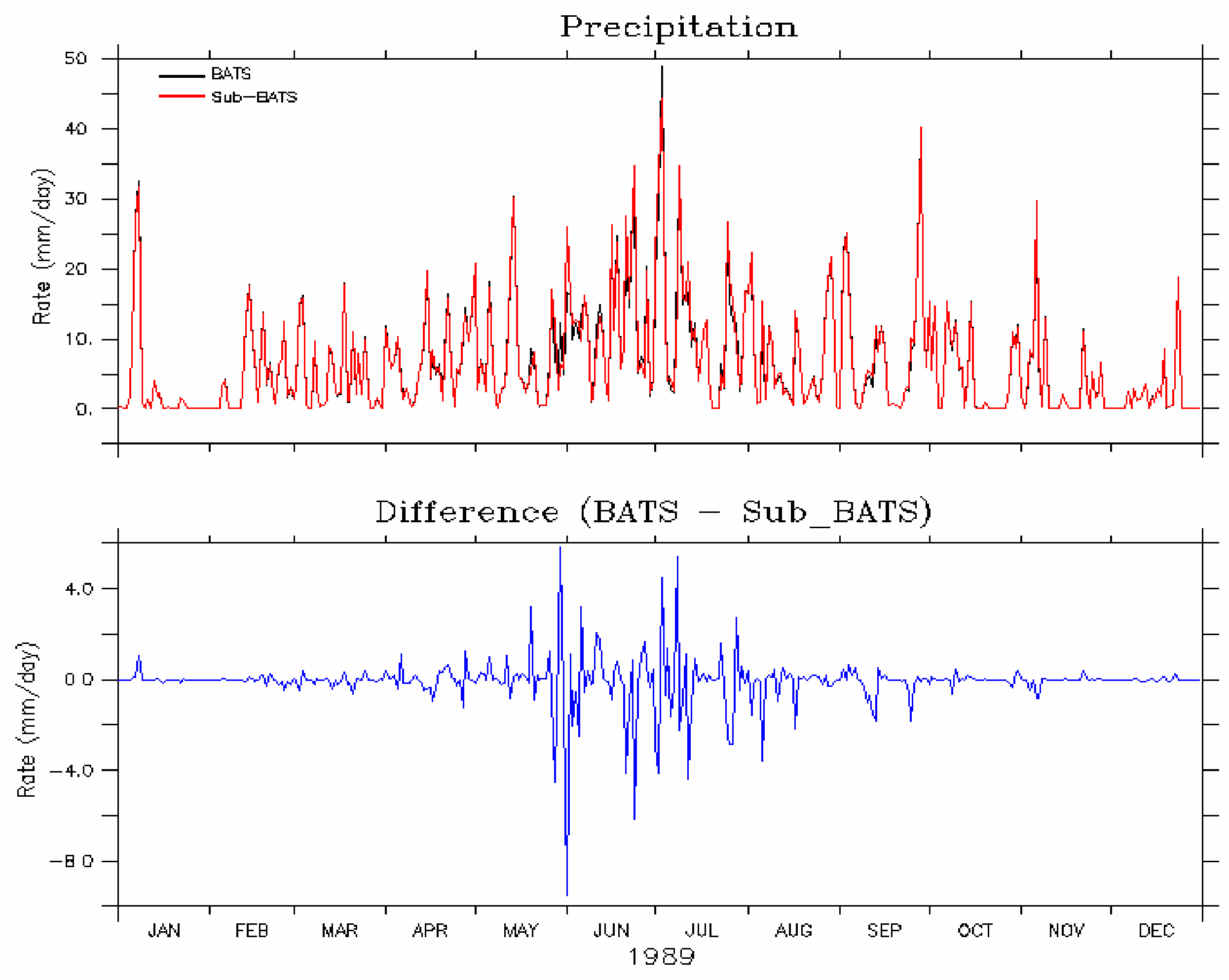


Figure 7: Precipitation within the Salzach catchment in Austria in 1989. Upper panel average daily rain rate for the coarse and sub-scale run. Lower panel difference between the runs.

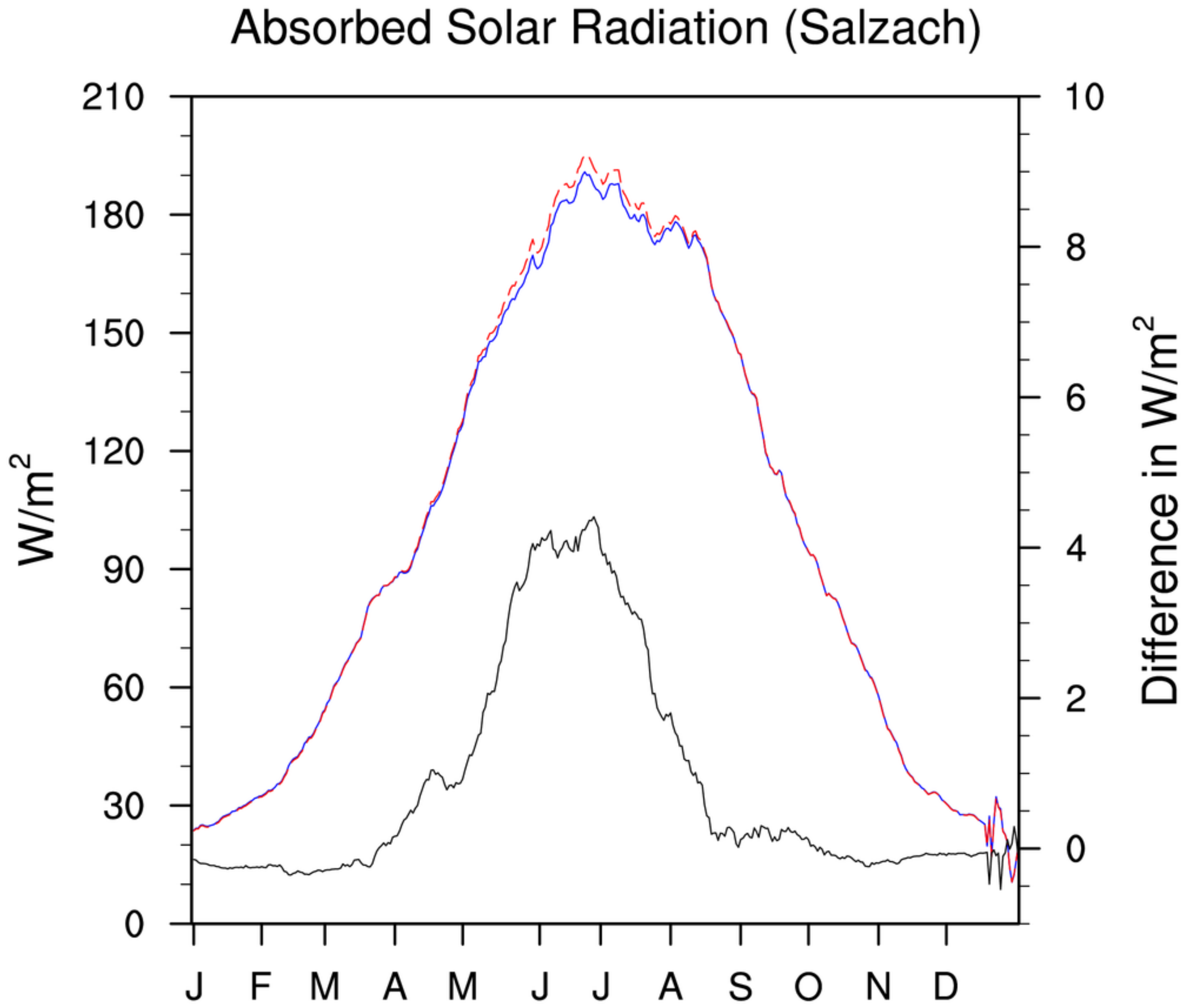


Figure 8: Average annual cycle of absorbed solar radiation within the Salzach catchment in Austria. Standard and sub-scale version and difference.

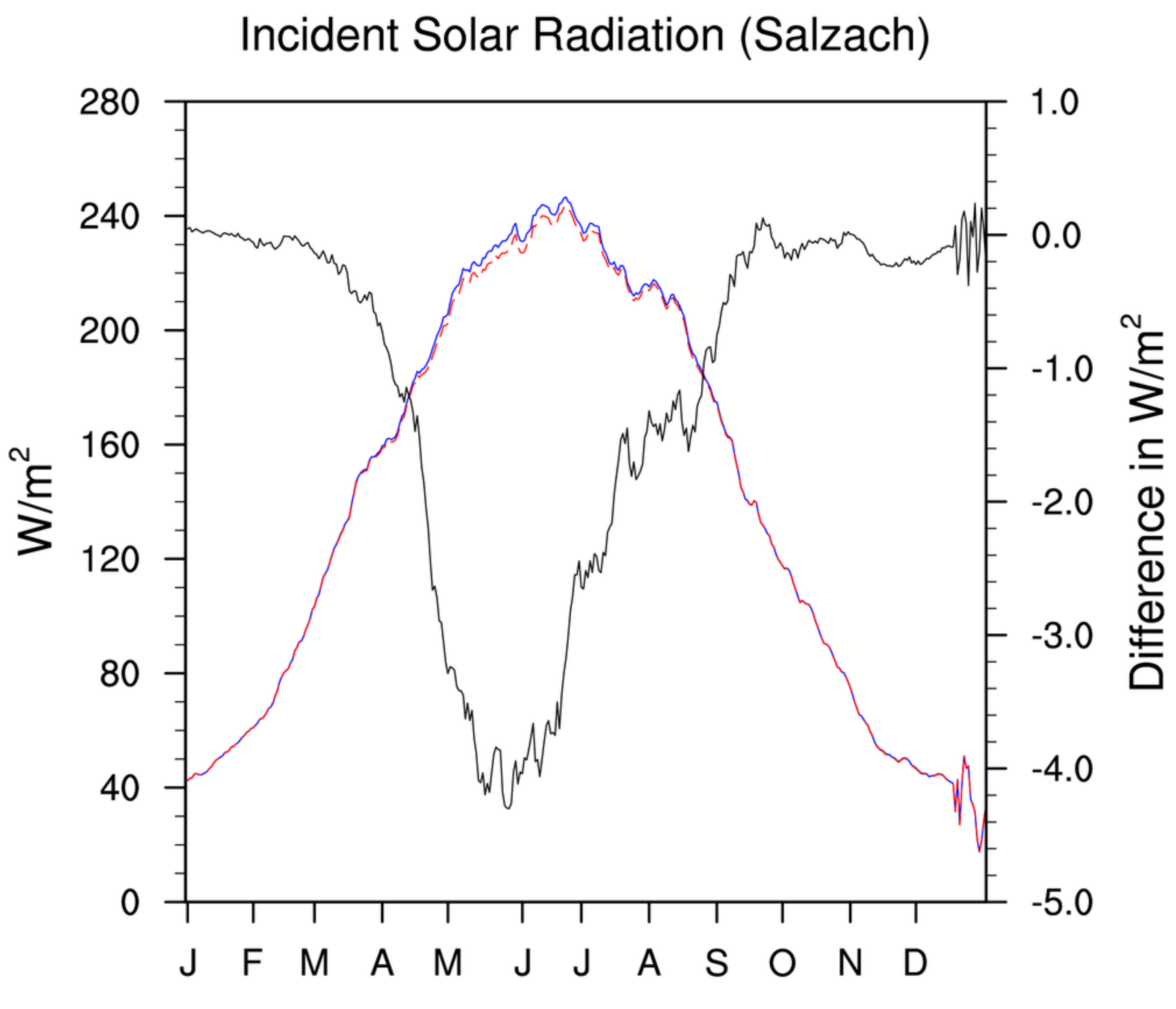


Figure 9: Average annual cycle of incident solar radiation within the Salzach catchment in Austria. Standard and sub-scale version and difference.

UNEXPECTED RESULTS

Some findings in the model results can not be explained by now and need further investigations. In general it looks as if snow melting is faster in the sub-scale scheme than in the standard version. In the coarse standard version we observe at 10 grid-points (1000 km²) snow accumulation during the whole year. This can be interpreted as a glacier formation (see Fig.10). This happens in altitudes between 2.200 and 2650m, which is much below the real snow line at ~ 3000 m. In the sub-scale scheme the glacier formation is decreased and only 360 km² show constant snow accumulation and this happens on grids with elevations between 2430 and 3580 m. For the standard version the glacier formation in low altitudes can be explained by an overestimation of the precipitation in this part of the Alps. The question is why we to not have more glacier formation in the sub-scale runs as the precipitation sums are quite similar in both runs. Here we have grids in elevations at and above 3000m, where in reality the accumulation areas of the glaciers could be found. So there should be continuous snow accumulation at these grid points. There seems to be a different treatment in the snow modelling between the standard version and the sub-scale scheme. Detailed studies indicate differences in the snow melting between the two versions, which should not be the case.

On the right side of Fig. 10 the effect of the sub-scale scheme on the observed solar radiation is shown. Beside snow also the land-use differences between the two runs are essential. The highest differences occur at grid cells where we have glacier formation in the coarse run and not in the fine resolution run.

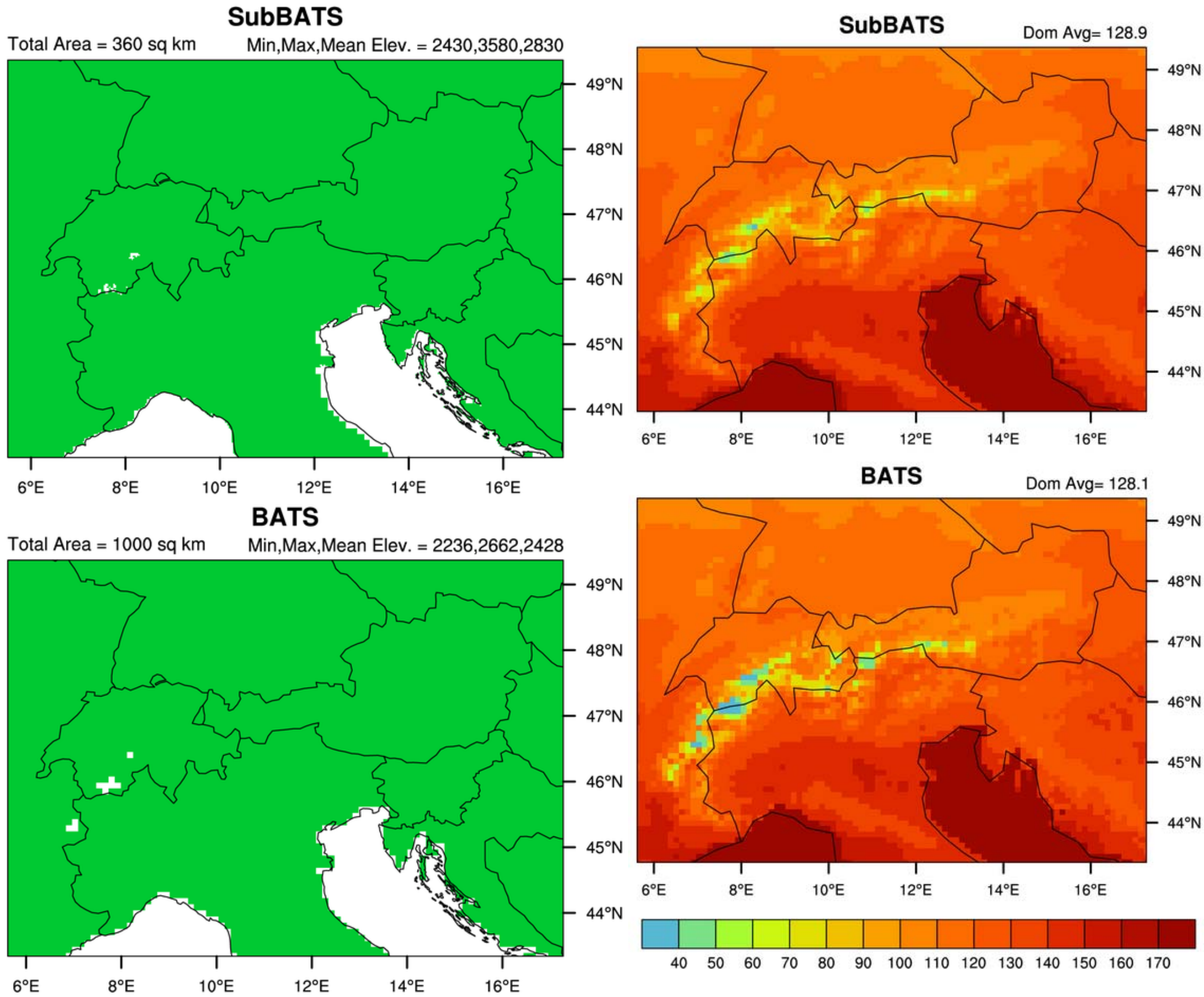


Figure 10: Left side: Areas with “glacier formation” in the coarse run (down) and the sub-scale run (up). Right side: Average absorbed solar radiation.

Study of the sensitivity of the regional climate model RegCM3 with respect to the convective scheme in use within the framework of WP2 for Central-Eastern Europe (Contribution by AUTH)

Results

Regional climate simulations have been performed over the greater European area for three individual years using three convective parameterizations, a) the Grell scheme with Arakawa-Schubert (AS) closure assumption, b) the Grell scheme with Fritsch-Chappell (FC) closure assumption and c) the MIT scheme. The comparison of the model results of near surface temperature with near surface temperature observations indicates a cold bias with both Grell scheme configurations (see Figure). This bias is significantly reduced when the MIT convective scheme is introduced, even during months of low convective activity (see Figure). The temperature differences between the Grell (with either AS or FC closure schemes) and the MIT scheme are largest in the lower troposphere extending up to 700 hPa. In terms of total precipitation, no systematical differences between Grell and MIT schemes are observed throughout the year for the European domain but the convective portion of total precipitation is greater in the MIT scheme simulations. For the central Eastern Europe region MIT scheme simulations generally produce more precipitation during the warm season than Grell simulations while for the southern Eastern Europe region the MIT precipitation enhancement is small and not systematically positive. It is evident that the cause of the differences between the convective schemes is the more intense convection in the MIT scheme configuration which in turn imposes a more effective drying of the atmosphere, less low-level clouds, more short-wave solar radiation absorbed from the ground and hence warmer low level temperatures.

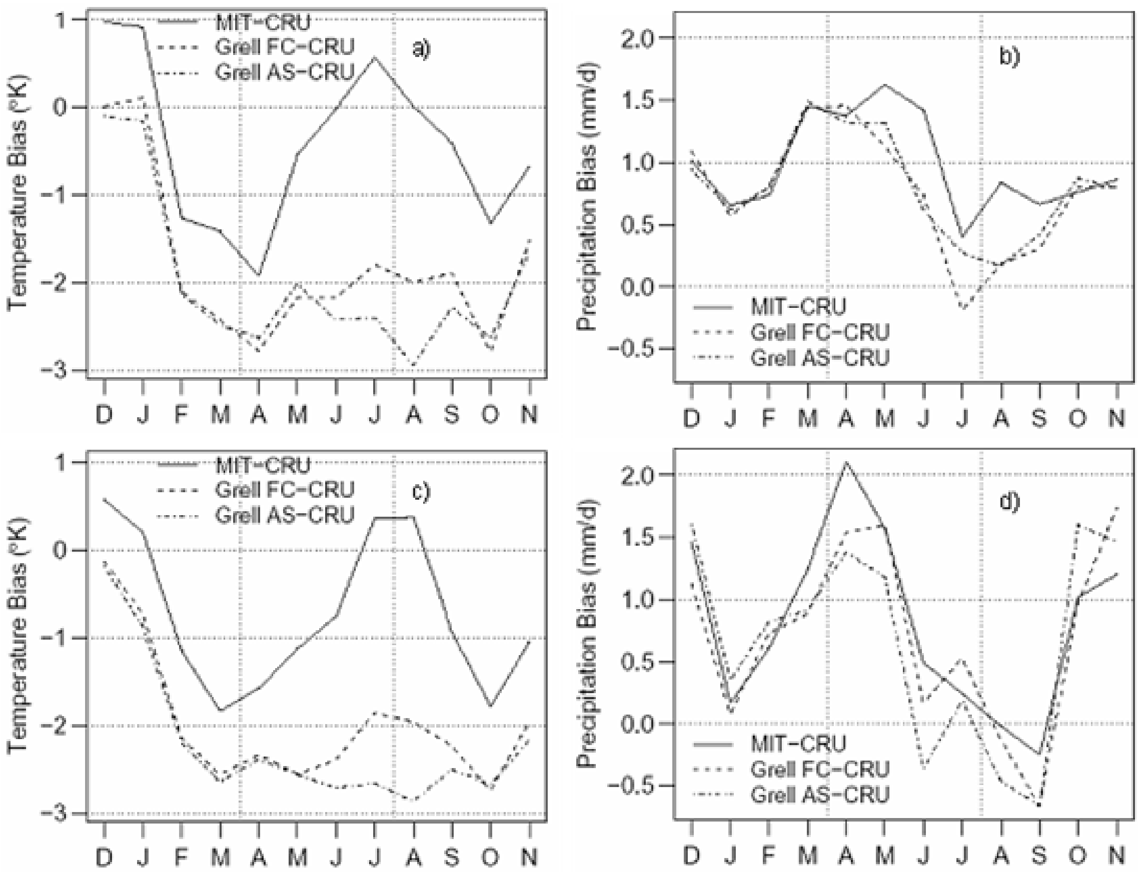


Figure Seasonal variability of the mean monthly bias of Temperature at 2m and Precipitation from the CRU gridded dataset for CEE and SEE sub-regions for the MIT, Grell-FC and Grell-AS convective schemes. The monthly values were calculated from the three study years.

Publications

Zanis P., C. Douvis, I. Kapsomenakis, I. Kioutsioukis and D. Melas, A sensitivity study of the Regional Climate Model (RegCM3) to the convective scheme with emphasis in central eastern and southeastern Europe, Theoretical and Applied Climatology, 97, 327–337, DOI 10.1007/s00704-008-0075-8, 2009.

Development of an alternative parameterization of the atmospheric boundary layer (Contribution by WUT)

Objectives

The primary goal of this work was to estimate sensitivity of climate projections within the atmospheric boundary layer (ABL) over central Europe. Since results of climate projections could significantly depend on a parameterization scheme within a climate model, the work was pursued through developing of an alternative (improved) parameterization of the atmospheric boundary layer (ABL) within the climate model (RegCM3).

Project Execution

In the first stage the improved parameterization of the convective boundary layer was developed. In 2009, based on an analysis of the results obtained during the first stage, it was concluded that the convective scheme needed to be augmented by a parameterization of the stable (nocturnal) conditions. Consequently, the second stage was executed in an initial form based on the large-eddy simulations and a single-column model. Finally the parameterization of both stable and convective cases was implemented within a single-column boundary layer model (developed especially for this project).

Non-local parameterization scheme of the convective boundary layer

An improved non-local parameterization scheme of the convective boundary layer was first developed. The parameterization involved a modified procedure (with respect to the scheme proposed by Troen and Mahrt, 1986, and followers) for calculating (i) the boundary-layer height, (ii) non-local terms for the momentum and scalar fluxes, and also (iii) entrainment fluxes for momentum and scalars. Figure 1 shows the agreement of the dimensionless heat flux H/H_o, and the dimensionless momentum flux R_x/u_*^2, obtained from the modified parameterization scheme, with results of the large-eddy simulation model (LES).

The convective parameterization scheme was first presented during the CECILIA meeting in Budapest (Feb. 4–6, 2008). In May 2008, preliminary tests of the improved parameterization scheme were run within the RegCM climate model at the International Center for Theoretical Physics (ICTP) in Trieste, Italy. Figure 2 shows some of the obtained profiles for the potential temperature, wind velocity components, and humidity, during July 3 2000 (at 6:00, 9:00, 12:00, 15:00, and 18:00 GMT), for the current (left) and for the modified parameterization (right), at a single grid point located in Europe (central Poland). It can be noticed that the profiles, obtained from the modified scheme for the potential temperature, show expected daily variations (contrary to the plot on the left), and that the velocity component *U* is more uniform with height (well-mixed). Changes of humidity are less pronounced, which could be caused by the fact that the entrainment flux was turned off in the modified schemed. On the other hand, in the actual RegCM scheme the non-local term is permanently turned off.

The convective scheme was described in a paper, entitled “Improving non-local parameterization of the convective boundary layer”, published in “Boundary-Layer Meteorology” (2009, 130, 57-69). Since the convective scheme is insufficient for a proper treatment of the diurnal variation of the atmospheric boundary layer, an additional scheme, describing processes in the nocturnal (stable) boundary layer was found necessary.

Improved parameterization scheme for stable (nocturnal) conditions

In the second stage, the improved parameterization scheme for stable (nocturnal) conditions, was developed. The scheme included cases of both stable and very stable stratification when the Richardson number is overcritical ($Ri > 0.2$) (the current RegCM model does not include such an option).

Figure 3 shows the flux-gradient expressions as functions of the Richardson number *Ri*, $f_m(Ri)=\tau/(\kappa zS)$ for the momentum flux, and $f_h(Ri)=H/[(\kappa zS)^2 S\Gamma]$ for the heat flux, where κ is the von Karman constant, z is height, S is the wind shear, and Γ is the potential temperature gradient. The above functions are employed within the scheme. The empirical functions $f_m(Ri)$ and $f_h(Ri)$ were evaluated based on measurements collected during the SHEBA experiment in the Arctic in 1999 (data provided by Dr. A. Grachev, NOAA) and CASES-99 experiment in Kansas). It should be mentioned that the resulting Prandtl number $Pr = K_m/K_h$ (not shown), defined as a ratio of the eddy viscosity and diffusivity, decreases with the increasing *Ri* (note that all previous schemes, in which *Pr* is assumed to increase with *Ri*, are incorrect). We also assumed that $Q/[(kzS)^2 Sg]=f_h(Ri)$, where Q is the humidity flux and g is the humidity gradient. The resulting paper, entitled "Evaluation of the flux-gradient relationship and gradient-based scaling in the stable boundary layer" has been accepted for publication in "Boundary-Layer Meteorology".

The scheme for stable condition was implemented, together with the convective scheme, within a single-column model, developed by the Sorbjan. The resulting paper, entitled "One-dimensional model of the atmospheric boundary layer", will be shortly submitted to Quarterly Journal of Royal Meteorological Society. The resulting code will be used to modify boundary layer subroutines in the RegCM model (work to be continued beyond the CECILIA project).

Final remarks

(i) The main accomplishment of this project is in developing of a new and improved boundary-layer scheme for climate models. The improved scheme includes corrected effects of the entrainment fluxes for wind, temperature and humidity in convective conditions, as well as the height of the mixed layer. It also involves improved physics in stable conditions (specifically, parameterization of very stable conditions, local approach, no need to specify the boundary-layer height).

(ii) Due to a reduced scope of this project, the parameterization could be tested only in a limited extent. A full evaluation of model sensitivity of climate projections to changes of parameterizations within the atmospheric boundary layer over central Europe could not be accomplished. The obtained preliminary results indicated, however, that the new scheme could significantly improve the performance of climate models within the atmospheric boundary layer.

Publications resulting from the project

Sorbjan Z. (2009): Improving non-local parameterization of the convective boundary layer. Boundary-Layer Meteorology, 130, 57-69, 2009.

Sorbjan Z. and A. Grachev (2009): Evaluation of the flux-gradient relationship and gradient-based scaling in the stable boundary layer. Accepted for publication in "Boundary-Layer Meteorology".

Sorbjan Z. (2009): One-dimensional model of the atmospheric boundary layer. To be submitted to Quart. J. Roy. Meteor. Soc.

Figures:

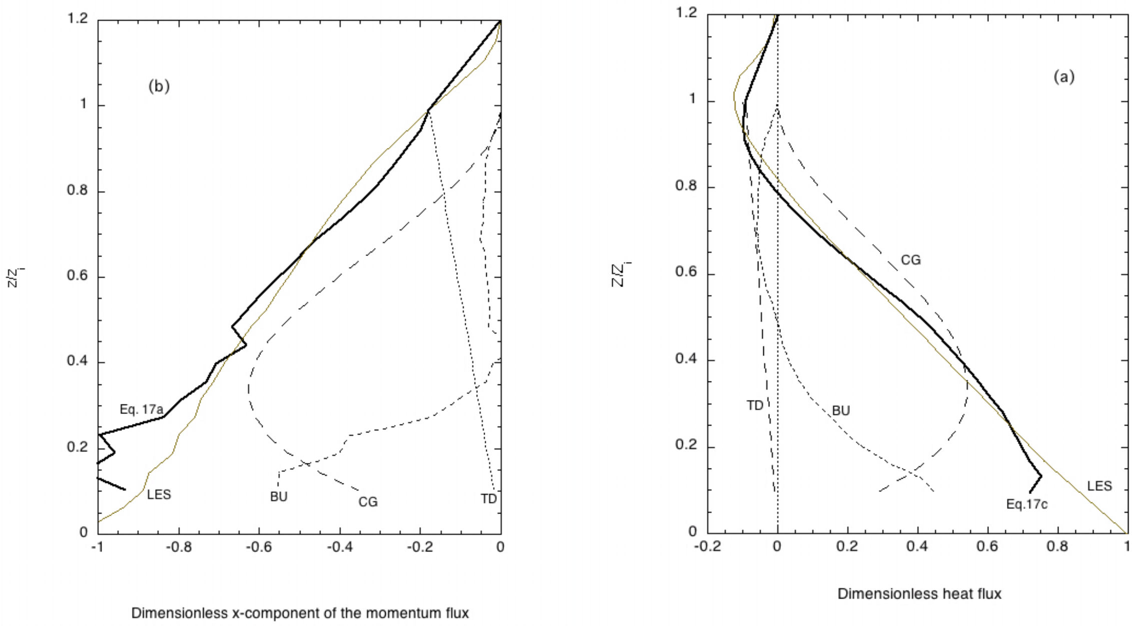


Figure 1. Dimensionless values of: (a) the dimensionless heat flux H/H_o, and (b) the dimensionless momentum flux R_x/u_*^2, obtained from the modified parameterization scheme (thin line) and from the LES model (thick line) of Sorbjan (2005). The local, countergradient and entrainment contributions to the fluxes are indicated by letters LOC, CTG, and ENT (Sorbjan, 2009).

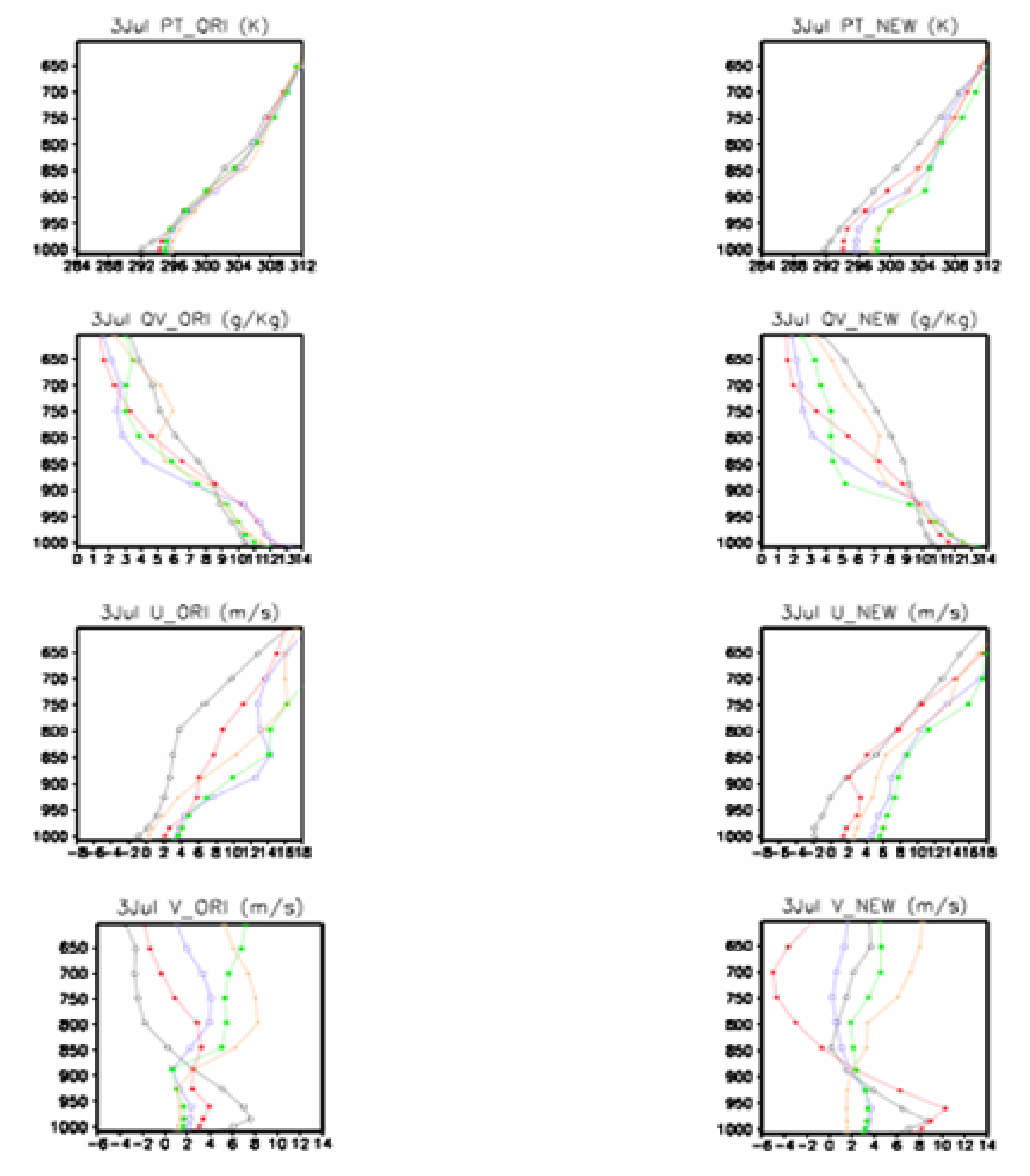


Figure 2 Profiles of the temperature, humidity, and wind components for the current (left) and for the modified ABL scheme (right), obtained at 6 (black), 9 (red), 12 (blue), 15 (green), and 18 GMT (orange) on July 3, 2000, at a gridpoint located in central Europe.

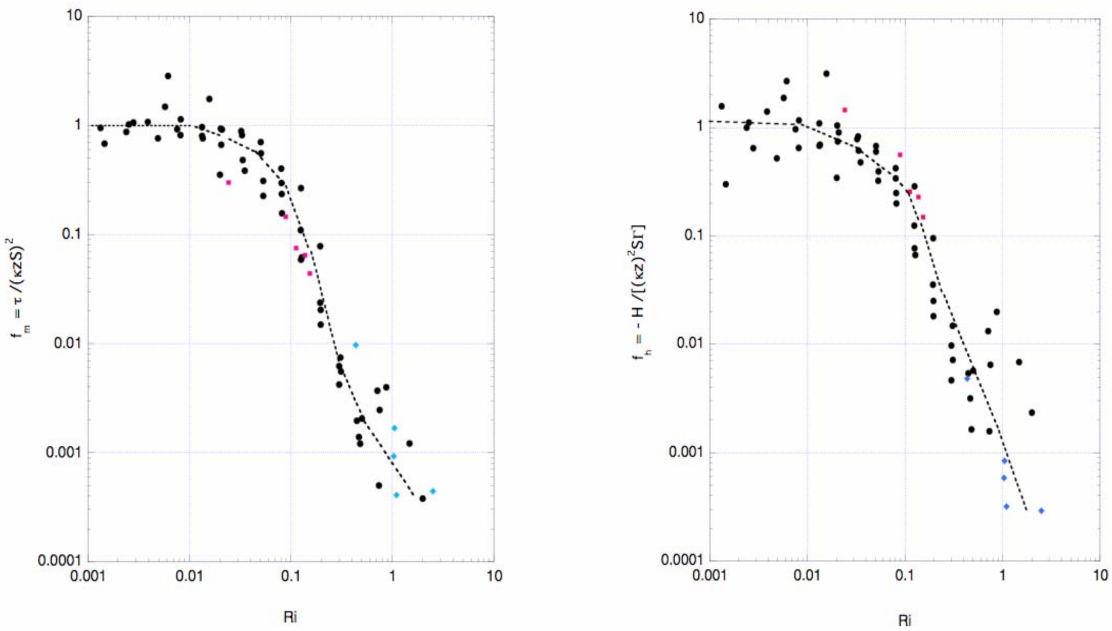


Figure 3. Dependence of the empirical dimensionless functions: (a) $f_m(Ri)$ for momentum τ, and (b) $f_h(Ri)$ for heat flux H, on the Richardson number Ri. The SHEBA data are marked by black points. The CASES-99 data are marked by red squares (strong turbulence) and blue diamonds (weak turbulence). Note that S is the local wind shear, Γ is the local temperature gradient, κ is the von Karman constant, and z is height (Sorbjan and Grachev, 2009).

Analysis of cloud formation proces in RegCM – fractional cloud cover experiment (Contribution by CUNI)

In addition to the application of the RegCM for regional climate change scenario construction as a basis for the CECILIA Project experiments have been performed in connection to the activities of WP2 dealing with further model development (D2.7) as well as for the WP4 where sensitivity of the models and some processes under the climate change was studied (D4.5). In RegCM application at CUNI, despite of the precipitation bias partly removed by modification done under cooperation of ELU and ICTP, the last decade simulation using this improved "beta" version has shown that there is still significant bias during winter season. Thus, at CUNI further experiments were carried out trying to find possible further reduction of precipitation bias. After some analysis of the processes it was believed that one important issue might be the choice of the threshold for cloud (and precipitable) water formation. Indeed, the value of 80% of relative humidity seemed to be too low. This is common value in the models of much coarser resolution and it aims to asure the possibility to give arise some clouds in the large gridbox eventhough the model air did not reach saturation. We expected, that increase of this value for the simulations in the resolution of 10km, might affect the cloud and precipitable water formation. Further on, we tried to introduce an s-shape function for this process representation.

First experiment of the set was based on adjusting the internal parameters *rh0land* (increasing its value from 0.8 to 0.9) and *rh0oce* (increasing the value from 0.9 to 0.95) in RegCM „beta" version, the second one described in this report used a modified function of fractional cloud coverage (s-shaped function, see Fig. 1) in RegCM „alfa" version. The period simulated was 1961 and values were averaged over the inner part of the CUNI domain (i.e., without the buffer zone). The Fig. 2 shows that the parameter adjustment results in precipitation reduction, but despite of the expectation of the large scale precipitation impact the effect can be seen mainly in spring and summer part of the year, but affecting rather convective precipitation in June and July, actually, in July the reduction occurs only in convective precipitation, while large-scale precipitation increases. Even in the summer months, the precipitation change is small (less than 10 %). Concerning the simple s-shape function choice shown in Fig. 1, the precipitation values decrease only in May, June and July and this is caused again by the decrease in convective precipitation. The differences are around or even more than 10 %, but not in the desired direction in the rest of the year (Fig. 3).

Comparing the two experiments, we see that the simple modification of fractional cloud cover parameters does not have the expected effect on precipitation. Although the modified parameters are connected rather with the large scale phenomena, both modifications end up affecting more the convection than large-scale precipitation. To get the intended bias reduction, further experiments and tests are planned together with more detailed analysis of the processes involved as well as radiation and cloudness outputs.

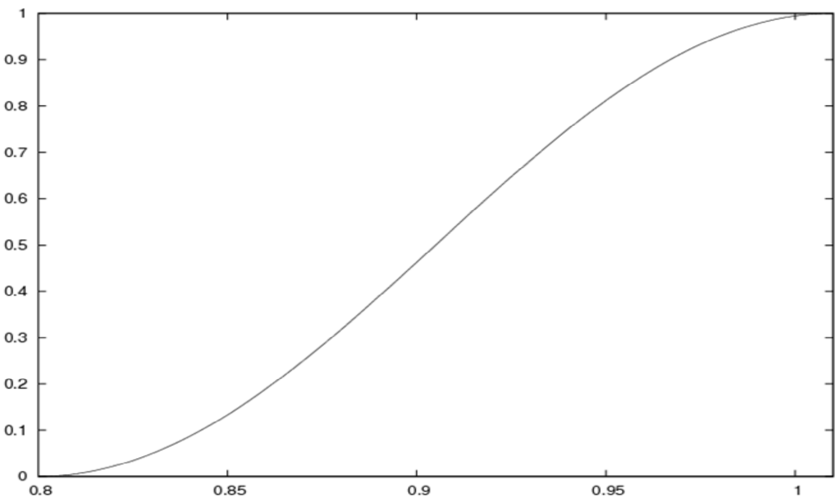


Figure 1: S-shaped function of fractional cloud coverage.

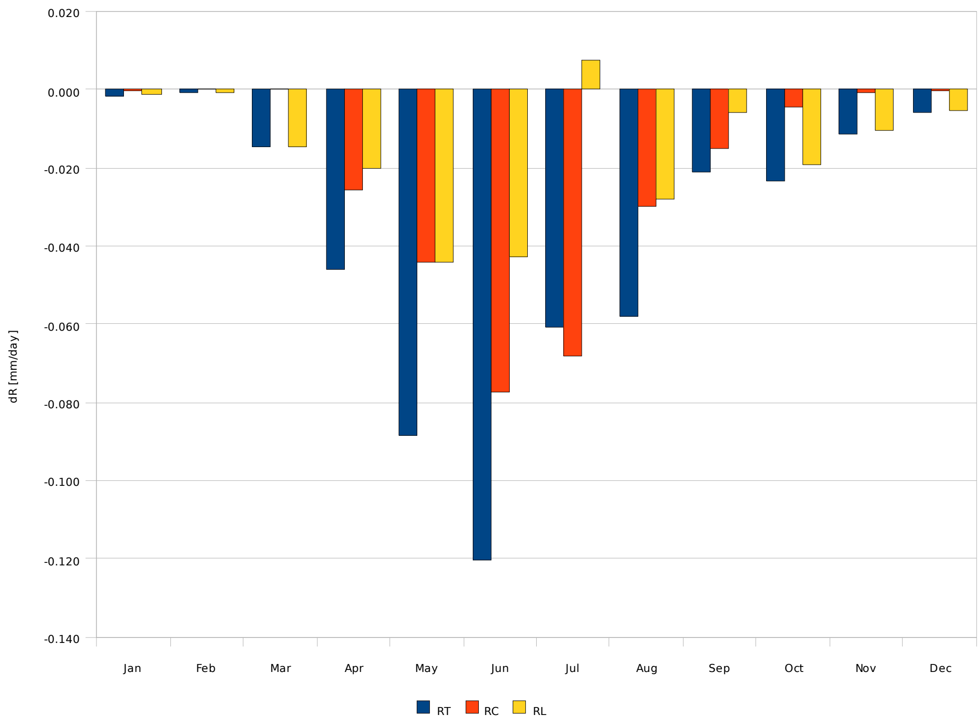


Figure 2: Precipitation change in adjusted model from original RegCM-beta, *rh0land* and *rh0oce* modified, RT = total precipitation, RC = convective precip., RL = large-scale precip.

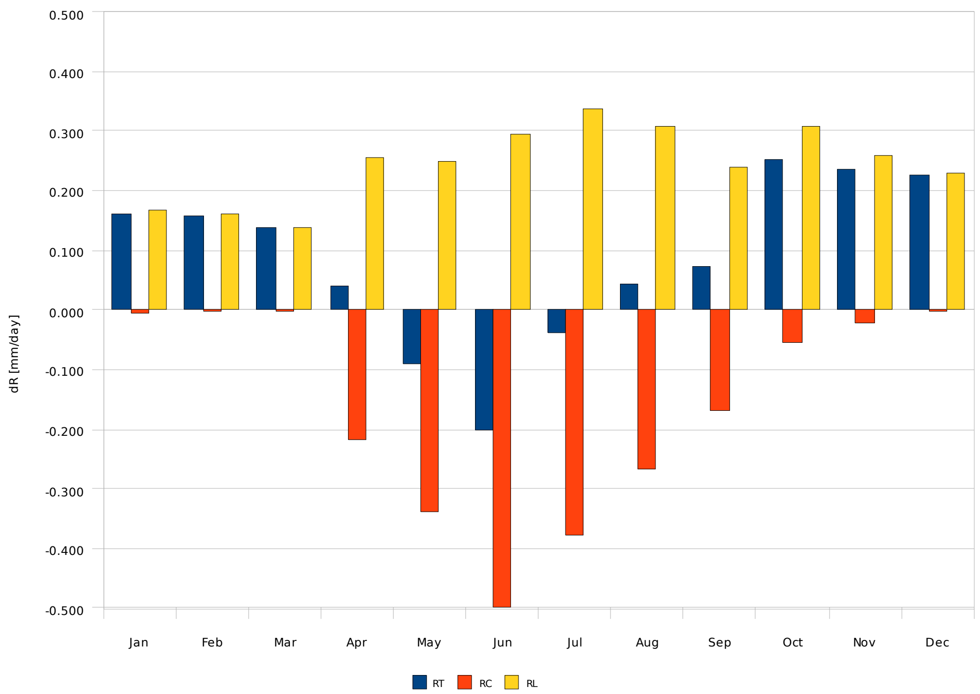


Figure 3: Precipitation difference between RegCM-alfa with original and modified fractional cloud coverage function.