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A sensitivity study of the Regional Climate Model (RegCM3) to the convective scheme with emphasis in central eastern and southeastern Europe

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Abstract Regional climate simulations have been performed over the greater European area for 3 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. This bias is significantly reduced when the MIT convective scheme is introduced, even during months of low convective activity. 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.

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1 Introduction

Regional climates are determined by the interactions of planetary/large-scale processes and regional-to-local-scale processes. The horizontal resolution of general circulation models (GCMs) is still of the order of a few hundred kilometers, which do not allow them to fully represent local and regional topographic characteristics and meso-scale weather features. Regional climate models (RCMs) are commonly used to dynamically downscale and enhance the regional climate information consistent with the large-scale circulation supplied by the driving GCM or by reanalysis data at the boundaries of the RCM.

An important step to study climate variability and climate change on a regional scale using RCMs is the evaluation of such models against environmental observations for different regions and testing of the sensitivity of the model with respect to the parameterizations of the important physical processes. One of the most important physical processes parameterized in an RCM is deep convection (e.g., Giorgi and Shields 1999; Liang et al. 2004). The importance of the representation of deep convection lies not only on its relation with most extreme weather events, such as severe storms and squall lines but also on its overall effect on the atmospheric dynamics and the climate through the determination of the vertical distribution of energy, water, and momentum. The vertical structure of the atmosphere in turn is a key factor in the formation of the clouds and the radiation budgets. An accurate representation of the hydrological cycle is therefore critical on the choice of convection scheme. The response of convection is further modified by boundary layer processes influencing the vertical transport of moisture out of the boundary layer (Gottschalk et al. 1999; Chaboureau et al. 2004; Jiao and Caya 2006; Tadross et al. 2006) and by entrainment mixing between convective plumes and the local environment (Derbyshire et al. 2004). Hence, deep convection plays a vital role for the determination of the water and the energy budget in global and regional climate. The Intergovernmental Panel on Climate Change (IPCC; IPCC (1995)) indicates that inclusion of different cloud representations could result in dramatic effects as much as to double the expected warming or to reduce it by half. The latest assessment report of the IPCC still indicates that the representation of cloud characteristics accounts for a large portion of the uncertainty in climate change predictions (IPCC 2007; Soden and Held 2006; Webb et al. 2006).

The dynamics of deep cumulus convection occur on scales far too small (typically at horizontal scales on the order of 1 km) to be resolved in present-day RCMs with typical grid resolution ranging from 10 to 60 km, despite the improved resolution with respect to GCMs. RCMs are thus required to parameterize convection, assuming that the statistical properties of convection can be deduced from the grid-scale (resolved) variables (e.g., Arakawa and Schubert 1974; Molinari and Dudek 1992). Numerous convective parameterizations have been developed that implicitly account for the associated subgrid exchanges of mass, heat, and moisture.

The differences in these formulations have a pronounced influence on numerical modeling results and vary with the convective environment being simulated (e.g., Giorgi and Marinucci 1996; Wang and Seaman 1997; Giorgi and Shields 1999).

The focus in this study is to investigate the sensitivity of the International Centre for Theoretical Physics (ICTP)

Regional Climate Model (RegCM3; Pal et al. 2007) to the choice of convective scheme with emphasis on central-Eastern Europe (CEE) and southeastern Europe (SEE). For this purpose, 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, (b) the Grell scheme with Fritsch-Chappell (FC) closure and (c) the MIT scheme.

2 Model description and methodology

The model used for the regional climate simulations in this work is RegCM3 (Pal et al. 2007), which was originally developed at the National Center for Atmospheric Research (NCAR) and has been mostly applied to studies of regional climate and seasonal predictability around the world (Giorgi et al. 2006). The dynamical core is based on the hydrostatic version of the NCAR-PSU Mesoscale Model version 5 (MM5) (Grell et al. 1994). The radiative transfer package is taken from the Community Climate Model version 3 (CCM3) (Kiehl et al. 1996). The large-scale cloud and precipitation computations are performed by Subgrid Explicit Moisture Scheme (SUBEX; Pal et al. 2000). Ocean surface fluxes are computed according to the scheme of Zeng et al. (1998) and the land surface physics according to Biosphere-Atmosphere Transfer Scheme (BATS; Dickinson et al. 1993).

A commonly used option for the convective scheme in RegCM3 is the Grell scheme (Grell 1993) implementing either the Arakawa and Schubert (1974) closure assumption (hereafter referred to as AS) or the Fritsch and Chappell (1980) closure assumption (hereafter referred to as FC), hereafter referred to as Grell-AS and Grell-FC, respectively. The newest cumulus convection scheme is the MIT convective scheme (Emanuel 1991; Emanuel and Zivkovic-Rothman 1999).

The Grell scheme is an entraining plume model considering clouds as two steady-state circulations, an updraft and a downdraft. Mixing occurs between the cloudy air and the environment at the bottom and at the top of the cloud while the mass flux is constant with height and no entrainment or detrainment occurs along the edges of the cloud. Due to the simplistic nature of the Grell scheme, AS and FC closure assumptions are adopted. Both Grell-AS and Grell-FC schemes used in this study achieve a statistical equilibrium between convection and the large-scale processes. AS assumes that convective processes stabilize the environment as fast as large-scale (non-convective) processes destabilize it. In AS, the difference between the buoyant energy available for convection and the total available buoyant energy (from convective and

non-convective processes) can be thought of as the rate of destabilization over time. FC assumes that clouds remove the available buoyant energy for convection in a given timescale. In the ICTP RegCM3, the Grell scheme with FC closure is the standard 'default' convective scheme.

The MIT scheme is an idealized model of subcloud-scale updrafts and downdrafts with a buoyancy sorting method, which determines the level of ascending or descending air parcels by finding the level where the liquid water potential temperature of the parcels equals that of the environment (Emanuel 1991). It assumes that mixing in clouds is highly episodic and inhomogeneous, rather than continuous as in the entraining plume models. Air that is entrained into the cloud from the environment is assumed to form a spectrum of mixtures of differing mixing fractions, which then ascend or descend to their level of neutral buoyancy. The mixing rate hypothesis in the MIT scheme allows cloud mass fluxes to adjust to cloud buoyancy and thus drive the system rapidly toward quasi equilibrium.

Three full-year simulations of the regional climate model RegCM3 were carried out for the periods December 1991 to November 1992, December 1996 to November 1997, and December 1999 to November 2000, forced by the $2.5° \times 2.5° \times$ L17 NCEP/DOE AMIP-II Reanalysis dataset with a spin -up time of 1 month for each one of the three yearly simulations. A European domain (30°W-60°E/20°N-65°N) with a grid resolution of 60×60 km was selected to dynamically downscale the NCEP/DOE AMIP-II reanalysis data (Fig. 1).

The simulations are carried out using three configurations for the convective scheme: (a) Grell-AS, (b) Grell-FC and (c) the MIT scheme. Emphasis in the analysis of the model results is given at two sub-regions, central-eastern Europe (CEE, 47°–52°N, 20°–30°E) and southeastern Europe (SEE, 40°–45°N, 20°–28°E), which are marked with white boxes in Fig. 1. The RegCM3 simulated monthly mean temperature at 2 m and precipitation are compared to the Climatic Research Unit (CRU)-gridded data base with 0.5° resolution (TS2.0; Mitchell et al. 2004).

3 Results

3.1 Comparison of near-surface temperature and precipitation

The most commonly studied meteorological variables in climatic studies are temperature and precipitation. In this section, the effect of the convection scheme choice on the model results of these two variables is presented and explained. Figure 2 shows that the simulations using MIT, Grell-FC, and Grell-AS convective schemes present similar seasonal variation of the mean monthly temperature at 2 m and precipitation for both CEE and SEE sub-regions. However, the MIT configuration model temperature results are higher than the two Grell configuration results throughout the year for both CEE and SEE with this difference maximizing in summer. Regarding the precipitation, no large systematic differences among the three model configurations were observed throughout the year, except for CEE, where MIT precipitation is higher compared to Grell-FC and Grell-AS from May until September. The high variability of the precipitation monthly values should be taken into consideration.

The seasonal variation of temperature monthly bias from the CRU-gridded dataset for CEE and SEE sub-regions for the MIT, Grell-FC, and Grell-AS convective schemes is shown in Fig. 3. In almost all of the cases, the MIT

Fig. 1 Topography of the European domain with a grid resolution 60 × 60 km. Emphasis in the analysis of the model results is given at two sub-regions, central-eastern Europe (CEE) and southeastern Europe (SEE), which are marked with *white boxes*
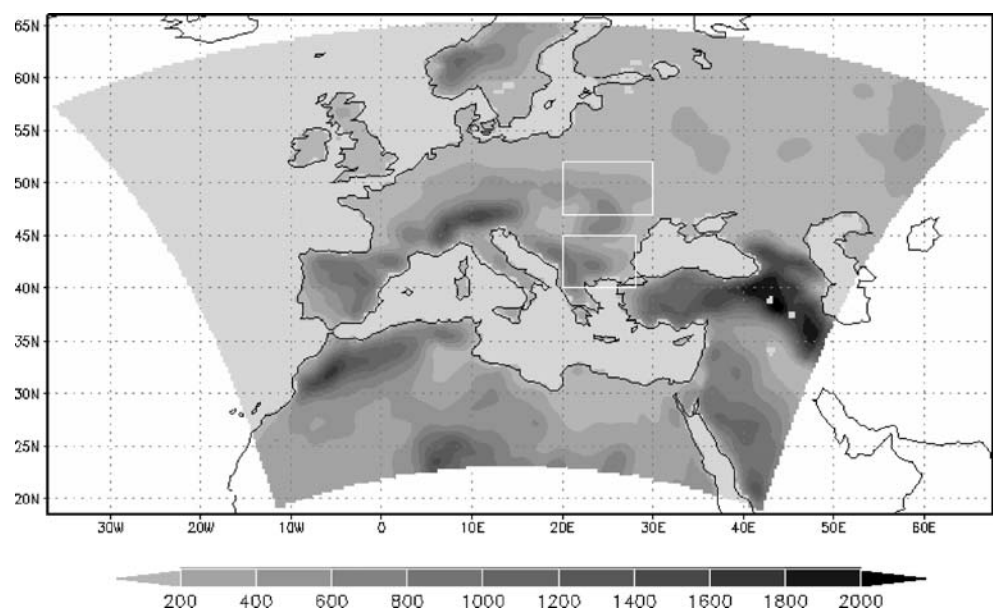
Fig. 2 Seasonal variation of the mean monthly temperature at 2 m and precipitation using MIT, Grell-FC, and Grell-AS convective schemes for CEE and SEE sub-regions. The monthly values were calculated from the three study years. The *error bars* denote the standard deviation of the monthly mean values and correspond from *left to right* to the MIT, Grell-FC, and Grell-AS convective schemes, respectively
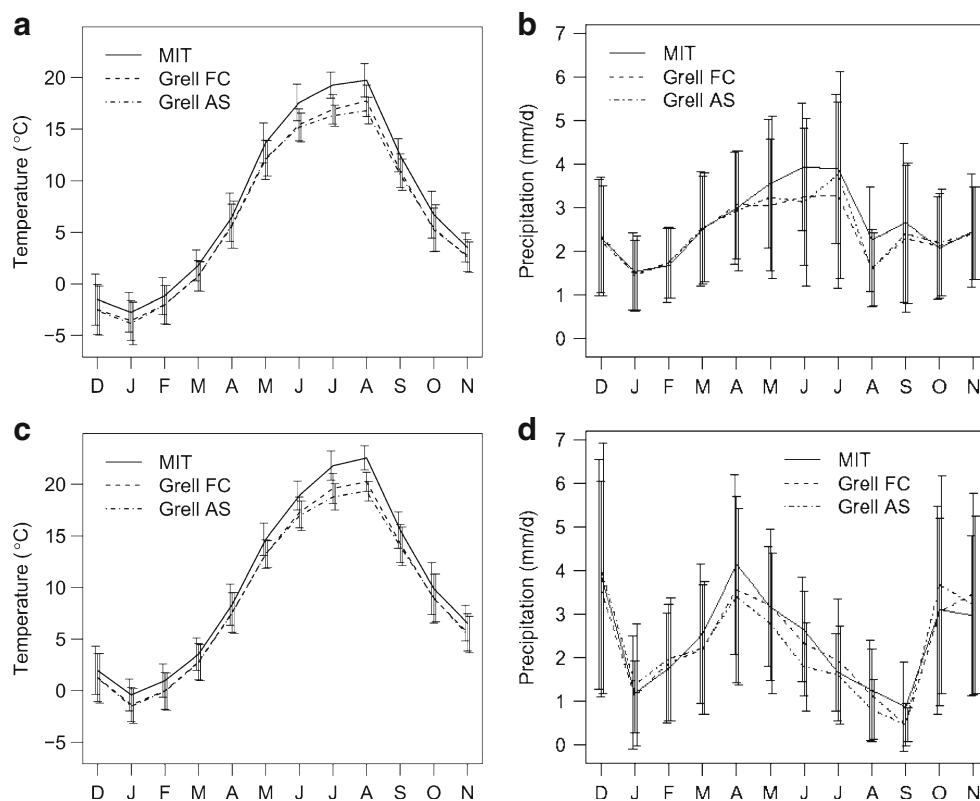
configuration model temperature results are closer to the CRU temperature than the two Grell configuration results, especially during the summer months (Fig. 3). The mean monthly near-surface temperature bias from CRU ranges from 0°C in winter months to −3°C in summer months for Grell-AS and Grell-FC configurations, while it ranges from 0.5°C to −2°C for the MIT configuration. Interestingly, the temperature cold bias in summer months from CRU in Grell-FC and Grell-AS simulations is significantly reduced by almost 2–3°C in the MIT simulations for both sub-regions. These results are in agreement with a recent sensitivity study to convective parameterization of RegCM3 for the Korea Peninsula by Im et al. (2008) who found that the MIT simulation in comparison with the Grell simulation is quantitatively in better agreement with the observed temperature estimates, indicating a substantial reduction in the cold bias.

As far as the seasonal variation of monthly total precipitation bias is concerned, no large systematic differences can be identified throughout the year (Fig. 3) except for the CEE sub-region where MIT shows a larger positive (wet) bias from the CRU data compared to Grell-FC and Grell-AS for the warm period from May to September.

The inter-model differences between the two Grell configurations and the MIT configuration (see Figs. 2 and 3) are larger than the differences between the two Grell configurations. There are almost no differences between Grell-AS and Grell-FC except during the warm season

(June to September) when Grell-FC is up to 1°C warmer. On the contrary, MIT predicts considerably larger near-surface temperatures in all months for both regions. The smallest differences between the configurations occur during the winter when convection is least active (~1°C) and the largest differences occur during the summer when convection is most active (~3°C).

The occurrence of the inter-model differences in near surface temperature and precipitation throughout the year is linked to the frequency and the way that the different convective schemes invoke deep convection. Overall, the greatest effect in the model results from the choice of the convection scheme is seen to occur during summer months when the deep convection is invoked most often. In general, RCMs exhibit greater skill at reproducing cold-season temperature and precipitation (e.g., Pan et al. 2001; Han and Roads 2004; Plummer et al. 2006) because the warm season climate is more controlled by mesoscale and convective-scale precipitation events, which are harder to simulate (Leung et al. 2003; Liang et al. 2004; Jiao and Caya 2006). Hence, since the greatest inter-model differences in near-surface temperature are seen in summer months, we give emphasis for the rest of the study on the month of July. The mean July bias of near-surface temperature from the CRU-gridded dataset over the European domain for the Grell-AS, Grell-FC, and MIT convective configurations is illustrated in the left column of Fig. 4.

Fig. 3 Seasonal variability of the mean monthly bias of temperature at 2 m 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
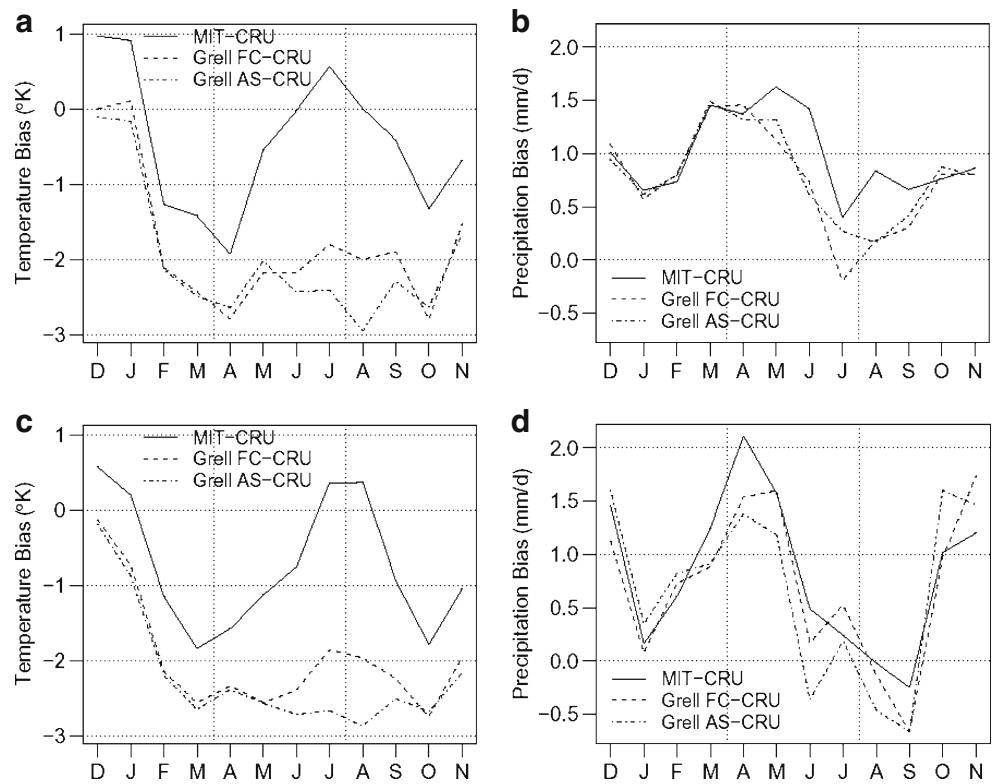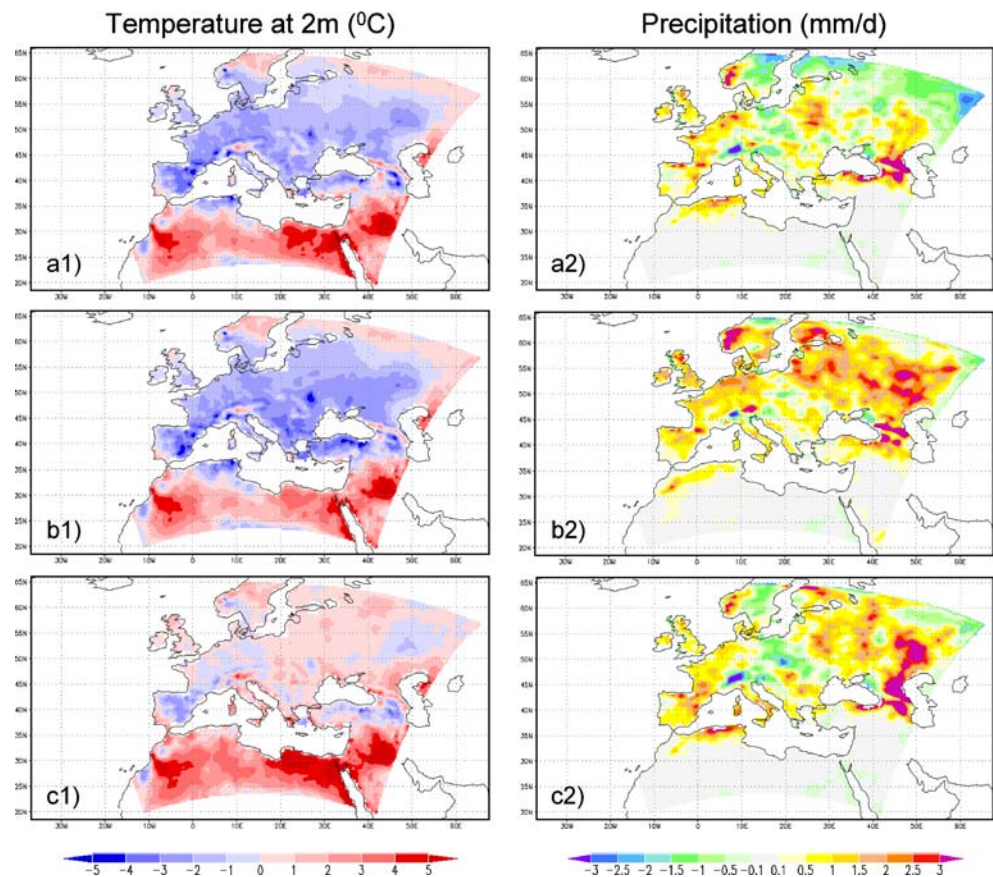

Fig. 4 Mean July bias of temperature at 2 m and total precipitation from the CRU-gridded dataset for the European domain for the Grell-AS (a1 and a2), Grell-FC (b1 and b2), and MIT (c1 and c2) convective schemes. All fields refer to mean July of the three study years

Comparison to the CRU data suggests that both Grell-AS and Grell-FC exhibit a large cold bias over most of the European domain and exceeds 3°C for large parts of Europe. This cold bias is largely reduced in the MIT simulation, especially in the areas of Balkan Peninsula at SEE and of CEE. All three configurations overestimate largely temperature over the Sahara and Arabian Deserts. This is likely due to the representation of the land surface physics (Steiner et al. 2008). The total precipitation biases display little systematic pattern among the three model configurations except for an underestimate over central Europe with the Grell configurations, and an underestimate over Scandinavia and Siberia with MIT.

It can be clearly seen from Fig. 5 when looking the total precipitation differences among the three model configurations that MIT is not wetter than Grell AS and Grell FC everywhere around Europe. Even though there are no large systematic differences in total precipitation among the three different convective configurations, there are substantial systematic differences in the fraction of convective precipitation to the total amount (Fig. 5). The July convective fraction and hence convective precipitation is greater over the European continent with MIT than with Grell-FC and Grell-AS. This implies that the non-convective precipitation is lower with MIT. However, over the

western Mediterranean, the convective precipitation in the Grell simulations is slightly larger than in the MIT simulation, while over the eastern Mediterranean and northern Africa, there are no significant differences, as there are very low amounts of precipitation at these regions in summer. Comparing Grell-AS and Grell-FC, it can be noted that convective fraction is slightly larger in the Grell-FC. These differences in convective and non-convective precipitation can be attributed to the fact that the non-convective precipitation is modified by the efficiency of the deep convection scheme in removing water vapor from the atmosphere.

The differences in convection between the Grell configurations are in agreement with other sensitivity studies. Zhang (2002) reports that the Arakawa-Schubert quasi-equilibrium assumption, which was developed largely based on observations in the tropical maritime environment, is not well suited for mid-latitude continental convection. Gochis et al. (2002) report that the use of Grell-AS convection scheme in MM5 produced a marked underestimation of convective precipitation over the northern North American Monsoon (NAM) region as it was triggered less frequently; however, in the southern NAM regions (south of 25° N), the simulation compared well to the observations.
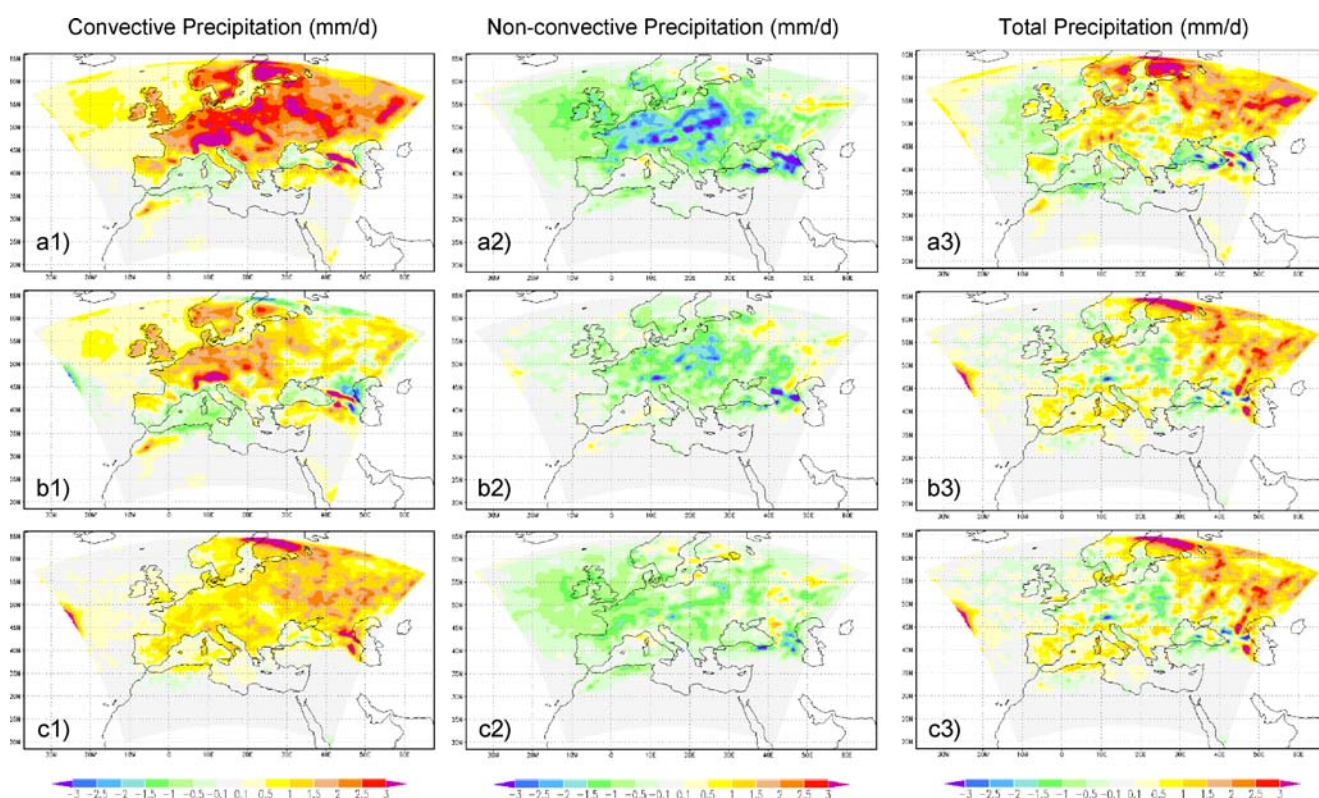

Fig. 5 Mean July inter-model differences of convective, non-convective and total precipitation over the European domain for the three convective schemes. **a** Upper panel: MIT-Grell-AS (a1, a2 and a3). **b** Middle panel: MIT-Grell-FC (b1, b2 and b3). **c** Lower panel: Grell-FC-Grell-AS (c1,c2 and c3). All fields refer to mean July of the three study years

In order to judge how efficiently the three convective configurations invoke deep convection, the time series of the 6-hourly convective and non-convective precipitation are compared (Fig. 6). Although the monthly amounts of total precipitation are fairly similar between the configurations, the daily variability is quite different. This is especially the case with MIT, where during the daytime a significant amount of precipitation is simulated while during the nighttime little or no rain is simulated. The SUBEX large-scale precipitation scheme on the other hand is inactive during the day in the simulations, but in some occasions it produces significant precipitation during the night although the monthly total of rainfall amount is much less than that produced by the convection. Grell-AS behaves in the opposite manner; the greatest portion of the precipitation is produced by SUBEX while neither convective nor large-scale precipitation display large diurnal variation. The Grell-AS scheme is invoked mainly at times when the SUBEX scheme is also invoked due to major weather systems. The Grell-FC simulation behavior lies in between MIT and Grell-AS showing a reduced diurnal variability compared to MIT.

Overall, the MIT convective scheme is triggered more frequently and is more efficient in generating convective precipitation than the Grell-AS and GrellFC schemes, while the non-convective precipitation produced by the SUBEX scheme generates the complementary amount so that the total precipitation in the three model configurations is comparable.

Another interesting result is deduced from Table 1, which shows how well MIT and Grell configurations compare to the observed interannual variation. Table 1 indicates that the MIT configuration captures better the observed (CRU) interannual variation between 2000 and 1992 in near-surface temperature and precipitation for both CEE and SEE than the Grell-AS and Grell-FC configurations. This is in agreement with a recent study by Segele et al. (2008) who evaluated the ability of RegCM3 to

capture the rainfall patterns and the interannual variations over the Horn of Africa.

3.2 Comparison of vertical profiles

An understanding of the convective vertical transport is obtained by comparing the vertical profiles of temperature, water vapor mixing ratio (WVMR), relative humidity (RH), fractional cloud cover (FCC) (Fig. 7). The first point to be highlighted is that the warmer near surface temperature of the MIT configuration compared to the two Grell configurations is maintained from the surface up to 800-hPa pressure level. Above this altitude, the temperature differences among the three schemes are negligible. The water vapor mixing ratio between approximately 800 hPa and 500 hPa is also greater in MIT than in both Grell-AS and Grell-FC for both sub-regions. Above 500 hPa, the WVMR values become very small and therefore similar. Below 800 hPa, the values between the three configurations are also similar for the CEE sub-region. However, for the SEE sub-region, MIT is slightly drier than Grell-AS and Grell-FC. Taking into account that WVMR is a conserved variable in transport processes for air masses (if there is no mixing with the surrounding air), these results suggest that the MIT convective scheme is more efficient in convecting humid air from the surface layers to the free troposphere (between 800 hPa and 500 hPa) than the Grell-AS and Grell-FC schemes.

The profiles of RH from the three convective schemes emphasize that the two Grell configurations produce considerably different results than the MIT configuration. More specifically, Grell-AS and Grell-FC are more humid near the surface (below 800 hPa) and less humid aloft (between 800 and 500 hPa) compared to MIT. This difference can be attributed to the differences in the profiles of temperature and specific humidity. The lower values of near-surface RH with MIT are mainly due to the higher temperatures (the saturation vapor pressure increases with
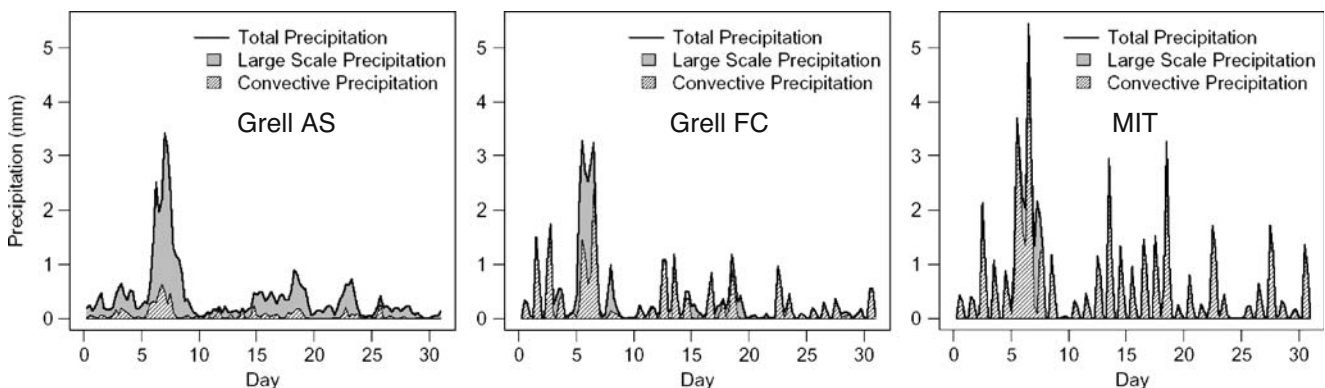

Fig. 6 Six-hourly time series of convective, non-convective, and total precipitation in CEE, in July of 1992 for the three convective schemes, Grell-AS, Grell-FC, and MIT

Table 1 Near-surface temperature and precipitation differences between July 2000 and July 1992 in observed (CRU) and modeled values (MIT, Grell-AS and Grell-FC) for the sub-regions CEE and SEE

Difference 2000–1992	CRU	MIT	Grell-AS	Grell-FC
Temperature (°C)				
CEE	−2.0	−2.2	−2.3	−3.1
SEE	2.3	2.3	3.5	2.8
Precipitation (mm/d)				
CEE	2.3	1.5	3.8	3.2
SEE	−0.7	−0.6	−0.6	−0.5

According to the CRU data, July 1992 was the warmest and driest for CEE and the coldest for SEE while July 2000 was the coldest for CEE and the warmest and driest for SEE among the three study years

temperature), while the higher values of RH with MIT in the free troposphere (between 800 and 500 hPa) can be attributed to the higher values of specific humidity caused by the more effective convection of humidity from the surface.

The high near-surface RH values for the Grell configurations indicate that during a large portion of July, the humidity is near saturation. This is not the case for the MIT configuration. The importance of this difference is relevant to the SUBEX scheme for the non-convective clouds and precipitation. The FCC is highly sensitive to RH and when the latter approaches 80% over land clouds begin to form (see Fig. 2 of Pal et

al. (2000)). Therefore, both Grell-AS and Grell-FC simulations show higher mean monthly values of cloudiness than MIT in the lower layers (between the surface and about 700 hPa) for both sub-regions (Fig. 7). This is a consistent feature for each individual year of simulation indicating that the low clouds are denser and more persistent in the Grell configurations than in the MIT configuration. Furthermore, it should be noted that Grell-AS generates denser low clouds compared to Grell-FC. These results are of major importance for the cloud-radiation feedback and hence the energy balance in the model simulations.

3.3 Cloud-radiation feedback

As can be clearly noted from the mean July inter-model differences among the three convective schemes of the total column fractional cloud cover (TCFCC) (Fig. 8), MIT is considerably less cloudy than Grell-FC and much less cloudy than Grell-AS scheme for most of the European domain. The largest differences between MIT and Grell-AS and Grell-FC occur over CEE and SEE. Investigating the inter-model differences in FCC fields at different model levels, it is evident that the main inter-model difference among the three convective schemes is in the generation of clouds between the surface and about 700 hPa. This has been already demonstrated in the discussion of Fig. 7 in Section 3.2.
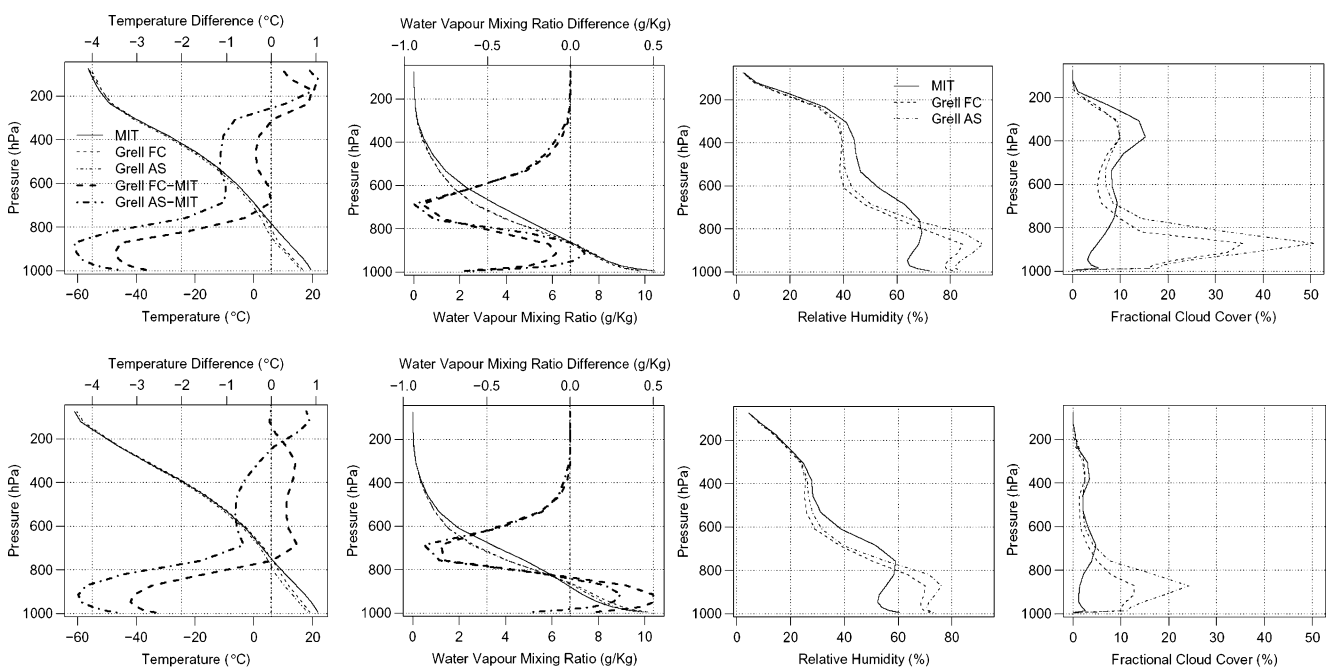

Fig. 7 Mean July vertical profiles of temperature, water vapor mixing ratio, relative humidity, and fractional cloud cover for both CEE (*upper panel*) and SEE (*lower panel*) sub-regions for the three convective schemes, Grell-AS (*dotted-dashed line*), Grell-FC (*dashed line*) and MIT (*solid line*). For the vertical profiles of temperature and water vapor mixing ratio, the differences of Grell-FC-MIT (*bold dashed line*) and Grell-AS-MIT (*bold dotted-dashed line*) are superimposed. Mean July values were calculated from the three study years
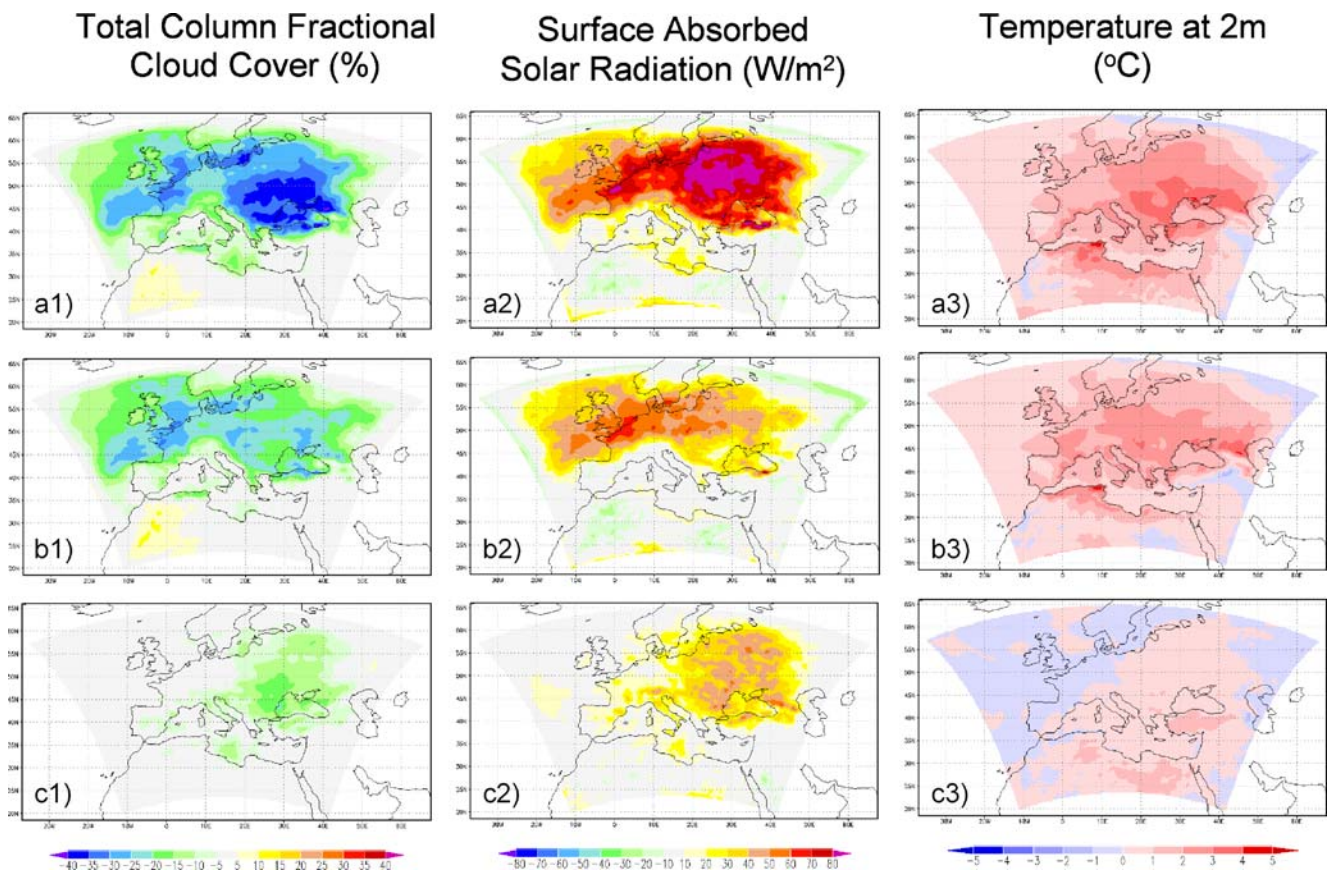
Fig. 8 Mean July inter-model differences of total column cloud cover, surface absorbed solar radiation, and temperature at 2 m over the European domain among the three convective schemes. **a** Upper panel: MIT-Grell-AS (a1, a2 and a3). **b** Middle panel: MIT-Grell-FC (b1, b2 and b3). **c** Lower panel: Grell-FC-Grell-AS (c1, c2 and c3). All fields refer to mean July of the three study years

The impact of the differences in cloud cover among the three convective schemes on the energy balance is clearly revealed from the mean July inter-model differences of the surface absorbed solar radiation (SASR), which is negatively correlated with TCFCC. The simulations implementing the MIT scheme absorb greater amounts of surface solar radiation than the simulations implementing the Grell-FC scheme over the largest part of Europe and even greater amounts than the simulations with the Grell-AS scheme, especially over CEE and SEE. Furthermore, comparing Grell-FC and Grell-AS, we also note a similar negative correlation between TCFCC and SASR for the eastern parts of Europe.

The reduced SASR with MIT results in warmer near-surface temperature by about 2 to 4°C and by about 1 to 3°C than Grell-AS and Grell-FC, respectively, over most of Europe with the largest differences in Eastern Europe. Furthermore, the simulations with Grell-FC scheme are warmer by about 0 to 1°C than the simulations with the Grell-AS scheme over the eastern parts of Europe. It should be noted that although the results shown here refer to mean July of the three study years, consistent results are found for each individual year.

Overall, the cause for the inter-model differences among the three convective schemes in near-surface temperature fields originates from the inter-model differences in generating low clouds thus affecting the surface energy balance. This stimulates a positive feedback mechanism. Stronger convection induces more effective drying of the atmosphere by means of convective precipitation. This results in less low clouds and hence more SASR, and causes more surface warming. This in turn enhances further thermal convection, resulting in positive feedback. In contrast, less convection reduces effective drying of the atmosphere, increases the relative humidity and low-level clouds in the lower to middle troposphere, and decreases SASR and surface warming, thus enhancing convective stability that further reduces thermal convection.

This positive feedback between warmer surface temperatures and atmospheric drying outweighs the classical negative feedback between surface temperature and cloudiness. In this negative feedback, an increase in surface air temperature could increase evaporation; this in turn would increase the extent of cloud cover, reducing SASR and surface temperature (Cubasch and Cess 1990; Pal and Eltahir 2001).

4 Conclusions

Regional climate simulations have been performed over the greater European area for three individual years using three convective parameterizations implemented in the ICTP Regional Climate Model, (a) the Grell-AS scheme, (b) the Grell-FC scheme and (c) the MIT scheme. The evaluation of the performed regional climate model simulations led to the following highlighted results:

- The greatest differences in near-surface temperature among the three convective schemes occur during the warm season with the MIT scheme producing the warmest conditions. The differences in near surface temperature between the two Grell model configurations are moderate with the Grell-FC scheme producing somewhat higher temperatures compared to the Grell-AS scheme. The inter-model differences in mean monthly temperature are confined in the lower troposphere between the surface and 700 hPa. When comparing with the CRU data it is evident that with the use of the MIT scheme, the cold temperature bias present in both Grell-AS and Grell-FC schemes is significantly reduced throughout the year.

- Although the choice of the convective scheme does not indicate a systematic influence on the total monthly amount of precipitation (except the small MIT wet bias in CEE from May to September), it does affect greatly the partitioning between convective and non-convective precipitation, the vertical profiles of humidity and the amount of low clouds with the MIT scheme being the most effective at convection. As a result, mean monthly values of relative humidity and cloud fractional cover in the lower troposphere are reduced by the use of the MIT scheme compared to the Grell-FC and Grell-AS schemes.

- The increase of temperature in the lower tropospheric levels when using the MIT scheme (in comparison with the Grell-FC and Grell-AS schemes) is attributed to a feedback mechanism that involves the large-scale precipitation and cloud scheme as well as the radiation scheme. More specifically, the reduction in low level clouds in the MIT simulations causes an increase of the surface absorbed solar radiation, and therefore higher near-surface temperature. This stimulates the following positive feedback mechanism: stronger convection induces more effective drying of the atmosphere by means of convective precipitation, less stratiform clouds, increased surface absorbed solar radiation and increased surface warming. This further enhances the thermal convection resulting in positive feedback.

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