



This discussion paper is/has been under review for the journal Geoscientific Model Development (GMD). Please refer to the corresponding final paper in GMD if available.

Evaluating the performance of SURFEXv5 as a new land surface scheme for the ALADINcy36 and ALARO-0 models

R. Hamdi¹, D. Degrauwe¹, A. Duerinckx^{1,2}, J. Cedilnik³, V. Costa⁴, T. Dalkilic⁵, K. Essaouini⁶, M. Jerczynki⁷, F. Kocaman⁵, L. Kullmann⁸, J.-F. Mahfouf⁹, F. Meier¹⁰, M. Sassi¹¹, S. Schneider¹⁰, F. Váňa^{12,*}, and P. Termonia^{1,2}

¹Royal Meteorological Institute, Brussels, Belgium

²Department of Physics and Astronomy, Ghent University, Ghent, Belgium

³Meteorological Office, Slovenian Environment Agency, Ljubljana, Slovenia

⁴Instituto de Meteorologia, Lisbon, Portugal

⁵Turkish State Meteorological Service, Ankara, Turkey

⁶CNRM, Direction de la météorologie nationale, Casablanca, Morocco

⁷Instytut Meteorologii i Gospodarski Wodnej, Krakow, Poland

⁸Hungarian Meteorological Service, Budapest, Hungary

⁹CNRM/GAME, UMR3589, Météo-France, CNRS, Toulouse, France

¹⁰Zentralanstalt für Meteorologie und Geodynamik, Vienna, Austria

¹¹Institut National de la Météorologie, Tunis, Tunisia

¹²Czech Hydrometeorological Institute, Prague, Czech Republic

* now at: ECMWF, Reading, UK



Received: 17 June 2013 – Accepted: 24 June 2013 – Published: 25 July 2013

Correspondence to: R. Hamdi (rafiq.hamdi@meteo.be)

Published by Copernicus Publications on behalf of the European Geosciences Union.

GMDD

6, 4053–4104, 2013

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Abstract

The newly developed land surface scheme SURFEX (Surface Externalisée) is implemented into a limited area numerical weather prediction model running operationally in a number of countries of the ALADIN and HIRLAM consortia. The primary question addressed is the ability of SURFEX to be used as a new land surface scheme and thus assessing its potential use in an operational configuration instead of the original ISBA (Interactions between Soil, Biosphere, and Atmosphere) scheme. The results show that the introduction of SURFEX either gives improvements or neutral impact on the 2 m temperature, 2 m relative humidity, and 10 m wind. However, it seems that SURFEX has a tendency to produce higher maximum temperatures at high elevation stations during winter daytime which degrades the scores. In addition, surface radiative and energy fluxes improve compared to observations from the Cabauw tower. The results also show that promising improvements with a demonstrated positive impact are achieved by introducing the Town Energy Balance (TEB) scheme. It was found that the use of SURFEX has a neutral impact on the precipitation scores. However, the implementation of TEB within SURFEX for a high resolution run tends to cause rainfall to be locally concentrated and the total accumulated precipitation decreases obviously during the summer. One of the novel features developed in SURFEX is the availability of a more advanced surface data assimilation using the Extended Kalman Filter. The results over Belgium show that the forecast scores are similar between the Extended Kalman Filter and the classical Optimal Interpolation scheme. Finally, concerning the upper air scores, the introduction of SURFEX either gives improvement or neutral impact in the free atmosphere.

1 Introduction

Numerical weather prediction models need parameterizations of the surface processes to estimate the fluxes for physical budgets such as sensible heat, latent heat,

GMDD

6, 4053–4104, 2013

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



momentum and radiation between the upper atmosphere and the surface features such as soil, vegetation and sea. The budgets depend strongly on the characteristics of the underlying surface, and with the increase of resolution in most applications up to kilometer scales, the role of the surface interactions in atmospheric models is steadily increasing.

The international ALADIN (Aire Limitée Adaptation Dynamique Développement International) consortium (ALADIN, 1997), has over the past two decades developed a limited-area model (LAM) to serve the specific needs of its participating partners. Currently this consortium consist of 16 partners roughly covering Europe and the Mediterranean region, including some North African countries. The code of the ALADIN model (Bubnová et al., 1995) is mostly shared with the code of the French global ARPEGE (Action de Recherche Petite Echelle Grande Echelle) model and the IFS (Integrated Forecast System) of ECMWF (European Centre for Medium-Range Weather Forecasts). The lateral-boundary conditions (LBCs) of the operational ALADIN model configurations are imposed by the Davies scheme (Davies, 1976; Radnóti, 1995; Termonia et al., 2012) at regular time intervals of 3 h (Termonia et al., 2009) with LBC data provided by either ARPEGE, IFS or a bigger ALADIN domain. For the present study the version of Radnóti (1995) is used.

ALADIN has been further developed with a physics parametrization package called ALARO that has been designed specifically to be run at convection permitting resolutions. The key concept behind this package lies in the precipitation and cloud scheme called: the Modular Multiscale Microphysics and Transport (3MT), developed by Gerard and Geleyn (2005), Gerard (2007) and Gerard et al. (2009). The multi-scale behavior of 3MT has been validated in a NWP context up to a spatial resolution of 4 km (see Gerard et al., 2009). The ALARO model version, called ALARO-0 that was used for the present study, utilizes the ACRANEB scheme for radiation (Ritter and Geleyn, 1992), a semi-Lagrangian horizontal diffusion scheme called SLHD (Váňa et al., 2008), some pseudo-prognostic Turbulent Kinetic Energy (TKE) scheme (pTKE, i.e. a Louis-type scheme for stability dependencies, but with memory, advection and auto-diffusion of the overall

GMDD

6, 4053–4104, 2013

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



intensity of turbulence) and a statistical sedimentation scheme for precipitation within a prognostic-type scheme for microphysics (Geleyn et al., 2008). The ALARO physics package is coupled to the dynamics of the ALADIN model via a physic-dynamics interface based on a flux-conservative formulation of the equations proposed by Catry et al. (2007). The configuration of the model with this physics runs operationally in a number of countries of the ALADIN and HIRLAM consortia¹ for the national NWP applications, the first of them already since 2008.

Historically ARPEGE, ALADIN, and ALARO models relied on the ISBA scheme developed by Noilhan and Planton (1989) and Noilhan and Mahfouf (1996), for the parametrization of the surface processes. It is also used within the ARPEGE climate model of Météo-France (Mahfouf et al., 1995). The ISBA scheme has also been implemented in the meso-NH model of Météo-France (Lafore et al., 1998). Masson (2000) developed the Town Energy Balance (TEB) scheme for the simulation of the interactions with urban areas and this scheme became part of the meso-NH model. Within the ALADIN community the code also runs with the physics parametrization of meso-NH. This configuration is called the AROME model (Seity et al., 2011).

During the last decade, the surface scheme, including ISBA and TEB, has been externalized from the core of the atmospheric meso-NH model following the approach of Polcher et al. (1998) and Best et al. (2004). This led to the creation of the SURFEX scheme (SURFEX stands for surface externalisée). Additionally, parameterizations for all components of the surface (ocean and inland water) has been added to SURFEX. Recently, a new multilayer parametrization for the natural and urban canopy (Hamdi and Masson, 2008; Masson and Seity, 2009) was also added to SURFEX in the so-called CANOPY scheme. The rationale for this externalization was twofold. First, once this externalization is done and if the scheme is plugged in any applications, it becomes available within all the applications. Secondly, SURFEX contains the ISBA scheme for its soil and vegetation interactions, so there is a priori no need to maintain the ISBA scheme separately in the different model version ARPEGE, ALADIN, AROME, ALARO,

¹At, Be, Cz, Hr, Hu, No, Pt, Ro, Se, Si, Sk and Tr.

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



ARPEGE climate and ALADIN climate. In operational contexts it is important that the scheme is sufficiently numerically stable to run with the long time steps imposed by the operational applications. Hence the implicit coupling proposed by Best et al. (2004) has been used. The physiographic characteristics of the surface in SURFEX are specified by the ECOCLIMAP database, see Masson et al. (2003) and Champeaux et al. (2005). An extra advantage of this externalization is that SURFEX can be used in an off-line mode for scientific applications where the atmospheric feedbacks are not taken into account, for instance for studying the Urban Heat Island (UHI) evolution (Hamdi et al., 2009, 2011).

The value of operational weather forecasts is determined by verification scores. So if the particular ISBA scheme in one of the models other than the AROME model is replaced by the ISBA version in the SURFEX scheme one would a priori expect to reproduce exactly the same model performance. This is the problem of reproducibility in model development. However, the implementation of ISBA in ALADIN and its evolution in meso-NH and then later its implementation in AROME diverged slowly, and the versions are not any more interchangeable. An attempt to find reproducibility of the model behavior by replacing the old ISBA scheme within the ALADIN configuration by the SURFEX-ISBA did not succeed. Nevertheless, the question of the first rationale still stands; why should one maintain different ISBA schemes to serve a large community of users? The obviously preferable version of the two ISBA is the one within SURFEX due to its higher potential for rapidly scientific evolution. For instance, new surface data assimilation schemes are being developed for SURFEX, as will be briefly discussed in the last section of the present paper and it will be necessary to switch to SURFEX in order to benefit from these developments.

The aim of the present study is not on a full reproducibility of the model behavior while replacing the old ISBA scheme by the SURFEX-ISBA scheme, but rather we would like to address the following questions: “Can one, by exhibiting the novel features developed in SURFEX over the past decade plus the additional options in the configuration of the upper-air part of ARPEGE/ALADIN/ALARO models, reproduce forecast performance

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



that is equivalent or better in terms of the set of verification scores that are put forth in the operational context of each of the participating ALADIN partners”. Apart from the user-oriented goal of allowing a science-based decision for the configuration of the NWP system by each partner within the consortium, this provides a very extensive validation of the SURFEX scheme rather than a specific validation such as in Hamdi et al. (2012) for the use of TEB within ALARO. Finally, it should be stressed that the present paper does not address other important issues which represent crucial criteria such as efficiency, code optimization, code design, its interface to the upper-air part, and the user-friendliness of the SURFEX implementation.

2 Model: description and configurations

The description of SURFEXv7.2 can be found in Masson et al. (2013) (in this SURFEX special issue). Note that at the time of testing, we used version 5 of SURFEX. Table 1 presents a summary of the different model configurations available within the model code.

2.1 Two radiation schemes

There are two radiation schemes available in the model code. AROME and ALADIN uses the ECMWF radiation scheme (named FMR hereafter). It has a shortwave radiation scheme (Fouquart and Bonnel, 1980) with six spectral bands, whereas the long-wave radiation with 16 spectral intervals is computed by the Rapid Radiative Transfer Model (RRTM) code (Mlawer et al., 1997) using climatological distributions of ozone and aerosols. For the ozone monthly profiles it uses the analytical functions that have been fitted to the UK Universities Global Atmospheric Modeling Program (UGAMP) climatology (Li and Shine, 1995). Distributions of organic, sulfate, dust like and black carbon, plus uniformly distributed stratospheric background aerosols, are extracted from the Tegen climatology (Tegen et al., 1997).

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



The ALARO physics package has been developed with the ACRANEB scheme built on Ritter and Geleyn (1992). This is a two-stream approximation with a Net Exchange Rate (NER) formulation for solving the thermal part. All the computations consider two spectral bands (for the solar and thermal part) with the contribution of three gases (H₂O, CO₂ equivalent, and O₃). The gaseous optical depths are computed by means of a Padé fit of the equivalent scale width computed by the Malkmus formula (Malkmus, 1967). The scheme has been extended by using a Voigt-line profile for coping with the high model levels (Geleyn et al., 2005). These schemes, FMR and ACRANEB, represent two different approaches for the problem of the extensive computing cost in radiation schemes. FMR is called intermittently to save computing costs. Only the shortwave flux dependency on the zenithal solar angle is updated at every time step. The rest of the radiation computations are updated with a frequency of 1 h for ALADIN and 15 min for AROME. This is how SURFEX is used in the Météo-France versions of ALADIN (Masson et al., 2013).

ACRANEB on the other hand is in itself designed for cost-effectiveness and is called every time step. Both schemes can be called in all model versions of the ARPEGE/ALADIN/ALARO model configurations.

2.2 Urban effects

TEB is based on the canyon concept, where the town is represented with a roof, a road, and two facing walls. The advantage is that relatively few individual surface energy balance evaluations need to be resolved, radiation interactions are simplified, and therefore computation time is kept low. Water, energy, and momentum fluxes are computed by each parameterization and then aggregated at the grid-mesh scale according to the cover fraction of each tile.

For operational application running with long time steps, the TEB scheme is not activated and the town is replaced by rocks. The ISBA scheme is, therefore, used for all grid points of the domain because of numerical instabilities in the coupling with TEB

at the time of testing. This is the way how SURFEX is used in the French double suite of ALADIN (Masson et al., 2013).

2.3 Surface boundary layer computation

The 2 m temperature, relative humidity and 10 wind are diagnostically calculated in the ARPEGE/ALADIN/ALARO model by complex interpolation between the lowest level and the surface, making use of the stability functions of the dry static energy and applying the Monin–Obukhov similarity theory for the surface boundary layer (Geleyn, 1988). However, Best and Hopwood (2001) found that the choice of stability functions at night can have significant impact on both the surface temperature and the sensible heat flux and therefore on the diagnostic of screen temperature in stable situations.

In order to improve the description of the physical coupling between the air and the surface, one dimensional surface boundary layer has been implemented in SURFEX (CANOPY scheme) following the methodology described in Hamdi and Masson (2008) and Masson and Seity (2009). With this version, 6 prognostic air layers (0.5, 2, 4, 6.5, 10, and 17 m above the ground) are added from the ground up to the lowest atmospheric level. The surface boundary layer is, thus, resolved prognostically (there is no need of analytical extrapolation such as Geleyn, 1988), taking into account large-scale forcing, turbulence, and if any, drag and canopy forces.

2.4 Surface data assimilation

The initialization of the soil variables is very important in order to provide accurate short and medium range forecasts. Surface assimilation techniques mainly use screen-level observations of relative humidity and temperature to infer realistic estimates about the soil variables (i.e. soil moisture and soil temperature) by optimally combining the screen-level observations with a short-range forecast. Two common soil analysis techniques are Optimum Interpolation (OI) and the Extended Kalman Filter (EKF) or

GMDD

6, 4053–4104, 2013

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



a simplified version of the Extended Kalman Filter (SEKF) in which the background error covariance matrix is kept constant.

A local OI algorithm is available in SURFEX. Its coefficients have an analytical formulation that mostly depends on the diurnal cycle and the vegetation fraction. The coefficients have been derived from Monte Carlo single column experiments performed by Mahfouf (1991) with an analytical formulation proposed by Giard and Bazile (2000). A drawback of the OI is that it is difficult to incorporate new observation types that may improve the analysis. An alternative method is the EKF, for which it is easier to add new observation types. An EKF has been developed for SURFEX that is capable of assimilating screen-level observations (Mahfouf et al., 2009), and has been extended to include AMSR-E surface soil moisture retrievals (Draper et al., 2009), radar precipitation information (Mahfouf and Bliznak, 2011) and ASCAT surface soil moisture (Mahfouf, 2010). In contrast to OI, the EKF uses dynamical coefficients that depend on the Jacobian of the model observation operator which projects the the model state into the observation space. The Jacobian elements are calculated using a finite differences approach, by comparing a perturbed run to a reference run for each of the soil prognostic variables. In order to make the EKF computationally efficient, these runs are calculated using SURFEX in off-line mode, i.e. with the surface scheme decoupled from the atmospheric model.

3 Operational validation

The use of SURFEX as a new land surface scheme for the ALADIN and ALARO models has been extensively tested during the last two years by several partners of the ALADIN consortium. In Masson et al. (2013), SURFEX was tested within the ALADIN model running over France and using the FMR radiation scheme. They found that the introduction of SURFEX was neutral on surface pressure, precipitations, total cloudiness and 10 m wind direction but improved the scores for the 2 m temperature and humidity and 10 m wind speed. In the present study a more complete set of test will be

GMDD

6, 4053–4104, 2013

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



presented over the operational Belgian domain while giving pertinent illustration for the other partners (Hungary, Morocco, Poland, Slovenia, and Turkey).

At the Royal Meteorological Institute (RMI) of Belgium, the operational version of the code is the ALARO configuration, running with the ACRANEB radiation scheme and ISBA, with a resolution of 7 km and 4 km (see Fig. 1). Tests were carried out to replace the ISBA scheme by SURFEX for the 7 km domain and, additionally, making a comparison by switching on TEB for the 4 km high-resolution domain. The primary goal of this study is to examine the operational viability of ALARO coupled with SURFEX. As a result, the set up of the ALARO model was designed to mimic an operational configuration over the domain presented in Fig. 1. It is a regular grid on a Lambert projection, with its centre at (50.57° N, 4.55° E), the domain is vertically divided in 46 layers, separated by hybrid pressure terrain-following levels (Simmons and Burridge, 1981). The height of the lower layer is about 17 m above the ground. The model time step is 300 s and 180 s for the 7 km and 4 km domain, respectively. The ALARO model is run operationally 4 times a day (at 6 h interval) based on analyses coming from the ALADIN France analyses, which is the model providing also the 3 h lateral boundary coupling data. 60 h and 36 h forecasts are issued from the 00:00, 06:00, 12:00, and 18:00 UTC nominal analysis times for the 7 km and 4 km domain, respectively. Upper air model fields are post-processed by interpolation of fields onto pressure or altitude levels each hour. For non-urban surfaces, the SURFEX scheme diagnoses the 2 m temperature, 2 m relative humidity, and 10 m applying the interpolation method of Geleyn (1988). For urban areas, the standard 2 m temperature, 2 m humidity and 10 m wind are obtained from the diagnosed TEB canyon temperature, humidity and wind, respectively. Three tiles are activated (sea, nature, lakes) (town is replaced by rock for the 7 km domain while TEB is used for the 4 km domain). A three-layer force-restore version of ISBA is used (instead of the former two-layer version) with a one-layer snow scheme of Douville et al. (1995). The ECUME (Exchange Coefficients from Unified Multi-campaigns Estimates) parametrization of sea surface fluxes is used over seas (Belamari and Pirani, 2007). It is a bulk iterative scheme developed in order to obtain an optimized

GMDD

6, 4053–4104, 2013

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



improvement in bias and rmse obtained when using SURFEX. The 95 % confidence intervals for $|\text{bias}_{\text{OPER} + \text{SFX}}| - |\text{bias}_{\text{OPER}}|$ and $\text{rmse}_{\text{OPER} + \text{SFX}} - \text{rmse}_{\text{OPER}}$ were calculated with the bootstrap method explained above. Table 2 shows the average day-time/nighttime scores for the flat (less than 100 m altitude) and high elevation and coastal synoptic stations (total of 8 stations belonging to the synoptical network of the Royal Meteorological Institute of Belgium), sign (+) means improvement, sign (0) means neutral effect, and sign (–) means degradation of the scores with respect to the 95 % confidence levels calculated with the bootstrap method.

During the winter nighttime (which is longer in January than in July), forecasted 2 m temperatures are generally colder than observations over Belgium for both simulations, with and without SURFEX. The origin of the cold bias is that the model physics yields too little near-surface vertical turbulent mixing during calm nighttime conditions (i.e. stable nighttime low-level temperature inversions, referred to as the stable boundary layer). This problem is amplified in the cold season because of longer nights, the increased tendency during the cold season of nighttime winds to become very weak, and the cooling effect of snow cover yielding even stronger nighttime temperature inversions. Moreover, the nighttime situation has a positive feedback character, because as the low-level inversion sets in, the surface vertical turbulent mixing of heat falls off, which in turn acts to strengthen the inversion and so forth. Moreover, Best and Hopwood (2001) found that the choice of stability functions at night can have significant impact on both the surface temperature and the sensible heat flux and therefore on the diagnostic of screen temperature in stable situations. In fact, using Monin–Obukhov similarity theory with log-linear stability functions cuts off the flux of heat with increasing stability too quickly, compared to the observations (Best and Hopwood, 2001). This leads to incorrect lower surface temperatures as the warmer atmospheric air is no longer mixed down to the surface. The average mean bias and rmse for the Uccle station (Flat) is significantly reduced when using SURFEX. It can also be seen from Fig. 3 that the improvement of bias and rmse is statistically significant. The average mean

bias is significantly reduced when using SURFEX, with an average of +2°C for OPER vs. almost zero for OPER + SFX at the Uccle station.

It can also be seen from Table 2 that OPER + SFX simulation gives better results at the coast. The improvement of bias and rmse during the summer is statistically significant. For the high elevation synoptic station, the use of SURFEX has a neutral impact on the scores and the null hypothesis is not accepted during winter and summer.

During winter, OPER + SFX has a tendency to produce higher maximum temperature at high elevation station. The average mean bias is significantly warmer when using SURFEX, with an average of ±1°C for OPER vs. ±1.5°C for OPER + SFX. It can also be seen from Table 2 that OPER + SFX did not give any improvement and the null hypothesis is not accepted during the winter. However, during the summer, OPER + SFX gives an improvement. For the flat topography and coastal synoptic stations, the use of SURFEX either gives improvements or neutral impact on the scores.

The use of the CANOPY scheme within the ALADIN model has been tested over the Moroccan operational domain for a winter period from 1–20 January 2010. Figure 4 presents the rmse and bias scores of a 60 h forecast of 2 m temperature against observations at the OUarzazat station for: ALADIN without SURFEX, ALADIN with SURFEX, and ALADIN with SURFEX and CANOPY (2 m temperature is prognostically computed). During daytime the three simulations compare relatively well to the observations with a rmse below ±2°C. However, during the nighttime the use of CANOPY improves significantly the results, while the introduction of SURFEX gives much a lower bias than the operational run (−3°C for ALADIN against −4°C for ALADIN with SURFEX). Masson and Seity (2009) found that the use of CANOPY improves the forecast of near-surface air temperature at night when stability is too strong.

3.2 2 m relative humidity

Figure 5 presents the scores obtained for the Uccle station and Fig. 6 shows the improvement in bias and rmse obtained when using SURFEX. Table 2 shows the average daytime/nighttime scores. The temperature results correlate with the 2 m relative

GMDD

6, 4053–4104, 2013

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



humidity results that show a large improvement during winter and summer. It can also be seen from Fig. 6 that during winter, the OPER + SFX improve significantly the scores. However, during the summer, the improvement is only seen during the nighttime.

5 Over the Slovenia domain SURFEX has also been tested within the ALARO model using the FMR radiation scheme for two short test period: 4–11 February 2011 and 12–17 July 2011. The introduction of SURFEX was tested on two horizontal resolutions (4.4 and 9.5 km). Table 3 and 4 present the average daytime/nighttime 2 m temperature and relative humidity scores for 5 locations for the 9.5 km and 4.4 km horizontal resolution, respectively. For this short period, scores are in general neutral or marginally positive, only in some cases there is a medium deterioration (particularly in winter time for the 9.5 km run with a cold bias at Novo Mesto, Kranjska Gora, and Ljubljana stations). SURFEX yields improved relative performance for the high resolution run. For the 4.4 km run almost all scores are neutral or positive in winter and summer period. Significant deterioration is only observed in Kranjska Gora for the 2 m relative humidity during winter nighttime.

In Poland, SURFEX has been tested during the last decade of March 2011 within the ALADIN operational suite and the results show a neutral impact on the 2 m temperature and relative humidity scores.

20 As can be seen from Figs. 7 and 8, and Table 2, the use of SURFEX has a neutral impact on the 10 m wind direction while it improves the 10 m wind speed during the night for flat and coastal stations.

3.3 Surface fluxes: test with data from Cabauw tower

25 The Cabauw tower is situated in the central river delta in the south-western part of the Netherlands 0.7 m below mean sea level. The surroundings are flat and consist of meadows and ditches with scattered villages, orchards, and lines of trees. The immediate surroundings of the tower are free of obstacles up to a few hundred meters in all directions, with the local surface consisting mainly of short grass. For the predominant

GMDD

6, 4053–4104, 2013

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



wind direction (south-west), the flow is unperturbed over an upstream distance of about 2 km. The routine observations include profile of wind speed, wind direction, air temperature and dew point temperature at 10, 20, 40, 80, 140, and 200 m (a.g.l.). The temperature is also measured at 2 m, and fluxes of momentum and heat at 5 m. In addition, there are sensors for a number of surface radiation fluxes and precipitation at the site: (www.cosmo-model.org/srnwp/view/). Figure 9 presents the scores obtained with the 4 km domain for the 2 m temperature at the Cabauw station, and Fig. 10 shows the improvement in bias and rmse obtained when using SURFEX. Table 5 shows the improvement in the radiative balance and energy balance for the following parameters: (1) downward longwave radiation, (2) upward longwave radiation, (3) downward shortwave radiation, (4) upward shortwave radiation, (5) sensible heat flux and (6) latent heat flux, and (7) storage heat flux.

3.3.1 Nighttime

Just as found for the Uccle station, the average mean bias and rmse for the Cabauw station is significantly reduced during the summer when using SURFEX (see Fig. 9). It can be seen from Fig. 10 that the improvement of bias and rmse is statistically significant. During the summer the average mean bias is significantly reduced, with an average of $+1.5^{\circ}\text{C}$ for OPER vs. almost zero for OPER + SFX. During the winter OPER + SFX simulation did not give any improvement and the null hypothesis is not accepted. As it can be seen from Table 5, there is also a significant improvement of the upward longwave radiation and storage heat flux during the summer nighttime. In fact, the average mean bias and rmse of the storage heat flux is significantly reduced when using SURFEX (not shown), with an average overestimation of 10 W m^{-2} for OPER + SFX vs. 34 W m^{-2} for OPER. The use of SURFEX has a neutral impact of the partitioning between sensible and latent heat flux during summer and winter (their values are very small during the night).

3.3.2 Daytime

During daytime, the use of SURFEX has a neutral impact on the 2 m temperature at the CABAUW site. However, as it can be seen from Table 5, there is a significant improvement of the upward short wave radiation and surface heat flux (latent, sensible, and storage) especially during the summer.

3.4 Urban effect

Recently, in Hamdi et al. (2012), the TEB scheme was implemented within ALARO, running operationally at 4 km resolution. The primary question addressed was the ability of TEB to work properly at this relatively coarse resolution and, thus, assessing its potential use in an operational configuration to improve sensible weather performance over Belgium. Results in Hamdi et al. (2012) show that promising improvements are achieved by introducing TEB. The 2 m temperature and 2 m relative humidity improve compared to measurements in urban areas. Important urban characteristics, such as increased heat storage and Bowen ratio and the urban heat island effect, were successfully reproduced. In addition, comparison of wind speed and wind direction above the urban canopy indicate that the structure of the flow in urban areas is better reproduced with TEB (Hamdi et al., 2012). These improvements of the treatment of the urban areas within ALARO have implications for simulating air chemistry processes over Belgium at this scale (Delcloo et al., 2012).

The use of TEB within SURFEX has also been tested over Turkey using the ALARO model and the FMR radiation scheme at 4 km resolution. Figure 11 presents the rmse of 2 m temperature and 2 m relative humidity against observations at the Istanbul city station averaged over July 2010 for ALARO with SURFEX run and ALARO with SURFEX and TEB. The results show a demonstrated positive impact when activating TEB within SURFEX. The forecasted 2 m temperature and 2 m relative humidity improve compared to measurements in Istanbul especially during the nighttime which is due to the urban heat island effect of Istanbul.

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



3.5 Precipitation

In order to investigate the influence of introducing SURFEX on winter and summer precipitation, the precipitation fields of the run with (OPER + SFX) and without SURFEX (OPER) are verified against a quantitative precipitation estimates with radar-gauge merging method (Goudenhoofd and Delobbe, 2009) using the SAL (SAL stands for: Structure, Amplitude, and Location) method of Wernli et al. (2008). This method characterizes the quality of a forecasted precipitation field by means of three components: structure, amplitude, and location. The structure component characterizes the size and shape of the precipitation objects and ranges from -2 (predicted precipitation objects too small or too peaked) to 2 (predicted precipitation objects too large or too flat). The value of $S = 0$ indicates that the model has the correct structure. The amplitude component also varies between -2 and 2 , with a value of -2 indicating an under-predicted total precipitation amount and a value of 2 indicating an over-predicted total precipitation amount and zero denotes a perfect forecast in terms of amplitude. Finally, the location component quantifies whether the predicted precipitation objects are situated at the correct location, and ranges from 0 (predicted precipitation objects at correct position) to 2 (predicted precipitation objects at incorrect position). Figure 12 shows the Structure and Amplitude precipitation scores for January 2010 for the ALARO 7 km with (SFX) and without (OPER) SURFEX against radar observations. As a sensitivity test, SAL scores were also computed for the run with SURFEX against the operational runs. Table 6 presents the average (for January and July 2010) SAL scores for the 4 km and 7 km runs with and without SURFEX.

From Fig. 12 and Table 6, it appears that the use of SURFEX has a neutral impact on the three components of the SAL method when comparing the ALARO runs against the observations. However, it seems that the use of SURFEX tends to cause rainfall to be locally concentrated ($S < 0$) and the total accumulated precipitation decreases slightly ($A < 0$). When comparing the 4 km runs against observations during July 2010, this effect becomes clearer with $A = 0.0548$ for OPER against $A = 0.0161$ for OPER + SFX.

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Thus the use of SURFEX reduces slightly the bias of the total precipitation amount (the cross marker is closer to the center, not shown). Hamdi et al. (2012) found that the implementation of TEB within SURFEX for the 4 km run during the summer tend to cause rainfall to be locally concentrated and the total accumulated precipitation decreased obviously, but extended validation would be needed to address this further.

3.6 Surface data assimilation

In order to compare OI and the EKF for surface assimilation, several experiments were run. All experiments have the same setup. The experiments are run with ALARO in combination with the external land surface model SURFEX. All runs were performed on the 4 km domain with 46 vertical levels. Surface assimilation is performed every 6 h. There is no atmospheric assimilation as in Mahfouf et al. (2009). The screen-level relative humidity and temperature observations are taken from SYNOP and TEMP reports in the Meteorological Archival and Retrieval System (MARS). The screen-level observations are interpolated on the model grid using an optimum interpolation technique with high background error covariances to minimize the influence of the analysis background. The gridded observations are then used for the point-wise EKF or OI assimilation. The parameters used for the EKF are the following: The observation error covariance matrix \mathbf{R} is a diagonal matrix with elements set to 1 K for 2 m temperature and 10% for 2 m relative humidity. The background error covariance matrix \mathbf{B} is also a diagonal matrix, with values of 2 K for the background errors of surface and deep soil temperature (T_s and T_2) and $0.1(W_{fc} - W_{wilt})$ for surface and deep soil moisture content (WG_1 and WG_2), with W_{fc} and W_{wilt} the volumetric water content at field capacity and at permanent wilting point. The \mathbf{B} matrix is kept constant, i.e. the EKF is in fact a SEKF. The setup and values are the same as in Mahfouf et al. (2009). Runs have been performed with surface assimilation (EKF and OI), without assimilation where surface fields are taken from the previous 6 h forecast of the coupled model (*free run*) and without assimilation where surface fields are interpolated from an ARPEGE analysis (*open loop*). The experiments were run over the period of one month, July 2010.

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



range. So, as soon as WG_2 drops below the wilting point at a certain location, the EKF will not give any increments (not even positive ones) until the soil moisture rises above the wilting point again, while OI will only block the negative increments in such case and allow positive ones. Therefore it will be easier for OI to recover from negative SWI values than for the EKF and OI will allow more positive WG_2 increments. This results in regions with a small or negative accumulated WG_2 increment for the EKF where OI has a larger positive increment. For WG_2 above but close to the wilting point the link between the root zone soil moisture and the screen-level variables is the largest, resulting in high gain coefficients and increments in the regions neighboring the ones with negative SWI values.

The EKF can be changed to include a limitation for the increments to make sure they are not too big and do not push the SWI value outside of the sensitivity range (like in Mahfouf et al., 2009). This is more similar to what is done in OI, although there will still be no positive increments allowed in the EKF for negative SWI values. When the EKF is modified in this way, the spatial structure is already less irregular and more like that of OI (see Fig. 14).

In general, there is a good correspondence between the increments of OI and EKF with the EKF increments showing a more fine-grained spatial structure. Also the forecast scores (RMSE and BIAS) for T_{2m} and RH_{2m} are similar for EKF and OI (Fig. 15).

3.7 Upper air scores

In Hungary, SURFEX has been tested using the ALARO physics and the FMR radiation scheme over a continental European domain with 8 km grid based on upper air analyses coming from ECMWF/IFS global model, which is the model providing also the 3 h lateral boundary coupling data. The surface analyses was taken from ARPEGE due to the different surface schemes between IFS and ARPEGE/ALADIN/ALARO. For two periods in summer (1 July–15 August 2010) and winter (10–29 December 2010), simulations are performed, with (S003) and without SURFEX (A003), with a forecast range of 48 h, starting at 00:00 UTC. Scores are averaged over the whole domain.

GMDD

6, 4053–4104, 2013

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Extended Kalman Filter. The comparison for Belgium shows that the forecast scores are similar between the Extended Kalman Filter and the classical Optimal Interpolation scheme. Finally, concerning the vertical scores, the introduction of SURFEX either give improvement or neutral impact on the upper air layer. However, it was found that during the winter SURFEX deteriorates slightly the temperature scores for the lowest model levels. Overall, it can be stated that forecast performance can be improved on average when using SURFEX in ALARO.

References

- ALADIN international team: The ALADIN project: Mesoscale modelling seen as a basic tool for weather forecasting and Atmospheric Research, WMO Bull., 46, 317–324, 1997.
- Balsamo, G., Bouyssel, F., and Noilhan, J.: A simplified bi-dimensional variational analysis of soil moisture from screen-level observations in a mesoscale numerical weather prediction model, Q. J. Roy. Meteorol. Soc., 130, 895–915, 2004.
- Belamari, S. and Pirani, A.: Validation of the optimal heat and momentum fluxes using the orca2-lim global ocean-ice model, Marine environment and security for the European area, Integrated Project (MERSEA IP), Deliverable D4.1.3, 88, 2007.
- Best, M. J. and Hopwood, W. P.: Modelling the local surface exchange over a grass-field site under stable conditions, Q. J. R. Meteor. Soc., 127, 2033–2052, 2001.
- Best, M. J., Beljaars, A., Polcher, J., and Viterbo, P.: A proposed structure for coupling tiled surfaces with the planetary boundary layer, J. Hydrometeorol., 5, 1271–1278, 2004.
- Bubnová, R., Hello, G., Bénard, P., and Geleyn, J.-F.: Integration of the fully elastic equations cast in the hydrostatic pressure terrain-following coordinate in the framework of ARPEGE/ALADIN NWP system, Mon. Weather Rev., 123, 515–535, 1995.
- Catry, B., Geleyn, J.-F., Tudor, M., Bénard, P., and Trojáková, A.: Flux-conservative thermodynamic equations in a mass-weighted framework, Tellus, 59, 71–79, 2007.
- Champeaux, J., Masson, V., and Chauvin, R.: Ecoclimap: a global database of land surface parameters at 1 km resolution, Meteorol. Appl., 12, 29–32, 2005.
- Charnock, H.: Wind stress over a water surface, Q. J. R. Meteor. Soc., 81, 639–640, 1955.

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



GMDD

6, 4053–4104, 2013

Coupling SURFEXv5
with ALADINcy36 and
ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



- Davies, H. C.: A lateral boundary formulation for multi-level prediction models, *Q. J. R. Meteor. Soc.*, 102, 405–418, 1976.
- Delcloo, A. W., Deckmyn, A., Hamdi, R., Van Langenhove, H., Foret, G., De Backer, H.: Coupling of the CTM CHIMERE to the high resolution LAM ALADIN for Belgium, *Air Pollution Modeling and its application XXI*, NATO Science for peace and security series C: Environment security, vol. 4, Pt. 2, 315–319, doi:10.1007/978-94-007-1359-8_54, 2012.
- Douville, H., Royer, J.-F., and Mahfouf, J.-F.: A new snow parameterization for the French community climate model, Part I: Validation in stand-alone experiments, *Clim. Dynam.*, 12, 21–35, 1995.
- Draper, C., Mahfouf, J.-F., and Walker, J.: An EKF assimilation of AMSR-E soil moisture into the ISBA land surface scheme, *J. Geophysical Res.*, 114, D20104, doi:10.1029/2008JD011650, 2009.
- Fouquart, Y. and Bonnel, B.: Computations of solar heating of the earths atmosphere: a new parameterization, *Beitr. Phys. Atmos.*, 35–62, 1980.
- Geleyn, J.-F.: Interpolation of wind, temperature and humidity values from the model levels to the height of measurement, *Tellus*, 40, 347–351, 1988.
- Geleyn, J.-F., Bénard, P., and Fournier, R.: A general-purpose extension of the Malkmus band-model average equivalent width to the case of the Voigt line profile, *Q. J. R. Meteor. Soc.*, 131, 2757–2768, 2005.
- Geleyn, J.-F., Catry, B., Bouteloup, Y., and Brozková, R.: A statistical approach for sedimentation inside a micro-physical precipitation scheme, *Tellus*, 60, 649–662, 2008.
- Gerard, L.: An integrated package for subgrid convection, clouds and precipitation compatible with the meso-gamma scales, *Q. J. R. Meteor. Soc.*, 133, 711–730, 2007.
- Gerard, L. and Geleyn, J.-F.: Evolution of a subgrid deep convection parametrization in a limited area model with increasing resolution, *Q. J. R. Meteor. Soc.*, 131, 2293–2312, 2005.
- Gerard, L., Piriou, J. M., Brozková, R., Geleyn, J. F., and Banciu, D.: Cloud and Precipitation parameterization in a Meso-Gamma-Scale operational weather prediction model, *Mon. Weather Rev.*, 137, 3960–3977, 2009.
- Giard, D. and Bazile, E.: Implementation of a new assimilation scheme for soil and surface variables in a global NWP model, *Mon. Weather Rev.*, 128, 997–1015, 2000.
- Goudenhoofd, E. and Delobbe, L.: Evaluation of radar-gauge merging methods for quantitative precipitation estimates, *Hydrol. Earth Syst. Sci.*, 13, 195–203, doi:10.5194/hess-13-195-2009, 2009.

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Hamdi, R. and Masson, V.: Inclusion of a drag approach in the Town Energy Balance (TEB) scheme: offline 1-D evaluation in a street canyon, *J. Appl. Meteor. Clim.*, 47, 2627–2644, 2008.

Hamdi, R., Deckmyn, A., Termonia, P., Demarée, G. R., Baguis, P., Vanhuyse, S., and Wolff, E.: Effects of historical urbanization in the Brussels capital region on surface air temperature time series: a model study, *J. Appl. Meteor. Clim.*, 48, 2181–2196, 2009.

Hamdi, R., Termonia, P., and Baguis, P.: Effects of urbanization and climate change on surface runoff of the Brussels capital region: a case study using an urban soil-vegetation-atmosphere-transfer model, *Int. J. Climatol.*, 31, 1959–1975, doi:10.1002/joc.2207, 2011.

Hamdi, R., Degrauwe, D., and Termonia, P.: Coupling the Town Energy Balance (TEB) scheme to an operational limited-area NWP model: evaluation for a highly urbanized area in Belgium, *Weather Forecast.*, 27, 323–344, 2012.

Lafore, J. P., Stein, J., Asencio, N., Bougeault, P., Ducrocq, V., Duron, J., Fischer, C., Hérel, P., Mascart, P., Masson, V., Pinty, J. P., Redelsperger, J. L., Richard, E., and Vilà-Guerau de Arellano, J.: The Meso-NH Atmospheric Simulation System. Part I: adiabatic formulation and control simulations, *Ann. Geophys.*, 16, 90–109, doi:10.1007/s00585-997-0090-6, 1998.

Li, D. and Shine, K. P.: A 4-dimensional ozone climatology for UGAMP models, *Tech. Rep. 35, UGAMP*, 1995.

Mahfouf, J.-F.: Analysis of soil moisture from near-surface parameters: a feasibility study, *J. Appl. Meteorol.*, 30, 1534–1547, 1991.

Mahfouf, J.-F.: Assimilation of satellite-derived soil moisture from ASCAT in a limited-area NWP model, *Q. J. Roy. Meteor. Soc.*, 136, 784–798, 2010.

Mahfouf, J.-F. and Bližňák, V.: Combined assimilation of screen-level observations and radar-derived precipitation for soil moisture analysis, *Q. J. Roy. Meteor. Soc.*, 137, 709–722, doi:10.1002/qj.791, 2011.

Mahfouf, J.-F., Manzi, A., Noilhan, J., Giordani, H., and Dequé, M.: The land surface scheme ISBA within the Météo-France climate model ARPEGE, *J. Climate*, 2039–2057, 1995.

Mahfouf, J.-F., Bergaoui, K., Draper, C., Bouyssel, F., Taillefer, F., and Taseva, L.: A comparison of two off-line soil analysis schemes for assimilation of screen level observations, *J. Geophys. Res.*, 114, D08105, doi:10.1029/2008JD011077, 2009.

Malkmus, W.: Random Lorentz band model with exponential-tailed S-1 line intensity distribution function, *J. Opt. Soc. Am.*, 57, 323–329, 1967.

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



- Masson, V.: A physically-based scheme for the urban energy budget in atmospheric models, *Bound.-Lay. Meteor.*, 94, 357–397, 2000.
- Masson, V. and Seity, Y.: Including atmospheric layers in vegetation and urban offline surface schemes, *J. Appl. Meteor. Clim.*, 48, 1377–1397, 2009.
- 5 Masson, V., Champeaux, J. L., Chauvin, F., Meriguet, C., and Lacaze, R.: A global database of land surface parameters at 1 km resolution in meteorological and climate models, *J. Climate*, 16, 1261–1282, 2003.
- Masson, V., Le Moigne, P., Martin, E., Faroux, S., Alias, A., Alkama, R., Belamari, S., Barbu, A., Boone, A., Bouysse, F., Brousseau, P., Brun, E., Calvet, J.-C., Carrer, D., Decharme, B., Delire, C., Donier, S., Essauini, K., Gibelin, A.-L., Giordani, H., Habets, F., Jidane, M., Ker-
10 draon, G., Kourzeneva, E., Lafaysse, M., Lafont, S., Lebeaupin Brossier, C., Lemonsu, A., Mahfouf, J.-F., Marguinaud, P., Mokhtari, M., Morin, S., Pigeon, G., Salgado, R., Seity, Y., Taillefer, F., Tanguy, G., Tulet, P., Vincendon, B., Vionnet, V., and Voldoire, A.: The SURFEXv7.2 land and ocean surface platform for coupled or offline simulation of earth surface variables and fluxes, *Geosci. Model Dev.*, 6, 929–960, doi:10.5194/gmd-6-929-2013, 2013.
- Mlawer, E. J., Taubman, S. J., Brown, P., Iacono, M. J., and Clough, S. A.: Radiative transfer for inhomogeneous atmospheres: RRTM, a validated correlated-k model for the longwave, *J. Geophys. Res.*, 102, 16663–16682, 1997.
- Noilhan, J. and Mahfouf, J.-F.: The ISBA land parameterization scheme, *Global Planet. Change*,
15 13, 145–159, 1996.
- Noilhan, J. and Planton, S.: A simple parameterization of land surface processes for meteorological models, *Mon. Weather Rev.*, 117, 536–549, 1989.
- Polcher, J., McAvaney, B., Viterbo, P., Gaertner, M.-A., Hahmann, A., Mahfouf, J.-F., Noilhan, J., Phillips, T., Pitman, A., Schlosser, C., Schulz, J.-P., Timbal, B., Versegny, D., and Xue, Y.:
25 A proposal for a general interface between land-surface schemes and general circulation models, *Global Planet. Change*, 19, 263–278, 1998.
- Radnóti, G.: Comments on A spectral limited-area formulation with time-dependent boundary conditions applied to the shallow-water equations, *Mon. Weather Rev.*, 123, 3122–3123, 1995.
- 30 Ritter, B. and Geleyn, J.-F.: A comprehensive radiation scheme for numerical weather prediction models with potential application in climate simulations, *Mon. Weather Rev.*, 120, 303–325, 1992.

- Sassi, M. Z.: Réalisation et Experimentation d'une Version ALADIN-TUNISIE avec SURFEX, Rapport de stage, Météo-France, Toulouse, 28 pp., 2012.
- Seity, Y., Brousseau, P., Malardel, S., Hellow, G., Bénard, P., Bouttier, F., Lac, C., and Masson, V.: The AROME-France convective scale operational model, *Mon. Weather Rev.*, doi:10.1175/2010MWR3425.1, 976–991, 2011.
- 5 Simmons, A. and Burridge, D. M.: An energy and angular-momentum conserving finite-difference scheme and hybrid vertical coordinates, *Mon. Weather Rev.*, 109, 758–766, 1981.
- Tegen, I., Hoorig, P., Chin, M., Fung, I., Jacob, D., and Penner, J.: Contribution of different aerosol species to the global aerosol extinction optical thickness: Estimates from model results, *J. Geophys. Res.*, 102, 23895–23915, 1997.
- 10 Termonia, P., Deckmyn, A., and Hamdi, R.: Study of the lateral boundary condition temporal resolution problem and a proposed solution by means of boundary error restarts, *Mon. Weather Rev.*, 137, 3551–3566, 2009.
- Termonia, P., Voitus, F., Degrauwe, D., Caluwaerts, S., Hamdi, R.: Application of Boyd's periodization and relaxation method in a spectral atmospheric limited-area model – Part I: Implementation and reproducibility tests, *Mon. Weather Rev.*, 140, 3137–3148, doi:10.1175/MWR-D-12-00033.1, 2012.
- 15 Vána, F., Bénard, P., Geleyn, J.-F., Simon, A., and Seity, Y.: Semi-Lagrangian advection scheme with controlled damping: An alternative to nonlinear horizontal diffusion in a numerical weather prediction model, *Q. J. Roy. Meteor. Soc.*, 134, 523–537, 2008.
- 20 Wernli, H., Paulat, M., Hagen, M., and Frei, C.: SAL – a novel quality measure for the verification of quantitative precipitation forecasts, *Mon. Weather Rev.*, 136, 4470–4487, 2008.
- Wilks, D. S.: *Statistical Methods in the Atmospheric Sciences*, Academic Press, 467 pp., 1995.

**Coupling SURFEXv5
with ALADINcy36 and
ALARO-0**

R. Hamdi et al.

[Title Page](#)[Abstract](#)[Introduction](#)[Conclusions](#)[References](#)[Tables](#)[Figures](#)[⏪](#)[⏩](#)[◀](#)[▶](#)[Back](#)[Close](#)[Full Screen / Esc](#)[Printer-friendly Version](#)[Interactive Discussion](#)

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Table 1. Summary of the different model configuration available within the model code.

Scheme	Option
Radiation	FMR, ACRANEB
Urban effect	TEB (on/off)
Surface boundary layer computation	Geleyn (1988), CANOPY
Upper-air physics	ALADIN, ALARO
Surface assimilation	Optimal Interpolation, Extended Kalman Filter

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Table 2. The average daytime/nighttime scores for the flat/high elevation and coastal synoptic stations, sign (+) means improvement, sign (0) means neutral effect, and sign (–) means degradation of the scores.

		Winter _{NIGHT}	Winter _{DAY}	Summer _{NIGHT}	Summer _{DAY}
2 m Temperature	Flat	+	+	+	0
	High	0	–	0	+
	Coast	0	0	+	0
Wind speed at 10 m	Flat	+	0	+	0
	High	0	0	0	0
	Coast	+	0	+	0
Wind direction at 10 m	Flat	0	0	0	0
	High	0	0	0	0
	Coast	0	0	0	0
2 m Relative humidity	Flat	+	+	+	0

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Table 3. The average daytime/nighttime scores of 2 m temperature (2 m T) and relative humidity (2 m RH) of the 9.5 km horizontal resolution run for 5 locations over the Slovenian domain sign (+) means improvement, sign (0) means neutral effect, and sign (–) means degradation of the scores.

		Winter _{NIGHT}	Winter _{DAY}	Summer _{NIGHT}	Summer _{DAY}
Ljubljana (basin city)	2 m T	+	–	0	0
	2 m RH	–	0	0	–
Maribor (flat, low hills)	2 m T	+	0	–	–
	2 m RH	–	0	0	0
Piran (sea, buoy)	2 m T	+	0	0	0
	2 m RH	+	0	0	0
Novo mesto (hilly terrain)	2 m T	–	–	–	0
	2 m RH	–	0	–	0
Lranjska gora (deep valley)	2 m T	+	0	–	0
	2 m RH	–	0	0	0

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Table 4. The average daytime/nighttime scores of 2 m temperature (2 m T) and relative humidity (2 m RH) of the 4.4 km horizontal resolution run for 5 locations over the Slovenian domain sign (+) means improvement, sign (0) means neutral effect, and sign (–) means degradation of the scores.

		Winter _{NIGHT}	Winter _{DAY}	Summer _{NIGHT}	Summer _{DAY}
Ljubljana (basin city)	2 m T	+	0	0	0
	2 m RH	0	0	0	0
Maribor (flat, low hills)	2 m T	+	+	+	–
	2 m RH	–	0	0	0
Piran (sea, buoy)	2 m T	0	0	+	0
	2 m RH	0	0	0	0
Novo mesto (hilly terrain)	2 m T	+	0	+	+
	2 m RH	–	+	0	0
Lranjska gora (deep valley)	2 m T	–	+	0	0
	2 m RH	–	+	0	0

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Table 5. The average daytime/nighttime scores for the radiative balance, energy balance at the Cabauw tower station, sign (+) means improvement, sign (0) means neutral effect, and sign (–) means degradation of the scores.

	Winter _{NIGHT}	Winter _{DAY}	Summer _{NIGHT}	Summer _{DAY}
Radiative Balance				
Long wave↓	0	0	0	0
Long wave↑	0	0	+	0
Short wave↓	0	0	0	0
Short wave↑	0	0	0	+
Energy Balance				
Latent heat flux	0	+	0	+
Sensible heat flux	0	0	0	+
Storage heat flux	+	+	+	+

[Title Page](#)
[Abstract](#)
[Introduction](#)
[Conclusions](#)
[References](#)
[Tables](#)
[Figures](#)

[Back](#)
[Close](#)
[Full Screen / Esc](#)
[Printer-friendly Version](#)
[Interactive Discussion](#)


Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Table 6. The average (for January and July 2010) S (Structure) A (Amplitude) L (Location) scores, for the 4 km and 7 km runs with (OPER + SFX) and without SURFEX (OPER) against radar observations. A third column is added for each run corresponding to the SAL scores for the run with SURFEX with respect to the operational run.

		7 km			4 km		
		OPER _{OBS}	OPER + SFX _{OBS}	OPER + SFX _{OPER}	OPER _{OBS}	OPER + SFX _{OBS}	OPER + SFX _{OPER}
Jan	S	0.2084	0.2195	-0.0615	0.1842	0.1995	-0.0378
	A	0.4682	0.4842	-0.0187	0.4461	0.4481	-0.0202
	L	0.0536	0.0555	0.0352	0.0609	0.0630	0.0152
Jul	S	0.1004	0.1417	-0.0300	0.0831	0.0857	-0.0219
	A	0.1722	0.1567	-0.0180	0.0548	0.0161	-0.0506
	L	0.2634	0.2549	0.0187	0.2424	0.2523	0.0356

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



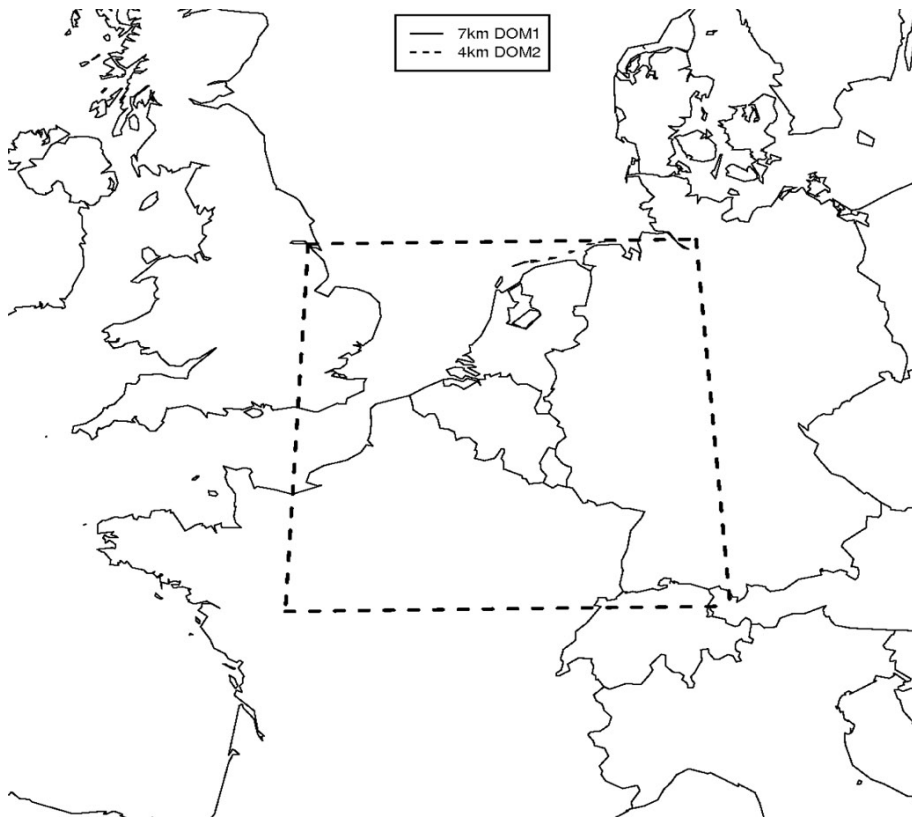


Fig. 1. Domains corresponding to the 7 km and 4 km operational applications.

GMDD

6, 4053–4104, 2013

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract Introduction

Conclusions References

Tables Figures

◀ ▶

◀ ▶

Back Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



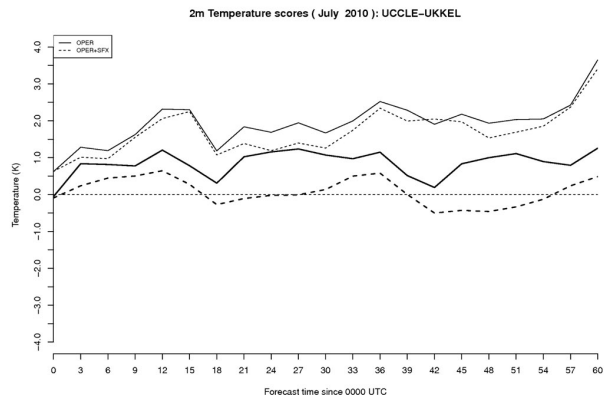
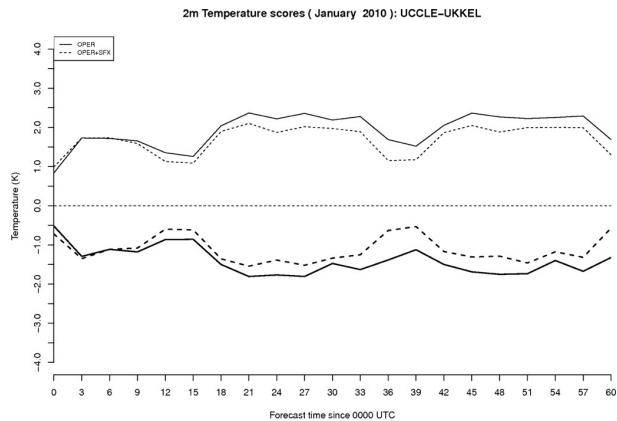


Fig. 2. Statistical scores of 2 m temperature against observations at the suburban Uccle station (bias: thick line; rmse: thin lines) for January (top) and July (bottom) for ALARO without SURFEX (OPER, solid lines) and with SURFEX (OPER + SFX, dashed lines) simulations.

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

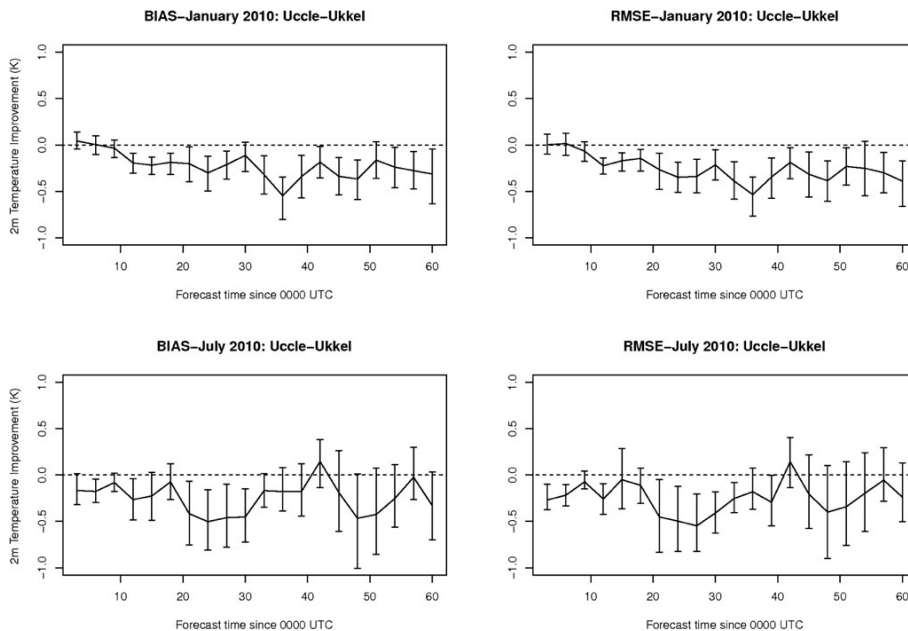


Fig. 3. The improvement in bias (left) and rmse (right) of the 2 m temperature obtained when using SURFEX for January (top) and July (bottom). The 95 % confidence intervals for $|\text{bias}_{\text{OPER} + \text{SFX}}| - |\text{bias}_{\text{OPER}}|$ and $\text{rmse}_{\text{OPER} + \text{SFX}} - \text{rmse}_{\text{OPER}}$ were calculated with the bootstrap method.

[Title Page](#)
[Abstract](#)
[Introduction](#)
[Conclusions](#)
[References](#)
[Tables](#)
[Figures](#)
[⏪](#)
[⏩](#)
[◀](#)
[▶](#)
[Back](#)
[Close](#)
[Full Screen / Esc](#)
[Printer-friendly Version](#)
[Interactive Discussion](#)


Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

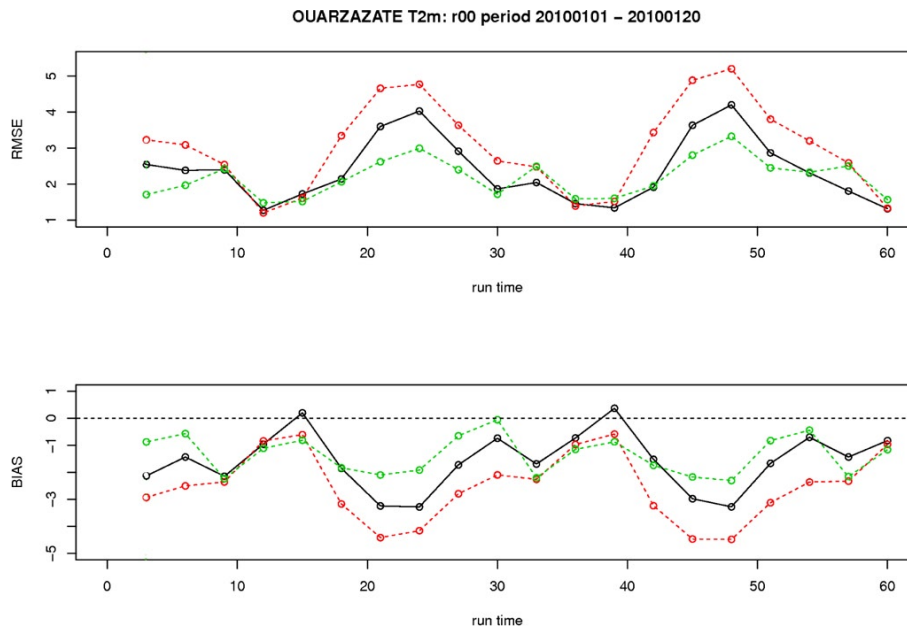


Fig. 4. Statistical scores (rmse: top and bias: bottom) of 2 m temperature against observations at the Ouarzazat station for a winter period 1–20 January 2010 for ALADIN without SURFEX (black continues line), ALADIN with SURFEX (red dashed line) and ALADIN with SURFEX and CANOPY (green dashed lines).

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

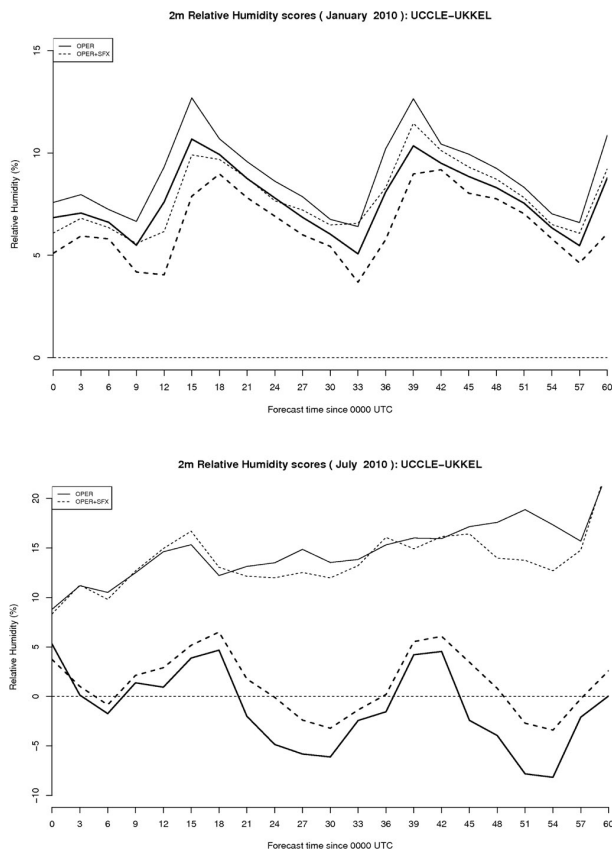


Fig. 5. Statistical scores of 2m relative humidity against observations at the suburban Uccle station (bias: thick line; rmse: thin lines) for January (top) and July (bottom) for ALARO without SURFEX (OPER, solid lines) and with SURFEX (OPER + SFX, dashed lines) simulations.

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

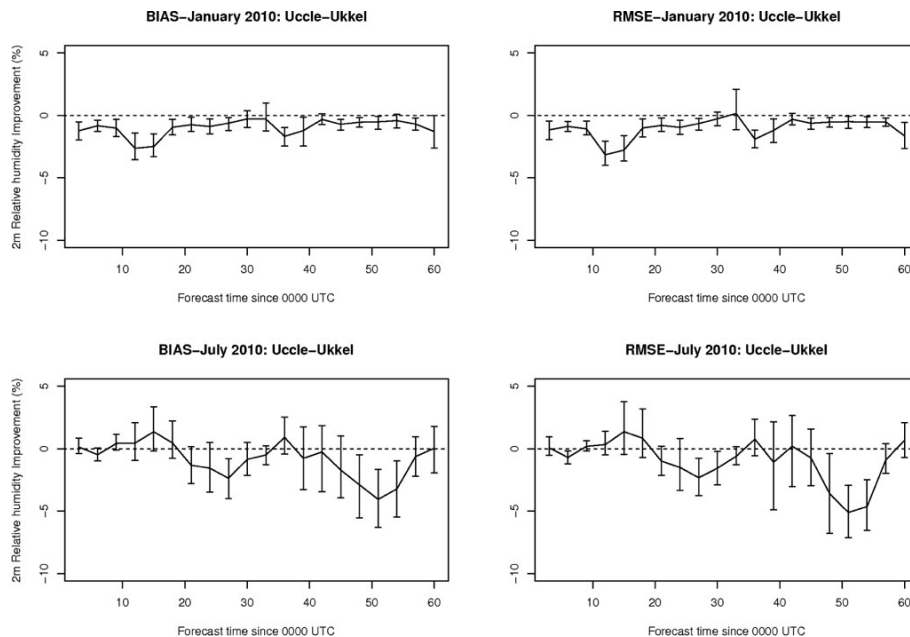


Fig. 6. The improvement in bias (left) and rmse (right) of the 2 m relative humidity obtained when using SURFEX for January (top) and July (bottom). The 95 % confidence intervals for $|\text{bias}_{\text{OPER} + \text{SFX}}| - |\text{bias}_{\text{OPER}}|$ and $\text{rmse}_{\text{OPER} + \text{SFX}} - \text{rmse}_{\text{OPER}}$ were calculated with the bootstrap method.

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

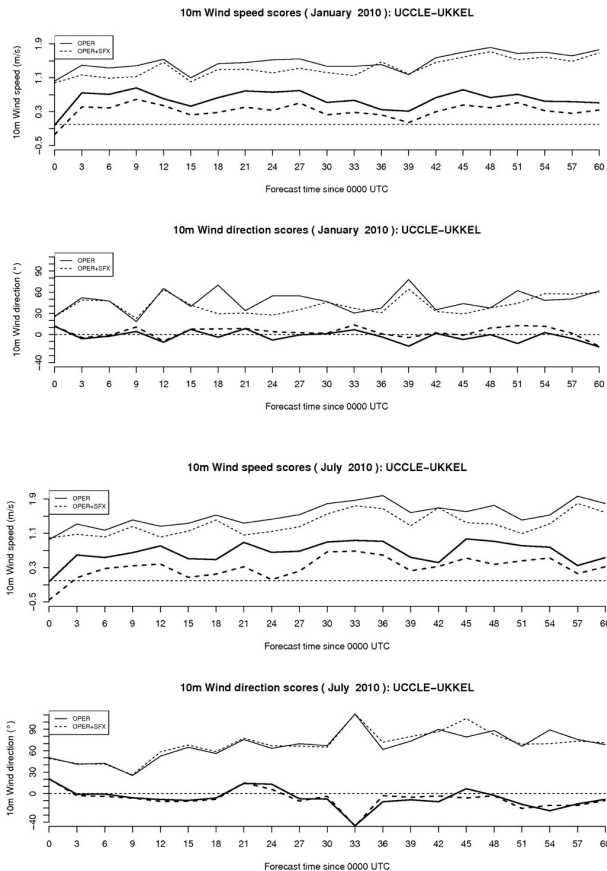


Fig. 7. Statistical scores of 10 m wind speed and direction against observations at the suburban Uccle station (bias: thick line; rmse: thin lines) for January (top) and July (bottom) for ALARO without SURFEX (OPER, solid lines) and with SURFEX (OPER + SFX, dashed lines) simulations.

[Title Page](#)
[Abstract](#) [Introduction](#)
[Conclusions](#) [References](#)
[Tables](#) [Figures](#)
⏪ ⏩
◀ ▶
[Back](#) [Close](#)
[Full Screen / Esc](#)
[Printer-friendly Version](#)
[Interactive Discussion](#)



Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

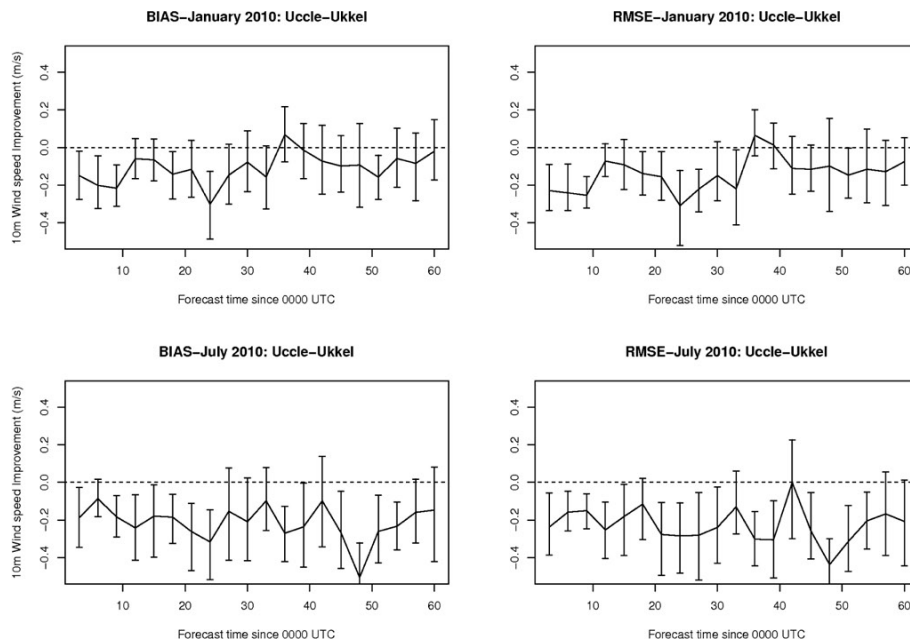


Fig. 8. The improvement in bias (left) and rmse (right) of the 10m wind speed obtained when using SURFEX for January (top) and July (bottom). The 95% confidence intervals for $|\text{bias}_{\text{OPER} + \text{SFX}}| - |\text{bias}_{\text{OPER}}|$ and $\text{rmse}_{\text{OPER} + \text{SFX}} - \text{rmse}_{\text{OPER}}$ were calculated with the bootstrap method.

[Title Page](#)
[Abstract](#)
[Introduction](#)
[Conclusions](#)
[References](#)
[Tables](#)
[Figures](#)
[⏪](#)
[⏩](#)
[◀](#)
[▶](#)
[Back](#)
[Close](#)
[Full Screen / Esc](#)
[Printer-friendly Version](#)
[Interactive Discussion](#)


Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

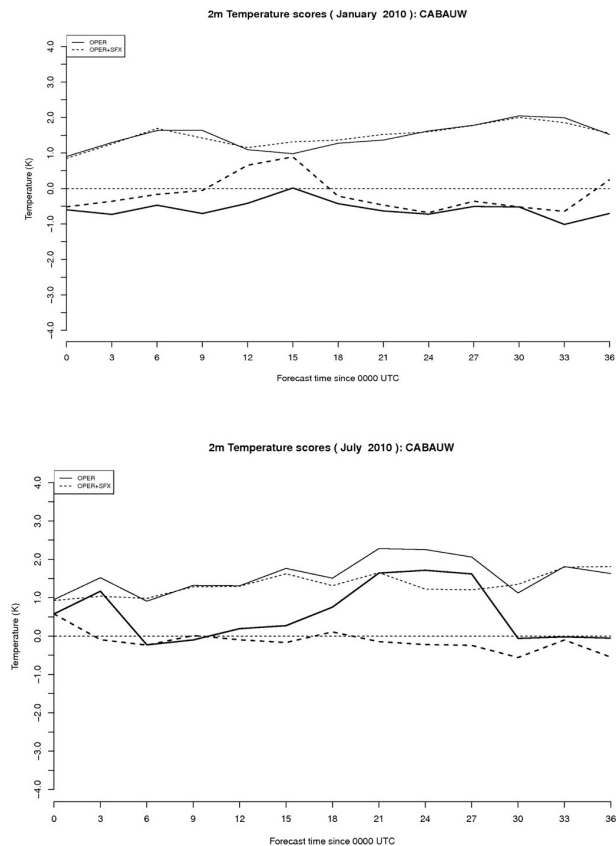


Fig. 9. Statistical scores of 2 m temperature against observations at the Cabauw station (bias: thick line; rmse: thin lines) for January (top) and July (bottom) for ALARO without SURFEX (OPER, solid lines) and with SURFEX (OPER + SFX, dashed lines) simulations.

[Title Page](#)[Abstract](#)[Introduction](#)[Conclusions](#)[References](#)[Tables](#)[Figures](#)[◀](#)[▶](#)[◀](#)[▶](#)[Back](#)[Close](#)[Full Screen / Esc](#)[Printer-friendly Version](#)[Interactive Discussion](#)

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

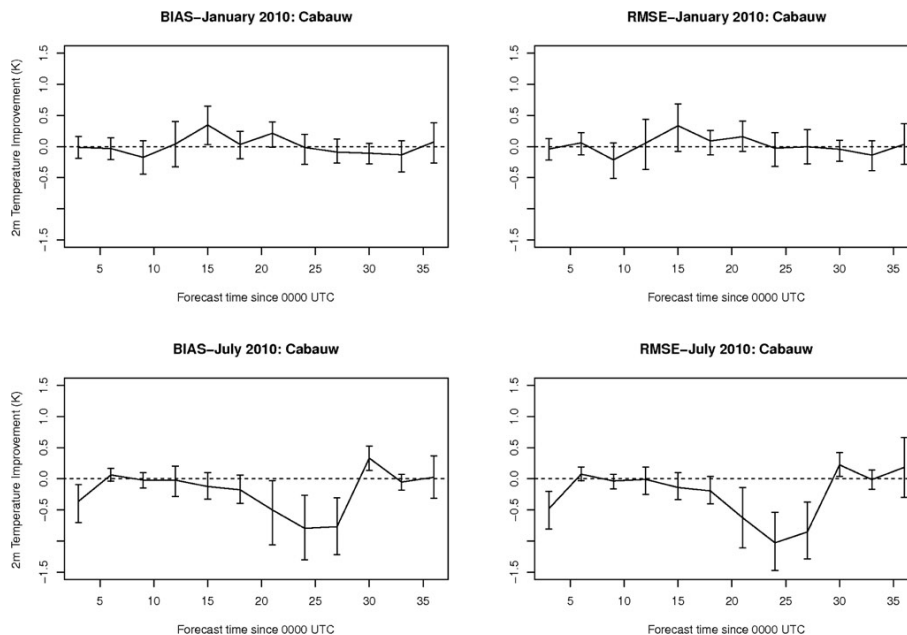


Fig. 10. The improvement in bias (left) and rmse (right) of the 2 m temperature obtained when using SURFEX for January (top) and July (bottom). The 95 % confidence intervals for $|\text{bias}_{\text{OPER} + \text{SFX}}| - |\text{bias}_{\text{OPER}}|$ and $\text{rmse}_{\text{OPER} + \text{SFX}} - \text{rmse}_{\text{OPER}}$ were calculated with the bootstrap method.

[Title Page](#)
[Abstract](#)
[Introduction](#)
[Conclusions](#)
[References](#)
[Tables](#)
[Figures](#)
[⏪](#)
[⏩](#)
[◀](#)
[▶](#)
[Back](#)
[Close](#)
[Full Screen / Esc](#)
[Printer-friendly Version](#)
[Interactive Discussion](#)

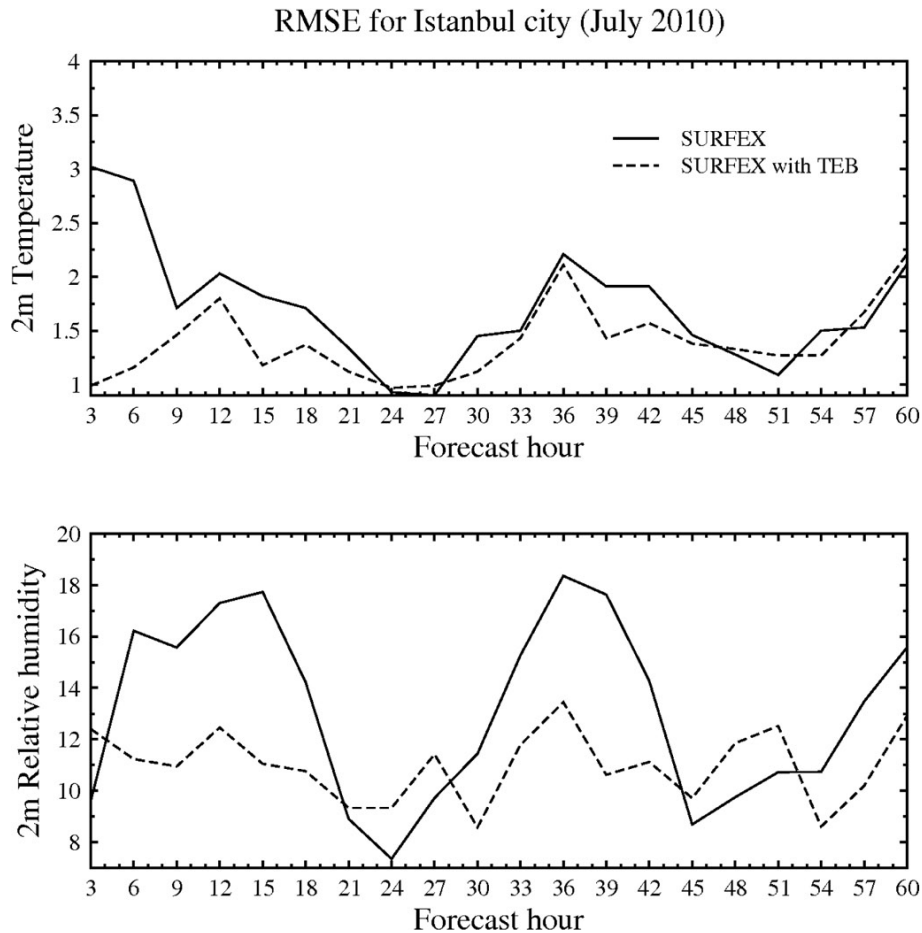



Fig. 11. Rmse of 2 m temperature (top) and 2 m relative humidity (bottom) against observations at the Istanbul city station averaged over July 2010 for ALARO with SURFEX (continue line) and ALARO with SURFEX and TEB (dashed lines).

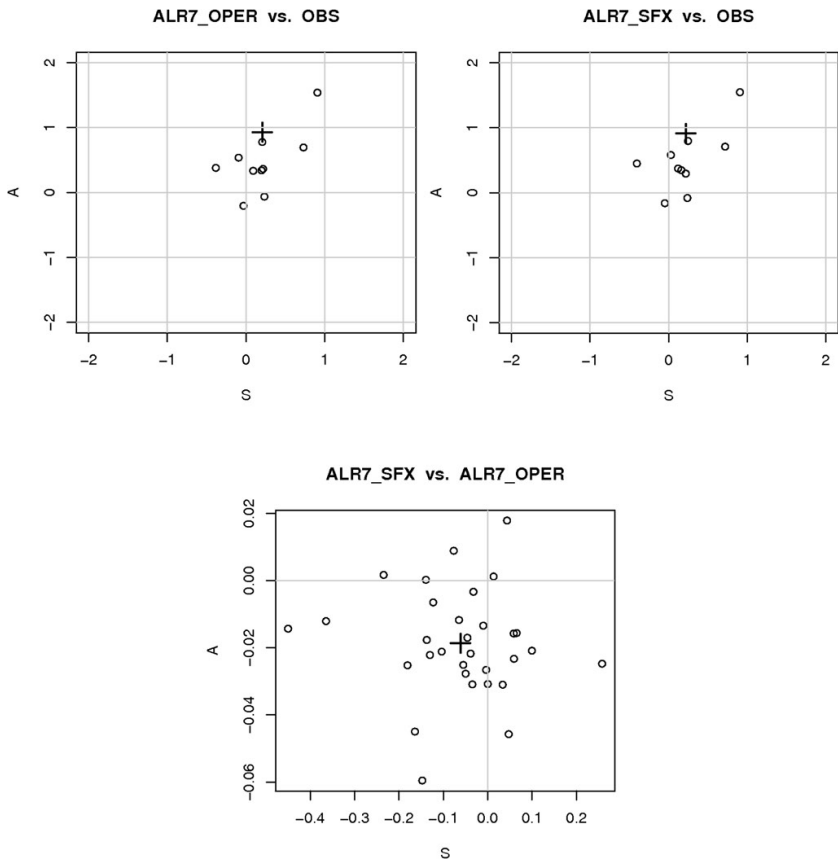


Fig. 12. Structure and amplitude precipitation scores of the 7 km ALARO run for January 2010. Top: against radar observation; the OPER run (left) and the run with SURFEX (right). Bottom: the run with SURFEX against the operational run (OPER) where each point corresponds to 1 day. The cross indicates the weighted mean.

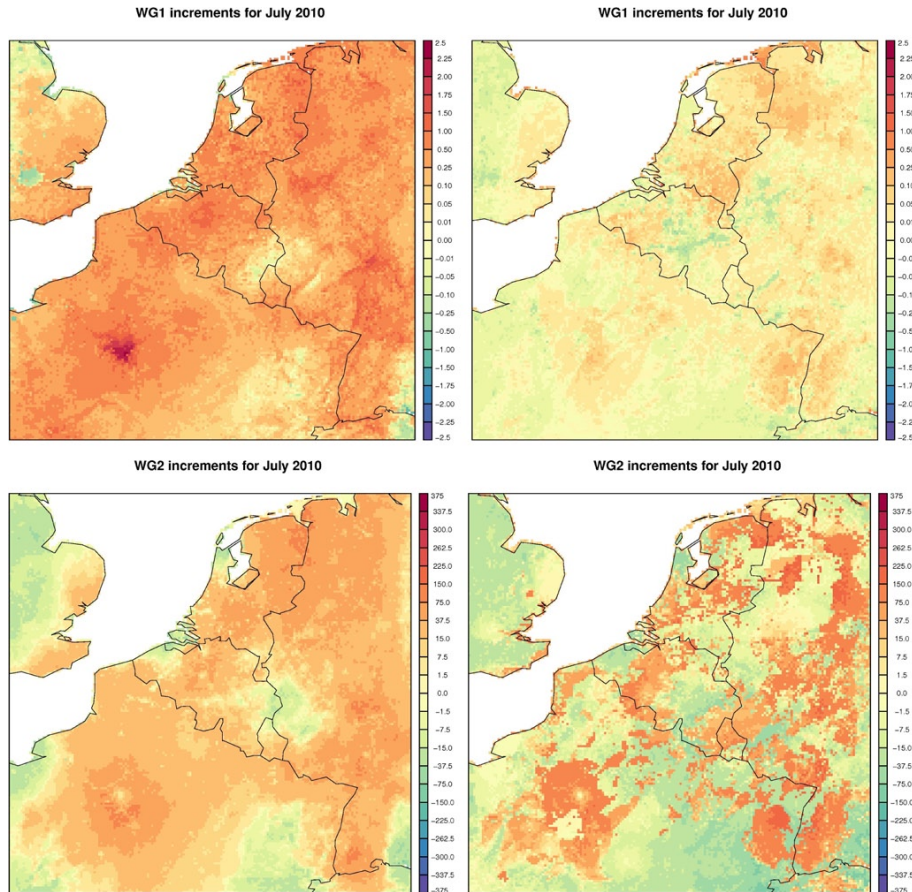


Fig. 13. Soil moisture content (mm) accumulated over the month of July 2010: top-left superficial produced by OI analysis; Top-Right superficial produced by the EKF analysis; Bottom-Left deep produced by OI analysis; and Bottom-Right deep produced by the EKF analysis.

WG2 increments for July 2010

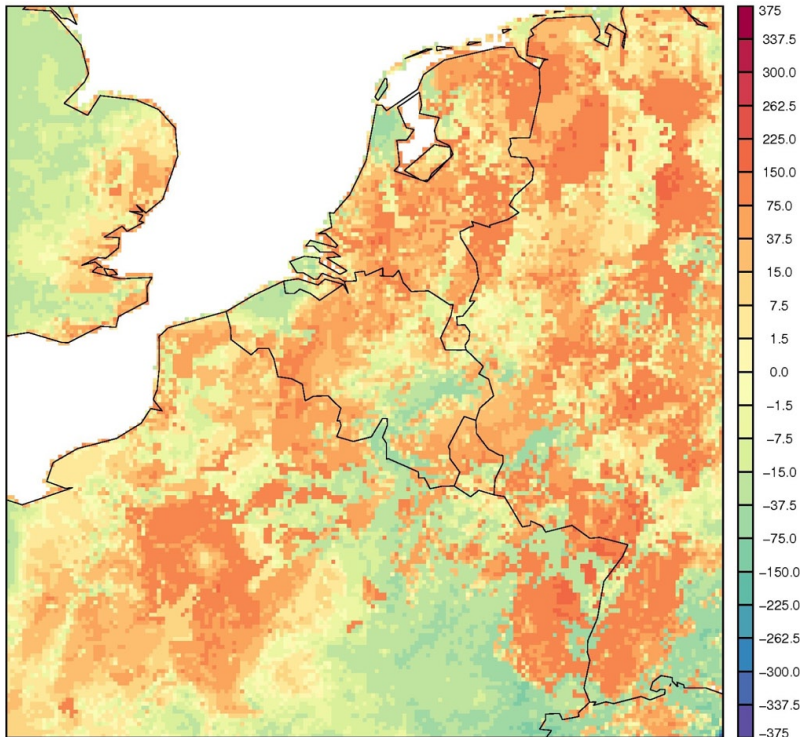


Fig. 14. Deep soil moisture content accumulated over the month of July 2010, produced by EKF analysis where SWI is kept between 0 and 1.

Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

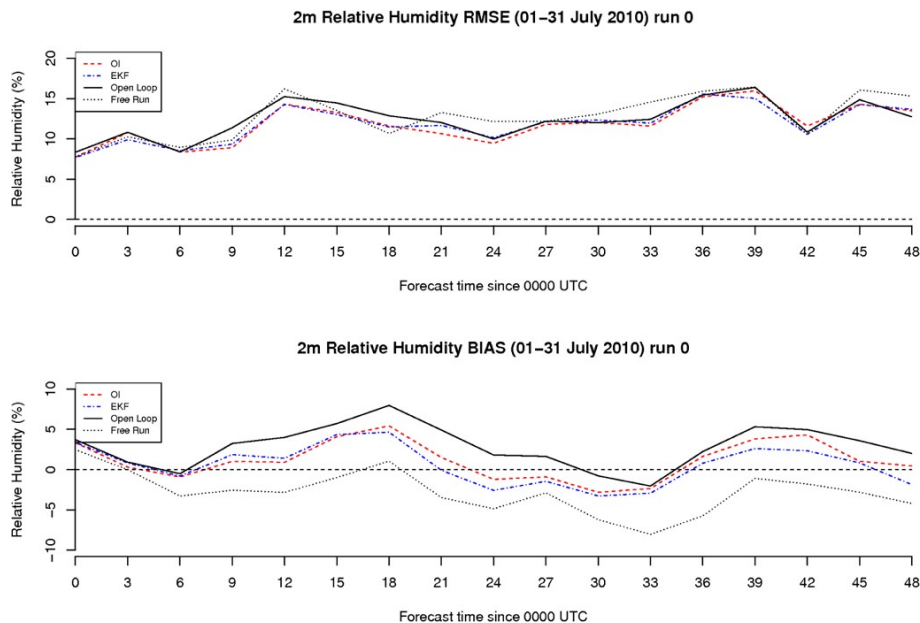


Fig. 15. Root Mean Square Error and BIAS for Relative Humidity at Uccle averaged over the month July 2010 for Optimum Interpolation (OI), Extended Kalman Filter (EKF), Open Loop and Free Run.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Coupling SURFEXv5
with ALADINcy36 and
ALARO-0

R. Hamdi et al.

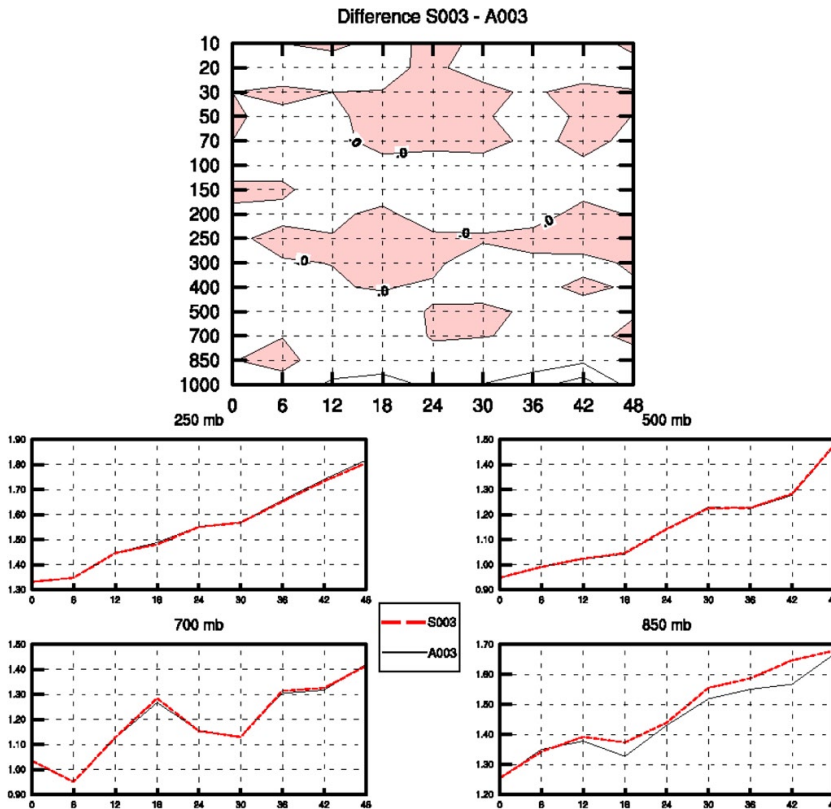


Fig. 16. Top: vertical profile of the temperature rmse difference between a run with (S003) and without SURFEX (A003) as a function of forecast range averaged over a winter period 10–29 December 2010 and over the whole domain. Red shaded areas means that the use of SURFEX improve the scores. Bottom: temperature rmse of the run with (red line) and without (black line) SURFEX at different pressure levels (250, 500, 700, and 850 mb).

Coupling SURFEXv5
with ALADINcy36 and
ALARO-0

R. Hamdi et al.

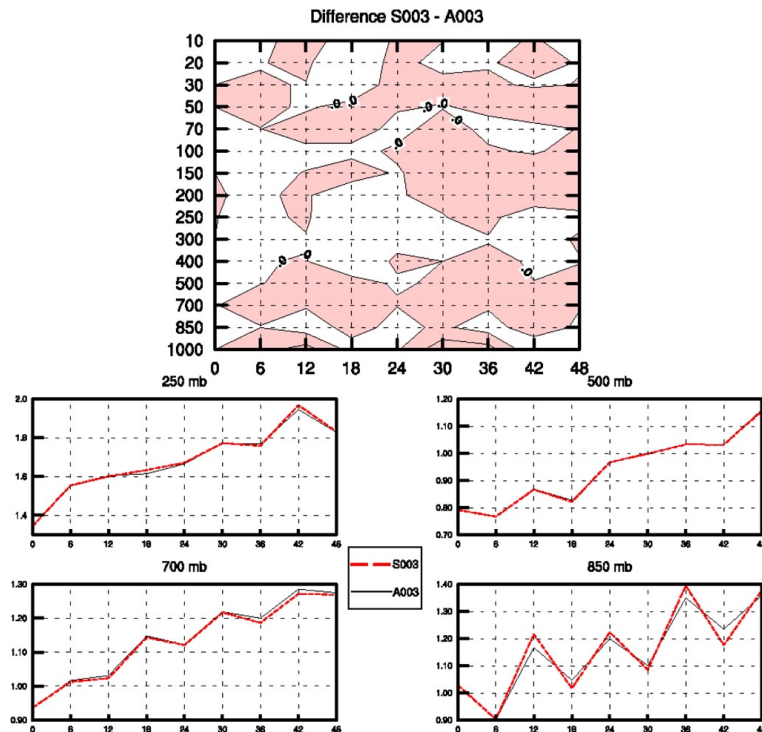


Fig. 17. Top: vertical profile of the temperature rmse difference between a run with (S003) and without SURFEX (A003) as a function of forecast range averaged over a summer period 18 July 2010–15 August 2010 and over the whole domain. Red shaded areas means that the use of SURFEX improve the scores. Bottom: temperature rmse of the run with (red line) and without (black line) SURFEX at different pressure levels (250, 500, 700, and 850 mb).

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Coupling SURFEXv5 with ALADINcy36 and ALARO-0

R. Hamdi et al.

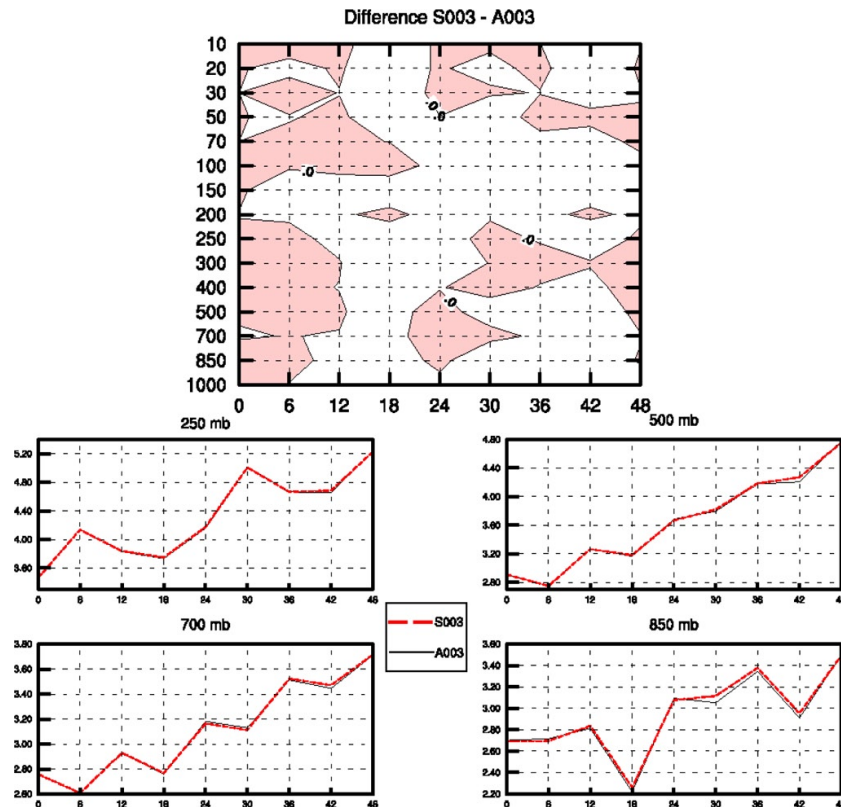


Fig. 18. Top: vertical profile of the wind speed rmse difference between a run with (S003) and without SURFEX (A003) as a function of forecast range averaged over a winter period 10–29 December 2010 and over the whole domain. Red shaded areas means that the use of SURFEX improve the scores. Bottom: wind speed rmse of the run with (red line) and without (black line) SURFEX at different pressure levels (250, 500, 700, and 850 mb).

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Coupling SURFEXv5
with ALADINcy36 and
ALARO-0

R. Hamdi et al.

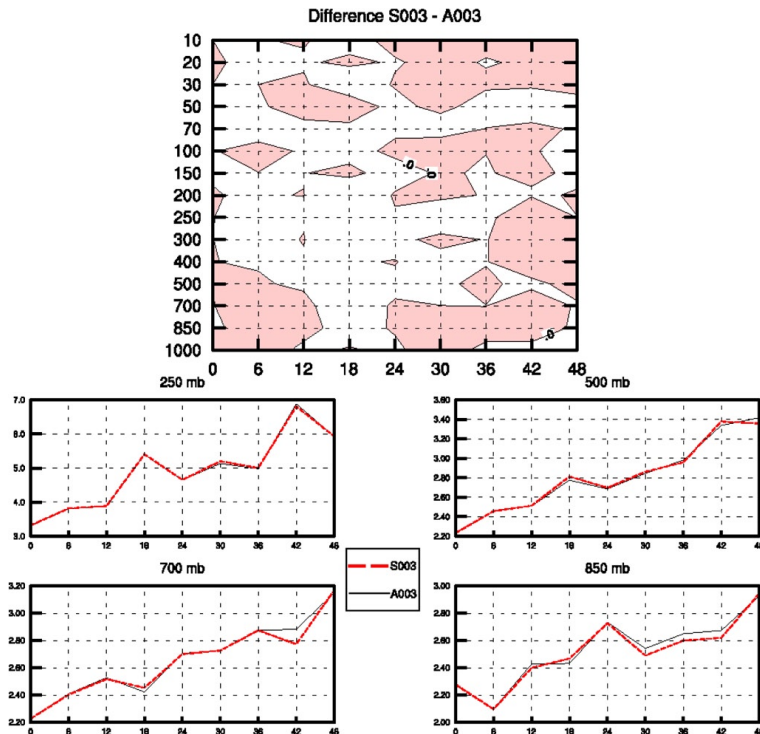


Fig. 19. Top: vertical profile of the wind speed rmse difference between a run with (S003) and without SURFEX (A003) as a function of forecast range averaged over a summer period 18 July 2010–15 August 2010 and over the whole domain. Red shaded areas means that the use of SURFEX improve the scores. Bottom: wind speed rmse of the run with (red line) and without (black line) SURFEX at different pressure levels (250, 500, 700, and 850 mb).

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion