Recent developments in land surface modeling and data assimilation in ALADIN

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- **Both ARPEGE and ALADIN relied on the ISBA scheme for the parameterization of the surface processes.** (Noilhan and Planton 1989 ; Mahfouf et al. 1995 ; Noilhan and Mahfouf 1996)

- **The ISBA scheme has also been implemented in the meso-NH model of Météo-France.** (Lafore et al. 1998)

- **In 2000 Valéry Masson developed a scheme for simulation the interactions with urban areas and this scheme became part of the meso-NH surface model.** (TEB, Masson 2000)

- **During the last decade, the surface scheme (ISBA+TEB) has been externalized from the atmospheric part of the meso-NH model following the approach of** (Best et al. 2004)

- **This led to the creation of the SURFEX scheme (SURface Externalisée) where the characteristics of the surface are specified by the ECOCLIMAP database** (Masson et al. 2003)

- **Additionally, more schemes has been added to SURFEX for: Sea and oceans (prescribed SST, ECUME, 1-D ocean model), lakes (prescribed ST, FLAKE), Surface boundary layer scheme CANOPY...etc.**

- Once this externalization is realized and if SURFEX is plugged in one of the different operational model version: ARPEGE, ALADIN, AROME, ALARO it becomes automatically available within all these applications.

- SURFEX contains the ISBA scheme for soil and vegetation interaction, so there is no need to maintain the ISBA scheme separately in the different operational model version.

- In operational contexts it is important that the scheme is sufficiently numerically stable to run with the long time steps, hence the need for the implicit coupling proposed in Best et al. (2004).

- An extra advantage of this externalization is that SURFEX can be used in an offline mode for specific scientific applications where the feedback of the upper-air processes is eliminated.

- And this is an extra argument for user developing and deploying an externalized surface scheme.

- **SURFEX is used operationally within the AROME model with the physics parameterization of meso-NH** (Seity et al. 2011)
- **The value of operational weather forecast is determined by verification scores. So, if the 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 find back EXACTLY the same model performance.**
- **However, the implementation of ISBA in ALADIN and its evolution in meso-NH and later its implementation in AROME diverged slowly. An attempt to find reproducibility of the model behavior within the ALADIN model of the old ISBA scheme by the SURFEX-ISBA scheme FAILED.**
- **Nevertheless, this question still stands: Why should one maintain different ISBA schemes to serve a large community of users?**
- **The obvious version of the two ISBA version is the one of SURFEX since one can argue that this will be the one that will scientifically continue to evolve the most.**

- **ALADIN partners from Algeria, Austria, Belgium, Hungary, Morocco, Poland, Slovenia, and Turkey participated to the SURFEX working week in Brussels 18-22 April 2011.**
- **They carried out tests within the frame of their operational applications.**
- **The aim of this exercise was to make an extensive validation of SURFEX used for the configuration of the NWP system by each partner within the consortium.**
- **And to examine if one can, 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 ALADIN/ALARO models, reproduce forecast performance 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.**
- **Finally, the present exercise does not address other important issues which represent crucial criteria for operational application such as: code optimization, the user-friendliness of the SURFEX implementation..etc**

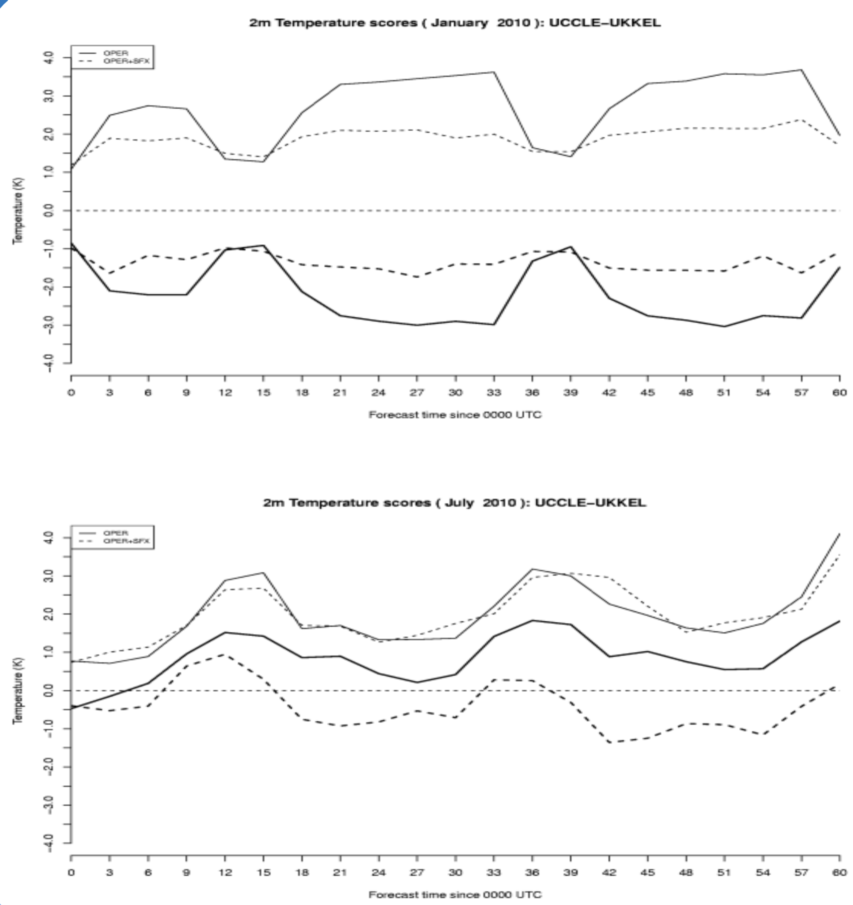
- **Two radiation schemes: AROME uses the Foucart-Morcrette Radiation scheme (FMR, Morcrette 1991). This scheme is also used in the French double suite of ALADIN where SURFEX is used.**

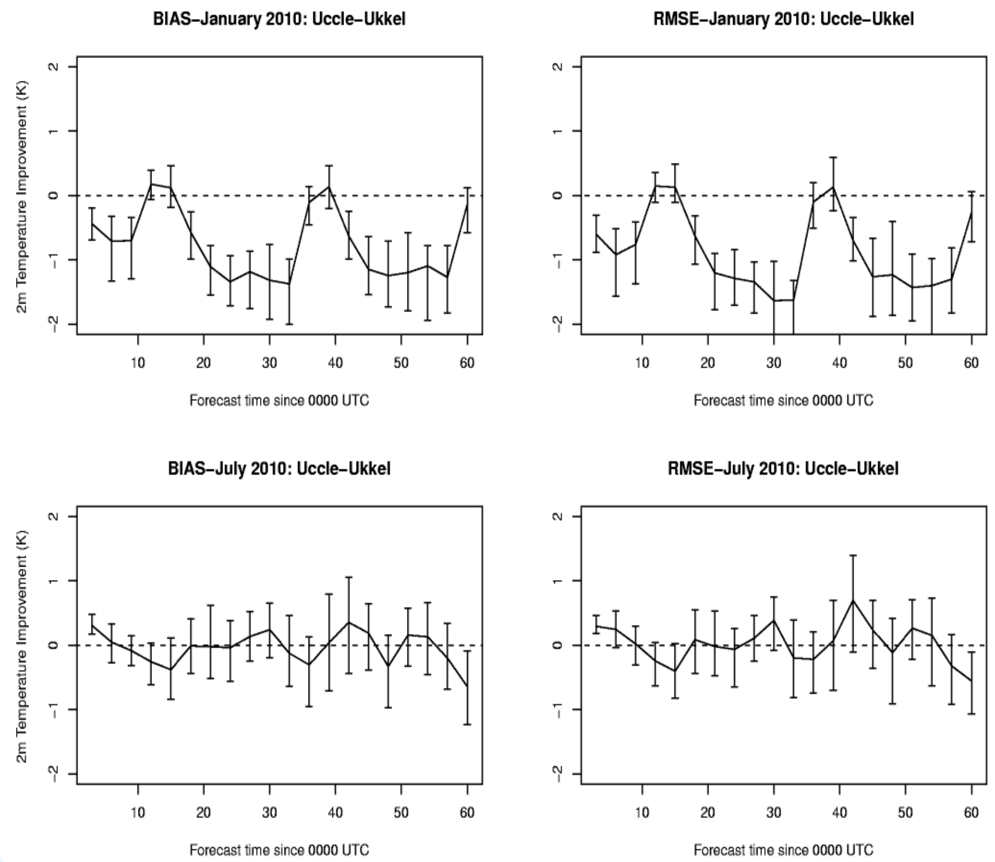
- **The ALARO physics package has been developed with the ACRANEB radiation scheme built on Ritter and Geleyn (1992).**

- **FMR is called intermittently to save computing costs. ACRANEB on the other hand is 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.**

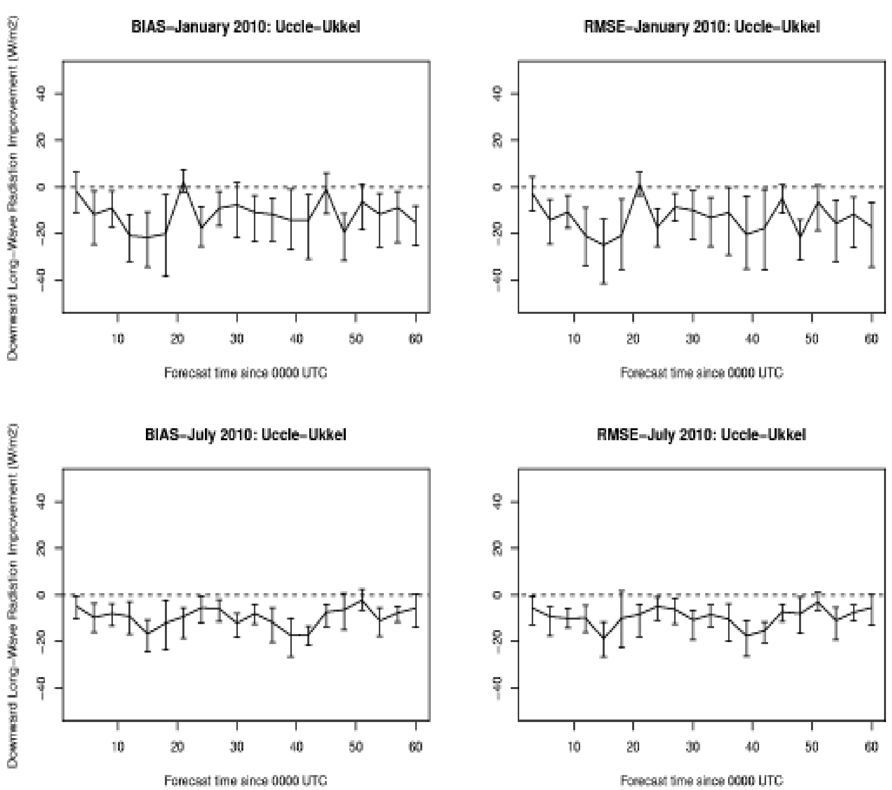
- **Three ways to calculate the standard meteorological variables (2m temperature and relative humidity and 10m wind) in the surface boundary layer: Interpolation using the Paulson (1970) law, Interpolation using the Geleyn (1988) method, as a Prognostic variables using the CANOPY scheme.**

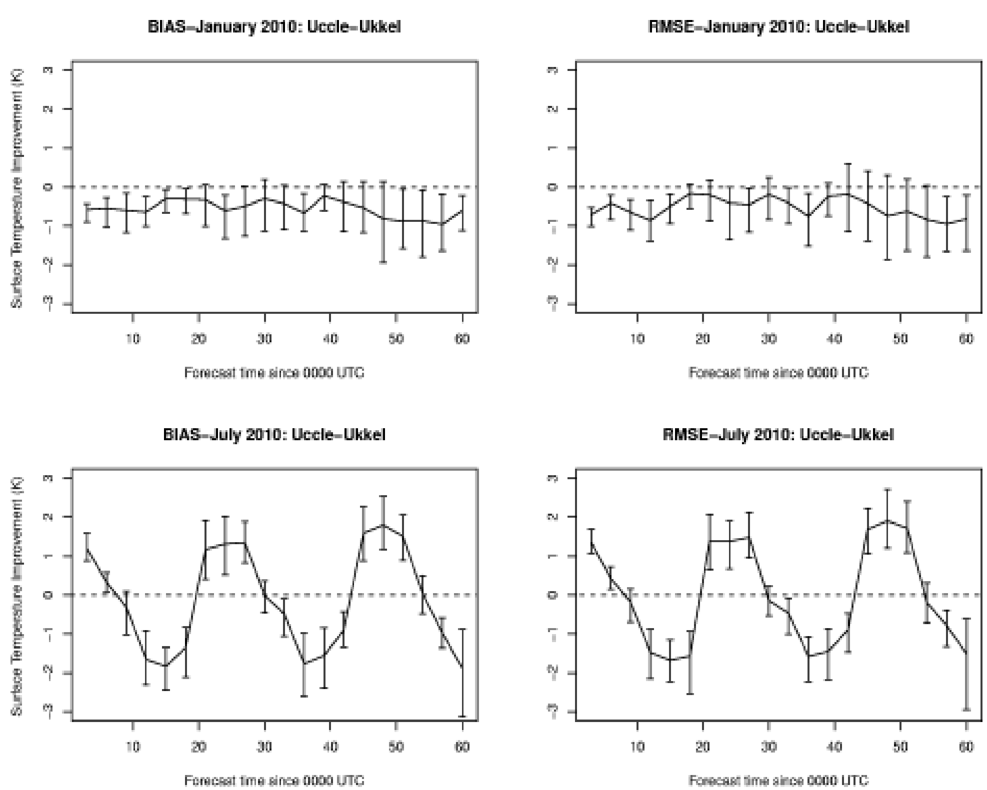
ALADIN+FMR+SURFEX Vs ALADIN+ACRANEB run over Belgium





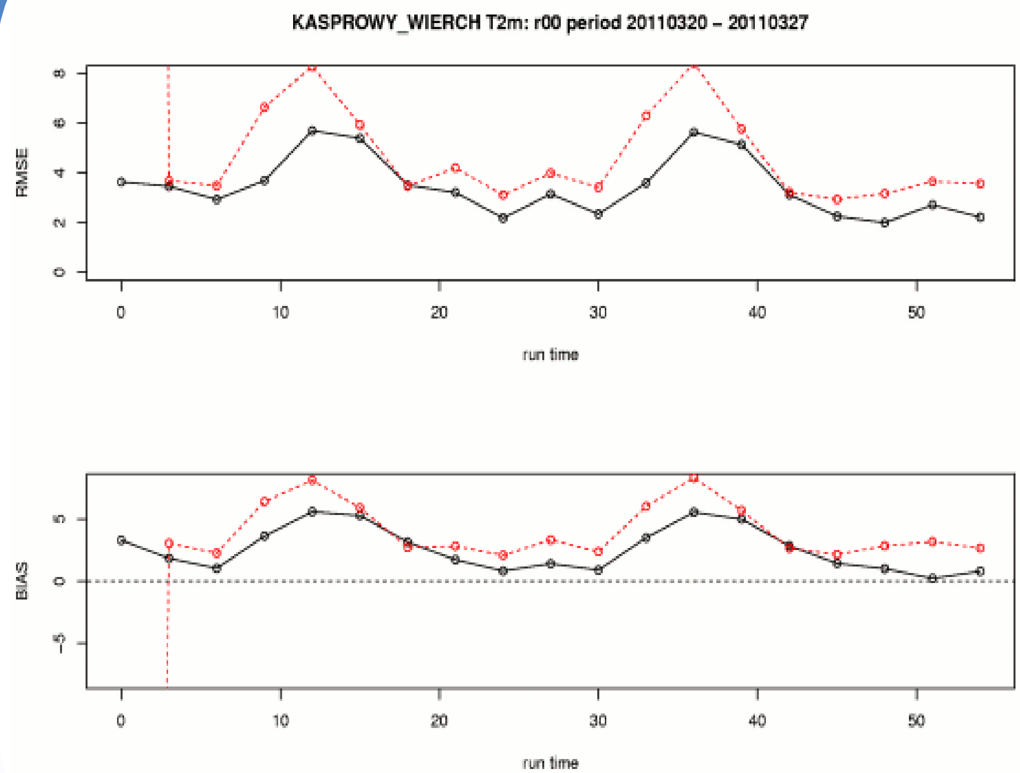
ALADIN+FMR+SURFEX Vs ALADIN+ACRANEB run over CABAUW using the COLOBOC database





ALADIN+FMR+SURFEX Vs ALADIN+ACRANEB run over Poland 20110320-20110327

ALD			
		Day	Night
T2m	Flat	0	+++
	High	---	---
	Coast	+++	+++
RH2m	Flat	0	0
	High	+++	0
	Coast	+++	+++

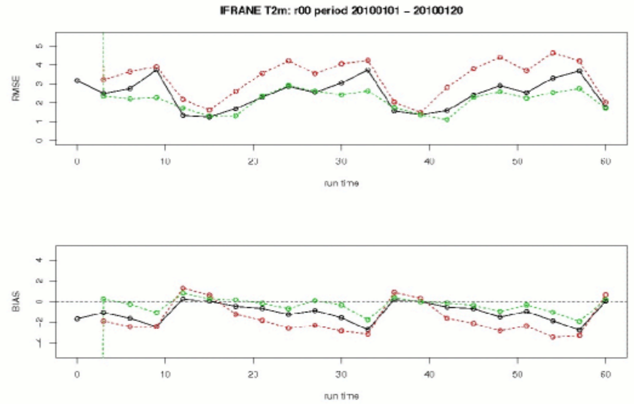


ALADIN+FMR+SURFEX+CANOPY Vs ALADIN OPER run over Morocco

ALD		Winter		Summer	
		Day	Night	Day	Night
T2m	Flat	+++	0	---	-
	High	---	---	0	---
	Coast	0	0	0	0
	Sahara	0	---	0	---
RH2m	Flat	+++	+++	---	0
	High	0	0	0	0
	Coast	0	0	0	0
	Sahara	0	0	0	---

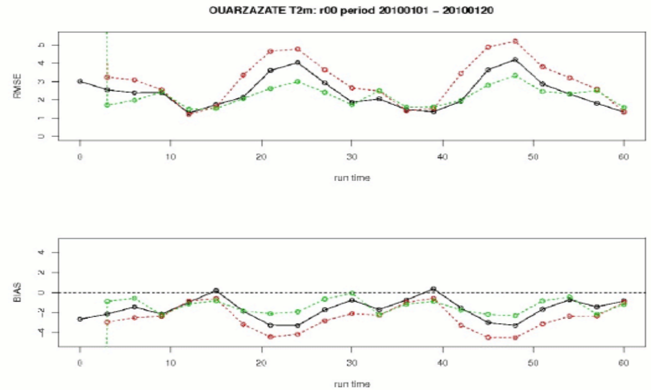
Ifrane (Relief du moyen Atlas)

Hiver :
Amélioration

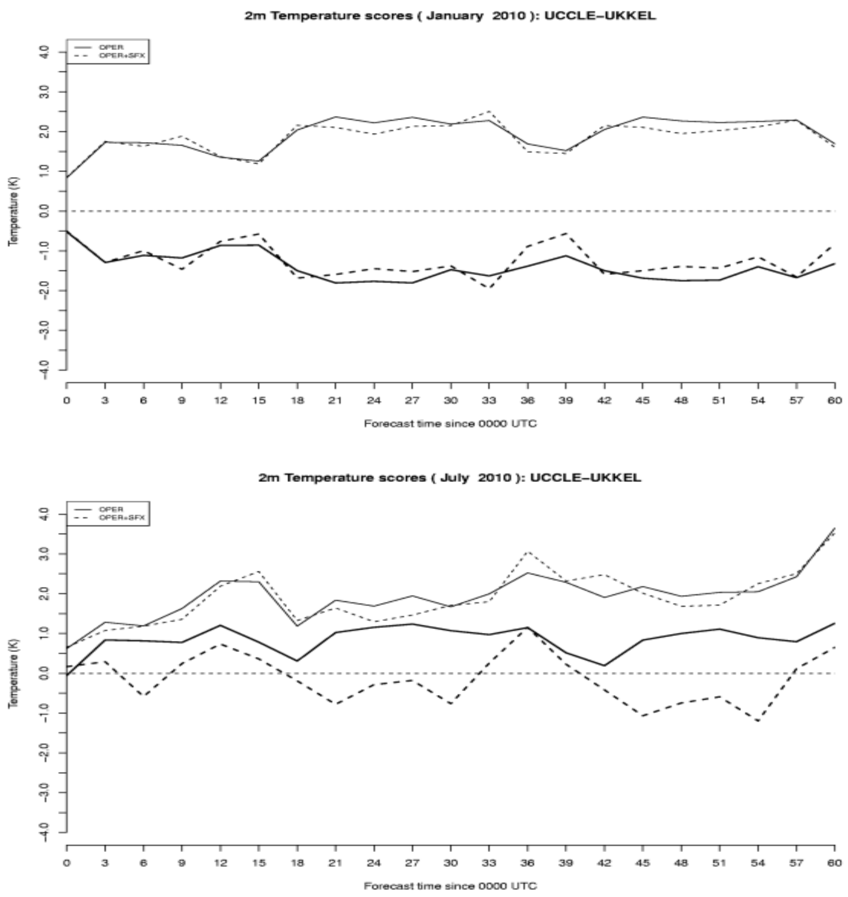


Ouarzazate (Pied du petit Atlas versant Sud : Porte du Sahara) :

Hiver :
Amélioration net durant la nuit



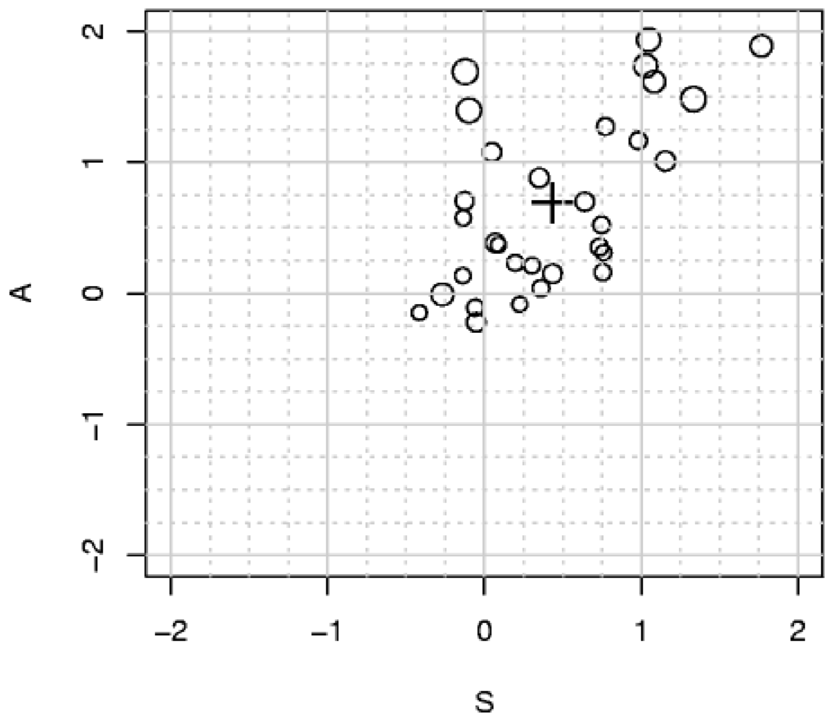
ALARO+FMR+SURFEX Vs ALARO+ACRANEB run over Belgium



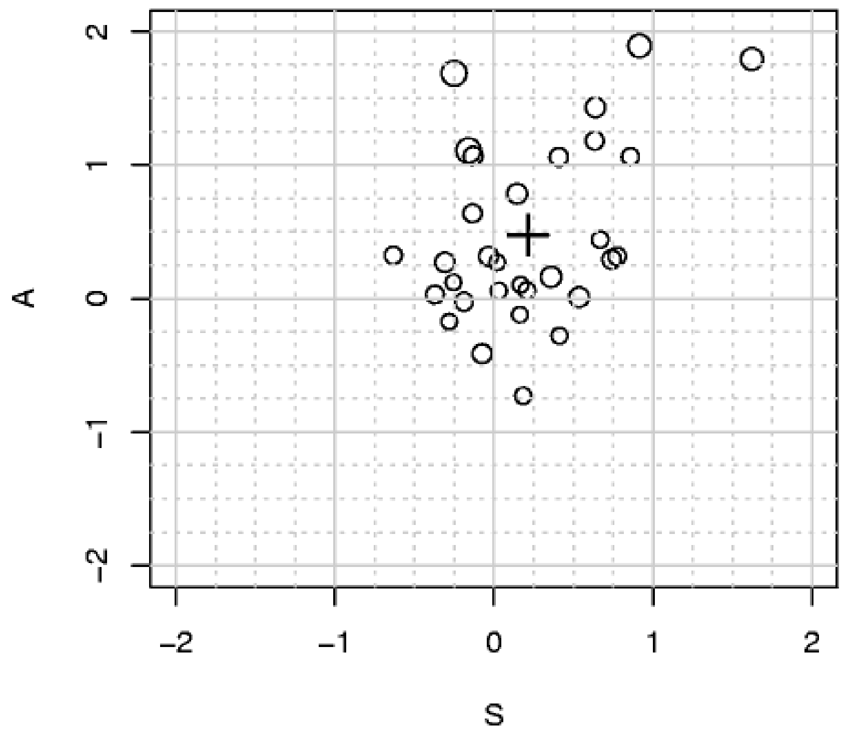
ALR7		Winter		Summer	
		Day	Night	Day	Night
T2m	Flat	0	0	0	0
	High	---	0	0	++
	Coast	0	0	0	+++
W10m	Flat	0	0	0	0
	High	0	0	0	0
	Coast	---	---	0	0
RH2m	Flat	+++	+++	0	+++

ALARO+FMR+SURFEX Vs ALARO+ACRANEB run over Belgium

ALARO



ALARO + SURFEX



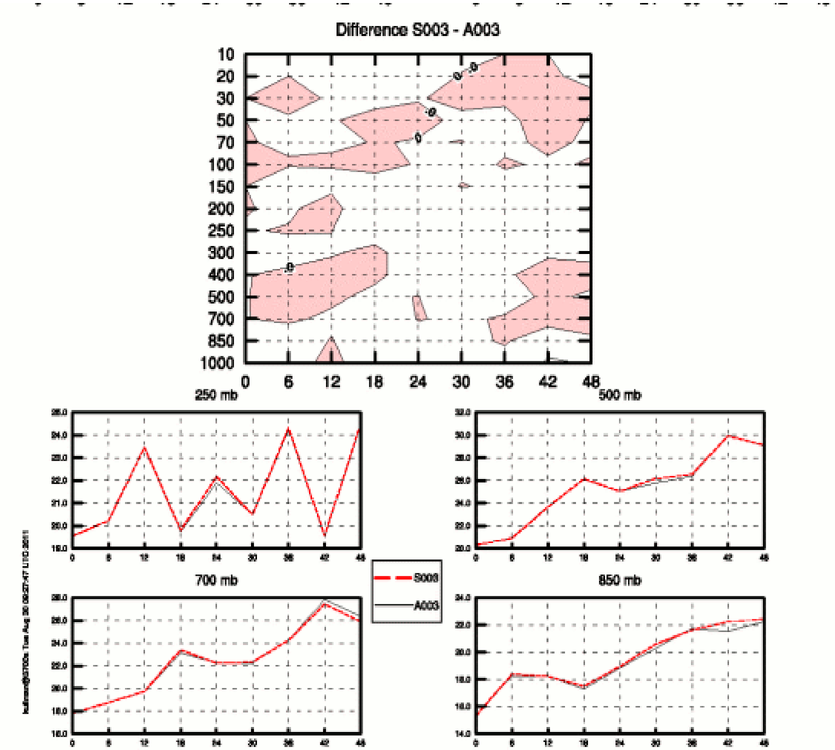
ALARO+FMR+SURFEX Vs ALARO+ACRANEB run over Slovenia

		Ljubljana (basin, city)		Maribor (flat, low hills)		Piran (sea, buoy)		Novo mesto (hilly terrain)		Kranjska gora (deep valley)	
		T2m	RH2m	T2m	RH2m	T2m	RH2m	T2m	RH2m	T2m	RH2m
9.5 km	winter, day	-	0	0	0	0	0	-	0	0	0
	winter, night	++	-	++	---	+	+	--	-	+	-
	summer, day	0	-	-	0	0	0	0	0	0	0
	summer, night	0	0	-	0	0	0	--	-	--	0
4.4 km	winter, day	0	0	+	0	0	0	0	+	+	+
	winter, night	+++	0	++	-	0	0	++	-	-	--
	summer, day	0	0	-	0	0	0	++	0	0	0
	summer, night	0	0	+	0	+	0	0	0	0	0

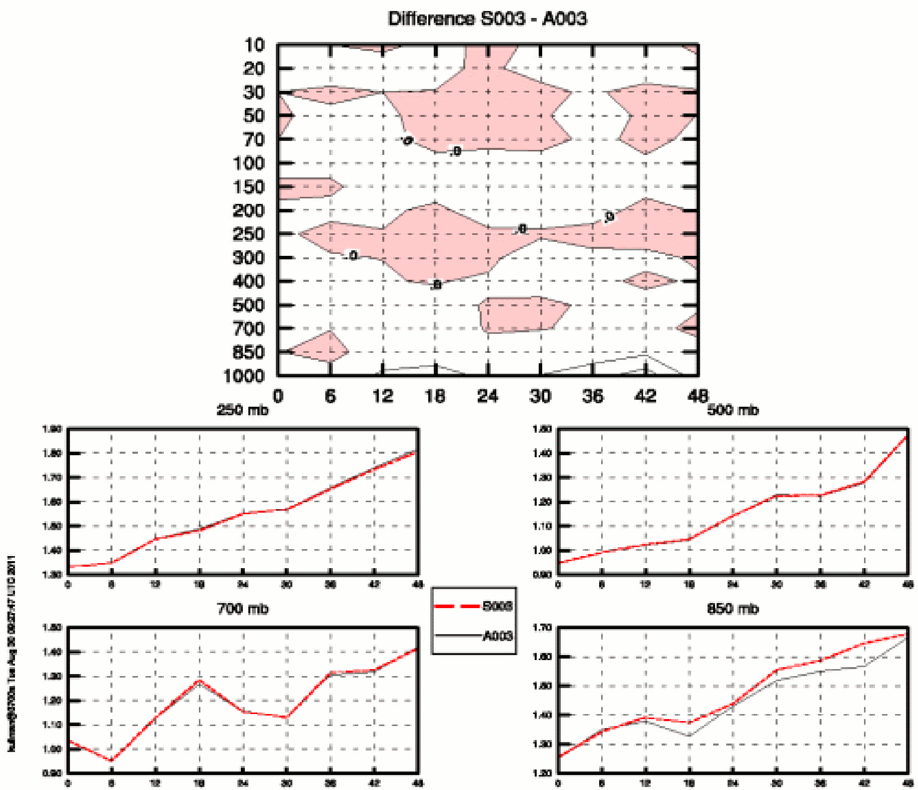
The additional computational cost to run integration with SURFEX is rather low: the time needed to complete an average timestep is on the order of 5% (compared to ACRADIN with old isba). This addtional time is actually 10-20% less than an average timestep with ACRANEB run (though radiation is not called every timestep in case of ACRADIN).

ALARO+FMR+SURFEX Vs ALARO+ACRANEB run over Hungary winter

Relative Humidity (RMSE)

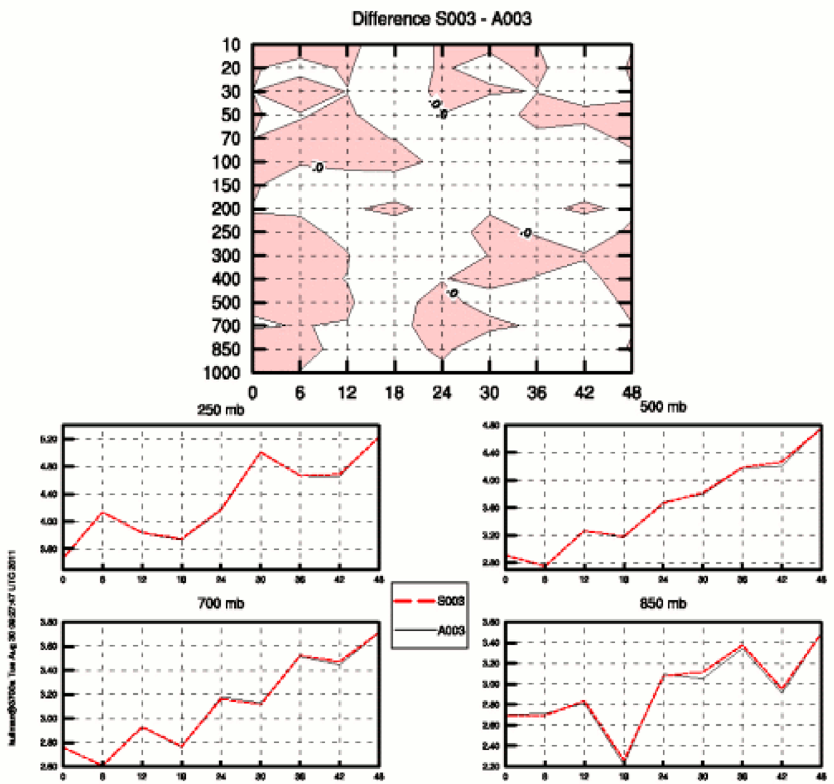


Temperature (RMSE)



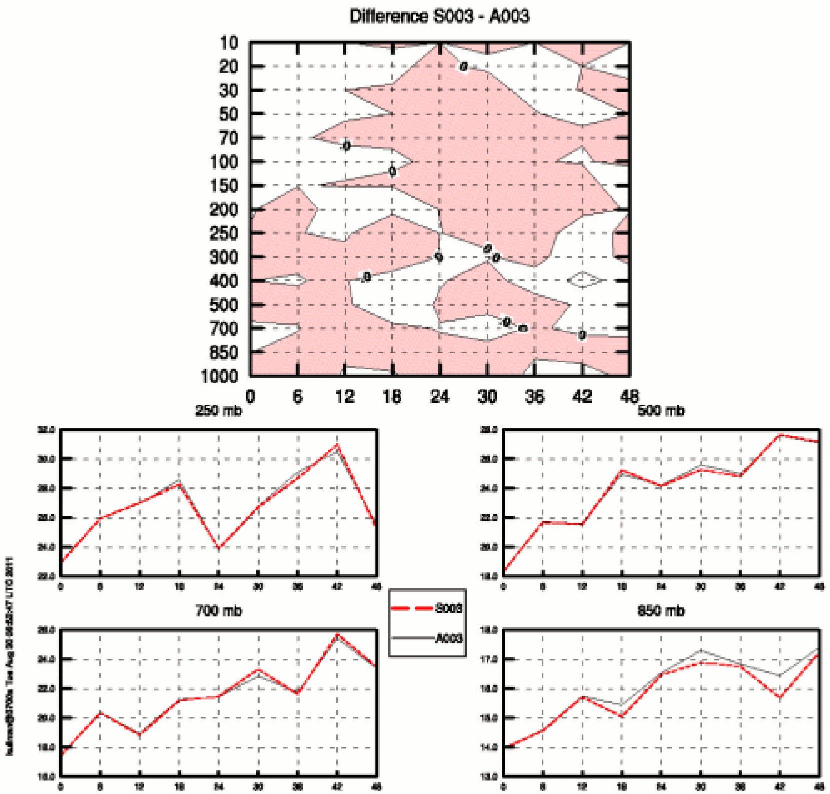
ALARO+FMR+SURFEX Vs ALARO+ACRANEB run over Hungary winter

Wind speed (RMSE)

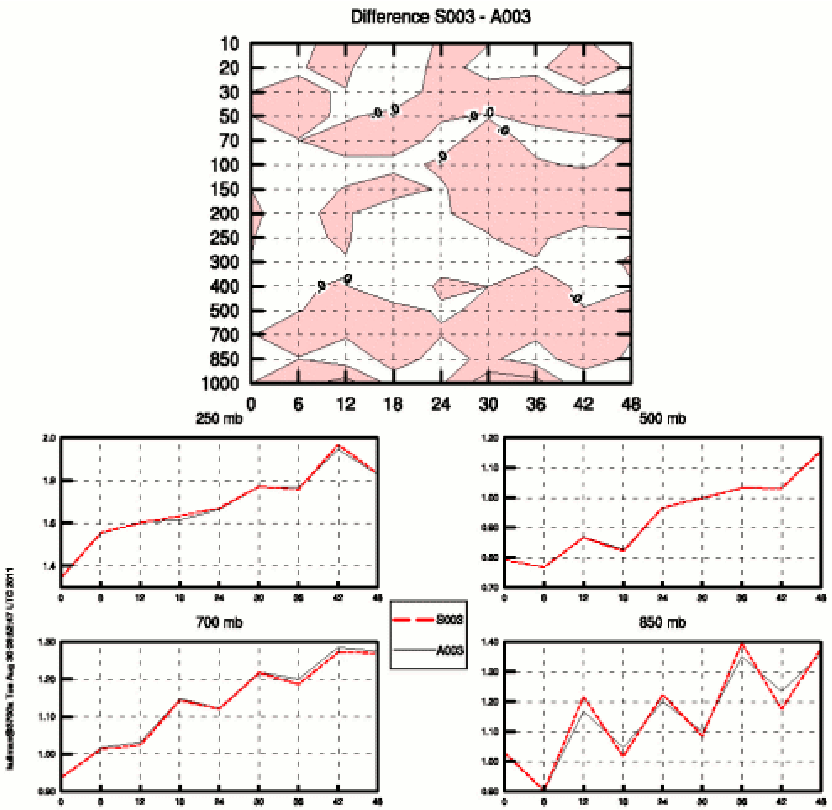


ALARO+FMR+SURFEX Vs ALARO+ACRANEB run over Hungary summer

Relative Humidity (RMSE)

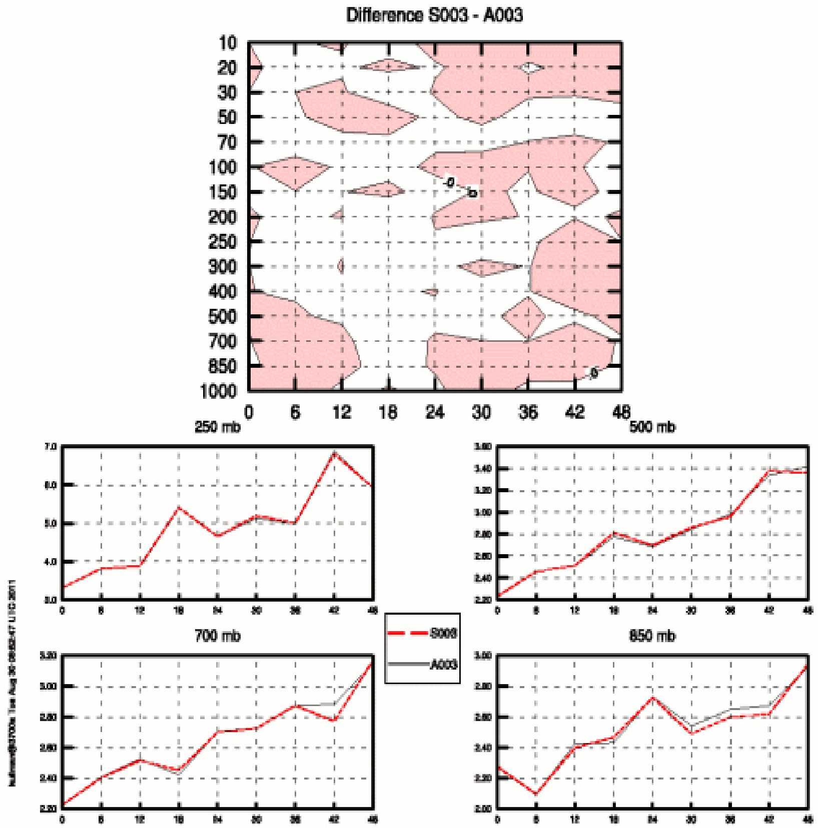


Temperature (RMSE)

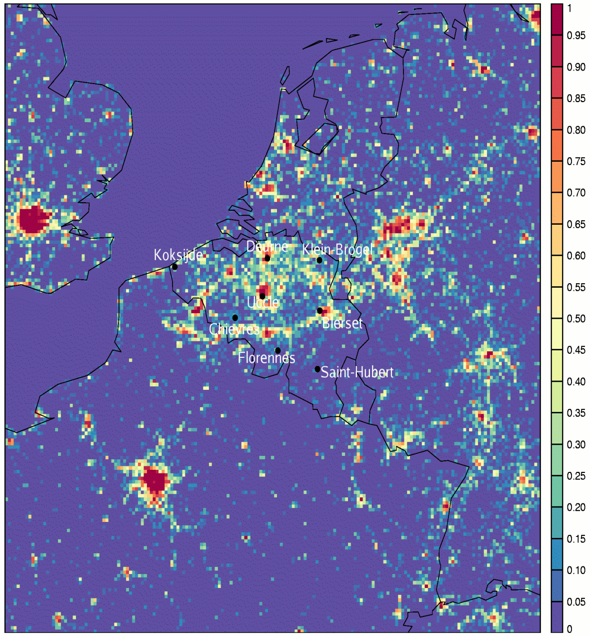


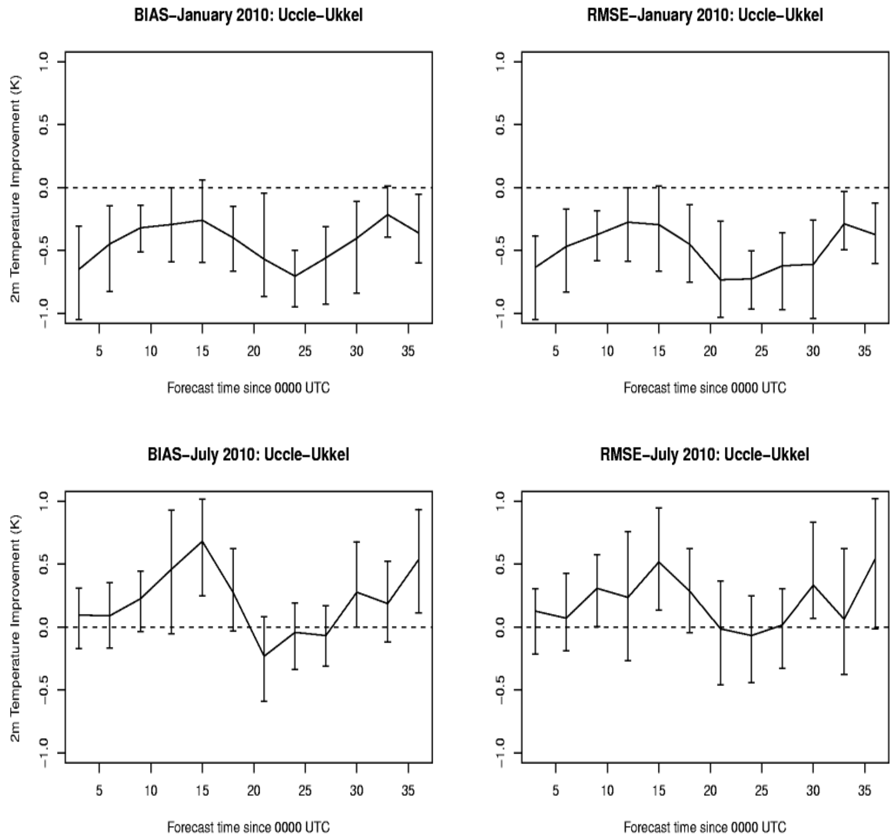
ALARO+FMR+SURFEX Vs ALARO+ACRANEB run over Hungary summer

Wind speed (RMSE)

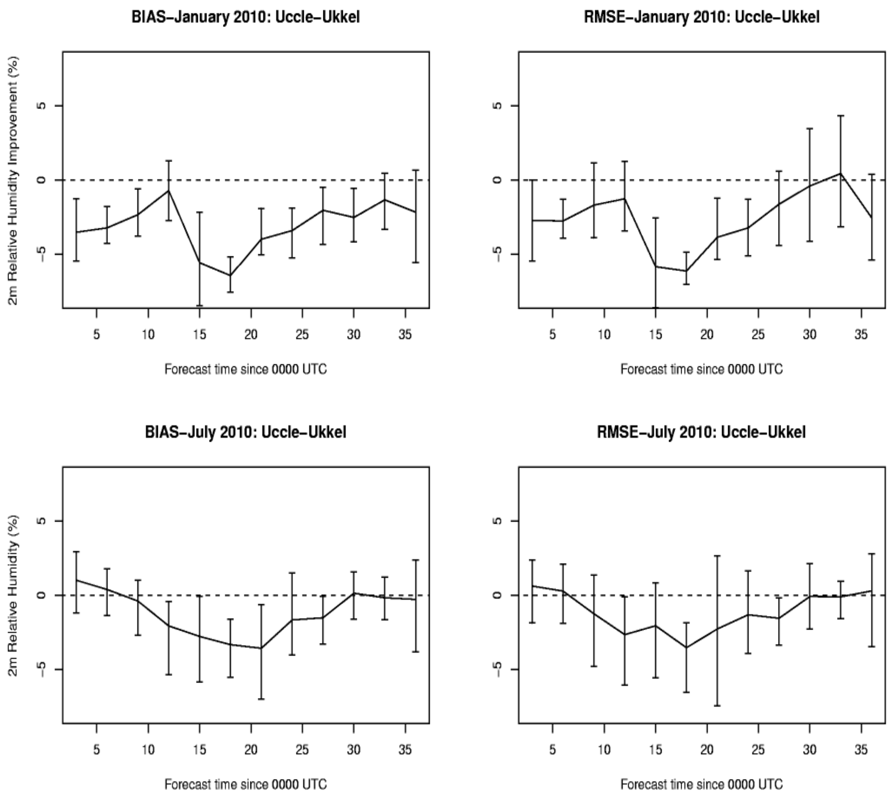


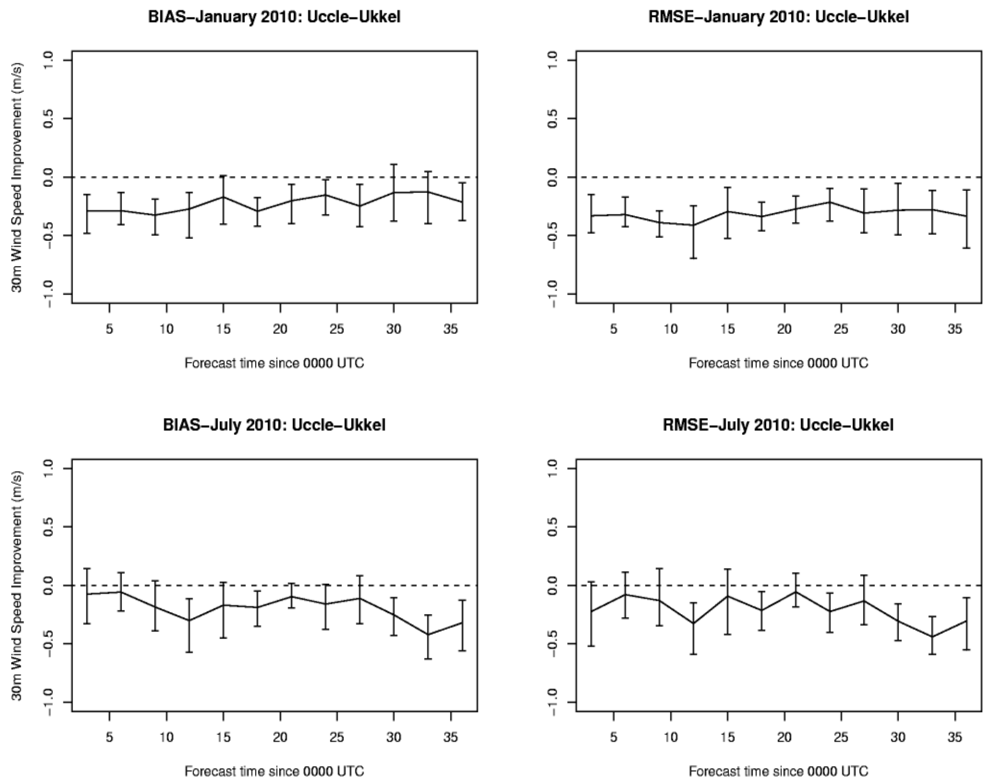
ALARO4+FMR+SURFEX+TEB Vs ALARO4+ACRANEB over Belgium





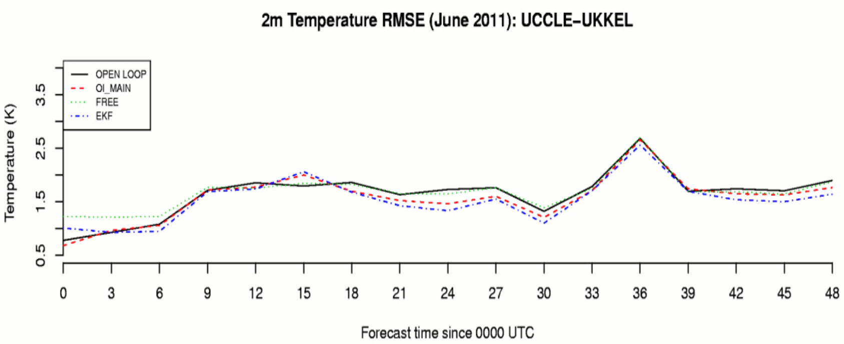
ALARO4+FMR+SURFEX+TEB Vs ALARO4+ACRANEB over Belgium

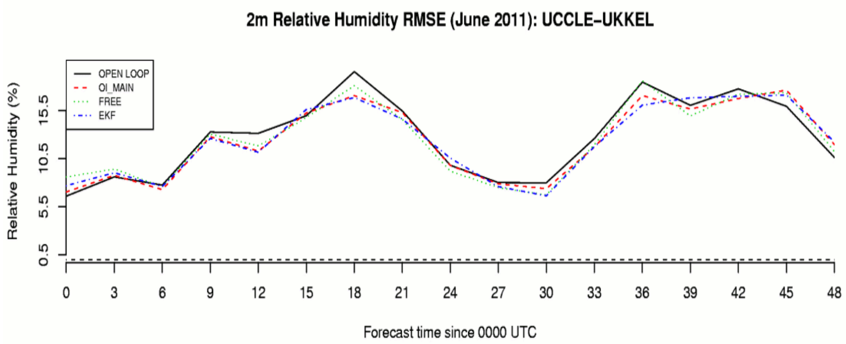


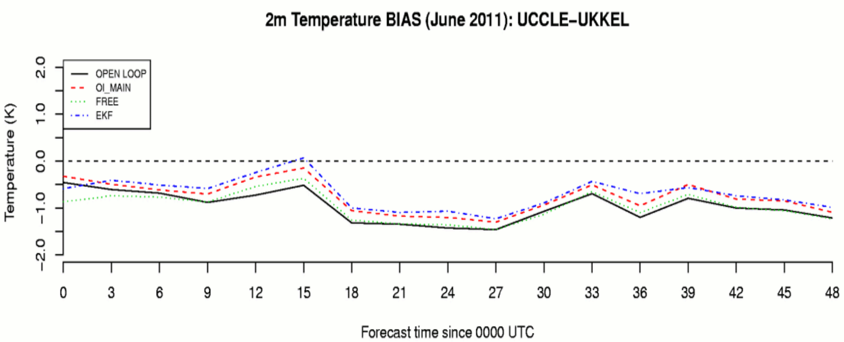


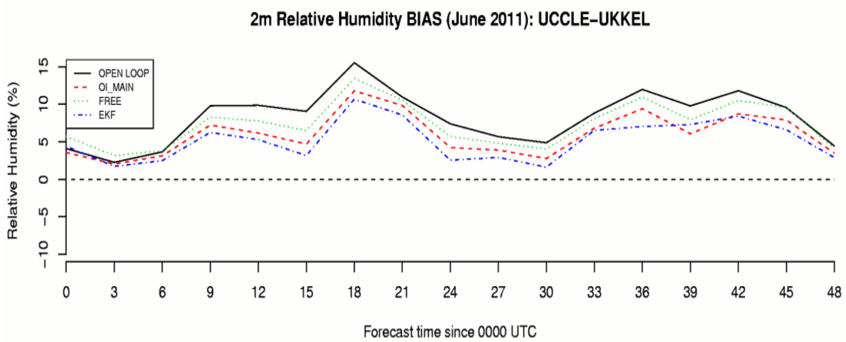
We have run experiments to compare OI and EKF with open loop simulation. The studied period was 01/06/2011 – 20/06/2011. The verification was done only between 05/06/2011 and 20/06/2011. In the verification we have also included the free surface simulation.

In general both assimilation method improves the scores (not always) but EKF has a higher impact.









Recently, Carrassi and Vannitsem (2011) introduced an alternative formulation of the EKF where the uncertain model parameters are estimated along with the system state variables. The algorithm, Short Time Augmented Extended Kalman Filter (STAEKF), uses a deterministic formulation for the model error dynamics (Nicolis, 2003).

The forecast model, is augmented with P model parameters:

$$\mathbf{z}^f = \begin{bmatrix} \mathrm{x}^f \\ \lambda^f \end{bmatrix} = \mathcal{F}\mathbf{z}^a = \begin{bmatrix} \mathcal{M}\mathrm{x}^a \\ \mathcal{F}^\lambda \lambda^a \end{bmatrix}, \tag{1}$$

$\mathbf{z} = (\mathrm{x}, \lambda)$ is the augmented state vector. The augmented dynamical system $\mathcal{F}$ includes the dynamical model for the system's state, $\mathcal{M}$, and a dynamical model for the parameters $\mathcal{F}^\lambda$. In the absence of additional information, a persistence model for $\mathcal{F}^\lambda$ is often assumed so that $\mathcal{F}^\lambda = \mathrm{I}$ and $\lambda^f_{t_{k+1}} = \lambda^a_{t_k}$; the same choice has been adopted here.

The forecast/analysis error covariance matrix, $\mathbf{P}_z^{f,a}$, for the augmented system reads:

$$\mathbf{P}_z^{f,a} = \begin{pmatrix} \mathbf{P}_x^{f,a} & \mathbf{P}_{x\lambda}^{f,a} \\ \mathbf{P}_{x\lambda}^{f,a\,T} & \mathbf{P}_\lambda^{f,a} \end{pmatrix} \tag{2}$$

where the $I \times I$ matrix $\mathbf{P}_x^{f,a}$ is the error covariance of the state estimate $\mathrm{x}^{f,a}$, $\mathbf{P}_\lambda^{f,a}$ is the $P \times P$ parametric error covariance and $\mathbf{P}_{x\lambda}^{f,a}$ the $I \times P$ error correlation matrix between the state vector, x, and the vector of parameters λ. These correlations are essential for the estimation of the parameters. In general one does not have access to a direct measurement of the parameters, and information are only obtained through observations of the system's state.

The forecast error propagation in the STAEKF is given by $\mathbf{P}_z^f = \mathbf{C}\mathbf{P}_z^a\mathbf{C}^T$, with $\mathbf{C}$ being the STAEKF forward operator defined as:

$$\mathbf{C} = \begin{pmatrix} \mathrm{M} & \frac{\partial g}{\partial \lambda}|_{\lambda^a \tau} \\ 0 & \mathrm{I}_P \end{pmatrix} \quad (3)$$

where I_P is the $P \times P$ identity matrix. Equation (3) embeds the key feature of the STAEKF; the presence of the term $\frac{\partial g}{\partial \lambda}|_{\lambda^a \tau}$ allows for accounting for the contribution of the parametric error to the forecast error as well as to the error correlation between model state and parameters.

An augmented observation operator is introduced, $\mathcal{H}_z = [\mathcal{H} \quad 0]$ with $\mathcal{H}$ as for the standard EKF. Its linearization, $\mathbf{H}_z$ is now a $M \times (I + P)$ matrix in which the last P columns contain zeros. The augmented state and covariance update complete the algorithm and are equivalent to those of the EKF except that they refer now to the augmented system, and the gain matrix has dimension $(I + P) \times M$ (see Carrassi and Vannitsem, 2011a, for details).

EKF ; SEKF ; STAEKF

- **The two-layers version of the land surface model ISBA (externalized platform SLDAS; Mahfouf, 2007).**
- **Observation system simulation experiments (OSSE).**
- **The forcing data are the same for the truth and the assimilation solutions. They consist of 1-hourly air temperature, specific humidity, atmospheric pressure, incoming global radiation, incoming long-wave radiation, precipitation rate and wind speed relative to the ten summers in the decade 1990-1999 extract from ECMWF Re-analysis ERA40.**
- **ISBA is run in one o ine single column mode for a 90 day period.**
- **The simulated observations are T2m and RH2m , interpolated between the forcing level (20 m) and the surface with the Geleyn (1988) interpolation scheme, at 00, 06, 12 and 18 UTC; assimilation interval   = 6 hours.**
- **The initial Pf (B) and Pm (Q) required by the EKF, are taken from Mahfouf (2007)**
- **Parametric errors are introduced by perturbing either alternatively or simultaneously, the Leaf Area Index, LAI , and the albedo.**

EKF ; SEKF ; STAEKF

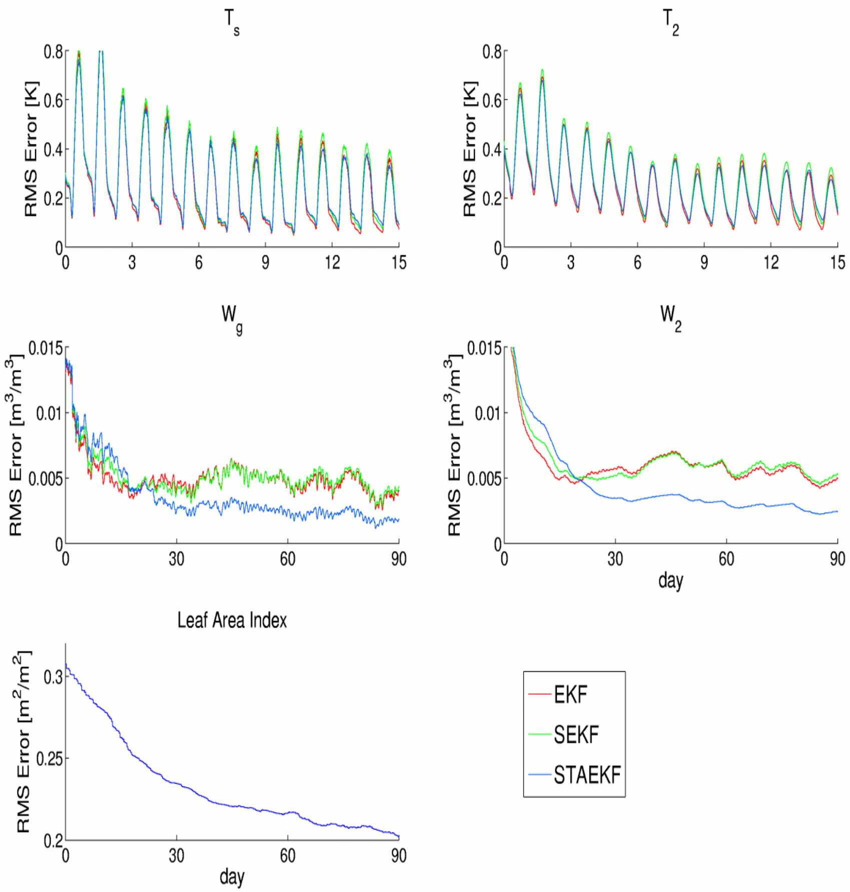
- **For each summer in the period 1990 - 1999, a reference trajectory is generated by integrating the model with LAI = 1 m2 /m2 and albedo = 0.2.**

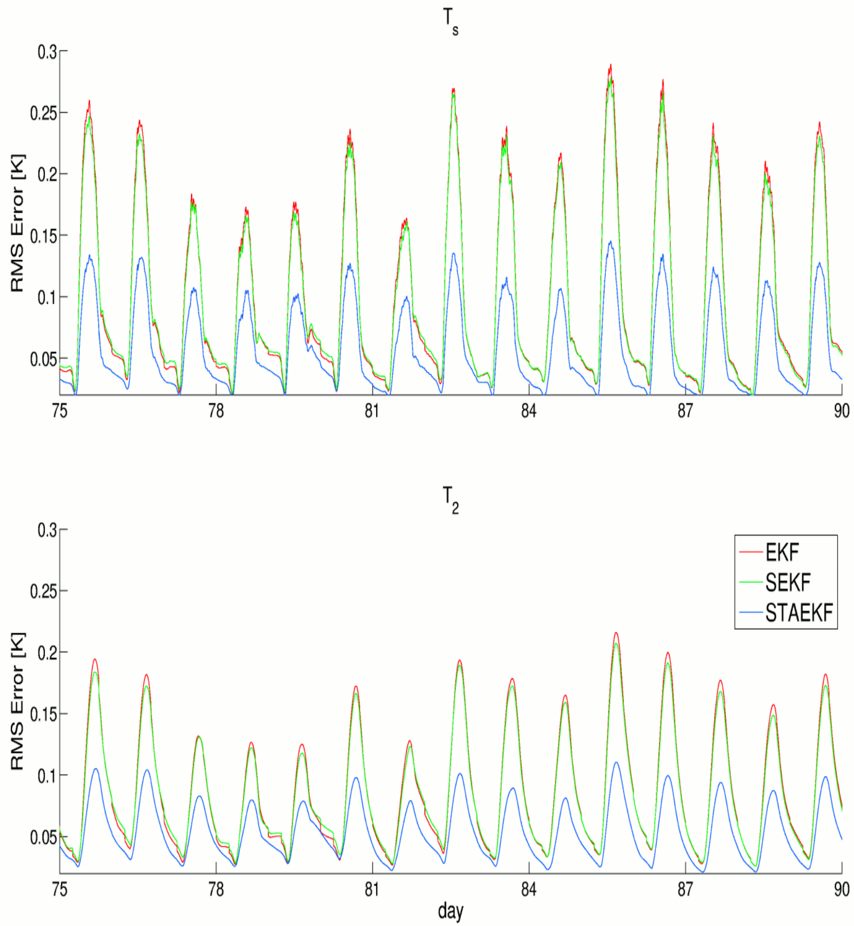
- **Around each of these trajectories, Gaussian samples of 100 initial conditions and uncertain parameters are used to initialize the assimilation cycles.**

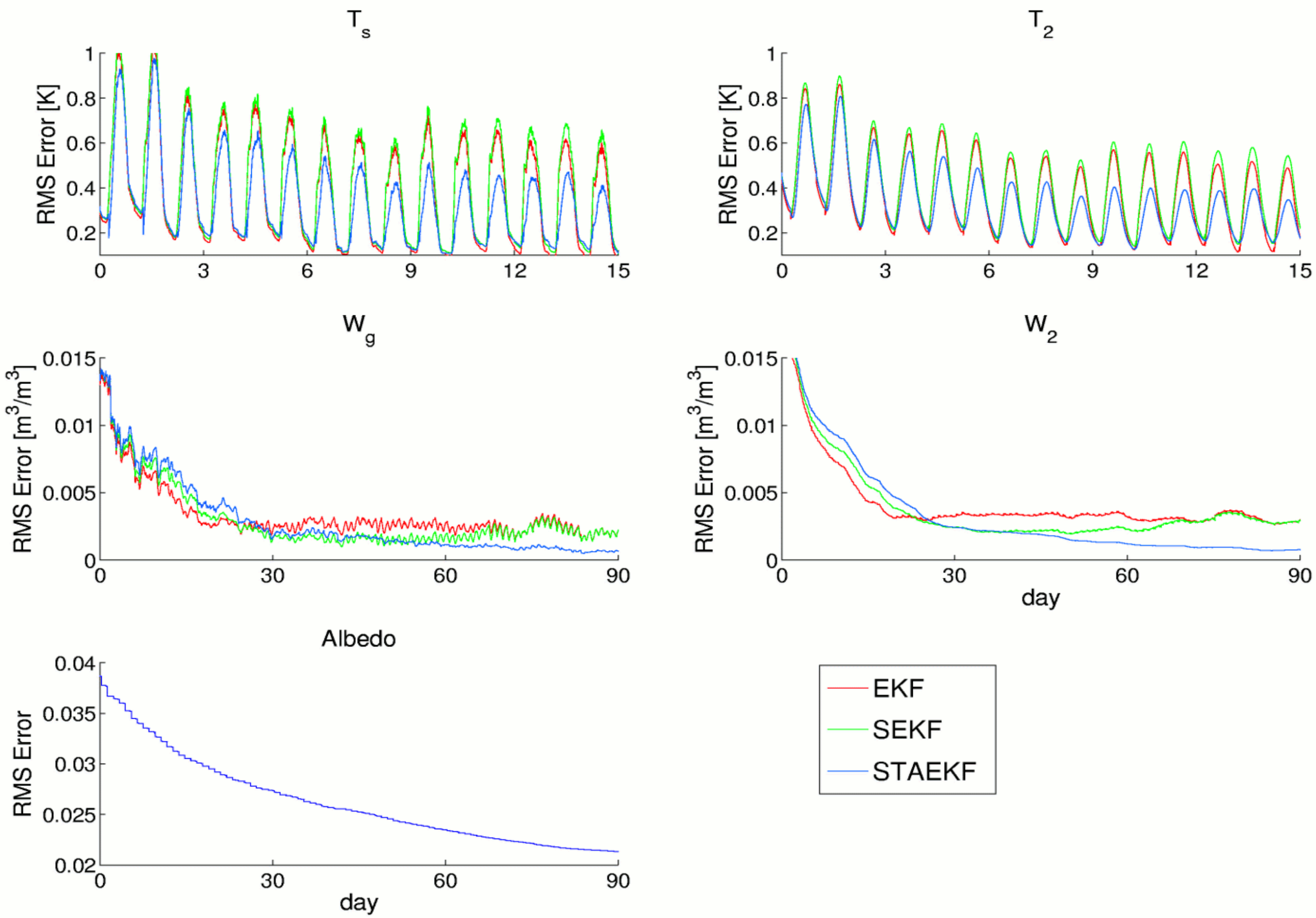
- **The initial conditions are sampled from a distribution with standard deviation (Ts , T2 , wg , w2) = (5, 5, 1, 1).**

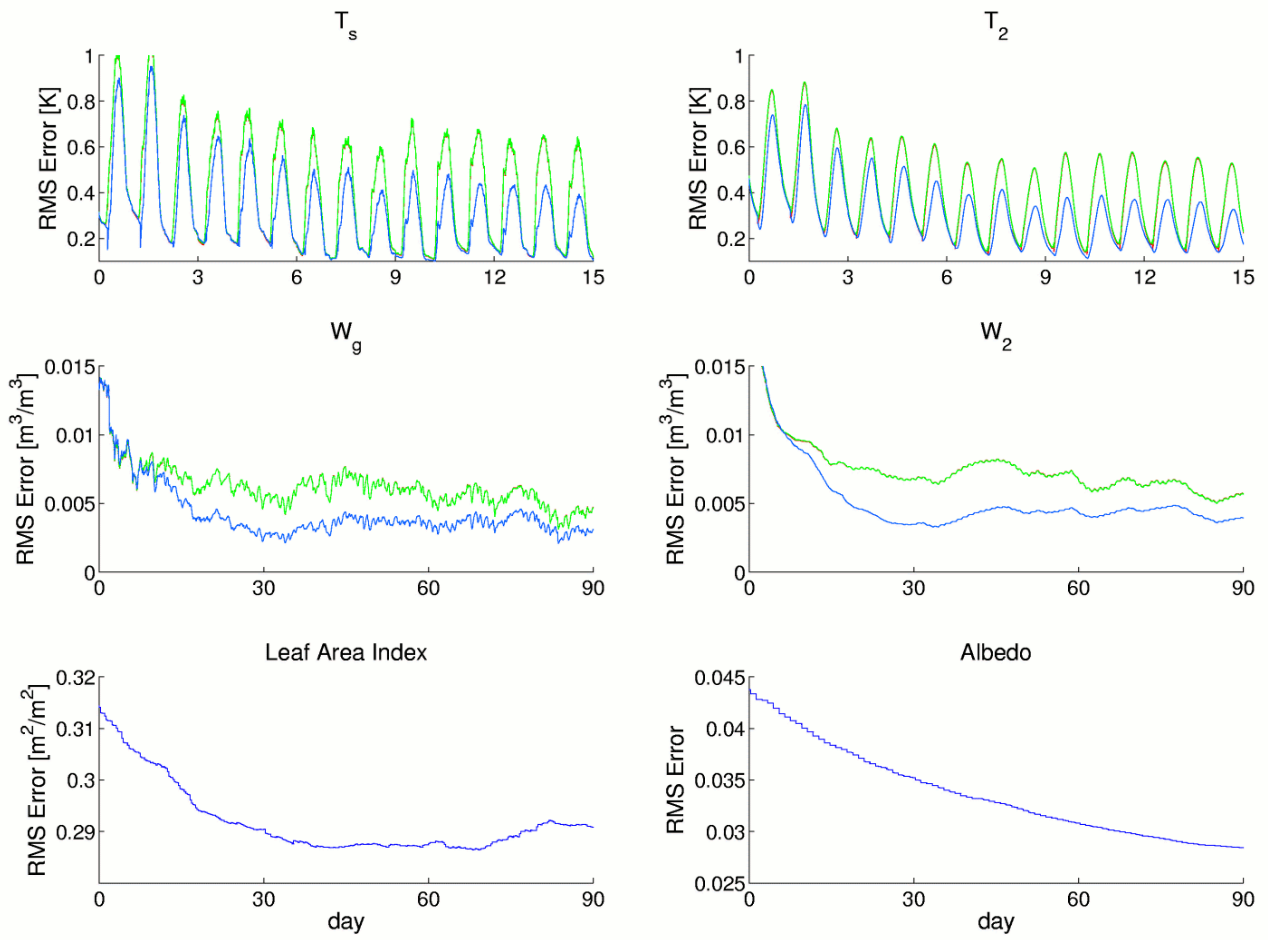
- **LAI and albedo, are sampled with standard deviations, LAI = 0.5 and albedo = 0.1.**

- **These values are used to initialize P λ in the STAEKF, while Px is taken as in the EKF; Px, λ is initially set to zero.**


T_s
RMS Error [K]
T_2
W_g
RMS Error [m^3/m^3]
W_2
day
Leaf Area Index
RMS Error [m^2/m^2]
EKF
SEKF
STAEKF


T_s
RMS Error [K]
T_2
EKF
SEKF
STAEKF
day


T_s
T_2
RMS Error [K]
W_g
W_2
RMS Error [m^3/m^3]
Albedo
RMS Error
day
EKF
SEKF
STAEKF


T s
RMS Error [K]
T 2
W g
RMS Error [m3/m3]
W 2
Leaf Area Index
RMS Error [m2/m2]
Albedo
RMS Error
day

- Continuing the Validation of SURFEX, a scientific paper is in preparation: Integrating the SURFEX scheme in a wide range of national applications: performance within operational weather prediction models. Termonia P., Hamdi R., Bouyssel F., et al. 2011 GMD.

- The installation of the SURFEX Steering Committee. First meeting in October.

- Continuing the evaluation of the STAEKF, a scientific paper is submitted: Short Time Augmented Extended Kalman Filter for Soil Analysis. Carrassi A., Hamdi R., Termonia P., and Vannitsem S., 2011 ASL.

- Study the behaviour of the STAEKF with the 3-D model.