SURFEX for ALARO

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1. SURFEX as a new land surface scheme -- Hamdi et al., 2014, GMD

2. SURFEX/EKF as a new surface DA scheme – Duerinckx et al., 2015, GMD

3. Other applications & Future work

- **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.**

- SURFEX is used operationally within the AROME model with the physics parameterization of meso-NH

- 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.

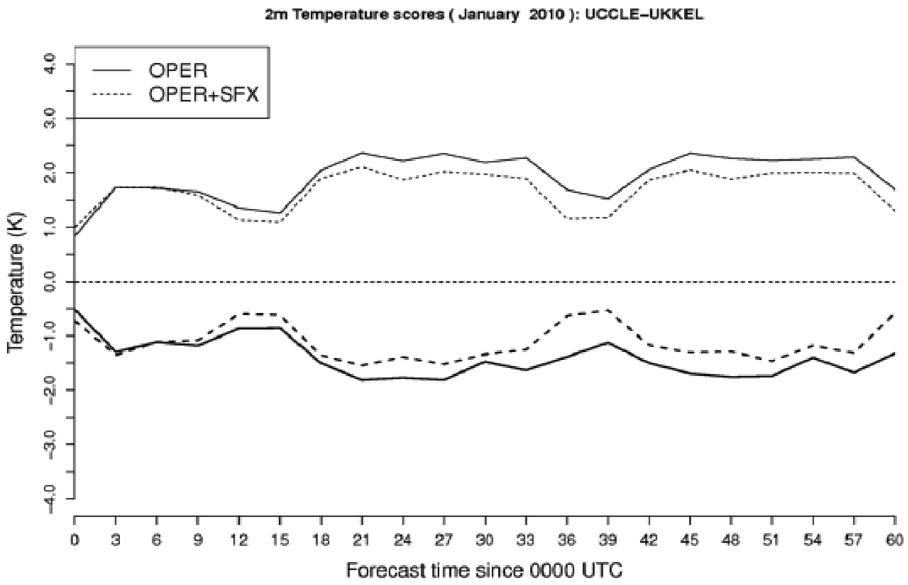
- Nevertheless, this question still stands: Why should one maintain different ISBA schemes to serve a large community of users?

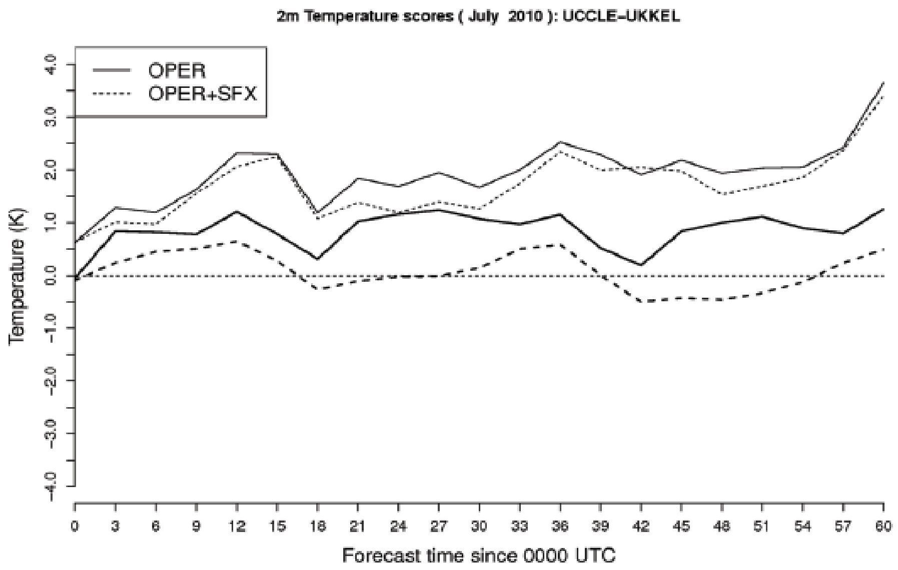
- ALADIN partners from Algeria, Austria, Belgium, Hungary, Morocco, Poland, Slovenia, and Turkey participated to the SURFEX working week in Brussels 18-22 April 2011.

- 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.



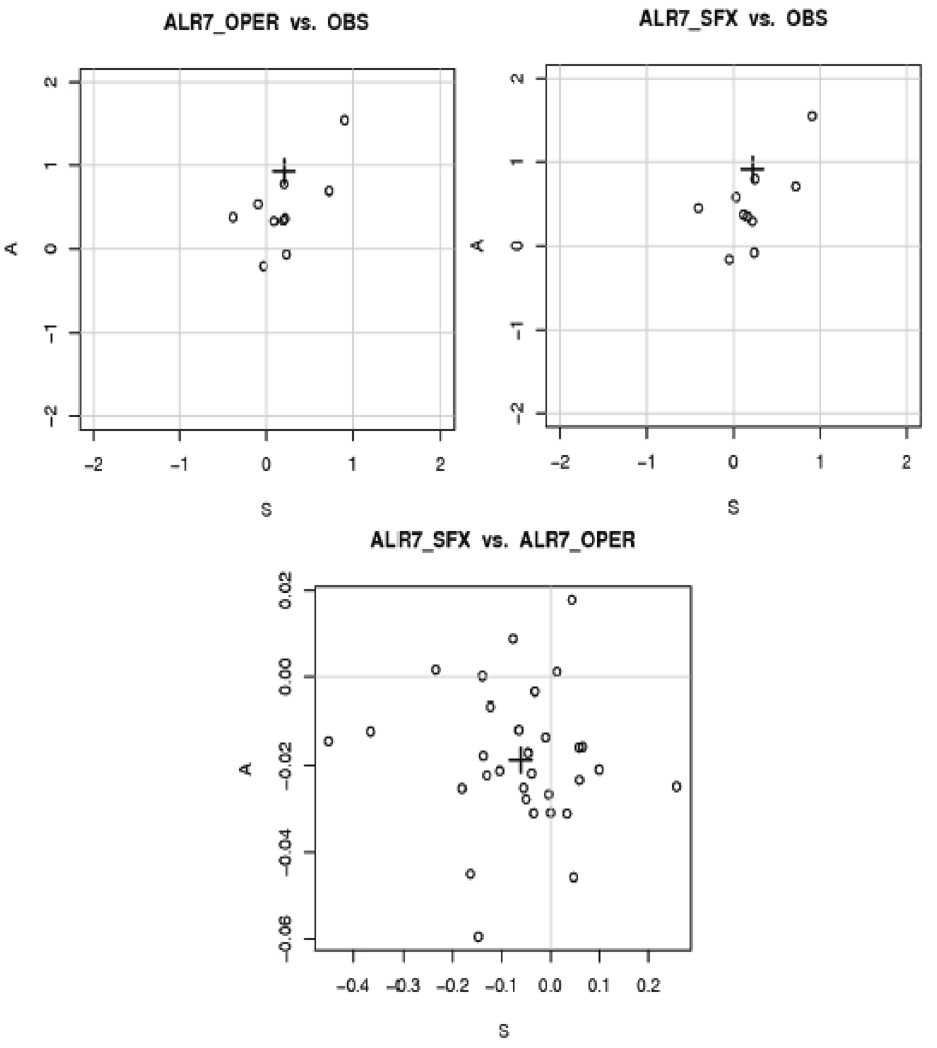


		$Winter_{NIGHT}$	$Winter_{DAY}$	$Summer_{NIGHT}$	$Summer_{DAY}$
2 m temperature	Flat	+	+	+	0
	High	0	–	0	+
	Coast	0	0	+	0
Wind speed at 10 m	Flat	+	0	+	0
	High	0	0	0	0
	Coast	+	0	+	0
Wind direction at 10 m	Flat	0	0	0	0
	High	0	0	0	0
	Coast	0	0	0	0
2 m relative humidity	Flat	+	+	+	0

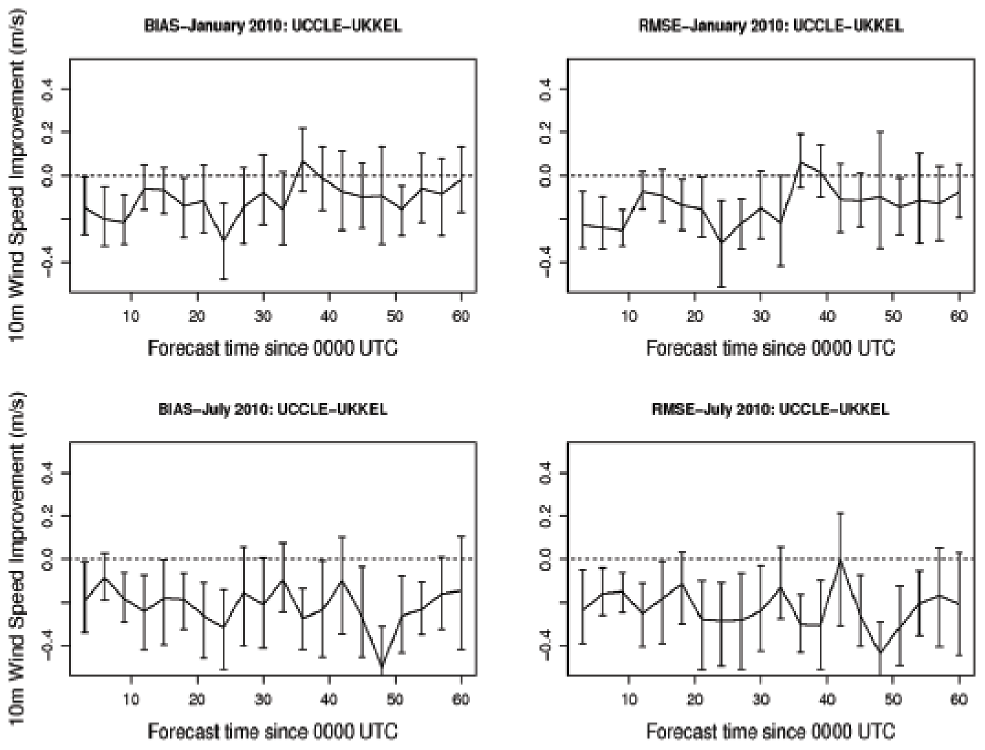
Fluxes from Cabauw

	$Winter_{NIGHT}$	$Winter_{DAY}$	$Summer_{NIGHT}$	$Summer_{DAY}$
Radiative balance				
Longwave ↓	0	0	0	0
Longwave ↑	0	0	+	0
Shortwave ↓	0	0	0	0
Shortwave ↑	0	0	0	+
Energy balance				
Latent heat flux	0	+	0	+
Sensible heat flux	0	0	0	+
Storage heat flux	+	+	+	+

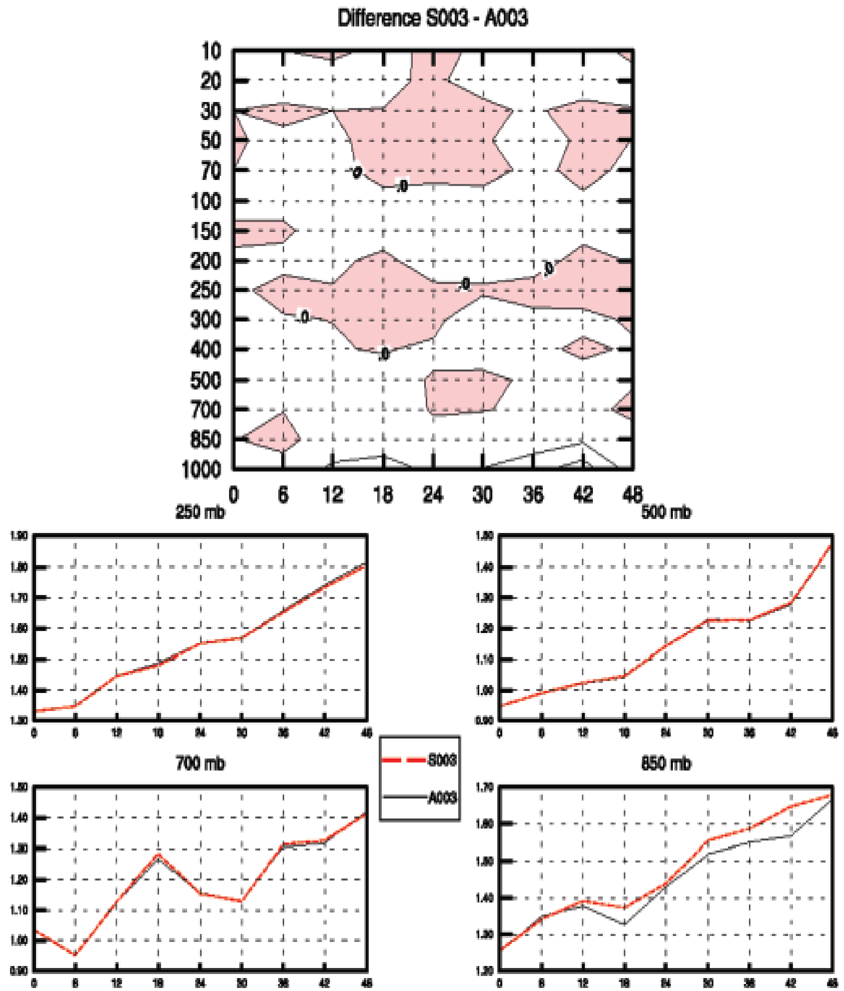
Precipitation SAL



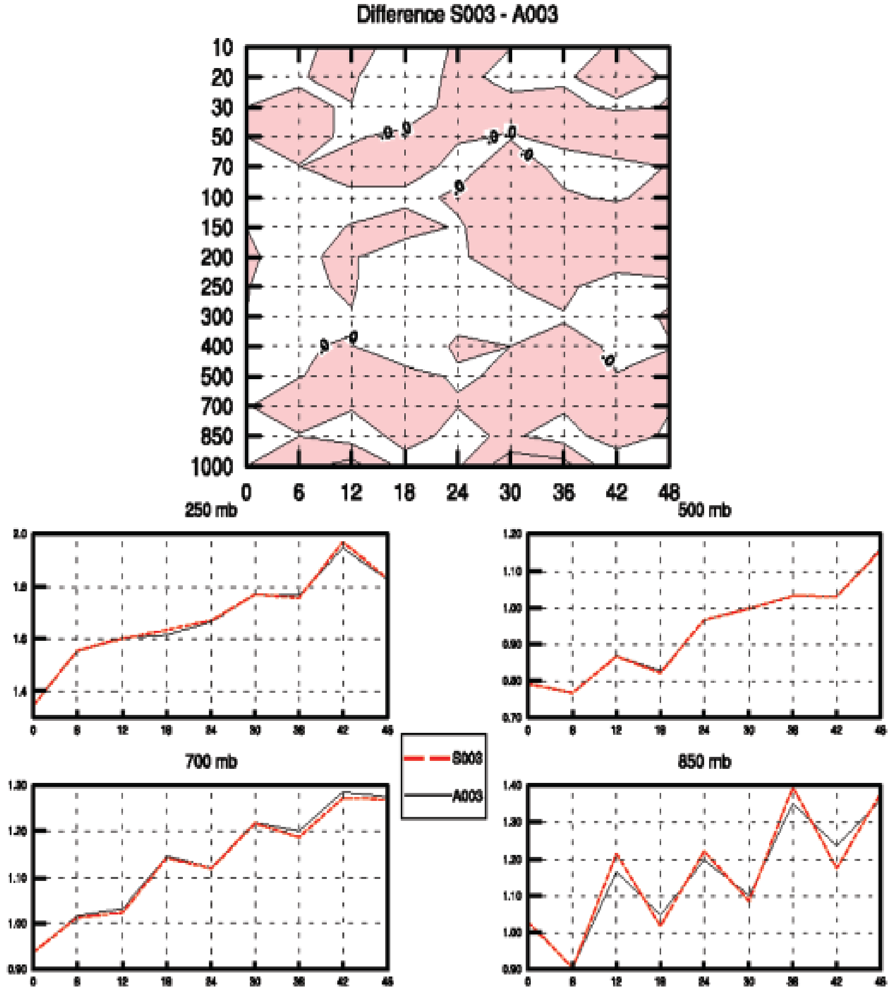
10m wind speed



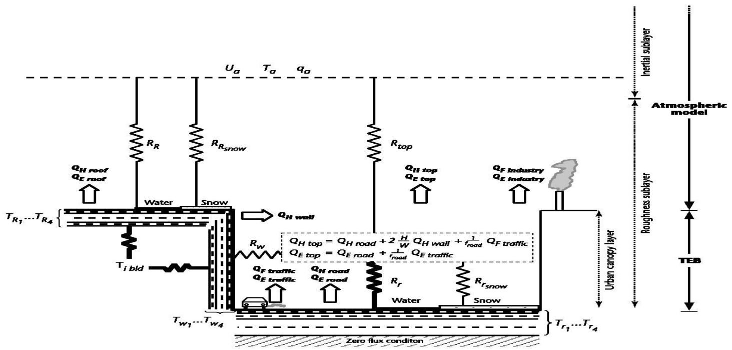
Winter 2010



Summer 2010

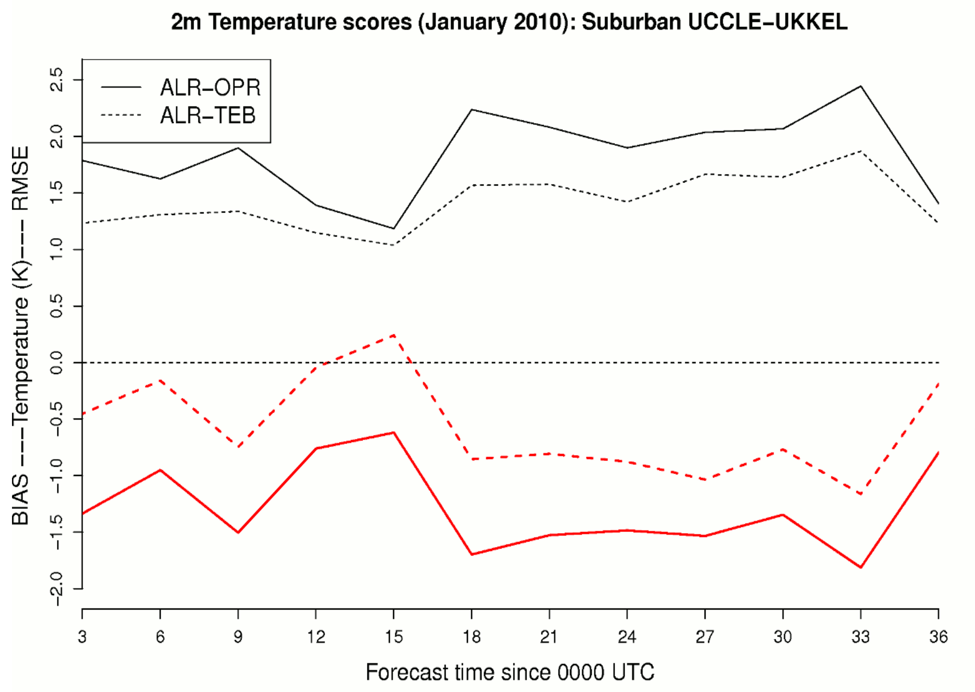


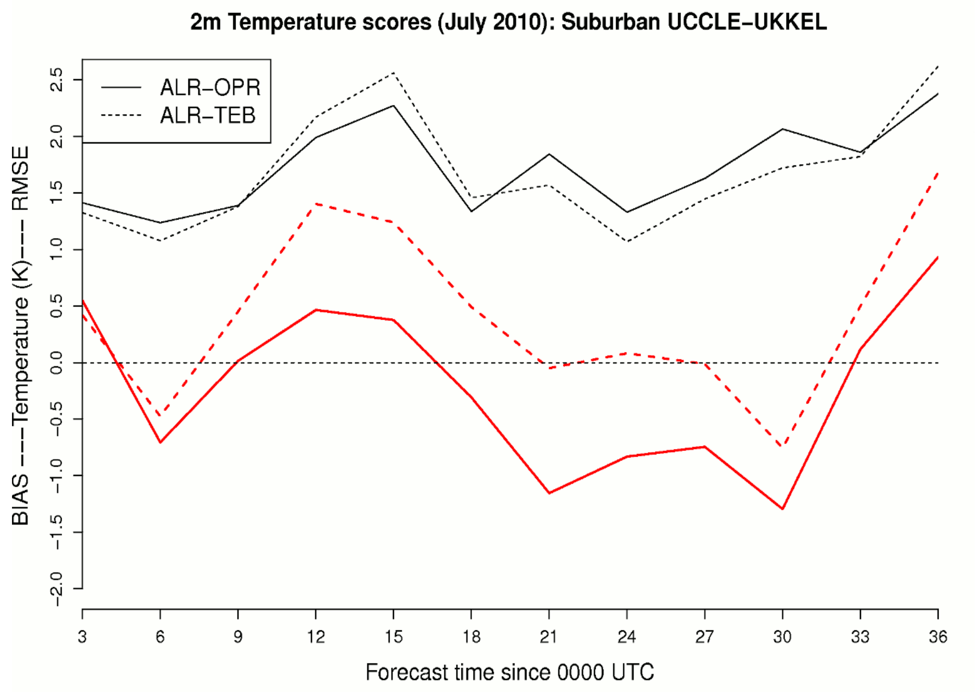
(TEB, Masson 2000)



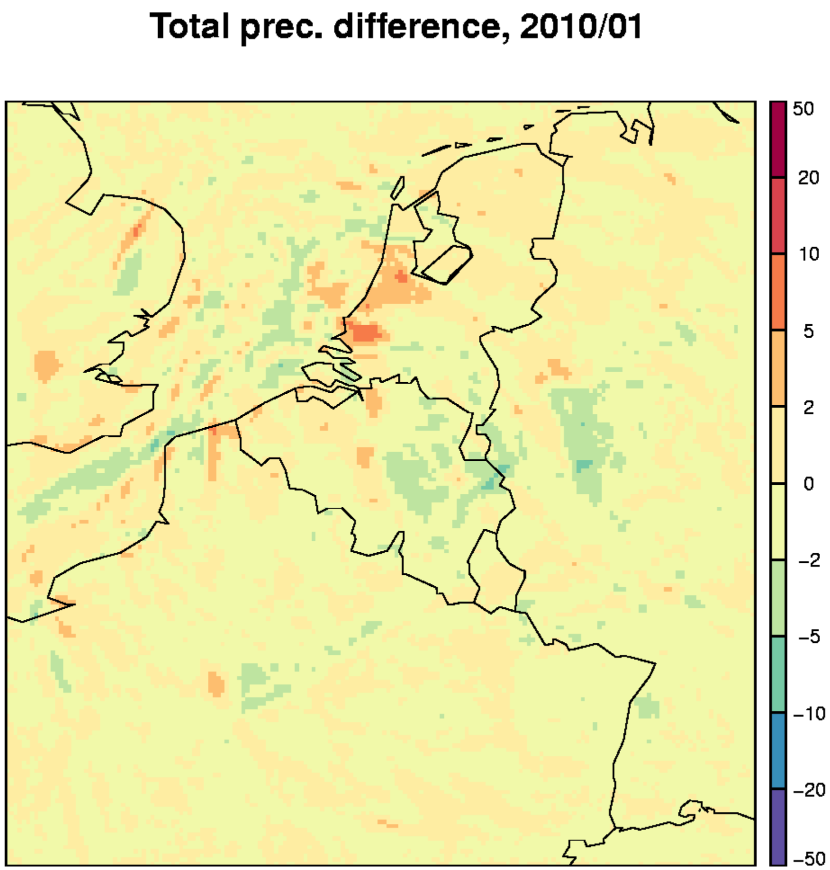
Rocks

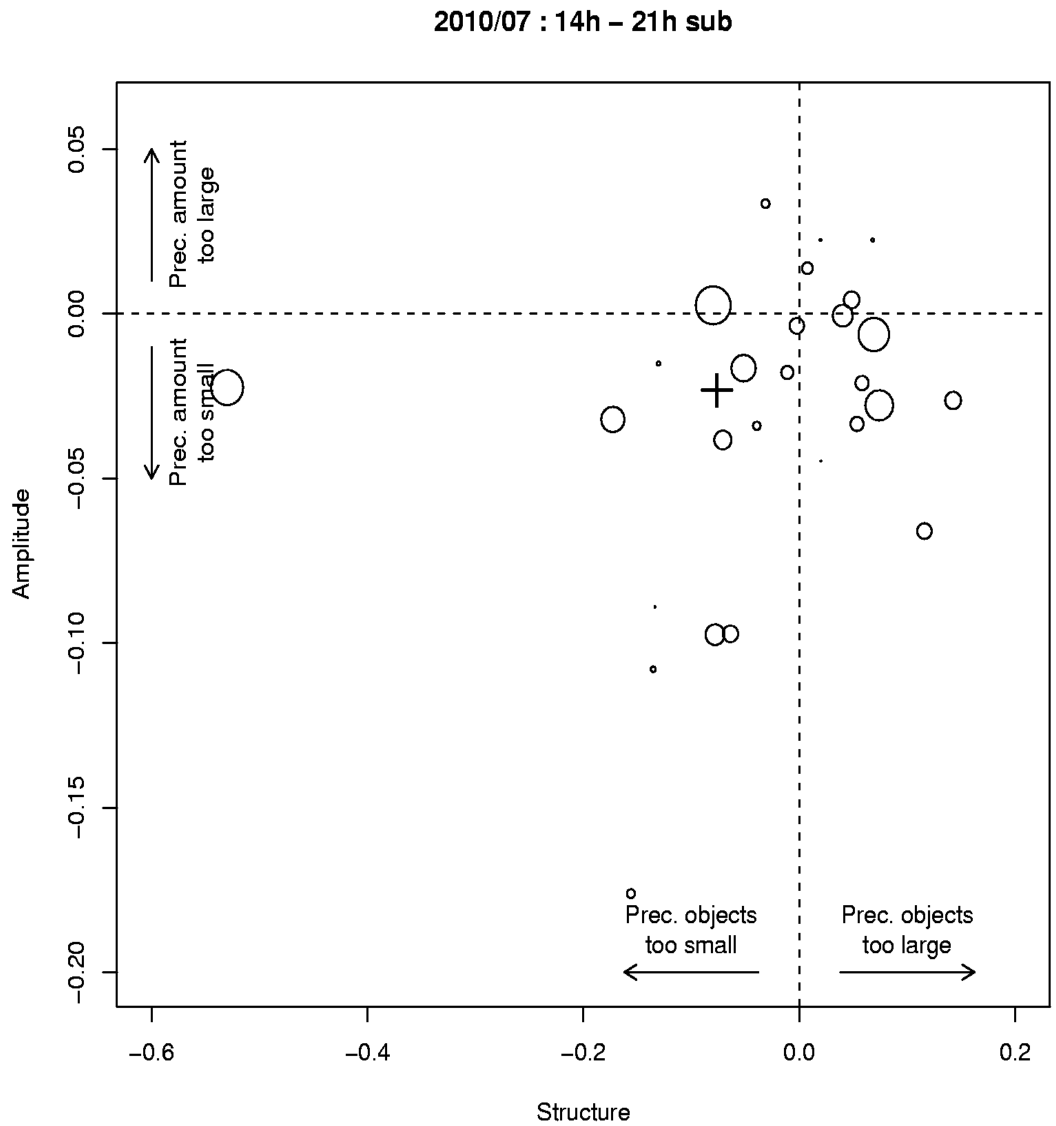
For two months (January and July 2010), a series of simulations is performed, with (ALR-TEB) and without TEB (ALR-OPR), with one simulation of 36h each day starting at 0000 UTC.





Hamdi et al., 2012, WAF





Hamdi et al., 2012, WAF

2. SURFEX/EKF as a new surface DA scheme – Duerinckx et al., 2015, GMD

1) Optimum Interpolation of T_{2m} and RH_{2m} using 2m observations interpolated at the model grid-point by a 2m analysis **(2-D CANARI OI)**

$$\Delta T_{2m} = T_{2m}^{\ a} - T_{2m}^{\ b} \qquad \Delta RH_{2m} = RH_{2m}^{\ a} - RH_{2m}^{\ b}$$

2) Correction of 4 surface parameters (T_s, T_p, W_s, W_p) using 2m increments between analysed and forecasted values.

$$T_p^{\ a} - T_p^{\ b} = \Delta T_{2m} / 2\pi \qquad T_s^{\ a} - T_s^{\ b} = \Delta T_{2m}$$

$$W_s^{\ a} - W_s^{\ b} = \alpha_{WsT} \Delta T_{2m} + \alpha_{WsRH} \Delta RH_{2m}$$

$$W_p^{\ a} - W_p^{\ b} = \alpha_{WpT} \Delta T_{2m} + \alpha_{WpRH} \Delta RH_{2m}$$

OI coefficients

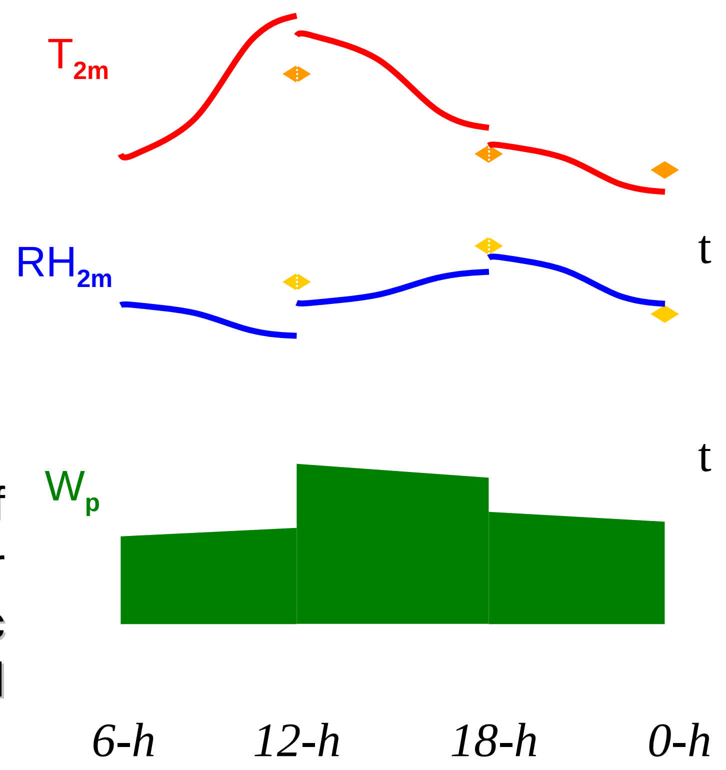
$$\alpha_{Ws/pT} = \frac{\sigma^b_{Ws/p}}{\Phi \sigma^b_{T2m}} \left\{ \left[1 + \left(\frac{\sigma^a_{RH2m}}{\sigma^b_{RH2m}} \right)^2 \right] \rho_{T2m,Ws/p} - \rho_{T2m,RH2m} \rho_{RH2m,Ws/p} \right\}$$

$$\alpha_{Ws/pRH} = \frac{\sigma^b_{Ws/p}}{\Phi \sigma^b_{RH2m}} \left\{ \left[1 + \left(\frac{\sigma^a_{T2m}}{\sigma^b_{T2m}} \right)^2 \right] \rho_{RM2m,Ws/p} - \rho_{T2m,RH2m} \rho_{T2m,Ws/p} \right\}$$

$$\Phi = \left[1 + \left(\frac{\sigma^a_{T2m}}{\sigma^b_{T2m}} \right)^2 \right] \left[1 + \left(\frac{\sigma^a_{RH2m}}{\sigma^b_{RH2m}} \right)^2 \right] - \rho^2_{T2m,RH2m}$$

- Very strong dependency of these background error statistics to **physiographic** properties and **meteorological conditions.**

Sequential analysis (every 6h)



EKF for soil analysis

$$\mathbf{x}_t^a = \mathbf{x}_t^b + \underbrace{\mathbf{B}\mathbf{H}^T(\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R})^{-1}}_{\text{Kalman gain (weight)}}\underbrace{[\mathbf{y}_t^o - \mathcal{H}(\mathbf{x}_o^b)]}_{\text{Departure (error)}}$$

Background error covariance matrix

Observation error covariance matrix

$\mathbf{y}_t^o$ Observations (T2m, RH2m)

$\mathbf{x}_o^b$ Model variables (Wg, W2, Ts, T2)

$\mathcal{H}(\mathbf{x}_o^b)$ Model counterpart of Observations (T2m, RH2m)

	Parameter	Value
R – *matrix*	T_{2m}	1 K
	RH_{2m}	10 %
B – *matrix*	T_s	2 K
	T_2	2 K
	W_g	$0.1(w_{fc} - W_{wilt})$
	W_2	$0.1(w_{fc} - W_{wilt})$

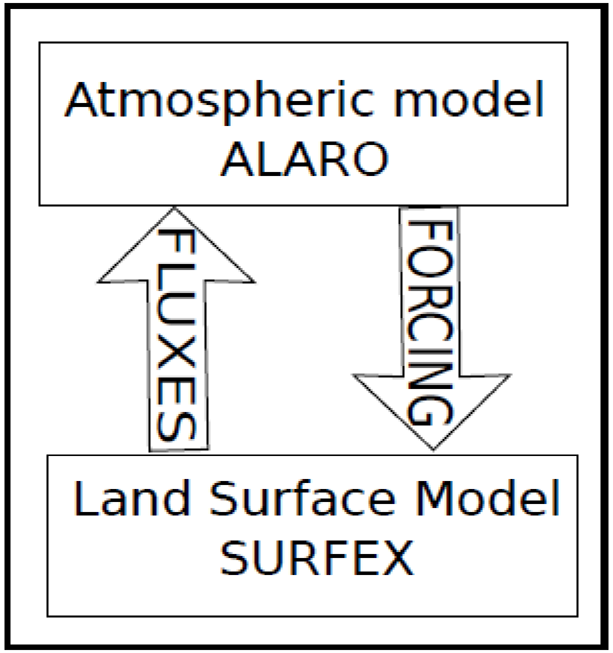
EKF: The Jacobian

$$\mathbf{x}_t^a = \mathbf{x}_t^b + \mathbf{B}\mathbf{H}^T(\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R})^{-1}[\mathbf{y}_t^o - \mathcal{H}(\mathbf{x}_o^b)]$$

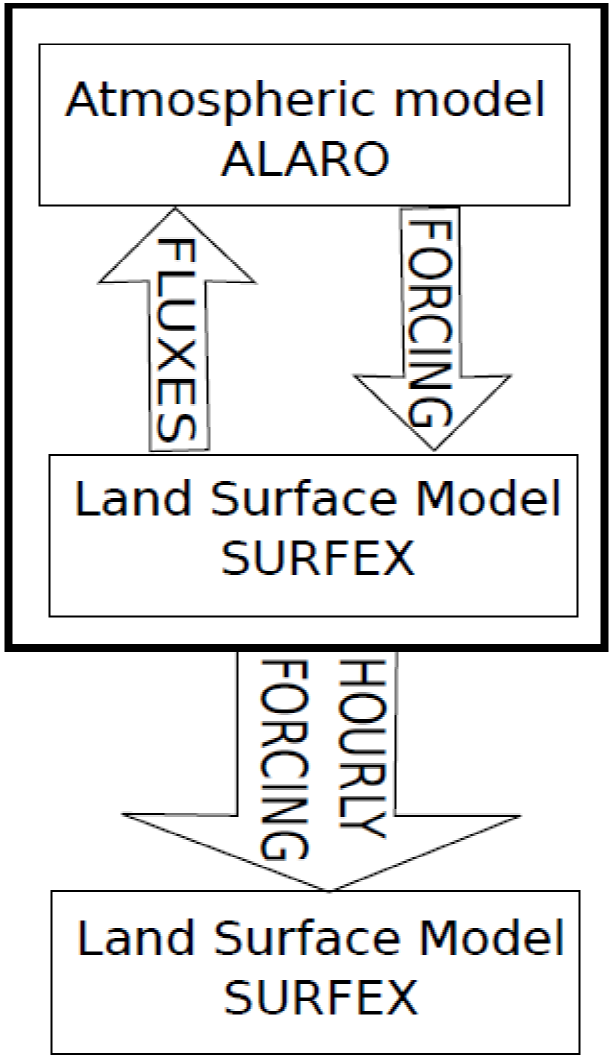
- $\mathcal{H}$: observation operator
  includes a model propagation
- **H**: Jacobian of the observation operator
  Calculated with finite differences

$$H_{i,j} = \frac{\delta y_{i,t}}{\delta x_{j,t0}} = \frac{y_i(x + \delta x_j) - y_i(x)}{\delta x_j}$$

EKF: The Jacobian



Coupled

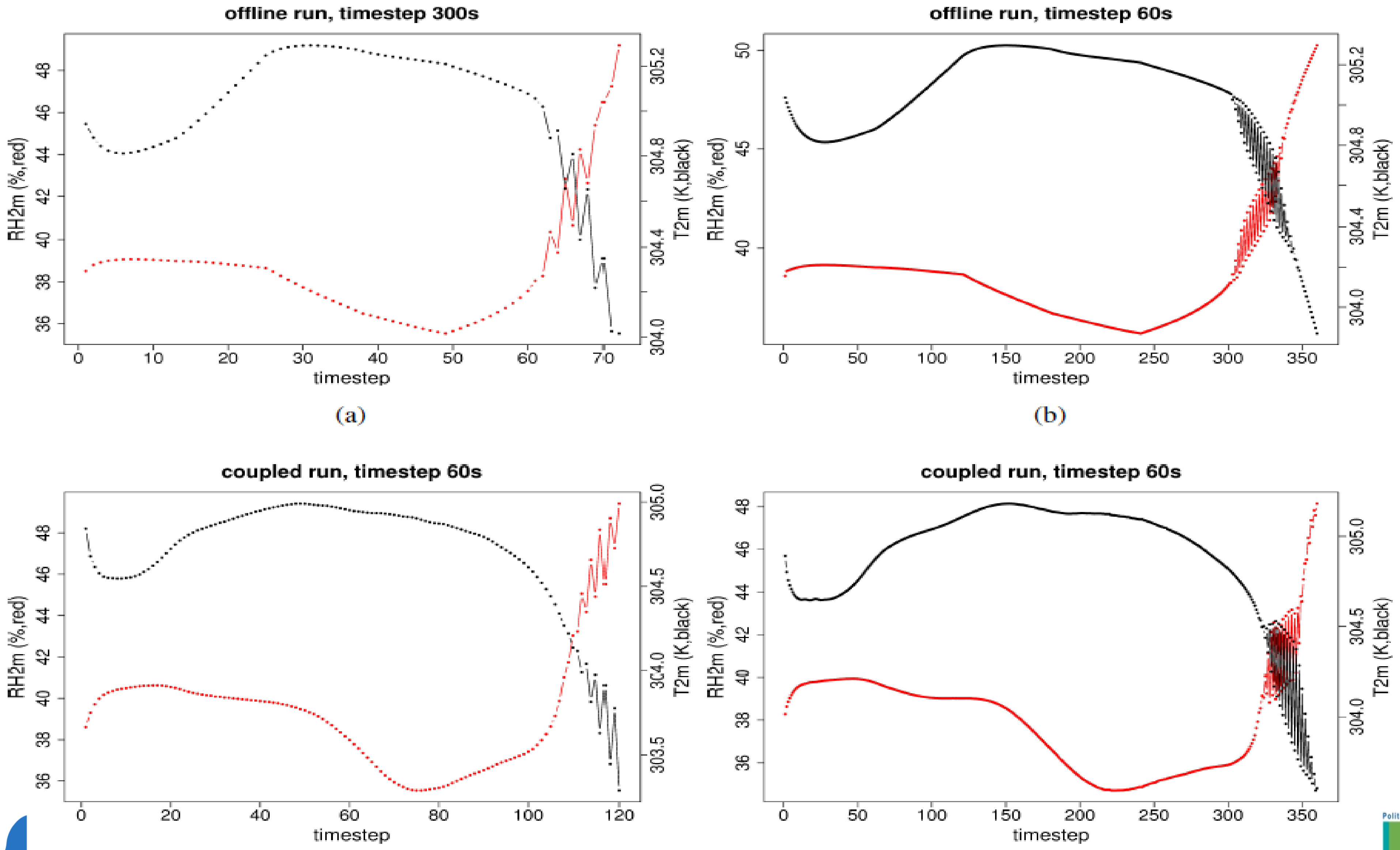


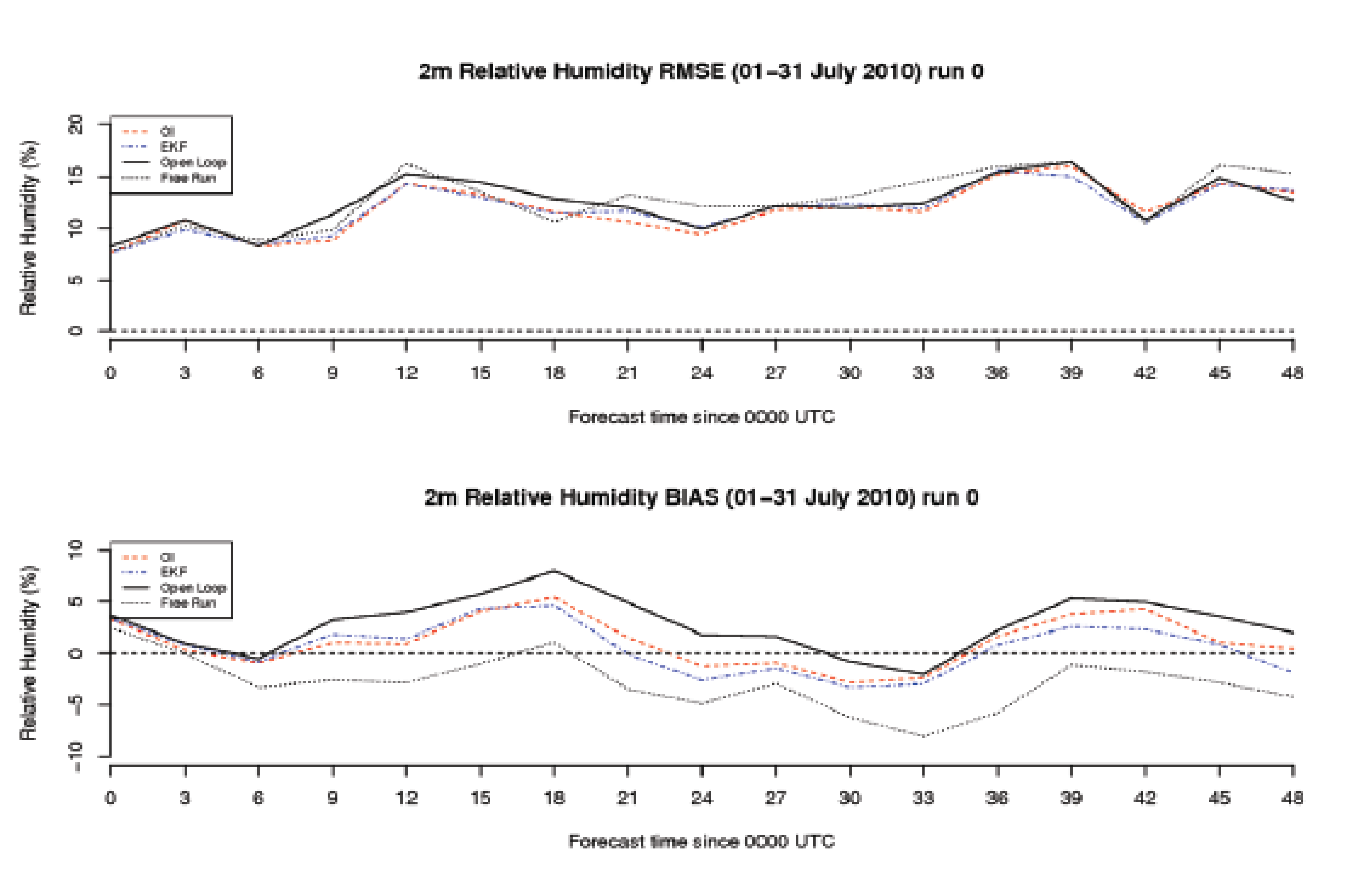
Offline

Coupled : used for the forecast

Offline : used in the EKF to calculate the Jacobian

Oscillations

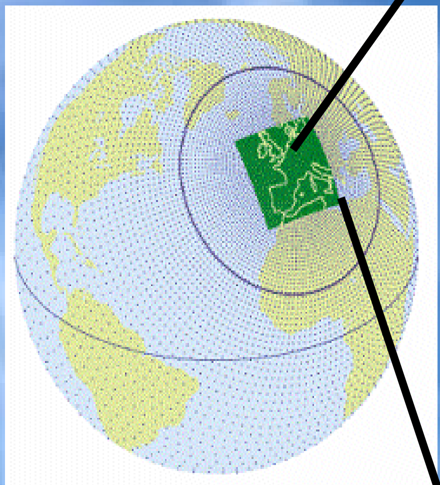



2m Relative Humidity RMSE (01–31 July 2010) run 0
OI
EKF
Open Loop
Free Run
Relative Humidity (%)
Forecast time since 0000 UTC
2m Relative Humidity BIAS (01–31 July 2010) run 0
OI
EKF
Open Loop
Free Run
Relative Humidity (%)
Forecast time since 0000 UTC

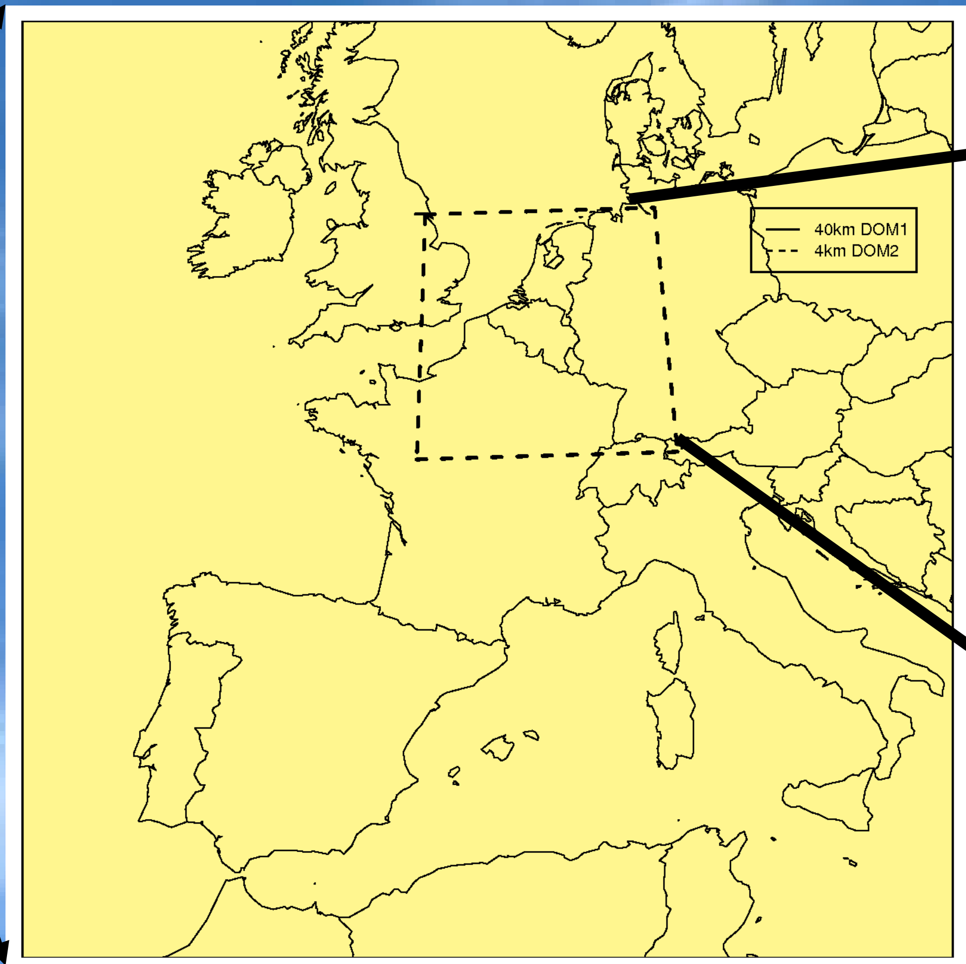
3. Other applications & Future work

Regional climate simulations using ALARO+SURFEX+TEB

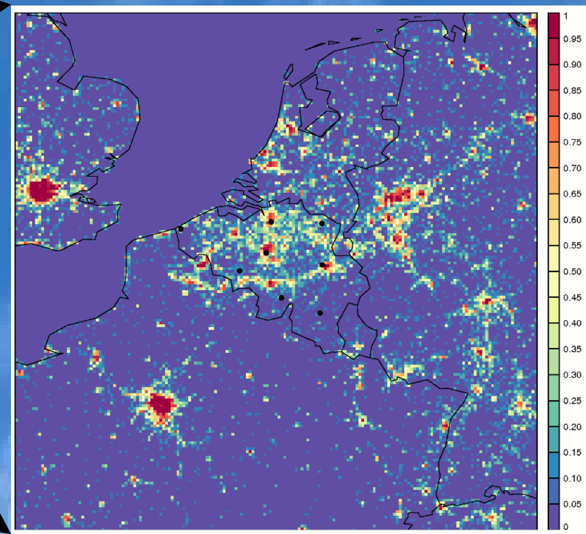
GLOBAL



20 km

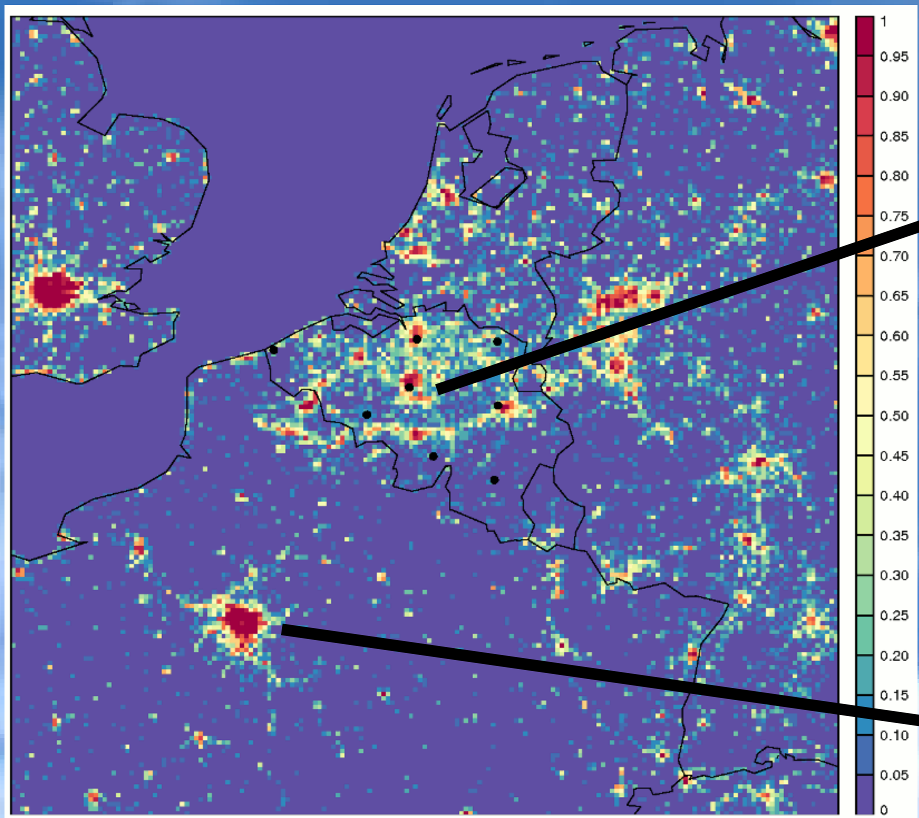


4km

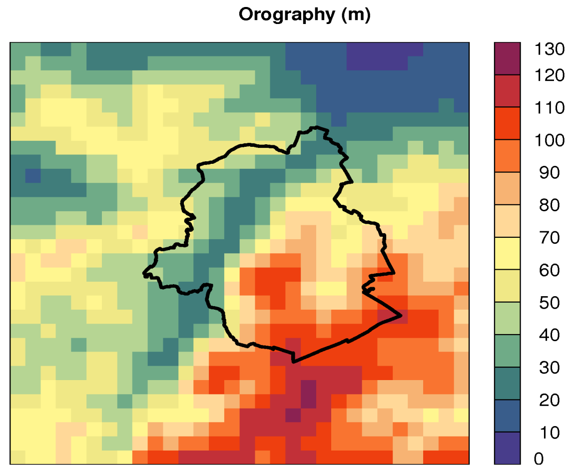


Urban climate simulations using SURFEX+TEB+SBL

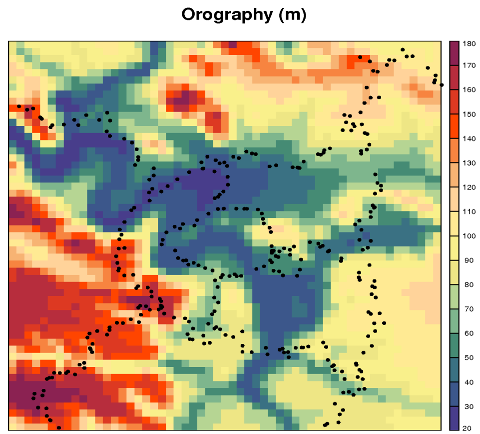
ALARO+SURFEX INLINE 4km

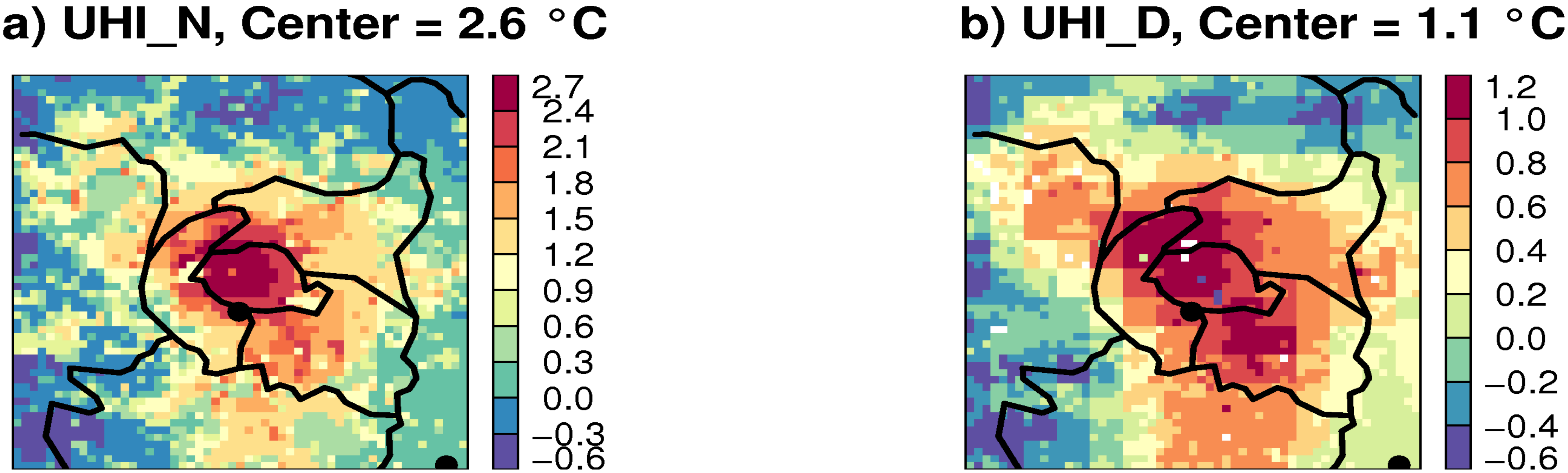


SURFEX OFFLINE 1 km, Brussels, 30x30



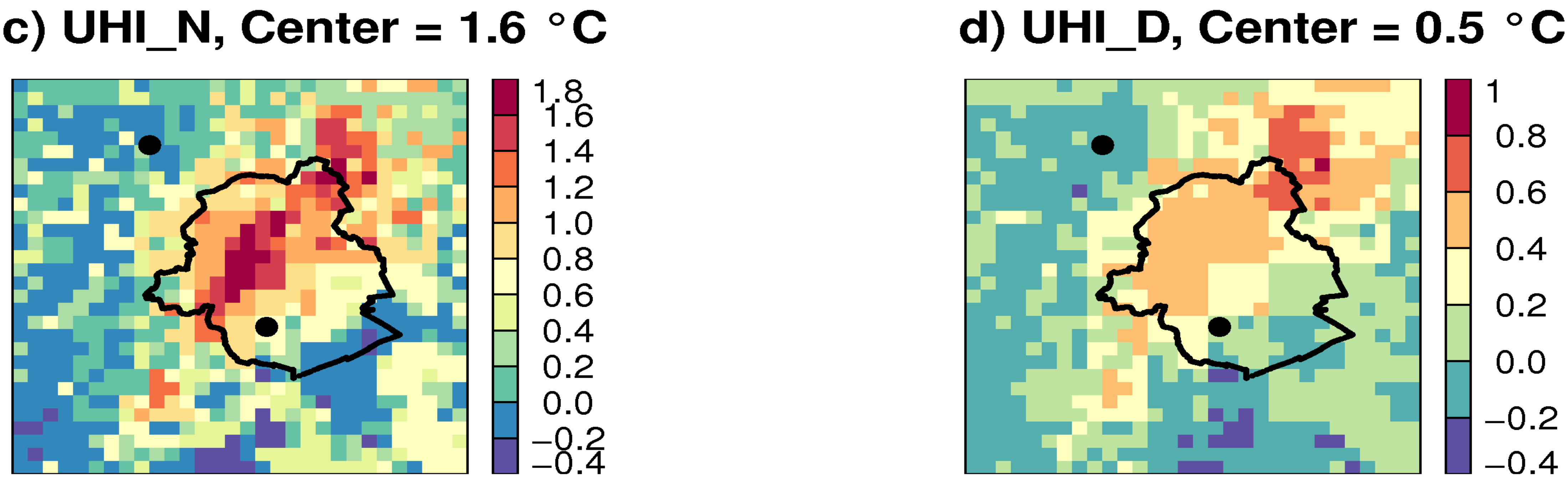
SURFEX OFFLINE 1 km, Paris, 55x55





Hamdi et al., 2015, UC

Era-interim 2001-2010 UHI simulations



Combining the EKF soil analysis with a three dimensional variational upper-air assimilation for ALARO

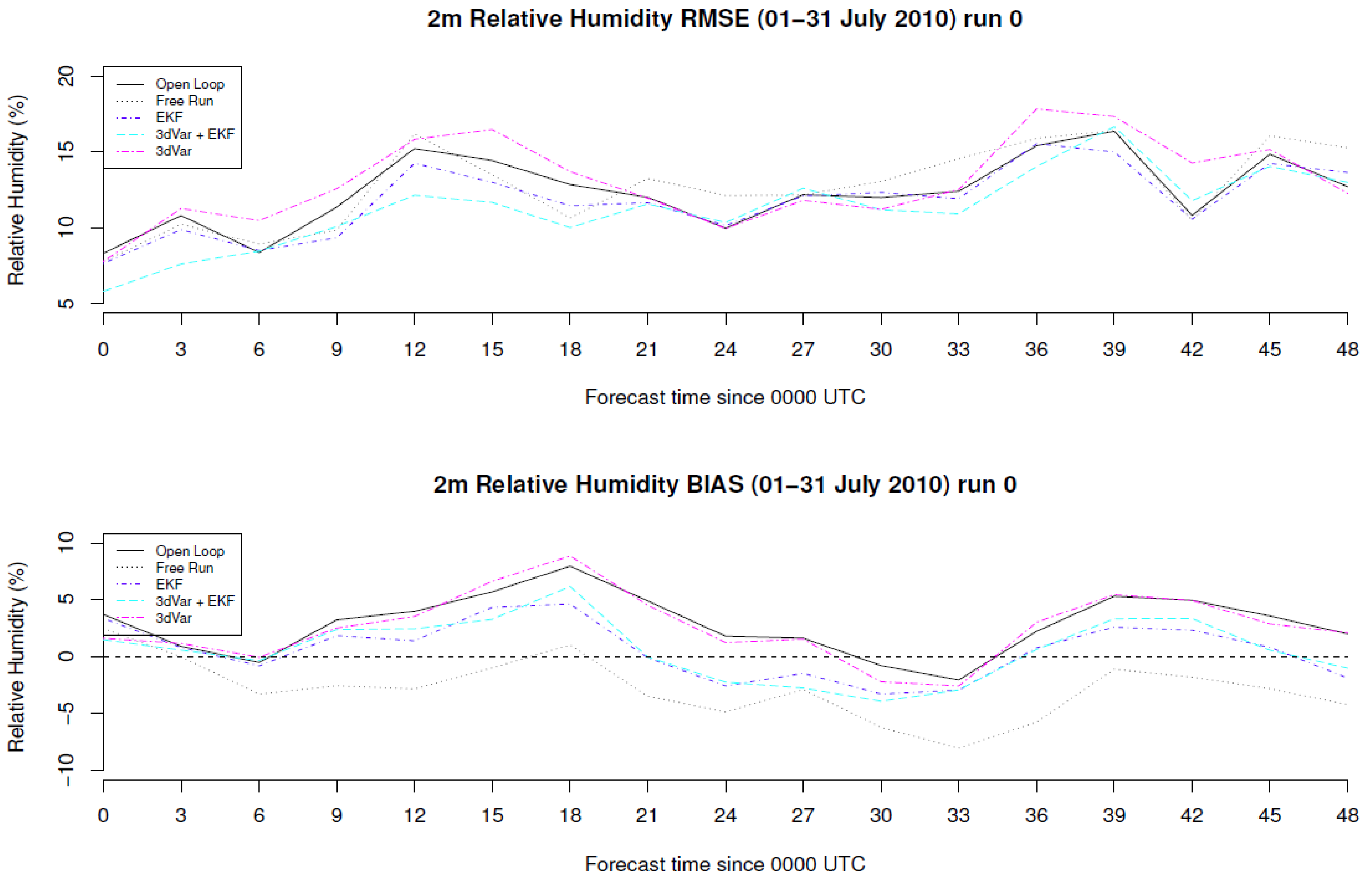


Figure 3.12: Root-mean-square error and BIAS for relative humidity at Uccle averaged over the month July 2010 for extended Kalman filter (EKF), open loop, free run, 3D-Var, 3D-Var+EKF.

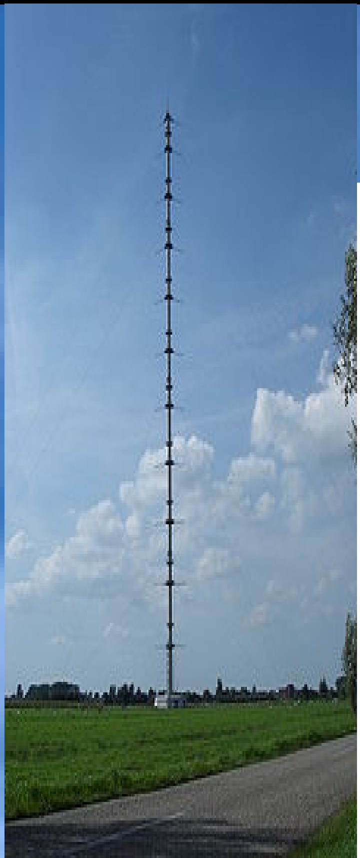
STAEKF

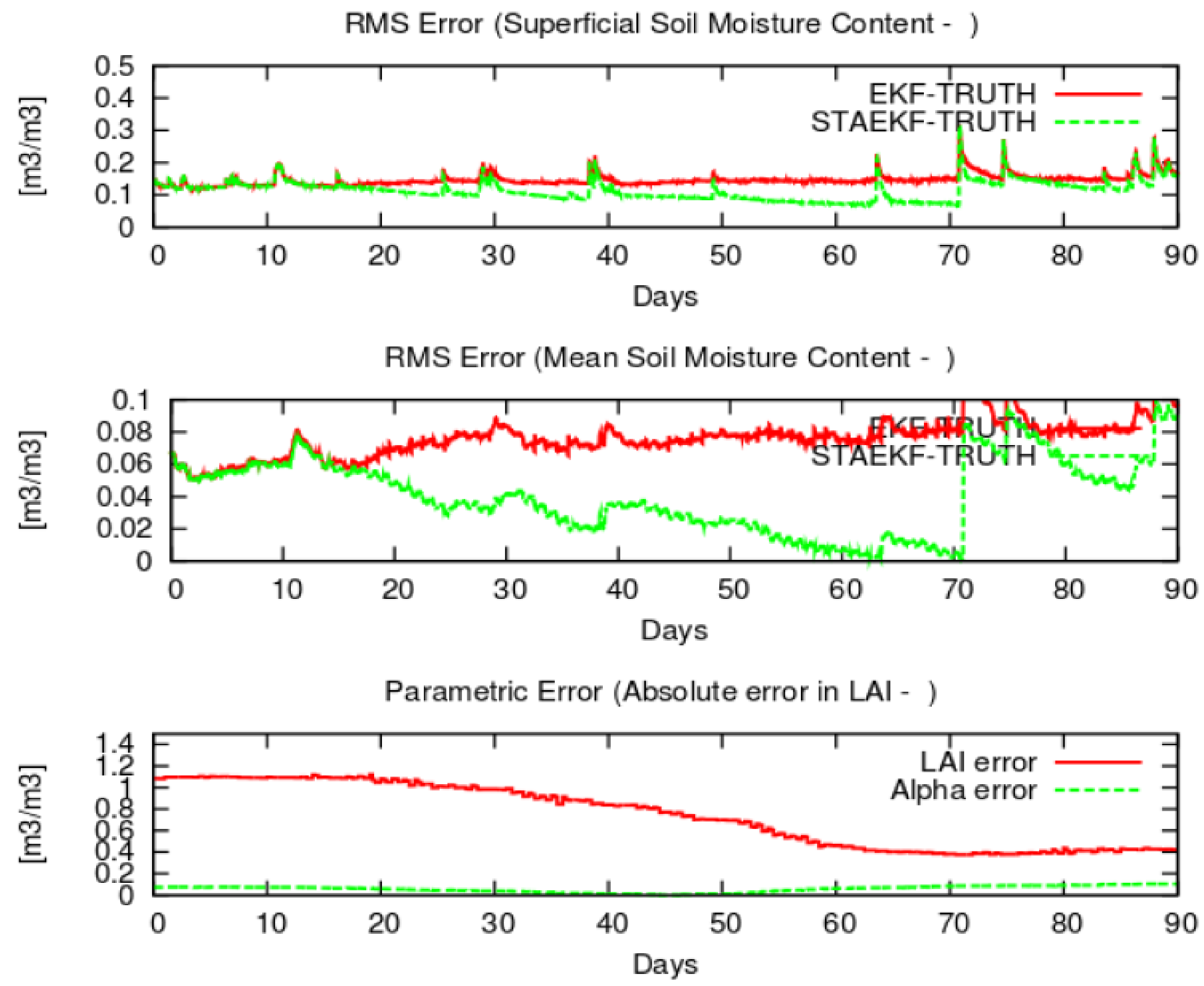
The forecast model, is augmented with P model parameters:

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

$\mathbf{z} = (\mathbf{x}, \lambda)$ 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.

STAEKF at Cabauw





Outlook:

1. Coupling ALARO-1 with SURFEX_V8 for NWP/climate applications.

2. Use of Land SAF product as forcing for SURFEX offline runs: solar downward and longwave radiation

2. Use albedo and LAI from new sensors ProbaV and combine this information with STAEKF.

3. Test STAEKF in a real enviromenet within SODA and ALARO for NWP application

4. Combine 3d-var with STAEKF for NWP application.

5. Use of STAEKF for study about the coupling between atmosphere and land surface and for seasonal recasting.