THE LAND SURFACE MODEL UPDATE: SURFEX

THE LAND SURFACE DATA ASSIMILATION UPDATE: EKF

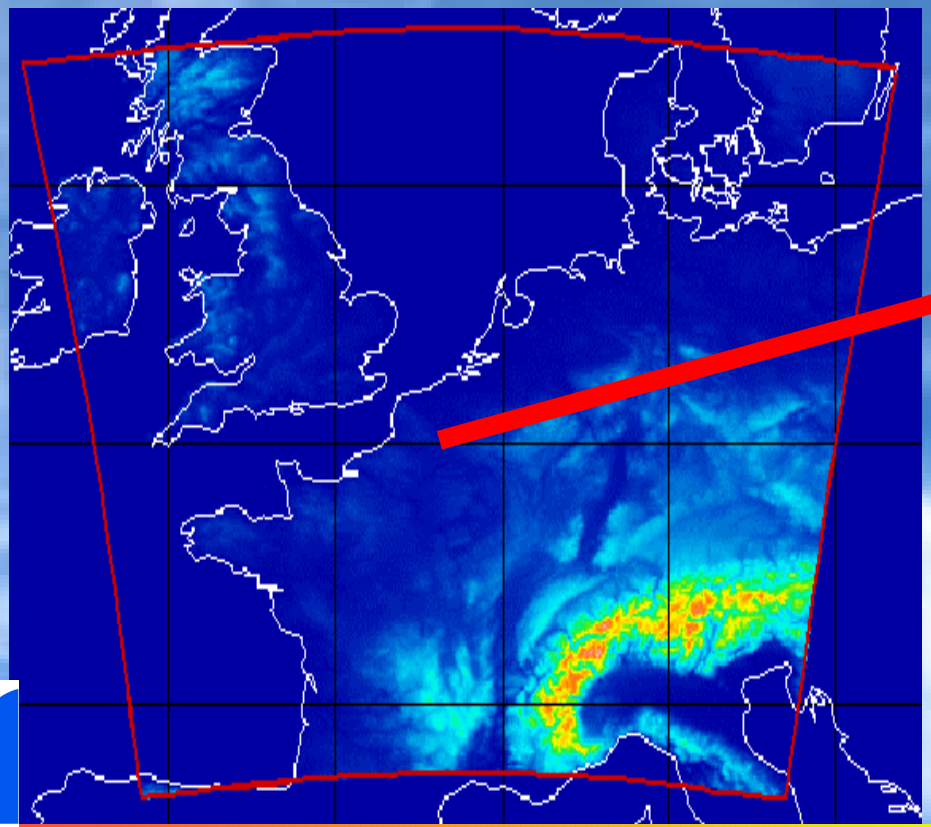
Recent developments in land surface modeling and data assimilation in ALADIN at the RMI

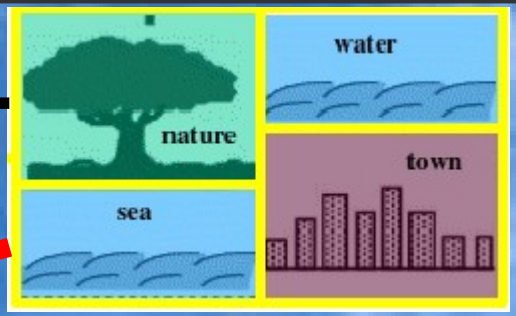
Hamdi R. et al.

FMI, 21th September 2012

Tiling

One important feature of the externalized surface:
each grid cell is divided into 4 elementary units called tiles according to the fraction of covers in the grid cell





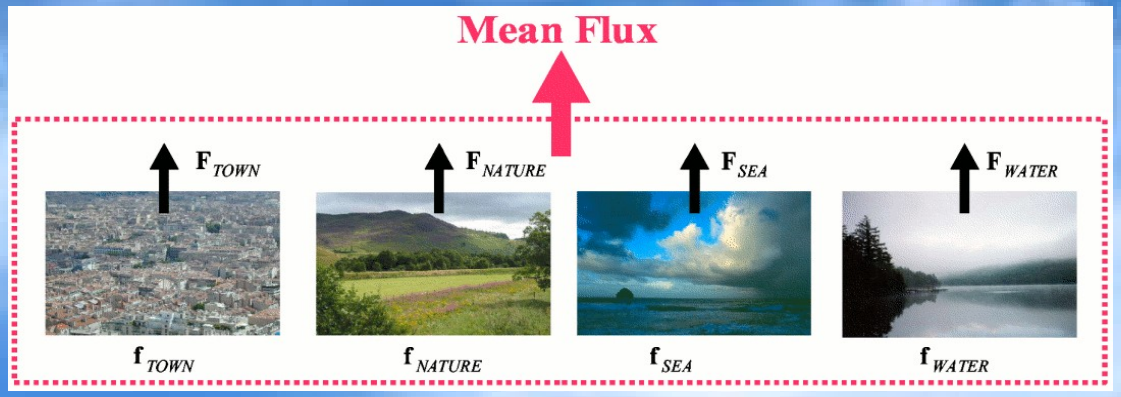
1: bare ground
2: rocks
3: permanent snow
4: deciduous forest
5: conifer forest
6: evergreen broadleaf trees
7: C3 crops
8: C4 crops
9: irrigated crops
10: grassland
11: tropical grassland
12: garden and parks

Surfex output as surface boundary conditions for atmospheric radiation and turbulent scheme.

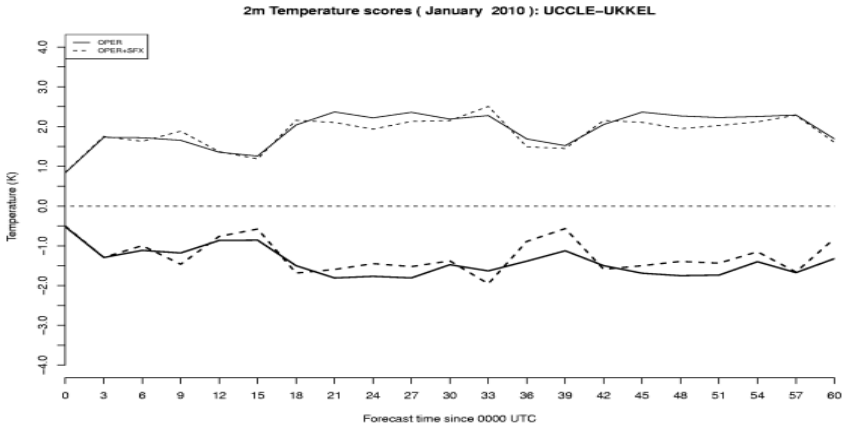
albedo
emissivity
radiative temperature
momentum flux
sensible heat flux
latent heat flux
CO_2 flux
chemical flux

Atmospheric model

Atmospheric forcing
Sun position
Downward radiative flux



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



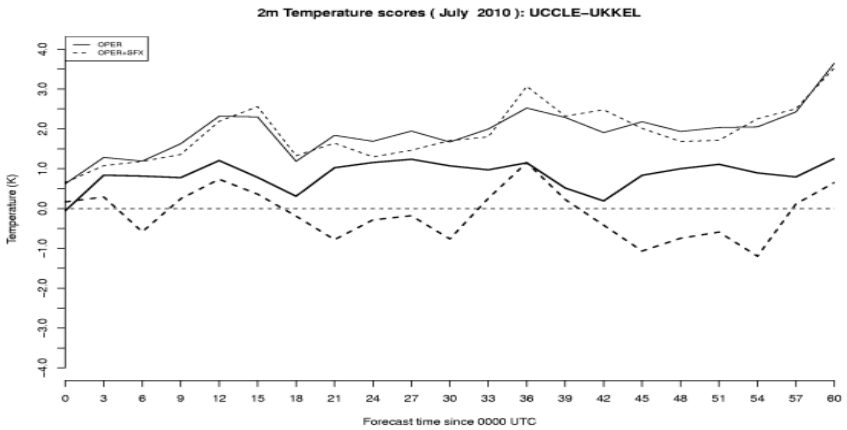
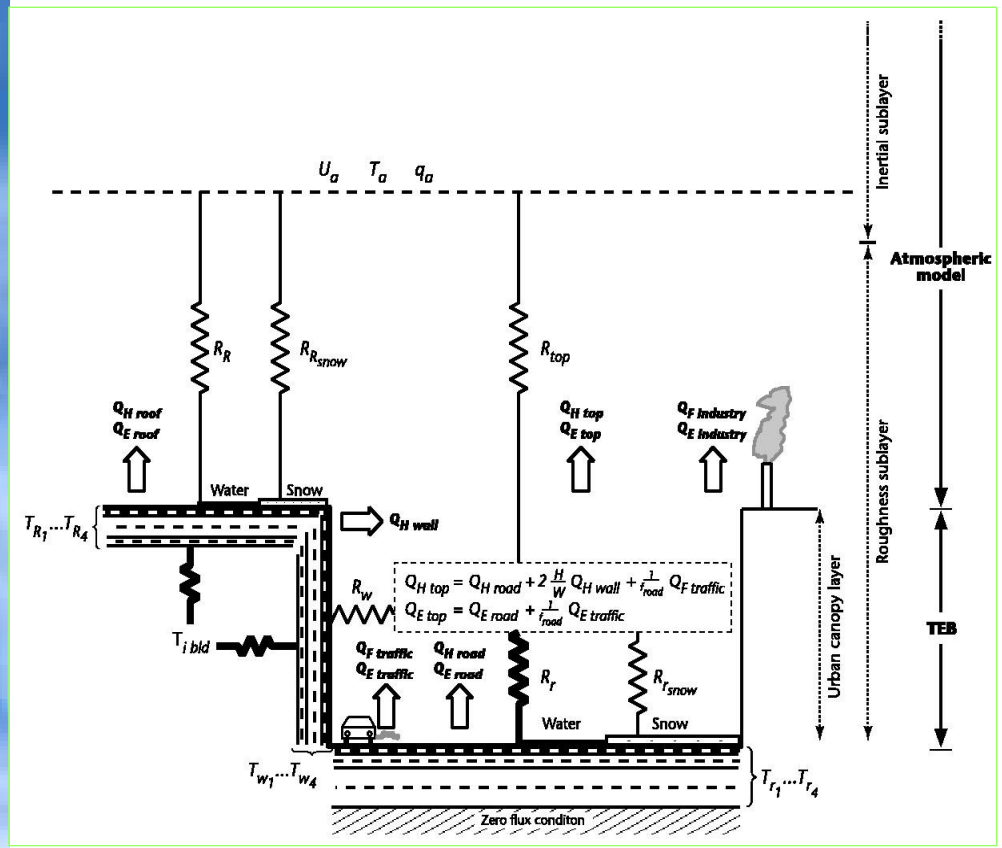


Table 2. the average daytime/nightime scores for the flat/high topography and coastal synoptic stations, sign (+) means improvement, sign (0) means neutral effect, and sign (-) means degradation of the scores.

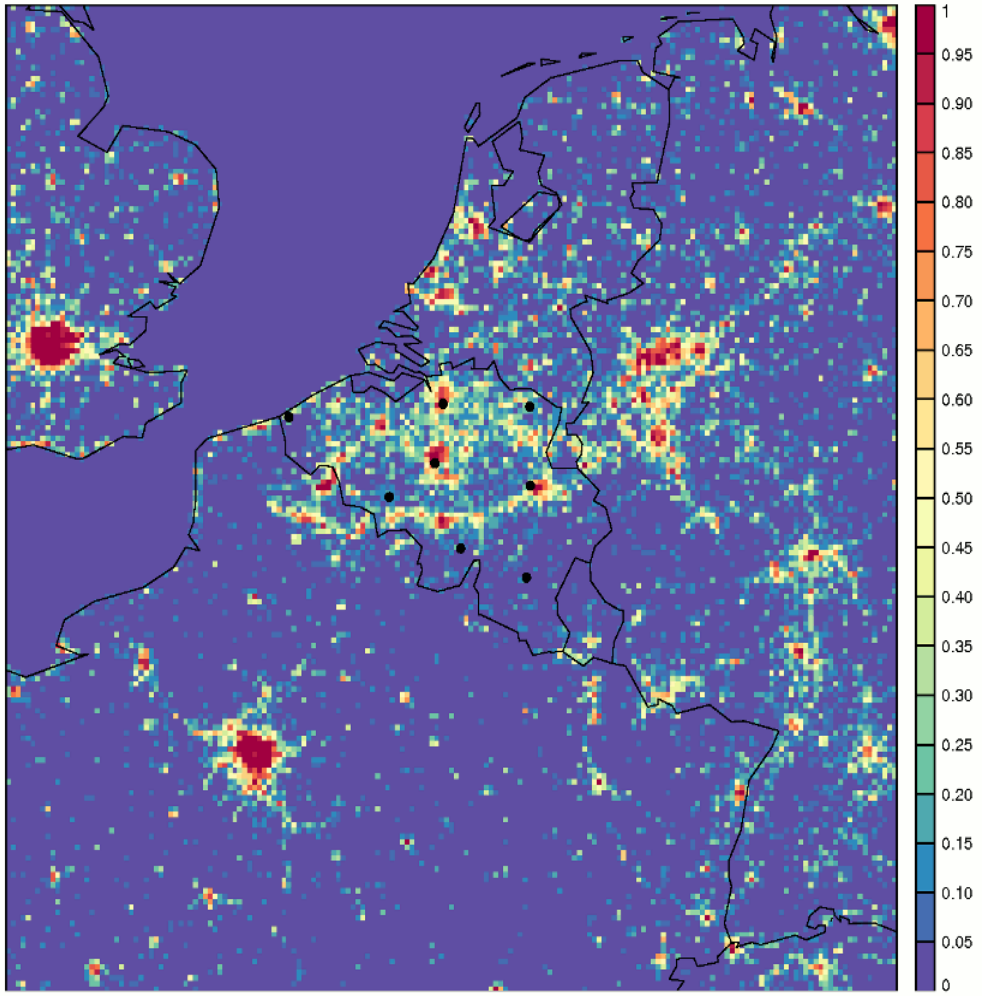
	$Winter_{Night}$	$Winter_{Day}$	$Summer_{Night}$	$Summer_{Day}$
Temperature at 2m				
Flat	+	0	0	0
High	0	-	0	0
Coast	0	0	+	0
Wind speed at 10m				
Flat	0	0	0	0
High	0	0	0	0
Coast	0	0	0	0
Wind direction at 10m				
Flat	0	0	0	0
High	0	0	0	0
Coast	0	0	0	0
Relative humidity at 2m				
Flat	+	+	0	0

THE LAND SURFACE MODEL UPDATE: SURFEX

THE LAND SURFACE DATA ASSIMILATION UPDATE: EKF



(TEB, Masson 2000)



(ECOCLIMAP, Masson et al. 2003)

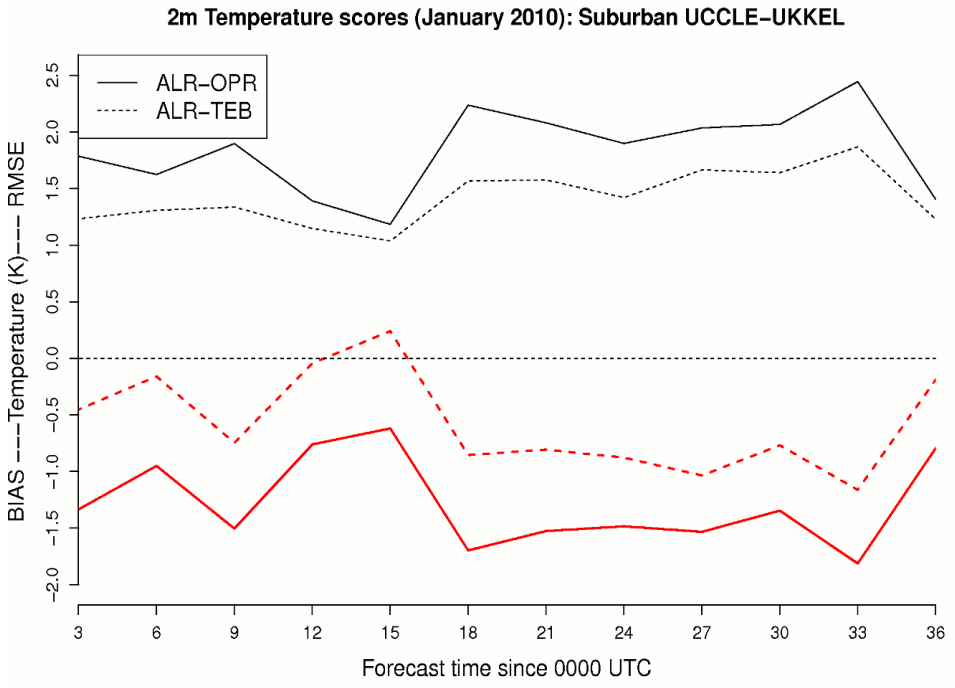
The ALARO model is run operationally 4 times a day (at 6-h intervals) based on analyses coming from the operational version of the ALADIN model running at Météo-France.

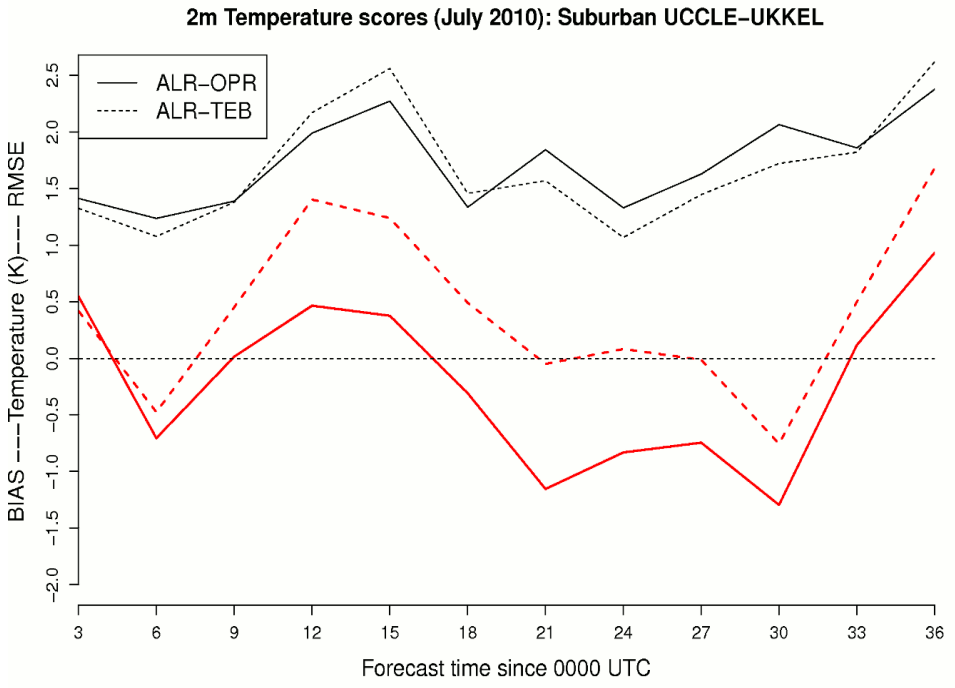
For nonurban surfaces, the SURFEX scheme diagnoses the 2-m temperature, 2-m relative humidity, and 10-m wind by complex interpolation between the lowest ALARO level and the surface, making use of the Geleyn (1988) formulation.

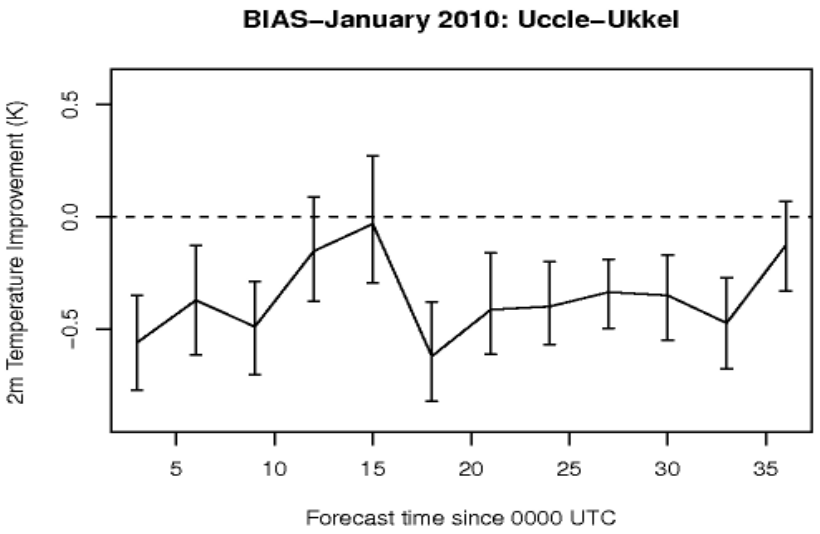
For urban area, the standard 2-m temperature, 2-m humidity, and 10-m wind are obtained from the diagnosed TEB canyon temperature, humidity, and wind respectively.

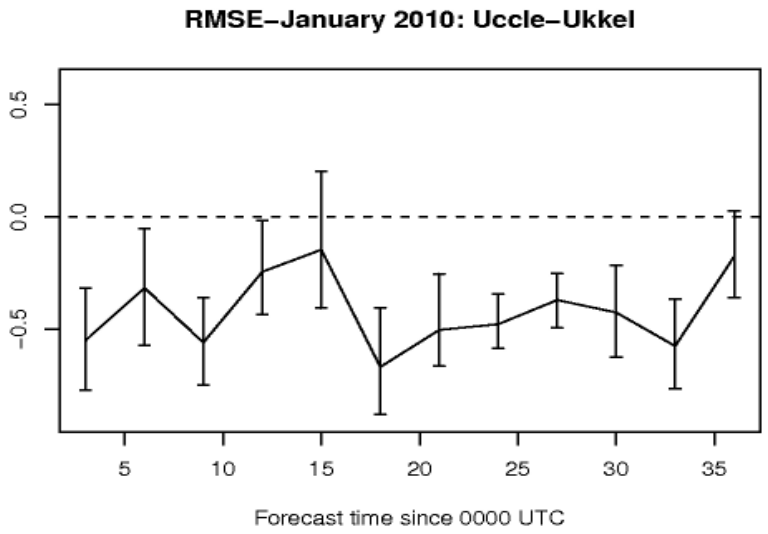
The additional resources needed to run ALARO with TEB for our operational domain using the computing resource available at our institute are rather low; the time needed to complete a 36-h forecast is on the order of **0.6%** and the memory increase is about **1.6%**.

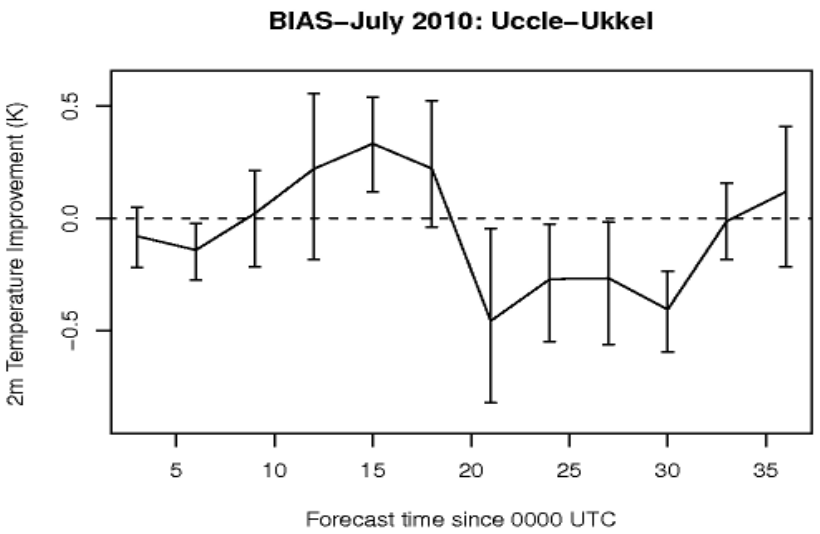
For two months (January and July 2010), a series of simulations is performed, with (ALR-TEB) and without TEB (ALR-OPR), with one simulation of 36h each day starting at 0000 UTC.

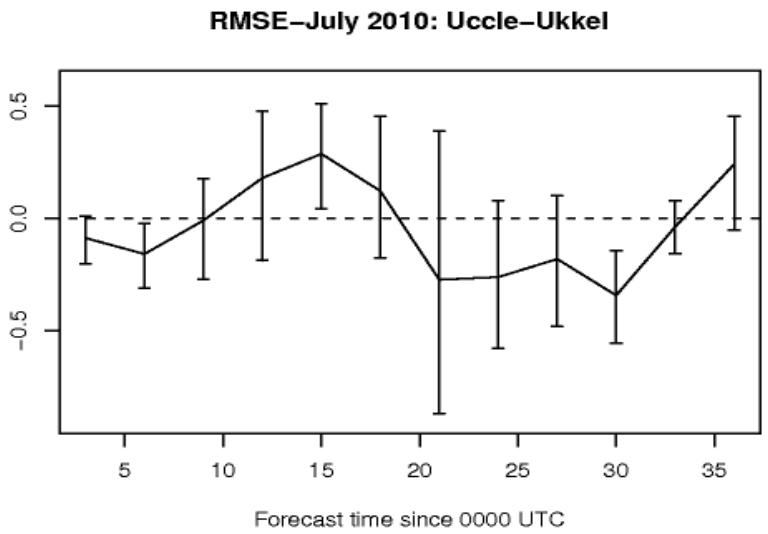





BIAS–January 2010: Uccle–Ukkel
2m Temperature Improvement (K)
0.5
0.0
−0.5
5
10
15
20
25
30
35
Forecast time since 0000 UTC

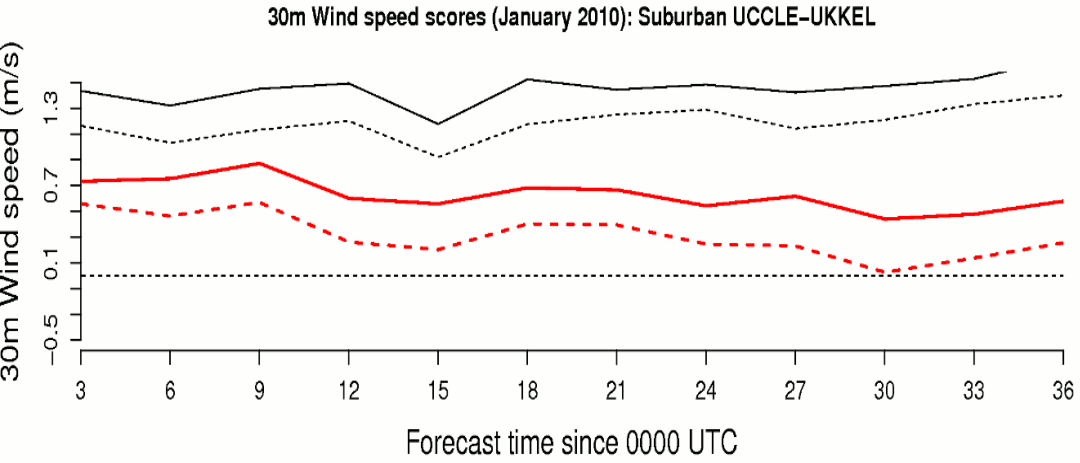

RMSE–January 2010: Uccle–Ukkel
0.5
0.0
−0.5
5
10
15
20
25
30
35
Forecast time since 0000 UTC

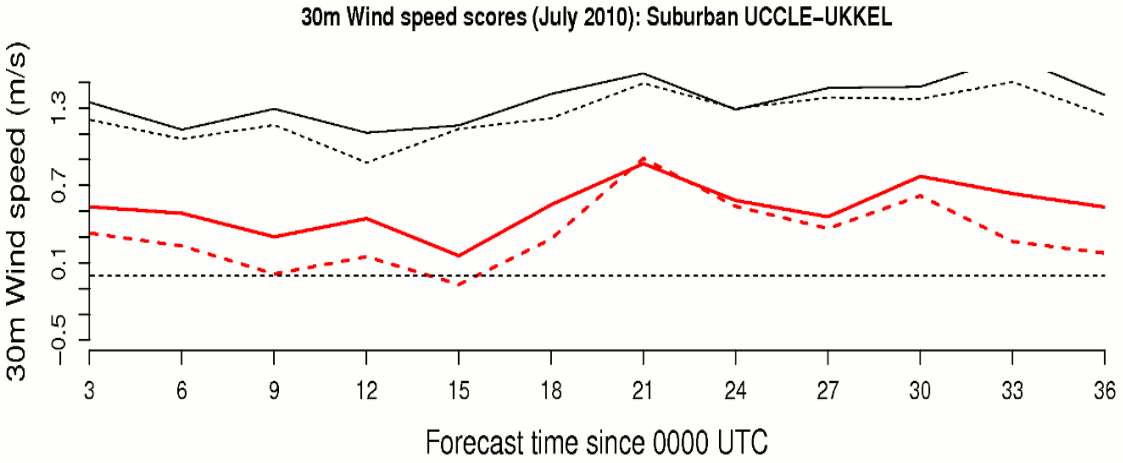

BIAS–July 2010: Uccle–Ukkel
2m Temperature Improvement (K)
0.5
0.0
−0.5
5
10
15
20
25
30
35
Forecast time since 0000 UTC

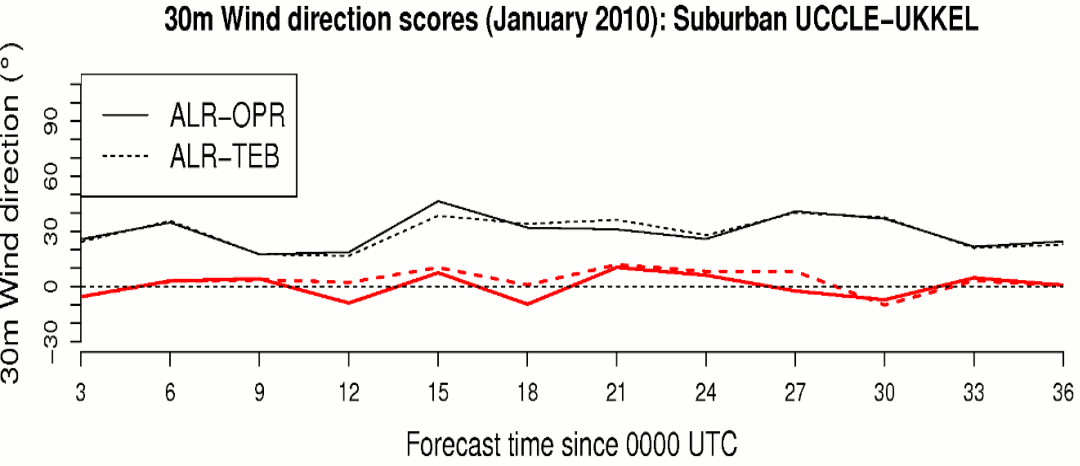

RMSE–July 2010: Uccle–Ukkel
0.5
0.0
−0.5
5
10
15
20
25
30
35
Forecast time since 0000 UTC

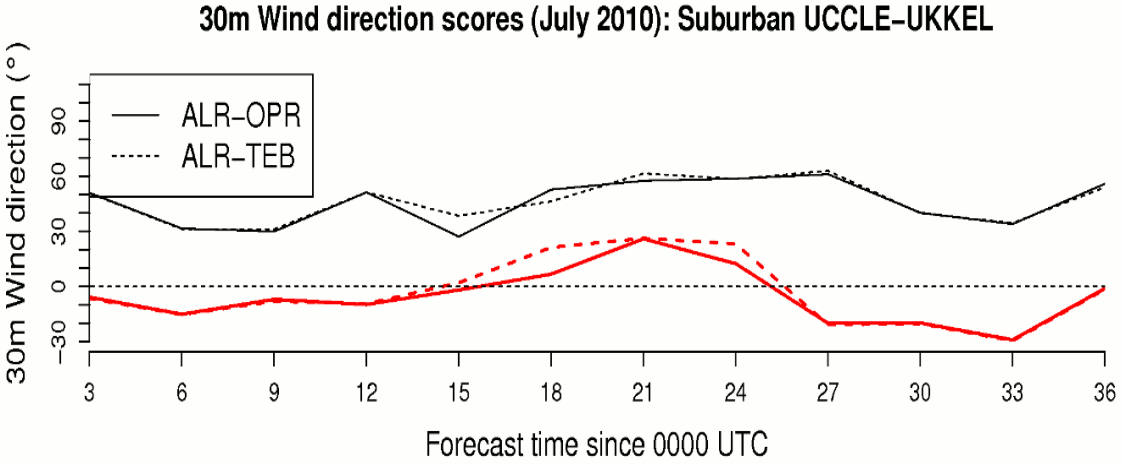
THE LAND SURFACE MODEL UPDATE: SURFEX

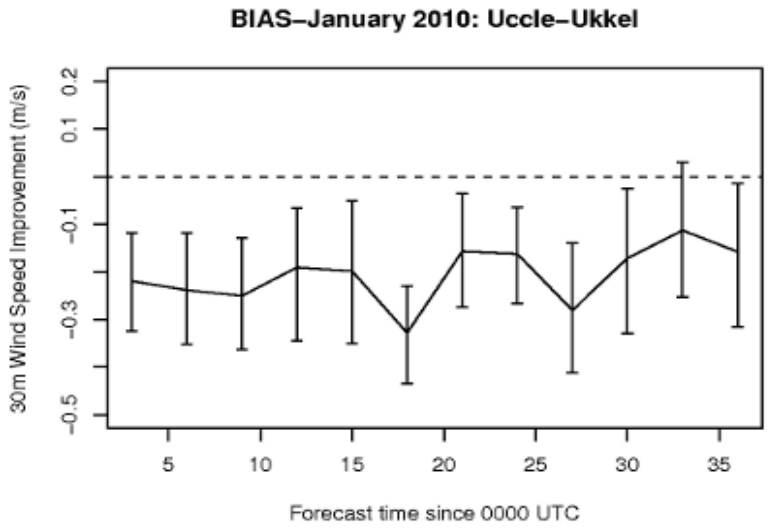
THE LAND SURFACE DATA ASSIMILATION UPDATE: EKF

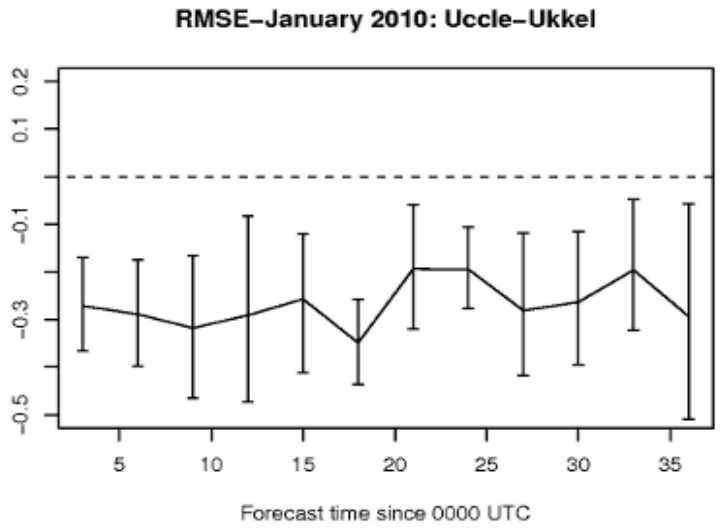


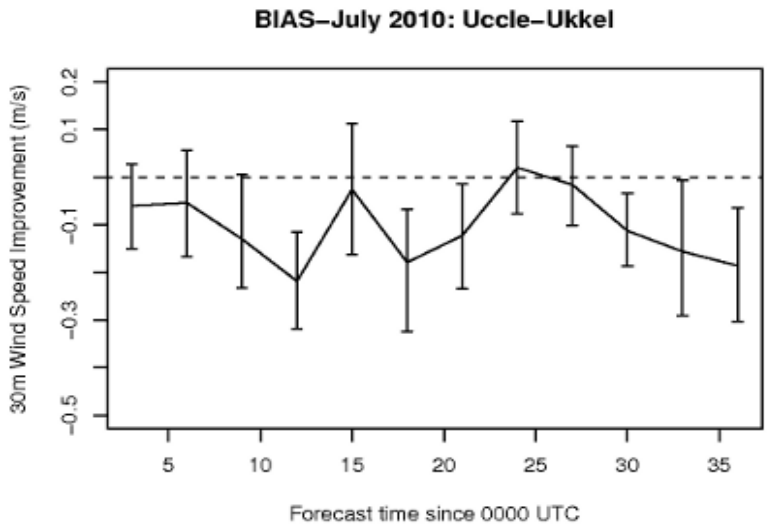


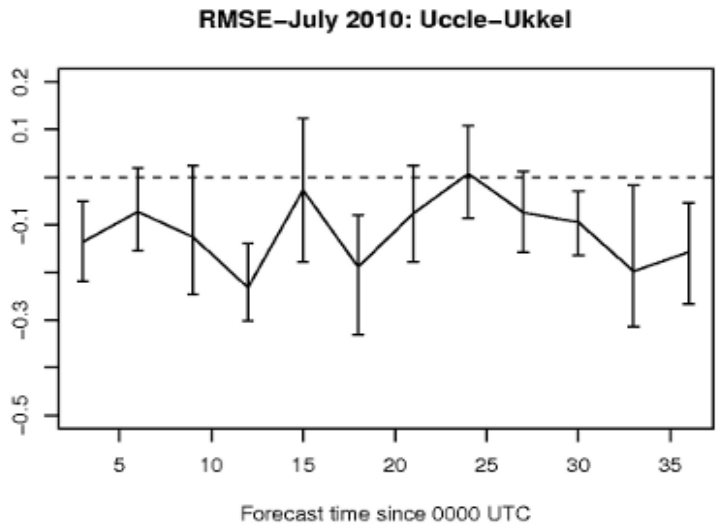




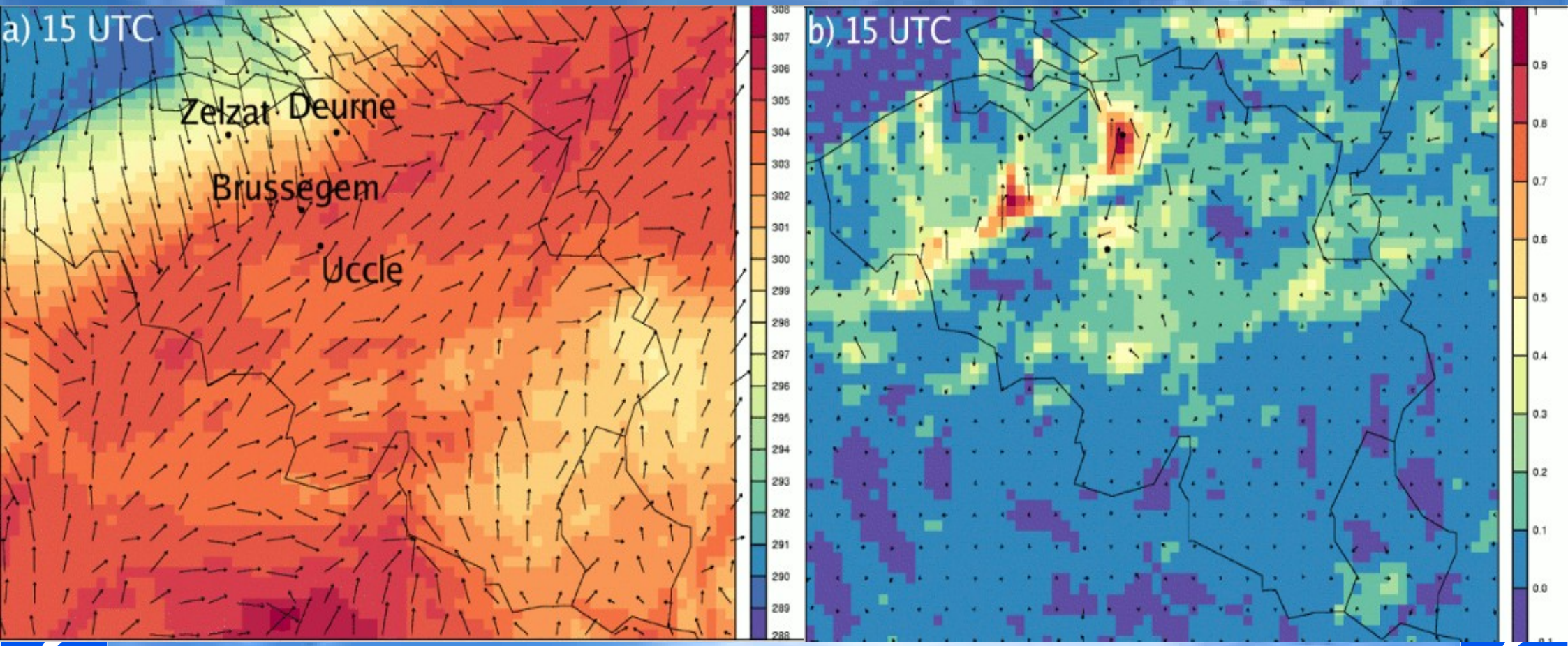

BIAS–January 2010: Uccle–Ukkel
30m Wind Speed Improvement (m/s)
0.2
0.1
−0.1
−0.3
−0.5
5
10
15
20
25
30
35
Forecast time since 0000 UTC


RMSE–January 2010: Uccle–Ukkel
0.2
0.1
−0.1
−0.3
−0.5
5
10
15
20
25
30
35
Forecast time since 0000 UTC


BIAS–July 2010: Uccle–Ukkel
30m Wind Speed Improvement (m/s)
0.2
0.1
−0.1
−0.3
−0.5
5
10
15
20
25
30
35
Forecast time since 0000 UTC


RMSE–July 2010: Uccle–Ukkel
0.2
0.1
−0.1
−0.3
−0.5
5
10
15
20
25
30
35
Forecast time since 0000 UTC

The two model simulations are examined in greater detail for the 36-h time period starting at 0000 UTC 8 July 2010. On this day, with an anticyclone covering Belgium and a near-record high temperature, a sea-breeze developed in the afternoon with an intense front penetrating nearly 150 km inland.



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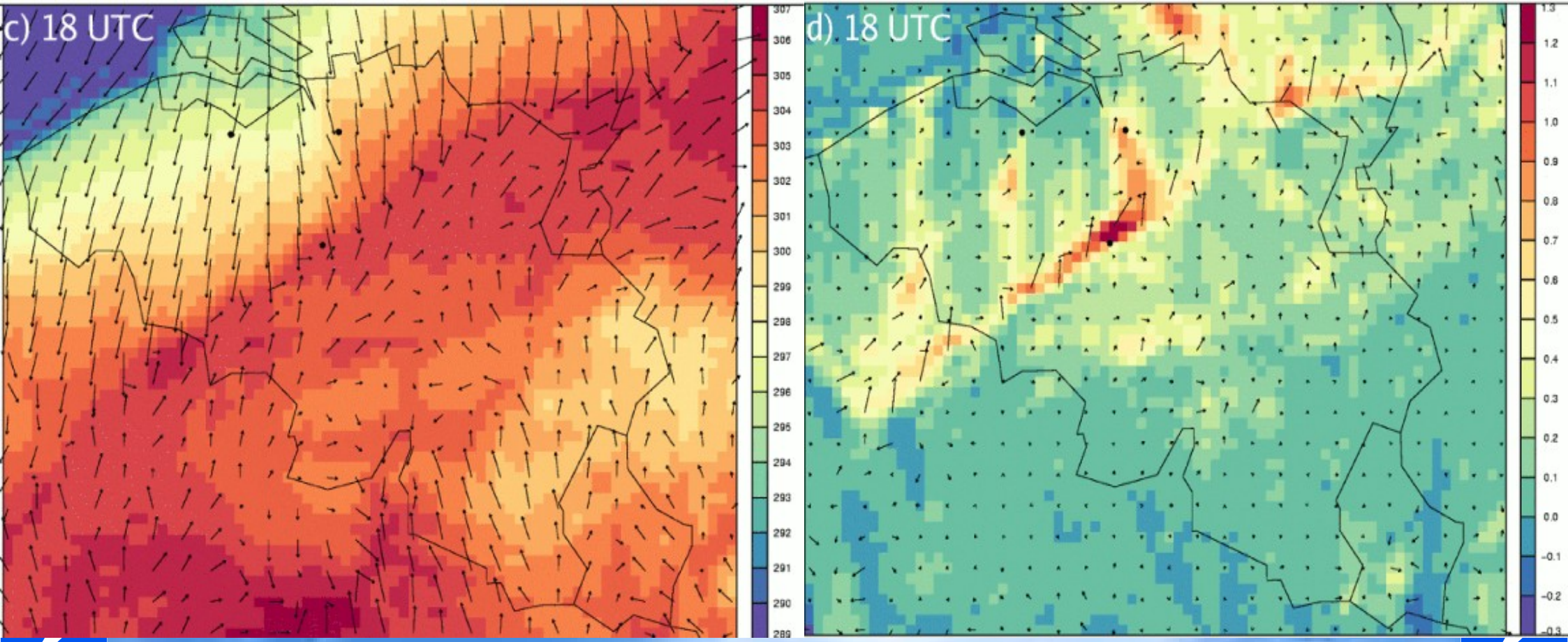

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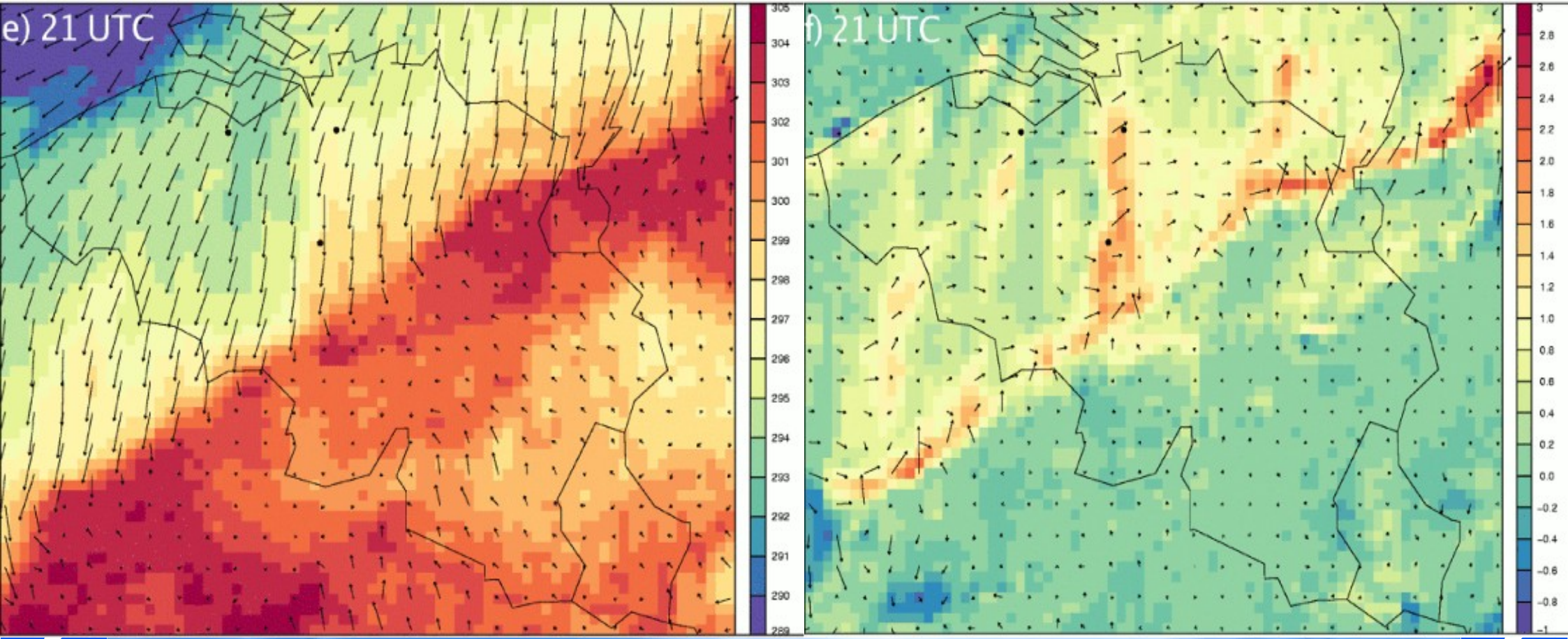
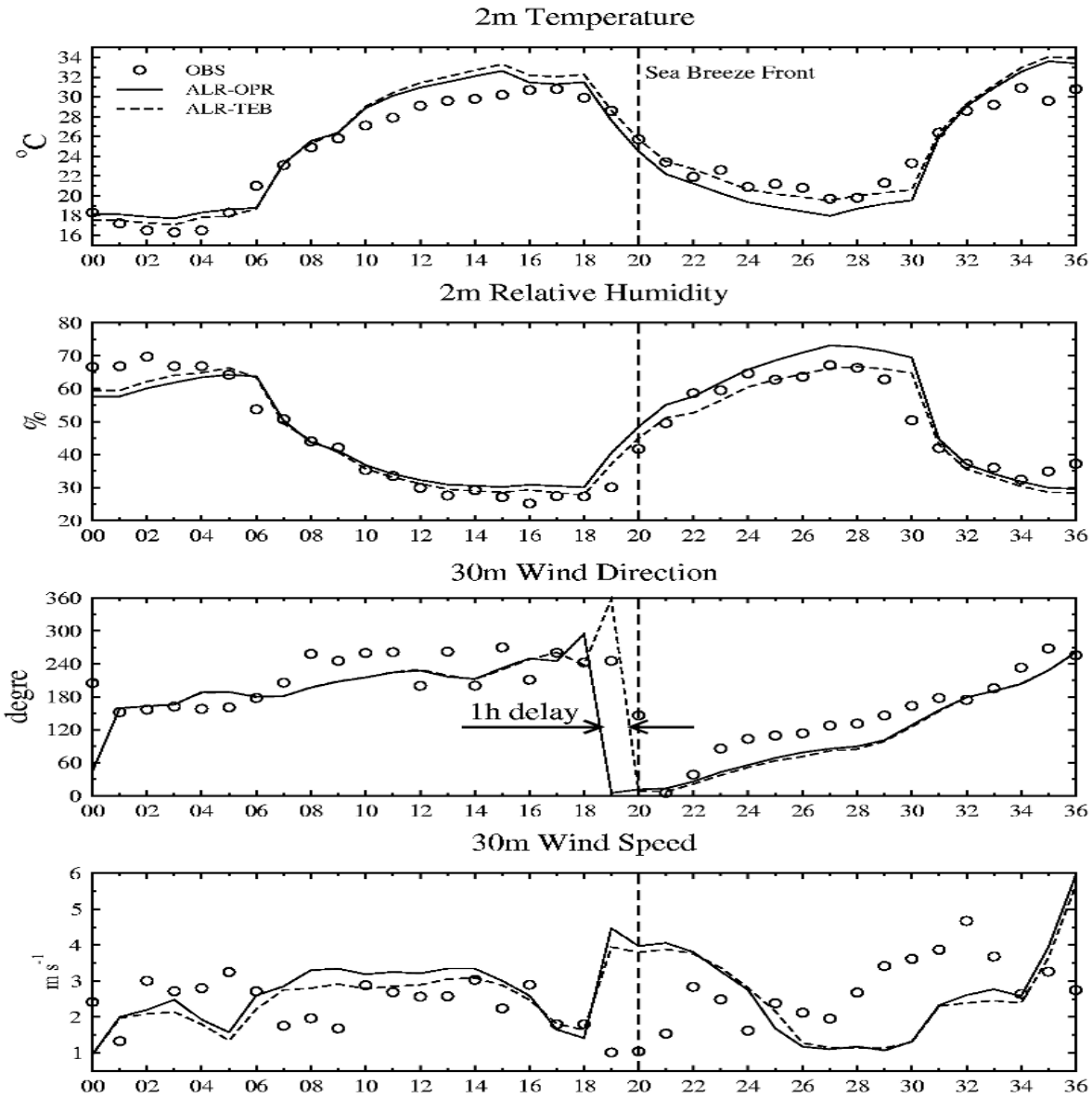
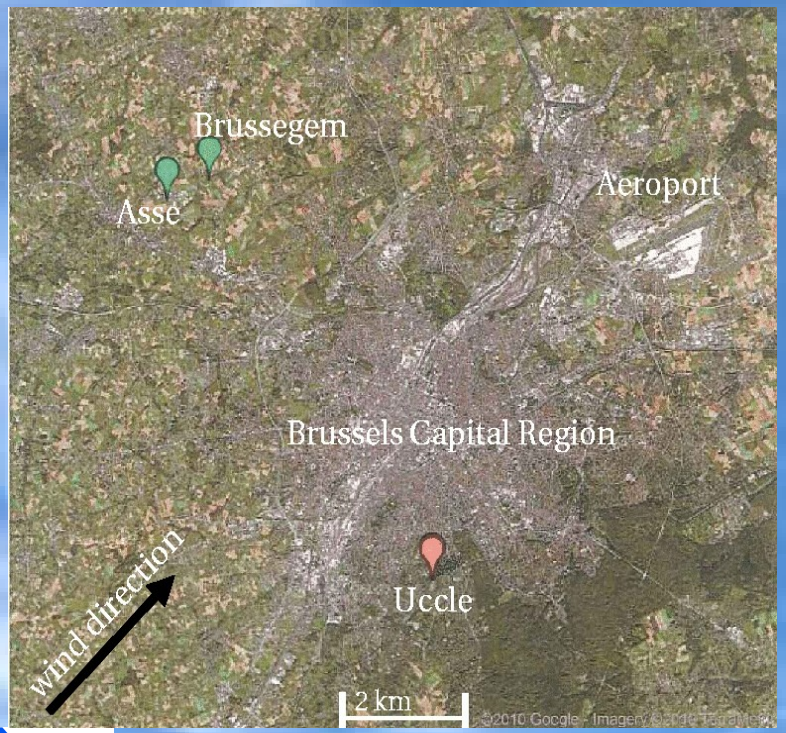
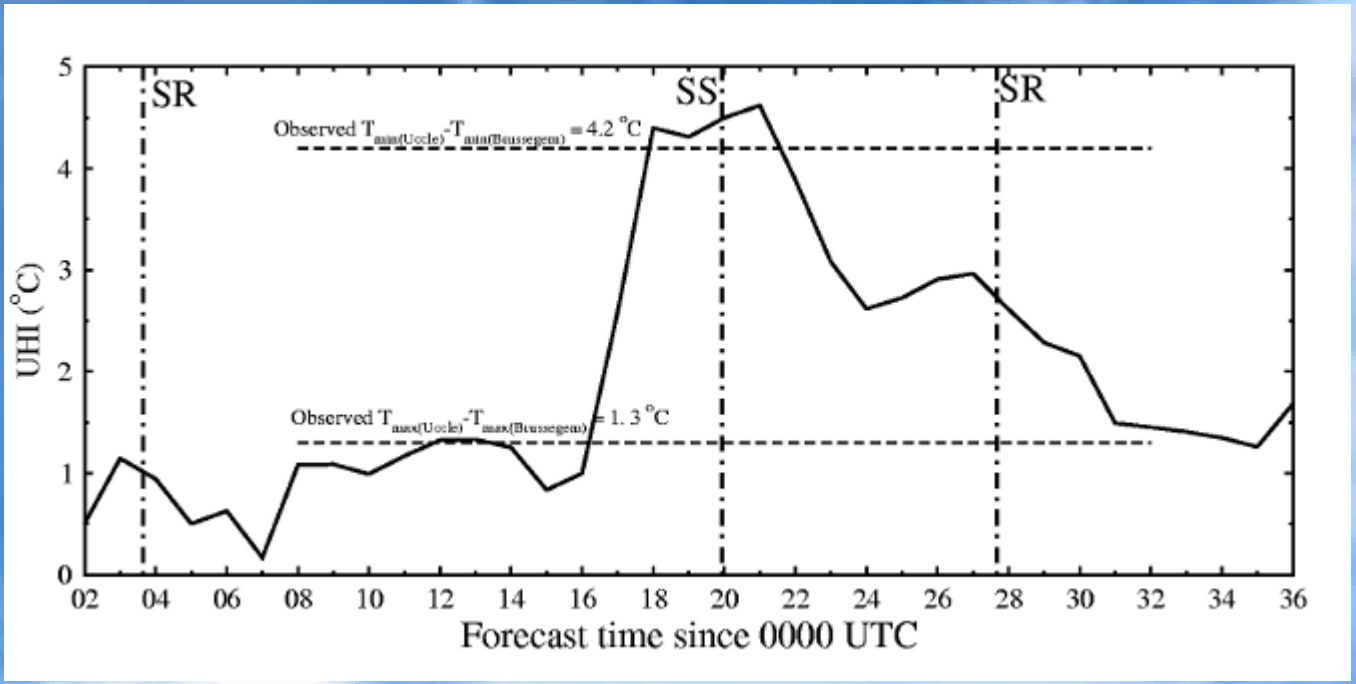



2m Temperature
OBS
ALR-OPR
ALR-TEB
Sea Breeze Front
°C
2m Relative Humidity
%
30m Wind Direction
degre
1h delay
30m Wind Speed
m s-1

The strength of the UHI of Brussels is estimated using the temperature observed at Uccle and at the rural Brussegem climatological station situated 20 km north-west of the center of Brussels.

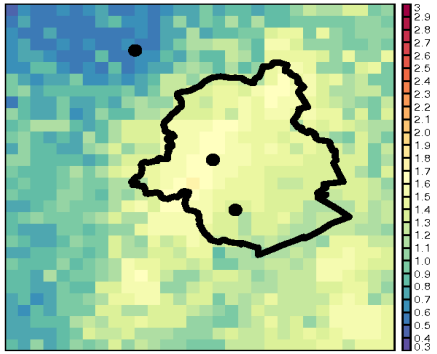




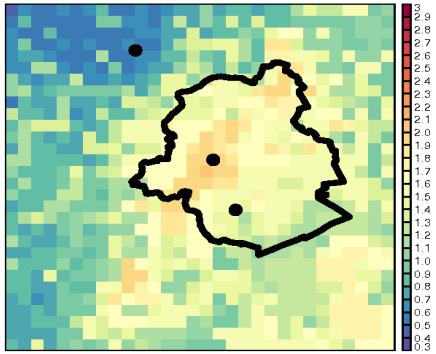
Downscaling global climate projections at the city level

Evolution of the Brussels's urban climate under an A1B emission scenario

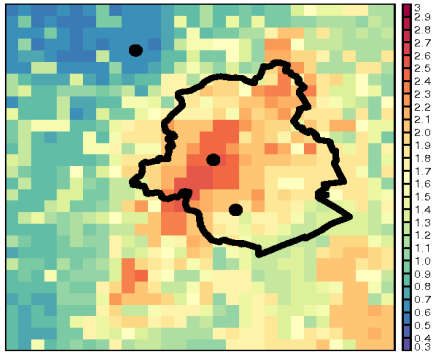
ARP_RF, UHI[T_MIN] = 1.71 °C



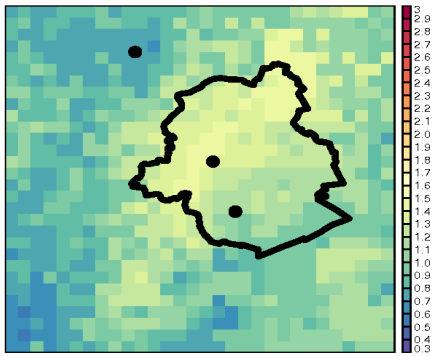
ARP_OF, UHI[T_MIN] = 1.97 °C



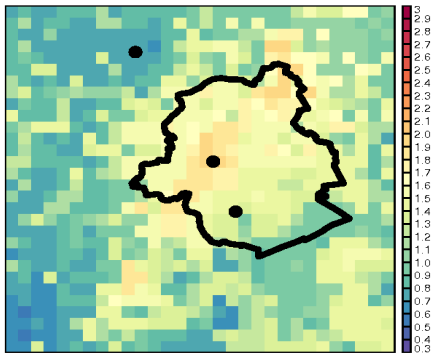
ARP_IN, UHI[T_MIN] = 2.56 °C



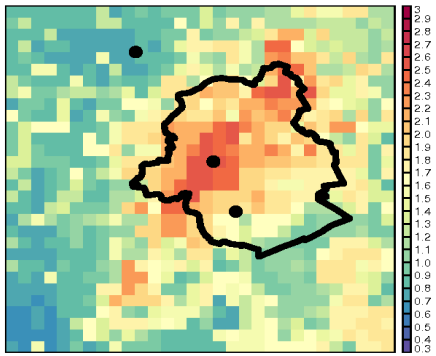
ERA_RF, UHI[T_MIN] = 1.46 °C



ERA_OF, UHI[T_MIN] = 1.86 °C

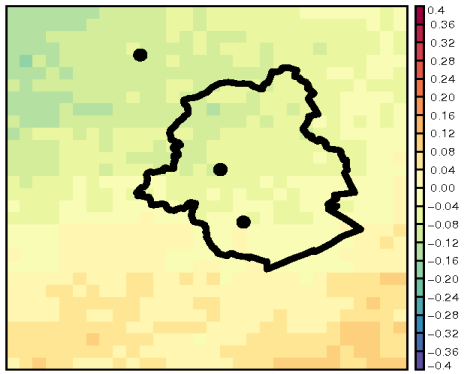


ERA_IN, UHI[T_MIN] = 2.54 °C

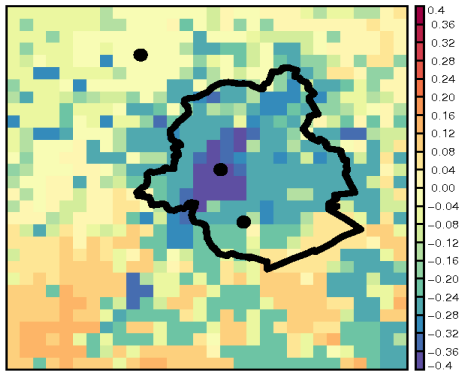


Evolution of the Brussels's urban climate under an A1B emission scenario

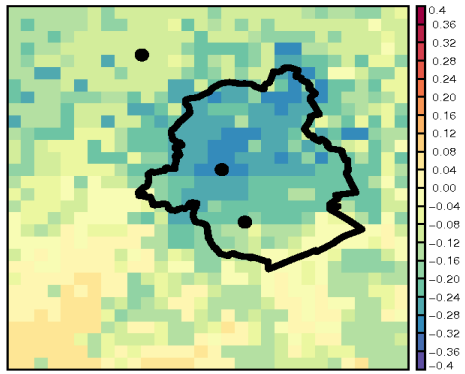
A1B_RF–ARP_RF, D–UHI[T_MIN] = –0.07 °C



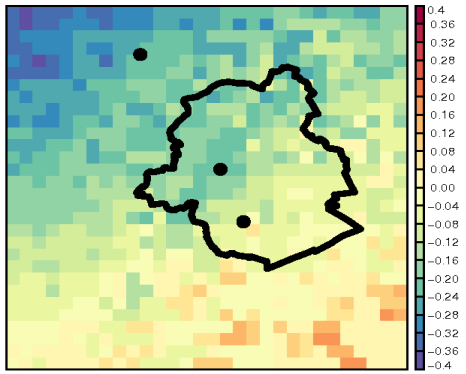
A1B_OF–ARP_OF, D–UHI[T_MIN] = –0.36 °C



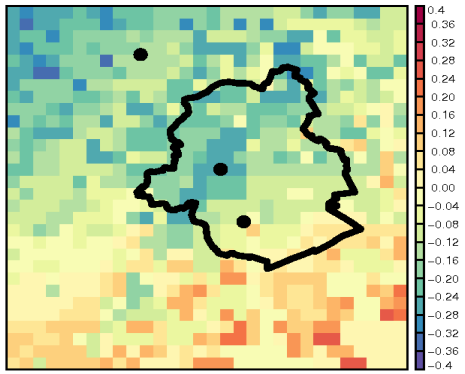
A1B_IN–ARP_IN, D–UHI[T_MIN] = –0.26 °C



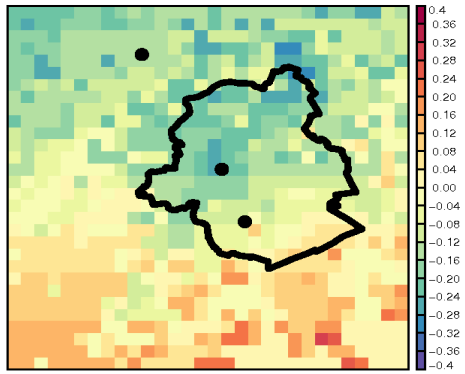
A1B_RF–ARP_RF, D–UHI[T_MAX] = –0.21 °C



A1B_OF–ARP_OF, D–UHI[T_MAX] = –0.24 °C



A1B_IN–ARP_IN, D–UHI[T_MAX] = –0.2 °C



1. Development of a SURFEX EKF for ALARO and comparison of the offline and coupled version with the OI analysis.

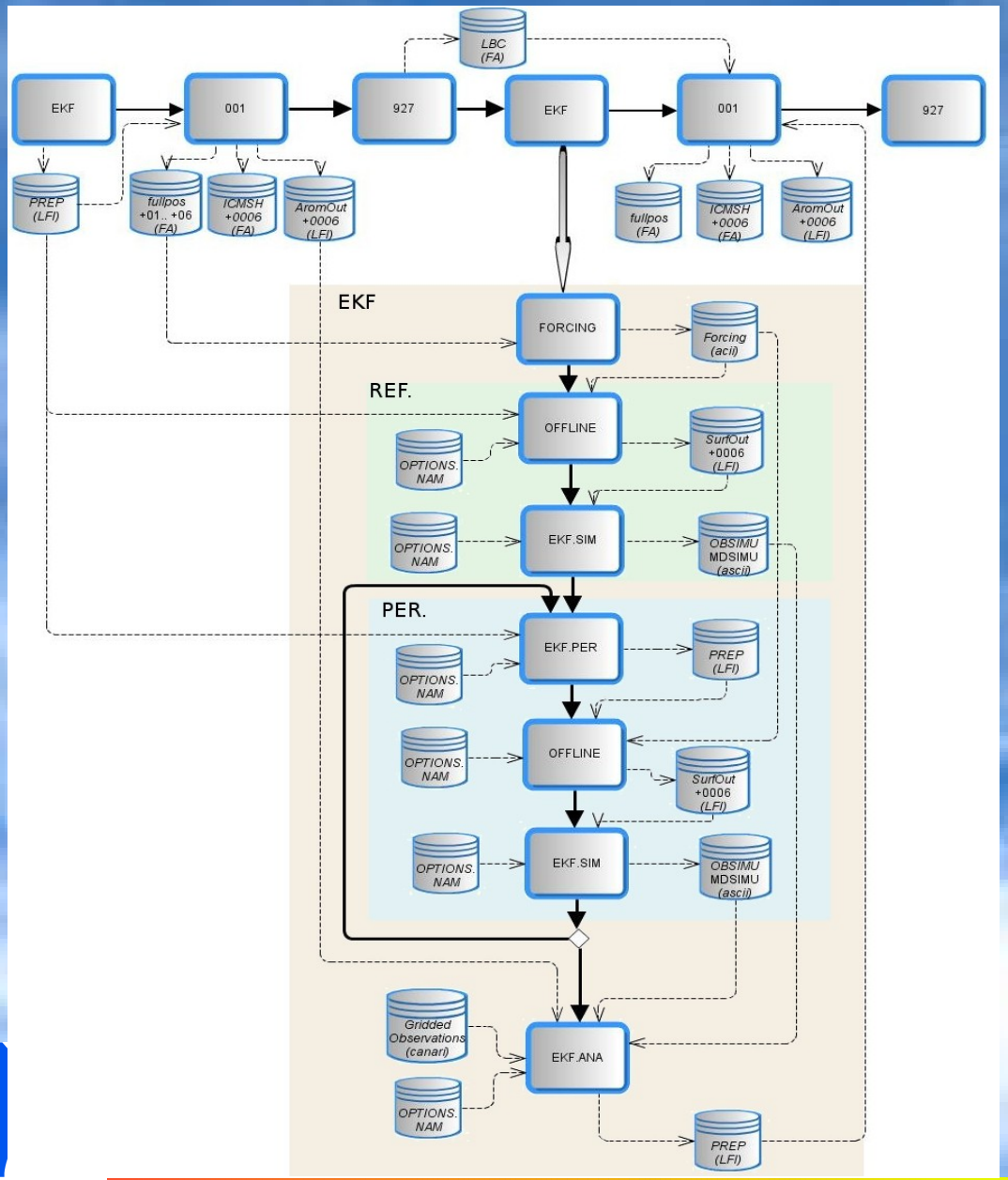
2. Preliminary results on combining SURFEX EKF with 3dVar atmospheric assimilation.

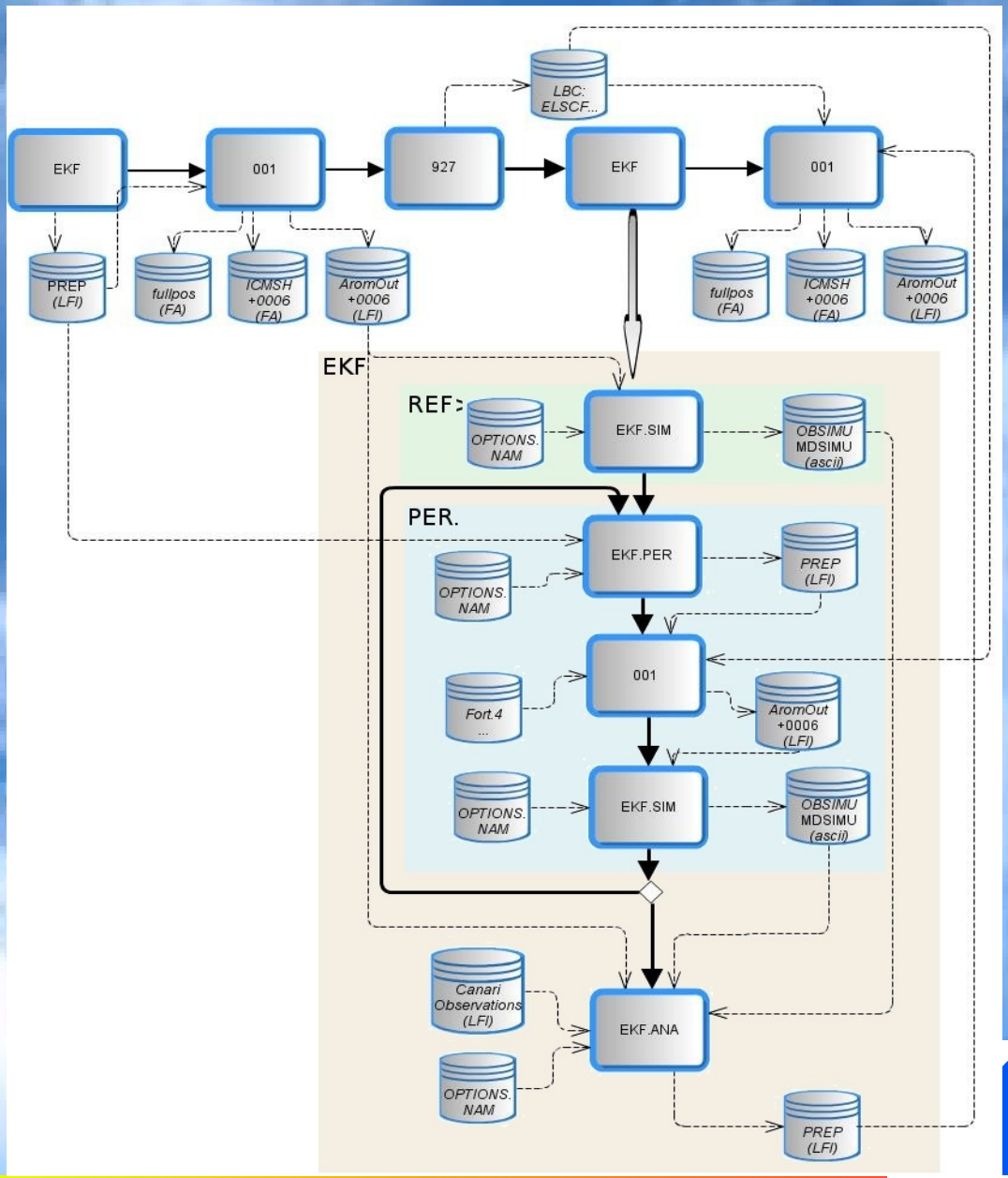
3. A feasibility study of using a Short Time Augmented Extended Kalman Filter (STAEKF) for Soil Analysis.

THE LAND SURFACE DATA ASSIMILATION UPDATE: EKF

- In Balsamo et al. (2007,JH), the offline approach is compared to the coupled approach for a single day during the summer with the GEM model. The gain components are found to be smaller for the offline approach but with similar patterns as the coupled approach.
- In Balsamo et al (2004,QJRMS) it is mentioned that for coupled experiments the choice of the perturbation size is important. Small perturbations can lead to a noisy H matrix and inaccurate corrections.
- This presentation:
  - Implementation of offline and coupled SURFEX EKF for ALADIN
  - Comparison between offline and coupled EKF: jacobians, gain, increments
  - Comparison of forecast scores of EKF, OI and runs without assimilation

THE LAND SURFACE DATA ASSIMILATION UPDATE: EKF





THE LAND SURFACE DATA ASSIMILATION UPDATE: EKF

- Prognostic variables:
  - Superficial water content (wg1)
  - Root zone water content (wg2)
  - Surface temperature (Tg1)
  - Deep soil temperature (Tg2)
- Observations:
  - Screen level temperature (T2m)
  - Screen level relative humidity (RH2m)
- Additional information:
  - LBC data from Aladin France
  - Assimilation interval τ = 6 hours, with assimilation at 00,06,12,18 UTC
  - Forecasts with surfex + alaro and inline fullpos (interval 1 hour)
  - Background error covariance matrix **B** is kept constant (WG set to 0.1,TG set to 2 K)
  - Error covariance matrix **R:** T2m set to 1K, RH2m set to 10%

Experiments:

- Free run: (no assimilation)

  Surface field from 6h forecast of previous run

- Open loop: (no assimilation)

  Surface is interpolated from Arpege analysis

- Surface Assimilation runs:

  Optimum Interpolation

  EKF with offline jacobian calculation

  EKF with coupled jacobian calculation

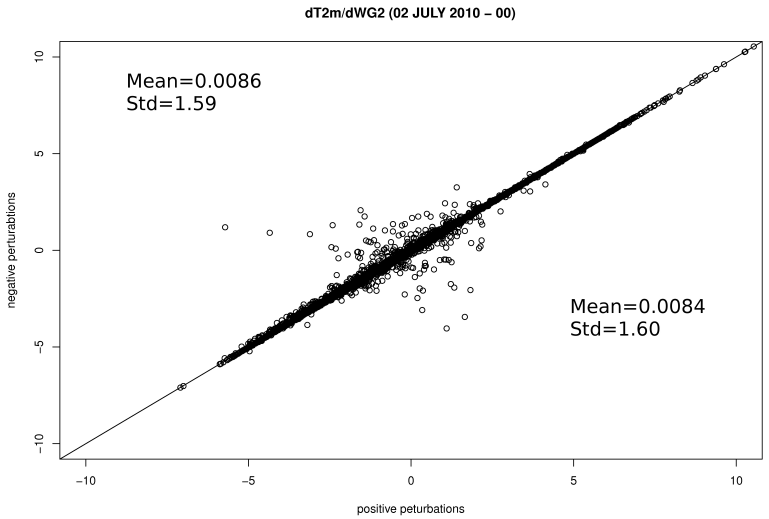
  → Surface guess for assimilation is taken from 6h forecast of previous run

THE LAND SURFACE DATA ASSIMILATION UPDATE: EKF

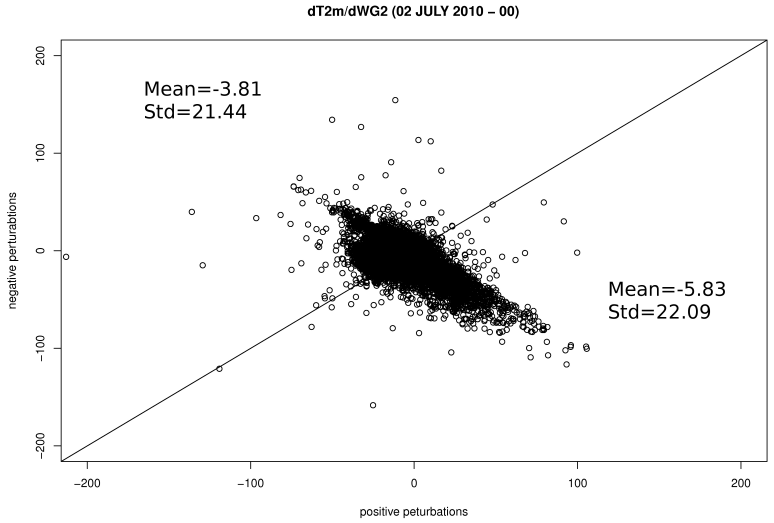
EKF offline

EKF Coupled

Pert. size: 10^{-4}



Pert. size: 10^{-1}



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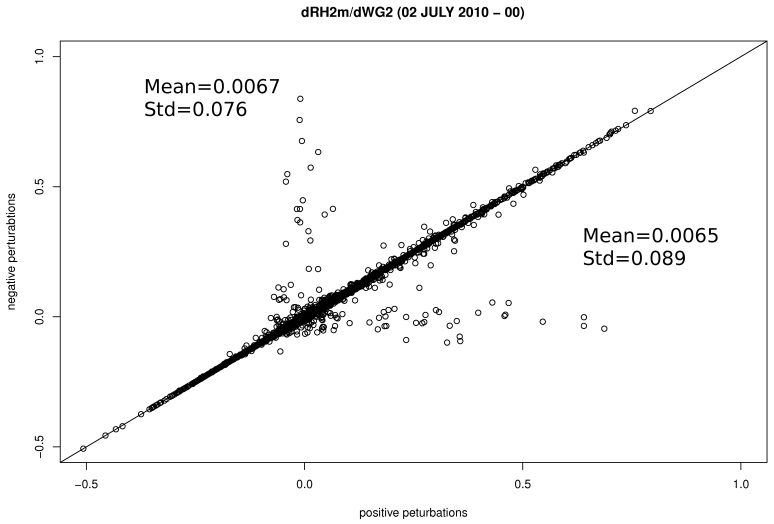

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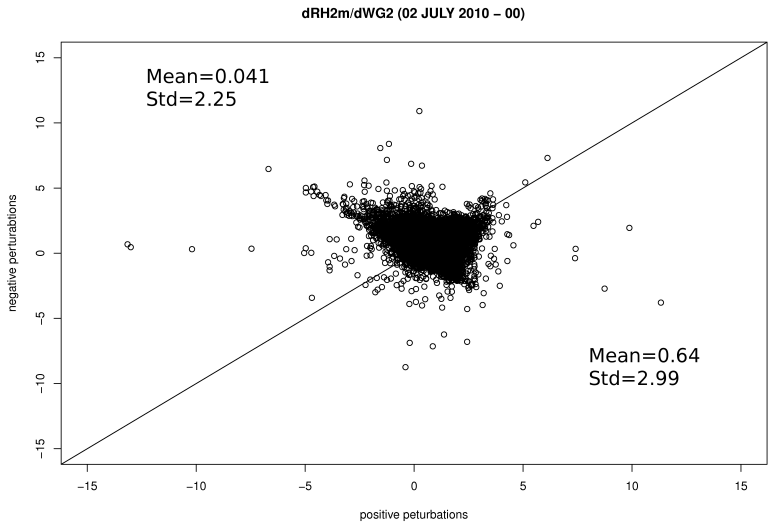
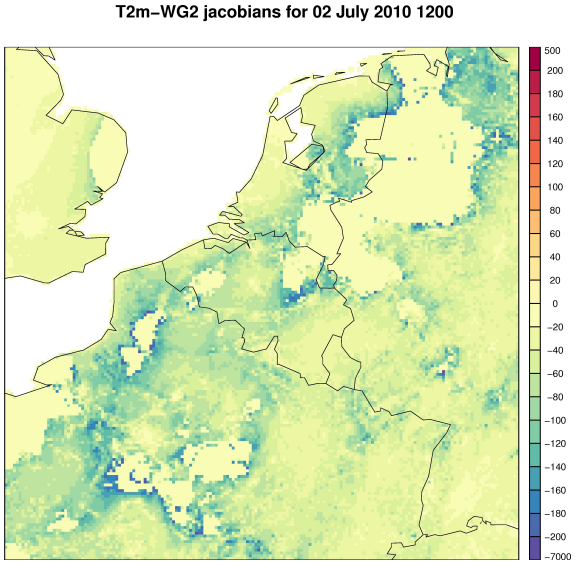


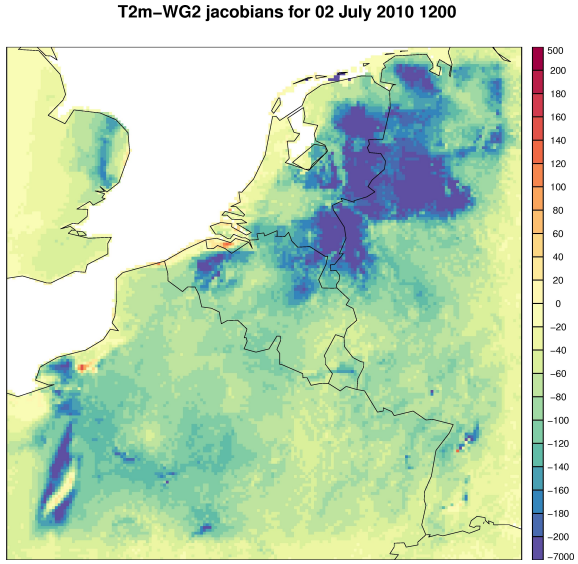
THE LAND SURFACE DATA ASSIMILATION UPDATE: EKF

EKF offline

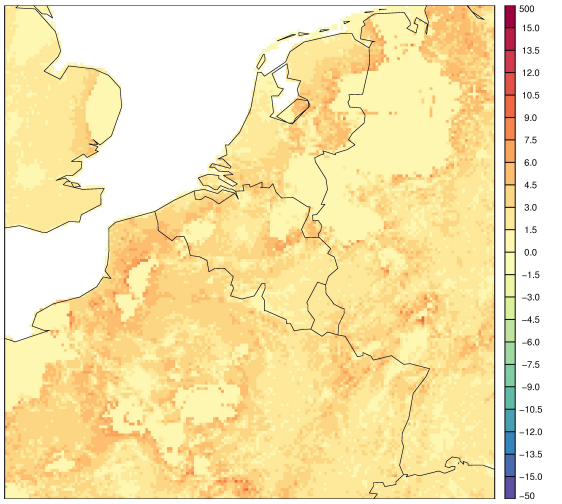
EKF coupled

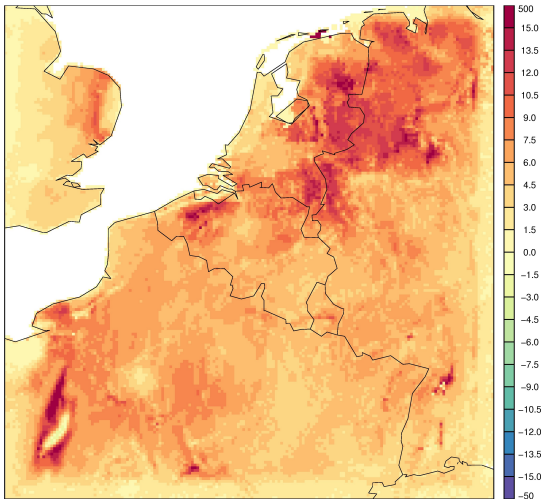
T2m-WG2





RH2m-WG2





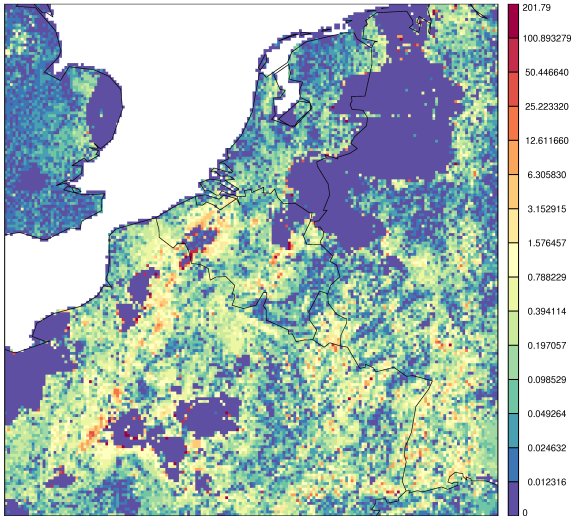
THE LAND SURFACE DATA ASSIMILATION UPDATE: EKF

EKF offline

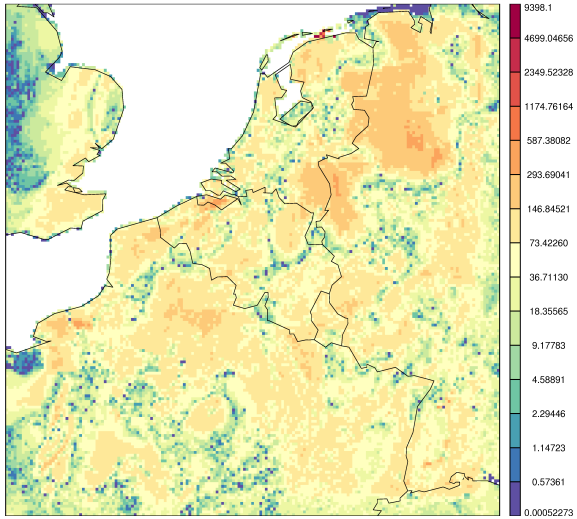
EKF coupled

T2m-WG2

|H+ – H–| for dT2m/dWG2 02 July 2010 1200

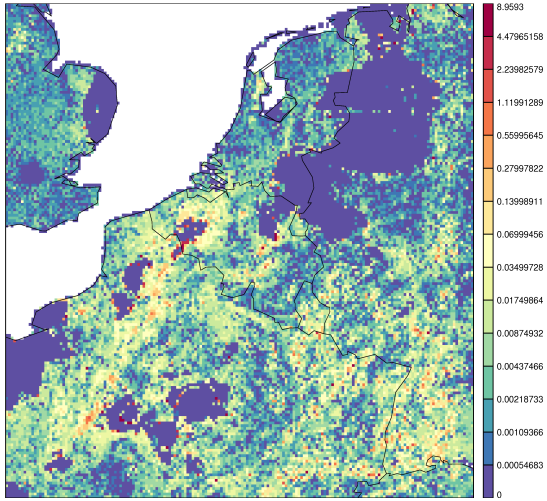


|H+ – H–| for dT2m/dWG2 02 July 2010 1200

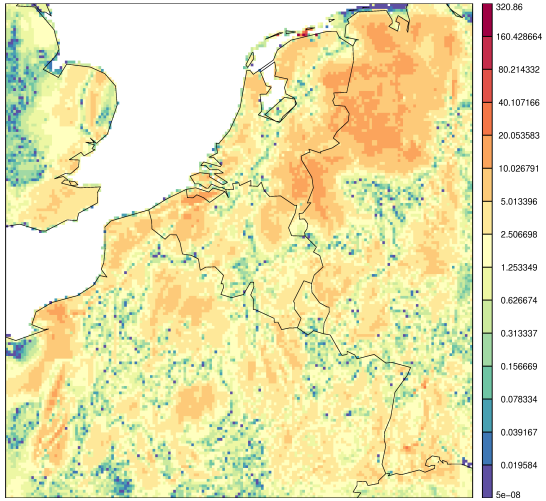


RH2m-WG2

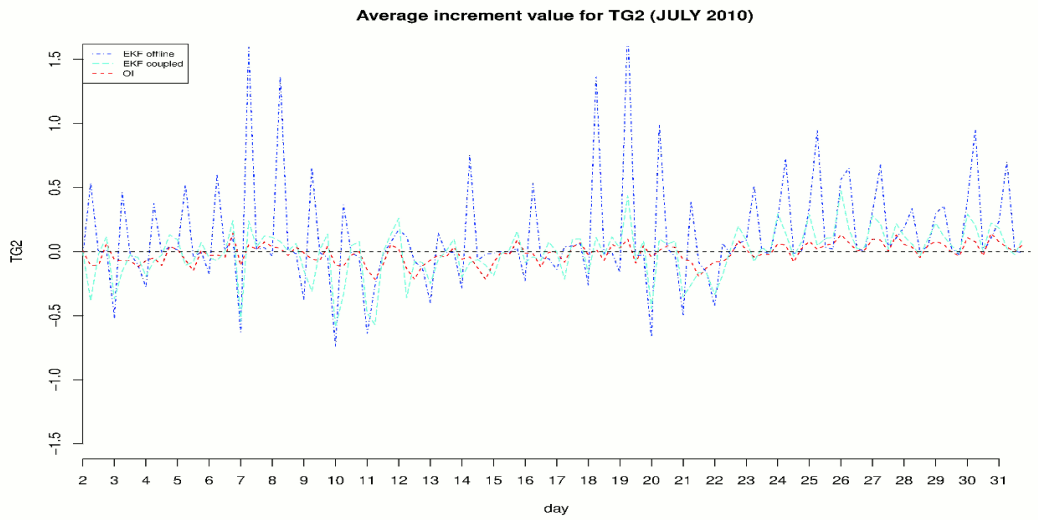
|H+ – H–| for dRH2m/dWG2 02 July 2010 1200



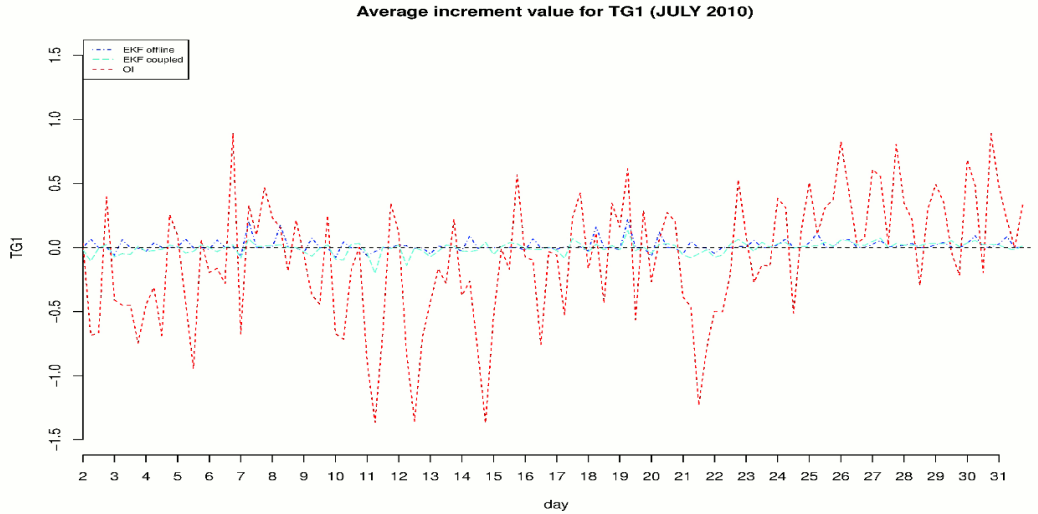
|H+ – H–| for dRH2m/dWG2 02 July 2010 1200



THE LAND SURFACE DATA ASSIMILATION UPDATE: EKF



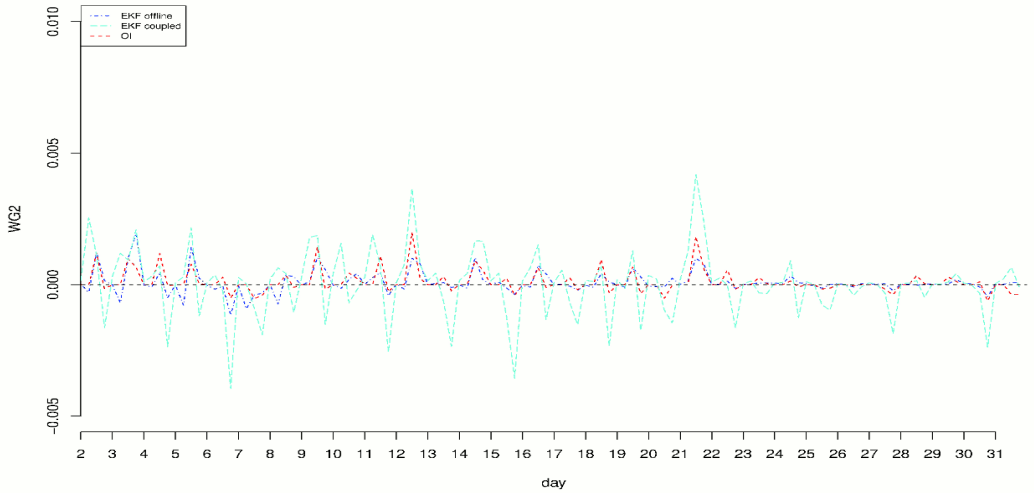
(28.1) Evolution of the TG2 increments averaged over the domain for July 2010



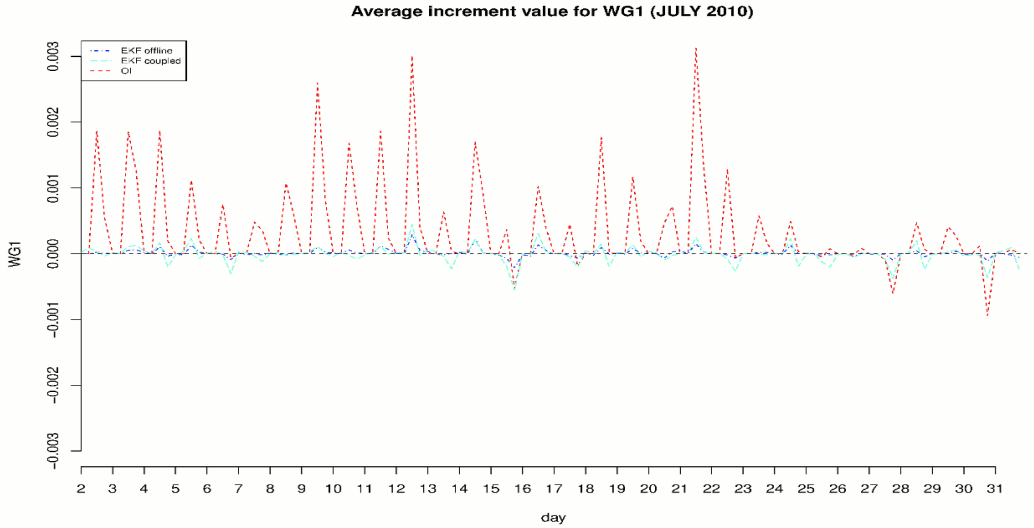
(28.2) Evolution of the TG1 increments averaged over the domain for July 2010

Figure 28

THE LAND SURFACE DATA ASSIMILATION UPDATE: EKF



(28.3) Evolution of the WG2 increments averaged over the domain for July 2010



(28.4) Evolution of the WG1 increments averaged over the domain for July 2010

Figure 28: Evolution of the increments of the soil prognostic variables

THE LAND SURFACE DATA ASSIMILATION UPDATE: EKF

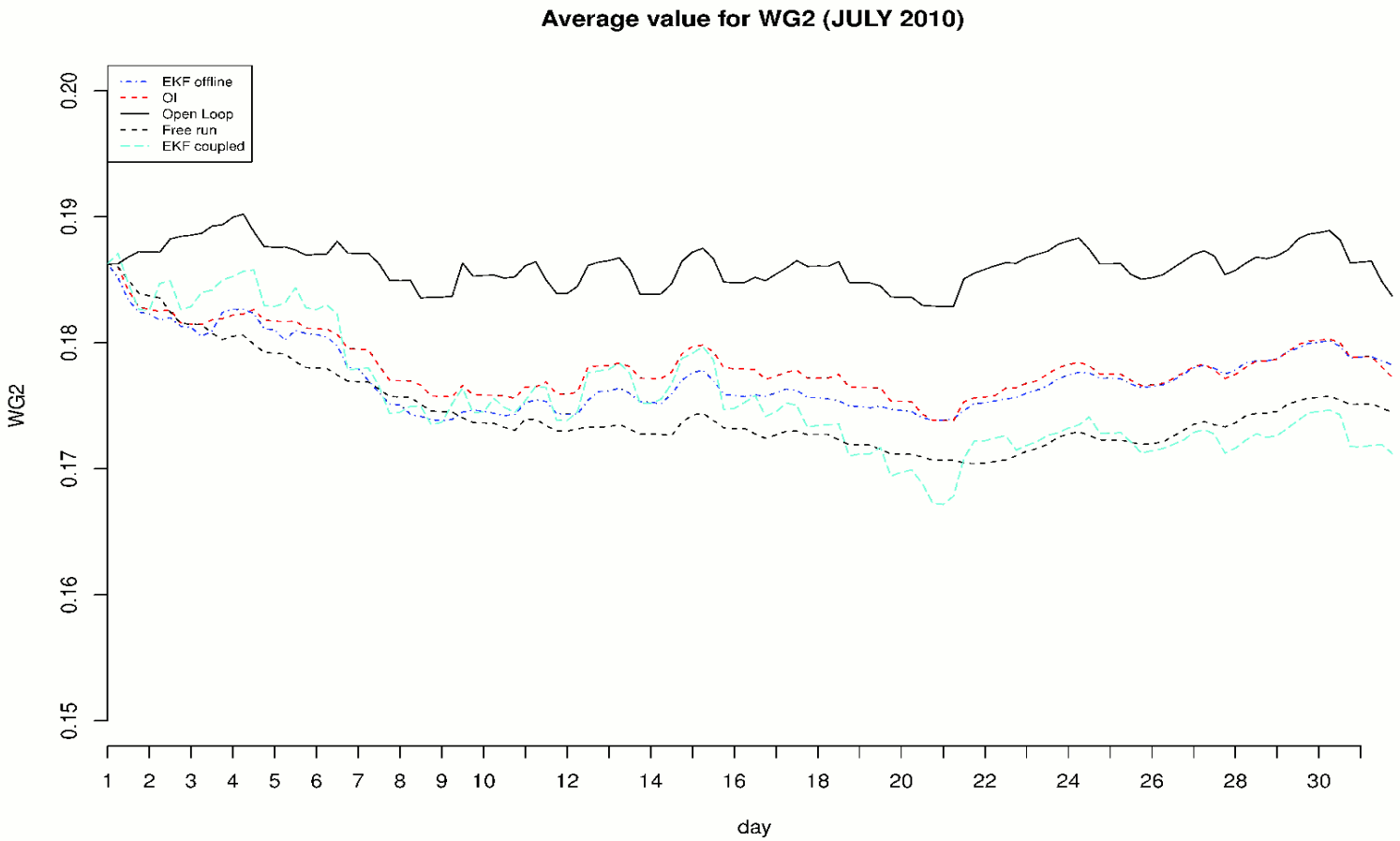
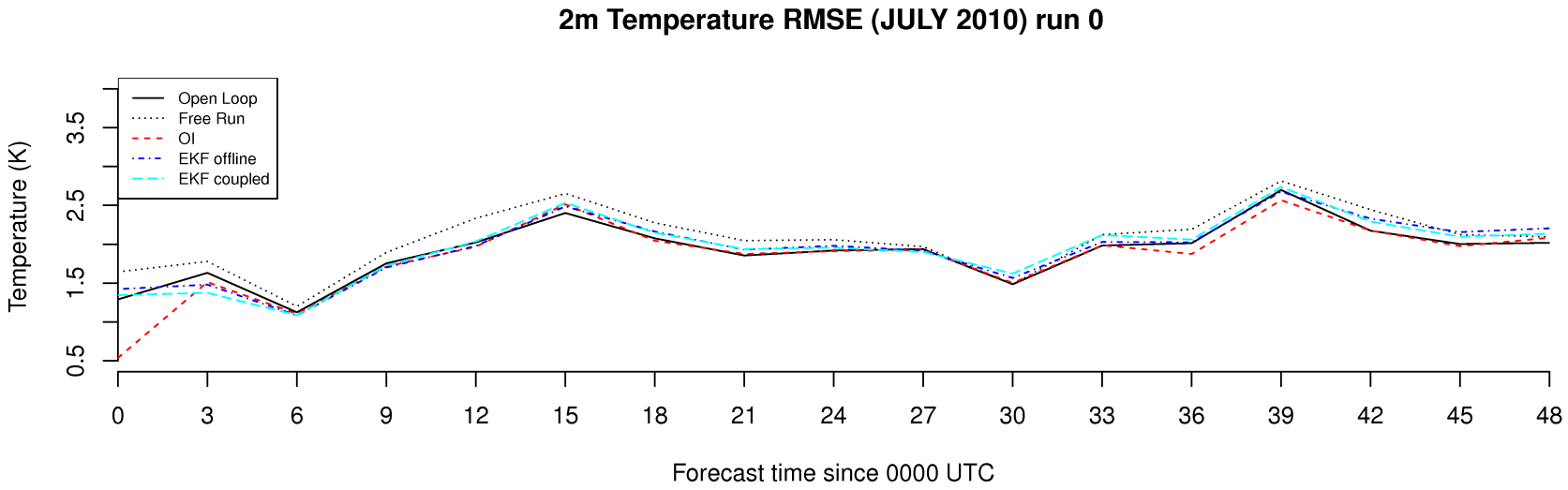
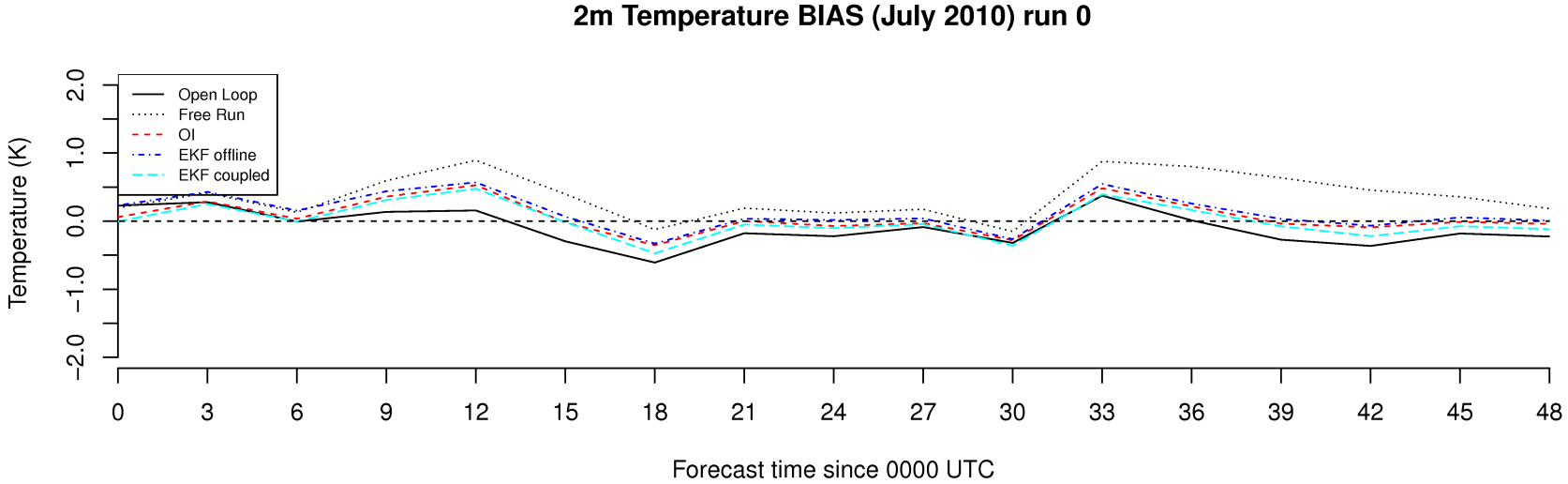


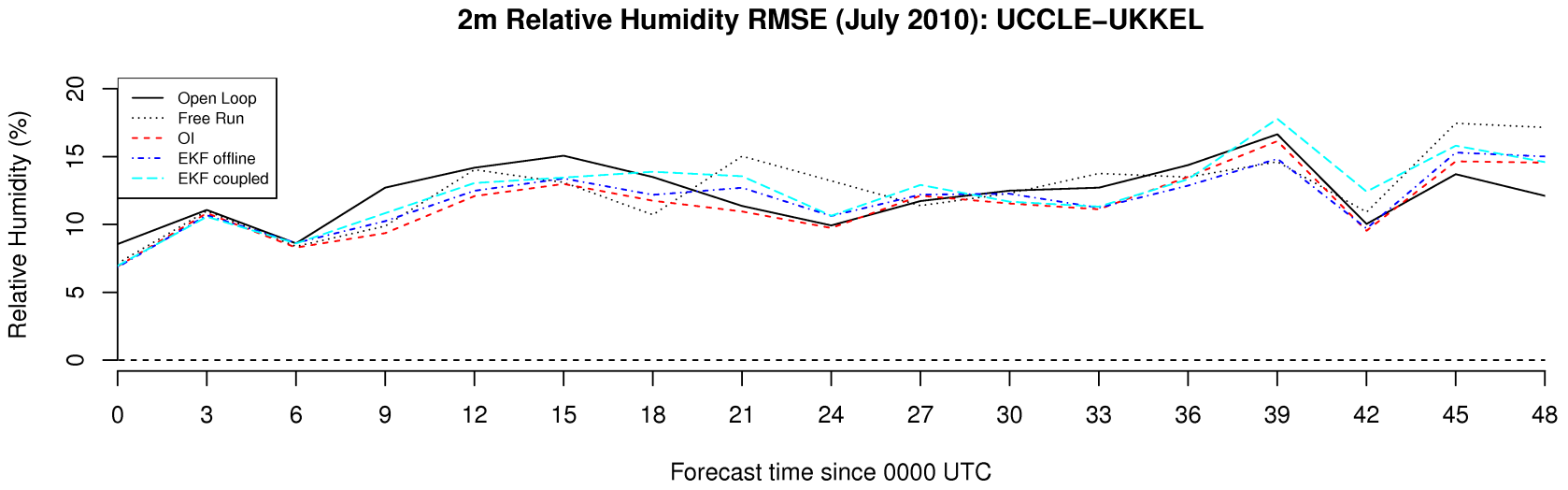
Figure 32: Evolution of the WG2 values averaged over the domain for July 2010

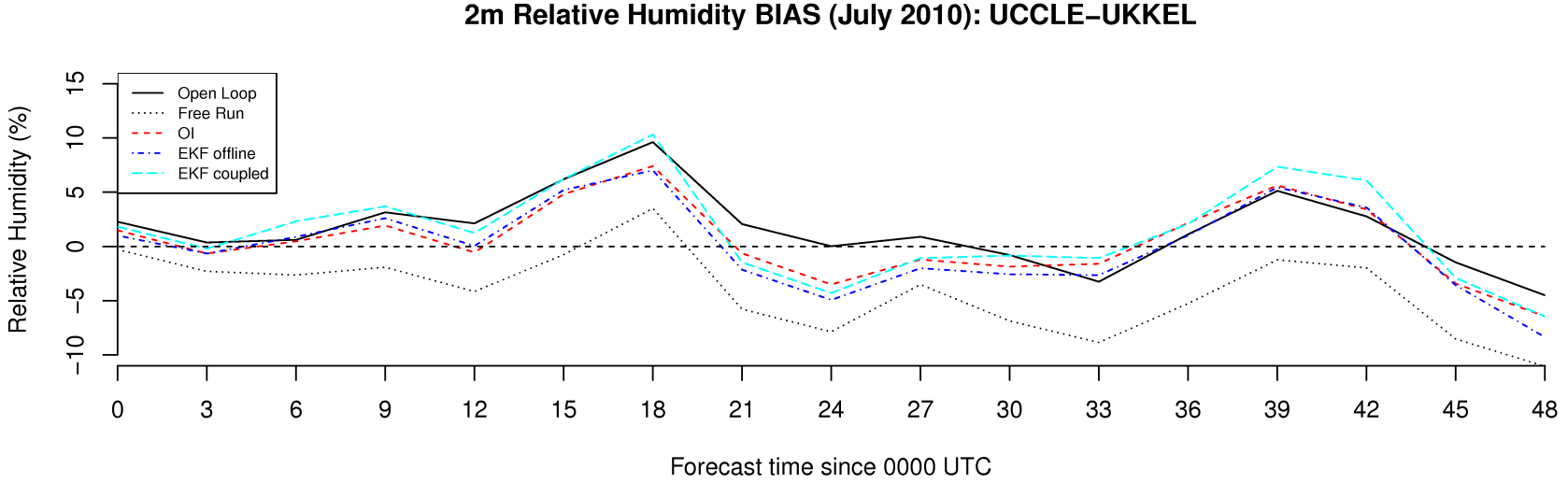
THE LAND SURFACE DATA ASSIMILATION UPDATE: EKF





THE LAND SURFACE DATA ASSIMILATION UPDATE: EKF





1. Development of a SURFEX EKF for ALARO and comparison of the offline and coupled version with the OI analysis.

2. Preliminary results on combining SURFEX EKF with 3dVar atmospheric assimilation.

3. A feasibility study of using a Short Time Augmented Extended Kalman Filter (STAEKF) for Soil Analysis.

Experiments:

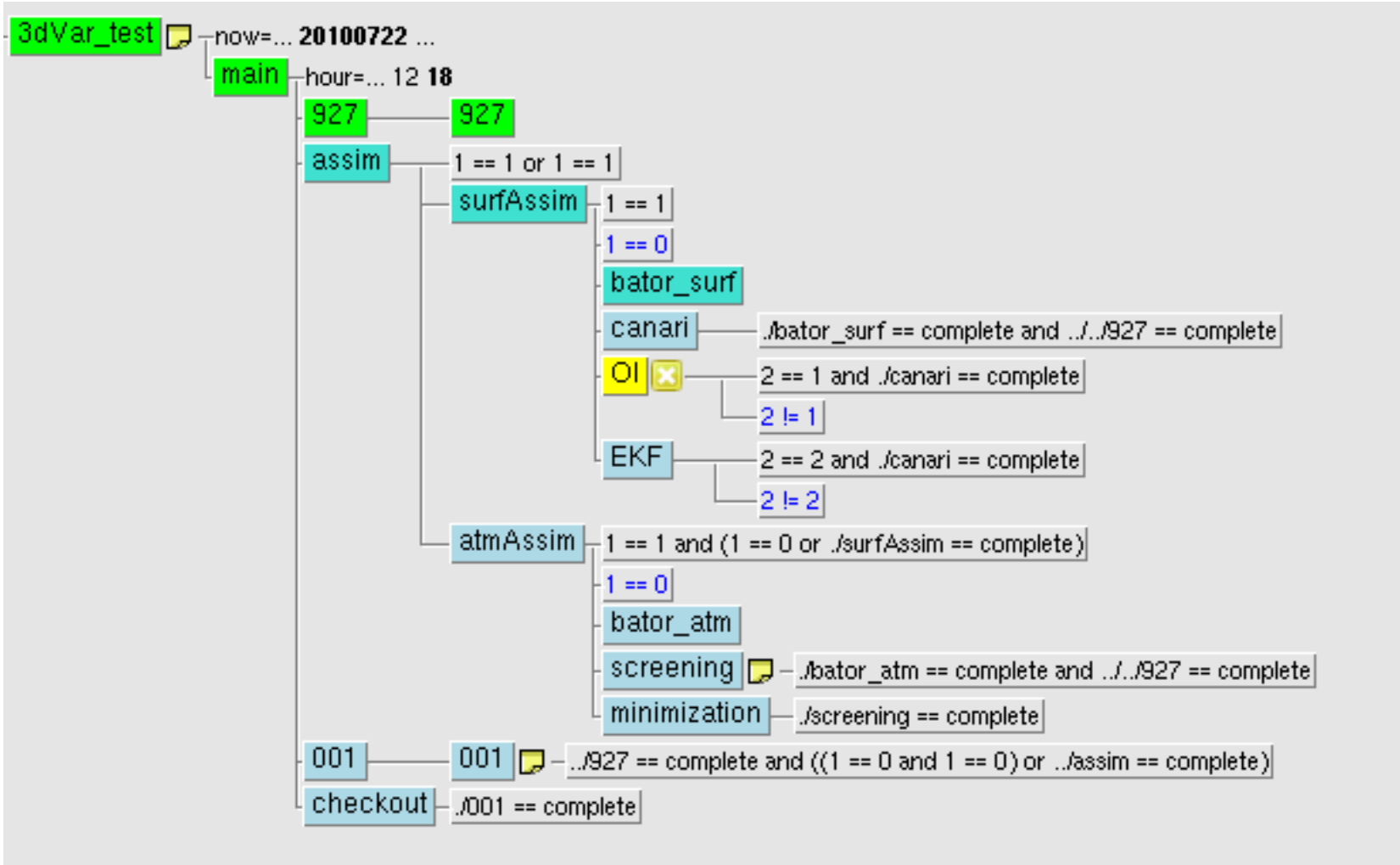
- **Free run**: (no assimilation)

  Atmospheric fields from ARPEGE analysis. Surface field from 6h forecast of previous run

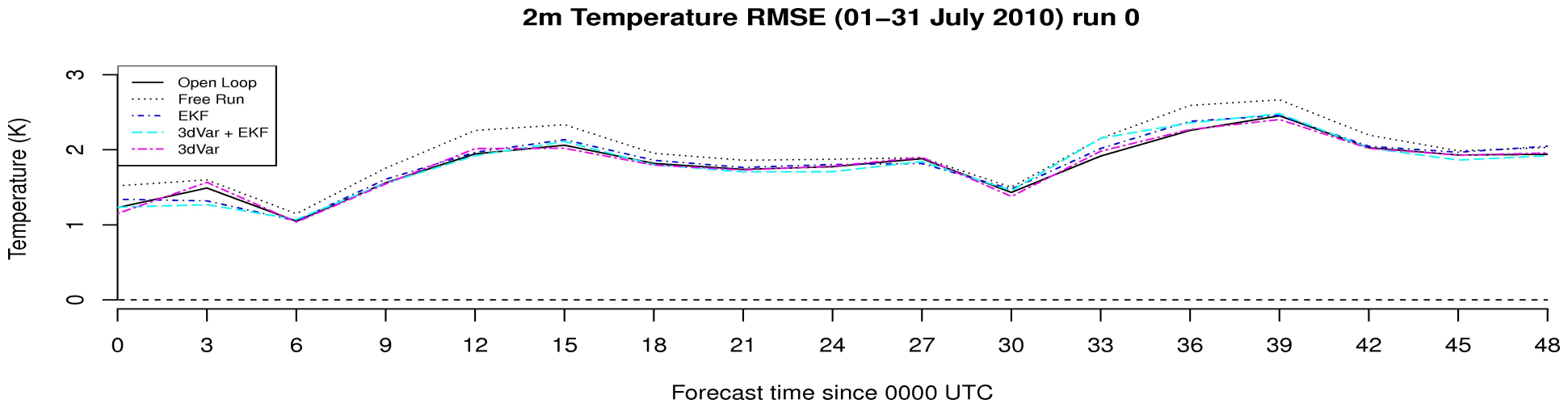
- **Open loop**: (no assimilation)

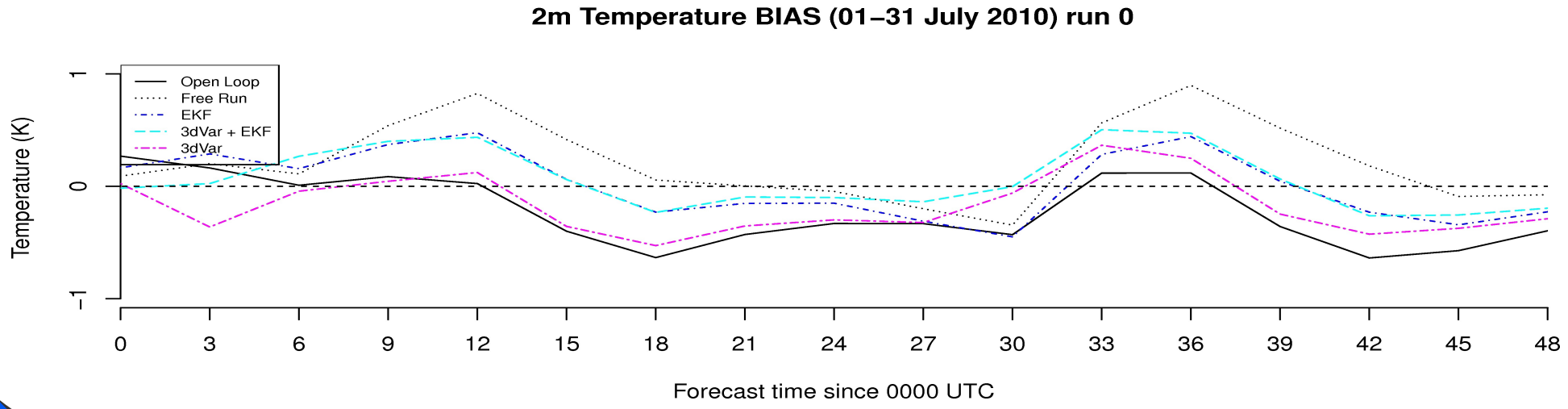
  Atmospheric fields and surface fields are interpolated from Arpege analysis

- **EKF** with surface assimilation.
- **3DVAR** With atmospheric assimilation using only conventional observations (no satellite, no radar)
- **3DVAR+EKF** surface assimilation is done before atmospheric assimilation.

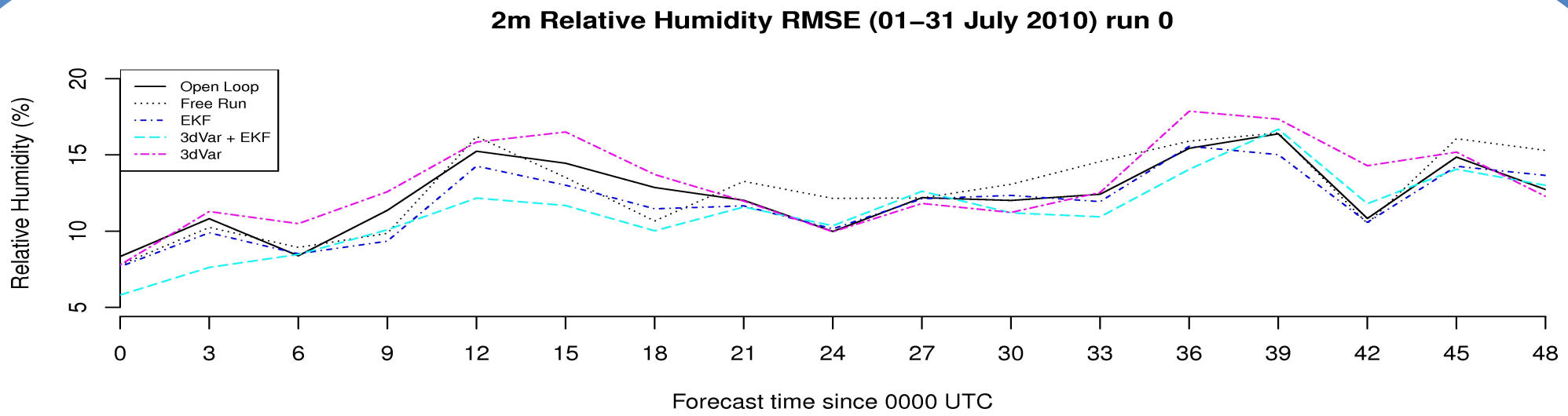

3dVar_test
now=... 20100722 ...
main
hour=... 12 18
927
927
assim
1 == 1 or 1 == 1
surfAssim
1 == 1
1 == 0
bator_surf
canari
./bator_surf == complete and ../../927 == complete
OI
2 == 1 and ./canari == complete
2 != 1
EKF
2 == 2 and ./canari == complete
2 != 2
atmAssim
1 == 1 and (1 == 0 or ./surfAssim == complete)
1 == 0
bator_atm
screening
./bator_atm == complete and ../../927 == complete
minimization
./screening == complete
001
001
../927 == complete and ((1 == 0 and 1 == 0) or ../assim == complete)
checkout
./001 == complete

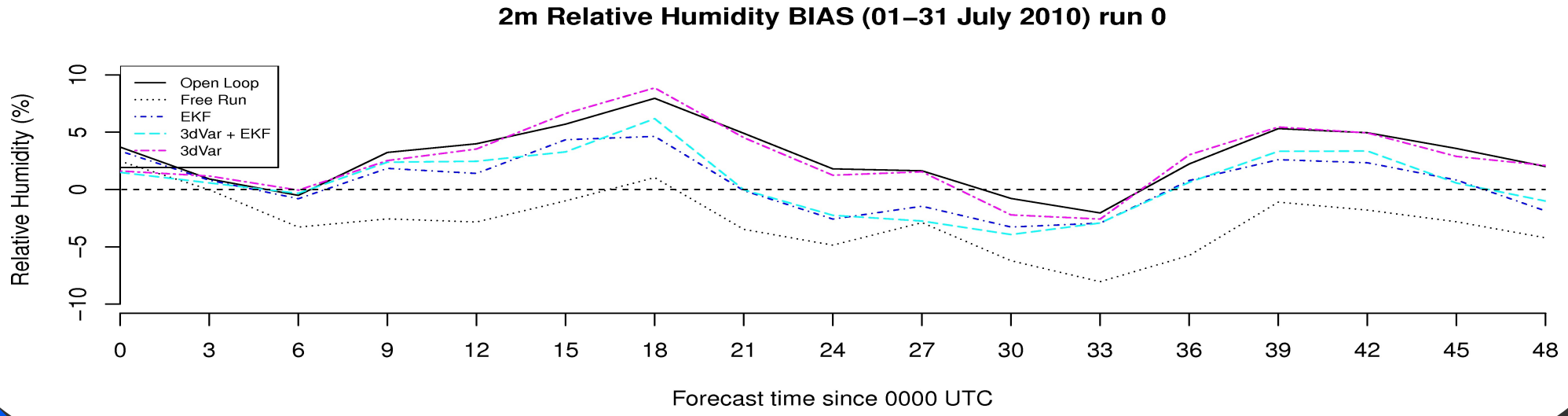
THE LAND SURFACE DATA ASSIMILATION UPDATE: EKF





THE LAND SURFACE DATA ASSIMILATION UPDATE: EKF





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THE LAND SURFACE DATA ASSIMILATION UPDATE: EKF

- **Recently, Carrassi and Vannitsem (2011, QJRMS) introduced an alternative formulation of the EKF where the uncertain model parameters are estimated along with the system state variables.**

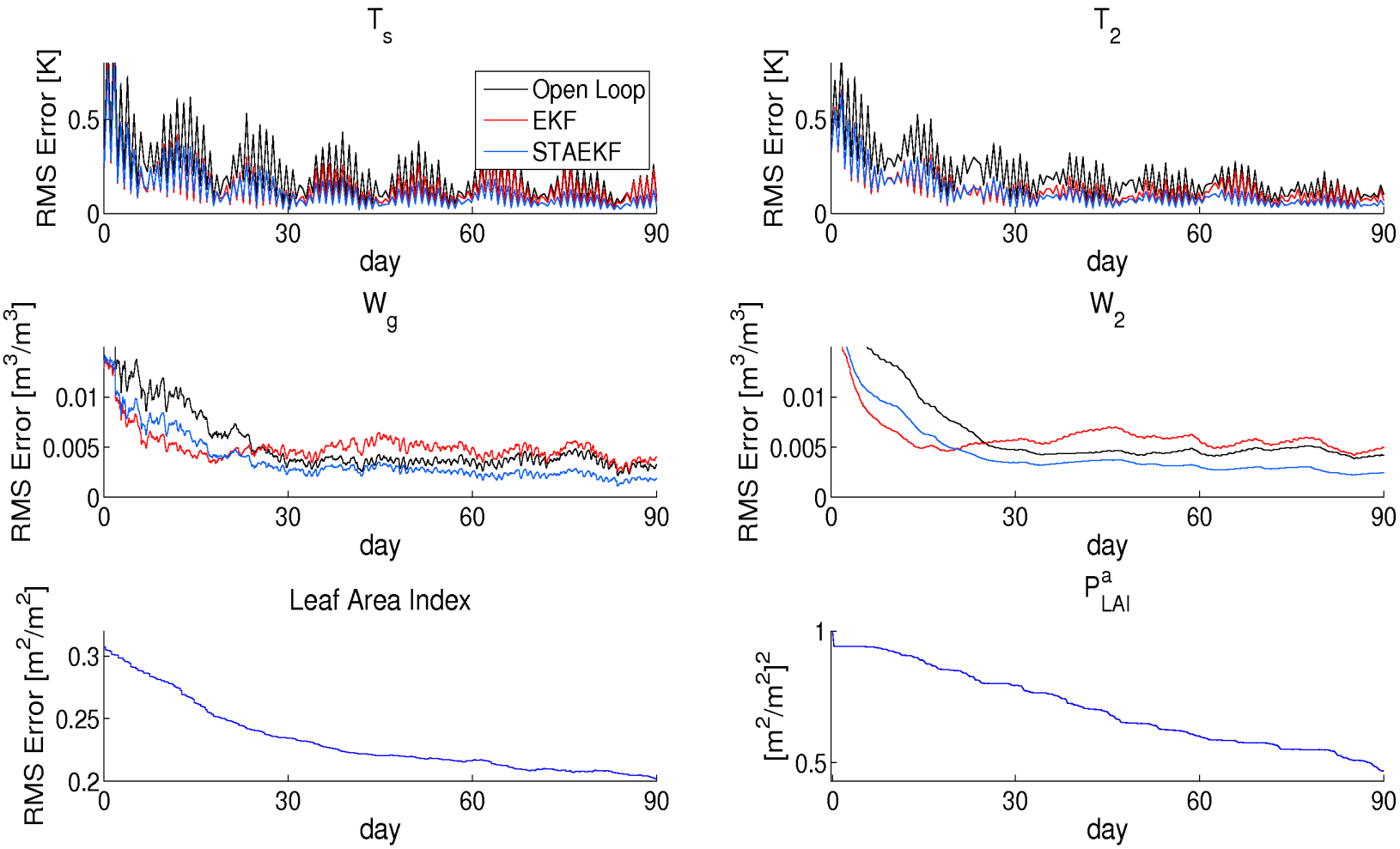
- **The algorithm, Short Time Augmented Extended Kalman Filter (STAEKF), uses a deterministic formulation for the model error dynamics (Nicolis, 2003, JAS).**

- **The same formulation has been used for the treatement of the error arising from the unresolved scales (Carrassi and Vannitsem, 2011, IJBC) and in the context of variational assimilation (Carrassi and Vannitsem, 2010, MWR).**

- **We undertake here a set of numerical twin experiments designed to test the STAEKF in estimating three land surface parameters: LAI, the albedo, and the minimum stomatal resistance RSmin.**

- **Assimilation of 2m temperature and relative humidity using an offline version of ISBA.**

THE LAND SURFACE DATA ASSIMILATION UPDATE: EKF



THE LAND SURFACE DATA ASSIMILATION UPDATE: EKF

- **Continuing the evaluation of the STAEKF, with data from the Cabauw Tower.**

- **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. 2012 GMD.**

- **The second SURFEX WW is planed next week in Brussels.**

- **Continuing the evaluation of the STAEKF with data from the Cabauw tower.**

- **Introducing the STAEKF within the SODA system and test it within ALADIN.**

- **A scientific paper about the coupling 3DVAR + EKF for ALADIN is in preparation (PhD of Annelies).**