Combining an EKF soil analysis with a 3dVar atmospheric assimilation in a limited area NWP model

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Reykjavik

April 2013

Introduction

Atmospheric Model

ALARO

FLUXES

FORCING

Surface Scheme

SURFEX

Introduction

Atmospheric Model
ALARO

Atmospheric Analysis:
- 4dVar
- 3dVar
- …
- none

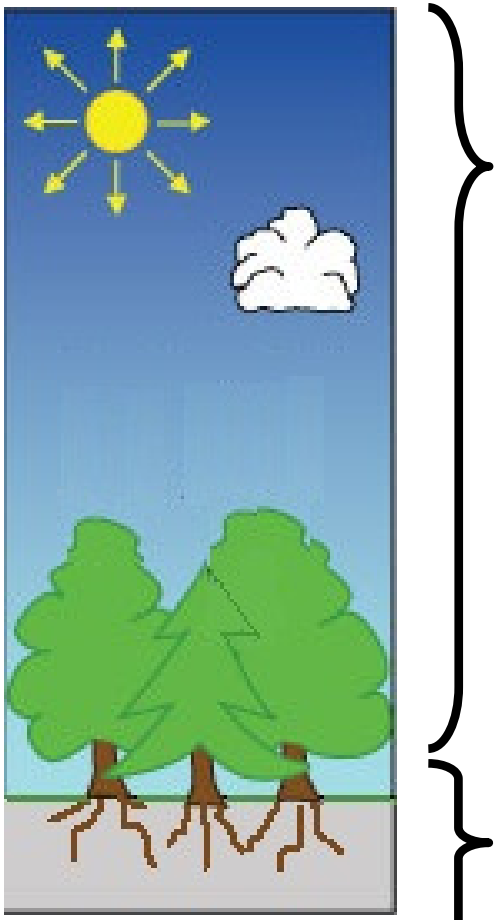
FLUXES

FORCING

Surface Scheme
SURFEX

Soil Analysis:
- OI
- EKF
- none

Introduction



Atmospheric Model
ALARO

FLUXES

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Surface Scheme
SURFEX

Atmospheric Analysis:
- 4dVar
- 3dVar
- …
- none

Soil Analysis:
- OI
- EKF
- none

Initial Conditions

	Atmosphere	**Soil**
Open Loop	Interpolated from Arpege	Interpolated from Arpege
Free run	Interpolated from Arpege	6h forecast from previous run
3dVar	3dVar	Interpolated from Arpege
EKF	Interpolated from Arpege	EKF
OI	Interpolated from Arpege	OI
EKF+3dVar	3dVar	EKF
OI+3dVar	3dVar	OI

Soil Analysis

- 6h Cycling
- Prognostic Variables:
  - Soil moisture content: W_g, W_2
  - Soil temperature: T_s, T_2
- Observations: T_{2m}, RH_{2m}
  - Interpolated to model grid with CANARI
  - To be used in point-wise EKF or OI

Soil Analysis

- Extended Kalman Filter (EKF)

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

Increment

Soil Analysis

- Extended Kalman Filter (EKF)

Background error covariance matrix

Observation error covariance matrix

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

$\mathbf{y}_t^o$ 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)

Soil Analysis

- Extended Kalman Filter (EKF)

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

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

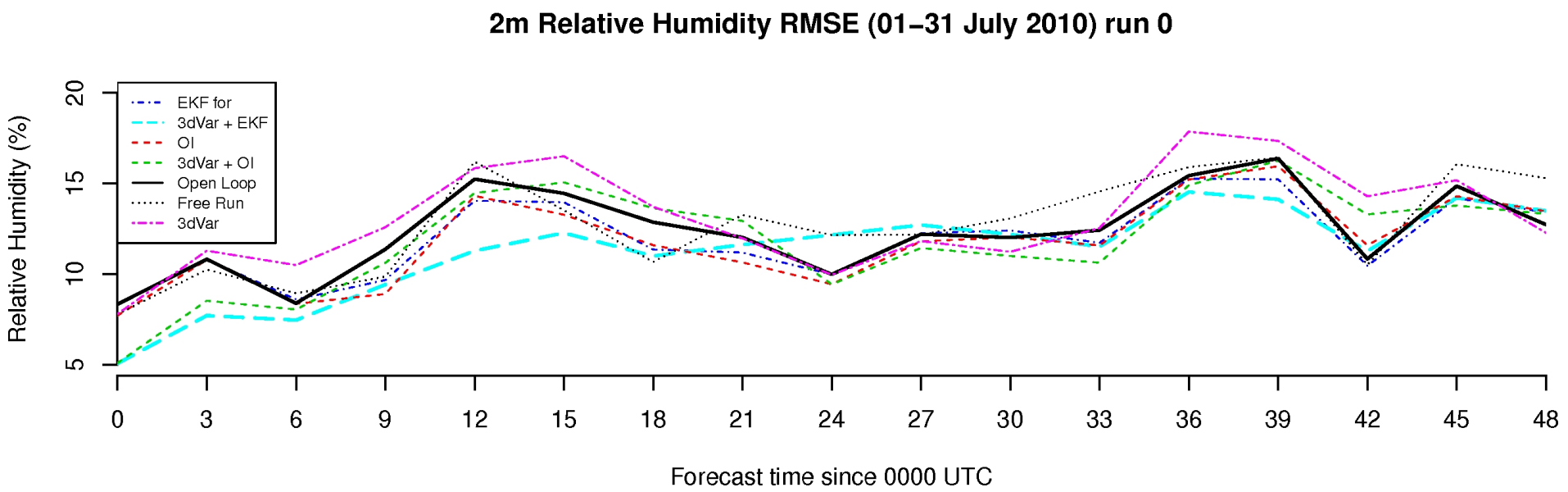
$$H_{i,j} = \frac{\delta y_{i,t}}{\delta x_{j,t0}} = \frac{y_i(x + \delta x_j) - y_i(x)}{\delta x_j}$$

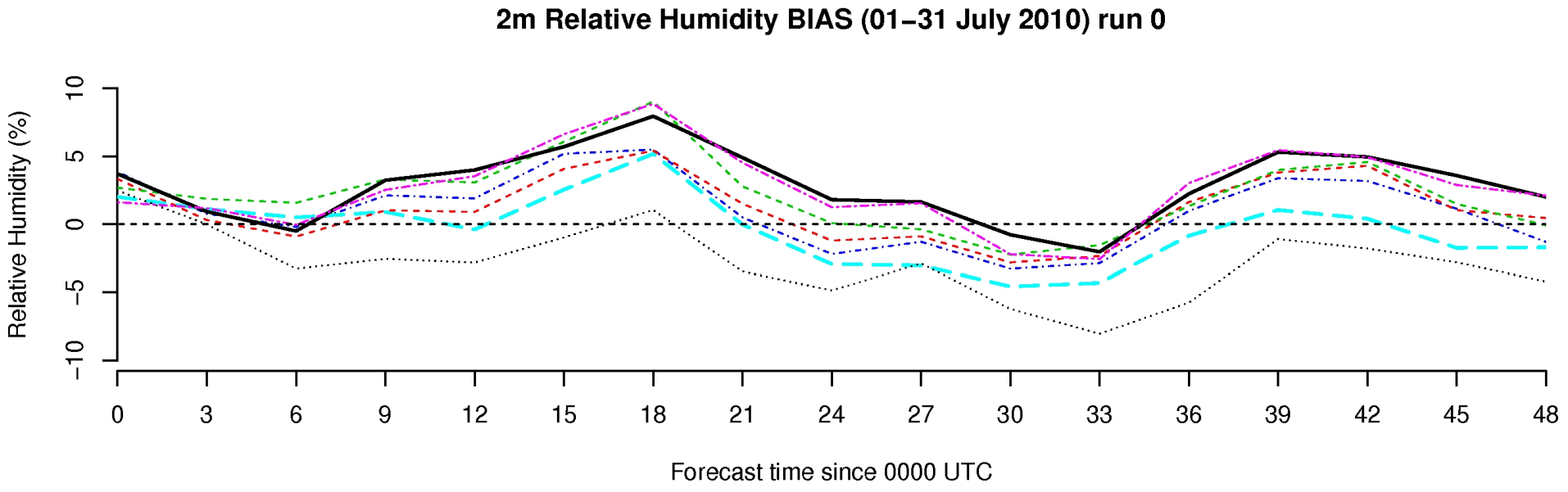
Atmospheric Analysis

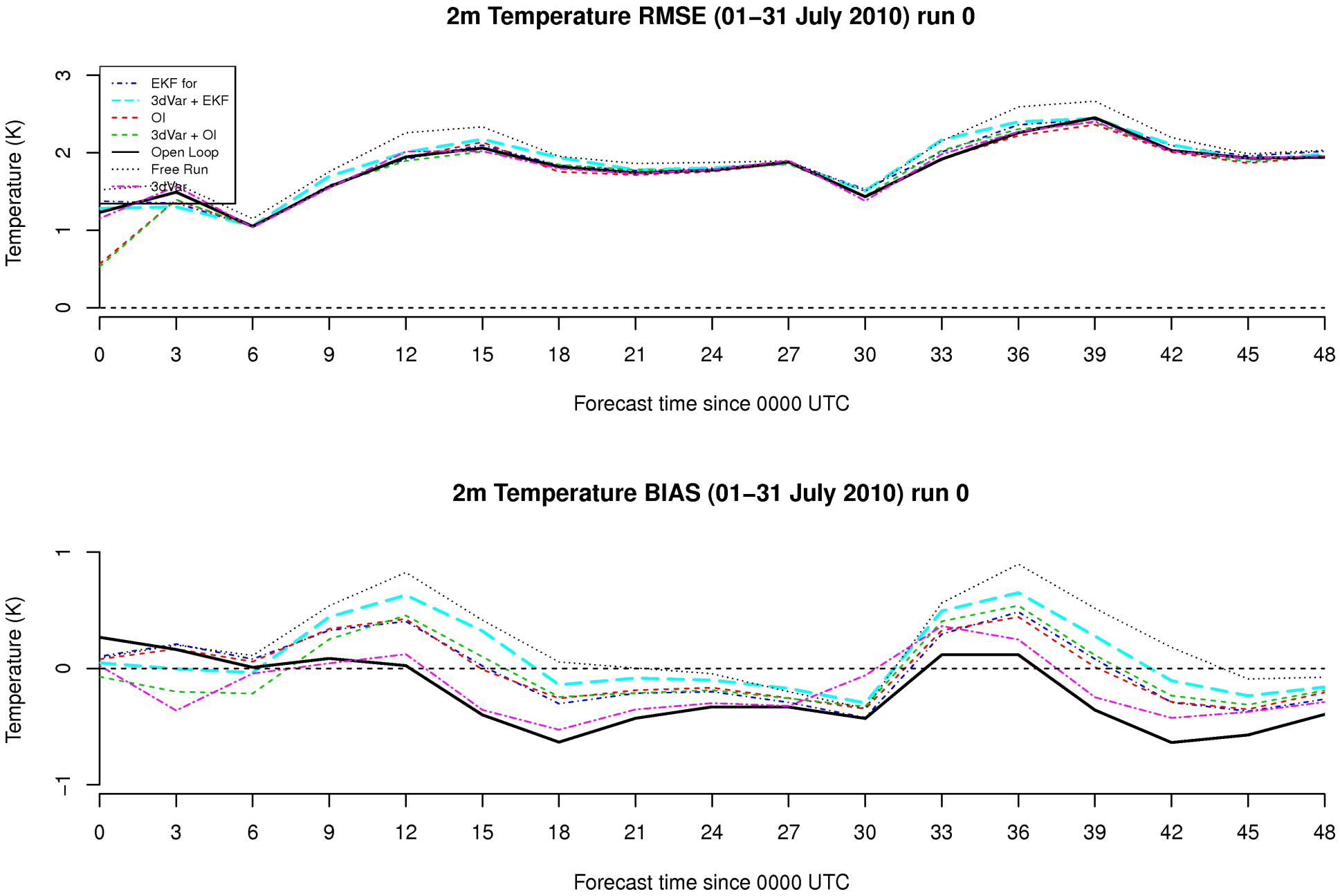
- 3 dimensional variational assimilation (3dVar)
  - 6h cycling
  - Only conventional observations

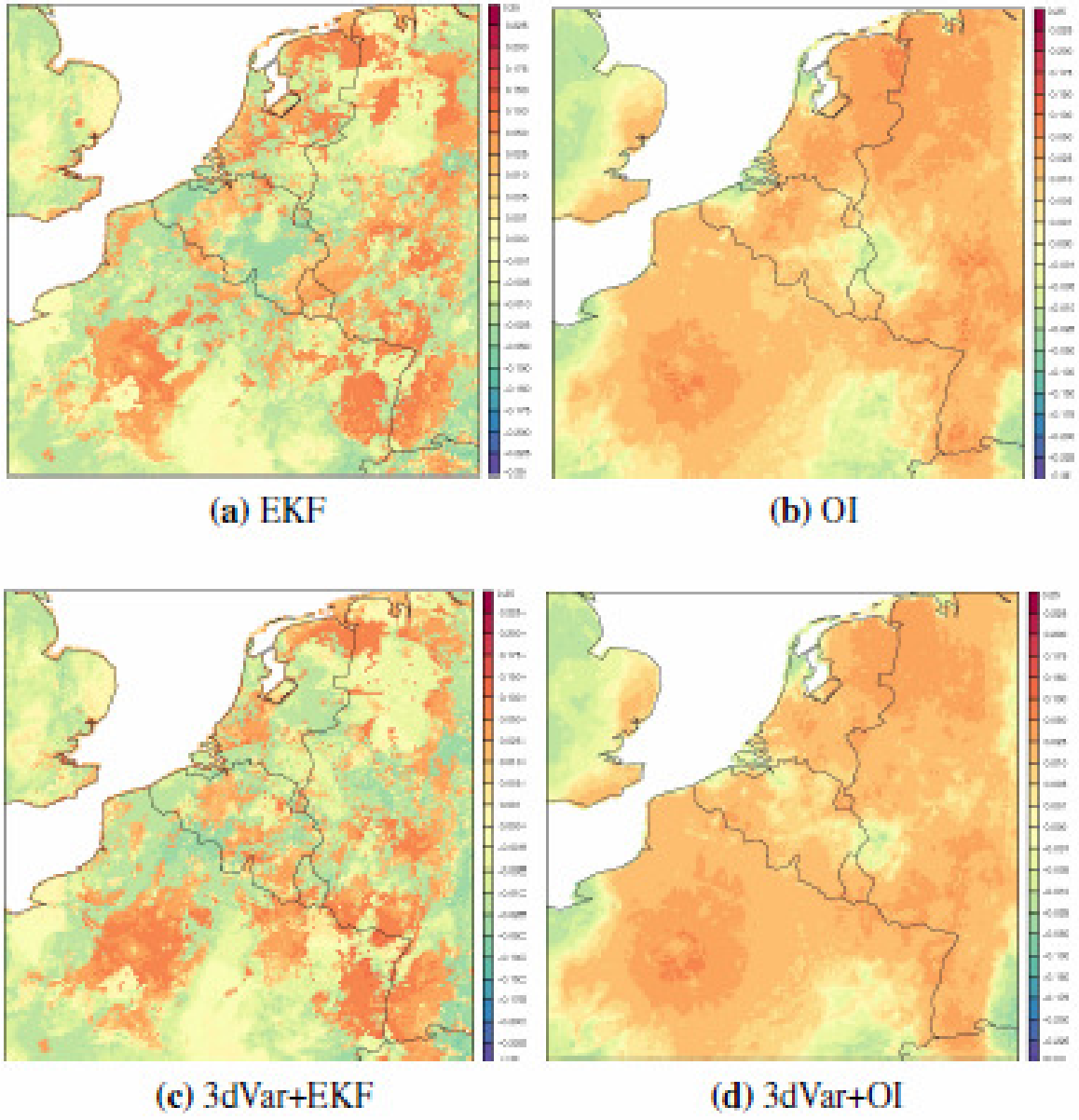
    SYNOP, SHIP, TEMP, PILOT

    from MARS database
  - B-matrix: analysis-ensemble method


2m Relative Humidity RMSE (01–31 July 2010) run 0
Relative Humidity (%)
5
10
15
20
EKF for
3dVar + EKF
OI
3dVar + OI
Open Loop
Free Run
3dVar
0
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
Forecast time since 0000 UTC


2m Relative Humidity BIAS (01–31 July 2010) run 0
Relative Humidity (%)
−10
−5
0
5
10
0
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
Forecast time since 0000 UTC


2m Temperature RMSE (01–31 July 2010) run 0
EKF for
3dVar + EKF
OI
3dVar + OI
Open Loop
Free Run
3dVar
Temperature (K)
0
1
2
3
0
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
Forecast time since 0000 UTC
2m Temperature BIAS (01–31 July 2010) run 0
Temperature (K)
−1
0
1
0
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
Forecast time since 0000 UTC



(a) EKF (b) OI

(c) 3dVar+EKF (d) 3dVar+OI

Figure 2. Cummulative increments over July 2010 for root zone soil moisture (W_2)

Comparison with soil moisture observations at Lonze (Belgium)

Table 2. Correlation between soil moisture observations and deep soil moisture content of the analysis and the 6h forecast

	$W2_{fc+00}$	$W2_{fc+06}$
EKF	0.814	0.778
3dVAR + EKF	0.815	0.801
OI	0.263	0.207
3dVAR + OI	0.022	-0.049
3dVAR	-0.052	-0.086
OL	-0.052	-0.086

Conclusion

- Combination of 3dVar + EKF provides the best results
- Work in progress:
  - Q. J. R. Meteorol. Soc.
  - Comparison of offline vs. coupled EKF
  - To be clarified: large EKF increments in T_2

Discussion

Table 2. Mean cummulative increments over July 2010 averaged over the domain

	W_2	W_g	T_s	T_2
EKF	0.0116	0.00120	1.282	7.625
3dVAR+EKF	0.0109	0.00154	1.434	8.531
OI	0.01293	0.03932	-10.914	-1.737
3dVAR+OI	0.01281	0.03761	-11.412	-1.816

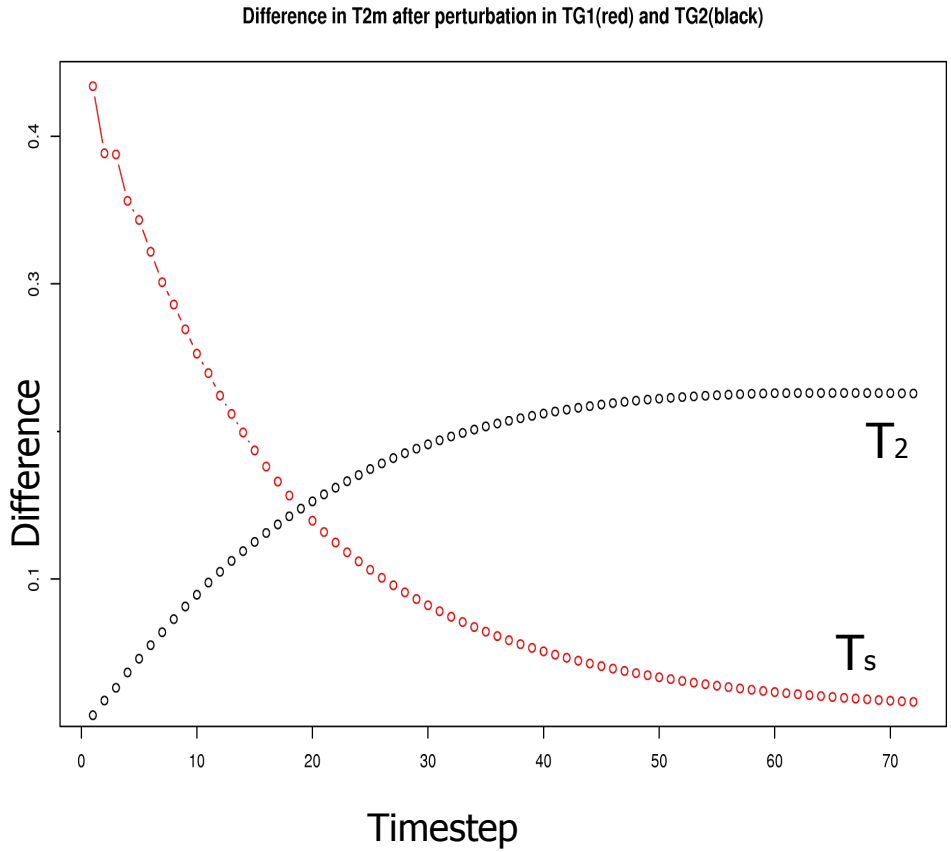
Table 1. T_2 increments for 2 July 2010: mean

	18-00	00-06	06-12	12-18
OI	0.00546	-0.109	-0.107	0.0629
EKF	-0.258	0.415	-0.0171	-0.02067

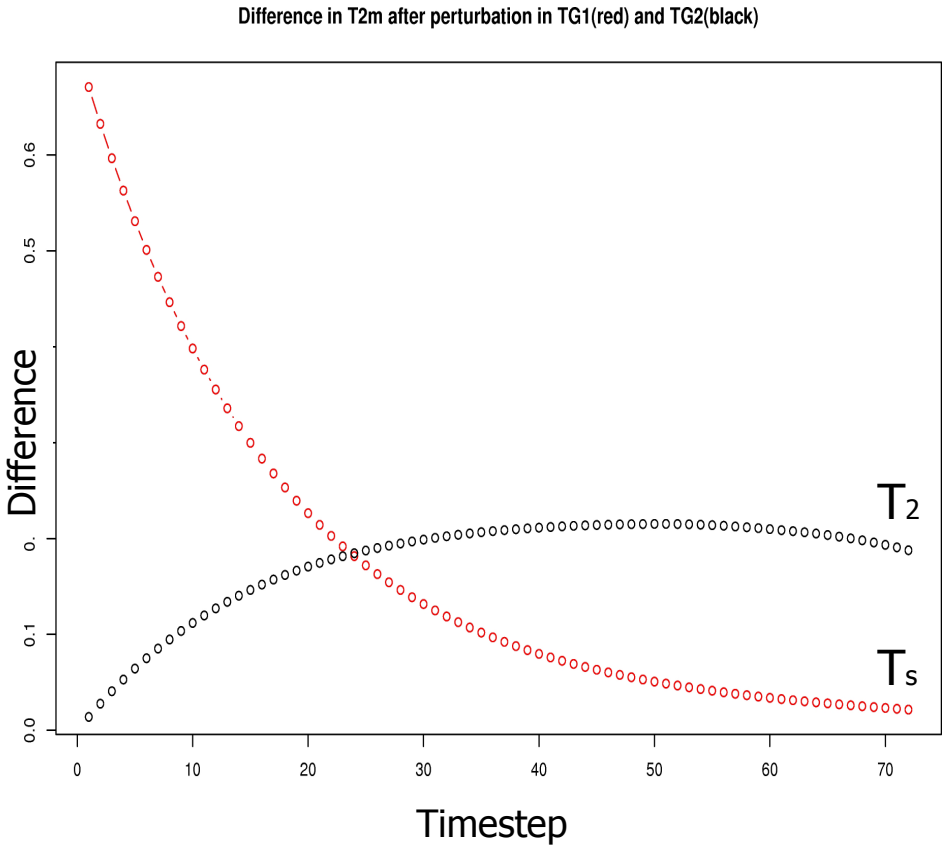
$$H_{i,j} = \frac{y_i(x + \delta x_j) - y_i(x)}{\delta x_j}$$

Difference in T_{2m} between reference run and perturbed run at t_1

Perturbation in T_s (red) or T_2 (black) at t_0



18-00 UTC



00-06 UTC

Thank you for your attention!