Status of HIRLAM surface DA activities

Patrick Samuelsson
SMHI

with contributions as acknowledged

General surface comments

cy40h1.1 is our latest operational version of the ALADIN-HIRLAM NWP system (HARMONIE-AROME model configuration).
cy40h1.2 has been under development for a while but suffers from convective precipitation problems.
cyxxh represents a future ambitions

	c**y40h1.1**	**cy40h1.2**	**cyxxh**
Land			
Patches	1	**1 or 2 (no SBL model)**	3 patches with excl. canopy
Soil	Force-restore	Force-restore	Diffusion (14 layers)
Snow	D95	D95	Explicit snow (12 layers)
Glacier	-	-	Explicit snow as glacier
Assimilation	CANARI-OI	CANARI-OI	MESCAN-EKF/EnKF
Sea	SICE	SICE	Sea ice
Lake	Deep soil temp	**FLake (optional)**	FLake (later with EKF)
Town	TEB	TEB	TEB (more options)
Physiog.	ECOCLIMAP	**ECOCLIMAP (modified)**	Utilize high res. data

SMHI IMPREX NWP contributions by Magnus L and Tomas L

WP3:

Improvement of short-term (days) prediction of extreme precipitation events by:

- Assimilating surface remote sensing data (snow and soil moisture, derived products) and in-situ observations.
- Include new horizontal background error variation to better derive small scale variations in surface conditions.

The starting point of WP3 is cy38h1.2 HARMONIE-AROME configuration where:

- 3D-Var is used for upper-air with conventional observation types and satellite observations (AMSU-A,AMSU-B/MHS).
- Surface data assimilation is based on Optimal Interpolation using horizontally homogeneous and isotropic background error statistics and measurements from SYNOP stations.

SMHI IMPREX NWP contributions by Magnus L and Tomas L

OVERVIEW OF SMHI IMPREX SURFACE DATA ASSIMILATION STUDIES

Southern SMHI IMPREX model domain

Three-hour data assimilation cycle and four parallell runs:

- Oimain (RH2m, T2m)
- OImain using MESCAN (RH2m, T2m)
- (S)EKF using MESCAN (RH2m, T2m)
- (S)EKF using MESCAN and (RH2m, T2m, SCAT)

Cases (circle indicate area of main events):

- 12-19 June 2013 (South-west France, Pyrenees area, Upper Garonne river basin; total rainfall of 110-180 mm or more in the higher altitudes in less than 48 hours)
- 21-28 July 2013 (a huge convective precipitation cell crossing France during the night of the 26 and 27 July 2013)
- 22-25 June 2014 (Pyrenees; 38mm in 1h at Mauléon; 70-100 mm over a few hours at some points)
- 28 June-5 July 2014 (22-25 June and then 3-4 July 2014 Pyrenees; 38mm in 1h at Mauléon; 70-100 mm over a few hours at some points)

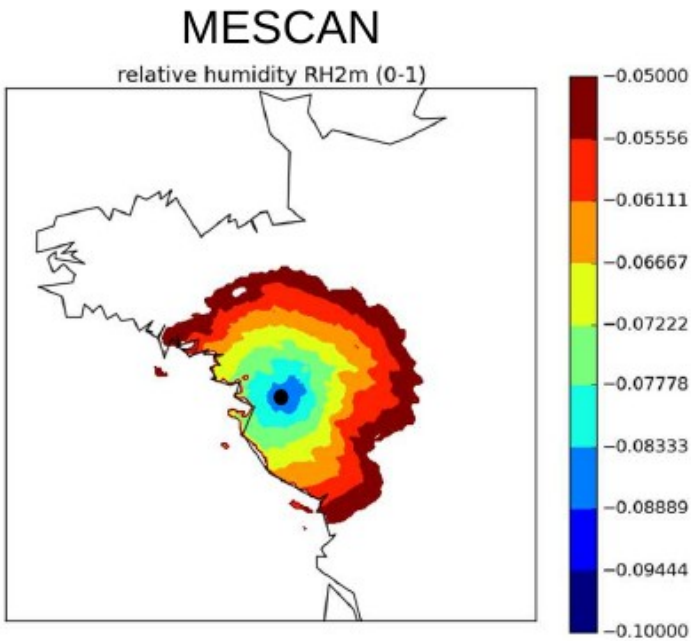
Investigate sensitivity to surface da, in particular 21-28 July might be sensitive.

All runs started from spinned up surface states, based on long spin-up period with Oimain.

SMHI IMPREX NWP contributions by Magnus L and Tomas L

For MESCAN:

- Same RH2m/T2m sigmao/simab used in MESCAN as for original CANARI
- Horizontal length scale of MESCAN set to provide same horizontal correlation distances as in original CANARI.



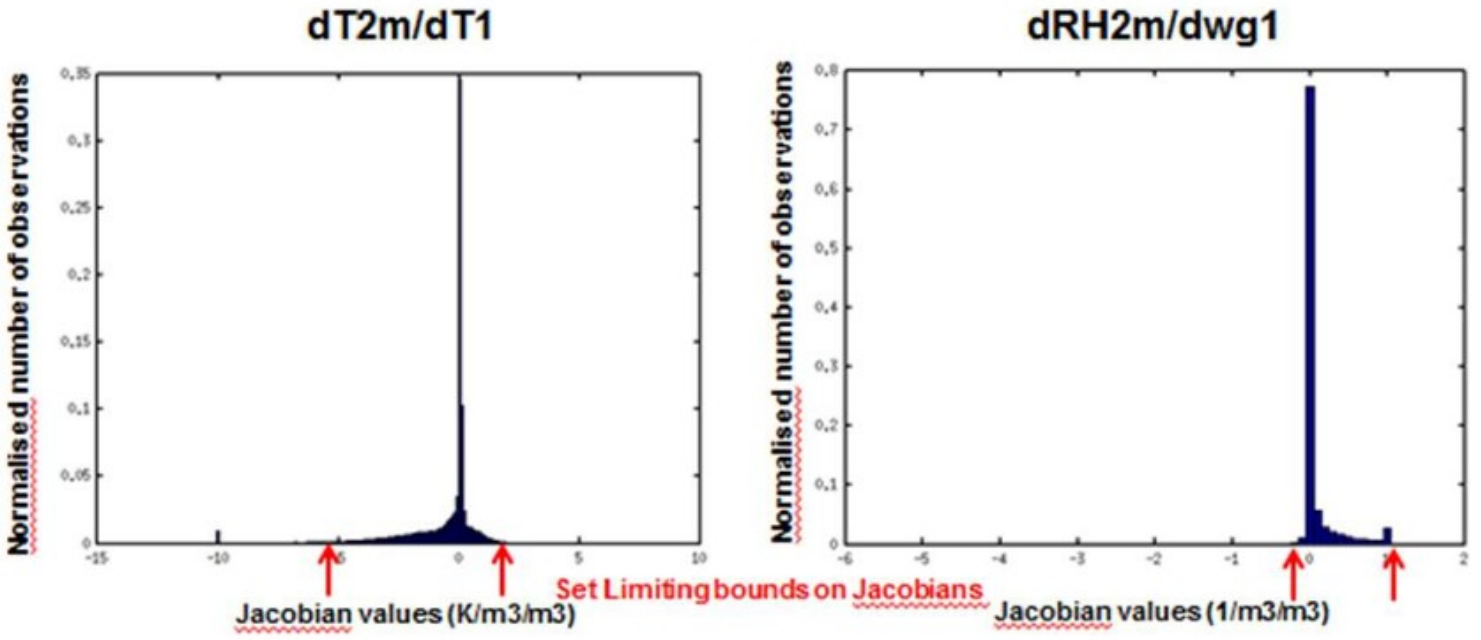
$$Corr(r_{ij}, d_p, d_z) = 0.5\left[e^{-\frac{r_{ij}}{L}} + \left(1 + \frac{2r_{ij}}{L}\right)e^{-\frac{2r_{ij}}{L}}\right] \cdot F_p(d_p)F_z(d_z)$$

L – 195 km
(vertical correlation scale ~500m)

SMHI IMPREX NWP contributions by Magnus L and Tomas L

For (S)EKF:

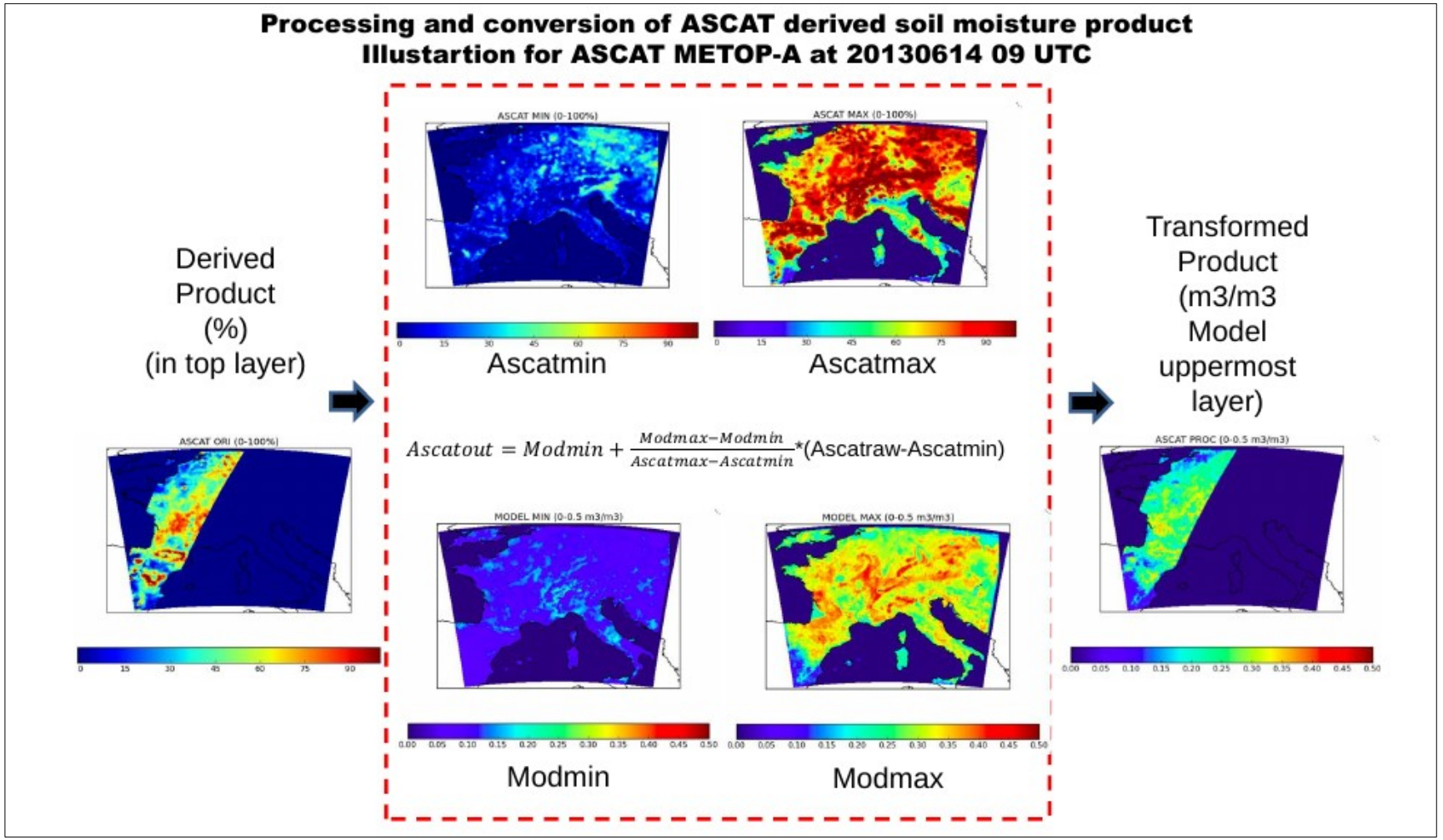
- Magnus experienced problems with crazy Jacobian values in some situations. His pragmatic solution for now is to limit the Jacobians as shown below based on their statistical distributions.
- Non-evolving B-matrix.



Regarding crazy Jacobians...

SMHI IMPREX NWP contributions by Magnus L and Tomas L

Scaling method of METOP data to fit model amplitude in soil moisture

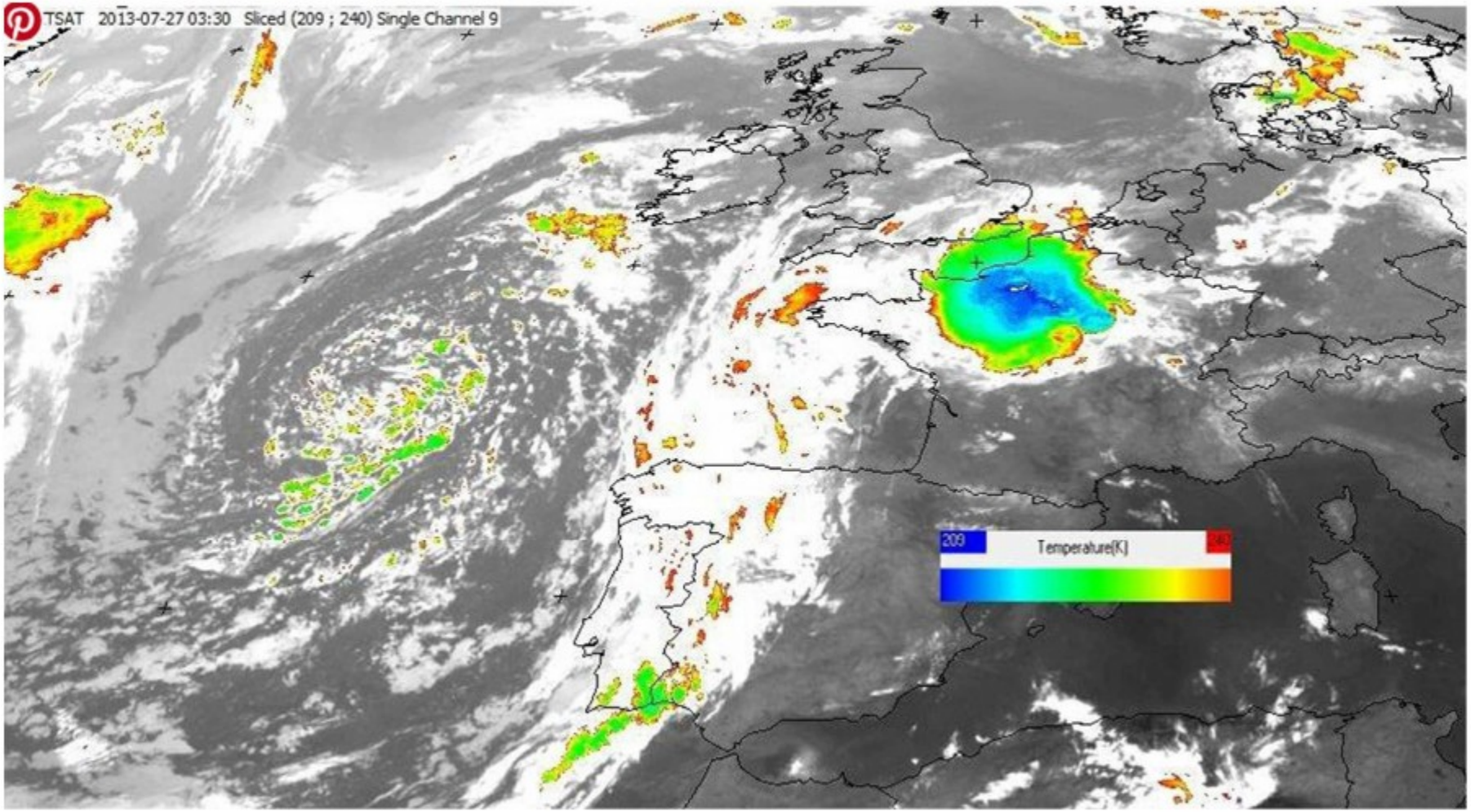


SMHI IMPREX NWP contributions by Magnus L and Tomas L

Preliminary results...

CASE 2 large convective system over Northern France

26-27 July 2013

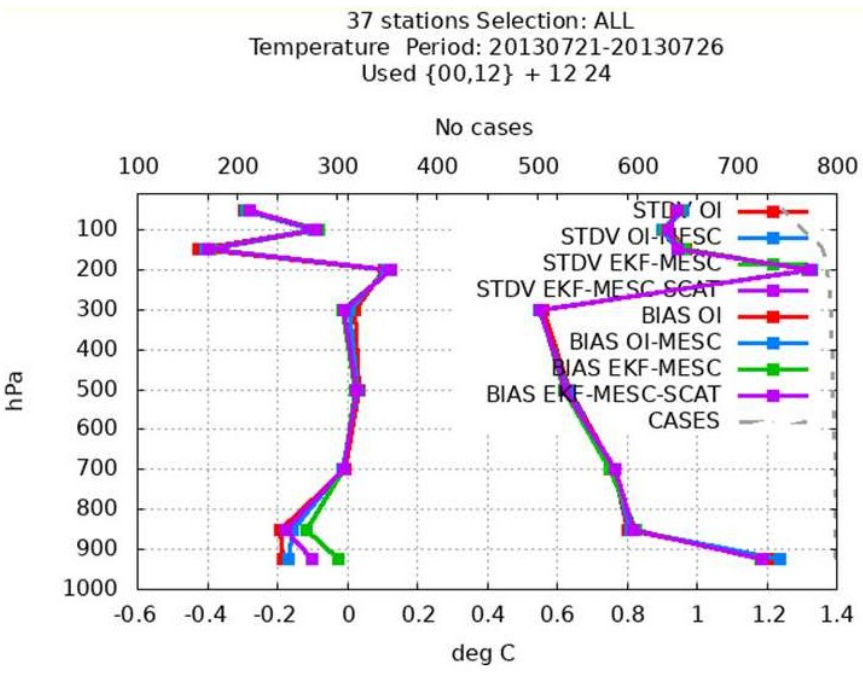


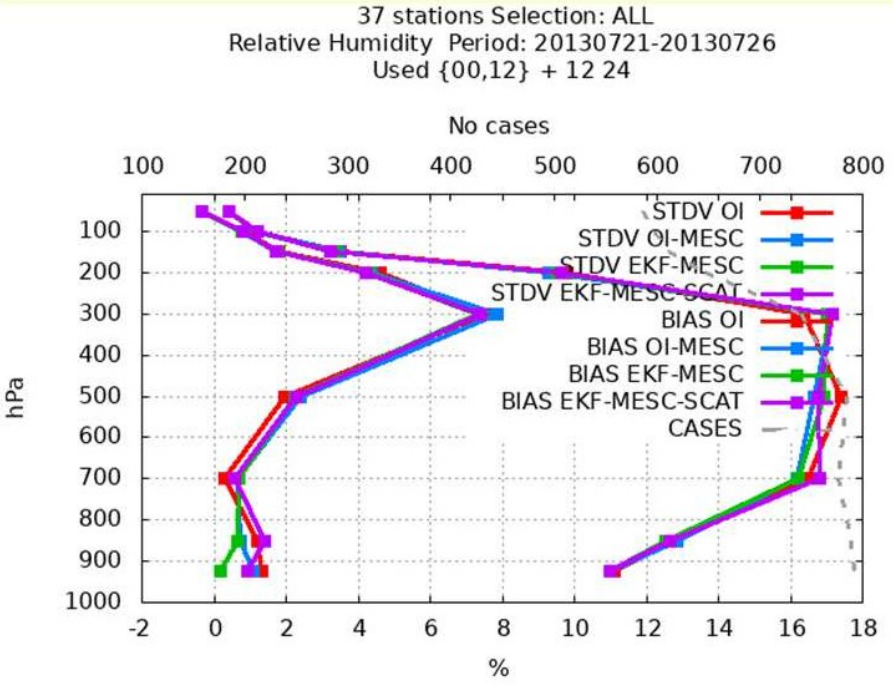
SMHI IMPREX NWP contributions by Magnus L and Tomas L

Preliminary results…

CASE 2 large convective system over Northern France

26-27 July 2013





Temperature and relative humidity profiles: improves OI → OI-MESC → EKF-MESC. But degrade again with EKF-MESC-SCAT

Sensitivity in upper-air forecasts T,RH to surface modifications, needs to be looked at in more detail

SMHI IMPREX NWP contributions by Magnus L and Tomas L

Concluding remarks

• More detailed analysis of case-studies ongoing looking at model upper air and surface fields and comparing with obs.

• Model runs for cases 3 and 4 to be finalised. SEKF running stably when applying Jacobian limits.

• Results to be analysed in more detail.

• Future work will as well be devoted to snow cover assimilation over Northern domain cases (old MetCoOp domain).

STAEKF for LAI by Jelena Bojarova

1) A bug in the interpolation of LAI to the grid-points with a SMALL fraction of NATURE TILE (cy40h trunk version).

2) I have SEKF control variables with a parameter LAI. Parameter LAI is kept unchanged during the model forward run, but is updated together with Wg, Ts, W2, T2 during the assimilation. The scheme is working technically and produces physically sound results. As soon as some remaining problems are solved I will start a strict evaluation of the STA-SEKF scheme.

3) I have tested STA-EKF setup as well (with evolving B-matrix). The performance of EKF depends crucially on the quality of the numerical approximation to the Jacobians (now too crude). Does not work for quick variables as Ts. Looks better for slow variables.

4) When patches are taken into account the sensitivity to the perturbation gives a more realistic estimate of the Jacobian. I think there is little meaning to continue the work on STA-EKF with one NATURE patch only. A challenging question is how to treat an observation when different patches are present (some type of respresentativity error need to be introduced).

MESCAN tests by Mariken Homleid

Surface analysis of T2m and RH2m with modified correlations functions and error statistics harmonie_namelists.pm - NALORIE

- LMESCAN = TRUE ==> correlation functions including terms depending on orography and LSM differences
- VARSIGO = TRUE ==> observation error standard deviation is a function of temperature

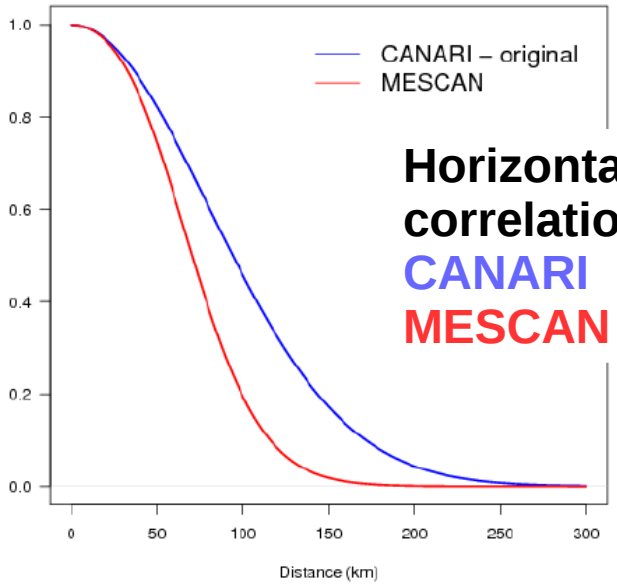
Time periods: 1-31 July 2016, 1-31 October 2016 and 1-31 December 2016

Results

- The effect of the surface analysis is very clear at analysis time, but does not persist.
- The surface analysis has positive impact on T2m and humidity forecasts in all experiments
- Neutral impact of “MESCAN settings” when forecasts are evaluated by summary scores at observing sites
- Reduced analysis increments with MESCAN settings

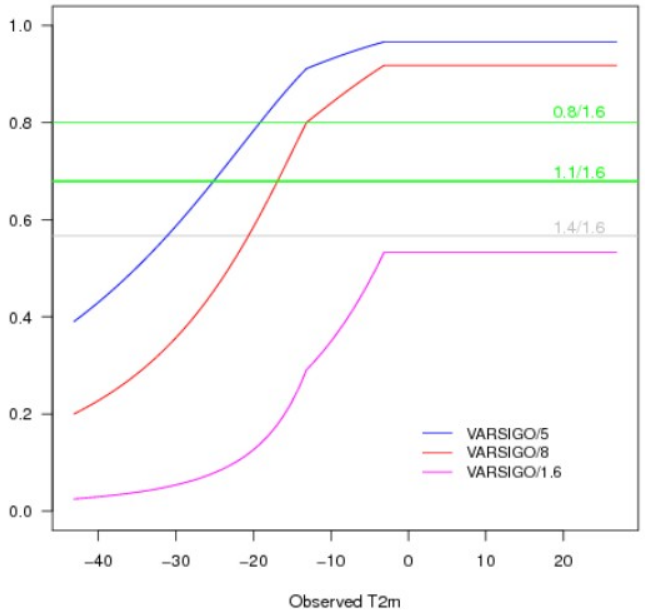
Mariken's presentation can be found via the Surface Workshop wiki page:

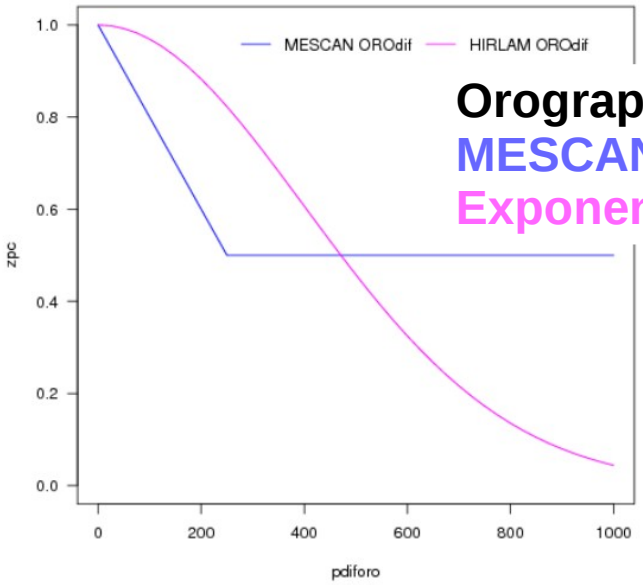
MESCAN tests by Mariken Homleid: Structure functions



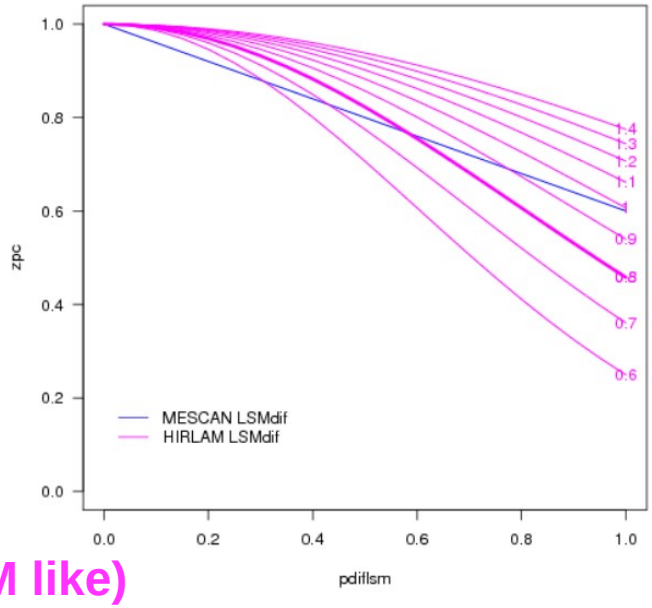
Horizontal correlation
CANARI
MESCAN

Temperature
CANARI
MESCAN





Orography difference
MESCAN default
Exponential (as HIRLAM)

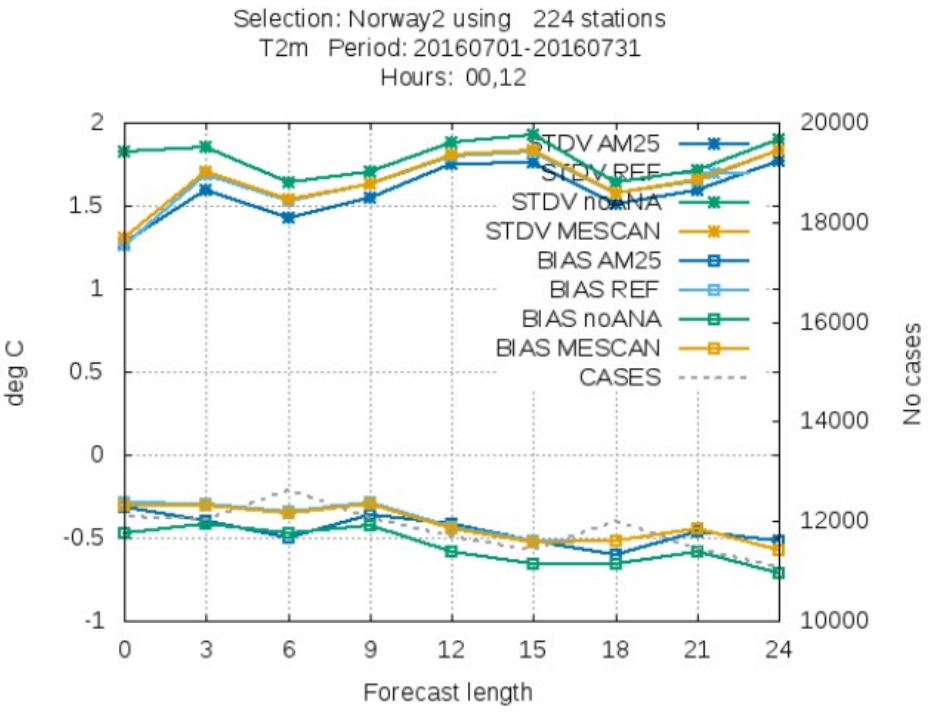


LSM difference
MESCAN default
Exponential (HIRLAM like)

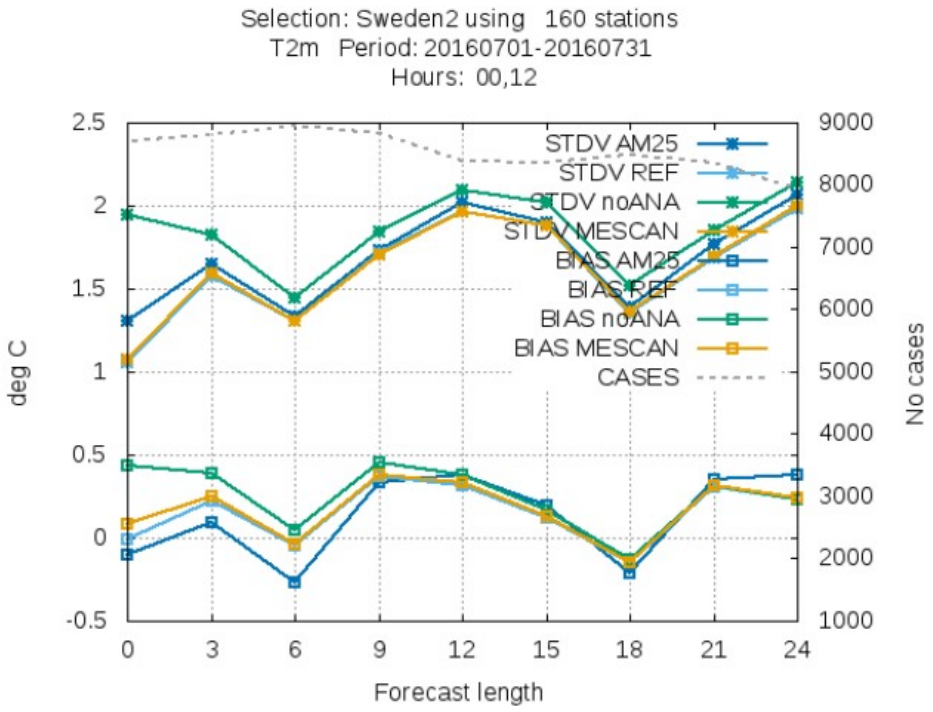
MESCAN tests by Mariken Homleid

T2m, July, 1-31, 2016

224 Norwegian stations



160 Swedish stations



- MEPSctrl - REF - NOANA - MESCAN expB

Conclusion: MESCAN introduce a very small difference over the MetCoOp domain. But, maybe it can make a difference in more convective driven domains (compare Magnus' results). So, worth trying out over the Spanish domain for severe convective cases….?

Regarding crazy Jacobians

Hmhm, Clément Albergel argues that Jacobians should not be limited since it may introduce biases. Yes, that's possible…

EKF assumes a linear behaviour in the model response during the assimilation window (here 3 hours) due to a perturbation. For short-memory variables (Ts, wg) this assumption is seldom fulfilled. And, for example, in the case of a precipitation events during the assimilation window the response is less linear.

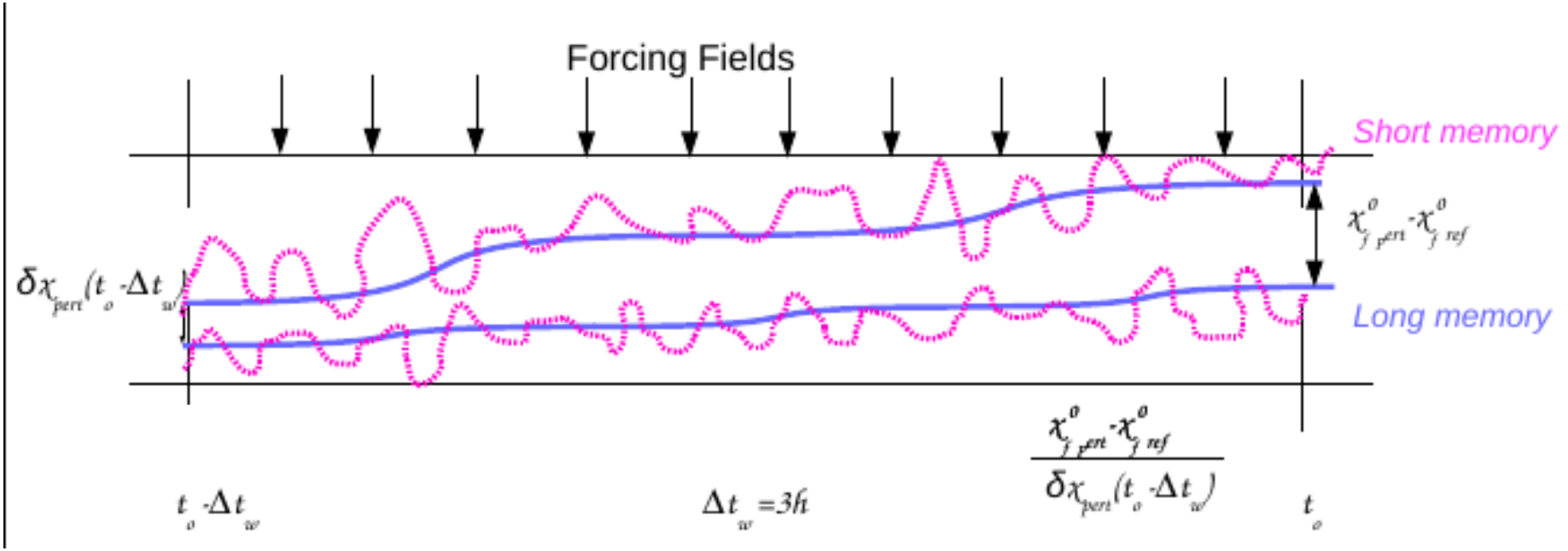
A solution may be to avoid updating the soil variables in case of precipitation...

Annelies Duerinckx says: “Balsamo et al. (2004) mention oscillatory trajectories of the screen-level variables that can introduce noise in the Jacobian matrix of the EKF. … occur in cloudy and rainy conditions and can be linked to evapotranspiration thresholds. ...we document another kind of oscillation, a 2Δt oscillation that can be linked to the stability parameters and the formation of a stable boundary layer in the late afternoon. We ...propose a method for filtering” the oscillations in T2m and Rh2m before calculating the Jacobian.

$$x_{\text{filtered}} = 0.5 \times w \times x_{t-1} + (1-w)x_t + 0.5 \times w \times x_{t+1}$$

Regarding crazy Jacobians

In Jelena's implementation of STAEKF for LAI in cy40h she has noticed that a functionality available in old VARASIM is no longer available in SODA. Namely the possibility to calculate the derivative over the assimilation window using all values along the offline integration and not only the start and end values.
Such a functionality may limit problems related to short-memory variables.



Also, Jelena has suggested that the derivatives may be more representative for the analysis time if they are represented by the mid-value. I.e., for a 3h assimilation window we should utilize forcing from 6h forecasts...

Regarding crazy Jacobians

Jelena has also started to look into SODA in SURFEXv8.1. She has used the 1D test setup provided by Clément for the Zagreb surface workshop last year. In this setup soil moisture and LAI are assimilated with EKF using SURFEX with prognostic LAI and 12 patches.

Her preliminary conclusions are that, when physical processes are better represented (i.e. each patch, forest, bare soil, crop, grass, is treated separately) the Jacobians are less problematic. In other words, we should not dig into Jacobian problems too much before we have the physical processes represented as we would like to have them. Thus,

- First, with at least 2 patches, activate 14-layer soil layers, 12 layers snow and Multi-Energy Balance with EKF
- Then seriously study/solve any remaining problems with Jacobians.

Ideas for CANARI development (Trygve, Patrick, Mariken)

Currently the first guess for CANARI is always based on grid-averaged values for T2m, Rh2m and SWE (via the atmospheric fa-files)

But imagine a sunny spring-time situation with a grid box dominated by sea water and a small portion of land with a SYNOP station. Here a grid-averaged first guess can be totally crazy.

Similarily, when two patches are introduced in combination with more advanced surface physics. Snow SWE in forest and over open land can be quite different. Again, a grid-averaged SWE as first a guess would be stupid.

Thus, ideas are formulated on how CANARI may be modified so SURFEX tile/pach information can be used for first guess.

Also, we would like to modify CANARI so it interpolates snow depth instead of SWE (which is currently estimated from snow depth using a climatological snow density).