

Impact of UKV soil moisture data assimilation on operational forecasts

Breo Gomez, Cristina Charlton-Perez, Huw Lewis, and Chris Harris.

Satellite inspired hydrology in an uncertain future: a H-SAF and HEPEX workshop ECMWF, 27th November 2019

www.metoffice.gov.uk



Outline

- Overview of current operational implementation
- New regional soil moisture analysis for UK NWP
- Impact on river flow
- Land temperature analysis



Operational Soil Moisture DA



Simplified Extended Kalman Filter

$$x_i^a = x_i^b + K_i [y_i^o - H_i(x_i^b)]$$

 $\mathbf{K}_{i} = \mathbf{B}\mathbf{H}_{i}^{\mathrm{T}} [\mathbf{H}_{i}\mathbf{B}\mathbf{H}_{i}^{\mathrm{T}} + \mathbf{R}]^{-1}$

- Global analysis every 6h
- Weakly coupled with atmosphere
- UK interpolated once a day





Simplified Extended Kalman Filter

$$x_i^a = x_i^b + K_i [y_i^o - H_i(x_i^b)]$$

 $\mathbf{K}_{i} = \mathbf{B}\mathbf{H}_{i}^{\mathrm{T}} \left[\mathbf{H}_{i}\mathbf{B}\mathbf{H}_{i}^{\mathrm{T}} + \mathbf{R}\right]^{-1}$

- Adapts the methodology used at the global model, except:
- Analysis every 1h
- Screen observations taken from 4Dvar Atmospheric analysis
- More-than-weakly coupled to atmosphere
- ASCAT soil wetness is converted to soil moisture rescaling the climate.



Simplified Extended Kalman Filter

- Horizontal error correlations are ignored.
- B and R diagonal and homogeneous. We use realistic observation and background errors (based on comparisons with in situ soil moisture networks & other sources of soil moisture)
- $H_i(x_i^b)$ is taken from the UM at previous cycle
- H_i is computed via finite differences using the JULES land model. Represent instantaneous conditions

$$x_i^a = x_i^b + K_i [y_i^o - H_i(x_i^b)]$$
$$K_i = BH_i^T [H_i BH_i^T + R]^{-1}$$

Met Office Estimation of H for Kalman Gain with Jacobians



- 2 month trials for summer and Winter
- Small impact in atmosphere
 - Improves screen humidity in summer
 - Slight degradation of temperature in winter
- Large impact on hydrology, with promising results. (next slides)

Surface (1.5m) Relative Humidity (%), Current UK Index station list, Equalized and Meaned between 20180716 00:00 and 20180913 23:00, Surface Obs



 \pm 1 standard error bars calculated assuming independent observations

Summer

7 grid lengths

- 2 months trials for summer and Winter
- Small impact in atmosphere
 - Improves screen humidity in summer
 - Slight degradation of temperature in winter
- Large impact on hydrology, with promising results. (next slides)

																	1	пах	- 2	0																
TempCRPS	Δ	•				1					1																	1					1	•		•
WindRPS	•	. [•]			ŀ		۵								•	•		•									•	۵			•	۵	۵		
loudFractionRPS			•		٠	•	•	۵					٠		•	•	٠	•			•	•									۵	•		•	•	
CloudBaseRPS			•		٠	•	۵			•	•						•	•					•	•				٠	•		1	•	•	•		
VisibilityRPS							•	۷				•					•			٠	٠	۲		•	▼	۲	•			•						
PrecipitationRPS		•	- 1	۲		1.		•		•	•	۲	٠			•	٠			٠	۲	•	۲	•	•	۲				ŀ	1.					
	1+1 - 1	7+1	n +	T+4	T+5	T+6	T+7	T+8	T+9	T+10	T+11	T+12	T+13	T+14	T+15	T+16	T+17	T+18	T+19	T+20	T+21	T+22	T+23	T+24	T+25	T+26	T+27	T+28	T+29	T+30	T+31	T+32	T+33	T+34	T+35	T+36
																,	W	'in	te	er																
																	7 g n	rid nax	eng = 2	ths 0																

																			-																	
TempCRPS		.]	1					1	۷	1	•	٠	۷	۷	•	۷	•	۷	•	۷	۷	۷	•	*	۷	۷	•	•	۷	۷	۷	•	•	۳	۷	
WindRPS		•	•	٠	•		•	•		۷			•	•	•		۷	ŀ	•	•		•		•	•				•	•	•		•	•		
loudFractionRPS	•		•	٠		•	•	•	•	•	•				•		•	•				•			٠		•			۵		•			۷	▼
CloudBaseRPS			•	•		•	•	•		•		•	•	•		•		٠		•		•	•	•	•		▼	•		•		•	•	•	•	•
VisibilityRPS	•	•	۲	۲	•	▼	•		▼	•	•	▼	▼	•	▼	▼	۲	٠	•	۲	•	▼	▼	٠	٠	۲	•	•	٠	•	•	٠	٠	٠	۲	
PrecipitationRPS	•	•	•		•	•		•				۲	٠				۲	•		•	•	٠	•			•		•		•			•	•		
	1+1 +1	> + + + + +	T+3	T+4	T+5	T+6	T+7	T+8	T+9	T+10	T+11	T+12	T+13	T+14	T+15	T+16	T+17	T+18	T+19	T+20	T+21	T+22	T+23	T+24	T+25	T+26	T+27	T+28	T+29	T+30	T+31	T+32	T+33	T+34	T+35	T+36

H-SAF HEPEX Workshop

UKV Soil Moisture analysis Impact on hydrology

Summer – Soil Saturation Winter – Soil Saturation Control mi-ax266 Control mi-ax265 0.95 Trial mi-ax456 Trial mi-ax455 0.70 0.90 evel 0.85 0.80 0.55 Jul 05 2017 Jul 12 2017 Jul 19 2017 Jul 26 2017 Aug 02 2017 Aug 09 2017 Aug 16 2017 Aug 23 2017 Aug 30 2017 Sep 06 2017 Dec 05 2017 Dec 12 2017 Dec 19 2017 Dec 26 2017 Jan 02 2018 Jan 09 2018 Jan 16 2018 Jan 23 2018 Jan 30 2018 Feb 06 2018 Control mi-ax266 Control mi-ax265 Trial mi-ax455 Trial mi-ax456 0.85 0.90 evel 0.80 0.85 0.75 0.80 0.70 0.75 Jul 19 2017 Jul 26 2017 Aug 02 2017 Aug 09 2017 Aug 16 2017 Aug 23 2017 Aug 30 2017 Sep 06 2017 lul 05 2017 lul 12 2017 Dec 05 2017 Dec 12 2017 Dec 19 2017 Dec 26 2017 Jan 02 2018 Jan 09 2018 Jan 16 2018 Jan 23 2018 Jan 30 2018 Feb 06 2018

27th November 2019

Impact of UKV soil moisture data assimilation on operational forecasts

H-SAF HEPEX Workshop

UKV Soil Moisture analysis Impact on hydrology

0.0010



Plymouth Marine Laboratory

PML

UK Environmental Prediction research



Centre for

Ecology & Hydrology

National

Oceanography Centre

Set Office UKV Soil Moisture analysis

Link to river flow verification



Daily averaged sub-surface runoff

H-SAF HEPEX Workshop



UKV Soil Moisture analysis

Link to river flow verification

The biggest contribution of new DA system is to the surface and sub-surface runoffs.



Surface and sub-surface run-offs from operations (purple) and trial (blue) are routed with JULES river model.



Severn

realistic for the trial with EKF





Land temperature analysis

Operational temperature increments

- Atmospheric temperature increments are added to:
 - Skin temperature
 - Top soil temperature
 - Snow temperature
- Assumes synchronisation of the evolution of the temperature between the evolution of the lowest atmospheric level and the top soil.





-0.06

Simplified Extended Kalman Filter

$$x_i^a = x_i^b + K_i [y_i^o - H_i(x_i^b)]$$

$$\mathbf{K}_{i} = \mathbf{B}\mathbf{H}_{i}^{\mathrm{T}} [\mathbf{H}_{i}\mathbf{B}\mathbf{H}_{i}^{\mathrm{T}} + \mathbf{R}]^{-1}$$

- Adapts the methodology used at the global model, except:
- Analysis every 1h
- Screen observations taken from 4Dvar Atmospheric analysis
- More-than-weakly coupled to atmosphere
- ASCAT soil wetness is converted to soil moisture rescaling the climate.



^{∞ Met Office} Temperature increments

- Analysis for:
 - Soil Moisture
 - Soil Temperature
 - Skin Temperature
 - Snow Temperature

 Consistency between the increments across variables



Summer – 2 month trial

Soil Moisture DA



Soil Moisture and Land Temperature DA



H-SAF HEPEX Workshop

Winter – 2 month trial

Soil Moisture DA



Soil Moisture and Land Temperature DA



Source Met Office

Summary

- New Soil Moisture Analysis for UK NWP
 - Small impact in atmosphere
 - Large impact in hydrology, with promising results
 - Accepted for inclusion in operations, live in 2nd Dec 2019.
- Despite neutral impact in atmosphere, having the system in place allows for further improvements:
 - Re-tuning parameters (i.e. background and observation error covariance)
 - New observations
- Land temperature analysis shows promising results in improving the forecasting of screen temperature



EXTRA FIGURES

Met Office Land temperature Analysis NH / 1.5m Temperature RMSE and BIAS Experiment – Control / N320 Summer



% Difference (LTDA ScreenErr 0.75K 4.0% - ScreenEC 1 K% vs. PS43 Control) - overall 0.16% RMSE against observations for 20180715 to 20181014

						1	ma	x =	20	С							
NH_PMSL	·															surf	
NH_W250					٠											AME	DARS
NH_W500																son	des
NH							•							•		Saty	vind
NH W10m	•	1														surf	
NH_T250	1								٠		·			۰		son	des
NH_T500																son	des
NH_T850	1			۸												son	des
NH_T_2m					۸						۵					surf	
NH_Z250	1	•	•	•	•	•	•									son	des
NH_Z500		•	•	•												son	des
NH_Z850	1															son	des
TR_W250																AME	ARS
TR_W500	1		•													son	des
TR_W850	\mathbf{x}_{i}															Satv	vind
TR_W10m	1															surf	
TR_T250	+					•		1				٠		•		son	des
TR_T500	1															son	des
TR_T850					٠	٠	۷	۳	۷	۷	۷	۷	۷	٧		son	des
TR_T_2m	•															surf	
SH_PMSL				•		•			•	•	•		•	•		surf	
SH_W250									•	•		•	•			AME	DARS
SH_W500	·									•			•	÷.		son	des
SH_W850	•											•				Satv	vind
SH_W10m	+	·		•	•	•							•			surf	
SH_T250	1					•				•						son	des
SH_T500	Ľ.					۵	•	•	•			•	•			son	des
SH_T850	·									•	•					son	des
SH_T_2m	•	4	۸			•		•	•				•	•		surf	
SH_Z250	1	•		•						۵		•		•		son	des
SH_Z500	1		•					٠	•	•				•		son	des
SH_Z850	•						•	•				•	•	•		son	des
Euro_PMSL	·				۸			1	۷				•	•		surf	
Euro_W250						•			•	•	•		•	•		AMD	DARS
Euro_W850	1	1						1					•	٠		Satv	vind
Euro_W10m	· ·	1			•				•				•			surf	
Euro_T250	1						1					•				son	des
Euro_T850	Ŀ	1.		۸	۸	۵	۸						÷	•		son	des
Euro_T_2m		۸	۸	۸	۸	۸	۸	۸	۸	÷	۵	÷	۸	۵		surf	
Euro_2500	•															son	des
Euro_RH_2m		4	۸	٨	۸	۸	۵	•	۸	۸	۸	٠	۸	٠		surf	
UK4_T_2m			۸								•		•	•		surf	
UK4_RH_2m	•				۸	Ŀ	•					•	4			surf	
UKINDEX_T_2m	•								1		•			÷		surf	
Kindex_RH_2m		۸	۸	۸	۸				1	1	1		۸	1		surf	
	9	1 9	12	24	36	\$	00	72	84	96	80	20	22	4	80		
	F	F	÷	Ě	÷	Ť	Ť	+	Ť	÷		7		÷	7		

H-SAF HEPEX Workshop