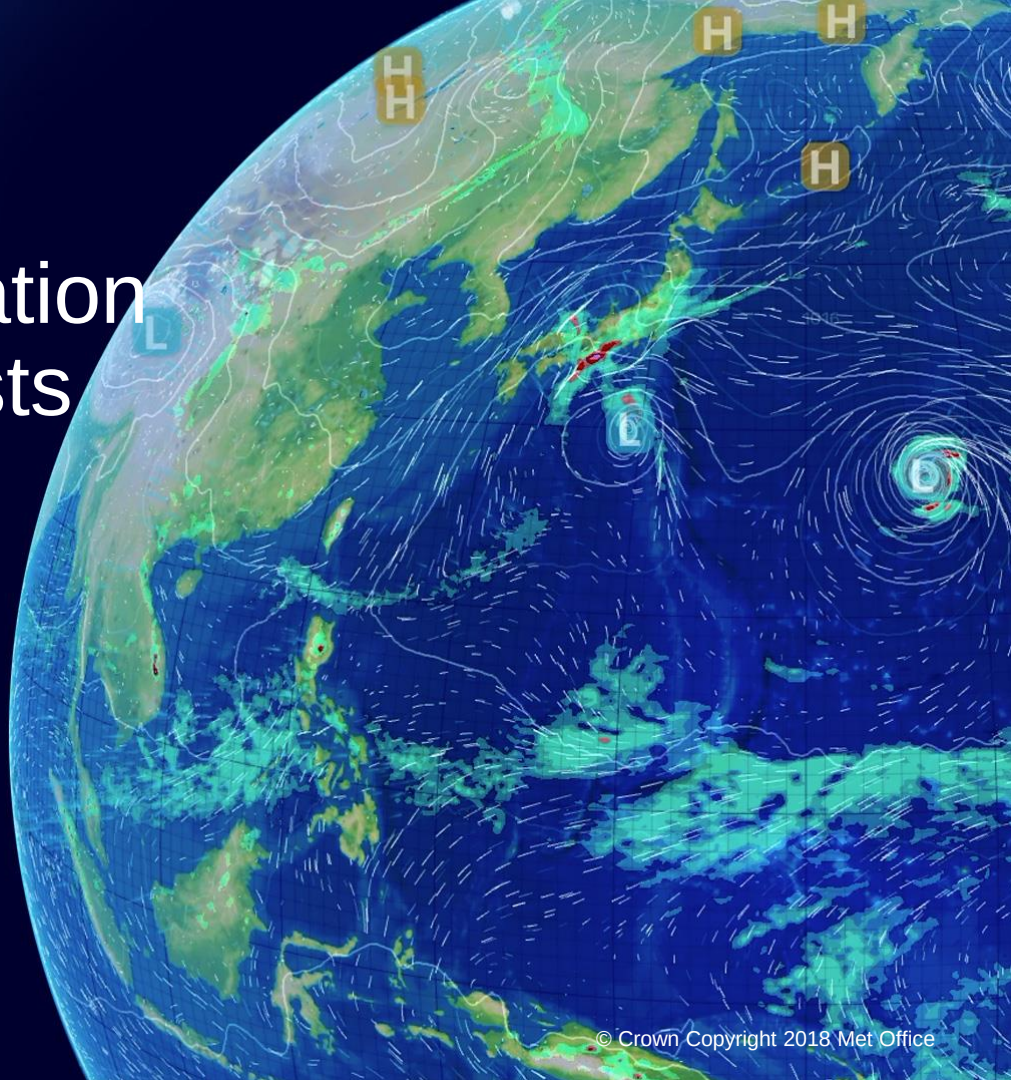
Impact of UKV soil moisture data assimilation on operational forecasts

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

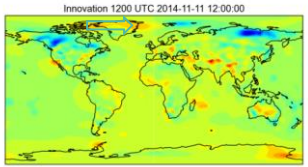
Met Office

Outline

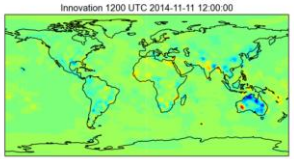
- Overview of current operational implementation
- New regional soil moisture analysis for UK NWP
- Impact on river flow
- Land temperature analysis

Operational Soil Moisture DA

Observations



1.5 m Temp (Gridded)



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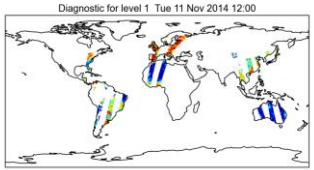


ASCAT soil saturation

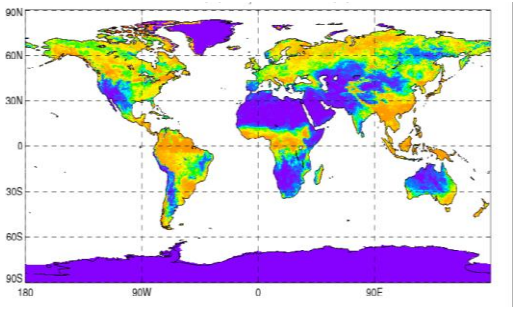
Simplified Extended Kalman Filter

$$x_i^a = x_i^b + \mathrm{K_i}\left[y_i^o - H_i\left(x_i^b\right)\right]$$

$$\mathrm{K_i} = \mathrm{BH_i^T}\left[\mathrm{H_iBH_i^T} + \mathrm{R}\right]^{-1}$$

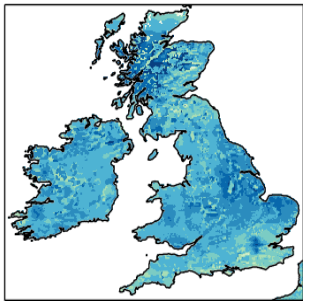
- Global analysis every 6h
- Weakly coupled with atmosphere
- UK interpolated once a day

Soil moisture analysis



Interpolation into UKV domain

Global Recof



SM DA for the UK NWP system

Observations

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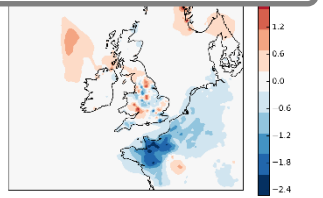
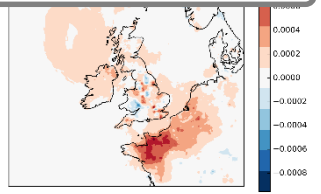
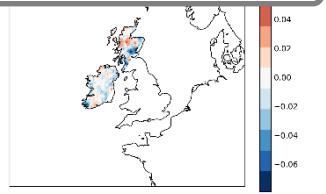


1.5m Spec Hum (Gridded)



ASCAT Soil Saturation



Simplified Extended Kalman Filter

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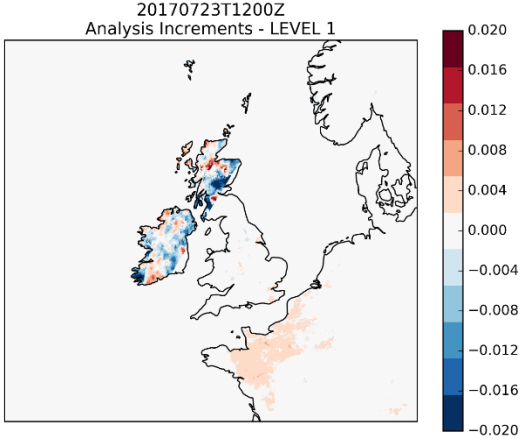
- Adapts the methodology used at the global model, except:
- Analysis every 1h
- Screen observations taken from 4Dvar Atmospheric analysis
- *More-than-weakly* coupled to atmosphere
- ASCAT soil wetness is converted to soil moisture rescaling the climate.

Soil moisture analysis increments



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)
- $H_i\left(x_i^b\right)$ is taken from the UM at previous cycle
- $\mathrm{H_i}$ is computed via finite differences using the JULES land model. Represent instantaneous conditions

$$x_i^a = x_i^b + \mathrm{K_i}\left[y_i^o - H_i\left(x_i^b\right)\right]$$

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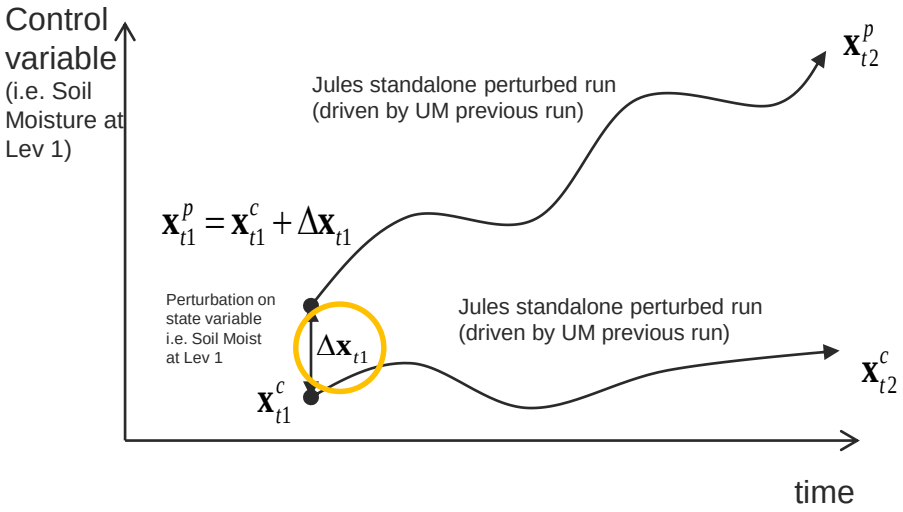
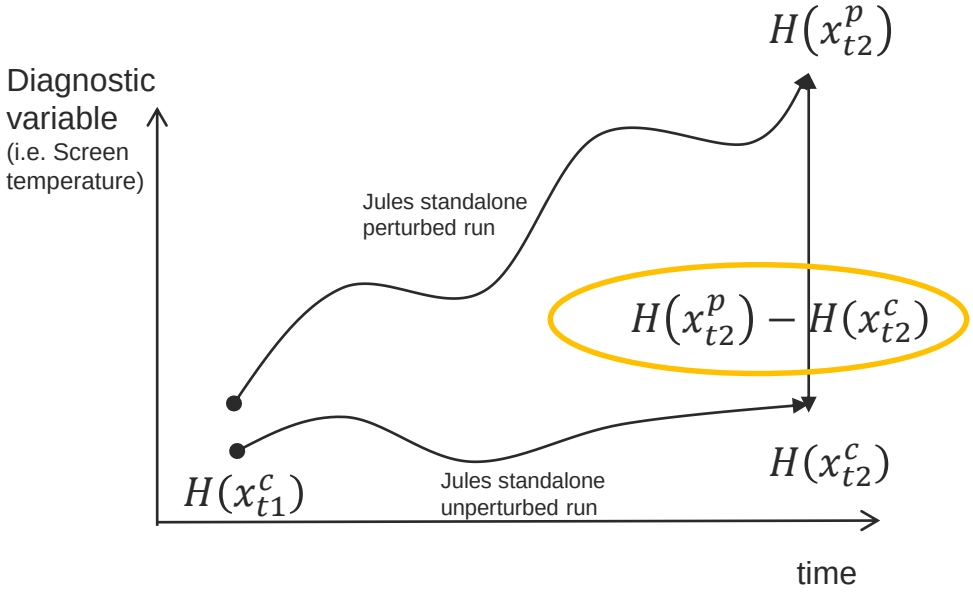
Estimation of H for Kalman Gain with Jacobians





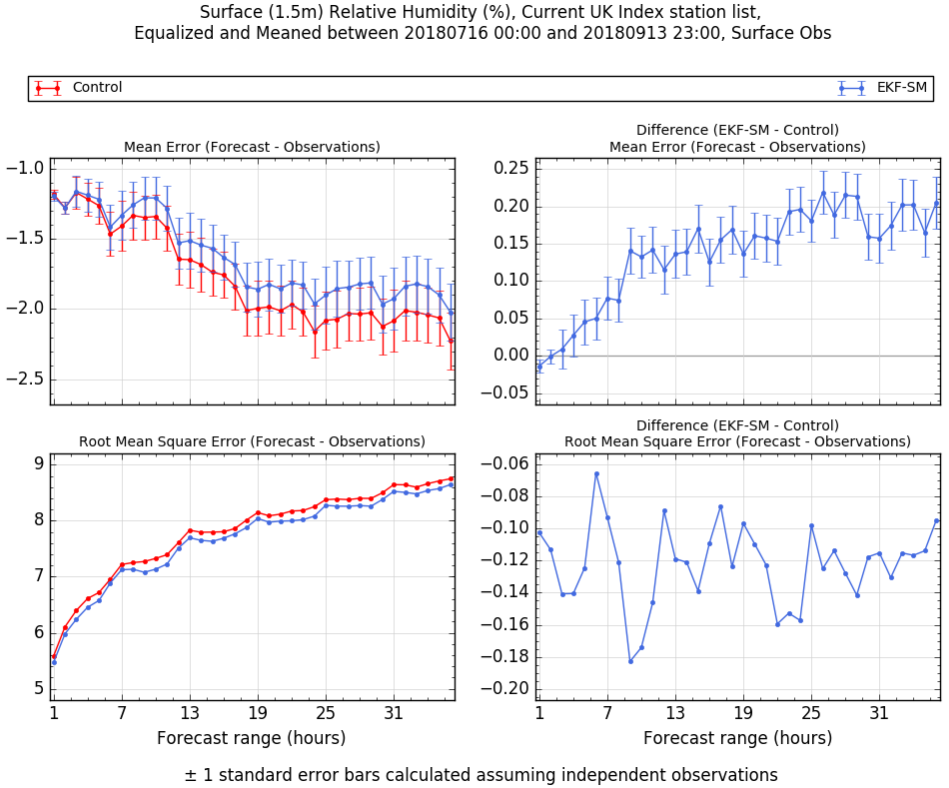
$$\mathbf{H}_{m,n} \approx \frac{\partial H(x)}{\partial x} \approx \frac{H^p_m(x^p_{t2}) - H^c_m(x^c_{t2})}{\Delta x_{n,t1}}$$

Example

$$\mathbf{H}_{SML1,ScreenSpecH} = \frac{SpecH^p_{t2} - SpecH^c_{t2}}{\Delta SML1_{t1}}$$

SM DA for the UK NWP system

- 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)



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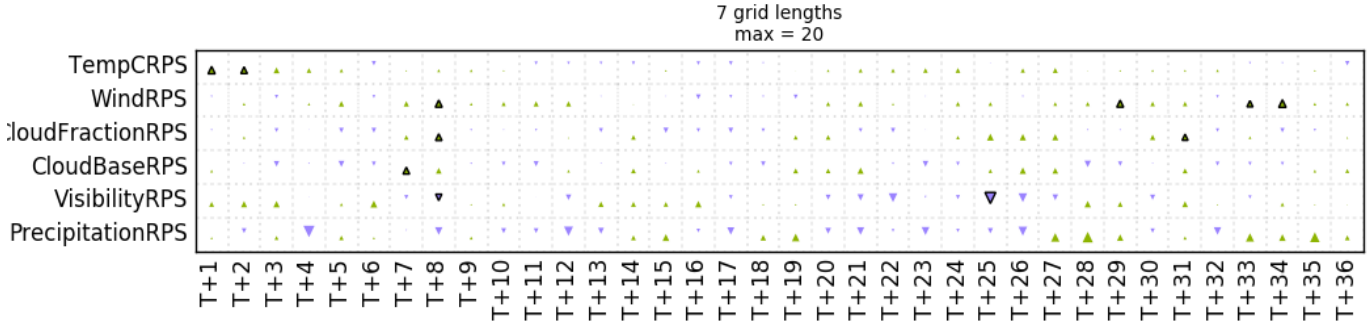
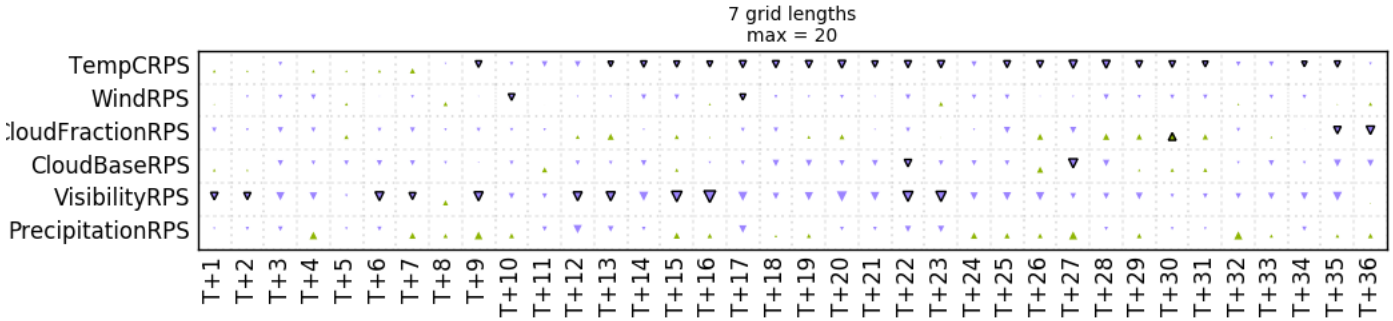


Winter



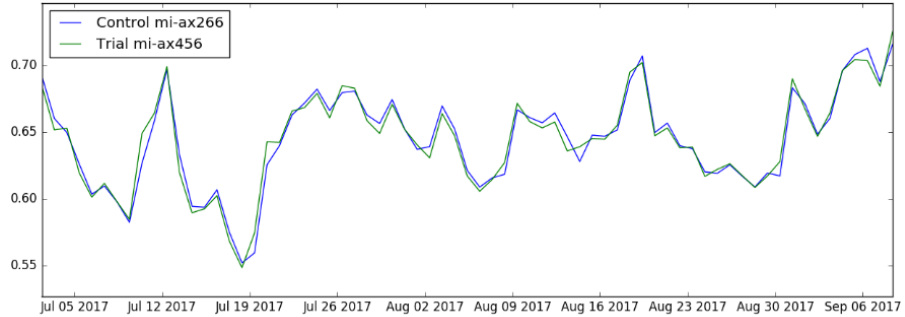
UKV Soil Moisture analysis

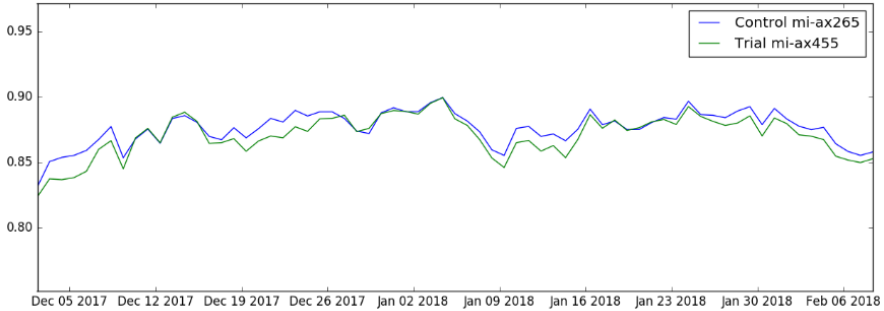
Impact on hydrology

Summer –Soil Saturation

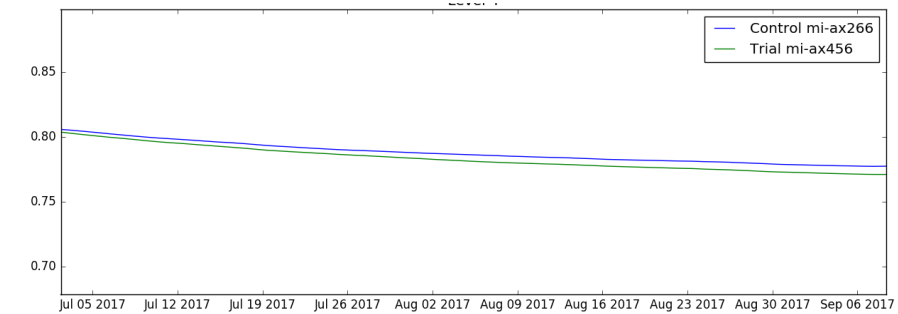
Winter –Soil Saturation

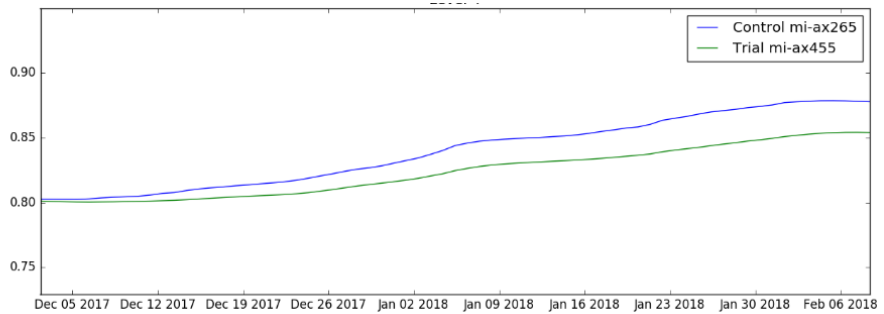
Level 1





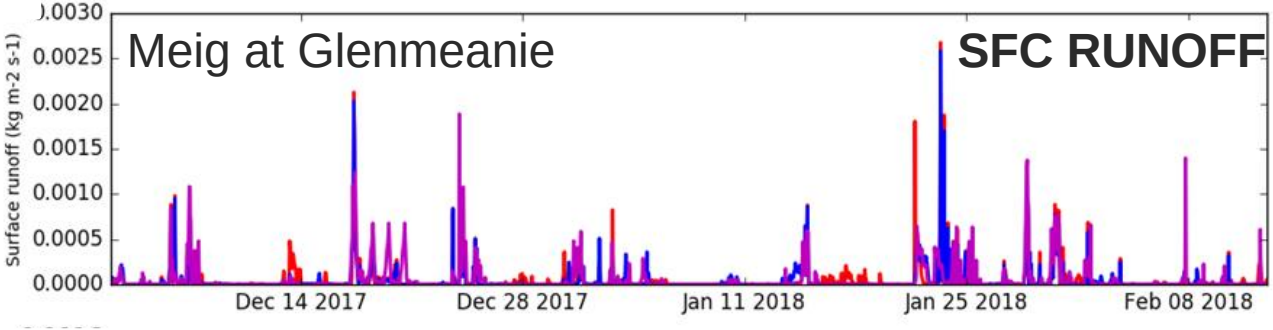
Level 4

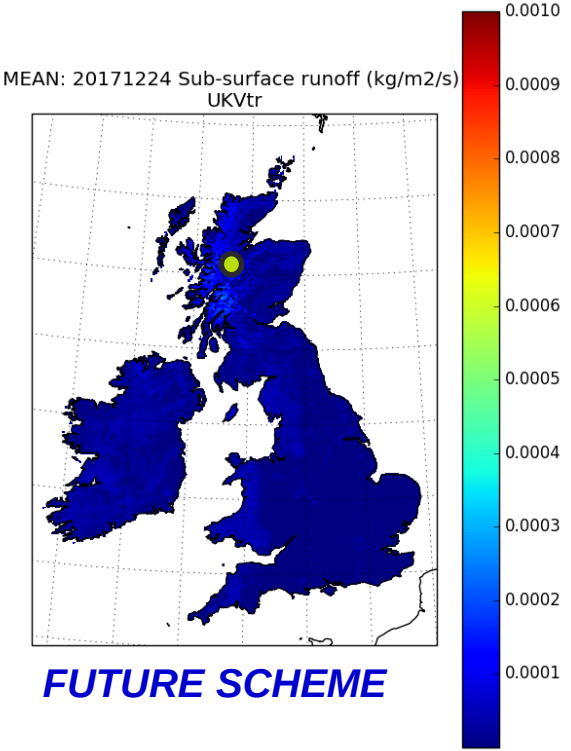




UKV Soil Moisture analysis

Impact on hydrology





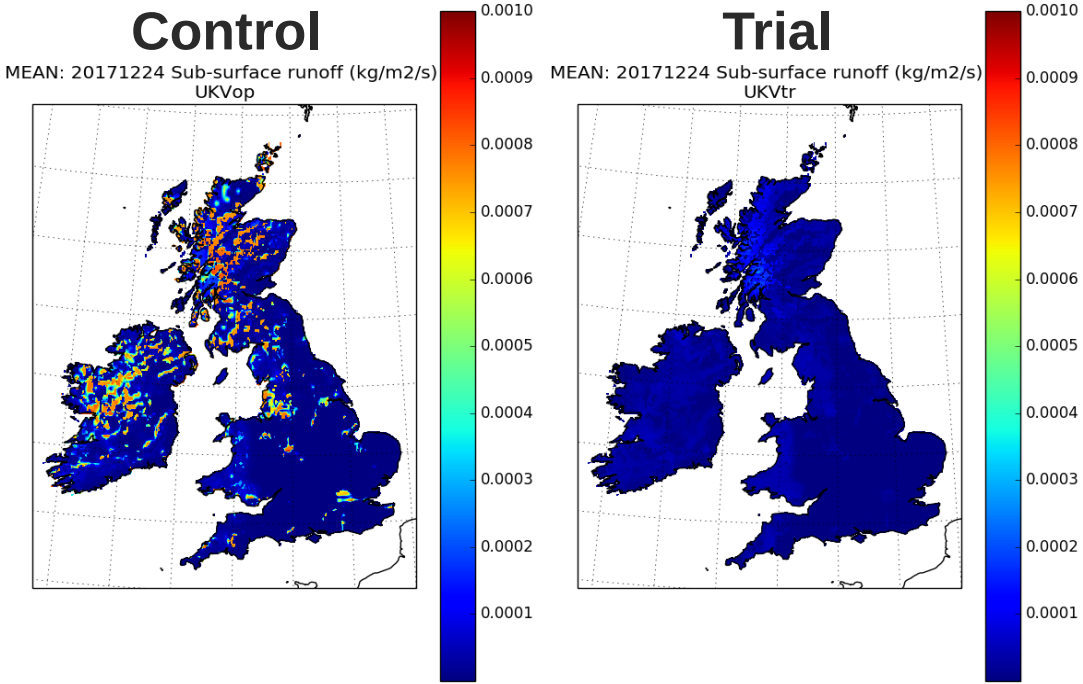
FUTURE SCHEME

CURRENT SCHEME (global recon)

FUTURE SCHEME (UK analysis)

UKV Soil Moisture analysis

Link to river flow verification



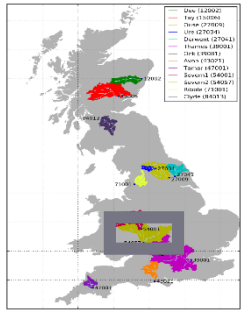
Daily averaged sub-surface runoff

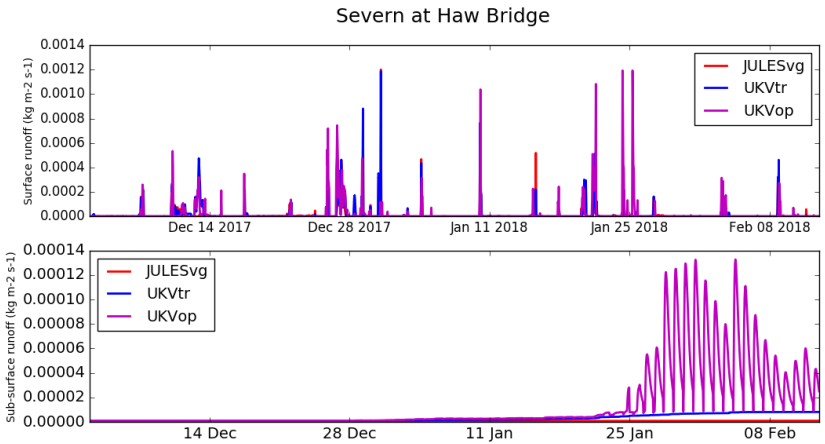
UKV Soil Moisture analysis

Link to river flow verification

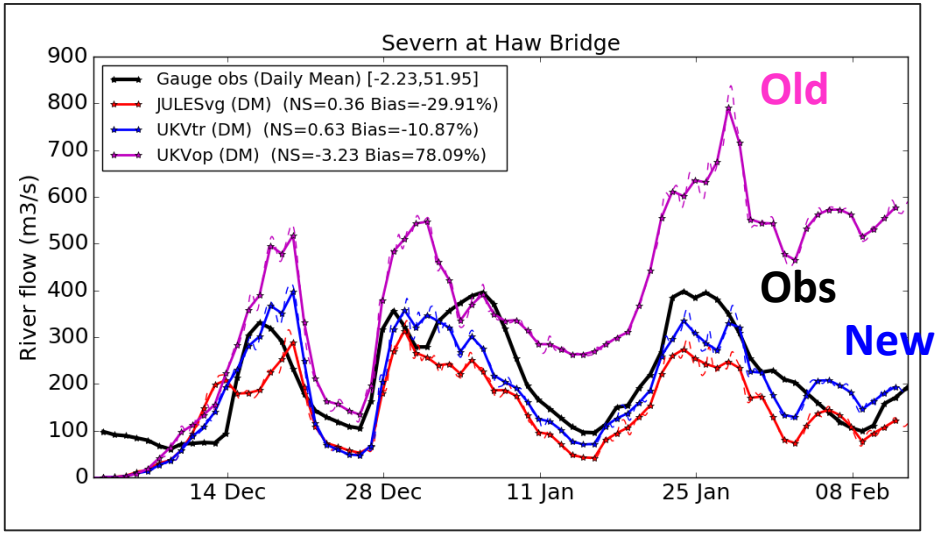
The biggest contribution of new DA system is to the surface and sub-surface runoffs.

Severn river basin





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



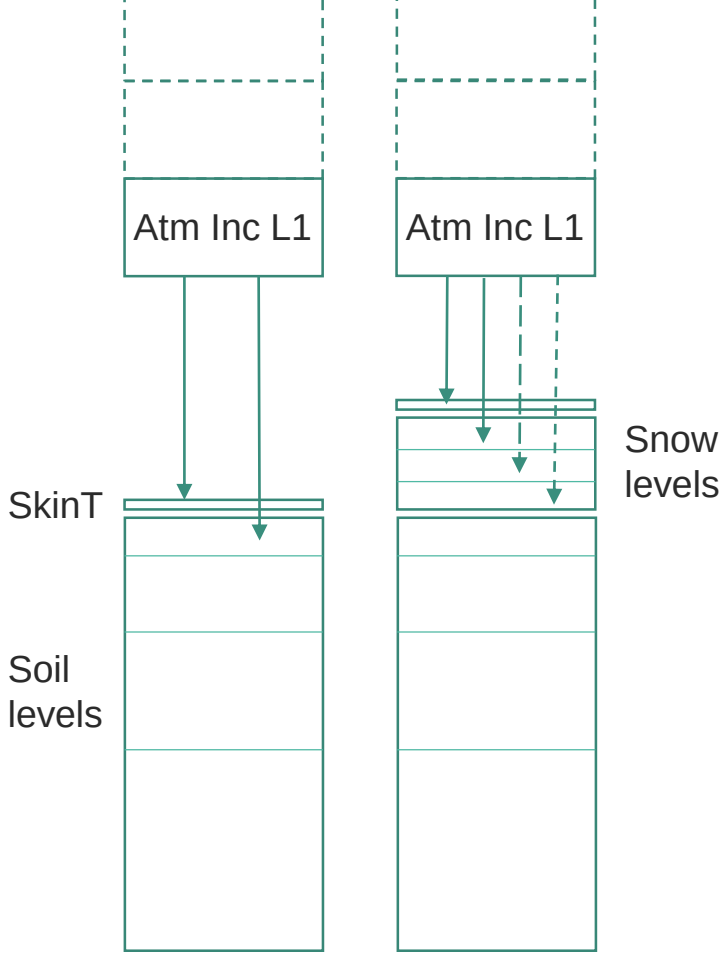
Simulated river flows are much more realistic for the trial with EKF

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.



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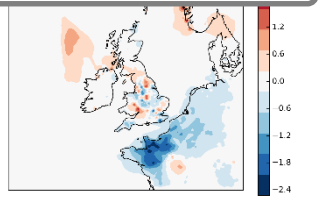

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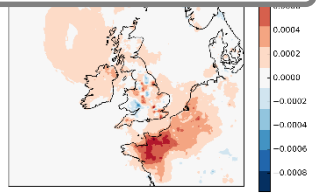

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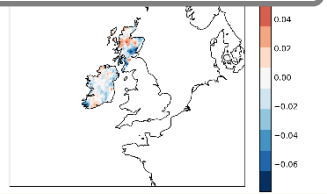

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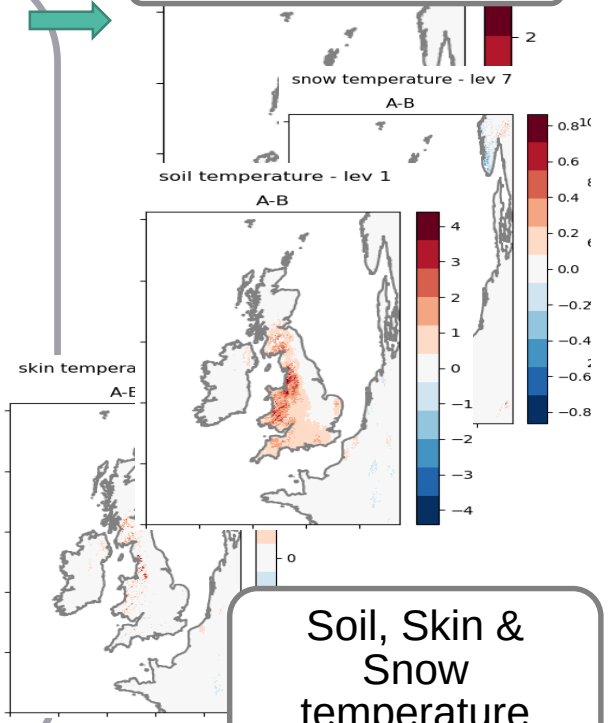
Soil moisture

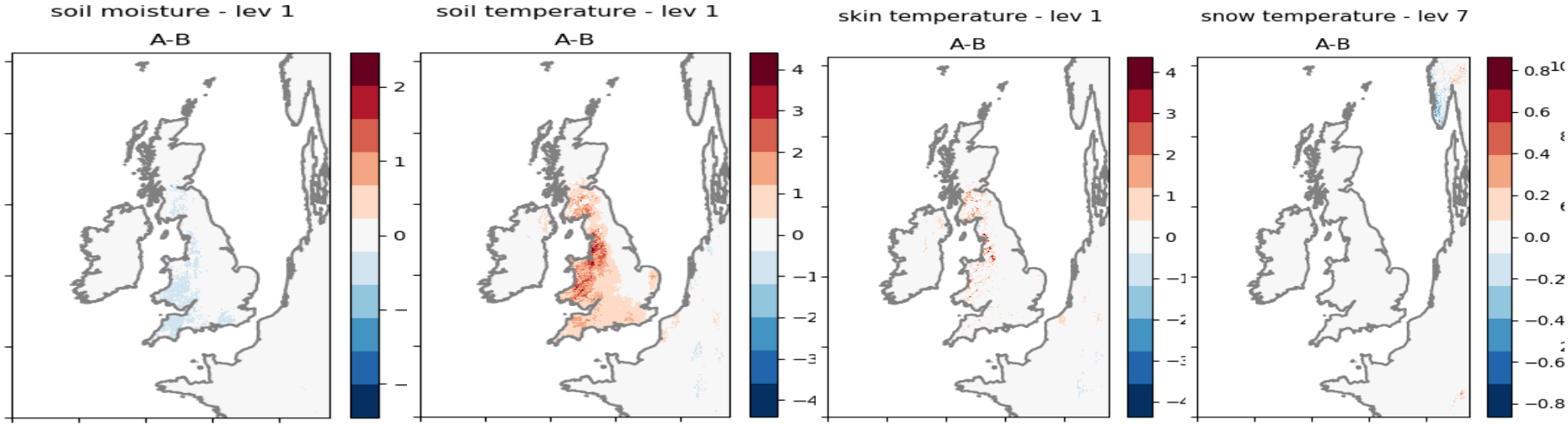


Soil, Skin & Snow temperature

Temperature increments

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

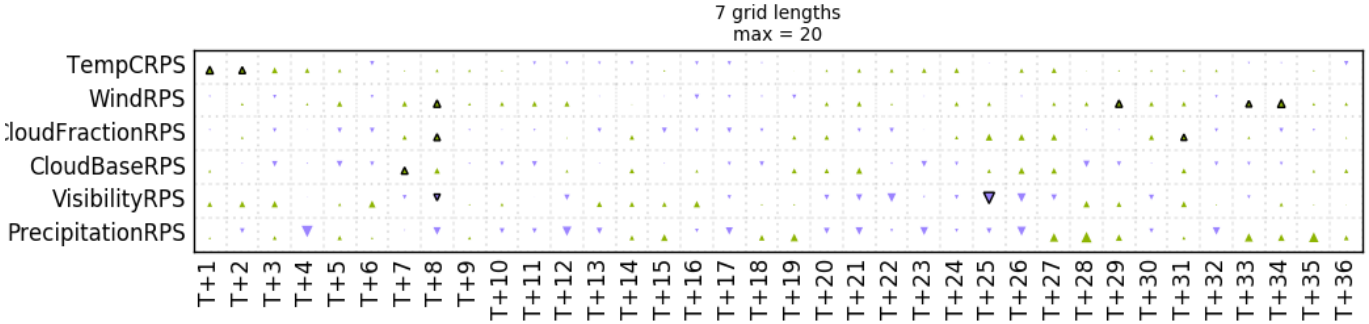
- Consistency between the increments across variables



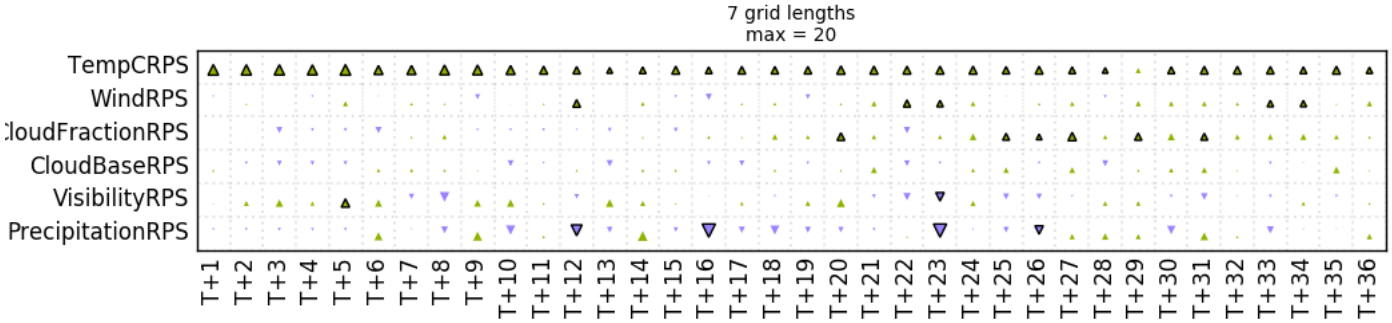
SM DA for the UK NWP system

Summer – 2 month trial

Soil Moisture DA



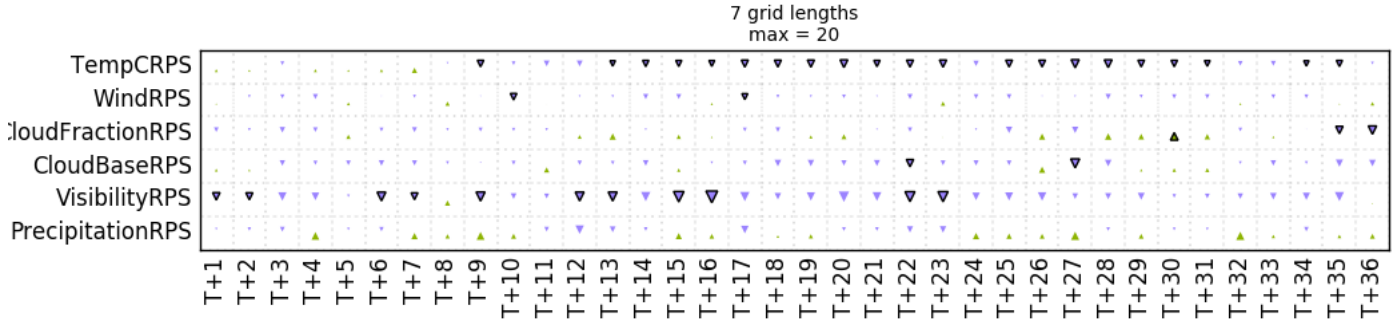
Soil Moisture and Land Temperature DA



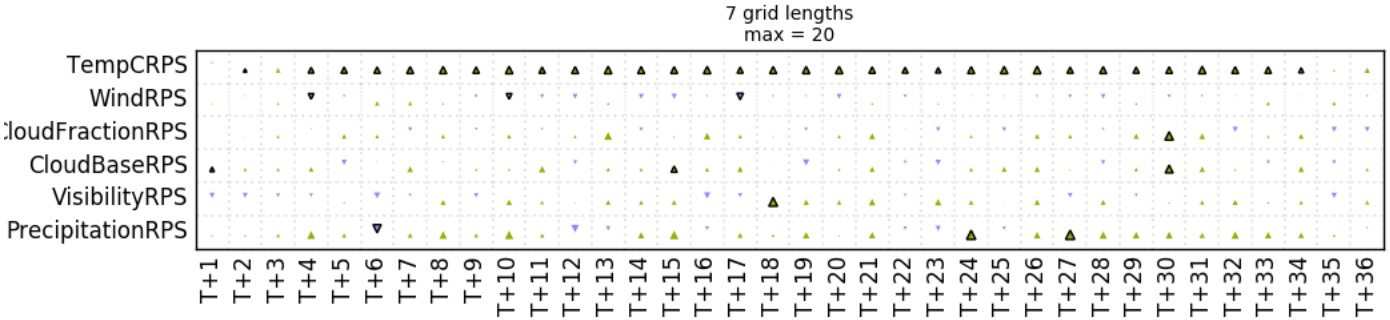
SM DA for the UK NWP system

Winter – 2 month trial

Soil Moisture DA



Soil Moisture and Land Temperature DA



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

Land temperature Analysis

NH / 1.5m Temperature RMSE and BIAS
Experiment – Control / N320 Summer