EWGLAM 2012

Met Office

Land Surface Data Assimilation at the Met Office

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This presentation covers the following areas

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  - Recent improvements to ASCAT processing
- Overview of the EKF
- Production of Jacobians
- Methods to determine observation and background errors
  - Triple Collocations
  - Desroziers Diagnostic
- Trials
- Next Steps

Current Operational Land DA System

- ❑ Soil Moisture Nudging Scheme driven by:
  - Screen T/q Errors (Physically Based)
  - ASCAT soil wetness

- ❑ Recent improvements to use of ASCAT soil wetness product:
  - Increased ASCAT weighting [slight benefit]
  - Improved Quality Control based on Level 2 product quality flags
  - Preparation for ASCAT on MetOp-B

Extended Kalman Filter land-surface DA: motivation

- Improve propagation of surface information to deeper layers

- Cater for more satellite measurements e.g. SMOS, SMAP, Land Surface Temperature estimates.

- In addition to soil moisture, move towards a consistent analysis of soil temp, albedo, snow amount…

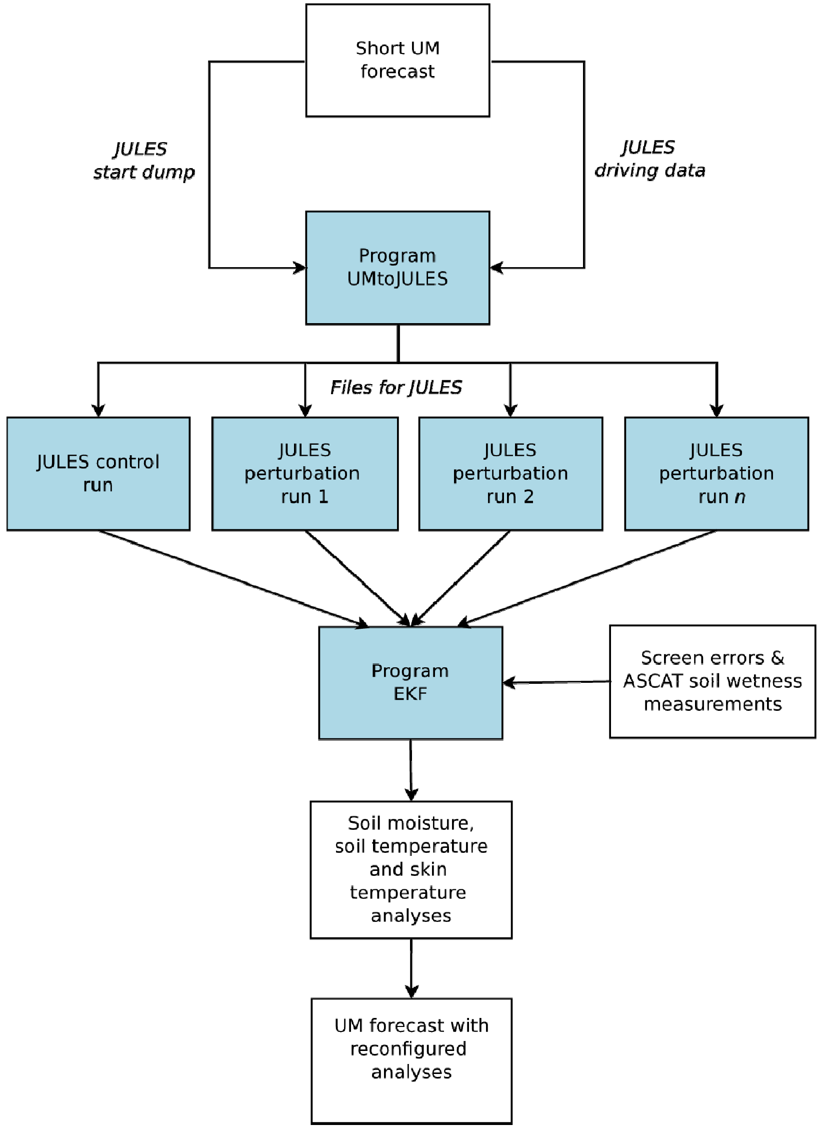
- Other centres , notably ECMWF, Meteo France, have already demonstrated the use of an EKF for Land DA and we take advantage of their work in our strategy eg offline Jacobian generation, static **B**.

Extended Kalman Filter

- $x_a = x_b + K(y - Hx_b)$ where K is Kalman gain:
  - $K = B H^T (HBH^T + R)^{-1}$
  - H requires one control fc + one fc per model variable/layer analysed
    - $H_{jk} = \dfrac{H_k(\mathbf{x}+\delta x_j) - H_k(\mathbf{x})}{\delta x_j}$

EKF-land surface DA: Jacobians

- Jacobians computed from offline runs of *JULES* – the land surface exchange scheme within the Met Office Unified Model.
- We run one unperturbed run of the land-surface model and one perturbed run per control variable (soil moisture on 4 levels + 1 skin temp + 4 soil temp = 9 perturbed runs).
- Potentially allows increments in deeper levels arising from satellite derived soil moisture, as well as at the surface.
- Length of perturbation runs set to 3 hours.



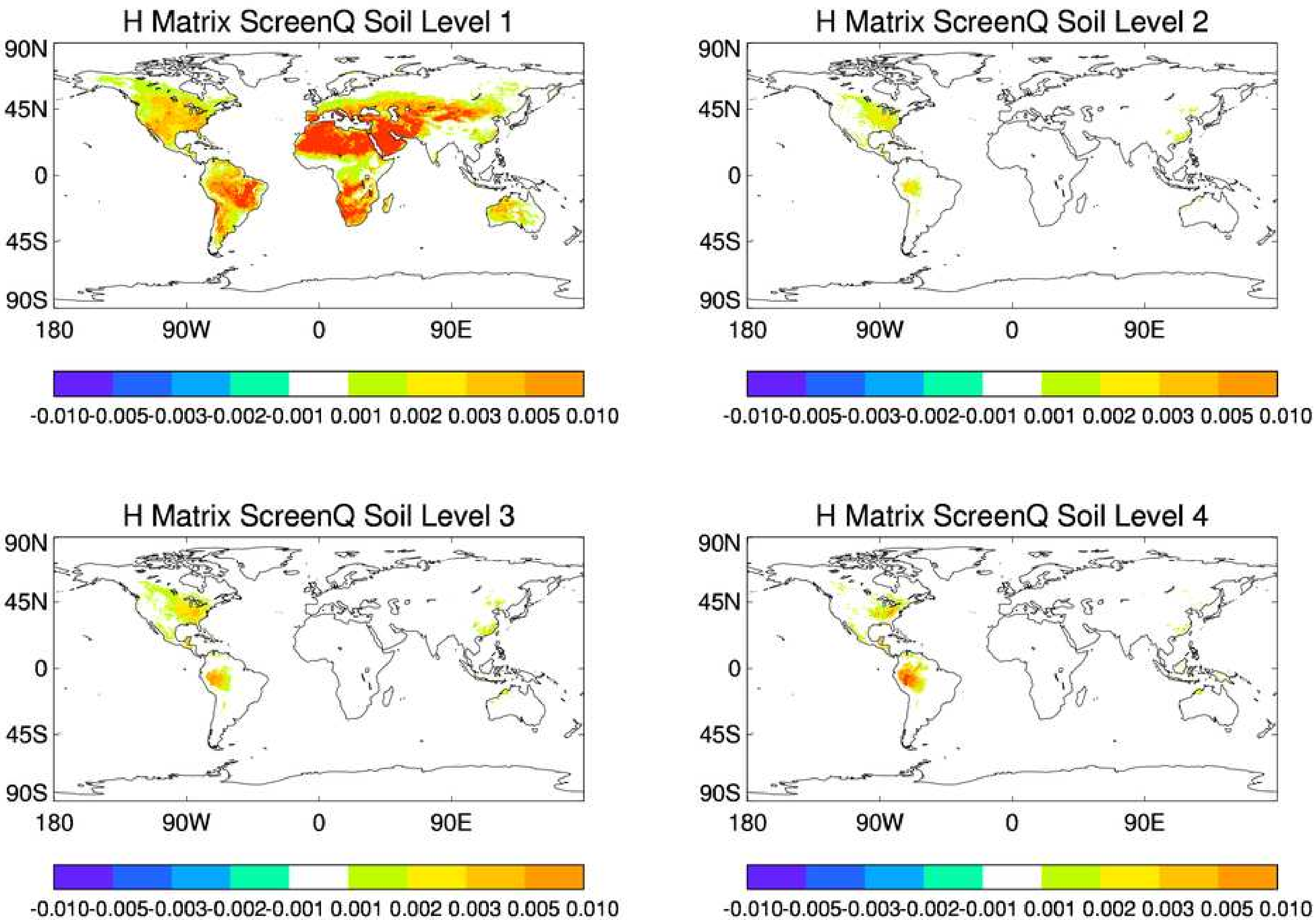
Jacobians – monthly means mid Aug- mid Sept

dscreenQ/dsm or soil moisture sensitivity to Screen Humidity

Midnight

Connection to deep layers via evapotranspitation

Too strong over bare soil at night?



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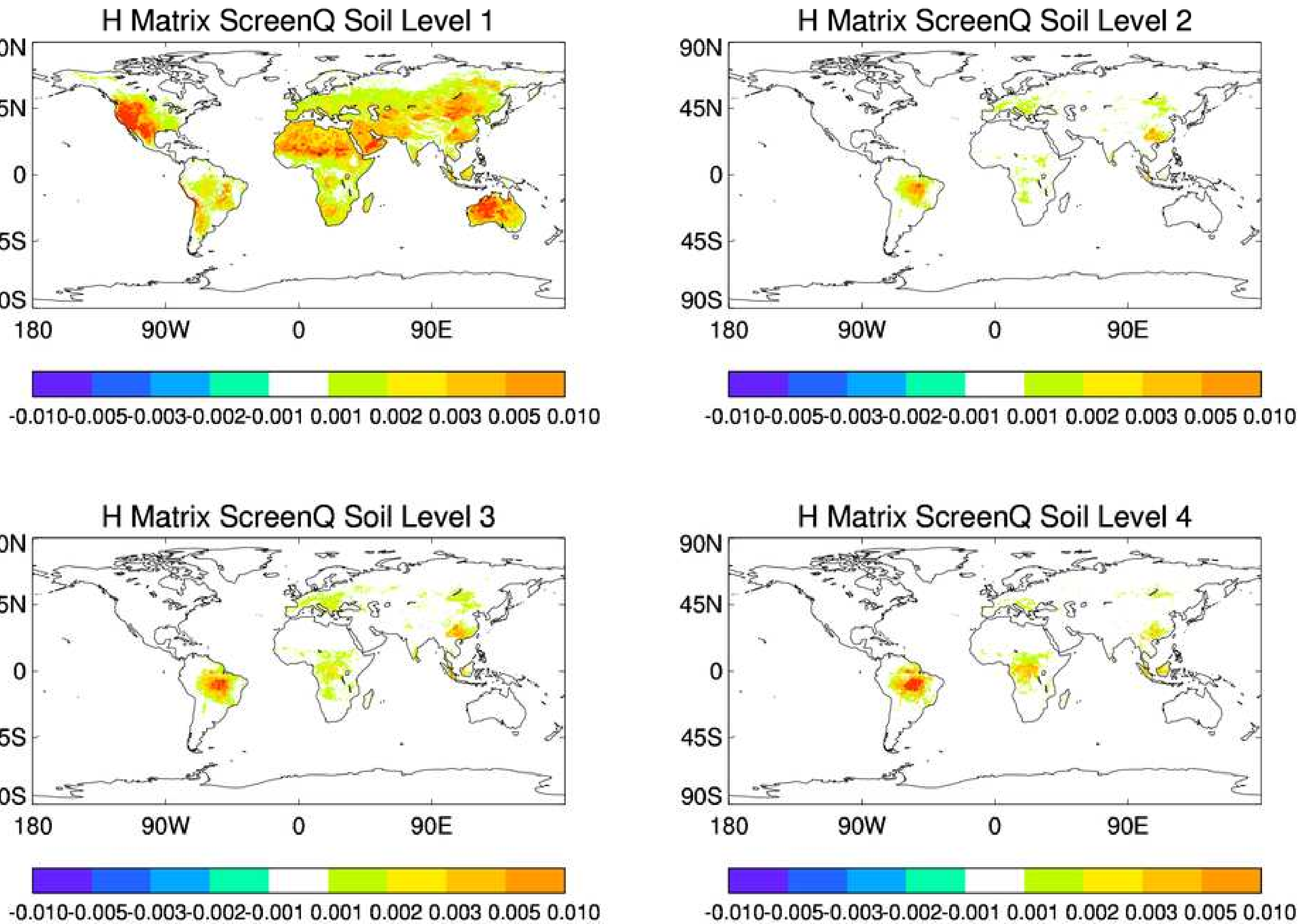
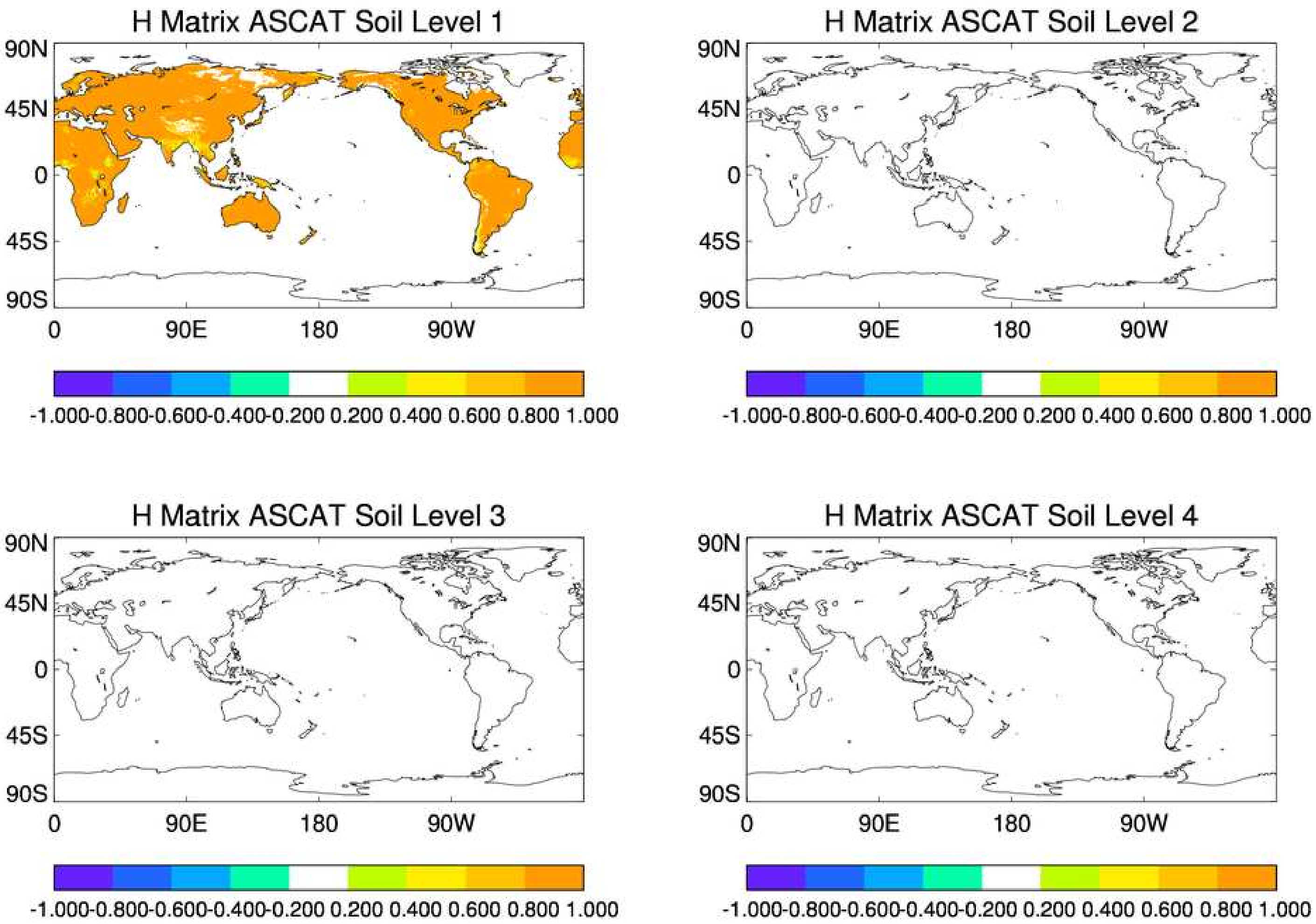


Near surface (satellite) Jacobians dsm_1/dsm_j

Investigate run times over which Jacobians computed?

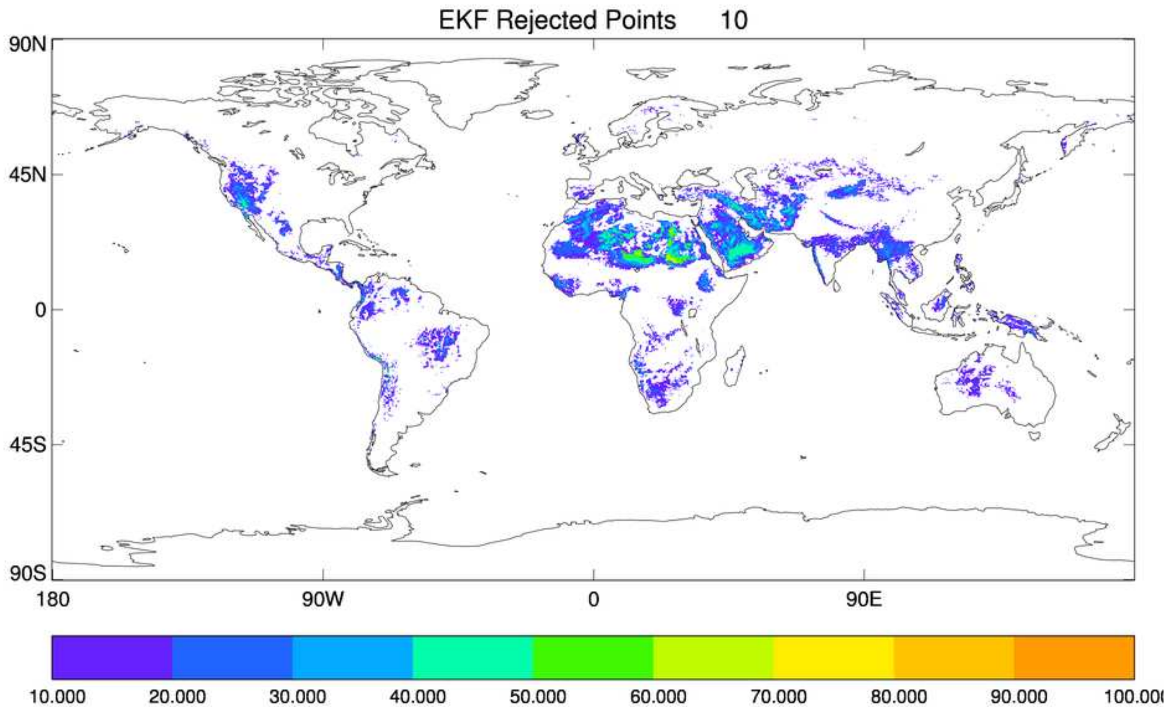


QC of Jacobians

- Screen Jacobians can become very (unphysically) large over bare soil surfaces
- Limit of Jacobians computed by assuming effective optimal wt of screen ob is < 0.5 which means that max value of H is HBH~R , ie |Jacobian| <= oberr/bgerr

Plot shows the % of time each grid point is rejected due to the threshold test

(set at ±70K/(*m3m-3)* for screen temperature and ± 0.03 g/g/(*m3m-3)* for screen humidity)



Determining Observation & Background Errors

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- Kalman Gain Matrix **K** requires realistic estimates of the observation and background errors

$$\mathbf{K} = \mathbf{BH}^{\mathrm{T}}(\mathbf{HBH}^{\mathrm{T}} + \mathbf{R})^{-1}$$

- **B is** the background error covariance matrix and **R** the observation error covariance matrix. We assume the covariances are small in each matrix. The problem then becomes estimation of the soil moisture background errors (at each level) and the observation errors e.g. the ASCAT error

- NB: The errors are specific to the model and the way we use the observations (ie not off the shelf or from other systems)

- Triple collocations employed – a common technique to diagnose observation errors in remote sensing

Determining Observation and Background Errors – Triple Collocation

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- Take 3 collocated estimates of the same parameter (e.g. soil moisture at level 1). If the estimates are *independent* then the errors can be determined from the variances

- In situ data extracted from networks shown (courtesy International Soil Moisture Network)

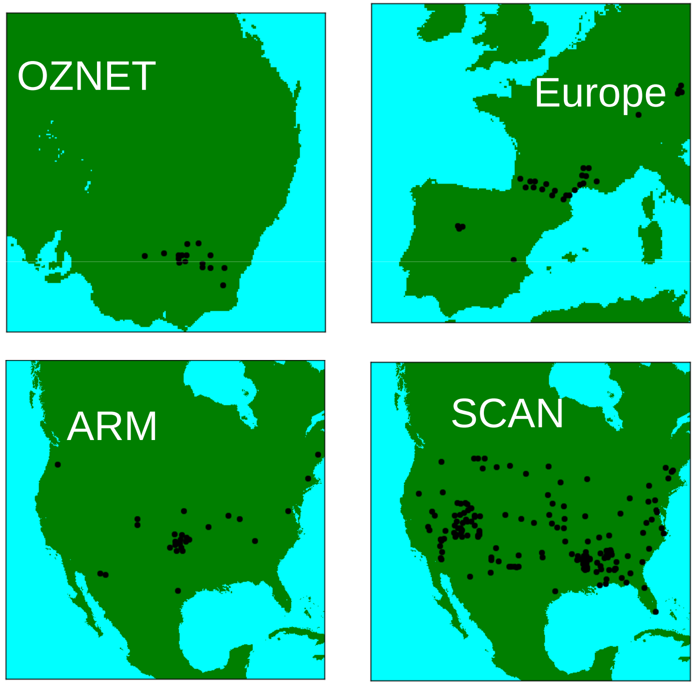
- To determine the background error:

In situ, SMOS Level 2 estimates, Met Office short range forecasts of soil moisture

- To determine the ASCAT observation error:

In situ, SMOS Level 2 estimates, ASCAT

The results here used data from 2010. More recent results suggest the satellite products have improved accuracy



parameter	Error m3/m3
Background	0.030
SMOS (v500)	0.052
ASCAT (version 1)	0.041

Determining Observation and Background Errors – Cross check with Desroziers Diagnostic

- The triple collocations provide useful estimates of errors. However we have assumed a) independent errors and b) results from regional networks are representative globally

$$(\sigma^b)^2 = \frac{1}{n}\sum_{i=1}^{n}(a-b)(o-b)$$

- Use Desroziers Diagnostic as a crosscheck. For an optimal system (e.g. VAR, Kalman Filter) where o-b , o-a are the ob-background and ob-analysis differences. 24 hours of ASCAT monitoring statistics show the following for 2011. The diagnostics are computed within *observation space* - Since ASCAT is principally sensitive to top layer moisture – we can obtain estimate for background error at this level.

$$(\sigma^o)^2 = \frac{1}{n}\sum_{i=1}^{n}(o-a)(o-b)$$

$$\sigma^{ascat} = 0.041 m3/m3$$

$$\sigma^{b} = 0.031 m3/m3$$

- Very good agreement with triple collocations

- Future improvement: spatially dependent errors?

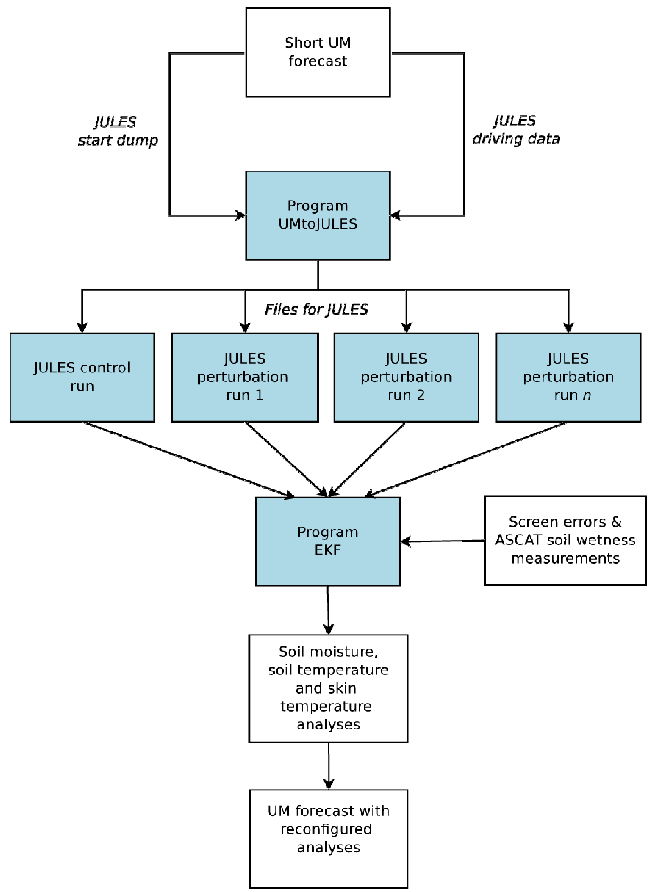
A monthly test of the EKF

A cutdown suite:

Model Soil moisture updated every cycle via the EKF or the existing nudging scheme.

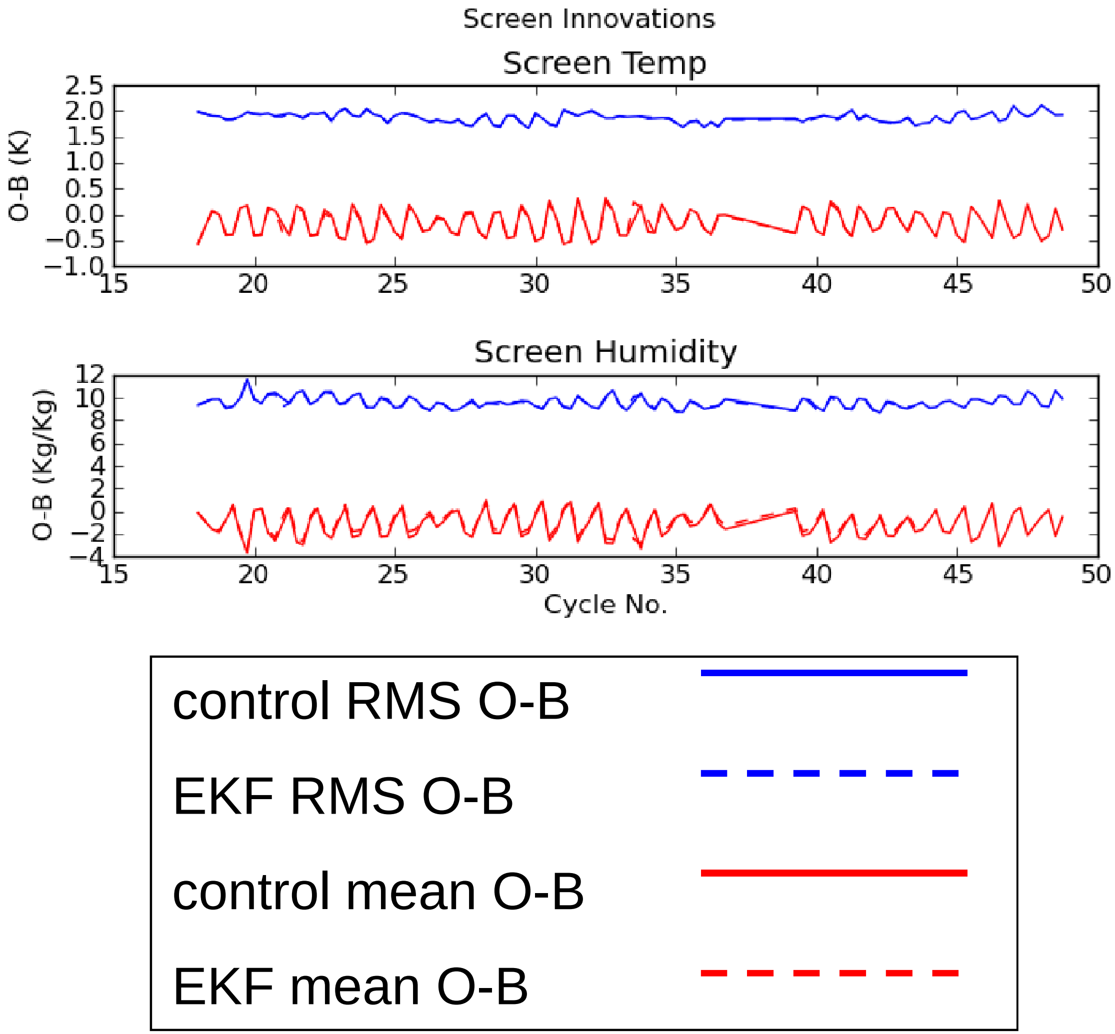
Atmospheric analysis increments taken from the operational archive for both trial and control

Runs at operational global resolution ~25km at mid latitudes



EKF land-surface DA: screen innovations

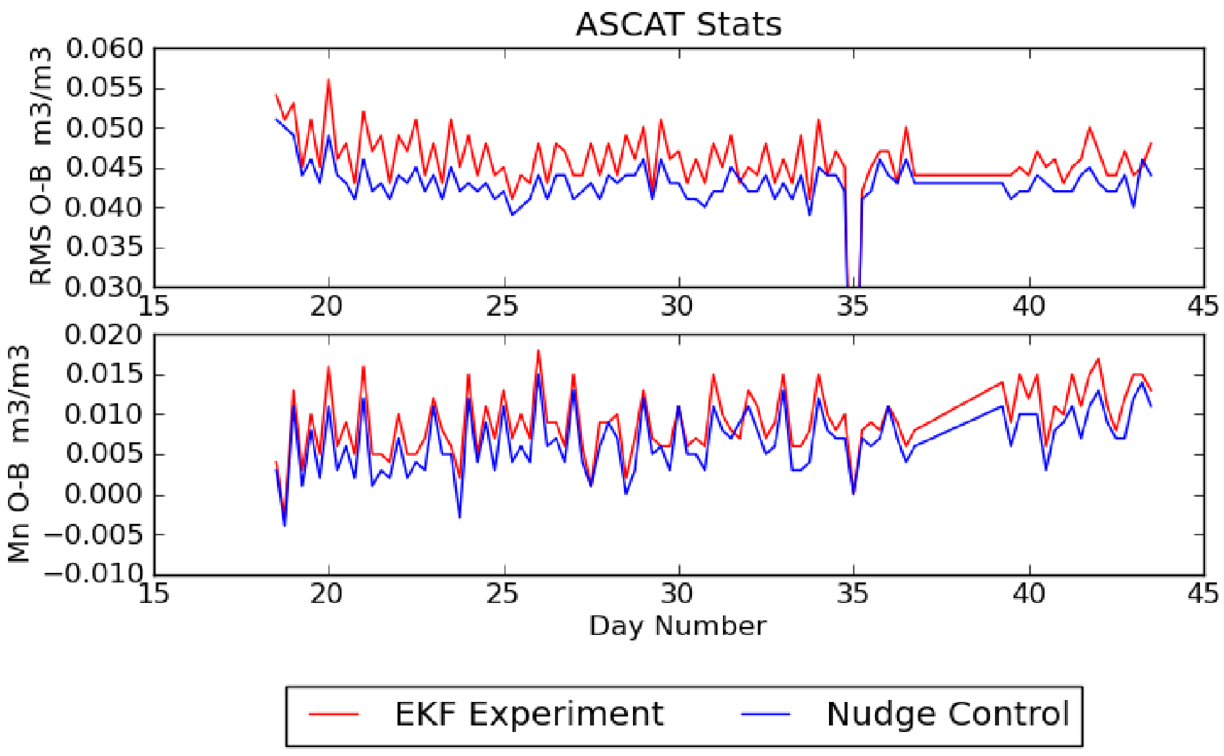
- Innovation plots show that for screen observations the fit of the observations to the background (6-hour) forecasts are very similar between control and EKF trial.



EKF land-surface DA: ASCAT innovations

- The ASCAT innovation plots highlight that the fit is less close in the EKF than the nudging scheme.

- This is to be expected as the operational nudging weight for ASCAT is **0.5**, whereas collocation studies suggests the optimal weight in the EKF is **0.35**.



Comparisons of analyses against in situ networks

Italics in each 2nd row represent EKF experiment

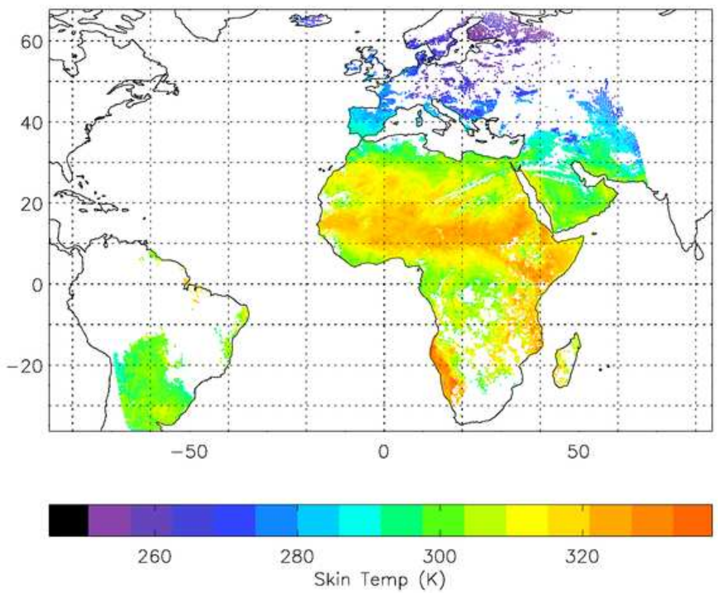
Network	**Location &No.**	**Depth (cm)**	**Station - Analysis Bias**	**Station - Analysis SD**	**Correl'n**
SCAN	US 134	5	-0.063 *-0.044*	0.037 *0.033*	0.52 *0.45*
ARM	US 10	5	0.133 *0.141*	0.023 *0.020*	0.13 *0.20*
COSMOS	US 15	~10	0.033 *0.046*	0.049 *0.046*	0.39 *0.41*
EURO	EU 9	5	-0.064 *-0.055*	0.026 *0.026*	0.15 *0.22*

Encouraging improvement to fit of analysis (both bias and sd) for SCAN network over US

Next Steps

- Full atmospheric trial underway (3 month model runs)
- Feed soil temp analysis into forecasts
- Prepare for first use of Land Surface Temperature data from polar and geostationary satellites

  LandSAF LST product from SEVIRI – 1 midday slot -



- Test forecast impact of JULES run lengths used for Jacobian generation

Conclusions

- The first version of an Extended Kalman Filter has been developed for providing soil moisture and temperature analyses. It is designed to replace the screen/ASCAT nudging scheme.

- Jacobians generated via offline runs of the JULES land surface model. Strong daytime coupling observed between low level soil moisture and screen obs in tropical forested regions.

- Observation and background errors are critical to the successful running of the EKF. Initial estimates have been derived through triple collocations and these agree well with those derived from the Desroziers diagnostic.

- As a by product of the triple collocations we find that the SMOS observation error is higher than that for ASCAT.

- A trial of the EKF, uncoupled from the atmosphere, but allowing the soil moisture to evolve, showed that the analyses have similar fit to those from nudging – compared to in situ stations.

- Trials now underway to determine the impact on atmospheric forecasts, particularly near surface temperature and humidity.

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Questions?