Land Surface Data Assimilation at the Met Office

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Outline

- SURF
  - Current System
  - Recent developments: Variable Grids, LST
  - Work in progress: Snow OI analysis
- LIS
  - New Land DA Software to replace SURF
Current System
Soil Moisture and Soil Temperature Analysis
Snow Analysis
Simplified Extended Kalman Filter

\[ x_i^a = x_i^b + K_i \left( y_i^o - H_i(x^b) \right) \]

\[ K_i = BH^T \left( H^T BH + R \right)^{-1} \]

- Implemented in the Global model since 2013.
- \( x \) Control Vector – soil moisture and soil temperature at 4 depths down to 3m.
- \( y \) Observation Vector
- \( H \) Jacobians, observation operator
- 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)
Current Observation Sources

Pseudo-observations

1.5m Temperature

1.5m Humidity

ASCAT L2 soil wetness product

- Soil wetness from ASCAT instruments onboard Metop-A,B
- Rescaled to Soil moisture using model soil climatology

3dVAR
Jacobian Calculation

H operator

\[ H_{m,n} = \frac{\partial H(x)}{\partial x} \approx \frac{H_m(x_{t2}^p) - H_m(x_{t2}^c)}{\Delta x_{n,t1}} \]

H(x) represents a prognostic or diagnostic variable from Jules (i.e. 1.5m Temp or Hum, Soil moisture at Lev 1)
Soil Moisture and Soil Temperature Analysis

- Soil Moisture and Soil temperature are calculated every 6h on the global domain.
- Only soil moisture is used in operations.
- Global soil moisture is interpolated to the UK domain every 24 hours.
Recent Developments
Extended Kalman Filter for variable grids

- Error-covariance statistics from the Global set-up.
- Screen temperature and humidity pseudo-observations
- Analysis every 3 hours. Jacobians are calculated on a 2 hour window.
- Two different start conditions were tested:
  - Global Reconf: Global, low resolution, temperature and humidity. Temperature has a coarse structure. Soil moisture structure is defined by soil properties.
- Trial period: from 15/06/2015 to 15/07/2015.
EKF for variable grids

Trials initialisation

Soil Wetness

Global Reconf  Jules Spin-up

Soil Temperature

Global Reconf  Jules Spin-up
EKF for variable grids

Relative humidity

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<th>Score</th>
<th>Test - control</th>
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Temperature

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– Control – G. Reconf – Jules Spin-up
Land Surface Temperature

• Contract with ESA to test possible uses for GlobTemperature product.

• There are now several sources of good quality land surface temperature (LST) measurements from both polar and geostationary infrared instruments. These observations have the potential to improve both the soil temperature and soil moisture.
Comparisons between Met Office Global Model LST [left] and observations from ESA's GlobTemperature LST dataset reveal large biases (model not warm enough), particularly during daytime.

This result is also seen when other sources of satellite LST are compared to the NWP Model.
Land Surface Temperature

- Trial ran on August 2013
- Data is assimilated only at nighttimes
- Verification against surface obs in Africa.

Despite these differences in model and satellite, after bias correction of the observations initial experiments show a small improvement to near surface air temperature forecasts, for instance over Africa.

**Red**
Control
[met station data & scatterometer ]

**Blue**
Control + LST assimilated
Future developments
Optimal Interpolation for Snow Depth
Snow DA for the UK NWP system

In development....

**Data source**
- Ground-based obs of snow depth, and state of ground (snow or no snow) from synoptic network
- Satellite-derived snow cover from H-SAF (MSG-SEVIRI) daily product
- Model first-guess SD

**Snow depth values**
- SD where reported
- 0 m SD from snow-free state of ground reports
- 0 m SD from snow-free pixels
- 0.05 m SD from snow-covered pixels where model snow-free

**Optimal Interpolation**
- Snow depth analysis
Land Information System
LIS Evaluation

- Met Office has been evaluating LIS for the last 6 months
- Many aspects have been considered: technical, scientific and strategic.
- Conclusion of the evaluation is to replace SURF with LIS in the medium term: 2-3 years.
LIS Evaluation

- Capability for modelling, DA, quality control, bias correction and verification, among others

- A mature standalone application used by a growing community.

- Allows addition of new observations and algorithms in a relatively easy way.
Summary and Plans

- SURF is now able to:
  - Use the Extended Kalman Filter for any type of UM grid, i.e.: Global, Limited area rotated pole and variable grids.
  - Assimilate LST data from ESA GlobTemperature product (this product is not operational)
- Under development:
  - Snow DA using optimal interpolation
- LIS will replace SURF in the medium term.
- Use of observations:
  - SMOS, SMAP
  - AMSR-2, SAR (Sentinel-1)
  - ...
A mailing list to enhance collaboration and communication

• Discussion of research and developments at our respective institutes
  • Circulation of relevant publications
  • Advertising workshops and conference sessions
• Raising issues and initiatives of interest to the land DA community
• Managed at the Met Office (current list owners Breo Gomez and Samantha Pullen)

To subscribe to the list:
Mail to: majordomo@metoffice.gov.uk
Body : subscribe land-surface-da

To write to the list:
Mail to: land-surface-da@metoffice.gov.uk

To contact list owners:
land-surface-da-owner@metoffice.gov.uk
land-surface-da-approval@metoffice.gov.uk

Please forward information to any colleagues who might be interested
Thank You
Snow observations

Ground based snow depth reports
As a member of the Global Cryosphere Watch Snow Watch Team, Sam is involved in efforts to improve in situ reporting practice and exchange of national network data. A recommendation to WMO CBS-16 (late Nov 2016) has been drafted on International Exchange of Snow Data, and includes guidance on:

- Snow depth should be reported whether snow is present or not, i.e. zero snow depth (0 cm) should be reported when snow is not present. This will provide the NWP community with valuable extra data for use in assimilation and validation of satellite snow products, e.g. constraining model snow extent

- Member States are encouraged to exchange the snow depth data from their national networks, in BURF format, on the GTS. This will give NWP centres much improved data coverage for data assimilation (impact studies at ECMWF show benefit of adding national network data from Sweden and Bulgaria to their snow DA)

For more details, see: http://globalcryospherewatch.org/projects/snowreporting.html

Snow observations for potential future assimilation
- AMSR-2 snow depth – plan to assess product for potential global assimilation (in addition to in situ obs) – uncertainties may be too large, v2 will have dynamic density/grain size estimation

- UK wet snow cover from SAR (sentinel-1) – useful for UK snow (which tends to be wet) to complement snow cover from optical instruments, in cloudy conditions

- Microwave radiance assimilation with snow emission RT model? Longer term plans!
Daily NH snow analysis

NESDIS IMS 4km Snow Cover

Relative resolutions

Gridbox Fractional Cover

Relating fc and depth

Model Background T+6 Snow Amount (kgm⁻²)

Currently being trialled.

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JULES 4

- SURF is fully compatible with JULES 4, including variable resolution grids.
- Allows to set-up Jules to the same version, and model configuration as in the atmospheric model.
- Various trials show neutral impact on data assimilation and the atmospheric model solution.
- Much more efficient use of resources: (MPI, IO)
JULES 4

Jules 3 vs Jules 4.4

EKF Statistics Soil Moisture Level 1

EKF Statistics Soil Moisture Level 2

EKF Statistics Soil Moisture Level 3

EKF Statistics Soil Moisture Level 4
LIS evaluation

It also has some limitations for Met Office applications, which would imply an effort in development time and resources:

- It only allows for sequential data assimilation
- Does not read the observation types that the Met Office uses in operations
- Current Met Office operational algorithm, Extended Kalman Filter, not available
- However, USAF 557th Weather Wind is interested in implementing current SURF capabilities into LIS. The Met Office is going to be involved in the development.
Extended Kalman Filter scheme

- Jacobians are computed offline runs of \textit{JULES} – the land surface exchange scheme within the Met Office Unified Model.

- To do this 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).

- This potentially allows increments arising from satellite derived soil moisture to update in deeper levels as well as at the surface.

- The length of perturbation runs have been set to 3 hours.