# Snow data assimilation developments at the Met Office

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## Why does snow matter for the UK?

- In the UK snow is a low frequency high impact event
- $\bullet$  Errors in snow depth  $\rightarrow$  large surface temperature bias







Aim of performing snow analysis:

- 1. Improve representation of snow at analysis time
- 2. Improve forecasts of screen level variables



## Snow DA for the UK NWP system

## H SAF snow cover product



H-SAF daily snow cover (H31)

- MSG-SEVIRI (geostationary), ~4 km at mid-lat
- Fully snow-covered, partially snow-covered, snow-free
- Composite from temporal integration of scene classifications at 15 minute intervals, over previous 24 hours.
- High temporal sampling of H-SAF product results in large reductions of cloud-affected pixels in composite product relative to products from sun-synchronous sensors
- Comparable or higher mapping accuracy, despite coarser spatial resolution of SEVIRI product (Surer et al., 2013 doi:10.5194/hessd-10-12153-2013)



Support to Operatione Hydrology and Water Management

Network of Satellite Application Facilities

## Optimal interpolation method

Following Brasnett et al, 1999, and ECMWF operational snow DA

The analysis is represented by a weighted combination of the background and observations, where optimum weights are found in order to give the minimum variance of analysis error.

$$x^{a} = x^{b} + W[y - Hx^{b}]$$

$$\Delta S_{g}^{a} = \sum_{i=1}^{N} W_{i} \Delta S_{i}$$
Analysis increments are calculated as the sum of weighted observation innovations for each gridbox.
Weights are calculated from ob and gerror covariances, which depends on relative horizontal and vertical separations between obs and gridbox, and their error variances.
We (B+0)^{-1}(b)  $\sigma_{b}^{2} \times \alpha(r_{i}) \times \beta(\Delta z_{i})$ 

$$\sigma_{b}^{2} \times \alpha(r_{i}) \times \beta(\Delta z_{i}) \qquad \sigma_{b}^{2} \times 1$$
Definition of the error variance of

~(\* (j)

## Quality control and tuning

## QC on observations



#### *In situ* obs

- Reject observations with unrealistic snow depth for their reported screen temperature (T1.5 > 278 K and SD > 1cm)
- Remove duplicate reports from same station (use the one closest to cycle time)

Satellite obs

- Reject snow-covered where model also snow-covered
- Apply mountain mask (reject if >1500m)



Based on observation and background error variance

- Reject obs for which O – B > 0.25 m tolerance ×  $\sqrt{(\sigma_o^2 + \sigma_b^2)}$ 

## Observation and background errors

- Background error sdev ( $\sigma_{b} = 0.03 \text{ m}$ )
- Synop observation error sdev ( $\sigma_o = 0.04 \text{ m}$ )
- HSAF observation error sdev ( $\sigma_0 = 0.08 \text{ m}$ )



QC on analysis increments

- Max increment allowed = 37.5 kgm<sup>-2</sup> (0.15 m)
- Positive increment allowed only if model T1.5 < 281 K</li>
- Check for negative snow amounts
- No increments on land ice, inland water, urban surface – increments scaled for remaining surface types for consistency with grid-box mean
- No increments where majority of gridbox land ice, inland water, urban

Optimal Interpolation parameters

Horizontal correlation length scale (L = 5.5 km)
Vertical correlation length scale (h = 400 m)
Search radius around gridbox within which obs can be used (R = 50 km)

Max number of obs to consider for each gridbox (N = 50)

## Met Office Assimilation trials

- Assimilation trials run for Winter 2017, Summer 2018
  - 1 month, full UK NWP suite (4D-Var, hourly cycling)
  - snow analysis run once a day at 06Z, analysed gridbox-mean and tile snow amounts reconfigured in before forecast run
- Dec/Jan 2017 trial period lots of snow activity, ideal testing conditions
- Verification of model snow depth hard!
  - use satellite snow cover products to validate snow extent, but only if cloud-free
  - lack of suitable independent observations of snow depth/SWE
- Evaluation mainly through effects on forecast errors of atmospheric variable
- Small modification in progress to handle some unwanted effects related to urban roof tile
- Further trials in coming weeks, in preparation for potential implementation in next upgrade package for parallel testing



### Observations going into OI

**Met Office** 





#### **Met Office** NWP forecast verification





### **≫Met Office** Next steps...

- Further assimilation trials
  - Additional verification using station location error maps
  - Consultation with forecasters
  - Check multi-layer snowpack evolution
  - Interaction with land temperature analysis
- Target next operational upgrade package
- Adapt for use in global model
  - Alternative satellite snow cover data
  - Use additional national network snow depth and SWE obs
- Increase frequency of snow analysis to 4 times daily



