Overview of operational land surface data assimilation at the Met Office

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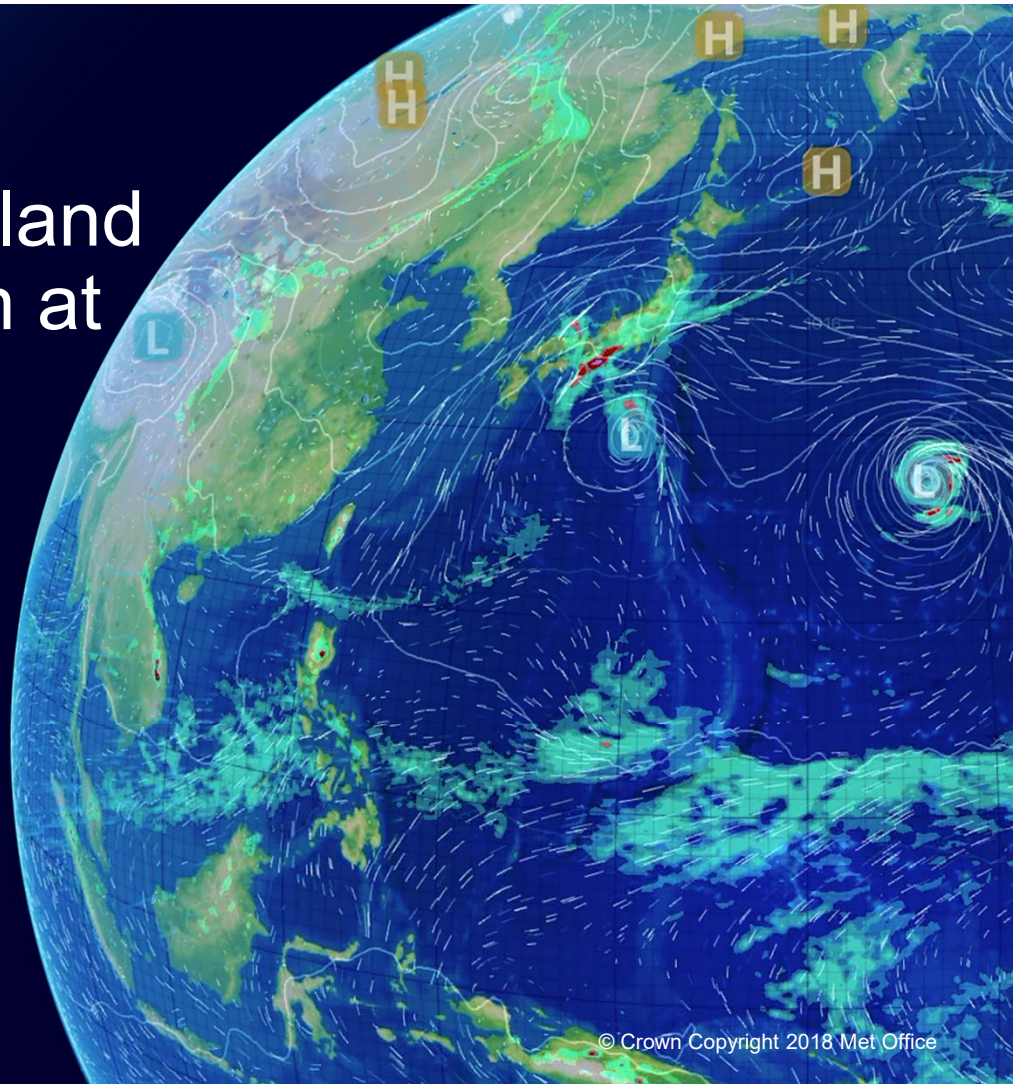
ISWG July 2019

Montreal, Canada



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Outline of talk

- Global soil moisture analysis *current*
- Regional soil moisture analysis *current and imminent*
- Assimilation of new soil wetness product: MetOp-C ASCAT L2

- Global Snow analysis *current*
- Regional snow analysis *(Samantha Pullen's talk at 9:50, Wednesday)*

- Future work

Met Office

Operational Status: Global Soil Analysis

- Global analysis of soil moisture produced every 6 hours
- Global assimilation method: **S**implified **E**xtended **K**alman **F**ilter

$$x^a = x^b + K\left(y - \mathcal{H}(x^b)\right)$$

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

- Pseudo-observations computed using 3DVar on surface obs. provides gridded fields of 1.5m Temperature and Humidity.
- ASCAT soil wetness product converted to soil moisture content (SMC)

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Met Office land surface model

- JULES (the **J**oint **U**K **L**and **E**nvironment **S**imulator) is a community land surface model
- References:
  - Best et al. (2011): *The Joint UK Land Environment Simulator (JULES), model description – Part 1: Energy and water fluxes.* Geosci. Model Dev. 4:677–699.
  - Clark et al. (2011): *The Joint UK Land Environment Simulator (JULES), model description – Part 2: Carbon fluxes and vegetation dynamics.* Geosci. Model Dev. 4:701–722.
- 4 soil layers, thickness: 10 cm, 25 cm, 65 cm and 2 m
- van Genuchten soil hydraulic model

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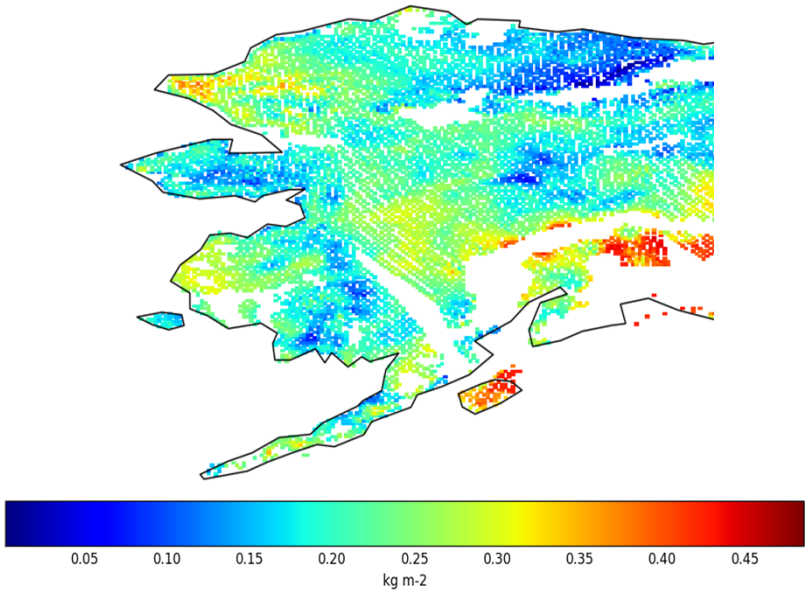
ASCAT to Model: Interpolation

- Global atmospheric model upgraded from ~17km to ~10 km resolution (July 2017).
- Each ob. uniquely paired with model grid point
- Model resolution became sufficiently higher than obs resolution leaving model grid points without information.
- **Solution: Inverse Distance Weighting**



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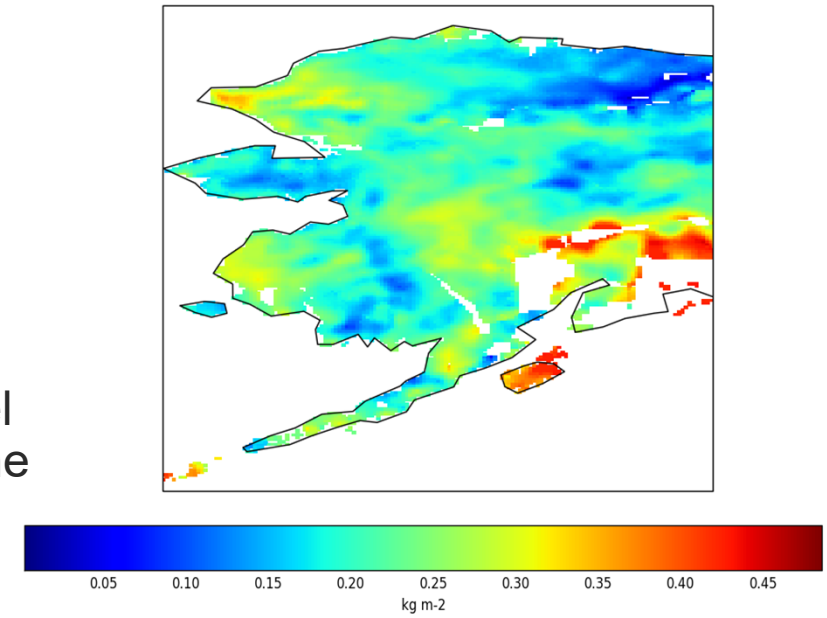
ASCAT to Model: Interpolation

Inverse Distance Weighting

- Handles coastlines
- Is applicable to both Global and LAM
- Can be expensive: requires loop over model grid points to calculate distances between the model grid points and all observations, but...
- …it can work efficiently with a subset of points or *neighbourhood search*
- Depends on parameter choices: search distance and weighting function



ASCAT to Model: Variable

- ASCAT soil wetness converted to UM units: Soil Moisture Content [kg/m^2]
- Bias correction applied using UM soil moisture climatology.

$$\theta_{L1} = \overline{\theta_{L1}} + \frac{\theta_{DR}}{SW_{DR}}(SW - \overline{SW})$$

- $\overline{\theta_{L1}}$ estimated by running standalone Jules at 0.5deg with the WFDEI
- SW ASCAT Soil Wetness Index measurement
- $\overline{SW}$ ASCAT Soil Wetness Index climatology
- θ_{DR} Soil moisture dynamic range (model soil properties)
- SW_{DR} Soil wetness index dynamic range (1.0)

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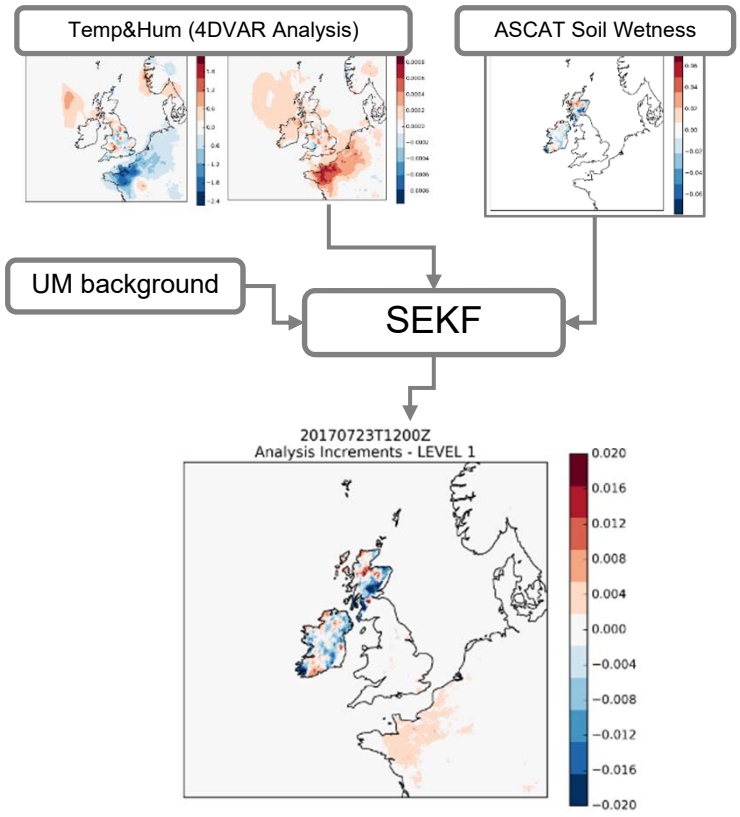
Regional (UKV) Soil Moisture Analysis

Currently in operations:

Daily (09Z) reconfiguration of global analysis to the regional domain

New: UKV Soil Moisture analysis

- *Replaces the daily reconfiguration of the Global SMC analysis*
- Follows the same methodology used in the Global NWP suite.
  - Algorithm: **S**implified **E**xtended **K**alman **F**ilter
  - Observations: Screen temperature and humidity from 4DVAR atm. analysis & ASCAT soil wetness
- Hourly cycling
- Provides soil moisture analysis



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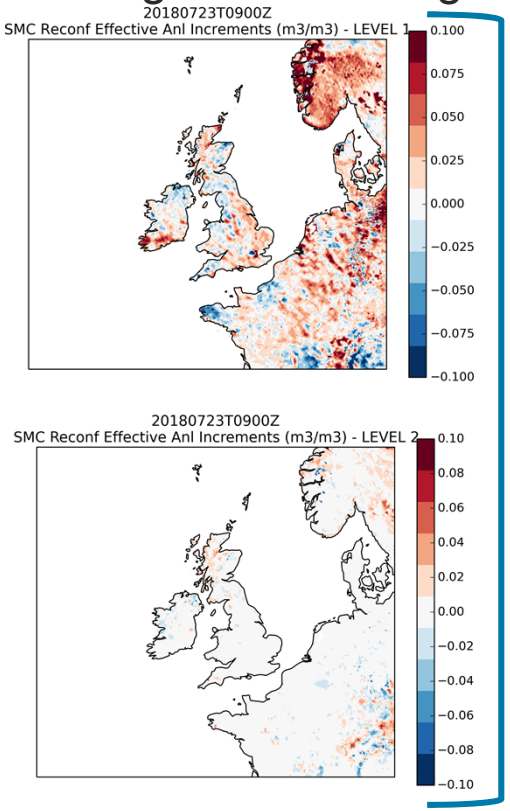
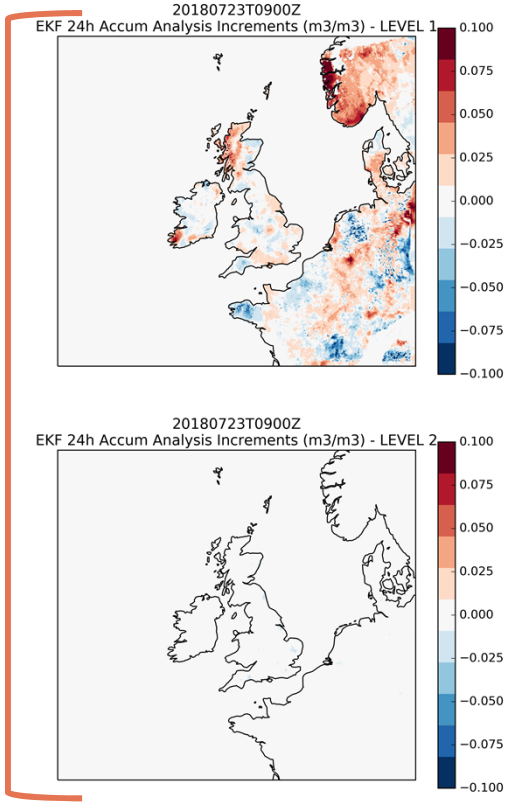
Old: Reconfiguration from global

New: Assimilation via SEKF

Level 1
Soil moisture
increments





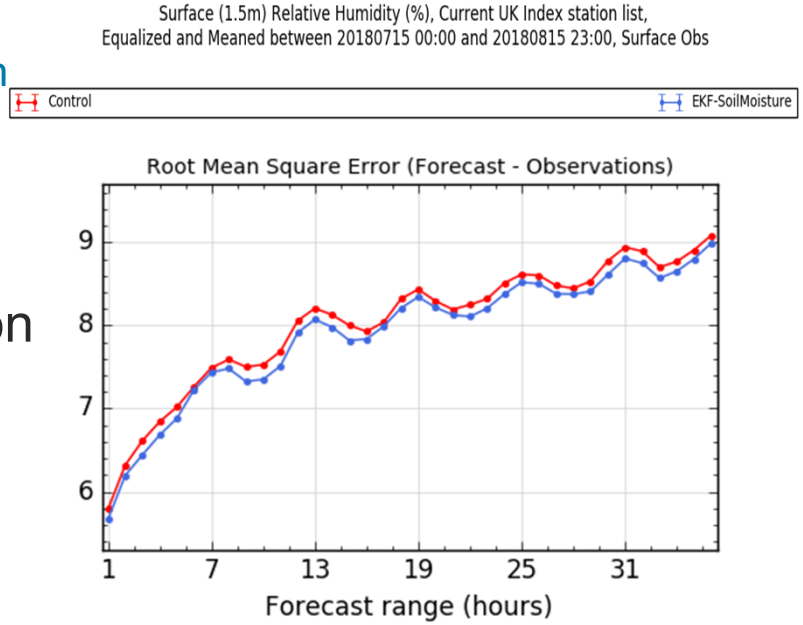
Level 2
Soil moisture
increments

old increments (24 h) are both larger and noisier than equivalent new increments (24 h accumulation)

Summer Trial

Trialling UKV Soil Moisture analysis

- Summer and Winter trials (1 month each)
- Verification scores show neutral results across all variables except:
  - Small improvement in the RMSE of summer screen humidity
  - Very small degradation in the bias of winter screen temperature and humidity
- Why does the system have a small impact on the surface?
  - We might need to fine tune the parameters (e.g. observation errors)
  - Conflict with land temperature increments
  - The impact happens in other areas: hydrology



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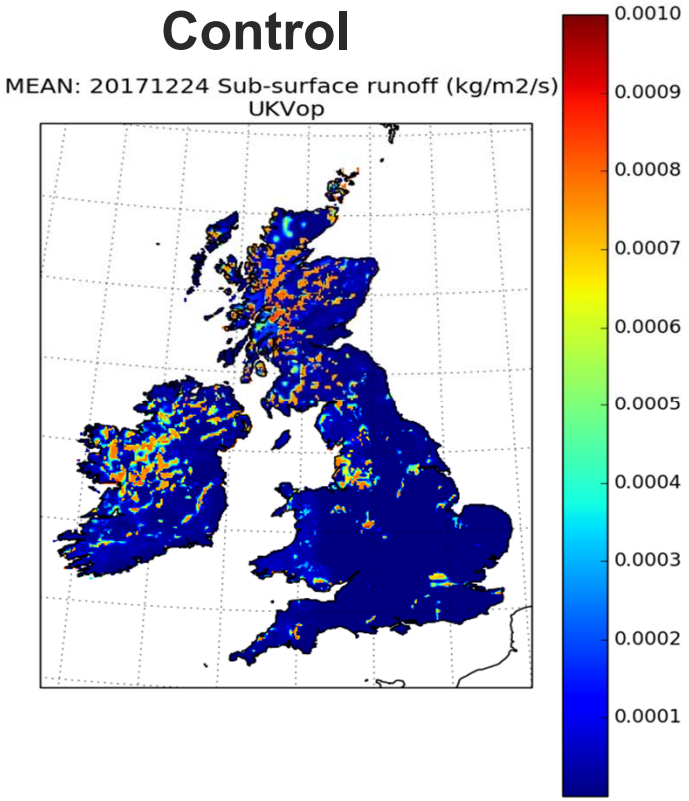
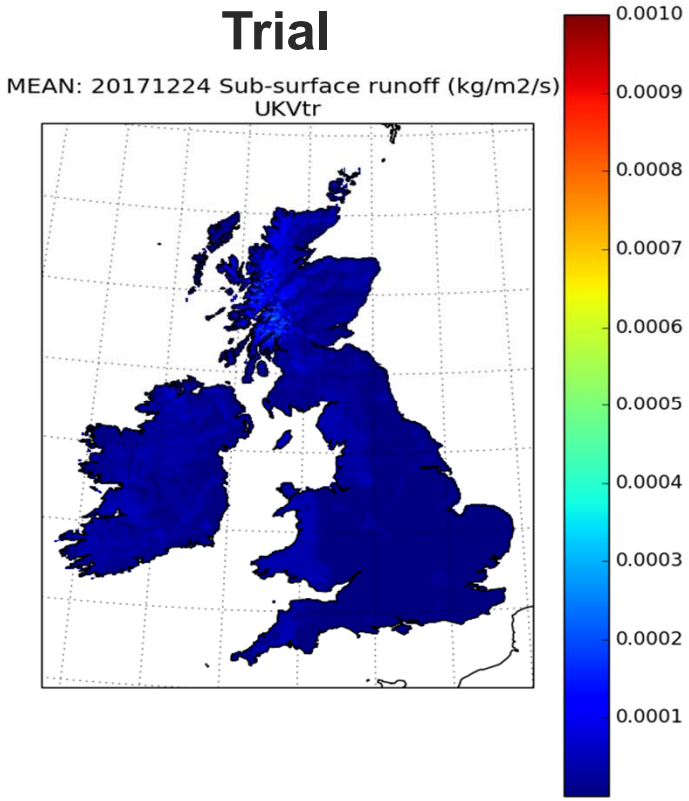
Daily averaged sub-surface runoff (Winter trial)

Control



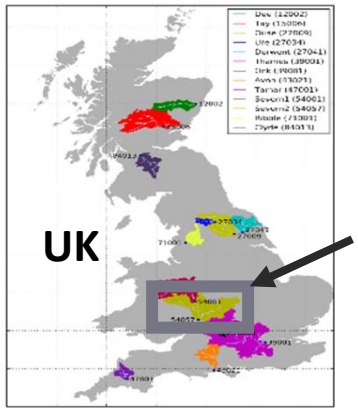
Trial



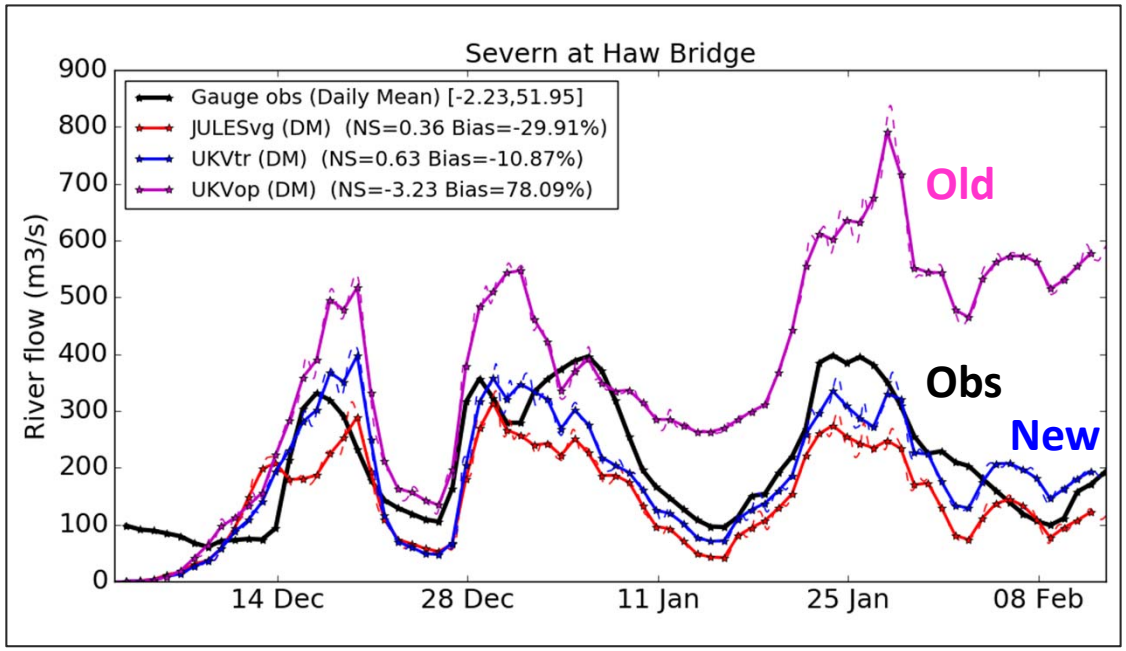
UKV Soil Moisture analysis changes surface and subsurface run-off

Special thanks to Huw Lewis

New: UKV Soil Moisture analysis



- Improved run-off leads to improved river flow
- Simulated river flows are much more realistic for the trial with EKF



Special thanks to Huw Lewis

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Summary: New UKV soil moisture analysis

- Small impact in atmosphere
- Large impact on hydrology, with very promising results! (Huw Lewis)
- Fully compatible with rotated pole grids since February 2019
- Will become operational in November 2019.

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New Soil Wetness Observations

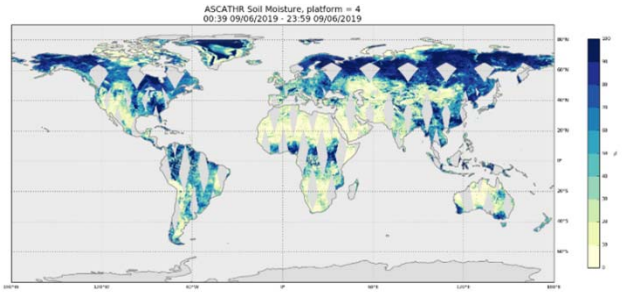
Assimilation of ASCAT L2 product from MetOp-C satellite

Starting July 2019

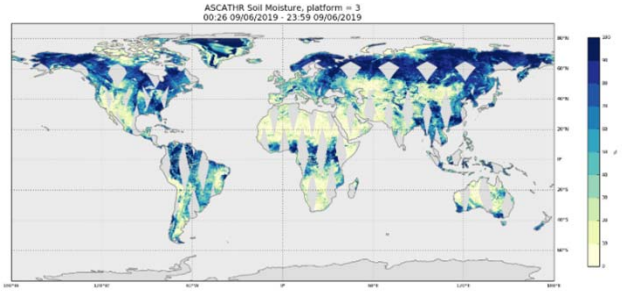
ASCAT soil wetness from new MetOp-C

Monitoring against established products already assimilated

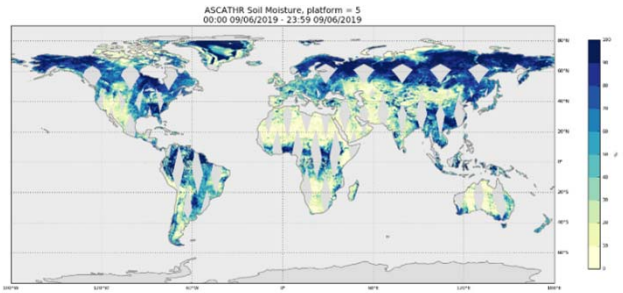
MetOp-A: From 19/10/2006



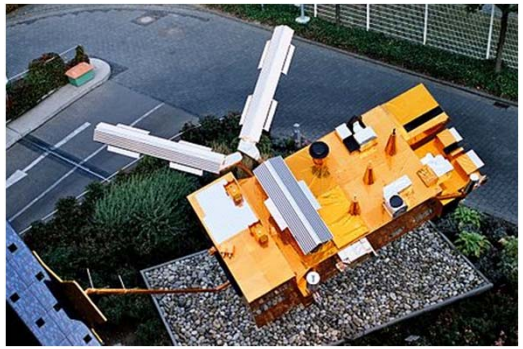
MetOp-B: from 17/09/2012



MetOp-C: from 07/11/2018



- Same sensor as MetOp-A&B



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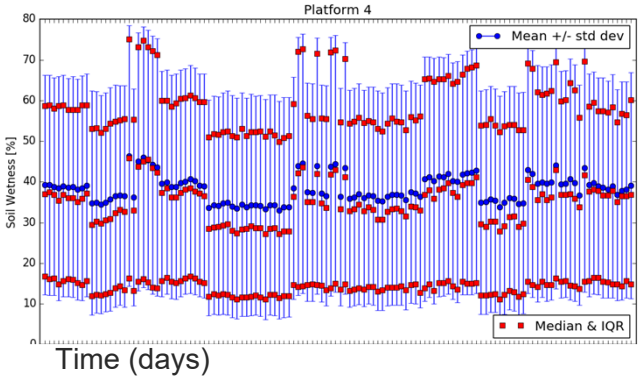
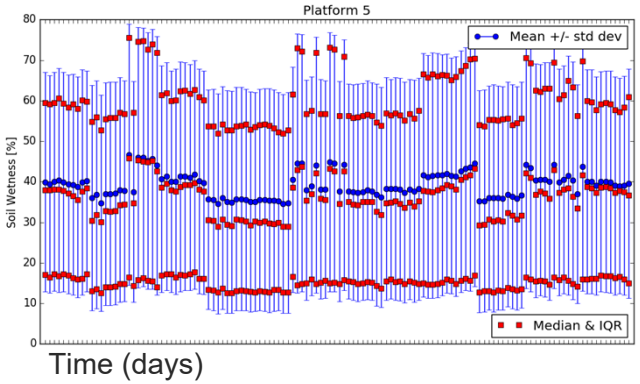
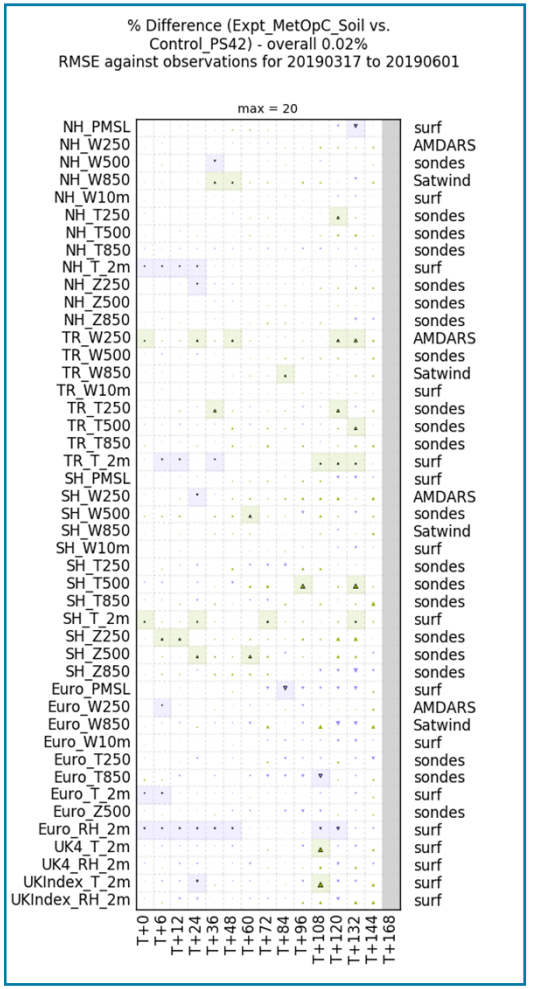
Extensive daily monitoring of obs and innovations 1 Feb 2019 - present

MetOp-A ASCAT soil wetness



MetOp-C ASCAT soil wetness





- Global (N320) trial
- 3 month evaluation: 17 March- 6 June 2019
- Neutral impact
- Will be added as operational change (no further testing)
- Provides resilience in case of a MetOp-A or -B failure.

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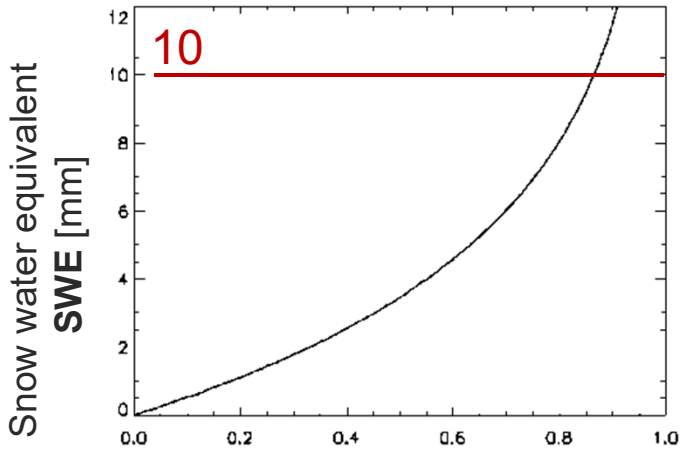
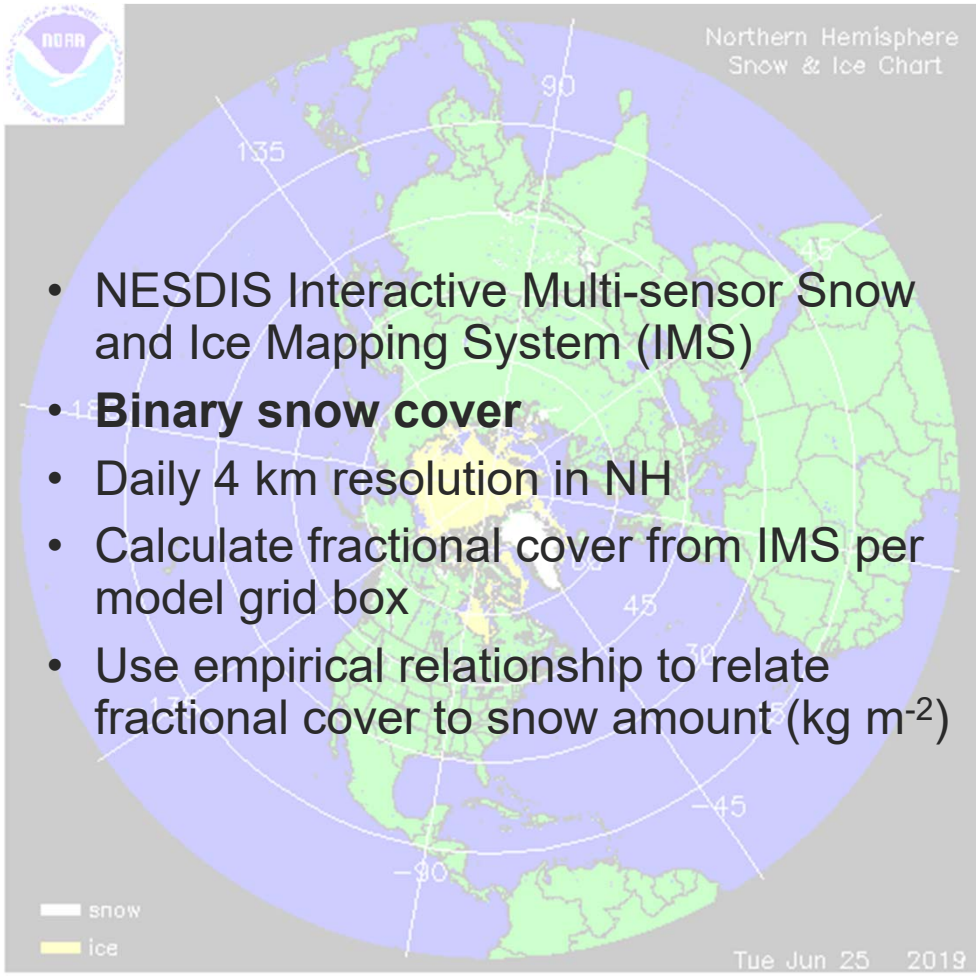
Global NH Snow Analysis

Convert obs snow cover to model snow amount



$$SWE = \frac{[-\ln(1 - fc)]}{D}$$

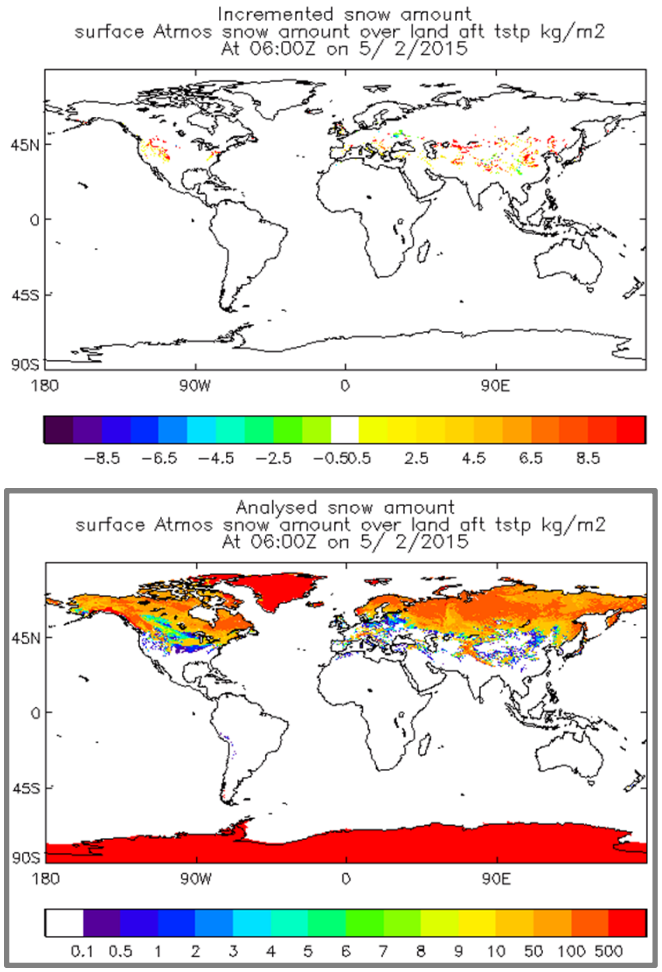
D = masking depth of vegetation (0.2 m^2 kg^{-1})



- NESDIS Interactive Multi-sensor Snow and Ice Mapping System (IMS)
- **Binary snow cover**
- Daily 4 km resolution in NH
- Calculate fractional cover from IMS per model grid box
- Use empirical relationship to relate fractional cover to snow amount (kg m^{-2})

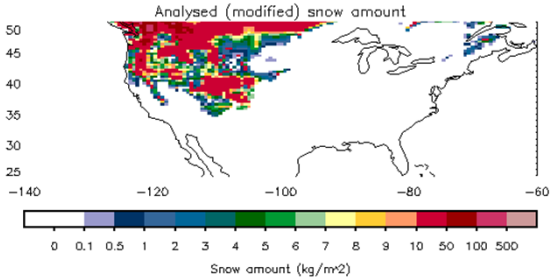
Simple update scheme

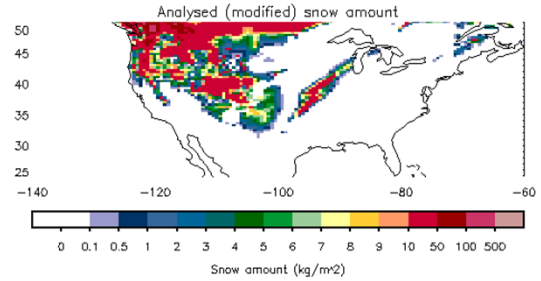
- Compare presence of snow in obs and model
- Remove snow where obs snow-free and model snow-covered
- Add snow where obs snow-covered and model snow-free *use empirical relationship to relate fractional cover to snow amount*
- Reconfigure into model to give 6Z T+0 snow amount (analysis)

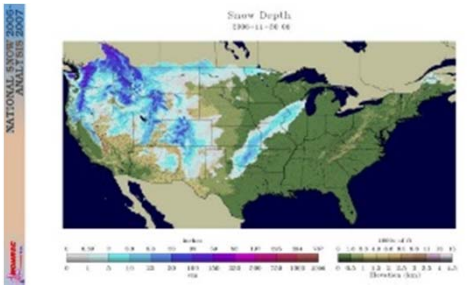


Take care in removing snow

- Daylight hours/cloud cover can cause delays in IMS snow product
- Genuine snowfall events may be removed by snow analysis scheme because the IMS data has not yet recorded the snowfall
- Use added constraint of previous day's background snow in cases of snow removal.
- Where model forecasts a snowfall event well, IMS data may compare better with the previous day's background than the current one. Then we can assume the model evolution is correct and make no change in the analysis.

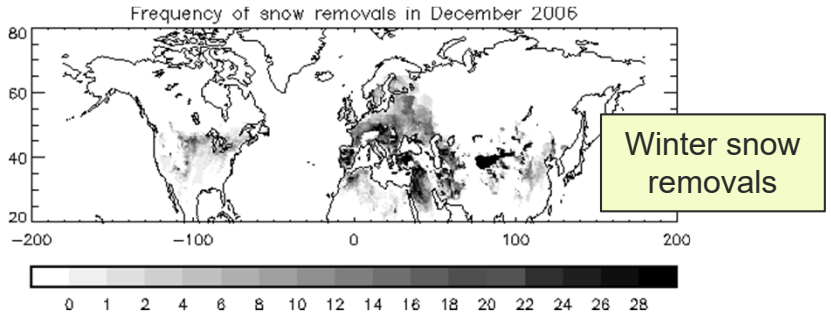




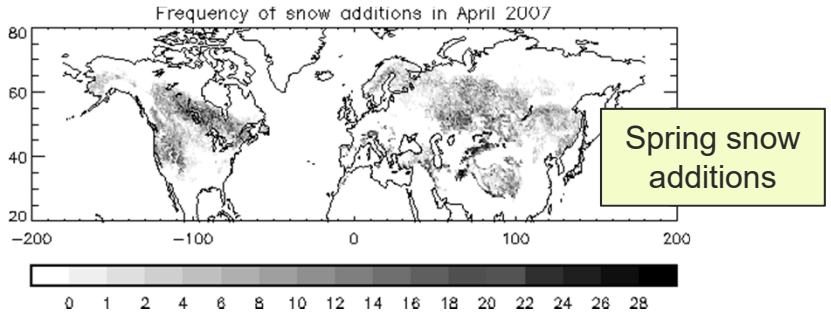


Behaviour of the snow analysis

- Winter snow removal when snow builds up too quickly
- Spring snow addition when snow line retreats too early
- Improved snow extent at analysis time
  - Qualitative examples
  - Verification against in situ (SYNOP) stations ‘state of ground’ and snow depth
- Forecast impacts largely neutral - some improvements in surface/low level T and RH, especially where snow is predominantly removed by the analysis.



Winter snow removals



Spring snow additions

It can be hard to retain the information introduced by the analysis in subsequent forecasts, especially where snow has been added.

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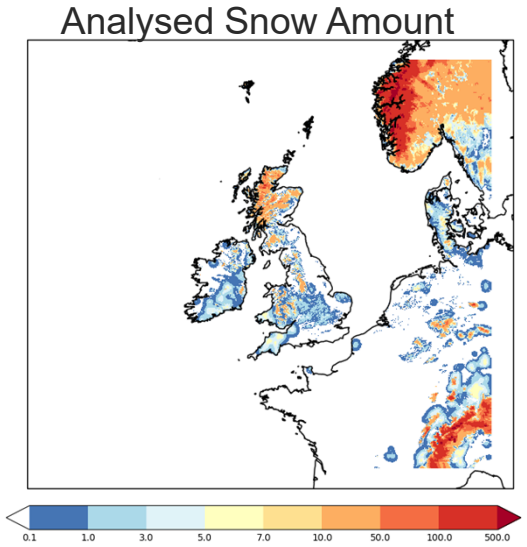
Regional (UKV) Snow Analysis

Advertisement for Samantha Pullen's talk

Snow Amount analysis for the UK NWP system

Summary

- Algorithm: Optimal interpolation scheme
- Observations:
  - Snow depth from *in situ* SYNOP network
  - Snow cover from EUMETSAT H SAF product (MSG-SEVIRI)
- Assimilation trials run for Winter 2017, Summer 2018. Further trials in progress now.
- Plans to extend this methodology to the global model (using alternative satellite observations)
- Samantha Pullen's talk at 9:50 Wednesday



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Operational status Met Office LSDA

Soil moisture

Global: SEKF

Regional model: Daily reconfiguration from global. *move to SEKF imminent*

Snow

Global analysis scheme *potentially moving to OI*

Regional OI scheme *is in trial stage*

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Future Work

- Assimilation of new observations: SMOS NN NRT product
- Update soil climatology (used for bias correction of observations) to new science configuration of Jules
- Optimal Interpolation scheme for global snow analysis *(Sam Pullen's talk)*
- Land temperature analysis
- Global land surface temperature assimilation
- Review error covariance matrices (**R** and **B**)

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