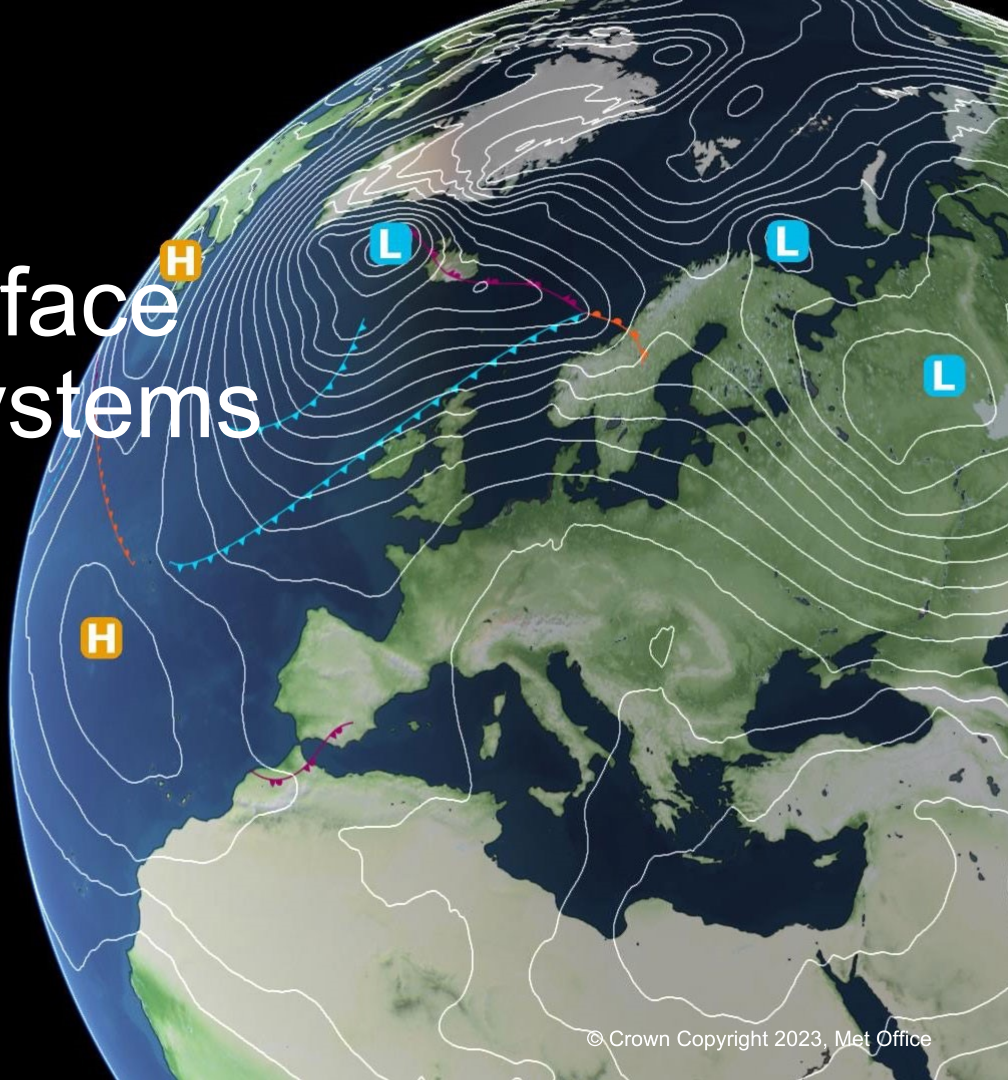
Met Office

A review of current Met Office Land Surface Data Assimilation systems



Cristina Charlton-Perez

Rhiannon Davies

Samantha Pullen

Chris Harris

5th IESWG

Helsinki, Finland

26 September 2023

Outline

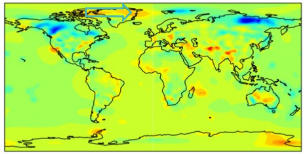
- Current global and regional soil moisture DA
- Assimilation of ASCAT soil wetness index
  - Bias correction of the ASCAT observation product
  - Issues with high soil wetness from ASCAT in urban areas
  - New ASCAT product
- Current global and regional (UK) snow DA
- SURF-LFRic: LSDA with the next generation LFRic modelling system
- Beyond SURF: future Met Office LSDA system within the JEDI framework

SURF

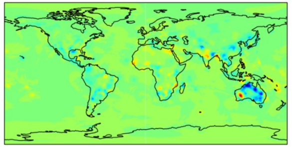
Fortran Code base used to perform all current operational Met Office land surface data assimilation

Operational LSDA: soil

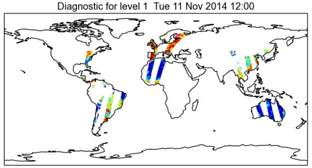
Observations



1.5 m Temp (Gridded)



1.5 m Hum (Gridded)



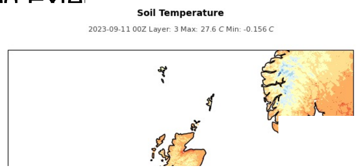
ASCAT soil wetness index

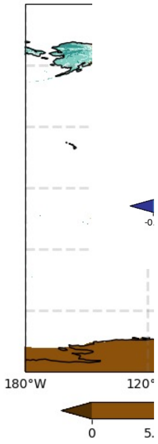
Method
- ASCAT bias correction
- Column-based system (1D)
- Simplified Exte

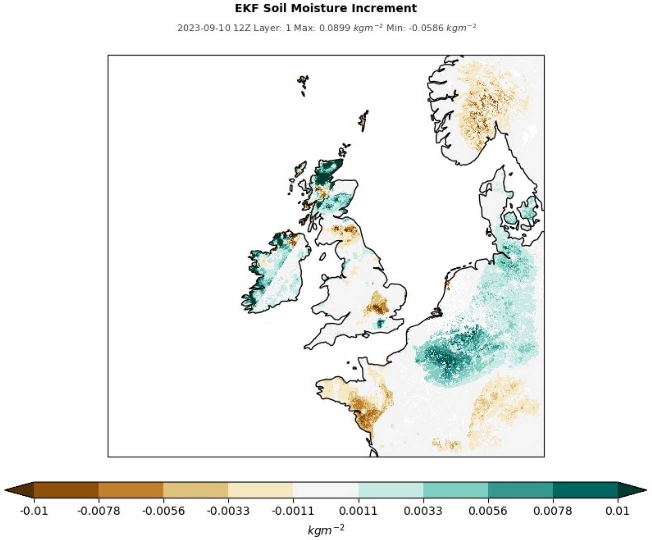
Analyses
- Global analysis every 6 hours
- UK regional analysis every hour

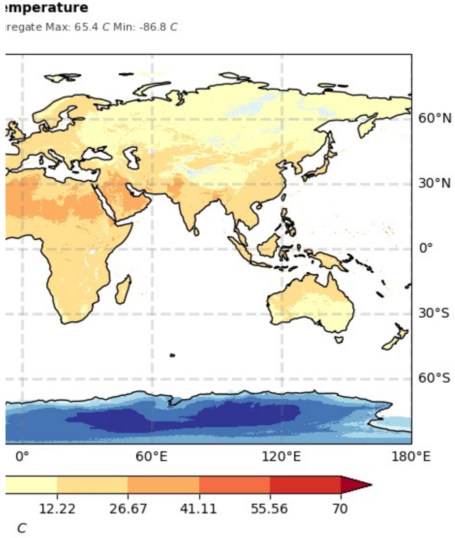
re on 4 layers
yers and tiles

urban)









[The Met Office Operational Soil Moisture Analysis Syster](#)

Met Office

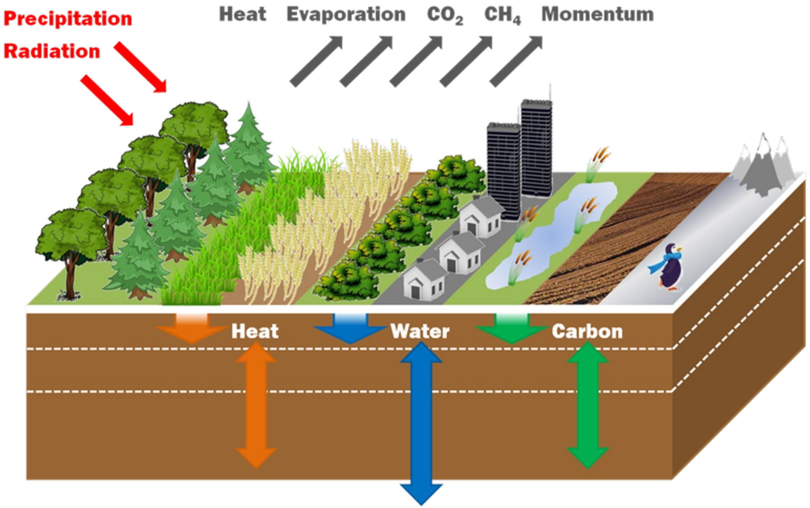
JULES or Joint UK Land Environment Simulator

JULES uses tiles to take into account the sub-grid heterogeneity of land:

- 5 plant functional types*: Broadleaf trees, Needleleaf trees, C_3 (temperate) grass, C_4 (tropical) grass, Shrubs*
- 4 non-vegetation types*: Urban, Inland water, Bare soil, Land-ice*

JULES simulates many fields including:

- surface temperatures,
- soil moisture,
- short-wave and long-wave radiative fluxes,
- sensible and latent heat fluxes,
- ground heat fluxes,
- canopy moisture contents,
- snow mass (multi-layer snow scheme),
- surface and sub-surface run off…



JULES has 4 soil layers (thickness: 0.1, 0.25, 0.65, 2.0 m). Soil in each grid box has constant characteristics.

Assimilation of satellite observations

ASCAT: scatterometer (C-band) delivers backscatter measurement which is translated into a soil wetness index

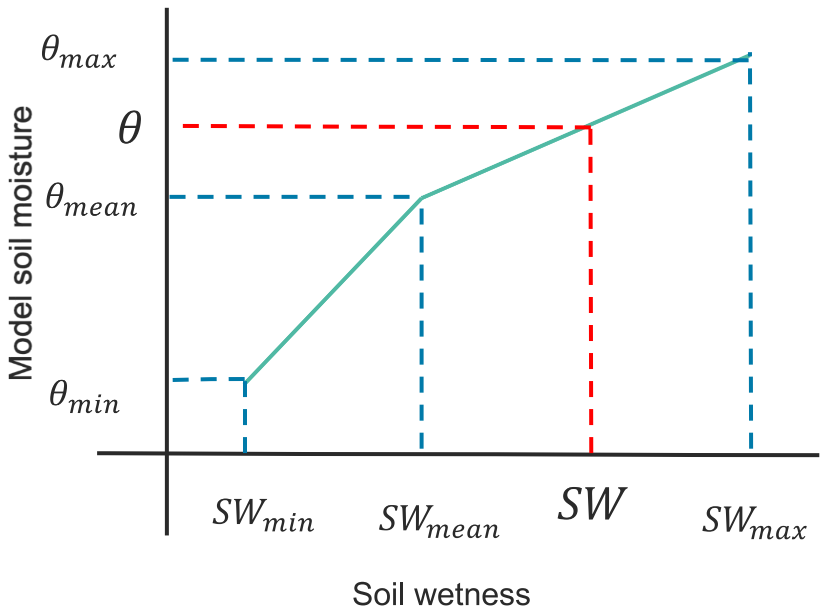
Two satellite platforms deliver the backscatter: MetOp-B and MetOp-C

MetOp-C image. Credit: EUMETSAT

Met Office

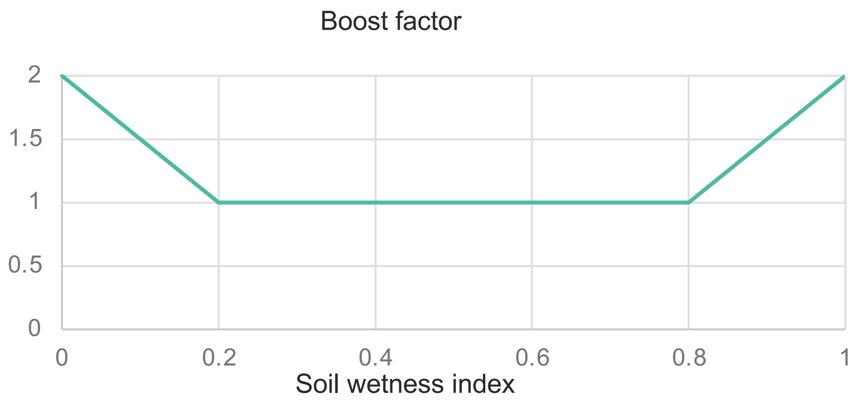
Processing ASCAT Soil Wetness

- ASCAT Soil Wetness product is provided as unstructured grid ~12.5Km (MetDB)
- Observations collected between t-3 and t+3 and treated as valid at t+0
- Interpolated to UM grid using Inverse Distance Weighting (implemented in SURF)
- Converted to soil moisture using a piecewise linear function, loosely based on a CDF matching
    - Climate model parameters $\theta_{\text{mean}}, \theta_{\text{max}}, \theta_{\text{min}}$ are estimated by 40-year standalone JULES run forced by the WFDEI (0.5deg) dataset & CRU precip.
    - SW_{mean} Soil Wetness mean, provided with product
    - $SW_{min} = 0$ and $SW_{max} = 1$ by construction



ASCAT Error boost

- Error is boosted at very dry and wet regimes to account for errors in the Soil Wetness Index calculation
- Boosting factor is calculated using the observation before bias correction
- Boost values are user configurable by a piece wise linear function as shown here



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ASCAT Soil wetness in urban areas

- BoM (UM Partner) brought up the issue of overestimation of model soil moisture in urban areas in Australia (Melbourne, Sydney, Brisbane and Perth)
- Their investigation led to two culprits:
  - ASCAT backscatter is high in urban areas and is erroneously interpreted as high soil wetness and
  - JULES allows infiltration but suppresses evaporation on the urban tile.
- Together we created some QC for the ASCAT obs in urban areas as defined by model ancillaries.
- Testing underway at both BoM and MO. Different model configurations and ASCAT bias correction make comparing our results difficult.
- BoM's initial results show the ASCAT QC alone results in drier model soil in urban areas and an increase in surface temperature in suburban areas.

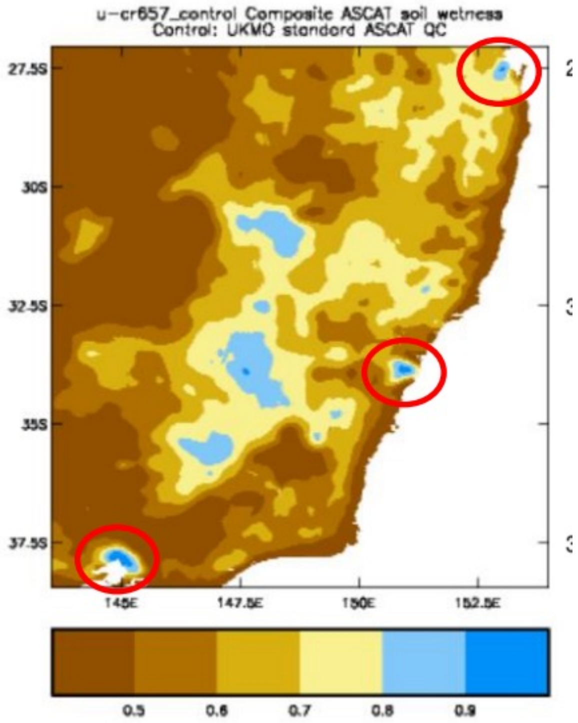
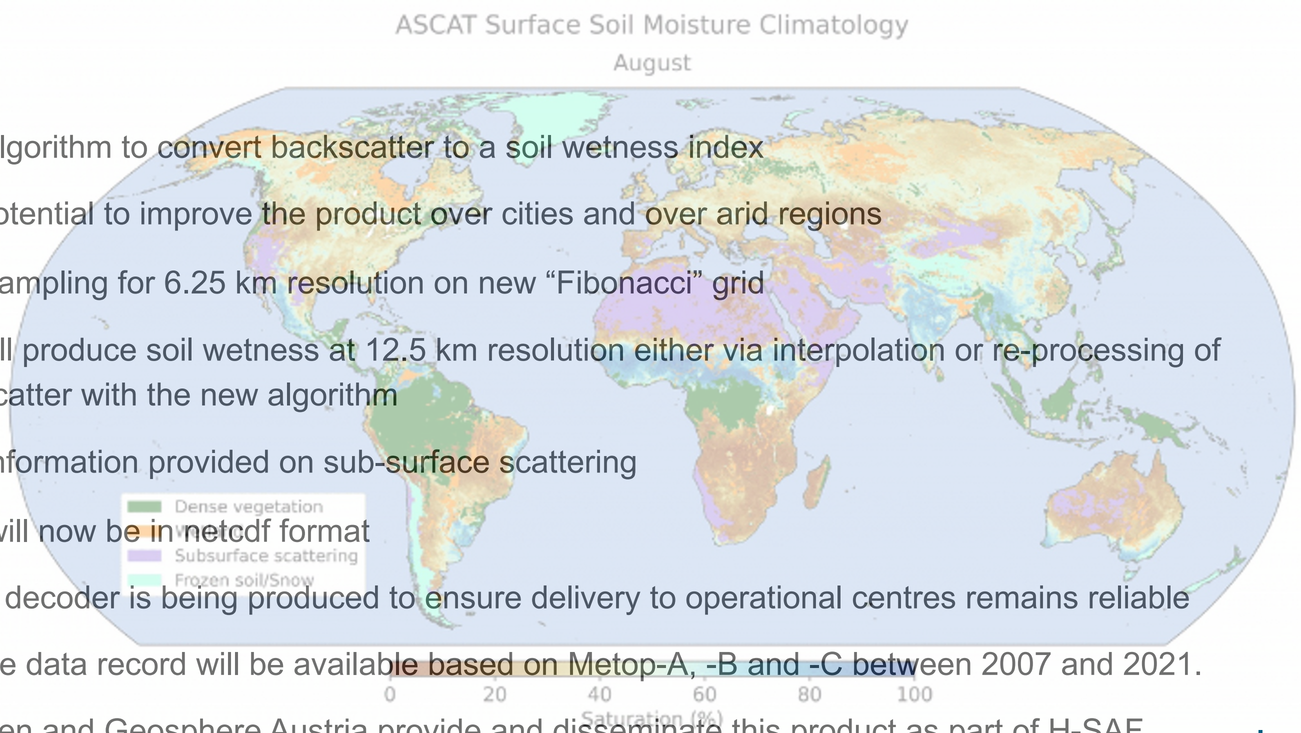
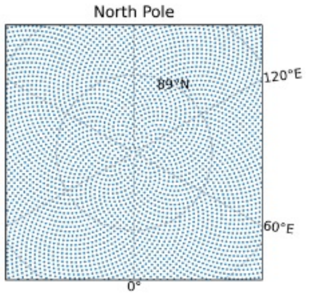


Figure courtesy Imtiaz Dharssi (BoM)

New high resolution ASCAT SWI product



- New algorithm to convert backscatter to a soil wetness index
- Has potential to improve the product over cities and over arid regions
- New sampling for 6.25 km resolution on new “Fibonacci” grid
- Still will produce soil wetness at 12.5 km resolution either via interpolation or re-processing of backscatter with the new algorithm
- New information provided on sub-surface scattering
- Data will now be in netcdf format
- BUFR decoder is being produced to ensure delivery to operational centres remains reliable
- Climate data record will be available based on Metop-A, -B and -C between 2007 and 2021.
- TU Wien and Geosphere Austria provide and disseminate this product as part of H-SAF



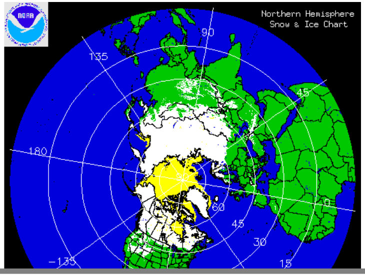
Example of Fibonacci grid at the pole

Images Courtesy Sebastian Hahn, TU Wien

Snow observations and assimilation

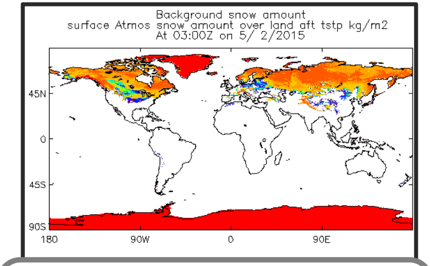
Global and regional systems use different observations and different schemes to create analyses of snow amount.

Operational Global Snow Update Scheme



NESDIS
IMS 4km

Observation
Snow cover converted into gridbox Fractional Cover



UM
N1280
~10km

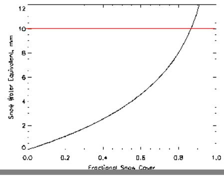
Background
Snow amount (kg m^{-2})
T+6 from previous cycle

Observation/Background

no snow/no snow or snow/snow
⇨ do nothing

snow/no snow
⇨ +

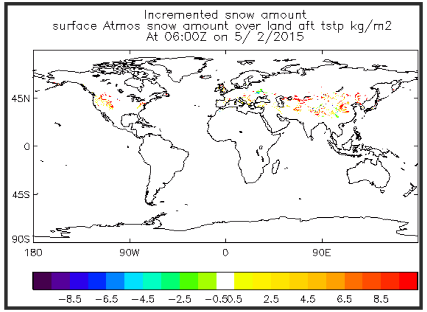
Relating fc and depth



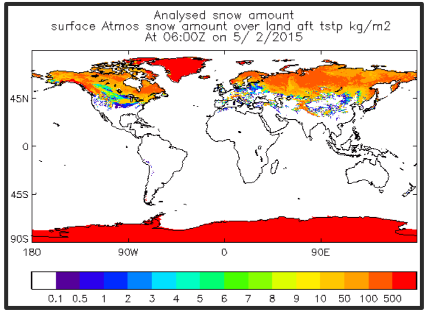
no snow/snow
⇨ Remove snow

Time delay check
Using T+6 from previous day

06 UTC Increments

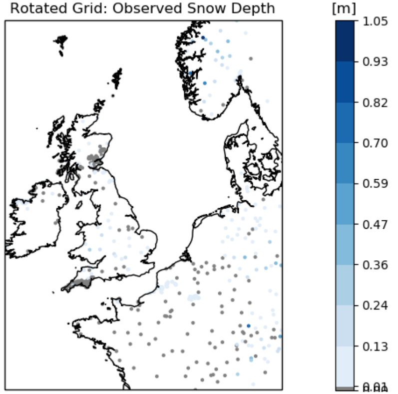


06 UTC Analysis



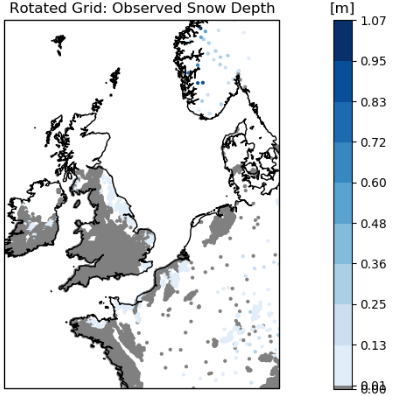
Operational Regional (UK) Snow DA

Observations



Ground-based Synop network

- snow depth
- state of ground (snow or no snow)
- 4 times per day



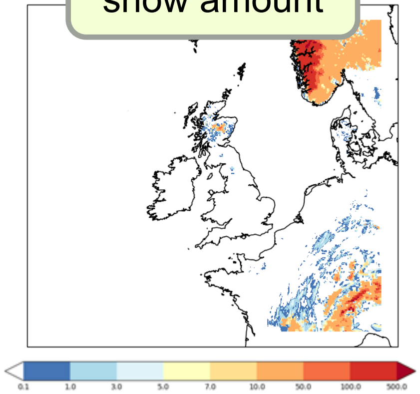
Satellite data from MSG-SEVIRI

- H SAF daily snow cover product
- Once per day

"Observed" snow depth

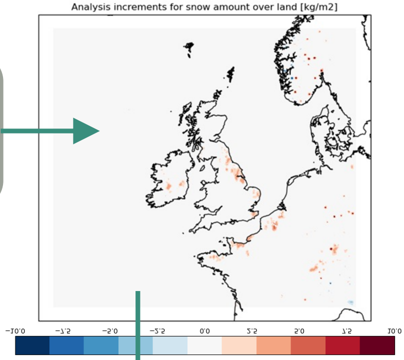
(0.05 m snow depth from snow-cover product where model snow-free)

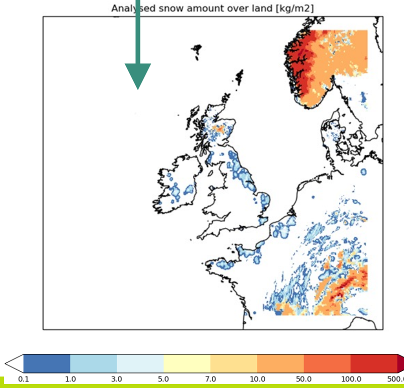
Background snow amount



2D Optimal Interpolation

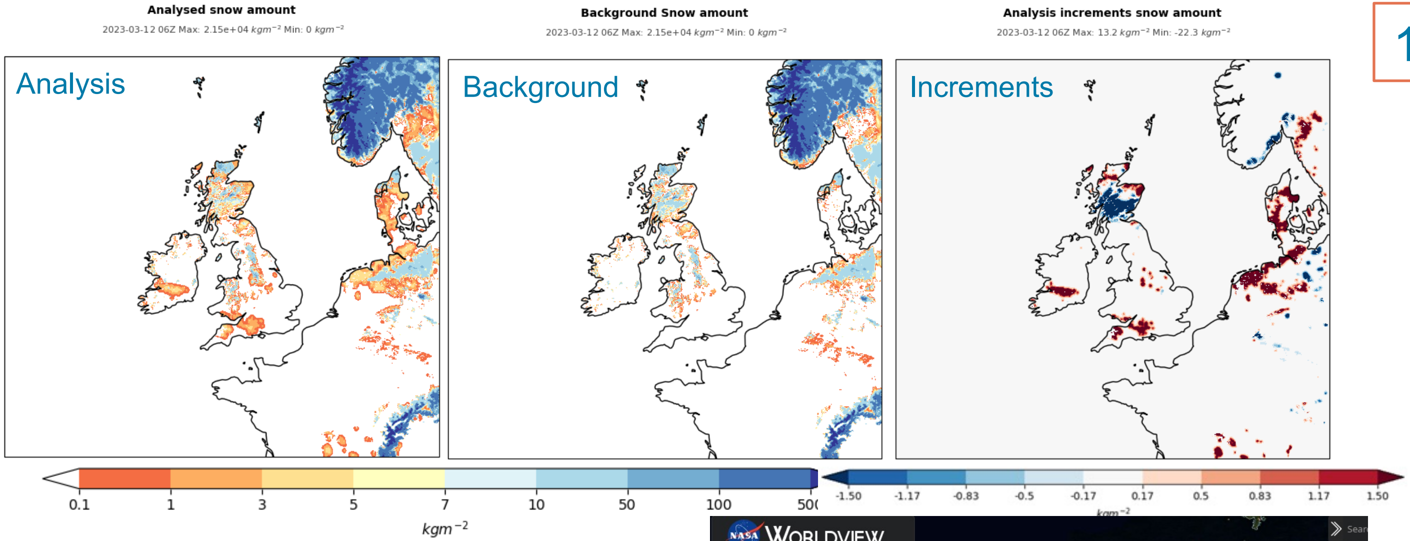
Analysed snow amount

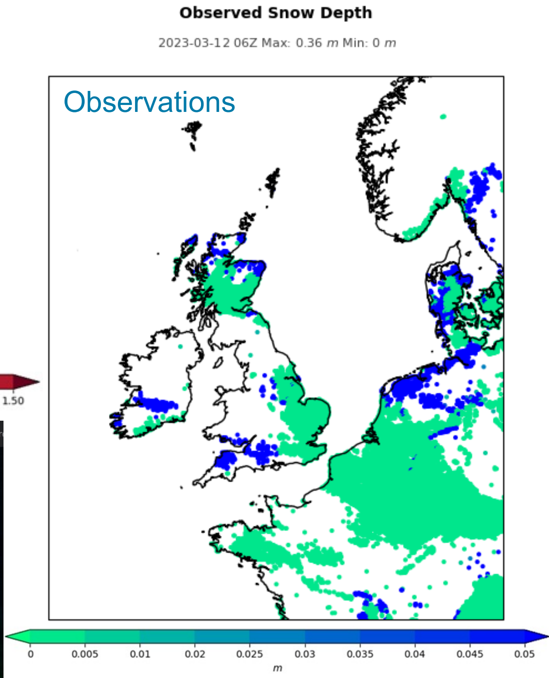




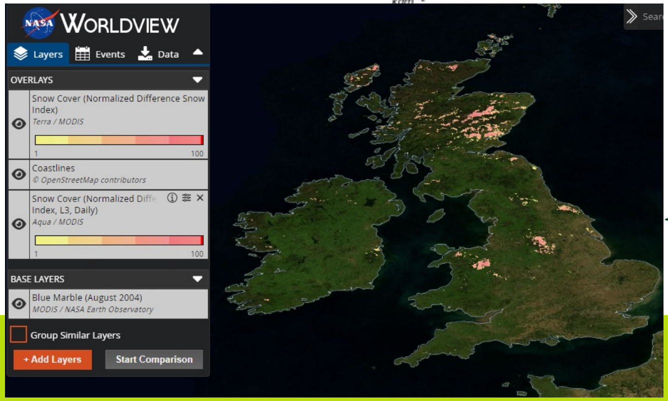
Anomalous snow cover in H SAF product

12-03-2023 0600H





- Overestimation of widespread lying snow over SW UK and Ireland
- Local snow cover verified on Dartmoor
- Potential mis-classification of surface water
- Occurs most frequently in western parts



Global snow depth reports

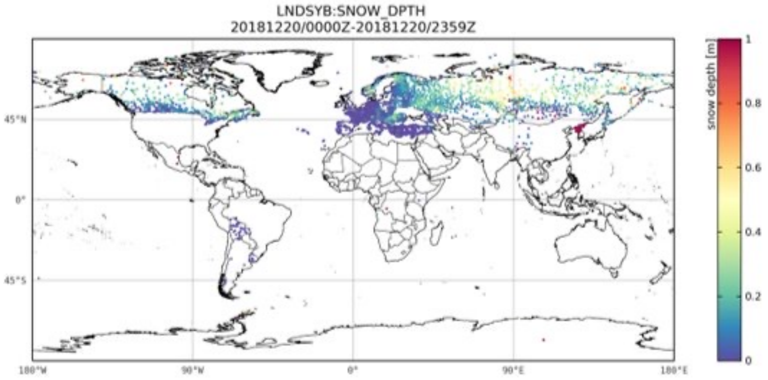
Year on year improvements in availability of global station snow depth reports since adoption by WMO of Resolution 15 (EC-69) in 2017

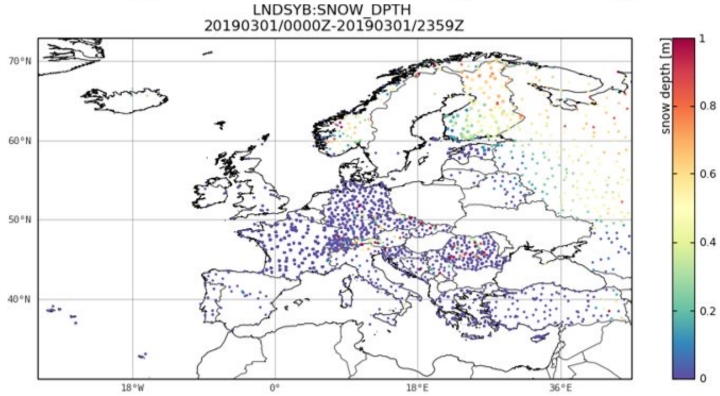
- Improved reporting and exchange of station snow depth obs (SYNOP network)
- Increase in reporting of zero snow in snow-free conditions during winter season
- Exchange of national network obs using new dedicated BUFR sequence
- Addition of US SNOTEL network (>1000 new stations) from 29 March 2023

Extend OI snow depth assimilation to global model to exploit these observations…..

Snow depth reports available on GTS 11 April 2023

WIGOS Newsletter April 2023, vol. 9, no. 2





SURF-LFRic

Enabling our current operational LSDA to work with both the UM and our future LFRic system

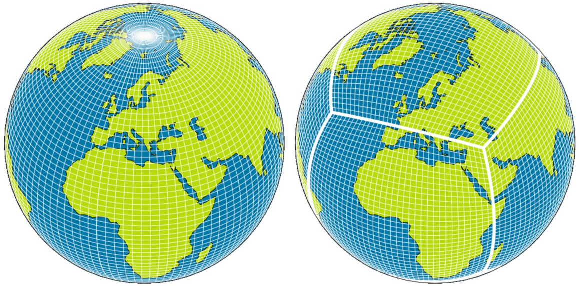
LFRic and the unstructured grid

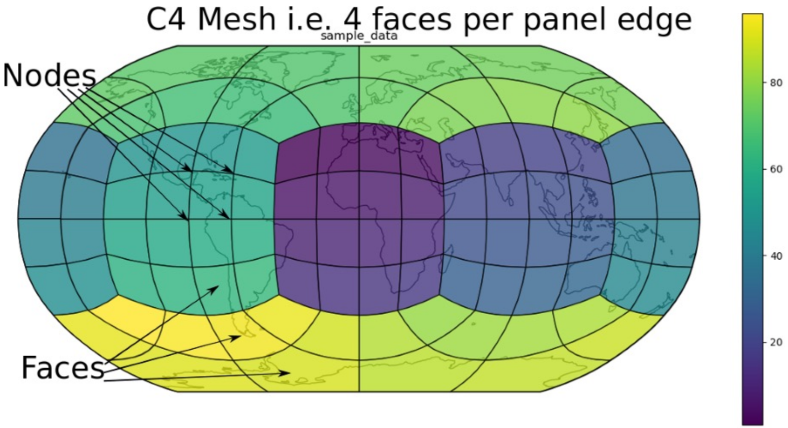
What is LFRic? Post-GungHo (dynamical core project)

LFRic modelling infrastructure project will

- change from the latitude-longitude mesh to the cubed-sphere mesh,
- enable equations to be solved using a finite-element method replacing the finite-difference method,
- implement “separation of concerns”: separate the natural science aspects from the technical implementation. Key to this is automatic code generation. STFC developed the Psyclone application to auto-generate parallel code for LFRic
- use netcdf files for I/O

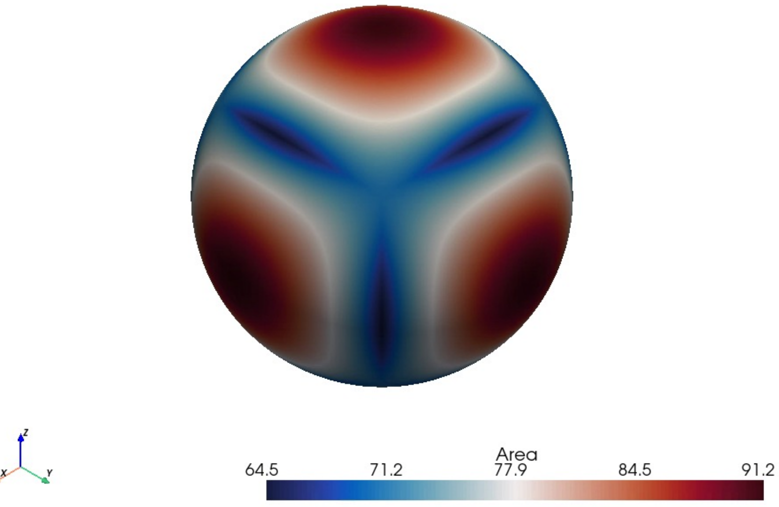
Next Generation (NG) MO Systems

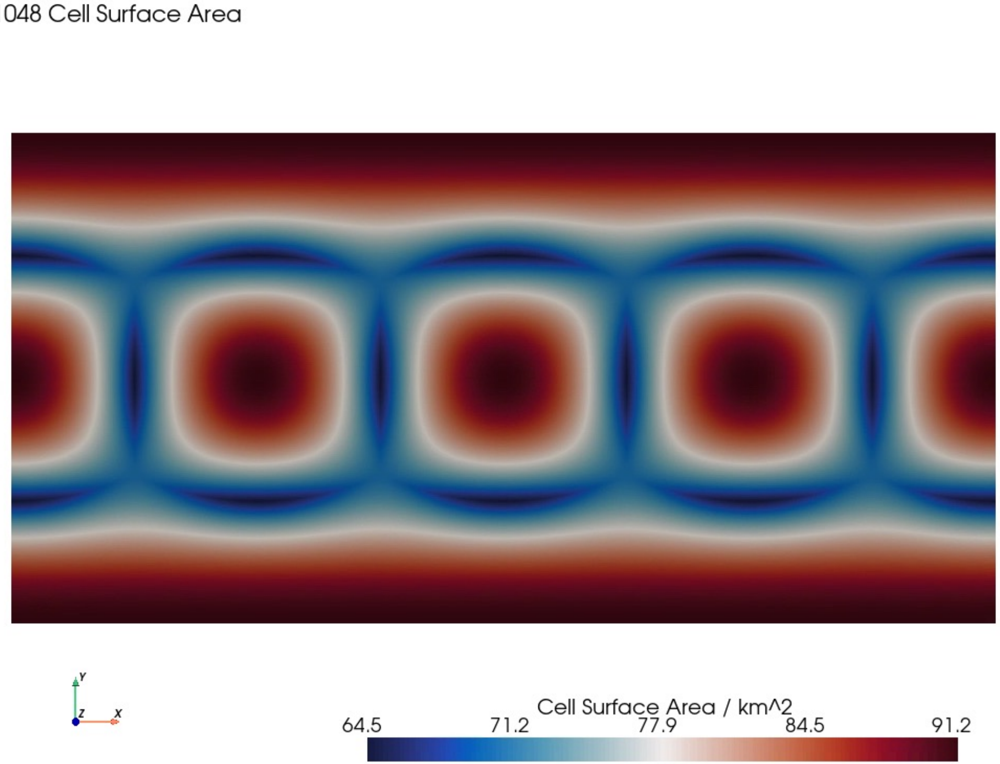




Cell Surface Area C1048

Example of cubed sphere mesh close to current operational resolution



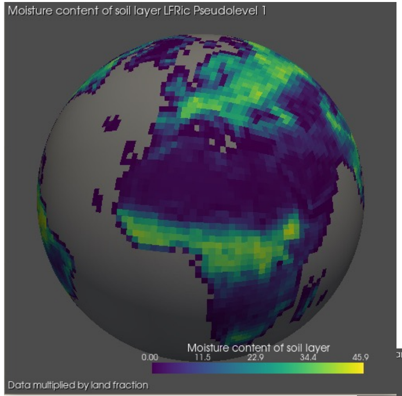


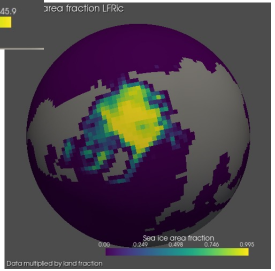
Images: Bill Little, plotted using **publicly available** geovistaPython library

Met Office

Adapt SURF to work for both UM and LFRic

- **Adapt interpolation and nearest neighbour routines for placing obs. on either lat/lon regular grid or the cubed sphere mesh**
- *Remains a column by column set-up with ability to analyse same land variables on lat/lon regular grid or the cubed sphere mesh*
- *No change to observations or DA schemes*
- Modernise the data structures for ease of use on either grid
- Ensure that SURF can work with netcdf files for I/O and interfaces throughout
- Use new LFRic ancillary files (e.g., land fraction)
- Ensure that SURF interacts with JULES as required
- Read LFRic inputs and produce LFRic outputs
- This work is separate to development of Next Generation LSDA in the JEDI framework





Cristina Charlton- Perez and Rhiannon Davies

Met Office

Beyond SURF: Next Generation LSDA

Please attend
Samantha Pullen’s talk:

“Planning a new JEDI-based land surface DA system for the Met Office”

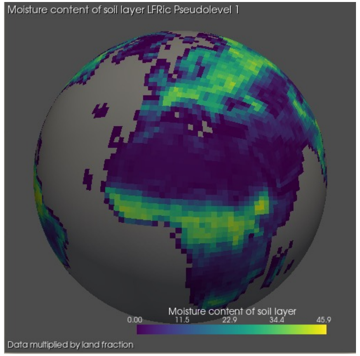
9:00 Wednesday

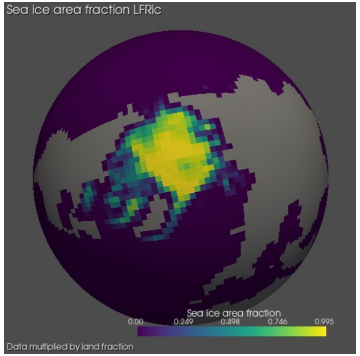
JEDI-based
Observation
Processing
Application

JEDI-based
Application for
Data
Assimilation

Summary

- Met Office produces operational analyses for soil and snow variables in global and regional systems using a range of observations and methods.
- LSDA will be enhanced to ensure it can operate in both the UM and LFRic modelling systems. New unstructured grid!
- No new observations are planned until we are using JEDI. Though new ASCAT product will have to be in operations by November 2024.
- Future LSDA using JEDI will eventually make SURF obsolete





Met Office

Thank you for your attention!

Questions now or later:

c.charlton-perez@metoffice.gov.uk

JEDI - Joint Effort for Data assimilation Integration

Met Office

Model Interfaces

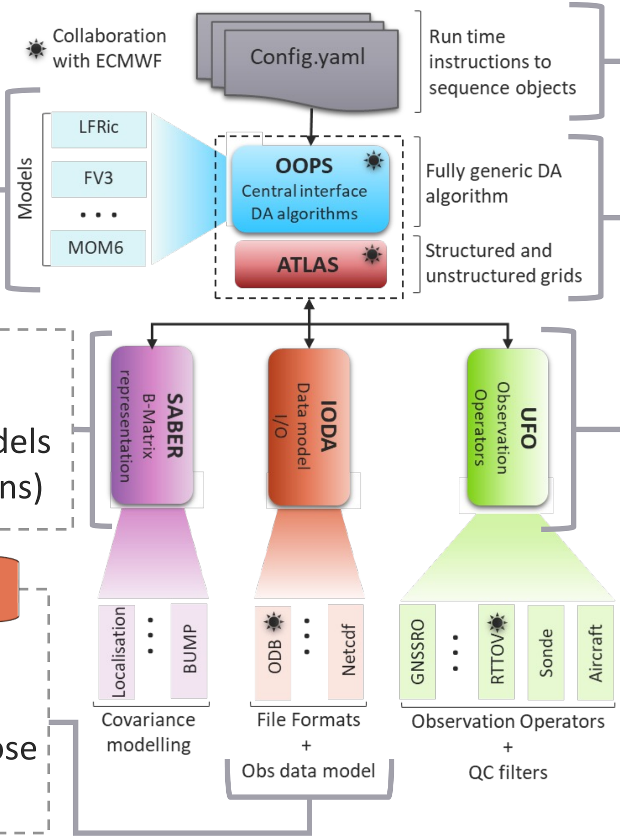
Provide the link between the individual models and the agnostic JEDI code.

System Agnostic Background Error Representation

Holds background error covariance models (both static and ensemble-based versions)

Interface for Observation Data Access

Provides the interfaces that bridge the external observation data to the components within JEDI that utilize those data, namely OOPS and UFO.



Configuration files

Provide the scientific instruction for running the JEDI code.

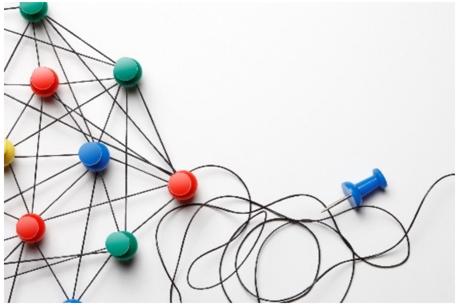
Object Oriented Prediction System

Provides a generic, portable, model-agnostic DA system interface

Unified Forward Operator

Contains a collection of forward operators and abstract observation filters

Planning the new JEDI-based LSDA system



Planning will take place over the course of this year

What we know already:

- We will not port the current system
- Aim to harmonise with a single multi-variate land surface analysis
- Starting point will use all the obs types we currently use (at least)
- Observation processing will build on capability introduced for our atmospheric DA (JOPA)
- Aim to exploit DA methods that already exist in JEDI
- Will be part of an ensemble-based NWP system
- Enabling future enhanced coupling between atmosphere and land surface will be a key consideration for our choice of DA methodology