Planning a new JEDI-based Land Surface DA system for the Met Office

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IESWG-5, Helsinki

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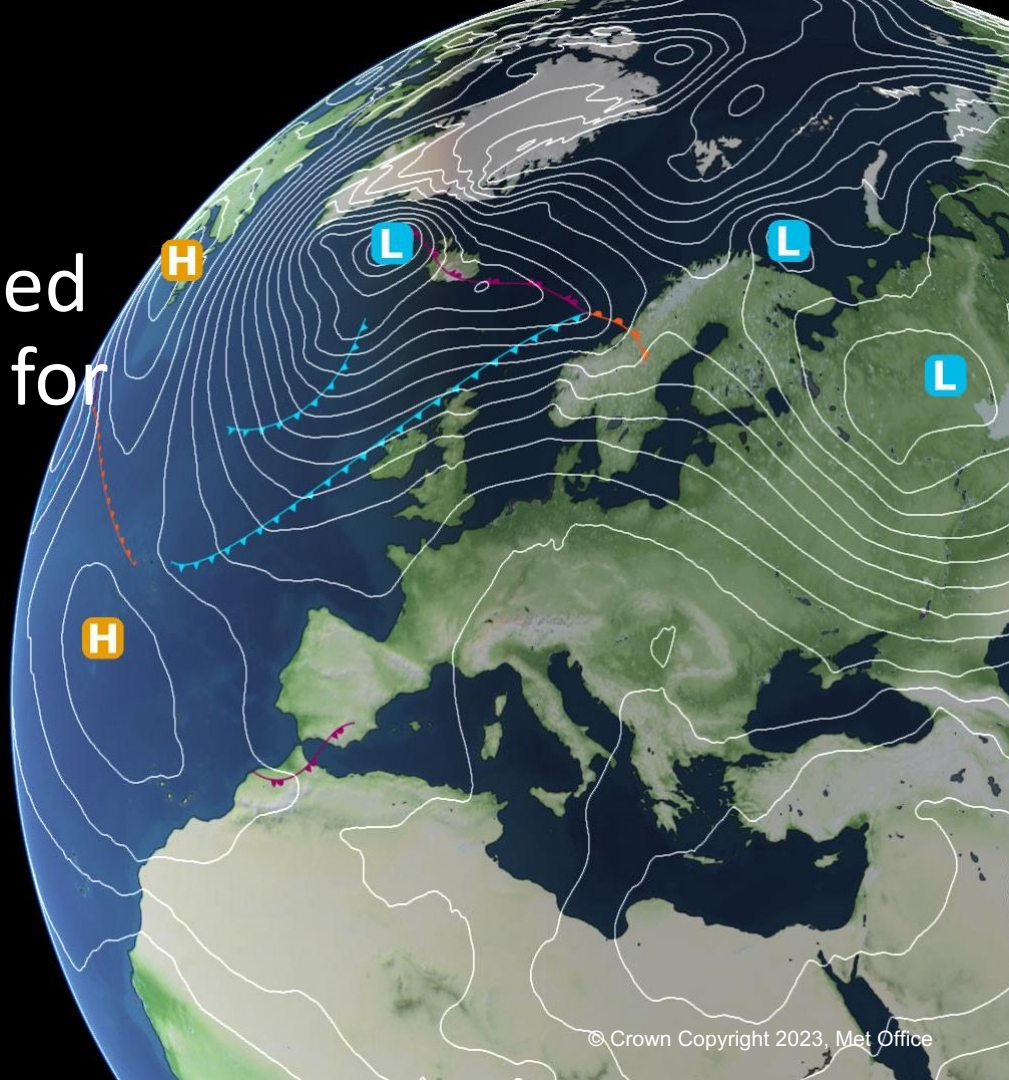
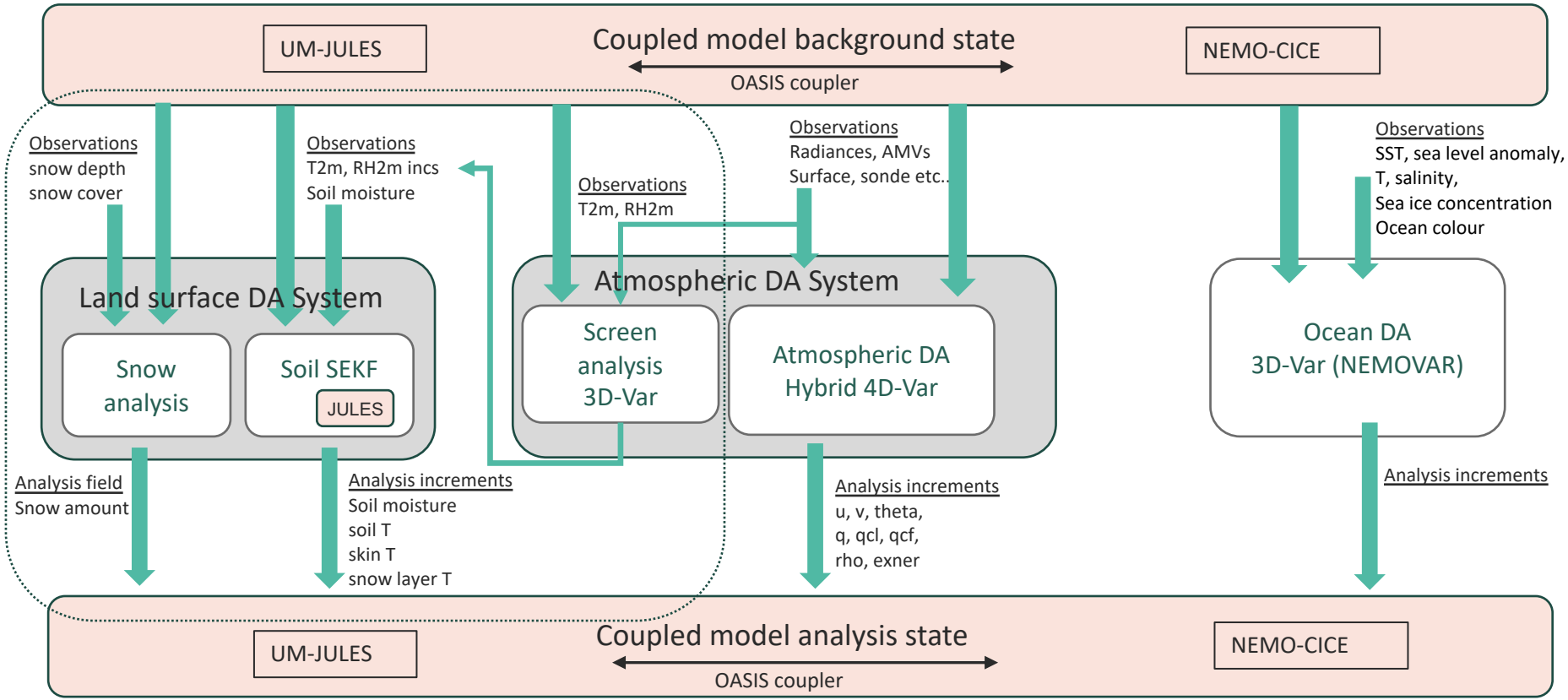


Outline

- The current Met Office land surface DA and coupled NWP system
- The Next Generation Modelling Systems Programme
- JEDI for Met Office observation processing and data assimilation
- Land Surface DA with JEDI
  - Aims and motivation
  - Requirements
  - Planning

Current Coupled NWP System



Big changes for Met Office NWP…

2 key aspects of Met Office Strategy:

- Next Generation Modelling Systems (NGMS) Programme: "*Reformulating and redesigning our complete weather and climate research and operational/production systems, including oceans and the environment, to allow us to fully exploit future generations of supercomputer for the benefits of society*"
- Met Office Strategic Action: *"Placing ensembles at the heart of what we do – ensembles by default"*

Numerical model dynamical core (GungHo) and modelling infrastructure – LFRic

Observation processing and data assimilation system using the JEDI framework

JEDI-based Observation Processing Application

JEDI-based Application for Data Assimilation

JEDI - Joint Effort for Data assimilation Integration

Model Interfaces

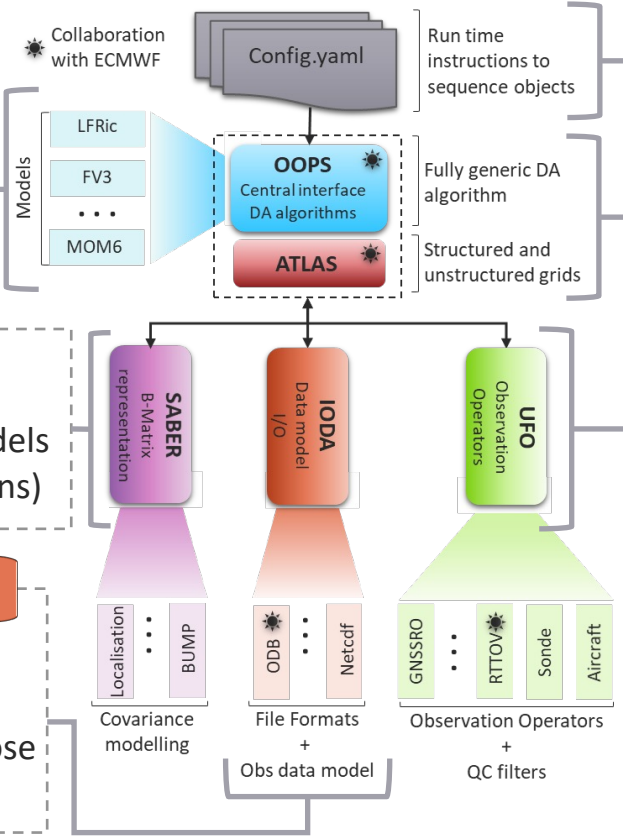
Provide the link between the individual models and the agnostic JEDI code.

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

https://www.jcsda.org/jcsda-project-jedi

Next Generation Observation Processing

OPS

Observation processing

OPS processes in excess of 30,000,000 individual atmospheric observation locations in a 6-hour window. Each location can have multiple channels/levels.

21 atmospheric observation types

- Satellite radiances
- Satellite winds and active sensors
- Conventional and radar data
- Level 2 products (cloud, aerosol optical depth)

6 marine observation types

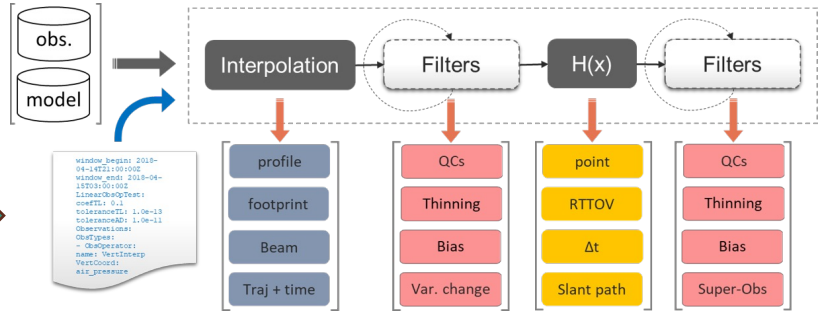
- Sea surface temperature (SST)
- Sea ice
- Ocean sounding and colour
- Altimeter

OPS carries out data selection, quality control (QC), error assignments, bias correction, 1D-Var, thinning, and the application of the observation operator.

JOPA

JEDI-based Observation Processing Application

Aim: Replicate our current observation processing for atmospheric and ocean data assimilation



New code in UFO for:

- Data selection
- Quality control
- Error assignments
- Bias correction
- 1D-Var
- Thinning
- Observation operators

All code **validated against OPS** to ensure the close match.

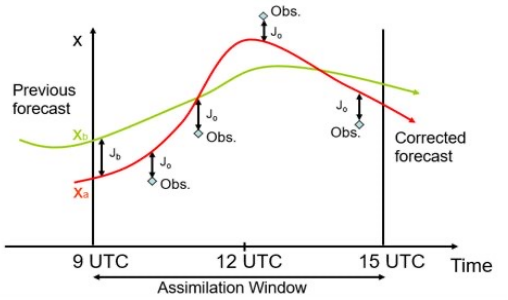
Met Office has provided close to half of all QCs routines and forward operators

Next Generation Data Assimilation

VAR

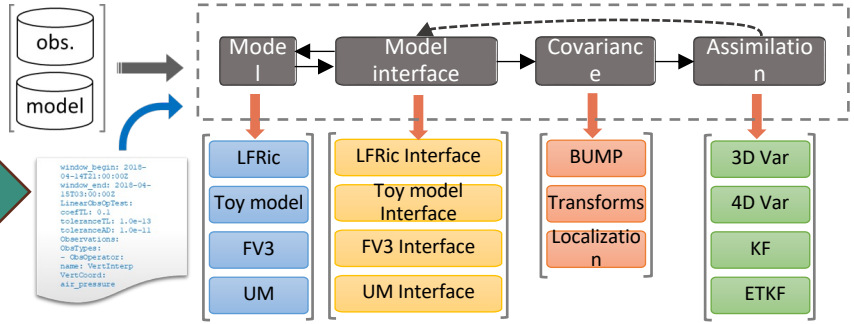
The current global forecasting system uses a hybrid 4DVar assimilation scheme.

- Deterministic system: Hybrid 4D-Var
- Linear model with limited physics parameterisations
- Linear model out of sync with non-linear model
- Ensemble system: En-4DEnVar
- Complex system of additive inflation



JEDI-based Application for Data Assimilation

Aim: Develop new science and code to redesign our data assimilation capabilities and allow us to "put ensembles at the heart of everything we do"



Control(4D-Var)-perturbation(3D-Var) method – new science
Hybrid ensemble Tangent Linear Model – new science

- Hybrid background error covariance
- model interface to connect LFRic to JEDI
- Rapid update cycling

Not a like-for-like replacement for VAR

A Hybrid Differential-Ensemble Linear Forecast Model for 4D-Var, T. J. Payne (2020)
https://doi.org/10.1175/MWR-D-20-0088.1

LSDA in the JEDI Framework

Motivation and aims

- Common infrastructure for atmosphere and land surface observation processing and data assimilation
  - Opens opportunities for stronger coupling between atmosphere and land surface
  - Enables sharing of scientific and technical expertise
  - Streamlined system maintenance
  - Observation processing for LSDA can build on existing capabilities in JOPA (MO "JEDI-based Observation Processing Application")
- Modularity of the JEDI approach offers us opportunities to test and incorporate new obs, obs operators and DA schemes faster than before
  - Numerous DA algorithms available to use in OOPS
  - Observation operators can be added to JEDI via an abstract interface to UFO
- Opportunities to collaborate with JCSDA Partners using JEDI
  - NOAA has already implemented support for snow observations (IMS and station snow depth)
  - Common developments will be needed for processing soil moisture and screen observations

General Requirements

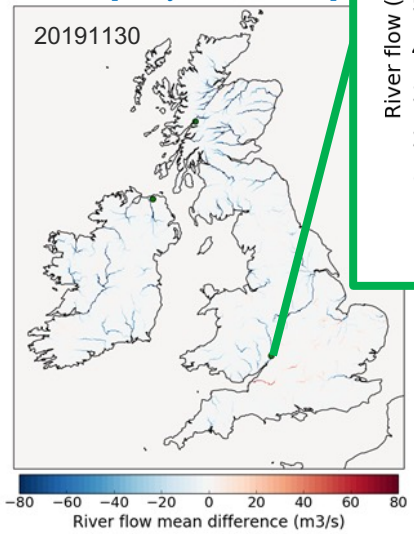
- Make use of existing capabilities wherever possible – generic science capabilities, tools, monitoring and benchmarking, methods, QC filters
- Incorporate observation processing for LSDA into JOPA – one system to maintain!
- Pull in expertise and development resources from atmospheric observation processing and data assimilation teams
- Dispense with the need to run an ensemble of offline perturbed JULES runs – very expensive
- Minimise the time that SURF is static (no further science upgrades) while new system is under development
- Requirement to better understand the impact, strengths and limitations of the LSDA system to enable more informed use of its outputs.

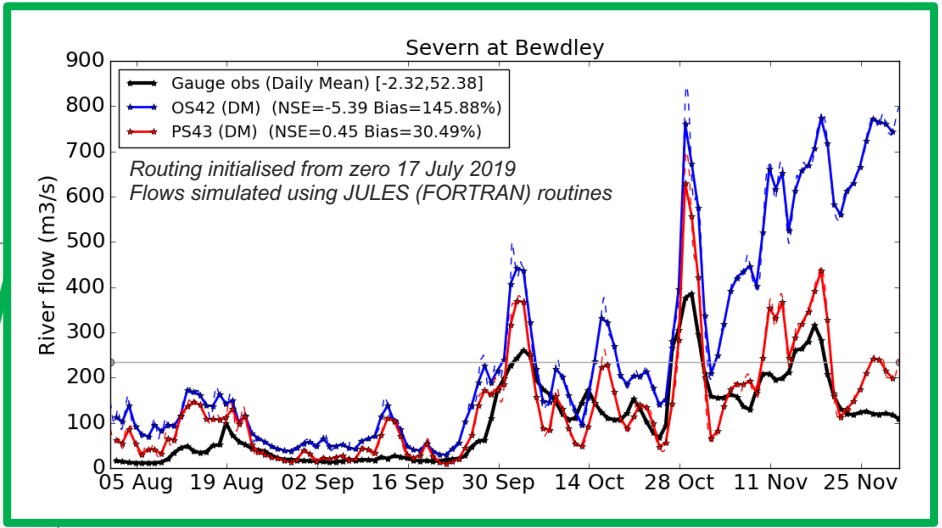
Science requirements for NWP

- LSDA in both **Global** and **Regional** NWP systems

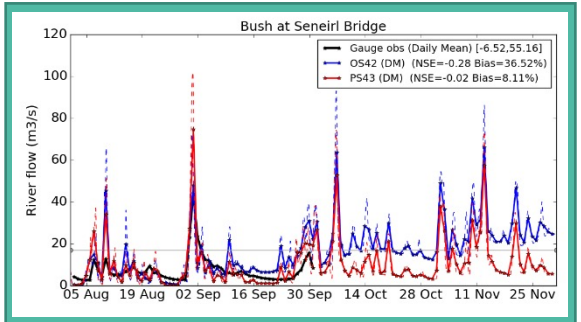
Impact of regional soil moisture DA on hydrological prediction

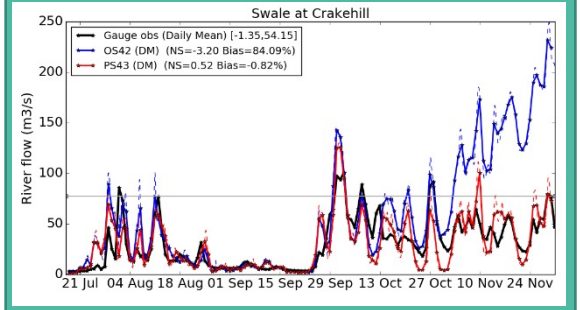
Output of offline routing of OS42 and PS43 runoff diagnostics using JULES RFM river routing code (default parameters) [Daily mean flows]

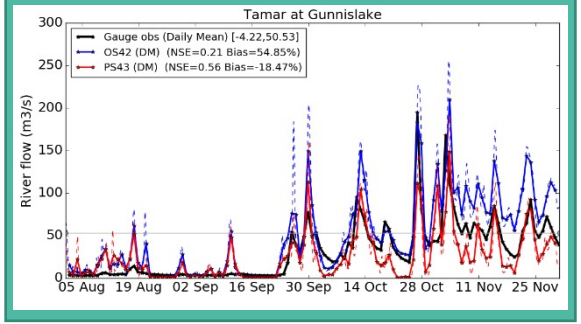




- Clear improvement to simulated river flows relative to observations using PS43 runoffs
- Substantial high bias when using OS42
- The basis of a hydrologically useful system?







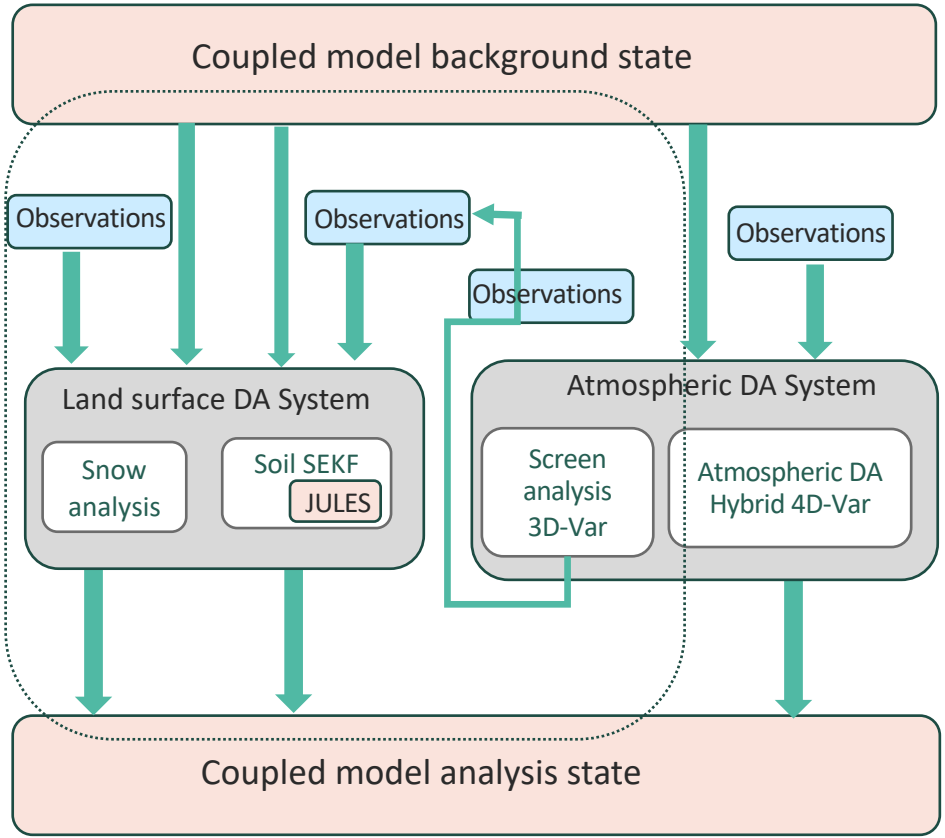
Slide courtesy Huw Lewis

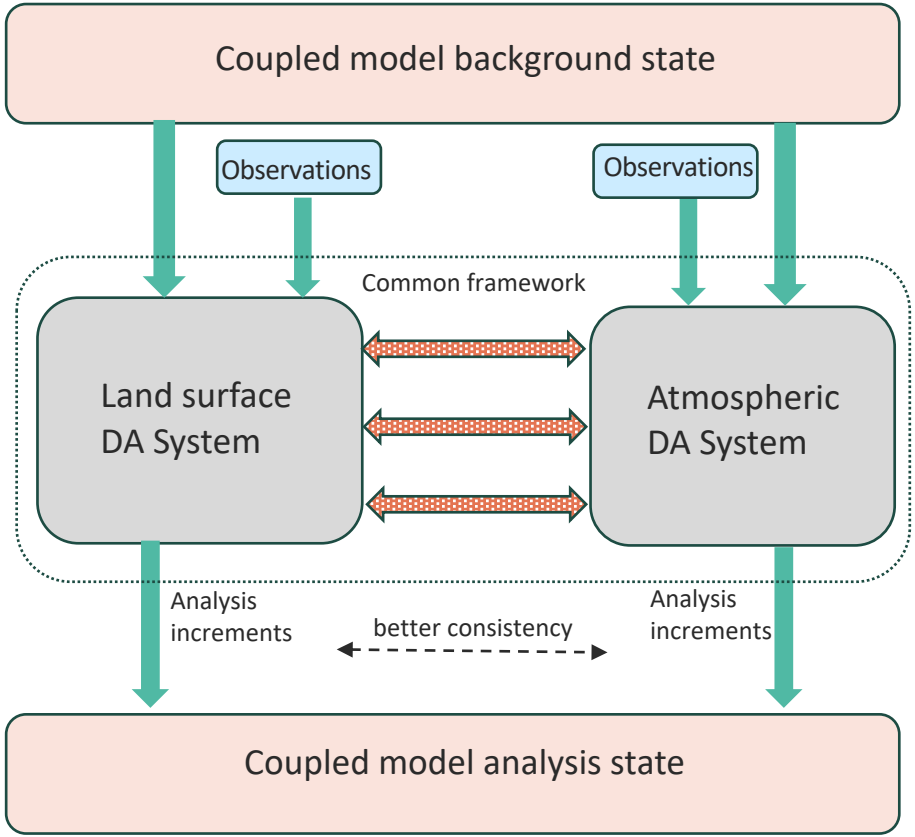
For more see Gomez, et. al. (2020)

Science requirements for NWP

- LSDA in both **Global** and **Regional** NWP systems – see river flow slide – want to retain this value
- More consistent treatment of analysed surface and near-surface variables
  - Single multi-variate LSDA system that can be extended to analyse additional variables
  - Alignment with atmospheric DA system to enable stronger coupling

Enabling atmosphere-land coupled DA





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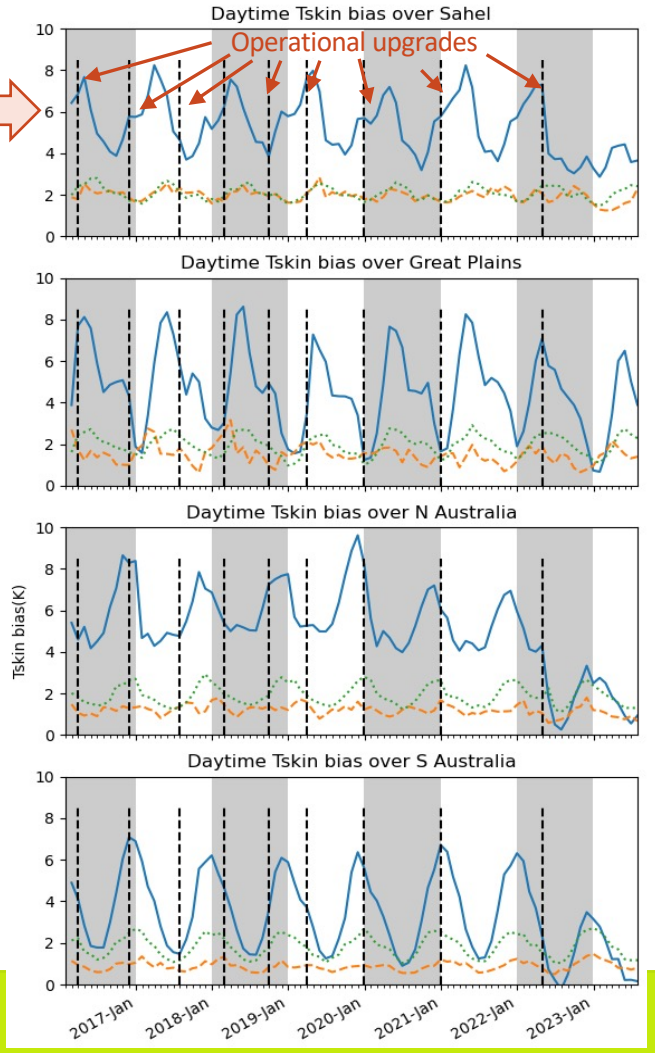
- The new LSDA system should be designed to work more effectively with the **ensemble** (making better use of the ensemble and being able to be better used by the ensemble).
- For the **global system** main focus is to provide land surface initial conditions that best impact subsequent forecasts of NWP (atmospheric) variables, through fluxes at the surface-atmosphere boundary.
  - Particular interest in improving the representation of skin temperature to enable better exploitation of satellite sounding data in the lower troposphere

Met Office

Tskin bias = 1D-Var retrieval - background



Assimilation of IASI radiances:

- Over land, due to uncertainties in Tskin, we throw away 71 surface-affected channels – these channels contain important lower tropospheric temperature and humidity information.
- Recent model upgrades have brought significant improvements in Tskin representation
- Improved modelling and/or assimilation of Tskin should allow assimilation of these near surface sounding channels leading to improved forecasts in the lower atmosphere.
- Strong driver for coupled land-atmosphere DA

Slide courtesy Chawn Harlow

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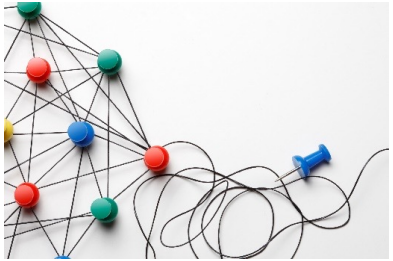
- For the **regional UK system** there is much greater focus on the representation of the land surface variables themselves in the analysis state, in particular soil moisture and snow depth.
  - hydrological applications will become increasingly important so soil moisture assimilation (continuation and improvements to) should be a priority area for UK LSDA
  - Urban scale modelling and hydrology – future requirement for high resolution LSDA

Planning the new JEDI-based LSDA system



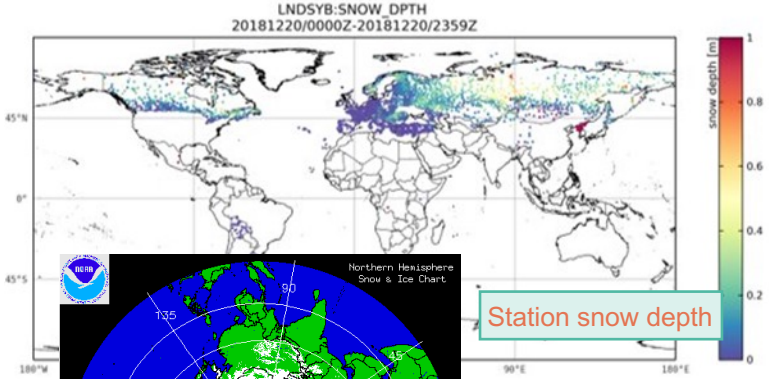
What we know already:

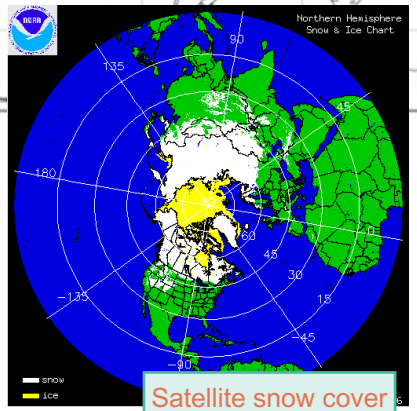
- We will not port the current system
- Aim to harmonise with a single multi-variate land surface analysis
- Starting point will use all the obs types we currently use (at least)
- Observation processing will build on capability introduced for our atmospheric DA (JOPA)
- Aim to exploit DA methods that 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
- Global and UK DA will be planned separately (global first)

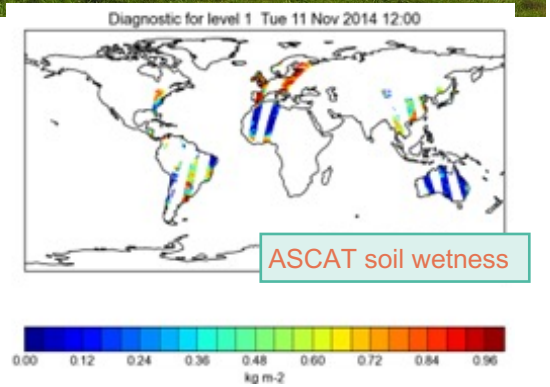
Still to do or decide:

- OSSE-type experiments to establish a benchmark
- Investigate representation of land surface variables in new LFRic ensemble (not yet available)
- **Decide DA methodology**
- Develop full plans for (i) observation processing (ii) DA – it will be a 2-stage project

LSDA observation processing







- Screen T and RH already complete
- Prototype station snow depth processing
- Observation into ODB format
- Stationlists
- QC filters
- Observation operators
- Bias correction

```
# GetValues configuration
    get values:
      time interpolation: linear

#Observation operator
    obs operator:
      variables: [totalSnowDepth]
      name: Product
      geovals to scale hofx by: snow_density
      geovals to act on: snow_amount
      geovals exponent: -1

# QC Filters
    obs filters:
    - filter: Temporal Thinning
      filter variables:
      - totalSnowDepth
      min_spacing: PT06H00M
      seed_time: *window_begin
      category_variable:
        name: MetaData/station_number

    - filter: Bounds Check
      filter variables:
      - totalSnowDepth
      test variables:
      - name: ObsValue/surface_temperature
      maxvalue: 275

    - filter: Background Check
      filter variables:
      - name: totalSnowDepth
```

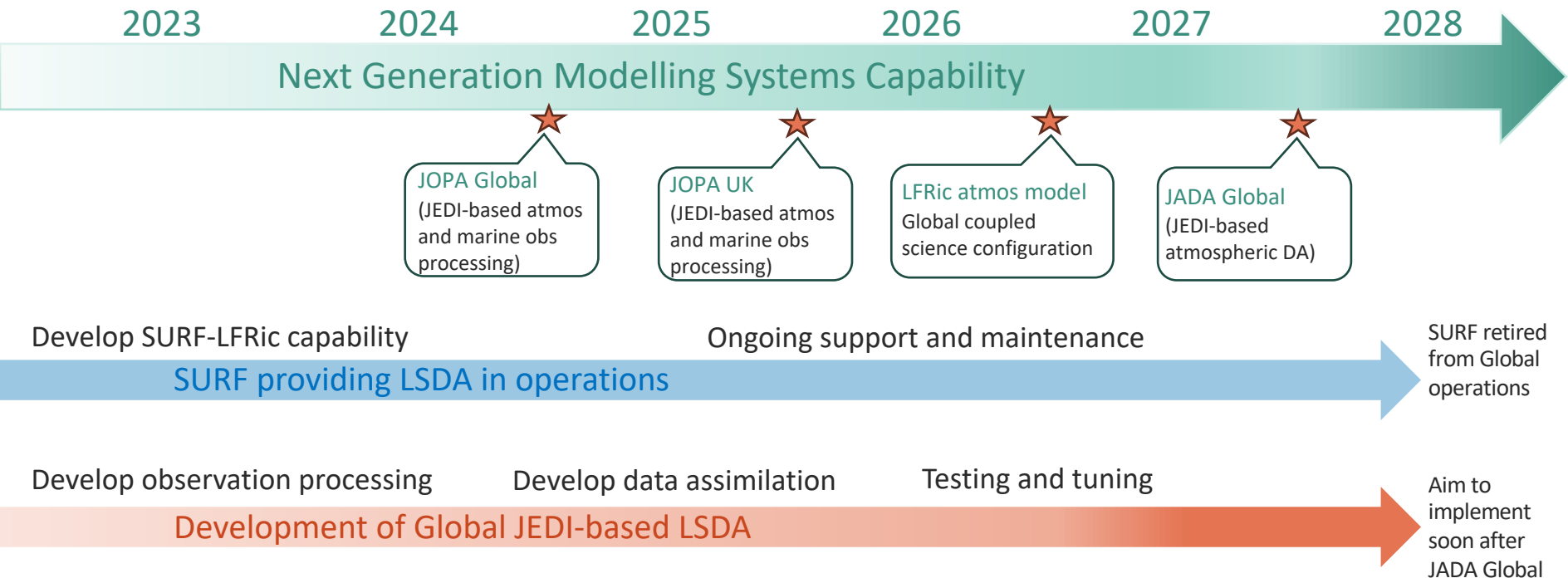
Develop observation processing capability within JOPA

Borrow resource from atmospheric JOPA development team

Deciding the DA methodology

- Ensemble DA method or ensemble of DAs?
- Variational or Kalman Filter based method?
- Global and UK same method?
- Align with atmosphere to maximise coupling options?
- Can we get good enough cross-variable correlations from our coupled ensemble?

Approximate expected timescales

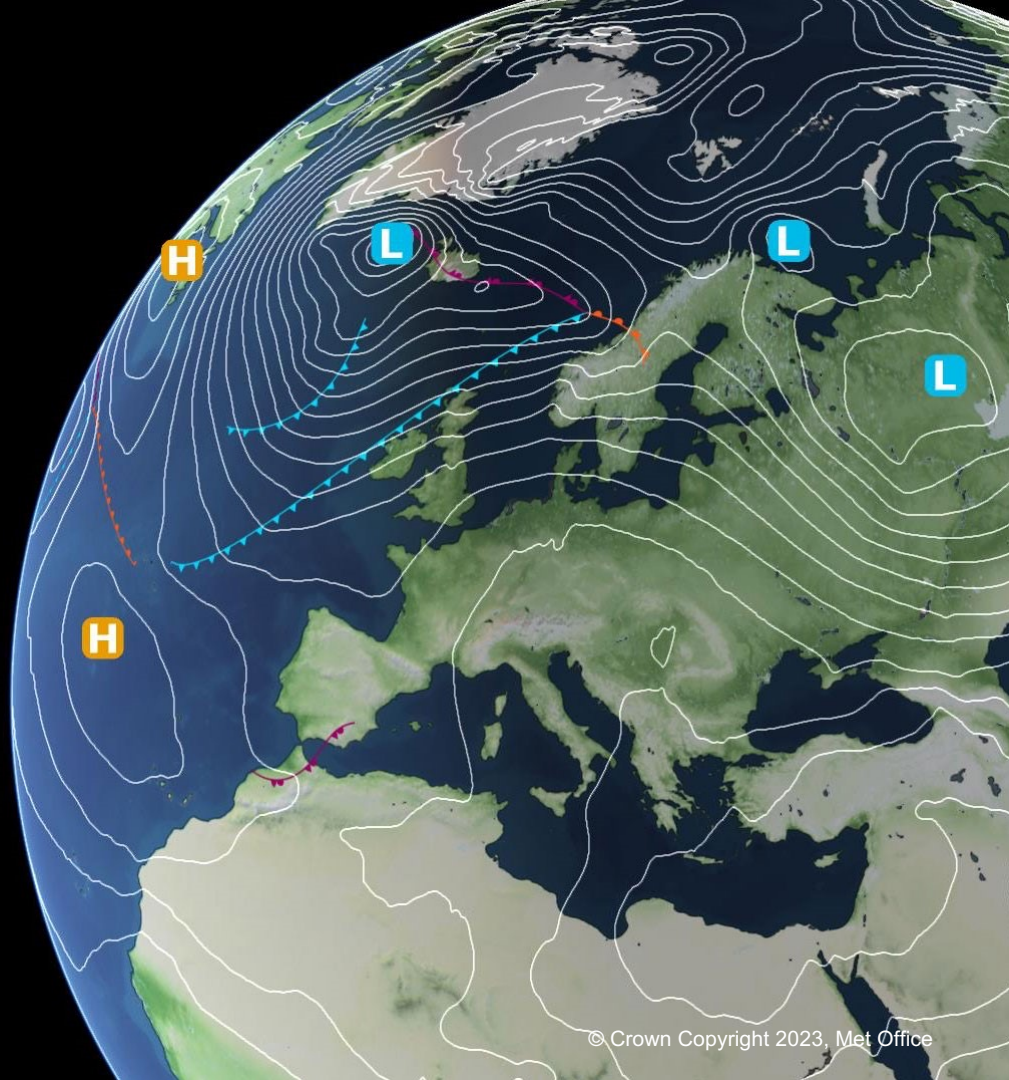


UK LSDA planning to align with JADA UK plans

Met Office

Thank you!

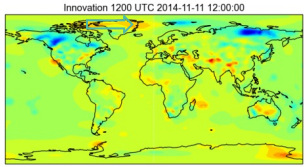
Any questions?



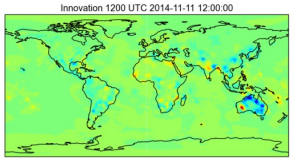
samantha.pullen@metoffice.gov.uk

Operational soil DA system

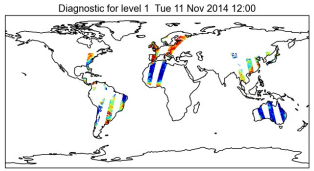
Observations



1.5 m Temp (Gridded)



1.5 m Hum (Gridded)



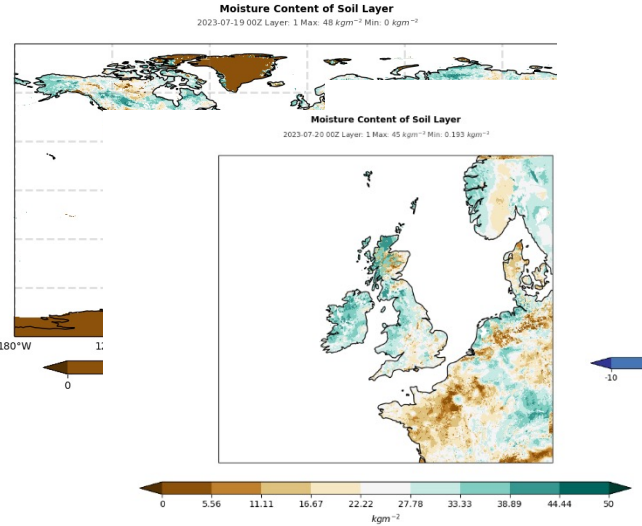
ASCAT soil wetness index

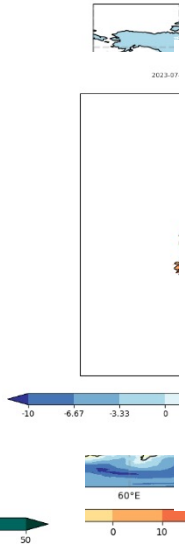
Method

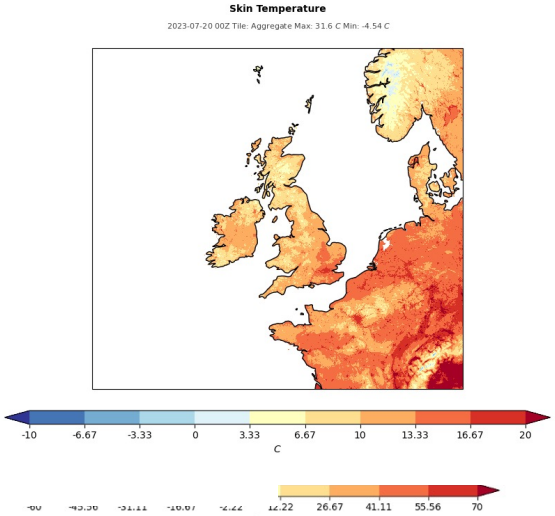
- ASCAT bias correction
- Simplified Extended Kalman Filter uses column-based system(1D) and JULES land surface model used to estimate Jacobian

Analysed variables

- Global analysis every 6h
- UKV regional analysis every hour



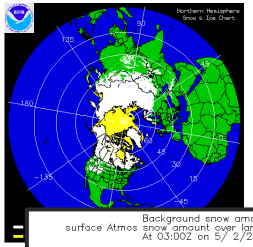


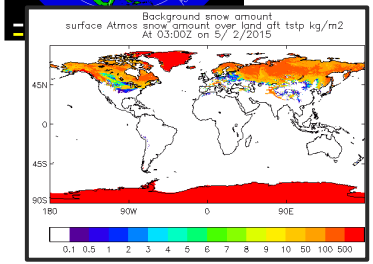


The Met Office Operational Soil Moisture Analysis System (Gomez, Charlton-Perez, Lewis, Candy, 2020)

Snow Data Assimilation

Global DA system

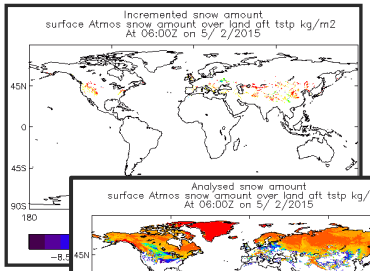


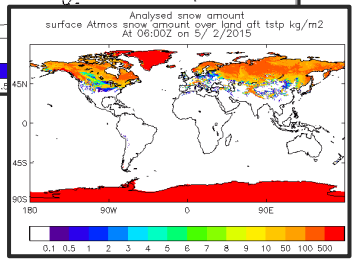


Observations
Satellite-derived daily snow cover product (NESDIS IMS NH snow analysis)

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

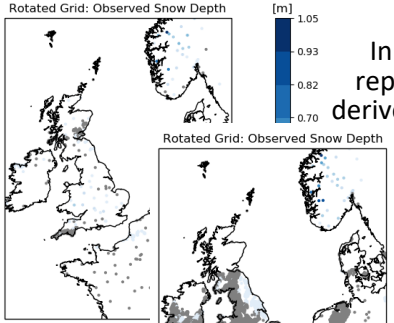
simple update scheme





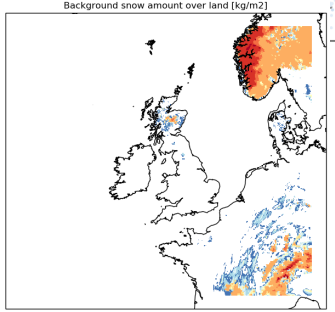
Analysis
Snow amount (kg m^{-2})
Daily at 06Z

UK DA system

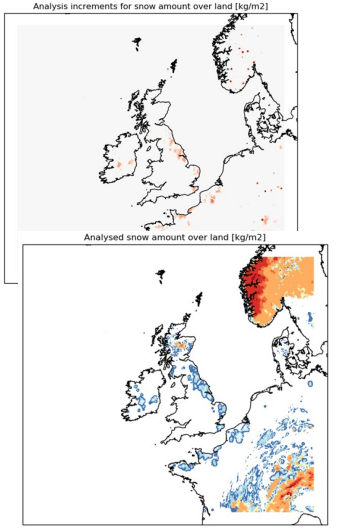


Observations
In situ snow depth reports and satellite-derived daily snow cover product

interpolation



Background
Snow amount (kg m^{-2})



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