Satellite radiance assimilation at the Met Office

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Introduction

The Met Office is collaborating with the Joint Center for Satellite Data Assimilation (JCSDA) to develop a data assimilation system based on the Joint Effort for Data assimilation Integration (JEDI) framework (see Figure 1). The system is divided into two components: the JEDI-based Observation Processing Application (JOPA), to read, process and quality control both direct and remotely sensed observations, and the JEDI Application for Data Assimilation (JADA), to assimilate the observations both in the global and the regional model configuration, to generate an ensemble of initial conditions for the next forecast cycle.

For the global model configuration, the currently operational Observation Processing System (OPS) is due to be replaced by JOPA at the end of Parallel Suite 47, due to start in summer 2025. This decision follows from JOPA having successfully met three objectives: system robustness (measured against operational-grade benchmarks for HPC tasks runtime and memory requirements); observation capability and scientific quality (produce a neutral impact); system performance (process all observations within 15 minutes, see Figure 2)

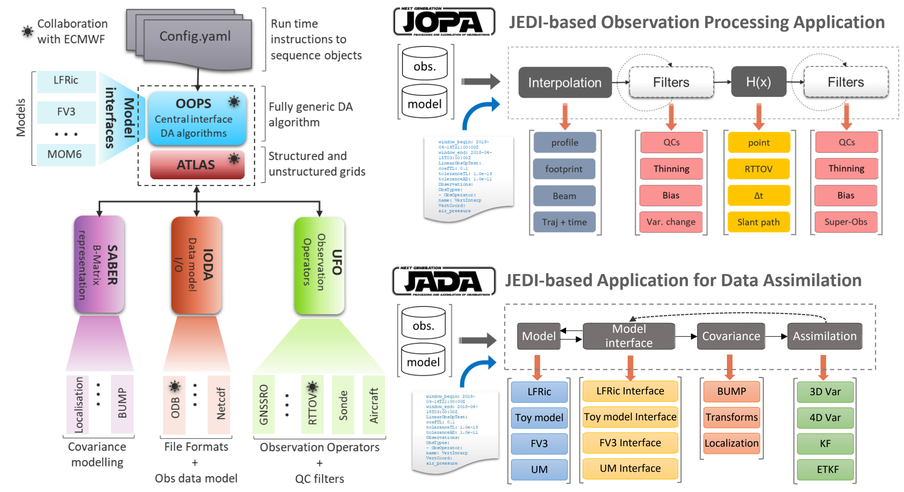

Figure 1: JEDI-based observation processing and data assimilation system under development at the Met Office

Current use of obs for global assimilation in OPS

The Met Office observation database (MetDB) archives about 300 million of observations per day (Figure 3). At every six-hourly data assimilation cycle, OPS extracts the following observations:

Surface stations (land stations, ships, buoys): p, u, v, T, rh

Sondes: theta, u, v, rh

Ground GNSS: sensitive to total column WV

Aircraft: theta, rh, u, v

Atmospheric motion vectors: u, v

Scatterometer (ASCAT on Metop-B and C): u, v

Satellite MW data: Metop-B, Metop-C, NOAA 15,18,19 ATOVS; FY3C MWHS-2; FY3D MWRI, MWTS-2 and MWHS-2; GPM GMI; SNPP, NOAA 20 ATMS, DMSP-F17 SSMIS; GCOM-W1 AMSR-2

Satellite IR data: Aqua AIRS; Metop-B, Metop-C IASI; NOAA 20 CrIS, Meteosat-9 SEVIRI; GOES 16 ABI; Himawari-9 AHI

GNSSRO: GPS, Galileo, GLONASS, BeiDou – TerraSAR-X, Cosmic-2, Sentinel-6A, Metop-B/C, FY-3D, PAZ, Spire, PlanetiQ (and GRACE-C/D from June 2025)

Products: Sentinel-3A and -3B, total column WV (OLCI); Aqua and Terra, aerosol optical depth (MODIS)

Marine observation types: sea surface temperature (SST); sea ice; ocean sounding and colour, altimeter

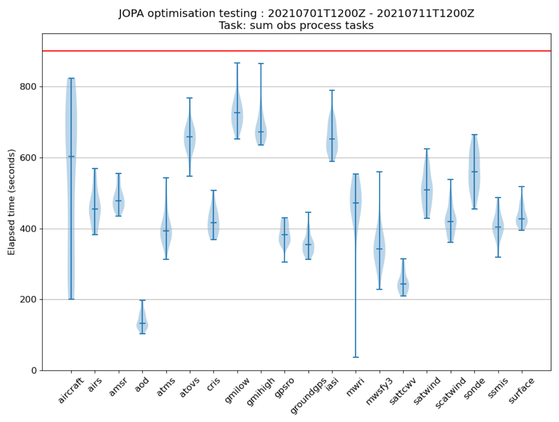

Figure 2: Total JOPA processing times for all the atmosphere observation types. Violin plots show the min, median, max, and distribution of runtimes over a 10-day period. The red line indicates the required 15-min threshold.

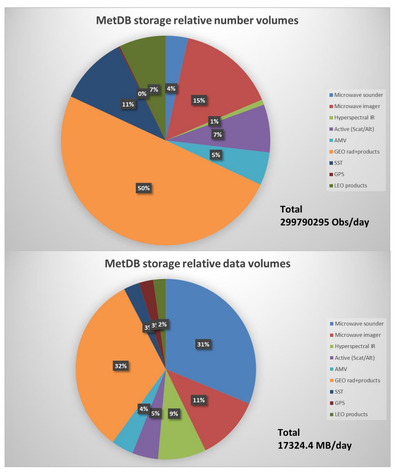

Figure 3: Number of observations and number of MB stored every day in the Met Office observation data base (MetDB)

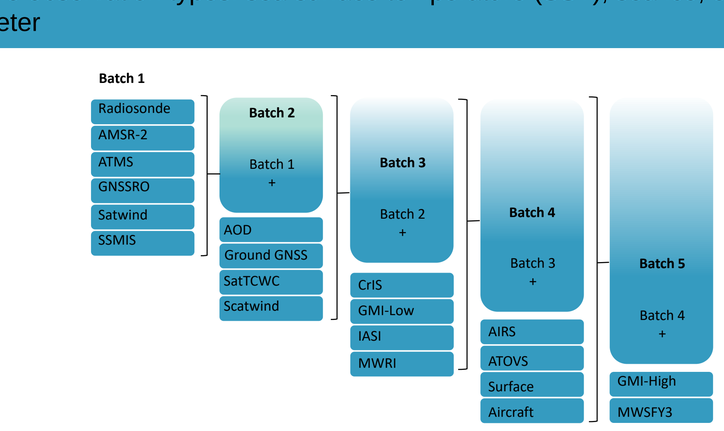

Figure 4: Batches of different obtypes through JOPA

Testing JOPA against OPS in the global model

Use of a “comparison suite” to read hourly Unified Model (UM) forecasts for the given data assimilation six-hourly cycle; extract observations from the MetDB, which are fed to both OPS and JOPA; quality-controlled obs are passed to the currently-operational hybrid 4D-Var data assimilation system (VAR). At least four six-hour cycles were tested, where JOPA and OPS output, as well as VAR analysis increments from both JOPA and OPS were compared, for each of these observation types (11 radiance obs types): AMSR-2, AMV, SSMIS, GNSS-RO, IASI, ATMS, AOD, Radiosonde, ATOVS, Scatterometer, SurfaceSST, SeaIce, SatSST, GMI-low, GMI-high, CrIS, AIRS, Surface, Aircraft, SatTCWV, GB-GNSS, MWRI, MWSFY3, OceanSound, Altimeter.

A three-month trial was then run for each obs type, where JOPA is used instead of OPS, while all other obs are processed with OPS, to demonstrate neutral impact for each obs type.

Finally, a set of three-month-long batch trials (see Figure 4), with increasing number of obs types using JOPA, was run to demonstrate combined neutral impact.

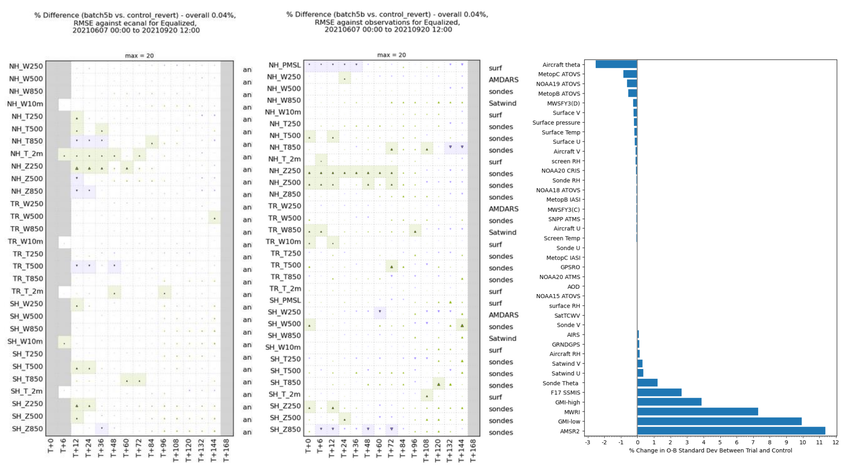

Figure 5: Score card results (left and mid panels) and forecast fit to observations from “batch 5” trial.

JOPA batch global trial results

Batch 5 contains JOPA processing for 20 out of 21 observation types (only one missing is GEO-Radiances): uncoupled, with flow dependent error modes and SST and sea ice fields from operational archive. Figure 5 (left and mid panels) shows mean relative RMSE over the different score card parameters and forecast lead times equal to +0.04% wrt obs and ECMWF analyses. These results can be considered neutral, as absolute relative difference from control is lower than 0.1%, which is the difference we get from uncoupled three-month-long trials when the experiment is identical to control except for non-significant changes (e.g. different number of used processors).

Figure 5 (right panel) shows the forecast fit to observations. RMSE results are within ±0.3% for most obs types. The largest positive differences are for MW imager data (AMSR-2, GMI-low, MWRI), owing to a larger number of used observations in JOPA, resulting from an erroneous too-strict QC of some obs in OPS, which was fixed only in JOPA.

Future work

Final JOPA tests to replace OPS for the UKV regional model configurations are planned for PS48, scheduled in 2026. A decision was taken, based on data denial experiments, to focus on exploiting geostationary radiances, particularly from MTG-IRS (see Figure 6), and to remove the use of IASI, CrIS, AIRS, GMI and MWHS radiances for data assimilation in the UKV, while retaining those from MHS, SEVIRI, ATMS as well as GeoCloud obs from SEVIRI radiance processed into a cloud-fraction column on model levels at each observation location. We will reassess the impact of the removed instruments in the future (in view of PS50, scheduled for summer 2029) when JADA Regional, based on an Ensemble Kalman Filter, will be ready for testing.

For the global model, in addition to the porting of data from currently operational instruments to JOPA, we have been monitoring and evaluating the impact of NOAA-21 ATMS and CrIS radiances, as well as geostationary radiances from GOES-19. We are also ready to evaluate the data from the Flexible Combined Imager (FCI) on Meteosat 12, which may lead to their inclusion in the set of data that are operationally assimilated in the global model. We have also plans to introduce RTTOV v14 into the operational system.

Finally, we are currently monitoring radiances from the Microwave Radiometer for Arctic Weather Satellite (AWS) mission, precursor of the EPS-Sterna constellation. We are also starting preparations to monitor radiances from the Hyperspectral Microwave Sounder In Orbit Demonstrator (HYMS IOD) as well as from instruments on board the EPS Second Generation satellites.

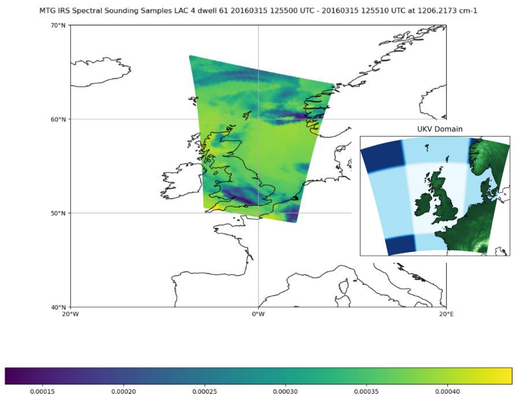

Figure 6: MTG-IRS reconstructed radiances over the UK at about 1200 cm^{-1} (8.3 µm) from test data and regional model domain over the UK (right panel).

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