Monitoring visible observations at ECMWF

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1 Visible radiance assimilation is the next exciting frontier for satellite exploitation

Observations at visible wavelengths can provide valuable additional information about clouds and aerosols, complimentary to that obtained from microwave and infrared data. Visible data have so far not been assimilated operationally in global NWP models due to the complexity of the radiative transfer and the cloud modelling.

The integration of MFASIS in RTTOV has made it possible to simulate solar reflectances in individual channels of specific satellites.

Using this approach, Steele *et al.* (2022) performed at ECMWF a preliminary monitoring of simulated reflectances from IFS short-range forecasts against OLCI (Ocean and Land Colour Imager) observations from two polar- orbiting Sentinel satellites at the chosen 665 nm wavelength (Section 3).

Lopez *et al.* (2022) performed at ECMWF a first validation of solar-spectrum reflectances simulated by running RTTOV/MFASIS on input operational IFS forecast data, against observations from geostationary satellites (GOES-16/17, Meteosat-11 SEVIRI and Himawari-8) at 0.64 microns wavelength (Section 4).

The findings from these studies are useful for the planned assimilation of visible reflectances in ECMWF's 4D-Var system (quality control; observation screening), with MFASIS selected as the visible reflectance observation operator.

2 MFASIS – a fast radiative transfer model for the visible spectrum

Data assimilation critically depends on the observation operators. The simulation of reflectances from IFS forecast data relies on the lookup-table-based radiative transfer model MFASIS developed by Scheck *et al.* (2016) and implemented within RTTOV (Radiative Transfer for TOVS; Saunders *et al.*, 2018)

To limit the size of the LUT, the state of the atmosphere and the viewing/solar geometry is described by a limited set of parameters:

- Vertically-integrated optical depths for water and ice clouds.
- Average effective particle radii for water and ice clouds.
- Surface albedo.
- Solar and satellite zenith angles.
- Difference between solar and satellite azimuth angles.

The multiple scattering treatment has been improved recently in MFASIS, and this will be available in RTTOV v13.1, whereas the results shown here uses RTTOV v12.

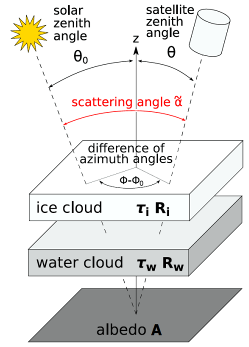
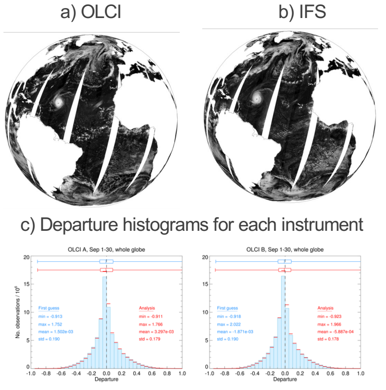


***Fig. 1**: Parameters in the MFASIS LUT.*

3 Monitoring OLCI visible radiances

- To enable comparisons against predictions of ECMWF's Integrated Forecasting System (IFS), the spectral radiances were converted into reflectances. The data are transformed ('superobbed') to a resolution of 9.6 km, as this more closely resembles the resolution of the operational monitoring experiments. Due to the complexities of the scattering of visible radiation from land and ice surfaces, initially OLCI data was considered only over ice-free oceans.
- The monitoring period includes Hurricane Larry, which began as a tropical storm on 1 September and reached peak intensity as a category 3 hurricane on 5 September, with winds of 125 mph. In general, the location of the hurricane in the IFS is in close agreement with the observations throughout its lifespan, although the presentation of the eye and the structure of the cloud bands show some discrepancies.


a) OLCI

b) IFS

c) Departure histograms for each instrument

***Fig. 2**: Global comparison between observed and predicted reflectances at 665 nm from:*
a) OLCI-A and OLCI-B observations for 5 September 2021
b) Short-term IF/MFASIS predictions.
c) Departure histograms for each instrument for September 2021

- Both instruments have departures with a normal distribution around a slightly negative mean, with the same standard deviations. Analysis reduces standard deviations and brings the means closer to zero. There does not appear to be any instrumental bias
- Extensive stratus-like clouds around the UK, and stratocumulus off the western coasts of the Americas, are not captured in the IFS. This causes a positive departure in the monthly average.
- The negative departure is related to convective clouds. Convective cells are too large in the IFS, even at 9 km resolution. Similar features were noted by Lopez *et al.* (2022)

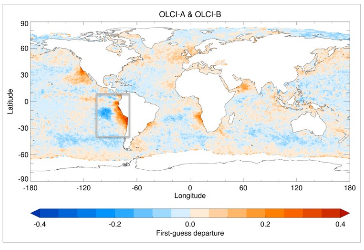
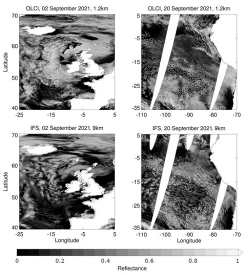


***Fig. 3**: Monthly-average first guess departures between OLCI observations and the IFS reflectances. The (red,blue) shading shows where the IFS has reflectances that are too (low,high) compared to the observations*



4 IFS+RTTOV/MFASIS against GEO satellite solar-spectrum reflectances

- The solar-spectrum reflectance simulator RTTOV/MFASIS (v12.2) has been run on 3D fields from operational short-range IFS forecasts and simulated reflectances have been compared against geostationary observations.
- The study has confirmed that the main deficiency of RTTOV/MFASIS radiative transfer is the systematic negative bias in simulated reflectances near the terminator, which results from interpolation errors in the look-up table at large solar zenith angles, and the treatment of multiple Rayleigh-cloud scattering.
- Away from the terminator, the best agreement between simulated and observed reflectances is found in the extratropics, with generally low mean biases and high correlations with respect to observations.

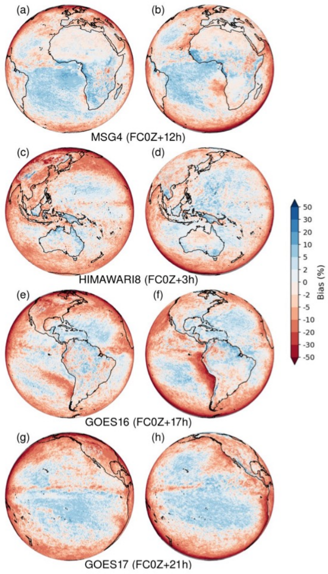


***Fig.4**: Mean bias in 0.64-μm reflectance between IFS+RTTOV/MFASIS (Cy47r1) and geostationary satellite observations over two months: 2021-01-15 to 2021-02-15 (left column) and 2021-07-15 to 2021-08-15 (right column). The shortest IFS forecast range corresponding to sub- satellite local noon (see bottom of each row) is chosen to be as close to the analysis time as possible. The rows correspond to the field of view of (a,b) MSG-4, (c,d) Himawari-8, (e,f) GOES- 16 and (g,h) GOES-17. Bias is expressed in units of reflectance (percent).*

5 Outlook and Future work

- RTTOV/MFASIS was used at ECMWF both, online within the IFS (CloVIS project) and offline with the satellite simulator (e.g., in satellite view projection to mimic the real geostationary satellite imagery).
- Preparatory and research work continued to support evaluation/assessment of SEVIRI and ABI Visible L1b reflectances in the IFS (all done at first using the IFS 'experimental obs' framework as BUFR data were not yet available; in-house finalising the development of a BUFR template for these data).
- The next step in the development of ECMWF's visible assimilation capability will be to perform preliminary assimilation experiments. Initial testing will be performed without explicit cloud variables in the 4D-Var control vector, where cloud affected reflectance innovations force temperature and humidity increments (like the current all-sky approach for microwave data). The possibility of adding an explicit cloud control variable in the future will also be explored.
- The validation of simulated solar reflectances will also be part of the evaluation of kilometre-scale experiments that will be run in the course of the DestinE projects.

Acknowledgements

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