Progress towards assimilating cloud visible reflectances at ECMWF

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Introduction

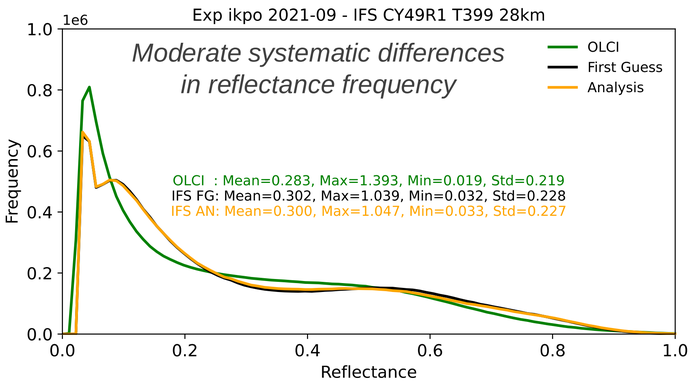
Overarching goal: All-sky assimilation of visible reflectance satellite observations to improve the representation of clouds in numerical weather prediction.

Poster content: First-ever assimilation of visible reflectances using 655nm satellite observations in ECMWF IFS Cycle 49R1. Assimilation experiments assess the impact of visible reflectance data on analysis and forecasts of clouds and key forecast variables.

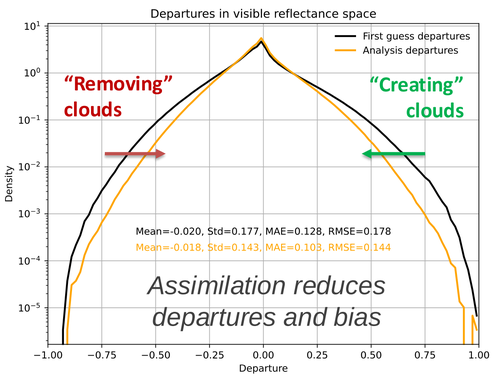
Experimental setup: MFASIS NN forward operator; ECMWF's 4D-Var system; Visible observations captured by the Ocean and Land Colour Instrument (OLCI) aboard ESA's Sentinel-3A and Sentinel-3B satellites; Periods: Sept. 2021 or Dec. 2024 – Feb. 2025

Visible reflectance histograms

Frequency histograms of reflectances for September 2021



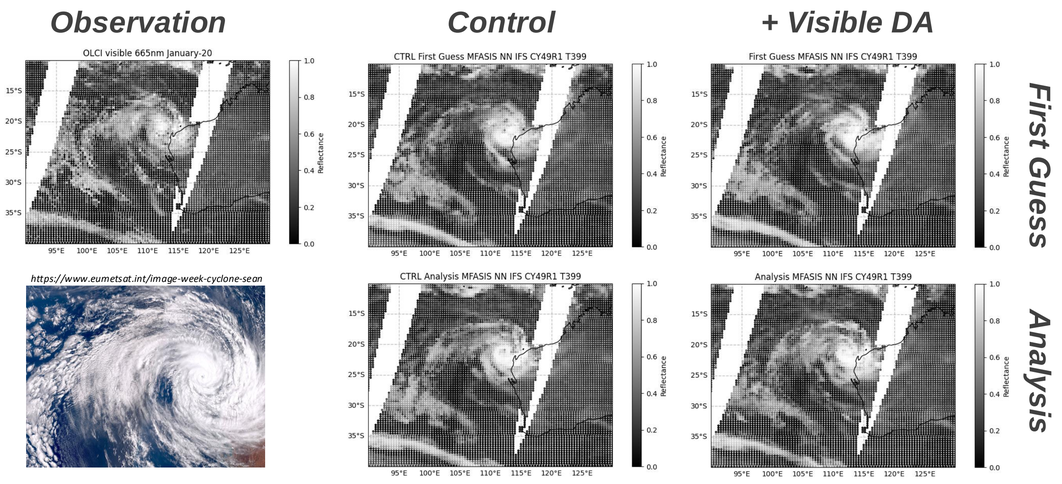
Departure histograms for September 2021



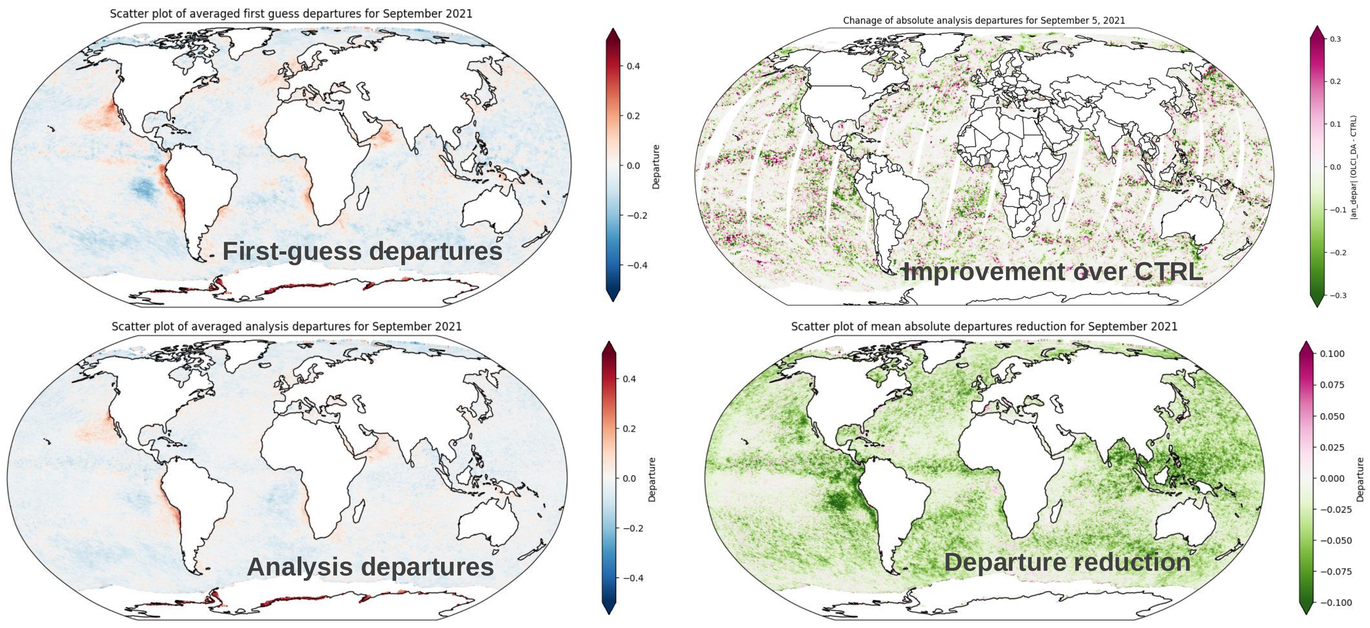
departure *= observation minus model equivalent in visible reflectance space*

Analysis impact in visible reflectance space

Case study of Tropical Cyclone Sean: January 2025

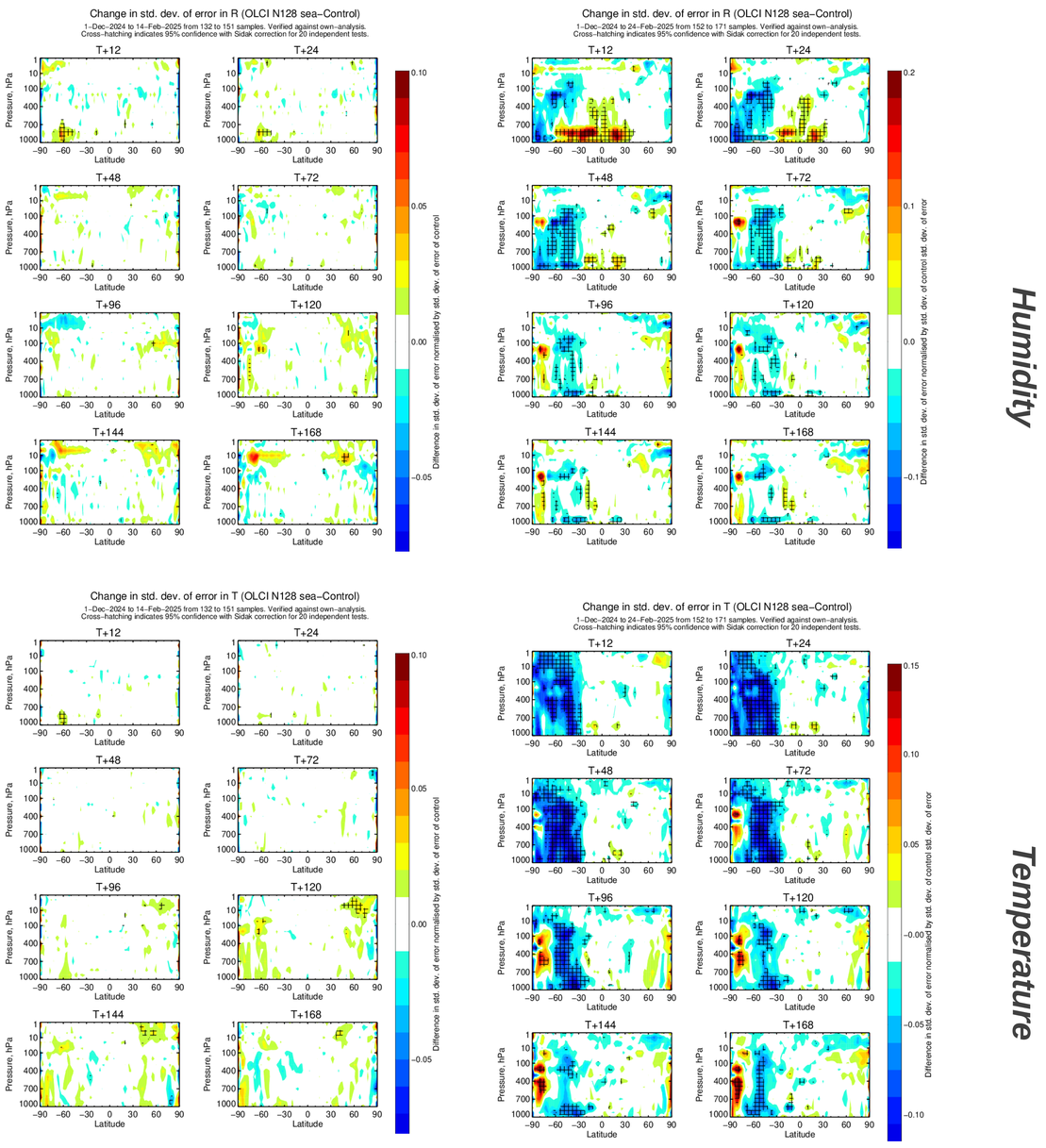


Monthly mean statistics assessing observation minus model departures



Forecast impact: Full vs. depleted obs. system

Forecast error changes in model space: Adding visible assimilation with a large beneficial impact for the depleted observing system



Discussion

- **First-ever visible reflectance assimilation at ECMWF**: Successfully integrated 665 nm visible observations from Sentinel-3A/B into ECMWF's IFS, marking a milestone for global NWP.
- **Analysis impact:** Assimilation improves model equivalent in visible reflectance space, enabling improved cloud representation
- **Forecast impact**: Neutral impact for the full observing system given suboptimal settings and a small amount of additional visible observations. Finding an optimised setup and adding the GEOS ring bears much room for improvement.
- **Statistical significance:** Two seasons are needed to obtain statistically significant results and to ensure consistent performance across different seasons.
- **Re-analysis**: Depleted observing system experiments suggest a large potential of visible observations to improve cloud representation and future re-analysis products, considering visible observations have existed since the 60s.

Next steps

What is the progress on GEOS satellite visible monitoring and assimilation?

- **Visible channels on geostationary satellites** are integrated into IFS in parallel (SEVIRI & FCI on MET-9/10/11, ABI on GEOS-16/18, and AHI on Himawari 9)
- **Model inter-comparison** between ICON and IFS with visible satellite observations (See poster by DWD / Christina Stumpf with monitoring results)

What is needed to improve future visible assimilation?

- **Optimisation** of super-obbing, thinning and observation error model
- **Enhanced data screening** protocols to remove detrimental observations (varQC)
- **Reduce systematic differences and biases** between model and observations (varBC plus operator and model refinements are crucial)

References

Scheck, L.: A neural network based forward operator for visible satellite images and its adjoint, J. Quant. Spectrosc. Ra., 274, 107841, 2021

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