Shared-Latent-Space Transformer for Multi-Sensor Harmonization in Earth Observation

Zayd M. Hamdi*, Martin Jung, Gregory Duveiller, Qi Yang, Sebastian Hoffmann, Fabian Gans, Ulrich Weber, Claire Robin, Vitus Benson, Jacob Nelson, Jiaxin Xie, Marco Körner, Christian Reimers, Sophia Walther

KEY FINDINGS

Maintains continuity across satellite missions

Our model performs time-aware bidirectional translation between MODIS and VIIRS to maintain time-series continuity.

Eliminates Gap-Filling processing steps

Imputes missing sensor data at comparable performance with standard gap-filling methods

Direct Downstream Compatibility

Allows models trained on long-term MODIS data to be used after transition to VIIRS, without retraining.

MOTIVATION

MODIS' retirement threatens a 25-year climate record

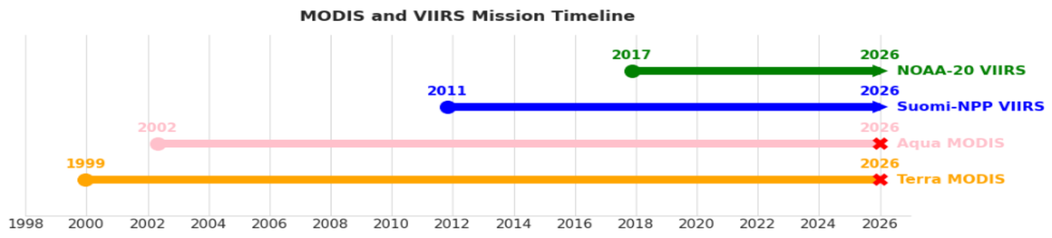

Fig. 1. multi-mission timeline of MODIS and VIIRS satellites

The MODIS science data collection is scheduled to cease by 2026[1]

VIIRS is the successor, but not a plug-and-play replacement

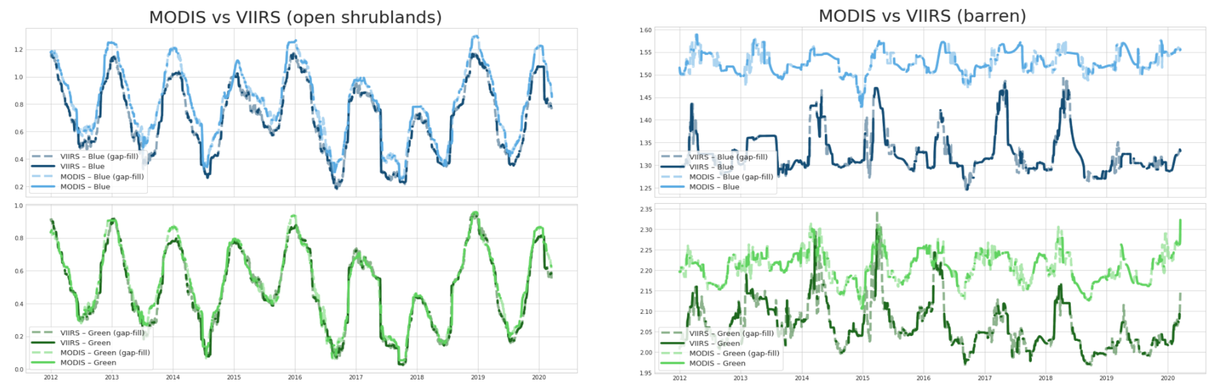

Fig. 2. MODIS vs VIIRS Blue/Green time-series showing location-dependent bias

METHOD

Data

We sample from daily paired MODIS and VIIRS reflectances and create a dataset of 40,000 globally stratified pixels from 2012 to 2023.

Training Objective

We minimize the Continuous Ranked Probability Score (CRPS)[2] between the predicted cumulative distribution F_t and the observed reflectance x_t

$$\mathrm{CRPS}(F_t, x_t) = \int_{-\infty}^{\infty} \left[F_t(y) - \mathbf{1}_{\{y \geq x_t\}}\right]^2 dy$$

The CRPS loss is evaluated only at time steps with good quality observations.

Model Architecture

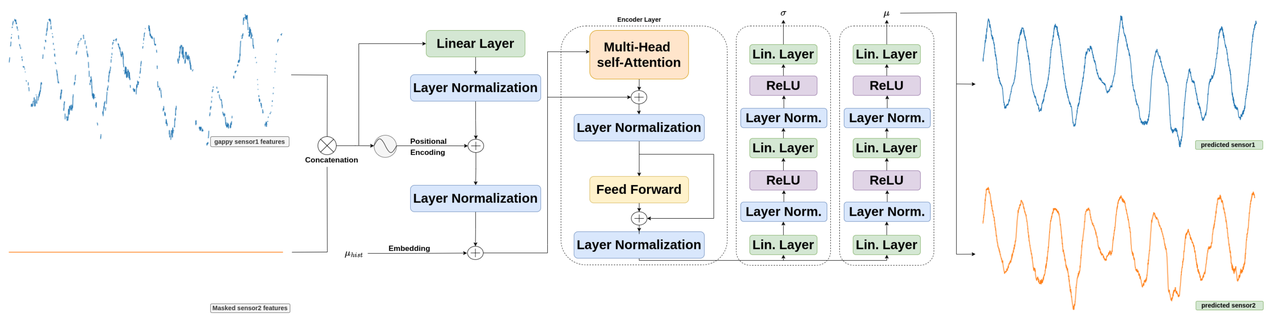

Fig. 3. Overview of SatFuseNet's architecture

RESULTS

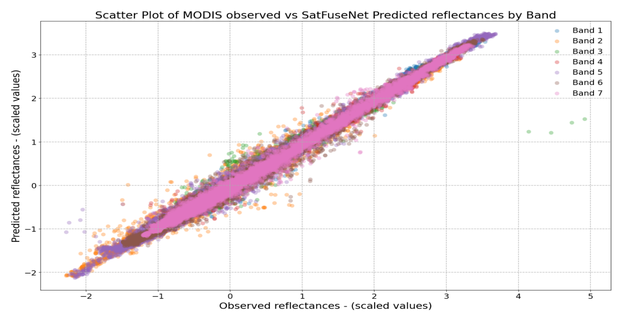

Fig. 4. Scatter plot of Predicted vs Observed MODIS reflectances.

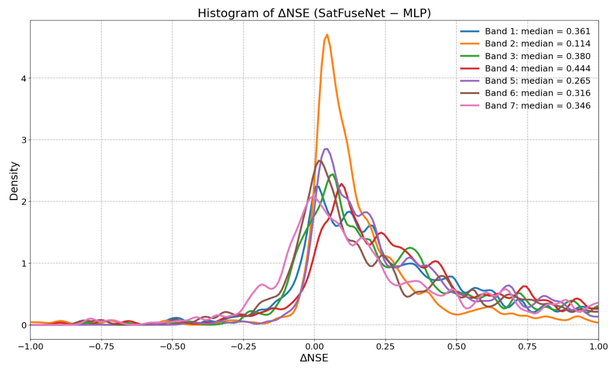

Fig. 5. Distribution of ΔNSE (ours − MLP) across MODIS bands; positive values indicate improved performance over the baseline.

Predictions closely match MODIS observations, and ΔNSE is consistently positive across all bands, indicating clear improvement over the MLP baseline.

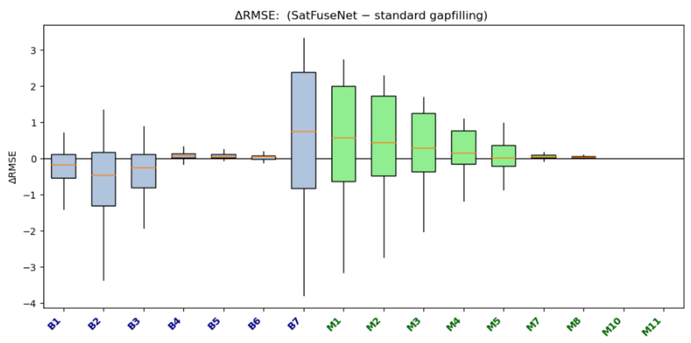

Fig. 6. Distribution of ΔRMSE (ours - standard) for reconstructed MODIS bands.

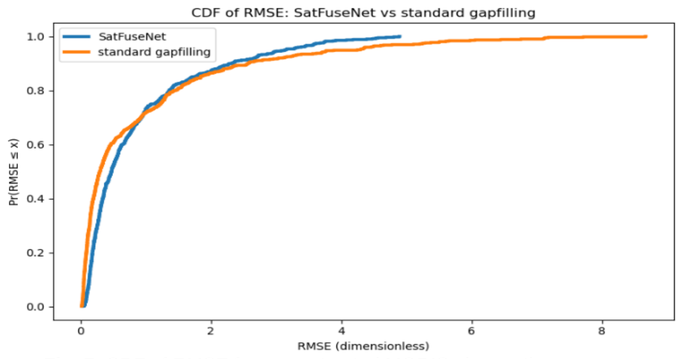

Fig. 7. CDF of RMSE for reconstructed MODIS observations.

Reconstructs missing observations at performance levels comparable to standard gapfilling methods across MODIS bands.

A GPP model trained on MODIS inputs was evaluated under three test-time scenarios:

- using MODIS inputs (reference),
- replacing MODIS with VIIRS directly,
- replacing MODIS with synthetic MODIS generated from VIIRS.

This tests whether MODIS-trained models remain usable after transition to VIIRS without retraining/fine-tuning.

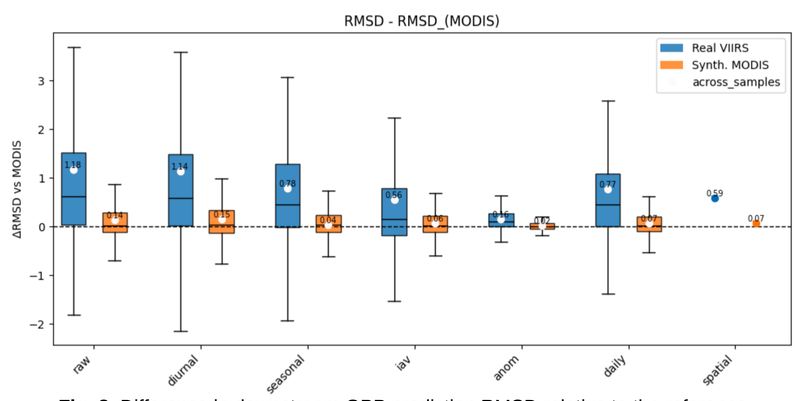

Fig. 8. Difference in downstream GPP prediction RMSD relative to the reference model's

Our model's outputs allows models and downstream workflows trained on the long MODIS record to remain usable after transition to VIIRS as plug-and-play, with performance remaining substantially close to the original MODIS reference.

REFERENCES

* zmhamdi@bgc-jena.mpg.de

[1] **NASA LAADS DAAC**. MODIS to VIIRS Transition for Atmospheric Science Products (white paper, 18 April 2025), section "End of MODIS Operations in 2026-27."

[2] **Gneiting, T. and Raftery**, A. E. (2004). Strictly proper scoring rules, prediction, and estimation. Technical Report no. 463, Department of Statistics, University of Washington, Seattle, USA.

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