JEDI SkyLab use for Observation Evaluation

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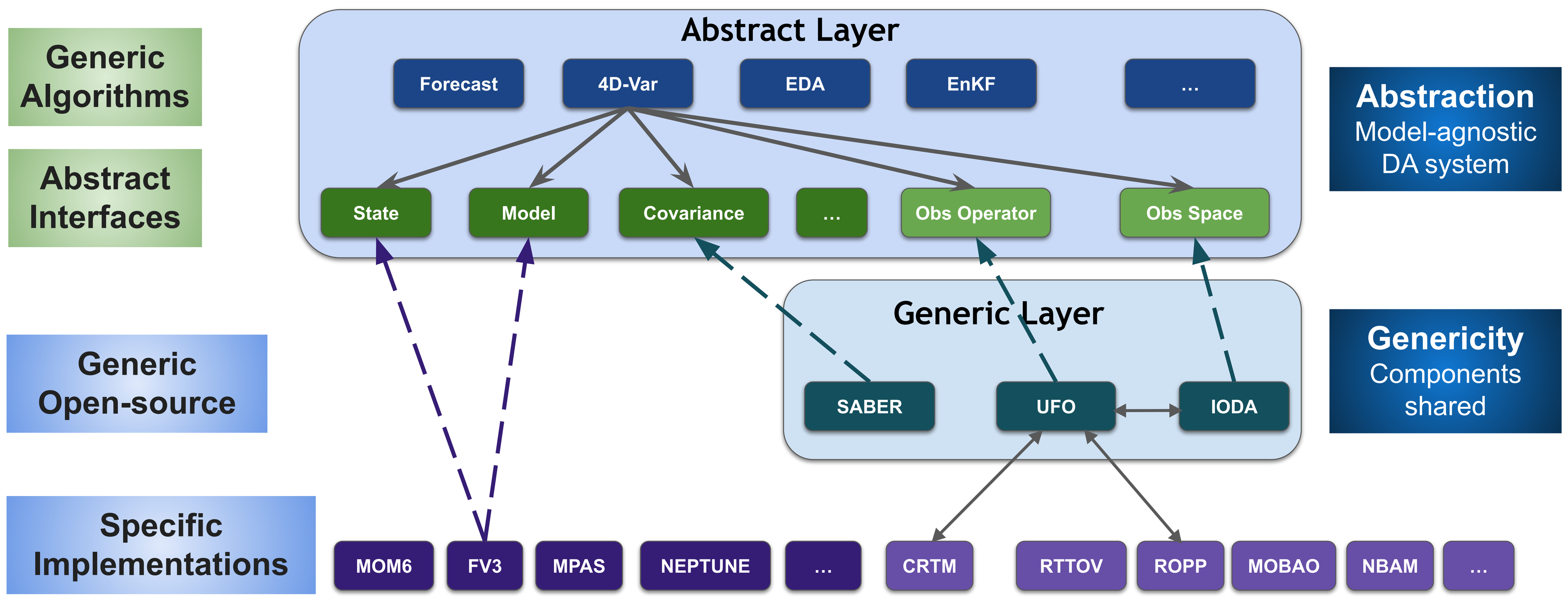
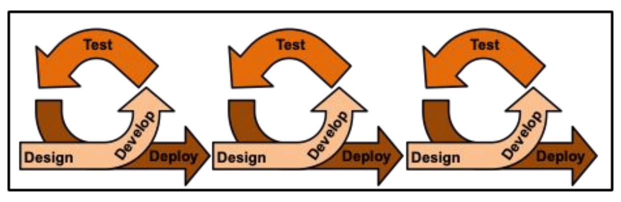
Empowering Environmental Analysis: The JCSDA's JEDI Project

The Joint Center for Satellite Data Assimilation (JCSDA) is an interagency partnership dedicated to advancing research in applying satellite data to operational goals in environmental analysis and prediction. Within JCSDA, the **Joint Effort for Data Assimilation Integration (JEDI)** project plays a crucial role. JEDI involves collaboration between scientists and software engineers to establish a unified data assimilation framework, specifically focusing on different components of the Earth system and various applications. The primary goal of JEDI is to streamline community efforts, enhance efficiency, and facilitate the transfer from development teams to operational use. The JEDI framework is known for its versatility, and has been integrated over a diverse set of regimes including: ocean, atmosphere, sea-ice, atmospheric composition and space weather. JEDI application for weather, ocean, climate, and environmental analysis and prediction systems, is actively in use to accelerate advancements in satellite data utilization.



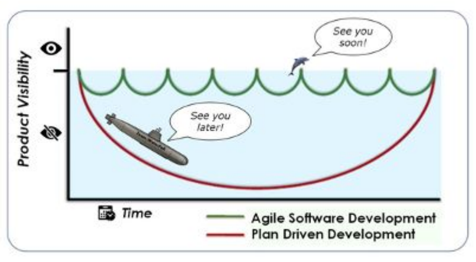
The Dynamic Design of JEDI

In pursuit of innovation, the JEDI framework deploys abstracted interfaces over a diverse range of data assimilation approaches. This departs from conventional numerical weather analysis and prediction systems that include proprietary, numerous and disjointed algorithms. The JEDI approach ensures specific configurations and instructions for the system are maintained in yaml control files. This transformative shift allows development of new methods and strategies without the need to modify the code itself. It also provides an exchange mechanism for comparability and integration. Continuously and rapidly developed with an agile approach, the dynamic JEDI system enhances operational use and feature design.



Agile testing

- Continuous process, feedback for each iteration
- Issues are fixed within the same iteration
- Easier to review



Efficient and Adaptable: JEDI's UFO

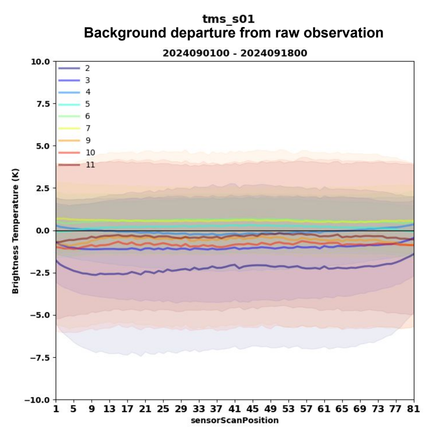
The JEDI system efficiently incorporates multiple options for simulating observations, quality control modification, and observation error specification through the many observation filters and functions. The **Unified Forward Operator (UFO)** contains observation operators, each a subclass of the UFO base classes for the nonlinear forward operator and its tangent linear and adjoint, this allows seamless operation of the varying observation operators through abstraction of model interfaces. In addition, the UFO includes wide-ranging generic observation filters and functions to implement quality control, and observation error assignment. Specific well-established packages such as the ROPP and RTTOV from EUMETSAT ROM and NWP SAF's respectively are available as is the JCSDA Community Radiative Transfer Model (CRTM). Notably, without enacting any code changes, the UFO component easily adapts observation usage, data assimilation, quality control, and error assignment, enabling rapid development.

Tomorrow.io/TROPICS Microwave Sounder (TMS*)

The NASA TROPICS and Tomorrow.io microwave sounders have a common heritage, and are 12 channel radiometers with nearly identical frequency bands.

Channel	Center Frequency (GHz)	Bandwidth (GHz)	NEdT (K)	Beamwidth (deg)
1	91.65	2	0.95	2.9
2	115.25	1	0.85	2.4
3	116.125	0.75	0.90	2.4
4	118.75±1.875	0.75	0.90	2.4
5	118.75±1.25	0.5	0.90	2.4
6	118.75±0.75	0.5	0.90	2.4
7	118.75±0.375	0.25	1.00	2.4
8	118.75±0.125	0.25	1.00	2.4
9	184.41	2	0.44	1.5
10	186.51	2	0.44	1.5
11	190.31	2	0.44	1.5
12	204.8	2	0.55	1.4

Table 1: TMS channel performance design specifications. Beamwidths are Full Width at Half Max (FWHM).

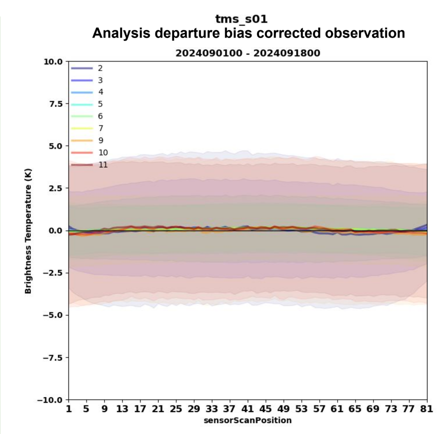


JCSDA's current TMS runs

Sep-Oct 2024 (T.io S1/S2)
Jan 2025 (T.io S3/S4)
NASA TROPICS-03, -05, -06

We use a JEDI-MPAS 30km global 3D-EnVar system and a 31-member ensemble B.

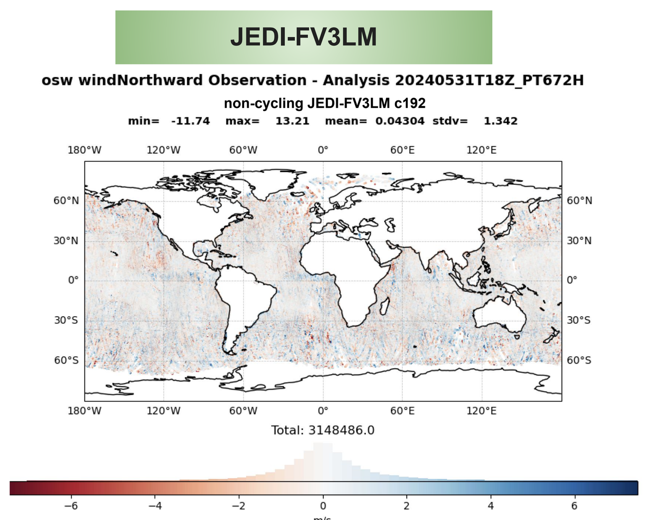
Shown are the departures from background (left) from raw observation and from analysis (right) after bias correction.



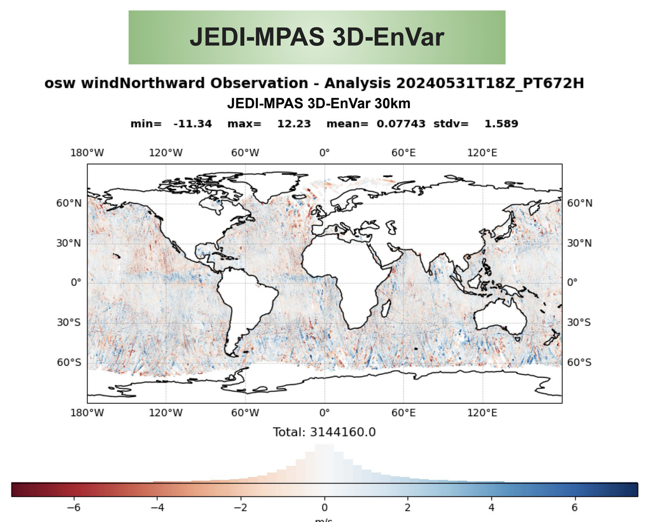
GNSS-R OSW

GNSS-R (reflectometry) can be used to retrieve an ocean surface wind (OSW) speed. We have evaluated the NASA CyGNSS mission, Spire via NOAA CDP and Muon via USAF CDP. An assimilation pathway that includes an observation function allowing use of background wind direction is being used to assess impact on NWP. The JCSDA has used the NOAA FV3-LM (linearized model) and NSF NCAR MPAS models, with our final analysis using a 30km global 3D-EnVar with 31 member ensemble derived B (background error).

JEDI-FV3LM



JEDI-MPAS 3D-EnVar



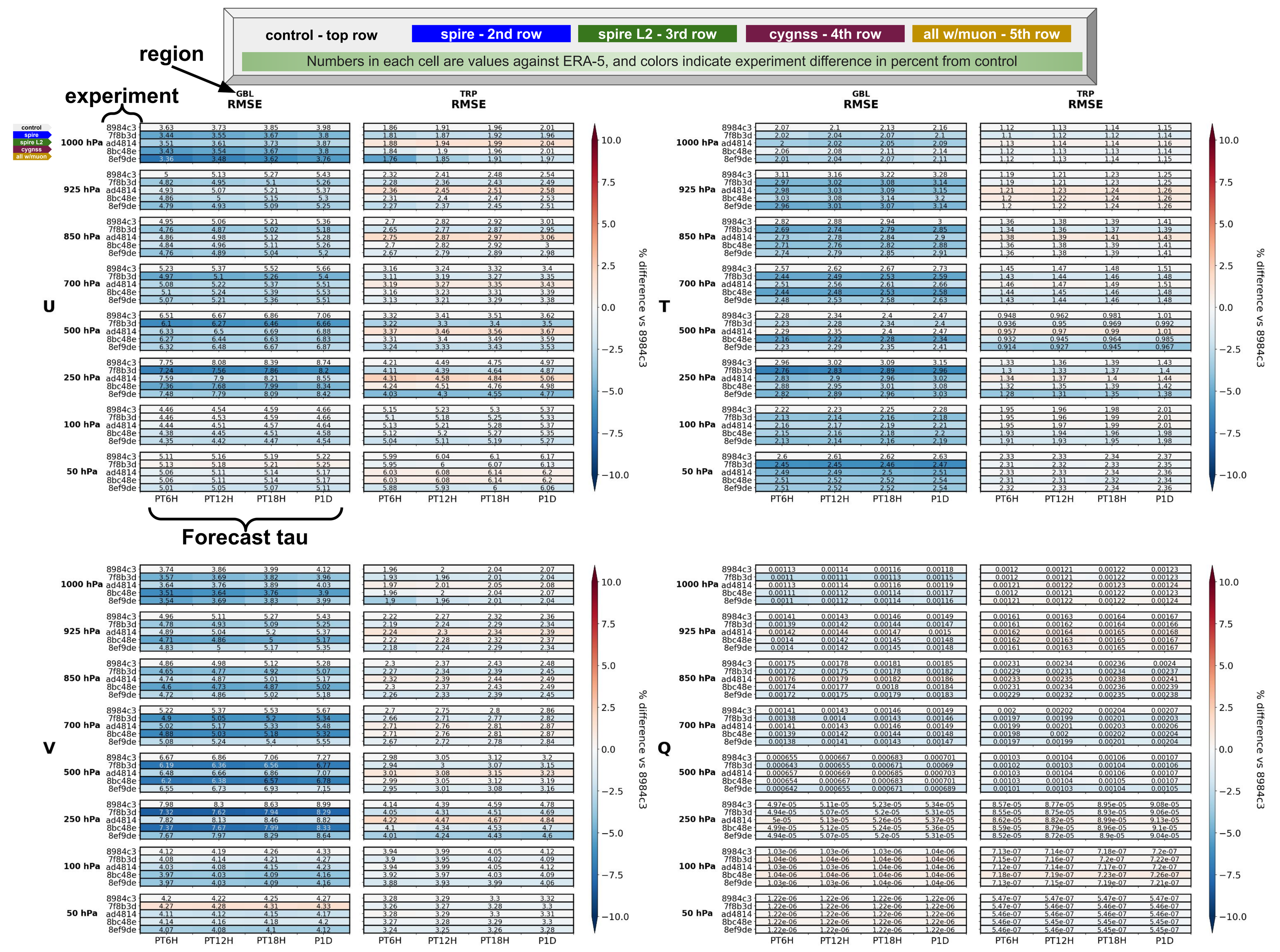
Observation Evaluation

A core function for the JCSDA is the exploration of new and emerging data sources. Rapid prototyping and developing strategies for quality control and assimilation can be transferred directly for the benefit of the partner agencies. Beyond the demonstration above for the Tomorrow.io/TROPICS Microwave Sounder (TMS) and GNSS-R Ocean Surface Wind (OSW), JCSDA and its partners are using JEDI in other regimes besides NWP such as ocean, sea ice, soil moisture, ionospheric observations and many others. The JCSDA has worked to create enhanced the diagnostic and verification packages to allow robust evaluation in both observation space and model space (analyses and forecasts).

GNSS-R Ocean Surface Wind (OSW)

Overall, we have found a positive impact of the GNSS-R OSW on the analysis and forecasts. This was shown by an improvement in the global fit to u- and v-wind and temperature that was greatest outside of the tropics (even for CyGNSS). Reductions of RMSE for a JEDI-MPAS system against ERA-5 are greatest in the lowest pressure levels and range generally from a 1% to 5% reduction over the control run. The impact of these observations, particularly the impact on temperature, is expected to be greatly reduced with the introduction of satellite radiances. Any technological advances to allow the GNSS-R OSW to retrieve higher wind regimes (above 20 m/s) would also increase their impact. All of these factors in this study suggest that the GNSS-R OSW is an observation that would provide benefits to existing NWP systems. However, care should be taken to ensure the model resolutions are aligned with the observed data. Current operational model resolutions finer than 30 km should be suitable for using these observations without the need for thinning.

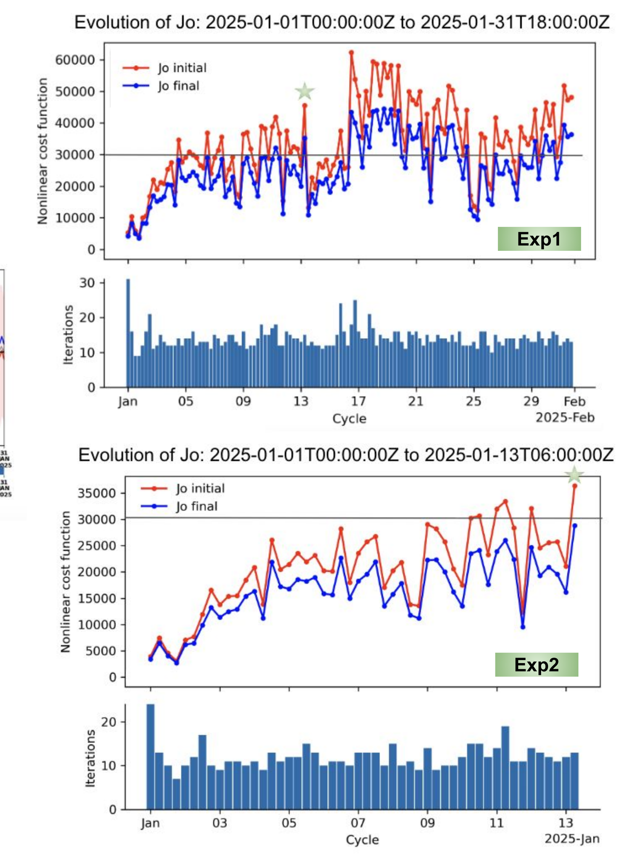
June 2024 RMSE vs ERA-5



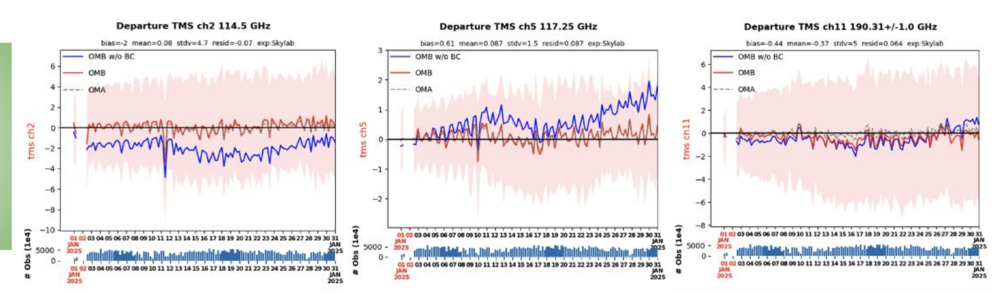
Tomorrow.io microwave sounder

The JEDI-MPAS 30km global system is also in use to explore Tomorrow.io Microwave Sounder (TMS) impact on NWP analysis. At present, we are confirming the forward and adjoint calculations with the operators – at this time CRTM-only. As of 01 May 2025, there have been seven successful TMS launches, with S1 lost mid-Oct 2024 while the rest remain active. Through the USAF CDP, S1 through S4 have been made available for evaluation: S1 and S2 in Sep-Oct 2024; and S3 and S4 in Jan 2025.

JCSDA is actively examining the performance of the Tomorrow.io Microwave Sounder (TMS). After doing a preliminary analysis, we have begun assimilation trials. A first experiment (Exp1) was conducted with S1 & S2 (Sep/Oct 2024) and S3 & S4 (Jan 2025) using all 12 channels actively. The observation cost function (Jo) for Exp1 in Jan 2025 is shown in the upper right figure. This run was used to produce a Desrosier error estimate. This Desrosier estimate, the Exp1 error and a new estimate for an Exp2 is shown per channel below.

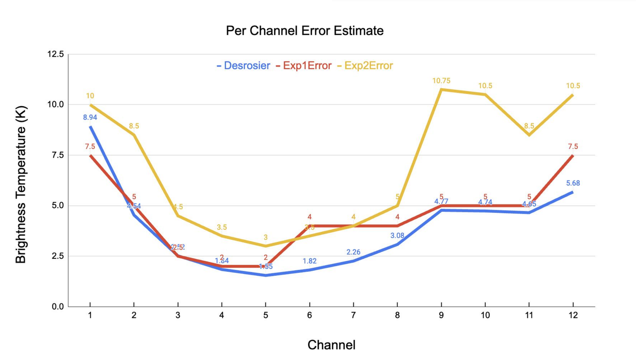


Time Series
Exp1 global departures for TMS S04 before and after bias correction



Error Estimate
Experiment 1: all channels active
Desrosiers: estimated from Exp1
Experiment 2: remove ch 1, 8, 12

A second experiment is ongoing that removes channels 1, 8 and 12 and revises the observation error.



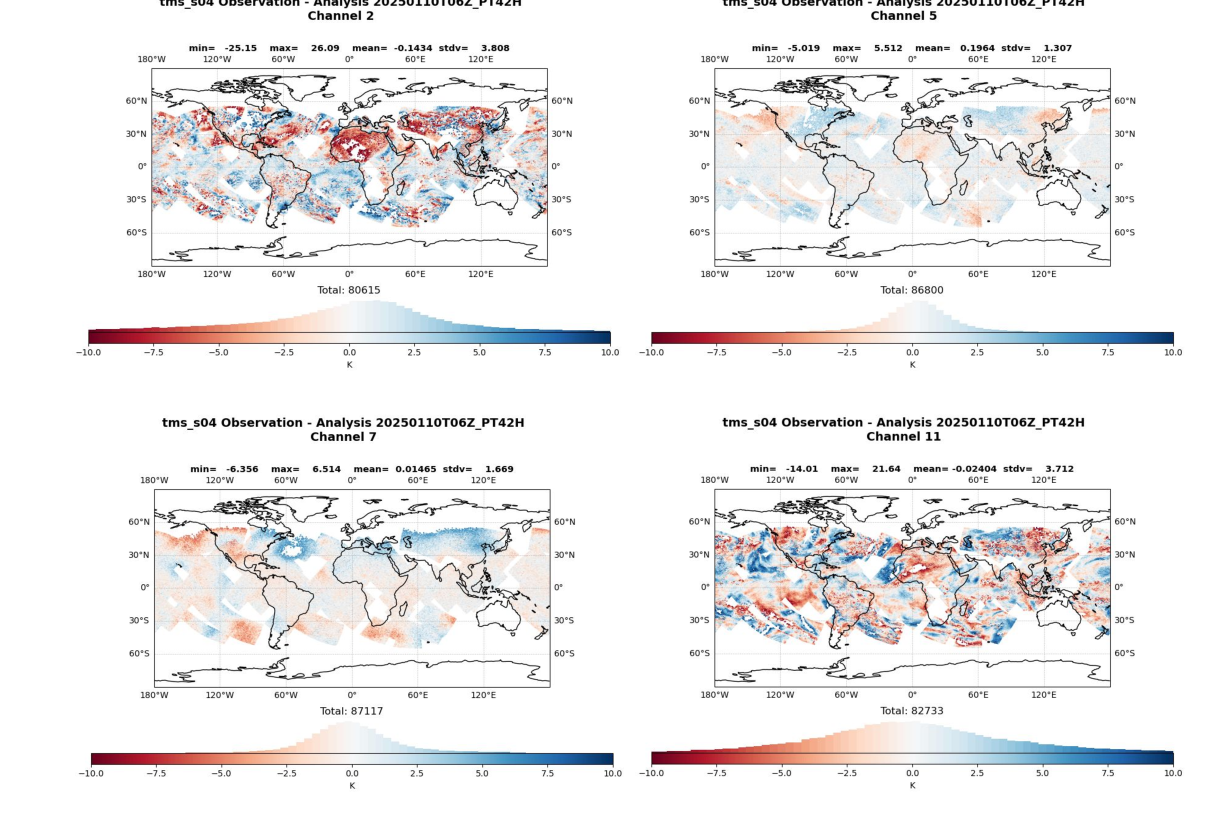
TMS S04 Analysis Departures

The Tomorrow.io Microwave Sounder (TMS) shows stable performance over the delivery period and we have been able to establish an initial set of bias predictors that reduce the scan bias and provide largely gaussian departure statistics to the assimilation system.

The analysis departures are shown over 2 days of 6-hourly assimilation cycles for "dirty" window channel 2, two sounding channels 5 and 7 with temperature weighting function peaks at approximately 8km and 18km, and the lowest peaking water vapor channel 11.

There are residual biases particularly in channel 7 that we feel may be alleviated with additional bias predictors. The orbital bias predictor is a potential additional predictor.

Lastly, these trials used a fully ensemble-B that remains deficient, and though all-sky scenes are used there is no direct feedback to the cloud state variables.



JEDI Skylab Exploration

The JEDI Skylab system is an evolving framework for demonstrating new and emerging technologies. The growing capabilities of the system are being routinely demonstrated across environmental prediction regimes. The JCSDA has been actively exercising JEDI using Skylab to evaluate the performance of the assimilation system and help partners in feature development and integration. We have shown a functional variational bias correction, and the ability to evaluate impact against other observations and an external analysis.

More on JCSDA

JCSDA acknowledges support and data access provided by CDP programs at NOAA NESDIS and USAF