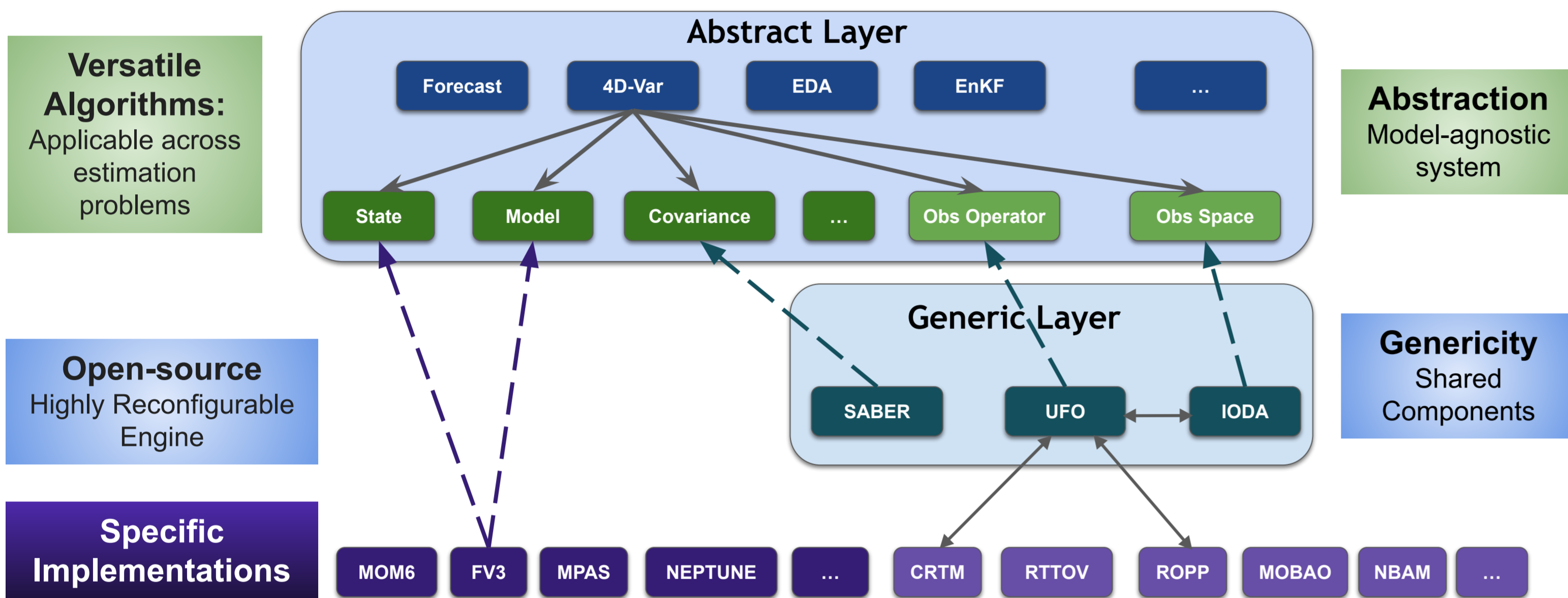




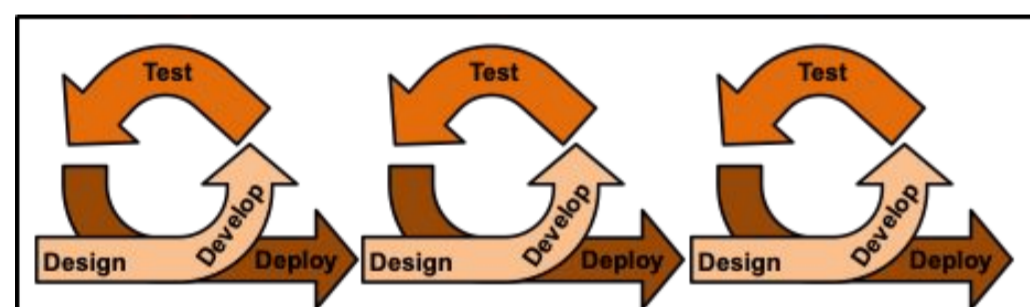
Empowering Environmental Analysis: The JCSDA's JEDI Project

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.

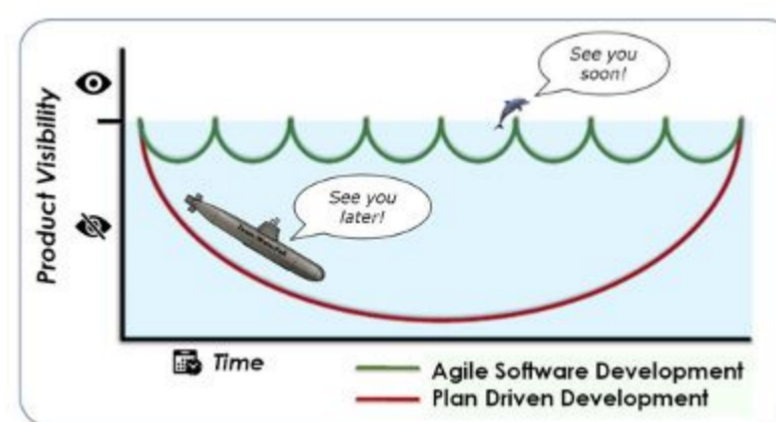


The Dynamic Design of JEDI

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.

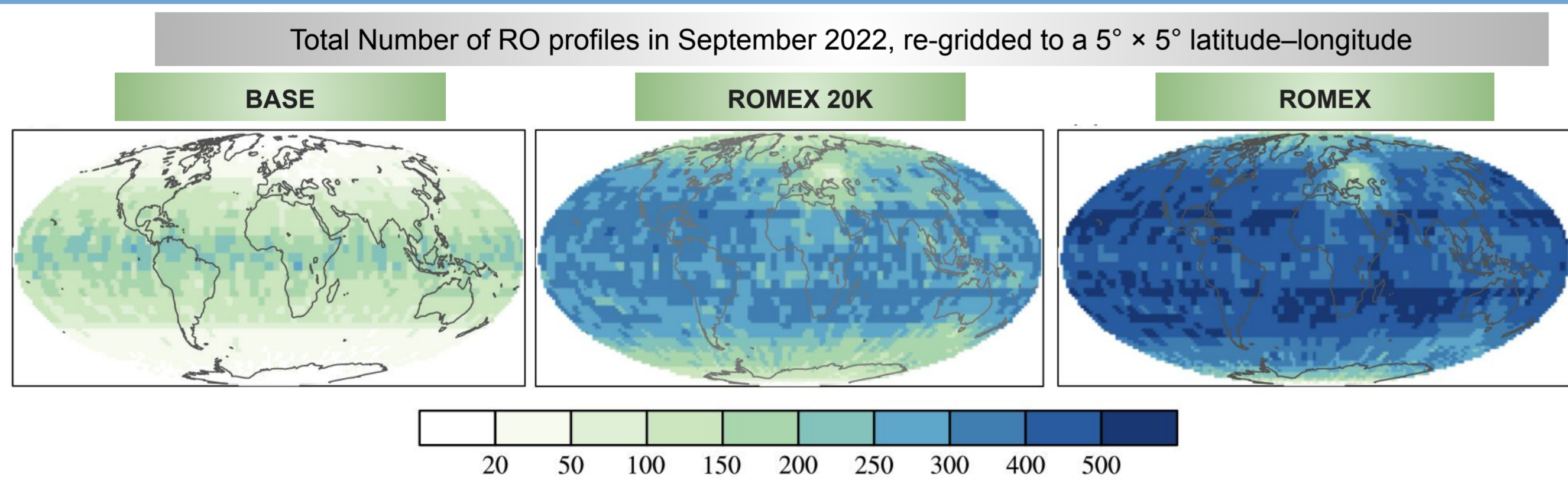


- ### Agile testing
- Continuous process, feedback at each iteration
 - Issues are fixed within the same iteration
 - Easier to review

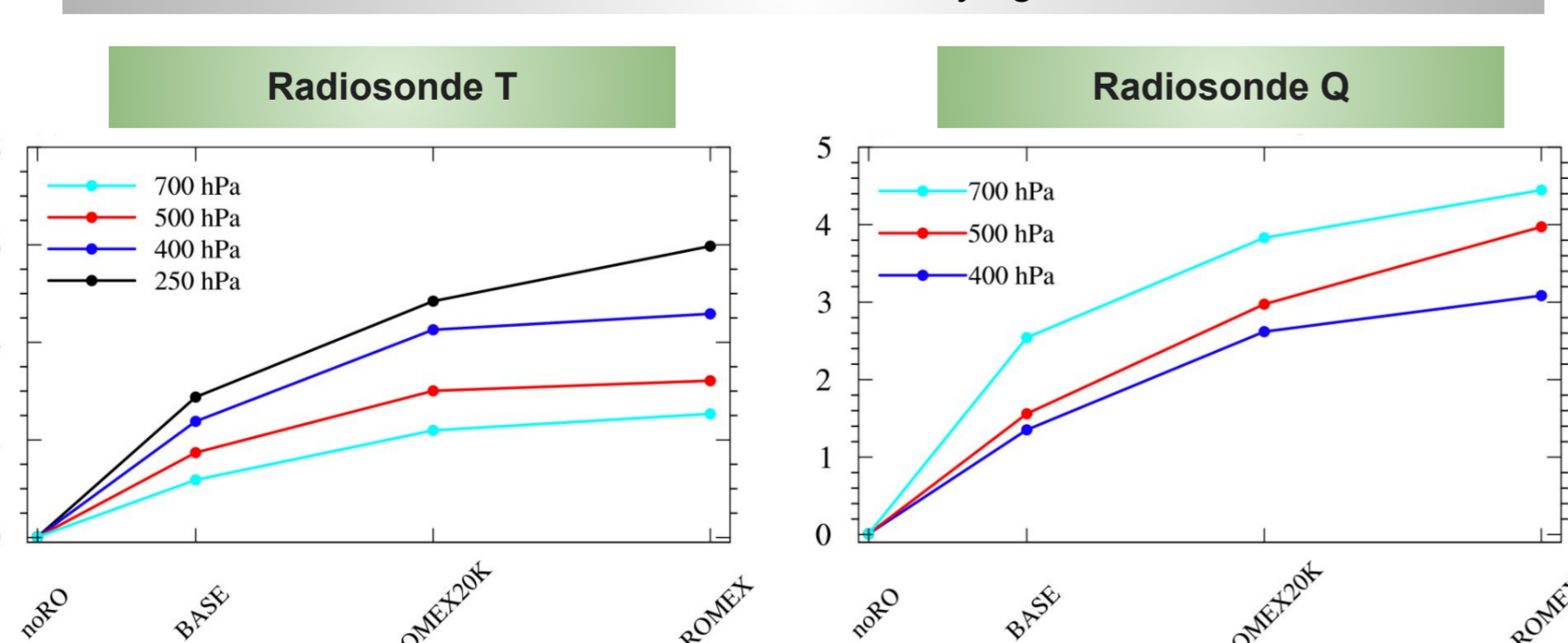


Efficient and Adaptable: JEDI's UFO

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. The UFO component includes wide-ranging generic observation filters and functions to implement quality control, and observation error assignment. Well-established packages such as the JCSDA Community Radiative Transfer Model (CRTM) and the ROPP and RTTOV from the EUMETSAT ROM and NWP SAFs respectively. Notably in JEDI, without enacting any code changes, the UFO component easily adapts observation usage, data assimilation, quality control, and error assignment, enabling rapid development.



RMSE reduction w.r.t Radiosonde for varying GNSS-RO Volumes



ROMEX

The Radio Occultation Modeling Experiment (ROMEX) is an international experiment lead by the CGMS International Radio Occultation Working Group. ROMEX enabled the use of approximately 35,000 RO profiles—nearly triple the number typically available to operational centers, which is about 8,000 to 12,000 per day (BASE). JCSDA contributed an experiment using JEDI and the NOAA global forecast system (GFS) atmospheric model. The results confirm that assimilating additional RO data further improves forecasts across all major meteorological fields, including temperature, humidity, geopotential height, and wind speed, for most of vertical levels.

<https://doi.org/10.5194/egusphere-2025-3235>

Observation Evaluation

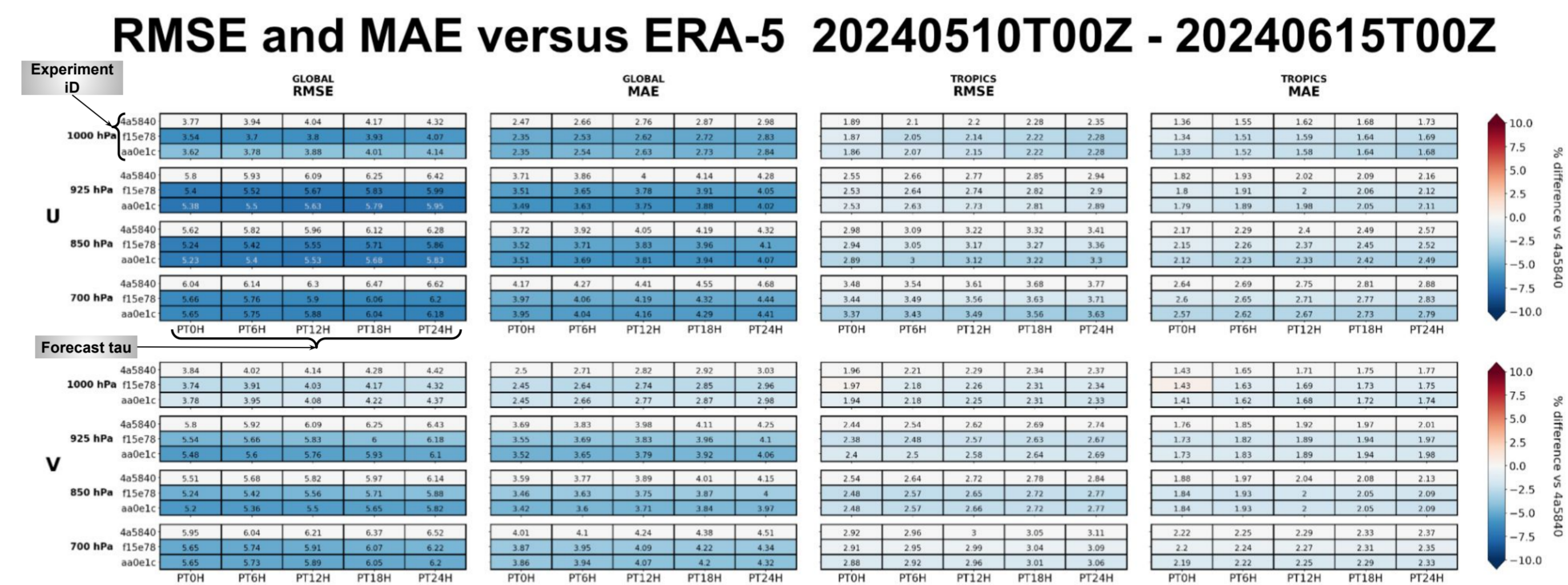
A core function for the JCSDA is the exploration of new and emerging data sources. Rapid prototyping and developing strategies for quality control and assimilation which can be transferred between partners and JEDI-enabled systems. JCSDA and its partners are using JEDI in regimes including NWP, ocean and/or sea ice modeling, land surface, and the ionosphere. The JCSDA has worked to develop the SkyLab system, this can ingest observations and backgrounds for a cycling analysis and forecasting system and includes enhanced diagnostic and verification packages that allow robust evaluation in both observation and model space. This has been applied to observation evaluation for the US Air Force and NOAA NESDIS, and for contribution to collaborative studies such as the Radio Occultation Modeling Experiment (ROMEX).

Commercial Data Pilots

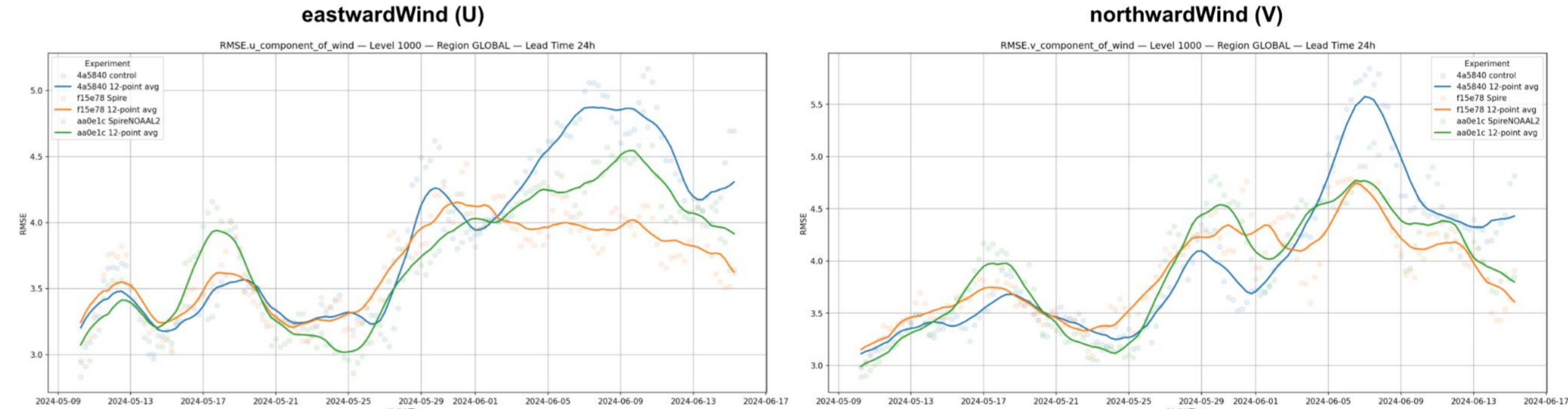
A core at the creation of the JCSDA is to **improve and accelerate** the quantitative use of research and operational **satellite data** in weather, ocean, environmental analysis and prediction systems. JCSDA has contributed to data pilots for the US Air Force and NOAA NESDIS. These programs aim to acquire high-impact observations that improve environmental awareness and prediction tools.

Enabling Flexible Diagnostics

When using SkyLab the system the model analysis and forecast files are managed using Research Repository for Data and Diagnostics (R2D2). These can then be used in downstream applications for comparing to self analysis or reference analysis. It is in the best interest of the JCSDA and its partners to use established and document methods for diagnostics and verification. The Model Evaluation Tools Plus (METplus) repository is a natural fit for SkyLab to provide a well-known and robust tool. Further the WeatherBench-X framework has been integrated with SkyLab and enables an additional flexible evaluation tool.



Timeseries of RMSE versus ERA-5 20240510T00Z - 20240615T00Z

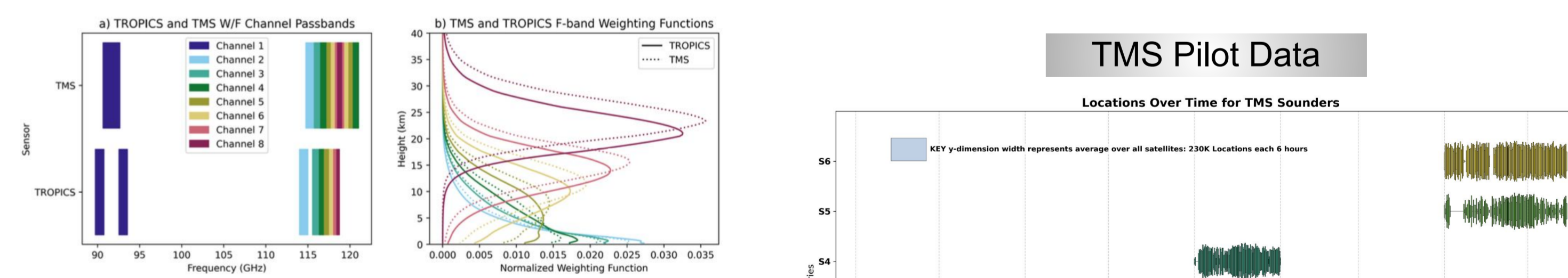


GNSS-R OSW

Global Navigation Satellite Systems (GNSS) transmit strong L-band signal that reflect off the ocean, ice and earth surface. The art of collecting these signal is called GNSS-Reflectometry (GNSS-R). GNSS-R signals can be collected and used to produce estimates of **Ocean Surface Wind (OSW)**. Data purchased by NOAA through the **NESDIS Commercial Data Pilot (CDP)** was evaluated, results from a JCSDA OSW assessment are shown above. The upper figure, is a scorecard and shows verification of RMSE and Mean Absolute Error (MAE) against ERA-5 for three experiments using a 30km global JEDI-MPAS system including: control (4a5840 - blue), Spire (f15e78 - orange), and Spire NOAA-L2 (a0e1c - green) from May 10 - Jun 15, 2024. The lower figures are the RMSE time series for each experiment. JCSDA has found a positive impact of the OSW winds, and delivered a report along with the JEDI configurations to NOAA to be run with any JEDI-enabled system.

Verification from Observations

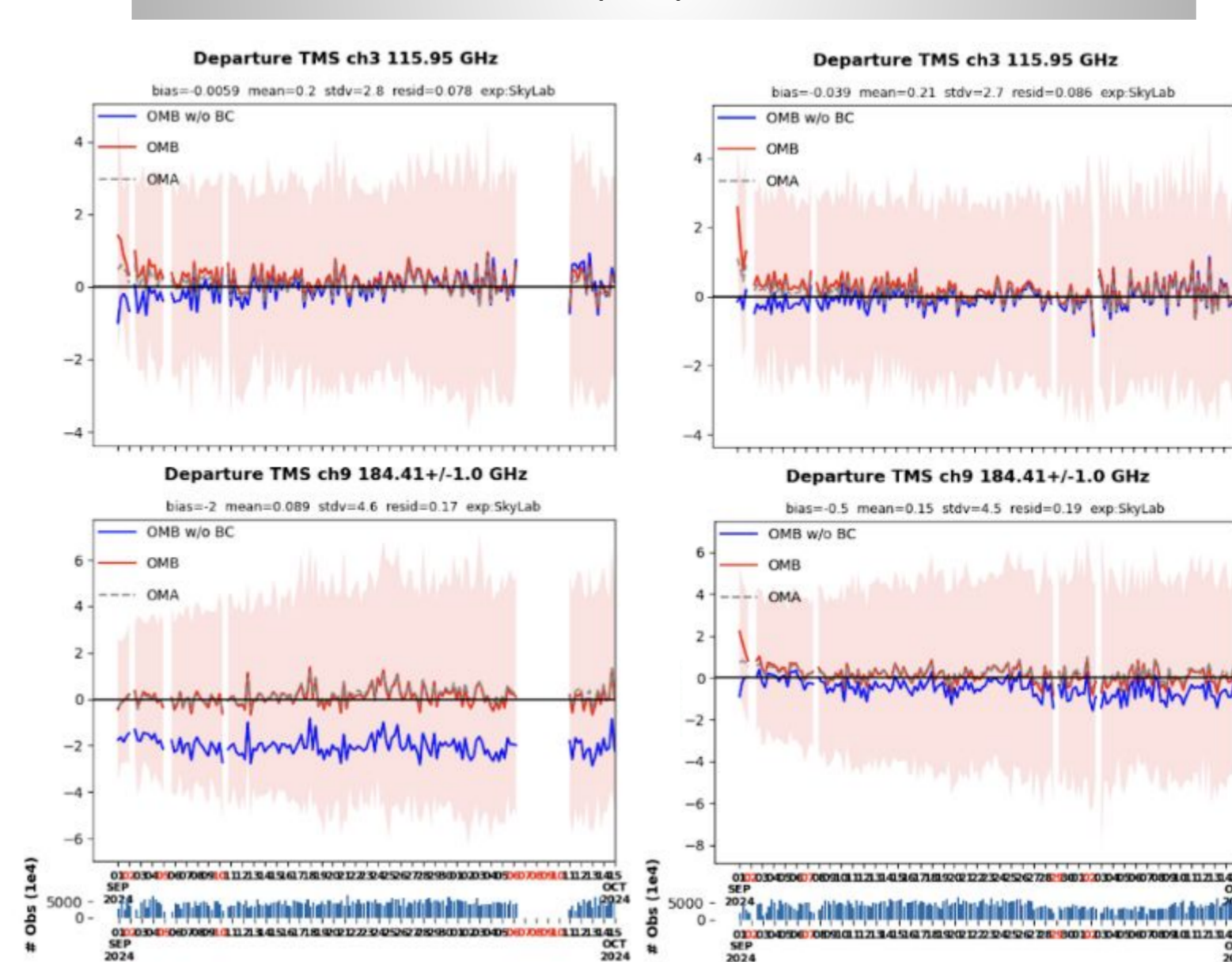
The observations alone carry a wealth of information. We can use the SkyLab system to collect information by observation type, and as we modify model backgrounds, assimilation configurations, observation usage and error estimation we can examine the response in the observations. These are collected in the common format. The format is defined by the JEDI Interface for Observation Data Access (IODA), by abstraction of the this component the observations and the information from the assimilation system such as estimates of the observation and its error can be stored together.



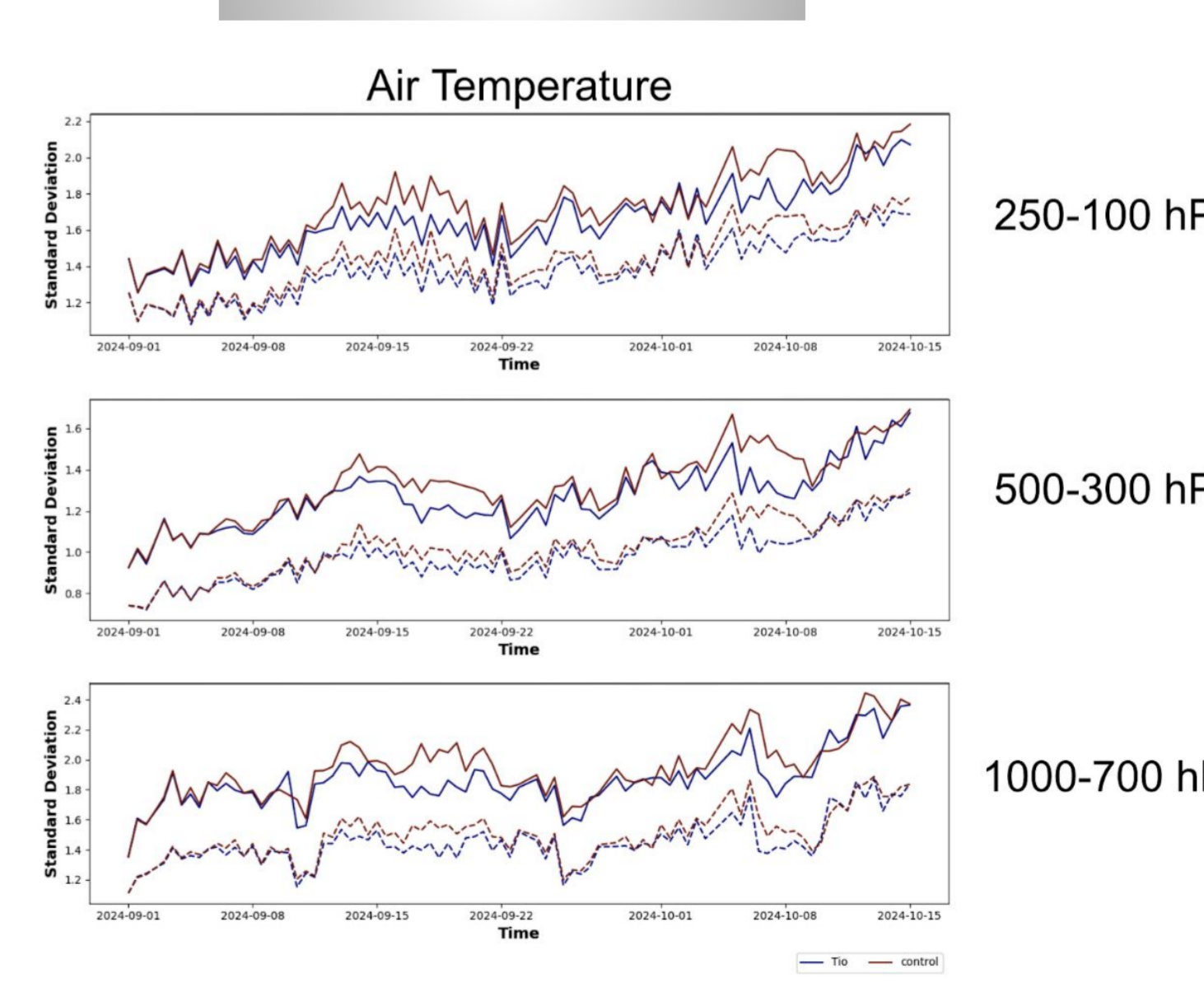
Tomorrow.io Microwave Sounder (TMS)

A JEDI SkyLab system was used to explore Tomorrow.io Microwave Sounder (TMS) impact on NWP analysis. As of 01 September 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. The evaluation found the TMS had an overwhelmingly positive response on analyses, forecasts and the fit to other observations such as radiosonde shown lower right for air temperature.

Fit to Tomorrow.io (Tio) Microwave Sounder



Fit to Radiosonde



JEDI SkyLab Exploration

The JEDI SkyLab system is a framework to verify the JEDI performance and can further be used to demonstrate 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 system and to assist partners in development of new features and in support of integration. The JCSDA and its partners have shown functional operators across diverse model and state spaces, and the ability to evaluate impact against other observations and an external analysis.

More on JCSDA



JCSDA acknowledges support of their sponsors and the data access provided by CDP programs at NOAA NESDIS and USAF