National Aeronautics and Space Administration

Leveraging Observing System Simulation Experiments for Satellite Instrument Design: Advancements and Challenges

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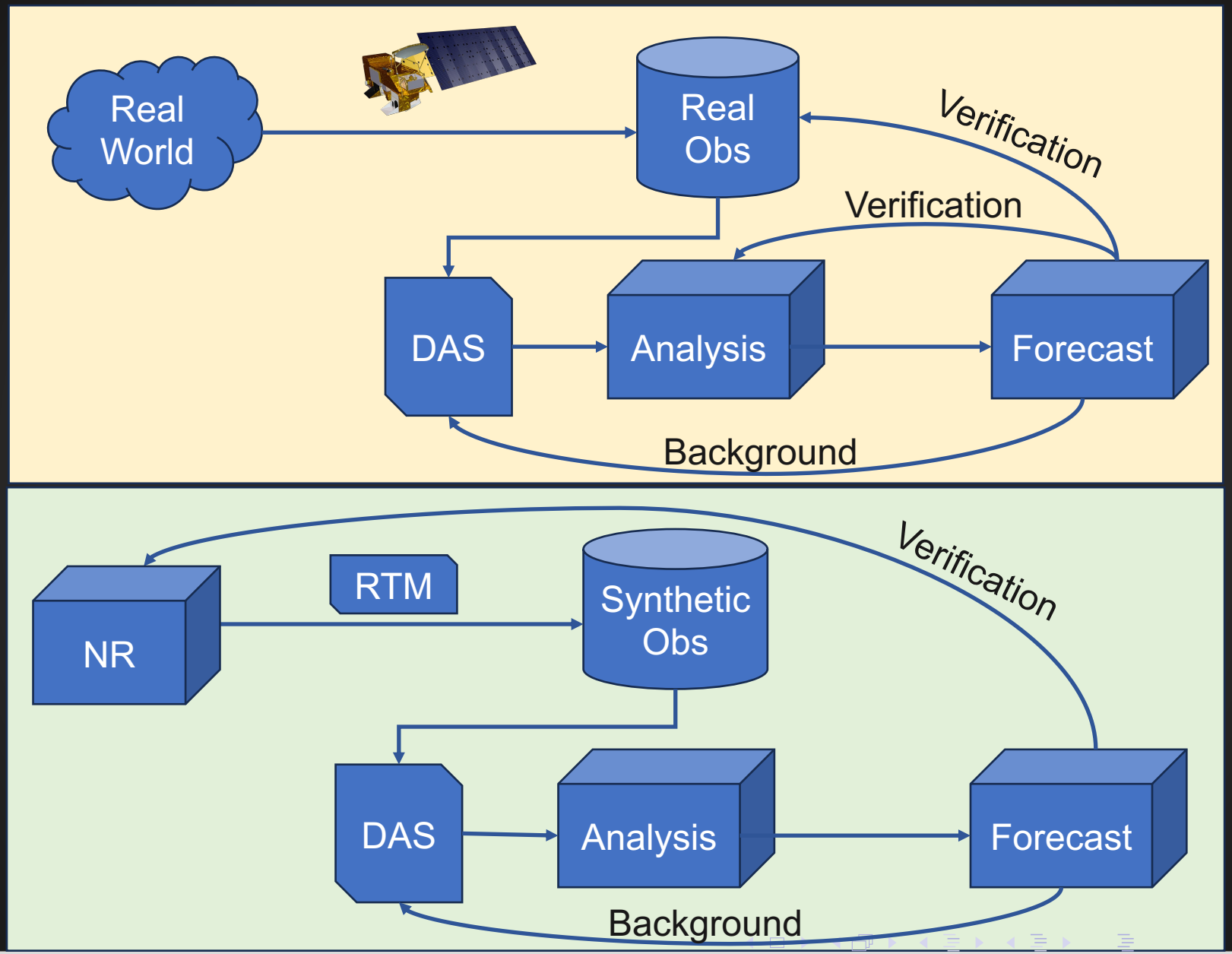
AGU Fall Meeting
Wednesday, 13 December 2023
San Francisco, CA

What are OSSEs?

- Studies where synthetic observations are used in lieu of real observations mainly to be assimilated in the NWP models
- Real observations are measurements collected by an imperfect instrument with errors and biases and assimilated using an imperfect RT or NWP model
- OSSEs employ synthetic observations that are sampled from a nature run and simulated by a forward model and assimilated often by the same forward model
- The ”identical or fraternal twin " in an OSSE refers to the situation where the synthetic observations used in the assimilation process are generated by the same model that is being tested or improved.

OSSEs vs real observations



Nature Runs

- **Baseline for Truth**: Nature runs act as the ground truth or reference state in an OSSE, representing a synthetic atmospheric state.
- **Realistic Modeling**: Nature runs must realistically model the atmospheric and environmental phenomena of interest.
- **Comprehensive Capabilities**: The nature run should be capable of representing a wide range of meteorological and environmental variables, including temperature, humidity, wind, and other relevant parameters. It should realistically simulate complex processes, such as cloud formation, radiation, and turbulence.
- **Idealized Errors**: Ideally, the nature run should be superior to the operational model used in the OSSE experiments. It should be a model that possesses a different set of errors and biases than the operational model.
- **Independence from Assimilation**: The term "free-running" signifies that nature runs operate independently of observational data assimilation.

GEOS-5 Nature Run (G5NR)

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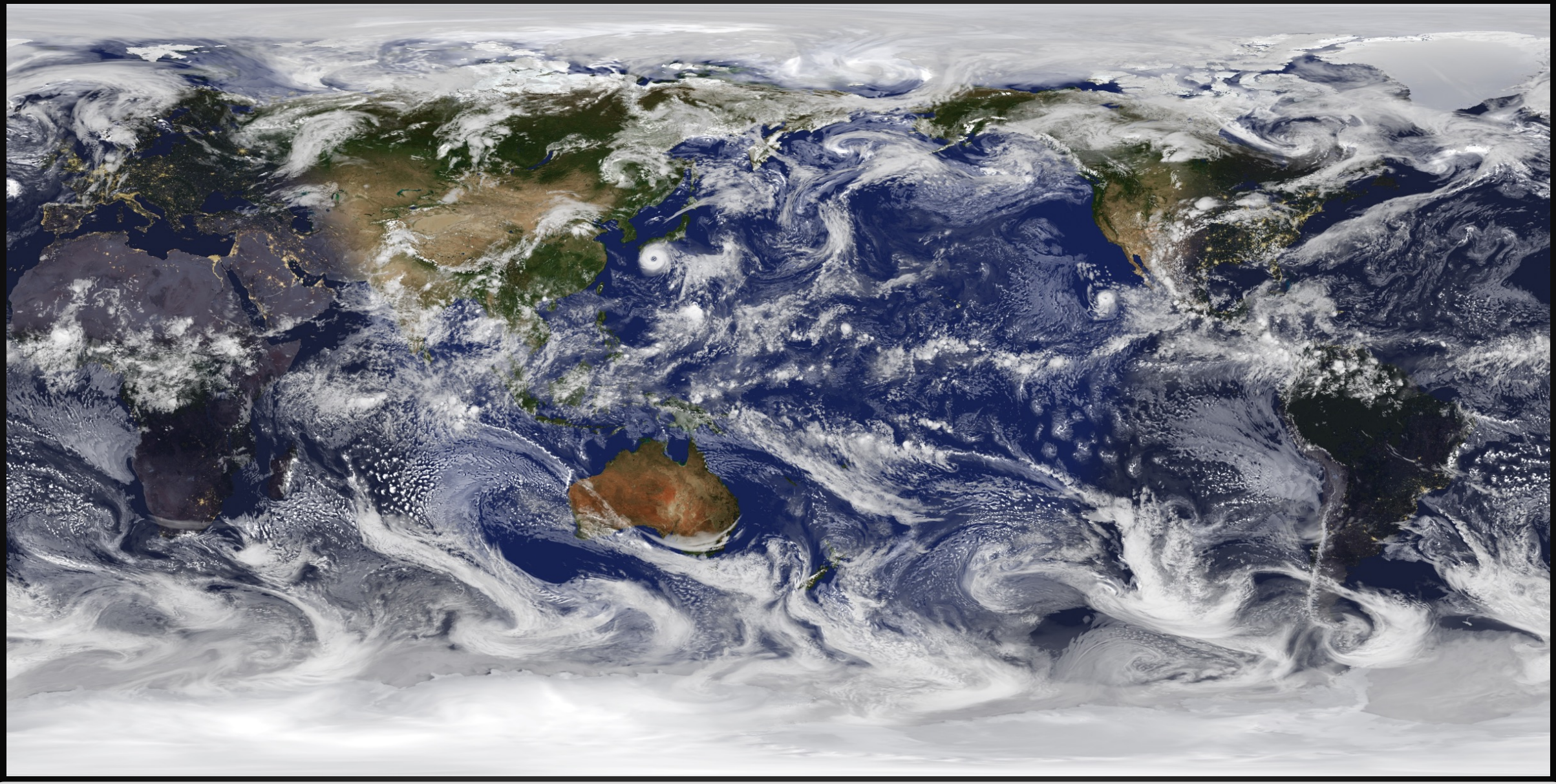

GMAO Global Modeling and Assimilation Office
gmao.gsfc.nasa.gov

GODDARD EARTH SCIENCES

Simulated versus real observations

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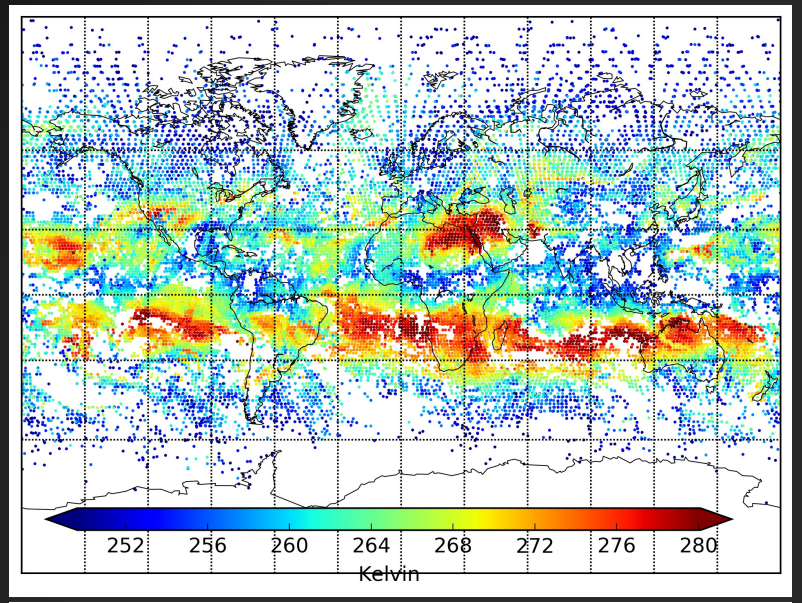
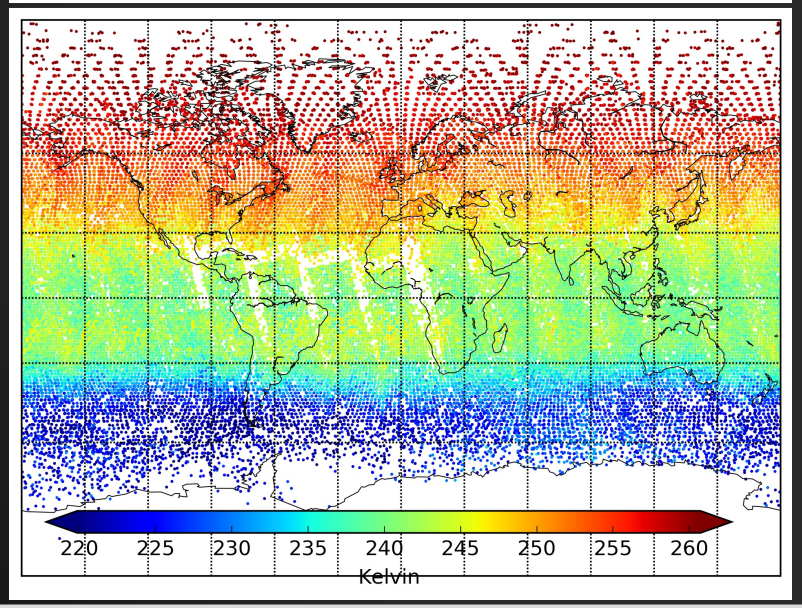
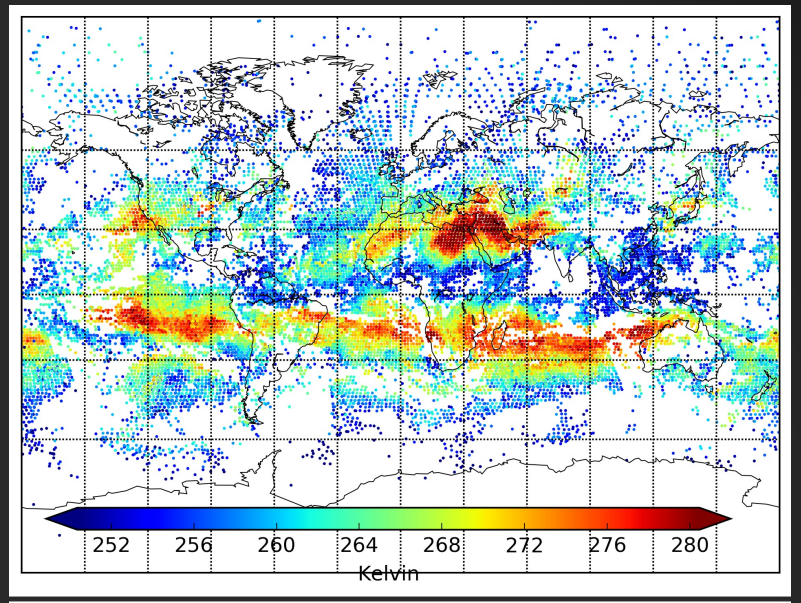
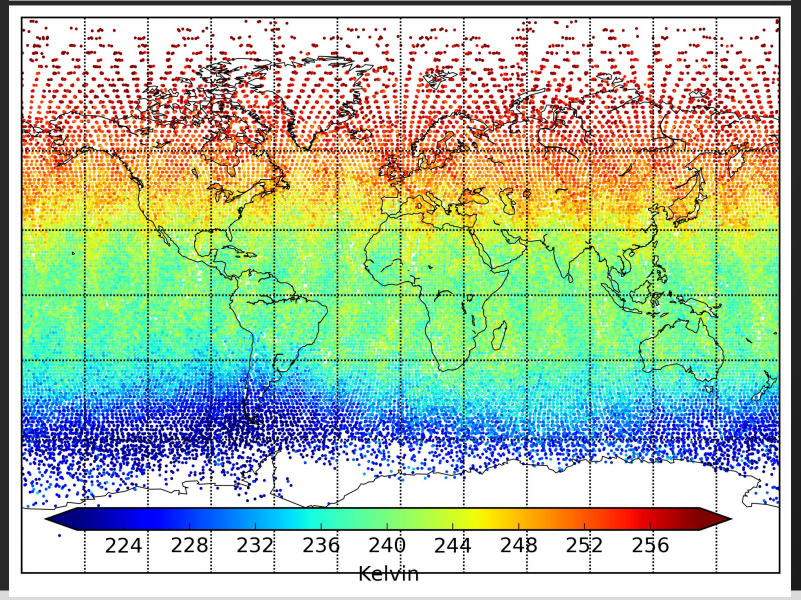
Real observations



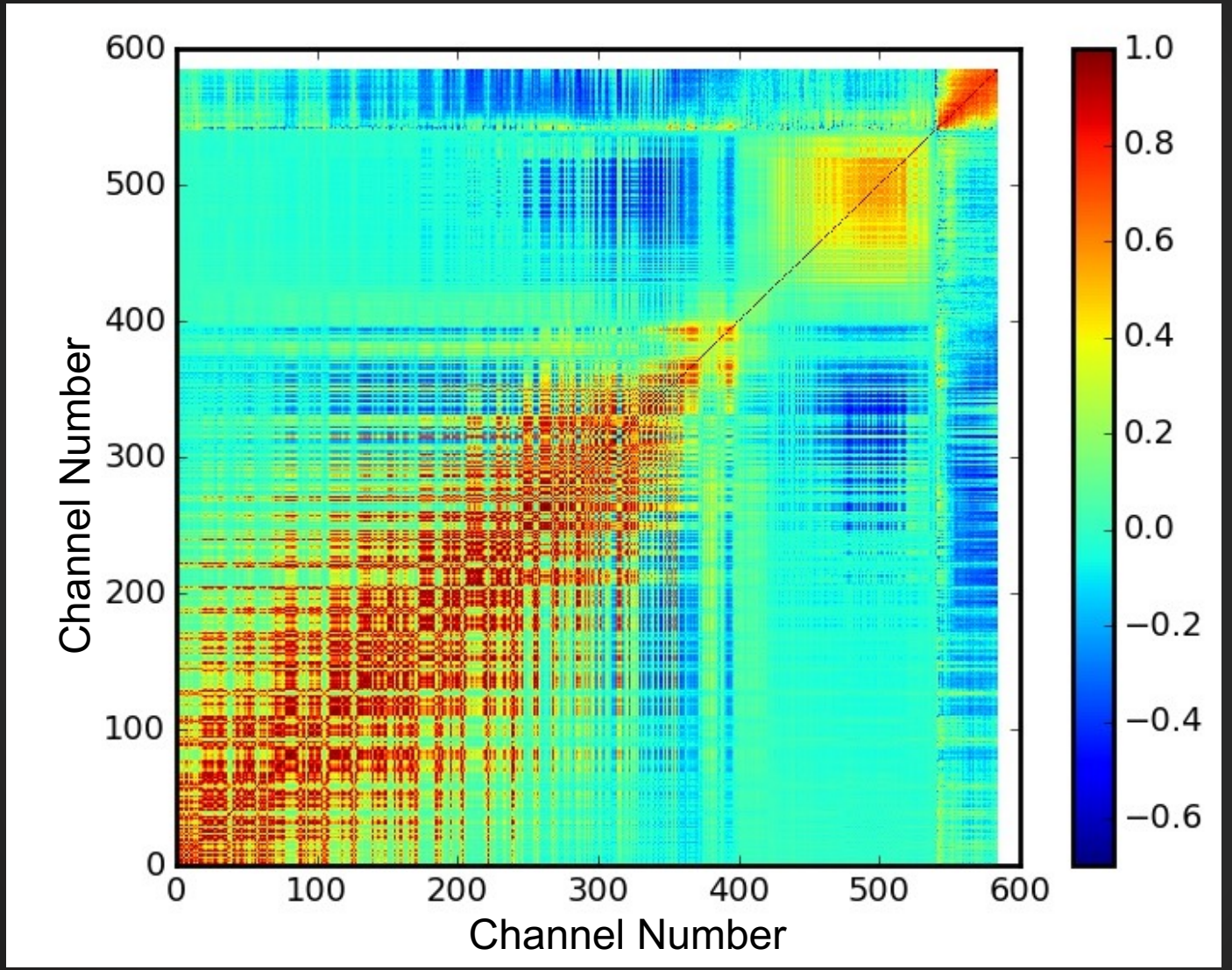


Synthetic Observations





Correlated observation error



Validation

Several critical properties of DAS are considered when comparing the OSSE and Real results:

- Numbers of observations assimilated by the DAS system
- Spatial and temporal distributions of observations
- RMSE of increments as it shows how the analysis is affected by the observations
- Characteristics of instrument and representativeness errors, including biases, variances, and correlations
- Anomaly correlations as well as observations impact

Only QC-passed observations are considered as the results solely depends on what has been used not provided!

Evaluating the increments

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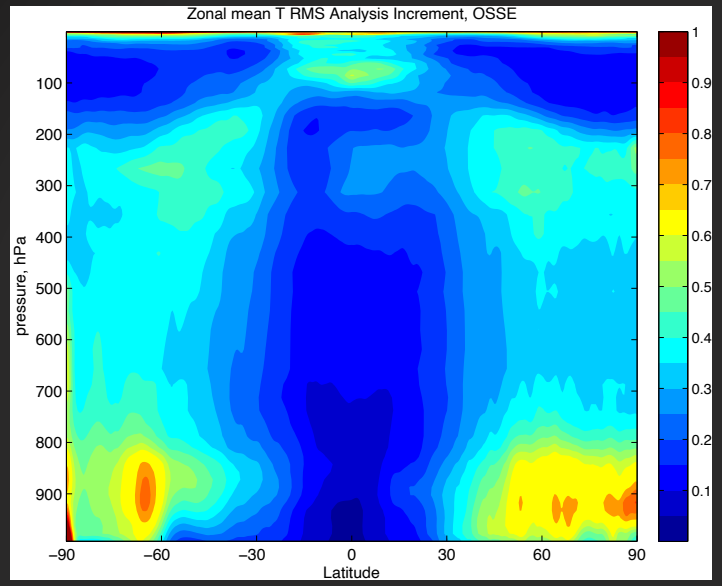
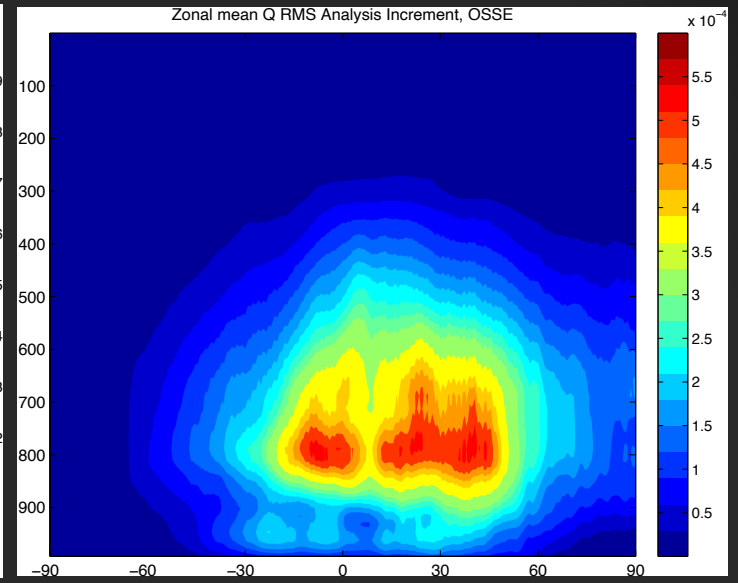
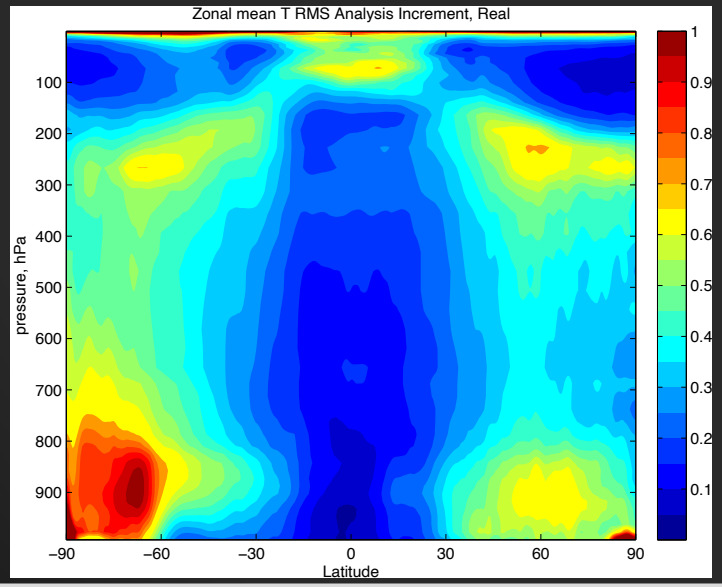
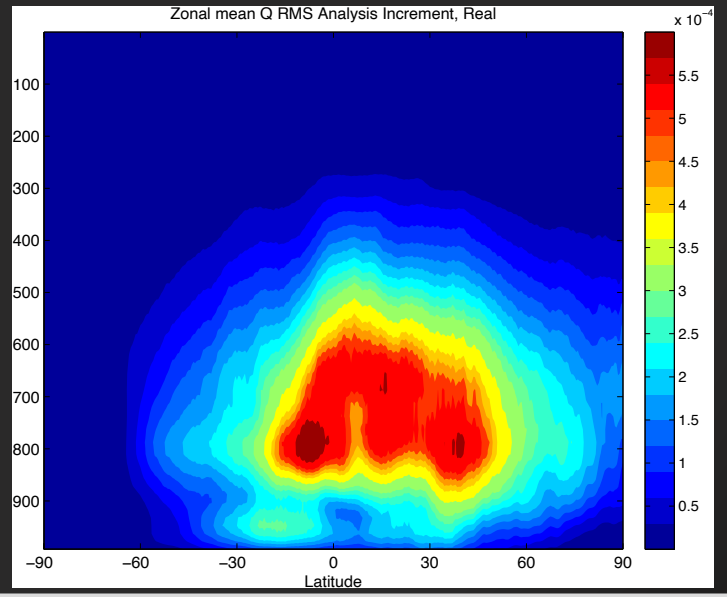
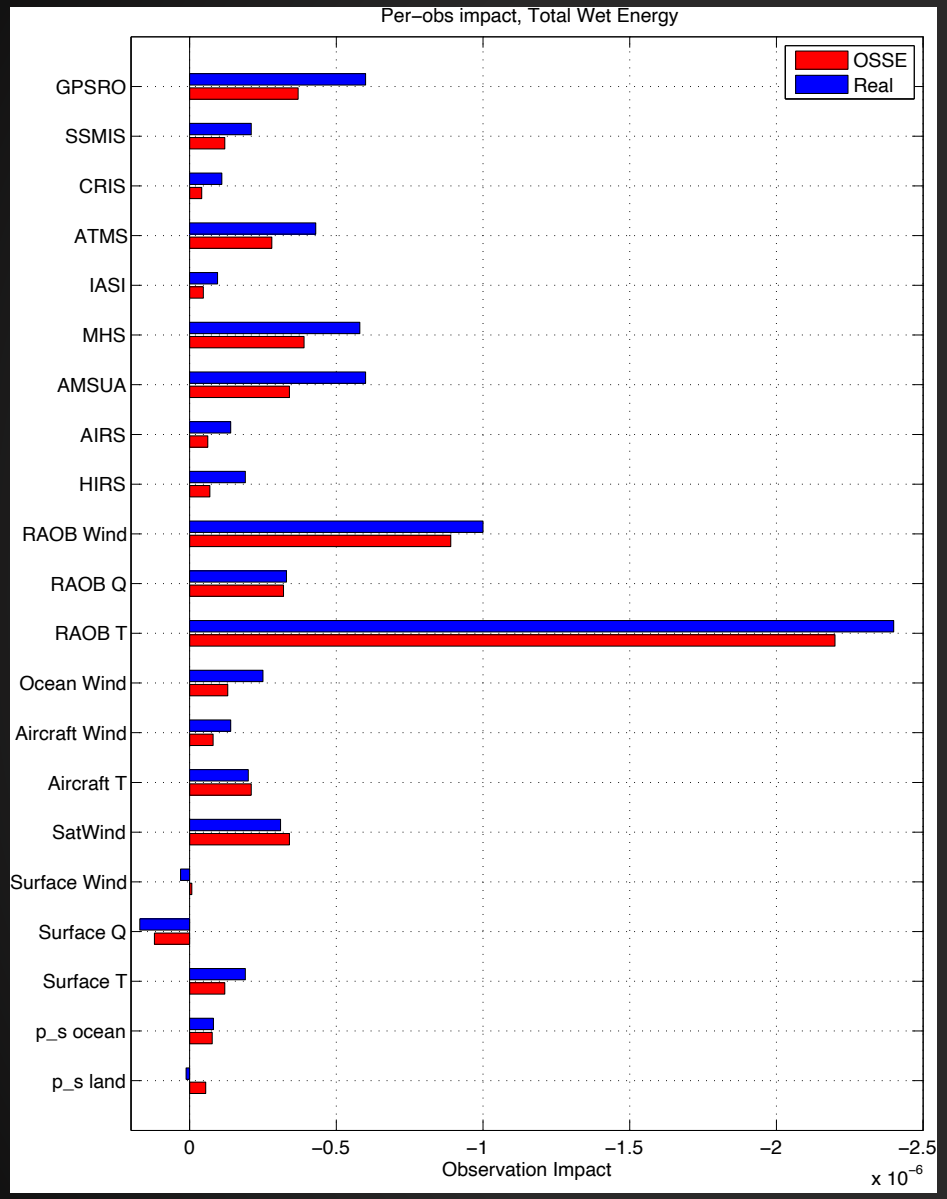
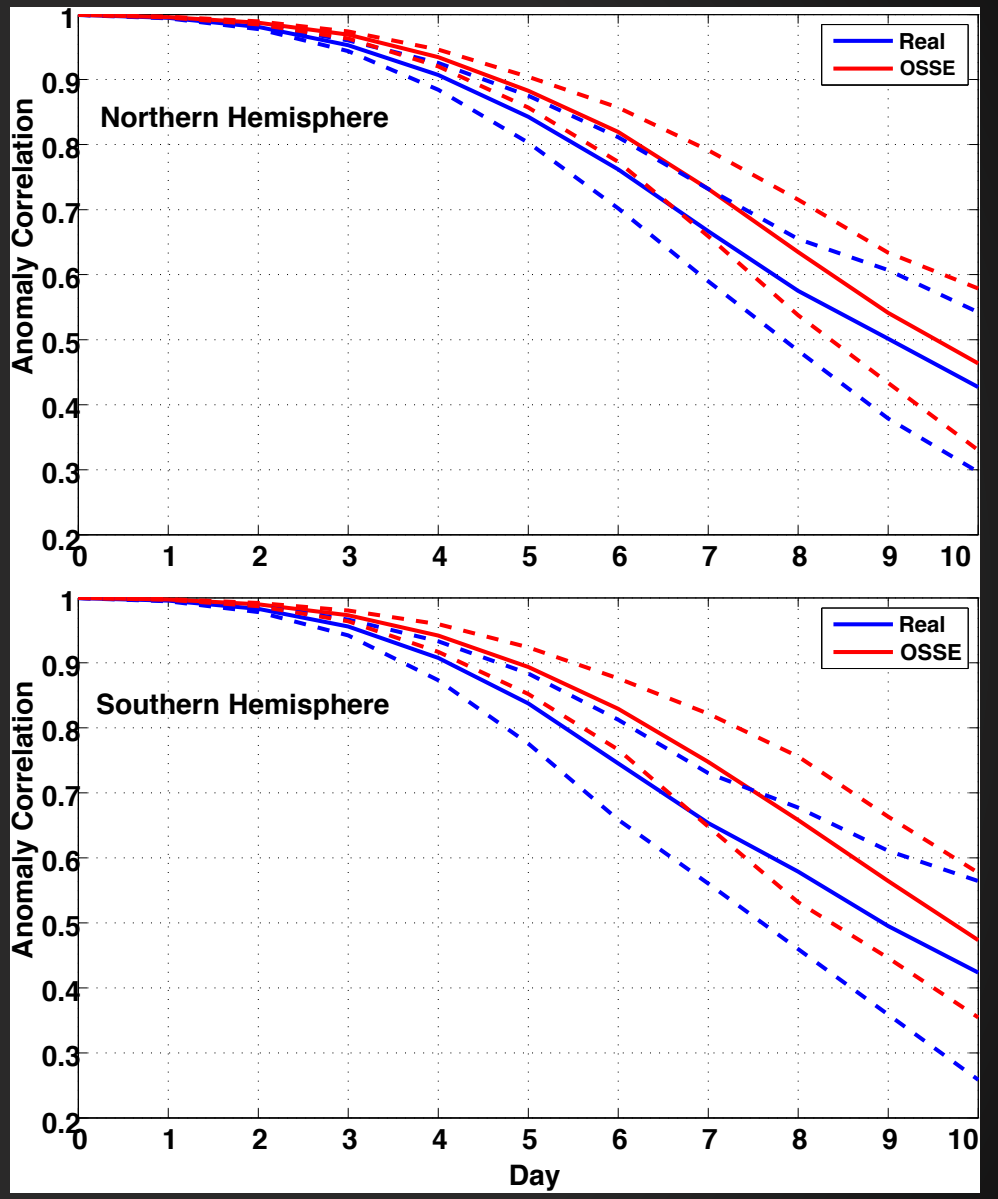
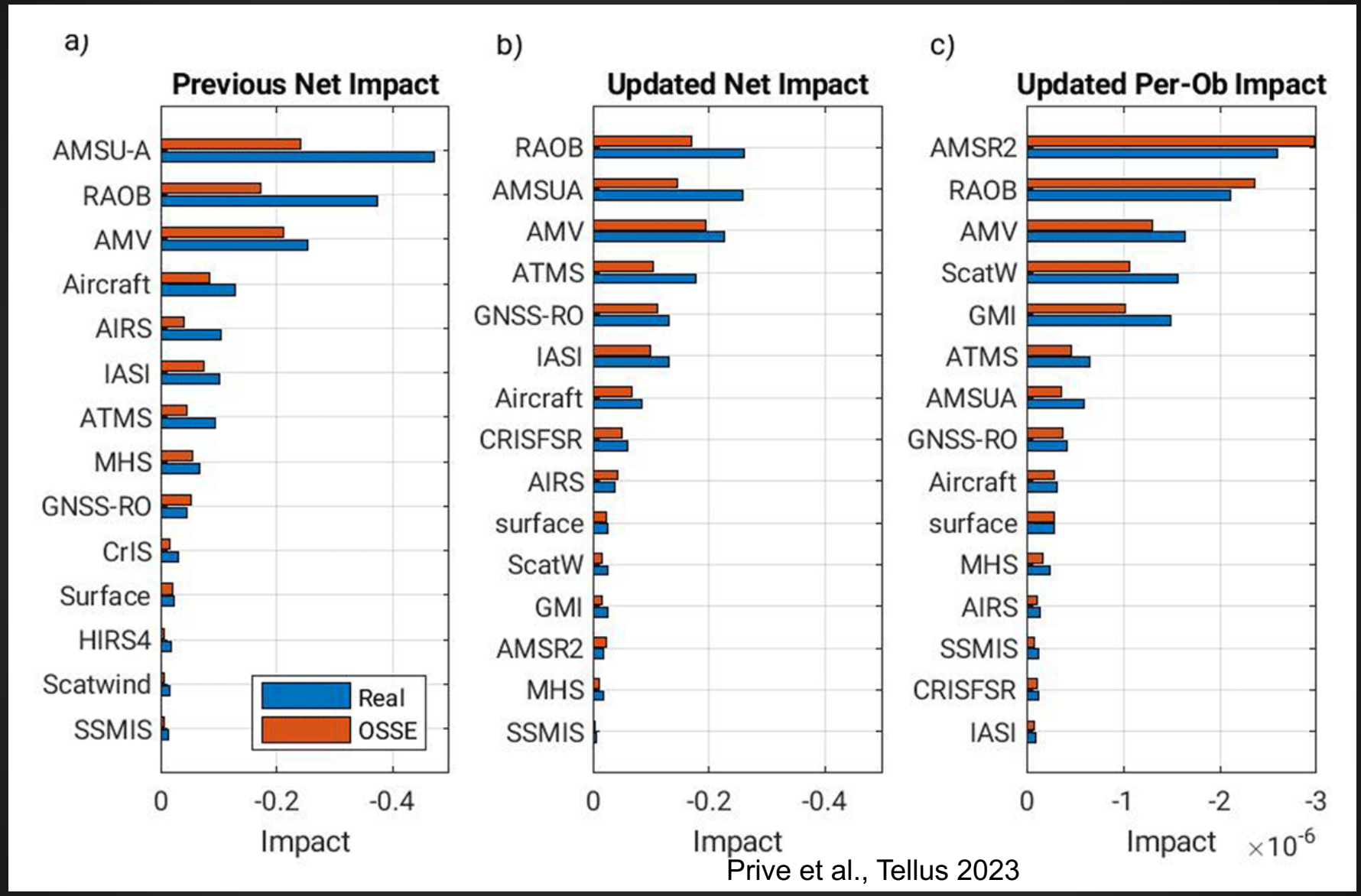
	Temperature	Humidity
OSSE		
Real		

Obs impact and anomaly correlation





Obs impact considerations

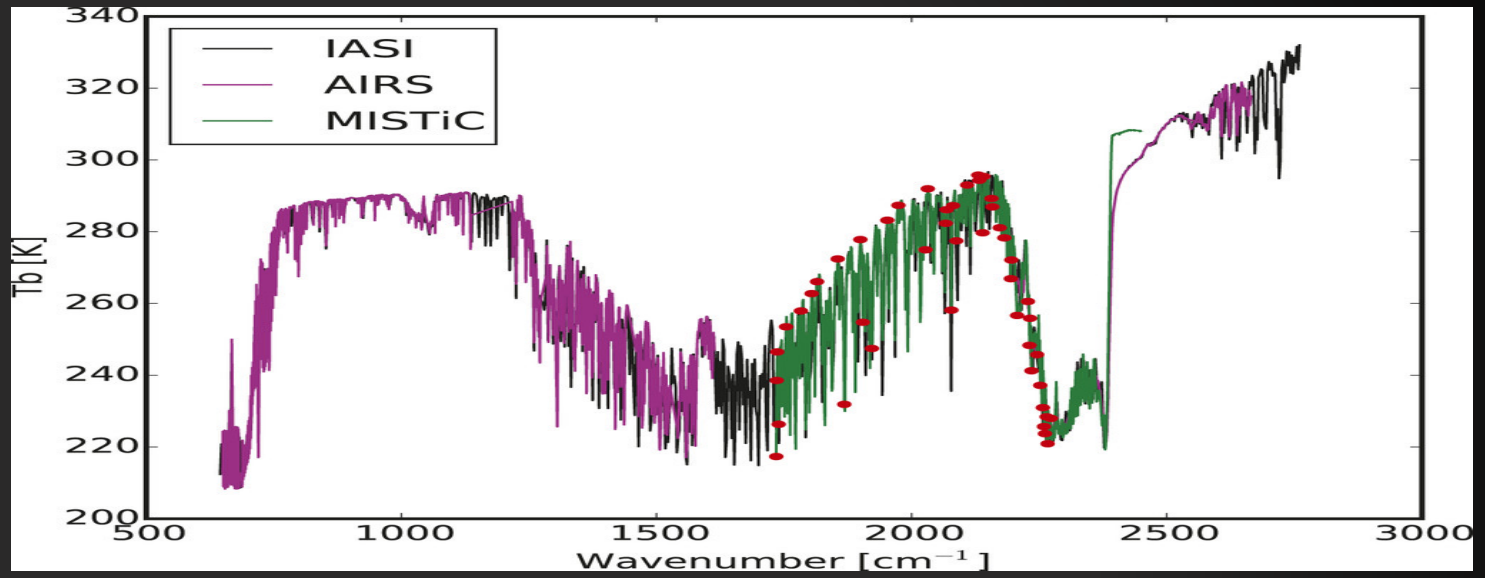


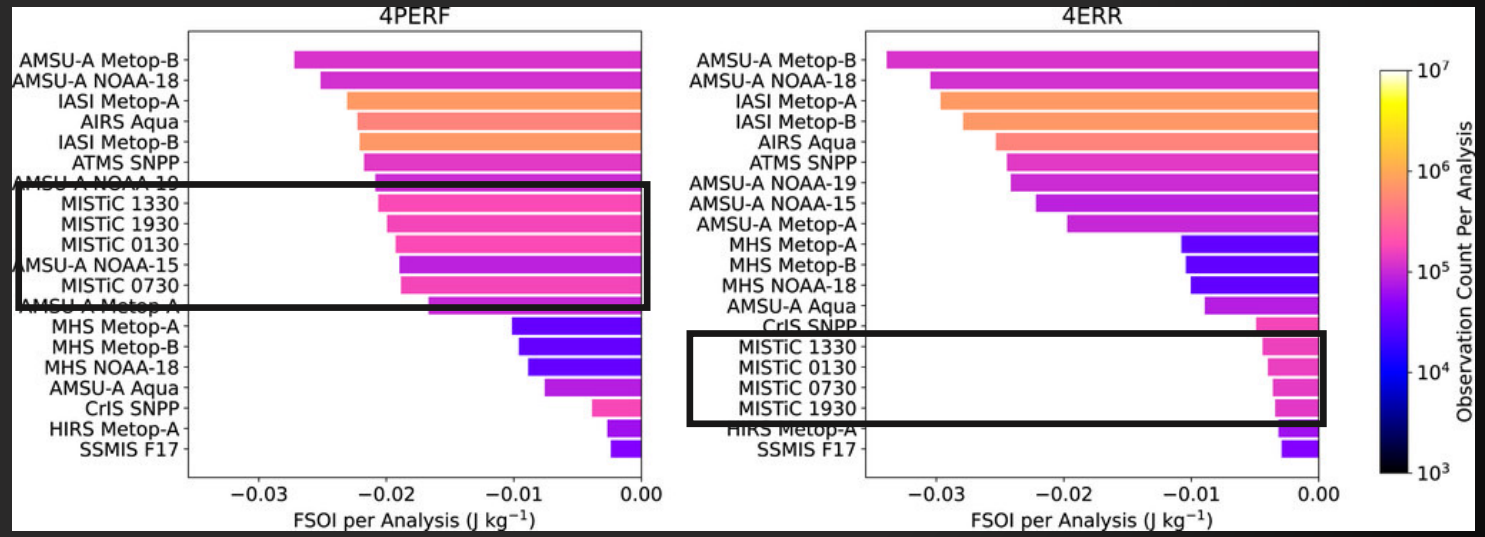
Prive et al., Tellus 2023

Impact of observation error

Midwave Infrared Sounding of Temperature and humidity in a Constellation for Winds (MISTiC Winds)

McCarty et al., JAOT 2021





Criticisms of OSSEs

- Results within OSSEs have no direct applicability to the real world, remaining confined to the OSSE system.
- Even the most robust OSSEs exhibit imperfections due to challenges in observation generation and various issues, including errors and limitations of Nature Run and twin models.
- OSSE Data Assimilation Systems (DAS) and models consistently lag behind operational systems.
- Upon the deployment of a new instrument, changes in both the global observing network and forecast models/DAS have already taken place.
- In OSSEs, the term 'identical or fraternal twin' signifies that synthetic observations used for assimilation originate from the same model being tested or enhanced."
- Nature Runs often lack the required spatial and temporal resolution to study phenomena such as clouds.
- Many OSSEs are conducted without meticulous attention to details, potentially rendering otherwise sound OSSEs invalid.
- Instrument teams typically focus on OSSEs until they achieve the specific results they seek.

Conclusions

- OSSEs offer valuable insights into the utility of new observational techniques or instruments.
- The development and assessment of data assimilation systems can greatly benefit from the incorporation of OSSEs.
- Calibration and validation is a critical step in the OSSE process, ensuring the reliability of results.
- Undertaking OSSEs is challenging, with high-quality OSSEs presenting even greater difficulty.
- Mere data assimilation using synthetic observations doesn't constitute a (comprehensive) OSSE.
- OSSEs should be rooted in practical feasibility within the existing system, rather than being driven solely by individual preferences and requirements.

Thank you for your attention!