Exploring Impacts of the Tomorrow.io Microwave Sounder (TMS) Constellation

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Jackson, MS

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Tomorrow Microwave Sounder (TMS)

- Next-generation of TROPICS-like sensor design
- 18 CubeSat sounders launch 2024-2026

- 2200 km swath, with horizontal resolution of:
  - 14 x 17 km @ nadir (204 GHz)
  - 26 x 28 km @ nadir (91 GHz)

- Two imaging channels (1 and 12)
- Seven temperature-sounding channels (F band)
- Three water vapor-sounding channels (G band)

Channel	Center Freq. (GHz)	Bandwidth (GHz)	NEDT (K)
1	91.65	2	0.95
2	118.75±3.5	1	0.85
3	118.75±2.625	0.75	0.90
4	118.75±1.875	0.75	0.90
5	118.75±1.25	0.5	0.90
6	118.75±0.75	0.5	0.90
7	118.75±0.375	0.25	1.00
8	118.75±0.125	0.25	1.20
9	184.41	2	0.80
10	186.51	2	0.80
11	190.31	2	0.80
12	204.8	2	0.80

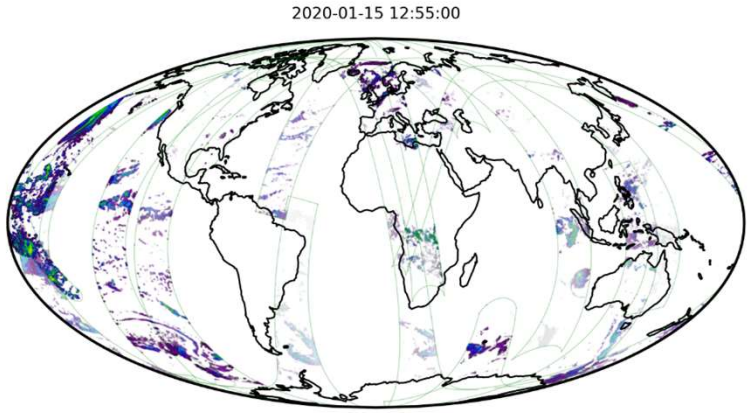
Observation System Simulation Experiments

We add our instruments to a “baseline” system, with similar instruments as NOAA’s Global Data Assimilation System (GDAS) to:

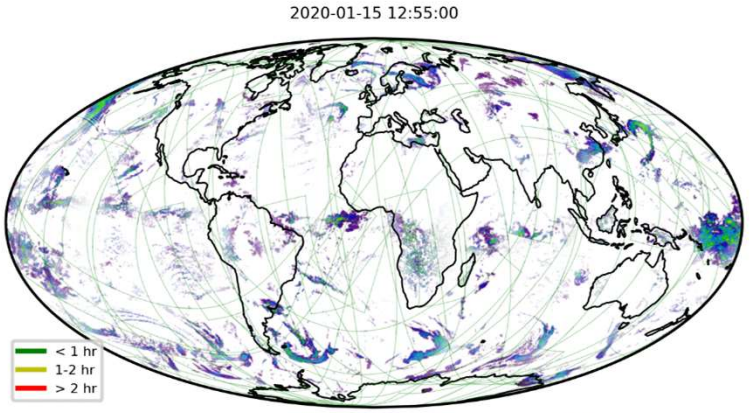
1. Develop the science and algorithms needed to assimilate TMS observations

2. Assess the impact of our observations on forecasts

Existing Multi-Agency MW Sounder Constellation



Tomorrow.io MW Sounder Constellation

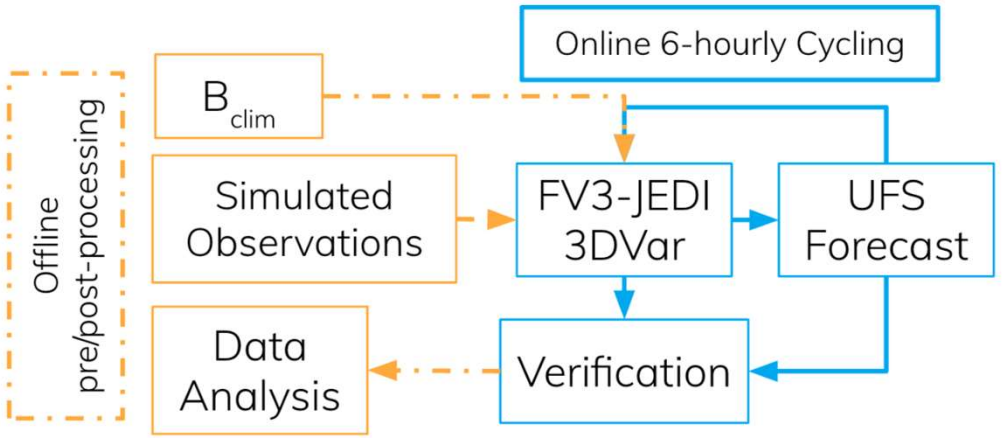


Top: NOAA and NASA microwave sounders. Bottom: T.io sounders. One hour of coverage is shown.

Experiment Setup

- Nature run (NR): GMAO DYAMOND Phase II
  - C2880 grid (~3km)
  - 181 vertical levels
  - 50 days of simulation (Jan - Mar 2020)
- Assimilation: JEDI-FV3
  - 3DVar with NR-trained static B matrix
  - B-matrix validated against 20-member GEFS ensemble during NR spin-up
- Forecasts: UFS-ATM
  - C768 grid (~13 km)
  - 64 vertical levels
- Observation Operator: CRTM 3.1

Components of our setup for mid-range global weather experiments.



Observation Error Model

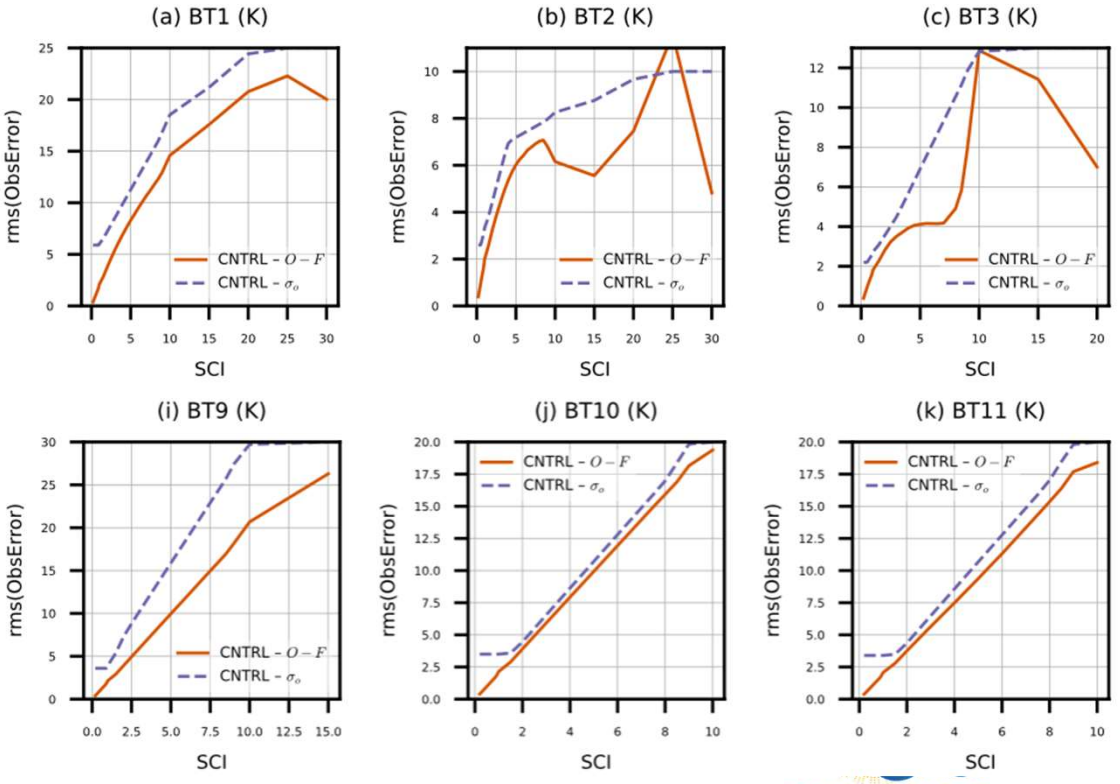
Observation error (weight assigned to observations for DA purposes):

The RMS of 6-hr O-F should match our parameterization for observation error (σ_0).

We employed a symmetric cloud impact (SCI) predictor to gauge hydrometeor impact following the Okamoto et al. (2013; 2023) developments in the IR assimilation community.

$SCI = (|TB_{clear} - TB_{obs}| + |TB_{clear} - TB_{model}|) / 2$

Obs error at various channels with the symmetric cloud impact model



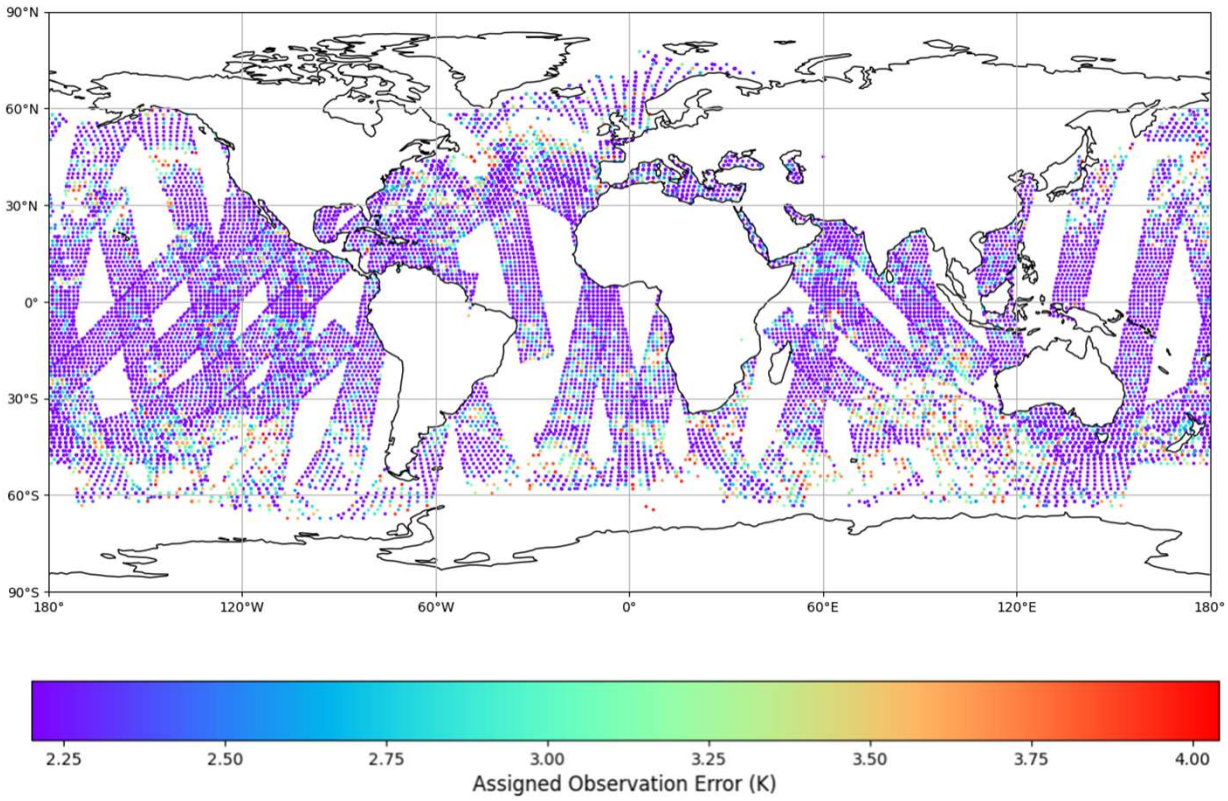
Observation QC Model

These filtering steps address issues with 3DVAR, FV3, model resolution, and CRTM. We remove:

1. Edges of swath
2. Land-sensitive observations
3. Large O-B errors
4. Cloud-contaminated observations at high sounding channels
5. Large discrepancies in O vs. B hydrometeor impact, cloud phases and heights

We further thin observations to a reduced Gaussian grid.

Assimilated Observations - Four TMS Satellites - 6 hr Cycle - Channel 3



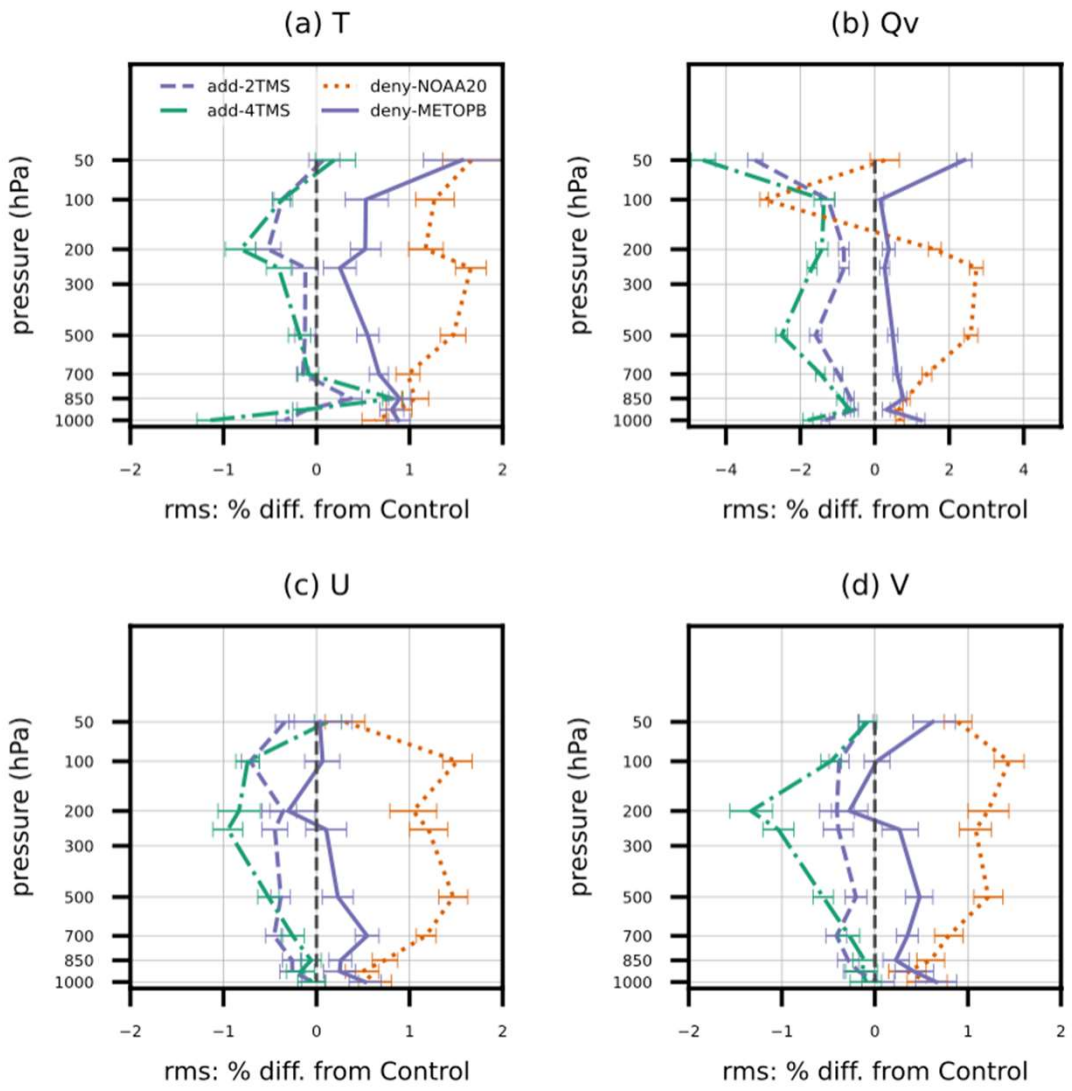
Overall 6 h TMS Impact

Our “Control” run is a global month-long experiment using observations similar to what you would find in NOAA’s Global Data Assimilation (GDAS) system.

We compare this to:

- Control + Two TMS satellites
- Control + Four TMS satellites
- Control without NOAA-20 (ATMS)
- Control without Metop-B (AMSU-A and MHS instruments)

Left of zero = **reduction** in forecast error

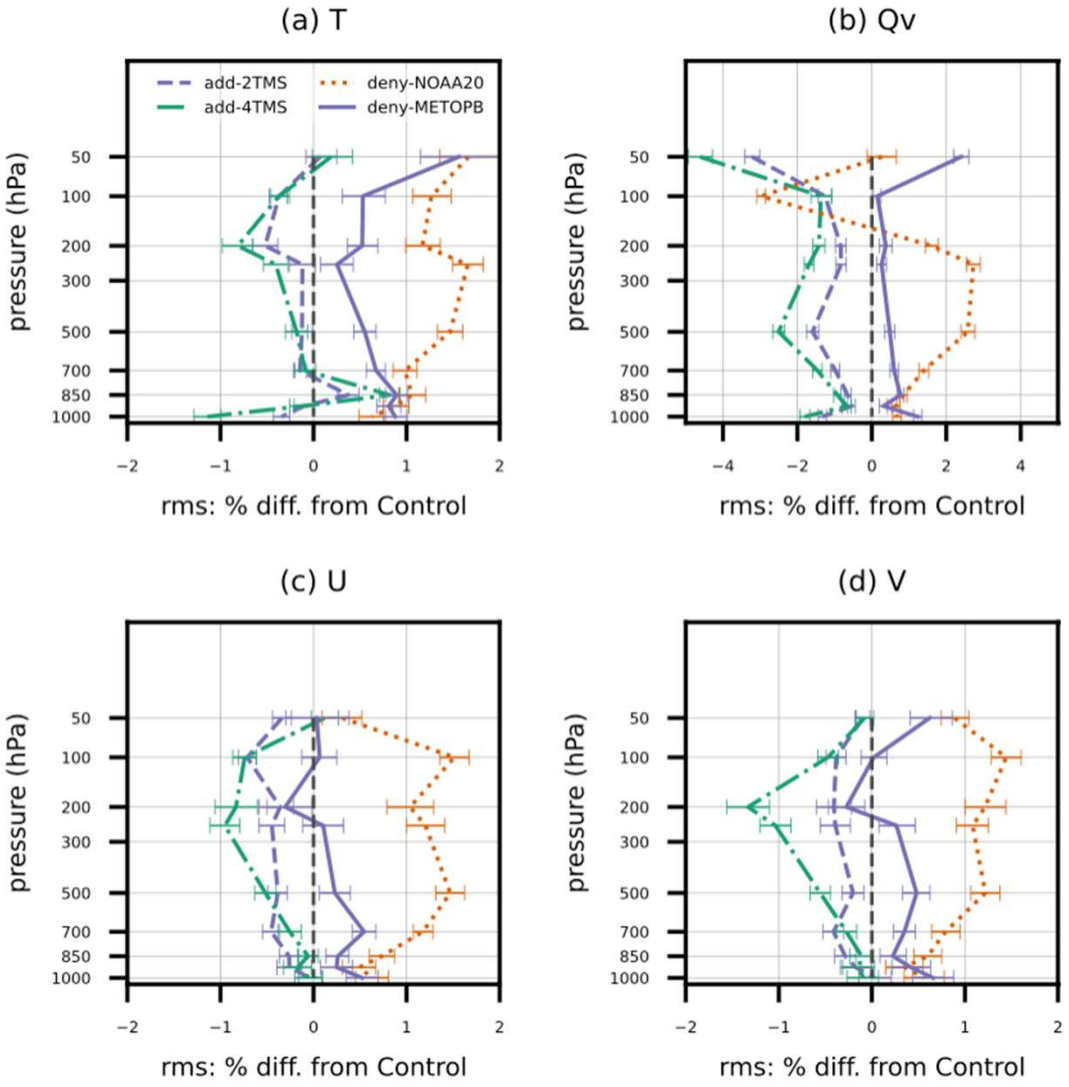


Overall 6 h TMS Impact

Takeaways:

1. TMS makes direct observations of atmospheric water vapor (Qv) and temperature (T). This improves forecasts directly.

2. Improvements in these fields affect weather development and also improve forecasts of wind fields (U and V).

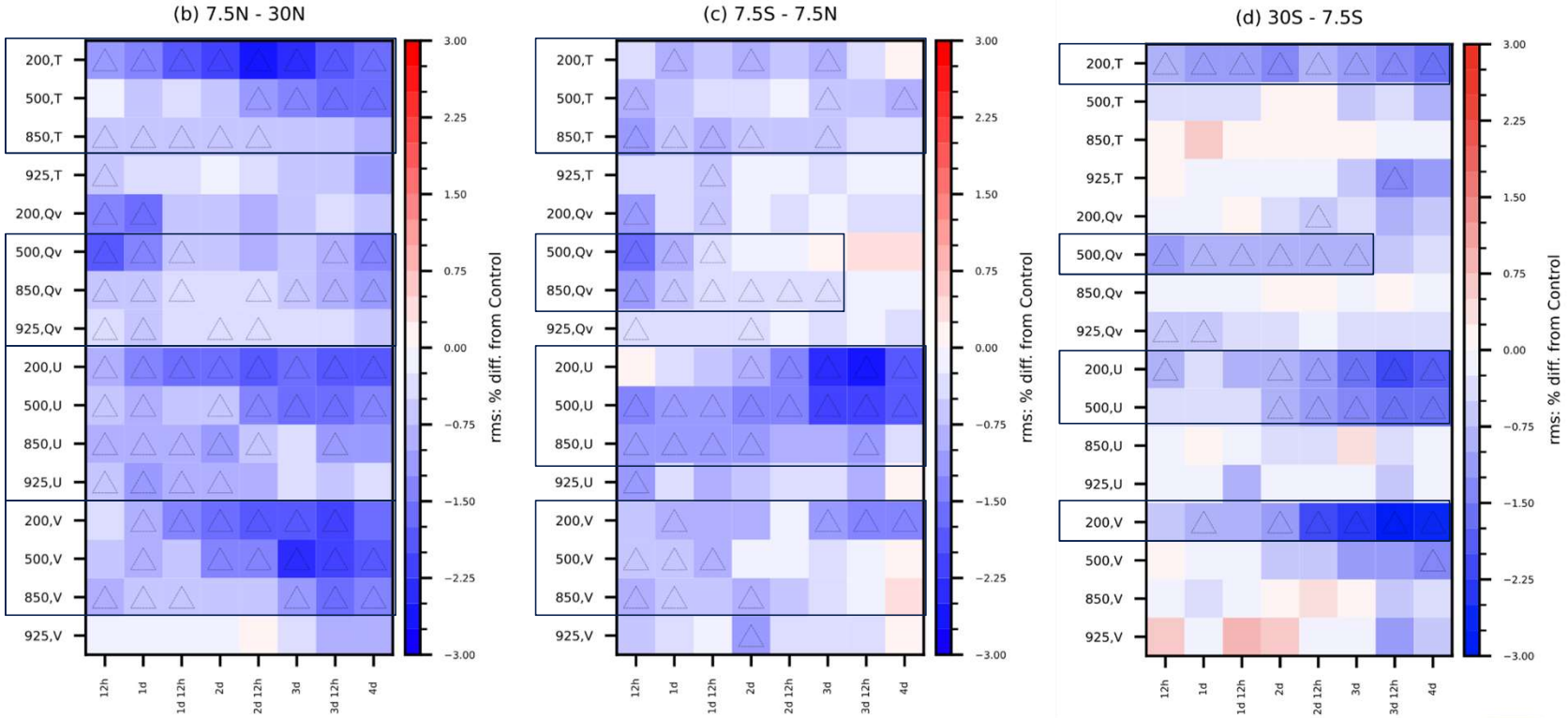


Forecast Impacts at Tropics: Add 2TMS

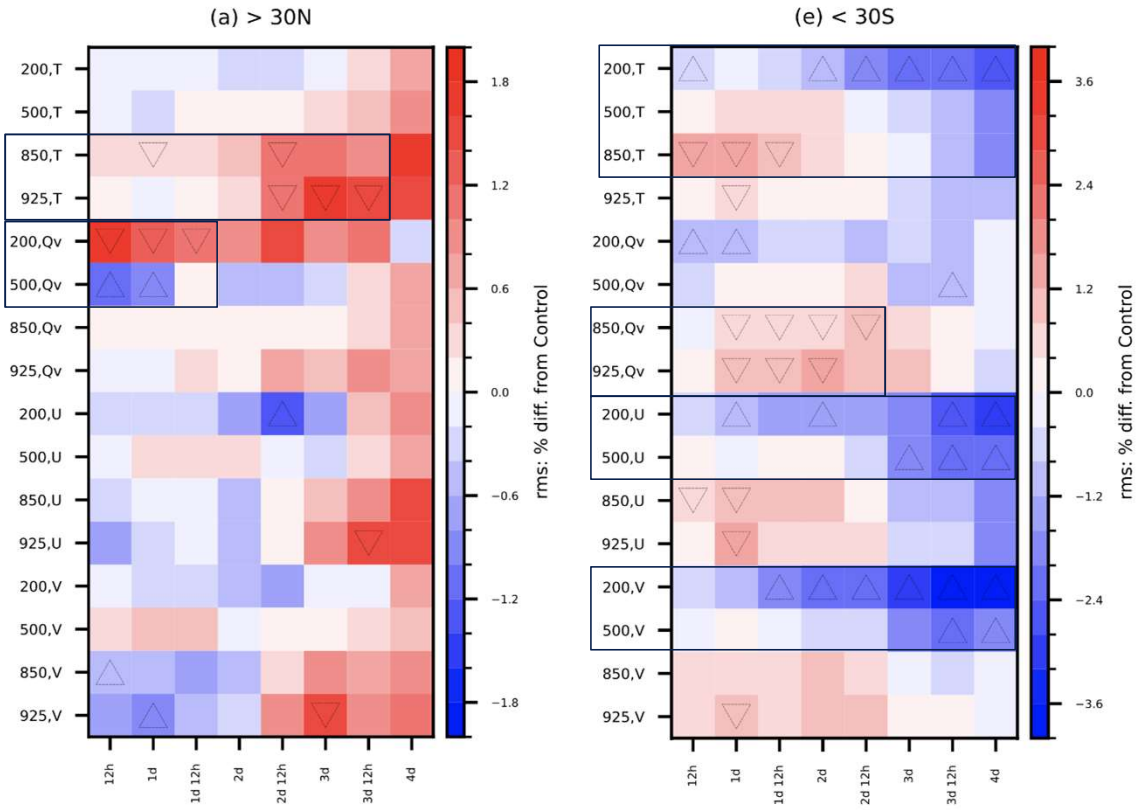
~95% confidence of **improvement**

~95% confidence of **degradation**

37 forecast samples, initialized from 00z on 22 Jan to 28 Feb



Forecast Impacts at extratropics: Add 2TMS



~95% confidence of **improvement**

~95% confidence of **degradation**

37 forecast samples, initialized from 00z on 22 Jan to 28 Feb

- We have extended to 3DEnVar DA, and are awaiting a GSI-validated B matrix formulation and improved performance for 4DEnVar

- Instrument algorithm development remains a work in progress for:
  - T-sounding channels in all-sky conditions
  - WV-sounding outside tropics

- We are refining our all-sky error model for lower-level T-sounding channels 2 and 3 in extratropics.

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Summary

1. The Tomorrow.io Microwave Sounders (TMS) are launching in 2024 and 2025.

2. An OSSE-based methodology has allowed us to develop candidate clear-sky and all-sky error models for TMS and other TROPICS-like instruments.

3. This is one of the first OSSE attempts using JEDI, and it reflects recent progress for that in-development system.

4. TMS observations will significantly improve forecasts, particularly in the tropics.

5. Forecast improvements increase as more satellites are launched. Further experiments will try to find a saturation point for NWP.

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