Impact of ROMEX Data on NCEP GFS Forecast

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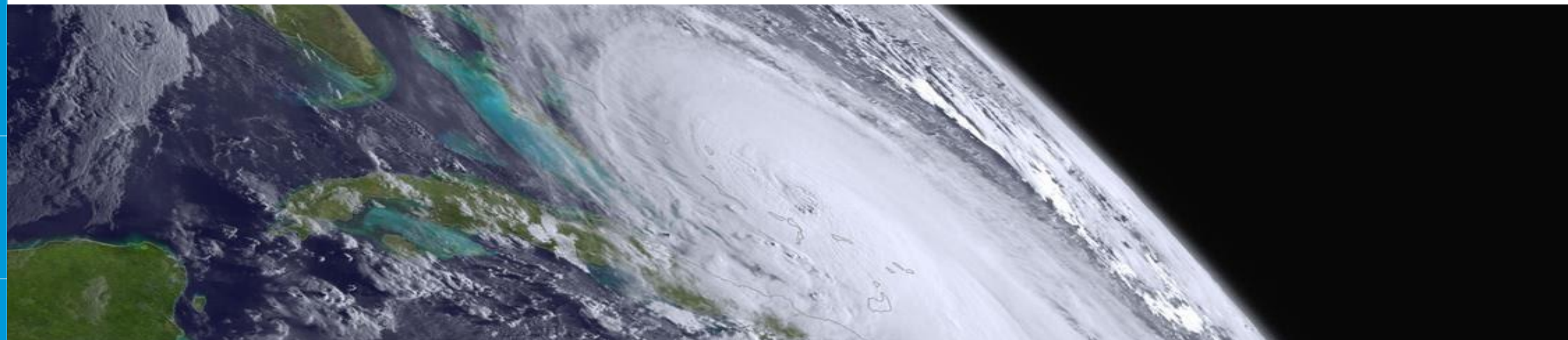
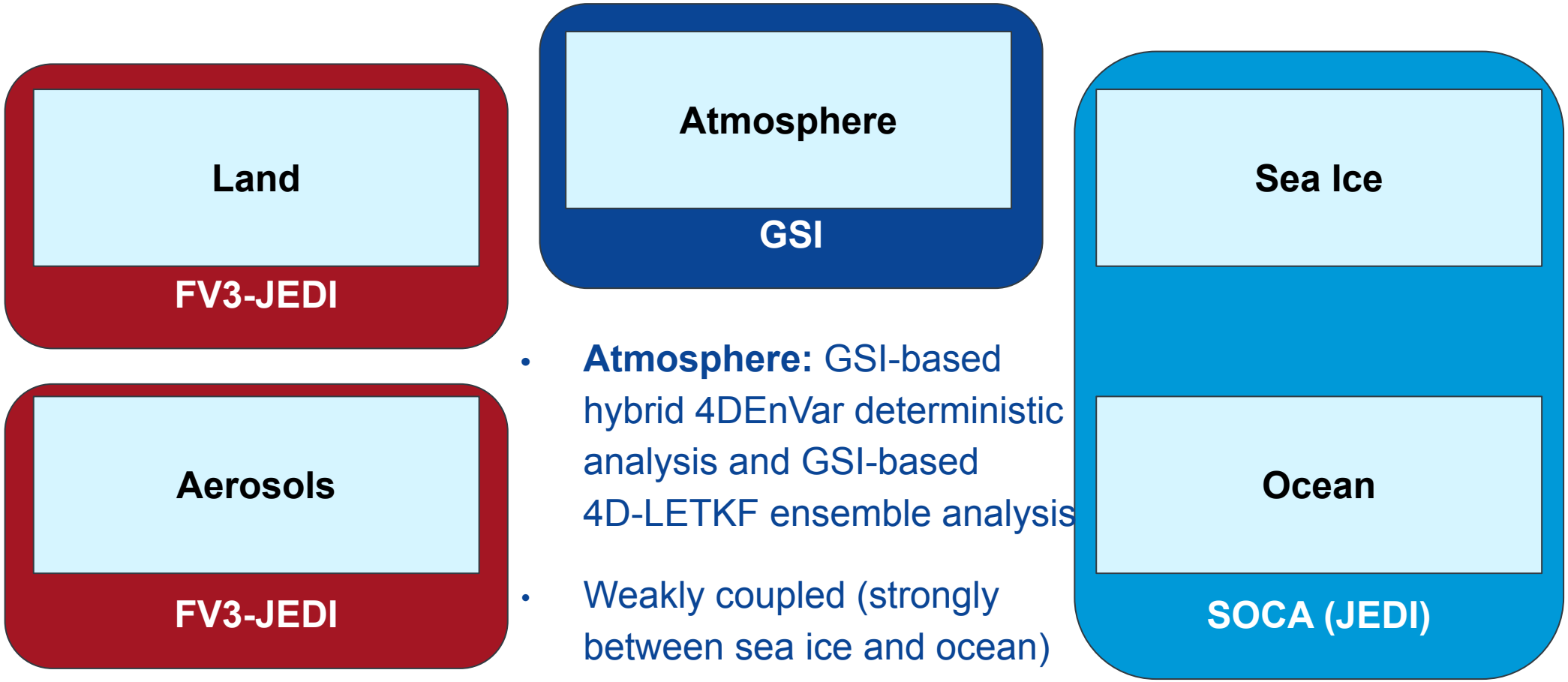
IROWG-10
September 13, 2024



GFS v17 New Coupled DA



- **Atmosphere:** GSI-based hybrid 4DEnVar deterministic analysis and GSI-based 4D-LETKF ensemble analysis
- Weakly coupled (strongly between sea ice and ocean) DA will be introduced for all Earth system components except for waves.

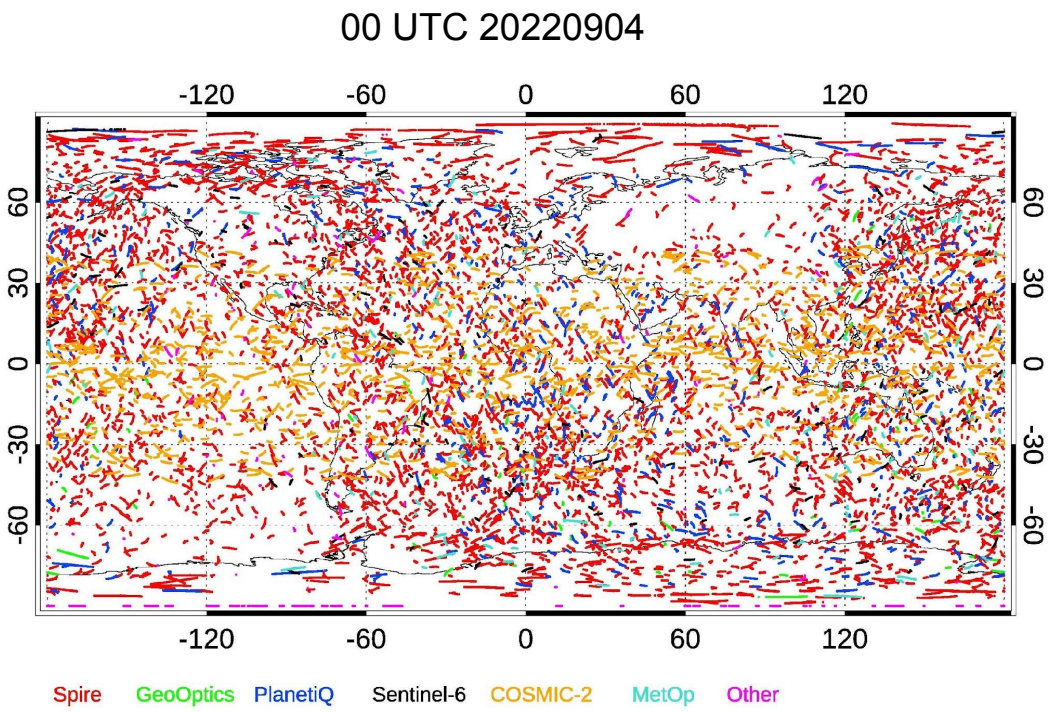
ROMEX Experiments with GFSv17

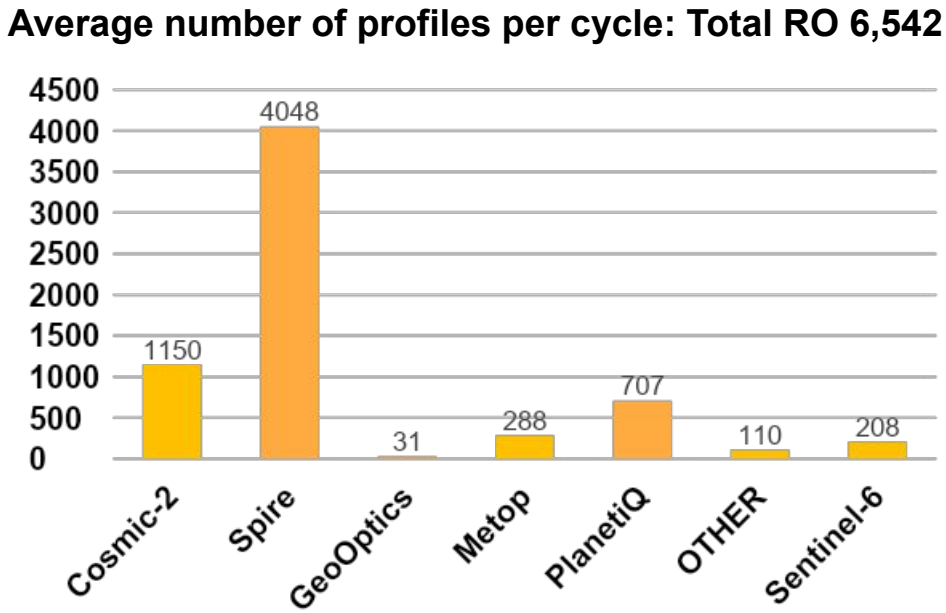
- Global parallel experiments using GFSv17
- 80 ensemble members, half resolution C384 (25 km) + C192
- Thompson microphysics scheme employed in model forecast
- Noah-MP Land Surface Model
- Model is not coupled

- Atmosphere-only DA
- Atmosphere DA has been updated to Thompson microphysics scheme, but was not available at the time of the experiments
- Scale-Dependent Localization is not incorporated

ROMEX Experiments

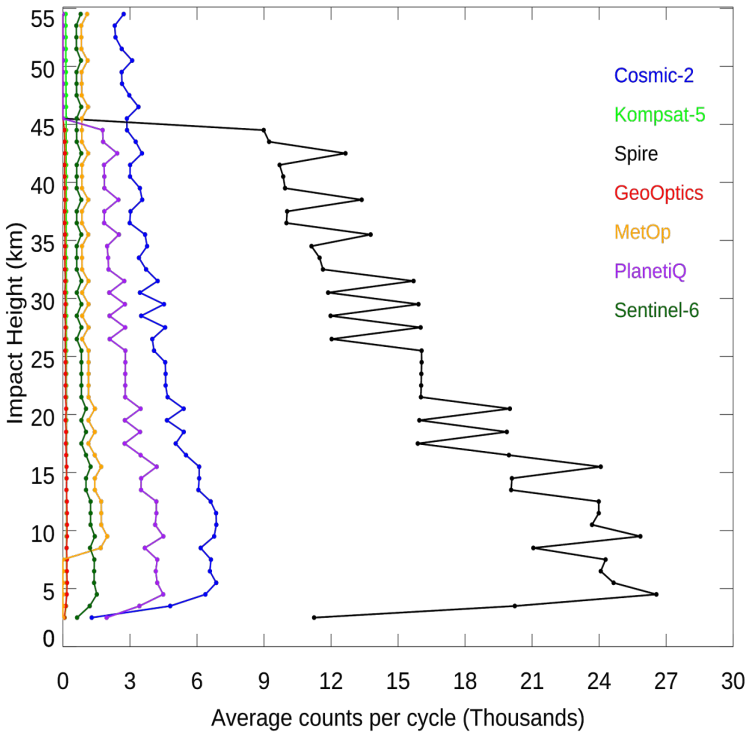
- **Verification:** September 7 - October 20, 2022
  - **baseline**: COSMIC-2, MetOp, Kompsat-5, TandemX, TerraSarX, PAZ, and Sentinel-6 (~7,000 profiles/day)
  - **supplement**: baseline data + Spire, GeoOptics, and PlanetiQ (~26,000 profiles/day)



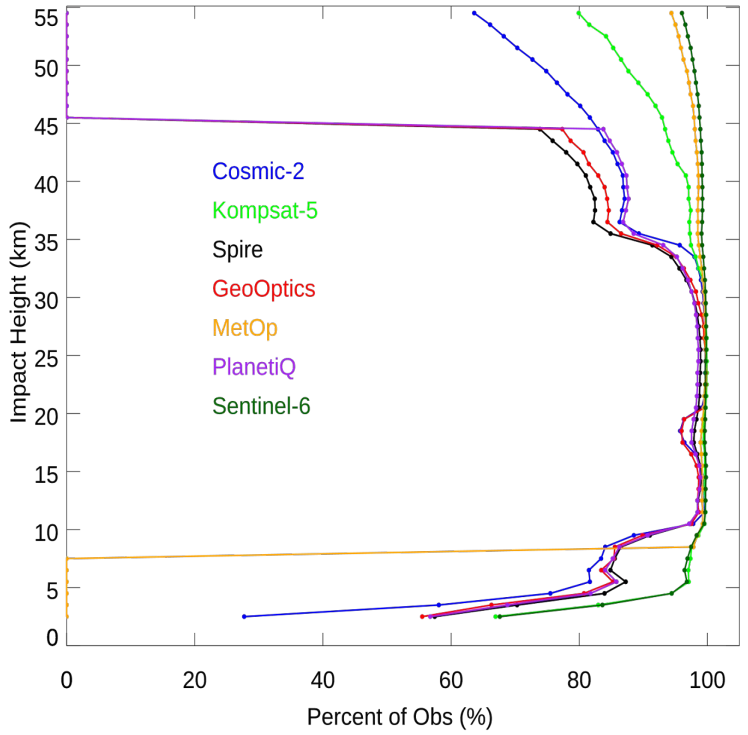


Data Quality

Counts



Percent of obs passing QC

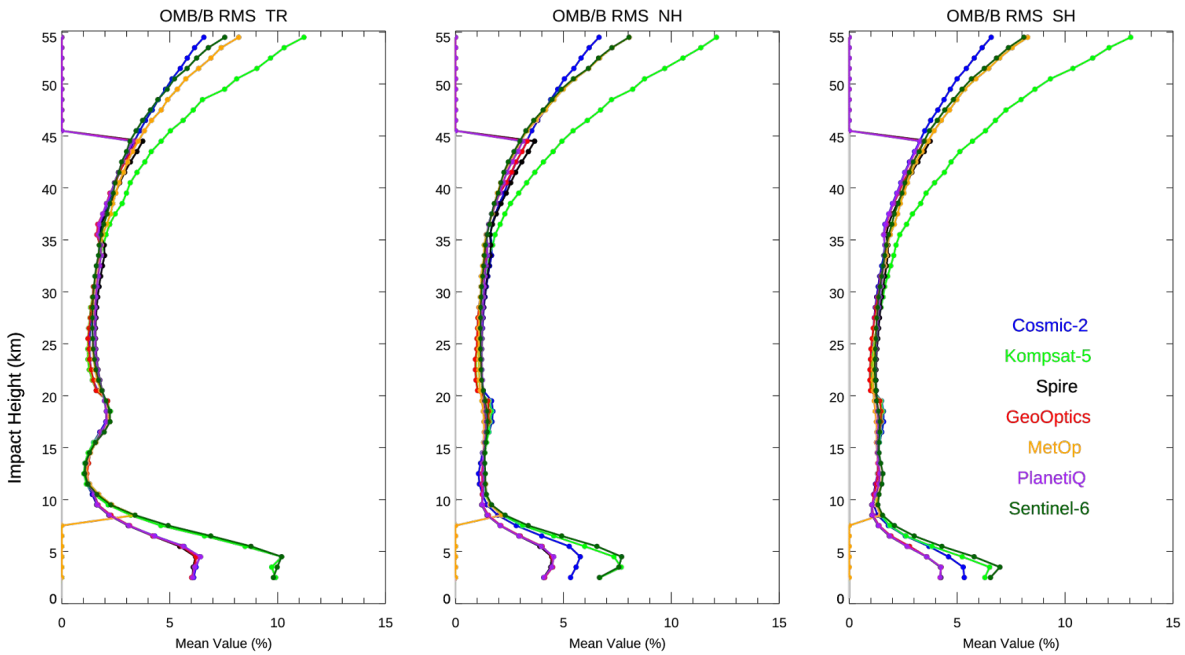


20220907 - 20221020

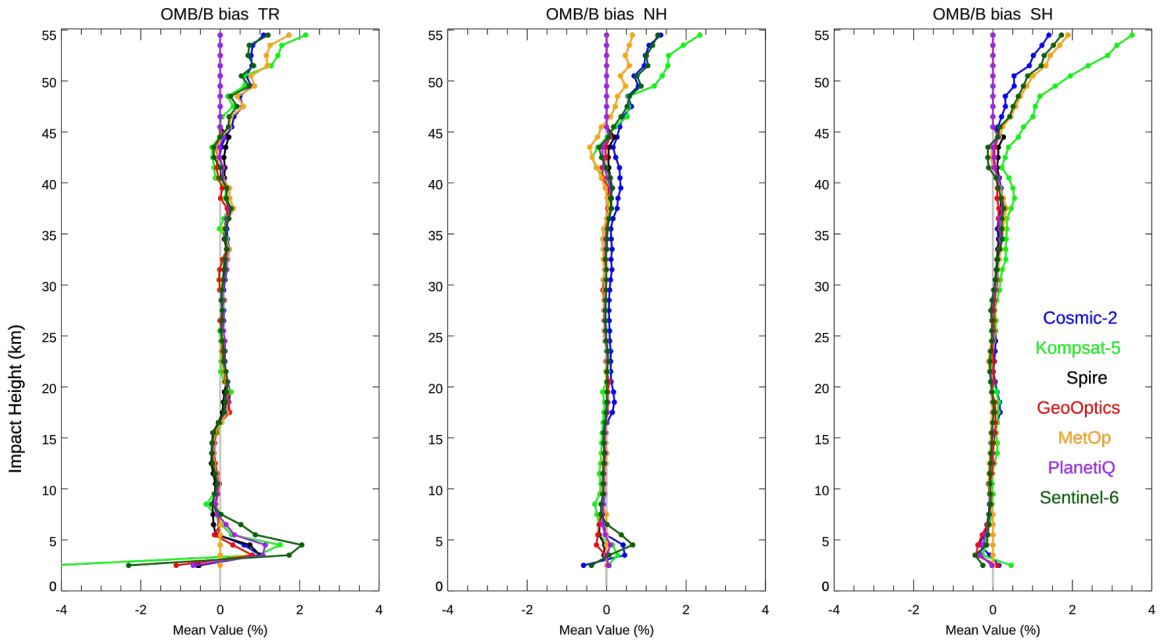
- From the supplement experiment
- GSI: Stricter statistic QC for COSMIC-2 and commercial RO data utilizing smaller O-B/O threshold values results in a lower percentage of obs passing QC below 10 km and above 35 km
- MetOp: Rejected below 8 km
- Commercial data: Rejected above 45-km impact height

Data Quality – OmB/B

RMS



Bias



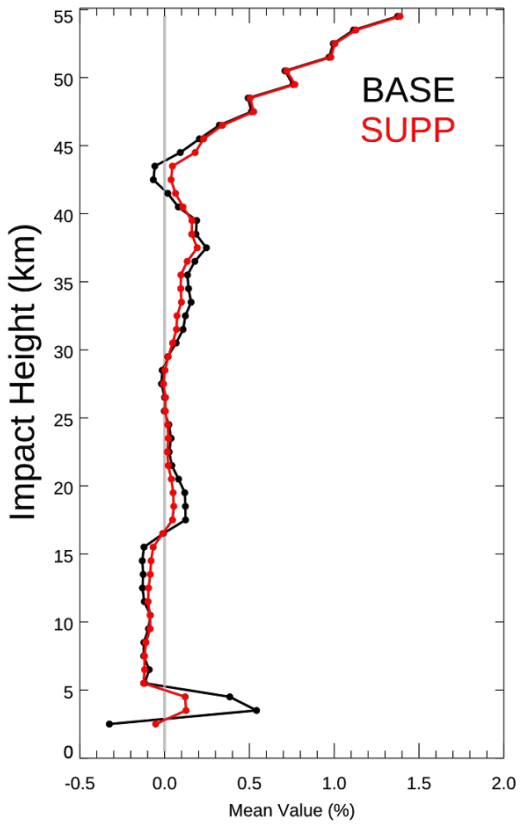
20220907 - 20221020

- Consistent with the past experiments using GFSv16
- Kompsat-5: Larger RMS and bias >35 km and <10 km
- Larger bias and RMS in Tropics <10 km for all missions

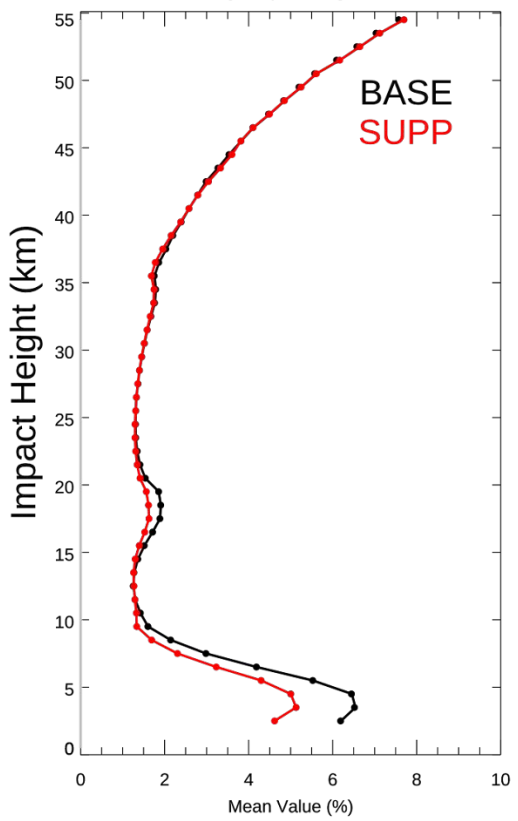
Sentinel-6: larger RMS and bias <10 km

Data Quality – OmB/B baseline vs. supplement

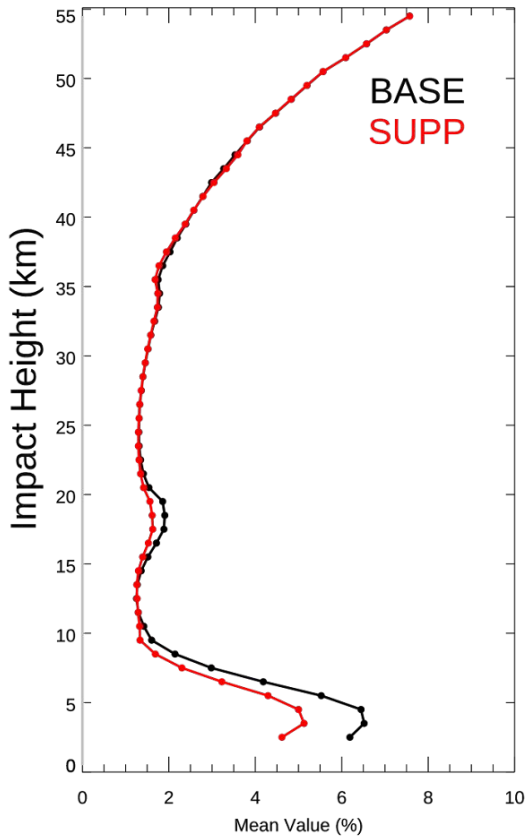
Bias



RMS



STDDEV



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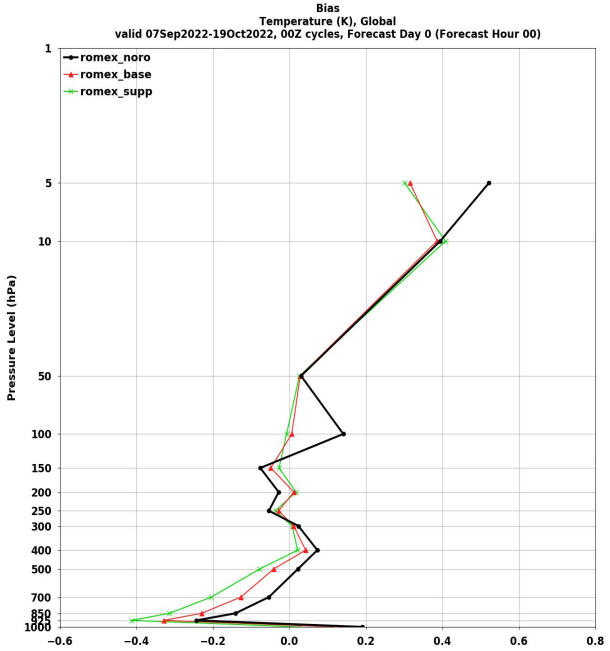
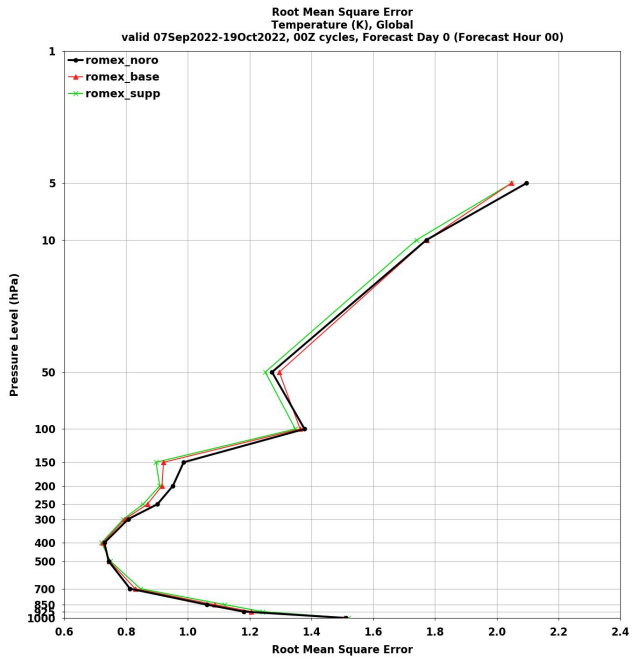
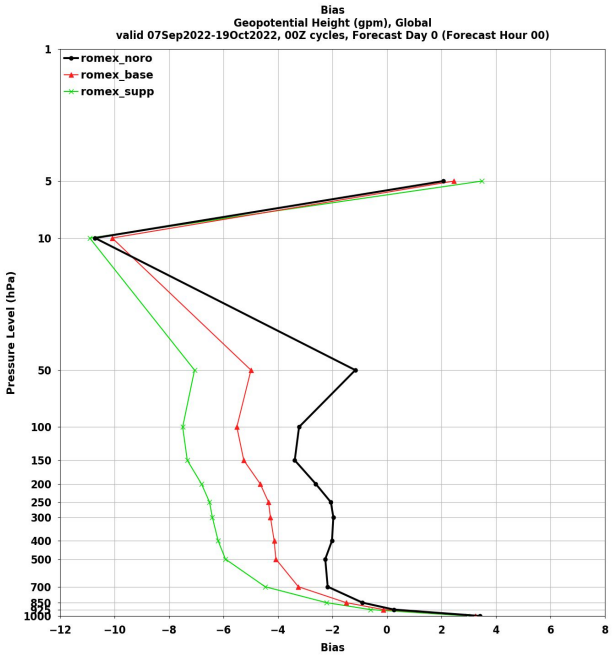
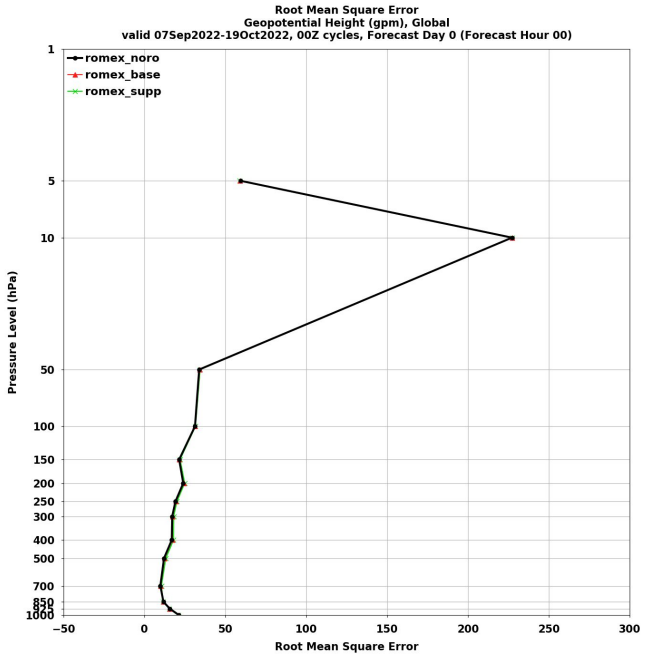
- Bias: Smaller below 5 km and 10 – 40 km
- RMS and STDDEV: Smaller below 20 km









Data Impact – Fit to Radiosonde Data

- Cold bias in temperature and slightly larger RMSE at mid to low troposphere
- Slightly smaller RMSE above 250 hPa
- Lower height bias below 10 hPa
- Height RMSEs are very close

Scorecard against ECMWF Analysis

			N. America						N. Hemisphere						S. Hemisphere						Tropics					
			Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10
Bias	Heights	10hPa	▾			▼	M	M					M	M	▼			▵	M	M	▲	▲	▼	▼	M	M
		20hPa	▲	▲			M	M	▲	▲	▵		M	M	▲	▲	▲	▲	M	M	▼	▼			M	M
		50hPa	▲	▲	▲		M	M	▲	▲	▲	▲	M	M	▲	▲	▼	▼	M	M	▼	▼	▲	▲	M	M
		100hPa	▲	▲			M	M	▼	▼	▼	▼	M	M	▼	▼	▼	▼	M	M					M	M
		200hPa	▲	▲			M	M	▼	▼	▼	▼	M	M	▾	▼			M	M	▼	▲			M	M
		500hPa	▼	▼			M	M	▼	▼	▼	▼	M	M	▼	▼	▼		M	M	▲	▲	▵		M	M
		700hPa	▼	▼			M	M	▼	▼	▾	▾	M	M	▲	▲			M	M	▲	▲	▲		M	M
		850hPa	▲				M	M	▼				M	M	▲	▲			M	M	▼	▼	▾		M	M
		1000hPa					M	M	▲	▼			M	M					M	M	▼	▼	▾		M	M
	Wind Speed	10hPa					M	M					M	M	▲	▵			M	M					M	M
		20hPa	▼				M	M	▼	▼	▼		M	M		▵			M	M	▼	▼	▼	▼	M	M
		50hPa	▼	▲			M	M	▲	▲	▾		M	M		▾			M	M	▲	▲	▲	▲	M	M
		100hPa	▲	▲			M	M	▲	▲	▼	▾	M	M	▾				M	M	▼				M	M
		200hPa					M	M				▼	M	M	▲	▲	▵		M	M					M	M
		500hPa					M	M	▲				M	M					M	M	▲	▲	▲		M	M
		700hPa	▵				M	M	▲				M	M	▲				M	M	▼	▼			M	M
		850hPa					M	M	▵				M	M	▼				M	M	▵				M	M
		1000hPa					M	M					M	M					M	M					M	M
	Temp	10hPa			▾	▼	M	M		▾		▾	M	M	▲	▲	▲	▵	M	M	▲	▵	▵		M	M
		20hPa	▼	▼	▼	▼	M	M	▼	▼	▼	▼	M	M	▲	▼	▼	▼	M	M	▲	▲	▲	▲	M	M
		50hPa				▾	M	M			▾	▼	M	M					M	M	▲	▼	▼	▼	M	M
		100hPa	▲	▲	▲	▵	M	M	▲	▲	▲	▲	M	M	▵				M	M	▲	▲	▲	▲	M	M
		200hPa					M	M		▼			M	M	▼	▼	▼	▼	M	M	▲				M	M
		500hPa	▲	▲			M	M	▲	▲	▲	▵	M	M	▲	▲	▵		M	M	▲				M	M
		700hPa	▼	▼	▾		M	M	▼	▼	▼	▼	M	M	▼	▼	▼		M	M	▲	▲			M	M
		850hPa	▼	▼			M	M	▼	▼	▼	▼	M	M	▼	▼	▼	▾	M	M	▲	▲			M	M
		1000hPa	▼	▾			M	M	▼	▼	▼		M	M	▼	▼			M	M	▼				M	M

			N. America						N. Hemisphere						S. Hemisphere						Tropics					
			Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10
Anomaly Correlation Coefficient	Heights	250hPa	▾				M	M					M	M	▲	▵	▵	▵	M	M						
		500hPa					M	M					M	M	▲		▵	▵	M	M						
		700hPa					M	M	▾				M	M	▲	▵	▵		M	M						
		1000hPa					M	M					M	M	▲	▵	▲		M	M						
	Vector Wind	250hPa					M	M					M	M	▲	▲	▲	▲	M	M						
		500hPa					M	M					M	M	▲	▵	▲	▵	M	M						
		850hPa					M	M					M	M	▵	▵	▲		M	M						
	Temp	250hPa					M	M					M	M	▲	▲	▵		M	M						
		500hPa					M	M					M	M	▲	▲	▵	▲	M	M						
		850hPa	▾				M	M	▼				M	M	▵	▲	▲	▵	M	M						
	MSLP	MSL					M	M					M	M	▲	▵	▲		M	M						
RMSE	Heights	10hPa	▼		▾	▾	M	M					M	M		▲	▲		M	M	▲	▵			M	M
		20hPa	▲	▲			M	M	▲	▲			M	M	▲	▲	▵		M	M					M	M
		50hPa	▲	▲			M	M	▲	▲			M	M	▲	▲			M	M	▼				M	M
		100hPa	▲	▵			M	M	▲				M	M	▲	▵			M	M	▵				M	M
		200hPa					M	M	▼				M	M	▲	▵	▵		M	M					M	M
		500hPa	▼				M	M	▼				M	M	▲		▵	▵	M	M	▲	▲			M	M
		700hPa					M	M	▼				M	M	▲	▵	▵		M	M	▲				M	M
		850hPa					M	M	▼				M	M	▲	▲	▲		M	M					M	M
		1000hPa					M	M					M	M	▲	▵	▲		M	M		▾			M	M
	Vector Wind	10hPa				▼	M	M					M	M	▾				M	M	▲	▲	▲		M	M
		20hPa	▼	▼	▼	▼	M	M	▼	▼	▼	▼	M	M	▼	▼	▼	▼	M	M	▲	▲	▲	▲	M	M
		50hPa	▼	▼			M	M	▼	▼	▾		M	M	▼	▼			M	M	▲	▲			M	M
		100hPa	▼				M	M	▼				M	M	▼				M	M	▲	▲	▲		M	M
		200hPa					M	M					M	M	▼				M	M	▲	▲	▲	▲	M	M
		500hPa					M	M					M	M					M	M	▲	▲			M	M
		700hPa					M	M					M	M					M	M	▵	▵	▲		M	M
		850hPa					M	M					M	M					M	M	▵	▵	▲		M	M
		1000hPa					M	M					M	M					M	M					M	M
	Temp	10hPa				▾	M	M					M	M					M	M	▲	▲	▲		M	M
		20hPa	▼	▼	▼	▼	M	M	▼	▼	▾	▾	M	M	▲	▲	▵		M	M	▲	▲	▵		M	M
		50hPa	▼	▼			M	M	▼	▼			M	M	▲	▲	▲		M	M	▲	▲			M	M
		100hPa	▵	▵			M	M	▲	▲			M	M	▲	▲	▲	▵	M	M	▲	▲	▲	▲	M	M
		200hPa					M	M					M	M	▲	▲	▲	▲	M	M	▲				M	M
		500hPa					M	M	▵				M	M	▲	▲	▲	▲	M	M	▲	▲			M	M
		700hPa	▾				M	M	▼				M	M				▵	M	M	▲				M	M
		850hPa	▼				M	M	▼				M	M	▼	▵	▵	▵	M	M	▲				M	M
		1000hPa	▼				M	M	▼	▼			M	M	▼				M	M	▼	▾			M	M

▲ v17_romex_base_qosap is better than v17_romex_noro at the 99.9% significance level
▵ v17_romex_base_qosap is better than v17_romex_noro at the 99% significance level
▫ v17_romex_base_qosap is better than v17_romex_noro at the 95% significance level
▼ v17_romex_base_qosap is worse than v17_romex_noro at the 99.9% significance level
▾ v17_romex_base_qosap is worse than v17_romex_noro at the 99% significance level
▫ v17_romex_base_qosap is worse than v17_romex_noro at the 95% significance level
No statistically significant difference between v17_romex_base_qosap and v17_romex_noro
Not statistically relevant

Dates: 20220907-20221019

- Baseline vs. NoRO
- Positive impact in ACC and RMSE over SH and Tropics
- Degradation in RMS of height in troposphere and wind and temperature at upper atmosphere

Scorecard against ECMWF Analysis

			N. America						N. Hemisphere						S. Hemisphere						Tropics					
			Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10
Bias	Heights	10hPa	▲	▲	▲		M	M	▲	▲	▲	▲	M	M	▲	▲	▲		M	M	▼	▲	▲	▲	M	M
		20hPa	▲	▲	▲		M	M	▲	▲	▲	▲	M	M	▲	▲	▲	▵	M	M	▼	▼	▼	▲	M	M
		50hPa	▼	▲	▼		M	M	▼	▼	▼	▼	M	M	▼	▼	▼	▼	M	M	▼	▼	▼	▲	M	M
		100hPa	▼	▼	▼		M	M	▼	▼	▼	▼	M	M	▼	▼	▼	▼	M	M	▼	▼	▼	▼	M	M
		200hPa	▼	▼	▾		M	M	▼	▼	▼	▼	M	M	▼	▼	▼	▼	M	M	▼	▲	▲	▲	M	M
		500hPa	▼	▼			M	M	▼	▼	▼		M	M	▼	▼	▼	▼	M	M	▼	▲	▲	▲	M	M
		700hPa	▼	▼			M	M	▼	▼			M	M	▼	▲			M	M	▼	▼	▼	▲	M	M
		850hPa	▼				M	M	▼				M	M	▲	▲			M	M	▼	▼	▼	▼	M	M
		1000hPa					M	M					M	M	▲	▲			M	M		▼	▼	▼	M	M
	Wind Speed	10hPa	▼	▾			M	M	▼	▼			M	M					M	M					M	M
		20hPa	▲				M	M	▲	▲			M	M		▲			M	M					M	M
		50hPa	▲				M	M	▲	▲			M	M	▵				M	M	▼	▼		▵	M	M
		100hPa					M	M					M	M					M	M					M	M
		200hPa	▲				M	M	▲				M	M	▲	▵			M	M	▲	▵			M	M
		500hPa	▲	▲		▾	M	M	▲	▲			M	M	▼	▼			M	M	▲	▲			M	M
		700hPa	▲	▵			M	M	▲	▲			M	M	▼	▼			M	M	▼	▼			M	M
		850hPa	▲				M	M	▲	▲			M	M	▼	▼			M	M	▲				M	M
		1000hPa	▲				M	M	▲	▵			M	M	▼	▾			M	M					M	M
	Temp	10hPa	▾				M	M	▼	▼	▼		M	M	▵	▲			M	M					M	M
		20hPa	▼	▼	▾		M	M	▼	▼	▼	▼	M	M	▼	▼			M	M	▼	▼	▼		M	M
		50hPa					M	M			▼	▾	M	M	▼	▼	▼	▾	M	M	▼	▼			M	M
		100hPa					M	M	▵				M	M	▲	▲	▲		M	M		▾			M	M
		200hPa	▼	▼			M	M	▼	▼	▾		M	M					M	M	▼	▼	▼	▼	M	M
		500hPa	▲	▲	▵		M	M	▲	▲	▲	▲	M	M	▲	▲	▼	▼	M	M	▲	▵			M	M
		700hPa	▼	▼	▾		M	M	▼	▼	▼	▼	M	M	▼	▼	▾	▾	M	M	▼	▲	▲		M	M
		850hPa	▼	▼	▾		M	M	▼	▼	▼	▾	M	M	▼	▼	▾		M	M	▲	▲	▵		M	M
		1000hPa	▼	▾	▾		M	M	▼	▼	▼	▾	M	M	▵				M	M	▼	▼			M	M

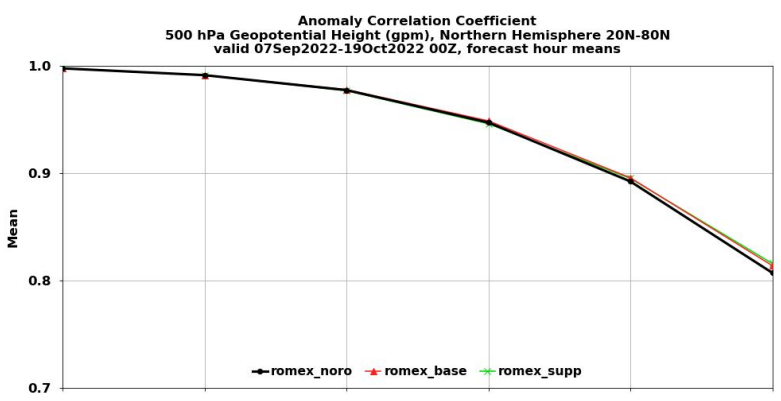
Anomaly Correlation Coefficient	Heights	250hPa					M	M					M	M					M	M	▲				M	M
		500hPa					M	M					M	M					M	M	▲				M	M
		700hPa					M	M					M	M					M	M	▲				M	M
		1000hPa					M	M					M	M					M	M	▲				M	M
	Vector Wind	250hPa					M	M					M	M					M	M	▲				M	M
		500hPa					M	M					M	M					M	M	▲				M	M
		850hPa					M	M					M	M					M	M	▲				M	M
	Temp	250hPa	▵				M	M	▲				M	M					M	M	▲				M	M
		500hPa					M	M					M	M					M	M	▲				M	M
		850hPa	▼				M	M	▾				M	M					M	M	▲				M	M
	MSLP	MSL					M	M					M	M					M	M	▲				M	M
RMSE	Heights	10hPa	▲	▲	▲	▲	M	M	▲	▲	▲	▵	M	M	▵				M	M			▵	▵	M	M
		20hPa	▲	▲	▲	▲	M	M	▲	▲	▵	▵	M	M	▲				M	M	▼	▾			M	M
		50hPa	▲	▲			M	M		▵			M	M					M	M	▼				M	M
		100hPa	▼				M	M	▼	▾			M	M	▼				M	M	▼	▼	▼		M	M
		200hPa	▼				M	M	▼				M	M	▼				M	M	▼				M	M
		500hPa	▼				M	M	▼				M	M	▾				M	M		▵			M	M
		700hPa					M	M	▼				M	M	▲				M	M					M	M
		850hPa					M	M					M	M	▲				M	M					M	M
		1000hPa					M	M					M	M	▲			▵	M	M					M	M
	Vector Wind	10hPa	▲				M	M	▲	▲	▵		M	M	▲	▵			M	M					M	M
		20hPa	▲	▲		▵	M	M	▲	▲	▲	▲	M	M	▲	▲			M	M	▲	▲	▵	▲	M	M
		50hPa	▲	▲			M	M	▲	▲	▲	▵	M	M	▲				M	M	▲		▵	▵	M	M
		100hPa	▲				M	M	▲	▵			M	M	▲				M	M	▲				M	M
		200hPa					M	M					M	M	▲				M	M	▲			▾	M	M
		500hPa					M	M					M	M	▲				M	M					M	M
		700hPa					M	M					M	M	▲				M	M					M	M
		850hPa					M	M					M	M	▲				M	M					M	M
		1000hPa					M	M					M	M	▵				M	M					M	M
	Temp	10hPa	▲				M	M	▲				M	M	▲				M	M	▲	▵			M	M
		20hPa	▲	▲			M	M	▲	▲		▵	M	M	▲	▲			M	M	▲	▲			M	M
		50hPa	▲	▲			M	M	▲	▲	▲		M	M	▲	▲			M	M	▲	▲			M	M
		100hPa	▲				M	M	▲	▵			M	M	▲	▵			M	M	▲				M	M
		200hPa					M	M	▵				M	M	▲				M	M		▼	▼	▾	M	M
		500hPa					M	M					M	M	▲				M	M	▲		▾		M	M
		700hPa	▼	▾			M	M	▼				M	M					M	M					M	M
		850hPa	▼	▼			M	M	▼	▾			M	M	▵				M	M	▲	▲			M	M
		1000hPa	▼				M	M	▼	▼			M	M	▲				M	M	▼	▾		▾	M	M

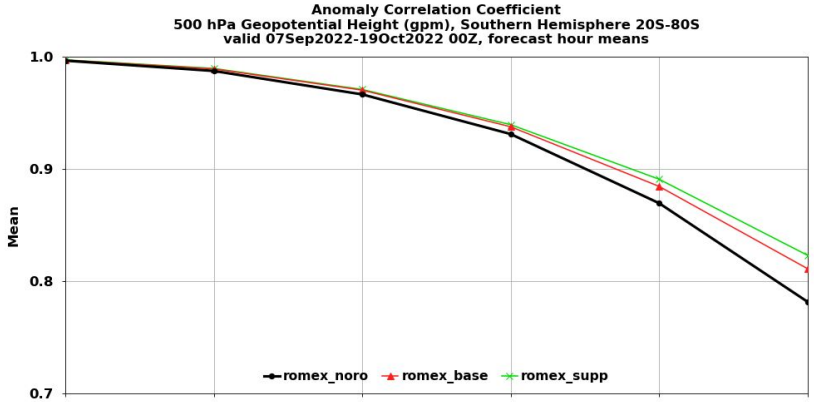
▲	v17_romex_supp2 is better than v17_romex_base_qosap at the 99.9% significance level	▼	v17_romex_supp2 is worse than v17_romex_base_qosap at the 99.9% significance level
▵	v17_romex_supp2 is better than v17_romex_base_qosap at the 99% significance level	▾	v17_romex_supp2 is worse than v17_romex_base_qosap at the 99% significance level
	v17_romex_supp2 is better than v17_romex_base_qosap at the 95% significance level		v17_romex_supp2 is worse than v17_romex_base_qosap at the 95% significance level
	No statistically significant difference between v17_romex_supp2 and v17_romex_base_qosap		Not statistically relevant

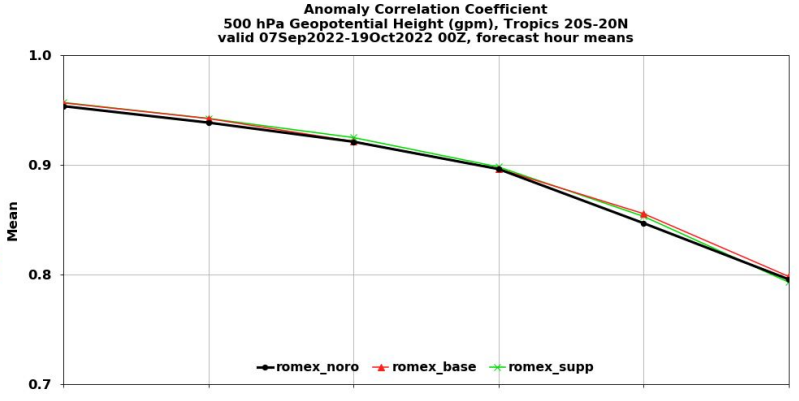
Dates: 20220907-20221019

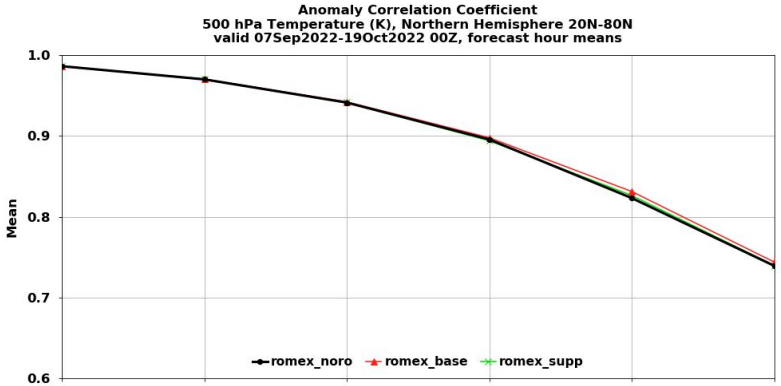
- Supplement vs. baseline
- Overall positive impact in ACC and RMSE for short range over SH and RMSE in Tropics except for height
- Positive impact on wind and temperature RMSE at upper atmosphere over NH

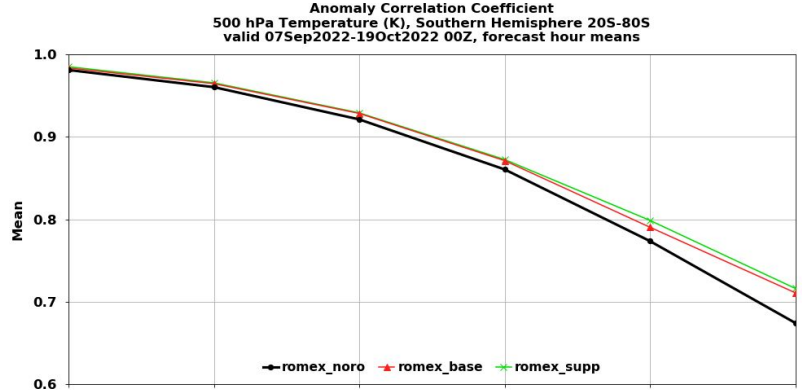
Verification against ECMWF Analysis

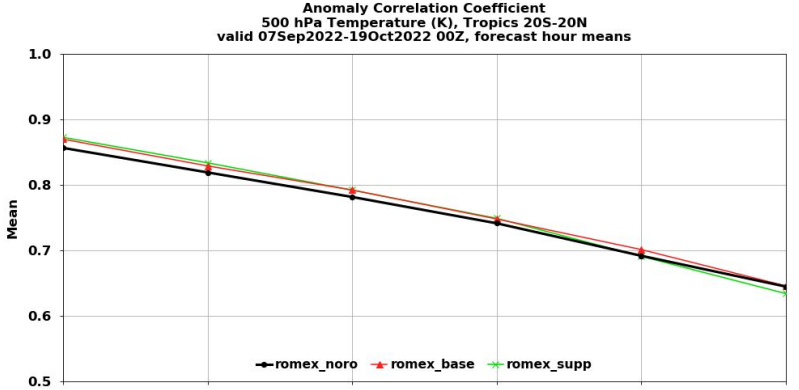






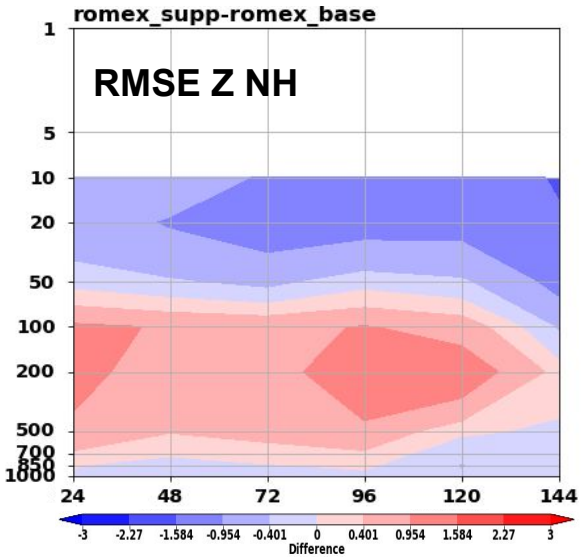


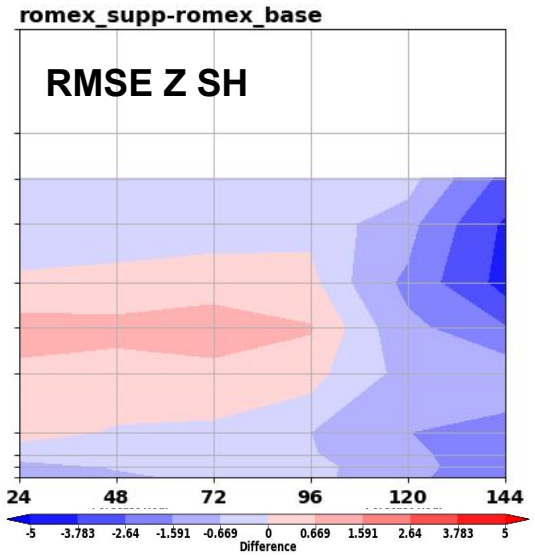


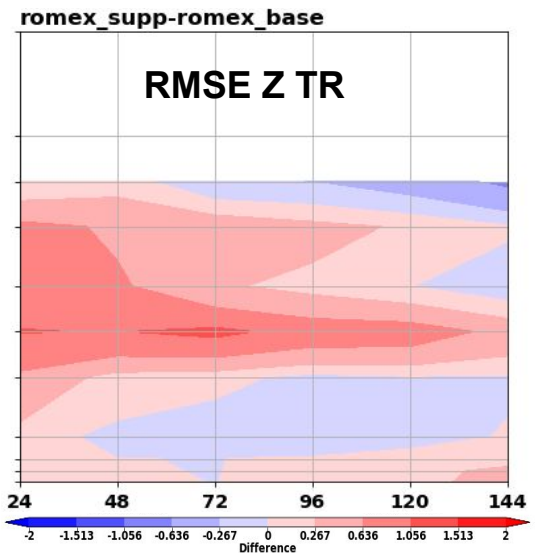


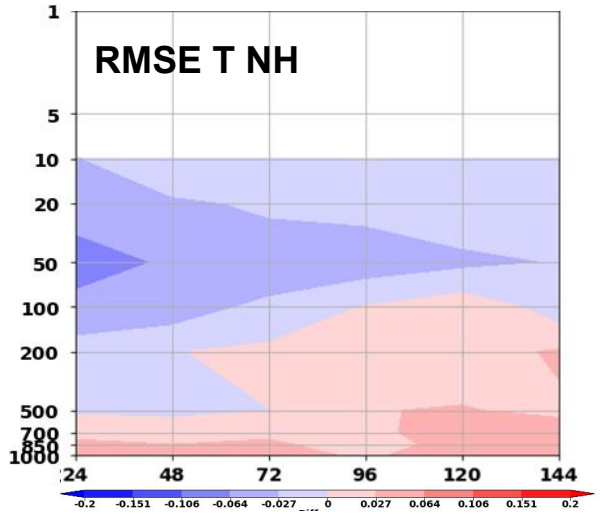
- Height ACC at 500 hPa: Improvement over SH
- Temperature ACC at 500 hPa: Improvement over NH, SH and Tropics
- Significant improvement in SH

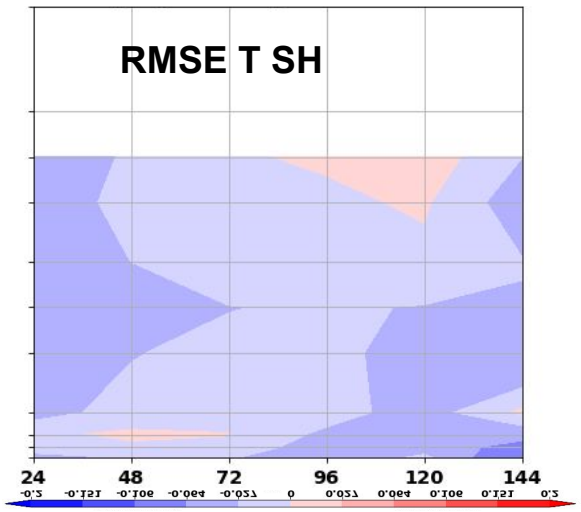
Verification against ECMWF Analysis

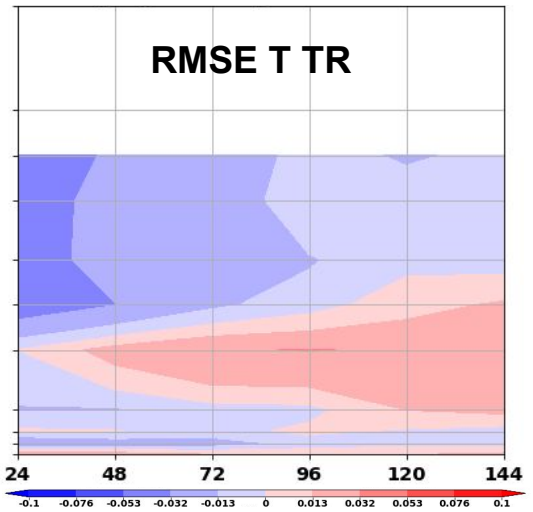












- Red: Degradation
- Blue: Improvement

Summary

- ROMEX data verification on GFSv17 for 1.5 months with atmosphere-only DA
- More positive signs than 3-week results: Improvement in |O-B|/B bias < 40 km and RMS < 20 km in the supplement experiment
- Larger impact when more ROMEX data was assimilated
- Against radiosonde data: ROMEX data resulted in a cold bias in the mid to low troposphere and a lower height bias below 10 hPa
- Against ECMWF analysis: Positive impact on ACC and RMSE especially over SH and Tropics; Positive impact in NH as well with ROMEX supplement data

- Further tests required for GFSv17
- NOTE: Yunyao, Tianmu, and GNOS data are not utilized in current experiments