

Impact of ROMEX in the U.S. Navy's Global Numerical System

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Global NWP at NRL

NWP Model		
Name	Horz. Res.	Vert. Res.
NAVGEM (Hogan et al. 2014)	T681 (~19km)	L60 (to 0.04hPa)
Data Assimilation system		
Technique	Ensemble	Forward Operator for RO
Hybrid Incremental 4DVar (Xu et al. 2005; Rosmond and Xu, 2006)	Ensemble transform (Bishop and Toth 1999; McLay 2007, 2008)	Radio Occultation Processing Package (ROPP) (Culverwell et al., 2015)

- 1 D Abel integral
- Tangent point drift applied
- Obs error and QC as in Ruston and Healy (2021)

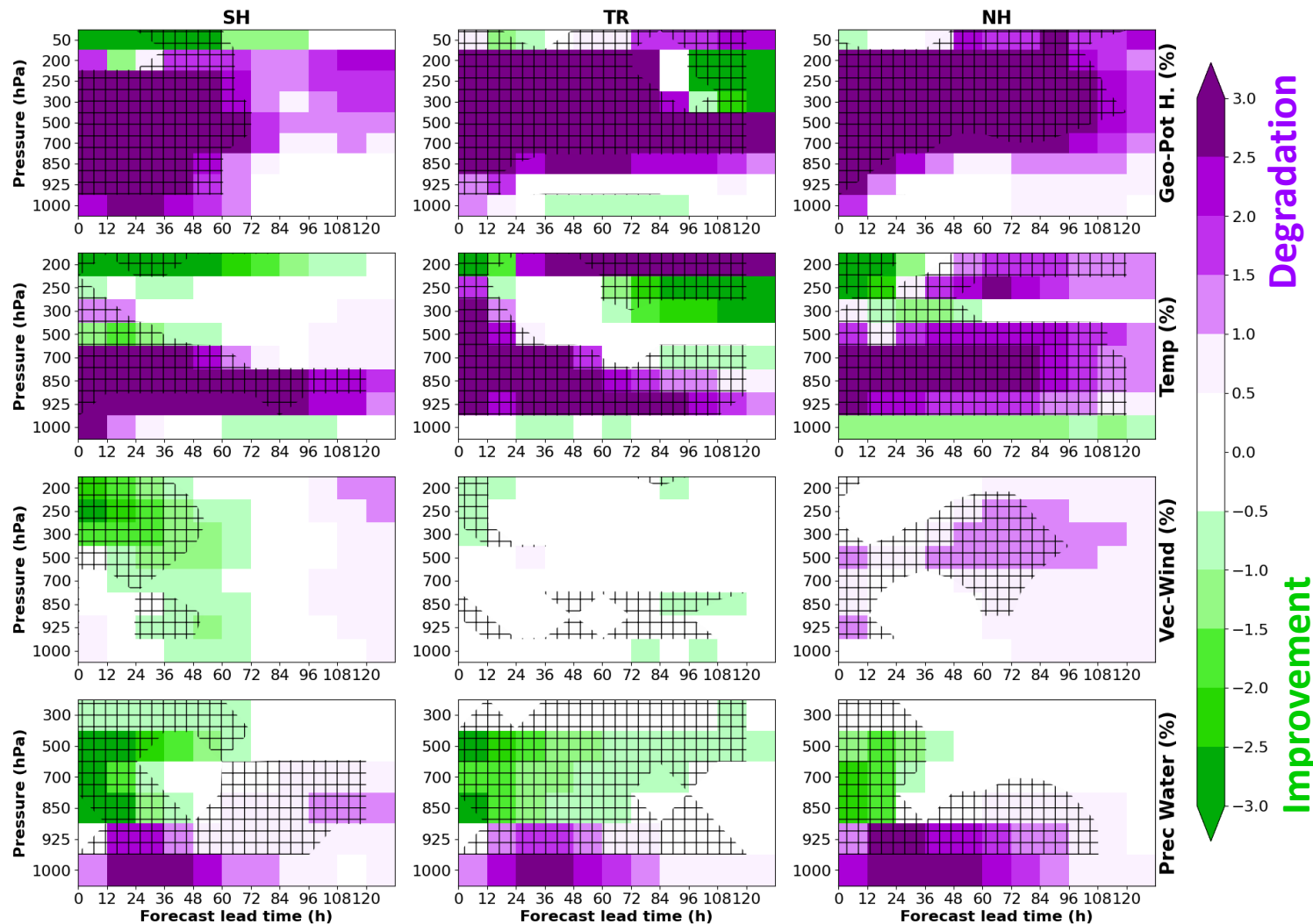


ROMEX Experiments

Name	Description	Duration	RO Missions	# of profiles
romex_ctl	Assimilate RO as in operational NAVGEM, exclude data sources are from commercial and Chinese providers	1 Sep -30 Nov, 2022	MetOp, Sentinel-6, COSMIC-2, Kompsat-5, PAZ, TerraSAR-X, TanDEM-X	~7,000 profiles/day
romex_exp	Assimilate all RO data from ROMEX		Those in “Control” & <i>Spire, PlanetIQ, GeoOptics, FY3x, Yunyao, Tiamu</i>	~35,000 profiles/day
NoRO	No GNSS RO data			

Initial ROMEX Impact on Forecasts

Verified against ECMWF Analysis



$$100 * \frac{RMSE_{romex} - RMSE_{ctl}}{RMSE_{ctl}}$$

statistically significant at the 95% level

Initial results

Verification against ECMWF analyses or radiosondes (not shown) shows that ROMEX data assimilation **degrades significantly** the medium-range forecasts for geopotential or temperature forecasts

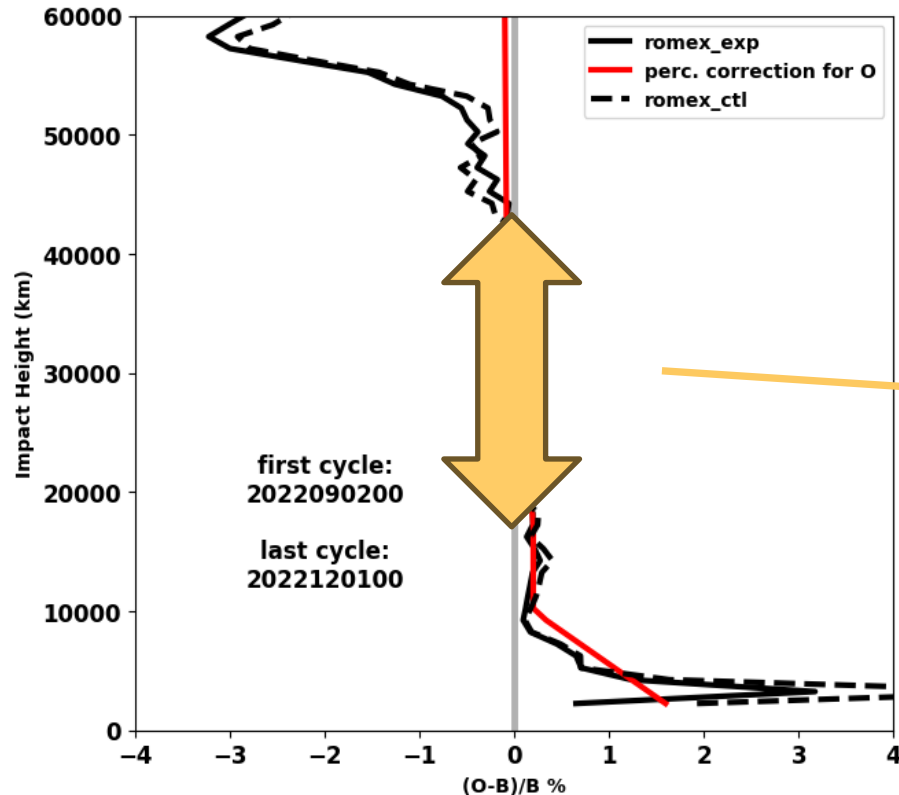
Additional ROMEX Experiments

Name	Description	Duration
romex_ctl		1 Sep – 30 Nov, 2022
romex_ctl_bc	Applies simply observation correction	1-30 Sep, 2022
romex_exp	Assimilate all RO data from ROMEX	1 Sep – 30 Nov, 2022
romex_exp_bc	Applies simply observation correction	1-30 Sep, 2022
NoRO	No GNSS RO data	1 Sep – 30 Nov, 2022

- Following the work by Bowler (2024), we applied a simple bias correction to the observations and tested for a month
- BC model was applied for all missions for both ROMEX experiment and control run
- No mission specific correction attempted this time

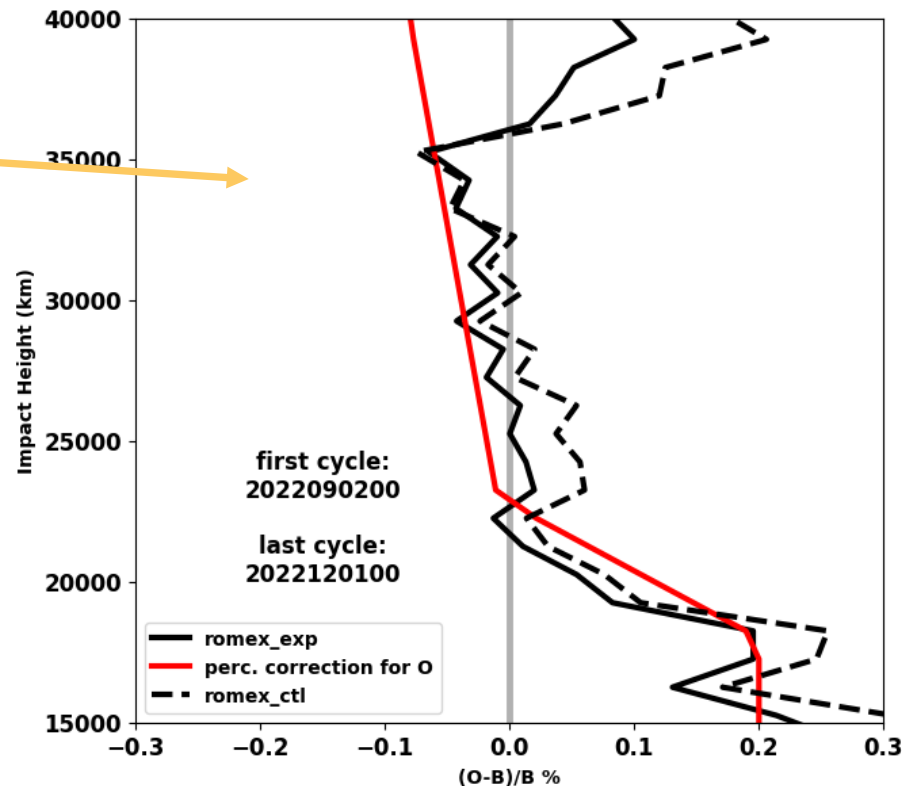
Additional ROMEX Experiments

Global BA Innovation



- Bias correction model was developed on all ROMEX data
- Chose to create a simple model with linear interpolation between a few hinge points

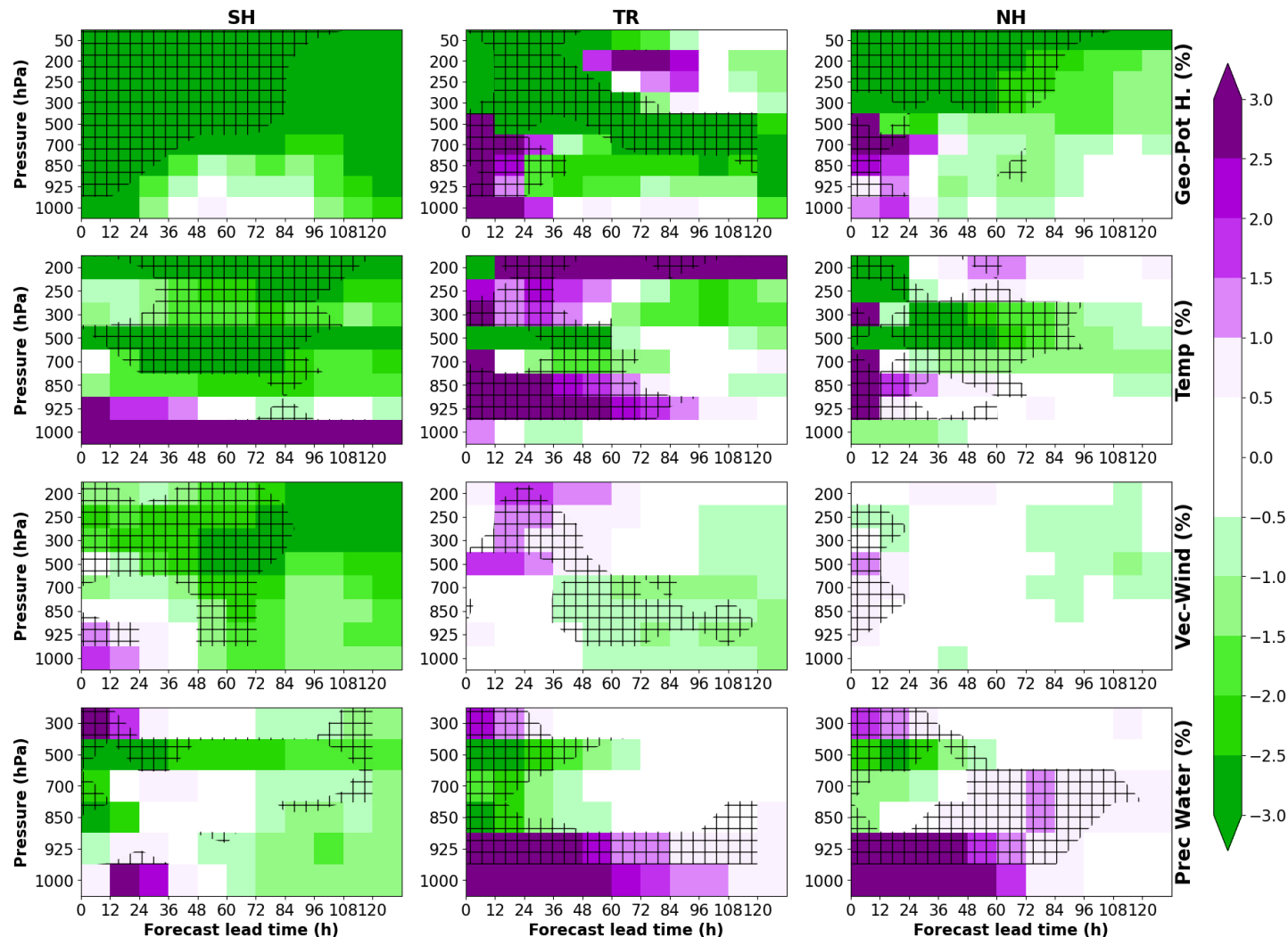
Global BA Innovation



- <10km: linearly ramped to 2%
- 10-18km: 0.2%
- 18-23km: -0.01% to 0.2%
- 23-40km: -0.01% to -0.08%
- >40km: 0.1%

ROMEX Impact on Model Forecasts

Verified against ECMWF Analysis



$$100 * \frac{RMSE_{romex_bc} - RMSE_{ctl}}{RMSE_{ctl}}$$

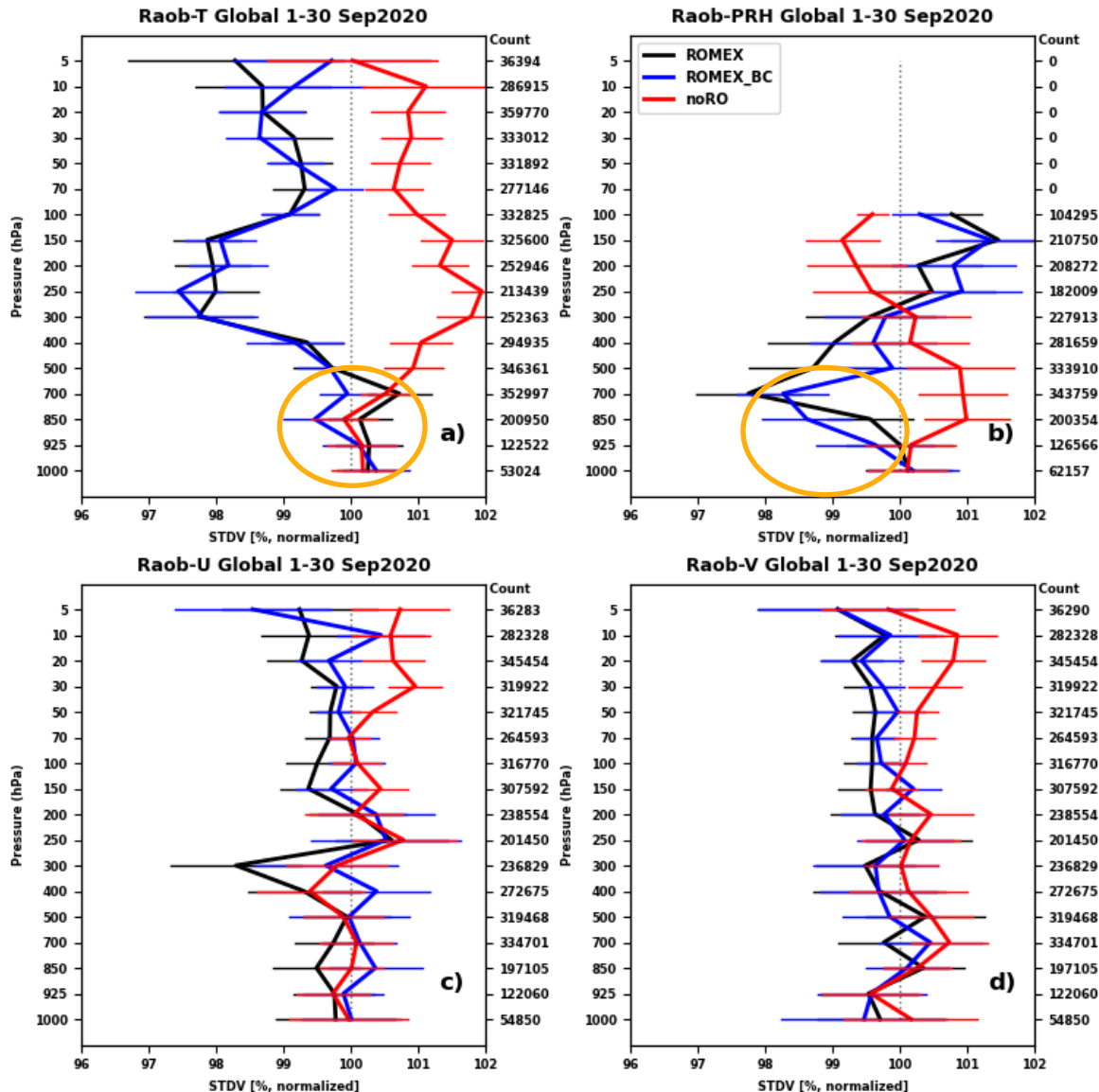
statistically significant at the 95% level

Bias corrected ROMEX

Assimilation of all ROMEX data significantly improves nearly all model variable forecasts out to 5-day forecasts



Fit to Radiosondes

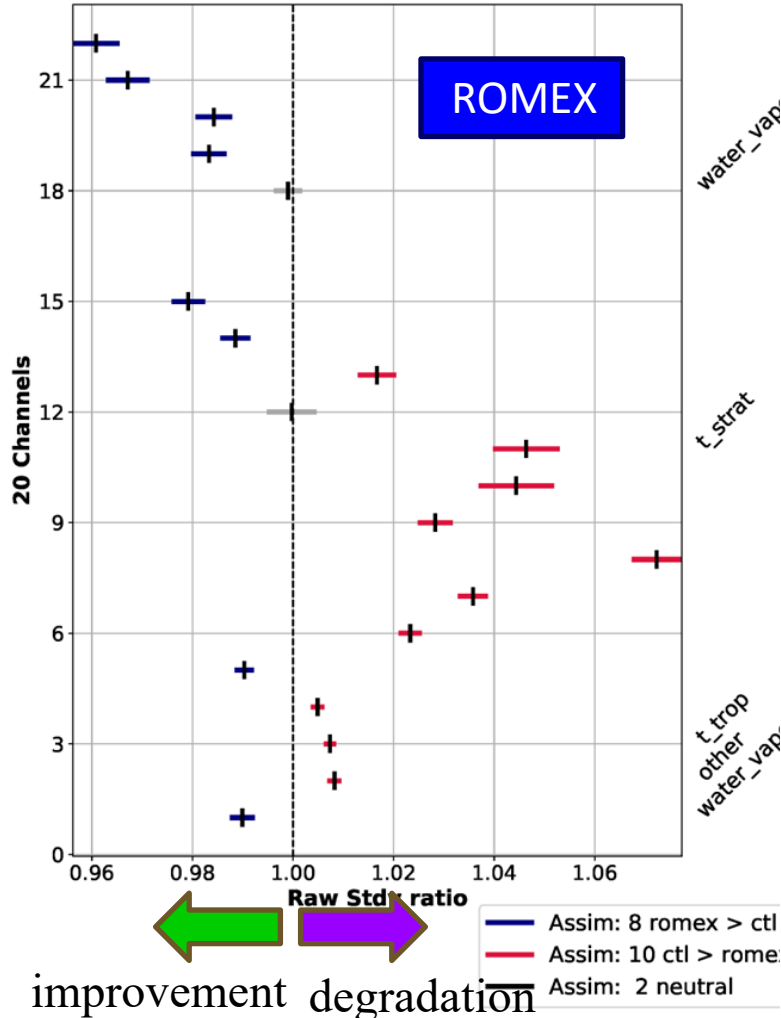


Radiosonde Verification

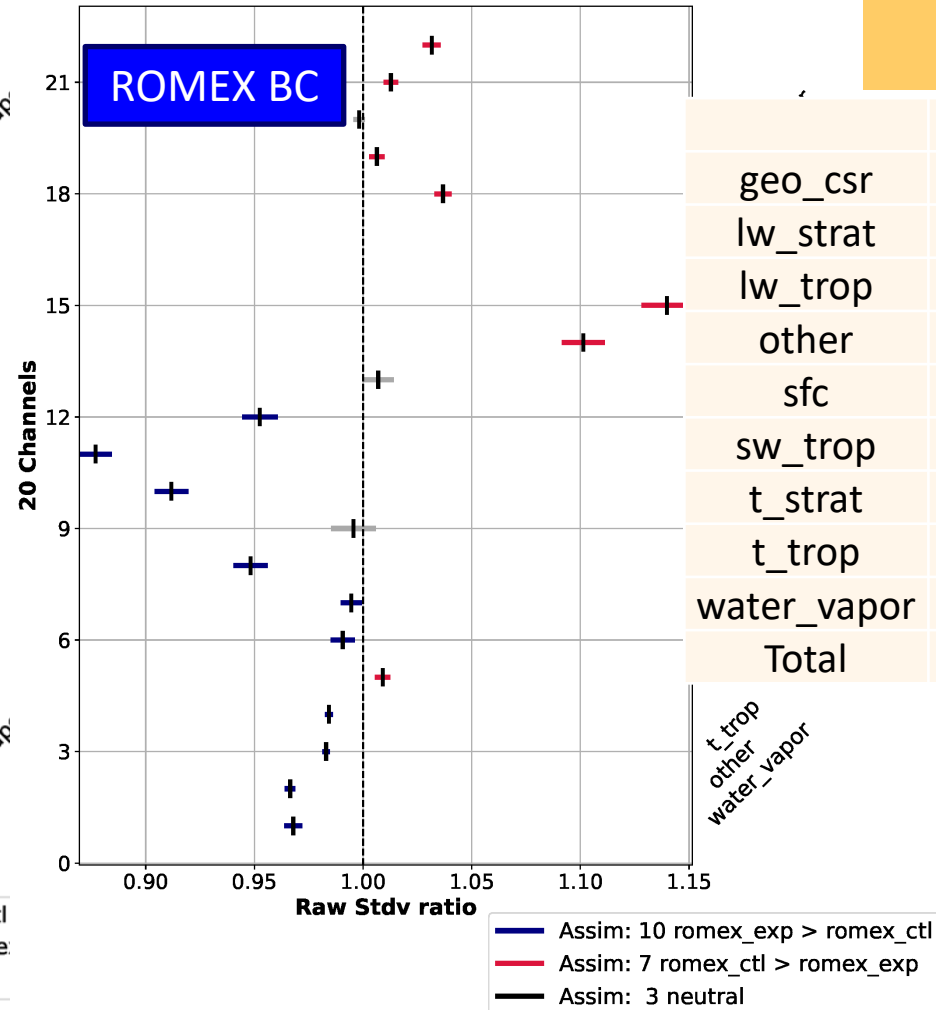
- ROMEX with bias correction (ROMEX_BC) shows better fit to T and moisture in the lower troposphere (<500hPa)
- No RO shows degradations on T, winds, and lower moisture

Fit to Satellite Radiances

romex vs ctl (Global)
NOAA20_ATMS Raw Stdv ratio (CI=95.00)
119 dtgs from 2022-09-01T06 to 2022-09-30T18



romex_exp vs romex_ctl (Global)
NOAA20_ATMS Raw Stdv ratio (CI=95.00)
119 dtgs from 2022-09-01T06 to 2022-09-30T18



Standard global scorecard for ROMEX BC: +8

	ChanCount	win	tie	loss	wlt_score
geo_csr	41	21	8	12	1
lw_strat	127	65	6	56	1
lw_trop	71	57	6	8	1
other	13	13	0	0	1
sfc	6	2	1	3	0
sw_trop	13	13	0	0	1
t_strat	37	29	2	6	1
t_trop	54	47	2	5	1
water_vapor	89	46	14	29	1
Total	451	293	39	119	8

For all the assimilated sat radiances
Win-tie-loss score: #win > (#tie + #loss)
Table similar to Frolov et al. (2019)

Geopotential Height Verification

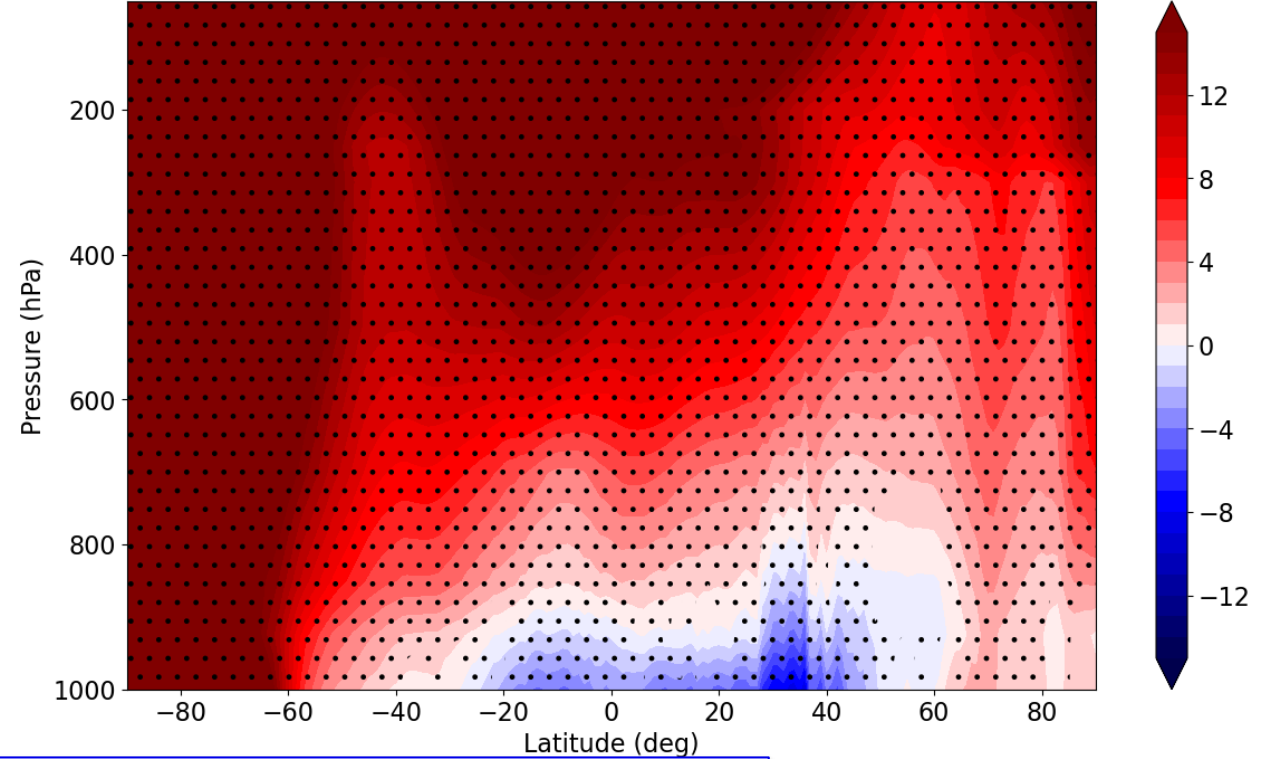
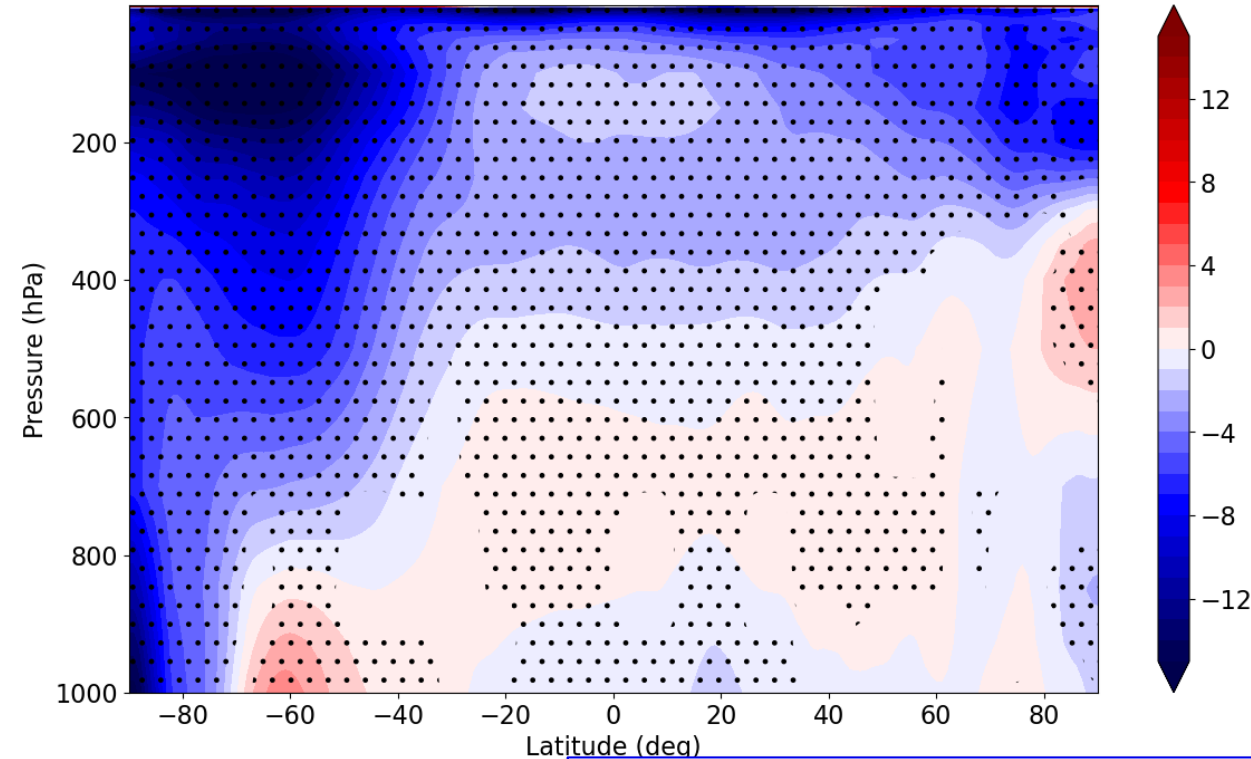
ROMEX BC – Control BC

Lead time = 12 h

Control BC - ECMWF

romex_exp-romex_ctl Geo. Pot. (gpm) 2022090100-2022093000
min:-18.55 max:317.94 tau=012

romex_ctl-ecmwf Geo. Pot. (gpm) 2022090100-2022093000
min:-8.86 max:152.82 tau=012



... statistically
significant at the
95% level

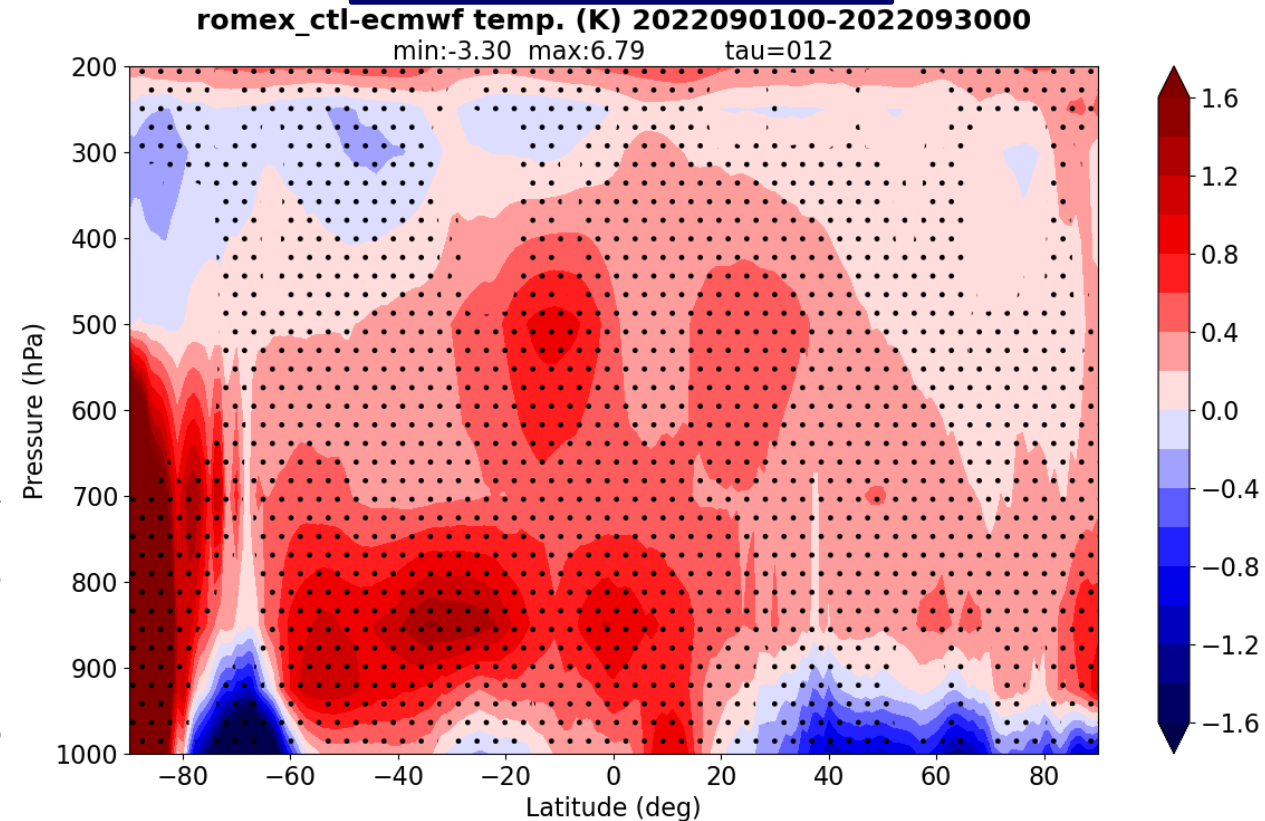
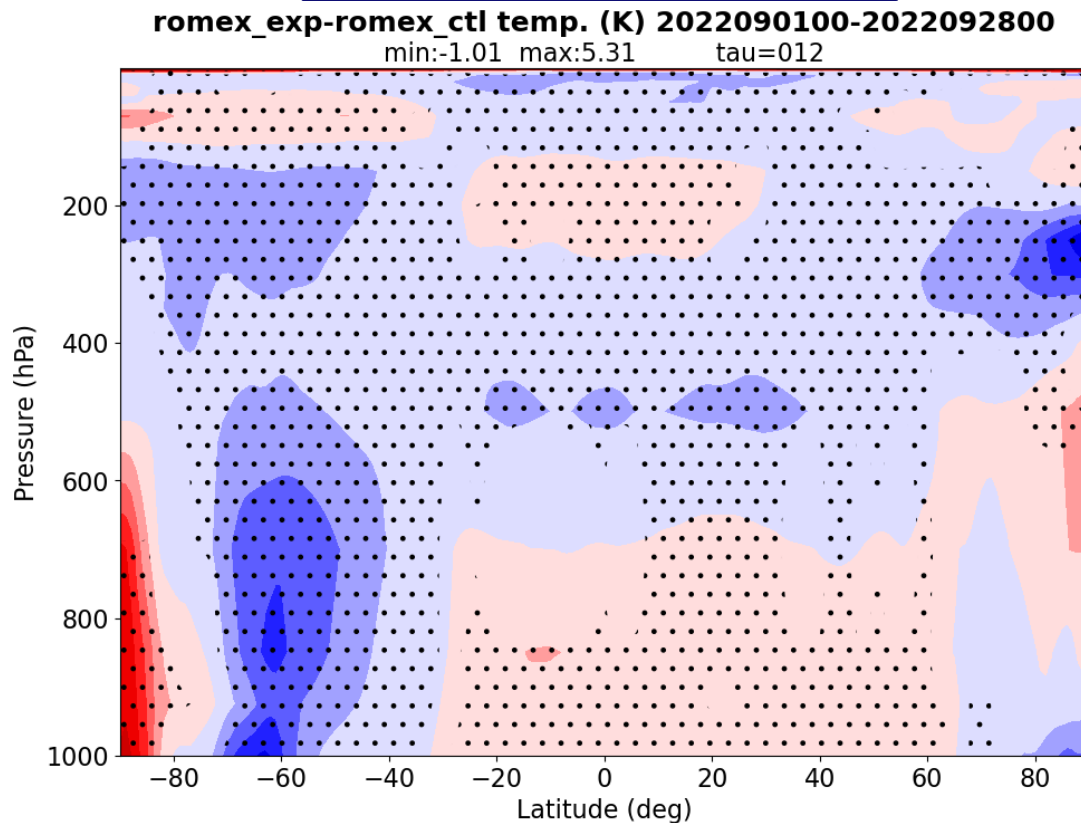
**Bias corrected ROMEX experiment largely corrects the high
geopotential bias seen in the model control run**

Temperature Verification

ROMEX BC – Control BC

Lead time = 12 h

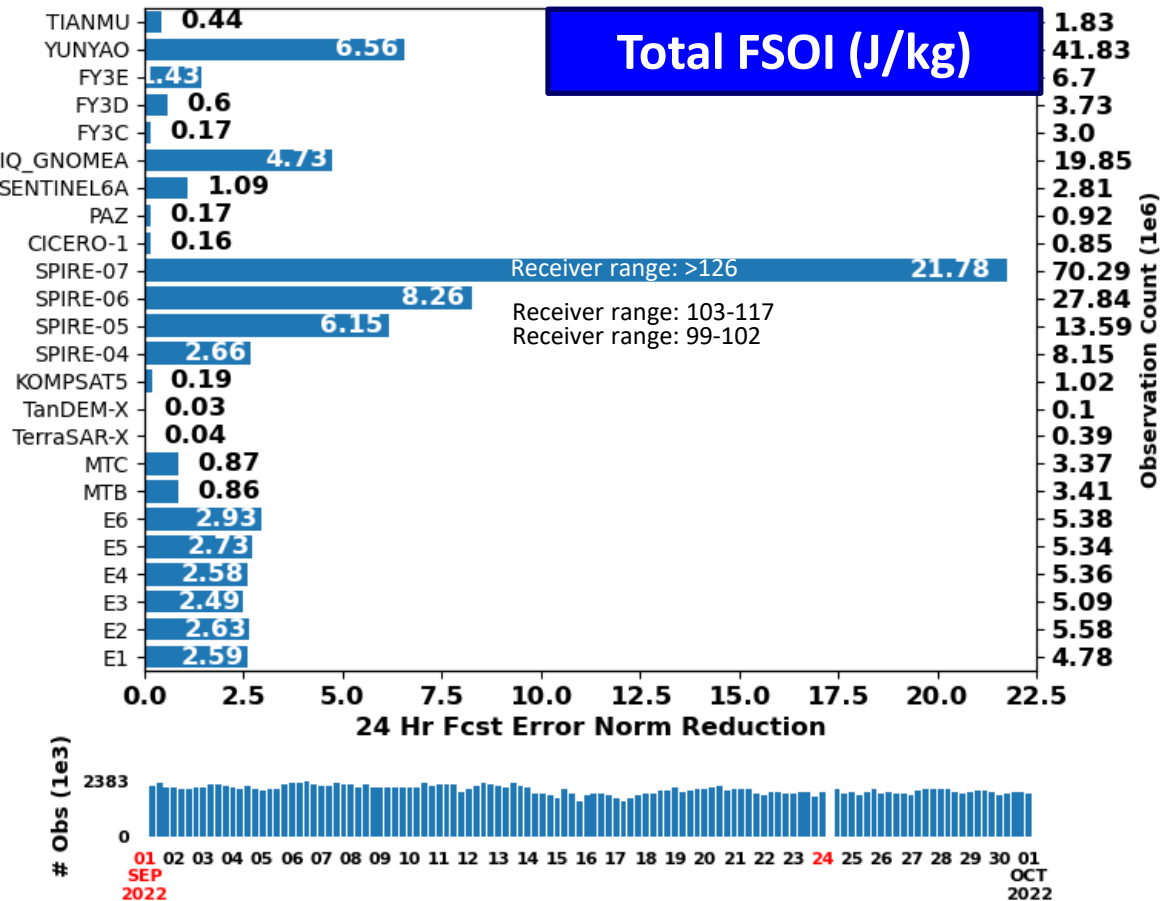
Control BC - ECMWF



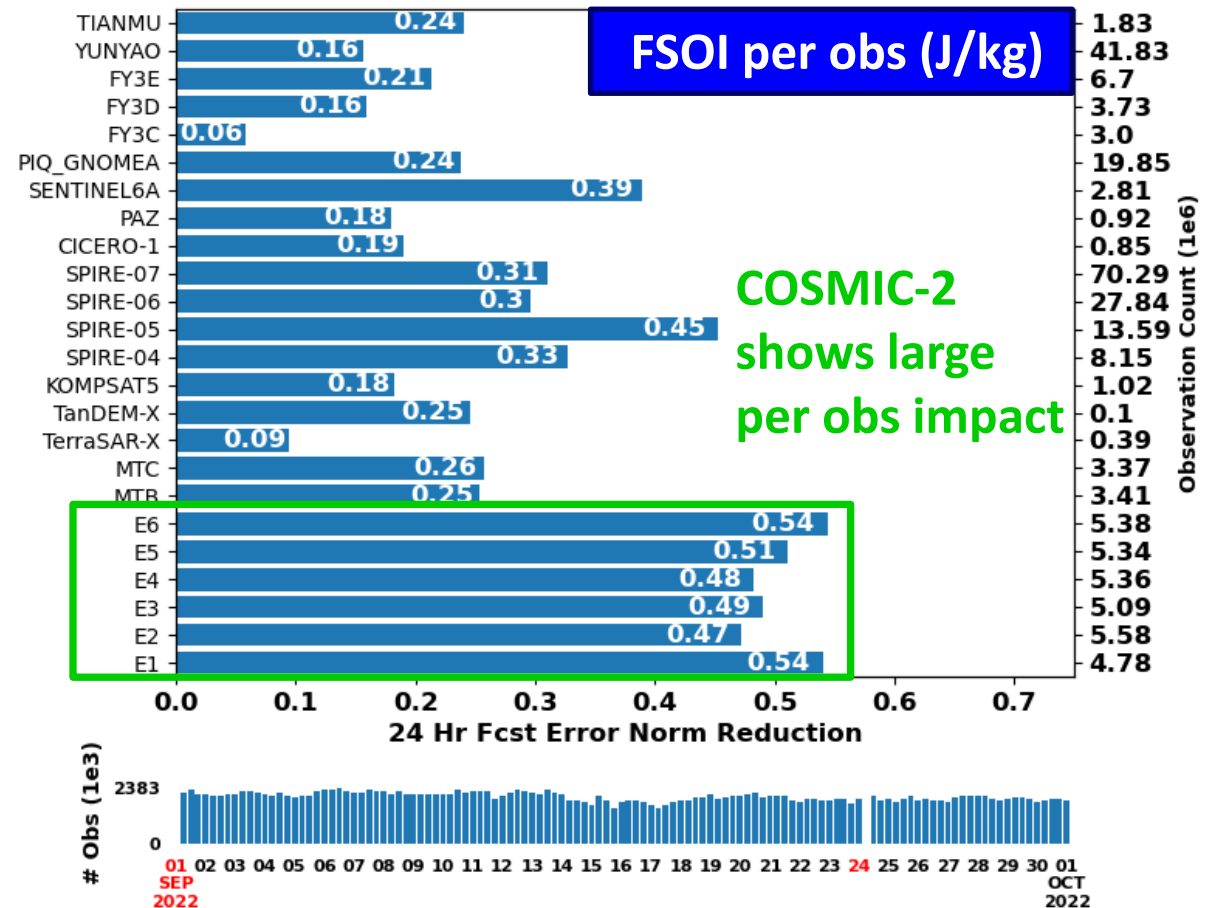
Temperature modified by ROMEX assimilation may be worse in the lower tropical regions

FSOI for ROMEX BC

NAVDAS-AR GPS Ob Sensitivity

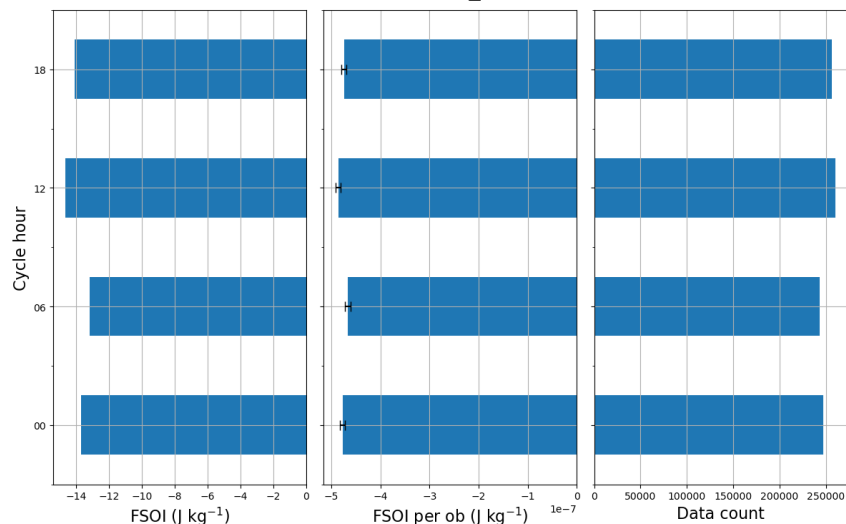


NAVDAS-AR GPS Per Ob Sensitivity (1e-6)

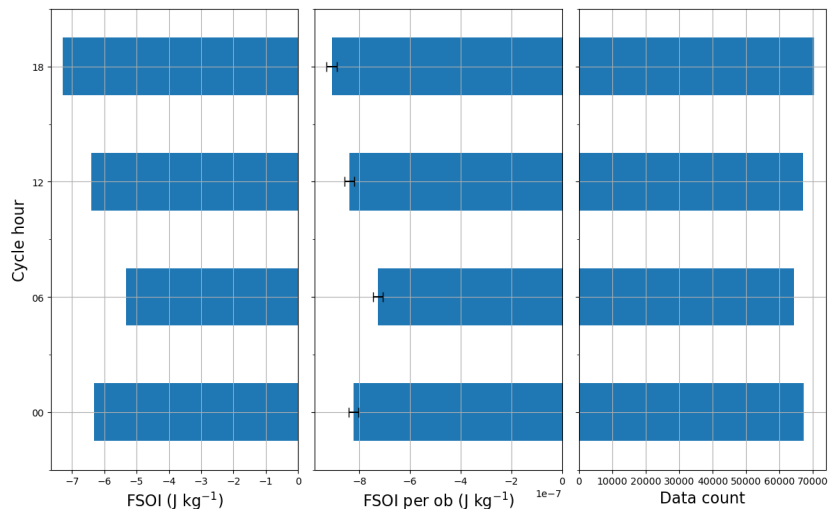


FSOI Impact for Different DA Cycle

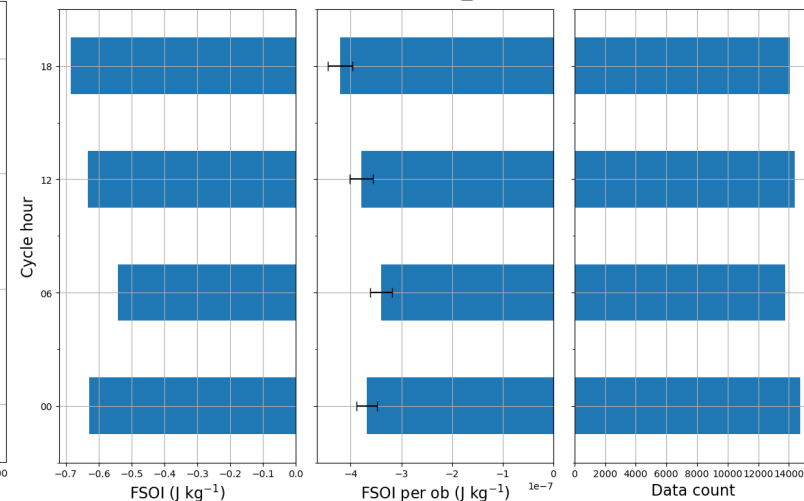
SPIRE 2022090118_2022093018



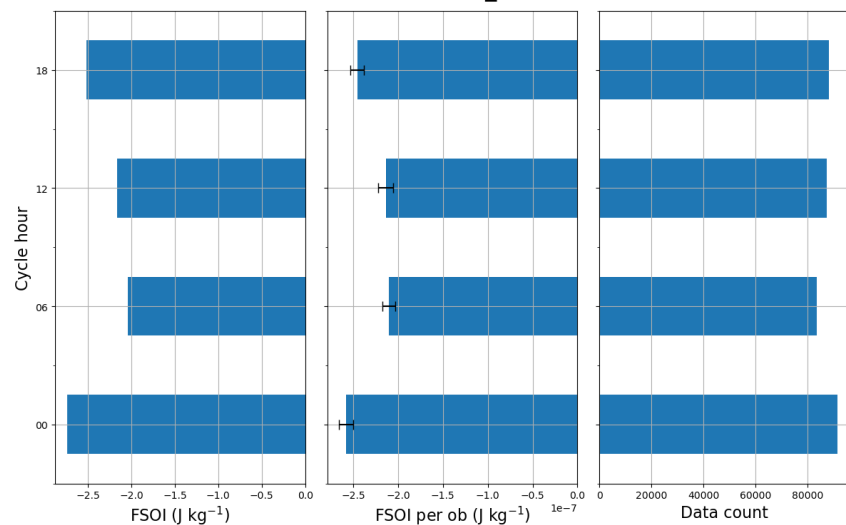
COSMIC2 2022090118_2022093018



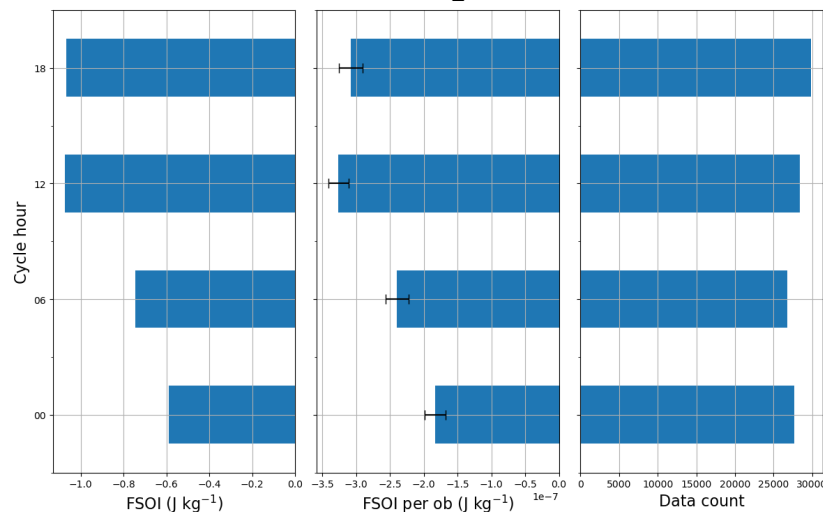
MetOP 2022090118_2022093018



YUNYAO 2022090118_2022093018



FY3x 2022090118_2022093018



FSOI impact at different DA cycles largely driven data counts

Conclusion

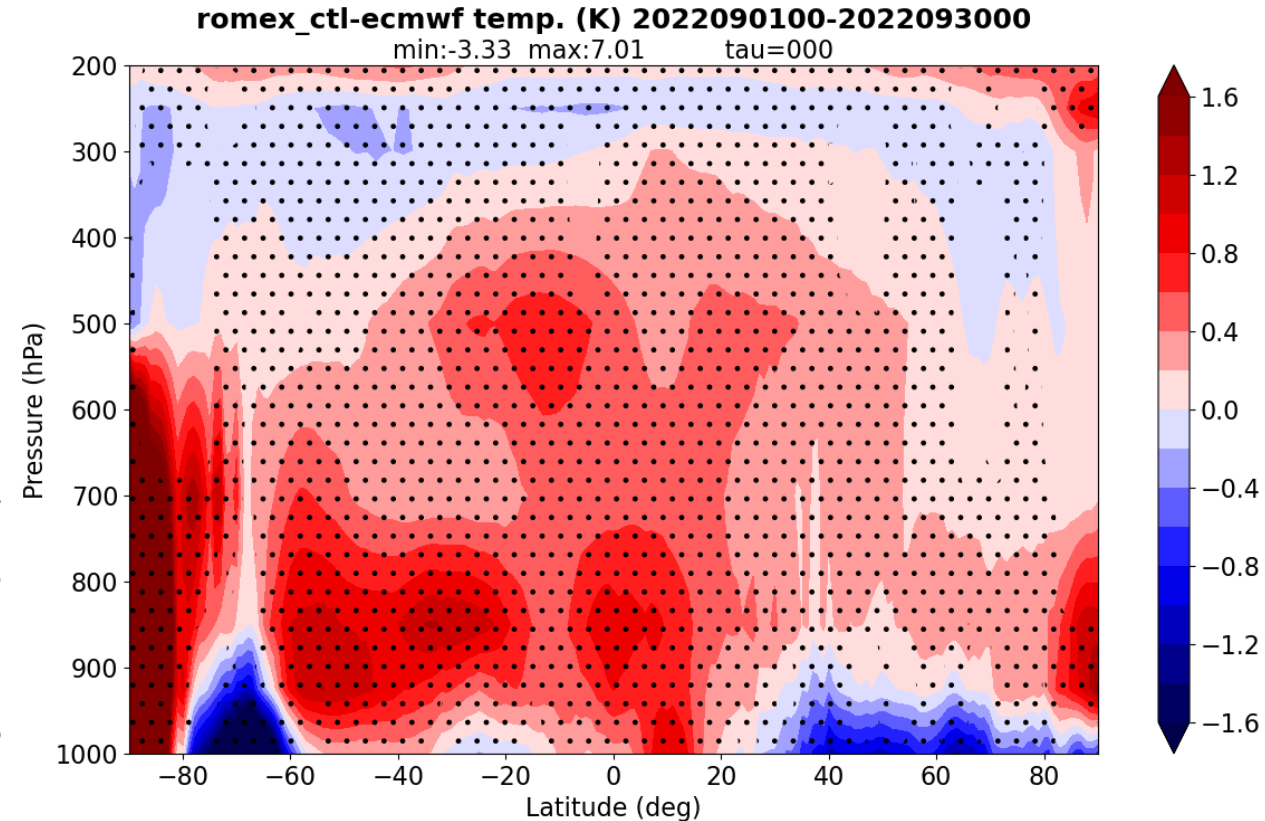
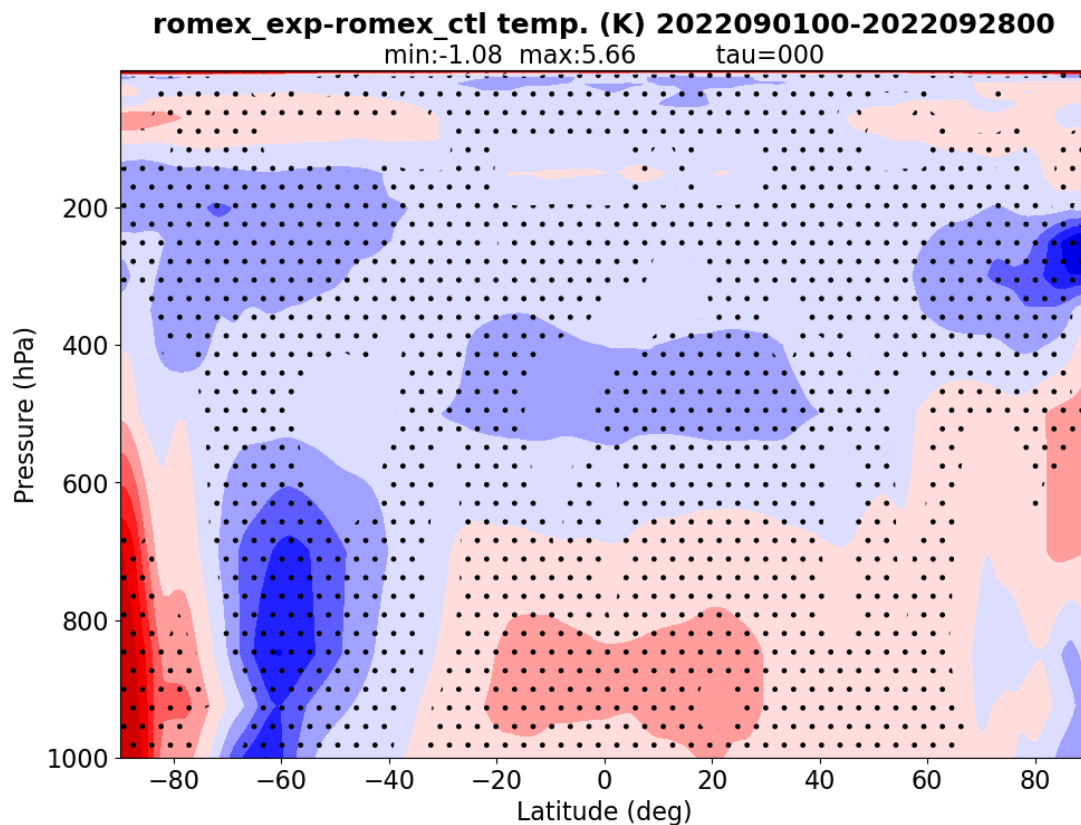
- Model bias may obscure the expected beneficial impact from ROMEX assimilation
- A simple observation bias correction appears to enhance the ROMEX's impact in the U.S. Navy's global model, particularly geopotential height forecasts
- ROMEX improves short-range forecasts, showing a better fit to observations
- RO observations from Chinese providers exhibit greater variability at different cycling hours
- Final results contributing to ROMEX are targeting the bias corrected experiments

Acknowledgement: Dan Tyndall (NRL) and NRL legal team to make participation of ROMEX feasible.

Extra Slides

Mean Change in Temperature

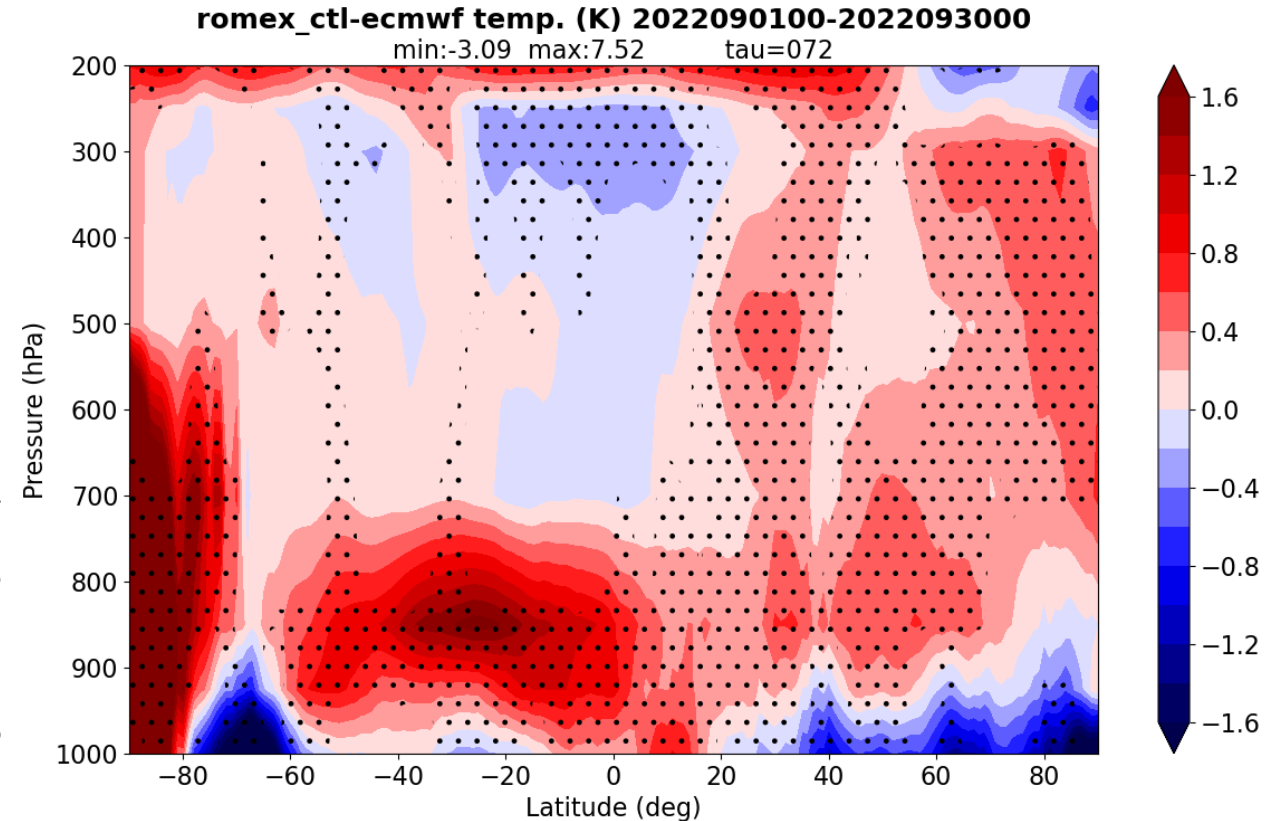
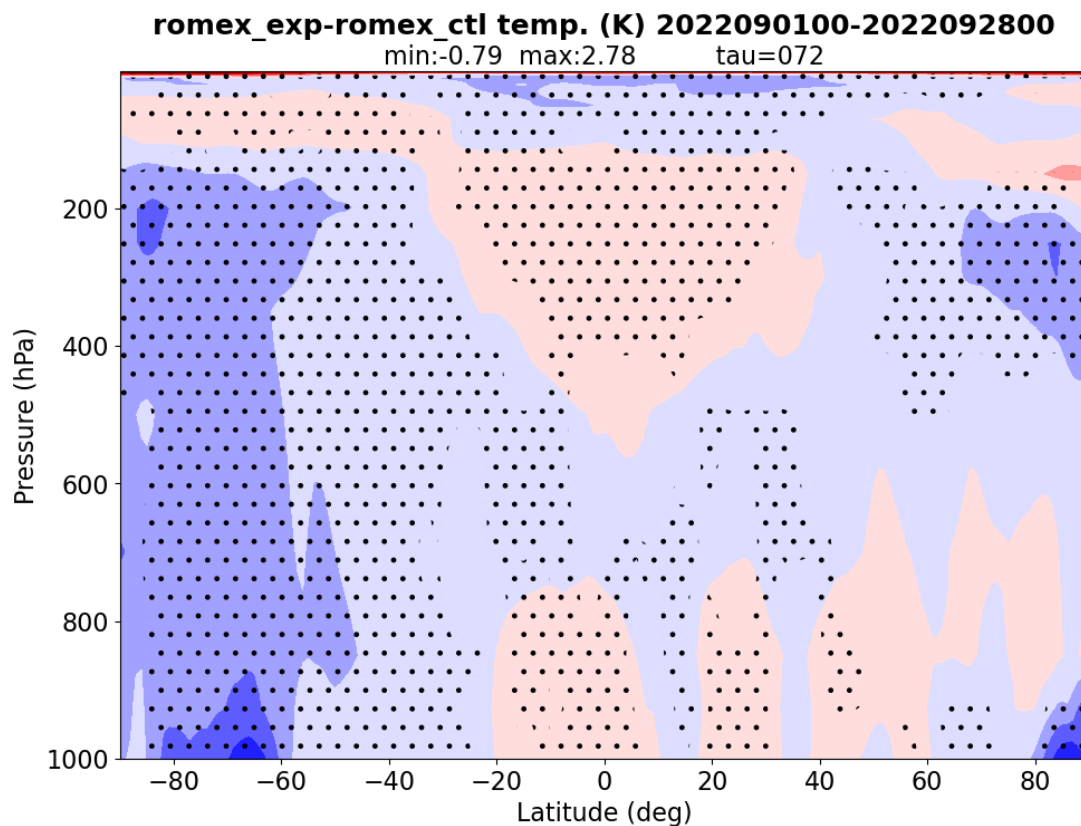
Lead time = 0 h



Maybe temperature modified by ROMEX assimilation worsens in the lower tropical regions?

Mean Change in Temperature

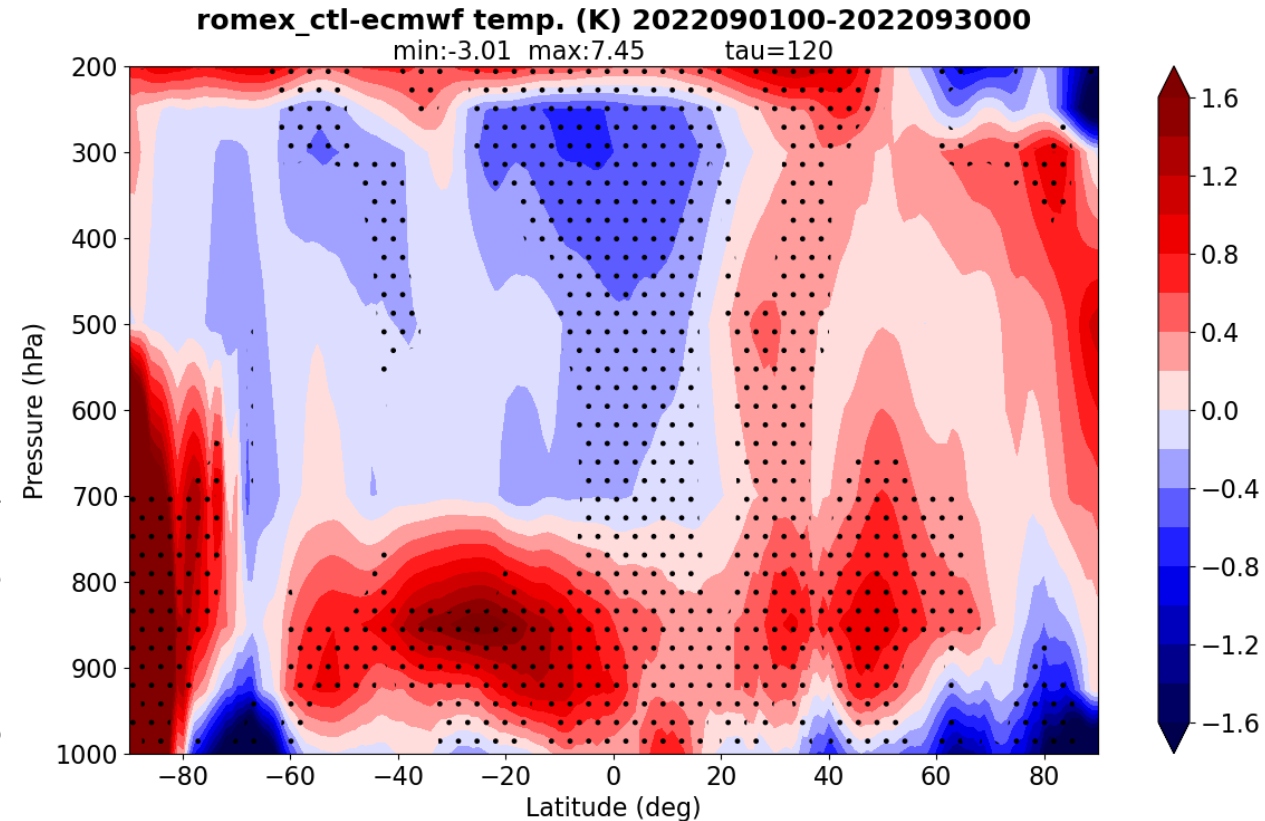
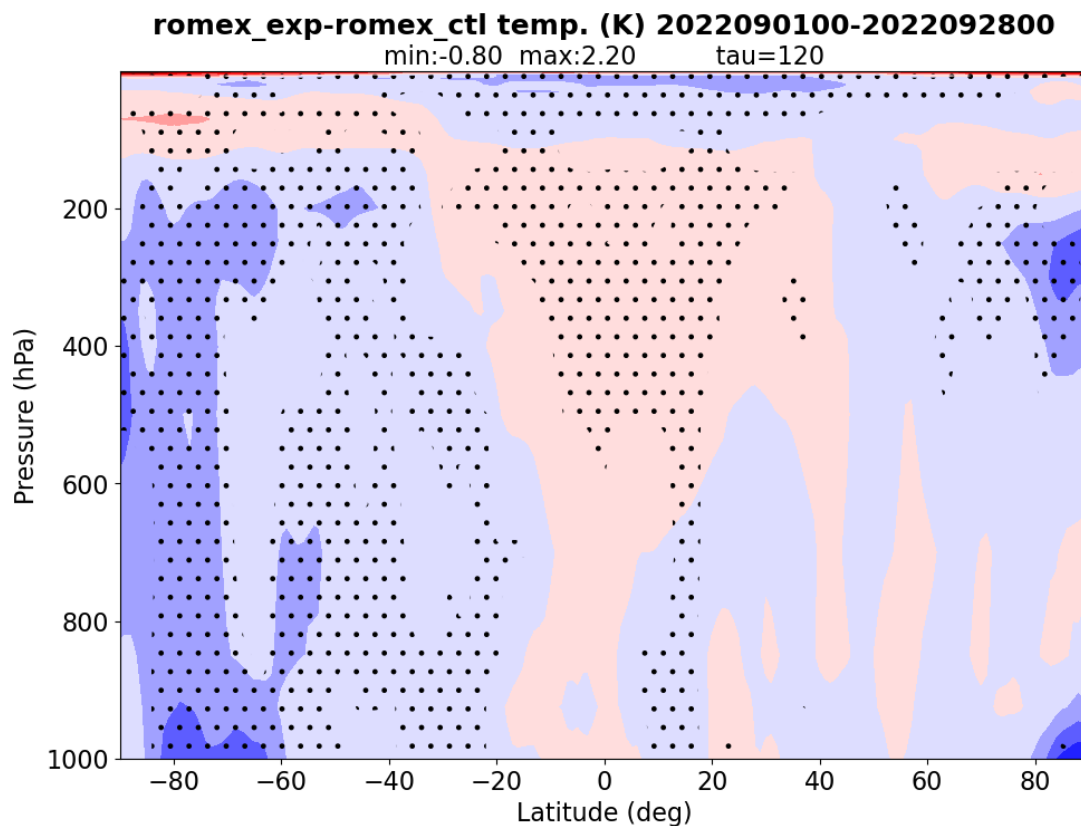
Lead time = 72 h



Maybe temperature modified by ROMEX assimilation worsens in the lower tropical regions?

Mean Change in Temperature

Lead time = 72 h



Maybe temperature modified by ROMEX assimilation worsens in the lower tropical regions?

