



# Adaptive Estimation of ATMS Observation Uncertainty to Improve Atmospheric Prediction

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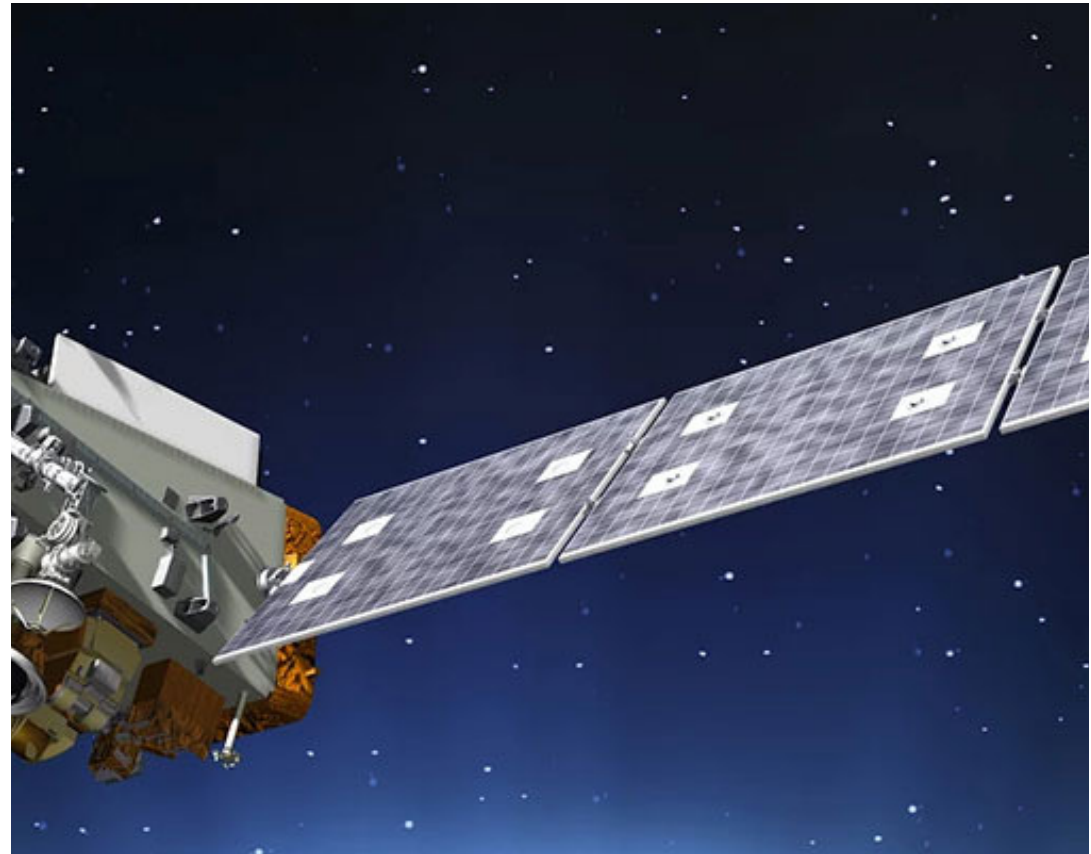
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# Motivation

- With a growing number of satellite obs used in operational forecasting comes a growing need to optimize its info content.
- **CURRENTLY:** Most op centers assume satellite obs well calibrated & uncertainty does not vary in space or time.
- **Q:** Can we improve U.S. NAVy Global Environmental Model (NAVGEM) forecasts by adaptively (either in space or time) estimating the uncertainty of Advanced Technology Microwave Sounder (ATMS) obs?



# Background

Desroziers et al. (2005):

$$\mathbf{E}[\underbrace{(\mathbf{o} - \mathbf{a})}_{\substack{\text{Vector of obs-} \\ \text{minus-analysis} \\ \text{values} \\ \text{("residuals")}}} \underbrace{(\mathbf{o} - \mathbf{b})}_{\substack{\text{Vector of obs-} \\ \text{minus-background} \\ \text{values} \\ \text{("innovations")}}}^T] = \mathbf{R}_{\text{DES}} \longleftarrow \text{Observation error} \\ \text{covariance matrix}$$

This Desroziers diagnostic predicts  $\mathbf{R}$ , from which the observation error standard deviation ( $\sigma_o$ ) and error correlation ( $\rho$ ) between 2 channels can be determined.



# Overview of Experiments

## July 2022 with 10-day prior spinup

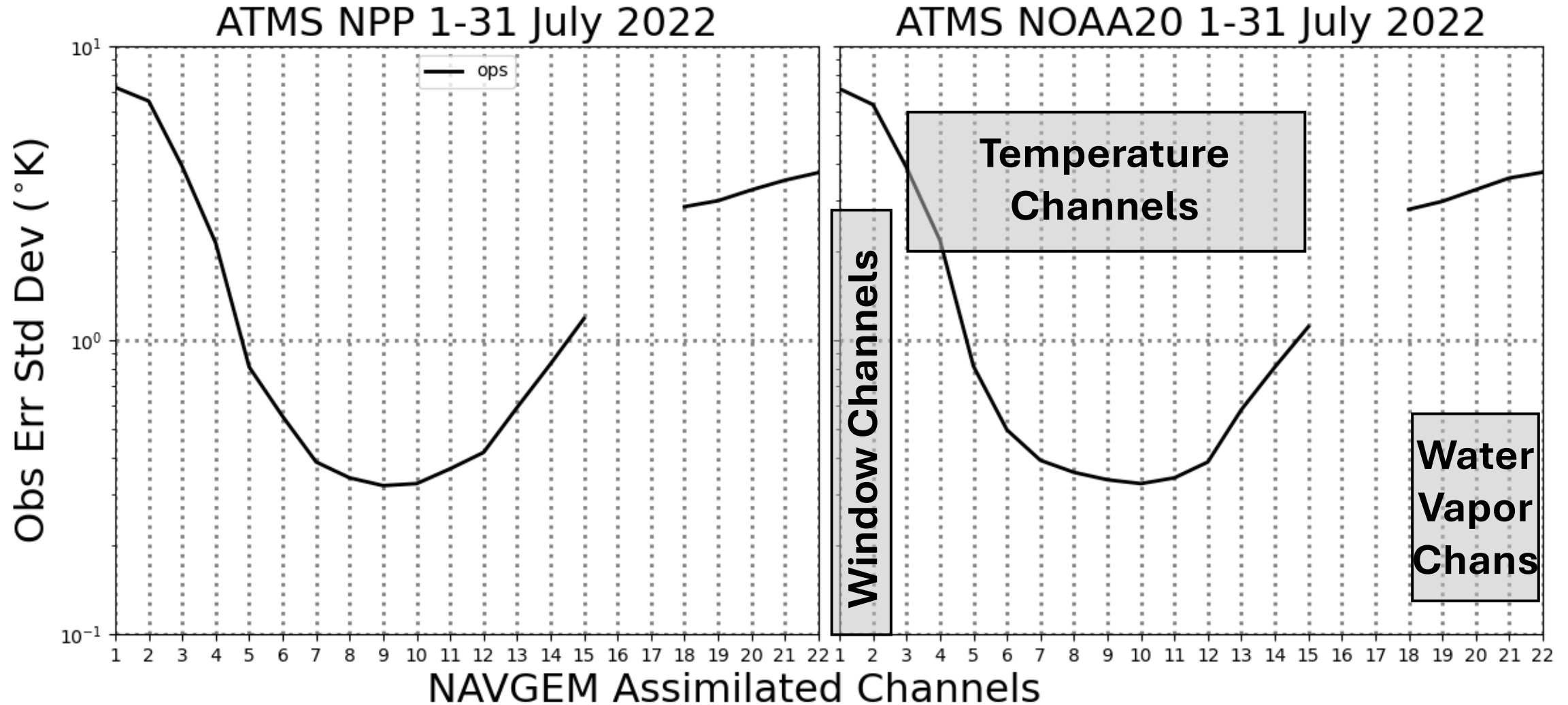
<b>GL_STAT_OPS</b> “global static operational values”	Used $\sigma_{o,ops}$ & $\rho_{o,ops}$
<b>GL_STAT_NEW</b> “global static new”	Used $\sigma_o$ , $\rho_o$ from inflated reconditioned $R_{DES}(ops, global, Jul-Sep\ 2022)$
<b>VARYREGION</b> Regions: <i>SMidlats: 20°S → 90°S    Tropics: 20°S → 20°N    NMidlats: 20°N → 90°N</i>	Used $\sigma_o$ , $\rho_o$ from inflated reconditioned $R_{DES}(ops, regional, Jul-Sep\ 2022)$
<b>GL_VARYTIME</b> “global varytime” (10-day sliding window)	Used $\sigma_o$ , $\rho_o$ from inflated reconditioned $R_{DES}(self, global, Jul-Sep\ 2022)$

varyregion & gl\_varytime used  $\sigma_{o,gl\_stat\_new}$  &  $\rho_{o,gl\_stat\_new}$  20 June → 30 June

# Results Overview

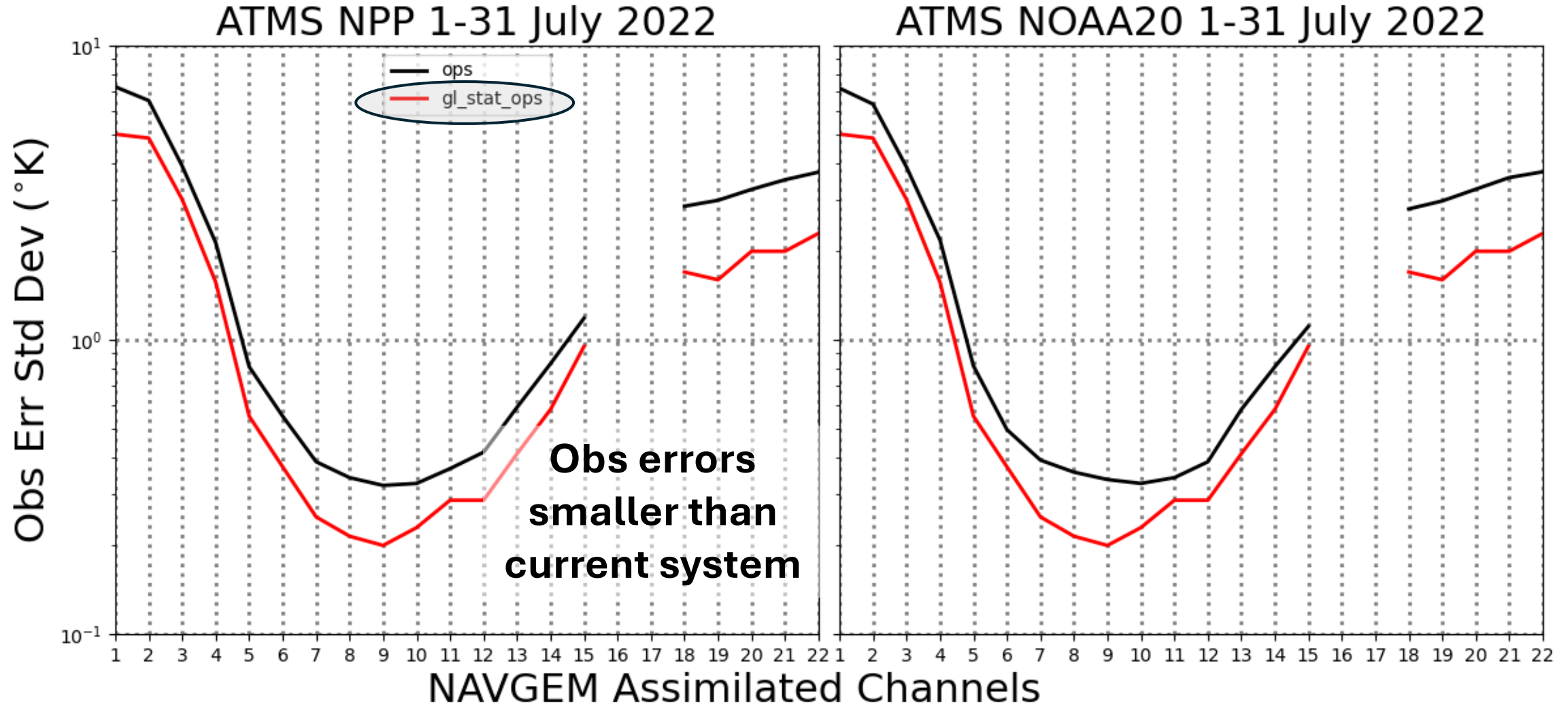
- 1) Examine prescribed  $\sigma_o$  of each experiment.
- 2) Analyze the dynamic feedback between Desroziers diagnostic & QC.
- 3) Investigate the impact on forecasts.

# Prescribed $\sigma_0$



***These are the values that were used by the operational system until late 2022.***

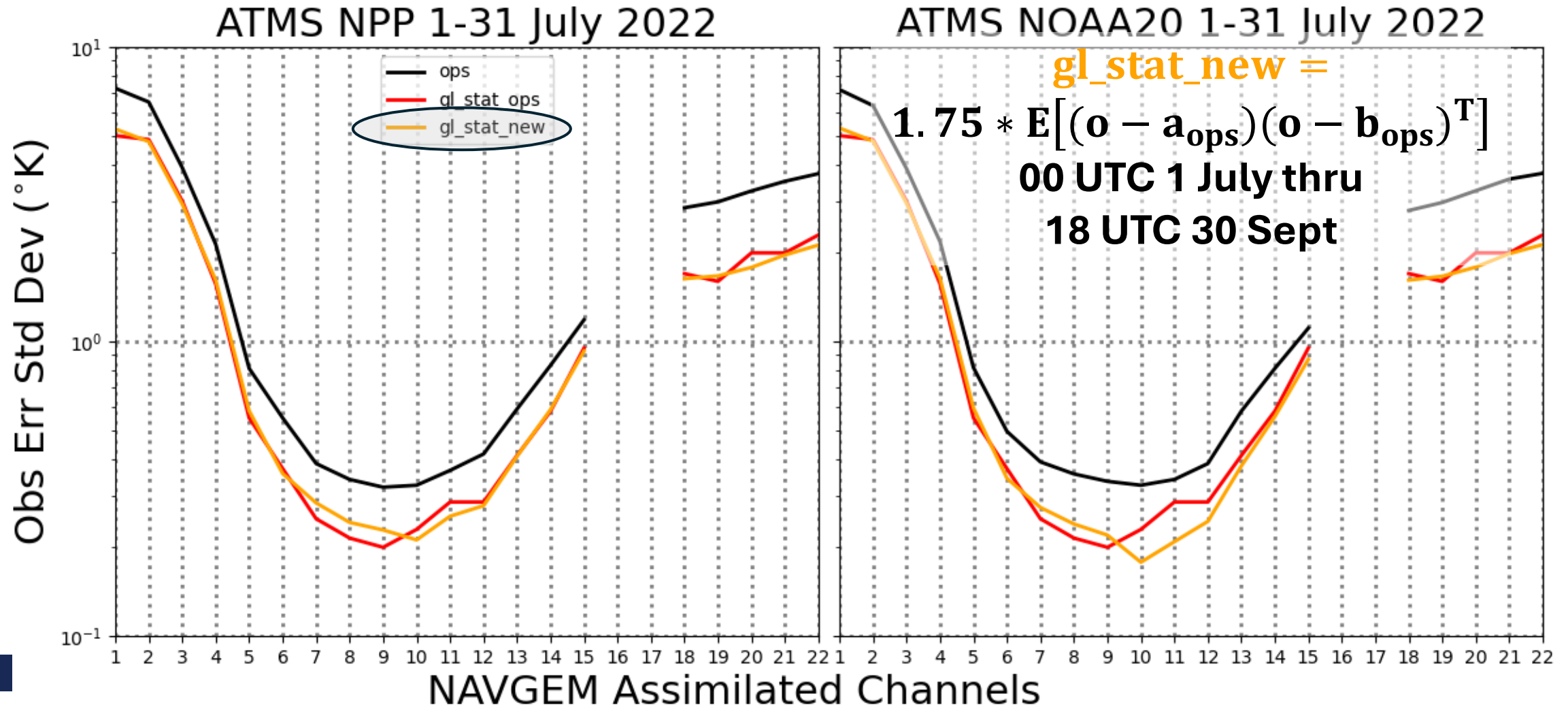
# Prescribed $\sigma_0$



*gl\_stat\_ops used the values the current operational system uses.*



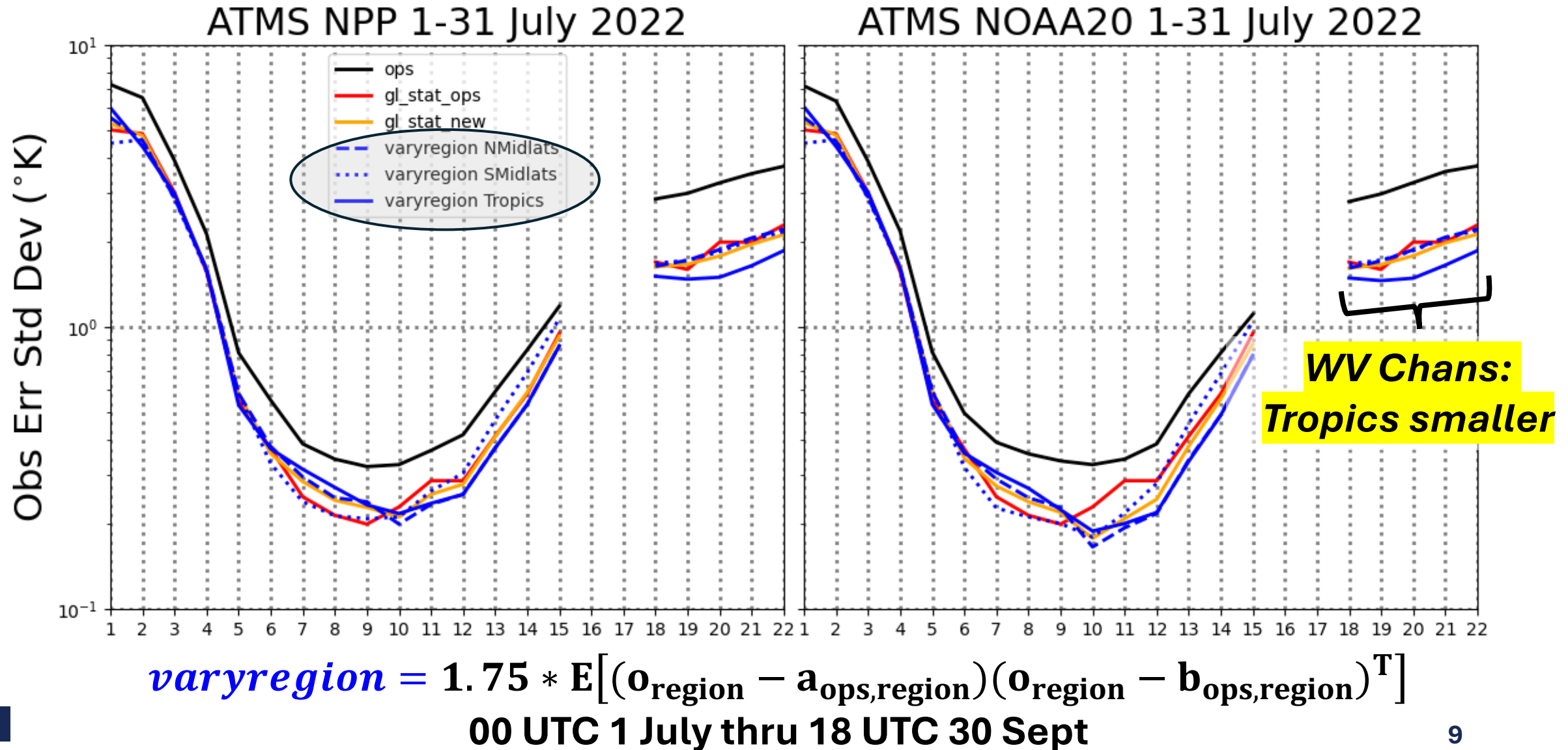
# Prescribed $\sigma_o$



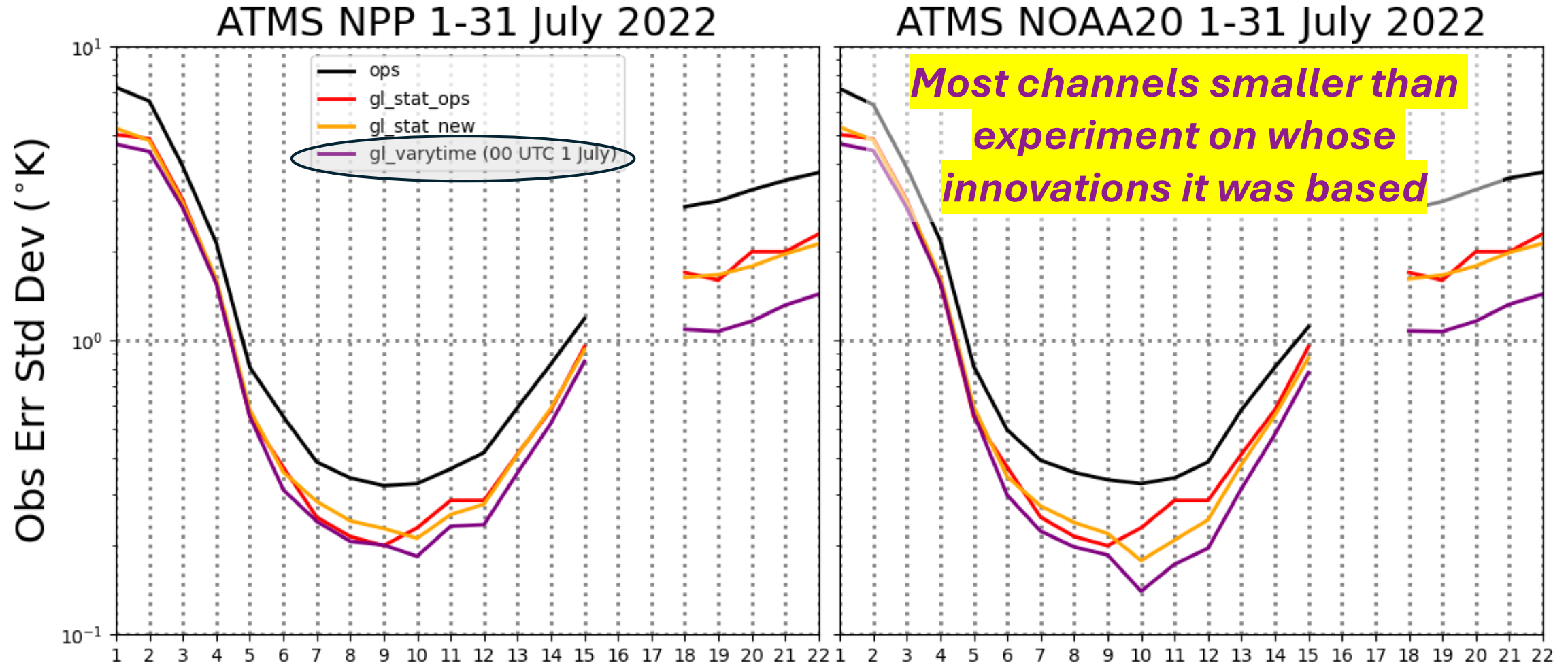
*Innovation-based values smaller than prescribed ones; comparable to gl\_stat\_ops*



# Prescribed $\sigma_0$



# Prescribed $\sigma_0$



$$\text{gl\_varytime} = 1.75 * \text{E}[(\mathbf{o}_{\text{global}} - \mathbf{a}_{\text{global}})(\mathbf{o}_{\text{global}} - \mathbf{b}_{\text{global}})^T]$$

of previous 10 days

# QC Ratio Thresholding

## FIRST

If channel 1-15, then reject when  $\frac{|o-b|}{\sigma_o} \geq 2.15$

If channel 18-22, then reject when  $\frac{|o-b|}{\sigma_o} \gtrsim 0.96$

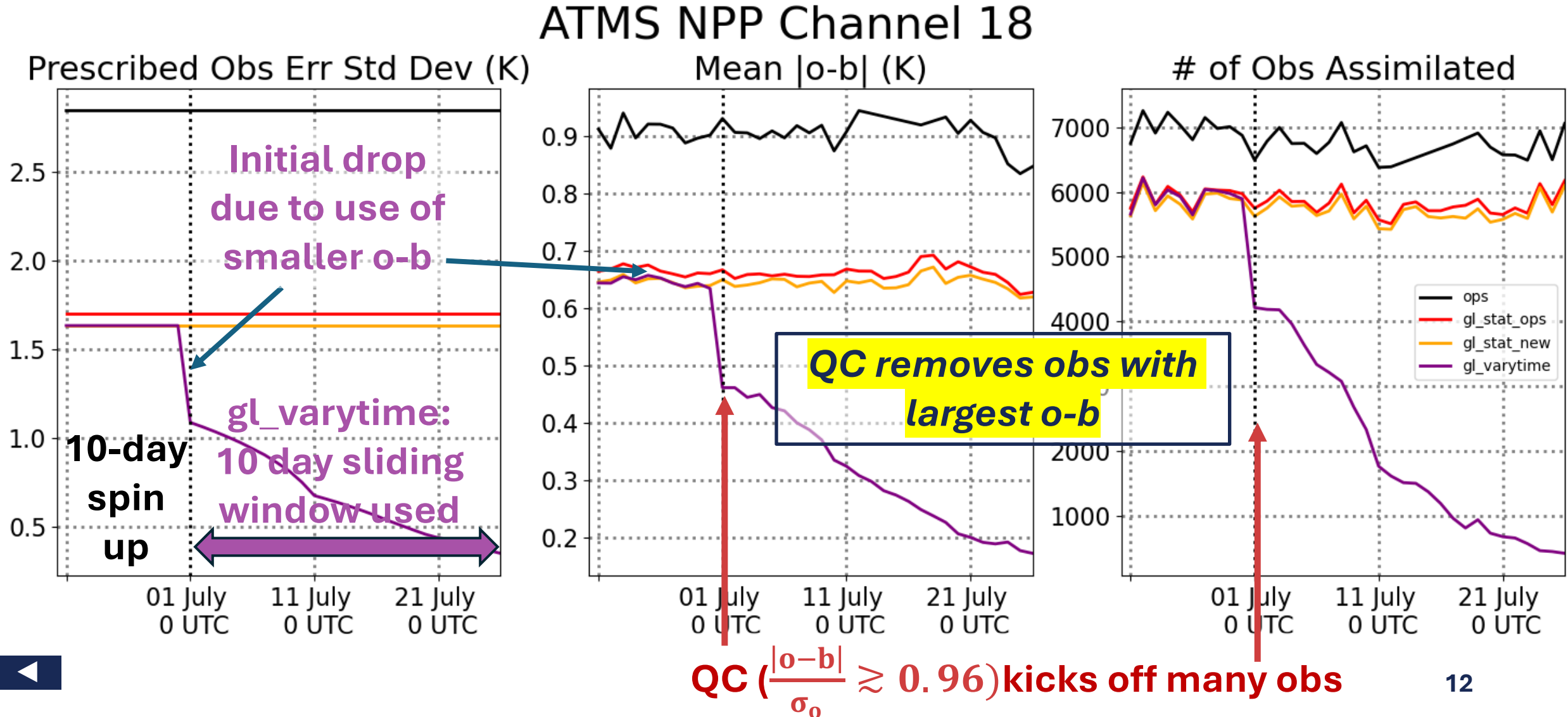
## THEN

For all channels, reject when  $\frac{|o-b|}{\sqrt{\sigma_b^2 + \sigma_o^2}} > 3.0$

***The experiments used stricter QC for water vapor channels.***

$\sigma_b$  = background err std dev

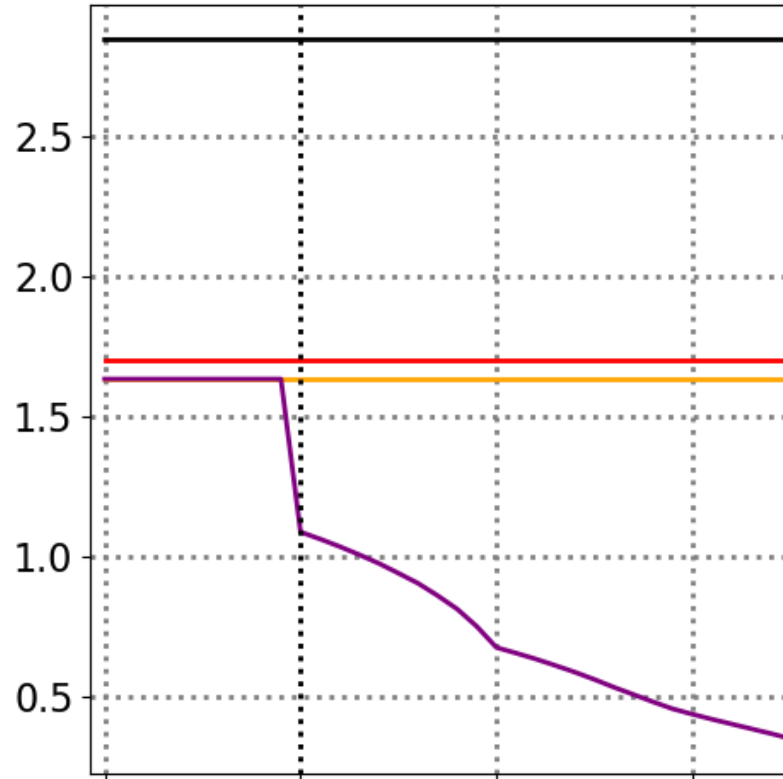
# QC-Desroziers Feedback for Moisture Channels



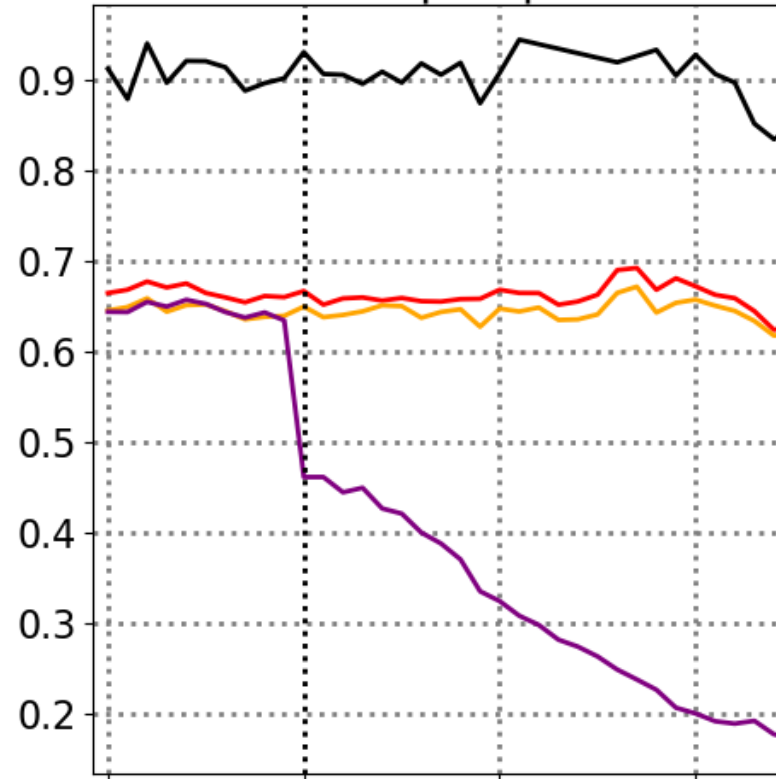
# QC-Desroziers Feedback for Moisture Channels

## ATMS NPP Channel 18

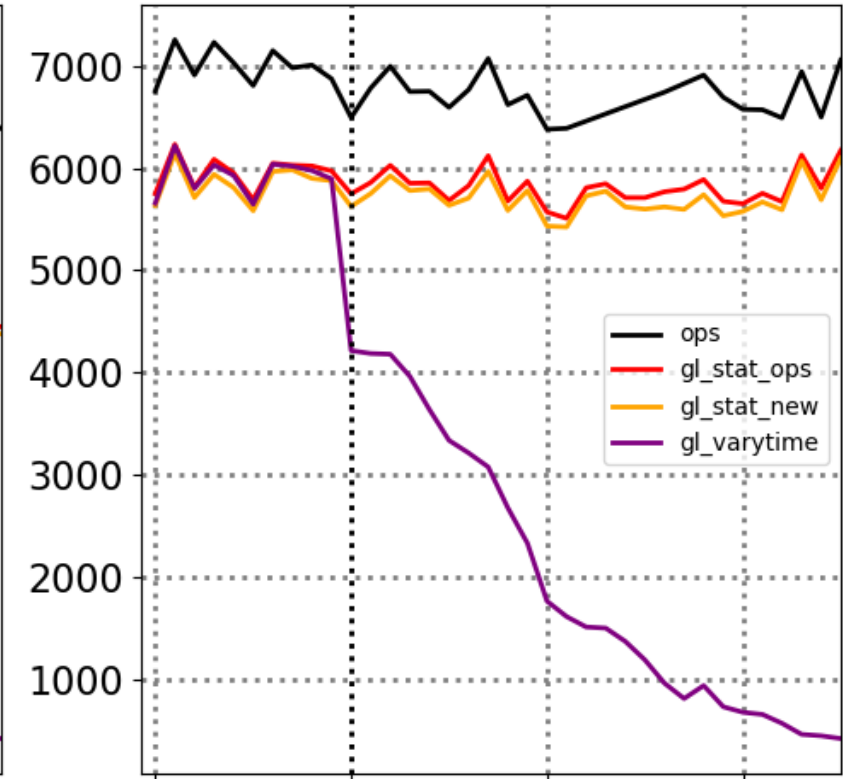
Prescribed Obs Err Std Dev (K)



Mean |o-b| (K)

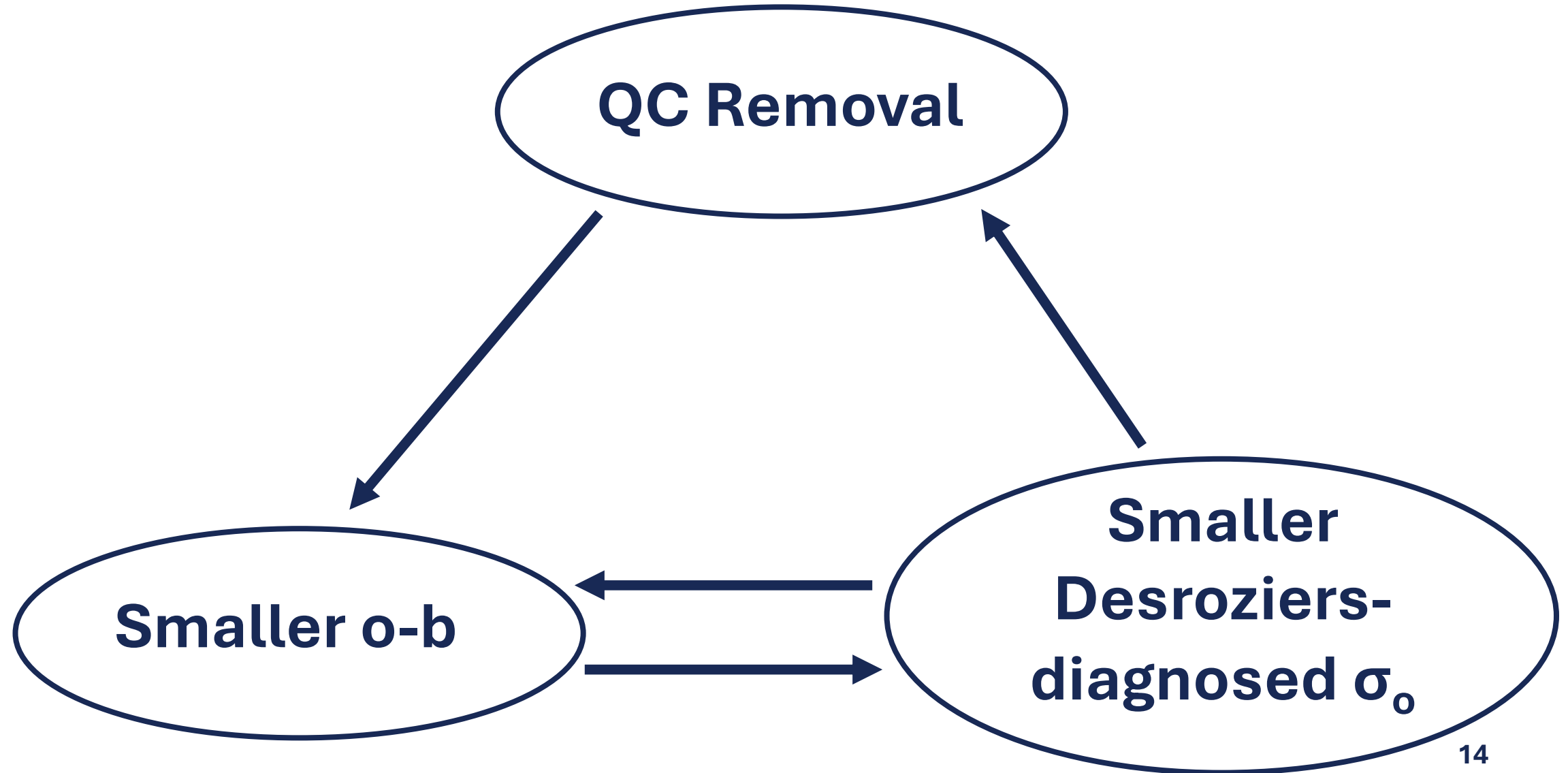


# of Obs Assimilated



**Smaller  $\sigma_o$  favors smaller o-b in subsequent cycles, as the state gets pulled towards observations (ignoring effects of  $\sigma_b$ ).**

# QC-Desroziers Feedback

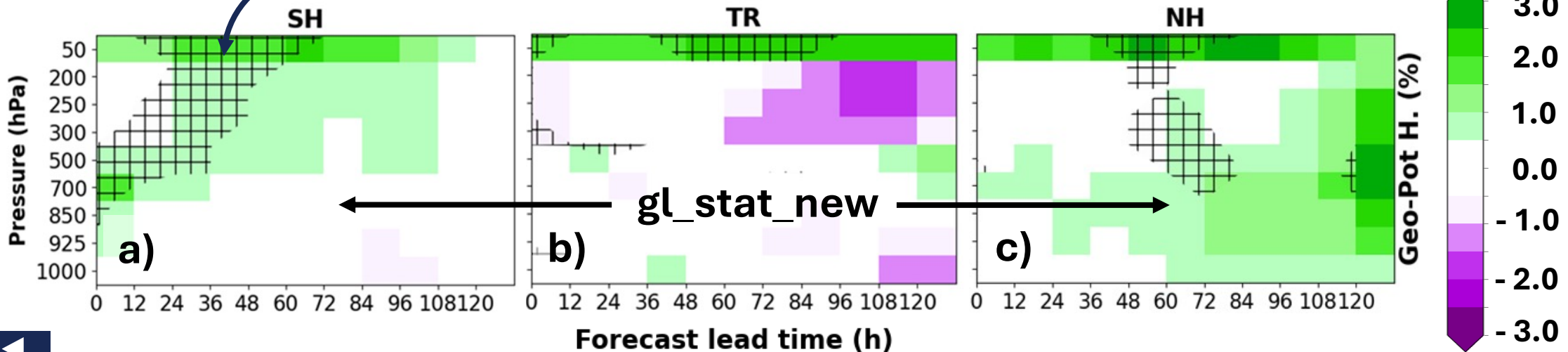


# Relative Impact on Forecasts

*RMSD = root-mean-squared  
difference between forecasts &  
ECMWF analyses*

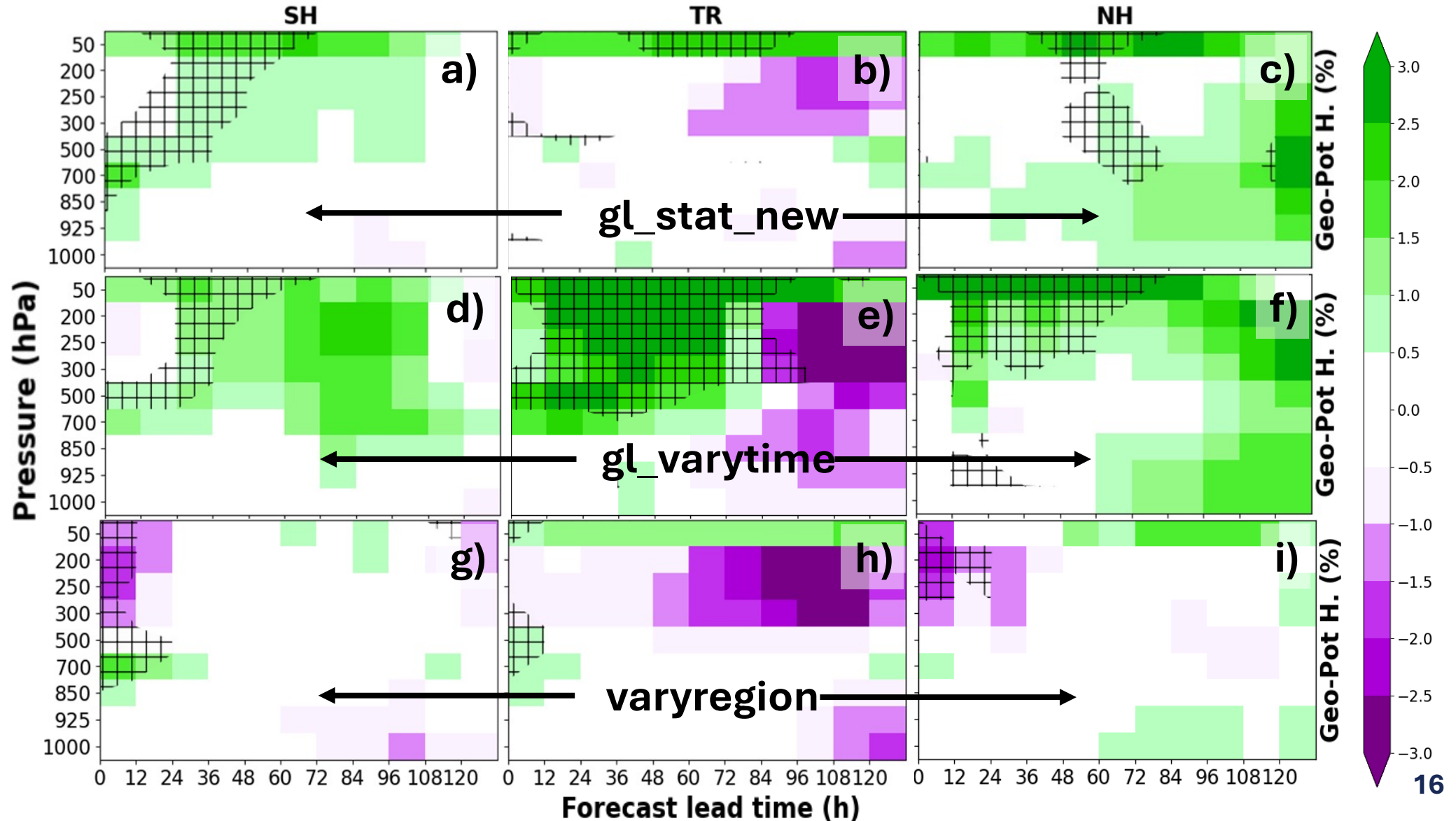
$$100 \times \frac{\text{RMSD}_{\text{gl\_stat\_ops}} - \text{RMSD}_{\text{gl\_stat\_new}}}{\text{RMSD}_{\text{gl\_stat\_ops}}}$$

≥ 95% statistical  
confidence

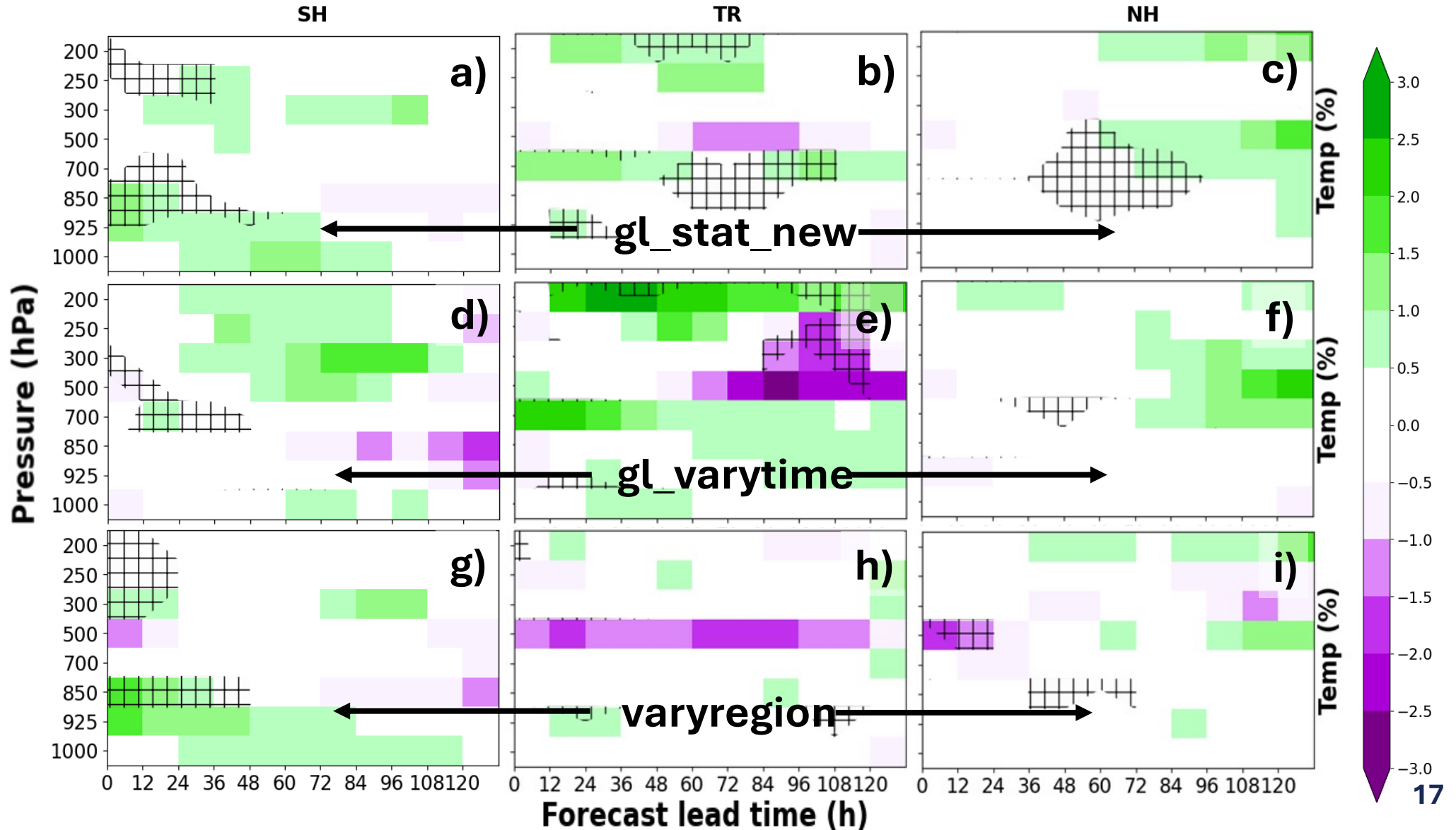




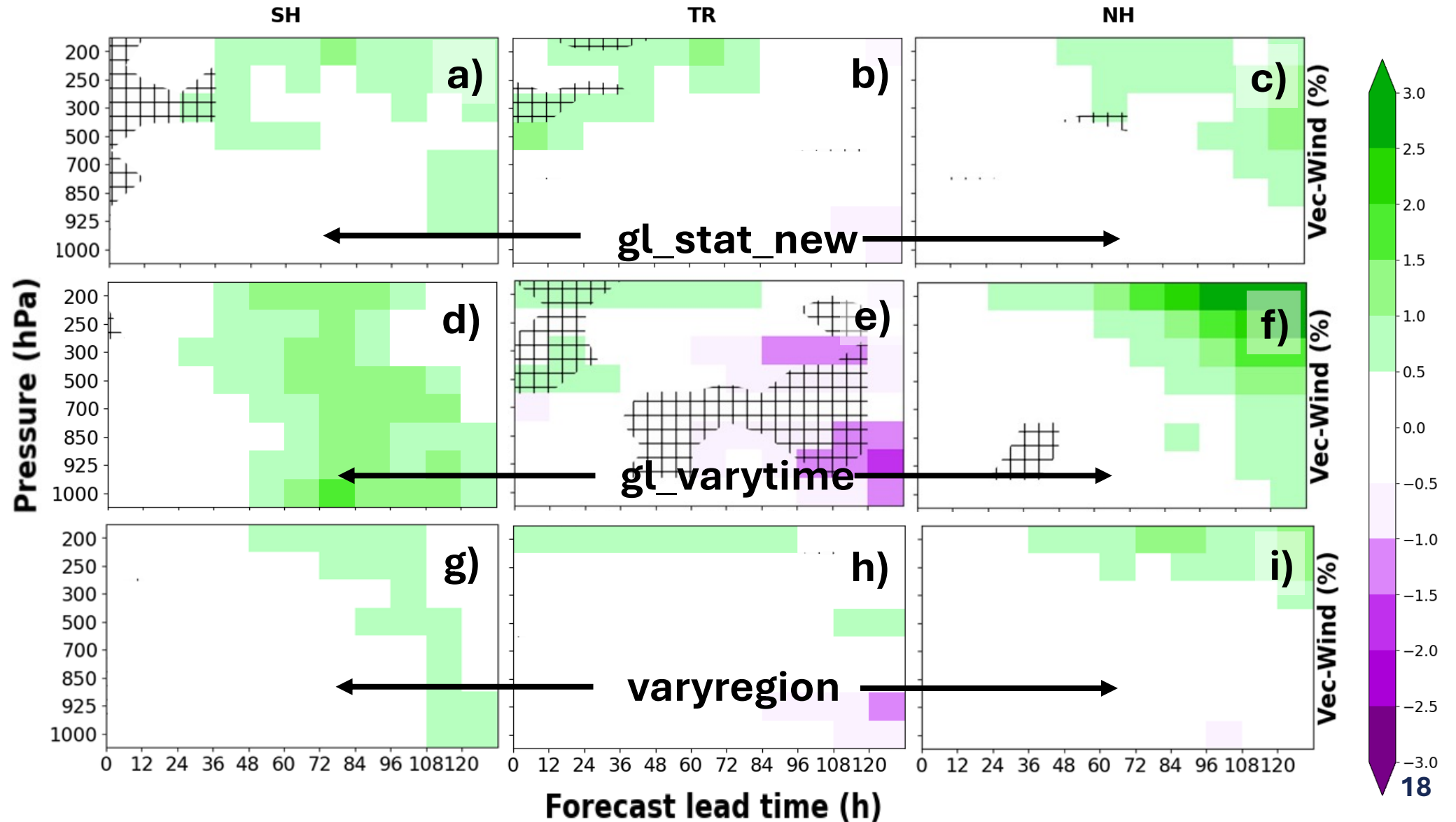
# Relative Impact on Geopotential Height Forecasts



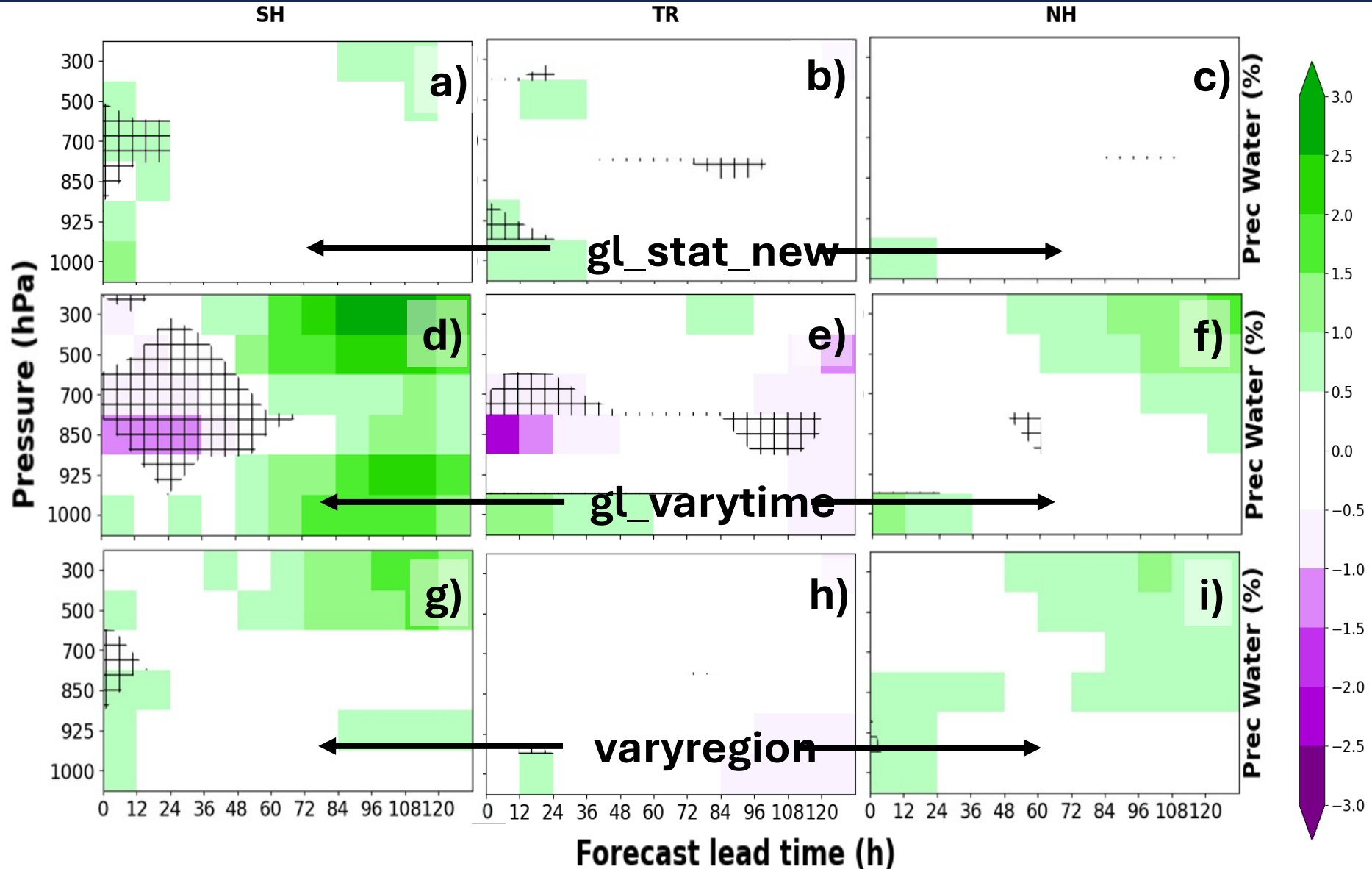
# Relative Impact on Temperature Forecasts



# Relative Impact on Wind Forecasts



# Relative Impact on Precipitable Water Forecasts



# Summary

- 1) Based on July 2022, using Desroziers-diagnosed ATMS observation errors has the potential to improve 3-day mid- to upper-level geopotential height forecasts when using global innovations.**
- 2) For NAVGEM, Desroziers-diagnosed ATMS observation errors of an experiment tend to be lower than its prescribed values.**
- 3) These lower observation errors can lead to a runaway rejection of observations if QC is too strict.**

# Future Work

- 1) Repeat the study without the more conservative initial QC check, relying only on the 3-sigma check.**
- 2) Deeper analysis of the impacts on forecasts, including why regional innovations did not improve them.**

# Summary

- 1) Based on July 2022, using Desroziers-diagnosed ATMS observation errors has the potential to improve 3-day mid- to upper-level geopotential height forecasts when using global innovations.**
- 2) For NAVGEM, Desroziers-diagnosed ATMS observation errors of an experiment tend to be lower than its prescribed values.**
- 3) These lower observation errors can lead to a runaway rejection of observations if QC is too strict.**





# Supplemental Slides

# Overview of Experiments: GL\_STAT\_OPS

*“global static operational values”*

00 UTC  
20 June  
2022

00 UTC  
1 July  
2022

18 UTC  
31 July  
2022

spin up  
(6-hourly cycling)

cycling experiment  
(6-hourly cycling)

$\sigma_{o,ops}$  &  $\rho_{o,ops}$  used

$\sigma_{o,ops}$  &  $\rho_{o,ops}$  used

# Overview of Experiments: GL\_STAT\_NEW

00 UTC  
20 June  
2022

00 UTC  
1 July  
2022

*“global static new”*

18 UTC  
31 July  
2022

spin up  
(6-hourly cycling)

cycling experiment  
(6-hourly cycling)

$\sigma_{o,DESROZ(ops,JAS,global)}$  &  $\rho_{o,DESROZ(ops,JAS,global)}$  used

≡ Desroziers-diagnosed values  
using global innovations of  
operational system in JAS

# Overview of Experiments: VARYREGION

00 UTC  
20 June  
2022

00 UTC  
1 July  
2022

18 UTC  
31 July  
2022

spin up  
(6-hourly cycling)

cycling experiment  
(6-hourly cycling)

$\sigma_{o,gl\_stat\_new}$  &  
 $\rho_{o,gl\_stat\_new}$  used

$\sigma_{o,DESROZ(ops,JAS,region)}$  &  $\rho_{o,DESROS(ops,JAS,region)}$  used

Regions:

*SMidlats: 20°S → 90°S*

*Tropics: 20°S → 20°N*

*NMidlats: 20°N → 90°N*

≡ Desroziers-diagnosed values  
using regional innovations of  
operational system in JAS

# Overview of Experiments: GL\_VARYTIME

00 UTC  
20 June  
2022

00 UTC  
1 July  
2022

*“global vary time”  
(10-day sliding window)*

18 UTC  
31 July  
2022

spin up  
(6-hourly cycling)

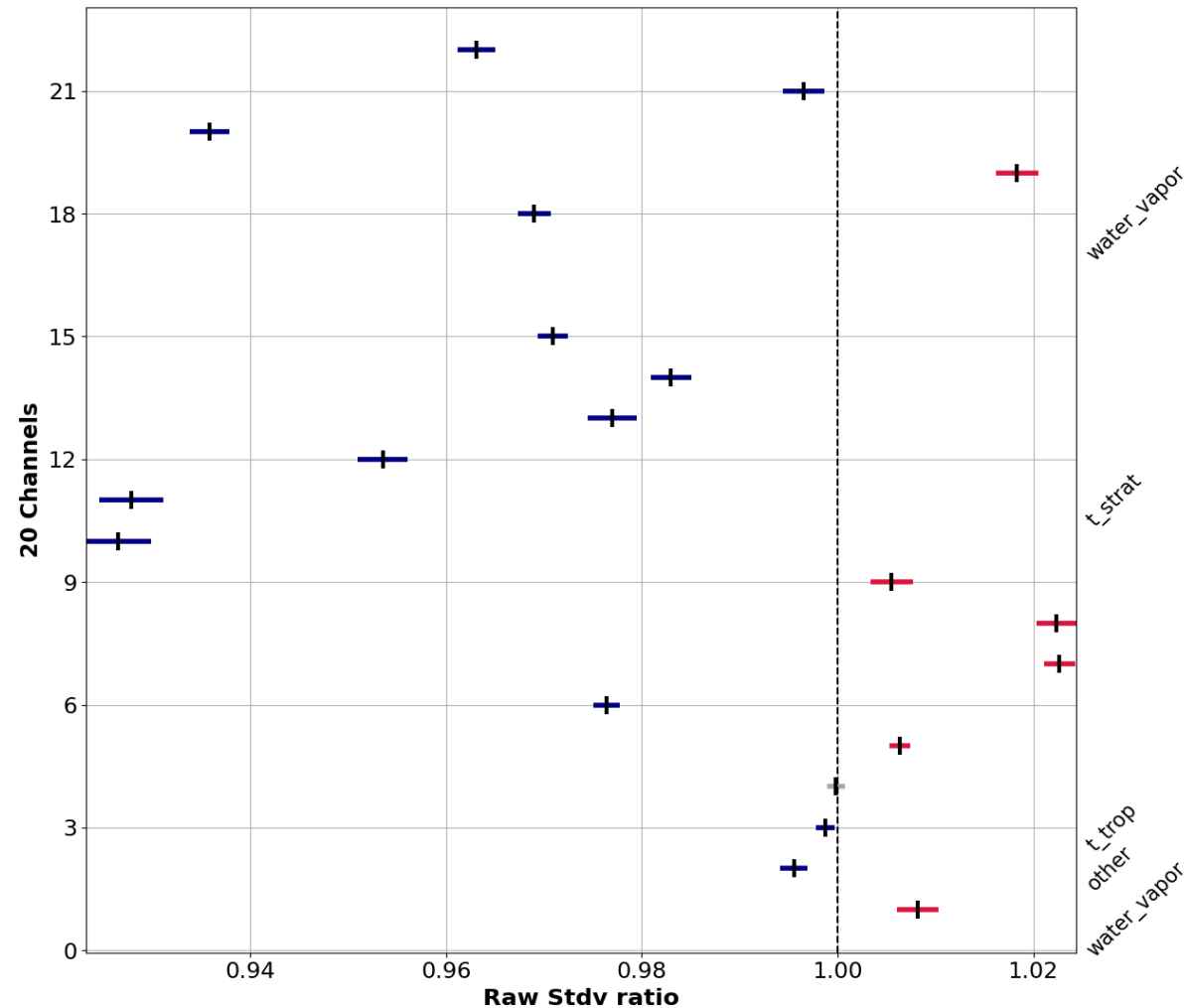
cycling experiment  
(6-hourly cycling)

$\sigma_{o,gl\_stat\_new}$  &  
 $\rho_{o,gl\_stat\_new}$  used

$\sigma_{o,DESROZ(itself,prev\ 10\ days,global)}$  &  
 $\rho_{o,DESROZ(itself,prev\ 10\ days,global)}$  used

≡ Desroziers-diagnosed values  
using its own global innovations of  
previous 10 days cycling

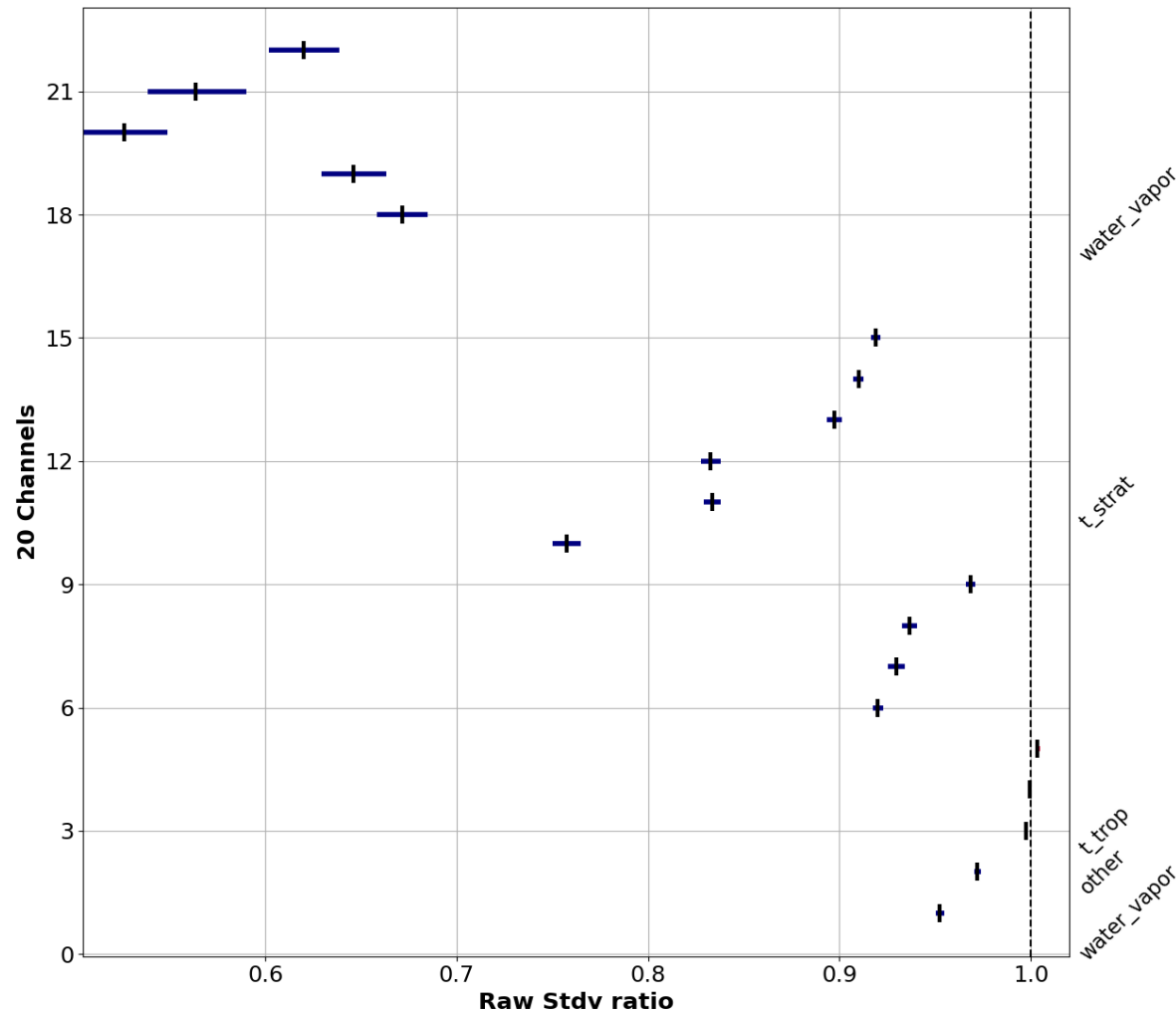
# Fit to Obs



gl\_stat\_new vs gl\_stat\_ops (Global)  
NOAA20\_ATMS Raw Stdv ratio (CI=95.00)  
124 dtgs from 2022-07-01T00 to 2022-07-31T18

Assim: 13 gl\_stat\_new > gl\_stat\_ops  
Assim: 6 gl\_stat\_ops > gl\_stat\_new  
Assim: 1 neutral

# Fit to Obs

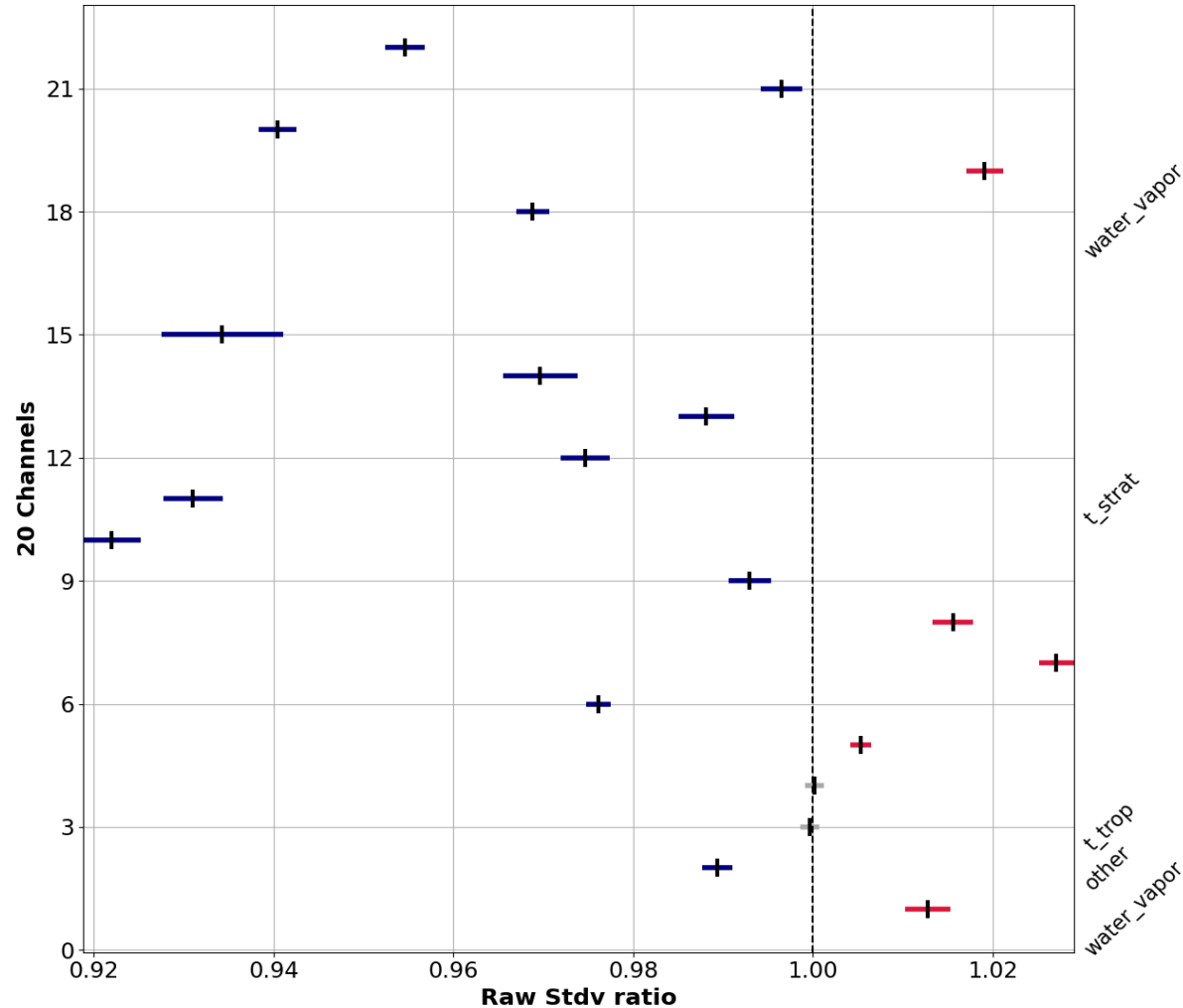


gl\_varytime vs gl\_stat\_ops (Global)  
NOAA20\_ATMS Raw Stdv ratio (CI=95.00)  
124 dtgs from 2022-07-01T00 to 2022-07-31T18

- Assim: 18 gl\_varytime > gl\_stat\_ops
- Assim: 1 gl\_stat\_ops > gl\_varytime
- Assim: 1 neutral



# Fit to Obs



varyregion vs gl\_stat\_ops (Global)  
NOAA20\_ATMS Raw Stdv ratio (CI=95.00)  
123 dtgs from 2022-07-01T06 to 2022-07-31T18

- Assim: 13 varyregion > gl\_stat\_ops
- Assim: 5 gl\_stat\_ops > varyregion
- Assim: 2 neutral

# Fit to Obs

<i><u>gl stat new v gl stat ops</u></i>						
ChGroup	CI	ChanCount	win	tie	loss	wlt_score
geo_csr	0.950	43	13	29	1	0
lw_strat	0.950	165	81	59	25	0
lw_trop	0.950	71	0	70	1	0
other	0.950	13	12	1	0	1
sfc	0.950	6	4	2	0	1
sw_trop	0.950	13	0	13	0	0
t_strat	0.950	37	20	16	1	1
t_trop	0.950	55	17	28	10	0
water_vapor	0.950	89	44	39	6	0
Total	0.950	492	191	257	44	3

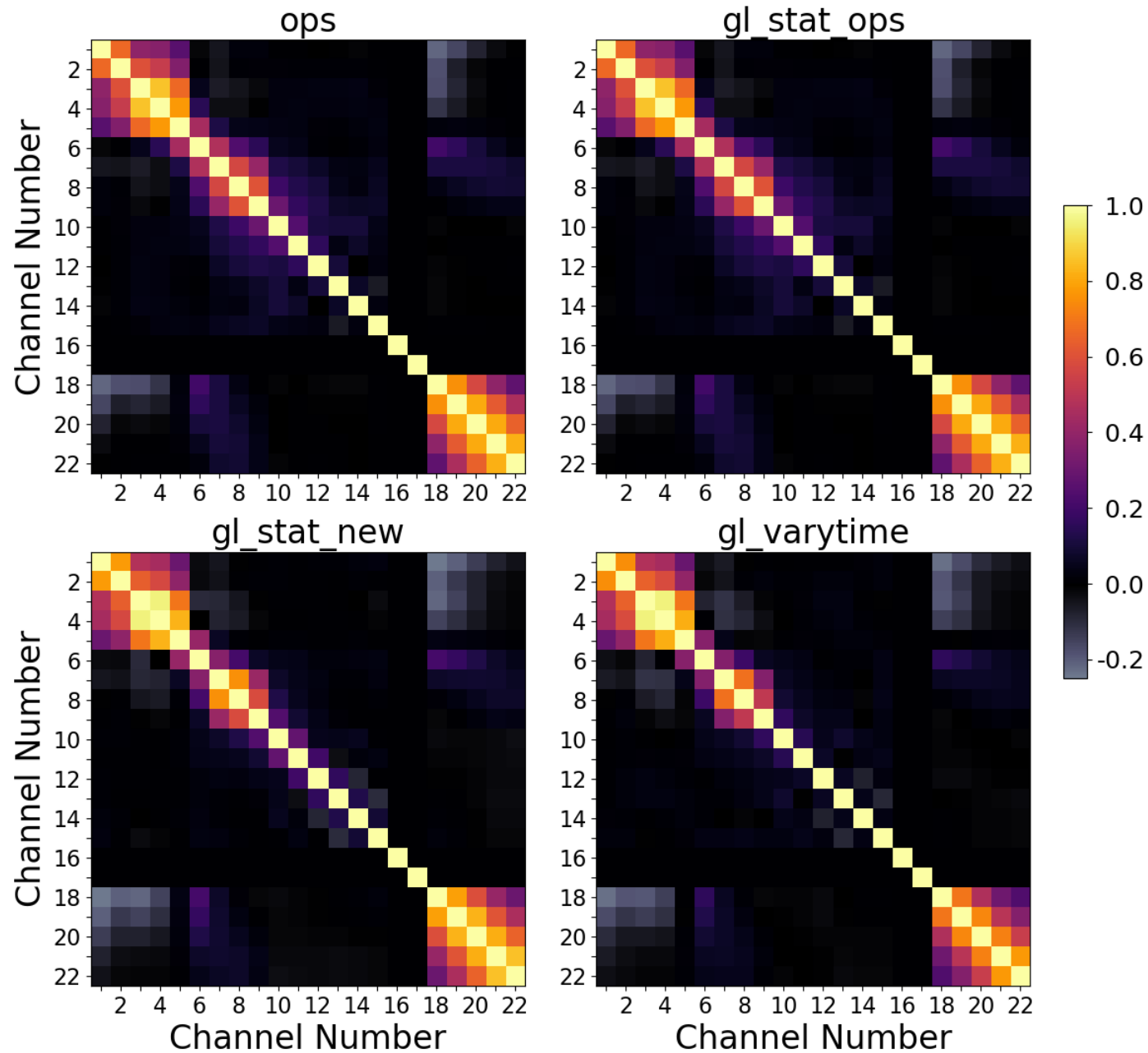
# Fit to Obs

<u><i>gl varytime v gl stat ops</i></u>						
ChGroup	CI	ChanCount	win	tie	loss	wlt_score
geo_csr	0.950	43	12	21	10	0
lw_strat	0.950	165	78	48	39	0
lw_trop	0.950	71	12	54	5	0
other	0.950	13	13	0	0	1
sfc	0.950	6	6	0	0	1
sw_trop	0.950	13	8	5	0	1
t_strat	0.950	37	17	9	11	0
t_trop	0.950	55	34	14	7	1
water_vapor	0.950	89	55	14	20	1
Total	0.950	492	235	165	92	5

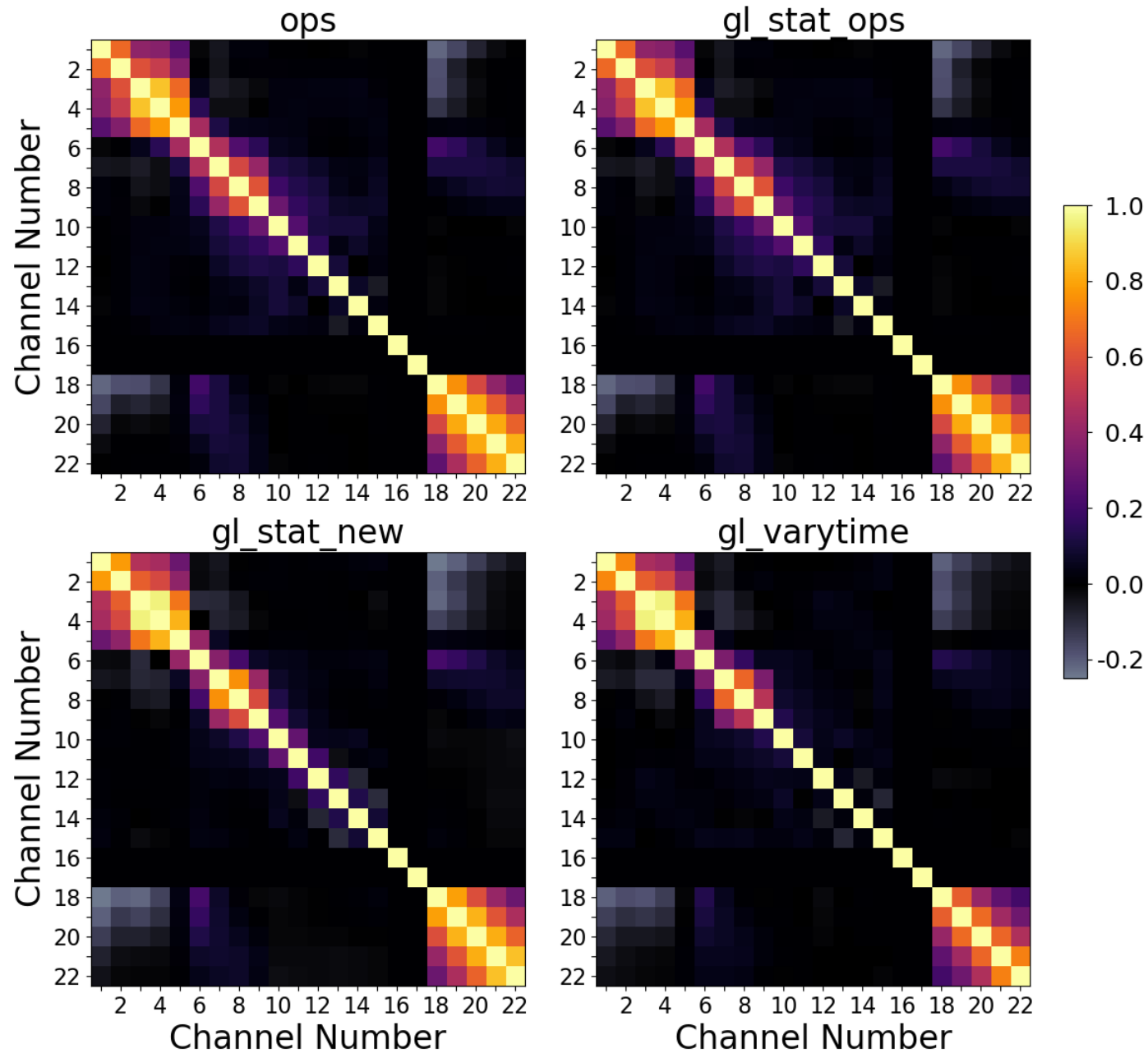
# Fit to Obs

<u><i>varyregion v gl stat ops</i></u>						
ChGroup	CI	ChanCount	win	tie	loss	wlt_score
geo_csr	0.950	43	12	26	5	0
lw_strat	0.950	165	81	48	36	0
lw_trop	0.950	71	3	56	12	0
other	0.950	13	6	7	0	0
sfc	0.950	6	1	5	0	0
sw_trop	0.950	13	0	6	7	-1
t_strat	0.950	37	28	6	3	1
t_trop	0.950	55	27	21	7	0
water_vapor	0.950	89	21	63	5	0
Total	0.950	492	179	238	75	0

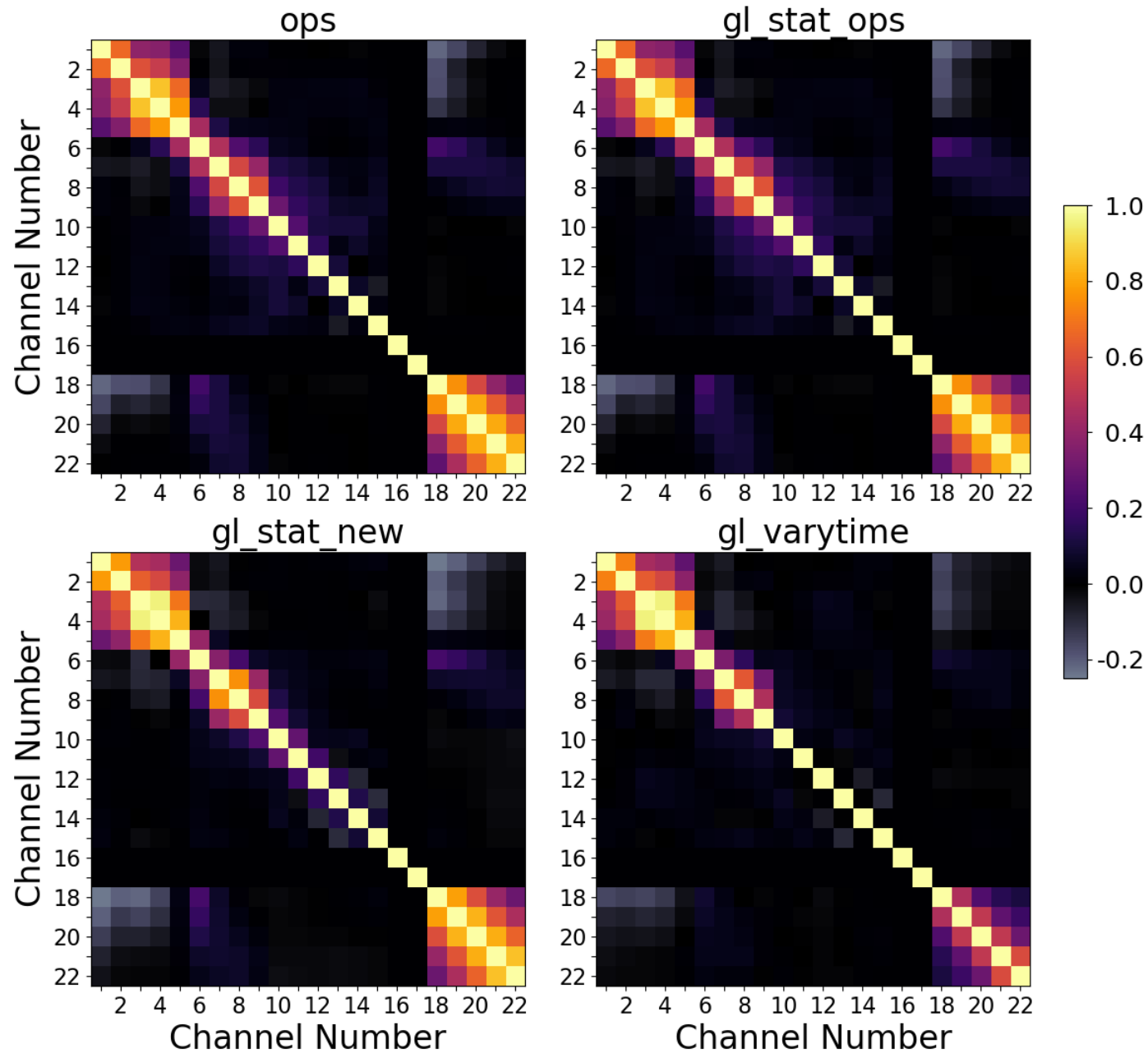
# ATMS NOAA20 Obs Error Correlations 00 UTC July 01



# ATMS NOAA20 Obs Error Correlations 00 UTC July 07

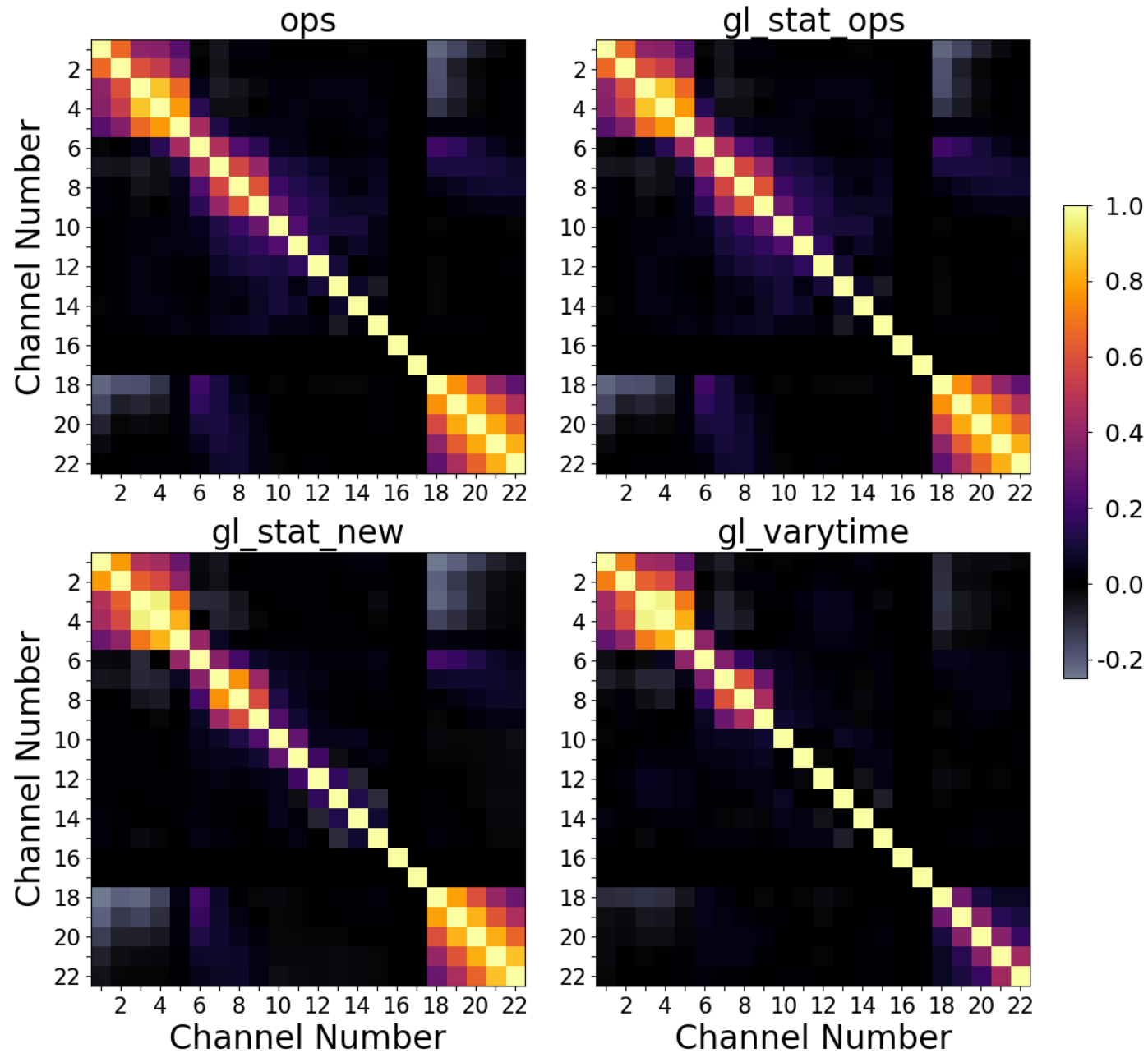


# ATMS NOAA20 Obs Error Correlations 00 UTC July 13

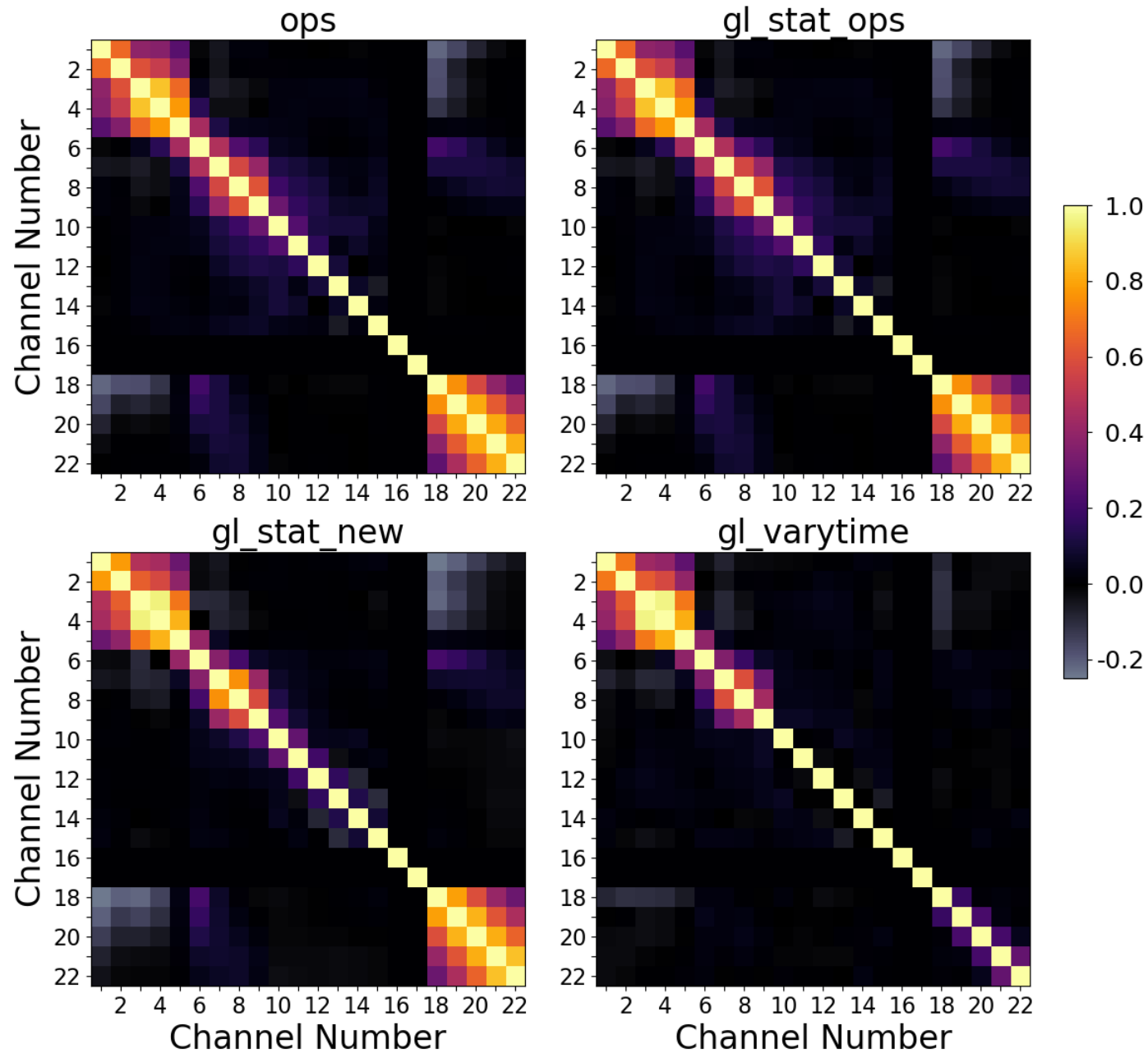




# ATMS NOAA20 Obs Error Correlations 00 UTC July 19



# ATMS NOAA20 Obs Error Correlations 00 UTC July 25



# Iterations Required for Convergence

