Results

Run Parameters

- **Satellite**: Starlette
- **Observation Datatype**: SLR
- **Arc time**: 14 days (2003/09/14 - 2003/09/28)
- **Estimated Empirical Gen. Accelerations**: Off
- **Density Models**: NRLMSISe86, NRLMSISe00, NRLMSISe2.0
- **Adjusted Parameters**: Time dependent C_d (42 estimates), State Vector, Arc biases (SLR stations?)

Goals of Project

This project seeks to offer an easy-to-use, science-oriented orbital dynamics package for Ionosphere-Thermosphere-Mesosphere (ITM) researchers to use for satellite trajectory tracking and atmospheric drag research.

Itemized Goals:

1. Construct generalized readers of the GEODYN output
2. Construct simple visualizations of the GEODYN output
3. Add MSISe00 and MSISe2.0 into GEODYN
4. Implement density model verification methods
5. Generalize the GEODYN readers to work for GPS type runs
6. (groundwork) Implement a user friendly method for switching satellites (or document how to do this)
7. (groundwork) Implement an improved vehicle implementation (or document how to do this)
8. Interface GEODYN with the CCMC Kamodo package

Note: Since our goal is to use the atmospheric drag in an orbit determination as a means of studying the atmospheric density, it is important to control for as many errors external to the density as possible. This leads us to omit the estimations of empirical accelerations, or any other estimations that would improve the POD other than increasing the fidelity of the atmospheric model.

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1 Questions for Code 61

NOTE: All data presented here are depicting the last iteration unless otherwise specified.

1. Is such a small change in the RMS of fit (as shown in Table 1) still a significant enough result to show that the density model has improved?
2. Figure 6 appears to show that the observed residuals on MSISe2.0 are higher than those of MSISe00 and MSISe86. Wouldn't we expect to see these residuals decrease if the density model is introducing less error to the orbit determination? Can the overall RMS of fit still be lower if the observation residuals are higher?
3. The plots in Section 6 seem to show that the RMS at each iteration (but especially the last iteration) are higher in MSIS 2.0 than in MSISe86, but this is different from what Table 1 shows. Is there something that we are missing here? Why are there inconsistencies between these results?
4. Section 5.1 provides my understanding for why empirical accelerations should be omitted when assessing density models. Is there anything in this understanding that is flawed (from a GEODYN perspective)?
5. What other results would be good to see if the density model has improved?

2 Compare Run Statistics

Statistics from the end of IIEOUT file

Parameter	MSIS 86	MSIS 00	MSIS 2.0
X POS	-1228611.047711857	-1228611.000644256	-1228611.002860558
Y POS	4721160.098619740	-4721160.116960314	-4721160.115078840
Z POS	5602824.670083221	5602824.663907633	5602824.663322780
X VEL	6644.663061993014	6644.663072193405	6644.663073195048
Y VEL	-2852.907078978589	-2852.907047211658	-2852.907048276599
Z VEL	-798.7567429058066	-798.7567797112002	-798.7567790814259
RMS Position	0.051571	0.050316	**0.050103**
RMS Velocity	0.000050	0.000049	**0.000049**

Table 1: Comparison the the RMS position and RMS velocity for the three MSIS versions

Table 1 shows that MSISe2.0 has the best RMS of Fit for the position and velocity. The change is small, but there nonetheless.

3 External Verification of the Density Output

The MSISe00 and MSISe2.0 models were verified externally using the pymsis module. (https://pypi.org/project/pymsis/).

Figures 1 and 2 show that the implementation of the new model versions into GEODYN matches up very closely (within 0.5 a percent for MSISe00 and within a hundredth of a percent for MSISe2.0). The differences seen here are likely due to computational rounding.

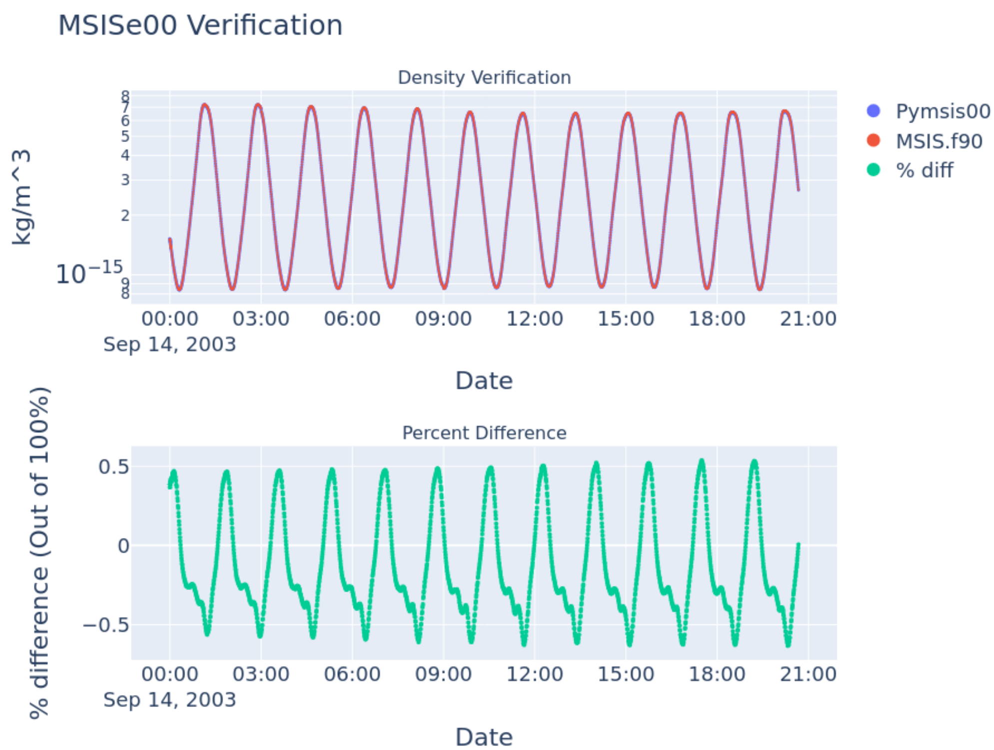

Figure 1: MSISe00 External Verification

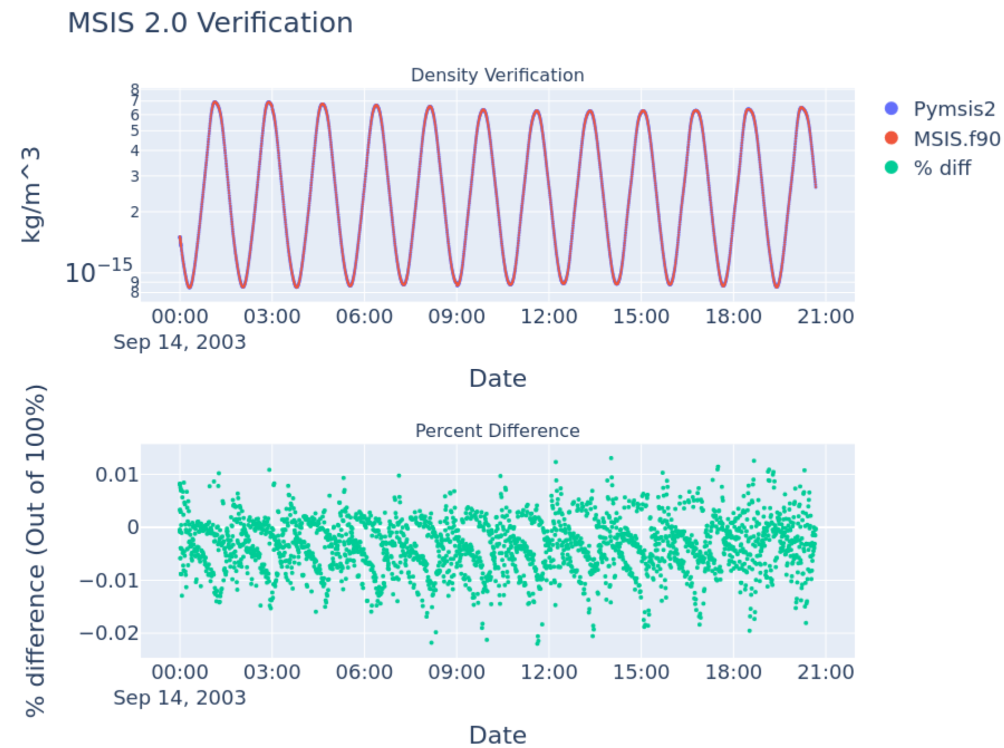

Figure 2: MSISe2.0 External Verification

4 Compare Density Outputs

Figure 3 shows that MSISe2.0 has a slightly lower density than that of MSISe86 or of MSISe00. MSISe2.0 included significant updates to the temperature and composition data in the mesosphere and thermosphere (including data from TIMED/SABER, AURA/MLS, ACE, AIM, OSIRIS, and lidar data). The inclusion of these datasets, and the reworking of the temperature and compositional profiles, contributes the results seen in these plots (a lower density at 1000 km along the orbit of Starlette).

Figure 4 shows the percent difference of the density output between the models. The most noteworthy result here is the red line showing the percent difference in MSISe86 and MSISe2.0. From 9/17-9/19, MSISe86 shows density values that are 30% higher that those depicted in MSISe2.0.

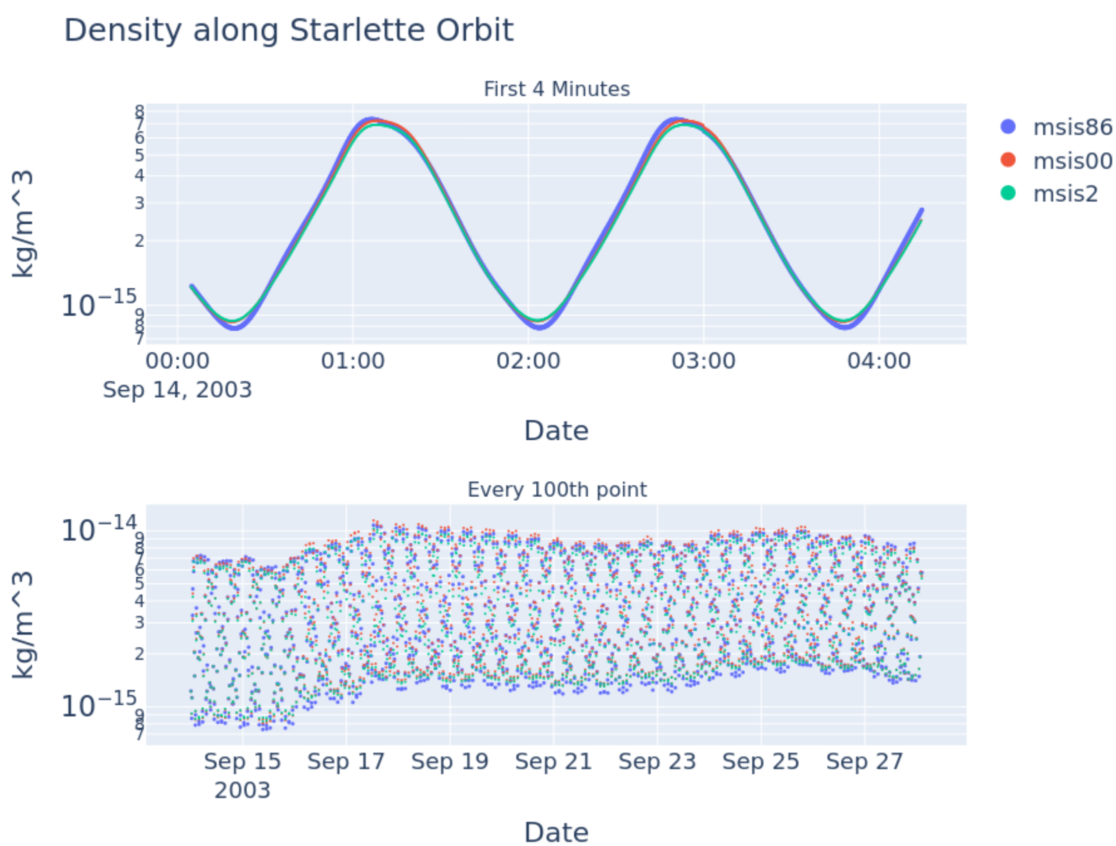

Figure 3: Density comparison along the orbit of Starlette

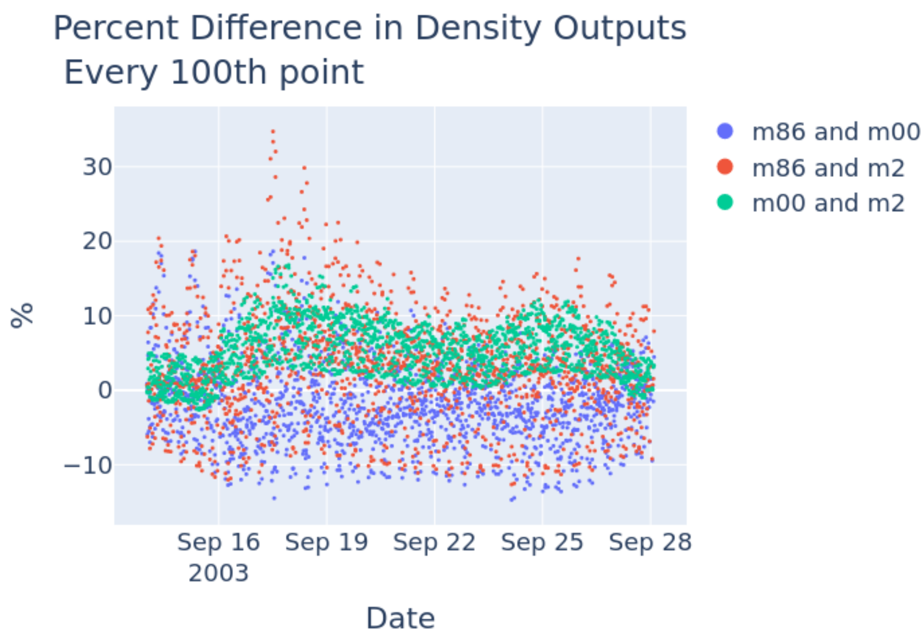

Figure 4: Percent difference between density outputs

5 Drag Coefficients

Figure 5 shows the time dependent drag coefficient being estimated by GEODYN. Since the density of MSIS 2 is lower, its drag coefficient is subsequently higher for the majority of the orbit.

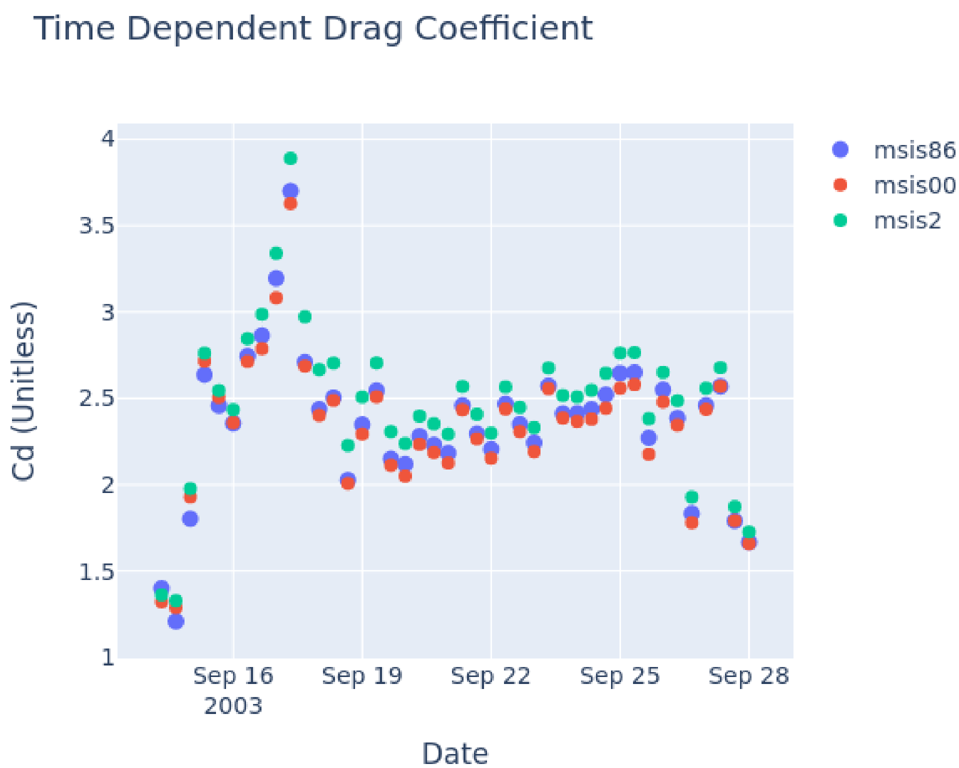

Figure 5: Time dependent drag coefficients

5.1 On Empirical Accelerations

We do not include adjusted empirical accelerations (through the ACCEL9 card).

Once per revolution empirical accelerations can be estimated (using least square methods) to account for non-conservative forces that are possibly misrepresented. This increases the accuracy of the orbit significantly, but absorbs some of the accelerations that would otherwise have gone into the estimation of drags contribution to the acceleration and the estimation of the drag coefficient.

Allowing an estimation of empirical accelerations complicates the estimation of the drag coefficient by absorbing some of the inherent error and the uncertainty surrounding the acceleration of drag itself. For these reasons, it is omitted.

6 Residuals

6.1 Observation Residuals

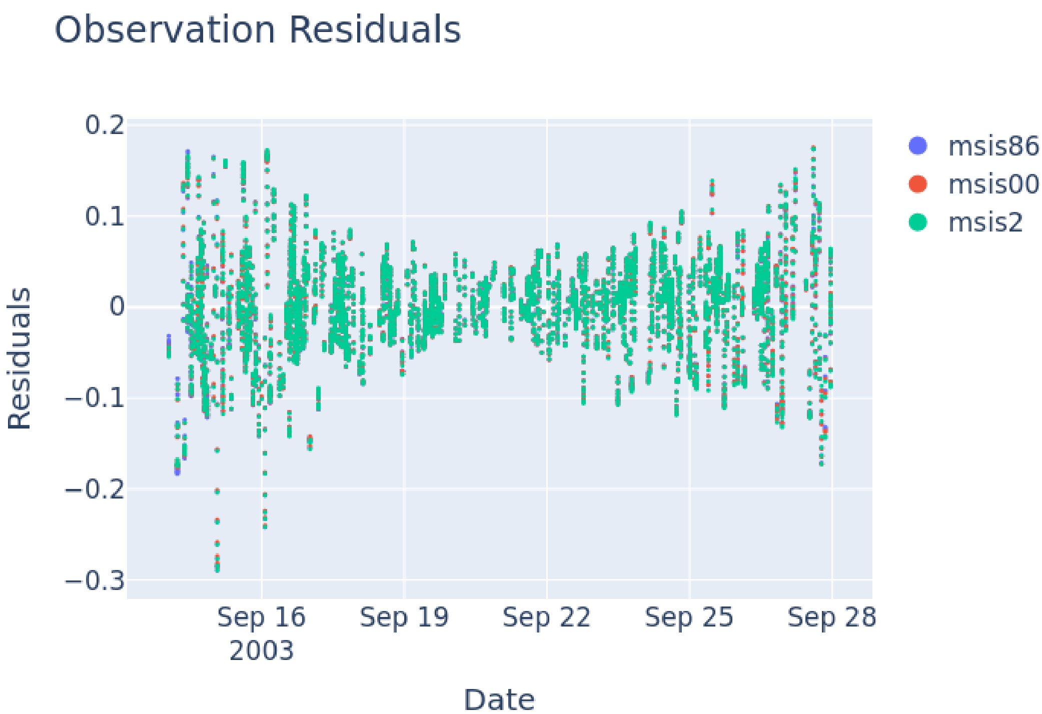

Figure 6: Observed residuals at last iteration

6.2 Residual Measurement Summary

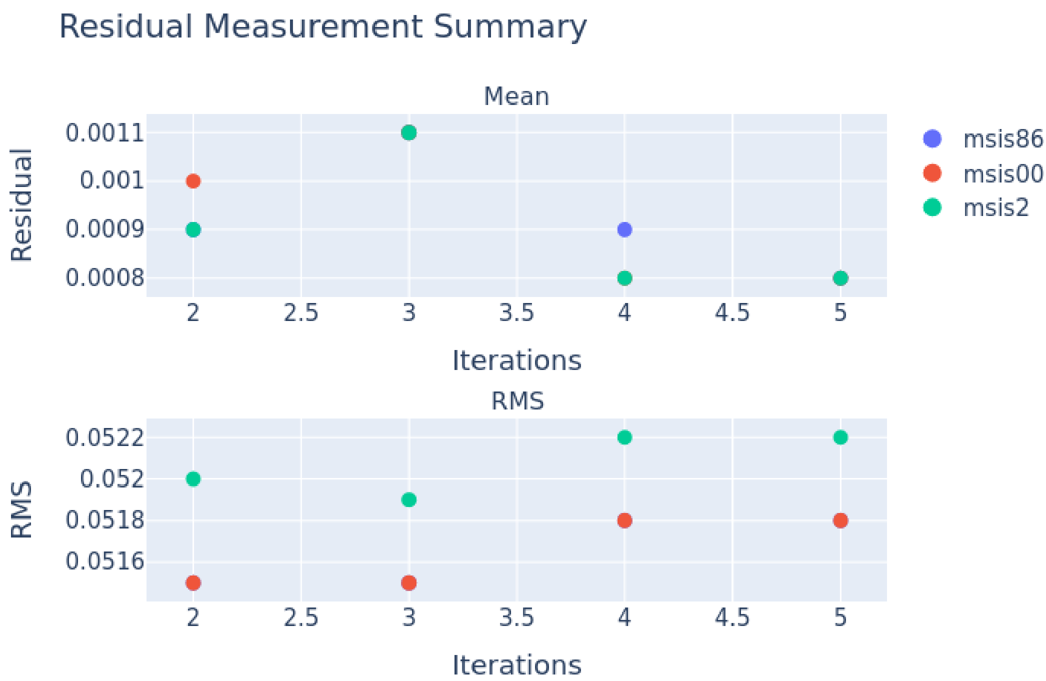

Figure 7: Mean and RMS of residuals from the residual measurement summary

6.3 Residual Summaries By Station

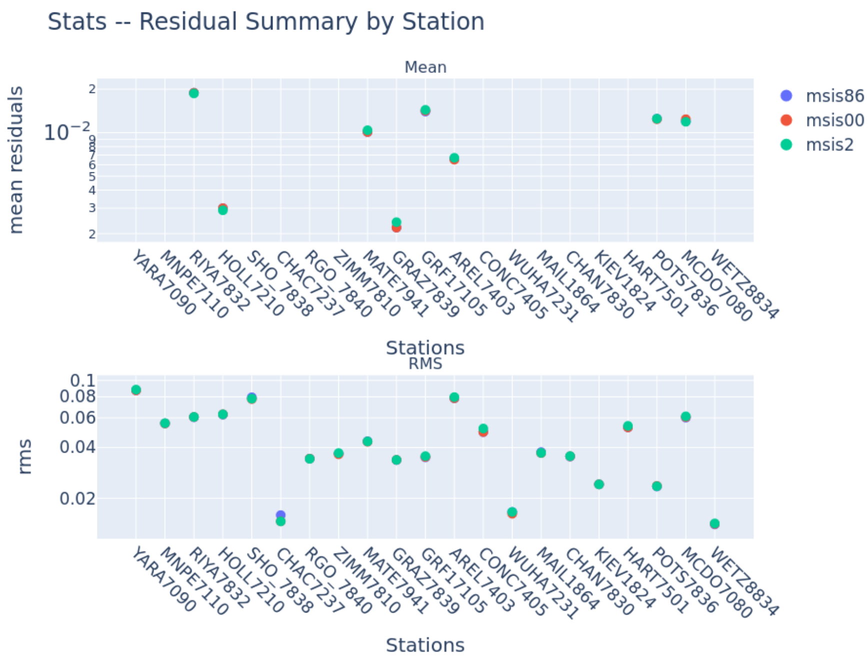

Figure 8: Mean and RMS of residuals by station

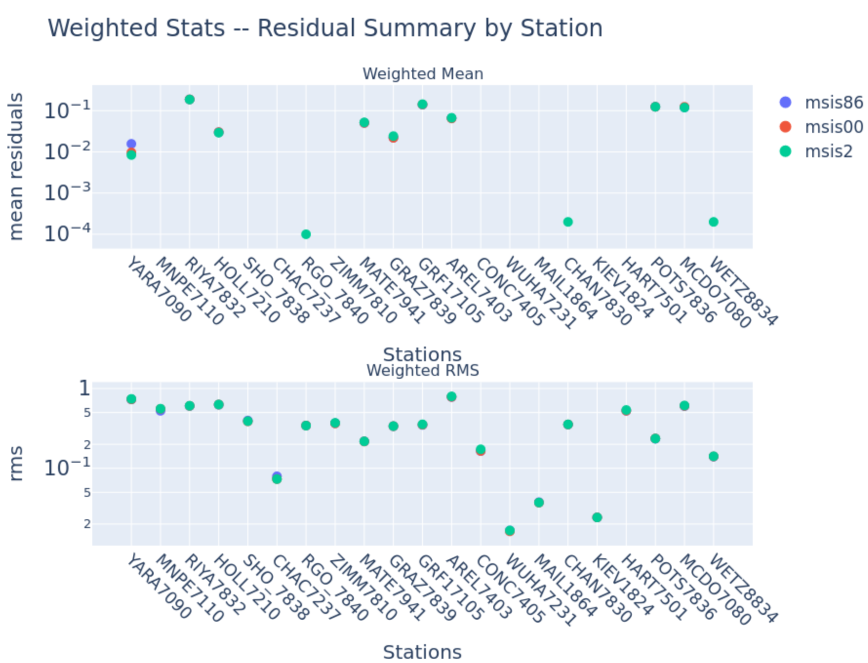

Figure 9: Weighted mean and weighted RMS of residuals by station