IRS Large Offset Test

The IRS Large Offset Test (ILOT) was conceived as a simple test of the pointing accuracy during the long gyro-based offsets available to observers utilizing the SPOT Cluster Target option (multiple targets separated by up to one degree on the sky). The test was carried out for gyro offsets spanning 30 and 60 arcminutes, respectively. The test was made up of three separate IERs, running back-to-back over a period of 2 hours. Over the course of each test, the telescope was repeatedly offset from one target to the next and back. The targets were imaged with short exposures on the blue peak-up array. Image centroids were measured to look for any offset or drift over time, and to provide detector "truth" data to compare with PCS telemetry.

The test has run in both IRS Campaigns 4 and 9, and is scheduled to execute once more in IRS Campaign 12.

Targets:

The targets were chosen to be in the continuous viewing zone to avoid scheduling problems and to enable repeated observations of the same targets at arbitrary times of the year.

Targets were chosen to test offsets in two orthogonal directions for any given offset distance. In the case of the 30 arcminute offset tests, two pairs of stars were chosen from the 2MASS catalog and observed in separate IERs. For the 60 arcminute offset test, a convenient triangle of stars was found which enabled offsets in orthogonal directions within the same IER. All stars were selected to have fluxes that would be comfortably below the IRS blue peak-up saturation threshold. The IERs and their respective targets are given below:

IER	Target RA	Target dec	Separation (arcmin)	Position angle (degrees E of N)
30_arcmin_a	17h48m07.71s	+66d04m26.1s		
	17h46m30.50s	+66d31m06.6s	28.4	160
30_arcmin_b	17h35m24.47s	+64d22m49.6s		
	17h39m41.32s	+64d32m11.1s	29.2	71.3
60_arcmin	18h20m01.14s	+65d28m42.0s		
	18h16m23.45s	+64d31m09.9s	62.1	202
	18h29m43.76s	+65d06m02.1s	65.4	290

Commanding: IRS Campaign 4

The 30 arcminute IERs each proceeded as follows:

- Set PCS_INERTIAL,
- Initial slew to the target.
  - This involved a high rate, PCS_OBS_B slew to the target, with PCS_PRI_SETUP for a 6 second exposure, PCS_POINT, followed by a wait until GV_POINTING_READY != 0,
- A VML delay of 300 seconds after GV_POINTING_READY != 0,
- A PCS_GYRO_UPDATE,
- A PCS_ATT_DET to INC_POINT_B,
- Switching to IRU_LOW_RATE and PCS_PRI "DISABLE",
- Repeating 5 times:
  - Commanding a 6 second IRS exposure,
  - Offsetting ~30 arcmin to the second target via PCS_OFFSET,
  - VML delay of ~36 seconds,
  - Commanding a 6 second IRS exposure,
  - Offsetting 30 arcmin back to the first target via PCS_OFFSET,
  - VML delay of ~36 seconds,
- Commanding a 6 second IRS exposure,
- A VML delay of 100 seconds,
- A PCS_GYRO_UPDATE (16 minutes into the sequence – note that the telescope was inertial for 100 seconds + 17 seconds (DCE time) + 10 seconds (fixed settle time) since the last SLEW_COMPLETE = 1),
- Repeating 6 times:
  - Commanding a 6 second IRS exposure,
  - Offsetting ~30 arcmin to the second target via PCS_OFFSET,
  - VML delay of ~36 seconds,
  - Commanding a 6 second IRS exposure,
  - Offsetting 30 arcmin back to the first target via PCS_OFFSET,
  - VML delay of ~36 seconds,
- Concluding the sequence with a switch to PCS_OBS_B, and disabling both PCS_LOWRATE_MODE and PCS_PRI.

The 60 arcminute AOR was the same, except that:

- Offsetting proceeded from target 1 to 2 to 3 and back to 1.
- Additional VML delays of 100 seconds and PCS_GYRO_UPDATEs were carried out at 34 and 51 minutes into the sequence.
- A PCS_ATT_RESET "CURRENT OBSERVER" was commanded at 35 minutes,
- A total of 10 circuits of the three targets (30 DCEs) were commanded.

The 30 arcminute IERs executed in roughly 30 minutes, while the 60 arcminute IER executed in roughly 60 minutes.

Commanding: IRS Campaign 9

The commanding in IRS Campaign 9 was very similar to that used in IRS Campaign 4. However, at D. Swanson's recommendation, all but the initial PCS_GYRO_UPDATES in each IER were removed. In addition 180 seconds were spent with the telescope stationary in "IRU_ONLY" mode at the beginning and at the end of each IER.

Execution:

The IERs making up the IRS Large Offset Test were executed as follows:

IER	Request Key	DOY/week	Sclock (1st DCE)	Sclock (Last DCE)
Campaign 4				
30_arcmin_a	9188608	63/14	762800140	762801590
30_arcmin_b	9188864	63/14	762802032	762803574
60_arcmin	9189120	63/14	762804046	762807165
Campaign 9				
30_arcmin_a	10012928	176/31	772514556	772516006
30_arcmin_b	10013184	176/31	772516440	772517982
60_arcmin	10013440	176/31	772518428	772521547

The targets were imaged using the IRS CHEAP mode, which uses offsets with respect short-lo slit to place the target in one of the Peakup arrays. This has the advantage (over slits) that it gives accurate centroiding information in two dimensions.

Centroids accurate to <0.05 arcseconds were computed using the IDP3 package at the IRS Science Center at Cornell. These centroids were then delivered to D. Swanson at LMA as detector truth data to complement his analysis of the engineering data.

Results

Figures 1 and 2 show plots of the successive centroids measured in the IRS Campaigns 4 and 9 Large Offset Tests. If the gyros had performed perfectly (and assuming the stellar coordinates were perfect), all points would have overlain one another. Instead, each experiment shows a significant "drift" of the centroids across the peak-up array. For the first 30 arcminute experiment in IRS Campaign 4, the drift measures about 5.4 arcseconds per hour. For the second, orthogonal 30 arcminute experiment and the 60 arcminute experiments in Campaign 4, the drift measures about 25 arcseconds per hour. The major component of the drift is oriented along the +V,-W to –V,+W direction in detector coordinates. In the telescope pointing frame, this is equivalent to going from –Z,+Y of the focal plane to the +Z,-Y side. The drift appears more or less uniform in both magnitude and direction despite the occurrence of 8 separate gyro bias calibrations and updates over the course of the experiment. This argues that the drift cannot be attributed simply to noisy bias estimates, and that a systematic misestimation of some combination of bias and scale factors has taken place.

For the first 30 arcminute experiment and for the 60 arcminute experiment in IRS Campaign 9, the drift measures about 14 arcseconds per hour. For the second, orthogonal 30 arcminute experiment in Campaign 9, the drift measures about 7 arcseconds per hour. The drift is again oriented in the +V,-W, –V,+W direction in detector coordinates, though the field has presumably rotated in the focal plane by ~100 degrees in the 113 days since the IRS Campaign 4. This suggests that the problem (be it a scale factor error or a poor bias estimate or something else) may be largely confined to one gyro axis only. Note that some time between Campaigns 4 and 9 the updates of scale factors during IRU calibrations was discontinued in favor of fixed, average values based on ground analysis.

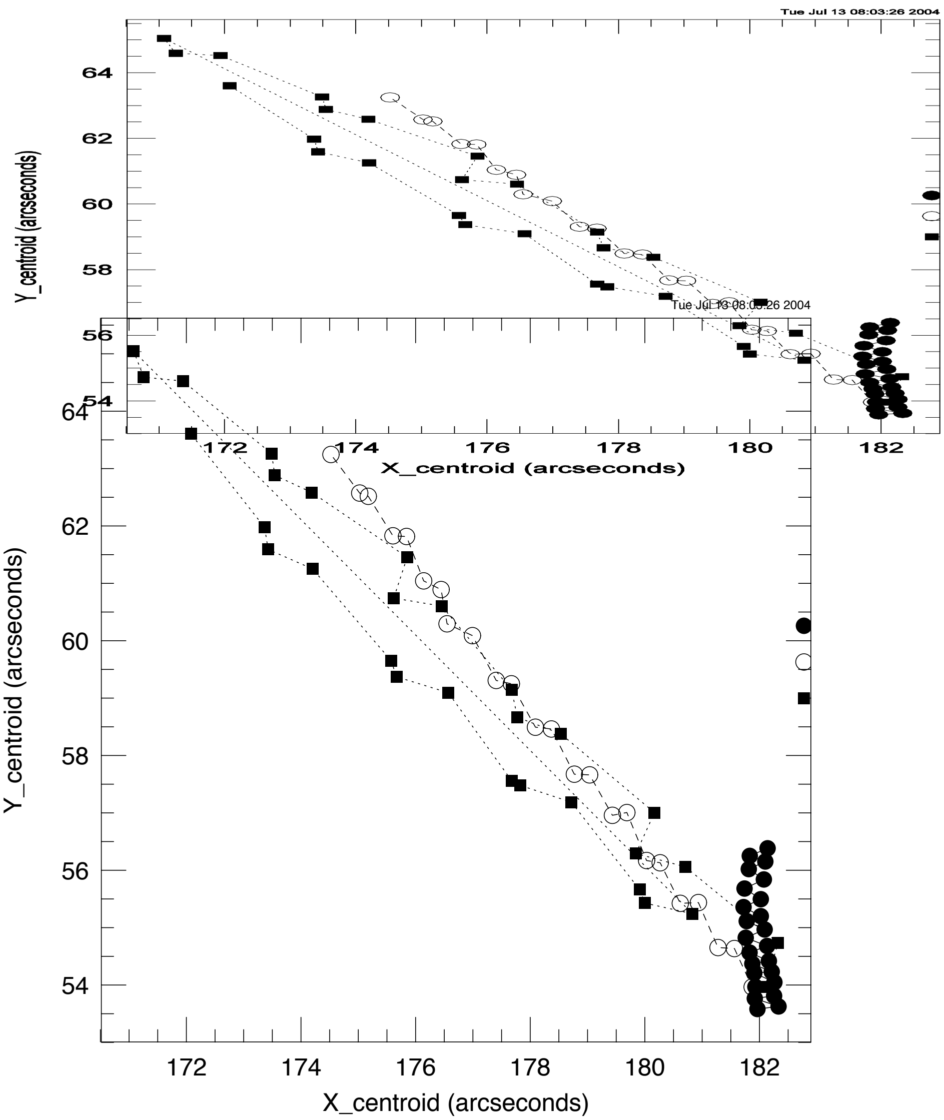


Figure 1. Measured centroids of stars placed on the blue peak-up array over the course of the IRS Campaign 4 Large Offset Test. The filled and open circles show successive centroids for alternating stars in the two orthogonal 30 arcminute experiments, while the filled squares show the results for the 60 arcminute offsets. The 60 arcminute test contained one 300 second and 3x127 second inertial holds and PCS_GYRO_UPDATEs.

It also contained an attitude reset 35 minutes into the experiment, which is why two tracks are apparent. If the gyro offsets, all points would have fallen on top of one another.

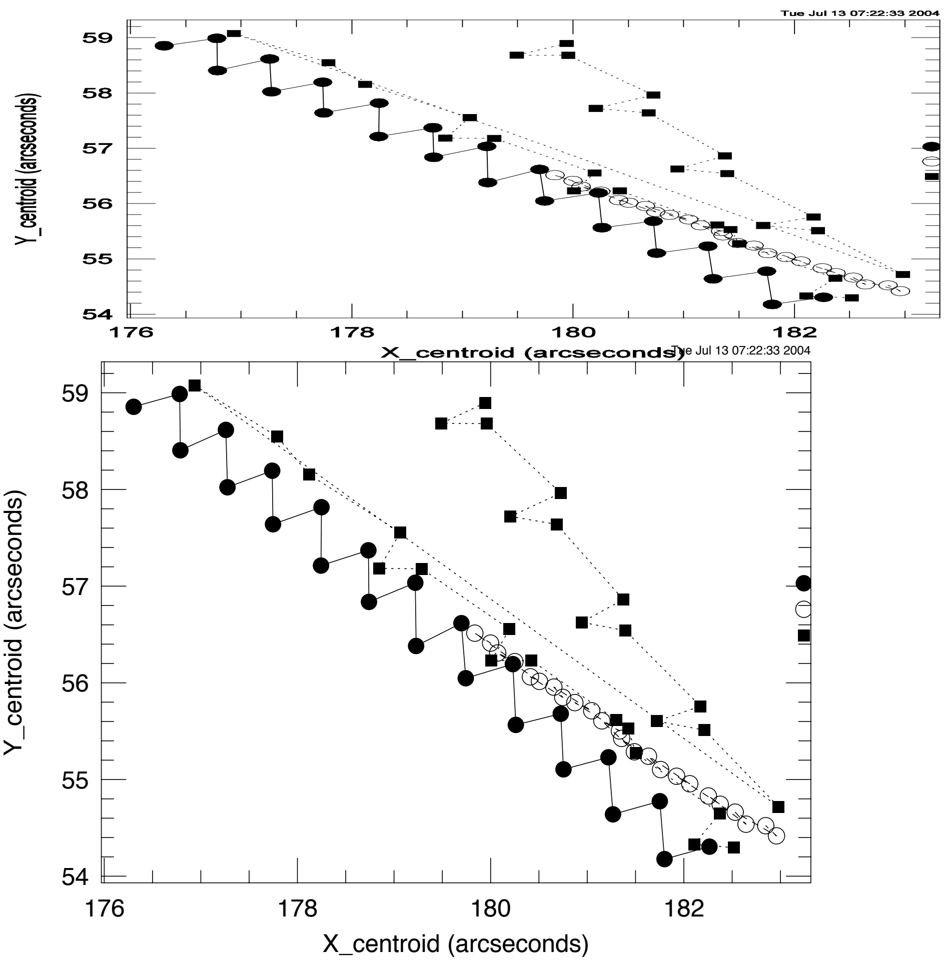
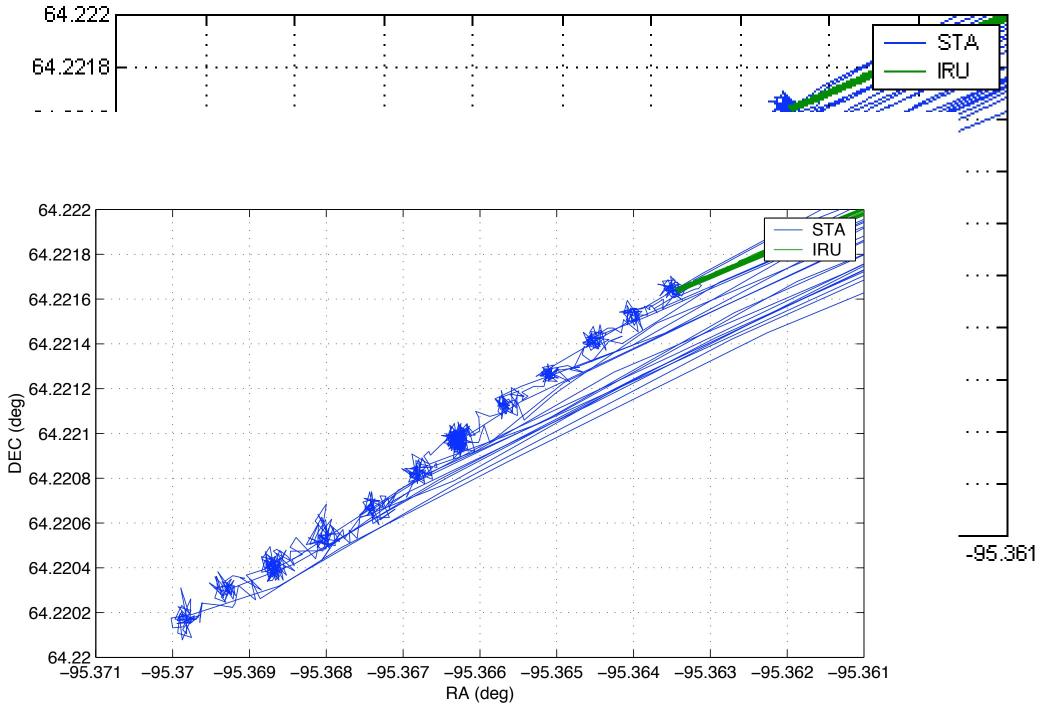


Figure 2. Measured centroids of stars placed on the blue peak-up array over the course of the IRS Campaign 9 Large Offset Test. Symbols are as in Figure 1. No intermediate

PCS_GYRO_UPDATEs were carried out in this experiment, but the 60 arcminute experiment did contain an attitude reset 35 minutes into the experiment, which is why two, roughly parallel tracks are apparent.

Additional analysis by D. Swanson:

Figure 1. IRS Offset Test#2 (ier_0x8000008C3600). FLIGHT performance. Two plots show the two endpoints of the 30 arcmin back-and-forth offsetting executed in this test. The star tracker attitude (blue) shows that the actual attitude was stepping across the sky. The IRU attitude (dark green), which was where PCS thought the observatory was pointing, doesn't move at all. The star tracker data says that PCS is incorrect.


STA
IRU
DEC (deg)
RA (deg)
64.222
64.2218
64.2216
64.2214
64.2212
64.221
64.2208
64.2206
64.2204
64.2202
64.22
−95.371
−95.37
−95.369
−95.368
−95.367
−95.366
−95.365
−95.364
−95.363
−95.362
−95.361

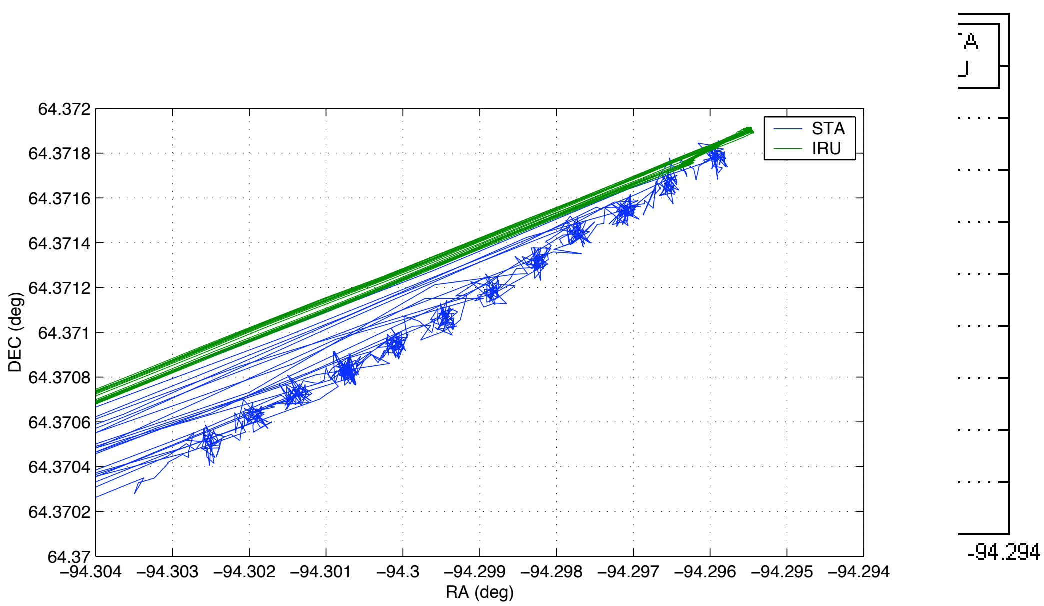

STA
IRU
DEC (deg)
RA (deg)
64.372
64.3718
64.3716
64.3714
64.3712
64.371
64.3708
64.3706
64.3704
64.3702
64.37
−94.304
−94.303
−94.302
−94.301
−94.3
−94.299
−94.298
−94.297
−94.296
−94.295
−94.294

Figure 2. IRS Offset Test#2 (ier_0x8000008C3600). IRU data reprocessed by changing the A2X gyro absolute scale factor from its flight value (3.59e-04) to a new value (0.60e-4). The new value was selected to get the IRU attitude as close as possible to the STA attitude. This change dramatically improves the IRU_ONLY performance.

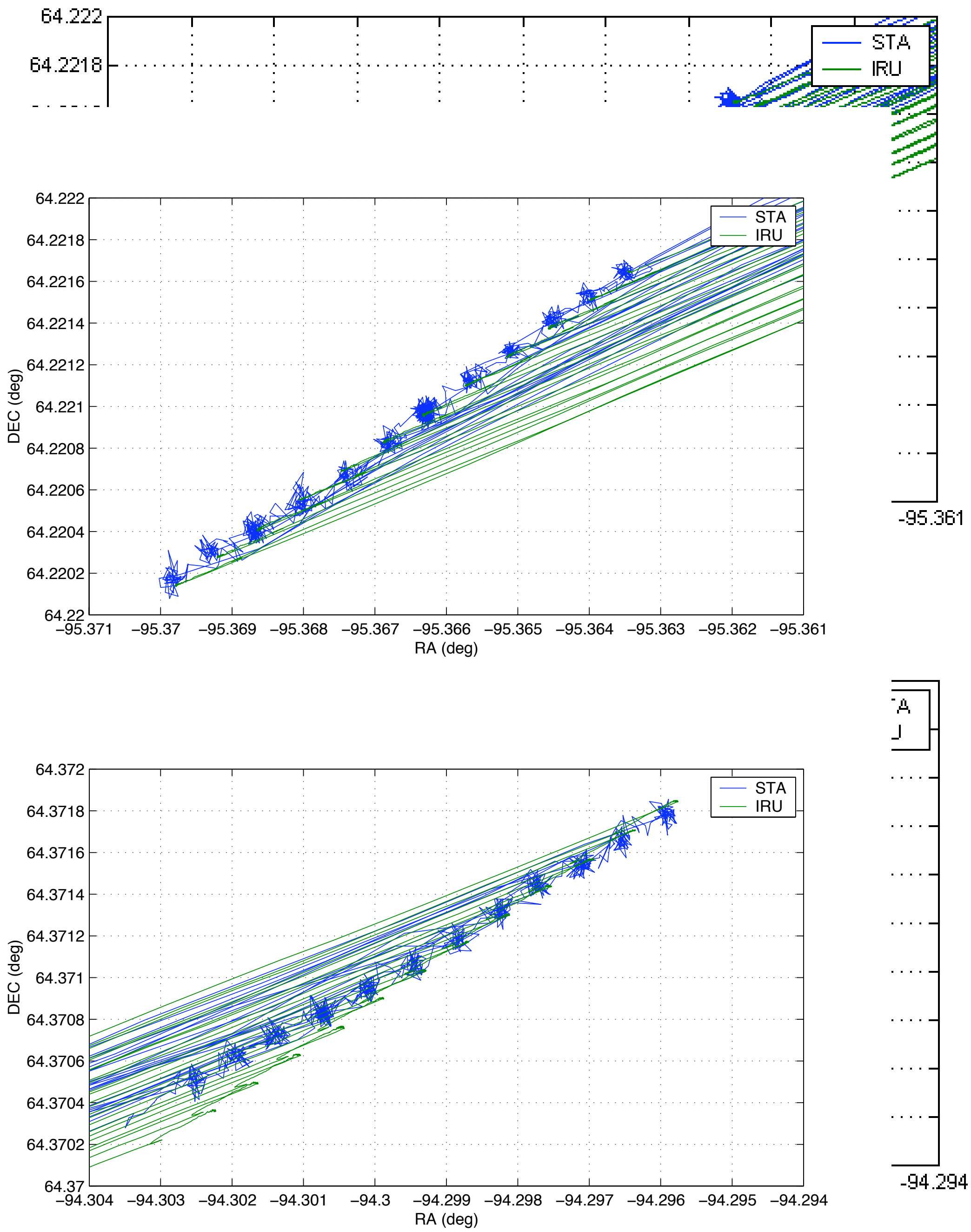


Figure 3. IRS Offset Test#1 (ier_0x8000008C3500). FLIGHT performance. Test was similar to Test#2, except the 30 arcmin offset direction was orthogonal to that of Test#2. Plot is to same scale as Figures 1 and 2. Drift was nowhere near as bad in this test as it was in Test#2.

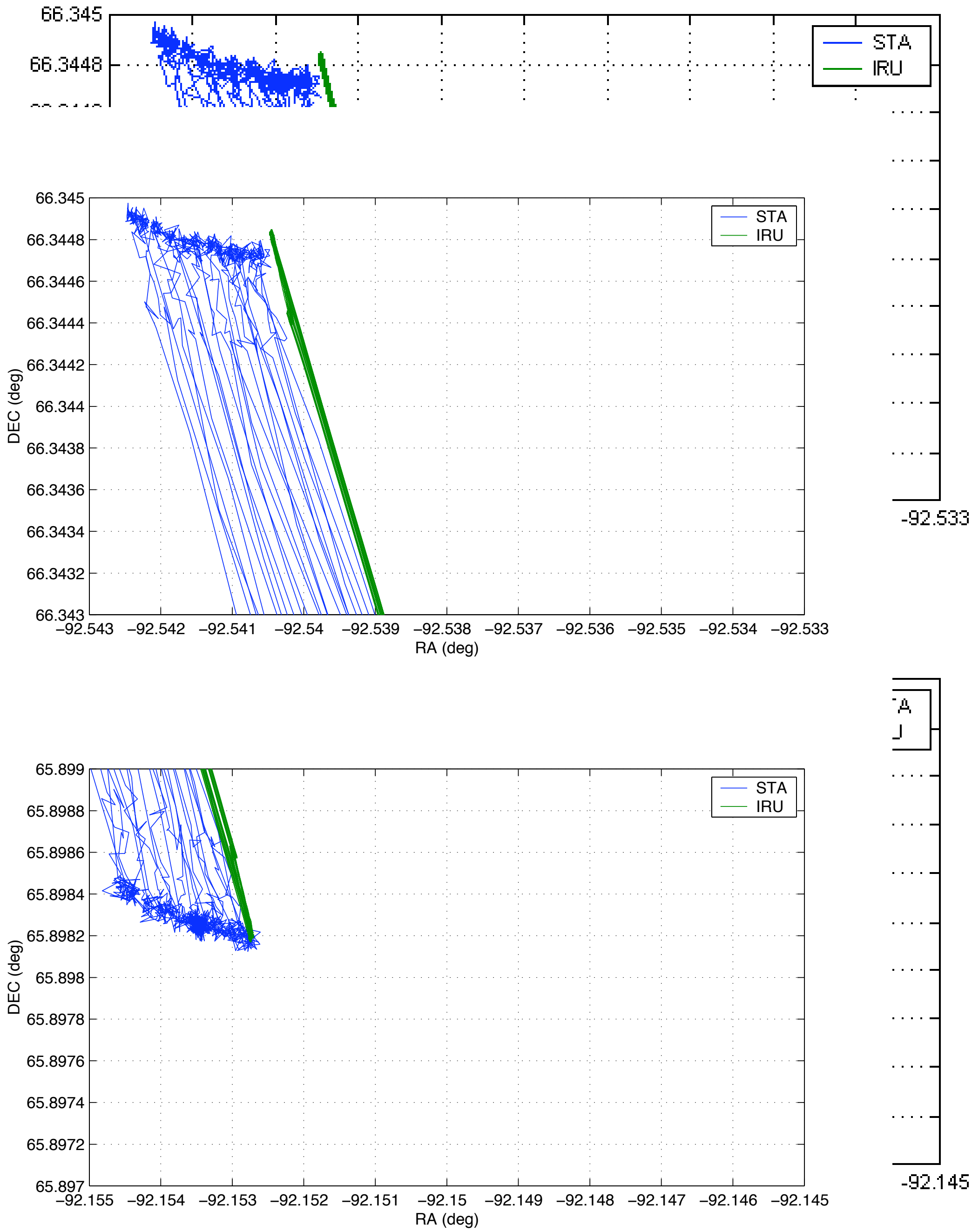
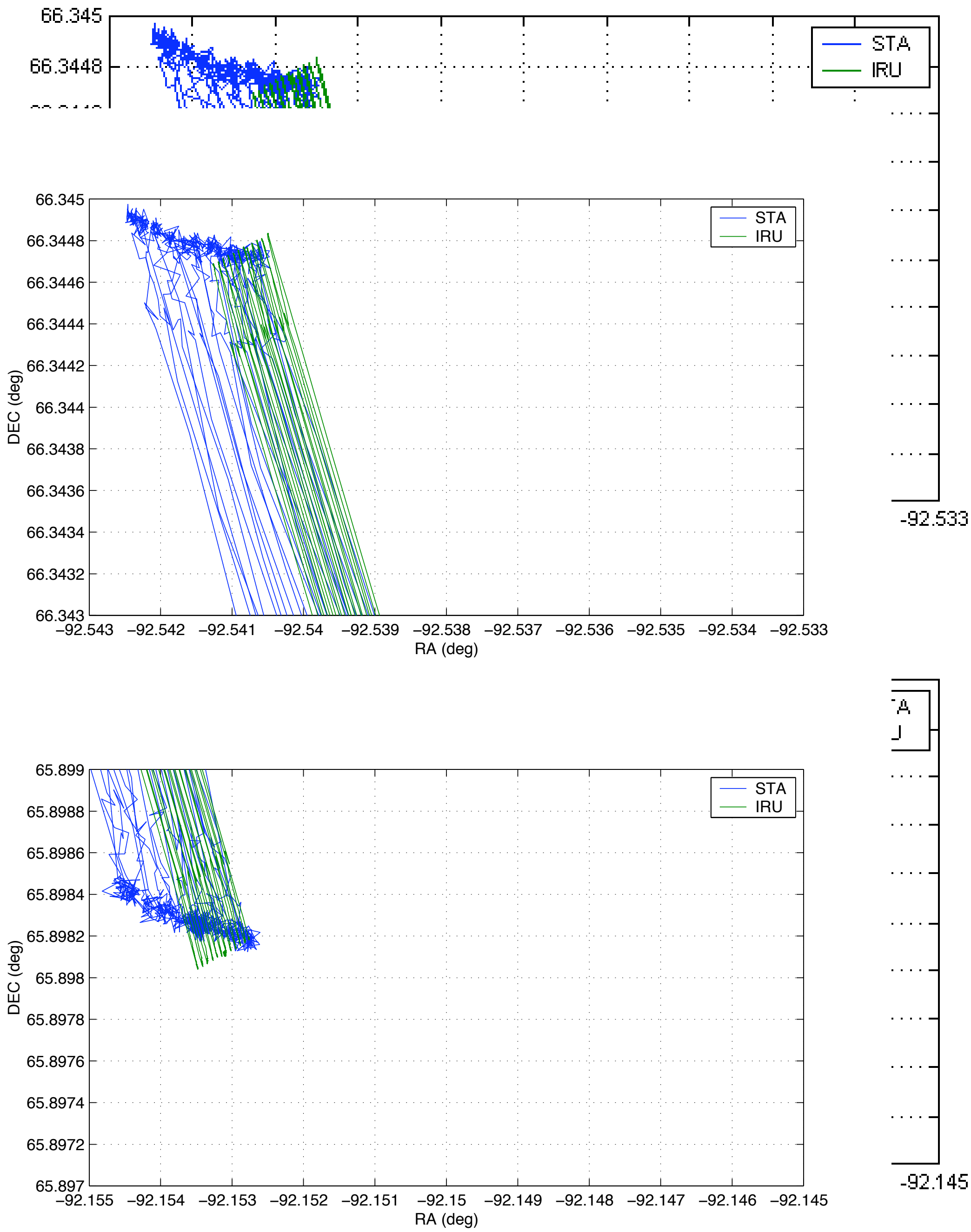


Figure 4. IRS Offset Test#1 (ier_0x8000008C3500). Gyro data reprocessed with the exactly the same scale factor change as in Figure 2 (A2X = 0.6e-4). Again the estimated attitude shows a marked improvement.



I am still varying other gyro calibration parameters to see if the fit can be improved further. This dataset is not very sensitive to changes to the A1Y or A2Y absolute scale factor, which is not surprising since the offset direction was essentially parallel to A2X. The data shows some sensitivity to changes in the LSM (linear scale factor / misalignment) matrix elements, but so far all tweaks I've tried there have made the fit worse. This implies that the GCF has likely identified the correct values for the parameters forming this matrix. I have yet to try playing with the GCF rate bias parameters.

To do:

- Try varying the GCF rate bias parameters
- Expand to Tests #3 from the IRS Offset test, and then to other datasets