VLBA Scientific Memo No. 34
Error Found In EOP Corrections In AIPS Task CLCOR

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Summary

Versions of the AIPS task CLCOR released between Sept. 21, 2009 and Aug. 4, 2011 used the wrong sign on the station Y coordinate when calculating Earth Orientation Parameter (EOP) corrections. The main adverse impact will be on phase referencing projects for which sufficiently large EOP corrections were made that the difference in the relative correction between calibrator and target is significant. Analysis of astrometric VLBA data indicates that the effect on the data scales with the magnitude of the EOP correction and the separation between target and calibrator.

Details

An error has been found in the Earth Orientation Parameter (EOP) corrections done by versions of CLCOR released after Sept. 21, 2009 but before Aug. 4, 2011. In 2009, AIPS was changed to use a right handed coordinate system for all arrays. Prior to that time, VLBI data sets used a left handed coordinate system in AIPS for historical reasons. Since 2009, the routine that reads the antenna tables can tell which system is in use because it recognizes a large number of antenna names and knows what the sign of station coordinate Y should be, which is the only difference between the systems. If it finds a left handed system is in use, it changes the sign of all of the Y values to make it right handed. Then other AIPS routines assume a right handed system. All tasks that had code for dealing with left handed VLBI coordinates were changed when this behavior was installed. Unfortunately the EOP correction code in CLCOR was overlooked, and the change of the sign of Y for VLBI data sets was inadvertently left in place.

To test that the current corrections are correct, we recently correlated a few scans of a normal VLBI project with EOP values that were set very far from the correct values. We then used CLCOR to correct the data. The correlator output from this test, with no corrections, shows much higher fringe rates than normal. When the EOP are corrected with the CLCOR containing the error, the residual fringe rates got even higher, clearly showing that the correction was not being done properly. When the latest CLCOR, as released on Aug 4, 2011, was used, the residual rates returned to small values. The phase differences on a strong source between the data with the "good" corrections and the data from the normal processing run, done with the same "correct" EOP values used in the test, were under a few degrees, and less than the scatter, on all but 3 stations. For the outer stations (MK, SC, HN), the offsets were 20 to 30 degrees and, curiously, all of the same sign.

We are still trying to understand the phase offsets on the outer stations. But the EOP corrections involved in the test (0.02s in UT1-UTC and 0.2 arcseconds in X and Y) were far larger than anything expected to be seen in real observations. So for real cases, we expect any such differences to be very small. In the interests of getting this message to our users quickly, we are not waiting until we fully understand those remaining differences.

The data processing sequence recommended for all projects in the AIPS Cookbook includes making EOP corrections in Step 9. This is normally done using the procedure VLBAEOPS. It can also be done by running CLCOR directly and requesting OPTYPE='EOPS'. The reason for making these corrections was originally that there was a period of a few months when the correlator was using poor values. But regardless, the correlator has to use values determined before the data are correlated, which is before the final, best values are obtained by the geodetic groups. For CLCOR, a file with the most current values provided by the USNO is downloaded and used to make a differential correction to what was used on the correlator. Unfortunately, for the last 2 years, this step has had the effect of degrading the data.

The magnitude of the issue depends on how much change there was in the EOP values between those used for correlation and those used by CLCOR. For the large majority of projects, those changes will be small. Roughly, a change in UT1-UTC has an effect about like a source position error of that amount in the RA. Changes in X and Y are also about like source position changes. The harm that can be caused is mainly the result of the differential correction on source and calibrator for phase reference operations, such as for weak source detection or for astrometry. For calibrator data, or for self calibration imaging, the errors in the correction will be removed by fringe fitting or self calibration and so it is not a concern. The magnitude of the harmful effect for phase referencing will be reduced by the calibrator-target separation in radians. In cases where the corrections were small, or the separation is small, the error may not have a significant impact.

To determine whether a particular data set is adversely affected, it might be best to rerun the EOP correction to see how big a difference the corrected code makes. Usually the EOP correction is run early in the processing sequence, although possibly after the ionospheric correction. The CL tables at this stage are pretty simple so changes should be easy to see. First check that there is any difference. There won't be (other than due to small changes in the current EOP tables vs those used in the original processing) if the most recent CLCOR was used or, more likely, if a version from before Sept. 21, 2009 was used on a data set with left handed coordinates. If that is the case, there is no further concern. If there are differences, you will have to decide if they are large enough to affect the final scientific results. The main concern is the differential differences between calibrator and target scans for phase referencing. Those differences should be checked by examining the CL tables carefully. Often the EOP used on the correlator will be good enough that the corrections made by CLCOR will be small enough to ignore. But there may well be a few projects for which that is not true. If you are unlucky and one of those is yours, you will need to redo all the processing that affects phases that was done after the EOP corrections were applied. For example, data editing, polarization calibration, and calibrator imaging should be ok, but fringe fitting, final self calibration on calibrators, and phase transfer to the target will need to be redone.

To obtain the corrected version of CLCOR, run the AIPS midnight job on either 31DEC11 or 31DEC10 (there has been a patch).

Effect on the data, a case study

The effect of this error on the data should directly scale with the EOP corrections that were applied with CLCOR. The following links give the differences between the EOP values used during correlation and the final USNO values for most VLBA observations correlated in Socorro since 2006:

https://science.nrao.edu/facilities/vlba/proposing/eop-difference-2006
https://science.nrao.edu/facilities/vlba/proposing/eop-difference-2007
https://science.nrao.edu/facilities/vlba/proposing/eop-difference-2008
https://science.nrao.edu/facilities/vlba/proposing/eop-difference-2009
https://science.nrao.edu/facilities/vlba/proposing/eop-difference-2010
https://science.nrao.edu/facilities/vlba/proposing/eop-difference-2011

The *combined* EOP correction here is calculated by adding the POLE X POLE Y, and UT1-UTC (converted to mas) in quadrature. Those data show that most correlations were done with good

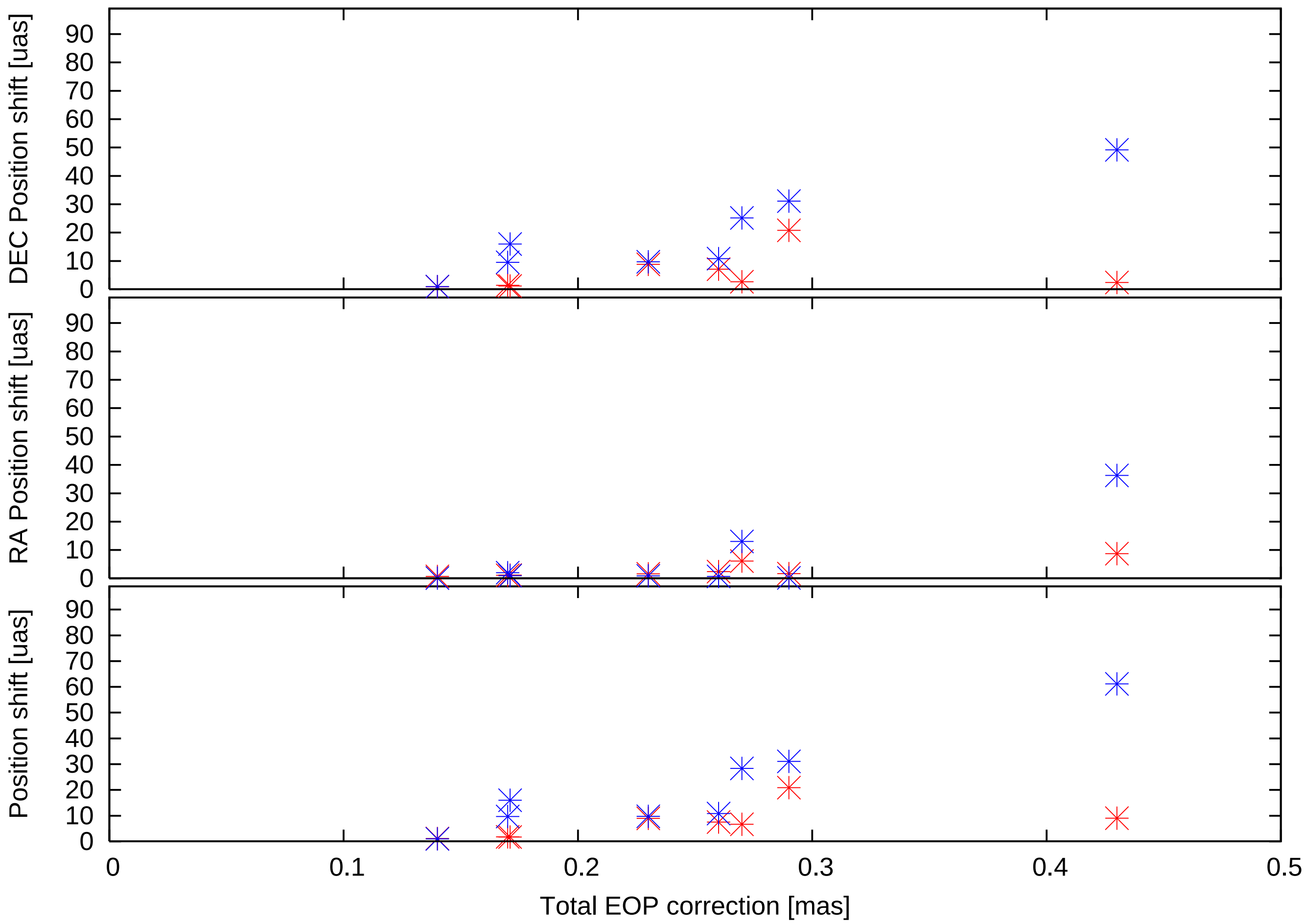

Figure 1: Position shifts of the two background quasars as function of total EOP correction.The red and blue stars refer to the nearby (0.32°) and more distant (0.81°) quasars, respectively.

EOP values, but there are some exceptions.

To investigate the effect of this error on astrometric VLBA data, eight epochs of VLBA data were reduced using exactly the same ParselTongue pipeline, once with the old version of CLCOR and once with the new (corrected) version of CLCOR. The observations used a strong water maser as phase reference and two background quasars, separated by 0.32° and 0.81° from the maser. The eight observations had EOP corrections ranging from 0.14 – 0.43 mas. Note that the three sources are at very low declination (-28°).

Fig. 1 shows the position shifts induced by the wrong EOP correction for the two quasars in the eight observations as function of the *combined* EOP correction. The plot shows the following:

- There is a general trend for higher position shifts for larger EOP corrections. However, it is not a very strong correlation.
- The closer quasar shows smaller position shifts.
- The position shift is usually larger in declination than in right ascension.

It is not clear how much this (in particular the last point) changes for higher declination sources. Note that for most phase referencing experiments (with calibrator – target separations of $> 1-2°$) the expected position shift will be larger than in this example with two relatively nearby quasars.