CORE: Continuous, High-Accuracy Earth Orientation Measurements

D. S. MacMillan, W. E. Himwich, C. C. Thomas, and N. R. Vandenberg
NVI, Inc/Goddard Space Flight Center, Greenbelt, Maryland

J. M. Bosworth, B. Chao, T. A. Clark, and C. Ma
Goddard Space Flight Center, Greenbelt, Maryland

Abstract. The international geodetic VLBI community will inaugurate during 1999 a new phase of the program called CORE (Continuous Observations of the Rotation of the Earth). The capabilities of the new Mark IV correlators, available as of mid-1999, will enable greater sensitivity, more frequent observing sessions, and improved system throughput. The CORE program, begun in 1996 with the CONT96 campaign, has gradually increased the number of observing sessions per week. As of early 1999 the average is 2.5 24-hour sessions per week (including the NEOS sessions). This will expand to 3.5 sessions per week beginning in the second half of 1999, with the goal of continuous observing by the year 2001. The concept of CORE requires that Earth orientation measurements will be made with several networks, each operating on a different day. It is therefore important to determine whether there are systematic differences between EOP derived from different networks. We have been acquiring data from different networks observing on the same day or on sequential days in order to validate this concept. Recent analysis comparing data from CORE-A, CORE-B, and NEOS sessions shows that there are systematic differences in EOP, which are now under active investigation.

Introduction

Changes in the Earth Orientation Parameters (EOP) are due to either external torques, or to internal redistribution of angular momentum between the Earth's core, atmosphere, and oceans. Measurements of EOP can therefore place constraints on geophysical models of the solid Earth, the atmosphere, and the oceans. VLBI is one of the most important sources of Earth orientation information that is available. Recognizing the importance of EOP measurements, the international VLBI community is engaged in a program, CORE (Continuous Observations of the Rotation of the Earth) to make continuous EOP measurements beginning in 2001 ramping up from 3.5 24-hour sessions per week during 1999. Two critical elements of the CORE are the Mark-IV correlator that can process much more data and the Mark-IV VLBI hardware that will provide much more precise measurements due to an increase in recorded bandwidth by a factor of 8 The Mark-IV correlator will be capable of supporting continuous data acquisition. The evolution of CORE program is shown in Figure 1. Continuous measurements of EOP will be made with several networks, each operating on a different day. For the CORE program to be successful, EOP derived from the different VLBI networks that will be used need to agree. To investigate this question, we have run a series of VLBI experiments starting in 1997, that are either simultaneous (CORE-A) with the weekly NEOS network or on adjacent days (CORE-B). Here we present results of comparisons of EOP measurements made by these networks.

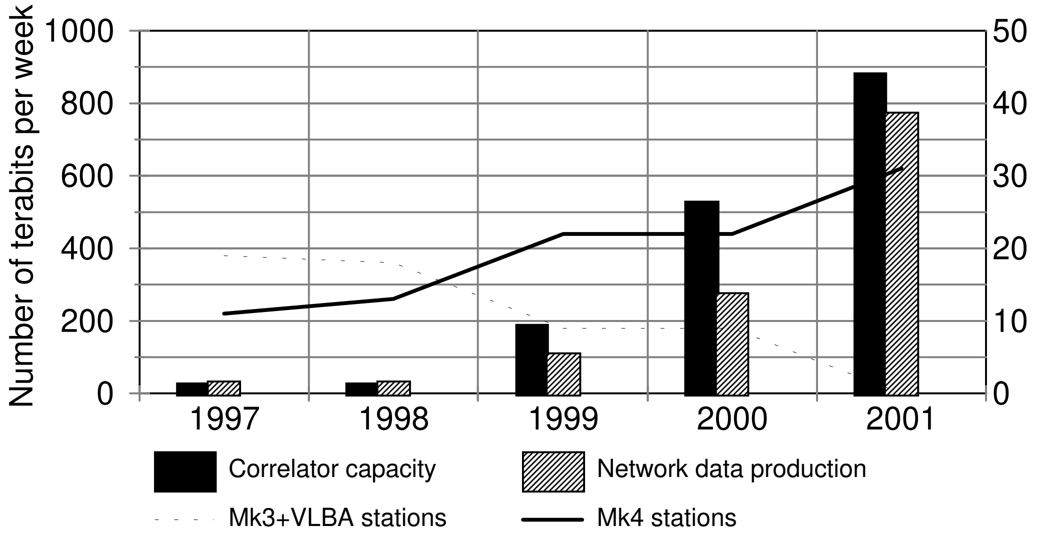

Figure 1. Amount of data collected as CORE evolves.

CORE-NEOS Comparisons

The precision of VLBI measurements has continued to improve by about an order of magnitude each decade. As can be seen in Figure 2, the best UT1 precision has been attained for the NASA R&D experiments. The current best VLBI measurements of UT1 have a precision of about 2 μs.

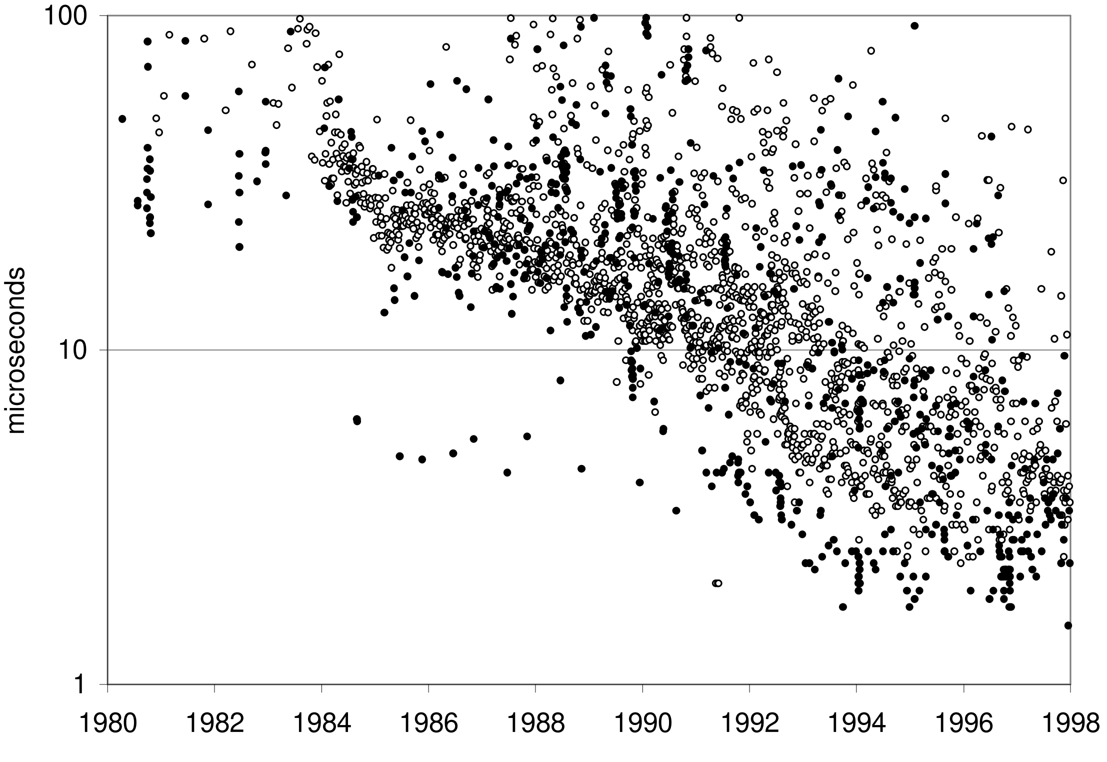

Figure 2. Precision of UT1 measured by VLBI. Dark filled circles are NASA R&D sessions and the open circles are all other sessions.

One of the principal problems with high precision VLBI EOP is determining the measurement accuracy. In the CORE program, EOP measurements will be made with several different networks, where each network will operate on a different day. It is therefore important to determine whether there are systematic differences between EOP derived from different networks. Our basic test of accuracy consists of examining the differences between EOP derived from independent VLBI measurements made by different networks.

From the history of VLBI sessions from 1980 to the present, there are about 300 simultaneous sessions. Comparisons of these simultaneous sessions imply that the formal EOP errors should be increased by a factor of 1.5-2.0. As can be seen in Figure 2 for UT1, the EOP precision of these measurements varies over a wide range, which is greater than a factor of ten compared to current precision. This reflects the evolution of the improvement of precision. Therefore it is difficult to determine from this comparison whether the differences are caused by random or systematic errors.

To determine the current EOP accuracy, we have compared measurements made by CORE and NEOS networks. The least squares estimation program (SOLVE) used in the analysis and the theoretical models applies in the analysis are generally described by *Ma et al.* [1990]. The weekly NEOS network uses Kokee, Green Bank, Fortaleza, Nyalesund, and Wettzell. The CORE-A network sessions are simultaneous with NEOS sessions and use antennas at Fairbanks, Westford, Hobart, Hartebeesthoek, and Matera. CORE-A should give the same EOP as NEOS. There are 3 different CORE-B networks: (1) Algonquin, Fortaleza, Fairbanks, Kashima, and Onsala, (2) Crimea, Fairbanks, Kashima, Kokee, Medicina, and Nyalesund, (3) Fairbanks, Kokee, Noto, Green Bank, Seshan, Urumqi, and Yebes. NEOS and CORE-B sessions are on adjacent days. During 1998, CORE-A and CORE-B were also on adjacent days. For comparisons between networks operating on sequential days, we have extrapolated EOP to the midpoint between each of the experiments.

Figure 3 shows the difference between EOP measurements from the CORE-A and the NEOS network. Tables 1-3 summarize the differences between networks. Based on the χ^2/dof of the differences, there are clearly unmodeled sources of random or systematic error. One could argue that the unmodeled error is entirely random and that the formal uncertainties of the EOP estimates are too small by a factor of 1.3-2.0. This is consistent with *Ryan et al.* [1993], who determined that the formal VLBI site velocity uncertainties were too small by a factor of 1.5-2.0 using data decimation tests. There is evidence that there are also systematic EOP errors. The mean differences between networks are also given in Tables 1-3 along with the expected uncertainty of the mean difference assuming that all errors are random. In many cases, the mean difference is significant and is a factor of 4-5 larger than the uncertainty of the mean.

For the NEOS-CORE-A, the differences are significant for X,Y, and UT1. For NEOS-CORE-B, the differences are significant only for UT1. Although the significance of these mean differences is clear from the size of the mean differences compared with the uncertainty of the mean, we have done an F-test to evaluate the significance. We suppose that there is reallya systematic difference between networks, given by the mean difference and compute the χ^2/dof about the mean. The F-test simply determines the probability that random error could reduce the χ^2/dof by the observed amount when one parameter (the mean difference) is estimated. This probability is very small for those cases where the mean difference is several times the expected mean error. For NEOS/CORE-A, the probability is less than 0.1% for X and Y and less than 2% forUT1. In the case of NEOS/CORE-B, it is less than 2% for UT1.

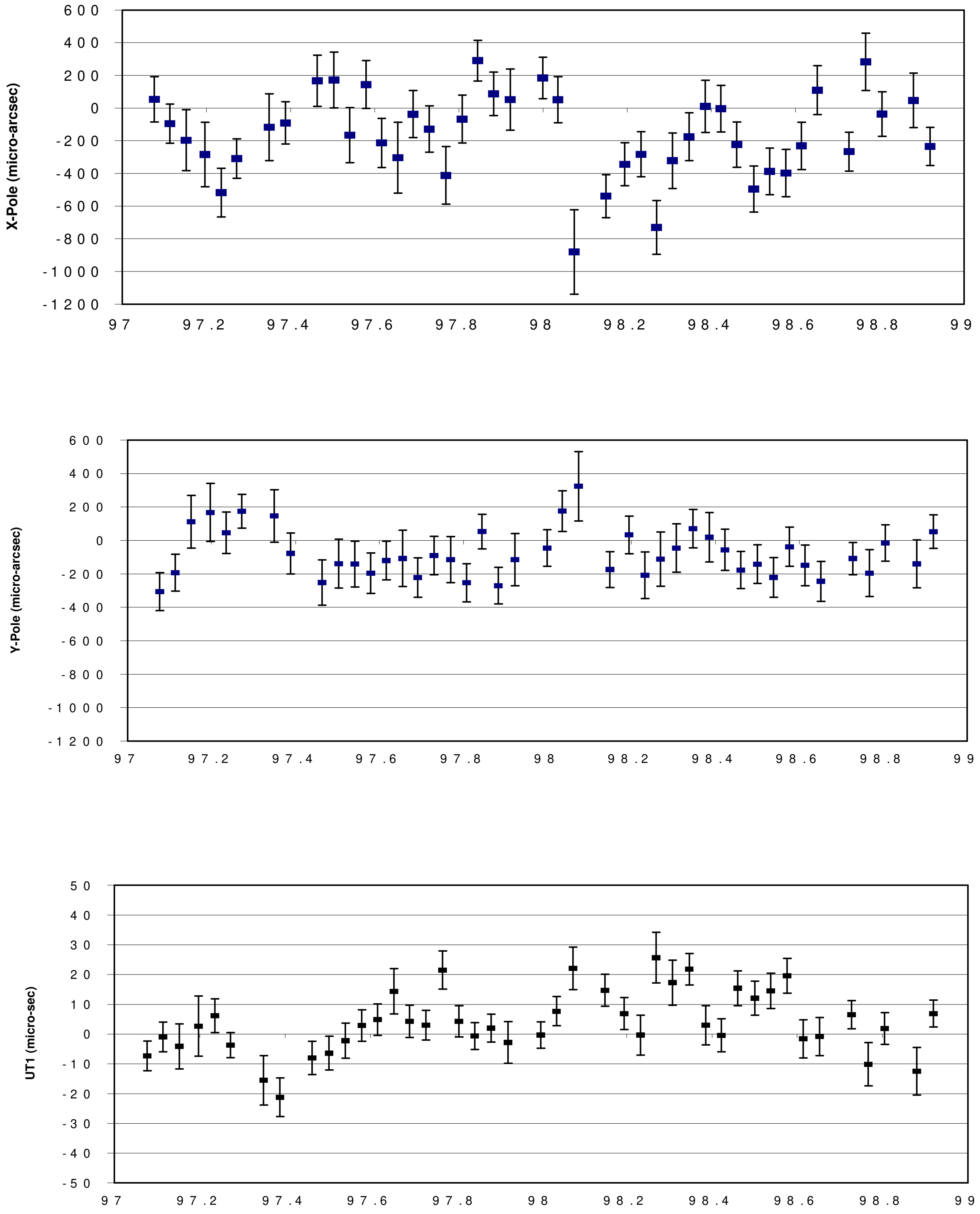

Figure 3. NEOS minus CORE-A EOP estimates for 1997-1998

Table 1. NEOS - CORE-A Differences

	#sessions	χ^2/dof	Wrms	<σ>	Mean	<σ>/√N
X(μas)	43	3.6	280	153	-147	23
Y(μas)	43	1.7	280	128	-85	20
UT1(μs)	43	3.0	11.1	6.0	3.7	0.9
LOD(μs)	43	1.9	18.2	14	2.2	2.1

Table 2. NEOS - CORE-B Differences

	#sessions	χ^2/dof	Wrms	<σ>	Mean	<σ>/√N
X(μas)	30	3.9	285	151	-18.2	28
Y(μas)	30	2.6	198	130	-30.1	24
UT1(μs)	30	3.2	15.2	8.9	10.6	1.6
LOD(μs)	30	3.8	24.6	14	-7.4	2.5

Table 3. CORE-B - CORE-A Differences

	#sessions	χ^2/dof	Wrms	<σ>	Mean	<σ>/√N
X(μas)	14	4.4	242	118	-99	33
Y(μas)	14	4.3	206	102	-74	27
UT1(μs)	14	2.3	9.6	6.5	-5.7	1.7
LOD(μs)	14	4.5	21	10	11	2.7

Summary

Analysis of 73 comparisons between NEOS and CORE networks indicates that formal errors of EOP measurements are too small by a factor of 1.3-2.0. We have found evidence of systematic differences between the EOP measurements made by different networks. These differences appear as a statistically significant mean offsets between the EOP derived from the networks. For networks operating on consecutive days, some of this difference may be due to the interpolation between days. The source of the difference between EOP from the CORE-A and NEOS networks is not clear since these networks operate on the same day. It is possible that network geometry is producing these differences. The cause of these systematic differences is under active investigation.

References

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