SEARCH'92 CAMPAIGN: NOAA EARTH ORIENTATION RESULTS USING VLBI OBSERVATIONS

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ABSTRACT. Earth orientation results are reported for the SEARCH'92 campaign period (21 June - 22 September 1992) based on VLBI observational data analyzed by NOAA.

1. Analysis Procedures

The very long baseline interferometry (VLBI) data sets and the analysis procedures, methods, and models used by the U.S. National Oceanic and Atmospheric Administration (NOAA) have been described by Carter *et al.* (1993). The only significant difference in the analysis results presented here is the inclusion of more observational data, primarily collected during 1993. For the current solution, a total of 849,480 bandwidth-synthesis group delay observations from 1336 one-day observing sessions was included, 21.8% more than in our previous report. In general, the latest *IERS Standards* (McCarthy, 1992) are enforced and our reference frames are aligned with the IERS celestial (ICRF-91) and terrestrial (ITRF-91) frames.

Data from 14 new VLBI sites were used, including: six of the 25-m VLBA antennas, the newly erected 14.2-m antenna at Fortaleza (Brazil), the new 20-m Kokee antenna on Kauai (Hawaii, USA), a new 10-m dish at Mizusawa (Japan), and the 9-m antenna at the O'Higgins Base (Antarctica). Geocentric coordinates for all the VLBI reference points (at epoch 1988.0) are given in the file SSC (NOAA) 93R03. The associated three-dimensional velocities for these sites are given in SSV (NOAA) 93R03. Of the 69 sites, 31 have insufficient data spans (less than about 2 years) to permit meaningful velocity estimates. For those sites (denoted by velocity uncertainty values of zero), the NNR-NUVEL-1 global plate motion model (Argus and Gordon, 1991) has been used to project station coordinates to the 1988.0 reference epoch.

The number of radio source positions in our current solution, RSC (NOAA) 93R03, has increased by 45 to 152. However, most of the new sources are only sparsely observed.

Our Earth orientation parameter (EOP) time series are presented in two files. Results from the 24-hour observing sessions are given in EOP (NOAA) 93R07. File EOP (NOAA) 93R08 contains an independent series of quasi-daily UT1 values from the 1-hour single-baseline IRIS 'Intensive' observing sessions.

2. Tidal Variations in Earth Rotation

The NOAA analysis procedures to account for tidal variations in the rotation of the Earth have already been described by Carter *et al.* (1993). However, because of the significance of sub-daily tidal effects, their relevance to the SEARCH'92 campaign objectives, and the fact that this frequency regime is not dealt with in the *IERS Standards*, our methodology is repeated here.

In the least-squares modelling of the VLBI delay observables, five Earth orientation offset parameters are adjusted for each 24-hour observing session: x and y coordinates of the pole position, UT1, and celestial pole offsets in longitude and obliquity. (For the 1-hour Intensive sessions, only UT1 is adjusted.) Consequently, it is important that the time-variation of the *a priori* EOP values, apart from a possible offset error, reflect as closely as possible the actual variations of the Earth's rotation. Most significant in this respect are tidal variations with periods of about one day or less. The procedure we have developed to form *a priori* EOP values at any VLBI observation epoch is: 1) tabulated EOP values are taken from a previous NOAA solution for the set of all IRIS-A, NAVNET, and NEOS-A observing sessions (with spacings of 3.5, 5, or 7 days depending on epoch); 2) known tidal contributions based on models described below are removed from the tabular values; 3) a cubic spline interpolation is performed on the tidally corrected EOP values from the five nearest tabular epochs; 4) the model tidal contributions are restored. The models used to account for the tidal contributions are: 1) 'UT1S' tidal terms, which include periods between 5.64 days and 18.6 years with corrections due to oceanic tides for the largest terms (see *IERS Standards*, McCarthy, 1992); 2) diurnal and semi-diurnal variations of x, y, and UT1 derived by Herring (1992) based on analysis of 8.5 years of VLBI data. To minimize the effects of residual unmodelled Earth orientation variations, the EOP adjustments are made at the weighted mid-point epoch of each observing session. Non-periodic sub-daily EOP variations will be at least partially averaged out in our analysis. The EOP results reported here are 'total' values, in the sense of including the effects of diurnal and semi-diurnal variations, rather than being strongly smoothed over the 24-hour observing periods or otherwise modified after the least-squares adjustment.

Our *a priori* modelling of the time-variation of the nutation offsets follows analogously the procedure described above for x, y, and UT1. However, the ZMOA-1990.2 nutation model of Herring (1991) is used instead of a tidal model. The reported nutation offsets are with respect to the IAU 1980 model.

3. Discussion of Results

The NOAA EOP results for the SEARCH'92 period (21 June through 22 September 1992) are displayed in Figures 1-3 relative to the IERS combination series EOP (IERS) 90C04. Corrections for diurnal and semi-diurnal variations in x, y, and UT1 have been applied using the model of Herring (1992). Results from a few regional networks, with poor sensitivity to EOP variations, have not been included in Figures 1-3. The weighted rms differences, after removing mean offsets, are: 399.4 μas for x, 496.2 μas for y, 31.4 μs for UT from the 24-hour sessions only, 32.7 μs for UT from all sessions including the 1-hour 'Intensives', 594.0 μas for nutation offset in longitude ψ, and 248.6 μas for nutation offset in obliquity

ϵ. Included in these statistics are results from 62 24-hour VLBI sessions plus an additional 68 1-hour sessions to measure UT1.

The NOAA-IERS residuals are not entirely random but appear to be most systematic for UT1. Figure 1 shows periods of a week or longer with apparently systematic variations of up to about 100 μs. Considering that the results are determined from a variety of independent observing networks and that the largest VLBI technique-dependent systematic errors (such as atmospheric propagation effects) are expected to be primarily site-dependent, we conclude that the systematic residuals are caused either by: 1) deficiencies in the NOAA analysis methods or 2) excessive smoothing of UT1 variations in the IERS combination series EOP (IERS) 90C04. Comparisons of our results with independent analyses of the same VLBI data sets should determine whether the first possibility is significant.

In addition, there are occasional VLBI results that appear to be true outliers. The most obvious example is the UT1 determination from the Intensive session on 22 August 1992 (see lower plot in Figure 1). In this particular case, only one of the usual two low-declination radio sources produced useful data. Apparently, the nearly 50% increase in the formal error for that session, compared to neighboring Intensive sessions, does not fully account for the systematic UT1 error introduced by this data loss.

4. References

Argus, D.F. and Gordon, R.G. (1991) 'No-net rotation model of current plate velocities incorporating plate motion model NUVEL-1', *Geophys. Res. Lett.*, **18**, 2039-2042.

Carter, W.E., Abell, M.D., Dillinger, W.H., Morrison, M.L., Ray, J.R., and Robertson, D.S. (1993) 'NOAA Earth orientation time series and reference frames from VLBI observations: 1. Description of analysis procedures', in P. Charlot (ed.), *IERS Tech. Note 14*, IERS, Observatoire de Paris, pp. R-47 - R-52.

Herring, T.A. (1991) 'The ZMOA-1990 nutation series', in J.A. Hughes, C.A. Smith, and G.H. Kaplan (eds.), *Proc. IAU Coll. 127 -- Reference Systems*, U.S. Naval Observatory, Washington, pp. 157-166.

Herring, T.A. (1992) 'Diurnal and semi-diurnal variations in Earth rotation', in M. Feissel (ed.), *Adv. Space Res., 13*, Pergamon, pp. 11281-11290.

McCarthy, D.D. (1992) 'IERS Standards 1992', *IERS Tech. Note 13*, IERS, Observatoire de Paris, 150 pp.

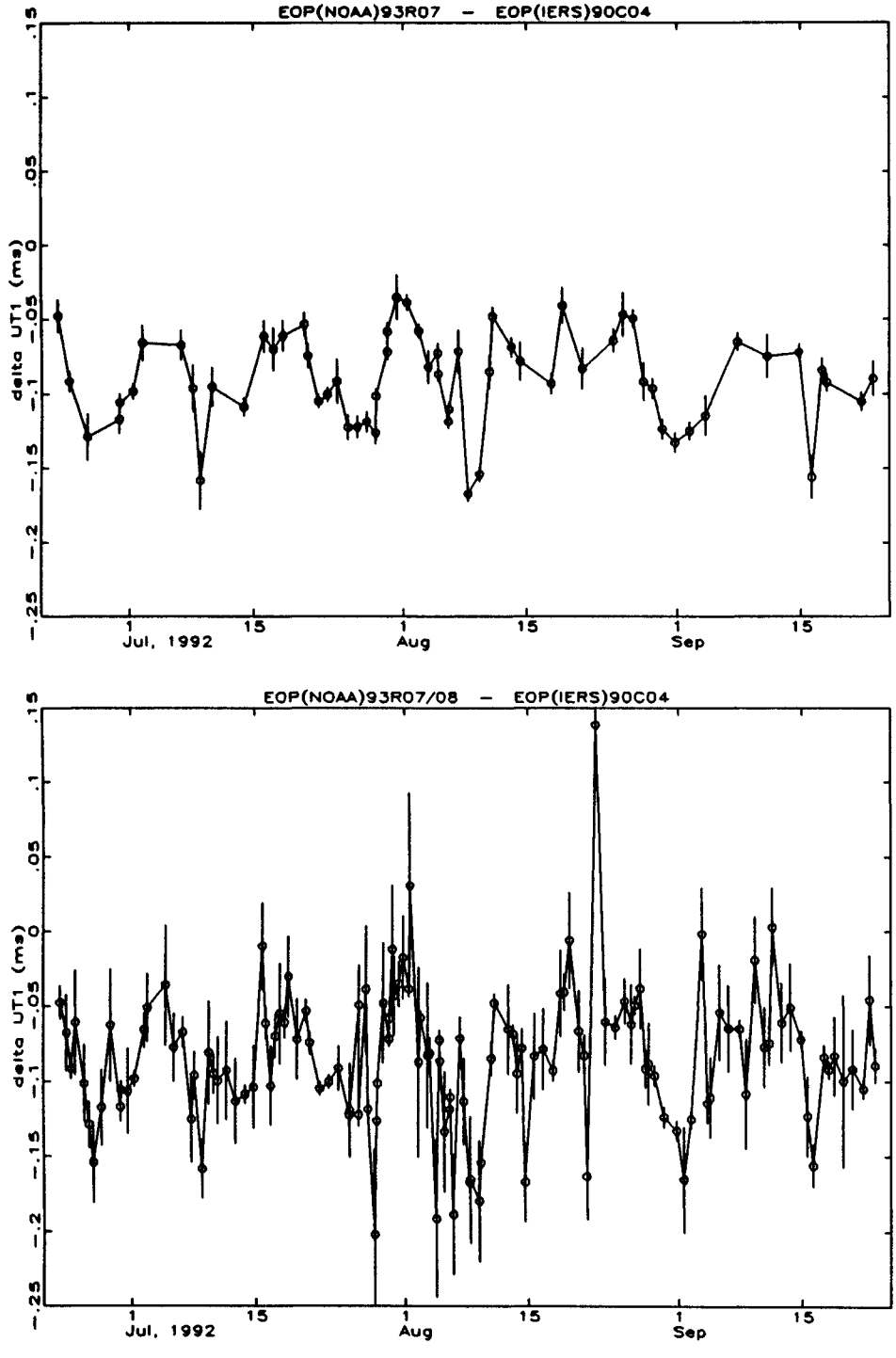

Figure 1. NOAA UT1 results for the SEARCH'92 period relative to the IERS combination series EOP (IERS) 90C04. Results for only the 24-hour sessions are shown in the top plot; 1-hour sessions are included in the bottom plot. Corrections for diurnal and semi-diurnal variations (Herring, 1992) have been applied.

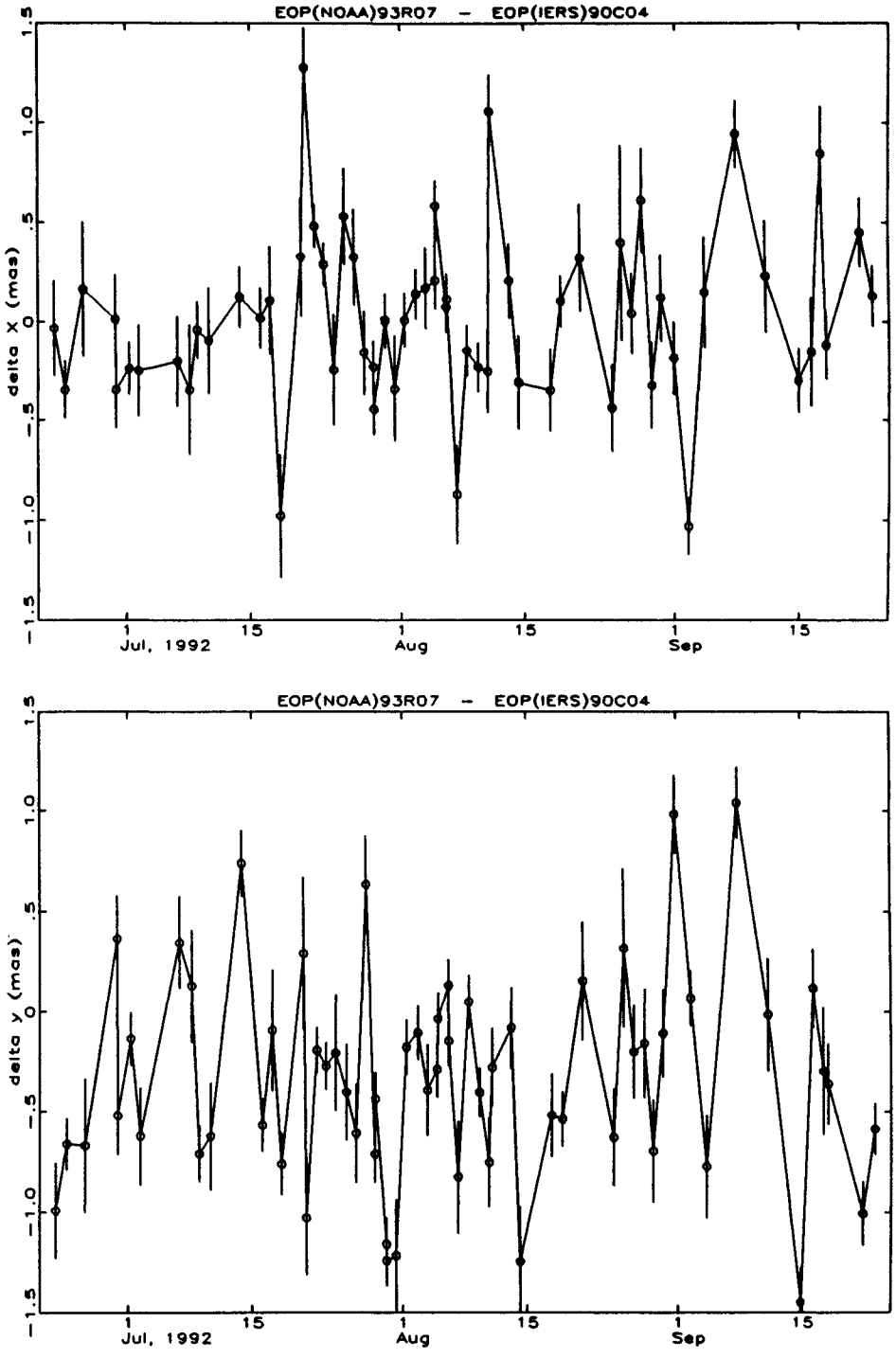

Figure 2. NOAA results for pole coordinates x (top) and y (bottom) shown relative to the IERS combination series EOP (IERS) 90C04. Corrections for diurnal and semi-diurnal variations (Herring, 1992) have been applied.

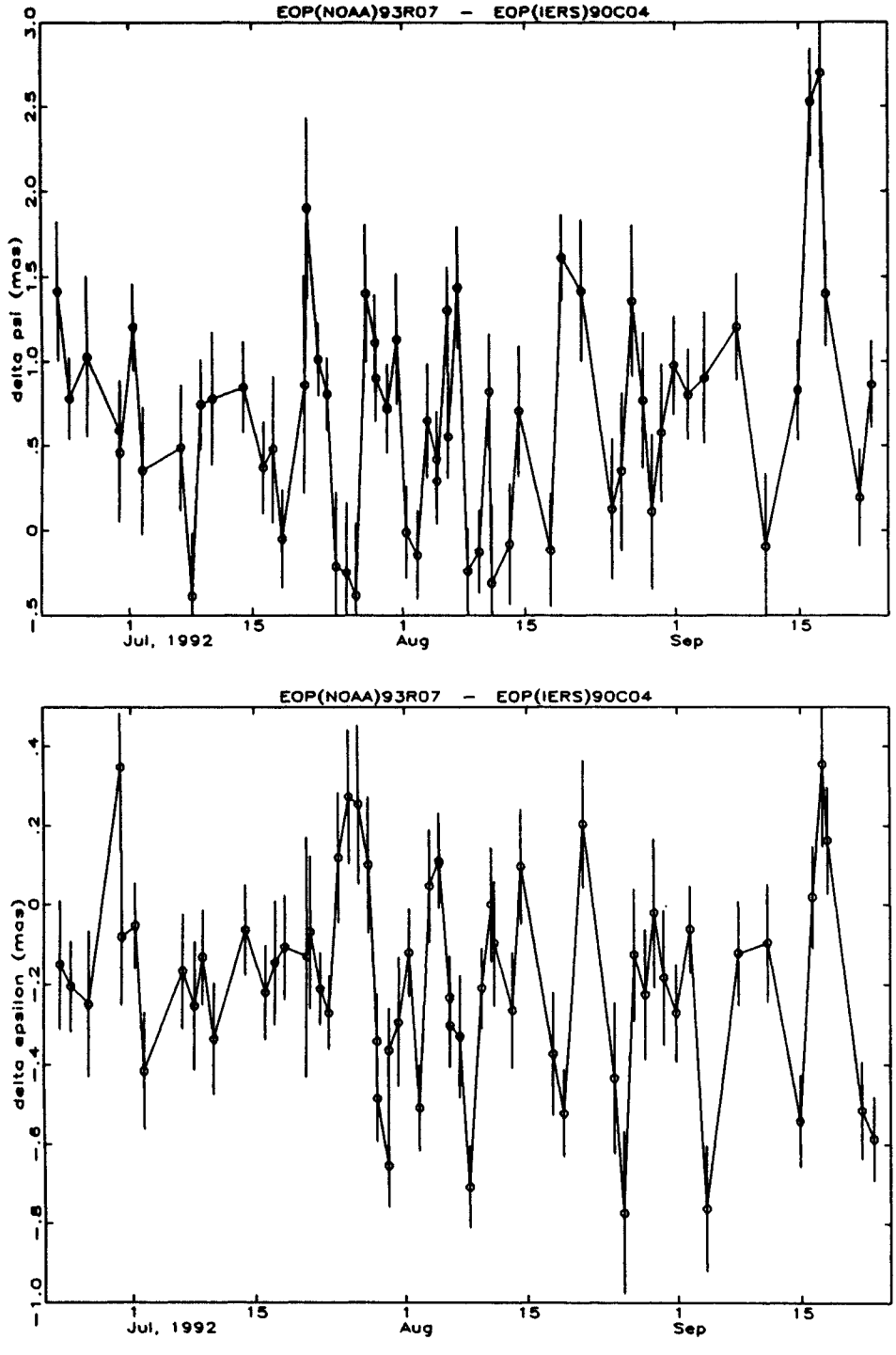

Figure 3. NOAA nutation offset results relative to the IERS combination series EOP (IERS) 90C04.

SUMMARY SHEET FOR THE DESCRIPTION OF THE TERRESTRIAL SYSTEM ATTACHED TO A SET OF STATION COORDINATES

1 - Technique: Bandwidth-synthesis Mark III VLBI

2 - Analysis Center: NOAA VLBI Analysis Center, N/OES13
SSMC 4
1305 East-West Highway
Silver Spring, MD, USA 20910

3 - Solution ID: solution rundate = 05 January 1994
IERS filenames: SSC (NOAA) 93R03, SSV (NOAA) 93R03, RSC (NOAA) 93R03, EOP (NOAA) 93R07 and 93R08

4 - Software Used: COREL and FRNGE for the Mark III data correlation;
DE200 ephemerides, CALC-7.6, and SOLVE-3 for data analysis

5 - Relativity Scale: Radio source coordinates are in solar system barycentric system;
Terrestrial site coordinates are geocentric (ignoring the local gravitational potential of the Earth)

6 - Permanent Tidal Correction on Station: No correction is applied to remove the zero-frequency displacement introduced by the solid Earth tide model.

7 - Tectonic Plate Model: NNR-NUVEL-1 is used to specify the large-scale motion of the entire terrestrial reference frame in both translational and rotational senses for nine VLBI sites (see Carter *et al.*, 1993); the same model is also used to propagate the relative positions of sites with data spans too brief to permit reliable determinations of VLBI velocities.

8 - Velocity of Light: 299792458. m/s

9 - Geogravitiational Constant: not applicable

10 - Reference Epochs: Station coordinates -- 1988 January 01
Source coordinates -- J2000.0
EOP fixed epoch -- 1991 August 12 19:49:50 UT

11 - Adjusted Parameters: XYZ geocentric station coordinates and linear station velocities adjusted globally for all sites at their mean observation epochs;
radio source coordinates adjusted globally for all sources;
pole x and y coordinates, UT1, nutation longitude and obliquity offsets adjusted for each 24-hour observing session;
UT1 is the only EOP adjusted for 1-hour Intensive sessions;
clock polynomial coefficients adjusted for all but one station in each observing session;
atmosphere offset parameters for each hour interval for each station

for each 24-hour observing session (no atmosphere parameters are included in the analysis of the 1-hour Intensive sessions)

12 - Definition of the Origin: The coordinate origin of the terrestrial reference frame is specified by setting the vector sum of the adjusted coordinates for 16 VLBI sites equal to the corresponding vector sum for ITRF-91 (see Carter *et al.*, 1993);
the right ascension origin of the celestial reference frame is specified by setting the sum of the adjusted right ascensions for 36 radio sources equal to the corresponding sum for ICRF-91

13 - Definition of the Orientation: The relative orientation of the terrestrial and celestial reference frames is specified by fixing the EOP values to those interpolated from the EOP (IERS) 90 C 04 series (corrected for the offsets and drift rates reported by the IERS to give consistency with the ITRF-91 and ICRF-91 frames) for the reference epoch 1991 August 12 19:49:50; the interpolation method is described in the text.

14 - Constraint for Time Evolution: The secular translational velocity and rotational velocity of the terrestrial reference frame are specified through constraints; see item 7 above and text.

Format Notes:

SSC & SSV files -- Instead of the DOMES information in fields 2-4, the CDP monument number is given. X, Y, and Z values and their formal errors are reported to the 0.1 mm level so that the decimal points are shifted by one column from the specified format. Instead of reporting the time span of observations for each site in field 10, the number of observations is given.

RSC file -- Fields 11 (correlation coefficient), 12 (epoch of coordinates), 14 (time span of source observations), and 15 (number of sessions for each source) are filled with 0 values.