Paris Observatory Analysis Center OPAR: Report on Activities, January - December 2008

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Abstract

We report on activities of the Paris Observatory VLBI analysis center (OPAR) for calendar year 2008. Among the main issues is the inclusion of OPAR solutions in the IVS rapid solution. We also summarize various scientific results concerning the stabilization of the celestial reference frame, the determination of the dissipative factor associated with the Earth's fluid core by the use of VLBI and superconducting gravimeters, improvements in the theory of nutation and precession, and the determination of the relativistic parameter γ from VLBI delays. OPAR continuously publishes results from routine analysis on its Web site http://ivsopar.obspm.fr.

1. Developments at OPAR

1.1. Operational Status

OPAR personnel continued to produce quarterly global solutions every three months. The corresponding Earth orientation parameter (EOP) time series were submitted to the IVS. A radio source coordinate catalogue and station coordinates and velocities were made available through the Web site. These solutions differ from other analysis centers' by the use of the 247 stable sources of Feissel-Vernier et al. (2006) as defining sources instead of the 212 ICRF defining sources as provided by Ma et al. (1998). EOP series were updated by new data as soon as new experiment data bases were released. Daily SINEX files for IVS R1 and R4 experiments were generated and submitted to the IVS. UT1 series from intensives starting in April 2006 were maintained and aligned to the ITRF 2005. Polar motion is forced by the IERS EOP 05 C 04 series. Radio source coordinate time series were updated every three months. Our Web site provides plots for sources having a reasonable number of observations.

1.2. Working Groups

OPAR members are involved in various working groups. A.-M. Gontier is a member of the IVS WG 4 and of the IAG WG 1.4.1. S. B. Lambert is chair of the IAG WG 1.4.3. Both are members of the IVS/IERS WG on the Second Realization of the ICRF.

1.3. Virtual Observatory and VOTable Data Format

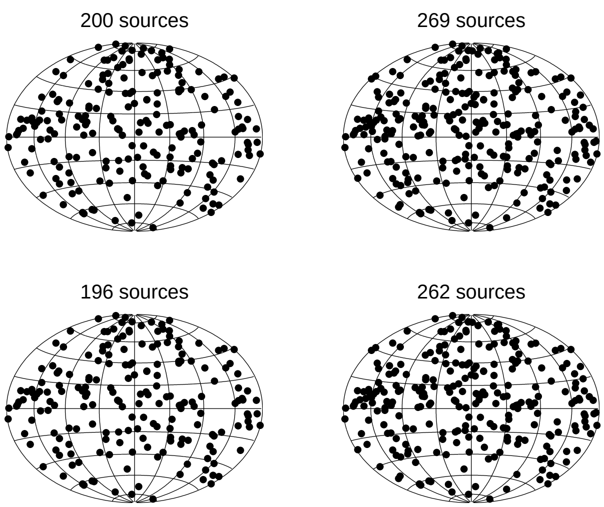
[8] summarizes the French activities in the frame of the astronomical and geodetic Virtual Observatory (VO), an international proposal that provides uniform, convenient access to disparate, geographically dispersed archives of astronomical data from software which runs on the computer on the astronomer's desktop. VOTable is an XML-based format for representing astronomical data, and that takes advantage of computer-industry standards and uses standard software and tools. VO standards had initially been developed for Earth-centered or body-centered reference frames in order to extend the VO to Earth and planetary sciences. Nevertheless, some improvements had to be made to adapt the existing VO to geodesy. We recently proposed to the International Virtual Observatory Alliance (IVOA) the adoption of new standards relevant to the Earth orientation

data. OPAR products are now provided in VOTable format using these new standards. This includes terrestrial and celestial reference frames, station and radio source coordinate time series, and EOP. Thanks to the VOTable format, the latter can directly be viewed in the VO-designed software Aladin (http://aladin.u-strasbg.fr) with which various operations can be done in a few clicks (cross-identifications, superimposition of optical images, etc.). In addition, a page that allows one to locate the observing antennas used in OPAR solutions using Google Earth has been released. Visit http://ivsopar.obspm.fr/vo to learn more.

2. Research Activities Involving OPAR

2.1. Towards the ICRF2

We actively participated in IVS WG 4 analyses. We attended the Saint-Petersburg and Dresden meetings. We developed existing and new tools to assess rotations and deformations of submitted catalogues with respect to the ICRF-Ext.2 [5], to make vectorial harmonics decomposition of these catalogues and comparative analysis of the submitted time series. Results of these analyses were made available to the working group members.



One of the goals of the next ICRF realization is to obtain a set of defining sources that is definitely more stable in time than the current 212 defining sources of the ICRF ([15]). In [6], we already presented a simple scheme, partly inspired by the work of [4], to obtain a set of core sources reaching this goal. In [12], we improved the selection algorithm and applied it to source coordinate time series obtained from the analysis of 26 years of VLBI observations.

Figure 1. Distribution of the source subsets considered in [12].

The selection criterion considered the positional rms, the slope, and the observational history of the sources. We obtained four frames made of 196, 200, 262, and 269 sources, respectively, showing a satisfactory sky coverage in both hemispheres (Fig. 1). Our selections provide a frame stability improved by up to 40% with respect to the ICRF, and by 20% with respect to [4]. Reanalysis of data with respect to this frame gives astrometric catalogues aligned to the ICRF-Ext.2 within 17 μas. Effects on EOP estimates and terrestrial reference frame determination remain marginal.

2.2. Earth's Interior

Observation of the Earth's nutation allows one to determine some properties of the Earth's internal layers. In 2007, we examined whether the VLBI analysis configuration to produce EOP could have a substantial impact on determinations of the free core nutation (FCN) and free inner core nutation (FICN) frequencies ([9]) that describe the free rotation modes of the fluid outer core and of the solid inner core, respectively. We concluded that the instability of the celestial reference frame could force one to constrain the FCN and FICN at better than 0.1 day and 100 days, respectively, which is smaller than the error that arises from the internal noise of the EOP series. In 2008, we focused on the dissipation at the core-mantle boundary (CMB) that shows up observationally in the quality factor Q of the FCN (i.e., imaginary part of the FCN frequency). The dissipation factors estimated from VLBI nutation data and from local tidal displacement measured by superconducting gravimeters were known to be in disagreement, the latter being about 30% smaller than the former, leaving open questions about the values of possible dissipative torques emerging from electromagnetic or topographic couplings at the CMB. After a wise treatment of gravimetric data (especially concerning the ocean loading correction) and the use of optimized estimation methods, we got a value close to $Q \sim 16\,000$ for both techniques ([17, 18]).

2.3. Theory of the Earth's Nutation and Precession

Theoretical formulation of the second-order contribution to the nutation of the interaction between the tidal potential and the tides arising at the Earth's surface ([7]) has been reexamined for the precession part ([11]), and extended to the axial rotation of the planet ([14]). Note that the additional terms, which emerge mainly from dissipation processes in the oceans, are at the level of current VLBI observational accuracy.

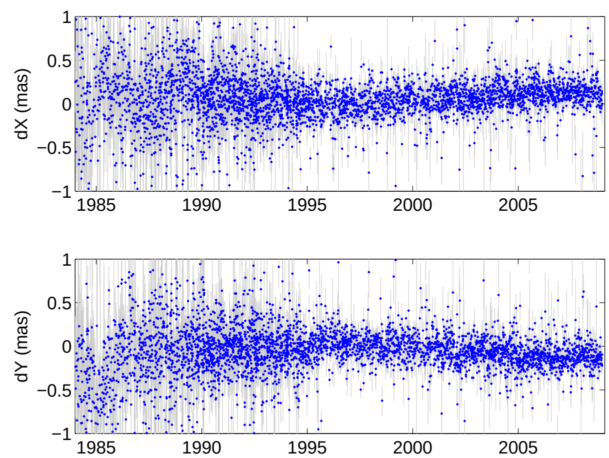


Figure 2. Nutation offsets with respect to IAU 2006 after removal of the FCN.

Fundamental aspects of the semi-analytical precession-nutation models that were adopted by IAU Resolutions in 2000 and 2006 ([16, 1]) were discussed in [2, 3]. In these studies, we also reported on the most recent comparisons of the models with VLBI observations (Fig. 2). We showed that a combination of linear and 18.6-year corrections is the most credible model for explaining the currently observed residuals, but that a longer span of observations is required before the true character of the effect can be determined.

2.4. Test of Relativity

Relativistic bending in the vicinity of a massive body is characterized by the post-Newtonian parameter γ within the standard parameterized post-Newtonian formalism, which is unity in General Relativity. We retrieved γ from the analysis of geodetic VLBI observations recorded since 1979. We compared estimates of γ and errors obtained using various analysis schemes including global estimations over several time spans and with various Sun elongation cut-off angles, and analysis of radio source coordinate time series. We concluded that γ cannot be estimated at better than 2×10^{-4}. The main factor of limitation is the uncertainty in the determination of radio source coordinates. A sum of various instrumental and modeling errors and analysis strategy defects, that cannot be decorrelated and corrected yet, is at the origin of the limiting noise ([10, 13]).

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