PROGRESS IN THE 2ND REALIZATION OF ICRF

C. MA[1]
[1] Goddard Space Flight Center
Code 698.0
8800 Greenbelt Road, Greenbelt, Maryland, 20771, USA
e-mail: Chopo.Ma@nasa.gov

ABSTRACT. The ICRF derived from VLBI observations of extragalactic radio sources up to 1995.6 and effective since 1998.0 was a radical change from the FK5 stellar/equinox celestial system. The number of geodetic/astrometric VLBI observations has since tripled and the number of radio sources with astrometrically useful data has quadrupled. A systematic program for monitoring astrometric sources has been established although the available observing capability limits this to only a fraction of all such sources. Advances in modeling, generation of source position times series, and greater availability of source structure information will permit the identification of better "defining" sources. The VLBA Calibrator Survey will provide a large number of additional sources although most are observed at only one epoch. Working groups have been established by the IAU, IERS and IVS with the goal of presenting the second realization of the ICRF at the IAU General Assembly in 2009.

1. INTRODUCTION

The ICRF (International Celestial Reference Frame) was adopted by the IAU in 1997 and became the formal basis for celestial positions from 1 January 1998. The ICRF catalogue was derived from VLBI data and analysis available in mid-1995. The catalogue was extended in ICRF-Ext.2 (Fey et al. 2004) using data through 2002, and the positions of the non-defining sources were improved. See figure 1. The axes of the frame were left unchanged since the positions of the 212 defining sources were retained. Since 2002 the data set and analysis have improved considerably, and several steps have been taken towards the second realization of the ICRF.

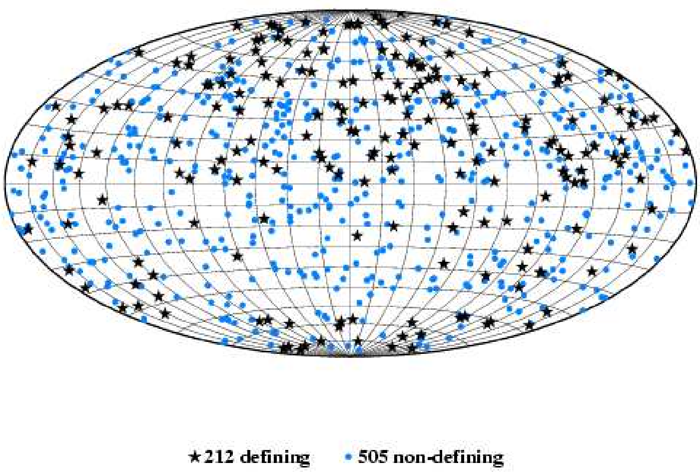

Figure 1: ICRF Ext.2 Sources

2. DATA CONSIDERATIONS

The balance of the global VLBI observing program for geodesy and astrometry has always been heavily weighted towards geodesy, in large part because the geodetic parameters such as EOP (Earth Orientation Parameters) and station positions are constantly changing and require regular monitoring. The radio sources observed for these purposes have changed over time and were selected for being relatively strong, compact, and well distributed at the particular time. However, since geodetic observing sessions generally now use only 50 to 60 sources (the earliest sessions used fewer than 20 very strong sources), the geodetic catalogue has only ∼100 sources, a small fraction of the sources with useful astrometric positions. The geodetic sources do have many epochs of observation, some extending more than 20 years. The geodetic catalogue does not include many defining sources (see Figure 2), and some geodetic sources do not have stable positions according to the analysis by Feissel-Vernier (2003). (See Figure 3). In order to improve the data for the ICRF, a CRF monitoring program was begun in 2004 to observe stable, potential stable, and defining sources at least semi-annually. (See Figure 4). This goal has generally been met for the defining sources. (See Figure 5).

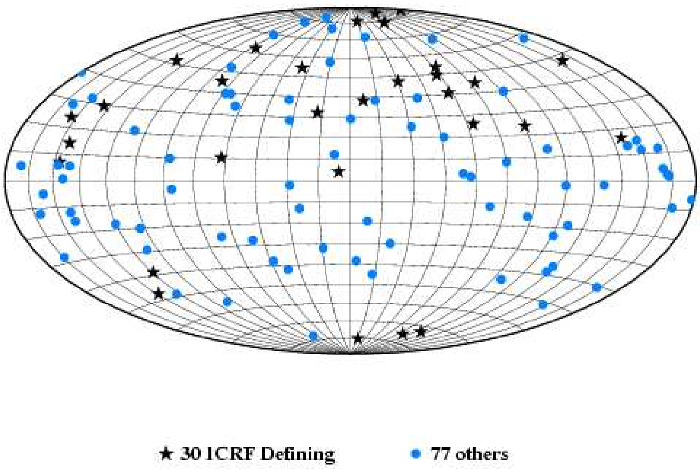

Figure 2: Geodetic sources.

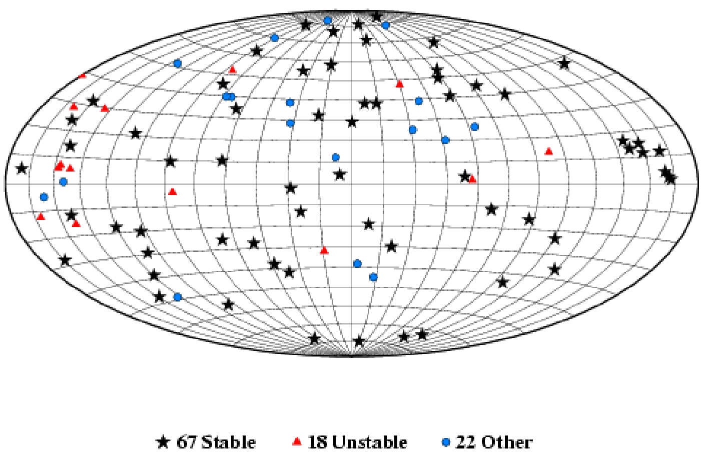

Figure 3: Geodetic source stability.

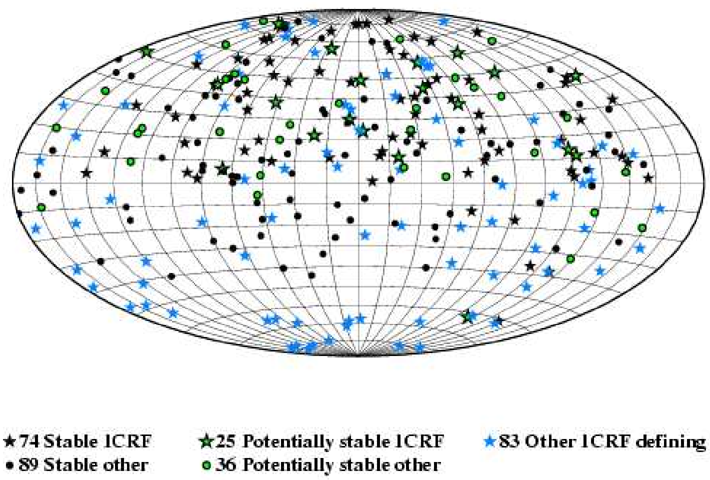

Figure 4: Total CRF monitoring sources.

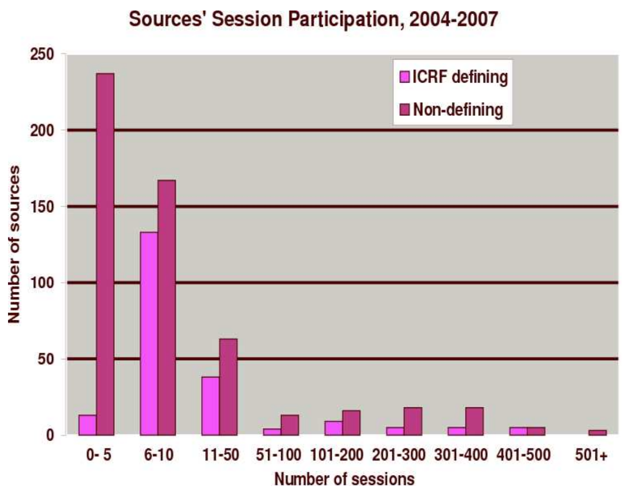

Figure 5: Sources' session participation, 2004—2007.

3. GENERATION OF SOURCE POSITION TIME SERIES

Although radio sources observed for geodesy and astrometry are relatively compact, they are not ideal points. All sources have some degree of structure, which is astrometrically benign if radially symmetric. However, there is clear evidence that some source positions can vary with time at the level of precision achieved with VLBI while others are quite stable. (See Figure 6). The generation and analysis of position time series is therefore an important factor for the analysis of the next realization of the ICRF.

As part of the work of the IERS/IVS working group for the second realization of the ICRF, several VLBI analysis centers have generated source position time series. (See Table 1). Different strategies were used to decide how a source position was defined or estimated at a particular epic, what sources, if any, were adjusted as global parameters, i.e., a single position averaged over the entire data set, and how the reference frame was established. It is impossible to estimate the position of every source in a given session without some type of constraint. For most analyses, some set of sources was estimated globally. Then the position of each of the remaining sources was estimated in the sessions in which it appeared. Alternatively for a single session all positions were estimated with no-net-rotation and no-net-translation conditions. The choice of globally adjusted sources had two variations, either only stable sources or some fraction of all sources chosen for uniform sky distribution. To get time series for all sources it is necessary to treat globally adjusted sources in one solution as non-global sources in another solution. The reference frame for time series was set by the ICRF defining sources or by a set of sources with stable positions.

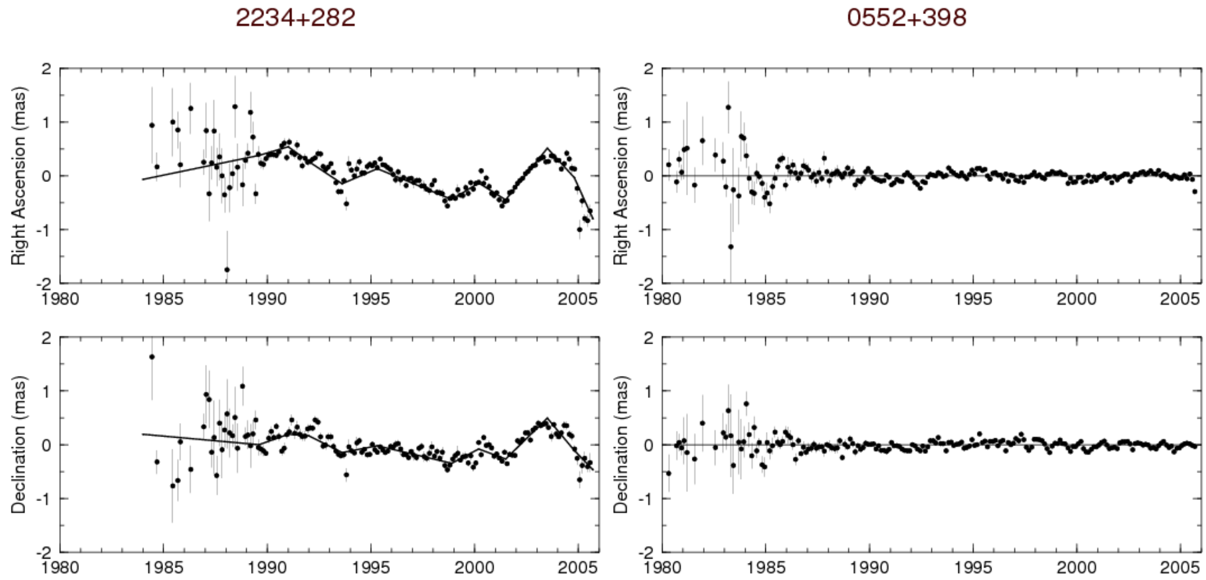

Figure 6: Examples of sources with unstable (left) vs. stable (right) positions.

Table 1: Centers that generated source position time series.

Geoscience Australia
Paris Observatory
BKG (Germany)
DGFI (Germany)
Institute of Applied Astronomy (Russia)
Main Astronomical Observatory (Ukraine)
Goddard Space Flight Center (USA)
U. S. Naval Observatory

Another variable factor was the choice of data. Some series were generated using all data from 1979-2007 while others restricted the data by date (as earlier data are not as good for various reasons) or by minimum network size or number of observations per source in a single session.

4. ANALYSIS OF TIME SERIES

Work has begun in comparing the time series to determine how to generate series that best characterize the actual variability of source positions given the extreme heterogeneity of the overall data set.

The time series will provide basic information to guide analysis for the next ICRF. On one hand, time series will be used to decide which sources have so high a level of systematic or random position variation that they should not be treated as having a single value over the entire time span of the data. On the other hand, defining sources must have small position variations. There are several factors that complicate the analysis. First, there is a wide range of the number of epochs in the time series but only the small number of geodetic sources have dense time series. This disparity is somewhat mitigated by the CRF monitoring program since 2004, but this interval is only a small fraction of the overall time span. Second, the observing sessions are irregularly spaced in time, so measures that require even spacing such as Allan variance are difficult to apply. Third, the quality of the data varies with source declination, a reflection of the dearth of observing stations and time in the southern hemisphere.

Consequently the visual and statistical tests that are applicable to the geodetic sources will need to be carefully adapted to the majority of sources with many fewer points. Likewise the criteria for selecting the defining sources may need to be modified, particularly in mid-southern declinations, in order to have a sufficient number in all parts of the sky.

5. ISSUES FOR THE SECOND RADIO ICRF

The most important point is to improve the selection of defining sources based on time series analysis and supplemented by source structure information. On the other extreme estimating variable positions for some sources should be refined over the method used in the first ICRF in order to extract the most information for the ICRF and for other parameters estimated simultaneously including EOP and TRF. The geophysical and astronomical modeling has improved significantly in the last decade, particularly for the troposphere. These improvements must be included in the ICRF analysis. The effects of station-dependent correlated errors and elevation-dependent errors on CRF parameters need to be studied. Since the intrinsic data quality has improved in terms of instrumental sensitivity and network geometry over time, it may be better to discard some early or small network data that are particularly noisy. However, a significant part of the data for the south is from single baseline or small network sessions, so judicious data selection will be required. Finally it must be decided how the final ICRF catalogue will be derived, e.g., a single solution or a rigorous combination.

6. REFERENCES

Feissel-Vernier, M., 2003, "Selecting Stable Extragalactic Compact Radio Sources from the Permanent Astrogeodetic VLBI Program", A&A , 403, pp. 105–110.

Fey, A.L., Ma, C., Arias, E.F., Charlot, P., Feissel-Vernier, M., Gontier, A.-M., Jacobs, C.S., Li, J., MacMillan, D.S., 2004, "The Second Extension of the International Celestial Reference Frame: ICRF-Ext.2", AJ , 127, pp. 3587–3608.