

## Summary of the Fifth IVS Analysis Workshop

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### Abstract

On February 12, 2004, the Fifth IVS Analysis Workshop was held at the Lord Elgin Hotel at Ottawa, Canada. The one-day meeting was attended by almost 60 participants. Here, a short summary of the discussion topics and the most important results are given.

On invitation of the National Resources Canada's Geodetic Survey Division the Fifth IVS Analysis Workshop was held in conjunction with the Third IVS General Meeting at the Lord Elgin Hotel at Ottawa, Canada, on February 12, 2004. Almost 60 participants attended the meeting which was, more than ever, driven by many fruitful discussions. The program of the meeting contained a number of important parts of routine and scientific data analysis with many more aspects being raised during the discussions. This summary can, however, reflect only the general headlines of the workshop.

### 1. Implementation of IAU2000 Resolutions

Nicole Capitaine presented the latest developments with respect to the IAU2000 Resolutions and its effects on earth orientation parameters (EOP). The new paradigm will make the transformations easier to understand and will be a necessary innovation for improvements in UT1 determinations.

It became clear that a change to the new paradigm of the celestial pole modeling will also have an effect on the current UT1 time series itself. Currently, nutation offsets relative to IAU1980 are just transformed into celestial pole offsets relative to the IAU2000 model. However, until VLBI analysis software packages treat the parameter estimation completely consistent with the IAU2000 resolutions, also UT1 has to be transformed accordingly. In order to keep the set of EOP consistent a transformation of the estimated UT1 values has to be applied taking into account the differences in the old and the new formulation of the Equation of the Equinoxes. This difference is unofficially called the Equation of the Origins.

Currently, geodetic VLBI data analysis software packages are being modified to include the paradigm of the IAU2000 Resolutions. For the Calc/Solve software Calc 10.0 will be released in about three months, for OCCAM the modifications are also underway. GLORIA and Steelbreeze are operational in this mode already for some time while MODEST will need some more time to be converted.

### 2. IVS Tropospheric Parameters and Tropospheric Mapping Functions

For some time now the Institute for Geodesy and Geophysics of the Technical University of Vienna (IGG) has been computing and disseminating the official IVS tropospheric parameters. So

far the series had been restricted to include only the IVS-R1 and IVS-R4 sessions. IGG is now preparing the extension of its routine processing to all IVS observing sessions. A call for proposals has been issued for IVS Analysis Centers to respond to by May 31, 2004.

Another issue related to the troposphere is the fact that met sensors have failed occasionally at some sites and surface met data has, therefore, not been available in the respective databases. These gaps in the data should be filled as soon as possible. Johannes Böhm has volunteered to extract this data from the ECWFM files if somebody will provide the epochs and the stations where the surface met data is missing. In addition, a volunteer is also needed to enter the met data in the databases.

It was noted that modeling the troposphere of Mauna Kea (VLBA) which is about 4000 m above sea level is particularly troublesome and the continuous fraction form of current mapping functions seems to fail. It was suspected that this is caused purely by the hydrostatic component since water vapor should be at a minimum at this altitude.

### 3. IVS EOP Combinations

The current status of the two IVS combined series was presented. The “rapid” series started on January 1st, 1999, and, by now, contains 357 data points (NEOS-A and IVS-R1/-R4 resp.). This series is updated on a weekly basis. The second series is the so-called quarterly solution which contains all sessions suitable for EOP determination (3080 data points). A comparison to IERS C04 shows that the precision of the rapid series is around 100  $\mu$ as for each component (3mm on the earth’s surface). One of the major problems which still has to be solved is the treatment of two sessions on the same day (e.g. NEOS-A and CORE-A or IRIS and western (eastern, central) Pacific networks).

Some additions to the paper presented at the 3rd IVS General Meeting [4] were presented. Two additional series (St. Petersburg University (SPU), Main Astronomical Observatory, Kiev (MAO)) have been incorporated in the investigations of the correlations between IVS Analysis Centers. It has been shown that the MAO EOP solution provides a high degree of independence from other EOP series mainly due to the fact it had been generated with the Steelbreeze software (S. Bolotin). For this reason, the solution submitted by MAO should routinely be used in the combination.

Daniel Gambis of the IERS Product Center for EOP stated that the IVS combined EOP series will only be included in the routine IERS combination if it also includes the IVS Intensive Series and if the data points are provided in a more timely manner.

### 4. Consistency of CRF, EOP and TRF

An extensive discussion centered around the issue of a consistent solution of the celestial reference frame (CRF), earth orientation parameters (EOP) and the terrestrial reference frame (TRF). The background is that the ICRF and its extensions were generated with a special setup which is optimized for the determination of radio source positions only.

Recently, several solutions have been generated estimating CRF, EOP and TRF in a consistent way. A critical point here is the correct modeling of non-linear station behaviour and of apparent proper motions of some of the radio sources. In order to validate these “complete” solutions a concerted effort has to be started to analyse the resulting radio source catalogues and compare them to the ICRF.

For phase referencing applications consistency between CRF, EOP and TRF is an essential issue. Craig Walker of the VLBA expressed the general wish of the astronomy community that IVS produces reference frames and links them with consistent EOP. Regular updates with daily EOP values would be of great help since the current unequally spaced series are not suitable for their routine operation.

Since there are currently three independent entities, the ICRF, the ITRF2000 and the IERS EOP series, it is a political question of what to change in order to arrive at a consistent set of geometric relationships.

## 5. Free Core Nutation

A proposal was brought forward by Zinovy Malkin to make Free Core Nutation (FCN) parameters products of the IVS since geodetic VLBI is the only technique to observe this phenomenon. The quality of current time series of nutation offsets seems to a good basis to start such a product, even more so because the MHB2000 Nutation Model includes this contribution only on an empirical basis. Since it is based on observations until 2000 it is degrading rapidly since then. There was a strong vote for this proposal and it was decided that an Analysis Working Group will be established to discuss the procedures.

## 6. Height Corrections

The height positions of VLBI antenna reference points are known to be affected by several phenomena. With ever increasing observing and analysis accuracy these effects have to be taken into account rigorously.

- Atmosphere Models

The use of a simple annual model for the hydrostatic mapping function, as given by NMF for example, still leaves significant height error at annual and semi-annual periods, in addition to the shorter term noise associated with weather systems. The annual amplitude can be up to 8 mm (for 5 degree minimum elevation), as judged by comparison with the IMF mapping function, which is based on numerical weather model analysis. The semi-annual amplitude is about half of the annual amplitude. With the increased interest in assessing seasonal effects, for example to determine the signal that might be due to hydrological loading, it is imperative that the most accurate atmosphere models be used, including both the mapping functions and pressure loading corrections. Two mapping functions are available that are based on a Numerical Weather Model, IMF [3] and VMF [1]. IMF offers the advantage that an a priori hydrostatic gradient may be removed, leaving primarily an estimate of the gradient attributed to water vapor, while VMF is about a factor of two more accurate in the azimuthally symmetric hydrostatic mapping function. Since the height errors due to both IMF and VMF are considerably smaller than the sum of other error sources, the improvement in the repeatability of VLBI baseline lengths, compared to using NMF is similar but very significant [1].

- Antenna Thermal Deformatiion

A database of antenna dimensions for modeling thermal deformation effects is available at the IVS Analysis Coordinator's web page (<http://giub.geod.uni-bonn.de/vlbi/IVS-AC>). So far

the respective parameters of a few telescopes are still missing and the Analysis Coordinator asks for input by anyone who can provide this information.

In addition, Onsala has an invar rod and Wettzell an invar wire to routinely measure the height variations continuously. The equipment and results were presented as very good examples of how to establish such devices at other telescopes as well. However, wheel and track antennas may need different setups since they do not have easily accessible mount points.

Although the measurements at Onsala and Wettzell have been carried out already for a long time no standardized method of including this data in the VLBI data analysis has been developed yet.

- **Local Hydrology**

A talk given by Shigeru Matsuzaka at the General Meeting about height changes at Tsukuba emphasized the importance of monitoring local hydrology in the form of ground water table heights.

- **Gravitational Loading**

Since gravitational loading is a phenomenon which also effects the results of other techniques like SLR and GPS and since the IERS has a separate Special Bureau for Loading it became clear that IVS should not proceed with developing its own approach. The decision on a reference pressure value (or values) for atmospheric loading, as an example, was, thus, postponed and the IERS will be asked for advice.

All these effects should be tabulated in some form or other for easy integration in the VLBI analysis chains. In order to prepare the respective procedures and file formats, a small Analysis Working Group will be established.

## 7. IERS Combination Pilot Project

The Analysis Coordinator outlined the call for proposals of the IERS Combination Pilot Project which was issued by the IERS Analysis Coordinator and the IERS Working Group on Combination. The Pilot Project aims at generating EOP which are consistent with the ITRF and the ICRF using datum-free SINEX files as input. The services, IVS, IGS, ILRS and IDS, are called to contribute “weekly” SINEX files which have been combined from input files of technique analysis centers. In this context “weekly” is one file per week from the satellite techniques and one file per session from IVS. From the SINEX files generated for each technique, IERS Combination Centers are planned to generate inter-technique combinations. The main products of the Pilot Project are time series of EOP, time series of station coordinates and possibly, at a later stage, also time series of source positions.

## 8. Assorted Analysis Topics

Leonid Petrov prepared a list of currently unsolved problems in geodetic and astrometric VLBI data analysis. A few very important ones are listed here:

- **Expansion analysis to the level of phases and amplitudes** per channel, per accumulation period (AP), down from the level of normal points. Most important advantages:

taking into account ionosphere contribution to delay at the AP-by-AP basis; solving G-code problems, computation of realistic errors of the estimates of group delays.

- **Automation of analysis** of log-files, including extraction of system temperature, post-correlator output and operational data analysis.
- Development of the technology of analysis of **observations of other types** than 24 hour sessions of R4-type and 1.5 hour Intensive-type sessions: differential VLBI, astrometry of weak objects, space navigation, etc.
- Modeling of **source structure delay**.
- Investigation of **errors caused by polarization leakage** and developments of methods for their calibration.
- Application of a model of **spurious signals in phase calibration** for routine data analysis.

## 9. Miscellaneous

- Oleg Titov presented his investigations in degree-1 load moment deformation.
- Anne-Marie Gontier reported on progress of developing code for the implementation of the PIVEX format (Platform Independent VLBI Exchange Format, [2]).
- A location for the next IVS Analysis Workshop early in 2005 has not been fixed yet and suggestions are still very welcome.

## 10. Acknowledgements

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