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Dissemination of SLR data-related products through a Virtual Observatory

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Abstract. *This paper presents the astronomical so-called Virtual Observatory (VO), and gives some examples of Webservices hosted by GRGS Analysis Center webpages, that can be used for Earth sciences applications, and for SLR station operations, that we developed during 2012 and 2013. In this paper, we pay a particular attention on (i) Space Station Coordinates time series deduced from SLR, DORIS and GPS data, (ii) EOP time series deduced from SLR and VLBI data, (iii) SLR station biases.*

Introduction

As an official Analysis Center of the ILRS, we were asked by our institutions to write some webpages displaying the products that we are building and delivering to the Data Centers on a routinely basis. For several reasons that we explain in this paper, we chose the framework of the Astronomical Virtual Observatory. As mentioned on the *International Virtual Observatory Alliance* (IVOA) website (http://www.ivoa.net), the IVOA was formed in June 2002 with a mission to "facilitate the international coordination and collaboration necessary for the development and deployment of the tools, systems and organizational structures necessary to enable the international utilization of astronomical archives as an integrated and interoperating Virtual Observatory. The work of the IVOA focuses on the development of standards. Working Groups are constituted with cross-project membership in those areas where key interoperability standards and technologies have to be defined and agreed upon. The Working Groups develop standards using a process modeled after the World Wide Web Consortium. Recommendations are ultimately endorsed by the Virtual Observatory (VO) Working Group of Commission 5 (Astronomical Data) of the International Astronomical Union (IAU). GRGS now routinely delivers geodetic products to most of the space geodetic services of the International Association of Geodesy, some of these products being natively archived following the data format recommended by IVOA, the VO-Table format, an improved version of the XML format.

Several independent Java-based tools have been developed in the VO framework, that can be used in geodesy and more generally in Earth's Sciences. These tools can either be downloaded and set up in PCs as Java applications, or used through a web browser as Java applets. We address here the results of our recent effort to develop with SLR data such tools based on VO, to make them be available by the whole SLR community.

1. Basic principles of the Virtual Observatory

VOTable is the XML-based format for representing astronomical data, recommended by IVOA (e.g. catalogues, as tables of the properties of celestial objects, celestial coordinates, brightness etc.). The VO-Table format has been defined in terms of XML in order to take advantage of computer-industry standards and to utilize standard software and tools. Also, astronomical tables are rich in *metadata*, which in this context means annotation, interpretable by either computers or humans, both of the tables and the individual columns that they contain. It is important to keep in mind that these metadata should be preserved with the table and the VO-Table has features to permit this. It is crucial to point out the fact adopting the VO-Table format does not mean giving up of its own data format: the VO-Table format can encapsulate existing files and simply supplies metadata to understand its content and facilitate data exchanges.

There exists several software packages to treat metadata files, but the so-called "Virtual Observatory", as an ensemble of VO-Table-based software packages, is now widely used within the astronomical community, by several thousand users worldwide. The Virtual Observatory takes advantage on the notion of *Unified Content Descriptors* (UCD) to be inserted into metadata files to describe the data, following the self-descriptive format VO-Table based on these standards and XML (Figure 1).

Figure 1. Example of a VOtable file: ILRS station coordinate time series. First part: header of the time series (describing the content of 7 columns).

The main difference between VOtable and XML files lies in the use of UCD. As a consequence, many tools already exist to manage, plot or analyze data supplied in VO-Table format, and are well-documented on the web: visualization tools, UCD finders, automatic transformation script from and to each usual data format etc…Converting ones own data in VO-Table format is the

only required step to benefit of all existing tools, some of them providing a conversion from unformatted data files into the VO-Table format, as well. As a consequence, data will be described non-ambiguously, ensuring further exchange and better understanding between different scientific communities.

VO standards have been developed for Earth-centered or body-centered reference frames in order to extend the VO to Earth and planetary sciences. They now contain as well terms that can describe all the products built by the ILRS community (polar motion, UT1—UTC, etc.). As it can be seen Figure 1, a VOtable file contain all the information related to the references of the data, in terms of space and time reference frames, units of the various quantities appearing in the files, number of significant digits etc… and a Data Model is specified (here: the Space and Time Coordinate, STC, Data Model).

2. GRGS on-line tools to compare time series provided by GRGS ACs

The project that we develop seems to be quite similar to other webpages provided by other ACs, but our starting point is a "VO" approach, that enables to easily compare the same kind of products obtained from different techniques, such a the polar motion. A WG was formed inside GRGS to make results be comparable, and data format compatible.

Two main tools were developed:

- Plottool for time series analysis (Figure 2);

- Mapshup for network selection (Figure 3), with different criteria (technique, number of data per week…).

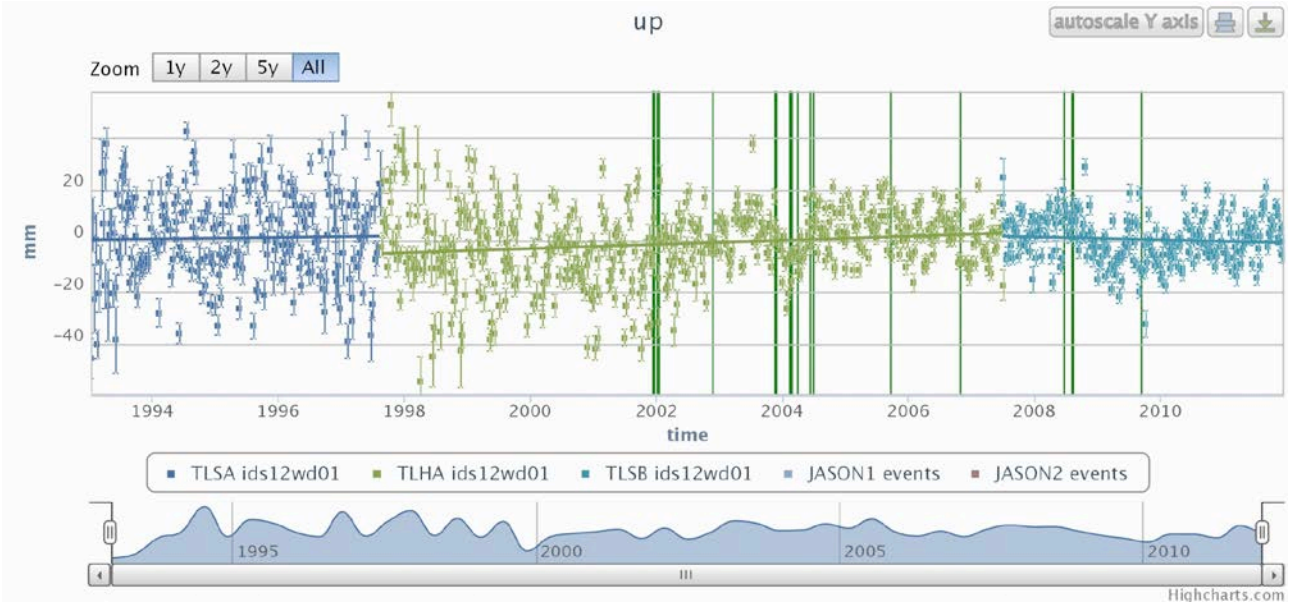

Figure 2. Example of a coordinate time series provided by IDS @ CLS, containing additional information (here: satellite events): http://ids-doris.org/plottool/stcd/stcdtool.php

Figure 3. Station and network selection with Mapshup

Figure 2 shows an example of a DORIS station, with different information displayed on the same figure: time series of differences of coordinates with respect to ITRF, superimposed with satellite events, that can explain some strong changes (drifts, gaps, jumps, etc…) in the time series. Such a tool could be of great interest for the AWG, and such a tool for SLR is under construction on the GRGS ILRS AC website (see hereafter).

Another capability of that time series comparison tool is the superimposition of time series of a same quantity, to analyze in an easy way the differences between them, as well as some additional information such as statistics, that are performed automatically.

What is important to keep in mind is that metadata have to be preserved along with the tables, in a dedicated database, a metadata being defined as "all the framework description of the data" (reference frame, units etc…).

3. The GRGS ILRS Analysis Center Website

A prototype (written in French, up to now) is now on line as the official GRGS ILRS Analysis Center at: http://vo.imcce.fr/slr-ac/ Its development is still under progress.

The following quantities can be plotted, and compared, at least for the operational weekly solution, and some of the reanalyses that we provided to the AWG as the results of Pilot Projects:

- Time series projected into a homogeneous reference frame: weekly Helmert transformations w.r.t. ITRF2008
- ASCII and .vot files provided
- Stations; SSC and biases
- Helmert transformation parameters: translation, rotations, scale

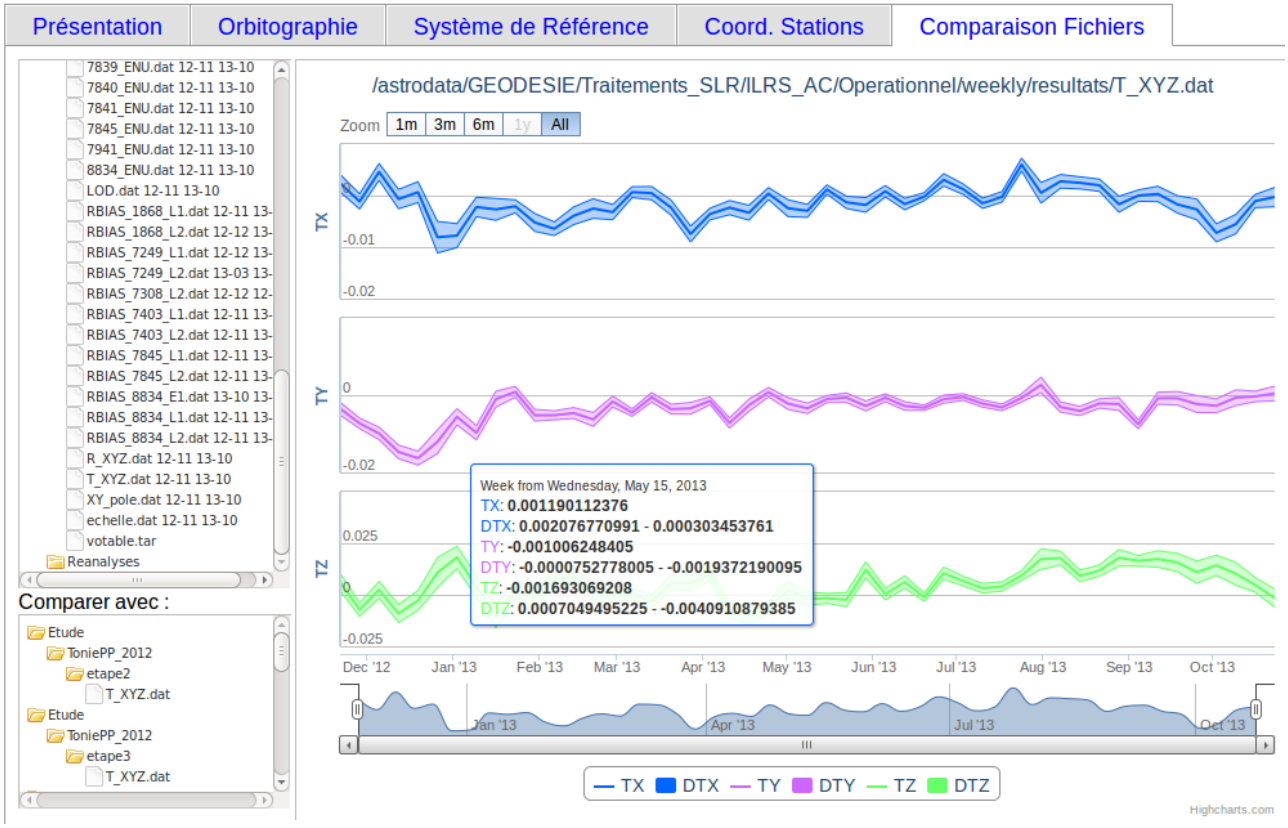

Figure 4. What is available on http://vo.imcce.fr/slr-ac/

Conclusions

The systematic use of approaches such as the VO is likely to be generalized in the next few years within various scientific communities, and the « space geodesy » community in particular. We think that projects such as the GGOS projet should investigate to what extent they can follow, or not, the recommendations provided by IVOA (namely: the VO-Table and associated web services).

The “space geodesy” community could benefit from the VO concept mainly through two points. On the one hand, the concept of metadata (following or not the recommendations provided by IVOA) permits to gather up in a single file some data together with a description supposed to be exhaustive. This means, for example, that a user can immediately know, when comparing station coordinate time series, if these time series are expressed with respect to an homogeneous and compatible reference frame. If not, and this is the second point to be reminded of, this user can easily transform these time series through web services –providing an interface with classical geodetic software, running on local computers where the web service is set up –, to make these time series compatible.

To our opinion, such tools can give an extraordinary visibility of all data and products built by the ILRS community, and can reinforce in a strong way the links between the Analysis Working Group and the station network. Both corner stones of the SLR technique could discuss in “real time”, and it is nice to see that several groups started to develop web services inside the AWG.

Obviously, the VO-Table format is not mandatory for such a goal, but “only” a very efficient solution, anyway.

Many new applications can be expected using VO concepts in geodesy and associated fields. It should be very well adapted to use existing tools such as VOPlot, and Top-cat, devoted to data plotting and cross identifications, with SLR data. It would be very challenging to use in our context other tools originally developed for celestial bodies, such as the Aladin software package, an interactive software sky atlas allowing the user to visualize and manipulate astronomical images in multi-wavelength, superimpose entries from astronomical catalogues and so on.

Web links

Here are some VO resources:

The International Virtual Observatory Alliance web site: http://www.ivoa.net

The IERS/ICRS Product Center: http://hpiers.obspm.fr/icrs-pc

GRGS: http://grgs.obs-mip.fr/

GRGS ILRS Analysis Center: http://vo.imcce.fr/slr-ac/

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