Dissemination of SLR data-related products through a Virtual Observatory: developments 2014-2015.

Florent Deleflie[1] **Laurent Soudarin**[2] **Christophe Portmann**[3]
Jérôme Berthier[1] **Christophe Barache**[4] **David Coulot**[5,1]
Sébastien Bouquillon[4] **Xavier Collilieux**[5]

1-**IMCCE** - Institut de Mécanique Céleste et de Calcul des Ephémérides / GRGS, Paris, France
2-CLS, Toulouse, France 3- Observatoire de la Côte d'Azur, France
4- Observatoire de Paris/SYRTE, GRGS, Paris, France 5- IGN/LAREG, GRGS, Université Paris Diderot,Paris, France
Corresponding author: Florent.Deleflie@imcce.fr
http://vo.imcce.fr/slr-ac/ http://grgs.obs-mip.fr

Abstract

This poster presents the tools that we develop on the GRGS ILRS AC website in the framework of the so-called Virtual Observatory (VO). They can be used for Earth sciences applications, and for SLR stations operations. 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. GRGS now routinely delivers geodetic products to most of the space geodetic services of the International Association of Geodesy. Some of these products are now natively archived following the data format recommended by IVOA, the VO-Table format, derived from the XML format.

1. What is the Virtual Observatory?

Virtual Observatory (VO) is an ambitious international proposal to provide uniform, convenient access to disparate, geographically dispersed archives of astronomical data from software which runs on the computer on the astronomer's desktop. The VO could be of interest for the geodetic community: we present here some of our efforts in this direction that we have recently achieved.

Astronomers using that Virtual Observatory are now organized within an international association called the International Virtual Observatory Alliance (IVOA). As noted on the IVOA website, 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."

Figure 1: *IVOA logo*

Visit the IVOA Website !
http://www.ivoa.net/

2. Why choosing the Virtual Observatory?

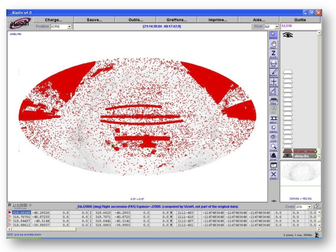

Figure 2: *Plot of the quasars of the Large Quasar Astrometric Catalogue (LQAC) of Souchay et al. (2008). Illustration of the tool Aladin, freely available, that manipulates VO-TABLE.*

- ⋆ Existing standards.
- ⋆ Existing self descriptive format based on these standards and XML : the VO-TABLE.
- ⋆ Many tools already exist to manage, plot or analyze data supplied in VO-TABLE format (described non-ambiguously). Convert ones own data in VO-TABLE format means benefiting of all existing tools.
- ⋆ Easy access to data by other scientific communities. Data that need to be distributed can be registered to a "registry". See for example http://esavo.esac.esa.int/registry/.
- ⋆ Successful project in Astronomy. The historical collaboration and close foundation between Astronomy and Geodesy encourages an adoption of VO standards by the geodetic community.
- ⋆ **Can be seen as the common output format shared by a whole WG, deduced from various internal format that can continue to be used inside analysis scheme.**

3. Exchanging, understanding and analyzing geodetic data: thanks to VOTable data format

The VOTable Data Exchange Format

VOTable is a XML-based format for representing astronomical catalogues (properties of celestial objects : celestial coordinates, brightness etc.).

The VOTable 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, as well as geodetic 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 that these metadata should be preserved with the table and the VOTable has features to permit this**. Adopting VOTable does not mean giving up of its own data format. VOTable may encapsulate existing files and simply supplies metadata to understand its content and facilitate data exchanges. VOTable is designed to describe a wide variety of physical parameters. However when it is itself not sufficient for an accurate description of complex data, it can be used conjointly with an external data model. An example of such model for reference system is the STC (Space-Time Coordinate Metadata for the Virtual Observatory) .


```
▼<VOTABLE xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns="http://www.ivoa.net/xml/VOTable/v1.1" version="1.1"
 xsi:schemaLocation="http://www.ivoa.net/xml/VOTable/v1.1 http://www.ivoa.net/xml/VOTable/v1.1">
 ▼<!--
    !  VOTable written by STIL version 2.9-2x (uk.ac.starlink.votable.VOTableWriter)
    !  at 2013-11-05T13:17:34
    !
  -->
 ▼<RESOURCE>
  ▼<TABLE name="7810_ENU.dat" nrows="34">
   ▼<DESCRIPTION>
     /Users/fde/Downloads/7810_ENU.vot Serie temporelle de la station 7810 Nom station : Zimmerwald/Users/fde/Downloads/7810_ENU.vot No DOMES : 14001S007 Unite
     position stations : m
    </DESCRIPTION>
   ▼<FIELD datatype="double" name="DATE" ucd="time.epoch;obs" unit="TBD">
     <DESCRIPTION>Description</DESCRIPTION>
    </FIELD>
   ▼<FIELD datatype="double" name="E" ucd="pos.topocentric.east" unit="m">
     <DESCRIPTION>Description</DESCRIPTION>
    </FIELD>
   ▼<FIELD datatype="double" name="DE" ucd="stat.stdev;pos.topocentric.east" unit="m">
     <DESCRIPTION>Description</DESCRIPTION>
    </FIELD>
   ▼<FIELD datatype="double" name="N" ucd="pos.topocentric.north" unit="m">
     <DESCRIPTION>Description</DESCRIPTION>
    </FIELD>
   ▼<FIELD datatype="double" name="DN" ucd="stat.stdev;pos.topocentric.north" unit="m">
     <DESCRIPTION>Description</DESCRIPTION>
    </FIELD>
   ▼<FIELD datatype="double" name="U" ucd="pos.topocentric.up" unit="m">
     <DESCRIPTION>Description</DESCRIPTION>
    </FIELD>
   ▼<FIELD datatype="double" name="DU" ucd="stat.stdev;pos.topocentric.up" unit="m">
     <DESCRIPTION>Description</DESCRIPTION>
    </FIELD>
   ▼<DATA>
    ▼<TABLEDATA>
     ▼<TR>
       <TD>2012.9467441434</TD>
       <TD>0.08469498281</TD>
       <TD>0.4746076191</TD>
       <TD>-0.01521956223</TD>
       <TD>0.2846708053</TD>
       <TD>0.1032882536</TD>
       <TD>0.7130183565</TD>
      </TR>
     ▼<TR>
```


Figure 3: *Space Station Coordinates time series (Zimmerwald), provided through the VOtable format. Such files can easily and **automatically be built** thanks to dedicated tools from common ASCII files, such as "**stilts**" and "**TOPcat**".*

Following our recommendations, IVOA adopted the new standards relevant to the Earth orientation data (polar motion, UT1-UTC, nutation etc.) and to space geodesy, to exhaustively **describe in the VO all the products delivered by the ILRS** to a wide community.

4. GRGS web and VO Tools

4.1 What is available on the websites:

- GRGS AC Time series projected into a homogeneous reference frame: weekly Helmert transformations w.r.t. ITRF2008
- ASCII and .vot files
- Status of the operational solutions, and reanalyses
  - Stations: SSCs, and biases
  - Additional informations: global transformation parameters: translations, rotations, scale
- Comparison tools between different time series

4.2 GRGS on-line tools to visualize and compare station coordinates time series of DORIS, GPS, SLR and VLBI sites.

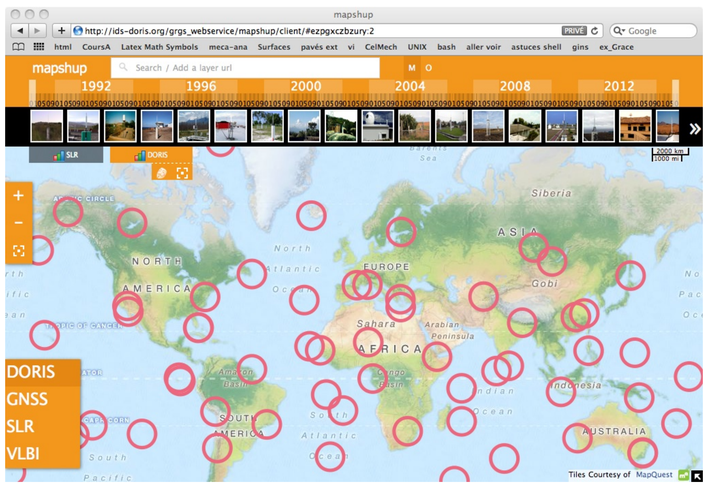

Figure 4: *Selection of the technique(s) and the station(s) through a dedicated page*

GRGS provides tools to browse station coordinates time series provided by the GRGS Analysis Centers. This service allows comparing time evolutions of coordinates for DORIS, GPS, SLR and VLBI sites. The time series are differences at observation epochs relative to a reference position (North, East and Up trended time series).
The tools proposed by this web service are:

- ⋆ a network viewer to select sites
- ⋆ a plot tool to display time series

Capabilities:

- ⋆ selecting charts to plot
- ⋆ displaying time series, editing data, changing plot appearance, specifying scaling
- ⋆ downloading data, plots and graph statistics in several formats
- ⋆ statistic tools for the calculation of mean, slope and weighted rms with respect to the slope (Weighted Relative Standard Deviation)
- ⋆ several series can be viewed and compared on the same graph
- ⋆ additional data can also be displayed, such as station or satellite events
- ⋆ the plot tools are based on the Highcharts/Highstock libraries.

Figure 5: *Superimposition of SSC (North component) of the Hartebeesthoek station (SLR : 7501, coming from GRGS computation for ITRF2013), for various techniques*

north

Series	Mean	WRSD	Fitted slope	Period
7501 grg01rl01	522.22mm	24.66mm	18.53+/-0.26mm/year	1993/7/14-2013/12/18
HBMB ids14wd04	204.92mm	8.16mm	17.88+/-0.23mm/year	2007/3/7-2013/12/25
HBKB ids14wd04	71.4mm	10.17mm	19.56+/-0.35mm/year	2000/8/16-2006/9/20
HBLA ids14wd04	-11.98mm	13.99mm	16.24+/-1.19mm/year	1997/6/11-2000/8/9
HBKA ids14wd04	-73.07mm	13.57mm	19.54+/-0.86mm/year	1993/7/14-1997/5/21
HARB grg14dp01	4.77mm	3.98mm	18.65+/-0.02mm/year	2000/8/11-2013/12/30

Figure 6: *Corresponding statistics*

4.3 Other web and VO tools provided by GRGS Analysis Centers, in the frame of IDS, ILRS, IVS, IGS

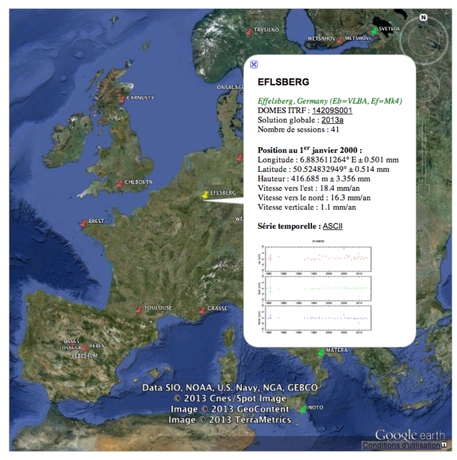

Figure 7: *IVS-OPAR Virtual Observatory portal http://ivsopar.obspm.fr/vo/*

IERS/ICRS-PC provides as well its products in VOTable format, including station coordinates and Earth Orientation Parameter time series.

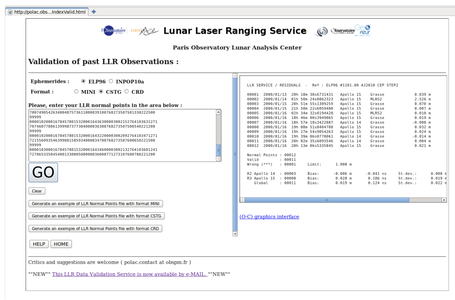

Figure 8: *Lunar Laser Ranging: Support Tools for observers (http://polac.obspm.fr/PaV/)*

We developed two web-tools to assist LLR observers.

- The first tool offers the capability to compute predictions of topocentric and geocentric coordinates of lunar targets (as retro-reflectors or craters) and predictions of round-trip times of laser-pulses between terrestrial stations and lunar retro-reflectors.
- The second tool allows observers to compute differences between their LLR observations and POLAC reduction model for LLR data. The residuals obtained in this way allow observers to have a validation of their observations.

These tools can be used in already operational observatories for the laser lunar ranging but they are more particularly aimed at the new teams who begin to carry out LLR observations.
A proof of the usefulness of this tool is its use by MeO station during winter 2012-2013 to obtain a signal back from the lost reflector Lunokhod 1 for the fist time since the start of LLR observations in the early eighties.