TREPS, a tool for coordinate and time transformations in space physics

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Abstract

TREPS, a user friendly online tool which helps performing coordinate transformations, is presented. The reference frames commonly used in planetology and heliophysics are available. They are described internally as SPICE kernels developed by NASA/NAIF. The usage of the tool is simplified by its clear, 4-step approach and the many import/export facilities. In particular the interoperability with external services is made possible via the use of Virtual Observatory standards.

1. Introduction

The variety of celestial bodies in the solar system makes space physics data representation incomplete if reference frame information is not clearly exposed. Position, velocity, attitude and all vector quantities make sense in particular reference frame be they related to the Sun, a planet, a moon, a comet or an observation platform (the spacecraft itself). Comparing data from heterogeneous sources often implies to homogenise the reference frame in which vector data are displayed. It is generally a tedious, if not complex, task for data analysts when they are confronted to the need for such transformations. NAIF SPICE kernel libraries (http://naif.jpl.nasa.gov/naif/aboutspice.html) convey all necessary information to perform these operations. These libraries are available in different languages, are directly implemented in specific operation and analysis software, and are also integrated in general public tools like 3DView (http://3dview.cdpp.eu, Génot et al., this issue) or Cosmographia (http://naif.jpl.nasa.gov/naif/cosmographia.html). However these software and tools are generally multi-purposes and complex. A simple, friendly, and focused tool, exclusively devoted to coordinate transformations, was missing in the planetary and heliophysics communities. The CDPP (http://cdpp.eu/) therefore designed TREPS (Transformation de REpères en Physique Spatiale http://treps.cdpp.eu/) in this very aim. This paper explains the architecture of the tool, describes the variety of reference frames which are taken care of, and finally presents some brief use cases showing how TREPS integrates interoperability and connects to companion tools in the Virtual Observatory world.

2. TREPS architecture and usage

TREPS is simply accessible via a user friendly interface in a browser window; it is coded in Javascript (Ext-JS). The transformation themselves are done via web-service calls to the companion tool 3Dview (orbitography and data visualization, Génot et al., this issue) which makes use of SPICE kernels internally. An example of reference frame definition is given below (HEE).

```
Heliocentric Earth Ecliptic frame (HEE)
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   The Heliocentric Earth Ecliptic frame is defined as follows (from [3]):
      -  X-Y plane is defined by the Earth Mean Ecliptic plane of date,
         therefore, the +Z axis is the primary vector, and it defined as
         the normal vector to the Ecliptic plane that points toward the
         north pole of date;
      -  +X axis is the component of the Sun-Earth vector that is
         orthogonal to the +Z axis;
      -  +Y axis completes the right-handed system;
      -  the origin of this frame is the Sun's center of mass.
   All vectors are geometric: no aberration corrections are used.

  \begindata

      FRAME_HEE                      =  1600010
      FRAME_1600010_NAME             = 'HEE'
      FRAME_1600010_CLASS            =  5
      FRAME_1600010_CLASS_ID         =  1600010
      FRAME_1600010_CENTER           =  10
      FRAME_1600010_RELATIVE         = 'J2000'
      FRAME_1600010_DEF_STYLE        = 'PARAMETERIZED'
      FRAME_1600010_FAMILY           = 'TWO-VECTOR'
      FRAME_1600010_PRI_AXIS         = 'Z'
      FRAME_1600010_PRI_VECTOR_DEF   = 'CONSTANT'
      FRAME_1600010_PRI_FRAME        = 'ECLIPDATE'
      FRAME_1600010_PRI_SPEC         = 'RECTANGULAR'
      FRAME_1600010_PRI_VECTOR       = ( 0, 0, 1 )
      FRAME_1600010_SEC_AXIS         = 'X'
      FRAME_1600010_SEC_VECTOR_DEF   = 'OBSERVER_TARGET_POSITION'
      FRAME_1600010_SEC_OBSERVER     = 'SUN'
      FRAME_1600010_SEC_TARGET       = 'EARTH'
      FRAME_1600010_SEC_ABCORR       = 'NONE'
```

The workflow in TREPS consists in four steps: first the user loads his/her quantity to be transformed, second he/she chooses the source and target reference frames and, optionally, the time base and the vector definition, then the transformation is realized and the result can be visualized, and finally exported. Let us see these steps in more details.

Step 1

The home page of TREPS (Figure 1) is also the home for the first step for which the source data must be gathered, either from a local file (it can be dragged and dropped directly in the squared box), or an URL, or via SAMP (see below) or even via manual edition. The right part of the page displays help for the different functionalities, general references on coordinate transformations, as well as information on underlying web-services. Once the source data are chosen, via whatever mean, hitting the Next button loads them and transfers to Step 2.

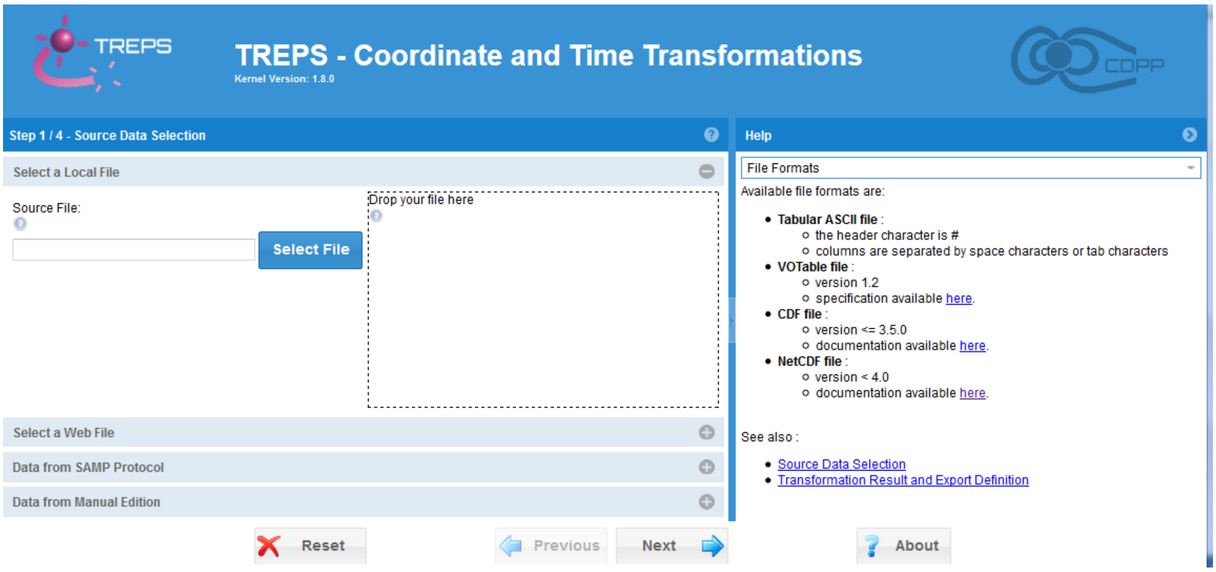

Figure 1: TREPS welcome interface where source data selection is realized (Step 1, see text).

Step 2

In Step 2 the window changes if data are correctly loaded (Figure 2). Time appears in yellow while the 3 vector component appear in red/green/blue. The time format is recognized and displayed in “Time field”. At this step the user must enter important information: the Source and Destination coordinate systems (or leave them blank in the aim is only to perform time transformation, see below), and whether the vector is a position or not. In case it is a position the centre of the source and destination systems may differ and the transformation must take this information into account (and perform the correct translation). If the user only wants to perform time format transformation, the selection of Source and Destination is not mandatory. In case the Source file contains more than a single vector, or a mix of scalar and vector quantities, the user must choose which column represents the x/y/z component respectively (this is the “edit mode”). Once this is done the system is ready to proceed to the transformation itself and then to Step 3.

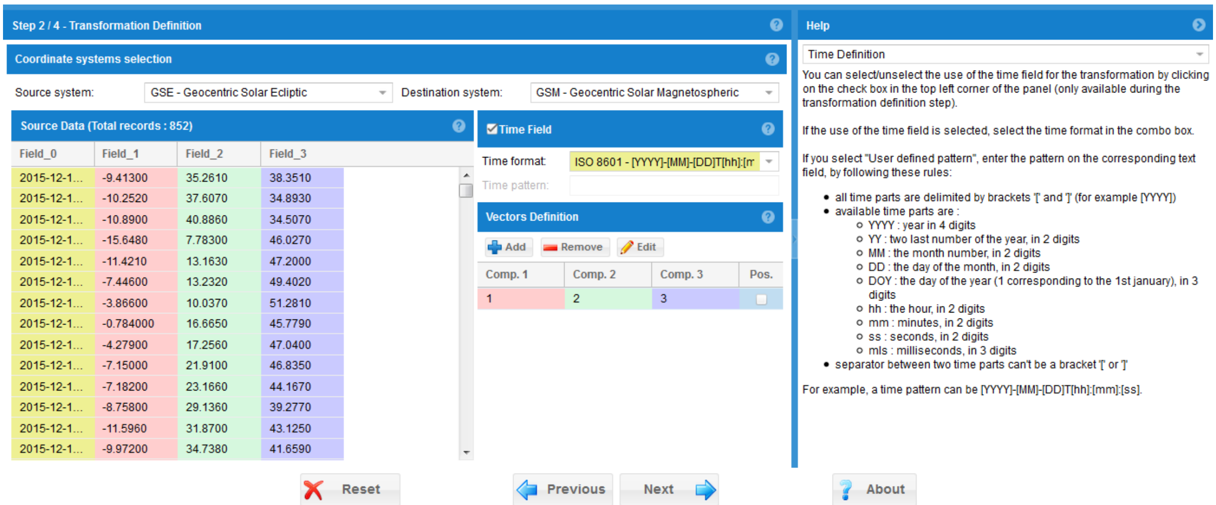

Figure 2: TREPS interface at Step 2 (see text).

Step 3

In Step 3 the resulting transformation is displayed either as a grid result (i.e. similarly to the coloured vector representation in Step 2) or as a plot as it is illustrated in Figure 3. Source and destination vectors are plotted and individual components can be selected. At this stage the user has to choose how the transformed vector must be exported. The time format must be specified as well as the file format itself. Source and destination vectors can be gathered in the exported file. If the user wants to use SAMP to send the transformed vector to companion tools the export format must be VOTable (standardized XML).

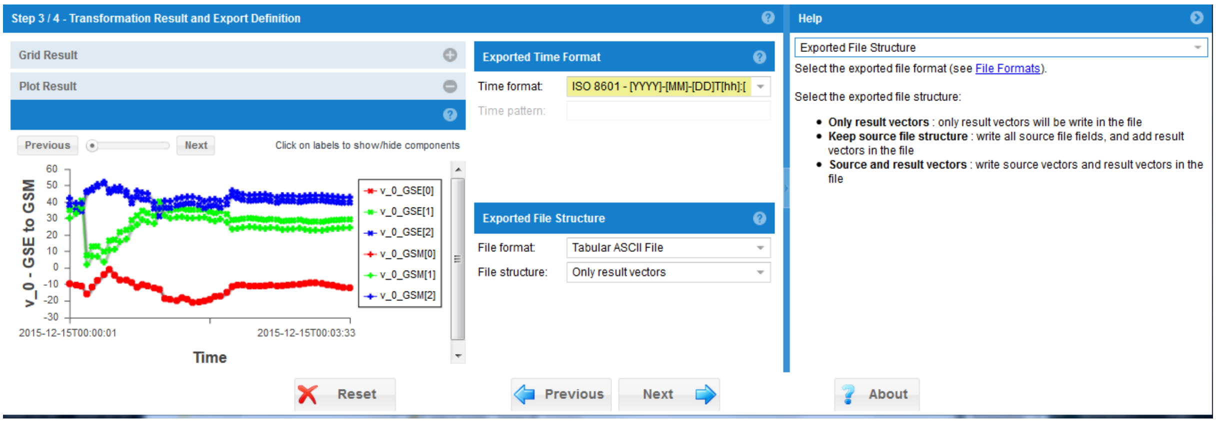

Figure 3: TREPS interface at Step 3 (see text).

Step 4

Finally the export operation is performed on Step 4 (Figure 4). A SAMP hub must be active for this functionality to be used. A SAMP can be started with Topcat, Aladin, or other dedicated tools (see Génot et al., 2014 for more details on how to use SAMP). The resulting file can also be simply downloaded on the user disk.

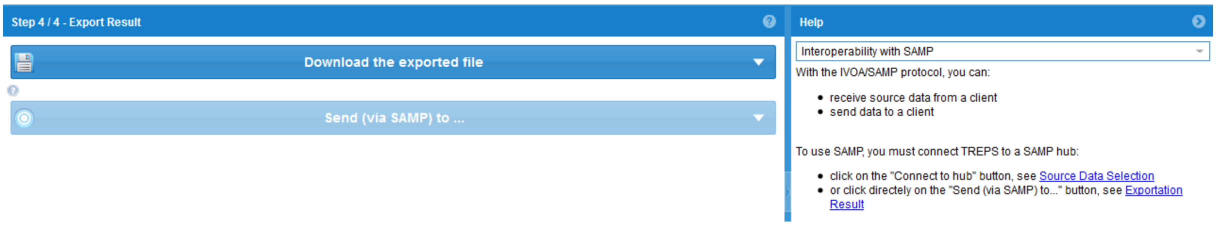

Figure 4: TREPS interface at step 4 (see text).

The complete list of reference frames available at the date of publication is

- 67PCG_EME - EME2000 centered on comet Churyumov Gerasimenko
- CPHIO - Callisto Phi-Omega
- DIIS - Dione Inter-action coordinate System
- ECLIPDATE - Earth Mean Ecliptic and Equinox
- ECLIPJ2000 - Ecliptic coordinates based upon the J2000 frame
- ENIS - Enceladus Inter-action coordinate System
- EME - Earth Mean Equator and Equinox
- EPHIO - Europa Phi-Omega
- GPHIO - Ganymede Phi-Omega

- GRIGGSKELL_EME - EME2000 centered on asteroid GRIGG-SKJELLERUP
- GSE - Geocentric Solar Ecliptic
- GSEQ - Geocentric Solar Equatorial
- GSM - Geocentric Solar Magnetospheric
- HALLEY_EME -EME2000 centered on asteroid HALLEY
- HCI - Heliocentric Inertial
- HEE - Heliocentric Earth Ecliptic
- HEEQ - Heliocentric Earth Equatorial
- IAU_EARTH - International Astronomical Union Earth
- IAU_JUPITER - International Astronomical Union Jupiter
- IAU_MARS - International Astronomical Union Mars
- IAU_MERCURY - International Astronomical Union Mercury
- IAU_NEPTUNE - International Astronomical Union Neptune
- IAU_PLUTO - International Astronomical Union Pluton
- IAU_SATURN - International Astronomical Union Saturn
- IAU_URANUS - International Astronomical Union Uranus
- IAU_VENUS - International Astronomical Union Venus
- IPHIO - Io Phi-Omega
- J2000 - Earth mean equator, dynamical equinox of J2000
- JECLIP - ECLIPJ2000 centered on Jupiter
- JEME - EME2000 centered on Jupiter
- JSM - Jovian Solar Magnetospheric
- JSO - Jovian Solar Orbital
- KECLIP - ECLIPJ2000 centered on Saturn
- KEME - EME2000 centered on Saturn
- KSM - Kronian Solar Magnetospheric
- KSO - Kronian Solar Orbital
- LME - Moon Mean Equator
- LSE - Selenocentric Solar Ecliptic
- LUTETIA_EME - EME2000 centered on asteroid LUTETIA
- MAG - Geomagnetic coordinate system
- MECLIP - ECLIPJ2000 centered on Mercury
- MEME - EME2000 centered on Mercury
- MESO - Mercury-centric Solar Orbital
- MIIS - Mimas Inter-action coordinate System
- MME - Mars Mean Equator
- MSO - Mars-centric Solar Orbital
- NECLIP - ECLIPJ2000 centered on Neptune
- NEME -EME2000 centered on Neptune
- PECLIP - ECLIPJ2000 centered on Pluto
- PEME - EME2000 centered on Pluto
- RHIS - Rhea Inter-action coordinate System
- SM - Solar Magnetic coordinates
- STEINS_EME - EME2000 centered on asteroid STEINS
- SYSTEM_3 - SYSTEM 3 centered on Jupiter
- TEIS - Tethys Inter-action coordinate System
- TIIS - TItan Inter-action coordinate System
- UECLIP - ECLIPJ2000 centered on Uranus
- UEME - EME2000 centered on Uranus
- VME - Venus Mean Equator

- VSO - Venus Solar Orbital

Time transformations are also possible from/to different formats such as: Iso8601 in several representations for day, month, year, etc, time stamps (number of sec. since 1970), decimal year, user defined patterns (multiple options), epoch time for CDF format, TT2000 for CDF format, DDTime for CDPP/DD server. These formats have to be chosen for the source and target files at Steps 2 and 3 in the TREPS workflow.

3. *Science cases*

TREPS can be used individually to transform vector/position files, however its possibilities are greatly enhanced when it is part of a data analysis workflow. As an illustration, we propose here the first necessary steps to analyze Titan's flow-induced magnetosphere (Bertucci et al., 2008). The aim of theis science case is to obtain, and subsequently visualize, the magnetic field measured by Cassini in Titan centered reference frame, TIIS (Titan Interaction System). The (+x) axis of the TIIS is aligned with the direction of ideal co-rotation, whereas the (+y) axis points from Titan to Saturn. The (+z) axis completes the right-handed coordinate system, pointing northward (i.e., it is approximately parallel to Saturn's magnetic moment/rotation axis). We use data from NASA/PDS as they are archived in the CDPP data analysis tool AMDA (http://amda.cdpp.eu/). It should be noted that AMDA holds a collection of time tables, or event lists, shared by all users, and among them a list of (83 among the 118 to date) Titan's fly-bys by Cassini (3h interval centered on the closest approach). The science case is conducted in accordance with the following steps: the user logs in AMDA, opens the Cassini data tree and chooses the MAG instrument. A SAMP hub is opened (via TOPCAT[1] or other means) and AMDA and TREPS are both connected to the hub. In the AMDA download interface the magnetic field at 1 min resolution in the KSO coordinate frame is selected together with the time table "List_of_Cassini_Titan_flybys". Internally a file containing all magnetic field records for the 83 (flybys) times 3h of data is produced. Via SAMP, the user then sends this file directly to TREPS and, because it is already connected to the hub, all fields are automatically filled (Step 2). The user chooses KSO as "Source system" and TIIS as "Destination system". Hitting the Next button performs the KSO→TIIS transformation. At Step 3 the user can prepare the way he/she wants to export the data. Selecting VOTable (an XML format practical for machine to machine exchange) it is then possible on Step 4 to 'SAMP' the transformed data back to AMDA, or alternatively to push them to TOPCAT or 3DView for further analysis or visualisation (as illustrated on Figure 5), respectively. A broad survey of Titan's flybys have been conducted in Simon et al., 2013. They made use of TIIS magnetic field as the starting point of their analysis to study the influence of the field draping on the structure of the induced magnetosphere. It is demonstrated that a DRAP system is more relevant for the analysis; however this new system makes use of the specific orientation of Saturn's field at each flyby and cannot be implemented in a systematic way in TREPS. AMDA or TOPCAT could help in this matter.

[1] http://adsabs.harvard.edu/abs/2005ASPC..347...29T

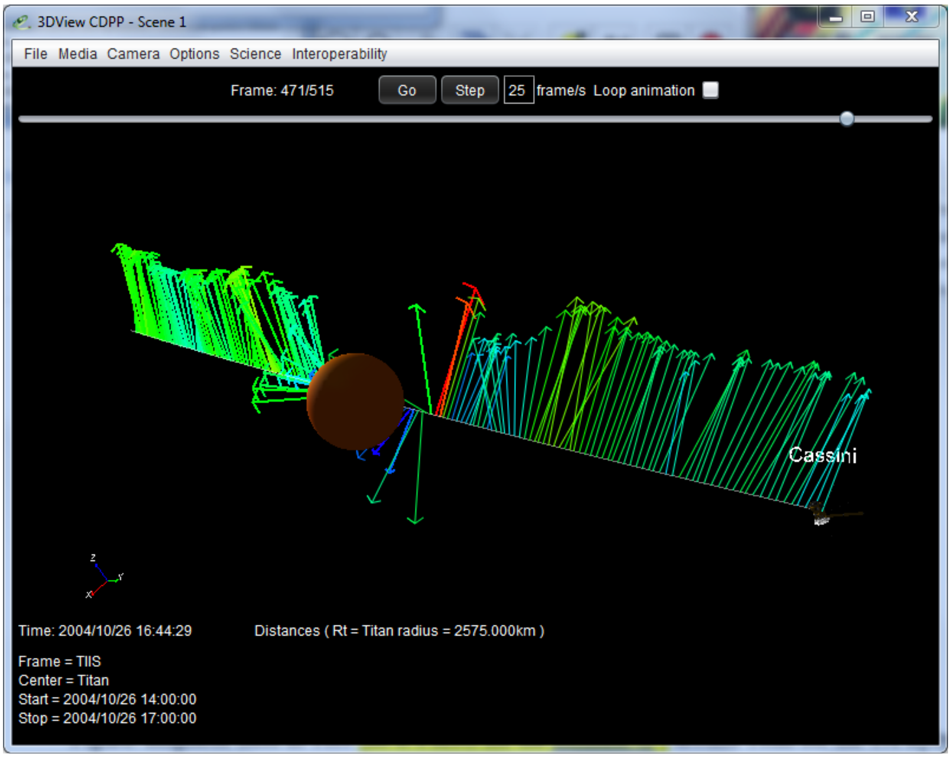

Figure 5: magnetic field vector in TIIS coordinate system around Titan for the TA flyby (3h on the 26/10/2004) visualized in the 3DView tool. The colour and the length of the arrows both code the field amplitude (colour scale: blue to red).

Another science case combining AMDA, 3DView and TREPS is presented in Génot et al., 2014. It shows how to transform magnetic field vector, measured by the THEMIS C spacecraft orbiting the Moon and available on the AMDA database, from the archived GSE (Earth-centered) coordinate system to the LSE (Moon-centered) coordinate system. The transformed vector is then sent to the 3D visualization tool 3DView to be displayed and manipulated in context.

4. Conclusion

This paper shows the main functionalities of a web-based coordinate transformation tool, TREPS, designed and developed by the French Plasma Physics Data Centre (CDPP). The usage is simplified by a step by step approach and associated documentation. The transformations are based on the well referenced SPICE libraries from NASA/NAIF. The simplicity of the tool makes it an ideal software for students in planetology and heliophysics with very few IT prerequisites; it is also very convenient for the general space physics scientist who has to often juggle between coordinate systems. Connections to the outside world is possible via the virtual observatories (IVOA) standards, namely SAMP and VOTable. Future developments will take care of additional coordinate systems, at the same time they are added in the companion tool 3DView which holds the SPICE libraries.

Acknowledgments

The CDPP wishes to warmly thank all members of its User Committee (CDPP CU) for the time spent at testing the tool and for the judicious discussions and comments. Other users, and among them numerous students, are also thanked for their useful contribution at enhancing the tool by reporting bugs and typos. The CDPP is strongly supported by CNES.

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