Consistent processing standards and reference models

Ralf Schmid

Deutsches Geodätisches Forschungsinstitut

Motivation

WP5410: Definition of unified modeling and parameterization

- **homogenization** of different space geodetic techniques
- critical review of present approaches and standards
- unification of models
- definition of identical parameters for the processing

Action item (Kick-off meeting, Bonn):

„All analyses should be based on identical models and parameterization in order to achieve **consistency**. PN5 will organize the iteration of a list of these items which will be based on the GGOS-D project specifications.“

Base

- common standards for the **GGOS-D** processing (Rothacher et al., 2011; Table 2): **a few years old**
- models and parameterizations for the IERS Working Group on **Combination at the Observation Level** (COL): **not very detailed**
- **detailed list** (draft) **of a lot of phenomena** to be standardized, compiled by the **GGOS Bureau for Standards and Conventions** (GGOS-BSC)

General problems

1. **Which level of detail?**

   The more detailed the list of phenomena/models,

   - the smaller the chance that all different software packages can follow the standards in every respect
   - the less clear which models have a big impact

2. **Unified vs. up-to-date models**

   - Groups that have implemented an up-to-date model into their software package are interested to apply that model
   - Unification requires a selection of models that **every** software package is able to apply, even if the models were „outdated“
   - Minimization/optimization of coding effort!?

General standards

General	Speed of light	299792458 ms^-1
	Gravitational constant of the Earth	3.986004418 × 10^14 m^3s^-2
	Equatorial radius of the Earth	6378136.6 m
	Dynamical flattening	3273795 × 10^-9
	Time system	terrestrial time: TT, barycentric time: TCB
	Terrestrial reference frame (a priori)	ITRF2008/IGb08/SLRF2008/VTRF2008
	Celestial reference frame (a priori)	ICRF2
	Ephemerides	JPL ephemerides DE421 or DE405?

- Bernese: transition from DE405 to DE421 might be time-consuming, as binary version of the **JPL ephemerides** is used
- other software packages probably ready to use DE421

Station coordinates

Station coordinates	Solid Earth tides	conventional routine from Dehant & Mathews
	Permanent tide	conventional tide free system
	Solid Earth pole tide	polynomial (IERS2010) or linear (IERS2003) trend for mean pole offsets?
	Ocean pole tide loading	Desai (2002)
	Tidal ocean loading	FES2004; HARDISP.F; CoM-corrected values
	Non-tidal ocean loading	not applied
	Tidal atmospheric loading	not applied
	Non-tidal atmospheric loading	not applied

- (non-)tidal **atmospheric loading** would have to be applied consistently with corresponding gravity effects (SLR!)
- routines available from Global Geophysical Fluid Center (GGFC, T. van Dam) or from TU Vienna?
- **solid Earth pole tide**: IERS2010 implemented by all?
- Bernese: Desai (2002) not implemented; available soon?

Gravity field

Gravity field	A priori terrestrial model	EGM2008
	A priori lunar model	Konopliv et al. (2001)
	Solid Earth tides	Mathews et al. (2002)
	Permanent tide	conventional tide free system
	Ocean tides	FES2004
	Solid Earth pole tide	IERS2010
	Ocean pole tide	Desai (2002)
	S1/S2 atmospheric tides	not applied

- Bernese: Desai (2002) not implemented; available soon?
- **atmospheric tides** would have to be applied consistently with the corresponding effects on station coordinates (SLR!)
- also **non-tidal** atmospheric effect to be considered?

Earth orientation parameters

Earth orientation parameters	A priori EOP	IERS 08 C04 http://hpiers.obspm.fr/iers/eop/eopc04/eopc04_IAU2000.62-now
	Interpolation of a priori polar motion	linear interpolation
	Interpolation of a priori UT1	(1) reduction to UT1R and LODR (2) linear interpolation using UT1R and LODR (3) conversion to UT1 and LOD
	Interpolation of a priori nutation	linear interpolation
	Subdaily ocean tidal effects	IERS2010, Eanes (2000)
	Atmospheric tidal effects	not applied
	Precession-nutation model	IAU 2006/2000A
	Free core nutation	not applied, if nutation parameters are estimated; IERS 08 C04 corrections, if nutation parameters are not estimated
	Subdaily nutation	IERS2010; Ray et al. (1994)
	UT1 libration	Brzezinski and Capitaine (2003)

- former link pointed to the old **nutation representation**

Atmosphere

Troposphere (microwave)	Hydrostatic a priori model	computed from 6-hourly ECMWF grids; account for the station and mean grid height differences
	Hydrostatic mapping function	hydrostatic VMF1
	Wet a priori model	none; wet delay estimated
	Wet mapping function	wet VMF1 = wet VMF
	A priori gradients	none; gradients estimated
	Gradient mapping function	Chen and Herring (1997)
Trop. (SLR)	A priori model	Mendes and Pavlis (2004)
Ionosphere	Earth's magnetic field	IGRF-11
	First order effect	accounted for by linear combination of multi-frequency observations
	Second order effect	Fritsche et al. (2005) using IGRF-11
	Third order effect	
	Ray bending	IERS2010

- non-zero **a priori gradients** in the case of VLBI (see VLBI effects)?

Relativistic model

Relativistic model	Schwarzschild terms	IERS2010
	Lense-Thirring precession	IERS2010
	Geodesic (de Sitter) precession	IERS2010
	Gravitational time delay	Shapiro (1971?)

$$\Delta\ddot{\vec{r}} = \frac{GM_E}{c^2r^3}\left\{\left[2(\beta+\gamma)\frac{GM_E}{r} - \gamma\dot{\vec{r}}\cdot\dot{\vec{r}}\right]\vec{r} + 2(1+\gamma)(\vec{r}\cdot\dot{\vec{r}})\dot{\vec{r}}\right\} + (1+\gamma)\frac{GM_E}{c^2r^3}\left[\frac{3}{r^2}(\vec{r}\times\dot{\vec{r}})(\vec{r}\cdot\vec{J}) + (\dot{\vec{r}}\times\vec{J})\right] + \left\{(1+2\gamma)\left[\dot{\vec{R}}\times\left(\frac{-GM_S\vec{R}}{c^2R^3}\right)\right]\times\dot{\vec{r}}\right\}, \tag{10.12}$$

$$t_2 - t_1 = \frac{|\vec{x}_2(t_2) - \vec{x}_1(t_1)|}{c} + \sum_J \frac{2GM_J}{c^3}\ln\left(\frac{r_{J1}+r_{J2}+\rho}{r_{J1}+r_{J2}-\rho}\right), \tag{11.17}$$

- every software package able to apply **Lense-Thirring and de Sitter precession**?

GNSS effects

GNSS effects	Phase center corrections for satellite and receiver antennas	ftp://igs.org/igscb/station/general/igs08_1711.atx
	Receiver antenna heights	IGb08.snx + IGSMAIL/IGSSTATION
	Horizontal antenna excentricities	IGb08.snx + IGSMAIL/IGSSTATION
	Satellite attitude model	nominal attitude; exclude shadow crossings
	A priori radiation pressure	none
	Phase wind-up	Wu et al. (1993)

- should **a priori radiation pressure** be considered?

SLR/VLBI effects

SLR effects	Center of mass corrections (laser reflector array offsets)	standard corrections from http://ilrs.gsfc.nasa.gov/missions/spacecraft_parameters/center_of_mass.html
	Range/time biases	ILRS_Data_Handling_File.snx
	Arc length	7 days
VLBI effects	Thermal telescope deformations	Nothnagel (2009)
	A priori tropospheric gradients	MacMillan and Ma (1997), provided in SINEX format
	Gravitational sag	not applied

- necessary to specify more phenomena?
- non-zero **a priori gradients** necessary to allow for a proper constraining in the VLBI case? at least useful in the early years!
- different a priori values could be homogenized in the combination step

Parameterization

Parameter	Representation	Resolution	A priori values	Stored in SINEX?
Station coordinates	constant offset	1 d or 7 d	ITRF2008/IGb08/SLRF2008/VTRF2008	yes
Pole coordinates	piecewise linear or offset+drift	24 h	IERS 08 C04; IERS subdaily ERP model	yes
ΔUT1	piecewise linear or offset+drift	24 h	IERS 08 C04; IERS subdaily ERP model	yes
Nutation	X, Y representation; piecewise linear or offset+drift	24 h	none (parameters represent corrections to a priori model)	yes
Troposphere zenith delays (MW)	piecewise linear	2 h	hydrostatic VMF1	yes
Troposphere gradients (MW)	piecewise linear	24 h	none	yes
Quasar coordinates	constant offset	1 d	ICRF2	yes
Gravity field coefficients	constant offset		EGM2008	yes

- Bernese: new **nutation representation** not yet implemented

DGFI

CGE

Summary

- all groups should try to **follow the standards** agreed upon
- **discrepancies should be reported**, especially if results were exchanged between different projects/groups
- standards might be less relevant for projects devoted to special studies (without interaction with other projects)
- additional **coding effort should be minimized**, so that data analysis could start soon