

Meeting of the IAG Working group “Relativistic Geodesy” Leibniz University Hannover, May 15-16, 2017

Jakob Flury, chair of the WG, opened the meeting at 10h on May 15th, and welcomed the participants.

All participants (see list below) briefly introduced themselves.

J. Flury reminded the role of the WG and its links to many other IAG activities He presented the meeting’s [agenda](#),

1. Theory

C. Lämmerzahl presented a talk on “General relativistic geodesy, towards an exact formalism” (see [slides](#))

S. Kopeikin presented a talk on “Technical problems of relativistic geodesy”.

Vivid discussions followed on several issues such as

- How to derive the metric for the next level of uncertainty?
- Which multipole moments should be used in the expansion?
- What is the exact formalism for transmission in fibers?

It was reminded that taking into account first PN effects in the definition of the geoid would imply changes at the level of 2 mm ($\approx 2 \times 10^{-19}$) so that it is not considered a very urgent issue at this moment. However, the WG must remain alerted to ensure that the uncertainty from the theory remains below that of the applications by a significant factor.

2. Reference frames, geoid, mean sea level, height networks, time

C. Hughes presented a talk on “The mean dynamic topography of the ocean: Applications for local geopotential measurements” (see [slides](#)) outlining the societal importance of relating the mean dynamic topography (MDT) of the oceans to the sea levels locally measured at tide gauges. This can be performed to within about 5 cm RMS for the best cases, but with several locations where decimetric discrepancies subsist. He outlined that centimetric point geopotential values from ultra-accurate clocks would help greatly with looking at coastal MDT at tide gauges, also envisioning more futuristic applications to open-ocean measurements.

G. Petit presented a talk on “Definition and realization of timescales and links with geodesy” (see [slides](#)). He reminded the current definitions of timescales outlining the need for a new definition of International Atomic Time, currently under work, and the need of guidelines for operators of frequency standards to compute the relativistic shift with the best possible accuracy.

There was a consensus among the WG that the value of the constant L_G defining Terrestrial Time TT is conventional and so provides a conventional value of the gravity potential defining a “chronometric geoid”, and that it should not be changed to track the progresses in determining a “classical geoid” whose surface corresponds to mean sea level.

J. Flury presented general concepts on the gravimetric (dynamic) reference frame (see [slides](#)), outlining the parallel between the present geometric reference network (ITRF) and a possible future gravimetric frame also based on a network of reference points.

3. Classical gravity potential determination

J. Flury presented a talk on “Classical potential and geoid modeling” (see [slides](#)) He discussed that potential reference from clock networks could overcome the limitations of the determination of potential and height reference from spirit levelling, and could complement and strengthen high-resolution combined geoid modelling from spaceborne and terrestrial gravity-related data.

H. Denker presented a talk on “Classical potential and geoid modeling” taking examples of gravity potential determinations carried out for the ITOC campaign between Paris and several sites in Germany with uncertainty of order 3 cm equivalent height, and for a clock comparison between Torino and Modane with uncertainty of order 10 cm [To Be Checked].

4. Frequency transfer, fibre links, campaigns

P. Defraigne presented a talk on “GNSS Time and Frequency Transfer: state of the art and possible evolution” (see [slides](#)), stating that the ultimate frequency accuracy with GNSS is somewhat below 1×10^{-16} in one day and that the technique of Precise Point Positioning with integer ambiguity determination is approaching this limit. Although this is far from sufficient to compare the best optical clocks, it is the only technique readily available capable of frequency transfer in the 10^{-17} domain between any two clocks worldwide.

P.E. Pottié presented a talk on “Optical fibre links for optical clocks comparisons” (see [slides](#)) outlining the various developments performed and under way to establish fibre links in Europe, as well as the achieved performances. He mentioned the new consortium CLONETS aiming at offering « on the shelf » solutions and procedures to establish a fibre link.

He also included some slides from D. Calonico, who chairs a Study Group on optical fibre links for UTC of the CCTF, and who could not attend the meeting. The full presentation is available [here](#).

The meeting was adjourned at 18:00.

An enjoyable dinner took place in a city centre restaurant, under beautiful skies.

The meeting was reconvened at 8h30 on May 16th.

5. Optical clocks, calibration and comparisons

G. Petit presented a talk on “Frequency standards: Work in the Consultative Committee for Time and Frequency” (see [slides](#)) showing the large increase in the number of optical transitions studied, compared and reported, with several measurements of optical frequency ratios having uncertainties much smaller than the current realization of the second. This work should lead to a future redefinition of the second for which a roadmap is being established.

Ch. Lisdat presented a talk on optical clocks outlining recent work at the PTB in this field. He presented developments under way for transportable optical standards, with emphasis on the PTB

operational device. He discussed practical questions linked to the operation of a transportable optical clock at a new site and indicated that the accuracy level of 1×10^{-17} is within reach.

U. Schreiber presented the IAG WG 1.1.1 “Co-location usings Clocks and New Sensors” which he chairs (see [slides](#)). Based on the example of Wettzell, he emphasized the importance of all geodetic systems sharing the same clock with well calibrated delays to a unique reference point.

6. Use of accurate clocks for gravity potential determination

P. Visser presented a talk on “Gravity potential determination with clocks” (see [slides](#)), where he discusses the capabilities of accurate space clocks for geopotential determination. While their usefulness for this determination seems limited, this conversely means that space clocks can provide the reference for Earth-based clocks to measure the gravity potential on Earth.

J. Flury presented a talk on “Use of accurate clocks for gravity potential determination” (see [slides](#)). It addressed several perspectives: the assessment of classical height networks, least square collocation, the investigation of the time variable gravity potential, and a strengthening of the gravimetric part of global reference frames.

7. General discussion: plans and perspectives

General discussion led to an extensive list of action items to be addressed by the WG (see [slides](#)). Among them, an important item is to develop a document, based on recent publications by WG members, to serve as a users’ guide for groups who need to estimate the gravity potential at the location of their clock with a few 10^{-18} uncertainty.

It was agreed to hold the next full meeting of the WG in 2018 in the Paris area, to be organized by G. Petit.

The meeting was closed at 16:00.

Minutes published Sep 8 (J. Flury, G. Petit)

List of participants

Jakob Flury	U Hannover	flury@ife.uni-hannover.de
Gerard Petit	BIPM	gpetit@bipm.org
Sergei Kopeikin	U Missouri	KopeikinS@missouri.edu
Jürgen Müller	U Hannover	mueller@ife.uni-hannover.de
Paul-Eric Pottie	Obs Paris	paul-eric.pottie@obspm.fr
Pascale Defraigne	ORB	pascale.defraigne@oma.be
Claus Lämmerzahl	ZARM	laemmerzahl@zarm.uni-hannover.de
Piet Schmidt	PTB	Piet.Schmidt@quantummetrology.de
Christian Lisdat	PTB	Christian.Lisdat@ptb.de
Pieter Visser	TU Delft	P.N.A.M.Visser@tudelft.nl
Chris Hughes	U Liverpool	c.w.hughes@liverpool.ac.uk
Elena Mazurova	MIIGAIK	e_mazurova@mail.ru
Eva Hackmann	U. Bremen	eva.hackmann@zarm.uni-bremen.de
Dennis Philipp	U. Bremen	dennis.philipp@zarm.uni-bremen.de
Heiner Denker	U Hannover	denker@ife.uni-hannover.de
Ulrich Schreiber	TU Munich	Schreiber@fs.wettzell.de (16/5 only)