# Definition of European Vertical Reference System

## Introduction

During the last ten years significant progress has been achieved in the definition and realization of the European Vertical Reference System, especially by the IAG Subcommission EUREF. After four years' work, the solution of the United European Levelling Network (UELN) 95/98 was distributed to the 20 participating countries in the beginning of 1999. One year later at the EUREF Symposium 2000 in Tromsø the conventions for the European Vertical Reference System 2000 (EVRS2000) were approved, and the realization, the European Vertical Reference 2000 (EVRF2000) based on the UELN 95/98 solution was adopted (see IHDE, J., AUGATH, W., 2000 and 2002, RUMMEL, R., HECK, B., 2000)

The need for the harmonisation of the vertical reference of spatial coordinates was raised at the 9th EC GI-GIS conference on 24-26 June 2003 in La Coruña. It is driven by the fact that exact knowledge, understanding, management, and subsequent processing of the spatial coordinates of any European GI dataset is one of the central aspects of cross-border GI interoperability.

The adoption of a common European Vertical Reference System is a necessary condition for a future simplification in data harmonisation and interoperability.

At a workshop on "Vertical Reference Systems for Europe", held on April 5th to 7th, 2004 in Frankfurt am Main, the needs, requirements, and problems in establishing a pan-European Vertical Reference System were debated to fulfil scientific and practical requirements for vertical georeferencing of the next decades. This workshop was jointly organised by the Joint Research Centre (JRC) of the European Commission and by EuroGeographics, Expert Group Geodesy with support from the IAG Sub-Commission for Europe EUREF.

At the EUREF Symposium 2007 in London the Technical Working Group (TWG) of the EUREF was asked to prepare the technical specifications (conventions) for a new EVRS and its realisation (EVRF2007).

The enhancing of the EVRS needs a revision of EVRS2000 conventions and parameters, and a new realization EVRF2007. From practical point of view, the tendency is not to change height values if not necessary. The EUREF community prefers to tie the height values to the height level of EVRF2000 and to keep normal heights. The transformation parameters between the EVRS realization and national height reference systems have to be specified to higher accuracy and topicality.

## Definition

The European Vertical Reference System (EVRS) is a kinematical height reference system. The EVRS definitions fulfil the following four conventions:

(1) The vertical datum is defined as the equipotential surface for which the Earth gravity field potential is constant:

$$W_0 = W_{0E} = const.$$

and which is in the level of the Normaal Amsterdams Peil.

(2) The unit of length of the EVRS is the meter (SI). The unit of time is second (SI). This scale is consistent with the TCG time coordinate for a geocentric local frame, in

agreement with IAU and IUGG (1991) resolutions. This is obtained by appropriate relativistic modelling.

(3) The height components are the differences $\Delta W_P$ between the potential $W_P$ of the Earth gravity field through the considered points *P*, and the potential $W_{0E}$ of the EVRS conventional zero level. The potential difference $-\Delta W_P$ is also designated as the geopotential number $c_P$

$$-\Delta W_P = c_P = W_{0E} - W_P$$

Normal heights are equivalent with geopotential numbers, provided that the reference gravity field is specified.

(4) The EVRS is a zero tidal system, in agreement with the IAG Resolutions No. 9 and 16 adopted in Hamburg in 1983 (Appendix 2).

### Reference ellipsoid, normal gravity field

The EVRS2007 is defined in terms of geopotential. It is realized using geopotential numbers determined by levelling, or alternatively a geopotential model and 3-D coordinates. None of these quantities depend on ellipsoidal reference, and therefore a reference ellipsoid is not part of the EVRS definitions as long as we are only concerned with geopotential numbers. However, to convert the geopotential numbers to normal heights, a normal gravity field and geodetic latitude is required. The GRS80 normal gravity field is adopted for the purpose, evaluated at ETRS89 coordinates.

Normal gravity at the ellipsoid is computed from the Gravity Formula 1980 (Moritz H., 1980) using the series expansion

$$\begin{aligned}\gamma_0 = 9.783\,267\,715 \big(1 &+ 0.005\,279\,0414 \sin^2\varphi \\ &+ 0.000\,023\,2718 \sin^4\varphi \\ &+ 0.000\,000\,1262 \sin^6\varphi \\ &+ 0.000\,000\,0007 \sin^8\varphi\big) \ \mathrm{m\,s^{-2}}\end{aligned} \qquad (1)$$

where the latitude $\varphi$ is in ETRS89. The normal heights $H_P$ were computed by $H_P = c_P/\bar{\gamma}$ where $\bar{\gamma}$ is the average value of the normal gravity along the normal plumb line between the ellipsoid and the telluroid. The average value of the normal gravity along the normal plumb line is determined by the formula

$$\bar{\gamma} \approx \bar{\gamma}_H = \gamma_0 \left[1 - \left(1 + f + m - 2f \sin^2\varphi\right)\frac{H}{a} + \frac{H^2}{a^2}\right] \qquad (2)$$

where $H$ is an approximate value for $H_P$ and $\gamma_0$ is from Eq. (1). The notation and the numerical values for the other quantities are according to (Moritz H., 1980)