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Geodetic Infrastructures for GNSS Positioning Services (GIPS) - General Concept and GIPS-Development for the State of Brazil -

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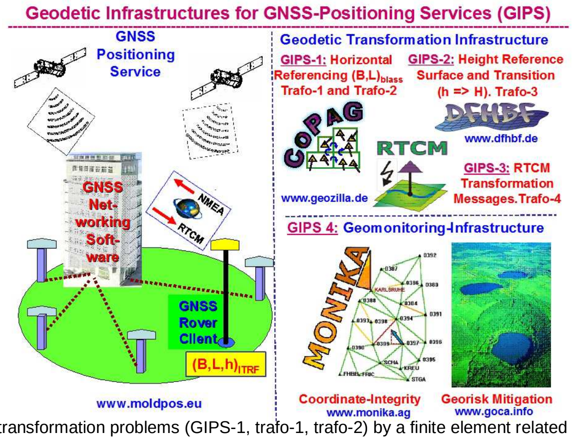
Introduction and Motivation

The worldwide ongoing process of the establishment of high precise DGNSS-positioning services and respective GNSS-reference station networks, which are related to the globally GNSS-consistent ITRF and ITRF-derivatives (e.g. ETRF89 in Europe or SIRGAS in Brazil), implies the replacement of the georeferencing in the old independent classical national reference frames by ITRF-related ones. Accordingly the new age of GNSS-positioning services - as interdisciplinary tool with a broad and growing spectrum of precise satellite positioning, navigation, mobile GIS and mobile IT applications (www.navka.de) - requires the establishment and maintenance of a geodetic infrastructure for GNSS positioning services (GIPS). GIPS is divided into a transformation and a geomonitoring component (www.moldpos.eu). As concerns the transformation component, the old plan position data, which is related to a classical reference frame, has to be transformed to the ITRF-related horizontal geoferencing (B, L) provided by the GNSS-service. This forward transformation (GIPS-1, trafo-1, see figure right) concerns the establishment of modern GNSS-related databases for the infrastructure for spatial information in Europe (INSPIRE) and worldwide (cadastre, GIS, navigation, urban planning, construction, transportation, meteorology, land management, precise agri-culture, etc.). It is necessary for a future direct horizontal positioning by GNSS services. The backward transformation (GIPS-1, trafo-2, see figure right) of the ITRF–related GNSS-position to an old classical datum is needed, because the classical non-ITRF reference frames will still be relevant for at least one decade or more.

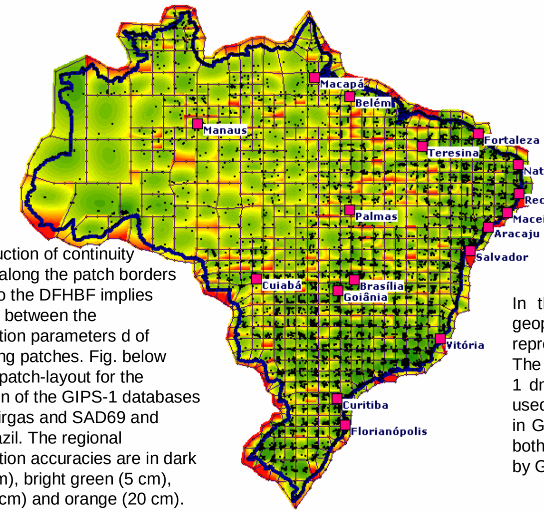


The presented concept and software CoPaG (www.geozilla.de) solves the above 3D-datum transformation problems (GIPS-1, trafo-1, trafo-2) by a finite element related mathematical modelling (FEM) and in a strict and general concept, including quality control. The computed high precise parameters are stored to transformation parameter data-bases. The ellipsoidal GNSS-heights always need a further processing, in order to transform h - by H=h-N - to the physical height H referring to the height reference surface (HRS) N.

The software DFHBF (www.dfhbf.de) solves that height transformation problem (GIPS-2, trafo-3) and models again in a Finite Element (FEM) concept. Global geopotential models (GPM), existing HRS models, vertical deflections, terrestrial gravity g and identical points (h, H) can be used as observations for the computation of a HRS database by the DFHBF-software. The above databases can be used on GNSS-controllers and can be implemented reference transformations for setting up RTCM 3.x transformation messages for the GNSS rover-clients (www.rtcm.org, www.moldpos.eu, www.geozilla.de). The capacity of an absolute positioning by GNSS-positioning services requires, that possible changes of the coordinates of the GNSS reference stations in the amount of few millimetres are detected immediately. To solve that task, the GNSS-referencestation MONitoring by the KArlsruhe approach and software (MONIKA) has been developed (www.monika.ag, www.goca.info). The MONIKA approach and software can, besides the coordinate control of GNSS-positioning services, also be applied for a use of the permanent GNSS-stations as a geosensor-network for geodynamical questions and research, as well for a setting up temporary GNSS-arrays as a disaster monitoring and early warning GNSS service, e.g. for land-slides, flood and construction areas.

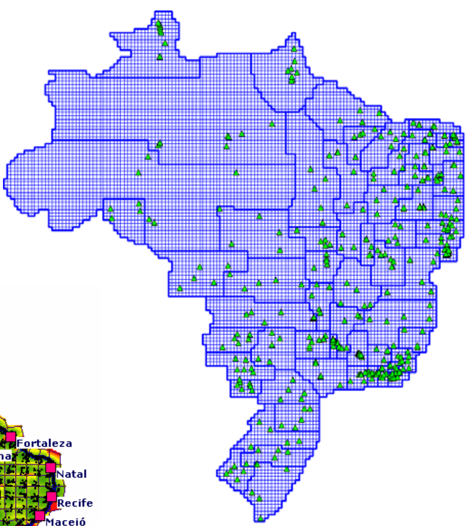
DFLBF/CoPaG-DB Computation

The CoPaG concept is dealing with the precise and continuous transformation of plan positions (N,E)class to the ITRF datum (N,E)ITRF. From the theoretical point of view a respective transformation can not renounce completely on height information. The so-called CoPaG (Conti- nuously Patched Geoferencing, see www.geozilla.de) concept however, has the advantage that the point height information is needed only on a poor accuracy level in the target system. If precise height information is available in both systems, it can be introduced as third ob-servation equation in system. Further basic considerations and a respective prob- lem solution for the plan datum transition are due to the occurrence and the mathematical treatment of 'weak-shape'. These are long-waved deflections of the shape of classical networks, reaching a range of several meters in the nation-wide scale. This requires the partition of the total net- work area into a set of different "patches" in a FEM similar to DFHBF (right).



The introduction of continuity conditions along the patch borders analogue to the DFHBF implies restrictions between the transformation parameters d of neighbouring patches. Fig. below shows the patch-layout for the computation of the GIPS-1 databases between Sirgas and SAD69 and SAD96 Brazil. The regional transformation accuracies are in dark green (1 cm), bright green (5 cm), yellow (10 cm) and orange (20 cm).

DFHBF-DB Computation



The computation of the precise Brazil height reference surface (HSR), namely the Brazil Geoid, was done with the DFHRS software, vers. 4. Here the DFHRS DB contains a continuous FEM representaion NFEM of the HRS to transform by H=h-NFEM(**p**|B,L) ellipsoidal GNSS heights h into physical heights H. The HRS, a geoid or a quasigeoid, can be modelled in a first method, in an arbitrary large area as a continuous surface by the parameters **p** of bivariate polynomials over a FEM mesh grid. Geometric observations, e.g. existing geoid grids N, vertical deflections (ξ,η) and identical points (B,L,h|H) can directly be related to NFEM(**p**|B,L). N or (ξ,η) grid or GPM-related information may be par-ted into different "patches" with individual datum-parameters **d** in order to reduce the effect of existing medium- and long-waved systematic errors.

In the DFHBF-software, version 5 gravity values g and the information of global geopotential models GPM are parametrized in regional Spherical Cap Harmonics representations (C_{nm}', S_{nm}').

The computation of a Geoid for Brazil led to a closed geoid surface with an accuracy of < 1 dm. As further observation components the geopotential model EGM2008 has been used. The respective final result of the Brazil geoid as DFHBF database is ready for use in GNSS heighting. It can used for the determination of physical orthometric heights H, both on GNSS controllers, and by setting up RTCM transfor- mation messages (GIPS-3) by GNSS-services.

Brazilian Reference Frames and CoPaG-/DFLBF-/DFHBF-DB Computations

The geodetic infrastructures for GNSS-positioning services (GIPS) at Brazil have been developed in 2011 at IAF/HSKA in cooperation with the Universidade Fe-de-ral Rural do Rio de Janeiro (UFRRJ), Instituto de Tecnologia, Departamento de Engenharia and the Instituto Brasileiro de Geografia e Statística (IBGE), which provided about 5000 control points ($(B,L,h)_{ITRF}$ | $(B,L)_{Class}$ | H) for the computation of the GIPS-1 and GIPS-2 transformation parameter databases. As concerns GIPS-1, trafo-1 (DFLBF) and GIPS-1, trafo-2 (COPAG) databases were computed between the ITRF-related SIRGAS and all three classical reference frames (Corrego Alegre, SAD96 and SAD96) using the sofware COPAG. As concerns GIPS-2 (trafo-3) the Geoid database for Brazil has been computed using the software DFHBF, version 4. The Brazil project and the GIPS-1 component as an online service for demonstration are available at http://www.geozilla.de/transformations.copag_brazil.php .

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