EPOS GNSS - Description of the Products

1 Details of processing options for time series solutions

1.a GAMIT solution at UGA-CNRS-ISTerre

EUROPEAN PLATE OBSERVING SYSTEM – GNSS products UGA-CNRS-ISTerre Double Difference Analysis Center Strategy Summary	
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Software used	GAMIT v. 10.71, GLOBK v. 10.71, developed at MIT/SIO
Preparation date	January 29, 2016
DOI	10.17178/GNSS.products.EPOS.2019
Modification dates	January 29, 2016 Creation November 26, 2020 Modification September 5, 2023 Modification
Date last complete data analysis	
Automatic updates of the time series	Automatic update at D-2 and D-25
MEASUREMENT MODELS	
Observable	Doubly differenced, ionosphere-free combination of L1 and L2 carrier phases. Pseudoranges are used only to obtain receiver clock offsets and in ambiguity resolution.
Data weighting	Sigma on doubly differenced LC phase: Site- and elevation-dependent based on iterated Cleaning at 30-second rate. Sampling rate: 2 minutes Elevation angle cutoff : 10
Data Editing	Cycles slips detected and fixed. Unresolved cycle slips estimated in solution. Postfit editing using 4 times RMS deletion.
RHC phase rotation corr.	Phase polarization effects applied (Wu et al, 1993)
Ground antenna phase center cal.	Elevation- and azimuth-dependent phase center corrections are applied according to the model IGS14.

Troposphere	Atmospheric mapping functions and hydrostatic zenith delays from VMF1 numerical model (Boehm et al., 2006b) 2-hour piecewise linear function estimated, 1 NS and EW gradient per day.
	Met data input: VMF1 global numerical model (Boehm et al, 2006) Mapping Function: VMF1 grid Estimation: Zenith delay and horizontal gradients
Ionosphere	For daily D-2 and D-25 automatic processing: Not modeled (1st order term eliminated by forming the ionosphere-free linear combination of L1 and L2). For annual reprocessing : Use of the total electron content (TEC) model from the ionex file (2nd and 3rd order terms).
Plate motions	ITRF2014 velocities
Tidal	Solid earth and tidal displacement: constant Love number tides frequency dependent radial tide (K1)
	Pole tide: Applied to Mean IERS pole position
	Ocean loading: FES2004 (Lyard et al., 2006)
Non-tidal loading	Atmospheric Pressure: Applied for annual reprocessing, not applied for automatic D-25 and D-2 processing. Ocean Bottom Pressure: Not applied Surface Hydrology: Not applied Other Effects: None applied
Earth Orientation Parameter (EOP) Model	IERS Bulletin B plus diurnal and semidiurnal variations in x,y, and UT1 models (EOP) R. Ray [1995], IERS Tech. Note 21 [1996]
Satellite phase center calibration	Phase centers offsets from ngs14_2101.atx applied
Relativity corrections	Relativistic corrections applied
GPS attitude model	Yaw computed using model of Bar-Sever (1996), using nominal rates or estimates supplied by JPL
ORBIT MODELS	
Geopotential	EGM2008 12x12 and order 9 (Pavlis et al., 2012) GM = 398600.4415 km**3/sec**2 AE = 6378.1363 km
Third-body	Sun and Moon as point masses Ephemeris: CfA PEP NBODY 740 GMsun = 132712440000 km**3/sec**2 GMmoon = 4902.7989 km**3/sec**2
Solar radiation pressure	Block II/IIA/IIR: JPL empirical SRP model, GSPM-13; Bar-Sever and Kuang, (2004); Sibois et al, 2014 Estimate GPS "Y-Bias" and solar radiation pressure(SRP) coefficient as constant with no a-priori constraint. Make small time-varying (stochastic) adjustments to SRP coefficients in spacecraft body-fixed X and Z directions (1% process noise sigma with 1 hr 11 sec updates and 4-hour correlation time.) Estimate tightly constrained time-varying empirical acceleration in spacecraft Y direction (0.01 nm/s^2 process noise sigma with 1 hr 11 sec updates and 4-hour correlation time.) Earth shadow model: umbra and penumbra Earth albedo: not applied Satellite attitude model not applied
Tidal forces	Solid earth tides: frequency independent Love number K2= 0.300 Ocean tides: None

Relativity	applied (IERS 1996, Chapter 11, Eqn.1)
Numerical Integration	Adams-Moulton fixed-step, 11-pt predictor-corrector with Nordsieck variable-step starting procedure (see Ash, 1972 and references therein) Integration step-size: 75 s; tabular interval: 900 s Arc length: 24 hours
ESTIMATED PARAMETERS (APRIORI VALUES & SIGMAS)	
Adjustment	Weighted least squares plus Kalman filter
Stations coordinates	As of 2020, up to 17 networks (40 stations per network) 2 common sites between networks Weak constraints applied to site coordinates
Satellite clocks bias	Initial values from linear fit to Broadcast ephemeris. Values estimated during data cleaning.
Receiver clock bias	Time estimated from pseudoranges.
Orbital parameters	Initial Position and Velocity (IC) plus 9 radiation pressure terms: constant and sin/cos once-per-rev terms for a direct, y-axis, and b-axis acceleration. ICs estimated each day. Radiation parameters treated as random walk with process noise based on independent daily estimates. ICs fixed to IGS Final orbit values.
Troposphere	Piece-wise linear function in zenith delay estimated once per 2-hr for each station constrained by a random-walk process to 20mm/sqrt(hr); 1 N-S & 1 E-W gradient parameter per day per station, constrained to 30 mm at 10 deg elevation angle Mapping function: VMF1
Ionosphere	1st order effect estimated by linear combination of L1 and L2 phase.
Ambiguity	Resolution attempted for all baselines but resolving Melbourne-Webena Widelines for L2-L1 using pseudo-ranges with differential code biases applied, and then L1 from geodetic solution using ionospheric free observable.
Earth Orientation Parameters (EOP)	Pole X/Y and their rates, and UT1 rate estimated once per day.
GPS attitude model	Not estimated
REFERENCE FRAMES	
Inertial	J2000 Geocentric
Terrestrial	IGS14 station No constrained coordinates and velocities
Interconnection	Precession: IAU 1976 Precession Theory Nutation: IAU 2000 Nutation Theory
REFERENCES	

Ash, M. E., Determination of Earth satellite orbits, Tech. Note 1972-5, Lincoln Laboratory, MIT, 19 April 1972.

Bar-Sever, Y. E., A new module for GPS yaw attitude, in Proc. IGS Workshop: Special Topics and New Directions, edit. G. Gendt and G. Dick, pp. 128-140, GeoForschungsZentrum, Potsdam, 1996.

Beutler, G., E. Brockmann, W. Gurtner, U. Hugentobler, L. Mervart, and M. Rothacher, Extended Orbit Modeling Techniques at the CODE Processing Center of the International GPS Service for Geodynamics (IGS): Theory and Initial Results, Manuscripta Geodaetica, 19, 367-386, 1994.

Boehm, J., and H. Schuh, Global Pressure and Temperature (GPT): A spherical harmonic expansion of annual pressure and temperature variations for geodetic applications, J. Geod., 2006

Boehm, J., A. Niell, P. Tregoning, and H. Schuh, Global Mapping Function (GMF):A new empirical mapping function based on numerical weather model data, Geophys. Res. Lett., 33, L07304, doi:10.1029/2005/GL025546, 2006a.

Boehm J, Werl B, Schuh H, Troposphere mapping functions for GPS and very long baseline interferometry from European Centre for Medium-Range Weather Forecasts operational analysis data, J Geophys Res 111:B02406. doi:10.1029/2005JB003629, 2006b.
Dong, D., and Y. Bock, Global Positioning System network analysis with phase ambiguity resolution applied to crustal deformation studies in California, Journal of Geophysical Research, 94, 3949-3966, 1989.
Dong, D., T. A. Herring, and R. W. King, Estimating Regional Deformation from a Combination of Space and Terrestrial Geodetic Data, J. Geodesy, 72, 200-214, 1998.
Lyard, F., F. Lefevre, T. Letellier and O. Francis. Modelling the global ocean tides: a modern insight from FES2004, Ocean Dynamics, 56, 394-415, 2006.
Niell, A. E., Global mapping functions for the atmospheric delay, J. Geophys. Res., 101, 3227-3246, 1996.
Pavlis, N.K., S.A. Holmes, S.C. Kenyon, J.K. Factor,The development and evaluation of the Earth Gravitational Model 2008 (EGM2008), J. Geop. Res., 117(B4), 2012.
Ray, R.D., ftp://maia.usno.navy.mil/conventions/chapter8/ray.f (IERS Standards), 1995
Schaffrin, B., and Y. Bock, A unified scheme for processing GPS phase observations, Bulletin Geodesique, 62, 142-160, 1988.
Springer, T. A., G. Beutler, and M. Rothacher, A new solar radiation pressure model for the GPS satellites, IGS Analysis Center Workshop, Darmstadt, 9-11 February 1998.
Wu, J. T., S. C. Wu, G. A. Hajj, W. I. Bertiger, S. M. Lichten, Effects of antenna orientation on GPS carrier phase. Manuscripta Geodaetica 18, 1993, 91- 98, 1993.

2 Details of processing options for velocity solutions

2.a MIDAS velocity generation from GAMIT solution at UGA-CNRS-ISTerre

To estimate rates of motion for each station and associated uncertainties from the daily time series we applied the robust MIDAS trend estimator (Blewitt et al., 2016). The MIDAS-estimated velocity is essentially the median of the distribution of values calculated using pairs of data in the time series separated by approximately 1 year, making it insensitive to seasonal variation and time series outliers. MIDAS provides uncertainties based on the scaled median of absolute deviations of the residual dispersion.