EPOS GNSS - Description of the Products

1 Details of processing options for time series solutions

1.a GIPSY solution at INGV

EUROPEAN PLATE OBSERVING SYSTEM – GNSS products INGV Precise Point Positioning Analysis Center Strategy Summary	
Analysis center	Osservatorio Nazionale Terremoti Istituto Nazionale Geofisica e Vulcanologia Via Vigna Murata 605 00143 Roma ITALY Fax: +39 06 51860541 Data Archive: http://ring.gm.ingv.it ftp://gpsfree.gm.ingv.it
Contact person(s)	PPP Gipsy INGV analysis center E-mail: pppgipsyingv (at) ingv.it | Phone: +39-06-51860537
Software used	GIPSY/OASIS-II Version 6.3 developed at JPL
Preparation date	January 21, 2016
Version number	
DOI	
Modification dates	December 14, 2020
Date last complete data analysis	2000-01-01 onward using JPL version 2 reprocessing with IERS2010/IGS14 conventions
Automatic updates of the time series	
MEASUREMENT MODELS	
Observable	Undifferenced ionosphere-free carrier phase, LC; Undifferenced ionosphere-free pseudorange, PC;
Data weighting	Elevation angle cutoff: 0 degrees; Sampling rate: 5 minutes; Data weight, LC: 1 cm; Data weight, PC: 1 m; Weighting: Sigma^2=1/sin(e)
Data Editing	Undifferenced LC and PC combinations; CA-P1 biases from CODE applied
RHC phase rotation corr.	Applied
Ground antenna phase center cal.	PCV model from igs14_wwww.atx applied; Receiver antenna and radome types from IGS sinex file
Troposphere	A priori model: Wet and Dry from VMF1 model (Boehm et al, 2006); Mapping Function: VMF1 grid; Estimation: Zenith delay and horizontal gradients

Ionosphere	1st order effect: Removed by LC and PC combinations; 2nd order effect: Modeled
Plate motions	Not applied to a-priori positions
Tidal	Solid earth tide: IERS 2010 Conventions
	Permanent tide: NOT removed from model, so NOT in estimated site coordinates
	Pole tide: IERS 2010 Conventions; Ocean Tide Loading: Diurnal, Semidiurnal, MF, and MM Model: FES2004 Semiannual: Self-consistent equilibrium model hardisp.f from IERS2010 Surface deformations computed at JPL with respect to instantaneous center of mass; Ocean Pole Tide Loading: Applied
Non-tidal loading	Atmospheric Pressure: Not applied; Ocean Bottom Pressure: Not applied; Surface Hydrology: Not applied; Other Effects: None applied
Earth Orientation Parameter (EOP) Model	IERS 2010 Conventions for diurnal, semidiurnal, and long period tidal effects on polar motion and UT1
Satellite phase center calibration	Phase centers offsets from igs14_wwww.atx applied; PCV model w.r.t. phase center from igs14_www.atx applied
Relativity corrections	Periodic Clock Corrections, (-2*R*V/c): Applied; Gravity Bending: Applied
GPS attitude model	GYM95 nominal yaw rate model from Bar-Sever (1996) and yaw rates estimated for Block II satellites
ORBIT MODELS	
Geopotential	EGM2008 12x12 C20, C30, C40, C21, S21 from IERS2010 standards GM = 398600.4415 km**3/sec**2 AE = 6378.1363 km
Third-body	Sun, Moon, and All Planets Ephemeris: JPL DE421
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: conic model with oblate Earth, umbra and penumbra Earth albedo: applied Attitude Model: GYM95 yaw model from Bar-Sever (1996)
Tidal forces	Solid earth tides: IERS 2010 Conventions Ocean tides: FES2004 to degree and order 30 with convolution formalism of Desai and Yuan (2006) Solid Earth Pole tide: IERS 2010 conventions Ocean Pole tide: IERS 2010 conventions
Relativity	Applied

	Acceleration due to point mass of Earth Acceleration due to geodesic precession Acceleration due to Lense-Thirring precession
Numerical Integration	Variable high order Adams predictor-corrector with direct integration of second-order equations; Integration step: variable Starter procedure: RKF Arc length: 30 hours centered at 12:00 of each day
ESTIMATED PARAMETERS (APRIORI VALUES & SIGMAS)	
Adjustment	Stochastic Kalman filter/smoother implemented as square root information filter with smoother
Stations coordinates	Daily free-network estimates for all sites; Combine free-network estimates to get daily solution; Apply three rotations to daily solution
Satellite clocks bias	Estimate every 5 minutes relative to reference clock; Recompute every 30 seconds relative to reference clock
Receiver clock bias	Estimate every 5 minutes relative to reference clock; Reference clock usually USN3 or AMC2
Orbital parameters	Epoch state, solar pressure parameters, Y-bias; Solar scale X and Z, Y acceleration
Troposphere	Zenith delay: random walk 5.0d-8 km/sqrt(sec) Horizontal delay gradients: random walk 5.0e-9 km/sqrt(sec) Mapping function: VMF1
Ionosphere	1st order effects removed by LC and PC combinations and 2nd order effects modeled
Ambiguity	Global ambiguities resolved
Earth Orientation Parameters (EOP)	Estimate polar motion, polar motion rate, and LOD; UT1 integrated from estimated LOD
GPS attitude model	Estimate yaw rates for eclipsing spacecraft; Yaw rates used for measurement but not dynamic models
REFERENCE FRAMES	
Inertial	J2000 Geocentric
Terrestrial	IGS14 station coordinates and velocities
Interconnection	Precession: IAU 2006 Precession Theory; Nutation: IAU 2006 Nutation Theory; A priori EOPS: BulA updated daily, with polar motion and length of day estimated daily

REFERENCES

Bar-Sever, Y. E. (1996), "A new model for GPS yaw attitude", Journal of Geodesy, 70:714-723

Bar-Sever, Y. E., and D. Kuang (2004), New empirically-derived solar radiation pressure model for GPS satellites, IPN Progress Reports 42-159, JPL.
Available online: http://ipnpr.jpl.nasa.gov/progress_report/42-160/title.htm

Bassiri, S., and G. A. Hajj, (1993), Higher-order ionospheric effects on the global positioning systems observables and means of modeling them, Manuscripta Geodtica, 18, 280-289, 1993

Blewitt, G., (1990), An automatic editing algorithm for GPS data. Geophysical Research Letters, Vol. 17, No. 3, p. 199-202

Boehm, J., A.E. Niell, P. Tregoning, H. Schuh (2006), "Global Mapping Functions (GMF): A new empirical mapping function based on numerical weather model data", Geophysical Research Letters, Vol. 33, L07304 DOI:10.1029/2005GL025545.

Boehm J, Werl B, Schuh H (2006a), "Troposphere mapping functions for GPS and very long baseline interferometry from European Centre for Medium-Range Weather Forecasts operational analysis data"," Journal Geophys Res 111:B02406. doi:10.1029/2005JB003629

Boehm, J., R. Heinkelmann and H. Schuh (2007), "Short Note: A global model of pressure and temperature for geodetic applications", Journal of Geodesy, DOI: 10.1007/s00190-007-0135-3

IERS Conventions 2003, D.D. McCarthy & G. Petit (editors), IERS Technical Note 32, Frankfurt am Main: Verlag des Bundesamts fuer Kartographie und Geodaesie, 2004.

Kedar, S., G. Hajj, B. Wilson, and M. Heflin (2003), The effect of the second order GPS ionospheric correction on receiver positions, Geophys. Res. Lett., 30(16), 1829, doi:10.1029/2003GL017639

Moyer, T.D., (2000) Formulation of observed and computed values of deep space network data types for navigation, Deep Space Communications and Navigation Series, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, Chapter 4, pp, 19-28.

Sibois, A., C. Selle, S. Desai, A. Sibthorpe, and J. Weiss, GSPM13: An updated empirical model for solar radiation pressure forces acting on GPS satellites, IGS Workshop 2014, Pasadena, CA, 2014.

Sibthorpe, A., J. Weiss, N. Harvey, D. Kuang, and Y. Bar-Sever, Empirical modeling of solar radiation pressure forces affecting GPS satellites, AGU Fall Meeting, San Francisco, CA, 2010.

2 Details of processing options for velocity solutions

2.a MIDAS velocity generation from GIPSY-OASIS solution at INGV

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.