EPOS GNSS - Description of the Products

1 Details of processing options for time series solutions

1a GipsyX PPP solution at UGA-CNRS

EUROPEAN PLATE OBSERVING SYSTEM – GNSS products UGA-CNRS Precise Point Positioning Analysis Center Strategy Summary	
Analysis center	UGA-CNRS Observatoire des Sciences de l’Univers de Grenoble ISTerre Université Grenoble Alpes BP 53 38041 Grenoble CEDEX 9 FRANCE Fax: +33 (0)4 76 63 52 52
Contact	e-mail: isterre-epos-gnss(at)univ-grenoble-alpes.fr Phone: +33 (0)4 76 63 52 08
Software used	Gipsy X v. 2.3, developed at JPL
Preparation date	March 27th , 2026
DOI	10.17178/GNSS.products.EPOS.2026
Modification dates	March 27th , 2026 Creation
Date last complete data analysis	
Automatic updates of the time series	Daily automatic update (using rapid orbits at d-2 or d-3, update with final orbits around d-15)
MEASUREMENT MODELS	
Preprocessing	RINEX header must be interpretable - approximate XYZ replaced with Station database (staDB) values - alias table interprets antenna type as IGS standard - algorithm attempts to fix formatting errors - requires antenna type has IGS ANTEX calibrations - non-calibrated radome set to "NONE" (IGS standard) Requires minimum file size, typically ~4 hr/day Apply CA-P1 biases Cycle slip detection and correction using TurboEdit Delete phase connected arcs < 20 minutes Carrier Phase: Decimated to 5 minutes Pseudorange: Carrier-aided smoothing to 5 minutes
Basic observable	Undifferenced ionosphere-free carrier phase, LC Undifferenced ionosphere-free pseudorange, PC Elevation angle cutoff: 7 degrees Sampling rate: 5 minutes Data weight, LC: 0.01 m Data weight, PC: 1 m

	Elevation weighting: SqrtSin: DataSigma / sqrt(sin(el))
Modeled observable	Undifferenced LC and PC combinations CA-P1 biases from CODE applied
RHC phase rotation corr.	Applied
Marker -> antenna ARP eccentricity	dN, dE, dU eccentricities from EPOS site logs applied to compute station marker coordinates
Ground antenna phase center cal.	PCV model from igs20_wwww.atx applied Receiver antenna and radome types from EPOS site logs
Troposphere	A priori model: Wet and Dry interpolated from VMF1 grid Nominal gradients are zero Mapping Function: Vienna Mapping Function VMF1 Estimation: Zenith delay and gradients as random walk every 5 minutes
Ionosphere	1st order effect: Removed by LC and PC combinations 2nd order effect: Modeled using IONEX data with IGRF13
Plate motions	Not applied to apriori positions
Tidal	Solid earth tide: IERS 2020 Conventions Permanent tide: Not removed from model Pole tide: IERS 2020 Conventions Ocean Tide Loading: Diurnal, Semidiurnal, MF, MM, and SSA Model: FES2022b Surface deformations computed with respect to instantaneous center of mass Ocean Pole Tide Loading: Not 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 2020 Conventions for diurnal, semidiurnal, and long period tidal effects on polar motion
Satellite center of mass correction	Phase centers offsets from igs20_wwww.pcm applied
Satellite antenna phase variation	PCV model phase center from igs20_wwww.atx applied
Relativistic corrections	Periodic Clock Corrections, (-2*R*V/c): Applied Gravity Bending: Applied
GPS attitude model	GYM95 nominal yaw rate model
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: GOT4.8ac 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 PPP estimates for all sites Apply daily transformation into IGS20
Satellite clocks bias	Fixed to JPL clock products, which are given every 5 minutes relative to reference clock.
Receiver clock bias	Estimate every 5 minutes relative to satellite clocks
Orbital parameters	Fixed to JPL ECEF orbit products interpolated to 5 min
Troposphere	Zenith delay: random walk 0.5 1e-7 km/sqrt(sec) Horizontal delay gradients: random walk 1.0 1e-8 km/sqrt(sec). Mapping function: VMF1
Ionosphere	1st order effects removed by LC and PC combinations and 2nd order effects modeled using ionex file from JPL
Ambiguity	Resolve ambiguities using WLPB products from JPL
Earth Orientation Parameters (EOP)	Fix to JPL products: polar motion, polar motion rate, and LOD, where UT1 is integrated from estimated LOD
GPS attitude model	Fixed to JPL products: yaw rates when in eclipse
REFERENCE FRAMES	
Inertial	J2000 Geocentric
Terrestrial	Daily transformed coordinates into IGS20 and relevant plate-fixed frames using plate rotation model of Kreemer et al. (2014)
Interconnection	Precession: IAU 2006 Precession Theory Nutation: IAU 2006 Nutation Theory A priori EOPS: EOPC04 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 Geodaetica, 18, 280-289, 1993

Bevis M., S. Businger, S. Chiswell, T.A. Herring, R.A. Anthes, C. Rocken, and R.H. Ware (1994), GPS meteorology: Mapping zenith wet delays onto precipitable water. Journal of Applied Meteorology, Vol. 33, p.378-386

Blewitt, G., (2024), An improved equation of latitude and a global system of graticule distance coordinates. Journal of Geodesy, 98(6) https://doi.org/10.1007/s00190-023-01815-0

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

Blewitt, G., W.C. Hammond, and C. Kreemer (2018), Harnessing the GPS data explosion for interdisciplinary science. Eos, Vol. 99, https://doi.org/10.1029/2018EO104623

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

Kreemer, C., G. Blewitt, and E. Klein (2014), A geodetic plate motion and Global Strain Rate Model. Geochemistry, Geophysics, Geosystems, Vol.15 pp. 3849-3889, doi:10.1002/2014GC005407

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.

Young, Z.M., G. Blewitt, C. Kreemer (2024). Improved GPS tropospheric path delay estimation using variable random walk process noise. Journal of Geodesy, 98(89), https://doi.org/10.1007/s00190-024-01898-3

2 Details of processing options for velocity solutions

2a MIDAS velocity generation from GipsyX PPP solution at UGA-CNRS

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.

3 Details of processing options for offset solutions

3a ITSA time series offset generation from GipsyX solution at UGA-CNRS

ITSA is a python tool that produces a trajectory model for GNSS time series.

Inputs are the time series in PBO pos format, the dates and types of discontinuities (antenna, earthquakes, slow-slip events, swarms, station coordinates (used to get earthquakes-station distance).

ITSA calculates the 3 dimensional offset for each equipment discontinuity, post-seismic relaxation, currently without inversion (tau is an input parameter), and linear, seasonal, and acceleration on the full time series. ITSA identifies and removes outliers.

Outputs are the final time series and all modelled and applied corrections.

As part of EPOS-GNSS, ITSA is used to estimate offsets associated with:
- documented instrument changes (present in EPOS site log), noted as I or Instrument
- earthquakes: such offsets are labelled as co-seismic in the offset json file, and as E (Earthquake) on the EPOS-GNSS products gateway.

References:
Marill et al, 2021 https://doi.org/10.1029/2020JB021226