INGV-ONT-GIPSY Analysis Center Strategy Summary

ANALYSIS CENTER	Osservatorio Nazionale Terremoti Istituto Nazionale Geofisica e Vulcanologia Via Vigna Murata 605 00143 Roma ITALY Data Archive: http://ring.gm.ingv.it ftp://gpsfree.gm.ingv.it
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SOFTWARE USED	GIPSY/OASIS-II Version 6.3 developed at JPL
SITE TIME SERIES SSSS = site ID MR = mon/rec ID CCC = country code AC = analysis c. RS = ref. system	http://4.232.136.103/data-analysis-and-product/ SSSSMRCCC_AC_RS.pos final daily x,y,z,e,u,n
INGV SITE VEL.	http://4.232.136.103/data-analysis-and-product/
PRODUCTS USED	Final, NNR daily Repro3.0 products from JPL archive: https://sideshow.jpl.nasa.gov/pub/JPL_GNSS_Products/Final/ Including: GPS satellite orbit position/velocity estimates GPS satellite clock estimates GPS satellite attitude parameters WLPB estimates (widelane & phase biases) Daily transformation parameters from NNR to IGS14 Time-pole parameter estimates GPS satellite eclipse shadow times Name of IGS antenna calibration files IONEX data from JPL for higher order ion calibrations https://sideshow.jpl.nasa.gov/pub/iono_daily/IONEX_final/ VMF1 gridded ECMWF tropo parameters from TU Vienna http://vmf.geo.tuwien.ac.at/trop_products/GRID/2.5x2/VMF1/STD_OP/ Auxiliary data updated periodically from JPL: https://sideshow.jpl.nasa.gov/pub/gipsy_products/gipsy_params/ IGS ANTEX antenna calibration file JPL DE431 planetary ephemeris CODE CA-P DCB (differential code biases) GPS receiver type codes GPS constellation configuration history IERS/BIH leap seconds history IERS earth orientation parameters NOAA IGRF12 Earth magnetic field model Auxiliary data updated from IGS Central Bureau: https://igscb.jpl.nasa.gov/igscb/station/general/igs_with_former.snx IGS station receiver/antenna configuration history Auxiliary data from Chalmers University, Sweden: http://holt.oso.chalmers.se/loading/ FES2004 ocean tidal loading coefficients at sites Custom data (from INGV/ONT) Approximate latitude, longitude, height at sites

	Internal: antenna+radome and receiver type aliases	
GPS DATA USED:	RINEX files from various archives, including: RING ftp://bancadati2.gm.ingv.it UNAVCO ftp://data-out.unavco.org CDDIS ftp://cddis.gsfc.nasa.gov EUREF ftp://ftp.epncb.oma.be VENETO https://retegnssveneto.cisas.unipd.it FREDNET https://frednet.crs.ogs.it GEODAF ftp://geodaf.mt.asi.it SPINGNSS https://www.spingnss.it ...and many more	
PREPARATION DATE	2024-04-30 for INGV's Gipsy/IGS14 products	
MODIFICATION DATES	2024-04-30 initial creation	
EFFECTIVE DATE FOR DATA ANALYSIS		

MEASUREMENT MODELS		
Preprocessing	RINEX header must be interpretable - approximate XYZ replaced with INGV database values - alias table replaces antenna type with IGS standard - algorithm attempts to fix formatting errors - require antenna type has IGS ANTEX calibrations - non-calibrated radome set to "NONE" (IGS standard) Require minimum file size, typically ~18 hr/day Apply CA-P1 biases Fix non-compliant time-tags for older receiver types Remove non-GPS GNSS data (e.g., GLONASS) Remove L2C and C2 data 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: Sigma^2=1/sin(e)	
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 IGS SNX or RINEX header applied to compute station marker coordinates	
Ground antenna phase center cal.	PCV model from igs14_wwww.atx applied Receiver antenna and radome types from RINEX header	
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 Integrated water vapor: from wet zenith delay using	

		Bevis et al. (1994) refractivity coeffs, SI units: k1=0.776, k2=0.704, k3=3739.0, Rv = 461.5 and k2'=k2-k1*m where ratio m = 18.0152/28.9644 and using VMF1 interpolated mean atmospheric temperature
Ionosphere	1st order effect: Removed by LC and PC combinations	
	2nd order effect: Modeled using IONEX data with IGRF12	
Plate motions	Not applied to apriori positions	
Tidal	Solid earth tide: IERS 2010 Conventions	
	Permanent tide: Not removed from model	
	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 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 center of mass correction	Phase centers offsets from igs14_wwww.pcm applied	
Satellite antenna phase variations	PCV model w.r.t. phase center from igs14_www.atx applied	
Relativistic corrections	Periodic Clock Corrections, (-2*R*V/c): Applied	
	Shapiro Delay: Applied	
GPS Attitude model	GYM95 nominal yaw rate model from Bar-Sever (1996) and yaw rates estimated for Block II satellites	

ORBIT MODELS (JPL ORBIT PRODUCTS)		
Orbit Arc	30 hours	
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/IIF/IIR/III: JPL empirical 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 (Knocke, 1989)
	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 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
Station coordinates	Daily PPP estimates for all sites Apply daily transformation into IGS14
Satellite clock	Fixed to JPL clock products, which are given every 5 minutes relative to reference clock
Receiver clock	Estimate every 5 minutes relative to satellite clocks
Orbital	Fixed to JPL ECEF orbit products interpolated to 5 min
GPS Attitude	Fixed to JPL products: yaw rates when in eclipse
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	Resolve ambiguities using WLPB products from JPL	
Earth Orientation Parameters	Fix to JPL products: polar motion, polar motion rate, and LOD, where UT1 is integrated from estimated LOD	

REFERENCE FRAMES		
Inertial	J2000 Geocentric	
Terrestrial	Daily transformed coordinates into IGS14 and relevant plate-fixed frames using plate rotation model	
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	

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