EPOS-IP GNSS Processing

On the 20th of November 2015, we agreed that the objective for 2016 is to run, and generate products on a subset of stations. Test solutions will be processed in the 2 EPOS processing centers (CNRS with GAMIT, INGV with GIPSY), and another one will be processed in KOERI with Turkish sites + some EPN sites

NB: the contribution of other processing centers to the densified solution will be discussed later (in January or Feb. 2016), and coordinated by A. Kenyeres.

1. Contours of the prototype solutions

a- for CNRS and INGV processing centers

+ RENAG: 73 stations
+ RING (191 = 186 sites -1 site [KLOK] delivered by NOA + 6 sites [CARO; INGP, MESS, MMME, MURB and PESA] now out of service but with data spanning more than 3 years)
+ NOA sites (around 22 sites)
+ EPN: 265 stations
+ local IGS sites (10 in Italy + 11 in France + 1 in Greece)

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= 573 stations, Time span = 2005-2015

b- for KOERI

+ MAGNET: 22 stations
+ a subset of EPN (to be discussed with A. Kenyeres → ~15 stations)
over a minimum time period spanning = 2011-2015

2. General processing Instructions

a- Preparation

1. Download the RINEX observation files of the network for the period to be processed through existing GSAC nodes :
    - RENAG: http://epos.unice.fr:8080/renagbgsac/
    - INGV: http://ring.gm.ingv.it
    - NOA: http://194.177.194.238:8080/noanetgsac
    - The data of EPN stations are available at the EPN data centres (see http://www.epncb.oma.be/_dataproducts/data_access/dailyandhourly/).
2. Download the satellites orbits, clocks (if necessary) and Earth Rotation Parameter (ERP) files from the IGS/JPL/MIT. Final products have to be used. For information about access to IGS products see http://igs.org/.
3. Download the coordinates and velocities of the actual IGS realisation of the ITRF (e.g. IGb08) from the IGS CB at ftp://igscb.jpl.nasa.gov/.

4. Prepare a table of ocean loading displacements for involved sites (or convert into a grid) through the online computation service of OSO at http://holt.oso.chalmers.se/loading/index.html using FES2004 model.
5. Prepare the receiver and satellite antennae calibration table using IGS antenna calibrations ANTEX files.

6. Make sure the correct meta-data (provided through GSAC servers and in ftp://epncb.oma.be/pub/station/general/euref.snx) is used during all steps of the data analysis, independent of the information in the RINEX header.

b- Processing options

During 2015/12/09 visioconference, we agreed that for the prototype solution at least we will perform the best solution possible, making the best use of each processing softwares (GAMIT & GIPSY). For this reason, we do not always use the same processing option for both solutions. The processing options of each center will be fully detailed and should be available to the products users (A. Socquet & N. d'Agostino are the contact persons).

1. Use IGS/JPL/MIT final products (satellite orbits, satellite clocks and Earth orientation parameters). Take in particular care on the usability of orbits for unhealthy satellites. Obits can either be fixed or re-estimated.
2. Introduce ocean-loading corrections for the stations, using FES2004 Ocean tidal loading.
3. Use the 0° elevation cut-off angle. Apply elevation dependent weighting of observations.
4. Use the tropospheric mapping function with a priori ZHD model using the Vienna Mapping Function (VMF1) to map the tropospheric delay in zenith direction.
5. Don't implement atmospheric loading (tidal and non-tidal) for the prototype solution. The results will be compared to the current RENAG solution that implements atmospheric loading. Depending on this comparison, atmospheric loading might be introduced in the next solution.
6. Estimate station specific troposphere parameters every 2 hours. Estimate one couple of horizontal tropospheric gradients per 24h session.
7. Fix the initial phase ambiguities to integer numbers for GPS data processing.
8. Distribute the loosely constrained solution.
9. Align the solution to the IGb08 at the current epoch, e.g., through applying "minimum-constraint-conditions" to the reference sites (do NOT "fix" any reference coordinates).

3. Details of processing options for GIPSY solution at INGV

INGV-CNT-GIPSY Analysis Center Strategy Summary

ANALYSIS CENTER	Centro 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)	Dr. Nicola D'Agostino E-mail: nicola.dagostino (at) ingv.it Phone: +39-06-51860537
SOFTWARE USED	GIPSY/OASIS-II Version 6.3 developed at JPL
PRODUCTS USED	Final, non-fiducial daily products from JPL archive: ftp://sideshow.jpl.nasa.gov/pub/JPL_GPS_Products/Final Including: GPS satellite orbit estimates GPS satellite clock estimates WLPB estimates (widelane & phase biases) Name of TRF (terrestrial reference frame) Transformation parameter estimates to named TRF Time-pole parameter estimates GPS satellite eclipse times Name of IGS ANTEX antenna calibration file Auxiliary data updated periodically from JPL: IGS ANTEX antenna calibration file JPL 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 Auxiliary data updated from IGS Central Bureau: http://igscb.jpl.nasa.gov/ IGS station receiver/antenna configuration history Auxiliary data from Chalmers University, Sweden: http://holt.oso.chalmers.se/loading/ Ocean tidal loading coefficients for all stations
PREPARATION DATE	January 21, 2016
MODIFICATION DATES	January 21, 2016 Creation
EFFECTIVE DATE FOR DATA ANALYSIS	2000-01-01 onward using JPL version 2 reprocessing with IERS2010/IGS08 conventions

MEASUREMENT MODELS	
Preprocessing	RINEX header must be interpretable - alias table replaces antenna type with IGS standard - fix obvious 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 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: 0 degrees Sampling rate: 5 minutes Data weight, LC: 1 cm Data weight, PC: 1 m 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 sinex file applied to compute station marker coordinates
Ground antenna phase center cal.	PCV model from igs08_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 apriori 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: GOT4.8ac 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 center of mass correction	Phase centers offsets from igs08_wwww.atx applied	
Satellite antenna phase variations	PCV model w.r.t. phase center from igs08_www.atx applied	
Relativistic 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 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 free-network estimates for all sites Combine free-network estimates to get daily solution Apply three rotations to daily solution
Satellite clock	Estimate every 5 minutes relative to reference clock Recompute every 30 seconds relative to reference clock
Receiver clock	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

GPS Attitude parameters	Estimate yaw rates for eclipsing spacecraft Yaw rates used for measurement but not dynamic models
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	Estimate polar motion, polar motion rate, and LOD UT1 integrated from estimated LOD

REFERENCE FRAMES	
Inertial	J2000 Geocentric
Terrestrial	IGS08 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

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3. Details of processing options for GAMIT solution at CNRS-ISTerre

EUROPEAN PLATE OBSERVING SYSTEM
CNRS-OSUG-ISTERRE GAMIT Analysis Center Strategy Summary

ANALYSIS CENTER	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 Data Archive: http://epos.unice.fr:8080/renagbgsac/
CONTACT PERSON(S)	Pr. Anne Socquet E-mail: anne.socquet (at) univ-grenoble-alpes.fr Phone: +33 (0)4 76 63 52 08
SOFTWARE USED	GAMIT v. 10.5, GLOBK v. 10.5, developed at MIT/SIO
PREPARATION DATE	January 29, 2016
MODIFICATION DATES	January 29, 2016 Creation
EFFECTIVE DATE FOR DATA ANALYSIS	

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 difference LC phase: Site and elevation dependent based on iterated Cleaning at 30-second rate. Sampling rate: 2 minutes Elevation angle cutoff : 0
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 IGS08.

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	Not modeled (ionosphere eliminated by forming the ionosphere-free linear combination of L1 and L2).
Plate motions	ITRF2008 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: Not applied
	Ocean Bottom Pressure: Not applied
	Surface Hydrology: Not applied
	Other Effects: None applied
Earth Orientation Parameter (EOP)	IERS Bulletin A plus diurnal and semidiurnal variations in x,y, and UT1 models (EOP) R. Ray [1995], IERS

Model	Tech. Note 21 [1996]
Satellite center of mass correction	Block I x,y,z: 0.2100, 0.0000, 0.8540 m
	Block II/IIA x,y,z: 0.2790, 0.0000, 0.9519 m
	Block IIRA/IIRB x,y,z: -0.0031, -0.0012, 0.0000 m
	Block IIRM x,y,z: 0.0000, 0.0000, 0.0000 m
	Block IIF x,y,z: 0.3940, 0.0000, 1.6000 m
Satellite phase center calibrat	Phase centers offsets from igs08_wwww.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
Station coordinates	~15 networks of ~40 stations per network 2-3 common sites between networks Weak constrains applied to site coordinates
Satellite clocks bias Receiver clock bias	Initial values from linear fit to Broadcast emphemeris. Values estimated during data cleaning. 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 effects removed 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 ionosperic 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	IGS08 station No constrained coordinates and velocities
Interconnection	Precession: IAU 1976 Precession Theory Nutation: IAU 2000 Nutation Theory

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