# std2400 Precise Orbit Determination (POD) standards

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This document summarizes the std2400 POD standards applied to the latest computation of precise NASA GSFC SLR+DORIS-based orbits for the TOPEX/Poseidon (*Fu et al., 1992*), Jason-1 (*Ménard et al., 2003*) , Jason-2 (*Lambin et al., 2010*), Jason-3 and Sentinel-6A (*Donlon et al., 2021*) satellites. The orbits determined with these std2400 standards are called std2400. The orbits were computed using the NASA Precise Orbit Determination and Geophysical Parameter estimation software (*Nicholas et al., 2025*).

The orbits are archived in sp3 format at the IDS data Centers (the NASA CDDIS, https://cddis.nasa.gov/archive/doris/products/orbits/gsc/
and at the IGN Data Center, ftp://doris.ign.fr/pub/doris/products/orbits/gsc).

The sp3 files have the naming convention: **AAASATVV.bXXDDD.eYYEEE.D_L.sp3.FFF**
AAA = **GSC -- name of analysis center.**
SAT = **TOP, JA1, JA2, JA3, S6A --- Satellite ids**
XXDDD = year and day of year that the orbit file starts.
YYEEE = year and day of year that the orbit file ends.
"D_L" = indicates a DORIS+SLR-based orbit & "_XS" indicated Altimeter Crossover + SLR orbits.
VV = **20, 21** for the std2400 series orbits.
(based on DPOD2020/SLRF2020; GRGS_RL05 to 2021.0, COSTG/FSM after 2021.0;
GOT5.5 to 30x30 for tidal geopotential and ocean loading is used for all orbits).
FFF = File release number:

VV=20: Orbits computed with the grgs_rl05 gravity model
(TOPEX, Jason-1, Jason-2, Jason-3 (through 2020-DOY353)).

VV=21: Orbits computed with the COSTG_FSM + GSFC SLR TVG gravity model (Jason-3 from 2020-DOY352 onwards, and Sentinel-6A) and the GFZ AOD1B RL06 atmosphere-ocean dealiasing model.

| Geopotential | |
|---|---|
| Static Gravity Model 1992.7–2020.96 (TP, J1, J2, J3) | GRGS RL05 91x180 (*Lemoine, J.M. et al., 2023*) |
| Time-variable gravity 1992.7–2020.96 (TP, J1, J2, J3) | GRGS RL05 90x90 (*Lemoine, J.M. et al., 2023*) offset, rate, annual, semi-annual terms |
| Static Gravity Model 2020.96 -> present (J3, S6A) | COSTG_FSM 91x180 (*Peter et al., 2022*) |
| Time-variable gravity 2020.96 -> present (J3, S6A) | SLR weekly solution 2x2+C30 (*Loomis et al., 2020*)<br>COSTG_FSM 3x90 (*Peter et al., 2022*) offset, rate, annual, semi-annual terms |
| Atmospheric/oceanic non-tidal gravity | GFZ AOD1B RL06 90x90@3hrs dealiasing products with IB correction assumed over oceans (mean pressure and tidal signal removed from data) (*Dobslaw et al., 2017a*) |
| Solid Earth tides | From IERS 2010 conventions (*Petit and Luzum, 2010*) |
| Ocean tides | GOT5.6 30x30. (*Ray and Erofeeva, 2014; Ray, 2025*) |
| Air tides | Removed from Atmospheric gravity and applied separately, up to 30x30 for 12 terms (*Dobslaw et al. 2017b).* |
| Ocean Pole tide | (*Desai, 2002*) Applied to 60x60. |
| Third Body | Sun, Moon, Planets (DE430 & DE440 ephemerides; *Folkner et al., 2014*; *Park et al., 2021*) |
| Earth GM | GM: 398600.4415D+9 $m^{3/}s^2$. |
| Relativity | Lense Thirring & Schwarzschild applied. |

| Reference Frame & Displacement of Reference points | |
|---|---|
| SLR | ITRF2020 (SLRF2020 (*Altamimi et al., 2023*; *ILRS 2025*)) |
| DORIS | ITRF2020 (DPOD2020 (*Moreaux et al., 2023)*) |
| Solid Earth tides | From IERS 2010 conventions |
| Ocean loading | GOT5.6 (*Ray, 2025*) |
| Geocenter motion | ITRF2020 annual, semi-annual model (*Rebischung et al, 2024)* |
| Tidal Geocenter | GOT5.5 tidal variations. (*Ray, 2025*) |
| Mean Pole | IERS (2018) linear mean pole. (*Ries and Desai, 2017*). |
| Precession/nutation | IAU2000 |
| EOP | Daily values, IERS Bulletin A<br>(*Bizouard et al., 2019; IERS Message 478, June 15, 2023*) |
| High Freq. EOP | Diurnal and semidiurnal variations in polar motion & UT1 due to ocean tides (*Desai and Sibois, 2016*) |

| Surface forces and attitude | |
|---|---|
| Total solar irradiance | 1360.45 W/m$^2$ (*Kopp and Lean, 2011*) |
| Albedo/IR | *Knocke et al. (1988).* |
| Atmospheric drag | NRLMSIS2 (*Emmert et al.,2020*). |
| Radiation Pressure (macromodels) | • TOPEX: retuned Heritage 8-plate macromodel<br>(derived from *Marshall & Luthcke, 1994; Marshall et al., 1995*).<br><br>Jason-1,2,3 macromodels originally from CNES (*Couhert et al., 2021*)<br>• Jason-1: GSFC tuned 10-panel macromodel.<br>• Jason-2: GSFC tuned 10-panel macromodel<br>• Jason-3: 10-panel macromodel<br><br>• Sentinel-6A: 12-panel macromodel (*Conrad et al., 2023, Table 2*) |
| Radiation pressure scale factor ($C_R$) | Pre-estimated per arc in separate OD runs without empirical accelerations and then applied in POD (following *Flohrer et al. (2011))*. |
| Attitude: | • TOPEX: GEODYN attitude model for most arcs; measured attitude quaternions only available for 11 percent arcs with off-nominal attitude.<br>• Jason-1, Jason-2, Jason-3: body quaternions and solar array quaternions.<br>• Sentinel-6A: body quaternions corrected for yaw bias of -0.43 degrees (*provided by the Copernicus POD group, Sept. 2023*). |

<table>
<tr><th colspan="6">Tracking Data, Corrections, Parameterization & Modelling</th></tr>
<tr><td>Tracking Data</td><td colspan="5">SLR: Imported from the NASA CDDIS or the EDC data centers (Noll et al., 2010; Noll et al., 2019).<br>DORIS:<br>• TOPEX, Jason-1: DORIS V2 data.<br>• Jason-2 (T2L2 corrected; Belli et al., 2021), Jason-3, Sentinel-6A: DORIS RINEX data.</td></tr>
<tr><td>Parameterization</td><td colspan="5">Dynamic orbit modelling:<br>• Drag/8 hrs + OPR along & cross-track /24 hrs + DORIS time bias /arc.</td></tr>
<tr><td>SLR station biases</td><td colspan="5">• Range bias estimated for every station per arc;<br>• T2L2-derived time bias corrections (Exertier et al., 2017)</td></tr>
<tr><td>DORIS est. parameters</td><td colspan="5">Estimate range-rate bias and troposphere scale bias per station-pass.</td></tr>
<tr><td>DORIS data a priori edits</td><td colspan="5">Selected subset of edit conditions identified in DPOD2014 SINEX “DATA_REJECT” section (such as “corrupted data” or “antenna tilt”)</td></tr>
<tr><td>Troposphere model</td><td colspan="5">SLR: Mendes-Pavlis (Mendes and Pavlis, 2004); DORIS: VMF1 (Böhm and Schuh 2004), estimate wet-component / station pass</td></tr>
<tr><td>Satellite Center-of-mass</td><td colspan="5">Time-variable: Mass & post-launch center-of-gravity are routinely updated by the satellite operators.</td></tr>
<tr><td>SLR LRA phase center:</td><td colspan="5">• TOPEX: LRA station-dependent model by receiver type. (Varghese, 1992; Nerem et al., 1993; Marshall et al., 1995).<br>• Jason-1: 49 mm range corr., GSFC-tuned vector offset (Luthcke et al., 2003) + GSFC elevation-dep. phase model<br>• Jason-2: 46 mm range corr., GSFC-tuned vector offset (Luthcke et al., 2003) + GSFC elevation-dep. phase model<br>• Jason-3: 46 mm range corr., GSFC-tuned vector offset (a-priori from Couderc, 2015) + GSFC elevation-dep. phase model<br>• Sentinel-6A: 46 mm range corr., vector offset (Cullen, 2021)</td></tr>
<tr><td>DORIS phase center:</td><td colspan="5">Starec: (Tourain et al., 2016);<br>Alcatel: 2017 Updated phase law (Manfredi et al., 2016)</td></tr>
<tr><td>SLR data weight</td><td colspan="5">All satellites: 10 cm. Some stations downweighted based on performance.</td></tr>
<tr><td rowspan="3">DORIS data weight:</td><td>TOPEX</td><td>Jason-1</td><td>Jason-2*</td><td>Jason-3*</td><td>Sentinel-6A*</td></tr>
<tr><td>2 mm/s</td><td>3 mm/s</td><td>$1/(\sin(e))^{-1/2}$</td><td>$1/(\sin(e))^{-1/2}$</td><td>$1/(\sin(e))^{-1/2}$</td></tr>
<tr><td colspan="5">*Apply elevation-dependent data weighting.<br>Some stations downweighted based on performance.</td></tr>
<tr><td>DORIS station SAA modelling</td><td colspan="5">• TOPEX: none:<br>• Jason-1: downweight 12 geographic SAA sites; Use corrected data (Lemoine & Capdeville., 2006).<br>• Jason-2: none.<br>• Jason-3: downweight 10 geographic SAA sites.<br>• Sentinel-6A: downweight 10 geographic SAA sites.</td></tr>
</table>

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