**TOPEX/Poseidon External Attitude/Solar Array Panel Quaternion data**

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The TOPEX/Poseidon satellite Attitude & Yaw steering and the Solar Array pointing were considered to follow nominal attitude laws over about 90% of the TOPEX mission. Thus, the spacecraft followed a prescribed attitude law most of the time (*Perrygo, 1987; Nerem et al., 1993*). This attitude law was coded into subroutines for the NASA Precise Orbit Determination and Geodetic Parameter Estimation Program (*GEODYN*). The initial POD expectation at launch was the radial orbit error budget of 13.3 cm (*Nerem et al., 1993*). Although the early POD results produced orbits with a radial orbit precision of 2 – 2.5 cm in 1995 (*Marshall et al., 1995*), and a radial orbit precision of 1.5 cm by 2006 (*Lemoine et al., 2006*), it was never expected that quaternions would be used to define the spacecraft attitude on a routine basis. In fact, according to the interface exchange protocols of the TOPEX project, external attitude data [satellite attitude quaternions and solar array pitch angle (SAPA) information] were generally only provided for what were deemed “off-nominal” arcs. Therefore, unlike for later missions such as Jason-1/-2/-3 or Sentinel-3A/-3B/-6A, external attitude information for TOPEX/Poseidon was available only on a limited basis.

The raw telemetry attitude data were provided to NASA GSFC by colleagues at the University of Colorado/Colorado Center for Astrodynamics Research (CU/CCAR), who had access to the TOPEX telemetry data. CU/CCAR was a partner on the TOPEX precise orbit team. NASA GSFC preprocessed these telemetry data: The raw data were screened for outliers; a continuity check was made to ensure that there were no sign changes in the quaternion data time series. The data were reformatted into a *GEODYN* external attitude data file. In the process, the external attitude data were interpolated to an even time step. It is these *GEODYN*-reformatted data that we provide with this release. The external attitude data that we provide are quaternions, which compactly represent rotations of a vector from one coordinate system to another (*Dam et al., 1998*).

The external measured Attitude and SAPA quaternion data are available by arc in two ASCII files:

- gsfc_TP_quaternion_sbf.$CYCLE.$ARC
- gsfc_TP_quaternion_sapa.$CYCLE.$ARC

For example:

- gsfc_TP_quaternion_sbf.cyc147.960909
- gsfc_TP_quaternion_sapa.cyc147.960909

The cycles ($CYCLE) refer to the repeat ground track cycles of the TOPEX mission. TOPEX cycles start with cycle 1 on Sept. 25, 1992. A partial list is available at the URL: https://openadb.dgfi.tum.de/en/missions/topex/cycles/

The $ARC refers to the start date (yymmdd) of a set quaternion data, corresponding to a particular arc processed at NASA GSFC.
If a gap of more than 4.5 minutes existed between the original quaternions then a value of -99 is output to these datasets in the quaternion fields, and the data interval spacing is maintained.

! Output GSFC SBF quaternion order = (q1, q2, q3, +qs); SBF -> J2000; TAI
! Output GSFC SAPA quaternion order = (0, a1, 0, a2); move SA panels; TAI
c... SBF --> Spacecraft Body Fixed Frame
c... J2000 --> J2000 Earth Equator and Equinox Frame (TOD)
c... SAPA --> Solar Array Pitch Angles

The SBF quaternions rotate the spacecraft body into the J2000 orbital frame, and the SAPA quaternions rotate the solar array panels positively from the spacecraft (SBF) X-axis about the Y-axis to orient them in the measured direction. The time system is TAI. The typical data interval spacing is 8.193 seconds.

Each line contains:

Modified Julian Date, quaternions (q1, q2, q3, +qs) or sapa (0, a1, 0, a2), calendar date (yymmdd), and time (hhmmss.sss) in the format (f15.9, 4f13.9 ,2x, i6.6, f10.3).

For example:

SBF (Spacecraft Body Quaternions)

52530.708703704 -0.194907300 0.078598300 0.195475100 0.957926400 020913170032.000

SAPA:

52530.708703704 0.000000000 0.900249600 0.000000000 0.435374200 020913170032.000

This release provides the GEODYN-formatted external attitude data for 27 TOPEX arcs. A description of the use of these data can be found in the publication by Zeitlhöfler et al. (2024).

If users wish to amalgamate (combine) quaternion files that partially overlap, users should be sure to perform a continuity check to avoid sign changes in the quaternions in the combined data set. A sign change can occur since quaternions, +q= (q0, q1, q2, q3) and −q= (−q0, −q1, −q2, −q3) produce identical rotations. If a continuity check is not imposed, then an erroneous rotation matrix and satellite attitude will be introduced at the time steps between where the sign changes in the quaternions occur.

These files were produced at the NASA Goddard Space Flight Center by N.P. Zelensky and F.G. Lemoine. The files were tested at DGFI-TUM by J. Zeitlhöfler and M. Bloßfeld prior to public release using the DGFI-TUM POD software, DOGS-OC (*DGFI-TUM Orbit and Geodetic Parameter Estimation Software – Orbit Computation*). X. Yang (NASA GSFC) currently contributes to the maintenance of the NASA Precise Orbit Determination and Geodetic Parameter Estimation Program (*GEODYN*). Daniel G. Kubitschek (*University of Colorado, Boulder, USA*) provided the raw TOPEX external attitude data in the 1990's and early 2000's that were processed into a form to be used by the GEODYN POD software.

The 27 pairs of files provided with this release are listed below:

| | |
|---|---|
| gsfc_TP_quaternion_sapa.cyc147.960909 | gsfc_TP_quaternion_sbf.cyc147.960909 |
| gsfc_TP_quaternion_sapa.cyc148.960914 | gsfc_TP_quaternion_sbf.cyc148.960914 |
| gsfc_TP_quaternion_sapa.cyc202.980309 | gsfc_TP_quaternion_sbf.cyc202.980309 |
| gsfc_TP_quaternion_sapa.cyc203.980319 | gsfc_TP_quaternion_sbf.cyc203.980319 |
| gsfc_TP_quaternion_sapa.cyc204.980328 | gsfc_TP_quaternion_sbf.cyc204.980328 |
| gsfc_TP_quaternion_sapa.cyc205.980407 | gsfc_TP_quaternion_sbf.cyc205.980407 |
| gsfc_TP_quaternion_sapa.cyc229.981201 | gsfc_TP_quaternion_sbf.cyc229.981201 |
| gsfc_TP_quaternion_sapa.cyc230.981211 | gsfc_TP_quaternion_sbf.cyc230.981211 |
| gsfc_TP_quaternion_sapa.cyc231.981221 | gsfc_TP_quaternion_sbf.cyc231.981221 |
| gsfc_TP_quaternion_sapa.cyc279.000410 | gsfc_TP_quaternion_sbf.cyc279.000410 |
| gsfc_TP_quaternion_sapa.cyc287.000628 | gsfc_TP_quaternion_sbf.cyc287.000628 |
| gsfc_TP_quaternion_sapa.cyc288.000708 | gsfc_TP_quaternion_sbf.cyc288.000708 |
| gsfc_TP_quaternion_sapa.cyc295.000916 | gsfc_TP_quaternion_sbf.cyc295.000916 |
| gsfc_TP_quaternion_sapa.cyc309.010202 | gsfc_TP_quaternion_sbf.cyc309.010202 |
| gsfc_TP_quaternion_sapa.cyc318.010502 | gsfc_TP_quaternion_sbf.cyc318.010502 |
| gsfc_TP_quaternion_sapa.cyc365a.020811 | gsfc_TP_quaternion_sbf.cyc365a.020811 |
| gsfc_TP_quaternion_sapa.cyc365b.020815 | gsfc_TP_quaternion_sbf.cyc365b.020815 |
| gsfc_TP_quaternion_sapa.cyc365c.020819 | gsfc_TP_quaternion_sbf.cyc365c.020819 |
| gsfc_TP_quaternion_sapa.cyc367.020831 | gsfc_TP_quaternion_sbf.cyc367.020831 |
| gsfc_TP_quaternion_sapa.cyc368a.020910 | gsfc_TP_quaternion_sbf.cyc368a.020910 |
| gsfc_TP_quaternion_sapa.cyc368b.020913 | gsfc_TP_quaternion_sbf.cyc368b.020913 |
| gsfc_TP_quaternion_sapa.cyc368c.020916 | gsfc_TP_quaternion_sbf.cyc368c.020916 |
| gsfc_TP_quaternion_sapa.cyc369.020920 | gsfc_TP_quaternion_sbf.cyc369.020920 |
| gsfc_TP_quaternion_sapa.cyc436.040715 | gsfc_TP_quaternion_sbf.cyc436.040715 |
| gsfc_TP_quaternion_sapa.cyc437.040725 | gsfc_TP_quaternion_sbf.cyc437.040725 |
| gsfc_TP_quaternion_sapa.cyc438.040803 | gsfc_TP_quaternion_sbf.cyc438.040803 |
| gsfc_TP_quaternion_sapa.cyc439.040814 | gsfc_TP_quaternion_sbf.cyc439.040814 |

Additional external attitude data covering more TOPEX cycles are available but were not considered in the paper Zeitlhöfler et al. (2024). These additional TOPEX external attitude data will be published after they have been validated by an external partner outside of NASA GSFC (e.g. DGFI-TUM).

**References:**


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