



APN-086

Datum Transformations & Plate Tectonics Compensation

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Introduction to Datum Transformations and Plate Tectonics

Compensation

Consider the earth as if it were a large solid ball with a grid printed on it. The grid is an “Earth-Centered, Earth-Fixed” reference system, like ITRS or WGS. Earth-Fixed reference systems are realized by Earth-Fixed reference frames (datums) such as ITRF2014 or WGS84. If a survey marker was put directly on the ball, it would be in the same location in this system year after year.

Consider continental plates as stickers on the outside with grids printed on them. Over time, the different continental plates move slightly in different directions and rotations over the surface of the ball. These grids are “Plate-Fixed” reference systems, like NAD (North America), ETRS (Europe) and GDA (Australia). Plate-Fixed reference systems are realized by Plate-Fixed reference frames (datums) such as NAD83(CSRS), ETRF2014, and GDA2020. If a survey marker was put in the ground, it will have the same location in this system year after year, even as it moves around in the Earth Fixed system.

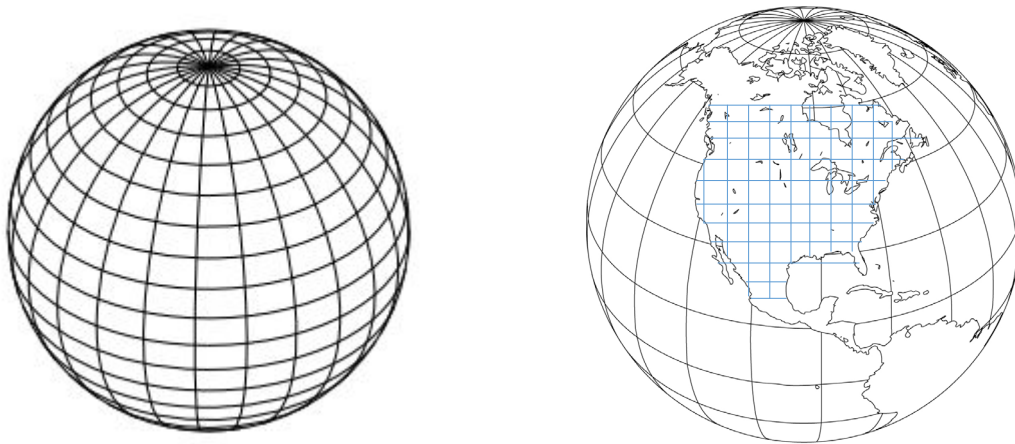


Figure 1: Earth-Centered, Earth-Fixed reference system (left) compared to a Plate-Fixed reference system (right)

The rigid outermost layer of earth’s crust is divided into several plates that float on the fluid-like layer below. These plates move slowly both relative to one another and to fixed, global definitions of the earth’s orientation. Relative to fixed global frames the plates can move up to 7 cm a year. The amount of motion can be significant for higher accuracy GNSS positioning types such as RTK and PPP.

Global PPP operates in fixed global frames and so earth-fixed coordinates are natively reported from a GNSS receiver. Most users of GNSS are less-interested in their absolute earth-fixed coordinates than they are in the coordinates relative to nearby features on the plate they’re operating on.

The mean motion of the plates is modelled by Plate Motion Models. These models track the movement of the bulk of the plates as if they are completely rigid using Euler’s spherical rotation theorem: each plate’s motion is parametrized as a rotation around a pole. Application of these models to global coordinates permits an order-of-magnitude increase in year over year repeatability over most of the plates: residual error is some millimeters per year, well below the actual plate motion of some centimeters

per year. However, “orogenous” regions near the edges of plates tend to stretch and deform in unmodelled ways.

With plates possibly moving with respect to both earth-fixed and plate-fixed datums, the concept of a “coordinate epoch” becomes important. The coordinate epoch answers the question “*At what point in time did this location on this plate have the given coordinates in the given datum?*”. The answer to this question is significant when one considers Plate-Fixed datums and Earth-Fixed datums. For a Plate-Fixed datum the answer is “all the time”; however, for an Earth Fixed datum or a datum fixed to a different plate, we can find a location *now* from previously recorded coordinates by compensating for plate motion (similar to winding forward in time) if we know when those coordinates were true. Similarly, we can calculate the coordinates of a location at a previous or future time by compensating for plate motion. Thus, an Earth-Fixed reference frame can function like a Plate-Fixed datum by specifying a fixed coordinate epoch – all measurements are “rewound” to a fixed point in time, so they are repeatable year over year on the ground.

For example, NAD83 is often used in California, but the California plate is moving in a different direction from the rest of North America. Using NAD83 with a fixed epoch results in repeatable coordinates.

Similarly, using ITRF2014 with a fixed epoch also provides repeatable coordinates anywhere the plate motion model is accurate. The accuracy of the plate motion model degrades in orogenous zones which can typically be found in regions with high volcanic activity or where two or more tectonic plates meet.

New Datum Handling Implementation

A GNSS receiver can do RTK and PPP at the same time, and one of the differentiators between the two positioning types is about the correction source: in RTK, there is a base receiver fixed to the plate (plate-fixed) providing corrections to the rover (i.e. the corrections move with the plate); in PPP (e.g. Terrastar-C PRO, Terrastar-X) however the corrections are the outcome of a global (Earth-fixed) computation effort. A large jump in position can occur when switching between an Earth-Fixed datum and a Plate-Fixed datum or vice versa when users switch between PPP and RTK solutions. Position jumps due to different datums are not a concern if e.g. RTK positioning has the RTK Assist™ feature enabled alongside.

The previous datum handling implementation (DATUM and USEREXPDATUM) prior to 7.06.01 firmware applied the *same transformation to all available positioning solutions regardless of the solution’s natural datum*¹. This meant that the receiver could not transform just the PPP solution to be in the same datum as RTK.

With firmware 7.06.01 and beyond, the new² implementation transforms *different positioning solutions independently based on the positioning solution’s natural datum* and outputs positions in the user specified datums. The new implementation can also account for the motion of plate tectonics allowing for year over year repeatability for even earth-fixed datums. Receivers running in RTK mode and having

¹ A solution’s natural datum is set by the datum of the solution’s correction source.

² https://docs.novatel.com/OEM7/Content/New_In_OEM7/New_For_OEM7_06_01.htm



access to advanced PPP correction services such TerraStar-X³ will benefit from the new firmware implementation for its added accuracy and seamless transition capability between PPP and RTK positioning solutions. Overall, the new firmware implementation:

1. Transforms the position types to a user-specified datum (the initial implementation is available only for PPP so users can align PPP and RTK position solutions)
2. Applies plate tectonic compensation
3. Automatically selects the correct tectonic plate, including warning at orogenous zones

Datum Transformations

How it works

The new implementation transforms solutions *independently* based on input datums as opposed to transforming all solutions regardless of their input datum (older firmware implementation). This requires the input datums to be known and their parameters be stored and available in the receiver. The transformation parameters between input and desired output datums must also be stored in the receiver.

The section below outlines the new logs and commands related to the new datum transformation implementation.

OUTPUTDATUM

The [OUTPUTDATUM](#) command is used to select the geodetic datum and the co-ordinate epoch to then transform the datum of the PPP⁴ solution.

The factory default is the service datum and service epoch of the PPP corrections. For TerraStar and Veripos, this is ITRF2014 and the current epoch.

In order to choose a datum with the [OUTPUTDATUM](#) command to transform the PPP solution, the selected datum must be in the list of datums reported by the [GEODETI CDATUMS](#) log, and there must be a transformation between the current service datum and target datum as reported in the [DATUMTRANSFORMATIONS](#) log. These two logs are described next.

GEODETI CDATUMS

The [GEODETI CDATUMS](#) log shows a list of available datums. It lists the default datums and user specified datums that were added using the [GEODETI CDATUM](#) command. Users can restore the GEODETI CDATUMS log to the firmware default by issuing the “FRESE T USER_ DATUM” command.

³ More details about TerraStar-X can be found in our application note .

⁴ Current support is only for PPP, future firmware versions will have OUTPUTDATUM transform the coordinates from other solution types.

```
<GEODETI CDATUMS COM1 0 81.0 UNKNOWN 0 0.596 1a000000 e7f2 15731
< 11
< "WGS84" 6326 EARTH_FIXED 6378137.00 298.2572235630
< "ITRF2005" 6896 EARTH_FIXED 6378137.00 298.2572221010
< "ITRF2008" 1061 EARTH_FIXED 6378137.00 298.2572221010
< "ITRF2014" 1165 EARTH_FIXED 6378137.00 298.2572221010
< "ETRF2000" 1186 PLATE_FIXED 6378137.00 298.2572221010
< "ETRF2005" 1204 PLATE_FIXED 6378137.00 298.2572221010
< "ETRF2014" 1206 PLATE_FIXED 6378137.00 298.2572221010
< "NAD83(NSRS2011)" 1116 PLATE_FIXED 6378137.00 298.2572221010
< "NAD83(CSRs)" 6140 PLATE_FIXED 6378137.00 298.2572221010
< "GDA94" 6283 PLATE_FIXED 6378137.00 298.2572221010
< "GDA2020" 1168 PLATE_FIXED 6378137.00 298.2572221010
```

DATUMTRANSFORMATIONS

The [DATUMTRANSFORMATIONS](#) log reports available datum transformations which the receiver can apply. It includes firmware default transformations and also user-defined transformations (entered with the [DATUMTRANSFORMATION](#) command). Users can restore the DATUMTRANSFORMATIONS log to the firmware default by issuing the "FRESE T USER_DATUM_TRANSFORMATION" command.

```
<DATUMTRANSFORMATIONS COM1 0 77.0 UNKNOWN 0 0.597 1a000000 f957 15731
< 9
< "ITRF2014" "ITRF2005" 2010.000 0.0026 0.0010 -0.0023 0.0000 0.0000 0.0000 0.920 0.0003 0.0000 -0.0001 0.0000 0.0000 0.0000 0.030
< "ITRF2014" "ITRF2008" 2010.000 0.0016 0.0019 0.0024 0.0000 0.0000 0.0000 -0.020 0.0000 0.0000 -0.0001 0.0000 0.0000 0.0000 0.030
< "ITRF2014" "ETRF2000" 2010.000 0.0547 0.0522 -0.0741 1.7010 10.2900 -16.6320 2.120 0.0001 0.0001 -0.0019 0.0810 0.4900 -0.7920 0.110
< "ITRF2014" "ETRF2005" 1989.000 0.0523 0.0490 -0.0372 0.0000 0.0000 0.0000 0.290 0.0003 0.0000 -0.0001 0.0540 0.5180 -0.7810 0.030
< "ITRF2014" "ETRF2014" 2010.000 0.0000 0.0000 0.0000 1.7850 11.1510 -16.1700 0.000 0.0000 0.0000 0.0000 0.0850 0.5310 -0.7700 -0.000
< "ITRF2014" "NAD83(NSRS2011)" 1997.000 0.9950 -1.9014 -0.5228 -25.9147 -9.4264 -11.5993 1.305 0.0008 -0.0006 -0.0014 -0.0667 0.7574 0.0513 -0.072
< "ITRF2014" "NAD83(CSRs)" 1997.000 0.9950 -1.9014 -0.5228 -25.9147 -9.4264 -11.5993 1.305 0.0008 -0.0006 -0.0014 -0.0667 0.7574 0.0513 -0.072
< "ITRF2014" "GDA94" 1994.000 -0.0831 -0.0175 0.0360 0.4254 -2.2578 -2.4015 9.210 0.0014 0.0013 0.0008 -1.5461 -1.1820 -1.1551 0.139
< "ITRF2014" "GDA2020" 2020.000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.000 0.0000 0.0000 0.0000 -1.5038 -1.1835 -1.2072 0.000
```

GEODETI CDATUM

The GEODETI CDATUM command is used to add or remove user-defined datums. List of datums available to the user are reported in the GEODETI CDATUMS log; hence any changes from the GEODETI CDATUM command are reflected in the GEODETI CDATUMS log. The GEODETI CDATUM command can be used to overwrite the parameters of a user defined datum as well as those of a firmware default datum. If the user subsequently deletes a default datum whose parameters were overwritten, then the firmware restores the default parameters on that default datum.

In order to save a new geodetic datum to receiver's NVM, user should issue as in the example below. No additional SAVECONFIG command is necessary to retain user defined datums and transformations in case a RESET or FRESE T command is sent to the receiver:

```
GEODETI CDATUM save NAD83(MA11) 1118 EARTH_FIXED 6378137.0 298.257222101
```

```
[COM1]<GEODETI CDATUMS COM1 0 87.0 FINESTEERING 2067 156491.764 02044000 e7f2 15526
< 12
< "WGS84" 6326 EARTH_FIXED 6378137.00 298.2572235630
< "ITRF2005" 6896 EARTH_FIXED 6378137.00 298.2572221010
< "ITRF2008" 1061 EARTH_FIXED 6378137.00 298.2572221010
```

```
< "ITRF2014" 1165 EARTH_FIXED 6378137.00 298.2572221010
< "ETRF2000" 1186 PLATE_FIXED 6378137.00 298.2572221010
< "ETRF2005" 1204 PLATE_FIXED 6378137.00 298.2572221010
< "ETRF2014" 1206 PLATE_FIXED 6378137.00 298.2572221010
< "NAD83(NSRS2011)" 1116 PLATE_FIXED 6378137.00 298.2572221010
< "NAD83(CSRS)" 6140 PLATE_FIXED 6378137.00 298.2572221010
< "GDA94" 6283 PLATE_FIXED 6378137.00 298.2572221010
< "GDA2020" 1168 PLATE_FIXED 6378137.00 298.2572221010
< "NAD83(MA11)" 1118 EARTH_FIXED 6378137.00 298.2572221010
```

In order to remove an existing datum from the NVM, user should issue as shown in the example below. Once deleted, no additional SAVECONFIG command is necessary:

```
GEODETICDATUM delete NAD83(MA11)
```

DATUMTRANSFORMATION

The [DATUMTRANSFORMATION](#) command allows user to enter user-defined datum transformation parameters. An example to enter the parameters of a transformation between ITRF2008 and NAD83(MA11) datums is:

```
DATUMTRANSFORMATION SAVE ITRF2008 NAD83(MA11) 1997.0 0.908 -2.0161 -0.5653 28.971 10.42 8.928
1.1 0.0001 0.0001 -0.0018 -0.02 0.105 -0.347 0.08
```

PPPDATUMINFO

The [PPPDATUMINFO](#) log reports the datum and co-ordinate epoch of the PPP solution in the current PPPPOS log. EPSG code of datum can also be found in this log.

Following from the example given above, *prior to* entering the OUTPUTDATUM command mentioned earlier to use “NAD83(MA11)” with fixed epoch 2018, PPPDATUMINFO log reports as below by firmware default:

```
[COM1]<PPPDATUMINFO COM1 0 70.5 FINESTEERING 2062 147847.500 1a000000 ea8d 15731
< "ECEF" 0 2019.536 GOOD
```

Within 2 hours of receiving TerraStar corrections (and every 2 hours thereafter) ~~in the TerraStar correction feed~~ a message gets delivered that the receiver firmware uses to update the PPP datum information reported in the PPPDATUMINFO log. The PPPDATUMINFO log will switch to report the correct datum of the Terrastar corrections: “ECEF” reported in the PPPDATUMINFO log above changes to “ITRF2014” as shown below. The updated “ITRF2014” will persist RESET and power cycles but after an FRESET, the PPPDATUMINFO log will report “ECEF” as its datum. If, in the future, TerraStar updates the datum of their corrections the PPPDATUMINFO log will automatically report the updated datum.

```
[COM1]<PPPDATUMINFO USB3 0 69.0 FINESTEERING 2066 154047.000 1a000000 ea8d 15731
< "ITRF2014" 1165 2019.625 GOOD
```



After entering the OUTPUTDATUM command to select the geodetic datum of the PPP solution output to be e.g. NAD83(MA11) with fixed epoch 2018 as below, PPPDATUMINFO log reports as shown further below:

```
OUTPUTDATUM NAD83(MA11) FIXED_EPOCH 2018.000
```

```
[COM1]<PPPDATUMINFO COM1 0 85.0 FINESTEERING 2067 157960.000 02004000 ea8d 15526  
< "NAD83(MA11)" 1118 2018.000 ECEF_EQUIVALENCY
```

In the PPPDATUMINFO log above, "ECEF_EQUIVALENCY" indicates that an earth-fixed (ECEF) datum was involved in the transformation but instead of an exact-match datum a best-match earth-fixed datum was used.

In the example above, PPP is computing its solution in ITRF2014 (earth-fixed) but there isn't any transformation available from ITRF2014 to user's requested NAD83(MA11). The only transformation available (as reported in DATUMTRANSFORMATIONS log) is from ITRF2008 (earth-fixed) to desired NAD83(MA11) so the datum handling picks that one and reports ECEF_EQUIVALENCY. Once there is a transformation between ITRF2014 and NAD83(MA11) (entered by "DATUMTRANSFORMATION" command) it will be reported as "GOOD".

BESTDATUMINFO

The [BESTDATUMINFO](#) log reports the datum and co-ordinate epoch of the solution that is reported in the BESTPOS log. An "UNKNOWN" is reported for datum in differential solutions where the base station datum is not known. For single point and SBAS position types "ECEF" is reported as the datum with an EPSG code of "0".

```
<BESTPOS COM1 0 67.0 FINESTEERING 2062 149347.000 1a040000 b1f6 15731  
< SOL COMPUTED WAAS 51.15042940871 -114.03068237041 1097.1943 -17.0000 WGS84 0.9499 0.8986  
2.0434 "131" 5.000 0.000 36 9 9 9 00 06 00 03
```

```
<BESTDATUMINFO COM1 0 66.0 COARSESTEERING 2062 149180.000 1a040000 0c2b 15731  
< "ECEF" 0 2019.536 GOOD
```

BESTGNSSDATUMINFO

The [BESTGNSSDATUMINFO](#) log reports the datum and co-ordinate epoch of the solution that is reported in the BESTGNSSPOS log. An "UNKNOWN" is reported for datum in differential solutions where the base station datum is not known. For single point and SBAS position types "ECEF" is reported as the datum with an EPSG code of "0".

```
<BESTPOS COM1 0 64.5 FINESTEERING 2062 149530.000 1a040000 b1f6 15731  
< SOL COMPUTED SINGLE 51.15043498045 -114.03068326128 1097.3805 -17.0000 WGS84 1.2083 1.0269 2.1568 ""  
0.000 0.000 33 24 24 24 00 06 30 33
```

```
<BESTGNSSDATUMINFO COM1 0 69.5 FINESTEERING 2062 149400.000 1a040000 1790 15731  
< "ECEF" 0 2019.536 GOOD
```


Plate Tectonics Compensation

Plate compensation is important when an earth fixed datum (such as that of Terrastar-X, Terrastar-) is used. For an earth-fixed output datum, using a fixed epoch will help compensate for plate motion giving users repeatability of coordinates over time (year over year) for a location.

How it works

The receiver automatically detects the tectonic plate on which the receiver operates and takes into account its plate motion.

For information on the plate model currently used, the TECTONICSCOMPENSATION log should be checked.

TECTONICSCOMPENSATIONSOURCE

The [TECTONICSCOMPENSATIONSOURCE](#) command is used to enable or disable tectonics compensation. Tectonic compensation is enabled by default in the firmware, and in case disabled it can be enabled as shown below:

```
TECTONICSCOMPENSATIONSOURCE PLATE_MOTION_MODEL
```

To disable compensation against plate motion, below command should be issued:

```
TECTONICSCOMPENSATIONSOURCE NONE
```

TECTONICSCOMPENSATION

The [TECTONICSCOMPENSATION](#) log reports the status of the tectonics compensation. A warning is reported to the user if tectonics compensation may not be very precise in a region.

Example on New Datum Handling Implementation

1. To transform a solution from one datum to another, the datum must first exist in the GEODETICDATUMS log. The receiver firmware includes a default set of datums as seen below:

```
<GEODETICDATUMS COM1 0 78.5 UNKNOWN 0 0.596 1a000000 e7f2 15731
< 11
< "WGS84" 6326 EARTH_FIXED 6378137.00 298.2572235630
< "ITRF2005" 6896 EARTH_FIXED 6378137.00 298.2572221010
< "ITRF2008" 1061 EARTH_FIXED 6378137.00 298.2572221010
< "ITRF2014" 1165 EARTH_FIXED 6378137.00 298.2572221010
< "ETRF2000" 1186 PLATE_FIXED 6378137.00 298.2572221010
< "ETRF2005" 1204 PLATE_FIXED 6378137.00 298.2572221010
< "ETRF2014" 1206 PLATE_FIXED 6378137.00 298.2572221010
< "NAD83(NSRS2011)" 1116 PLATE_FIXED 6378137.00 298.2572221010
< "NAD83(CSR5)" 6140 PLATE_FIXED 6378137.00 298.2572221010
< "GDA94" 6283 PLATE_FIXED 6378137.00 298.2572221010
< "GDA2020" 1168 PLATE_FIXED 6378137.00 298.2572221010
```

2. If a datum does not exist in the GEODETICDATUMS log, then it can be created using the GEODETICDATUM command. In order to add a new datum, you will require the following information:

- Name of the datum
- EPSG⁵ code (zero if a custom datum is used)
- Datum type; either earth fixed, plate fixed, or unknown
- Semi-major axis of the datum's ellipsoid in meters
- Inverse flattening of the datum's ellipsoid

A sample command to add NAD83 (MA11 epoch) would be:

```
GEODETICDATUM save NAD83(MA11) 1118 EARTH_FIXED 6378137.0 298.257222101
```

Where:

- NAD83(MA11) is the name of the datum
- 1118 is the EPSG code
- EARTH_FIXED is the datum type
- 6378137.0 is the semi-major axis in meters
- 298.257222101 is the flattening value

The new datum "NAD83(MA11)" can be seen in the GEODETICDATUMS log as the last entry:

```
<GEODETICDATUMS COM1 0 72.5 FINESTEERING 2062 146050.857 1a000000 e7f2 15731
< 12
< "WGS84" 6326 EARTH_FIXED 6378137.00 298.2572235630
< "ITRF2005" 6896 EARTH_FIXED 6378137.00 298.2572221010
< "ITRF2008" 1061 EARTH_FIXED 6378137.00 298.2572221010
< "ITRF2014" 1165 EARTH_FIXED 6378137.00 298.2572221010
< "ETRF2000" 1186 PLATE_FIXED 6378137.00 298.2572221010
< "ETRF2005" 1204 PLATE_FIXED 6378137.00 298.2572221010
< "ETRF2014" 1206 PLATE_FIXED 6378137.00 298.2572221010
< "NAD83(NSRS2011)" 1116 PLATE_FIXED 6378137.00 298.2572221010
< "NAD83(CSRS)" 6140 PLATE_FIXED 6378137.00 298.2572221010
< "GDA94" 6283 PLATE_FIXED 6378137.00 298.2572221010
< "GDA2020" 1168 PLATE_FIXED 6378137.00 298.2572221010
< "NAD83(MA11)" 1118 EARTH_FIXED 6378137.00 298.2572221010
```

3. Once the datum exists, there must be a transformation available in the DATUMTRANSFORMATIONS log between the service datum of the solution and the desired datum in order to change the output datum. Receiver can also apply a reverse transformation if needed such as when the user wants to e.g. transform PPP solution from ITRF2014 to NAD83(MA11) but a transformation *from* NAD83(MA11) to ITRF2014 is available. Receiver will in this case use the

⁵ The EPSG Geodetic Parameter Database (www.epsg-registry.org) is a commonly referenced database of coordinate reference systems and coordinate transformations.

existing transformation but in the opposite direction i.e. by flipping the sign on all parameters of transformation.

A desired transformation between any two datums can be added using the DATUMTRANSFORMATION command. In order to create a new transformation, a user will need the following information:

- Service datum⁶ the solution is in (in the GEODATICDATUMS log)
- Datum the user wishes to transform to (in the GEODETICDATUMS log)
- Reference epoch of the parameters (decimal year)
- Translations at the reference epoch in meters (tx, ty, and tz)
- Rotations at the reference epoch in milliarcseconds (rx, ry, and rz)
- Scale difference at reference epoch in parts per billion
- Translation rates in meters/year (tx_vel, ty_vel, and tz_vel)
- Rotation rates in milliarcseconds/year (rx_vel, ry_vel, and rz_vel)
- Scale difference rate in parts per billion/year

An example command to create a new transformation from ITRF2008 to NAD83(MA11) datum is:

```
DATUMTRANSFORMATION SAVE ITRF2008 NAD83(MA11) 1997.0 0.908 -2.0161 -0.5653  
28.971 10.42 8.928 1.1 0.0001 0.0001 -0.0018 -0.02 0.105 -0.347 0.08
```

Where:

- 1997.0 is the reference epoch of the parameters
- 0.908, -2.0161 and -0.5653 are the translations at the reference epoch
- 28.971, 10.42, and 8.928 are the rotations at the reference epoch
- 1.1 is the scale difference at the reference epoch
- 0.0001, 0.0001, and -0.0018 are the translation rates
- -0.02, 0.105, and -0.347 are the rotation rates
- 0.08 is the scale difference rate

The transformation parameters for this newly added datum can be seen in the last entry of DATUMTRANSFORMATIONS log:

⁶ Service datum for TerraStar and Veripos is ITRF2014.



```
<DATUMTRANSFORMATIONS COM1 0 79.0 FINESTEERING 2062 146270.276 1a000000 f957 15731
```

```
< 10
< "ITRF2014" "ITRF2005" 2010.000 0.0026 0.0010 -0.0023 0.0000 0.0000 0.0000 0.920 0.0003 0.0000 -0.0001 0.0000 0.0000 0.0000 0.030
< "ITRF2014" "ITRF2008" 2010.000 0.0016 0.0019 0.0024 0.0000 0.0000 0.0000 -0.020 0.0000 0.0000 -0.0001 0.0000 0.0000 0.0000 0.030
< "ITRF2014" "ETRF2000" 2010.000 0.0547 0.0522 -0.0741 1.7010 10.2900 -16.6320 2.120 0.0001 0.0001 -0.0019 0.0810 0.4900 -0.7920 0.110
< "ITRF2014" "ETRF2005" 1989.000 0.0523 0.0490 -0.0372 0.0000 0.0000 0.0000 0.290 0.0003 0.0000 -0.0001 0.0540 0.5180 -0.7810 0.030
< "ITRF2014" "ETRF2014" 2010.000 0.0000 0.0000 0.0000 1.7850 11.1510 -16.1700 0.000 0.0000 0.0000 0.0000 0.0850 0.5310 -0.7700 -0.000
< "ITRF2014" "NAD83(NSRS2011)" 1997.000 0.9950 -1.9014 -0.5228 -25.9147 -9.4264 -11.5993 1.305 0.0008 -0.0006 -0.0014 -0.0667 0.7574 0.0513 -0.072
< "ITRF2014" "NAD83(CSR)" 1997.000 0.9950 -1.9014 -0.5228 -25.9147 -9.4264 -11.5993 1.305 0.0008 -0.0006 -0.0014 -0.0667 0.7574 0.0513 -0.072
< "ITRF2014" "GDA94" 1994.000 -0.0831 -0.0175 0.0360 0.4254 -2.2578 -2.4015 9.210 0.0014 0.0013 0.0008 -1.5461 -1.1820 -1.1551 0.139
< "ITRF2014" "GDA2020" 2020.000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.000 0.0000 0.0000 0.0000 -1.5038 -1.1835 -1.2072 0.000
< "ITRF2008" "NAD83(MA11)" 1997.000 0.9080 -2.0161 -0.5653 28.9710 10.4200 8.9280 1.100 0.0001 0.0001 -0.0018 -0.0200 0.1050 -0.3470 0.080
```

4. Once the datums and transformations exist in the receiver, user can select the geodetic datum and coordinate epoch in which the PPP solution should be output. If not set, the factory default is used which is the service datum and epoch of the PPP corrections.

An example command to output PPP coordinates in NAD83(MA11) this physical location had on Jan 1, 2018 is:

```
OUTPUTDATUM NAD83(MA11) FIXED_EPOCH 2018.000
```

Where:

- "NAD83(MA11)" is the name of the datum to output, which needs to be present in the GEODETICDATUMS log
- "FIXED_EPOCH" specifies that the coordinates be output at the specified epoch as opposed to the current epoch or the epoch of the corrections.
- "2018.000" is the coordinate epoch specified by the user.

The receiver then automatically determines which plate it is on and applies both the datum transformation indicated and the plate motion required for the given coordinate epoch.

Example on Tectonic Compensation

Tectonics Compensation is enabled by default, however it will not actually perform anything until it has been given an epoch to compensate to. An epoch to compensate to can be provided by sending the OUTPUTDATUM command. Ex:

```
OUTPUTDATUM "ITRF2014" FIXED_EPOCH 2010.000
```

This will enable tectonics compensation to output coordinates in ITRF2014 as if it was January 1st 2010.

Enable tectonic compensation as shown below. The actual epoch that tectonics compensation outputs to is controlled by the OUTPUTDATUM command:

```
TECTONICSCOMPENSATIONSOURCE PLATE_MOTION_MODEL
```

Then request below log to see the information on the currently used plate model:

```
LOG TECTONICSCOMPENSATION ONCHANGED
```

The receiver will output the following data:

```
<TECTONICSCOMPENSATION COM1 0 73.5 FINESTEERING 2062 151968.341 1a000000 3af4  
15731  
< AVAILABLE "North America" -0.018 -0.000 -0.006
```

Where:

- “AVAILABLE” indicates that compensation is available
- “North America” is the name of the plate used to determine station velocities
- “-0.018 -0.000 -0.006” are the station velocities for the location of the receiver in m/year

If user disables tectonic compensation as shown below, then the TECTONICSCOMPENSATION log will report “UNAVAILABLE” for compensation status:

```
TECTONICSCOMPENSATIONSOURCE NONE  
  
<TECTONICSCOMPENSATION COM1 0 70.5 FINESTEERING 2062 151968.341 1a000000 3af4  
15731  
< UNAVAILABLE "" 0.000 0.000 0.000
```

Legacy Datum Transformation Commands

DATUM

The [DATUM](#) command (legacy) is used to select the datum (and its corresponding ellipsoid) for converting Cartesian coordinates to geodetic (latitude, longitude and height) and the transformation applied to positions calculated by the receiver before they are output.

The datum transformation selected by this command is applied to *all* solutions calculated by the receiver regardless of input datum. Differential solutions such as RTK and PSRDIFF are naturally in the datum of the base station and naturally plate fixed, while PPP, SBAS and Single point solutions are in ITRF2014 or WGS84 Earth Fixed . If different solutions are in different datums then a single transformation will not work in all cases.

With RTK, it is normally intended to output a position in the datum of the base station. A transformation applied to the receiver position solution will shift it out of the base station datum. Therefore, the DATUM command is generally not suitable for use with RTK.



Use of the factory default setting “WGS84” will result in no transformation being applied to any solution. That is, “WGS84” does not transform into the WGS84 datum, it simply assumes all input solutions are already in WGS84.

Datum transformations matter mostly for precise solutions like PPP and RTK, where the difference between datums can be significant compared to the solution accuracy. As already outlined, RTK solutions are typically already in the desired datum.

In most cases, PPP solutions will need datum transformation and for that purpose the new OUTPUTDATUM command should be used. Do not use both OUTPUTDATUM and DATUM commands at the same time.

Users should also note that the datum ID field of the position logs is depreciated and will show WGS84 for backwards compatibility.

USERDATUM / USEREXPDATUM

[USERDATUM](#) command (legacy) is similar to [USEREXPDATUM](#) command (legacy) but without the rate parameters. When USERDATUM command is issued, the receiver internally issues the USEREXPDATUM⁷ command with the values from USERDATUM command.

User defined datums can be used after first being created with the [USERDATUM](#) or [USEREXPDATUM](#) command.

The USERDATUM command permits entry of customized ellipsoid and datum transformation parameters. At any given time, only a single set of USERDATUM or USEREXPDATUM command parameters are valid. Any new parameter entry overwrites the previously entered parameters.

The command DATUM USER must be sent for the parameters set by the user in the USERDATUM command to take effect. Furthermore, DATUM USER command should not be mixed with the OUTPUTDATUM command: While the former sets the datum to be the one defined by the user (by using the USERDATUM command to enter customized ellipsoid and datum transformation parameter values), the latter command sets the datum to output the PPP solution in.

The transformation used by the USERDATUM command is the 7 parameter Helmert transformation, with the parameters provided being for the transformation from the user datum to WGS84:

$$\begin{bmatrix} X_s \\ Y_s \\ Z_s \end{bmatrix} = \begin{bmatrix} T_x \\ T_y \\ T_z \end{bmatrix} + (1 + s) \begin{bmatrix} 1 & -R_z & R_y \\ R_z & 1 & -R_x \\ -R_y & R_x & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

Where:

⁷ RXCONFIG log reports the USEREXPDATUM command.

X, Y, Z are the coordinates in the user datum

Xs, Ys, Zs are the coordinates in WGS84

Tx, Ty, Tz are the translation parameters corrected for translation rate (metres)

Rx, Ry, Rz are the rotation parameters corrected for rotation rate (radians)

s is the scale difference corrected for scale rate (unitless)

A given parameter **P** is corrected for rate as:

$$P(t) = P(tr) + \dot{P}(tr) (t - tr)$$

Where:

tr is the reference epoch of the parameters

t is the current epoch

P(tr) is the parameter at the reference epoch

$\dot{P}(tr)$ is the rate of the parameter at the reference epoch

The convention used by this command differs from that used by the [DATUMTRANSFORMATION](#) command, and from parameter conventions seen typically in transformation sources. Care should be taken that the parameter convention matches that in the equation above.

Commands and Logs

Commands (new and legacy):

- OUTPUTDATUM
- GEODETICDATUM
- DATUMTRANSFORMATIONS
- TECTONICSCOMPENSATIONSOURCE
- USERDATUM / USEREXPDATUM
- DATUM

Logs (new and legacy):

- GEODETICDATUMS
- DATUMTRANSFORMATIONS
- TECTONICSCOMPENSATION
- PPPDATUMINFO
- BESTDATUMINFO
- BESTGNSSDATUMINFO

References

https://docs.novatel.com/OEM7/Content/New_In_OEM7/New_For_OEM7_06_01.htm



https://docs.novatel.com/OEM7/Content/Operation/RTK_ASSIST_Enabling.htm

NovAtel Support

To help answer questions and/or diagnose any technical issues that may occur, the NovAtel Support website is a first resource: www.novatel.com/support/

Remaining questions or issues, including requests for test subscriptions or activation resends, can be directed to NovAtel Support by visiting www.novatel.com/support/contact/. To enable the online form and submit a ticket, first select a "Product Line" and then an associated "Product" from the list.

However, before contacting Support, it is helpful to collect data from the receiver to help investigate and diagnose any performance-related issues. In those cases, if possible, collect the following list of logs (the LOG command with the recommended trigger and data rate is included):

```
LOG ALMANACB ONCHANGED
LOG BESTDATUMINFO ONCHANGED
LOG BESTGNSSDATUMINFO ONCHANGED
LOG BESTPOSB ONTIME 1
LOG DATUMTRANSFORMATIONS ONCHANGED
LOG GEODETICDATUMS ONCHANGED
LOG GLORAWEPHEMB ONCHANGED
LOG GLORAWALMB ONCHANGED
LOG GLOCLOCKB ONCHANGED
LOG IONUTCB ONCHANGED
LOG PPPDATUMINFO ONCHANGED
LOG RANGE ONTIME 1
LOG RAWEPHEMB ONCHANGED
LOG RXCONFIGA ONCE
LOG TECTONICSCOMPENSATION ONCHANGED
LOG RXSTATUSA ONCHANGED
LOG VERSIONA ONCE
```

The data described above can be collected using a terminal program that supports binary data logging, or NovAtel's CONNECT utility can be downloaded and installed from the NovAtel website: www.novatel.com/support/info/documents/809.

Documentation

All logs and commands described below can be found in documentation for OEM7:

Documentation Portal: <http://docs.novatel.com/OEM7/Content/Home.htm>

