TICON-3: Tidal Constants based on GESLA-3 sea-level records from 5,119 globally distributed tide gauges including gauge type information

User Manual

M. Hart-Davis, D. Dettmering, F.Seitz

Deutsches Geodätisches Forschungsinstitut, Technical University of Munich (DGFI-TUM), Arcisstraße 21, Munich 80333, Germany

---

1. Introduction

The TIdal CONstants (TICON) dataset was first published in Piccioni et al (2019). This dataset provided estimations of 40 tidal constituents from 1,145 tide gauge records. These tide gauge records were taken from the GESLA-2 database (Woodworth et al 2017). The dataset has served the community well as it was used for the validation of global ocean tide models in several studies (e.g. Hart-Davis et al 2021; Sulzbach et al 2021). Since this, a more recent database has been produced, GESLA-3 (Haigh et al 2022), which significantly increases the number of tide gauge records to 5,119 tide gauges. This has led to the need for an update to the TICON dataset in order to account for the increased number of observations as well as the increased time-series records of the already existing tide gauges.

This need has resulted in the development of the TICON-3 dataset, which is presented here. Following the same approach as described in Piccioni et al (2019), least-squares harmonic analysis was conducted on every individual tide gauge of the GESLA-3 database. Additional processing was done to remove any tide gauges with insufficient data (at least 70% of valid measurements) as well as the removal of tide gauges with less than 1 years worth of valid measurements. This has resulted in the availability of 3,471 tide gauges within the TICON-3 dataset, a significant increase of 2,323 tide gauges relative to the previous TICON version.

A further addition to the TICON dataset is based on gauge type information newly provided by the GESLA-3 database, which has also been included as the final column of the TICON-3 dataset. These gauge types are either ‘Coastal’, ‘River’ and ‘Lake’. Distinguishing between these tide gauge types is vital based on the applications where the data is used and it is, therefore, important that users select the appropriate gauge type.

2. Data description

The new dataset is available via a text file called TICON_3.txt. In total, 40 tidal constituents are available within this dataset for 3,471 tide gauges globally. These data are stored in thirteen columns, that are structured as follows:

1. Latitude of the tide gauge station in degrees
2. Longitude of the tide gauge station in degrees, with range [0 360]
3. Constituent name
4. Amplitude in cm
5. Phase lag (Greenwich lag) in degrees, with range [0 360]
6. The standard deviation of the amplitude in cm
7. The standard deviation of the phase lag in degrees
8. Percentage of missing observations
9. The total number of observations analyzed
10. Length of the maximum temporal gap found in the time series in days
11. Date of the first observation [day/month/year]
12. Date of the last observation [day/month/year]
13. Code that corresponds to the original source of the record
14. Tide gauge type (either coastal, lake or river)

3. Using the data (Python)

To access the data and use the data using Python, the following code can be used:

```
# useful packages
import numpy as np
import pandas as pd
# load data
ptd = # path to data
fnm = "TICON_3.txt" # TICON-3 file
df = pd.read_csv(ptd+fnm,sep='\t',header=None)
# select a constituent, in this case M2
indx_cons = np.where(df[2] == 'M2')
df = df.iloc[indx_cons]
# select tide gauge type [options are: River, Lake and Coastal]
indx_type = np.where(df[13] == 'Coastal')
df = df.iloc[indx_type]

lon = np.array(df[1]) # assign longitude
lat = np.array(df[0]) # assign latitude
amp = np.array(df[3]) # assign amplitude
pha = np.array(df[4]) # assign phase
```

This code allows the user to load all the TICON-3 data as well as extract all the information about any individual constituent, in this example the M2 tidal constituent (Figure 1).

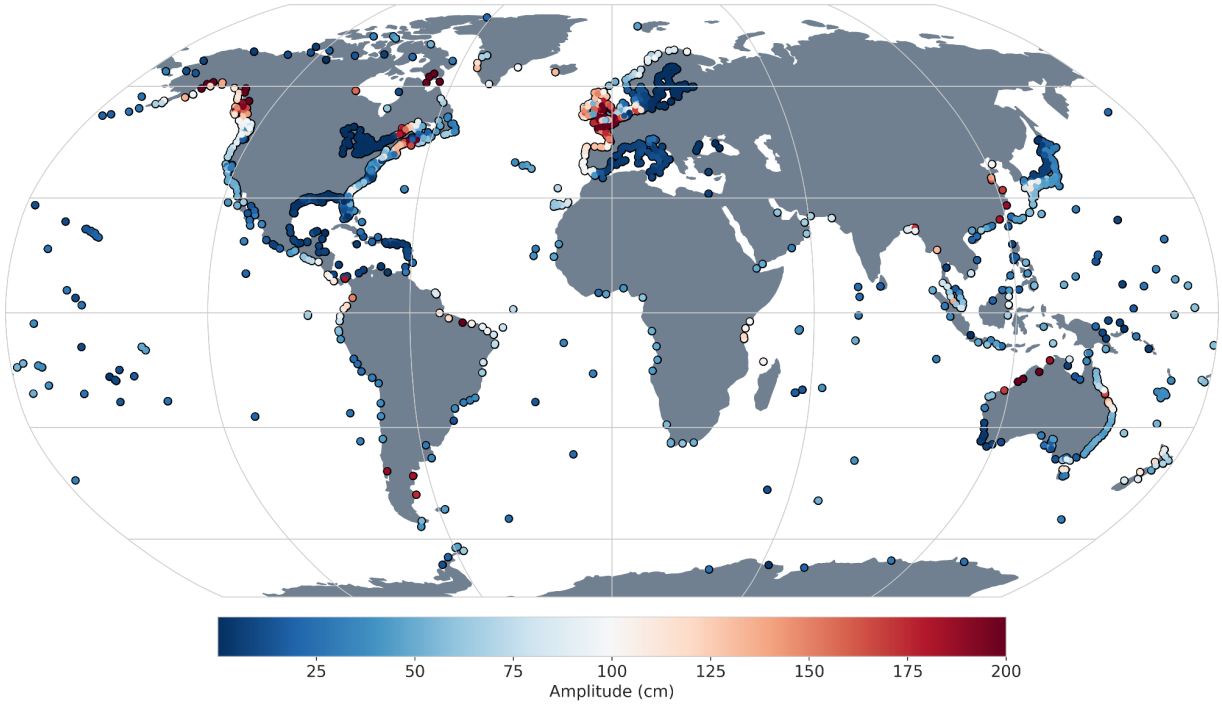

Figure 1. The global distribution of the tide gauges, with the colours representing the amplitude of the M2 tidal constituent as provided from TICON-3.

4. Changes relative to TICON-1

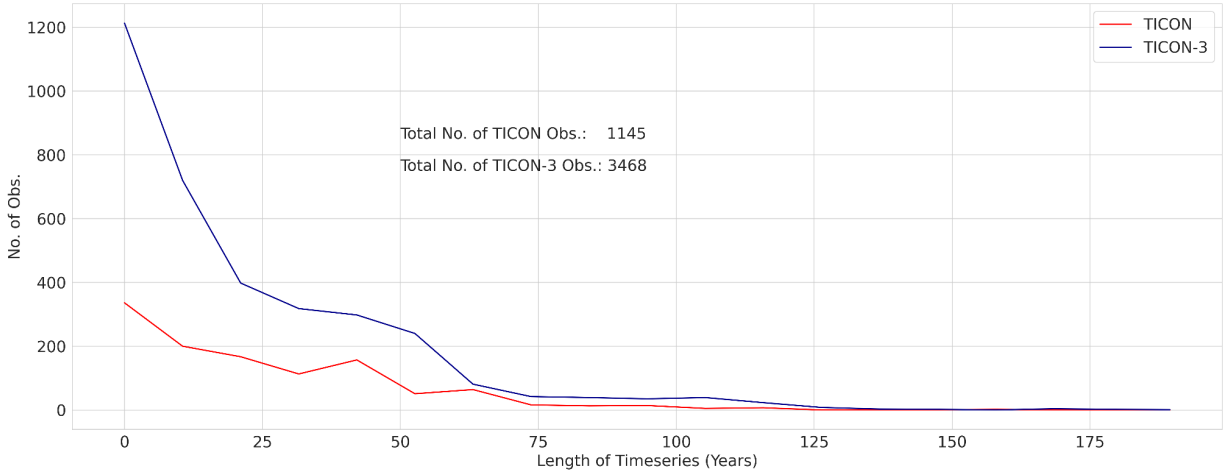

Figure 2. A line graph demonstrating the changes made in the number of tide gauge observations available in 10-year periods for both the TICON and TICON-3 databases.

As highlighted in the introduction, there is a significant increase in the number of tide gauges available in the new GESLA-3 dataset but there also has been an extension in the available time series of previously available tide gauges.

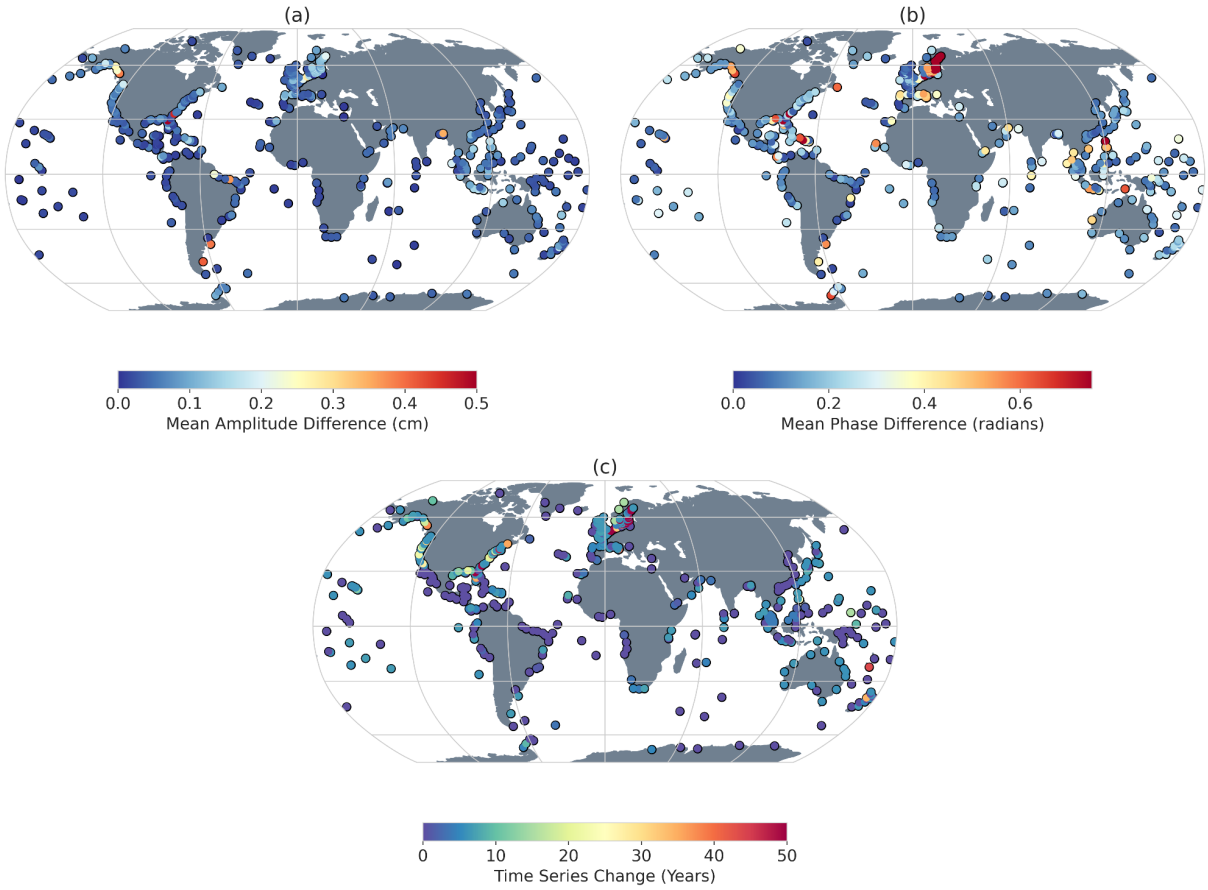

Figure 3. A comparison between the TICON and TICON-3 databases, demonstrating only the mutual tide gauges. The absolute mean change in the amplitude (a) and phase (b) of all the 40 tidal constituents, with (c) showing the change in the time series length.

In Figure 2 it can be seen that within the GESLA-3 dataset, there is a large increase in tide gauges with a length between 1 and 50 years but there are also a few additional longer period tide gauges. Figure 3(c) shows the increase in available data for tide gauges that were previously available in TICON-1 and are now available in TICON-3. These increased time series' mean that the estimation of tidal constituents becomes more accurate, especially for the longer-period constituents and very short-period constituents which require a lot of data in order to provide accurate estimations. Figures 3(a) and 3(b) demonstrate the mean differences between the amplitude and phase of TICON and TICON-3, with regions such as the North-West of America and the Baltic Sea showing larger differences that align with changes in the time series lengths of the data used.

5. Acknowledgements

This dataset builds on the previously published TICON dataset (Piccioni et al 2018), which contains additional information as to how the data is processed. The GESLA-3 data was obtained from https://www.gesla.org/ and particular gratitude is given to Dr Ivan Haigh and Dr Marta Marcos whose fruitful discussions proved valuable input into this dataset creation.

References

Haigh, I.D., Marcos, M., Talke, S.A., Woodworth, P.L., Hunter, J.R., Haugh, B.S., Arns, A., Bradshaw, E. and Thompson, P., 2021. GESLA Version 3: A major update to the global higher-frequency sea-level dataset. https://doi.org/10.31223/X5MP65

Hart-Davis, M.G., Piccioni, G., Dettmering, D., Schwatke, C., Passaro, M. and Seitz, F., 2021. EOT20: A global ocean tide model from multi-mission satellite altimetry. *Earth System Science Data*, 13(8), pp.3869-3884. https://doi.org/10.5194/essd-13-3869-2021

Piccioni, G., Dettmering, D., Bosch, W., Seitz, F., 2018. TICON: Tidal Constants based on GESLA sea-level records from globally distributed tide gauges (data). *PANGAEA,* https://doi.org/10.1594/PANGAEA.896587

Piccioni, G., Dettmering, D., Bosch, W., Seitz, F., 2019. TICON: TIdal CONstants based on GESLA sea-level records from globally located tide gauges. *Geosci. Data J.*; 6: 97– 104. https://doi.org/10.1002/gdj3.72

Sulzbach, R., Dobslaw, H. and Thomas, M., 2021. High-Resolution Numerical Modeling of Barotropic Global Ocean Tides for Satellite Gravimetry. Journal of Geophysical Research: Oceans, 126(5), https://doi.org/10.1029/2020JC017097.

Woodworth, P.L., Hunter, J.R. Marcos, M., Caldwell, P., Menendez, M. and Haigh, I., 2017. Towards a global higher-frequency sea level data set. *Geoscience Data Journal*, 3, 50-59, https://doi.org/10.1002/gdj3.42.