Deutsches Geodätisches Forschungsinstitut
TUM School of Engineering and Design
Technische Universität München

Tide of the Time: Global tidal characteristics

M.G. Hart-Davis[1], R. Sulzbach[2], S.A. Talke[3], I.D. Haigh[4,5], M. Marcos[6], P. Woodworth[7], R. Ray[8], O.B. Andersen[9], F. Lyard[10], E. Fouchet[11], D. Dettmering[1], M. Thomas[2,12], F. Seitz[1]

[1] Deutsches Geodätisches Forschungsinstitut, Technische Universität München, Germany
[2] GFZ Helmholtz Centre for Geosciences, Telegrafenberg, Potsdam, Germany
[3] Department of Civil and Environmental Engineering, California Polytechnic State University, California, USA
[4] Dept. of Civil, Environmental and Construction Engineering, University of Central Florida, Florida, USA
[5] Center for Integrated Coastal Research, University of Central Florida, Florida, USA
[6] IMEDEA (UIB-CSIC), Esporles, Balearic Islands, Spain
[7] National Oceanography Centre, Liverpool, UK
[8] NASA Goddard Space Flight Center, Greenbelt, MD, USA
[9] DTU Space, Technical University of Denmark, Kongens Lyngby, Denmark
[10] LEGOS, Université de Toulouse, CNES, CNRS, IRD, Toulouse, France
[11] Mercator Ocean International, Toulouse, France
[12] Institute for Meteorology, Freie Universität Berlin, Berlin, Germany

For more information: michael.hart-davis@tum.de

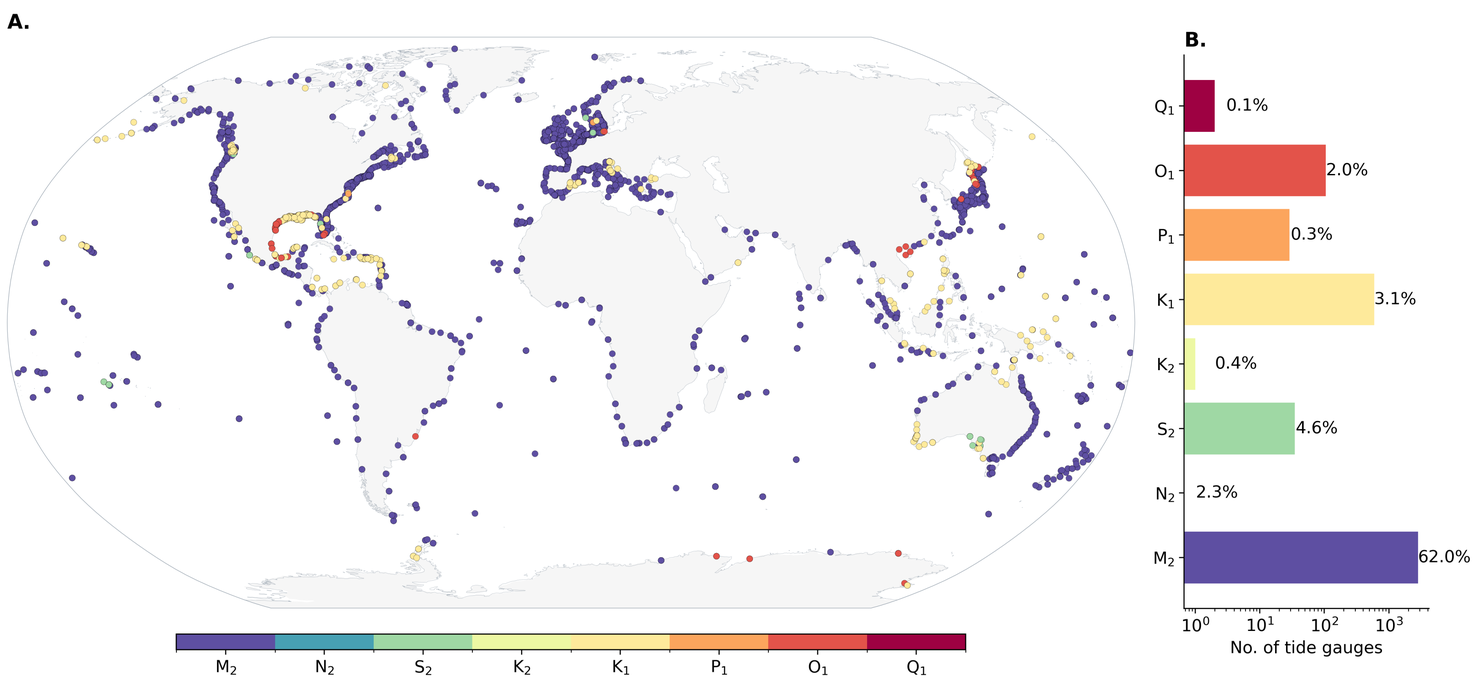

Figure 1. Largest Tidal Constituent

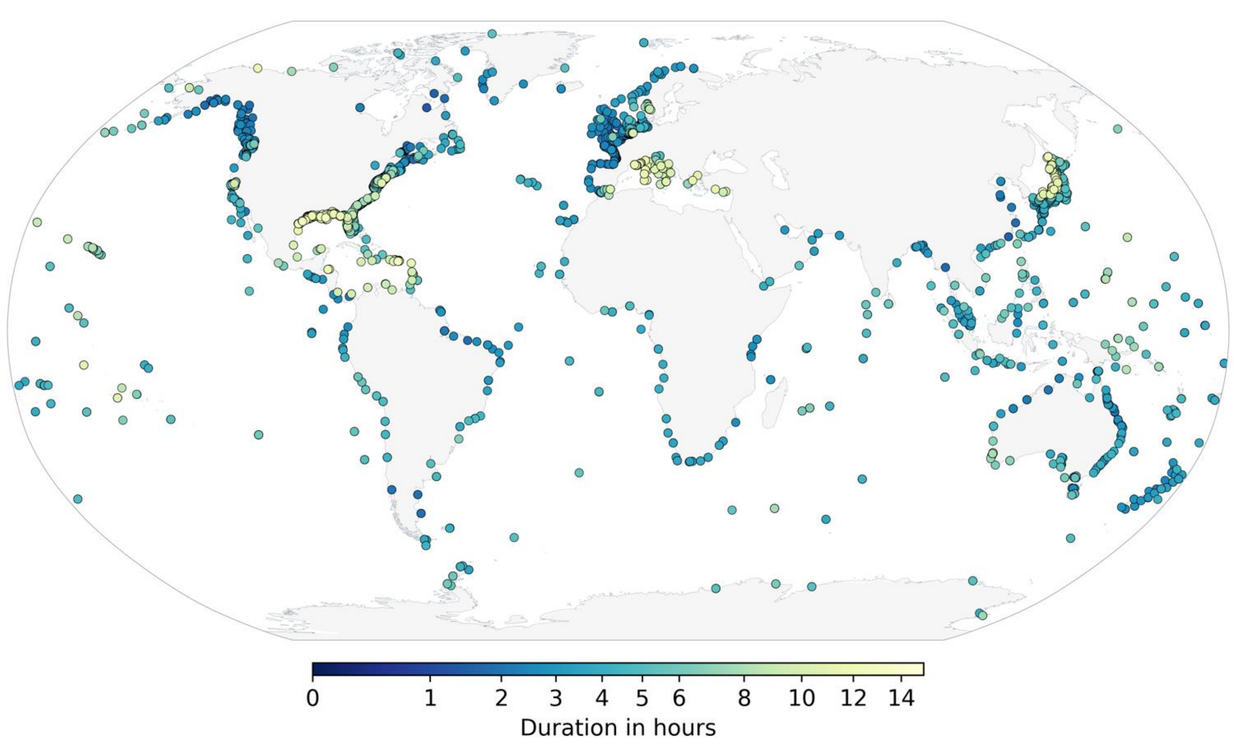

Figure 2. Duration of High Tide

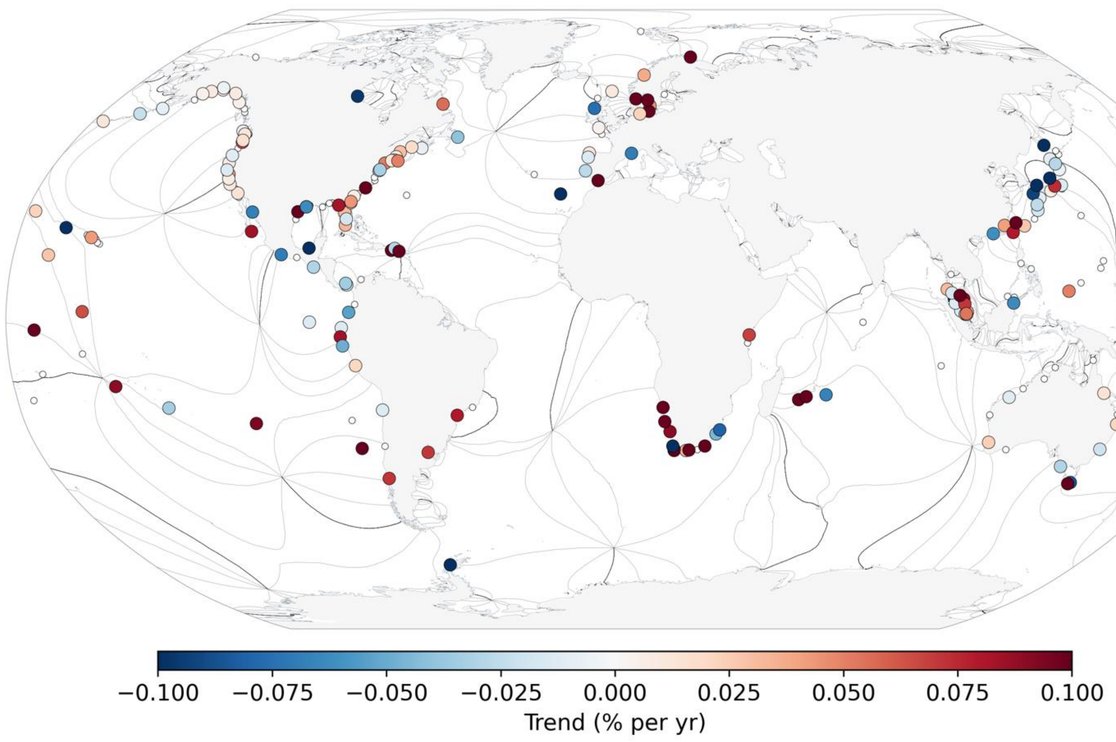

Figure 3. Amplitude trend of M_2 tide

Introduction

- Tide gauges have been critical sources for sea level research, enabling the development of tidal theory and an understanding of local variations that occur across the global oceans.
- In this presentation, **we analyse coastal characteristics of ocean tides** based on 3,591 high-frequency tide gauge observations from the recently updated GESLA-4 database.
- We use these tide gauges **to inform global tide modelling efforts** by evaluating **the importance of tidal constituents** and whether they should be included in ocean tidal corrections.
- Finally, we **provide novel insights into global tidal characteristics**, particularly the duration of high-water stands during spring tides and the changes observed in tidal constituents, allowing us to better understand the impact tides can have on coastal flooding.

In situ tide gauge data

- The updated GESLA dataset, **GESLA-4, provides 6474 tide gauges spanning 119 countries globally**.
- Using these data, TICON-4 was derived using a harmonic analysis, which provides tidal constituents from all these observations based on several processing criteria, **resulting in only 3,591 gauges being used in our analysis.**
- Gauges in rivers, lakes, the Baltic Sea, the Black Sea, and swamplands excluded to isolate meaningful coastal tidal signals
- Records span from the 19th century to the present; the majority cover the last 20–50 years

Tidal characteristics

- **(Figure 1) M_2 (principal lunar semidiurnal) dominates globally,** explaining 62% of tidal variance; the eight major constituents together explain 74.8%.
- Minor tidal constituents are locally significant: at 15% of coastal gauges, at least one minor tide exceeds all major tides in amplitude.
- **(Figure 2) High-tide duration (within 20 cm of peak) varies globally from 1 to 14 hours** — diurnal regions (e.g. Gulf of Mexico) exhibit the longest high-water stands; semidiurnal regions with large ranges (e.g. North Sea) the shortest
- **(Figure 3) Of 237 long-record gauges analysed for trends**, 52–53% show statistically significant changes in M_2 or S_2 amplitude, ranging from −1.47 to +1.80 mm yr^{-1}.

Summary

- This study a most comprehensive global synthesis of coastal tidal characteristics to date, spanning datums, regime classification, nonlinear effects, trends, and flood duration.
- TICON-4 is available: https://doi.org/10.17882/109129 , with an interactive map of the tidal datums available at: https://openadb.dgfi.tum.de/en/ocean-tides/map-tidal-datum/
- Hart-Davis, M. G., Sulzbach, R., Talke, S. A., Haigh, I. D., Marcos, M., Woodworth, P., Ray, R., Andersen, O. B., Lyard, F., Fouchet, E., Dettmering, D., Thomas, M., and Seitz, F.: Tide of the Time: Global tidal characteristics observed from in-situ measurements, Ocean Sci., 22, 1681–1709, https://doi.org/10.5194/os-22-1681-2026 , 2026.

Ocean Surface Topography Science Team Meeting, Wiesbaden, Germany, 2026