Spatial-temporal Variability of the Global Ionospheric Maps Against 16 Years of Jason Altimetry Observations

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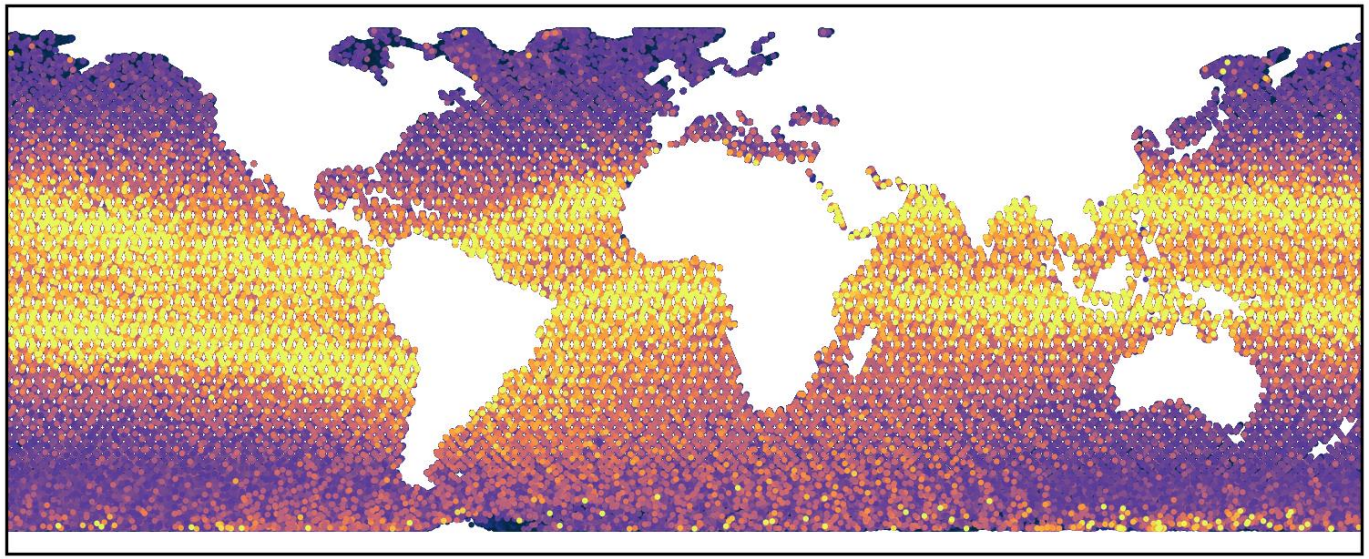
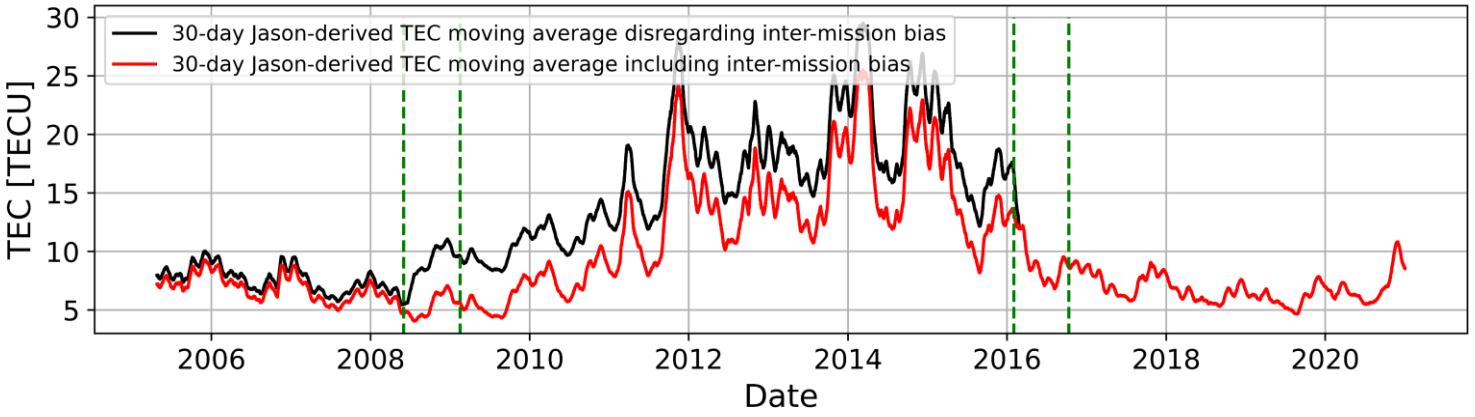
Introduction

- During our study, we checked the variability of the final ionospheric map products from CODE, ESA, IGS, JPL, UPC and WHU centers against the filtered and aligned data from the Jason altimetry missions.
- From the analyses we conducted, we observed cyclic variability on a spatial-temporal basis.



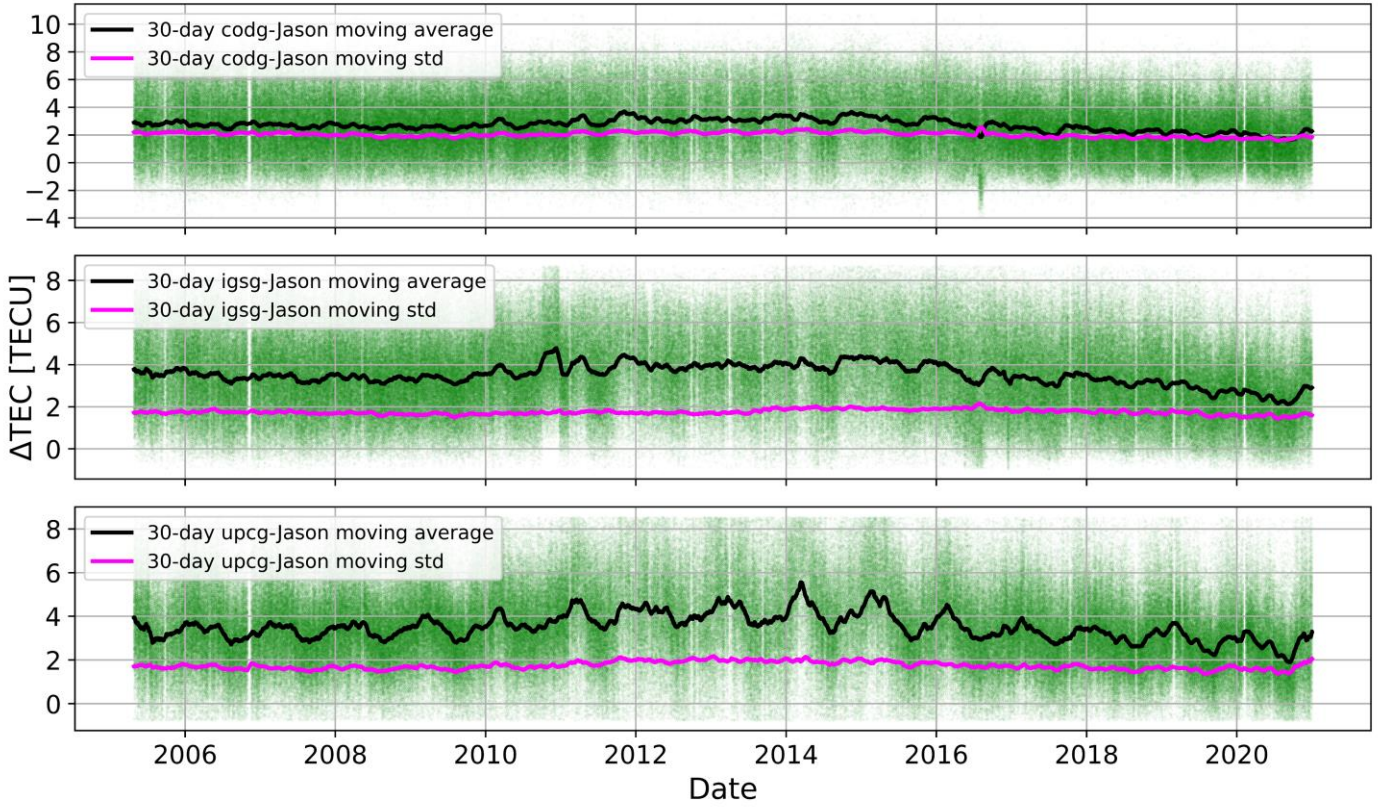
Methodology: Jason Altimetry Observations

- Calibration terms used:
  - June 2008 until mid−February 2009
  - February 2016 until early October 2016
- Calculated biases:
  - Jason-1E – Jason-2D: 3.22 ± 2.84 TECU
  - Jason-2D – Jason-3F: −3.97 ± 2.23 TECU



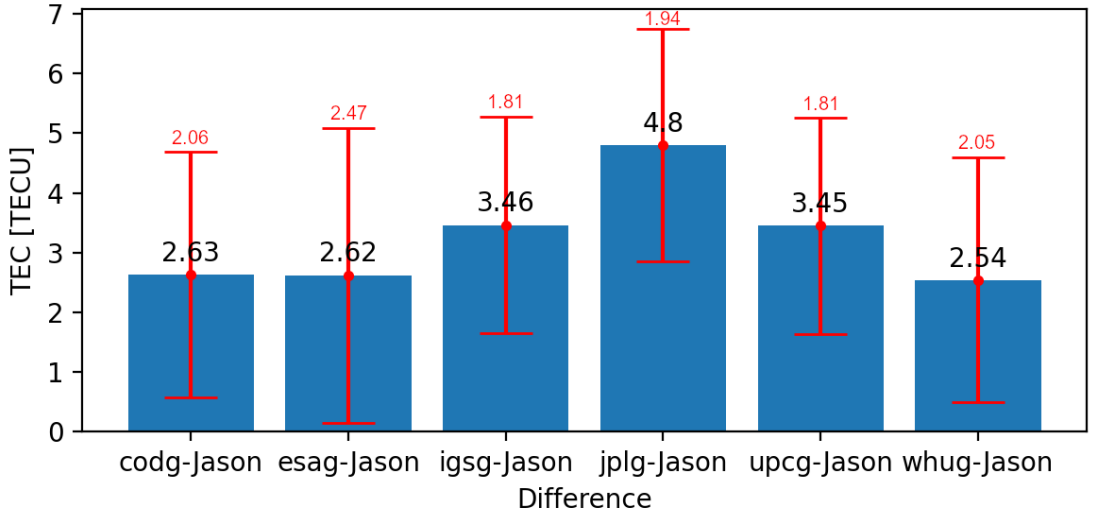
Methodology: Global Ionospheric Maps

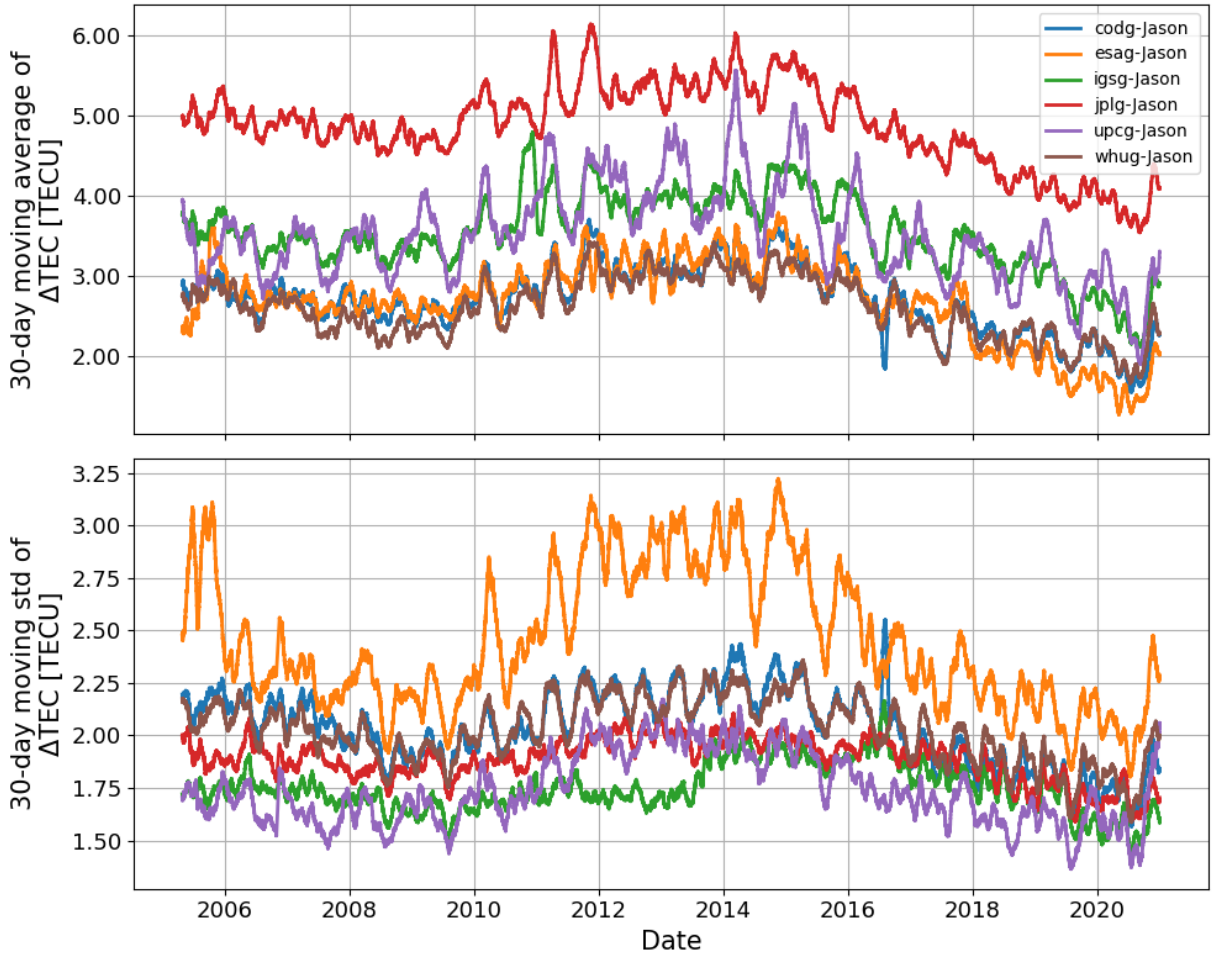
- The effect of the plasmasphere on TEC measurements from altimeter satellites was taken into account. As the Jason satellites move in orbits of 1,336 km, up to an altitude of 20,000 km, the data were supplemented with the IRI-2016 model



Results

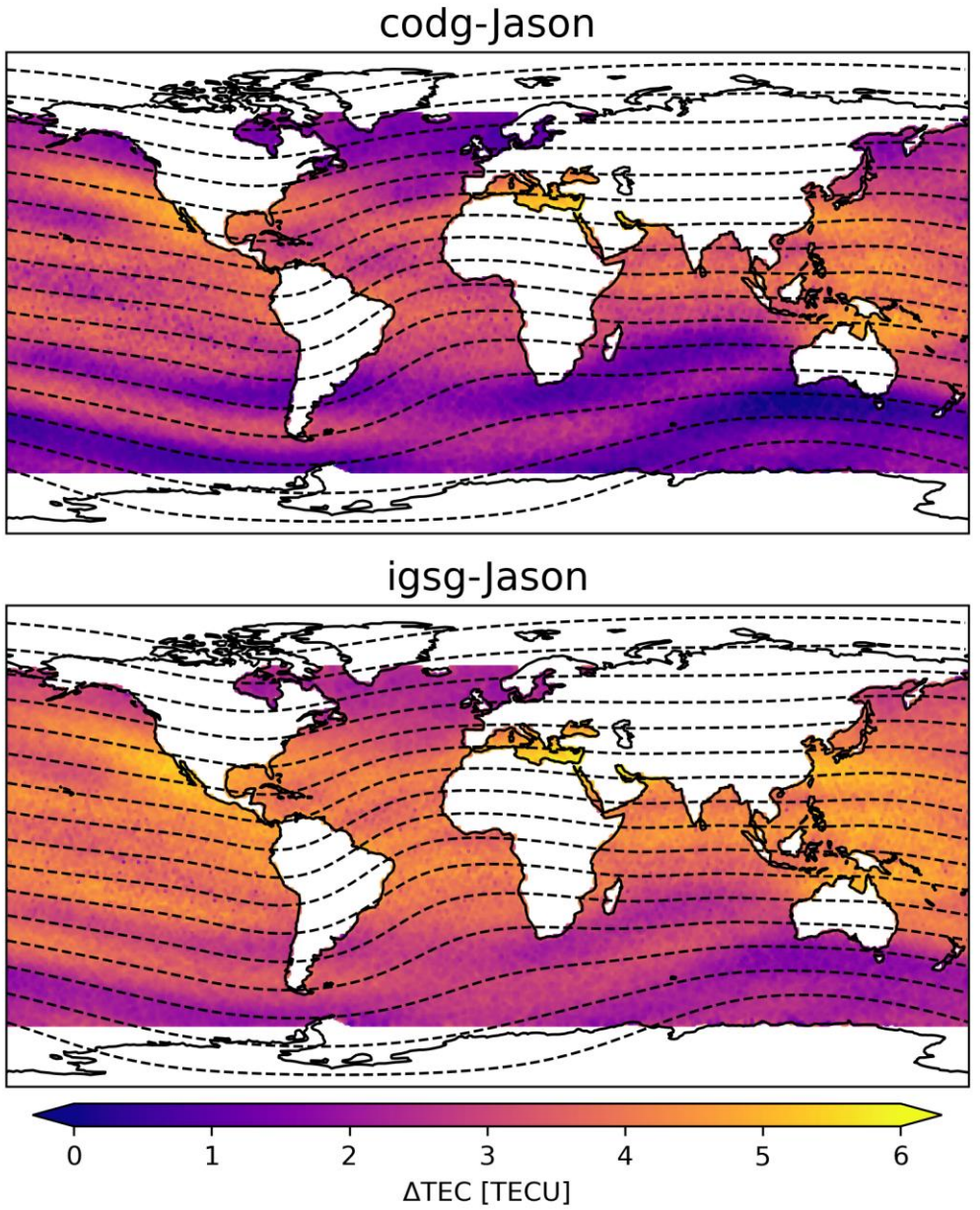
- A 30-day window was used to filter out noisy data. A monthly window was chosen because of the period close to the period of the sun's rotation around its axis.
- The data filtered in this way formed the basis for further analysis.





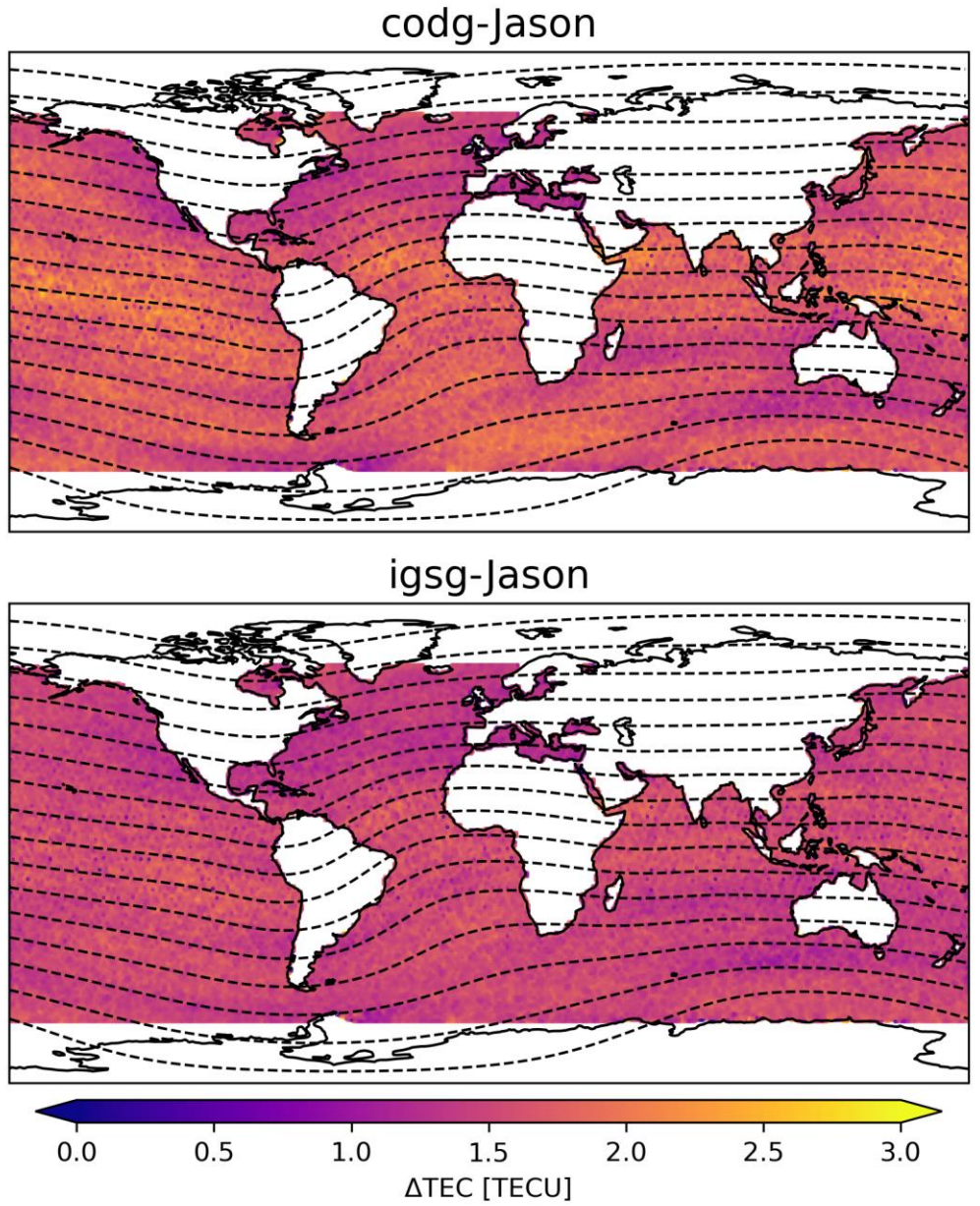
Spatial Variability: Mean

	codg-Jason [TECU]	esag-Jason [TECU]	igsg-Jason [TECU]
North Hemisphere	3,0	3,0	3,7
Intertropical area	3,5	3,5	4,2
South Hemisphere	1,9	**1,8**	2,8
Whole Globe	2,7	2,7	3,5
	jplg-Jason [TECU]	**upcg-Jason [TECU]**	**whug-Jason [TECU]**
North Hemisphere	5,1	3,4	2,9
Intertropical area	**5,6**	3,6	3,3
South Hemisphere	4,2	3,3	1,9
Whole Globe	4,9	3,5	2,6



Spatial Variability: STD

	codg-Jason [TECU]	esag-Jason [TECU]	igsg-Jason [TECU]
North Hemisphere	1,6	1,9	**1,5**
Intertropical area	1,9	**2,3**	1,6
South Hemisphere	1,7	2,2	1,6
Whole Globe	1,8	2,2	1,6
	jplg-Jason [TECU]	**upcg-Jason [TECU]**	**whug-Jason [TECU]**
North Hemisphere	1,6	1,6	1,6
Intertropical area	1,8	1,8	1,8
South Hemisphere	1,7	1,8	1,8
Whole Globe	1,7	1,8	1,8

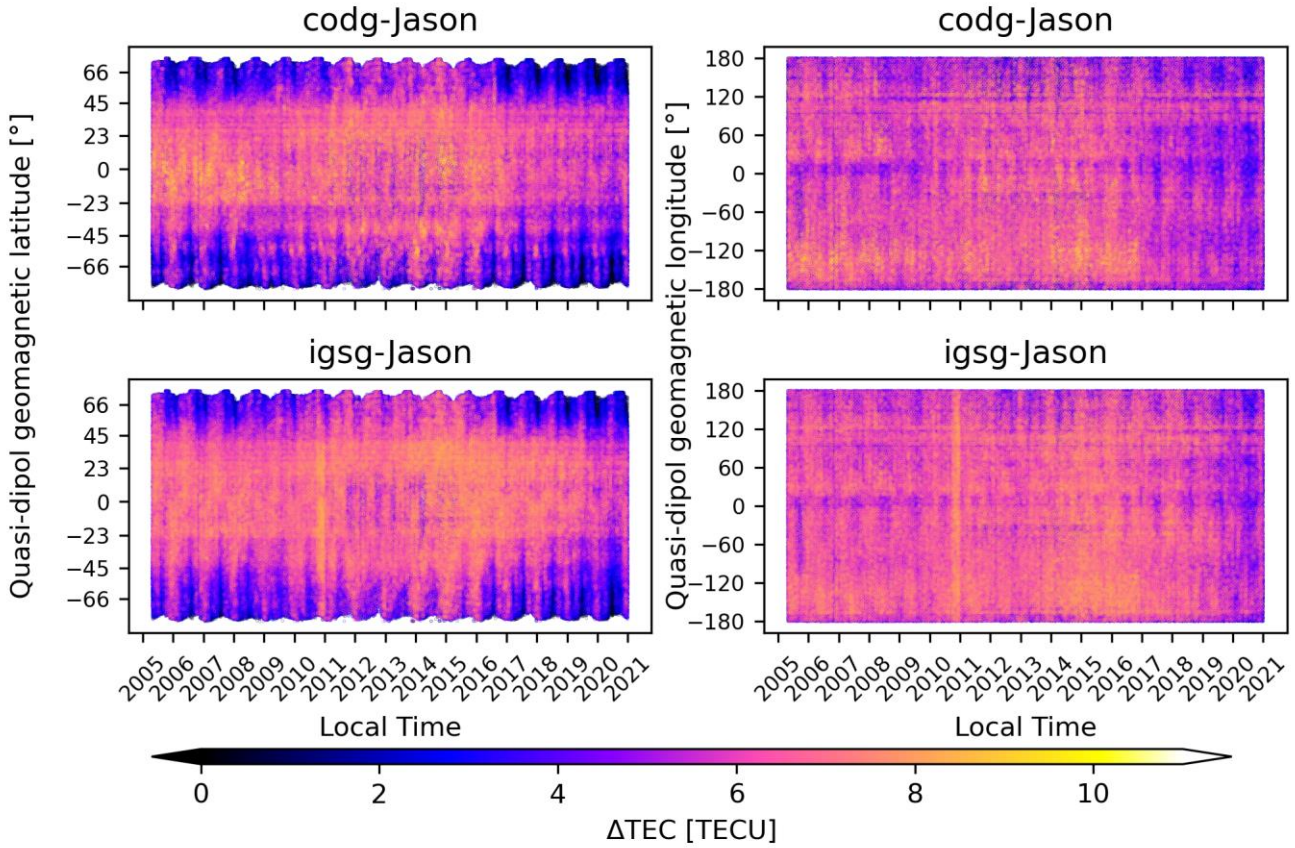


Spatial-Temporal Variability: Oscillations

A cyclic change in TEC was observed in particular noted for above 45° geomagnetic latitude

The increase in the value of differences increases markedly in the intertropical area

Differences between IAAC center data and Jason-derived TEC increase with increasing solar activity in the 11-year cycle.

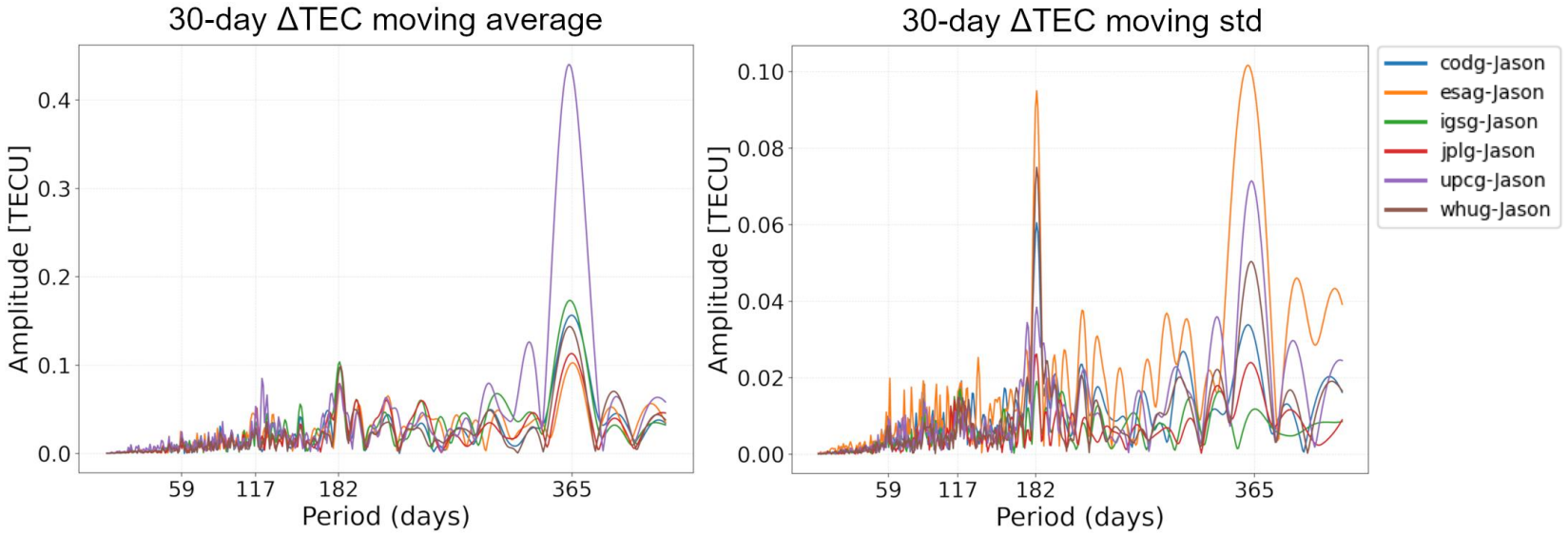


Temporal Variability: Amplitude analysis

Removed the nonlinear trend in the data by fitting a polynomial of degree 6 into data.

For the 30-day moving average and moving standard deviation, distinctive oscillations were detected for periods of 182 and 365 days.

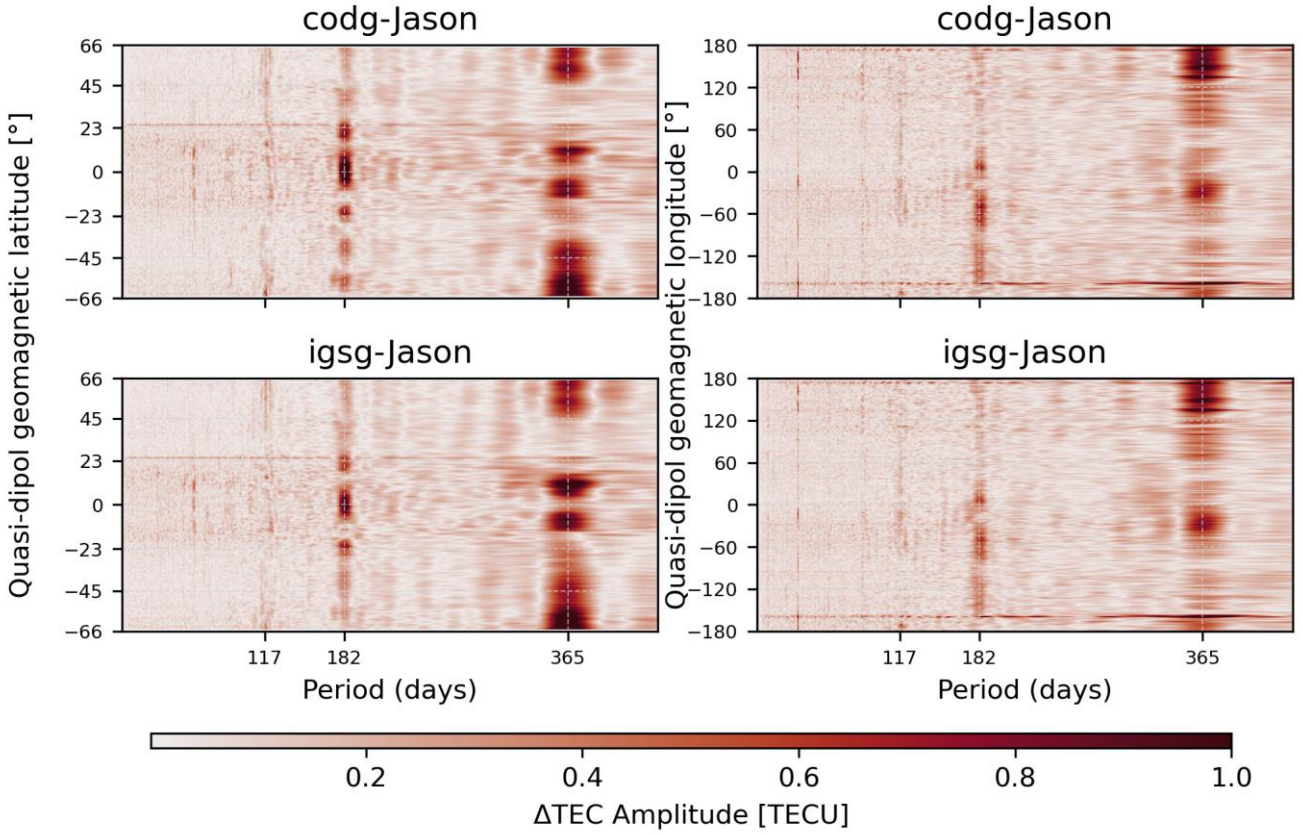
A 117-day oscillation and weak 27- and 59-day oscillations were also detected in the studied data, which were subjected to additional analysis.



Spatial-Temporal Variability: TEC Amplitude analysis

By putting our data under spatial-temporal spectral analysis, we observed the latitudes and geomagnetic lengths for which the oscillations detected in the differences are the strongest.

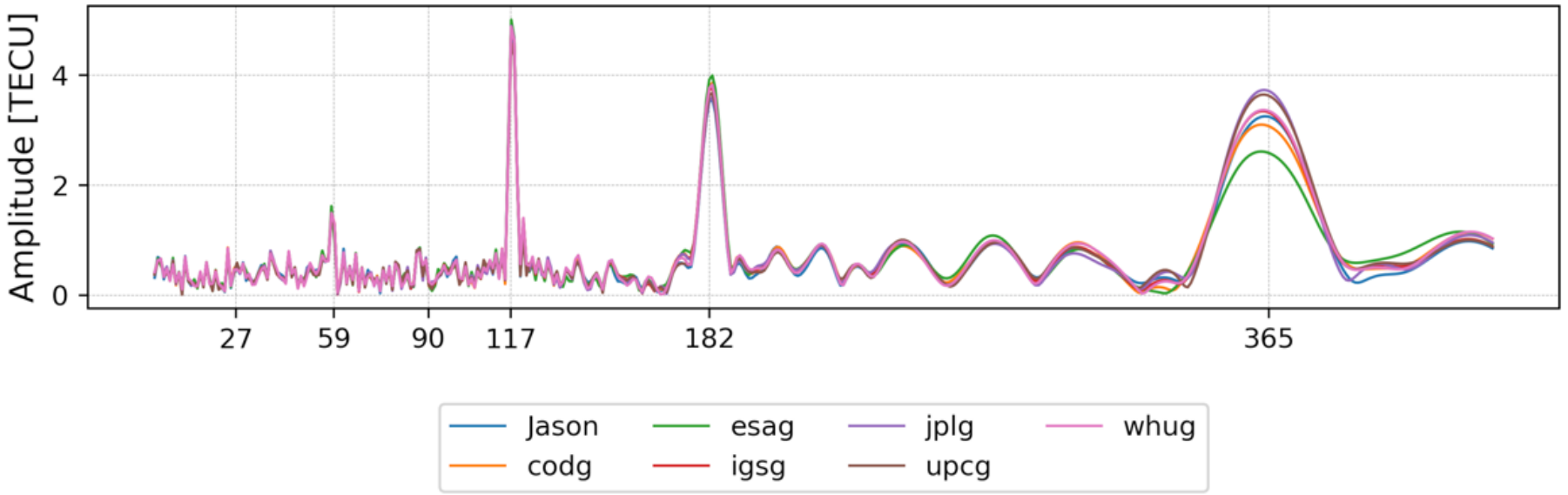
It should be taken into account that the data set subjected to the study did not have information over land.



Temporal Variability: Periodograms

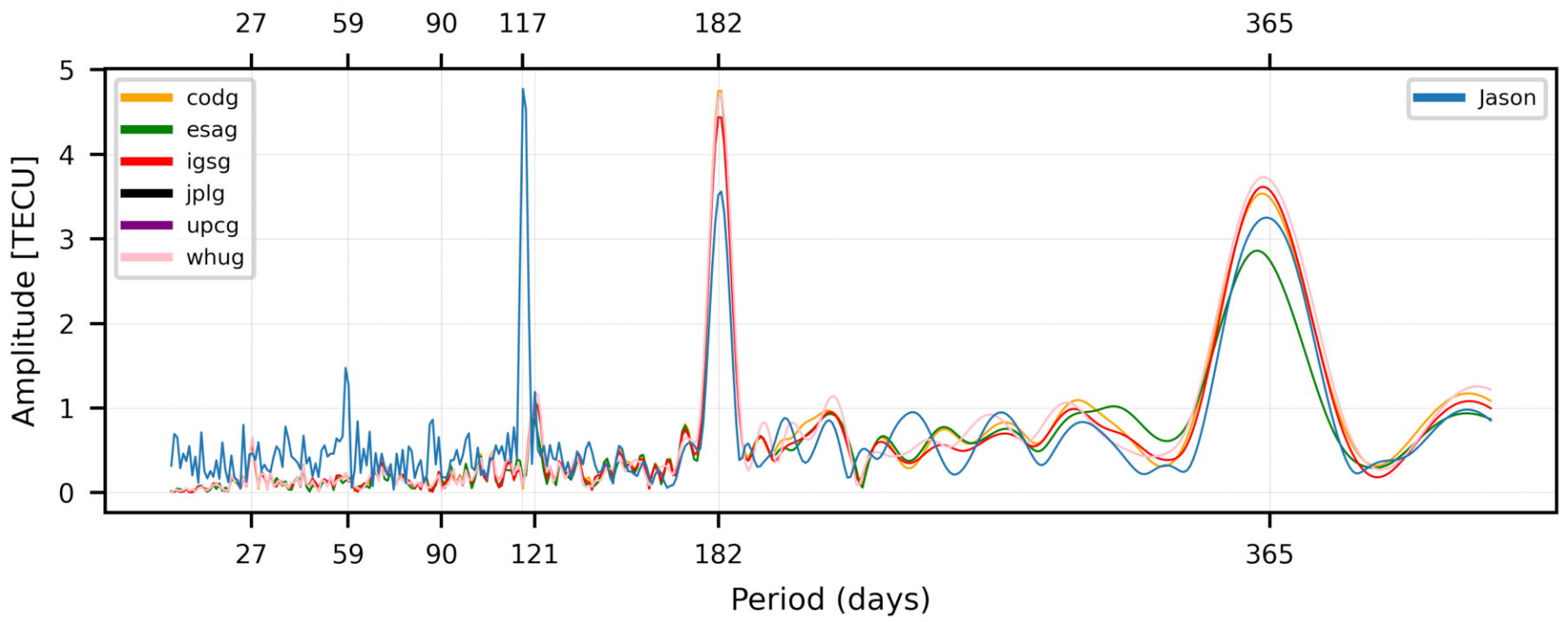
A spectral analysis for a small area was performed for the individual TEC sources used in our study.

A distinctive 117-day oscillation can be observed for data interpolated to the position and epoch of measurements from Jason satellites.



Temporal Variability: Periodograms

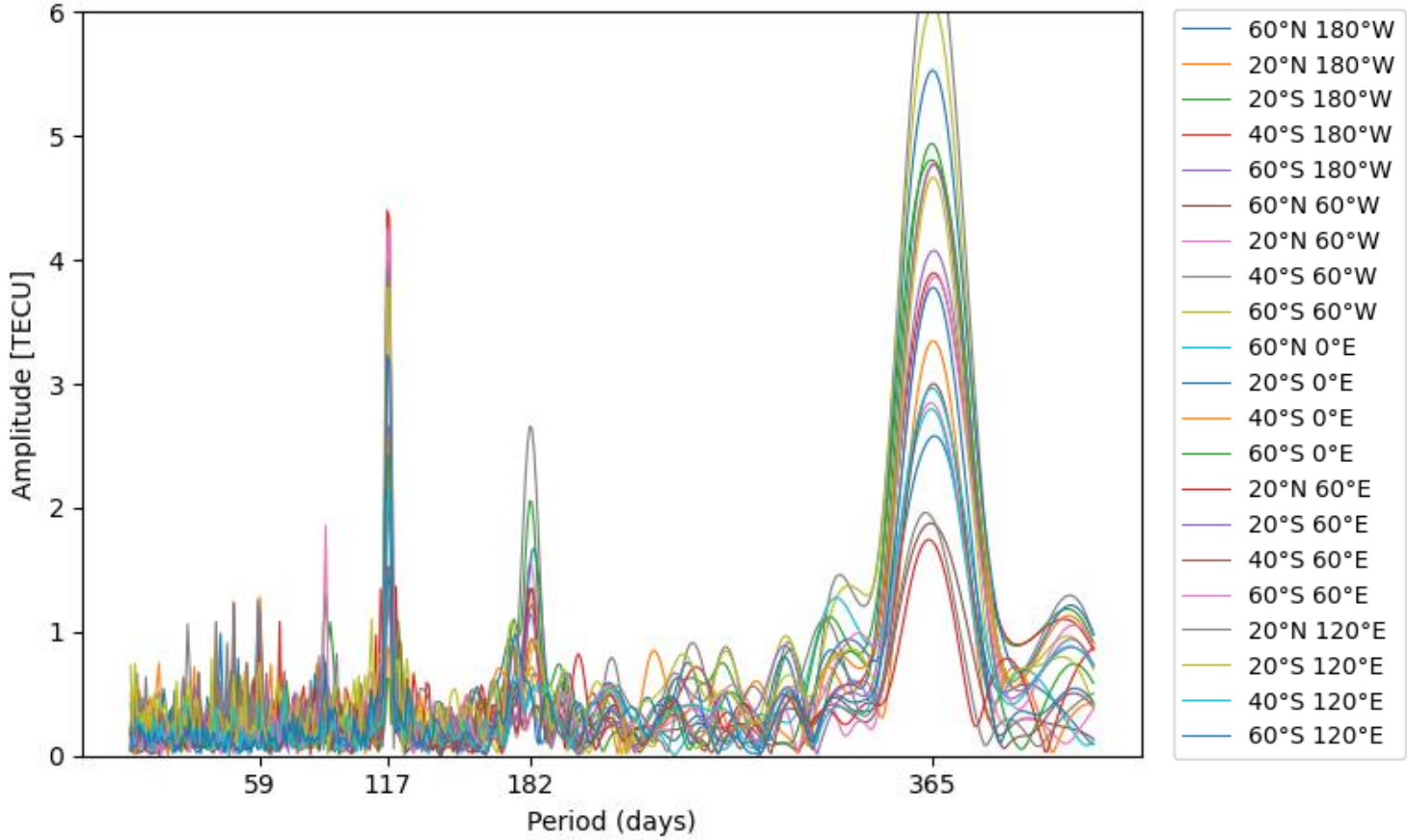
To remove the effect of interpolation on the spectral analysis, we used all Jason measurements from a 10° × 10° window around the 0°N, 0°E point. IAAC center data were extracted directly from global ionospheric maps for this location.



Spatio-Temporal Variability

Jason's measurements for each latitude and longitude show variable strength of oscillations.

For each position, the occurrence of three oscillations can be observed: annual and semiannual, as well as a 117-day oscillation occurring in the data. This cyclicity is related to the draconic period of the Jason satellites.

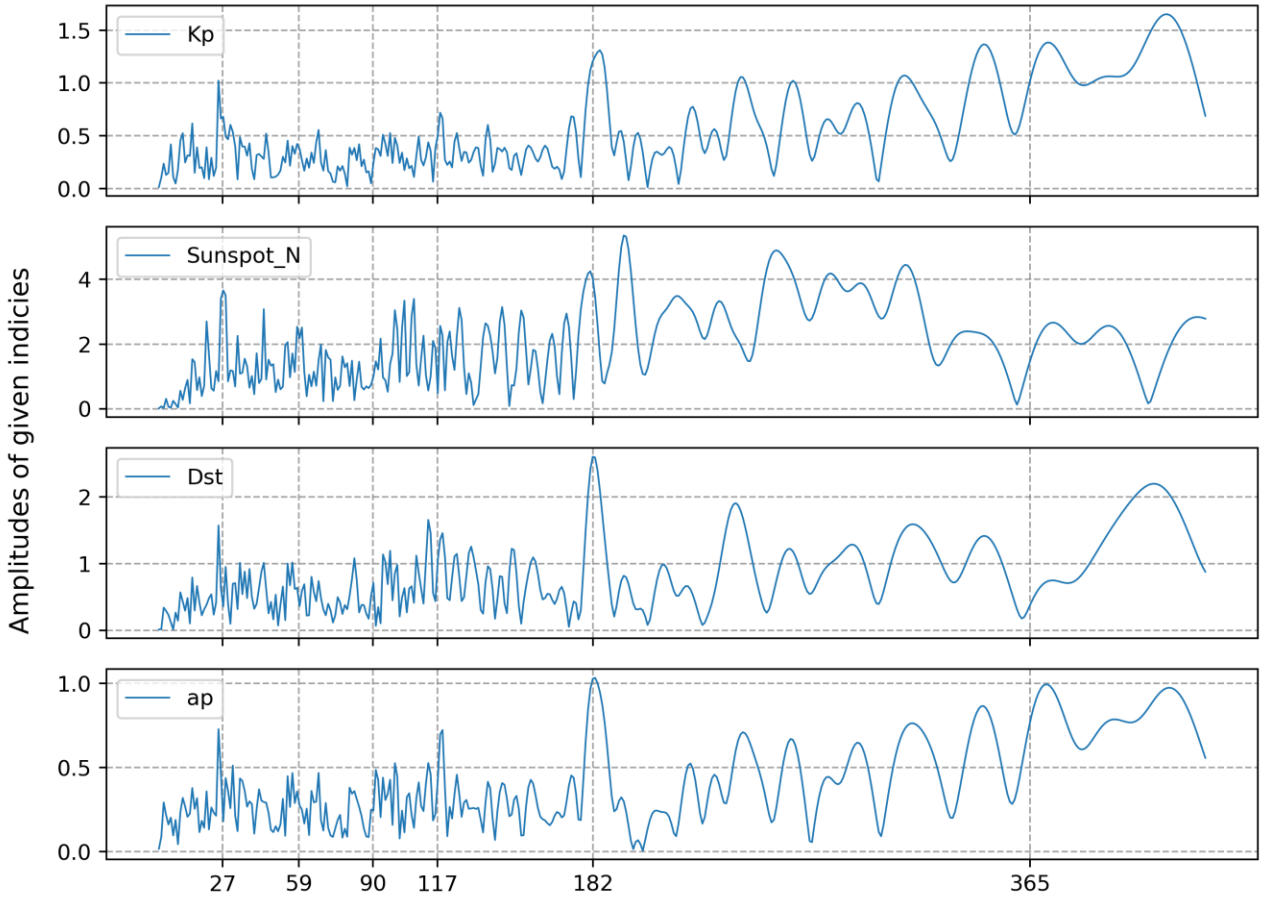


Variability of solar and geomagnetic activity indices

A clear semiannual oscillation can be noted for each of the indices shown. In addition, a cyclicity of about 27 days due to the period of the sun's rotation around its axis can be noted.

For the Kp and ap indices, oscillations of about 120 days can also be observed.

We did not observe the influence of solar or geomagnetic activity on the 117-day oscillation



Conclusion

- Through our research, we were able to determine the biases between the various Jason missions.
- Cyclicities were detected, the strength of which depends on the location.
- Among them, the most pronounced have periods of 365 days (TEC annual oscillation), 182 days (semiannual oscillation) and 117 days (oscillation associated with the draconic period of Jason satellites).
- Bilinear interpolation from the global ionospheric maps to the position and epoch of Jason makes the data from the IAAC centers exhibit a 117-day cyclicity (where in the map nodes it is 121 days).
- Weaker 27-day and 59-day oscillations were also observed, where the 27-day one is related to the sun's rotation cycle around its axis, while the 59-day one is a harmonic of the 117-day one.
- The occurrence of similar oscillations was noted when considering for parameters describing solar and geomagnetic activity.

Poniatowski, M.; Nykiel, G.; Borries, C.; Szmytkowski, J. Spatio-Temporal Validation of GNSS-Derived Global Ionosphere Maps Using 16 Years of Jason Satellites Observations. *Remote Sens.* **2023**, *15*, 5053. https://doi.org/10.3390/rs15205053