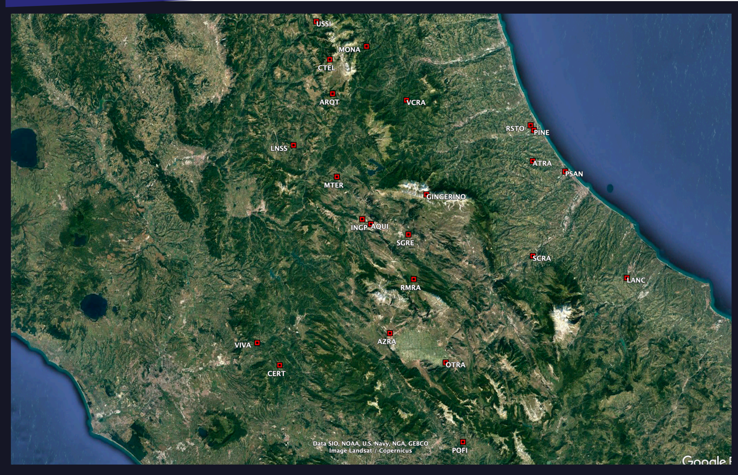
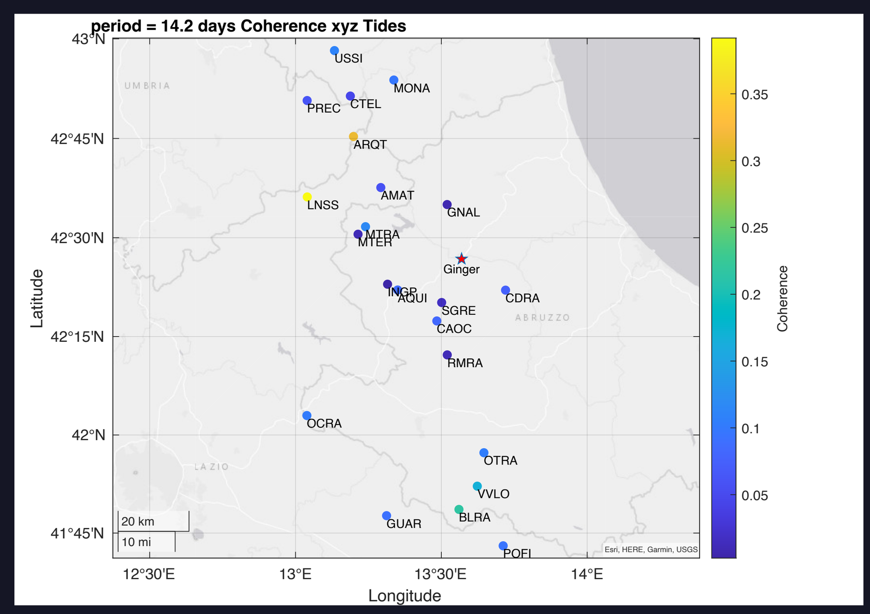
Comparative analysis of local deformations between GNSS stations and the Ring Laser Gyroscope GINGERINO

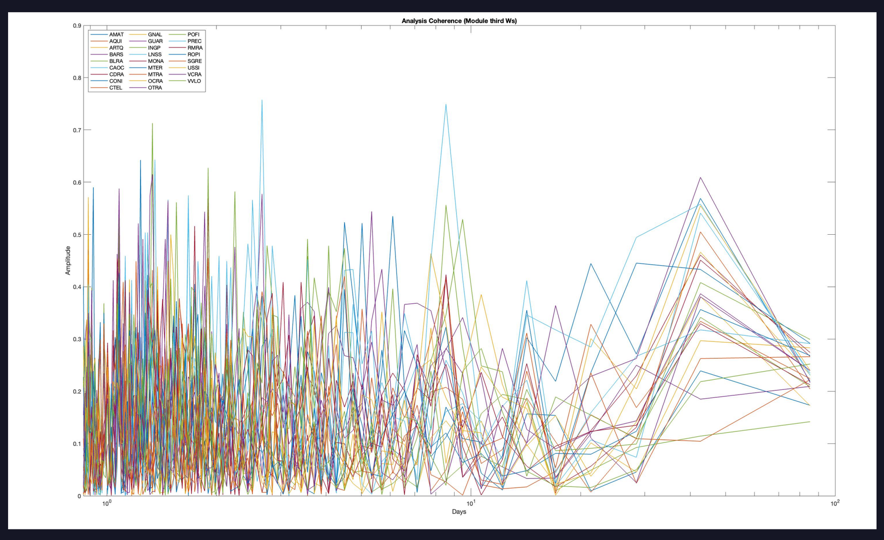
Giuseppe Di Somma, Nicolò Beverini, Giorgio Carelli, Simone Castellano, Donatella Ciampini, Roberto Devoti, Francesco Fuso, Enrico Maccioni, Paolo Marsili, Angela D.V. Di Virgilio.



The detection of local deformations is a hot topic in geodesy. In our analysis for the first time a comparison between these instruments has been performed, we compare the signal from Gingerino with the ones from the GNSS stations, homogeneously selected around the position of Gingerino.



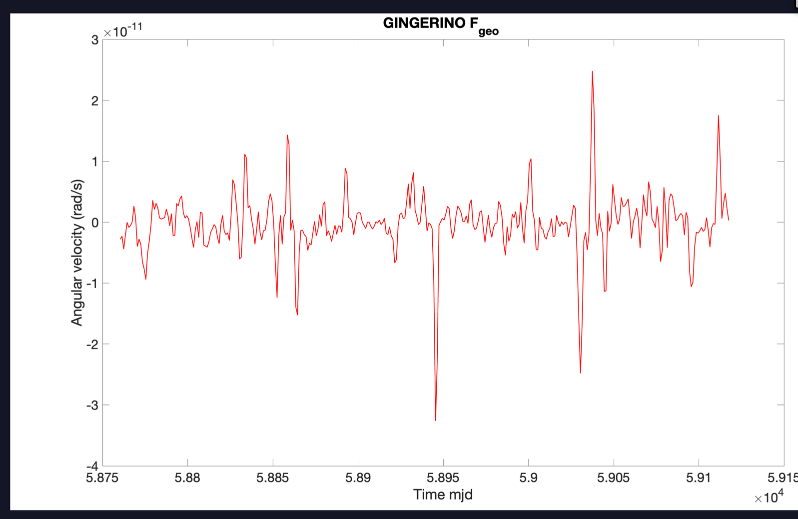
At the bottom, we observe coherence across all time periods. On the right side, our focus is on identifying a shared peak among all periods, but no clear topographical pattern emerges.



Since we are solely considering the stations and their positions relative to Gingerino, a direct comparison becomes challenging. To address this, we employ two distinct methods to compare the rotations observed by the GNSS stations with the Gingerino signal, which inherently represents a rotation.

Gingerino Signals

We have on the right the Gingerino signal in which systematic laser corrections and terrestrial rotational componete, including polar motion and Chandler wobble (obtained from IERS measurements [1]) were removed.



At the bottom we have the Gingerino signal, obtained starting from the previous one, in which we solved and subtracted the tides through the use of the GOTIC2_mod program [2].

As you can see by solving the tides, the amplitude drops by an order of magnitude, thus becoming compatible with the signals obtained from the GNSS stations, in which the tides were resolved.

To ensure consistency with the analysis conducted on GNSS stations, we applied a 24-hour average to the Gingerino signal. This approach yielded a single data point per day, resulting in a total of 359 days of signal data that we present here.

Monobeam 1

Monobeam 2

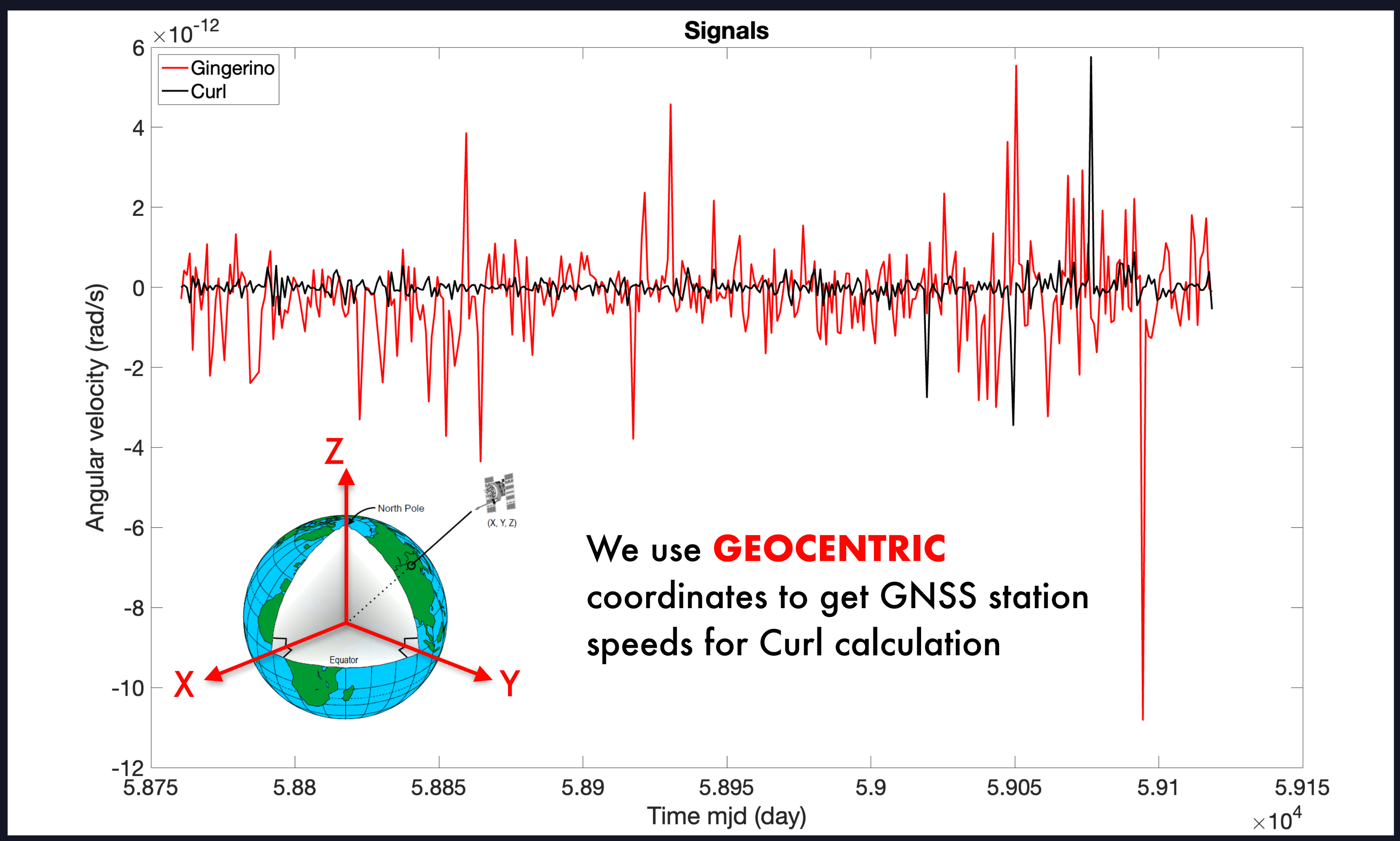
Discharge

Curl z-component seen from GNSS calculated in Gingerino position

In a method of extracting a rotation vector from the displacement signal of GNSS stations, we calculate the z-component of the curl of the area circumscribed by the constellation of stations at Gingerino position [3].

$$\omega_z = \left(\frac{\partial v_x}{\partial y} - \frac{\partial v_y}{\partial x}\right)$$

$$v_i = t_i + \frac{\partial v_i}{\partial x_j} x_j = t_i + e_{ij} x_j \qquad e_{ij} = \epsilon_{ij} + \omega_{ij} = \frac{(e_{ij} + e_{ji})}{2} + \frac{(e_{ij} - e_{ji})}{2}$$



We use **GEOCENTRIC** coordinates to get GNSS station speeds for Curl calculation

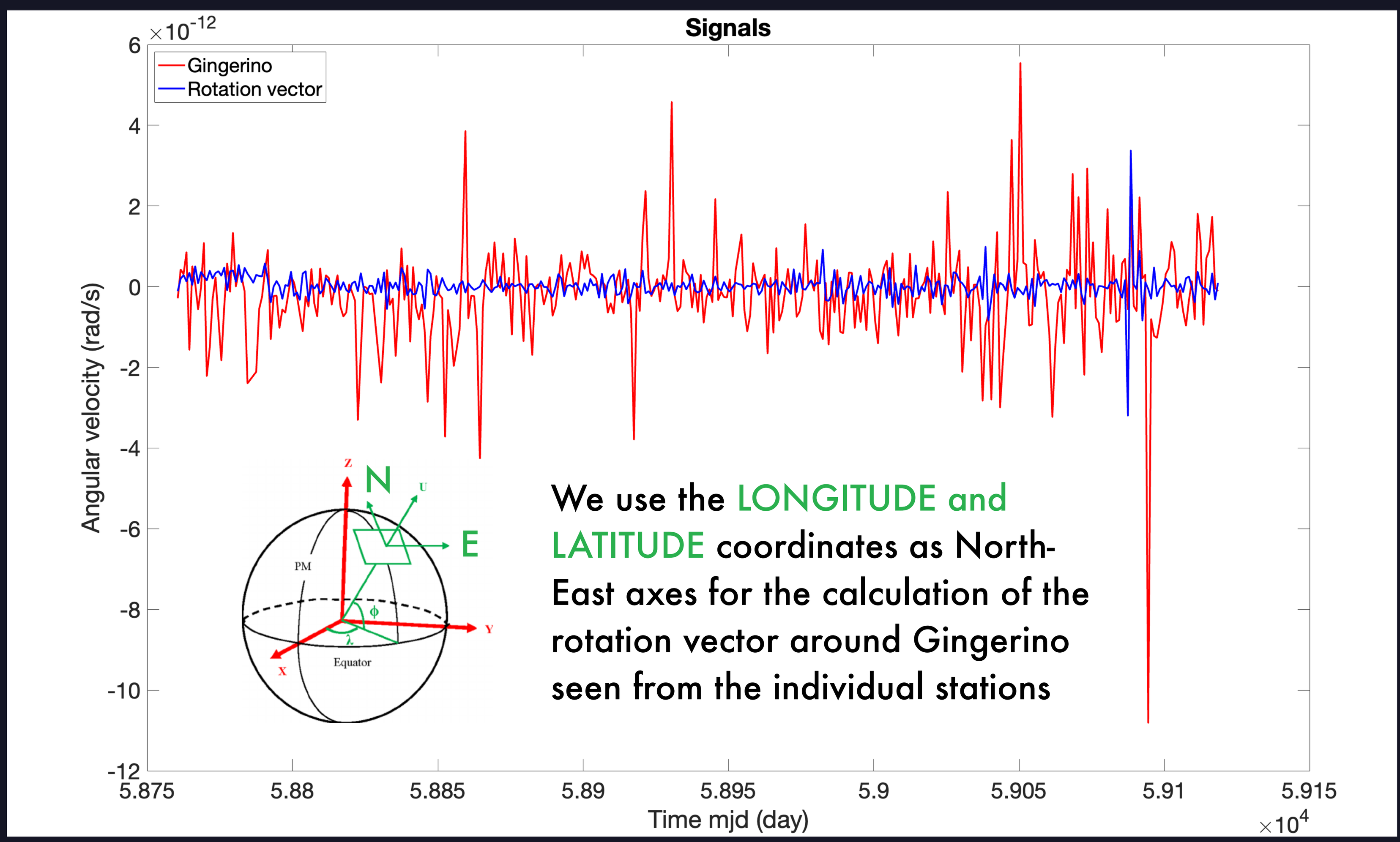
Rotation around Gingerino: equations for single station

$$\omega_1 = \frac{|v_1|}{|r_1|}\sin(\alpha_1 - \theta_1)$$

$$v_1 = \sqrt{v_E^2 + v_N^2} \qquad \alpha_1 = \arctan\left(\frac{v_N}{v_E}\right)$$

Using Gingerino position as the pole, the rotational component of each individual station is derived and then the rotation vector associated to the area circumscribed by the stations is obtained by performing a weighted average.

$$\sigma_{\omega_1} = \sqrt{\left(\frac{\partial \omega_1}{\partial v_1}\right)^2 \sigma_{v_1}^2 + \left(\frac{\partial \omega_1}{\partial r_1}\right)^2 \sigma_{r_1}^2 + \left(\frac{\partial \omega_1}{\partial \alpha_1}\right)^2 \sigma_{\alpha_1}^2 + \left(\frac{\partial \omega_1}{\partial \theta_1}\right)^2 \sigma_{\theta_1}^2}$$

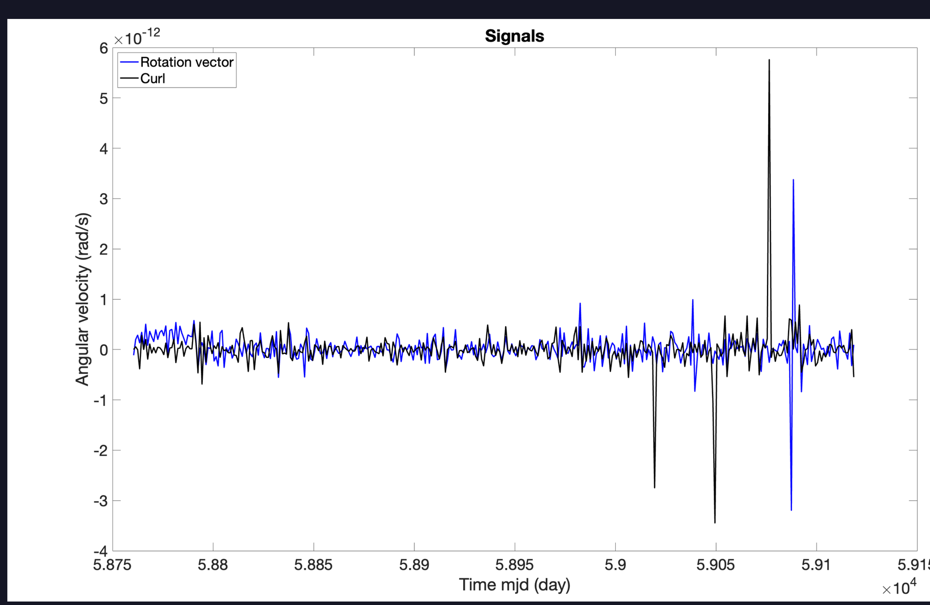


We use the LONGITUDE and LATITUDE coordinates as North-East axes for the calculation of the rotation vector around Gingerino seen from the individual stations

$\sigma_{r_1}, \sigma_{\theta_1}$ are evaluated with a MonteCarlo method, because they are obtained with the "distance" function of Matlab

Beam Splitter

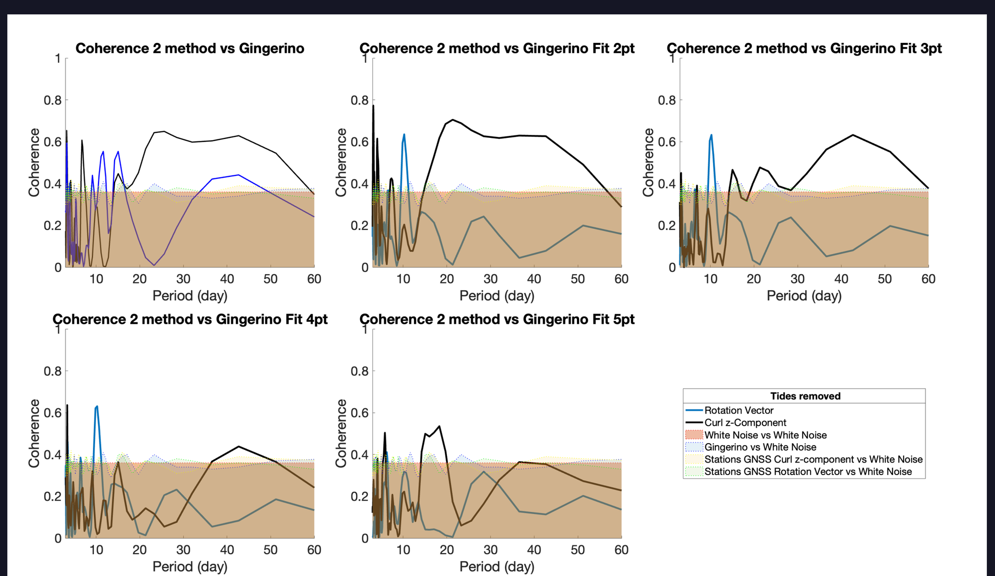
Results and conclusions

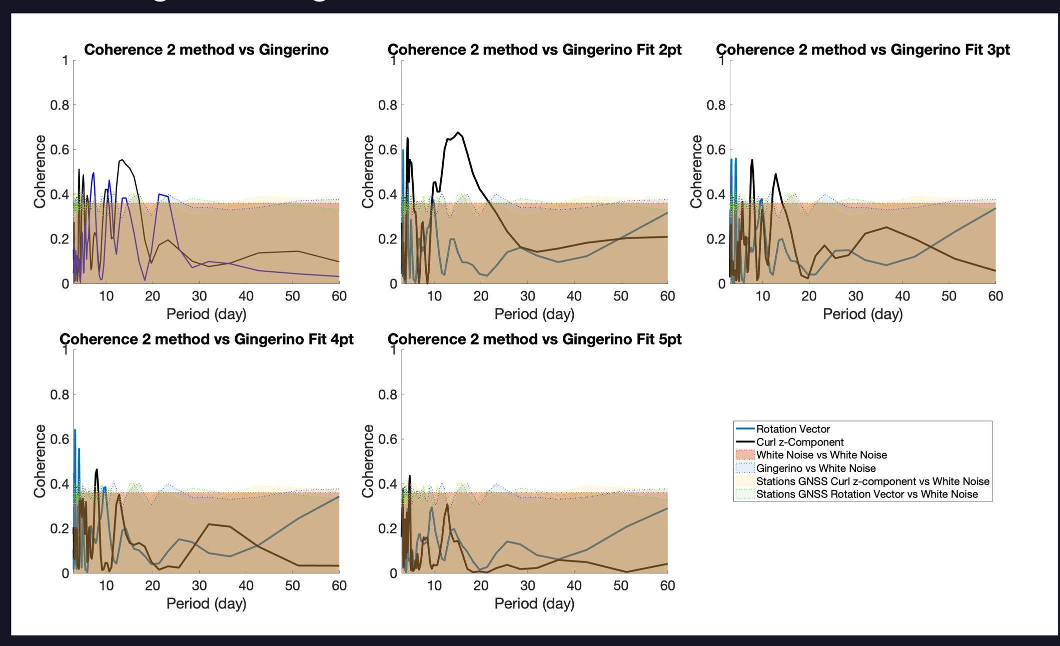


It is noteworthy that the signals obtained, with two different methods, share a common feature: they exhibit identical amplitudes, with some points even reaching peak values, and display coinciding trends.

On the left we have a signals of duration about a year, while below we have the coherence made with the Gingerino signal.

On the right we have the coherence obtained without subtracting the contribution of the tides, clear structures are clear with the 2-point fit.

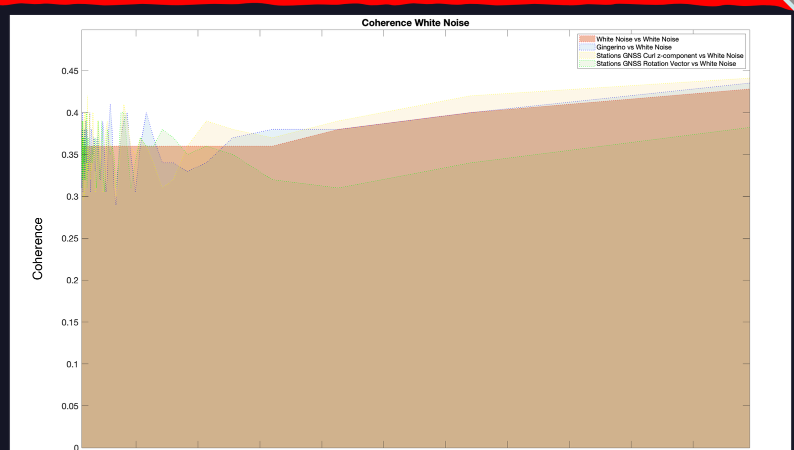


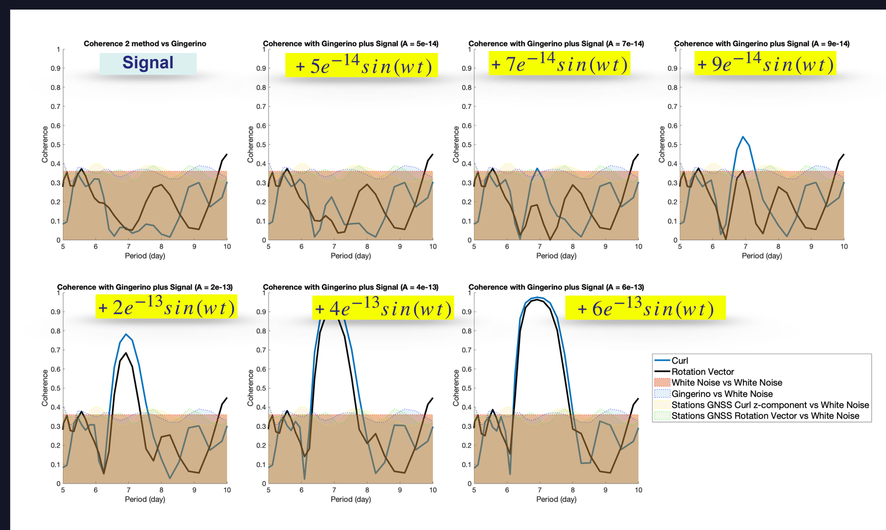


On the left, we observe the coherence achieved through the resolution of tides in Gingerino. The usual tidal peaks are reduced, revealing previously hidden structures with periods exceeding 20 days.

Noise Simulation

To determine the actual degree of coherence between the two signals, we conducted tests using the **mscohere** function along with simulated white noises. Employing a Monte Carlo simulation approach.





We enhanced the angular speeds obtained through the aforementioned methods by introducing a simulated signal that exhibited spikes over a duration of 7 days. This simulated signal had a variable amplitude, reaching up to two orders of magnitude lower than the actual signal.

Sagnac 2

Sagnac 1

References

[1] https://hpiers.obspm.fr/eop-pc/index.php?index=rotation&lang=en
[2] https://www.gsj.jp/data/openfile/no0705/openfile0705indexEN.html
[3] Allmendinger, Richard & Reilinger, Robert & Loveless, John. (2007). Strain and Rotation Rates from GPS in Tibet, Anatolia, and the Altiplano. Tectonics. 26. 10.1029/2006TC002030.

giuseppe.disomma@pi.infn.it