

# Improvement of GNSS Interferometric Reflectometry processing to improve studies of sea level change

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## Abstract

Global Navigation Satellite System Interferometric Reflectometry (GNSS-IR) is a method of determining the near-field environment of a GNSS station. By analyzing the received signal, it is possible to estimate the height of the GNSS antenna if placed above a planar surface. Placing the antenna by the coast, the station can estimate the sea level and act as a tide gauge. The sea level change has been estimated at four sites in Esbjerg, Tejn, Gedser and Fynshav with GNSS-IR and tide gauges. For the GNSS-IR data, multiple models have been developed to find possible breakpoints in the timeseries due to e.g. software updates or antenna replacements. These breakpoints have been necessary to consider in order to get the same accuracy of the sea level changes as with tide gauges.

## Finding breakpoints

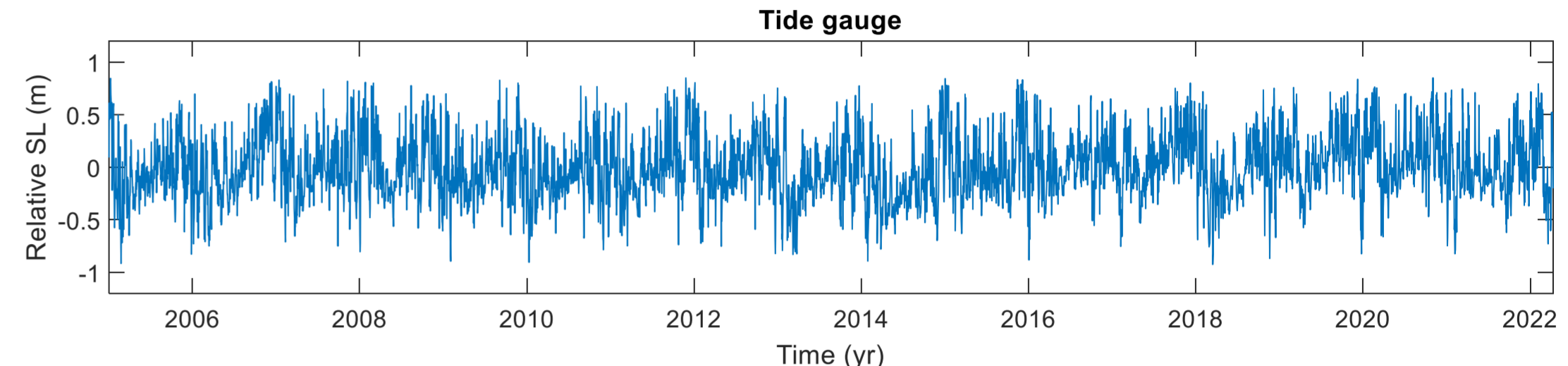
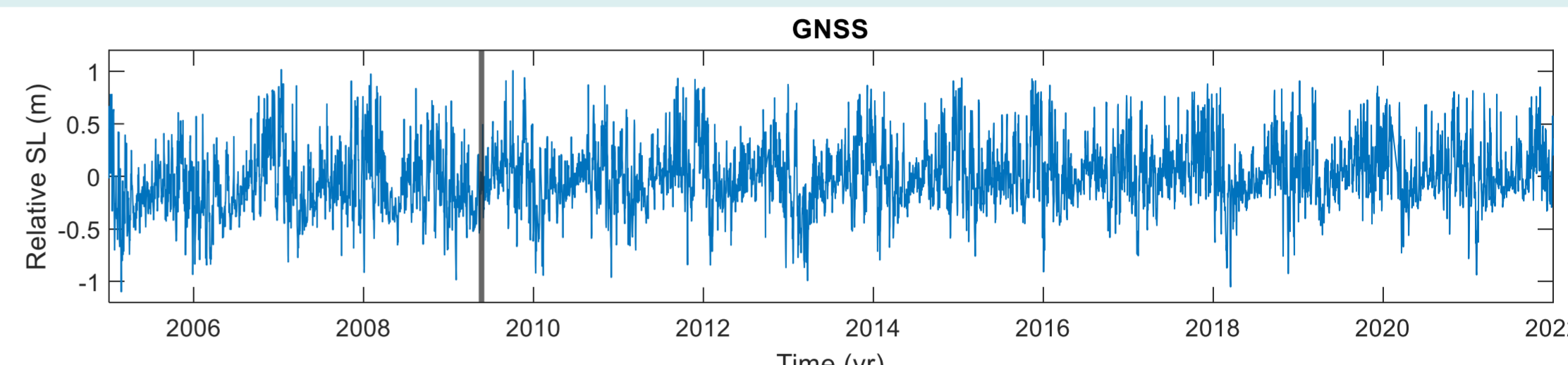
MATLAB has been used to find possible offsets in the time series. In Esbjerg and Gedser these offsets have been found at times where the antennas have been replaced. In order to estimate the trend of the sea level and the size of the offsets, an ordinary least squares method has been used.



## Esbjerg

Data is available from January 2005 to January 2022. An offset of 5.7 cm has been detected when the antenna was replaced in 2009.

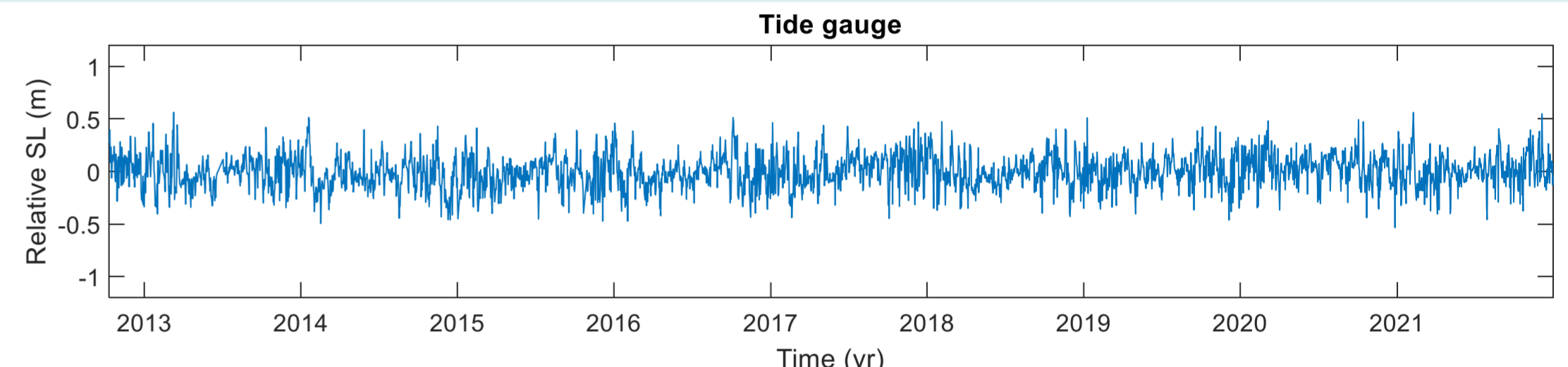
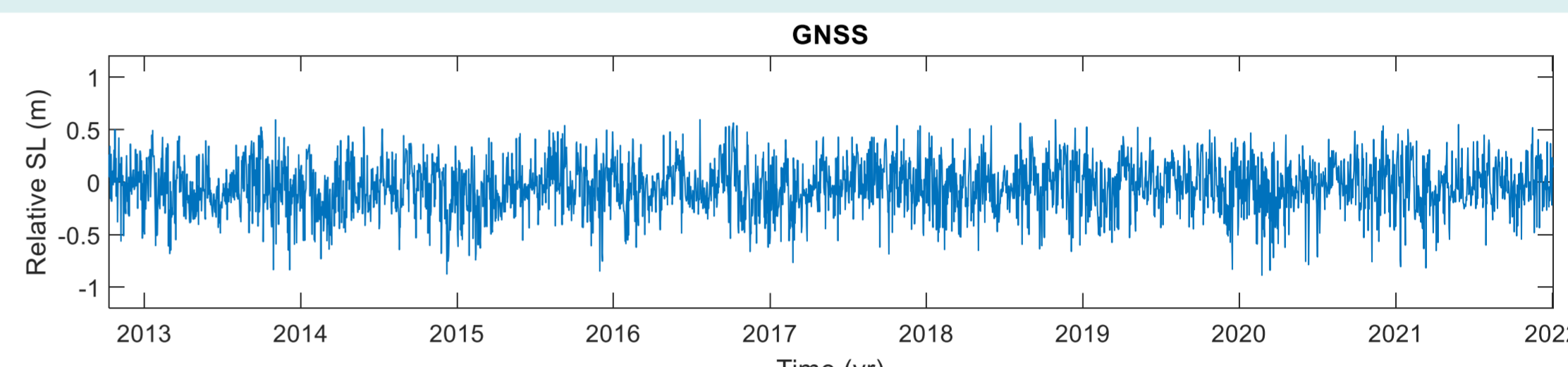
GNSS-IR : 6.2 mm/yr  
Tide gauge : 5.3 mm/yr



## Fynshav

Data is available from October 2012 to January 2022.

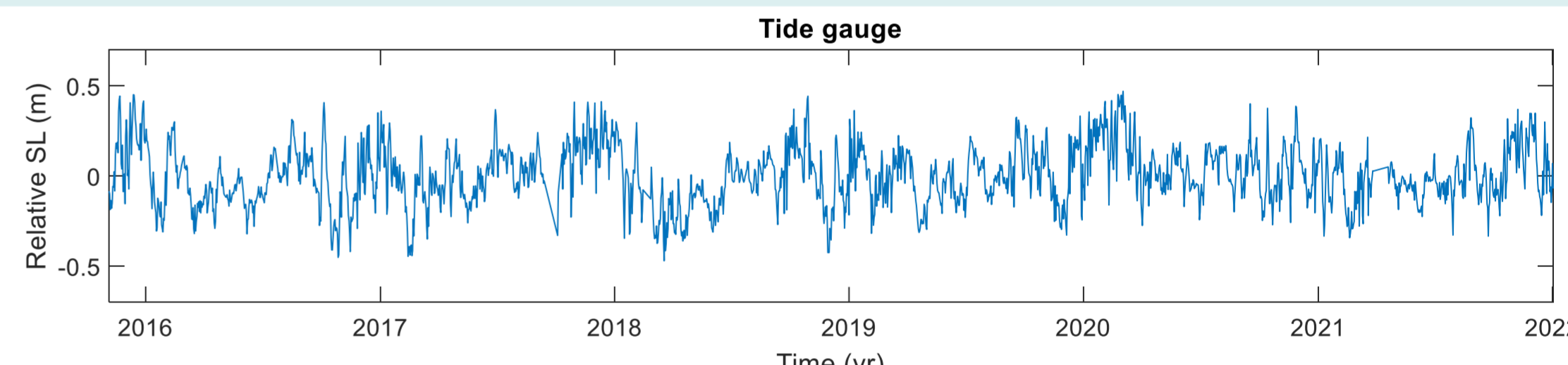
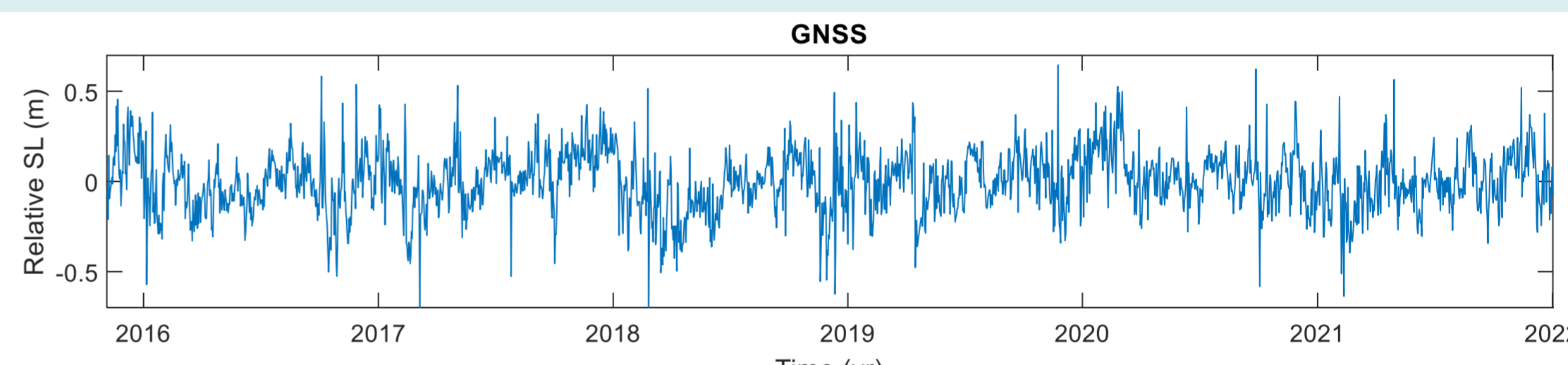
GNSS-IR : 2.9 mm/yr  
Tide gauge : 5.3 mm/yr



## Tejn

Data is available from November 2015 to January 2022.

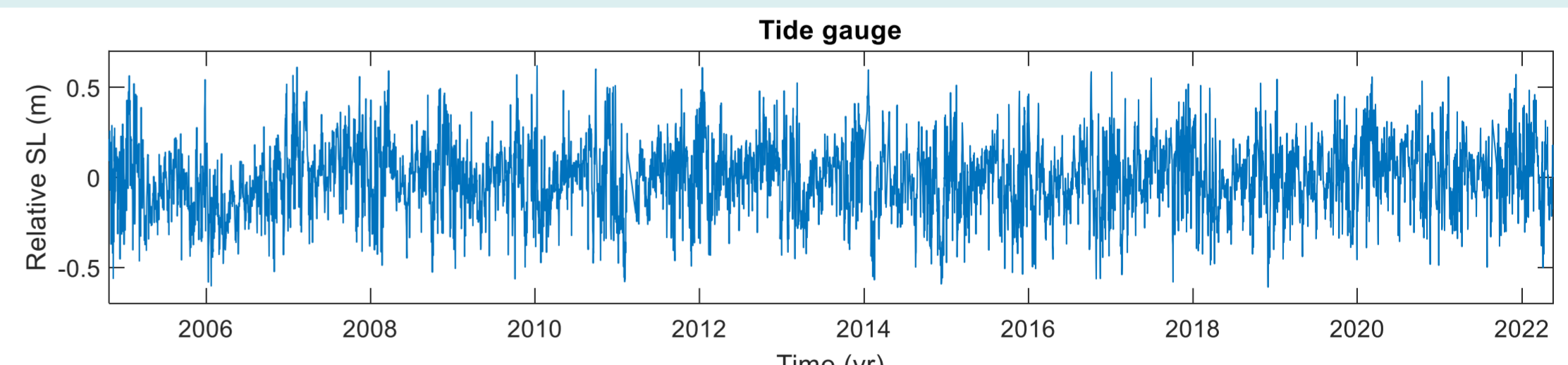
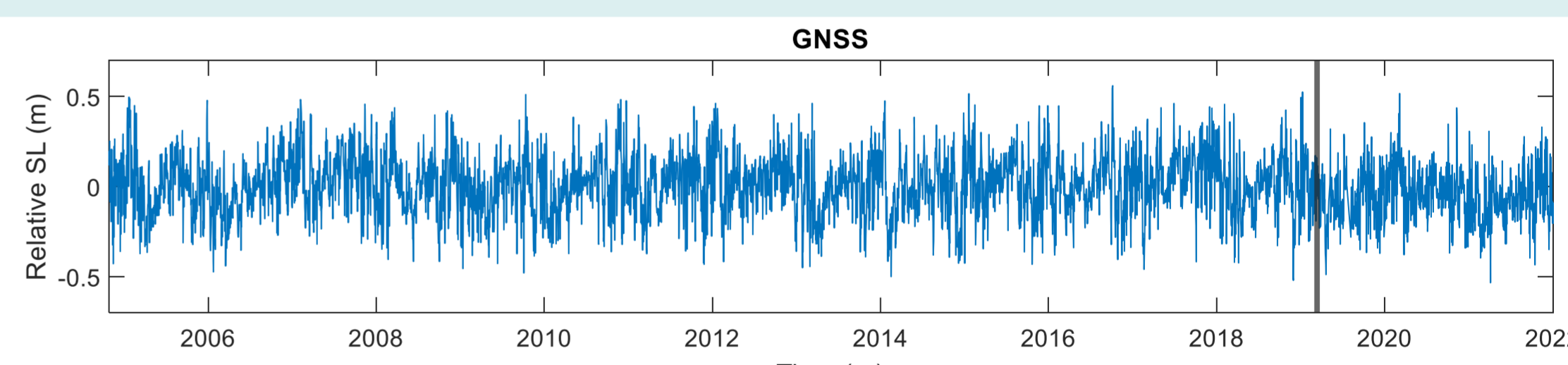
GNSS-IR : 4.4 mm/yr  
Tide gauge : 6.7 mm/yr



## Gedser

Data is available from October 2004 to January 2022. An offset of -7.3 cm has been detected when the antenna was replaced in 2019.

GNSS-IR : 1.2 mm/yr  
Tide gauge : 3.0 mm/yr



## Challenges

### Antenna replacements

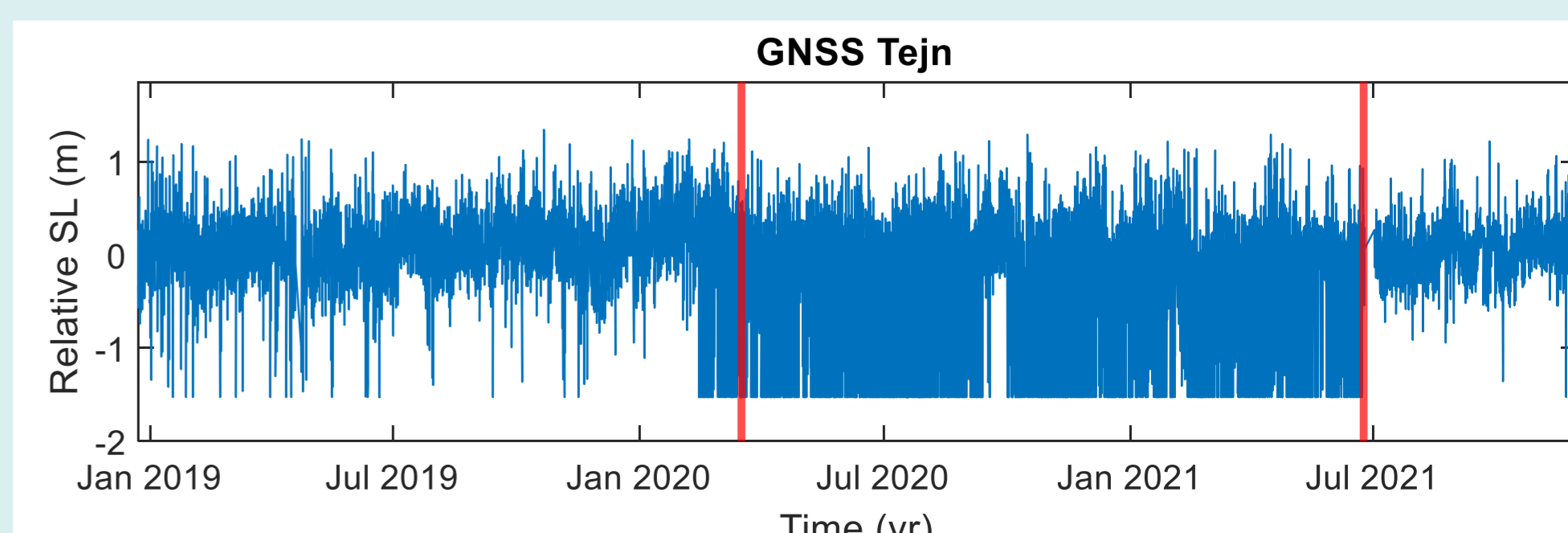
When the antenna of the GNSS station is changed, an offset is often created. This is the case in Esbjerg and Gedser. If these offsets are not taken into account, the sea level change will be wrongly estimated. Therefore, the ordinary least squares method is used to determine the size of the offset.

### Receiver firmware

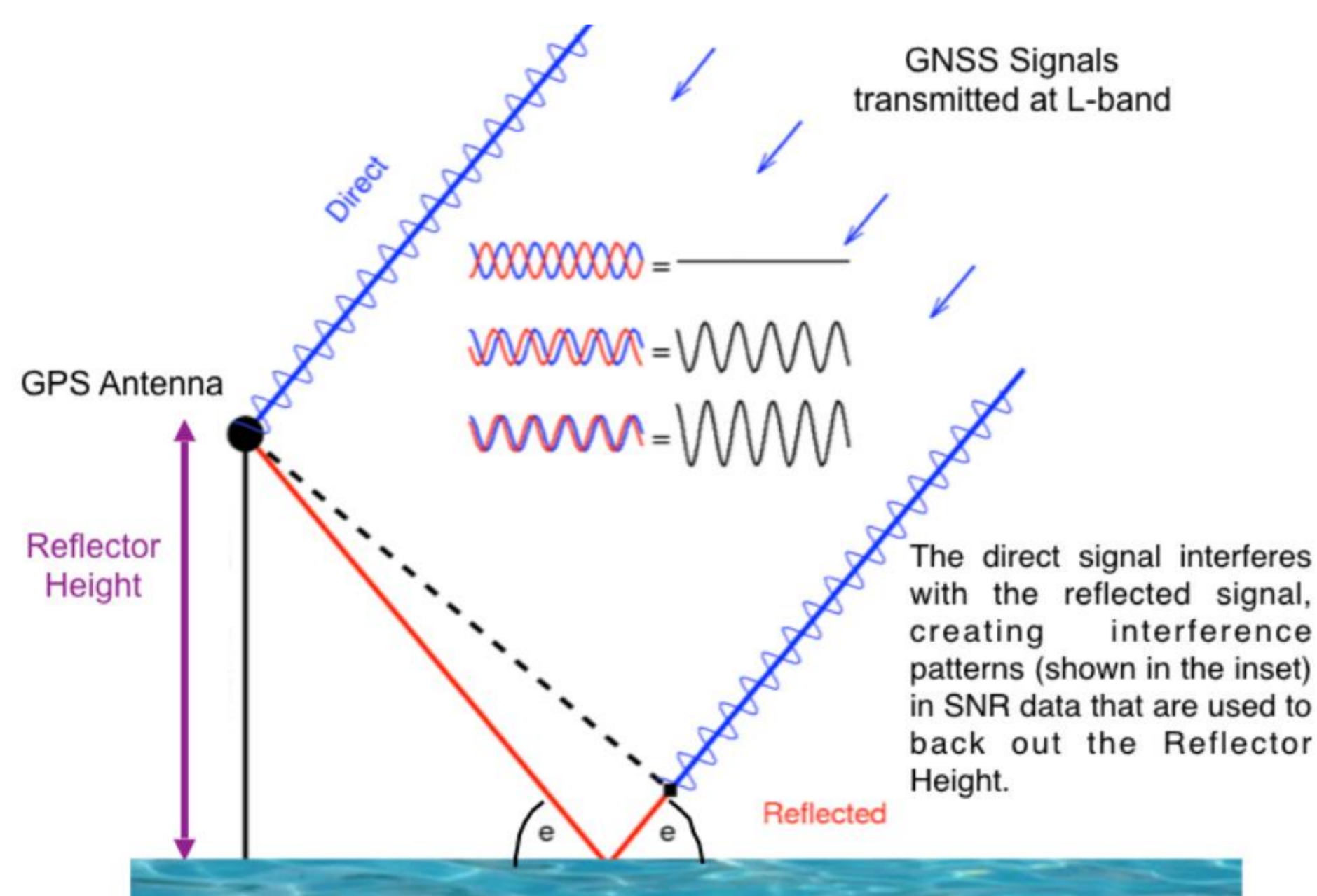
In Tejn, Gedser and Fynshav there are examples of systematic errors created by the firmware version. In the figure below, the errors are created by data from the L2 band. The red vertical lines show the dates where the firmware has been changed. With the firmware update in June 2021 the systematic errors stop.

3.8 Receiver Type	: LEICA GR50
Satellite System	: GPS+GLONASS+GAL+BDS+QZSS
Serial Number	: 1870369
Firmware Version	: 4.31.101
Elevation Cutoff Setting	: 0
Date Installed	: 2020-03-17T16:09Z
Date Removed	: 2021-06-24T12:00Z
Temperature Stabiliz.	:
Additional Information	:

Tejn GNSS log book.



Raw GNSS-IR data from Tejn. The red lines indicate updates in the receiver.



Principle of GNSS-IR.



Fresnel zones at Esbjerg Harbour. GNSS station marked with a red arrow and tide gauge marked with a blue arrow.