Regional Mean Sea Surface Model (SY20MSS) from Multi-Mission Radar Altimeter Data over the Eastern Mediterranean Sea

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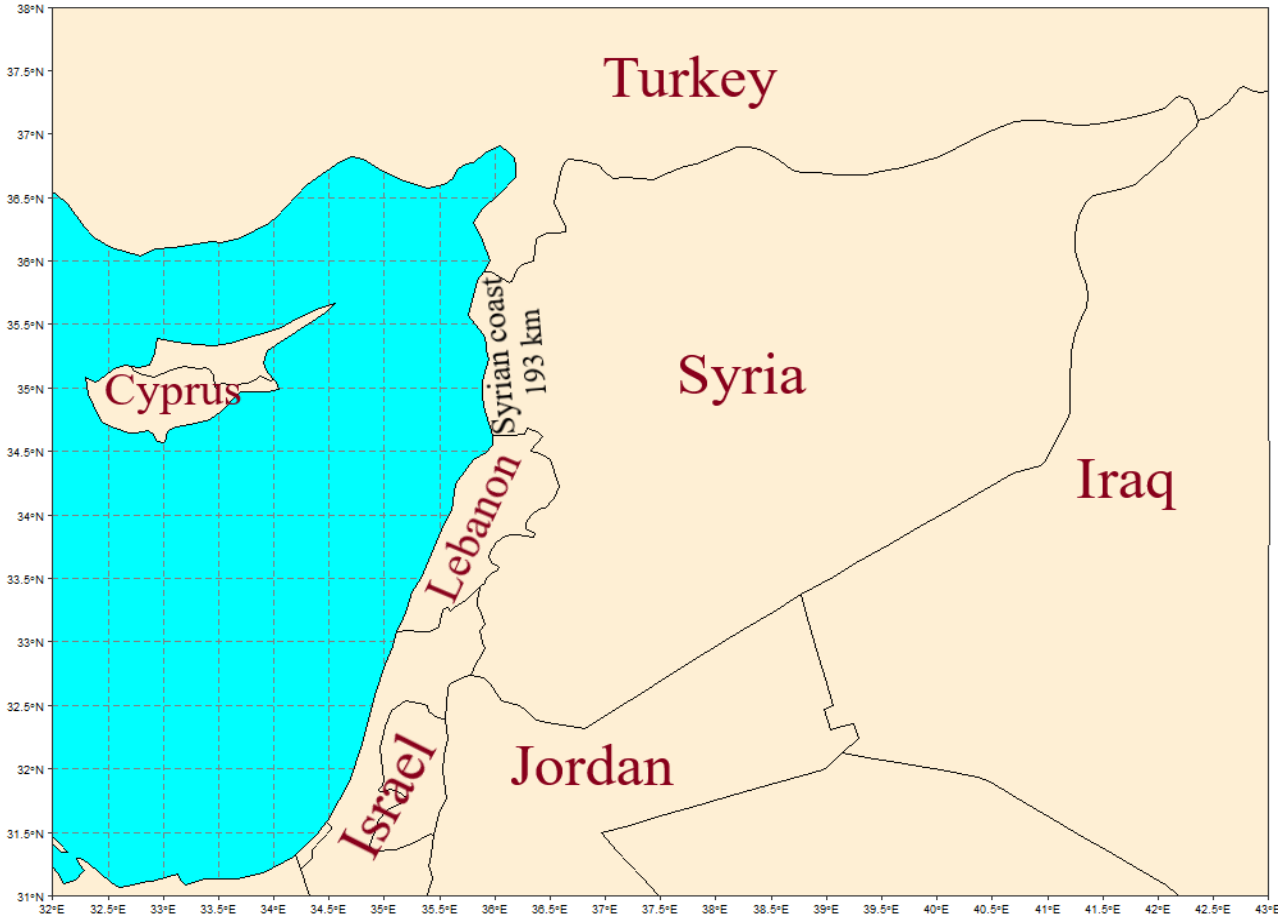
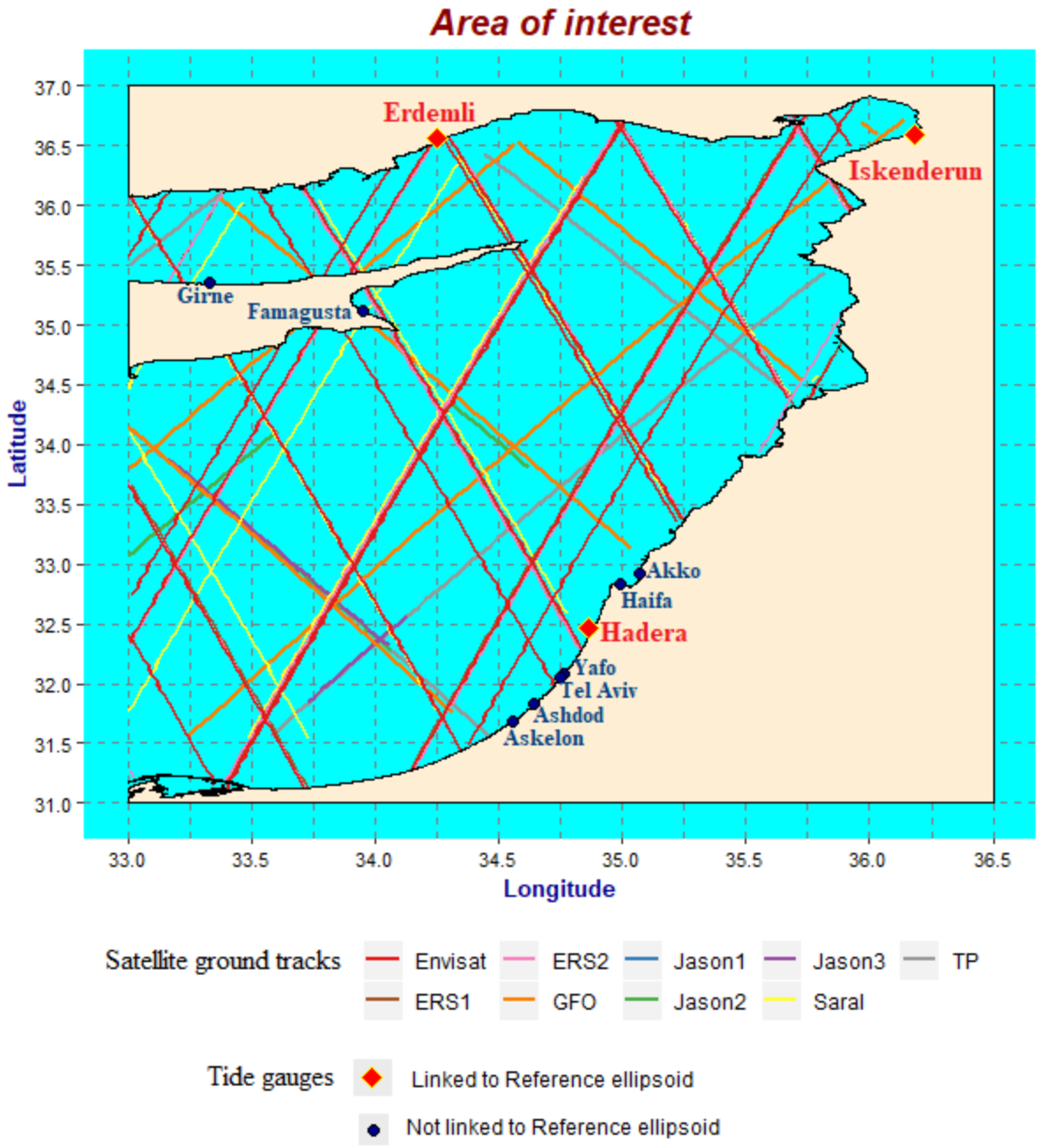
Motivation

- The satellite altimeter technique is chosen for studying the SL changes at the Syrian coast as there are no tide gauge measurements in this region.
- The existing leveling network in Syria originated from MSL measured in Lebanon and then transferred to Syrian land by using spirit leveling.
- With no information on the tidal gauges in Syria, satellite altimetry observations will be the alternative solution.



Data

- **Ground tracks:** Nine missions (T/P, Jason_1, 2 ,3, GFO, Envisat, SARAL, and ERS_1, 2). (Source: OpenADB)
- **Tide Gauges:** 11 stations (Akko, Tel Aviv, Haifa, Hadera,Askelon, Ashdod, Yafo and in Isreal), (Iskenderun, and Erdemli in Turkey), and (Famagusta, and Girne in Cyprus) (Source: PSMSL)



Tide gauge location and timespan

Station name	Latitude (°)	Longitude (°)	Elevation (m)	Time span of data	Country
AKKO [1]	32.919	35.070	7.019	Feb-2012 to Dec-2018	**Israel**
HAIFA II [1]	32.829	34.991	7.031	Jun-2013 to Dec-2018	**Israel**
HADERA [2]	32.470	34.863	19.285	Jul-1992 to Jun-2019	**Israel**
TEL AVIV [1]	32.083	34.767	7.110	Feb-1996 to Oct-2010	**Israel**
TEL AVIV-YAFO [1]	32.053	34.750	7.046	Feb-2011 to Dec-2018	**Israel**
ASHDOD II [1]	31.831	34.641	7.059	Feb-2012 to Dec-2018	**Israel**
ASHKELON [1]	31.682	34.557	7.020	Feb-2012 to Dec-2018	**Israel**
FAMAGUSTA [1]	35.117	33.950	2.755	Nov-1938 to Dec-1940	**Cyprus**
GIRNE [1]	35.350	33.333	7.148	Dec-2000 to Nov-2003	**Cyprus**
ISKENDERUN II [2]	36.594	36.181	26.879	Feb-2005 to Dec-2009	**Turkey**
ERDEMLI [2]	36.567	34.250	26.468	Jul-2003 to Dec-2009	**Turkey**

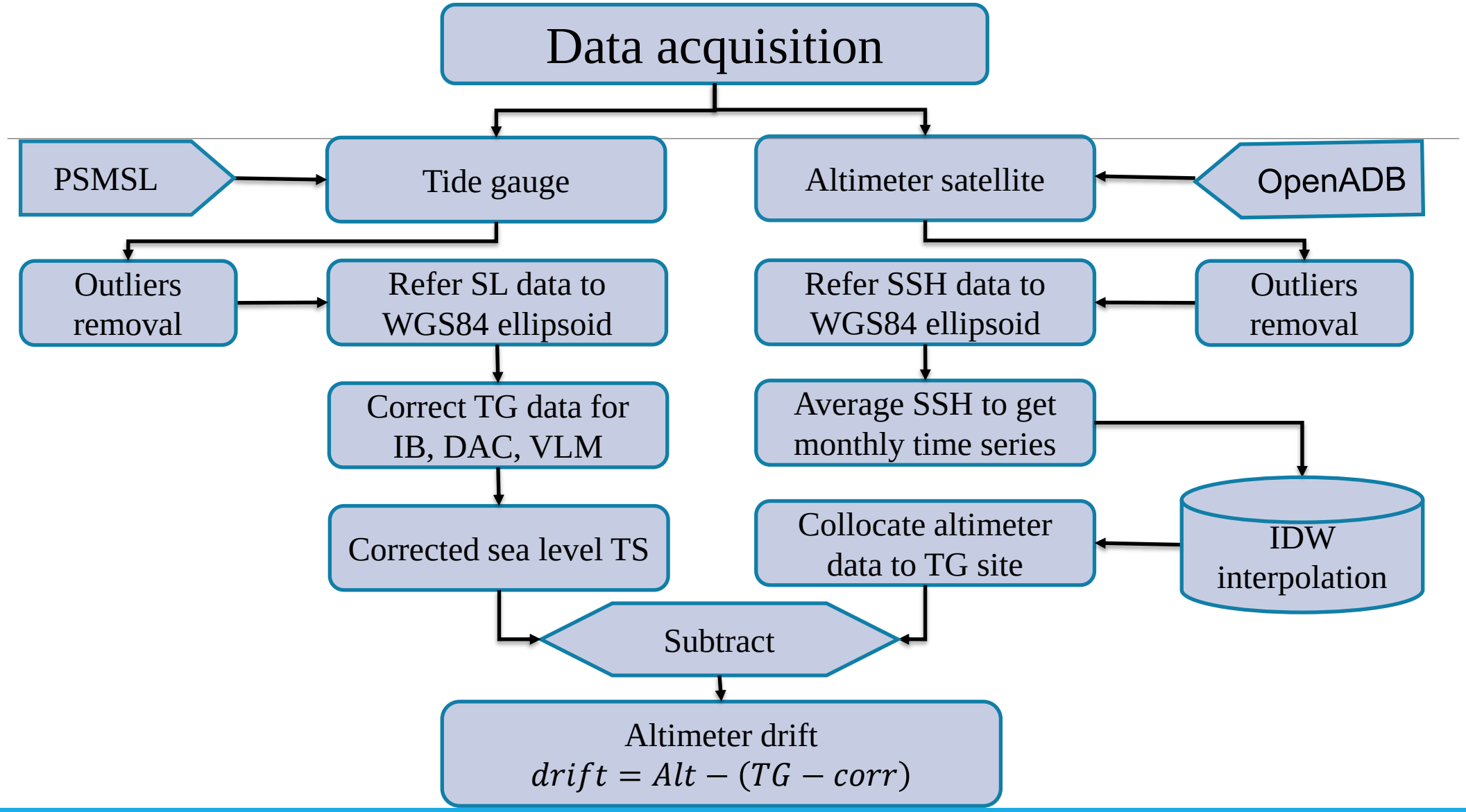
[1] The station is referred to Local Tide Gauge Datum
[2] The station is linked to Reference Ellipsoid GRS80

Data

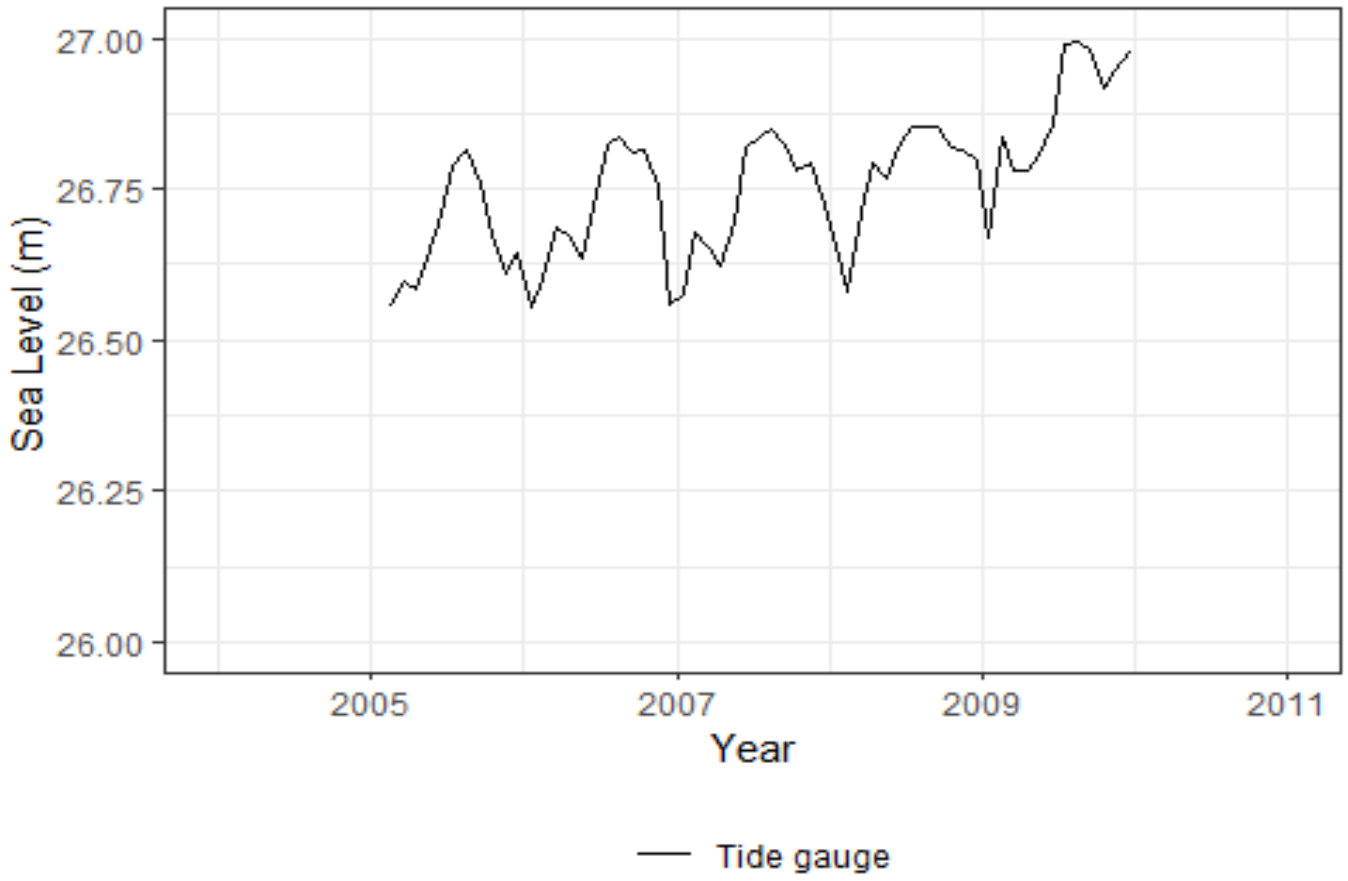
Altimeter Satellite	No. of passes	No. of cycles	No. of year	Time span	Precision of mean profile (cm)
TP	4	471	14	1992 - 2005	1.14
Jason1	2	359	11	2002- 2012	0.56
Jason2	3	316	10	2008 - 2016	0.45
Jason3	2	33	2	2016 - 2017	0.51
Envisat	20	103	11	2002 - 2012	0.91
ERS1	11	28	4	1992- 1996	0.62
ERS2	12	86	9	1995 -2003	3.51
SARAL	11	35	4	2013 - 2016	0.66
GFO	6	176	9	2000 - 2008	1.54

Calibration of Altimeter Data

Comparison method between altimetry and tide gauge



Sea level time series at Iskenderun station



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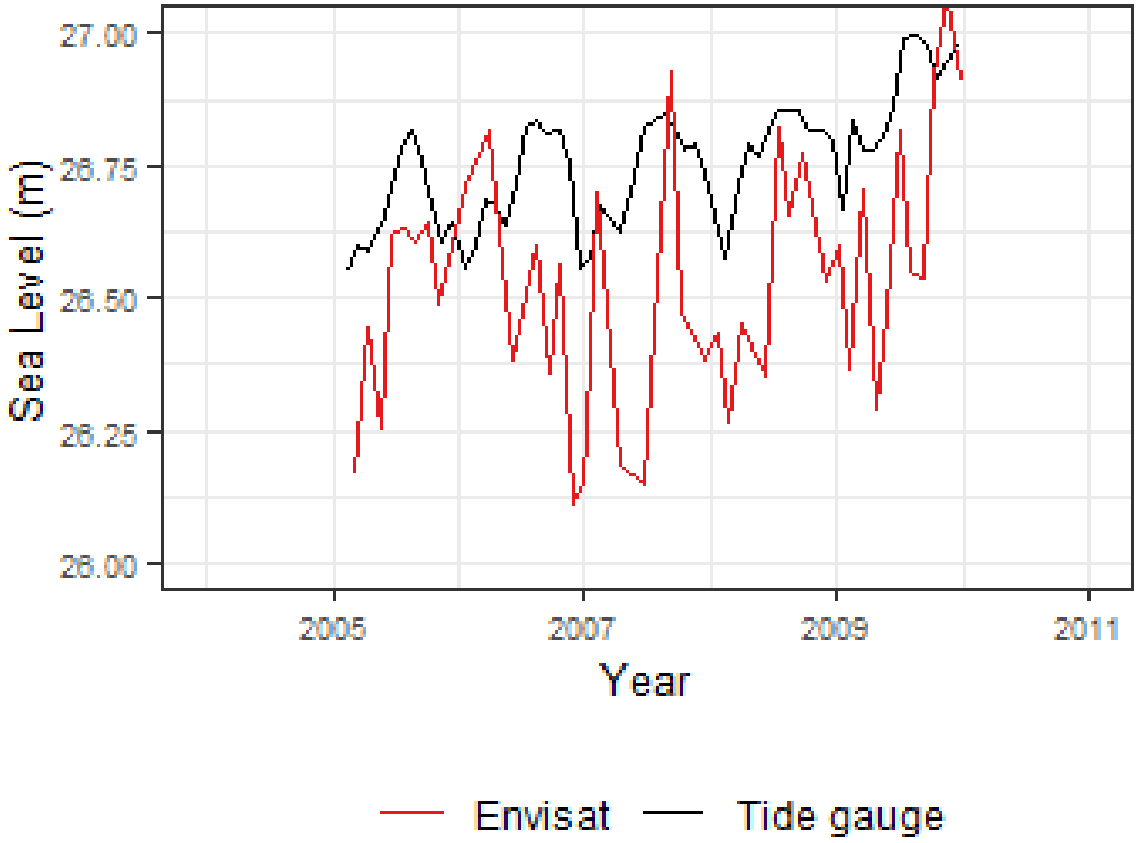

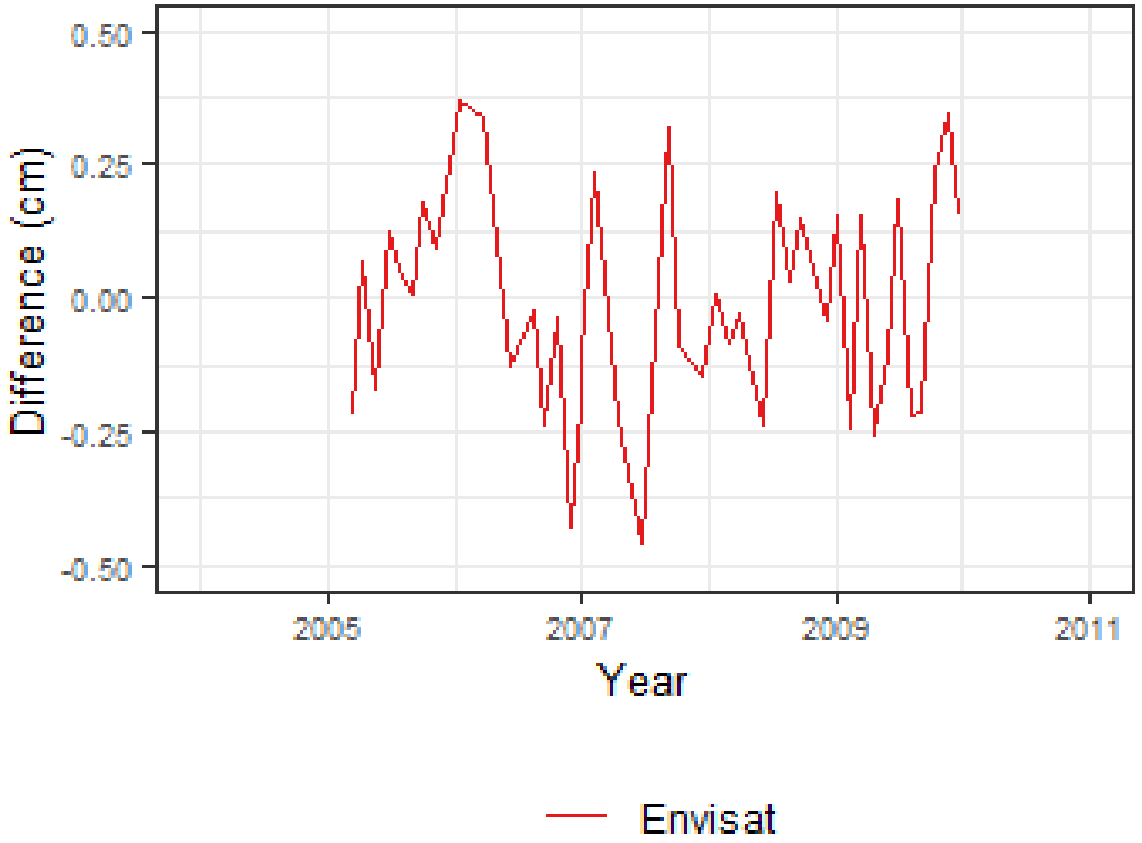

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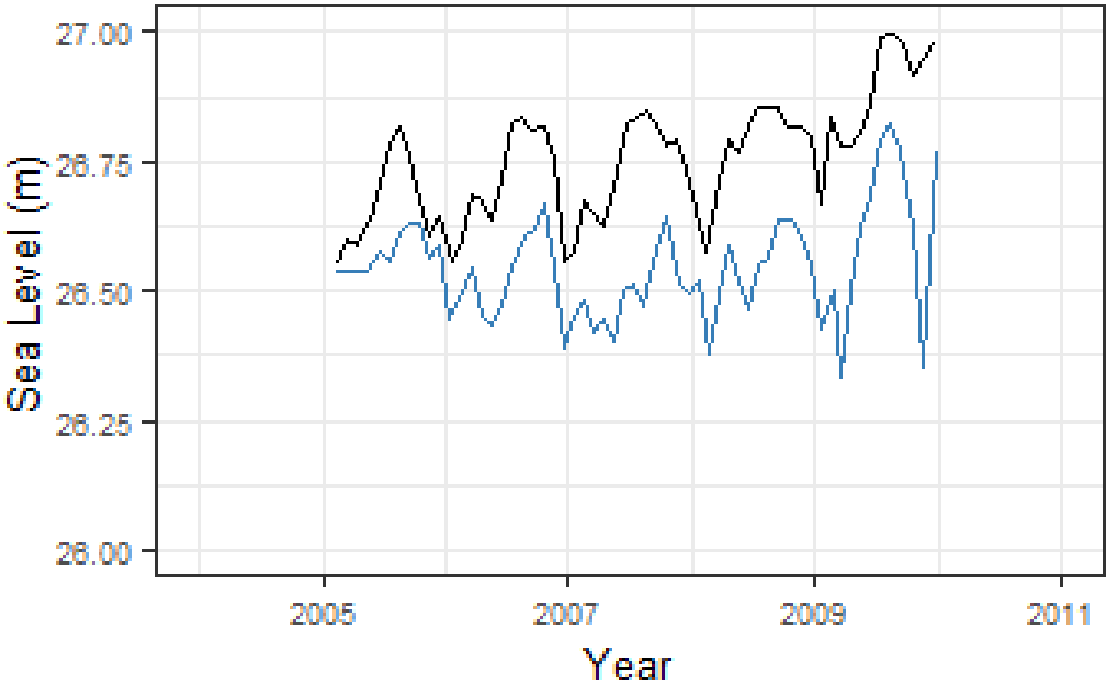

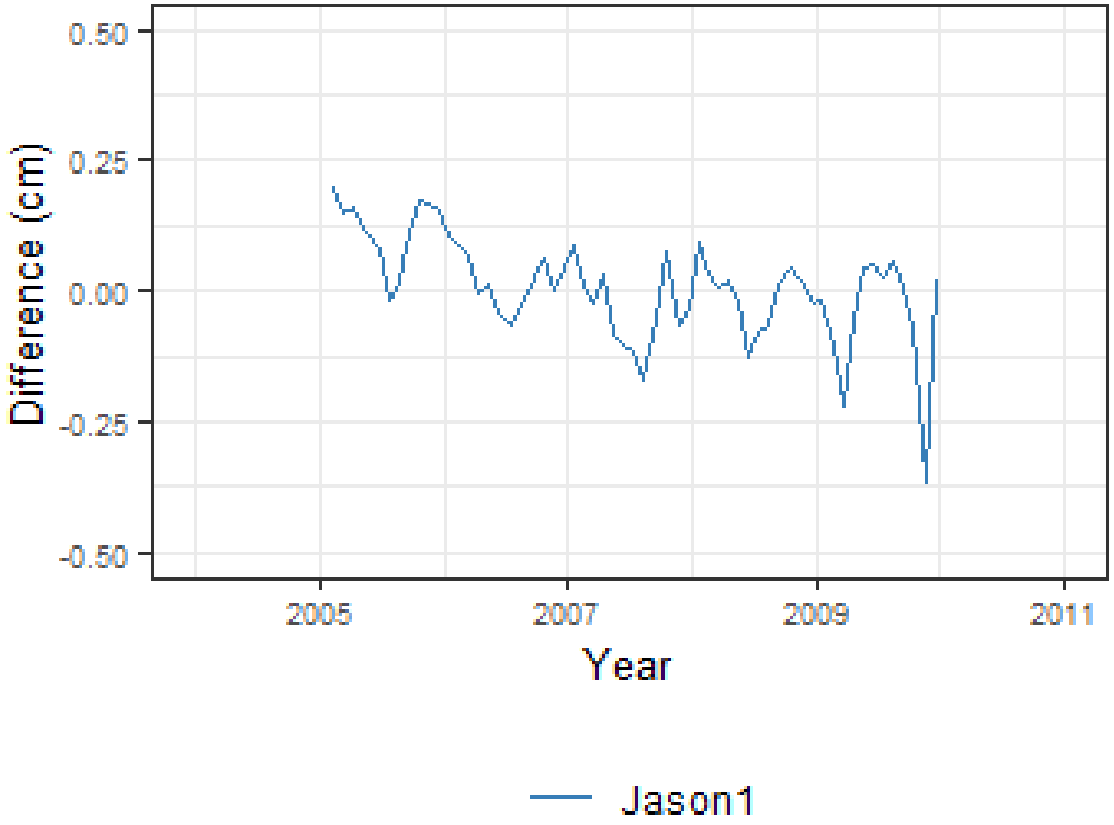

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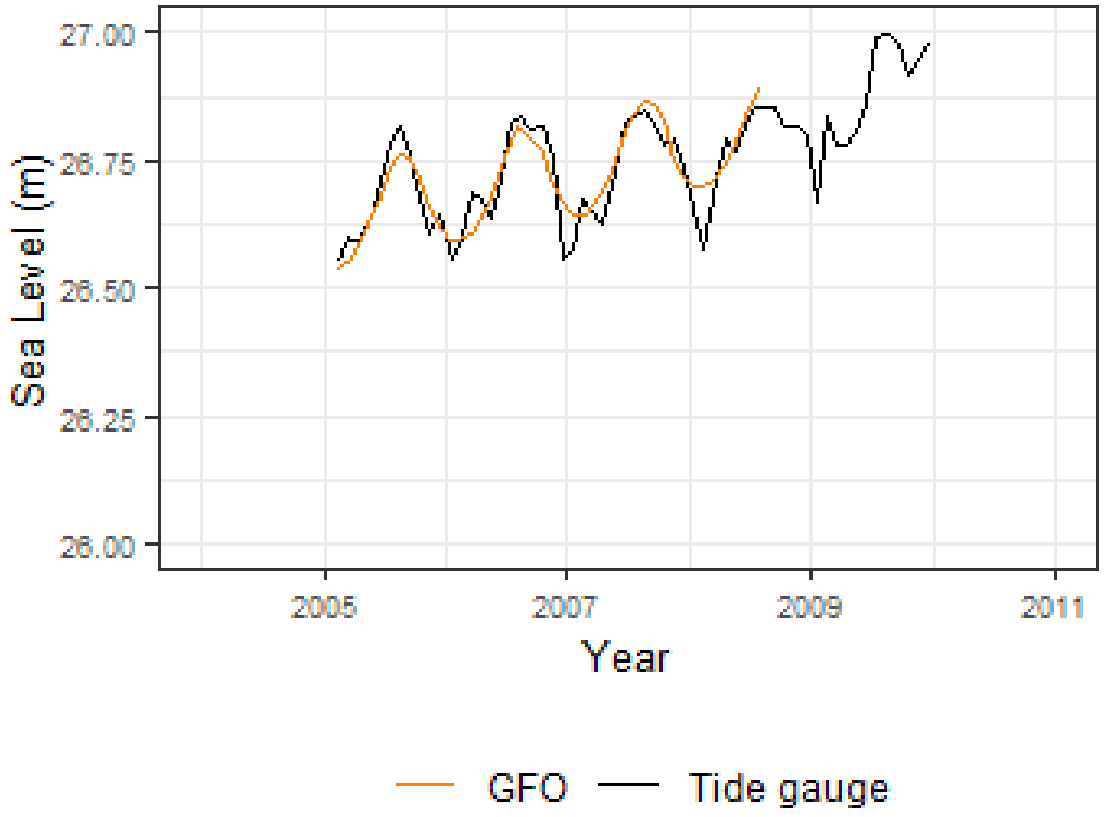
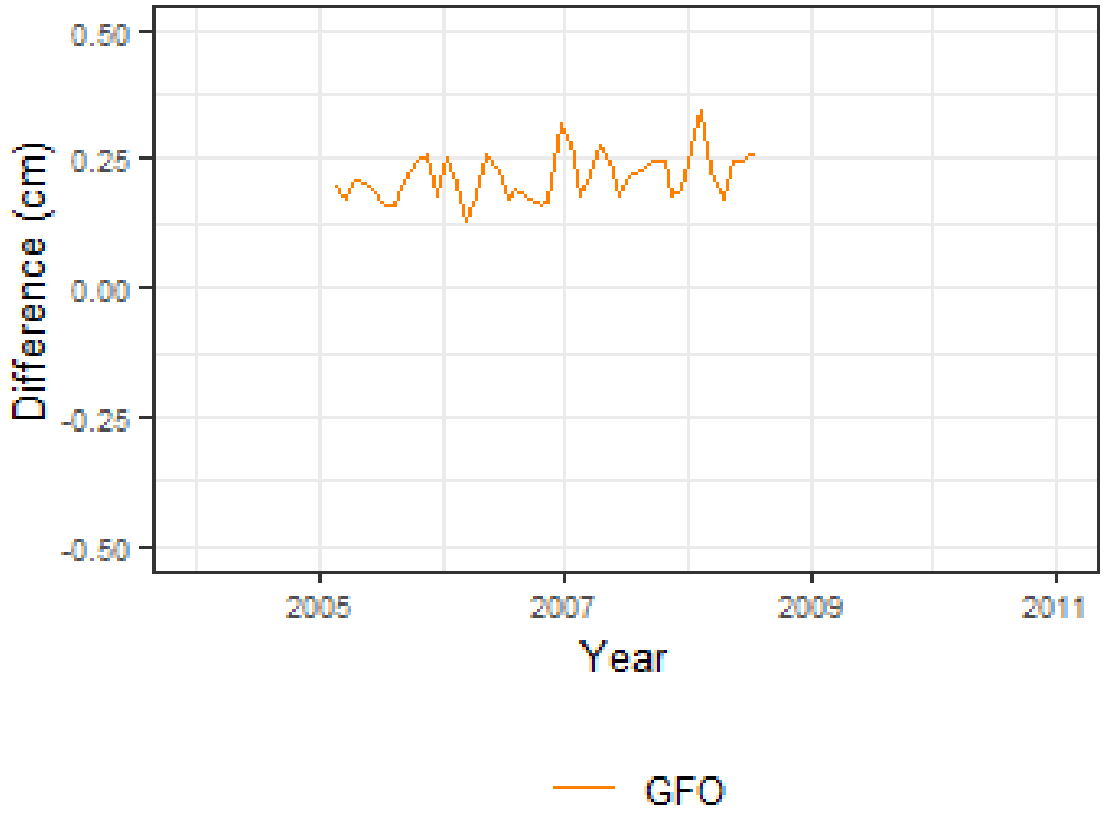
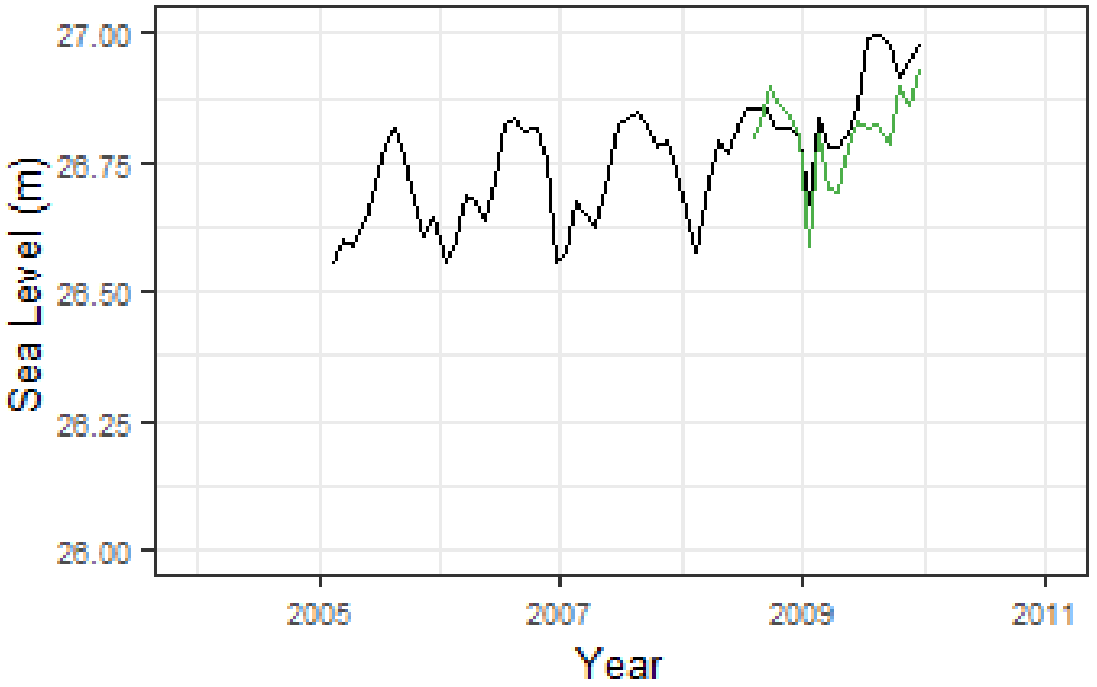
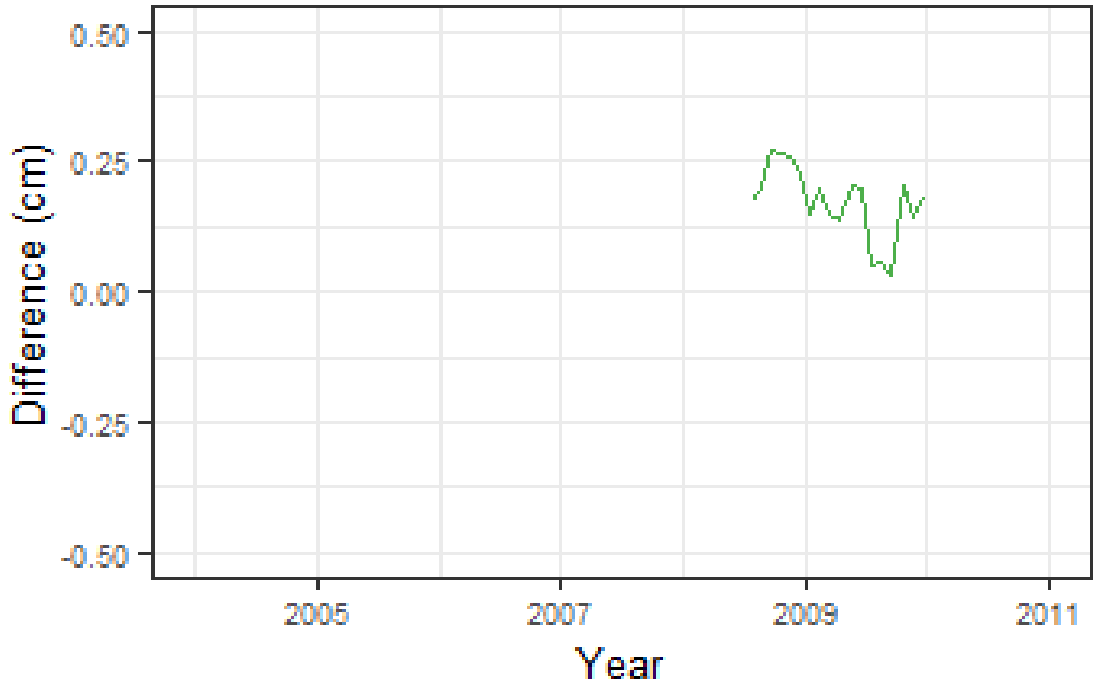




Sea level time series at Iskenderun station

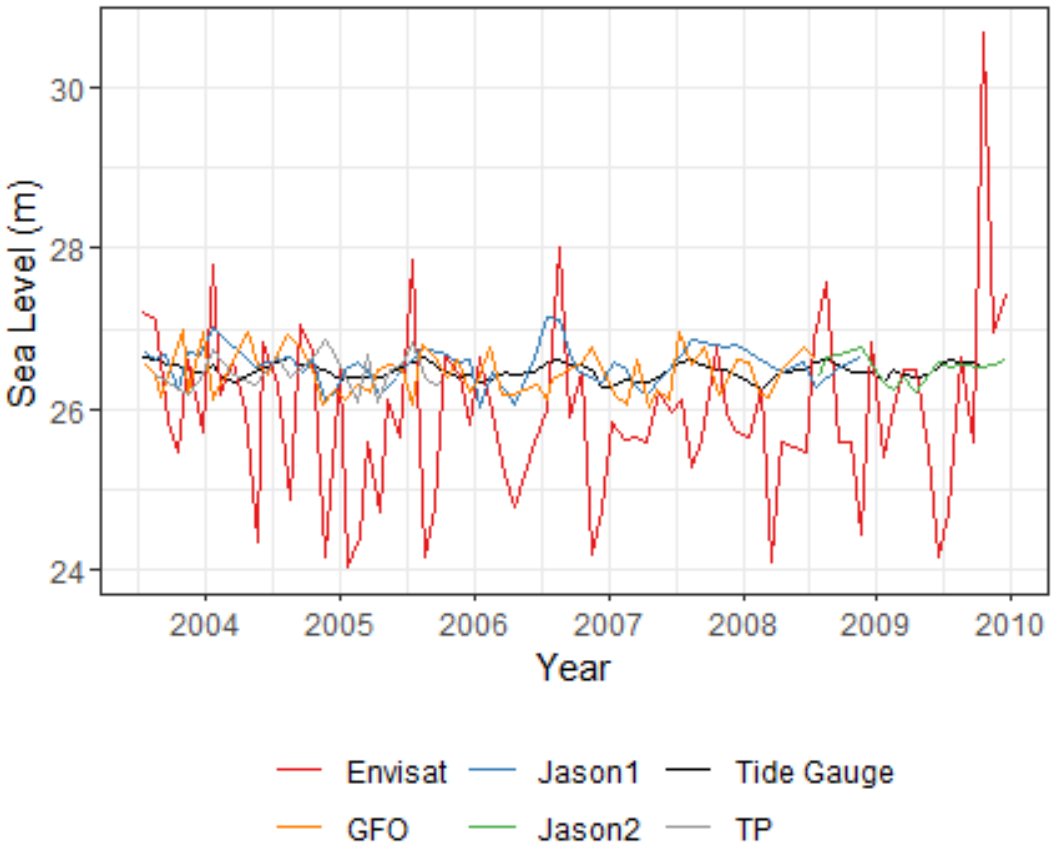




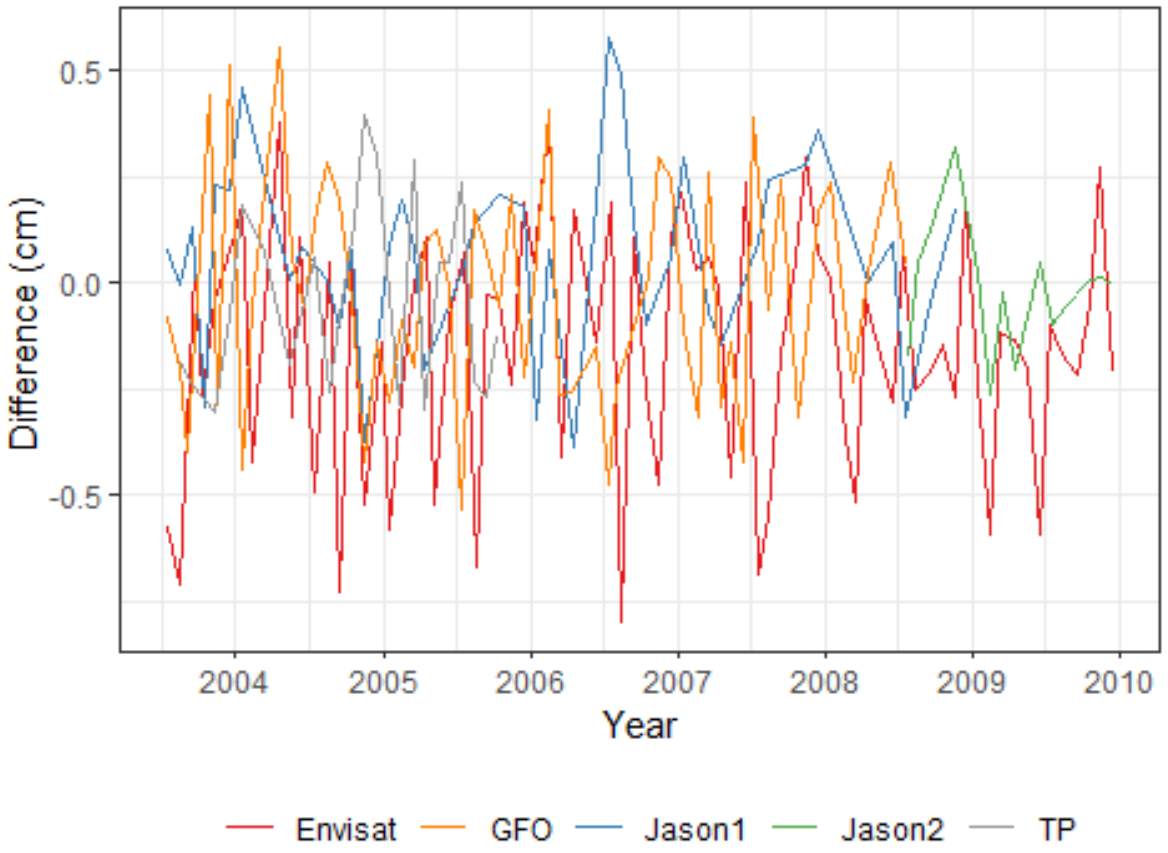
Jason2 Tide gauge

Jason2

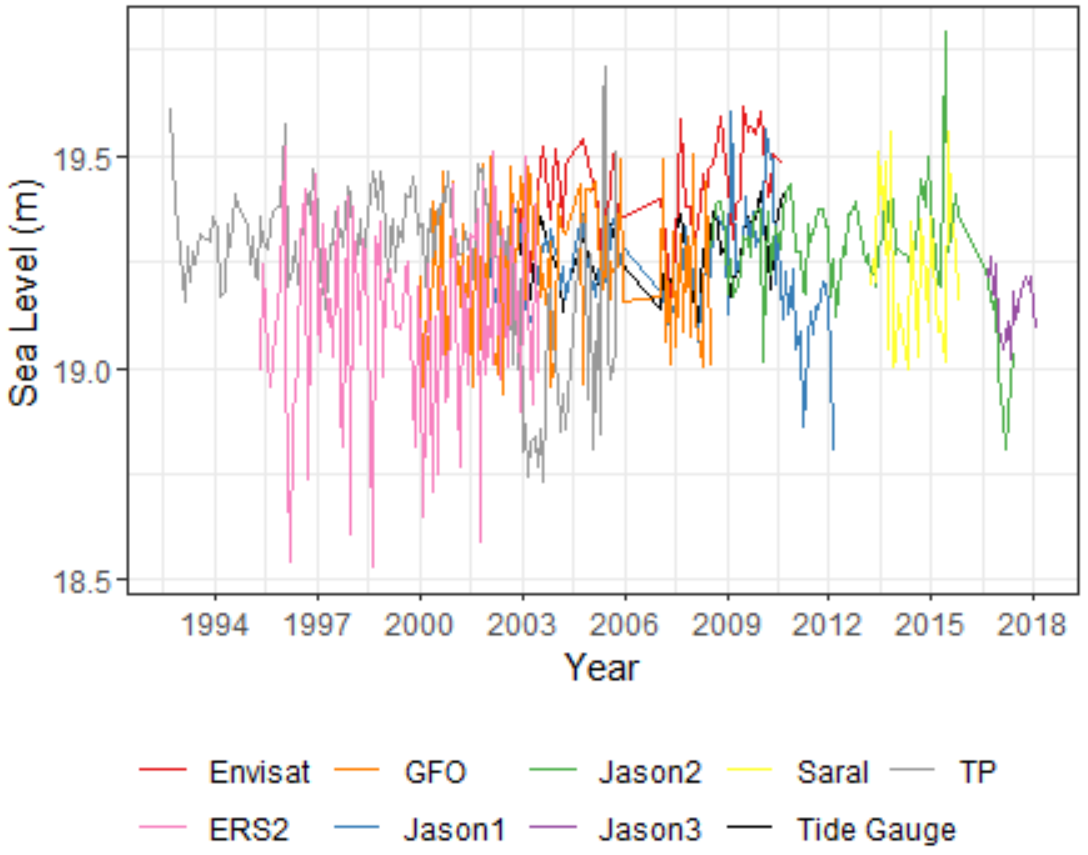
Sea level at Erdemli station



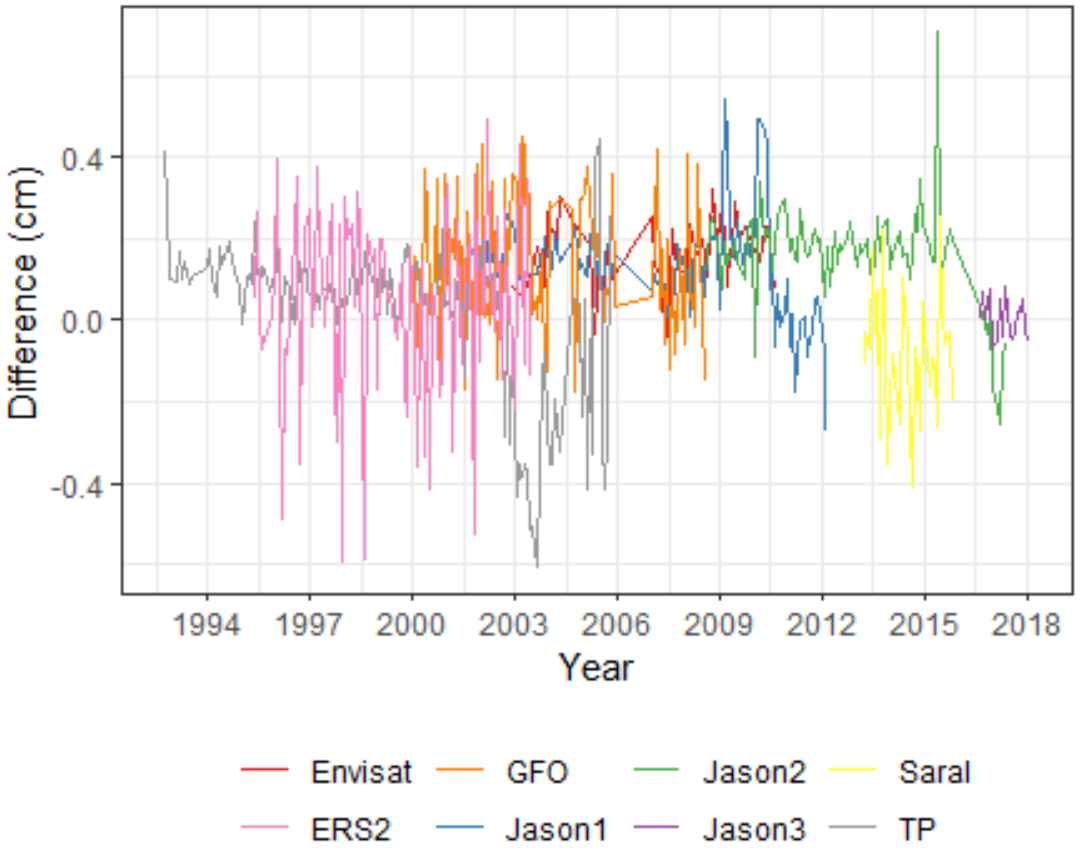
Difference between tide gauge and altimeter time series



Sea level at Hadera station



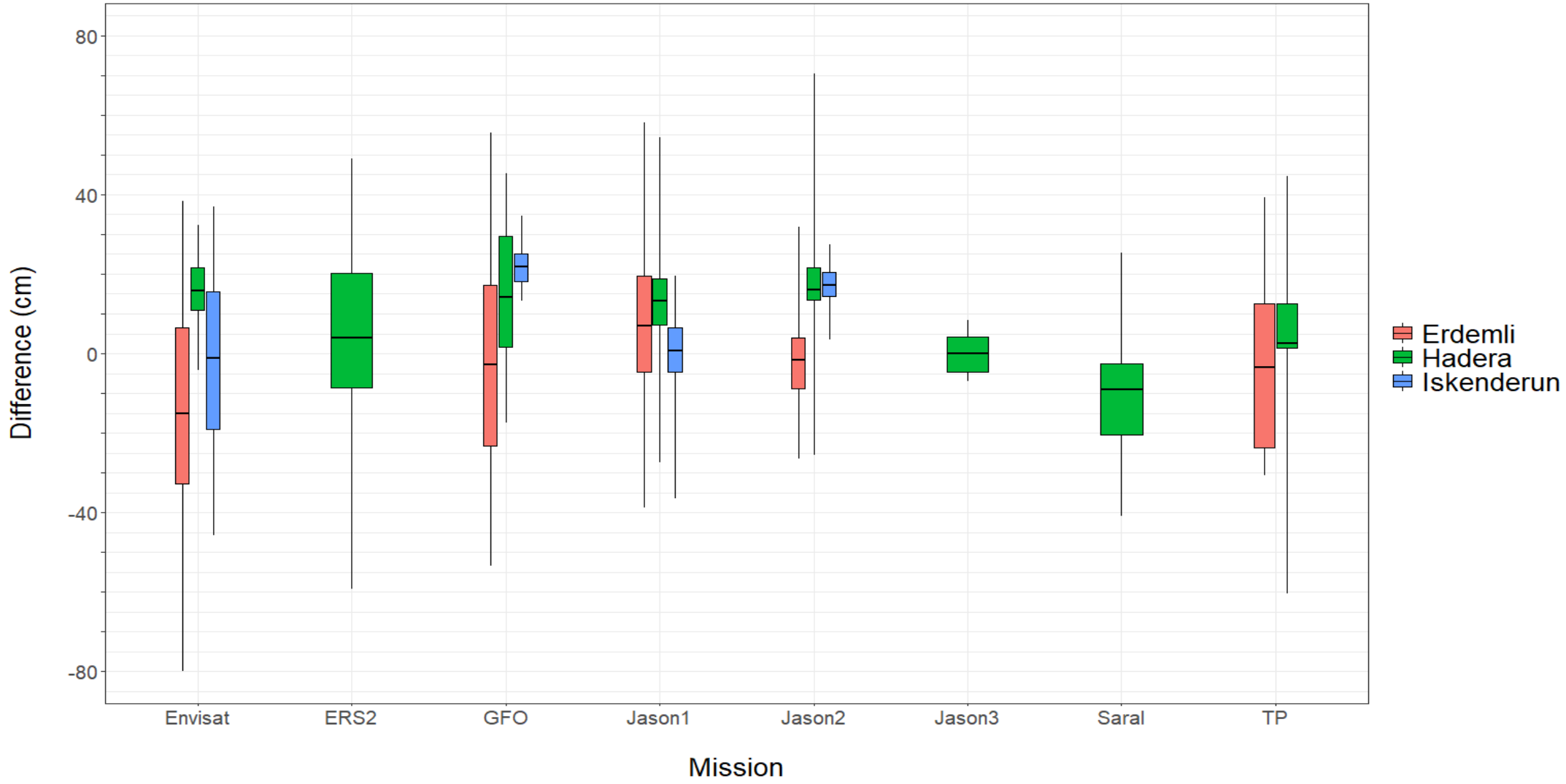
Difference between tide gauge and altimeter time series



Iskenderun station

Sea Level of Iskenderun station					
Statistics	**Tide gauge**	**TG - Envisat**	**TG- GFO**	**TG – Jason1**	**TG – Jason2**
	m	cm	cm	cm	cm
Max.	26.99	36.91 cm	34.69	19.51	27.34
Min.	26.55	-45.71cm	13.33	-36.45	3.52
Mean	26.76	-1.16 cm	21.79	0.78	17.19
S.D.	0.1167	20.84 cm	4.65	9.83	7.03
RMS	-	20.62 cm	22.27	9.78	18.5
Distance to TG	-	430 km	250 km	350 km	350 km
Linear sea level change*	4.33 mm/year	3.98 mm/year	4.33 mm/year	0.86 mm/year	2.30 mm/year

Statistics of the difference between altimeter missions and tide gauge



Mean Sea Surface Computation

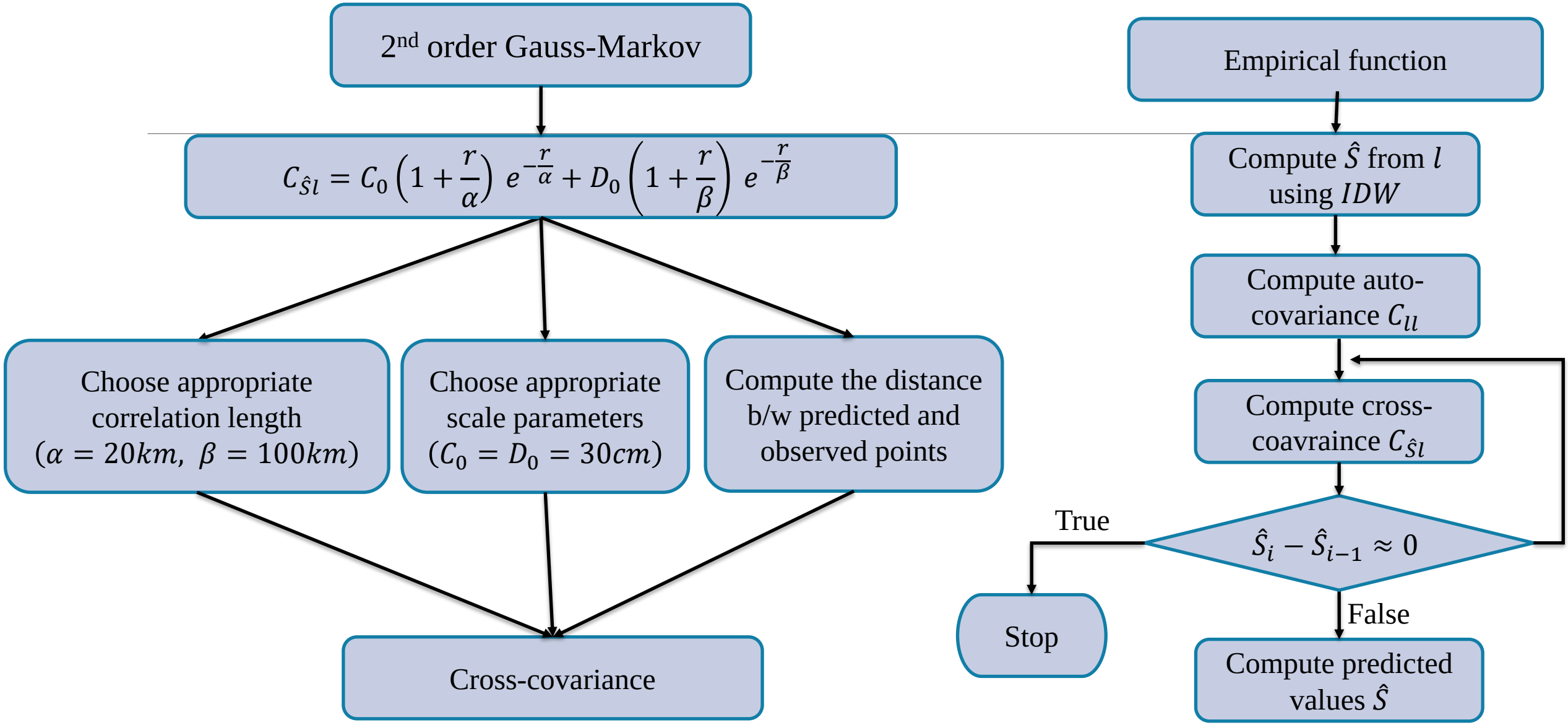
Methodology for altimeter-derived MSS model

- Set a reference epoch (here is Jan-2010).
- Correct the SSH data for the drift (obtained from comparison with TG).
- Combine the missions having same ground track to get long duration time series.
- Compute the mean profile using the following model

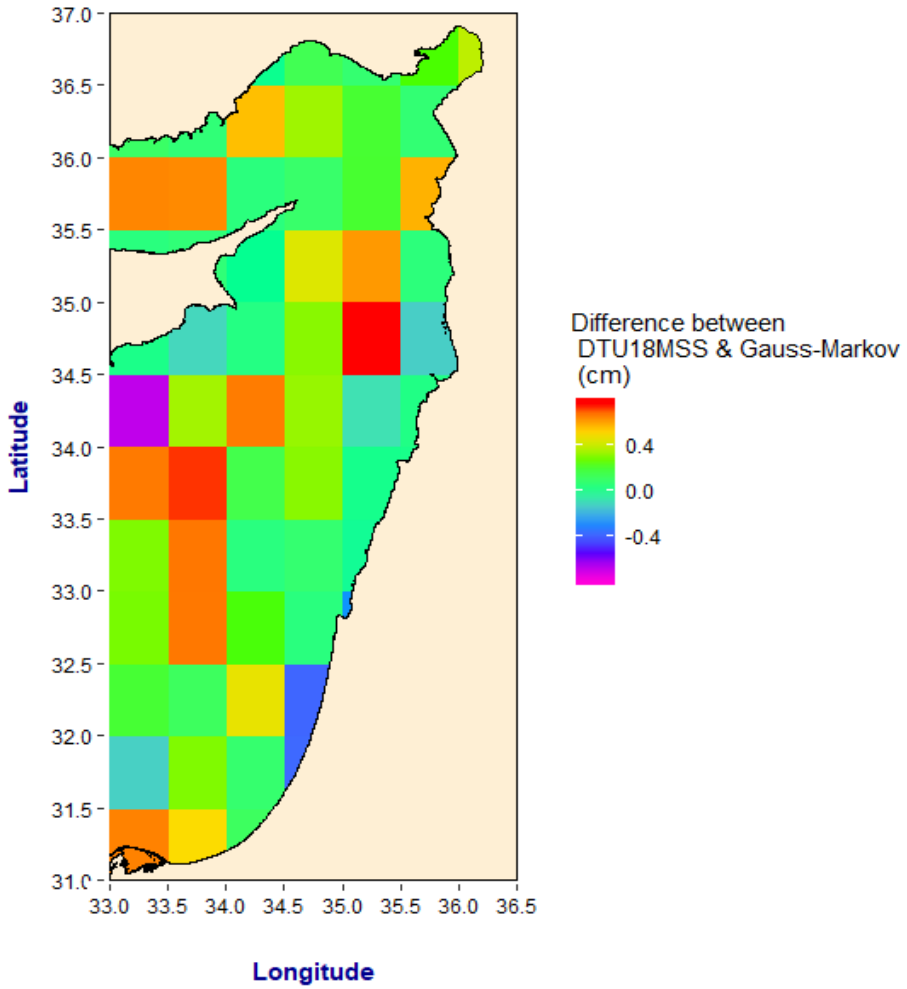
$$h_{obs-i} = h_{0i} + h_{1i} \cdot t_j + h_{2i}cos(\omega_1 \cdot t_j) + h_{3i}sin(\omega_1 \cdot t_j) + h_{4i}cos(\omega_2 \cdot t_j) + h_{5i}sin(\omega_2 \cdot t_j)$$

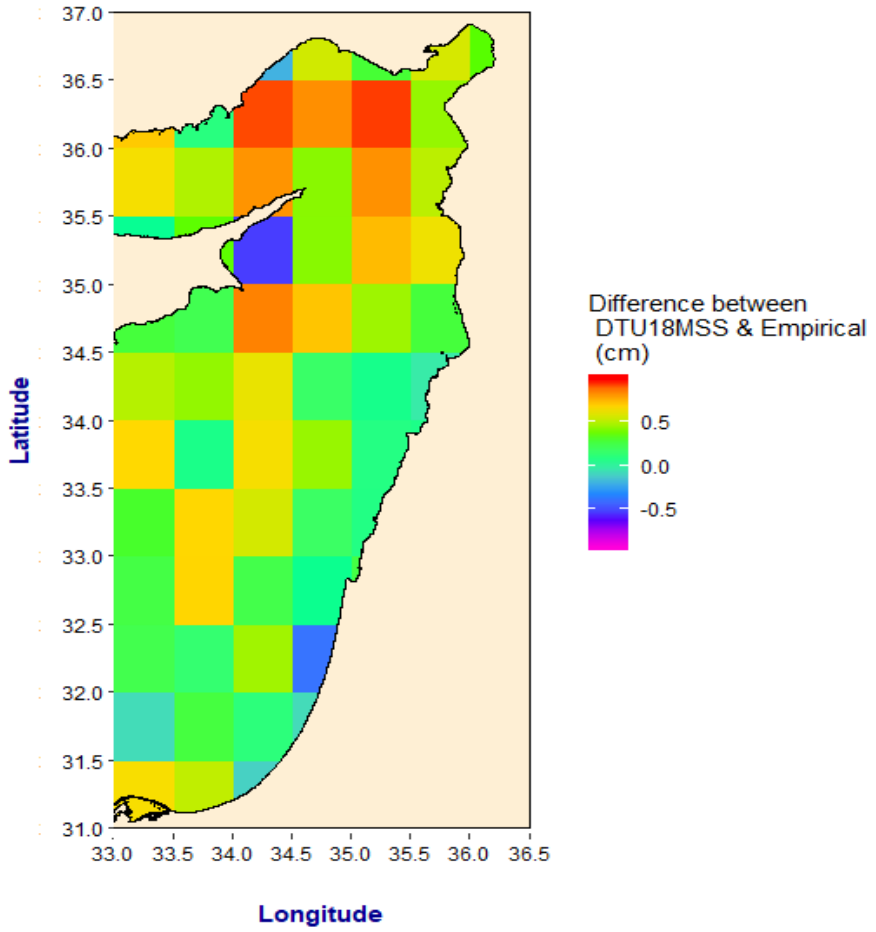
- Solve the model by ordinary least squares method.
- Interpolate the mean profile data into grid of size $0.5° \times 0.5°$ using LSC.

Covariance function in LSC approach



Comparison between two covariance function and DTU18MSS





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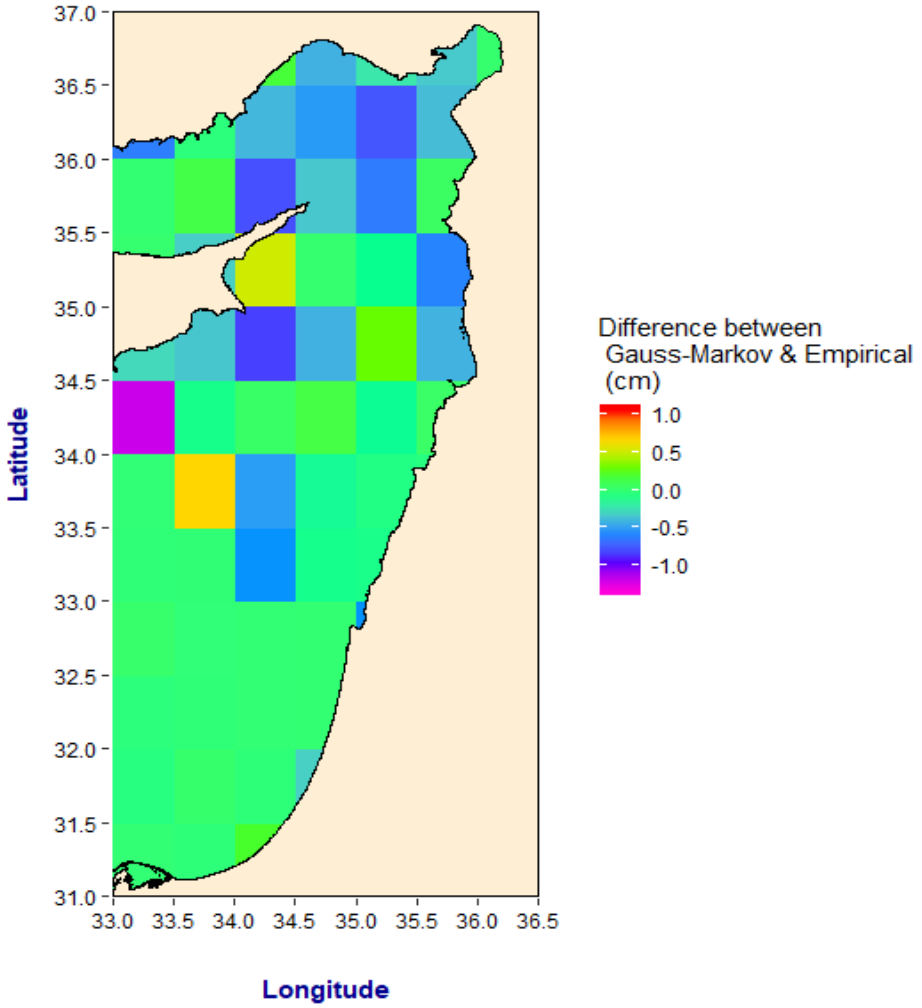

Summary	DTU18MSS minus Gauss-Markov	DTU18MSS minus Empirical	Gauss-Markov Minus Empirical
Min.	-77.99	-92.22	-132.62
Max.	76.89	99.69	106.79
Mean	15.382	39.15	-23.77
S.D.	30.22	34.20	38.72
RMS	33.75	51.85	45.24

Units in cm

Summary

- VLM correction were applied only for Hadera station not for the other two (Iskenderun and Erdemli).
- SD of the difference between Envisat and tide gauge at Iskenderun is greater than the SD of sea level from tide gauge and altimeter.
- The 2nd order Gauss-Markov showed better agreement with DTU18MSS than the empirical function,
- The MSS is taken based on the 2nd order Gauss-Markov function