Satellite Analytics

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1. Summary

From 02/01/2017 to 26/10/2017	299 days	3 variables

Number of satellites

2. Satellites

MODIS Aqua

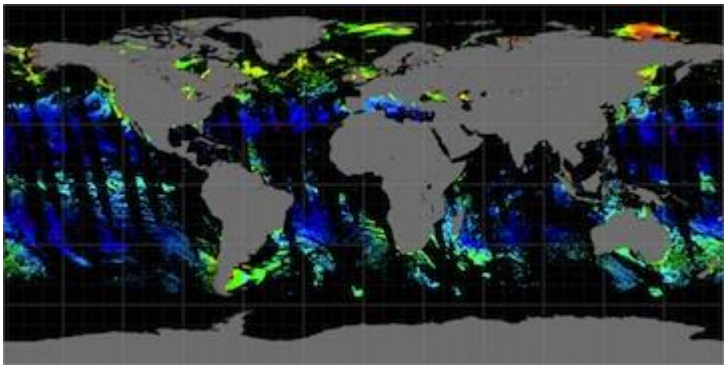
The MODIS Aqua is a satellite property of the NASA. It collects data from the ocean several biological and physical variables.

https://oceancolor.gsfc.nasa.gov/

The acquisition of data from MODIS aqua is performed with the application wget.

We are using the level 3 mapped data of the satellite. This data consists in separated NETCDF data files for each day and variable.

The satellite retrieve data daily. It gets the data while orbiting the globe. This cause that the data could have zones without valid data.



The next table shows the possible variables that the satellite offers.

The yellow variables are the same information with different algorithms. A correlation study must be done to determine which one is the best.

Variable	Description	Units
chl_oc3	Chlorophyll Concentration, OC3 algorithm	mg/m^3
chlor_a	Chlorophyll Concentration, OCI algorithm	mg/m^3
Ipar	Instantaneous Photosynthetically Available Radiation	$einstein/m^2\ s$
Nflh	Normalized fluorescence line height	$W/m^2\ um^1\ sr^1$
adg_443_gsm	Absorption due to gelbstoff and detrital material (443nm), GSM algorithm	1/m
bbp_443_gsm	Particulate backscattering (443nm), GSM algorithm	1/m
chl_gsm	Chlorophyll Concentration, GSM model	mg/m^3
a_412_giop	Total absorption (412nm), GIOP model	1/m
a_443_giop	Total absorption (443nm), GIOP model	1/m
a_469_giop	Total absorption (469nm), GIOP model	1/m
a_488_giop	Total absorption (488nm), GIOP model	1/m
a_531_giop	Total absorption (531nm), GIOP model	1/m
a_547_giop	Total absorption (547nm), GIOP model	1/m
a_555_giop	Total absorption (555nm), GIOP model	1/m
a_645_giop	Total absorption (645nm), GIOP model	1/m
a_667_giop	Total absorption (667nm), GIOP model	1/m
a_678_giop	Total absorption (678nm), GIOP model	1/m
adg_443_giop	Absorption due to gelbstoff and detrital material (443nm), GIOP model	1/m
adg_s_giop	Detrital and gelbstoff absorption spectral parameter for GIOP model	$1/m^1\ nm^1$
adg_unc_443_giop	Uncertainty in absorption due to gelbstoff and detrital material (443nm), GIOP model	1/m
aph_443_giop	Absorption due to phytoplankton (443nm), GIOP model	1/m
aph_unc_443_giop	Uncertainty in absorption due to phytoplankton (443nm), GIOP model	1/m
bb_412_giop	Total backscattering (412nm), GIOP model	1/m

bb_443_giop	Total backscattering (443nm), GIOP model	1/m
bb_469_giop	Total backscattering (469nm), GIOP model	1/m
bb_488_giop	Total backscattering (488nm), GIOP model	1/m
bb_531_giop	Total backscattering (531nm), GIOP model	1/m
bb_547_giop	Total backscattering (547nm), GIOP model	1/m
bb_555_giop	Total backscattering (555nm), GIOP model	1/m
bb_645_giop	Total backscattering (645nm), GIOP model	1/m
bb_667_giop	Total backscattering (667nm), GIOP model	1/m
bb_678_giop	Total backscattering (678nm), GIOP model	1/m
bbp_443_giop	Particulate backscattering (443nm), GIOP model	1/m
bbp_s_giop	Backscattering spectral parameter for GIOP model	$1/m^1$ nm^1
bbp_unc_443_giop	Uncertainty in particulate backscatter (443nm), GIOP model	1/m
Kd_490	Diffuse attenuation coefficient (490nm), KD2 algorithm	1/m
Ndvi	Normalized difference vegetation index	---
Sst	Sea surface temperature	ºC
Par	Photosynthetically available radiation	$einstein/m^2$
Pic	Calcite concentration	mol/m^3
Poc	Particle organic carbon	mg/m^3
a_443_qaa	Total absorption (443nm), QAA algorithm	1/m
adg_443_qaa	Absorption due to gelbstoff and detrital material (443nm), QAA algorithm	1/m
aph_443_qaa	Absorption due to phytoplankton (443nm), QAA algorithm	1/m
bbp_443_qaa	Particulate backscattering (443nm), QAA algorithm	1/m
Angstrom	Aerosol angstrom exponent	---
aot_869	Aerosol optical thickness (869nm)	---
Rrs_412	Remote sensing reflectance (412nm)	1/sr
Rrs_443	Remote sensing reflectance (443nm)	1/sr
Rrs_469	Remote sensing reflectance (469nm)	1/sr
Rrs_488	Remote sensing reflectance (488nm)	1/sr
Rrs_531	Remote sensing reflectance (531nm)	1/sr
Rrs_547	Remote sensing reflectance (547nm)	1/sr
Rrs_555	Remote sensing reflectance (555nm)	1/sr
Rrs_645	Remote sensing reflectance (645nm)	1/sr
Rrs_667	Remote sensing reflectance (667nm)	1/sr
Rrs_678	Remote sensing reflectance (678nm)	1/sr
sst4	4um sea surface temperature	ºC
Zeu_lee	Euphotic depth, Lee algorithm	M

Sentinel

The Sentinel-3 satellite belongs to the European programme Copernicus. It provides data of concentration of several components of the water and information of the sea and the currents.

http://marine.copernicus.eu

The acquisition of data from Sentinel aqua is performed using a.dedicated Python API.

The access to the data must be done via a Python script in the server. Also, this satellite requires an account to retrieve the data.

The variables of this satellite are separated in physical and biological variables.

Physical variables

The physical variables come from the status of the sea itself.

Variable	Description	Units
usi	Sea ice eastward velocity	m/s
so	Salinity	practical salinity unit

Sithick	Sea ice thickness	M
Thetao	Temperature	ºC
Siconc	Ice concentration	fraction
Uo	Eastward velocity	m/s
Depth	Depth	m
Vo	Northward velocity	m/s
Mlotst	Density ocean mixed layer thickness	m
Zos	Sea surface height	M
Vsi	Sea ice northward velocity	m/s
bottomT	Sea floor potential temperature	ºC

Biological variables

The biological variables represent the concentration of different elements in the sea.

Weekly variables

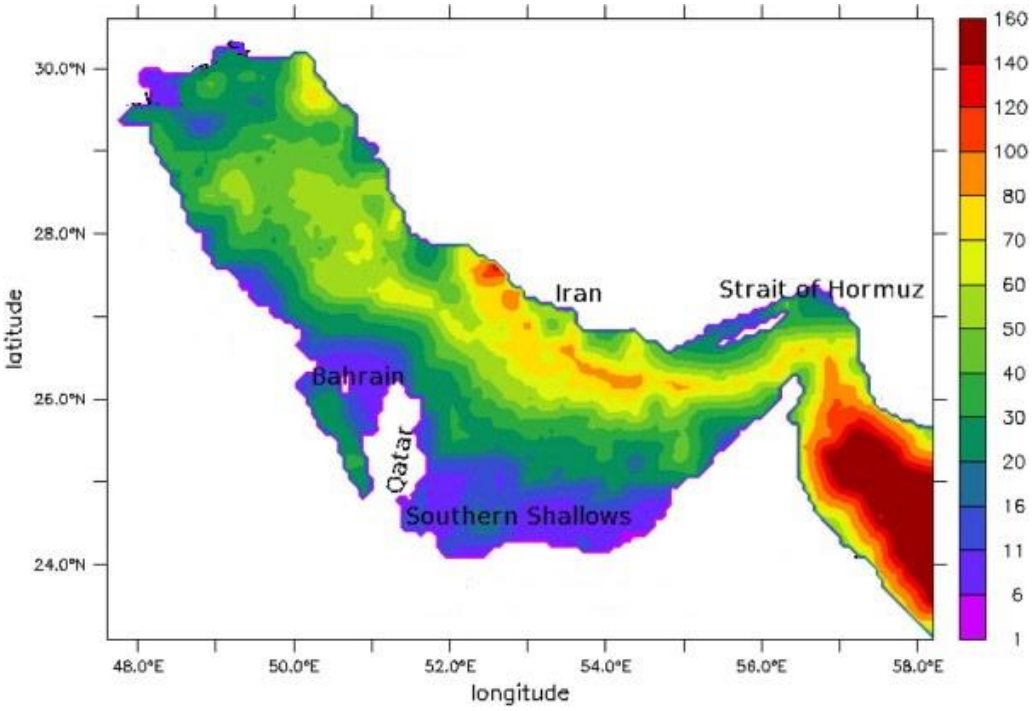
Variable	Description	Units
Fe	Mole concentration of dissolved iron	$mmol/m^3$
PP	Net primary productivity of carbon	$g/m^3/day$
Si	Mole concentration of silicate	umol/L
NO3	Mole concentration of nitrate	$mmol/m^3$
CHL	Mass concentration of chlorophyll	mg/m^3
PHYC	Mole concentration of phytoplankton expressed as carbon	$mmol/m^3$
PO4	Mole concentration of phosphate	$mmol/m^3$
O2	Mole concentration of dissolved oxygen	$mmol/m^3$

Daily variables

Variable	Description	Units
CHL	Mass concentration of chlorophyll	mg/m^3
SPM*	Inorganic suspended particle matter	g/m^3

(*) Data from 1997-09-04 to 2016-08-31 and from 2017-07-06 to present.

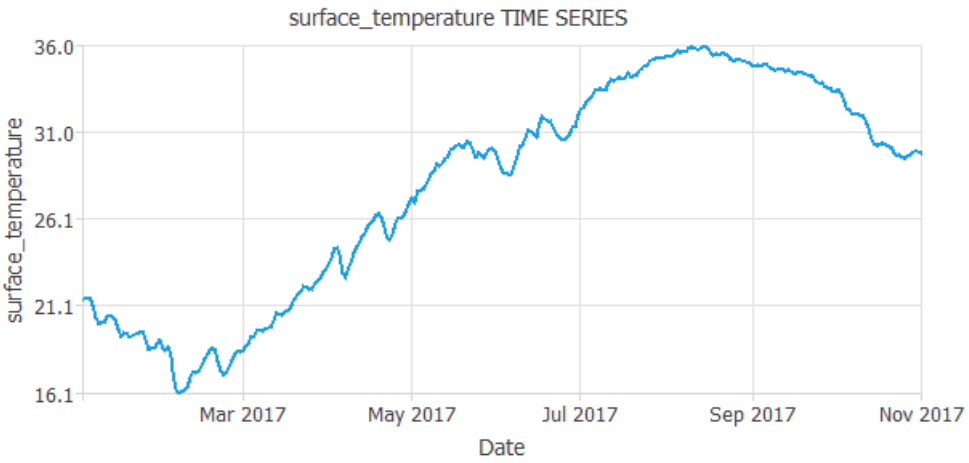
3. General circulation



Region	Characteristics
Strait of Hormuz	High current
Southern Shallows	High salinity
Iran Coast	High depth
Bahrain Gulf	River plume

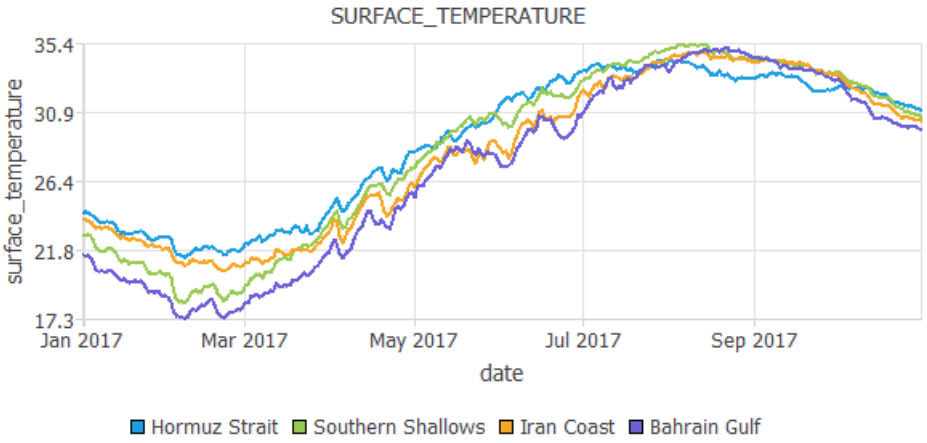
4. Surface temperature (C)

Surface temperature time series (entry point)



The surface temperature follows the stationary trend.

Surface temperature time series (regions)



The temperature of all zones follows the stationary trend.

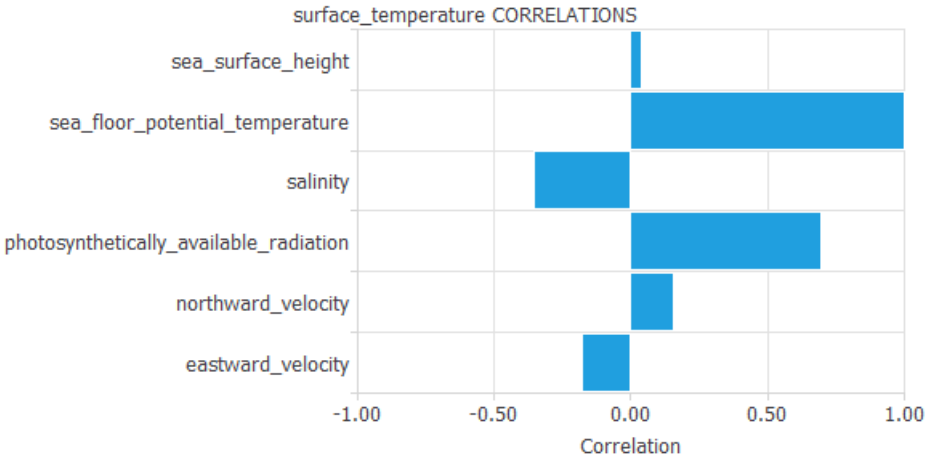
The Bahrain Gulf temperature has the biggest range, and the Hormuz Strait one the smallest.

Surface temperature statistics

	Minimum	Maximum	Mean	Standard deviation
Entry point	15.96	35.98	28.61	5.48
Strait of Hormuz	21.32	34.39	28.95	4.60
Southern Shallows	18.37	35.43	28.40	5.75
Iran Coast	20.48	34.89	28.21	5.07
Bahrain Gulf	17.31	35.13	27.13	6.04

The mean temperatures of all regions are similar.

Surface temperature correlations (entry point)

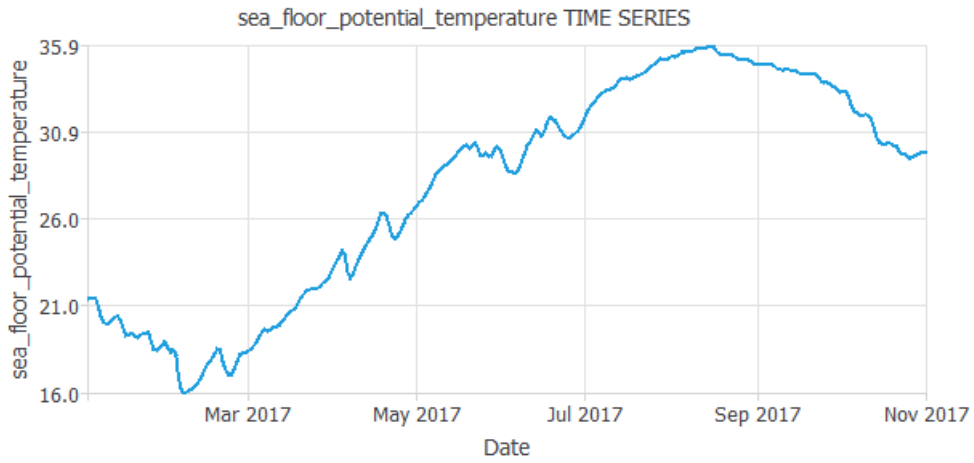


The surface temperature is highly correlated with the floor temperature and the photosynthetically available radiation, as expected.

The correlation between temperature and salinity is medium and negative.

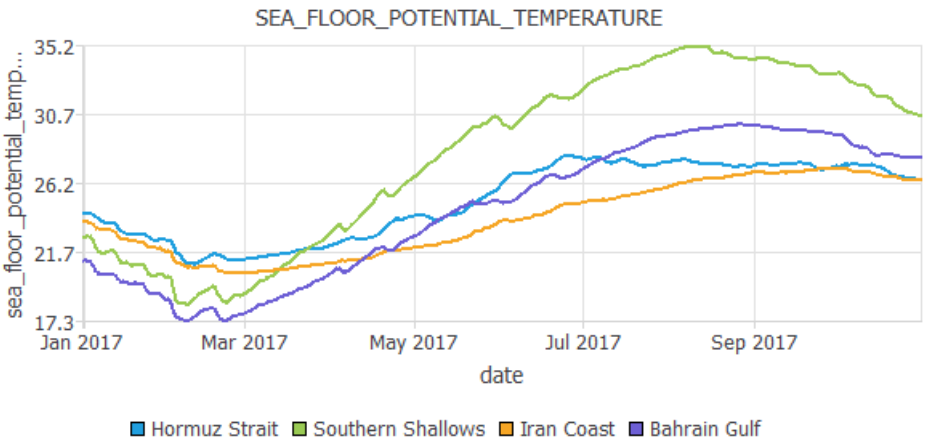
5. Sea floor potential temperature (C)

Sea floor potential temperature time series (entry point)



At the entry point, the floor potential temperatures are very similar to the surface temperatures.

Sea floor potential temperature time series (regions)



The highest floor temperature is at the Southern Shallows (low depth).

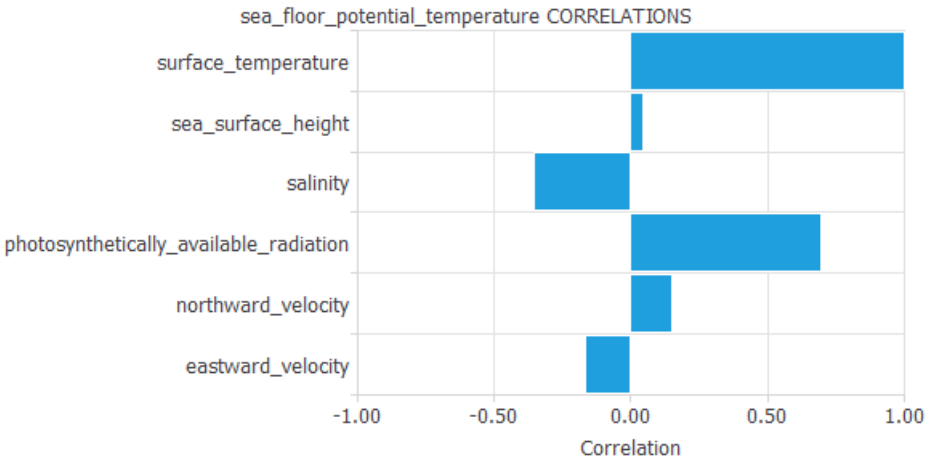
The lowest floor temperature is at the Iran Coast (high depth).

Sea floor potential temperature statistics

	Minimum	Maximum	Mean	Standard deviation
Entry point	16.04	35.89	27.79	6.25
Strait of Hormuz	20.96	28.00	25.09	2.45
Southern Shallows	18.33	35.15	28.07	5.74
Iran Coast	20.39	27.18	23.85	2.39
Bahrain Gulf	17.25	30.05	24.50	4.43

The floor temperature at the entry point is high, since it has low depth.

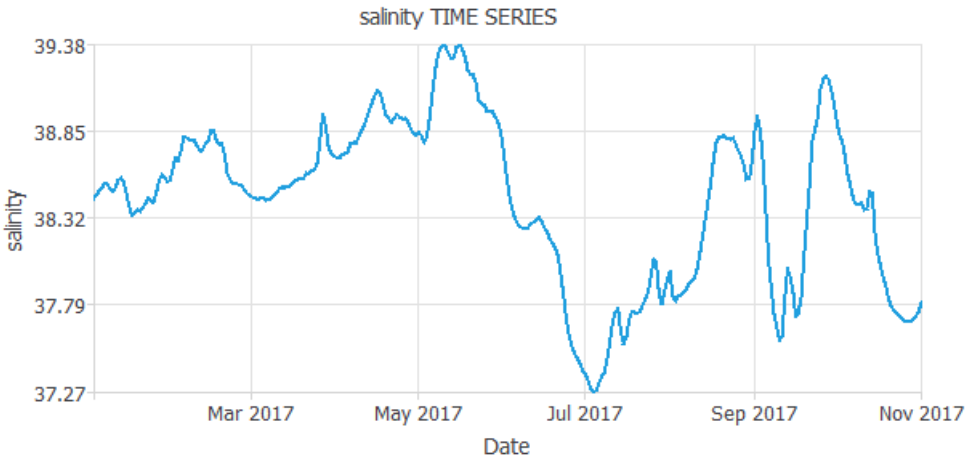
Sea floor potential temperature correlations (entry point)



The correlations here are very similar than those for the surface temperature.

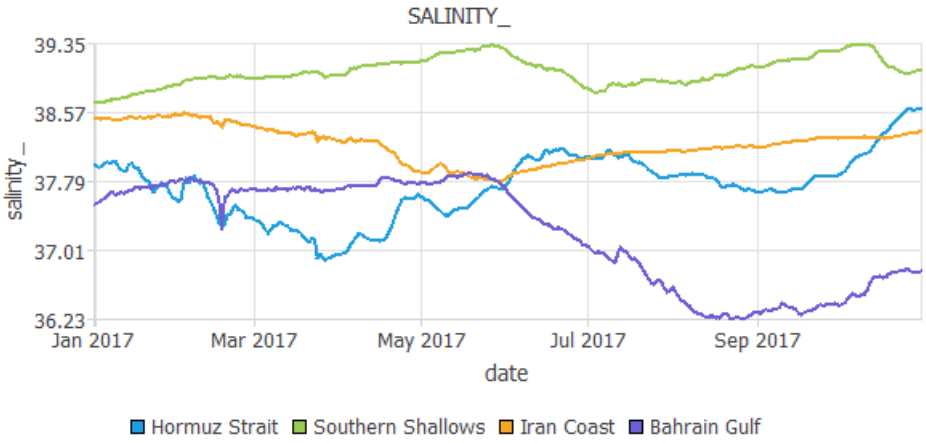
6. Salinity (practical salinity units)

Salinity time series (entry point)



The salinity at the entry point has a big drop from June to July.

Salinity time series (regions)



The highest salinity is at the Southern Shallows.

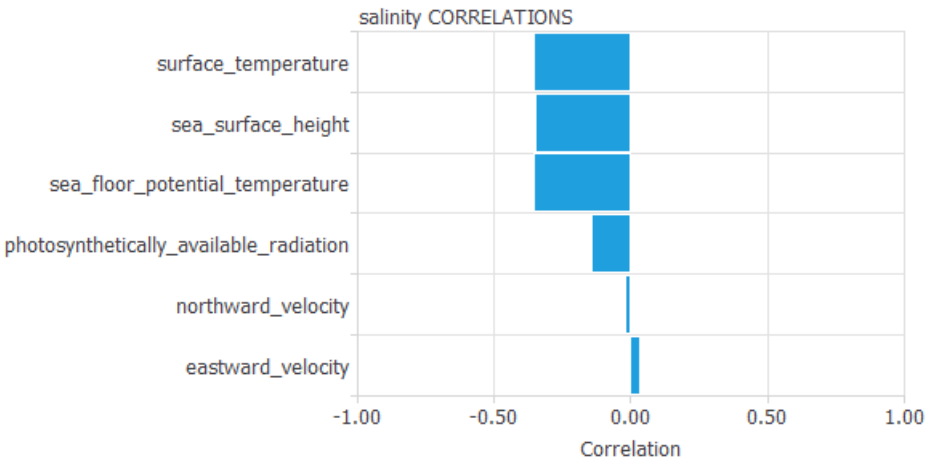
The lowest salinity is at the Bahrain gulf.

Salinity statistics

	Minimum	Maximum	Mean	Standard deviation
Entry point	37.26	39.37	38.43	0.497
Strait of Hormuz	36.89	38.61	37.72	0.36
Southern Shallows	38.68	39.35	39.04	0.16
Iran Coast	37.78	38.56	38.21	0.20
Bahrain Gulf	36.22	37.88	37.21	0.59

The salinity at the entry point is higher than that at most of the other regions.

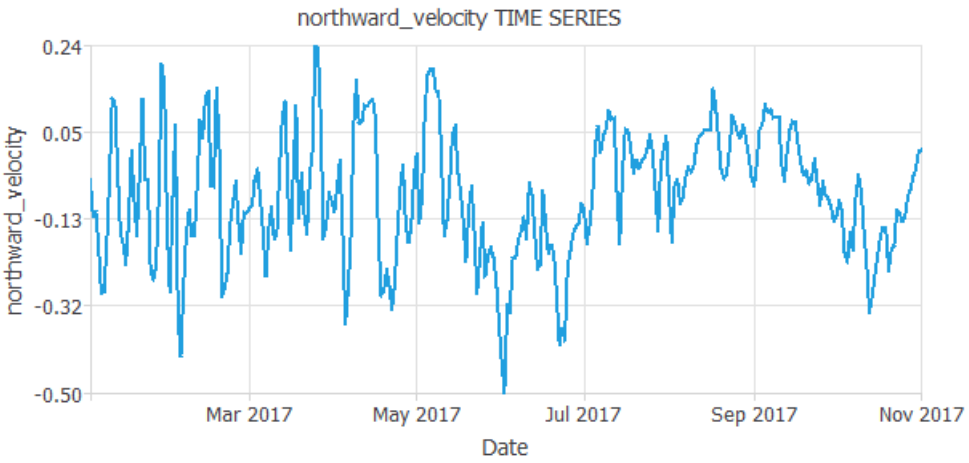
Salinity correlations (entry point)



The variables which are more correlated with the salinity are the temperature and the surface height.

7. Northward velocity (m/s)

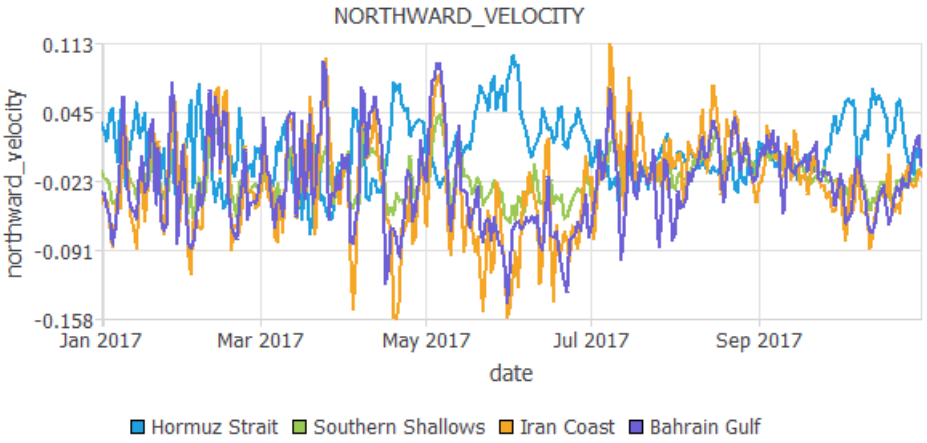
Northward velocity time series (entry point)



The wind direction has bigger oscillations between Januray and June, and it becomes more stable between July and November.

During the first half of the year there were some turbidity problems at the plant.

Northward velocity time series (regions)



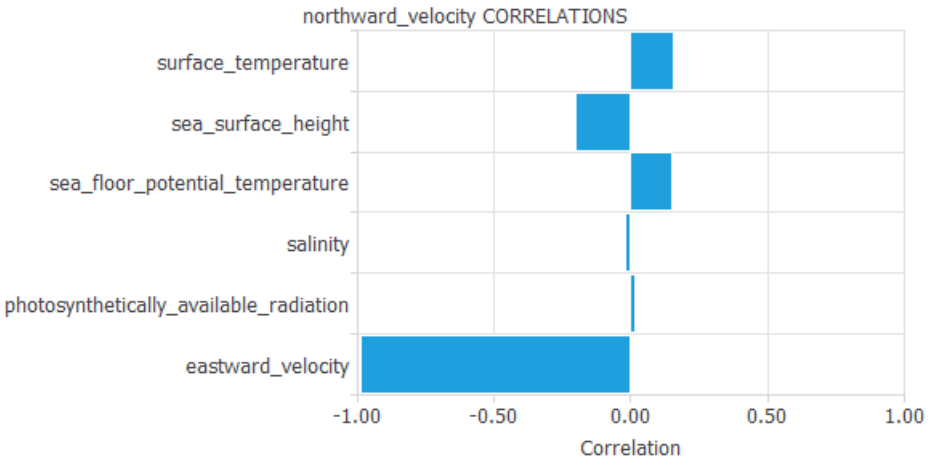
The wind direction at the Strait of Hormuz seems more different than that at the other regions.

Northward velocity statistics

	Minimum	Maximum	Mean	Standard deviation
Entry point	-0.503	0.236	-0.082	0.133
Strait of Hormuz	-0.074	0.101	0.008	0.031
Southern Shallows	-0.063	0.042	-0.018	0.020
Iran Coast	-0.158	0.113	-0.025	0.048
Bahrain Gulf	-0.142	0.095	-0.025	0.044

Most of the wind in the Persian Gulf comes from the south.

Northward velocity correlations (entry point)

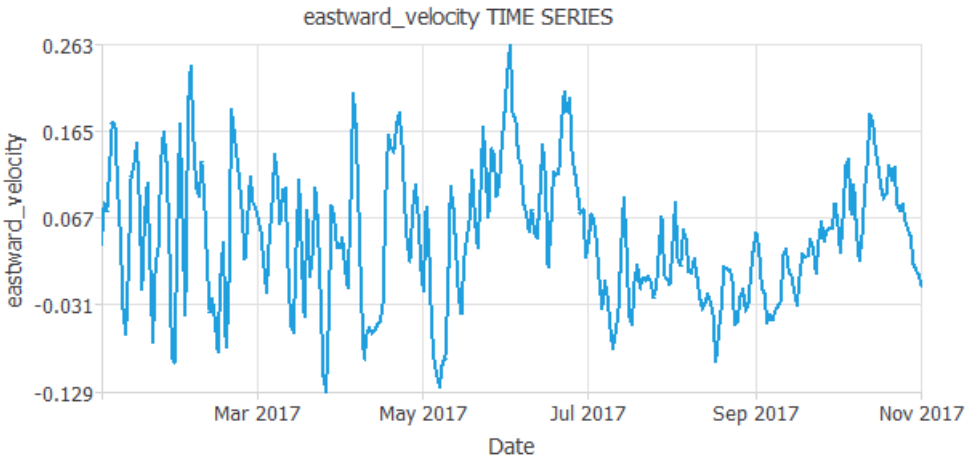


The northward velocity is highly correlated with the eastward velocity.

Also, there is a low correlation with the temperatures and the surface height.

8. Eastward velocity (m/s)

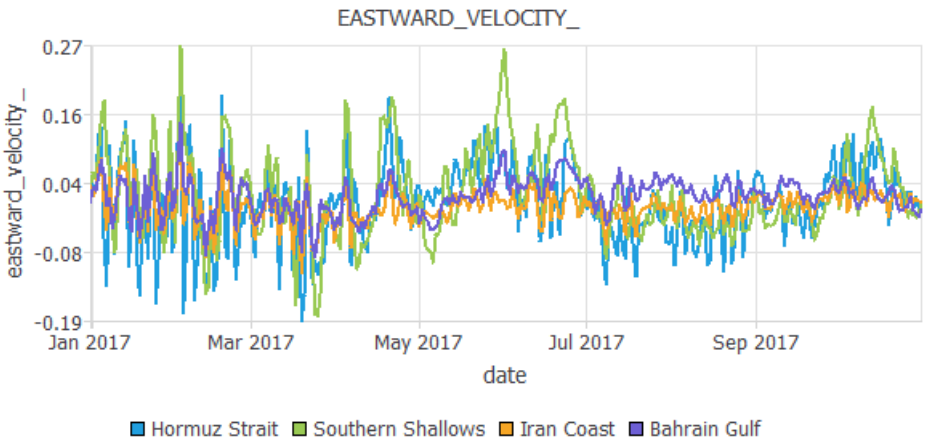
Eastward velocity time series (entry point)



The horizontal temperature also seems less stable during the first half of the year.

During the first half of the year there were some turbidity problems at the plant.

Eastward velocity time series (regions)

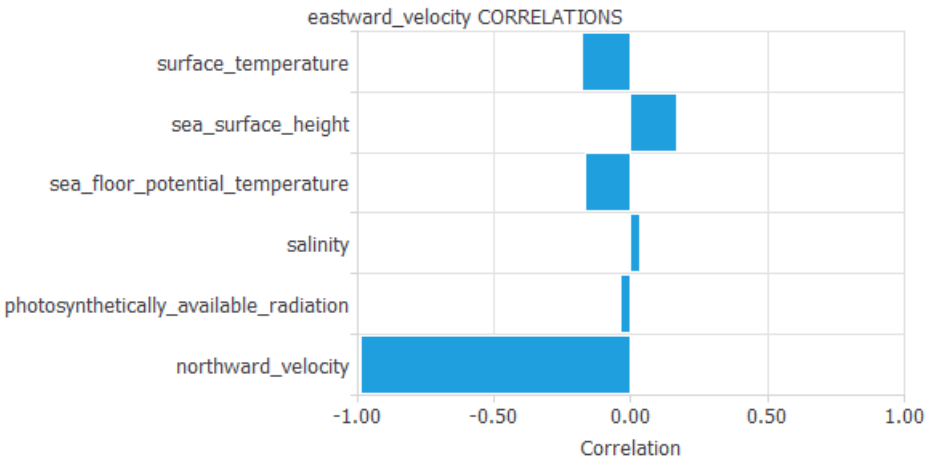


The eastward velocity seems more stable at the Iran Coast and less stable at the Southern Shallows.

Eastward velocity statistics

	Minimum	Maximum	Mean	Standard deviation
Entry point	-0.129	0.263	0.045	0.075
Strait of Hormuz	-0.074	0.101	0.008	0.031
Southern Shallows	-0.063	0.042	-0.018	0.020
Iran Coast	-0.158	0.113	-0.025	0.048
Bahrain Gulf	-0.142	0.095	-0.025	0.044

Eastward velocity correlations (entry point)

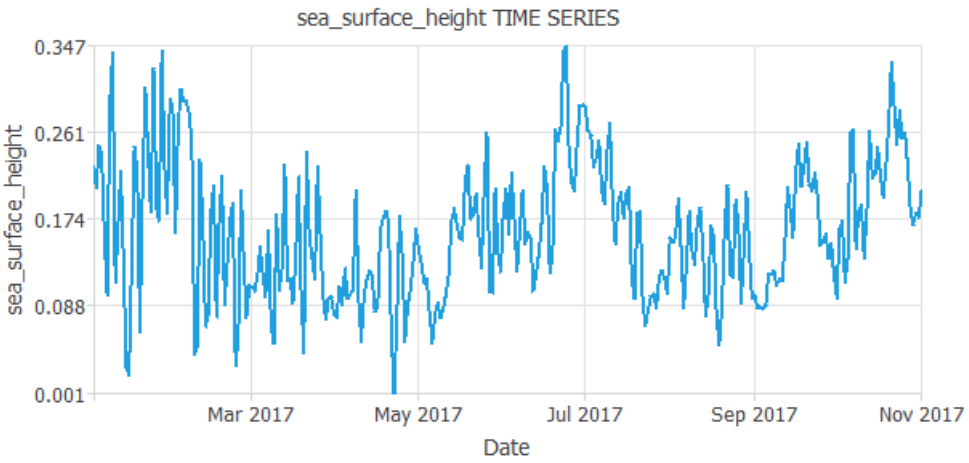


The eastward velocity is highly correlated with the northward.

There is a medium correlation with the temperatures and the surface height.

9. Sea surface height (m)

Sea surface height time series (entry point)



The surface height oscillates more in the first half of the year.

This might have an impact on the turbidity at the plant.

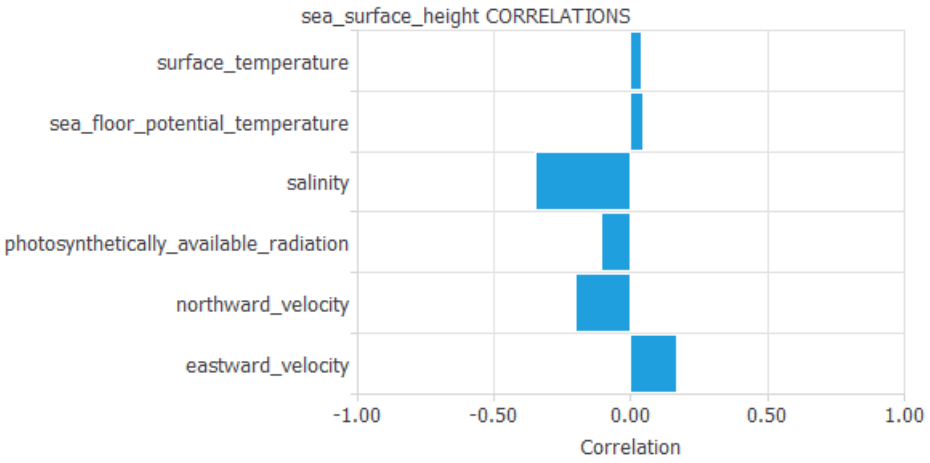
Sea surface height statistics

	Minimum	Maximum	Mean	Standard deviation
Entry point	-0.089	0.347	0.157	0.072
Strait of Hormuz	0.064	0.294	0.163	0.050
Southern Shallows	0.005	0.421	0.168	0.070
Iran Coast	0.001	0.338	0.130	0.064
Bahrain Gulf	0.004	0.333	0.148	0.066

The biggest mean and standard deviation are produced at the Southern Shallows.

At that region, the salinity is higher. Will that influence the plant?

Sea surface height correlations (entry point)

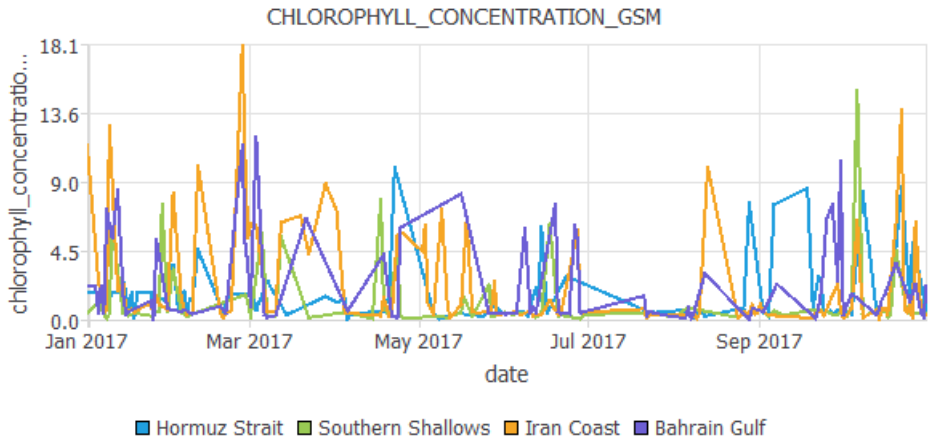


The variable most correlated with the sea surface height is the salinity.

10. Chlorophyll concentration GSM (mg/m^3)

Chlorophyll concentration GSM time series (regions)

The chlorophyll concentration GSM data for the entry point is not available, since it has many missing values at that particular coordinates.



There are a lot of missing values even for the regions, where the data has been averaged.

The missing values have been imputed using the time series data.

We can see peaks of chlorophyll concentration, specially during the winter months.

Chlorophyll concentration GSM statistics

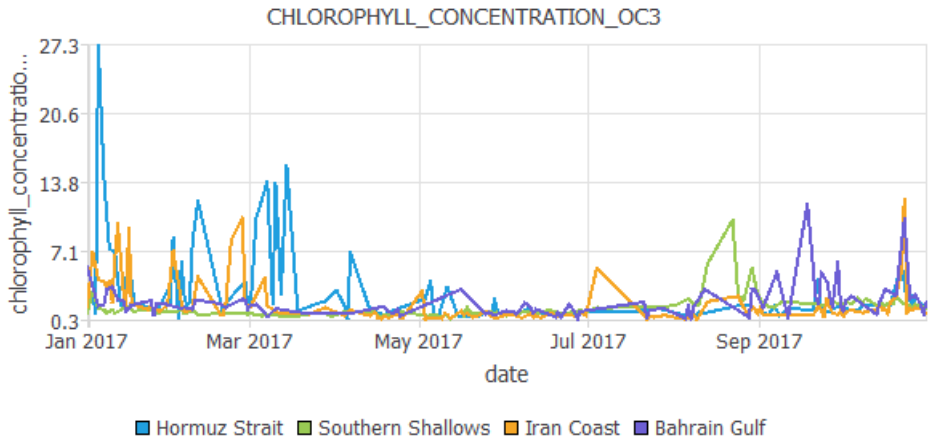
	Minimum	Maximum	Mean	Standard deviation
Strait of Hormuz	0.005	10.00	1.96	2.19
Southern Shallows	0.06	15.10	0.98	1.60
Iran Coast	0.04	18.07	2.42	3.08
Bahrain Gulf	0.009	12.01	2.49	2.51

The regions with the highest chlorophyll are the Bahrain Gulf and the Iran Coast.

11. Chlorophyll concentration OC3 (mg/m^3)

Chlorophyll concentration OC3 time series (regions)

The chlorophyll concentration OC3 data for the entry point is not available, since it has many missing values at that particular coordinates.



This variable has high peaks of chlorophyll, especially in the Strait of Hormuz and between January and May.

Chlorophyll concentration OC3 statistics

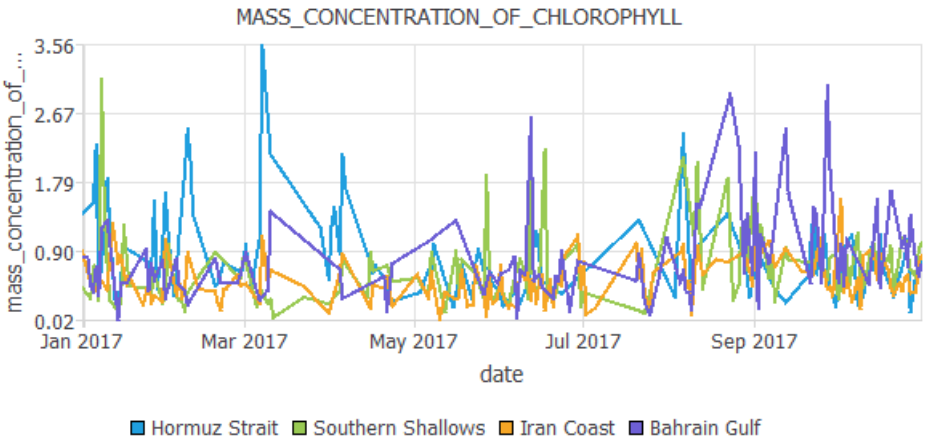
	Minimum	Maximum	Mean	Standard deviation
Strait of Hormuz	0.43	27.33	2.57	3.20
Southern Shallows	0.34	10.11	1.58	1.39
Iran Coast	0.30	12.16	1.75	1.82
Bahrain Gulf	0.35	11.70	1.97	1.48

The regions with the highest mean chlorophyll using the OC3 algorithm is the Strait of Hormuz.

12. Mass concentration of chlorophyll (mg/m^3)

Mass concentration of chlorophyll time series (regions)

The mass concentration of chlorophyll data for the entry point is not available, since it has many missing values at that particular coordinates.



We can see peaks of this variable at the Hormuz Strait, the Southern Shallows and the Bahrain Gulf.

There are more peaks at the Hormuz Strait during the first half of the year and more peaks

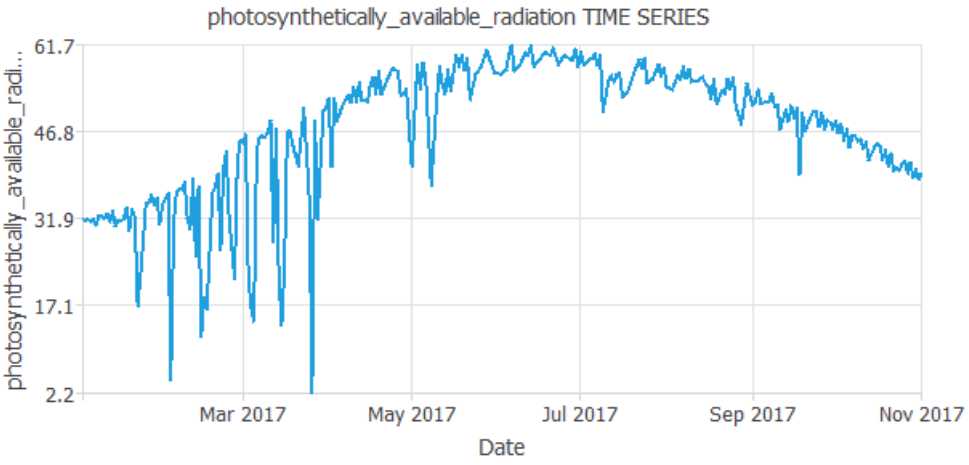
Mass concentration of chlorophyll statistics

	Minimum	Maximum	Mean	Standard deviation
Strait of Hormuz	0.12	3.56	0.85	0.51
Southern Shallows	0.04	3.11	0.63	0.42
Iran Coast	0.03	1.56	0.54	0.25
Bahrain Gulf	0.01	3.04	0.85	0.52

The highest means are for the Strait of Hormuz and the Bahrain Gulf.

13. Photosynthetically available radiation (Einstein/m^2)

Photosynthetically available radiation time series (entry point)



The photosynthetically available radiation follows the solar declination, as expected.

Between January and March, there are high drops, due to the high cloudiness during that period.

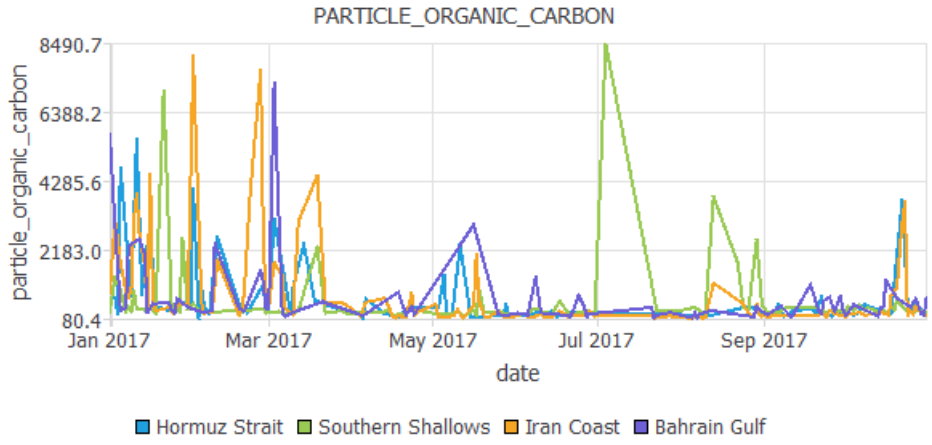
Photosynthetically available radiation statistics

	Minimum	Maximum	Mean	Standard deviation
Strait of Hormuz	6.76	61.35	47.89	12.09
Southern Shallows	11.51	61.04	48.08	11.18
Iran Coast	8.13	61.87	48.07	12.30
Bahrain Gulf	6.55	61.83	47.25	12.19

This variable is very similar for all regions.

14. Particle organic carbon (mg/m^3)

Particle organic carbon time series (regions)



There are high peaks of the particle organic carbon at all regions.

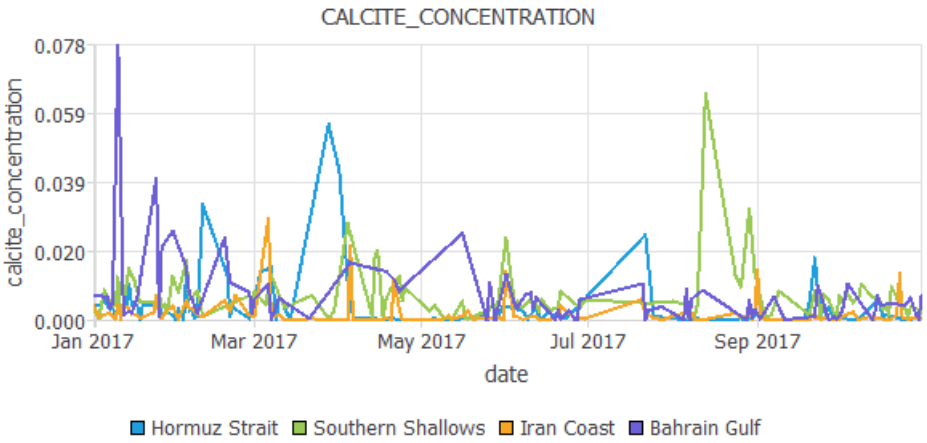
Particle organic carbon statistics

	Minimum	Maximum	Mean	Standard deviation
Strait of Hormuz	99	5568	613	782
Southern Shallows	136	8490	861	1436
Iran Coast	80	8102	746	1217
Bahrain Gulf	90	7280	701	864

The region with the highest average of particle organic carbon is Southern Shallows.

15. Calcite concentration (mol/m^3)

Calcite concentration time series (regions)



The calcite concentrations have also high peaks at different regions.

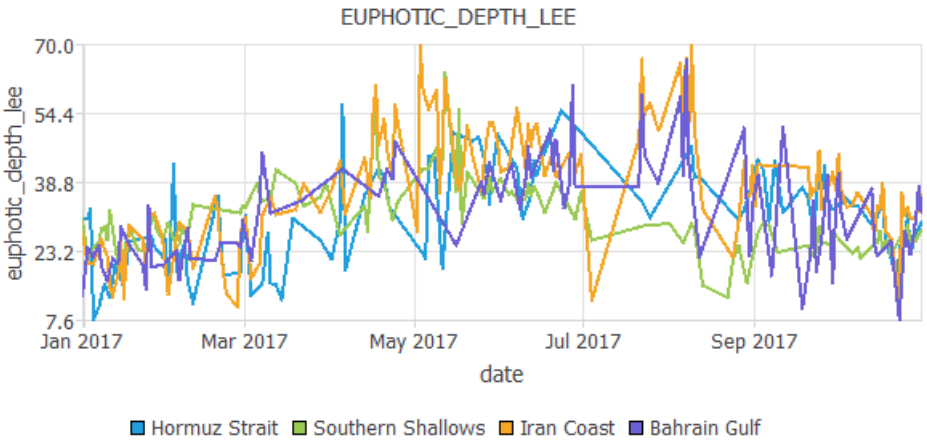
Calcite concentration statistics

	Minimum	Maximum	Mean	Standard deviation
Strait of Hormuz	1.3e-05	0.055	0.005	0.010
Southern Shallows	1.3e-05	0.064	0.007	0.008
Iran Coast	1.3e-05	0.028	0.002	0.003
Bahrain Gulf	1.2e-05	0.078	0.008	0.008

The region with more calcite concentration is the Bahrain Gulf.

16. Euphotic depth Lee (m)

Euphotic depth lee time series (regions)



The euphotic depth in all regions follows the solar declination shape.

Does this variable have a relationship with the turbidity?

Euphotic depth lee statistics

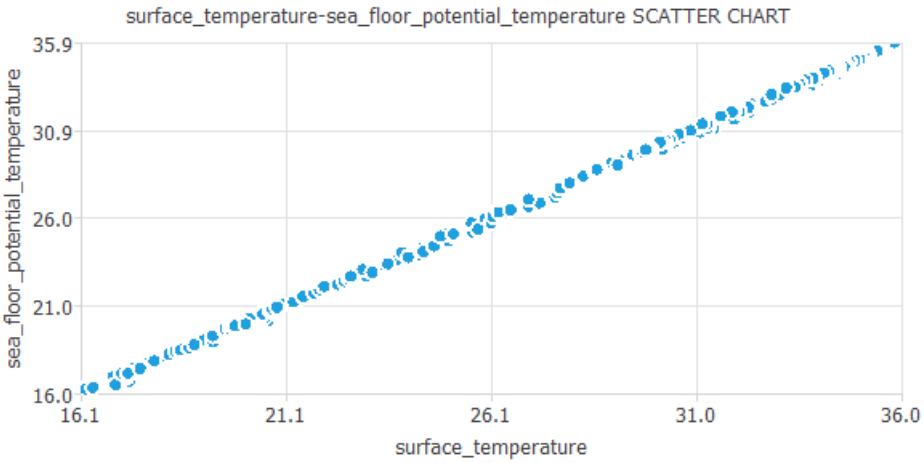
	Minimum	Maximum	Mean	Standard deviation
Strait of Hormuz	7.57	56.20	32.59	10.48
Southern Shallows	12.55	63.49	30.37	7.49
Iran Coast	10.58	69.96	36.62	12.03
Bahrain Gulf	7.65	66.42	32.99	9.50

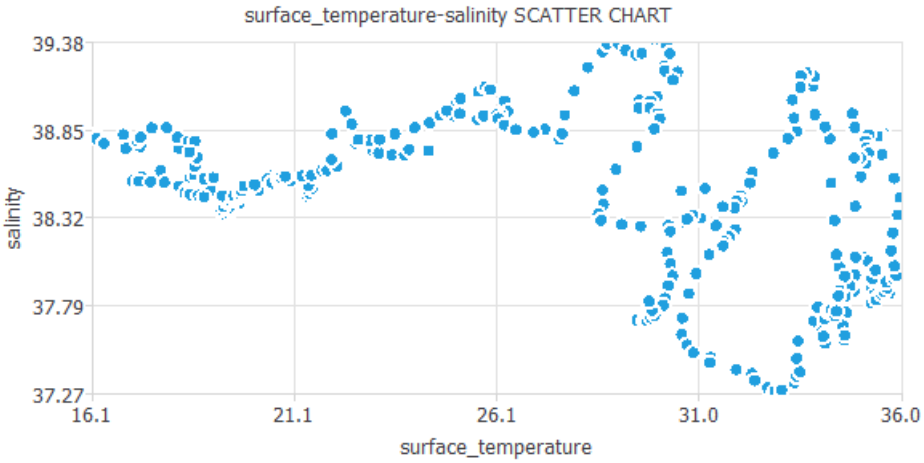
The region with the highest euphotic depth is the Iran coast.

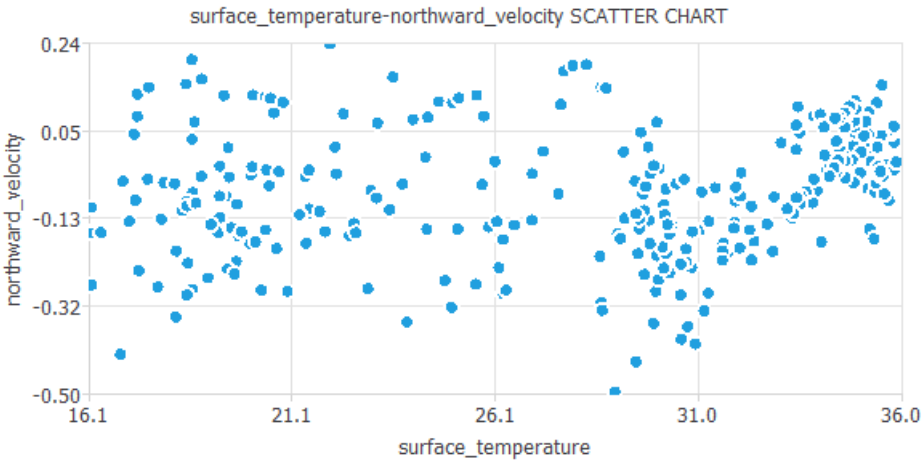
The smallest average value is at the Southern Shallows.

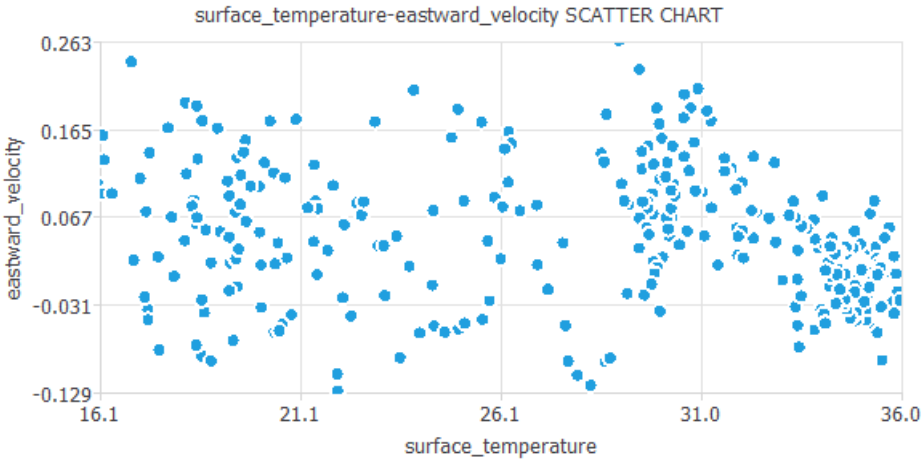
17. Satellite scatter charts (entry point)

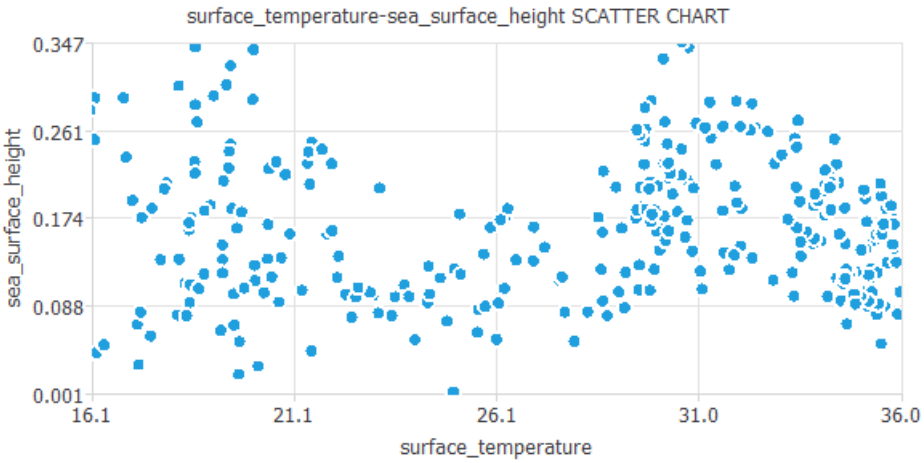
Surface temperature scatter charts

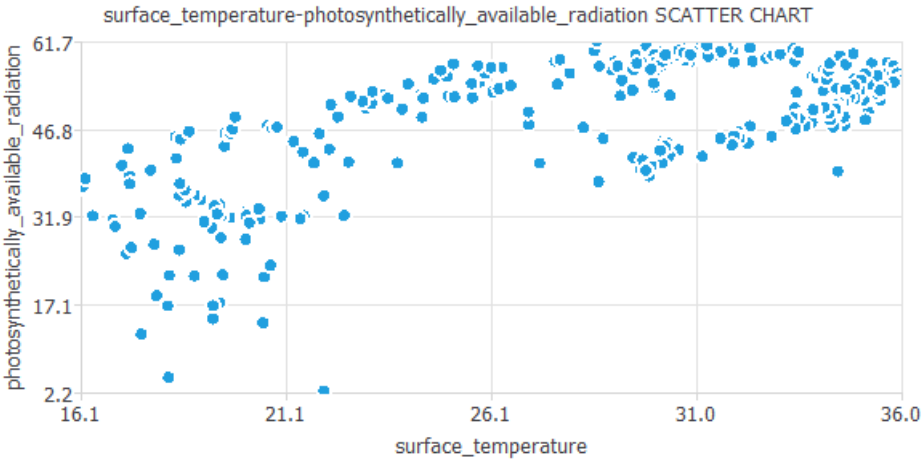




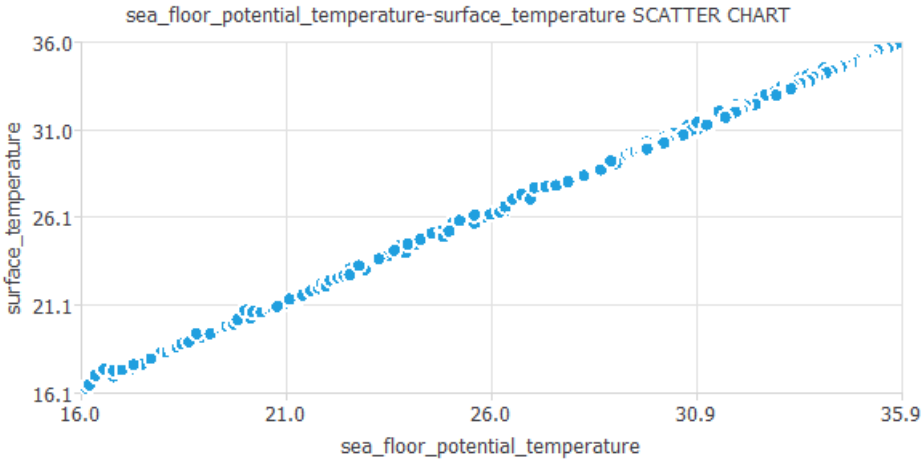

surface_temperature-northward_velocity SCATTER CHART
0.24
0.05
-0.13
-0.32
-0.50
northward_velocity
16.1
21.1
26.1
31.0
36.0
surface_temperature

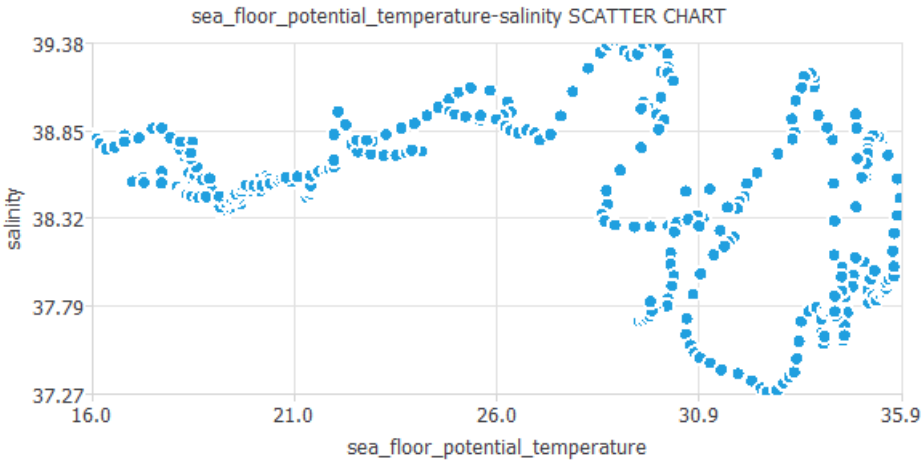

surface_temperature-eastward_velocity SCATTER CHART
0.263
0.165
0.067
-0.031
-0.129
eastward_velocity
16.1
21.1
26.1
31.0
36.0
surface_temperature

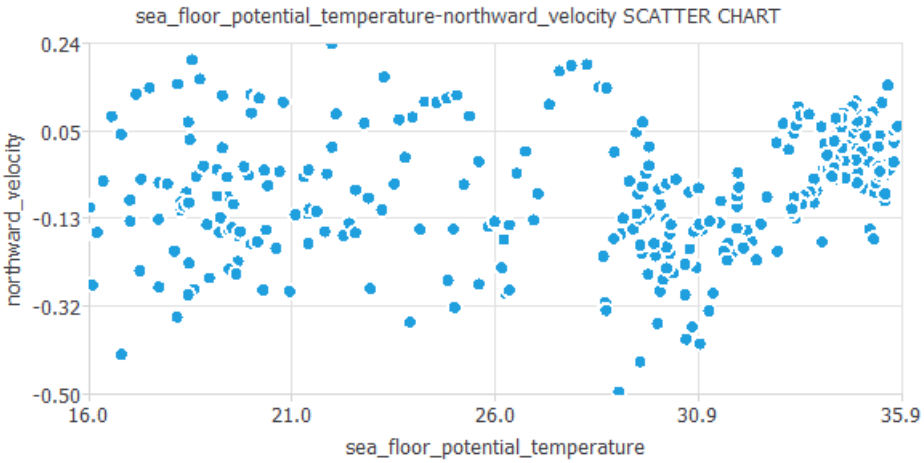

surface_temperature-sea_surface_height SCATTER CHART
sea_surface_height
0.347
0.261
0.174
0.088
0.001
16.1
21.1
26.1
31.0
36.0
surface_temperature

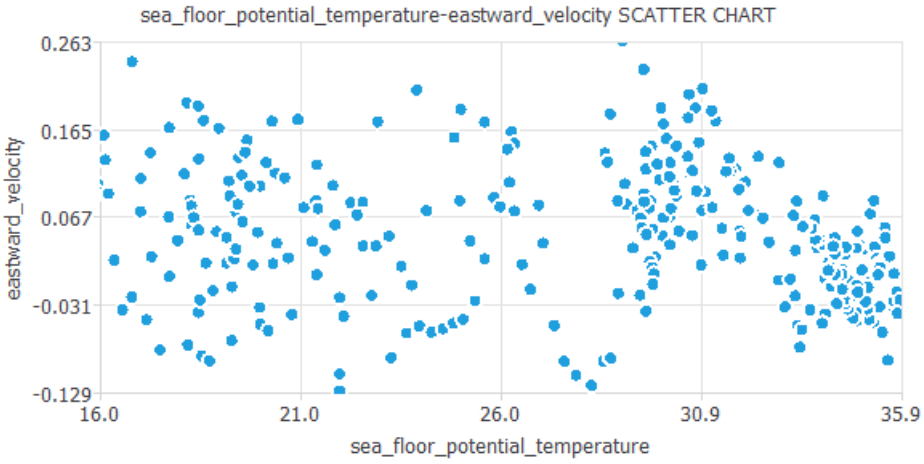

surface_temperature-photosynthetically_available_radiation SCATTER CHART
photosynthetically_available_radiation
61.7
46.8
31.9
17.1
2.2
16.1
21.1
26.1
31.0
36.0
surface_temperature

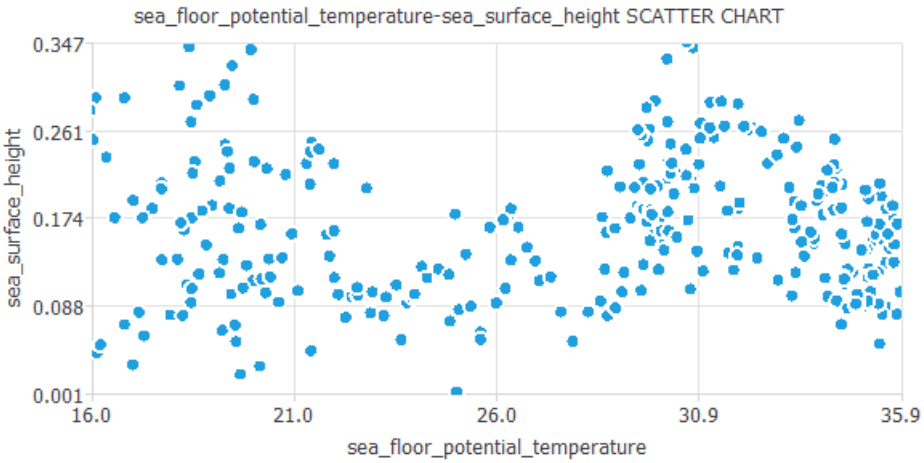
Sea floor temperature scatter charts

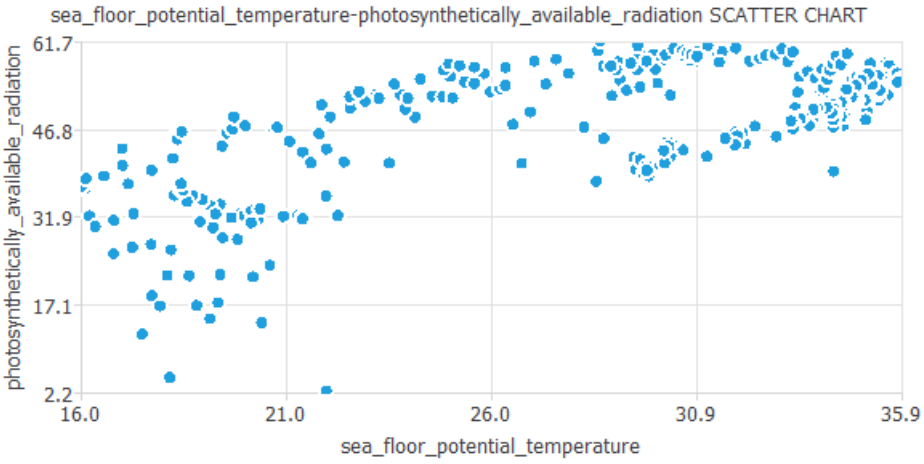




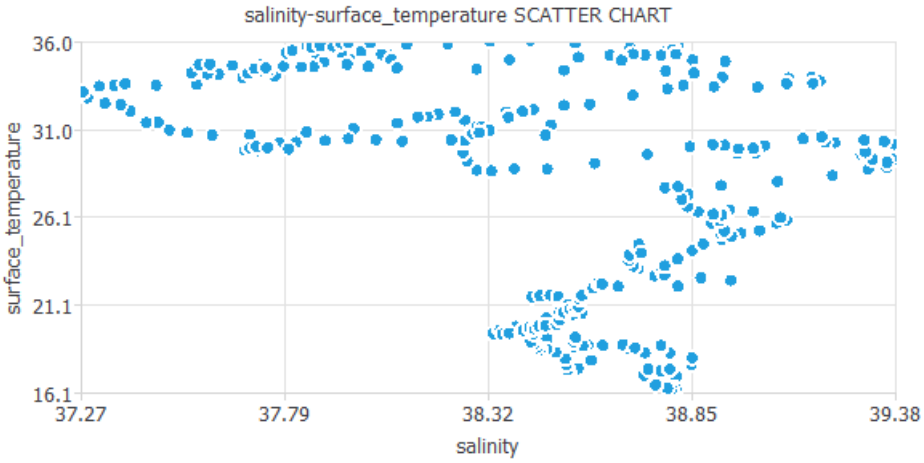

sea_floor_potential_temperature-northward_velocity SCATTER CHART
0.24
0.05
-0.13
-0.32
-0.50
northward_velocity
16.0
21.0
26.0
30.9
35.9
sea_floor_potential_temperature

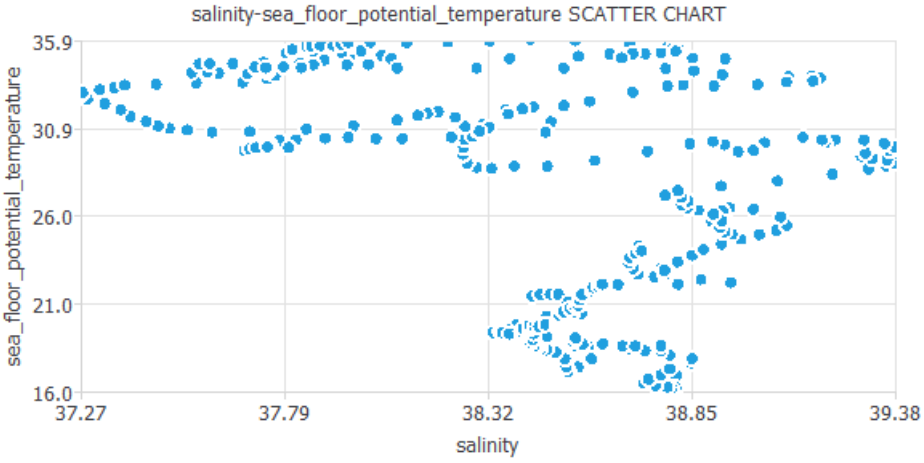

sea_floor_potential_temperature-eastward_velocity SCATTER CHART
0.263
0.165
0.067
-0.031
-0.129
eastward_velocity
16.0
21.0
26.0
30.9
35.9
sea_floor_potential_temperature

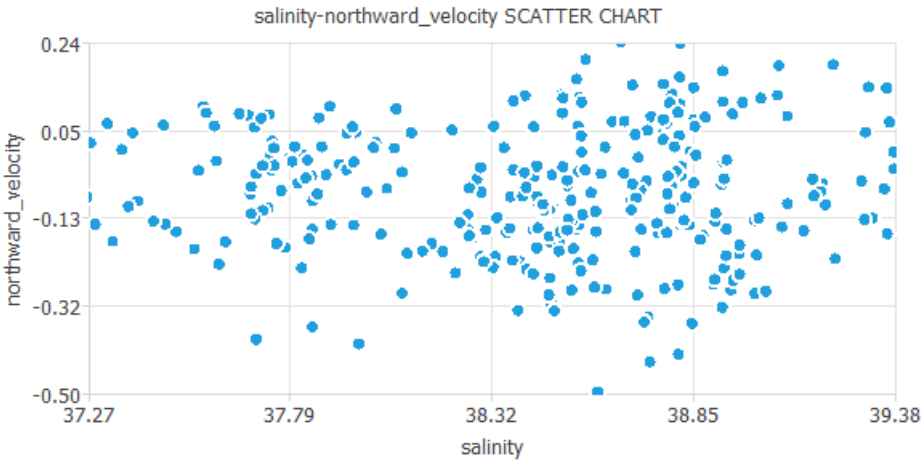

sea_floor_potential_temperature-sea_surface_height SCATTER CHART
sea_surface_height
0.347
0.261
0.174
0.088
0.001
16.0
21.0
26.0
30.9
35.9
sea_floor_potential_temperature

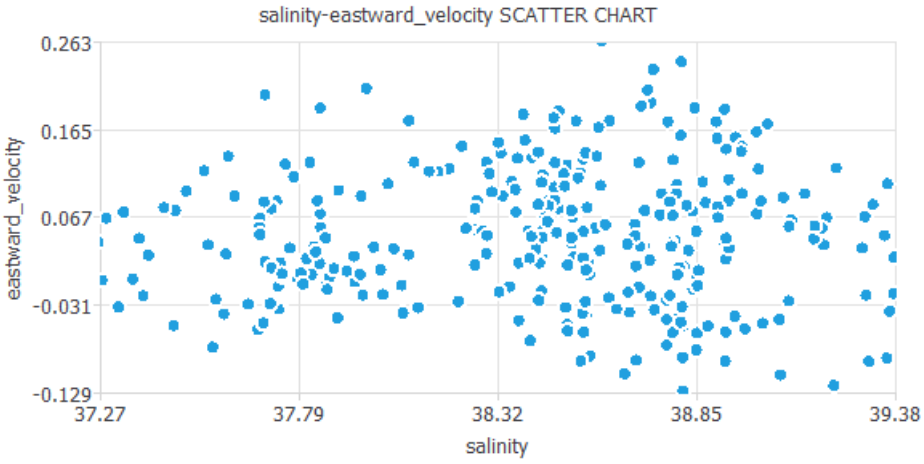

sea_floor_potential_temperature-photosynthetically_available_radiation SCATTER CHART
photosynthetically_available_radiation
61.7
46.8
31.9
17.1
2.2
16.0
21.0
26.0
30.9
35.9
sea_floor_potential_temperature

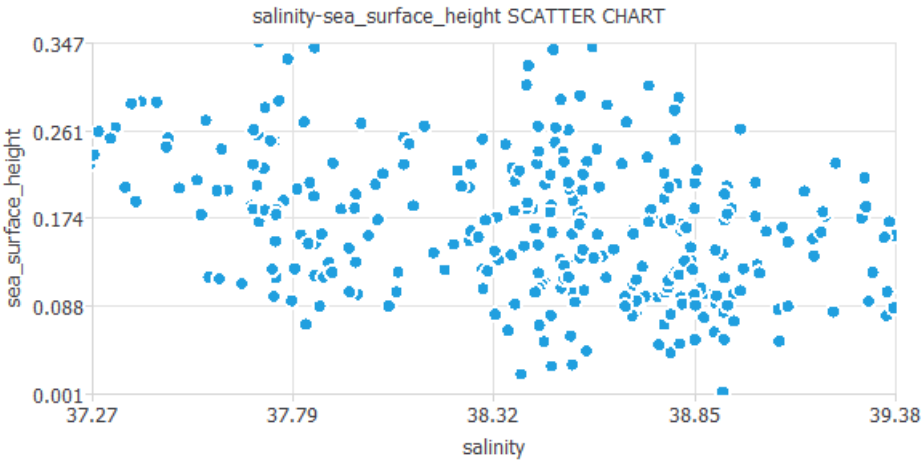
Salinity scatter charts

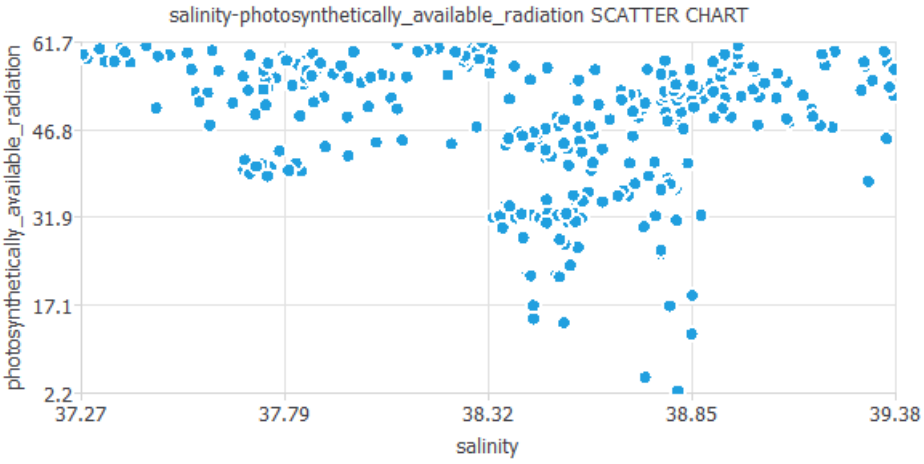




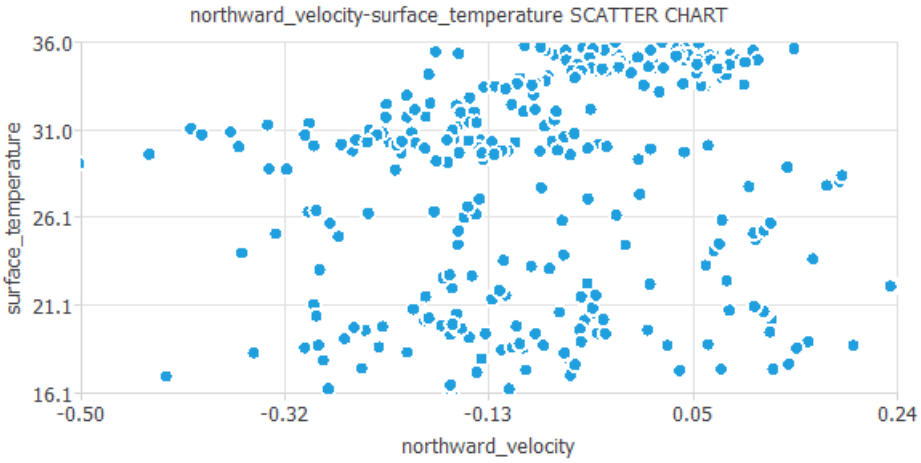

salinity-northward_velocity SCATTER CHART
0.24
0.05
-0.13
-0.32
-0.50
northward_velocity
37.27
37.79
38.32
38.85
39.38
salinity

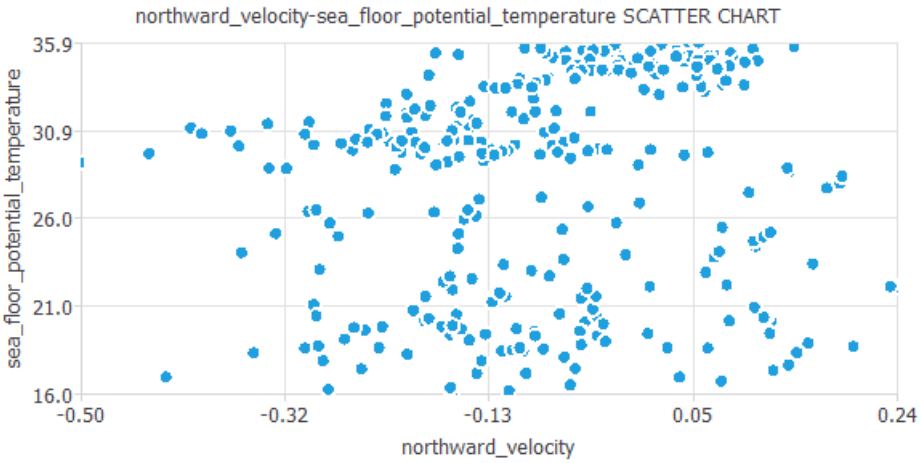

salinity-eastward_velocity SCATTER CHART
0.263
0.165
0.067
-0.031
-0.129
eastward_velocity
37.27
37.79
38.32
38.85
39.38
salinity

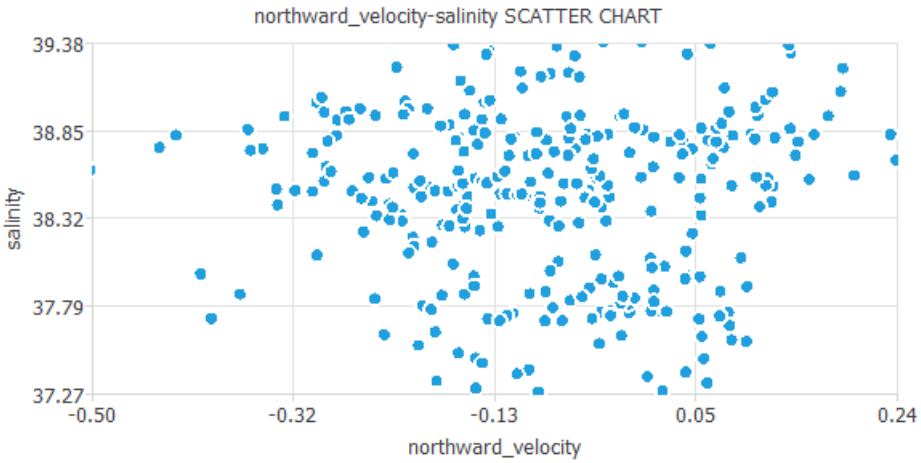

salinity-sea_surface_height SCATTER CHART
0.347
0.261
0.174
0.088
0.001
sea_surface_height
37.27
37.79
38.32
38.85
39.38
salinity

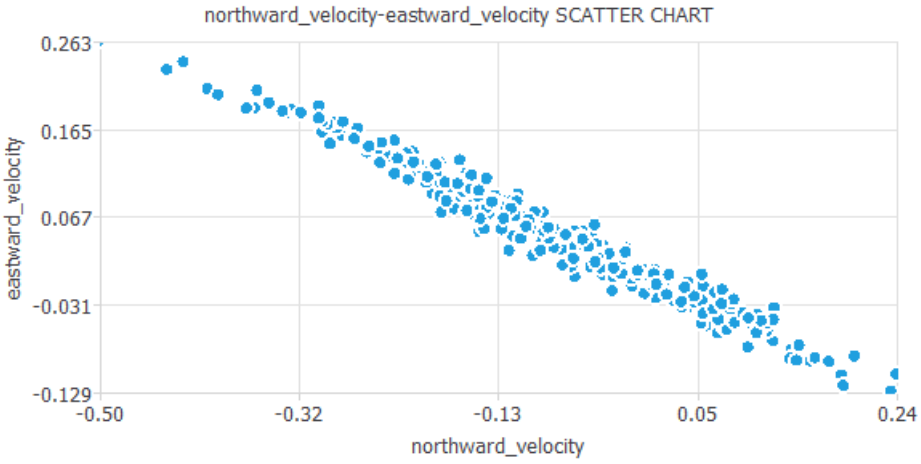

salinity-photosynthetically_available_radiation SCATTER CHART
61.7
46.8
31.9
17.1
2.2
photosynthetically_available_radiation
37.27
37.79
38.32
38.85
39.38
salinity

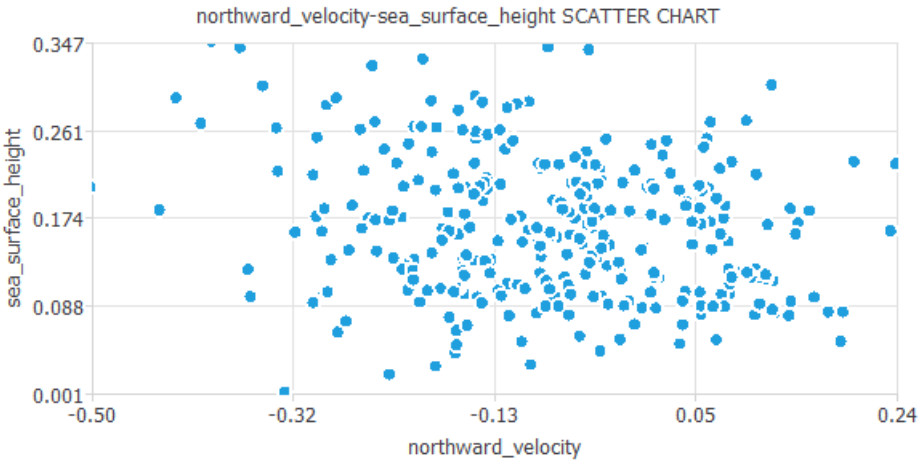
Northward velocity scatter charts

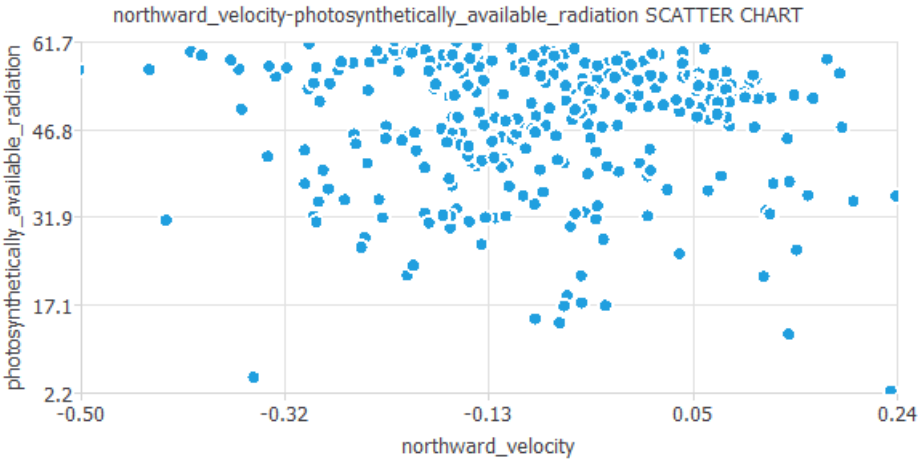




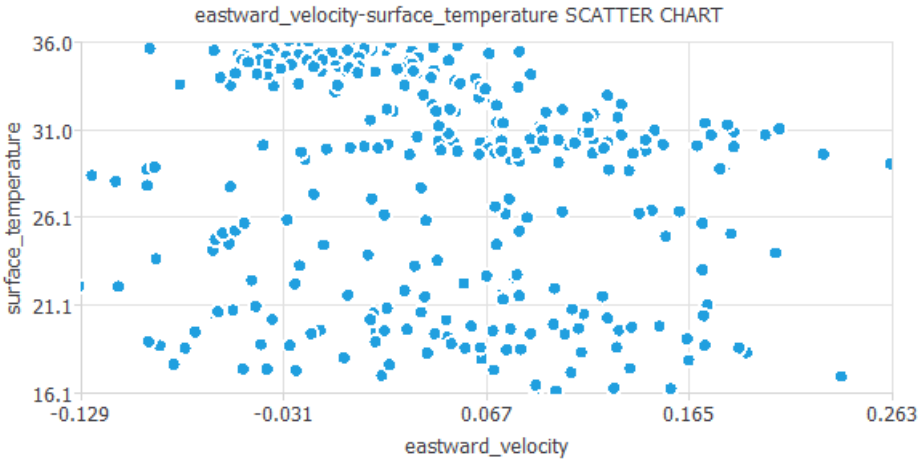

northward_velocity-salinity SCATTER CHART
39.38
38.85
38.32
37.79
37.27
salinity
-0.50
-0.32
-0.13
0.05
0.24
northward_velocity

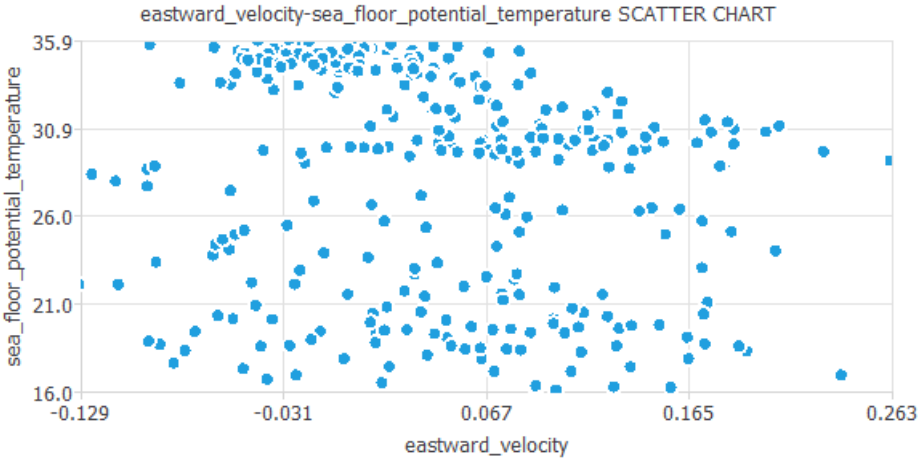

northward_velocity-eastward_velocity SCATTER CHART
0.263
0.165
0.067
-0.031
-0.129
eastward_velocity
-0.50
-0.32
-0.13
0.05
0.24
northward_velocity

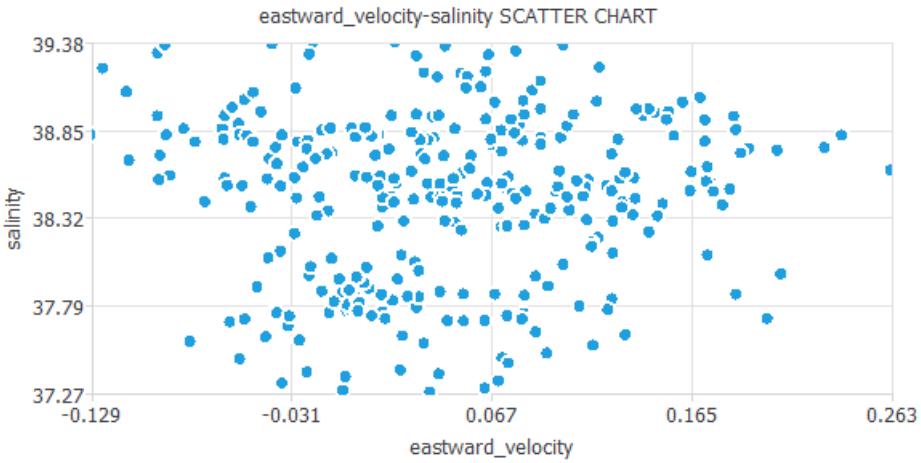

northward_velocity-sea_surface_height SCATTER CHART
sea_surface_height
0.347
0.261
0.174
0.088
0.001
-0.50
-0.32
-0.13
0.05
0.24
northward_velocity

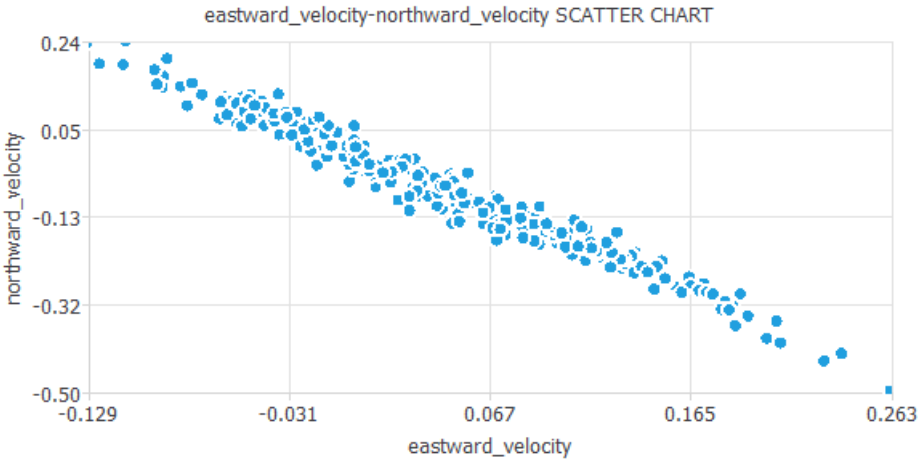

northward_velocity-photosynthetically_available_radiation SCATTER CHART
photosynthetically_available_radiation
61.7
46.8
31.9
17.1
2.2
-0.50
-0.32
-0.13
0.05
0.24
northward_velocity

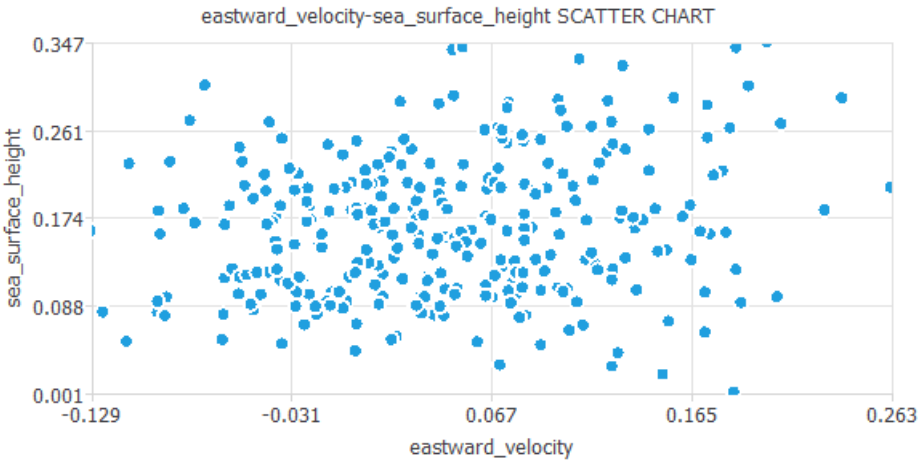
Eastward velocity scatter charts

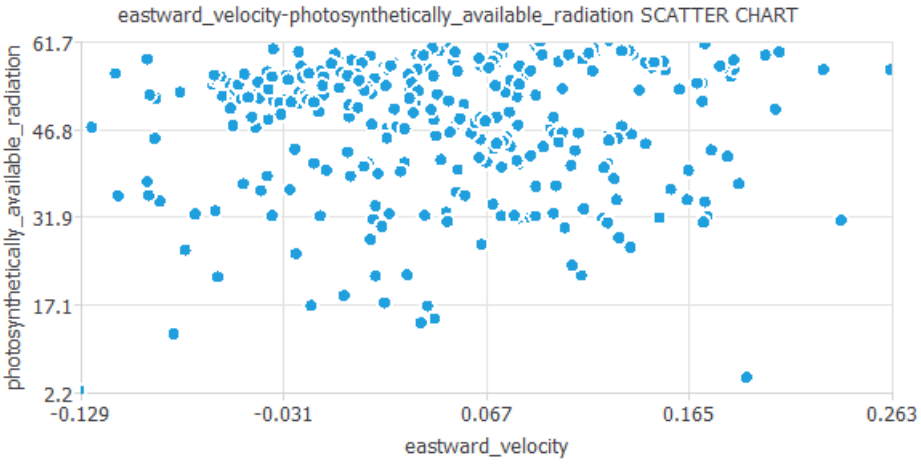




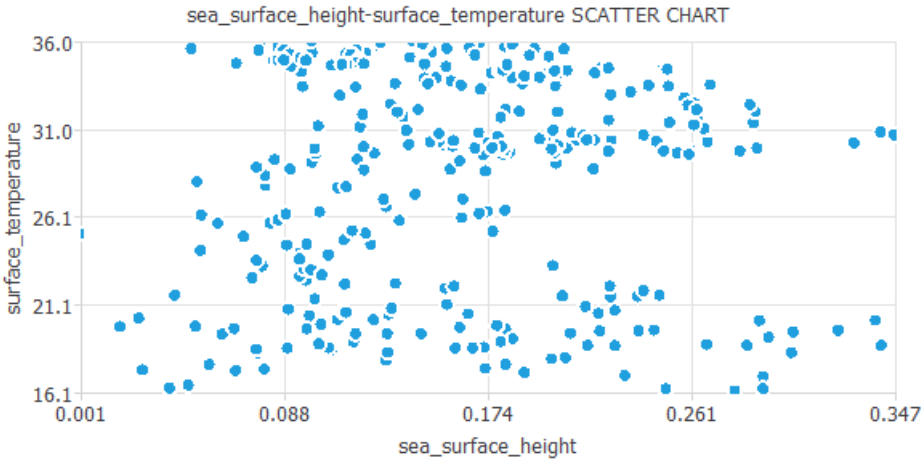

eastward_velocity-salinity SCATTER CHART
39.38
38.85
38.32
37.79
37.27
salinity
-0.129
-0.031
0.067
0.165
0.263
eastward_velocity

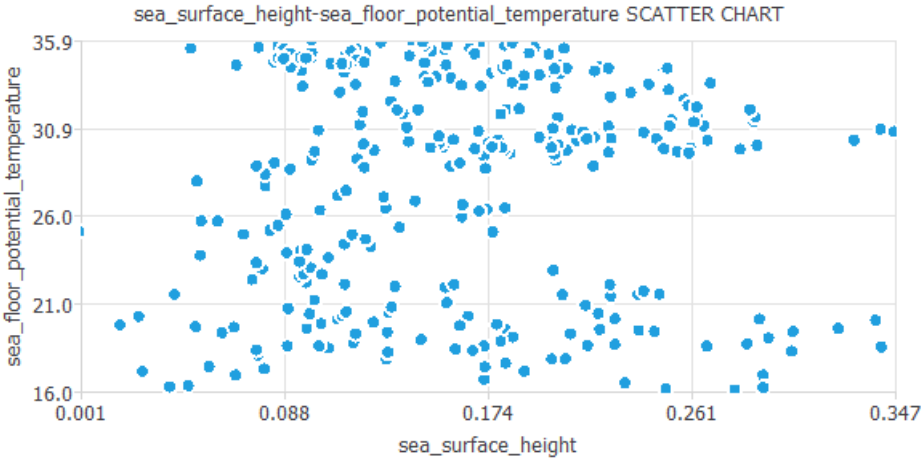

eastward_velocity-northward_velocity SCATTER CHART
0.24
0.05
-0.13
-0.32
-0.50
northward_velocity
-0.129
-0.031
0.067
0.165
0.263
eastward_velocity

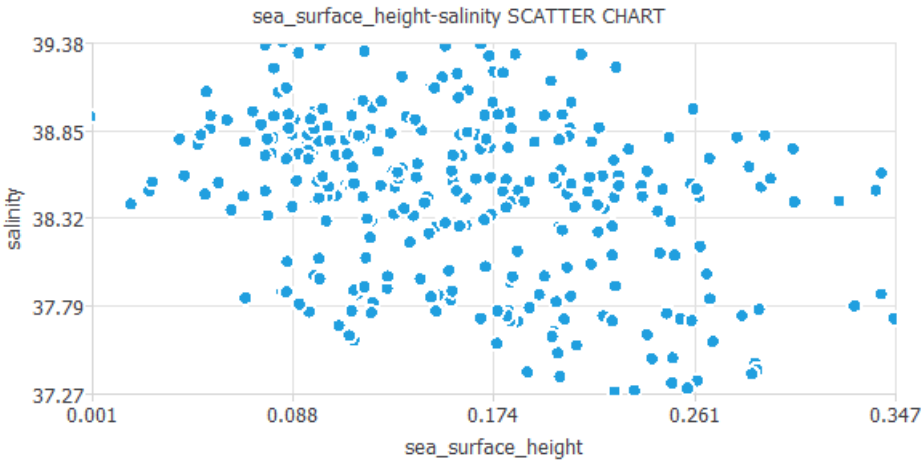

eastward_velocity-sea_surface_height SCATTER CHART
0.347
0.261
0.174
0.088
0.001
sea_surface_height
-0.129
-0.031
0.067
0.165
0.263
eastward_velocity

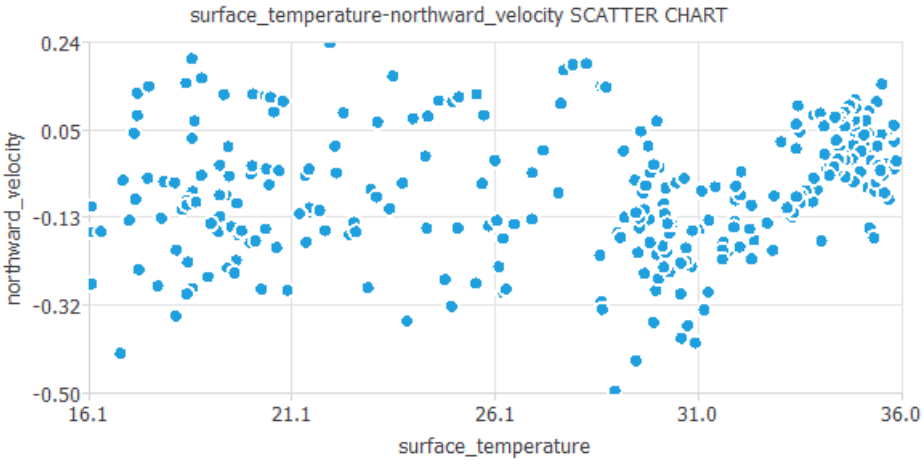

eastward_velocity-photosynthetically_available_radiation SCATTER CHART
61.7
46.8
31.9
17.1
2.2
photosynthetically_available_radiation
-0.129
-0.031
0.067
0.165
0.263
eastward_velocity

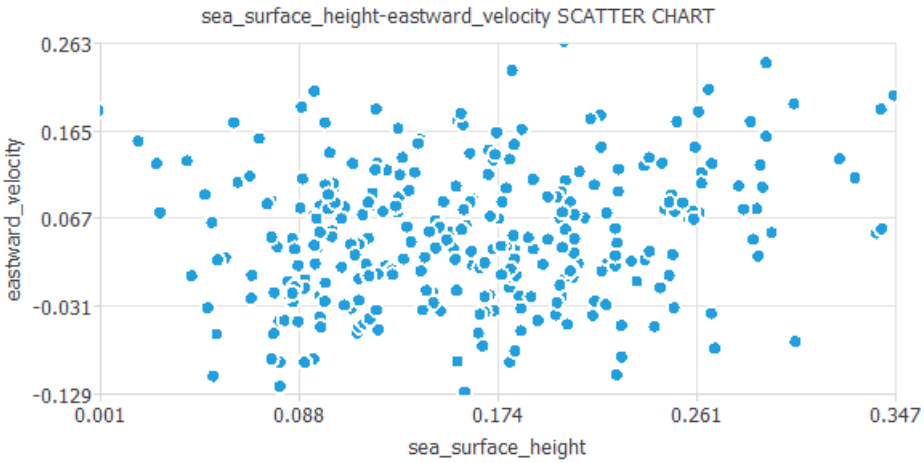
Sea surface height scatter charts

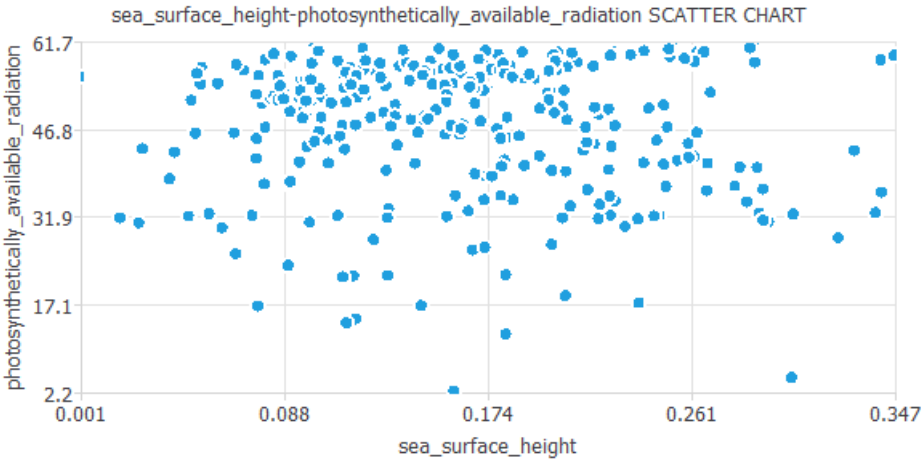




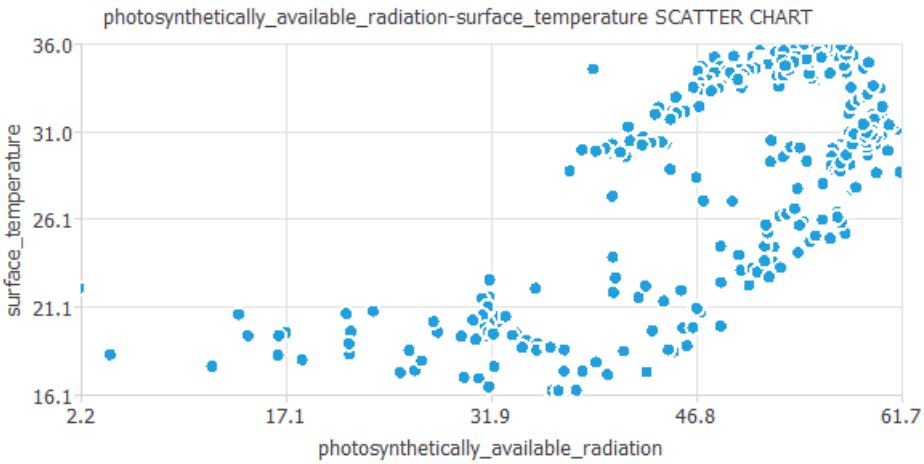

sea_surface_height-salinity SCATTER CHART
39.38
38.85
38.32
37.79
37.27
salinity
0.001
0.088
0.174
0.261
0.347
sea_surface_height

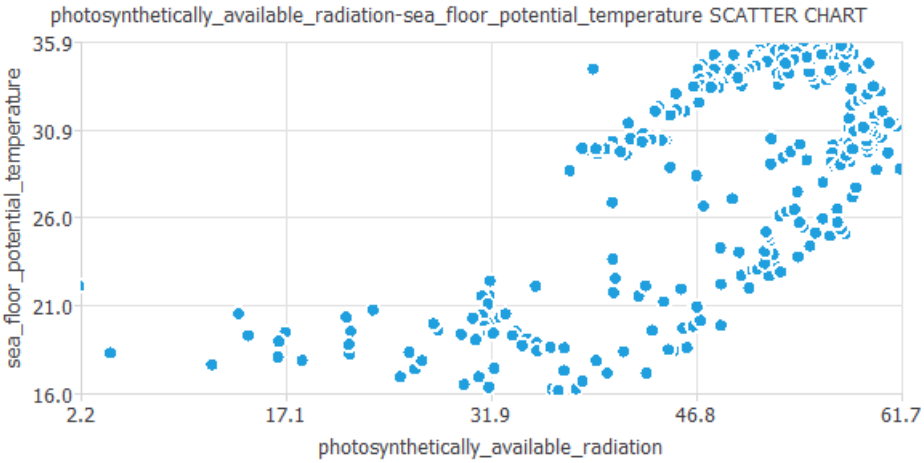

surface_temperature-northward_velocity SCATTER CHART
0.24
0.05
-0.13
-0.32
-0.50
northward_velocity
16.1
21.1
26.1
31.0
36.0
surface_temperature

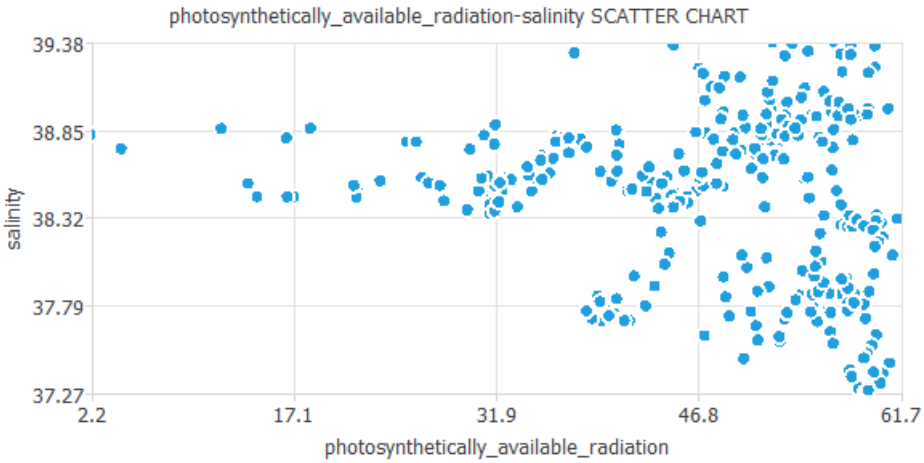

sea_surface_height-eastward_velocity SCATTER CHART
0.263
0.165
0.067
-0.031
-0.129
eastward_velocity
0.001
0.088
0.174
0.261
0.347
sea_surface_height

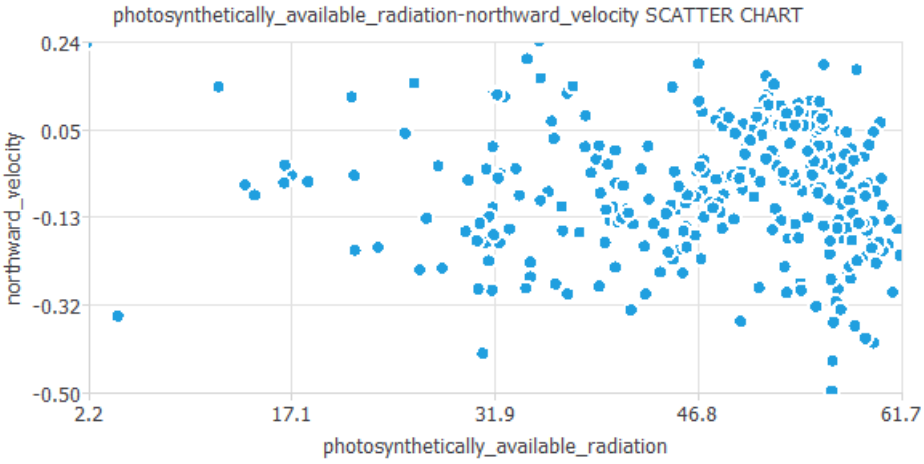

sea_surface_height-photosynthetically_available_radiation SCATTER CHART
61.7
46.8
31.9
17.1
2.2
photosynthetically_available_radiation
0.001
0.088
0.174
0.261
0.347
sea_surface_height

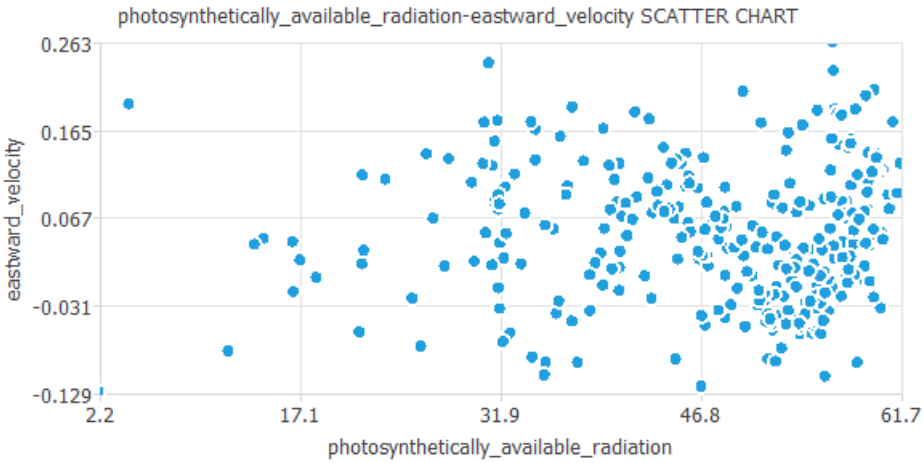
Photosynthetically available radiation scatter charts

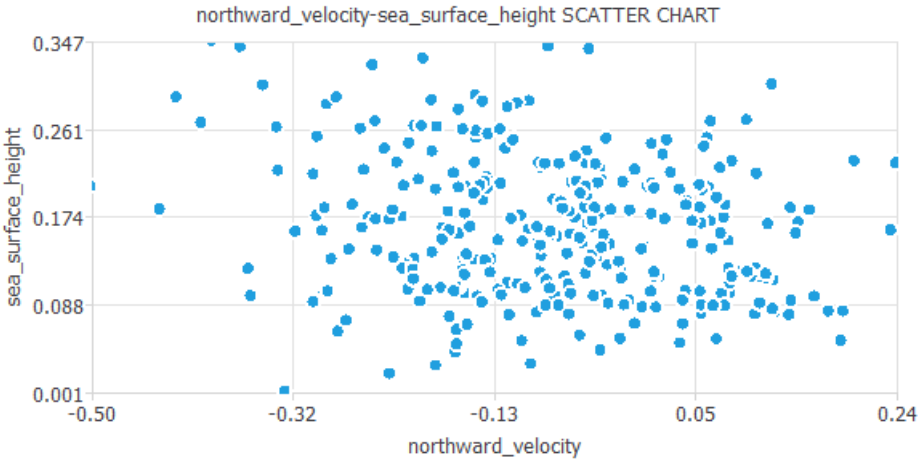





photosynthetically_available_radiation-salinity SCATTER CHART
39.38
38.85
38.32
37.79
37.27
salinity
2.2
17.1
31.9
46.8
61.7
photosynthetically_available_radiation


photosynthetically_available_radiation-northward_velocity SCATTER CHART
0.24
0.05
-0.13
-0.32
-0.50
northward_velocity
2.2
17.1
31.9
46.8
61.7
photosynthetically_available_radiation


photosynthetically_available_radiation-eastward_velocity SCATTER CHART
0.263
0.165
0.067
-0.031
-0.129
eastward_velocity
2.2
17.1
31.9
46.8
61.7
photosynthetically_available_radiation


northward_velocity-sea_surface_height SCATTER CHART
0.347
0.261
0.174
0.088
0.001
sea_surface_height
-0.50
-0.32
-0.13
0.05
0.24
northward_velocity