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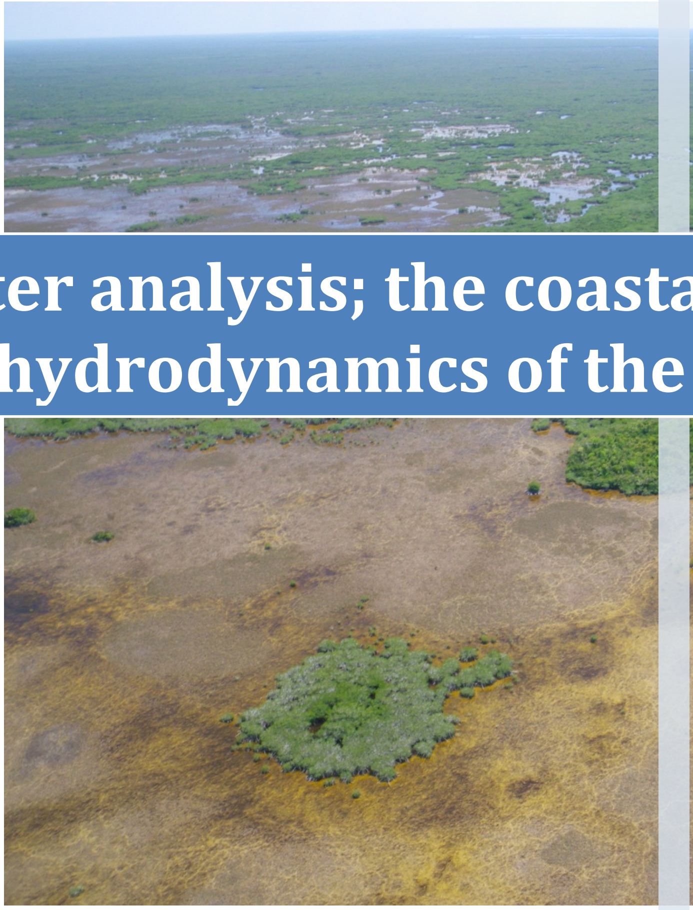

Water analysis; the coastal estuary-marsh hydrodynamics of the Everglades, USA

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United States Geological Survey

Van Hall Larenstein, University of Applied Sciences

12/20/2012

University of Applied Sciences VAN HALL LARENSTEIN PART OF WAGENINGEN UR

USGS science for a changing world

Water analysis; the coastal estuary-marsh hydrodynamics of the Everglades, USA

Bachelor

Thesis

Land and Water Management

December 2012

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Velp, the Netherlands

United States Geological Survey

Van Hall Larenstein, University of Applied Sciences

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Summary

To fulfill the demands for my Bachelor thesis (March to July 2012), I served an internship with the U.S. Geological Survey at Everglades National Park. Everglades National Park is situated on the southern tip of the Florida Peninsula. Everglades National Park is the only subtropical preserve in North America. It contains both temperate and tropical plant communities, including sawgrass prairies, mangrove and cypress swamps, pinelands, and hardwood hammocks, as well as marine and estuarine environments. The Shark River is the primarily drainage river for the Shark River Slough, that is situated up northeast of the actual river. From the north of the Shark River Slough, the freshwater flows into Everglades National Park. The water exits the park at the Gulf of Mexico on the southwest.

The objective for this project is to answer the research questions that are stated. The main objective is to find out what the water data indicates about the quality and quantity (salinity levels and water levels) of the years 2004 to 2011. This is relevant for the understanding of possible on-going changes in the Everglades. Therefore, research on water datasets of the Shark River is vital.

The main question of the project is:

What do the water-data (salinity, rainfall, ground- and surface water levels) indicate about the water quality and quantity of the years 2004 to 2011?

This project was conducted with a literature study, data collection, data analysis and interpretation. Existing study sites were used and the data of these corresponding sites were collected and analyzed by using programs like MatLab and Excel. From October the 1st till the 30th of September for every year (2004-2011) data is collected. This local data consists of groundwater levels, surface water levels and salinity levels.

For the analysis, the program MatLab was used. This program can perform statistical analysis on water data.

Further interpretation of the observations is key to determine what is going on in the Everglades.

In conclusion there can be said that the water quality and quantity of the Shark River during the 7 years, do change. Seasonal and annual trends are present every year. Looking at the 7 years as a whole, the years do not really differ. The levels of salinity and the levels of ground- and surface water, show similar trends for every year. Just before the wet season starts, the highest salinity levels are measured. The salinity levels in surface water have the highest values for every Shark River site in May/June every year. Ground and surface water levels, keep almost the same averages per year. Groundwater lags 2 months behind (levels go up), compared to the surface water change.

Because the river is situated in a delta, the river has influences by tidal movements. For the site SH3 (Shark River 3, situated at the Shark River and 7 kilometers from the coast), clear trends are noticeable. Especially the 14day, 28day, 180day and 365day trends are clear. The reason that there are 14day and 28day trends is because the tidal influence caused are by cycles of the Moon and the Sun. The other two trends come from seasonal weather changes.

Concluding, the Everglades, the Shark River in particularly, is a dynamic environment. Salt- and freshwater, rainfall and tidal cycles are the most important influences in the area. So far, influences

of climate change were not measured. The Everglades will always be an interesting topic for research projects about salinity and water data analysis.

Glossary

Correlogram	= A curve plotted to show the autocorrelation between two values for a certain lag. (Autocorrelation graph) Using water- and salinity levels as data input for these graphs.
DataforEVER	= An online-database of all the data that is collected in the Everglades National Park.
Dry Season	= The dry season is the winter. The dry season starts around October and ends around the month May. During the wintertime there is almost no rainfall.
Ecotone	= Transition zone in the Everglades consisting of mangroves.
FCE-LTER	= Florida Coastal Everglades Long-Term Ecological Research
Forcings	= Influences from the outside, such as tides, seasonal freshwater runoff, rainfall and urbanization.
Gage	= A measuring point. (In English "gauge")
GOES	= Geostationary Operational Environmental Satellite
Hydrodynamics	= Hydrologic dynamics of a certain area.
NAVD 88	= North American Vertical Datum, that is established in the year 1988. The NAVD 88 is the database that contains all the ground elevations in North America.
Noise	= Random and unreliable patterns at the end of the spectral analysis plots, often shaped as wide peaks. This comes primarily from gaps in data sets, the reason that the expected peaks are not present and vice versa.
PPT and PSU	= Parts Per Thousand (chemical) and Practical Salinity Units (electrical)
Slough	= A slough is a low-lying area of land that channels water through the Everglades. These shallow marshy rivers are the drainage pathways from the freshwater Everglades to the coastal estuaries.
Stage	= Surface water level.
Wateryear	= A wateryear starts at 10/01/year and ends at 09/30/year.
Wet Season	= The wet season is in the summer. It starts around May and ends around the month October. During the summertime there is a lot of rainfall.

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1. Introduction

To fulfill the demands for my Bachelor thesis (March to July 2012), I served an internship with the U.S. Geological Survey at Everglades National Park. The United States Geological Survey (USGS) is a science organization that provides impartial information on the health of ecosystems and the environment, the natural hazards, the natural resources, the impacts of climate and land-use change.

The goal for my graduation project is to draw conclusions from analyses of USGS coastal water data collected 2004-2011 from six coastal gages located in and near the Shark River estuary/drainage. This is a follow up research, after Theo Vlaar's research in the year 2005[1], with the following main hypothesis; "The influence of regional physical forcings, such as freshwater discharge, ocean exchange, and atmosphere, varies spatially on the water levels and salinity along the Shark River transects."

I used time-series analysis, spectral-analysis and autocorrelation techniques. This analysis will help the USGS scientists to understand more about the hydrologic patterns and trends, so they can use it as useful information and as guidance for future researches.

The Everglades is vulnerable to climate change. If the seasonal changes of flood and drought are changed, it will have devastating consequences for the flora and fauna in the Everglades National Park. Furthermore, climate change is attended by sea level rise. This probably leads to higher salinity levels, forced by tides. (Florida Coastal Everglades Long Term Ecological Research, 2012)[2] These changes are the effects of climate change in the area. For this National Park, effects of dryer and wetter periods can lead to extreme floods and droughts. Although not fully proven, ecological changes like the manatees that are moving up to northern parts of Florida, indicate that changes are going on. Manatees need freshwater to survive and less and less freshwater is present in the south of Florida.

Climate change will influence the water system as it is nowadays. The effects of climate change will also have a big influence on flora and fauna. For instance, the endangered "Cape Sable Seaside Sparrow" will probably become extinct in a few decades if the climate change continues. The sea level rise will most likely also have negative effect on fish and other species. But for this all to happen, the data can say if climate change is already effecting the water system or not. The emphasis is more on the possible changes caused probably by natural influences but also by human influences. The results of the analysis will say if these changes are present.

The Everglades coastal system is under influence by both marine and freshwater. The monitoring and analysis of ground- and surface water levels, salinity and rainfall is vital for evaluating and managing the estuary system in Everglades National Park. Tidal cycles, climate change and salt- and freshwater trends are the study objects of this research. That is why these following questions have been setup.

[1] Hydrologic conditions of Shark River Estuary Everglades, Theo Vlaar; for more information, see Bibliography, page 54.
[2] Sources are referred by title and year; see bibliography, page 54.

The main question of the project is:

What do the water-data (salinity, rainfall, ground- and surface water levels) indicate about the water quality and quantity of the years 2004 to 2011?

To answer the main question, these sub questions are relevant:

1. *What are the ground and surface water salinity seasonal patterns?*

2. *How do surface and groundwater levels differ on site and with other sites?*

3. *How do tidal exchange, freshwater discharge and rainfall forcings influence hydrodynamics in the Shark River and adjacent mangrove-marsh communities?*

This project was conducted with literature study, data collection, data analysis and interpretation. Existing study sites were used and the data of these corresponding sites were analyzed by using software like MatLab and Excel.

Results of the analysis should be an aid to understand sea level rise and seasonal hydrodynamics of the coastal Everglades ecosystem.

The report begins with an introduction about the Everglades and the Shark River Slough. The project objectives are next. These explain what the project is really about. The methods are described in the following chapter. The results are found in chapter 4, all observations can be found in that chapter. The results are interpreted in Chapter 5, this chapter concludes maps and describes the water system.

With all this in mind, a discussion was made, plus a few recommendations. And at the end of this thesis conclusions were deduced, giving answers on the research question. For examples and clearer figures, consult the annexes.

2. Framework

Water in south Florida once flowed freely from the Kissimmee River to Lake Okeechobee and southward over low-lying lands to the estuaries of Biscayne Bay and Florida Bay. This shallow, slow-moving sheet of water covered almost 11,000 square miles, creating a variety of ponds, sloughs, sawgrass marshes, hardwood hammocks, and forested uplands. For thousands of years this complicated system evolved into a finely balanced ecosystem that formed the biological infrastructure for the southern half of the state. See figure 1. (National Park Service, 2012)

However, to early colonial settlers and developers the Everglades were potential farmlands. By the early 1900s, the drainage process began to transform wetland to land ready to be developed. The results of this were severely damaging to the ecosystem and the species it supported. (National Park Service, 2012)

With the support of many early conservationists Everglades National Park was established in 1947 to conserve the natural landscape and prevent further degradation of its land, plants, and animals.

Although the captivation of the Everglades has mostly stemmed from its unique ecosystem, an alluring human story of the Everglades is deeply entwined with its endless marshes, dense mangroves, towering palms, alligator holes, and tropical fauna. Various groups and people navigated through and wrestled with the watery landscape to make it home, and even to exploit its natural wonder at times. (National Park Service, 2012)

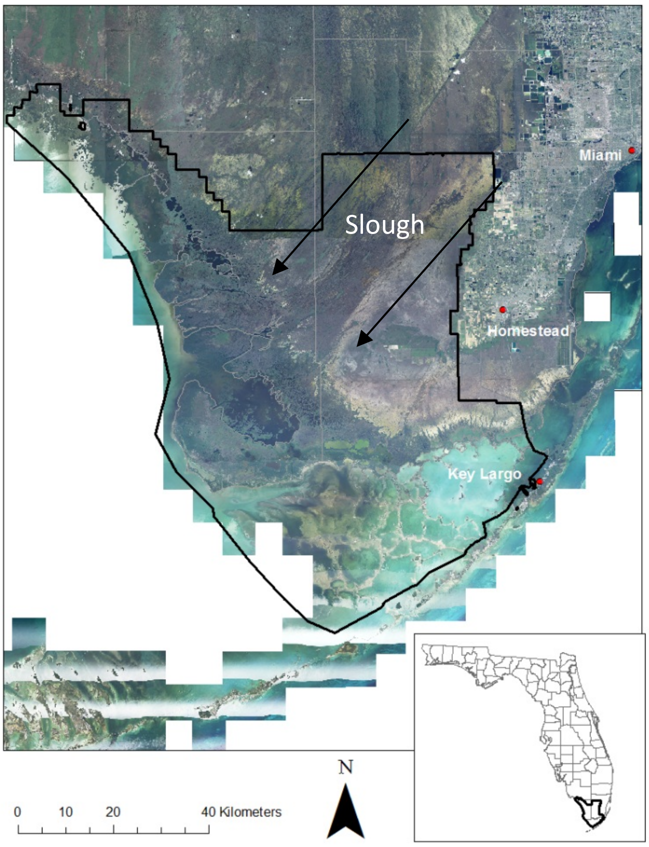

Figure 1; The Everglades, Florida

Everglades National Park has been designated a World Heritage Site, an International Biosphere Reserve, and a Wetland of International Importance.

Everglades National Park is now situated on the southern tip of the Florida Peninsula. Everglades National Park is the only subtropical preserve in North America. It contains both temperate and tropical plant communities, including sawgrass prairies, mangrove and cypress swamps, pinelands, and hardwood hammocks, as well as marine and estuarine environments. The park is known for its rich bird life. It is the only place in the world where alligators and crocodiles exist side by side. (National Park Service, 2012)

The park is bounded by the Gulf of Mexico to the west, the Tamiami Trail and mostly state lands to the north and the Florida Keys to the south and southeast. It includes most of Florida Bay. Everglades National Park is a shallow basin tilted to the southwest and underlain by extensive

Pleistocene (the era before the Holocene) limestone. The park serves as a vital recharge area for the Biscayne Aquifer, a major source of freshwater for Miami and southeast Florida. It lies at the interface between temperate and subtropical America and between fresh and brackish water, shallow bays and deeper coastal waters. This creates a complex of habitats supporting a high diversity of flora and fauna. The most important trees are mangroves, taxa, slash pine and cypress. Prairies can be dominated by sawgrass, muhley grass, or cordgrass in coastal areas.

For this project The Florida Coastal Everglades Long-Term Ecological Research (FCE-LTER) is important. It already has a lot of data information and will go on to study this important topic (the Everglades). The research involves all stakeholders and will be an important research for the Everglades and her problems containing every aspect that influences the National Park. (Florida Coastal Everglades Long Term Ecological Research, 2012)

2.1 Shark River Slough

A slough ("river of grass") is a low-lying area of land that channels water through the Everglades. These marshy rivers are relatively deep and remain flooded almost all year-round. Though they are the main avenue of mainly freshwater flow, the current remains leisurely, moving about 100 feet (30 meters) per day.

The Shark River is the primarily drainage river in the Everglades that begins at the end of the slough, see figure 2. From the north of the Shark River Slough, the freshwater flows into Everglades National Park. The water exits the park at the Gulf of Mexico on the southwest and the Florida Bay on the southeast side of the Peninsula. For the FCE-LTER, the estuarine ecotones of the Shark River Slough are of particular interest to the scientists who contribute to the research. Estuarine ecotones are the regions where freshwater mixes with saltwater and the grassy marshes give way to mangrove forests.

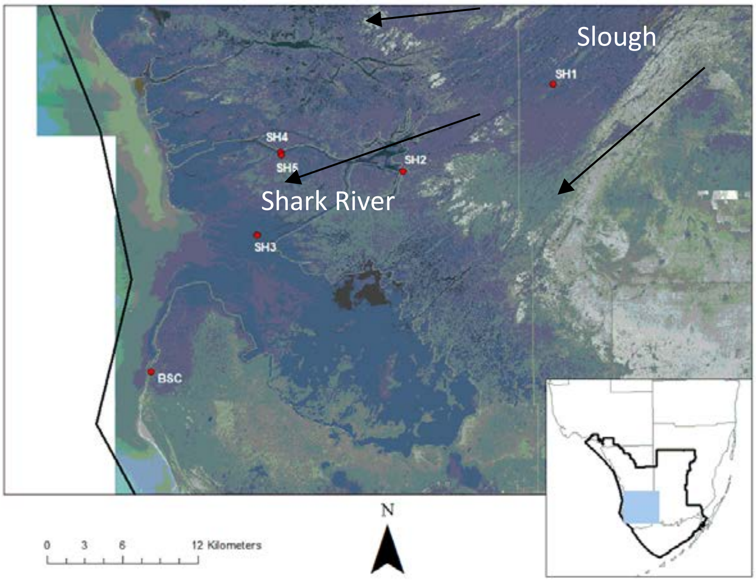

Figure 2; Flow direction, Shark River

Mangroves are salt-tolerant trees that dominate the forests near the creeks along the shoreline. The mangrove forests in the coastal area get flooded regularly. In the Everglades, the red mangrove, the white mangrove en the black mangrove can resist the large annual variation in salinity. Near the shoreline, the salinity of the water approaches the salinity of the sea. More inlands the salinity levels go down. (National Park Service, 2012)

One of the ecotones is a part of the Shark River Slough. All the gages that are used in this research are situated at the Shark River, south of the Shark River Slough and take also part in a bigger research project (the FCE-LTER).

2.2 Project Objectives

The Everglades coastal system is under influence by both marine and freshwater. Ecotones can be seen in figure 3. The monitoring and analysis of ground- and surface water levels, salinity and rainfall is vital to evaluating and managing the coastal ecosystem in Everglades National Park. Monitoring and analyzing water levels en salinity levels are important for evaluating the ecotone in Everglades National Park. As written before, the FCE-LTER scientists find this the most important part of the Everglades.

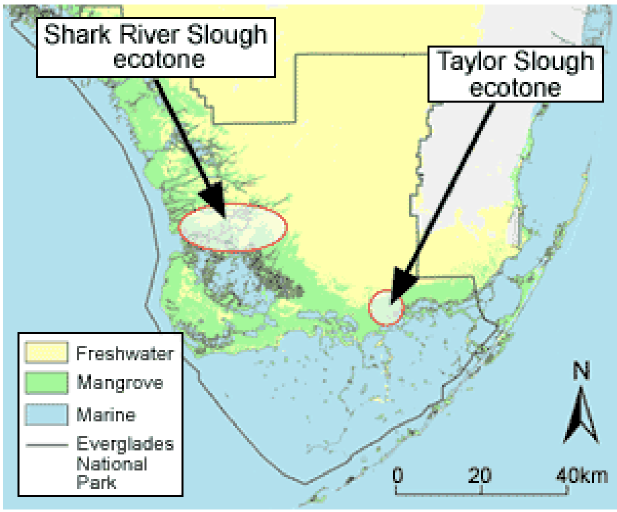

Figure 3; Position SRS, the Everglades

The objective for this project is to provide a clear view of the trends and patterns in the huge amount of data that were collected in the Everglades over the years 2004-2011. This way the US Geological Survey may conclude whether climate change is already affecting the area or that only natural trends are occurring.

The focus is to find out what the water data say about the quality and quantity (e.g. salinity levels and water levels). This is relevant for the understanding of possible ongoing changes in the Everglades. By completing this research, more things can be said about the seven-year data collection. For instance, trends in water data time-series can be found and seasonal and/or tidal patterns in the Florida Everglades can result from analyzes. So research on water datasets of the Shark River sites is vital.

3. Methods

This project was conducted by data collection, data analysis, and interpretations. Existing study sites were used and the data of these corresponding sites were collected. After collecting all the data (DataforEVER), the data was analyzed by using programs like MatLab and Excel.

3.1 Study sites

The study sites are situated in the southwest of the National Park, The Everglades. In figure 4 on the right, the situation is shown. From the gage in the north (SH1) to the gage in the south (BSC), the distance is about 20 miles (30 km). During the way down southwest, the water will pass the gages in following order; the first gage is SH1, the second gage is SH2, the 3rd en 4th gages are titled as SH4 and SH5. After these four gages, the water will pass SH3 (this is in the center of the inlet of the river, were salt- and freshwater get mixed). The site BSC, is situated in the same line but is not connected with the water from the Shark River. The gage at Big Sable Creek (BSC) measures the seawater and water from the creek itself. And in that way it is separated from the other measuring sites.

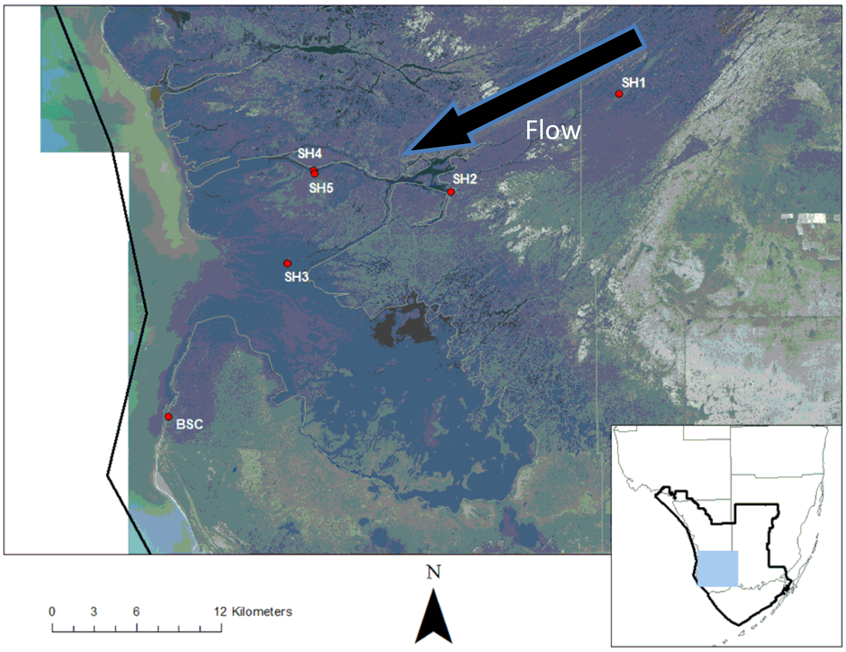

Figure 4; Study sites; The Everglades, Florida

For all the study sites that are used in this research, the ground elevation is known. All water level data is based on the North American Vertical Datum of 1988 (NAVD 88). From October the 1st till the 30th of September for every year (2004-2011) data is collected. This local data consists of groundwater level, surface water level and the salinity of the ground- and surface water. These parameters are used to answer the research questions that are stated for this research (see chapter 1).

For the gage at Big Sable Creek (BSC), this information about the ground elevation is irrelevant because this gage does not measure groundwater levels or salinity in these groundwater levels whatsoever. This gage measures the surface water level and salinity level for surface water. This gage is situated on a tidal creek near the shoreline of the Gulf of Mexico, and so the ground elevation constantly changes.

These values are the ground elevations of the sites based on the NAVD 88:

- SH1: -0.32 feet
- SH2: -0.52 feet
- SH3: +0.27 feet
- SH4: +0.37 feet
- SH5: +0.16 feet

Big Sable Creek (BSC)

The gage “BSC” is situated at the south arm of Big Sable Creek, terminating into a large mud tide flat. This creek gets the name from the cape “Big Sable”. This station is the closest station to the Gulf of Mexico. It has a big tidal influence. It has a bigger influence by the sea than gage SH3. This site (BSC) is situated on water and the gage of site is located on the side of the river. The station (BSC) does not measure groundwater, because it has no well for it. So for water data, only surface water levels (and salinity values) are used.

Shark River 1 (SH1)

SH1 is a freshwater site located in the Shark River Slough. It has a mixed vegetation community of sawgrass *(Cladium jamaicense)* and spikerush *(Eleocharis cellulose)*. This site is northernmost site that is used for this research. Here freshwater flows overland, coming from the north along a slight downward gradient of the Shark River Slough. Local precipitation also contributes the water input to the site SH1. Since SH1 is upstream of tidal influences, tidal forcings are not significant.

Shark River 2 (SH2)

The marsh-estuary transitional site SH2 is situated adjacent to Tarpon Bay and is characterized as an ecotone site. This is an area between the freshwater marsh and saline estuary in which the hydrodynamics are influenced by daily tides, freshwater flow, and local precipitation. Medium (height <6 meter) red, white and black mangroves are present. Mangroves are key to the ecotone of the Shark River Slough.

Shark River 3 (SH3)

This station is the mangrove estuary site, with trees up to 20 meters. This station is located just three miles northeast of the Gulf of Mexico. This site is under a big influence by the saltwater coming in to the Shark River, although the gages are situated 30 meters from the riverbank. With the tides coming in, the bank where the gage is placed becomes flooded. When the tides are low, the soil is still saturated with water but there is not “visible” water anymore.

Shark River (SH4)

This site is located in a tall mangrove forest and surface water is most influenced by periodic tidal forcings, especially during springtides. It is also influenced by local precipitation. This gage (next to the Shark River) and the station SH5 have the same distance towards the Gulf of Mexico, but SH5 is 1000 feet inland and is not as influenced by tidal forcings as SH4.

Shark River 5 (SH5)

SH5 is less influenced by the sea than SH4 (marshy land 1000 feet inland). Except for extreme tides and storm events. This site is more influenced by local precipitation and overland flow. Freshwater flows from the Shark River Slough are not significant because the sites are located on a coastal island. So, SH5 is actually isolated from the tidal creeks and Shark River Slough flow.

Tables of gage information:

Gages	BSC	SH1	SH2	SH3	SH4	SH5
Salinity GW (PPT)		x	x	x	x	x
Salinity SW (PPT)	x	x	x	x	x	x
Groundwater level (ft absl)		x	x	x	x	x
Surface water level (ft absl)	x	x	x	x	x	x

Table 1, Gage information; parameters.

Gages	BSC	SH1	SH2	SH3	SH4	SH5
Fresh water		x				
Salt water	x			x	x	
Brackish water			x			x

Table 2, Gage information; water type.

Gages	BSC	SH1	SH2	SH3	SH4	SH5
River	x		x	x	x	
Land		x				x

Table 3, Gage information; land/river.

3.2 Data collection

Data is collected from October the 1st 2004 till the 30th of September 2011. This local data consists of groundwater levels, surface water levels and the salinity values of the same water levels. All years together from 2004 till 2011, is a total of 7 years. The data comes from different kinds of sources. For the data collection, DataForEVER is used. This is an online-database of all the data that is collected in the Everglades National Park. Not only data is based here, with this online-database additional statistics could be calculated, like exceedance curves.

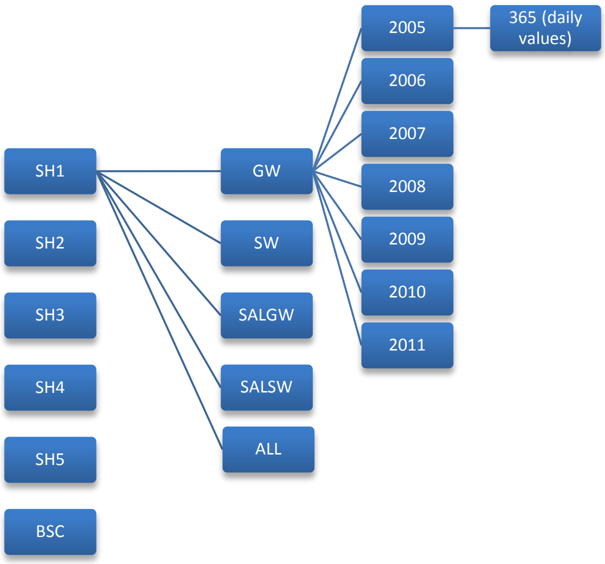

Figure 5, Visualization the data collection

For every year, for every gage, water levels (in foot, the English System) and salinity (in PPT (Parts Per Thousand)) levels were collected (≈70.000 values are used during this research). For the structure, see figure 5. These data sets can show interesting findings. Before the data is stored in the online database, data is transmitted via GOES satellite, transferred directly to the database from the corresponding field station.

During all the years of collecting data, missing values will sometimes appear. This has various reasons, but the two main reasons for this are power failures and faulty equipment, due to accidental hurricanes, salt water and moisture. For this project, missing data values (nulls) are integrated as zero values. This means that the missing data values became zeros (0's). And these zeros were included in the calculations during the analysis of the data series.

3.3 Data Analysis

The programs used for this project are programs that have a good connection with analyzing data that comes from water measuring stations. Eventually the graph of, for example site Shark River 3 (SH3), ground water level (GWL) will show the time-series graph, spectral-analysis graph and an autocorrelation graph.

Except the analysis-type “Exceedance curves” (see chapter 3.3.1), all the analyzing is done with one program. This program is called MatLab and is a programming environment for algorithm development, data analysis, visualization, and numerical computation. MatLab can be used in a wide range of applications, including signal and image processing, communications, control design, test and measurement, financial modeling and analysis. For an example, see annex 4. (Mathworks, 2012)

To eventually have all the graphs and analysis completed, a few methods were used. These methods are the key for looking at water data in a way, that lots of information about certain trends, correlations en remarkable points will show. The following methods below were used for this research about the water data of the Shark River and Big Sable Creek.

3.3.1 Exceedance curves

To find out the answer for the possible influence of climate change, exceedance curves are made. In the Everglades there are lot of interactions between discharging and recharging of surface water. With graphs such as exceedance curves, there will be clear view of the water level during a period of time. Thus, an exceedance curve is a graph that represents the percent of time water levels exceeds a reference elevation (ground surface). For every site and year, exceedance curves are used. Via DataforEVER (see glossary), the datasets are processed and graphs are made with the online database (by DataforEVER, graphs are stored on the included CD, see annex 6).

3.3.2 Autocorrelation

When analyzing a time-series, study of the interdependence of the outcomes of two consecutive measurements of a single variable is important. The extent to which the two measured values correlate, is calculated (autocorrelation, Y). Note that the time between the two measurements of the variable, the lag, can be different. Next, a correlogram is created by plotting the autocorrelations (Y) as a function of the lags (X). The correlogram in Figure 14 shows that for a 1-day lag, the correlation is extremely high (1.0 or 100%) as it is for a lag of 360 days (0.6 or 60%). For a lag of 180 days, however, autocorrelation is strongly negative (-0.4 or -40%). This sinusoidal shape reflects a clear seasonal influence. A tool is made as an example to show the interpretation for different lags, see Figure 14, the time-series graph.

3.3.3 Spectral analysis

To find patterns in water and salinity data, such as trends that occur by influence of the sea, spectral analysis is used. Instead of plotting the amplitude (an example; the data set for 1 year of groundwater levels) versus the time-domain (e.g. time-series), spectral-analysis is plotting the amplitude (for instance; the groundwater levels again of the same year) versus the frequency of all these different groundwater levels. If a certain groundwater level often occurs with the same regularity, there will be a peak in the spectral analysis graph. For water levels, which not often occur, there will be smaller peaks or even no peaks at all.

With spectral-analysis, the original data is being dissected in order to find monthly, seasonal, and annual cycles. So the resulting graph may show peaks that indicate a cycle for a certain period of time. A high and slim peak means, that a particular data-type frequently occurs. The graphs are the result of datasets that are transformed and processed by a program in the MatLab software.

3.3.4 Time-series

A definition of time-series is:

> *An ordered sequence of values of a variable at equally spaced time intervals. (Investopedia, 2012)*

So, a time series is simply a sequence of numbers collected at regular intervals over a period of time. These graphs are done for every year for every station. It gives a clear view of the data that is collected during the seven years concerning this project.

4 Results

This chapter shows the results of the data analysis, concluding the time-series, spectral-analysis, autocorrelations and exceedance curves. The graphs indicate the probable trends and patterns in the data, per gage and site, which were collected during the years 2004-2011.

4.1 Big Sable Creek (BSC)

4.1.1 Surface water level (see figure 6)

- For the spectral analysis graph, there are no peaks at 30 days (4week cycle of the moon) and for instance at 180 days (seasonal). That is really striking, because this gage has a lot of influence by the sea (Gulf of Mexico).
- In the time-series graph, constants peaks are noticeable, but are not noticeable in the spectral analysis graphs.
- Further in the time-series, the average water level is 0.8 foot below sea level.
- From late October 2005 to August 2006 there is no collected data because the gage equipment was destroyed by Hurricane Wilma (October 26).
- Just before equipment was lost, there was a water level of about 3 feet below sea level.
- Highest levels were measured during the wateryear of 2007, with levels of 0.5 foot above sea level in the time-series chart.
- The driest periods are around the month February.
- The wettest periods are around the month October.
- The red fitted line, that is noticeable in the time-series graph, indicates the average slope of the graphs. This fitted line is the mean and is taken from the corresponding data set. In the formula (y = …) the slope is given. The gradient can be positive and negative for different time-series graphs. But not for the same graph.
- “Noise”[3] can be found in the spectral analysis plot. Pointed out in the corresponding graph (with the black arrow), as an example. In all the spectral analysis graphs there are noise peaks present.
- There is a strong autocorrelation for the 1day lag, for a lag of 1,5 year (around the 550 day) there is a 0.2 strong negative correlation. This means that for every lag of 1,5 year, the two measurements are not very similar.

4.1.2 Salinity surface water level (see figure 7)

- In the time-series graph, there is an average salinity level of 33 Parts Per Thousand. This is directly related to salt seawater with an average of 35 PPT.
- There is not a lot of fluctuation in the time-series graph.
- The fitted line, indicates a positive slope, the main reason of the big slope are the missing data values for the wateryear 2005-2006.
- From late October to August 2006 there is no data. This is because of the hurricane.
- A 400-day peak is visible in the spectral analysis graph. No further specific peaks are visible.
- Because of the big gap in data, the autocorrelation will not work very well. With the lag starting at 1 day and keeps getting bigger the correlation is going to be negative. Because the lags after 365 days are negative, the two measurements are not similar. There is no seasonal pattern visible.

There is no groundwater well so there is no data available for this site for Big Sable Creek.

[3] “Noise” explained in the Glossary; see page 6.

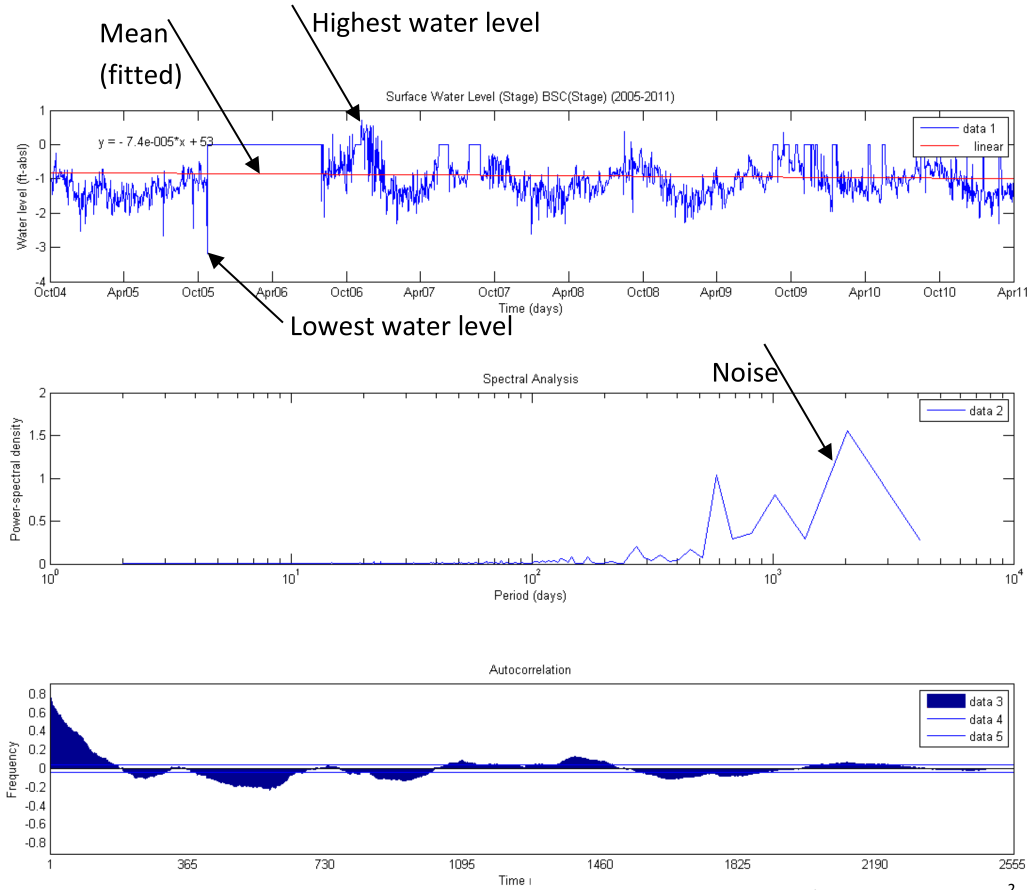

Figure 6; Time-s., spectral., autoco.; BSC, SW [2]

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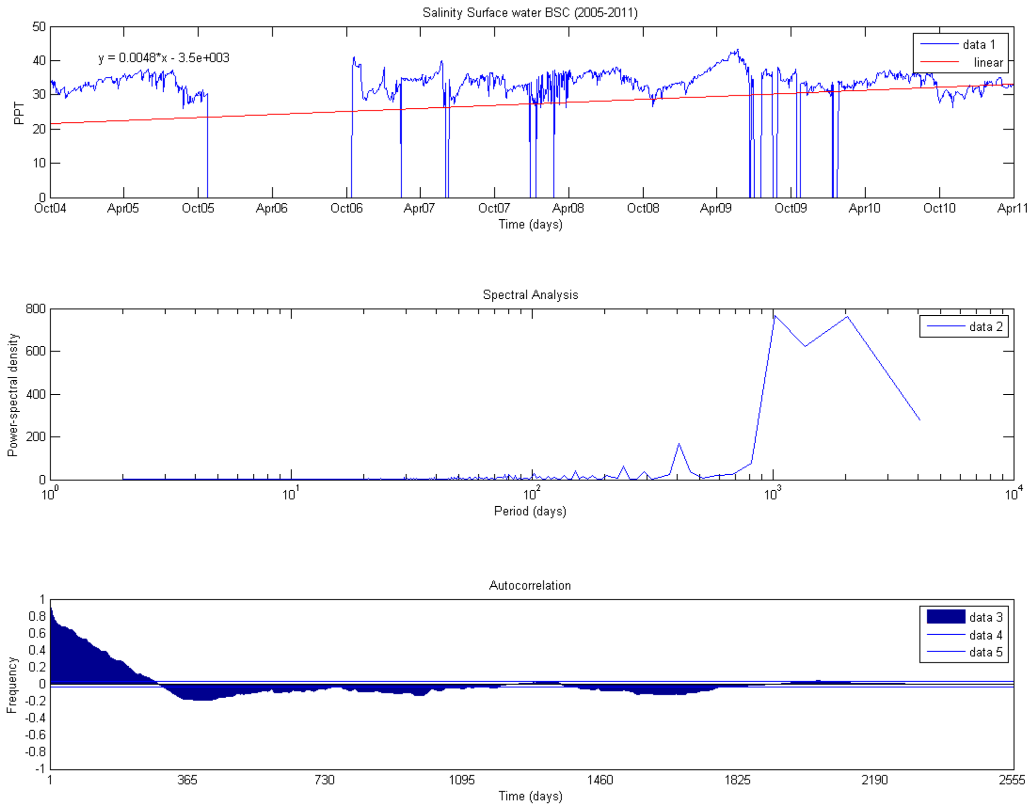


Figure 7; Time-s., spectral., autoco.; BSC SALSW

[4] For full title, see figure list page 7.

4.2 Shark River 1 (SH1)

4.2.1 Ground water level (see figure 8)

- For the time-series graph, the beginning of the wateryear of 2005(October), the ground water level is 1.5 feet above sea level and in the beginning of wateryear 2011 the groundwater level is 1.8 feet above sea level.
- At the end of the wateryear of 2005 the water level is 2 feet above sea level and at the end of wateryear 2011 the water level is 1.5 foot above sea level, looking at the time-series graph.
- In the winter season the groundwater level goes down. In the summer season the groundwater level goes up in the all-year graph of the time-series.
- Fluctuation in groundwater levels per year is present.
- The fitted line, indicates a light negative slope, the main reason of the negative slope are the missing water values for the months October - March of wateryear 2008-2009.
- Per wateryear there no real patterns noticeable, looking at the spectral analysis graph, but looking at the 7year graph a 300 and 600day peak is present.
- The seasonal and yearly patterns are present in the 7year time-series graph (time-series graph). These patterns are not visible in the spectral analysis graph. But in the correlogram they are visible (≈180 days per season).
- From October 2008 till February 2009 there is no data.
- June and May are dry months, looking at the time-series.
- This groundwater gage fluctuates from 2.5feet (highest level) above sea level to about -0.8 feet (lowest level).
- For the autocorrelation graph, there is a slowly decrease in the pattern. The negative and positive difference gets less during the time.
- The sinusoidal shape reflects a clear seasonal influence. For a 1-day lag, the correlation extremely high (1.0) as it is for a lag of 360 days (0.4). For a lag of 180 days, however, autocorrelation is strongly negative (-0.35 or -35%). A lag of 550 day (1.5 year) is also negative (-0.4).

4.2.2 Salinity ground water level (see figure 9)

- Looking at the time-series there is a fluctuation of 0.2 PPT for the 2 seasons.
- In the time-series, the wateryear of 2010, in the winter the salinity level is around the 0.75 parts per thousand. And becomes 0.5 PPT again in the early summer months. This is almost for every year.
- For the wateryear of 2006, there are really high values for the salinity, almost 1 PPT. These are the months before the hurricane.
- There are missing values for the months June – February. Further Salinity values keep stable during the years in the time-series graph.
- The fitted line, indicates a light positive slope, the main reason of the positive slope are the missing data values for the wateryear 2006-2007.
- The average salinity level during the years is around the 0.75 Parts Per Thousand.
- No real clear peaks for the spectral analysis graphs, so the high and low salinity levels of every year in the time-series are not noticeable in the spectral graph.
- A start of a seasonal pattern is visible, but because there is a gap, this pattern kind of stops. A negative correlation for the lag of 180 days.

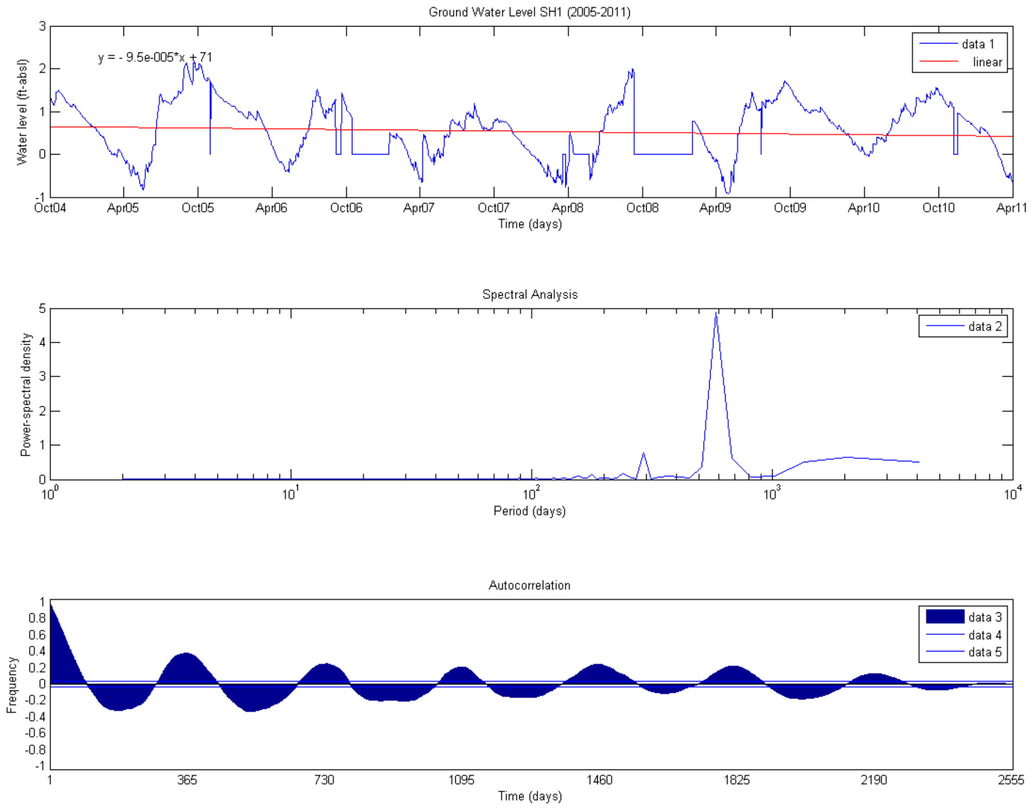


Figure 8; Time-s., spectral., autoco.; SH1 GW

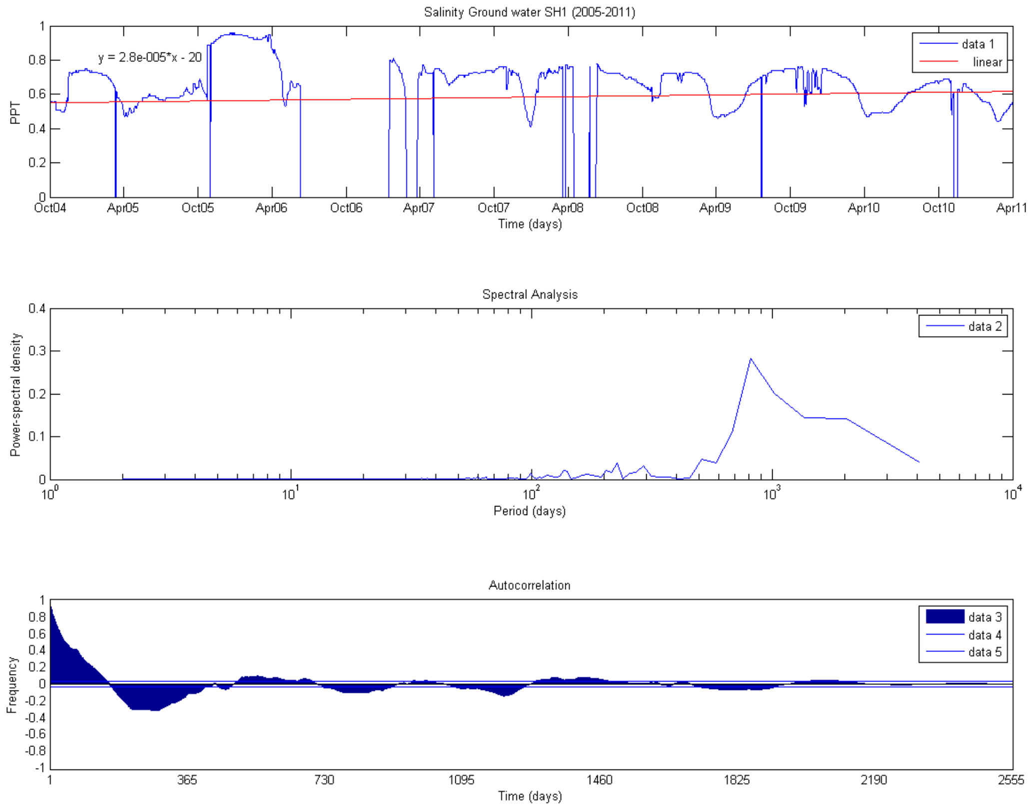


Figure 9; Time-s., spectral., autoco.; SH1 SALGW

4.2.3 Surface water level (see figure 10)

- In the time-series graph, for the wateryear 2010, the months of February, March and April have a really low surface water level. Just above the 0 feet.
- There are high water levels from July to January, around the 2 feet above sea level. For the low values, in the dry season, the average is about 0 feet above sea level.
- The highest surface water levels are measured in October and the lowest in around the month May.
- So every year there is a pattern noticeable in the time-series, but this patterns in not visible in the spectral analysis graph.
- There is though, a clear peak at 600 days for the spectral analysis.
- The fitted line with the red color, has almost no slope, the main reason for this is almost no change of water levels during the years.
- Seasonal patterns can be found in the correlogram. These seasons are about a half-year, with a lag of 180 days, there is a strong negative autocorrelation (-0.4). For a lag of about 360 days the autocorrelation is positive (0.4). This seasonal influence is also visible for the water levels for the time-series).

4.2.4 Salinity surface water level (see figure 11)

- Looking at the time-series diagram, in June for the wateryear 2005 there is a salinity level of 3 PPT and in the wateryear 2011 there is a peak with a value of 5 PPT.
- On average the salinity will rise from 0.2 PPT in October to about 0.6 PPT in April, May and June.
- The fitted line, indicates a positive slope, the main reason of this positive slope is the large salinity peak in the wateryear 2005.
- An 180day peak can be seen in the spectral diagram. Although this peak is kind of wide, there can be said that this indicates a seasonal pattern. Further there are no really clear trends to see in the spectral analysis graph.
- This most wide peak, indicating a seasonal change (in the spectral analysis) is not noticeable in the correlogram. The frequency is about 0 and indicates of no autocorrelation.

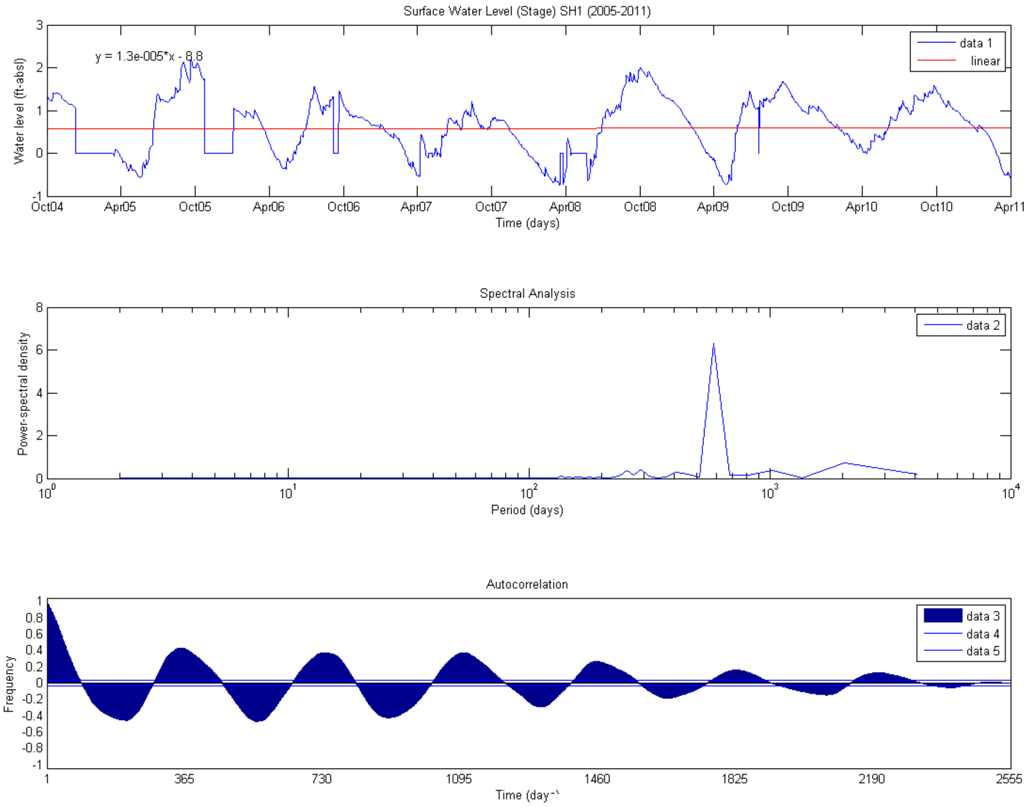


Figure 10; Time-s., spectral., autoco.; SH1 SW

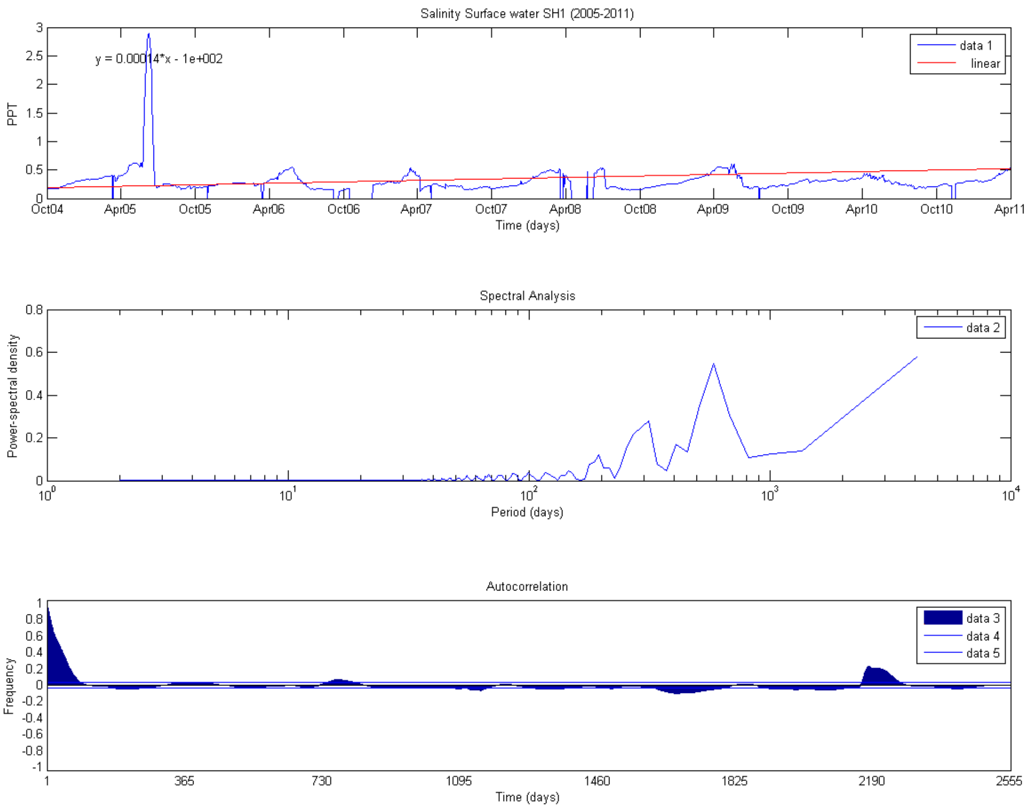


Figure 11; Time-s., spectral., autoco.; SH1 SALSW

4.3 Shark River 2 (SH2)

4.3.1 Ground water level (see figure 12)

- There is missing water data from September 2008 till mid July 2009.
- Looking at the time-series graph, the average water level is -0.25 foot under sea level.
- Between the maximum water level and the minimum water level is a distance of almost 2 feet as seen as in the time-series graph.
- The lowest level is -1.2 feet and the highest levels are around the +0.6 foot over the 7 years, looking at the time-series.
- The seasonal and yearly patterns are present in the 7year time-series graph (time-series graph).
- For the spectral analysis graph, a peak is visible at around the 600 days; this means that every 600 days there is a trend in the water fluctuation. The seasonal and yearly trends that are visible in the time-series are not present.
- All the years compared have a lot of similarities. There are no big differences.
- The fitted line that is visible has a slightly positive slope. This is because the missing data from September 2008 till mid July 2009. Because the missing data was entered as zero, the level is quite high. The reason for the positive slope of the red line.
- For a 1-day lag, the correlation extremely high (0.8) as it is for a lag of 360 days (0.4). For a lag of 180 days, however, autocorrelation is strongly negative (-0.4 or -40%). The sinusoidal shape reflects a clear seasonal influence. Because of the fluctuation in the time-series graph, there are little dents in the sinusoidal shape.

4.3.2 Salinity ground water level (see figure 13)

- For the salinity of groundwater, the values go up during the 7 years. This is noticeable with the red fitted line and because of the 2 high salinity years (2008 and 2009).
- With the sensor deeper in the ground, there is more fluctuation noticeable in the salinity levels.
- So you can say the ground water is getting saltier. From the year 2005 starting with 5 PPT to the year 2011 with an average of 10 PPT.
- This increase of salinity is because of a change in the position of the sensor in the groundwater well. Till 2007 the sensor was based 4 feet below ground elevation, after this the sensor was moved to 3 feet downwards.
- There are no real clear peaks in all of the spectral graphs.
- For a 1-day lag, the correlation extremely high (1.0) as it is for a lag of 360 days (0.4). For a lag of 180 days, however, autocorrelation is negative (-0.2 or -20%). For a lag of 1300 days, the autocorrelation is negative (-0.3). The sinusoidal form indicates a seasonal influence.

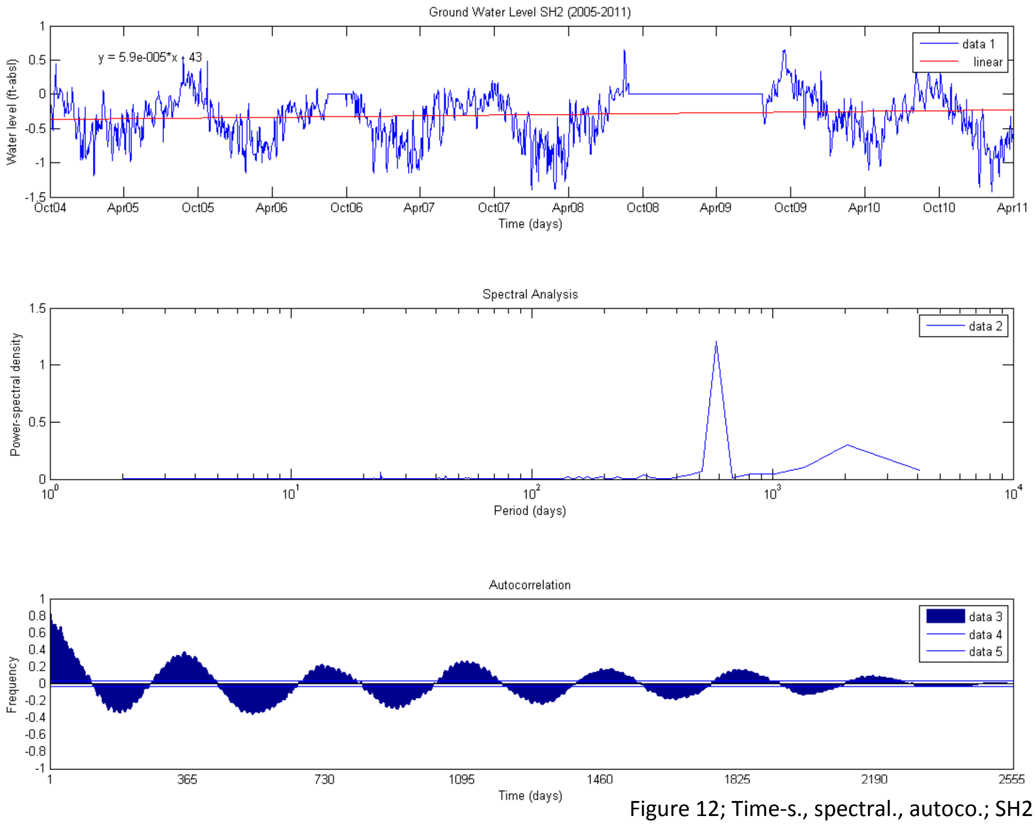


Figure 12; Time-s., spectral., autoco.; SH2 GW

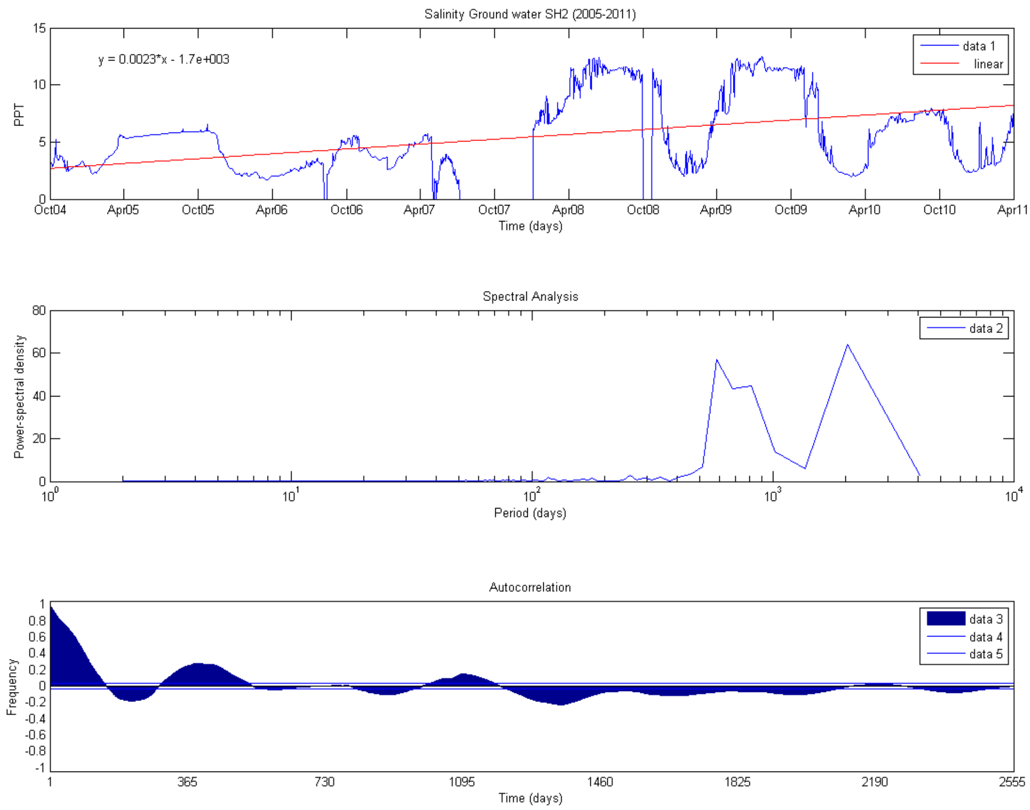


Figure 13; Time-s., spectral., autoco.; SH2 SALGW

4.3.3 Surface water level (see figure 14)

- Looking at the time-series chart, there is almost no missing data, you can see the annual cycle real clear again. The dry and wet seasons are present.
- In the time-series graph, the lowest values are in the driest months at the water years of 2008 and 2009, these years are slightly drier than the other dry periods for the other years.
- Looking at the red colored fitted line, the surface water level stays the same during the years. With max values in October around the 0.3 foot above sea level. And minimum values in April with values around the -1.2 feet below sea level.
- Around the month May the water level will start to rise.
- In the spectral analysis graph, there is a really clear 600-day peak. And the seasonal patterns are not visible, even though they are seen in the time-series diagram.
- Clear seasonal pattern in the autocorrelation graph. The sinusoidal shape indicates this. For a 1-day lag, the correlation extremely high (0.7) as it is for a lag of 360 days (0.5 or 50%). For a lag of 180 days, however, autocorrelation is strongly negative (-0.5 or -50%). For a lag of 2 (0.4) and 3 (0.3) years, the autocorrelation is strongly positive. For 1,5, 2,5 and 2,5 years, the autocorrelation is negative. In the time-series the fluctuation over the years is already an indication for the correlogram.

4.3.4 Salinity surface water level (see figure 15)

- Looking at the time-series chart, there is almost no missing data, you can see the annual cycle real clear again.
- For SH2 salinity surface water (time-series), the patterns are really clear. Big difference between the 2 seasons.
- For around 180 days and 300 days, there are peaks. There is also a 600-day peak.
- You can see low values in the summer months (3 PPT) and high values (22 PPT) in winter months (the dry season) just before the groundwater level rises again.
- During the 7 years the salinity goes up. The water becomes saltier. The average salinity in 2005 is 5 PPT and the wateryear of 2011 has an average of 7 PPT. This can be seen in the time-series chart.
- Because the full data set and clear pattern, there is also a clear seasonal pattern in the autocorrelation graph, the same as the previous 3 graphs of the surface water level (chapter 4.3.3). For a 1-day lag, the correlation extremely high (1.0) as it is for a lag of 360 days (0.6). For a lag of 180 days, however, autocorrelation is strongly negative (-0.4 or -40%).

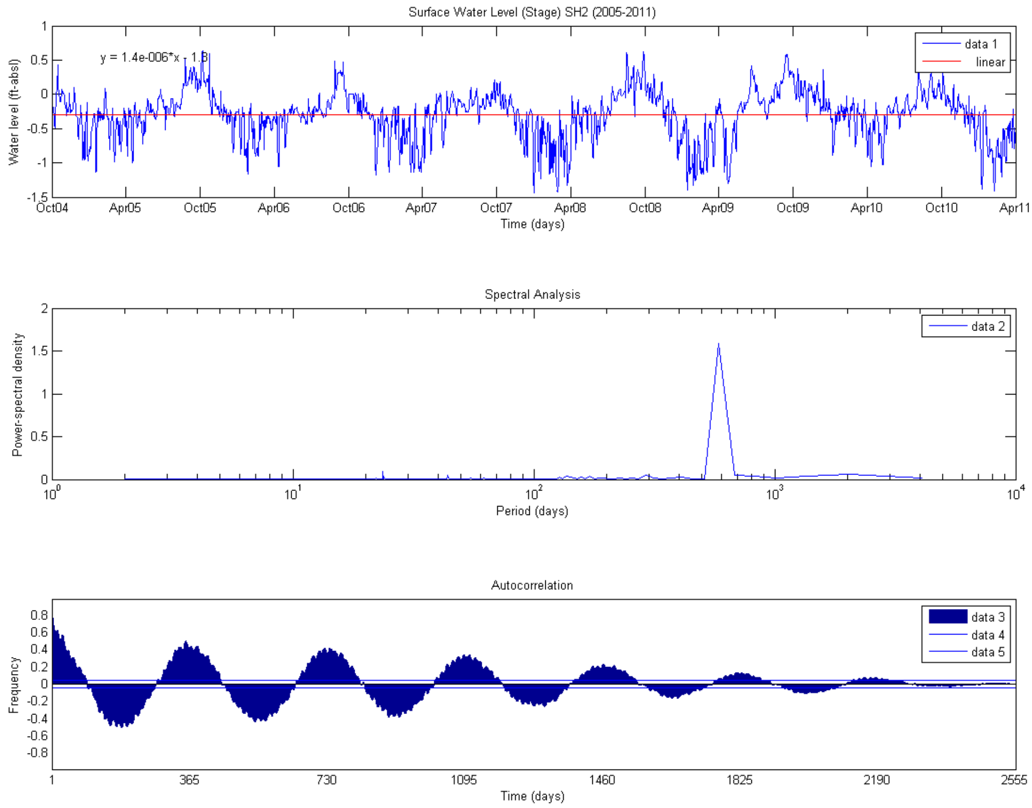


Figure 14; Time-s., spectral., autoco.; SH2 SW

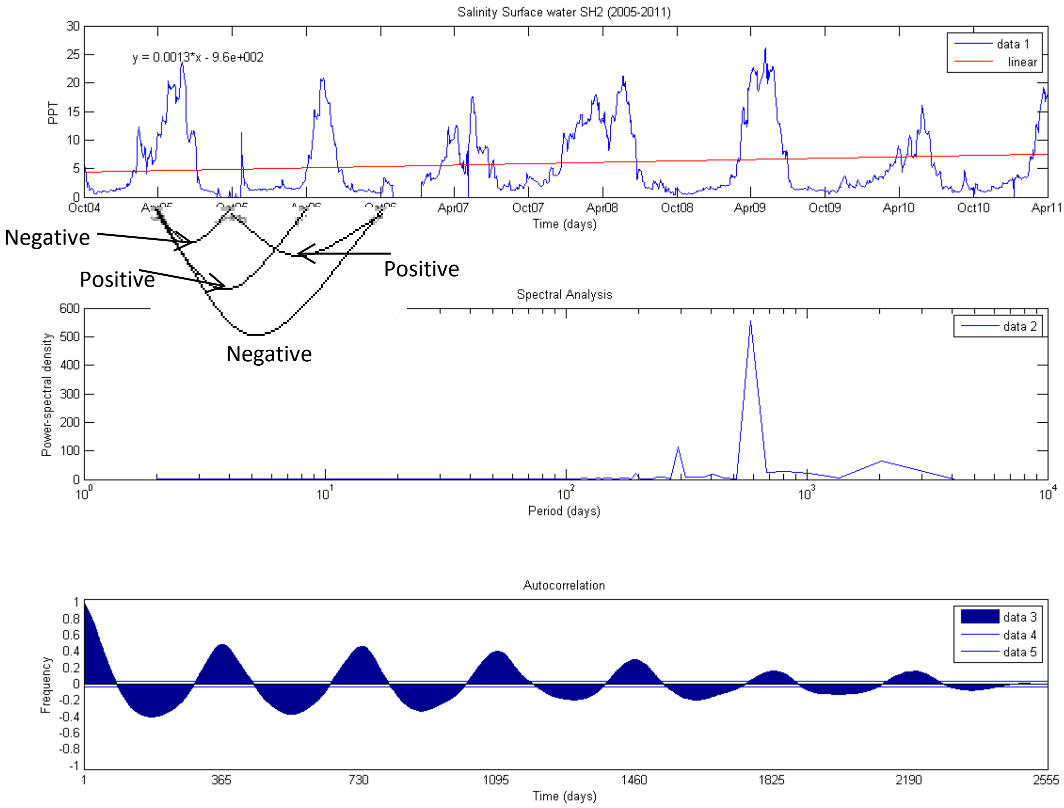


Figure 15; Time-s., spectral., autoco.; SH2 SALSW

4.4 Shark River 3 (SH3)

4.4.1 Ground water level (see figure 16)

- For the water data, almost the entire wateryear of 2006 missing, this is because the station was damaged by hurricane Wilma.
- Looking at the time-series graph, the groundwater levels do not fluctuate a lot. The most fluctuation is found for the wateryears 2008 and 2009.
- For this station, the lowest water level was around the -1.8 feet below sea level in January 2008. The highest water level was around the 1 foot above sea level. The average water level is near the sea level (0 feet).
- Looking at the fitted line, it has a slightly positive slope. This is because the missing data is filled in with the value, 0. And also looking at the fluctuation that gets lets during time and the slightly higher water levels in the wet seasons during the time, the line gets that positive slope.
- For the spectral analysis graph, there are clear peaks of the tidal influence at this station. A 14-day peak is present and a strong tidal peak for 28 days is there as well.
- In the same graph, the annual and seasonal peaks are clearly visible. These are the trends of 180 days and 365 days.
- There is a fault in the correlogram. Only 365 days are at the x-axe. In the correlogram, the autocorrelation can be seen for lags of also for instance, 180 days. This is strongly negative (-0.4). Because it is only 365 days, it is “zoomed-in”. The fluctuation is better visible than looking at a correlogram with 2555 lags. A sinusoidal shape is present and this indicates a seasonal influence.

4.4.2 Salinity ground water level (see figure 17)

- For the water data, almost the entire wateryear of 2006 missing, this is because the station was damaged by hurricane Wilma.
- Looking at the time-series graph, the salinity levels are fairly constant, around the 25/30 Parts Per Thousand (PPT).
- The red fitted line is also based on the bad data for the year 2006. So this line is not entirely correct. It has a positive slope because of the missing values.
- Still for the time-series graph, around the month April the salinity levels are the lowest. Only these lower values do not really differ from the high salinity values. The fluctuations between these salinity levels are around the 4 PPT.
- Looking at the spectral analysis graph, there are no real clear peaks in all of the spectral graphs. After a lag bigger than 365 days (1 year), the autocorrelation is continuously negative. No seasonal (sinusoidal) shape is visible.

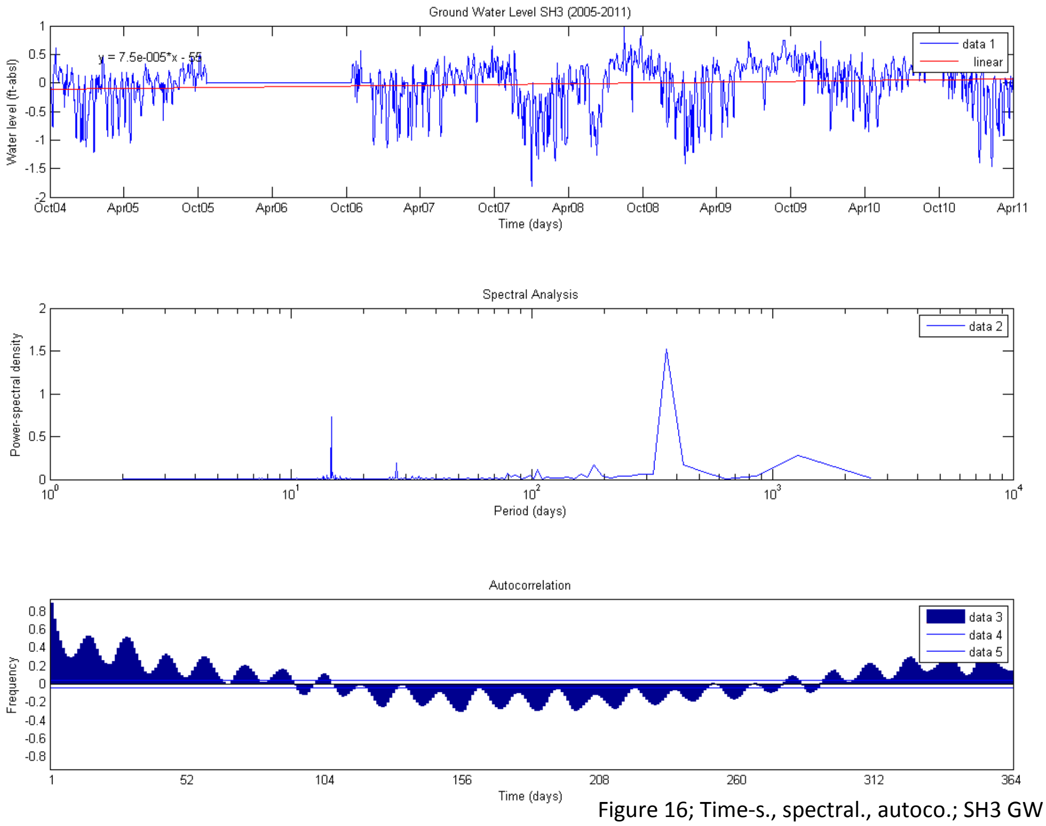


Figure 16; Time-s., spectral., autoco.; SH3 GW

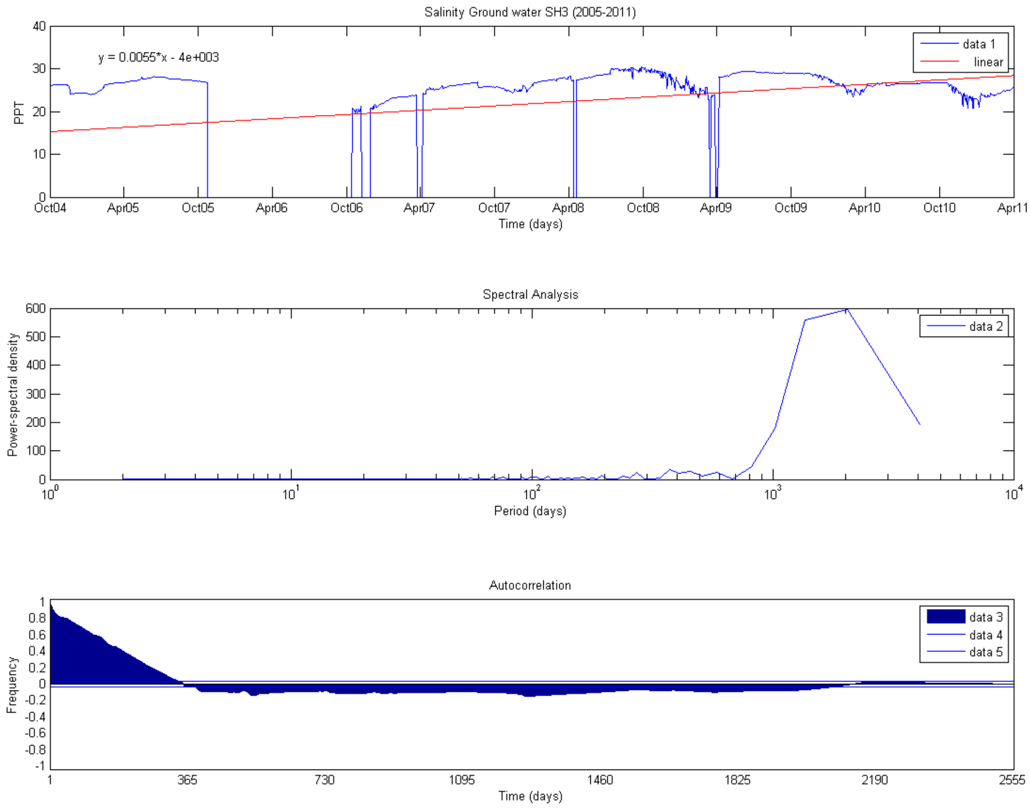


Figure 17; Time-s., spectral., autoco.; SH3 SALGW

4.4.3 Surface water level (see figure 18)

- Looking at the time-series graph, there is a lot of fluctuation at this site. This gage has the most influence of tidal changes of all the gages (only looking at the graphs and not topography of all the sites that are included in this research).
- In the time-series graph, the lowest levels are almost -1.5 feet below sea level and the highest level is around the +1 foot above sea level. On average the level is +0.1 foot above sea level.
- The wateryear 2010 was a wet year, noticeable in the time-series graph.
- Looking at the fitted line, it has a slightly positive slope. This is because the missing data is filled in with the value, 0. Also looking at the fluctuation that gets lets during time and the slightly higher water levels in the wet seasons during the time, the line gets that positive slope.
- In the 7-year graph (spectral analysis graph) of the surface water levels, the tidal influences are clearly visible with the related peaks. For the same spectral analysis graph, the 14-day cycle and the 28-day trend are very clear. Almost every year they are present, except the year without data of course.
- A 600-day trend is also noticeable in the spectral graph.
- A sinusoidal shape is visible and this indicates a seasonal influence. For a 1-day lag, the correlation high (0.4) as it is for a lag of 360 days (0.4 or 40%). For a lag of 180 days, however, autocorrelation is strongly negative (-0.3 or -30%). Because of the tidal influences (spectral analysis plot), there are fluctuations in the time-series graph. This is again noticeable in the correlogram.

4.4.4 Salinity surface water level (see figure 19)

- Looking at the time-series graph, the average salinity value is about 30 PPT (Parts Per Thousand). The months May and June have the highest salinity values. Values of 35 PPT.
- In July the high values drop slowly down to December. After December the values go up again.
- For the 7-year graph of spectral analysis, the 180-day peak (seasonal) can be seen and the yearly trend too (365 days). A 600-day trend is also visible at the spectral analysis graph.
- The red line is not there for the time-series graph. This is probably because of an error in programming.
- There is no seasonal influence noticeable; there is no sinusoidal shape visible. Even if the spectral analysis graph show trends for 180 and 365 days.

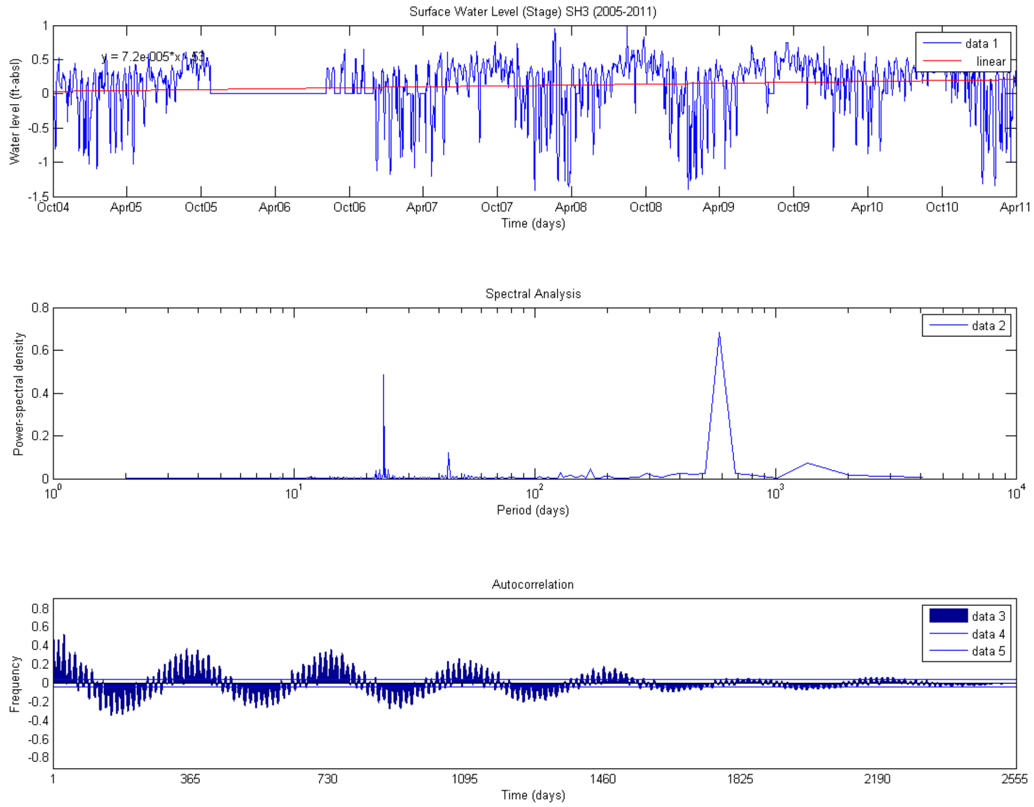


Figure 18; Time-s., spectral., autoco.; SH3 SW

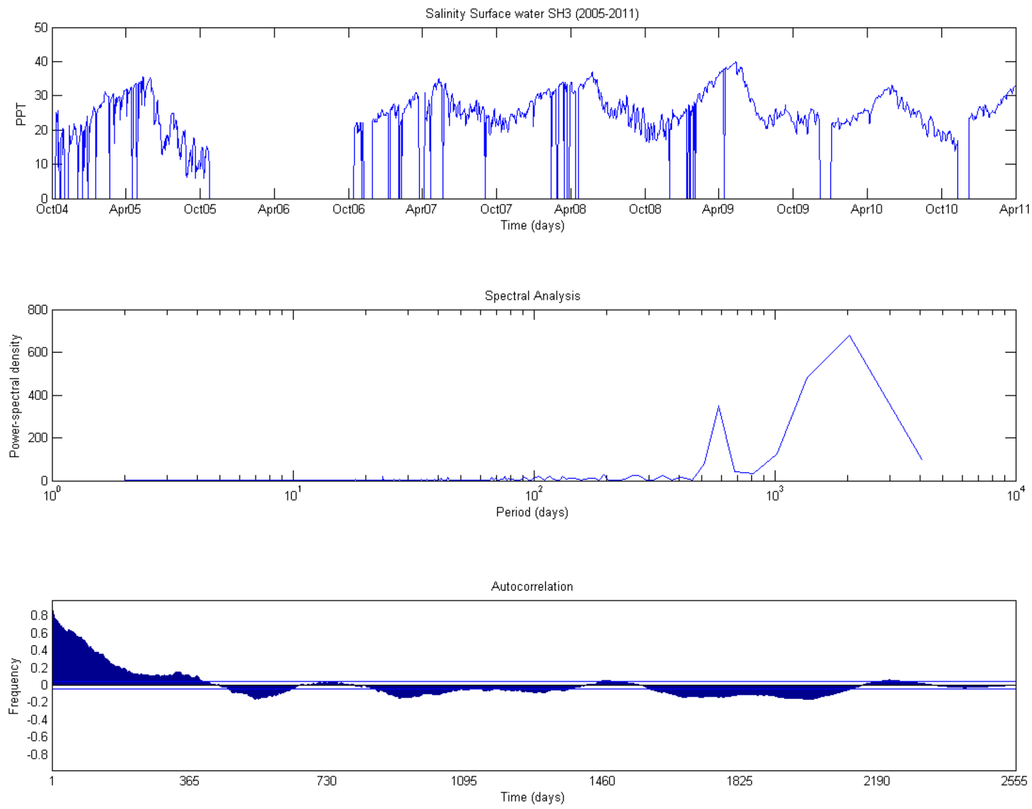


Figure 19; Time-s., spectral., autoco.; SH3 SALSW

4.5 Shark River 4 (SH4)

4.5.1 Ground water level (see figure 20)

- The wateryear 2009 misses data. Only data for the months October and November are known.
- Looking at the time-series graph, there is a high level peak at October 2005, 1.5 feet above sea level. There is not a big fluctuation for the water levels. The average water depth is +0.1 foot above sea level; the lowest values are around the 1 foot below sea level.
- The fitted line has almost no slope; there is no rise or decrease in the groundwater.
- Noticeable is the influence of the tidal cycles.
- The spectral analysis graph shows for every year a trend for every 40 days. Also a 600-day trend is visible at the spectral analysis graph. The same for every 20 days.
- The waved shape indicates a seasonal influence. For a 1-day lag, the correlation extremely high (0.8 or 80%) as it is for a lag of 360 days (0.4). For a lag of 180 days, however, autocorrelation is strongly negative (-0.4 or -40%). This site is less influence by tides (spectral analysis graph; peaks for 20 days) than SH3, but the influence of the tides is still noticeable with the knurled edge.

4.5.2 Salinity ground water level (see figure 21)

- The months May and June there are higher salinity levels than other months. This is because of the lack of fresh water. The average value is at 18/20 PPT. The low salinity values are around the 12 PPT.
- The salinity values fluctuate from 30 PPT to 12 PPT. This means a difference of 18 PPT.
- The red colored fitted line is present for the time-series graph. This is probably because of an error in programming.
- The repetitive peaks in the time-series can be seen as tiny peaks in the spectral analysis graph (180 and 300 day peaks). These peaks are small because the 600day trend is really powerful.
- The sinusoidal shape is clear in the correlogram. This indicates a seasonal influence, the wet and the dry season. For a 1-day lag, the correlation extremely high (1.0) as it is for a lag of 360 days (0.5 or 50%). For a lag of 180 days, however, autocorrelation is strongly negative (-0.3 or -30%). For a lag 1,5 year (550 days), the autocorrelation is negative (-0.4), a stronger negative autocorrelation than for a lag 0.5 (180 days).

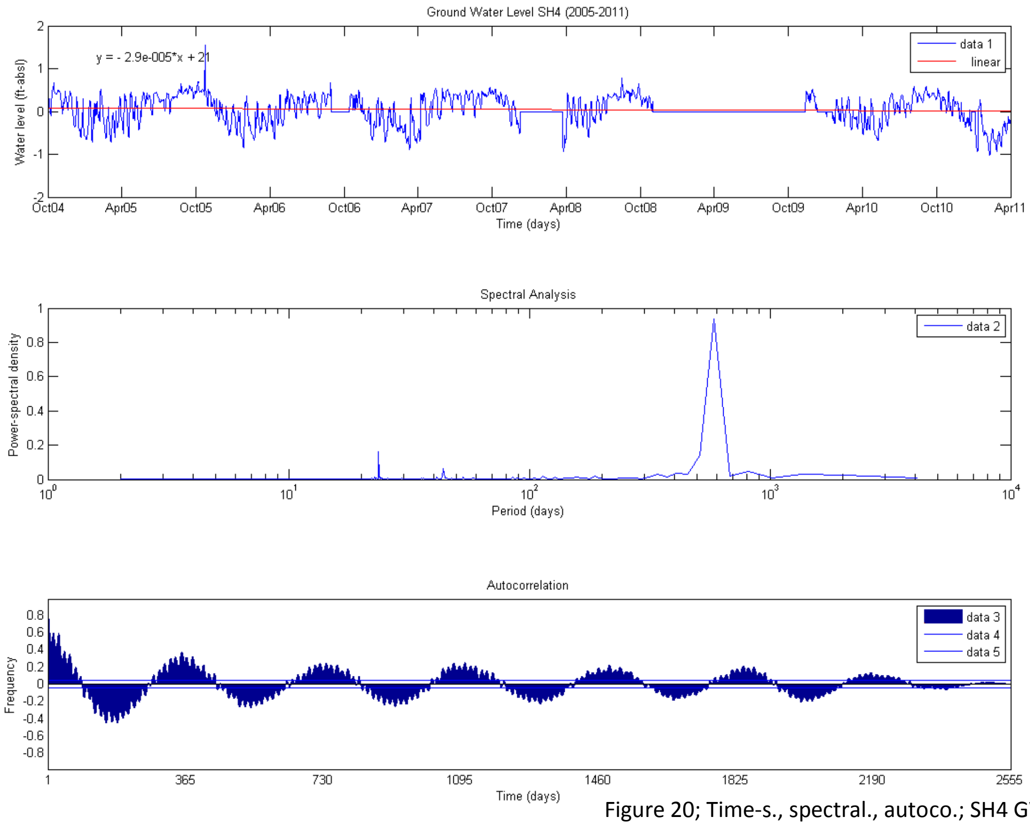


Figure 20; Time-s., spectral., autoco.; SH4 GW

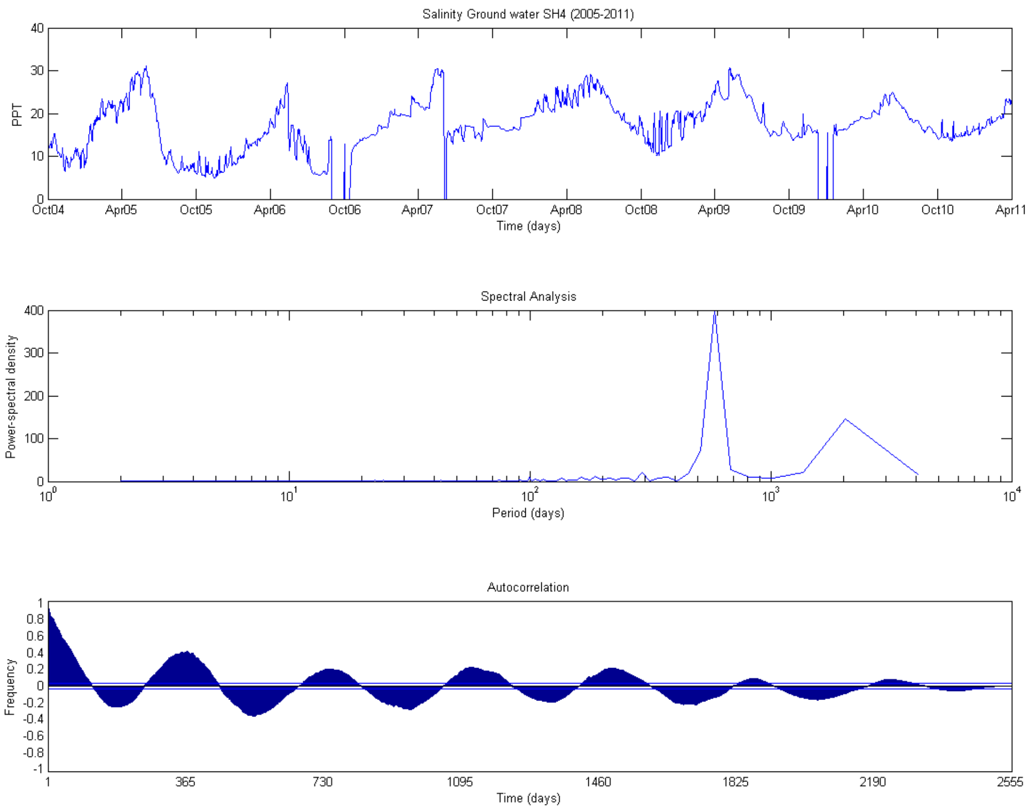


Figure 21; Time-s., spectral., autoco.; SH4 SALGW

4.5.3 Surface water level (see figure 22)

- The entire data set for surface water only contains some missing data.
- Looking at first graph of the three (time-series), there is a high water level just before the hurricane in October of the year 2005. There is a nice peak in the time series to show that. The water level of that particular moment is almost 1.9 feet above sea level.
- The average water level is 0.1 foot above sea level. For the dry periods, the values are about 1.2 feet below sea level. March and April are the driest months.
- The fitted line has a slightly positive slope and this indicates a slightly higher water levels.
- For the spectral analysis graph, a 600-day trend is visible. But also a 22day peak is present and 40day peak as well.
- The sinusoidal shape indicated a seasonal influence. The knurled edge in this shape indicates the tidal influence (visible in the spectral analysis plot). For a 1-day lag, the correlation extremely high (0.8), because day by day, the levels always are almost the same. For a lag of 360 days also a strong autocorrelation (0.5). For a lag of 180 days, however, autocorrelation is strongly negative (-0.5 or -50%), the same for a lag of 550 days (1,5 year).

4.5.4 Salinity surface water level (see figure 23)

- The year and seasonal characteristics are clear in the time-series graph. Although there are some gaps in the data.
- For the time-series graph, wateryear 2009 has the highest values in salinity in the months April and May. Also there are big fluctuations in salinity values for this station. The high salinity peaks reach the 40 Parts Per Thousand; the lowest salinity levels are around the 2 Parts Per Thousand.
- The average salinity level is 15 PPT.
- The fitted (red) line has a slightly positive slope towards the year 2011 (1 or 2 PPT difference over 7 year). This indicates that surface water becomes more saline. Because of the range of the salinity values, it is hard to say that high salinity values in the later years constant occurrence is. Maybe these years after, the salinity value drops down again.
- For the spectral analysis curve, a 180day, 300day and 600day trend is visible.
- The sinusoidal shape indicated a seasonal influence. The slightly knurled edge in this shape indicates the slightly tidal influence (visible in the spectral analysis plot). For a 1-day lag, the correlation extremely high (0.8), because day by day, the levels always are almost the same. For a lag of 360 days also a strong autocorrelation (0.4). For a lag of 180 days, however, autocorrelation is strongly negative (-0.3 or -30%), the same for a lag of 550 days (1,5 year), with a negative autocorrelation (-0.3).

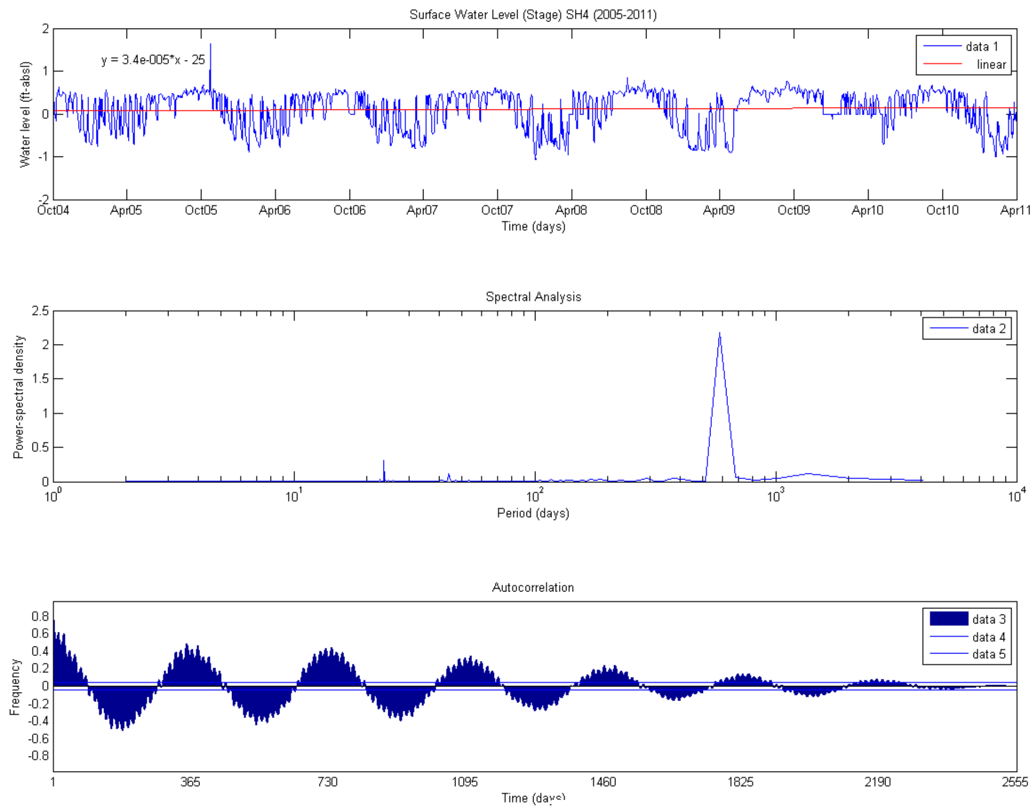


Figure 22; Time-s., spectral., autoco.; SH4 SW

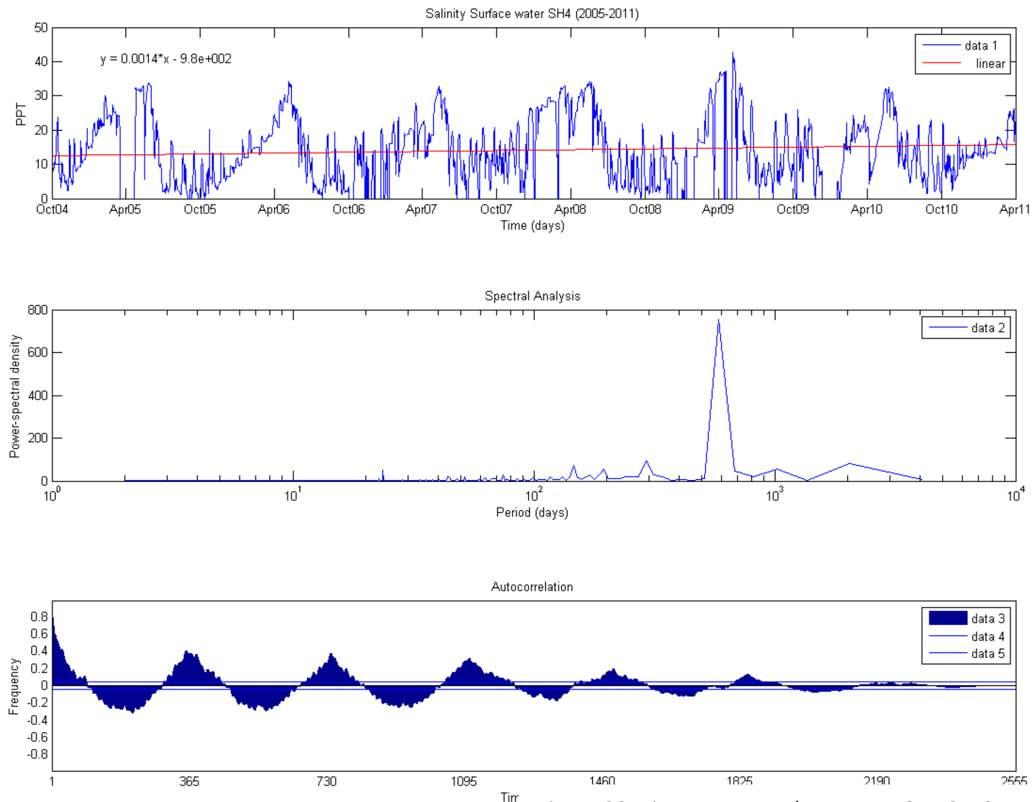


Figure 23; Time-s., spectral., autoco.; SH4 SALSW

4.6 Shark River 5 (SH5)

4.6.1 Ground water level (see figure 24)

- For the entire data set, there is missing data for the wateryear 2009. From May tot November there is no data available. This missing data values all have a value of 0.
- The seasonal patterns can be seen in the time-series graph. The water levels go up and down during the seasons. The average groundwater level is 0.1 feet over the 7 years.
- The highest value is measured in late October 2005 with a peak of 1.8 foot above sea level. The lowest levels are around the month March and in the year 2008, the lowest levels where measured with values of around -1.2 foot below sea level.
- Looking at the spectral analysis chart, there is a 600day peak. The pattern in the time-series chart is not present in the spectral plot.
- A sinusoidal shape is visible. This indicates a seasonal influence for this site. The sinusoidal shape indicated a seasonal influence. For a 1-day lag, the correlation extremely high (0.9), because day by day, the levels always are almost the same. For a lag of 360 days also a strong autocorrelation (0.4). For a lag of 180 days, however, autocorrelation is strongly negative (-0.5 or -50%).

4.6.2 Salinity ground water level (see figure 25)

- For the entire data set, salinity data is missing. This is for the period, May till November, for the wateryear 2007. This can be seen in the time-series plot.
- This site is just 1000 feet away from SH4, away from the Shark River, and has stable salinity values. And these salinity levels are around the 10 PPT.
- Looking at the time-series graph, in July of 2005 the value of salinity was only 6 PPT. This is probably caused by the hurricane.
- For the spectral analysis plot, there are peaks at 70, 90 and 180 days.
- The salinity levels go slowly up during the period of 7 years. With 1 or 2 PPT over the 7 years. This can be read wrong because of the fitted line. This line has a big positive slope and is caused by the missing data.
- No sinusoidal shape is visible and this indicates that there is no seasonal influence in the salinity groundwater.

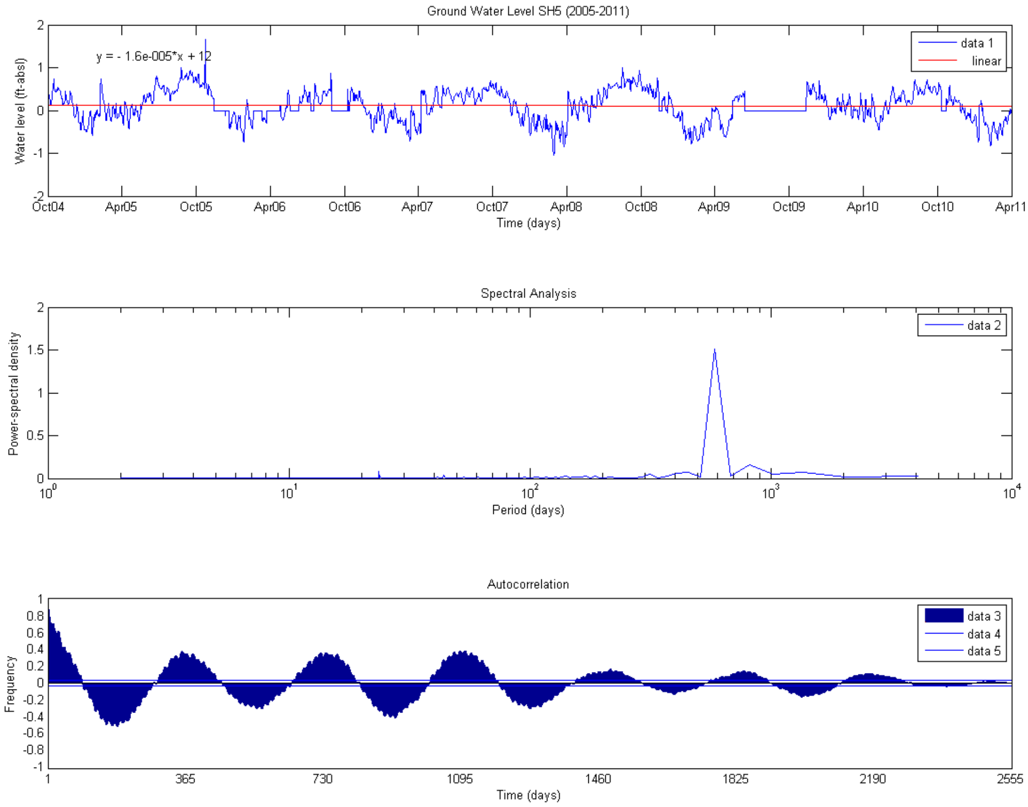


Figure 24; Time-s., spectral., autoco.; SH5 GW

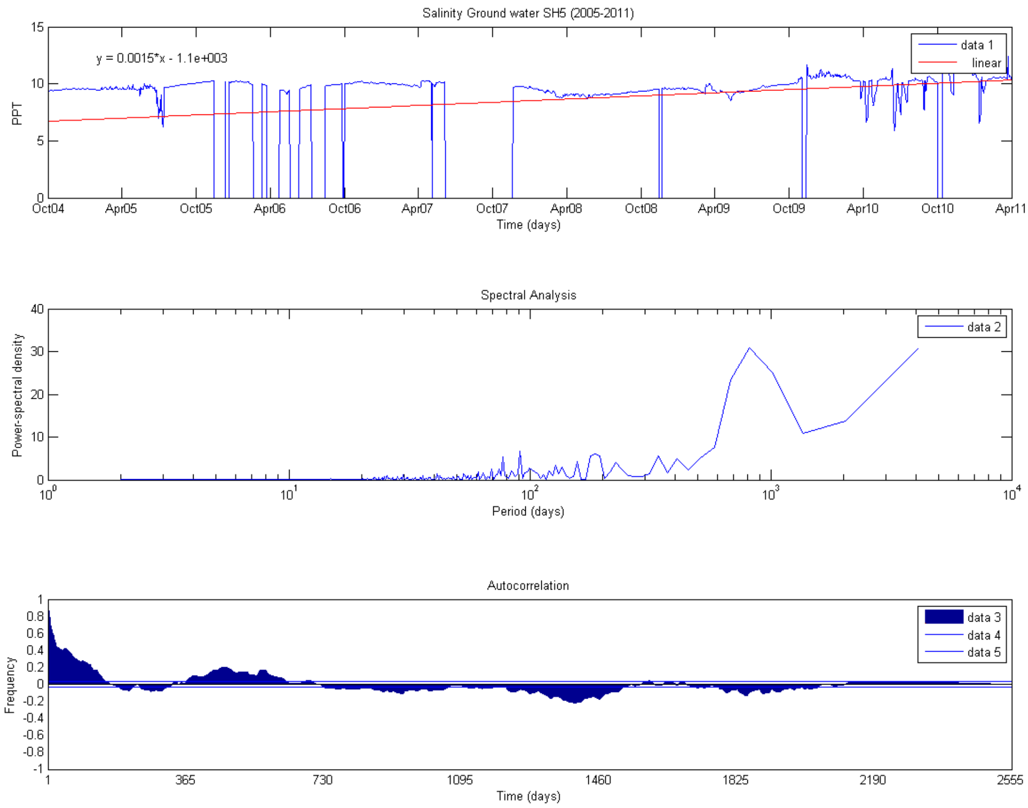


Figure 25; Time-s., spectral., autoco.; SH5 SALGW

4.6.3 Surface water level (see figure 26)

- The seasonal and yearly patterns are present in the 7year time-series graph.
- Looking at the time-series plot, the lowest water level periods are just before the summer season and have values of 0.8 foot below sea level. The average water level is 0.2 feet above sea level.
- The hurricane peak can be seen in late October 2005.
- Even though the seasonal patterns can be seen in the time-series graph, they are not present as peaks in the spectral plot.
- The fitted line is almost completely horizontal and means that there is no rise of surface water level.
- Further for the spectral analysis graph, a 600-day trend is present. A real small peak for the 22-day peak is noticeable.
- Seasonal pattern is present in the autocorrelation chart; this is indicated by the sinusoidal shape. The very slightly knurled edge in this shape indicates the tidal influence (visible in the spectral analysis plot). For a 1-day lag, the correlation extremely high (0.9), because day by day, the levels always are almost the same. For a lag of 360 days it is also a strong autocorrelation (0.4). For a lag of 180 days, however, autocorrelation is strongly negative (-0.5 or -50%), almost the same for a lag of 900 days, 2,5 year, a negative autocorrelation of 0.4.
-

4.6.4 Salinity surface water level (see figure 27)

- There are extreme high values of salinity in the wateryear 2005 in the months of April, May and June. The salinity levels are around the 22 PPT with two peaks in late May with values of 32 PPT. The salinity values have an average of 12 Parts Per Thousand.
- In October 2005 the hurricane came and destroyed the equipment. No data is available until August 2006.
- For the spectral analysis plot, There a lot of peaks noticeable, all the between the 10^2 and 10^3. No real indication of any seasonal trend.
- Because there is missing data for the wateryear 2006, the red fitted line has a positive slope. No real conclusions can be made with this line.
- No sinusoidal shape is visible and this indicates that there is no seasonal influence in the salinity groundwater. Also because of the data gap mentioned before.

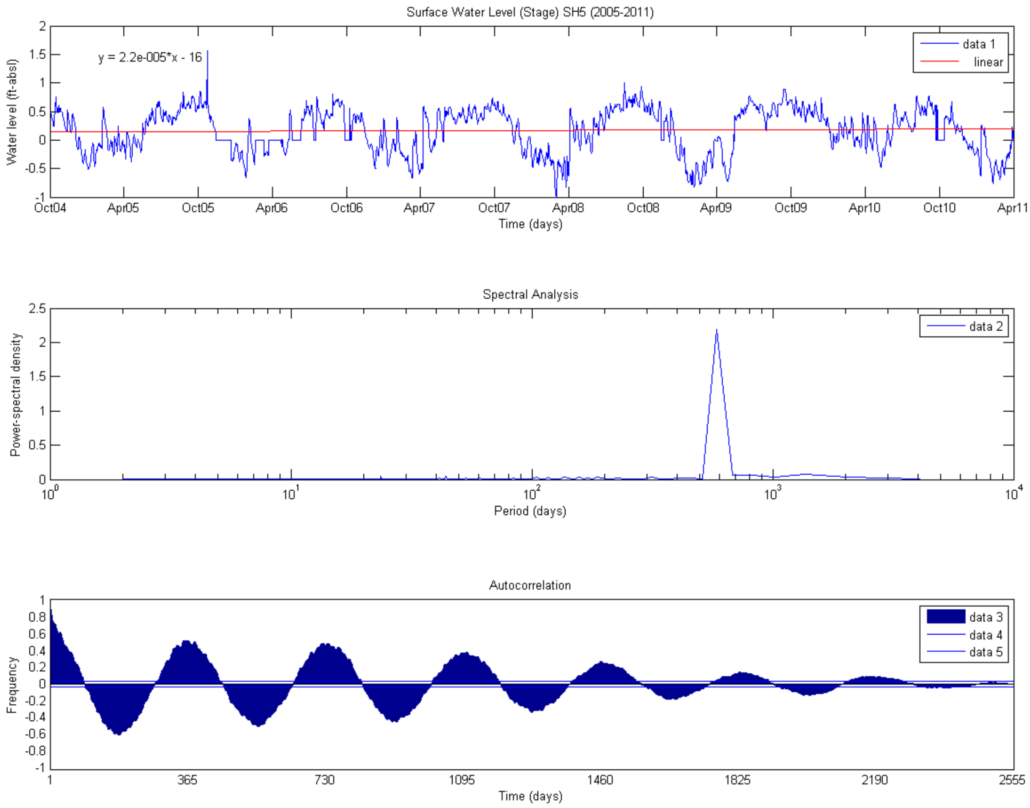


Figure 26; Time-s., spectral., autoco.; SH5 SW

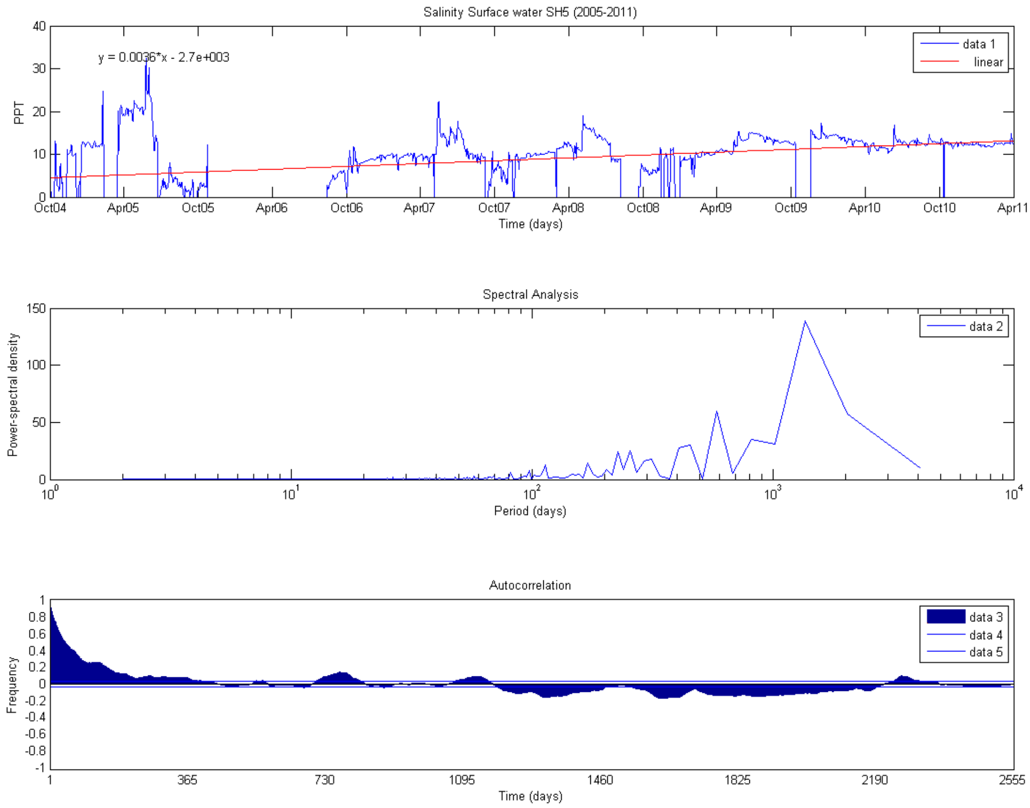


Figure 27; Time-s., spectral., autoco.; SH5 SALSW

4.7 Exceedance tables

Percentages in this table are below ground elevation; estimated from the exceedance graphs (the actual exceedance graphs are on the CD. For an example, see annex 5);

SH1	2005	2006	2007	2008	2009	2010	2011
GWL	10%	3%	7%	20%	15%	0%	25%
STAGE	13%	4%	5%	20%	10%	0%	27%

SH2	2005	2006	2007	2008	2009	2010	2011
GWL	25%	35%	33%	40%	no data	20%	35%
STAGE	16%	15%	22%	30%	30%	12%	30%

SH3	2005	2006	2007	2008	2009	2010	2011
GWL	85%	65%	80%	78%	70%	68%	78%
STAGE	77%[5]	55%	67%	60%	55%	52%	55%

SH4	2005	2006	2007	2008	2009	2010	2011
GWL	75%	80%	80%	75%	86%	85%	86%
STAGE	60%	57%	60%	50%	55%	30%	58%

SH5	2005	2006	2007	2008	2009	2010	2011
GWL	47%	43%	50%	50%	63%	43%	55%
STAGE	55%	45%	35%	45%	47%	44%	34%

Table 4; Gage information, exceedance percentages

1. Wateryear 2010 was really wet; this is visible in the exceedance charts for SH1 GWL/STAGE, SH2 STAGE, SH3 GWL, SH4 STAGE, and SH5 STAGE. So especially for the surface water data, a wet wateryear is concluded.

2. The average rainfall in South Florida in that year was around the 1500 mm. Tropical storm Bonnie on July 23 and in late September; Nicole arrived in Florida (Tropical Storm). There were 3 severe thunderstorm events, and the winter was wetter and stormier than normal. Two big storms at February the 12th and February the 24th. On March the 29th a tornado ripped through South Florida.

3. Shark River 2 (SH2), Shark River 3 (SH3) and Shark River 4 (SH4), the stations near the river, the stage level of 2010 has high values. So for wateryear 2010 the percentages are low.

4. For site SH2 in wateryear 2009 there is no data due to problems (with the pressure transducer (measures groundwater levels (was installed in late July)) with the apparel at the stations.

[5] Green box refers to annex 5.

5. For the years 2006, 2007 and 2010, water levels were high at station SH1. SH1 is situated in the Shark River Slough and has a low ground elevation. So, water from adjacent area will flow in the dry months to this part of the shark river slough. This is why this station site has low percentages.

6. The groundwater is not really influenced by the rainfall and freshwater flow from the North.

7. For the groundwater level (GWL) for every site (except SH3), the water level exceeded the ground elevation less in 2011 than in 2005. But looking at all the years per site for the GWL, you can see some averages per site.

8. The surface water levels for the sites SH1 and SH2 are going down.

5. The hydrodynamics

Interpretation of the observations is key to determine what is going on in the Everglades. Below are the interpretations found that came forth from analyzing the water data of the existing sites. By using the research questions as guidance, the hydrodynamics are interpreted.

What are the ground and surface water salinity seasonal patterns?

The dry season pattern contains a larger amount of days than the wet season. The patterns do not really change. Both seasons are around the 180 days long. The autocorrelation analysis shows thee sinusoidal wave for at least every site in the Shark River area. For the site on Big Sable creek, there is no season influence, looking at the correlograms. For every 360-day, the two seasons are noticeable. The seasons have a strong autocorrelation. But during time, these seasonal patterns get weak.

Rainfall in the wet season will cause fresh water discharge. On average per year, 60 inches of rain falls down in Florida, including the Everglades. This freshwater influences the salinity levels, and in the graphs, lower values of salinity are measured during the wet season. During the dry season, higher salinity levels are measured.

Just before the wet season starts, the highest salinity levels are measured. The salinity in surface water in May/June have the highest values every year for every Shark River site. This is because the freshwater flow is almost zero. So the salt will not dilute with the freshwater from the north. This does not count for the site on the Big Sable Creek, this site has almost no influence by freshwater.

The salinity in ground water lags behind for about 2 months after the high salinity in the surface water. You can see that the water levels get the highest salinity value at the end of the dry season. For SH1 as an example, the salinity levels get higher during the dry season, because there is less water to dilute with.

How does surface and groundwater levels differ on site and with the estuary?

For the two water levels (ground- and surface water), there is a lag in the rise of water after drought periods are ending. For the groundwater level, there is about 1 or 2 months lag noticeable. This means that the (fresh) water has to infiltrate the ground and this takes about 1 or 2 months. As surface water can flow over land and in the river, it does not take long when the sensor will measure faster, higher water levels for surface water. Because for instance the site SH1, is the most by freshwater influenced site, the salinity level drops quick. And because this (fresh) water still has to infiltrate after it flows overland. The drop in salinity takes about just over 2 months longer. The surface water levels for the sites SH1 and SH2 are going down.

For the site SH3 there is a lot of fluctuation in groundwater and surface water. This is because this site is under influence by the tidal cycles. This differs with the sites more inland. The tidal influences do not reach these sites.

The Shark River sites 4 and 5 have the same distance to the Gulf of Mexico but they still have different water level characteristics. This is because site SH5 is more inlands, and will not be flooded by every high tide. The study site SH4 is situated next to the river and gets flooded every time there is a flood tide.

Another difference is that between the surface water and groundwater, with the "wave-shaped" appearance in the time-series graphs. For the groundwater levels, the graphs have a more shallow appearance than the surface water level graphs. There is a bigger difference in the maximum-minimum range of the values of the surface water level graphs than for groundwater. Thus, the groundwater level graphs have less fluctuation in values, with shallower levels than for surface water.

Looking at the salinity and surface water gages for every site, the sites that are situated in the ecotone and thus the estuary too, have more fluctuation than the sites that are not in this particular area. SH1 and BSC have more consistent values.

Over the years the groundwater and surface water levels hardly change. The levels stay the same for the most sites for the 7-year data set. The same for the salinity levels for the same sites. So there is not enough indication to say that the sea level rises. Even the surface water levels for the sites SH1 and SH2 slightly go down.

How do tidal exchange, freshwater discharge and rainfall forcings influence hydrodynamics in the Shark River and adjacent mangrove-marsh communities?

On average, the salinity levels in the surface water fluctuate more than for groundwater. Except for SH1, this site works the other way around. It has only the influence by fresh water and this freshwater will mix with low amounts of salt (values of around the 0.5 PPT). For all the other sites that are influenced by saltwater, fluctuation in the groundwater is less than in the surface water salinity levels. The groundwater shows a more blunted shape in the low water levels for the time-series graphs.

For the years 2006, 2007 and 2010, water levels were high at station SH1. SH1 is situated in the Shark River Slough, just north of the Shark River and has a low ground elevation. So in the driest months, water from adjacent areas will flow to this part of the Shark River slough. This is also noticeable in the low salinity levels; these levels are around the 0.5-1 PPT.

The land gets more flooded than before. This is probably because of the more rainfall in the last few wateryears. For the last 5 years, 3 years are wetter than the years before 2006. This can indicate a potential climate change. But because these data sets are till 2011, this cannot be concluded with this research.

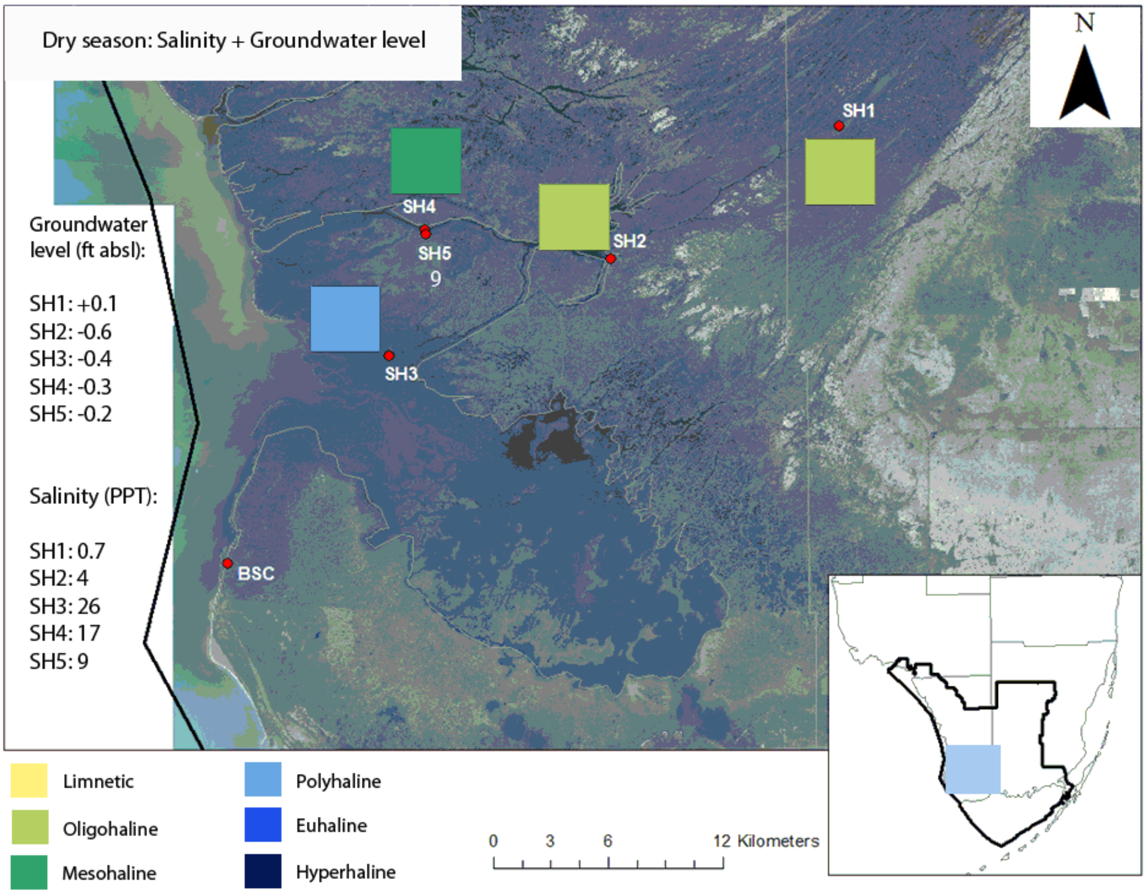
The highest peaks in salinity and for surface water especially are most likely caused by hurricanes. This is because the storm surge forces salt water (seawater) inland. This results in higher water levels and higher salinity levels for surface water. An example, the cause for SH1's salinity peak in the year 2005 (page 31) is the hurricane Wilma. Because of this hurricane, saltwater from came up the river and raised the salinity level, by bringing more seawater inland reaching this most east situated site.

Because the river is situated in a delta, the river has influences by tidal movements. For the site SH3, clear trends are noticeable. Especially the 14day, 28day, 180day and 365day trends are clear. The reason that there are 14day and 28day trends is because the influence of the Moon and the Sun, every two weeks the Moon and Sun are at a 90-degree angle to each other (first and third quarter moons). This is called Neap Tides and happens every two weeks. The other two cycles (180 and 365 days) have the origin of the change in seasons. The wet season brings a higher water level and in the dry season, low groundwater levels are noticeable.

5.1 Synthesis

To show what the water system for the research area around the Shark River (Everglades National Park) entails, there are four maps indicating each a different situation. For the values that are used to make these maps, averages are taken from the graphs that are shown earlier in this report. These graphs can be found in the chapter “Results”, and contains information about ground- and surface water and the salinity for these water levels. Because it is important to determine whether the ground- and surface water is very saline or less saline, salinity values (Parts Per Thousand) are used. The following maps are divided in to the wet- and dry season, for the obvious reason of the influence of rainfall. Because the gages measure ground- and surface water levels, these parameters are divided too.

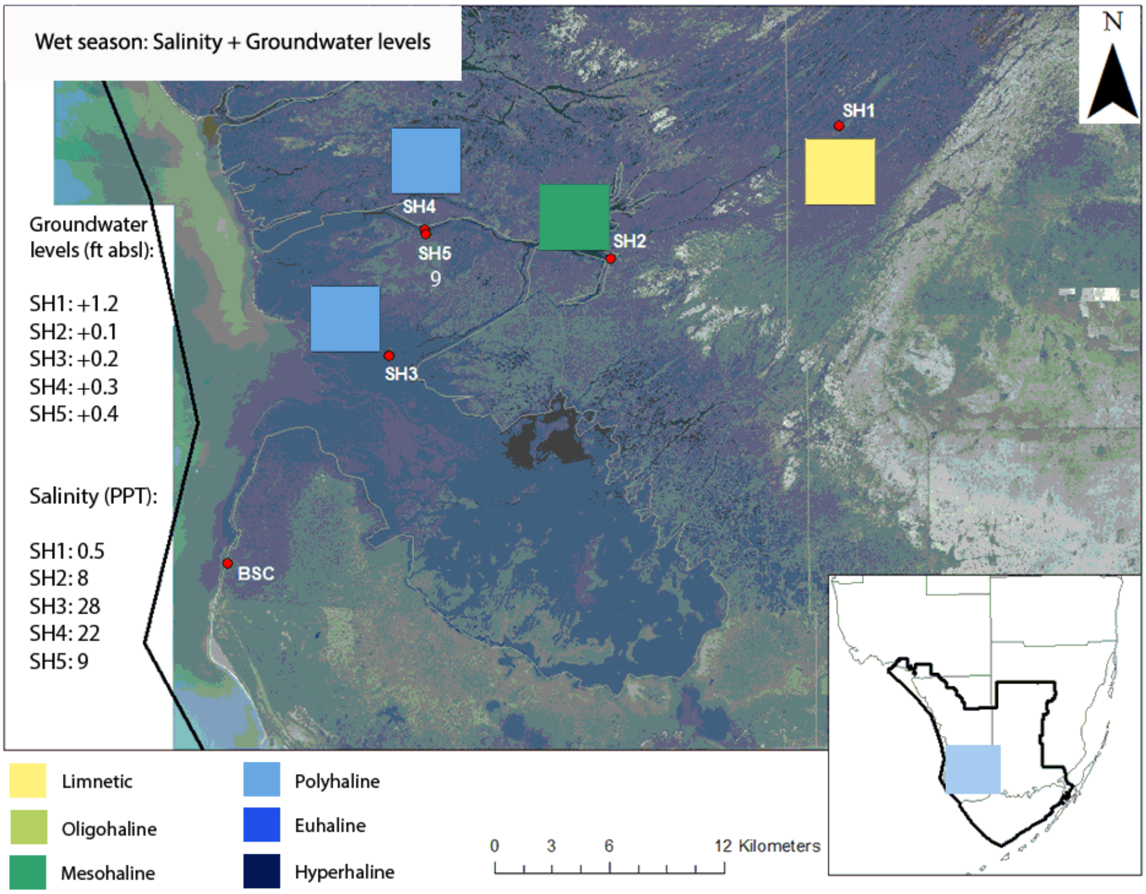
Map 1; Dry season, Salinity groundwater:



Map 1, USGS legenda, water system

This map contains information about the salinity levels for groundwater in the dry season. At first there is a gradient noticeable. The first box on the right corresponds to the station SH1. The average salinity value falls within the oligohaline waters (fresh water). The value of 0.7 PPT is just in range of the oligohaline class. This class starts from 0.5 PPT and ends at 5 PPT. This station is the most northern most upstream of the 6 stations. It has the lowest salinity value of all the sites. For the site SH2, the salinity level is slightly more saline with 4 PPT. This also corresponds to the oligohaline waters (estuary), noticeable with the light-green color in the map. As the Shark River continues to the shore, is the salinity level at SH4, 17 PPT. This value corresponds to the mesohaline water (estuary), indicated with the dark-green color. And for SH3 the average salinity value is 26 PPT, the polyhaline water class (estuary). This site has the highest salinity class within the map. The site SH5 has a value 9 PPT. This means that for SH5, the class of mesohaline (estuary) waters.

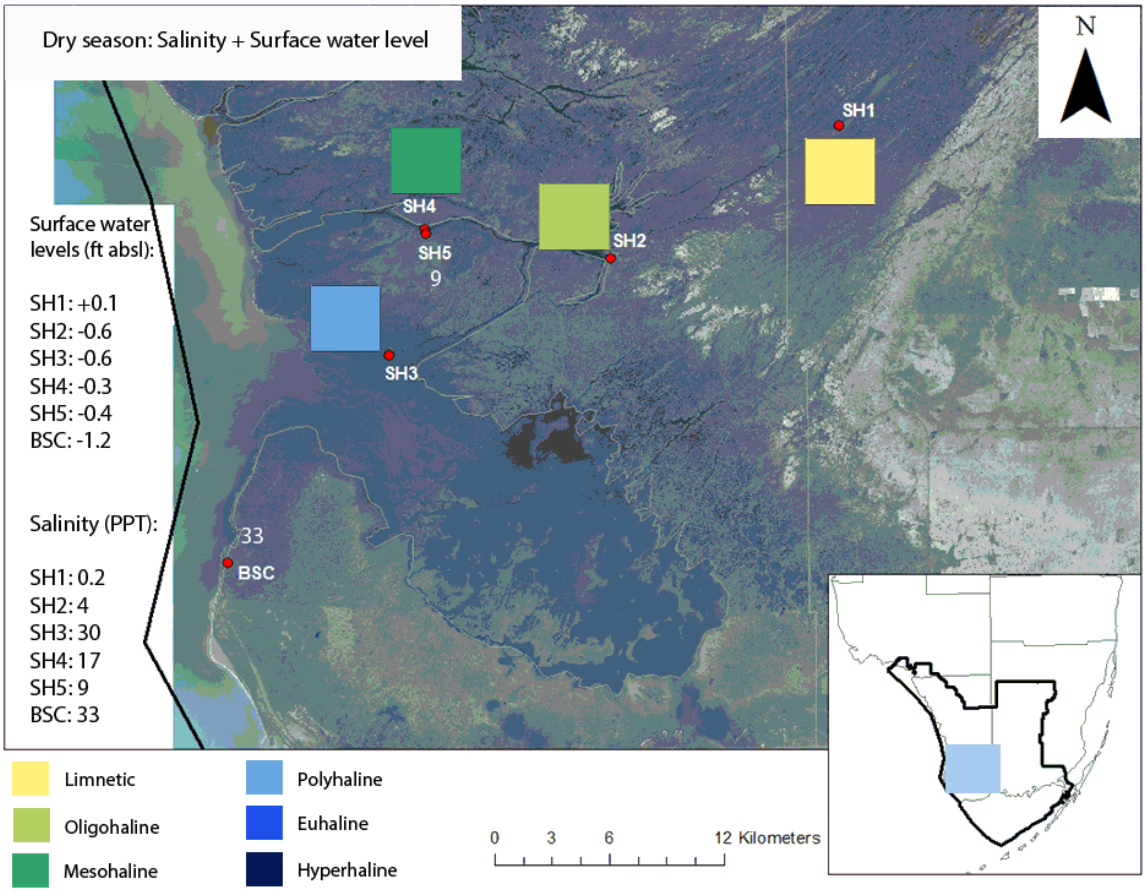
Map 2; Wet season, Salinity groundwater:



Map 2, USGS legenda, water system

This map contains information about the salinity levels for groundwater in the wet season. The yellow box corresponds to the limnetic waters (fresh water). The salinity value for the site SH1 is 0.5 PPT. In the wet season this site gets a lot of drainage water, this water comes forth from rainfall. The site SH2, more to the left, has an average salinity value of 8 PPT. This value belongs in the class of mesohaline waters (estuary). Indicated with the green color. Water moving towards the left, will reach the sites SH4 and SH3. These sites have values that correspond to polyhaline waters (estuary). The station SH4 has an average salinity value of 22 PPT. For the site SH3, the value is 28 PPT. Even though these sites differ 6 PPT, they are both classified as part of the polyhaline waters. The site SH5 has a value 9 PPT. This means that for SH5, the class of mesohaline (estuary) waters.

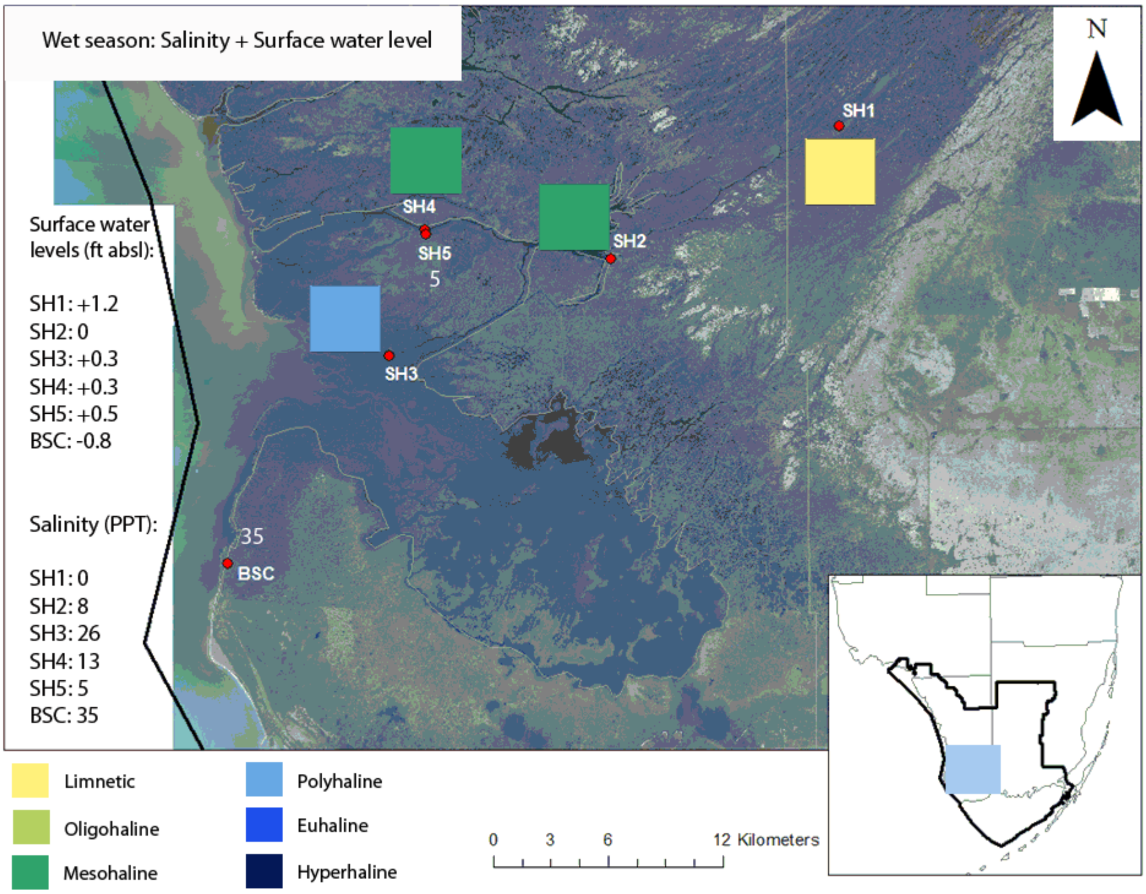
Map 3; Dry season, Salinity surface water:



Map 3, USGS legenda, water system

This map contains information about the salinity levels for surface water in the dry season. For the site SH1, the average salinity value of 0.2 PPT corresponds to limnetic waters (fresh water). As given in the table before, the limnetic water scale varies from 0 to 0.5 PPT. This site always has the lowest values of salinity. Down the river, so towards the Gulf of Mexico, the type of salinity waters is changed. The site SH2 is situated in oligohaline (estuary) waters. The average salinity value is 4 PPT. For the site SH4, the salinity value is 17 PPT and so mesohaline (estuary). This is the green box near the station SH4. To the south of SH4, SH3 is noticeable. This site is has a higher average salinity value than SH4. The average value of 30 PPT falls within the polyhaline (estuary) waters. Marked with the light-blue box on the left. The site SH5 has a value 9 PPT and the site BSC has an average value of 33. This means that for SH5, the class of mesohaline (estuary) waters. And for BSC, the class of euhaline waters (seawater).

Map 4; Wet season, Salinity surface water:



Map 4, USGS legenda, water system

This map contains information about the salinity levels for surface water in the wet season. The station SH1 has an average of 0 PPT for salinity in surface water. This corresponds to limnetic waters, marked with the yellow color, and thus it is fresh water. If the water reaches the site SH2, the salinity values jumps to 8 Parts Per Thousand, making it mesohaline (estuary). This is marked with the green color. This is the same for the site SH4, but has on average 5 PPT more than the water at site SH2. It has an average salinity value of 13 PPT, the mesohaline class. This is also marked with the same green color as site SH2. The most left box in the map corresponds to station SH3. This site is the closest to the Gulf of Mexico and the average salinity value is 26 PPT. and this corresponds to polyhaline waters (estuary). The site SH5 has a value 5 PPT and the site BSC has an average value of 35 PPT. This means that for SH5, the class of oligohaline (estuary) waters. And for BSC, the class of euhaline waters (seawater).

5.1.1 The water system

For the classification of the water types, table 5 is used. This table is used by the United States Geological Survey (USGS). The classification system is an adapted version of the Venice System. The salinity scale is focused on marine rather than freshwater. So, this table is adapted from its original structure and it has 4 classes with 6 different sub-classes. This is because, for this research area in the Everglades, it is more convenient to use this structure. The PSU (Practical Salinity Units) can also be seen as PPT (Parts Per Thousand) in the table beneath.

Classification	Values in PSU
Fresh water	
• Limnetic	< 0.5
Estuary	
• Oligohaline	0.5 > 5
• Mesohaline	5 > 18
• Polyhaline	18 > 30
Seawater	
• Euhaline	30 > 40
Brine	
• Hyperhaline	> 40

Table 5, Adapted Venice System, classification of saline waters

Looking at an area that has two different seasons, looking at fluctuations in average values of the measuring points, is a good way to see differences or similarities. An example for a fluctuation in the average salinity is for the station SH1; the dry season salinity value for groundwater is 0.7 PPT and corresponds to oligohaline waters, and for the wet season the value is 0.5 and corresponds to limnetic waters. These classes are also indicated with a color and the boxes in the map show these different classes. So for the maps, there is a clear view of the area with its measuring stations and the type of saline waters. The average salinity values are situated on the left side. These values correspond with the station in the map.

The site Shark River (SH5) and the site on Big Sable Creek (BSC) are examined apart from the sites listed above. This is because the sites SH5 and BSC are not in direct contact with the Shark River. The site SH5 is situated at 300 feet from the riverbank. The site BSC has no connection with the river, and is situated on the Big Sable Creek and is the closest to the Gulf of Mexico. These sites still give a lot of information, but are not connected with the others.

Table 6, seen below shows the salinity values for each site. An example, in the dry season for groundwater and for the site SH1 the salinity value is 0.5 PPT (marked with the green color). The values in this table corresponds with the values seen in the maps.

	Average salinity values (PPT)			
	Groundwater level		Surface water level	
Sites	*Dry season*	*Wet season*	*Dry season*	*Wet season*
SH1	0.7	0.5	0.2	0
SH2	4	8	4	8
SH3	26	28	30	26
SH4	17	22	17	13
SH5	9	9	9	5
BSC	X	X	33	35

Table 6. Average salinity levels of the stations

Looking at the values for the dry seasons for the two water levels, there are not a lot of differences. Only the sites Shark River 1 and Shark River 3 have a different value. For the site SH1, the values differ 0.5 PPT and for the site SH3 the difference is 4 PPT. So there can be said in general for the wet season, the salinity values for the sites do not vary a lot. The two water levels are almost similar to each other.

The other season is the wet season. This season has more influence of the rain that falls during the months. Almost for every site there is a difference in salinity values. The site SH2 has the same salinity value of 8 PPT for both water levels. There can be said that the rainfall has more direct influence on the salinity for surface water because the salinity values for surface water are almost all lower than for groundwater.

To see possible changes in the salinity levels in groundwater, the wet- and dry season are compared with each other. The salinity value for SH1 only differs 0.2 PPT. For this site the changes in salinity are most common in this range. For surface water, the values of salinity are lower on average. Freshwater flows from the North to the southwest and passes by the site SH1, and that is why this site always has these low values. In the wet season, there is more freshwater to dilute the low amounts of salt and so the value of salinity is 0 PPT, and in the dry period it is 0.2 PPT higher. The salinity levels for groundwater for the site SH2 differ 4 PPT. In the dry season, the average salinity value is 4 PPT and in the wet season it is 8 PPT. So there are higher salinity values in the wet season. This remarkable observation is the same for the salinity level in surface water. This situation is present in the discussion later on in the report. The salinity values for the site SH3 do not differ that much. The difference is 2 Parts Per Thousand, 26 PPT in the dry season and 28 PPT in the wet season. Because the salinity decreases with a lag of 2 months (thus 2 months included in the dry season), the salinity level is lower in the dry season. For surface water, a lower average salinity level is noticeable for the wet season. The values differ 4 PPT; the freshwater flow has probably a big influence. Because surface water has a direct connection with the freshwater flow, the salinity levels drops. The site SH4 has a higher salinity value in the wet season for groundwater. Similar to SH2 and SH3, a higher salinity level occurs and is remarkable, because it is not expected. But for surface water, the average salinity level is higher in dry season. The difference is 4 PPT, which is expected.

So the salinity levels go up going to the southwest. Because the freshwater has a big influence for the salinity levels, there are changes noticeable for the sites comparing the seasons. Differences in seasons are noticeable for both groundwater and surface water. Looking at the same seasons for both groundwater and surface water, there are only slight differences. Which is expected because there are almost no changes during the 7 years.

6. Discussion

For this project I had a time span of 5.5 months. I began with this project in the beginning of March and ended in late August 2012. During these months I worked for 4 months for the United States Geological Survey in The United States of America. These were the first 4 months of my graduation period. A major benefit was that I could work on this project with people who knew a lot of the Everglades and could help me. In the beginning, my supervisor and me set the planning for this project. But later on we came to the conclusion that some topics had to be skipped. The end result of this project differs from the planning and goals from my project plan.

During this project period I had to make decisions, some I regret and would have done differently and some I have chosen correctly. The wrong decisions that I have made are explained below.

Quality assurance and quality checking is not performed. This makes the first discussion point. And so this is about processing/working with the collected data. Getting the data and processing them in MatLab, I had to put these files in a format that MatLab could read. In some cases during the 7 years of data collection equipment broke. These “no data” points were recorded as 0 values. While changing the data into the correct format, I changed every null into a zero. This is incorrect and I had to change it into a different number that had no correlation with these kind of data values. For instance, I could have changed the nulls in to 999 (a random number that easily can be found, because it is not a natural value whom you can expect for these sites), so it would not be a problem. But with this error in the entire process, out comings of the data are not 100% (probably 70 %) reliable and thus provisional. This is noticeable in the time-series graphs and this line drops down to zero every time the value is null. Better would be if the line ended and begun again.

With the outputs of all the data that is processed, analyzed and interpreted, there are a few remarks on whether these out comings are valid and/or where they origin from. These observations are still unclear for me. At first are the seasonal patterns in the time-series graphs. There are clear seasonally and annually trends noticeable, but looking at the spectral analysis graphs for the corresponding time-series graphs, the peaks who indicate trends, are not present. Is this because there are really not there, the seasonal trends? Or did something go wrong with programming these graphs? What I also still don’t know is the fact that the wet season is more saline for the site SH2 (surface- and groundwater, SH3 and SH4 (surface water) than for the dry season. Example given, for the wet season the salinity value is 8 PPT and for the dry season 4 PPT. Is this because of more influence of freshwater in the dry periods? That is most likely not the answer.

There is no real climate change conducted with the research, since there are almost no changes throughout the 7 years in the data for the research sites. However, there are some observations that maybe indicate climate change. For the last five years, 3 years were relatively wet. Only for this observation by itself, there maybe can be said that climate change is going on. Suppose, for the slightly increasing salinity level for the site SH2 (surface water), the freshwater of the wetter years can suppress this increase.

Another discussion point is about working with the graphs in The Netherlands. Because I had no access to the program MatLab, I could not modify any data or graphs. In a lot of graphs there is a 600day trend visible. This is probably because of not fully detrending (substracting the linear trend from the data sets, this enables a better focus on the fluctuations in the data) the data with the program. Before the detrending process there were more peaks visible, for instance the peaks that come from the tidal influence, but after the detrending process, these peaks were gone.

7. Conclusion

With the interpretation and discussion in mind, the conclusion and recommendations are written below. It will answer the main research question that is setup for this research project.

What do the water-data (salinity, rainfall, ground- and surface water levels) indicate about the water quality and quantity of the years 2004 to 2011?

In conclusion there can be said that the water quality and quantity of the Shark River during the 7 years, almost stay the same. The levels of salinity en the levels of ground- and surface water, show similar trends every year.

The north part of the project area (near the site SH1) is the least influenced by saltwater coming from the Gulf of Mexico, groundwater has the most influence of the two water levels. The closer to the coast, the more the sites are influenced. The salinity levels go up. For sites such as BSC and SH3 that are close to the shoreline, the salinity levels are around 30-35 PPT. For the site BSC (500 meters from the coast), the salinity levels almost even the salinity values of the ocean (33 PPT and the oceans salinity level is at 35 PPT).

In the time-series and for some spectral analysis graphs, the seasonal influence can be seen. The correlograms correspond to this, and indicates that there is seasonal influence. For lags of for instance 180 and 550 days, the autocorrelation is negative and for a lag of 365 days, the autocorrelation is positive. For water levels and salinity. Because wet season starts after a half year in every wateryear, these do not correlate with the salinity or water levels of the dry season.

Just before the wet season starts, the highest salinity levels are measured. The salinity levels in surface water in May/June have the highest values every year for every site that is situated close to the Shark River. Over the years the groundwater and surface water levels hardly change. The levels stay the same for the most sites for the 7-year dataset. With a dataset of 7 years, sea level rise cannot be observed.

Because the river is situated in a delta, the river has influences by tidal movements. For the site SH3, clear trends are noticeable. Especially the 14day, 28day, 180day and 365day trends are clear. The reason that there are 14day and 28day trends is because the influence of the Moon and the Sun. The other two trends come from seasonal weather changes.

Rainfall is also of importance. The rain that falls (especially in the wet season) influences salinity of the water. It bring extra freshwater in the hydrologic system. Salinity levels will go down and sometimes areas, which are normally quite dry, will be wet. In the last few years, there has been more rainfall, and this may cause a reduction in the salinity levels. These wet years could also be an indication of the start of climate change.

Concluding, the Everglades, the Shark River in particularly, is a dynamic environment. Salt- and freshwater, rainfall and tidal cycles are the most important influences in the area. The Everglades will always be an interesting topic for research projects about salinity and water data analysis.

As a recommendation; it would be great that this study would be carried on in the future. These results can be used for further research. If there are still funds for research on the Shark River, research on data with a time span of 25 years (entire water data collection), will give lots of interesting and useful information on a larger scale. Maybe climate change will be noticeable, with a bigger (more years) data set.

Another nice thing would be, that maybe someone is willing to rewrite my wrongs in a follow-up study. This will give a better and more accurate view on this subject. Especially the graphs will improve and with better graphs, that data and analysis will be trustworthier.

Because there are almost no funds anymore from the government, a possibility is that the Florida International University will carry on with this research. If this would happen, it would be great to still gain information about the Shark River and its hydrodynamics. Maybe other students can carry on with the work and make a bigger and better research out of it. Connection between relevant studies such as mangrove studies near the Shark River can be used together, for a clearer view of the Everglades water system.

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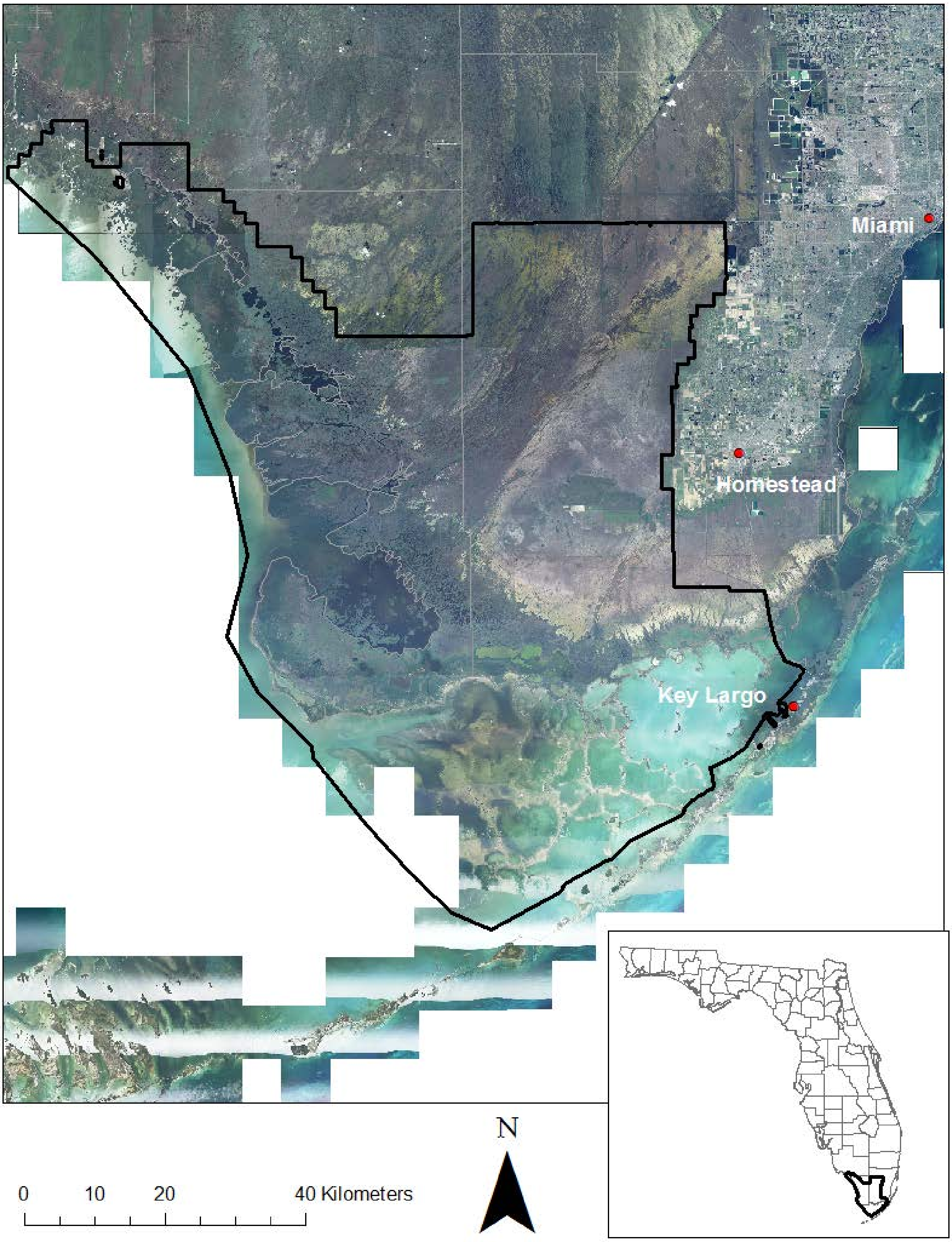
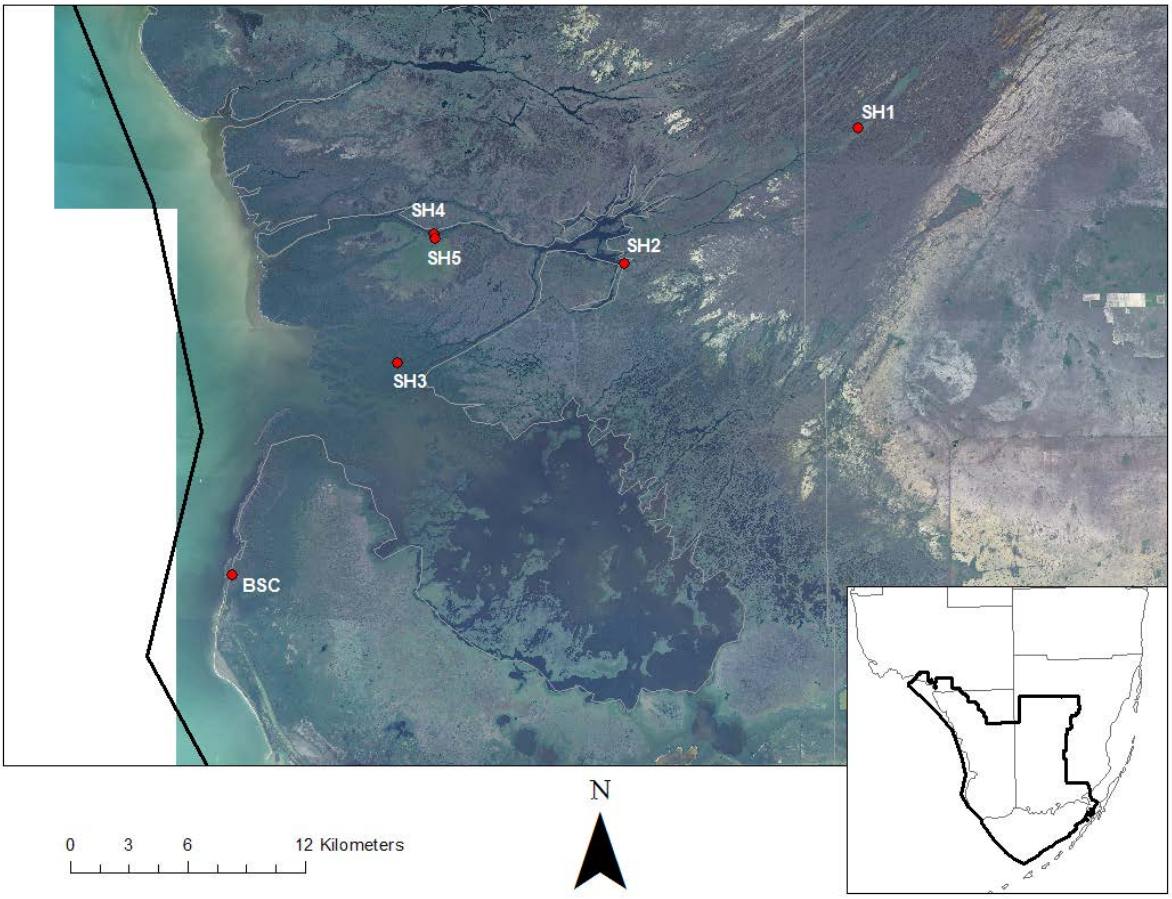
Annexes

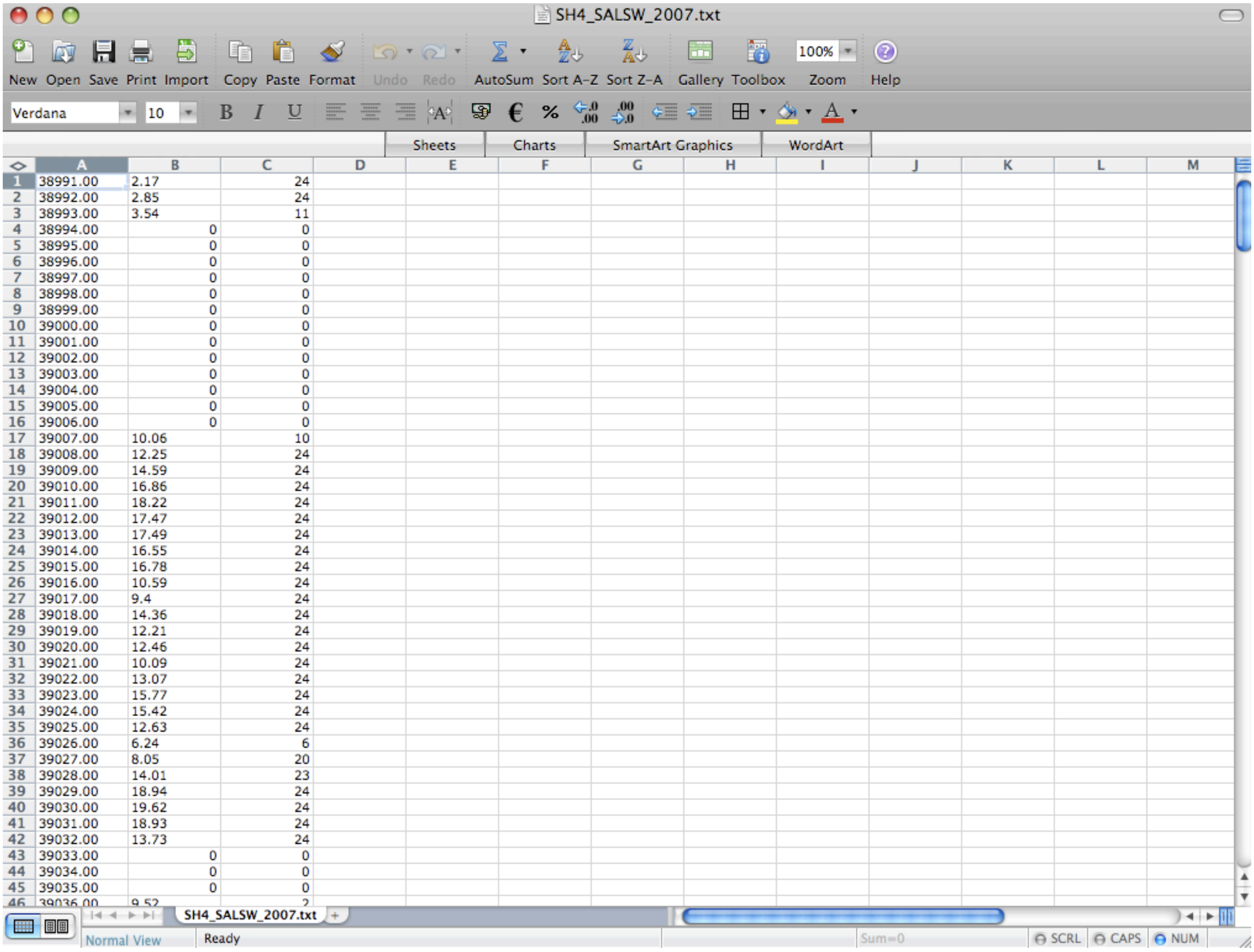
1. The Everglades, Florida



2. Study sites; the Everglades, Florida



3. Example of an Excel data set



	A	B	C
1	38991.00	2.17	24
2	38992.00	2.85	24
3	38993.00	3.54	11
4	38994.00	0	0
5	38995.00	0	0
6	38996.00	0	0
7	38997.00	0	0
8	38998.00	0	0
9	38999.00	0	0
10	39000.00	0	0
11	39001.00	0	0
12	39002.00	0	0
13	39003.00	0	0
14	39004.00	0	0
15	39005.00	0	0
16	39006.00	0	0
17	39007.00	10.06	10
18	39008.00	12.25	24
19	39009.00	14.59	24
20	39010.00	16.86	24
21	39011.00	18.22	24
22	39012.00	17.47	24
23	39013.00	17.49	24
24	39014.00	16.55	24
25	39015.00	16.78	24
26	39016.00	10.59	24
27	39017.00	9.4	24
28	39018.00	14.36	24
29	39019.00	12.21	24
30	39020.00	12.46	24
31	39021.00	10.09	24
32	39022.00	13.07	24
33	39023.00	15.77	24
34	39024.00	15.42	24
35	39025.00	12.63	24
36	39026.00	6.24	6
37	39027.00	8.05	20
38	39028.00	14.01	23
39	39029.00	18.94	24
40	39030.00	19.62	24
41	39031.00	18.93	24
42	39032.00	13.73	24
43	39033.00	0	0
44	39034.00	0	0
45	39035.00	0	0
46	39036.00	9.52	2

An example of a fragment of a data set is shown here. There can be seen, that the null's were replaced by zero's (0). These data sets are the source for the graphs that are present in the chapter "Results". This data set corresponds to the site SH4, the salinity in surface water for the year 2007.

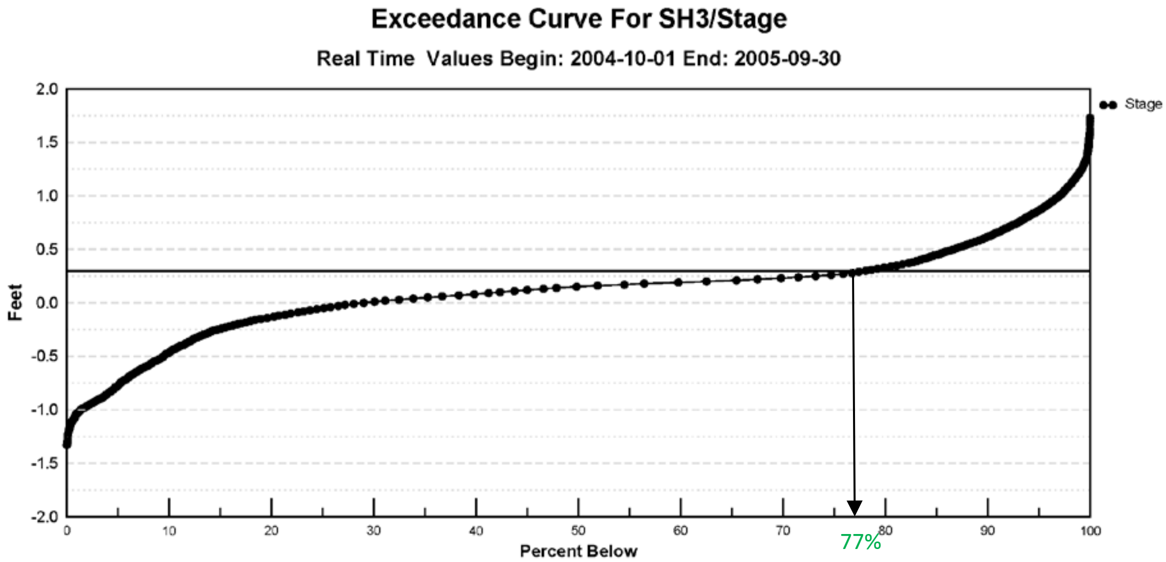
4. Example of a MatLab program

Shark_river_m_file.m

```
%Power spectra
P_Uq11= 2.*A_Uq11.*A_Uq11;
P_Uq10= 2.*A_Uq10.*A_Uq10;
P_Uq09= 2.*A_Uq09.*A_Uq09;
P_Uq08= 2.*A_Uq08.*A_Uq08;
P_Uq07= 2.*A_Uq07.*A_Uq07;
P_Uq06= 2.*A_Uq06.*A_Uq06;
P_Uq05= 2.*A_Uq05.*A_Uq05;
P_Uqall=2.*A_Uqall.*A_Uqall;

%%Frequency vector
f_quake=0:1/dt_q/N_quake:(N_quake-1)/dt_q/N_quake;
f_all=0:1/dt_q/N_all:(N_all-1)/dt_q/N_all;
% f_green=0:1/dt_green/N_green:(N_green-1)/dt_green/N_green;
% %Period vector
T_quake= 1./f_quake(2:N_quake/2);
T_all= 1./f_all(2:N_all/2);



figure(1)%%%SALSW SH4 2011
h1=subplot (3,1,1); plot (M_Date11, uq11);
     title('Salinity Surface water SH4 (2011)');
     xlabel('Time (days)');
     ylabel('PPT');
set(h1,'position', [.1 .75 .8 .2]);
%      axis ([40452 40816 -2 2]);
%%%%%%%%%%%%%%
set(gca,'XTick',M_Date11(1:31:end))
datetick('x','mmmyy','keepticks')
%%%%%%%%%%%%%%

h2=subplot (3,1,2); semilogx (T_quake, P_Uq11(2:N_quake/2));
     title('Spectral Analysis');
     xlabel('Period (days)');
     ylabel('Power-spectral density');
set(h2,'position', [.1 .42 .8 .2]);

h3=subplot (3,1,3)
     acf_year= acf(uq11,y_year);
     title ('Autocorrelation')
     xlabel ('Time (days)')
     ylabel ('Frequency')
set(h3,'position', [.1 .08 .8 .2]);

%%%%%%%%%%%%%%%%
```

This annex shows the master file that is used in MatLab for this research. This is only a part of the program that is made. This master file contains all the programming lines that are needed to eventually get the graphs. The graphs are the result of conversion datasets. The screenshot above, the gage SH4 for salinity in surface water is used. Three examples can be found, for the conversion of the salinity values in surface water for only the year 2011, the time-series graph, the spectral analysis graph and the autocorrelation graph. This annex gives a glimpse of a part of the entire master file.

5. Example of an exceedance curve



6. CD with extra information added

For more information about this project, check the CD. The CD contains all the relevant information.