The Meuse Explained.

Geography PO
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Preface

The Meuse is a river which has its source in the Langres Plateau in France, and flows out in the North sea in the Netherlands. It flows through Rotterdam, which is the area that will be used as a reference in this research paper. The Meuse flows from its source right through the French and Belgian Ardennes, which is why those areas have also been a focus of our research, particularly looking at weather conditions in those regions. Furthermore, the weather patterns in the North Sea have also been looked at, as they could influence the Ph levels and salinity of the Meuse.

Important to take into account is the fact that the Meuse converges with many different rivers, such as the Lek, a river which stems from the Rhine. This means that when researching the extent to which the source of a river has an impact on its characteristics, the most comprehensive and accurate conclusion can only be drawn when looking at every single source of the converging rivers. As that would take an incredible amount of research and data, this paper will focus on the main source of the Meuse: the Langres Plateau.

Drainage basin of the Meuse

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Summary

In this research paper, the correlation between weather conditions in the Langres Plateau and the velocity, river flow and salinity of the Meuse, which has its origin in the Langres Plateau and flows into the North Sea near the city of Rotterdam. Data from a website called Meteoblue and data from the rijkswaterstaat are compared and contrasted to see how they influence each other. Velocity are measured for this research paper. Furthermore, the pH-levels of the Meuse are also looked at by measuring them via the Globe Protocols. By looking at the collected data and by researching natural processes regarding the hydrological cycle and the formation of rivers, it is concluded that the hypotheses are correct to some extent, as the effect of precipitation cannot be measured in isolation, causing the raport to not be fully accurate. It is also concluded that precipitation is one of the many factors that influence a river's characteristics, and in itself does not have a major effect on the Meuse.

Introduction

The Meuse is one of the main rivers flowing through the Netherlands, and is the most important river to Rotterdam. In fact, a large proportion of Rotterdam's economy is reliant on the Meuse for trade and employment. It is also a river that provides fresh water that can be used for irrigation, tree cultivation and drinking water production (rotterdamnieuws.nl). It is therefore important to understand and be able to predict the behavior of the Meuse, as it could affect many people. That is why in this research paper, the correlation between weather and the behavior of the Meuse will be explored and analysed. If a clear correlation is found, this will help us predict the Meuse's behavior in the future, which is helpful when for example salinity levels are expected to rise or the river flow is expected to rise. This research paper will first explain the general factors that could hypothetically have an effect on a river, and will then deal with the guiding question of this raport. For this, data will be collected from the internet about weather conditions at different times in the Meuse's drainage basin, and will be compared to the respective state of the Meuse at that time. Two sets of data of the Meuse will be included that is measured by ourselves, namely the Ph-levels and the velocity. Finally, it will be determined whether the hypotheses were correct and a conclusion will be drawn from the measured data and data that has been collected.

Guiding questions and hypotheses

How do weather conditions in the Meuse's drainage basin affect its behavior?

- How do rainy and dry weather conditions in the Meuse's drainage basin, especially focussing on the source area the Langres Plateau in France, affect the Meuse's salinity levels and river flow?
- Is there a correlation between weather conditions in the Meuse's drainage basin and its Ph-levels and velocity?

It is expected that an increase in precipitation in the Langres Plateau and the drainage basin of the Meuse as a whole will cause a decrease in salinity levels and an increase in river flow, and that warm weather without precipitation will cause increased salinity levels and decreased river flow.

It is expected that increased precipitation in the Langres Plateau and the drainage basin of the Meuse as a whole will cause an increased velocity in the Meuse.

It is expected that precipitation in the Langres Plateau and the drainage basin of the Meuse will not have an effect on the pH-levels of the Meuse.

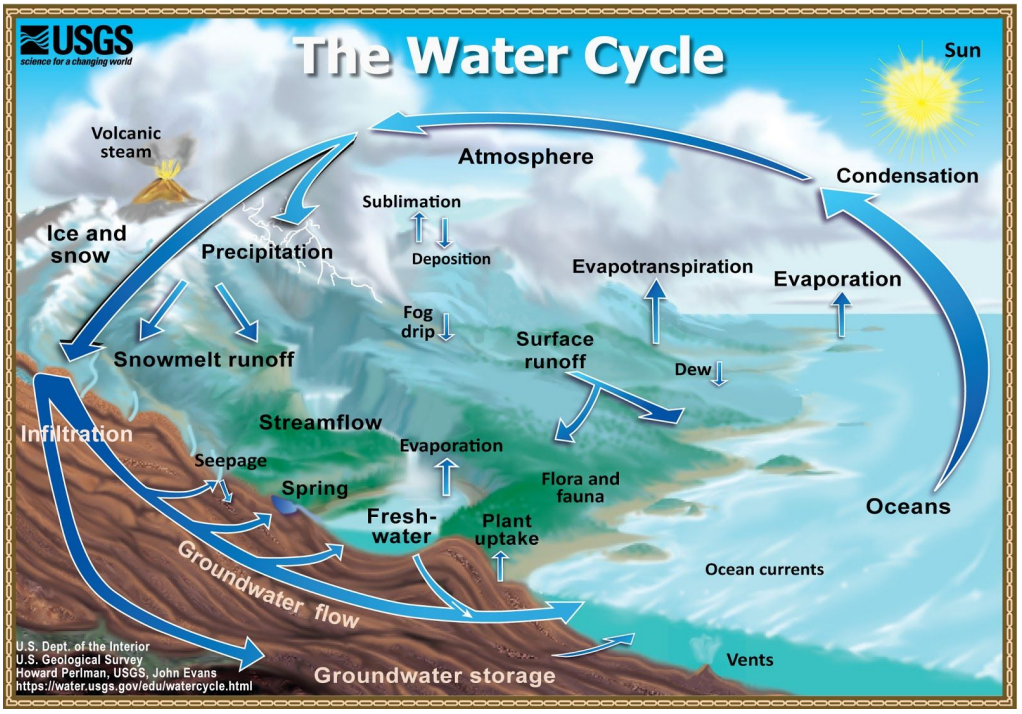
Justification of the chosen method and plan

As stated before, the Meuse has several sources which are not all included in this paper. The characteristics that we chose to investigate: salinity, velocity, river flow and Ph-levels are of significance because they all determine whether or not the water is suitable to be used for irrigation or drinking water production. The Meuse is one of the main river in the Netherlands providing fresh water, and therefore proves to be of high importance to the population of the Netherlands. It is therefore vital that predictions can be made about the water quality of the Meuse, as it can help prepare for periods of time where the Meuse might not provide us with safe and fresh water. It is also useful to know when to expect things such as floods from the Meuse, because it flows through quite a few densely populated areas. That is why the information obtained in this research paper will be valuable and useful.

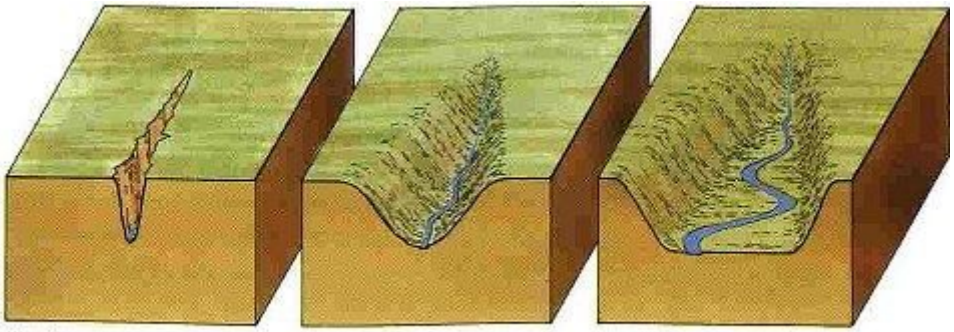
The way in which the research will be done in this paper is using reliable sources which showcase weather archives of the Meuse's drainage basin and the Langres Plateau. Secondly, the data about the Meuse will be obtained from the Rijkswaterstaat, who will be contacted for the needed data. Lastly, to explain the concepts explored in this research paper more comprehensively an introduction will be given to the hydrological cycle and the formation of rivers, as this helps to better understand how precipitation can influence a river. The obtained data will be looked at critically, and inconsistencies with the stated hypotheses will be addressed.

Factors that can influence a river.

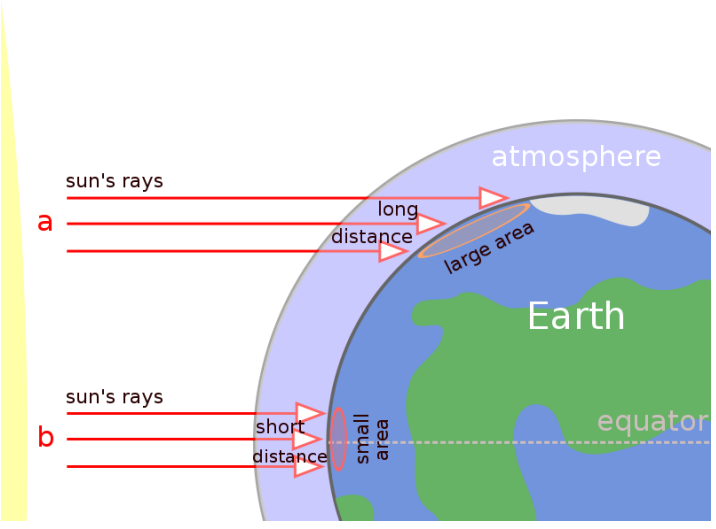
The formation of a river has everything to do with the hydrological cycle. Seawater evaporated by the energy of the sun, which then evaporated to form clouds. Transpiration from vegetation also adds to the formation of clouds. These clouds are transported by inland winds until they meet mountainous areas. As clouds meet the mountain, they are pushed upwards, causing the air to cool down until the water vapor condenses and causes precipitation (Britannica, 2018).



Precipitation leads to gully erosion as water finds its way in cracks and folds in the land. As small streams of precipitation run downhill, they may carve the land by wearing away rock. These carves grow overtime as more and more precipitation runs downhill. Eventually, a network of carves grows into a river system, flowing out into the ocean (Dorling Kindersley, 2018).



This system implies that the characteristics of a river heavily relies on weather conditions, as precipitation is one of the main sources of water that flows through the river. An important factor to take into consideration is the amount of rain that is intercepted by vegetation, and the amount of precipitation that seeps into the soil to create groundwater. These are factors that influence the amount of precipitation that actually enters the flow of the river.
First of all, impermeable soil will stop precipitation from seeping into the ground and forming ground water. What this means for a river, is that when the soil near the source of the river for example consist out of rock, it will be highly impermeable, causing the precipitation to be forced into the river. Near the mouth of the river, water levels can therefore rise after heavy rainfall.
Secondly, vegetation also plays a role in water levels in a river. If there is a lot of vegetation at the source of the river, a lot of precipitation will be intercepted before falling onto the ground, causing less water to enter the river. Especially during warmer seasons, when there is a lot of greenery and generally little precipitation, a very limited amount of water will enter a river (USGS, 2016).
Salinity of a river is also affected by precipitation. Precipitation near the source causes fresh water to enter the river. This will therefore decrease salinity, as there is less salt per cubic unit. However, precipitation near the mouth of a river has the opposite effect. When sea levels rise due to heavy rainfall, sea water will enter the river near the mouth. River levels will therefore rise, and salinity will also rise near the mouth of the river, as sea water has a very high salinity level (NASA).
The latitude of the river will determine the weather conditions that it experiences, thus shaping its characteristics. Near the equator, there is a low pressure zone, so a lot of precipitation occurs here, while near the sahara there is a high pressure zone and little to no precipitation (Weather Works, 2016). Low latitudes also mean that there is a very high temperature, which cause more evaporation during the course of the river (Kids Geo, 2018) This can also decrease water levels and increase salinity levels, as only water evaporates and salt stays in the water.



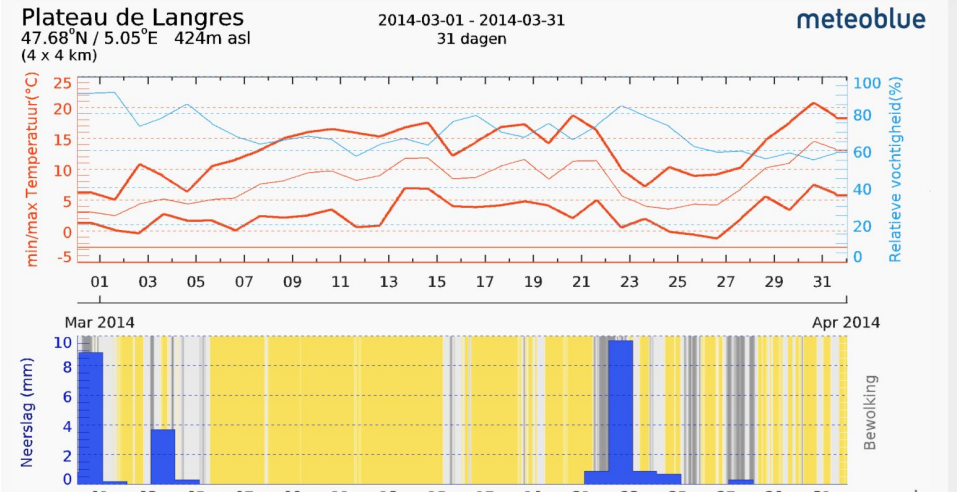
These are all ways in which weather conditions, latitude and soil can influence different characteristics of a river. Taking this knowledge into account, the weather conditions in relation to the Meuse can be analysed.

Factors that influence the Meuse

The weather data in this part of the research originates from Meteoblue.com. The data about the river Meuse originates from Rijkswaterstaat.

The Meuse has its main source in the north-east of France in the Langres Plateau (DV Media Farelli Producties, 2018). This region experiences a mixture of a continental climate and an oceanic climate, seeing as it is located more land inwards, but could still experience influence from the sea as neighboring regions do have an oceanic climate (VWK, 2013). Land warms and cools faster than water, so regions with a continental climate experience more extreme summers and winters than regions near the sea, which are influenced by the moderating effect of the temperature of the sea (Enviropedia.com). However, it is located on quite a northern latitude, 48°. This means that sun rays hit the earth at quite a low angle, decreasing the radiation density. This causes temperatures to be lower than, say, near the equator. What this means for this research is that changes between winter and summer weather in this area might be quite moderate in relation to the effects on the Meuse, as weather conditions have to be quite extreme to influence a river substantially. This could cause the acquired data to not show our hypotheses as clearly as desired.

To see how drought influence the Meuse, data of the weather of the Langres area will be shown below.



This data shows the weather conditions during March of 2014 in the Langres Plateau As seen in the graph, temperatures were quite moderate, and there was a largely clear skies with a period of no precipitation in the middle of the month. The effect on the Meuse near the mouth can be seen in the table below.

Locaties

- Brienenoord (kilometer 996.5)

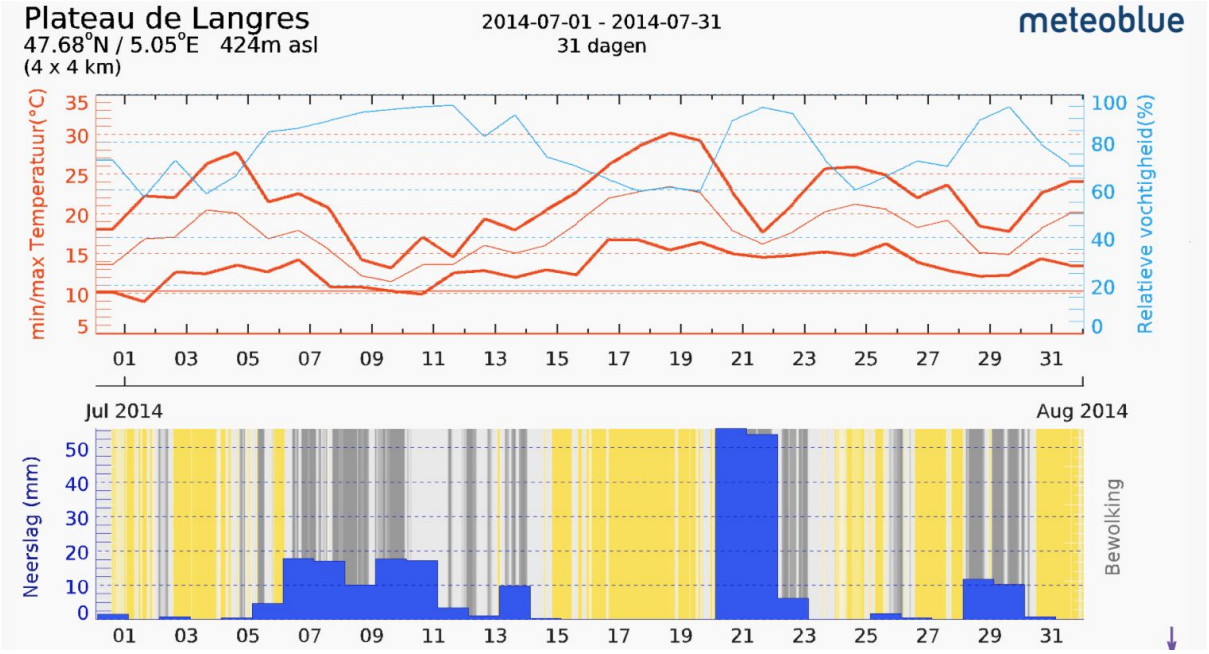
Alle tijdsaanduidingen zijn in GMT+1 (MET)

Brienenoord (kilometer 996.5)

Coordinaten in RD (EPSG: 7415): 95700, 434950

01-03-2014 12:00	684
02-03-2014 12:00	786
03-03-2014 12:00	655
04-03-2014 12:00	696
05-03-2014 12:00	674
06-03-2014 12:00	699
07-03-2014 12:00	565
08-03-2014 12:00	755
09-03-2014 12:00	334
10-03-2014 12:00	720
11-03-2014 12:00	750
12-03-2014 12:00	492
13-03-2014 12:00	336
14-03-2014 12:00	537
15-03-2014 12:00	94
16-03-2014 12:00	418
17-03-2014 12:00	505
18-03-2014 12:00	518
19-03-2014 12:00	370
20-03-2014 12:00	526
21-03-2014 12:00	143
22-03-2014 12:00	413
23-03-2014 12:00	326
24-03-2014 12:00	642
25-03-2014 12:00	504
26-03-2014 12:00	609
27-03-2014 12:00	592
28-03-2014 12:00	357
29-03-2014 12:00	414
30-03-2014 12:00	326

This table shows the flow of the Meuse in March. It shows that the net flow of the river is quite low during March, especially between the 12th and 23rd. This correlates with the data of the weather in the Langres area, as it starts to rain again on the 21st. The water needs some time to flow to its mouth, which is why on the 23rd you can see a rise in flow. This shows that periods of drought near the source have an effect on the flow of the Meuse near its mouth.
A short period of very heavy rainfall occurred in July of 2014. When looking at the soil type and vegetation present in the Langres Plateau, it is made up of mostly impermeable rock. Furthermore, during the winter there is not a lot of vegetation present in the area. During the winter there are also periods of thaw, causing ice and snow to melt and also enter the river. Lastly, the large relief of the Meuse makes for steep hills, causing water to flow relatively fast (De Grote Bosatlas, 53th edition). All of these factors intensify the effects that precipitation has on the Meuse. The data obtained of weather in the Langres area and the Meuse's river flow are be included below.



Around 5-15 July there was moderate rainfall, and from 20 to 22 July heavy rainfall. Its effects on the Meuse can be observed in the table below:

Locaties

- Brienenoord (kilometer 996.5)

Alle tijdsaanduidingen zijn in GMT+1 (MET)

Brienenoord (kilometer 996.5)

Coordinaten in RD (EPSG: 7415): 95700, 434950

01-07-2014 12:00	347
02-07-2014 12:00	391
03-07-2014 12:00	202
04-07-2014 12:00	337
05-07-2014 12:00	207
06-07-2014 12:00	410
07-07-2014 12:00	527
08-07-2014 12:00	492
09-07-2014 12:00	165
10-07-2014 12:00	772
11-07-2014 12:00	966
12-07-2014 12:00	890
13-07-2014 12:00	751
14-07-2014 12:00	785
15-07-2014 12:00	684
16-07-2014 12:00	774
17-07-2014 12:00	620
18-07-2014 12:00	661
19-07-2014 12:00	729
20-07-2014 12:00	811
21-07-2014 12:00	942
22-07-2014 12:00	1108
23-07-2014 12:00	860
24-07-2014 12:00	651
25-07-2014 12:00	662
26-07-2014 12:00	704
27-07-2014 12:00	717
28-07-2014 12:00	739
29-07-2014 12:00	677
30-07-2014 12:00	649

The table shows a sharp increase in flow on 20, 21 and 22 of July, which corresponds with the days of heavy rainfall.

However, in both cases there are sets of data which do not align with the hypothesis. For example, in the first table water flow levels are generally low, but do not display a rapid drop as would be expected in a very dry period, but a rather smooth transition. It can also be seen that on the 10th and 11th of March 2014, the Meuse seems to have quite a normal flow, while the drought in the source region had been going on for several days already at that time. In the second table, a dry period between the 14th and 20th of July can be seen, while this is not translated into the table of the flow of the Meuse during that time, which showcases a rather high flow compared to the amount of precipitation in the source region. Looking critically at the data obtained brings a new nuance to the analysis of the data, as it implies that precipitation in the source region is not the only factor influencing river flow. Other factors that could influence the river flow of the Meuse include, but are not limited to: evaporation, weather conditions on the North sea, weather condition in Rotterdam, weather conditions along the river itself and presence of vegetation. This is important to consider when eventually drawing a conclusion from the collected data.

As for salinity, one would expect salinity to drop during heavy rainfall near the source. The reason for this being that precipitation adds fresh water to the river, causing the salt solution to become more diluted. To see if the Meuse's salinity is affected by precipitation, the salinity levels of 2016 will be analysed by looking at the weather conditions both at the mouth and source region of the Meuse. A table of the salinity levels of 2016 will be included below.

WNS: Saliniteit in oppervlaktewater

Periode : 01-01-2016 tot 30-12-2016

Locaties

- Brienenoord (kilometer 996.5)

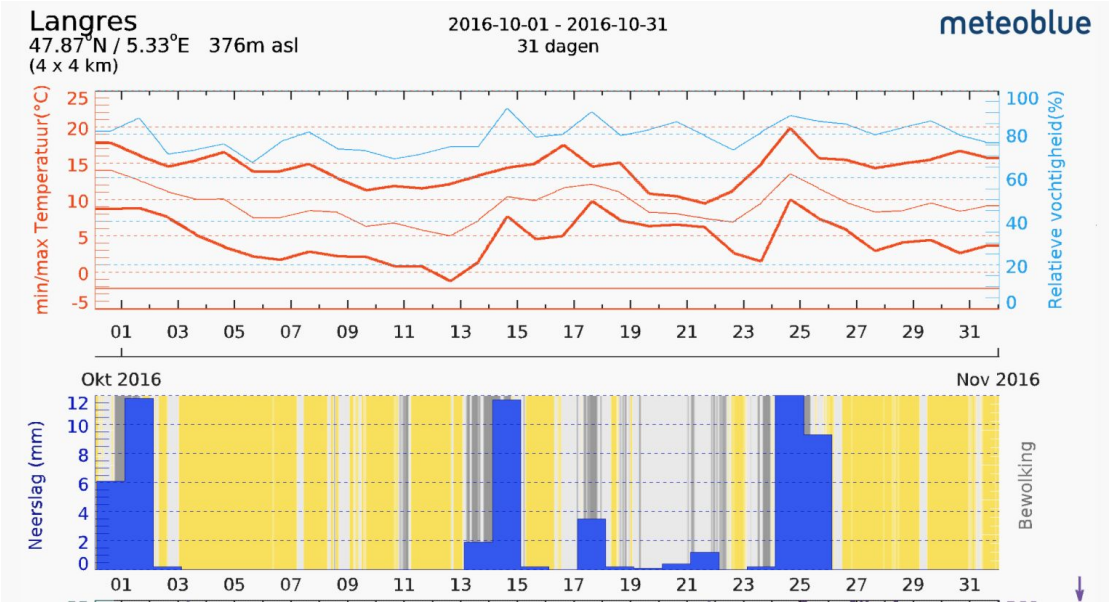
Alle tijdsaanduidingen zijn in GMT+1 (MET)

Brienenoord (kilometer 996.5)

Coordinaten in RD (EPSG: 7415): 95700, 434950

13-01-2016 12:01	0.370
10-02-2016 08:34	0.300
09-03-2016 11:21	0.280
06-04-2016 10:58	0.340
02-05-2016 12:49	0.270
01-06-2016 08:11	0.260
29-06-2016 07:36	0.230
27-07-2016 07:59	0.280
24-08-2016 07:26	0.310
21-09-2016 11:17	0.980
19-10-2016 08:05	7.57
16-11-2016 09:19	1.21
14-12-2016 11:56	0.420

The salt levels at the beginning of the year start off quite stable, and don't fluctuate too much. However, in September the salinity starts to suddenly rise from 0.3 to nearly 1. Then in October there is an extreme rise in salinity levels, reaching nearly 7.6. To explain this anomaly, several conditions need to be considered. Firstly, the weather conditions during this time in the source area Langres.



This graph shows precipitation levels in October of 2016. The graph does not display any kind of data that is out of the ordinary, and even show precipitation in the days before the increase in salinity. According to our hypothesis, to explain this anomaly, a drought would have had to occur in the month of October with extremely high temperatures if the weather near the source did in fact influence the salinity levels of the river.

As that is not the case, it would make sense to look at the conditions near the mouth area. When sea levels rise, seawater flows into the mouth of the river upstream, increasing the salinity levels near the mouth of the river. We do not have access to the water levels of the North Sea, however, the river flow of the Rhine and Meuse can also influence the amount of sea water entering the Meuse. Firstly, September and October were exceptionally dry months around the drainage basin of the Meuse. This caused rapid evaporation, and lowered the water levels of the Meuse. The lack of precipitation also limited the amount of fresh water added to the meuse. The biggest factor that caused the increase in salinity in the Meuse is the sudden decrease in river flow from the Meuse, allowing water from the North Sea to rapidly flow into the river. In fact, this is a problem that has even been addressed by the WWF at the end of 2016. They have stated that the usage of river water near Gouda for irrigation is unreliable, seeing as salinity levels have reached very high levels several times causing the water to be unfit for consumption. They therefore have proposed to use fresh water that is transported into the Netherlands by rivers in the west. This shows that the spikes in salinity levels are something that regularly happens in the Meuse, which helps to understand and explain the behavior of the Meuse. Due to several factors working together: prolonged high temperatures, lack of precipitation, decreased river flow and increased sea water levels, the Meuse's salinity levels spiked in October of 2016 (waterpeilen.nl).

Measured velocity and Ph-levels of the Meuse

For this paper, two experiments have been conducted, namely the measurement of the velocity of the Meuse and the Ph-levels of the Meuse. The Ph-levels measurements have been obtained following the Globe Protocols, while the measurement of the velocity did not follow the guidelines of the Globe Protocols. Both experiments were performed on the 30th of March, 2018.

First the data acquired from the velocity measurements will be discussed. The step-by-step plan used for this experiment will be included below.

For this experiment, the following equipment was used:

- 1 ping-pong ball.
- 1 stopwatch
- measuring tape

Person 1 stands beside the river with the ping-pong ball, while person 2 uses the measuring tape to position themselves 10 metres downstream with a stopwatch. Person 1 throws the ping-pong ball in the river, and person 2 stops the stopwatch when the ping-pong ball has passed them. The collected data will show the speed in seconds per 10 metres. This experiment was repeated 4 times for comparison. The location of this experiment was the Westerkade by the Euromast Park, a relatively linear part of the river.

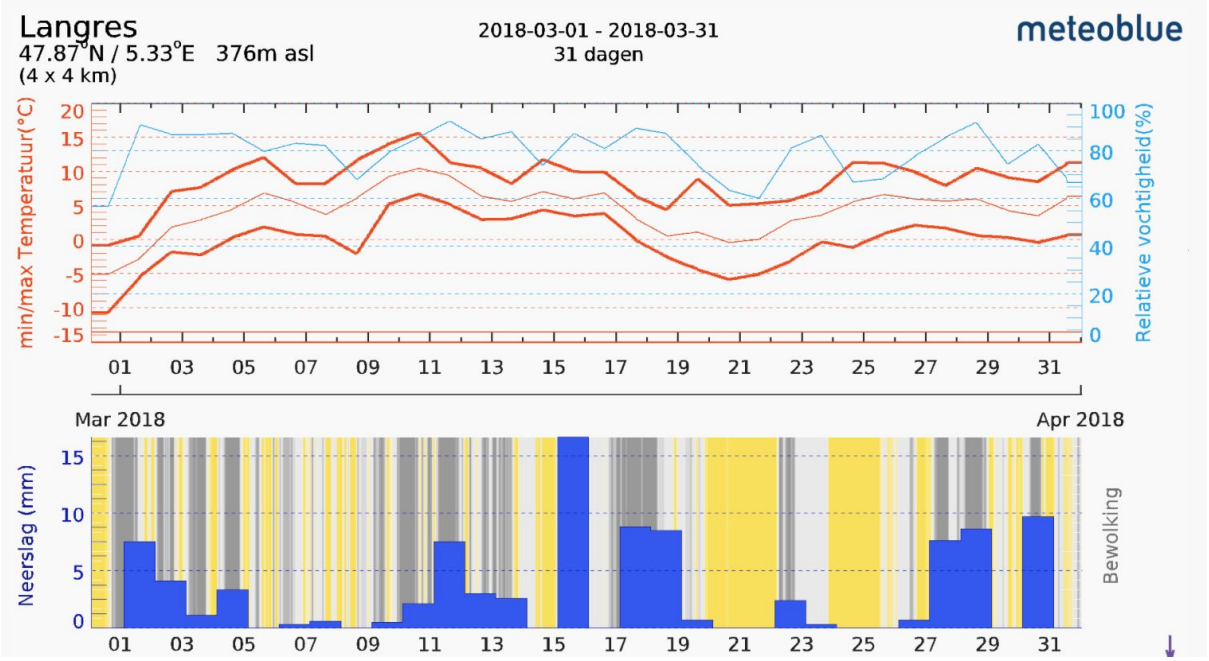
18.08s/10m = 1.99km/h
19.02s/10m = 1.89km/h
17.32s/10m = 2.08km/h
18.29s/10m = 1.97km/h

The average speed that has been measured is 1.98 km/h

Secondly, the pH-levels of the Meuse were determined. This was done through the use of a pH-meter. This consisted of a piece of paper with the numbers 0 through 14 on it. These number resemble the level of acidity of the river. If the pH level is below 7, the water is considered acidic, and above 7 is considered basic. The normal range for surface water system is between 6.5 and 8.5, which is also considered the safe range for drinking water. To measure the pH-levels of the river Meuse, the meter was used. This was done in a place called the Veerhaven, because here the water was easily accessible.

Ph-level measured: 7.2

The measured pH levels are quite regular for a river, but the measured velocity is a little lower than expected. Since the Meuse travels over quite a great relief, with a height of 409 m at its source and depths reaching below sea level near its delta in the east of the Netherlands. However, the velocity was measured at a location that is quite near the end of the Meuse. Rivers flow fastest near their source, as this is their 'youthful' stage. A river experiences 3 phases: youthful, maturity and the old stage. At the old stage, The valley of a river will have a wide and flat floor. More deposition of sediments takes place in this stage, because the velocity of the river decreases (Mandy Barrow, 2013). This all contributes to the slowing down of a river, and is the reason that the measured velocity does not reflect the Meuse's normal, relative high, velocity. Below a graph of the weather in the Langres Plateau will be included



The precipitation in Langres in this month is quite regular for this time of year. This means that it is hard to see whether there is a correlation between weather conditions and pH-levels

of the Meuse, as it can be seen best when abnormal weather conditions occur. Precipitation can influence pH-levels of a river when there is a high concentration of acidic pollutants present in the rain, which are caused by compounds like sulfur dioxide and and nitrogen oxide (US EPA). It is unlikely that the Meuse is affected by such acid rain, as the north of France is not a region that is prone to experiencing acid rain, unlike regions such as China or Poland (Wikispaces.com).

The hypothesis for the velocity of the Meuse has been partially disproven, as the data does not showcase an increased velocity when increased precipitation takes place in Langres. It is factually correct that increased input of fresh water in a river causes a higher discharge and therefore mostly a higher velocity. It is very likely that the location of measurement has to do with the discrepancy of the collected data, as it was measured in the 'old stage' of the Meuse. This part of the river has a natural lower velocity. The hypothesis about the pH-levels of the Meuse was partially correct. In the case of the Meuse it is true that precipitation at this moment does not have an effect on its pH-levels, but that does not mean that it is not possible. If there were to be a sudden increase in pollution near the North Sea, for example on the east coast of the Netherlands, in theory it would be possible for acidic rain to occur in the north of France, which the hypothesis did not account for.

Conclusion

The hypotheses states at the beginning of this paper have been tested throughout the conducted research. Generally speaking, the hypotheses have mostly held up.
Firstly, looking at how weather influences river flow, the collected data shows that heavy rainfall can increase the river flow of the Meuse, and that drought can lower the river flow. This has also been proven by the data collected from the Meuse's salinity levels, as one of the factors causing a spike in salinity was the lowered water levels and river flow. This was caused by high temperatures and drought in the river basing of the Meuse, which shows that little precipitation can lower the river flow.
Secondly, the hypothesis that rainfall and drought could influence salinity levels has been partially disproven. While a spike in salinity levels did go paired with drought, after thorough research it was determined that there were many factors working together to cause this change in salinity. This means that the hypothesis was correct in pointing out the correlation between precipitation and salinity levels, but incorrect in the amount of influence rainfall would have on salinity levels.
Lastly, the data measured by ourselves regarding velocity and pH-levels partly correspond with the stated hypotheses. The hypothesis that there is a correlation between precipitation and the velocity of a river is generally true for most rivers, but was not true for the specific measurements that we took. This was both due to the fact that measurements were done in the 'old stage' of the river and because measurements were performed on one day. The hypothesis about the pH-levels was correct for the river Meuse.

However, even though the hypotheses are correct in broad lines, inconsistencies have also been pointed out in this paper. For example, higher precipitation does not always lead to a higher river flow or lower salinity levels, and drought does not always lead to lower river levels and higher salinity levels. This shows that even though weather can have an effect on a river, it is almost never the only factor influencing the river. Because we cannot observe the isolated effects of weather on a river, it would be inaccurate to state that there is an undeniable correlation between precipitation and changes within the Meuse. However, it can be said with certainty that weather does play a role in the changing characteristics if the river Meuse.

Evaluation

Although the research in this paper tried to look at as many aspects as possible to portray the most accurate and complete analysis of the guiding question, there are several aspects that could be improved in the future to provide more reliable information. First of all, it is essential that all sources of the Meuse be looked at instead of only the Langres Plateau, as weather conditions in these regions all have an effect of the Meuse. Secondly, it is important to look more in depth at all of the other factors influencing the Meuse, such as the weather conditions on the North Sea, wind directions, the amount of vegetation along the entire drainage basin of the Meuse, rising sea levels due to increased global warming, increased pH-levels due to increased pollution thus increased pH-levels in precipitation etc. This would give a more comprehensive and reliable conclusion to the stated hypotheses, but would also require much more research, experiments and analysis. However, the research done in this paper could not have been more comprehensive with the resources that were available to us, looking at the acquired data from the Rijkswaterstaat, the limited information available about weather conditions along the Meuse's drainage basin and the limited instruments available to us for measuring velocity and pH-levels.

Logbook

date	**activity**	**Explanation**	**length**
05/03/2018 and 29/03/2018	Call rijkswaterstaat	We called the rijkswaterstaat for information about the Meuse river.	20 min
28/2/2018	Conduct experiments	We conducted the experiments to measure the velocity and pH-levels of the Meuse.	3 hours
09/03/2018	Visit Rijkswaterstaat	We went to visit Rijkswaterstaat to pick up information / data and ask some questions.	1 hour
Througout march	Work on the PO	Working on the PO and writing it.	8 hours
Throughout march	Do research	Researching information and statistics / archives.	1 and a half hours

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