**~~Peak Identification Algorithm~~**

**~~Methane Emissions with Water level~~**

~~On first visual inspection of the Methane emissions Peaks, they don’t seem to originate at completely random Times. In particular, a pattern can be observed when the Methane concentration Timeline is plotted together with the water level of the Elbe River. As seen in Plot~~ *~~1\_CH4\_WL.png~~*~~, which is a Section of the complete timeline. Here, the dominant Methane Peaks occur around 1-3 h after the Lowest Water Level. The Smaller Peaks are visually more challenging to identify and correlate to the Water level. The Peak identification algorithm has been used to identify a correlation between the Peaks and the Water level, which yields the expected correlation to the Water level.~~

~~To prove a correlation, Pearson's correlation coefficient has been used. Unfortunately, the occurrence of Ellevated Methan concentrations doesn’t seem to be a single variable correlation. So, a simple correlation of the Total water level and concentration yields practically no correlation. As will discuss later, wind direction and velocity are major contributing factors.~~

~~To establish a correlation between water level and Methane, each wind direction and corresponding Velocity had to be analysed separately. This was done by binning all methane and Water level measurements in 10° Direction and 1m/s Velocity bins. A Visual representation of the obtained results can be seen in Plot~~ *~~13\_CH4\_vs\_Waterlevel\_Correlation\_Geomatikum.png~~*~~. In this plot, each tile represents a wind Data bin with the colour representing Pearson's correlation coefficient, It can be seen that in three regions with particular Directions and Speeds, a strong correlation between the methane and the water level is observed. This indicated that three regions contribute to elevated methane emissions. The Suggested locations will be discussed later. To validate if the correlation can be trusted, a p-value test has also been conducted with a value of <(>)0.05. A plot visualizing the results can be seen in~~ *~~13\_CH4\_vs\_Waterlevel\_P\_Value\_Geomatikum.png~~*~~.~~

~~Fortunately, the Regions of interest pass the test, while the regions that don’t show a correlation to the water level fail the test as expected.~~

~~With the correlation results indicating a significant dependence of the methane emission to the water level, further investigation in this rection can be pursued.~~

**~~Methan correlation with Water Quality~~**

~~That the Elbe river seems to be the significant contributing factor to the methane peaks and generally to the composition of the Hamburg air composition can be seen when investigating the Water quality measurements provided by……..~~

~~Using the same correlation approach as before, a very clear influence of the Elbe can be seen in a particular Wind direction region and Wind Speeds. This region is around 180° to 300° for a Wind Speed between 1.5 m/s to 7 m/s. In this general direction to the Geomatikum the river is directed and has its largest influence by the Tides. Further to the est, a series of Locks block the tide.~~

~~When Looking at the correlation plots for Water temperature, Oxygen concentration, opacity and pH level. A very clear correlation can be observed. This strong indication the river Elbe is a large Methane emitter which is under the influence of multiple parameters that change over a daily, monthly and yearly cycle.~~

~~In the Literature (references) this is also strongly indicated…….~~

**~~Methane emission with meteorological observation~~**

~~Like the water level correlation, all other available meteorological observations have been investigated.~~

~~Most Meteorological Parameters don’t seem to have any correlation to methane emissions. Those include, for example, precipitation, air pleasure etc. Others do have a very strong correlation, while some seem to have a general correlation independent of the wind direction, like Dew Point ………. Of particular interest are other Meteorological parameters that show a very strong (negative) correlation to Methane emission, this includes Temperature, Solar radiation intensity. What is interesting is the significantly different Wind directions compared to the Water level correlation. The general region of the emissions is North-West to East-South-East, which points inland where the River Elbe is not present and is more agriculturally used. The p-value test shows that the correlations pass the test for the regions of most interest.~~

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**~~Methane Emissions with Wind~~**

~~As previously mentioned, dose the Wind plays a significant role in the measured methane concentration at the Geomatikum. Hence a detailed analysis of the observed wind is essential. A dominant wind direction could be observed with generally medium wind speeds during the entire measurement campaign. The Windrose Plot~~ *~~WindRose\_Total.png~~* ~~show rather well an average wind direction of South-West. While generally, Wind from all directions has been observed, four distinct directions have been observed, indicating some reoccurring and distinguished weather patterns in Hamburg. Most likely the Westerly winds, High-pressure regions over the Main and transitions of cyclones into central Europe. By additionally using the Methane measurements, one can see in a Pollutionrose that the Methane emission dose comes from every direction with a distribution closely reassembling the direction distribution. This shows us that the background methane concentration has no clear emission direction, hence no particular strong emitter nearby influences the Background. (find Average for direction)~~

~~When now only considering the methane peaks identified with the Peak finding algorithm, the distribution changes substantially. In plot~~ *~~WindRose\_Peaks.png~~* ~~and~~ *~~PollutionRose\_Peaks.png~~*~~. The Pollution rose plot, in particular, shows that the peaks, especially the high concentration ones, have three distinct directions, South-west, South-South-West and North-North-West. The directions observed are the same as that can be seen in the correlation plot with the Water level in the section~~ *~~Methane Emissions with the Water level.~~* ~~This is another strong indication that distinct emission regions are responsible for the methane peaks.~~

**~~Emission Distance~~**

~~The Sharpness of the Peaks, the relatively short duration of 1 to 3h and the very high methane concentration at the peaks indicate a location of the emitters relatively close to the measurement site. Together with the strong indications that the Methane Peaks correlate to the tidal cycle of the Elbe…~~

~~It is attempted to estimate the distance of the methane emission to the Measurement site at the Geomatikim. For this, a trek of a virtual Wind particle is modeled using the measured wind data at the Geomatikum. The Practical travel between the point of the max methan concentration per peak and the previeal Elbe river Low water Point. The totale distanze between the Geomatikum and the Esitmatet emission is than calculated.~~

~~The resulting distance ist plottet versus its Peakss Maxiam Methan concentration in a scatterplot seen below:~~ *~~14\_Low\_WL\_to\_Peak\_dist\_new.png~~*

~~Here it can be observed that the Significant Peaks with a high concentration forme a Peak at a distance from the Geomatikum of around 5 km. While most alleviated values are in the range of 1 to 13 km. Longer distances are obsert but with a significantlz lower concentation. When looking at the the Peks selected form with the Criteria dicribt above (Paper creteria) a corelation to concentration with distance can be seen. Schowing the thurther away the estimated sorce is the Lower the concentation. As one would expect. The Far away points are very likely less influenced directly by the Tidal cyle.~~

**~~Transport model~~**

~~It has been attempted to construct a Transport model to locate the emission regions. For this purpose, the temporally high-resolution wind data provided by the University of Hamburg and The Deutsche Wetterdienst have been used. The transport model uses the wind data to create Gaussian Plums with the measurement site as a particle emitter. The emitted partials travel backwards in time; this allows the calculation of reversed particle tracks. To Create Gaussian Plums, form a single emission time, a large number of particles are emitted at each investigated emission time. The direction and speed of each particle is randomised with a predetermined Standard deviation for each particle trek segment. The degree of randomisation has been taken from literature values for similar topography and wind Speeds (values and reference). The methane emission location can be estimated by calculating the particles' density by geographical distribution.~~

~~Additionally, two separate approaches have been tied to investigate if the results are comparable. At first, the particle tracks are calculated using the wind direction and speed for each measurement interval. So that the particle can follow changes in wind direction and speed over time. The track is randomised at each interval. Using this approach, it can be observed that many particle tracks follow the path of the river Elbe quite closely. One limitation of this approach is that if a particle travels too far from the wind measurement location, it could experience a different wind system not detected at the measurement location. This is particularly interesting when the particles leave the city borders, as it is well known that a City's climate can differ quite largely from its surrounding due to Topography and temperature differences. Unfortunately, no weather station with the same degree of standardisations as seen from the DWD and Uni Hamburg is available near the city. So that the assumption of uniform wind in the region must be taken.~~

*~~In the second approach, the wind direction and speed measurement were averaged for the time of the investigation. (Standard deviation verwenden????). In particular, interest in the duration of a methane peak. The particle tracks are calculated for each minute, with the track randomisation at each interval. In this approach, the wind is assumed to be uniform for the region, but as the wind is averaged over a longer time, it can be assumed that the predominant wind direction expresses a larger influence than short fluctuations in speed and direction.~~*

~~The Transport model has been used in tandem with the peak finding algorithm to investigate the peak methane emission locations.~~ *~~Here the First approach yields better results~~*~~. After the methane peaks are identified, the time of the lowest water level within the 12 hours before the Peaks are identified. As many regions of the Elbe River dry out sometime before the lowest water level is reached, half an hour before the low point is calculated. It is estimated that many riverbeds, fleets, and wetlands are already dry at this time. The Transport model estimates the tracks and distribution region from the methane peak maximum concentration to half an hour before the previous low water.~~

~~As seen in figure~~ *~~10\_Emission\_Distribution\_with\_Changing\_Measured\_Wind.png~~* ~~the Density is exceptionally high in certain Inner-city regions. Firstly, in the Historic city centre where the river Alster joins the Elbe (Paper high concentration measurements). This Part of the city has a large, still sweet water Lake, the Alster lake, which is relatively Shallow. Additionally, a large amount of interconnected small Fleets, Historic harbours, and channels are present in this region, most of them completely dry out for some amount of time during the tide cycle. Exposing sediment-rich ground.~~

~~The Second region is the South of Hamburg. The Hamburg Port is located in this region, which includes a vast network of channels, contributing rivers, small harbours and some small wetlands. This region also shows an elevated density following the river Elbe upstream land inward.~~

~~The Last region of higher density is on the western side. Notably, a significant amount of tracks follow the Elbe river downstream along the Elbe towards the sea. This region experiences the effects of the tide very strongly, with large regions that run dry during low tide. Indicating that the origin of the methane peak can be quite far away, but the accumulation of methane along the entire length of the river in the air can produce a high methane concentration in the city with favourable wind conditions. One can also notice that a higher density occurs north of the Geomatikum. But further investigation of the track shows that the wind at those peaks is quite slow and shows a turning wind direction. The tracks also lead to a large wetland region on the Elbe just outside the City bordered on the west side of the city.~~

~~This investigation indicates an elevated methane emission originating from the Water system and its surrounding in Hamburg and its outskirts. The first instinct is to conclude that the river is the main contributor to methane. Nevertheless, other contributing locations must be investigated. The first is the obvious presence of industry along the river. Example of those includes fossil fuel refineries, chemical production, Shipping etc. They are all heavily dependent on the river Elbe, and many of them have to follow the tidal cycle for their operation. But as seen by (Paper) the emission from these sources has been investigated and seems to be only a relatively small emission source. Additionally, as discussed later, the isotopic signature is not typical for Anthropogenic sources. So that this aspect is not a plausible explanation for the methane peaks.~~

~~The Second possible contributor in the Hamburg Port region is the presence of civil infersurture, which includes waste water treatment, garbage processing, etc. Those locations have also been investigated closely with drive-by measurements using a boat and a car. This is described in more detail in (Paper). No elevated concentrations have been observed near those locations. Further questioning of the facility's operators revealed that the facilities operate completely sealed from the environment, and Methane produced by the process is collected and introduced to the local gas grid. Additionally, it was ensured that no venting of the feasibility occurs at any time, eliminating the possibility of the Methane peaks occurring due to short methane venting events during their operation.~~

~~In the inner-city regions, no such infrastructure and industry are present. Only residential and business zones are located in this region.~~