STATISTICAL ANALYSIS OF THE RELATIONSHIP BETWEEN FRONTEX AERIAL SURVEILLANCE AND MIGRANTS' INTERCEPTIONS IN THE CENTRAL MEDITERRANEAN (2021-2022)

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SUMMARY

In the absence of a safe and legal passage to Europe, each day migrants risk their lives to flee Libya through the deadly Central Mediterranean route. It is now well-known that Libyan Coast Guards (LCG) intercept boats and force people back to Libya. What is however less transparent is the involvement of Frontex (European Border and Coast Guard Agency) in this process. The evidence gathered suggests that Frontex deploys aerial assets in the Central Mediterranean to provide LCG information for the purpose of intercepting people, aware that once they have been caught, they will be returned to Libya and face arbitrary detention, exploitation, and other forms of violent treatment.

This study aims at demonstrating statistically the extent of Frontex's complicity and responsibility in these pullbacks. To do so, multiple data sources of interceptions were gathered, as well as Frontex assets' flight data.

First, a descriptive analysis showed that Frontex is pursuing a strategy of targeted surveillance for boats present off the Libyan coasts. Indeed, Frontex contributes less to rescues and disembarkations of people in Europe than it actively participates to interceptions and pullbacks to Libya.

Then, a correlation analysis exposed a moderate to strong and statically significant correlation between the daily number of interceptions and the daily number of hours of Frontex's aerial asset deployment in the LCG interception area - where most LCG operations take place. This means that the more Frontex deploys aerial assets, the more interceptions by LCG occur at sea, leading to people being forced back to Libya.

Finally, a spatial autocorrelation analysis allowed for identifying distinctive clusters of high-density interception zones surrounded by high density of Frontex's aerial assets. Said otherwise, Frontex's flights and LCG interceptions are highly autocorrelated in space.

All in all, this study strongly supports the hypothesis that Frontex's strategy of deploying aerial assets acts in favor of LCG interceptions, leading to migrants being pulled back to Libya.

CONTEXT AND OBJECTIVES OF THE STUDY

At the request of Border Forensics, I have carried out a statistical analysis to inquire into the relationship between the deployment of Frontex's aerial assets in the Central Mediterranean and migrants' interception by Libyan forces for the 2021-2022 period.

To escape abuse in Libya and reach safety in Europe, migrants attempt to cross the Central Mediterranean on unseaworthy vessels. However, as a result of European authorities' collaboration with Libya, many of them are intercepted by Libyan Coast Guard (LCG)[1]. The evidence gathered by Border Forensics suggests that Frontex uses aerial assets (several planes and a drone) to closely monitor the Central Mediterranean and relay information to Libyan authorities, so that they can intercept boats before their arrival in the EU.

Therefore, a statistical analysis exploring the relation between LCG interceptions and the deployment of Frontex's aerial assets was carried out for the 2021-2022 timeframe. The analysis also explored how both variables (number of interceptions and the presence of aerial assets) affected the death rate of migrants during sea crossings.

We first compiled several statistical data sources allowing to measure migrant crossings and deaths, LCG interceptions, and Frontex aerial presence. We then tested the correlation between Frontex aerial presence and LCG interceptions over time and in space.

SITUATION MAP

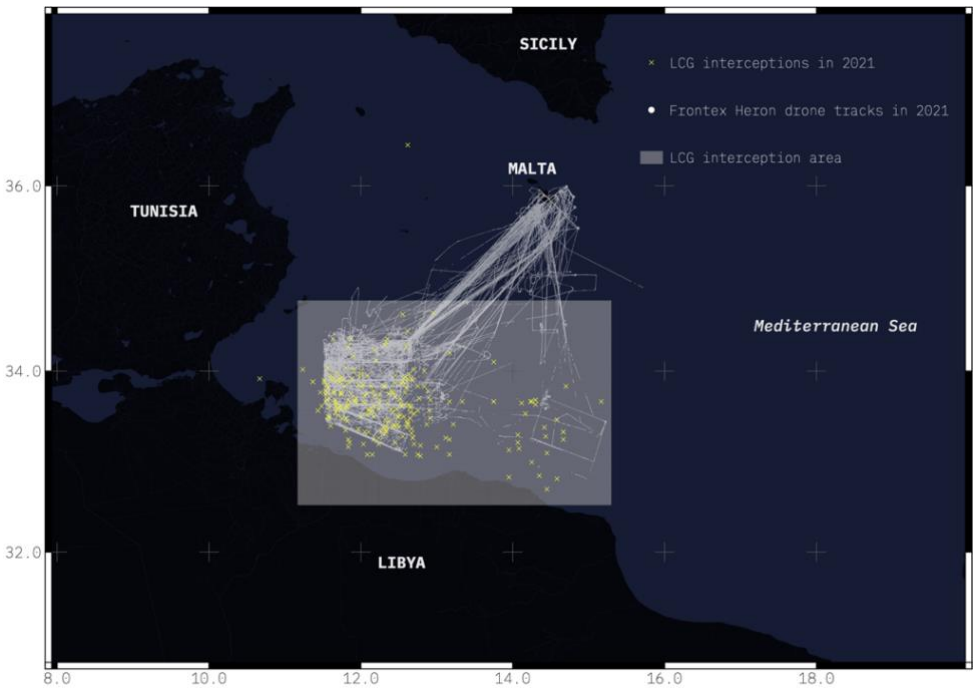


Figure 1 - Situation map of LCG interceptions area, interceptions performed by the LCG, and Frontex drone's flights tracks

Figure 1 illustrates the area of study. The location of 2021 interceptions were retrieved from a European Union External Action Service (EEAS) classified document pertaining to the Eunavfor Med Operation Irini monitoring of the Libyan Coast Guard and Navy. The map also shows the flight tracks of Frontex's drone in 2021 provided by the ADSB-exchange platform (see data section for details).

[1] Various groups and authorities are active in the interceptions of migrants' boats in Libya: for the purpose of this study, I will generically refer to all of them as Libyan Coast Guard.

DATA

The interception rate is calculated using the number of people intercepted by the LCG in relation to the total number of people who have attempted the crossing (i.e., the sum of migrant arrivals in EU, those who died or went missing during the crossing and LCG interceptions). The interception count is the number of intercepted boats. The data on the basis of which we calculated the interception rate and established the interception count were obtained from IOM Libya[2], Frontex JORA database (obtained by the nongovernmental organization Frag den Staat via Freedom of Information request)[3], a European Union External Action Service (EEAS) classified document and retrieved online from the UNHCR Operational Data Portal[4] and IOM's database on dead or missing migrants[5].

These different datasets are not always consistent. The following subsection aims at describing the datasets, exposing their limitations, and explaining the criteria that guided our decisions.

UNHCR provides what appears to be one of the most reliable monthly count of people intercepted by the LCG for the period 2017-2022. This dataset, however, only provides the number of people intercepted by the LCG and does not mention the number of boats they were travelling on, which is the main metric that is used in this study for reasons explained below.

The second dataset obtained from IOM Libya offers a daily count of intercepted migrants over the 2020-2022 period, as well as some information regarding the number of boats intercepted. When confronted with empirical observations and other interception datasets, however, IOM Libya's boat count often does not match.

The third dataset concerning interceptions comes from Frontex's own JORA (Joint Operation Reporting Application) database. The dataset we could consult covers interceptions for the period 2016-2021. For the purpose of this study, we extracted a sub dataset including all incidents at sea that led to a disembarkation in Libya. Amongst them, only events for which a Frontex aerial asset was responsible for the initial detection of a boat (i.e., in the "DetectionInitatedBy" column "MAS" -Frontex Multipurpose Aerial Surveillance program- is mentioned) were used. Events for which Frontex only facilitated the interception (value "YES" in the column "DetectionByFrxAsset", i.e., the boat was first detected by an NGO or LCG, and at some point a Frontex aerial asset supported the interception) were not considered in this study.

The last dataset is obtained from two European Union External Action Service (EEAS) classified documents drafted by the Eunavfor Med Operation Irini as part of their monitoring of the Libyan Coast Guard and Navy. Together, these documents cover the period between April 2021 and November 2021 and provide a daily count of migrant boats intercepted by the LCG, with precise geographical coordinates as to the location of interceptions. This dataset does not appear to account for all people intercepted as compared to the IOM database but seems to be the most accurate in terms of interception count i.e., the number of boats intercepted. Table 1 provides a comparison of all the datasets.

[2] Data was requested directly to IOM by BF and obtained on October 17th, 2022
[3] Jora Database – accessed November 3rd, 2022
https://aleph.occrp.org/entities/52913ea4c5b70cba04cd39208e19c42adfb8e2ca.99280319d57d7ce5675614290d06b3242df77666
[4] https://data.unhcr.org/es/dataviz/211
[5] IOM missing migrant project: https://missingmigrants.iom.int/data

Table 1 - Table summarizing total interceptions and interception count for all datasets across various timeframes

	April 2021 - Nov 2021		April 2021 - August 2021		30th July	
	# of people intercepted	# of boats intercepted	# of people intercepted	# of boats intercepted	# of people intercepted	# of boats intercepted
EEAS	13 253	241	10 634	189	205	5
JORA	-	-	7 177	135	87	4
IOM	24 853	208	17 581	134	191	2
UNHCR	25 086	-	17 678	-	-	-

One should note that IOM and UNHCR have a very similar count of intercepted people and stand as figure of reference for the total number of intercepted people. Discrepancies between IOM and EEAS/JORA datasets can be presumably explained by different data collection methodologies (at disembarkation versus based on sightings, etc.) and the multiplicity of actors in Libya performing interceptions. This might explain why IOM mentions a lower number of intercepted boats on the 30th of July, while having a value of total intercepted people close to UNHCR.

Concerning the events of July 30, 2021 the EEAS documents mentions 5 boats intercepted, while JORA mentions only 4. JORA also mentions a fifth boat, but the latter has not been considered for the purpose of this study as its interception was only facilitated and not initiated by Frontex (the column “DetectionInitatedBy” mentions “NGO call” as initial source of the detection).

The death rate was computed using the number of people who died or went missing during the crossing in relation to the total number of people who have attempted the crossing (i.e., the sum of migrant arrivals in EU, those who died or went missing during the crossing and LCG interceptions).

A main datafile was built – at a daily temporal resolution - with variables for the death rate and the interception count for each interception dataset for the timeframe 2021/06 – 2022/06. JORA data concerning interceptions covers the aforementioned time frame until 2021/08, and the data gathered by EEAS until 2021/11. The timeframe used in this study (2021/06 – 2022/06) was chosen because of the availability of flight tracking data. Prior to this period, data is very scattered, and would therefore induce bias through uncertainty.[6] This main file does not contain any geographic information.

As a reminder, for the purpose of this study by ‘’interception’’ I mean an event for which a boat was intercepted and its passengers disembarked in Libya exclusively, after detection by any actor. Thus, all disembarkations in Libya monitored by UNHCR or IOM are considered the outcome of interception events.

As for data regarding the presence of Frontex’s aerial assets, it was extracted from the ADSB-exchange platform, the world’s largest public source of unfiltered flight data. Data is collected through volunteer feeders and the platform has a not-filtering policy, which means they don't censor any signal (including military assets). In 2020 signal coverage was weaker and starts

[6] It should be noted that a certain level of uncertainty remains due to a lack of flight tracking sensors in Libya and other reasons. For a map of flight tracking coverage, see also : https://map.adsbexchange.com/mlat-map/

to improve over the course of 2021, which is why this study focuses only on flight tracking data collected as of 06/2021. The data set contains geolocated, discrete data points for all assets within the study's timeframe. Points do not cover the whole path flown by aerial assets. The number of flight hours used in this study was calculated by summing the time difference between every two successive data points for each asset, every day. The dataset containing discrete flight data points is used for the spatial analysis correlation, while the variable ''flight hours'' is merged into the first dataset for calculating the correlation between flight hours and interception count.

METHODOLOGY

To demonstrate the potential causal relationship between assets flight time and interceptions, the data gathered was explored in multiple ways.

First, a descriptive analysis of the different dataset allows to assess the impact of Frontex aerial surveillance activities and their relation to inceptions over time. How has the number of detections initiated by Frontex evolved over time? To what extent has Frontex been involved, in terms of raw statistics, in the interception process? These are the questions the data analysis has attempted to answer.

The main challenge of this study lies in the multi-variate aspect of the relationship between interception and assets deployment, which is dependent on time, space, and other variables such as weather or the number of maritime assets deployed. Thus, the correlation analysis is divided in two main parts: a first one which focuses on the correlation between number of interception and Frontex assets' flight hours at a daily time scale, and a second part focusing instead on the spatial correlation between the two phenomena.

- **Correlation between Frontex aerial assets' flight hours and number of interceptions**

Since this part of the study focuses on the correlation between Frontex aerial assets' flight hours and interceptions at a daily time scale, flight data must be filtered geographically as otherwise the correlation would be meaningless: empirically, it is known that the two studied variables must be in the same place to be potentially correlated (within +/- 20km which is likely to correspond to Frontex assets' approximate detection range – as deduced by the sweep and track spacing of the standard search pattern visible in their flight tracks). Thus, geographical filters were used to exclude irrelevant data.

The first geographical filter we used corresponds to the LCG interception area (the grey area in Figure 1 and 2). It was defined empirically based on the locations of interceptions listed in the EEAS documents and contains 99.7% of all the interceptions listed in such documents. This area also includes Frontex aerial assets' main search pattern. This filter excludes flight hours far away from the Mediterranean – when Frontex assets were flying to France or England – which are clearly not influencing the LCG interception variability in the Central Mediterranean.

While this first filter excludes most flight hours unrelated to surveillance activities (such as transit time between the assets' base in Malta and its patrol area), two additional geographical filters were added to make sure the calculated flight times refer precisely to surveillance activities only.

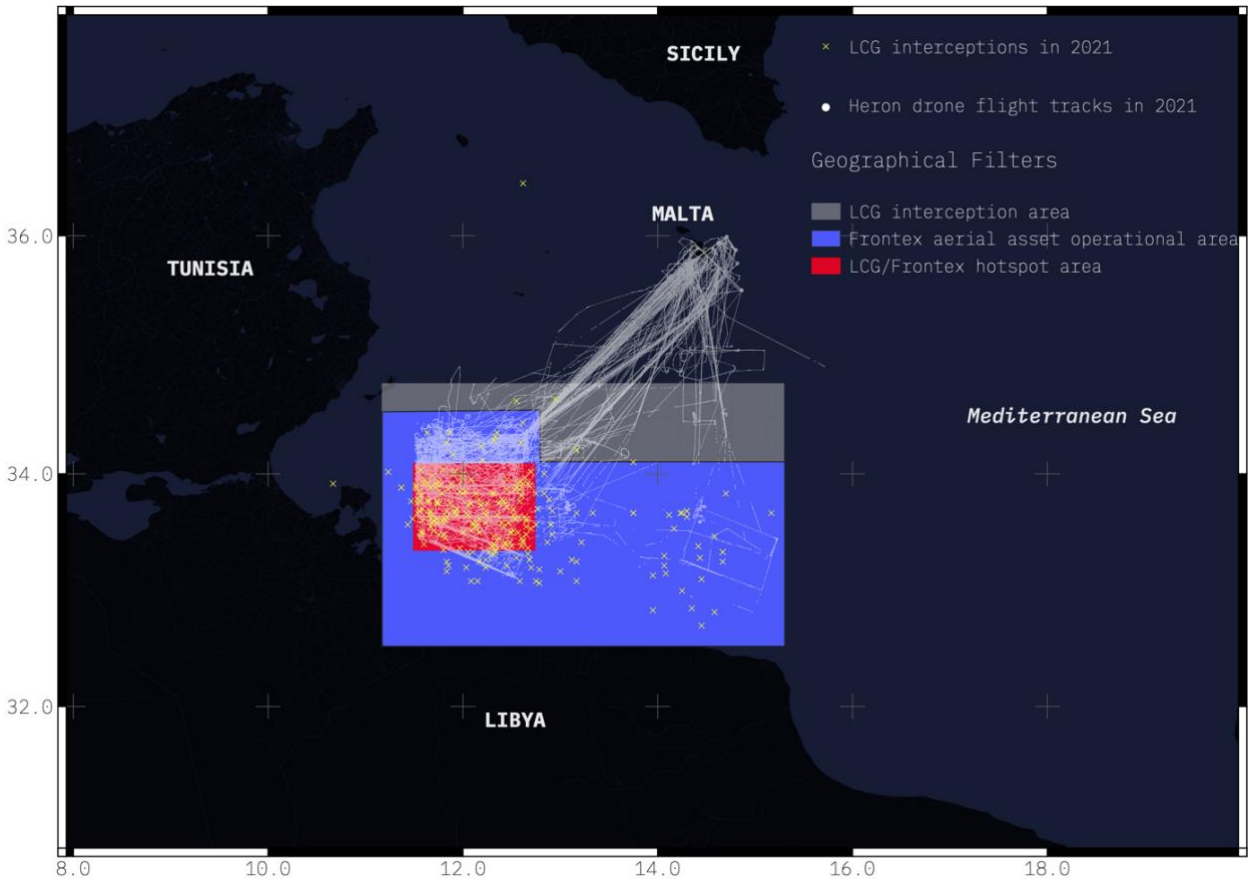


Figure 2 - Map of the different geographical filters used for the study. The grey area is the LCG interception area – where 99% of interceptions by LCG occur, and where all Frontex flight search patterns can be found. Frontex's operational area excludes back and forth flights between the assets' bases and their patrol areas. LCG/Frontex hot spot area is the area that presents the highest density of interceptions and flight tracks.

A second filter (blue area in figure 2) is designed to exclude the vast majority of the back-and-forth flight time of Frontex aerial assets from their bases. This area overlaps largely (82%) with the first filter (LCG interception area) and still contains 98% of monitored interceptions. We will refer to this zone with the term Frontex's aerial assets operational area.

A third filter (red area in figure 2) includes only the area which includes Frontex assets' standard search pattern, i.e., where Frontex assets are certainly conducting surveillance activities. This area is a very localized ''interception hotspot zone'' and represents only 10% of the overall LCG interception area (the grey area). But 65% of interceptions recorded by EEAS in 2021 lie within the boundaries of this filter, and 50% of the Frontex assets' tracks can be found in this grid. We will refer to this zone with the term "LCG/Frontex hotspot area". Note that this filter was also applied on interception data from the EEAS documents, the only one for which geographical coordinates are available.

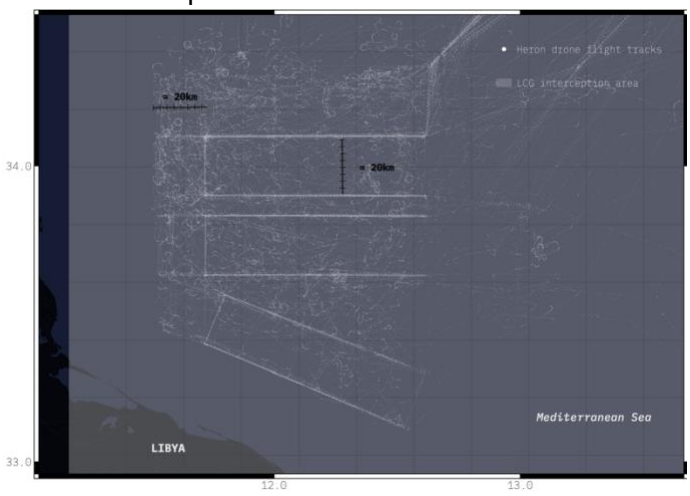
For each geographical filter, the following correlations were computed:

(1) LCG interception count * Aerial assets flight time
(2) Death rate * Aerial assets flight time
(3) LCG interception rate * Death rate

In this calculation, we used the interception count (i.e. Number of boats intercepted) instead of the interception rate (i.e. the rate of people intercepted) because the assets identify boats regardless of the number of people on board. Assets' daily efficiency are empirically better measured by considering the number of boats they identify than with the total number of people on board those boats.

- **Spatial correlation analysis**

As for the spatial correlation, it was chosen to discretize space, based on Frontex's aerial assets detection range we deduced. The LCG interception area (grey area) is divided into a grid squared 20km*20km. This grid size was chosen on the basis of what we assume to be a sensible estimation of Frontex's assets' detection capabilities: while online documentation published by the Heron drone manufacturer[7] mentions that small ship recognitions could be performed at more than 70km distance, in practice the detection range of the drone appears to be much lower. The search flight pattern adopted by the drone and the other assets during their missions is composed by parallel flight tracks with a distance of about 20km. This suggests the actual detection range of an asset in field conditions is about 10 to 20km depending on the sweep width and track spacing, and we thus considered this measure to define our grid size.



All flight tracking data points and interception points (locations where interceptions took place) were projected in each grid cell (i.e. a cell containing 25 points of flight track will add 25 in the FLIGHT field, and 2 interception of 70 people will add 2 in the INTERCEPTION field).

This spatial correlation analysis was performed for the year 2021 only as flight data for 2020 are partial, and 2022 geolocated interception data are not available.

While a qualitative description of the spatial phenomenon is insightful, quantifying the degree to which similar (or dissimilar) events are clustered with a spatial indicator will demonstrate the autocorrelation between the two events, and will contribute to the demonstration of the causality between interceptions and Frontex's aerial surveillance. The measure we use to quantify the spatial autocorrelation of the relationship is the Moran's I statistic. The Moran's I statistic is the correlation coefficient for the relationship between a variable (interceptions) and its surrounding values of the same variable or of another variable (flight tracks count). The global Moran's I statistic allow to measure how one object is like others surrounding it. If objects/events are clustered globally in space, it means they are autocorrelated and not independent.

With local Moran's I, we can decompose the global Moran's I down to its components thus constructing a localized measure of autocorrelation, i.e., a map of "hot spots" and "cold spots" that are autocorrelated. To construct the spatial autocorrelation statistics, spatial weight must be defined to provide the means to create spatially explicit variables, such as spatially lag. The spatial weight used is "queen contiguity": contiguity means that two spatial units share a common border of non-zero length. The queen criterion defines neighbours as spatial units sharing a common edge or a common angle.[8] Therefore, the number of neighbours according to the queen criterion will be either 3 (cell touches angle of the grid), 5 (cell touches border but not an angle of the grid), or 8 (cell does not touch border nor angle of the grid). This spatial weight is relevant in the studied process since Frontex's asset can detect a boat in any direction of a range of 20km.

[7] https://www.iai.co.il/sites/default/files/2022-01/ELTA-ELM-2022-MPR%20FOR%20MARITIME%20HERON_0.pdf
[8] See GeoDa resource center for further explanations. https://geodacenter.github.io/workbook/4a_contig_weights/lab4a.html

RESULTS AND DISCUSSION

- ### Descriptive statistics

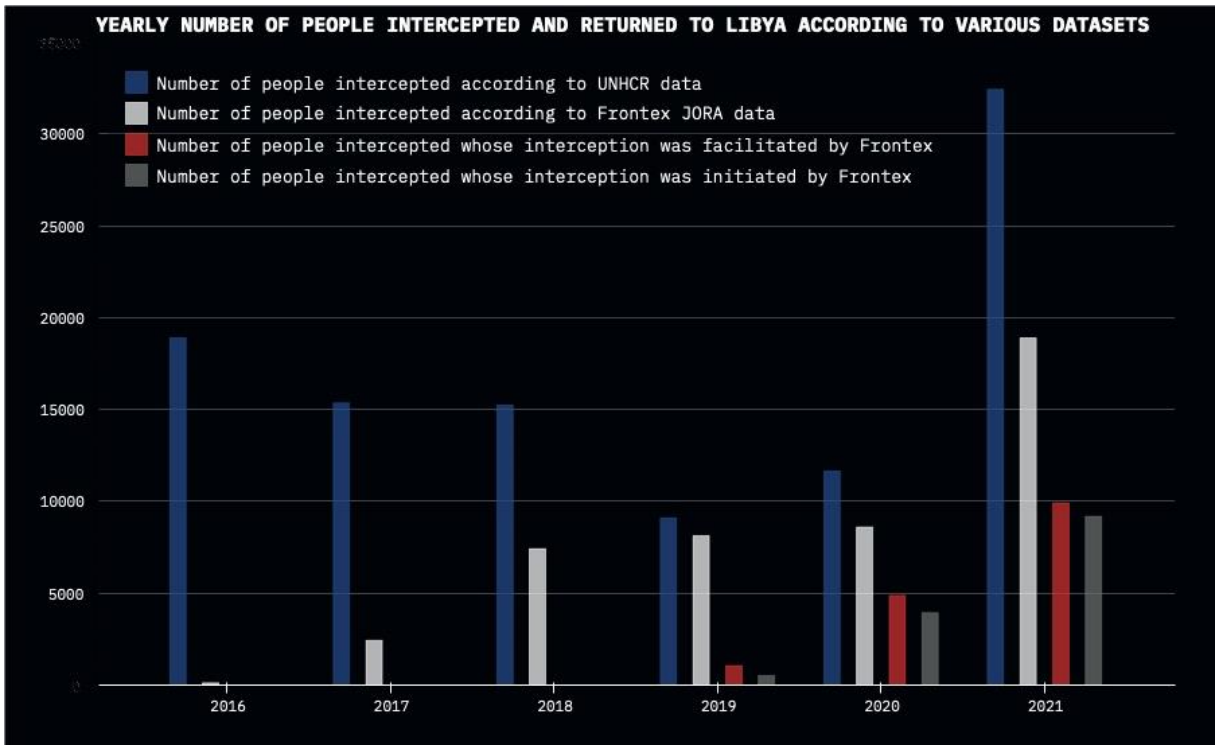


Figure 3 - Yearly interceptions, for which people were disembarked in Libya, categorized through Frontex's incident database. UNHCR data on interceptions (blue) is the most complete dataset. Frontex's recorded interceptions (white), are the interceptions that are mentioned in Frontex's JORA database. The red and grey bars represent the number of interceptions that were respectively facilitated by and initiated by Frontex.

Figure 3 shows the yearly number of people intercepted according to Frontex JORA database (white) as compared to the number present in UNHCR database (blue). One can notice the increasing recording capabilities of Frontex over time – indeed, in 2017, Frontex was aware of only 16% of people intercepted. This percentage climbs to almost 90% in 2019 and returns to 59% in 2021.

When observing the number of people intercepted whose interception was initiated by or facilitated by Frontex, we can see that in 2021 at least 9189 people were intercepted by the LCG because a Frontex asset detected the boat.

This figure demonstrates that Frontex's surveillance has been playing an increasing role in enabling LYCG interventions: from 531 initiated interceptions in 2019, representing a share of 6% in relation to UNHCR monitored interceptions, Frontex's initiated interceptions increased to 3941 in 2020, representing a share of 34%, and 28% in 2021. **Over the 2020-2021 period, at least 30% of intercepted people were first identified by an aerial Frontex asset and later intercepted by the LCG.**

We can observe the increasing proportion of interceptions events for which Frontex was involved over time. This can be explained with Figure 4, showing an increasing number of hours of deployment in the LCG interception area. Still, the 2020 values may not be representative as they are incomplete. This is the reason why the correlation study focuses on the time frame 2021/06-2022/06.

One can also assess the seasonality of Frontex's hours of deployment, which is concomitant with migrants' departure: most Mediterranean crossings occur during spring and summer when weather is favourable.[9]

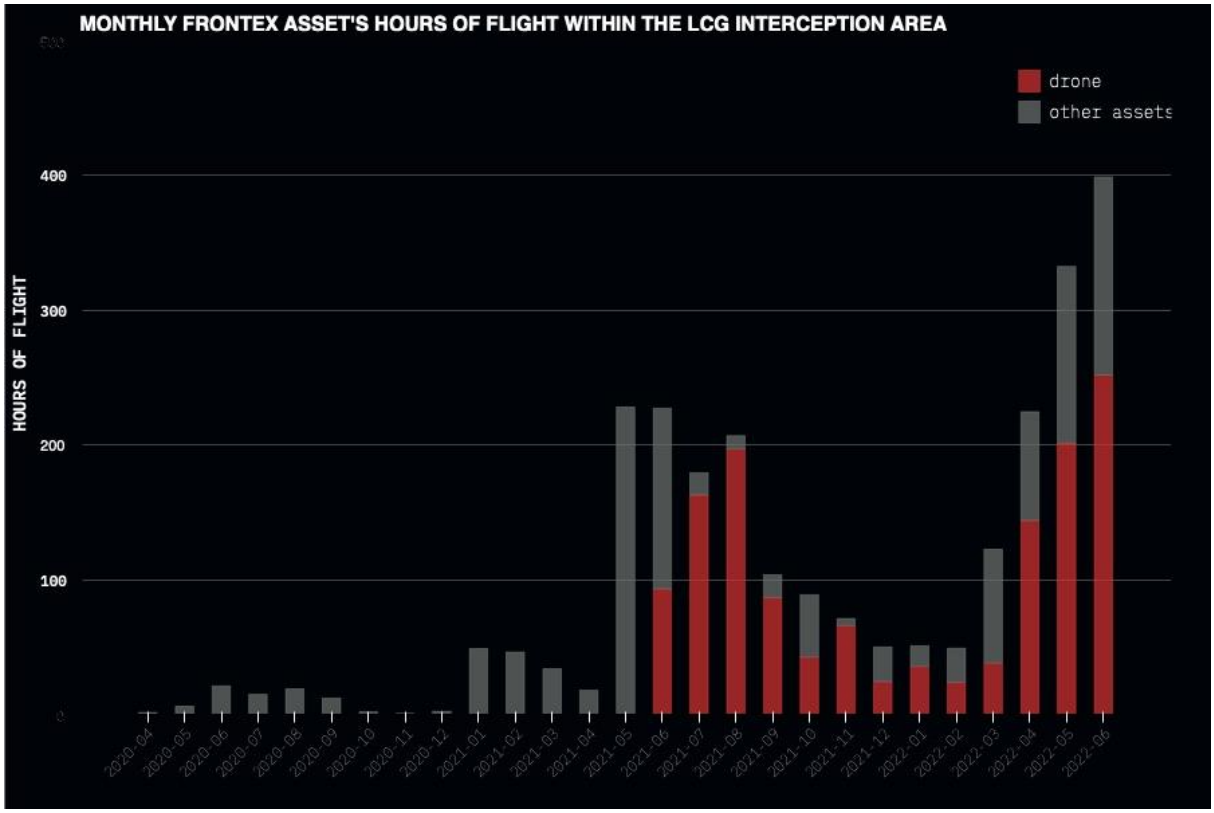


Figure 4 – Frontex aerial asset's hours of deployment within the LCG interception area with a monthly temporal resolution

Statistics present in Frontex JORA database concerning the number of arrivals (people disembarked) in Italy and Malta show another relevant aspect of Frontex activities. In the case of people who reach Italy and Malta, Frontex's JORA database accounts for almost the same number of people as that reported by UNHCR which monitors disembarkation at European ports, meaning that Frontex manages to account for the vast majority of boats whose passengers eventually reach Italian and Maltese shores. What is significant is that Frontex aerial surveillance contributes to the detection of these boats only in a very small proportion as compared to the detection of boats whose passengers are intercepted and eventually disembarked to Libya. Said otherwise, for what concerns the Central Mediterranean, the contribution to Frontex aerial surveillance to the arrival of people to safety in Europe is minimal when compared to its contribution to interceptions that result in people being returned to Libya.

[9] Weather factors influencing crossings behaviour - https://www.ecmwf.int/en/elibrary/18264-identification-weather-factors-affecting-number-refugees-and-migrants-following

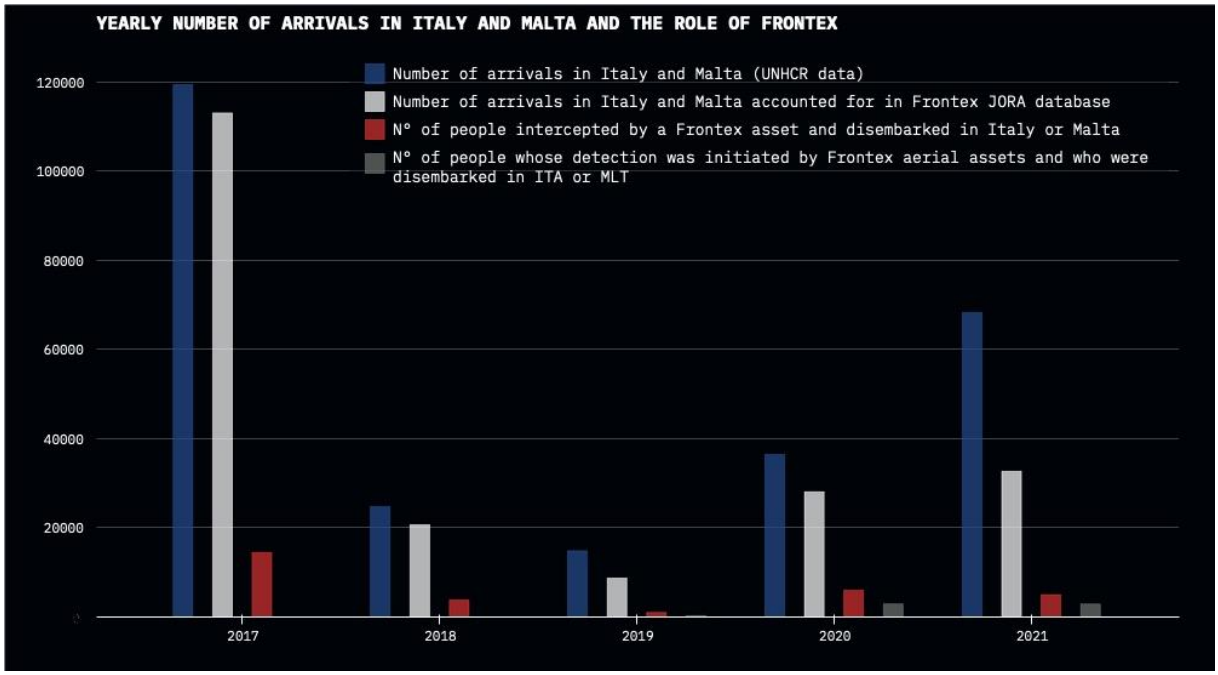


Figure 5 - Yearly interceptions, for which people were disembarked in EU, categorized through Frontex's incident database. Arrivals in Italy and Malta (blue) are based on UNHCR data. Arrivals in Italy and Malta accounted by Frontex (white), are the interceptions that are mentioned in Frontex's JORA database. The red and grey bars represent the number of people who arrived in Italy and Malta who were respectively intercepted by and initiated by Frontex.

Indeed, Figure 5 shows that over the period 2017-2021, Frontex monitored more than 75% of boats that were eventually disembarked in Italy and Malta. However, Frontex aerial surveillance program only initiated 2% of all the rescues that led to a disembarkation in Italy or Malta on the whole period. Frontex's naval assets rescued 12% of all arrivals in Italy and Malta over the whole timeframe, and only 7% of them in 2021 only.

This analysis indicates that Frontex actively participates in interceptions which lead to a Libyan disembarkation, while European disembarkations mobilize low Frontex activities, except for accounting purposes through monitoring.

- **Interception / flight hours relationship correlation**

As shown in Table 2, the results reveal a moderate to strong correlation coefficient with high statistical significance between the interception and flight hours (Pearson's R: 0.27 for LCG interception area with IOM interception data and 0.5 for JORA interception data) indicating that the higher the amount of time in which assets were deployed, the higher the interception count became. The results are statistically significant (p-values below 0.05), meaning that we can have high confidence in this correlation value, and that the correlation did not appear by chance.

Table 2 - Correlation coefficient and p-value between interception count and Frontex assets flight hours for all interception datasets and areas of study

Data	Timeframe	Zone	Correlation coef.	p-value
	06/2021 – 06/2022		0,27	9,00E-08
IOM	06/2021 -08/2021	LCG interception area	0,42	2,00E-5
	06/2021 - 11/2021		0,33	4,00E-06
JORA	06/2021 -08/2021	LCG interception area	0,5	4,00E-07
EEAS	06/2021 - 11/2021	LCG interception area	0,46	5,00E-11
		Frontex operational area	0,46	9,00E-11
		LCG/Frontex hotspot area	0,43	2,00E-09

Table 3 – Correlations coefficient between the deployment of aerial asset flight hours and interception count, interception rate and death rate.

	Death rate * flight hours (IOM/JORA/EEAS timeframes) for LCG interception area	LCG interception rate * death rate
Correlation coefficient	-0.08/-0.07/-0.006	-0.09
p-value	0.11/0.49/0.93	0.066

According to the results exposed in table 3, death rate and flight time are not correlated – the p-value being too high, we cannot reject the null hypothesis - which indicates that there is no linear relationship between two variables. The same goes for the interception rate and the death rate. While Frontex often claims that asset deployment can help reduce death at sea, since there is no correlation between Frontex's presence and the death rate, the analysis exposes that the way Frontex's assets are used does not make the Mediterranean safer.

The correlation coefficient's variability with respect to various databases can be explained by the nature of the dataset. Indeed, JORA database contains only interceptions whose detection was initiated by Frontex, which explains why there is such a strong correlation coefficient. The correlation coefficient with IOM data is lower because it includes interceptions for which Frontex was not involved. Also, for some days, Frontex assets are flying, and no LCG

interception occur (01/2022) – which can happen if the boat was not on the asset's trajectory +/- 20km, if there were few or no boat departures, or if the assets were deployed for other reasons than mobility surveillance. The specific example of 04/01/2022 shows 209 people that arrived in Italy, while assets were deployed for more than 15 hours. Conversely, the example of 11/07/2021 shows that some interceptions occur without any assets flying – indeed, the LCG can detect and intercept boats on their own.

Given that interception is a multi-causal driven phenomenon, a correlation coefficient of 0.27-0.5 between hours of flight and interceptions can be described as moderate to strong. Indeed, the studied relationship is involving human behaviour which is highly complex and hard to predict. Weather also plays an important role in the relationship. However, all considered empirical observations seem to corroborate the finding that the relationship between flight hours and interceptions is a causal one. Also, a spatial analysis will help supporting the demonstration of a causal relationship.

Visually, we can appreciate this correlation with figure 6. The interception count responds very well to the hours of flight in the LCG interception area. Most interceptions occur on days with a high hours of flight variable. Indeed, almost 75% of the boats intercepted in the EEAS database were intercepted on a day for which Frontex's assets were flying 5 hours or more in the LCG interception area.

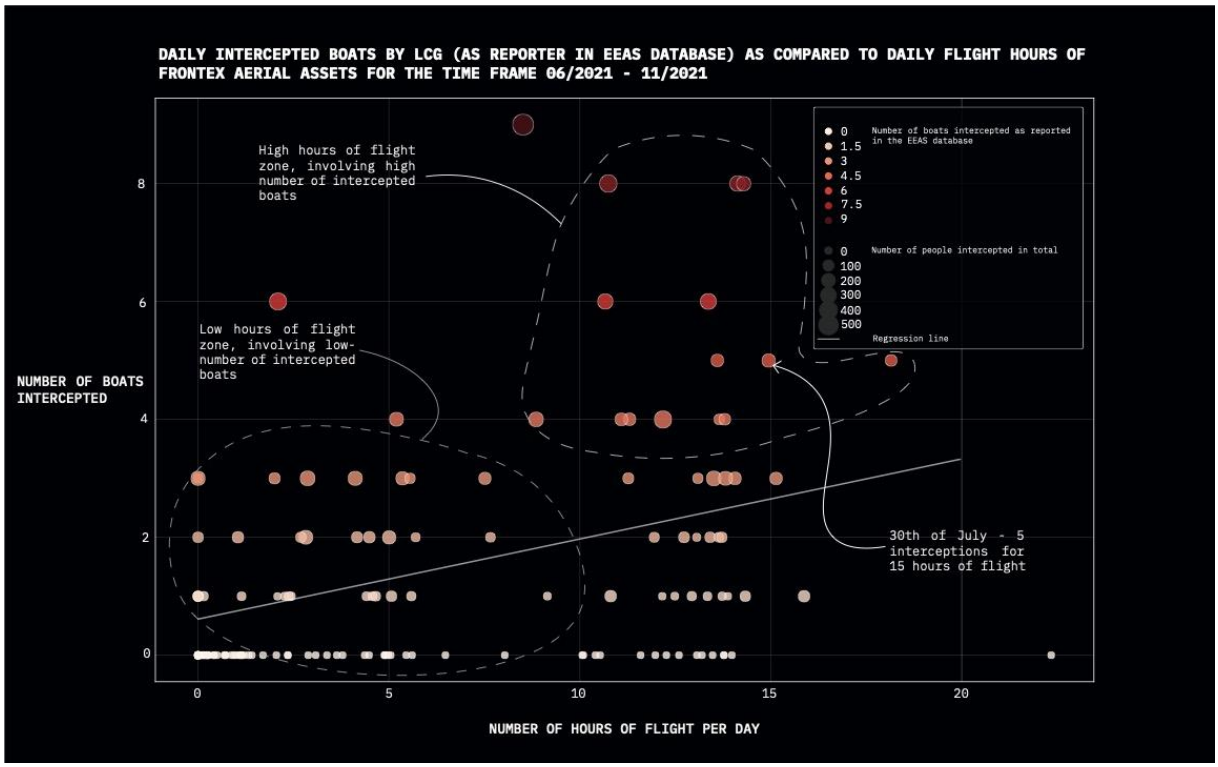


Figure 6 - Scatter plot of daily LCG interception (EEAS data) with respect to hours of assets flights

The fact that the interception count responds very well the hours of flight in the LCG interception area supports the first descriptive analysis: as Frontex deploys its aerial assets for longer within the LCG interception area, the number of interceptions in which they are involved increases. Similarly, the correlation analysis we performed highlights the co-occurrence of asset deployment and the number of interceptions over time.

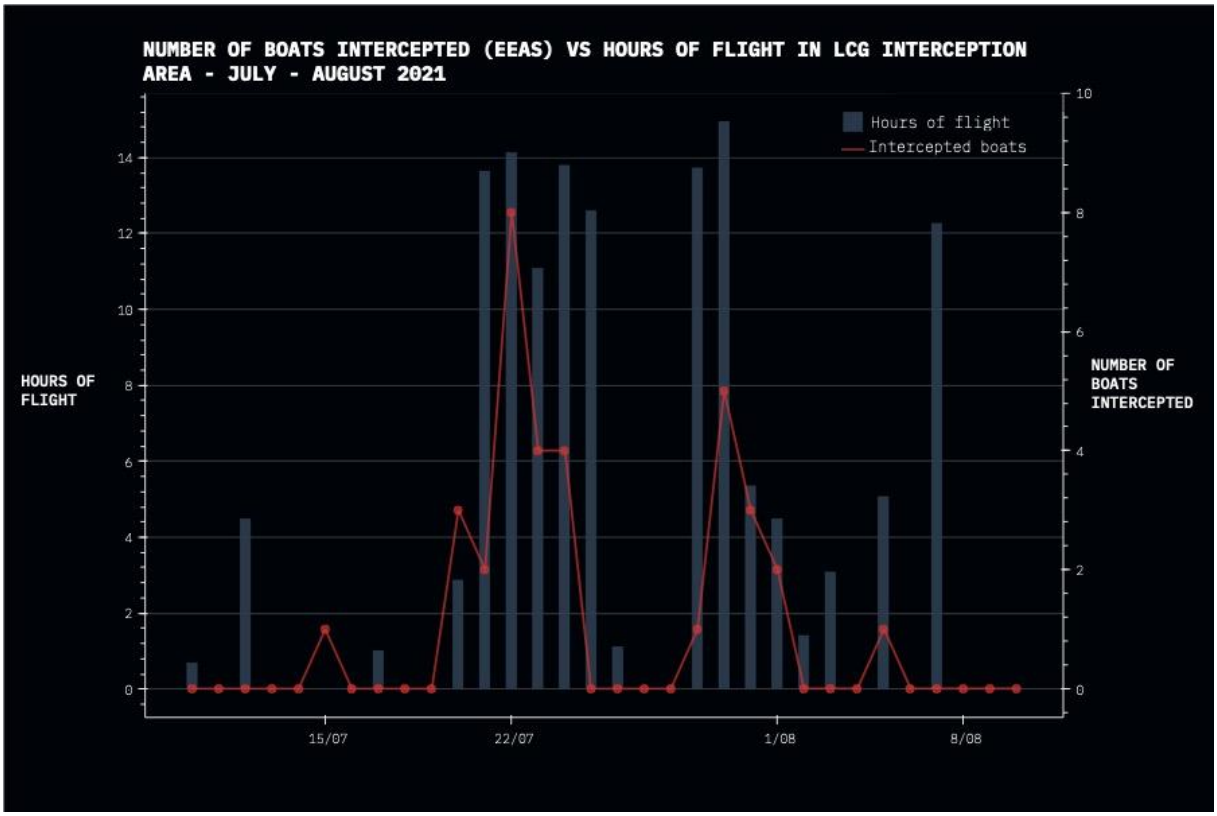


Figure 7 - Illustration of the correlation between LCG interception and Frontex assets flight hours for July - August 2021

The correlation analysis highlights the interdependence of the two variables of interest over time, even though they are also dependent on other variables (ie. spatial deployment, weather, number of maritime assets deployed, chance, political conditions, etc…). Indeed, with the JORA database, flight hours explain 25% of interception count's variance. In sum, the correlation analysis strongly supports the claim that Frontex aerial surveillance supports the increasing amount of LCG interceptions in the Central Mediterranean and supports the rejection of Frontex's claim stating that its asset deployment is reducing death at sea.

- **Spatial correlation analysis of LCG interception and Frontex aerial assets' flight tracks**

The previous correlation analysis focused on the relation between phenomena over time but did not consider the spatial dimension of the two processes that are being studied, apart from the use of a geographical filter that excluded flight hours during which Frontex aerial assets were most likely not performing surveillance duties.

We operated a spatial analysis to explore the spatial attributes of the studied phenomena. Figure 8 shows the spatial distribution of the interceptions over the LCG interception area.

One can observe a large cluster, a few smaller clusters, and some isolated points. The heatmap of flight tracks (dark red being high density of tracks, light/white being low density flight tracks) seems to be in similar zones to the interception clusters. Even the isolated interceptions are close to relatively dense areas of flight tracks.

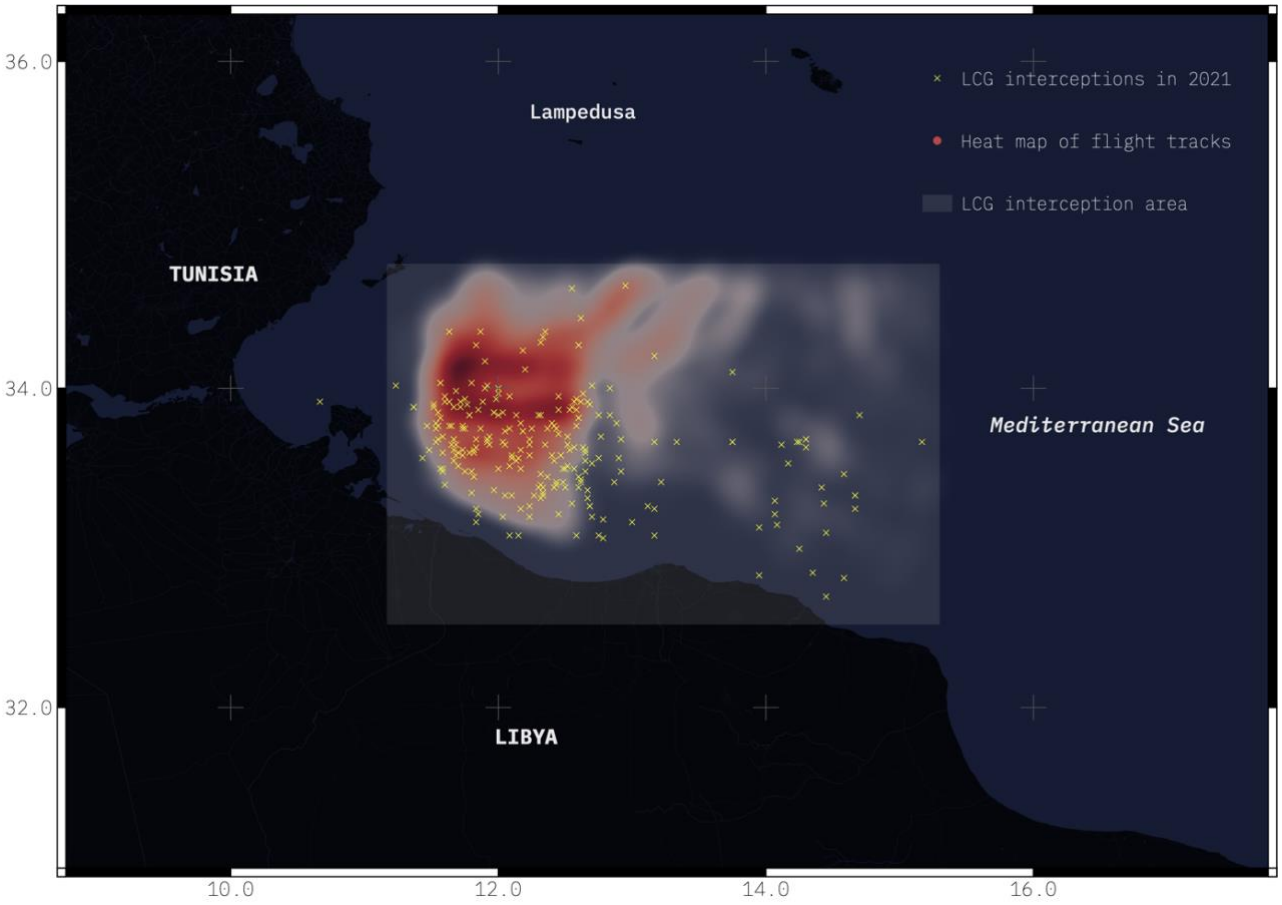


Figure 8 - Heatmap of flight tracks with LCG interception location for 2021 within the LCG interception area

While a qualitative description of spatial phenomenon is insightful, it may not be sufficient to support a causality demonstration; none the less here we will quantify the degree to which similar (or dissimilar) events are clustered. The measure we use to quantify the spatial autocorrelation of the relationship is the Moran's I statistic. The Moran's I statistic is the correlation coefficient for the relationship between a variable (interceptions) and its surrounding values of the same or another variable (flight tracking data points).

The global univariate Moran's I for the interception process is 0.5769, with a z-score of 20.87 and a p-value of 0.001 (999 permutations). This means that out of all the random distribution

of the interception processes, none gave a Moran's I result higher than the one computed. This means that the null hypothesis can be strongly rejected, and that interceptions are not random in space. There is a clustering of likewise values of interceptions.

The same goes for the univariate Moran's I for flight tracks, I = 0.82, Z-score=28.4 and p-value=0.001. Flight tracks are not distributed randomly in space.

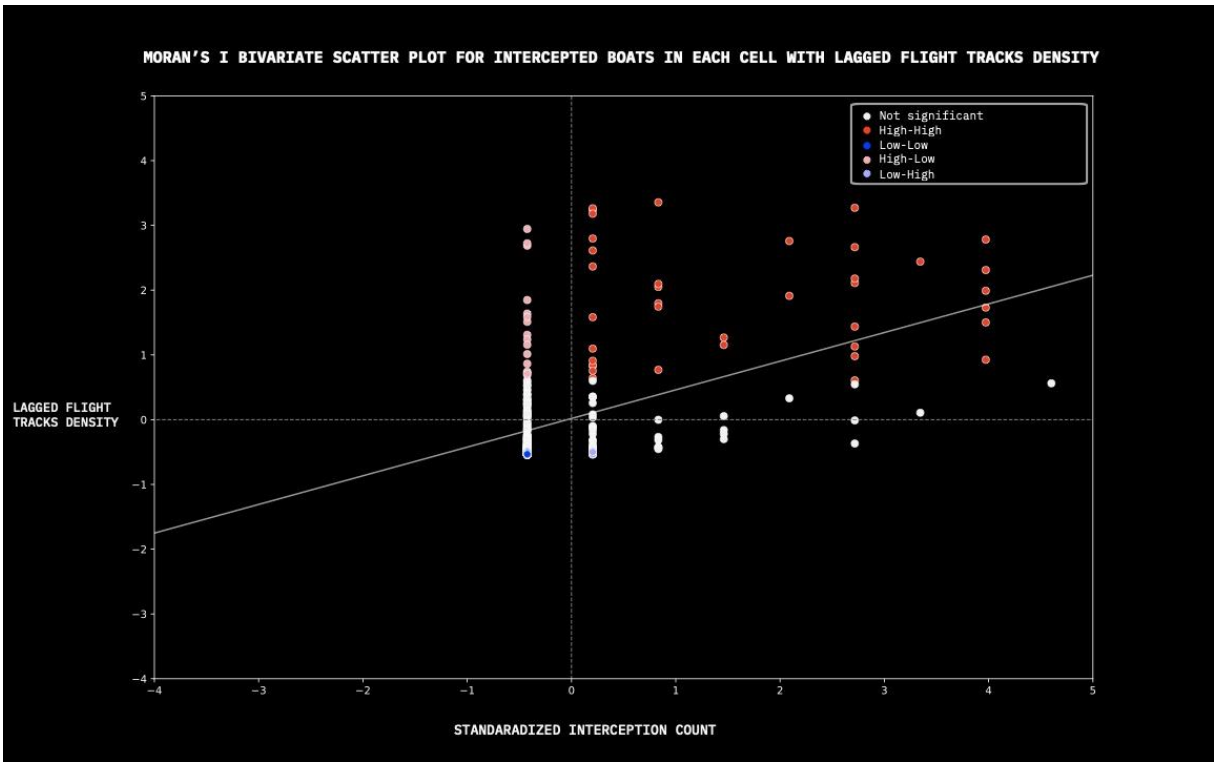


Figure 9 - Bivariate Moran's I scatter plot for interception count and lagged flight tracks

The global bivariate Moran's I of interception with spatially lagged flight tracks is 0.404 and is statistically significant (z-score = 20 and p-value = 0.001). Thus, there is an overall spatial autocorrelation of interception counts with surrounding flight tracks. Interceptions tend to occur in the area covered by Frontex aerial surveillance.

The local Moran's I cluster map result is exposed on figure 10.

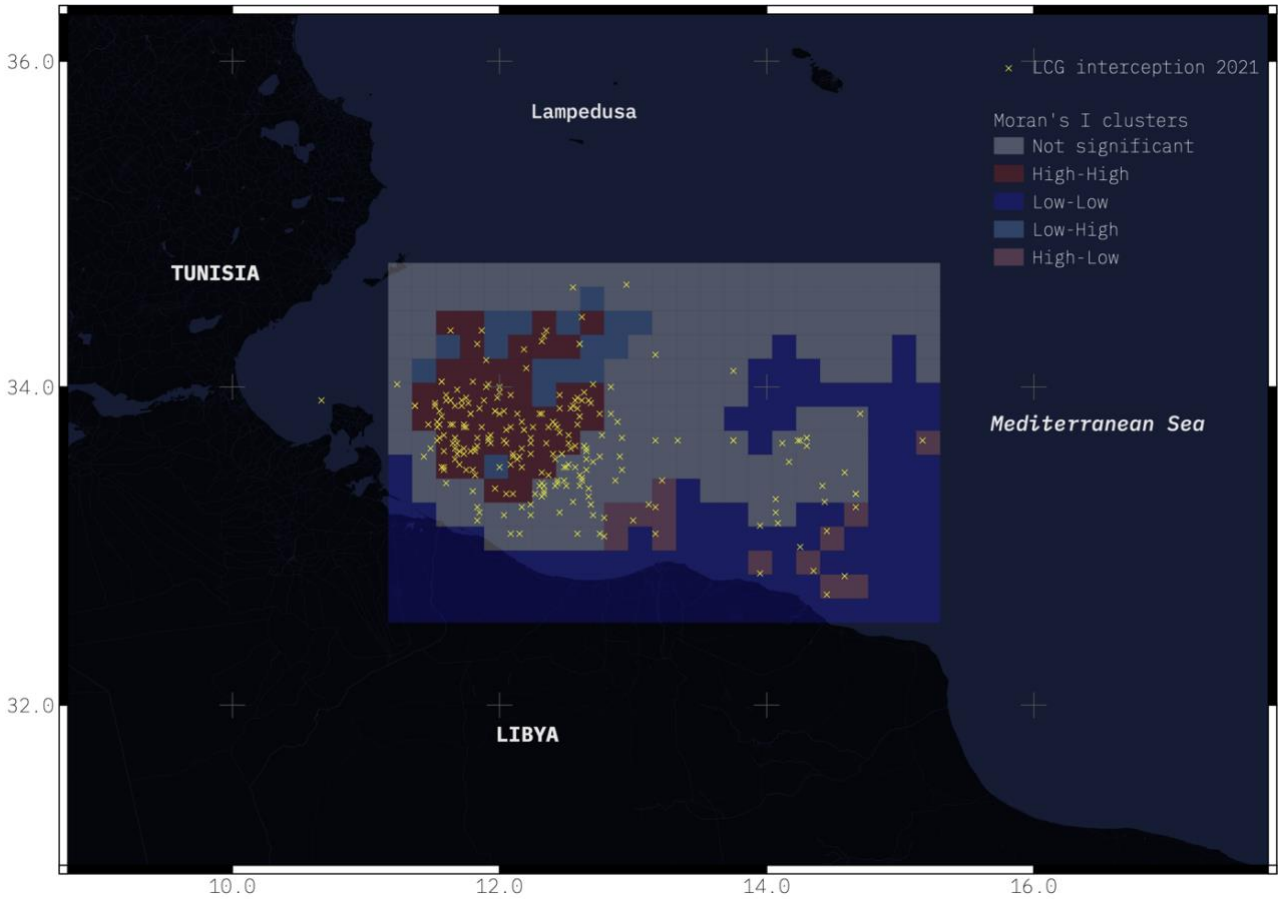


Figure 10 – Spatial clusters of interceptions with neighbouring flights tracks using Bivariate local Moran's I statistics. Statistical significance was assessed with a p-value threshold of 0.05.

- High-high values = cells with high number of interceptions surrounded with cells with high number of flight tracking data points
- Low-Low values = cells with low number of interceptions surrounded with cells with low number of flight tracking data points
- Low-High values = cells with low number of interceptions surrounded with cells of high number of flight tracking data points
- High-Low values = cells with high number of interceptions surrounded with cells of low number of flight tracking data points
- Not significant cells are those for which the Local Moran's I exposed a correlation that was not significant (p-value > 0.05). In those cells, the null hypothesis cannot be rejected, meaning that interceptions and flights tracks are distributed randomly in those cells, and are not spatially dependent.

This figure shows how correlated the interceptions are with flight tracks density in neighbouring cells.

Low-Low values are self-explanatory and are well expressed in the figure: these values appear in Libya and in irrelevant maritime zones, where neither Frontex aerial assets are patrolling, nor migrants' boats are to be found. High-High values appear in high density interception zone as expected with the qualitative map. It is now demonstrated quantitatively with Moran's I that interceptions tend to occur with surrounding flight tracks within assets detection range.

High-Low cells means that a high number of boats was intercepted with low presence of a Frontex aerial asset in neighbouring cells: they are located close to the coast. Indeed, these events are LCG interceptions that did not require air support as they happened closer to the coast and to the moment of departure.

Similarly, not significant cells that overlap with interceptions are mostly located close to the coast – in these cells, the spatial correlation between interception and the assets' presence is not significant very probably because these interceptions, being close to the coast, did not require aerial support to be performed by LCG.

Low-High values are cells with a low number of interceptions with high Frontex asset presence around. They are mostly located in correspondence to the path linking Frontex aerial base and their patrol zone: the back-and-forth trips to the LCG interception area made those cells associated with high ''flight track'' values, while this is not a zone in which the assets actively search.

We can thus say qualitatively and quantitatively that Frontex flight tracks and LCG interceptions are grouped in close zones within the LCG interception area. Those two events occur in well identified spatial clusters and are spatially autocorrelated. Furthermore, Moran's I analysis also allows to state that the interception process is not random in space, which is true also for the flight track density. Interceptions occur most of the time with surrounding Frontex aerial assets patrols. Last, Local bivariate Moran's I cluster map allows to identify clusters in space, but does not provide an explanation as to why these occur.

CONCLUSION

The gathered data shows that Frontex aerial surveillance activities have intensified over time, and that they have been increasingly related to interception events. Frontex incident database also shows that while Frontex's role is very significant in enabling interception to Libya, it has very little impact on boats whose passengers are eventually disembarked in Italy and Malta.

While the descriptive analysis exposes a global trend of intensifying Frontex involvement in interception process, a correlation analysis strives to highlight this trend more precisely in time.

Indeed, the correlation analysis shows that interceptions and flight hours are correlated in time, regardless of where the interception occurs. The results show a moderate to strong and statistically significant correlation coefficient depending on the interception data used. Also, the correlation analysis demonstrates that there is no correlation between Frontex's presence and the death rate - we can discard the hypothesis suggesting that assets presence makes the Central Mediterranean safer.

A spatial approach showed that interceptions and flight tracks are autocorrelated in space, regardless of when the interception occurs. The Moran's I bivariate analysis exposes a clustered distribution of interception and flight tracks in space, that reinforce the hypothesis that Frontex's activities increases LCG interceptions.

Both space and time correlation analysis show a strong correlation index between Frontex assets' flights hours and interception count occurring in LCG interception area, which corroborates empirical observation on the field, and supports the hypothesis that Frontex aerial assets presence increases LCG interceptions, leading to migrants being pulled back to Libya.