**Anuário do Instituto de Geociências - UFRJ**
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# Análise Observacional dos Eventos de Nevoeiros na Área do Porto do Rio de Janeiro, Brasil

Observational Analysis of Fog Events in the Area of the Rio de Janeiro Harbor, Brazil

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Recebido em: 12/12/2017 Aprovado em: 22/06/2018
DOI: http://dx.doi.org/10.11137/2018_2_123_132

**Resumo**

Nevoeiros são eventos meteorológicos nos quais a condensação de vapor d'água na atmosfera resulta em uma visibilidade horizontal inferior a 1000 m, dificultando o tráfego aéreo, marítimo e terrestre. São classificados de acordo com seus processos de formação e necessitam da presença de alta umidade relativa do ar, inversão térmica e estabilidade atmosférica. De uma forma geral, quando as temperaturas ambiente e de condensação se igualam, ocorre a formação de nevoeiros, podendo ocorrer tanto por resfriamento como por adição de umidade relativa do ar na atmosfera. O objetivo do trabalho é investigar restrições meteorológicas para operações do Porto do Rio de Janeiro através de análise de ocorrência de nevoeiros, assim como as condições meteorológicas associadas aos processos de formação. Foram estudados treze anos de dados de METAR, provenientes de estações meteorológicas de superfície presentes nos aeroportos Santos Dumont e Galeão. Os resultados mostraram uma forte sazonalidade dos eventos de nevoeiro, na qual as ocorrências de nevoeiros foram muito mais altas nos meses de outono e inverno. Também foi observada uma relação entre a variabilidade interanual e os ciclos do ENSO e uma forte dependência dos nevoeiros em relação às condições de pressão atmosférica e umidade relativa do ar.
**Palavras-chave**: METAR; Ocorrência de nevoeiro; Baía de Guanabara

**Abstract**

Fogs are meteorological events in which water vapor condensation in the atmosphere results in a horizontal visibility inferior to 1000 m, making air, sea and land traffic difficult. Fogs are classified according to their formation processes and require the presence of specific initial conditions, such as elevated humidity, thermal inversion and atmospheric stability. In general, when atmospheric temperature and dew point temperature are equal, there is fog formation. This can occur due to either atmospheric cooling or increase in atmospheric humidity. The objective of this study is to examine the meteorological conditions in Rio de Janeiro Harbor by analyzing the occurrence of fog, as well as observations of meta-oceanographic conditions associated with fog formation processes. Thirteen years of METAR data from surface meteorological stations located in Santos Dumont and Galeão airports were studied. The results revealed a strong seasonality of fog occurrence, showing a higher occurrence during autumn and winter. It was also observed that there is a relationship between the interannual variability and ENSO cycles and a strong fog event dependence on meteorological conditions such as atmospheric pressure and relative humidity.
**Keywords**: METAR; Occurrence of fog; Guanabara Bay

## 1 Introduction

According to the American Meteorological Society (AMS, 2016), the definition of fog is the presence of water droplets suspended in the atmosphere close to the surface of the Earth, whether it is water or soil, affecting the horizontal visibility, reducing it to less than 1000 m. Thus, by reducing the visibility, fog creates hazardous conditions to transportation. In industrial areas, fog can pose a major risk to human health because it may be contaminated with toxic waste, such as the London Smog in the United Kingdom (Wallace & Hobbs, 2006). Herckes *et al*. (2014) have also associated the chemical composition of the fog in Central Valley California with the local air pollution. In addition, fogs have an important role in the greenhouse effect of the planet since water vapor is one of the main gases that contribute to this effect (Varejão, 2006). These are just a few of many motivations to study the processes of formation and dissipation of fog.

The impacts of fog on the transport industry can range from delays in traffic and, consequent, financial losses to fatal accidents. As the focus of this paper is maritime navigation, specifically in the Rio de Janeiro Harbor, it is considered here that fog events can affect local operations when limited horizontal visibility hinders navigation and maneuverability, even with the presence of instruments, such as radars.

Fogs are classified according to their processes of formation. Generally speaking, fogs occur when ambient and dew point temperatures are equal and air becomes saturated. This can happen either by cooling of air temperature (cooling fog) or by adding water vapor into the atmosphere (evaporative fog) (França, 2008). Although there are several types of fog formation, they all include extremely important radiative processes (Ballard *et al*., 1991).

Cooling fogs are formed when the air reaches the saturation point, dew point, and evaporation and mixing fogs occur when water vapor is added to the air through evaporation and thus the dew point temperature rises and equals the ambient temperature. In order for a fog event to remain in place it is necessary that the formation conditions stay the same (Ahrens, 2009). Conversely, there are other ways to classify fog events. The main types of fogs are: radiation fog, advection fog and orographic fog. Radiation fogs are formed, basically, by the nocturnal cooling of the Earth by emission of radiant energy, irradiation (Varejão, 2006). Dupont *et al*. (2015) concluded in their study that low visibility events resulting from the radiative cooling processes are the consequence of a balance between dynamic, thermal and radiative processes. These events are associated with clear nights, weak winds and large areas of high pressure. Its development occurs from the surface upwards and become more intense as sunrise approaches (Wells, 2012).

The advection fog forming conditions involve moist air moving on a cooler surface (soil or water). The air then loses heat to the surface by conduction and cools from the bottom up. With a slightly intense wind, turbulent air mixing occurs inhibiting the thermal equilibrium and increasing the thickness of this cooled layer, resulting in fog formation once the air was already saturated (Varejão, 2006). Unlike radiation fog, the advection fog always involves air movement, as long as it is not strong enough to dissipate the fog or prevent its formation (Wells, 2012).

Occasionally, radiation and advection fogs are mixed and called advection-radiation fog, as is the case in the study area of this work. This happens when radiation fogs are influenced by winds more intense than 1 m/s. In these cases, the warm and humid air the wind brings is cooled when encountering the radiatively cooled surface, increasing the relative humidity of the air resulting in condensation and fog formation (Robalinho *et al*., 2004).

Pimentel *et al*. (2014) believe that fog formation processes can be better understood with a wind regime study. Moreover, several studies use winds as a way of identifying the type of fog present in a given location. Robalinho *et al*. (2004), for example, determined that radiation fog is the most common in the region of the Galeão Airport but the average wind speed between, 1 m/s and 3 m/s, led them to believe the local fog is actually radiation-advection. On the other hand, the type of fog identified in Santos Dumont Airport was advection fog. Keeping in mind that both Galeão Airport and Santos Dumont

Airport are located in the city of Rio de Janeiro and are the focus of the present study.

The main objective of this paper is to analyze the meteorological conditions associated with fog events in the eastern region of the Rio de Janeiro city, where the Rio de Janeiro Harbor is located. In this sense, a case study is conducted in order to show how the oceanographic conditions affect fogs in the region. Furthermore, one of the main motivations of this study was the important role it has in relation to the few existing articles on the subject focusing on the city of Rio de Janeiro.

## 2 Materials and Methods

### 2.1 Study Area

The city of Rio de Janeiro is characterized by a hot and rainy climate in summer, and cold and dry in winter. The local climate and oceanography dynamics are strongly influenced by the Atlantic Ocean, Guanabara Bay and Sepetiba Bay (Dereczynsk *et al*., 2013). The climatology of Rio de Janeiro is well marked by the seasonality of precipitation, with maximum rainfall in summer and minimum in winter. The high levels of precipitation in the region are associated with surface cyclone systems, while low rainfall levels in winter are associated with South Atlantic Subtropical Anticyclone, ASAS (Reboita *et al*., 2010). This high pressure center is responsible for the atmospheric stability necessary for the formation of fog and one of the reasons why winter presents a greater occurrence of this phenomenon in the study area.

Despite being under the influence of the ASAS, which would characterize a regime of winds with greater dominance of northeast winds, the most frequent winds in the city are of the south during the afternoon and the night and north in the morning. In this case, this pattern represents a behavior of sea breeze winds and terrestrial breeze (Dereczynski *et al*., 2013). This sea breeze circulation, along with local topography, influences the spatial distribution of air temperature.

The Rio de Janeiro Harbor is located in the Guanabara Bay and has extreme importance to the economy and commerce of Brazil, with an intense flow of boats, cargo ships and tourists. According to the Master Plan (Brasil, 2014), operations in the Rio de Janeiro Harbor are diverse, with iron and wheat exportation being two of the main. Therefore, studies that can contribute to improve safety of all sorts of harbor operations are of great importance to the development of the region. Figure 1 presents the study area, indicating the meteorological stations (SBGL and SBRJ), the oceanographic buoy and the Rio de Janeiro Harbor locations.

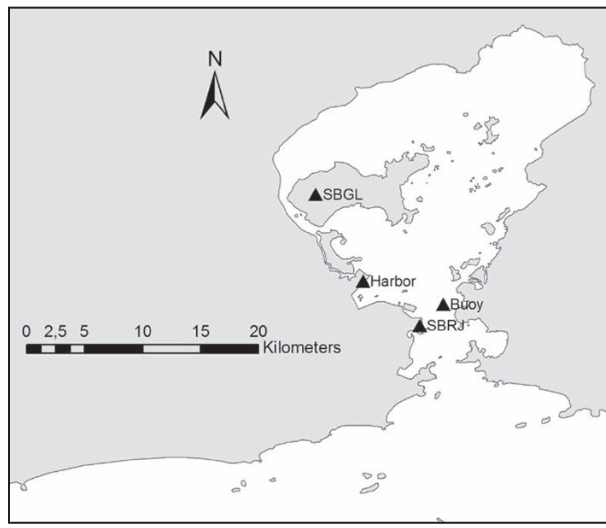


Figure 1 Study area indicating the meteorological stations (SBGL and SBRJ), oceanographic buoy and Rio de Janeiro Harbor locations.

### 2.2 Dataset and Methodology

This study uses observational data from automatic meteorological surface stations located at the airports of Galeão (SBGL) and Santos Dumont (SBRJ). These so-called METAR (Meteorological Aerodrome Report) are hourly records that compose the Meteorological Network of the Aeronautics Command (REDEMET, 2017). METAR data are coded and display information regarding various aspects related to the behavior of the atmosphere at that time. They are, wind (direction and intensity), horizontal visibility, weather (presence of rain, fog), clouds (height and quantity), temperature, condensation temperature, atmospheric pressure (BRASIL, 2009). This work focused on horizontal visibility and fog occurrence. Data from a meta-oceanographic buoy was also used to extract the sea surface temperature (SST) data for the case study on its influence over fog events. This buoy, located close to SBRJ, is part of the National Buoy Program (PNBOIA), one of the components of GOOS-Brasil (Global Ocean Observing System).

To reconstruct the fog formation scenarios and determine the favorable conditions for these events, a survey of fog occurrences was conducted from 2003 to 2015 and a basic statistical method was used to determine a pattern of behavior of the phenomenon, weighted average. The survey is based on hourly, monthly and annual occurrence of fog. For example, how many METAR data present fog, how many hours and how many days this result was found. The data used are provided in Greenwich time, so they were adjusted to Brasília time (-3 h) to facilitate the interpretation of the information. Wind (direction and intensity), atmospheric pressure, temperature, condensation temperature and psychometric depression was analyzed. The latter being the difference between the air temperature and the condensation temperature, making it possible to affirm that the smaller the psychometric depression the greater the relative humidity of the air.

## 3 Results and Discussion
### 3.1 Occurrence of Fog Events

In order to analyze the interannual and annual variabilities of fog occurrence in the Rio de Janeiro Harbor, data from both stations are interpreted as a single system. That is, a fog occurrence is accounted if reported in at least one of the two analyzed stations. Figure 2 shows the interannual variability of the Rio de Janeiro Harbor, indicating the occurrence of fogs (METAR records with FG as current weather condition) and the number of days in which these events occurred. In the present study we consider that each day when fog is present corresponds to a different fog event. The difference between the results for fog events and records of fog is observed in amplitude of the points of high and low occurrences. That is, not only the years with high occurrence of fog present a greater number of days with fog, but also events which lasted longer when compared to years with low occurrence of fog.

When comparing the interannual variability of days with fog occurrence and event records, we observed that although these two parameters follow the same pattern of high and low fog frequencies, the magnitudes are very different. For example, in 2007, there were 54 fogs recorded in the Rio de Janeiro Harbor in 17 days and in 2011 there were 65 records in 15 days. Thus, when analyzing the pattern and the reason for this interannual variability, it is suggested that there might be some relationship with the El Nino Southern Oscillation (ENSO).

Table 1 presents the ENSO phases that occurred during the time range of this study and the respective fog occurrences. Only moderate or stronger ENSO phases (SST anomalies of +/- 1 °C) were considered and discussed. Given that the average of fog records in one year is approximately 38, Table 1 considers a fog peak, years with high occurrence of fog, as years with more than 50 records of this phenomenon and years with low occurrence were defined as years with less than 35 records.

The 2009/10 El Nino was followed by a strong La Nina event in 2010/11. Due to the fact that this La

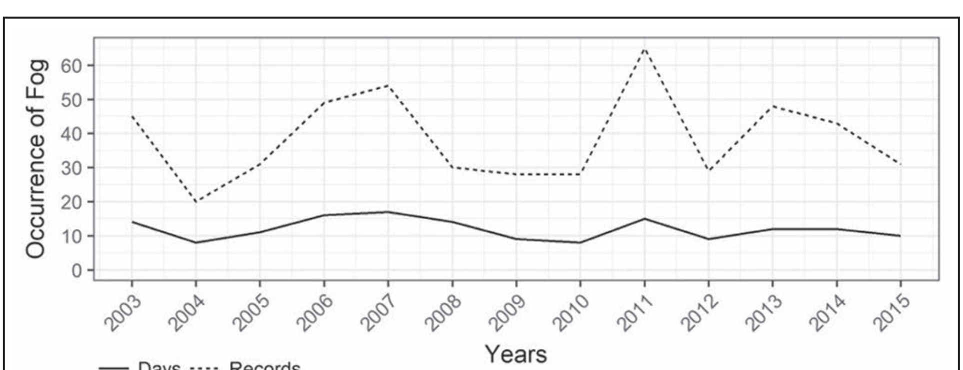


Figure 2 Interannual variability of the occurrence of fog in the Rio de Janeiro Harbor.

Nina comes soon after a significant El Nino we can only see the influence of La Nina on the occurrence of fogs in the Rio de Janeiro Harbor during the year 2011. It is possible to observe from Figure 2 that the peak of occurrences of 2011 is the most expressive of the entire temporal range of the study.

| Period | ENSO | | Occurrence of Fog | Fog Records |
|---|---|---|---|---|
| | Phase | Intensity | | |
| 2002/03 | El Nino | Moderate | - | - |
| 2007/08 | La Nina | Moderate | High | 54 |
| 2009/10 | El Nino | Moderate | Low | 28 |
| 2010/11 | La Nina | Strong | High | 65 |
| 2014/15 | El Nino | Very strong | Low | 31 |

Table 1 Relation of the periods with El Nino and La Nina occurrences according to NOAA (2015) and the respective fog frequencies of each period.

However, when comparing the amplitudes of the occurrences of fog records and number of days with fog in Figure 2 it is possible to observe that, although 2011 presents a higher occurrence of recorded fogs (65 records), it does not present the greatest number of different events (15 events). The year of 2007 presented the highest amount of different days with the presence of fog, a total of 17 events. Thus, it is concluded that a strong La Nina event does not mean higher occurrence of fog events than a moderate one, but it could mean that the events are more intense. Other issues should be taken into account, such as the meteorological and oceanographic conditions.

The ENSO phase of 2014/15, representing an event of El Nino, could not be completely analyzed because this study goes until December 2015. In addition, between 2002 and 2006 there were weak EN and LN events, as indicated by NOAA (2015). Even though, in this study it is taken into account that the periods of high and low frequencies of fog throughout the years might be related or explained by the ENSO cycle, it cannot conclude such relationship because of the short time range of the study.

Under global warming conditions, Li & Zhang (2013) predicted that sea fog occurrence would decrease on the east coast of China due to the weakening of SST fronts once the temperature gradient decreases. Garreaud *et al*. (2008) present in a occurrence analysis of fogs in the semi-arid region of Chile, that there is a greater occurrence of fogs in years of La Nina and fogs are less frequent in years of El Nino. This is explained by the pattern of temperature anomalies and precipitation rates generated by El Nino Southern Oscillation (ENSO).

Thus, there are evidences that ENSO has some influence in fog occurrence anomalies in places where these phenomena are recurrent. In this ENSO analysis it is important to highlight the methodological limitation of the work. The data series is too short to be considered a climatology, besides presenting few occurrences of positive and negative phases of ENSO. A longer study could confirm or contradict the relationship between ENSO and the fog in Rio de Janeiro.

The annual cycle study allows us to analyze the seasonality of the fog events. As stated by Cossich *et al*. (2009), in the case of Rio de Janeiro Harbor, there is a distinctive seasonality, with a higher occurrence of fog in the autumn and winter months, as presented in Figure 3. Rocha *et al*. (2010) also indicates June as the month of highest fog frequency in the study area. This result was expected because radiation fogs are more common in autumn and winter months due to greater stability of the atmospheric high-pressure centre and lower temperatures (Ahrens, 2009).

An analysis of days of occurrence was performed in order to verify if the results would be different from those using the general records with the presence of fog. Moreover, the individual events were used to examine the temporal behavior of the phenomenon throughout the day, such as start time and duration of events. Keeping in mind that results from the Rio de Janeiro Harbor includes data from both SBGL and SBRJ stations.

For the daily cycle analysis, the data from SBGL and SBRJ stations were not merged to represent the conditions in the Rio de Janeiro Harbor. That is, the events behave on a daily scale, while the analysis was conducted for each station. The reason for such methodology is the fact that the stations ra-

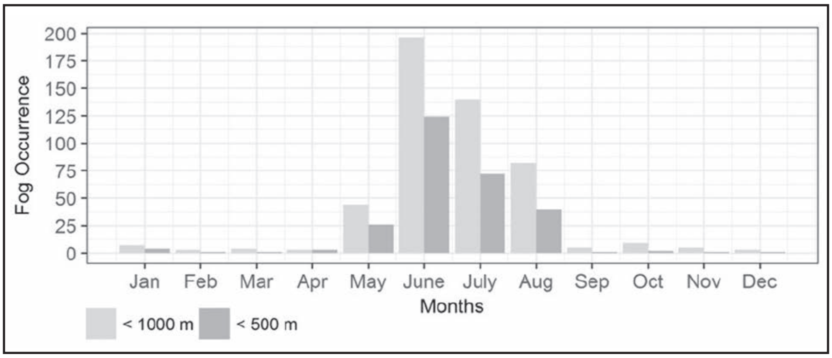


Figure 3 Fog occurrences in the Rio de Janeiro Harbor (SBGL + SBRJ) per month throughout the temporal scope according to limited horizontal visibility (< 1000 m and < 500 m, respectively), indicating the seasonal cycle of events.

rely present the same fog event (25 days during the thirteen years studied). And when they did, they had different start times, durations and intensity. Thus, by applying this method, the results would not be impaired or altered by multiple recordings of any single fog event.

In Figure 4 we can observe the occurrence and start time of fog events on each day throughout the temporal range of the study. Although the SBRJ station has a more diverse start time than SBGL, both stations have a concentration of fogs beginning in the morning. The peak of fog occurrence in SBGL occurs between 05:00 and 07:00 and in SBRJ between 06:00 and 07:00 (local time), compling with the results found in Cossich (2009). Other important information is the fact that no fog events start in the afternoon. This is because the afternoon is the hottest period of the day, i.e. atmospheric temperatures are higher. Thus, it is more difficult for relative air humidity to reach the dew point required for fog formation (Ahrens, 2009).

The results show that from early afternoon to early evening only two fog events occurred in the thirteen years of analyzed data and from the beginning of the afternoon there were only such events recorded at the SBRJ station. In addition, as shown in Figure 4, most events occurred between dawn and early morning, reinforcing the idea of Ahrens (2009) that radiation fog events are more intense and common near sunrise.

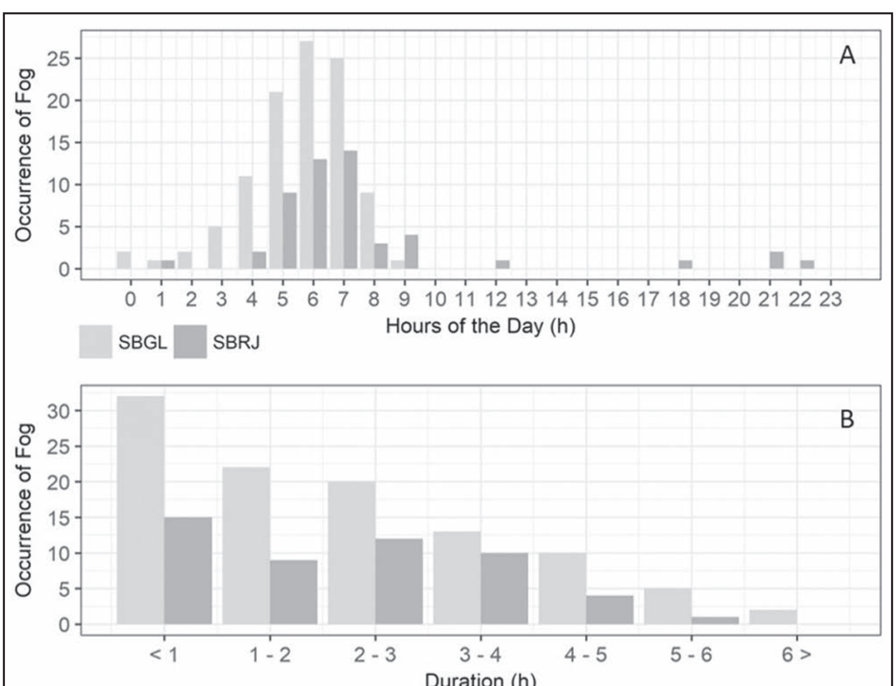


Figure 4 A. Occurrence and initiation time of recorded fog events throughout the day at analyzed stations, SBGL and SBRJ, during the entire temporal scope; B. Occurrence of fogs events classified by duration time at analyzed stations, SBGL and SBRJ, during time at analysed statios, SBGL and SBRJ, during the thirteen years of data studies.

During the analysis of the duration of the events, it is necessary to make approximations of the times they ended, taking into account that the fog ends when the registered horizontal visibility becomes greater than 1000 m. As demonstrated by Cossich (2009), both the SBGL station and the SBRJ station show the most common duration of fog events is up to 1 hour. Despite this, the average duration of events in SBGL is 2.49 h and in SBRJ is 2.52 h. At the SBRJ station, the longest fogs are 5.5 hours long and in SBGL, 6.5 hours. The results indicate that fogs with durations between 3 - 4 h at the two stations present a very similar occurrence. However, for fogs with duration up to 1h and of 1 – 2 h, SBGL presents many more events than SBRJ, concurring with Cossich (2009). That is, the large number of events that SBGL records in comparison to SBRJ represents short fog events.

### 3.2 Fog Formation Scenario

In order to simplify the analysis and to investigate which meteorological conditions are favorable to the formation of fogs in the region of the Harbor we calculated the weighted averages of such parameters. Table 2 shows a comparison between the average meteorological conditions during fog events in the Rio de Janeiro Harbor, at the SBGL and SBRJ stations and during years of both El Nino (EN) and La Nina (LN).

It is evident from Table 2 that the SBGL station presents conditions more favorable to the formation of fogs because the wind intensity is much lower than that of SBRJ, lower air temperature and higher atmospheric pressure also contribute to more auspicious conditions for fogs. The only parameter in which SBGL presents a less favorable result for fog formation in comparison to SBRJ is the psychometric depression. With this, it is possible to estimate that the relative humidity is higher in SBRJ. This is due to the fact that SBGL is an airport located on land deep inside a bay under the strong influence of its surrounding continent, while SBRJ is an airport located in a reclaimed area in the centre of the bay, closer to the ocean. The indications of higher values of relative air humidity and air temperature in SBRJ found in this study coincide with the results found by Cossich (2009).

These more propitious conditions at SBGL explain the reason for higher fog occurrence at this station than at SBRJ, in addition to a lower average horizontal visibility during the events, as indicated in Table 2.

| Parameter | SBGL | SBRJ | Harbor | El Nino | La Nina |
|---|---|---|---|---|---|
| Wind (m/s) | 0.98 | 2.50 | 1.44 | 1.69 | 1.44 |
| Atmospheric Temperature (°C) | 18.80 | 19.77 | 19.07 | 19.12 | 19.05 |
| Psychometric depression (°C) | 0.97 | 0.42 | 0.81 | 0.99 | 0.83 |
| Atmospheric pressure (hPa) | 1017.92 | 1017.19 | 1017.70 | 1017.67 | 1017.05 |
| Visibility (m) | 413.17 | 680.34 | 490.50 | 526.67 | 505.40 |

Table 2 Average weather conditions during fog events in the study area.

It is possible to explain the result found in this study in which LN years present more fog than years of EN, bearing in mind the characteristics of a typical Guanabara Bay fog are calm winds, high atmospheric pressure, low temperatures and high relative humidity. The results found indicate that fog events occuring during LN present winds of lower intensity than EN fog events. In addition, mean air temperature is lower in LN years along with psychometric depression values.

Finally, we can observe that the average horizontal visibility of LN is lower than in EN. That is, not only more fogs do occur during LN events, but they are also more intense than the ones that occur during EN.

### 3.3 Case Study – SST v. Fog

The atmosphere, more specifically, the boundary layer presents different reactions depending on positive and negative anomalies in sea surface temperature (SST). This may have a direct influence on the distribution and intensity of advection fogs and sea fogs (Wells, 2012). SST analysis was performed using a third dataset extracted from a meta-oceanographic buoy located in Guanabara Bay in order to exemplify a possible SST-fog interaction mechanism in the region. Not all events present equivalent data on the buoy due to the it being withdrawn from the water for maintenance at various times of the year and the data not being constant. Therefore the interpretation of SST at the moment is limited to that indicated in this article due to the observational data in the Guanabara Bay being very recent.

The SST case, chosen from this restricted sampling, was compared to what this paper found as standard meteorological conditions during fog events, as discussed previously. SST data was then used throughout the day to understand the behavior of the water. In this analysis only data from SBRJ was considered due to its proximity to the buoy, resulting in more real results and facilitating an initial association between the SST and the fog events.

Taking into account the results found, a typical fog event in the study area involves events developed during the morning with weak winds and high atmospheric pressure. Therefore, the case study chosen is presented in the Table 3. Figure 5 shows the SST on 06/06/2015 and inside the dashed box, the fog event. It is possible to observe that the SST begins to decrease when the fog is forming and during the event, it remains stable and low, representing the lowest SST of that day. The data shows that when the wind changes direction and the fog begins to dissipate, the SST remains low but gradually increases. The last record with the presence of fog has air temperature 3 degrees higher than recorded during the rest of the event, as well as higher dew point and sea surface temperatures. In other words, the SST remains low and stable at the time of day when temperatures should be rising due to solar heating.

When studying near-shore fogs it is difficult not to associate them with SST. The study area is not different. Under the strong influence of the Guanabara Bay, any surface water mass that enters this body of water may influence the formation of local fog. Thus, we have the classification of radiation-advection fog in this area. When studying the occurrence of sea fog in the Northwest Pacific, Tokinaga *et al*. (2009) also concluded that subsurface circulation processes in the ocean are very important for a better understanding of the fog events.

## 4 Conclusion

In the present study, 13 years of data were analyzed and the fog formation scenarios were reconstructed. It was taken into account that analyzing both stations (joining SBGL and SBRJ) together is suitable in order to represent the conditions within the Harbor area. In addition, we investigated the predominant meteorological characteristics during fog events and the behavior of the SST in a case study on 2015. In this sense, it was concluded that:

| 06/06/2015 | | Wind Direction | Wind Speed (m/s) | Horizontal Visibility (m) | Atmospheric Pressure (hPa) | Psychometric Depression (°C) | SST (°C) |
|---|---|---|---|---|---|---|---|
| Start (BRT) | 6:00 | NW | 2.6 | 800 | 1018 | 0 | 20.49 |
| Finish (BRT) | 9:25 | NE | 1.56 | 500 | 1020 | 2 | 20.62 |

Table 3 Atmospheric conditions when the fog event being studied started and its last record, as well as its respective SST, on 06/06/2015.

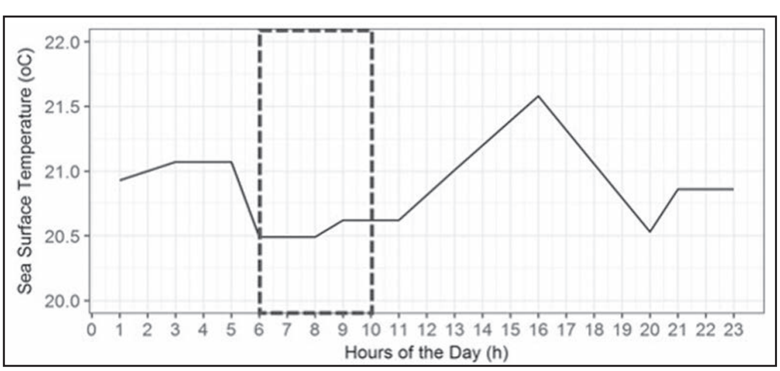


Figure 5 SST behavior during the fog event on 06/06/2015.


Anuário do Instituto de Geociências - UFRJ
ISSN 0101-9759 e-ISSN 1982-3908 - Vol. 41 - 2 / 2018 p. 123-132

The study found evidence of the influence of the positive and negative phases of ENOS on the coccurrence of fog. Peak of fog occurrence in Rio de Janeiro Harbor may be associated with phases of La Nina. On the other hand, years in which fog frequencies are lower are close to El Nino phases.

The SBGL station presents conditions more favorable to the formation of fogs due to the fact that the wind intensity is much lower than at the SBRJ, along with lower air temperature and higher atmospheric pressure. This explains the higher fog occurrence at this station in comparison to SBRJ, as well as lower horizontal visibility during events.

In the case study, the SST begins to fall at the moment the fog is forming and during the event it remains stable and low, representing the lowest SST of that day. Further evaluation should be conducted on fog events that deviate from the pattern found for this region, for example, anomalous events such as fog occurring in the afternoon need to be understood. Although the case study has addressed only 1 event, it is consistent in the SST-fog interaction in the vicinity of the Rio de Janeiro Harbor. In addition, such studies are rare and this is an unprecedented contribution in the region.

Finally, the results show that the conceptual conditions discussed at the beginning of the work were confirmed for the formation of fog in the study area. In addition, this conditions were quantified and compared in several scenarios.

This work presented some limitations during the case study with the SST analysis as the data was intermittent and the presence of the meta-oceanographic buoy in the Guanabara Bay is recent. A future study on oceanographic conditions of fog events is recommended when buoy data is more constant. In addition, it would be of great importance to have another source of SST hourly data inside the Bay of Guanabara, close to SBGL or Guapimirim Environmental Protection Area (APA).

In addition, studies using current data in the water column from the meta-oceanographic buoy in question are recommended to evaluate the real impact of a SST variation on the formation of fog. It would also be interesting to have a climate analysis (at least 30 years) that considers the cases of El Nino and La Nina and the occurrence of fog in the region to better understand the behavior of the fog in Rio de Janeiro.

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