Conjecturas

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Weather events and respiratory diseases in children: case studies in the metropolitan region of São Paulo, Brazil

Eventos meteorológicos e doenças respiratórias em crianças: Estudo de caso na região metropolitana de São Paulo, Brasil

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ABSTRACT

This paper presents a preliminary analysis of meteorological variables and their relationship with respiratory morbidity in children under two years old of São Paulo city, taking into account the synoptical systems and their constructive structures of residences. Measurements of indoor air temperature and relative humidity were collected using a thermohygrographic across of 378 residences, between years 2003 to 2006. Outdoor meteorological variables have been obtained from meteorological station. A summary with four case studies is shown relating the thermal behavior in each residence and the onset of respiratory illness in children (wheezing). The results show associations of children respiratory crises and air temperature fall and increase of relative humidity, associated with maritime polar air masses and frontal systems (cold front). Specific residences have higher indoor humidity values than others, due to their constructive types and it is an important factor to bring out wheezing problems. Considering such results, acknowledging periods favorable to occurrences of wheezing in children, as well as the constructive type of residences, it is feasible to predict respiratory morbidity and to establish public policy in order to alert the population, minimizing weather/climate impacts on children's health

Keywords: Meteorotropism; Children; Respiratory disease, Households.

RESUMO

O Artigo faz uma análise preliminar da influência das variáveis meteorológicas na morbilidade respiratória de crianças menores de dois anos em São Paulo/SP, considerando os sistemas sinópticos e as estruturas construtivas de residências. Medidas das variáveis temperatura e umidade relativa do ar no interior das residências foram obtidas de termoghigrógrafos instalados em 378 residências, entre os anos 2003 e 2006. As variáveis meteorológicas externas às residências foram obtidas de estações meteorológicas. São apresentados quatro estudos de caso relacionados com o comportamento térmico em cada residência e o aparecimento de doenças respiratórias em crianças (chiado). Os resultados mostram associações de crises respiratórias em crianças com a queda da temperatura e aumento da umidade do ar, associados a massas de ar polar marítimo e sistemas frontais (frente fria). Algumas residências têm valores de umidade interna mais elevados do que outras, devido ao tipo construtivo. Considerando tais resultados, e observando períodos mais favoráveis à ocorrência de sibilos nas crianças, bem como, o tipo construtivo de suas residências, torna-se possível prever a morbilidade respiratória e estabelecer políticas públicas a fim de alertar a população, minimizando os impactos do tempo e clima sobre a saúde das crianças.

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Palavras-chave: Meteorotropismo; Crianças; Doenças respiratórias; Residências.

INTRODUCTION

Since the earliest days of human history, the interest, necessity, or curiosity of understanding the relationship between the different weather conditions and human body's physiological response to these changes has always existed. Hippocrates, in his book "Air, Waters and Places", dated about 400 BC, described qualitatively the main variables that significantly affect thermal comfort: temperature, winds, relative humidity, and radiation; (Monteiro & Alucci, 2005). In the seventeenth century, the first measurements of air temperature were held in Florence and Beijing, however, if they the goal was to seek views on thermal sensations of certain environments, those were considered vague. In the early nineteenth century there were some preliminary studies investigating the influence of thermal stress in the textile industry workers who had health problems.

The air in the indoor environment is an exposure that dominates human beings. Since human beings spend approximately 90% of their lives indoors and more than half of the air breathed (about 90%) in a lifetime is inhaled in domestic environments, a good understanding of thermal conditions found within such environments is naturally necessary and very important. In that sense, many studies have been made taking into account not only the physical variables of the environment, but the characteristics of buildings and behavior of their occupants. The research has assessed thermal performance of buildings (homes) and their living conditions (Viamont, 1996; Givoni 1992 and 1999; Vechia 2005; Vecchia and Givonni, 2001; Papst and Lamberts, 2001; Cardoso, 2007; Nedel, 2008).

Studies on exposure to indoor environmental risk factors and their effects on health in developed countries have mainly been conducted in northern Europe and North America. Emenius et al. (2004) found that living in relatively new apartment buildings, in single-family homes with crawl space/concrete slab foundation, with elevated indoor humidity, and report wintertime windowpane condensation were associated with current wheezing in infants. Thus, according to these authors, improvements in the building quality may have potential to prevent infant wheezing. According to Sundell (1999), there is strong evidence of associations between indoor air quality and lung cancer, allergies and respiratory infections. Regarding indoor ventilation, Smith (2003), analyzing the condensation on glass windows, reported that inadequate ventilation was the main risk factor for the onset of coughing, asthma, and respiratory infection and a significant increase in allergies among residents.

Respiratory diseases, especially in childhood represent a major public health problem. The causes of these diseases can be infectious (virus and bacteria), such as colds and pneumonia, or non-infectious as asthma and bronchitis (Cardoso, 2007). Some children have wheezing as a manifestation of these respiratory diseases, sometimes accompanied by fatigue or shortness of breath. Cardoso also comments that the hiss is a type of most common manifestation in children of mothers with asthma or a history of allergy (allergic rhinitis, for example). Among the various factors for the increased number of respiratory diseases and severity of hospitalizations, environmental factors play a role of utmost importance. Sudden changes of time, for example, helps degrading the quality of breathing air, especially when the site is under the influence of cold and dry air masses, which makes the dispersion of pollutants in the atmosphere. Furthermore, the authors investigating the residences´ microclimate which was observed contribution for respiratory problems related to indoor conditions due to their deficient constructive characteristics. The high temperature ranges were observed and they were related to children wheezing.

Considering the above described, it becomes factual the importance of knowing the temperatures in home environments, not only regarding thermal comfort, but especially because of the fact that bad adequacy of local microclimate might affect health, especially among children. This paper is a preliminary view which aims to assess the meteorological conditions favorable to the occurrence of respiratory disease (wheezing) in children below two years old in the city of Sao Paulo, Brazil, as well as the role of homes for these illnesses. The hypothesis to be investigated is that the household, through their constructive kinds, can play an important role at the beginning of the wheezing in children, especially, with regard to meteorological variables: air temperature and relative humidity.

METODOLOGY

a) Study area

The area of this study is the Metropolitan Region of Sao Paulo (MRSP), located in the southeast portion of Brazil, which has a population of approximately 17,000,000 inhabitants and at currently with over 7,000,000 vehicles. The climate of the MRSP is considered subtropical (*Cwa* type, Köppen classification), with average temperatures of 15.5°C during July (winter), and 22.5°C during January (summer) (IAG/USP Weather Station, located at Southeastern of MRSP at 23º65S and 46º62, 800 m altitude). During the winter the temperature can reach minimum values close to zero degree and, sometimes, over 34 degrees during the summer or spring time, like in the years of 2003 and 2005, respectively. The relative humidity varies between 20% and 100%. Due to its proximity to the Atlantic Ocean (120 km away to the south) the region is influenced by the effect of sea breeze that is a constant in the local weather. The average annual precipitation is 1,317 mm (IAG/USP station) and can be divided into two main seasons: a rainy season which includes the period from October to April and a dry season that goes from May to September. Another factor of great importance to the health of the population is the high concentration of air pollutants observed in the city. Coming mainly from anthropogenic mobile sources pollutants such as PM_{10}, NO_x, SO_2, O_3, CO are the most commonly measured and the most worrying. Among the regulated pollutants that have their environmental concentrations increased during the winter, and eventually exceed the standards of air quality, there are inhalable particles (PM_{10}), carbon monoxide (CO) and nitrogen dioxide (NO_2). Moreover, in despite of being less favorable to the formation of ozone, exceeding the standards of air quality in this period is a frequent occurrence. Throughout the winter, such exceeding levels in the city of Sao Paulo are favored by the condition of thermal inversion - when a temperature inversion occurs, increasing with height and imprisoning the pollutants in the lower layers of the atmosphere - something constant in this season. In a simplified way, inhalable particles are those with aerodynamic diameter less than 10 μm, enabling these particles to penetrate the respiratory tract. Studies by the CETESB (*Companhia de Tecnologia de Saneamento Ambiental* - Brazilian version of EPA in the USA) in the MRSP show that about 40% of these particles are emitted by motor vehicles (mainly by diesel vehicles). Another source considered important is the dust of the streets, equivalent to about 25% of the pollutant concentration. Among the inhalable particles, there are inhalable thin particles, with a diameter less than 2.5 µm, for which there is no national legal concentration threshold, but which nevertheless are very important in terms of health, since they penetrate more deeply into the respiratory tract (Cançado et al, 2006).

b) The Wheezing Project

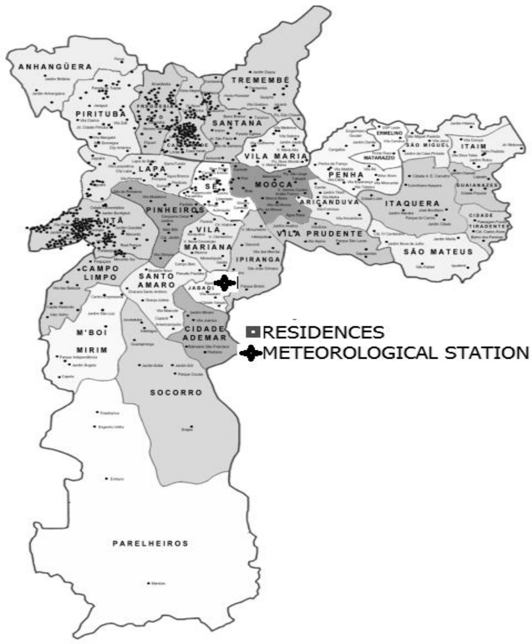
This study was developed in the city of Sao Paulo from January 2003 to July 2006, as part of cohort study - "*Wheezing Project*" - which aimed to study the influence of indoor environmental risk factors on the development of wheezing diseases, allergy and atopic sensitization in children living in São Paulo. Measurements of meteorological variables air temperature and relative humidity (moisture) have been carried out in the interior of 378 households, counting 3,279 days measured, mostly in residences of northern and western of the city. Children have been randomly selected amongst the ones born in four public hospitals and thus the households where they lived were consequently representative of different constructive types found in the city. Measurements have been performed in the children bedroom, with an analog Temperature/Humidity *Datalogger*, Oaktom brand, model 08369-70, for period where one day representing 24 hours of observation. Samples of fungi were also collected from the children's homes using an impactator *M air T*, *Millipore*, Fr. The households were classified and grouped into 10 types according to their construction characteristics (wall, floor, ceiling, and coverage). However, in this paper only 3 types, (extreme cases, the richest and the poorest types of construction) are presented.

c) Respiratory disease: case studies

The case studies were extracted from a basis of twenty-nine households which four events were selected for further analyzed. Those events have been chosen because they were measured during a similar period, under different climatic conditions (air mass, cold front), between 2003 and 2006, in which the children, living in different residences, had different respiratory complications (wheezing, noise breath, coughing, or other infections). The cases studies were also chosen due to fact that the children present clear wheezing periods in your medical consultations.

Table 1 presents the distribution of households with their child's identification, date of consultation, date of the beginning of the problem, as well as the respiratory complication. In order to assess the constructive types of buildings, it was used the classification proposed by Cardoso, 2007 (by cover/roof, ceiling and wall) which has characterized the dwellings in twelve different constructive types (Table 2).

Figure 1 – Spatial distribution of households in Sao Paulo city belonging to the *Wheezing Project*



Source: the authors

Table 1 - Wheezing children distribution (ID) by case study, hospital admissions data, the moment of the onset respiratory problem at your residences and the synoptical conditions over Sao Paulo city.

ID		Hospital date	Problem	Symptoms at home date	Synoptical system
Case Study I	1025	08/05/2003	wheezing	01/05/03	Cold front
	1027	08/05/2003	noise breath	05/05/03	Cold front
Case Study II	1008	19/09/2003	wheezing	15/09/03	Polar high masse
	1027	22/09/2003	wheezing	14/09/03	Polar high masse
Case Study III	1133	16/12/2004	noise breath	09/12/04	Cold front
	1196	13/12/2004	wheezing	06/12/04	Cold front
Case Study IV	1108	01/10/2004	wheezing	15/09/04	Polar high masse
	1196	01/10/2004	wheezing	17/09/04	Polar high masse

Table 2 - Classification of buildings by type of cover (roof), ceiling and walls.

Types of cover and roof	Types of walls	Group	Household in each group
Fibrocement without roof	Wood	1	3 (0.8%)
	Concrete block or brick stuck	2	34 (9.04%)
	Solid clay brick	3	3 (0.8%)
Ceramic Tile without roof	Wood	4	0
Fibrocement + wood roof	Concrete block or brick stuck	5	12 (3.19%)
	Solid clay brick	6	13 (3.46%)
Concrete slab and without roof	Concrete block or brick stuck	7	83 (22.07%)
	Solid clay brick	8	9 (2.39%)
Ceramic Tile + wood roof	Concrete block or brick stuck	9	67 (17.82%)
Fibrocement + concrete roof	Solid clay brick	10	8 (2.03%)
Ceramic Tile + concrete slab roof	Concrete block	11	89 (23.67%)
	Solid clay brick	12	55 (14.63%)

RESULTS AND DISCUSSION

In order to analyze the impact of dwelling types in the onset of wheezing problems in children, a correlation analysis of data was performed organized. Table 3 shows results for Factor Analysis (FA) considering the respiratory disease (wheezing), the residences constructive type of children and the outdoor meteorological variables, temperature and relative humidity (minimum, maximum and average). Residences which children had the most wheezing problems were considered. As noted, the best correlation with wheezing occurs for Group 11 (Ceramic Tile cover, concrete slab roof and walls with Concrete block: corr +0.53); Group 9 (Ceramic Tile cover, wood roof and walls of concrete block or brick stuck: corr. +0.50) and Group 7 (Concrete slab cover, without roof, walls with Concrete block or brick stuck: corr. +0.41). Regardless of these three residences groups to have common constructive characteristics - walls of concrete block or brick stuck (concrete block or brick walls stuck) - exists in these types (11, 9, 7) also a high moisture content, due to higher thermal resistance of your materials. This agrees with the observed in all other households studied (378) in São Paulo city: high values of indoor average humidity, 77.5% (the same measurements period for the outside showed humidity mean values of 74.6%). Other constructive types, however, as group 2 (fibrocement cover, without roof, brick or concrete block walls struck) have a smaller thermal insulation, and hence, lower indoor humidity values (not shown in this paper). It must be pointed out that this group 2 analysis, and a general analysis will perform in the following article (Household constructive effect and environmental variables on children wheezing in Sao Paulo City). Thus, the amount of moisture in households (specifically in child's bedroom) is a dominant and decisive factor for the wheezing onset on children. It is believed that the development of this disease in children depends also on other dwelling factors such as, geographic location, ventilation rate, occupation rate, indoor pollution, presence of animals (dogs and cats) at home, schooling and parental smoking, level of income, hygiene conditions, etc ... This hypothesis corroborates the results already found by other researchers (Hazucha and Bates 1975; Winslow and Herrington 1949; Prietsch et al 2003; Gonzales-Alonso et al 1999 apud Hondula et al 2013).

Analyzing with more detail the role played by the residences constructive type (groups) in the onset of wheezing in children, particular case studies were conducted. The purpose is to show that high (low) amount of inside moisture has influence to faster (slower) beginning of respiratory problem. Different residences are compared, located in diverse places of the city, sampled on the same periods (in order to compare indoor moisture in the residences).

The events are shown as it follows: from Case Study I to IV.

Table 3 – Factor Analysis for children with the highest wheezing number, between period 2003/2006.

Variables	Means	Std.Dev.	Wheezing	T	RH	Press	Wind	Tmax	Tmin	RHmax	RHmin	Type 7	Type 9	Type 11
Wheezing	0,3820	0,7453	1,0000	-0,0583	0,0670	0,0549	-0,0281	-0,0595	-0,0470	0,0145	0,0208	**0,4064**	**0,5046**	**0,5309**
T	0,0037	0,9997	-0,0583	1,0000	-0,3330	-0,5072	0,0650	0,8719	0,8508	-0,0904	-0,1976	-0,0156	-0,0342	-0,0462
UR	0,0078	1,0003	0,0670	-0,3330	1,0000	0,0574	-0,0188	-0,5926	0,1107	0,3539	0,4964	0,0051	0,0481	0,0298
Press	0,1609	1,0004	0,0549	-0,5072	0,0574	1,0000	-0,1786	-0,3728	-0,5122	-0,0238	0,0053	0,0005	0,0471	0,0396
Wind	0,0032	1,0001	-0,0281	0,0650	-0,0188	-0,1786	1,0000	-0,0734	0,1788	-0,0829	0,0897	0,0047	-0,0031	-0,0435
TMax	0,0035	0,9998	-0,0595	0,8719	-0,5926	-0,3728	-0,0734	1,0000	0,5468	-0,1326	-0,3895	-0,0083	-0,0375	-0,0292
TMin	0,0027	1,0000	-0,0470	0,8508	0,1107	-0,5122	0,1788	0,5468	1,0000	0,0100	0,0487	-0,0206	-0,0137	-0,0497
RHmax	0,0223	0,9981	0,0145	-0,0904	0,3539	-0,0238	-0,0829	-0,1326	0,0100	1,0000	0,3617	-0,0901	0,0433	0,0251
RHmin	0,0039	0,9993	0,0208	-0,1976	0,4964	0,0053	0,0897	-0,3895	0,0487	0,3617	1,0000	-0,0243	-0,0055	0,0430
Type 7	0,0235	0,1037	**0,4064**	-0,0156	0,0051	0,0005	0,0047	-0,0083	-0,0206	-0,0901	-0,0243	1,0000	-0,0164	0,0515
Type 9	0,0206	0,0821	**0,5046**	-0,0342	0,0481	0,0471	-0,0031	-0,0375	-0,0137	0,0433	-0,0055	-0,0164	1,0000	0,0511
Type 11	0,0275	0,0988	**0,5309**	-0,0462	0,0298	0,0396	-0,0435	-0,0292	-0,0497	0,0251	0,0430	0,0515	0,0511	1,0000

Legend: Std.Dev. Standar desviation; T: temperature; RH: relative humidity; Press: atmospheric pressure on surface; Wind: wind velocity; Tmax: maximun temperature; Tmin: minimun temperature, RHmax: maximun relative humidity; RHmin: minimun relative humidity; Types 7, 9, 11: constructive types of houses. Number of de cases 1254

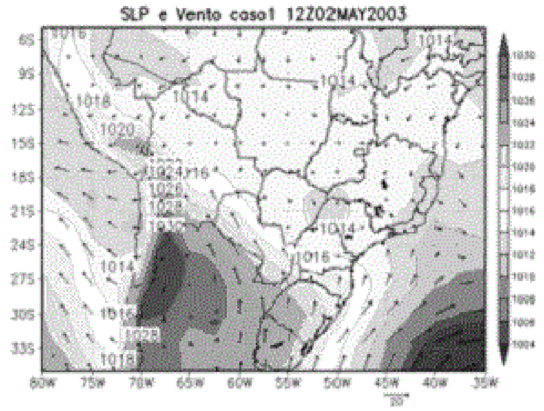
i) Case Study I: **Event of 05/01/2003 and 05/05/2003**

Figure 2 (a, b) shows the displacement of a frontal system from the south of Brazil toward São Paulo. During its trajectory the cold front (CF) had induced rainfall (7 mm) and decreased temperatures in the city. It has also been observed after the passage of the CF the approach of a continental cold air mass (CAM; or polar air masse) for the extreme south of Brazil, which reached on day 03/05 the northern region of Brazil (named as cold spell phenomena). According to data from the meteorological station (Figure 2b), between May 1st and 3rd there was a drop in 10°C in the maximum temperature (Tmax) and 7°C in the minimum temperature (Tmin) in the city of São Paulo. Table 1 shows that the arrival of a cold front in Sao Paulo on May 1st affecting differently the children of households 1025 and 1027. While one child presented wheezing problems (1025), the other one had complications with noisy breathing (1027).

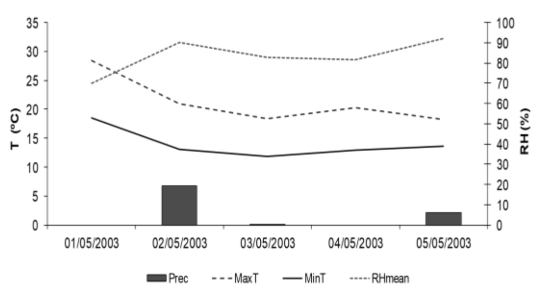
Analyzing the constructive characteristics of their homes, it has been observed that the 1025 household is composed of brick walls, no lining and asbestos cement roofing. This type of household is also characterized by having considerable openings for ventilation between the wall and roofing. This suggests that there is an immediate penetration of the external conditions weather to interior (temperature, humidity, wind), there is no damping or a large thermal inertia (thermal mass) by construction materials that can delay (buffer) these variables coming from the external environment. The impact of these variables in this constructive type (brick stuck/no ceiling/asbestos cement roof) is very fast and can cause the onset of respiratory complications (in this case, the appearance of wheezing) starts on the same day that the drop in temperature outside (lag 0). That is, any increase or decrease (though small) of Temperature and Relative Humidity outer (of household) modifies the conditions of the internal environment and the thermal comfort. This does not occur for other types (groups) of residential constructive (eg. 1027), where there is a greater delay/damping of such variables (high thermal mass), and so that it is felt internally; maintenance is required in such conditions for a longer period.

Figure 2 – (a) Sea level pressure (hPa) and wind vector (m/s), and (b) temporal variability of daily meteorological variables observed in the meteorological station IAG/USP: Tmax (maximum temperature), Tmin (daily minimum temperature), RHmed (relative humidity mean), Rain (total daily precipitation).

(a)



(b)



Source: the authors

Types of households similar to 1027, due to their construction (walls with hollow bricks, cover of slab, flooring, and carpet) seem to have poorer ventilation and storing a larger amount of humidity inside. The symptoms of noisy breathing, presented by child 1027 (May, 5th), illustrates this situation (poorly constructed households): The approach of a cold front (CF) increased humidity, causing rainfall weak and fall of temperatures (01/05 to 03/05). On day 05, instability areas caused light rain in Sao Paulo and provided further decline in temperature (maximum, figure 2). Despite this drop being small, the wind direction was kept East (E) and gave support for maintenance increase of air humidity on that day (figure 2a). The hypothesis that the constructive characteristics of the house (1027) have enabled to hold greater moisture storage inside of after a passage of the CF and the CAM from previous days, until the new precipitation occurred on day 05. This damp chill may have been the reason for the respiratory complications (noisy breathing), faced by the household 1027. In general, a small increase in air humidity may cause wheezing respiratory problems in the residence 1025 child, while for the child of the 1027 house, it was necessary that these moisture levels were kept higher.

Summarizing, this case study shows that a cold front could influences the residences of São Paulo city moisture levels in both children from both households 1025 and 1027. However, the child living in household 1025 presented the respiratory problem (wheezing) only for a few hours (one day; 02/05) after the beginning of the increase in humidity and rainfall, while the residence 1027 child presented the noisy breathing problems only 3 days later (05/05). The constructive characteristics of residences can be responsible for this difference. Table 4 shows the internal variables T and RH for simultaneous measurements periods in houses 1025 and 1027. Fifteen days were measured simultaneously, belonging to three climatic seasons of the year 2003 (summer, fall, and winter). Comparing the 1025 and 1027 households, it clearly seems that the household in 1025 presented warmer and drier during the day (higher Tmáx and lower RHrmín), and colder and "slightly" more humid during the night (morning) (smaller Tmín and larger RHmax), which can be explained by the constructions, with coverage of low thermal inertia (tile cement) that provides a greater accumulation of heat during the day (the incidence of solar radiation) and a rapid cooling at night with large spaces between their structures allowing the entry of large volumes of air (as earlier mentioned). The 1027 residence is characterized by having a greater amount of moisture (RHmin), mainly during the whole day. When the mean RH is observed, it is correct to say that, in average, this house is wetter than house 1025.

Table 4 – Values of minimum (Tmin), maximum (Tmax) and mean (Tmean) temperature (°C) and minimum (RHmín), maximum (RHmáx) and mean (RHmean) relative humidity (%) observed at houses 1025, 1027 and meteorological station IAG/USP, and its corresponding seasons: summer (S), fall (F), winter (W).

	1025 House						1027 House					
Data	*Tmín*	*Tmáx*	*Tmean*	*RHmín*	*RHmáx*	*RHmean*	*Tmín*	*Tmáx*	*Tmean*	*RHmín*	*RHmáx*	*RHmean*
31/01/03	21.4	27.0	24.2	74	98	86	24.0	25.0	24.5	72	77	74.5
01/02/03	21.4	39.0	30.2	35	98	66.5	25.0	27.0	26.0	69	85	77.0
02/02/03	21.4	39.8	30.6	27	98	62.5	27.0	28.0	27.5	35	83	59.0
13/05/03	19.8	27.4	23.6	35	80	57.5	22.4	23.2	22.8	70	90	80.0
14/05/03	18.4	28.0	23.2	39	90	64.5	22.0	24.0	23.0	75	94	84.5
15/05/03	19.0	30.0	24.5	42	94	68	22.8	24.0	23.4	76	95	85.5
16/05/03	18.8	30.0	24.4	50	96	73	23.4	24.4	23.9	73	98	85.5
17/05/03	18.2	31.0	24.6	40	96	68	24.0	25.0	24.5	69	98	83.5
18/05/03	16.6	30.6	23.6	42	83	62.5	24.0	25.0	24.5	62	88	75.0
19/05/03	16.2	29.8	23.0	47	88	67.5	24.0	25.0	24.5	60	87	73.5
22/08/03	19.0	35.0	27.0	43	97	70	22.0	24.0	23.0	59	96	77.5
23/08/03	24.0	36.0	30.0	44	98	71	23.0	25.0	24.0	60	94	77.0
24/08/03	22.0	35.0	28.5	41	87	64	24.0	26.0	25.0	70	98	84.0
25/08/03	17.0	25.0	21.0	75	98	86.5	24.0	26.0	25.0	91	98	94.5
26/08/03	16.0	20.0	18.0	92	98	95	21.0	24.0	22.5	91	98	94.5
Mean	**19.3**	**30.9**	**25.1**	**48.4**	**93.3**	**70.8**	**23.5**	**25.0**	**24.3**	**68.8**	**91.9**	**80.4**
SD	**2.4**	**5.3**	**3.6**	**17.8**	**6.1**	**10.4**	**1.4**	**1.3**	**1.3**	**13.5**	**6.6**	**8.8**

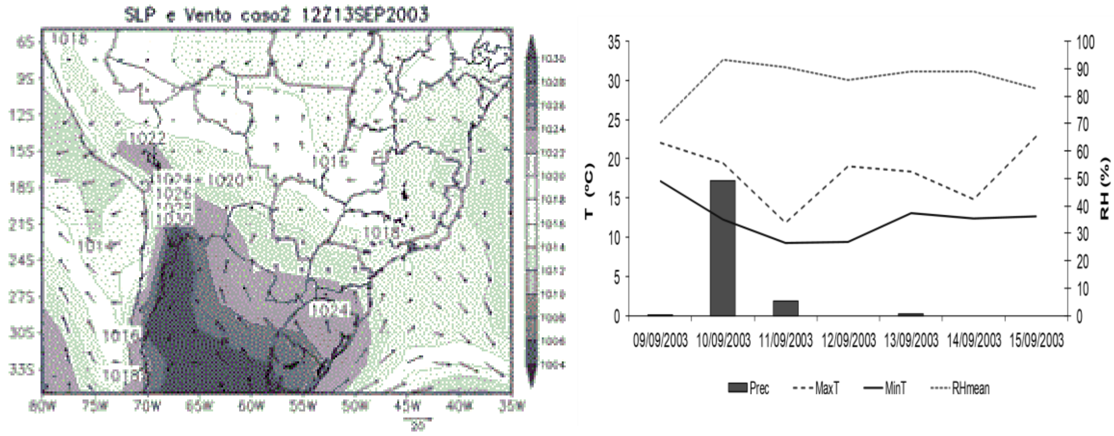
By characterizing the periods of measurements by seasons; summer, fall and winter, it is clear that in the summer and in the winter seasons these differences (T and RH) between the houses are more evident (in the Autumn, this difference is hardly noticeable). The 1025 house is the most uncomfortable for both seasons, being colder in winter and hotter in summer. Comparing two households with the outside environment (IAG/USP meteorological station, figure 1b), is observed in general that both are warmer and wetter than the outside environment (not shown here).

ii) Case Study II: **Events of 14/09/2003 and 15/09/2003**

Figure three (a and b) shows the Sea Level Pressure (SLP) and wind vector fields. It is feasible to notice the presence of a cold front (CF) moving from the north of the state of Rio Grande do Sul (RS) to the center of the Southeast region of Brazil. On September 14th (2003), this system was moving toward the ocean. The inflow of a cold air mass caused a slight temperature decrease in the south and southeast region of Brazil, later moving to the ocean. It is important to mention that since September 10th (2003) the city of São Paulo had cloudy and humid days, some rain, and low air temperatures. On 09/11, for instance, it was observed the minimum air temperature, 9.2°C, one of the lowest temperatures of that year (Figure 3b). In this case the approach of the cold front on Sao Paulo seems to affect similarly the children in houses 1008 and 1027. Both children presented problems with wheezing, however the children 1008 presented the crisis one day after the children 1027.

Figure 3 – (a) Sea Level Pressure (hPa) and wind vector (m/s), and (b temporal variability of daily meteorological variables observed in the meteorological station IAG/USP: Tmáx (maximum air temperature), Tmín (minimum air temperature), UR (Relative Humidity), Rain (total daily precipitation).

(a) (b)



Source: the authors

Analyzing the constructive characteristics of these households it is observed that both 1008 and 1027 are composed of walls with bricks, lack of lining and cover slab. These construction types store a large amount of moisture inside, and its type of coverage (concrete slab) and being under and on other floors (between floors) prevents the ideal (and equal) receipt of solar radiation in its total structure. In addition, the ventilation rate in such constructive characteristics seems to be poor (with very small areas or without windows, as the case of the house 1008). In the episodes of wheezing of the children 1027 and 1008 (09/14 and 09/15/2003, respectively), the city of São Paulo was under the influence of a cold air mass (CAM), which associated with the anticyclone positioned on the Atlantic Ocean continued the moisture flows and affect decrease of temperatures (as described in Figure 3). Table 5 shows T and RH inside and the respective periods of measurements for each residence. Comparing them with the outside environment, it is observed that the internal temperatures of both houses, 1027 and 1008, are higher (on average) than the external environment, particularly, the minimum temperatures. This was expected, since in this occurrence period, these temperatures (first hours of the morning) the residences are protected from outside environment (windows and doors are closed) and there is no radiation loss through the roof, as in household 1025 (no lining and asbestos cement roofing), for example. Close values have been observed concerning maximum temperature between the households and the external environment, especially between 1027 house and outside environment. This occurs due to the location of the 1027 residence (close to a vegetated area), constructive type with cover slab of concrete with limited availability of solar radiation. According to relative humidity in these households, the above hypothesis becomes more consistent, since there is a greater amount of RH inside the environment (on average), and this humidity is noticeably larger and more apparent during the day (in the afternoons, RHmin). During the nights (RHmax), it was observed that 1027 household had RH lower than the external environment, while in the residence 1008 the humidity is higher than outdoor environment. However, these differences (for indoors and outdoors) are not high (92% and 96% to 98% and 95%). Such case emphasizes the effect of synoptic weather conditions (CAM) in Sao Paulo city in the households 1027 and 1008. Children living in these households, presented the same respiratory symptoms (wheezing) in very close time (almost in the same days: May 14th and 15th), according to medical recorders. The constructive types present no significant differences which emphasizes only the weather impact.

Table 5 – Values of minimum (Tmin), maximum (Tmax) and mean (Tmean) temperature (°C), and minimum (RHmín), maximum (RHmáx) and mean (RHmean) relative humidity (%) observed at houses 1027 and 1008, and its corresponding season (S): summer (S), fall (F), winter (W).

1027 House						
	Tmin	*Tmáx*	*Tmean*	*RHmin*	*RHmáx*	*RHmed*
31/1/03	24.0	25	24.5	72	77	74.5
1/2/03	25.0	27	26	69	85	77
2/2/03	27.0	28	27.5	35	83	59
13/5/03	22.4	23.2	22.8	70	90	80
14/5/03	22.0	24	23	75	94	84.5
15/5/03	22.8	24	23.4	76	95	85.5
16/5/03	23.4	24.4	23.9	73	98	85.5
17/5/03	24.0	25.0	24.5	69	98	83.5
18/5/03	24.0	25.0	24.5	62	88	75
19/5/03	24.0	25.0	24.5	60	87	73.5
22/8/03	22.0	24.0	23	59	96	77.5
23/8/03	23.0	25.0	24	60	94	77
24/8/03	24.0	26.0	25	70	98	84
25/8/03	24.0	26.0	25	91	98	94.5
26/8/03	21.0	24.0	22.5	91	98	94.5
Mean	**23.5**	**25.0**	**24.3**	**68.8**	**91.9**	**80.4**
SD	**1.4**	**1.3**	**1.3**	**13.5**	**6.6**	**8.8**

1008 House						
Data	*Tmín*	*Tmáx*	*Tmean*	*RHmin*	*RHmáx*	*RHmean*
4/4/03	27.0	28.6	27.8	86.0	98.0	92.0
5/4/03	26.6	28.6	27.6	85.0	98.0	91.5
6/4/03	26.4	28.2	27.3	87.0	97.0	92.0
7/4/03	25.2	27.9	26.6	85.0	97.0	91.0
8/4/03	24.8	28.6	26.7	86.0	97.0	91.5
9/4/03	26.6	30.2	28.4	74.0	97.0	85.5
10/4/03	27.6	20.8	24.2	91.0	97.0	94.0
9/1/04	21.8	22.4	22.1	90.0	98.0	94.0
10/1/04	21.2	23.4	22.3	91.0	98.0	94.5
11/1/04	22.0	26.0	24.0	92.0	98.0	95.0
12/1/04	23.8	25.6	24.7	91.0	98.0	94.5
13/1/04	23.0	25.0	24.0	92.0	98.0	95.0
14/1/04	23.2	26.0	24.6	85.0	98.0	91.5
15/1/04	23.4	26.0	24.7	86.0	98.0	92.0
Mean	**24.5**	**26.2**	**25.4**	**87.2**	**97.6**	**92.4**
SD	**2.1**	**2.7**	**2.0**	**4.7**	**0.5**	**2.5**

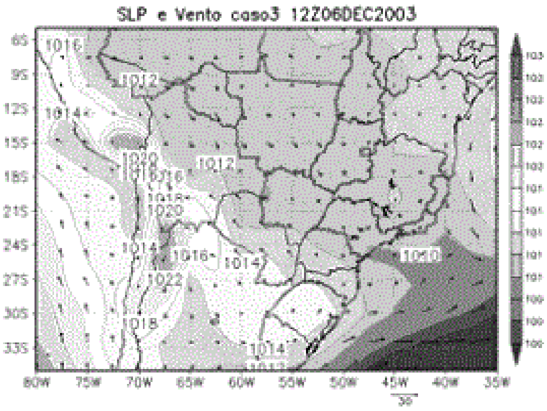
iii) Case Study III: **Events of 12/06/2004 and 12/07/2004**

Figure 4 shows the synoptic weather conditions on Sao Paulo states (SP). Sea level pressure (SLP) and wind vectors (4a) fields are presented and the observed meteorological dates at the meteorological station (IAG/USP, 3b), where it is possible to identify the penetration of a frontal system (cold front, CF) with fast displacement affecting Sao Paulo on the night of December, 06th, producing rainfall and temperature decrease. The city of Sao Paulo was facing very damp days with rainfall and temperature decreases until the December, 12. On December 06 a CF arrival was observed pronounced temperature decrease (10°C), with maximum daily temperature 29.2 °C at 12:00 P.M. and minimum daily temperature 19.2 °C at 19:00 P.M. (Figure 3b).

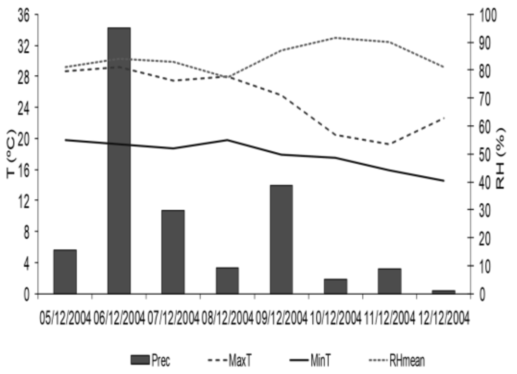
This case shows that CF had affected the children differently from households 1196 and 1133. While some had wheezing problems (1196), the other children had noisy breathing (1133). Analyzing the constructive characteristics of these households, it is observed that the residence 1196 is composed of walls with hollow bricks, no lining, covering and tile cement. This type of household is also characterized by presenting openings for ventilation between the wall and covering, low thermal insulation (residential structure similar to the house 1025; case I). There is, in this case, a quick penetration of external variables to inside of the residences (temperature, humidity, wind, pollution, and other variables inherent own children), there is no thermal resistance able to mitigate or minimize the effects of the external environmental. An increase/decrease in external of T and RH, for instance, can impact quickly and begin onset of respiratory illnesses (wheezing) in children on the same day of decrease of outside temperatures - or after a few hours ("lag" 0 day). Any increase or decrease in T and RH in the external environment (even small) could change the conditions of the indoor environment. In the case of the wheezing episode presented by children in 1196 house, it was noticed that the problem appeared on the same day of the arrival of the frontal system (at night, December, 06^{th}), which increased air humidity, producing rainfalls and drop in temperatures (Figure 4b).

Figure 4 – (a) Sea Level Pressure (hPa) and wind vector (m/s), and (b) temporal variability of daily meteorological variables observed in the meteorological station IAG/USP: Tmáx (maximum temperature); Tmín (minimum temperature); RH (Relative Humidity); Rain (total daily precipitation).

(a)



(b)



Source: the authors

House 1133 presented the following construction characteristics (walls with hollow bricks, cover slab) meaning that there is a greater retardation/attenuation of external variables and thus, for those changes in the outside environment are felt internally is necessary that such weather conditions (decrease of T and increase of RH, for instance) persist for more days. The health impact in these cases usually occurs in the subsequent days (lag of 1-3 days). This residence is similar to the constructive type of 1027 house, case I. Due to its characteristics, this type of construction seems to have poorer ventilation and store a greater amount of moisture inside. The event noisy breathing presented by children in 1133 house (December, 09^{th}) exemplifies this situation. It is a similar case to the problem presented by the child of the 1027 house (case I), when the arrival of an CF (December, 06^{th}) caused increased air humidity, rainfall and drop in temperatures. This instable weather condition (from 12/06) remained over Sao Paulo until December, 09th; that the contribution to the more stored of high humidity inside of the house (1133), and this can be directly associated with the onset respiratory complications in the child on subsequent days (noisy breathing; December, 09th). Table 6 shows the internal variables T and RH in houses measured in 1196 and 1133 residences. Residence 1196 (measured on the third coldest weeks of winter, 2004) is warmer and wetter when compared to the outside environment (larger Tmed and RHméd). This moisture is considerably higher during the day (RHmín: 71.5% and 39%, respectively). Throughout the night, the indoor humidity is also high, but slightly higher than the external environment (RHmáx: 98% and 95%, respectively). Considering only the temperature effects, it was observed maximum values very close between indoor and outdoor environment, and the minimum values higher (inside) than the ones measured outside (meteorological station). Regarding house 1133, it was also characterized as warmer as and wetter than outside environment, especially during the afternoons (when the RHmin was higher: 70% and 52%, respectively). However, the maximum temperature was smaller than outside temperatures (this might be an indication that there was no good sunlight in the house). During the night both RH (indoor, house 1133, and outdoor, IAG) are very high, being almost equal, recording values around 94% and 95%. Thus (similar to the case I studied), children living in residence with thermal lower resistance and, consequently, with greater influence of the external environment variables show quickly respiratory complications than children living household with good thermal insulation (for example, household number 1008). This suggests that the households have an important role in the onset of respiratory problems in children.

Table 6 – Values of minimum (Tmin). maximum (Tmax) and mean (Tmean) temperature (°C). and minimum (RHmín). maximum (RHmáx) and mean (RHmean) relative humidity (%) observed at houses 1196 and 1133.

1196 House						
	Tmín	*Tmáx*	*Tmed*	*RHmin*	*RHmáx*	*RHméd*
13/08/04	16.6	19.2	17.9	88.0	98.0	93.0
14/08/04	16.0	20.6	18.3	79.0	98.0	88.5
15/08/04	17.2	21.2	19.2	79.0	98.0	88.5
16/08/04	18.2	22.6	20.4	68.0	98.0	83.0
17/08/04	19.2	24.2	21.7	62.0	98.0	80.0
18/08/04	21.0	26.6	23.8	53.0	98.0	75.5
Mean	**18.0**	**22.4**	**20.2**	**71.5**	**98.0**	**84.8**
SD	**1.8**	**2.7**	**2.2**	**12.9**	**0.0**	**6.4**

1133 House						
	Tmín	*Tmáx*	*Tméd*	*RHmín*	*RHmáx*	*RHméd*
29/04/04	20.0	22.8	21.4	70	89	79.5
30/04/04	20.0	23.4	21.7	88	100	94
01/05/04	20.0	24.6	22.3	55	100	77.5
02/05/04	21.2	26.6	23.9	68	100	84
03/05/04	22.4	26.0	24.2	72	100	86
04/05/04	23.8	25.6	24.7	92	100	96
05/05/04	23.0	25.4	24.2	92	100	96
03/12/05	18.0	20.0	19.0	79	100	89.5
04/12/05	18.0	20.0	19.0	74	100	87
05/12/05	20.0	22.0	21.0	79	100	89.5
06/12/05	21.0	22.0	21.5	77	100	88.5
07/12/05	19.0	21.0	20.0	65	84	74.5
08/12/05	19.0	20.0	19.5	66	76	71
06/05/05	22.0	24.0	23.0	49	85	67
07/05/05	19.0	25.0	22.0	50	81	65.5
08/05/05	19.0	25.0	22.0	59	80	69.5
09/05/05	20.0	24.0	22.0	77	90	83.5
10/05/05	21.0	24.0	22.5	76	96	86
11/05/05	20.0	24.0	22.0	50	95	72.5
Mean	**20.3**	**23.4**	**21.9**	**70.4**	**93.5**	**81.9**
SD	**1.6**	**2.1**	**1.7**	**13.4**	**8.4**	**9.7**

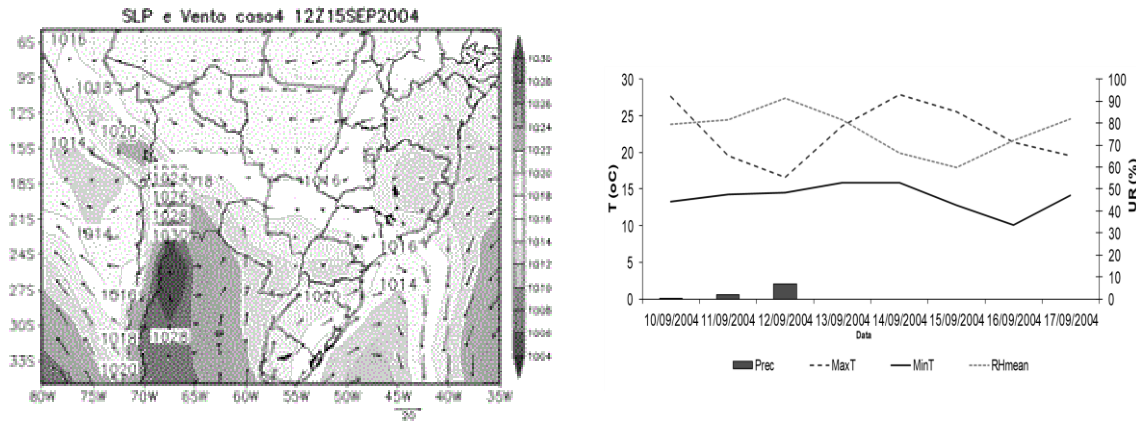
iv) Case Study IV: **Events of 15/09/2004 and 17/09/2004**

Through Figure 5 (a and b) it is possible to see the sea level pressure and wind vector fields (SLP) on surface (Figure 5a), and the observed meteorological dates on surface from September 10th to September 17th (Figure 4b). It is verified the formation of cold front (CF) between north coast of the states of São Paulo (SP) and Rio de Janeiro (RJ) (September, 12th; Figure 5a). According to CLIMANÁLISE (2004) this CF were responsible for rainfall and strong winds, happening in the coastline of the SP, moving later to Atlantic Ocean. The presence of the high-pressure system (anticyclone) associated with an extratropical cyclone positioned on the coast of the state of Rio Grande do Sul (RS) generated a "track wind" also favoring drop in temperatures on SP (September, 15th). Two days later (09/17) this system already on the ocean, but still maintained the temperature decrease. This case study shows the cold air mass (CAM) associated with the polar anticyclone acting over São Paulo from September 15th to 17th, and affected the children in households 1108 and 1196, with both presenting wheezing problems. The difference was that the child of the house 1108 presented wheezing on 09/15 and the child in 1196 house only presented it two days later, on 09/17. An analysis of the constructive characteristics in these houses observed that the 1196 house has constructive structure of walls with hollow bricks, no lining, and roofing of asbestos cement (similar 1025 house).

On the other hand, house 1108 (similar to house 1133, already discussed in this research), consisting of walls with hollow bricks, unlined, slab cover, and tile floor. Thus, it has a greater thermal insulation (roof slab) when compared to 1196 (title asbestos cement roof). Table 7 shows the indoor T and RH variables for households 1108 and 1196, and the periods of measurements. Analyzing the temperatures between houses, it is observed that in average both maximum and minimum values are noticeable very close, however, the difference between maximum and minimum is slightly larger in 1108. The first statement is maybe an indicative of a low (or nothing) sunshine incidence over both houses, particularly in house 1196, which also close to other neighboring houses and increasing the amount of shaded areas in this housing. Such hypothesis is supported by the fact that if there is incidence of sunlight in these residences, the 1196 house, due to the constructive type would present higher temperatures than 1108 house. In the outside environment, these days were sunny with low relative humidity, light winds, and cloudless.

Figure 5 – (a) Sea Level Pressure (hPa) and wind vector (m/s), and (b) temporal variability of meteorological variables observed daily in the meteorological station IAG-USP: MaxT (maximum air temperature); MinT (minimum air temperature); RHmean (mean Relative Humidity); Prec (total precipitation), September 10th to 17th.

(a) (b)



Source: the authors

Analyzing the RH of these households and the external environment can be observed the large amount of moisture present in such environments (RHmín: 71.5% and 75%; respectively to 1196 and 1108 houses, for same measured period). During the evenings, (RHmáx) a lot of moisture in these residences had been seen. Comparing the moisture between 1108 and 1196 houses, it was possible to observe that there is great similarity between the measured values of RH (minimum and maximum). This fact reinforces the hypothesis above that those houses did not receive sunlight. The drop in temperatures from day 14 (Figure 5b) added to high humidity existing inside the house caused problems of wheezing in children in both residences. House 1196 has presented the problem of wheezing two days later (09/17) of the respiratory problem presented in the house 1108 (09/15), may be due to internal factors, peculiar to the residence in 1196 (greater amount of shaded areas, due to proximity to neighboring residences and poor geographic location), as well as intrinsic biological factors of children.

Summarizing, houses with lower thermal insulation (1025, 1196) presented respiratory problems in children in a shorter time when compared to the houses with constructive structures of a higher thermal resistance (1027, 1008 and 1133). Such differences are due to the fact that synoptic systems more easily affect such residences since they present a lower thermal inertia. When houses of similar constructive are compared (1196 and 1108), the differences regarding respiratory problems in children are little and mostly due to biologic factors of the child, as well as a deficient geographic location of the house.

Table 7 – Values of minimum (Tmin), maximum (Tmax) and mean (Tmean) air temperature (°C), and minimum (RHmín), maximum (RHmáx) and mean (RHmean) relative humidity (%) observed at house 1108 and 1196, in the season of winter (W).

1108 House						
	Tmín	*Tmáx*	*Tméd*	*RHmín*	*RHmáx*	*RHméd*
24/01/04	23.8	26.6	25.2	85	98	91.5
25/01/04	25.0	29.0	27.0	74	98	86
12/08/04	15.4	20.4	17.9	80	98	89
13/08/04	16.0	20.6	18.3	78	98	88
14/08/04	16.6	22.0	19.3	72	98	85
15/08/04	18.0	23.6	20.8	83	98	90.5
16/08/04	19.0	24.8	21.9	67	98	82.5
17/08/04	19.4	24.8	22.1	85	98	91.5
18/08/04	20.0	26.4	23.2	64	98	81
11/05/05	24.0	27.0	25.5	43	62	52.5
12/05/05	22.0	27.0	24.5	45	63	54
13/05/05	24.0	28.0	26.0	45	66	55.5
14/05/05	24.0	28.0	26.0	39	62	50.5
15/05/05	24.0	28.0	26.0	50	60	55
16/05/05	24.0	28.0	26.0	39	60	49.5
17/05/05	25.0	27.0	26.0	45	59	52
06/12/05	23.0	29.0	26.0	55	67	61
07/12/05	20.0	24.0	22.0	50	70	60
08/12/05	19.0	26.0	22.5	50	65	57.5
09/12/05	20.0	28.0	24.0	41	61	51
10/12/05	23.0	29.0	26.0	50	60	55
11/12/05	20.0	25.0	22.5	55	62	58.5
Mean	**21.1**	**26.0**	**23.6**	**58.9**	**77.2**	**68.0**
SD	**3.0**	**2.6**	**2.7**	**16.2**	**17.9**	**16.7**

1196 House						
	Tmín	*Tmáx*	*Tmed*	*RHmín*	*RHmáx*	*URméd*
13/08/04	16.6	19.2	17.9	88.0	98.0	93.0
14/08/04	16.0	20.6	18.3	79.0	98.0	88.5
15/08/04	17.2	21.2	19.2	79.0	98.0	88.5
16/08/04	18.2	22.6	20.4	68.0	98.0	83.0
17/08/04	19.2	24.2	21.7	62.0	98.0	80.0
18/08/04	21.0	26.6	23.8	53.0	98.0	75.5
Mean	**18.0**	**22.4**	**20.2**	**71.5**	**98.0**	**84.8**
SD	**1.8**	**2.7**	**2.2**	**12.9**	**0.0**	**6.4**

CONCLUSIONS

The analysis of association between respiratory diseases (wheezing and noisy breathing) in children in the city of Sao Paulo and meteorological conditions, across these case studies, suggests the strong contribution of household constructive types in children, since the weather conditions changes seem to be modulating respiratory problems. Residences of lower thermal mass are the most harmful. In addition, meteorological events as cold fronts and cold air masses provide high amount of moisture inside environments, which are also highly prejudicial to children's health.

Among children who presented major problems (wheezing) live in buildings with high moisture content indoor (mainly) and lower thermal insulation (table 3). Observing other respiratory problems related to wheezing as noisy breathing and cough (not shown here) it was possible to notice, in general, that the residences also present these constructive types. However, of the days for the beginning of the problem are different for each child. In residences with less thermal insulation (1025 and 1196 houses) the children had, in general, the problem on the same day ("lag" of ~0.7 days, or few hours later) of drop in outdoor air temperature (meteorological station). On the other hand, children living in homes with better heat insulation and, consequently, with more moisture content inside the residence (1008, 1027, 1133 houses) present the beginning of wheezing complications two days later of decrease external air temperature ("lag" of ~2 days). These differences can be attributed to higher (lower) gain (loss) of heat through the roof, beyond the intrinsic biological conditions of each child (who were not evaluated in this study). It is also extremely useful to emphasize the role played by the areas of shading caused by the poor location of households (close to neighboring houses; 1196 and 1008 houses) which can accelerate the onset of respiratory problems in children, being an important factor in determining this disease. One important application of this study is not introducing more moisture environments (residences) of the city of Sao Paulo during low air humidity episodes (winter season, mainly). It is extremely unwise and dangerous, because it only could result in high indoor thermal discomfort and the beginning of allergic complications, such as fungi and mites damaging health, especially in children. We also encourage other studies to investigative the characteristics of each household (location, household habits, presence of fungi in walls, household crowding, smoking persons in family, maternal education, family genetics, etc ...), in addition, to each biological child. The findings showed in this paper are preliminary.

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