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Do ambient temperature and rainfall influence relative humidity in Goma (Democratic Republic of Congo)?

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Abstract

Goma, a rocky town in eastern DR Congo at an altitude of 1500m along lake Kivu has a low relative humidity. We set up to examine the influence of physical parameters (temperature, rain fall and atmospheric pressure) on the relative humidity in the town. Data collected in this study from January 2005 to October 2009 and additional data from both RVA Goma and Goma Volcano Observatory (OVG) were analyzed in main components using R-2.4.0 and Spadv5.0. It was found that both temperature and rainfall are not significant factors influencing relative humidity in Goma.

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INTRODUCTION

In nature, there are four water reservoirs: atmosphere, surface, ocean and underground water [Parriaux, 2003; Laborde, 2000]. Atmosphere reservoir is the most mobile in space and time. The volume of accumulated water as vapor or droplets or ice crystals is low compared to other reservoirs (15 120 km3 ~ 0.04%) [Parriaux, 2003].

In the troposphere, the atmosphere's layer near the ground, the ambient air is never dry, but contains water in gaseous form, « vapor water », [Laborde, 2000; Musy, 2005]. This is provided by the physical evaporation over the surface of open water (oceans, seas, lakes and rivers), soil devoid of vegetation and surfaces covered by snow or ice, and by plant transpiration, and other biological and geological processes which allow water vapor to escape from the plants to the atmosphere.

Relative humidity, the amount of water vapor in the air, is the ratio between the amount of water in the air and the maximum amount of water that air can contain. Moisture is always present in the atmosphere but in very different proportions. Indeed, the sun warms the surface of the earth and causes evaporation of water [Musy, 2005]. It comes a time when a particle of air is saturated with water vapor but not all the time.

The vapor content of air is measured with devices called hygrometers. The measurements are usually expressed as specific humidity or percent relative humidity. The temperatures of the atmosphere and the water surface determine the equilibrium vapor pressure; 100 % relative humidity occurs when the partial pressure of water vapor is equal to the equilibrium vapor pressure [Queney, 1974; Clifford, 2005]. This condition is often referred as complete saturation.

Goma is one of the cities of Democratic Republic of Congo. Its hydrological cycle is quite well known but existing data need to be updated. Both the Airways Board of Goma (RVA, Regie des Voies Aériennes) and the Volcano Observatory of Goma (OVG) collect regularly weather data such as rainfall, air pressure, and ambient temperature. RVA sampling intervals are so large (every hour) that many details information are lost and night-time data are not collected. Whereas OVG collect data every half an hour for 24 hours.

With a few reliable instruments (psychrometer, digital barometer, global positioning system) and setting a sampling interval every 20 minutes day and night, this work will help not only to update database but also to analyze if there are correlations between the parameters studied. Present work focuses on parameters influencing relative humidity.

MATERIEL ET METHODES

The investigation was carried out in Goma, capital of North Kivu province from January 2005 to October 2009. Data obtained from our own investigations and observations are compared for compliance and comparison tests with those collected both by RVA and OVG. They are found to have similar trends.

A site to collect data should be an open place to the normal circulation of air; totally or partially covered by vegetation. For each site, we collected ambient temperature (TD), wet temperature (Tw), atmospheric pressure (Pa) and altitude (Alt). We use software's R2.4; Spadv5.0 for analysis of the main components and Excel to plot graphs. The following instruments were used for data collection:

Assmann psychrometer (serial: 1203789, type: 5410). It consists of two thermometers, a dry bulb and wet bulb. Evaporation from the wet bulb lowers the temperature (TW), so that the wet-bulb thermometer usually shows a lower temperature. The dry-bulb thermometer measures dry-bulb temperature (TD) [Visscher, 1994; Cretinon, 2001]. The difference of TD - TW represents the cooling due to evaporation and this difference is larger when evaporation increases. But evaporation itself depends on the relative humidity of air: if air is more humid, evaporation is low, therefore the difference (TD - TW) will be small. Relative humidity is then determined by the intersection of the TD and TD - TW on a psychrometric.

Digital barometer (IT+, TX29-IT) was used to measure atmospheric pressure [Clifford, 2005; Burch, 2009; Middleton, 2002].

The Global Positioning System GPS (GARMIN GPS 12), it use a constellation between 24 and 32 Medium Earth Orbit satellites that transmit precise microwave signals, these allow GPS receivers to determine their current location, the time, and their velocity [Steven, 2008]. It was used to measure Geographical coordinates and altitude.

A maxima and minima thermometer. It indicates both, the highest and the lowest temperatures of the day as well as the temperature at the time of reading.

Description of Goma

Goma (Area: 75.72 km2; Coordinates: 1°41′S 29°14′E) is a city in eastern Democratic Republic of the Congo (Figure I). Located approximately at 1 500 meters above sea level in the Rift Valley. Goma is built along Lake Kivu on the ancient lava flows from the volcanic Virunga chain, and especially those of the Nyiragongo volcano that dominates almost 3 000 meters at 20 km north of the city

Goma, despite having a rocky ground, with a high altitude, along great lake (lake Kivu), has weather's parameters that differs from that of others similar cities at the same rocky ground (Boma, Matadi) It's relative humidity and atmospheric pressure are low[Rostha, 2014]. Hence, the necessity of understanding this paradox.

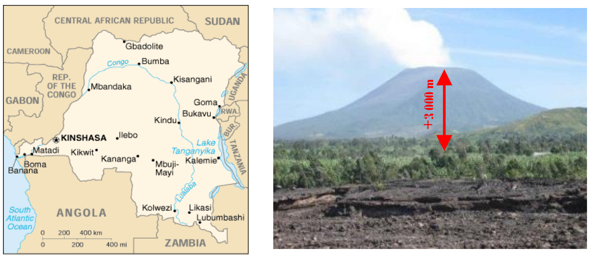

Figure I. **Goma City and Nyiragongo Volcano**

RESULTS AND DISCUSSION

Observation

Monthly averages of daily extrema temperature, difference between maximum and minimum temperature; monthly averages relative humidity,

Table I. Monthly Average Daily Extrema

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2005	T_{max}	28	30.5	27.9	28.5	27.2	26.2	27	29	29.3	28.5	28	28.5
	T_{min}	13.6	14.2	13.9	13.5	14	14	11.7	12.1	13.3	12	13	13.6
	ΔT	14.4	16.3	14	15	13.2	12.2	15.3	16.9	16	16.5	15	14.9
	Hr	66.4	63	69	67.2	70	67	58	62.5	65.3	64.4	61.2	62.1
	Rfl	129.4	93.9	120.7	51	51.1	6.2	1.4	96.3	117.2	76	62.2	56.6
	Pa	846	837.8	846.4	846.4	847.9	847.4	848.2	847	846.5	846.2	845.5	844.6
2006	T_{max}	31	29.5	29.2	27	26.4	27	26.5	27.9	27.4	29.8	26.1	27
	T_{min}	13	13.6	13.1	13.1	13.4	13	12.9	13.5	12.2	13.9	13.5	13.8
	ΔT	18	15.9	16.1	13.9	13	14	13.6	14.4	15.2	15.9	12.6	13.2
	Hr	65.2	67.5	67.5	65.4	69	63.2	64.1	64	57.1	58.2	67.2	68.5
	Rfl	103.8	101.5	113.4	127.3	90.2	15.1	66	158.3	69.3	81.4	153.5	86.95
	Pa	845.2	845.2	846	846	847	847.9	847.9	846.9	846.6	846	846.6	
2007	T_{max}	27.9	30	30	30	28	26.6	26	28	29	27.6	27.4	28
	T_{min}	14.1	14	13.4	13.4	10	10.2	13.5	13.6	14	13.5	13	13.7
	ΔT	13.8	16	16.6	16.6	18	16.4	12.5	14.4	15	14.1	14.4	14.3
	Hr	69.9	69.2	64.6	68.7	67.9	70.8	66.9	61.1	64.6	62.1	66.4	63.2
	Rfl	20.4	63.2	65.6	69.7	43.7	67.8	58	23.6	179.2	126	177	58.3
	Pa	846.7	845.9	845.6	845.8	845.6	847	847	846.3	846.3	845.5	844.9	844.8
2008	T_{max}	28.5	27.5	27	28.8	28.9	26.3	26	26.8	29.4	28	27.8	28.2
	T_{min}	12.5	13.5	13.5	13.9	13.1	13	12.2	13.9	11.6	12.7	14	14
	ΔT	16	14	13.5	14.9	15.8	13.3	13.8	12.9	17.8	15.3	13.8	14.2
	Hr	66.9	69.4	68.7	65.8	63.6	66.9	60.8	67.5	63.4	64.8	63	64.5
	Rfl	105.5	73.8	131.1	31.1	40	163.6	49.5	72.1	154.3	111.2	194.1	120
	Pa	845	845.9	845	844.8	845.9	847.1	847.3	845.8	846.1	845.9	845.2	844.8
2009	T_{max}	27.3	27.2	28.5	28.5	29.6	27.5	28.2	29	29.8	28.8	27.4	
	T_{min}	14.2	14.1	13	13.8	14.3	13.5	11.6	14.6	14.3	13.6	14	
	ΔT	13.1	13.1	15.5	14.7	15.3	14	16.6	14.4	15.5	15.2	13.4	
	Hr	68.4	69.3	67.2	67.2	65.7	68.8	63.8	64.3	64	63.4	64.7	64
	Rfl	91.1	63.5	89.3	71	160.9	27.2	0.1	66.9	76.4	160.1	223.3	135
	Pa	845.6	845	845	846.3	846.3	847.2	847.7	846.1	846.6	845.4	845.3	

Tmax: maximum temperature (0C); Tmin: minimum temperature (0C) ; ΔT = Tmax – Tmin: the difference between the two (0C); Rfl: rainfall (mm); Pa: atmospheric pressure (hPa) rainfall and atmospheric pressure for a period of 5 years are shown in Table I.

It is worth noticing that remarkable values are: Tmax> 29 °C ;Tmin ≤ 12.5 °C and ΔT ≥ 15.5 °C. The warmest months are (Tmax> 29 °C): February and September (2005) January-February - March and October (2006) February-March - April and September (2007), September (2008) May - August and September (2009).

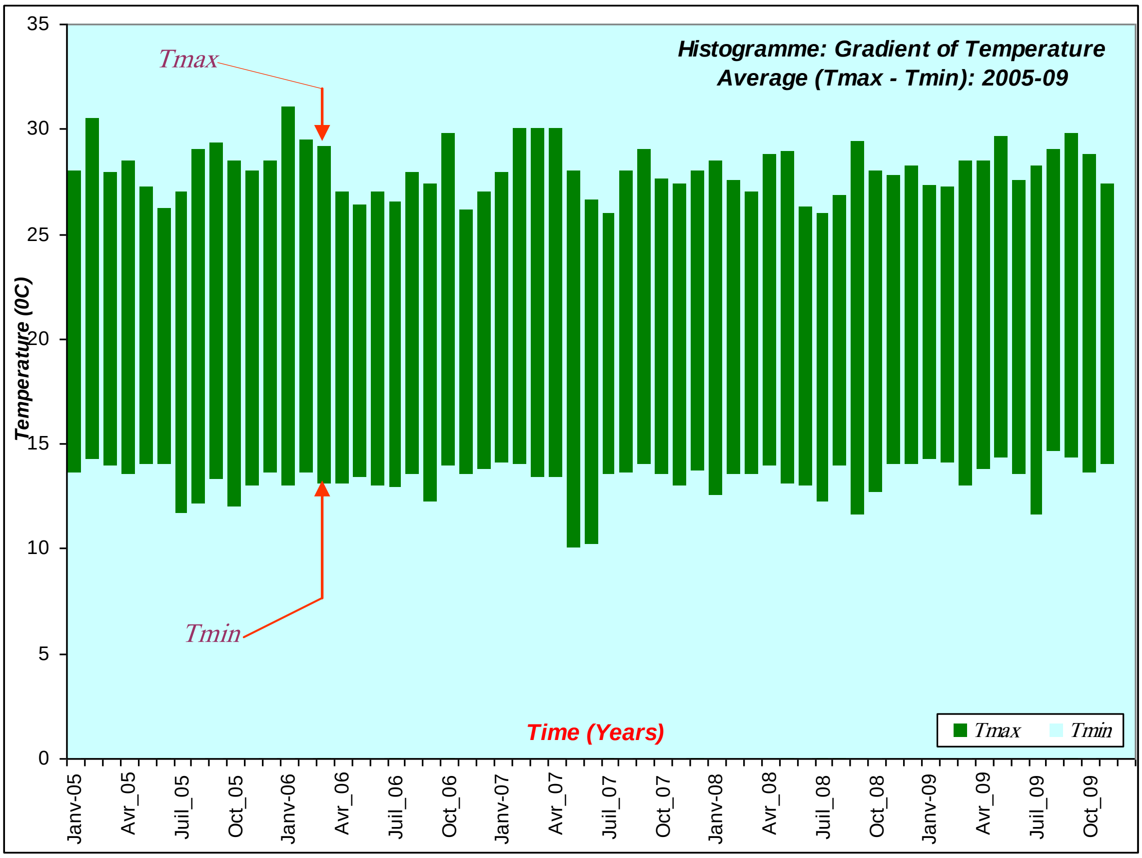

Figure II. ***Histogram of gradient of temperature***

In a day, the temperature gradient (the difference between the maximum temperature (Tmax) and minimum (Tmin)) is quite large (15 ± 2)0C. Left over months or years, this gradient has a certain consistency as shown in the Figure I. This gradient of temperature is remarkable when:

Daily maximum is very high Tmax> 29 °C, as in the case of: February, August, and September 2005; January, February, March and October 2006; February, March, April 2007; September 2008; September 2009.

Minimum nighttime temperature is low (Tmin ≤ 12.5 °C) as in the case of August, October 2005, May, June 2007; January; September 2008; July 2009;

Figure III represent an histogram of the temperature gradient from january 2005 to October 2009. The coldest month (Tmin ≤ 12.5 °C) were July, August and October (2005), September (2006) May, June (2007); January, July, September and October (2008), July (2009).

By plotting relative humidity as a function of temperature, as shown in Figure III, we observe that relative humidity increases with decreasing of the temperature and vice versa but not at any time. These values also depend on the season (dry or rainy).

As shown in Figure IV, the extrema of rainfall do not correspond to extrema of the relative humidity. The greatest rainfall is found in September (2005, 2006) and November (2007, 2008, 2009); while for the same period, the relative humidity is highest in May (2005, 2006), June 2007 and February (2008, 2009). In one year, relative humidity is at maximum several months before the maximum rainfall. This proves that rainfall is not a significant factor influencing the relative humidity. Its increase or decrease does not cause the increase of moisture. The minimum of the two parameters are fluctuating.

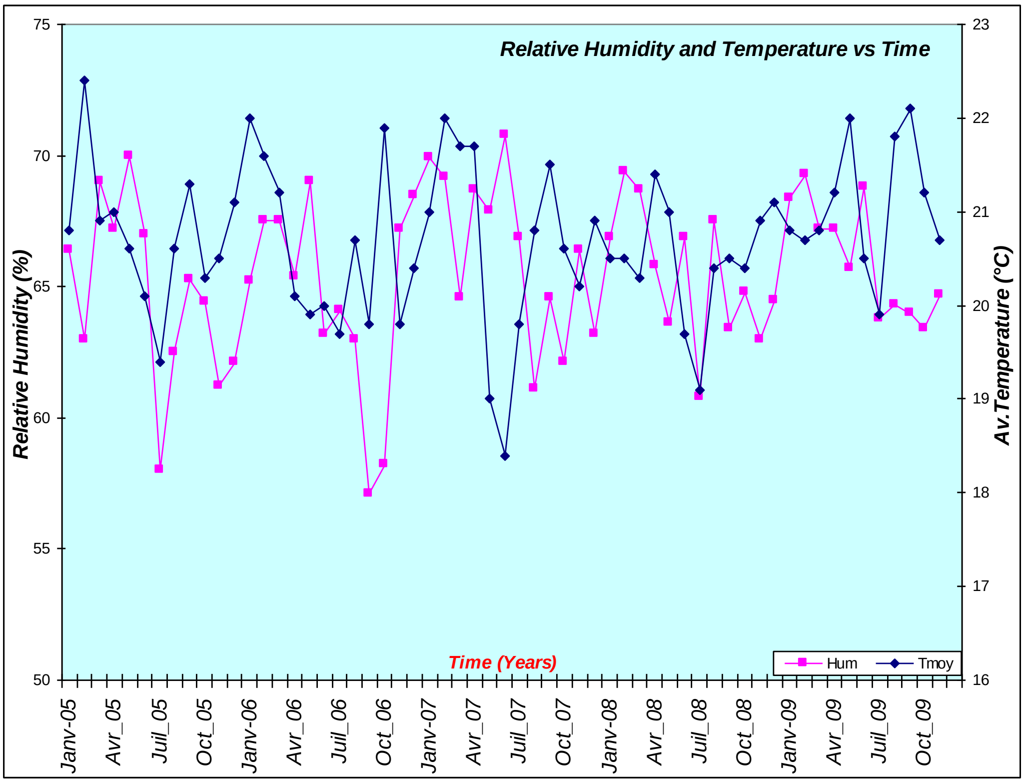

Figure III. **Relative humidity and temperature vs time**

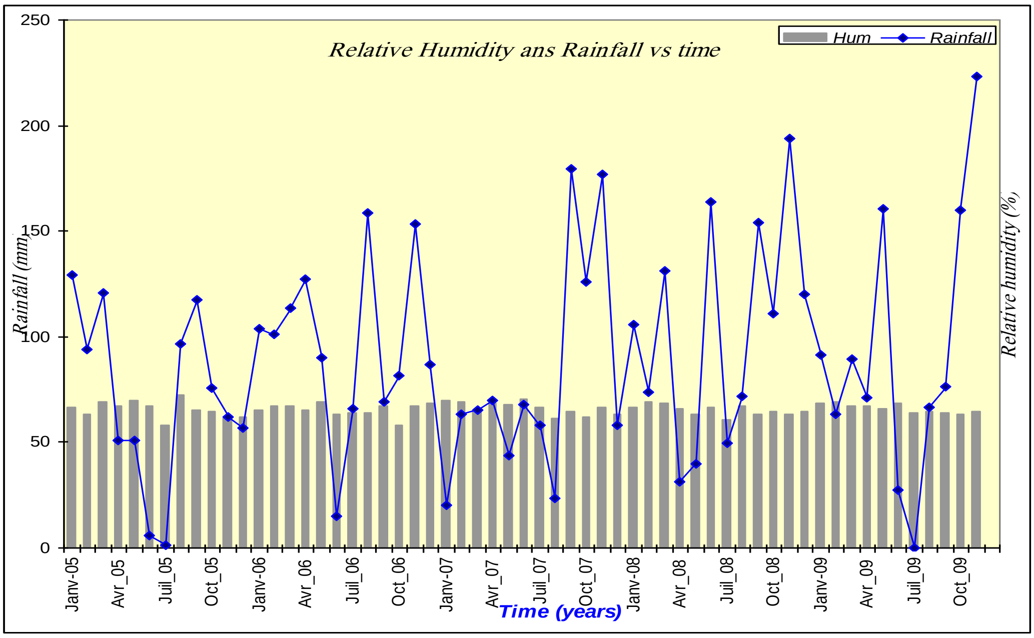

Figure IV. **Relative humidity and Rainfall vs time**

Since data are all quantitative, Principal Component Analysis (ACP) using the software R-2.4.0 and SPAD was used for analysis. The results of the analysis are shown in Table II.

In physics, certain parameters such as pressure, temperature, altitude, relative humidity and rain fall are theoretically dependent on each other [Bradu, 2009]. That dependence called correlation can be positive or negative when the two parameters change in the same or in the opposite direction. Such as relative humidity and temperature, atmospheric pressure and altitude are theoretically correlated negatively while the relative humidity and rainfall are positively correlated.

Table II. Correlation Matrix / R-2.4.0

2005	P_a	T_{max}	T_{min}	Hr	Rfl
Pa	1.000	-0.744	-0.395	0.179	-0.305
T_{max}	-0.744	1.000	0.049	-0.183	0.621
T_{min}	-0.395	0.049	1.000	0.651	0.197
Hr	0.179	-0.183	0.651	1.000	0.296
Rfl	-0.305	0.621	0.197	0.296	1.000

Table II summarizes the different correlations between on one hand relative humidity, temperature, rainfall and pressure, on the other hand, the correlations between rainfall, pressure and temperature.

The relative humidity correlated positively with the minimum night temperature Tmin. If Tmin increases, then Hr increases. The rainfall and maximum daily temperature are also positively correlated. A hot day ends with a shower. This is a way of forecasting time even in our rural towns. In extending this analysis to other years, we obtained data in Table III.

Table III. Correlation Matrix / R-2.4.0

Year	Hr/T_{max}	Hr/T_{min}	Hr/Rfl	Hr/P_a	Rfl/Pr	Rfl/T_{max}	Rfl/T_{min}
2005	- 0.18	**0.65**	0.29	0.18	- 0.30	**0.62**	0.19
2006	- 0.13	0.33	0.39	- 0.13	- 0.43	0.05	0.39
2007	- 0.02	- 0.39	- 0.21	0.41	- 0.33	0.01	0.14
2008	- 0.18	0.40	0.34	- 0.16	- 0.55	0.06	0.33
2009	**- 0.62**	0.15	- 0.28	- 0.23	- 0.58	0.09	0.44

We observe that the relative humidity correlates negatively with daily maximum temperature (T_{max}) and positively with the daily minimum temperature (T_{min}), but these correlations are not significant. The temperature is not a significant factor influencing the relative humidity in Goma.

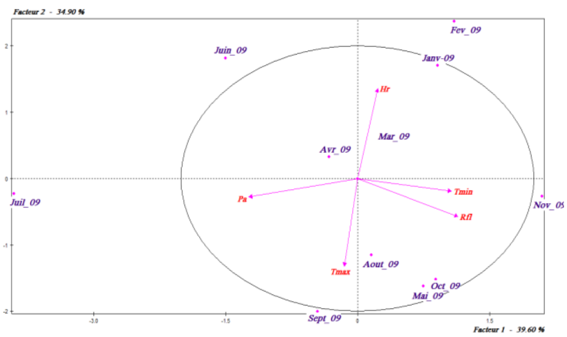

Figure V. **In the factorial design, the months of July and June are identifiable by the atmospheric pressure, November by rainfall and minimum of temperature; September and August by maximum temperature and January, March, by relative humidity.**

For the rainfall, we observe that it is negatively correlated with pressure and positively with the temperature extrema. However, it is sometimes positively correlated with moisture (2005, 2006, 2008), sometimes correlated negatively with moisture (2007, 2009). In both cases, these correlations are not significant. Therefore, as for temperature, rainfall is not a significant factor influencing the relative humidity.

CONCLUSION

This paper shows that both temperature and rainfall are not significant factors influencing the relative humidity in Goma. In the factorial design, June and July are identifiable by a high pressure, November is identified by a large rainfall. The other parameters are random. According to the Volcanic Observatory (OVG) in Goma [CRSN/Lwiro,2009], the region has experienced a major volcanic activity over the past decade. The most notable were in Jan-2002; May-2004; Nov-2006 and Jan-2010. Could these multiple volcanic activities be the basis of a lack of significant correlations between parameters studied? The next work will deal with.

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