NORTH-SOUTH VARIATION OF BIOCLIMATIC PARAMETERS IN ARGENTINA DURING SUMMER MONTHS

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ABSTRACT For the description of the thermal bioclimatic factors the parameters Predicted Mean Vote (PMV) and Physiologically Equivalent Temperature (PET) are well suitable. With the software RayMan we, for the first time, computed daily values for PMV and PET on the basis of the 8 or 24 per day synoptic observations at eight Argentine stations of La Quiaca (24° S) to Ushuaia (55° S) for 12 h, 15 h and 18 h local time for the period 1.1.1996 to 31.12.2005. To ensure comparability the calculations refer to a standard person with given clothing and activity. The investigated bioclimate conditions of a ten year period of PMV and PET for the summer months (December to February) show the variability of thermal comfort conditions at eight locations from north (La Quiaca) to south (Ushuaia) of Argentina. In the histograms, the frequency with which threshold values of PET were exceeded are shown. Clear differences between the locations in terms of bioclimate are also visible. The latter are of particular relevance for the description of climate for tourism as well as other recreational outdoor activities in Argentina.

KEYWORDS: *Argentina, bioclimatic indices, Predicted Mean Vote, Physiologically Equivalent Temperature*

INTRODUCTION

The human biometeorological conditions of a location can not only be described by meteorological parameters like air temperature, air humidity, wind vector and short- and long wave radiation fluxes, but also by thermal indices. These are depending on the meteorological conditions of the thermal environment of humans. Several models and methods exist: a) Predicted Mean Vote (PMV) after Fanger (1972) based on the thermal comfort equation or as a function of the full human energy balance of the human body and the derived PET (Physiologically Equivalent Temperature) (VDI, 1998). Both indices and methods link the meteorological and thermo-physiological conditions and describe the interactions between the human body and the thermal environment (Jendritzky et al., 1990, VDI, 1998).

Argentina has, because of its large north-south expansion a variety of bioclimates. The knowledge of those is not only important for the development of tourism possibilities but also for outdoor activities (Matzarakis et al., 2004). The variability is dominated by the elevation of locations and regional climatological characteristics in the several climate zones: from the higher lying Puna in the subtropics to the Patagonia, the southest area with mild climate in Argentina. Especially, the intensity of sun radiation, air temperature, air humidity and the cloud cover show high variations across the various geographic regions of the country.

Table 1 shows the stations number, the geographical coordinates and the elevation of the used synoptical stations.

Table 1: Code number, name, co-ordinates and elevation of the used stations in Argentina

Code	Synoptic Station	Latitude (°)	Longitude (°)	Height (m) asl
87007	La Quiaca Observatory	-22.10	-65.58	3462
87046	Jujuy Airport	-24.38	-65.09	908
87344	Cordoba Airport	-31.32	-64.22	474
87418	Mendoza / El Plumerillo	-32.82	-68.77	704
87576	Buenos Aires / Ezeiza	-34.82	-58.52	20
87715	Neuquen Airport	-38.95	-68.12	271
87765	San Carlos Bariloche	-41.13	-71.17	840
87938	Ushuaia (Arg Navy)	-54.78	-68.32	14

The geographical location of the eight synoptical stations is shown in Fig. 1.

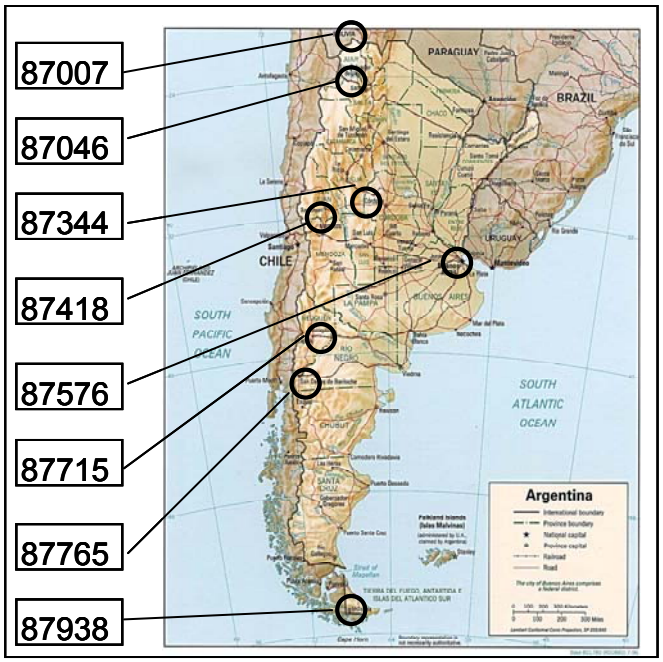

Figure 1: Location of the used synoptical station of Argentina

METHODS

For the calculation of the themal indices PMV and PET we use daily data of 8 and 24 observations resp. obtained from eight synoptical stations (Tab. 1) for the period 1 January 1996 to 31 December 2005. First, only the data of the summer months were processed. In order to use the wind data for thermal bioclimate analysis they were reduced from 10 m height to 2 m over ground, with the potential law based of a profile exponent of 0.20. Additionally, the relative humidity was calculated from air and dew point temperature data.

The calculation of the PMV and PET values was run with the RayMan model (Matzarakis et al., 2007) for the hours 12:00, 15:00 und 18:00 local time and for locations without horizon limitation (no builingds, no higher vegetation). As standard for the thermo-physiological values the standard values of the model were used (height 1,75 m, weight 80 kg, clothing clo=0.9, activity 80 W, position: standing). The calculation of the radiation fluxes was done with an albedo of the surface of α= 0.30 and a Linke turbidity factor between 3.0 and 4.0 (Jendritzky et al., 1990, Matzarakis et al., 2000, 2007).

The classification of the PMV and PET values based on grades of physiological stress was done according to the classification of Matzarakis and Mayer (1996).

RESULTS

The 10-year mean meteorological summer conditions (air temperature, relative humidity and cloud cover) are examined and discussed for 15:00 h local time (Tab. 2). The mean air temperature at the Mendoza station is the highest with 29.0 °C and also the absolute maximum with 43.0 °C is obtained here. The mean temperature of 11.5 °C and also the absolute minimum of 2.8 °C obtained at the station Ushuaia are the lowest. Remarkably low values of relative humidity are obtained at the station La Quiaca in 3462 m elevation and at the station Bariloche (840 m) with 2 %.and 5 % resp. In average the station Neuquen has the lowest values with 25.1 %, the station Ushuaia the highest with 62.9 %.

Table 2: Mean and extreme values of air temperature T (°C), relative humidity RH (%) and mean cloud cover C (octa) for 15:00 local time for the summer months (December, January, February) for the 1996 – 2005 period for eight station in Argentina

	87007	87046	87344	87418	87576	87715	87765	87938
	La Quiaca	Jujuy	Cordoba	Mendoza	Bue. Aires	Neuquen	Bariloche	Ushuaia
T Min	8.2	14.2	11.2	9.9	13.8	9.1	6.8	2.8
Max	26.4	39.8	39.5	43.0	39.4	37.6	32.8	27.4
Mean	19.0	25.8	27.1	29.0	27.6	28.1	20.4	11.5
RH Min	2	16	16	7	11	6	5	26
Max	90	96	100	95	100	97	94	100
Mean	46.9	51.6	54.4	36.3	48.2	25.1	33.2	62.9
C	5.1	4.8	4.1	3.4	3.8	3.1	3.4	5.9
N Obs.	855	901	872	903	903	899	903	902

The mean cloud cover is relatively high with a value of 5.1 octa because of the southern position of the inner tropical convergence zone in La Quiaca. The maximum of 5.9 octa in Ushuaia shows that the weather is dominated by cyclonal conditions in the area of the Drake Street. Under the influence of anti-cyclonic dominated weather conditions and the influence of the Andes on the stream patterns, the mean cloud cover of the other station lie between 4.1 octa and 3.1 octa, except for Jujuy.

As mentioned before, the Physiologically Equivalent Temperature PET differs from the measured air temperature (Tab. 3). PET reaches a maximum of 51.4 °C at the Mendoza station. 25 % of the values are above 39.0 °C. At most stations the mean PET is higher than the air temperature T (in Jujuy PET: 35.2 °C, T: 25.8 °C). Only in Bariloche and Ushuaia the mean value of PET is lower than the air temperature T.

Examining the values of PET at other observation times, 12:00 local time and 18:00 local time, reveals that a daily pattern exists (Tab. 3). For 12:00 local time at Station Jujuy the highest mean with 33.0 °C are obtained and also with 37.0 °C the highest third quartile. The mean PET in Mendoza is with 33.7 °C remarkably high for 18:00 local time, it is higher than for all other stations.

The means, extremes and also the first and third quartiles of PMV for all three observations are summarized in Tab. 3. For 15:00 local time the thermal bioclimate situation is (Tab. 2) dominated by moderate heat stress, with Bariloche (no thermal stress) and Ushuaia (moderate cold stress) being the only exceptions. Extreme heat stress occurs at the stations Jujuy and Mendoza. For the latter station a maximum of 5.2 is calculated (18:00 local time).

The histograms for the daily values of PMV and PET for 15:00 local time show the regional differences in the relative frequencies in the classes, which correspond to the above described characteristics of the regions (Fig. 2).

Table 3: Mean, Extremes und Quartiles of PMV and PET for 12:00, 15:00 und 18:00 local time in the summer months (December, January, February) for the period 1996 – 2005 for eight stations in Argentina

Local Time		87007		87046		87344		87418		87576		87715		87765		87938	
		PMV	PET	PMV	PET	PMV	PET	PMV	PET	PMV	PET	PMV	PET	PMV	PET	PMV	PET
12:00	Min	-2.8	7.9	-1.6	12.7	-1.6	12.5	-2.4	10.4	-1.7	12.6	-1.8	12.7	-4.0	3.4	-6.1	-6.2
	Max	3.3	40.8	4.4	46.1	4.4	45.3	3.8	42.2	4.4	45.6	4.6	47.9	3.2	40.4	0.9	27.4
	Mean	-0.3	21.0	2.1	33.0	1.6	29.9	1.7	30.9	1.7	30.6	1.3	29.1	-0.8	17.7	-2.5	9.7
	Q25	-0.8	18.0	1.6	30.0	0.9	25.9	1.2	28.0	1.0	26.7	0.6	25.0	-1.8	12.4	-3.4	5.6
	Q75	0.2	24.0	2.8	37.0	2.4	34.3	2.3	34.6	2.5	35.3	2.1	33.6	0.1	21.7	-1.7	13.7
15:00	Min	-2.8	8.3	-1.3	13.5	-2.6	8.8	-2.1	12.1	-2.1	10.5	-2.8	7.7	-3.9	3.6	-5.1	-2.0
	Max	2.5	37.2	4.8	48.1	4.6	46.8	5.3	51.4	4.8	47.8	4.5	47.2	4.0	45.0	1.6	30.2
	Mean	0.2	23.0	2.5	35.2	1.9	31.7	2.4	35.1	2.1	32.8	2.1	33.2	-0.3	19.7	-2.4	10.3
	Q25	0.3	19.9	2.0	32.0	1.3	28.1	1.9	31.9	1.4	28.9	1.4	29.1	-1.4	14.0	-3.3	6.0
	Q75	0.7	26.4	3.2	39.1	2.7	35.5	3.2	39.0	2.9	37.1	2.9	38.1	0.7	24.4	-1.5	14.4
18:00	Min	-3.4	6.2	-2.2	10.2	-2.5	9.0	-1.9	10.9	-2.5	8.2	-2.8	7.4	-4.6	0.3	-5.4	-3.0
	Max	1.3	28.1	4.1	43.5	4.0	42.4	5.2	50.2	4.1	43.4	4.3	45.3	2.9	38.5	1.3	29.0
	Mean	-0.2	17.8	1.6	29.3	1.4	27.8	2.3	33.7	1.3	27.4	1.9	31.5	-0.7	17.4	-2.9	7.6
	Q25	-1.2	15.0	1.0	25.7	0.8	24.1	1.7	30.5	0.7	23.6	1.2	27.0	-1.9	11.7	-3.7	4.0
	Q75	-0.1	20.5	2.3	33.2	2.1	31.9	3.1	38.0	2.0	31.5	2.8	36.7	0.4	21.8	-2.1	10.8

Legend: PMV Predicted Mean Vote
PET Physiologically Equivalent Temperature, °C
Q25 First Quartile
Q75 Third Quartile

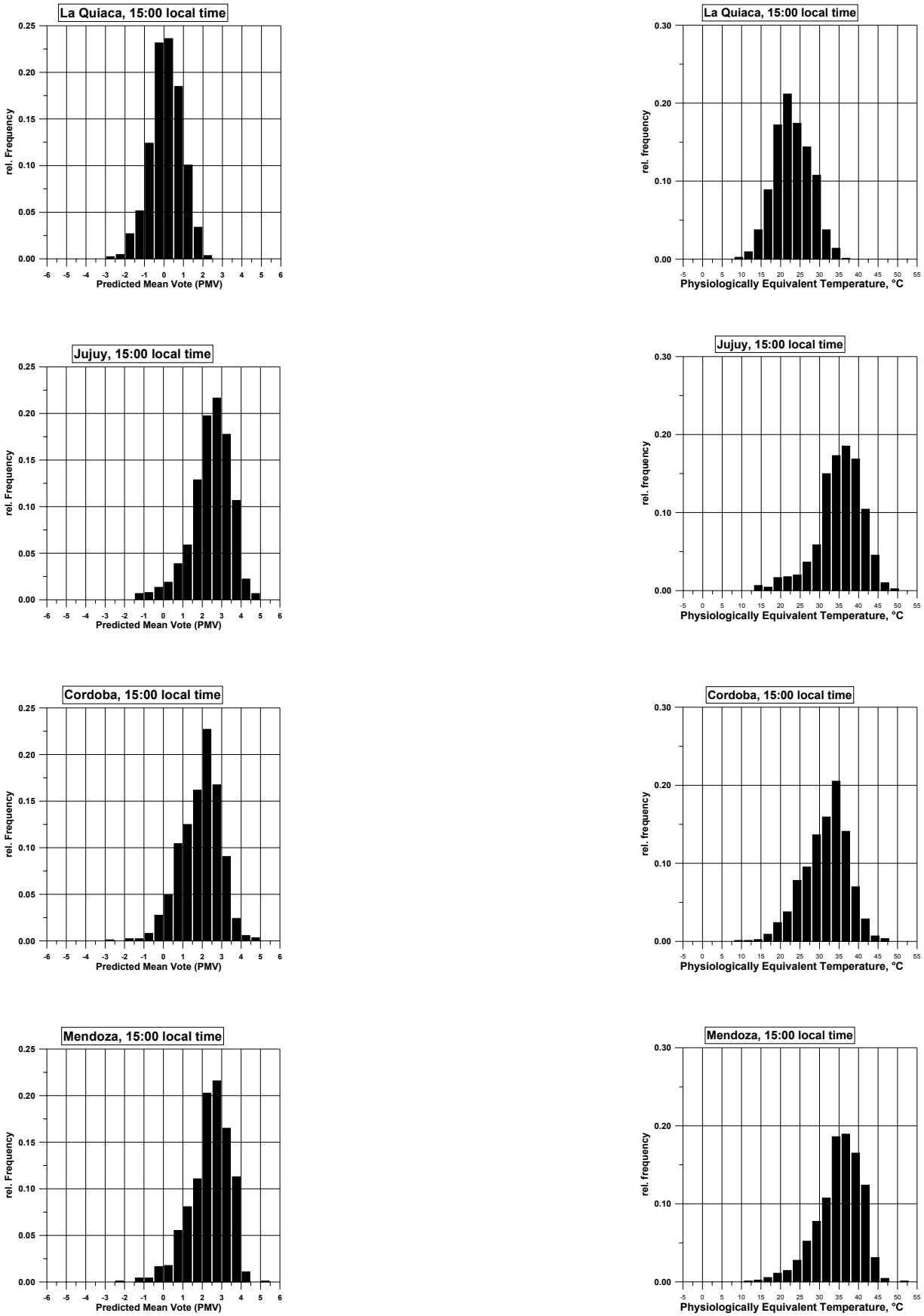

Figure 2: Histograms of PMV (left) and PET (right) for 15:00 local in the summer months for the 1996 – 2005 period

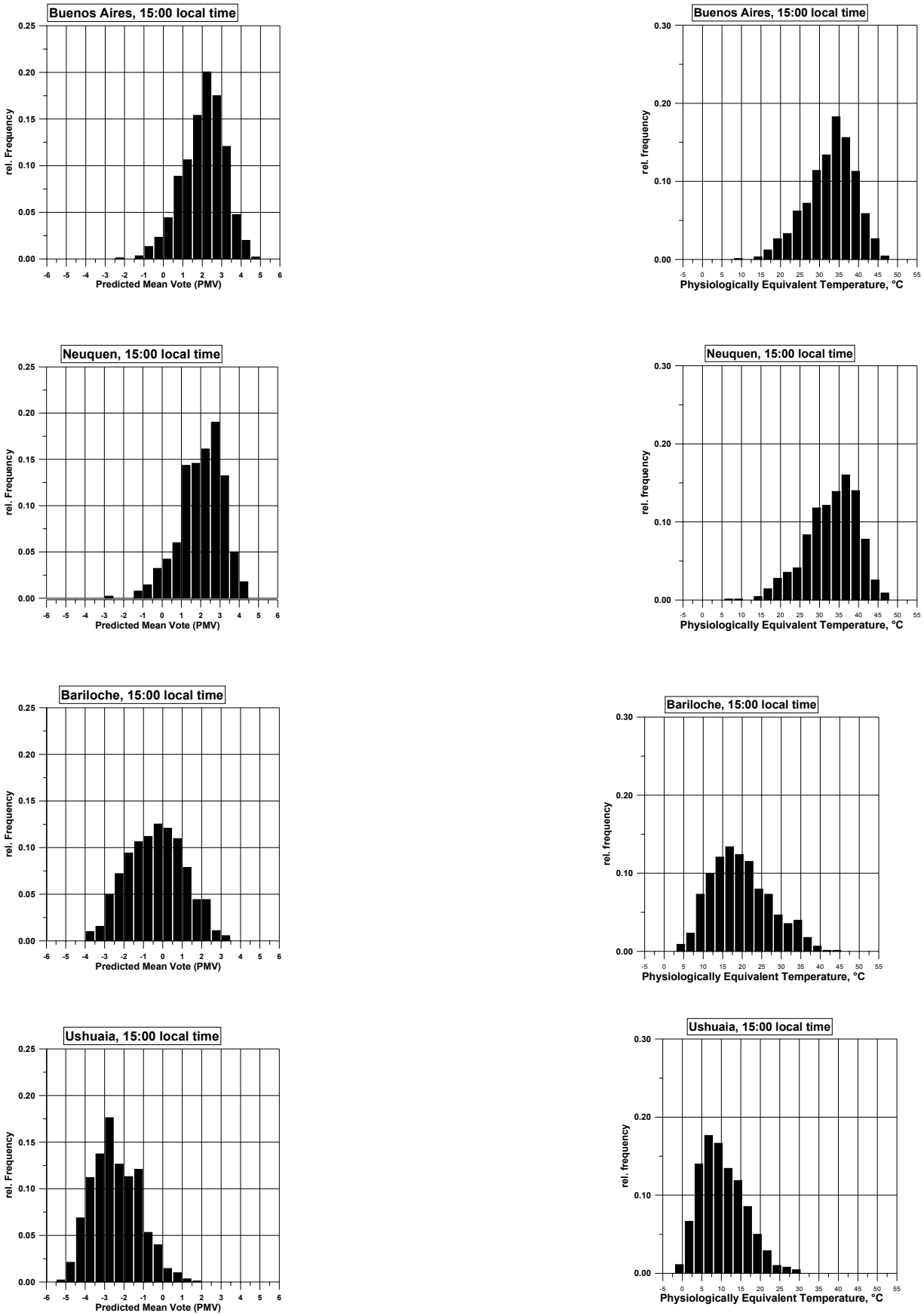

Figure 2 (continued): Histograms of PMV (left) and PET (right) for 15:00 local in the summer months for the 1996 – 2005 period

DISCUSSION AND CONCLUSION

The thermal bioclimatic conditions in Argentina are described here for first time based on the thermal indices Predicted Mean Vote and Physiologically Equivalent Temperature. Based on different synoptical time observations and stations of Servicio Meteorologico Nacional the calculation was performed using the RayMan model. Here the calculations were carried out for rural environments.

With the results obtained here a more adequate thermal bioclimatic assessment of individual locations can be carried out, compared to the primary or simple meteorological parameters used previously.

In addition, the analysis will be extended to more stations and other regions of Argentina. The calculations will be also performed for urban areas and forests.

Nevertheless, the analysis presented here represents the first step towards an integral analysis of the climatic tourism potential for a country with a very high variety of bioclimate in a north to south transect and elevation.

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