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SEASONAL VARIATIONS OF LATENT AND SENSIBLE HEAT FLUX TENDENCY IN SOUTH OF BRAZIL

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1. INTRODUCTION

The tendency of sensible heat and latent heat fluxes will be evaluated by analysis of temperature and specific humidity data measured in three cities of Rio Grande do Sul state, in the southern region of Brazil. The turbulent fluxes of latent heat (heat exchanged because of evaporation) and sensible heat (heat exchanged due to temperature gradients) are complex processes. They are also important in the thermal balance of atmosphere, specially near the surface. Therefore, the proposed analysis will provide better understanding of the energy balance and its seasonal variations in this region.

Interactions between atmosphere and land surface has been a central issue in atmospheric studies for some time due to the importance of their contributions to climate changes, specially those changes that might be consequence of human activities. Therefore, the study of energy exchanges within the atmosphere in this region might indicate the effects of human activities and resulting local climate changes. The identification of characteristic seasonal patterns can be accomplished analyzing the flux behavior. In spring, the surface fluxs produces little, but measurable answers in the temperature and humidity. For high and mid-latitudes, seasonal changes are associated to significant variation of the vegetal coverage and those can affect local climate (Fitzjarrald, 2001).

The tendency of sensible heat and latent heat fluxes will be estimate from temperature and specific humidity data in order to evaluate the characteristical patterns of the seasons. The differences of the fluxes at the three locations will also be presented.

2. METHODOLOGY

Meteorological data from Rio Grande, Porto Alegre and Santa Maria was selected. The location of the three places can be observed in Figure 1. Rio Grande is the one that differ the most in latitude, longitude and altitude, and the only one where coastal conditions influence climate. Located in the southern plain area of Rio Grande do Sul, its latitude is 32º 04’ 40” S, its longitude is 52º 05’ 40” W and it is 4 meters above sea level. The region is in a recent sedimentary basin (Calixto, 2005). Its climate is characterized by a even distribution of precipitation during the year, and it is influenced by the permanent Atlantic anticyclone, which generates predominating winds from northeast, and by the moving polar cyclones and anticyclone.

Santa Maria city is located in the central region of the state, and therefore it is not influenced by marine effects. It has a latitude of 29º 40’ 54” S and longitude of 58º 48’ 24” W, and it is 113 meters above sea level. It is strongly influenced by valley and mountain breezes, due to a mountain chain to the north of the city.

Porto Alegre is located at 32º 02’ 00” S and 51º 13’ 00” W, with a mean altitude is about 10 meters, but it is also surrounded by a low chain of mountain to the north and northeast. The Guaiba River runs along most of the city, and contributes with some humidity.

The data selected was maximum daily temperature and relative humidity. For Santa Maria and Porto Alegre stations the data was collected between 1994 and 2003, and for Rio Grande, from 1990 to 2005. Possible gaps in the time series were corrected using standard rules. When there was no information to fulfill the gap, linear interpolation was applied.

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Figure 1 – Map of area under study, where Santa Maria is located at 29°40'54"S, 58°48'24"W, Porto Alegre at 30°02'00"S, 51°13'00"W and Rio Grande at 32°01'40"S, 52°05'40"W.

The energy balance equation expressed in vertical flux terms, in the accordance with the model considered by Tanner (1960), can be written as :

$$SR_T + G + LE + H + P \cong 0 \qquad (1)$$

where SR_T is the total radiation balance available at the surface; G is the soil heat flux; LE is the convective latent heat flux; H is the sensible heat flux, and P is the energy spent in the photosynthetic process.

The methodology used to obtain the flux tendencies is the same as in Fuentes e Acevedo (2003). The equations for mean temperature and humidity variations (Stull,1988) can be rewritten, neglecting the diabatic heating contributions, and supposing horizontal homogeneity, obtaining :

$$\frac{\partial \bar{\theta}}{\partial t} = ADV_\theta - \frac{\partial \overline{\omega'\theta'}}{\partial z} - \frac{\partial R_n}{\partial z} \qquad (2)$$

$$\frac{\partial \bar{q}}{\partial t} = ADV_q - \frac{\partial \overline{\omega' q'}}{\partial z} \qquad (3)$$

where $\bar{\theta}$ is the average temperature, $\bar{q}$ is the specific humidity, $\overline{\omega' q'}$ is the vertical sensible heat transport, and $\overline{w'\theta'}$ is the vertical latent heat transport.

For long term series, the advection and radiation terms can be neglected (Silva, 2002), and the equations are written as:

$$\frac{\partial \bar{\theta}}{\partial t} = -\frac{\partial \overline{\omega'\theta'}}{\partial z} \qquad (4)$$

$$\frac{\partial \bar{q}}{\partial t} = -\frac{\partial \overline{\omega' q'}}{\partial z} \qquad (5)$$

These equations may be integrated over the boundary layer, from the surface to the height h, considering that the transports in the top tend to zero:

$$(\overline{\omega'\theta'})_0 = \int_0^h \frac{\partial \bar{\theta}}{\partial t} dz \qquad (6)$$

$$(\overline{\omega' q'})_0 = \int_0^h \frac{\partial \bar{q}}{\partial t} dz \qquad (7)$$

In the average, long series of temperature and humidity temporal variations tend to vary little over the whole layer.

Furthermore, the cinematic fluxes of latent (Q_L) and sensible heat (Q_s) may be defined as:

$$Q_S = -\overline{w'\theta'} = Hs / \rho C_P \qquad (8)$$

$$Q_L = -\overline{w' q'} = LE / \rho L \qquad (9)$$

where Hs is the sensible heat flux, ρ is the air density, C_p is the specific heat, and LE is the latent heat flux, and L is the latent heat of evaporation.

From equations (6) and (7), and (8) and (9), the tendency of heat fluxes may be analogously defined as:

$$Hs' = \rho Cp\, \partial\theta / \partial t \qquad (10)$$

$$LE' = \rho\, L \partial q / \partial t \qquad (11)$$

Bowen (1926) related the sensible (H) and latent (LE) heat fluxes, according to the equations below. This expression is known as Bowen ratio, which is widely used in the estimates of evapotranspiration (Fitzjarrald, 2001).

The same concept may be applied in the present work. The adapted Bowen ratio is defined as:

$$\beta' = LE' / Hs' \qquad (13)$$

where LE' and Hs' as in (10) and (11).

3. RESULTS

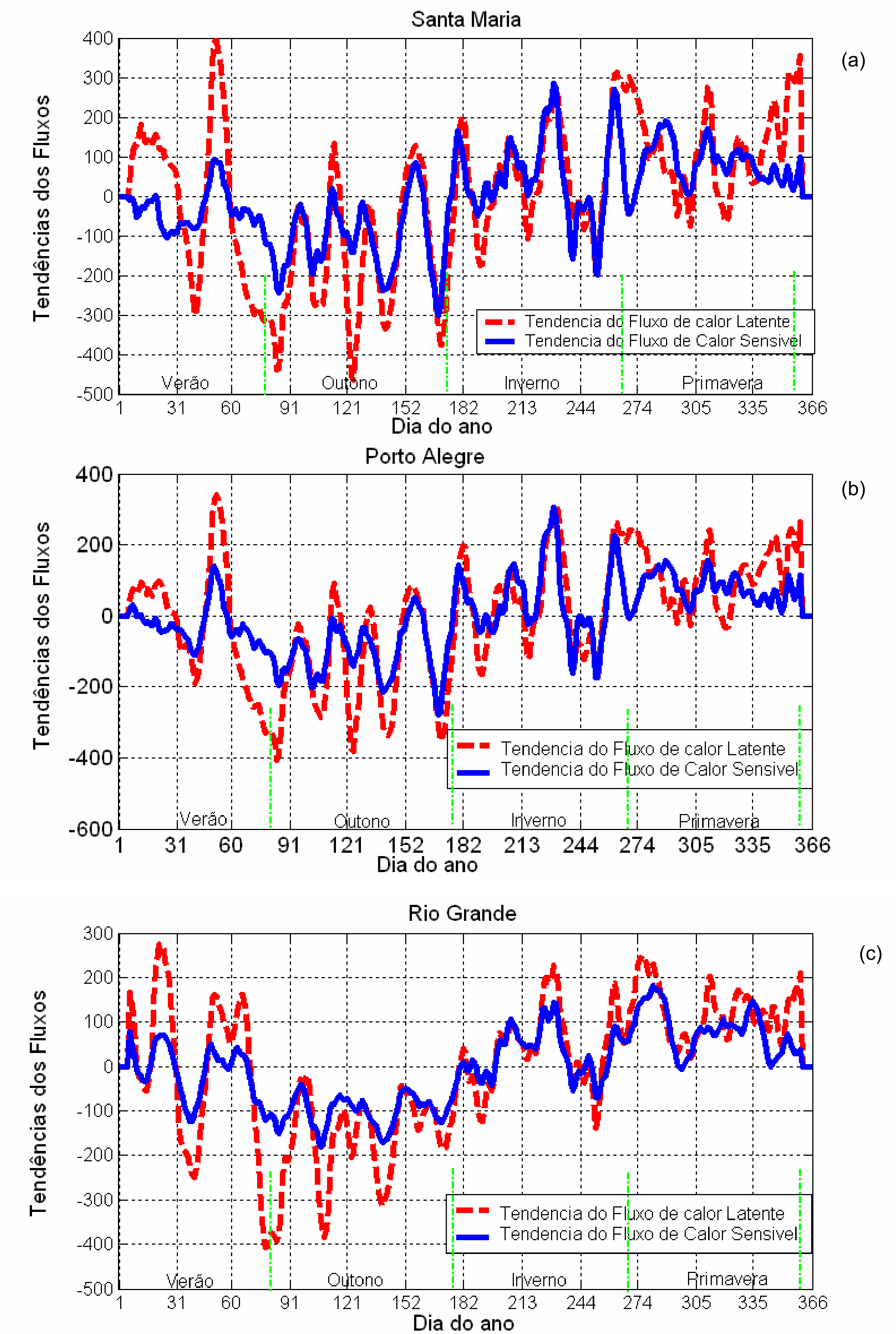

Figure 2 – Tendency of sensible heat and latent heat fluxes for (a) Santa Maria, (b) Porto Alegre, and (c) Rio Grande

The three locations presented the largest values of latent heat flux tendency in summer, except for February first weeks. That It can be noticed strongly in Santa Maria. In autumn, the sensible heat flux tendency predominate over the latent heat one. In Rio Grande, the latent heat flux tendency is always smaller than in the other places. This predominance shows the heat used by evaporation in the autumn was smaller than in the summer. In winter, sensible and latent heat flux are similar, with a little predominance of latent heat flux tendency in all stations.

There is a clear delay on the patterns for the beginning of the seasons, in relation to the astronomic values for the three places. Rio Grande shows, however, delays that are different from the other cities. It also has a less even distribution of energy, and the smaller absolute values of sensible and latent heat flux tendencies, while Santa Maria have the largest values.

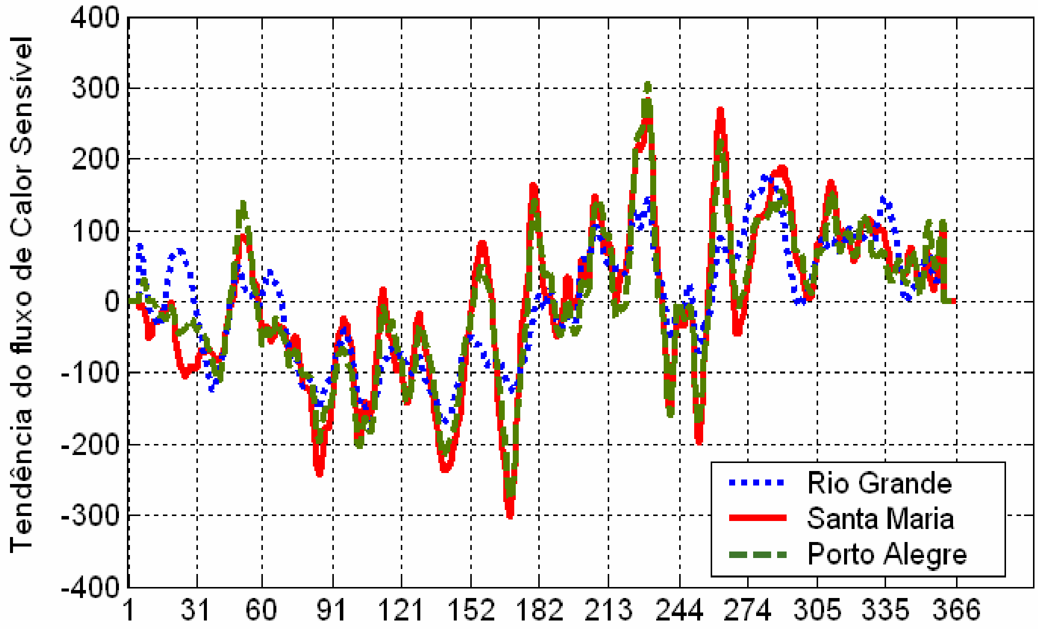

Figure 3 – Comparison of sensible heat flux tendency for the three places.

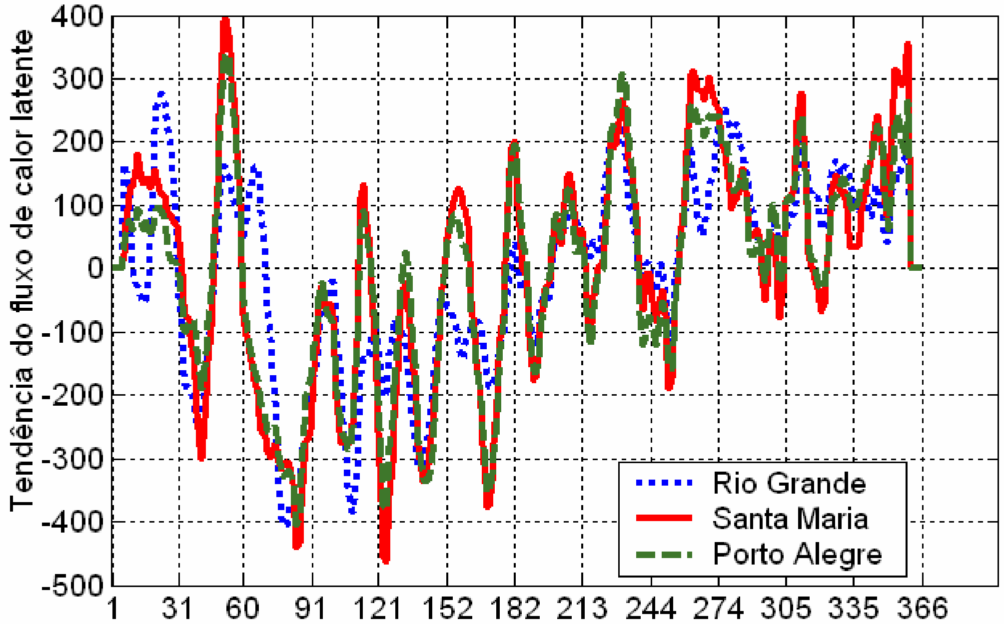

Figure 4 – Comparison of latent heat flux tendency for the three places.

Table 1 - Day of the beginning of the seasons, according to astronomical values and to the evaluation of the conditions presented in the last row, for the three locations.The conditions also represent the partition of energy.

	Summer	**Autumn**	**Winter**	**Spring**
Astronomical	March, 20 th	June, 20 th	September, 22 nd	December, 20 th
Rio Grande	March, 11 th	June, 16 th	September, 10 th	Not detected
Porto Alegre	March, 1 st	June, 12 th	September, 16 th	December, 15 th
Santa Maria	March, 1 st	June, 16 th	September, 16 th	Not detected
Conditions	**LE' > H'**	**LE' < H'**	**LE' ~ H'**	**LE' > H**

A comparison between the day of the beginning of the seasons and its astronomical values is presented in table 1.

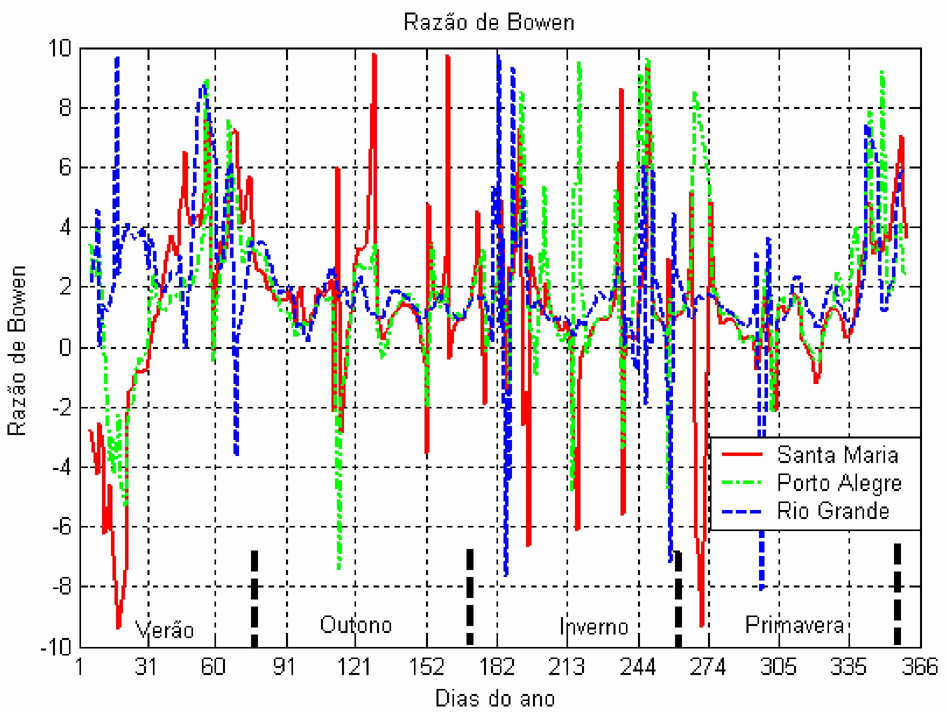

Figure 5 - Comparison of Adapted Bowen ratio for the three places.

The partition of energy, evaluated by the adapted Bowen ratio, may be observed in figure 5. There is a predominance of latent heat flux during the autumn and the winter, while in the spring and the summer the sensible heat flux is predominant. The energy partition is more uniformly distribute in Santa Maria and Porto Alegre than in Rio Grande, where there is a latent heat flux tendency predominance. The negative values of sensible heat flux that are predominant in autumn and in summer (February) indicate heat lost, since the soil is warmer than the atmosphere in that period (Shen, 2004). In Rio Grande, the sensible heat fluxes always are negative at this time of the year.

4. CONCLUSION

The results for Rio Grande can be attributed to the climate differences because of its coastal localization, as well as because of the latitude difference from Porto Alegre, which is warmer, and Santa Maria, which is warmer and dryer.

Although the series were not as long as recommended, they were suitable to evaluate the sensible and latent heat flux tendencies and to demonstrate differences between the places analyzed.

To further pursue the questions contained in this study, we intend to utilize longer time series which cover a larger area of this region.

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