Andes, menor/menor ao cruza-lo e menor/maior bem depois de cruza-lo no período que ocorre a intensificação do ciclone próximo à superfície. Durante esta evolução, o ar estratosférico atinge a média troposfera nos dias 05 e 06/03/1987 (figuras 4 e 5).

4 Considerações Finais

As anomalias negativas de VPI nas superfícies isentrópicas se formam a partir de intrusões de ar estratosférico proveniente de um "reservatório principal" localizado em latitudes altas. Neste estudo de caso, essas anomalias estavam associadas a presença de ventos fortes na alta troposfera sobre as regiões onde ocorreu instabilidade. Neste contexto, a tropopausa abaixou consideravelmente e ocorreu ciclogênese nos baixos níveis. Esses resultados sugerem que no sul do nosso continente, os vórtices ciclônicos de altos níveis podem atuar como um mecânismo de trocas de ar estratosférico e troposférico.

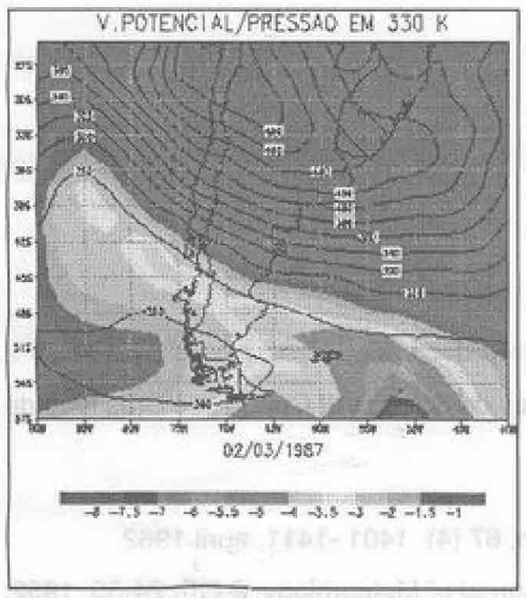

Fig. 1- Campo de Vorticidade Potencial, para o dia 02 de março de 1987, na superfície isentrópica de 330 K.

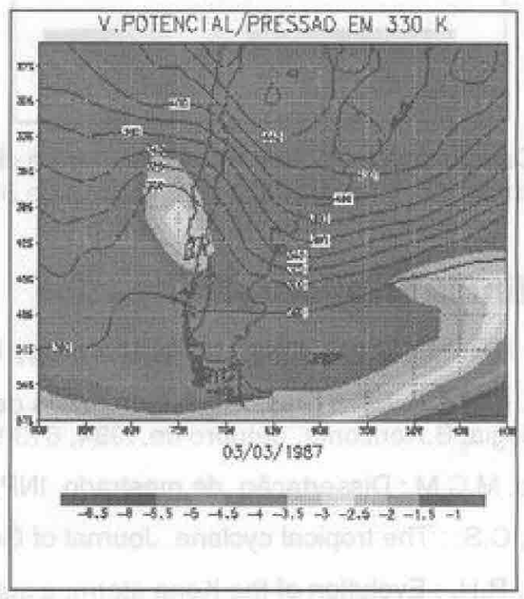

Fig.2- Campo de Vorticidade Potencial, para o dia 03 de março de 1987, na superfície isentrópica de 330 K.

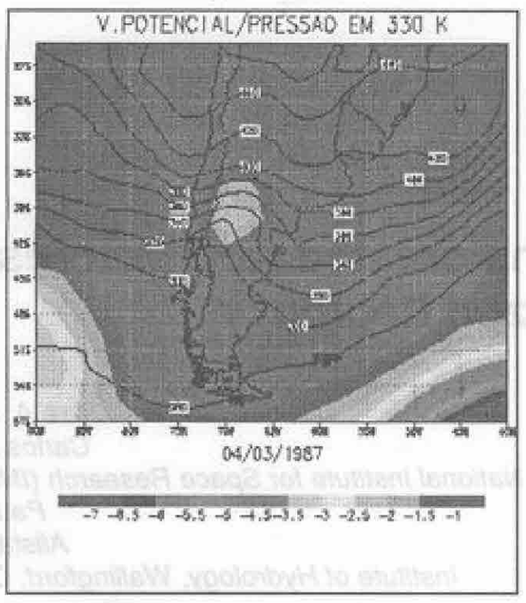

Fig.3- Campo de Vorticidade Potencial, para o dia 04 de março de 1987, na superfície isentrópica de 330 K.

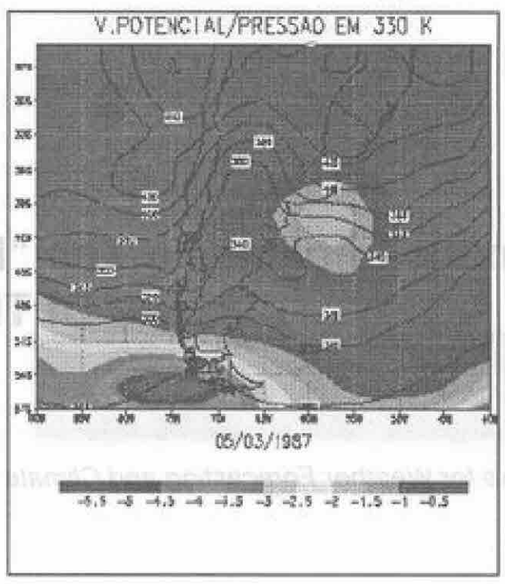

Fig.4- Campo de Vorticidade Potencial, para o dia 05 de março de 1987, na superfície isentrópica de 330 K.

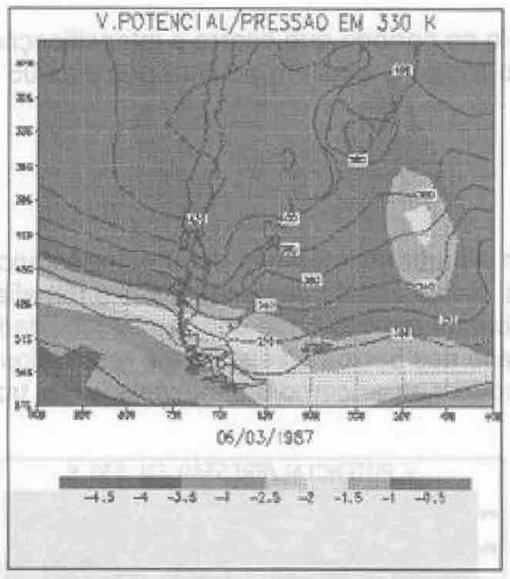

Fig.5- Campo de Vorticidade Potencial, para o dia 06 de março de 1987, na superfície isentrópica de 330 K.

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Climatic Impacts Of The "Friagens" In Forested And Deforested Areas Of The The Amazon Region

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Abstract

Observations from the ABRACOS experiment are used to study the spatial extent and intensity of the cold surges (friagem) of 26 June 1994. This has been characterized as very strong and has produced freezing conditions and extensive damage to the coffee grown in southeastern Brazil. Minimum temperatures in southern Amazonia (Ji-Paraná) dropped almost 15 °C in less than 24 hours. Central and in less degree western Amazonia (Manaus and Marabá sites, respectively), also show the temperature and moisture decreasing during the days with friagem. Based on our analysis, it seems that atmospheric conditions in Manaus and Maraba were favorable for radiative cooling, while in Ji-Parana and in southeastern Brazil the occurrence of minima temperatures with clear skies and strong winds is an indication of strong advection of cold air from the south.

1 Introduction

Early work by Serra and Ratisbona (1942) describe the friagens as strong thrusts of cold air from the south that manage to penetrate into the tropics and affect Amazônia. Later on, several papers have studied weather conditions and

predecessors of these events, with emphasis on their synoptic features, dynamic aspects and forecast (see reviews in Marengo et al. 1996a, 1996b), or on their impact on the weather conditions in the Amazon region (Fisch 1996, Brinkmann et al. 1971; Brinkmann and Goes-Ribeiro 1971) of the impact of these cold waves in the Amazon region or the degree of coolness they produce inside the forests.

Before 1990-91 there was only limited weather information available in the Amazon region at sufficiently high resolution in space and time to make a systematic study of temperature and humidity associated with the cold wave, especially in the tropical forest vegetation's microclimate. After that, data from the Anglo-BRazilian Amazonian Climate Observation Study (ABRACOS, Gash et al. 1996) at sites across Amazonia can be used to describe the advance of the cold surges in the Amazon region, and to assess the extension of the friagens over the forest. Temperature, humidity, wind, precipitation, radiation balance, as well as evaporation and soil moisture have been measured from 1991 to 1994 in three sites, representative of central, eastern and western Amazônia. The measurements in cleared and unperturbed environments also demonstrate the effect of the forest itself in regulating the thermal and moisture regimes in the lower-atmosphere, and provide a unique opportunity in comparing climate conditions from forests and regions recently affected by deforestation. From the three pairs of climatological sites, in the forested areas automatic weather stations were mounted on a top of towers between 45 and 52 meters, with continue undisturbed forest in the surroundings.

In the present investigation, data from the three ABRACOS sites have been used in describing the weather characteristics of the friagem of 26 June 1994 (Marengo et al. 1996b). We intend to provide a detailed pattern of the cold wave in cleared and forested regions in central, eastern and western Amazônia, complemented by studies of atmospheric moisture, wind and precipitation. Satellite imagery is used to document this case.

2 Description of the ABRACOS sites

The tree sites were implemented at: Manaus, in the state of Amazonas, in central Amazônia with rainfall maximum around March-April and the minimum from July-September; Marabá, in Pará, near to the edge of what is known as forest (Gash et al. 1996) and a pronounced dry season in July-September; and Ji-Paraná, in Rondônia, where the southern border of the tropical rain forests is located and with a pronounced dry season. Culf et al. (1996) indicate that there is a little seasonal variation of temperature at Manaus and Marabá, but there is a pronounced cooling during the dry season at Ji-Paraná. Both Marabá and Ji-Paraná have a marked seasonal cycle of humidity which is not observed in Manaus. Diurnal temperature range is larger for grass than over forests, and larger in the southern and eastern sides of the Amazon than in the central.

3 Meteorological Regional Situation During the Friagem of June 1994

The signature of the passage of the cold front is found in the time series of dew point, sea level pressure, air temperature and wind (Marengo et al. 1996a), with a larger contrast over southern Brazil than in Amazonia. Normally in Amazonia the air is very humid with a high dew point, even under clear skies at night therefore the temperature can not fall below the dew point limiting the minimum temperature somewhat. This was observed at the Reserva Jaru (Ji-Paraná) where mist often forms at night (Culf et al. 1996). During the friagens the air is much drier and with the lower dew point will be able to cool more at night than the "normal air". The amplitude of these changes indicate the degree of intensity of the phenomenon. The dew point and pressure curves show opposite trends during the friagens. The fall of the dew point temperature is fast, taking only 24 to 48 hours whereas the return to normal is slow taking more than 96 hours.

The surface weather conditions during 26 June , the coldest days in southern Brazil and southern-western Amazônia are described by Marengo et al. (1996a). On the third week of June, the atmospheric flow over the South Pacific and the southwest-northeast orientation of the subtropical jet over the continent favored the movement of frontal systems and anticyclones into lower latitudes. During 23 June, an intense cold air mass entered the southern part of Brazil. The surface chart of the 12 Z 26 June, the coldest day in southern Brazil and Amazonia. The high pressure center, with an intensity of 1026 hPa was located around 25 ^{o}S, 55 ^{o}W, and extending over most of Brazil between 15-30 ^{o}S, as well as over western Amazonia along the Andes as far as 5 ^{o}S. It also shows the development of an intense cyclonic circulation at 52 ^{o}S and 47 ^{o}W and the interaction of this strong cyclone with the anticyclone over southern Brazil seems to produce the strong wind flow from the south detected all the way from south of 60 ^{o}S along the coast of Argentina, and reaching Uruguay and southern Brazil. It is observed that the cold air took approximately 72 hours to reach southern Brazil after crossing the Andes at approximately 30-35 ^{o}S. From the quasi-geostrophic analysis, the cold front initially detected over the coast of southern Argentina may be partially due to the Andes influence producing a low level trough when the intense westerlies cross the Andes. Sea level pressure drops took place below the area where the westerlies were most intense. 26 June also exhibits the largest pressure lee drop. Vorticity and thermal advection play their roles in moving the transient anticyclone, and during these events the powerful upper-level vorticity advection dominates over the thermal advection with the result that the cold front moves to places where the negative vorticity advection gets the largest values.

4 Weather Conditions During the Friagem Of 26 June in the Pasture and Forested Areas

Figs. 1 and 2 show the air temperature, humidity, precipitation and wind for the period June 23-30 1996, for Ji-Paraná ans Manaus. Weather conditions for the deforested (pasture) and forested sites. From the analysis those figures, the weather conditions associated to the passage of a cold front are very well depicted in Ji-Paraná, as compared to Manaus or Maraba (not shown here). The front crosses the region approximately on June 24, and after that air temperature and humidity decreased reaching the lowest levels on the morning of 26 June. For the pasture site, air temperature dropped from 23 °C on the afternoon of 25 June to 10.5 °C on the morning of 26 June, and remained low until 28 June. By 29 June, temperature and humidity had reached the levels as before the passage of the cold front. During the coldest days, the wind was predominantly from the south with speeds of almost 8 m/s, twice the intensity of previous days. In the forested site, similar trend is observed, regarding temperatures, wind and humidity. The lowest temperature and moisture were reached on the morning of 26 June (11.3 °C), dropping from a maximum of 22.5 °C 24 hours before. The behavior of the cold wave above the forest and in the pasture site in Ji-Paraná indicates that the friagem affects this part of southern Amazônia, and affect the top of the forest where the measurements are made.

For Manaus (Fig. 2), cooling is observed from June 26-29, with the coldest days on 29 June (19.5 °C, where the average minimum is 22.6 °C), lower atmospheric moisture is also observed in those days and by 30 June, temperature and moisture reach their normal values. In this case, the maximum temperatures are almost 5-7 °C lower than the ones during the days without friagens, showing that the impact of the friagens in this part of Amazônia is more in reducing the maxima than the minima temperatures, due to increased cloudiness. As for wind speed, from June 26-28 they are not much stronger as in Ji-Parsns but they show a predominant south component, while after that the winds change direction constantly. The changes in air temperature and humidity are indicative of the friagem, but the relatively weak cooling, as compared to Ji-Paraná or southern Brazil, is an indicator that the cold air arrived to Manaus greatly modified.

In eastern Amazônia at Marabá (not shown here), the meteorological situation is different from Ji-Paraná and Manaus. The cooling and drying trend well depicted in Ji-Paraná and in some degree in Manaus is not observed here. Instead, lower diurnal thermal ranges are detected on 28 and 29 June, associated to cloudiness and rain during those days and low maximum temperatures. The lowest temperatures are reached on 27 July (19.4 °C at the pasture) and on 30 June (19.7 °C at the forest, and the fact that there is not a systematic reduction in air temperature and moisture as in Ji-Paraná indicate that the cold air arrived greatly modified. The passage of the cold front was more related to rain than a to a cooling and do not show any increase in the wind strength during the days with temperature drops. Hence, and the cooling mechanism could be related possibly to radiative effects due to clear days associated with high pressure to the north of the cold front.

From the temporal evolution of the friagem shows in the previous figures, it is observed that the friagem brings cold and dry air masses. Analyses based on the terms of incoming solar radiation (Fig. 3) and the energy balance for both pasture and forest in Ji-Parana have indicated that on 25 June, one day before the coldest day, clouded skies (possible low and middle clouds) determined low incoming solar and net radiation (consistent with lower thermal range in that day). In the meanwhile, from the night of 25 June to early 26 June the net radiation and the soil heat flux become very negative meaning a strong loss of energy by the surface, which is favored by the clear sky conditions that predominate on 26 June. On this day, due to increase solar radiation air temperatures start to increase. This later is observed by an increase of the sensible and latent heating as compared to the lower values from June 25. An analysis of GOES images for the period June 23-29 show low-middle level clouds over Ji-Parana by 25 June when the cold front is over Sao Paulo, and by 26 June clear skies predominate over Ji-Parana and southern Amazonia with the cold front over Rio de Janeiro and northern Minas Gerais. On the other sites, clouded skies are present one or two after the "coldest"day.

5 Discussions and Summary

The analysis here performed have demonstrated that in fact the cold air from these friagens have reached western Amazônia at the site of Ji-Paraná, and with less intensity extending to Manaus and Marabá due to the fact that the air mass is no longer "polar" but a much modified continental tropical, and deduced from the trend in air temperature and moisture. The duration of these phenomenon is from 5 to 6 days, from the passage of the cold front to the date when temperature and humidity get back to their values previous to the front's passage, with a 2 to 3 days period in which very low temperatures are affecting the local weather. For 26 June, Ji-Paraná was affected by the cold air on the same day as southeastern Brazil. The modified cold air arrived in Manaus and Marabá between 2 to 3 days later. Based on the intensity of the wind and direction of the winds, and based on the results of a parallel paper by Marengo et al. (1996a), it has been shown that cold air advection is the main mechanism for cooling in Ji-Paraná, while at Marabá and Manaus the cooling is more due to radiative effects.

The passage of the cold front associated to the friagem is detected in the variations of atmospheric pressure and humidity in the daily series during the occurrence of the phenomenon. The amplitude of the changes in these variables (large in southern Brazil, somewhat large in Ji-Paraná) and very small in Manaus, Marabá an other stations in central and eastern Amazônia, indicates a more intense friagem in southern than in central or eastern Amazônia. The impact of the friagens is also felt at the forest sites and may affect the local flora and fauna and perhaps even the local population all of which are adapted to warmer weather. While there is not economically important agriculture in Amazonia, the impact of the friagens there will always be less important than their sometimes devastating impacts on the coffee growing areas of southern Brazil. However, as has been shown, the phenomena are an important feature of

the climate in Amazonia, particularly in the southern and western fringes of the basin where these intermittent events can substantially reduce the mean monthly temperature and humidity during the winter months.

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Fig. 1 Site: Ji-Parana, RO. Friagem of June 26 1994

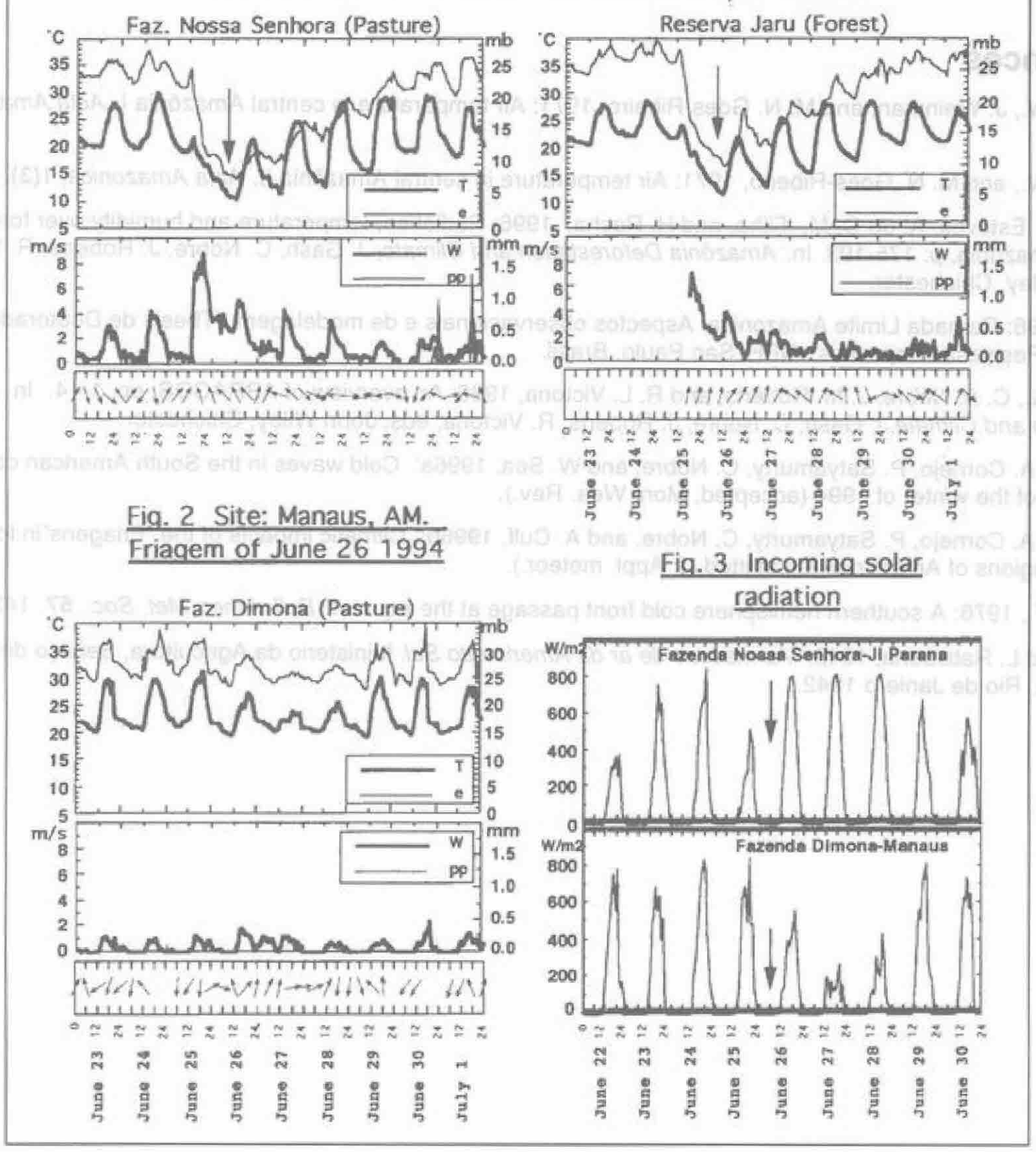

Fig. 2 Site: Manaus, AM. Friagem of June 26 1994

Fig. 3 Incoming solar radiation

Estimativa do Saldo de Radiação sobre um Cultivo de Videira

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Summary

This study used data of incident (R_s) and reflected (R_r) solar radiation and of net radiation (R_n) collected at agricultural meteorology experiment conducted in the irrigated field of Bebedouro, Petrolina-PE with the objective of identifying the best model for estimating R_n as a function of R_s and of (R_s - R_r). The observations were made above and between rows of a grape (*Vitis vinifera L.*) crop, variety Italy, two years old, grown in a trellis system, spaced 4m between rows and 2m between plants. The experiment covered two phenological cycles (from bud shooting to harvest). The measures of R_s , R_r and R_n were obtained in sensors installed at 1m above the trellis, daily from sunrise to sunset, using a data logger programmed to make measurements at each 5 seconds, storing the average values of each 10