Proceedings of 8 ICSHMO, Foz do Iguaçu, Brazil, April 24-28, 2006, INPE, p. 927-934.

CHARACTERIZATION OF BRAZILIAN DESERTIFICATION AREAS THROUGH NCEP/NCAR REANALYSIS AND NUMERICAL MODELING.

José Francisco de Oliveira Júnior , Alessandro Sarmento Cavalcanti,
Nilton Oliveira Moraes, Leonardo Aragão Ferreira da Silva,
Pamella Lacerda da Silva Moraes.

1. INTRODUCTION

Desertification is one of prime environmental problem around world. Its main symptom land degradation, and its causes are essentially two: alterations provoked by climate and human beings (antrophic processes) activities. Phenomenon is old, being attributed to term "desertification" by Aubreville (1949) in 40 years characterizing areas seemed as "desert" or deserts that were expanding around world. Affected or threatened areas estimative are great controversy by complexity and diversity, mainly in considered time scale (Gois et al, 2005). Desertification definition clearly distinguished from drought, which two years or more period with precipitation below historic average, and Aridness results from period in decades order(Pear tree, 1997). This controversy, far of being purely academic, and still has significant practical importance, therefore it can influence in such a way in politics combat formularization, as public investments destination in many regions around world, (OMM, 1993). As desertification as droughts cause social-politician-economic problems. Then were developed a United Nations Program for Environment (PNUMA), which invests in studies and deliberations in desertification combat. In early XXI century, (OMM, 1993) approximately a billion of people in some countries are damaged by desertification and been a great risk to planet to set up to 41% terrestrial surface be transformed into deserts. Desertification world data show that at least 70% semi-arid lands are affected, being approximately 3,6 billion hectares, diminishing productive capacities (OMM, 1993). In Latin America, problems still more serious by agriculturists and deforestation wrong managements, (Hastenrath, 1985). But, with these increases factors advance desertification processes (OMM, 1993). More affected areas around world are: south Africa and near Saara desert, and Brazil have strong indicius of desertification in Pampas Gauchos, northeastern semi-arid and cerrado. Clearly, Brazilian desertification damaged was not limited to previously mentioned regions, but fertile regions have to be included, for example, Mato Grosso, Mato Grosso of Sul and Goiás states. Despite desertification process occurring in Brazil been acelerated by deforestation, agriculture and minering. To diminish desertification advance following measures are necessary: reforestation and crops rotation. Aridness methodology definition developed for Thornthwaite (1941) and later used to map elaboration Arid regions Distribution, elaborated by UNESCO resulted in International Hidrologic Program (IHP), started at 1952. As defined, Aridness region degree depends of water rain (p) amount and possible maximum water loss through evaporation and transpiration, called Potential Evapotranspiration (PET). Formularization proposal by Thornthwaite, later adjusted by Penman (1953), so that classification was elaborated and accepted currently. After that ration between these variables were used to establishment risk areas and elaborated mentioned UNESCO map, used with studies parameter in many parts around world. Gomboluudev and Natsagdorj (2004) used RegCM3 model (Regional Climate Model) through surface BATS (Biosphere-Atmosphere Transfer Scheme) data to investigate Mongolian desertification. Than were made control simulation in summer season during three consecutive years representing humid, normal and dry conditions; validated with 62 stations precipitation and temperature monthly series. Xue and Shukla (1993) had shown through satellite images vegetation destruction over Sahel region. With significant Albedo increase, change in winds regimen and little precipitation, helped in desertification increase. Although, constant changes in climate related to Intertropical Convergence Zone(ITCZ) position, to El Nino-South Oscilation (ENOS) phenomenon, sea surface temperature oscillations (SST), causing variability in Brazilian northeast – NEB precipitation (Moura and Shukla, 1981; Nobre and Shukla; 1996 Hastenrath and Heller; 1977; Molion and Bernardo 2002), together with antrophic actions to intensify region desertification. Droughs had affected good part of Amazon region, during 2005 year, especially southwestern Amazon region and Acre states, characterized lower pluviometric index during last 40 years, exceeding 1925-26, 1968-69 and 1997-98 periods, until then considered most intense, (CPTEC, 2005). Were verified precipitation data in south Amazonian region during 2005 rainy season, presented values up to 350 mm lower than historical average. In 2005, one strong estiagem over year months. Rains below average in south region during 2004 observed, where rivers outflow and rains been minors than normal, in contrast of 2005 observed with extremely low values, (CPTEC, 2005). Therefore, study has objective to develop an applicable model to identify possible areas that present susceptible to Brazil desertification, through Aridness index using MM5(PSU/NCAR) Model data, developed by Pennsylvania State University(PSU) in National Center for Atmospheric Research(NCAR) by Anthes and Warner (1978) of Reanalysis project (Kalnay et al, 1996), to evaluate possible mechanisms that cause desertification.

1 NCQAr/LAMCE-PEC/COPPE/UFRJ
Departamento de Meteorologia, Universidade Federal do Rio de Janeiro, Av. Brigadeiro Trompowski, s/n Ilha do Fundão, Rio de Janeiro, CEP 21945-970, Brazil;
e-mail: juninho@acd.ufrj.br, juninho@coc.ufrj.br

2. METHODOLOGY

Three selected regions (Figure 1.) have strong indications to Brazilian susceptible desertification.

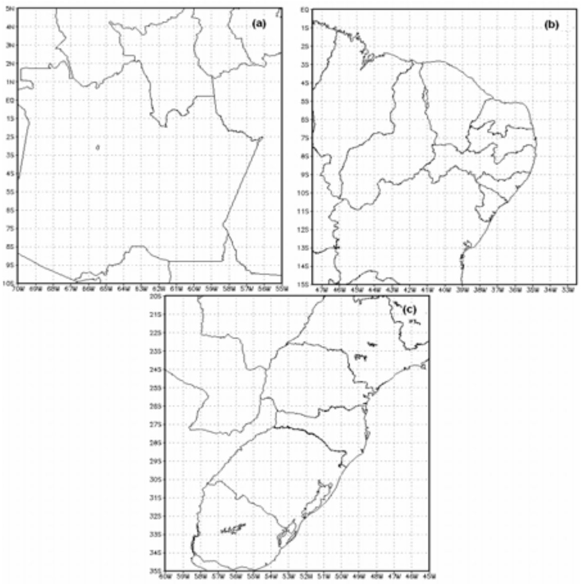

FIG 1. Study area cover three regions: Amazonian (5°n-10°s - 70°w-55°w), NEB (0°-15°S - 47,5°w-32°n) and Pampas Gauchos (20°-35°s-60°w-45°w).

Using climatologic variable precipitation and air temperature on reanalysis-NCEP (National Center Enviromental Prediciton), (1964-2004) period been determined ETP average, Thorntwaite humidity (Im) Penmam (IP) and Aridness (D) indexes. Than, were elaborated ETPM maps to June-July-Agust (JJA) and December-Janeiro-Fevereiro (DJF) periods, being calculated through Thornthwaite method (1948):

$$ETP_j = 0{,}533\, C_j \left(10 \frac{\overline{T_j}}{I}\right)^a \qquad (2.1)$$

$$a = (0{,}675\, I^3 - 77{,}1\, I^2 + 17920\, I + 492390).10$$

Where ETPj (mm. month-1) monthly average potential evapotranspiration, $\overline{T_j}$ (ºC) monthly average temperature, I (ºC) regional heat monthly index, j year month, and a, function exponent of regional heat monthly index, Cj correction factor leaving in account considered days-number month and effective duration.

Using D considered for Hare (1983) apud OMM (1993) were verified major area occurrence ($2 < D < 7$) values, near wet and underwet of dry limits zones, however, deserts meets interval near ($D \geq 10$). Mather (1974) apud OMM (1993) applied Thornthwaite humidity index (I_T), later modified by (Hare, 1977; 1983) apud OMM (1993), for D determination, given:

$$I_T = 100\left(\frac{P}{EP} - 1\right) \qquad (2.2)$$

Where, I_m Thornthwaite humidity index, P (mm.ano-1) annual average precipitation, ETP (mm.ano-1) annual average evapotranspiration and D Aridness Index.

$$I_T \times 10^{-2} = \frac{1}{D-1} \qquad (2.3)$$

$$D = \frac{100}{I_T} + 1 \qquad (2.4)$$

Still Penmam climatic index were used (IP) consists of ration between pluviometric annual precipitation average and annual evapotranspiration average, being:

$$I_p = \frac{P}{ETP} \qquad (2.5)$$

Some sensitivity experiments in relation to desertification using MM5, showing possible scenaries in region study. Simulations, following Table1.

Table 1. Parametrizations Schemes and respective nested grids used by MM5.

Parametrization	Scheme	Grid
Cumulus clouds	Grell, None	27 e 9 km
Atmospheric Boundary Layer	MRF	27 e 9 km
Soil	NOAH-LSM	27 e 9 km
radiation	Clouds, simple	27 e 9 km
Umidade	simple ice	27 e 9 km

3. RESULTS AND DISCUSSION

Based in reanalysis data were verified great variability between Amazonian region and others in relation to D, involving detected decadal oscillations frequencies, possibly produced by precipitation variability, as well as D explicitaly to represent soil water content seasonality, where index value is lower in wet area and bigger dry.

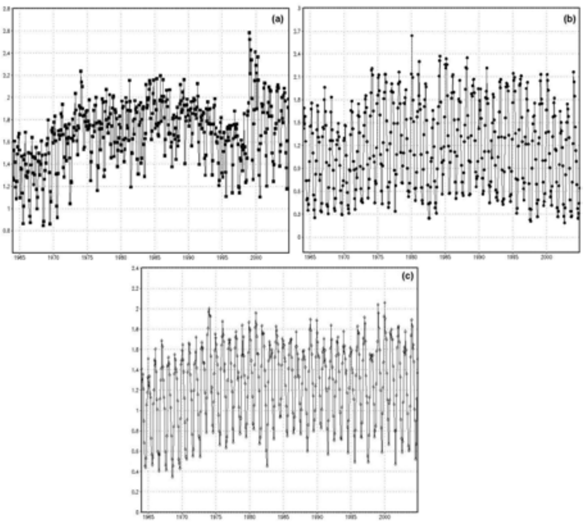

FIG 2. Aridness Index (D) Annual distribution using NCEP reanalysis (1964-2004) for three regions (a) Amazônia, (b) NEB and (c) Pampas Gauchos.

Verified through reanalysis data that in Amazonian region D varied between 0,8 and 2,6 (Figure 2a), in decadal evaluation were possible observe a regional desertification suceptibility. Observed an increase during 80 decade, correspondent to drough period and a significant reduction in 90's to wet period, except to 2000, where biggest D value occurred (Figure 2(a)). there is an possible evidence to desertification advance in region in last period cause by forest been converted to agricultural area and with strong changes occurred, Albedo and superficial net energy. These changes in continental surface properties had consequences last years probable increase, showed Figure 2(a). While NEB (Figure 3) notes that D varied between 0.3 and 2.7, as much, (b) where its behavior presented minor variability in comparison to other regions. One increase in D over 80 decade, however a significant reduction after (Figure 3(a)). D variability is conditioned to semi-Arid region, due to air masses subsidence from Amazonia that result in adiabatic heating and low relative humidity. Observed Pampas Gaucho region where D varies 0.4 and 2.0 (Figure 2(c)), not presenting significant variations in all periods through comparison with other regions. Therefore, through D calculation using reanalysis can be possible identify desertification indicius in three regions in some decadal scale periods.

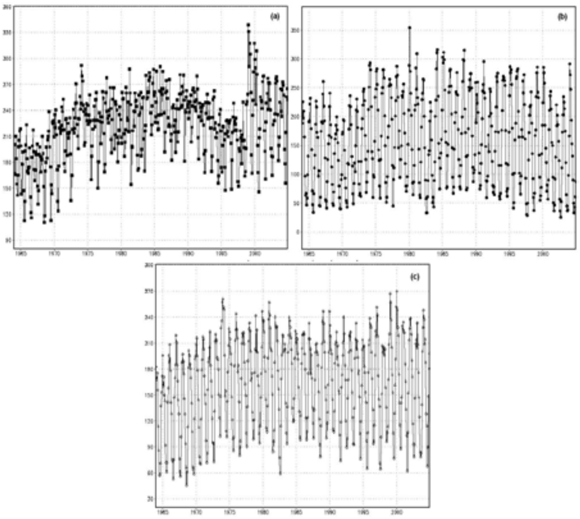

FIG 3. Annual distribution of the precipitation (mm/month) using of reanalysis of the NCEP (1964-2004) for the three regions (a) Amazônia, (b) NEB and (c) Pampas Gauchos.

Observed in Amazon region precipitation time scale regimen were sufficiently changeable, in some periods got a good agreeing with climatologic normal and upper and under estimate, however were possible to identify through reanalysis cooling tendency in 60 decade and inverting in 70 end, also in 2000 occurred a considerable regimen increase, follow D (Figure 3(a)). Being precipitation variability conditional to some regional factors: resultant diurnal convection surface heating, instability lines originated in Atlantic North-Northeastern coast and meso and great-scales convective clusters, associates with frontal systems (Friagens) penetration in Brazilian South/Southeastern region. In (Figure 3(b)) noted NEB annual precipitation 250 mm average through reanalysis, agreeing substantially to climatologic normal. There some phenomena in many scales, for example, ZCIT, breeze systems, mechanisms that cause great variability in precipitation and climate of region. Already, Pampas Gauchos region were identified a uniform precipitation distribution by reanalysis, must be direct influence of Cold Fronts and Mesoscale Convective Complex (MCC), (Figure 3(c)). Accumulated precipitation through reanalysis were highly changeable in three regions, particularly in Amazonian, (Figure 3.). Thus, using reanalysis were possible to verify that precipitation were sufficiently changeable in dry, under wet and humid (Amazon region, NEB and Pampas Gauchos), (Figure 3.).

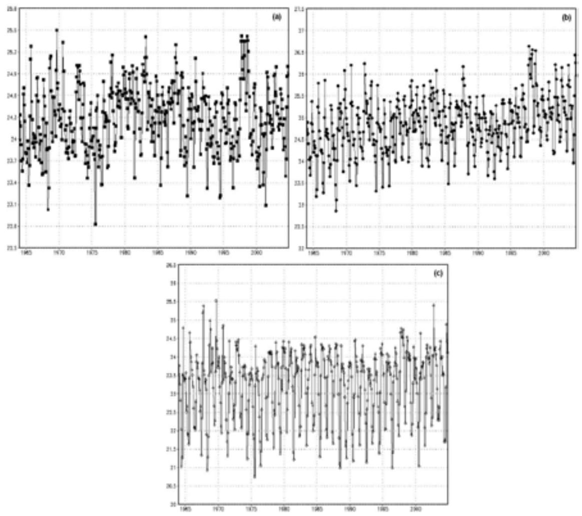

FIG 4. Annual distribution of the temperature of air (°C) using of reanalysis of the NCEP (1964-2004) for the three regions (a) Amazônia, (b) NEB and (c) Pampas Gauchos.

Verify that annual air temperature amplitude (Figure 4)were lower in coastal (NEB and Pampas Gauchos) regions than Amazônia. Showing that these regions air temperature distribution receives strong influences of: insolation regimen, surface nature, and topography; predominant winds regimen and oceanic currents. Characterized by reanalysis data, (Figure 4.).

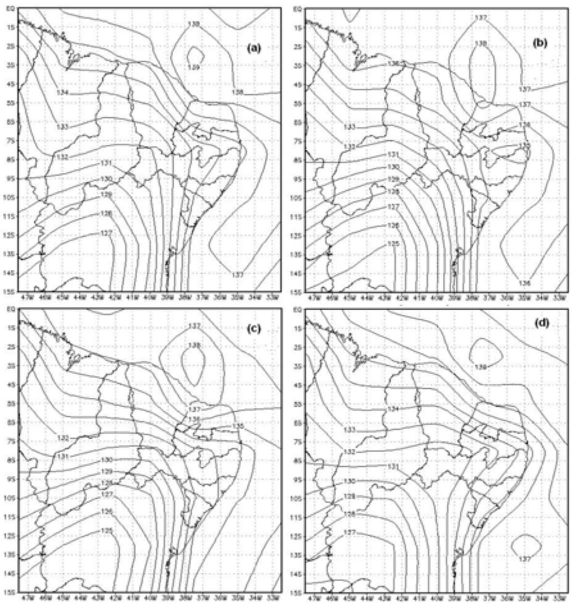

FIG 5. Seasonal distribution (DJF) of ETP (mm/month) using NCEP reanalysis (1964-2004) to NEB region, (a) 2000, (b) 2001, (c) 2002 and (d) 2003.

Through (Figure 5) highest ETP values occurred in coastal region and lowest in Droughs Polygon region. Verified by ETP increase, except in 2000 year. Evaporation NEB bias in period through reanalysis been sufficiently changeable, only exception 2000 year, (Figure 5.).

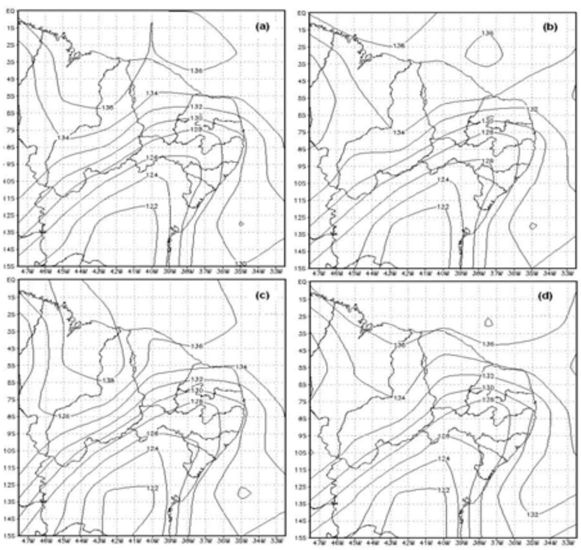

FIG 6. ETP seasonal distribution (JJA) (mm/month) using NCEP reanalysis (1964-2004) for NEB region, (a) 2000, (b) 2001, (c) 2002 and (d) 2003.

Verified in Figure 6 that a significant increase of corresponding ETP to period 2002 and 2003, except in coastal region presenting great variation due to reanalysis data been better answer in oceanic areas that continental. Maximum annual ETP identified by renalysis, (Figure 5 and 6), receives strong influence of trade winds regimen. ETP bias in determined area is influenced by two factors: (i) surface humidity available and (ii) meteorological controllers influences (solar radiation, temperature, wind speed and humidity), in NEB case, presents a great variability in relation to two factors, however not being well identified by reanalysis data, (Figure 5 and 6.).

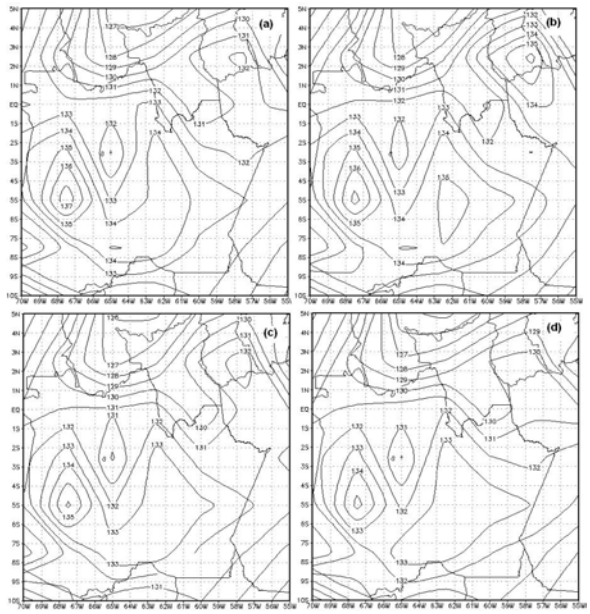

FIG 7. ETP seasonal distribution (DJF) (mm/month) using NCEP reanalysis (1964-2004) for Amazon region, (a) 2000, (b) 2001, (c) 2002 and (d) 2003.

Amazon region is strong conditional for solar energy availability, through net energy. Outstanding that Amazonia has maximum energy value in December-January and minimum in June-July (SALATI and MARQUES, 1984). Noted that ETP distribution were sufficiently changeable, mainly in Rondônia and Mato Grosso do Sul regions presenting ETP highest values for respective years, (Figure 7.). trimester DJF rain distribution presents high precipitation region (upper 900mm) situated in west and central Amazônia, connected with Bolivian High geographic position, for respective years were ETP well characterized through reanalysis. And considered increase characterized in NE sector after 2000. And distribution starts increase in south, NE and Central Amazonian region parts, (Figure 7.).

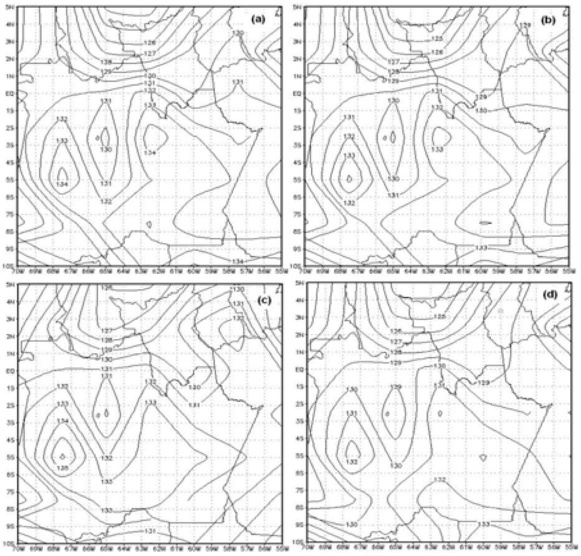

FIG 8. ETP seasonal distribution (JJA) (mm/month) using NCEP reanalysis (1964-2004) for Amazon region, (a) 2000, (b) 2001, (c) 2002 and (d) 2003.

Inverse process in Central region between 2000-2001, an ETP reduction, except in south and Southeast and in others two years following, returning to same behavior of other trimester, as Figures 7 and 8. Due to precipitation center maximum is dislocated northward. Amazon region, mainly central part its over descending branch of Hadley cell, inducing a period well characteristic drought. Observing reanalysis used data to ETP calculation, were underestimate for all study period (Figure 8). Reanalysis data sample obtained from maximum ETP values on continents in high humidity period. Perhaps insulation gradient increase and because forest water great losses.

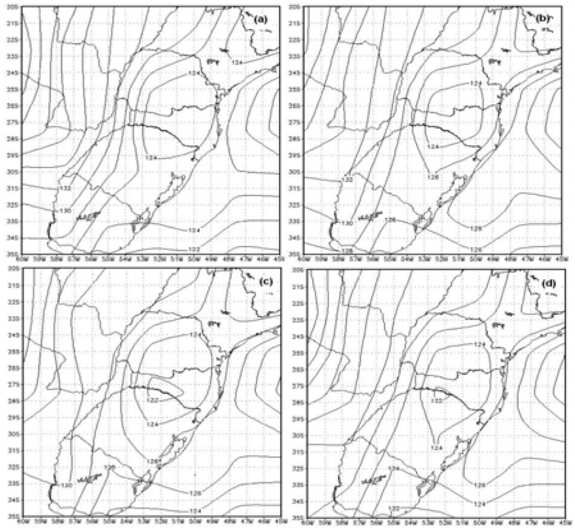

FIG 9. Seasonal distribution (DJF) ETP (mm/month) using NCEP reanalysis (1964-2004) to Pampas Gauchos region, (a) 2000, (b) 2001, (c) 2002 and (d) 2003.

Verified ETP Pampas Gauchos region is sufficiently low in central and coast parts, except in south, where similar ETP of other regions (Figure 9). Observed in Figure 9 that ETP over Pampas Gauchos region, changed due to humidity and precipitation annual oscillation (Figure 3). Thus with rain period, soil water discharge consequently increase air relative humidity and ETP decrease, being well characterized region, except in MCC region formation (Figure 9).

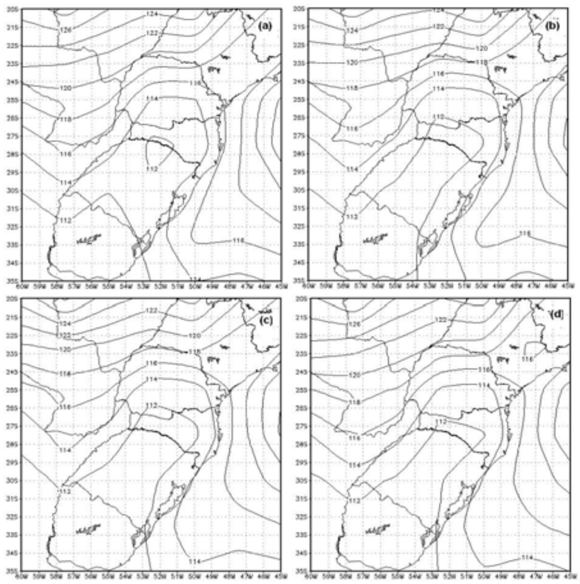

FIG 10. Seasonal distribution (JJA) ETP (mm/month)

using NCEP reanalysis (1964-2004) for Pampas Gaucho region, (a) 2000, (b) 2001, (c) 2002 and (d) 2003.

A drastic ETP reduction (Figure 10) due water entrance by precipitation, also decrease ETP (Figures 9 and 10). Thornthwaite methods assumes zero evaporation when average air temperature lower than 0°C, however questionable. And this formularization does not presents basic meteorological controllers. This formularization needs to be included humidity factor, because formula tends to underestimate values ETP in arid and semi-arid areas and, during dry seasons, in seasonally humid environments, being good characterized (Figures 6 and 8). Evaporation is higher over ocean than continent, being well identified by reanalysis data in both regions NEB (Figures 5 and 6) and Pampas Gauchos (Figures 9 and 10).

4. CONCLUSIONS

Through D calculation using reanalysis data can be pointed possible desertification indications inside three regions in some decadal scale period. Formularizations needs include meteorological controllers, because its lack tend to underestimate ETP values in arid, semi-arid and seasonally humid environmental areas, being well characterized in reanalysis data in both regions. One of serious problems, when desire studies involving desertification in great areas is ETP used models are punctual, or either, covers only small areas where climate components, ground and vegetal covering are known. An alternative would be estimates accomplishment in small areas; interpolating results in grids were able to cover study area. When data is transferred to regional scale results overestimate ETP totals, and consequently difficulting possible desertification areas identification. Therefore, future investigation its to compare surface stations observational data that compose three study regions and use other dryness indexes, for example, Palmer index.

5 - ACKNOWLEDGMENTS.

To support thats include investiments in Universidade Federal de Alagoas Laboratory and personal to second author powered by Fundação de Amparo à Pesquisa do estado de Alagoas – FAPEAL.

6. REFERENCES

Aubreville, A., 1949: *Climats, forets et desertification de l'Afrique tropicale*. Paris: Geogr. Marit. & Col., 351pp.

CPTEC. Seca na Amazônia em 2005. Disponível em http://www.cptec.inpe.br/clima/. Acessado em: 9 de Fev. 2005.

Dudhia, J., 2003: *PSU/NCAR Mesoscale Modeling System*. Tutorial Class Notes and User's Guide: MM5 Modeling System Version-3, 256pp.

Gois, G.; Souza, J. L.,Da Silva, P. R. T.,Oliveira Júnior, J. F., 2005: Caracterização da desertification no Estado de Alagoas utilizando variáveis climáticas. *Revista Brasileira de Meteorologia*, **20**, 301-314.

Hastenrath, S., 1985: C*lima and Circulation of the Tropics*. Riedel Publishing Company, KW Wer Academic Normell, 498pp.

Hastenrath, S.; Heller, L. , 1977: Dynamics of climatic hazards in northeast Brazil. *Quartely. Journal Royal Meteorological Society*, **103**, 77-92.

Molion, L. C. B.; Bernardo, S. O., 2002: Uma revisão da dinâmica das chuvas no nordeste brasileiro. *Revista Brasileira de Meteorologia*, **17**, 1-10.

Nobre, P.; Shukla, J., 1996: Variations of Sea Surface Temperature,Wind Stress, and Rainfall over the Tropical Atlantic and South America. *Journal of Climate*, **9**, 2464-2479.

OMM (Organization Meteorological Mundial), 1993: *Guide to Agricultural Practices*. 2ª Edition. WMO – nº 134, 429pp.

Penman, H. L., 1953: The Physical Bases of Irrigation Control, In: *Report 13th Int. Hort. Congr. 2*. Royal Horticultural Society, London, 913-924.

Pereira, A.R.; Vila Nova , N.A.; Sediyama, G.C.,1997: Evapo(transpi)ração. Piracicaba: FEALQ, 183pp.

Salati, E., Vose, P. B., 1984: Amazon Basin: a system in equilibrium. *Science*, **225**, 129-138.

Stauffer, D. R., N. L. Seaman, 1990: Use of Four-dimensional Data Assimilation in a Limited-Area Mesoscale Model – Part I. *Monthly Weather Review*, **118**, 1250-1277.

Thornthwaite, C. W., 1941: *Atlas of Climatic Types in the United States*. Miscell Publ. nº 421. U.S. Departament of Agriculure, Forest Service, 356pp.

Thornthwaite, C.W., 1948: An approach toward a rational classification of climate. *Geogr. Rev*, **38**, 55-94.

Thornthwaite, C.W.; Mather, J.R. 1955: *The water balance. Publications in Climatology*. New Jersey: Drexel Institute of Technology, 104pp.

Xue, Y., Shukla, J. 1993: The influence of land-surface properties on Sahel climate. 1. Desertification. *Journal of Climate*, **6**, 2232-2245.