Impacts of Weather and Climate-Related Extremes - Social and Economic Impacts

Jose A. Marengo,
Earth System Sciences Center/National Institute for Space Research (CCST/INPE)
Rodovia Dutra km, 40
12630-000 Cachoeira Paulista
São Paulo, Brazil.
Tel.: +55 12 3186 8464, marengo@cptec.inpe.br

Introduction

Large departures from a mean climate state (hereafter 'extreme events') occur on scales ranging from days to millennia though, and the most important for human activities are perhaps the short-term extreme (weather related) and the medium-term (climate related), events given their potential for significant impacts. Extreme weather and climate events are also an integral aspect of climate variability.

Where extreme weather events become more intense and/or more frequent, the economic and social costs of those events will increase, and these increases will be substantial in the areas most directly affected. In drier areas, climate change is expected to lead to salinisation and desertification of agricultural land. Productivity of some important crops are projected to decrease and livestock productivity to decline, with adverse consequences for food security. In Latin America, semi-arid and arid areas are particularly exposed to the impacts of climate change on freshwater, as indicated by the IPCC WG1 and 2 (IPCC 2007a, b). Areas such as Northeast Brazil may suffer a decrease of water resources due to climate change, with increasing precipitation variability with more dry spells and drought, and also a decrease in the groundwater recharge, and the rapid increase of population and water demand will exacerbate vulnerability. These situations have been detected during drought years in present climates, and would become more frequent in a warmer and drier climate.

Historical weather and climate extremes: Social and economical impacts

Climatic variability and extreme events have been severely affecting the Latin America region over recent years. As reported by IPCC WG 2, Chapter 13 (Magrin et al. 2007), highly unusual extreme weather events were reported, such as Venezuelan rainfall (1999, 2005); flooding in the Argentina Pampas (2000 and 2002), Amazon drought (2005), hail storm in Bolivia (2002) and the Great Buenos Aires area (2006), the unprecedented Hurricane Catarina in the South Atlantic (2004) and the record hurricane season of 2005 in the Caribbean Basin, and the recent drought in Northern Argentina and the intense rain and floods in Southern Brazil in 2008. Historically, climate variability and extremes have had negative impacts on population, increasing mortality and morbidity in affected areas.

Without adaptation measures, these regions will be even more affected in the future and populations living in there would not cope with climate change and their impacts and will be most vulnerable. Again using Northeast Brazil as an example, in this region with about 30 million people living in there, climate change increases the number of people at risk of hunger marginally, with respect to overall large reductions due to socio-economic development.

-*Weather related extremes:*

One of the most important questions regarding short-term extreme events is whether their occurrence is increasing or decreasing over time. Cold spells, heat and cold waves, intense rainfall, floods, dry spells among other extreme events affect South America in all seasons, and their impacts vary according to the sector. Heavy or extreme precipitation events have important effects on society, since flash floods associated with intense, but often brief, rainfall events may be the most destructive of extreme events. Studies on climate change in South America show that over the course of the last 50 years the surface temperatures increased by 0.75ºC, whereas minimum temperatures have raised almost 1ºC. They also show a higher frequency of heat waves and a lower frequency of cold nights. In many parts of southern South America, for which longer climatic records are available, an increase in the frequency of intense rain events has been observed, which partly explains the rising number of natural disasters, such as landslides and floods, responsible for an alarming number of casualties in large cities.

In many areas of South America, the frequency of heavy precipitation events has increased, consistently with warming, and widespread changes in extreme temperatures have been observed over the last 50 years (IPCC, 2007a, b, Marengo et al. 2009). Cold days, cold nights and frost have become less frequent; while hot days, hot nights, and heat waves have become more frequent (Vincent et al. 2005, Haylock et al. 2006, Caesar et al. 2006, Alexander et al. 2006, Tebaldi et al. 2006, Rusticucci e Barrucand 2004, Dufek and Ambrizzi 2007, Marengo et al. 2009). Such changes in extremes have impacts on human activities such agriculture, human health, urban development and planning and water resources management.

Floods cause huge economical disasters both for not insured people/companies, under insured people/companies and insurance companies. Floods always take also not small numbers of human lives. On the other hand, drought can cut off entire cities from their current by rain feed water sources, causing major economical damage. Water shortages will lead to severe societal turbulence and drifting of the populations of complete area's/regions.

In Southern Brazil, heavy rainfall affected Santa Catarina State from 22 to 24 November 2008 causing severe flooding and deadly mudslides, which affected 1.5 million people and resulted in 120 casualties and left 69,000 people homeless. Mudslides and flooding caused by the storms have blocked almost all highways in the region and have cut off water and electricity to thousands of homes. It was reported that most of the fatalities were caused by mudslides that swept away homes and business. Previous extremes events during the El Nino 1983 exhibited intense rains and floods in 1983 produced an economical loss of about US$ 1.1 billion in the entire state of Santa Catarina. Unofficial estimates of the losses due to this extreme rainfall and subsequent floods and landslides 2008 are of the order of US$ 350 million. In March 2004, a hurricane affected the coastal region of the same state, with losses of the order of US$ 1 billion (Pezza and Simmonds 2005).

-Climate related extremes

At seasonal level, a poor or extremely wet rainy season, accompanied by a relatively warm rainy season due to SST anomalies in the tropical Pacific (El Nino, La Nina), or in the tropical or subtropical Atlantic, can have strong impacts on population and economical sectors depending on water availability. The effects of the drought are devastating agricultural activities and the hydroelectric generation in populated areas. With the persistent reduction of precipitation in these areas, lakes dry-up, river flow decreases and fresh water supply is squeezed, overwhelming available conservation options and depleting fresh water reserves.

Rainfall deficits during summer and fall 2001 resulted in a significant reduction in river flow throughout Northeast, Central-West and Southeast Brazil, thereby reducing the capacity to produce hydroelectric power in these areas (90% of Brazil´s energy is from hydroelectric sources) In an anomalously dry and warm summer the excessive use of energy for air conditioning determined reductions in the levels of the reservoirs of the hydroelectric generation plans (Cavalcanti and Kousky 2004). The large-scale nature of the deficits, affecting nearly the entire country, resulted in an energy crisis that forced the government to impose energy conservation measures in order to avoid total loss of power (blackouts) during part of 2001 and 2002.

In 2005, large sections of southwestern Amazônia experienced one of the most intense droughts of the last hundred years. The drought severely affected human population along the main channel of the Amazon River and its western and southwestern tributaries, the Solimões (also known as Amazon River in the other Amazon countries) and the Madeira Rivers, respectively. The river levels fell to historic low levels and navigation along these rivers had to be suspended, isolating small villages and affecting tourism and cover along the Solimões and Madeira Rivers. The drought did not affect central or eastern Amazônia, a pattern different from the El Niño-related droughts in 1926, 1983 and 1998. The causes of the drought were not related to El Niño but to an anomalously warm tropical North Atlantic. The drought conditions were intensified during the dry season into September 2005 when humidity was lower than normal and air temperatures 3-5 oC warmer than normal.

Due to the extended dry season in the region, forest fires affected part of southwestern Amazônia almost 300% larger than normal. As a consequence of fires, air traffic was affected due to the closing of the Rio Branco International Airport in the Acre State in western Amazônia, schools and business were closed due to smoke and many people have to be attended in hospitals due to smoke inhalation (Marengo et al 2008a, b; Zeng et al 2008, Cox et al. 2008). There are not complete estimates of the cost of this drought. For the Acre State, the Defesa Civil estimated a lost of about US$ 87 million due to the fires only, about 10% of the State´s GDP.

The drought that affects northern Argentina since 2008 determined a reduction in the agricultural production, and together with the international price reductions determined a projection of reduction of about 30% in exportation, of about US$ 8-9 billion for 2009. This projection would change if rainfall backs to normal and if soybean prices increase.

Climate Change and changes in extremes

Climate change is expected to modify the frequency, intensity and duration of extreme events in many regions (Christensen et al., 2007). It is impossible to attribute single extreme events directly or solely to anthropogenic climate change because of the probabilistic nature of these events. There is always a chance that any given event may be a result of natural climate variability, even if an event of such magnitude has never been recorded. Therefore, it is necessary to use models to augment observations in attempting to understand the changing likelihood of extremes under climate change scenarios, e.g. through calculating the enhanced risk of an extreme attributable to climate change as in Stott et al., (2004) for the heat wave in Europe in summer of 2003. All of these evidences underscore the need to study how humans have influenced global climate and contributed to the divergence of the terrestrial climate system from natural variability.

Aside from major extreme events, climate change is seldom the main factor in considering stresses on sustainability (IPCC 2007b).The significance of climate change (positive or negative) lies in its interactions with other non-climate sources of change and stress, and its impacts should be considered in such a multi-cause context. Vulnerabilities to climate change depend considerably on relatively specific geographic and sectoral contexts. Where extreme weather events become more intense and/or more frequent with climate change, the economic costs of those events will increase, and these increases are likely to be substantial in the areas most directly affected.

In Brazil, a relatively small number of studies deals with climate change impacts on natural ecosystems and agro-ecosystems, coastal zones, renewable energies, water resources, mega-cities and human health; however, they leave no room for doubt: Brazil will not be left unharmed by climate change (Assad and Pinto 2008, Schaeffer et al. 2008, CEDEPLAR and FIOCRUZ 2008, Marengo et al. 2009). A few degrees rise of temperature may expose the tropical semi-arid region of Northeast Brazil to tangible risks, with clear social repercussions. Shorter residence time of soil moisture, increase of the frequency and intensity of droughts, and rainy periods with more concentrated and intense rainfall events are likely to diminish soil water availability in this region. This would lead to a scenario of desertification and accelerating desertification, and turn even more marginal the dry-land agriculture, which is the current way of subsistence of more than 10 million inhabitants of this region.

Risks and impacts of changes in extremes

Climate variability already poses a substantial challenge to society, and further changes in climate are now unavoidable even assuming effective implementation of present mitigation policies. This makes the development of adaptation strategies imperative, and begs attention to issues of ethics and justice highlights: the people most likely to bear the brunt of global climate change are those who have contributed and who will contribute least to it.

Impacts of inevitable climate change hit the poor the hardest. Poor communities and households are already under stress from climate variability and climate-related extreme events and they can be especially vulnerable to climate change because they tend to be concentrated in relatively high-risk areas, to have limited access to services and other resources for coping, and in some

regions to be more dependent on climate-sensitive resources such as local water and food supplies. Growing economic costs from weather-related extreme events are already increasing the need for effective economic and financial risk management. In those regions and locations where risk is rising and private insurance is a major risk management option, pricing signals can provide incentives for adaptation; but protection may also be withdrawn, leaving increased roles for others, including governments. In those regions where private insurance is not widely available, other mechanisms for risk management will be needed. In all situations, poorer groups in the population will need special help in risk management and adaptation. In many areas, climate change is likely to raise social equity concerns and increase pressures on governmental infrastructures and institutional capacities. In less prosperous regions, lacking of resources and capabilities required to adapt quickly to more severe weather and climate conditions, the problem is very likely to be exacerbated. For some countries and regions, climate change could become such a challenge that mass emigration results as the desperate peoples seek better lives in regions our countries that have the resources to adaptation.

That calls for unprecedented international collaboration to create far-reaching and effective adaptation programs worldwide, in which increased adaptive capacity goes hand in hand with increased capacity in science and technology in the developing world.

Sustainable development-human development-vulnerability to climate change

The sustainability of development in South America is strongly linked to the capacity of responding to the challenges and opportunities associated with climate change. The region is vulnerable to present-day climate change and will be profoundly impacted by projected climate changes in the future. The economy is strongly based on climate-dependent natural resources. Renewable energy sources, agriculture and biodiversity are potentially highly vulnerable to climate change. Social and regional inequalities put large sectors of the population vulnerable to climate change. Using the Human Development Index (HDI) as indicator, we see that the regions with lowest HDI values in Brazil, for instance are the Amazon and Northeast Brazil regions. The Cumulative Climate Change Index CCI developed by Baettig et al. (2007) suggests that these regions and tropical South America in general, the highest CCI values indicate regions where climate change would be most intense. The Amazon region and Northeast Brazil are the regions with highest CCI and also the regions with lowest HDI, and this would sort of confirm the main message from IPCC WG 2, that suggest that impacts of climate change would be strongest on poor regions in the tropics. However, it is clear that regions with high HDI may be also vulnerable to climate change and extremes, but their capacity to cope with climate change is higher than in regions with low HDI.

In Northeast Brazil, a recent study by CEDEPLAR and FIOCRUZ (2008) analyze the economical aspects of climate change and its economical impacts in terms of employment and rent distribution, as well as population migration. The economical impacts of climate change (under varios emission scenarios) include a re-definition of employment conditions and rent that affect not only the re-distribution of economical activites, but also the redistribution of population and of vulnerable groups in space, favoring the development of new situations and geographical patterns of vulnerability. The impacts of climate change on a primary sector comes as an element that redefines the economical and demographic dimensions on the region, being

that impact stronger where the sector is stronger, including its articulations with other sectors of the economy (mainly the agroindustry and services).

It is assumed that the impacts of climate change in the agricultural development in Northeast Brazil are relevant and representative of the gemeral impacts in the region´s economy, due to the large conbtribution of the agricultural sector in the economy in the region. This is more evident in the connection between agriculture and services and industry.

The mains results of this stysu suggest a major "climate schock" in the availability of land in Northeast Brazil, that will affect the economical values of the agricultural sector, lowering its activity and reducing the need for labor workforce. There would be a migration to oher regions and sectors of Brazil where the impacts of climate change would affect less strongly the economy, generating migration pattern for population and capital. In general de GDP of Northeast Brazil for the A2 scenario in 2050 would be 11.4% lower as compared to present climate.

Social and economical aspects of climate change: Need for integrated assessments and adaptation measures

Climate scenarios rely upon the use of numerical models. Global models have allowed for a better scientific understanding of anthropogenic global climate change and this led to commensurate developments of mitigation strategies. However, at the regional scale there remains an urgent need for relevant, targeted projections of regional climate change. Furthermore, adaptation, as opposed to mitigation, is inherently a local and regional scale issue, and limited by the measure of confidence in the projected changes at these scales. Without appropriate regional projections of climate change, it is arguable whether regional adaptation strategies can be developed or implemented, other than on a "no regrets, best practice" basis (IPCC 2007a, b, Marengo et al. 2009). Regional climate change projections that are tailored to the needs of the impacts community, and which demonstrate convergence of the projections across different forcing GCMs, are only now beginning to become more available.

Frequently, due to lack reliable climate change projections at regional level, the governmental actions are taken only after the occurrence of the event that causes the natural disaster, that is, to remedy the losses, which could not be prevented or mitigated before their occurrence.Thus, considering that inevitable global warming will aggravate the vulnerability of populations to the intensification of natural disasters, efforts must prioritise the improved early warning of extreme climate and weather events, which should be made rapidly available, as recognized by the Hyogo Declaration (ISDR, 2005), conceived as a mean of adaptation to climate change and suppression its devastating effects in a period of ten years (2005-2015).

Because the prevailing scenarios of gradual climate change could have negative impacts as those described above, an increasing number of business leaders, economists, policy makers, and politicians are concerned about the projections for further change and are working to limit human influences on the climate. As a consequence, efforts like the Stern Report published in 2006, and the ongoing regional studies EECB-Economics of Climate Change in Brazil) and RECCS (Regional Economics of Climate Change in South America) are important initiatives, but these efforts may not be sufficient if not implemented soon enough. Each of these local disasters

caused by severe weather and climate impacts surrounding areas whose natural, human, and economic resources are tapped to aid in recovery. The positive feedback loops and acceleration of the warming pattern begin to trigger responses that weren't previously imagined, as natural disasters and stormy weather occur in both developed and lesser-developed nations. Their impacts are greatest in less-resilient developing nations, which do not have the capacity built into their social, economic, and agricultural systems to absorb change.

South American countries must prepare for possible impacts of climate change and extremes, in both weather and climate, in order to develop vulnerability assessments and to provide input for the proposal of adaptation measures:

1) Improve regional and global climate models, including historical trend analyses

2) Assemble comprehensive integrated models of climate change impacts.

3) Create vulnerability metrics to understand country's vulnerability to the impacts of climate change.

5) Prepare and test adaptive responses to address and prepare for inevitable climate driven events such as massive migration and food and water supply shortages.

6) Explore local implications of climate change and extremes in urban and rural areas, and develop estimates economical damages. Risk management can be applied in all of these contexts.

7) Future sustainable development plans should include adaptation strategies to enhance the integration of climate change into development policies.

Not only places, but also persons have distinct vulnerabilities. Different social groups are exposed to different hazards of climate change and with different resources to respond to them (Hogan, 2001). It is therefore necessary to identify these groups, locate them in the urban space and describe them socially and demographically for more efficient public policy. There is a need for projects intended to integrate the projections of climate alterations and socio-economic models, such that an integrated analysis of the economic impacts of these phenomena can be produced. On the basis of that, adaptation and mitigation policies may be simulated.

References

Alexander, L. V., et al. (2006) Global observed changes in daily climate extremes of temperature and precipitation, J. Geophys. Res., 111, D05109, doi:10.1029/2005JD006290.

Assad, E, H. S. Pinto (2008) Aquecimento Global e a Nova Geografia da produção agrícola no Brasil. EMBRAPA-CEPAGRI, São Paulo, Agosto 2008. 82 pp.

Baettig, M., Wild, M., Imboden, M,)2007) A climate change index: Where climate change may be more proiminent in the 21st century. Geophys. Res. Letters, L01705, doi:10.1029/2006GL028159, 2007

Caesar, J., L. Alexander, and R. Vose (2006), Large-scale changes in observed daily maximum and minimum temperatures: Creation and analysis of a new gridded data set, J. Geophys. Res., 111, D05101, doi:10.1029/2005JD006280.

Cavalcanti, I. F, A., V. Kousky (2004) Drought in Brazil During Summer and Fall 2001 and Associated Atmospheric Circulation Feature, Climanalise, 2(1). 1-10.

CEDEPLAR and FIOCRUZ (2008) Mudanças Climáticas, Migrações e Sáude: Cenários para o Nordeste Brasileiro, 2000-2050. Relatório de Pesquisa (Research Report): Belo Horizonte, CEDEPLAR/FICRUZ, Julho de 2008.

Cox, P., P. Harris, C., Huntingford, R, Betts, M. Collins, C. Jones, T. Jupp, J. Marengo, C. Nobre, (2008) Increase risk of Amazonian Drought due to decreasing aerosol pollution In Nature (London), 453, 212-216.

Christensen, J.H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr and P. Whetton, (2007a) Regional Climate Projections. In: Climate Change 2007: The Physical Science Basis. Chapter 11, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Dufek, A. S. ; Ambrizzi, T. (2007) Precipitation variability in Sao Paulo State, Brazil.. Theoretical and Applied Climatology, 1, 1-12..

Haylock M. R., T. Peterson J. R. Abreu de Sousa. L. Alves. T. Ambrizzi J. Baez, J. Barbosa de Brito, V. R. Barros, M. A. Berlato, M. Bidegain. G. Coronel, V. Corradi, T. Garcia, A. M. Grimm, R. Jaildo dos Anjos, D. Karoly, J. A. Marengo, M. B. Marino, P.R. Meira,G. C. Miranda. L. C. B. Molion, D.Muncunil, D. Nechet, G. Ontaneda, J. Quintana, E. Ramirez, E. Rebello, M. Rusticucci, J. L. Santos, I. T. Varillas, L. Vincent, and M. Yumiko (2006) Trends in total and extreme South American rainfall 1960-2000 and links with sea surface temperature. Journal of Climate, 19, 1490-1512.

Hogan, D.J. (2001) Demographic aspects of global environmental change: What is Brazil's contribution? Pp 15-41 in D.J. Hogan e M.T. Tolmasquim (eds.), *Human Dimensions of Global Environmental Change.* Rio de Janeiro, Academia Brasileira de Ciências, 2001.

Intergovernmental Panel on Climate Change IPCC (2007a) *Climate Change 2007: The Physical Science Basis Summary for Policymakers Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Cange,* 18 pp.

Intergovernmental Panel on Climate Change IPCC (2007b) *Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerabilit,y* Summary for Policymakers, 23 pp.

International Strategy for Disaster Reduction ISDR (2005) World Conference on Disaster Reduction, 18-22 January, 2005, Kobe, Hyogo, Japan. Hyogo Framework for Action 2005-2015: Building the resilience of nations and communities to disasters. 2005, 25 p.

Magrin, G.; Gay, C.; Cruz, D.; Giménez, J.C.; Moreno, A.R.; Nagy, G.J.; Nobre, C.; Villamizar, A.. Latin America. In: Parry, M.L.; Canziani, O.F.; Palutikof, J.P.; Van der Linden, P.J.; Hanson, C.E. (eds.). Climate Change (2007) Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC, Cambridge, UK: Cambridge University Press, Cambridge, p. 581-615, 2007

Marengo J. A., C. Nobre, J., Tomasella, M. Oyama, G. Sampaio, H., Camargo, L.Alves, R. Oliveira, (2008a) The drought of Amazonia in 2005, Journal of Climate. , 21, 495-516

Marengo J. A., C. Nobre, J. Tomasella, M. Cardoso, M Oyama. (2008b) Hydro-climatic and ecological behaviour of the drought of Amazonia in 2005. Philosophical Transactions of the Royal Society of London. Biological Sciences, 21, 1-6

Marengo J. A., R. Jones, L, Alves, M. Valverde, (2009) Future change of temperature and precipitation extremes in South America as derived from the PRECIS regional climate modeling system. International Journal of Climatology (In press)

Pezza, A. B. ; Simmonds, I. (2005) The first South Atlantic hurricane: Unprecedented blocking, low shear and climate change.. Geophysical Research Letters, v. 32, p. 10.1029/2005GL0, 2005.

Rusticucci, M and M. Barrucand (2004) Observed trends and changes in temperature extremes in Argentina. J Climate, 17, 4099-4107.

Schaeffer, R, A. S. Sklo, A. F. de Lucena, R. de Souza, B. R. Borba, I. da Costa, A. Junior, S. H. da Cunha (2008) Mudanças Climáticas e Segurança Energética no Brasil. COPPE-UFRJ, Rio de Janeiro, Junho 2008, 65

Stott, P.A., D.A. Stone, and M.R. Allen, (2004) Human contribution to the European heatwave of 2003. Nature, 432, 610-614.

Tebaldi, C., K. Haohow, J. Arblaster, G. Meehl, (2007) Going to Extremes. Am intercomparison of model-simulated historical and future changes in extreme events. Climatic Change, 79: 185-21.

Vincent, L.A., T.C. Peterson, V.R. Barros, M.B. Marino, M. Rusticucci, G. Carrasco, E. Ramirez, L.M. Alves, T. Ambrizzi, M.A. Berlato, A.M. Grimm, J.A. Marengo, L. Molion, D.F. Moncunill, E. Rebello, Y.M.T. Anunciação, J. Quintana, J.L. Santos, J. Baez, G. Coronel, J. Garcia, I. Trebejo, M. Bidegain, M.R. Haylock, D. Karoly, (2005) Observed trends in indices of daily temperature extremes in South America 1960-2000. Journal of Climate, 18, 5011-5023.

Zeng, N, Y.Yoon, Marengo, J, Subrmanaiam, A, C. Nobre, A. Mariotti, (2008) Causes and impacts of the 2005 Amazon drought, Environmental Research, 3, 1-6.