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Climate Change in the Agricultural Sector of Developing Countries: Mitigation, Adaptation, and Decision Making

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Abstract

The warming of the climate system is undeniable and evident from observations of increases in global air and ocean temperatures, as well as in melting of snow and ice, and rising global sea levels. Measures are needed to reverse the current trend of increased accumulation of greenhouse gases (GHG) in the atmosphere. The two main paths to reverse this trend are: (a) reducing GHG emissions through cleaner energy generation, and (b) removing CO_2 through carbon "sinks" or carbon sequestration. The agricultural and forestry sectors can play a key role in both paths. Carbon markets are being developed worldwide and will likely encourage actions in the agricultural sector that will lead to increased amounts of sequestered carbon and reduced emissions of GHG. However, the implementation of carbon-market oriented projects for small farmers in least developed countries still remains a major challenge.

Even under the most optimistic scenarios, adaptation is necessary to address the impacts of warming which is already unavoidable due to past emissions. Incorporating the issue of climate change into decision-making is complicated by the uncertainty levels associated with climate change scenarios. This incorporation is also challenged by a frequent "double conflict of scales": (a) the temporal scales of climate change scenarios are frequently much farther in the future than the ones needed for decision-making, and (b) the spatial scales of the climate scenarios (e.g., regional up to global) are much coarser than the ones often needed for actual decision-making (i.e., local level).

Introducing the issue of "climate change" into the policy and development agendas can be facilitated by considering the longer-term variations as part of the continuum of the total climate variability (seasons to decades to centuries), and generate information at the temporal scale that is relevant and applicable for particular time frames or planning horizons of the different decisions. This approach introduces "climate change" as a problem of the present as opposed to a problem of the future.

Incorporation of climate change in the planning agendas requires the engagement of stakeholders from the beginning of the research and development activities. Stakeholder engagement is also facilitated by developing "discussion-support tools" and by establishing participatory pilot studies.

Keywords: Stakeholders; Development agendas; Decision-making; Simulation models; Policy agendas.

The Climate System is Warming

Fossil fuel combustion and changes in the land use (including deforestation) have resulted in an annual rate of carbon dioxide (CO_2) accumulation in the atmosphere. The global atmospheric concentration of carbon dioxide has increased from about 280 ppm (pre-industrial) to 379 ppm in 2005. The current atmospheric concentration of carbon dioxide largely exceeds the natural range recorded over the last 650,000 years (180 to 300 ppm) as determined from ice cores (IPCC, 2007a).

The accumulation of CO_2 and other greenhouse gases is expected to cause observable climatic changes in the 21st century. The International Panel on Climate Change (IPCC) has been publishing assessment reports to governments since the early 1990's. The newest report, to be published in 2007, concludes that the global temperature in the last 100-150 years has increased 0.76 ± 0.19ºC (IPCC, 2007a). The report also concludes that the warming of the climate system is unequivocal, as is evident from observations of increases in global air and ocean temperatures, as well as in melting of snow and ice, and a rising global sea level (IPCC, 2007a; IPCC, 2007b). The Fourth

Assessment Report also includes several evidences of the impact that the observed global warming is having on biological processes affecting agriculture, forestry and human health.

The IPCC report finally includes possible scenarios of future climate that would greatly impair agricultural production throughout the world. Research conducted since the late 1980's cited all four of IPCC's assessment reports as showing that crop yields in several regions of the world could be severely reduced under warmer conditions due to shorter crop growing seasons and increased pest and disease pressure (see, for example, Parry et al., Rosenzweig and Iglesias, 1994, Baethgen and Magrin, 1995; Schneider et al., 2001). Moreover, agricultural systems that are already fragile under current climate conditions could become unsustainable under the expected scenarios (e.g., Northeast Brazil, the Sahel –Baethgen, 1997). Most of the studies conducted suggest that the most severe impacts on agriculture will be felt around the tropics where most of the least developed countries are located.

Possible Responses to Climate Warming in the Agricultural Sector: Mitigation

Even though it is still difficult to determine how much of the global warming can be attributed to human activity, there is overwhelming agreement that measures should be taken to reverse the current trend of increased accumulation of greenhouse gases (GHG) in the atmosphere. In the jargon of the scientific, technical, and policy communities working in the climate change arena, the actions oriented to reverse such trend is generally referred to as "Mitigation" of climate change. There are basically two paths to reverse the current trend of increased accumulation of GHG: (a) reducing GHG emissions through cleaner energy generation, and (b) removing CO_2 through carbon "sinks" or carbon sequestration.

The agricultural sector in both developed and developing countries can play a key role in helping to reverse the trend. Regarding the reduction of GHG, there is increasing interest and growing opportunities to generate energy utilizing biofuels originated in the agricultural and forestry sectors, and thus reducing the net emissions of GHG. Hence, several developing countries and some developed countries are investing considerable efforts to increase the generation of energy with crop-produced alcohol (e.g., sugar cane, sweet sorghum, maize), biodiesel produced with oil crops (e.g., soybean, sunflower), and with residues originated in the harvest of annual crops (e.g. rice husks) as well as in the forest harvest and forest industries (Baethgen and Martino, 2004). The observed increased interest in these alternative energy sources is probably rooted mainly in economical, financial and geopolitical advantages of reducing the countries' dependence on fossil fuels. However, this is clearly a path that could lead to dramatic reductions in net GHG global emissions and generate important new alternatives for the agricultural sector in the developing world. On the other hand, several researchers are expressing increased concern with possible unintended and negative consequences that the production of biofuels could have on increasing world food prices and affecting global food security.

A second possible path to reverse the current increased accumulation of GHG in the atmosphere is removing CO_2 from the atmosphere. Soil science research has produced evidence that agricultural lands have the potential for removing 40,000 - 80,000 million metric tones of carbon over the next 50 to 100 years (Kolshus, 2001; IPCC, 1992). Thus, soil carbon sequestration in agricultural lands alone might offset the effects of fossil fuel emissions and land use changes for 10-20 years or longer. Additional carbon can be sequestered in well-managed forests and grassland soils.

There is a clear role for the agricultural sector to help reduce the enhanced greenhouse effect by introducing agronomic practices that result in increased removal of carbon dioxide from the atmosphere. Carbon dioxide is one of the most important gases that enhance the greenhouse effect. It is produced when coal, oil, wood, and other carbon-based fuels are burned. Plants absorb carbon dioxide and through photosynthesis convert it into dry matter (food, fiber, wood). Carbon fixed by plants can remain in the form of wood for several years, and/or return to the soil as plant residues increasing the soil organic matter content. The enhanced carbon sequestration strategy in the agricultural sector cannot be viewed as the permanent solution for the GHG emission problem, but it can be an excellent option for "buying time" and allow for the development and global adoption of new, clean and safe energy sources.

Past and recent research has evidenced that reduction in atmospheric carbon dioxide content can be achieved by large-scale applications of land management practices. Among others: reduced/zero tillage, use of pastures (e.g., clovers, alfalfa) in rotation with annual crops, improved strategies to enhance fertilizer use efficiency, increased efficiency of animal feed and return of animal waste, and the establishment of forests and grasslands in former croplands and degraded soils. Most importantly, increasing sequestered carbon in the soil will provide additional benefits to farmers such as improvement in soil fertility, water holding capacity and tilth, as well as reduction in soil erosion.

Two other gases with greenhouse effect are also important in the agricultural sector: nitrous oxide (N_2O) and methane (CH_4). The importance of these gases derives from their warming potential which is much higher than that of the CO_2 (the global warming potential of methane is about 20 times higher, and that of nitrous oxide is 300 times higher than that corresponding to CO_2). Nitrous oxide is mainly produced through transformations in the soil of the nitrogen added as fertilizers and/or plant residues. Methane in the agricultural sector is mainly produced as a result of the enteric fermentation occurring in the digestion process of ruminants. A second important role of the agricultural sector contributing to reduce the greenhouse effect is therefore to reduce the emissions of these gases. Since the emission of both gases are the result of inefficiencies in the production system, a reduction of the emissions would also lead to better results for the farmers (higher nitrogen use efficiency, and more efficient conversion of animal feed into milk, meat and wool).

The International community has reacted to the increased evidences of global warming by signing the Kyoto Protocol (United Nations Framework Convention for Climate Change). The protocol introduced mechanisms to reduce the net greenhouse gas emissions. While Kyoto negotiations are stalled for the time being, the discussions in the UNFCCC have stimulated an impressive amount of activity all over the world, with the increasing involvement of governments, business people, and scientists. In contrast with the slow progress in government negotiations of the Kyoto Protocol, the results of these side-track activities have been impressive, giving shape to the development of an International carbon market (examples of functioning markets are evident in Australia, Denmark, the United Kingdom, and the USA, among others) (Baethgen and Martino, 2004).

The development of mature carbon markets will probably encourage the establishment of joint projects between industry and farmers which will lead the latter to adopt agronomic practices that will result in increased amounts of sequestered carbon and reduced emissions of GHG (such as N_2O and CH_4). This in turn will provide farmers with additional income as well as improve their production systems and natural resource base. On the other hand, it will allow the industry to reduce their net GHG emissions during the process of adopting cleaner processes and energy sources. Important challenges however remain for the implementation of carbon-market oriented projects in the least developed countries, given the potential difficulties for small farmers ("atomized" carbon offer) to take advantage of the existence of such projects.

The Need of the Agricultural Sector to Adapt to a Changing Climate

Even under the most optimistic scenarios of globally coordinated actions to drastically reduce the net emissions of GHG during the next decades, atmospheric science confirms that warming is already unavoidable due to past emissions. As indicated by IPCC's Fourth Assessment Report, even if the atmospheric GHG concentrations remain at 2000 levels, the inertia of past emissions is estimated to cause some unavoidable warming and consequent changes in climate. Accordingly, even under this unrealistically optimistic scenario, adaptation will be necessary to address the impacts resulting from the warming which is already unavoidable due to past emissions. More realistic scenarios of GHG emissions and atmospheric concentrations impose more aggressive needs of the different socioeconomic sectors, including the agricultural sector, to further develop adaptive strategies to the already changing climate. In fact, recent research included in the Fourth Assessment Report of the IPCC suggests that several adaptive measures are already ongoing in agricultural production systems throughout the world (IPCC, 2007b).

Climate Change Adaptation and Decision-Making in Agriculture: Uncertainties and Frequent Conflict of Scales

Decision makers (including those who develop policies) working in the public and private sectors of developing countries, typically confront the pressure to act in response to problems that require immediate action. Moreover, the effect of such actions must also be evident during the usually short terms in which those decision makers operate (typically 2-5 years, sometimes up to 10 years). Consequently, relatively lower priority is assigned to issues that deal with the long term, such as 50-100 years in the future.

On the other hand, very frequently the scientific community has been approaching the research on climate change and its impacts on societies by proposing climate scenarios expected for the next few decades (typically 50-100 years in the future). This research approach and the communicated results have been crucial to raise the awareness of the general public on the climate change issue in both developed and developing countries. The research outcomes and the resulting increased public awareness have also contributed to the current efforts that some developed countries are placing in stimulating the use of cleaner energy sources, promoting agronomic practices that enhance carbon sequestration and encouraging other actions oriented to reduce net GHG emissions.

At the same time, this research approach based almost exclusively in possible scenarios expected 50 to 100 years in the future has also placed the issue of Climate Change as a problem that will affect societies in the future and in a timeframe that is far beyond the one in which policy makers and decision makers operate. In addition, the possible scenarios of future climate (e.g. for global future temperatures) produced with the best available scientific methods include uncertainty levels that often impose further challenges to be considered in decision making and planning activities. These uncertainties are partially due to limitations of the scientific knowledge included in the climate models used to produce the scenarios. Uncertainties are also the result of assumptions on the characteristics of different socioeconomic scenarios used to estimate the GHG emission levels that drive the climate models. Thus the socioeconomic scenarios include a wide range of assumptions dealing with trade, energy sources, technology transfer, etc. for the next 50-100 years that inevitably embrace uncertainties (see for example Figure 1).

Uncertainties are larger for establishing possible scenarios of rainfall as compared to those of global temperatures, and even much larger for the climate scenarios at regional or local spatial scales (as opposed to a global scale) that are the ones typically needed for planning and decision making. With respect to the latter, some recent methods allow the downscaling of global model runs to regional or even local levels. However, it should be noted that these methods do not reduce the uncertainty levels associated with the global scenarios described above. Consequently, these downscaled climate change scenarios can possibly be viewed as scenarios with a higher level of detail of the same uncertainties.

The challenge of effectively incorporating the information resulting from the research in climate change into decision-making is thus complicated by the general uncertainty levels discussed above, as well as by a frequent "double conflict of scales". On the one hand the temporal scales of climate change scenarios are frequently much farther in the future than the ones needed for decision-making and planning. On the other hand the spatial scales of the climate scenarios that can be established with the currently best available tools and methods still have a much larger spatial scale (e.g., global up to regional) than the ones often needed for actual decision-making (i.e., local level). As a result climate change has yet to be effectively introduced in the agendas of decision makers (including policy makers), especially in developing countries.

An Alternative Approach: Considering Climate Variability at Different Scales Including "Climate Change"

The earth's climate system includes processes that cause variability at different temporal and spatial scales. Some processes are local and act in the short or immediate term (a few days) and cause the variability of "weather". Other processes are affected by the interaction of the atmosphere with the oceans and the land surface. Some of these processes result in variations of climate at the scale of months to seasons. Still other phenomena depend on natural and anthropogenic factors that affect the chemical composition of the atmosphere and cause variability of the climate at the scale of several decades to centuries. The latter includes the variability of climate that is commonly referred to as "climate change".

All of these processes act simultaneously and result in the observed earth's total climate variability. The magnitude of the climate variability at these different temporal scales is different. Figure 2 illustrates the typical difference in the magnitude of climate variability at different time scales. The figure was constructed by partitioning the total variability observed in winter (DJF) air temperature of an area in northeastern USA. Panel (a) shows the variability at the long-term (linear trend in the last 100 years). This is the scale that can be called "climate change". The second panel (b) shows the variations of temperature measured at the decadal scale, and reveals decades when winter temperatures tended to be warmer than average (e.g., the 1930's and the 1950's) and decades when the winter temperatures tended to be colder than average (e.g., the 1960's and 1970's). Finally, panel (c) shows the observed variability of winter temperatures in the year-to-year time scale. The figure also shows the relative magnitude of the variability at these three temporal scales as measured by the standard deviation. The magnitude of the short-term (interannual) variability is 4.5 times greater than the long-term variability ("climate change"), and about 2.5 times greater than the decadal variability.

A possible approach to introduce the issue of "climate change" into the policy and development agendas is to consider the longer-term variations as part of the continuum of the total climate variability, from seasons to decades to centuries, and generate information at the temporal scale that is relevant and applicable for the particular time frames or planning horizons of the different decisions (Baethgen et al., 2004).

This approach introduces "climate change" as a problem of the present (as opposed to a problem of the future) and aims to inform the decision-making, planning, and policy-making processes, in order to reduce the socioeconomic vulnerability to climate variability and change. Some research organizations such as the IRI (International Research Institute for Climate and Society) are focusing on this approach and calling it "Climate Risk Management", and it is generally aimed to enhance the "climate knowledge" of the target socioeconomic sector. Such enhanced "climate knowledge" is based on: (a) understanding climate variability and its sources, and assessing the socioeconomic impacts observed in the past, (b) monitoring the present conditions of relevant environmental factors (climate, vegetation, water, insect vector population, etc.), and (c) providing the best possible climate information for the future through probabilistic seasonal-to-interannual climate forecasts and plausible longer-term climate change scenarios.

Considering the long term ("climate change") scale, the IPCC's most recent report cites some ongoing actions for adaptation to future climate scenarios in sectors that require measures at that temporal scale. For example, the design of infrastructure projects for coastal defense in the Maldives and The Netherlands, the prevention of glacial lake outburst flooding in Nepal, and policies for water management in Australia (IPCC, 2007b). Another example that would require consideration of long term climate scenarios for developing adaptive measures is the water provision to cities that depend on glaciers (e.g., Lima, in Peru).

The slow and persistent drift of the mean climate forced by increasing GHGs, is producing noticeable changes in the mean climate upon which shorter-term variability is superimposed. Increasing GHGs may also change the magnitude of the short-term variability, for example, by enhancing the strength of the hydrological cycle. Changes in the mean state, the variability, or both, will alter the statistical distribution of climate and weather, and will likely result in more frequent extreme events that can have devastating socioeconomic impacts. Consequently, an effective manner for assisting stakeholders to be prepared and adapt to possible climate change scenarios is by assisting them to cope better with current climate variability. This requires the establishment of climate-related risk assessment and risk management strategies (as opposed to crisis management), including the identification of practices that are better adapted to cope with climate variability, as well as transferring risks associated to climate variability (e.g. with insurance programs).

An advantage of this approach is that it provides immediate assistance to the public and private sector: while it helps stakeholders to confront possible future climate scenarios, it identifies immediate actions needed to manage the climate variability that is currently affecting societies. Furthermore, the impacts of the taken actions are also evident and verifiable in the short term making them more attractive to policy makers and decision makers.

International agencies and development banks are increasingly adopting this approach as a means to effectively incorporate adaptive measures into policies and development plans. For example Mr. Warren Evans, Environment Director at the World Bank, addressing the Global Environmental Fund (GEF) Assembly in Cape Town (August, 2006, Cape Town) stated that: *"adaptation to climate risks needs to be treated as a major economic and social risk to national economies, not just as a long-term environment problem. By enhancing climate risk management, development institutions and their partner countries will be able to better address the growing risks from climate change and, at the same time, make current development investments more resilient to climate variability and extreme weather events."*

A key premise of this approach to adaptation to climate change is that improving year-to-year planning activities and decisions lead to societies that are better adapted to longer term climate change. However, there are situations in the different socioeconomic sectors where important issues require fundamentally different approaches and activities. Thus, several important decisions require information and climate projections at temporal scales of 10-30 years (e.g., transportation infrastructure projects, water reservoir design, long-term business plans, etc.). Therefore, focus is also needed on climate risk management work for adaptation to "near-term" climate change, i.e., 10-30 years. This "decadal climate variability" is still posing important scientific challenges and the climate science community is investing huge efforts in exploring ways to improve the ability to predict it. In the meantime much can be gained by interpreting and characterizing the decadal trends in the observed historic records and on methods for producing seasonal forecasts under a changing climatic baseline (as opposed to the "static" baseline).

Involving Stakeholders

A common limitation of the research oriented to establish climate-related risk assessment and risk management strategies is that stakeholders are incorporated after the objectives have been defined and activities have been initiated. A crucial lesson learned in the work on adaptation to climate change and climate variability is that stakeholders must be engaged at the very start of the project development. Objectives, expected outcomes, target groups, methodologies, and communication strategies must be discussed and defined in a participatory process that must include both researchers and stakeholders.

Successful stakeholder engagement is also facilitated by developing sets of "discussion-support tools" (linking simulation models, climate scenarios, decision support systems) that can be used to jointly explore options for reducing the impacts of expected climate change and climate variability scenarios with government advisors, policy makers, and in general with decision makers acting in the public and private sectors of society. Finally, stakeholder engagement can also be promoted and strengthened by establishing participatory pilot studies to, for example: (a) demonstrate the ability of the mentioned "discussion-support tools" for exploring adaptive measures, and (b) study the potential of policies and financial tools (such as insurance programs and conditioned credit programs) to improve adaptation and reduce the social vulnerability to climate change.

Summary and Final Comments

The warming of the climate system is undeniable and evident from observations of increase in global air and ocean temperatures, as well as in melting of snow and ice, and rising global sea level.

Measures are needed to reverse the current trend of increased accumulation of greenhouse gases (GHG) in the atmosphere. The two main paths to reverse this trend are: (a) reducing GHG emissions through cleaner energy generation, and (b) removing CO_2 through carbon "sinks" or carbon sequestration. The agricultural and forestry sectors can play a key role in both paths. Carbon markets are being developed worldwide and will likely encourage actions in the agricultural sector that will lead to increased amounts of sequestered carbon and reduced emissions of GHG. However, the implementation of carbon-market oriented projects for small farmers in least developed countries still remains a major challenge.

Even under the most optimistic scenarios, adaptation is necessary to address the impact of the warming which is already unavoidable due to past emissions. Effectively incorporating the issue of climate change into decision-making is complicated by the uncertainty levels associated with climate change scenarios. It is also challenged by a frequent "double conflict of scales": (a) the temporal scales of climate change scenarios are frequently much farther in the future than the ones needed for decision-making and planning, and (b) the spatial scales of the climate scenarios (e.g., regional up to global) are much coarser than the ones often needed for actual decision-making (i.e., local level).

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Effective incorporation of climate change in the planning agendas requires the engagement of stakeholders from the very start of the research and development activities. Successful stakeholder engagement is also facilitated by developing sets of "discussion-support tools" (linking simulation models, climate scenarios, decision support systems) and by establishing participatory pilot studies.

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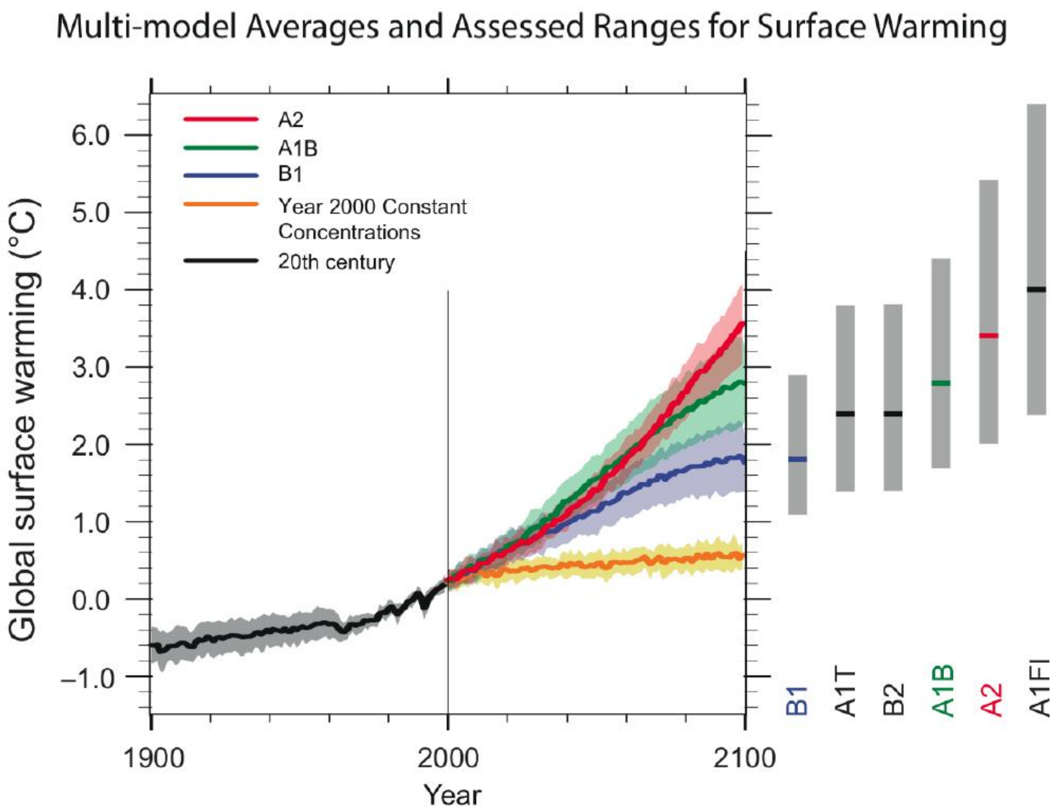

Figure 1: Observed (black line) and projected global surface temperature for different socioeconomic scenarios (B1, A1T, B2, A1B, A2, A1FI) as published in IPCC's Fourth Assessment Report.

(a)

(b)

(c)

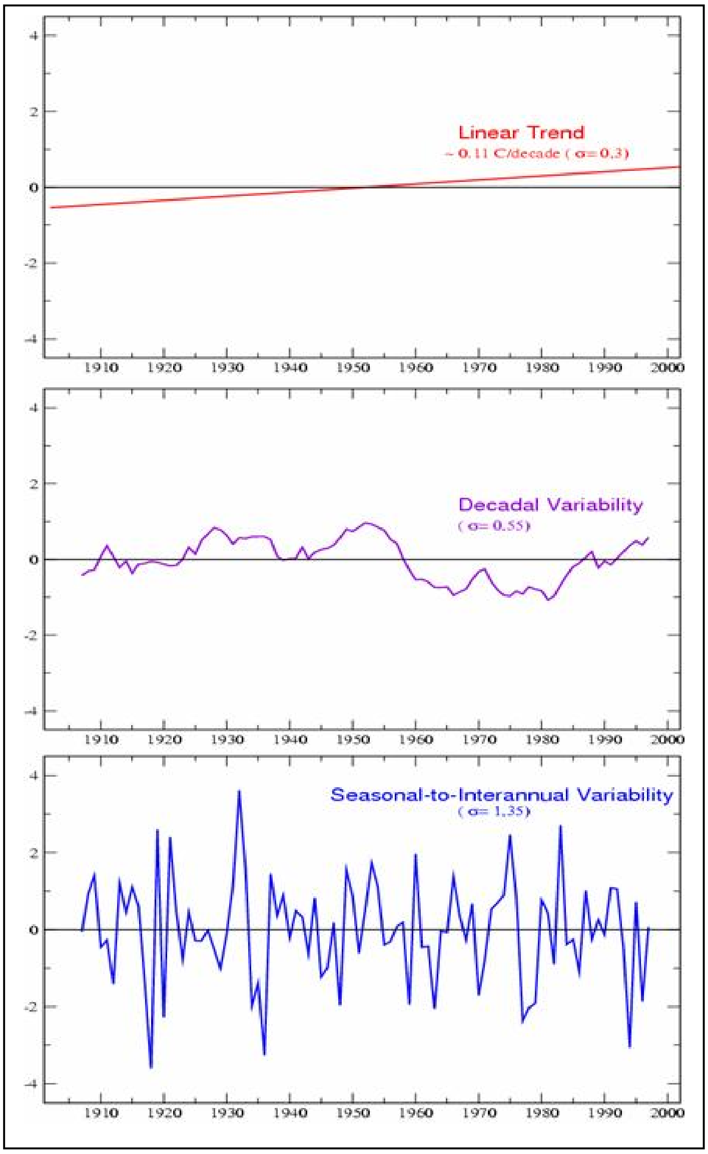

Figure 2: Partition of the total observed climate variability in northeastern USA into: (a) long-term variability (linear trend), (b) decadal variability, and (c) inter-annual variability.

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