Implications of Climate Change for China

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THE GREENHOUSE EFFECT

Greenhouse gases

The total global carbon emission is currently about 6 billion tonnes annually. One quarter of the emission is generated by North America, and China is responsible for up to 11% of the total amount. There is a large variation between the countries in growth rate of emission. The emission differences between the regions reflect differences in economic development, energy use efficiency, and population growth rate. The highest emission growth rate is 4.9% per year for Asia, followed by 4.1% for Africa and then 3.5% for Central and South America. The growth rate among the Asian countries are: 1.6% for Japan, 6% - 6.5% for China, India and Malaysia, and 7.5% to 8% for Bangladesh, S.Korea, and Indonesia.

Although Japan has the lowest growth rate, it also has the highest per capita emission rate, at 2.2 tons of carbon per person per year. Chinese emits 0.6 tons per person per year which is much less than the world average 1.1 tonnes.

There is some uncertainty regarding the sources of the increase in methane and nitrous oxide. Some methane comes from organic matter decomposition of rice paddy (15%), ruminant digestion (8%), and fossil fuel extraction and combustion (20-30%). N_2O comes with the use of chemical fertilizers since the 1940s. Halocarbons, notably CFCs, are a recent artificial addition to atmosphere. They are used as refrigerator coolants, aerosol propellants, solvents and blowing agents for foam packaging and other products. These compounds are also linked with ozone depletion.

Evidence of warming

The six warmest years have all occurred since 1980 and the single warmest year for the last century was 1990. Overall the world has warmed by about 0.5°C since the late 19th century. A similar pattern of change has occurred over East Asia. The

mean temperature has increased nearly 1°C there. Again, 1990 was the warmest year on record for East Asia. The correlation between the east Asia region and China was 0.95, which represents a high degree of agreement in the temperature trends between these regions.

CHANGES IN THE FUTURE

Future greenhouse gas emission assumptions

There is considerable uncertainty regarding future concentrations of the greenhouse gases. Uncertainties arise because of: (a) gaps in scientific knowledge concerning the source, sink and fluxes of major gases within the biogeochemical cycles of the planet; (b) difficulties in predicting the future patterns of energy production, agriculture and forest management; (c) unpredictability in policies and new inventions to reduce greenhouse gases emissions.

One scenario was proposed by the IPCC (Intergovernmental Panel on Climate Change) in 1992. This scenario makes certain key assumptions about population and economic growth. Rates of emissions of the gases are calculated based on the population and gross national product (GNP) increase rates. The predicted highest %GNP and %emission increases will occur in China and other centrally planned Asian countries and other developing countries.

General circulation models (GCM)

There are about a dozen major GCM modeling groups in the world. These models partition the earth's climate system into many grid boxes in both horizontal and verticle dimensions. GCMs attempt to model the physical processes of climate by solving a series of fundamental equations describing the conversion of momentum, mass, moisture and energy at each grid box for finite time steps. Feedback processes included are changes of ice and snow extension, clouds, water vapor, CO_2-fertilization, ozone depletion, and sulphate aerosol forcing. Many of these processes are poorly understood and specified, which add to uncertainties of the simulation. The sensitivity of the climate to changes in greenhouse gases can be estimated by GCMs. Results depend on the model. Current consensus is that the world should warm by between 1.5 and 4.5°C when CO_2 is doubled. Based on an IPCC scenario of future gas emissions, the temperature would increase by 0.8 - 1.8°C in 2050 and by 1.6 - 3.8°C in 2100.

IMPLICATIONS FOR CHINA

Introduction to China

China is one of the largest countries in the world with an area of about 9.6 million km^2 and a population of 1.2 billion. China is well endowed with natural resources. Rich mineral deposits are found throughout the country, good water resources occur in southern China, and abundant potential solar and wind resources are available in northwest China. The country also possesses a high diversity of wind, and rare and valuable animal and plant species.

The topography of China is complex. Conventionally, China is divided into three topographical units: the Qinghai-Xizang Plateau in the far west; the central plateau; and the hilly areas and plains of the east. Of the total land area, 10% is cropland, 34% permanent meadows and pastures, 14% forest and woodland, 4% water, 13% Desert and wasteland, 25% mountain and other types. Due largely to these topographic divisions, three natural vegetation (ecosystem) and agricultural planning regions are created, namely, the high and cold Qinghai-Xizhang Plateau, the arid northwest, and the east monsoon region. The Qinghai-xizhang Plateau with its high altitude (more than 3000 m above the sea level) and cold climate forms a distinct ecosystem. About 67% of the plateau is natural pasture and much of the vegetation is shrub steppe and meadow with only limited forest areas. Animal husbandry is the most important aspect of agriculture in this region. The arid northwest region has abundant sunshine but little precipitation due partly to its distance from the oceans. Vast areas of steppe and semi-steppe cover much of this region with only very localized areas of irrigated farming. Animal husbandry is again very significant here. The warmer and moister climate of the eastern monsoon region is very favorable for a wide range of agricultural practices. About 80% of this region is arable farming land and the vast majority of China's agricultural wealth originates here.

About 50% of the arable land in China is for cereal crop production. The production and yield has doubled in the last 20 years, from a 2t/ha to 4t/ha average yield. In the same period, the fertilizer consumption increased by 700%, and irrigated land expanded by 27%. Year to year variation in cereal production is mainly influenced by weather variation. Animal husbandry is also increasingly important: the number of cattle increased 30%, sheep and goats 24%, pig 79% and horses 53%.

China ranked third in the world for primary energy production and consumption (which was about 8% of the world consumption, behind the USA - 25% and Confederation of Independent States - 17%) in 1987. On a per capita basis, China ranked 80th in the world and was less than half of the world average.

In view of the size of China's population, the sensitivity for her economy to

climate, and its contribution to global greenhouse gases emission, it is important to understand the possible impact of climate change on China's economy and policies.

Climate scenarios for China

Results of seven GCMs (UKMO-L, UKMO-H, GFDL,GISS,OSU,LLNL and MPI) were used to develop regional scenarios of climatic change for China and East Asia. Results were interpolated to the same spatial resolution and the changes were standardized by the respective global mean warming predictions of each model. These standardized GCM changes were then averaged to form a composite GCM Scenario.

By combining the projected mean global warming for the IPCC emission scenario with the composite GCM regional estimates, it is possible to generate for any given year between 1990 and 2100 a best estimate of monthly temperature and precipitation changes for China. Some regional changes for winter and summer seasons in 2050 are:

For temperature:

Winter:	Northeast	+1.5° C
	Other Parts	+1.0 to +1.5° C
Summer:	Northwest	+1.5° C
	Other	+0.7 to 1.0° C
Annual:	Northwest	> +1.5° C
	Southeast	<1.0° C
	Other	1.0 to 1.5° C

For precipitation:

Winter	between -4.8% to +14.3%
Summer	between -5% to +10.6%
Annual	between -1.4% to +8.1%
	mostly increasing

Impact on natural ecosystem

The principal feature of the Chinese natural ecosystem are described below.

The northern region is dominated by the cold-temperate coniferous forests. Southward, as temperature increases, this gradually turns into temperate deciduous broadleaved forests, succeeded further south by tropical evergreen broadleaved forests. The most southerly region (Hainan Island) is dominated by tropical rainforests.

From east to west, vegetation patterns reflect a moisture gradient. The eastern regions are dominated by forests, which gradually change as one moves westward into the grassland steppes (inner Mongolia) and then into temperate deserts (Xinjiang region). The southwest region, the Qinghai-Xizhang Plateau, is dominated by tundra vegetation, typical of alpine environments.

There would be significant shifts between the different vegetation types in China by 2050. For example Tibetan alpine vegetation would decrease in extension and the area of tropical and monsoon rainforest would increase substantially in the south. The cold temperate coniferous forest in the northeast would disappear almost completely and the temperate mixed coniferous and broadleaved forests would also decrease significantly. Xinjiang is becoming hotter and dryer and the temperate desert and steppe of today will likely be replaced by a warm tropical desert. Livestock production could be much more difficult there.

The above described changes can be considered only as potential shifts. The vegetation may not be able to respond as rapidly as the climate change. Furthermore, the mechanisms by which geographic shifts in vegetation take place are complex. Changes in temperature and precipitation will alter the hydrological cycle, which influences runoff and moisture availability, patterns of sedimentation and erosion, and the recycling of organic matter and nutrients. These, in turn will influence plant productivity, competition between species, biodiversity, and the distribution and/or intensity of pest and disease. The actual vegetation response could differ markedly from the model predictions.

Impact on agricultural systems

The effects of greenhouse-gas related climate change on crop yield in China would be positive in some regions and negative in others.

The likely effect on crop yield in some central and southern region of China would probably be negative. Reasons are: (a) higher rates of evaporation offset fully any increase in precipitation and the improved water use efficiency; (b) incidence of extreme droughts for heat waves would probably rise; (c) photosynthesis is characterized by an optimal temperature range, while respiration continues to increase exponentially with increasing temperature. Rapid climate change is likely to upset the photosynthesis and increase respiration which would result in yield reduction; (d) higher temperature accelerates phase development; if occurs during critical stage, it would reduce yield. In northeast China where low temperature often prevents maturation or causes crop failure, there may be benefits from the warming.

Temperature change will also have a significant impact on the cropping systems

in China. Successful ripening of crops within different cropping systems depends mainly on the duration and intensity of the warm period throughout each growing season. A common index for these phenomena is the Active Accumulated Temperature (AAT), which is the sum of daily temperatures above a given threshold temperature. The threshold is defined as 0°C in this study. The AAT values 4000 and 5800 are significant in distinguishing between the single, double, and triple cropping systems with one, two and three different harvests respectively. Based on the AAT values, the potential changes in cropping systems projected by the composite GCM scenario in the year 2050 can be estimated. Large changes occur almost everywhere in China. The most significant changes occur in eastern China. The warmer climate causes large parts of the present double cropping area to be replaced by the different triple cropping systems, while the current double cropping area would shift northward towards the central part of the current single cropping area. These shifts leads to a significant decrease in the extent of a single cropping region.

To a certain extent it seems that climatic warming would be favorable for Chinese agriculture. However, the major crop that is cultivated in the multiple cropping system is rice and its growth requires a great volume of water. Unfortunately, by 2050 the net balance of precipitation and evapo-transpiration would be negative and less water would be available than there is today. Water will be the key limiting factor for future agriculture in China.

Impact on energy demand

A warmer China should reduce energy used for heating which in northern China is currently required from Oct. or Nov. until March. The change in "Heating Degree Days" (HDD) by the year 2050 can be calculated. HDD is the sum of the number of degrees below 12°C, for the days considered. The decrease in HDD is greatest over northern and central China where the decrease of 300 to 500 HDD represents about a 15% reduction. This reduction should lower energy consumption in these regions and hence lower CO_2 emissions as well.

Conversely, energy use for cooling, currently required between May and September may increase. The increase in Cooling Degree days (CDD) for the year 2050 provides a measure of energy requirement for cooling. In this case the CDD is the number of degrees per day above 25°C accumulated over all days when the mean temperature exceeds 25°C. An increase of 40% - 80% in CDD is expected in southeast and southwest China. In this case, the warming would increase energy use in China.

With a rapid economic growth (about 6-10% for the last decade), the use of energy for transportation has also been quickly increased. The number of vehicles

(cars, tractors etc.), although small on the basis of per capita, has a growth rate which is by far the fastest in the world since 1980. Other household electrical utilities such as refrigerator, washer, TV, motorcycles etc are all becoming popular.

Overall, the energy use in China will likely increase in future and will be exacerbated by the increased temperature due to climate change.

IMPLICATIONS FOR POLICY

There are many uncertainties surrounding the scale of the future greenhouse effect and its implications for China and other nations. These uncertainties challenge scientific communities to work closely and collaboratively in a scale that has never been required before: across boundaries of disciplines, agencies, and nations. Two conclusions, however, can be drawn.

First, despite the different assumptions behind the emissions scenarios and the rapidly diverging rates of CO_2 emissions, over the next few decades, there are only small differences in projected global warming rates. And the projected warming to about 2050 (+0.8 to +1.8 °C) is relatively insensitive to changes in global economic activity, or policy initiatives, which may be undertaken now.

Second, global warming under different scenarios begins to diverge substantially by the second half of the next century. The predictions ranged between +1.6 to +3.8 ^{0}C temperature increase. This discrepancy presents an opportunity for reducing the rate of global warming by the end of the next century if appropriate preventive measures can be implemented over the next few years.

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