Interdisciplinary Research of Carbon and Water Cycles in the Terrestrial Ecosystems of China: Linking Multi-Scale Remotely Sensed Data, Field Observations and Biogeochemistry Models

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BACKGROUND, OBJECTIVES AND APPROACHES:

For millennia, Chinese people have altered the landscape in many ways in pursuit of food, fuel and fiber. China's expanding economy, which is the fastest growing in the world along with continued population growth, will lead to continued land transformations in the next decades, including dramatic urbanization. While we have a qualitative sense that land transformations and other environmental stresses across China have affected and will continue to affect the ability of China's ecosystems to provide people with essential goods and services through influencing carbon and water cycling, OUR CHALLENGE NOW IS TO QUANTIFY EXACTLY HOW CARBON AND WATER CYCLES HAS CHANGED AND WHAT MECHANISMS HAVE HAD MAJOR EFFECTS ON THESE CHANGES.

Therefore, the overall objective of this study is to quantify spatial and temporal patterns of carbon and water cycles and their underlying mechanisms in China. Our study is organized by two linked questions:

Q1 – How have carbon and water cycles changed in China in the past decades?

Q2 – What mechanisms have had major effects on changes in carbon and water cycles? We will consider the relative roles of: (a) climate variability, (b) changes in land cover and use, (c) changes in fire disturbance, (d) changes in the chemistry of precipitation (particularly nitrogen), and (e) changes in the composition of the atmosphere (carbon dioxide, ozone).

Our approach is to combine remote-sensing data (MODIS, AVHRR, Landsat-TM/ETM) and a set of biogeochemical simulation models (TEM, Biome-BGC and DLEM) to quantify the consequences of land transformations and other environmental changes on productivity, carbon sequestration and water yield in forests and other "natural" ecosystems in China.

Multiple Environmental Stresses

1. Large-scale Land Transformation

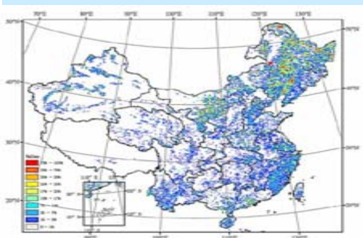

Fig. 1 Intensity of land transformation across China. With high resolution (30m) imagery from Landsat TM/ETM for the entire country, we show that between 1990 and 2000 the cropland area increased by 2.99 million hectares and urban areas increased by 0.82 million hectares. Documentation of these changes in a reliable and spatially explicit way forms the foundation for management of China's environment over the coming decades.

2. Climate Change

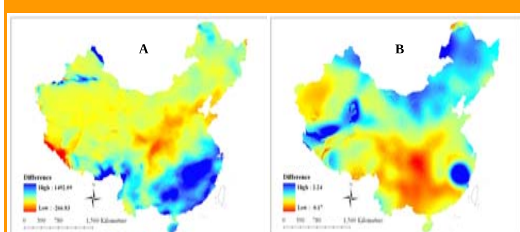

Fig. 2 Precipitation (A) and temperature (B) anomalies for 1990s (relative to long-term mean 1961-1990). Air temperature increases 0.21 °C per decade in the entire China from 1961 to 2000, while precipitation increases 5.88 mm (3.8% increase) per decade. In the same time period, the global average precipitation and temperature only increased 0.05-1.0% and about 0.1 °C per decade, respectively, which means that China has experienced faster climate change than global average. Precipitation and temperature change different for each climate zone in China. Precipitation decreases in the frigid highlands zone (-2.0 mm per decade) and warm temperate zone (-16.4 mm per decade), while it increases the fastest in tropical & subtropical zone (20.67 mm per decade).

2. Air Pollution and Nitrogen Deposition

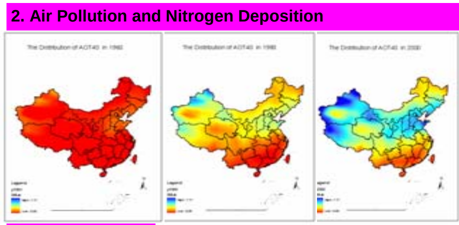

Fig. 3 The distribution of AOT40 in 1960,1980 and 2000 in China based on model results (Felzer et al. 2005)

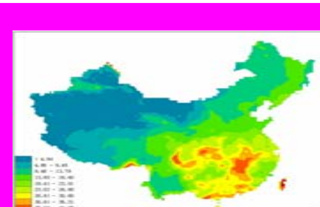

Fig. 4 Spatial patterns of nitrogen deposition across China (unit: kg N/ha/year)

Modeled and observed results indicated that China's tropospheric ozone concentration has been increased significantly (Chameides, et al. 1999). China's emissions of ozone precursors are expected to be doubled in the next 20 years (Aunan, et al. 2000). Evidence indicates that more than 90% terrestrial plants can be affected by ozone pollution (Adams et al., 1986). On the other hand, across China the total deposition rate on average was 13.62 kg N·ha^{-1}·yr^{-1}, and the total deposition fluxes summed to 12.96 Tg N per year. the total deposition rates of wet and dry deposition peaked over the central south China, with maximum values of 70.45 kg N·ha^{-1}·yr^{-1}, while the western China were characterized by fluxes less than 14 kg N·ha^{-1}·yr^{-1} (Fig. 4).

Impact of multiple environmental stresses on the carbon cycle:

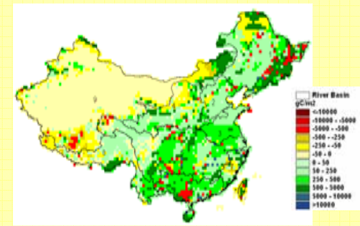

Fig. 5 Net C exchange between the atmosphere and terrestrial ecosystems during 1981-2000.

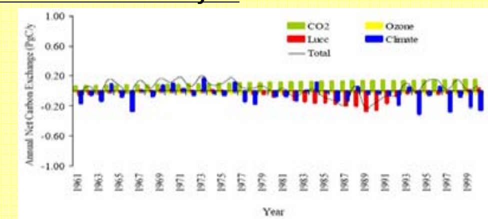

Fig. 6 Relative contribution of CO_2, O_3, climate and land use to net carbon exchange (NCE) (PgC year^{-1})

For the period of 1981-2000, simulated results with DLEM indicate that China's land ecosystems acted as small carbon sink. Net carbon storage between the terrestrial ecosystems and the atmosphere shows substantial spatial variations across the China (Fig. 5). Interannual variations in net carbon storage were primarily caused by climate variability; the effect of CO_2 fertilization was primarily responsible for the increase in carbon storage in China's terrestrial ecosystems (Fig. 6). Land-use change in China during 1661-2000 led to carbon loss of 14.5 PgC from land ecosystems (Fig. 7).

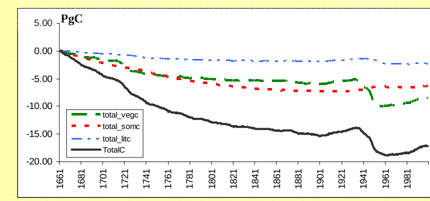

Fig. 7 Change in carbon storage during 1661-2000 (Unit: PgC)

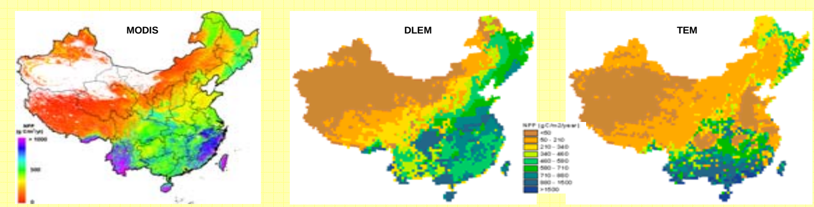

Fig. 8 Annual NPP as estimated by three models (MODIS-NPP, DLEM and TEM). Both MODIS-NPP and TEM underestimated NPP in cropland. In DLEM simulation, we have taken into account effect of irrigation and fertilization on crop productivity.

Impact of multiple environmental stresses on the water cycle:

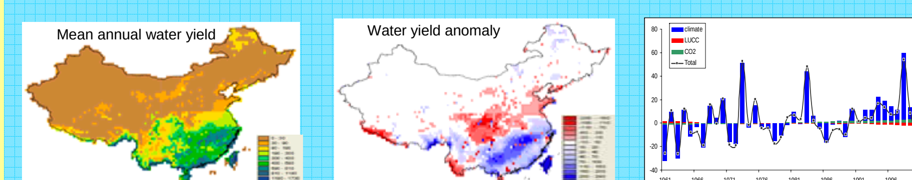

Fig.9 Mean annual water yield during 1961-2000 (A) and water yield anomaly in the 1990s (B) and relative role of climate, land use, CO_2 on historical change in water yield (mm/year)

According to DLEM results, the distribution of China's water yield shows substantially spatial variability with the highest water yield in southern China. **W**ater yield for the entire nation increased slightly during 1961-2000. In 1990s. water yield depth is 128 mm (millimeter), which is 12% more than that in the 1960s. Southeast China shows an increase in water yield, but North and Central China show a decrease since the 1960s. Total water yield in China is about 20% of total precipitation. Climate variability especially precipitation is the primary factor that controls the magnitude, spatial and temporal patterns of water yield. Our analysis indicates that climate variability caused an increase trend in water yield (5 mm per decades). Increasing atmospheric CO_2 also led to a slight increase in water yield (about 1 mm per decade). However, land-use change led to a decrease of about 5 mm during 1961-2000.

ACKNOWLEDGMENTS: This study is supported by NASA Interdisciplinary Science Program (NNG04GM39C).