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Atmospheric-hydrological modeling of severe precipitation and floods in the Huaihe River Basin, China

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Summary Our study focuses on the simulation of heavy precipitation and floods over the Huaihe River Basin (270,000 km^2), one of the seven major river basins in China. The simulation covers two periods in 1998 (June 28–July 3, July 28–August 17) and a third period in 2003 (June 26–July 22). The former two periods, with eight meteorological cases each of duration 72-h, correspond to the Intensive Observation Period of HUBEX/MAGE (Huaihe River Basin Experiment/Monsoon Asian GEWEX Experiment). The period in 2003 with 10 cases is the second most severe flooding event on record. The Canadian atmospheric Mesoscale Compressible Community Model (MC2) is used for precipitation simulation in the hindcast mode for all cases. The Chinese Xinanjiang hydrological model driven by either rain gauge or MC2 precipitation is used to simulate hydrographs at the outlet of the Shiguanhe sub-basin (5930 km^2), part of the Huaihe River Basin. The MC2 precipitation is also evaluated using observations from rain gauges. Over the Huaihe River Basin, MC2 generally overestimates the basin-averaged precipitation. Three of the eight 1998 cases have a percentage error less than 50% with the fourth having an error of 54%, while six of the ten 2003 cases have errors less than 50%. The precipitation over five different sub-regions and the Shiguanhe sub-basin of the Huaihe River Basin from MC2 are also compared with values from the Chinese operational weather prediction model; the latter data are only available for the ten 2003 cases. An excellent result is obtained in the hydrological

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simulation using rain gauge precipitation as revealed by the Nash—Sutcliffe coefficients of 0.91 for both summers of 1998 and 2003. The simulation using MC2 precipitation shows a reasonable agreement of flood timing and peak discharges with Nash—Sutcliffe coefficients of 0.63 and 0.87 for the two 1998 periods, and 0.60 for 2003. The encouraging results demonstrate the potential of using mesoscale model precipitation for flood forecast, which provides a longer lead time compared to traditional methods such as those based on rain gauges, statistical forecast or radar nowcasts.

Introduction

Severe floods caused by heavy precipitation have posed a serious problem for China in the past and continue to do so. The ''1949—1995 Chinese Disaster Report'' (National Bureau of Statistics of China, 1995) listed floods and droughts as being responsible for 71% of the country's natural disasters in terms of financial cost. The statistics in damage and lives lost are staggering. The Yangtze River flood in 1931 caused 3.7 million deaths with 28% of the country's farmland flooded. The 1975 flood in the Huaihe River Basin led to 26,000 deaths, with one million people affected and the collapse of two big reservoirs and 60 smaller ones. A quarter of China's troops were mobilized for the 1998 great Yangtze River flood that resulted in $US32 billion loss and 4150 deaths. Heavy precipitation is responsible for up to 80% of China's floods.

Flood fatalities and damages can be mitigated by improved structural and non-structural measures. An accurate and timely flood warning system is vital as a non-structural measure for minimizing flood damage. The ongoing Chinese National Flood Control and Command System project (Mo and Zhang, 1998) has identified as a key aspect quantitative precipitation forecast (QPF) using means other than rain gauges. The focus is on achieving the longest forecast lead time of heavy precipitation and subsequent flooding. High resolution limited area atmospheric models offer promising QPF potential. Recent work on the coupling of these models to hydrological models has shown model precipitation can be used to drive hydrological models to produce hydrographs at selected outlets. The lead time can thus be extended over traditional methods such as those based on rain gauges, statistical forecast or radar nowcasts.

This study focuses on the simulation of heavy precipitation and floods over the Huaihe River Basin and its Shiguanhe sub-basin (Fig. 1). The former is one of seven major river basins in China, and is located between the Yellow and Yangtze Rivers, with an area of 270,000 km^2. This region has China's highest population density (662 persons per km^2) and 17% of the country's cultivated land, and is thus of great socio-economic importance. Climatologically, it lies in the warm temperature semi-humid monsoon region, which is a transition zone between the climates of North and South China. Precipitation mainly occurs in the period from mid-May to mid-October, with a history of flooding over many centuries. Anomalies associated with the Meiyu rain season, which is in turn influenced by the South Asian monsoon, often cause basin wide flooding. The Huaihe River Basin is also the study site for the China GEWEX projects HUBEX (Huaihe River Basin Experiment) and MAGE (Monsoon Asian GEWEX Experiment). Data from two periods will be used for model validation: the 1998 May to August Intensive Observation

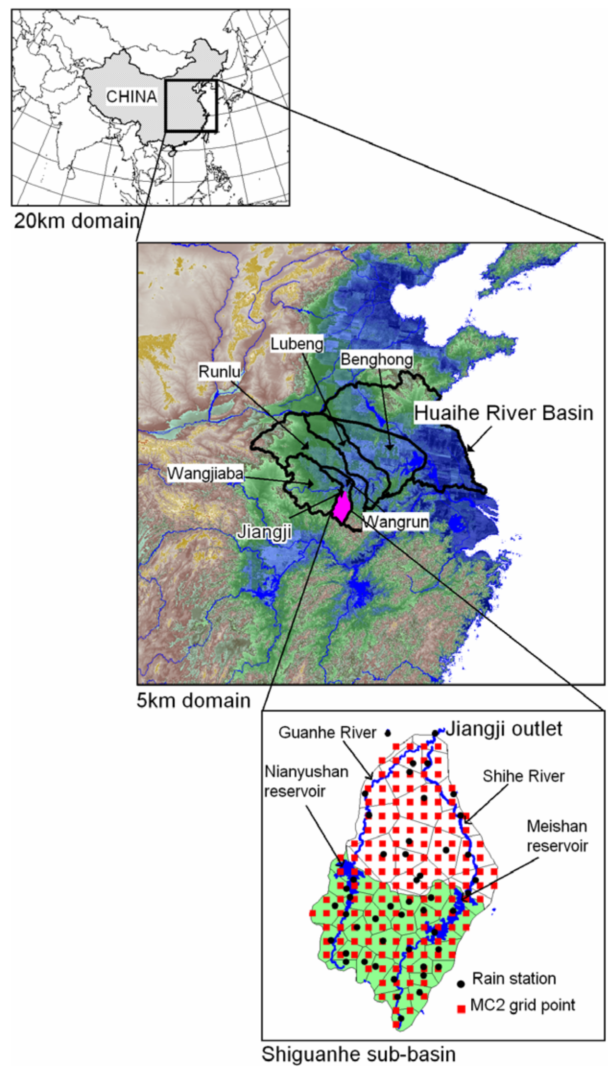

Figure 1 The top panel shows the 20-km MC2 model domain. The middle panel shows the 5-km domain, which includes the study area of the Huaihe River Basin (270,000 km^2) covered by 213 rain gauges and five sub-regions of the basin. The bottom panel shows the Shiguanhe sub-basin (5930 km^2) with Meishan and Nianyushan reservoirs and the Jiangji outlet identified. The delineation of the sub-basin using Theissen polygons, and the 48 rain gauge locations and model grid points are also shown.