Preface to the Special Issue on the "Observation, Prediction and Analysis of severe Convection of China" (OPACC) National "973" Project

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China is a country that is frequently affected by severe convective weather. Here, severe convective weather mainly refers to intense local heavy precipitation, thunderstorm-induced gale-force winds including those from tornadoes and downbursts, and hail and lightning. These types of severe weather are usually small in spatial scale and rapid in their development, and are therefore difficult to capture by observational networks and are poorly resolved in typical operational numerical weather prediction (NWP) models. Furthermore, many of the important dynamic and physical processes involved are not well understood. Within China, the impacts of severe convective weather rank only after those of landfalling typhoons and widespread heavy precipitation and flooding. Studies (e.g., Zhang and Zhai, 2011) have shown tendencies for an increased frequency in short-duration extreme precipitation during the past several decades over most of eastern China, where the population is most dense. An in-depth understanding of severe convective weather in China, as well as being able to accurately predict it, is clearly of great importance.

For historical and technical reasons, severe weather research in China has focused mainly on widespread flood-inducing heavy precipitation systems and events (as well as landfalling typhoons). Past major national-level research projects in China have mostly focused on the meso-α and meso-β scales. Severe convective weather occurs mostly at the even smaller meso-γ scale, as well as within organized meso-β scale convective systems. To study meso-γ scale weather, Doppler weather radar is the most important and essential observational tool.

In the past decade, rapid progress has been made in establishing modern, integrated meteorological observation systems in China (Li and Li, 2008). The operational weather radar network of the Chinese Meteorological Administration currently has over 180 Doppler radars, and will eventually be expanded to 216. A number of mobile research radars has also become available, paving the way for systematic research on convective weather in China. Through a competitive process, a project called "Observation, Prediction and Analysis of severe Convection of China" (OPACC) was funded by the Ministry of Science and Technology of China through a 5-year "973" Fundamental Research Program, with a total funding level of over $5 million. The project involves eight institutions: Nanjing University (the lead organization), Peking University, the Institute of Atmospheric Physics, the National Meteorological Center, the Nanjing University of Information Science and Technology, Lanzhou University, Zhejiang University, and the Beijing Institute of Urban Meteorology. The project includes 30 core scientists, with the current author serving as the principal investigator. OPACC emphasizes effective utilization of high-resolution, modern operational observing networks, as well as special experimental observing facilities including polarimetric Doppler radars during intensive observing periods (IOPs). The primary goals of the project include the understanding of the dynamic, thermodynamic and microphysical processes within specific types of mesoscale convective systems of China, and the physical mechanisms leading to severe damage. Developing new data assimilation and prediction capabilities for severe convective weather is also an important goal.

The project officially started in January 2013. As of the end of 2015, the project team had published 224 journal papers, including 108 in SCI/SCI-E journals. In June and July of 2013 and 2014, about 20 total number of IOPs were carried out, focusing on the lower Yangtze River and Huaihe River basin regions in Jiangsu and Anhui provinces. In the summer months, experimental real-time 48-h forecasts at 4-km grid spacing are also produced over the whole of continental China, for research and forecasting evaluation purposes. Journal papers published using the special field campaign data include Wen et al. (2016) and Wang et al. (2016a). Information on the OPACC project, together with its field data collection campaigns and real-time forecasts can be found at http://scw973.nju.edu.cn/.

To promote the publication of research results from OPACC, a special issue of *Advances in Atmospheric Sciences* has been organized, with the papers split between Part I (this issue) and Part II (next issue). These papers provide an insight into some of the research results supported by OPACC. The papers cover extreme precipitation and convection climatology (Zheng et al., 2016; Yang et al., 2016), orographic convective initiation (Wang et al., 2016b; Zhang et al., 2016), ensemble prediction of extreme rainfall (Zhu and Xue, 2016), ensemble forecasting system design and methodology (Li et al., 2016a; Deng et al., 2016), the parameterization of boundary layer processes (Liu et al., 2016a, b), and data assimilation methodology and data impacts (Chen et al., 2016b; Li et al., 2016b; Chen et al., 2016a).

Specifically, Zheng et al. (2016) use hourly rainfall measurements from nearly 2000 national-level rain gauges over six decades to document, for the first time, the spatial climatology of extreme rainfall at hourly, 3-, 6-, 12- and 24-h accumulation periods over China. The study also defines the thresholds that are used to separate three categories of extreme rainfall for all the accumulation periods that roughly correspond to the 70th and 90th percentiles among extreme rainfall across all stations examined. Wang et al. (2016b), as highlighted in Cao and Cai (2016), investigate the initiation of convection over the mesoscale Dabie Mountains in eastern China for a real case in the Mei-yu season, due to complex dynamic and thermodynamic effects of mountain forcing and their interactions with relatively weak environmental flows. Zhang et al. (2016) study the initiation of convection over the Donggong Mountains in Zhejiang Province of China instead, and show that the southeasterly winds, with rich moisture from the East China Sea, set up convergence on the windward slope of the Donggong Mountains and are easily lifted above the lifting condensation level to establish deep convection that evolves into a short squall line. Ran and Chen (2016) try to identify the physical processes responsible for the excitement of gravity waves within a simulated squall line over China, and suggest that the latent heating and other thermodynamic processes play the most important roles.

Shen et al. (2016) present a brief study on the precipitation responses to the radiative effects of ice clouds through analysis of five-day and horizontally averaged data from 2D cumulus ensemble model experiments of a pre-summer torrential precipitation event over China, and show that the radiative cooling associated with the ice clouds acts to increase the precipitation rate. Zhu and Xue (2016) present a detailed evaluation on multi-physics convection-allowing ensemble forecasts at 4-km grid spacing covering continental China, as applied to the historical 21 July 2012 extreme rainfall case over the Beijing region. The relative roles of initial conditions and physics perturbations in the ensemble for this case are also discussed. Some members of the ensemble forecasting system capture the historical extreme prediction reasonably well, and certainly better than available operational forecasts at that time, including the timing and location of extreme precipitation. The paper by Li et al. (2016a) performs a theoretical analysis on the benefits of adding additional ensemble members to an ensemble system in terms of improving the ensemble mean forecast, when the forecasts of the ensemble members have different degrees of correlation. Deng et al. (2016) show positive impacts of perturbing land surface processes within a global ensemble forecasting system, while similar methodologies could be tested in convective-scale models where land surface processes can be even more important. Next, Liu et al. (2016a, b) directly address the parameterization of the convective boundary in a sheared environment, and the scheme has potential to improve NWP model prediction skill.

The final set of papers deals with data assimilation. The paper by Chen et al. (2016a) describes the direct assimilation of surface observations together with radar data within a cloud-model-based four-dimensional variational (4DVAR) system and its advantage compared to assimilating surface data using a separate objective analysis via a two-step procedure. The method was tested with one of the 2014 OPACC IOP cases, using the 4-km OPACC China-domain real-time forecasts mentioned earlier to provide the initial background and boundary conditions. Li et al. (2016b) test and evaluate the WRF 3DVAR systems using the Cartesian horizontal wind components as the control variables instead of the original stream function and velocity potential for an eastern China squall line case, and find that the former performs better. This is consistent with the findings of Sun et al. (2016) tested for U.S. cases. Chen et al. (2016b) describe the inclusion of cloud water and cloud ice mixing ratios in the WRF 3DVAR system as additional control variables, which enables direct variational analyses of these state variables from cloud observations. The analysis and forecast results are improved when assimilating satellite cloud liquid/ice water path data, although the degree of improvement is found to be dependent on the microphysics parameterization scheme used.

For details on the above studies, please read the full-length papers in this (October 2016) or the next (November 2016) issue of *Advances in Atmospheric Sciences*.

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