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INTRODUCTION

Anticipated changes in the global atmospheric water cycle

Richard P Allan
Department of Meteorology, University of Reading, Reading, Berkshire, UK
r.p.allan@reading.ac.uk

Beate G Liepert
NorthWest Research Associates, Redmond, WA, USA
liepert@nwra.com

The atmospheric branch of the water cycle, although containing just a tiny fraction of the Earth's total water reserves, presents a crucial interface between the physical climate (such as large-scale rainfall patterns) and the ecosystems upon which human societies ultimately depend. Because of the central importance of water in the Earth system, the question of how the water cycle is changing, and how it may alter in future as a result of anthropogenic changes, present one of the greatest challenges of this century. The recent Intergovernmental Panel on Climate Change report on Climate Change and Water (Bates *et al* 2008) highlighted the increasingly strong evidence of change in the global water cycle and associated environmental consequences. It is of critical importance to climate prediction and adaptation strategies that key processes in the atmospheric water cycle are precisely understood and determined, from evaporation at the surface of the ocean, transport by the atmosphere, condensation as cloud and eventual precipitation, and run-off through rivers following interaction with the land surface, sub-surface, ice, snow and vegetation.

The purpose of this special focus issue of *Environmental Research Letters* on anticipated changes in the global atmospheric water cycle is to consolidate the recent substantial advances in understanding past, present and future changes in the global water cycle through evidence built upon theoretical understanding, backed up by observations and borne out by climate model simulations. Thermodynamic rises in water vapour provide a central constraint, as discussed in a guest editorial by Bengtsson (2010). Theoretical implications of the Clausius–Clapeyron equation are presented by O'Gorman and Muller (2010) and with reference to a simple model (Sherwood 2010) while observed humidity changes confirm these anticipated responses at the land and ocean surface (Willett *et al* 2008). Rises in low-level moisture are thought to fuel an intensification of precipitation (O'Gorman and Schneider 2009) and analysis of observed and simulated changes in extreme rainfall for Europe (Lenderink and van Mijgaard 2008) and over tropical oceans by Allan *et al* (2010) appear to corroborate this.

Radiative absorption by water vapour (Previdi 2010, Stephens and Ellis 2008) also provides a thermodynamic feedback on the water cycle, and explains why climate model projections of global precipitation and evaporation of around 1–3% K^{-1} are muted with respect to the expected 7% K^{-1} increases in low-level moisture. Climate models achieve dynamical responses through reductions in strength of the Walker circulation (Vecchi *et al* 2006) and small yet systematic changes in the atmospheric boundary layer over the ocean that modify evaporation (Richter and Xie 2008). A further consequence is anticipated sub-tropical drying (Neelin *et al* 2006, Chou *et al* 2007); Allan *et al* (2010) confirm a decline in dry sub-tropical precipitation while the wet regions become wetter both in model simulations and satellite-based observations. Discrepancies between observed and climate model simulated hydrological response to warming (Wentz *et al* 2007, Yu and Weller 2007) are of immediate concern in understanding and predicting future responses. Over decadal time-scales it is important to establish whether such discrepancies relate to the observing system, climate modeling deficiencies, or are a statistical artifact of the brevity of the satellite records (Liepert and Previdi 2009). Techniques for extracting information on century-scale changes in precipitation are emerging (Smith *et al* 2009) but are also subject to severe limitations. Past decadal-scale changes in the water cycle may be further influenced by regionally and temporally varying forcings and resulting feedbacks which must be represented realistically by models (Andrews *et al* 2009). The radiative impact of aerosols and their indirect effects on clouds and precipitation (Liepert *et al* 2004) provide an important example. Understanding surface solar 'dimming' and 'brightening' trends in the context of past and current changes in the water cycle are discussed in a guest editorial by Wild and Liepert (2010). The key roles anthropogenic aerosols can play on a regional scale are discussed by Lau *et al* (2010) through their study of the regional impact of absorbing aerosols on warming and snow melt over the Himalayas.

The overarching goal of climate prediction is to provide reliable, probabilistic estimates of future changes. Relating hydrological responses back to a sound physical basis, the motivation for this special focus issue, is paramount in building confidence in anticipated changes, especially in the global water cycle.

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