Influence of radiative forcing and land-cover changes on precipitation recycling in Alaska and Siberia

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1. INTRODUCTION

In recent years, public awareness of climate changes has grown. Among the variety of human impacts on weather and climate the release of greenhouse gases and land-cover changes brought on by agricultural use, irrigation, subsidization policies, urbanization, open-pit mining, and deforestation/afforestation have received special public interest. These human impacts namely may appreciably affect water availability, water quality and water cycling on various temporal and spatial scales (Mölders et al. 2007).

Water is essential for life, ecosystems, food production and prosperity. Water availability depends on precipitation (P) and losses by evapotranspiration (evaporation plus transpiration; E) and runoff (R). Advection of water components (as water vapor, liquid and solid cloud constituents, liquid and solid hydrometeors), and (2) precipitation-recycling make up the precipitation in a region. Here, precipitation-recycling refers to precipitation within a control volume that originates from evapotranspiration of precipitation within the same control volume. This study presents how selected anthropogenic and natural changes affect regional recycling of precipitation in two selected similar size Arctic regions.

2. EXPRIMENTAL DESIGN

2.1 Precipitation recycling model

The precipitation-recycling model (PRM) first introduced by Elthair and Brass (1994) is modified for application to climate-model data. The modifications avoid assumptions about negligible impact of liquid and solid atmospheric water and runoff on the regional water cycle, and about regional and global water cycle interactions. For more details and the consequences of the modifications see Mölders et al. (2007).

2.2 CCSM

The Community Climate System Model (CCSM) version 2.0.1 (e.g. Blackmon et al. 2001, Kiehl and Gent 2004) is used in this study. It consists of interacting models of the oceans, atmosphere, land, and sea-ice that exchange data by the flux coupler version 5.0.1 (cpl5) without flux corrections.

CCSM acceptably reproduces seasonal cycles of 2m-air temperature, precipitation, snow depth and runoff for current conditions (Dickinson et al. 2006). CCSM acceptably describes the annual cycle of precipitation and annual domain-average precipitation for Alaska and Siberia, but on average slightly overestimates monthly precipitation with larger differences between simulation and observation in winter and summer than spring and fall (Li et al. 2006).

2.3 CCSM simulations

The CCSM is run with reference (335 pm), doubled and tripled CO_2 concentrations without and with concurrent land-cover changes in the center of the study regions. These simulations and their results are denoted CTR, DBL, TPL, LUC, LUCDBL, and LUCTPL hereafter. The study regions are chosen to be of similar size for easy comparison. Note that regional recycling depends on the size of the region (e.g. Eltahir and Bras 1994).

2.4 Analysis

Due to various feedback mechanisms (e.g. temperature-albedo feedback), water-cycle changes due to altered radiative forcing are expected to be visible in the Arctic first. Thus, the impact of land-cover changes and/or altered radiative forcing on precipitation-recycling is investigated by means of the modified version of the PRM introduced by Eltahir and Bras (1994) for Alaska and Siberia. These two regions are of comparable size, but with different thermal and hydrological characteristics. The analysis encompasses 30 years after model spin-up.

3. RESULTS AND CONCLUSIONS

Under reference climate and land-cover conditions Alaska and Siberia receive nearly the same annual precipitation, but differ notably in evapotranspiration and runoff. However, the annual recycling rates differ. Under reference climate precipitation recycling amounts 39% and 42% in Alaska and Siberia, respectively.

The results show that land-cover changes affect a region's water cycle differently under different CO_2 conditions (Figs. 1, 2). For unchanged land-cover, in Alaska, increasing CO_2 reduces the region's control of its water cycle; the opposite is true for Siberia. Apparently, different partitioning of precipitation into runoff and evapotranspiration causes different behavior in the two regions (Mölders et al. 2007).

Generally, moisture export is higher for increased than for reference CO_2 conditions for both regions. This means that the regions and land-cover changes therein have longer-range impact in a warmer than in the reference climate.

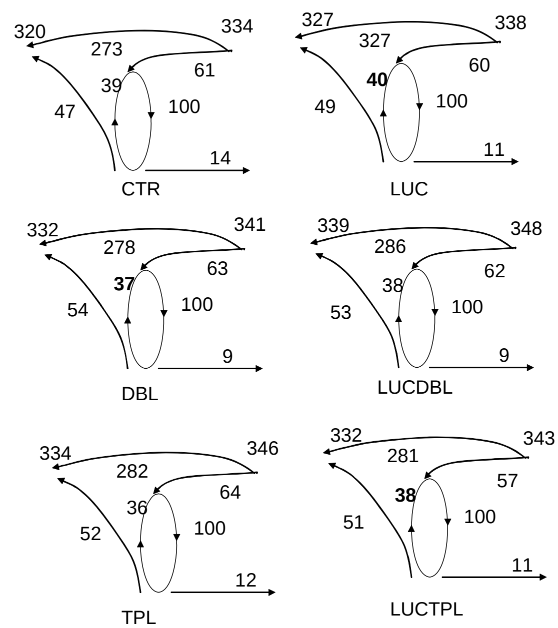

Fig. 1. Partitioning of precipitation and water cycle paths as obtained for Alaska for the six climate scenarios.

The recycling ratios found indicate a high potential for interactions between surface hydrology and climate for Alaska and Siberia (see Figs. 1, 2). Independent of the landscape, precipitation-recycling decreases in response to increased CO_2 levels in Alaska, while it increases in Siberia (except for tripled CO_2 in a modified Siberian landscape). In Alaska, the degree of CO_2 increase affects whether runoff or moisture export benefits from reduced recycling (Fig. 1). Consequently, either the ocean freshwater supply or the downwind regions are impacted.

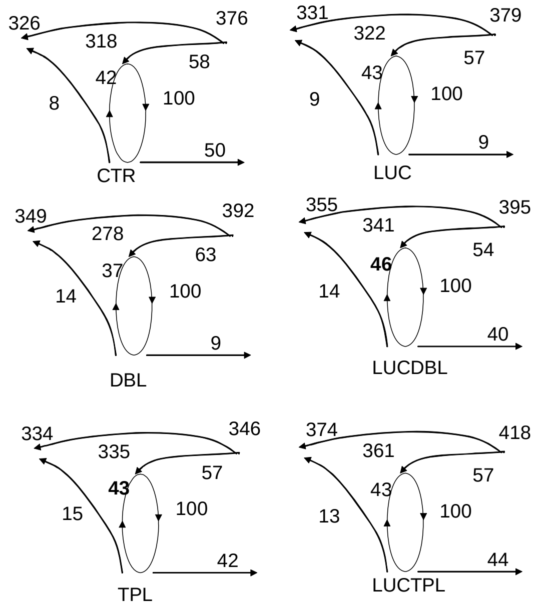

Fig. 2. Like Fig. 1, but for Siberia.

ACKNOWLEDGEMENTS

This research is partly funded by National Science Foundation contracts ATM0232198 and OPP-0327664. Further support stems from the Geophysical Institute. The Arctic Region Supercomputing Center and National Center for Atmospheric Research provided computational support.

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