6A.9 LAND-ATMOSPHERE FEEDBACKS: PRECIPITATION RECYCLING IN THE NAMS REGION

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1. Introduction

It has long been thought that in the semi-arid North American Monsoon System (NAMS) region, the moisture sources for monsoon precipitation are predominantly of oceanic origin. In this study we show that precipitation recycling is also a significant source of moisture for monsoon precipitation and it plays an important role during long monsoons. Here we present the analysis of precipitation recycling over the NAMS using Dynamic Recycling Model (Dominguez et al. 2006), which enables us to calculate precipitation recycling at the daily timescale. The input data for the model is obtained from the North American Regional Reanalysis (NARR) data which was developed as an improvement upon the earlier Global Reanalysis, and has focused significant efforts on improved hydrologic modeling (Mesinger et al. 2006). Furthermore, the Level II ecoregions of North America are the geographical units of analysis (See Figure 1). This classification implicitly takes into account the complex feedback mechanisms between the vegetated surface and the overlying atmosphere. One of the innovative features of this analysis is the delineation of the source and sink regions of recycled precipitation within the NAMS domain.

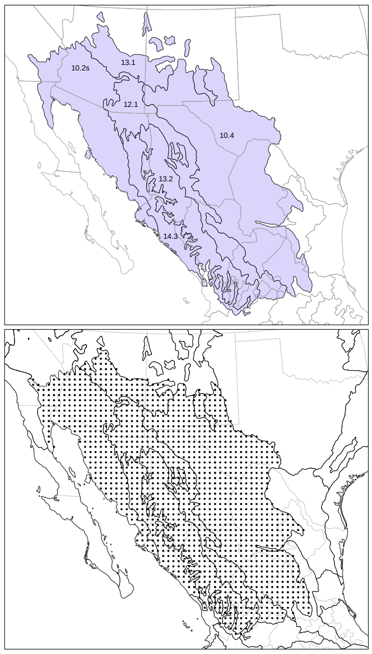

Figure 1: (Left) North American monsoon system domain, identified through six different Level II ecoregions (CEC 1997): 10.2s Sonoran desert, 13.1 Upper Gila Mountains, 14.3 Western Pacific Coastal Plain Hills and Canyons, 13.2 Western Sierra Madre, 12.1 Western Sierra Madre Piedmont, 10.4 Chihuahuan Desert. This delimitation follows Gutzler (2004). (Right) 32 km resolution North American Regional Reanalysis (NARR) grid points within the NAMS region.

2. Precipitation Recycling in the NAMS

The climatological analysis of NAMS precipitation recycling reveals a positive feedback mechanism between monsoon precipitation and subsequent increase in recycling. Along with the abrupt increase in precipitation, the NAMS is characterized by higher evapotranspiration rates, lower sensible heat flux and higher recycling ratios (See Figure 2). In agreement with previous work by Bosilovich et al. (2003), our study finds that evapotranspiration within the NAMS region significantly contributes to monsoon

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rainfall after NAMS onset. As seen in Figure 2, at the peak of the season, an average of 15% of precipitation comes from evapotranspiration within the NAMS domain, although some days it can be as high as 25%.

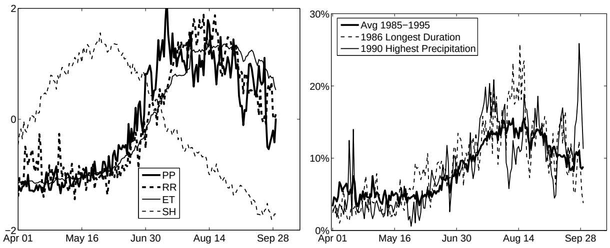

Figure 2: (Left) Normalized daily precipitation, recycling ratio, evapotranspiration and sensible heat. The values are averaged over the region and 11 years of analysis. (Right) Mean recycling ratio for the 11-year period, and for the years with monsoons of highest precipitation (1990) and longest duration (1986)

Our study shows that precipitation recycling is a mechanism for relocation of soil moisture within the NAMS domain, as seen from the moisture-weighted paths in Figure 3. While monsoon rainfall and evapotranspiration are predominantly located in the southwestern part of the domain, recycling is enhanced northeast of this region, indicating that evapotranspired moisture moves further inland to drier downwind regions (See Figure 4). Our results show that evapotranspiration from the seasonally dry tropical forests in Mexico are the most important contributor to precipitation of recycled origin within the NAMS domain. Consequently, the degradation of these forests, which is currently estimated to be 1.4% per year (Trejo and Dirzo 2000), could affect the precipitation patterns of a much larger region extending as far north as Arizona and New Mexico.

3. Precipitation Recycling during Long Monsoons

The three years with longest monsoons in the 1985-1995 period (1986, 1991 and 1993), show an interesting a-synchronous pattern between precipitation and recycling ratio (See Figure 5). The longest monsoons present a characteristic double peak in precipitation. Contrary to what one might expect, the

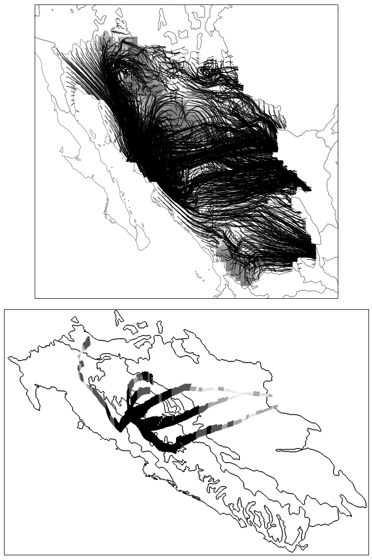

Figure 3: August 10th, 1986 (Left) Atmospheric paths of moisture at every grid point used to calculate the local recycling ratio. (Right) Three selected paths where the ratio of evapotranspiration to precipitable water is represented as shaded bars, indicating the regions that significantly contribute to evapotranspired moisture (The wind direction is generally from east to northwest).

recycling ratio peaks during the intermediate dry period. A clearer understanding of this asynchronous pattern during long monsoons comes from analyzing the vegetation. Looking at the NDVI data, we see that during long monsoons, the first precipitation peak promotes vegetation growth, which is maintained even during the dry intermediate period. Consequently, we see a continuous supply of evapotranspiration from the land. This implies that transpiration is maintaining high ET values which supply moisture to the overlying atmosphere and contribute to precipitation, even during the intermediate dry period of the monsoon.

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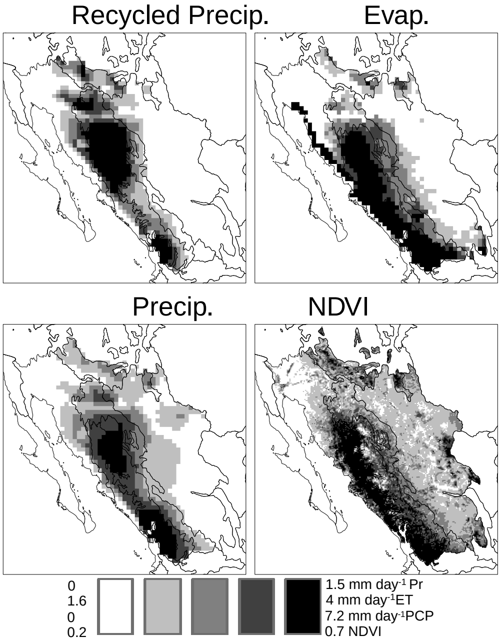

Figure 4: Average daily precipitation of recycled origin, evapotranspiration, precipitation and NDVI for the period of Aug 1 - Aug 15 of 1986 (long monsoon)

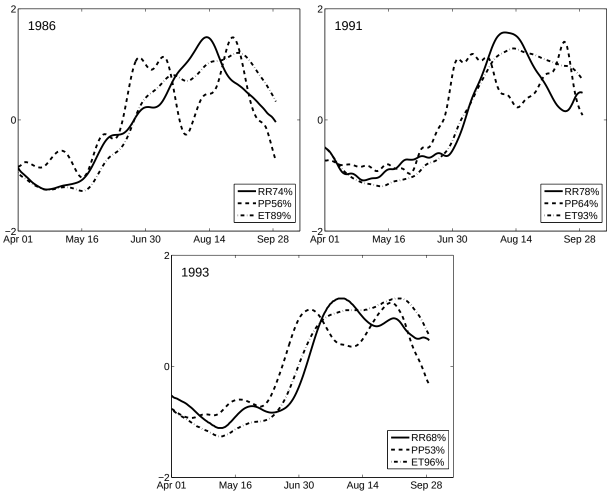

Figure 5: Smoothed precipitation (dashed), recycling ratio (solid) and evapotranspiration (dash-dot) for the three years of longest monsoons in the 1985-1995 period years: 1986, 1991 and 1993. The smoothing technique uses Multivariate Singular Spectrum Analysis on the normalized data of eighteen different variables over the NAMS domain.

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