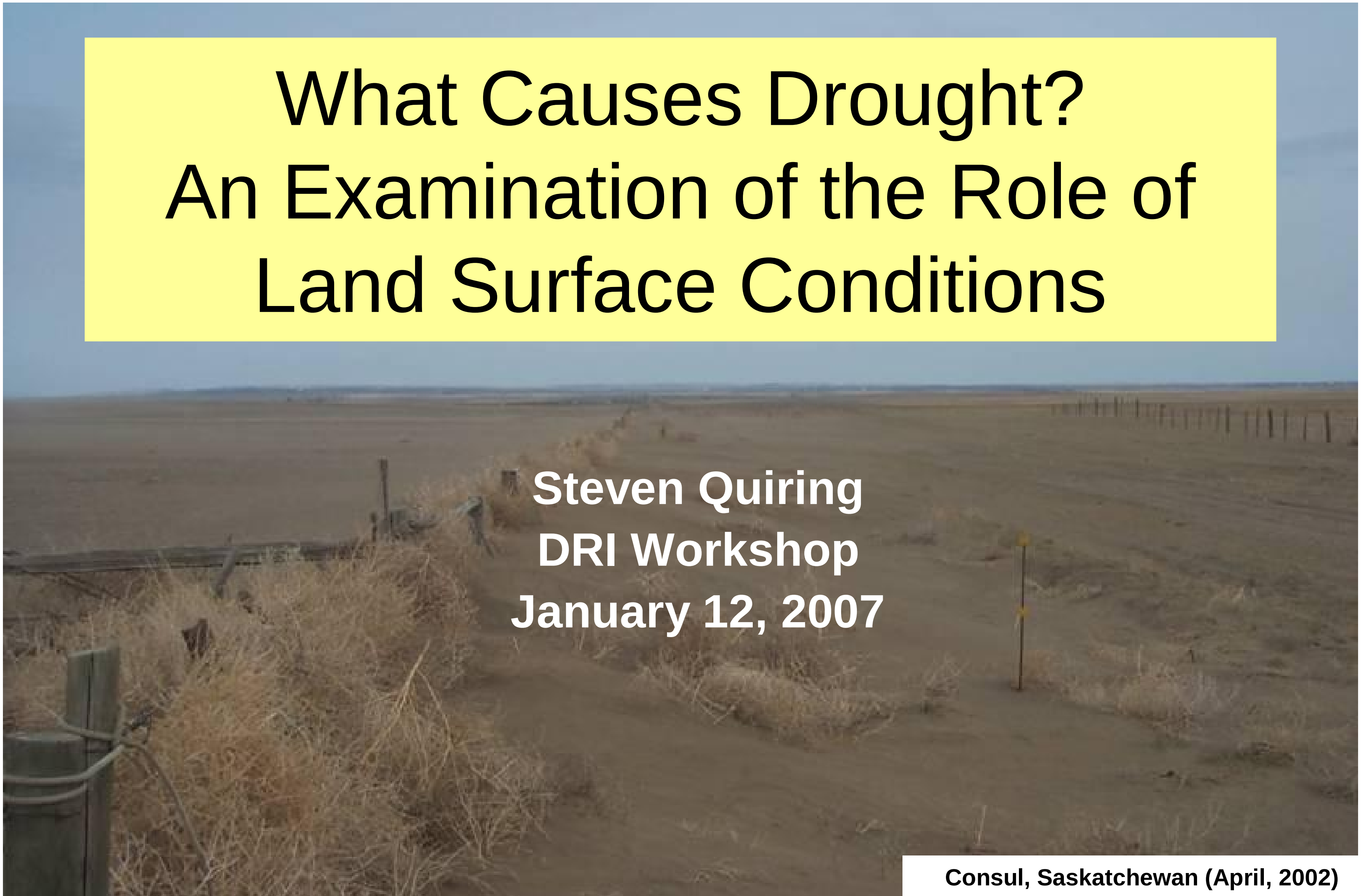
What Causes Drought? An Examination of the Role of Land Surface Conditions



Steven Quiring

DRI Workshop

January 12, 2007

Consul, Saskatchewan (April, 2002)
Ted Banks

Motivation

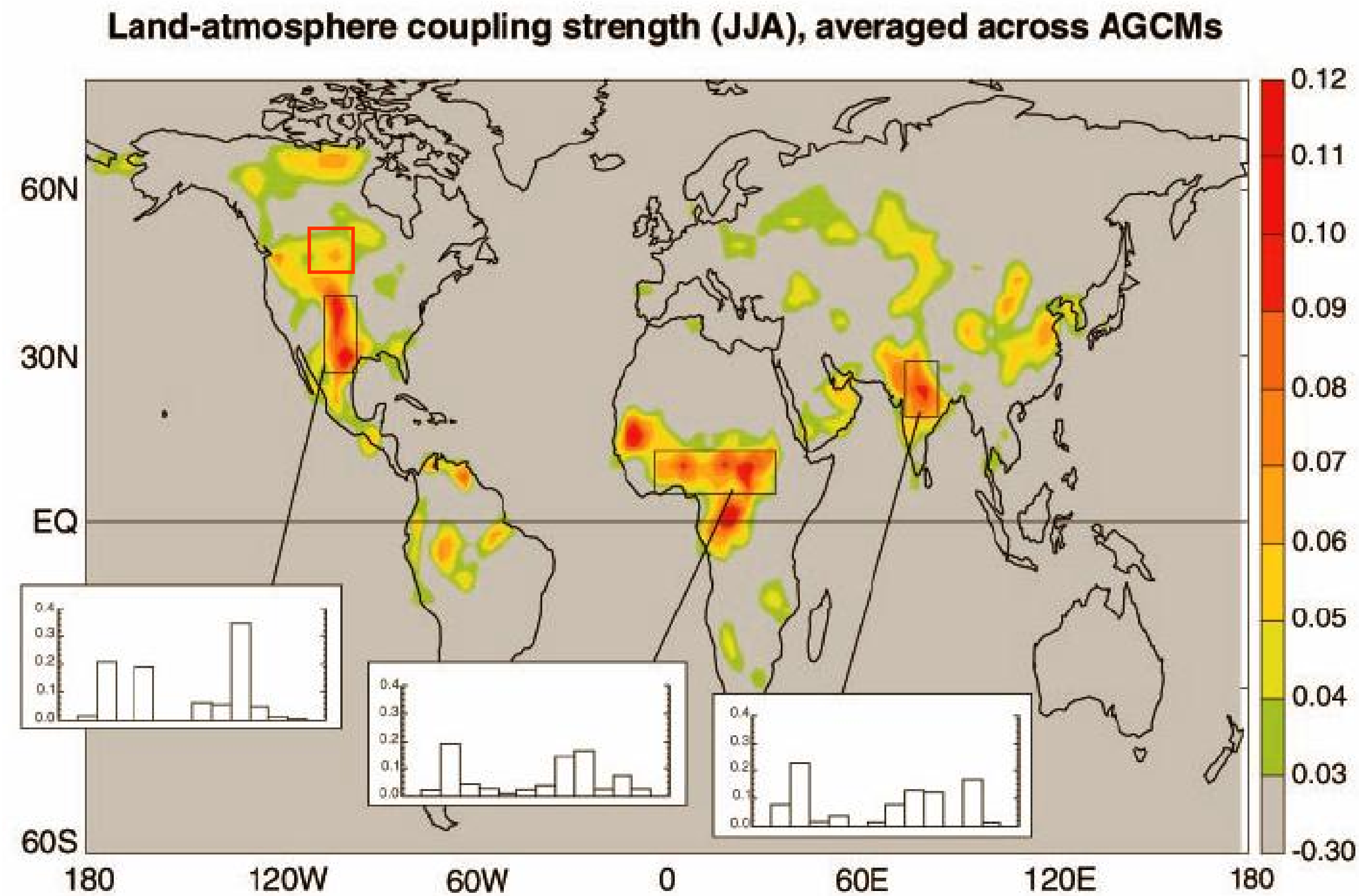


Fig. 1. The land-atmosphere coupling strength diagnostic for boreal summer (the Ω difference, dimensionless, describing the impact of soil moisture on precipitation), averaged across the 12 models participating in GLACE. (**Insets**) Areally averaged coupling strengths for the 12 individual models over the outlined, representative hotspot regions. No signal appears in southern South America or at the southern tip of Africa.

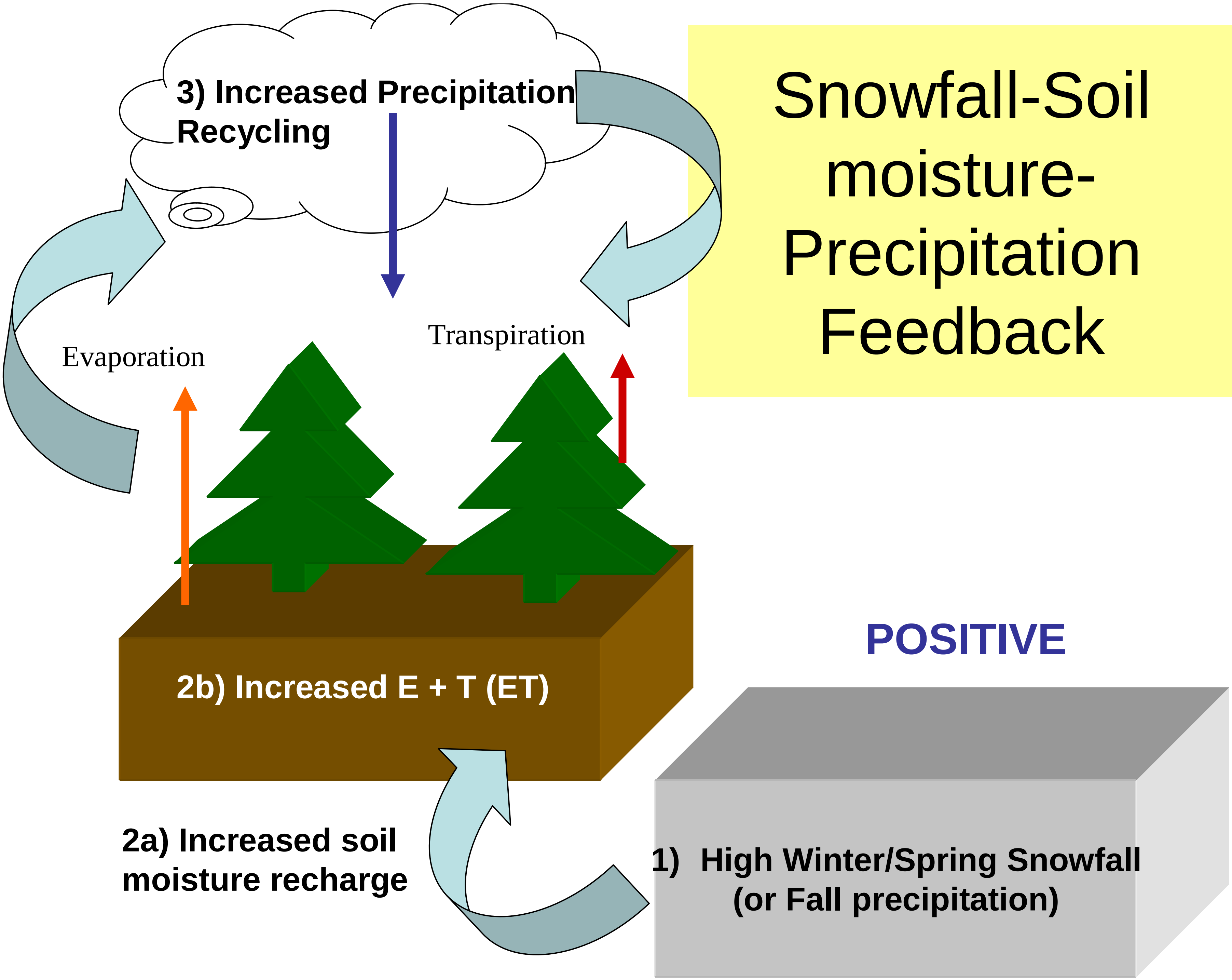
Koster *et al.* (2004)

Research Objectives

I. **Examine the importance of land surface conditions (snowfall and soil moisture) in initiating and/or exacerbating drought conditions in the Northern Great Plains (NGP)**

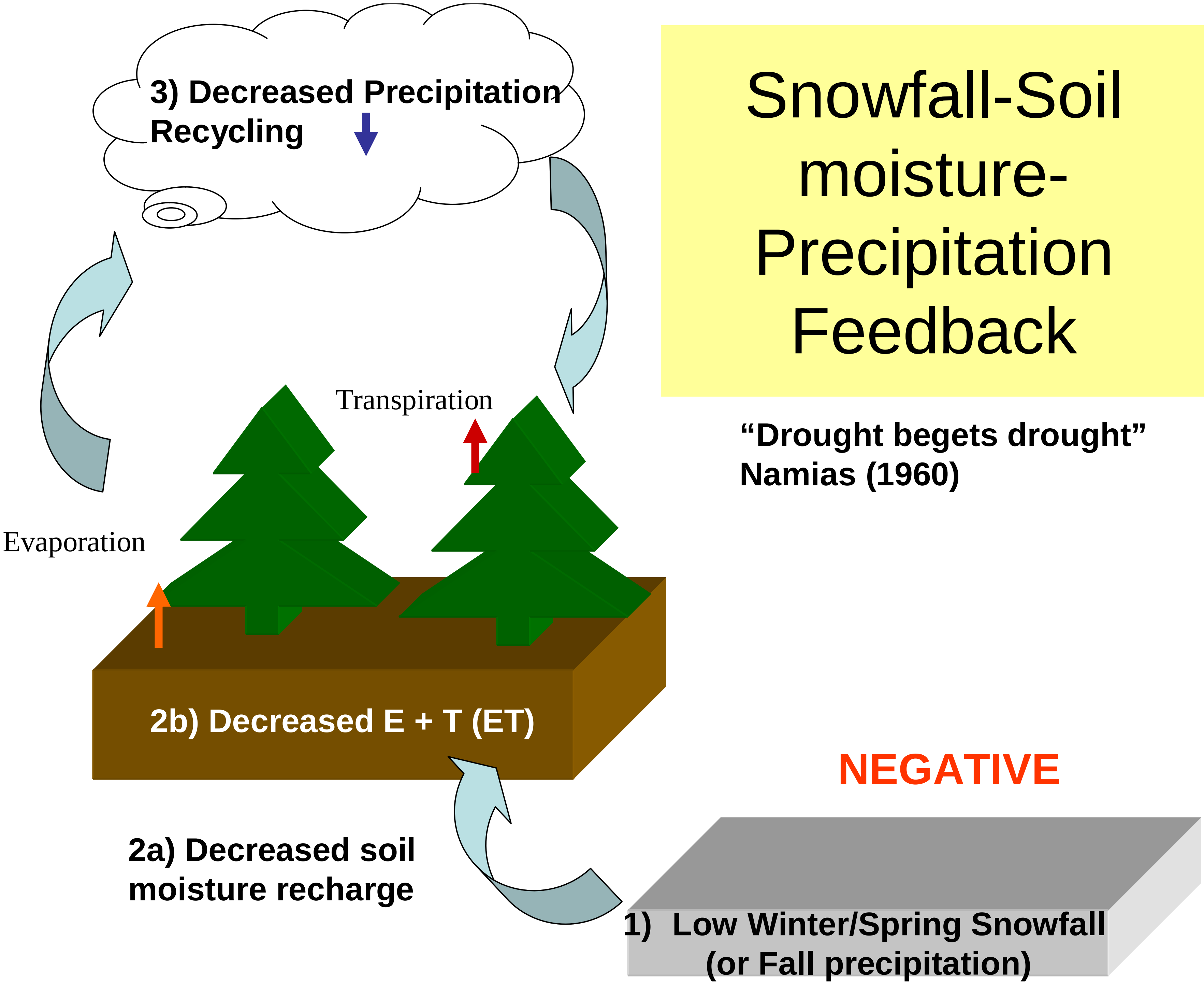
II. **Can we use snowfall and soil moisture conditions prior to the growing season to forecast drought?**

Snowfall-Soil moisture-Precipitation Feedback



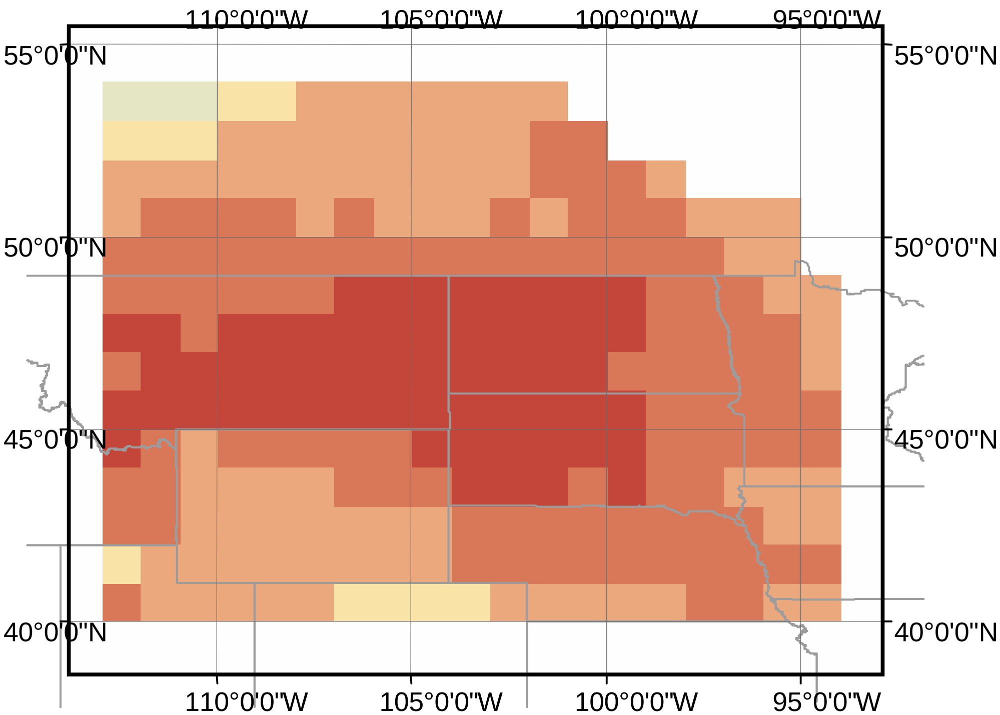
Snowfall-Soil moisture-Precipitation Feedback

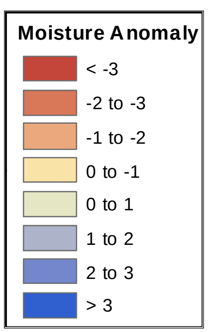
"Drought begets drought"
Namias (1960)



NEGATIVE

Study Region





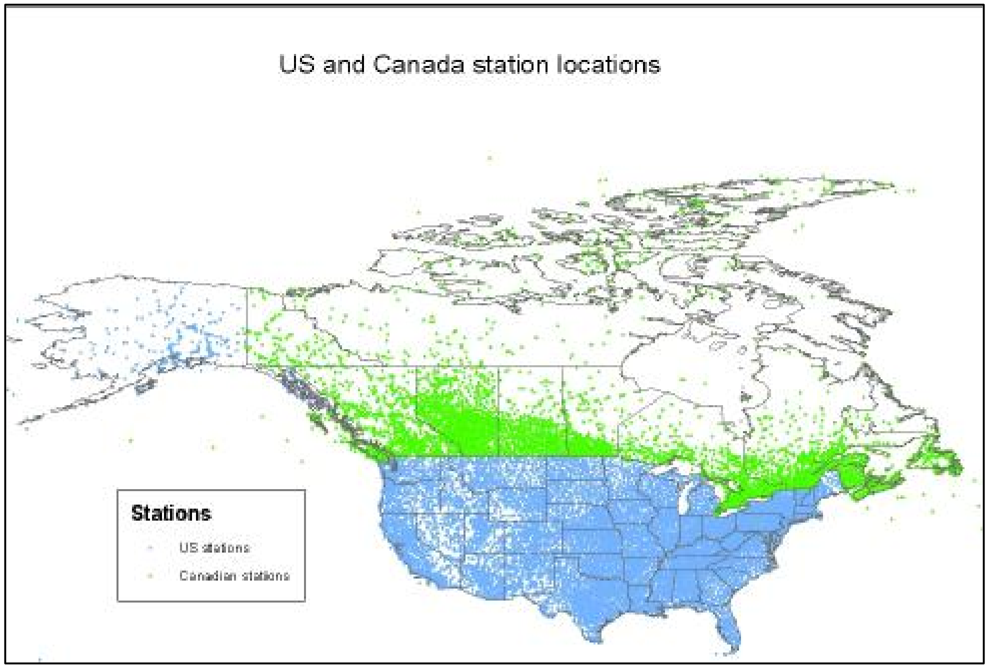
Summer (JJA) moisture anomalies associated with the 5 driest between 1929 and 1999

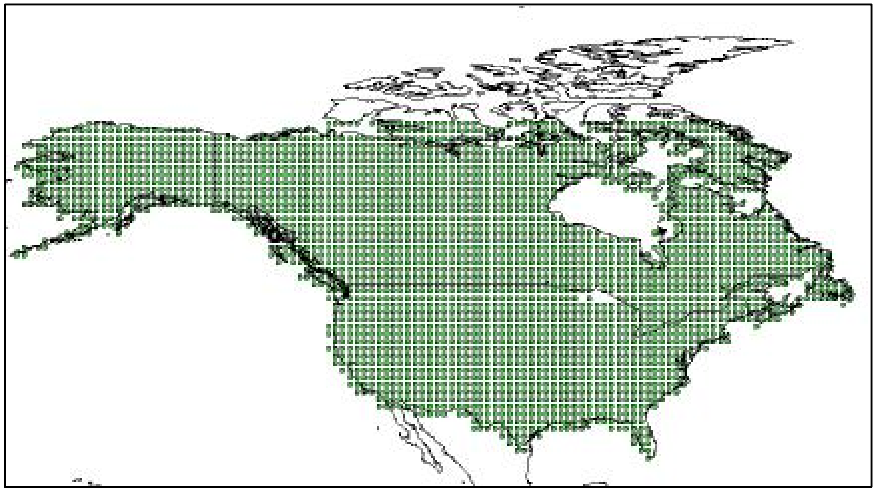
- **NGP = encompasses portions of Manitoba, Saskatchewan, Alberta & 12 US States**

- **Drought data based on Palmer's Moisture Anomaly Index calculated from station and climate division data (interpolated to a 1° by 1° grid)**

- **Monthly data (1929-1999), only summer (JJA) moisture anomalies were analyzed**

Snowfall Data



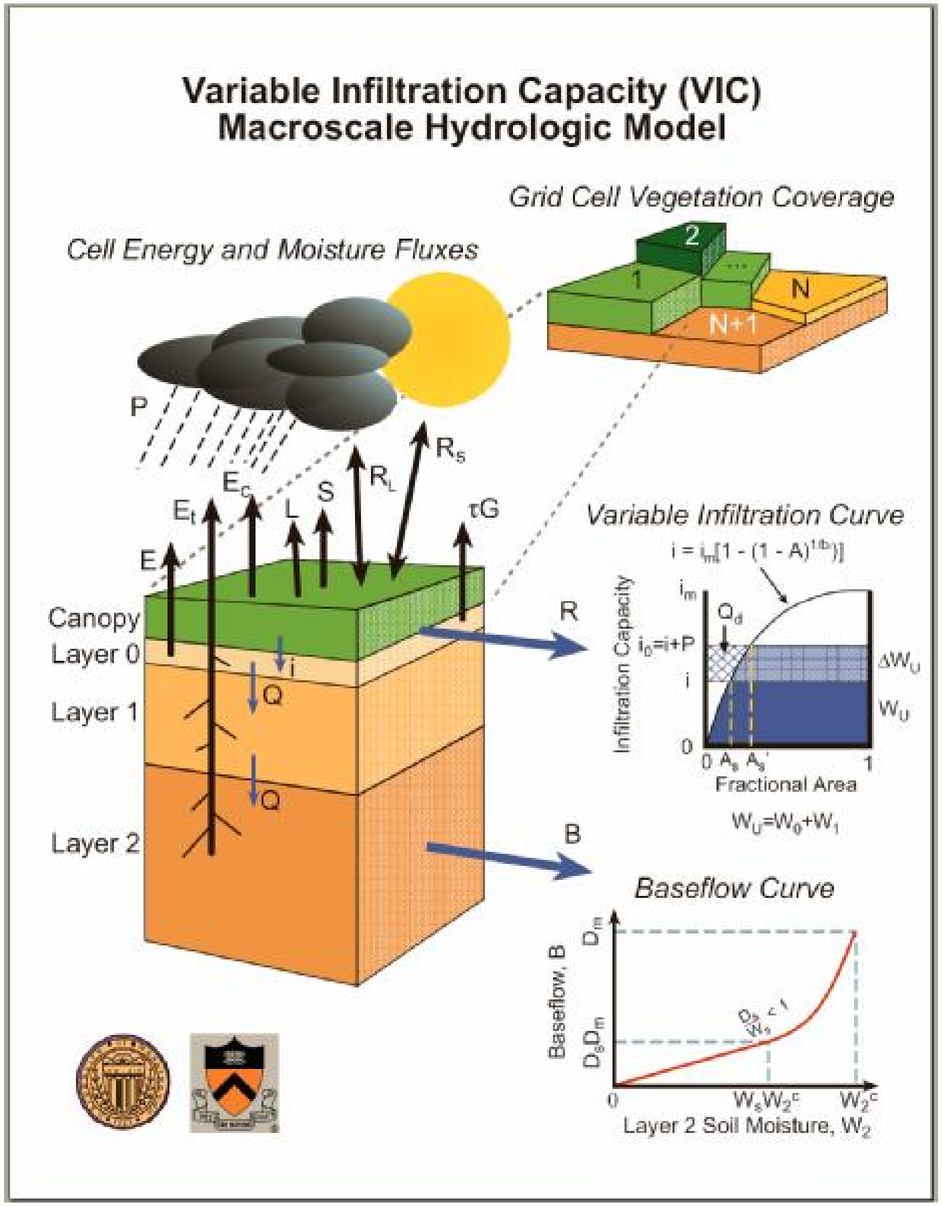


- North American gridded (1° by 1°) snowfall and snow cover developed by T. Mote (Univ. Georgia)

- Interpolated from U.S. National Weather Service (NWS) cooperative stations and the Canadian daily surface observations

- Daily data (1900-2000)

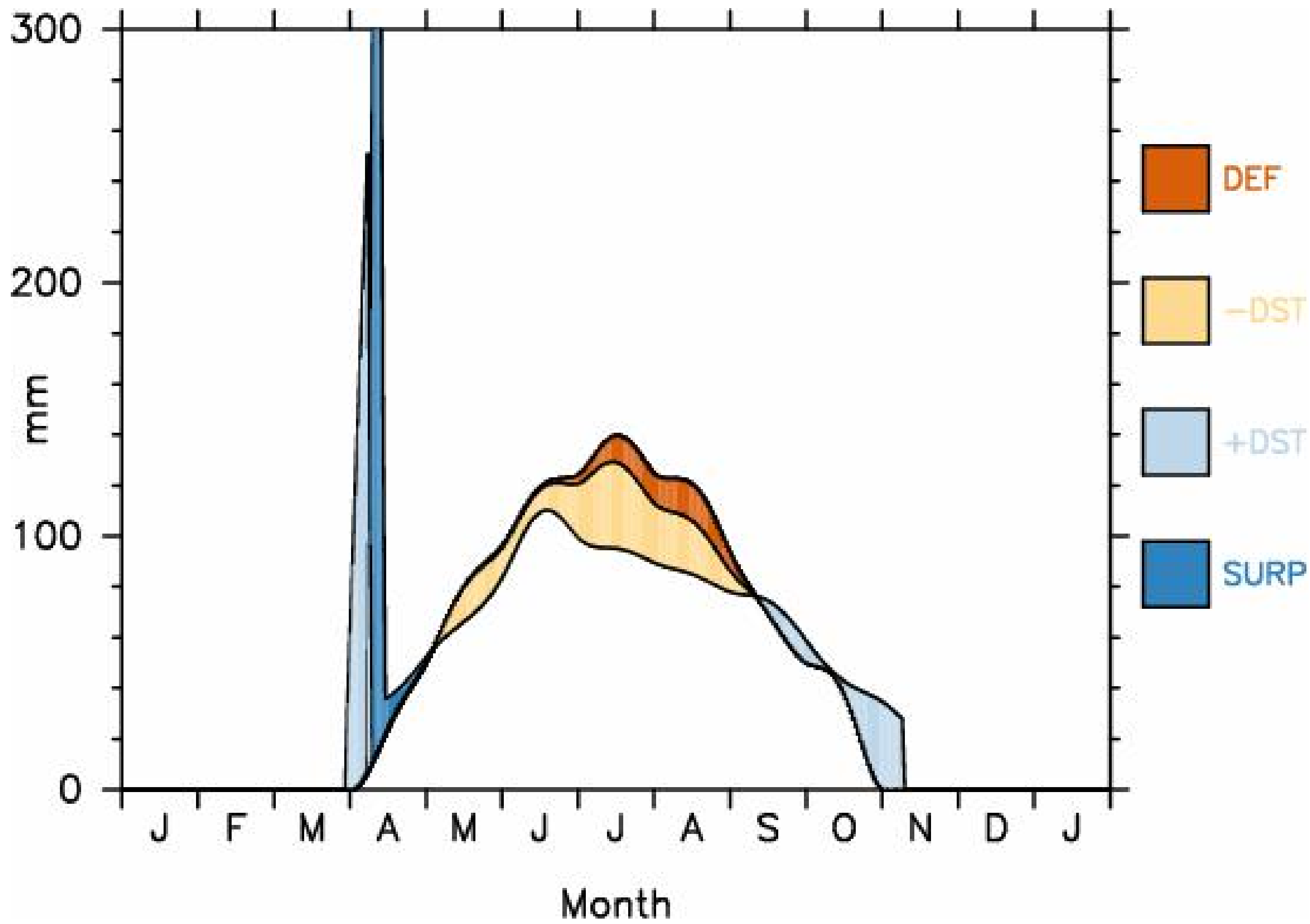
Soil Moisture



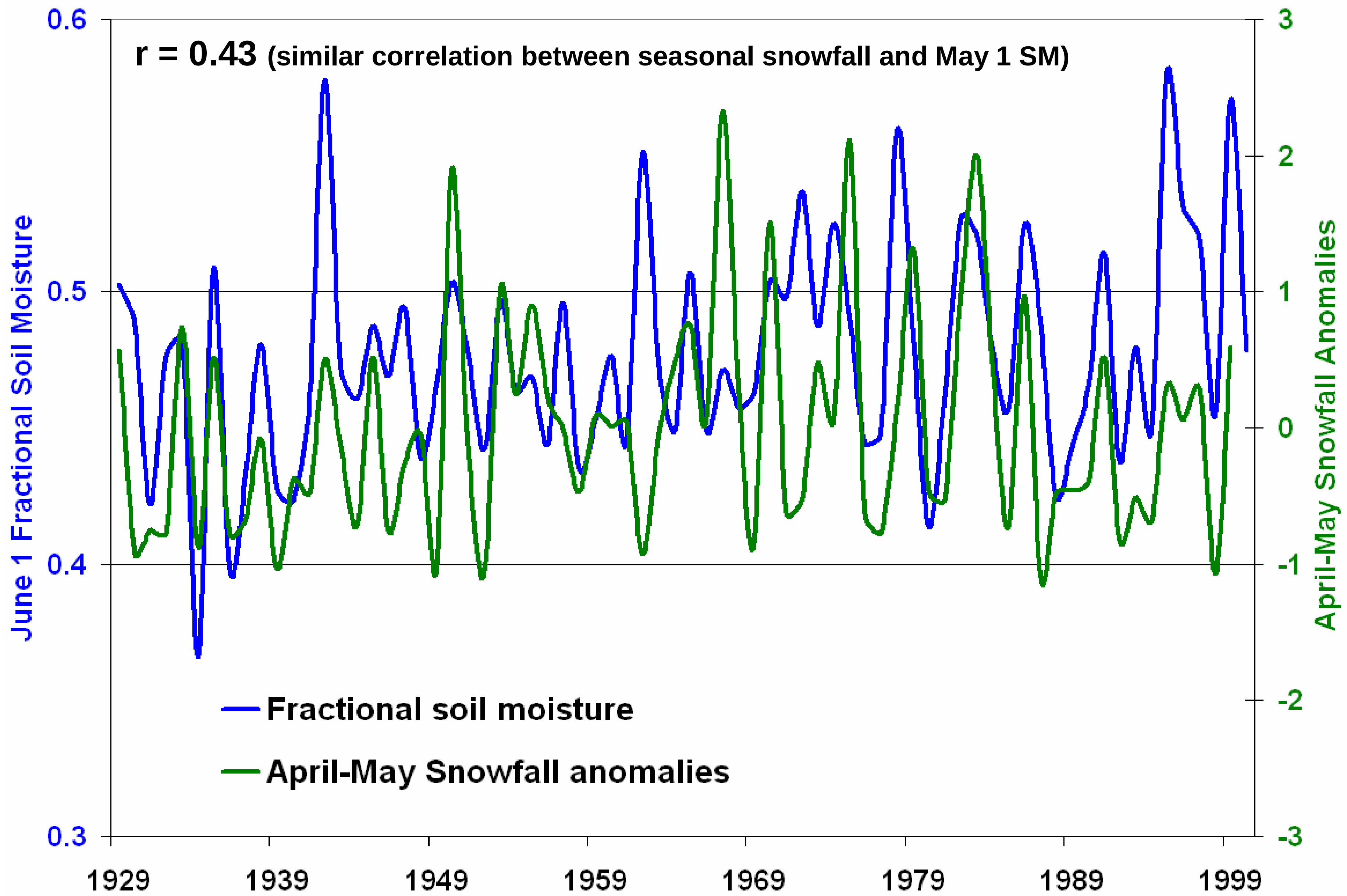
- Variable Infiltration Capacity (VIC) macroscale hydrological model
- Developed by Lettenmaier's hydrology group at University of Washington
- 3 layer soil water model that utilizes a soil-vegetation-atmosphere transfer scheme to account for land-atmosphere interactions
- Daily simulation over CONUS at (0.5° by 0.5°) (1915-2005)

1) Does decreased snowfall lead to decreased soil moisture recharge?

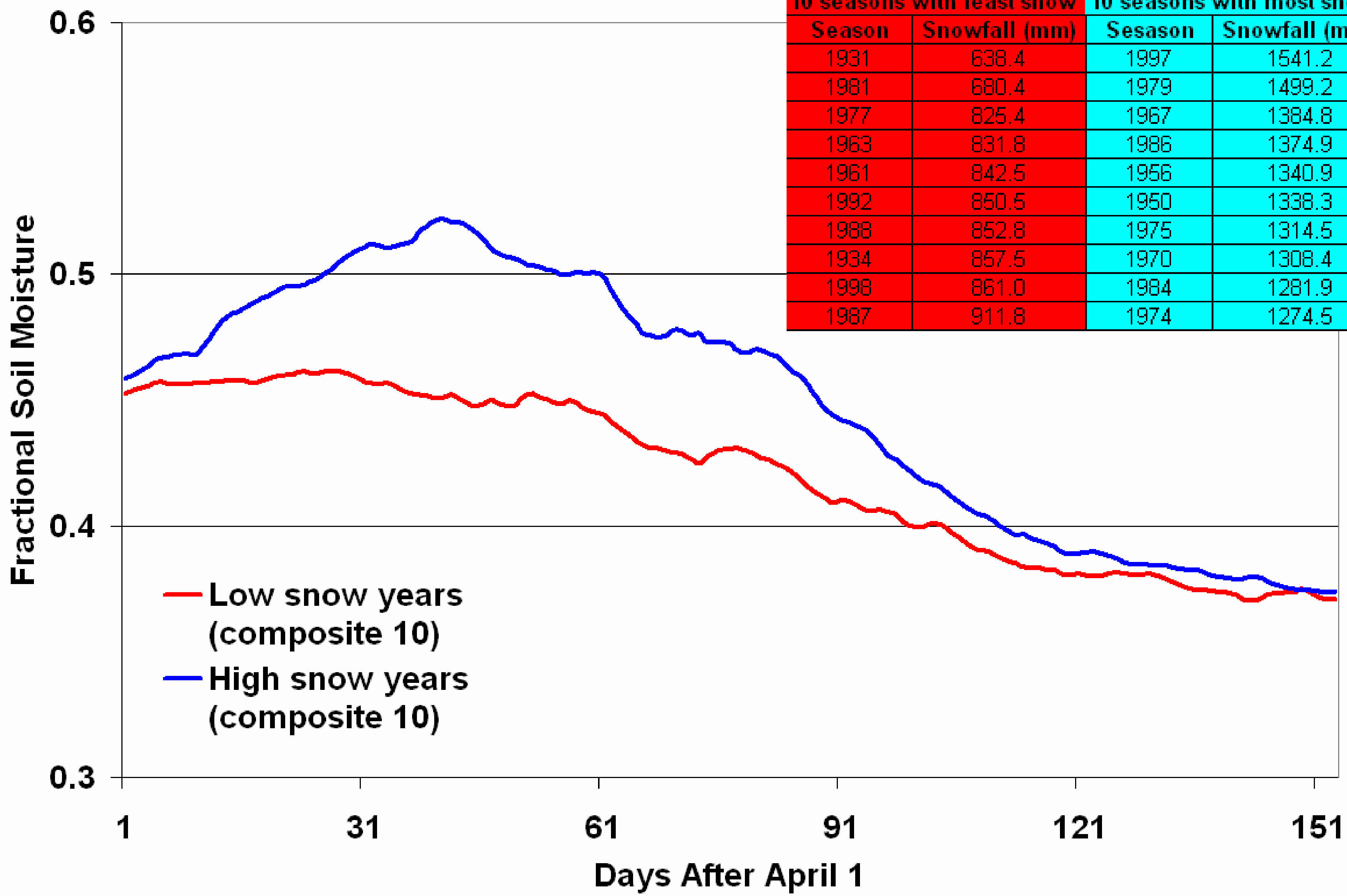
Climatic Water Budget for Northern Minnesota



NGP Snowfall & June 1 Soil Moisture



NGP Soil Moisture Composite



10 seasons with least snow		10 seasons with most snow	
Season	Snowfall (mm)	Sesason	Snowfall (mm)
1931	638.4	1997	1541.2
1981	680.4	1979	1499.2
1977	825.4	1967	1384.8
1963	831.8	1986	1374.9
1961	842.5	1956	1340.9
1992	850.5	1950	1338.3
1988	852.8	1975	1314.5
1934	857.5	1970	1308.4
1998	861.0	1984	1281.9
1987	911.8	1974	1274.5

2) Are droughts associated with reduced precipitation recycling?

- **Recycled precipitation = water from ET that falls again as rain within the same area (strongly influenced by size of region)**

- **Estimates of summer recycling ratios in the NGP vary (L = 500 km):**
  - **12% (Trenberth, 1999)**
  - **14-17% (Dominguez et al., 2006)**
  - **21% (Raddatz, 2006)**

- **Local ET provides water vapor and CAPE, linked to increased convection**

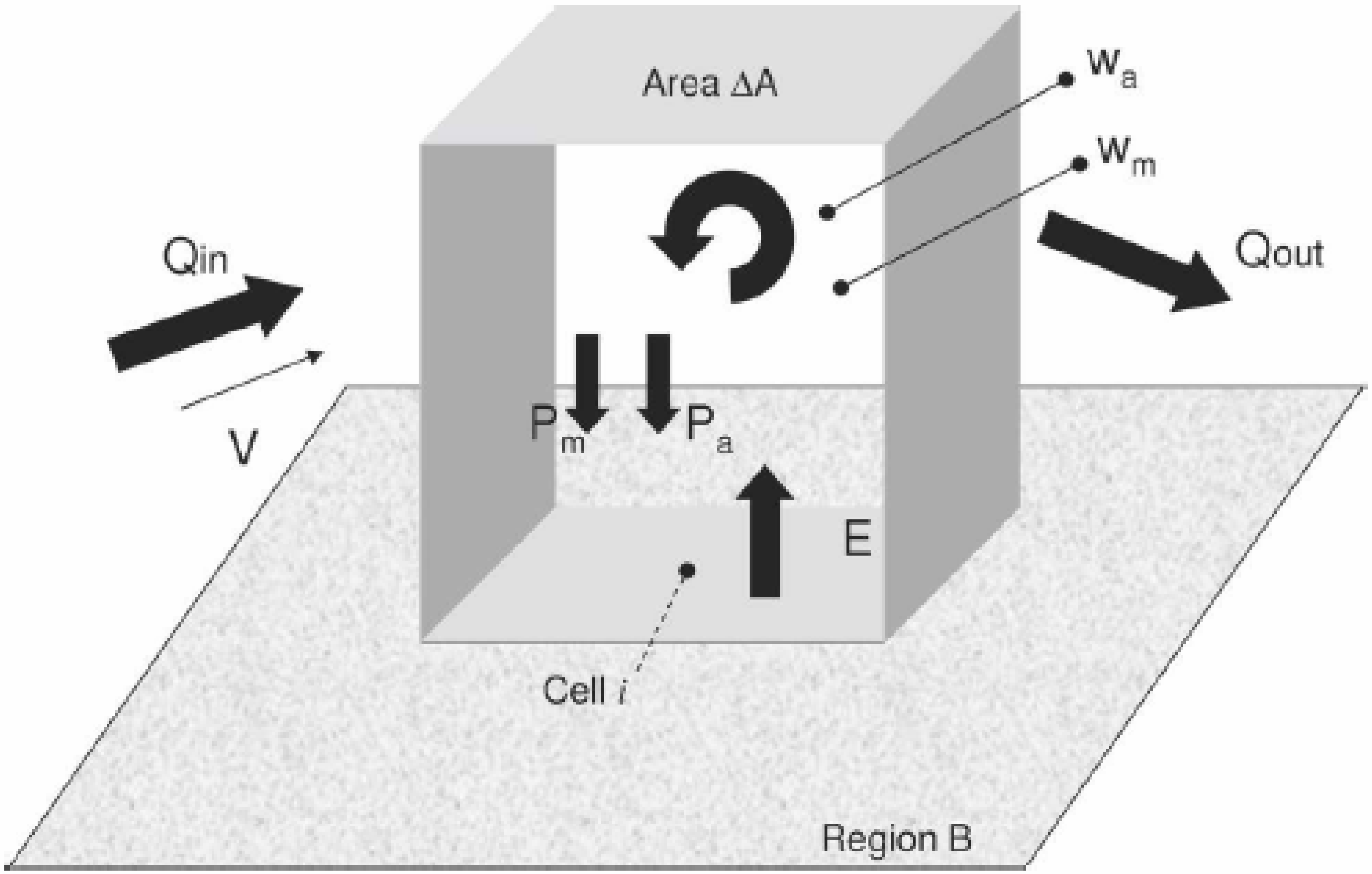


FIG. 2. Schematic representation of water vapor fluxes in an atmospheric grid box i, of area ΔA within region B. The precipitation P and precipitable water w can be divided into their recycled (m) and advective (a) components.

Dominguez *et al.* (2006)

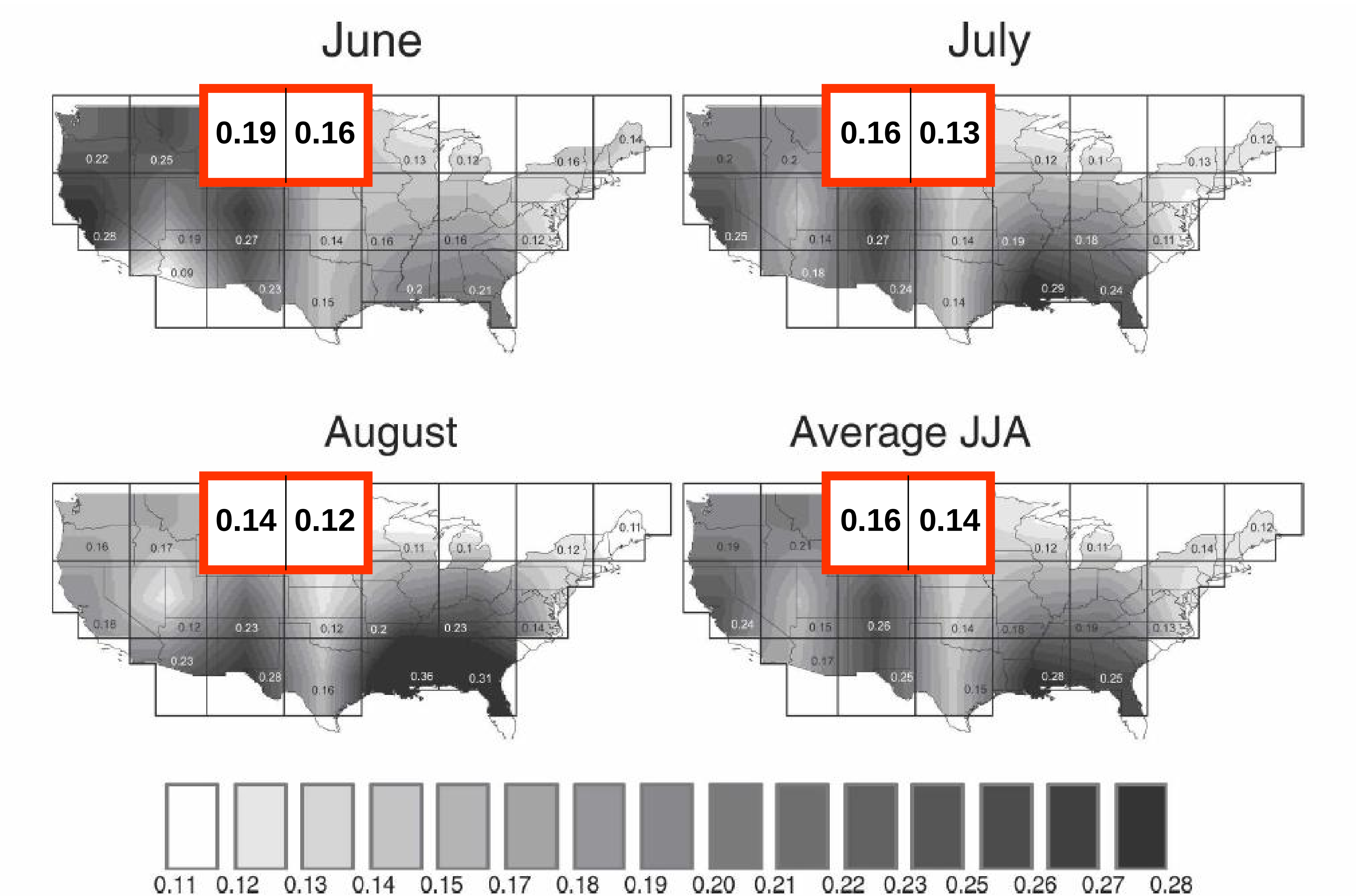
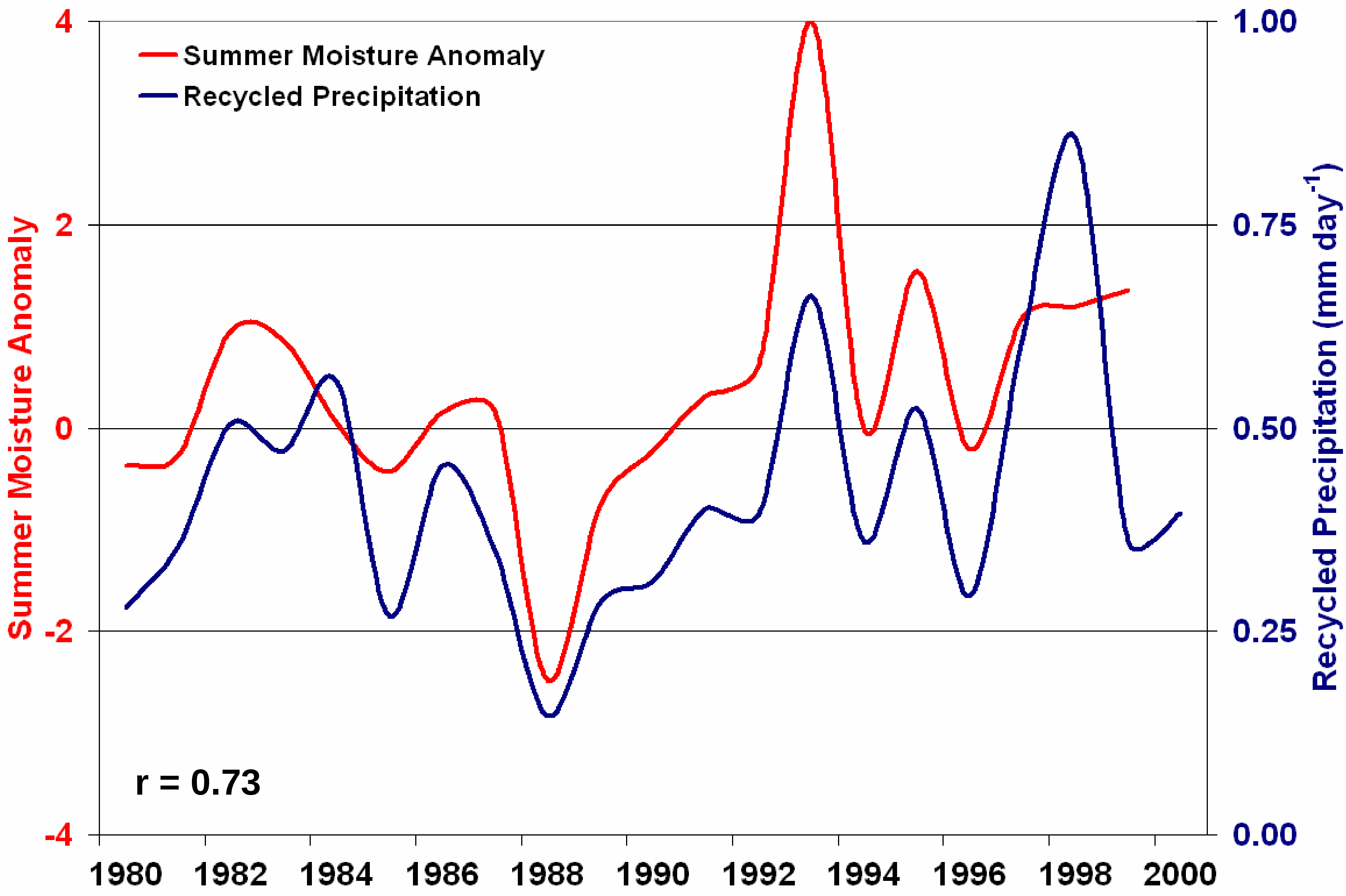


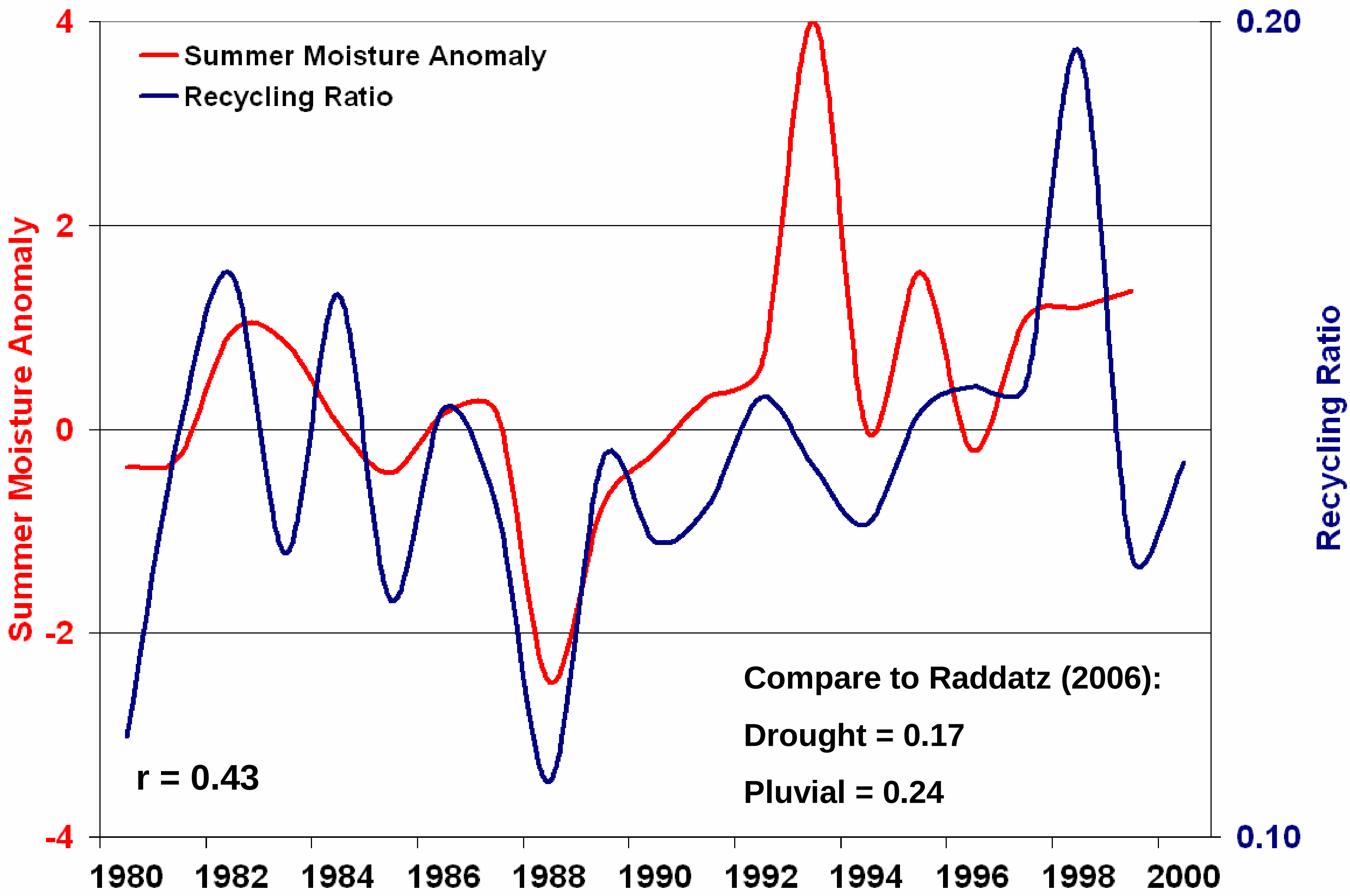
FIG. 10. June, July, August, and average JJA recycling ratios over the conterminous United States (1979–2000). The recycling ratio for each region is shown as the numerical value, and the shading shows the same recycling ratios smoothed using bilinear interpolation.

Dominguez *et al.* (2006)

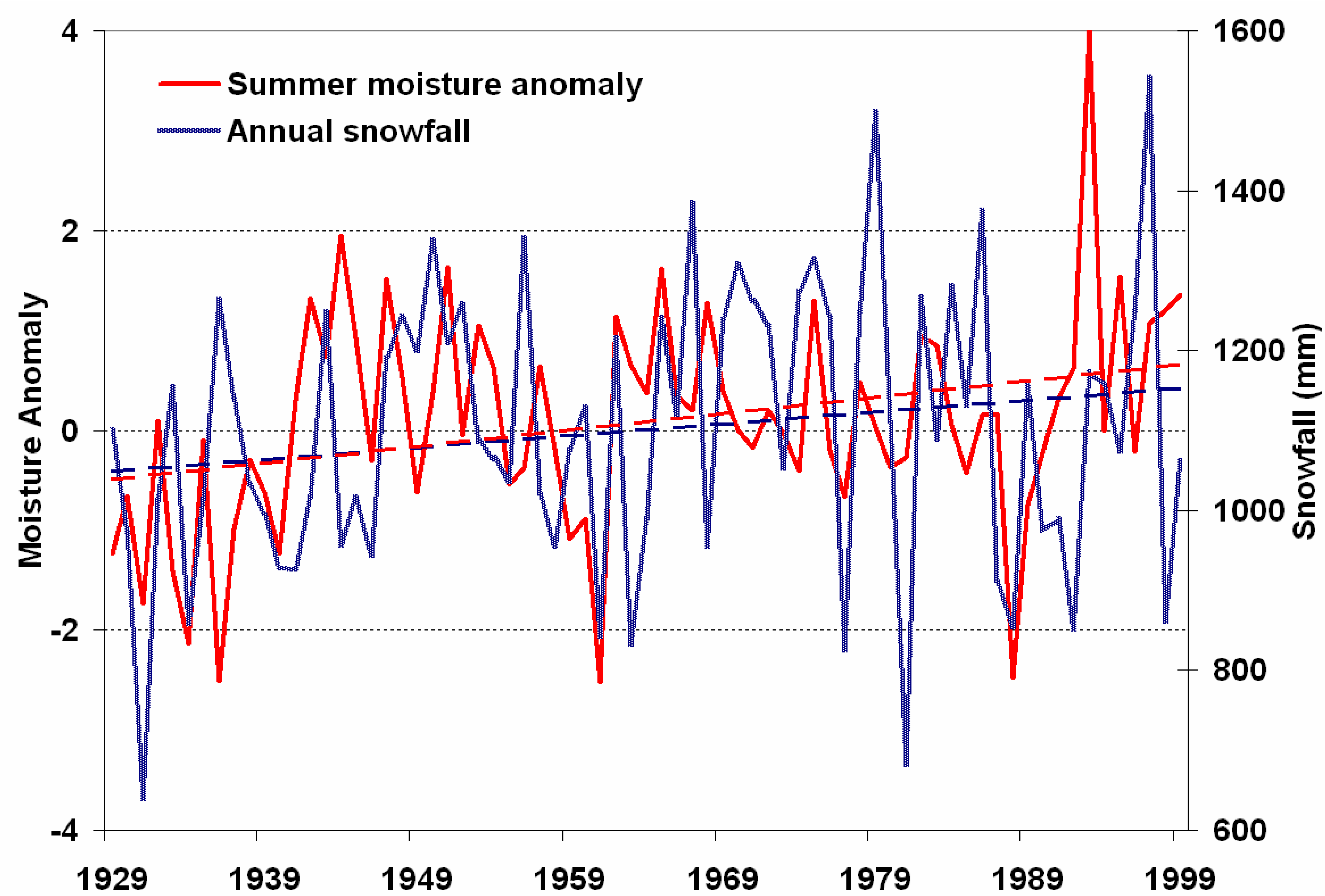
Recycled Precipitation (1980–1999)



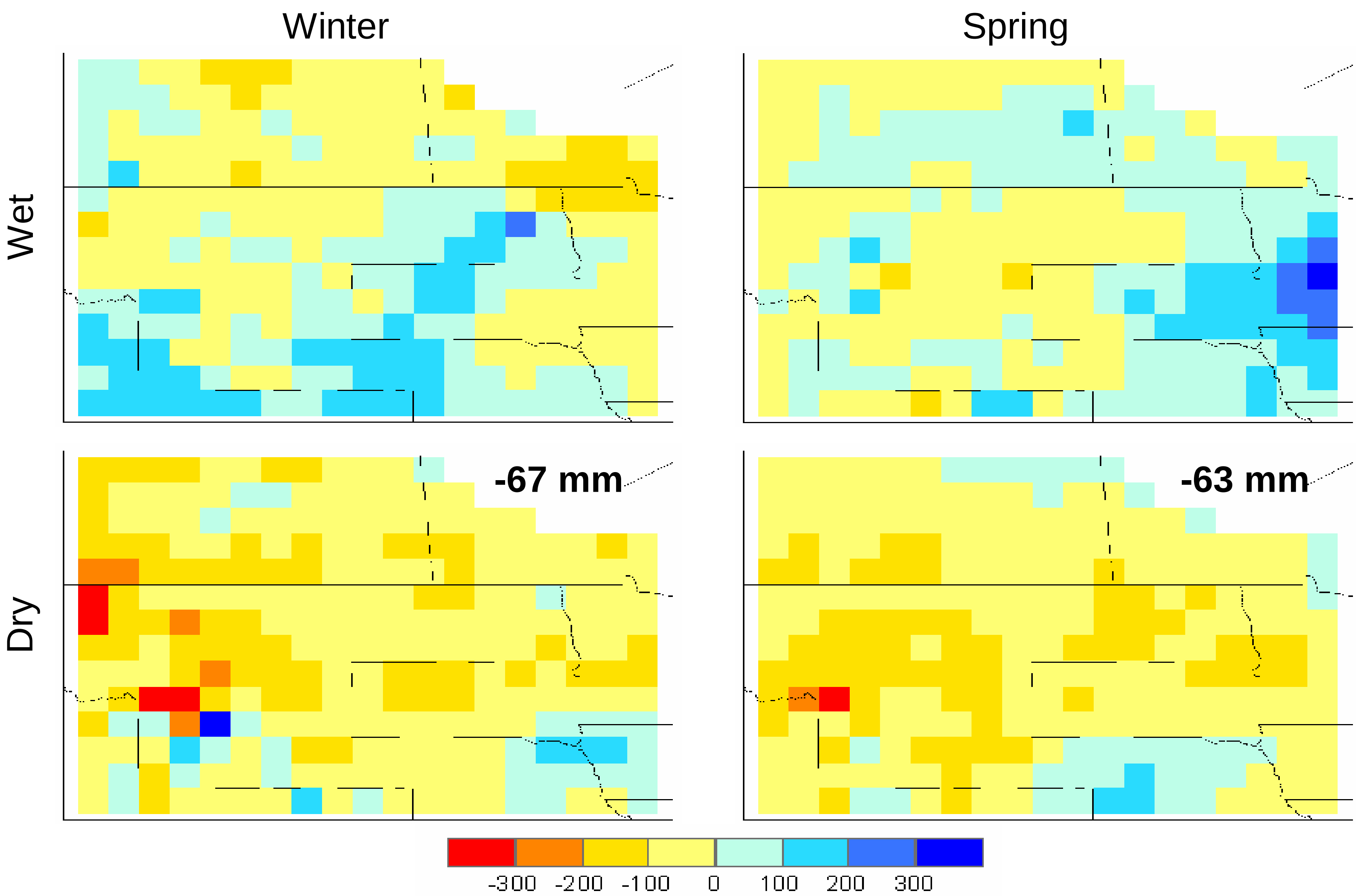
Recycling Ratio (1980–1999)



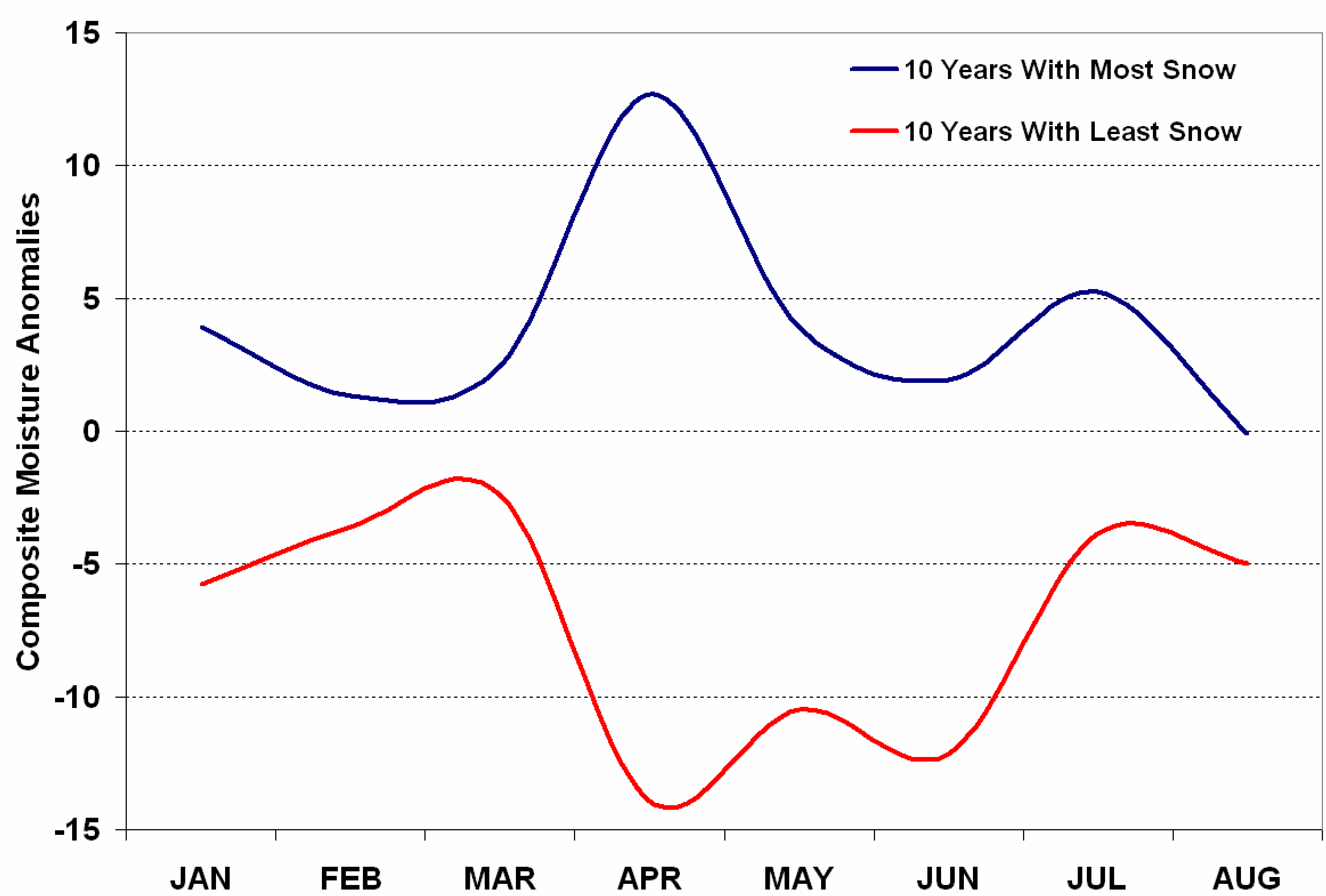
3) Are snowfall/SWE anomalies related to drought?



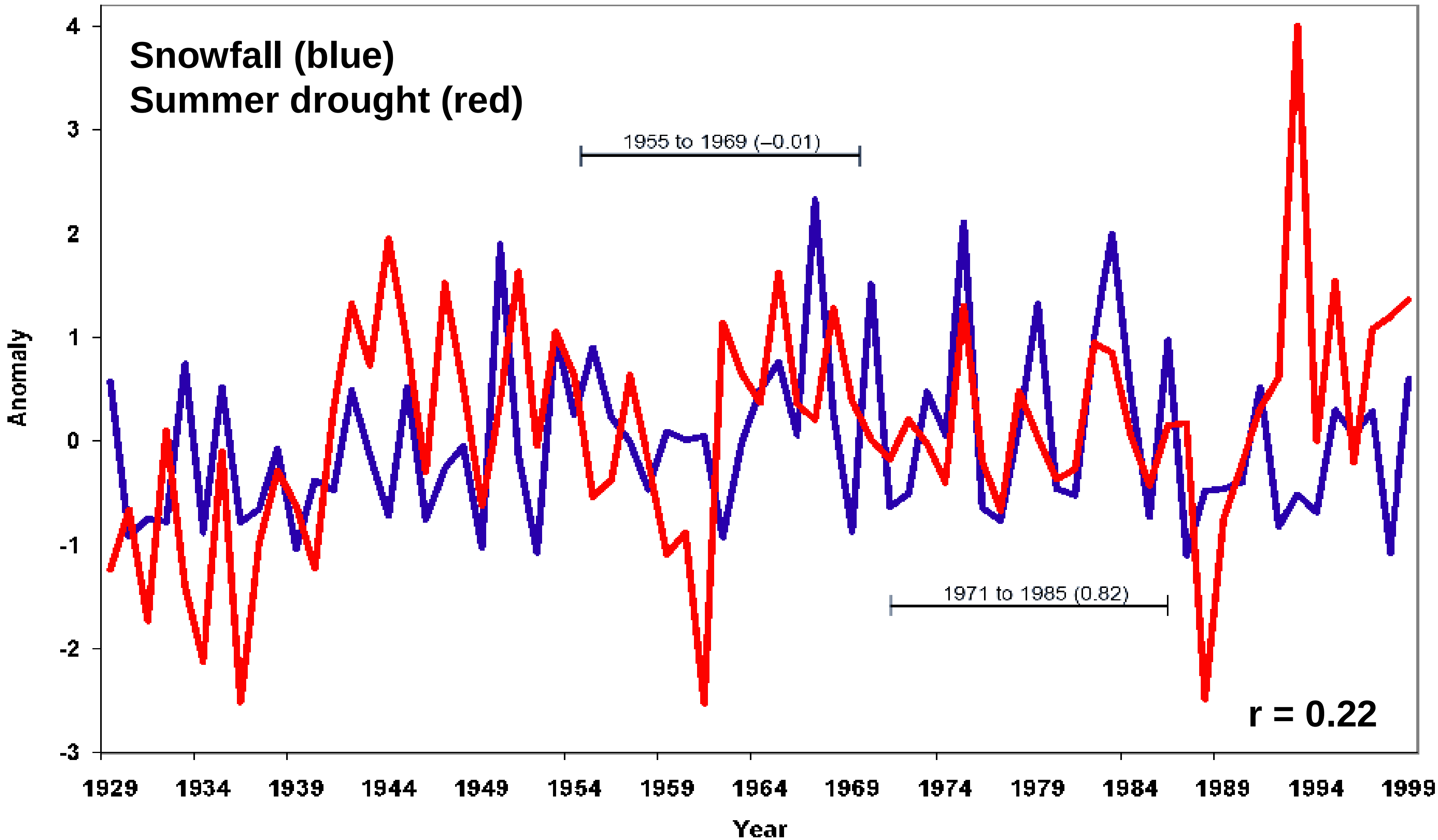
Snowfall Composites



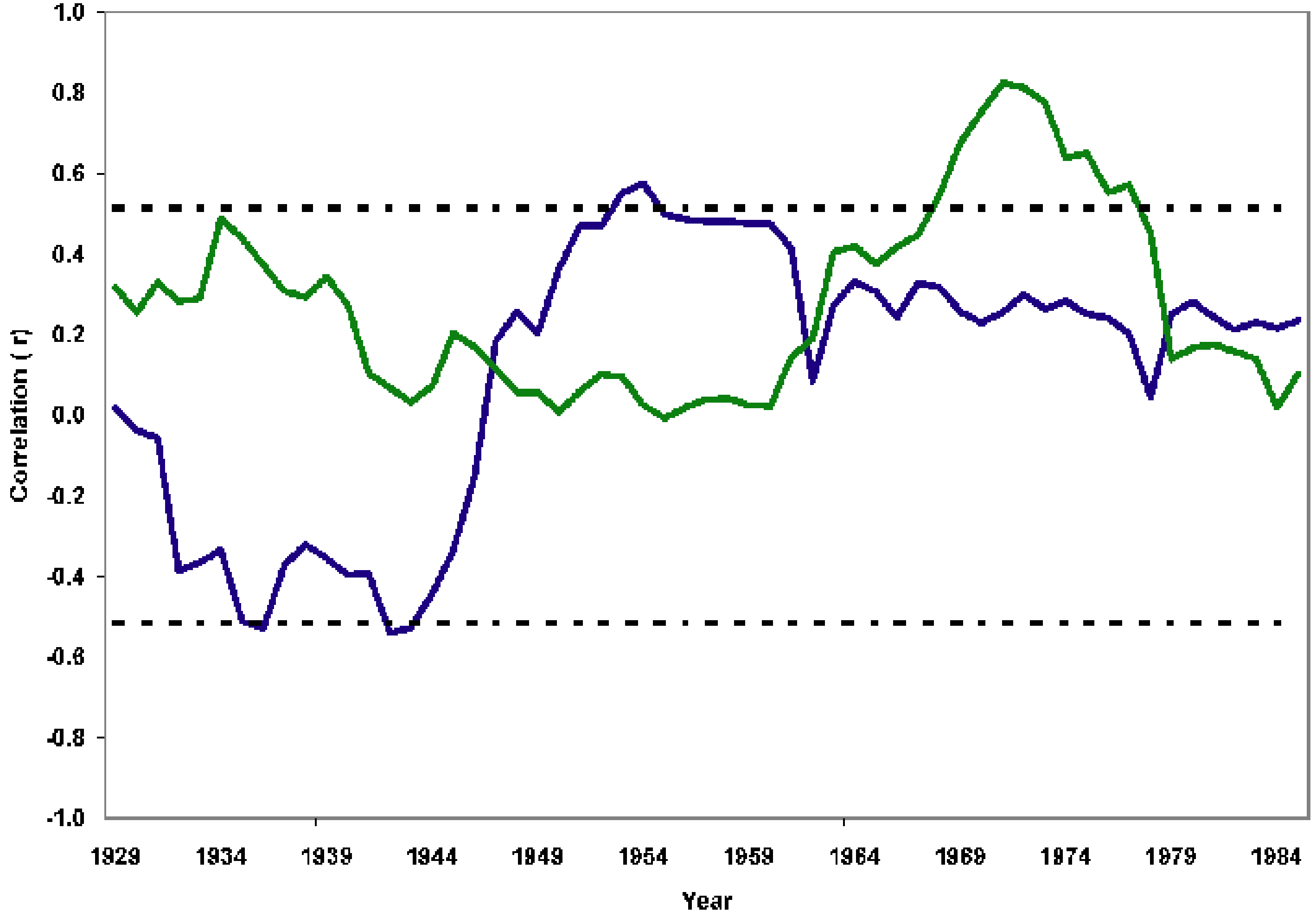
NGP Drought Composites



NGP April-May Snowfall & Drought



Temporal Variability



Winter (DJF) (blue line) and April-May (green line) snowfall anomalies and summer moisture anomalies (Z-index) calculated for all 15 yr time periods between 1929 and 1999. Dashed lines indicate the 95% significance level.

Summary & Conclusions

- **Below (above) normal snowfall in winter/spring is generally associated with anomalously dry (wet) soil moisture in May through July and lower (higher) than normal summer precipitation**

- **The strength of the relationship between winter/spring snowfall and summer moisture anomalies varies significantly over space and time**

- **Lack of spatial and temporal stability in the snowfall-drought and soil moisture-drought relationships have significant implications for understanding and forecasting these events**

Acknowledgements:

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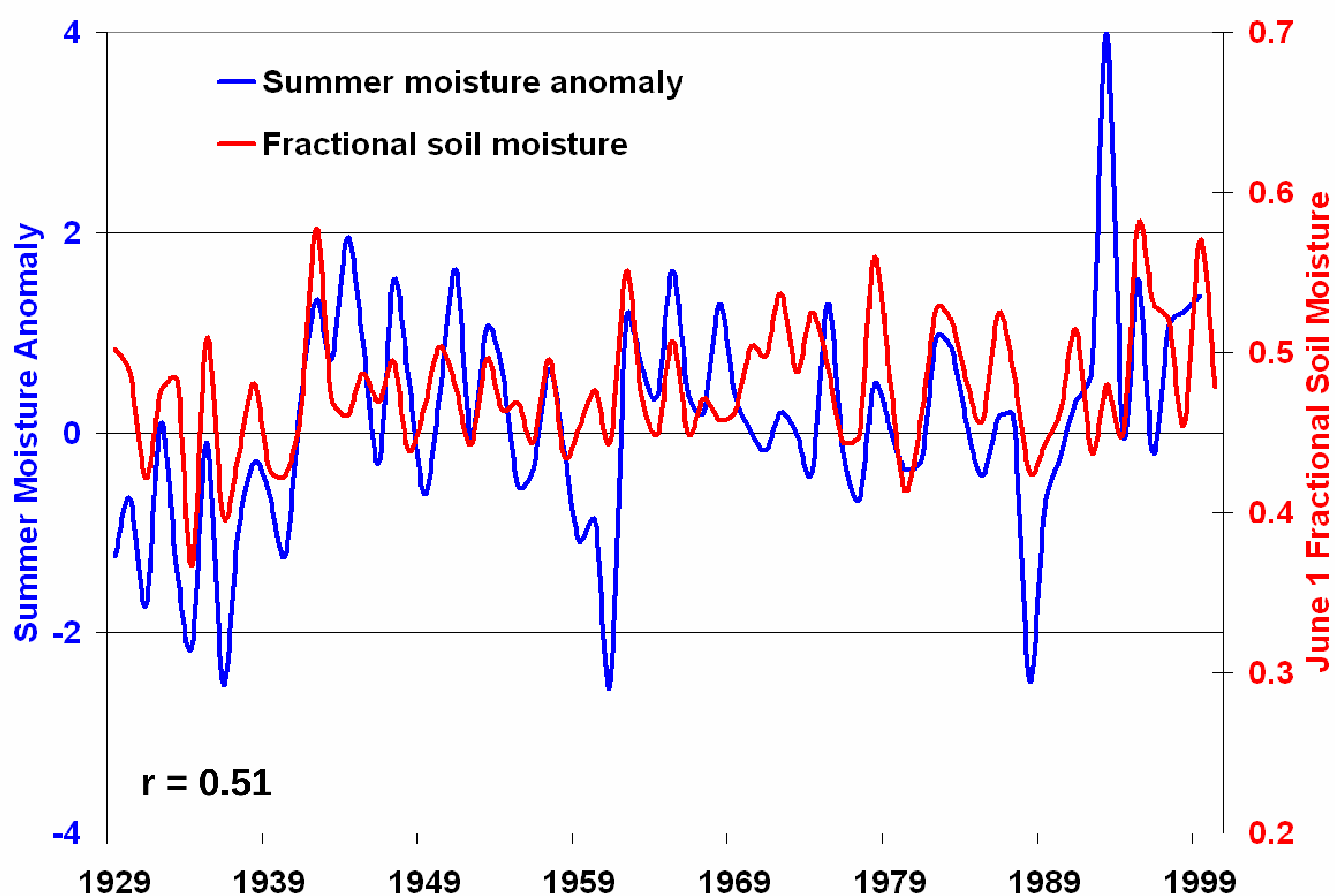
Ted Banks

4) Can we use soil moisture data to forecast drought?



Future Research

- **Further analysis of snow and soil moisture data**
- **Examine causes of spatial and temporal variability**
- **Modeling land-atmosphere interactions using regional climate model**
- **Developing hindcast and predictive drought models for the NGP**