Quantifying the Relative Roles of Local Versus Remote Effects on North American Summertime Drought

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I. Introduction and Motivation

Mid-latitude drought is thought to have both remote and local forcings. The remote forcings, typically associated with regional sea surface temperatures anomalies, influence the large-scale atmospheric flow, affecting moisture transports, as well as the lift necessary to cause the moisture to condense and precipitate out. The local forcings are associated with land surface-atmosphere interactions, and include the roles of vegetation, soil, moisture, and snow cover. These can affect the moisture fluxes between the surface and atmosphere, but importantly also the surface energy budget, with consequences for atmospheric stability. This project will investigate these various forcings, and their relations to drought, using the Weather Research and Forecasting model (WRF version 3.5.1). The effects of soil moisture anomalies is explored here.

Main Project Goals

- Quantify the relative roles of local and remote forcing in initiating, maintaining, and enhancing North-American summertime drought.
- Determine whether the soil moisture anomalies create a more severe drought and if they prolong the drought.

II. Domain and Methodology

**General Model Setup and Climatology:**

- Global runs were previously completed using CAMS5 to examine remote SST effects due to AMO, ENSO, and PDO.
- Three separate runs: Control, 1x Anomaly, and 2x Anomaly
- For each experiment, 3 especially dry years were chosen to force the WRF simulations.
- WRF simulations are being completed from April 21 to October 3 (April 22 to July 24 shown here)
- WRF version 3.5.1 with CLM4 utilized as the main LSM
- The 1x runs presented in the following results are for model years '2004' and '2016'.
- Two simulations completed for each of the years
  - Climatological soil moisture (CAMS5 and CLM4 input)
  - Soil moisture reduced to 1% of climatological values
- All WRF simulations are completed with two-way nesting turned on.
- This allows for the inner domain to feedback onto the outer domain to allow for a more accurate representation of the local, small-scale effects of drought.
- The following difference maps were made using (Reduced Soil Moisture runs – Climo runs)

**III. Results – 2004 and 2016**

**Soil Moisture (Top Layer)**

![Fig. 2. Surface soil moisture difference from 00Z April 22 to 00Z July 24 in (m) for a) 2004 and b) 2016.](image)

**Soil Temperature (Top Layer)**

![Fig. 3. Surface soil temperature difference from 00Z April 22 to 00Z July 24 in (K) for a) 2004 and b) 2016.](image)

**Precipitation**

![Fig. 4. Accumulated precipitation difference from 00Z April 22 to 00Z July 24 in (mm) for a) 2004 and b) 2016.](image)

**IV. Discussion**

- **Soil Moisture and Temperature (Local):**
  - Soil moisture remains reduced across all areas, especially across the Eastern United States. Where the surface is already dry, reducing the soil moisture further does not have a substantial impact (e.g., Texas and New Mexico).
  - Soil temperature is greatly increased, upwards of 14ºC, across the Midwest, Southeastern Canada, and central Canada in 2016. In 2004, soil temperatures remain neutral across the majority of the domain, with increased temperatures extending from the Central US into Southeastern Canada. This is expected given the much lower water content in the soil. 2004 also exhibits areas that are warmer in the climatological runs (e.g., Western Mexico).
  - Long-Wave Atmospheric Circulation (Large-Scale Effects)
    - There is general increased ridging across the entire domain in 2004, with the greatest increase in heights across the Central US. This indicates that the ridge has strengthened eastward towards the area where soil moisture reduction impacts are higher. This will help inhibit moisture transport into the region.
  - Precipitation
    - Despite the temperature extremes not being as high in 2004, the reduced soil moisture runoff showed a much greater reduction in precipitation. This coincides with the enhanced ridging throughout this time period.

**V. Concluding Remarks and Future Work**

- The reduction of soil moisture does indeed increase the severity of the drought, especially in terms of overall drought area. This increased severity of drought at the surface feeds back to the large-scale atmospheric circulation in terms of increased ridging. Precipitation is also greatly reduced, therefore decreasing moisture availability through evaportranspiration.
- **Future Work**
  - Complete simulations for the remaining dry years for the Control, 1x, and 2x experiments
  - Complete a suite of runs with full suite of runs using saturated soil for comparison

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