GROWING-SEASON SOIL MOISTURE PREDICTION USING A CLIMATE-PLANT-SOIL COUPLED AGROECOSYSTEM MODEL

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1. INTRODUCTION

Seasonal soil moisture prediction is a critical factor for economic decision-making in agriculture. The national outlook of soil moisture is given at grid resolution that is too coarse to resolve prominent weather systems on small scales and also unable to include locally observed soil information as input initial conditions. By coupling models of regional climate, surface hydrology, and crop growth, we are establishing a fully coupled agroecosystem water modeling system that can allow crop producers to inventory, update, and project seasonal soil water availability at field scale for planning strategies on cropping, seed selection, chemical application, planting, harvest, and marketing.

2. MODEL AND FORECAST SYSTEM

Although our region of interest for this study is Iowa and neighboring states, our model requires lateral boundary conditions from a global forecast. Our interest in the entire growing season requires knowledge of deep soil conditions, in addition to crop development. Therefore our forecasting system couples three main component models and one observing network. The lateral boundary conditions for our regional model come from the Experimental Climate Prediction Center (ECPC) at the Scripps Institution of Oceanography, which makes global and regional forecasts for up to 16 weeks in advance every weekend. The ECPC's atmospheric climate prediction system is based on the National Centers for Environmental Prediction (NCEP) global model with the T62L28 resolution (Roads et al., 2001).

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The regional forecast model used in this study is the MM5 version 3 developed at NCAR (Grell, et al. 1995). The model domain consists of 101x75 grid points with a horizontal resolution of Δx=52 km centered at (37.5^{o}N, 100^{o}W), covering the entire U.S. The most important parameterization scheme relevant to this study is the land surface scheme. Currently the OSU land surface scheme is being used for preliminary tests. The model implementation has 24 categories of land use and 16 soil types. The soil model consists of four layers at the depths of 10, 40, 100, and 200 cm (Chen and Dudhia, 2001).

A refined land surface scheme (Bonan, 1996) is also being coupled into MM5. The new versions CERES-maize and CROPGRO models, which have been recently combined into a single Cropping System Model (CSM) (http://www.agen.ufl.edu/csml), are also being coupled to the forecast system.

3. RESULTS

Since spring 2002 we have run the forecast system on a quasi real-time basis, forecasting soil moisture, precipitation, temperature, and other variables. The weekly model runs predict mean weather and soil conditions around Iowa 16 weeks in advance. The current forecast products are displayed at http://www.pircs.iastate.edu/Endowment. In this abstract we present results only for the period spanning March 16 to April 27 and analyze results only for Iowa and neighboring states where we have available soil moisture observations.

Directly observed soil moisture data are very scarce, especially on large scales, so we do not have enough observations to evaluate the spatial distribution of the forecast. We use observed soil moisture data from four SCAN sites: Ames, IA (42°00' N 93°43' W); Shagbark Hills, IA (42°26' N 95°46' W); Rodger's Farm, NE (40°51' N, 96°28' W); and Spickard, MO (40°14' N 93°42' W). They are about 200 km apart within our area of interest. The sensors measure hourly volumetric soil water content at 5 depths: 2, 4, 8, 20 and 40 inches.

Figure 1 shows the six forecasts initialized weekly starting March 16, 2002 which form an ensemble of 16-week forecasts of soil moisture at Ames, IA. We analyze soil moisture of the top model level only that approximately corresponds to the first two observed layers. Forecasts are similar in the first 2-3 weeks, then depart from each other, and finally follow a similar trend. Most individual forecasts showed a surprisingly good agreement with observations given the length of forecast and high variability of soil moisture. The forecasts captured the dry period in June and wet period in early July, although they failed to capture the August soil moisture increase.

The trend of forecast ensemble mean compares very well with the observations. It produced the relatively steady period 4/13-5/23 and fast drying period 5/24-7/5. The ensemble mean even captured the moistening period around mid-July, although with reduced amplitudes. The secondary peak at the beginning of August was missed in the forecast, although only one member extended to this date. The model had a consistent dry bias of about 5-15% in volumetric content. This dry bias is very likely attributable to two sources: dry initialization of soil moisture and underprediction of precipitation. All forecasts except for one ensemble (4/13) started drier by about 5-10% in volumetric content. To test this effect of dry bias in initialization, we reran the 4/27 case with the soil water volumetric content corrected to observation. As expected, the corrected forecast had a substantial improvement between weeks 3-10 (Fig. 2).

Direct input for soil moisture is precipitation. The temporal variation of precipitation was simulated reasonably well, reproducing the June dry period as indicated by the flat curves in Fig. 3, although forecasts underpredicted rainfall in all but one member of ensemble forecasts.

The model seems to have some skills in capturing the time evolution of precipitation events. During January-March, 2003 there were two high precipitation periods (Fig. 4). The two sharp heavy precipitation spikes in the forecast seems to resemble the observation although the exact time is roughly 5 days off. The precipitation amounts were underpredicted by about 50% for the two peak events.

5. SUMMARY AND DISCUSSION

A quasi real-time seasonal agroecosystem model was established for agricultural applications. The regional forecast model (MM5) was driven by global forecasts via lateral boundary conditions at 6-hourly intervals. Sixteen-week forecasts predicted soil moisture for spring 2002. The six-member ensemble forecasts captured the temporal variation of the top 10cm soil moisture well when compared with available observations in Iowa and neighboring states. The model's dry bias was very likely associated with underprediction of precipitation and dry bias of soil moisture at initialization.

Results from this one season forecast and long-term simulations (Pan et al. 2001) are very encouraging in their ability to provide useful information for agricultural decision making. Future plans include developing a method to correct initial soil moisture based on limited soil moisture observations from SCAN sites. Another area of interest is to forecast anomalies of soil water and precipitation (not their absolute amounts), so that persistent biases can be removed from the forecasts.

ACKNOWLEDGEMENTS

This research was sponsored by the Iowa State University Baker Endowment Program and the DOE/BER through Great Plains Regional Center of NIGEC (DE-FC03-90ER61010). Computer resources used for this study were provided by NCAR CSL facility.

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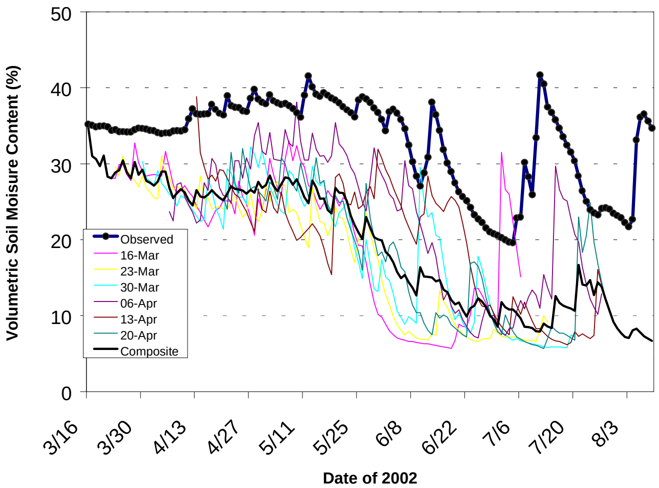

Figure 1. Sixteen-week forecasts of soil moisture at Ames, Iowa. Different lines represent ensemble members with various starting points. Note all forecasts captured the observed June dry period and early July wet period.

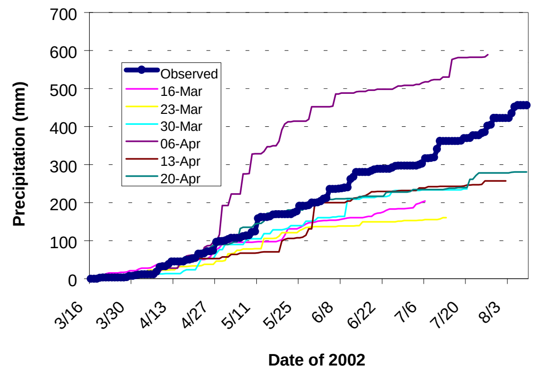

Figure 3. Sixteen-week forecasts of precipitation at Ames, Iowa. Different lines represent ensemble members with various starting points. Note all forecasts captured the June dry and early July wet periods.

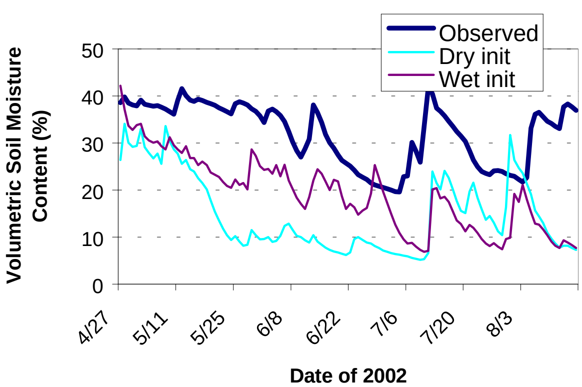

Figure 2. Forecast improvement by correcting initial soil water content using the observations. The forecast started on 27 April, 2002.

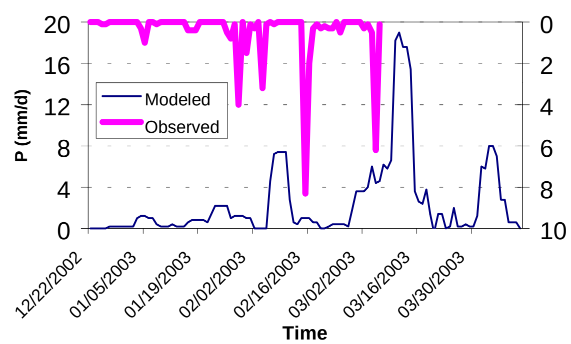

Figure 4. A comparison of forecast and observed precipitation at Ames, Iowa.