THE LINKAGE OF REGIONAL CLIMATE MODELS TO CROP MODELS

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1. INTRODUCTION

Agriculture is Florida's most weather-sensitive sector. There is a well-documented interest by growers and ranchers in Florida for advance information on the climate of the upcoming agricultural season. Seasonal forecasts offer the potential to modify outcomes and risks, and hence, impact decisions.

Future improvements in climate prediction science and forecast products are expected to come largely through larger ensemble datasets and improved dynamic climate models whose output can be used directly for agricultural applications (Phillips et al., 1998; Cane 2001; Druyan et al., 2001;Goddard et al., 2001). Therefore, even though their skill levels are still being investigated, it may be beneficial to couple agricultural models with the regional climate models for producing relevant information for use by agricultural decision makers.

The appropriate methodology for linking climate prediction and crop simulation models has been identified as a critical knowledge gap. The goal of this work was to examine these issues through a case study involving the integration of the Florida State University regional nested climate model (Cocke and LaRow, 2000) with a maize model in the widely used DSSAT family of crop models. The growing seasons during 1998 and 1999 were chosen because they represent significantly different climate regimes: 1998 was an El Niño year and 1999 was a La Niña year. Descriptions of the climate models and crop models will be summarized in Sections 2 and 3. Preliminary results from this study will be discussed in Section 4.

2. NESTED REGIONAL SPECTRAL MODEL

The climate model used in this study is a regional spectral model embedded within a global coupled ocean-atmosphere spectral model. The regional model is a re-locatable spectral perturbation model that can be run at any horizontal resolution and uses base fields and sea surface temperatures derived from the coupled global model as boundary conditions. The vertical structure of the global model consists of 14 unevenly spaced vertical levels and it is coupled to the Max Planck global ocean model (HOPE). Details of these models and the model physics are available in Cocke and LaRow (2000).

Two six-month experiments were conducted for the growing seasons (March-August) of 1998 and 1999. A ten-member ensemble was constructed for each year to assess uncertainty in initial conditions and variability of forecasts in space and time. Each ensemble member was six months (184 d) long with atmospheric initial conditions chosen from consecutive start dates centered on 1 March, obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF). The coupled model was initialized with a spun-up ocean state [see Cocke and LaRow (2000) for more details]. The global model was run on a coarse grid spacing of ~200 km and the regional model on a fine scale resolution of ~20 km.

3. CROP MODEL

The CERES-Maize simulation model (Ritchie et al. 1998) was used to delineate effects of various forecasts on simulated maize yield. The CERES-Maize model is a dynamic process based crop model that simulates how corn plants respond to soil, weather, water stress, and management. Using site-specific input data, it calculates development, growth, and partitioning processes on a daily basis, starting at planting and ending when harvest maturity is predicted. As a result, the response of the corn plant to different soils, weather, and management conditions can be predicted.

4. DISCUSSION

In 1998, none of the forecasts (measured by either mean or most likely yield) predicted the 1998 yield of 7.2 Mg ha^{-1} correctly (Figure 1). The yield simulated using 1998 weather was significantly lower than yields produced by all forecasts. The differences in maize yield forecasts arise because of the non-linearity of crop responses to weather. Expected yields from 30-yrs of historic weather data ranged from 6.12 to 11.89 Mg ha^{-1} with a mean of 9.90 Mg ha^{-1} and standard error (*s.e.*) of 0.25 Mg ha^{-1}. The range of yields estimated in El Niño years was smaller and ranged from 9.10 to 11.84 with a mean of 10.31 and *s.e.* of 0.37 Mg ha^{-1}. The 1998 yield of 7.2 Mg ha^{-1} was outside the range of yields expected using El Niño forecasts. Climatologically and using regional model forecasts, the probability of such a low yield was about once every 10 years or 10%. Prediction error (PE) (measured as the difference between the expected yield using a forecast and yield in 1998 using the same forecast specific management) varied from a low of +2.7 Mg ha^{-1} using climatological forecast to a high of +3.80 Mg ha^{-1} using regional model based forecasts.

The 1999 cropping season was a La Niña year with normal rainfall and resulted in a simulated yield considerably higher (13.94 Mg ha^{-1}) than yields predicted using 30-yrs of climatological or 6-yrs of La

Niña based forecasts (Table 1). The regional model-based forecast accurately predicted the observed 1999 yield (Figure 1). Predictions based on climatology, ENSO, and rainfall categories in 1998 and 1999 exhibited little skill, while the regional model forecast the 1999 yields with more accuracy.

5. CONCLUSIONS

We face many challenges as we seek to enhance the exciting prospect of bringing scientific seasonal climate forecasts to bear on agricultural systems. Presently, there is a capability to forecast synoptic weather (daily rainfall, temperatures and global solar radiation) specific to location/region by regional models nested within global models driven by the present state of the oceans. Results from this preliminary study indicate that the regional climate model exhibits some skill in the prediction of crop yields. More work needs to be done to evaluate the skill of the model and to determine if the model has similar skill during other seasons, different locations, or different crop types. Improvements to the model physics are currently underway and the newer version of the model will be tested in the near future. More details of these results are available in Jagtap et al. (2001).

6. ACKNOWLEDGEMENTS

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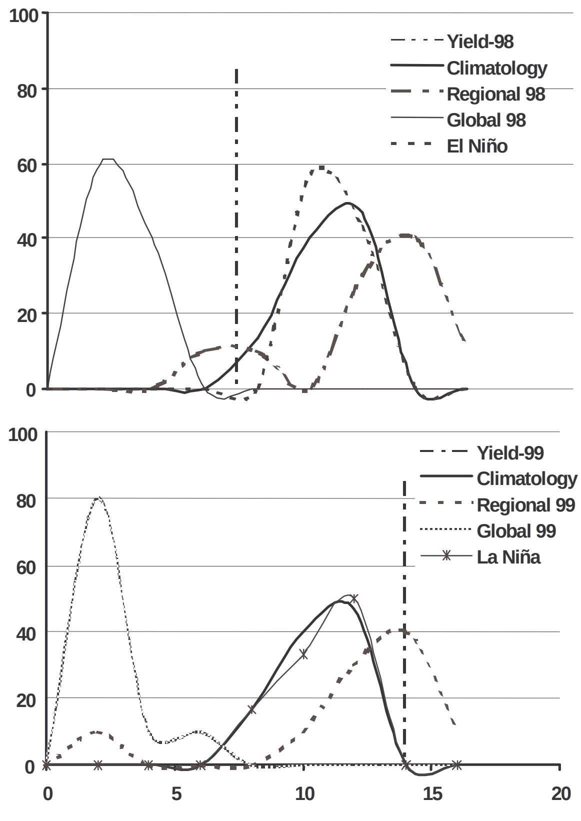

Figure 1. Relative frequency of maize yields forecast at Quincy, Florida, using different weather forecasting techniques and the current production practices for the (a) 1998 and (b) 1999 seasons. Yields were categorized into yield classes to create relative percentage values. More likely yields are indicated by higher percentages on the graphs. Figure reproduced from Jagtap et al. (2001b).