1.a October SST anomalies in the Pacific Ocean

1.b Correlation between Oct SST and average end-of-season WRSI

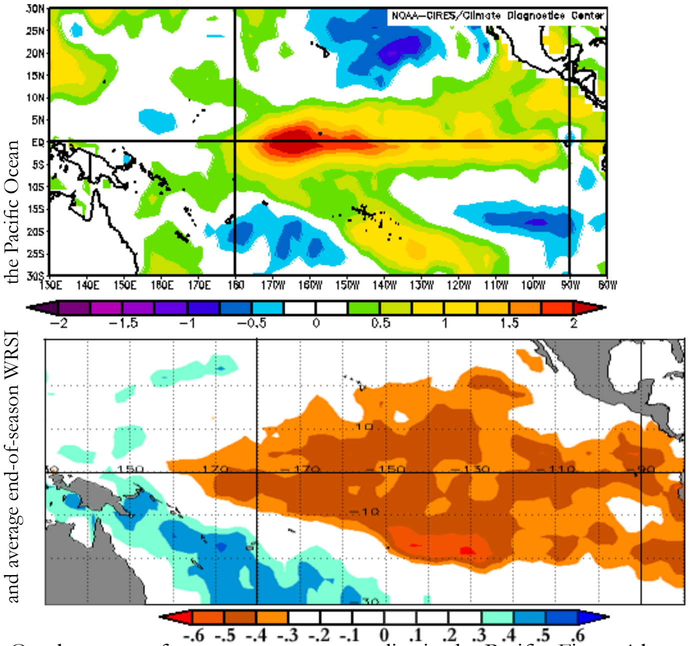

Figure 1.a October sea surface temperature anomalies in the Pacific. Figure 1.b correlation between October sea surface temperatures in the Pacific Ocean and average end-of-season WRSI values for the 11 crop growing regions used in this study. Anomaly image from www.cdc.noaa.gov.

2.a Oct SST anomalies in the Indian Ocean

2.b Correlation w/ Oct Indian ocean SST

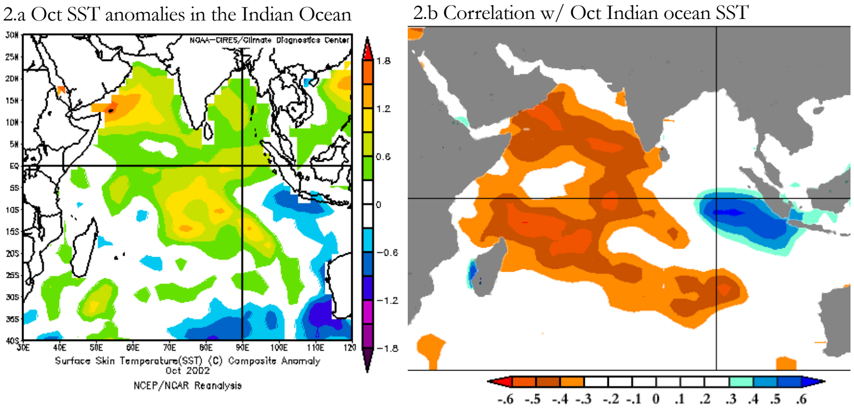

Figure 2.a October sea surface temperature anomalies in the Indian Ocean. Figure 2.b correlation between October sea surface temperaturesin the Indian Ocean and the average end-of-season WRSI values for the 11 crop growing regions used in this study. Anomaly image from www.cdc.noaa.gov.

3.a Oct 500 mb east-west wind anomalies [m/s]

3.b Correlation w/ Oct 500 mb east-west winds

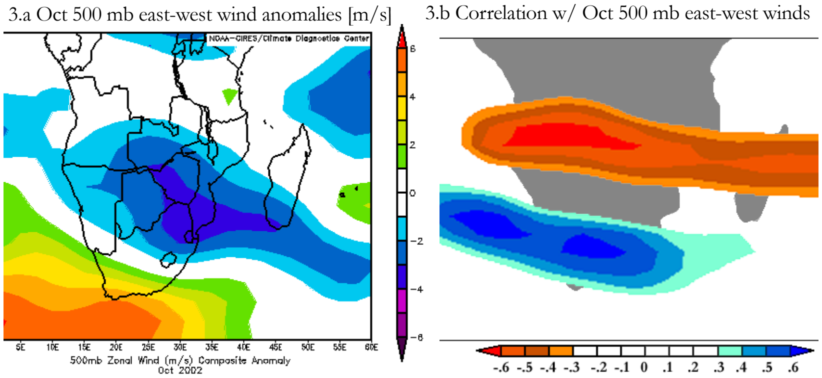

Figure 3.a October 500 mb east-west wind anomalies over Africa. Figure 3.b correlation between October 500 mb east-west winds winds over Africa and end-of-season WRSI averaged over the 11 crop growing regions in Southern Africa. Anomaly image from www.cdc.noaa.gov.

Forecasts of 2002/2003 Southern Africa Maize Growing Conditions Based on October 2002 Sea Surface Temperature and Climate Fields

December 2002

Introduction

This study presents forecasts of end-of-season maize water requirement satisfaction index (WRSI) averages for 11 crop growing regions in Southern Africa. The WRSI estimates the percentage of a crop's total seasonal water requirement that is met from available rainfall and soil moisture. Moisture deficits are directly related to crop yield reductions, making the WRSI a useful indicator of potential drought impact on maize production. Multivariate regression was used to translate October 2002 fields of sea surface temperature (SST),wind, and precipitable water into estimates of end-of-season maize WRSI for 11 crop growing regions in Southern Africa. The forecasts have good levels of cross-validated skill, with correlation values between 0.6 and 0.9. For most of the crop growing regions, the forecast suggests modest reductions in crop yield. For the crop growing regions as a whole, the forecast calls for a 1-in-3 year drought, with standard errors suggesting a likely range from slightly above average to much reduced crop yield. The northeastern part of the Republic of South Africa (RSA), and to a lesser degree, Southern Mozambique and Northern Namibia, have low forecasts for maize WRSI. A 1-in-5 year drought is suggested for Northeastern RSA with a relatively tight confidence interval.

Historical Relationships between Climate Fields and Maize WRSI

These forecasts rely on good correlations between October climate fields and end-of-season WRSI. Figure 1.b shows the correlation between October sea surface temperatures (SSTs) in the tropical Pacific and the end-of-season WRSI averaged over all 11 crop growing regions. The zones with red shading have negative correlations of less than -0.3. The zones with blue shading have positive correlations greater than 0.3. Figure 1.b shows negative correlations of less than -0.4 in the region just east of the dateline, where El Niño warming is ongoing (Figure 1.a). The combination of negative correlation with positive SST anomalies suggests drier than normal maize growing conditions for the region in aggregate for the 2002/2003 season.

Figure 2 shows a similar situation for Indian Ocean sea surface temperatures. Western Indian Ocean SSTs have a negative relationship with maize WRSI in Southern Africa, with the strongest negative correlations having values of between -0.3 and -0.6. The far eastern Indian Ocean SSTs show the opposite pattern, with positive correlations of between 0.3 and 0.6. The observed October SST anomalies (Figure 2.a) in the Indian Ocean are positive in the west and negative in the east, suggesting drier than normal maize growing conditions for the region as a whole.

Figure 3, however, suggests that upper-level wind fields may help mitigate the impacts of warm SSTs in the Pacific and Indian oceans, at least for some of the 11 crop growing regions. Figure 3.b shows the correlation between October mid-tropospheric (500 mb) east-west winds and end-of-season regional WRSI. Note that peak correlations are stronger than those for the Pacific and Indian ocean SSTs, with positive correlations greater than 0.6 at 30S latitude, and negative correlations between -0.6 and -0.7 at 15S latitude. October 2002 wind anomalies (Figure 3.a) show negative (easterly) anomalies in between these bands of positive/negative correlation, centered at about 22S. The impact of this wind anomaly field will vary from region to region, but will probably help offset the negative effects of

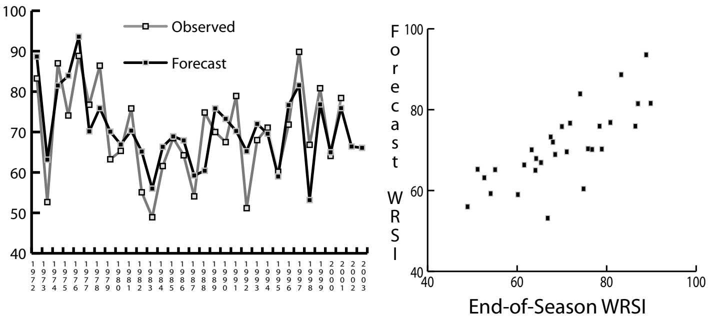

Figure 4. Time series and scatter plot of average WRSI for the 11 crop regions used in this study.

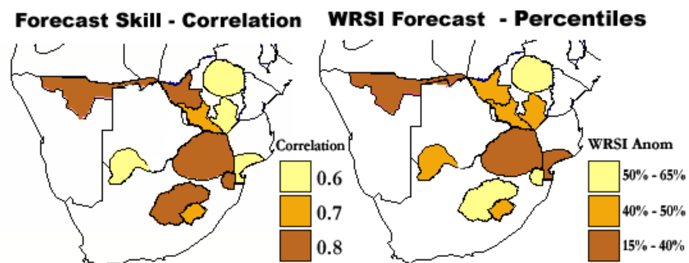

Figure 5. Cross-validated skill (correlation) and end-of-season WRSI percentile forecasts for 2003. Forecasts based on October 2002 sea surface temperatures in the Pacific, Atlantic, and Indian Oceans as well as mid and upper level winds and precipitable water variables. Forecast of 50 indicates median value. A forecast of 3 would indicate the lowest year on record (1971-2001).

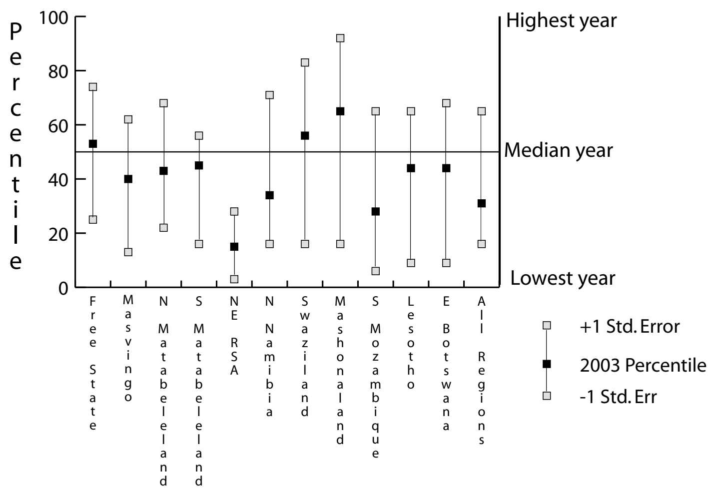

Figure 6. Forecast WRSI percentiles for the crop growing regions. The WRSI percentiles associated with +/- 1 standard error are also shown.

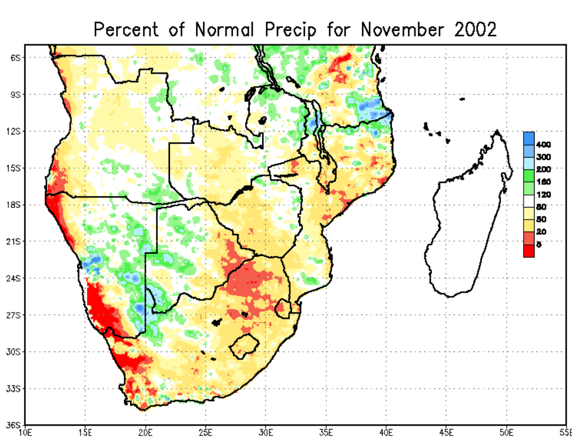

Figure 7. November rainfall anomalies, expressed as percent of normal. Image produced by the Climate Prediction Center.

warm SSTs over northern Zimbabwe and Mozambique, but not Northeastern RSA or Southern Mozambique, where the correlation is very low (no shading in Figure 3.b).

Note that the winds show the highest correlations (r~0.6), while the Indian Ocean is next in importance (r~0.5), and the Pacific Ocean third (r~0.4). The explanatory power of these correlations is 36%, 25%, and 16%, respectively, with a rough ratio of 4:3:2. Historically, anomalies in the atmosphere and oceans close to Southern Africa have been more tightly linked to end-of-season crop yield and production than anomalies in the distant Pacific.

Forecast Accuracy and Standard Errors

Data from 1970 through 2001 were used to fit statistical models and evaluate their forecast accuracy. Unique multivariate models were fit to each region's maize WRSI time series. Independent variables appearing in the models include October Pacific SST anomalies, Indian Ocean SST anomalies, Southern Africa wind field anomalies, and precipitable water anomalies. A cross-validated skill estimate for each crop growing region was created by removing each season's data, re-estimating the model parameters, and forecasting the end-of-season WRSI value for the withdrawn season. The forecast and actual WRSI values for all regions were averaged and plotted against each other in Figure 4. The models do a good job of catching the 1973, 1983, 1987 and 1995 low WRSI values. The low 1992 WRSI was not captured well, and the 1998 drought was over-estimated. The correlations between the Free State, Northeastern RSA, Northern Matabeleland, Northern Namibia and Swaziland observed WRSI time series were 0.8 with regard to their respective forecasts. The other regions had correlations ranging from 0.6 to 0.7. Standard errors were calculated for each region, and used to represent the uncertainty associated with each forecast. Note that a forecast with a correlation of 0.8 only explains 64% of the variance - leaving 36% of the variance unexplained - thus these forecast results must be used cautiously.

Forecast Results

Time series similar to the regional time series shown in Figure 4 were created for each of the 11 regions. The cross-validated skills for forecast end-of-season WRSI values are shown in Figure 5.a. Figure 5.b shows the forecasts for each region, expressed as percentiles. A percentile of 50 indicates that the forecast is similar to the median value over the period studied (1971-2001). A percentile value of 3 indicates a forecast of the lowest season on record. A value of 20 or 33 indicates a one-in-five or one-in-three dry year, respectively: 80% or 67% of the years had higher crop production values. Figure 6 shows the same percentile forecasts, but with +/- 1 standard error values. There is roughly a 67% chance that the end-of-season WRSI for the 2002/2003 season will lie between the standard errors. Most of the regions (Masvingo, North and South Matabeleland, Lesotho, Eastern Botswana) show moderately below-median WRSI values (~40 percentile). A few areas (Free State, Swaziland, and Mashonaland) are slightly above the median. Three regions - Southern Mozambique, Northern Namibia, and Northeastern RSA - show up as substantially lower than normal. The Northeastern RSA forecast is especially troubling, given that i) the forecast calls for a one-in-five dry year, and ii) the standard error interval is relatively small . In November, much of Northeastern RSA received less than 20% of its average November rainfall (Figure 7). Note, however, that the historical relationship between November rainfall totals and end-of-season WRSI values in this region is essentially 0 (r=0.02). Conversely, the correlation between Northeastern RSA end-of-season maize WRSI and December-February rainfall totals is extremely high (r=0.9). Much depends on the December-January-February rainfall.

Summary

As a region, the 2003 maize WRSI forecast calls for drier than normal crop growing conditions, with an expected percentile rank of about 30, suggesting that preparation for a one-in-three dry year is appropriate. There is substantial uncertainty in this estimate, with a 67% chance of WRSI percentile values ranging from 18 to 60, i.e. from very dry growing conditions to slightly above average conditions. [In a normal year, there would be a 67% chance of realizing values in the interval from 16.5 to 83.5] While there is a fairly good chance for all the regions except Northeastern RSA, Southern Mozambique and Northern Namibia to have normal yields, the chance of a bad year is quite high, with a one-in-four year low (25th percentile WRSI value) within the 67% error bars for all of the 11 regions. The possibility of dry growing conditions in these regions, together with the particularly dry forecasts for Northeastern RSA and Southern Mozambique, suggest an increased probability of a poor crop production season. While there is a good chance of a normal or good harvest in at least some of the regions analyzed, the risk on the downside is greater when considering the region as a whole.