TR10-13   TECHNICAL REPORT:

Linking Seasonal Forecasts into RiskView to Enhance Food Security Contingency Planning

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1. Rationale

RiskView is a tool developed by the World Food Programme (WFP) to translate weather data (real-time and historical) and other spatial information (e.g., crops, drought risk, population, etc.) into food security needs and response costs. It serves as a swift way of estimating costs in advance of food insecurity outlooks for financial planning, and for facilitating better resource allocations to disasters before on-the-ground needs assessments are produced.

One of the cores of RiskView is the calculation of Water Requirement Satisfaction Index (WRSI) to estimate drought risks at the aggregate scale. WRSI is used to determine the risk of a region being food insecure in a coming season. To accomplish this, RiskView applies a forward-looking approach in which observed rainfall from the current season is used to calculate WRSI up to the current date, then samples rainfall from historical years to calculate WRSI for the remaining part of the cropping season. This forward-looking approach allows RiskView to include estimates of uncertainty in the calculations of WRSI from historical information. However, this capability could potentially be enhanced by using seasonal climate forecasts to weight historical years instead of assigning them equal weights.

For this reason, WFP partnered with IRI to develop weights to be applied to WRSI values calculated for administrative regions in Africa. These would weight projections of end-of-season WRSI values based on the IRI Net Assessment seasonal precipitation forecasts. In RiskView, for a particular agricultural or pastoral season and administrative region, WFP calculates projected end-of-season WRSI values based upon historical RFE precipitation estimates from previous seasons (beginning with 1996) to reflect potential uncertainty in the projected WRSI estimate. The IRI weights based upon the latest IRI Net Assessment seasonal precipitation forecast would be applied to the historical end-of-season WRSI values from previous seasons to provide a forecast-based shift in the PDF to adjust the projected end-of-season WRSI values for the current agricultural or pastoral season of interest.

This report outlines the procedure used to develop these weights and how it can be incorporated within Africa RiskView and its outputs.

2. Calculation of Precipitation Forecast-based Weights for WFP RiskView Project

Each month the IRI Net Assessment produces probabilities that precipitation in each of four overlapping three month seasons in future months will fall within above-normal, near-normal, or below normal categories (terciles) in 2.5° lat/lon resolution grid boxes across the globe. For example, a seasonal forecast made in August 2010 will produce forecast probabilities of above-normal, near-normal, and below-normal precipitation for the seasons September-November 2010, October-December 2010, November 2010-January 2011, and December 2010-February 2011. For each season and grid box these three categories are defined by historical seasonal precipitation values from the 1971-2000 base period. For a given 3-month season in a given grid box the 30 seasonal precipitation values are ranked according to intensity. The ten most intense precipitation values define the above-normal category, the middle ten precipitation values define the near-normal category, and the lowest ten values define the below-normal category.

In the calculation of the weights for the RiskView project, the historical precipitation values used to define the 1971-2000 base period and to serve as the observed precipitation values in recent years from which the historical WRSI values were taken included data from the following data sets: University of East Anglia TS2.1 monthly precipitation (1971 to December 1978; New et al. 2000, Mitchell and Jones 2005), CPC Merged Analysis of Precipitation (CMAP; Xie and Arkin 1997) Version 2 January 2010 release monthly precipitation (January 1979 to September 2009), and CAMS-OPI v0208 monthly precipitation (October 2009 to present). The TS2.1 data set was regridded by averaging from 0.5° lat/lon resolution to 2.5° lat/lon resolution to match the CMAP and CAMS-OPI data sets and the gridding of the IRI Net Assessment seasonal precipitation forecast. With the exception of the use of CAMS-OPI data to fill in precipitation values from recent months not covered by the latest release of CMAP, the selection of these datasets is the same as that used in Barnston et al. 2010 in the evaluation of the skill of eleven years of IRI Net Assessment precipitation forecasts.

Shapefiles of the administrative areas in the three regions of Africa (West Africa, East Africa, and Southern Africa) for which the weights were to be calculated were received from the RiskView team and incorporated as data sets in the IRI Data Library. Weights were to be calculated for seven agricultural or pastoral seasons (or the remaining months in these seasons) in these regions, including:

Agricultural/Pastoral Season	Dates
East Africa First Season (EA1)	1 Feb – 20 Jul
East Africa Rangeland First Season (EAR1)	1 Feb – 31 Jul
East Africa Second Season (EA2)	1 Apr – 30 Oct
East Africa Rangeland Second Season (EAR2)	1 Aug – 31 Jan
East Africa Third Season (EA3)	1 Sep – 30 Apr
West Africa Main Season (WA)	1 Apr – 30 Oct
Southern Africa Main Season (SA)	1 Oct – 31 May

The calculation of the IRI seasonal forecast-based weights requires calculating, for each precipitation tercile category (above-, near-, below-normal), the forecast probability for the upcoming agricultural or pastoral season of interest, divided by the number of historical years (starting in 1996) in which total precipitation within that agricultural or pastoral season falls into the given tercile.

Calculating these weights for a given season and administrative area in Africa from seasonal forecast and historical monthly precipitation values originally on a 2.5° lat/lon grid requires several steps.

2.1 Calculate forecast precipitation tercile probabilities for the agricultural/pastoral season of interest using IRI Net Assessment forecast probabilities

For each 2.5° lat/lon grid box, the seasonal forecast for the agricultural or pastoral season of interest is calculated from the IRI Net Assessment seasonal forecast values. For each precipitation tercile category, this is done by calculating the average probability over the IRI seasonal forecast leads that overlap the agricultural or pastoral season of interest.

Sometimes the target seasons covered by the IRI Net Assessment forecast issued in a given month will cover only a portion of the agricultural or pastoral season of interest. In these cases, it was determined that weight files would be produced for only those forecasts in which the months included in the various leads of the IRI seasonal forecast cover at least half of the agricultural or pastoral season of interest (Table 1 shows the forecast schedule). In months when the IRI seasonal forecasts are used, but the seasonal forecasts do not cover the entire season, the average probability of each precipitation tercile is calculated using the probabilities from the overlapping seasonal forecasts AND values of equal probability (0.333) assigned to each tercile to represent the unknown probabilities for enough overlapping 3-month seasons to reach the end of the agricultural or pastoral season of interest. The forecast values for 3-month seasons beyond the reach of the IRI Net Assessment forecast are considered to have climatological probabilities for each precipitation tercile. This is done to keep from biasing the forecast values for the entire agricultural or pastoral season of interest too much toward the IRI seasonal forecasts that cover only a portion (but at least half) of the season.

Additionally, toward the end of an agricultural or pastoral season, it was decided to produce seasonal forecast-based weights only if a 3-month seasonal forecast period overlapped with at least two remaining months in the agricultural or pastoral season. For example, for the West Africa Main Season, which covers 1 April – 30 October, forecast weights would be produced using forecast values from the first lead of the August forecast (covering September-November) since the seasonal forecast covers two of the remaining months of the season (September and October), but weights would not be produced using forecast values from the September IRI forecast (the first lead of which covers October-December) since the seasonal forecast covers only one remaining month of the agricultural season. The IRI seasonal forecasts are meant to be representative of 3-month seasons, but a compromise was made here to allow for forecast information from the first lead time to be used late in the agricultural/pastoral season, even if only two months remained.

Another issue was the inclusion of dry season masks in the IRI seasonal forecasts. Since there are times of the year when some parts of the globe normally receive very little or no rainfall, the IRI seasonal forecast includes a dry mask for such regions and does not produce any forecast information. The dry mask is applied to a given location in a given 3-month season if the normal seasonal amount is less than 15% of the normal total annual precipitation and is also less than 50 cm. Some RiskView administrative regions and seasons overlap with locations and seasons in the IRI seasonal forecast that include the dry mask rather than an actual forecast value. In these cases dry masked missing values were replaced with equal probability values (0.333) for each tercile to be included in the calculation of the average probability over the agricultural or pastoral season.

2.2 Determine tercile of historical seasonal precipitation values and calculate weights for each grid box and historical season

The next step is to determine, for each 2.5° lat/lon grid box, which tercile the agricultural/pastoral seasonal precipitation in each historical year (from 1996 to the most recent

complete season) belongs to with respect to the 1971 to 2000 climatology. This climatological base period is chosen to match that used for the IRI seasonal forecasts.

A count is made of the number of these years that fall into each tercile. Then, for each historical year, which must be associated with one of the three terciles, the weight is calculated as the IRI seasonal forecast probability for that tercile divided by the number of historical years assigned to that tercile category. However, a problem arises if one of the terciles is not represented by at least one of the historical years in the sample. This would result in an attempt to divide an IRI seasonal forecast probability for this tercile by zero. If this case occurs, each historical year is simply assigned an equal weight. In other words, if 14 historical years are available but one of the terciles is not represented, the weight for each year is just calculated as 1/14.

2.3 Transfer weights from coarse-resolution grid boxes to RiskView administrative areas

So far in the calculation, all the calculations have been done on 2.5° lat/lon grid boxes over Africa, since that is the form in which the seasonal forecasts and historical precipitation data are available. However, these weights need to be projected onto the RiskView administrative areas. The shapes of these administrative areas were made available as shapefiles by WFP and are now held as data sets in the Data Library.

The *weighted-average* function in the Data Library is used to produce administrative area-average values from their intersection with gridded values. For each administrative area, each grid box in the domain is checked to determine what fraction of the area of the grid box is contained within the administrative area, assigning values between 0. (no intersection) and 1. (grid box is contained entirely within the administrative area). For a given administrative area, a weighted average of the grid box values is calculated, in which the weights are the fractional values between 0. and 1., and the resulting value is assigned to the administrative region.

If an administrative area is very small in relation to the spatial resolution of the grid boxes, it will be assigned a missing value. Therefore, before this weighted averaging was done for the RiskView administrative regions (some of which are quite small), the 2.5° lat/lon grid boxes were regridded to 0.5° lat/lon resolution before applying the weighted average command. This was able to accommodate nearly all the RiskView administrative regions, with a few exceptions for extremely small regions and for some islands for which no IRI Net Assessment values are available. In these cases, equal weights were simply assigned to each year.

For a given administrative region the weights thus calculated for each historical year should ideally add to 1. when summed over the historical years. In some cases small errors over the course of the calculation will result in weights whose sum is slightly less than 1 (spot checks found no sums below 0.99). To adjust for these slight deviations, each weight is simply divided by the sum of the weights so that the sum of the resulting adjusted weights will equal exactly 1.

When the weighted-average function is applied to transfer the weights from 2.5° lat/lon grid boxes to administrative areas, in general an administrative area is likely to draw information from more than one grid box. And since precipitation from a historical year in one grid box may fall into one tercile while precipitation from the same year from an adjacent grid box may fall

into another tercile, an administrative region may combine weights from both. This is why the final year weights for an administrative region will not necessarily group into three sets of equal values (the same weight values for each member of a tercile) like the grid box weights do.

3. Operational Production of the Weights

A script that automates the production of comma-separated values (csv) files containing the weights and related metadata has been developed to run on the 22nd day of every month, after the release of the IRI Net Assessment forecasts. This script will run on the IRI computer systems and produce csv files for each country within each region/season scheduled for production that month based upon the forecast schedule (see Table 1). These files will be placed at the following URL:

http://iri.columbia.edu/~datag/WFP/RiskView/

The file names include the following components, separated by underscores: the name of the country, the code for the region/season (EA1, EAR1, EA2, EAR2, EA3, WA, or SA), the range of months in the agricultural/pastoral season for which the forecast is being produced using the English three-letter abbreviations for the months with the first letter capitalized separated by a dash (-), the month (English three-letter abbreviation with the first letter capitalized) and year (four-digit integer) the forecast was issued, the word "Forecast", and the .csv extension. The file name structure is:

*Country name_SeasonCode_StartMonth-EndMonth_ForecastMonthYear_*Forecast.csv

For example:

Tanzania_EA2_Sep-Oct_Aug2010_Forecast.csv

In this case, the forecast weights are being produced for Tanzania, for the East Africa Second Season, for the months of September-October within that season, and the forecast was produced in August 2010. The names of the files will, therefore, change each month.

The files contain seven columns of information, separated by commas. There are no column headings in the files. The first column contains the full name of the region/season, the second column contains the name of the country, the third column contains the name of the administrative area for which the forecast weights are being produced, the fourth column indicates the historical year to which the weight is applied, the fifth and sixth columns contain the number of the beginning and ending calendar months within that season for which the weights are being produced, and the seventh column contains the weights themselves. The following describes what is in each comma-separated column and whether the column contains a text string, integer, or real number:

Column1,Column2,Column3,Column4,Column5,Column6,Column7

Region/Season,Country Name,Area Name,Year,Beginning Month,Ending Month,Weight

Text,Text,Text,Integer,Integer,Integer,Real

The rows in the weight files run through all the historical years for the first administrative area in the country, then through all the historical years in the next administrative area in the country, and so on, continuously, without any blank rows or other separators. Here is an example of several rows from a file containing weights for the East Africa Second Season in Tanzania:

East Africa Second Season,Tanzania,Arusha,1996,9,10,0.05401849
East Africa Second Season,Tanzania,Arusha,1997,9,10,0.06951004
East Africa Second Season,Tanzania,Arusha,1998,9,10,0.1091888
East Africa Second Season,Tanzania,Arusha,1999,9,10,0.1091888
East Africa Second Season,Tanzania,Arusha,2000,9,10,0.06631498
East Africa Second Season,Tanzania,Arusha,2001,9,10,0.09689231
East Africa Second Season,Tanzania,Arusha,2002,9,10,0.06643788
East Africa Second Season,Tanzania,Arusha,2003,9,10,0.06093527
East Africa Second Season,Tanzania,Arusha,2004,9,10,0.05401849
East Africa Second Season,Tanzania,Arusha,2005,9,10,0.05401849
East Africa Second Season,Tanzania,Arusha,2006,9,10,0.06259326
East Africa Second Season,Tanzania,Arusha,2007,9,10,0.06093527
East Africa Second Season,Tanzania,Arusha,2008,9,10,0.07335465
East Africa Second Season,Tanzania,Arusha,2009,9,10,0.06259326
East Africa Second Season,Tanzania,Dar es Salaam,1996,9,10,0.04761905
East Africa Second Season,Tanzania,Dar es Salaam,1997,9,10,0.08333333
East Africa Second Season,Tanzania,Dar es Salaam,1998,9,10,0.1111111
East Africa Second Season,Tanzania,Dar es Salaam,1999,9,10,0.04761905
East Africa Second Season,Tanzania,Dar es Salaam,2000,9,10,0.04761905
East Africa Second Season,Tanzania,Dar es Salaam,2001,9,10,0.04761905
East Africa Second Season,Tanzania,Dar es Salaam,2002,9,10,0.08333333
East Africa Second Season,Tanzania,Dar es Salaam,2003,9,10,0.04761905
East Africa Second Season,Tanzania,Dar es Salaam,2004,9,10,0.1111111
East Africa Second Season,Tanzania,Dar es Salaam,2005,9,10,0.04761905
East Africa Second Season,Tanzania,Dar es Salaam,2006,9,10,0.08333333
East Africa Second Season,Tanzania,Dar es Salaam,2007,9,10,0.08333333
East Africa Second Season,Tanzania,Dar es Salaam,2008,9,10,0.1111111
East Africa Second Season,Tanzania,Dar es Salaam,2009,9,10,0.04761905

The URL directory containing these weight files also includes a small file named "dateupdated.txt" that contains the date when the files at the URL were last updated, in YYYYMMDD (four-digit year, 2-digit month, 2-digit day) format. For example, if the file contains "20100922", it means that the files were updated on 22 September 2010. The names of the files will change each month as the forecast issue dates, agricultural/pastoral seasons and their remaining lengths change.

4. Concluding Remarks and Recommendation

The procedure for calculating weights for historical years based on the IRI Net Assessment have been developed and implemented. These are updated periodically and can be applied to the

RiskView method to estimate potential needs for food security planning with the expectation that it can provide better information than just climatological information alone.

With the way RiskView calculates needs estimates right now, the weighted WRSI could not be directly applied to the needs estimation procedure. Due to non-linearities associated with WRSI triggers used in the production of RiskView needs estimates and the fact that WRSI itself has an upper bound of 100, it was decided by WFP to apply these forecast weights to the historical needs estimates calculated from historical WRSI (un-weighted) values rather than directly to the WRSI values then ingest them onto the needs calculation procedure. To directly use forecast weights onto WRSI to estimate needs, revising the needs triggers, i.e., WRSI values into weighted values is recommended.

It is also recommended that WFP should evaluate the impact that the inclusion of IRI Net Assessment forecast information onto RiskView outputs. Did the IRI Net Assessment forecast information improve or worsen the RiskView estimates? Are there plans to produce RiskView estimates with and without the inclusion of seasonal forecast information so that such an evaluation could be done? A possible weakness of the seasonal forecast-based weights is the short length of the historical record (currently starting in 1996) from which seasonal precipitation values are drawn to categorize these historical years into terciles. As the length of the record increases, either through the passage of time, or with the possible extension of NOAA RFE values back in time before 1995, the sample size of historical precipitation will increase, which may result in an improvement of the estimation of the weights.

References

Barnston, A. G., S. Li, S. J. Mason, D. G. DeWitt, L. Goddard, and X. Gong, 2010: Verification of the first 11 years of IRI's seasonal climate forecasts. *J. Appl. Meteor. Climatol.*, **49**, 493-520.

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Tables:

Table 1. Schedule indicating (with Xs) which IRI Net Assessment forecasts and seasonal leads will be used to produce RiskView forecast weights in each calendar month

Forecast Month	IRI Net Assessment Seasonal Leads	EA1	EAR1	EA2	EAR2	EA3	WA	SA
		Regions for which forecasts are produced for and used by RiskView:						
January Forecast	Feb-Apr	x	x			x		x
January Forecast	Mar-May	x	x					x
January Forecast	Apr-Jun	x	x	x			x	
January Forecast	May-Jul	x	x	x			x	
February Forecast	Mar-May	x	x			x		x
February Forecast	Apr-Jun	x	x	x			x	
February Forecast	May-Jul	x	x	x			x	
February Forecast	Jun-Aug			x			x	
March Forecast	Apr-Jun	x	x	x			x	x
March Forecast	May-Jul	x	x	x			x	
March Forecast	Jun-Aug			x			x	
March Forecast	Jul-Sept			x			x	
April Forecast	May-Jul	x	x	x			x	
April Forecast	Jun-Aug			x			x	
April Forecast	Jul-Sept			x			x	
April Forecast	Aug-Oct			x	x		x	
May Forcast	Jun-Aug	x	x	x			x	
May Forcast	Jul-Sept			x			x	
May Forcast	Aug-Oct			x	x		x	
May Forcast	Sept-Nov				x			
June Forecast	Jul-Sept			x			x	
June Forecast	Aug-Oct			x	x		x	
June Forecast	Sept-Nov				x	x		
June Forecast	Oct-Dec				x	x		
July Forecast	Aug-Oct			x	x		x	
July Forecast	Sept-Nov				x	x		
July Forecast	Oct-Dec				x	x		x
July Forecast	Nov-Jan				x	x		x
August Forecast	Sept-Nov			x	x	x	x	
August Forecast	Oct-Dec				x	x		x
August Forecast	Nov-Jan				x	x		x
August Forecast	Dec-Feb					x		x
September Forecast	Oct-Dec				x	x		x
September Forecast	Nov-Jan				x	x		x
September Forecast	Dec-Feb					x		x
September Forecast	Jan-Mar					x		x
October Forecast	Nov-Jan				x	x		x
October Forecast	Dec-Feb					x		x

Forecast	Period						
October Forecast	Jan-Mar					x	x
October Forecast	Feb-Apr	x	x			x	x
November Forecast	Dec-Feb				x	x	x
November Forecast	Jan-Mar					x	x
November Forecast	Feb-Apr	x	x			x	x
November Forecast	Mar-May	x	x				x
December Forecast	Jan-Mar					x	x
December Forecast	Feb-Apr	x	x			x	x
December Forecast	Mar-May	x	x				x
December Forecast	Apr-Jun	x	x				

Appendix:

A. Algorithm development for calculating weights

The following method is used to compute weights for the 15 years 1996-2010.

1. The seasonal precipitation of each of the 15 years is classified as being in the below, above or normal categories. The categories are defined relative to same the 30-year climatology used in the IRI Net Assessment, currently 1971-2000.
2. Years in the same category are assigned the same weight which is equal to the forecast probability of that category divided the number of years in that category. Note that the weights sum to one by construction.

The above procedure fails when the 15-year sample does not have years in all three categories.

In the absence of forecast information, equally spaced percentiles are computed by sorting the 15-years of data. When forecast information determines weights for each year, the percentiles are no longer equally spaced, but instead the spacing is given by the weights.

B. Sample code for estimating weights

Example of the Ingrid (Data Library language) script used to calculate and produce a table of weights for all administrative areas in Southern Africa for historical years 1996-2009 for the Southern Africa Main Season, covering the period October-May, based upon the August 2010 IRI Net Assessment seasonal precipitation forecasts.

```
expert
 ds: SOURCES .IRI .FD .Seasonal_Forecast .Precipitation .prob
   X 2.5 60 RANGEEDGES
   Y -40 10 RANGEEDGES
   F (Aug 2010) VALUE
   L 2 4 RANGE
   33.33333 replaceNaN
   [L]sum
   33.33333
    3 mul
    add
   6 div
   0.01 mul
   home .mbell .Net_Assessment .Observations .monthly .merged .TS2p1_CMAP_OPI .prcp
    T (Nov 1995) (May 2010) RANGE
    X 2.5 60 RANGEEDGES
    Y -40 10 RANGEEDGES
    T (Oct-May) seasonalAverage
   home .mbell .Net_Assessment .Observations .monthly .merged .TS2p1_CMAP_OPI .prcp
    X 2.5 60 RANGEEDGES
    Y -40 10 RANGEEDGES
    T (Oct 1971) (May 2001) RANGE
    T (Oct-May) seasonalAverage
    [T]0 0.33 0.67 1. 0.8 replacebypercentile
    [percentile]boundedtablefunction
   {Below_Normal 0.33 Normal 0.67 Above_Normal} /C classify
   a: :a:
     [T]sum
     0 maskle
     :a
    mul
   a:
     [C]1. average
     dataflag
     0 maskle
     :a:
     0 maskle
     4 index exch div
     [C]maxover
```

Select IRI seasonal precipitation forecast gridded tercile probabilities over Southern Africa from the Aug 2010 start time for the Oct-Dec, Nov-Jan, Dec-Feb seasonal leads and replace missing/dry season values with equal probabilities for each tercile.

Assign equal probabilities to terciles in the remaining 3-month seasons in the Oct-May SA agricultural season, average the probabilities in each tercile over the six 3-month seasons covering Oct-May, and convert percentages to percentiles.

Assign Oct-May 1996-2010 historical seasonal precipitation values to below-normal, near-normal, and above-normal terciles based upon the 1971-2000 30-year climatology of Oct-May seasonal values

For each 2.5º lat/lon grid box, determine the number of Oct-May historical seasons assigned to each tercile, divide the forecast Oct-May precipitation probability of each tercile by the number of historical seasons in each tercile, and assign these weights to each historical year based upon its tercile. If any tercile is not represented by one of the historical years, replace the weights in each year by equal weights that sum to 1 (divide 1. by the number of historical seasons).

```
  :a
  mul
 T npts nip
  1. exch div
  replaceNaN
 X 2.75 0.5 59.75 evengridAverage
 Y -39.75 0.5 9.75 evengridAverage
 home .mbell .GISupload .RiskView .Mar2010shapes .val_sa_20100317_final .geometry
.the_geom
   [X Y]weighted-average
  /name /weights def
  /long_name (Weights) def
  dup
   [T]sum
   div
 T npts nip
  1. exch div
  replaceNaN
 home .mbell .WFP .RiskView .Mar2010names .val_sa_20100317_final .area
  /long_name (Area) def
  home .mbell .WFP .RiskView .Mar2010names .val_sa_20100317_final .country
   /long_name (Country) def
   home .mbell .WFP .RiskView .Season
   N (SA) VALUE
   :ds
 mark Season T country area weights
    table: mark :table
```

Regrid weights in 2.5º lat/lon grid boxes to 0.5º lat/lon grid boxes, and calculate RiskView administrative area-averages of weights from the 0.5º lat/lon grid box values that fall within each administrative area. Ensure that the weights sum exactly to 1. If an administrative area is too small or outside the region covered by the IRI seasonal forecast, assign equal weights to each historical season (divide 1. by the number of historical seasons).

Generate a table containing columns for agricultural/pastoral season and region, month range of remaining season, country name, area name, and weights, for each historical year for each area in Southern Africa. This table will be separated into country tables and reformatted by an automated Perl script.