A Seasonal Rainfall Performance Probability Tool For Famine Early Warning Systems over Africa

Nicholas S. Novella, and Wassila Thiaw

Climate Prediction Center, National Centers for Environmental Prediction

OVERVIEW

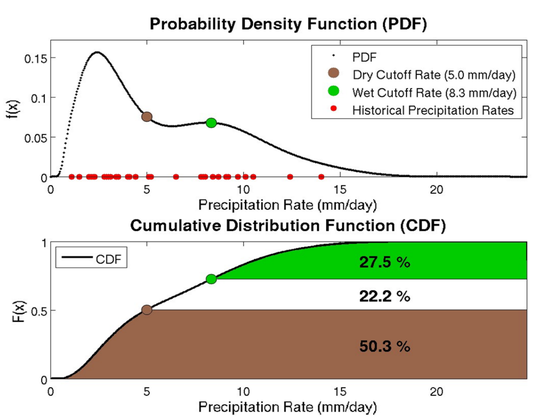
In this poster, we show the development of a new statistical tool which produces probabilistic outlooks of seasonal precipitation anomaly categories over Africa. Called the Seasonal Performance Probability (SPP), it quantitatively evaluates the probability of precipitation to finish at predefined percent of normal anomaly categories corresponding to below Average (<80% of Normal), Average (80-120% of Normal), and Above-Average (>120% of Normal) conditions. This is accomplished by applying Kernel Density Estimation (KDE) methods to compute smoothed, continuous density functions based on more than 30 years of historical precipitation data from the Africa Rainfall Climatology Version 2 dataset (ARC2). Also presented here are various KDE parameterizations tests to determine optimality of density estimates, and thus, performance of SPP for operational monitoring. Verification results using Heidke Hit Proportion (HHP) scores from 2010-2014 suggest that SPP reliably provides probabilistic outcomes of seasonal rainfall anomaly categories by early to mid-stages of rains seasons for major monsoon regions in east, west and southern Africa. SPP has been a useful tool in operational climate monitoring at CPC International desks, by providing early warning guidance for better decision making in food security, planning and response objectives for USAID/FEWS-NET.

Methodology:

Equation 1

$$f(x) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x - x(i)}{h}\right)$$

Figure 1



- The main goal in SPP lies in determining the probability density function (PDF) and cumulative distribution function (CDF) of historical rainfall rates in ARC2 during a monsoon season from the current day (**Tc**) in a season to the end of season (**Tf**).
- Using Kernel Density Estimation (KDE) methods (**Equation 1**), if we let **x(i)** be a set of historical precipitation estimate rates from **Tc** to **Tf**, and let **x** be an array of hypothetical rain rates required in the future [0 Inf] we may then solve for an unknown density, **f(x)**, and yield the probabilities for each respective hypothetical rain rate required to satisfy a number of anomaly thresholds.
- To illustrate, suppose the following for some location (i,j):
  - Current Seasonal Total = 100mm
  - Current Normal Total = 150mm
  - Current % of Normal = 66%
  - End of Season Normal Total = 500mm
  - Number of days remaining in the season = 60 days
- Therefore, we find that hypothetical precipitation rates of 5.0, 6.6, 8.33 (mm/day) are required for the remainder of the monsoon season to finish at least 80%, 100%, and 120% of normal, respectively. Plotting these threshold values (**Figure 1**), we find that the persistence of below-average conditions by the end of the season are climatologically favored (50%) over a seasonal rainfall recovery (28%) according to ARC2 data.

Parameterization:

Table 1

East Africa (March-May)

Kernel	Bandwidth	15-Mar	1-Apr	15-Apr	1-May	15-May
Gaussian	h1	0.5332	0.6142	0.7153	0.8149	0.8955
Gaussian	h2	0.5345	0.6168	0.7156	0.8133	0.8945
Epanechnikov	h1	0.5334	0.6148	0.7157	0.8146	0.8955
Epanechnikov	h2	0.5345	0.6167	0.7164	0.8136	0.8943

West Africa (July - September)

Kernel	Bandwidth	15-Jul	1-Aug	15-Aug	1-Sep	15-Sep
Gaussian	h1	0.6169	0.6542	0.7354	0.8141	0.8752
Gaussian	h2	0.6167	0.6539	0.7348	0.8138	0.8752
Epanechnikov	h1	0.6169	0.6541	0.7355	0.8140	0.8753
Epanechnikov	h2	0.6159	0.6537	0.7345	0.8137	0.8754

East Africa (October - December)

Kernel	Bandwidth	15-Oct	1-Nov	15-Nov	1-Dec	15-Dec
Gaussian	h1	0.5855	0.6296	0.7141	0.7829	0.8651
Gaussian	h2	0.5830	0.6270	0.7131	0.7808	0.8652
Epanechnikov	h1	0.5860	0.6293	0.7141	0.7824	0.8654
Epanechnikov	h2	0.5834	0.6268	0.7126	0.7814	0.8649

Southern Africa (December - February)

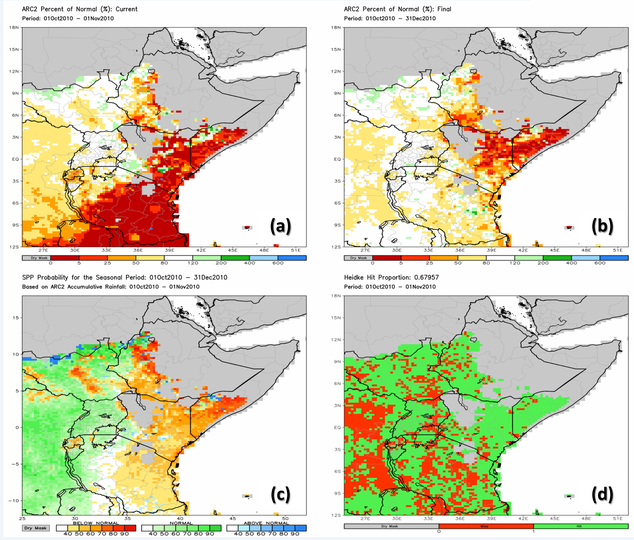
Kernel	Bandwidth	15-Dec	1-Jan	15-Jan	1-Feb	15-Feb
Gaussian	h1	0.5811	0.6323	0.7081	0.7817	0.8866
Gaussian	h2	0.5813	0.6318	0.7099	0.7831	0.8873
Epanechnikov	h1	0.5815	0.6322	0.7085	0.7819	0.8867
Epanechnikov	h2	0.5813	0.6326	0.7109	0.7834	0.8876

- In KDE, much literature has been written on the selection of bandwidth parameter, **h**, and kernel type, **K**, as both have a marked effect on the shape of the estimated density. The most attractive kernels for SPP are either the Gaussian and Epanechnikov kernels, and the bandwidth methods of (Silverman, 1986) and (Sheather and Jones, 1991).
- Because precipitation is a bounded quantity [0 Inf], a log transformation is applied within all kernels to prevent any leakage of the probability mass beyond the origin. This ensures **f(x)**=0 where **x** <0 and **f(x)** may integrate to 1.
- The SPP algorithm was reprocessed and validated using both kernel types and bandwidth methods over several key monsoon periods in eastern, southern and western Africa. HHP scores were averaged from 2010-2014 (**Table 1**).
- Differences in HHP scores appear to be negligible, suggesting that a particular kernel and bandwidth does not offer any advantage in improved performance and in scores.

Results / Discussion:

Case Study #1: Oct-Dec, 2010

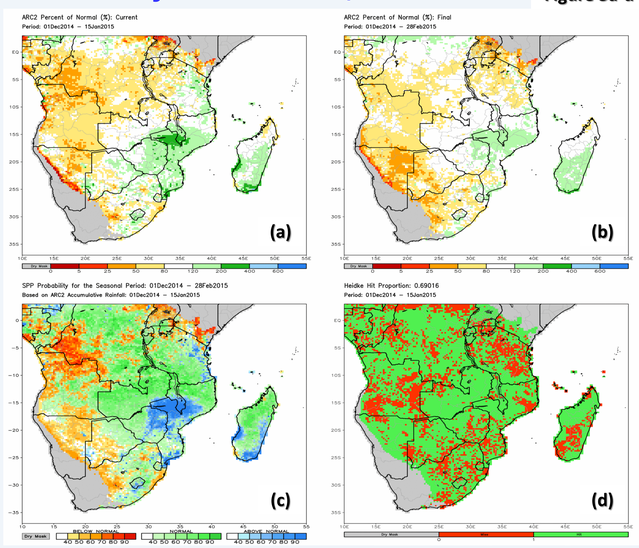
Figure 2a-d



- For several areas that experienced very poor rains (< 25% of normal) during early season **(Figure 2a),** SPP depicts high SPP probabilities (> 80%) for seasonal rainfall to finish in the below-average anomaly category **(Figure 2c).**
- These high SPP probabilities are explained in the climatology, where instances of inadequate rainfall during October has historically led to either persistence or worsening of drought conditions with little to no chance of recovery before the end of the season.
- Analysis of the final season percent of normal rainfall (**Figure 2b)** and verification score map on November 1st, 2010 (**Figure 2d)** indicate that nearly 70% of the seasonably active rain areas in east Africa had SPP probabilities that correctly verified in the respective anomaly categories. For decision makers in food security, the majority of correctly verified hits occurred before mid-season over agricultural and pastoral areas in Somalia, Kenya, Ethiopia, and Tanzania, which heavily rely on seasonal rainfall.

Case Study #2: Dec-Feb, 2014-15

Figure 3a-d



- A poorly distributed and erratic southern Africa rains season presented a greater challenge to SPP due to unusual reversals in the monsoon circulation and in the non-linear evolution of precipitation anomalies.
- By the end of December, SPP for below-average rainfall over southern Angola and northeastern Namibia did not correctly verify until an extended dry spell occurred in early January. After January 15th, 2015 SPP pointed to a much higher probability for below-average rains and verification scores had steadily increased **(Figure 3c-d).**
- Along the Zambezi River basin, seasonal rainfall accumulations had surpassed the climatological normal total well before the end of season. As a result, SPP depicts 100% probability for the above-average rainfall category since negative rainfall cannot exist.