

Future Occurrence of Threshold-Crossing Seasonal Rainfall Totals: Methodology and Application to Sites in Africa

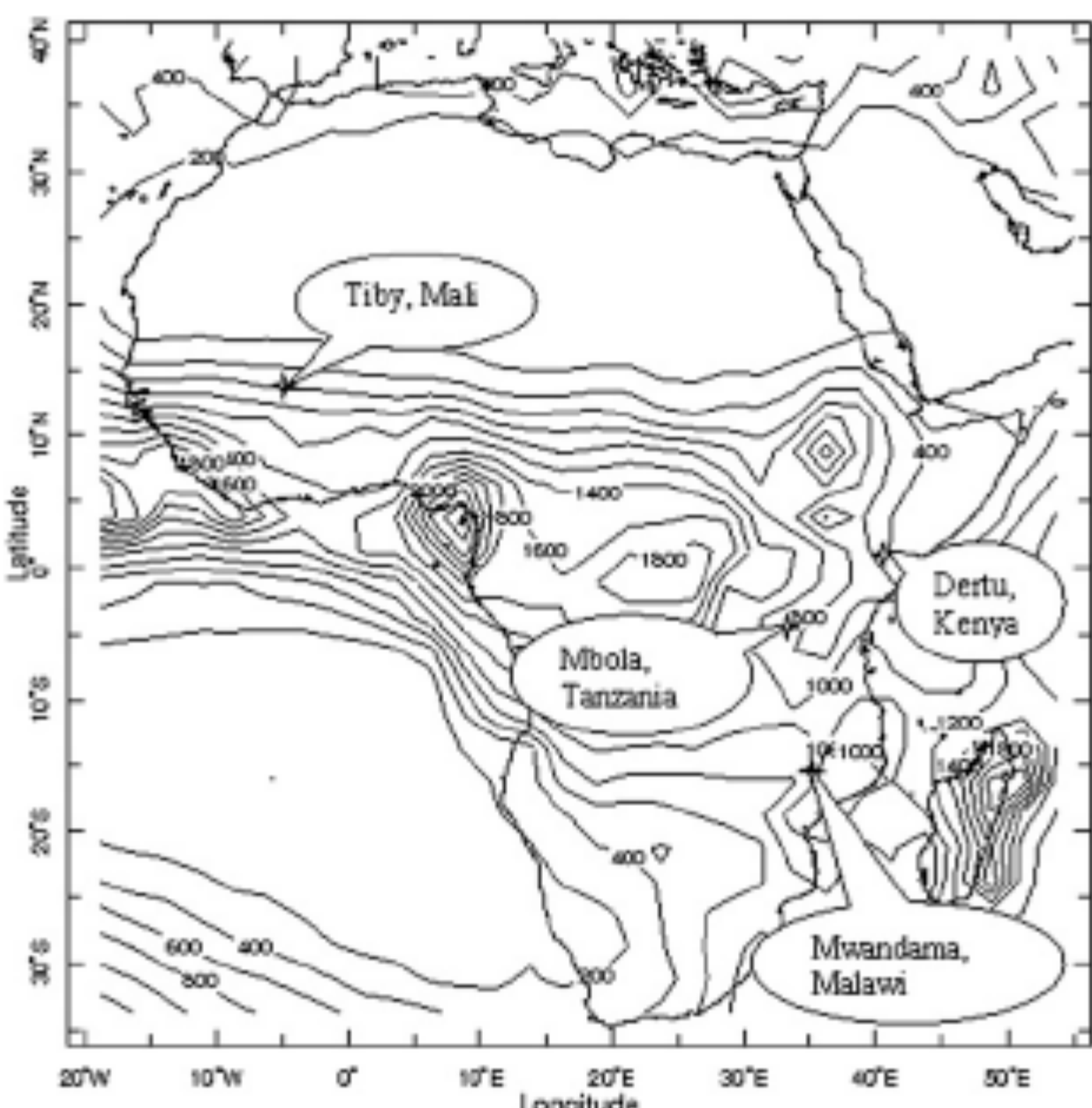
Asher Siebert, M. Neil Ward
asherb@eden.rutgers.edu, mneilward@gmail.com

Motivation

- Taking a statistical modeling and simulation approach, to understand and estimate changes in extreme weather/climate event frequency, in the presence of global change (GC) and multidecadal variability (MDV)
- To target risk management applications - notably index insurance

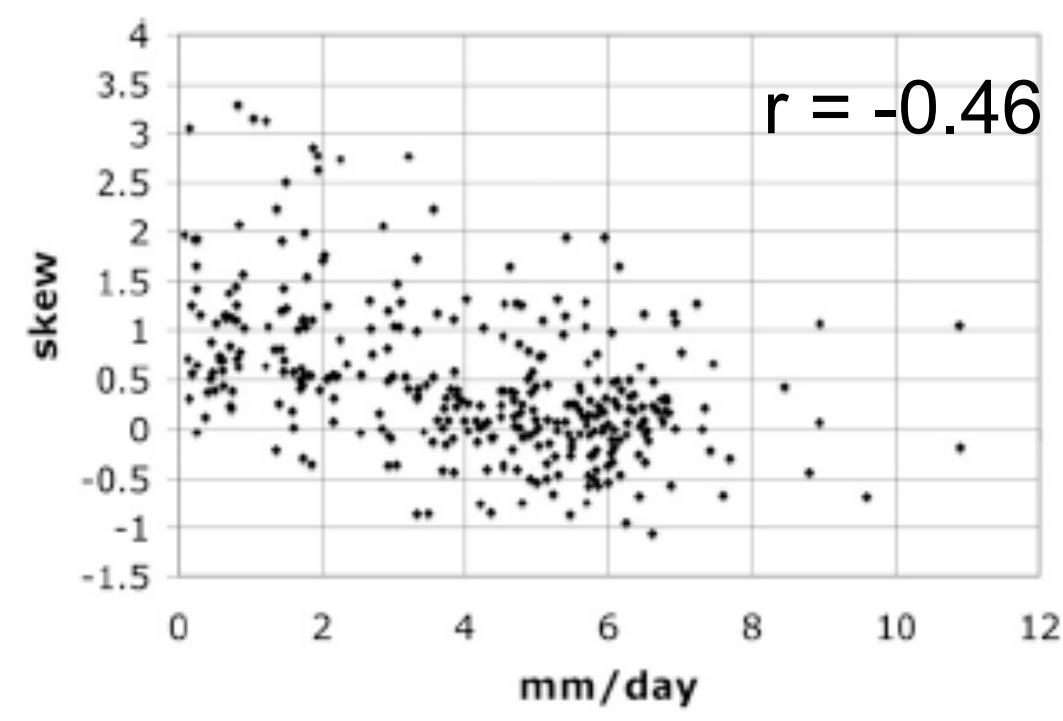
Method and Villages

- This research grew out of a drought index insurance project targeted for the Millennium Villages and supported by Swiss Re
 - CAMS-OPI monthly rainfall was one source used as the basis for determining drought frequency
 - Tiby, Mali (high skew, moderate climatology), Dertu, Kenya (positive skew, dry climatology), Mbola, Tanzania (negative skew, wet climatology) and Mwandama, Malawi (positive skew, wet climatology)
- We model seasonal rainfall using the Normal Distribution and the Skew Normal Distribution

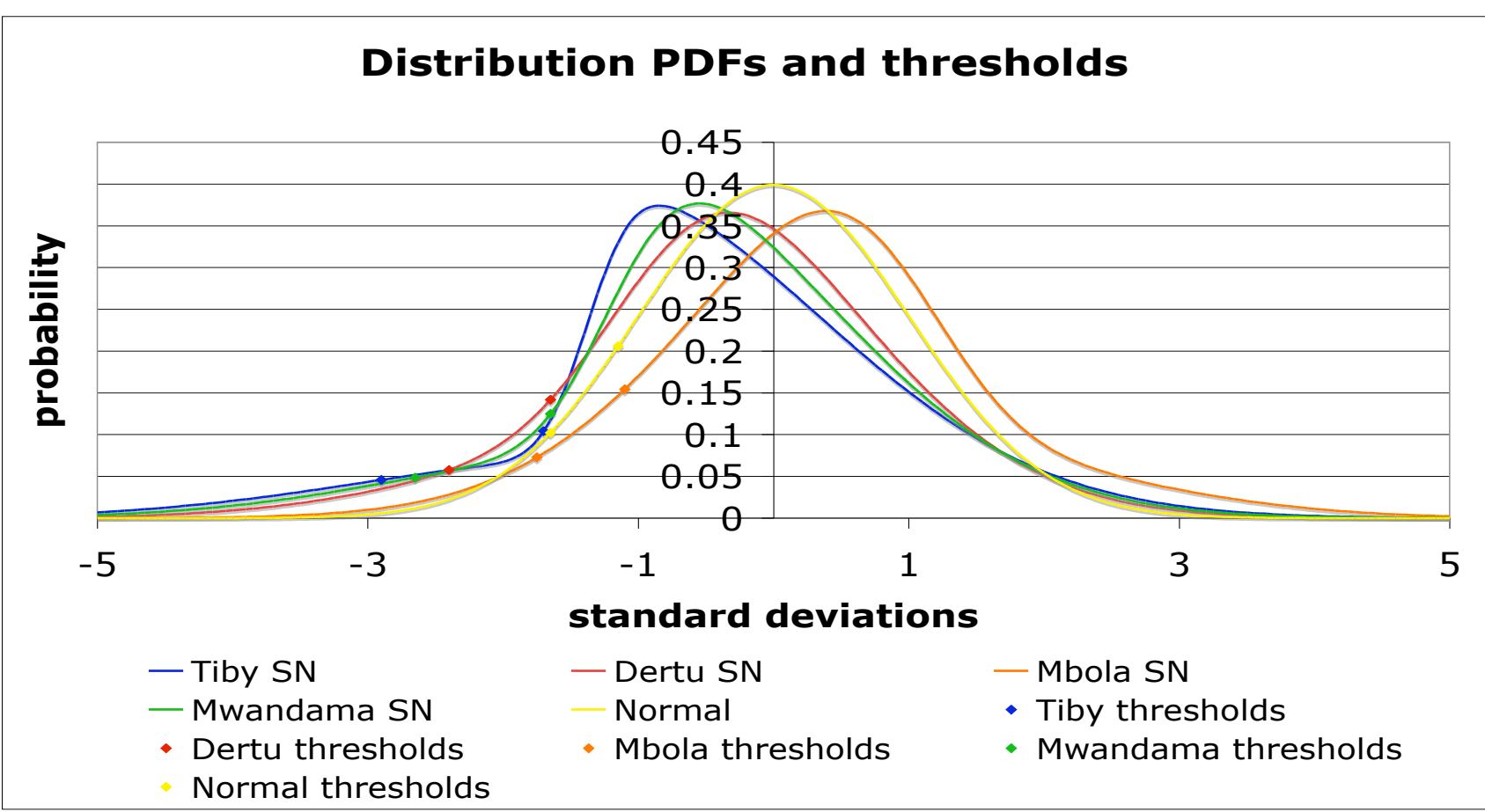


The location of the four case study sites superimposed on the 1979-2008 annual rainfall climatology (mm: based on the CAMS-OPI rainfall dataset)

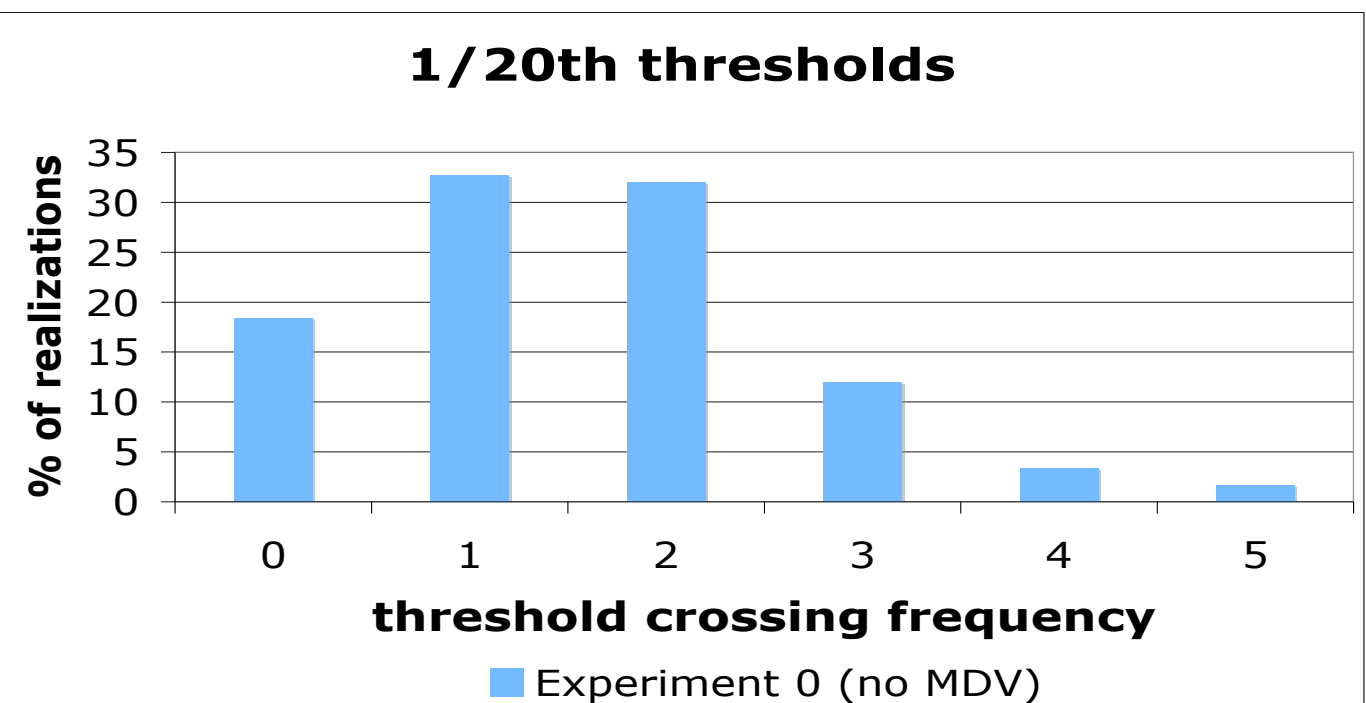
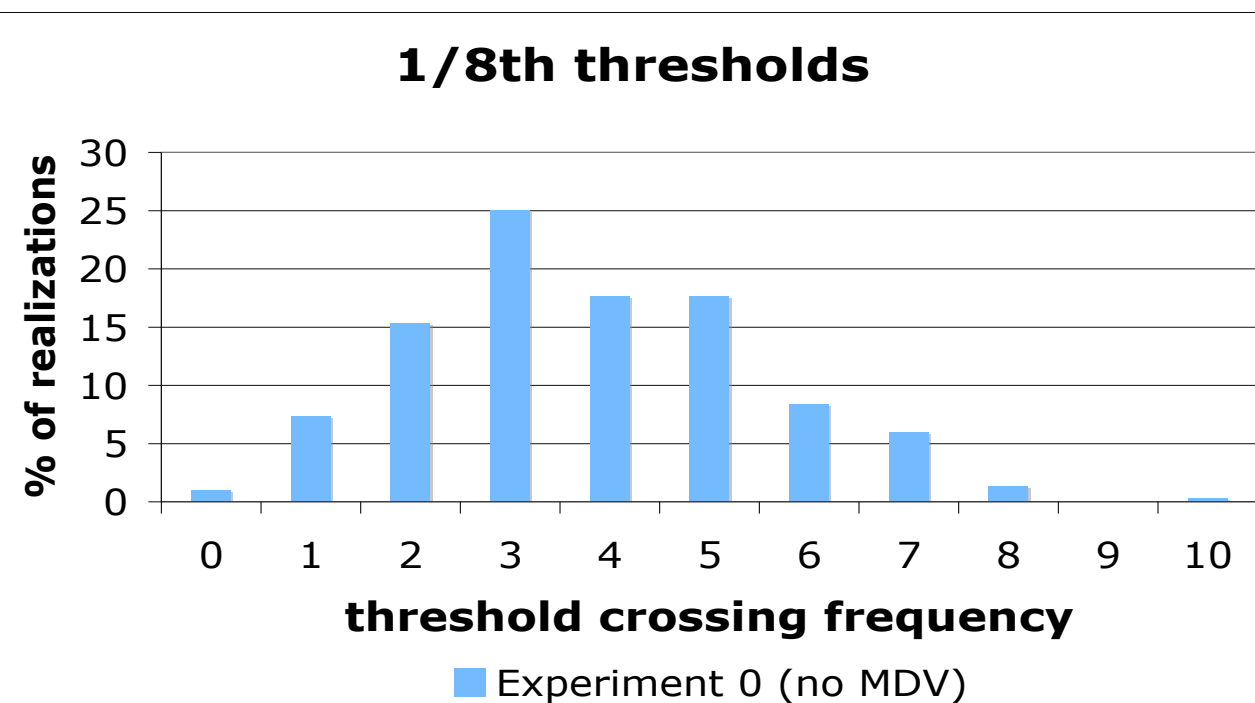
We focus on 1 in 8 and 1 in 20 events. Thresholds shown below assuming normal and skew normal (SN)



Scatterplot of climatological mean rainfall vs the skew statistic based on calculations for the rainy season at every gridbox in tropical Africa



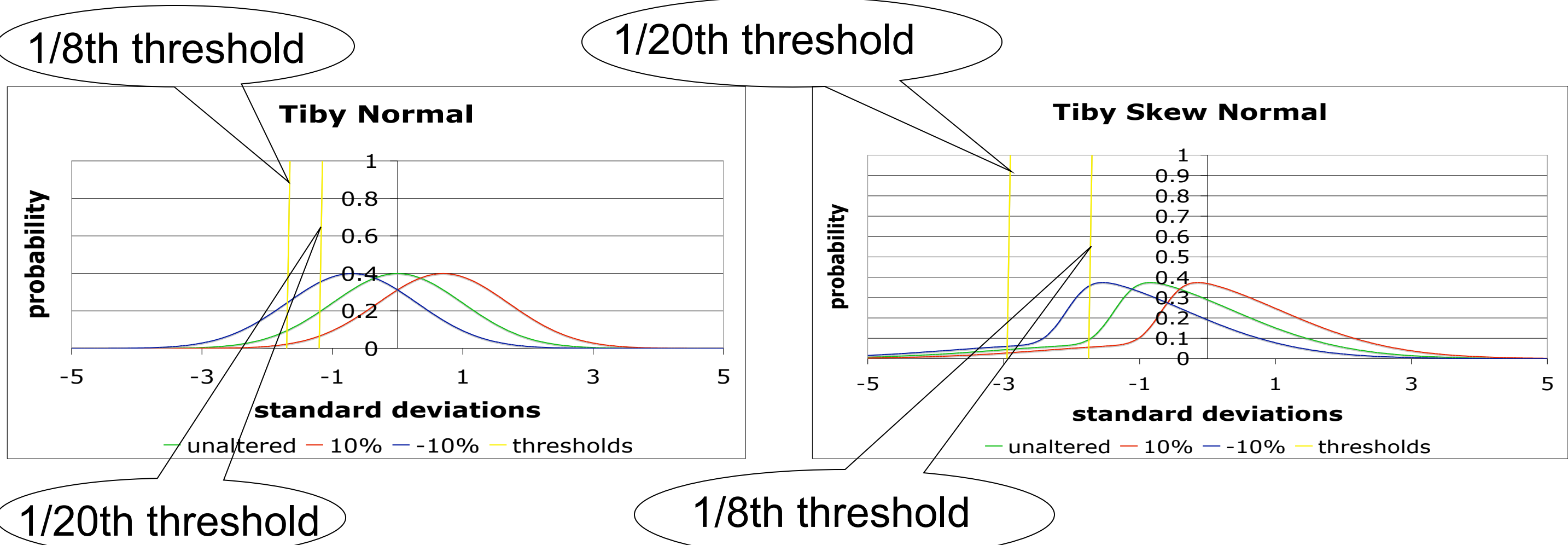
Baseline - No GC and no MDV



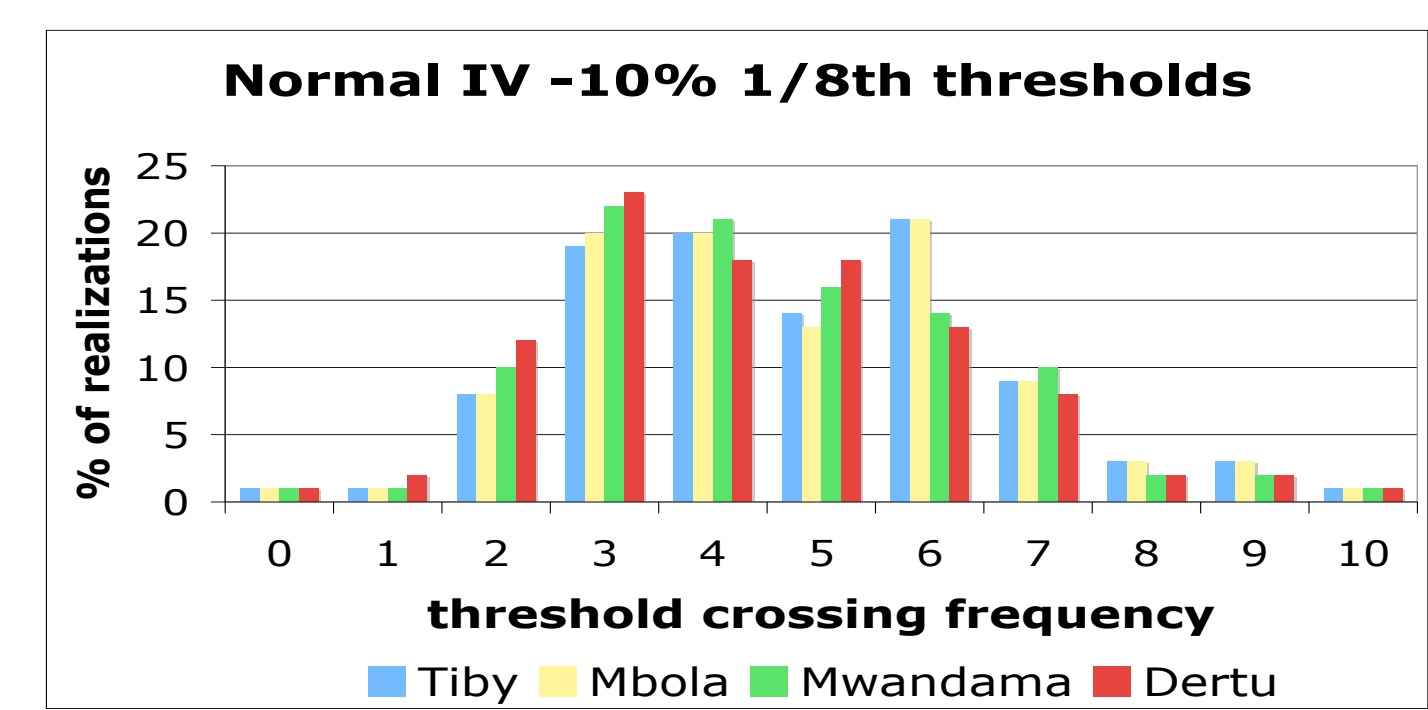
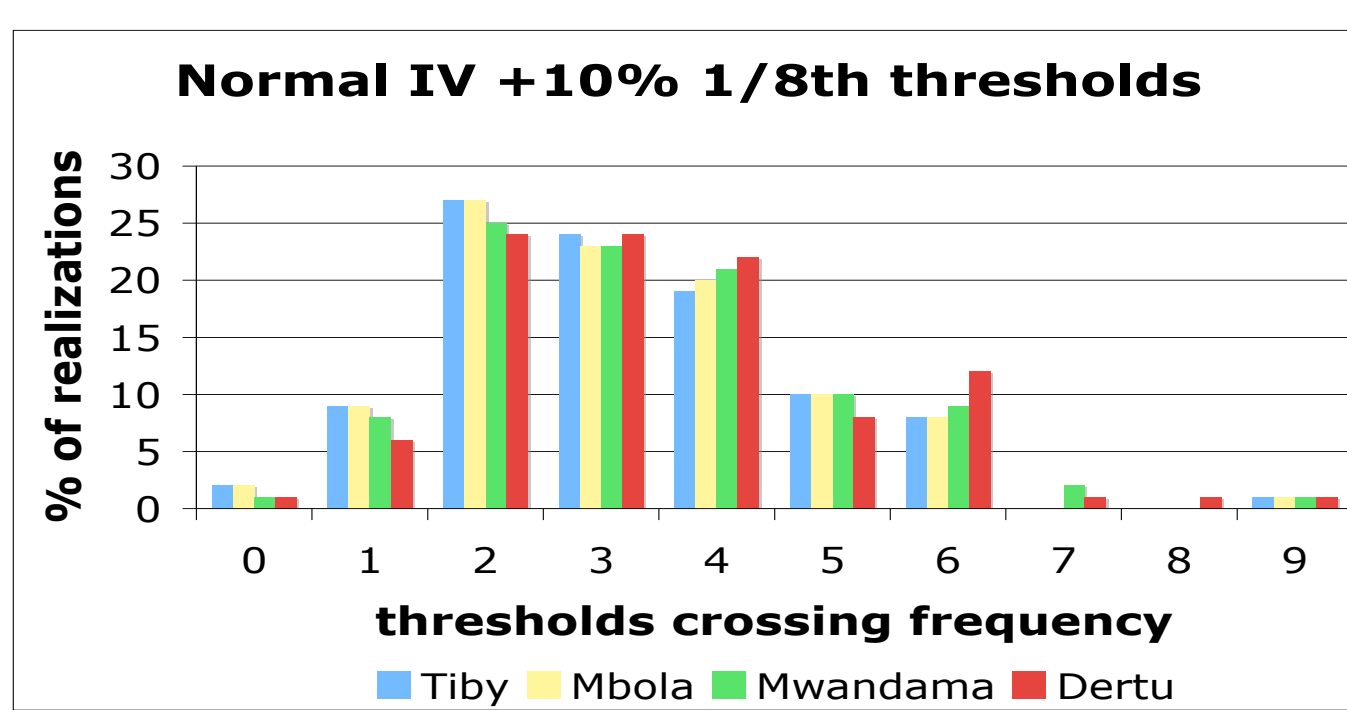
Counts of the number of events in a 30-year period. Expected value for 1 in 8 event is 3.75 and for 1 in 20 event is 1.5. These types of charts show the spread derived from Monte Carlo simulations, under different scenario assumptions. All results here are for the normal distribution. When GC is included (the following charts), results are for the 30 year period 2071-2100.

Effects of a 10% change with Fixed Thresholds

Area under the curve to the left of the yellow lines represents the frequency of extreme events: showing a marked increase for the blue curve (a 10% decline in rainfall) and decline in frequency for the red curve (a 10% increase in rainfall). Estimates of the frequency change can be quite sensitive to skew.

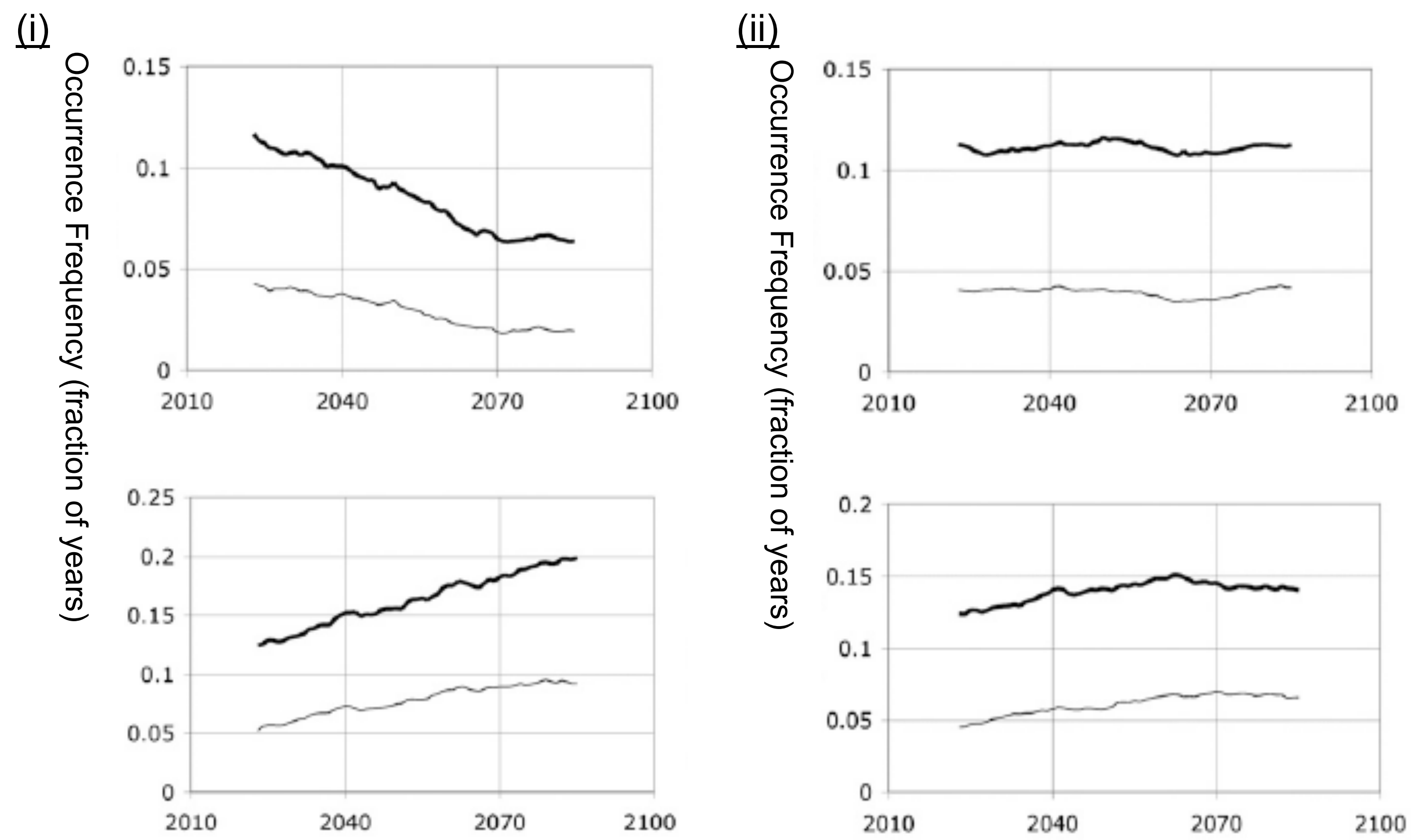


GC with Fixed Thresholds



Fixed vs. Evolving Thresholds

Thresholds for the 1 in 8 (heavy black line) and 1 in 20 (light black line) events are defined: (i) fixed, based on 1979-2008; (ii) evolving, always using the previous 30 year period. Bias grows during 21st Century using (i), but is almost stationary and greatly reduced using (ii). Top panels are +10% GC and bottom panels are -10% GC. Results shown are for Dertu.



Ratio of Evolving to Fixed Threshold Results

Parameter	Village	2011-2040	2071-2100
Bias 1/8	Tiby	0.54	0.19
	Mbola	0.54	0.19
	Mwandama	0.6	0.22
	Dertu	0.61	0.27

Results that Include MDV

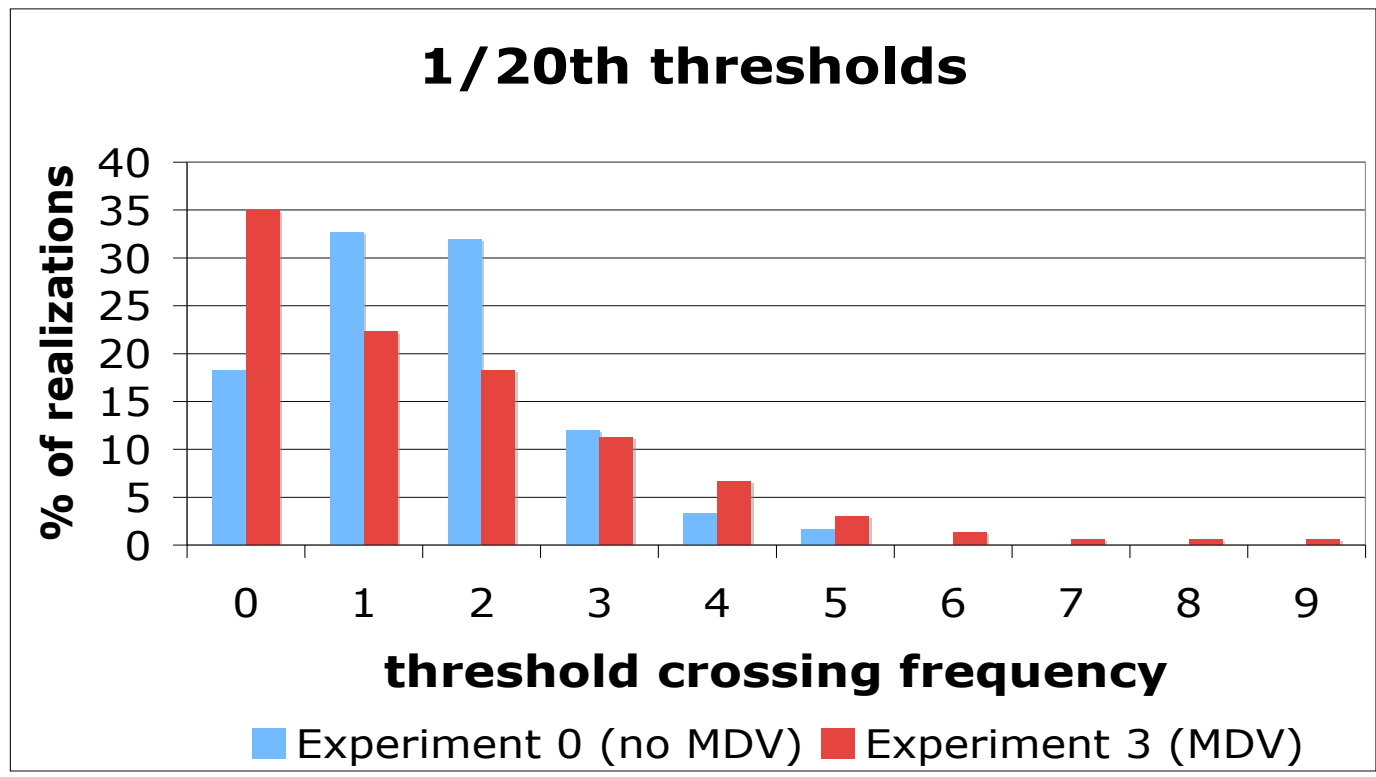
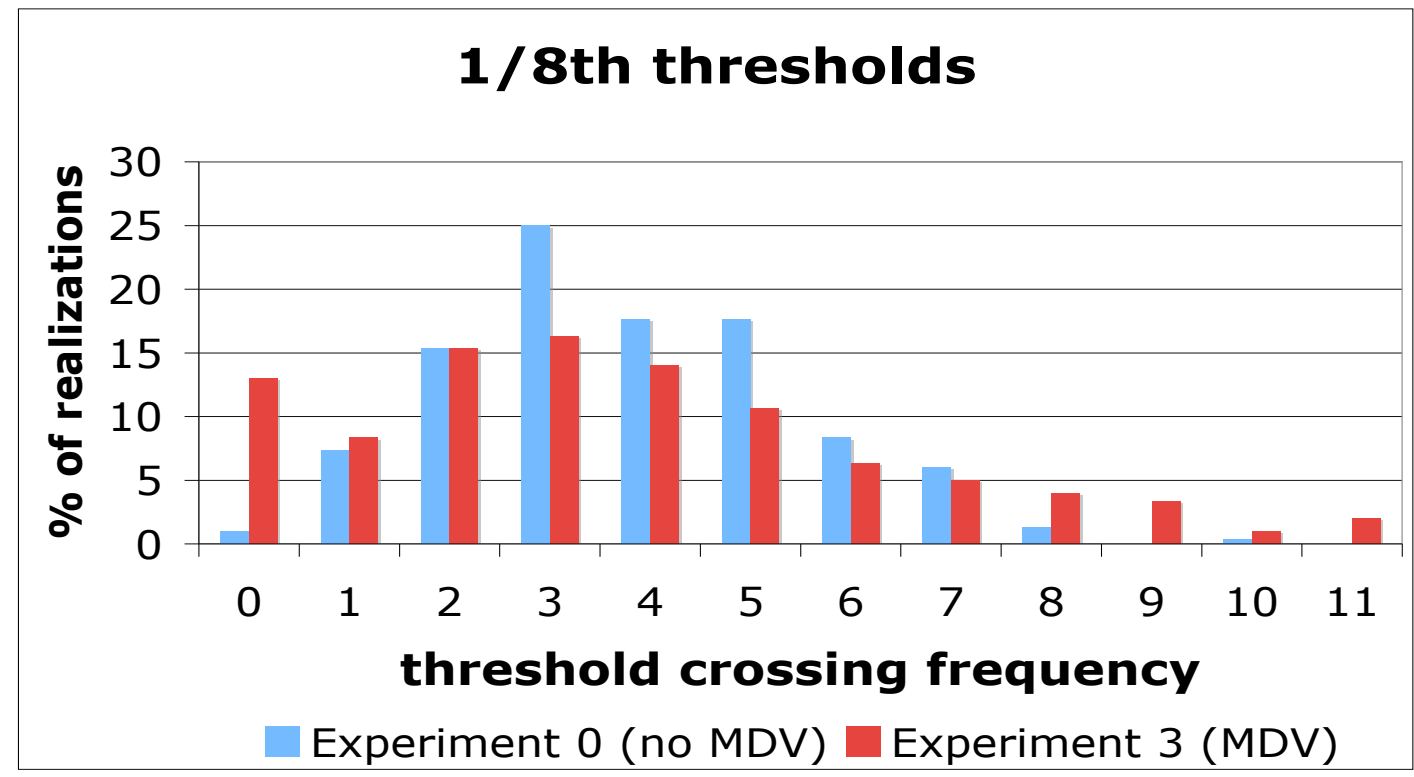
In the simulations here, MDV is represented by AR(1) process with lag 1 $r = 0.6$.

Top panels show the increase in spread from simply adding MDV

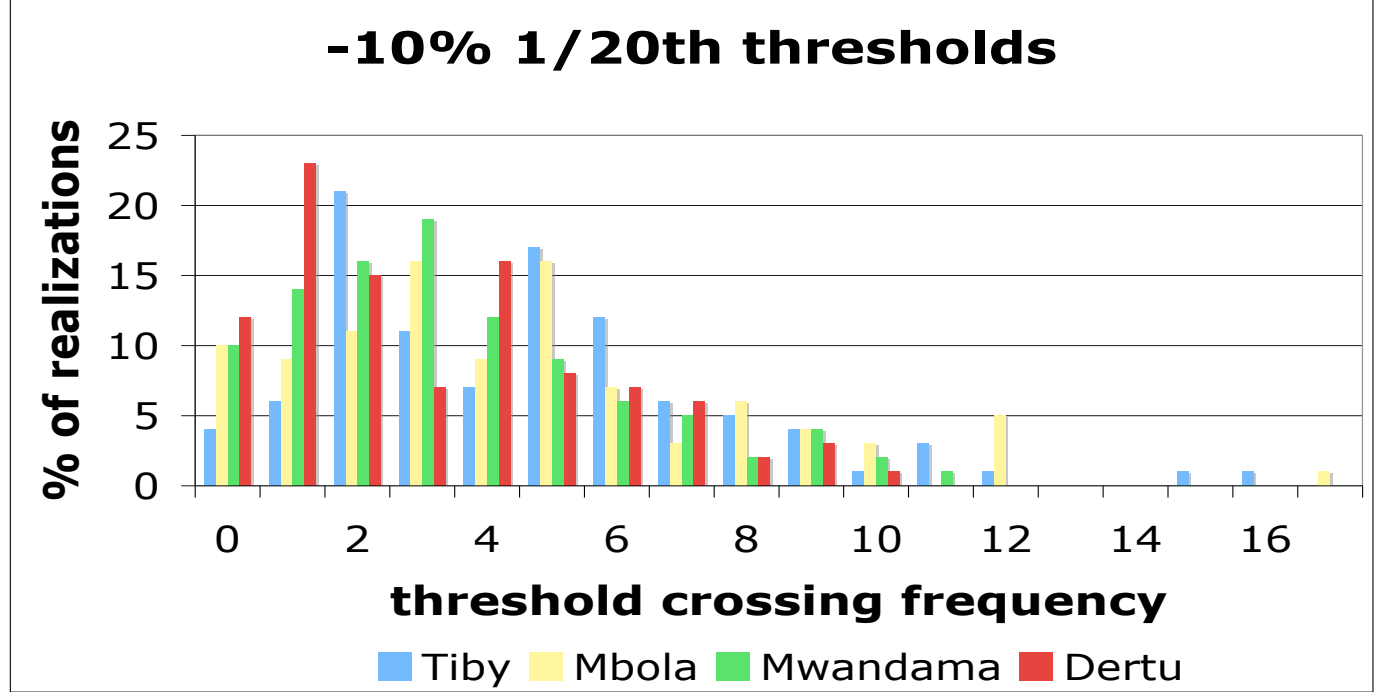
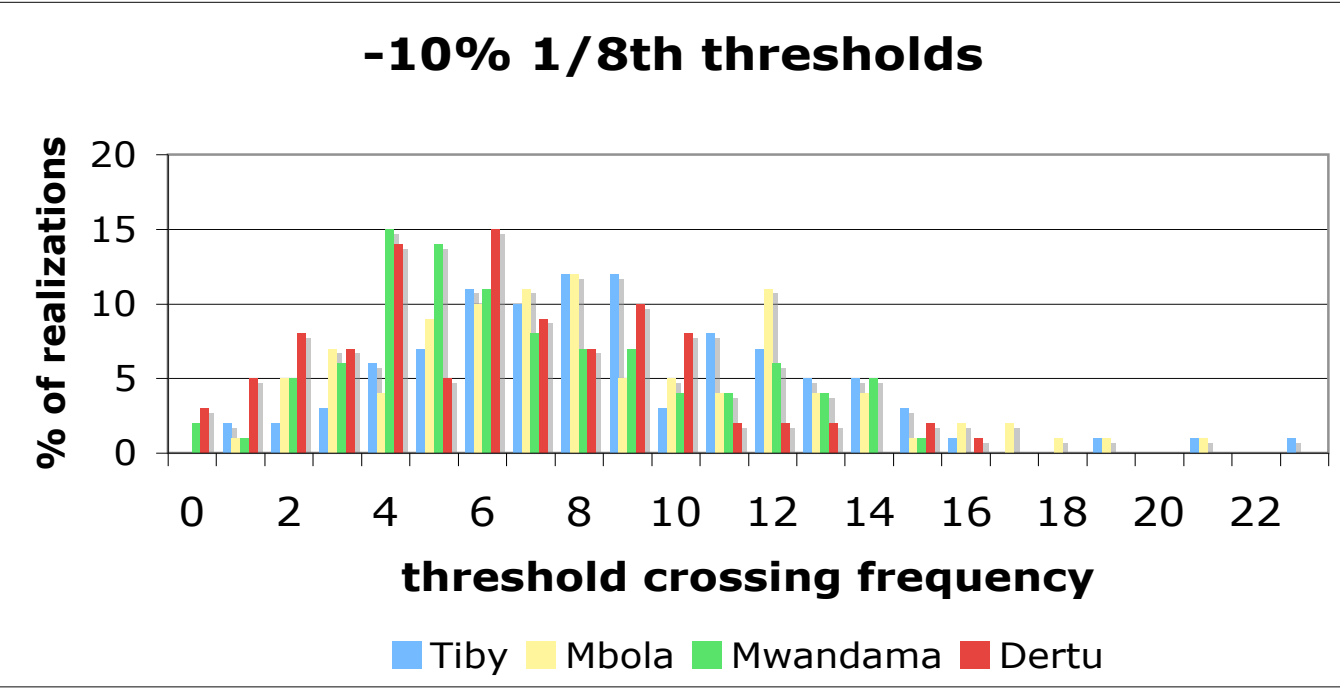
Middle panels shows the very large bias and spread when thresholds are held fixed.

Bottom panels show that bias is reduced, but spread is still large, when thresholds are updated. More sophisticated updating schemes may further reduce bias and also spread in the presence of MDV. Spread is a big problem for index insurance, it increases uncertainty and the risk of very extreme 30-year periods (eg for Tiby, there is an example of a 30-year period with 13 "1 in 8" events).

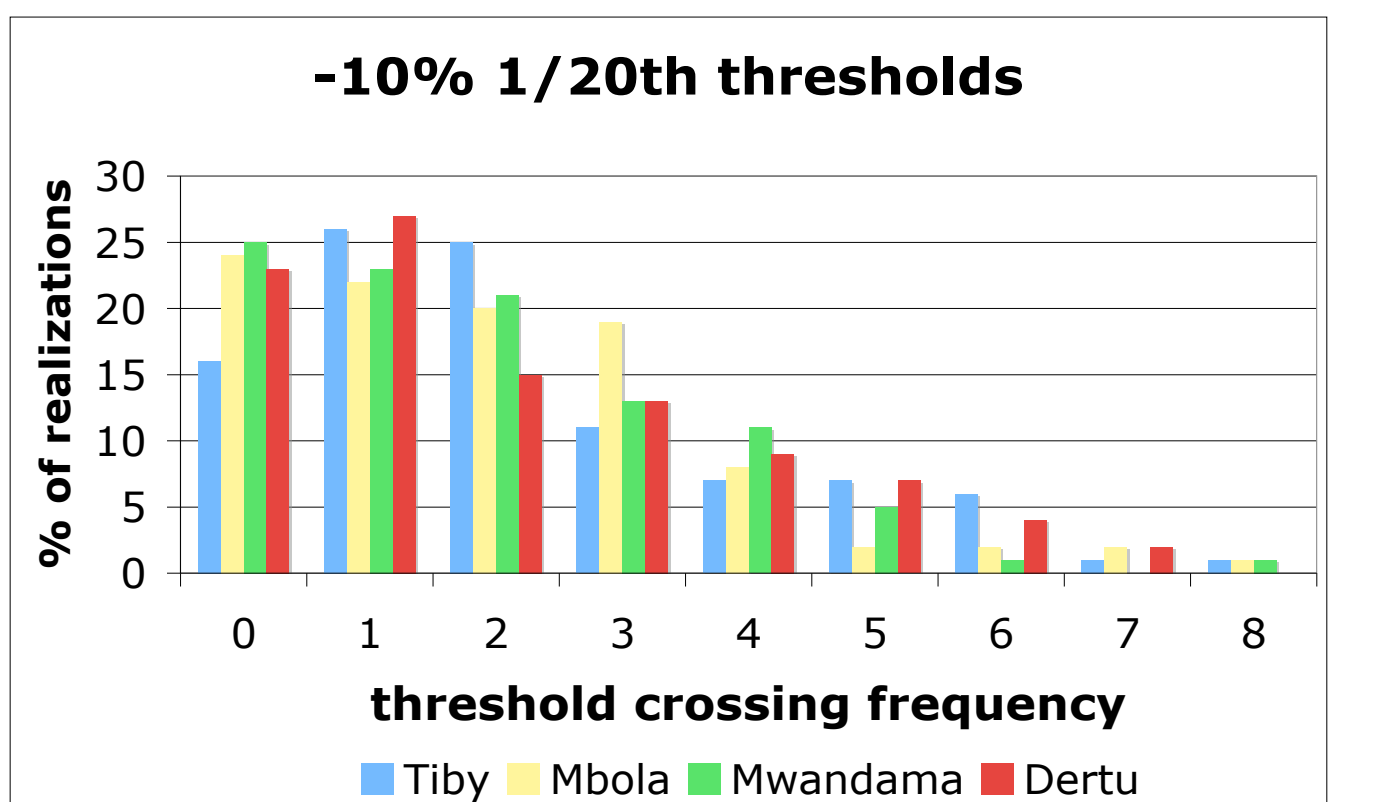
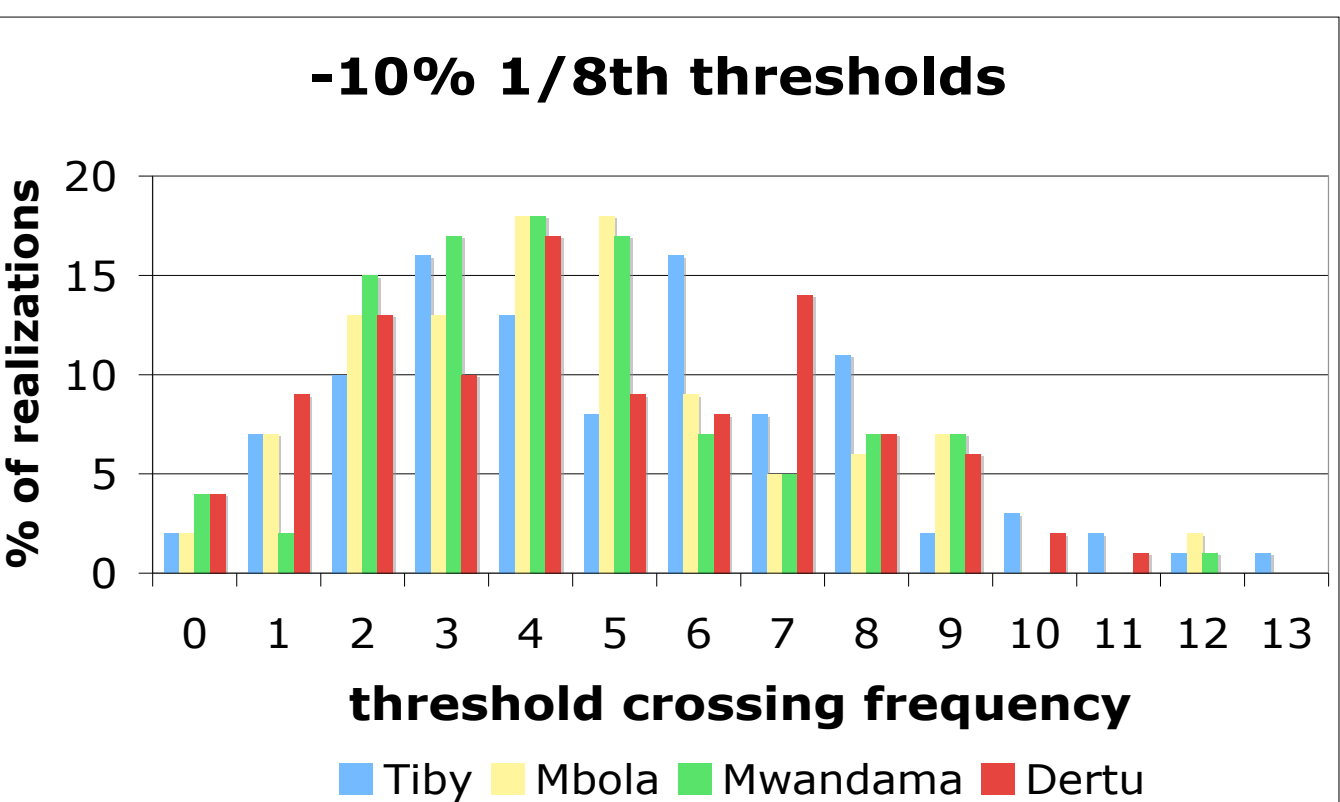
MDV v. Baseline



MDV+GC with Fixed Thresholds

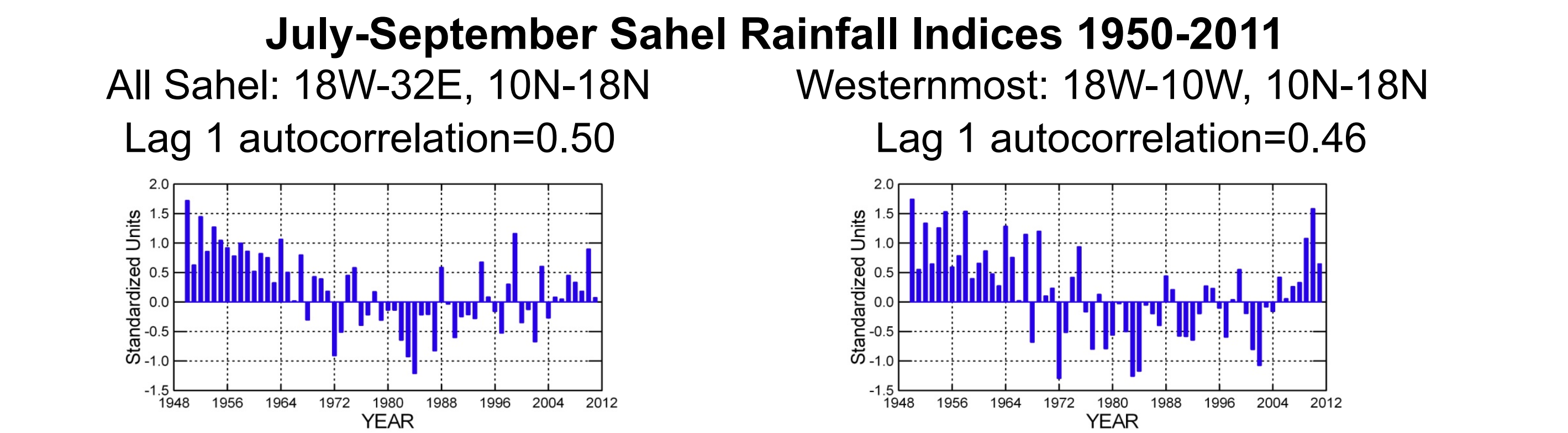


MDV+GC with Evolving Thresholds



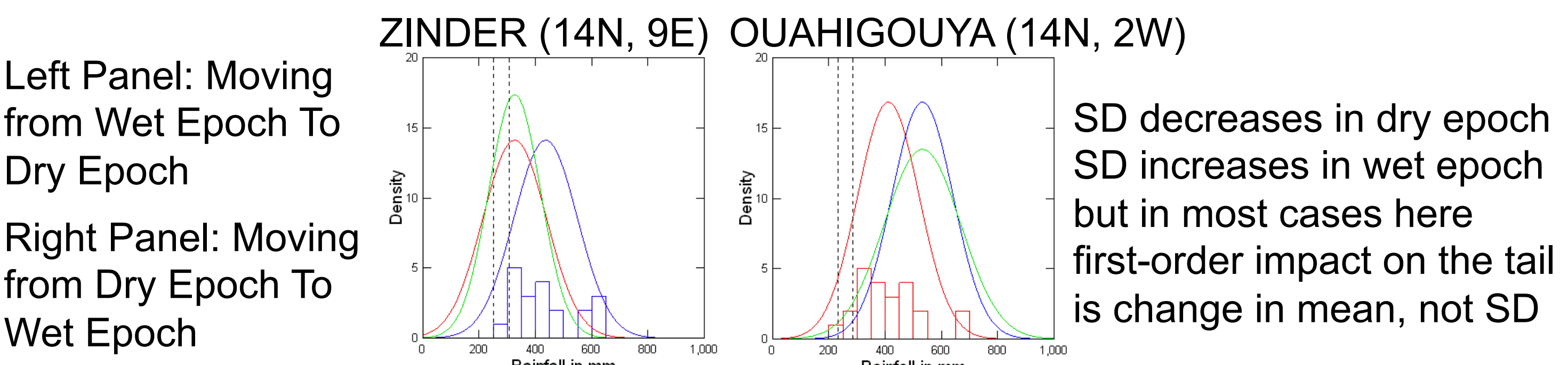
Hydroclimatic Changes in the Sahel (W. Africa)

Statistical properties of actual observed change, to inform further development of the statistical modeling system, and regional risk management challenges



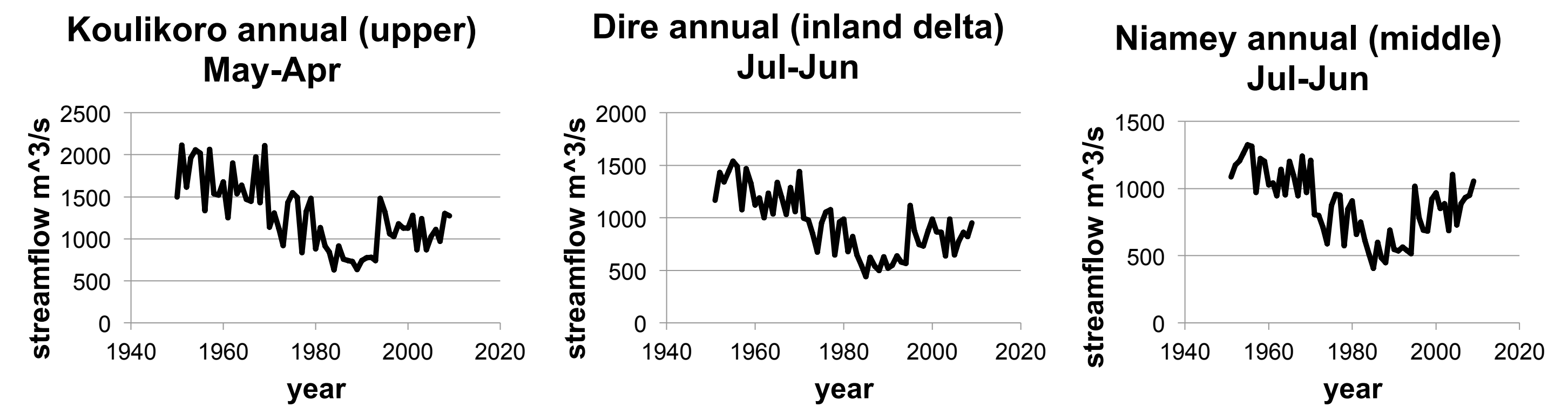
Notes: (i) Based on available stations in NOAA/NCDC GHCN dataset, (ii) actual northern limit used is the 100mm isohyet, (iii) autocorrelation shown is for 1950-2009, for comparison with Niger River result below

Comparing Wet epoch (1950-69), Dry epoch (1970-93), Wet epoch (1994-2010)



Preliminary Analysis from Niger River Streamflow Data

Sub-basin	r_1	Average COV	Range of COV
Koulikoro (upper)	0.60	0.32	0.29-0.55
Dire (inland delta)	0.73	0.31	0.12-1.22
Niamey (middle)	0.70	0.28	0.11-1.35



Conclusions

- Relatively modest changes in mean precipitation (+/- 10%) can imply a two fold change in extreme event frequency (even without change in distribution shape)
- The use of evolving thresholds can reduce bias considerably.
- The addition of MDV adds to spread of possible outcomes and increases the risk of periods of very high extreme event frequency.
- The increase in extreme dry years in a drying trend, is much greater than, the decrease in extreme dry years in an upward rainfall trend
- For a given percent shift in the mean precipitation, the ratio of the variance/mean will have a significant impact on the frequency of extreme events
- Properly characterizing the shape (e.g. skew) of the distribution (particularly the extreme tail) will be very important in determining the expected change in extreme event frequency

Future Work

- Flooding, other drought metrics, greater integration with hydrology
- Regional focus (example: West African Sahel)
- More sophisticated representation of trends
- Extreme value distributions (theory)
- Exploring distribution shape change over time
- Better methodology for threshold updating (making a better "decadal nowcast" of the 30-year event frequency)

Key References

- Azzalini, A., 1985: A Class of Distributions which Includes the Normal Ones. *Scandinavian Journal of Statistics*, **12**, pp. 171-178.
- Hellmuth M.E., Osgood D.E., Hess U., Moorhead A. and Bhojwani H. (eds) 2009: Index insurance and climate risk: Prospects for development and disaster management. Climate and Society No. 2. International Research Institute for Climate and Society (IRI), Columbia University, New York, USA.
- Janowiak, J. E. and P. Xie, 1999: CAMS-OPI: A global satellite-rain gauge merged product for real-time precipitation monitoring applications. *Journal of Climate*, **12**, pp. 3335-3342.
- Katz, R. W., and B. G. Brown, 1994: Sensitivity of Extreme Events to Climate Change: The Case of Autocorrelated Time Series, *Environmetrics*, **5**, pp. 451-462.
- Kharin, V. V., F. W. Zwiers, X. Zhang, and G. C. Hegerl, 2007: Changes in Temperature and Precipitation Extremes in the IPCC Ensemble of Global Coupled Model Simulations, *Journal of Climate*, **20**, pp. 1420-1444.
- Livezey, R.E., K. Y. Vinnikov, M. M. Timofeyeva, R. Tinker, and H. M. van den Dool, 2007: Estimation and Extrapolation of Climate Normals and Climatic Trends, *Journal of Applied Meteorology and Climatology*, **46**, pp. 1759-1776.
- Siebert, A. and M. N. Ward, 2011: Future Occurrence of Threshold-Crossing Seasonal Rainfall Totals: Methodology and Application to Sites in Africa, *Journal of Applied Meteorology and Climatology*, **50**, pp. 560-578.