Decadal-to-Multidecadal Variation in Sahel Rainfall Since 1950 and Associated Changes in the Frequency of Threshold-Crossing Seasonal Rainfall Totals

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Initial Motivation

- Relative role of changes in mean, SD, and distribution shape (skew) in controlling the change in frequency of events[1].
- Work on index insurance for Millennium Villages had used: 1in20 year and 1in8 year events (use same thresholds for illustration here)

This Presentation

1. How has mean rainfall changed?
   follows e.g., Lebel and Ali (2009), Fontaine et al. (2011), Hastenrath and Polzin (2011)
2. How has SD and Skew changed?
3. Comparing normal and skew-normal estimates of the thresholds
4. The change in the event frequency
5. (if time: Broader downscaling context)

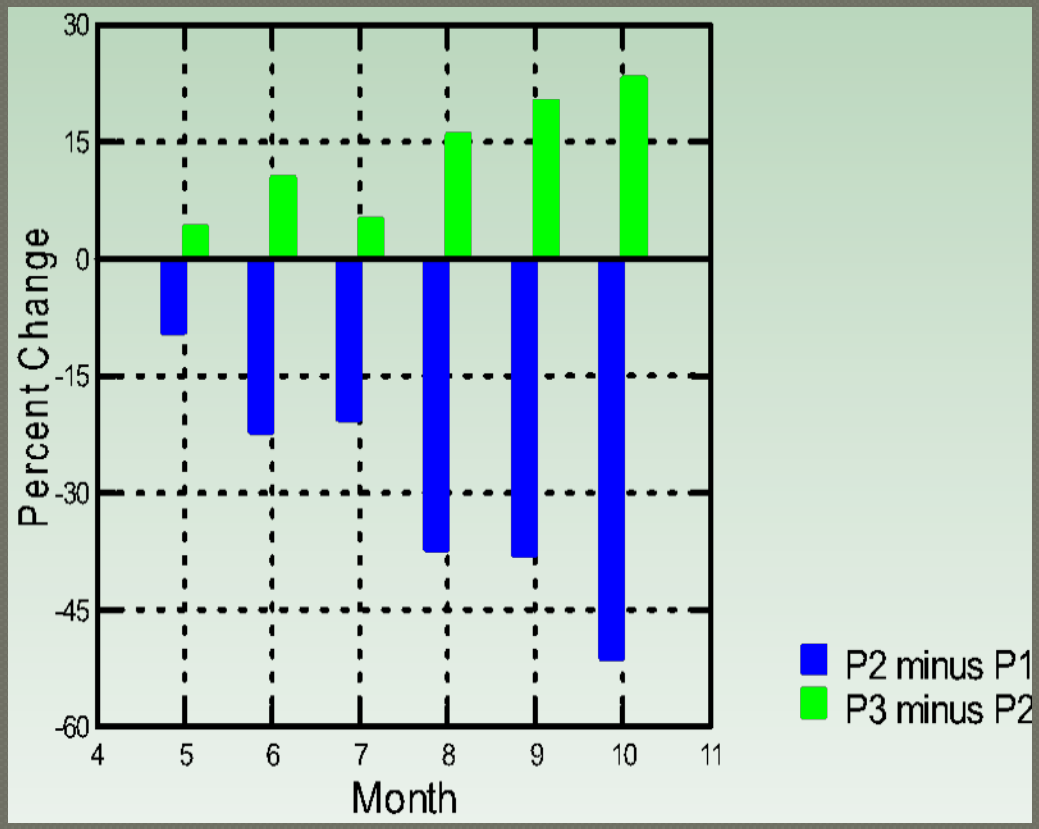
Data (monthly precip)

- 10-20N, 20W-30E: GHCN (1950-1993 = 133 stations, less through 2010)
- ANACIM (Senegal) (1968-2010 = 20 stations)
- GPCP (1979-2010)

[1]Stochastic simulation in Siebert and Ward (2011) assumed constant SD and shape

Sahel Rainfall, Composite Differences
Blue: 1970-93 minus 1950-69 (P2 minus P1)
Green: 1994-2010 minus 1970-93 (P3 minus P2)

Results for each month: 5=May …. 10=October



Senegal Rainfall, Composite Differences
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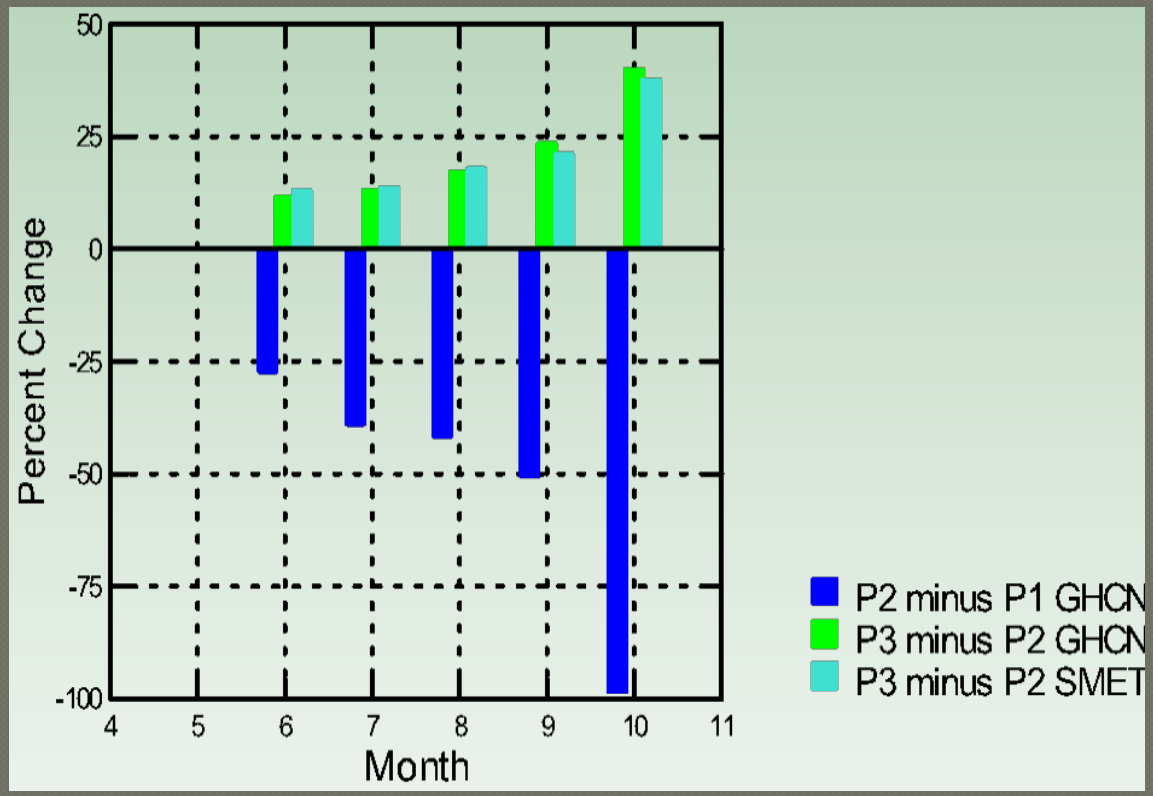
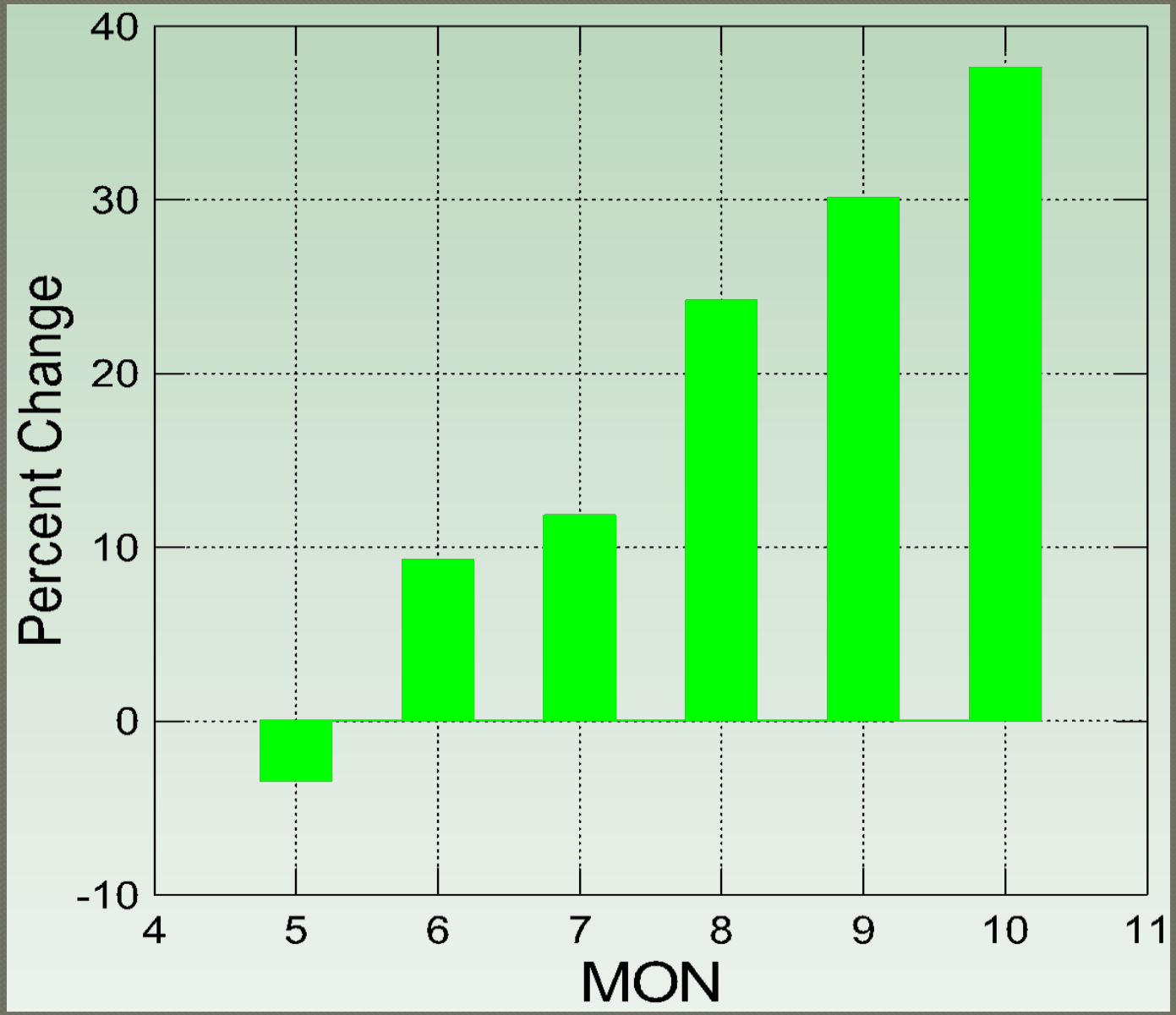
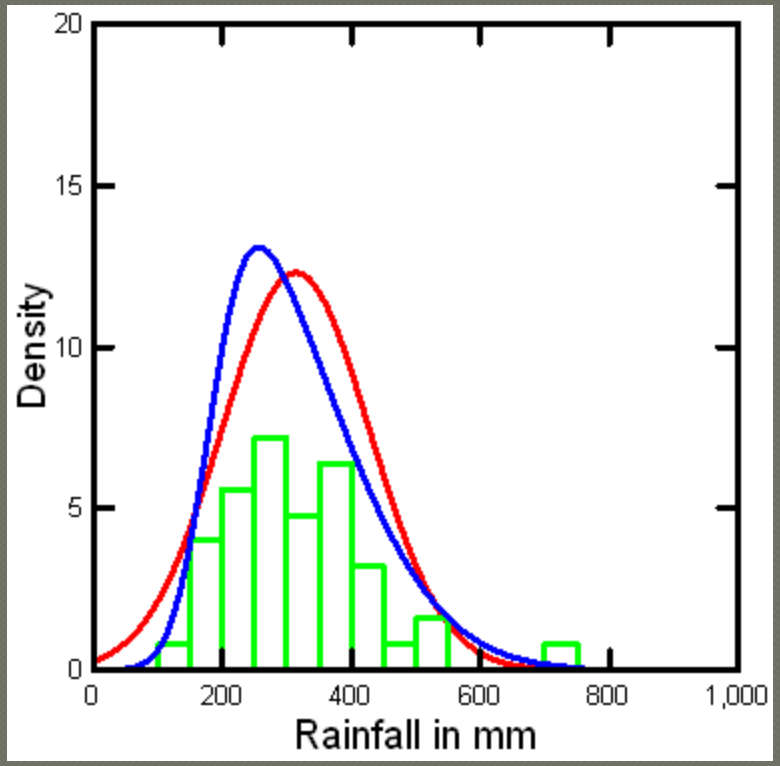


1994-2010 minus 1979-1993 (GPCP merged satellite-station data)



Distribution of Seasonal Rainfall Totals 1950-93 for Typical Station in the Sahel
(here, lat 15.3, lon -1.7; station HOMBORI,
JAS mean 315mm, SD 111mm, Skew coefficient +0.75)



Green: Empirical Distribution
Red: Fitting a Normal Distribution
Blue: Fitting a Skew-Normal Distribution (e.g., Azzalini and Capatanio, 1999)
Distribution specified by 3 parameters: location (mean), scale (SD) and shape (skew)

Frequency of Events, Estimating Thresholds Using Normal Distribution and Skew-Normal Distribution (133 stations, 1950-1993)

Here for 1in20 year Dry Event
(i.e., should be 5% frequency)

	Normal Distribution	Skew-Normal Distribution
All Stations	3.0%	5.1%
Skew>1.0	1.0%	5.5%

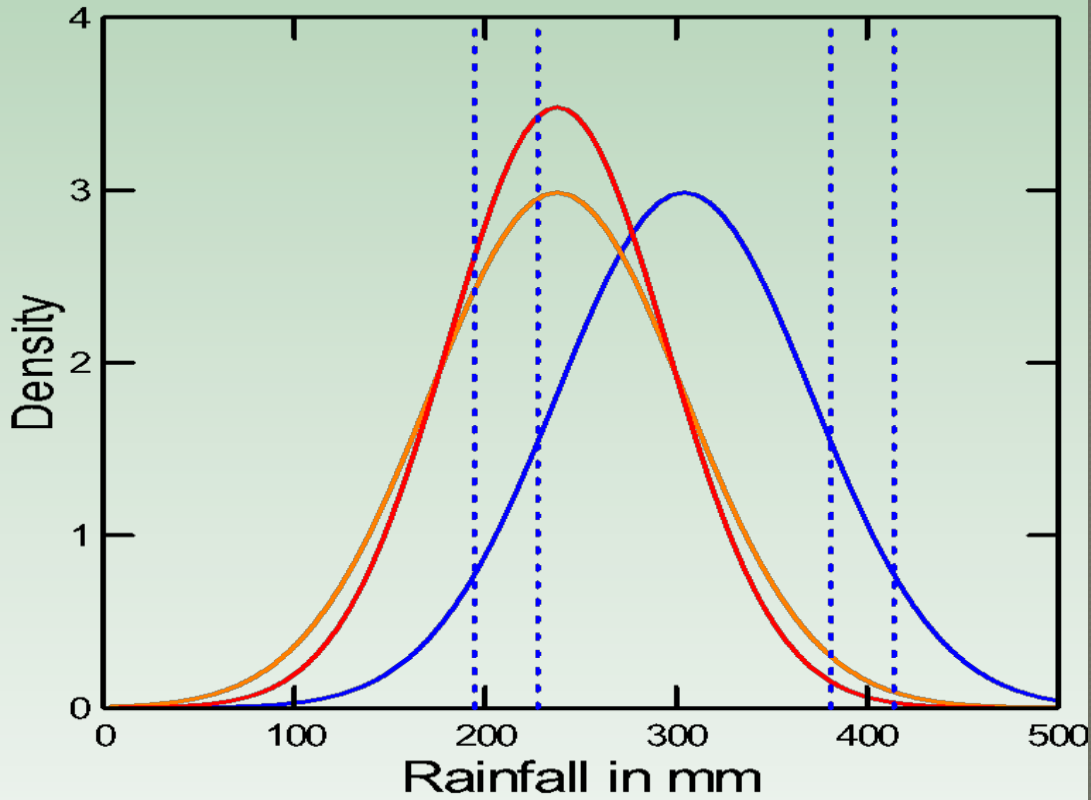
Change in the Mean, SD and Skew.
Results calculated for each station, and then averaged

	SAHEL P2 minus P1	SAHEL P3 minus P2	SENEGAL P3 minus P2
N Stations	133	18	20
Mean (%)	-33***	+14**	+17***
SD (%)	-19***	+13	+16*
Skew (*100)	+1	-1	-15

Statistical Significance (2-tailed) from Monte Carlo scrambling of year order:

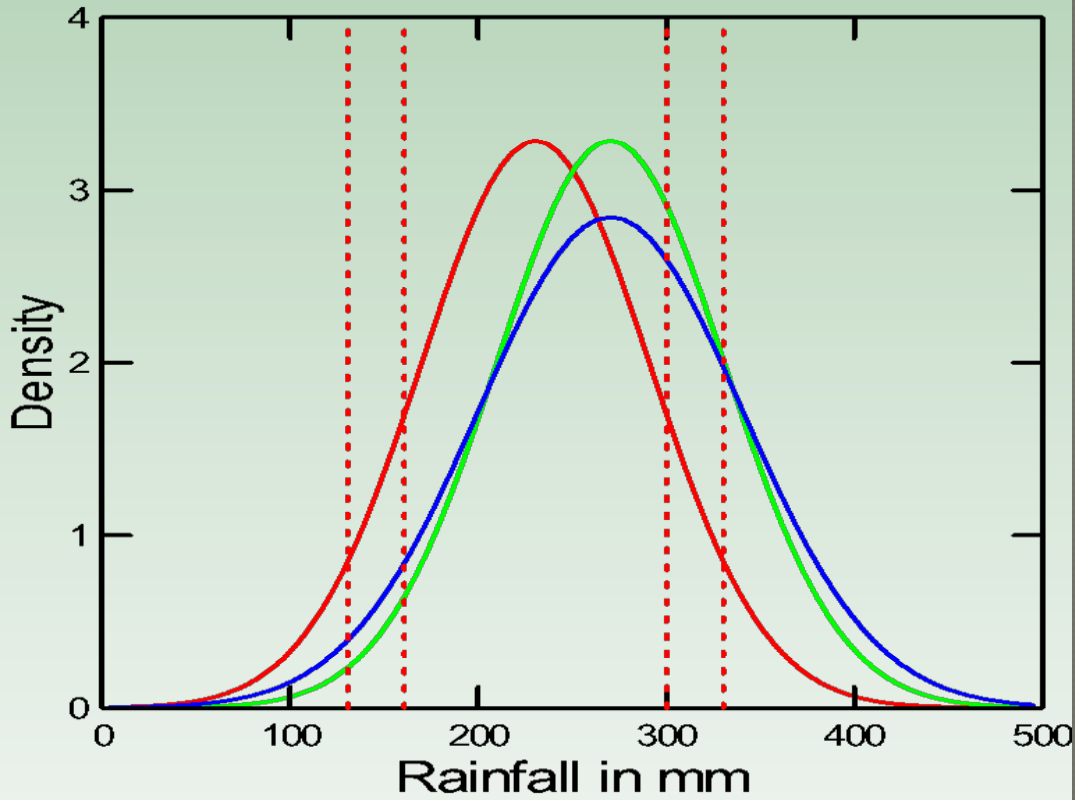
*** = 1% **=2% *=10%

Moving from Wet Epoch 1950-69 (blue curve)
To Dry Epoch (1970-93)
Orange curve = change in mean only
Red curve = change in mean and standard deviation
(based on statistics averaged over all Sahel stations)



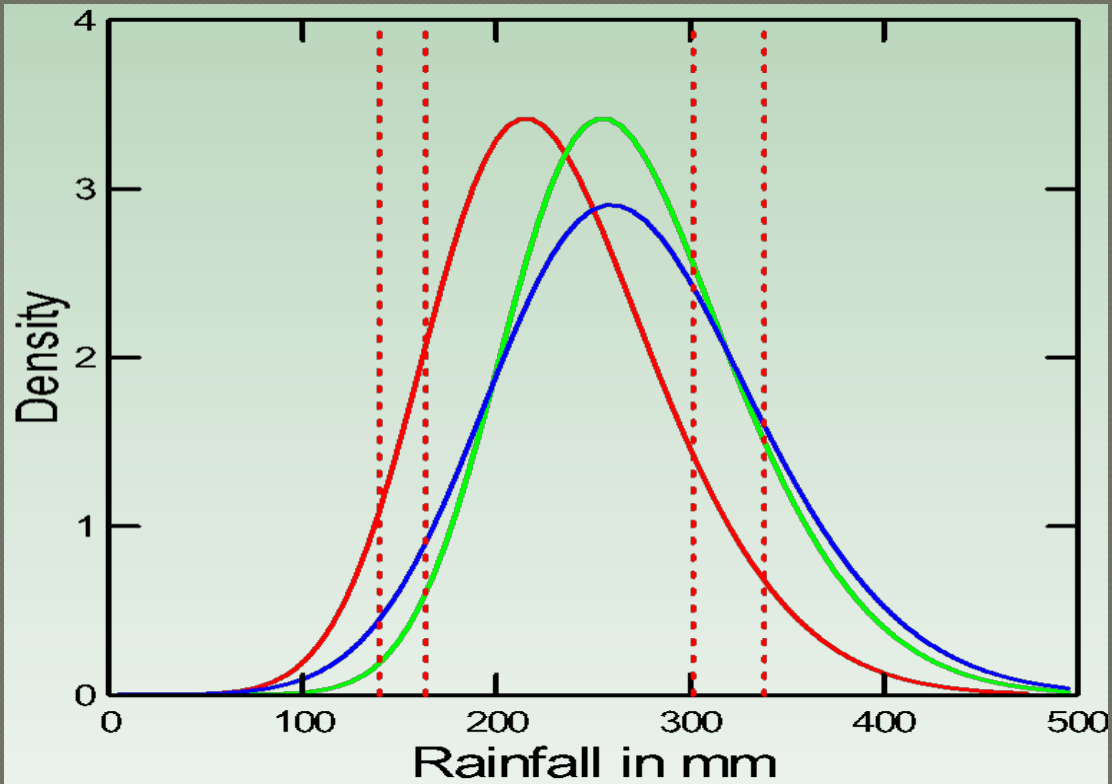
Blue vertical lines are thresholds (based on 1950-69) for, from left to right, 1in20(dry), 1in8(dry), 1in8(wet), 1in20(wet)

Moving from Dry Epoch 1970-93 (red curve)
To Wet Epoch (1994-2010)
Green curve = change in mean only
Blue curve = change in mean and standard deviation
(based on statistics averaged over all Senegal stations)



Red vertical lines are thresholds (based on 1970-93) for, from left to right, 1in20(dry), 1in8(dry), 1in8(wet), 1in20(wet)

Moving from Dry Epoch 1970-93 (red curve)
To Wet Epoch (1994-2010), FITTING SKEW-NORMAL DISTRIBUTIONS
Green curve = change in mean only
Blue curve = change in mean, standard deviation and skew
(based on statistics averaged over all Senegal stations)



Actual change in frequency of 1in20 dry and 1in20 wet events (i.e. base-period frequency is always 5%)

Base period for thresholds		Thresholds from empirical distribution	Thresholds from fitting skew-normal
1950-69	All Sahel, Dry event frequency 1970-93	31.0%	32.3%
1970-93	Senegal, Dry event frequency 1994-2010	3.5%	3.5%
1970-93	Senegal, Wet event frequency 1994-2010	14.2%	15.4%

Summary

1. Trends in All months June-October (and growing in % terms as season progresses).

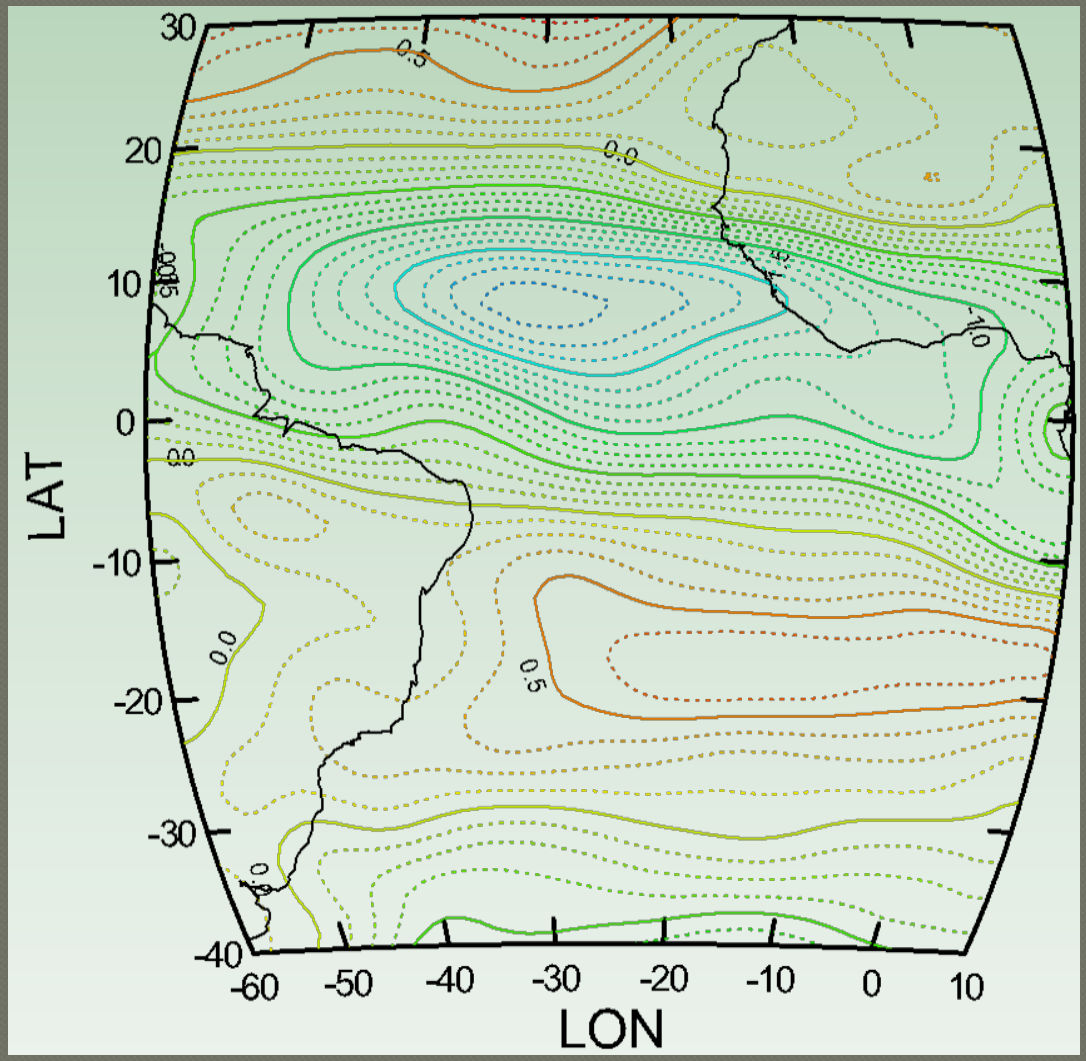
2. Comparing wet to dry epochs, we might anticipate
   higher standard deviation (yes, statistical significance achieved)
   less skew (yes, but.. only clear in Senegal dataset, needs more work)

3. First order impact on event frequencies is nonetheless from change in the MEAN

4. But .. the effects of SD and skew changes can combine: e.g., the relatively small reduction of dry events in a wetter climate.

5. Skew-normal approach is promising, and potential for downscaling …

Reanalysis 850 U-Wind PC1 (see Ndiaye et al. 2011 for specification of Sahel rainfall using this approach; and e.g., Lamb 1978 for basis of using wind fields)



Using U-850 PC1 to make a downscaled prediction to each of the 20 stations over Senegal, 1968-2010.

Average probability forecast for each category

Clear systematic bias using standard regression for the dry categories, because of the skew properties of the regression errors….