Analysis of the Monsoon's onset in the Volta Basin (West Africa)

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Outline

- 70% of inhabitants in West Africa depend on rainfed agriculture
- Determination of onset plays major role for sustainable food production (crop failure $\leftrightarrow$ lost vegetation time)

> onset date coincides with sowing date
> mobilization of manpower, seeds etc.
> traditional methods were failing recently
$\rightarrow$ increasing variability of onset-dates
$\rightarrow$ increasing number of "false starts"

- - Regionally based reliable definition of the Monsoon's onset
- - Positive trend in the onset dates (suspected by farmers)?
- - Judge rainy season's onset for ongoing year using simple methods
- - Detection of circulation pattern, which are significant for onset occurrence

Requirements for onset definition:

- Consideration of agricultural meaningful aspects (soil moisture, survival of seedlings, etc.)
- Easy to compute (simple input variable(s))
- Long records of variable(s) available

Stern et al.'s onset definition (3 constraints):

ONSET = First day after 1st March, where:

1.) at least 25 mm of precipitation falls within 5 consecutive days

→ ensures soil moisture level

2.) three or more consecutive days are wet (precip. > 0.1 mm)

→ excludes heavy single showers

3.) there's no dry spell of > 6 days within the following 30 days

→ ensures survival of the seedlings

Rotated Principle Component Analysis (RPCA) in spatial - mode

- 29 observation sites

Definition of Stern et al. (1981)

5 PCs, explaining ~60% of the daily precipitation variance

Spatial distribution of PCs:

Correlation between PCs and observation sites

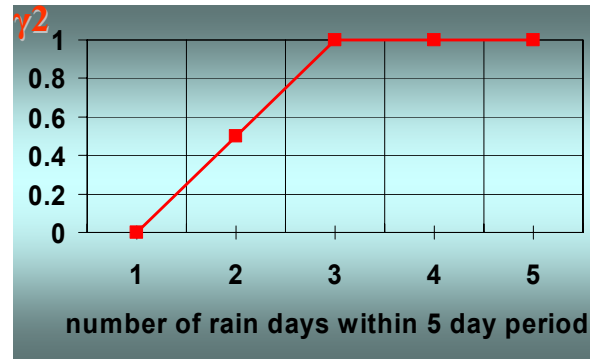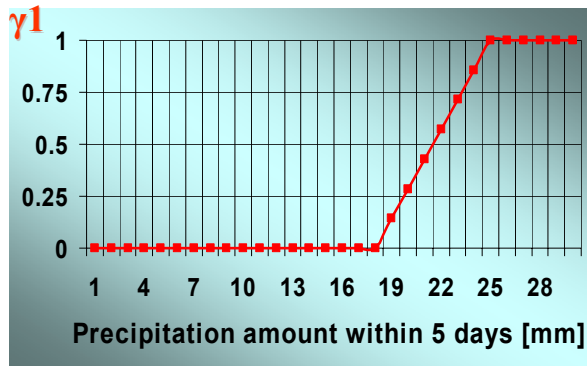Mean values of all observation sites within a PC

→ Years without hits (onset)

→ constraints are too strict
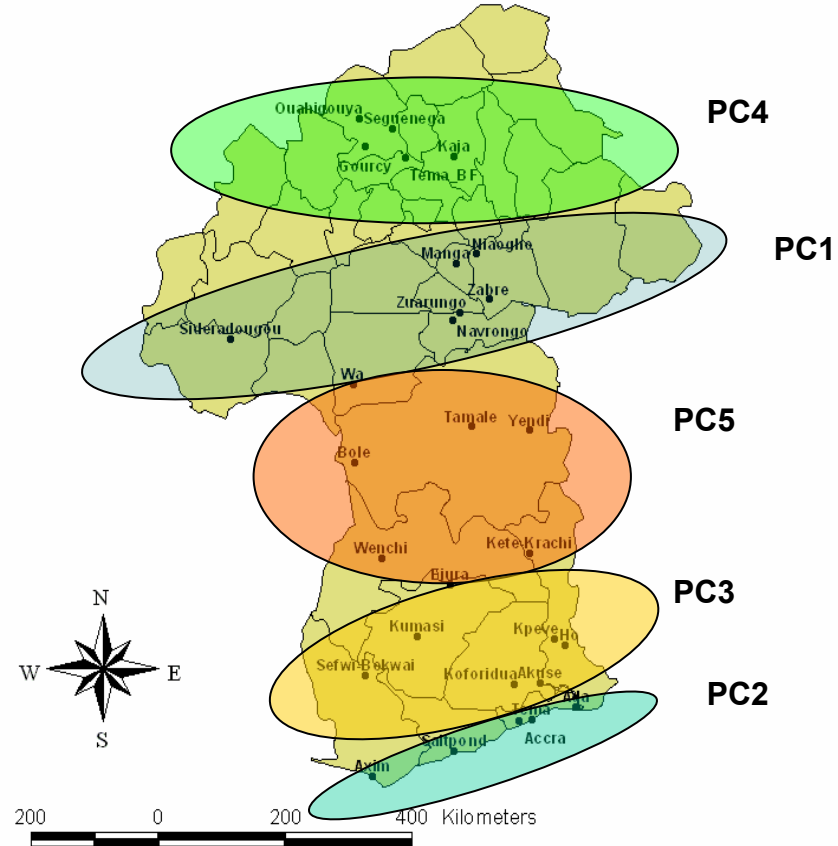
→ **Fuzzy-logic approach of Stern's definition**

Membership functions of Stern's onset constraints:

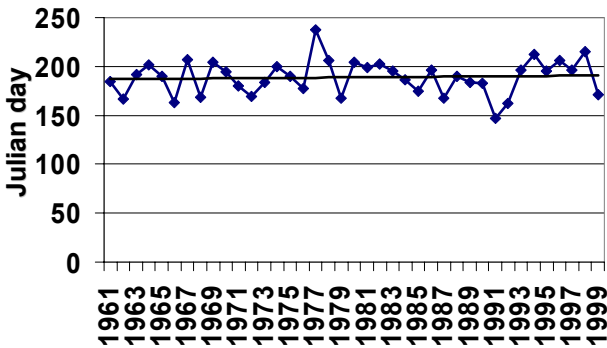**e. g. Onset, if $\gamma 1 * \gamma 2 * \gamma 3 > o.4$ (trial and error)**

Location of the Volta basin and spatial distribution of 5 different precipitation regions (PCs)
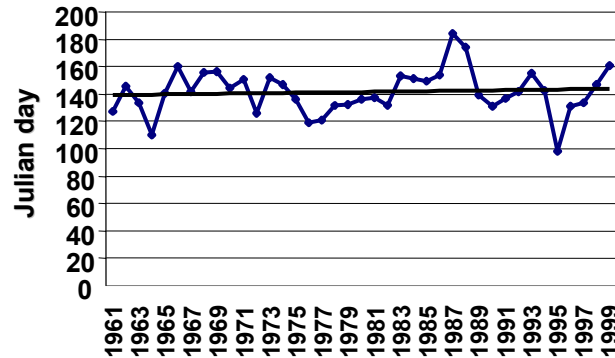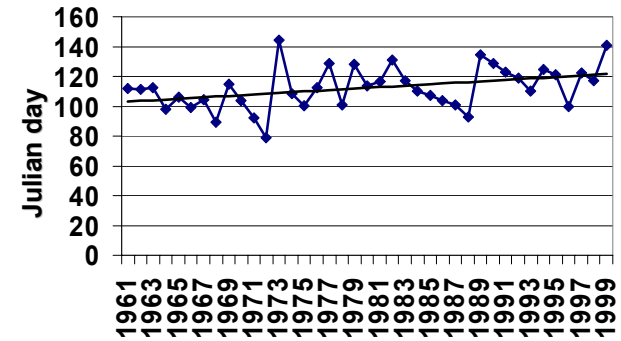
4. Linear trend analysis of onset dates
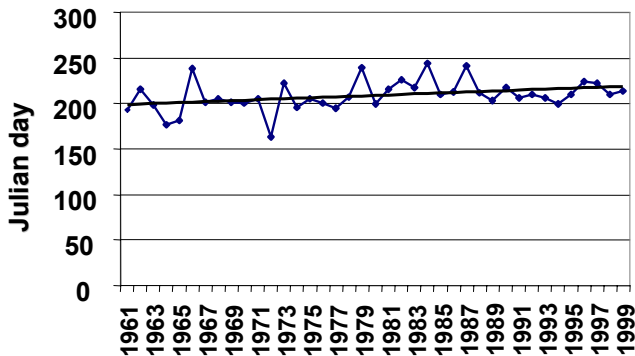
PC1

Trend: 0.106 d/year

Sign.: 61.6%

PC2

Trend: 0.237 d/year

Sign.: 96%

PC3

Trend: 0.347 d/year

Sign.: 99.8%

PC4

Trend: 0.388 d/year

Sign.: 99.5 %

PC5
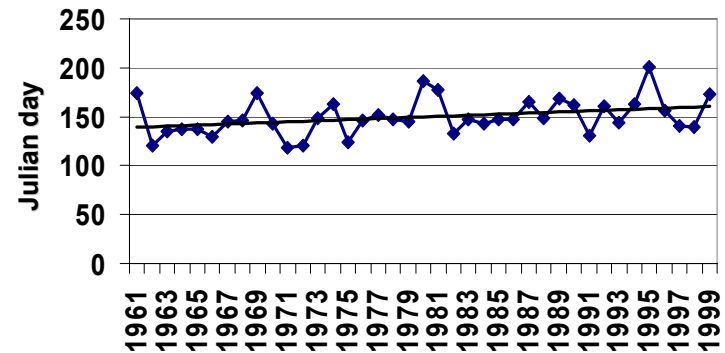
Trend: 0.334 d/year

Sign.: 99.1%

Station: Kpeve (PC3)
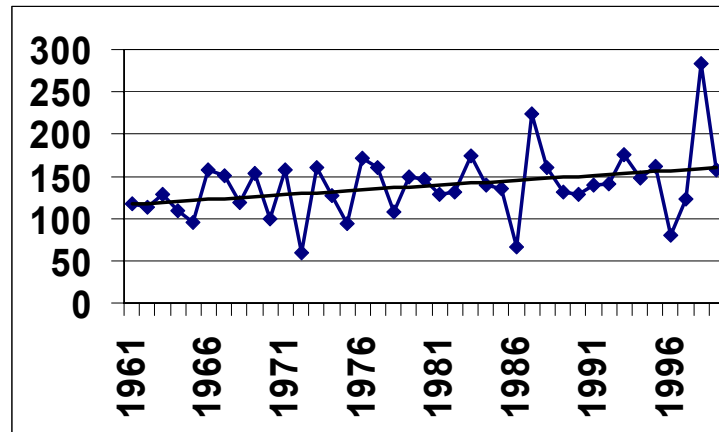
Trend > 30 d/40y

Sig.: 95%

- Positive trends of all regions (onset delay)

- significant and highly significant trends (PC2 – PC5)

- e.g. more than 2 weeks within 40 years (PC4)

- PC1 no significant trend

Method: stepwise linear discriminant analysis (LDA) (after DODD & JOLLIFFE)

Input variables: 1) precipitation amount 5, 10, 15, 20, 25, 30 days before potential onset

2) number of rainy days 5, 10, 15, 20, 25, 30 days before potential onset

3) $\gamma 1, \gamma 2, \gamma \mathbf{3}, \gamma$

Input variables: 1) precipitation amount 5, 10, 15, 20, 25, 30 days before potential onset

2) number of rainy days 5, 10, 15, 20, 25, 30 days before potential onset

3) $\gamma 1, \gamma 2, \gamma \mathbf{3}, \gamma$

Pre-defined class membership:

1. Dry season: 40 - 10 days before onset

2. Transition: 10 - 1 day(s) before onset

3. Onset of the rainy season: onset date + 4 consecutive days

4. Rainy season: 15 – 30 days after onset

5. Prediction of the onset for the ongoing season

Results:

1.) γ, precipitation amount 30 (vri30) & 10 (vri10) days before potential onset are most valuable parameters (most of the regions)

2.) very low influence of γ3 (excluded for definition)

3.) Confusion matrix of classification (exemplary shown for PC3)

		Class membership after application of linear discriminant analysis with cross validation [%]			
		dry season	transition	onset	wet season
Predetermined	dry season	**81.8 (81.3)**	13.5 (14.1)	1.0(0.8)	3.7 (3.8)
Class	transition	48.1 (40.7)	**40.8 (46.7)**	2.7 (2.5)	8.4 (10)
Membership	onset	12.7 (10.5)	12.9 (15.8)	**65.5 (61.8)**	8.9 (11.9)
[%]	wet season	10.5 (8.5)	7.2 (9.2)	8.3 (9)	**74.0 (73.2)**

➡ The monsoon's onset is reclassified accurately in 2/3 of all cases

Covariance of the four classes using most prominent variables

3.) 3 functions to discriminate 4 classes (exemplary shown for PC3) :

$f1(x) = -1.96 + 1.01 \cdot \gamma - 1.91 \cdot vri10 + 7.6 \cdot vri30$

$f1(x) = -0.22 + 2.17 \cdot \gamma + 6.81 \cdot vri10 - 5.3 \cdot vri30$

$f1(x) = 0.74 + 4.48 \cdot \gamma - 5.82 \cdot vri10 - 0.22 \cdot vri30$

- LDA valuable to discriminate between dry season, wet season & onset

- The monsoon's onset is reclassified accurately in 2/3 of all cases

- Not valuable for transition time ⟶ "On-Off-character" of onset

- Fuzzy logic based definition is useful to determine the onset in the Volta-basin

Method:

- automated objective circulation pattern classification based on optimized fuzzy rules (A. Bárdossy)

- originally developed and applied for downscaling of precipitation and temperature

- conditioning of anomaly fields on weighted class vector per region:

> 1. dry season == 0
> 2. Onset == 100
> 3. wet season == 2

- Sequence of operations:

> 1. Data transformation (computation of anomalies)
>
> 2. Definition of fuzzy rules
>
> 3. classification of observed data

Data: NCEP/NCAR reanalysis fields

domain: 10°S - 60°N and 30°E - 40°W

spatial resolution: 2.5°

temporal resolution: 6 hours (aggregated to daily values)

fields: Sea Level Pressure

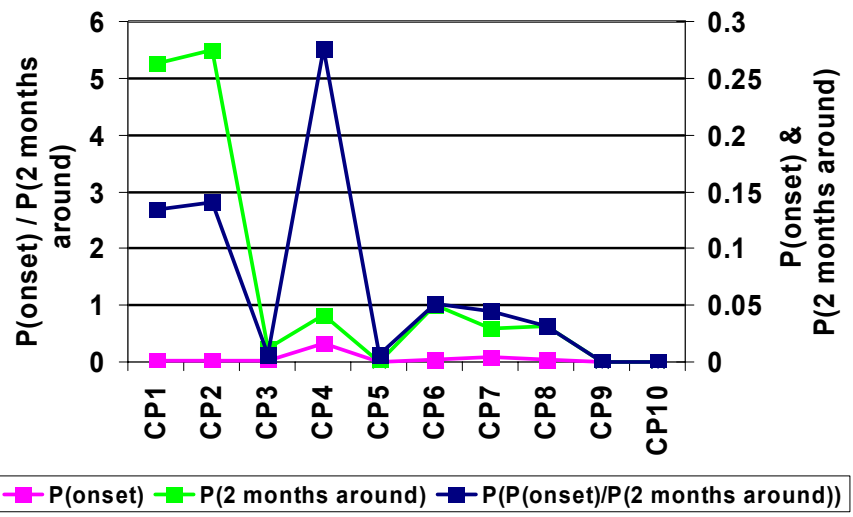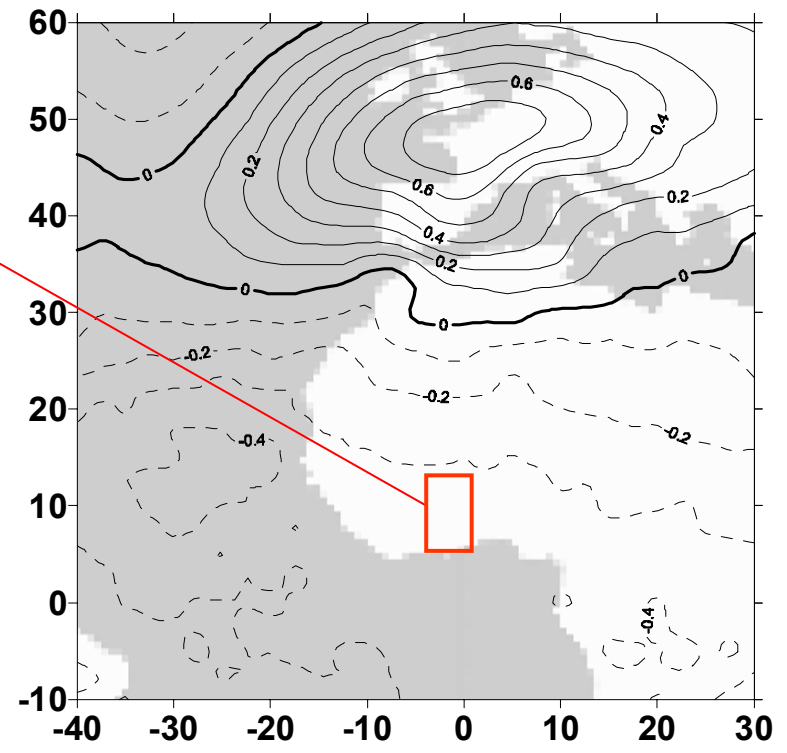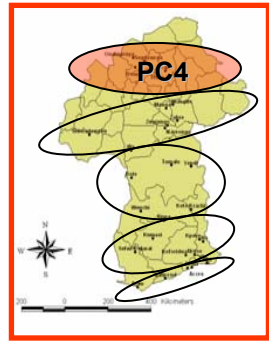Sea Surface Temperture

U-component (300 hPa, 500 hPa, 700 hPa)

Specific Humidity (500 hPa, 850 hPa, 1000 hPa)

Geopotential Height (500 hPa, 850 hPa)

Example 1: Sea Level Pressure conditioned on PC4

mean SLP anomaly pattern of CP4 (1961-1999), conditioned on onset of PC4

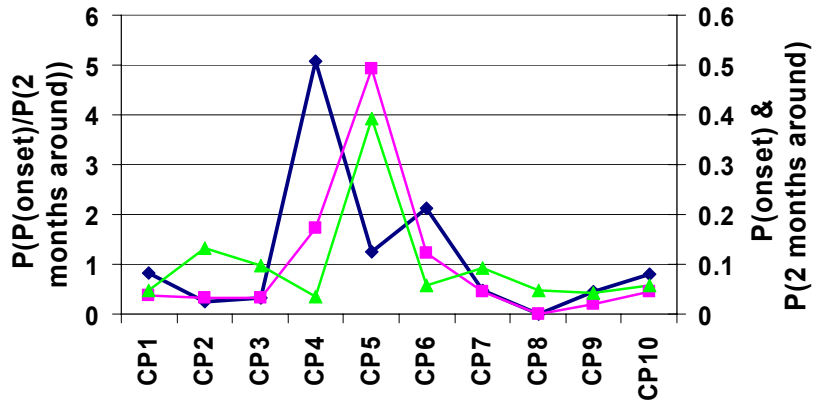Example 2: Geopotential height 500hPa conditioned on PC5
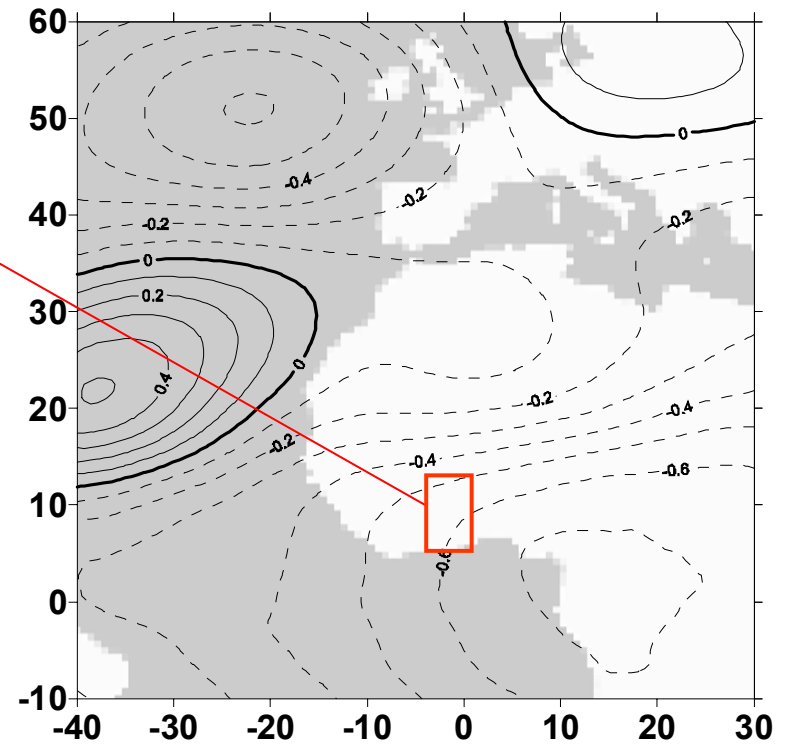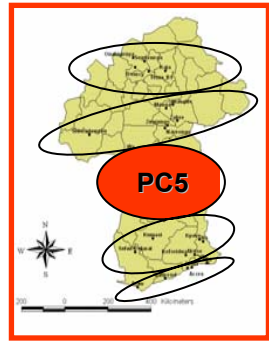
mean GPH anomaly pattern of CP4 (1961-1999), conditioned on onset of PC5

7. Summary

1. development of reliable regional onset definition

Thank you for your attention!

Tamale: dry season (source: www.glowa-volta.de)

Tamale: rainy season (source: www.glowa-volta.de)