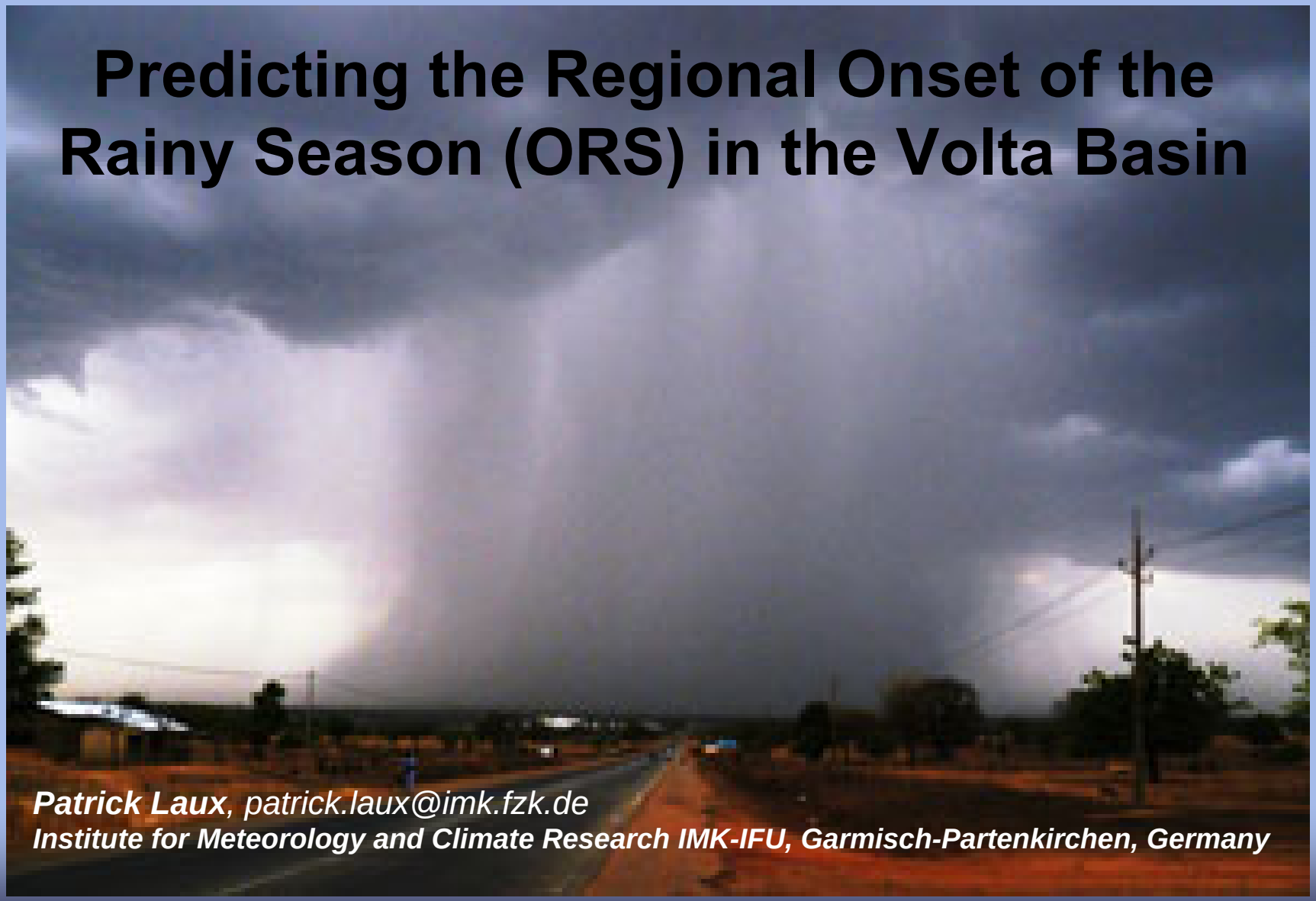
GLOWAVolta

# Predicting the Regional Onset of the Rainy Season (ORS) in the Volta Basin



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# Motivation

- 70% of the West African population depend on rainfed agriculture
- Rainfall (not temperature) is the crucial factor for West African agriculture
- Rainfall is limited to few months per year
  - Sowing as early as possible to avoid wasting of valuable growth time
  - Planting too early (misinterpretation of the ORS) may lead to crop failure and high economic losses
- Farmers report of a high inter-annual variability of the ORS

# Objectives

**1) Development of an operational ORS definition for the Volta Basin considering *agricultural meaningful* and *technical* aspects:**

- Adequate soil moisture content at beginning of growth period
- Numerous rainy days before planting
- Avoiding dry stress during the establishing period
- Flexible definition:

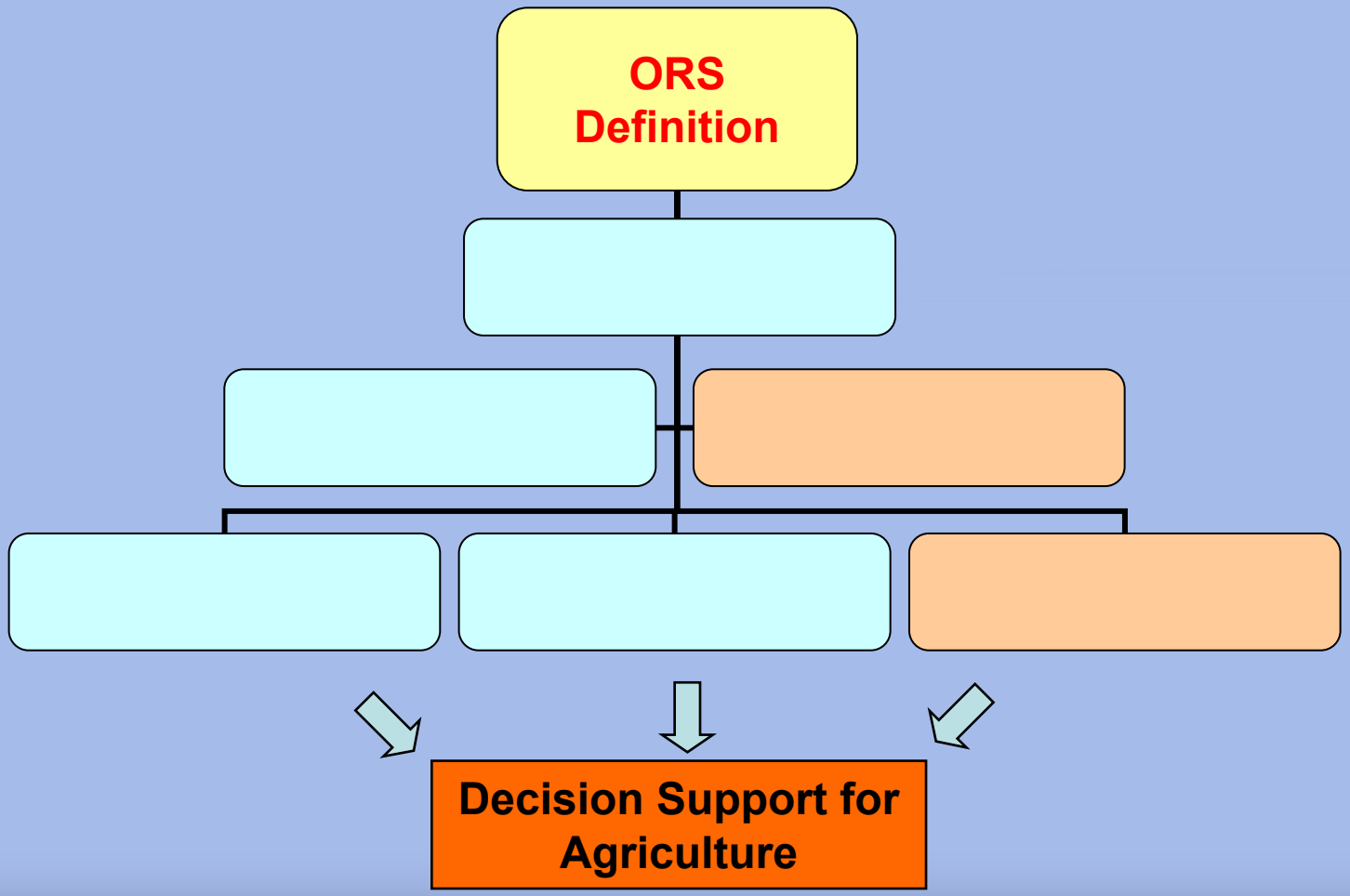
  adaptable to needs of different crop varieties
- Relay on “easy-access” data

# Objectives

**2) Development of maps for agricultural decision support ("risk mapping" for planting)**

- Mean ORS dates
- Standard deviations of ORS dates (risk of crop failure!)
- False start probabilities
- Exceedance probabilities of ORS dates
- Minimum dry spell probabilities
- Rainfall probabilities for certain rainfall amounts
- Drought probabilities (return periods)

**3) Prediction of the ORS for ongoing season**


ORS
Definition
Decision Support for
Agriculture

# ORS Definition

ORS = first day of the year, when these criterions are fulfilled simultaneously:

1. 25 mm precipitation falls within 5-day period
2. Starting day and two other days are rainy days
3. No dry period of 7 or more consecutive days allowed within following month (false start criterion!)

DEFINITION 2

DEFINITION 1

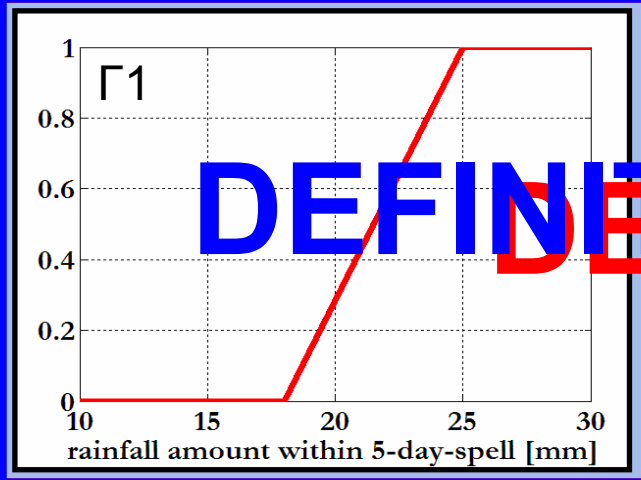
**Problem:** Sternness of the definition
**Solution:** Fuzzy-logic approach

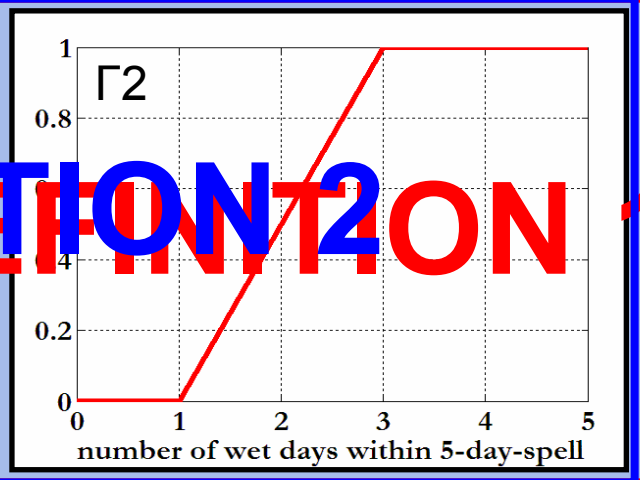
# ORS Definition

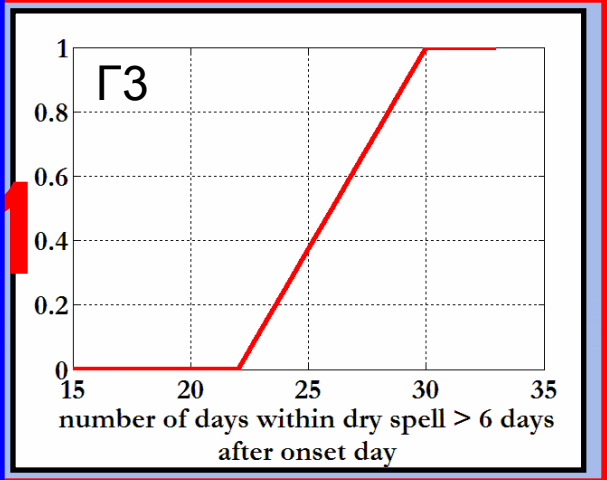
- Fuzzy logic approach:

  Step 1: Translation of the Definition arguments into membership functions

# ORS Definition




DEFINITION 2 DEFINITION 1

*False start* – criterion,

only applicable EX-POST!

# ORS Definition

- Fuzzy logic approach:

**Step 1**: Translation of the Definition arguments into membership functions

**Step 2**: Combining the membership functions

$\Gamma_{def1} = \Gamma 1 \cdot \Gamma 2 \cdot \Gamma 3$ $\Gamma_{def2} = \Gamma 1 \cdot \Gamma 2$

**Step 3**: Defuzzification:

If $\Gamma_{def1}$ ($\Gamma_{def2}$) > threshold, then ORS

# Regionalisation

## Data arrangement

$$X = \begin{pmatrix} x_{11} & x_{12} & \cdots & \cdots & x_{1p} \\ x_{21} & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ x_{n1} & \cdots & \cdots & \cdots & \end{pmatrix}$$

A map for time $t_1$

A time series for location $x_1$

## Principle Component Analysis:

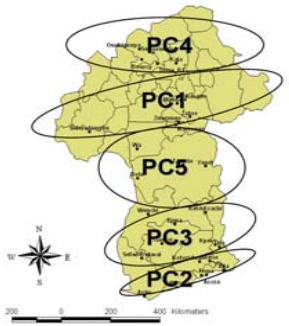
1. Covariance Matrix: $R = \frac{1}{n-1} X^T \cdot X$
2. Eigenvalue Problem: $RC = C\Lambda$
3. Expansion Coefficients: $\vec{a}_j = X\vec{c}_j$
4. Reconstruction TS: $X = \sum_{j=1}^{p} \vec{a}_j (EOF_j)$

**How to come from the stations to the regions ?**

## Correlation original TS and PCs

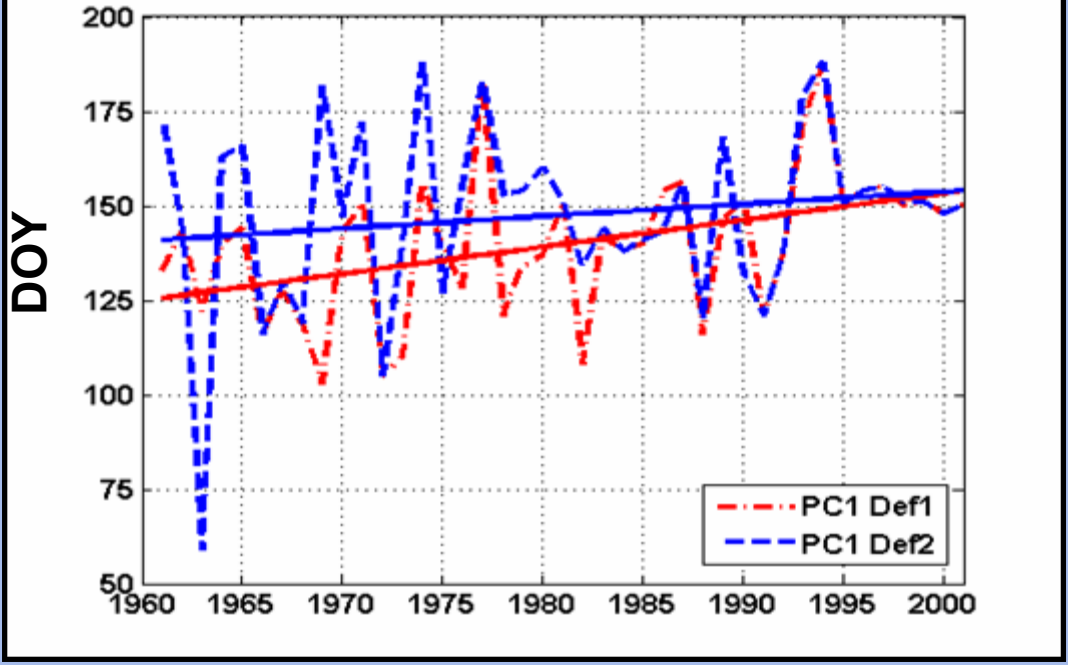
| Station | pc1 | pc2 | pc3 | pc4 | pc5 |
|---|---|---|---|---|---|
| Accra | **0.80** | 0.00 | 0.03 | 0.04 | 0.14 |
| Ada | **0.66** | 0.00 | 0.01 | 0.07 | 0.13 |
| Akuse | 0.40 | -0.03 | 0.09 | -0.01 | **0.50** |
| Axim | **0.51** | 0.02 | -0.02 | 0.10 | 0.14 |
| Bole | 0.07 | 0.05 | 0.08 | **0.66** | 0.10 |
| … | … | … | … | … | … |

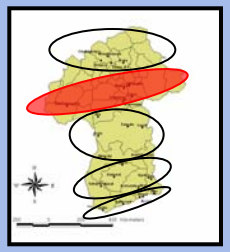
## Grouping of each station to a region



# Delay of the Onset of the Rainy Season

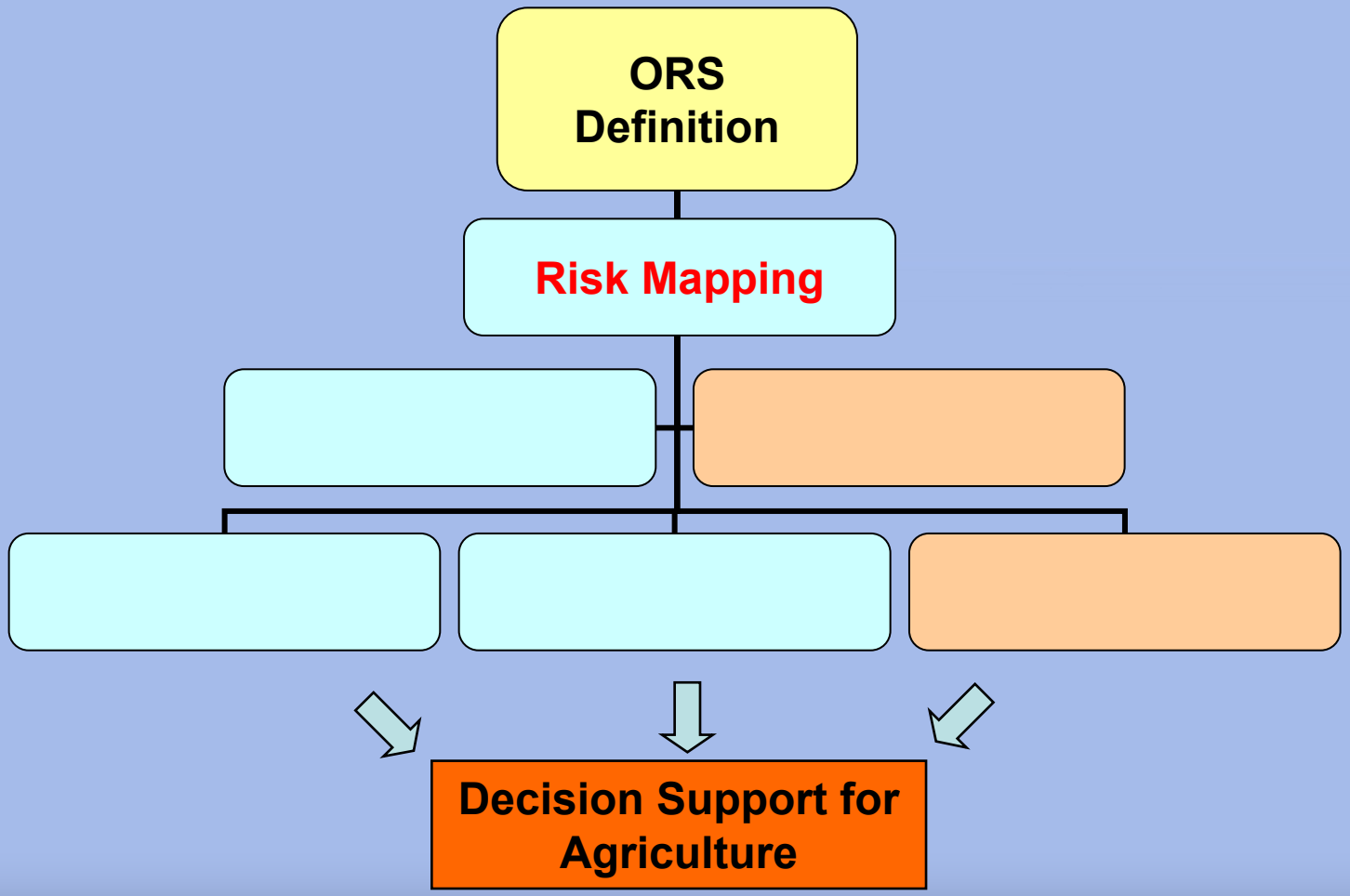
Interannual variability of the ORS date



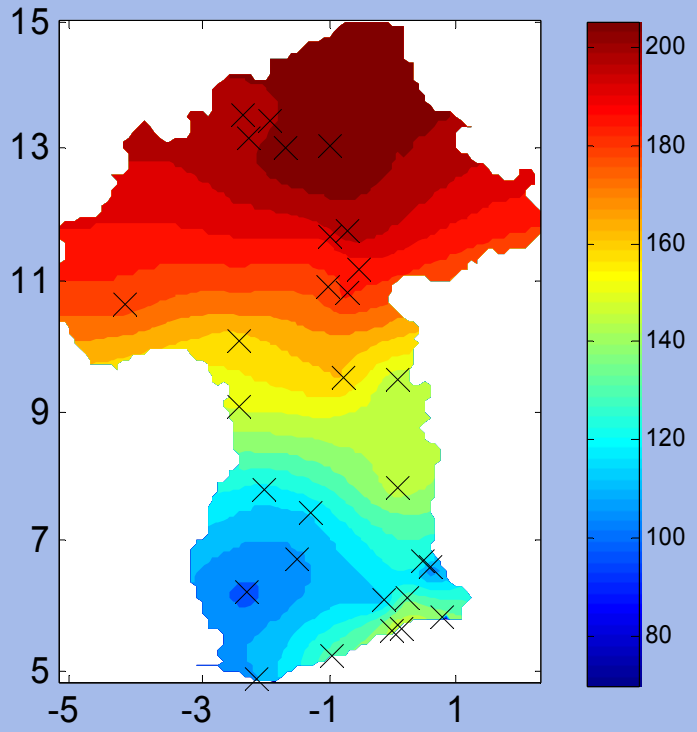



**Significant ORS delay of about 3 weeks within 40 years**

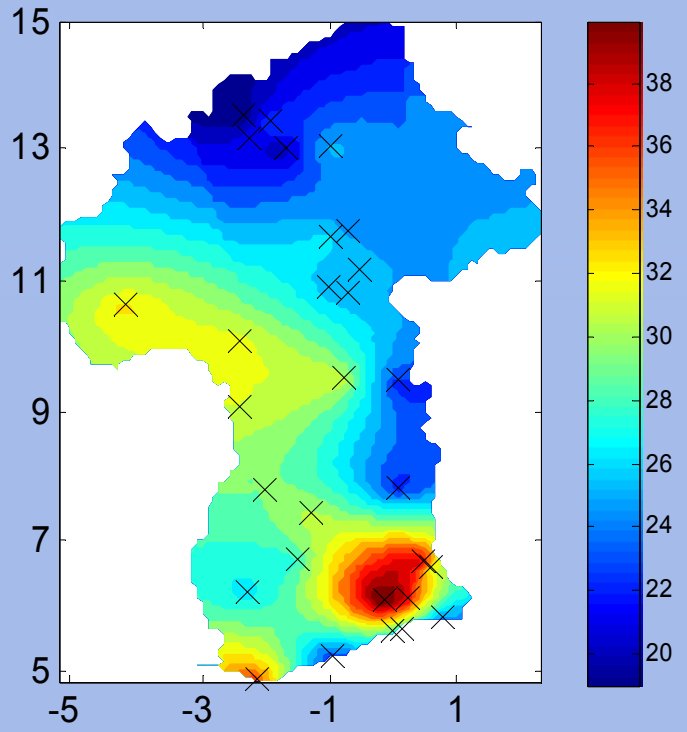
# Risk Mapping



# Maps for Agricultural Decision Support



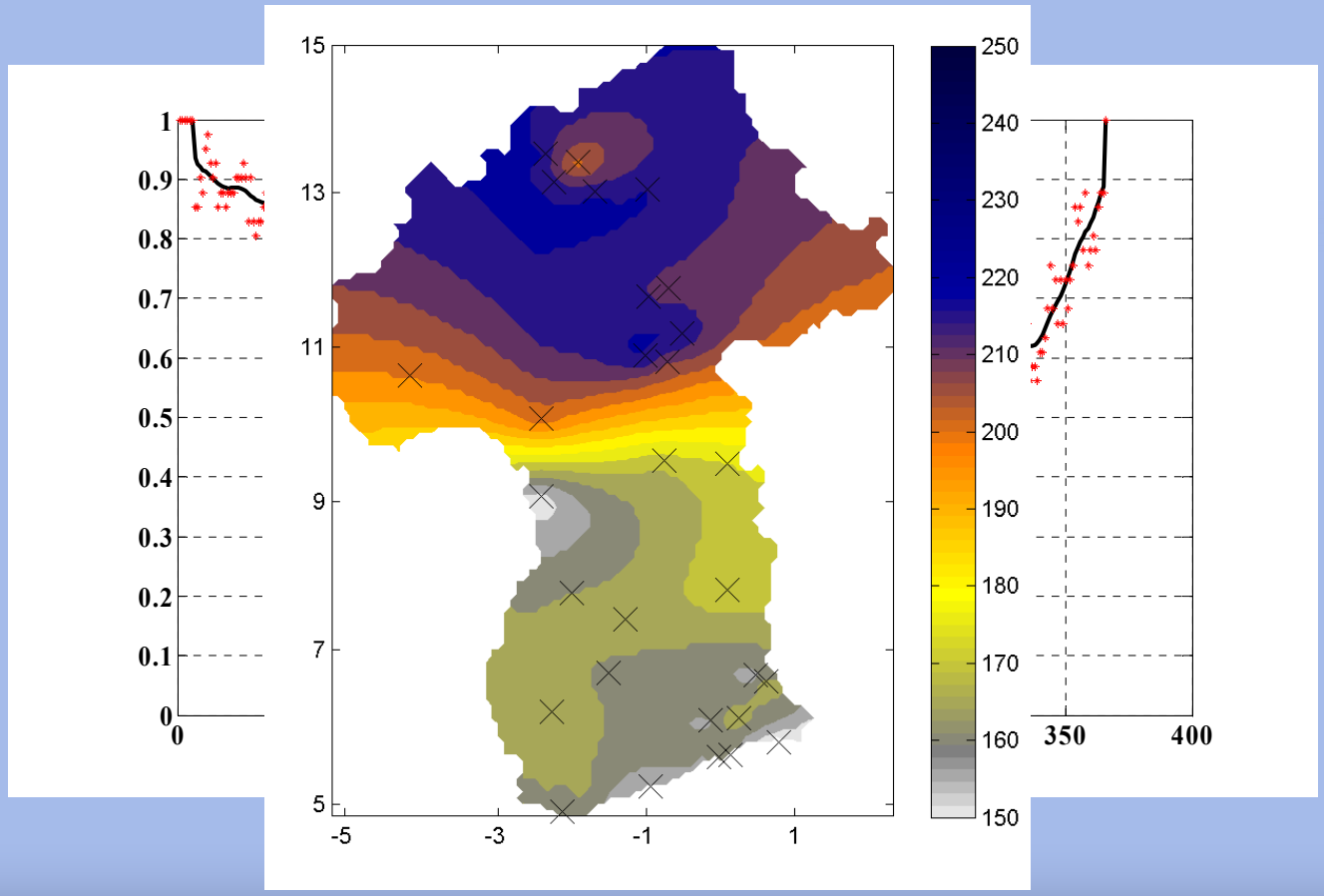

**Mean date** (DOY) of the Onset of Rainy Season (1961-2000)




**Standard deviation** (DOY) of the Onset of Rainy Season (1961-2000)

# Maps for Agricultural Decision Support

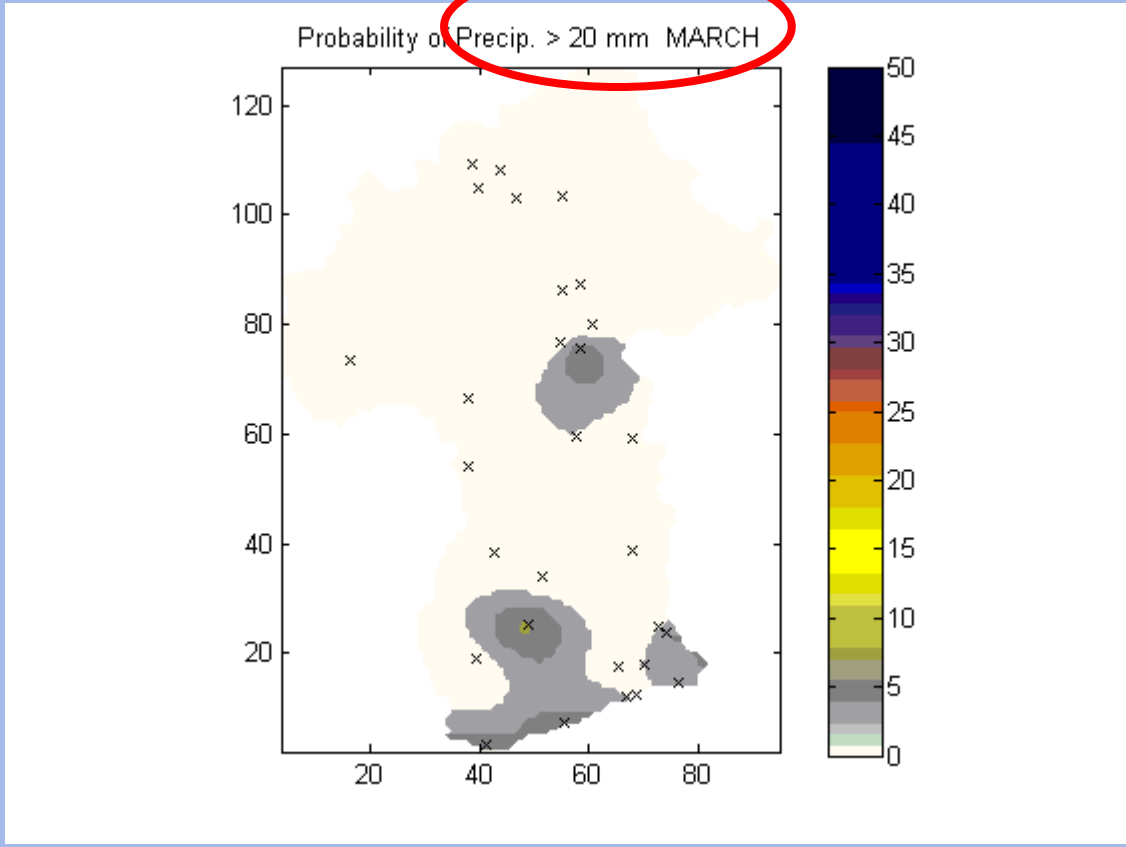
**Occurrence probability of a dry spell ≥ 7 days within the following month at station Bole for each DOY (1961-2000)**



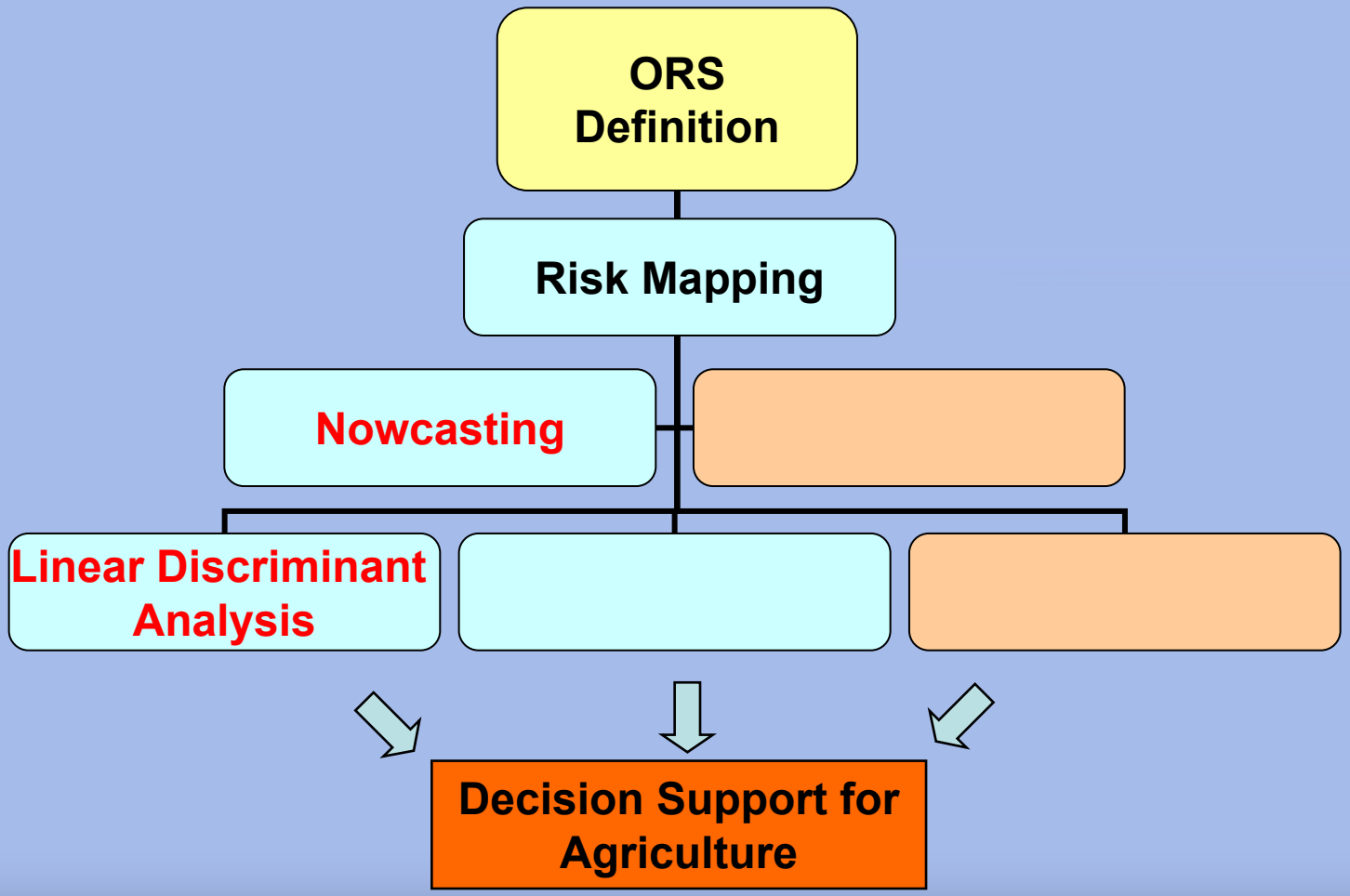

Map of minimal risk

# Maps for Agricultural Decision Support

**Rainfall probabilities exceeding certain amount / day**



# Prediction of the ORS (Ongoing Season)



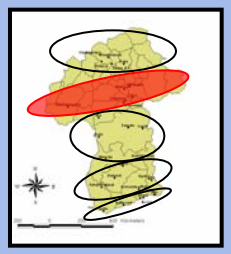
# Prediction of the ORS (Ongoing Season) via LDA

**Predictors:**

Number of rainy days & rainfall amount

various 5 day period before ORS

# Performance of ORS Prediction (Ongoing Season) via LDA



| | | Class membership after application of linear discriminant analysis [%] | | | |
|---|---|---|---|---|---|
| | | DRY class | TRANSITION class | ORS class | WET class |
| Predetermined Class Membership [%] | DRY class | **80.32** | 15.86 | 1.38 | 2.44 |
| | TRANSITION class | 52.99 | **27.97** | 4.01 | 15.03 |
| | ORS class | 7.20 | 5.80 | **79.44** | 7.56 |
| | WET class | 13.94 | 11.50 | 10.57 | **63.99** |

**Hit ratio: ~ 80% correct classified cases for the ORS**

# Summary Prediction ORS via LDA

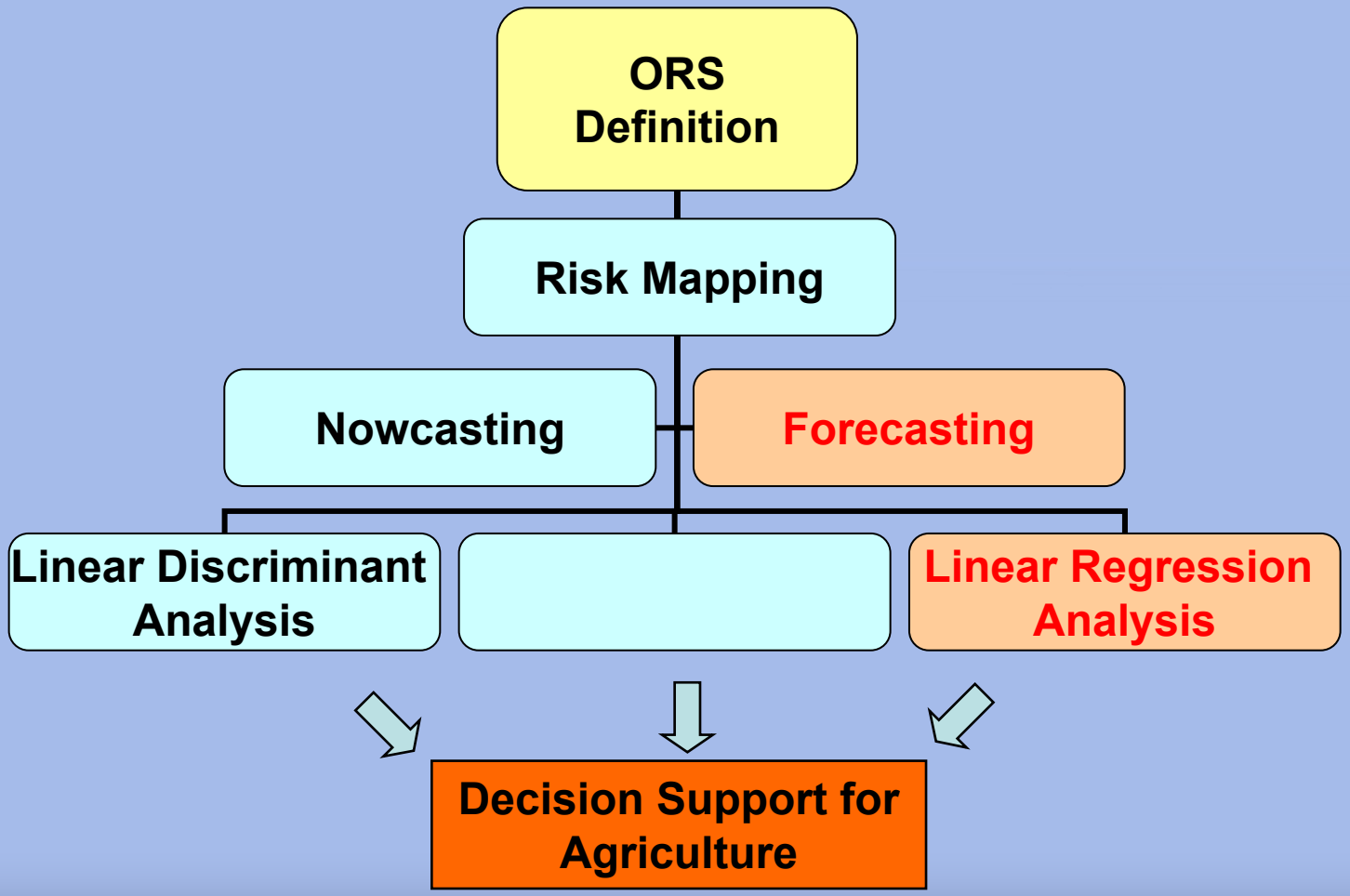
- Valuable tool to judge day by day whether the ORS has already begun
  - Current measured rainfall data
  - YES/NO-Decision about the ORS for each day
  - Alternatively usage of

    **numerical 5-day weather forecast**

    **http://www.gap.fzk.de/de/wetter/index_wetter_africa.htm**

- Performance is depending on the region
  - 60 – 80% correct classification of ORS

# Prediction of the ORS (Ongoing Season)



# Prediction of the ORS (Ongoing Season) via LRA

Linear Regression Analysis **(LRA)**

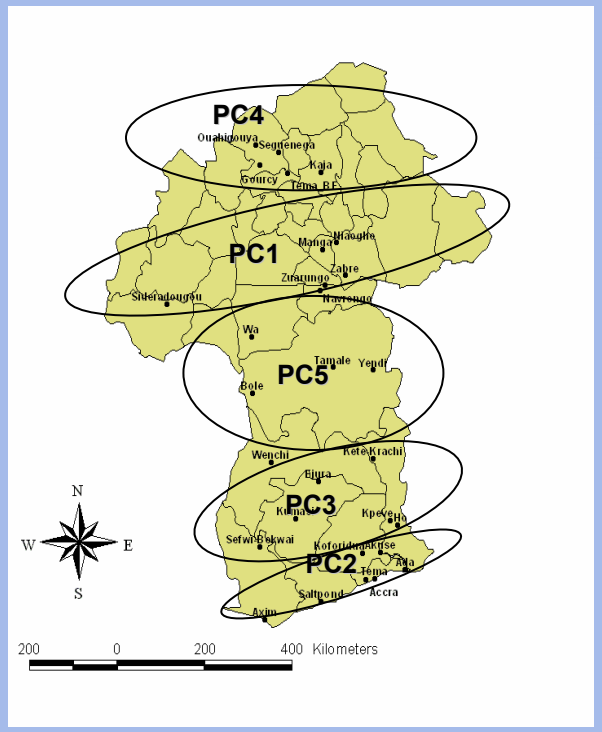
- Propagation time of monsoonal system from one region to another nearly constant over time

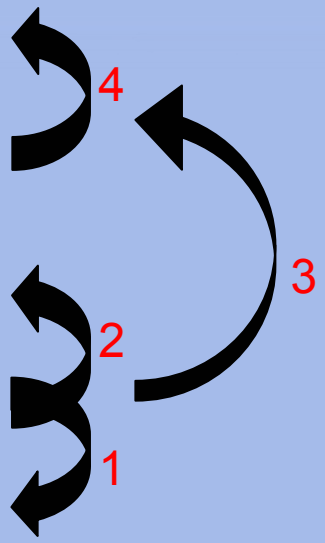
- Estimating **successively the regional ORS dates**:

  ORS dates (DOY) from regions with early ORS are predictors for regions with later ORS

# Prediction of the ORS (Ongoing Season) via LRA

## Direction of subsequent ORS prediction

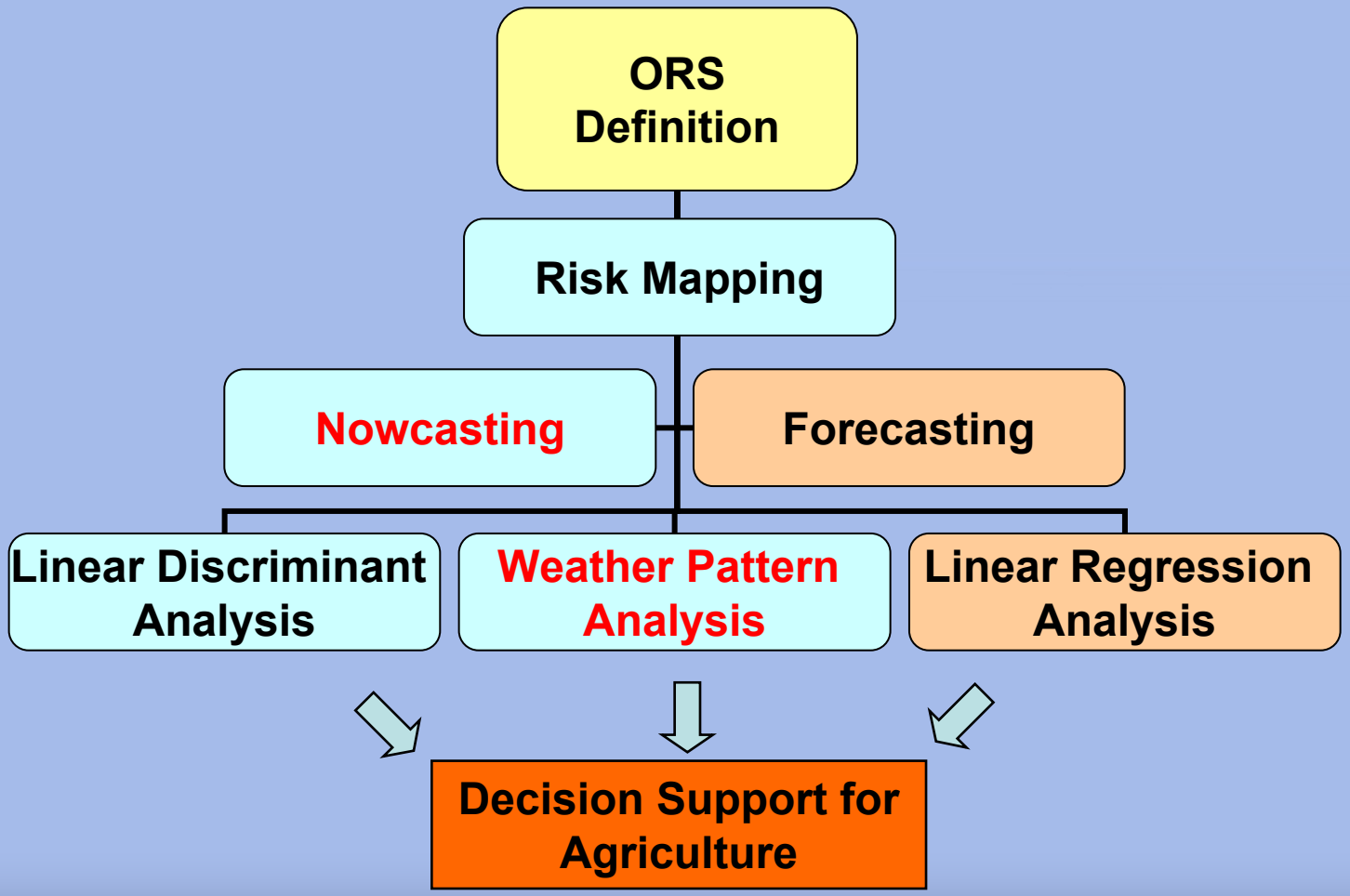


# Prediction of the ORS (Ongoing Season) via LRA

## Regression equations

| Model Number | Target PC | Indep. PC | μ threshold target PC | μ threshold indep. PC | Regression equation | r |
|---|---|---|---|---|---|---|
| 1 | PC5 | PC3 | 0.35 | 0.3 | PC5 = 52.36 + 0.61 PC3 | 0.52 |
| 2 | PC2 | PC3 | 0.3 | 0.85 | PC2 = 44.33 + 0.57 PC3 | 0.46 |
| 3 | PC1 | PC3 | 0.2 | 0.2 | PC1 = 78.64 + 0.80 PC3 | 0.57 |
| 4 | PC4 | PC1 | 1 | 0.8 | PC4 = 119.7 + 0.40 PC1 | 0.47 |

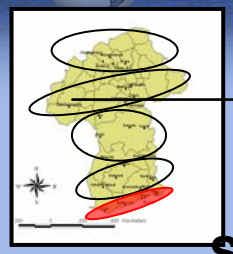

ORS Definition
Risk Mapping
Nowcasting
Forecasting
Linear Discriminant Analysis
Weather Pattern Analysis
Linear Regression Analysis
Decision Support for Agriculture

# Prediction of the ORS (Ongoing Season) via WPA

- Is the regional ORS linked to specific weather patterns/circulation patterns?
- Assumption: Regional & local scale variable (e.g. ORS) are depending on large-scale meteorological information

# Prediction of the ORS (Ongoing Season) via WPA

- Comprehensive screening with respect to
  - Predictor variable
  - Domain size and location of predictors
  - 5 different regions within the Volta Basin
  - Number of used weather patterns
- > 200 calculations of ~ 1 week duration each (Linux Cluster with ~200 CPUs)

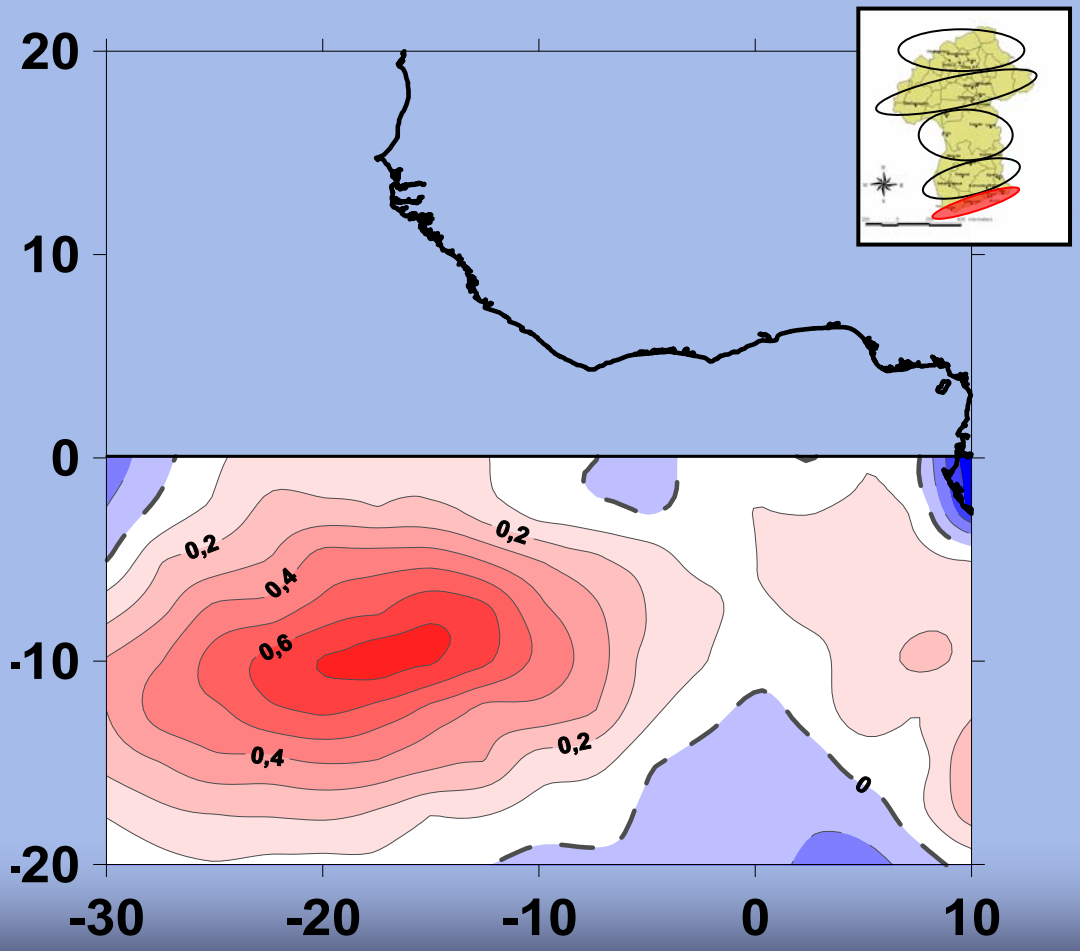


| SkT, pc2 | WP cond. Frequ. [%] | WP and Onset cond. Frequ. [%] | $O_p$ |
|---|---|---|---|
| **WP1** | 8.21 | 10.53 | 1.28 |
| **WP2** | 4.57 | 2.63 | 0.58 |
| **WP3** | 6.92 | 10.00 | 1.45 |
| **WP4** | 20.30 | 15.26 | 0.75 |
| **WP5** | 13.20 | 17.37 | 1.32 |
| **WP6** | 9.02 | 5.26 | 0.58 |
| **WP7** | 10.68 | 3.68 | 0.35 |
| **WP8** | **9.50** | **17.89** | **1.88** |
| **WP9** | 7.02 | 5.26 | 0.75 |
| **WP10** | 10.58 | 12.11 | 1.14 |

$$O_p = \frac{Frequency(WP|_{ONSET \wedge WP})}{Frequency(WP|_{WP})}$$

# WP8

Composite of the **Skin Temperature (1961-2000)**

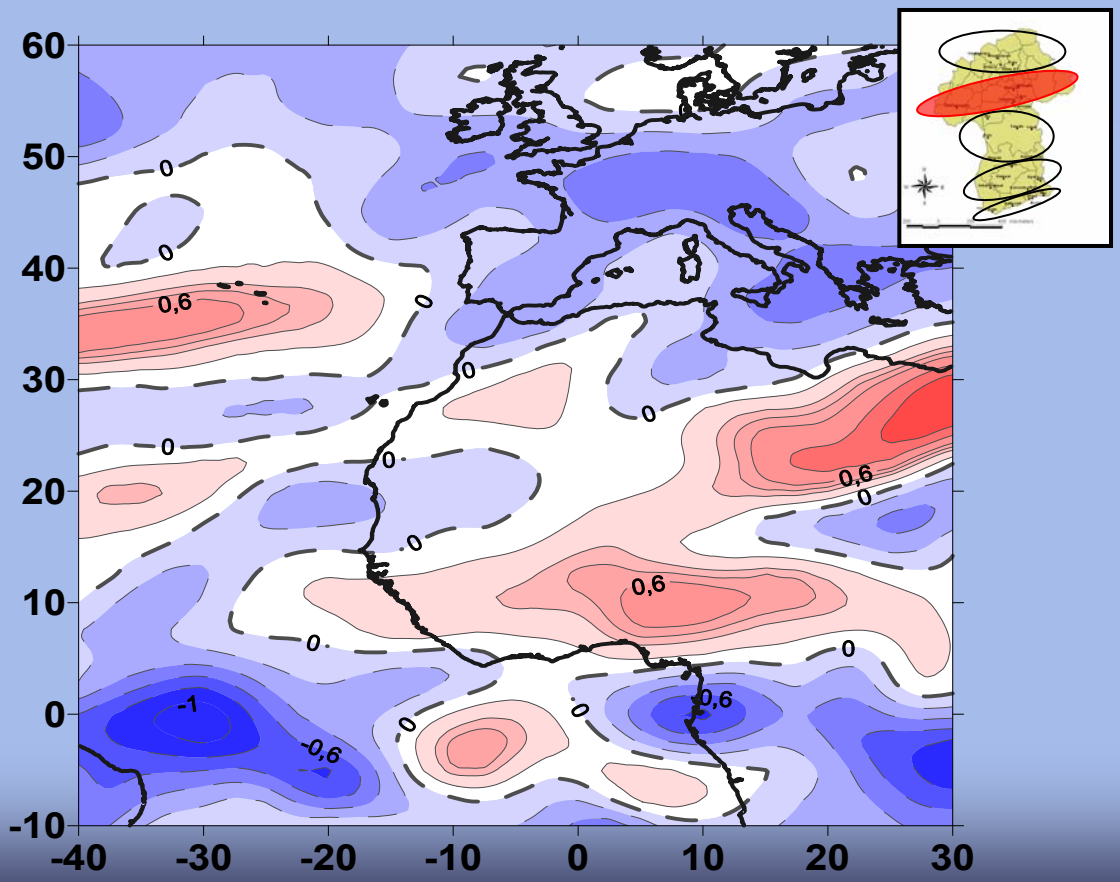


| MF_U(500hPa) PC1 | WP cond. Frequ. [%] | WP and Onset cond. Frequ. [%] | $O_p$ |
|---|---|---|---|
| **WP1** | 16.77 | 15.38 | 0.92 |
| **WP2** | 0.63 | 0.00 | 0 |
| **WP3** | 3.16 | 4.62 | 1.46 |
| **WP4** | 31.34 | 25.64 | 0.82 |
| **WP5** | **4.55** | **11.28** | **2.48** |
| **WP6** | 12.57 | 18.46 | 1.47 |
| **WP7** | 15.63 | 20.00 | 1.28 |
| **WP8** | 0.60 | 0.00 | 0 |
| **WP9** | 2.49 | 0.00 | 0 |
| **WP10** | 12.27 | 4.62 | 0.38 |

$$O_p = \frac{Frequency(WP|_{ONSET \wedge WP})}{Frequency(WP|_{WP})}$$

# WP5

Composite of the **eastward component of Moisture Flux in 500hPa (1961-2000)**



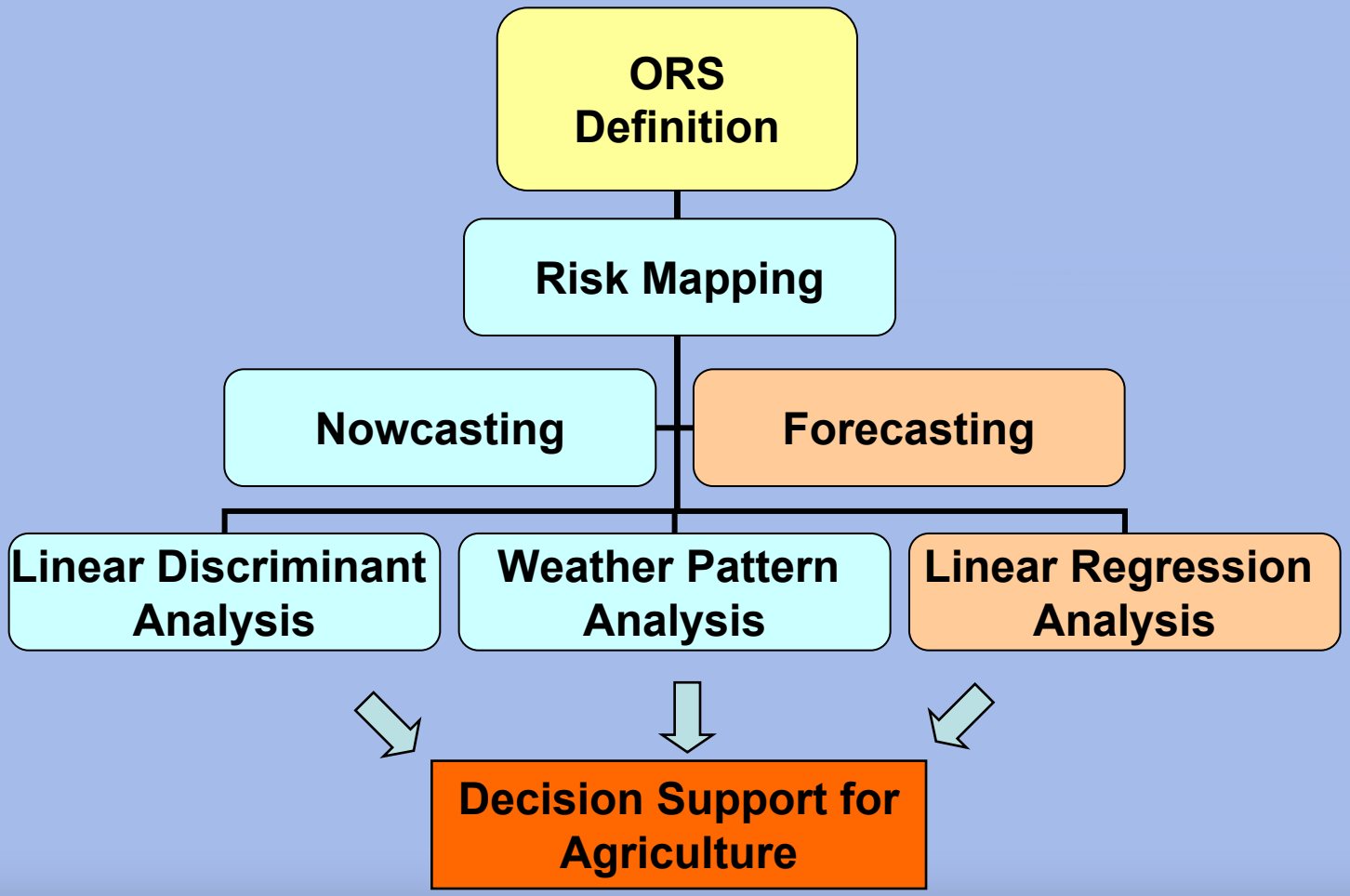
# Summary WPA

- Synoptic situation can be statistically related to the regional ORS
- Bootstrapping tests proofed significance of the identified weather patterns
- **Moisture Flux** in 500hPa, **SST** & **Skin Temperature** best predictor variables for the ORS

# Overall Summary

- Development of a fuzzy logic-based ORS definition in order to estimate the **„optimal“ planting date**
  - Easily adoptable to different agricultural needs
- Development of **“risk maps”**
- Development of 3 suitable **tools for predicting the ORS**
  - ~80% hit ratio for the ORS
  - Identification of weather patterns significantly linked with the ORS

# Overview of Methods



# Transfer of Knowledge

**14.01. - 18.01.08: Accra (Ghana)**
**22.01. - 25.01.08: Ouagadougou (Burkina Faso)**

# Some critical words …

- Recommendation to **use many methods** (and risk maps) for decision about planting
  - Including also traditional methods (migration of insects, birds, etc) ⇒ **"multi-cognitive framework"**
- Statistical inferences derived from 1961-2000 climate
  - But: Climate is "changing"

    ⇒ *Updating* of statistical relationships required every year
- **Risk management strategies** for coping with imperfect predictions still must be elaborated


Thank you for
your attention!