

# Climate Change impacts: challenges and opportunities German-Nigerian collaboration and its regional agricultural and hydrological impacts for West Africa Challenges and opportunities for a German-Nigerian collaboration

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# Motivation

- Rainfall distribution in time and space has significant impact on **water availability** and socio-economy in West Africa
  - Severe droughts in 1970s and 1980s (i.e. 1972-74, 1982-84)
- **Rainfed agriculture** highly exposed to rainfall variability
  - 70% of population dependent on rainfed agriculture
  - Food Security: severe shortages in 1970s and 1980s
- Crucial problem for rainfed agriculture: Decision about the **sowing date**
  - Sowing as late as possible to avoid wasting of valuable growth time
  - Sowing too early may lead to crop failure and high economic losses
- **Prediction of Onset of the Rainy Season (ORS)**

**Global climate change is expected to aggravate rainfall variability and water scarcity in 21. Century (IPCC, 2007)**

# “Challenge” West Africa



by L. Bharati

Required:  
Scientifically sound information  
under weak infrastructure

## Case study 1: Volta Basin (Ghana & Burkina Faso)

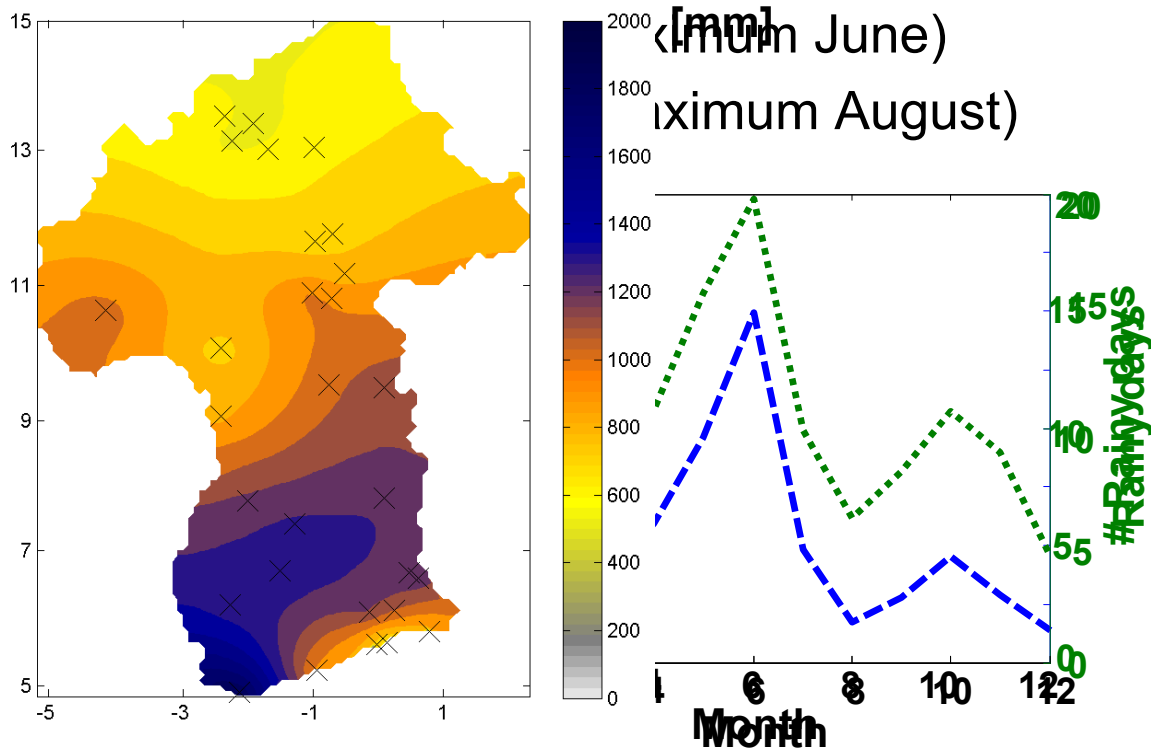
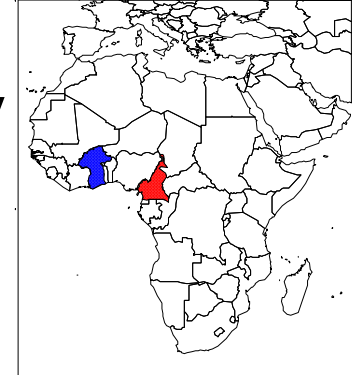
- Observed signals of climate change
- Regional climate modeling: expected future climate
  - Impact climate change on regional water availability
  - Impact climate change on agricultural sector

## Case study 2: Cameroon

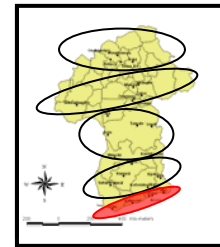
- Impact climate change on food production

## Conclusions

- Volta Basin (Ghana & Burkina Faso), Cameroon
- Similar climate: High spatial and temporal rainfall variability
  - Climate: sub-humid to arid
  - Rainy Season (*Intertropical Convergence Zone ITCZ*)



Volta Basin



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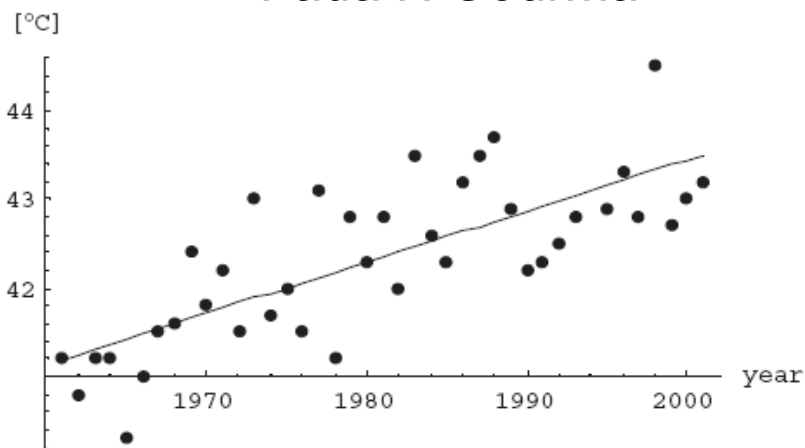
- Impact climate change on food production

## Conclusions

# Observed Climate Change (1961-2000)

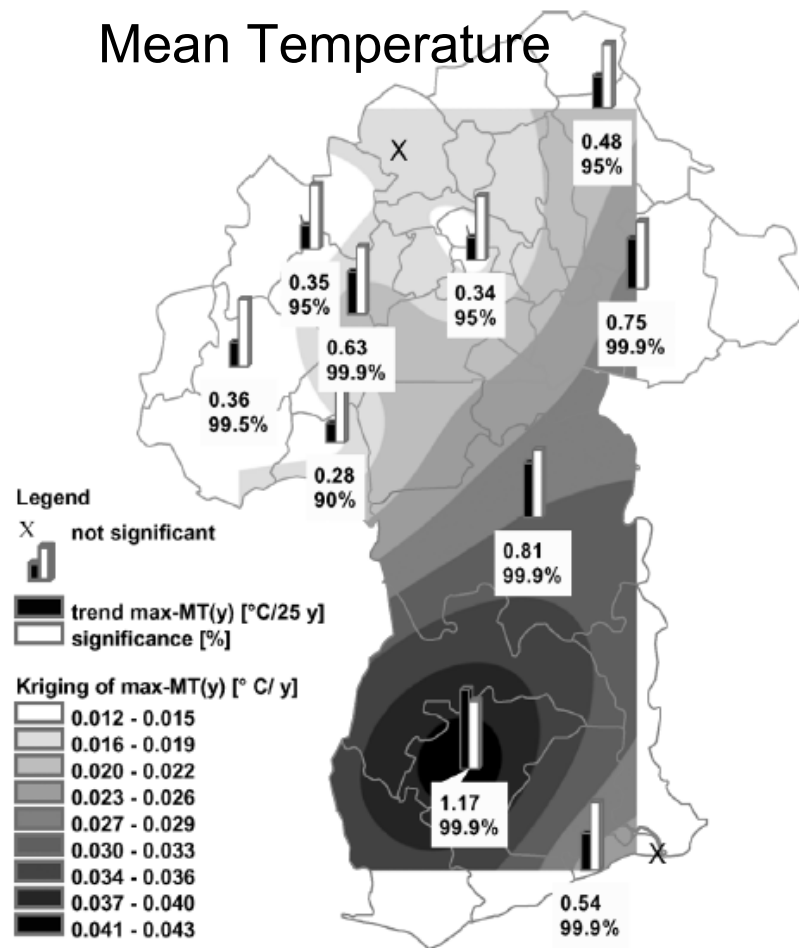
## Trends in Temperature

### Maximum Temperature Fada N'Gourma



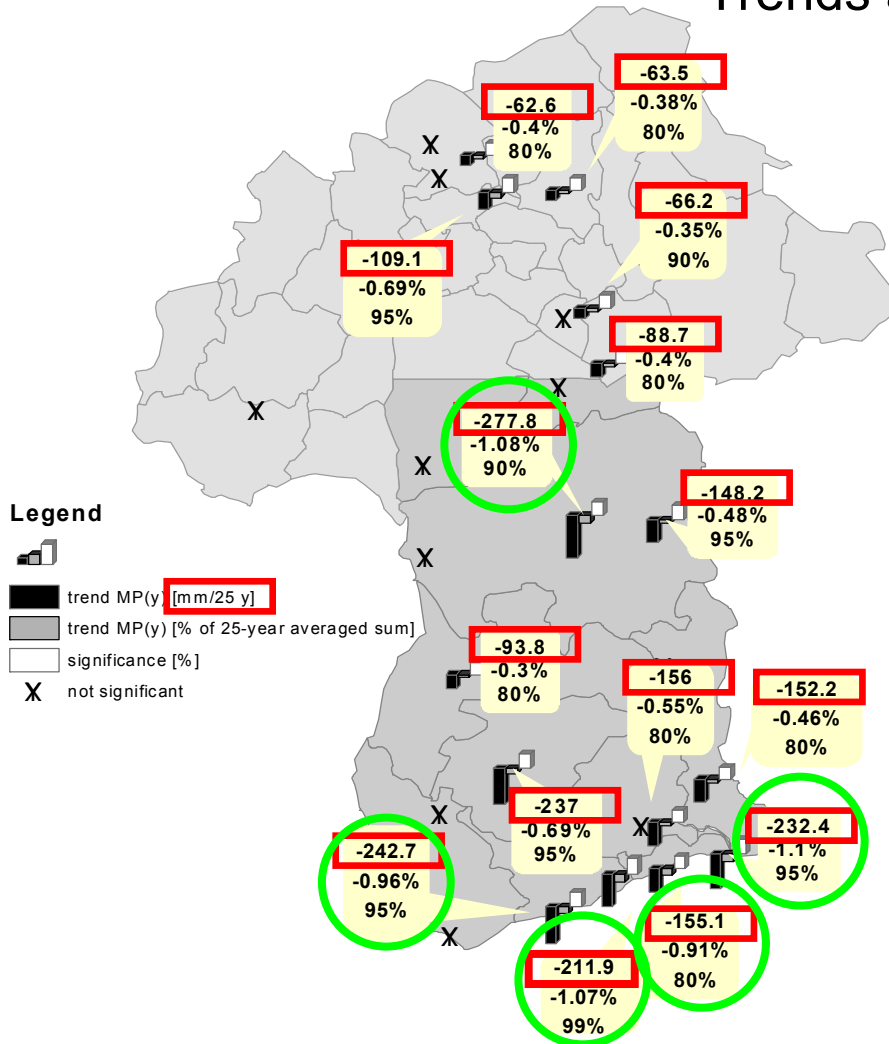
[Neumann et al., 2007]

### Mean Temperature



# Observed Climate Change (1961-2000)

## Trends annual rainfall amounts



**Significant decrease of annual rainfall amount**

**≈ 25% decrease annual rainfall amount within 25 years**



## Case study 1: Volta Basin (Ghana & Burkina Faso)

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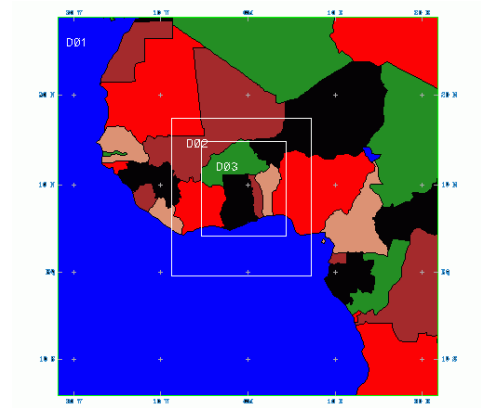
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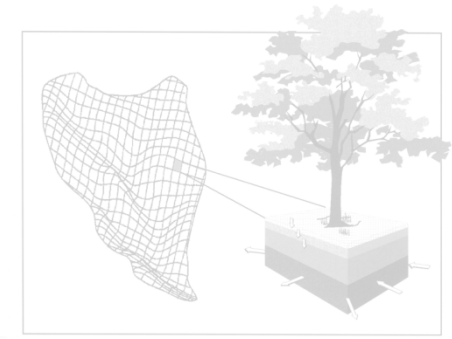
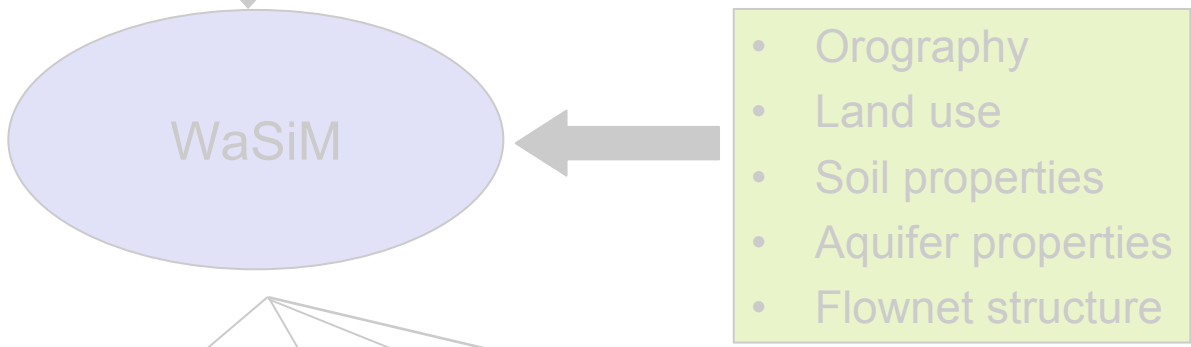
# Regional Climate Modeling (Dynamical Downscaling)

- Temperature
- Precipitation
- Wind
- Relative Humidity
- Radiation

ECHAM4 & MM5  
Scenario IS92a



2.8° → 9 km resolution

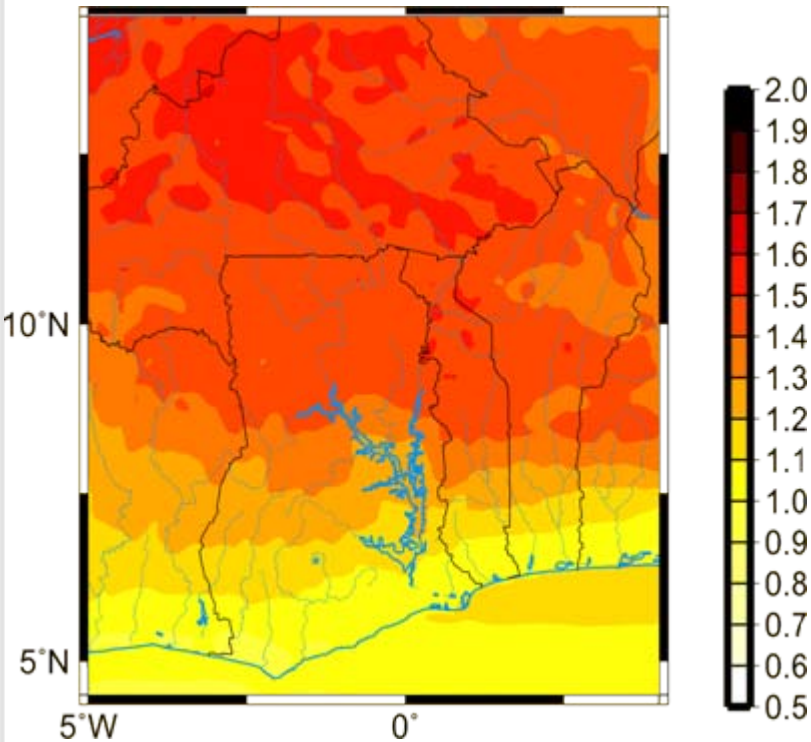


1 km resolution

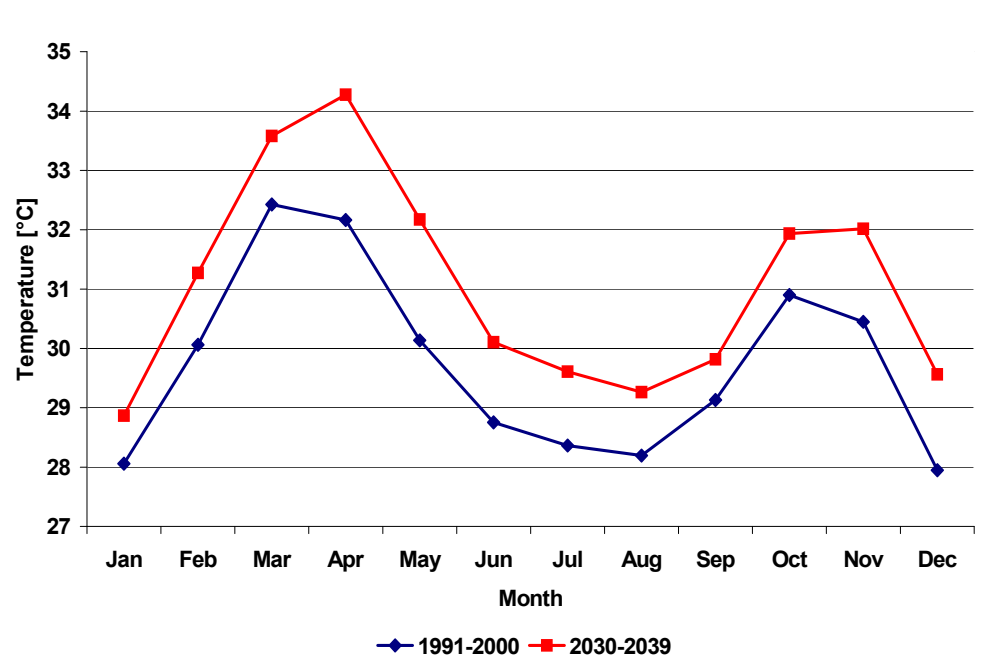
Evapotranspiration      Infiltration      Surface runoff      Groundwater flow

# Regional Climate Modeling

## Temperature Change till 2039



Mean annual temperature change [%]

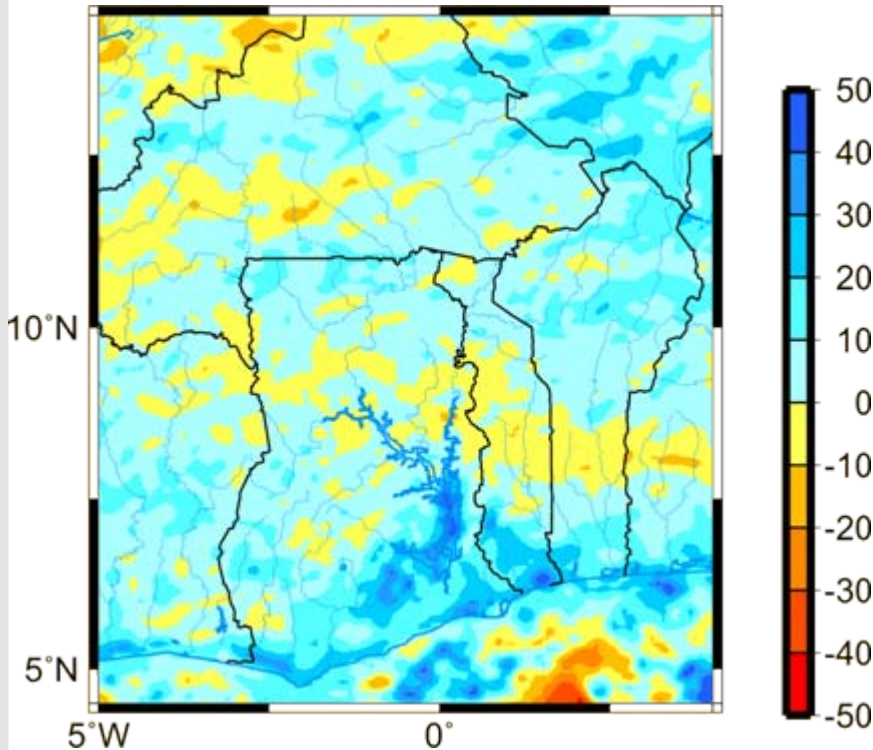


Mean monthly temperature [°C]  
(2030-2039 vs. 1991-2000)

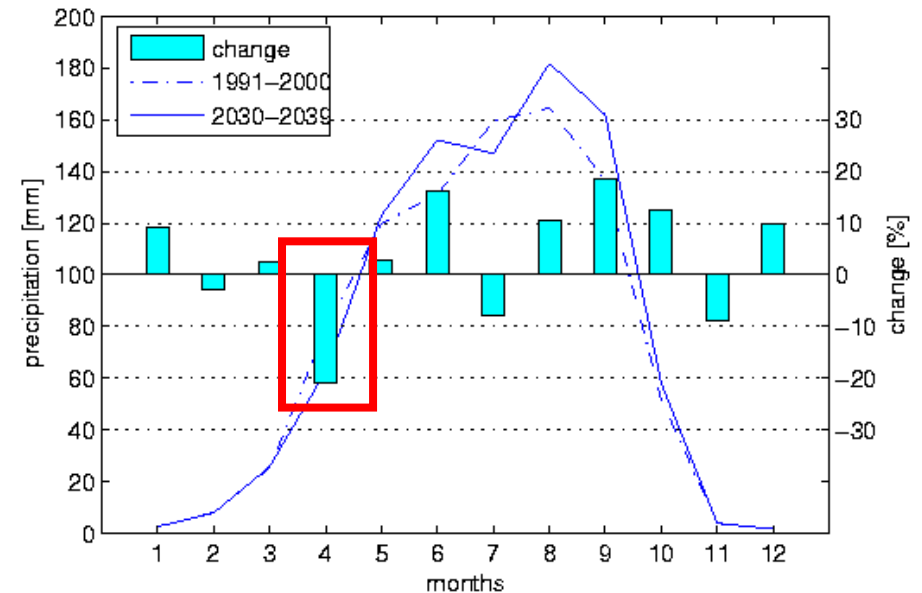
# Regional Climate Modeling

## Precipitation Change till 2039

### Significant decreases in April



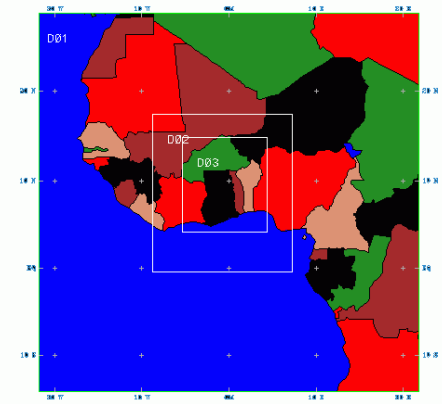
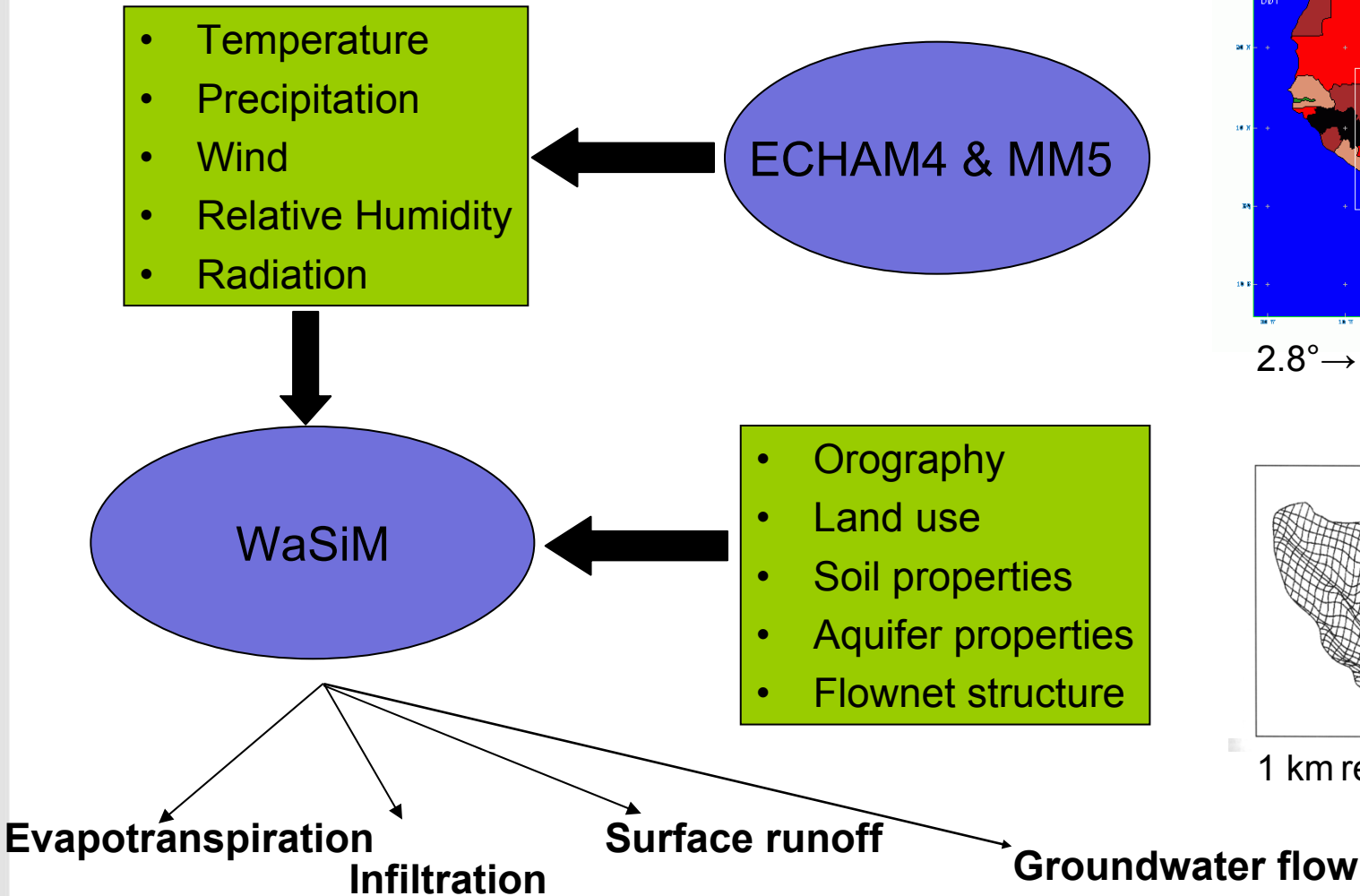
Mean annual precipitation change [%]



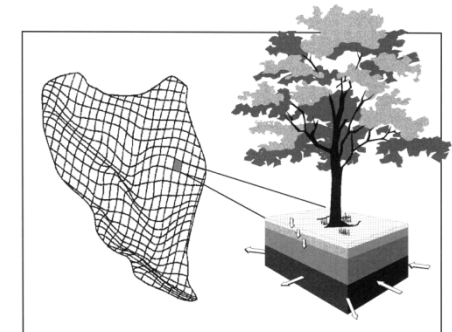
Monthly mean precipitation [mm] and change [%] (2030-2039 vs. 1991-2000)

# Regional Hydrological Modeling

## Joint Regional Climate-Hydrology Simulations



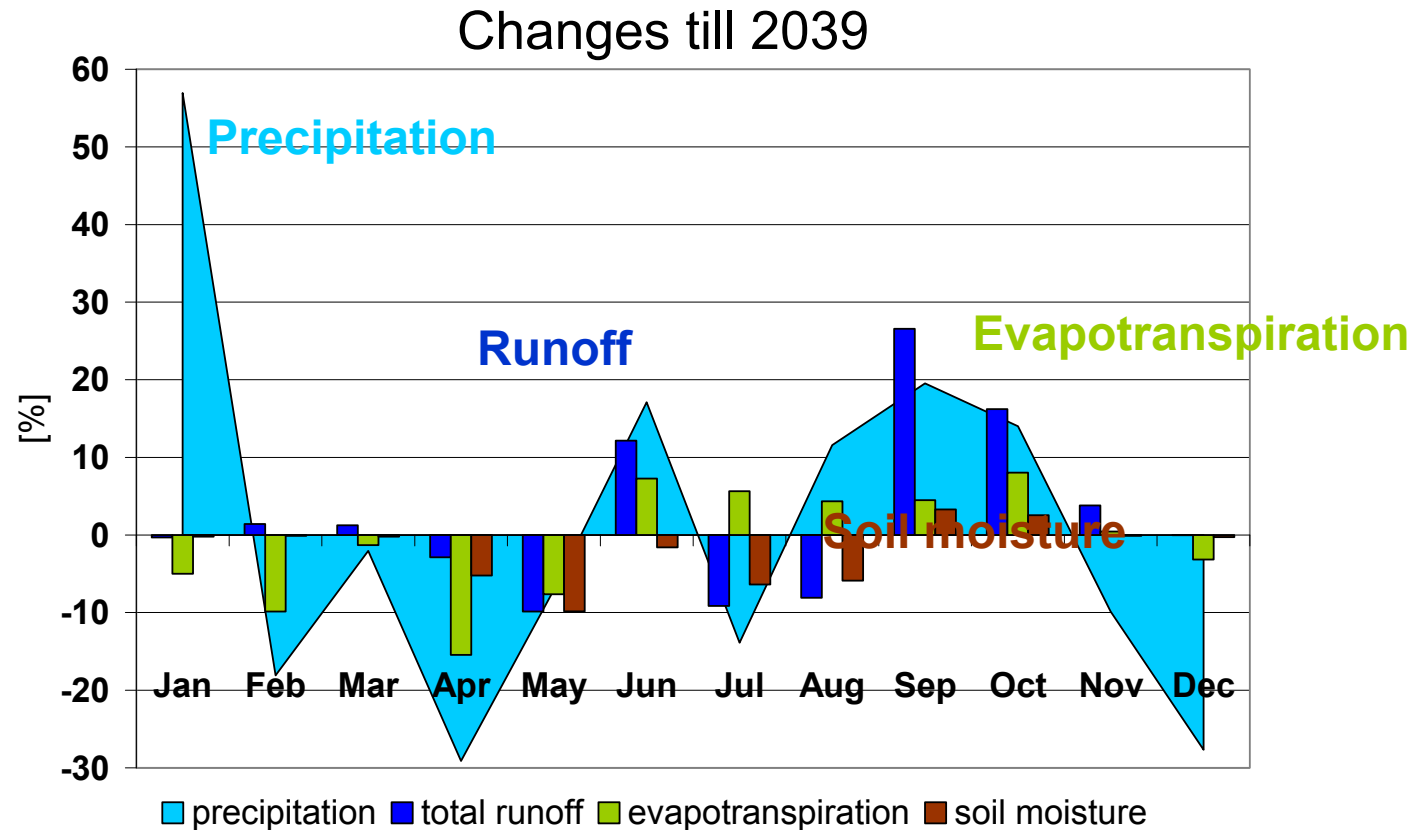
2.8° → 9 km resolution



1 km resolution

# Regional Hydrological Modeling

## Impact Climate Change on Water Balance



## Case study 1: Volta Basin (Ghana & Burkina Faso)

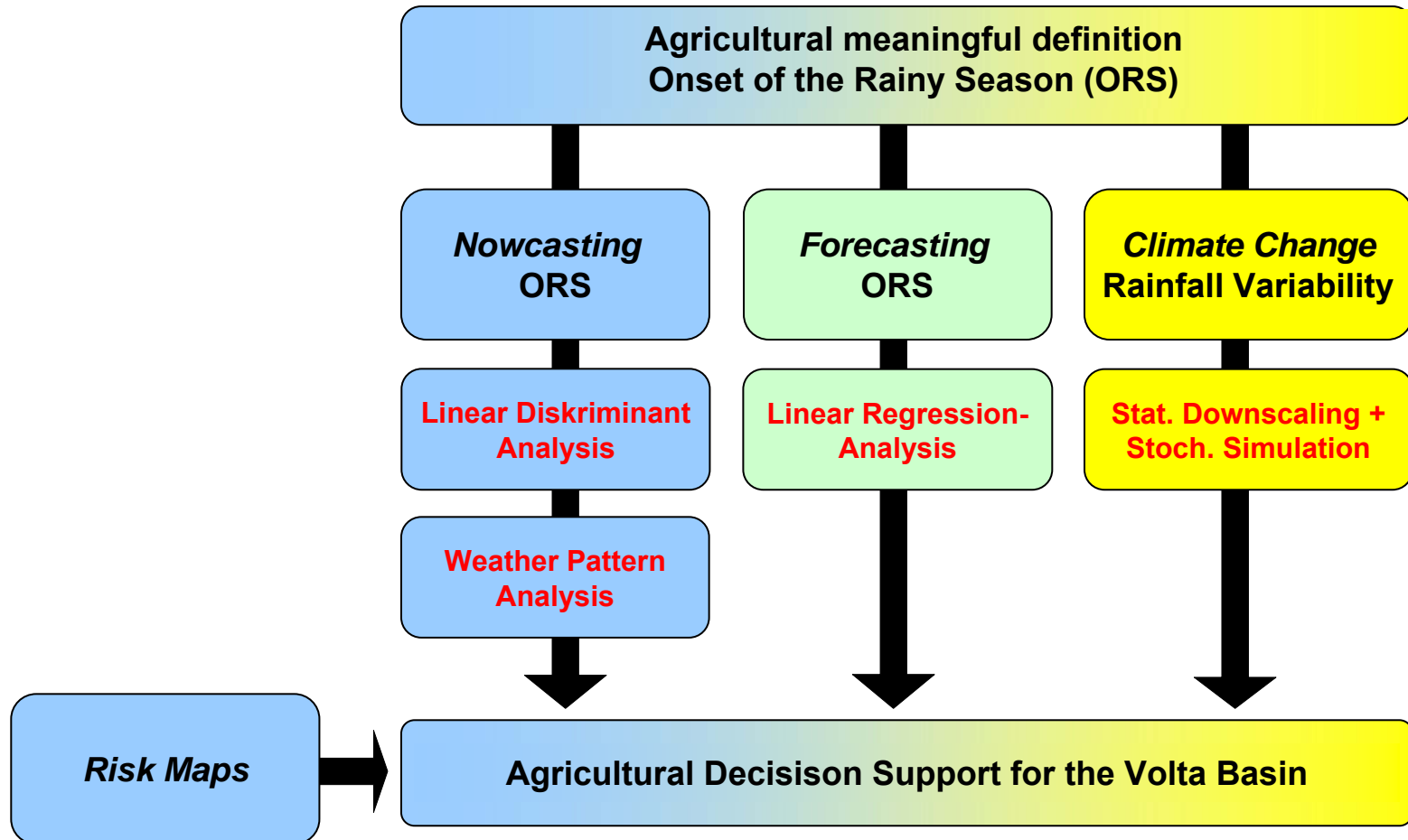
- Observed climate change
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## Case study 2: Cameroon

- Impact Climate Change on food production

## Conclusions

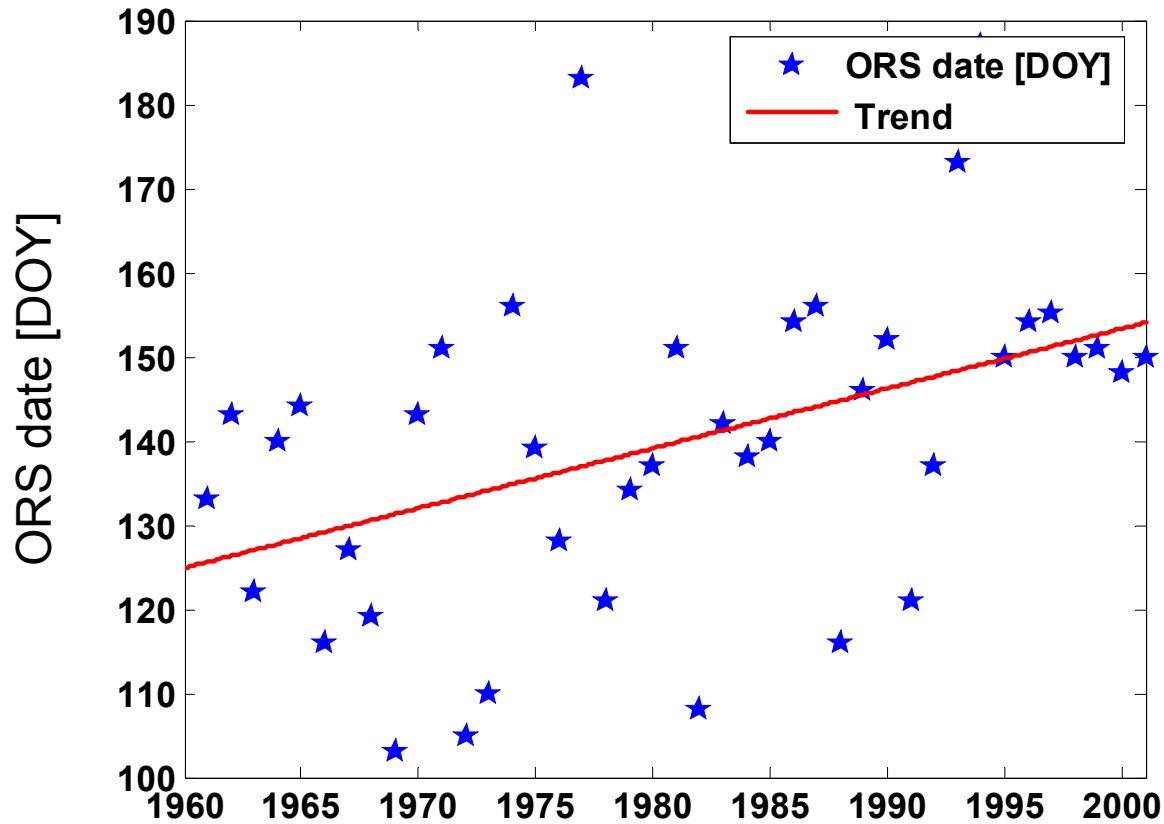
# Agricultural Decision Support System DSS



[Laux et al., 2007, 2008 & 2009]

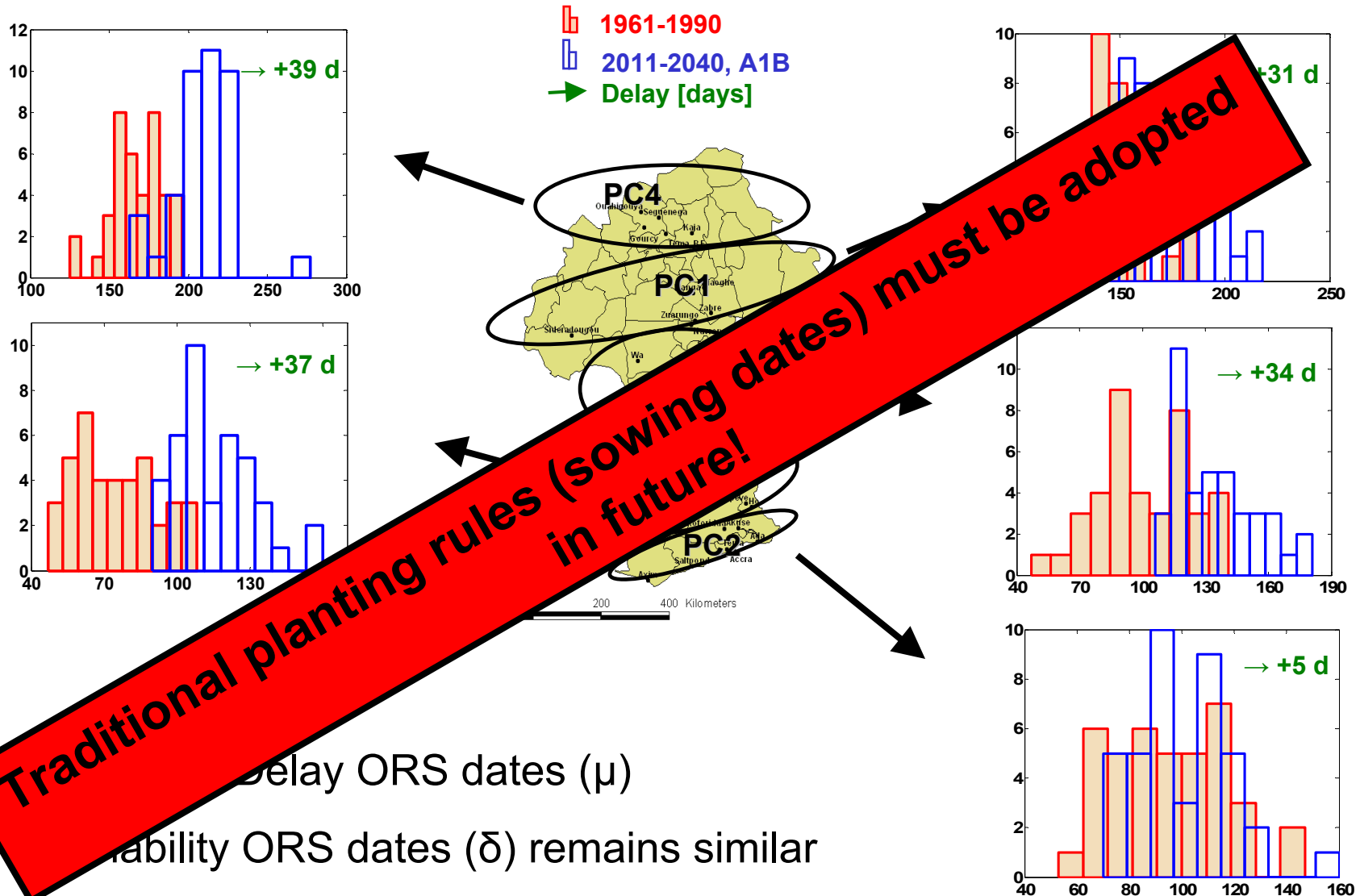


# Climate Change and Onset of the Rainy Season



→ Significant delay of the ORS up to 30 days for 1961-2001

# Onset of the Rainy Season in future?



Delay ORS dates ( $\mu$ )

Stability ORS dates ( $\delta$ ) remains similar

## Case study 1: Volta Basin (Ghana & Burkina Faso)

- Observed climate change
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  - Impact Climate Change on agricultural sector

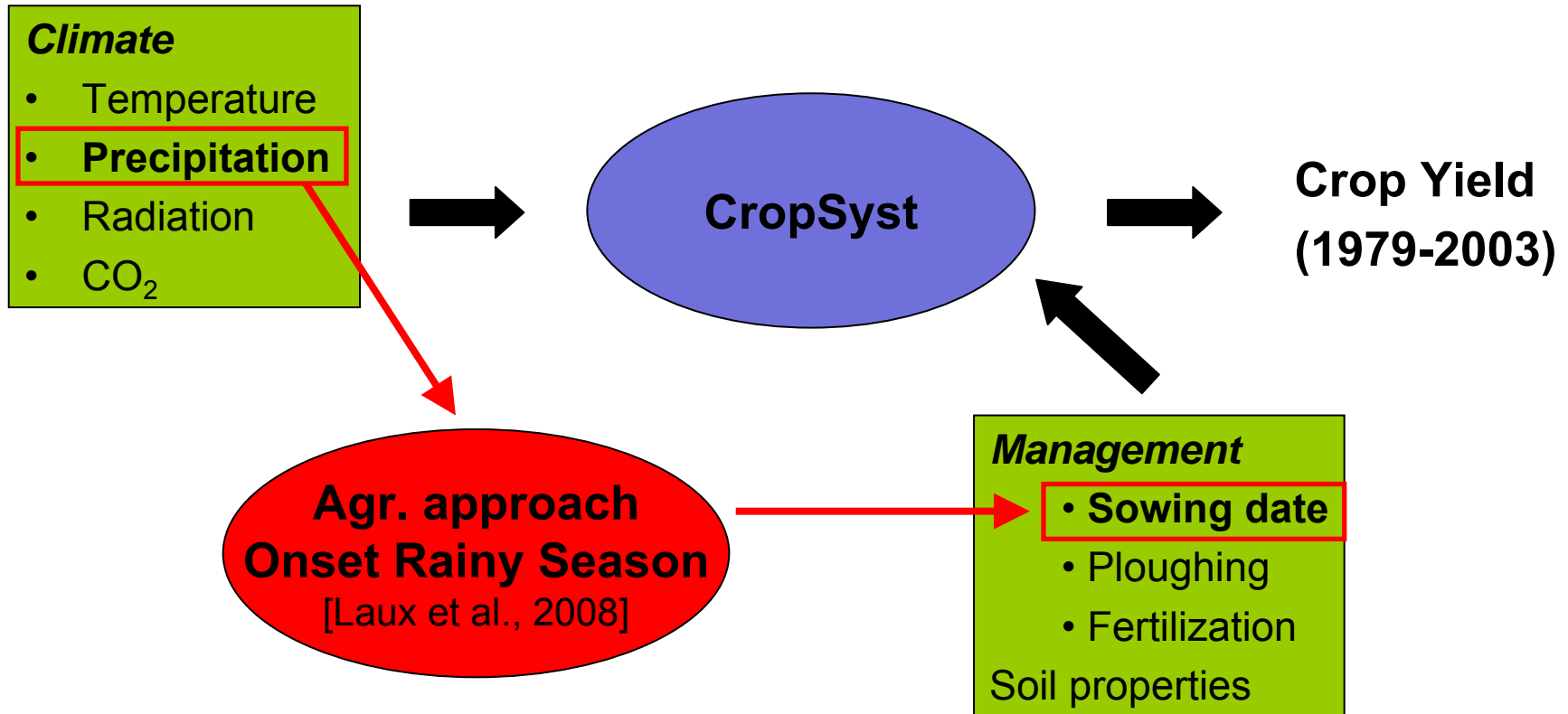
## Case study 2: Cameroon

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## Conclusions

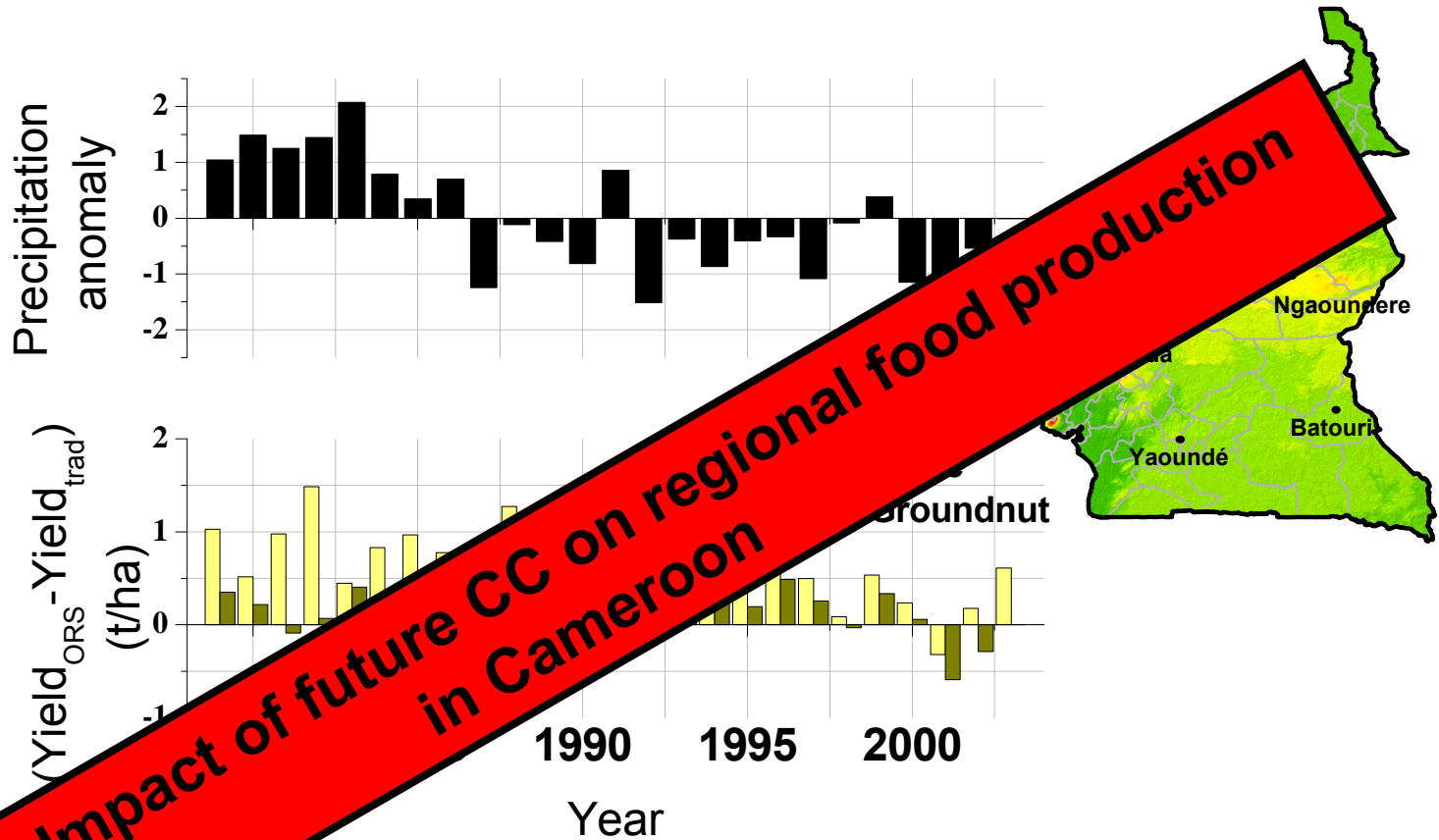
# Impact Sowing Date on Crop Yield

Joint Climate Crop Modelling (only useful for rainfed agriculture)



“optimal sowing date”

# Approach ORS vs. Traditional Sowing Rules



**In work: Impact of future CC on regional food production in Cameroon**

(1979-2003) increased up to 20% using ORS approach

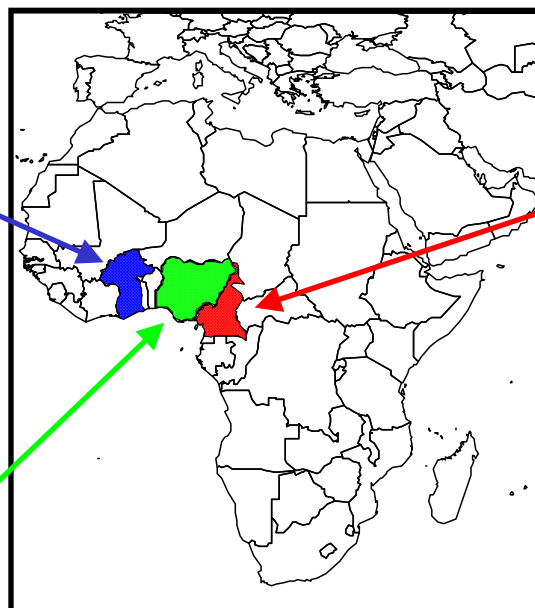
# Some conclusions

- Spatially distributed **change of precipitation** (between -20 and +50%) in the Volta Basin
  - Increase in the rainy season
  - Decrease at the onset of the rainy season
  - Significant delay of ORS expected in future
- **Agricultural DSS** could significantly increase crop yield (food security) in a cost-effective way
- Spatially distributed climate information **useful for different sectors** e.g. health sector

# Challenges and opportunities for a German-Nigerian collaboration

**Development** Agro-  
Hydro-Meteorological  
Decision Support System  
for **Ghana & Burkina Faso**

Status: finalized



**Evaluation** of  
methods for  
**Cameroon**

Status: ongoing

**Application** for **Nigeria**:  
German-Nigerian  
cooperation

Status: wanted?

# Further Information

Grote, R., Lehmann, E., Brümmer, C., Brüggemann, N., Szarzynski, J., Kunstmann, H. (2008) Modeling and observation of biosphere-atmosphere interactions in natural savannah and agriculture in Burkina Faso - West Africa, *Physics and Chemistry of the Earth*, accepted for publication

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Kunstmann, H., Jung, G., Wagner, S., Clotey, H. (2007) Integration of atmospheric sciences and hydrology for the development of decision support systems in sustainable water management, *Physics and Chemistry of the Earth*, doi:10.1016/j.pce.2007.04.010

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Jung, G., Kunstmann H. (2007): Modelling regional climate change and the impact on surface and sub-surface hydrology in the Volta Basin (West Africa). *IAHS publication 313, Quantification and reduction of predictive uncertainty for sustainable water resources management*, pp. 150-157

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Kunstmann, H., Jung, G. (2003) Investigation of feedback mechanisms between soil moisture, land use and precipitation in West Africa, *IAHS publication 280: Water Resources Systems – Water Availability and Global Change*, pp. 149-159.

Laux, P., Wagner, S. Wagner, A., Jacobeit, J., Bárdossy A., Kunstmann, H. (2009): Modelling daily precipitation features in the Volta Basin in West Africa; *Int. Journal of Climatology; International Journal of Climatology*, DOI: 10.1002/joc.1852.

Thank you

for your attention!

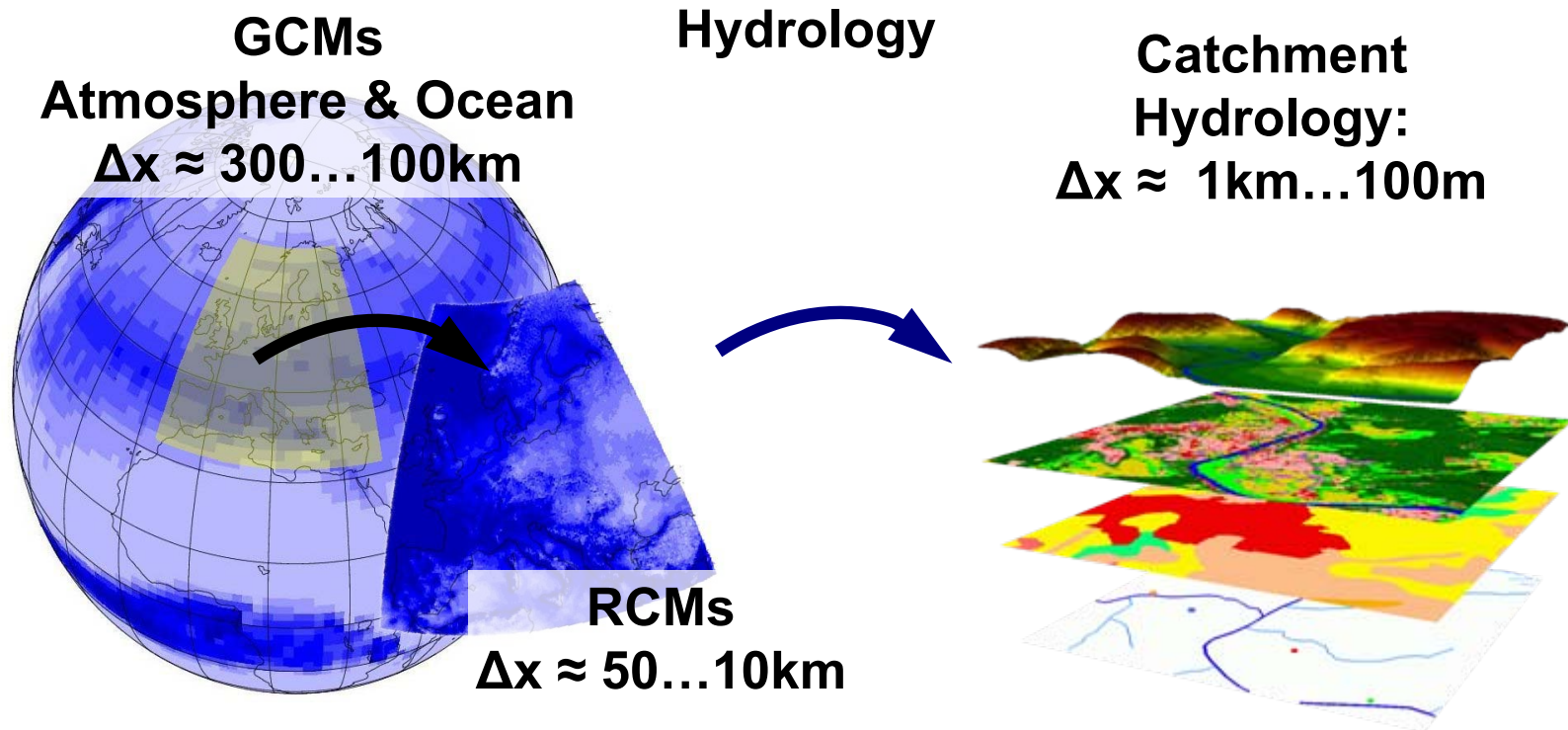


# What can be done to help farmers?

- **Evaluation & Improvement of existing tools (further projects)**
- **Capacity building at a very early stage of collaboration**
- **Reading the rains: intra-annual time scale**
- **Spreading the risk (alternatives)**
  - Irrigation strategies
  - Drought resistant species
  - DSS for rainfed agriculture ...



# Regional Climate Modelling: Downscaling



Dynamic downscaling by RCMs

# Regional Climate Modeling

**Momentum conservation**

$$\frac{\partial \vec{v}}{\partial t} + (\vec{v} \cdot \nabla) \vec{v} = -f \vec{k} \times \vec{v} - \nabla \Phi - \frac{1}{\rho_a} \nabla p_a + \frac{\eta_a}{\rho_a} \nabla^2 \vec{v} + \frac{1}{\rho_a} (\nabla \cdot \rho_a \mathbf{K}_m \nabla) \vec{v}$$

**Energy conservation**

$$\frac{\partial \theta_v}{\partial t} + (\vec{v} \cdot \nabla) \theta_v = \frac{1}{\rho_a} (\nabla \cdot \rho_a \mathbf{K}_h \nabla) \theta_v + \frac{\theta_v}{c_{p,d} T_v} \sum_{n=1}^N \frac{dQ_n}{dt}$$

**Gas law**

$$p = \frac{nR^*T}{V}$$

**Air mass conservation**

$$\frac{\partial \rho_a}{\partial t} + \nabla \cdot (\vec{v} \rho_a) = 0$$

**Conservation water mass**

$$\begin{aligned} \frac{\partial q_v}{\partial t} + (\vec{v} \cdot \nabla) q_v &= \frac{1}{\rho_a} (\nabla \rho_a \mathbf{K}_h \nabla) q_v + R_{evap} - R_{cond} - R_{iini} - R_{idep/sub} \\ \frac{\partial q_c}{\partial t} + (\vec{v} \cdot \nabla) q_c &= \frac{1}{\rho_a} (\nabla \rho_a \mathbf{K}_h \nabla) q_c + R_{cond} + R_{iini} + R_{idep/sub} - R_{aconv} - R_{accr} \\ \frac{\partial q_r}{\partial t} + (\vec{v} \cdot \nabla) q_r &= \frac{1}{\rho_a} (\nabla \rho_a \mathbf{K}_h \nabla) q_r - R_{evap} + R_{aconv} + R_{accr} - \frac{\partial V_f \rho_a g q_r}{\partial z} \end{aligned}$$

**Energy conservation at land surface**

$$\begin{aligned} \rho_a c_p \frac{\partial T_s}{\partial t} &= SW_{net} + LW_{net} \\ &= (1 - \alpha) SW \downarrow + LW \downarrow - \epsilon \sigma_B T_{surf}^4 \end{aligned}$$

**Soil temperature diffusion**

$$\rho_s c_s \frac{\partial T_s}{\partial t} = \frac{\partial}{\partial z} \left[ K_t(\Theta) \frac{\partial T_s}{\partial z} \right]$$

**Precipitation physics**

$$R_{evap} (rain) = \frac{2\pi N_0 r (S_w - 1)}{A_r + B_r} \left[ \frac{0.78}{\Lambda_r^2} + 0.32 \left( \frac{a_r \rho}{\eta_a} \right)^{1/2} S_c^{1/3} \frac{\Gamma(5/2 + b_r/2)}{\Lambda_r^{5/2 + b_r/2}} \right]$$

**Soil water infiltration**

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z} \left[ D(\Theta) \frac{\partial \theta}{\partial z} \right] + \frac{\partial k(\Theta)}{\partial z}$$

