The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

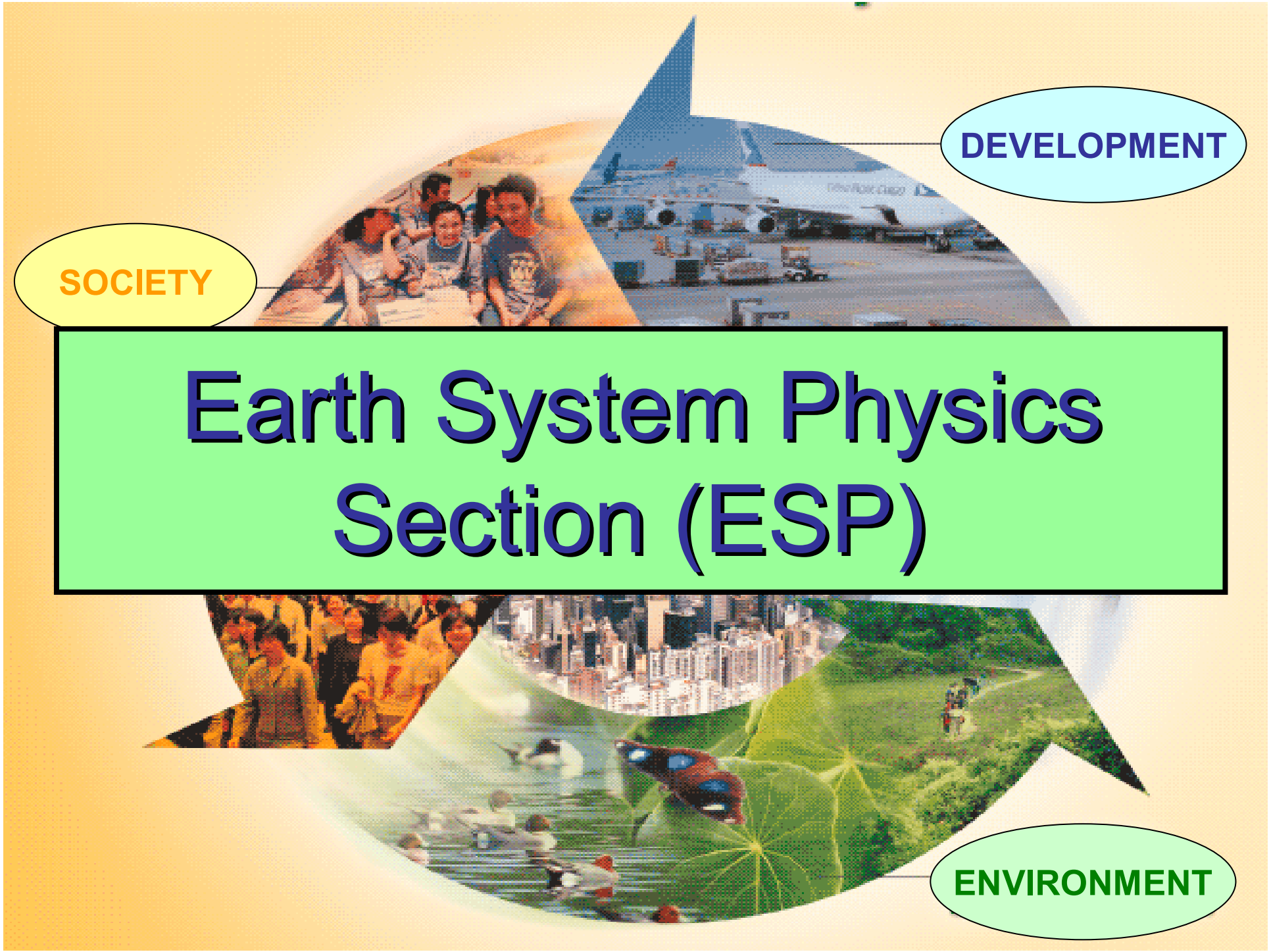
2242-6

Joint ICTP-IAEA Workshop on Uncovering Sustainable Development CLEWS; Modelling Climate, Land-use, Energy and Water (CLEW) Interactions

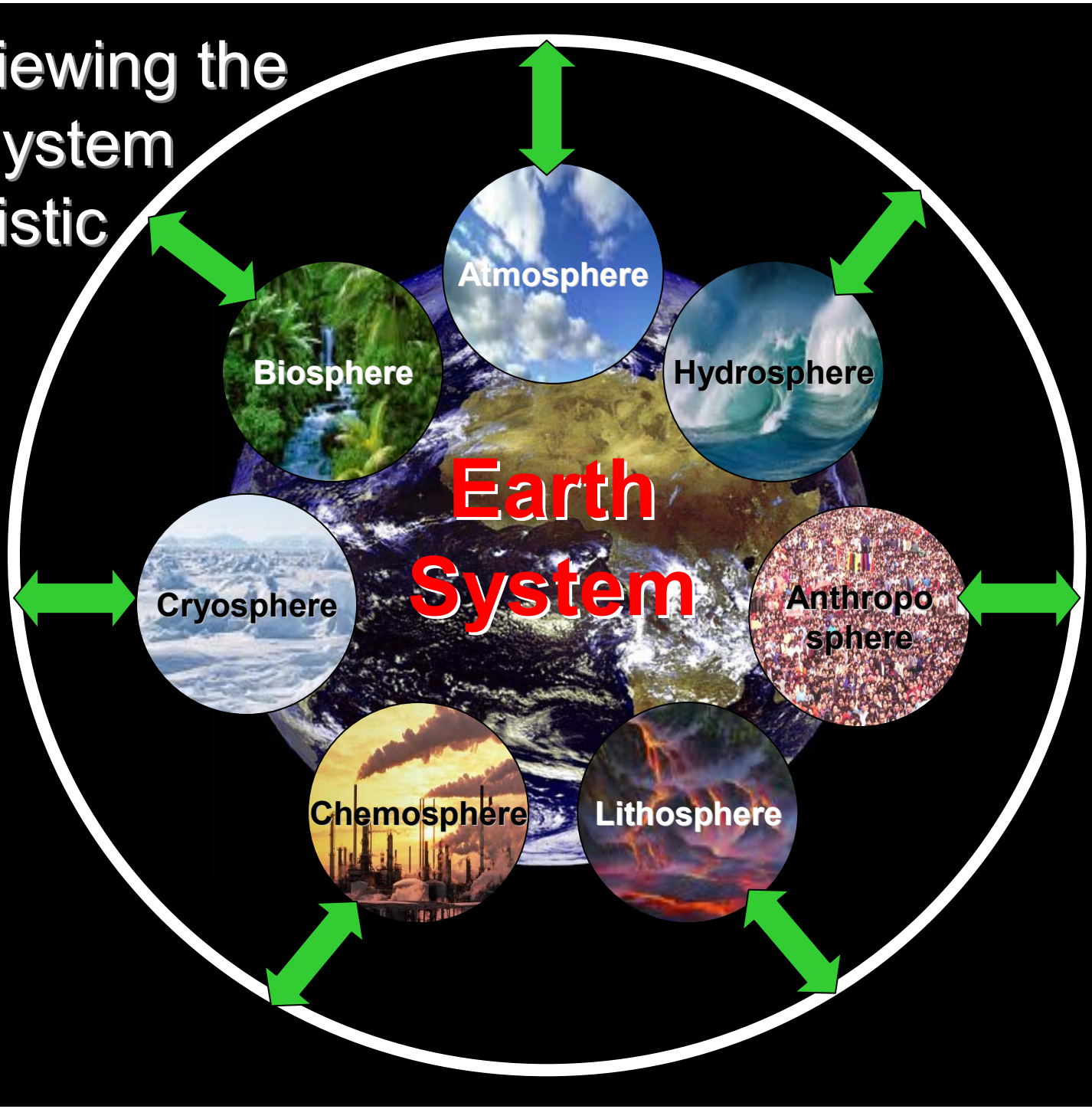
30 May - 3 June, 2011

Introduction to related activities in ICTP Earth System Physics Section (ESP)

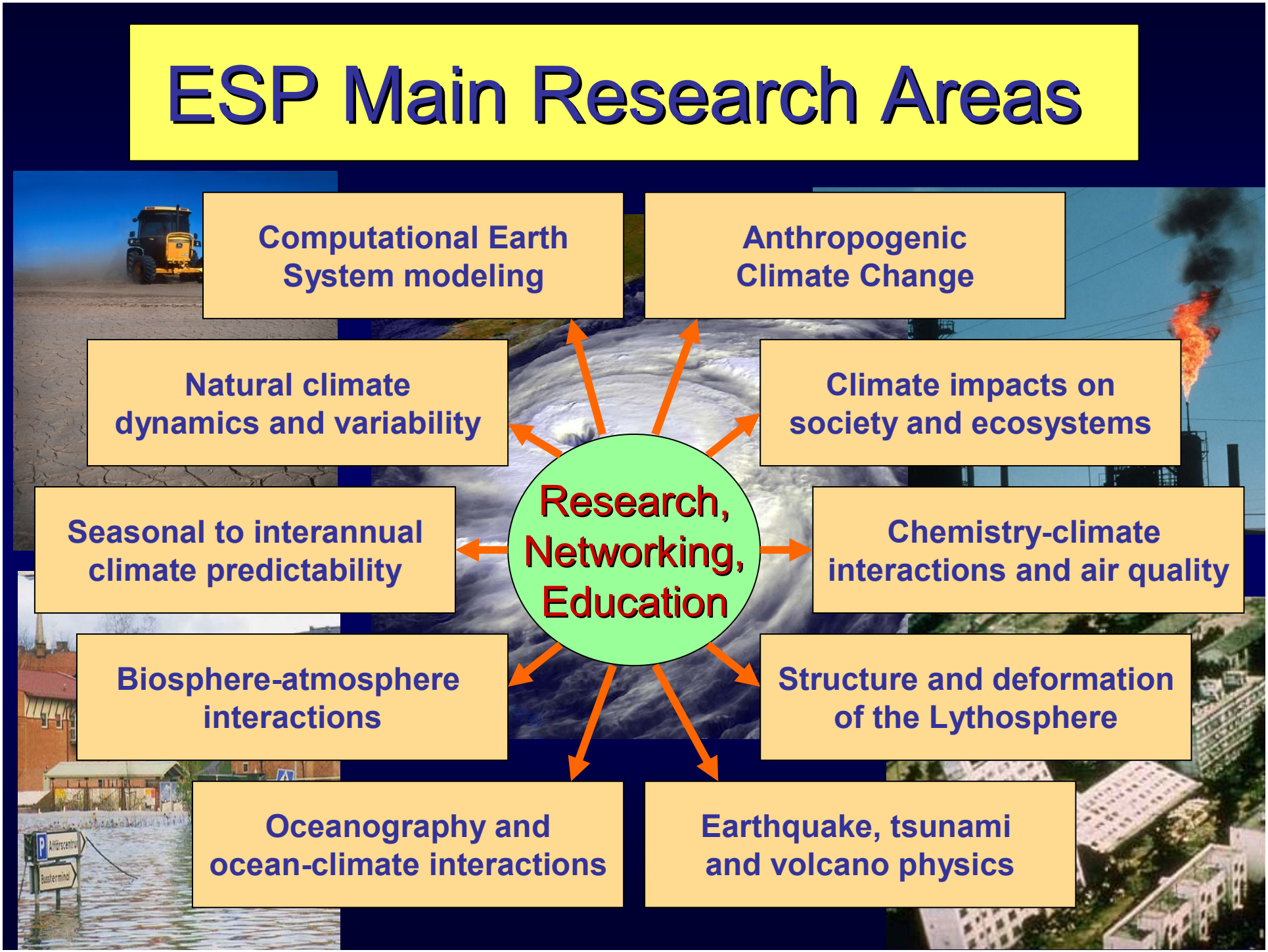
GIORGI Filippo
ICTP
the Abdus Salam International Centre for Theoretical Physics
Strada Costiera, n. 11
Trieste
Italy


DEVELOPMENT
SOCIETY
Earth System Physics Section (ESP)
ENVIRONMENT

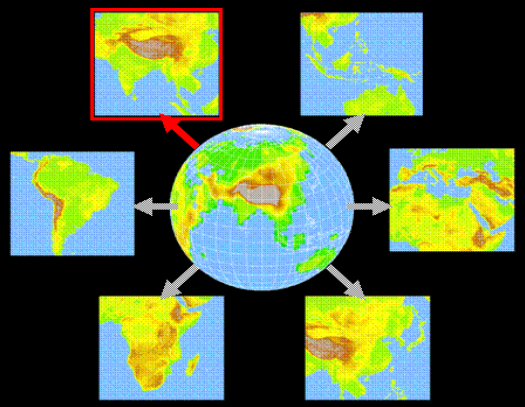
ESP: Viewing the Earth System in a holistic way



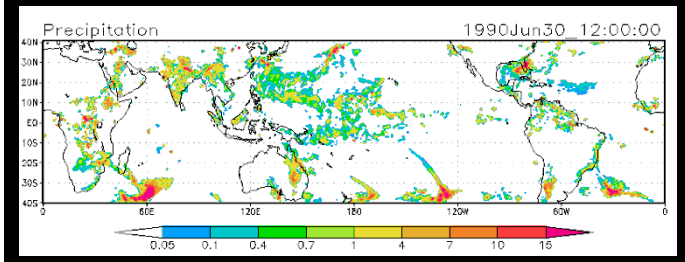
ESP Main Research Areas



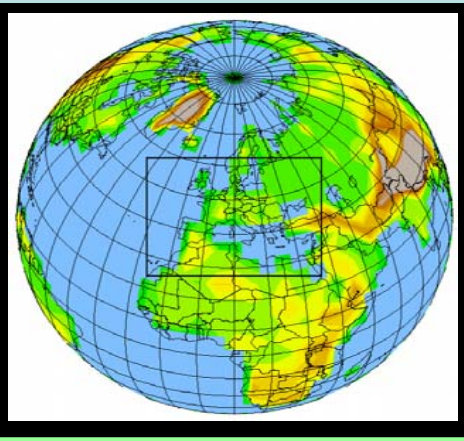
Computational Earth System modeling



Regional Earth System Modeling (RegCM)



Global Earth System Modeling (ECHAM, SPEEDY)



RegCM Tropical Band

Computing resources:
Local cluster (ARGO)
SISSA cluster
CINECA
ECMWF

Developing flexible and economical tools for developing country needs

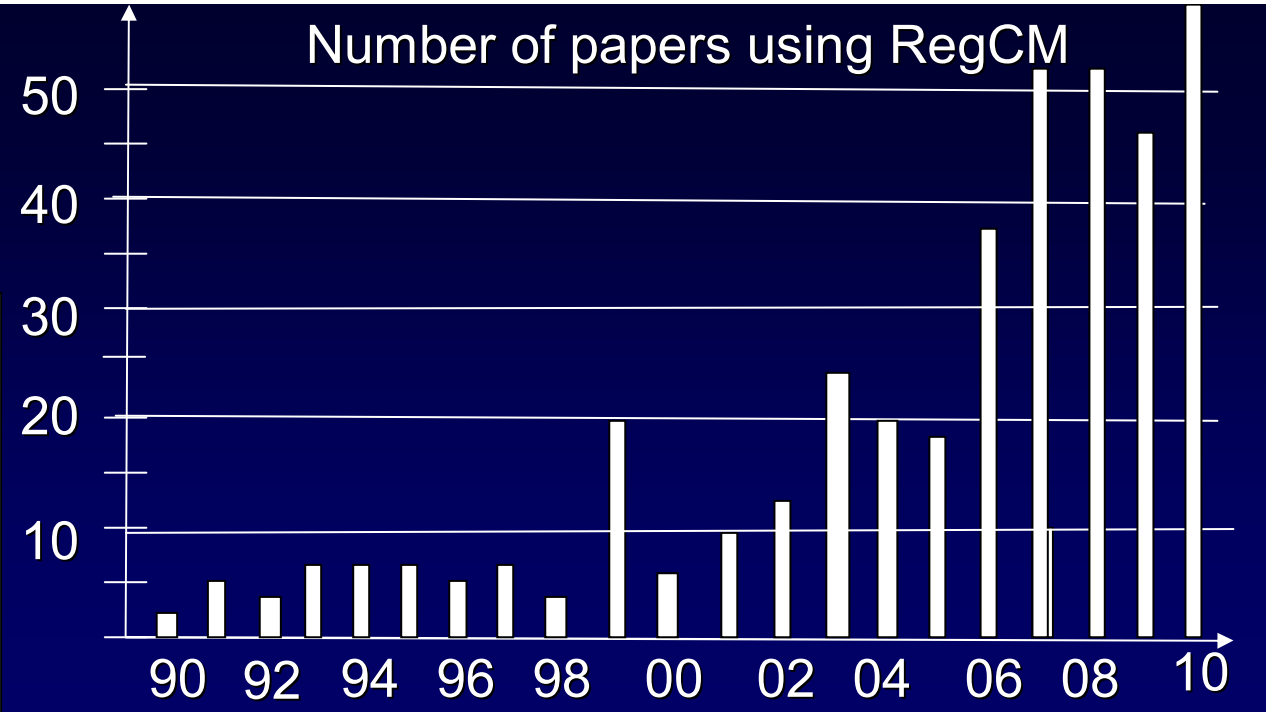
The RegCM System

Release of new version

RegCM4

CR Special issue

About 3000 downloads since June 2010



Countries where RegCM is used

RegCM training workshops:
ICTP, June 2010
Turunc, Turkey, August 2010
New Delhi, India, December 2010
Amman, Jordan, March 2011
ICTP, May 2011

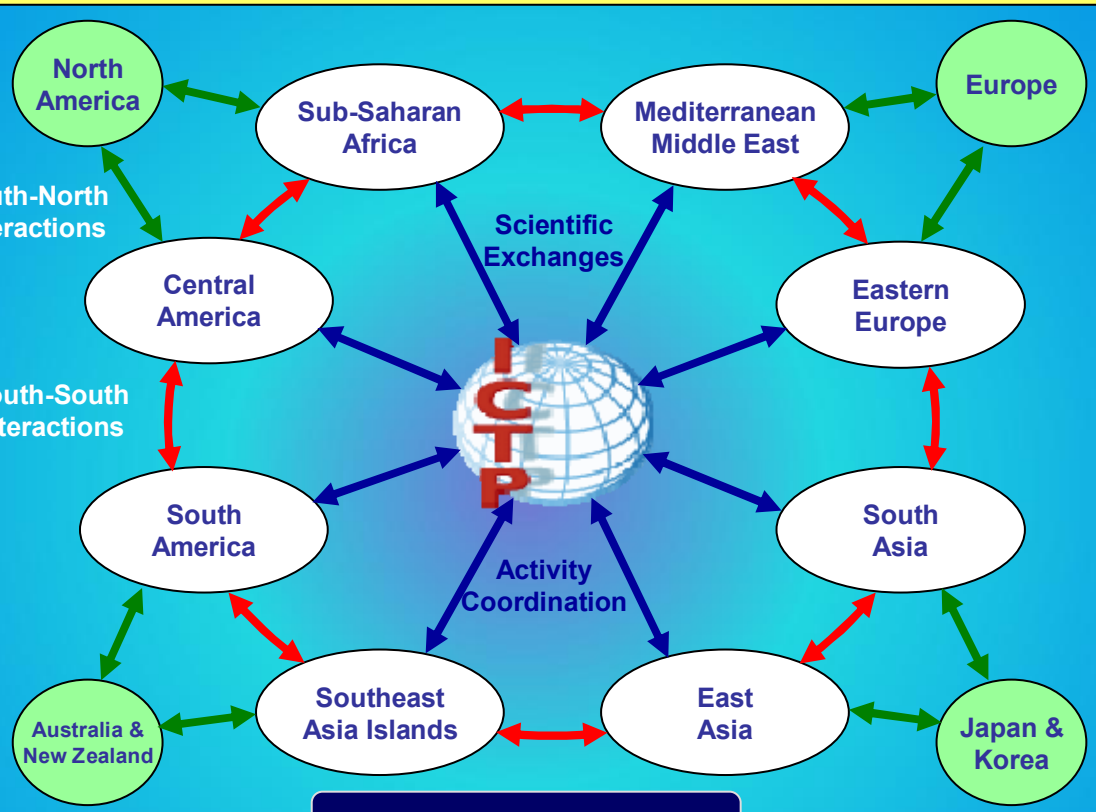
Strengthening of the model software development and user support team

ESP Networking: The Regional Climate research NETwork, RegCNET

Collaborative research projects

Use of ICTP model tools and datasets

Workshops at ICTP and on-site



E-mail list (over 750 p.)

Interactions with other international programs

Visitor program

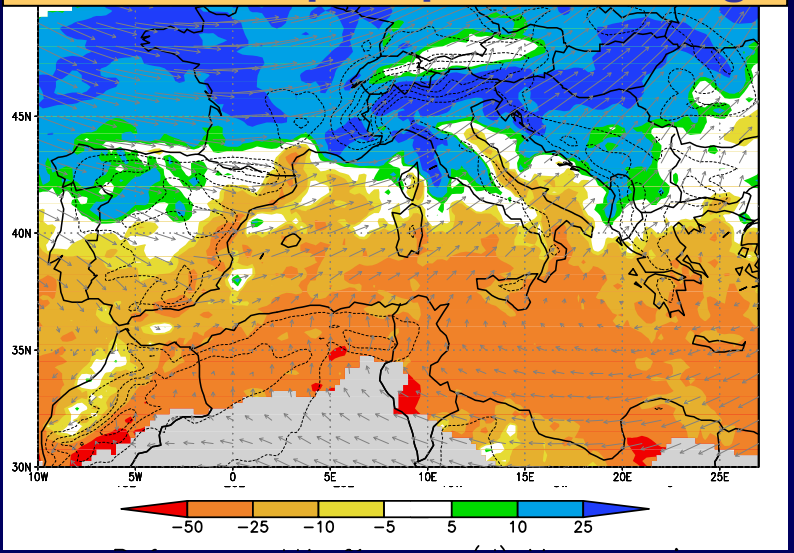
Regional Modeling

Weather Prediction | Seasonal Prediction | Climate Change

Storms | Flood | Drought | Water Resources | Energy | Agriculture | Landuse Change | Pollution | Health | Fisheries | Ecosystems

Anthropogenic Climate Change

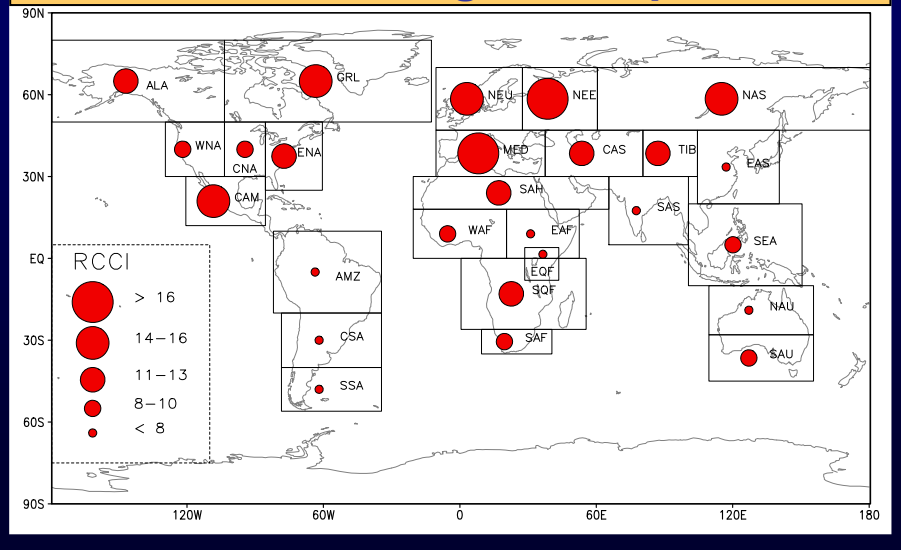
Mean winter precipitation change

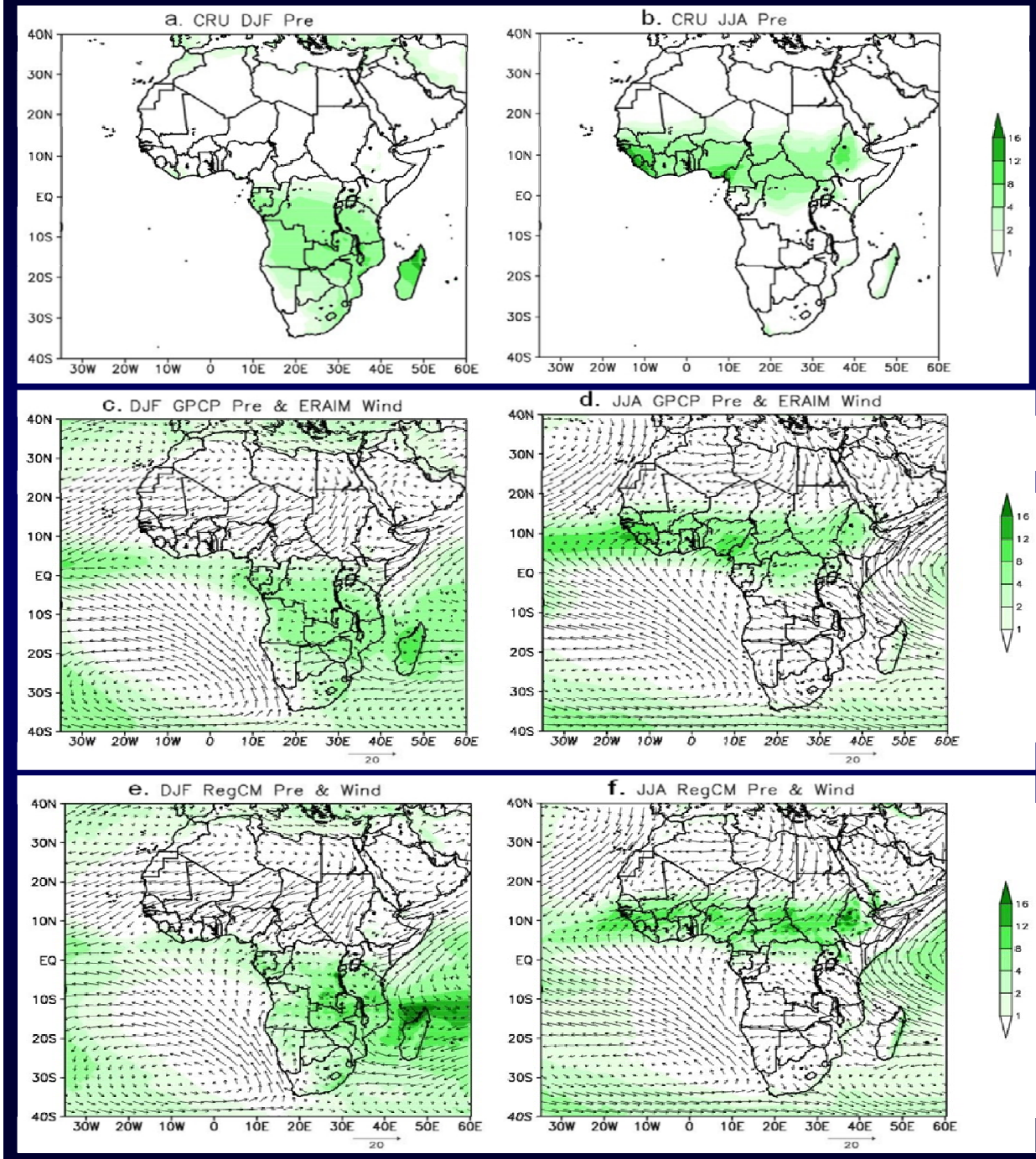


High resolution regional climate change simulations with the regional model RegCM

Uncertainty analysis and probabilistic climate change predictions based on output from ensembles of global model simulations

Climate change Hot-Spots



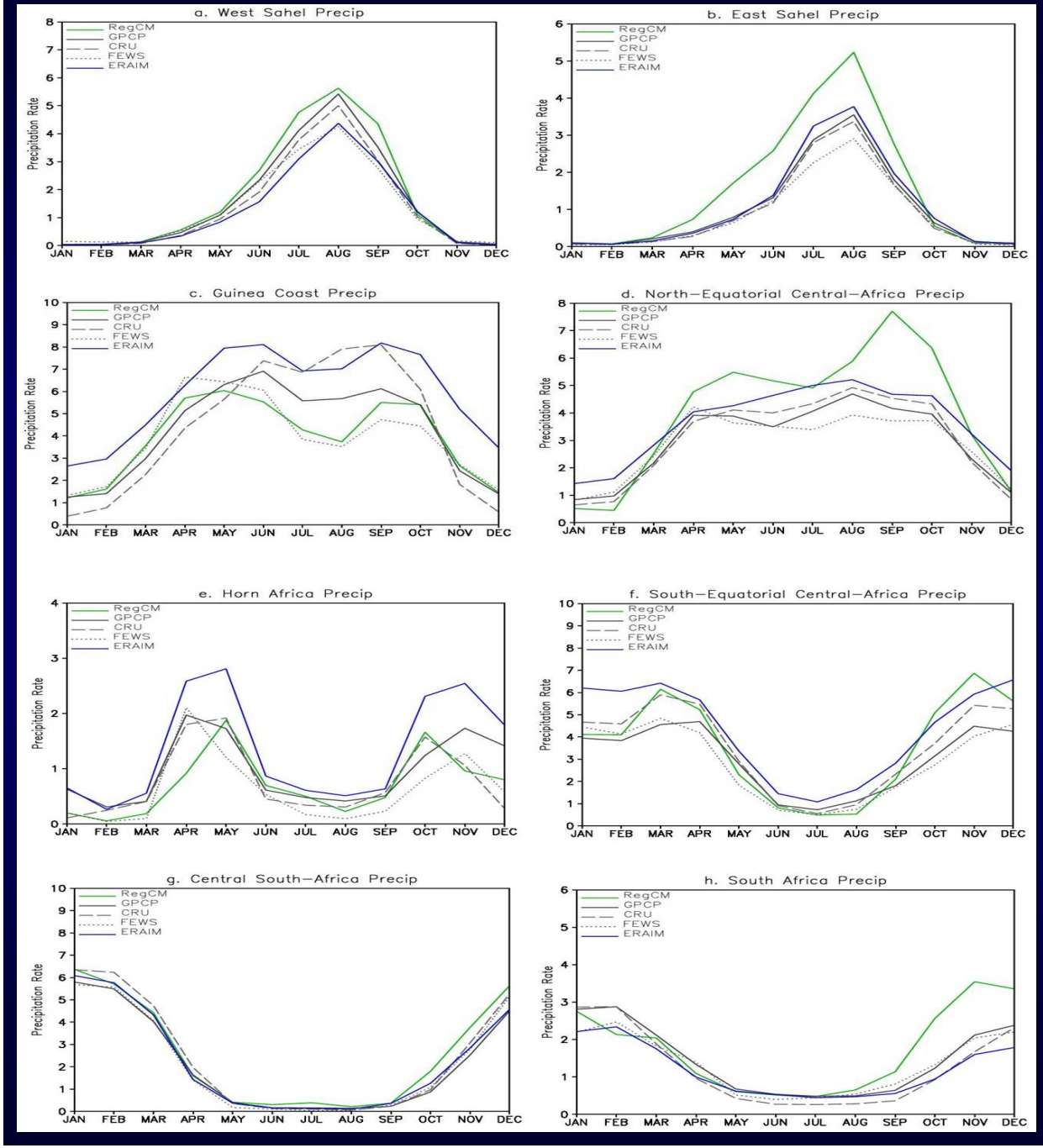


Simulation of mean precipitation for an all-Africa domain

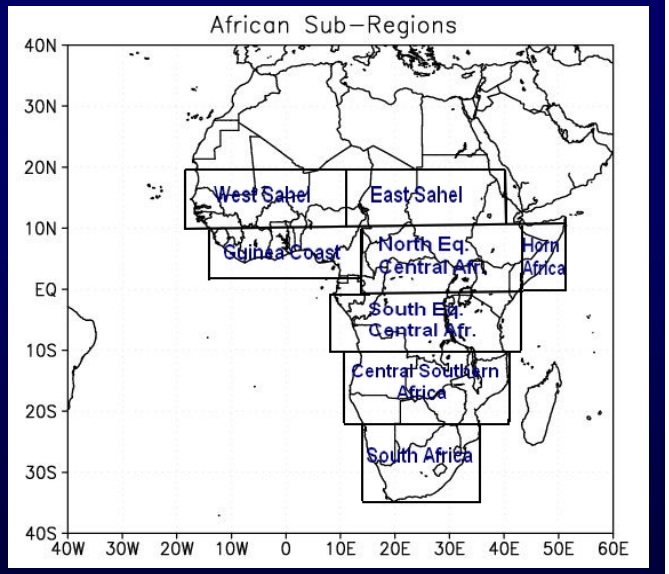
ERA-Interim LBC (1989-2005)

Sylla et al. 2009

Simulation of seasonal precipitation for an all-Africa domain



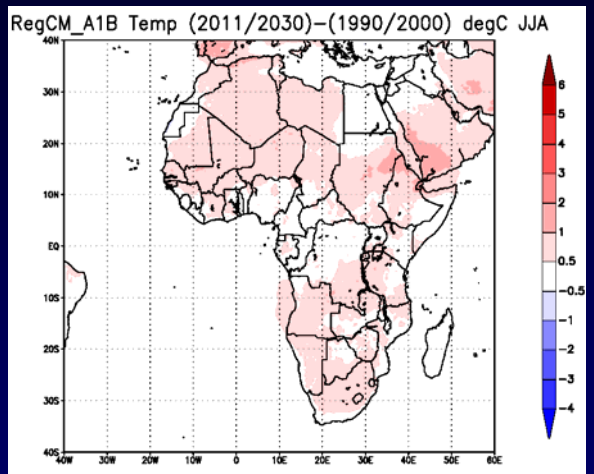
ERA-Interim LBC (1989-2007)

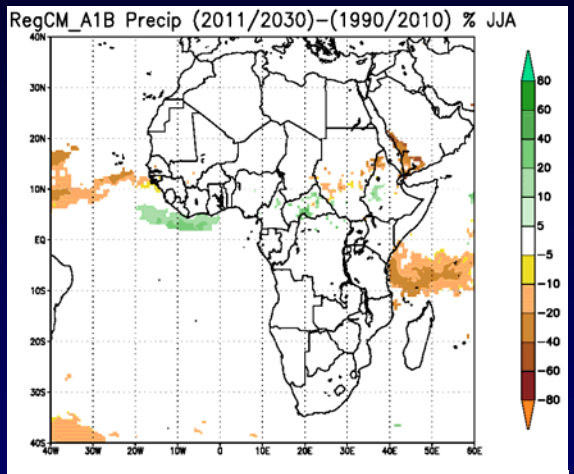


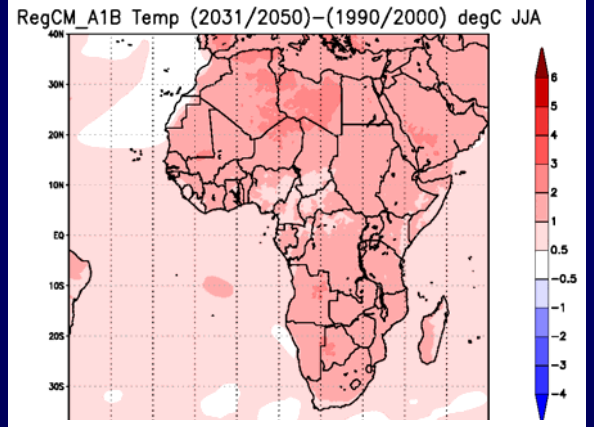
Sylla et al. 2009

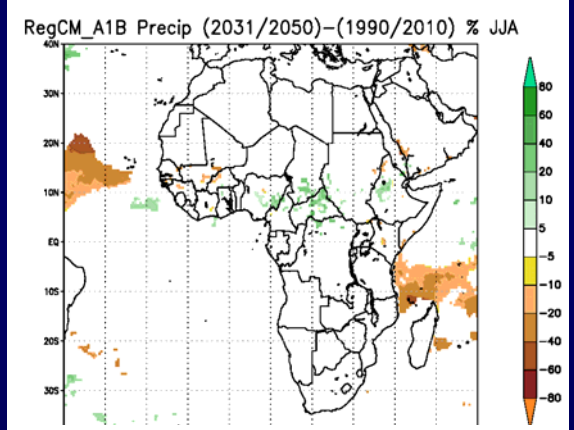
Temperature change

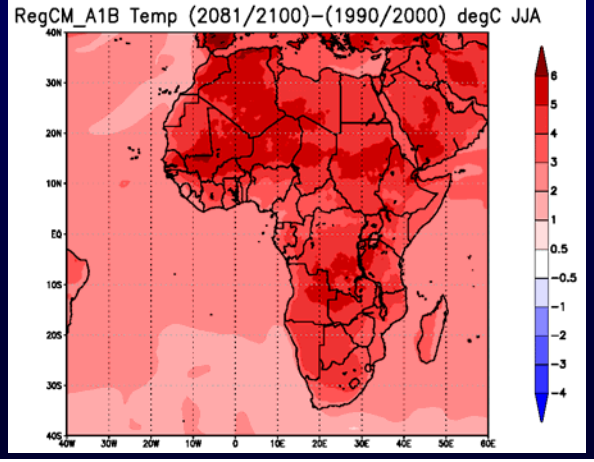
Precipitation change

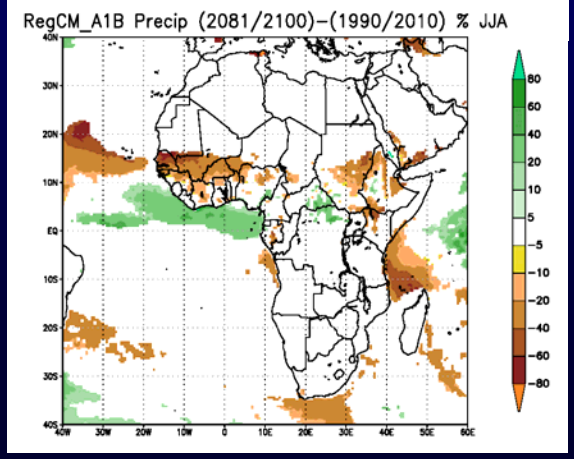












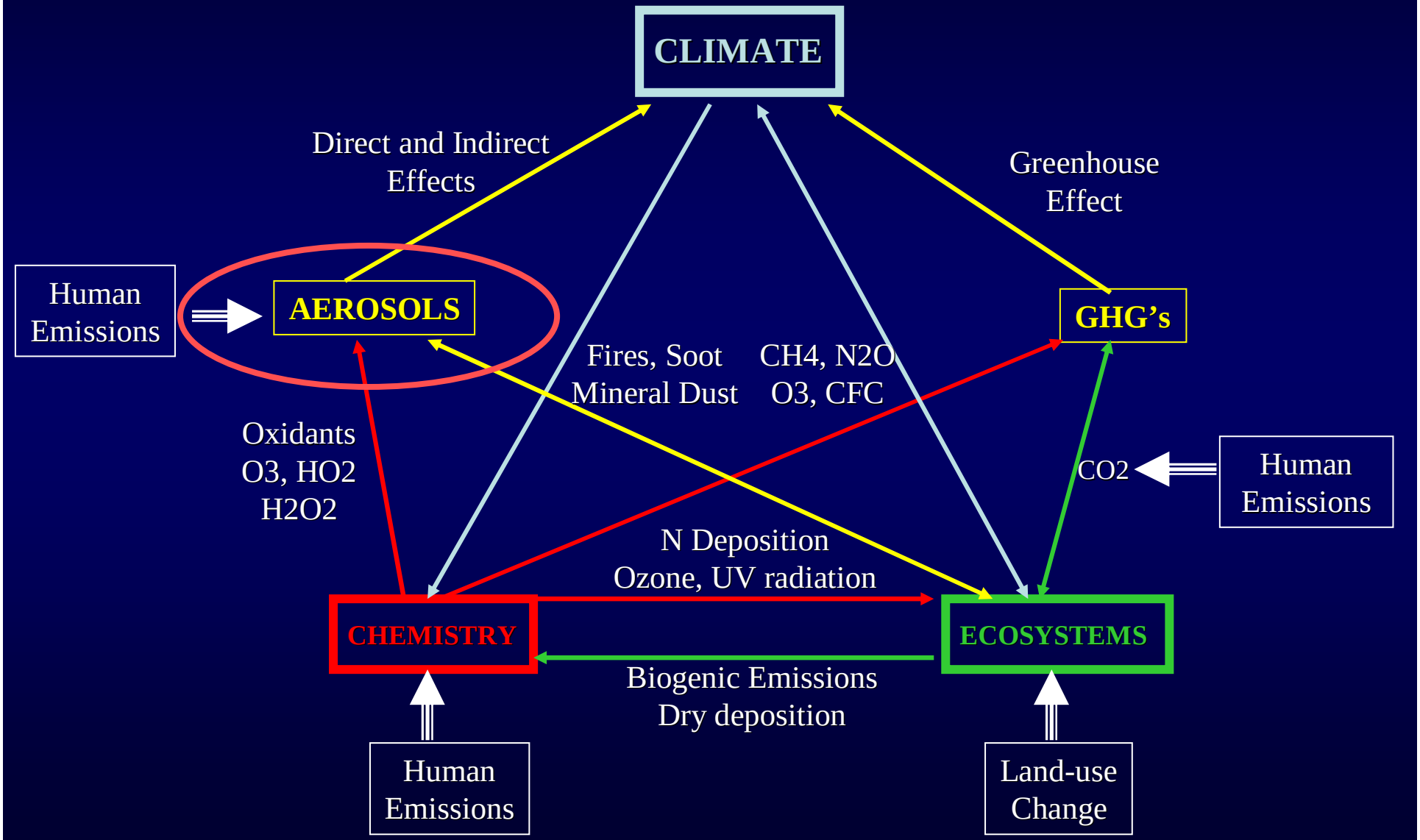
ECHAM-driven transient scenario simulation (A1B)

2011-2030

2031-2050

2081-2100

Climate-Chemistry Interactions



Aerosol radiative effects

Direct effects

Absorption and reflection of solar and IR radiation

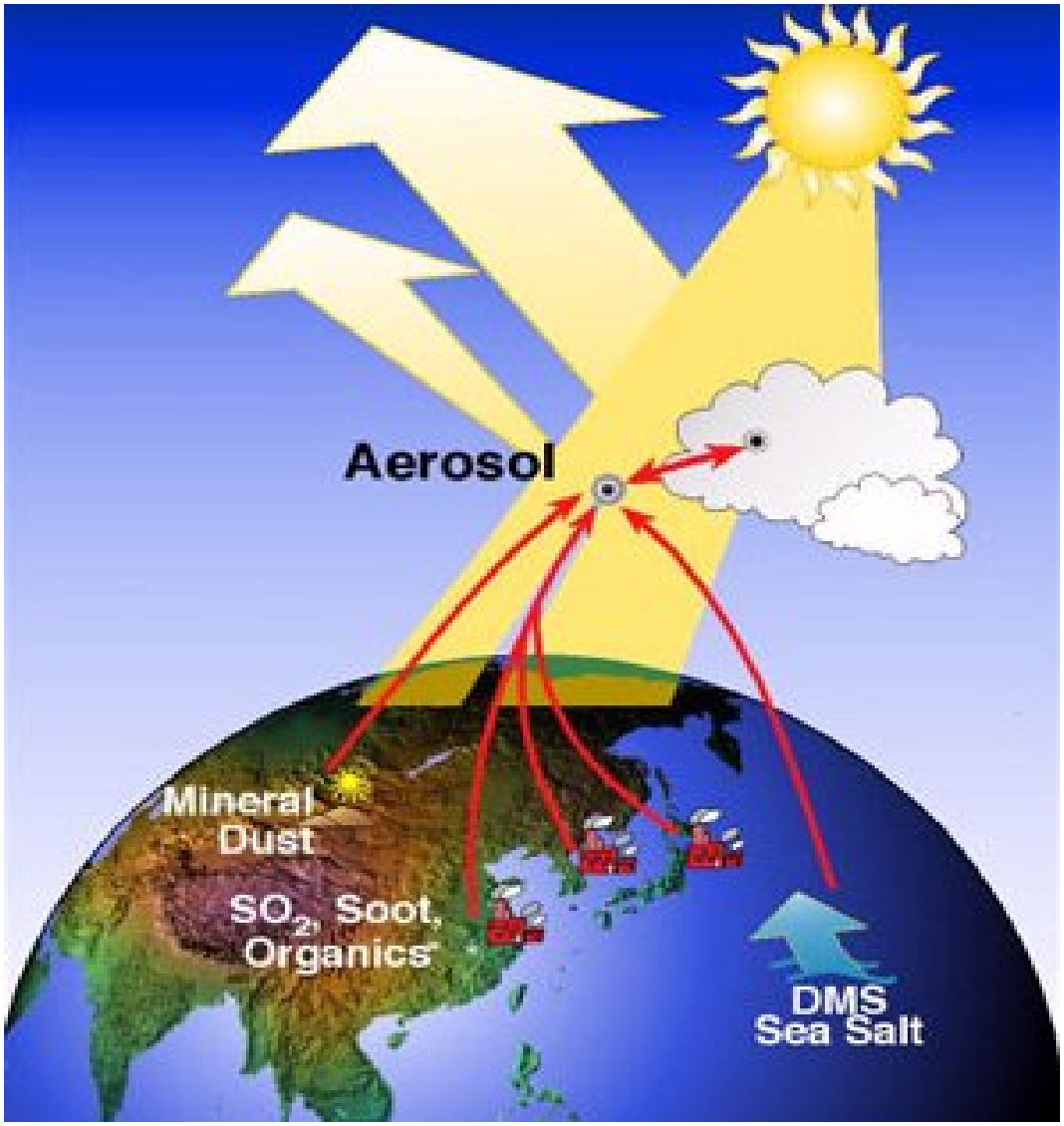
Indirect effects

Modification of cloud properties (reflectivity and lifetime)

Semi-direct effects

Modification of the thermal structure of the atmosphere

Aerosols with the longest atmospheric lifetime (d=0.1-1 micron) are also the most radiatively active



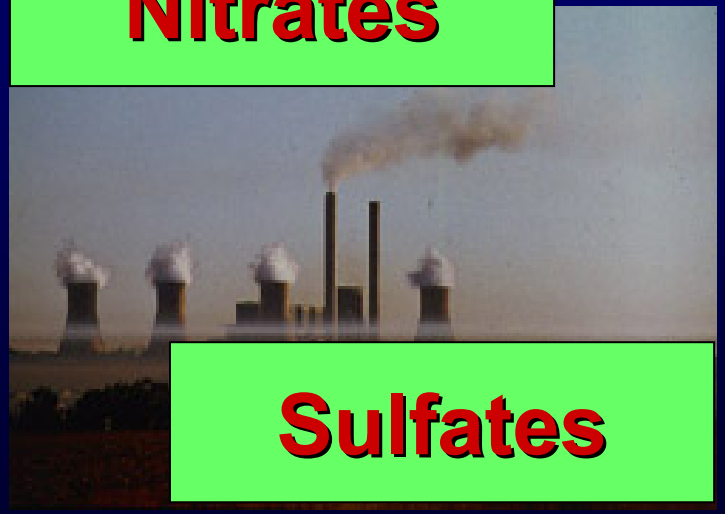
There are many types of aerosols

Volcanic

Sea Salt

Mineral dust

Black Carbon



Nitrates

Sulfates

Organic carbon

Courtesy Canadian Fire Research

Aerosols in RegCM3

- **General approach ⟺ Tracer model / RegCM3**

$$\frac{\partial \chi}{\partial t} = -\overline{V} \cdot \nabla \chi + F_H + F_V + T_{CUM} + S_\chi - R_{w,ls} - R_{w,cum} - D_{dep} + \sum Q_p - Q_l$$

Transport | Primary Emissions | Removal terms | Physico – chemical transformations

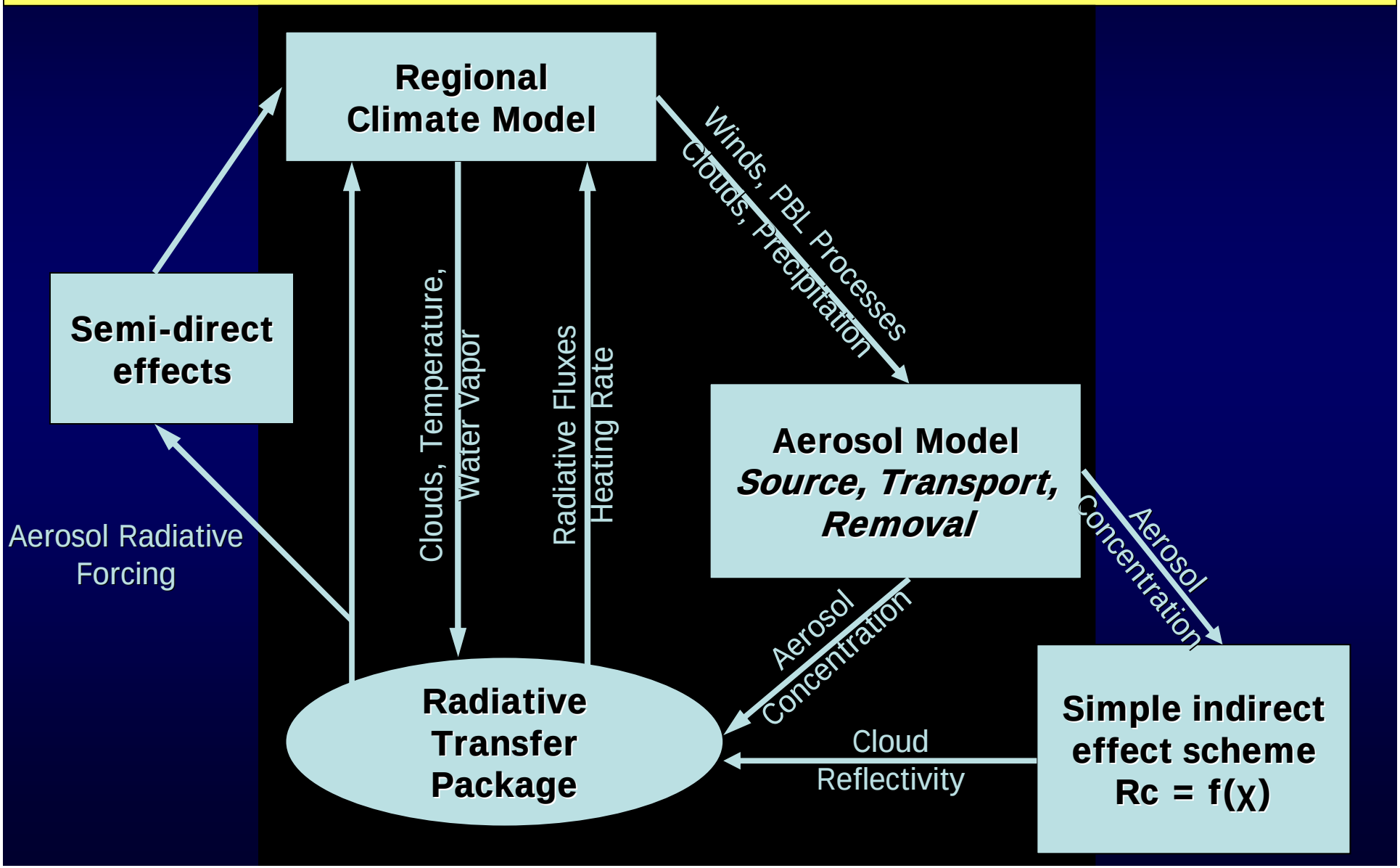
Strongly dependent on the nature of the tracer

- **Particles and chemical species considered (12 tracers).**

SO_2 ⟺ SO_4^-		**BC** (soot)		**OC** (total organic carbon)		**DUST** (4 bins)				**Sea-Salt** (2 bins)	
Aqueous and gazeous conversion (Qian et al., 2001)		*Hydrophilic (20% at emission)*	*Hydrophobic* (80%at emission)	*Hydrophilic (50%at emission)*	*Hydrophobic(50%at emission)*	0.01-1 µm	1-2.5 µm	2.5-5 µm	5-20 µm	0.05-1 µm	1.0-10 µm

Qian and Giorgi 1999; Qian et al. 2001; Solmon et al. 2006; Zakey et al. 2006; 2008

Climate-aerosol model coupling

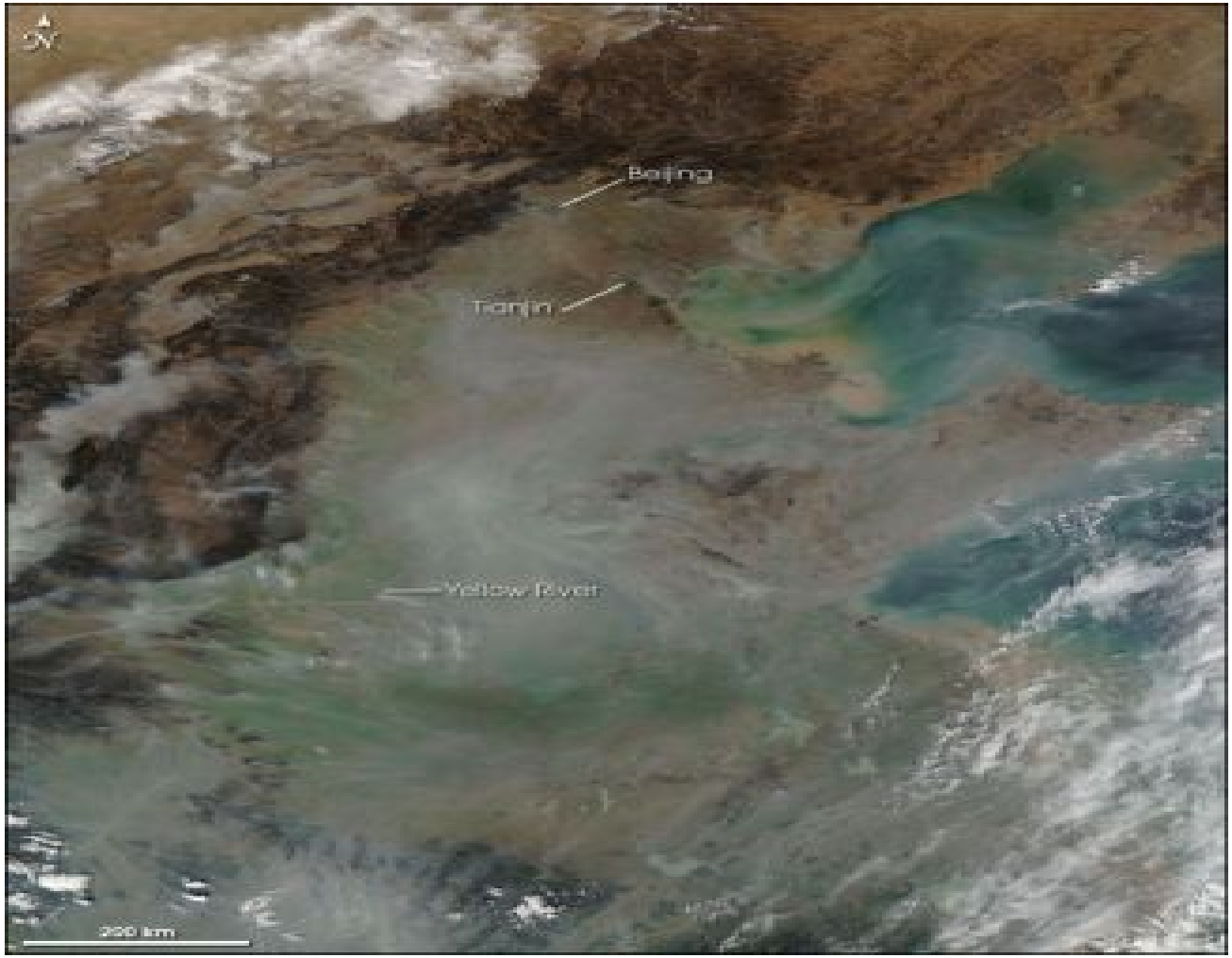


Example I
East Asia

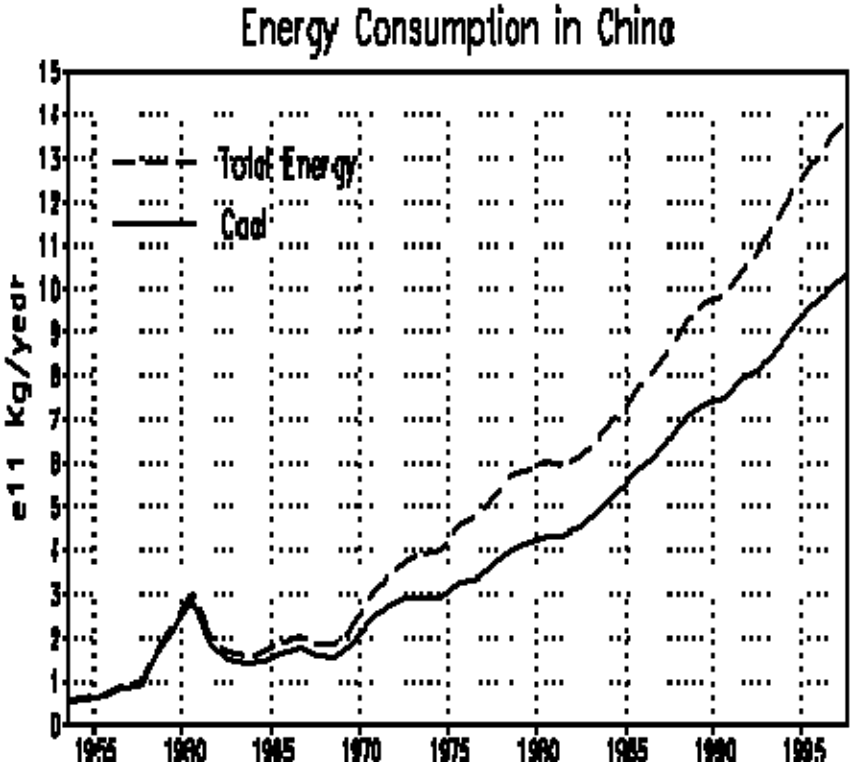
- During the last decades East Asia has been one of the most rapidly developing regions of the world
- As a result, anthropogenic aerosol emissions over the region have considerably increased, thereby (possibly) affecting the climate of the region
- A series of studies investigated the possible regional climatic effects of anthropogenic aerosols over East Asia
  - Qian and Giorgi (1999,2000), Qian et al. (2001, 2003), Chameides et al. (1999,2002),Streets and Waldhoff (2000),Kaiser and Qian (2002),Giorgi et al. (2002,2003)

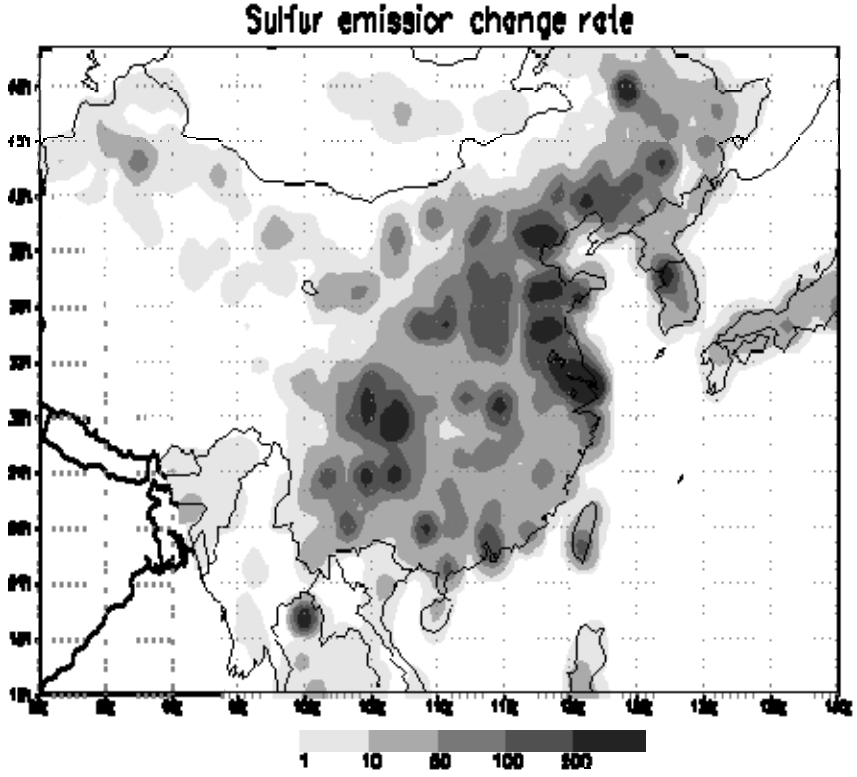
Brown cloud over China

17 November 2004

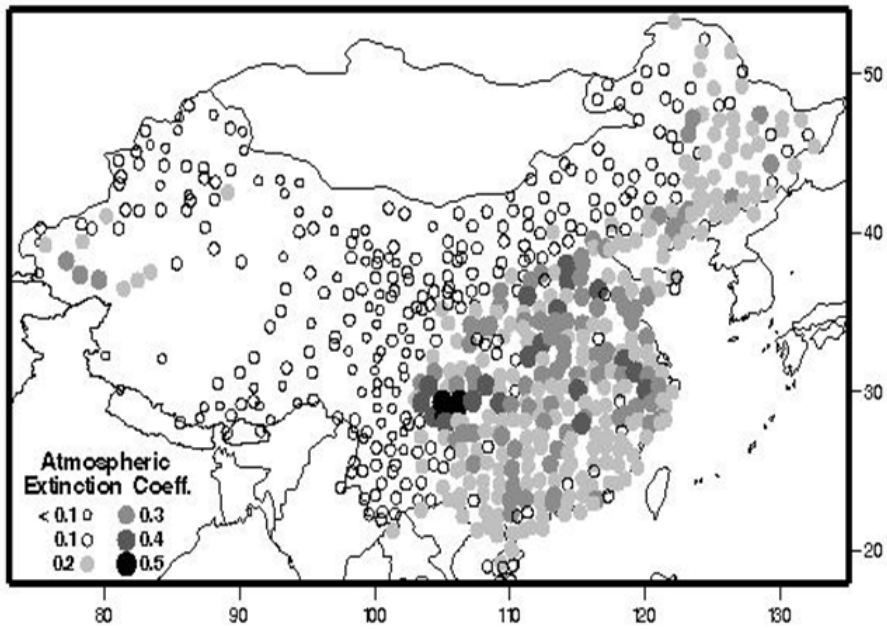


Yearly coal and total energy consumption in China from 1953-1997 (left) Spatial distribution of SO_2 emission yearly change rate during 1953-1997 (right). Data from Ren et al. (1997).

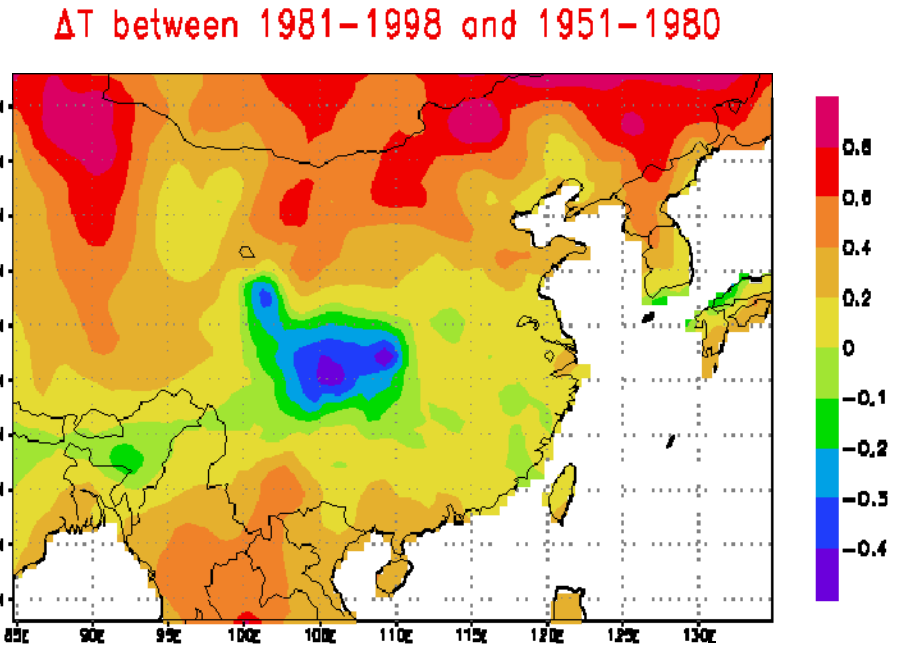




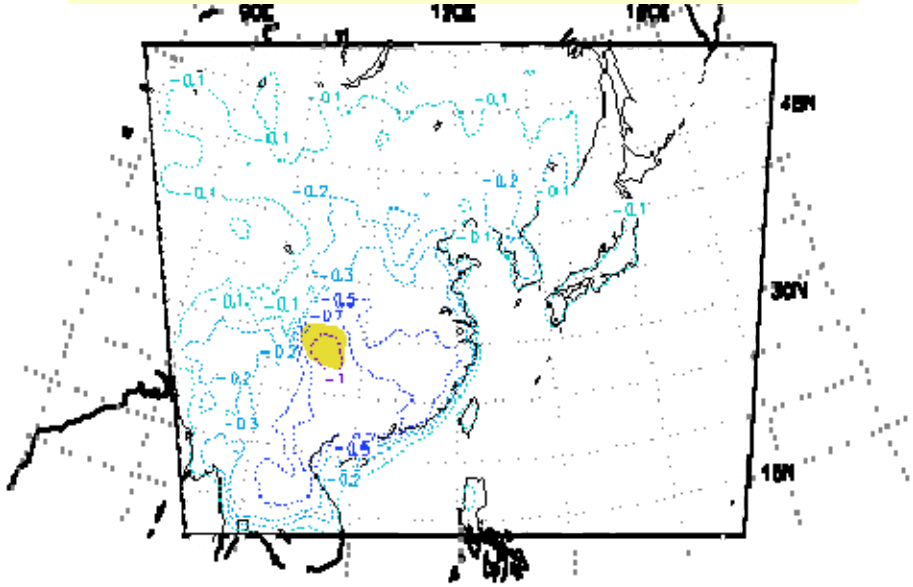
Aerosol extinction coefficient averaged for 1981-1998
Kaiser and Qian (2002)



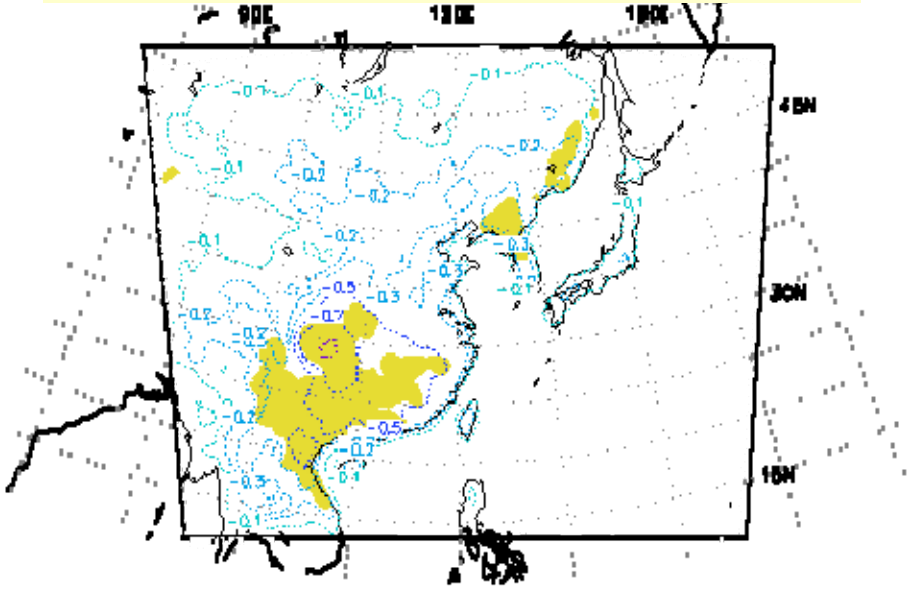
Change of observed mean temperature (°C) in China
Qian and Giorgi (2000)



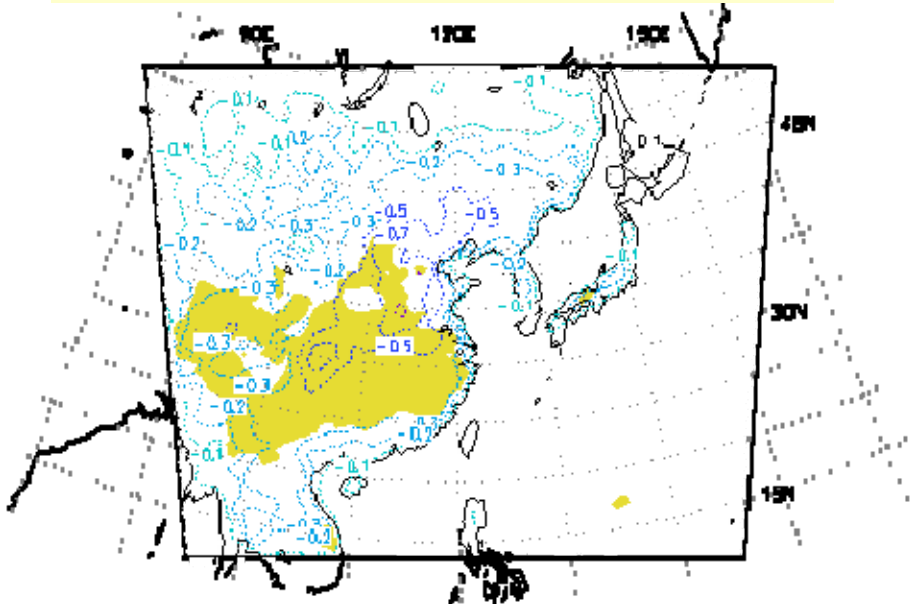
Temperature, DJF, IND1-CONT



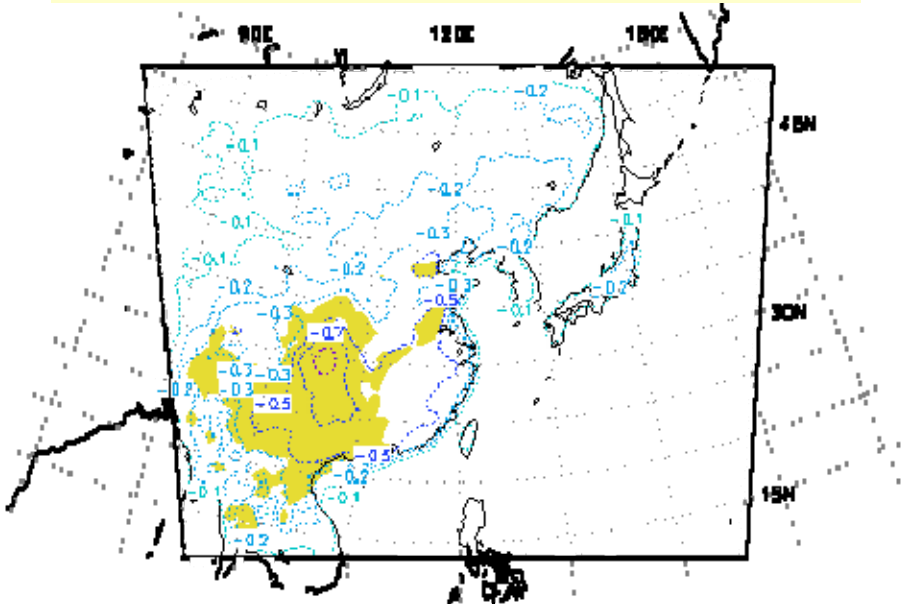
Temperature, MAM, IND1-CONT



Temperature, JJA, IND1-CONT



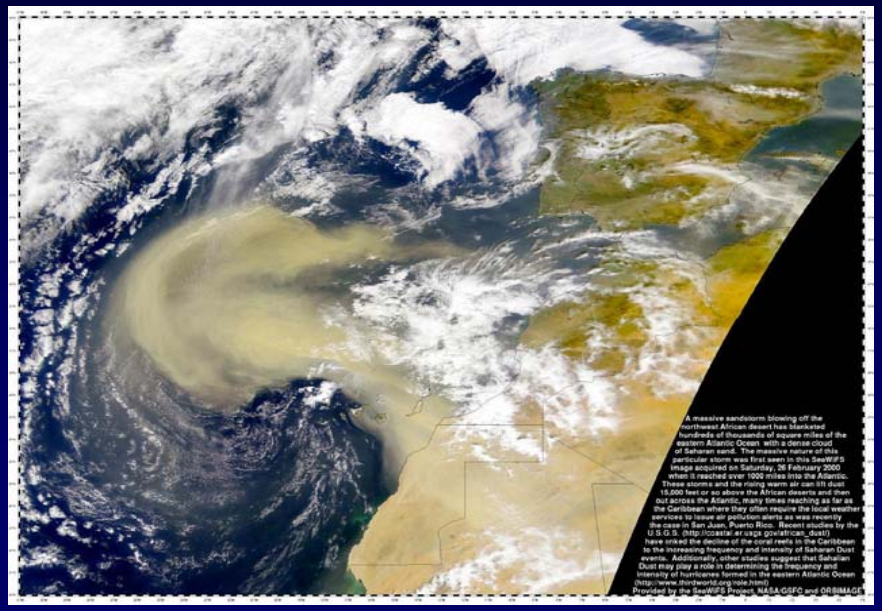
Temperature, SON, IND1-CONT



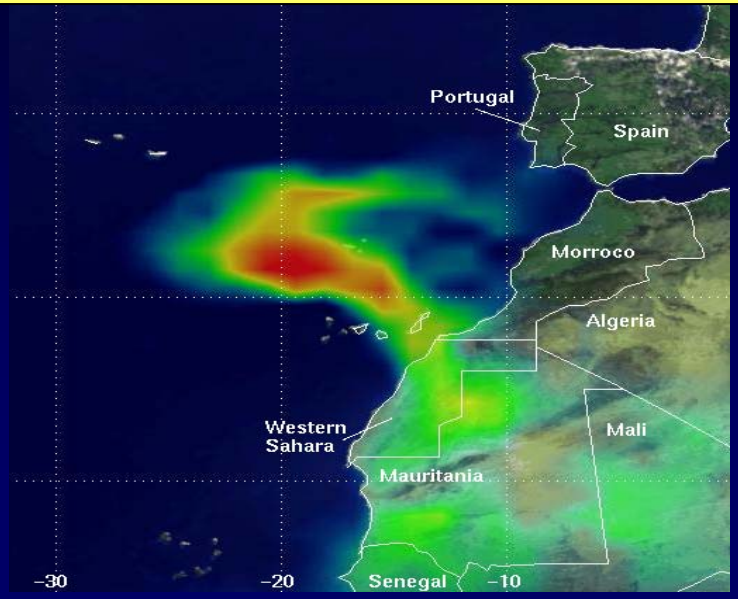
Example II: Effect of dust on the African monsoon

Solmon et al. 2006
Zakey et al. 2006
Konare et al 2008
Solmon et al. 2008

Case study: Dust storm of 20-28 February 2000



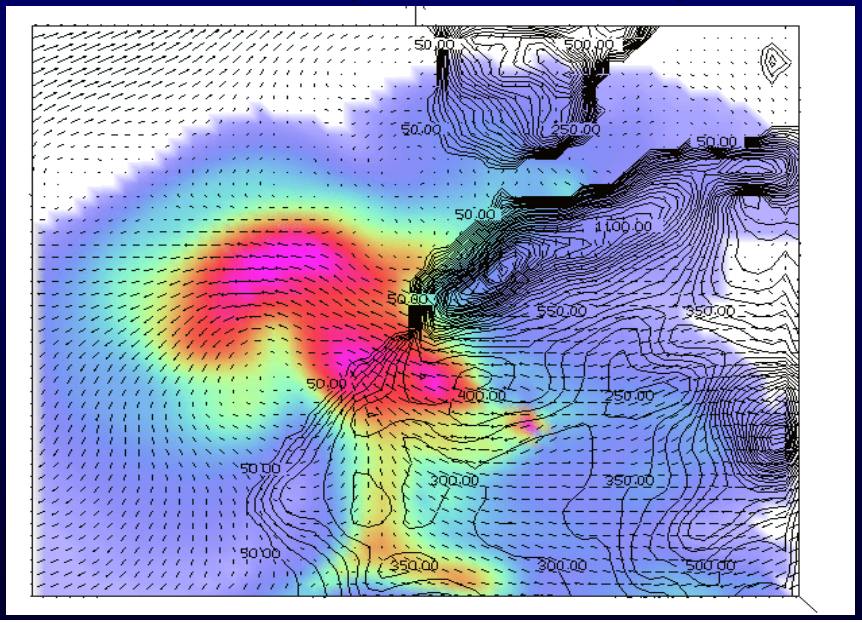
SeaWIFS (NGSFC)



TOMS (aerosol index)

RegCM

(0.1-10 μm dust burden)



Zakey et al, 2006

Validation in “climate” mode

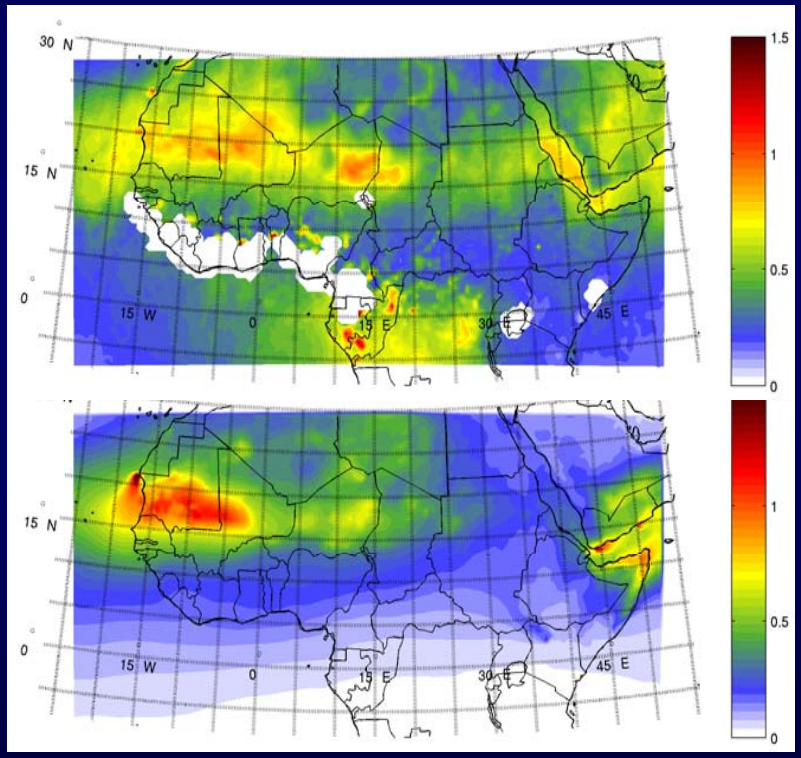
Konaré et al., 2008; Solmon et al., 2008

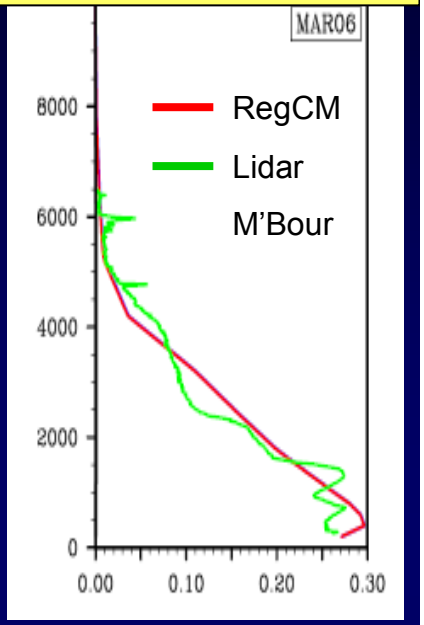
MISR AOD

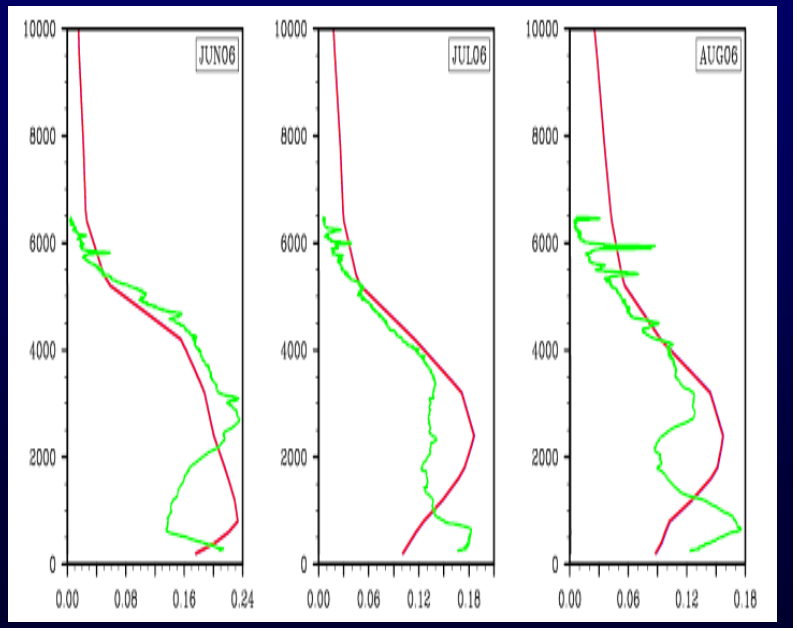
JJA

(2000-2006)

RegCM AOD



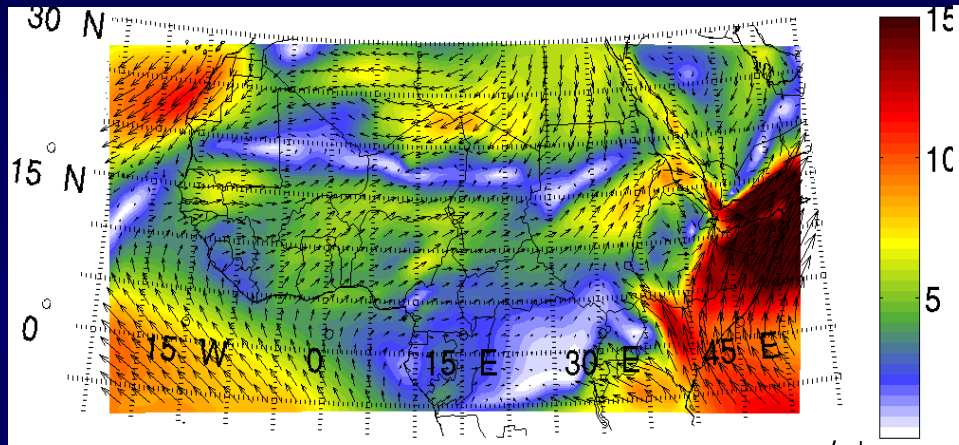




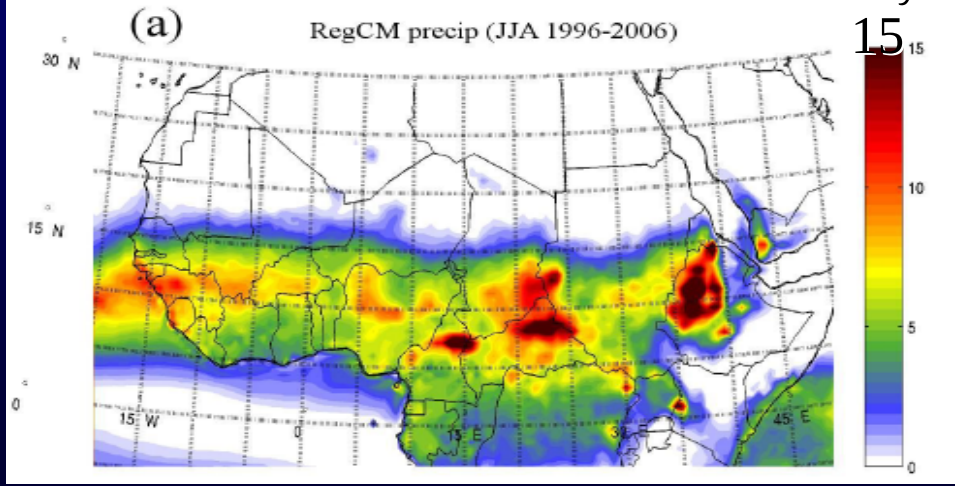
Dynamical and precipitation response to dust forcing

(NODUST, JJA 1996-2006)

Mean circulation at 865 hpa m.s^{-1}

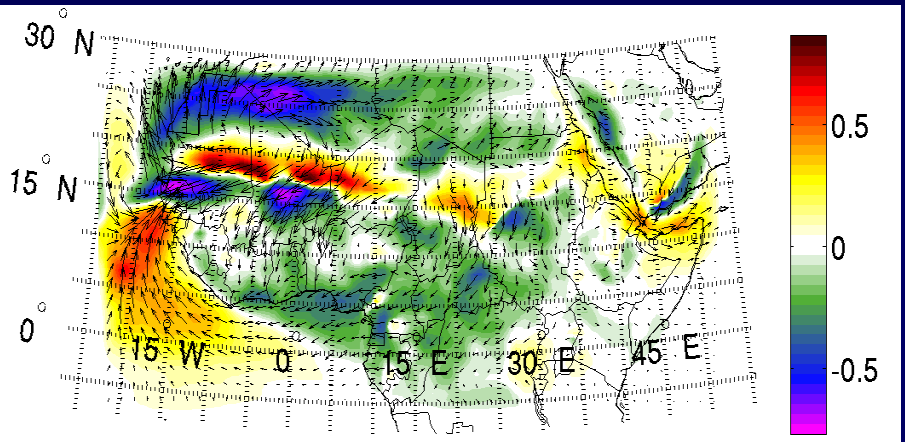


mm/day

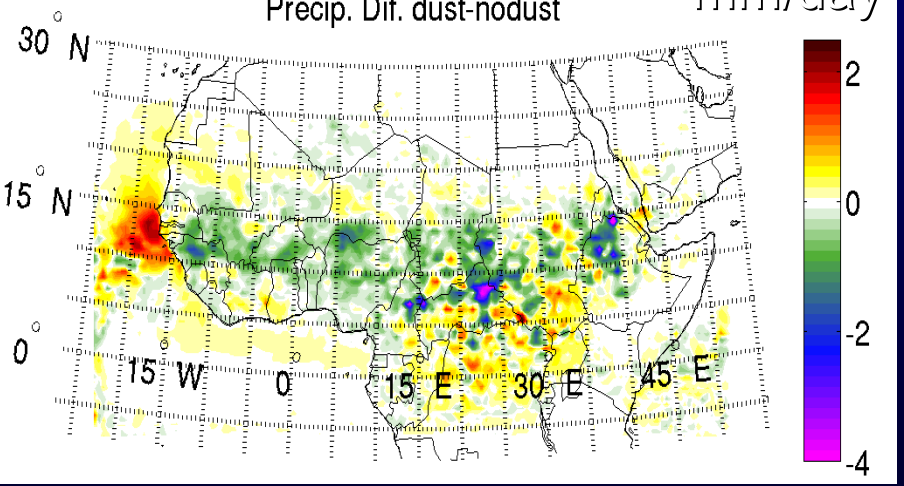


(DUST -NODUST, JJA 1996-2006)

Differential circulation at 865 hpa m.s^{-1}



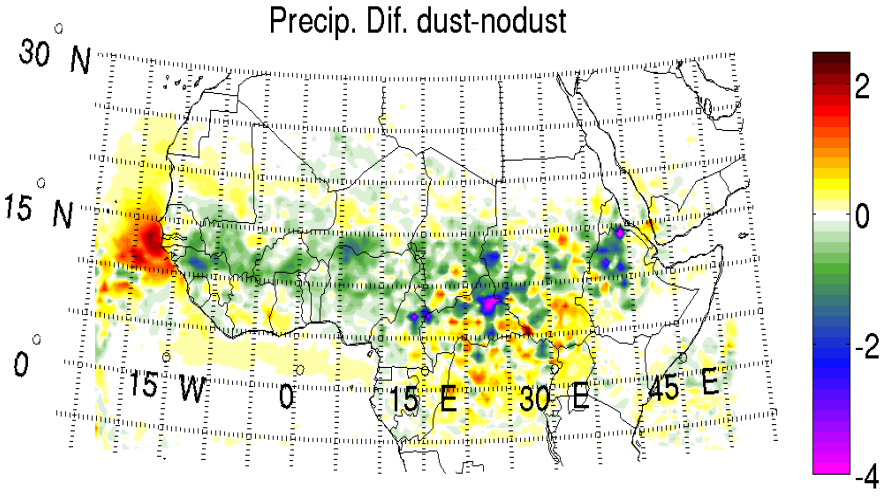
mm/day



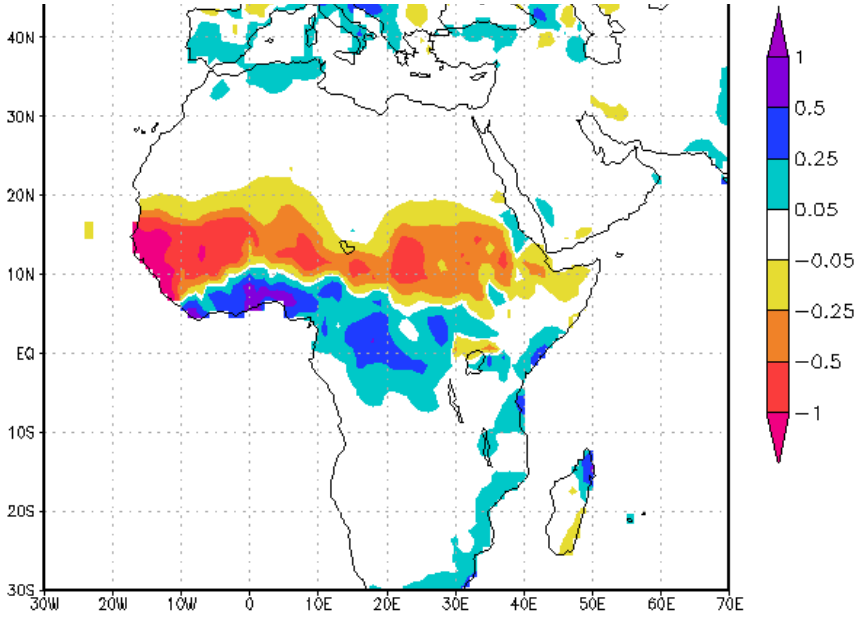
Konaré et al., 2008; Solmon et al., 2008

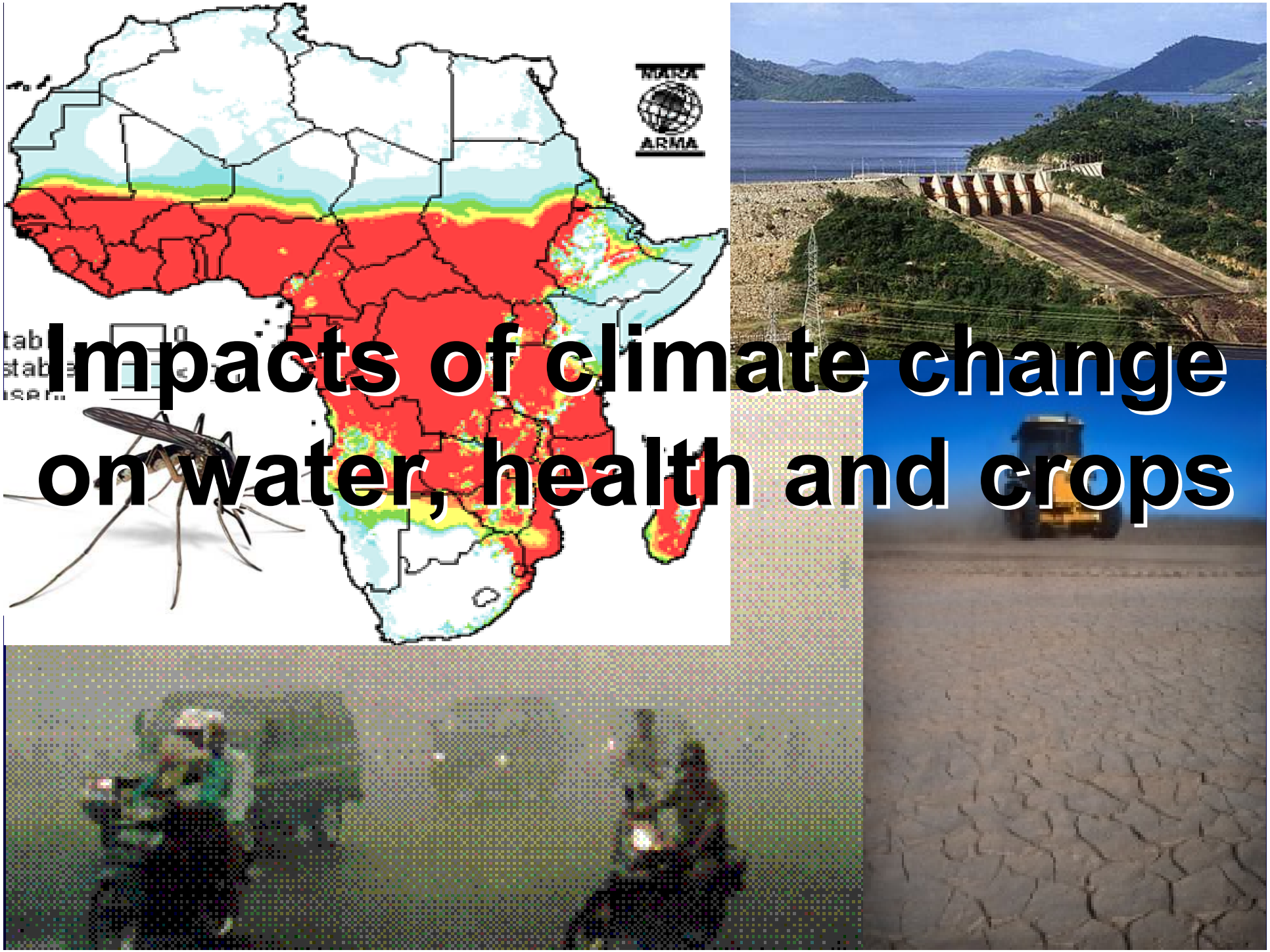
The dust forcing can strengthen the occurrence of drought in the Sahel

Precipitation
Dust - nodust

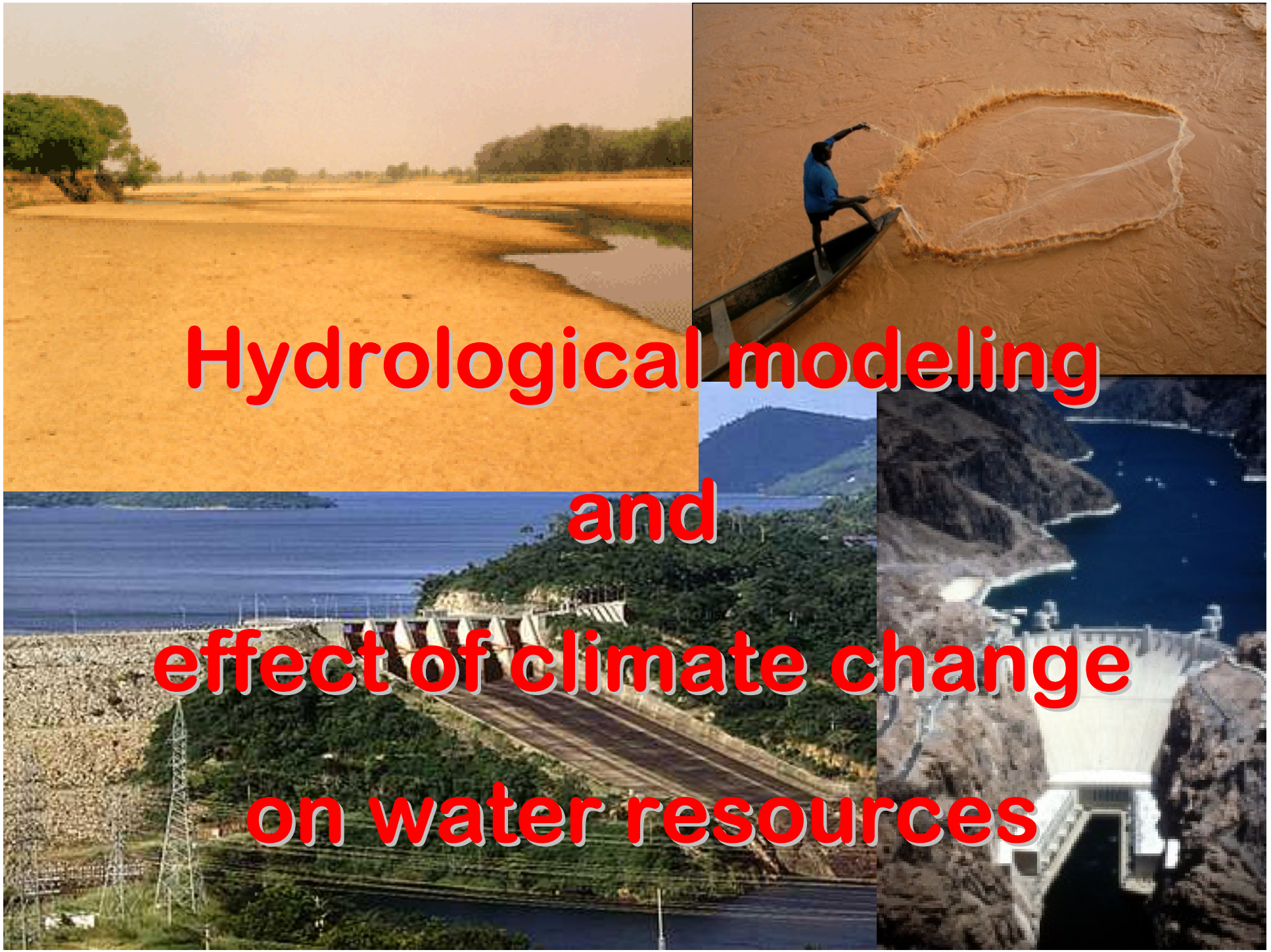


Precipitation, CRU
(1961-1990) – (1901-1980)





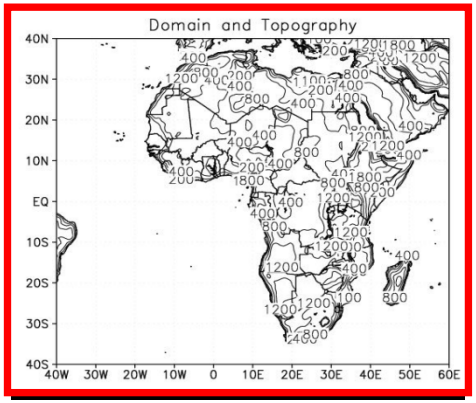
Impacts of climate change on water, health and crops

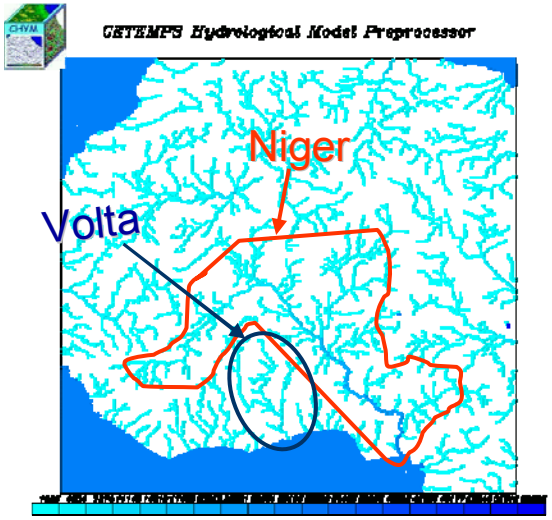

Hydrological modeling
and
effect of climate change
on water resources

Experiment Description

Regional Climate Model (RegCM3) simulations

- *Control simulation using ERA-Interim as boundary conditions (1990-2007) [Sylla et al. 2009]*
- *Scenario simulations using ECHAM5-GCM A1B (1980-2100) [Mariotti et al 2010, in preparation]*

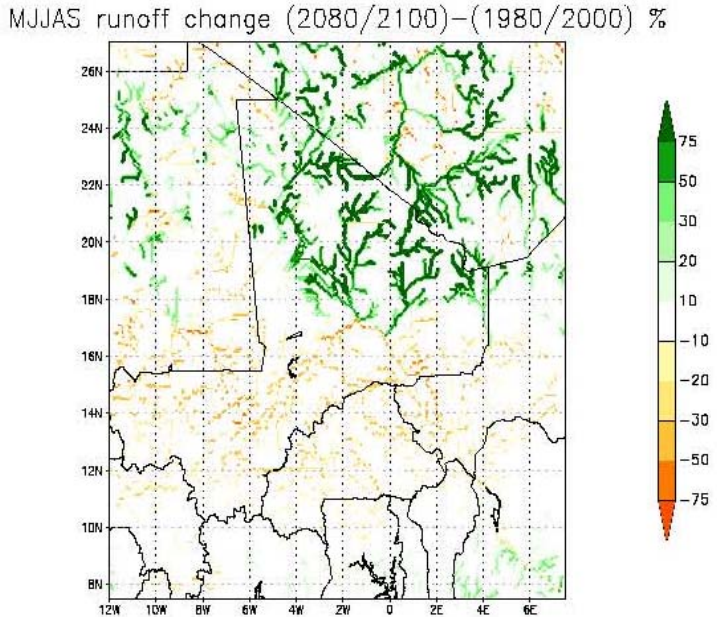


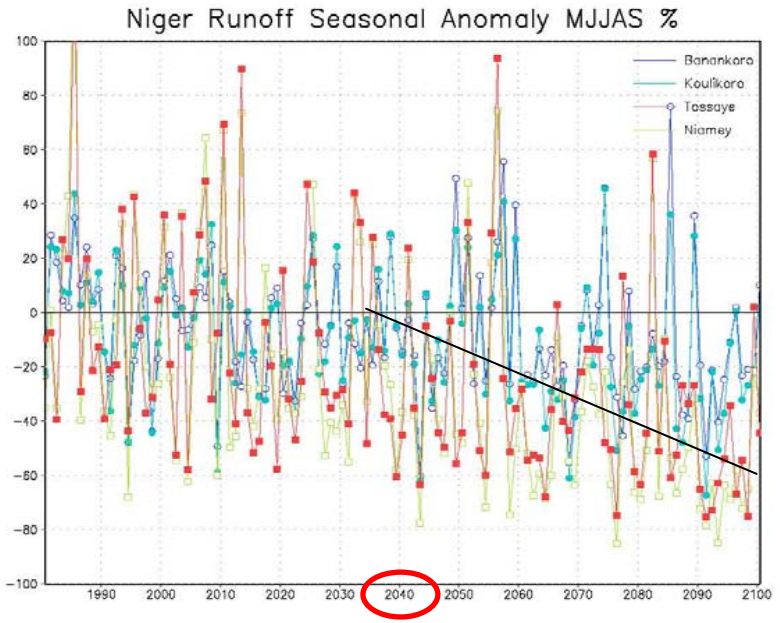


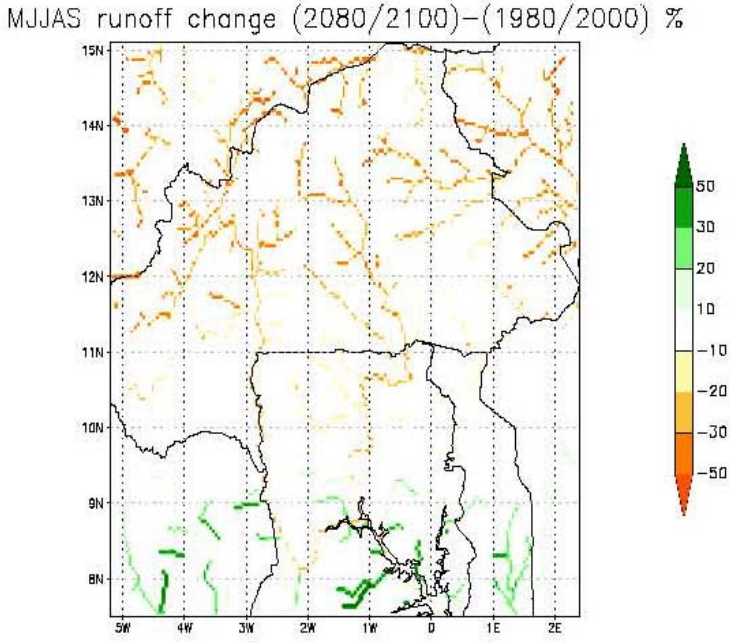
Cetemps Hydrological Model **CHyM** [*Coppola et al. 2007*] has been coupled with the regional climate model for the two western African river basins **Niger and Volta**

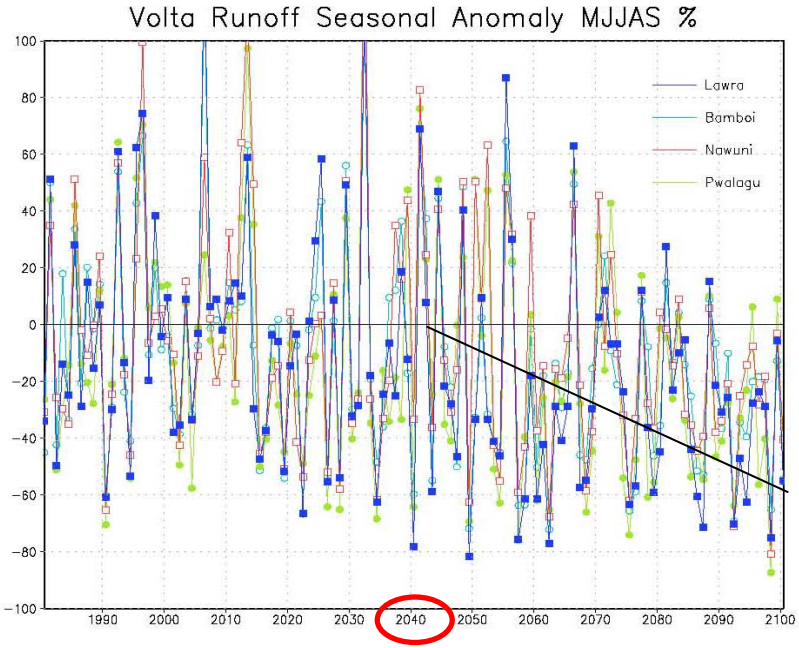
- *hydrological model calibration run - regional model perfect boudary simulation output as input (1990-2005)*
- *Transient hydrological scenario simulations - regional climate model output from the A1B transiet simulation as input (1980-2100)*

Runoff Seasonal Change





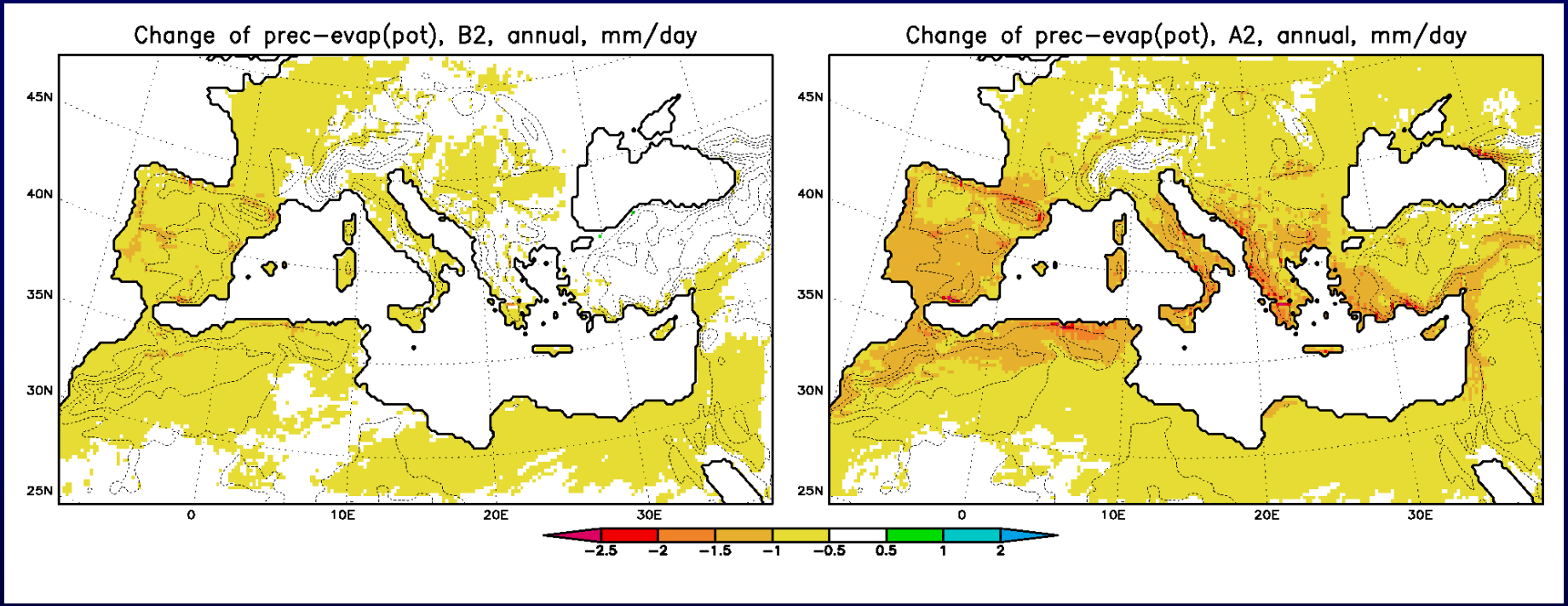




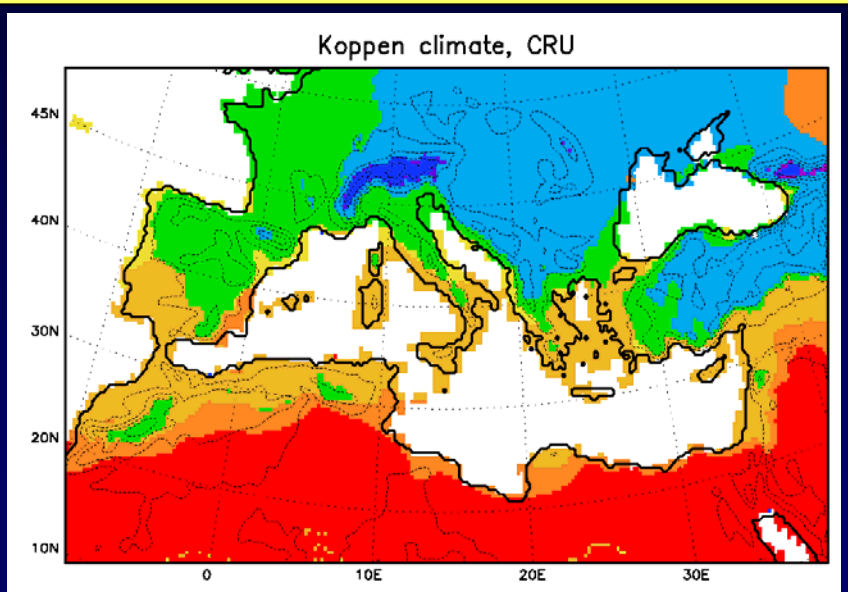
Change in precipitation minus potential evaporation

B2

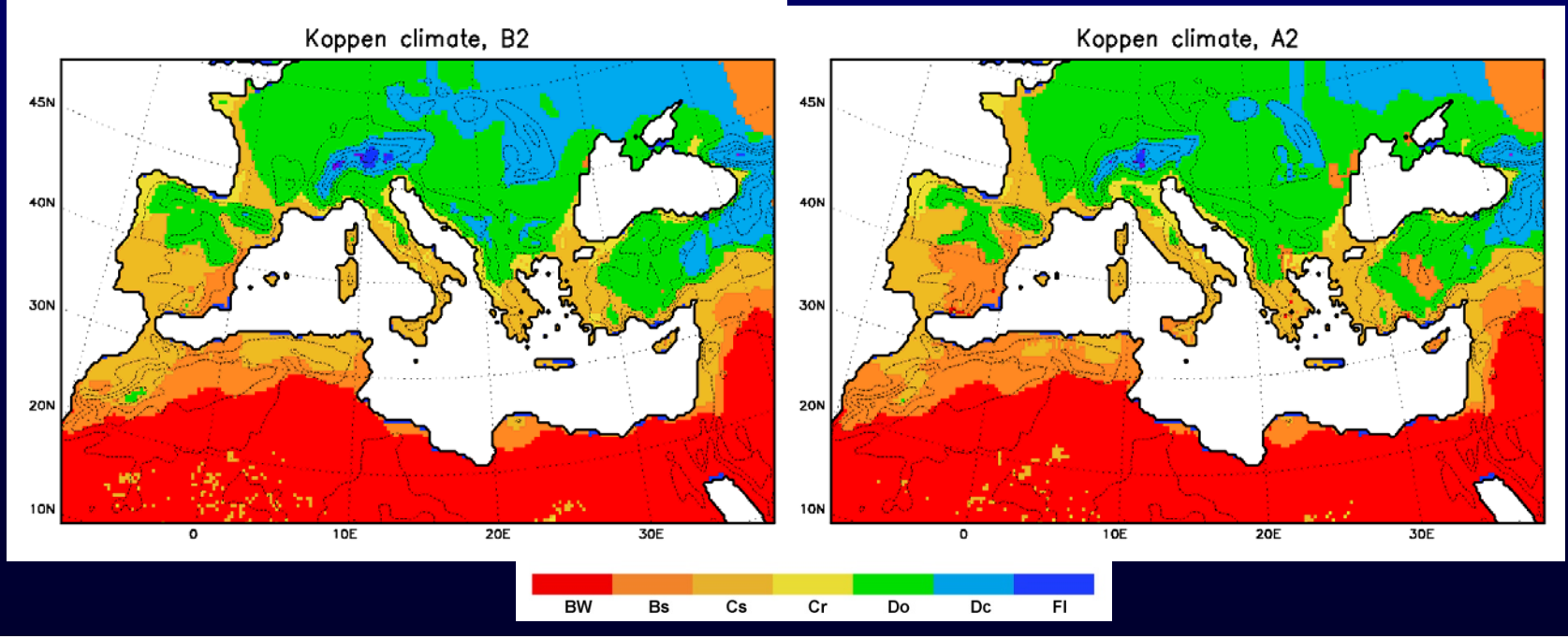
A2

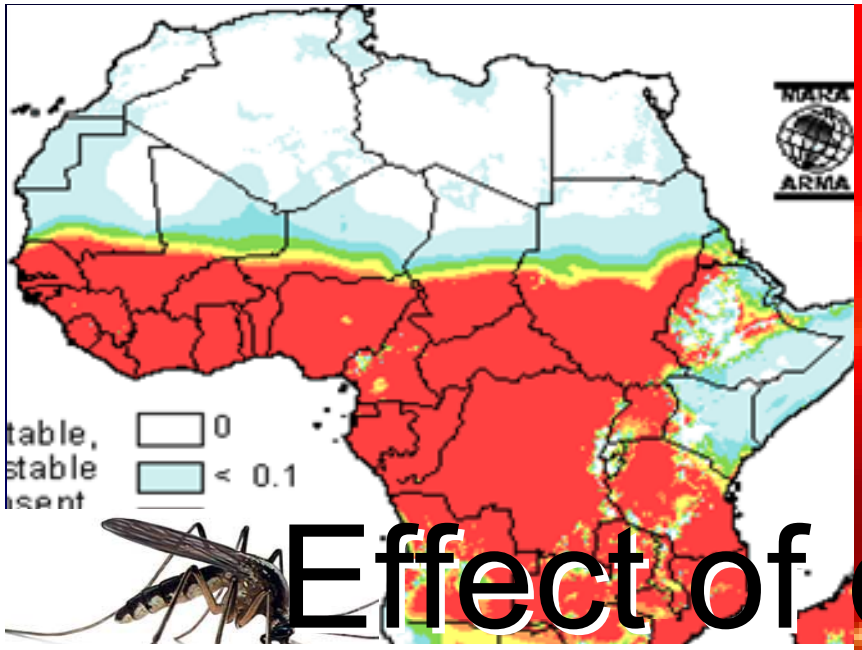


Change in Koppen climate classification types

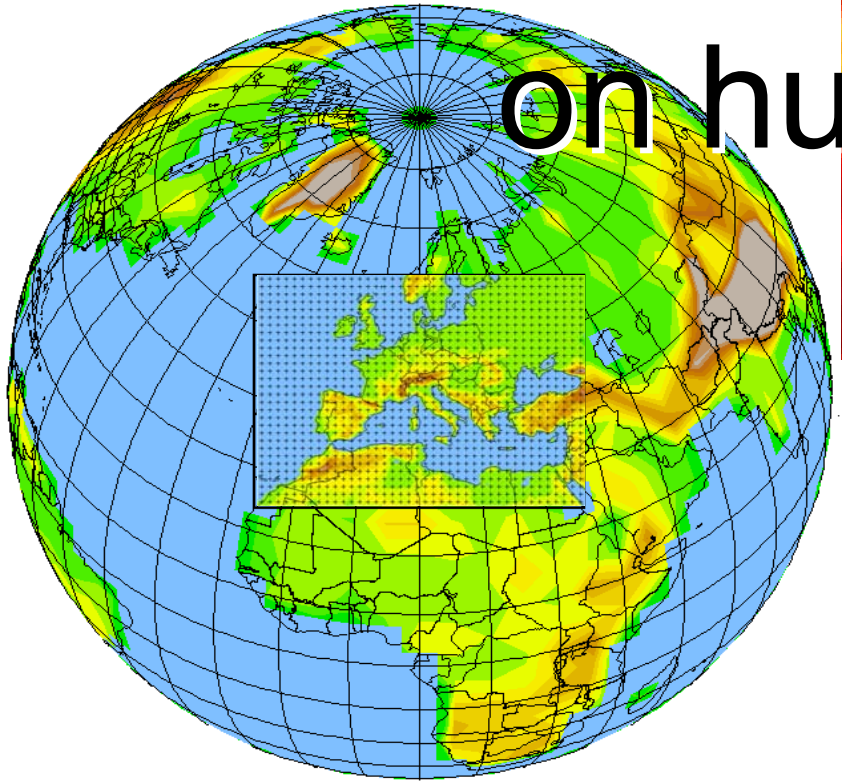


BW = Dry Land - Desert
BS = Dry Semiarid - Steppe
Cs = Sub-tropical/Summer dry – EG trees
Cr = Subtropical Humid – Dec. Trees
Do = Temperate Oceanic - Conifer. Forest
Dc = Temperate Continental – Broad. For.
Eo = Sub-arctic Oceanic - Needleleaf For.
Ec = Sub-Arctic Continental - Tayga
Fl = Ice Cap - Glacier



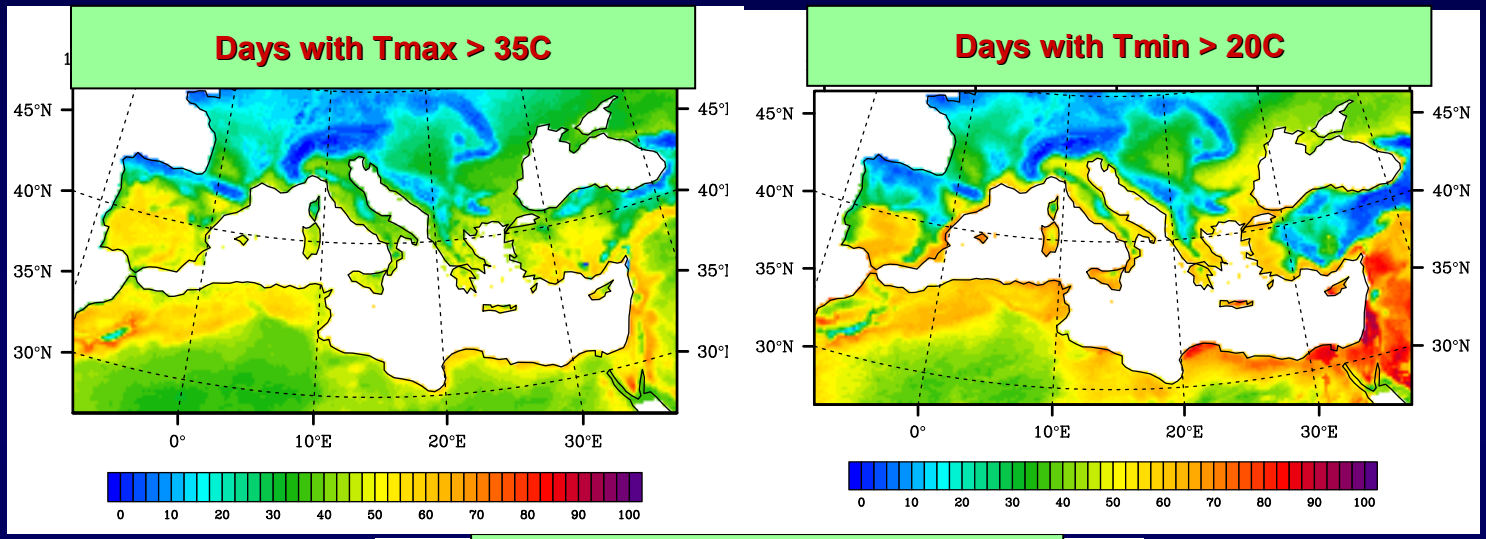


Effect of climate change on human health

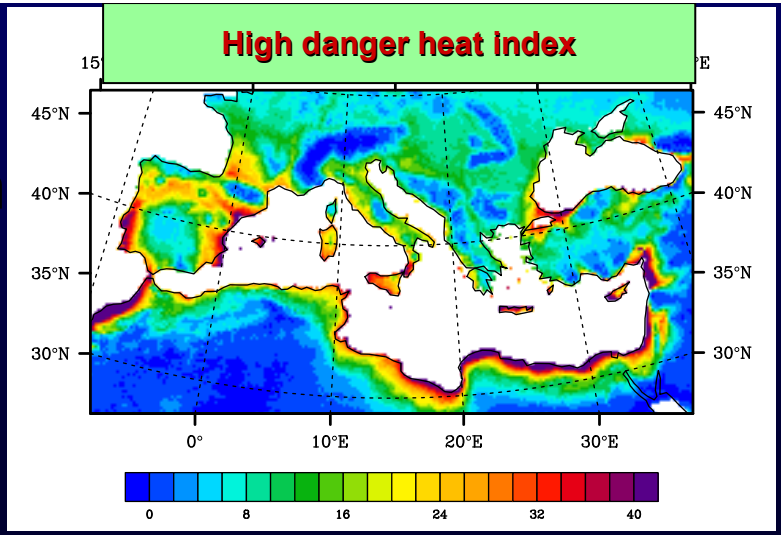


High resolution RCM information can be effectively used in a range of impact studies

Increase of pathologies related to heat stress



RegCM, dx = 20 km
A2 scenario

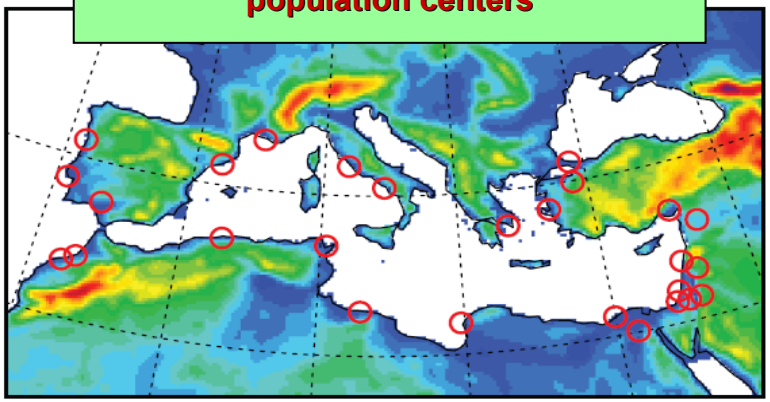


The heat index is obtained from a polynomial regression formula based on temperature and relative humidity

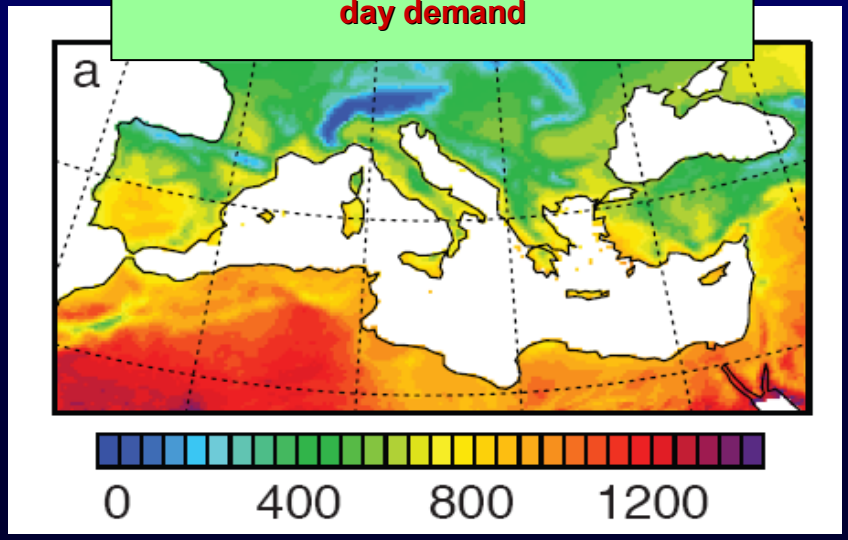
Diffenbaugh et al., GRL, 2007

A climate-change human-health feeback process

Location of major coastal population centers



Change in cooling degree day demand

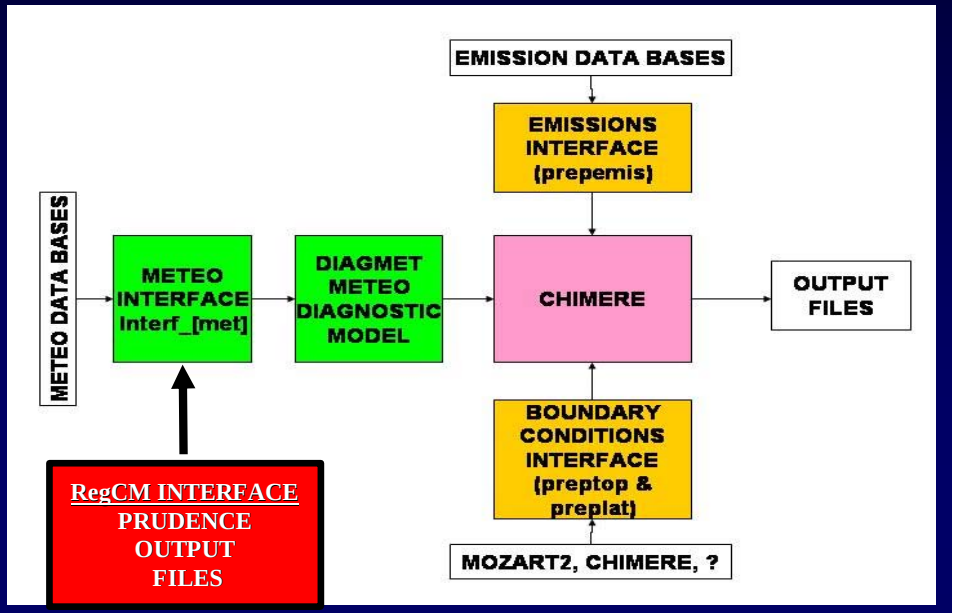


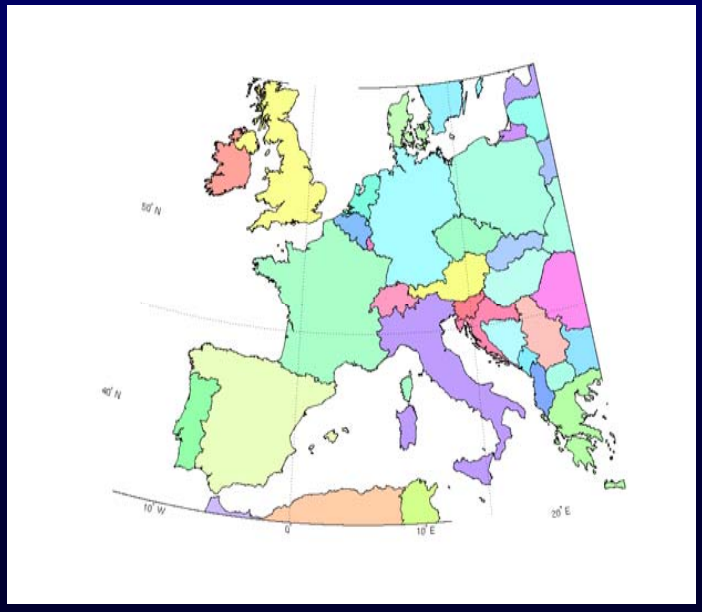
Heat stress will increase the demand or cooling and thus the GHG emissions


Climate change, air quality and health
Beijing
Yellow River
200 km

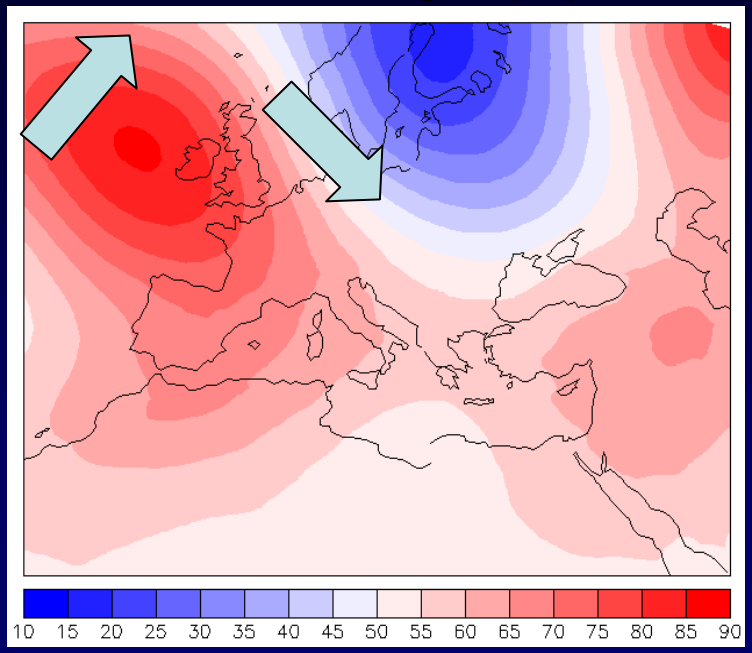
The CHIMERE-RegCM Model Set-Up

- European domain
  - Horizontal resolution: 0.5°x 0.5°
  - Vertical resolution: 8 levels up to 500hPa (~4500m)
- Meteorological data
  - RegCM outputs from Prudence runs
- Chemical Boundary Conditions
  - MOZART
- Chemical Emissions
  - EMEP
- Chemical Scheme
  - MELCHIOR reduced (~45 gaseous species, ~120 reactions)



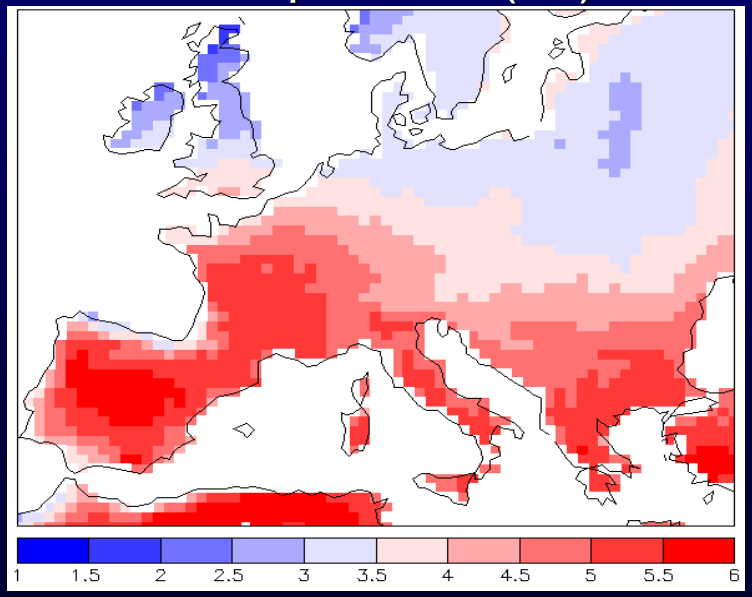


500 mb height (m)

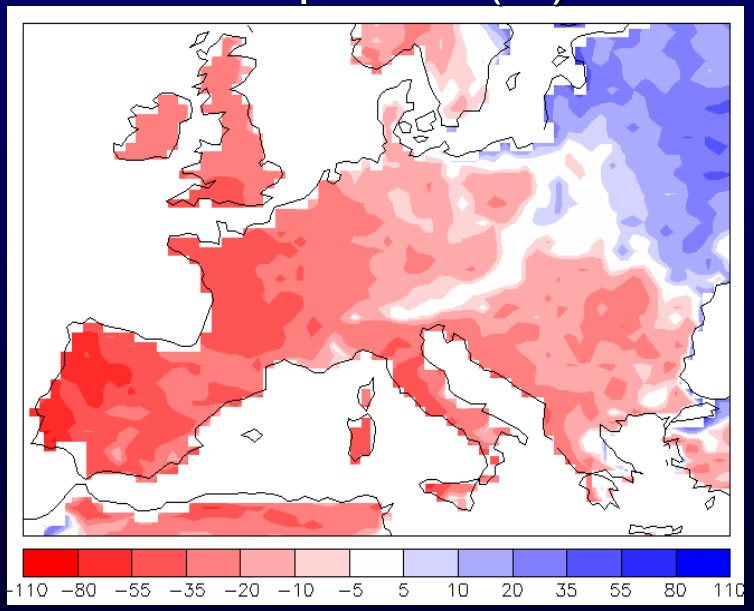


Changes in summer climate for **(2071-2100) – (1961-1990)** B2 scenario

Temperature (°C)

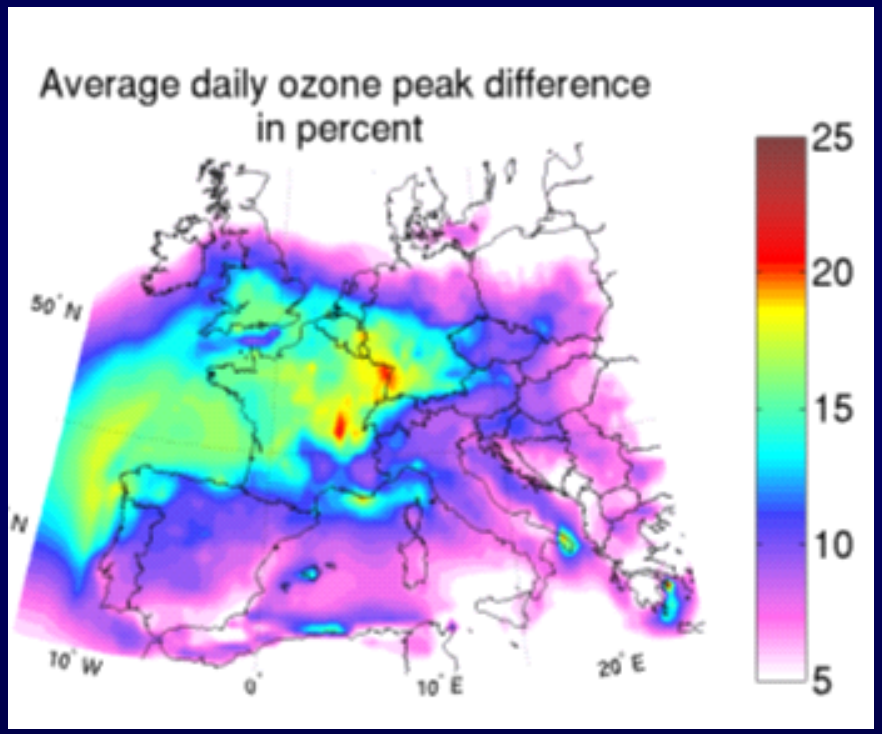


Precipitation (%)

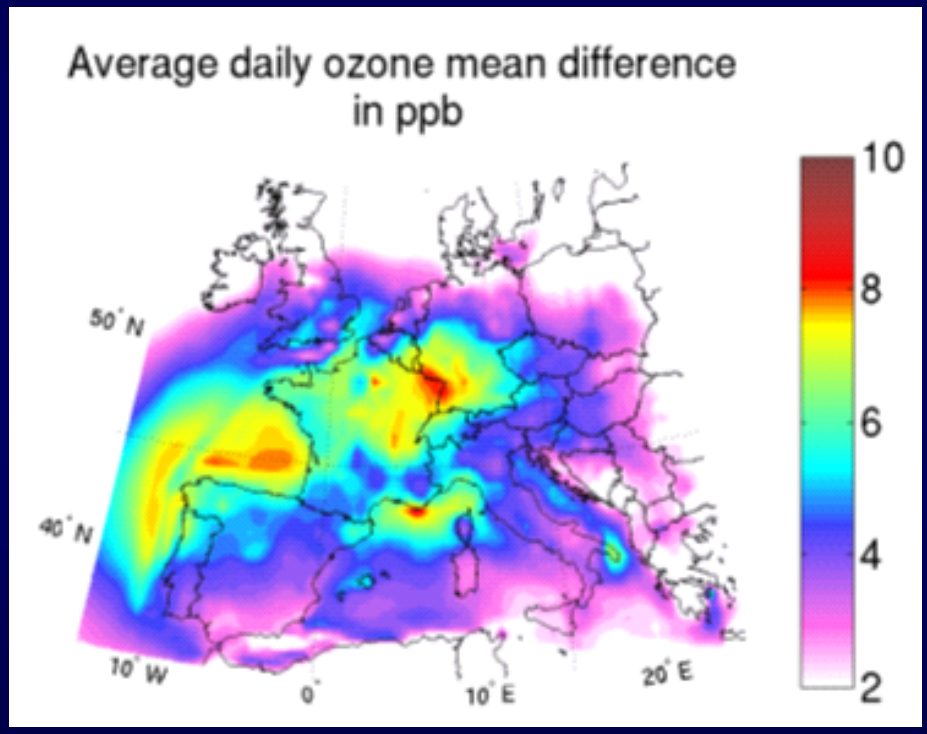


Change in summer ozone concentration statistics, A2 scenario (2071-2100) minus (1961-1990)

Peak daily ozone



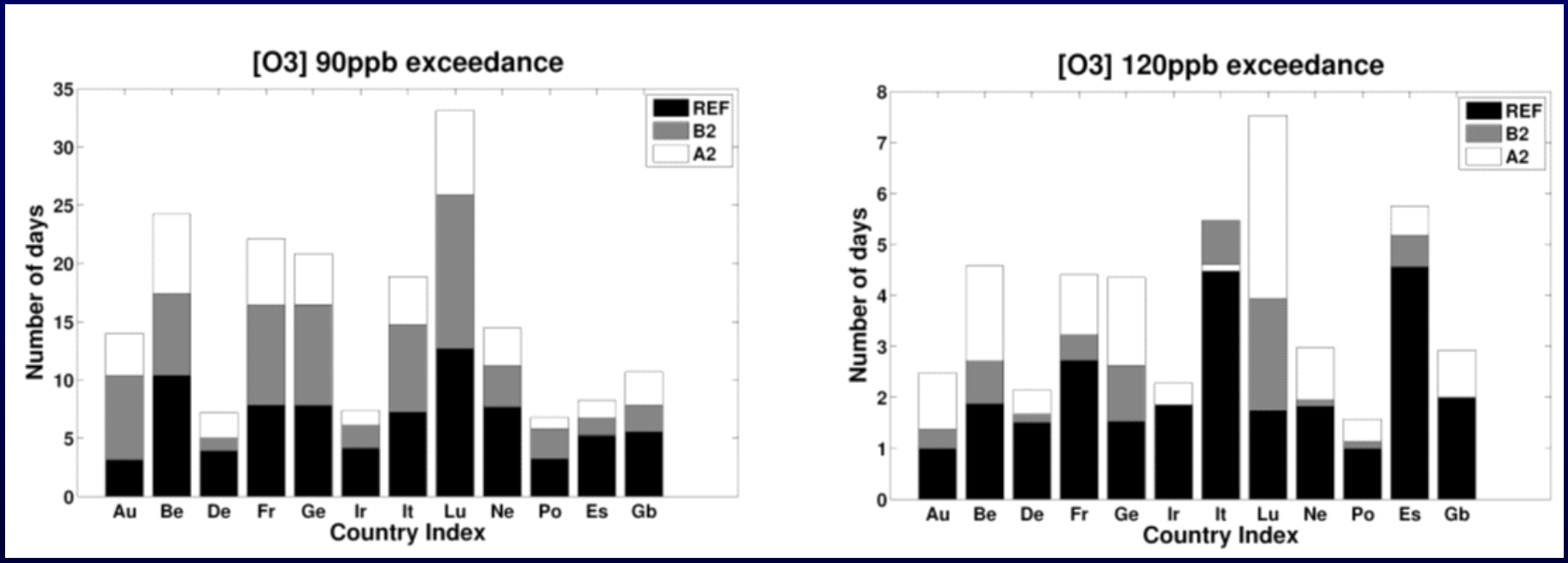
Mean daily ozone



Climate change will increase ozone concentrations over Europe because of higher temperatures, reduced precipitation and more stagnant conditions

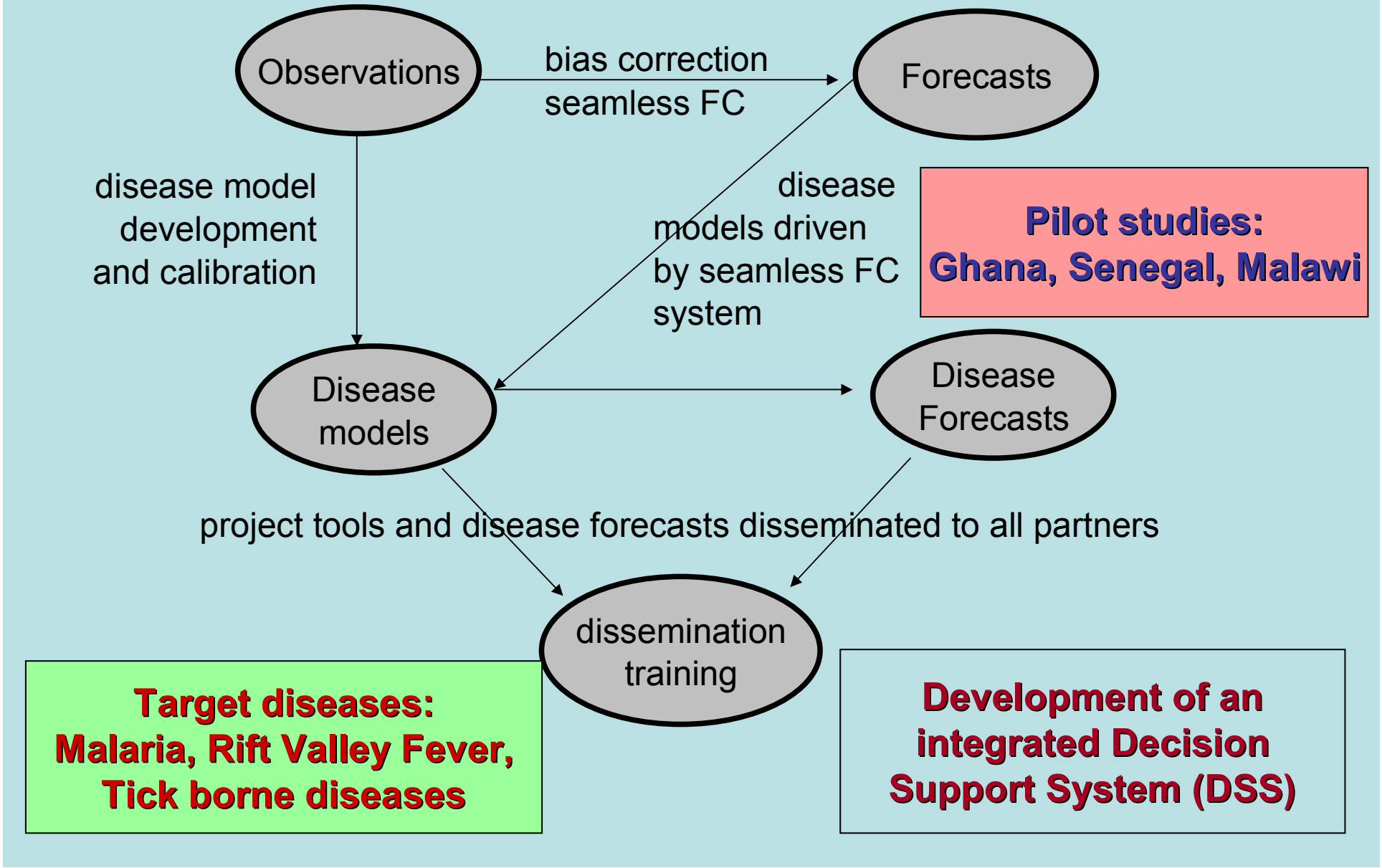
Number of exceedance days for different ozone concentration thresholds and different scenarios

Information threshold (90 ppb)



Warning threshold (120 ppb)

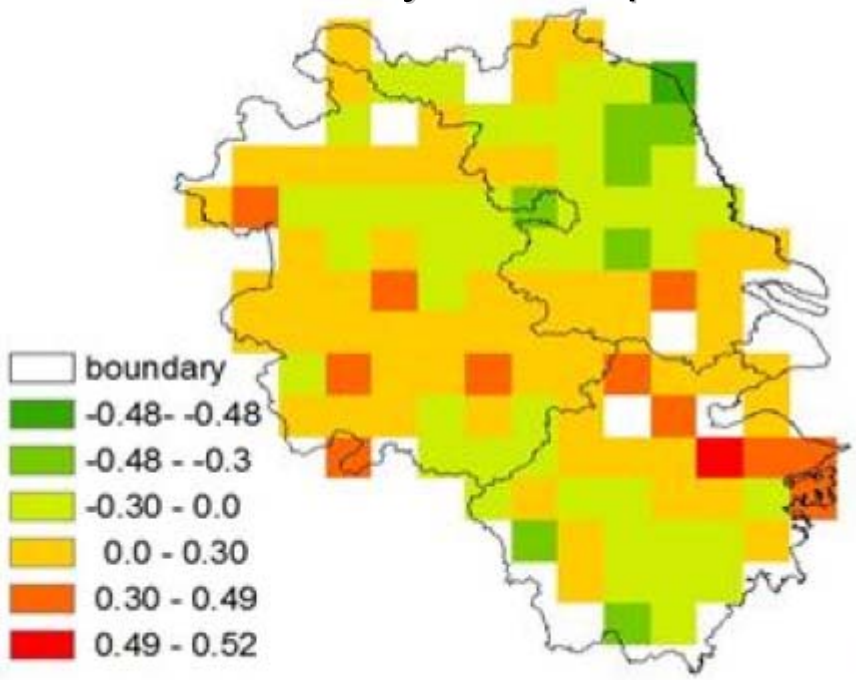
Project: Development of a forecast system for infectious disease outbreaks in Africa (QWECI project)



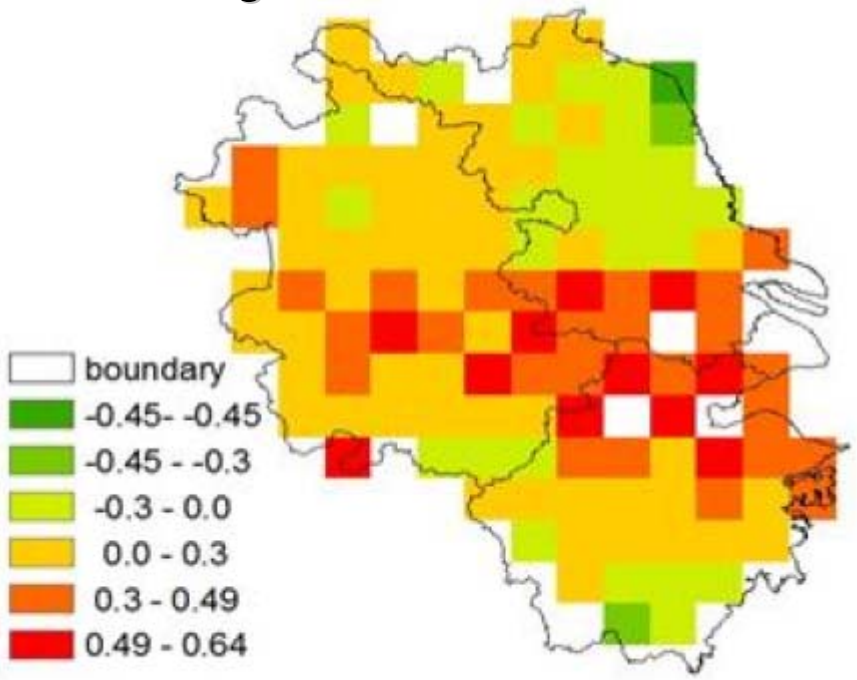
Use of GLAM crop model for studies of the effects of climate change on crop productivity

Comparison of correlation coefficient between observed and simulated yield at the 0.5◦ scale from 1985 to 2000

With flooding effect, yield predictions showed a better agreement with observed yield compared with no flooding effect

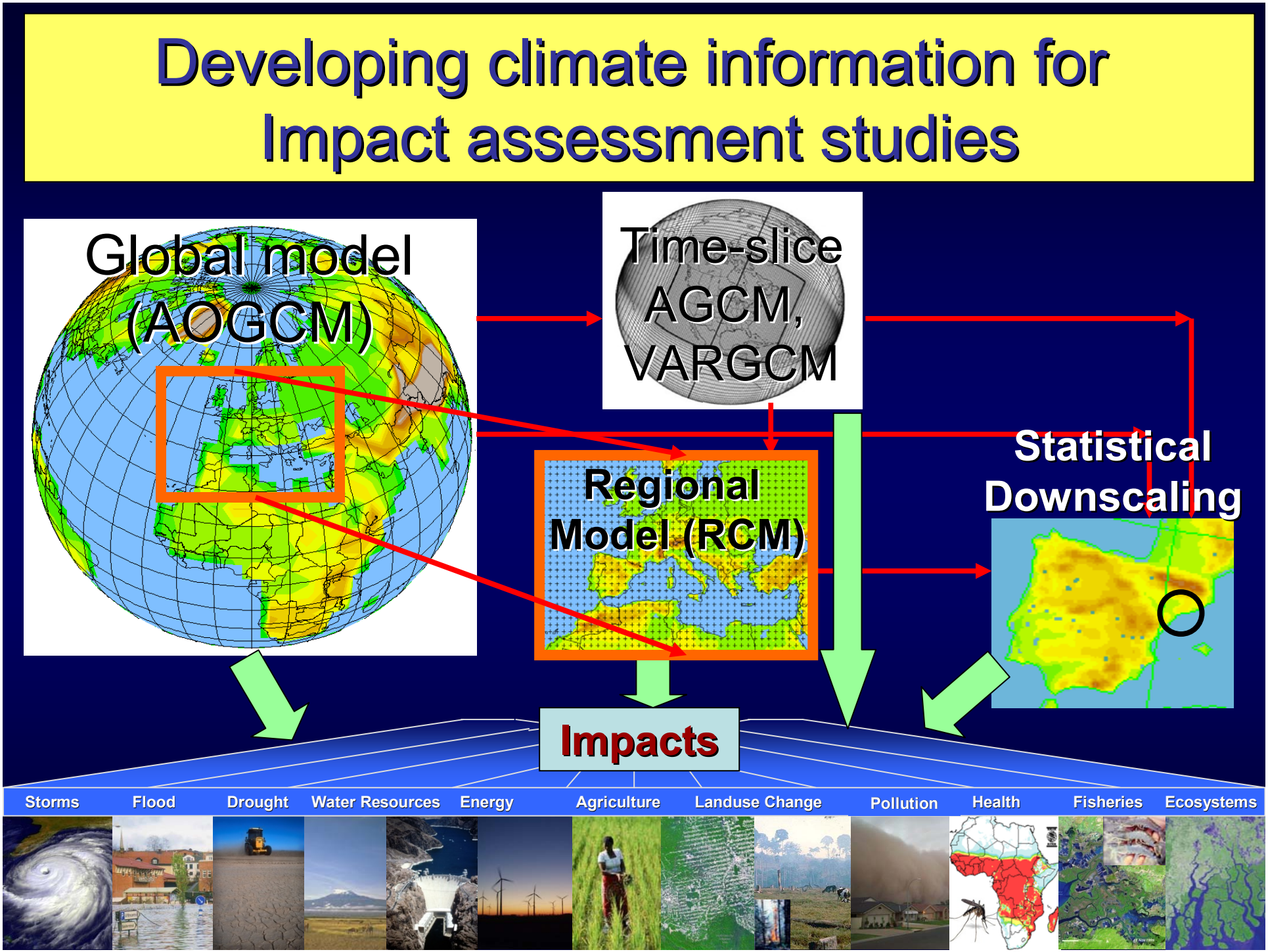


original



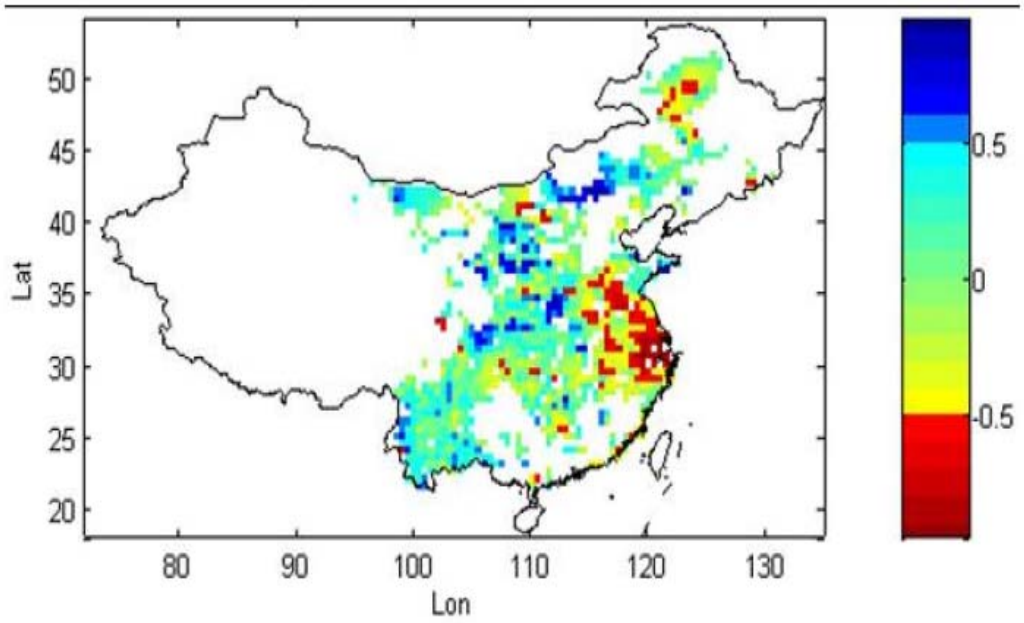
modified model

Developing climate information for Impact assessment studies



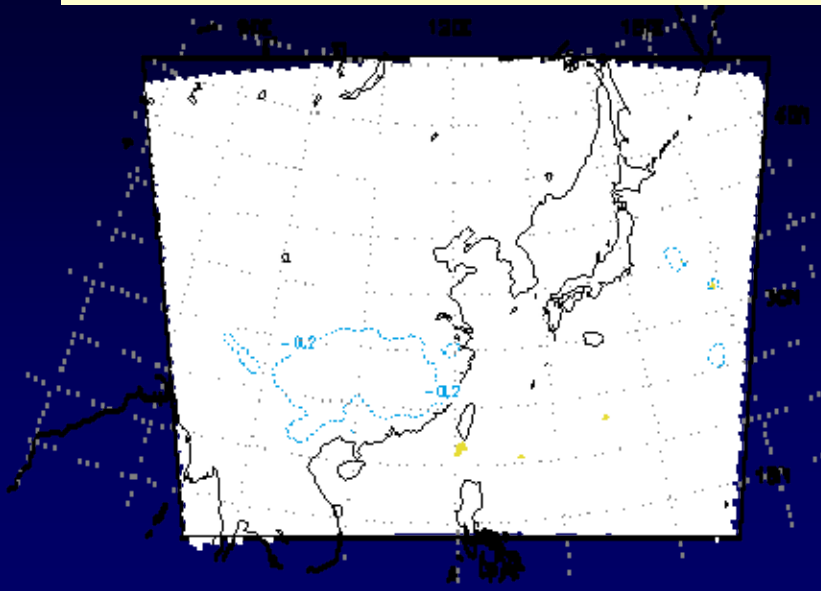

DEVELOPMENT
SOCIETY
Thank you
ENVIRONMENT

Crop yield modelling: correlation between rainfall and observed yield (1985-2000)

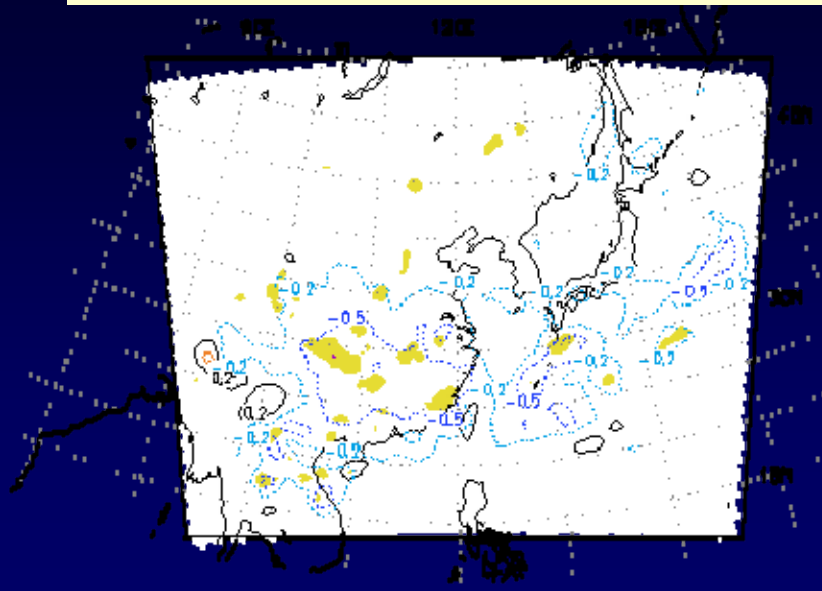


- Positive correlation in north west, rainfall limited.
- Negative in east where irrigation fraction is higher: Effect of flooding

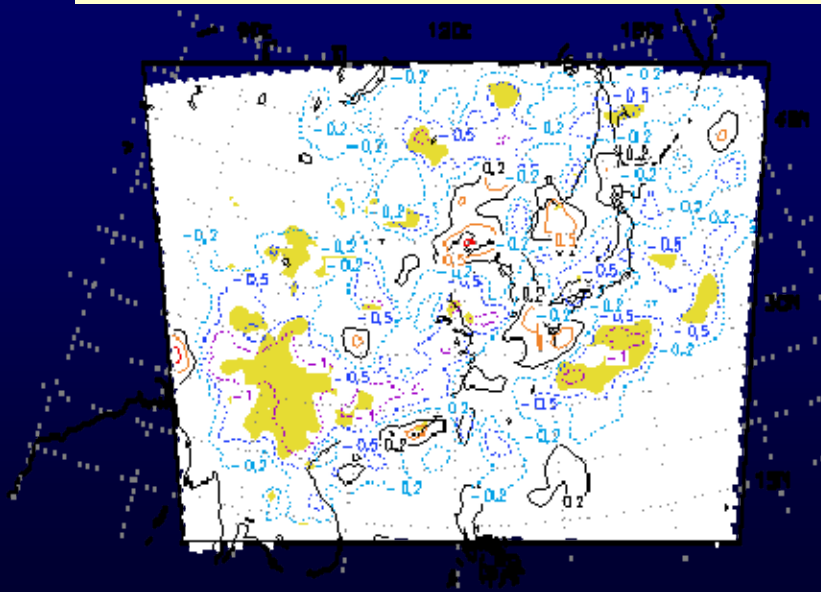
Precipitation, DJF, IND1-CONT



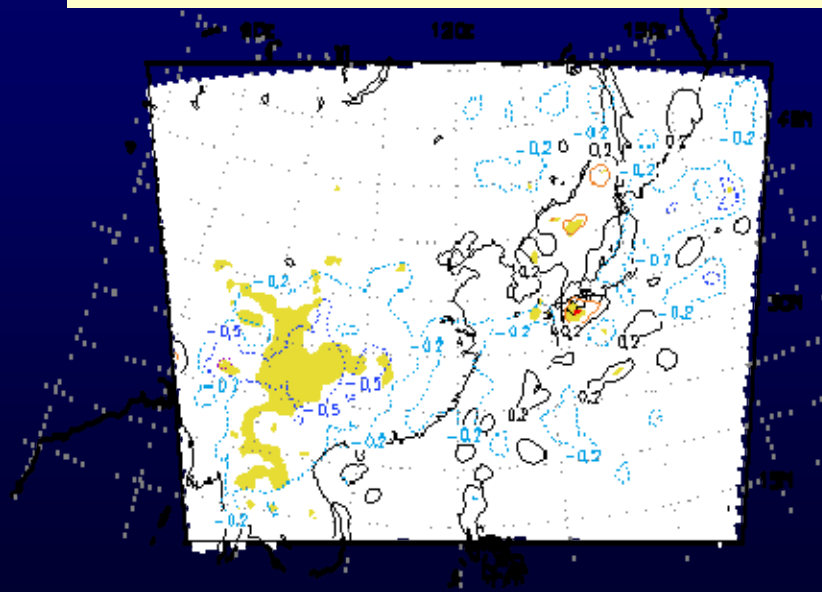
Precipitation, MAM,IND1-CONT



Precipitation, JJA, IND1-CONT



Precipitation, SON, IND1-CONT



Quantifying Weather & Climate Impacts

QWeCI

on health in developing countries

Many important diseases have clear climate drivers, Malaria and Rift Valley Fever:

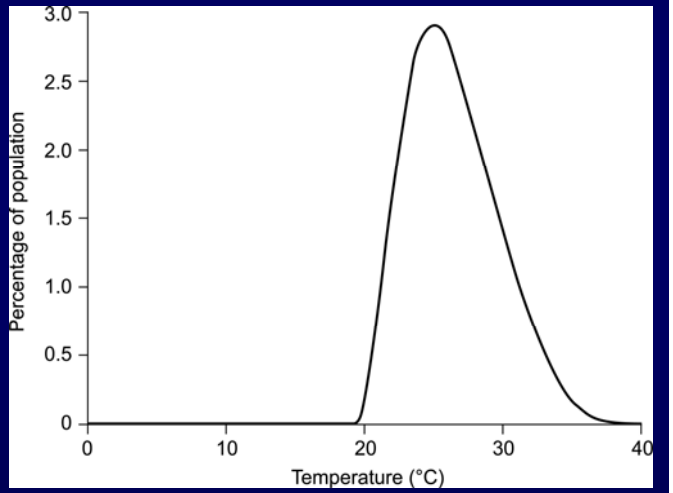
- Rainfall (vector breeding)
- Temperatures (parasite and vector cycles)
- Relative Humidity (vector mortality)

Aim of QWeCI: To examine the potential to produce malaria forecasts and risk projections from monthly to seasonal/decadal timescales

EUFP7 funded project 2010-2014, 13 partners (6 EU, 7 Africa) in **three target regions in Africa:** Senegal, Ghana and Malawi

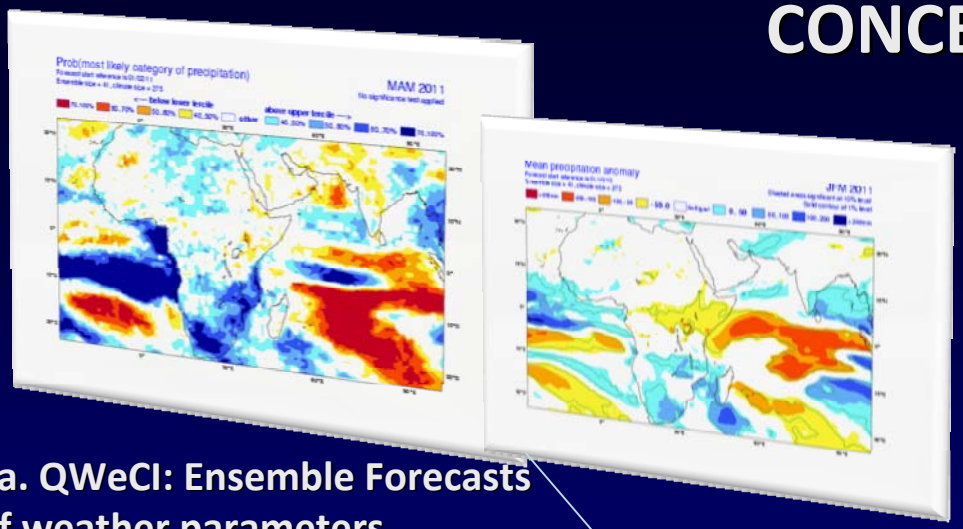
Role of ICTP:

- coauthored proposal - Funding level ~400Keuro
- Bias correction of forecasts
- Disease modelling (statistical and dynamical)
- Long Range WIFI use in data collection & FC dissemination



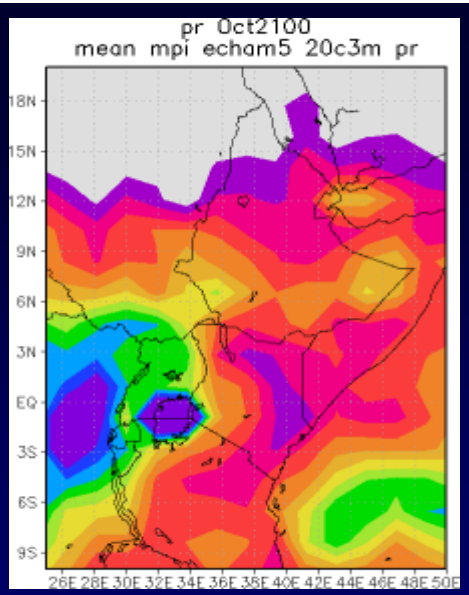
Percentage of mosquito population surviving to infectious stage. Adapted from Jones (2007) in Cui, Parker and Morse (2009)

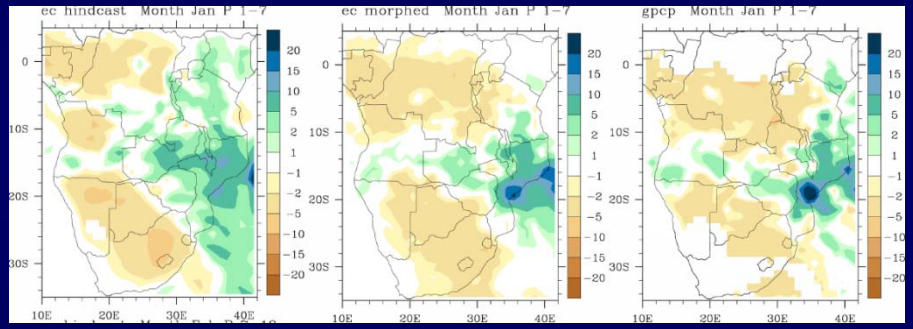
CONCEPT



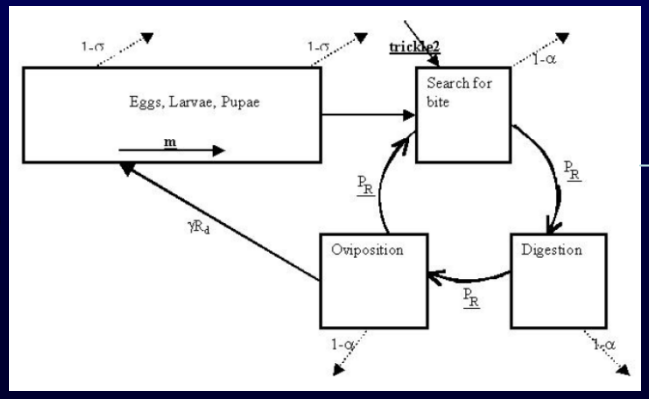
1a. QWeCI: Ensemble Forecasts of weather parameters (T,rain,RH)

1b. HF climate projection of weather parameters (T,rain,RH)

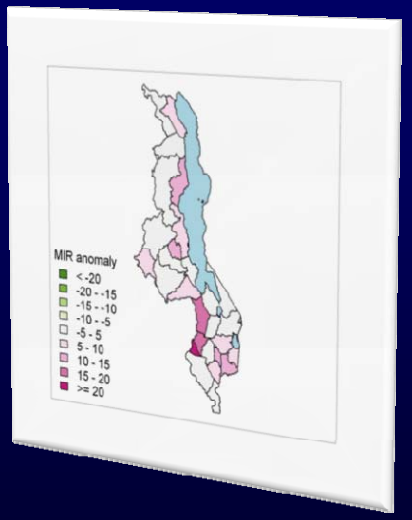




2. Biases corrected statistically and/or dynamically (CDF and EOF approaches)



3. Fed into statistical (ICTP) and dynamical disease models



4. To provide ensemble disease risk maps