Climate change impact assessment and use of downscaled climate information for adaptation planning

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Three communities

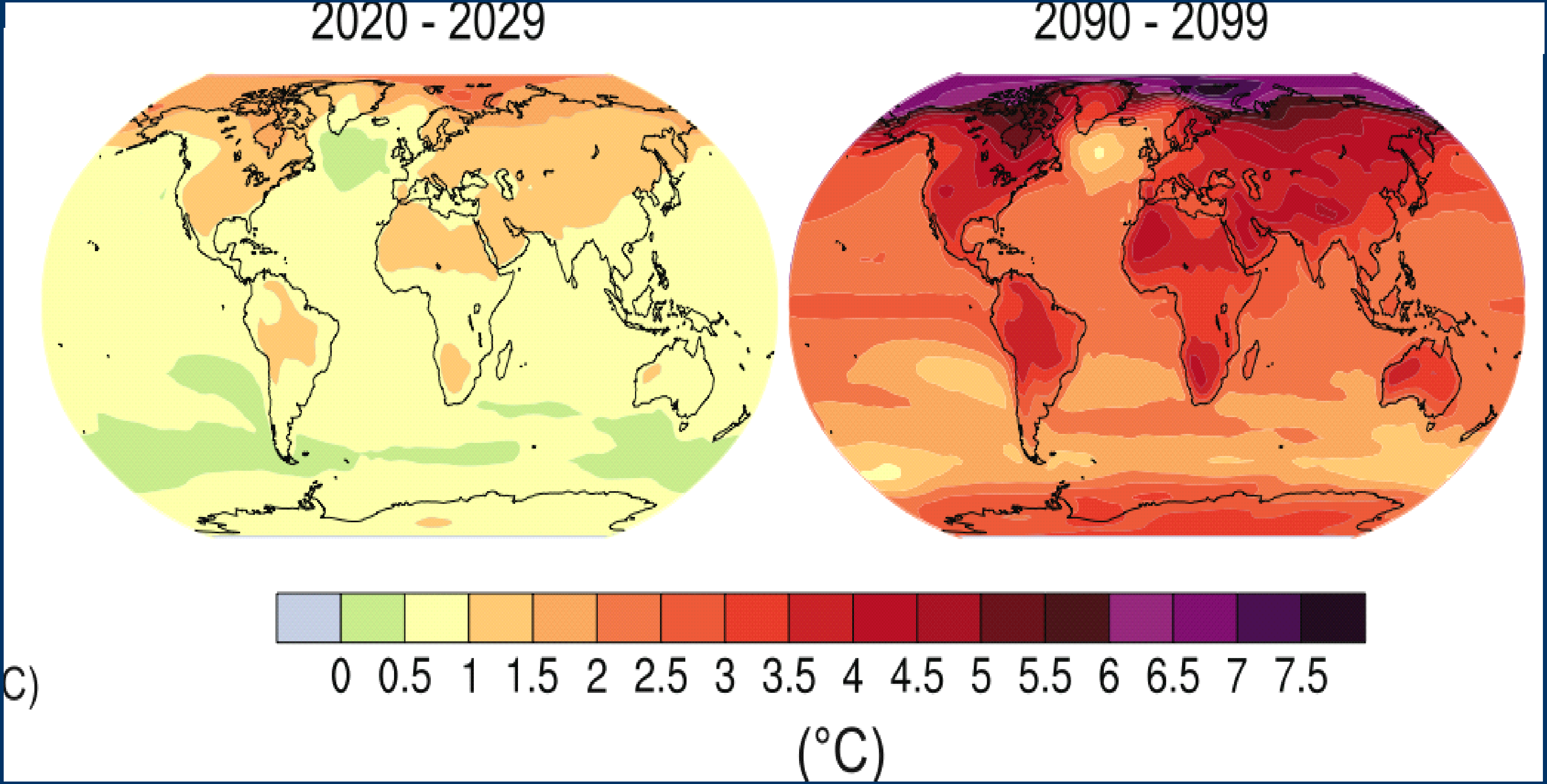
- Climate science community including downscaling modellers
- Impact assessment community (a variety of subjects – water resources, crop, health, etc)
- Climate change adaptation community

Climate science community

- Observations
- Detection and attribution of climate change
- GCM
- RCM

etc

Temperature projection

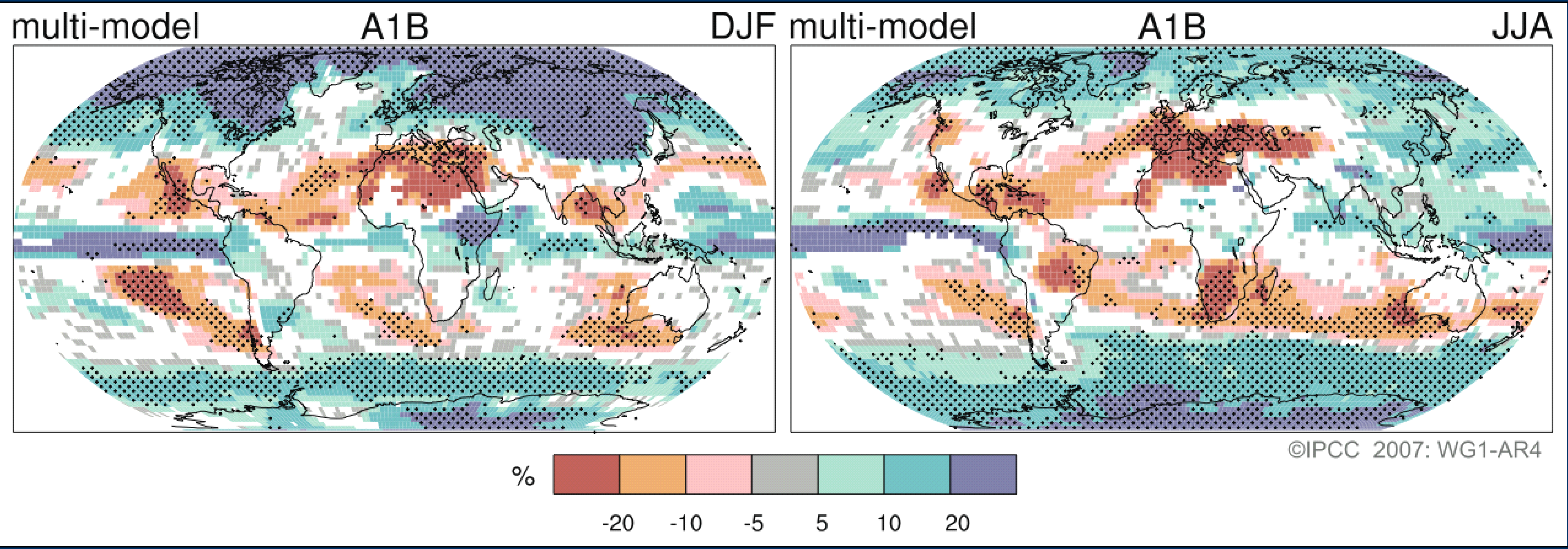


A1B scenario

Projected precipitation changes (%) 2090-2099 vs 1980-1999

NH Winter

NH Summer



IPCC (2007)

Impact assessment community

- **Sectors**
  - Water
  - Crop
  - Pasture
  - Livestock
  - Fisheries
  - Ecosystem
  - Forest
  - Economy
  - Coast
  - Industry
  - Health

  etc

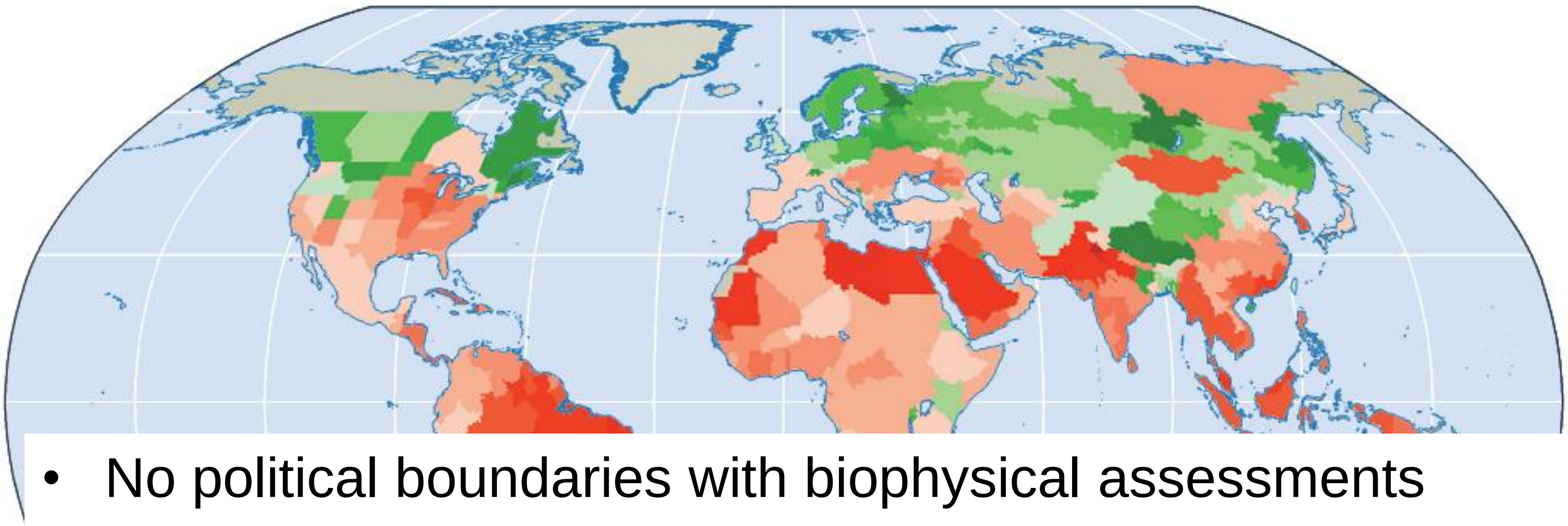
- **Spatial scale**
  - Global
  - Regional
  - National
  - Sub-national
  - Local

- **Temporal scale**
  - Intraseasonal
  - Seasonal
  - 10 years
  - 30 years
  - 50 years
  - 100 years
  - Centuries and beyond

Impact assessment itself is not a goal, but should be conducted with the objective to support robust adaptation planning

Impacts on yields - Global

Map 3.3 Climate change will depress agricultural yields in most countries by 2050 given current agricultural practices and crop varieties

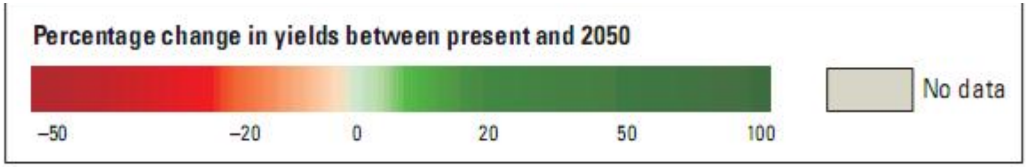


- No political boundaries with biophysical assessments

Or

- One country, one unit

-> not very useful for decision making at national level, sub-national level



Source: Müller and others 2009.

Climate change adaptation community

- Growing fast
- Local to national scales
- Readily available information is at coarse resolutions that are not useful (e.g., global studies)
- Often done without any impact assessments (Stock taking of local good practices -> Choose the best option(s))
- Tend to perceive downscaling is the answer (accuracy/precision)
- Limited understanding of how models work
- Good adaptation planning needs to be based on good understanding of past and future impacts of climate change

Knowledge and Information Gaps

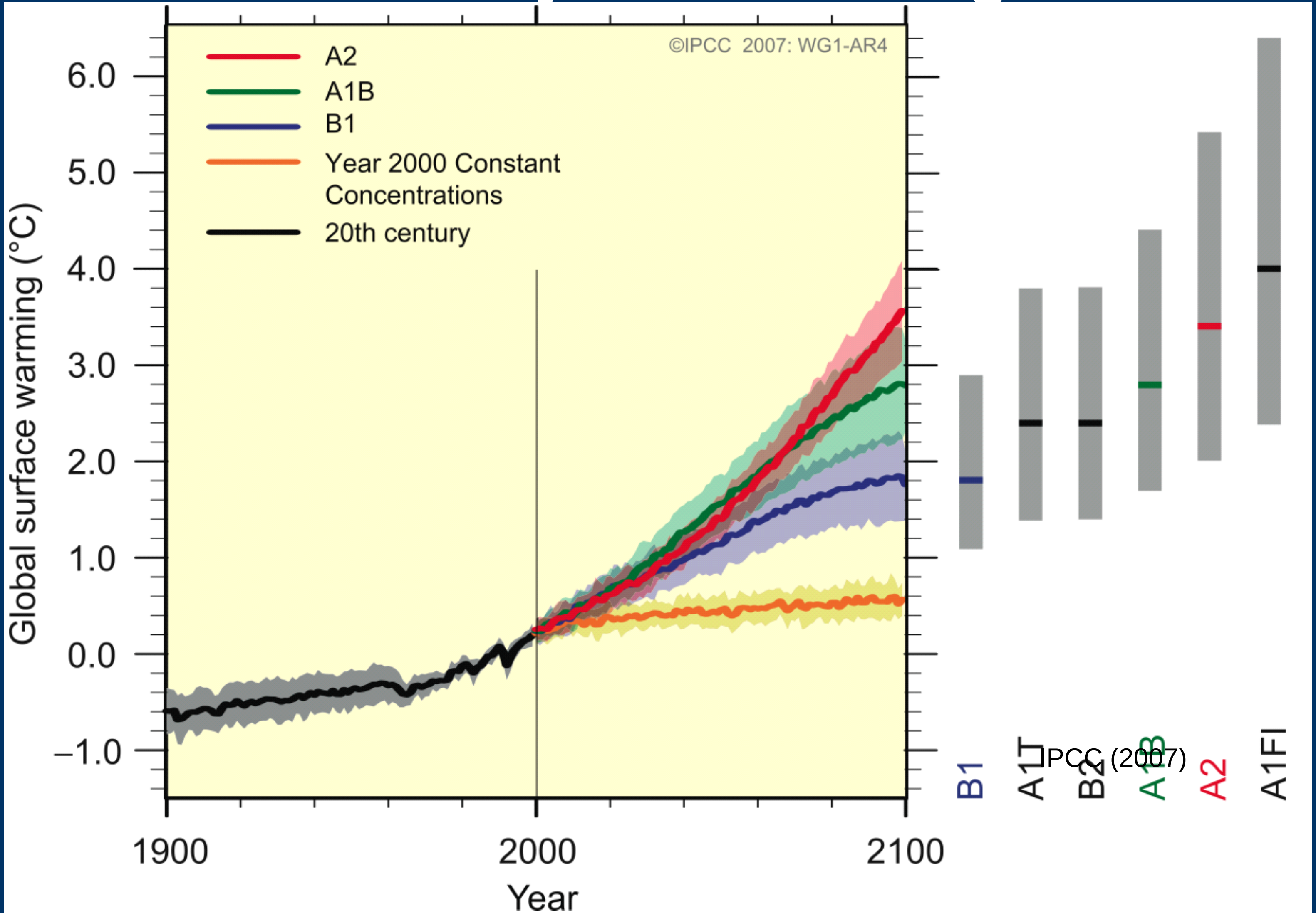
- Useful information for local adaptation planning is not readily available
- Access to climate data (e.g., daily GCM) for use in impact assessment models not easy
- Spatial resolution – finer resolution required
- Interdisciplinary (climate, crop, hydrology, economics, and many more) studies
- Education and efficient research and advisory system
- Policies to support adaptation and provide necessary resources

-> development of an integrated toolbox for climate change impact assessments (climate downscaling plus impact models)

Impact assessments, and subsequent adaptation planning, need to deal with deep uncertainties

- socio-economic changes and future emissions (timing of mitigation)
- imperfect models, lack of scientific knowledge
- natural randomness – climate variability and predictability of climate
- ability to adapt, costs of adaptation, speed of adopting new technologies

Surface warming projections depend on future socio-economic paths and emissions; vary also among models

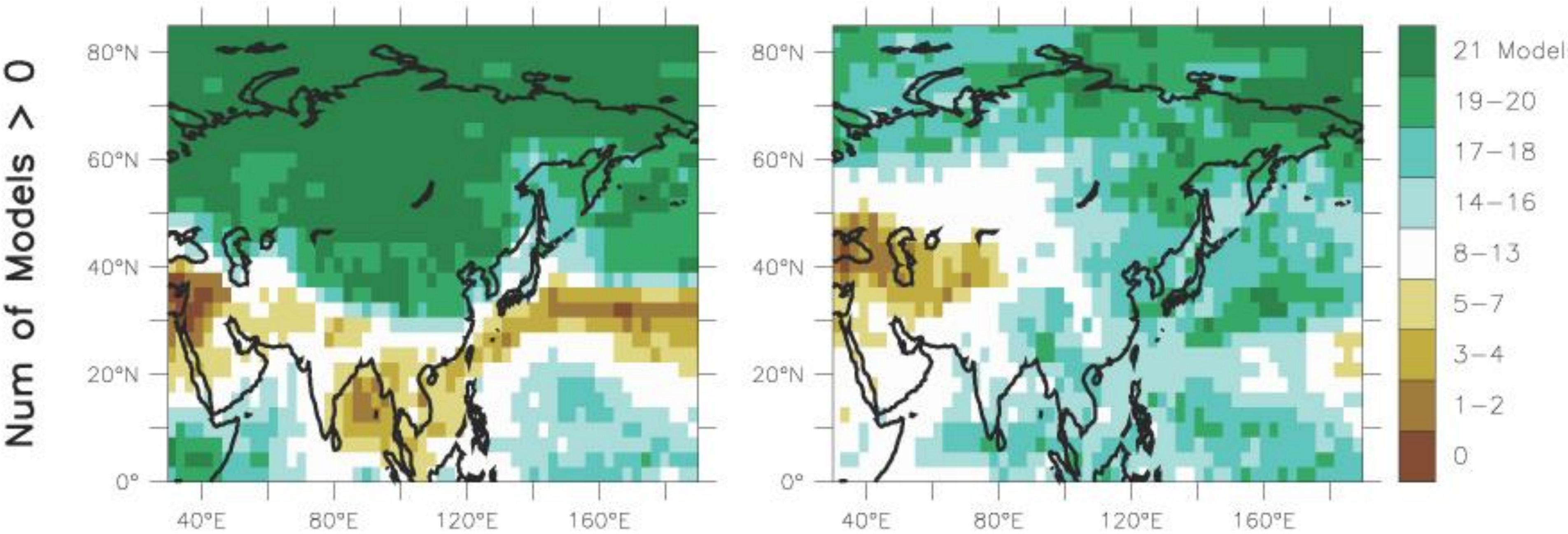


IPCC (2007)

Imperfect scientific knowledge -

e.g., Precipitation projections do not agree among climate models --> It is dangerous to rely on one climate model output or mean value! Need to understand the possible range of future projection from multiple models

Projected *winter* & *summer* precipitation change by 2100



White area: no confidence in projecting future precipitation

Robust adaptation planning from assessments

- Impact and vulnerability assessments should inform robust decision making (rather than optimal strategies) by asking questions such as:

- What is the best strategy that works well against a variety of possible outcomes (unpredictable futures with uncertainties)?

-> robust adaptation that is less sensitive to uncertainties and is flexible for revision as new information becomes available

adapted from WDR 2010, World Bank

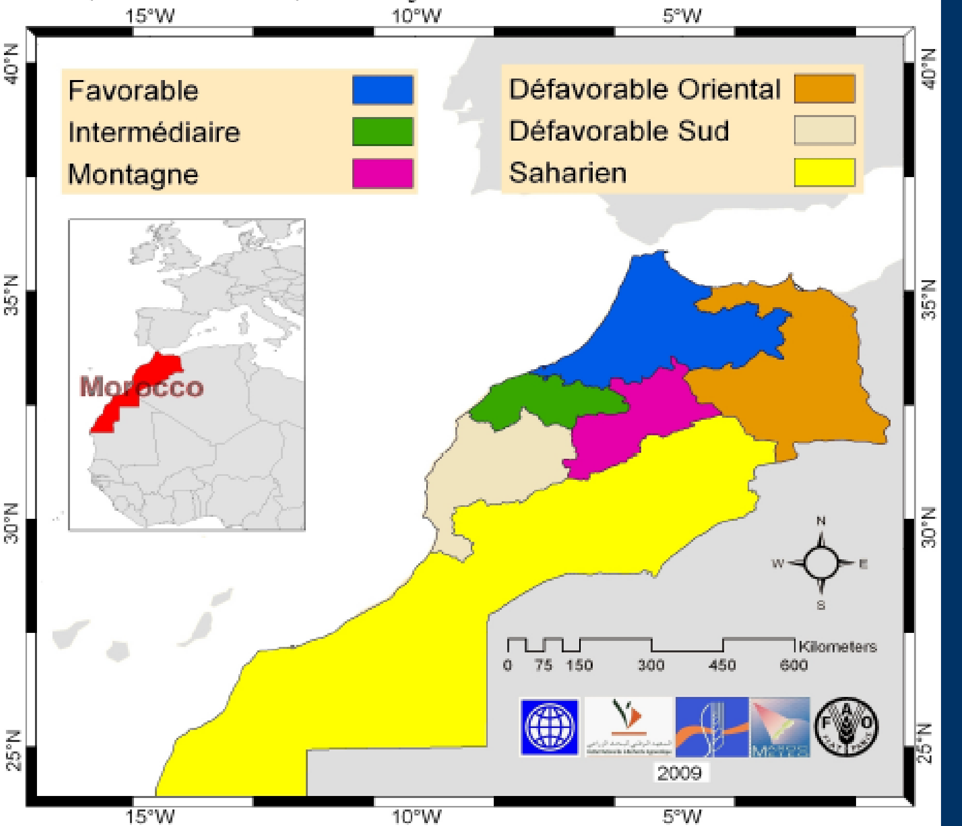
FAO MOSAICC

- **MO**delling **S**ystem for **A**gricultural **I**mpacts of **C**limate **C**hange
- Integrated impact assessment on crop yields, from climate data handling to economic assessment
- Expected outcomes (finalization phase):
  - Methodology
  - Software toolbox
  - Tool documentation
  - Sample data and tutorials

Impact assessments in Morocco

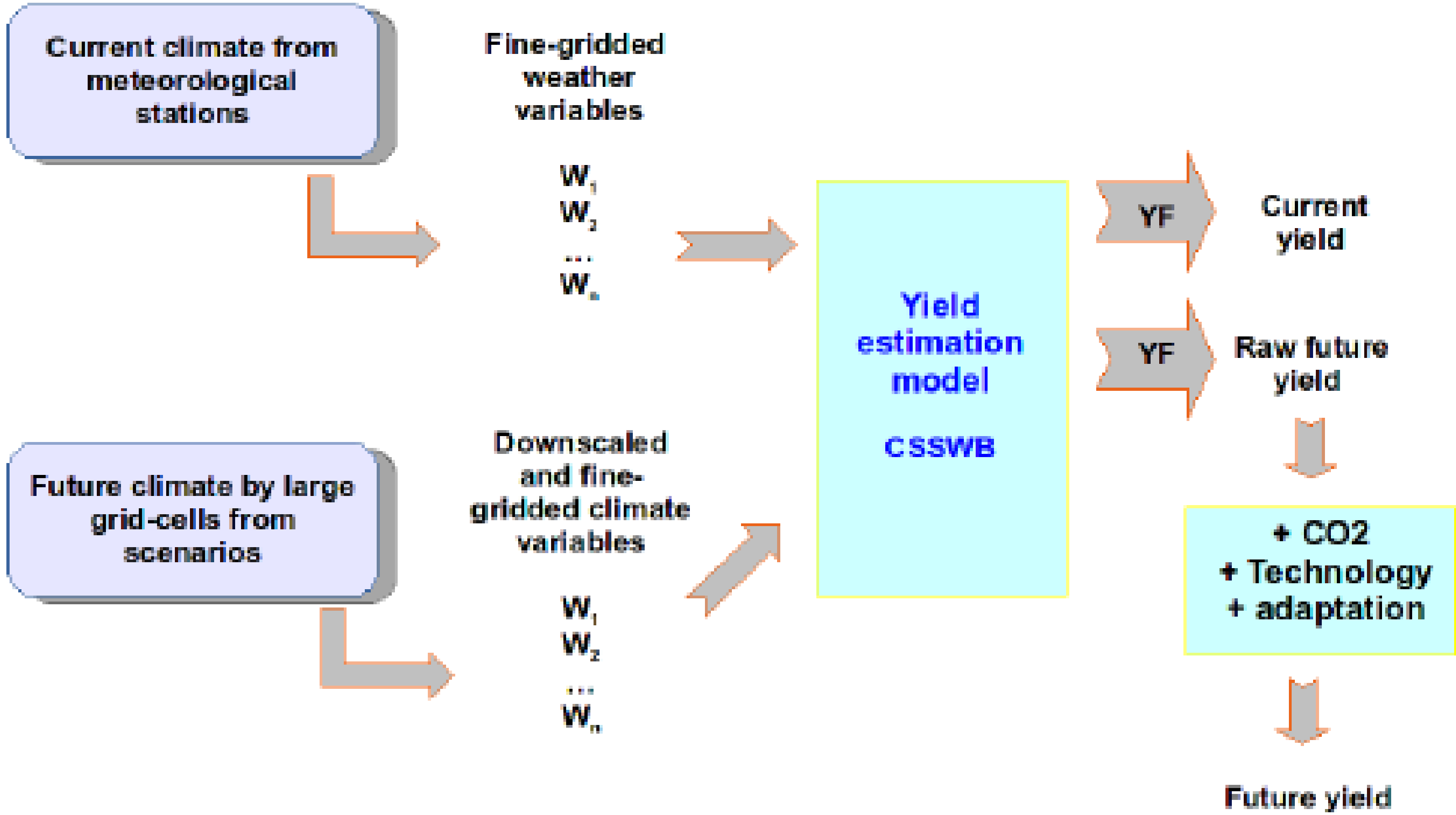
- FAO/World bank study on the impact of climate change on the agricultural sector in Morocco
- Yield projections for:
  - 1 GCM (HadCM3), two scenarios (A2, B2)
  - 4 time horizons: 2000, 2030, 2050, 2080
  - 50 rainfed and irrigated crops
  - 6 agro-ecological zones

Figure 1.01: Major agro-ecological zones of Morocco. FAV: *Favorable*, INT: *Intermédiaire*; DEF-or: *Défavorable oriental*; DEF-sud: *Défavorable sud*; MONT: *Montagne* and SAH: *Saharien*.



Models

Figure 2.01: General methodology and data flow into and from the Crop Specific Soil Water Balance (CSSWB) model; YF: yield function; $W_1 \ldots W_n$ are CSSWB input variables.



Lessons from Morocco

- What water availability for irrigated crops?
- Further improvements:
  - geographical data
  - more sophisticated crop model
  - economic modelling
  - database and data sharing
  - processing time

MOSAICC: Methodology

- 4 Main parts
  - Climate data downscaling and interpolation (data from GCM used by IPCC)
  - Hydrological modelling (STREAM): country-wide evaluation of the water resources
  - Crop modelling (AMS and AquaCrop): yield projections under climate change scenarios using a crop forecasting approach
  - Economic model: dynamic general equilibrium model ("Economically what would be the optimal reaction from the economic agents to changing yields under cc scenarios")

Climate data downscaling

- Global Climate Models (GCM) outputs:
  - Climate simulations under scenarios on the future state of the world/the economy/the atmosphere,
    e.g. SRES scenarios
  - Tmin, Tmax, Rainfall
  - Resolution: daily, 200 to 500km
- Input for crop models:
  - Tmin, Tmax, Rainfall, PET
  - Resolution: daily, 1 to 5km

⇒ Climate data is downscaled (tool based on the DAD Portal of the Santander Meteorology Group, Spain)

⇒ Weather is generated

⇒ PET is computed

Crop modelling

- Simulating the crop response to the weather conditions (observed and generated)
- 2 Models: AgroMetShell and AQUACROP (FAO)
- Inputs: climate data, soil characteristics, crop parameters, management options
- Outputs: according to the model, yield estimations, biomass production, crop water balance variable etc.

Hydrological modelling

- Simulating the water flow accumulation in river catchments
- Model: STREAM (enhanced precipitation – runoff model)
- Inputs: climate data, soil characteristics, land cover, discharge observations
- Outputs: discharges, water accumulation in dams

Economic modelling

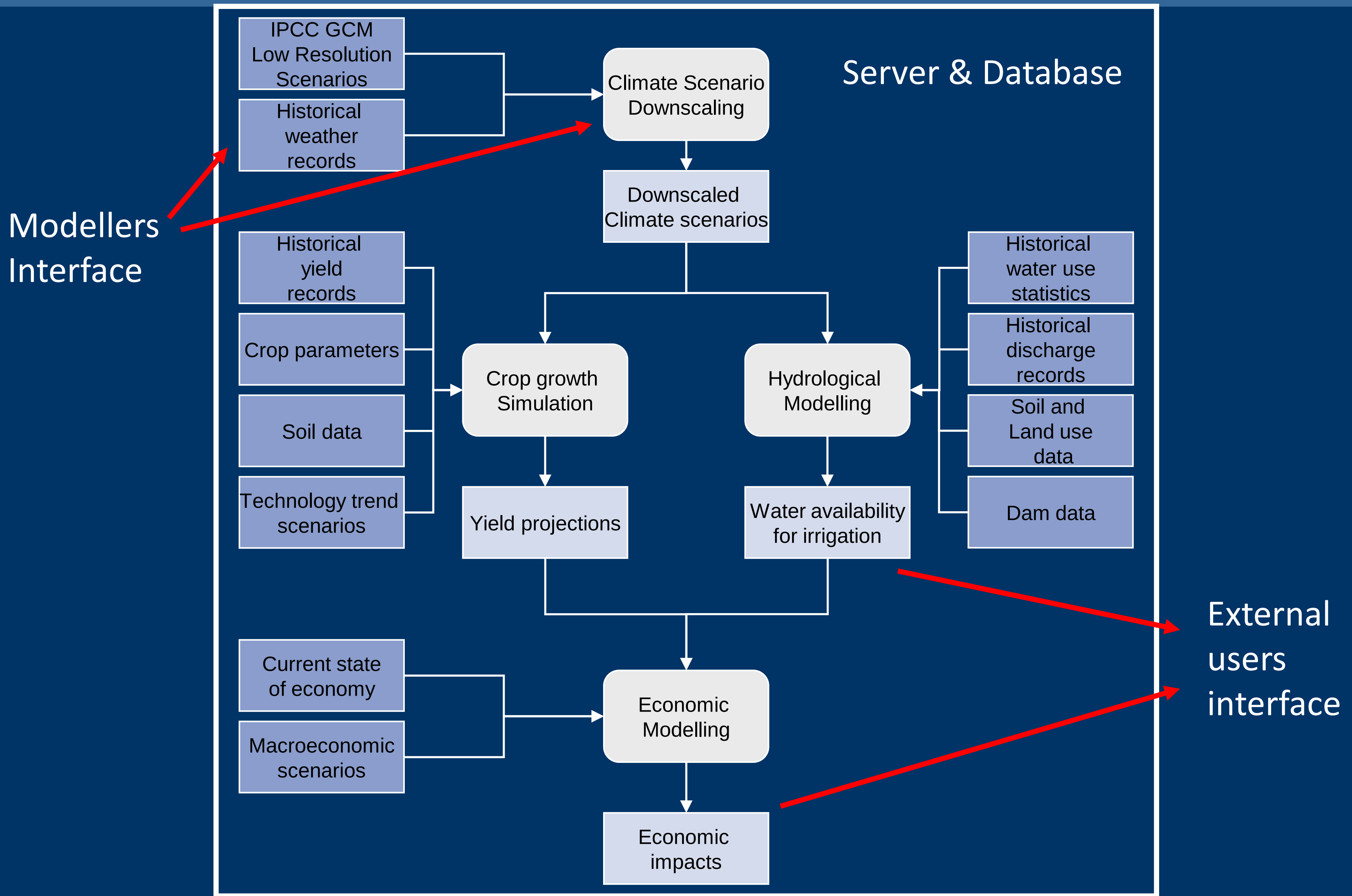
- Models the effects of changing yields on national economies
- Dynamic Computable General Equilibrium Model
- Inputs:
  - specifications of the sets of activities, commodities, institutions and time periods
  - benchmark data for all variables
  - model parameters
  - growth rate of exogenous variables
  - spatial and temporal specifications of the shocks (variations in crop yields due to CC)
- Outputs: values for all endogenous variables (e.g. commodity prices etc.)

Software architecture

- All modelling carried out on a central server
- All models are connected to a central database with which they exchange large amount of data
- Users send jobs through web interfaces

- Use of free software
- Web interfaces solve cross platform issues

Flowchart



Modellers Interface
IPCC GCM Low Resolution Scenarios
Historical weather records
Climate Scenario Downscaling
Server & Database
Downscaled Climate scenarios
Historical yield records
Crop parameters
Soil data
Technology trend scenarios
Crop growth Simulation
Yield projections
Hydrological Modelling
Water availability for irrigation
Historical water use statistics
Historical discharge records
Soil and Land use data
Dam data
External users interface
Current state of economy
Macroeconomic scenarios
Economic Modelling
Economic impacts

Interfaces

Home | Climate | Hydrology | Crop | Economy | Data Browsing | Tools | Documents

Available functions

- Principal Component Analysis
- Data Interpolation
- Planting Dekad
- Results
- Tasks

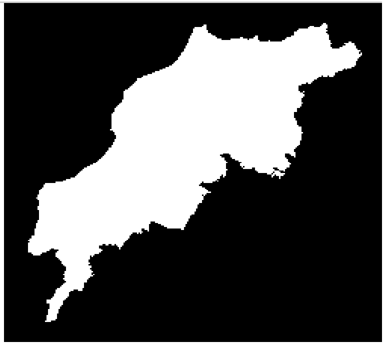
CCI - Climate scenario downscaling

AURELHY Interpolation

Step 2 - Variable and Predictors

The picture on the right shows the study mask calculated during the Principal Component Analysis: the white part represents the area of analysis, while the black one is outside it.

If you noticed any artefact in the image, it would be a good idea to check the data used as input in the Principal Component Analysis, because usually it means there are some errors in the administrative level definition.



Variable	Precipitation / Temperature			
Predictors	PC #1	show	PC #2	show
	PC #3	show	PC #4	show
	PC #5	show	PC #6	show
	PC #7	show	PC #8	show
	PC #9	show	PC #10	show
	Distance from the sea	show	Latitude	
	Longitude		Elevation	

Variogram Parameters

Sill of the variogram model component	1
Model type	Sph
Range of the variogram model component	10
Nugget component of the variogram	1
Anisotropic model	No / Yes
Direction	30
Anisotropy ratio	0.5

TOOLS

Correlation, Regression and Variogram	run tools on selected variable and predictors

Restart | << Previous | Next >>

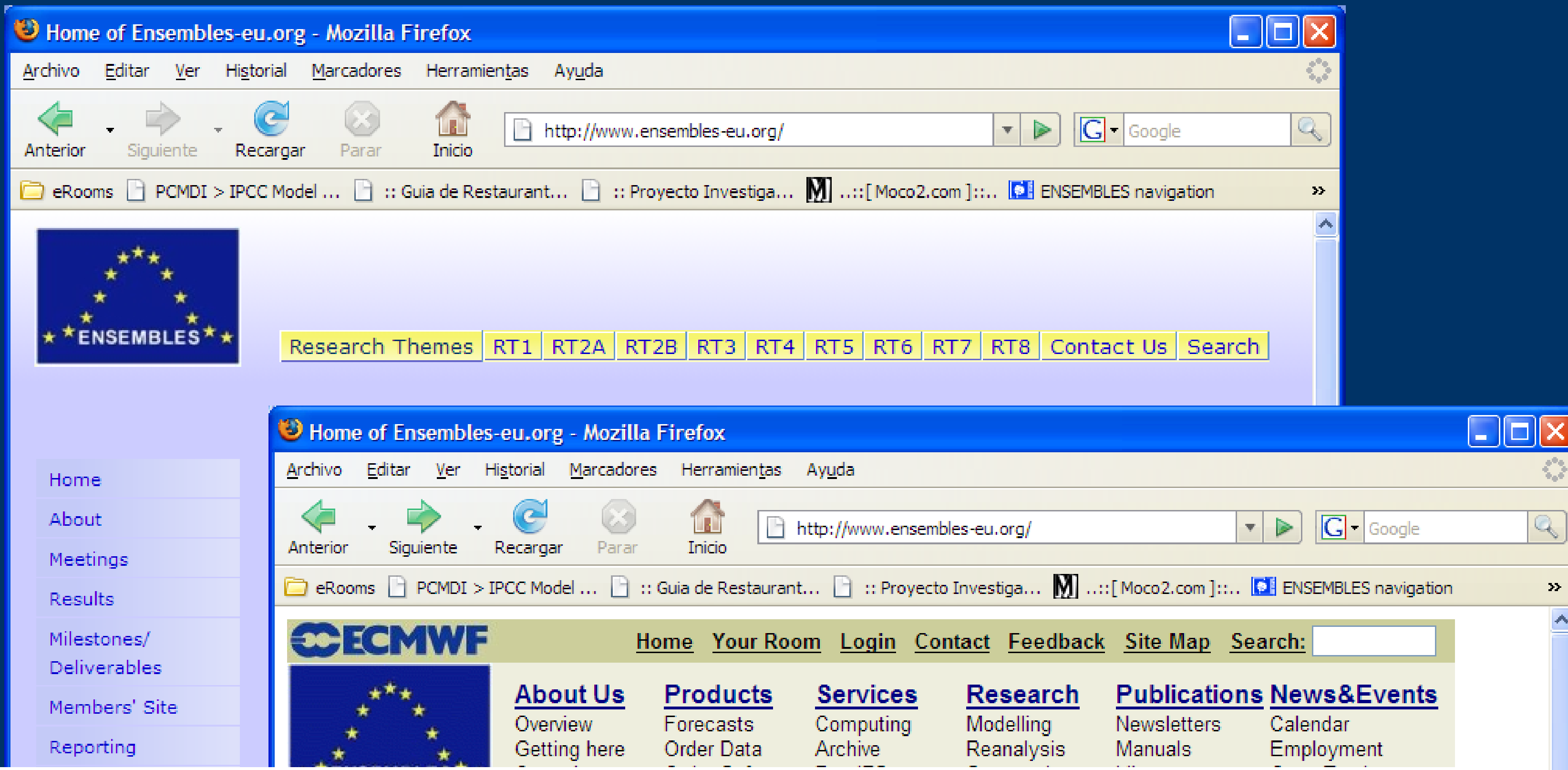
We chose statistical downscaling over dynamical downscaling…

- Computational resources requirements

-> multiple GCMs, multiple emission scenarios

- Grids or stations scale (impact assessments often use station weather observations and crop yields)
- Weather generator
- Portability of tools
- Capacity building

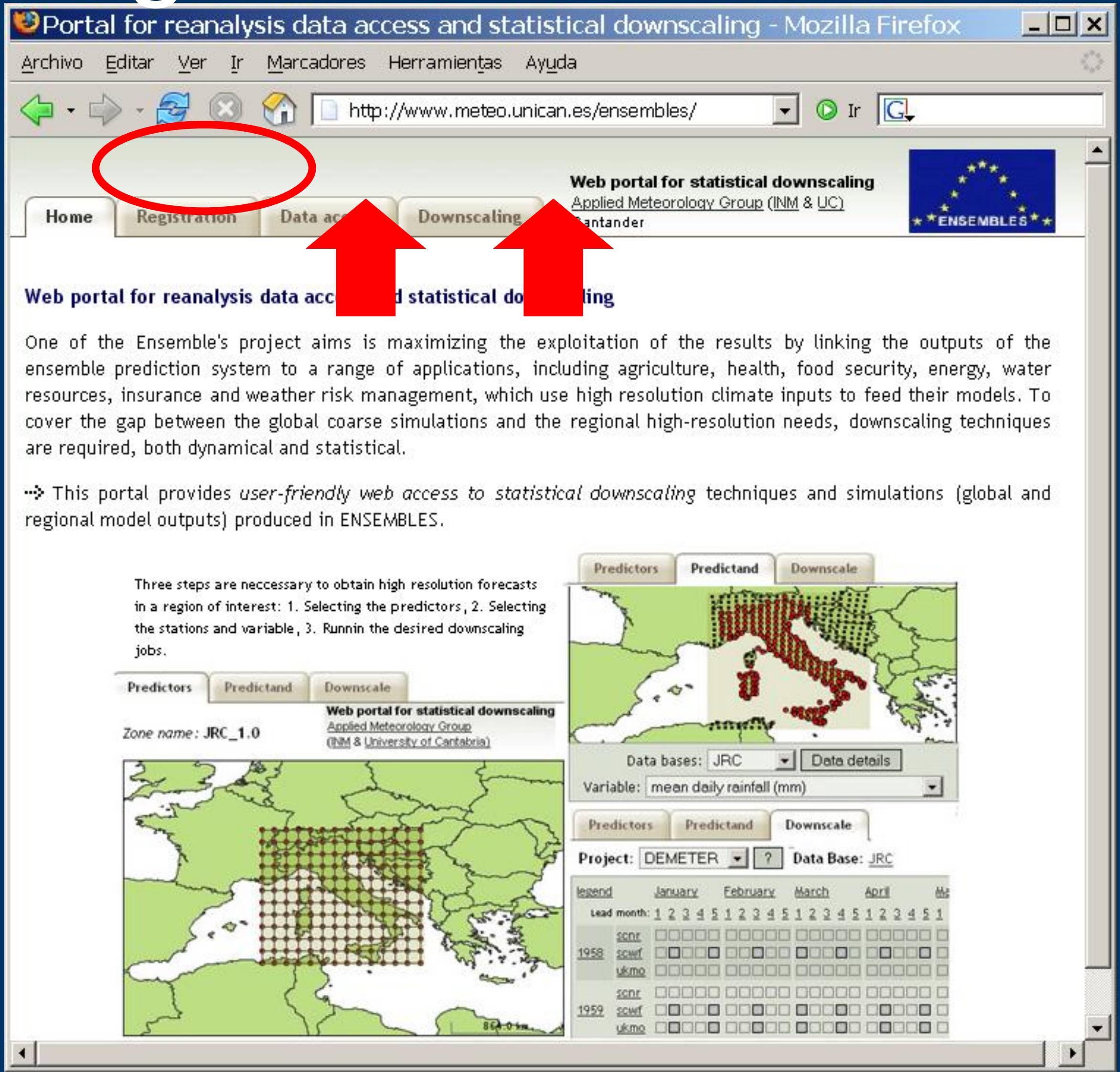
ENSEMBLES http://www.ensembles-eu.org



There is a need of friendly interactive tools so users can easily run interpolation/downscaling jobs on their own data using the <u>existing</u> downscaling techniques and simulation datasets.

-> ENSEMBLES Downscaling Portal

The portal has been upgraded for integration with MOSAICC



Statistical Downscaling in MOSAICC

- All available daily GCM data from CMIP3 archive) for two time-slices (2046-2065 and 2081-2100) with a possibility to include CMIP5 (RCP4.5 scenario) in 2011.
- Analog and regression, and weather types
- Any user-defined area in the world
- Spatial resolution – both gridded and point at station observation locations with ability to upload and use user-provided station data
- Temporal resolution – daily and 10-daily
- Variables – precipitation, maximum and minimum temperatures

Statistical Downscaling: Methods

- **Transfer-Function Approaches (generative)**
- **Non-Generative Algorithmic Methods**

	Advantages	**Shorcomings**
Linear Regression	Very simple Easy to interpret	Linear assumption Spatially inconsistent Selection of predictors
Neural Networks	Nonlinear “Universal” interpolator	Complex blackbox-like Optimization required Selection of predictors
Analogs	Nonlinear Spatial consistency	Algorithmic. No model. Difficult to interpret
Weather Typing	Nonlinear Easy to interpret Spatial consistency Adaptations for EPS	Algorithmic & Generative Loss of variance Problem with borders (for deterministic forecasts)

Variability of Statistical Downscaling

The variability of the results obtained using different types of downscaling models in some studies suggests the convenience of using as much statistical downscaling methods as possible when developing climate-change projections at the local scale.

Table I. Abbreviations, names and descriptions of the seven indices of daily precipitation used in the study

Index	Name	Description
pav	Mean precipitation	Average precipitation on all days
pint	Precipitation intensity	Average precipitation on days with >1 mm
pq90	Precipitation 90th percentile	90th percentile of precipitation on days with >1 mm
px5d	Maximum 5-day precipitation	Maximum precipitation from any five consecutive days
pxcdd	Maximum consecutive dry days	Maximum number of consecutive days with <1 mm
pfl90	Fraction of total from heavy events	Fraction of total precipitation from events > long-term 90th percentile
pnl90	Number of heavy events	Number of events > long-term 90th percentile

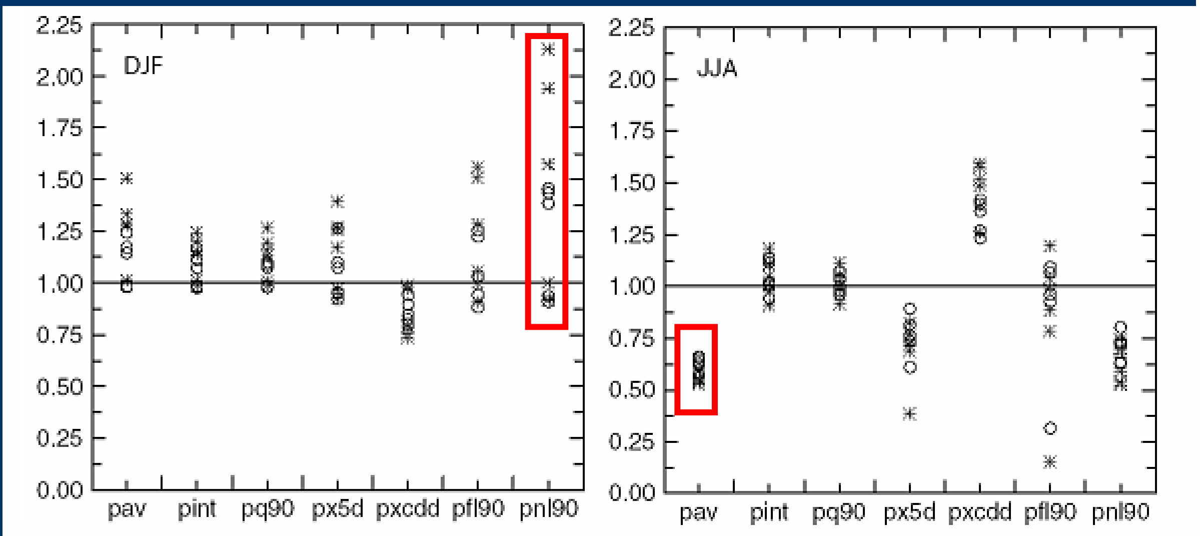


Figure 10. Change in indices using six downscaling models for Oxford under A2 (asterix) and B2 (circles) scenarios

For some indices and seasons, the spread is very small (e.g. pav in JJA) but for others it is much larger (e.g. pnl90 in DJF). Importantly, for each index the variability among models is of the same order of magnitude as the variability between the two scenarios.

DOWNSCALING HEAVY PRECIPITATION OVER THE UNITED KINGDOM: A COMPARISON OF DYNAMICAL AND STATISTICAL METHODS AND THEIR FUTURE SCENARIOS

(HAYLOCK *ET AL*. 2006)

Country-scale implementation of MOSAICC (tentative)

- Requirements:
  - host institution (e.g. national met office)
  - experts from relevant institutions: agrometeorologists, hydrologists, economists
- System installation (1 month):
  - server and clients
  - software setup

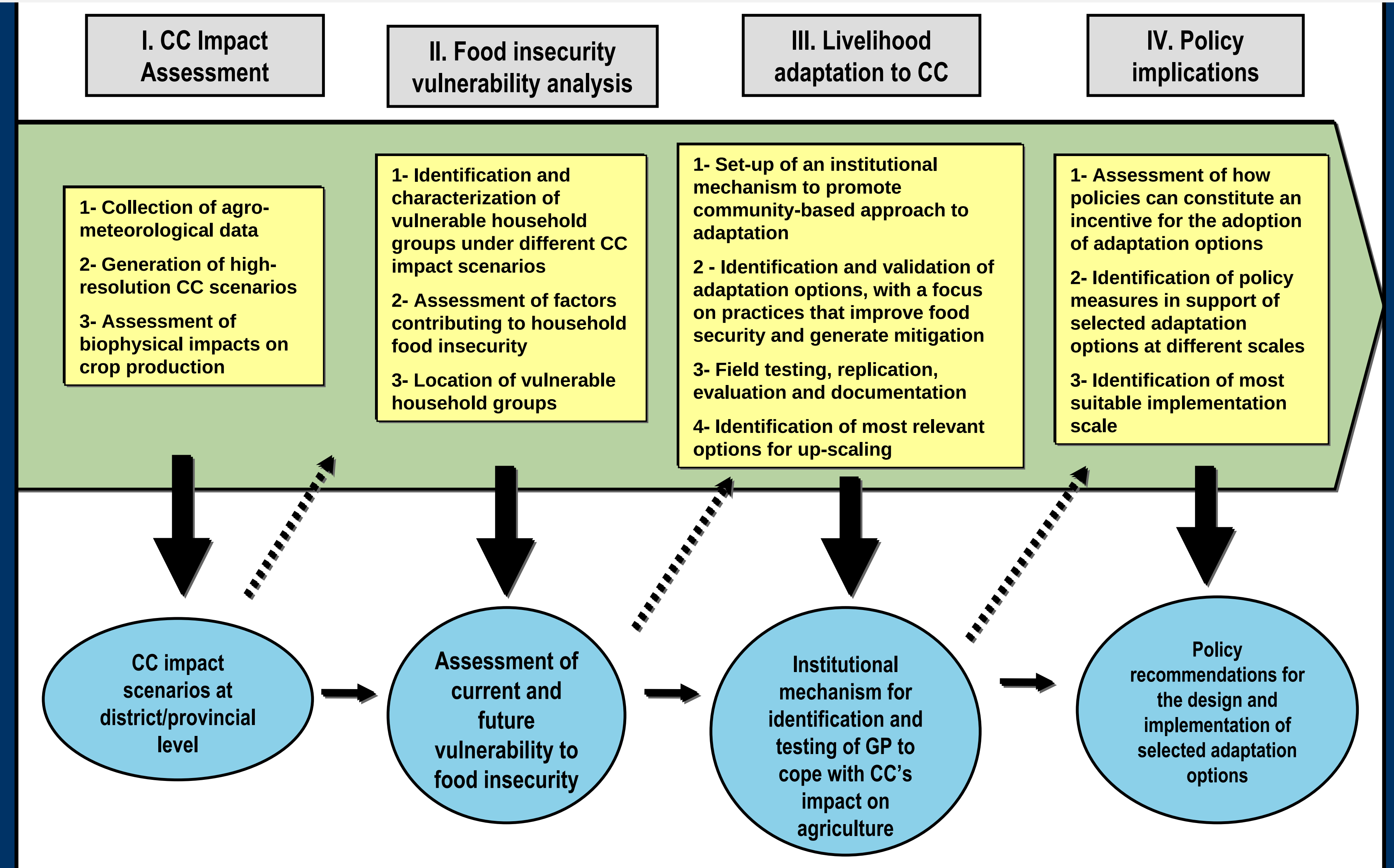
Country-scale implementation of MOSAICC (tentative)

- Training (2 months):
  - General workshop on MOSAICC
  - Training on each component (climate-hydrology-crop-economics) (~1 week each)
  - Capacity building for system maintenance
- Impact study (6-12 months):
  - Data collection
  - Support from our partners

Future Work

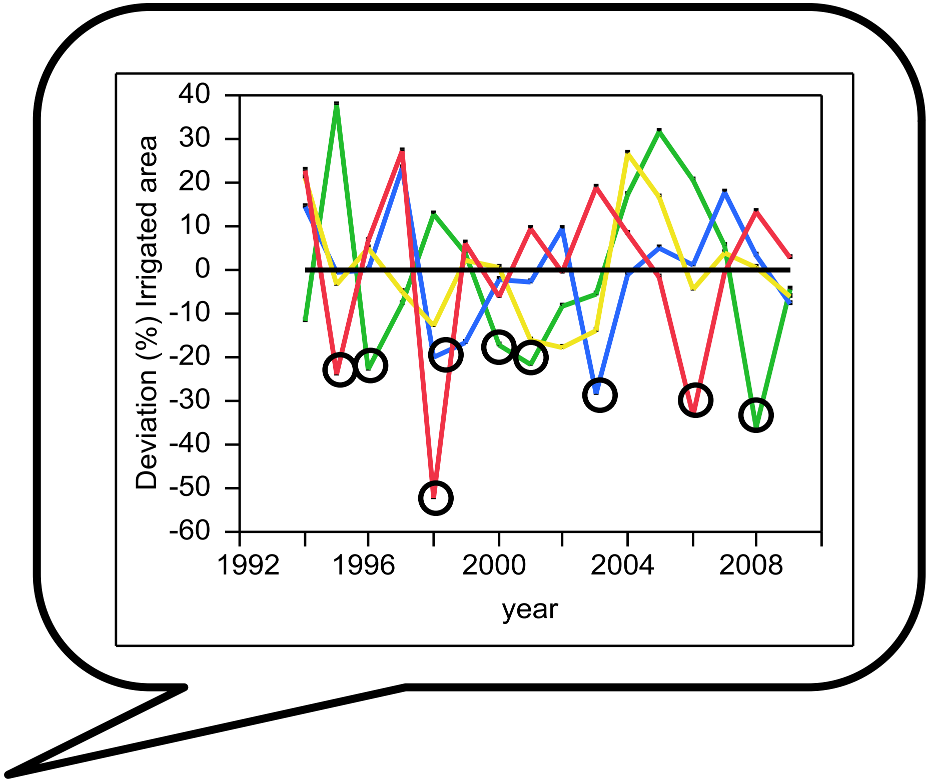
- Link MOSAICC closely with adaptation projects --- design of impact assessment studies to support adaptation
- Pilot implementation of MOSAICC in Morocco and a few countries

A framework for bridging impact assessment and livelihoods' adaptation approaches to strengthen household food security under climate change



Rice production loss in Bicol region of the Philippines and extreme events

	Rice			
Year	Qua 1	Qua 2	Qua 3	Qua 4
1994				
1995				Rainfall
1996	Rainfall			
1997				
1998		Drought		Rainfall Wind
1999				
2000	Rainfall			
2001				
2002				
2003		Drought		
2004				
2005				
2006				Wind
2007				
2008	Rainfall			
2009				



For downscaling scientists…

- Outreach to impact modellers and adaptation practitioners
- Spatial scale that impact models require
- Communicate uncertainties and appropriate use of model outputs
- Extreme events – link with disaster risk management
- Time scale up to 20 years at most

www.fao.org/climatechange