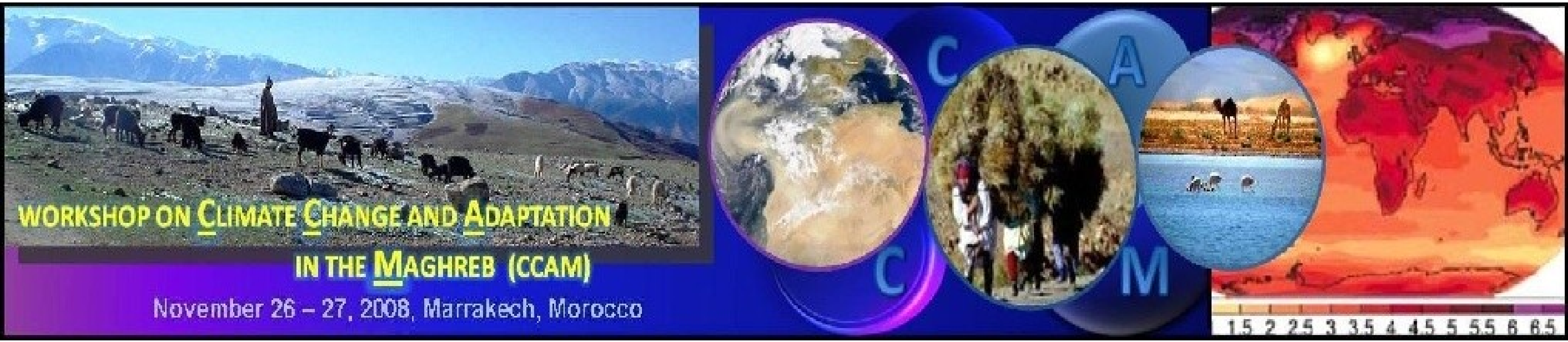
Modeling Tradeoffs between Climate Change Adaptation and Economic Development - Computable General Equilibrium Approach

Eihab Fathelrahman

Dana L. Hoag



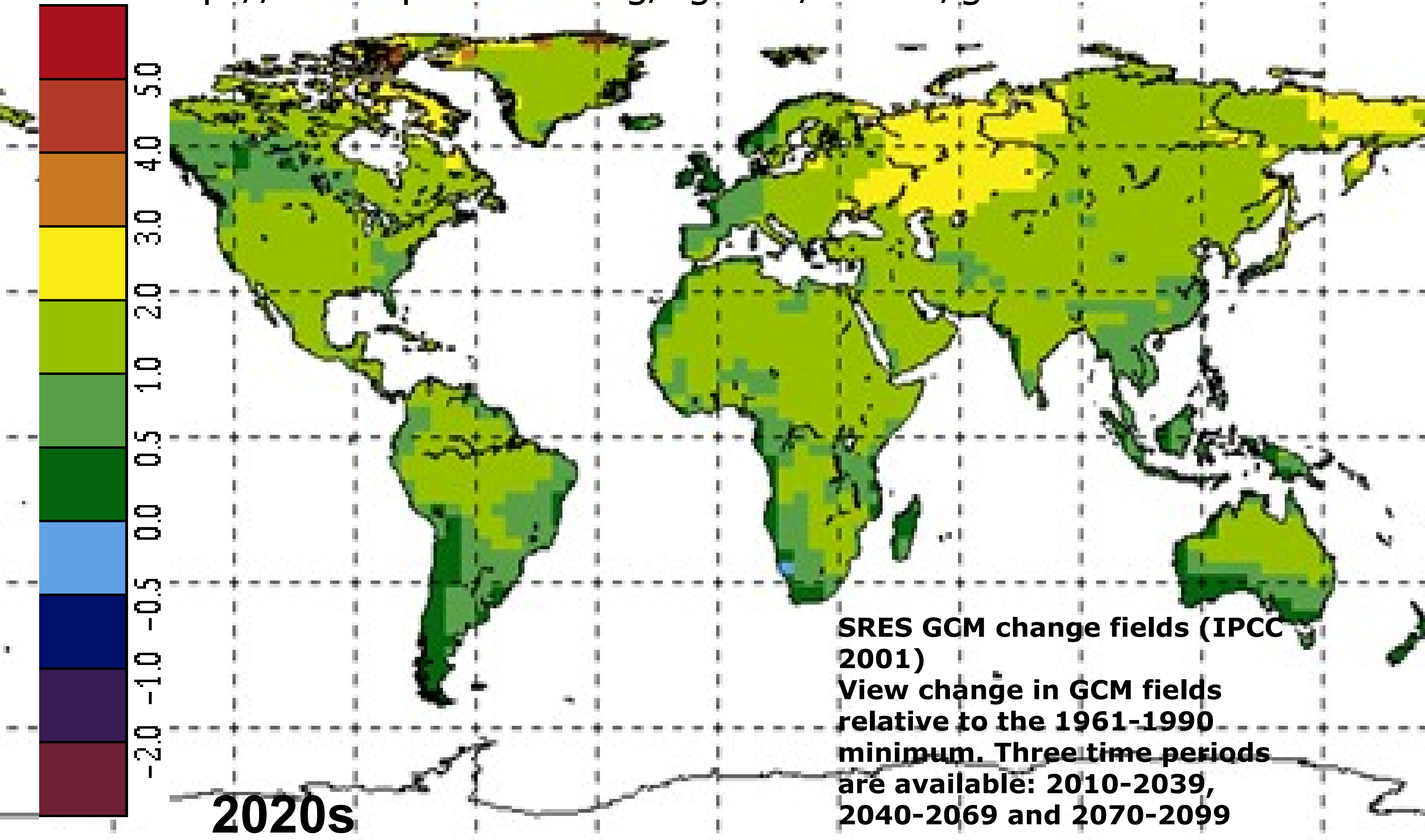
Outline

- General Circulation Model results
- Regional and Site specific results are possible
- Maghreb regional and site specific data are also possible
- Why hydrological modeling
- Integration of surface and groundwater hydrological model
- Economic data source and modeling
- Integrated hydro, climatic, and socio-economic (CGEs)
- Conclusions

General circulation models/ HadCM3/B2a Scenario* minimum temp. degree change over time

http://www.ipcc-data.org/cgi-bin/ddcvis/gcmcf

Minimum temp



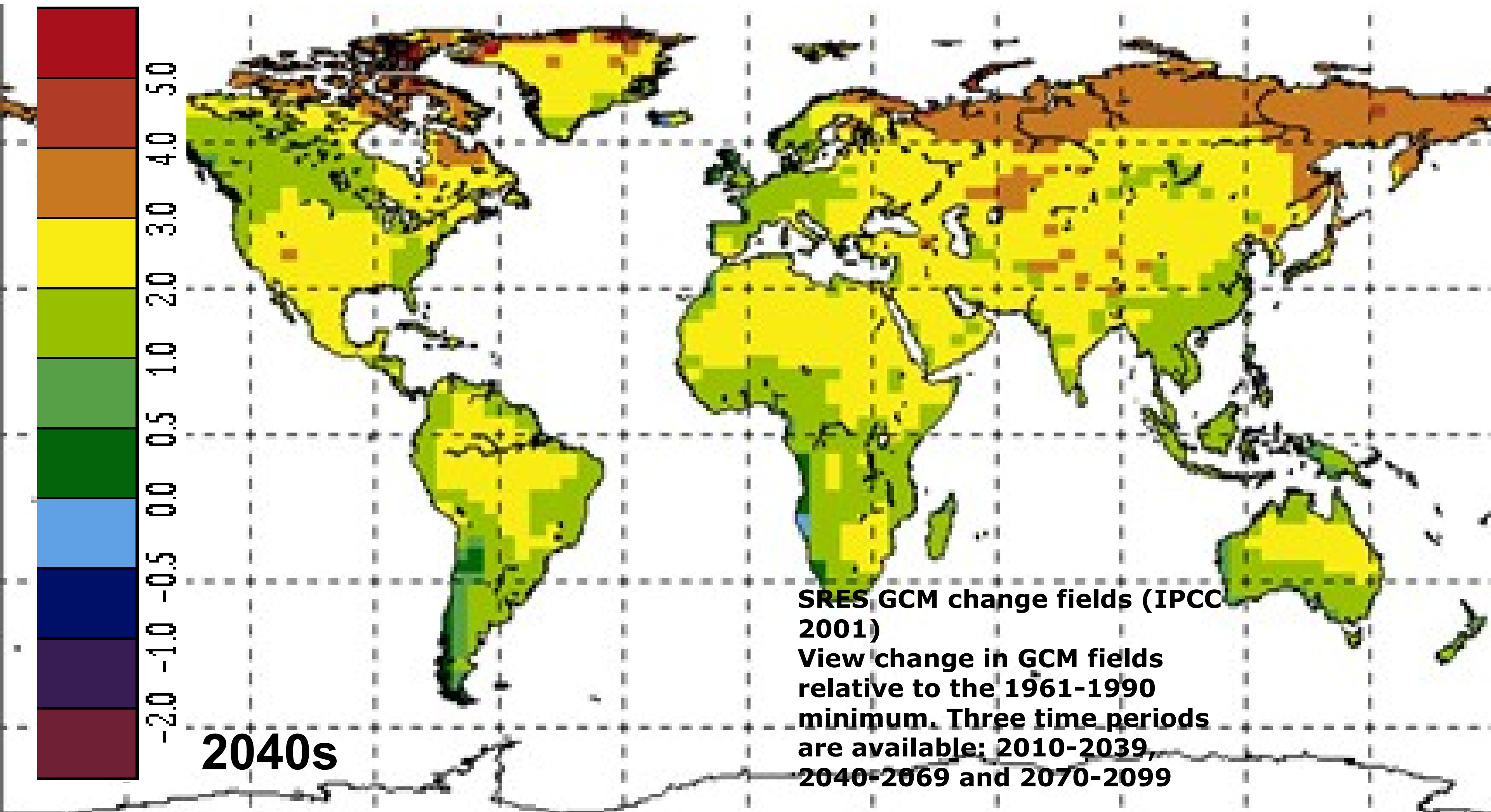
SRES GCM change fields (IPCC 2001)
View change in GCM fields relative to the 1961-1990 minimum. Three time periods are available: 2010-2039, 2040-2069 and 2070-2099

***UK Hadley Centre for Climate Prediction and Research**

January to December **degree (C)**

General circulation models/ HadCM3/B2a Scenario* minimum temp. C degree change over time

http://www.ipcc-data.org/cgi-bin/ddcvis/gcmcf

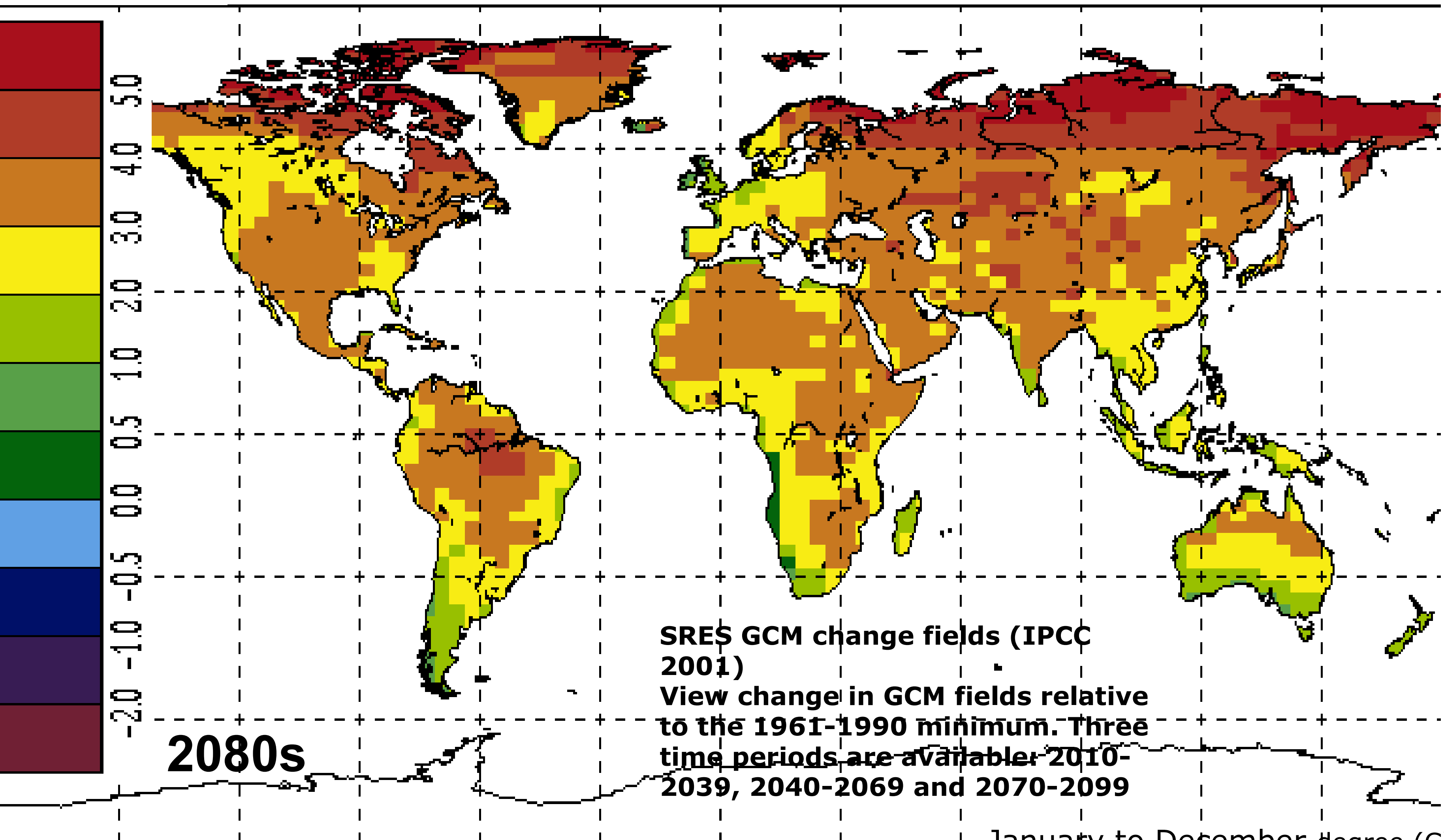


*UK Hadley Centre for Climate Prediction and Research

January to December degree (C)

General circulation models/ HadCM3/B2a Scenario* minimum degree change over time

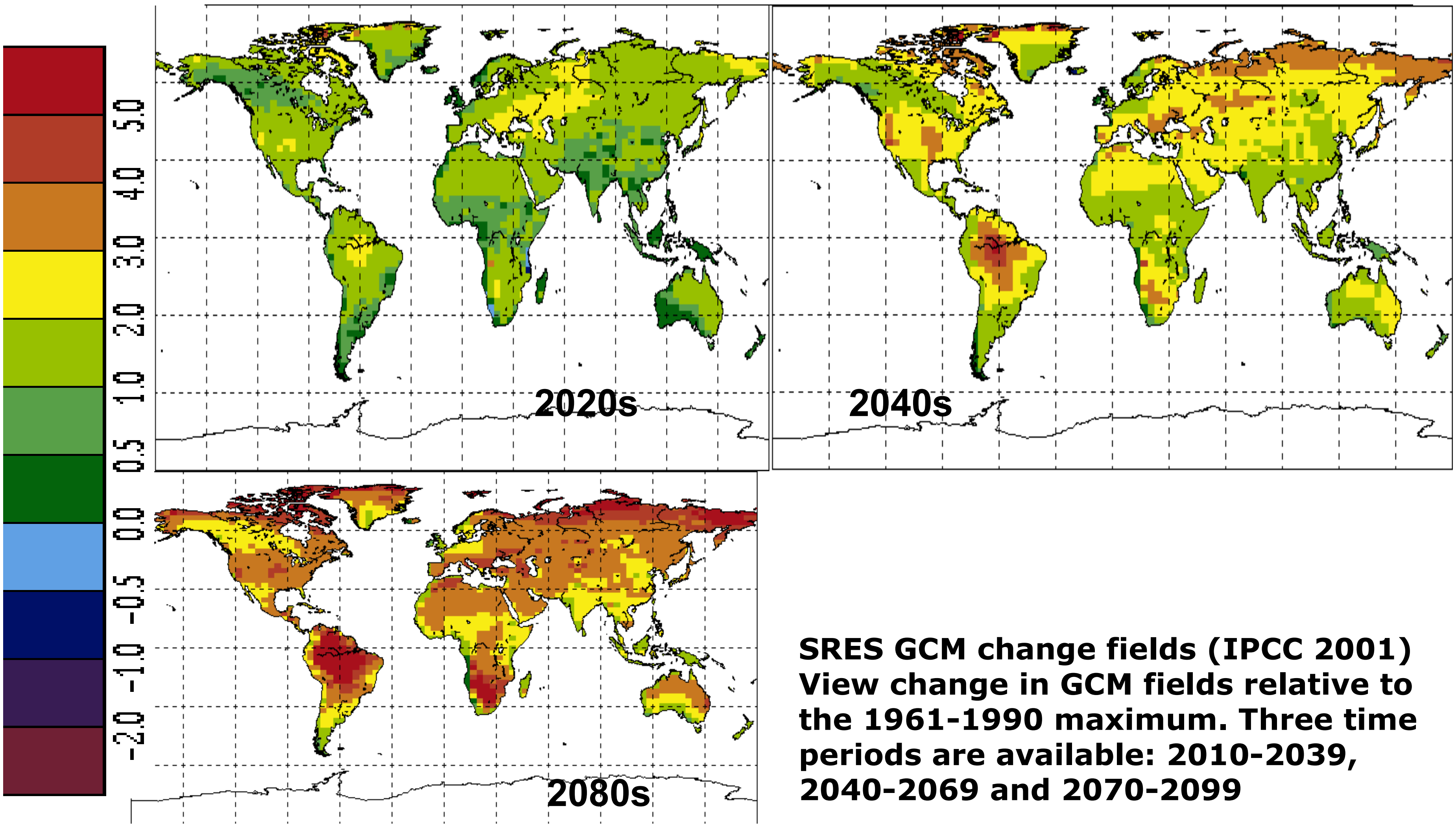
http://www.ipcc-data.org/cgi-bin/ddcvis/gcmcf **Minimum temp.**



* UK Hadley Centre for Climate Prediction and Research

General circulation models/ HadCM3/B2a Scenario* Maximum Temp. Change over time

http://www.ipcc-data.org/cgi-bin/ddcvis/gcmcf **Maximum temp.**

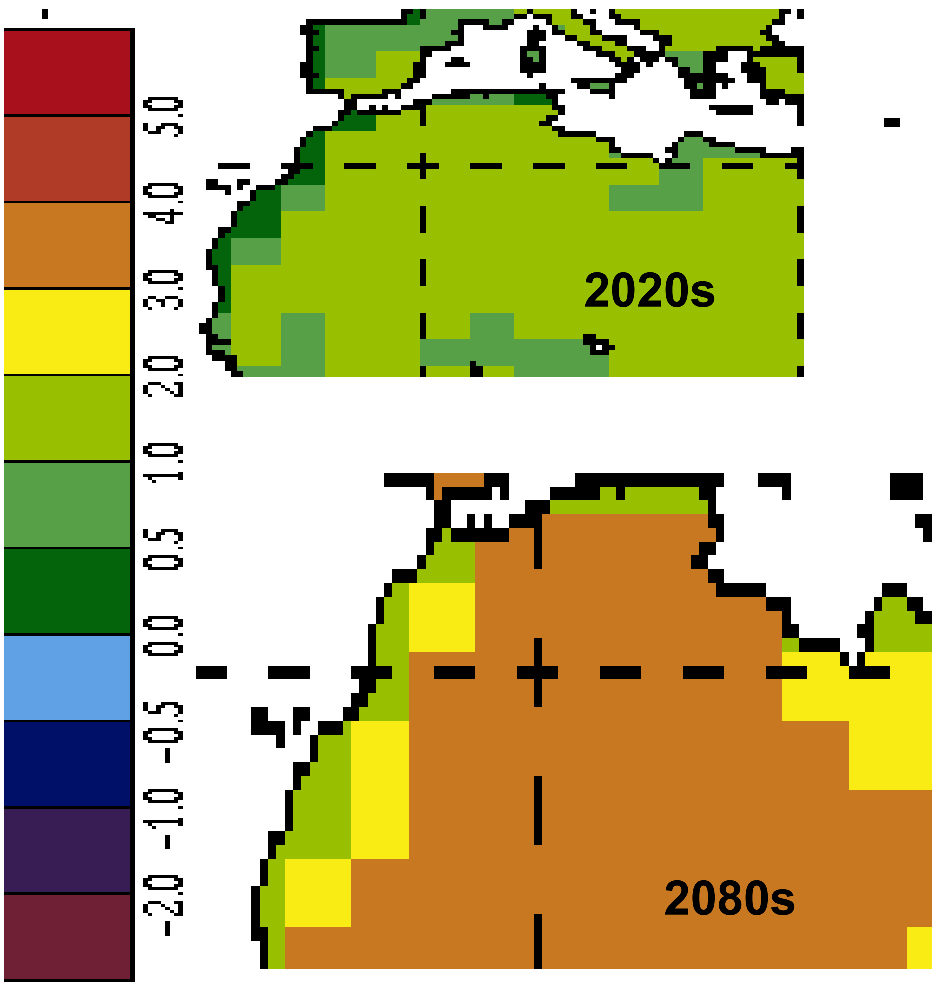


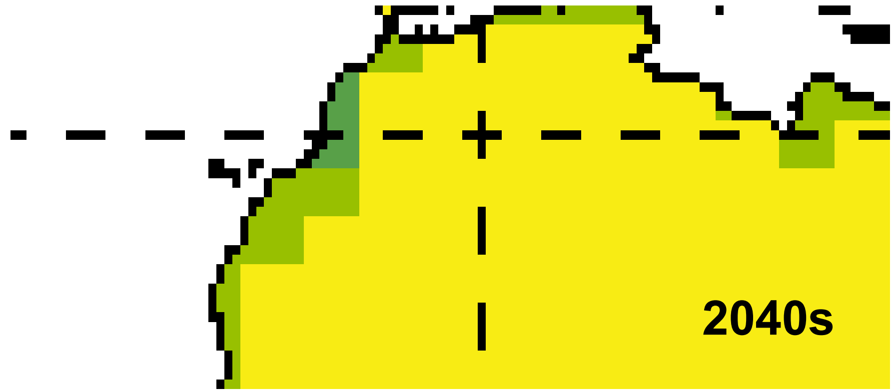
SRES GCM change fields (IPCC 2001) View change in GCM fields relative to the 1961-1990 maximum. Three time periods are available: 2010-2039, 2040-2069 and 2070-2099

*UK Hadley Centre for Climate Prediction and Research

General circulation models/ HadCM3/B2a Scenario* minimum degree change – Maghreb over time

Minimum temp.





January to December degree (C)

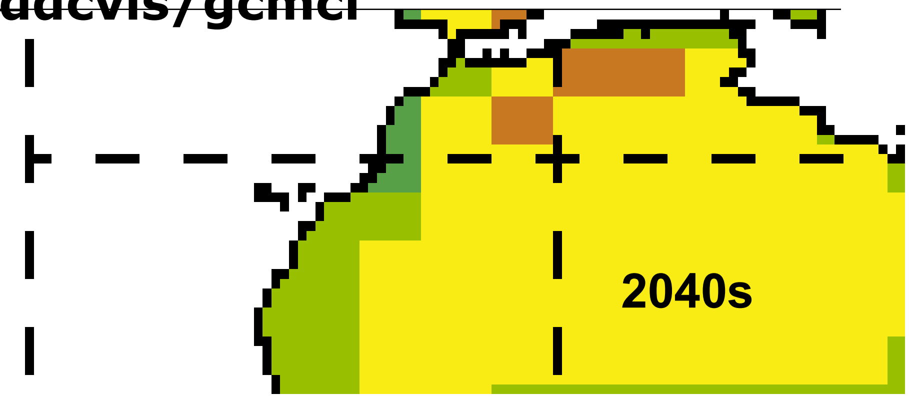
SRES GCM change fields (IPCC 2001)
View change in GCM fields relative to the 1961-1990 minimum. Three time periods are available: 2010-2039, 2040-2069 and 2070-2099

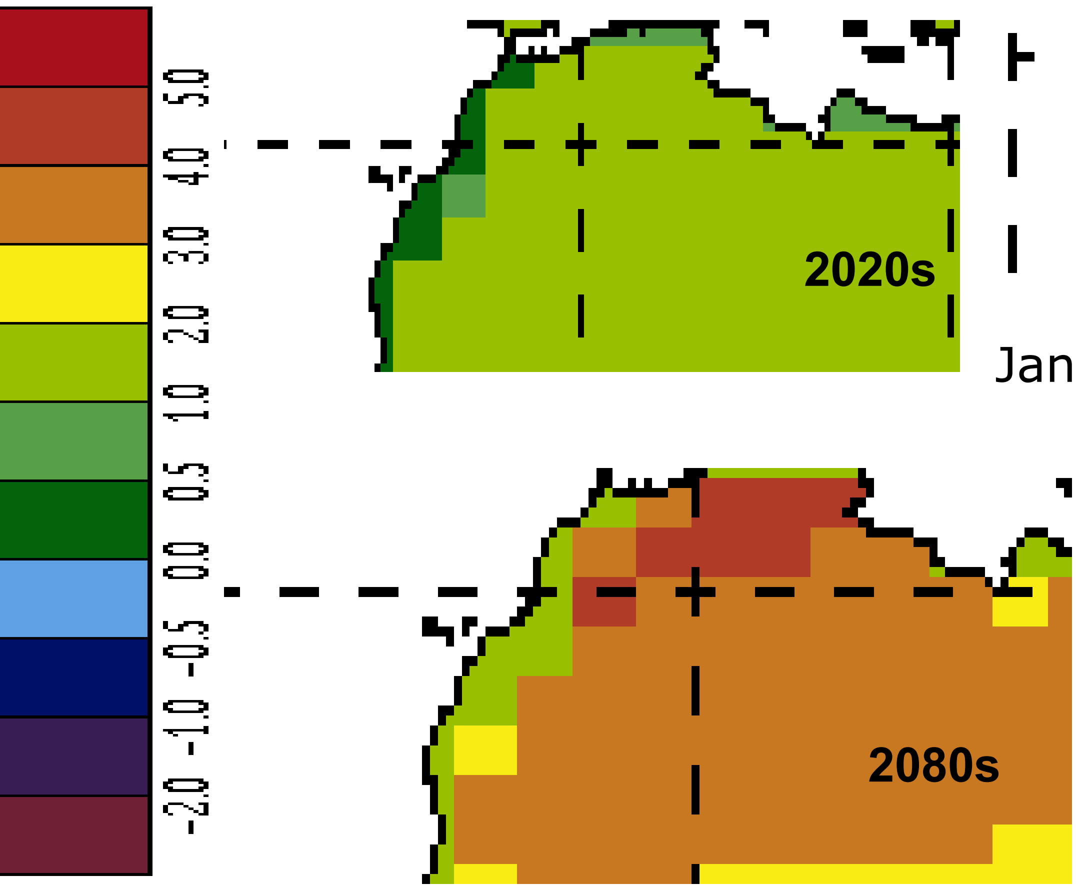
*UK Hadley Centre for Climate Prediction and Research

General circulation models/ HadCM3/B2a Scenario* Maximum Temp. Change over Time

http://www.ipcc-data.org/cgi-bin/ddcvis/gcmcf

Maximum Temp.





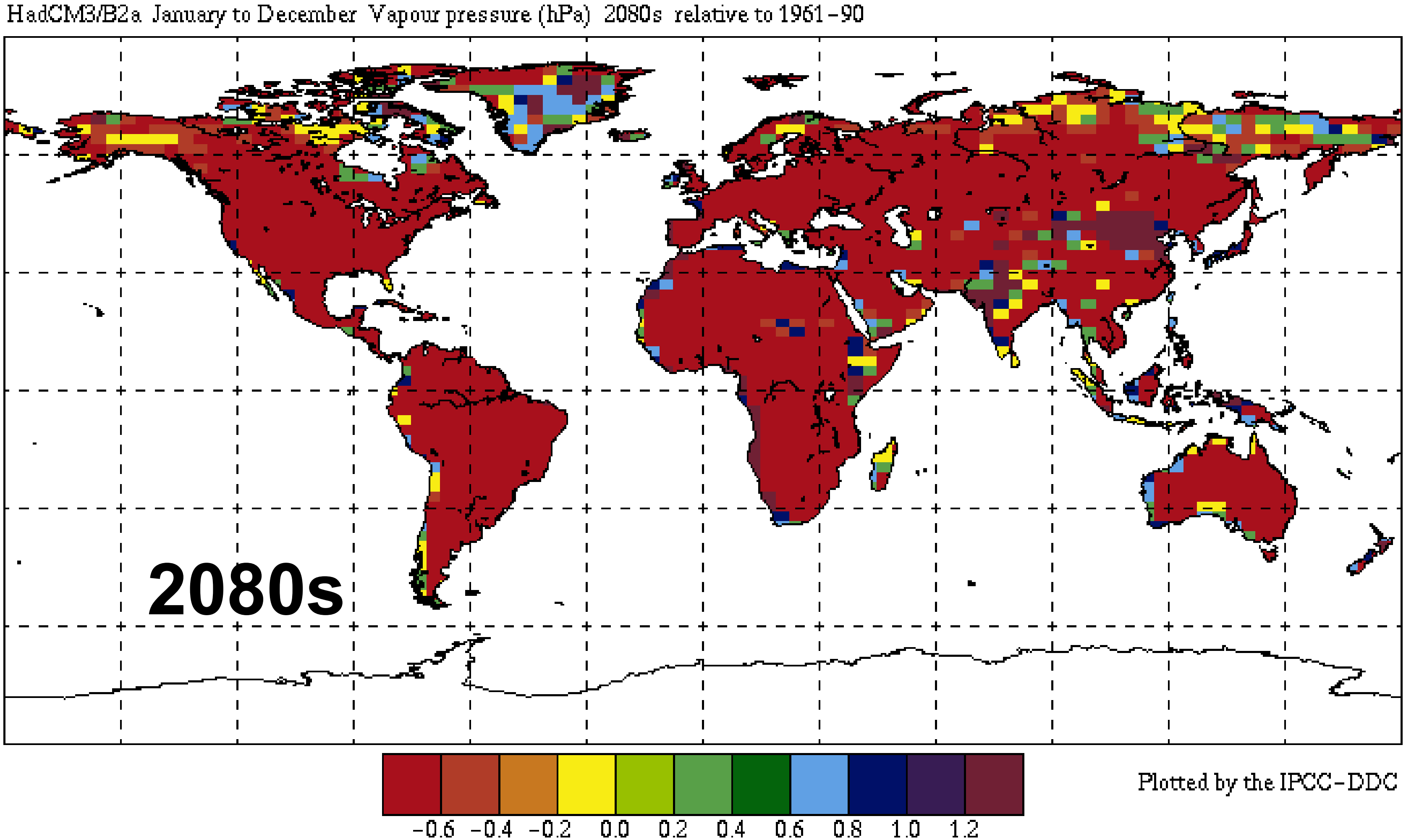
January to December degree (C)

SRES GCM change fields (IPCC 2001)
View change in GCM fields relative to the 1961-1990 maximum. Three time periods are available: 2010-2039, 2040-2069 and 2070-2099

*UK Hadley Centre for Climate Prediction and Research

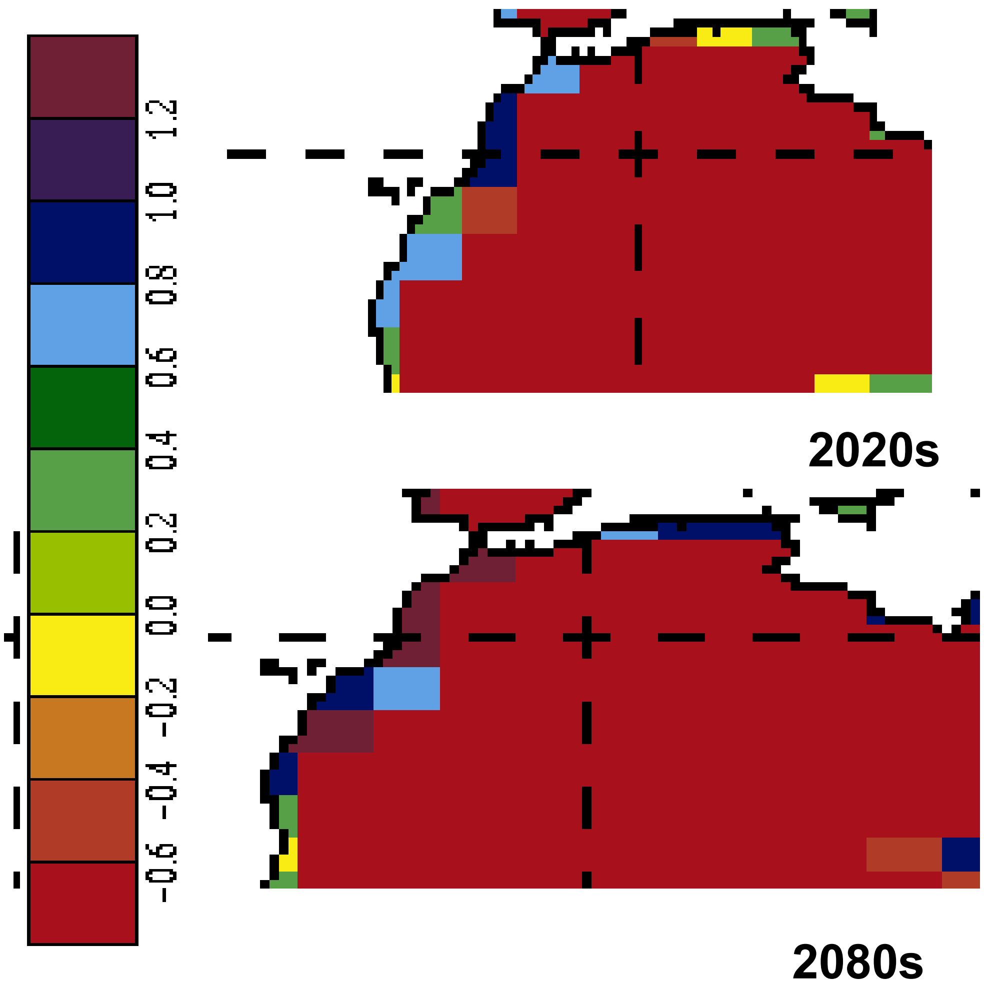
Prediction of Vapor Pressure Change by 2028s across the world space

http://www.ipcc-data.org/cgi-bin/ddcvis/gcmcf



General circulation models/ HadCM3/B2a Scenario* Vapour pressure – Maghreb over time

Vapour Pressure

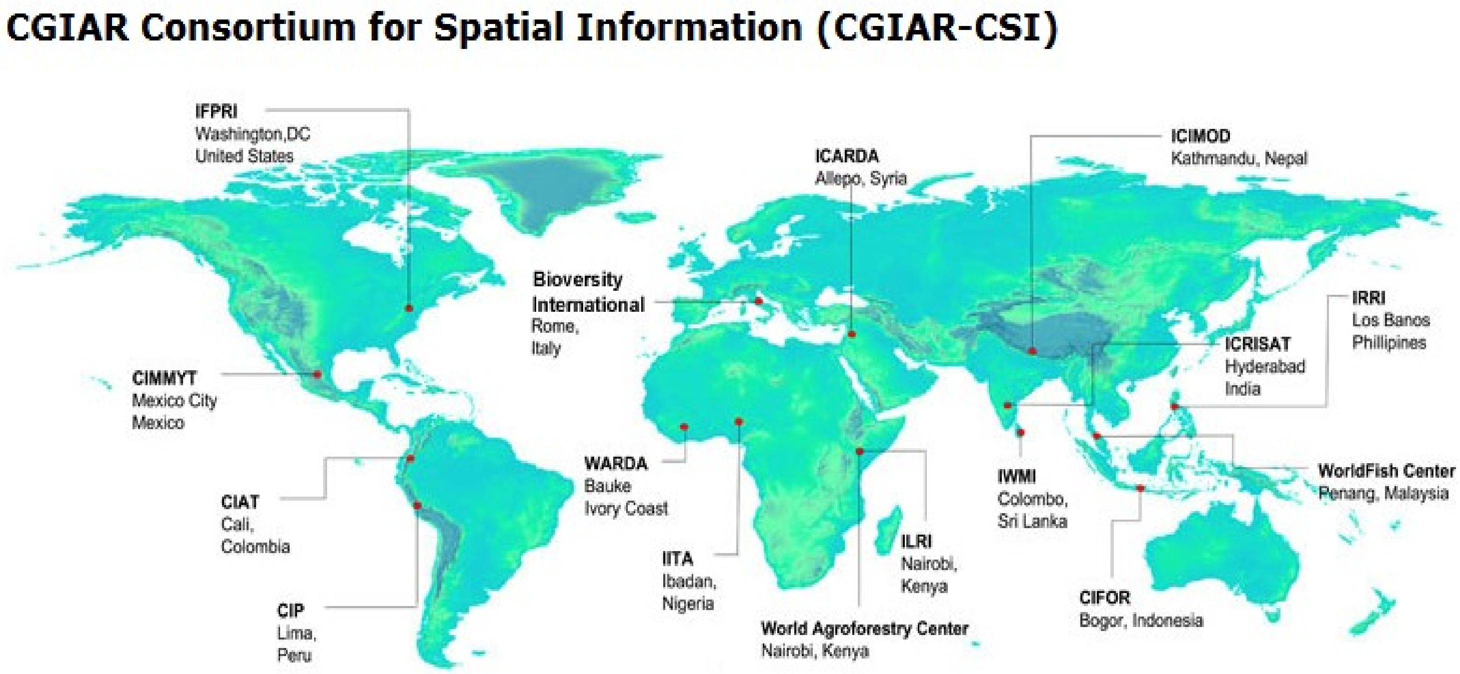


The Maghreb is one of the vulnerable regions in the world to climate change

http://www.ipcc-data.org/cgi-bin/ddcvis/gcmcf

*UK Hadley Centre for Climate Prediction and Research

Climatic Data example from Consultative Group on International Agricultural Research CGIAR -CSI



TMP:	**near-surface mean temperature (degrees Celsius).**
TMN:	**near-surface minimum temperature (degrees Celsius).**
TMX:	**near-surface temperature maximum (degrees Celsius).**
DTR:	**near-surface diurnal temperature range (degrees Celsius).**
PRE:	**precipitation (mm).**
WET:	**wet day frequency (days).**
FRS:	**frost day frequency (days).**
VAP:	**vapour pressure (hPa).**
CLD:	**cloud cover (percentage).**

Geo-spatial Data Climatic Data

SRTM Data Selection Options

1. Select Server: ○ CGIAR-CSI (USA) ◉ TelaScience (USA) ○ AGDevSolutions (USA) ○ JRC (IT) ○ King's College (UK)

2. Data selection method: ◉ Multiple Selection ○ Enable Mouse Drag ○ Input Coordinates

Many tiles can be selected at random locations. These selected tiles are listed in the results page for download.

○ Decimal Degrees (ie 34.5, -100.5) ◉ Degrees: Minutes: Seconds (ie 34 30 00 N, 100 30 00 W)

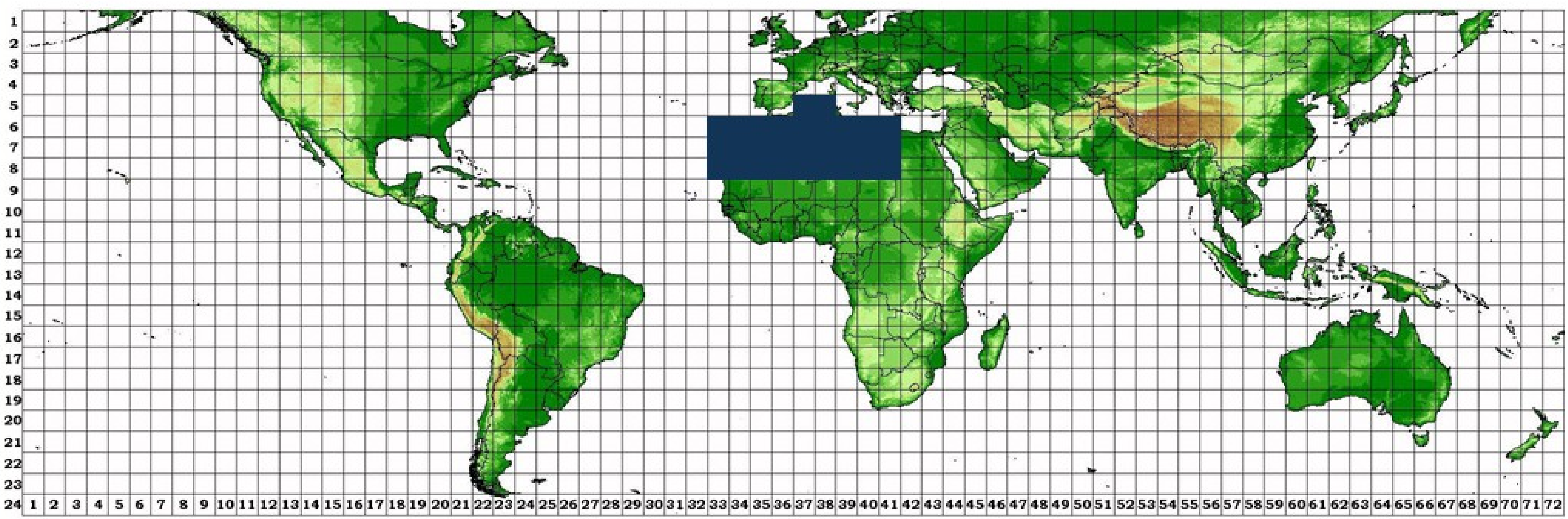
Longitude - min: max: **Longitude - min:** East max: East

Latitude - min: max: **Latitude - min:** North max: North

Longitute: 170.99 **Latitude:** 54.94 **Tile X:** 71 **Tile Y:** 2 Mark Area Clear Area

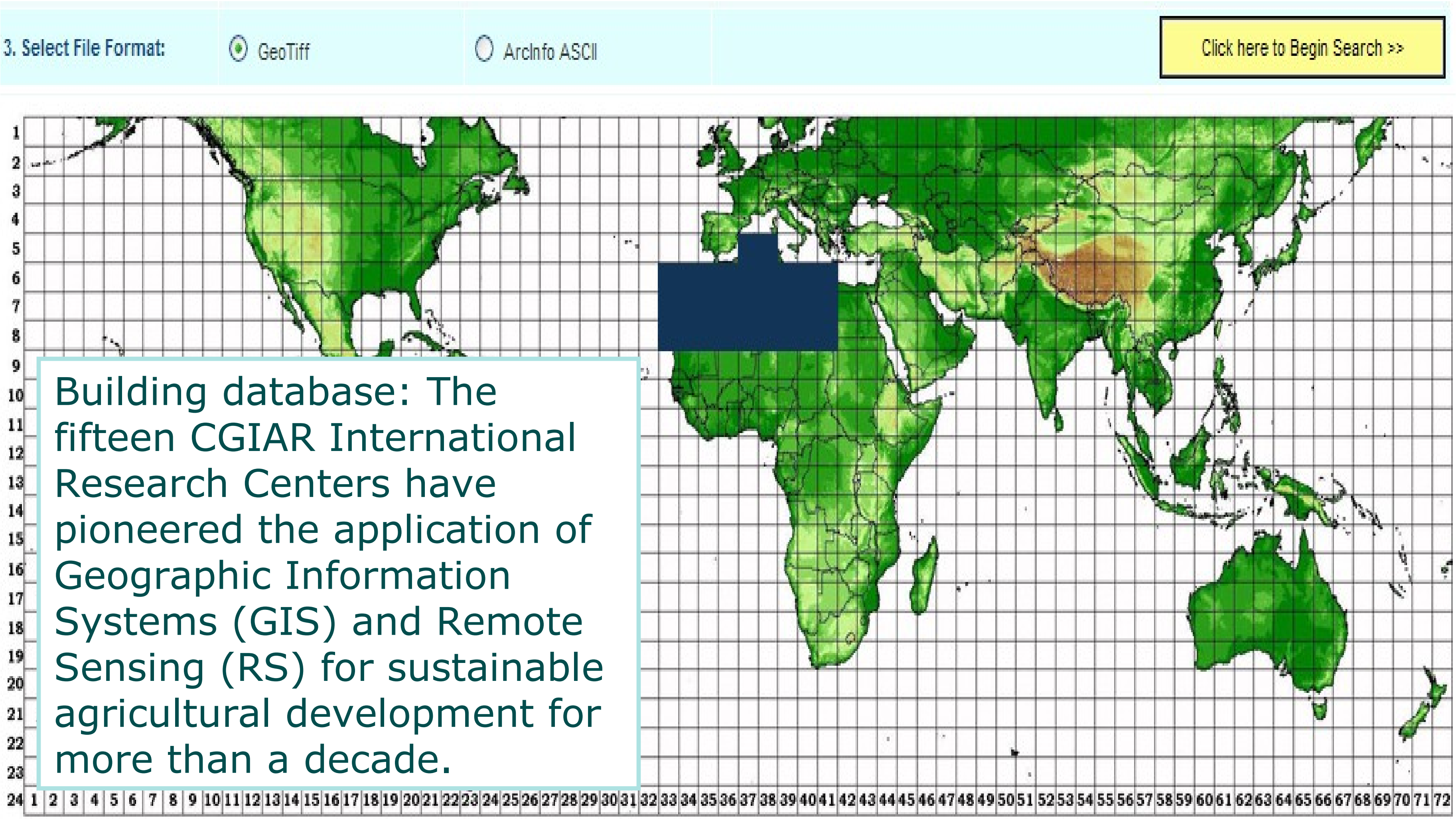
3. Select File Format: ◉ GeoTiff ○ ArcInfo ASCII

Click here to Begin Search >>



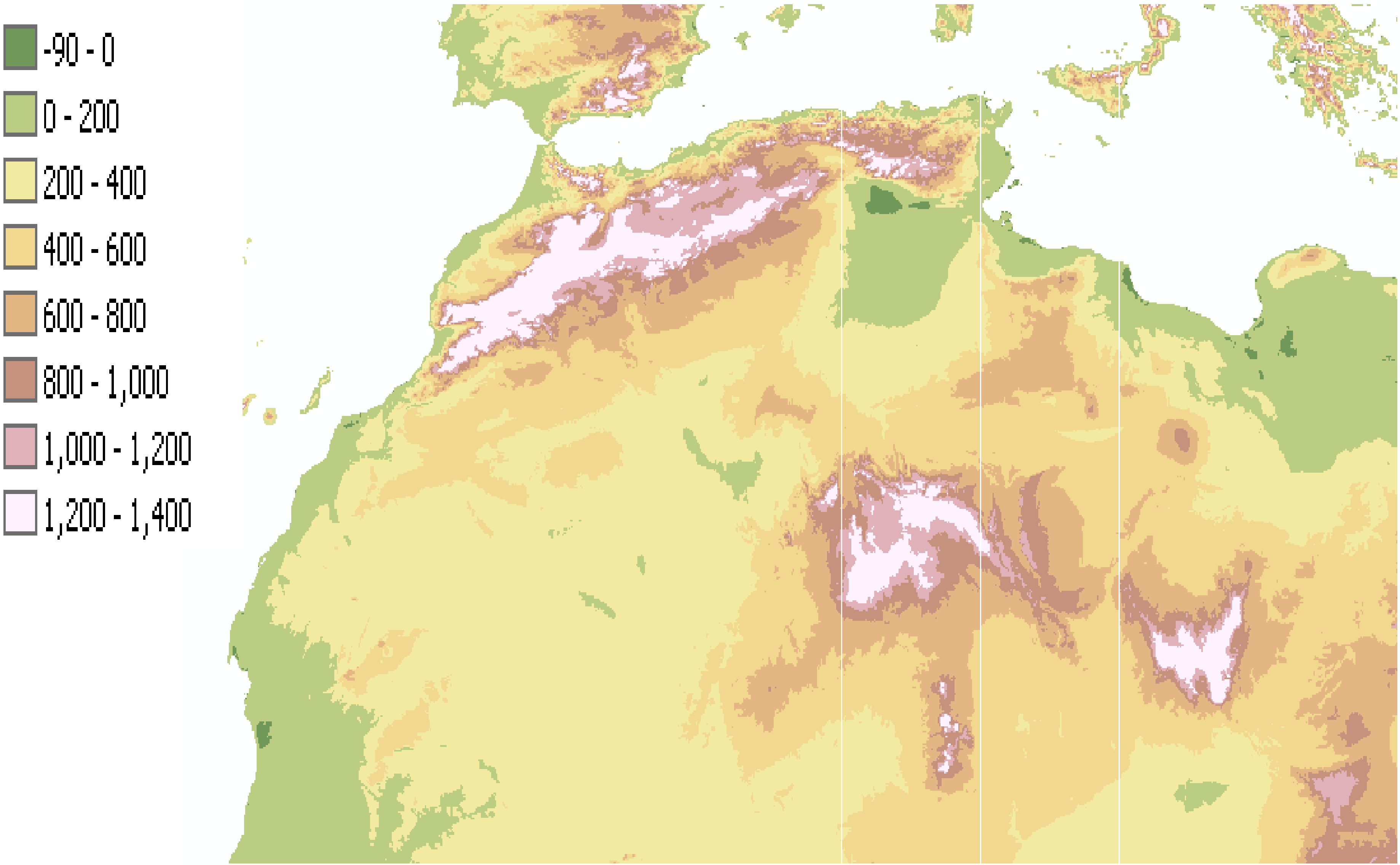
If you see above map flickering when using Microsoft Internet Explorer, please set the "Check for newer versions of stored pages" setting in Settings Tab in Internet Options

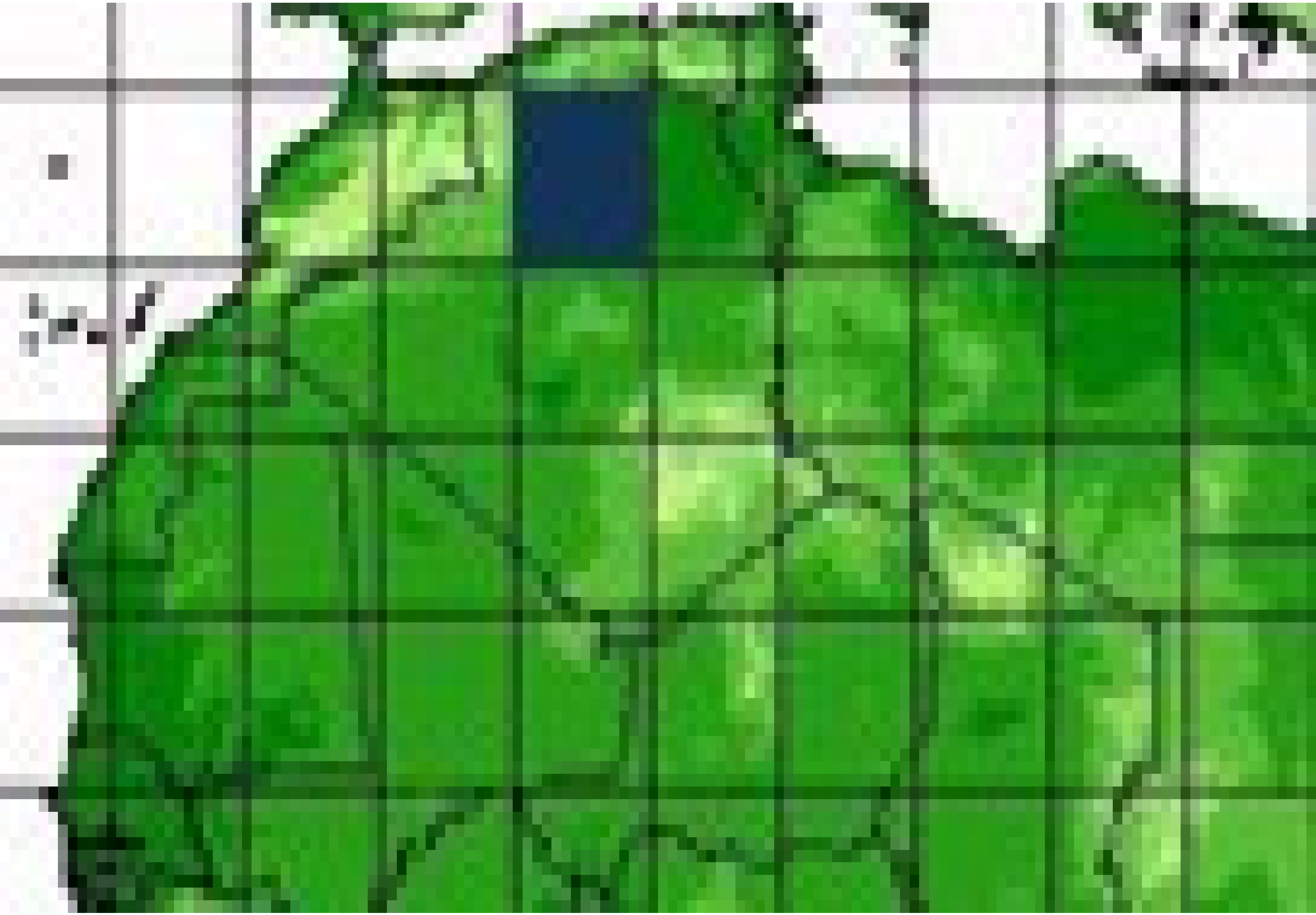
NASA Shuttle Radar Topographic Mission (SRTM) Data



Building database: The fifteen CGIAR International Research Centers have pioneered the application of Geographic Information Systems (GIS) and Remote Sensing (RS) for sustainable agricultural development for more than a decade.

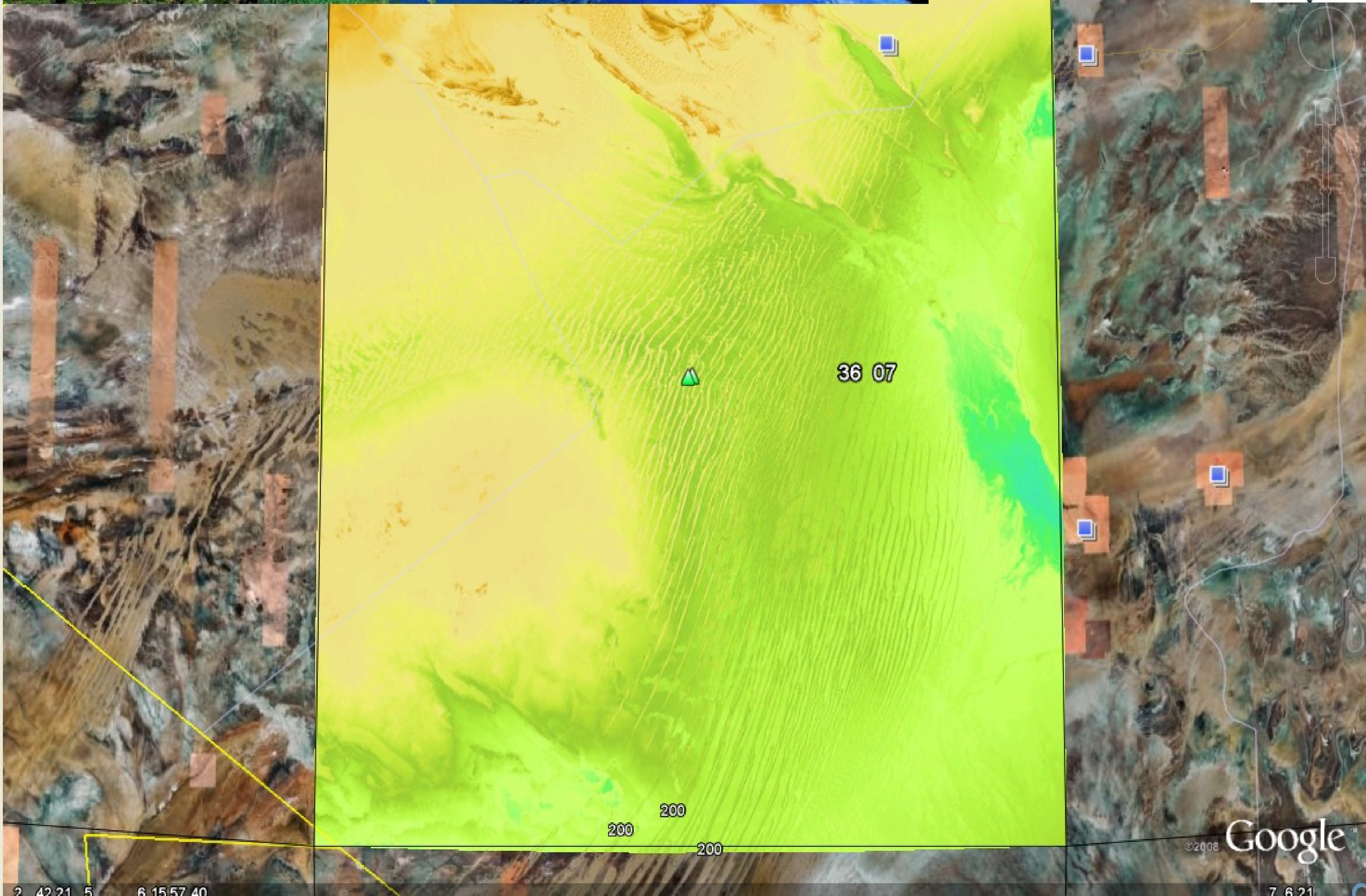
Regional and Local Impact Variables - Maghreb
Topology



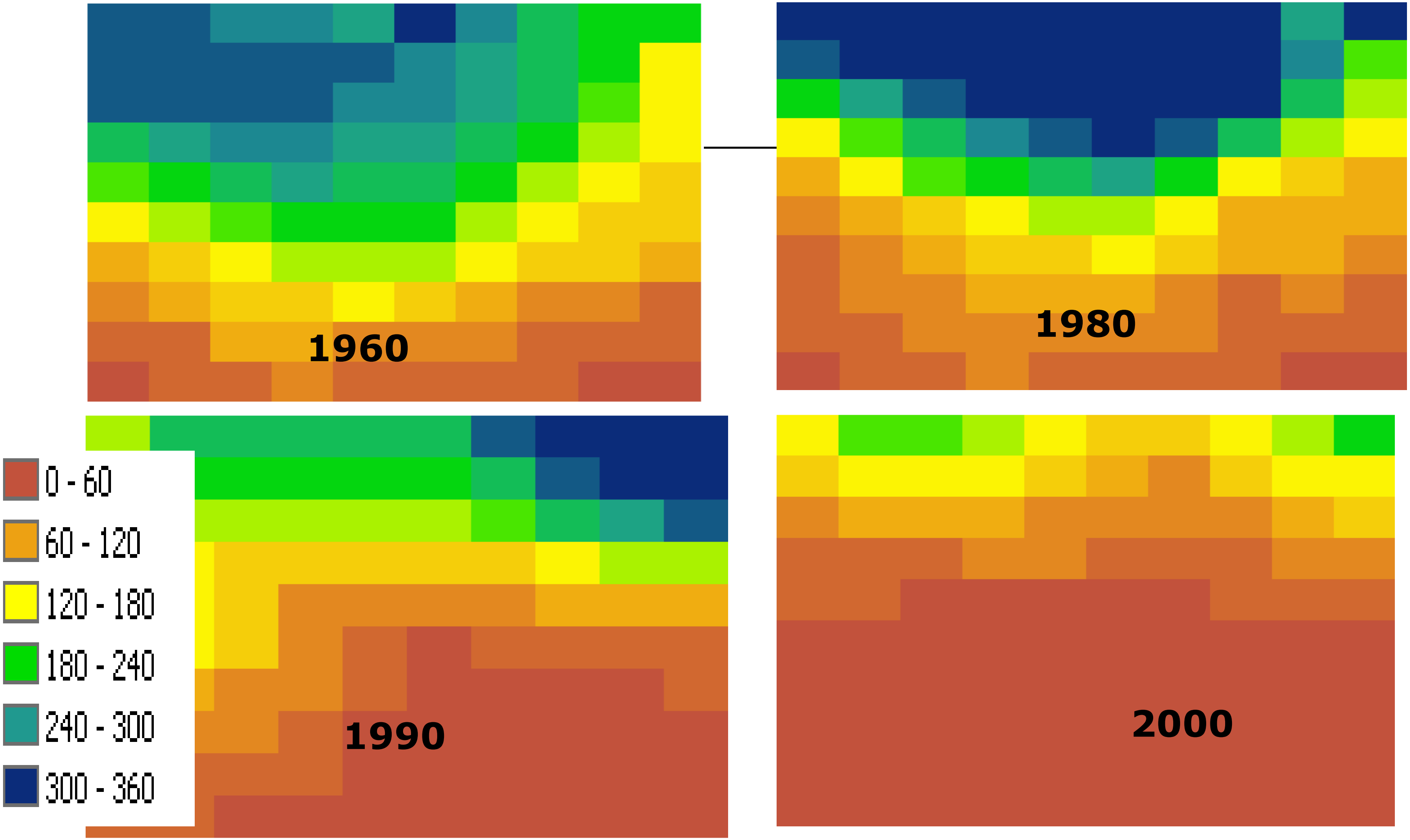


The CGIAR Consortium for Spatial Information (CGIAR-CSI)

Applying GeoSpatial Science for a Sustainable Future...



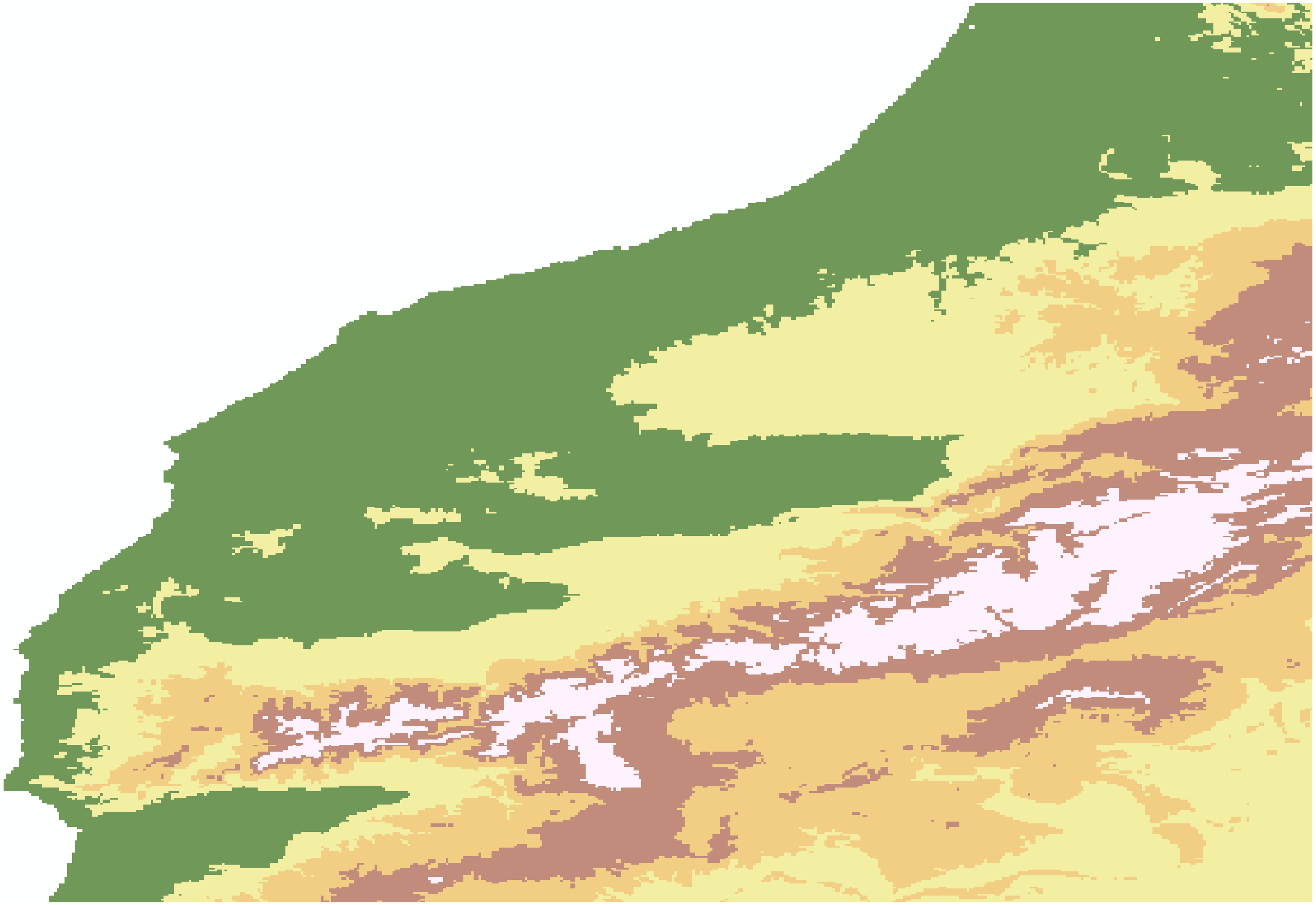
Precipitation during the month of December



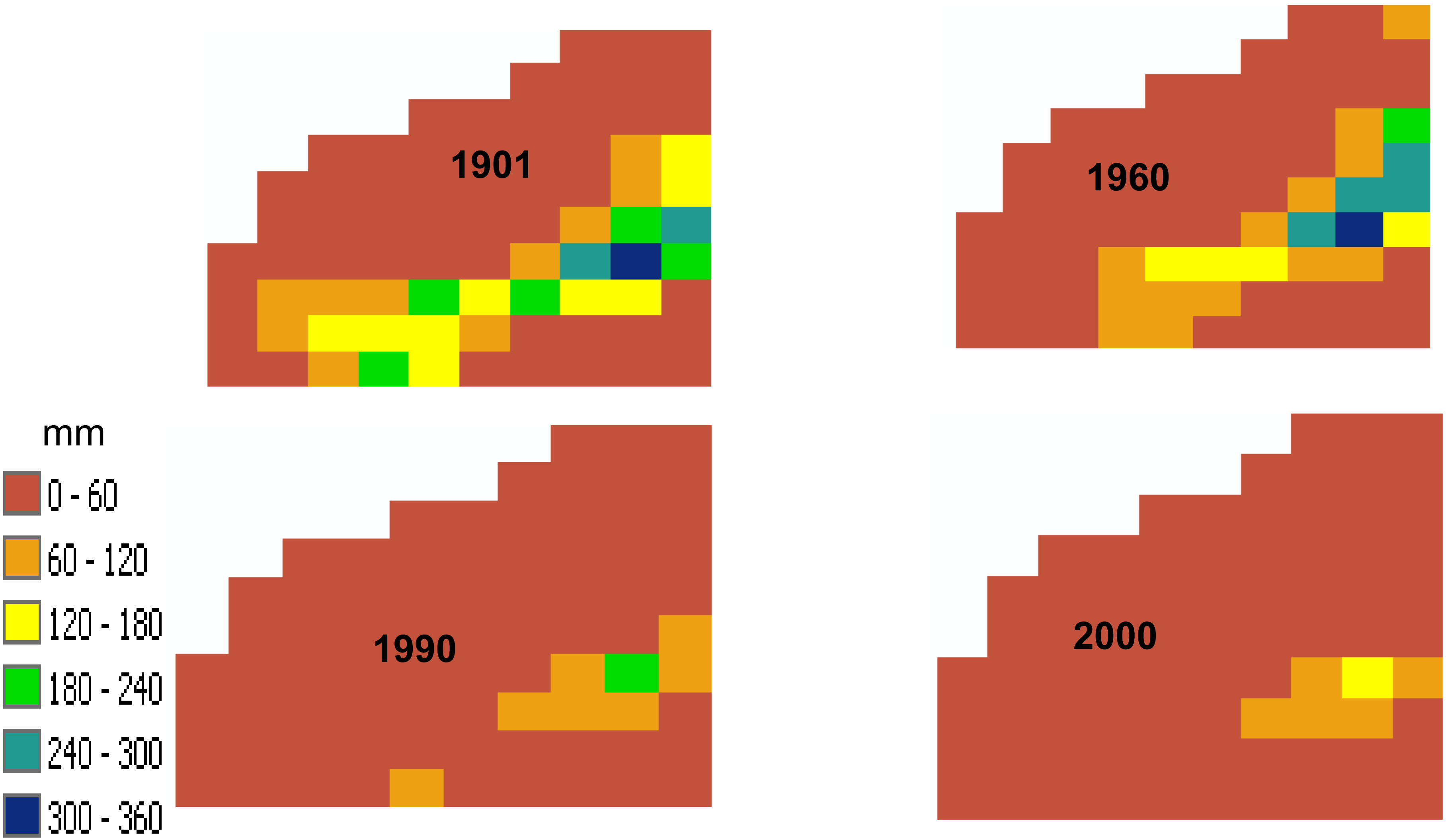
CRU 37 06 processed using ArGIS 9.2© ESRI

These data have been produced by the Climatic Research Unit (CRU) of University of East Anglia (UEA), and reformatted by the International Water Managment Institute (IWMI) to provide easy access and use in ArcGIS Grid format Jarvis, A., H.I. Reuter, A. Nelson, E. Guevara, 2008, Hole-filled SRTM for the globe Version 4, available from the CGIAR-CSI SRTM 90m Database: http://srtm.csi.cgiar.org.

Case study on selected grid 35 06

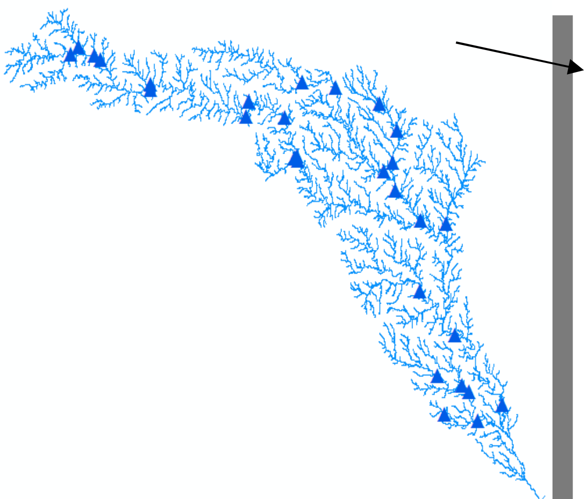


Precipitation during the month of July 1901 to 2000

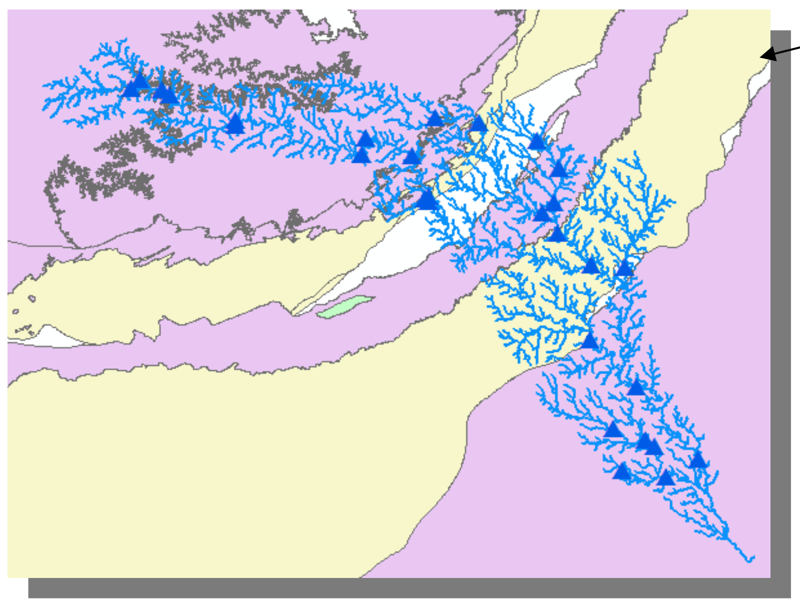


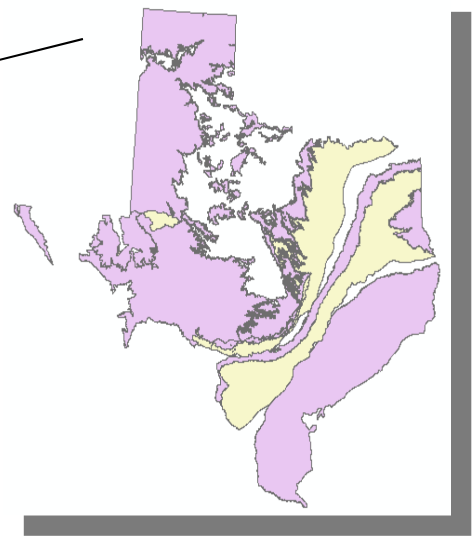
Integration of surface water and groundwater data

- Describe the relationship between surface water features (e.g. streams and waterbodies) with groundwater features (aquifers, wells).
- Enable the connection with the surface water data model



Hydro network





Aquifers

Source: Strassberg, Gil, 2003, Arc Hydro groundwater data model, CRWR GIS Hydro CD, ESRI Annual International User Conference.

Water table budget modeling

- Delleur (2007) recommended using water budget modeling using the following:

$$R = P - ET \pm O \pm \Delta S$$

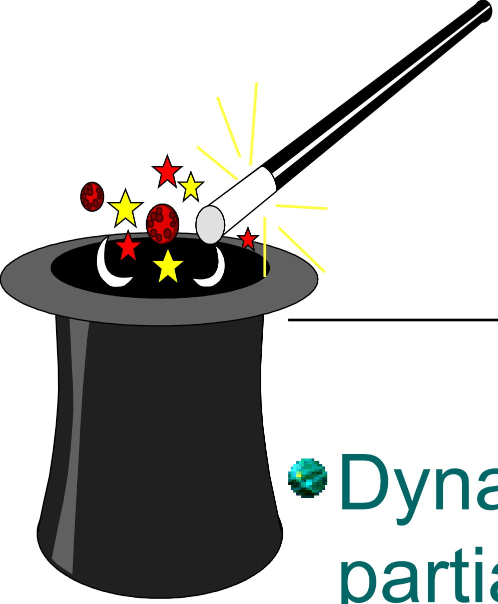
- R is the groundwater recharge;
- P is precipitation,
- ET is actual evapotranspiration,
- O is lateral surface runoff, and
- ΔS is the change in water storage in the unsaturated zone.

Delleur, Jaques (Editor). (2007) The handbook of groundwater engineering. Second edition. CRC Press.

Social Accounting Matrix for ECGE

	Industry	Commodity	Factors	Institutions	Gov't	Trade	TOTAL
Industry (detail)		Make					Total Industry Output
Commodity (detail)	Use			Consumption		Exports Output	Total Commodity
Factors -land -labor -capital	Returns to Primary Factors (value added)					Exported Primary Factors (e.g. labor flow)	Total Factor Income
Institutions -households -other	Sales	Sales	Distribution of factor Income		Transfer Payments	Exports	Total Institutional Income
Government	Indirect Business Taxes	Sales Tax	Factor Taxes		Intergover nmental Transfers		Total Government Income
Trade	Imported Purchased Inputs	Imports	Imports			Trans-shipments	Total imports
TOTAL	Total Industry Outlay	Total Commodity Outlay	Total Factor Outlay	Total Institutional Outlay	Total Gov't Outlay	Total Exports	

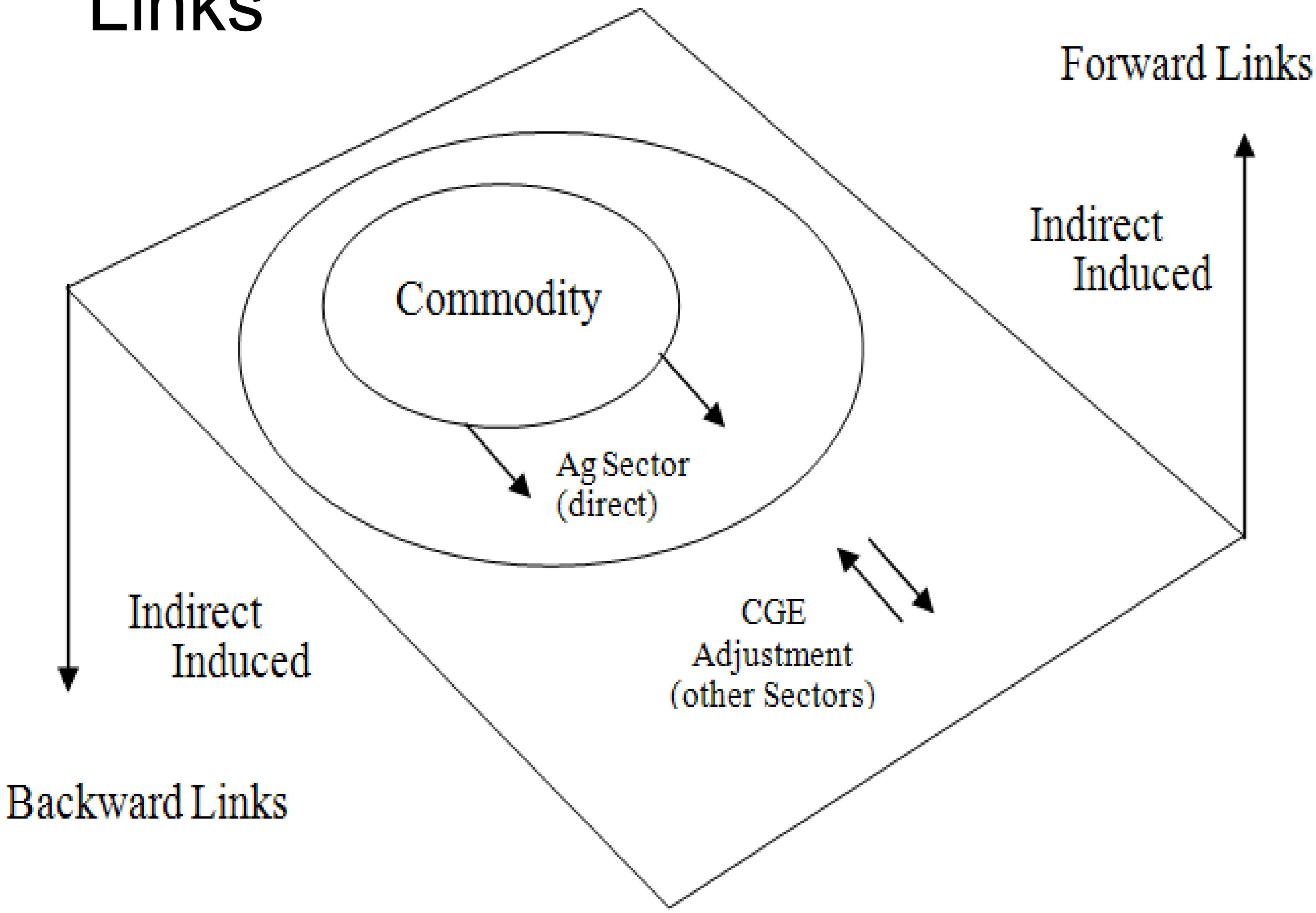
Modified from
http://rri.wvu.edu/WebBook/Schreiner/contents.htm



Economic Data and Economic Modeling -Why use ECGE?

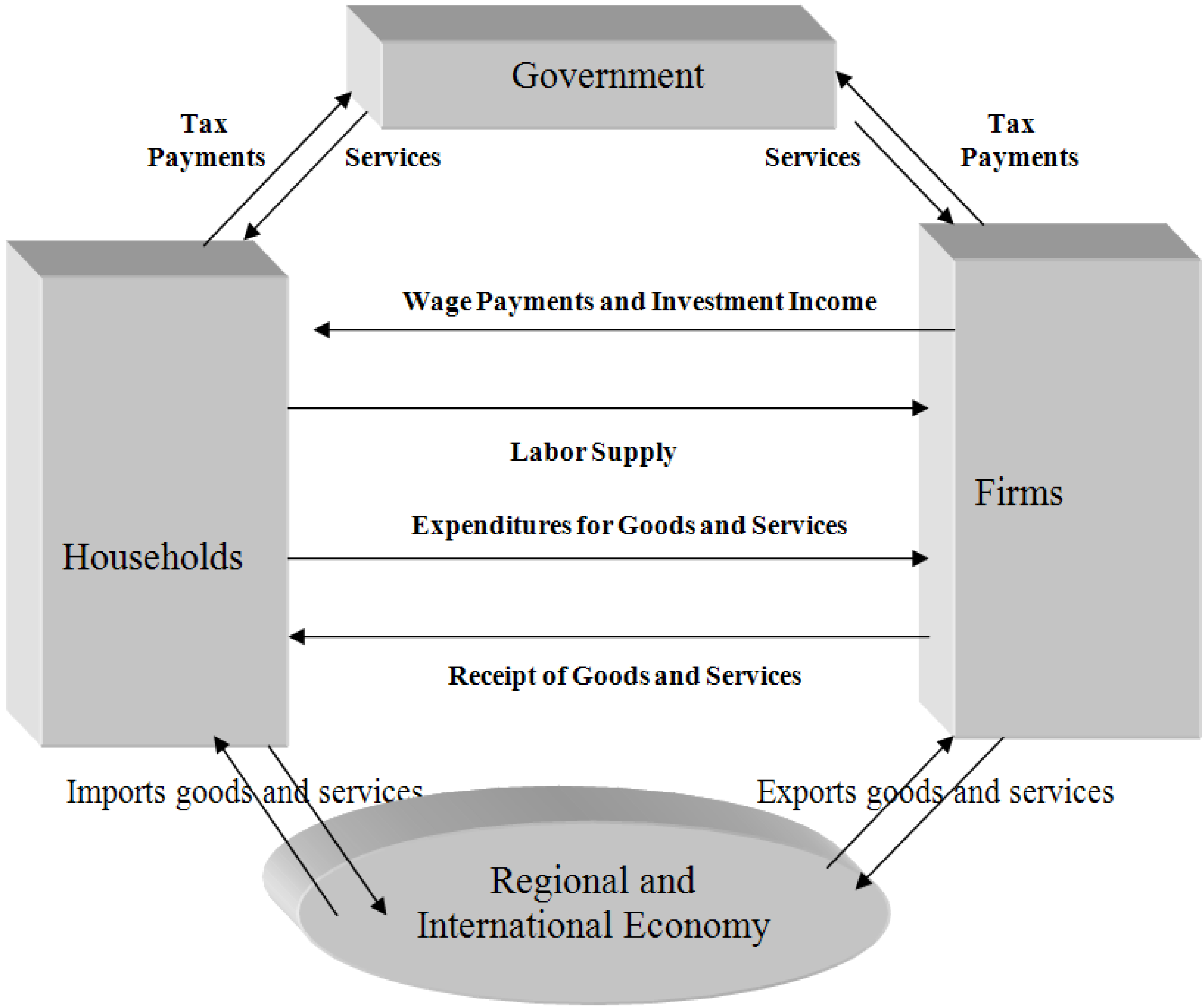
- Dynamic, general equilibrium rather than partial equilibrium
- Tracks many sectors simultaneously
- Generates estimates of producer and consumer surpluses
- Allows for more complexity
- Indigenize inter-country prices spill-over between sectors

Forward and Backward Economic Links



Potential Horizontal and Vertical Impacts of Climate Chnage

Successful Computable General Equilibrium Model Components

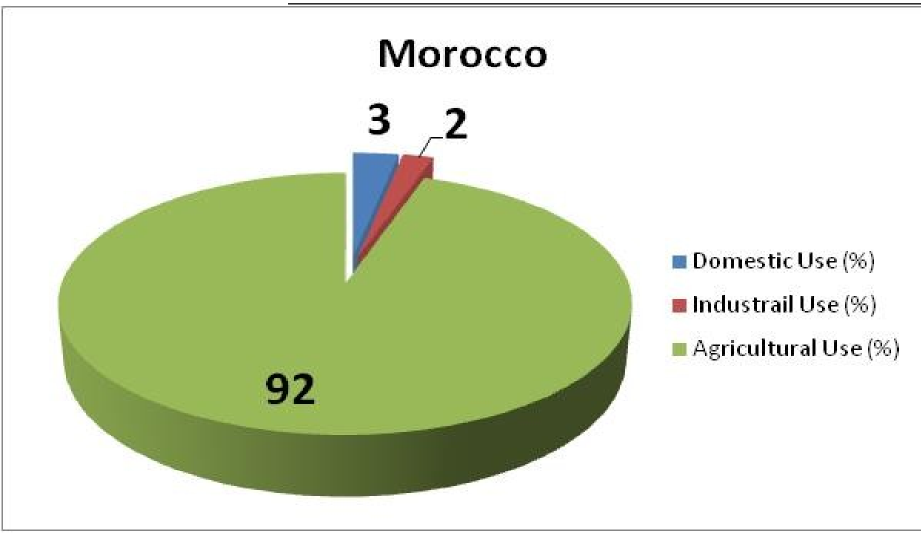


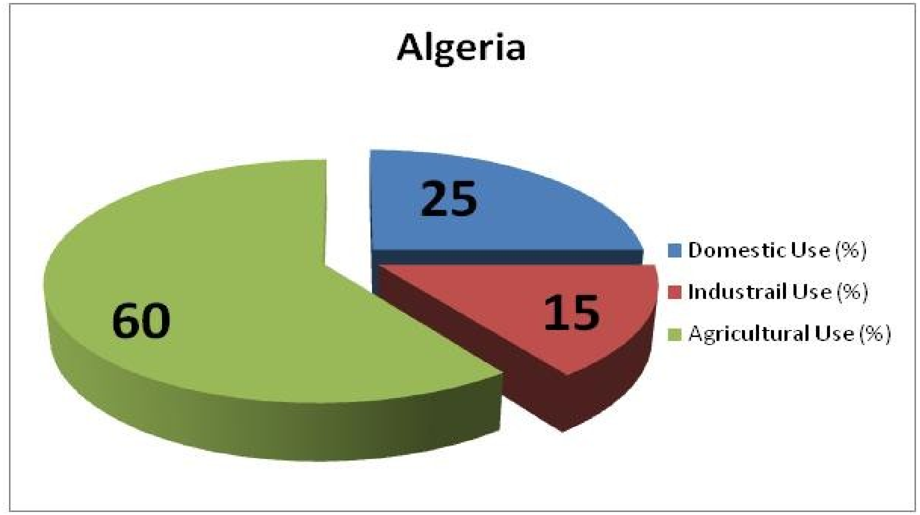
Major Macro-Economic and Freshwater Use Indicators in the Maghreb

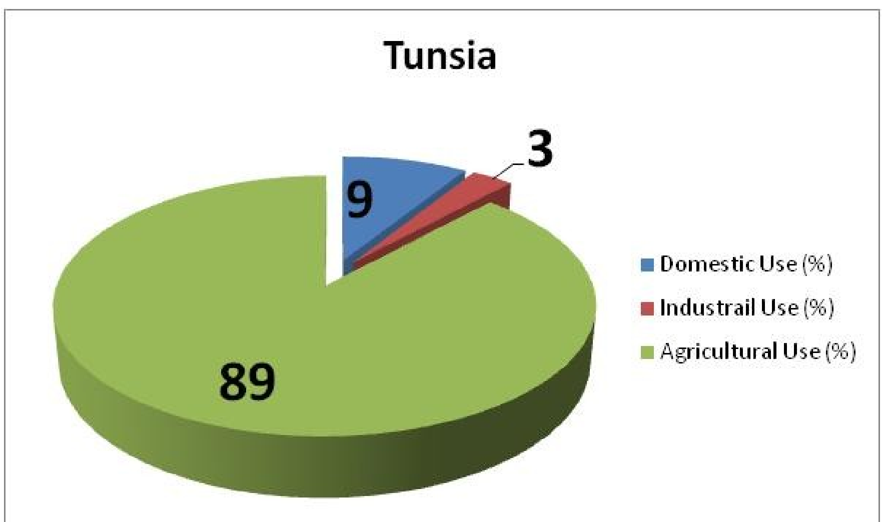
Country	Population (thousand)	Land area (000 km^2)	GPD ($)	Agriculture as % of GDP	Life Expectancy (years)	Freshwater per capita (m^3/year)	% of population with access to improved water services
Algeria	29 950	2 381.7	1 550	11	71	477	94
Egypt	62 655	995.5	1 380	17	67	930	95
Jordan	4 740	88.9	1 630	2	71	148	96
Lebanon	4 271	10.2	3 700	12	70	1 124	100
Morocco	28 238	446.3	1 190	15	67	1 062	82
Syria	15 711	183.8	970		69	2 845	80
Tunisia	9 457	155.4	2 090	13	73	434	
Palestine	2 839		1 780	17	72		
Yemen	17 048	528.0	360	17	56	241	69
Bahrain	666	0.7			73		
Cyprus	760	9.2	11 950		78	1 052	100
Iraq	22 797	437.4			59	1 544	85
Libya	5 419	1 759.5			71	148	72
Oman	2 348	212.5			73	426	39
Saudi Arabia	20 198	2 149.7	6 900	7	72	119	95

Source: *World Bank Atlas, 2001.*

Water Scarcity -Water Use by Sector in selected countries of the Maghreb





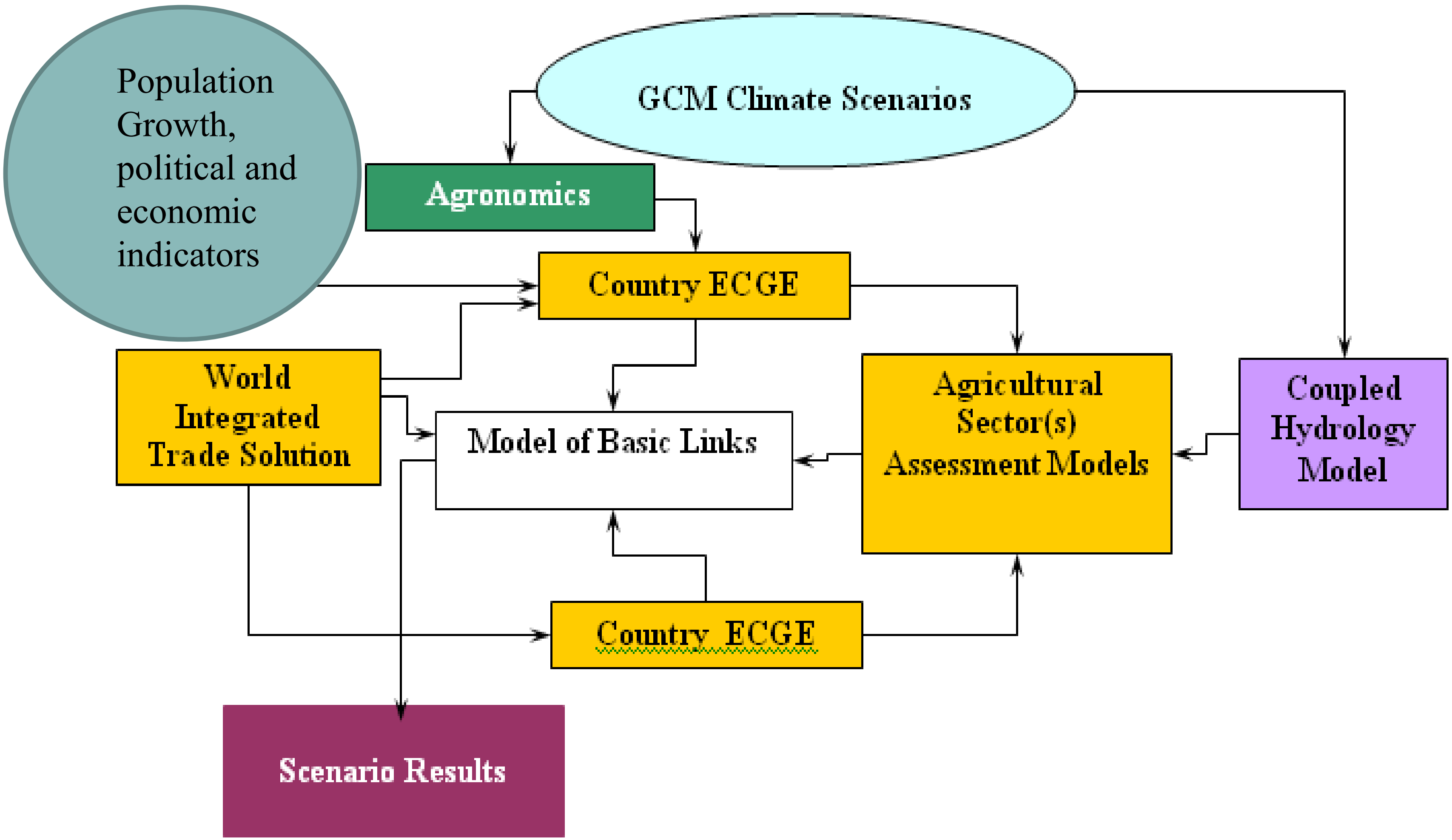


Water Withdrawals (Km^3/Year)

Morocco	**11.05**
Algeria	**4.5**
Tunisia	**3,08**

Source: IHP Program, Policies and strategic options, for water management, in the Islamic countries Proceedings of the Symposium organized, by the Regional Centre on Urban Water Management (RCUWM-Tehran), 15-16 December 2003

Proposed Models for



[a] The World Integrated Trade Solution (WITS) is software developed by the World Bank.

Tradeoff Analysis – Stochastic Efficiency Approach

Certainty Equivalent using the power function described as follow:

$$U(w) = \frac{w^{1-RRAC}}{1-RRAC}$$

Where,

$U(w)$ is the expected utility

w is the change in wealth or return (e.g. gross margin); and

RRAC is the relative risk aversion coefficient

For each risky management alternative and for each single value of risk aversion coefficient, the CE Calculates from:

$$CE = E(U)^{(1/(1-RAC))} - \varpi$$

Where

$E(U)$ is the expected utility

RAC is the Risk Aversion Coefficient

ϖ is the initial wealth

Conclusions

- **There is strong correlation between economic development and natural resource availability which makes Nile Basin countries very vulnerable to climate change**

- **Climate, water supply, water demand, and water value databases are needed**

- **Integrated models uncover new information about climate change impacts**

- **Climate adaptation strategies (e.g. water conservation programs) may contradict economic development in the short run but not in the long run**

- **Marketable water, definition of water rights, and water sharing should be highly supported within the Maghreb region (Pareto Efficiency applies) for climate change adaptation**

- **Climate change adaptation strategies (e.g. groundwater enhancement projects) complement economic development objectives**