Water resources management and climate change

Introduction to climate change. Climate models and data. Statistical and dynamic downscaling of climatic data for use in regional scales. Exercise with hydrological simulation under climate change.

By

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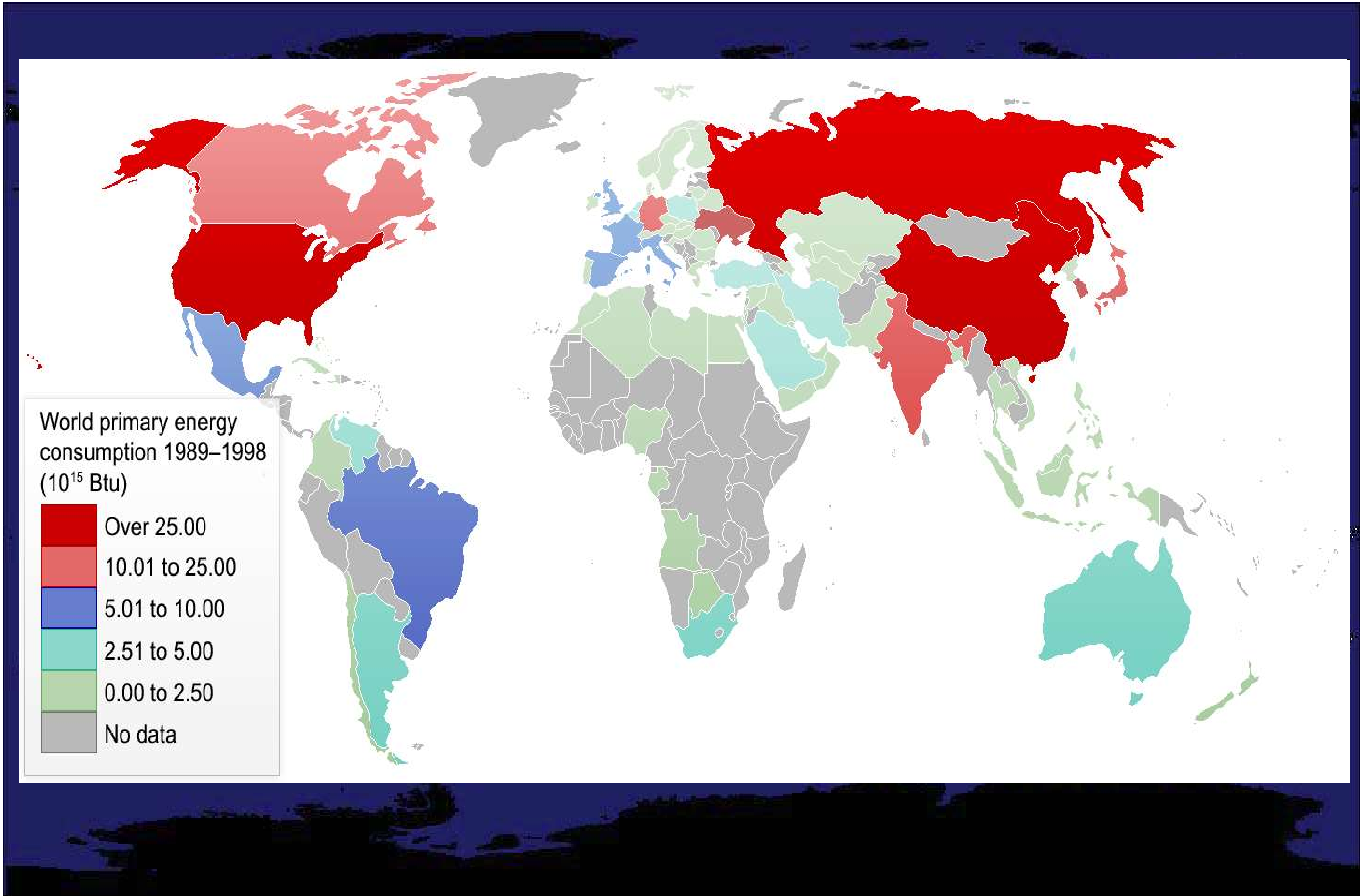
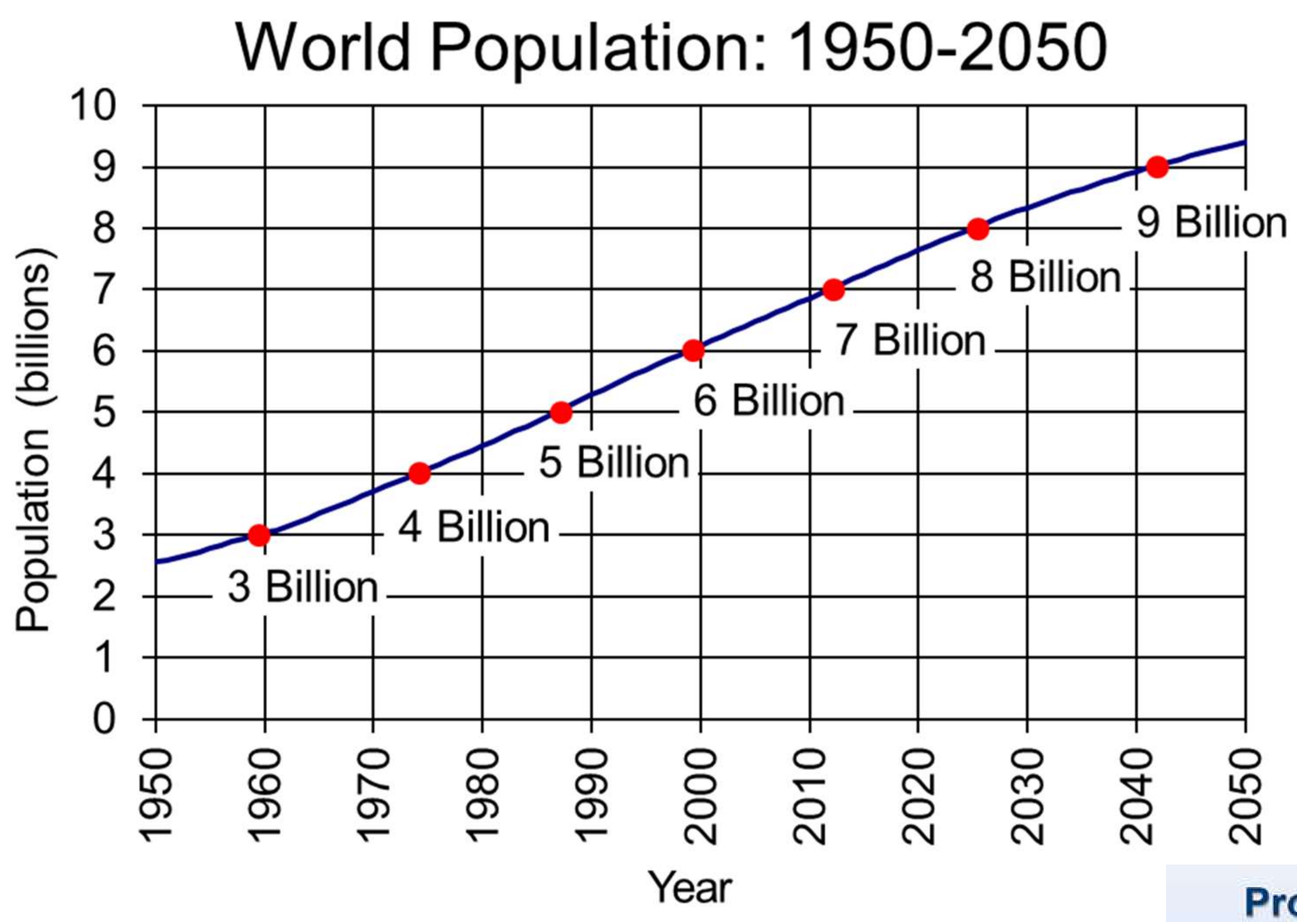
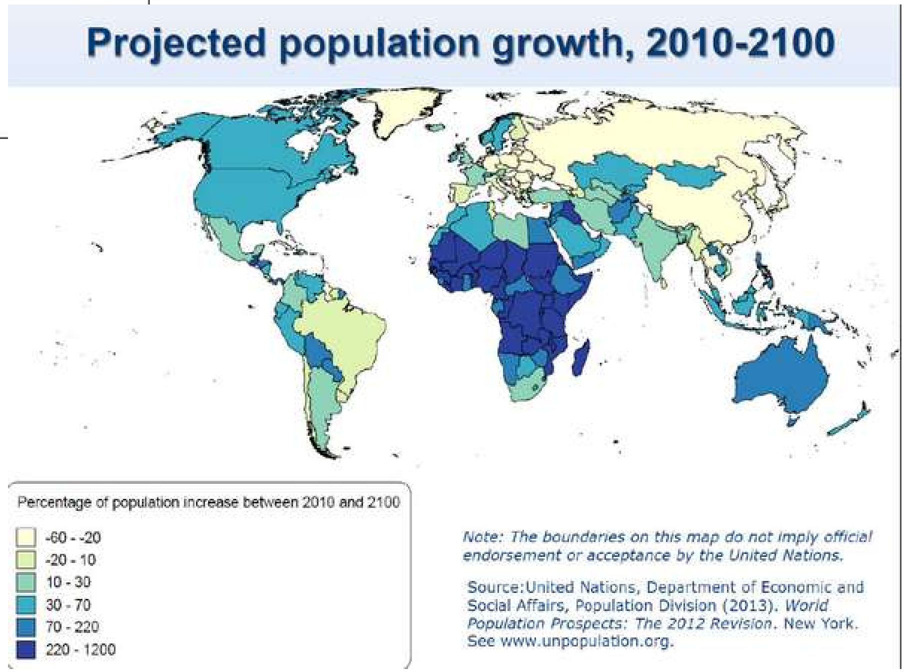
Wednesday, 15/12/2021

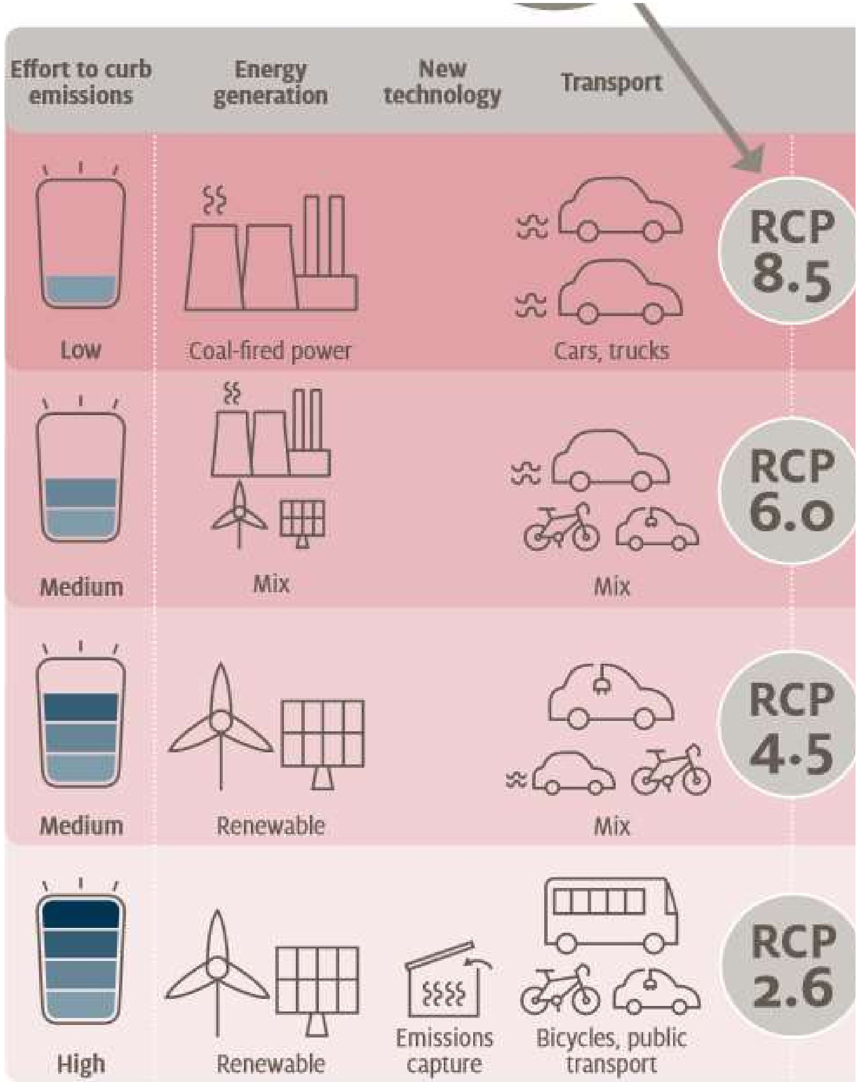
Energy and development

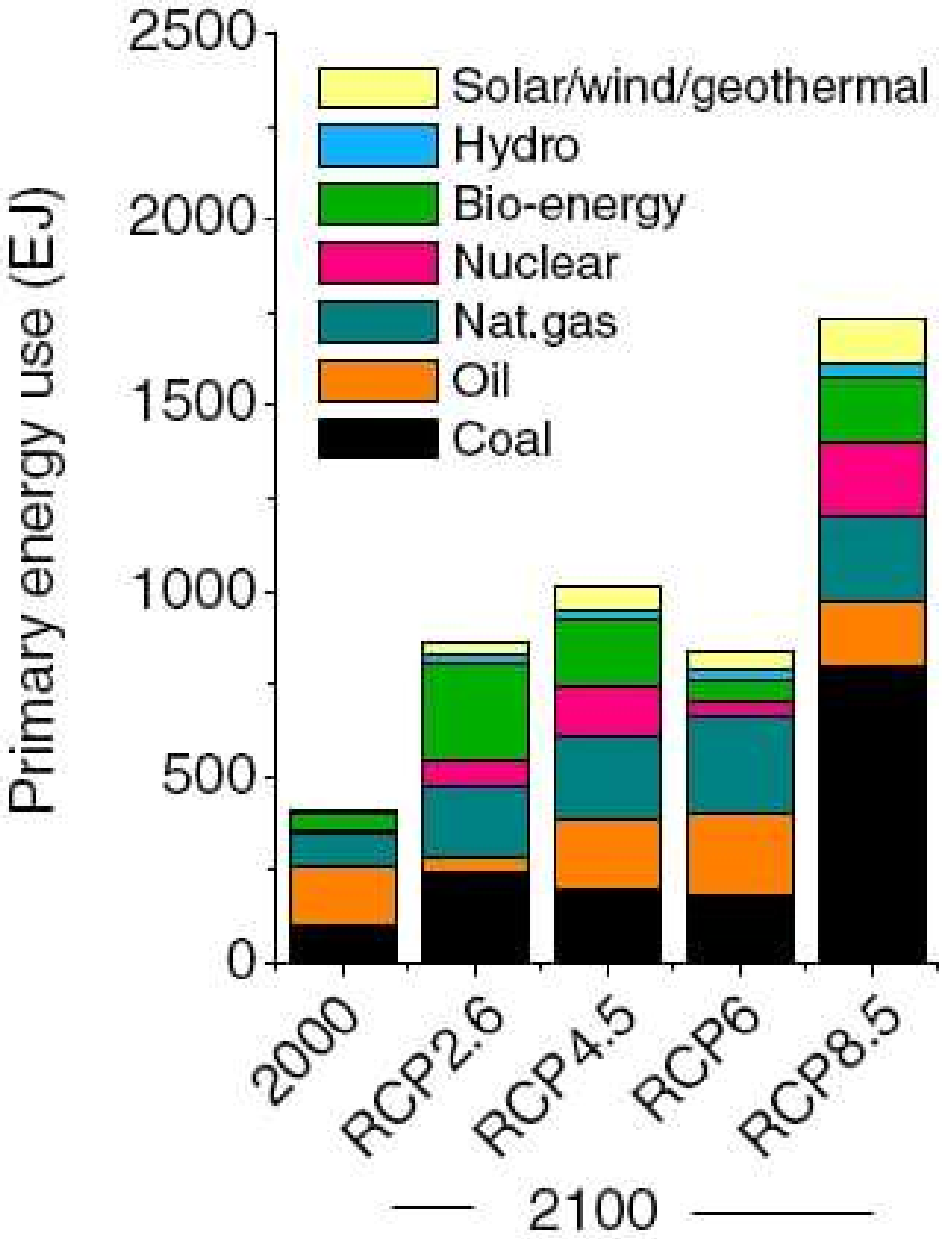




Source: U.S. Census Bureau, International Data Base, July 2015 Update.

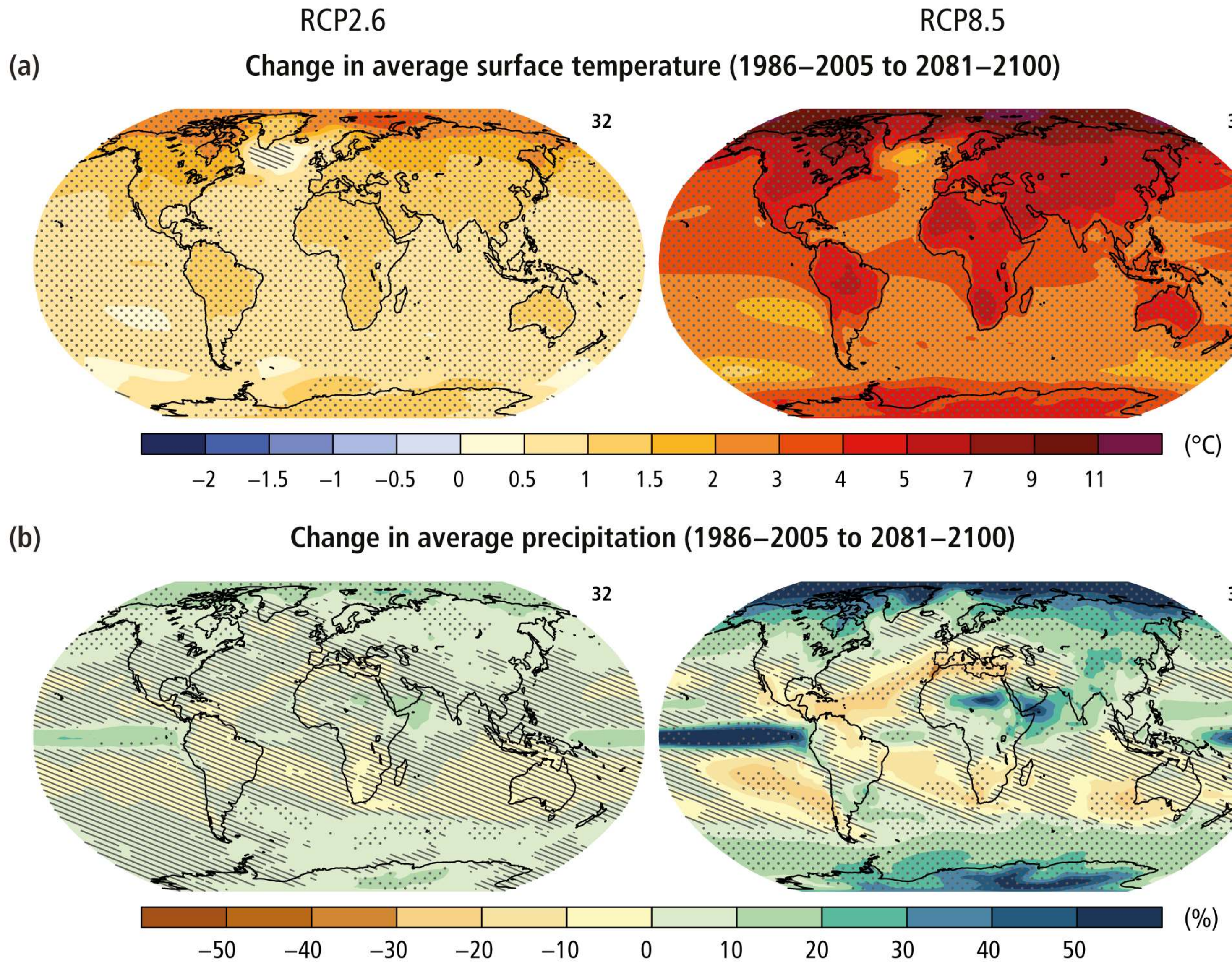




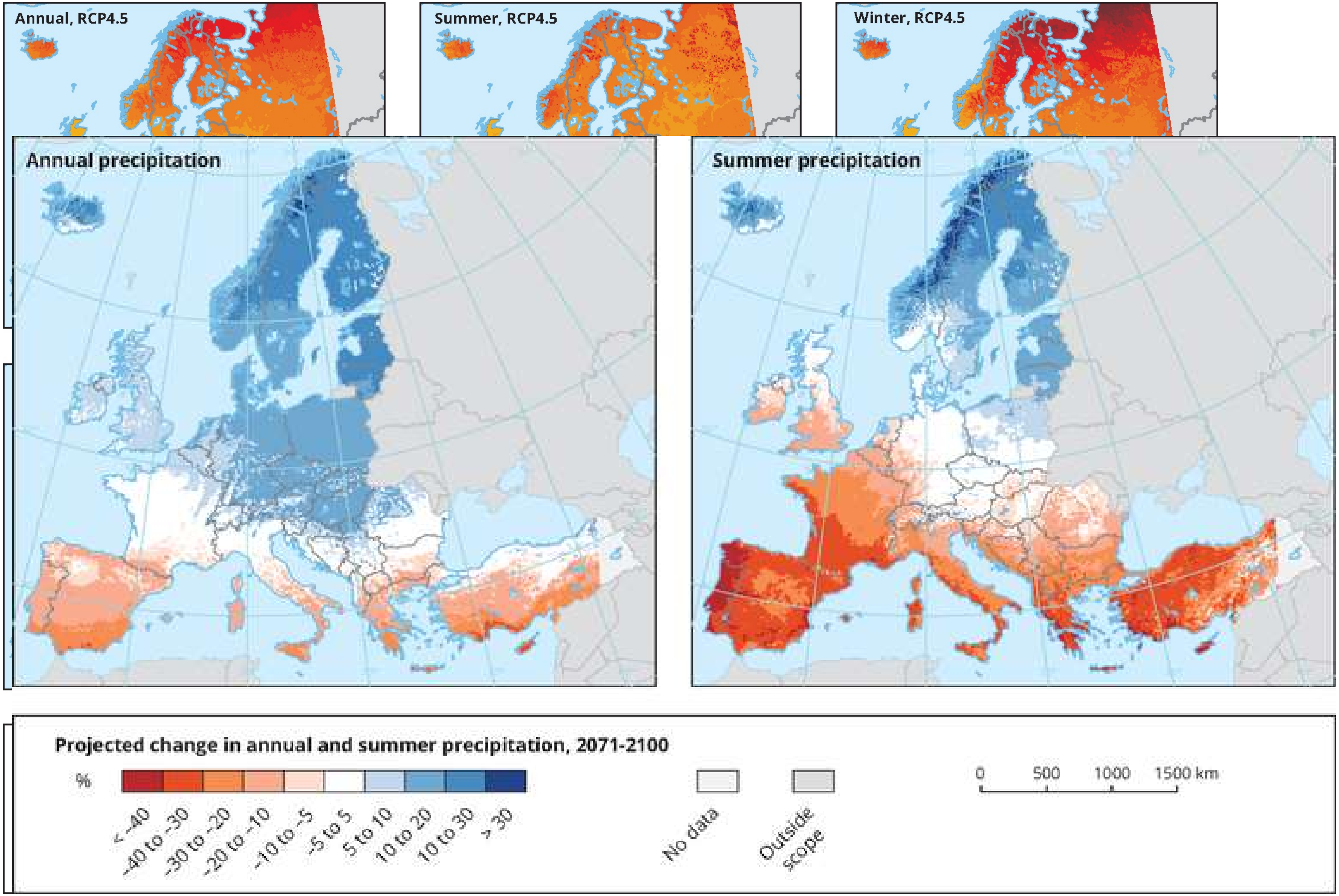


Energy sources by sector (van Vuuren et.al. 2011)

Changes in temperature and precipitation



Αλλαγής της μέσης επιφανειακής θερμοκρασίας **(a)** και αλλαγή της μέσης βροχόπτωσης **(b)** βάση της μέσης πρόγνωσης αριθμού μοντέλων για την περίοδο 2081–2100 σε σχέση με την 1986-2005 για τα σενάρια RCP2.6 (αριστερά) and RCP8.5 (δεξιά). Source: *PCC AR5 WGI: Climate Change 2013: The Physical Science Basis, Technical Summary*



__Source:__ European Environmental Agency https://www.eea.europa.eu/data-and-maps/indicators/global-and-european-temperature-9/assessment

Reasons that cause Climate Change

Fossil Fuels

Industrial activities


BRIDGESTONE
Transportations-

Intense farming


Deforestation

Impacts of CC


FLOODS

Population movements

General Circulation Models

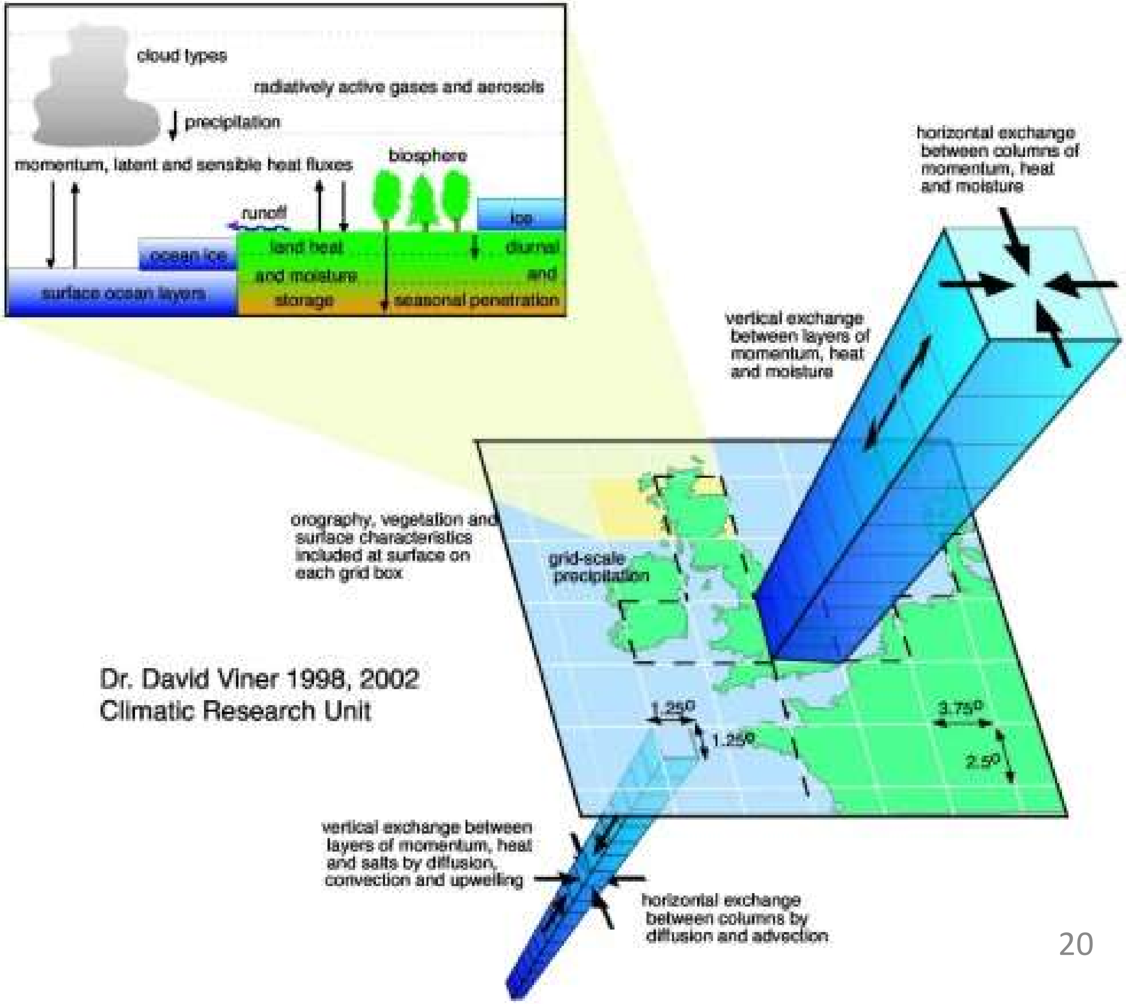
Numerical models (General Circulation Models or GCMs), representing physical processes in the atmosphere, ocean, cryosphere and land surface, are the most advanced tools currently available for simulating the response of the global climate system to increasing greenhouse gas concentrations.

GCMs depict the climate using a 3 dimensional grid over the globe:

• a horizontal resolution of between 250 and 600 km,

• 10 to 20 vertical layers in the atmosphere and

• as many as 30 layers in the oceans.



Uncertainties in GCM-based simulations

1. Many physical processes, such as those related to clouds, also occur at smaller scales and cannot be properly modelled. Instead, their known properties must be averaged over the larger scale in a technique known as parameterization.

2. The simulation of various feedback mechanisms in models concerning, for example, water vapour and warming, clouds and radiation, ocean circulation and ice and snow albedo. For this reason, GCMs may simulate quite different responses to the same forcing, simply because of the way certain processes and feedbacks are modelled.

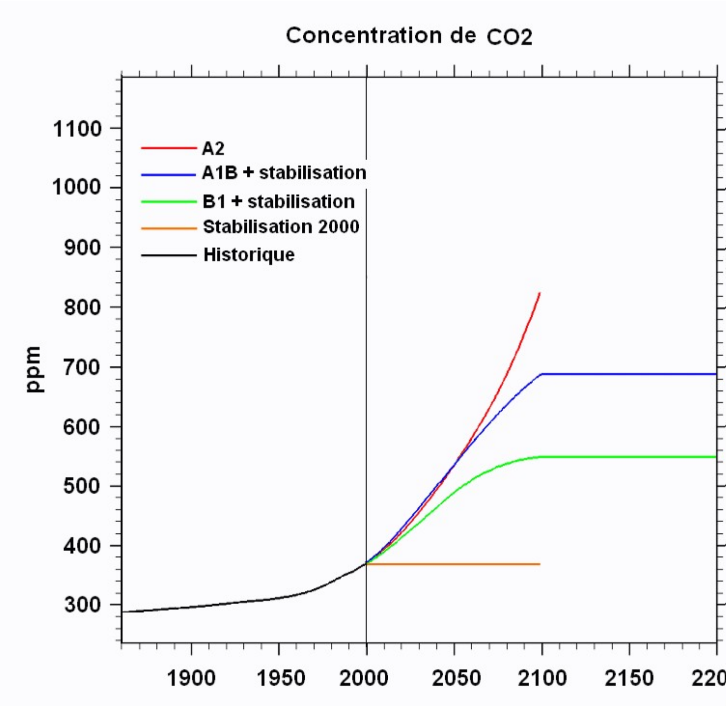
The climate change scenarios

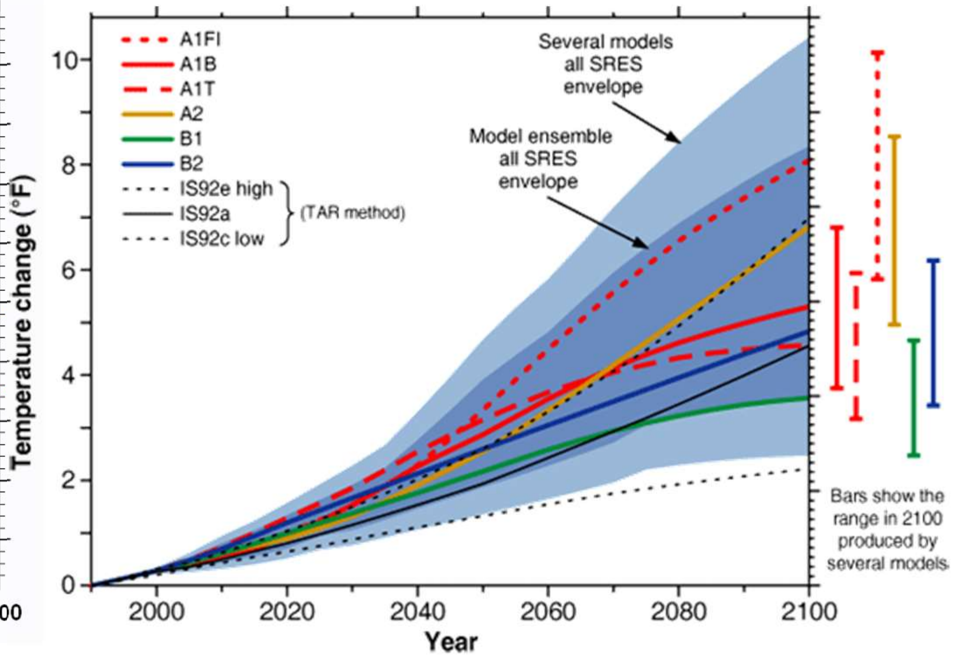
▪ Bulgaria: Decrease of precipitations ?

▪ The IPCC scenarios

The IPCC scenarios

In 1996 the Intergovernmental Panel on Climate Change (IPCC) created a report, the « **Special Report on Emission Scenarios » (SRES)**. It describes the possible climate change scenarios: « stabilisation 2000 », B1, B2, A1, A2 and their variants.





A1 : rapid economic growth (groups: A1T; A1B; A1FI) **1.4 - 6.4 °C**

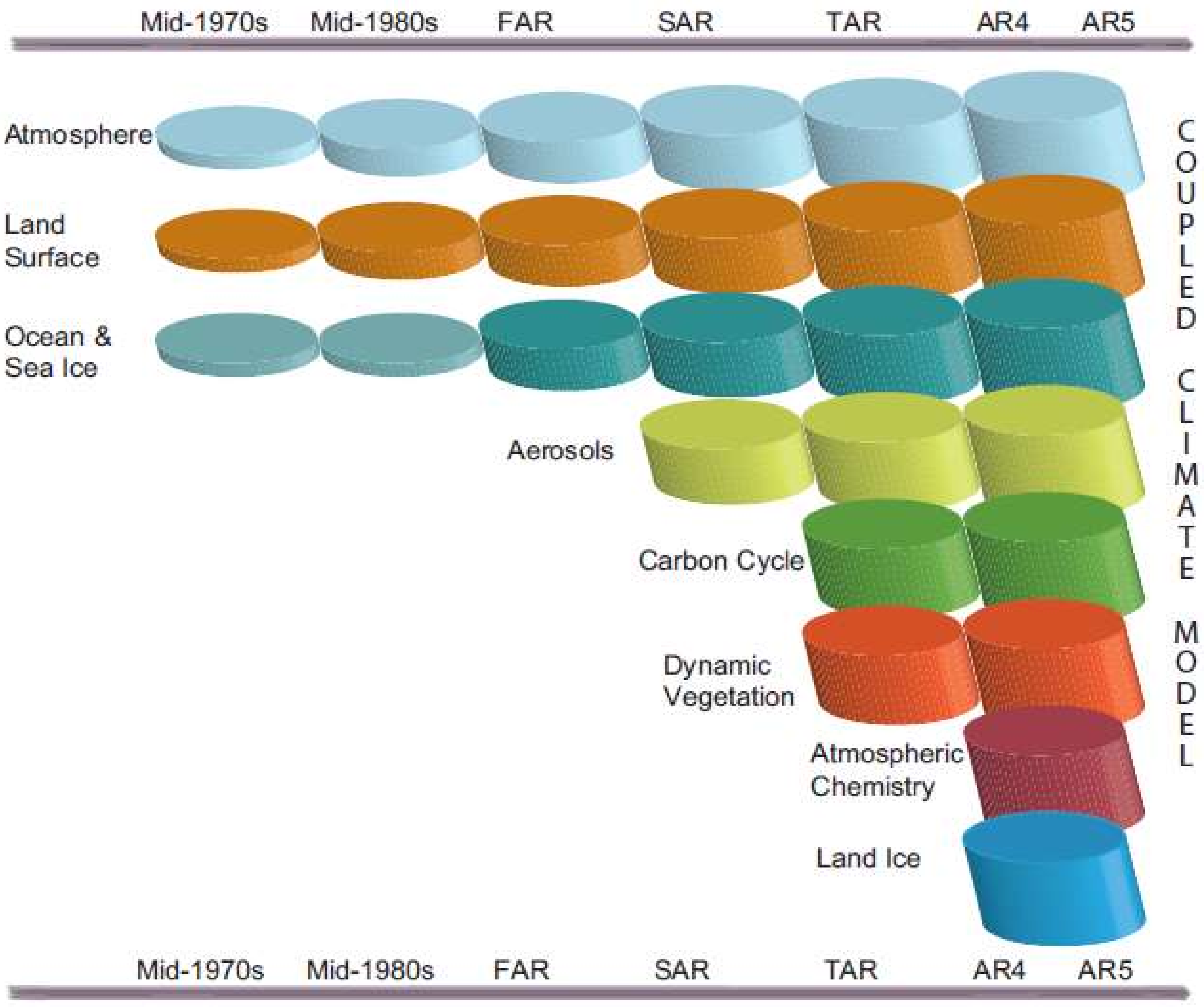
B1: global environmental sustainability **1.1 - 2.9 °C**

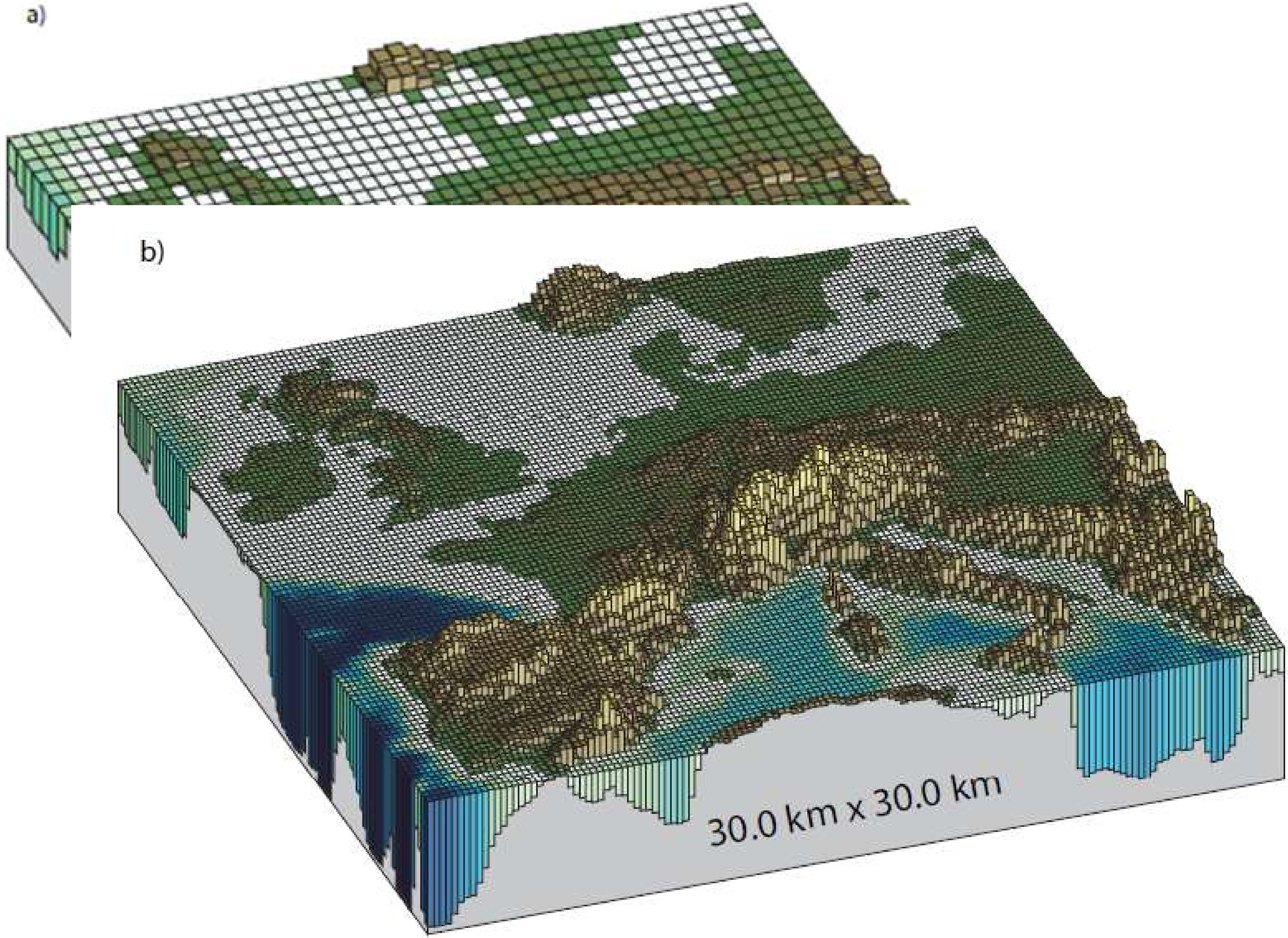
A2 : regionally oriented economic development **2.0 - 5.4 °C**

B2 : local environmental sustainability **1.4 - 3.8 °C**

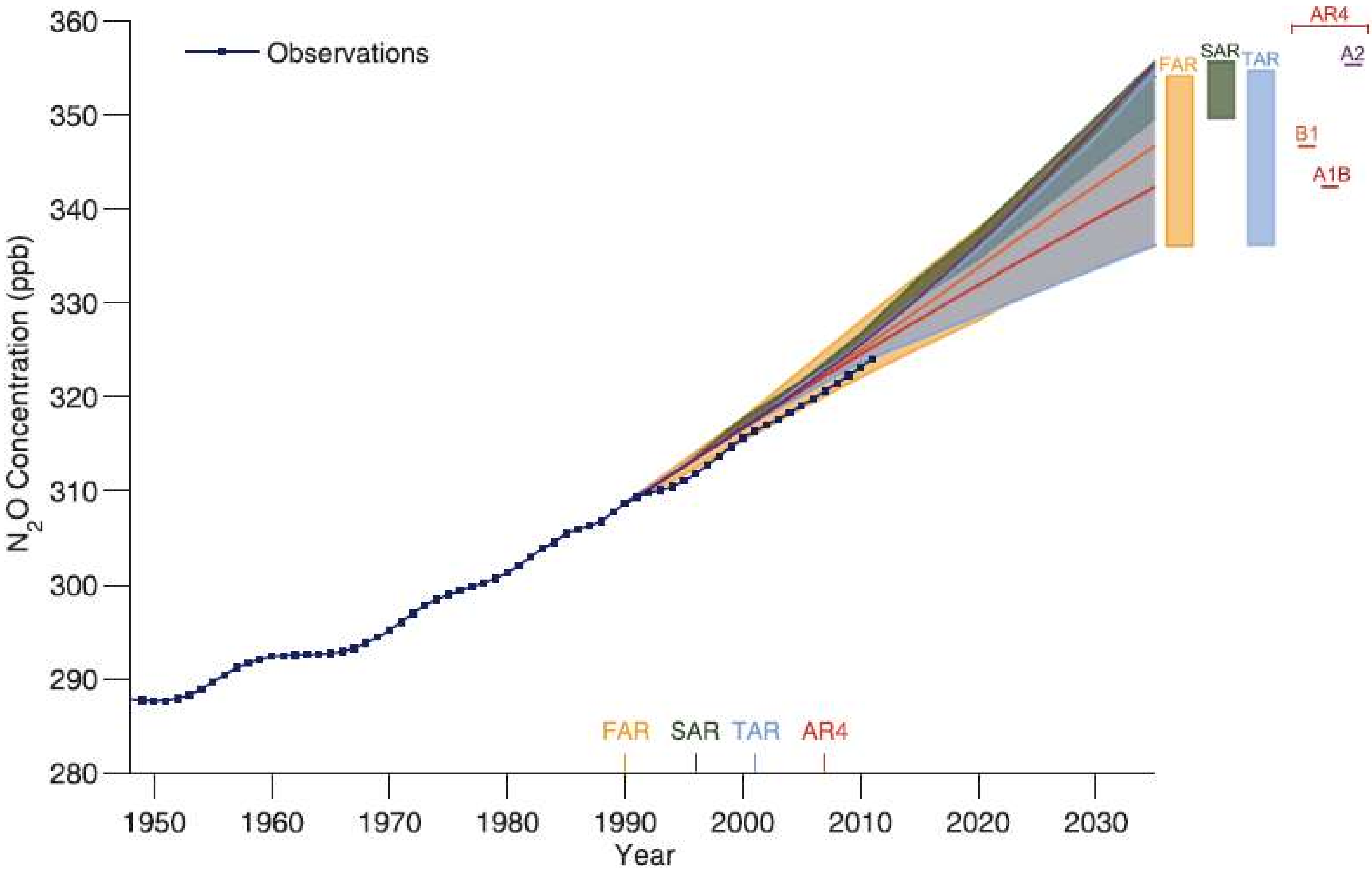
CC Assessment Reports

- ***IPCC First Assessment Report 1990 (FAR)***
- ***IPCC Second Assessment Report: Climate Change 1995 (SAR)***
- ***IPCC Third Assessment Report: Climate Change 2001 (TAR)***
- ***IPCC Fourth Assessment Report: Climate Change 2007 (AR4)***
- ***IPCC Fifth Assessment Report: Climate Change 2013 (AR5)***

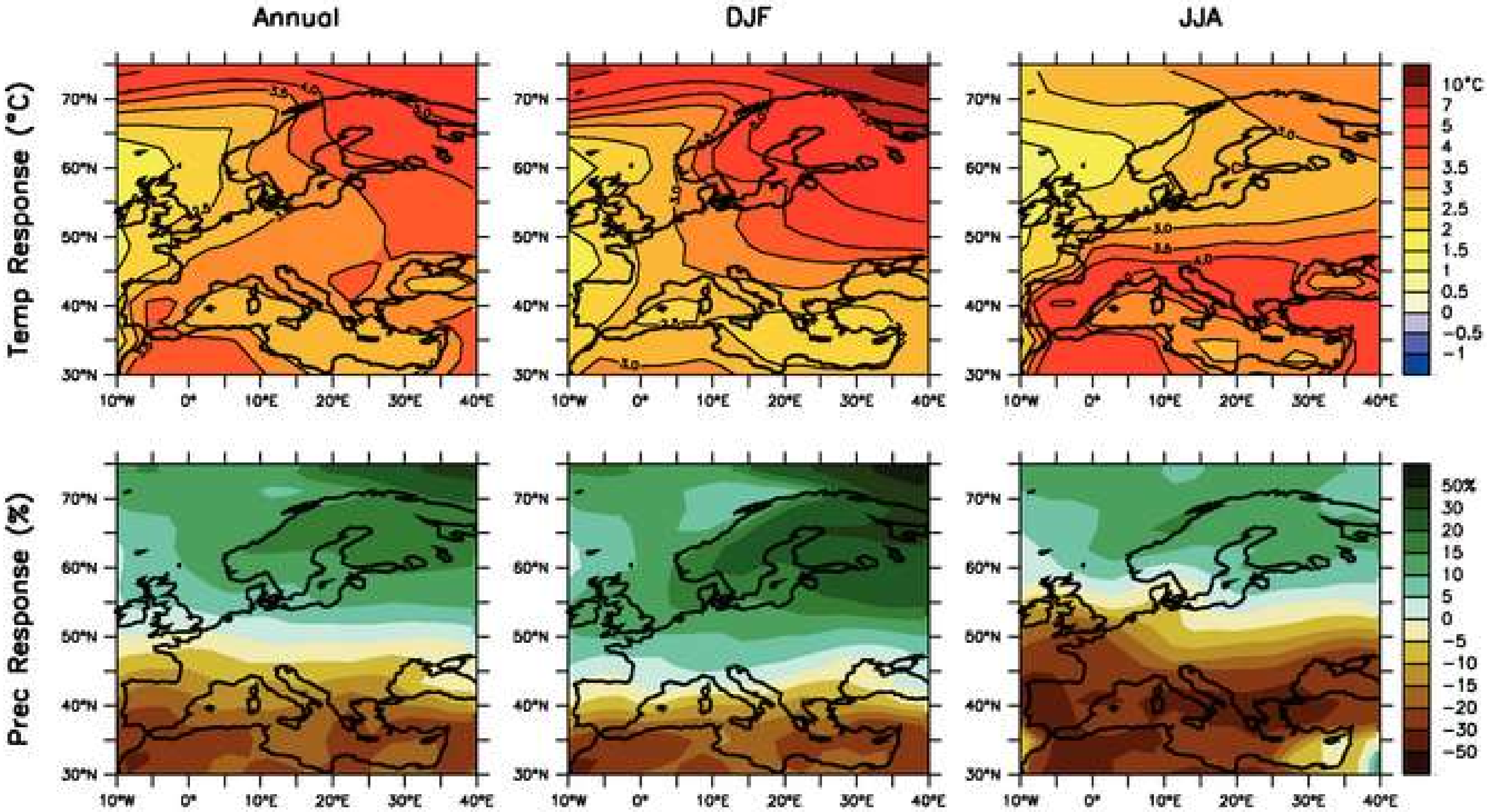

Mid-1970s
Mid-1980s
FAR
SAR
TAR
AR4
AR5
Atmosphere
Land Surface
Ocean & Sea Ice
Aerosols
Carbon Cycle
Dynamic Vegetation
Atmospheric Chemistry
Land Ice
COUPLED CLIMATE MODEL
Mid-1970s
Mid-1980s
FAR
SAR
TAR
AR4
AR5


a)
b)
30.0 km x 30.0 km

CO_2, CH_4, N_2O projections

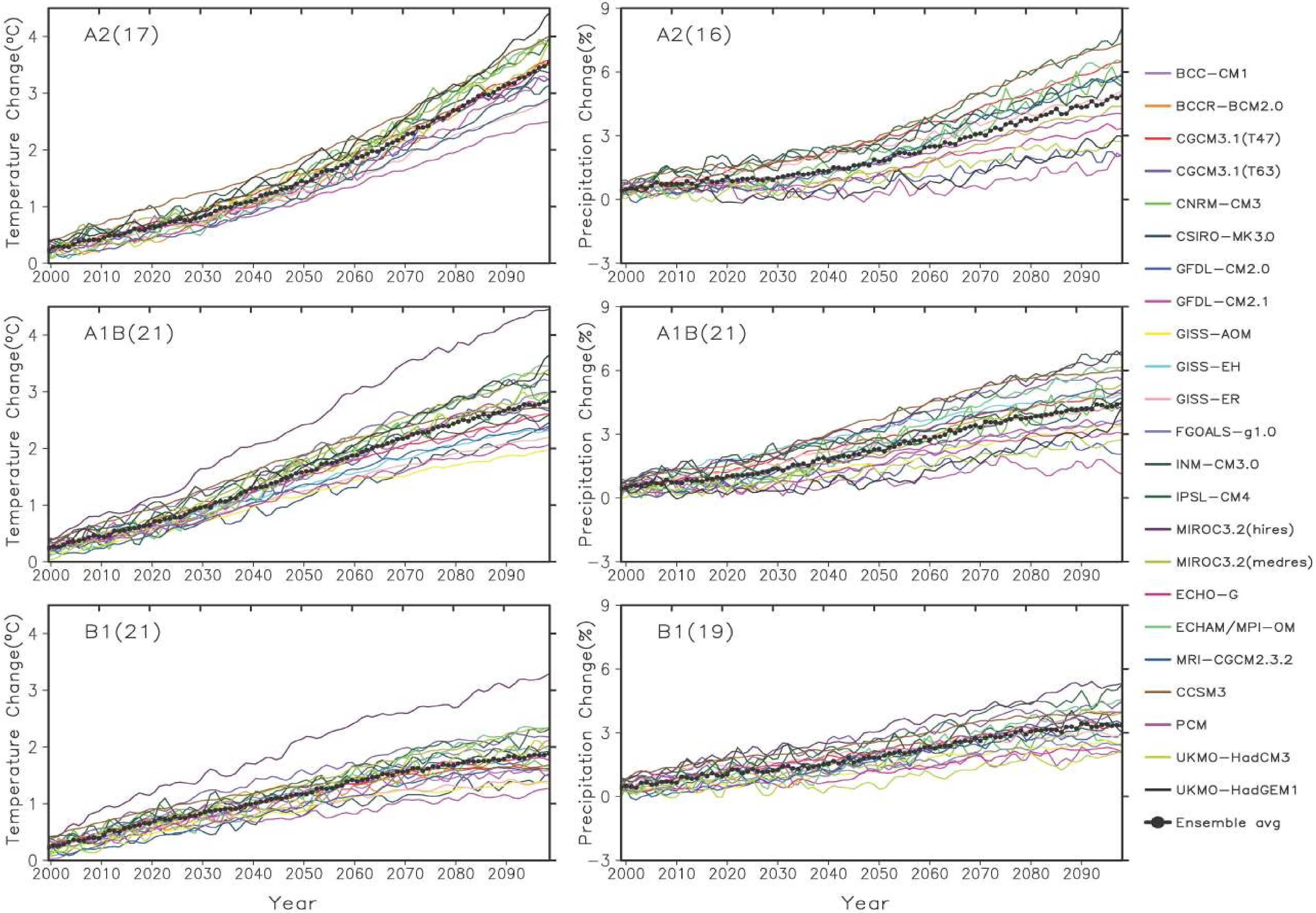


Climate Change Projections



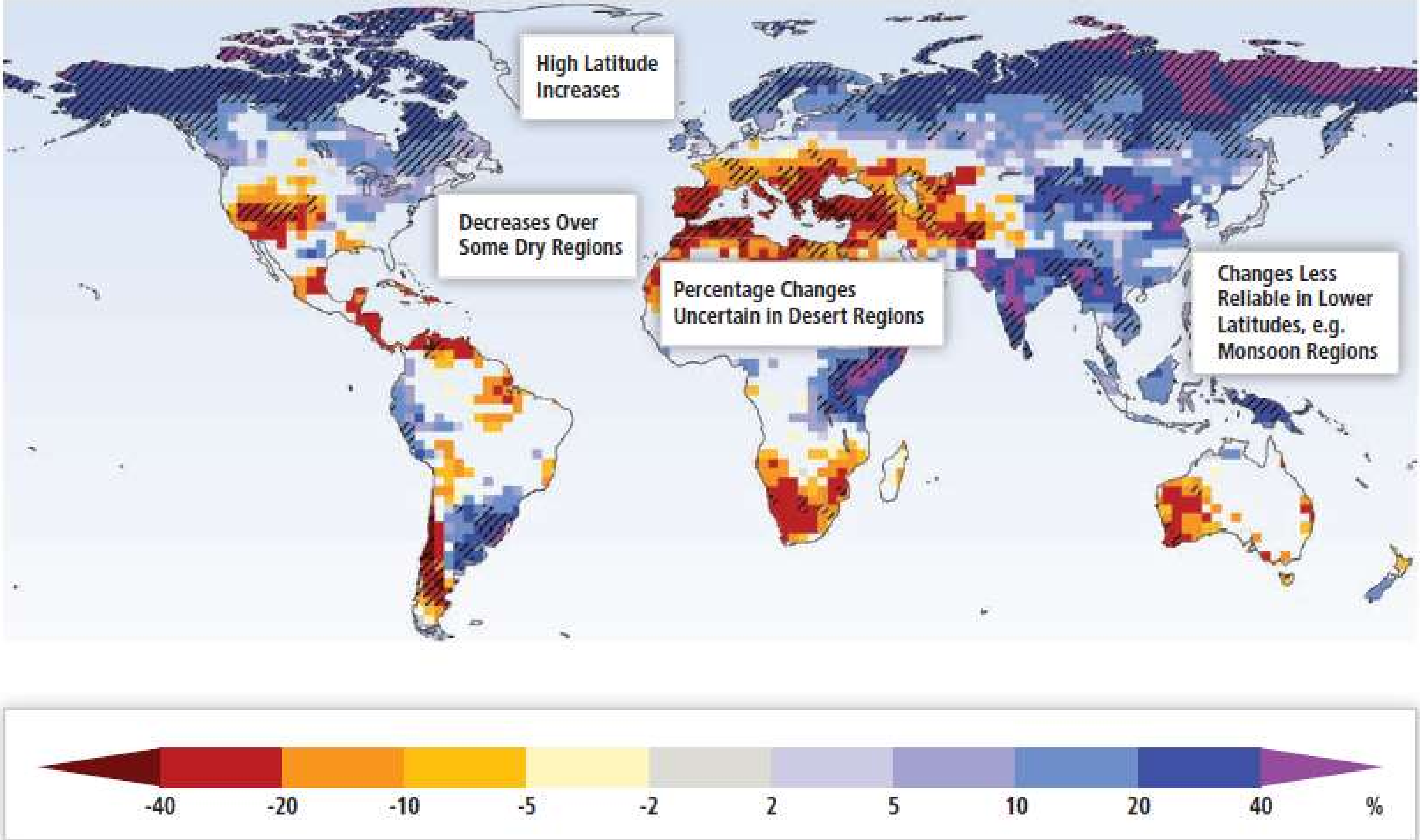
Temperature and precipitation changes over Europe from the MMD-A1B simulations, averaged over 21 models.

Source: GISS NASA



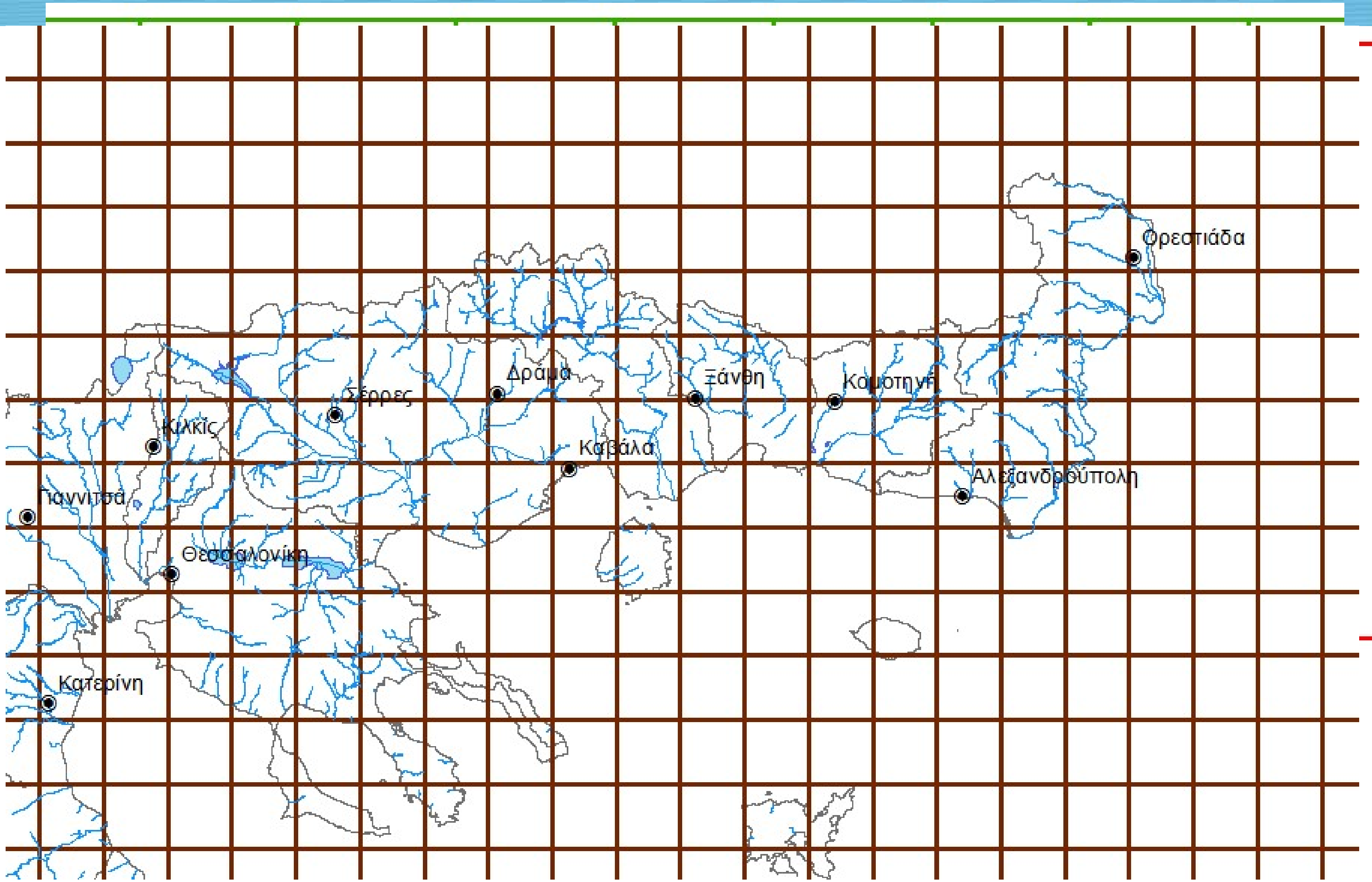
Source: IPCC Fourth Assessment Report: Climate Change 2007: WG I: The Physical science Basis

Changes in annual runoff



I | Large-scale changes in annual runoff (water availability, in percent) for the period 2090 to 2099, relative to 1980 to 1999. Values represent the median of 12 climate model projections using the SRES A1B scenario. White areas are where less than 66% of the 12 models agree on the sign of change and hatched areas are where more than 90% of models agree on the sign of change. Source: IPCC (2007a).

Why do we need climate downscaling?



- **Red gird: Grid of climate model with resolution of 200x200 km.**
- **Green gird : Grid of climate model with resolution of 50x50 km.**
- **Brown grid: Grid of climate model with resolution of 20x20 km.**

What is Climate Downscaling?

Downscaling: obtaining subgrid-scale information from coarser resolution fields

Climate model downscaling “bridges the gap” between what is provided by global climate modelers and what is needed by engineers, scientists, decision-makers and impact assessors

Two approaches: statistical
dynamical (regional climate models)

Statistical downscaling

Statistical downscaling is based on the view that the regional climate is conditioned by two factors:

- the large scale climatic state, and
- the regional physiographic features (e.g. topography, land-sea distribution and land-use).

From this perspective, regional or local climate information is derived by first determining a statistical model which relates large scale climate variables (or "**predictors**") to regional and local variables (or "**predictands**"). Then the large scale output of a GCM simulation is fed into this statistical model to estimate the corresponding local and regional climate characteristics.

Statistical downscaling involves developing quantitative relationships between large scale atmospheric variables (predictors) and local surface variables (predictands). The most common form has the predictand as a function of the predictor(s), but other types of relationships have been used (e.g. between predictors and the statistical distribution parameters of the predictand, or the frequencies of extremes of the predictands)

SD methods classification & description

- **Weather classification** methods group days into finite number of discrete weather types or "states" according to their synoptic similarity. The predictand is then assigned to the prevailing weather state, and replicated under changed climate conditions by resampling or regression functions.

- **Regression models** are a conceptually simple means of representing linear or linear relationships between predictands and the large scale atmospheric forcing. (problem with daily precipitation downscaling because of the relatively low relationships)

- **Weather generators** are models that replicate the statistical attributes of a local climate variable (such as mean and variance) but not observed sequences of events.

+ & - of SD methods

Method	Strengths	Weaknesses
Weather typing (e.g. analogue method, hybrid approaches, fuzzy classification, self organizing maps, Monte Carlo methods).	• Yields physically interpretable linkages to surface climate • Versatile (e.g., can be applied to surface climate, air quality, flooding, erosion, etc.) • Compositing for analysis of extreme events	• Requires additional task of weather classification • Circulation-based schemes can be insensitive to future climate forcing • May not capture intra-type variations in surface climate
Weather generators (e.g. Markov chains, stochastic models, spell length methods, storm arrival times, mixture modelling).	• Production of large ensembles for uncertainty analysis or long simulations for extremes • Spatial interpolation of model parameters using landscape • Can generate sub-daily information	• Arbitrary adjustment of parameters for future climate • Unanticipated effects to secondary variables of changing precipitation parameters
Regression methods (e.g. linear regression, neural networks, canonical correlation analysis, kriging).	• Relatively straightforward to apply • Employs full range of available predictor variables • 'Off-the-shelf' solutions and software available	• Poor representation of observed variance • May assume linearity and/or normality of data • Poor representation of extreme events

References and documentation

Guidelines for
Use of Climate Scenarios Developed from Statistical Downscaling Methods

RL Wilby[1,2], SP Charles[3], E Zorita[4], B Timbal[5], P Whetton[6], LO Mearns[7]

[1]Environment Agency of England and Wales, UK
[2]King's College London, UK
[3]CSIRO Land and Water, Australia
[4]GKSS, Germany
[5]Bureau of Meteorology, Australia
[6]CSIRO Atmospheric Research, Australia
[7]National Center for Atmospheric Research, USA

August 2004

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Framework Convention on
Climate Change

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- Overview
- Adaptation
- Climate Finance
- Mitigation
- Technology

PROCESS
- Essential Background

Compendium on methods and tools to evaluate impacts of, and vulnerability and adaptation to, climate change

Statistical DownScaling Model (SDSM)	
Description	SDSM is a user-friendly software package designed to implement statistical downscaling methods to produce high-resolution monthly climate information from coarse-resolution climate model (GCM) simulations. The software also uses weather generator methods to produce multiple realizations (ensembles) of synthetic daily weather sequences.
Appropriate Use	SDSM can be used whenever impact assessments require small-scale climate scenarios, provided quality observational data and daily GCM outputs for large-scale climate variables are available.
Scope	All locations

A COMPARISON OF STATISTICAL DOWNSCALING AND CLIMATE CHANGE FACTOR METHODS: IMPACTS ON LOW FLOWS IN THE RIVER THAMES, UNITED KINGDOM

JACQUELINE DIAZ-NIETO[1] and ROBERT L. WILBY[2,3]

[1]Department of Geography, Kings College, London, United Kingdom
[2]Climate Change Unit, Environment Agency, United Kingdom
E-mail rob.wilby@environment-agency.gov.uk
[3]Department of Geography, Kings College, London, United Kingdom

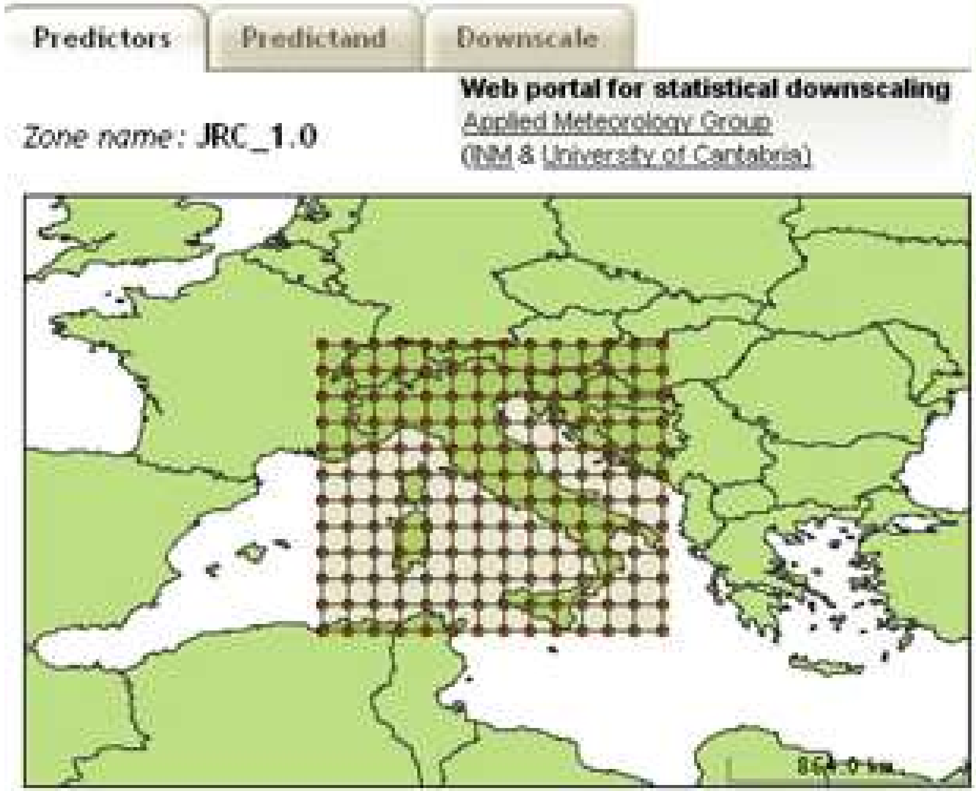
Wilby, R. L., Wigley, T. M. L., Conway, D., Jones, P. D., Hewitson, B. C., Main, J., & Wilks, D. S. (1998). Statistical downscaling of general circulation model output: a comparison of methods. *Water resources research*, *34*(11), 2995-3008.

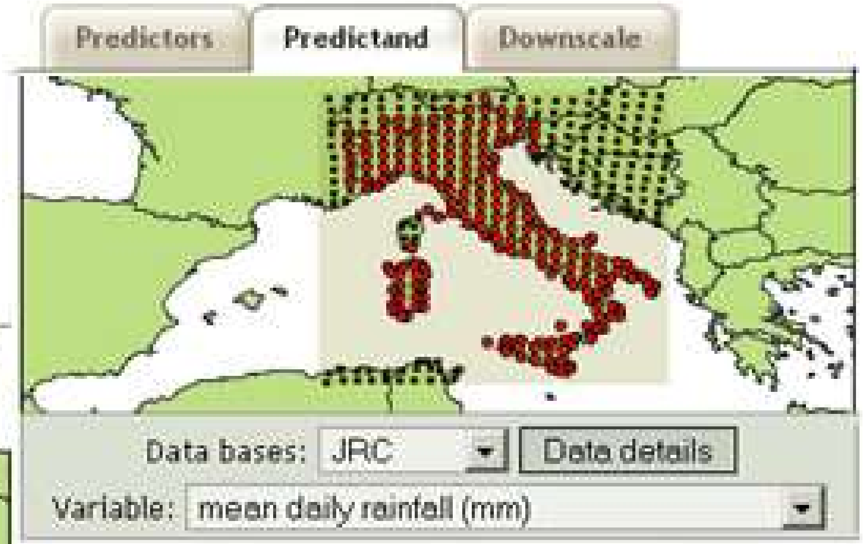
Wilby, R. L., Hay, L. E., Gutowski, W. J., Arritt, R. W., Takle, E. S., Pan, Z., ... & Clark, M. P. (2000). Hydrological responses to dynamically and statistically downscaled climate model output. *Geophysical Research Letters*, *27*(8), 1199-1202.

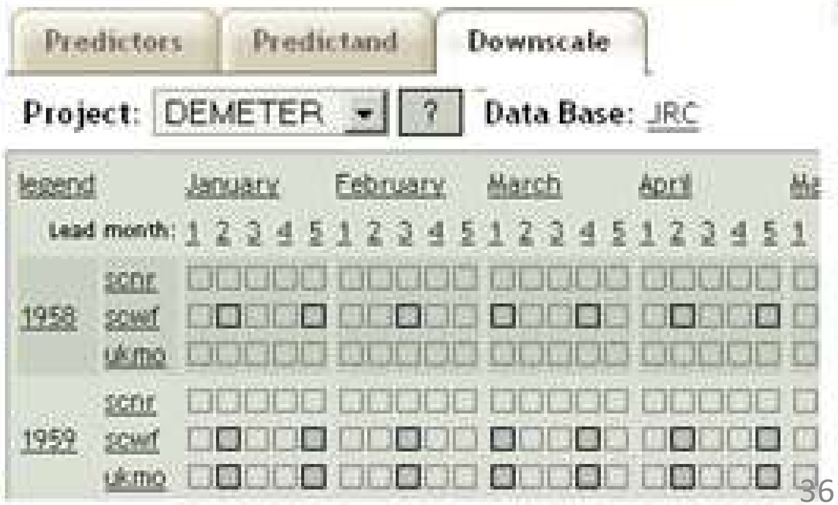
On line models for SD

Three steps are necessary to obtain high resolution forecasts in a region of interest:

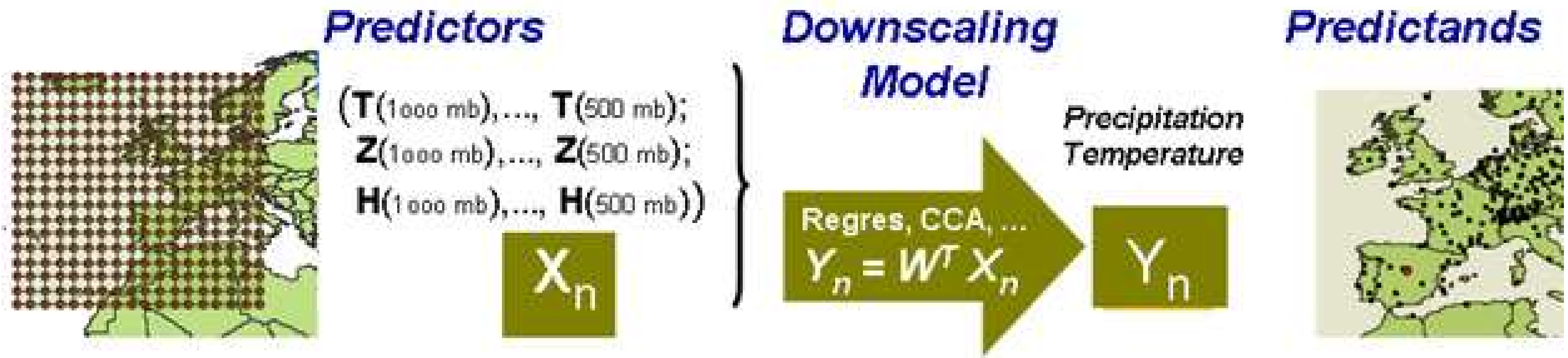
1. Selecting the predictors,
2. Selecting the stations and variable,
3. Running the desired downscaling jobs







Applied Meteorology Group
(UC & CSIC & AEMet)
Santander, Spain



The **main features** are:

•**PREDICTANDS**: JRC (0.5º) grid over Europe. ECA network (1000 stations) over Europe.

•**PREDICTORS**:

Climate Change perdictions: ENSEMBLES (ECHAM5-MPI Germany), PCMDI-IPCC (CSIRO-MK3 Australia; CGCM3 Canada), local providers (CNRM-CM3).

•**DOWNSCALING**: analogs and weather typing, regression and neural networks

http://grupos.unican.es/ai/meteo/ensembles/downscaling/index.html

Dynamic downscaling

Nesting a regional climate model into an existing GCM is known as a dynamic method to downscale data.

To do this, a specific location is defined and certain driving factors from the GCM are applied to the regional climate model.

A regional climate model is a dynamic model, like a GCM, but it can be thought of as being composed of three layers:

- One layer is largely driven by the GCM,
- another layer builds on some locally specific data, and
- the third layer uses its own physics based equations to resolve the model based on data from the other two.

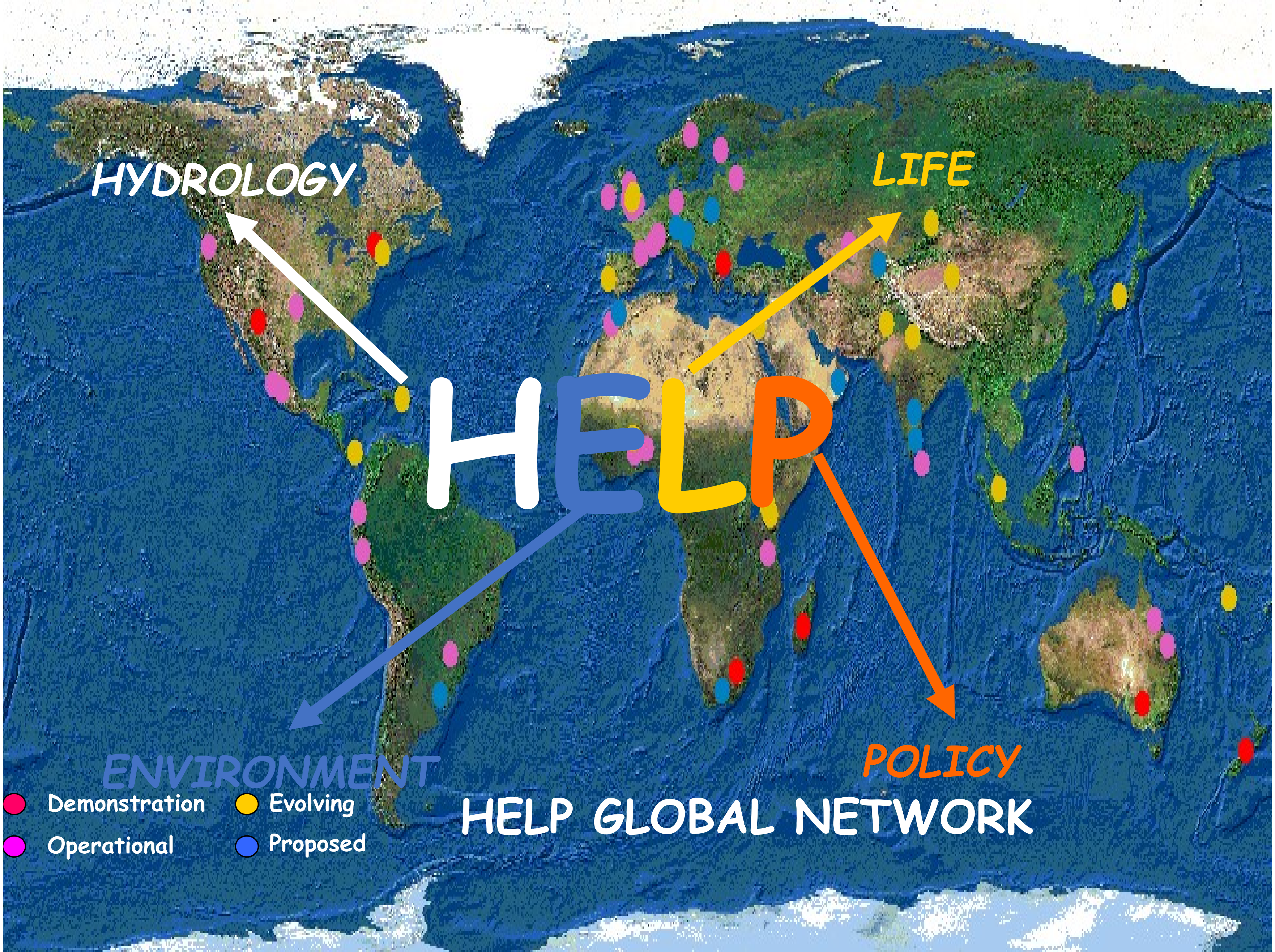
Climate change potential impacts to HPP

The resource potential for hydropower is currently based on historical data for the present climatic conditions. With a changing climate, this resource potential could change due to:

- **Changes in river flow** (runoff) related to changes in local climate, particularly in precipitation and temperature in the catchment area. This may lead to changes in runoff volume, variability of flow and seasonality of the flow (e.g., by changing from spring/summer high flow to more winter flow), directly affecting the resource potential for hydropower generation.

- **Changes in extreme events** (floods and droughts) may increase the cost and risk for the hydropower projects.

- **Changes in sediment loads** due to changing hydrology and extreme events. More sediment could increase turbine abrasions and decrease efficiency. Increased sediment load could also fill up reservoirs faster and decrease the live storage, reducing the degree of regulation and decreasing storage services.


HYDROLOGY
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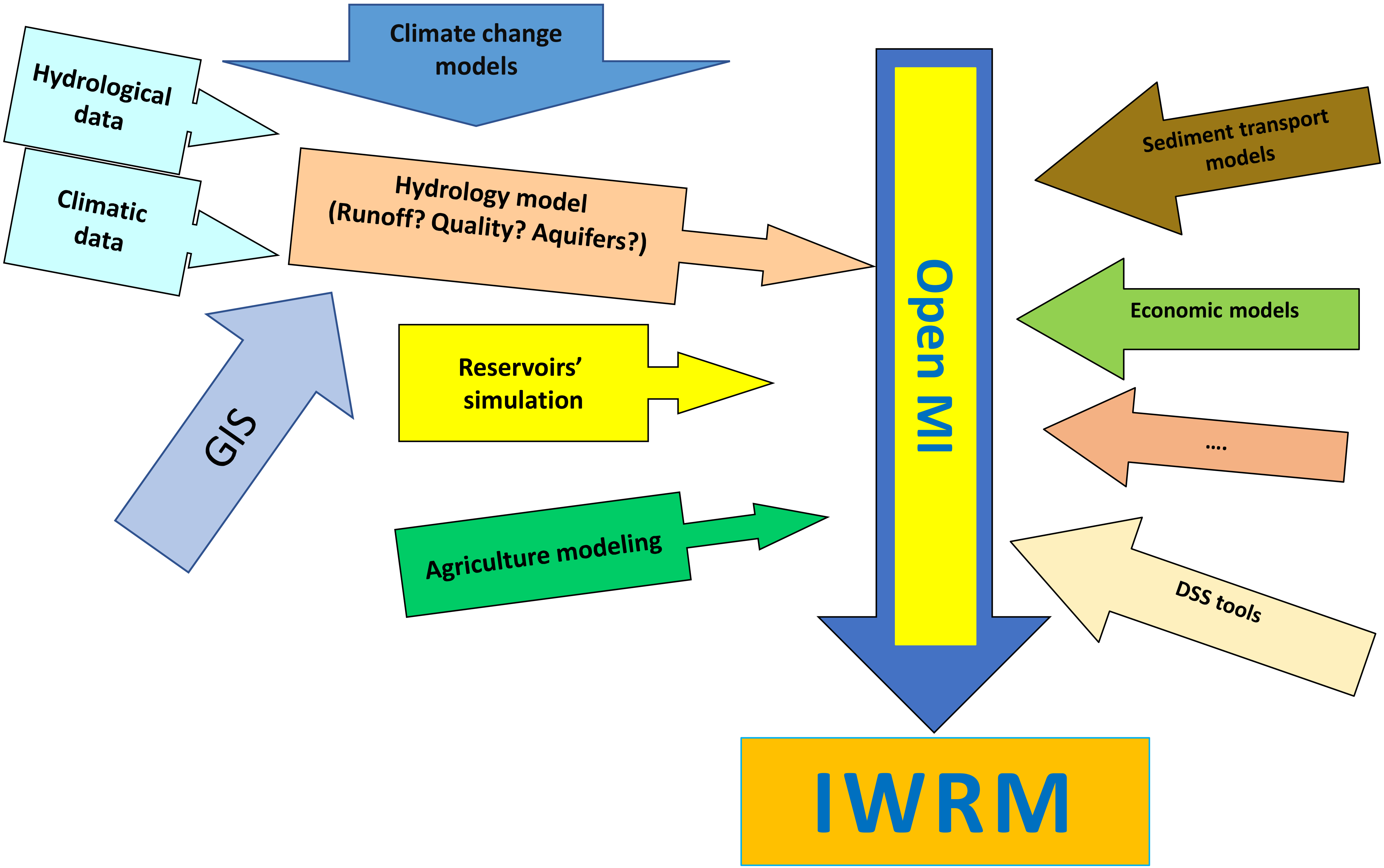
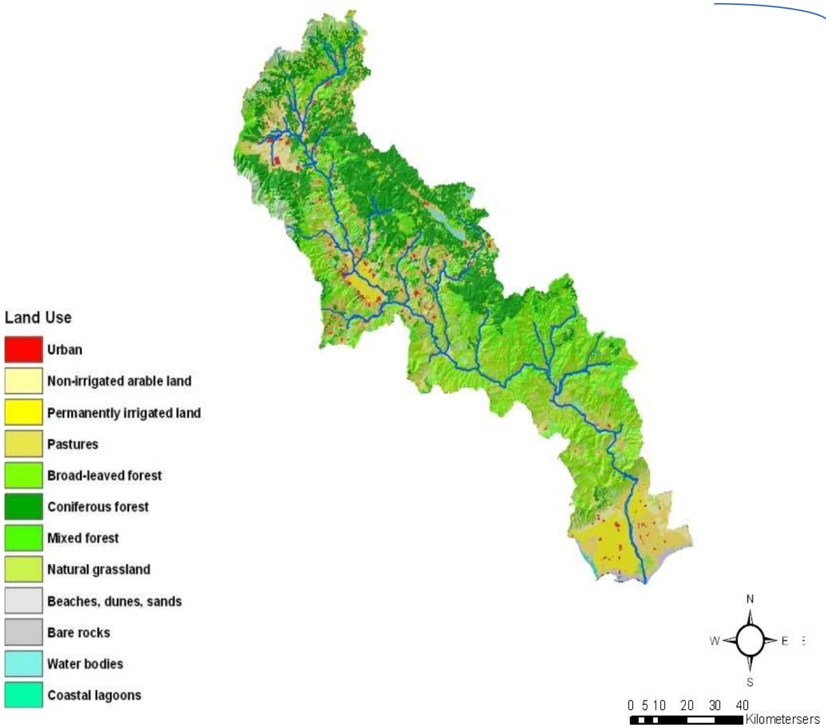
ENVIRONMENT
POLICY
Demonstration
Evolving
Operational
Proposed
HELP GLOBAL NETWORK

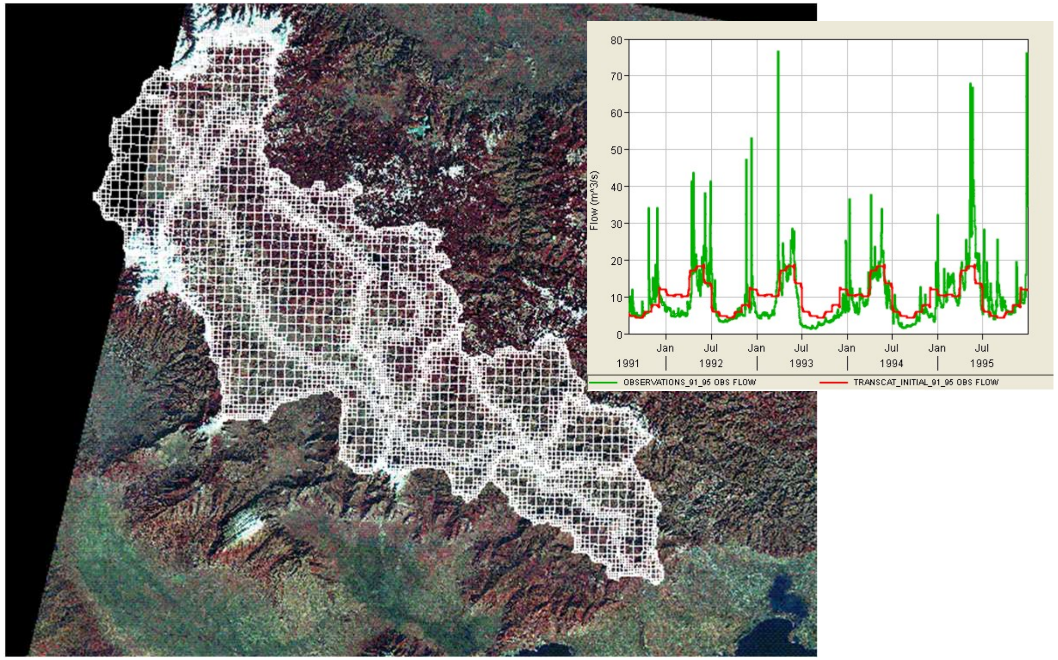
Modeling Coupling for the Integrated Water Resources Management



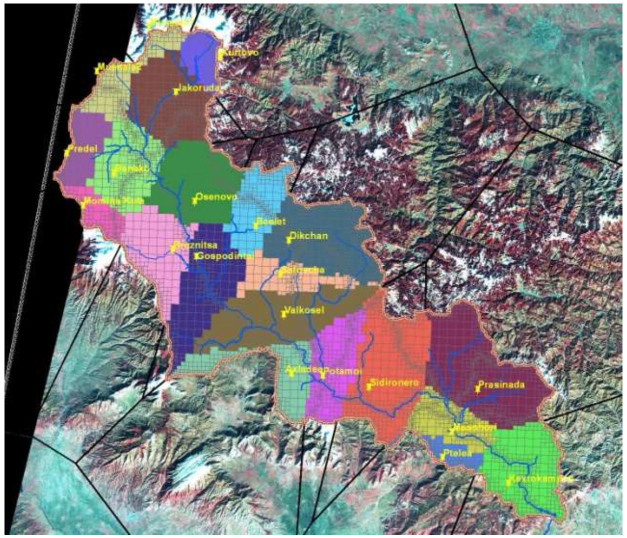
Geographic Information Systems - GIS



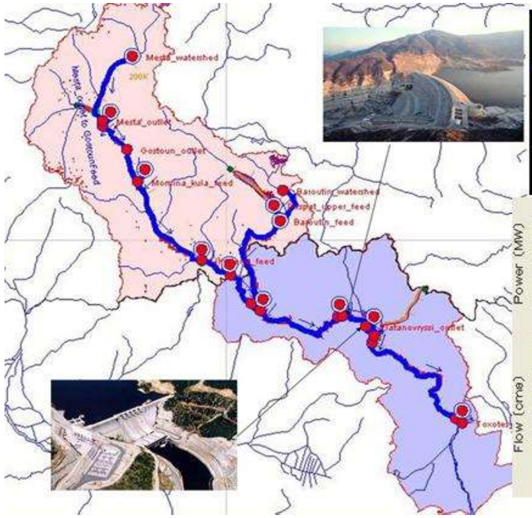
Hydrologic modelling



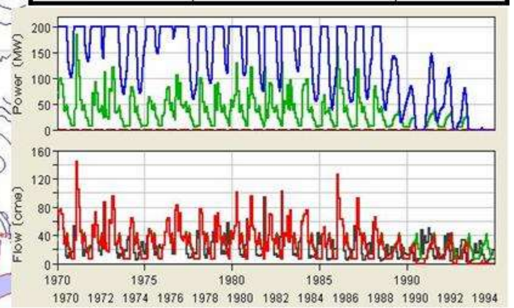
Meteorological data



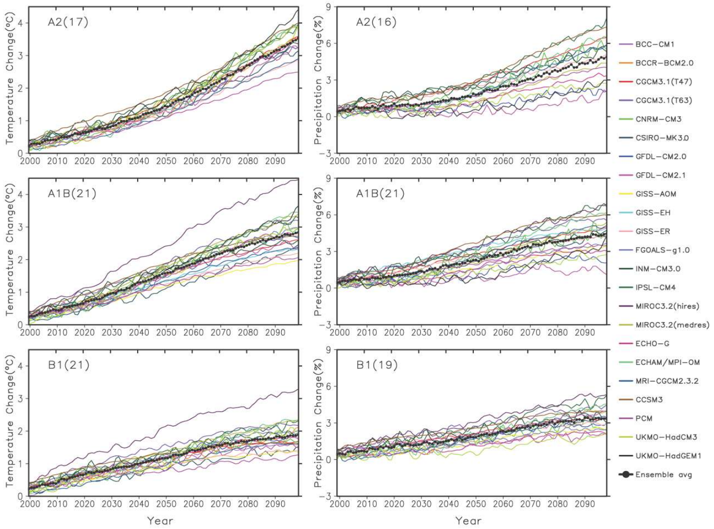
Reservoir simulation



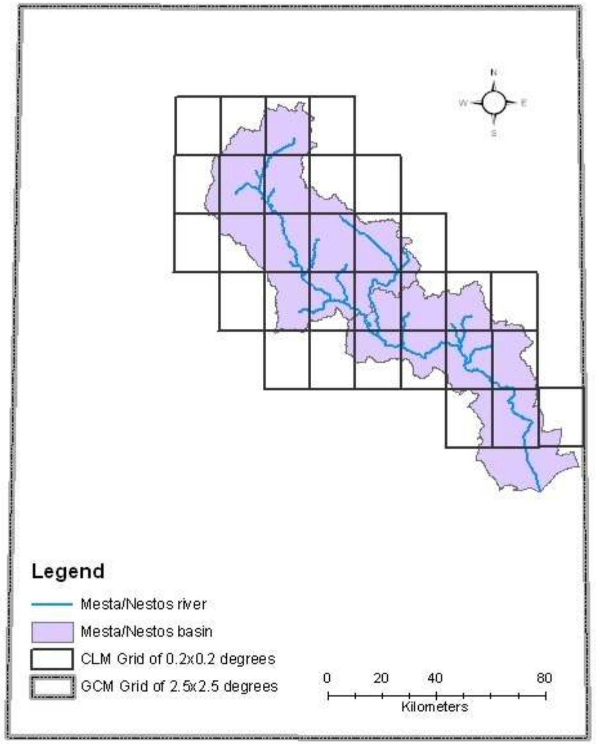
Dams of Nestos	Level of tailrace tunnel (m)	Power (MW)
Thissavros	226	300
Platanovryssi	151	100
Temenos	126	20

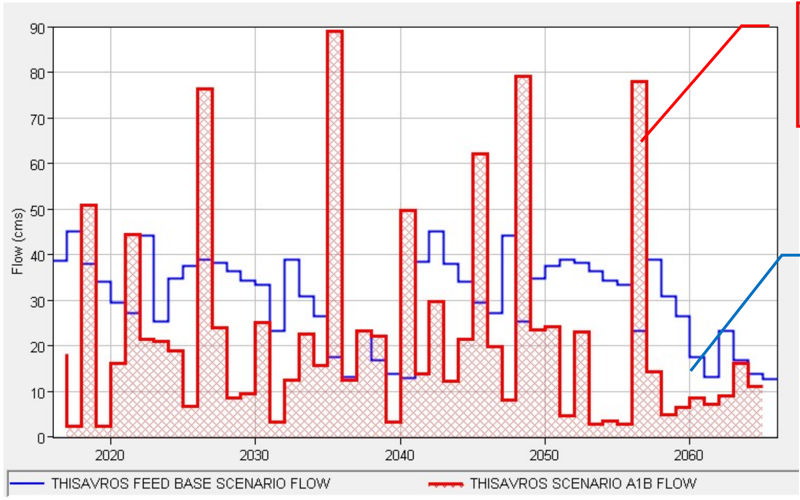


Climate change models



Downscaling techniques



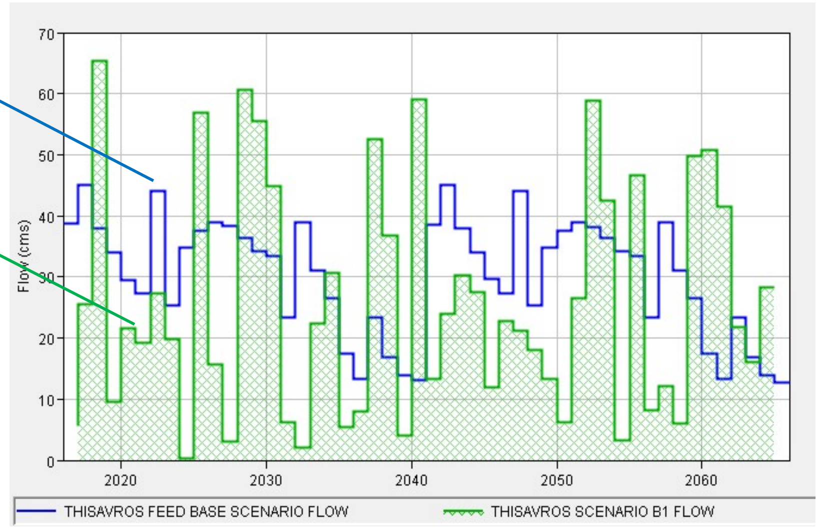


A1B Scenario

Base Scenario

Base Scenario

B1 Scenario



	Base	A1B	B1
Mean flow (m^3/day)	30.15	22.20	25.90

Case study: Mesta/Nestos River Basin

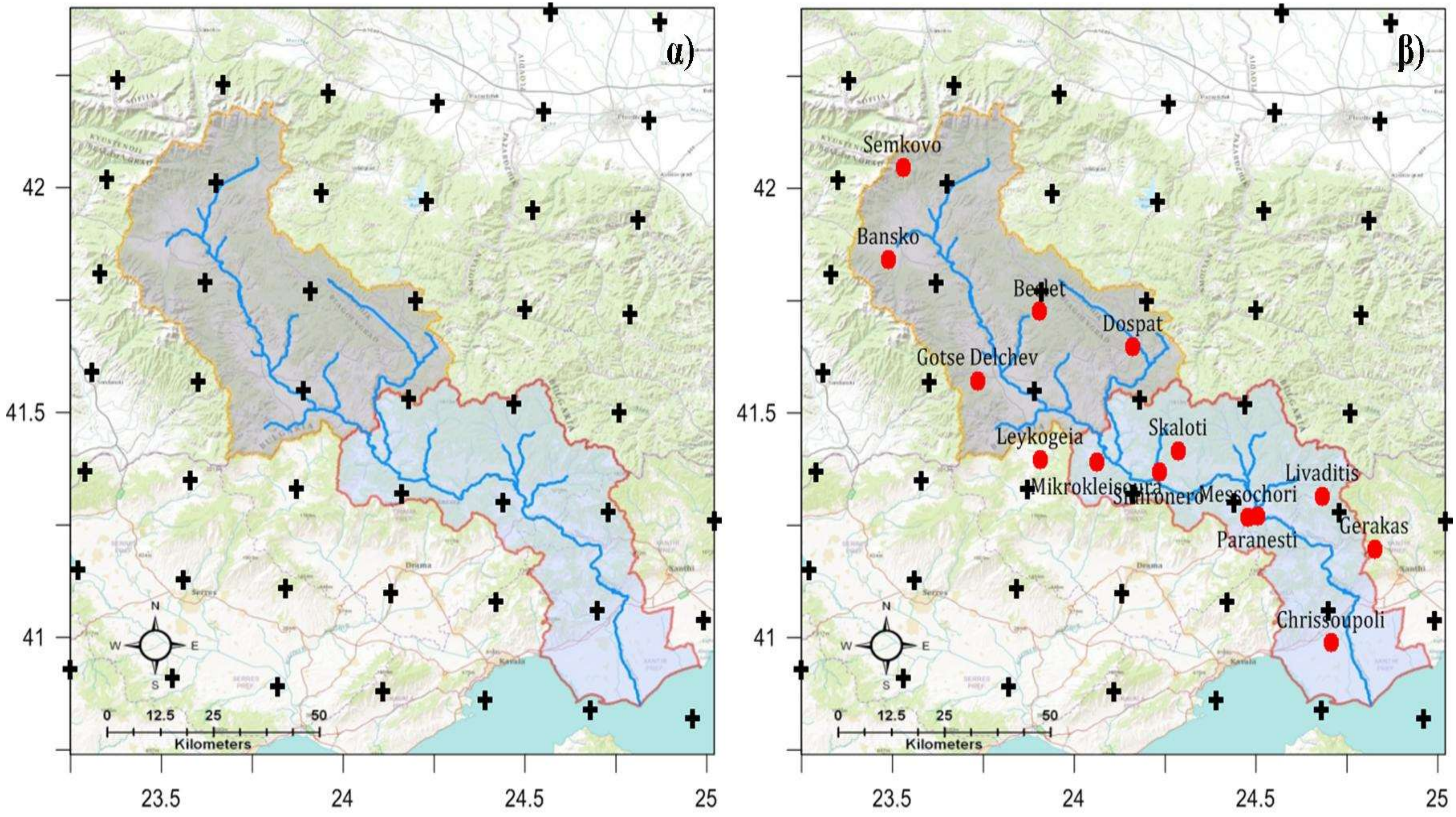
Surface: 6,218 Km^2

Length: 255 Km

Climate change RCMs

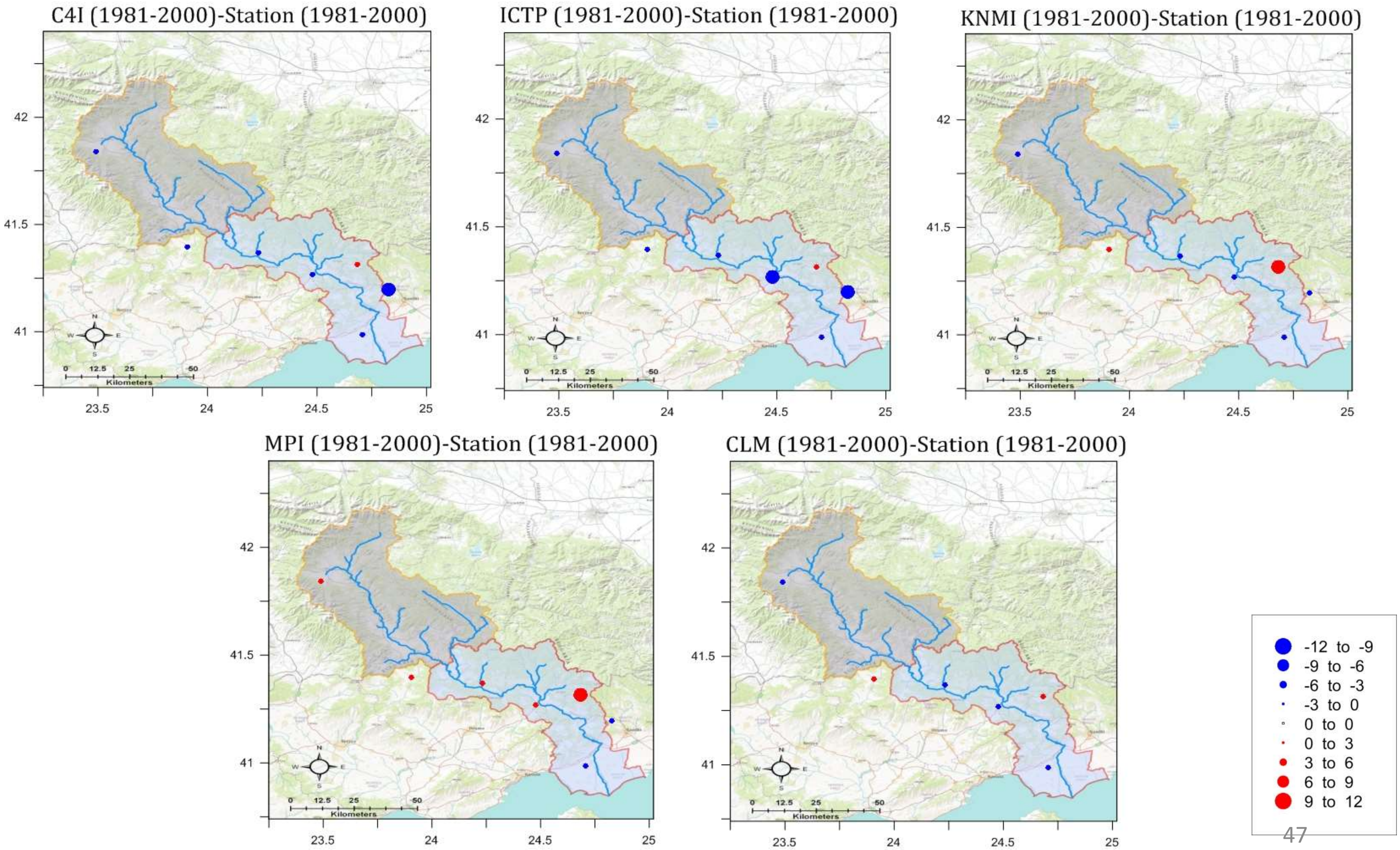
MODEL	Climate Institute	ABREVIATION	GCM	EMISSION SCENARIO
RCA3	Community Climate Change Consortium for Ireland	C4IRCA3	ECHAM5	A2 (- >2050)
RACMO2	Royal Netherlands Meteorological Institute	KNMI-RACMO2	ECHAM5-r3	A1B (- >2100)
RegCM3	International Centre for Theoretical Physics	ICTP-RegCM3	ECHAM5-r3	A1B (- >2100)
REMO	Max Planck Institute for Meteorology	MPI-M-REMO	ECHAM5-r3	A1B (- >2100)
CLM	Max Planck Institute for Meteorology	RCM-CLM	ECHAM5	B1 (- > 2100)

Climate change potential impacts to HPP



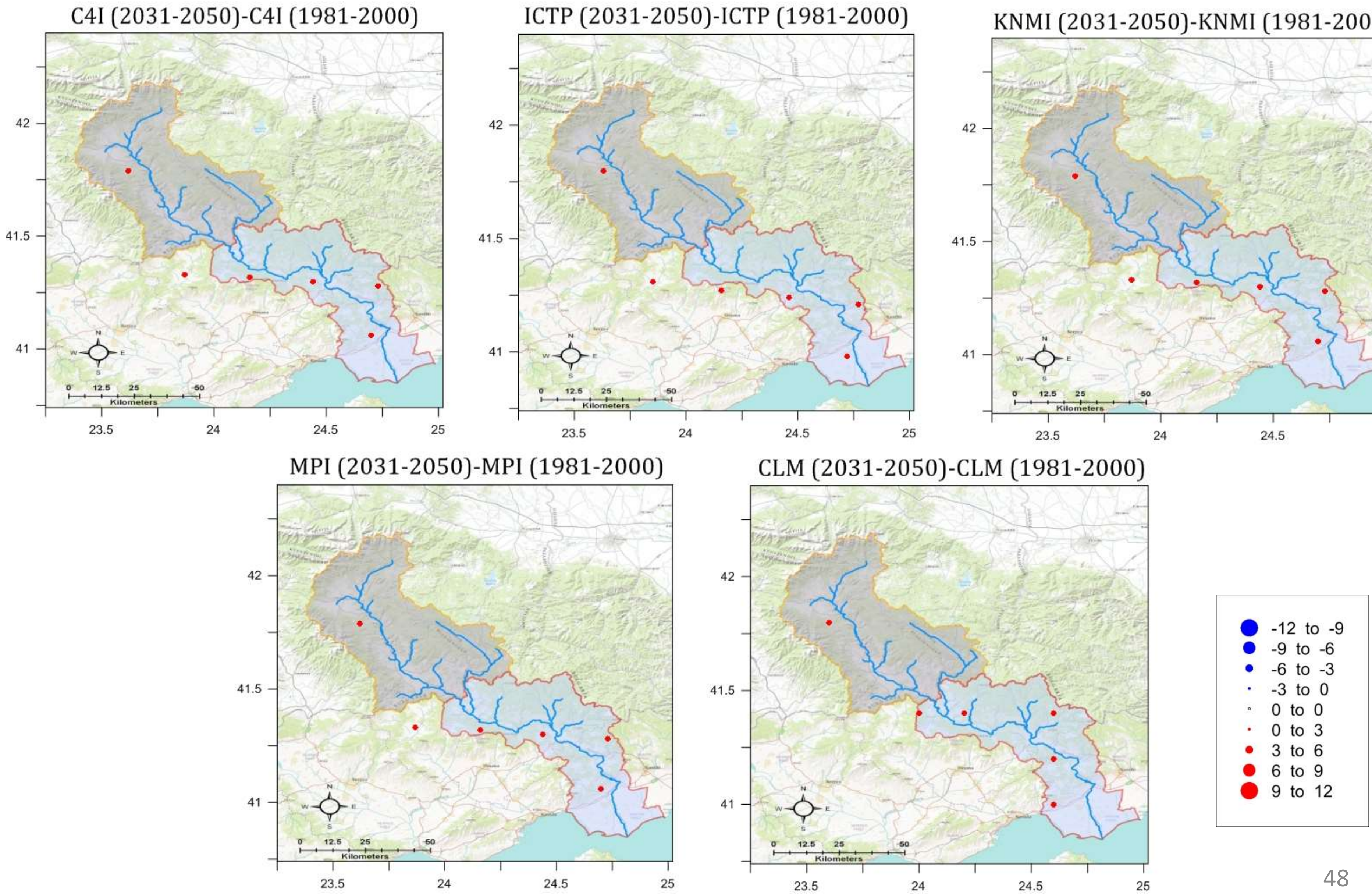
Hindcast: Temperature

Annual Temperature Differences

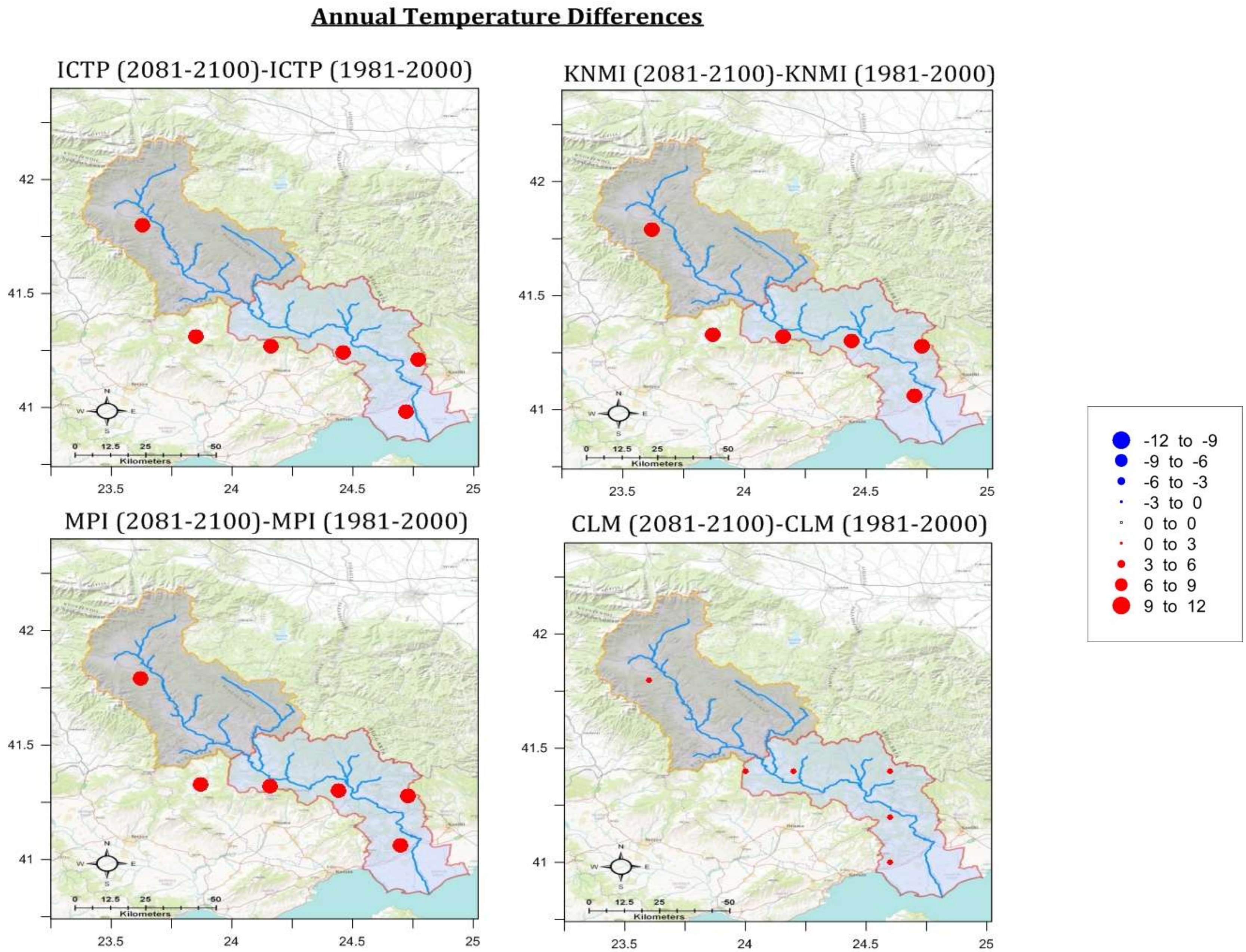


Temperature differences (1)

Annual Temperature Differences

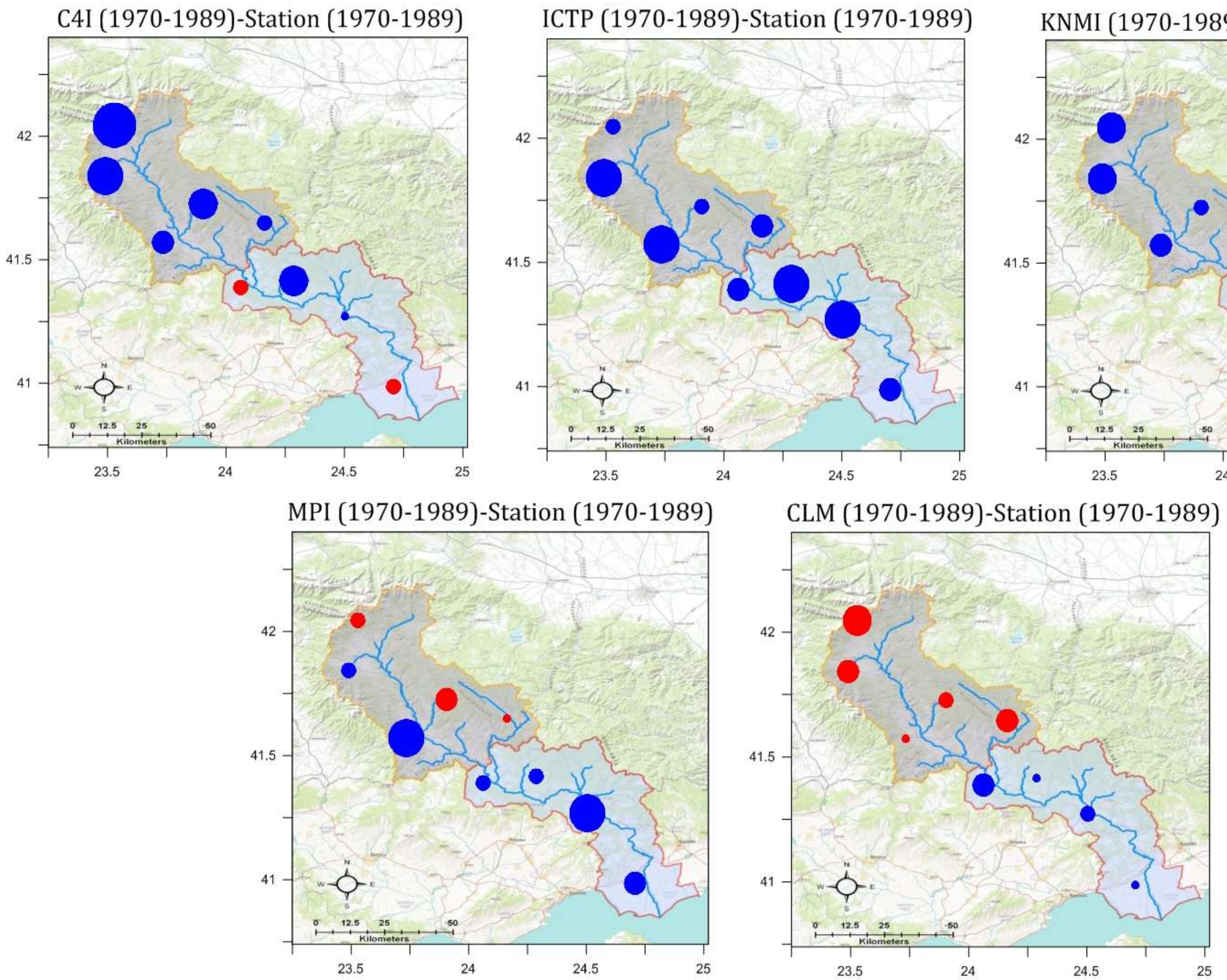


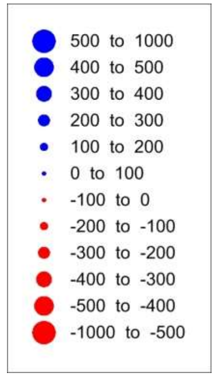
Temperature differences (2)



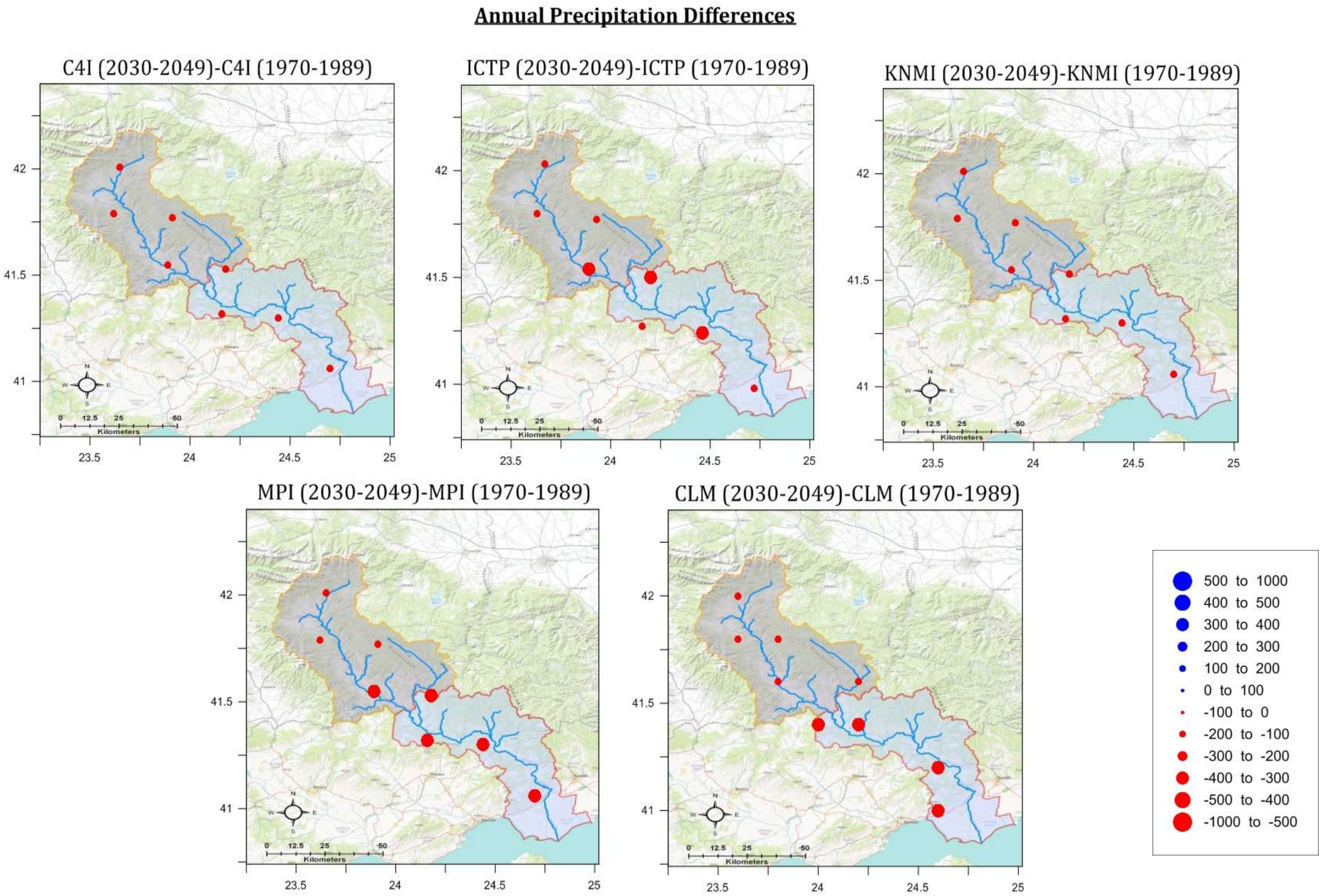
Hindcast: Precipitation

Annual PrecipitationDifferences



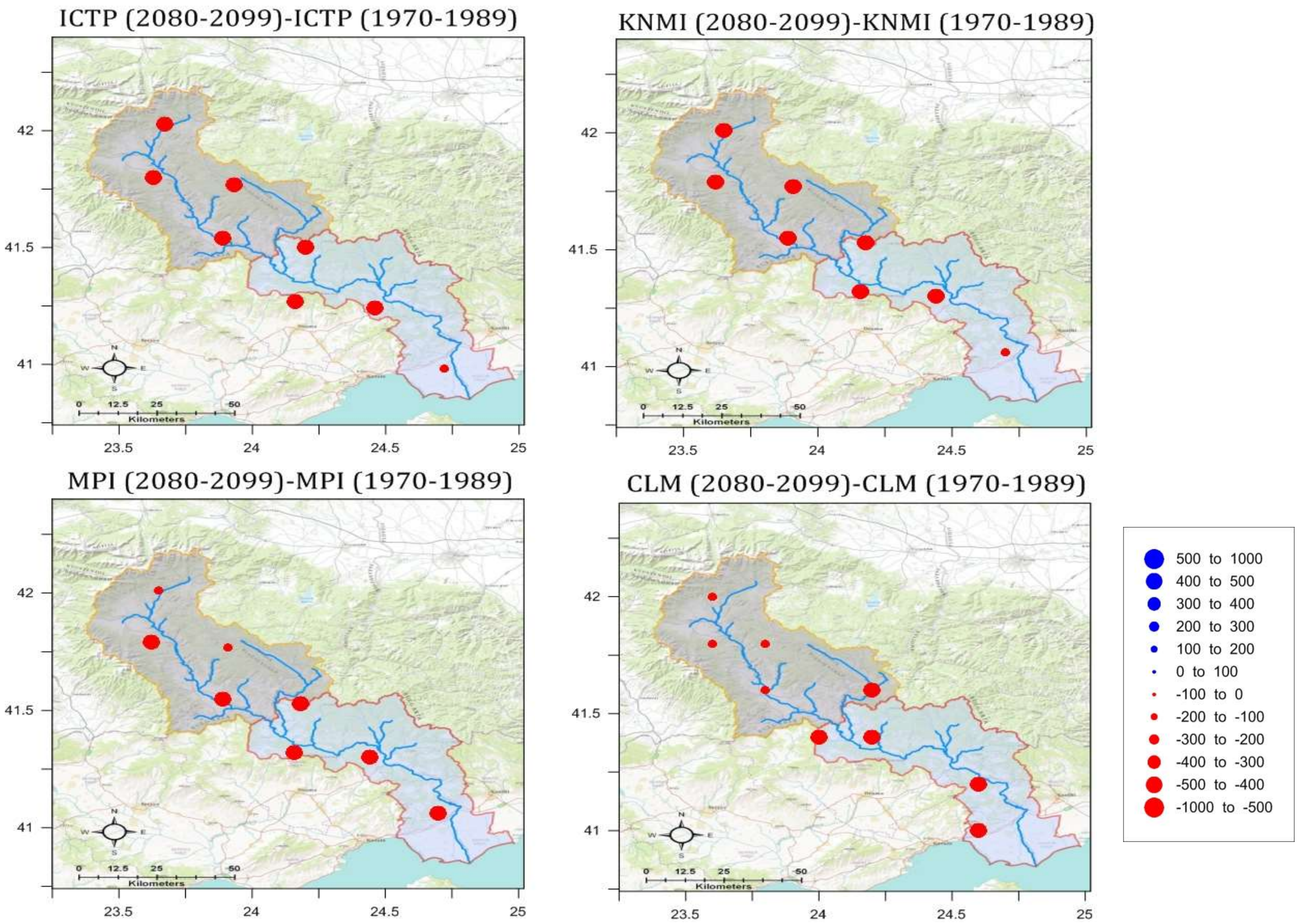


Precipitation differences (1)



Precipitation differences (2)

Annual Precipitation Differences



Evapotranspiration variations

Annual Evapotranspiration Differences