



Update on RegCM4 developments and CORDEX

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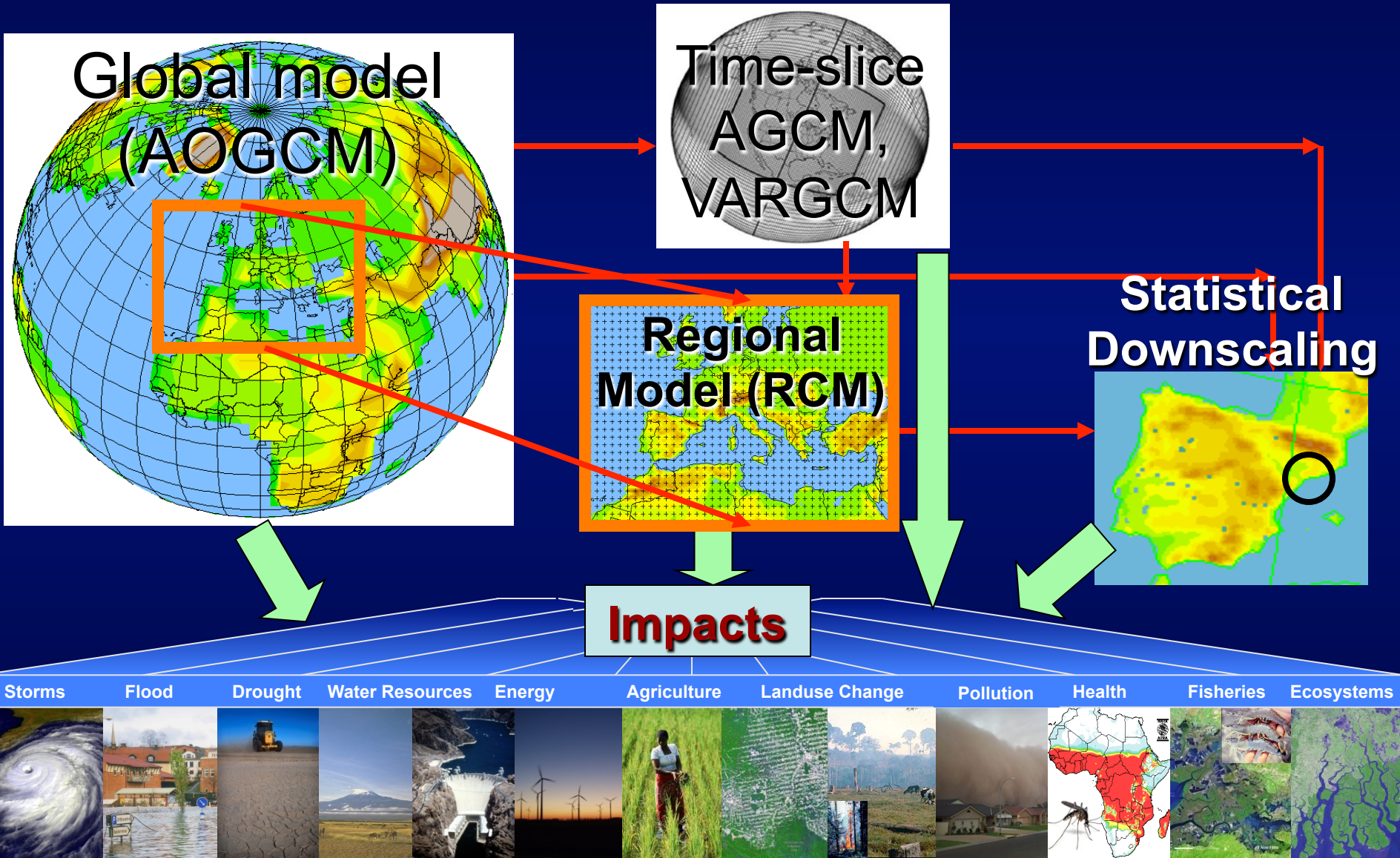
Outline

- Welcome and structure of the workshop
- Reminding you of what regional climate modeling is
- New developments in RegCM4
- CORDEX and the contribution of the RegCM community
- Objectives of the workshop

Welcome and structure of the workshop

- Welcome !!
- First week:
 - Morning: Lectures
 - Afternoon: Lab sessions/group projects work
- Second week:
 - Morning: Participants' presentations
 - Afternoon: Group projects work
 - Friday: Gran finale – Group project presentations

Downscaling regional climate information for impact assessment studies



“Nested” Regional Climate Modeling: Technique and Strategy

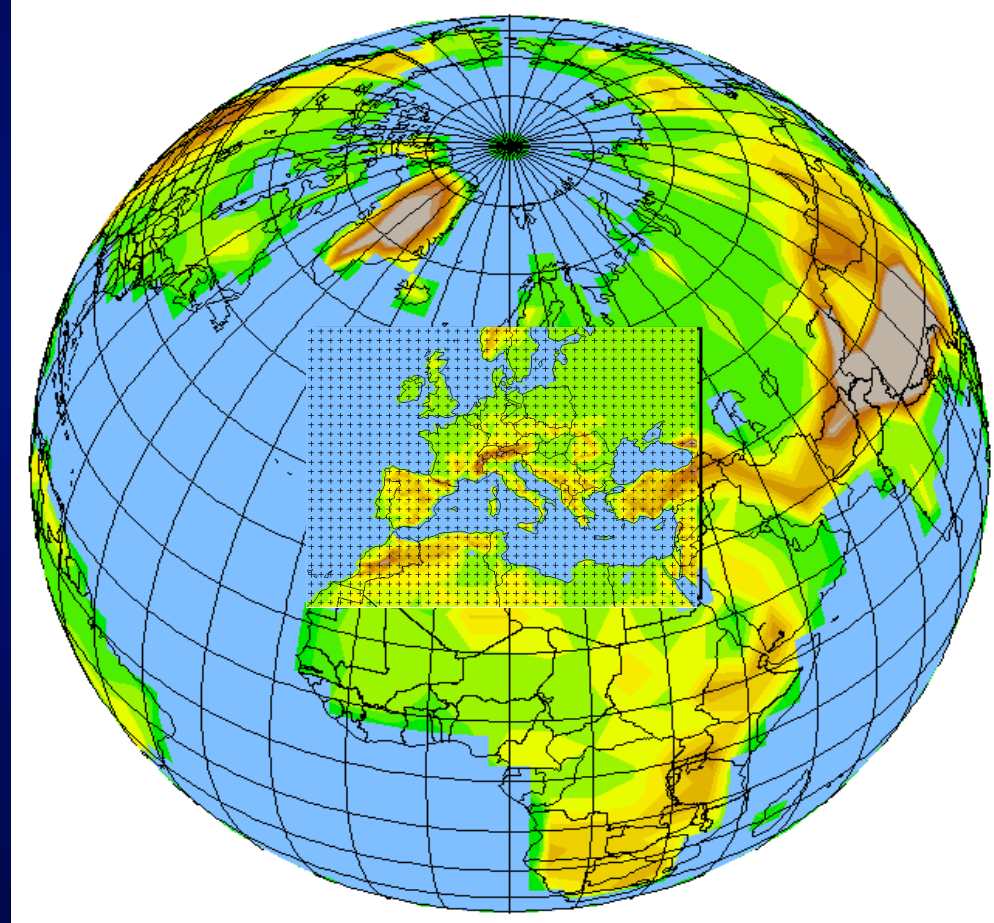
Motivation: The resolution of **GCMs** is still too coarse to capture regional and local climate processes

Technique: A “**Regional Climate Model**” (**RCM**) is “nested” within a GCM in order to locally increase the model resolution.

- Initial conditions (IC) and lateral boundary conditions (LBC) for the RCM are obtained from the GCM (“**One-way Nesting**”) or analyses of observations (**perfect LBC**).

Strategy: The GCM simulates the response of the general circulation to the large scale forcings, the RCM simulates the effect of sub-GCM-grid scale forcings and provides fine scale regional information

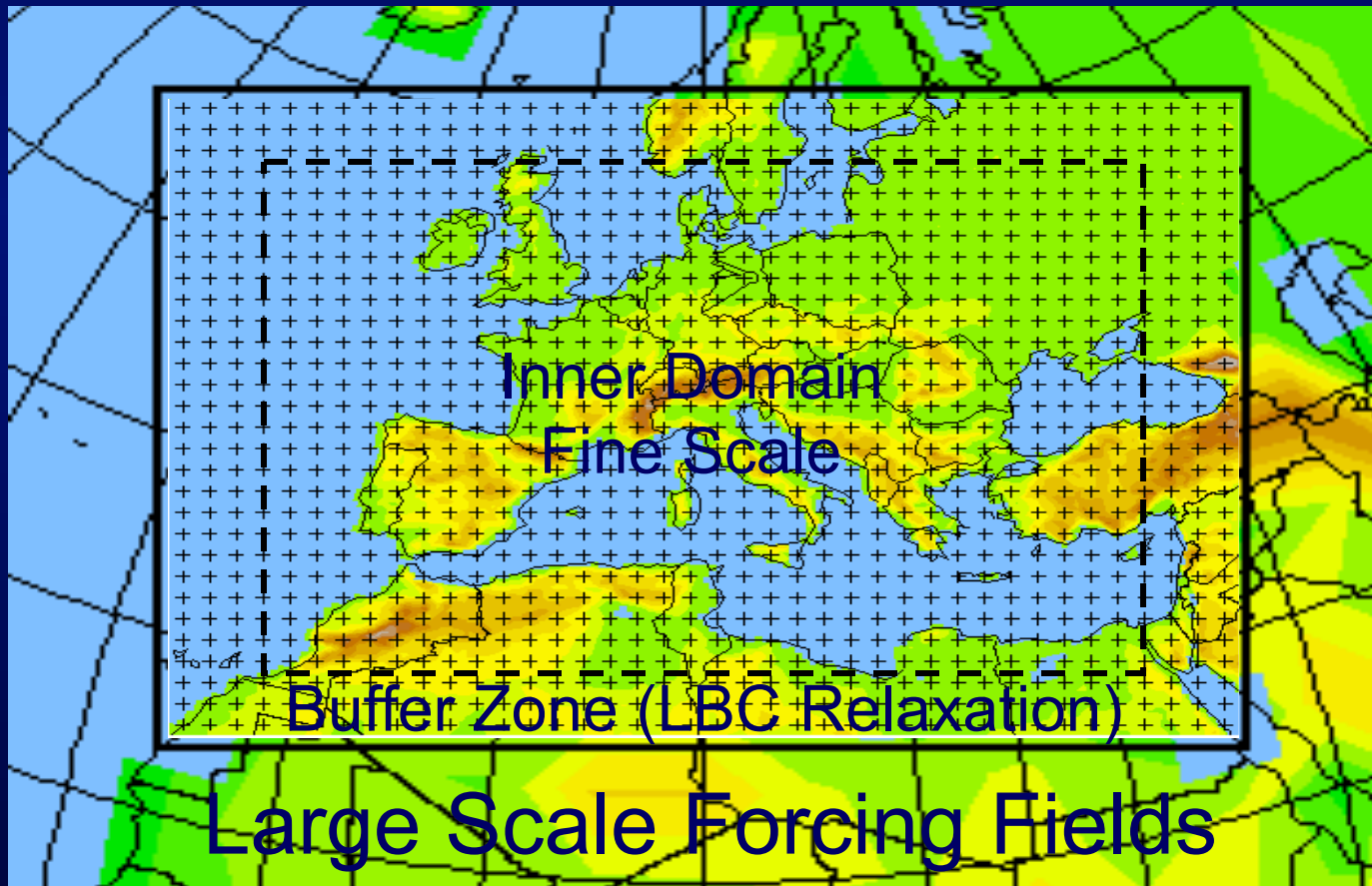
- **Technique borrowed from NWP**

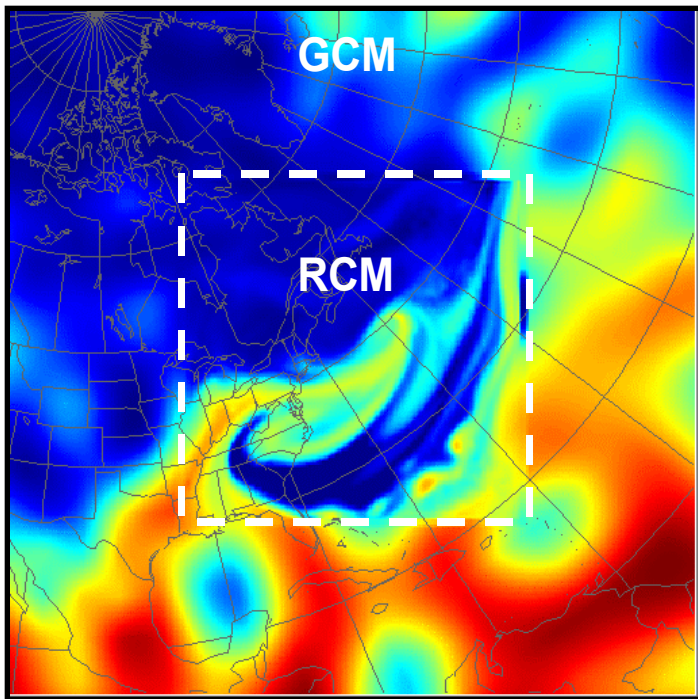
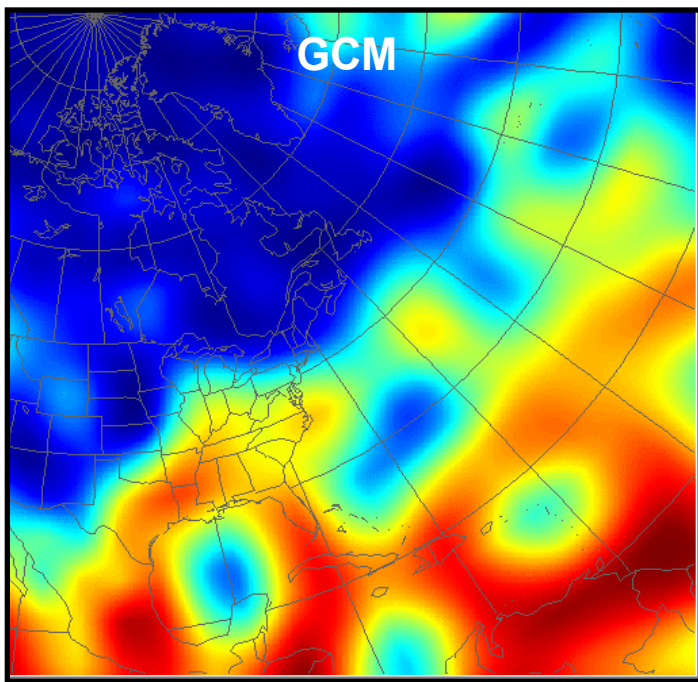


RCM Nesting procedure

$$\frac{\partial \alpha}{\partial t} = F(n)F_1 \cdot (\alpha_{LBC} - \alpha_{mod}) - F(n)F_2 \cdot \Delta_2(\alpha_{LBC} - \alpha_{mod})$$

Initial and lateral Boundary conditions can be from analyses of observations or from GCMs

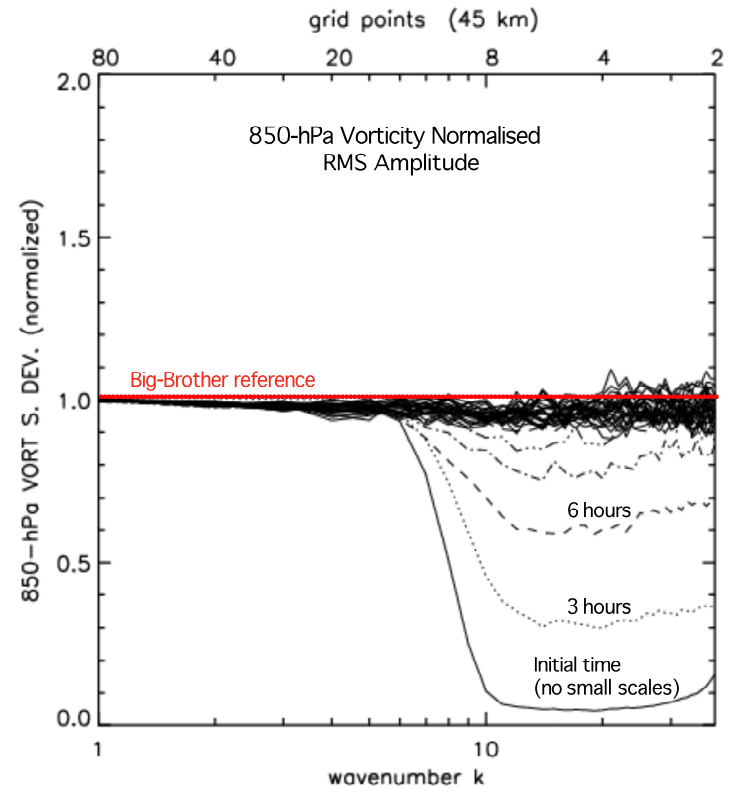




Dynamical Downscaling

Generation of small scales by a high-resolution RCM driven by low-resolution GCM data (900 hPa specific humidity)

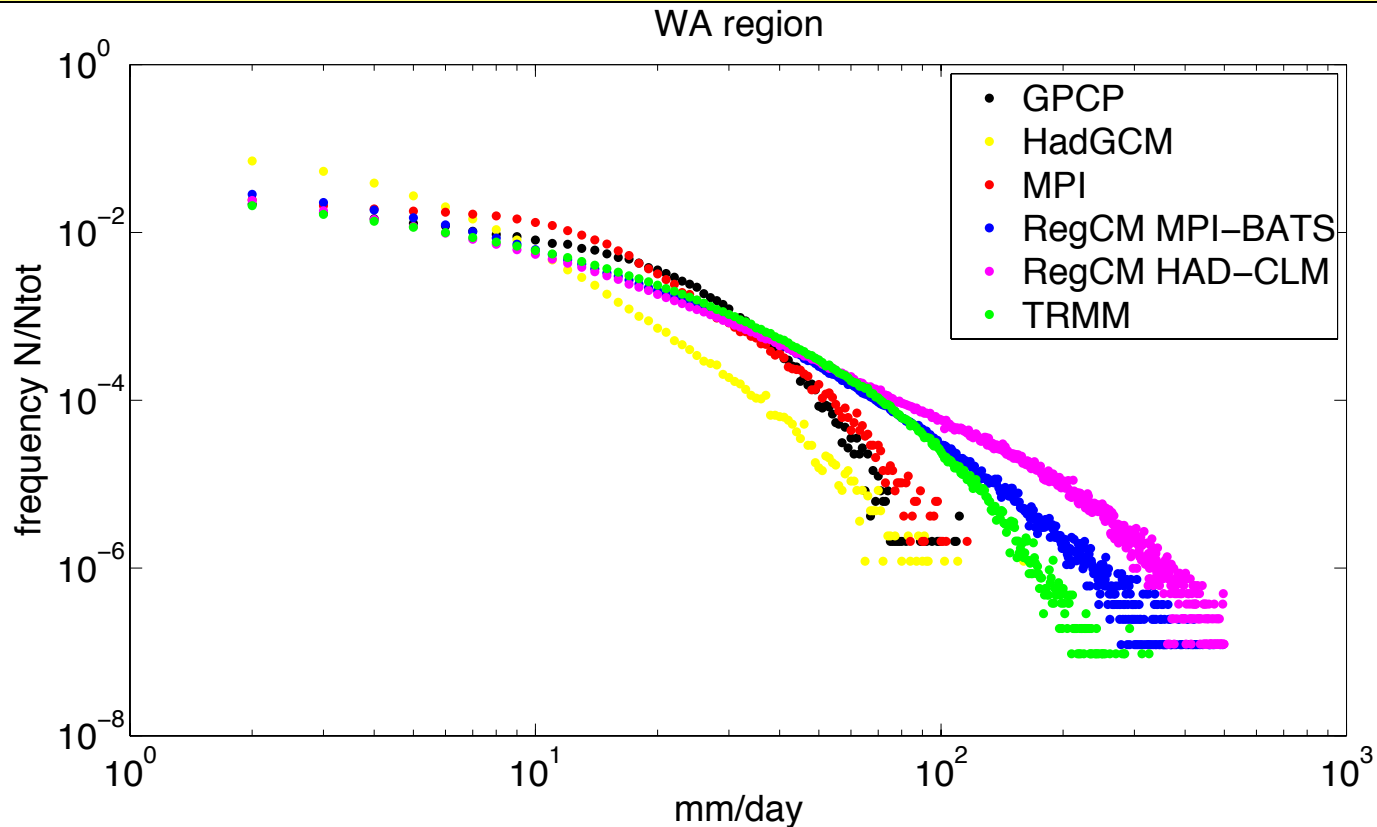
From R. Laprise



Large scales Short scales

Added value: Extremes

Daily precipitation PDFs over West Africa



**The GCM is close to the coarse resolution data,
the RCMs to the high resolution data**

This is what we expect from a downscaling exercise

Some key projects and literature

- **Review papers:** Giorgi and Mearns (1991), McGregor (1997), Giorgi and Mearns (1999), Giorgi et al. (IPCC 2001), Leung et al. (2003), Mearns et al. (2003), Wang et al. (2004), Giorgi (2006), Rummukainen (2010)
- **European projects:** PRUDENCE, AMMA, ENSEMBLES, CECILIA, CLARIS, ACQWA
- **Intercomparison projects:** PIRCS, RMIP, NARCCAP, NEWBALTIC, ARCMIP, PLATIN, ARC, NAMAP, QUIRCS, Transferability
- **Special issues:** JGR 1999; JMSJ 2004; TAC 2006; CC 2007; MAP 2004, 2008; CCH 2006; MET.-ZEIT. 2008; CR 2012; CC 2014.

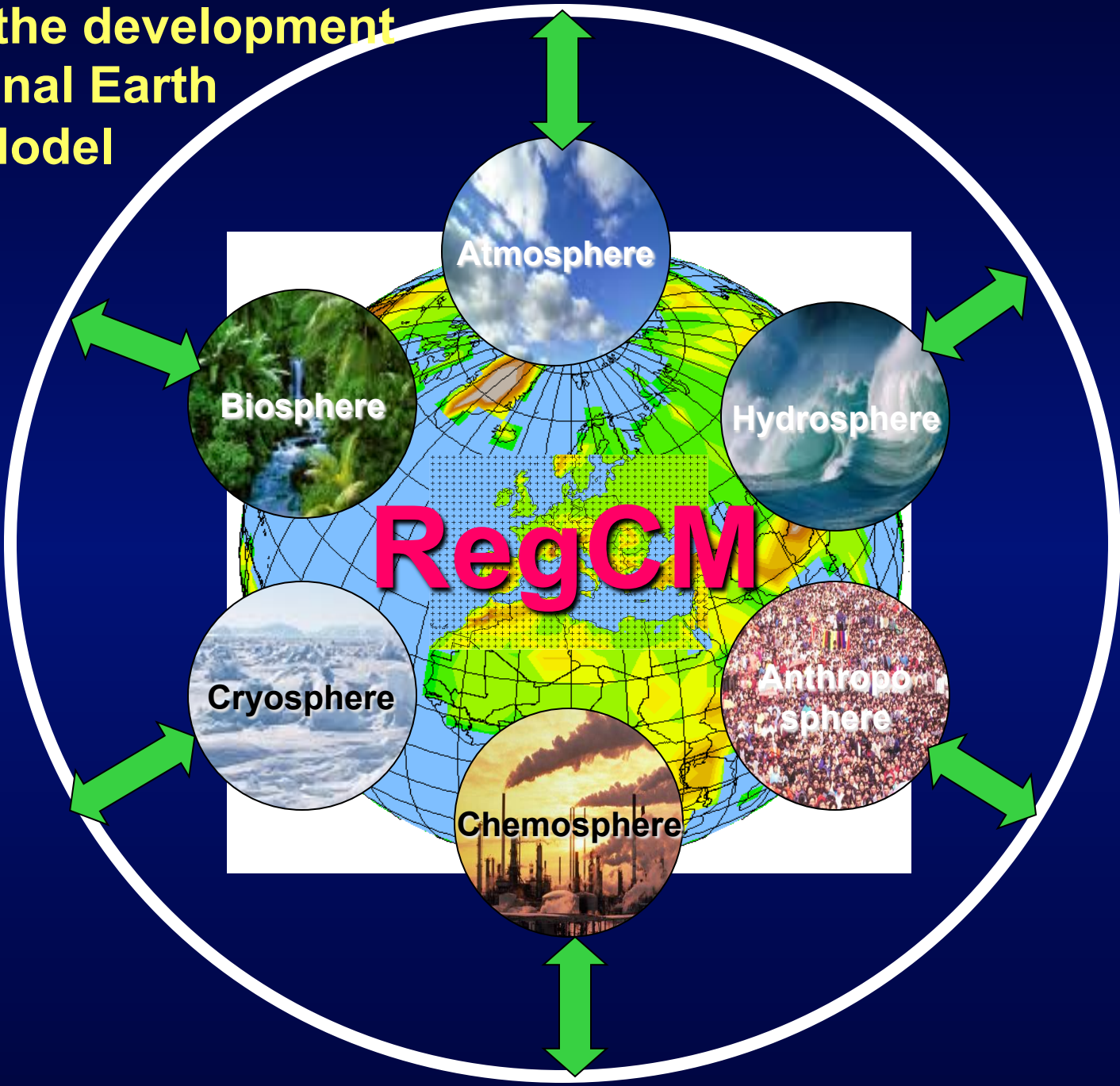
Regional Climate Modeling Advantages

- Physically based downscaling
 - Comprehensive climate modeling system
- Wide variety of applications
 - Process studies
 - Paleoclimate
 - Climate change
 - Seasonal prediction
- High resolution through multiple nesting (currently <10 to 50 km grid interval)

Regional Climate Modeling Limitations

- One-way nesting
 - No regional-to-global feedbacks
- Technical issues in the nesting technique
 - Domain, LBC procedure, physics, etc.
- Not intended to correct systematic errors in the large scale forcing fields
 - Always analyse first the forcing fields
- Computationally demanding

Towards the development of a regional Earth System Model



The RegCM regional climate model system

- RegCM1 (1989)
 - Dickinson et al. (1989), Giorgi and Bates (1989)
- RegCM2 (1993)
 - Giorgi et al. (1993a,b)
- RegCM2.5 (1999)
 - Giorgi and Mearns (1999)
- RegCM3 (2007)
 - Pal et al. (2007)
- RegCM4 (2012)
 - Giorgi et al. (2012)

The ESP **RegCM** and Regional Climate research **NETwork**, **RegCNET**

Collaborative research projects

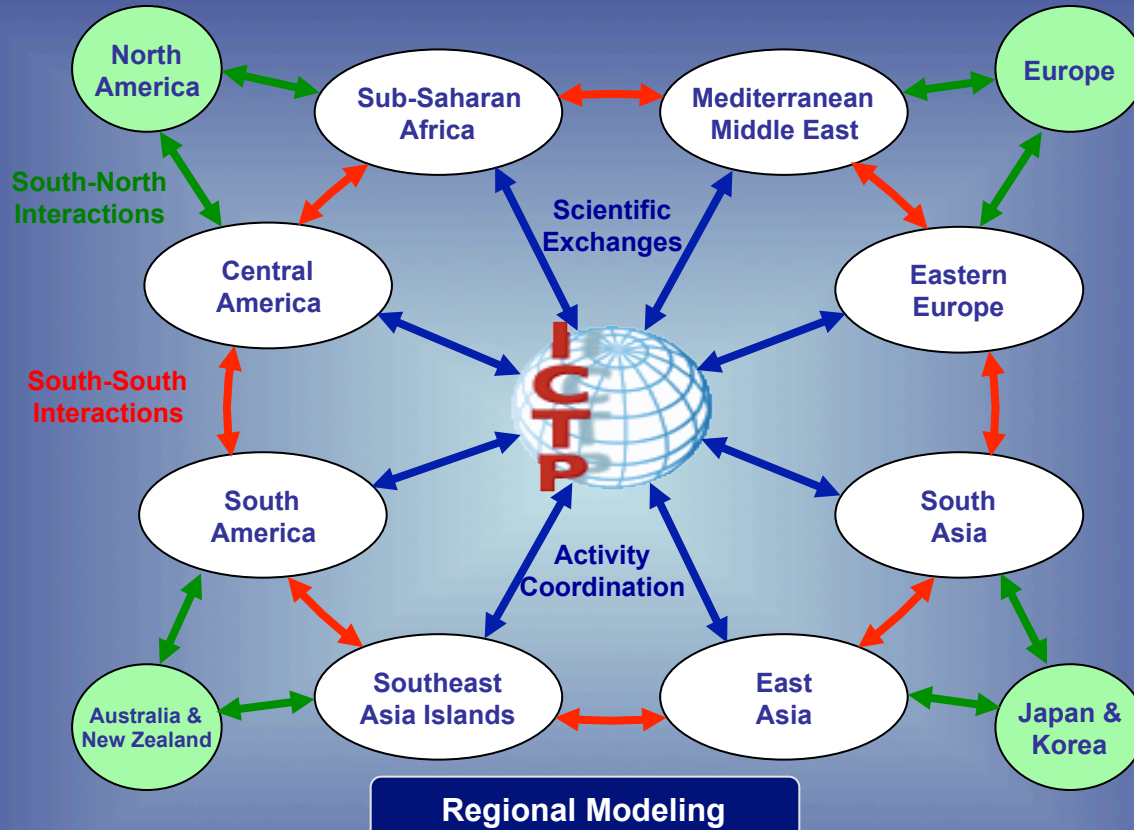
Use of ICTP model tools and datasets

Workshops at ICTP and on-site

E-mail list (over 900 p.)

Interactions with other international programs

Visitor program



The ICTP regional climate model system

RegCM4 (Giorgi et al. 2012, CR SI 2012)

- **Dynamics:**
 - Hydrostatic (Giorgi et al. 1993a,b)
 - Non-hydrostatic in progress
- **Radiation:**
 - CCM3 (Kiehl 1996)
 - NNRD (Solmon)
- **Large-Scale Precipitation:**
 - SUBEX_ (Pal et al 2000)
 - Explicit microphysics (Nogherotto)
- **Cumulus convection:**
 - Grell (1993)
 - Anthes-Kuo (1977)
 - MIT (Emanuel 1991)
 - Mixed convection
 - Tiedtke
- **Planetary boundary layer:**
 - Modified Holtslag, Holtslag (1990)
 - UW-PBL (O' Brien et al. 2011)
- **Land Surface:**
 - BATS (Dickinson et al 1993)
 - SUB-BATS_ (Giorgi et al 2003)
 - CLM3.5 (Steiner et al. 2009)
 - CLM4.5 (Oleson et al. 2012)
- **Ocean Fluxes**
 - BATS (Dickinson et al 1993)
 - Zeng (Zeng et al. 1998)
 - Diurnal SST
- **Configuration**
 - Adaptable to any region
 - Tropical belt configuration

The ICTP regional climate model system

RegCM4, coupled components

- **Coupled ocean**

 - MIT ocean model (Artale et al. 2010)

 - ROMS (Ratnam et al. 2009)

- **Interactive lake**

 - 1D thermal lake mode reactivated (Hostetler et al. 1994; Small et al. 1999)

- **Interactive biosphere**

 - Available in CLM but never tested

- **Interactive hydrology**

 - CHYM hydrological model available in “off line mode”

- **Aerosols:**

 - OC-BC-SO₄ (Solmon et al 2005)

 - Dust (Zakey et al 2006)

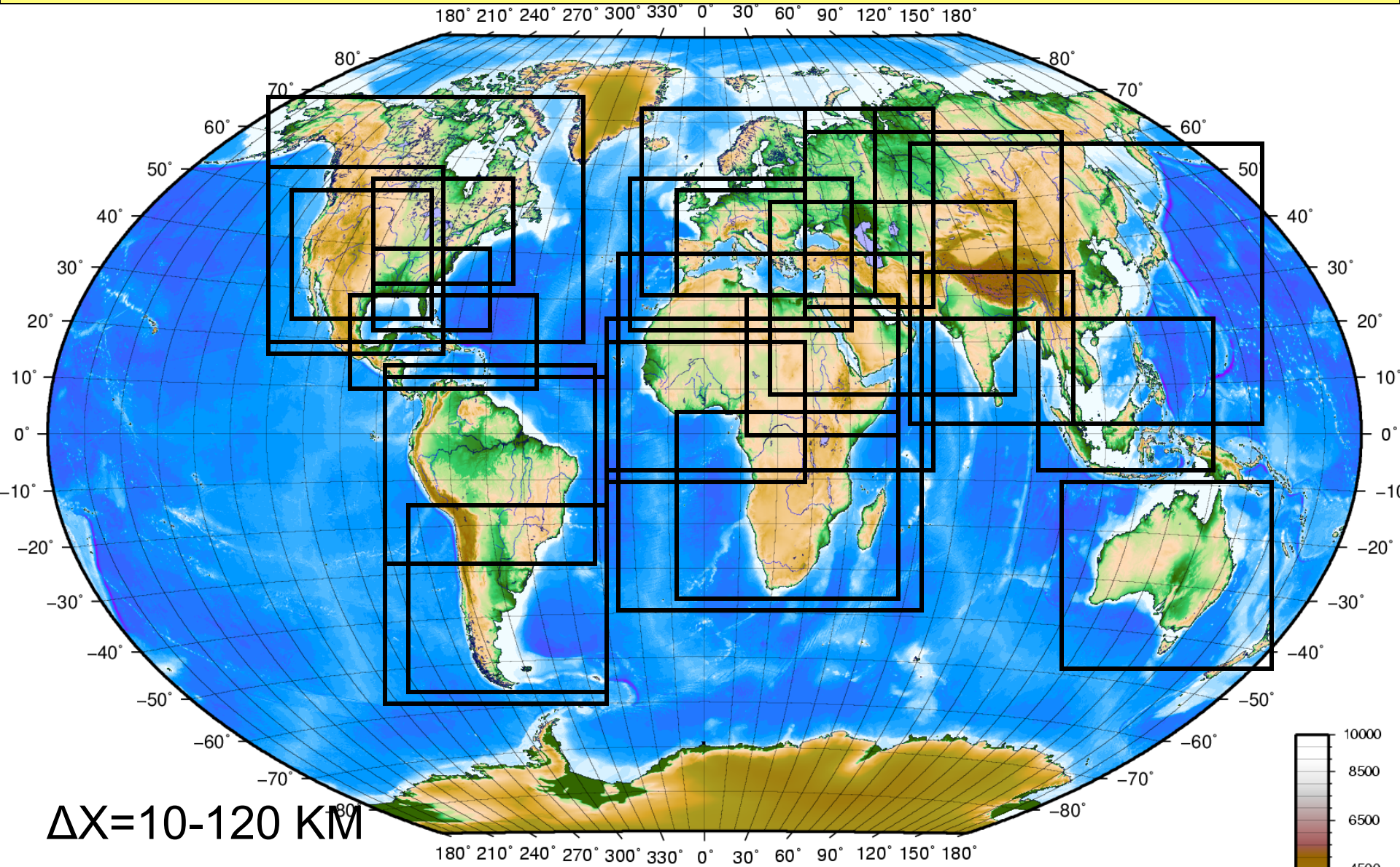
 - Sea Salt (Zakey et al. 2009)

- **Gas phase chemistry:**

 - Various schemes and solvers tested

 - CBMZ + Sillmann solver implemented (Shalaby et al. 2012)

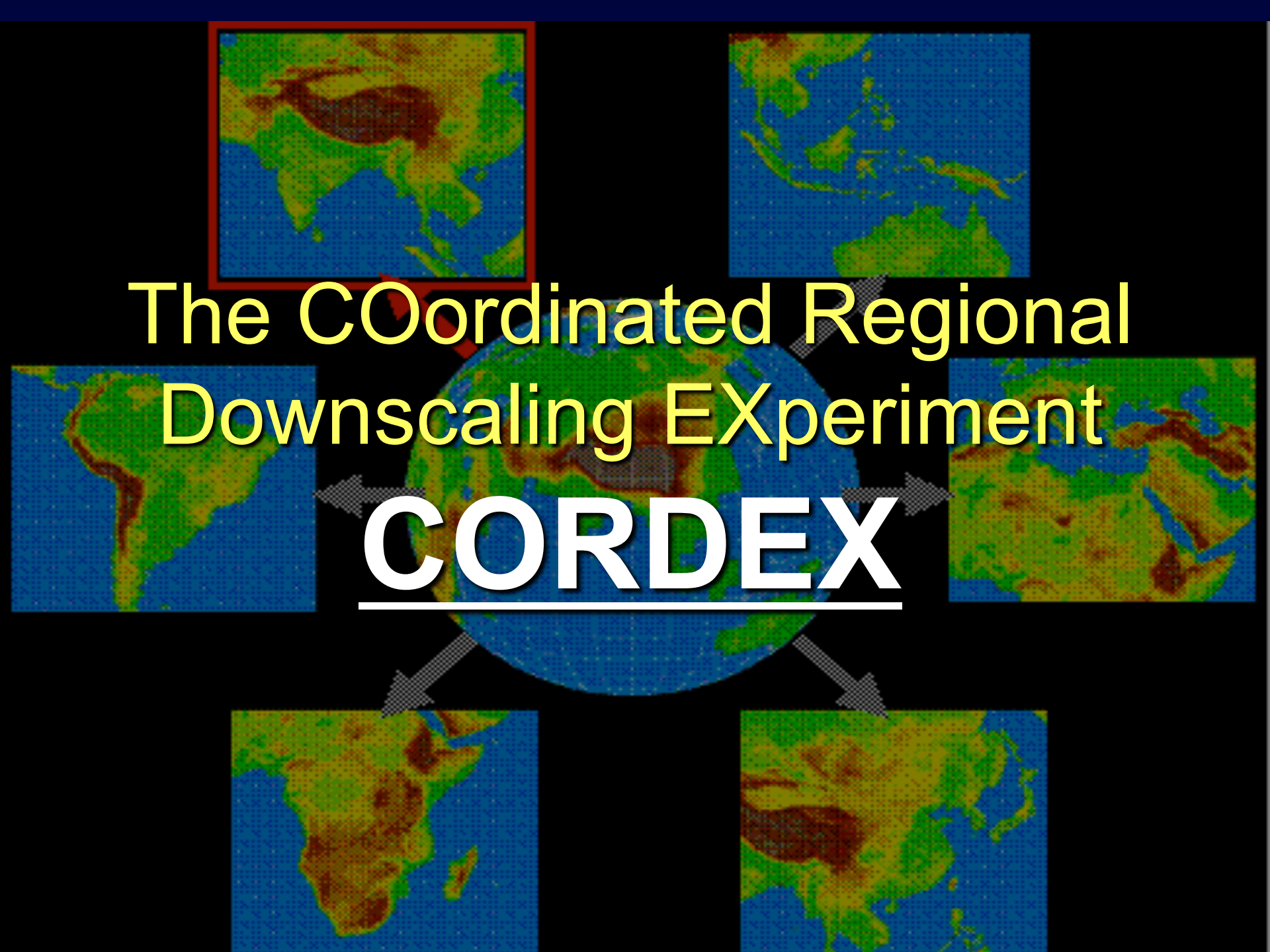
Sample of RegCM domains used



The RegCM regional climate model system

Participation to intercomparison projects

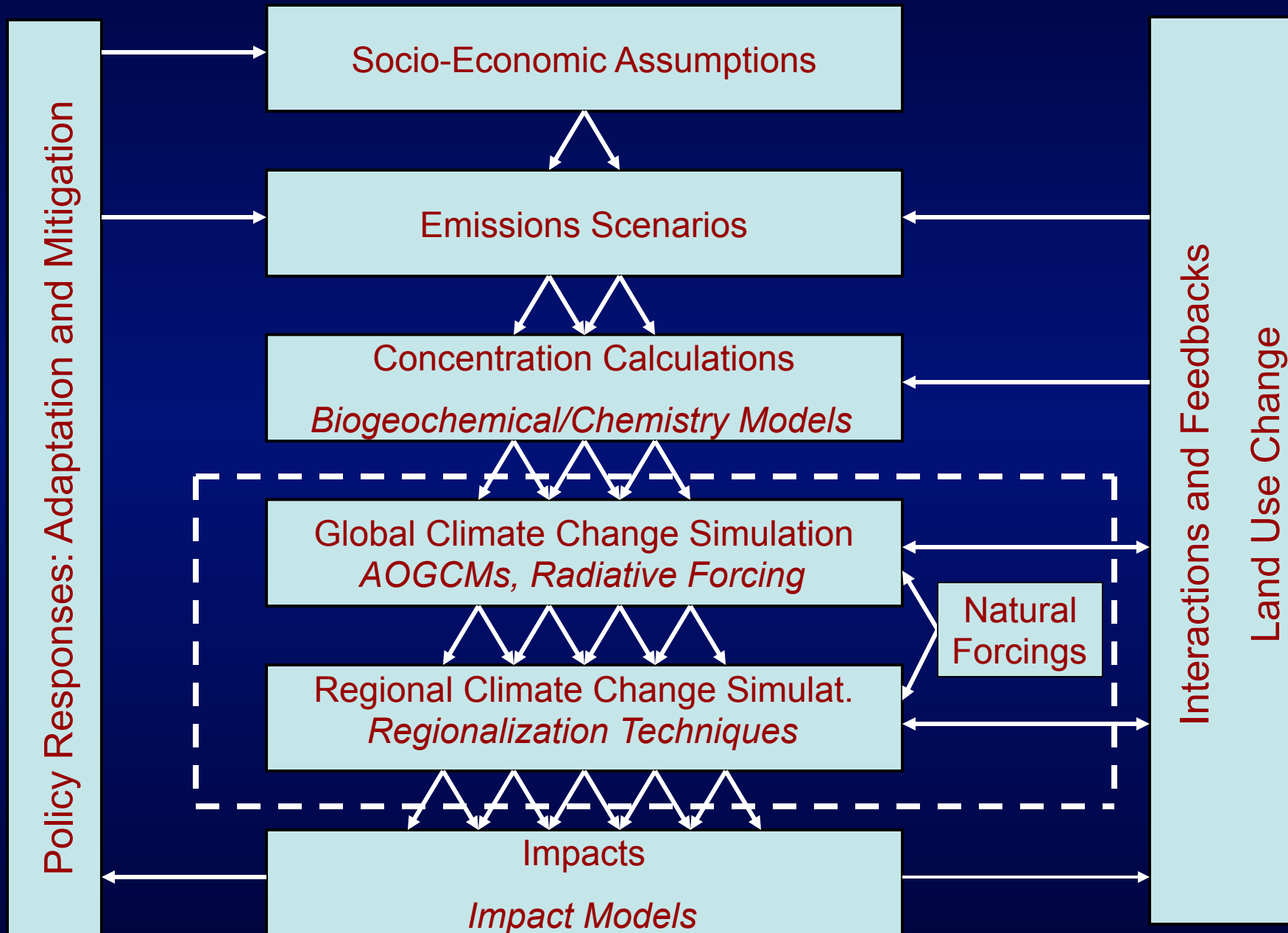
- **PIRCS** (US, ISU)
- **NARCCAP** (US, UCSC)
- **PRUDENCE** (Europe, ICTP)
- **ENSEMBLES** (Europe, ICTP)
- **CECILIA** (Central Europe, Central-Eastern European partners)
- **AMMA** (West Africa, ICTP, African partners)
- **CLARIS** (South America, U. Sao Paulo)
- **RMIP** (East Asia, CMA)
- **CORDEX** (Multiple domains, RegCNET)



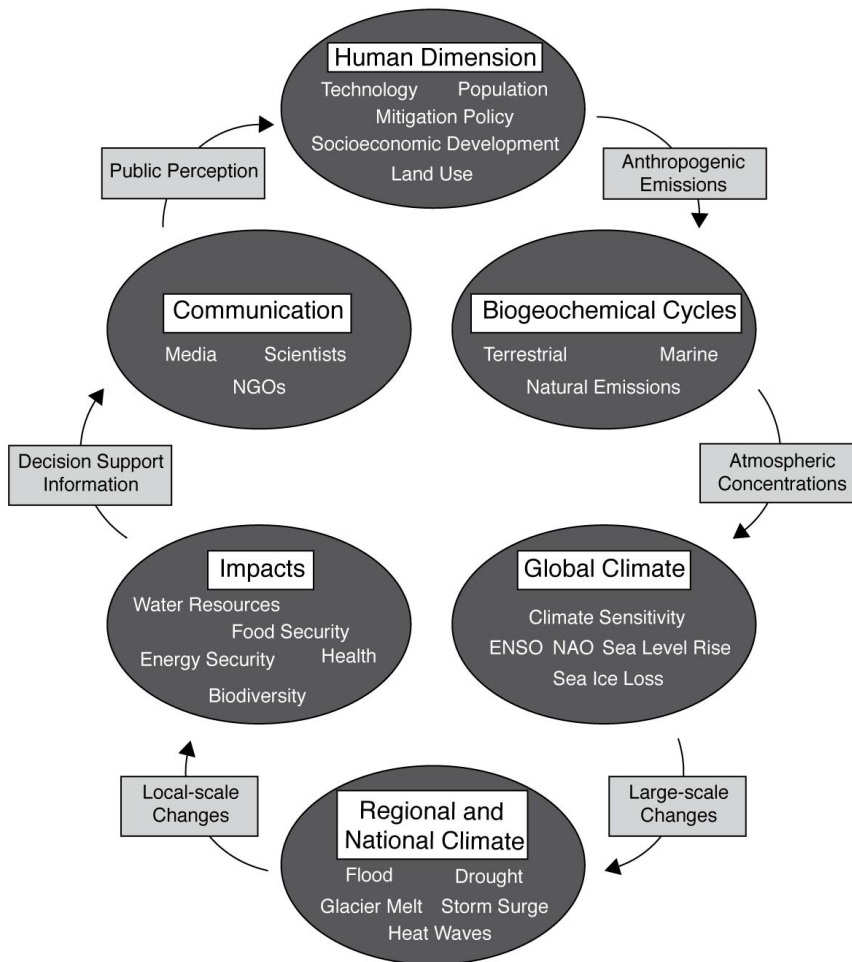
The COordinated Regional
Downscaling EXperiment

CORDEX

Cascade of uncertainty in climate change prediction



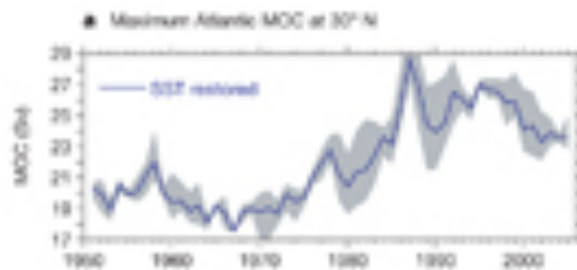
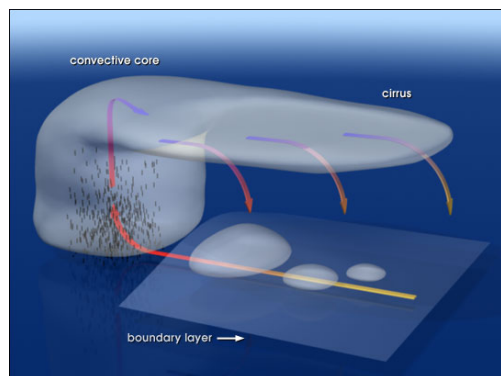
The production of climate change scenarios for impact/adaptation work requires proper characterization of uncertainties



To date RCM studies have not been coherent and comprehensive enough to sufficiently characterize uncertainties in climate change projections

Exceptions are Europe (PRUDENCE, ENSEMBLES) and (maybe) US (NARCCAP)

Regional Climate Change "Hyper-Matrix Framework" (HMF)



Internal
Variability

RCD
Configuration

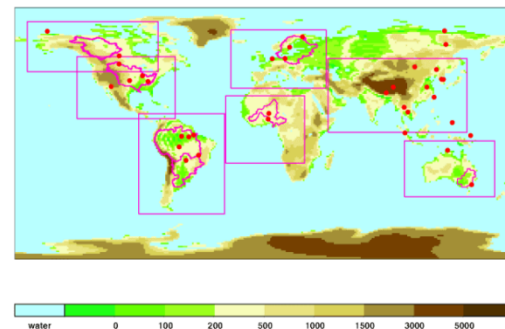
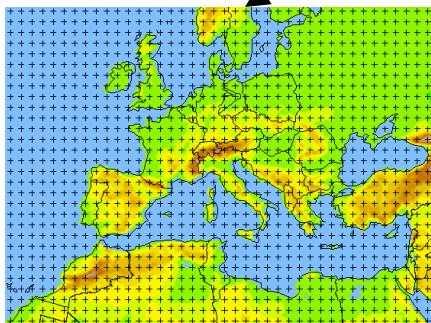
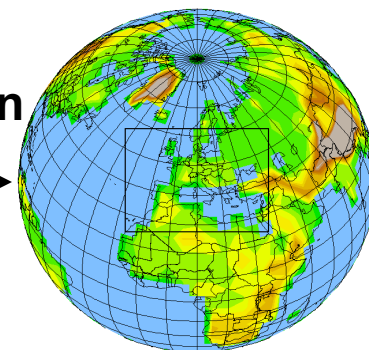
GCM
Configuration

Forcing
Scenario

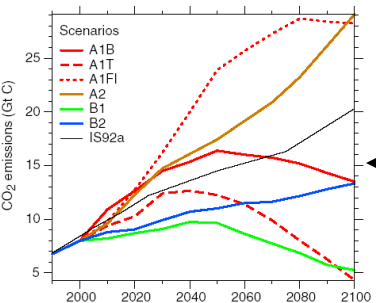
Experiment (i,j,k ...)

RCD
Approach

Geographic
Region



**Giorgi et al.
EOS 2008**



Coordinated Regional climate Downscaling Experiment: CORDEX

- Provide a framework for benchmarking and possibly improving RCD models and techniques (model evaluation framework)
- Produce a new generation of RCD-based climate change projections for regions Worldwide (model projection framework)
- Foster greater interactions between the climate science and end-user communities and a greater involvement of developing country scientists and end-user

CORDEX Phase I experiment design

Model Evaluation
Framework

Climate Projection
Framework

Multiple regions (Initial focus on Africa)
50 km grid spacing

ERA-Interim BC
1989-2007

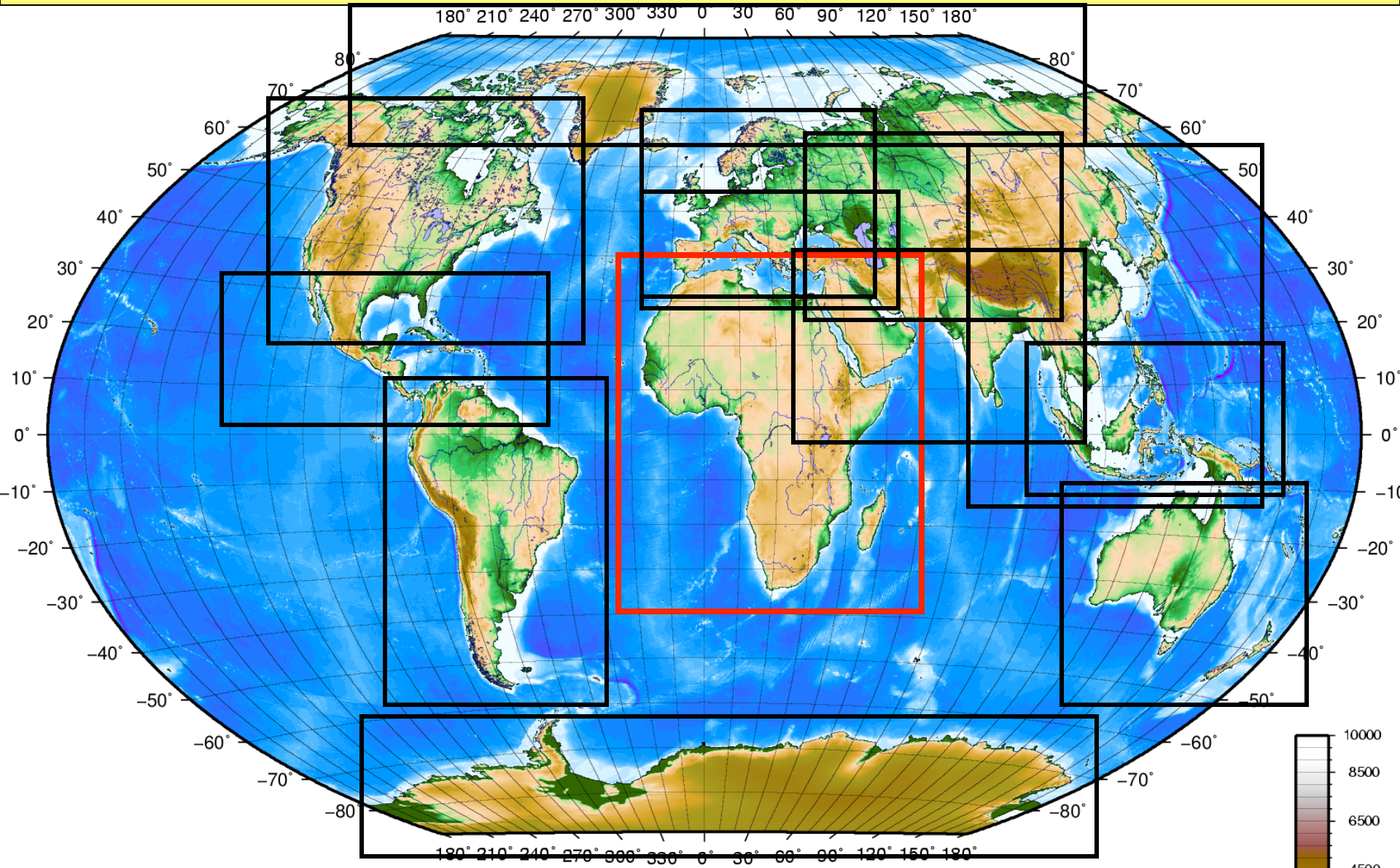
RCP4.5, RCP8.5
Decadal runs

Multiple AOGCMs

1951-2100 Transient
Selected Timeslices

Regional Analysis
Regional Databanks

CORDEX domains





WCRP

World Climate Research Programme



ICSU

International Council for Science



ipcc

INTERGOVERNMENTAL PANEL ON
climate change



International Conference on Regional Climate - CORDEX 2013

A partnership between WCRP, the European Commission and IPCC

4 - 7 November 2013 - Brussels, Belgium

The Conference brought together the international community of regional climate scientists to present and discuss results from WCRP regional climate studies, with a particular emphasis on the CORDEX initiative. More than 500 abstracts submitted. Web site: cordex2013.wcrp-climate.org.

4 Nov: High-Level Session

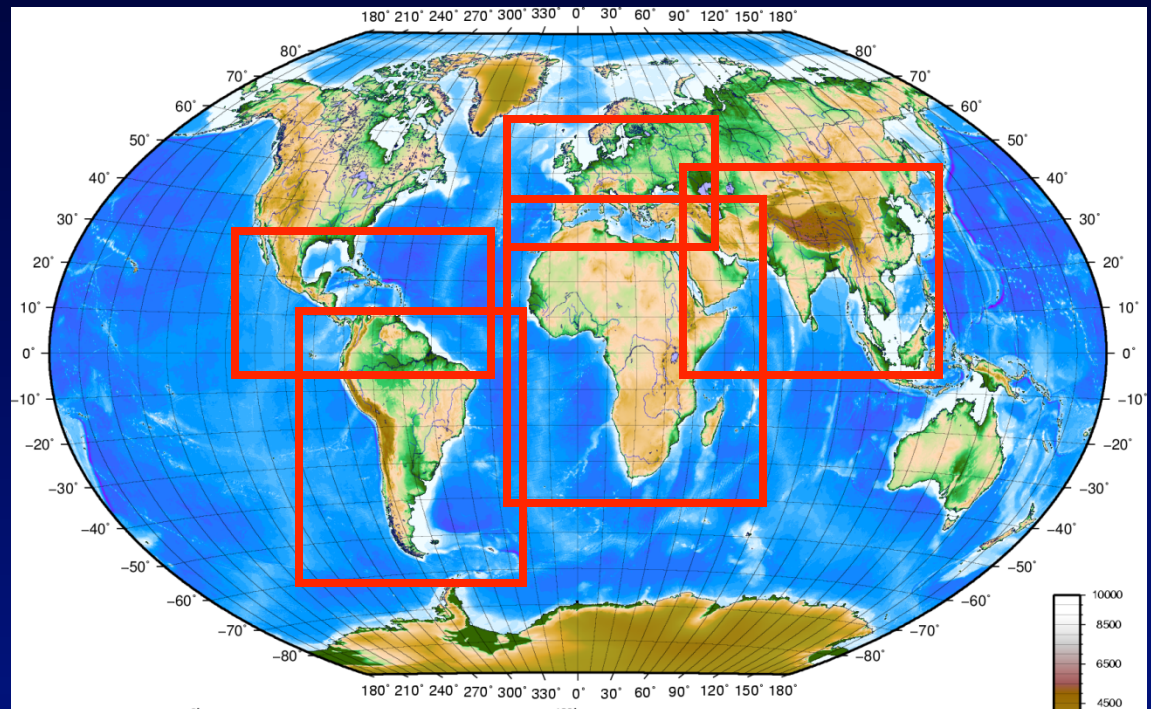
- High-Level Session: key findings from the IPCC AR5 WGI: The Physical Science Basis
- Stakeholder Dialogue: regional climate information for decision-makers

5-7 Nov: Science Segment

- Key results from Regional Climate Research and Phase I of the CORDEX project



**The CORDEX
RegCM
hyper-Matrix
(CREMA)
Phase I
Experiment
(see next talks)**



**Collaboration across
ICTP**

U. San Paolo (Brazil)

CICESE (Mexico)

Indian Institute of technology

U. Dakar (Senegal)

DHMZ (Croatia)

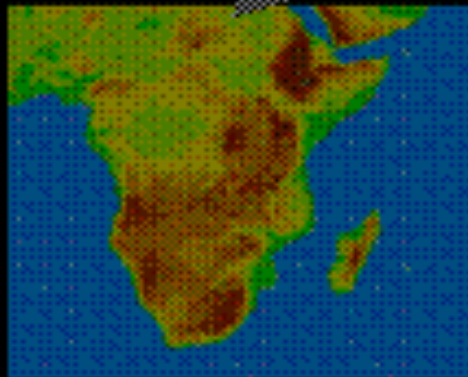
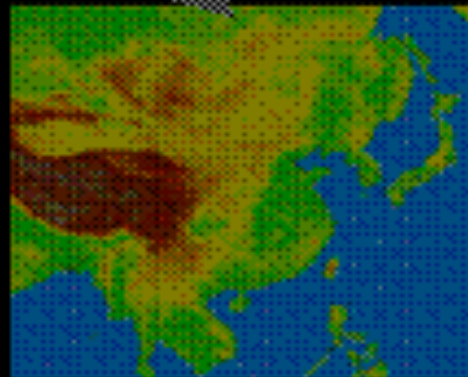
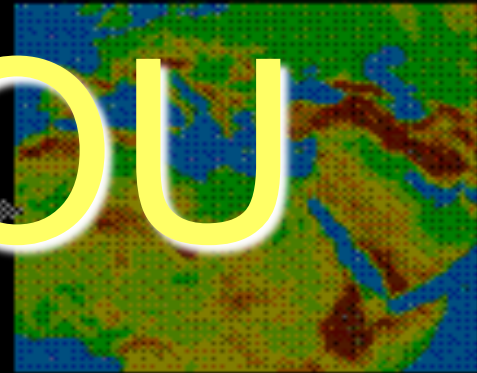
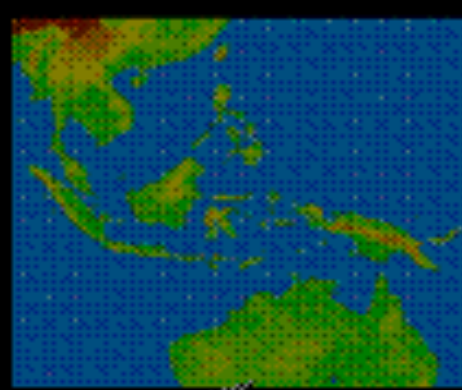
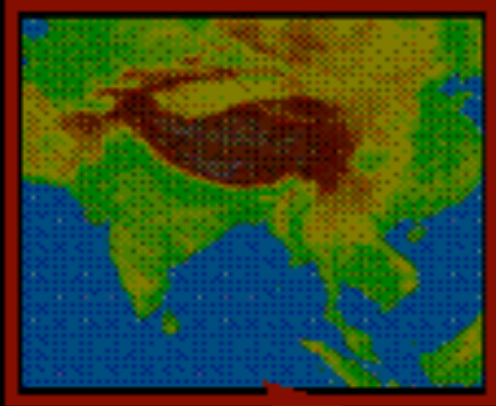
**Special Issue of
Climatic Change**

**34 Scenario simulations (1970-2100)
over 5 CORDEX domains
with RegCM4 driven by
three GCMs, 2 GHG
scenarios (RCP4.5/8.5) and
different physics schemes**

**3 months dedicated time on ~700
CPUs at the ARCTUR HPC
~200 Tbytes of data produced**

Objectives of the workshop

- Review RegCM developments and plans
 - CLM4.5
 - New microphysics scheme
 - Non-hydrostatic dynamical core
 - Coupling with ocean and chemistry models
- Provide an update on CORDEX activities
 - Discuss how the RegCM community can contribute to CORDEX
- Discuss future plans
 - Release of next and LAST version of RegCM4
 - Plan for RegCM5 development (target of 2016)



THANK YOU

Themes for group projects

- CLM4.5
 - Urban surface
 - Crops
 - Hydrologic cycle
 - Land-use change
- RegCM4 parameterizations
 - New microphysics
 - Tiedtke convection scheme
 - NNRD radiation
 - UW PBL scheme
 - Emissivity/albedo (in BATS)
- Coupled components
 - Chemistry
 - Aerosol
 - ocean

Themes for group projects

- CORDEX Domains
 - Africa
 - Europe
 - Mediterranean
 - MENA
 - North America
 - South America
 - Central America
 - South Asia
 - East Asia
 - South-east Asia
 - Australia