DEVELOPMENT

SOCIETY

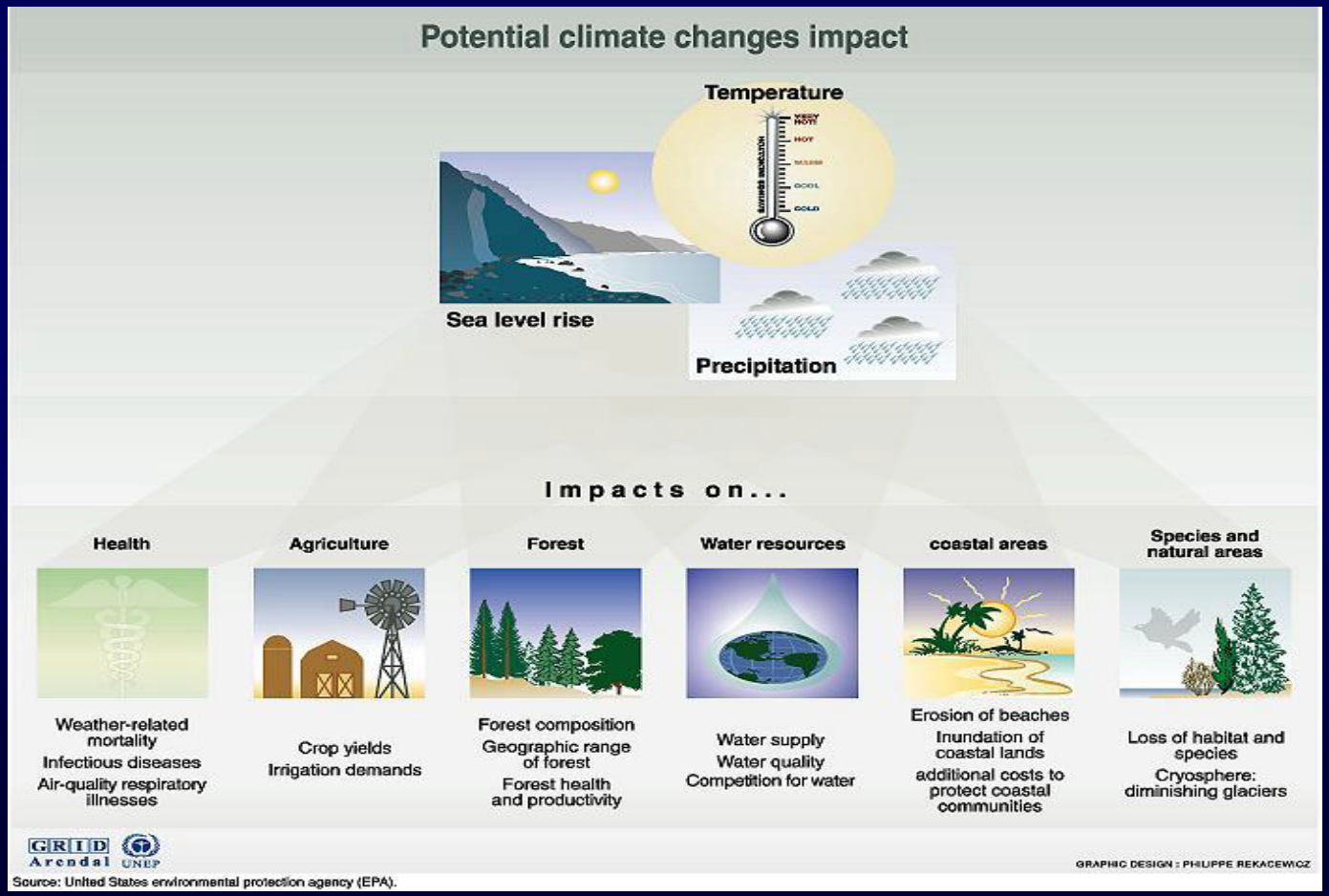
Earth System Physics Section (ESP)

An education laboratory

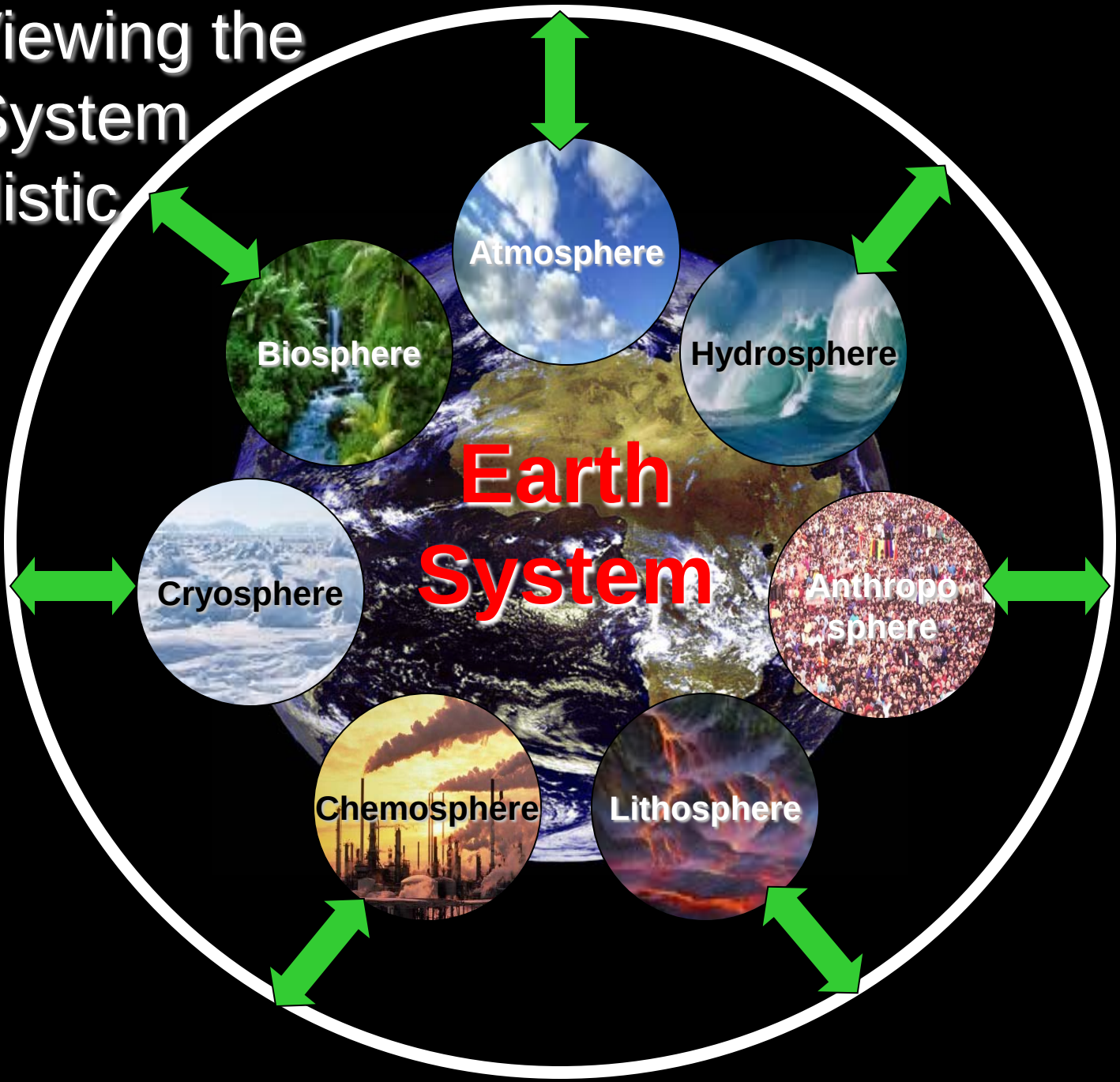
Filippo Giorgi, ICTP

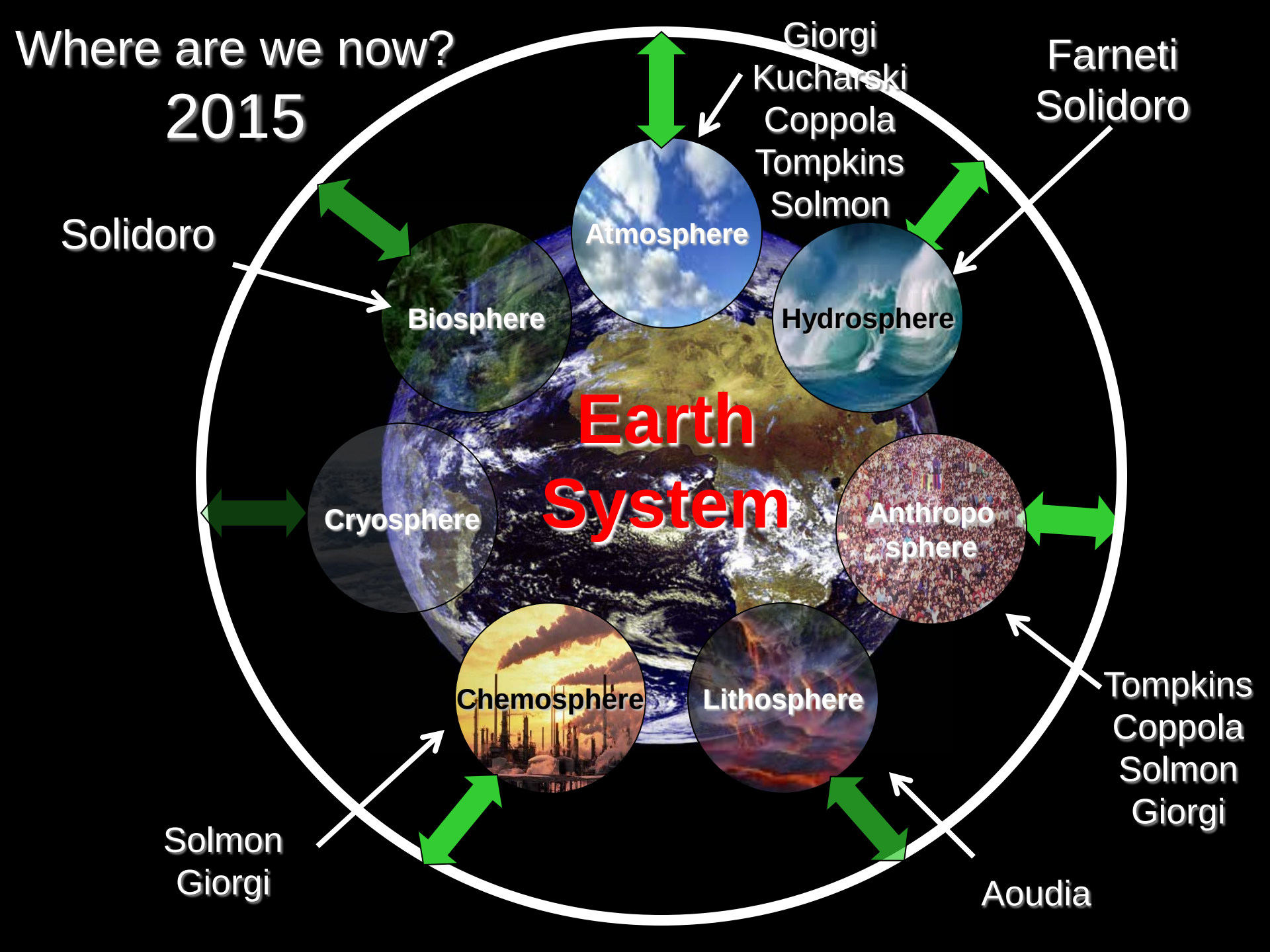
ENVIRONMENT

Education and capacity building in global change research is critical because developing countries are most vulnerable to the impacts of climate change

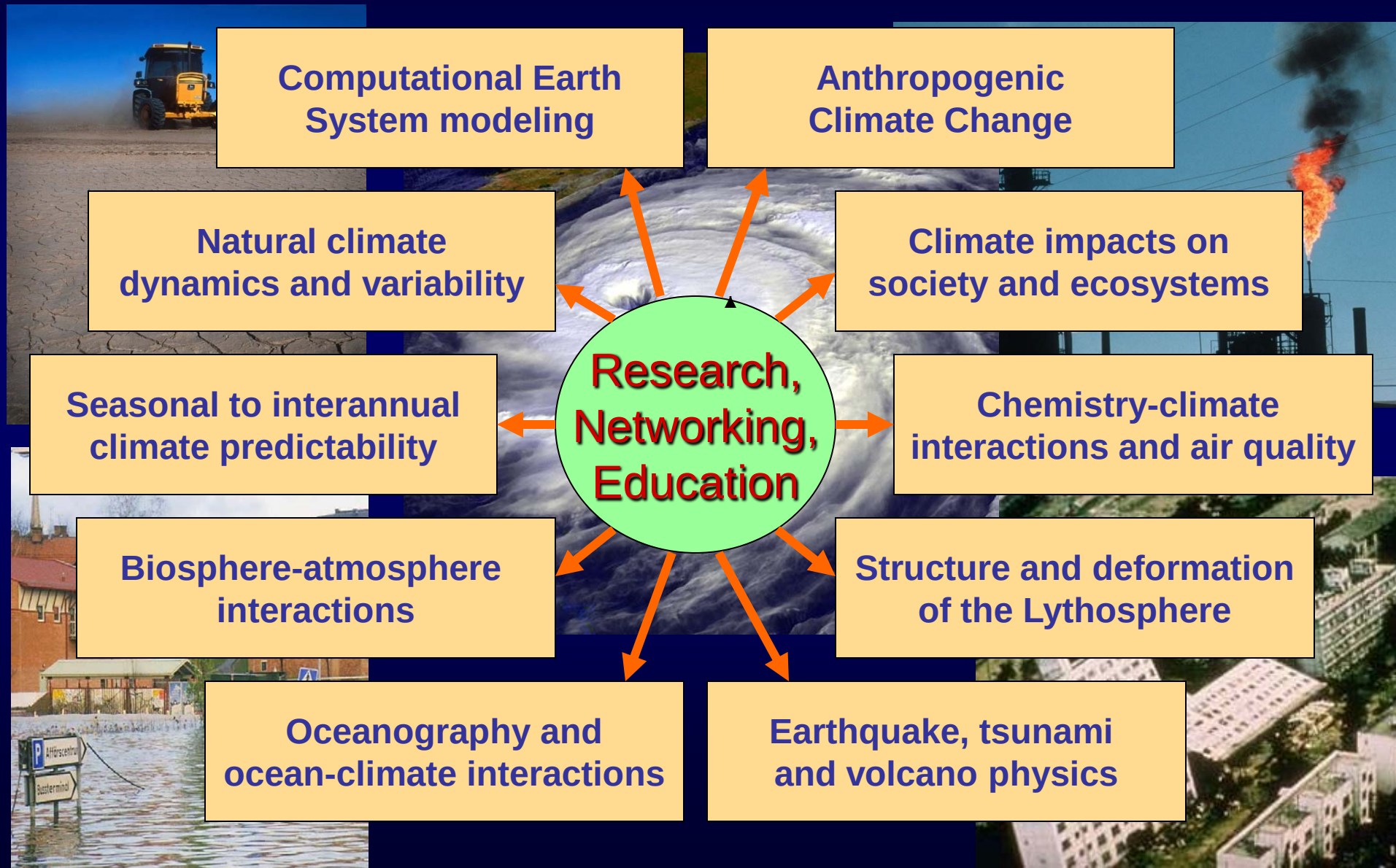


ESP: Viewing the Earth System in a holistic way




Where are we now?
2015
Giorgi
Kucharski
Coppola
Tompkins
Solmon
Farneti
Solidoro
Solidoro
Atmosphere
Biosphere
Hydrosphere
Earth System
Cryosphere
Anthropo sphere
Chemosphere
Lithosphere
Tompkins
Coppola
Solmon
Giorgi
Solmon
Giorgi
Aoudia

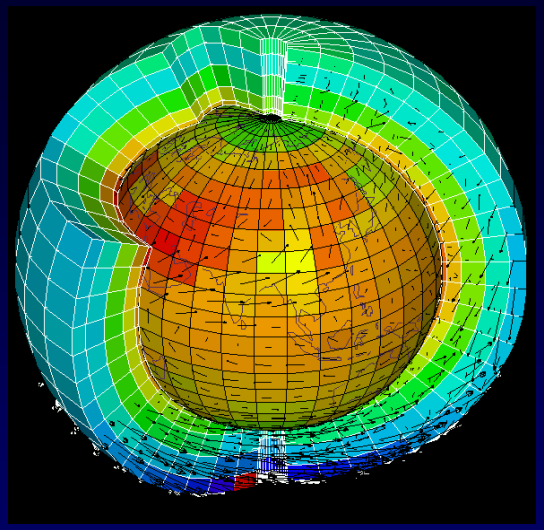
ESP Main Research Areas



ESP Educational activities

- 10-15 Workshops and conferences at ICTP and abroad (international collaborations: IUGG, WCRP, IPCC, WMO)
- 1-year Diploma course in Earth Science
- PhD program in Environmental and Geophysical Fluid Dynamics with U. Trieste
- MS program in Global Change Biology with the U. Trieste
- PhD STEP program
- ICTP Associates program
- Visiting scientist program

Earth Systems Physics Networks in Africa



The main tools we have to study climate change are Global Climate models (GCMs), which are however very complex and expensive to develop and run

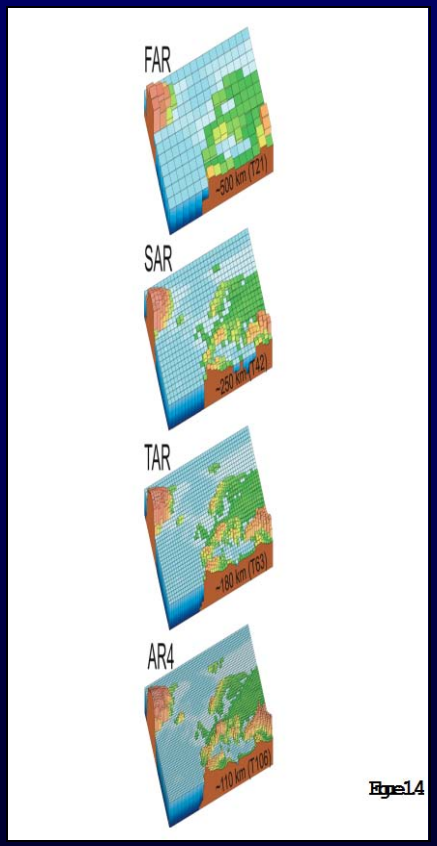


Figure 1.4

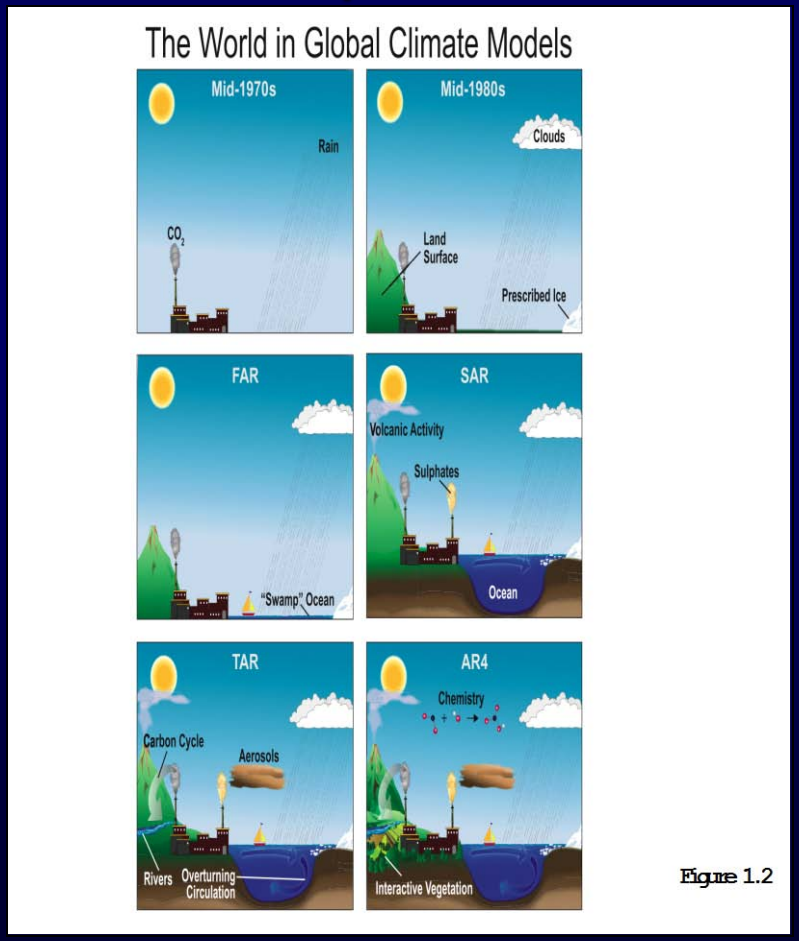
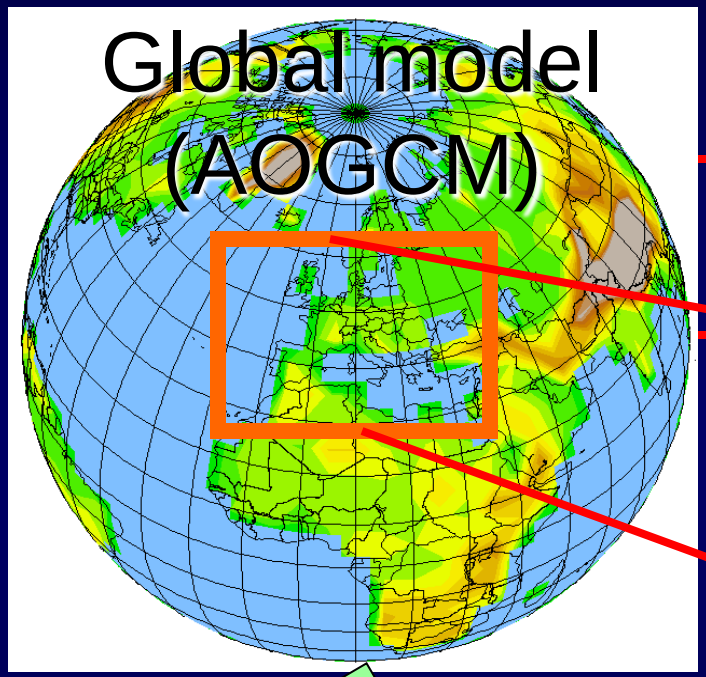
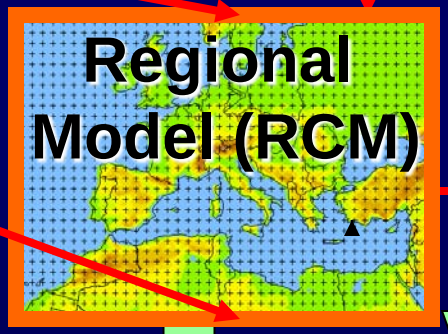
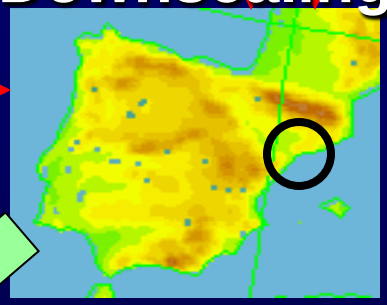


Figure 1.2

A number of “downscaling” techniques have been developed to produce regional information







Impacts

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

"Nested" Regional Climate Modeling: Technique and Strategy

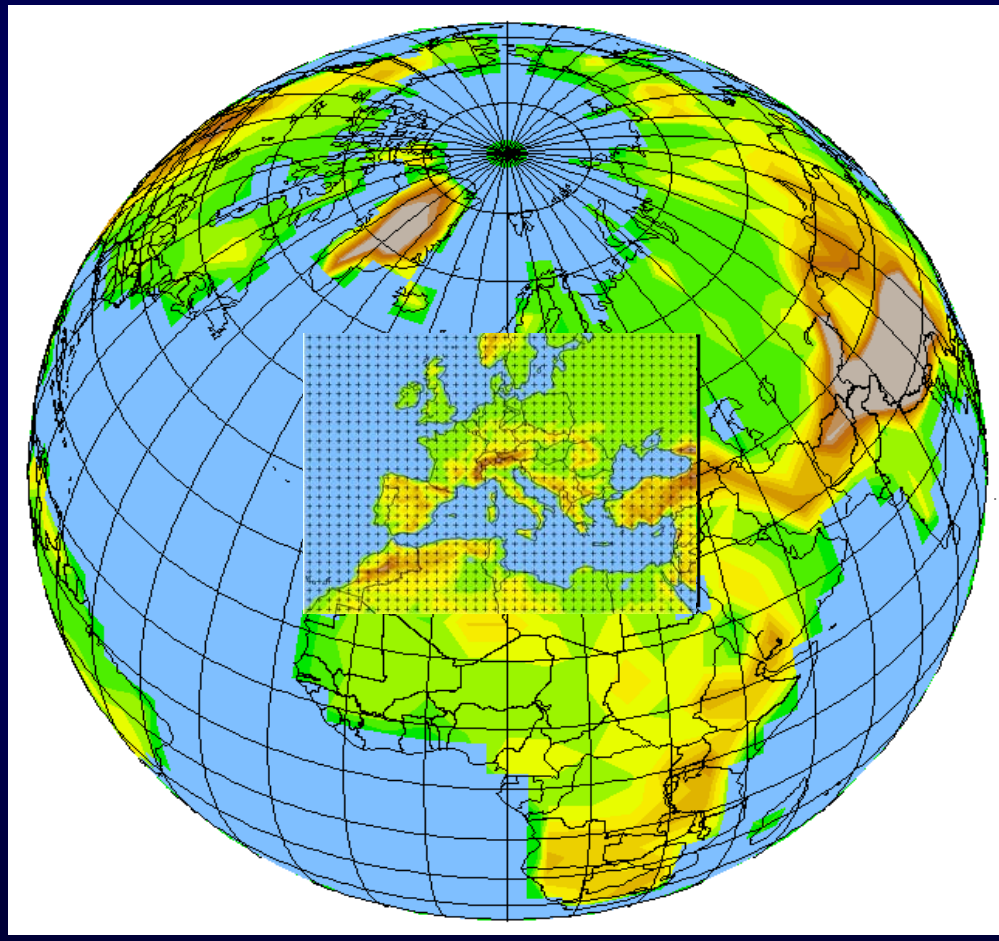
Motivation: The resolution of GCMs is still too coarse to capture regional and local climate processes

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

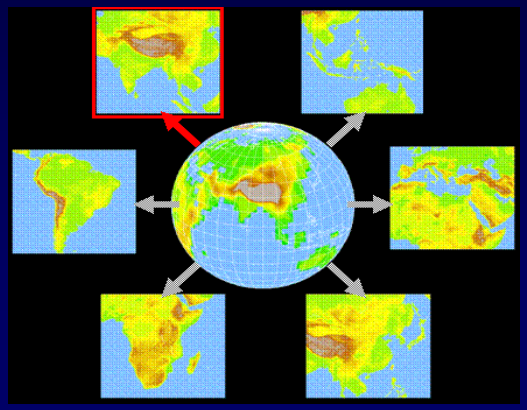
- Initial conditions (IC) and lateral boundary conditions (LBC) for the RCM are obtained from the GCM ("One-way Nesting") or analyses of observations (perfect LBC).

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

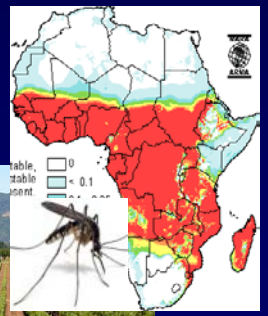
- Technique borrowed from NWP

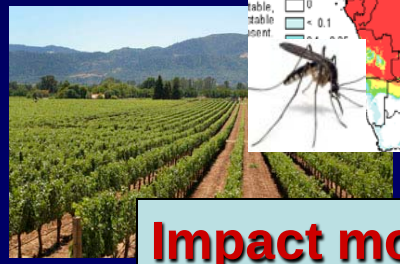


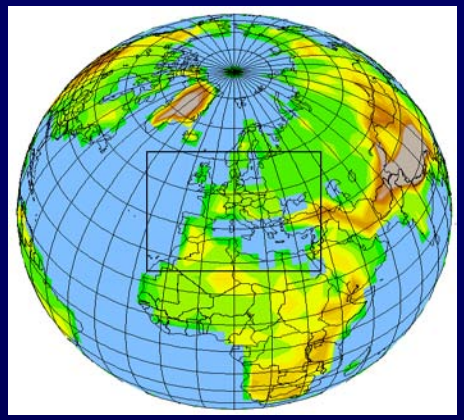
ESP: Computational modeling in support of developing country needs

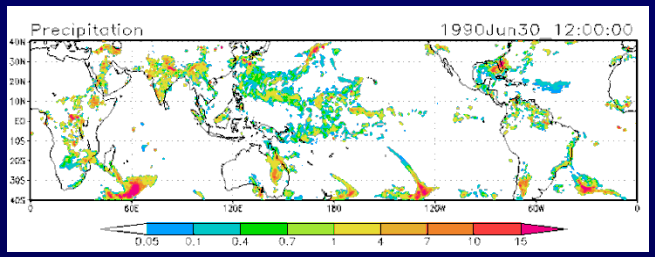


Regional Earth System Modeling (RegCM-ROMS)









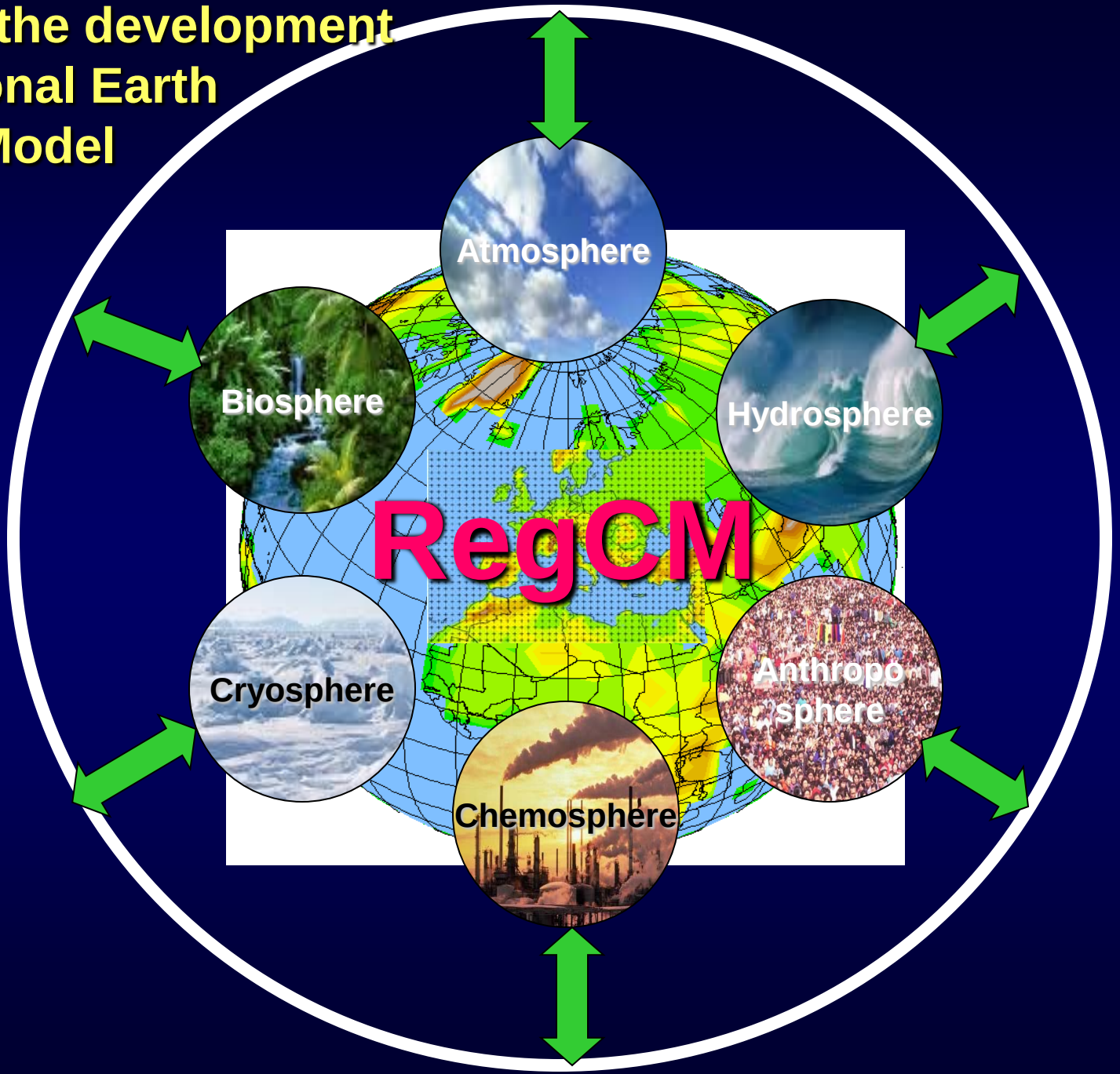
Impact models
Health
Food
Water
Land-use

RegCM Tropical Band

Intermediate Complexity Global Earth System Modeling (SPEEDY-NEMO)

Developing flexible and efficient tools for developing country needs

Towards the development of a regional Earth System Model



The RegCM regional climate model system

- Major recent releases
  - RegCM3 (2007), RegCM4 (2012)
- Source code public and accessible from the ICTP web site
- Code changes traceable through an SVN system
- User support through an email list (over 900 participants)
- Collaborative research projects
- Bi-annual RegCM workshop at ICTP + training workshops in developing countries

Structure of the RegCM training workshops

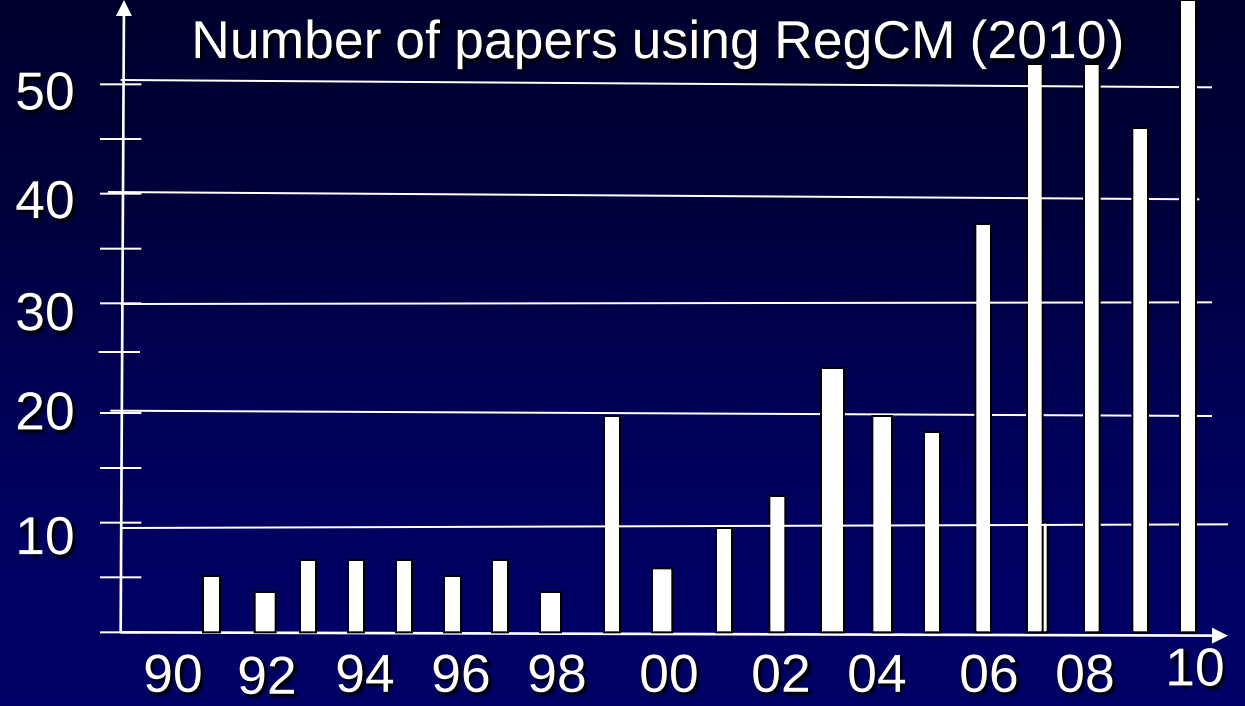
- Common structure + (changing) specific focus (e.g. extremes, coupling, high resolution, CORDEX, etc.)
- Theoretical lectures on regional climate processes and change
- Theoretical lectures on regional climate modeling
- Theoretical lectures on the RegCM system
- Hands-on laboratory sessions
- Small projects by the participants with final presentations

The RegCM System

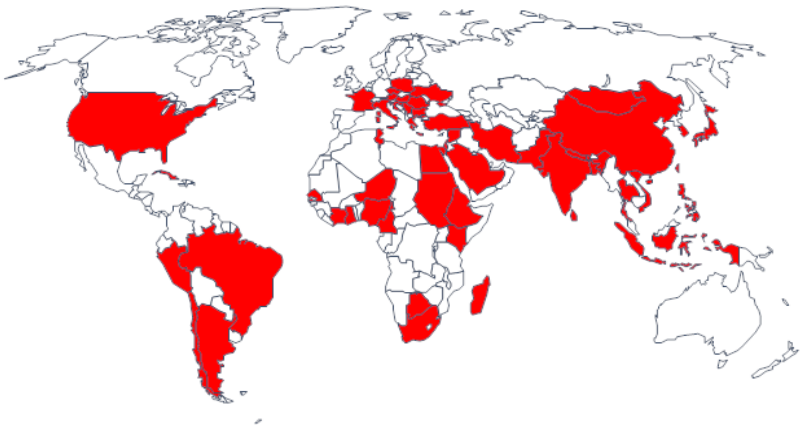
RegCM4

RegCNET (~900 part.)

More than 10000 downloads since June 2010

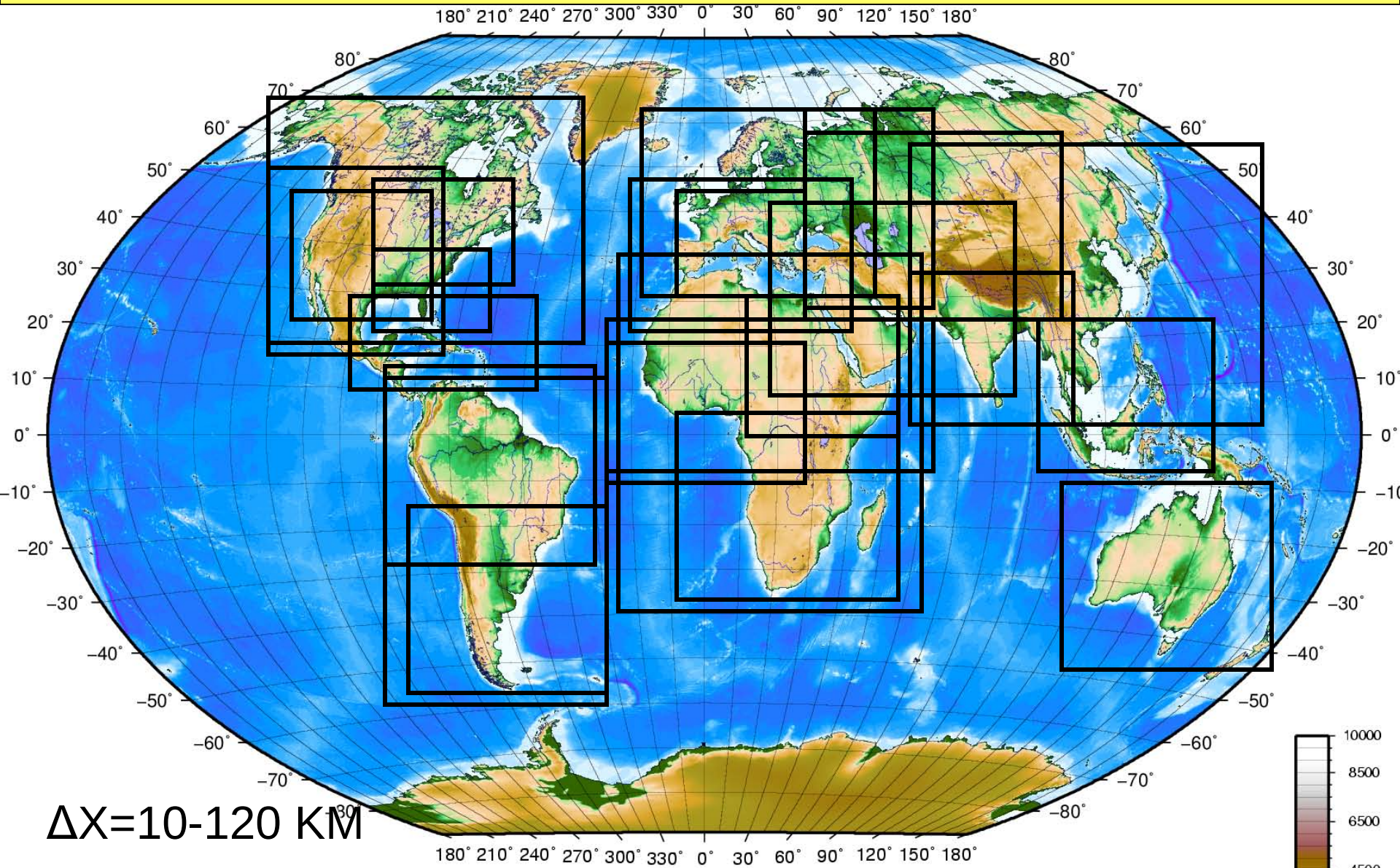


Countries where RegCM is used (2010)



RegCM training workshops:
ICTP, May 2012
Baijing, China, September 2013
ICTP, May 2014
Ensenada, Mexico, October 2014
Colombo, Sri lanka, April 2015
Manila, Philippines, May 2015
Sao Paolo, Brazil, February 2016
ICTP May 2016
San Jose', Costarica, November 2016

Sample of RegCM domains used



ΔX=10-120 KM

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 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 Precipitaion:**
  - 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

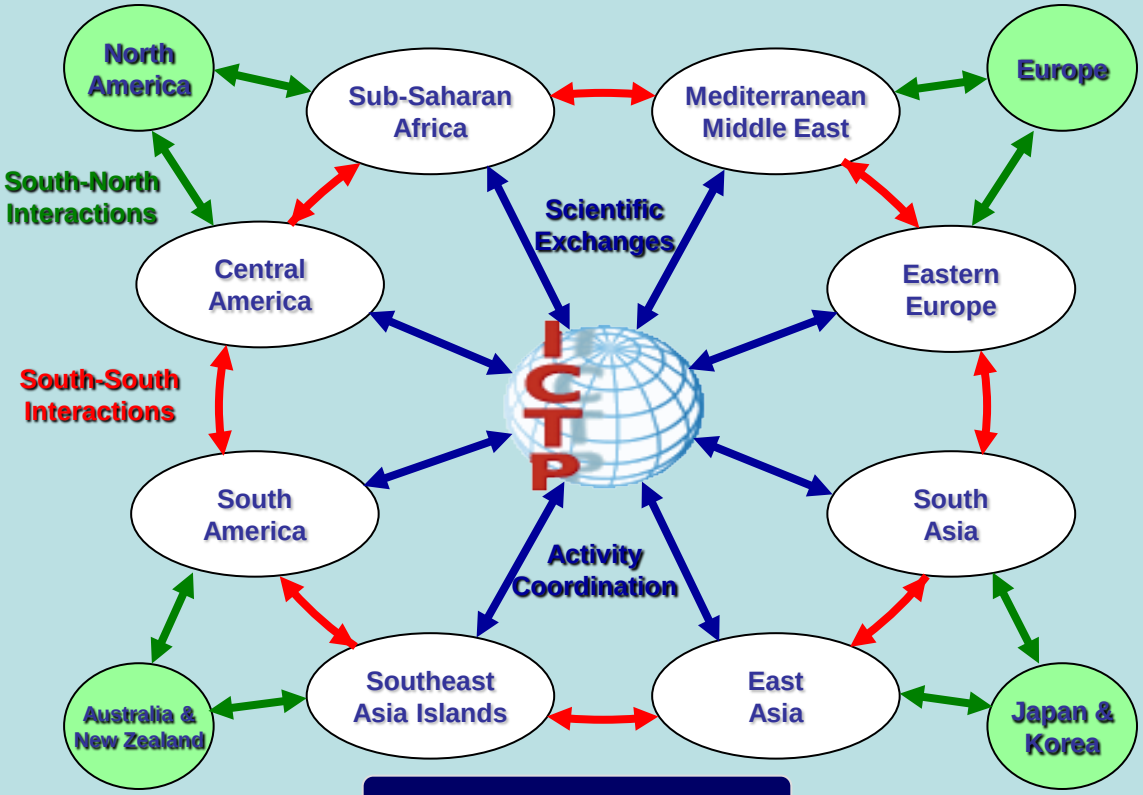
- **Coupled ocean**
  - MIT ocean model (Artale et al. 2010)
  - ROMS (Ratnam et al. 2009)
- **Interactive lake**
  - 1D thermal lake mode reactivated (Hostetler et al. 1994; Small et al. 1999)
- **Interactive biosphere**
  - Available in CLM, under testing
- **Interactive hydrology**
  - CHYM hydrological 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)

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

Regional Modeling

Weather Prediction | Seasonal Prediction | Climate Change

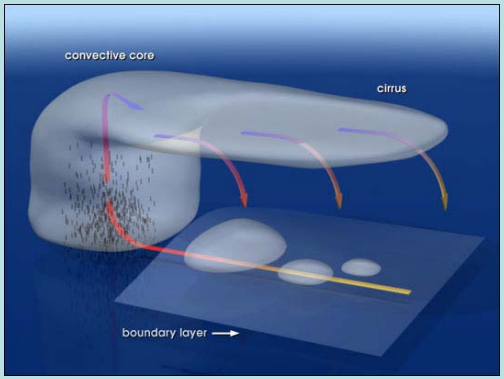
Storms | Flood | Drought | Water Resources | Energy | Agriculture | Landuse Change | Pollution | Health | Fisheries | Ecosystems

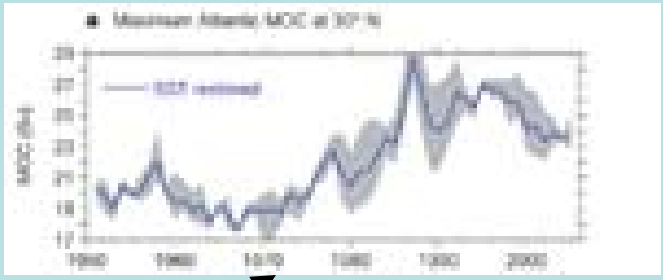
The COordinated Regional Downscaling EXperiment (CORDEX)

The CORDEX vision is to advance and coordinate the science and application of regional climate downscaling through global partnerships

- To better understand relevant regional/local climate phenomena, their variability and changes through downscaling
- To evaluate and improve regional climate downscaling models and techniques (RCM, ESD, VAR-AGCM, HIR-AGCM)
- To produce large coordinated sets of regional downscaled projections worldwide
- To foster communication and knowledge exchange with users of regional climate information

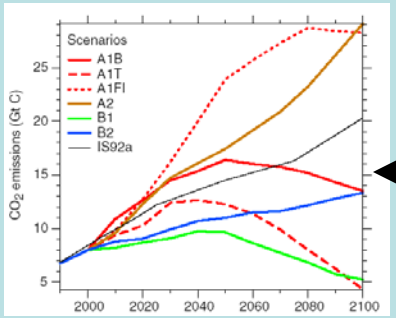
Large ensembles are needed to explore the multi-dimensional space of future climate uncertainty





Internal Variability

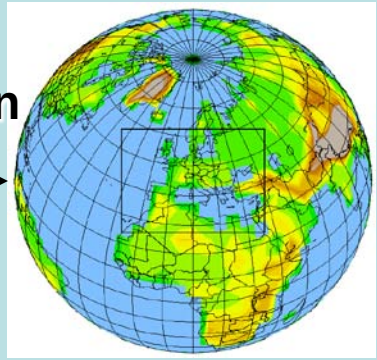
RCD Configuration



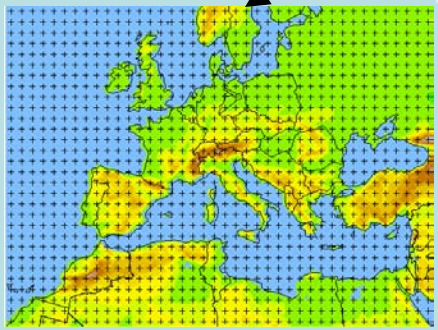
Forcing Scenario

Experiment (i,j,k …)

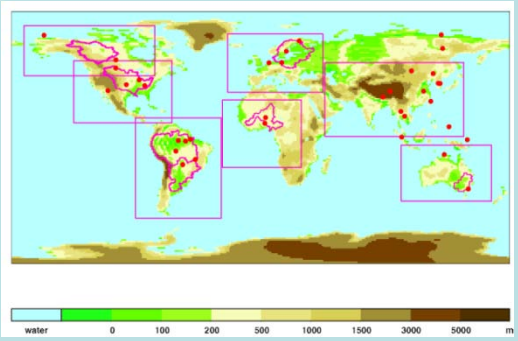
GCM Configuration



RCD Approach

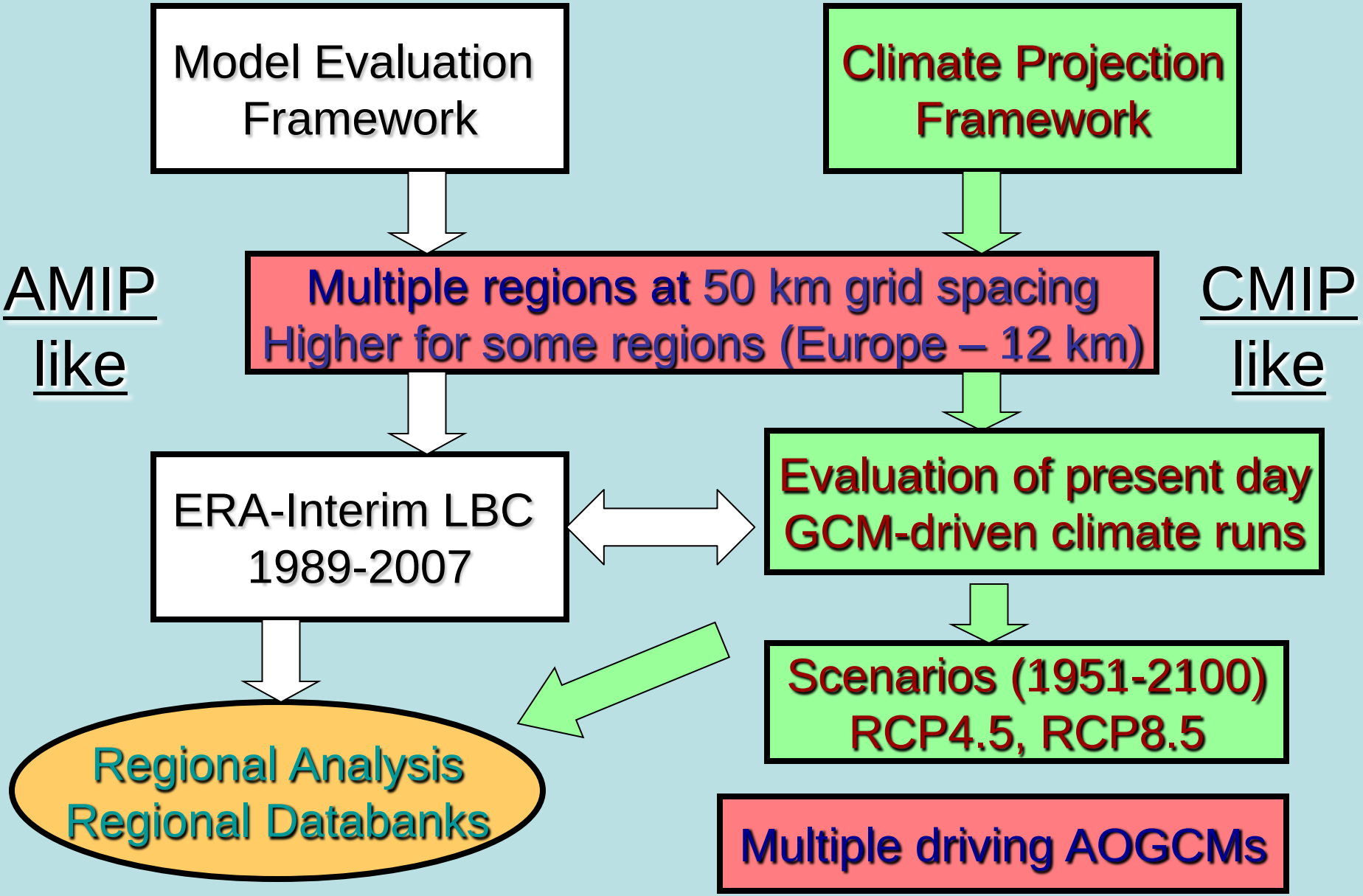


Geographic Region

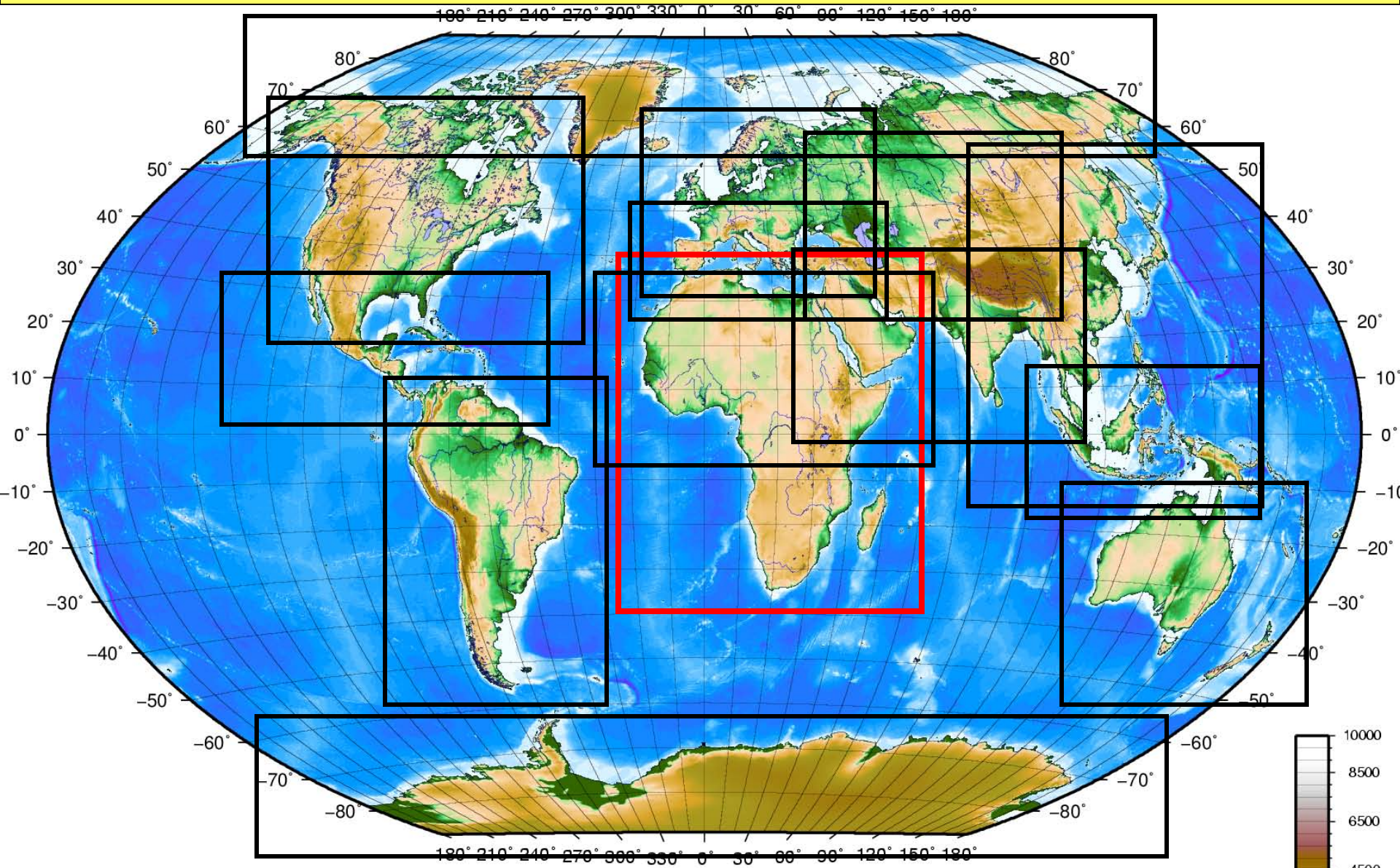


Giorgi et al. EOS 2008

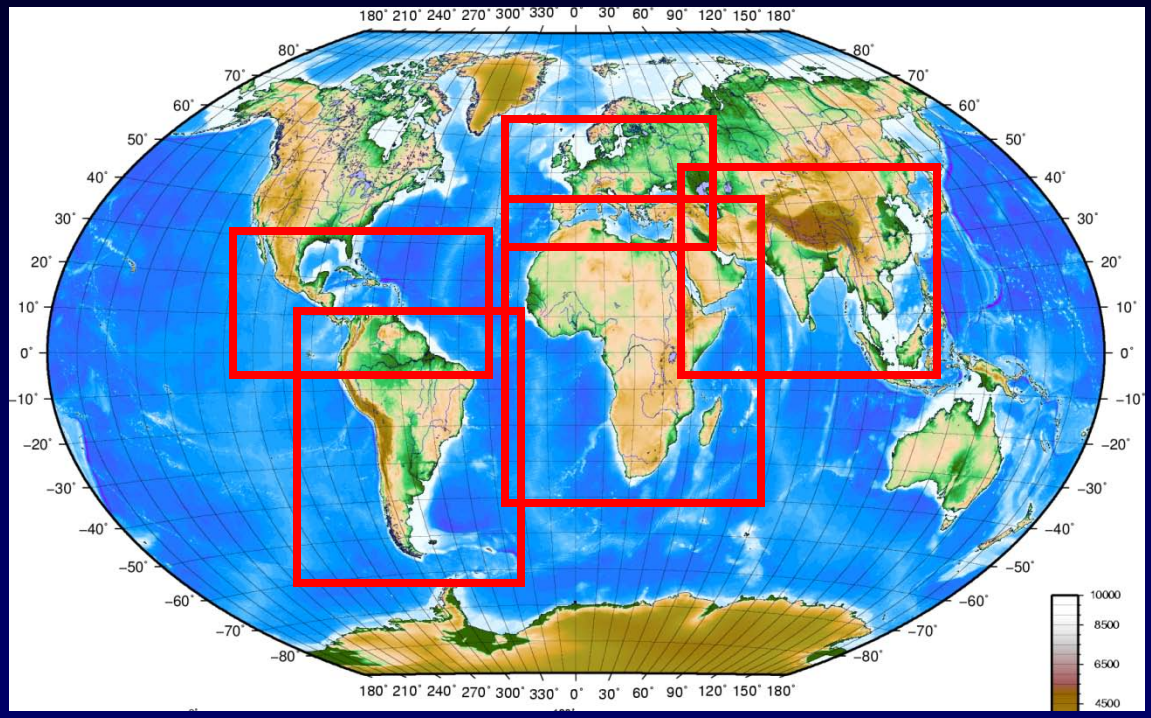
CORDEX Phase I experiment design



CORDEX domains



The CORDEX RegCM hyper-MAtrix Experiment (CREMA)



Contribution to the Coordinated Regional Downscaling Experiment (CORDEX) by the RegCM community

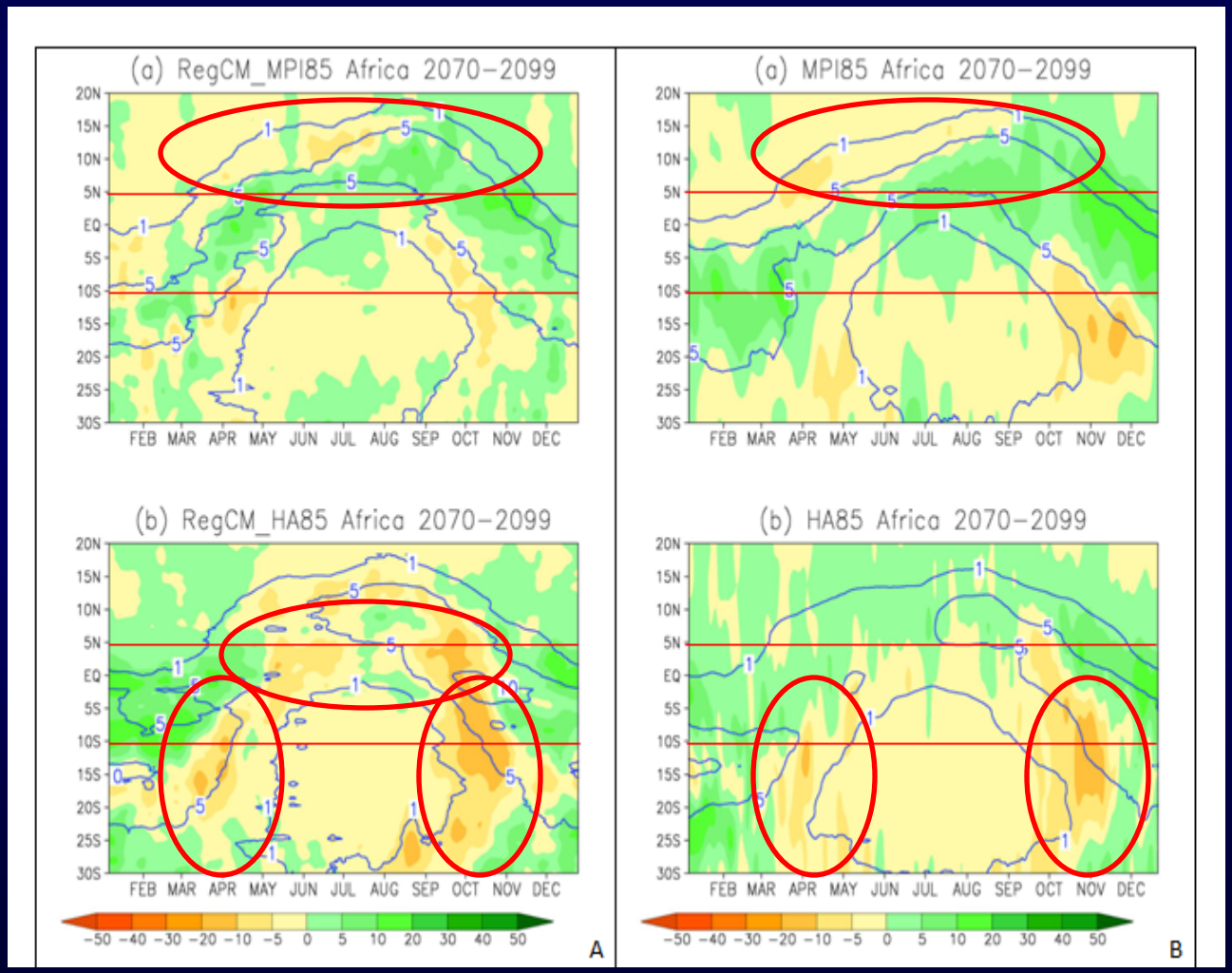
Collaboration with
U. San Paolo (Brazil)
CICESE (Mexico)
Indian Institute of technology
DHMZ (Croatia)

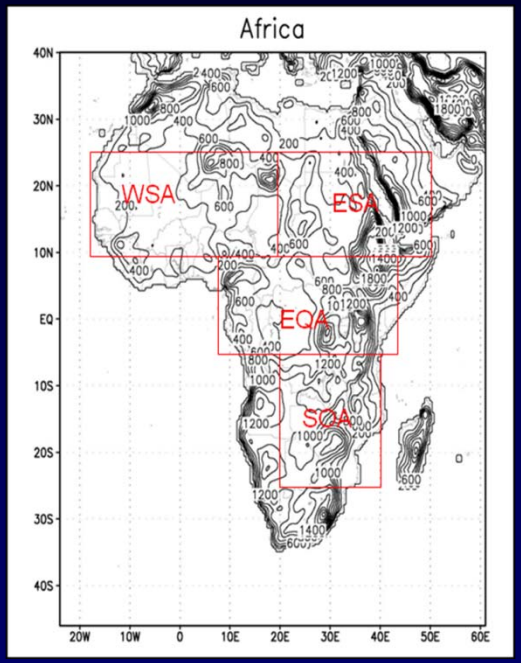
Special Issue of
Climatic Change (8 papers)

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 ~500 CPUs at the ARCTUR HPC
~200 Tbytes of data produced

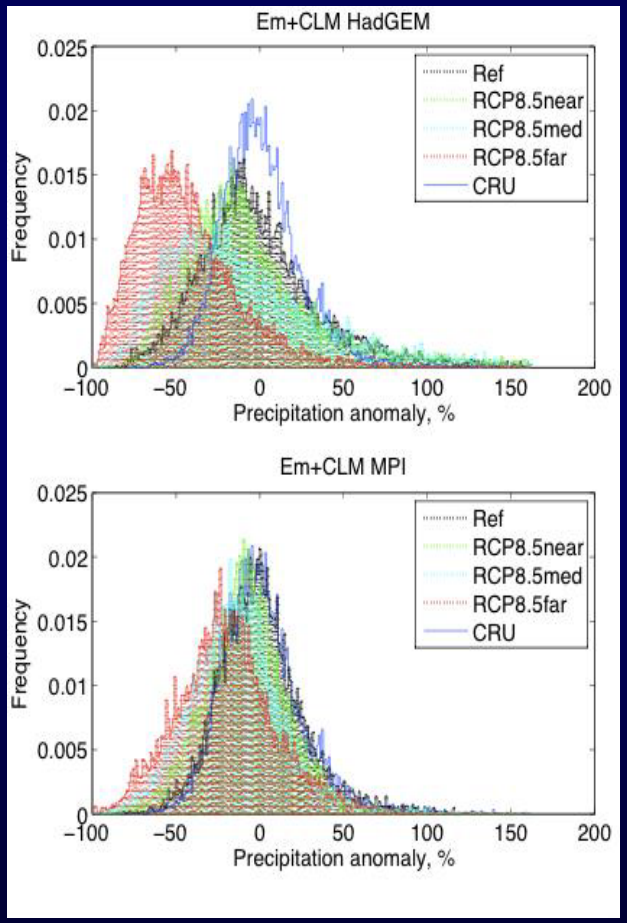
Hovmoller diagram of change in daily precipitation over Africa

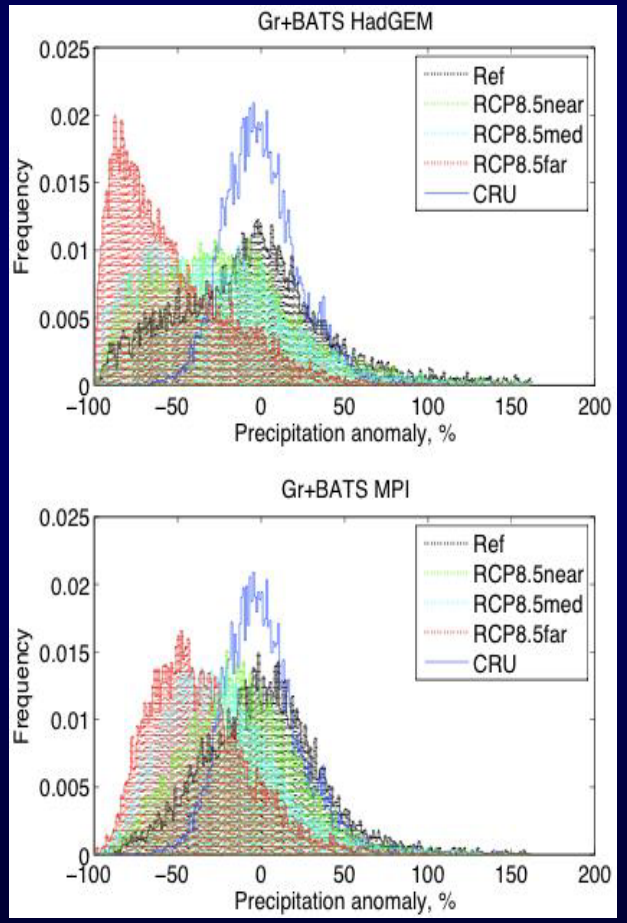


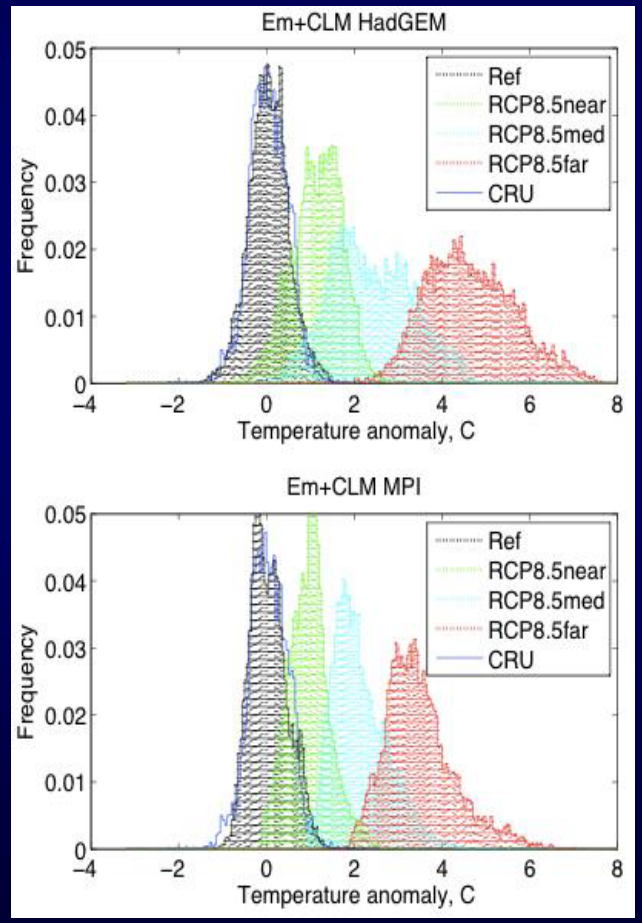


Mariotti et al. (2014)

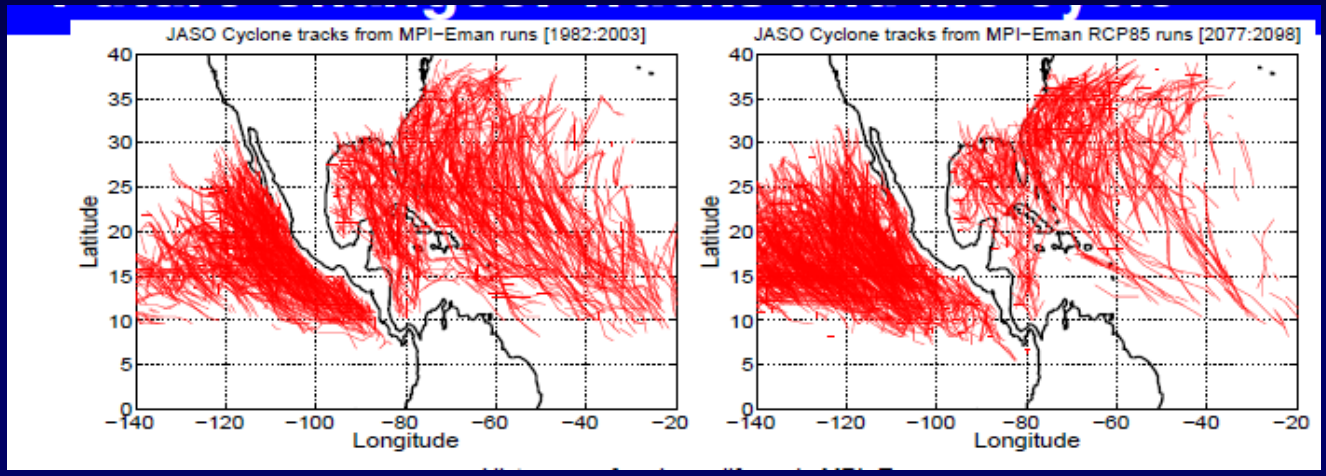
Empirical PDFs of present day and future seasonal precipitation and temperature anomalies over Central America (Fuentes-Franco et al. 2014)





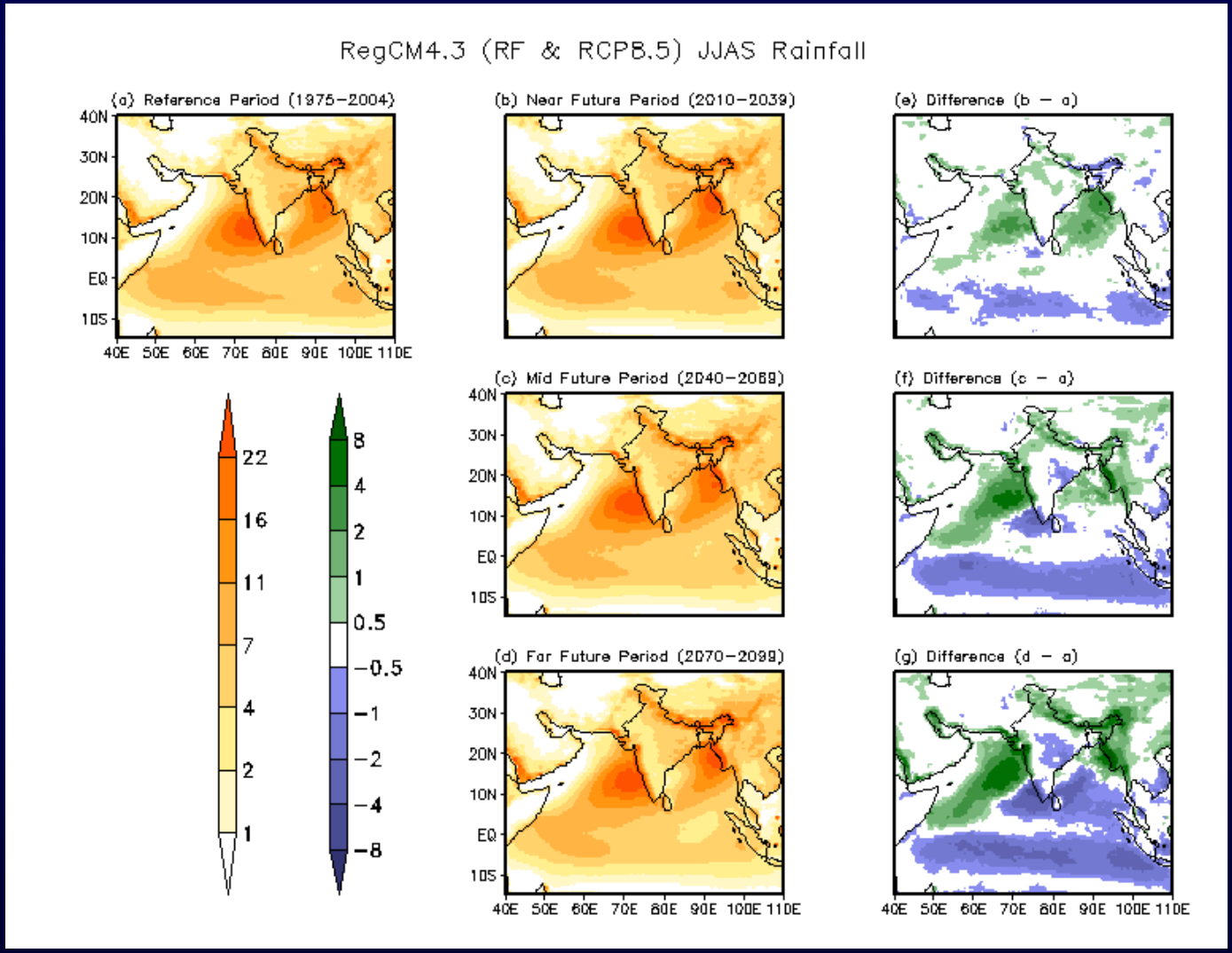


Change in tropical cyclones (Diro et al. 2014)

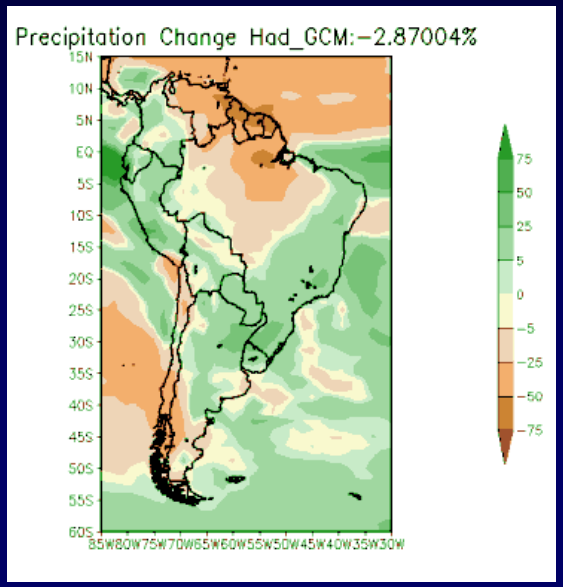


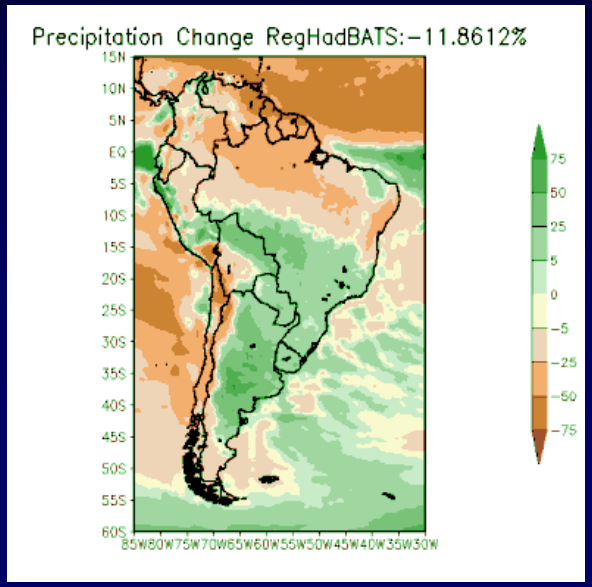
A decrease in the weak TCs but an increase in the frequency of the strongest TCs

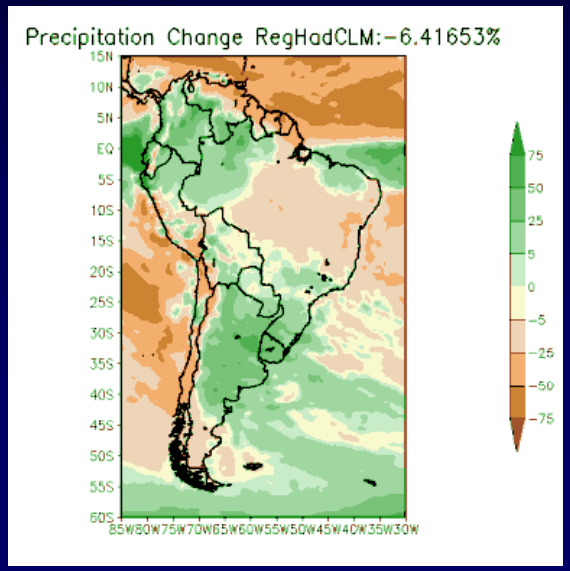
Weakening of monsoon precipitation over India (Dash et al. 2014)

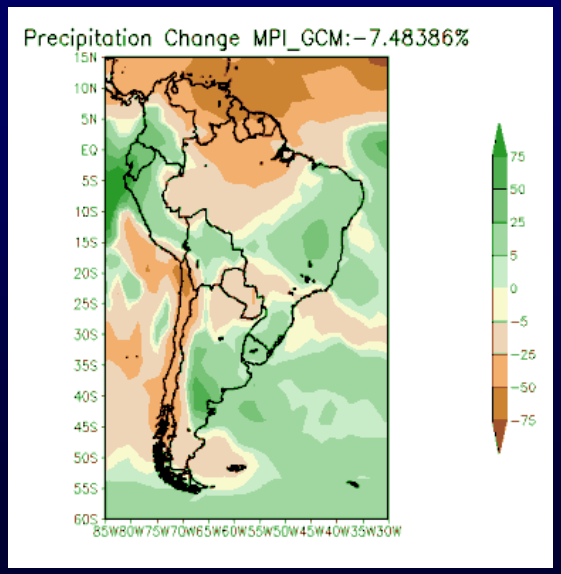


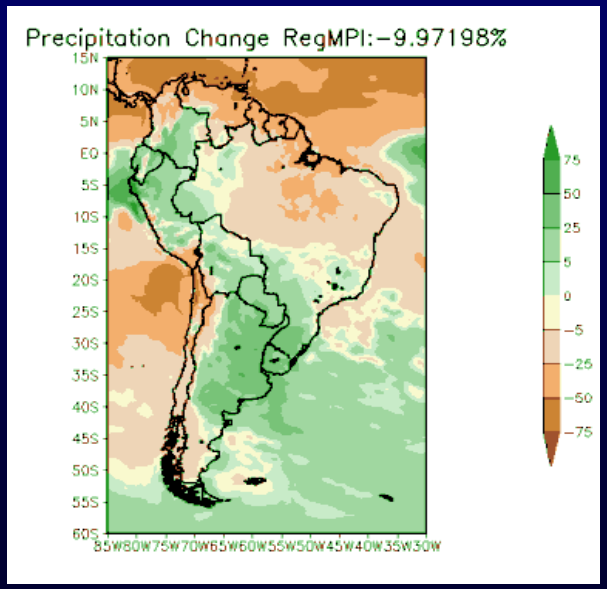
Effects of land surface feedbacks on precipitation change over South America



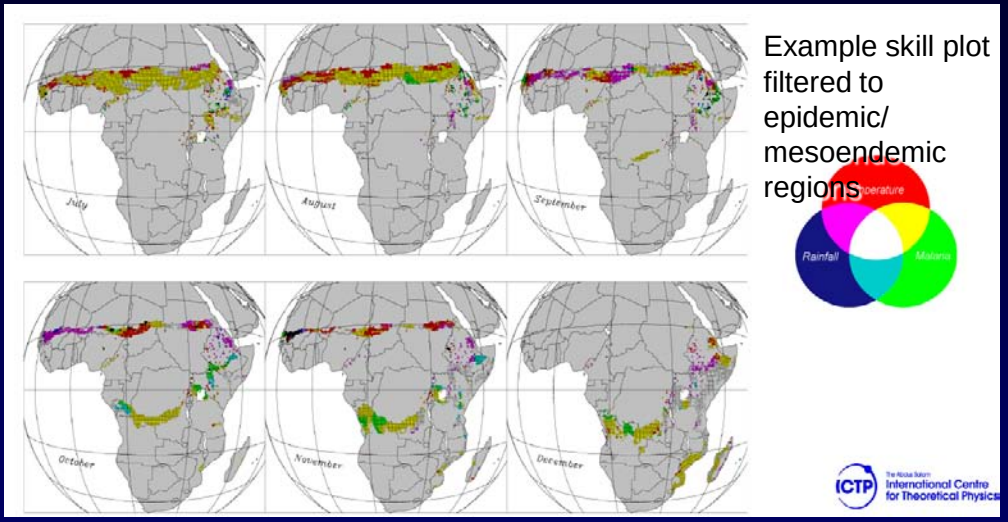






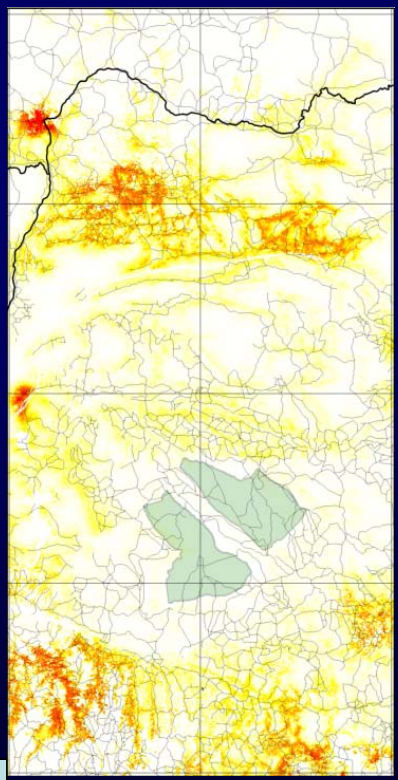


Llopart et al. (2014)

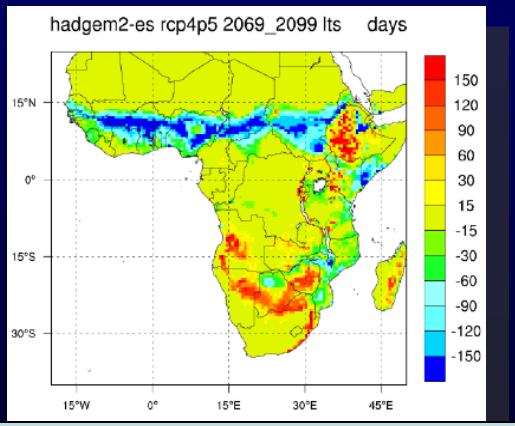


Impacts of climate variability and change (Agriculture, water, health, air quality) (Tompkins, Coppola, Giorgi, Solmon)

Deforestation simulations With FOREST-SAGE over the Congo Basin



Development and Distribution of impact models (VECTRI,CHYM, FOREST-SAGE) (Tompkins, Coppola)



Future malaria projections

Summary

- The ESP has a number of different educational activities that complement each other
- The ESP develops modeling tools specifically targeted for use by scientists in developing countries
- The ESP has created a number of research networks through which participants can exchange information and experience
- In order to be effective, education needs to be supported by research
  - Development of collaborative research projects


DEVELOPMENT
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