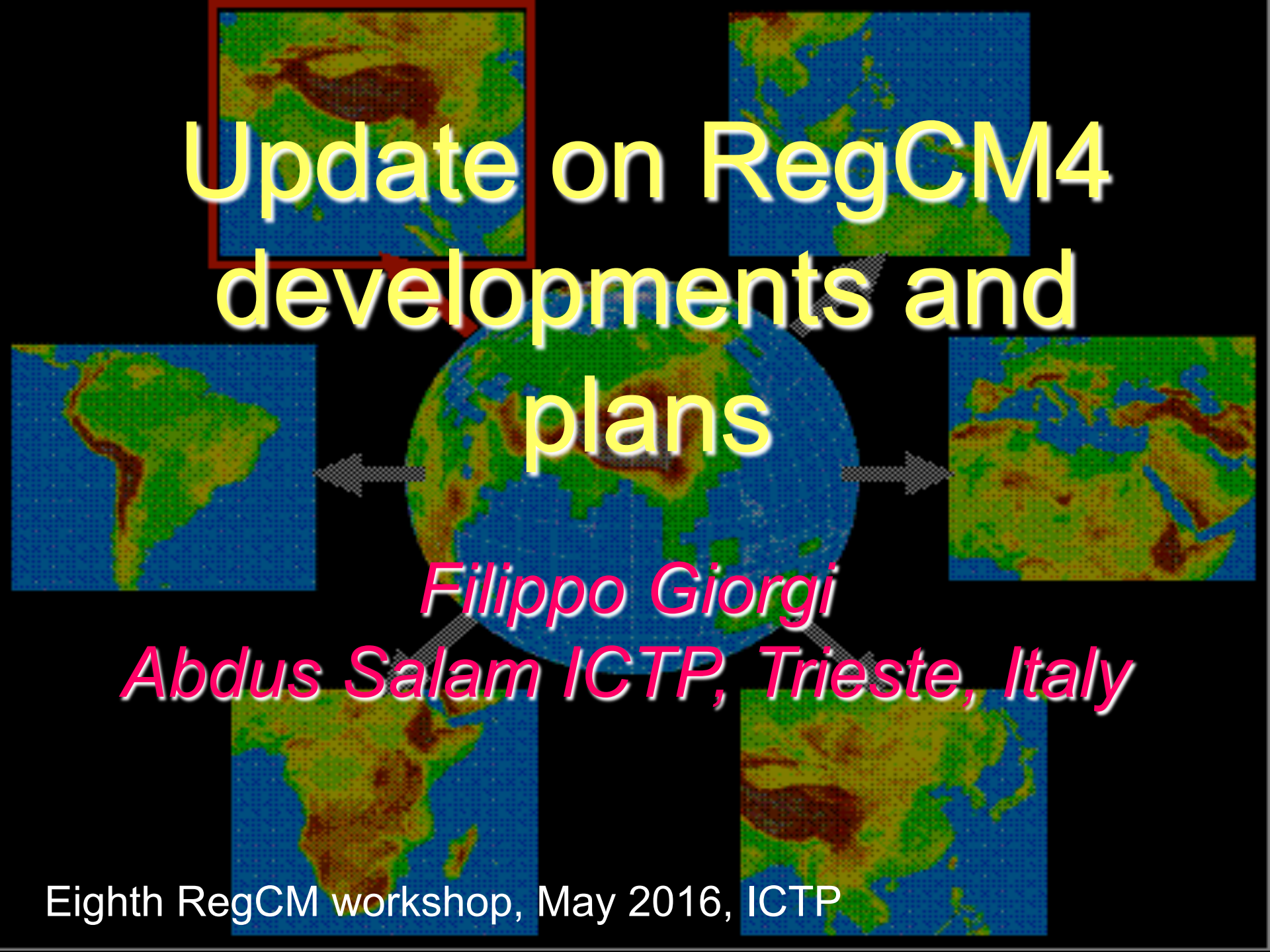
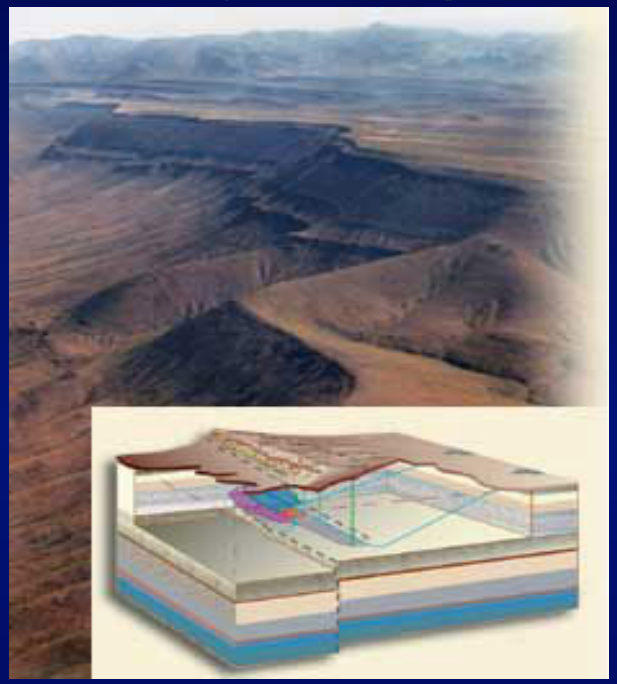


Update on RegCM4 developments and plans

Filippo Giorgi
Abdus Salam ICTP, Trieste, Italy

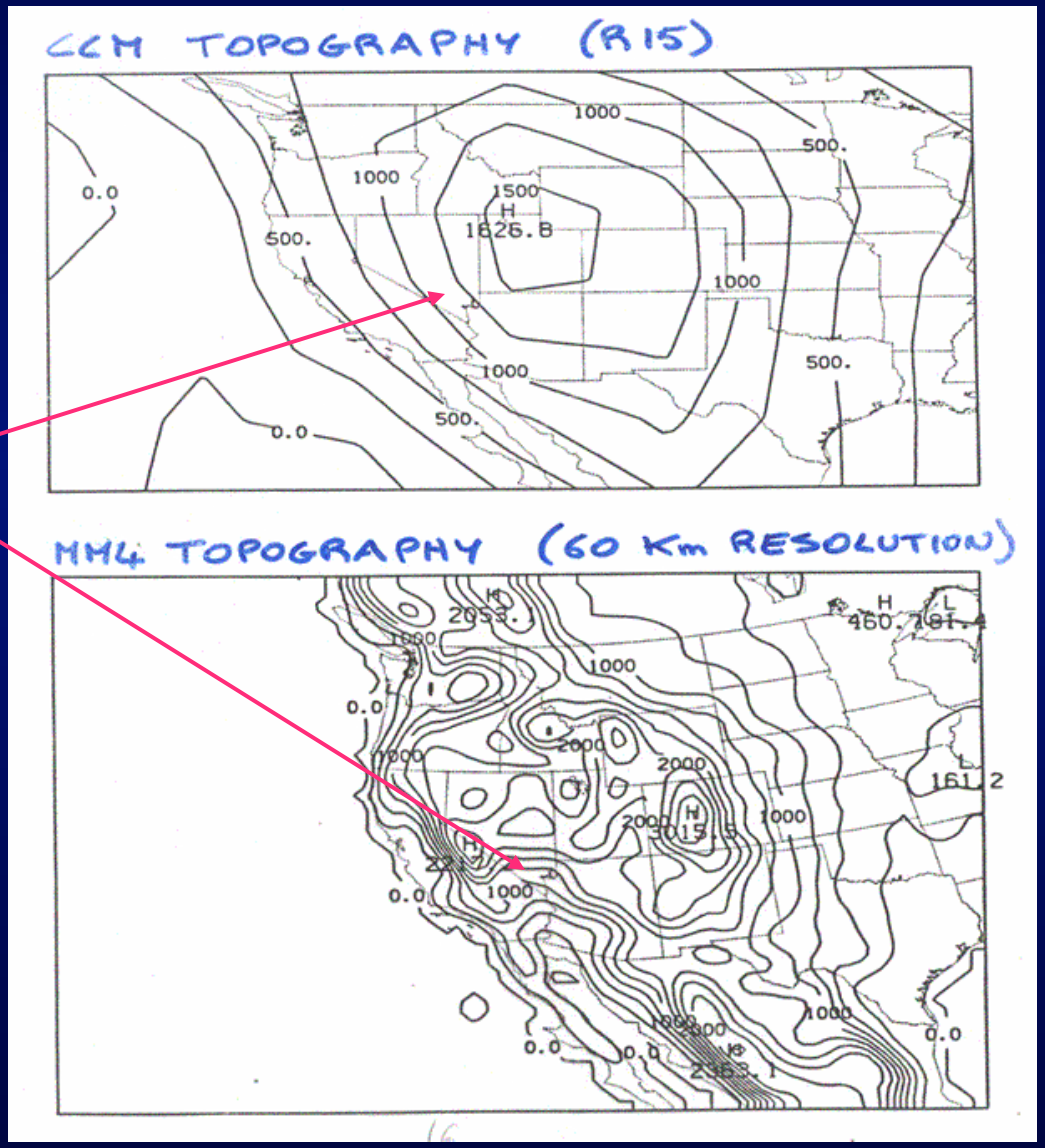
Eighth RegCM workshop, May 2016, ICTP

The beginning of regional modeling
The Yucca Mountain Project (1987)



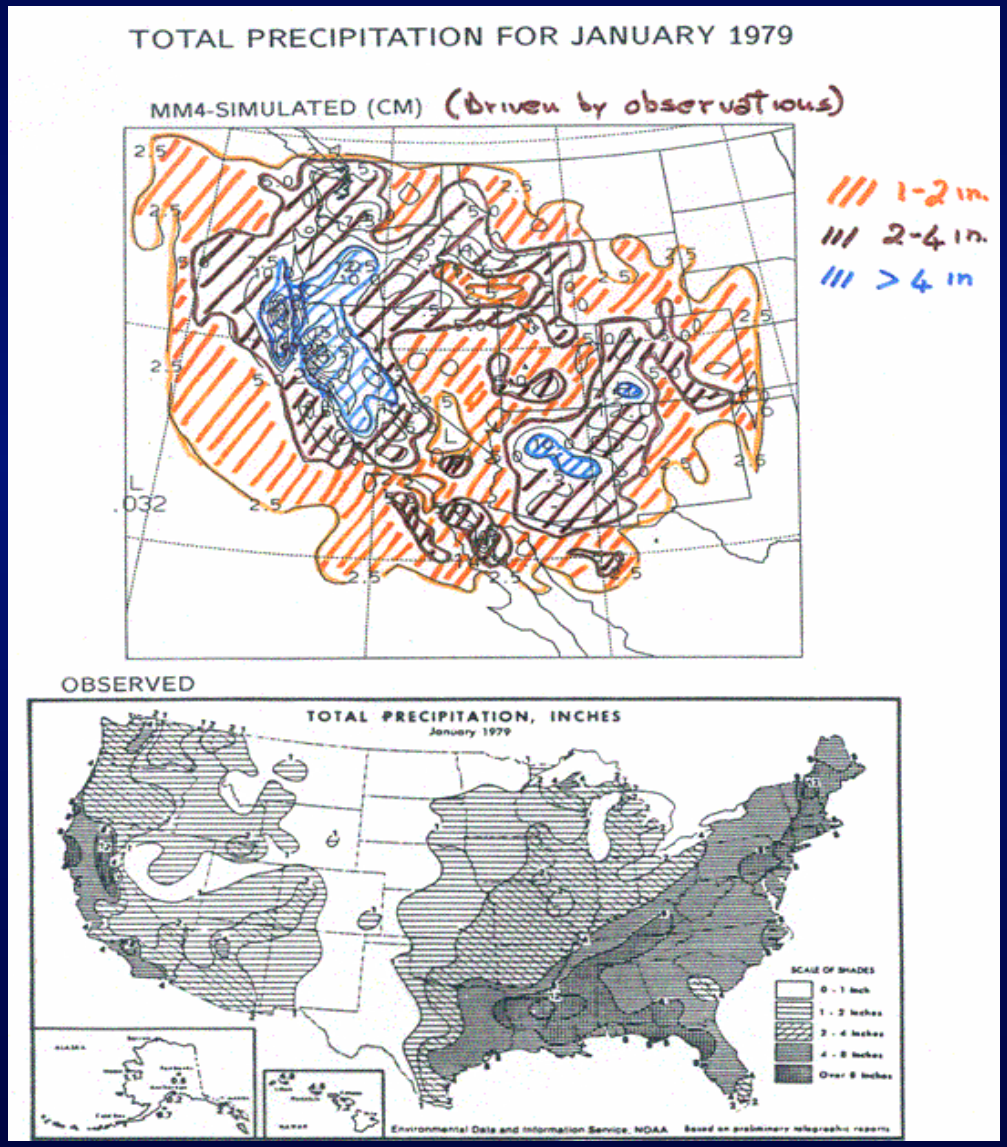
Model domain for the Yucca Mountain Project
Dickinson, Errico, Giorgi, Bates, CCH (1989)

Yucca Mountain

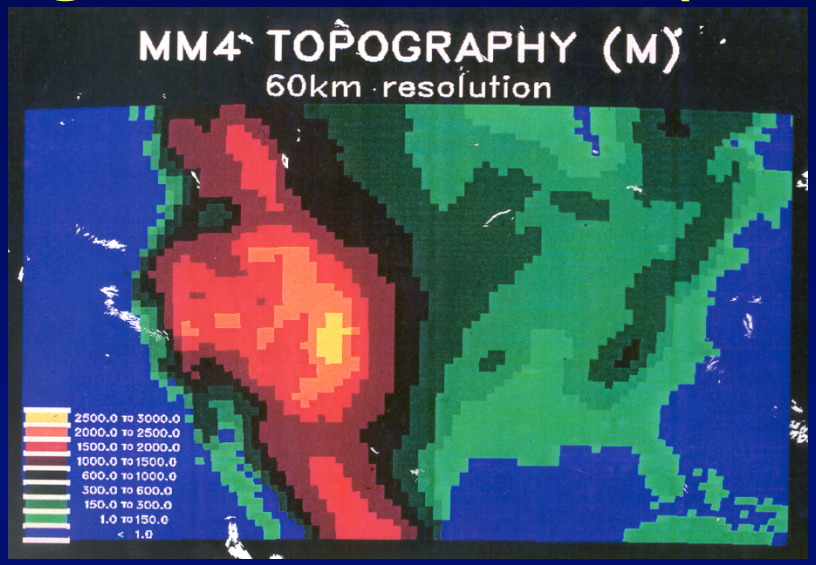


MM4 with BATS and CCM1 radiation

Giorgi and Bates, MWR (1989)
First run with a limited area model in climate mode



2CO2-Control Winter Precipitation Giorgi et al., JC (1994)

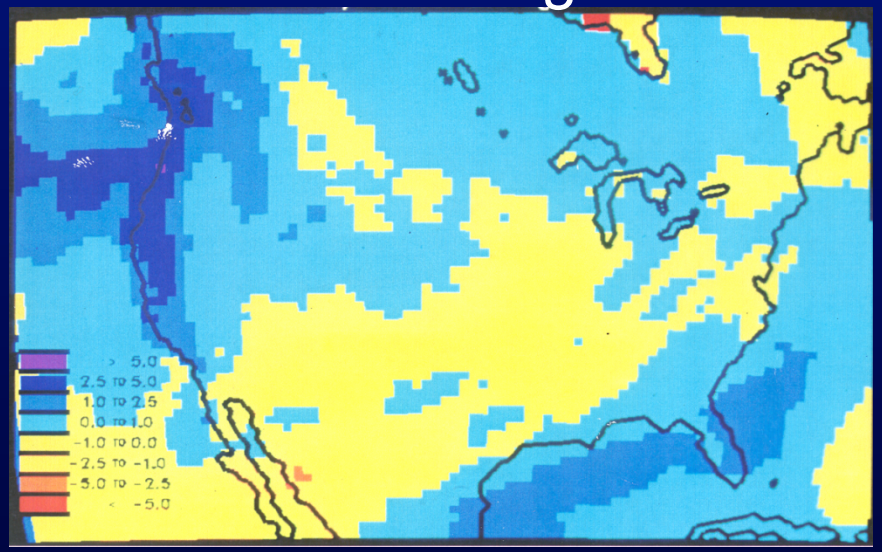


Model domain and topography

2CO2-Control DJF Precipitation

CCM

RegCM



The RegCM regional climate model system
RegCM1 (1989)

- Documentation
  - Dickinson et al. (1989), Giorgi and Bates (1989), Giorgi (1990)
- General features
  - Horizontal grid spacing of 50-100 km
  - Adaptable to any region of the world
  - Driving fields from NCEP analyses or GCMs
- Model dynamics (based on mesoscale model MM4; Anthes et al. 1987)
  - Hydrostatic assumption
  - Sigma-p vertical coordinates; Staggered Arakawa B-grid
  - Explicit 3-level time-integration scheme
- Model Physics (based on MM4 and the CCM1 GCM)
  - CCM1 radiative transfer package (Kiehl et al. 1986)
  - Local stability-dependent PBL scheme (Blackadar et al. 1982)
  - Kuo-Anthes cumulus convections scheme (Anthes et al. 1977)
  - Implicit resolvable scale precipitation scheme
  - BATS1A land surface scheme (Dickinson et al. 1986)

The RegCM regional climate model system
RegCM2 (1993)

- Development
  - Giorgi et al. (1993a,b)
- General features
  - Horizontal grid spacing of 10-100 km
  - Adaptable to any region of the world
  - Driving fields from ECMWF and NCEP analyses or GCMs
- Model dynamics (based on hydrostatic mesoscale model MM5; Grell et al. 1994)
  - Sigma-p vertical coordinates; Staggered Arakawa B-grid
  - **Split explicit time-integration scheme** (doubling of time step)
- Model Physics (based on MM5 and the CCM2 GCM)
  - **CCM2 radiative transfer package** (Kiehl et al. 1993)
  - **Non-local vertical diffusion PBL scheme** (Holtslag et al. 1990)
  - Kuo and Grell cumulus convections schemes (Grell 1993)
  - Implicit and **explicit** resolvable scale precipitation scheme (Hsie and Anthes 1984)
  - **BATS1E** land surface scheme (Dickinson et al. 1993)

The RegCM regional climate model system
RegCM2.5 (1999)

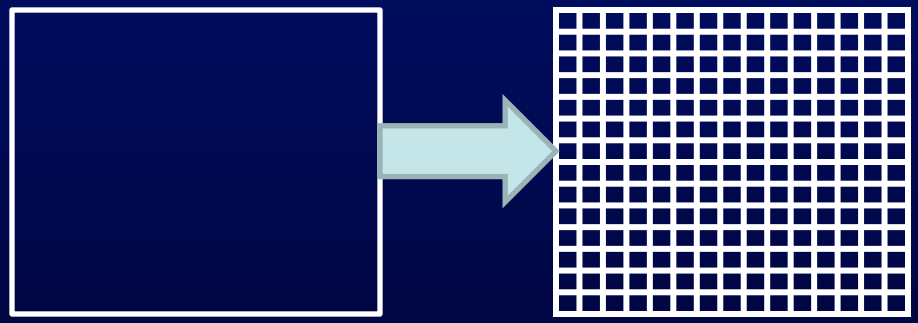
- Development
  - Giorgi et al. (1993a,b); Giorgi and Shields (1999); Small et al. (1999); Qian and Giorgi (1999); Special issue of JGR, April 1999.
- General features
  - Horizontal grid spacing of 10-100 km
  - Adaptable to any region of the world
  - Driving fields from ECMWF and NCEP analyses or GCMs
- Model dynamics (based on hydrostatic MM5; Grell et al. 1994)
  - Sigma-p vertical coordinates; Staggered Arakawa B-grid
  - Split explicit time-integration scheme
- Model Physics (based on MM5 and the CCM3 GCM)
  - **CCM3 radiative transfer package** (Kiehl et al. 1996)
  - Non-local vertical diffusion PBL scheme (Holtslag et al. 1990)
  - Kuo, Grell, **Zhang** cumulus schemes (Zhang et al. 1997)
  - **Simplified explicit precipitation scheme** (Giorgi and Shields 1999)
  - BATS1E land surface scheme (Dickinson et al. 1993)
  - **Coupled lake model** (Small et al. 1999)
  - **Coupled radiatively active aerosol model** (Qian and Giorgi 1999)

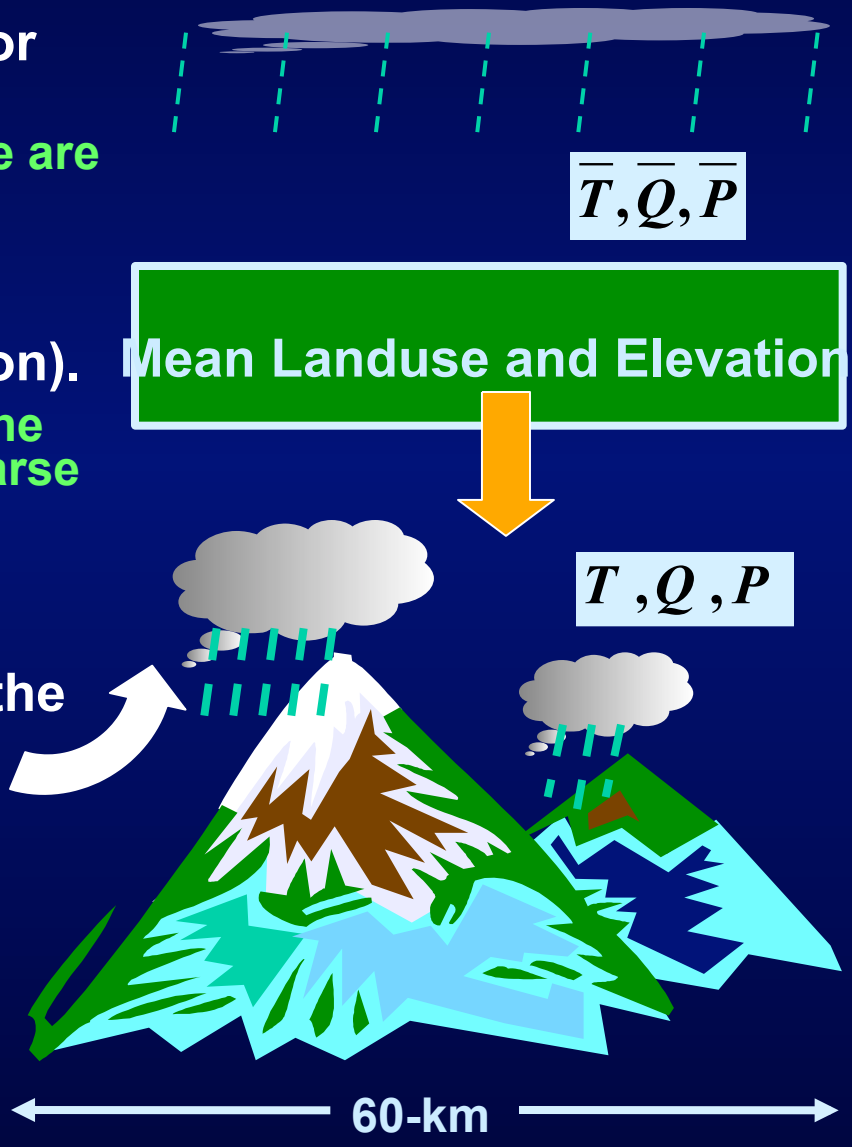
The ICTP regional climate model system
RegCM3, Pal et al. 2007, TAC SI 2006

- **Dynamics:**
  MM5 Hydrostatic (Giorgi et al. 1993a,b)
- **Radiation:**
  CCM3 (Kiehl 1996)
- **Large-Scale Clouds & Precipitaion:**
  SUBEX (Pal et al 2000)
- **Cumulus convection:**
  Grell (1993)
  Anthes-Kuo (1977)
  MIT (Emanuel 1991)
- **Boundary Layer:**
  Non-local, Holtslag (1990)
- **Tracers/Aerosols:**
  Solmon et al 2005
  Zakey et al 2006
- **Land Surface:**
  BATS (Dickinson et al 1993)
  SUB-BATS (Giorgi et al 2003)
- **Ocean Fluxes**
  BATS (Dickinson et al 1993)
  Zeng (Zeng et al. 1998)
- **Computations**
  Parallel Code
  Multiple Platforms
  More User-Friendly Code

Land surface sub-grid model
Giorgi et al. (2003)

- Define a regular fine scale sub-grid for each coarse scale model grid-box.
  - Landuse, topography, and soil texture are characterized on the fine grid.
- Disaggregate climatic fields from the coarse grid to the fine grid (e.g. temperature, water vapor, precipitation).
  - Disaggregation technique based on the elevation differences between the coarse grid and the fine grid.
- Perform BATS surface physics computations on the fine grid.
- Reaggregate the surface fields from the fine grid to the coarse grid.



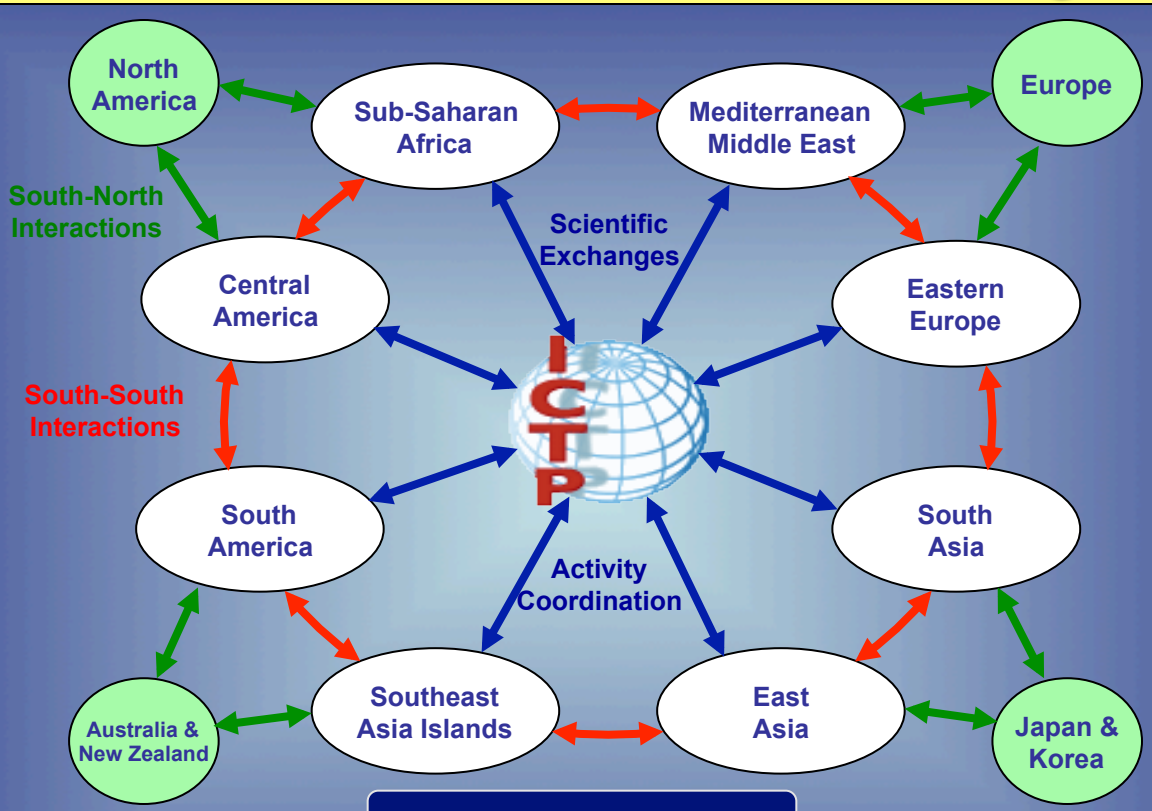


The ESP RegCM and Regional Climate research NETwork, RegCNET

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 ICTP regional climate model system RegCM4 (Giorgi et al. 2012, CR SI 2012)

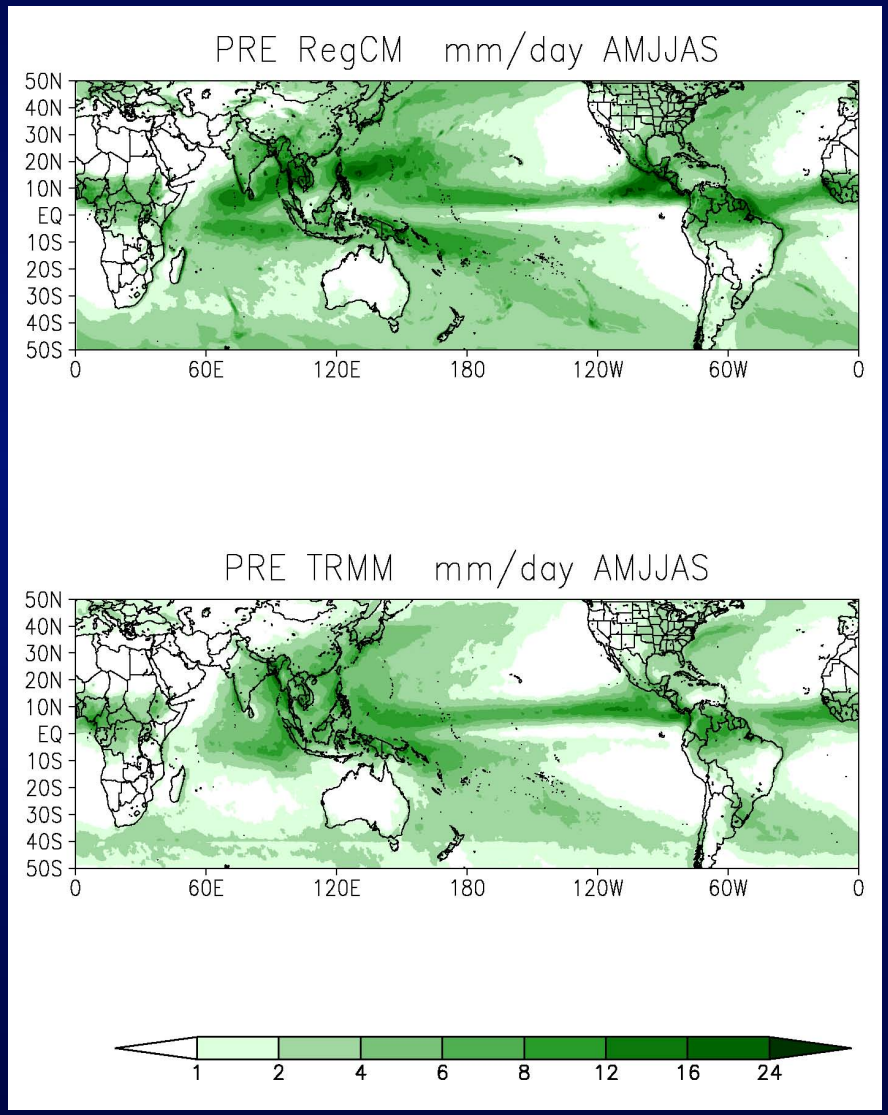
- **Dynamics:**
  - Hydrostatic (Giorgi et al. 1993a,b)
  - Adaptable to any region
- **Radiation:**
  - CCM3 (Kiehl 1996)
  - **RRTM (Solmon)**
- **Large-Scale Precipitation:**
  - SUBEX (Pal et al 2000)
- **Cumulus convection:**
  - Grell (1993)
  - Anthes-Kuo (1977)
  - MIT (Emanuel 1991)
  - **Mixed convection**
  - **Tiedtke**
  - **Betts-Miller (never really worked)**
- **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)**
- **Ocean Fluxes**
  - BATS (Dickinson et al 1993)
  - Zeng (Zeng et al. 1998)
  - **Diurnal SST**
- **Configuration**
  - Adaptable to any region
  - **Tropical belt configuration**
- **Extensive code remake**

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)

Tropical band configuration (Coppola et al. 2012)

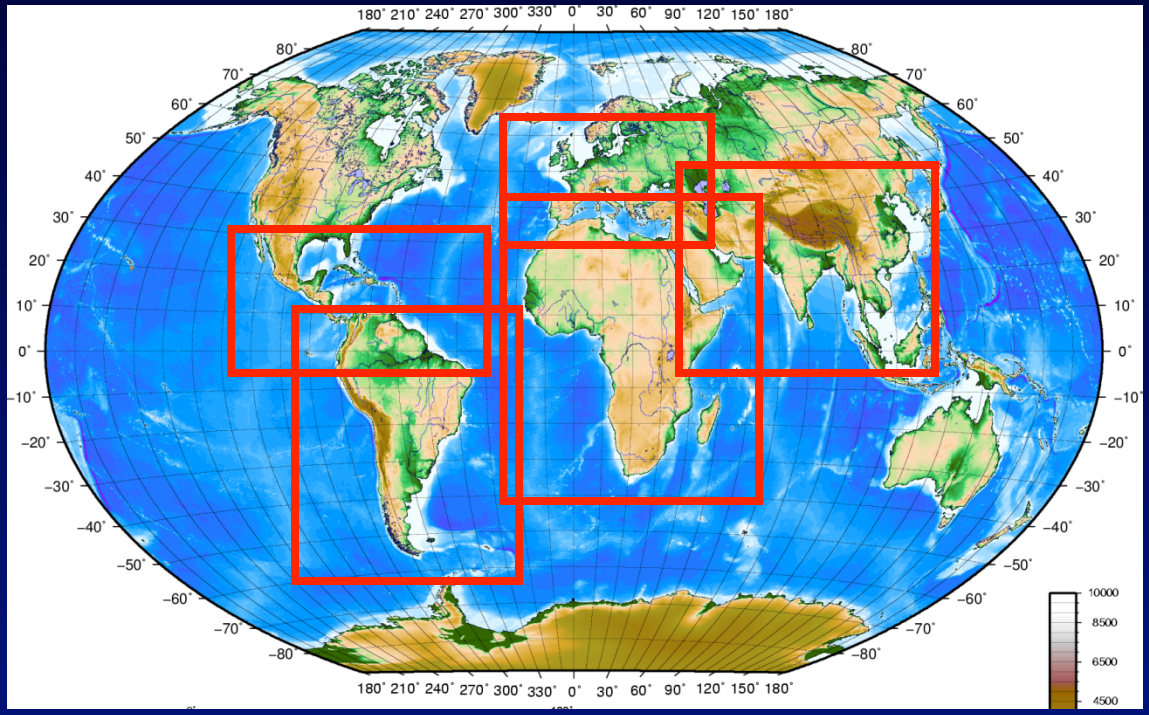


RegCM4

Precipitation
AMJJAS
1998-2002
ERA-Interim LBC

TRMM

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

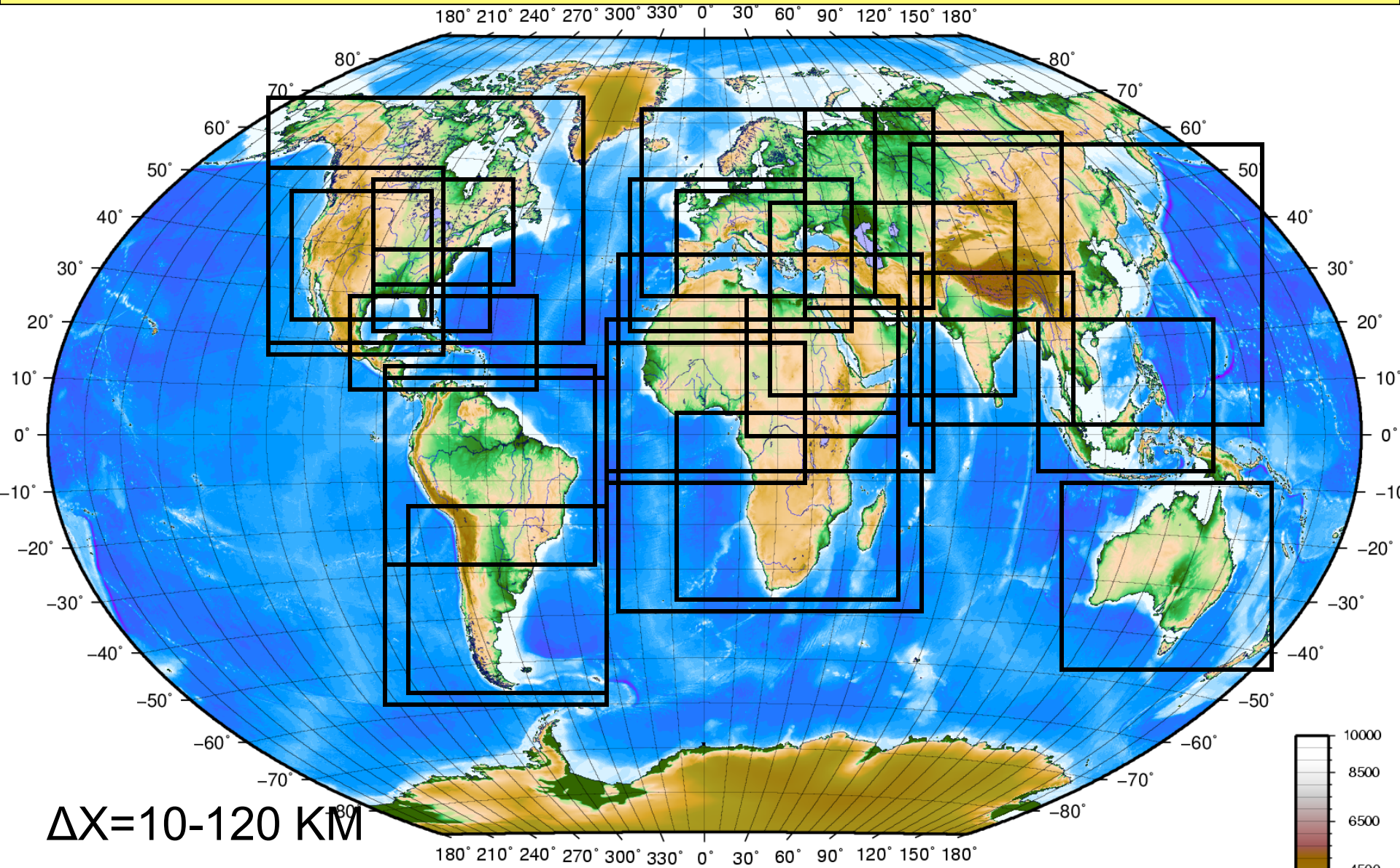
The ICTP regional climate model system
RegCM4: New developments

- **Dynamics:**
  - Hydrostatic (Giorgi et al. 1993a,b)
  - **Non- Hydrostatic (from MM5)**
- **Radiation:**
  - CCM3 (Kiehl 1996)
  - RRTM (Solmon)
- **Large-Scale Precipitation:**
  - SUBEX (Pal et al 2000)
  - **New microphysics** (Nogherotto)
- **Cumulus convection:**
  - Grell (1993)
  - Anthes-Kuo (1977)
  - MIT (Emanuel 1991)
  - Mixed convection
  - **Tiedtke**
  - **Kain-Fritsch**
- **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)
  - **CLM4.5 (Olson et al. 2014)**
- **Ocean Fluxes**
  - BATS (Dickinson et al 1993)
  - Zeng (Zeng et al. 1998)
  - Diurnal SST
- **Configuration**
  - Adaptable to any region
  - Tropical belt configuration
- **Single precision version (almost there)**

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 (Hostetler et al. 1994; Small et al. 1999)
- **Interactive biosphere**
  - **DVGM in CLM working**
- **Interactive hydrology**
  - **CHYM hydrological model coupled interactively**
- **Ocean biogeochemistry**
  - **Coupling with BFM under way (Reale)**
- **Aerosols:**
  - OC-BC-SO4 (Solmon et al 2005)
  - Dust (Zakey et al 2006)
  - Sea Salt (Zakey et al. 2009)
  - **Nitrates**
  - **Pollen (Li et al. 2016)**
- **Gas phase chemistry:**
  - CBMZ + Sillmann solver (Shalaby et al. 2012)

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)

Objectives of the workshop

- Test new RegCM developments
  - CLM4.5 (and DVGM)
  - New microphysics scheme
  - Tiedtke and Kain-Fritsch schemes
  - Non-hydrostatic dynamical core
  - Coupling with ocean and chemistry models
- Test and optimize the model for different domains
- Discuss and plan how the RegCM community can contribute to CORDEX2


THANK YOU