The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA

2148-1

Fifth ICTP Workshop on the Theory and Use of Regional Climate Models

31 May - 11 June, 2010

A brief history of the RegCM: From RegCM1 to RegCM4

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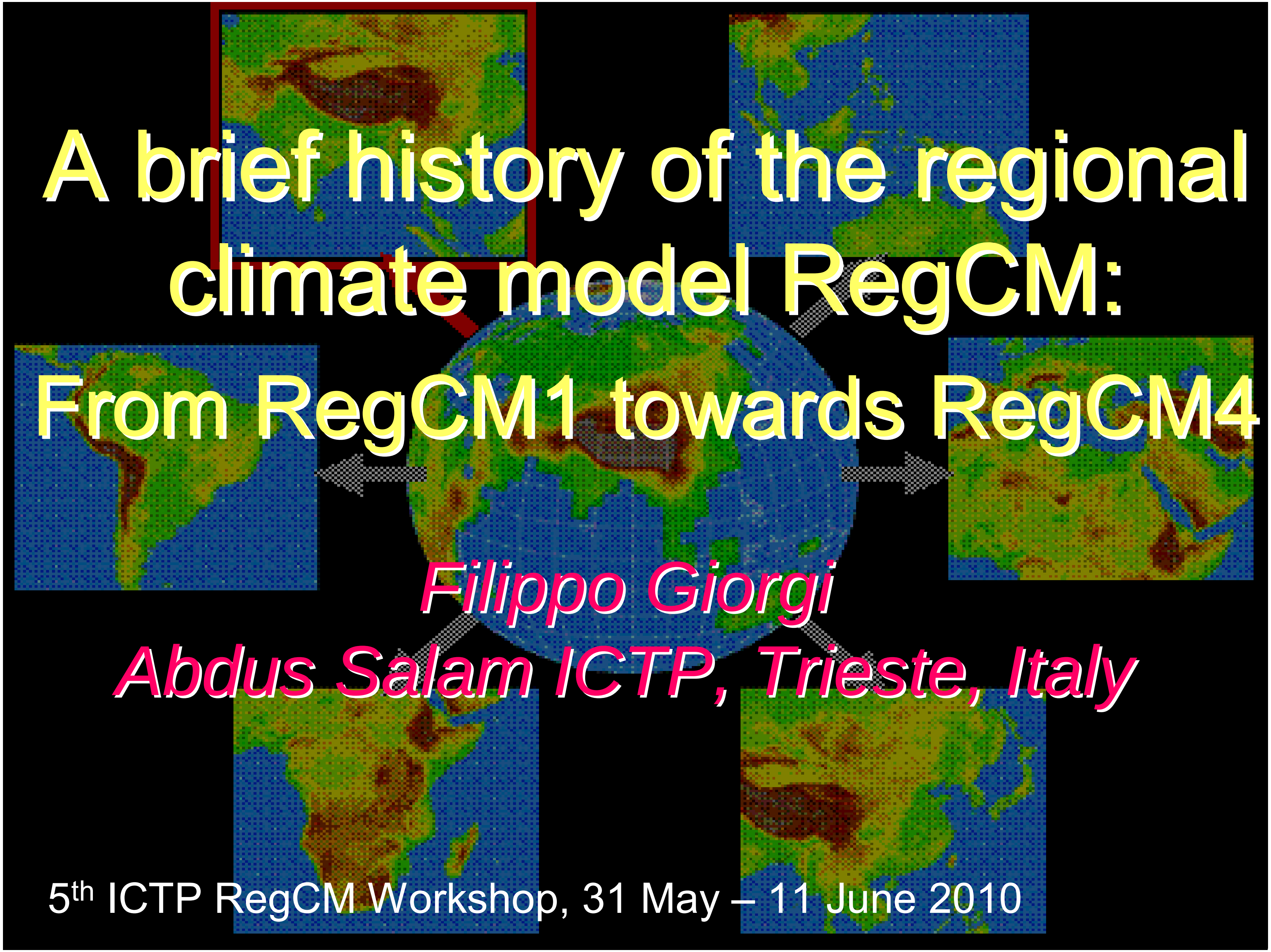


A brief history of the regional climate model RegCM: From RegCM1 towards RegCM4

Filippo Giorgi
Abdus Salam ICTP, Trieste, Italy

5th ICTP RegCM Workshop, 31 May – 11 June 2010

“Nested” Regional Climate Modeling: Technique and Strategy

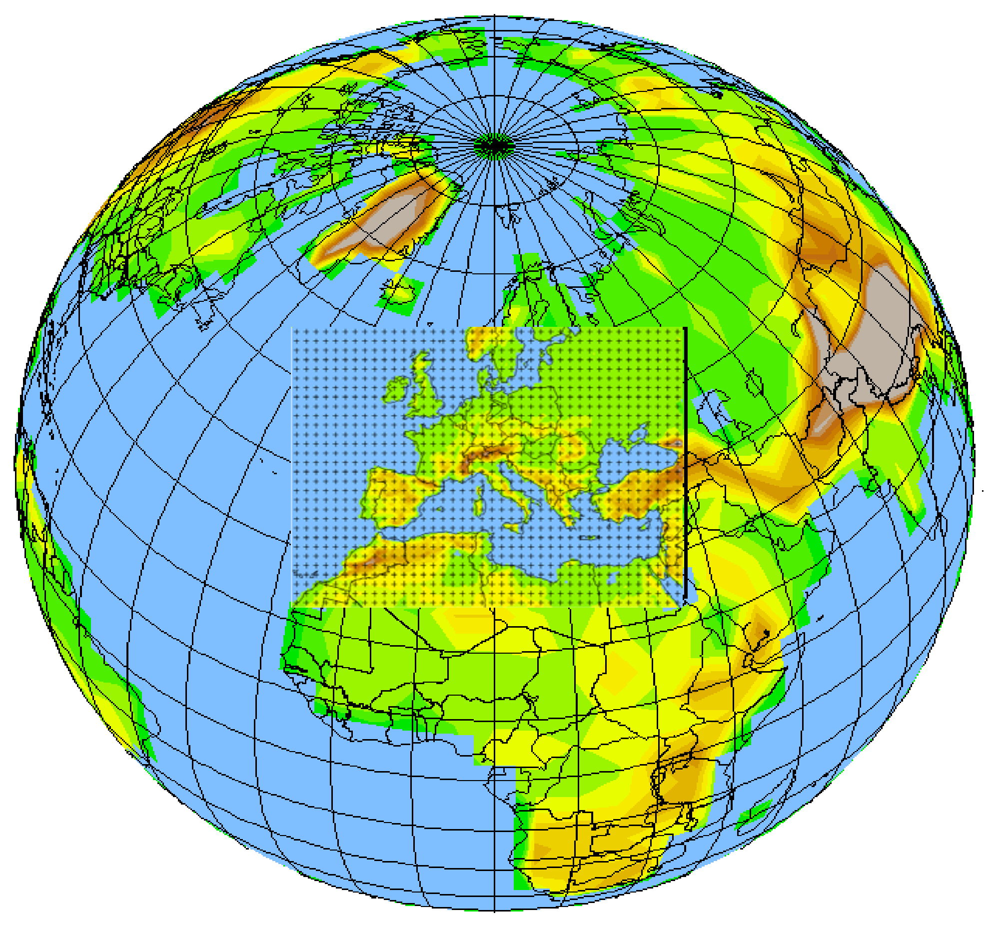
Motivation: The resolution of GCMs is still too coarse to capture regional and local climate processes

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

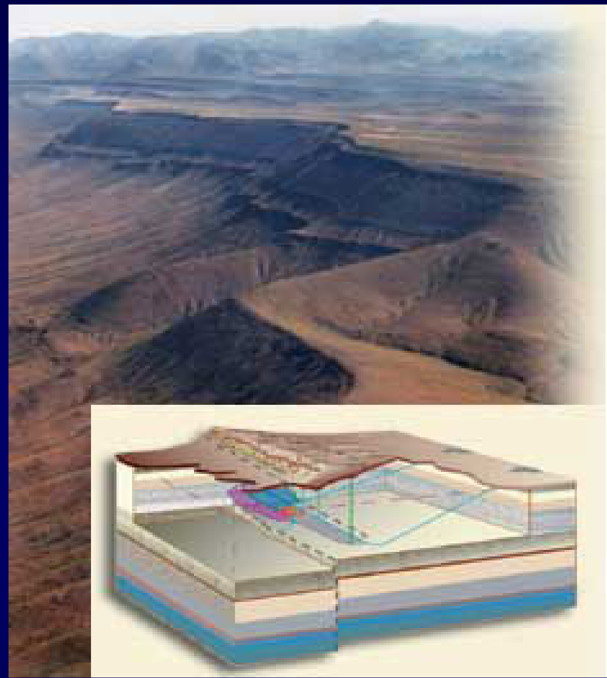
- Initial conditions (IC) and lateral boundary conditions (LBC) for the RCM are obtained from the GCM (“One-way Nesting”) or analyses of observations (perfect LBC).

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

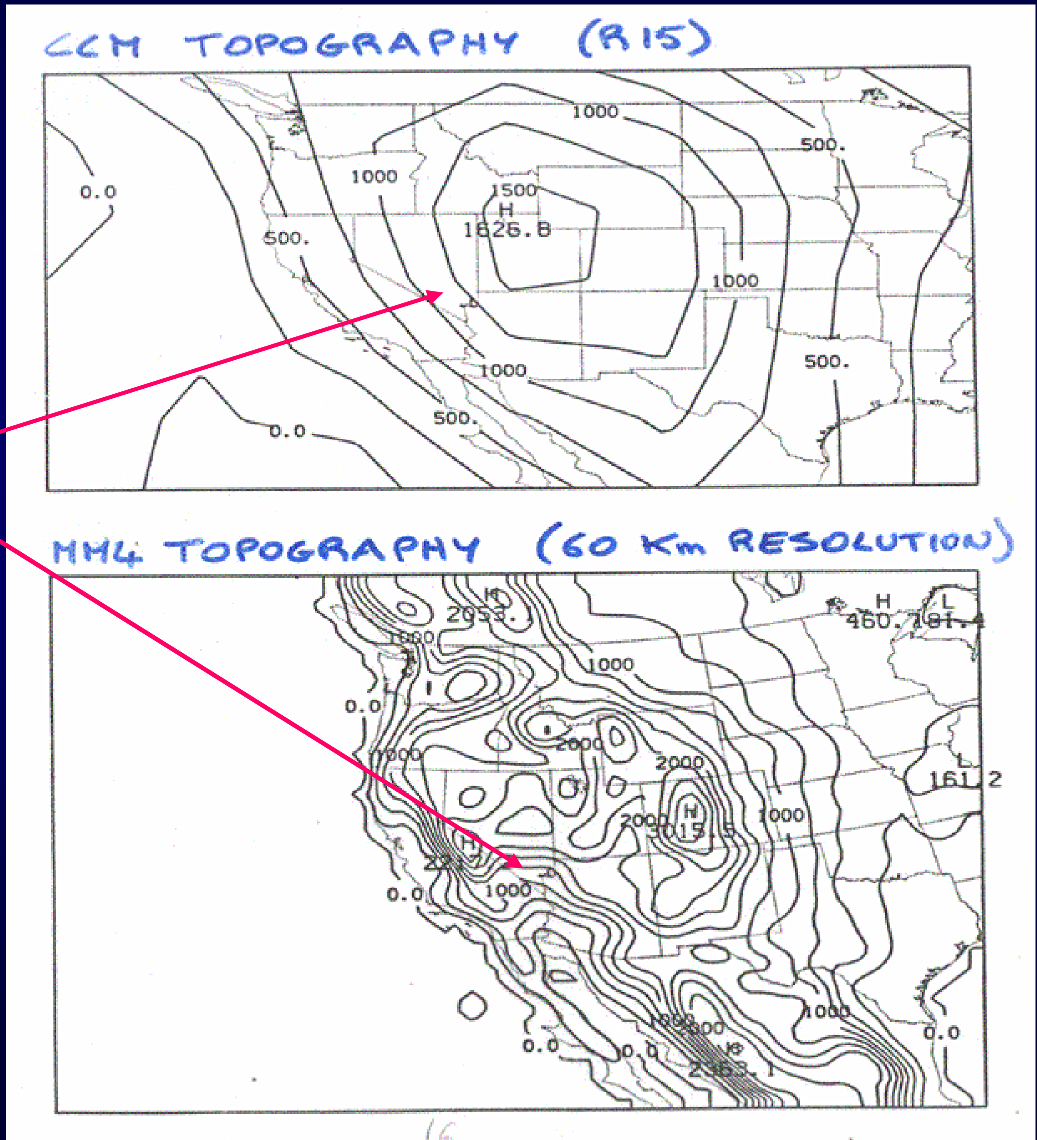


The beginning of regional modeling
The Yucca Mountain Project (1987)



Model domain for the Yucca Mountain Project

Yucca Mountain



The birth of the RegCM system (1989)

- Traditionally, limited area models (LAMs) had been used for numerical weather prediction involving simulations of 1-5 days in length.
- Dickinson et al. (1989) proposed to adopt the “nesting” approach to climate problems by generating statistics of large numbers of short LAM simulations driven by GCM fields
  - The model used was a suitably modified version of the NCAR/Penn State mesoscale model MM4
- Giorgi and Bates (1989) and Giorgi (1990) completed the first LAM simulations in “climate mode” (1-month long) driven by ECMWF analyses of observations and by the NCAR CCM, respectively.
- This lead to the generation of the first version of RegCM, which was based on MM4 with modified radiative transfer and land surface process schemes

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)

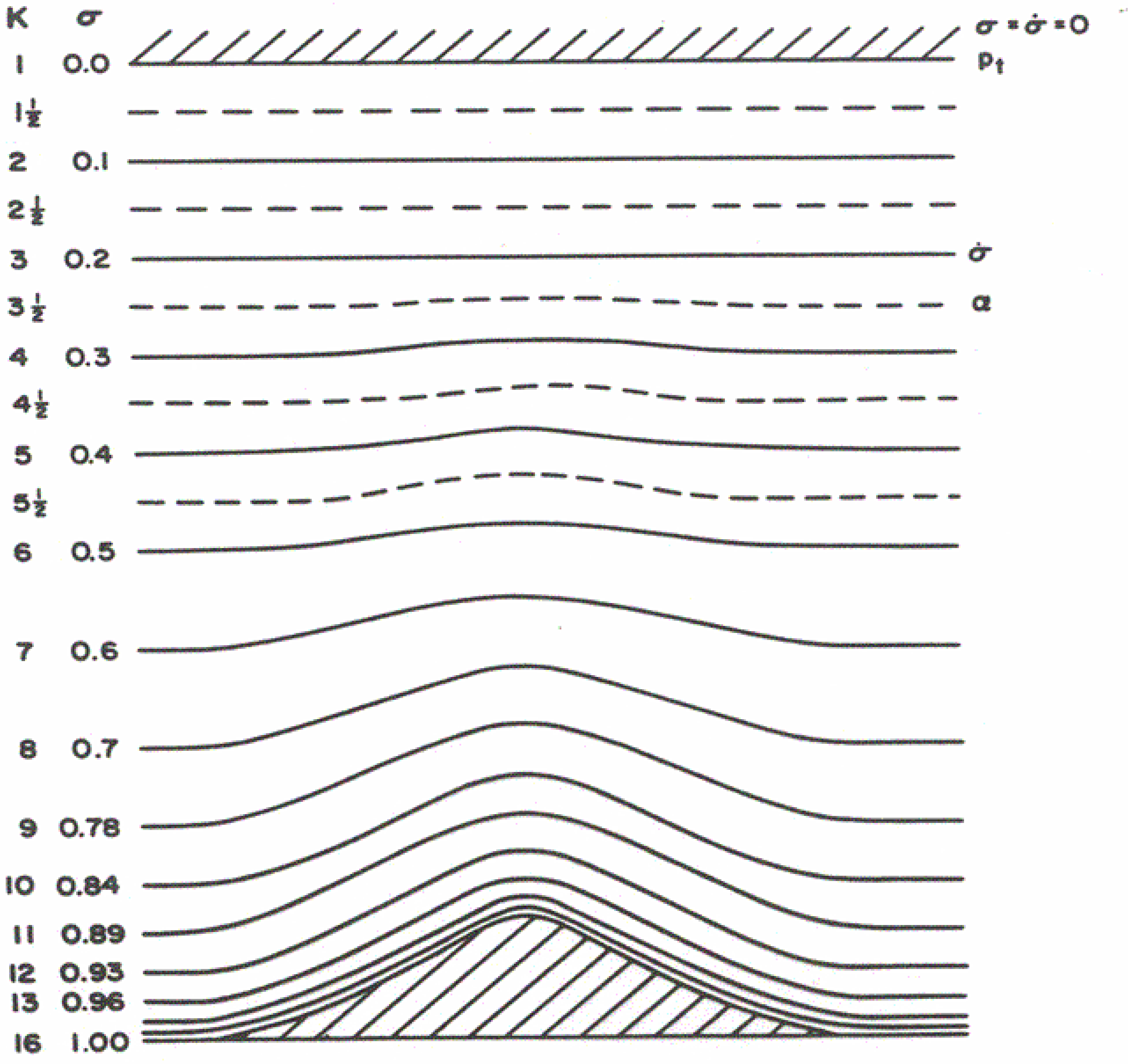
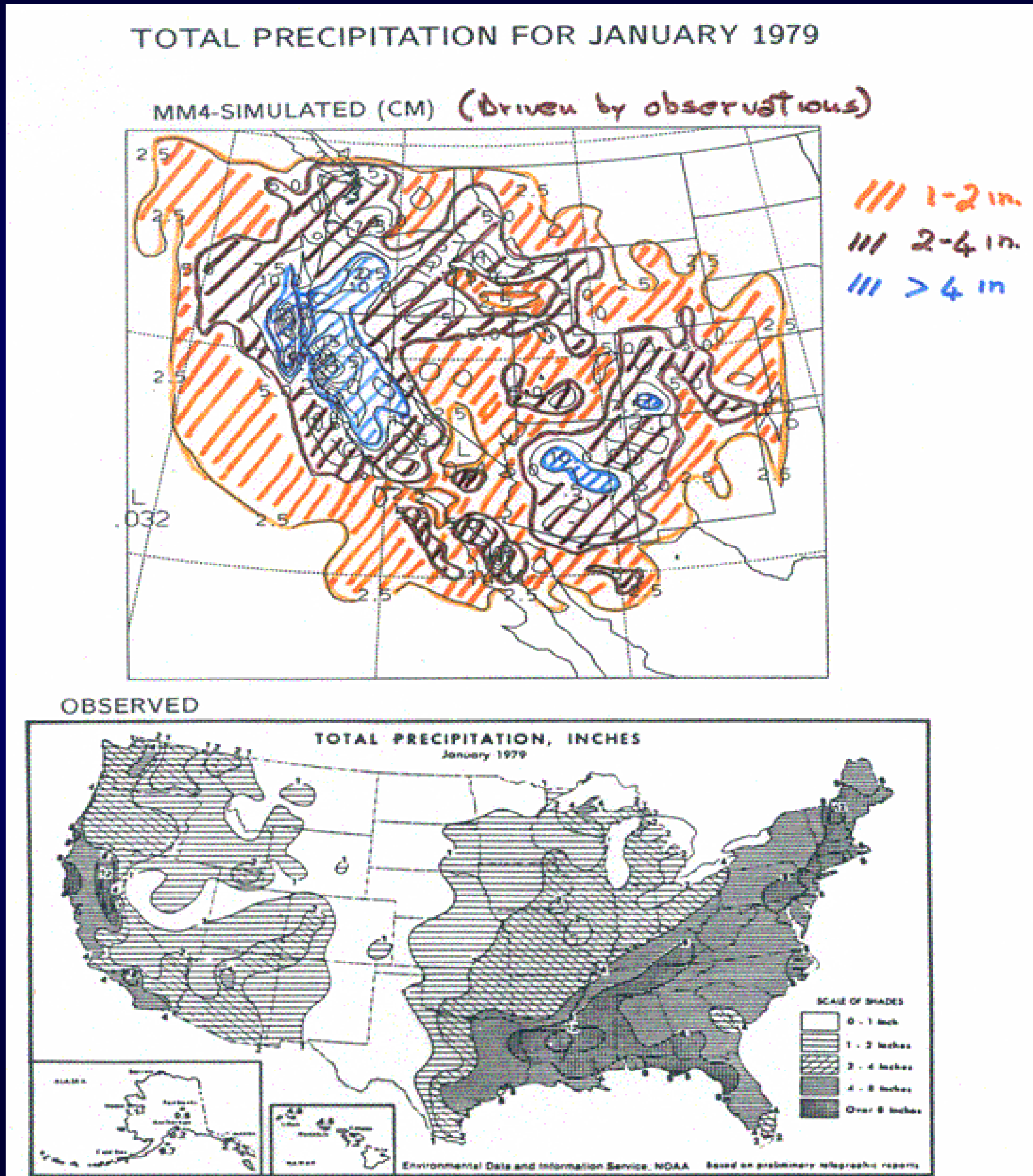
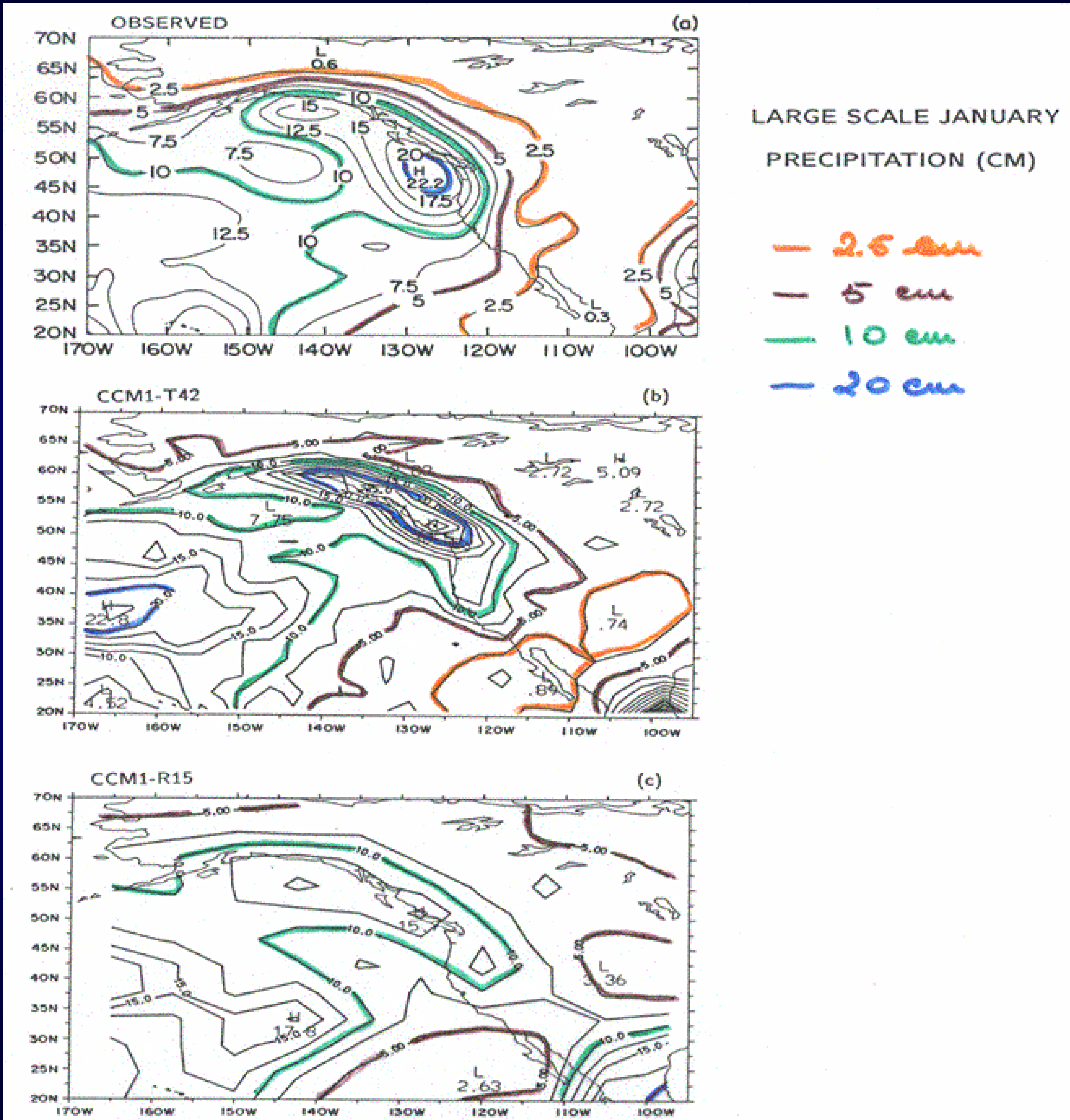


Figure 4.8 Vertical grid structure in the model. The variable $\dot{\sigma}$ is defined at the "full" model levels. All other variables, represented by α, are defined at the "half" levels.

Giorgi and Bates (1989)

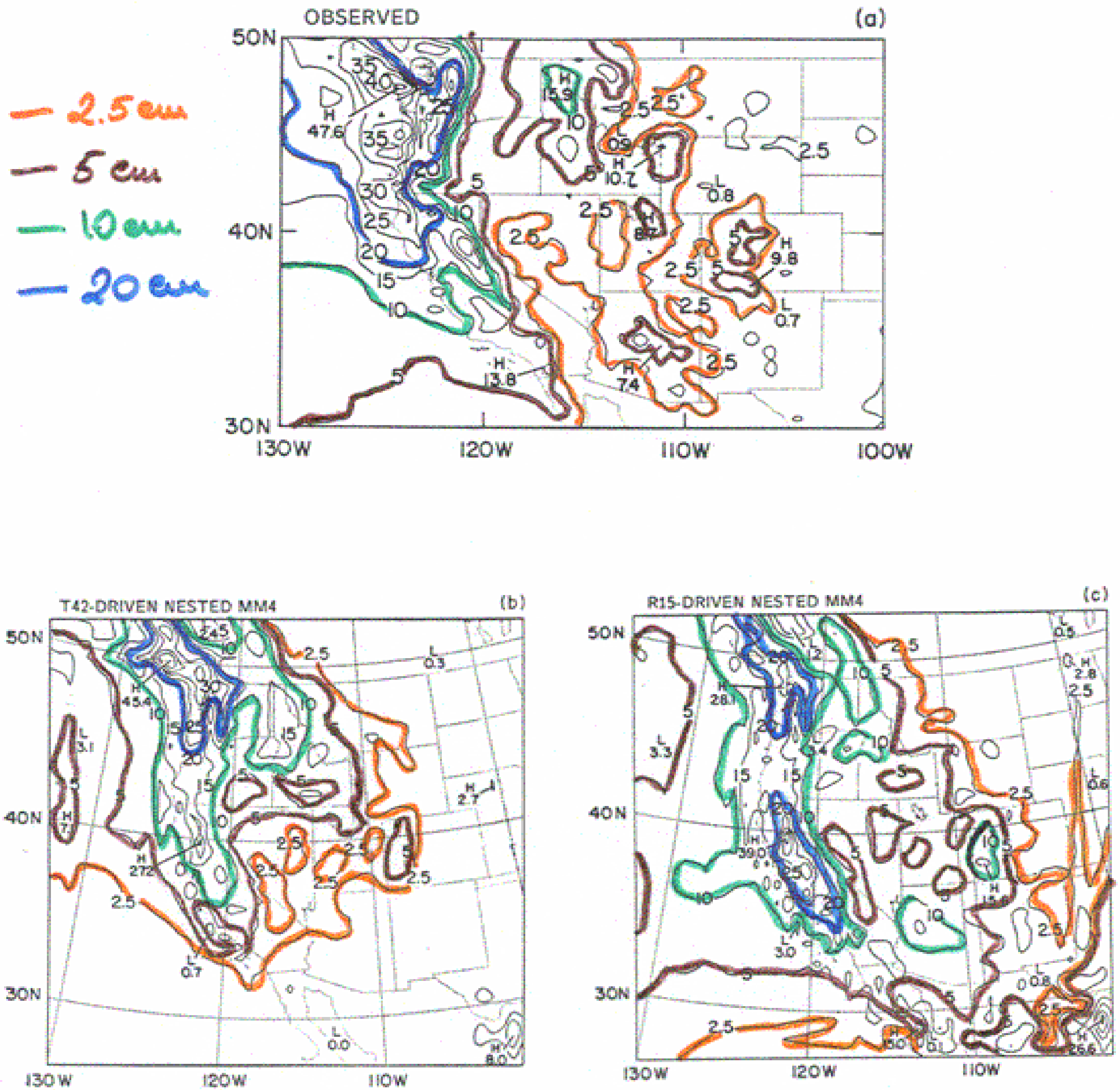




Nested regional climate simulation of the western U.S. January climate

Giorgi (1990)

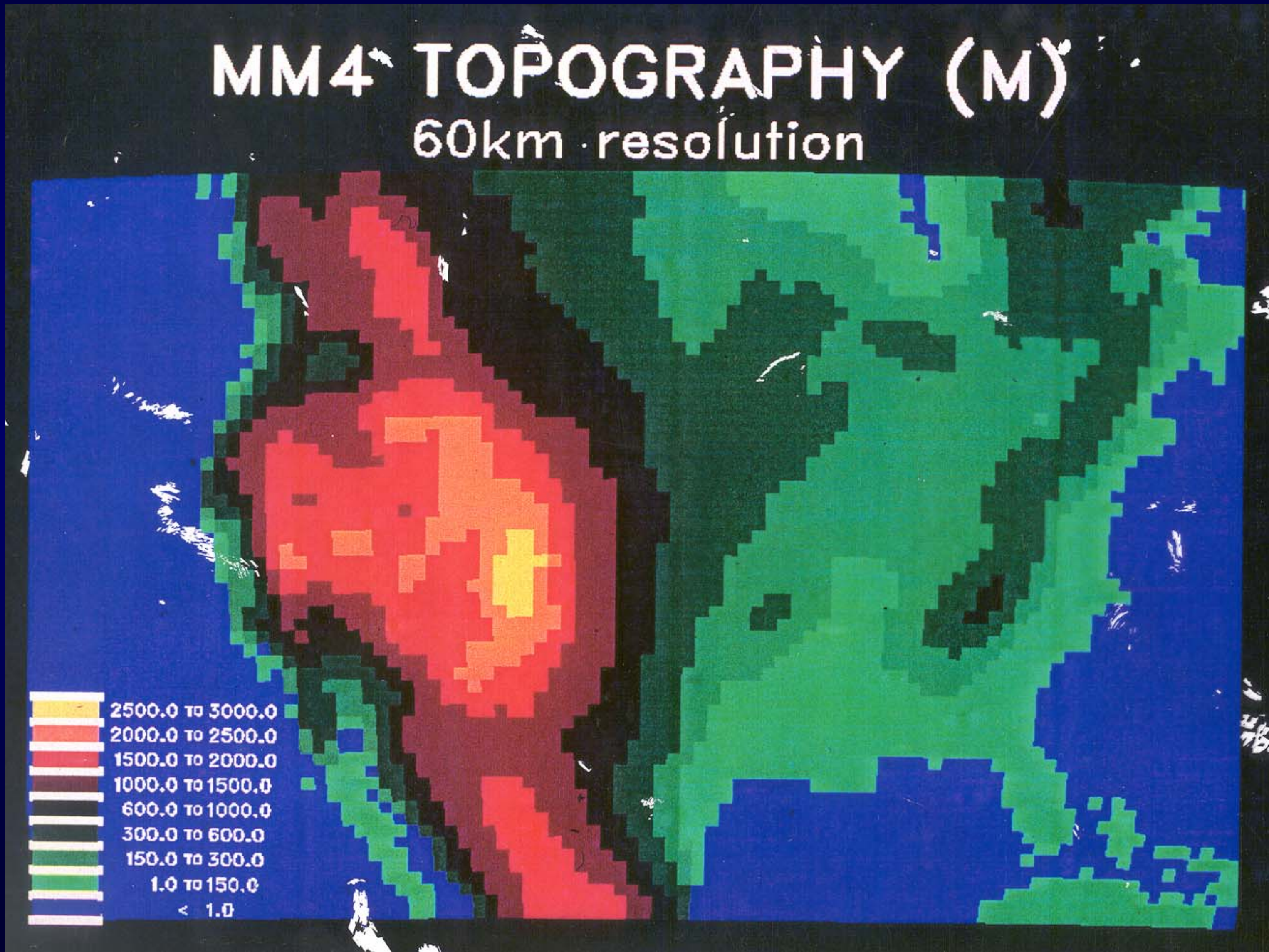
HIGH RESOLUTION JANUARY PRECIPITATION (CM)



The RegCM regional climate model system
RegCM2 (1993)

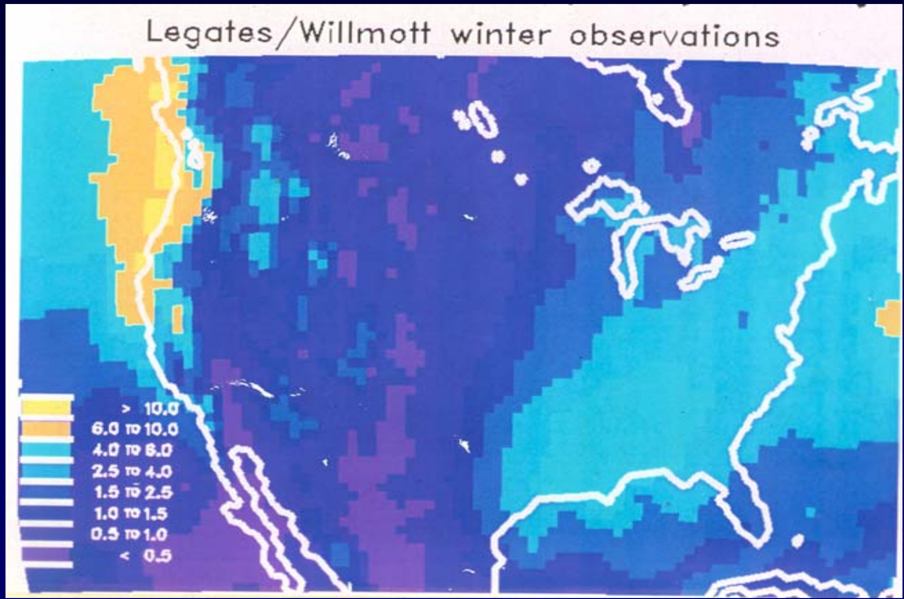
- Development
  - Giorgi et al. (1993a,b)
- General features
  - Horizontal grid spacing of 10-100 km
  - Adaptable to any region of the world
  - Driving fields from ECMWF and NCEP analyses or GCMs
- Model dynamics (based on hydrostatic mesoscale model MM5; Grell et al. 1994)
  - Sigma-p vertical coordinates; 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)

Giorgi, Shields Brodeur and Bates (1994)

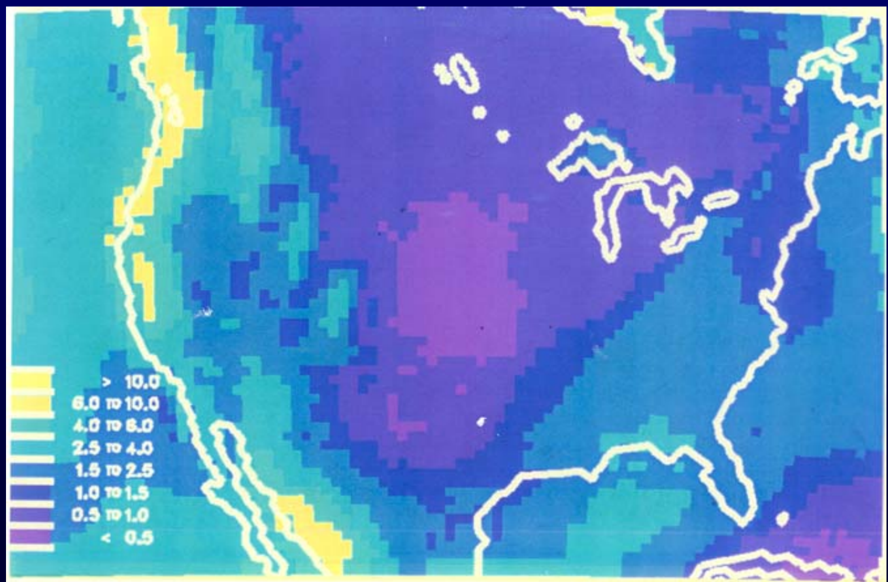


Winter Precipitation
Present Day

Observations



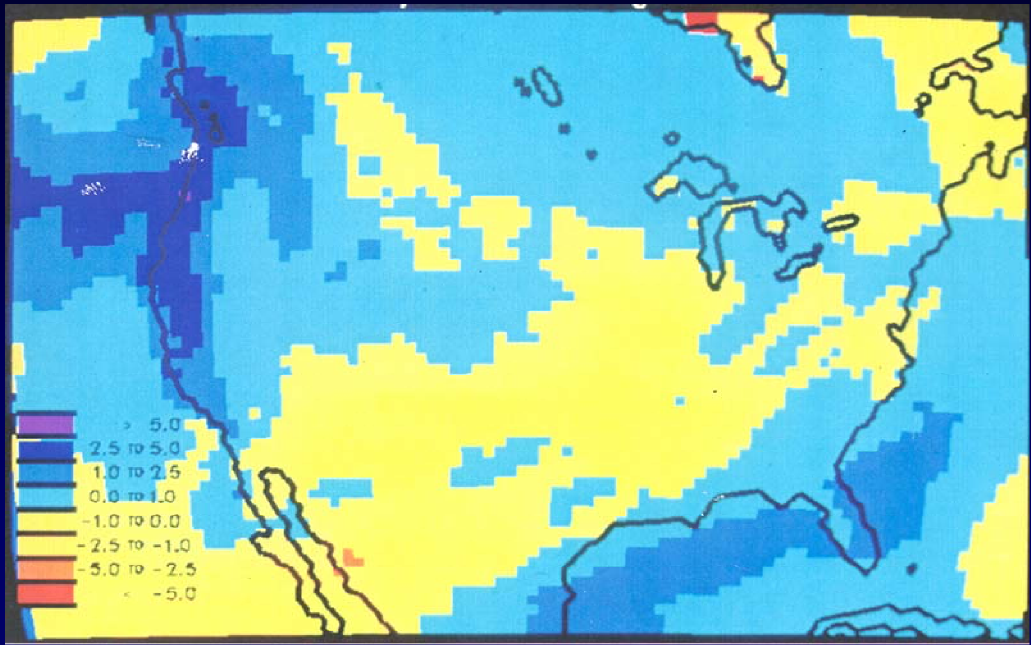
RegCM



CCM1

Winter Precipitation Change 2CO2-Control

RegCM



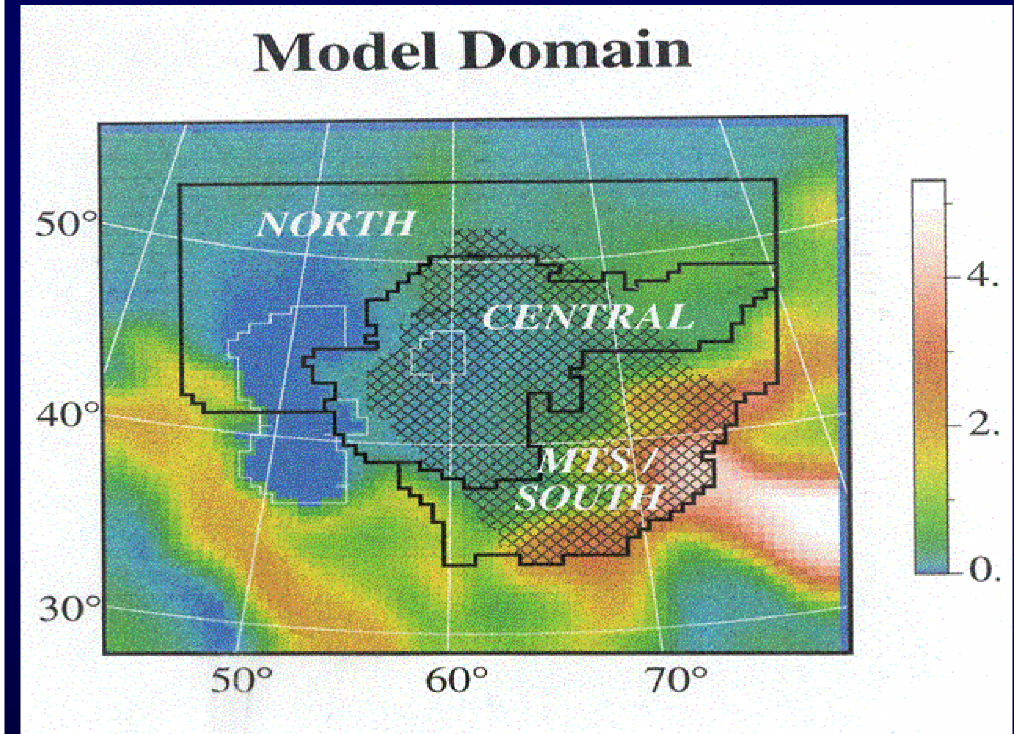
CCM1

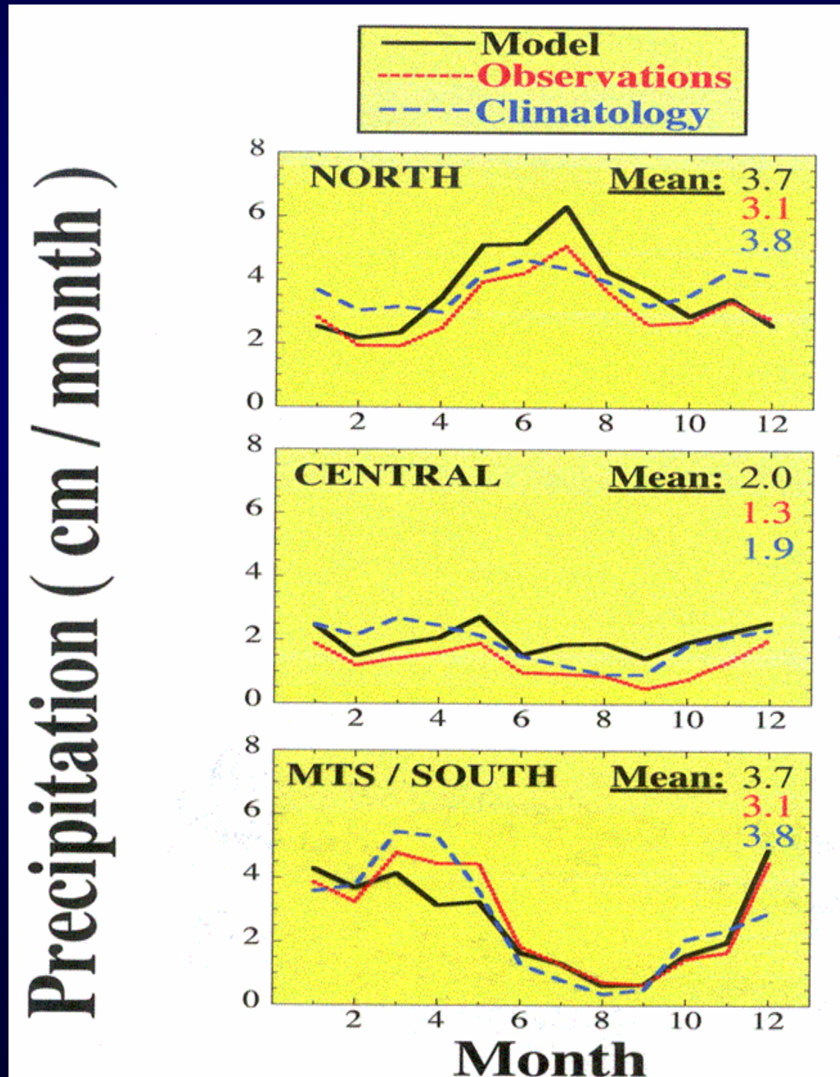
The RegCM regional climate model system
RegCM2.5 (1999)

- 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)

Small, Giorgi, Sloan, Hostetler (1999)

Five-year simulation, 1991-1995





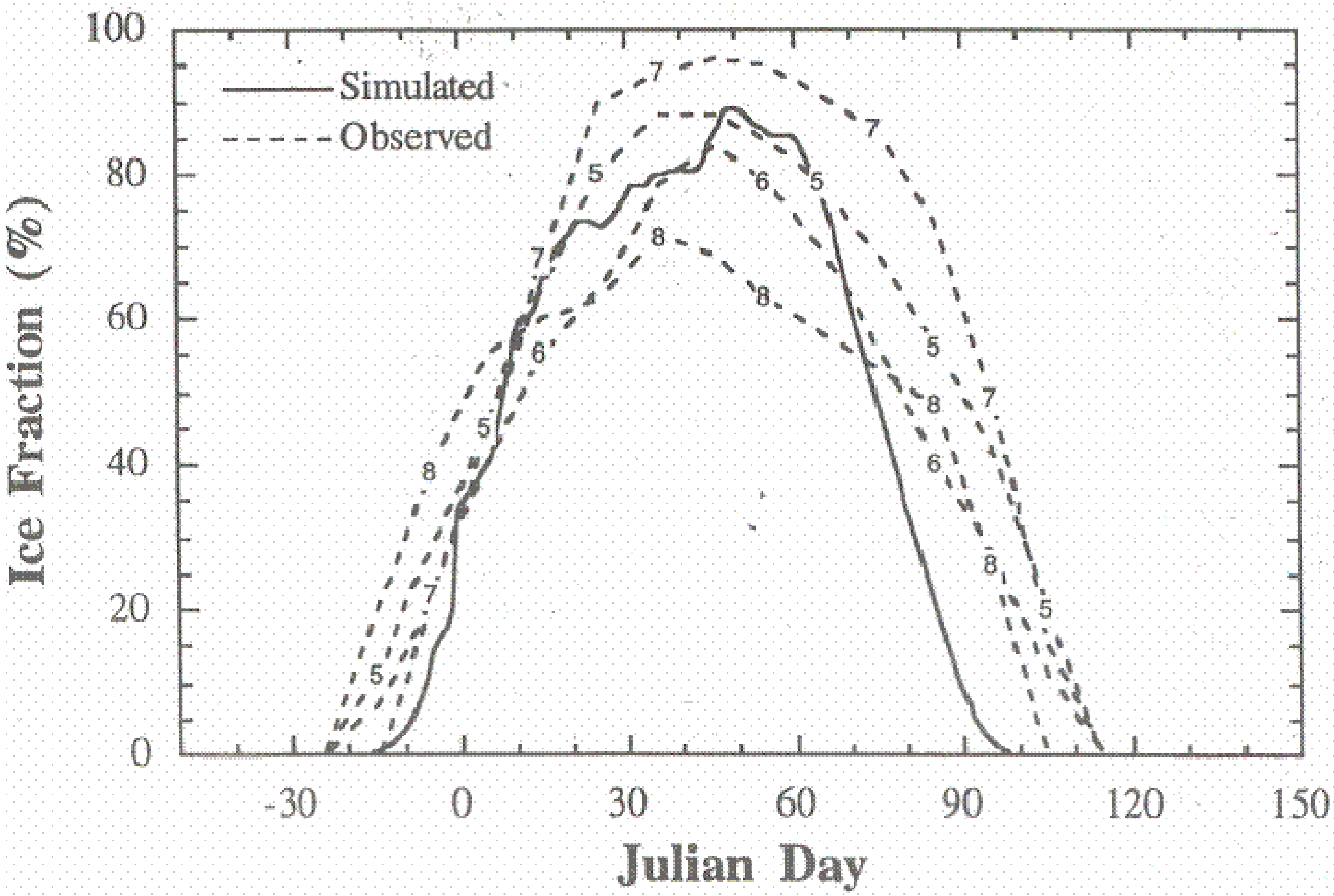
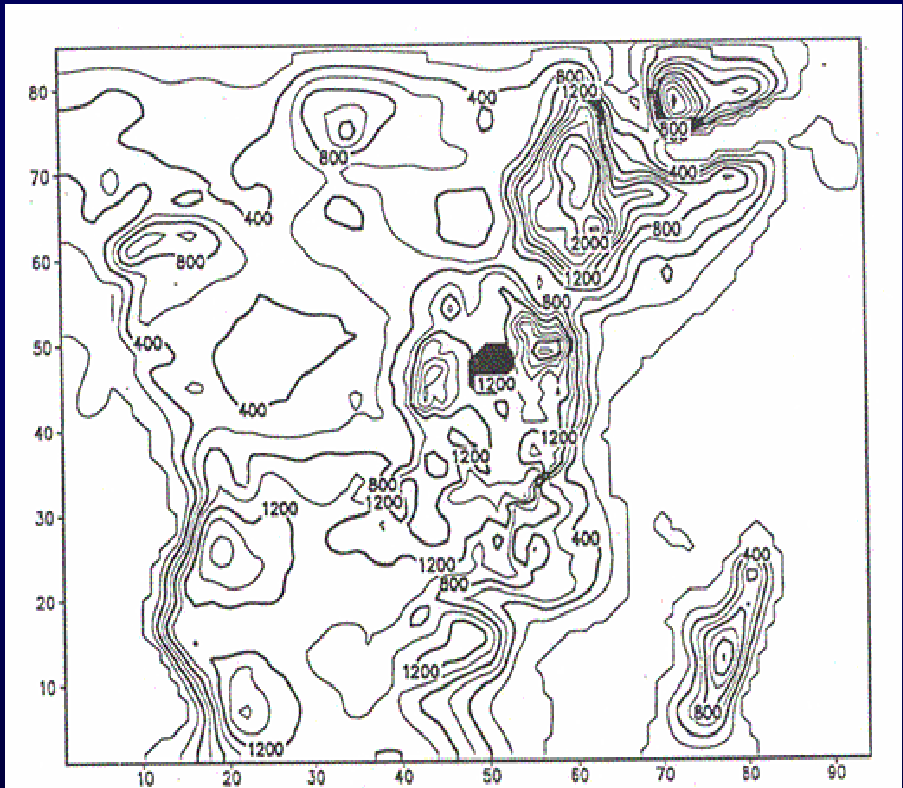
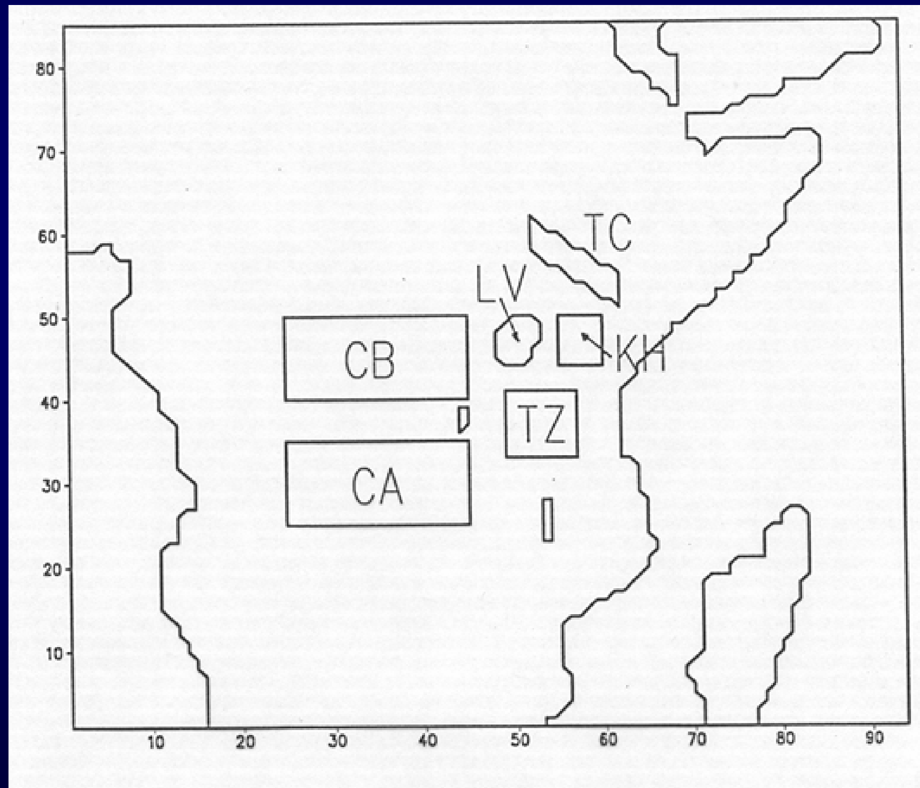
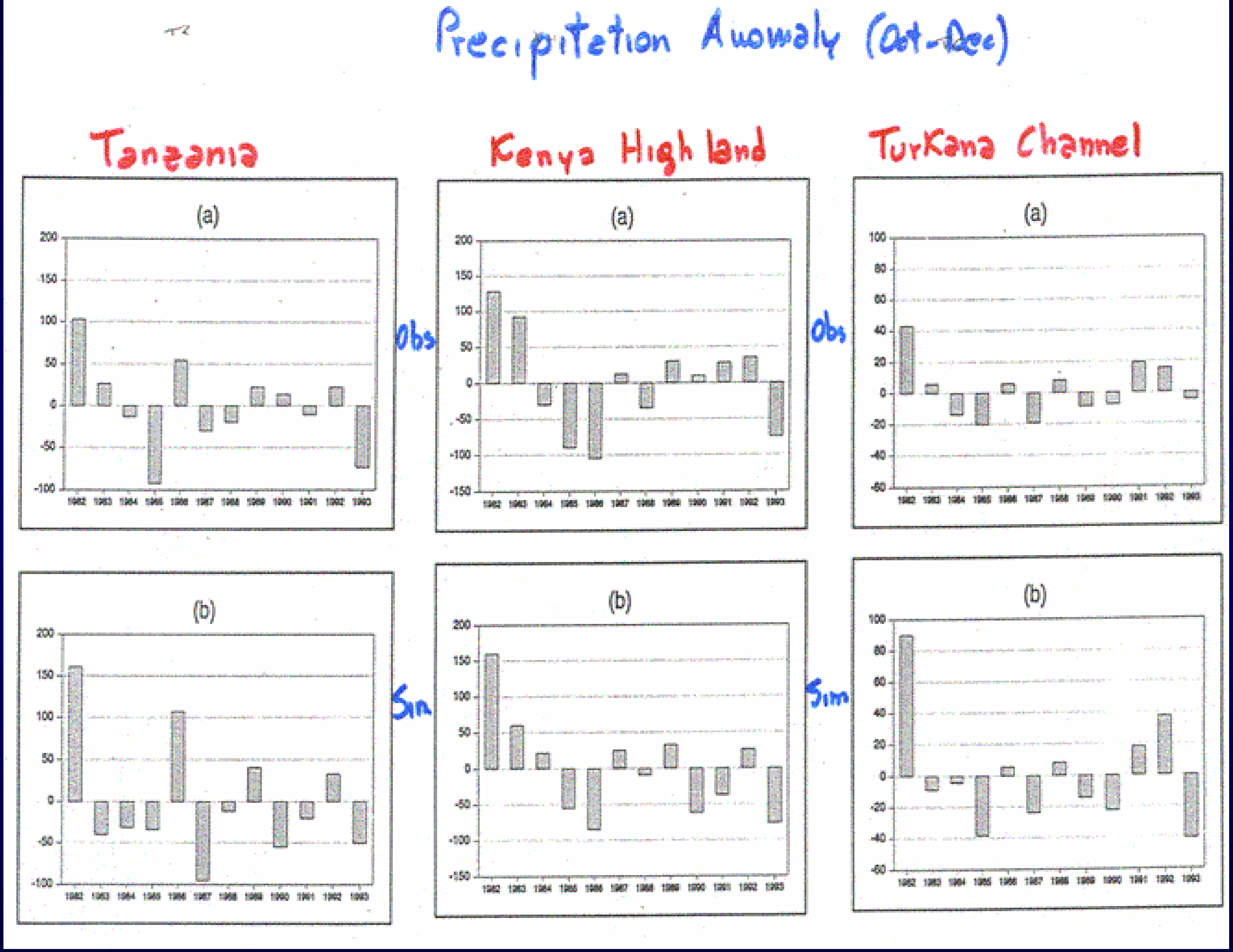


Figure 10. Simulated (solid) and observed (dashed) fraction of Aral Sea covered by lake ice, plotted by Julian day. Modeled values are averaged over period of simulation. Each observed line represents a different decadal average: 5 is 1951-1960; 6 is 1961-1970; 7 is 1971-1980; and 8 is 1981-1985.

Sun, Semazzi, Giorgi (1999)
Simulation of 10 short rain seasons







Precipitation Anomaly (Oct-Dec)
Tanzania
Kenya High land
Turkana Channel
(a)
Obs
Obs
(b)
Sim
Sim
1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993

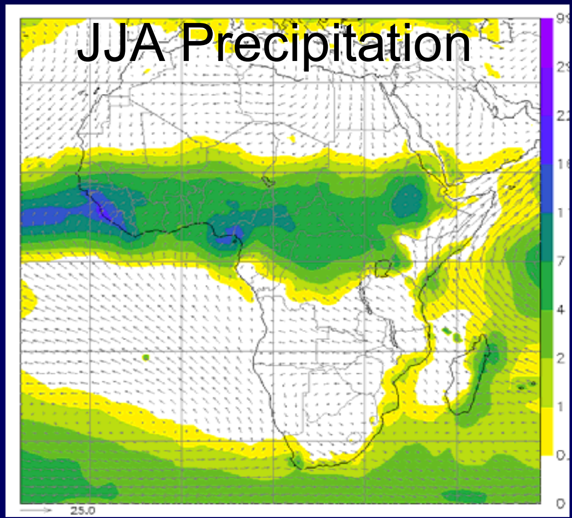
ICTP Regional Climate Model
RegCM3, Pal et al. 2007

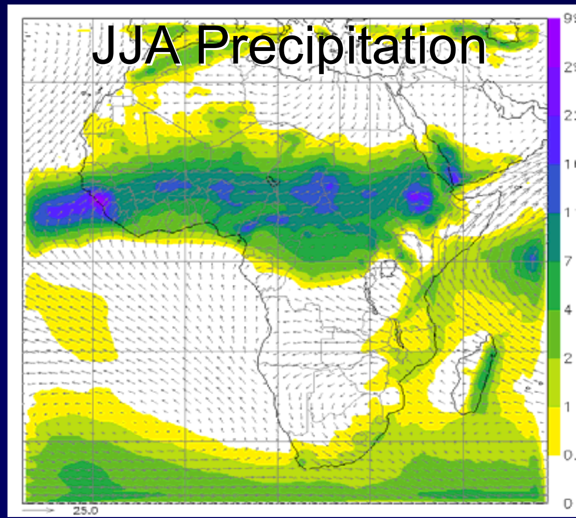
- **Dynamics:**
  MM5 Hydrostatic (Giorgi et al. 1993a,b)
- **Radiation:**
  CCM3 (Kiehl 1996)
- **Large-Scale Clouds & Precipitaion:**
  SUBEX (Pal et al 2000)
- **Cumulus convection:**
  Grell (1993)
  Anthes-Kuo (1977)
  MIT (Emanuel 1991)
- **Boundary Layer:**
  Non-local, Holtslag (1990)
- **Tracers/Aerosols:**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

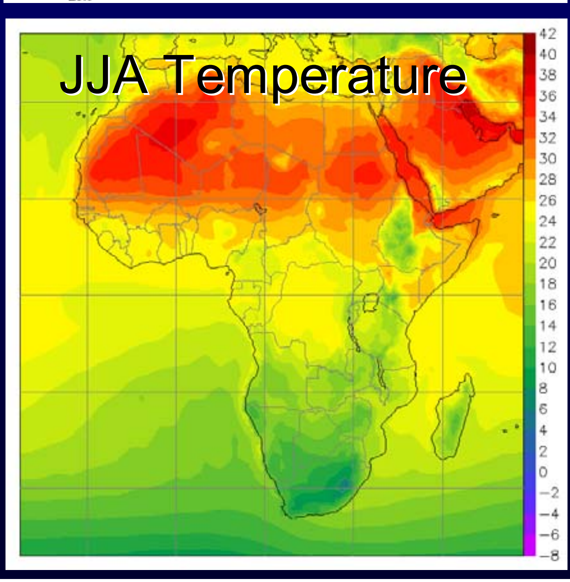
RegCM3, ERA40 LBC (1987-2000)
Pal et al. (2007)

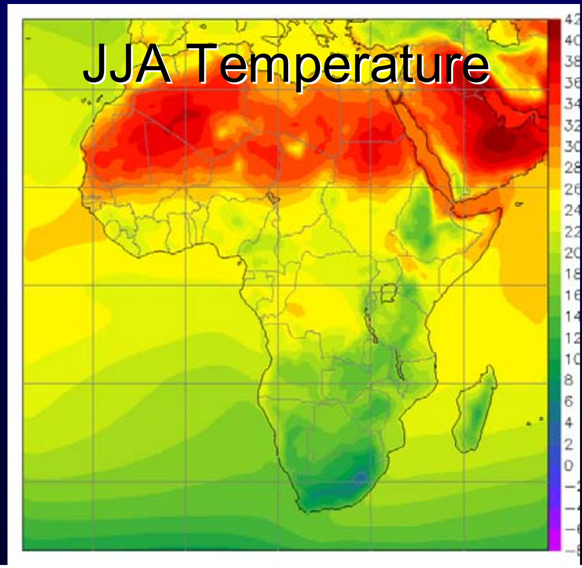
Observations

RegCM3



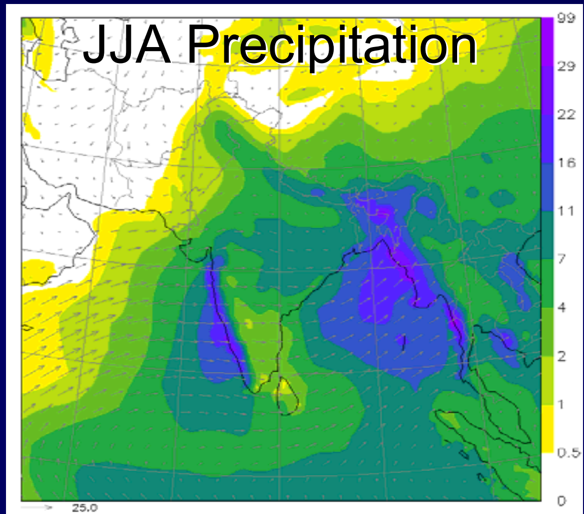


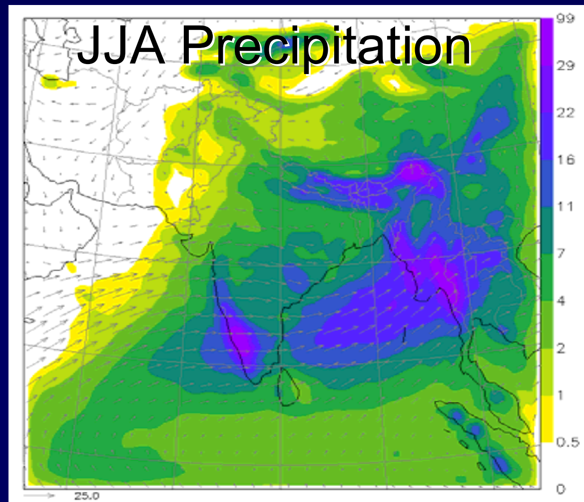


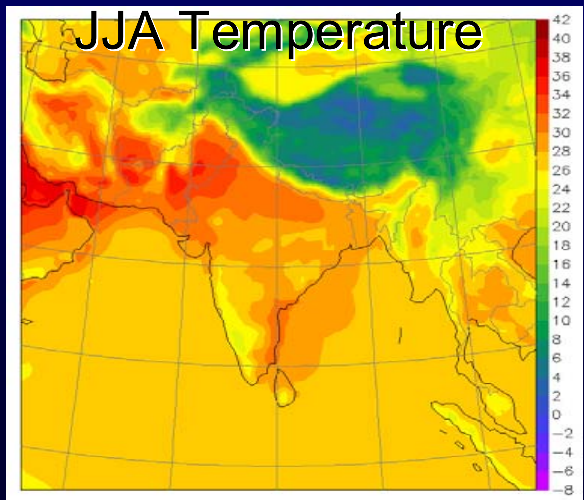


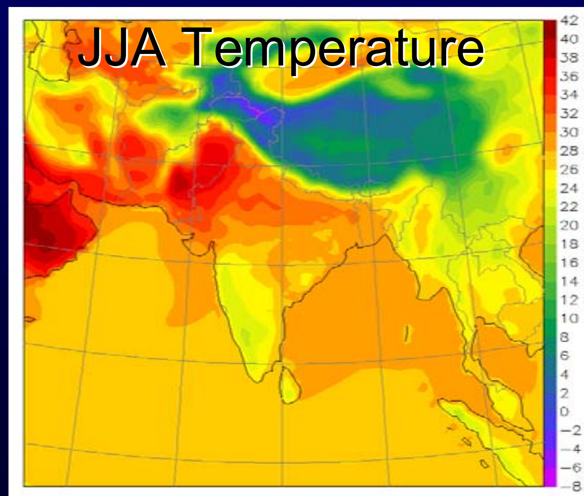
RegCM3, ERA40 LBC (1987-2000)
Pal et al. (2007)

Observations | RegCM3



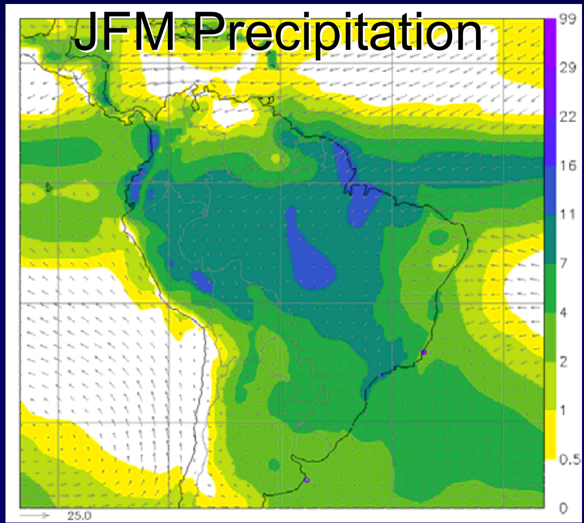


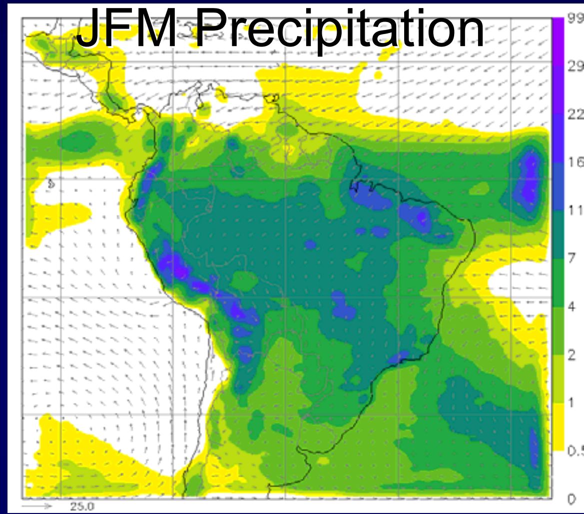


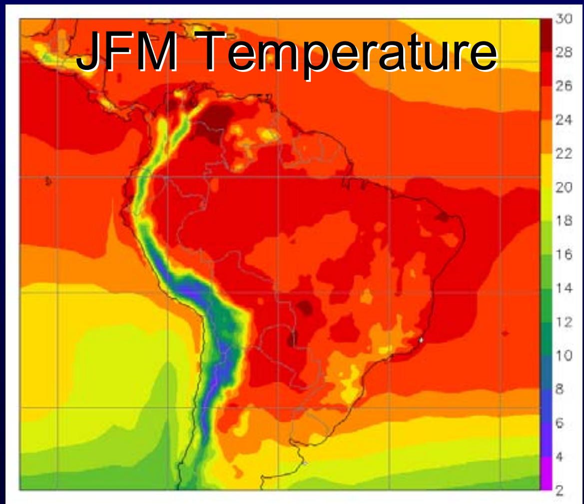


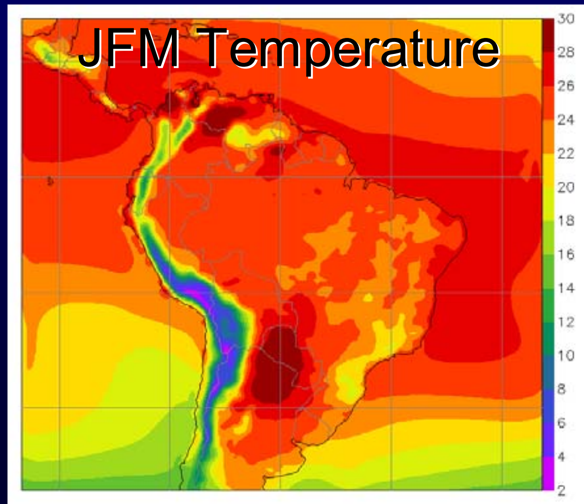
RegCM3 ERA40-LBC (1987-2000)
Pal et al. (2007)

Observations	RegCM3

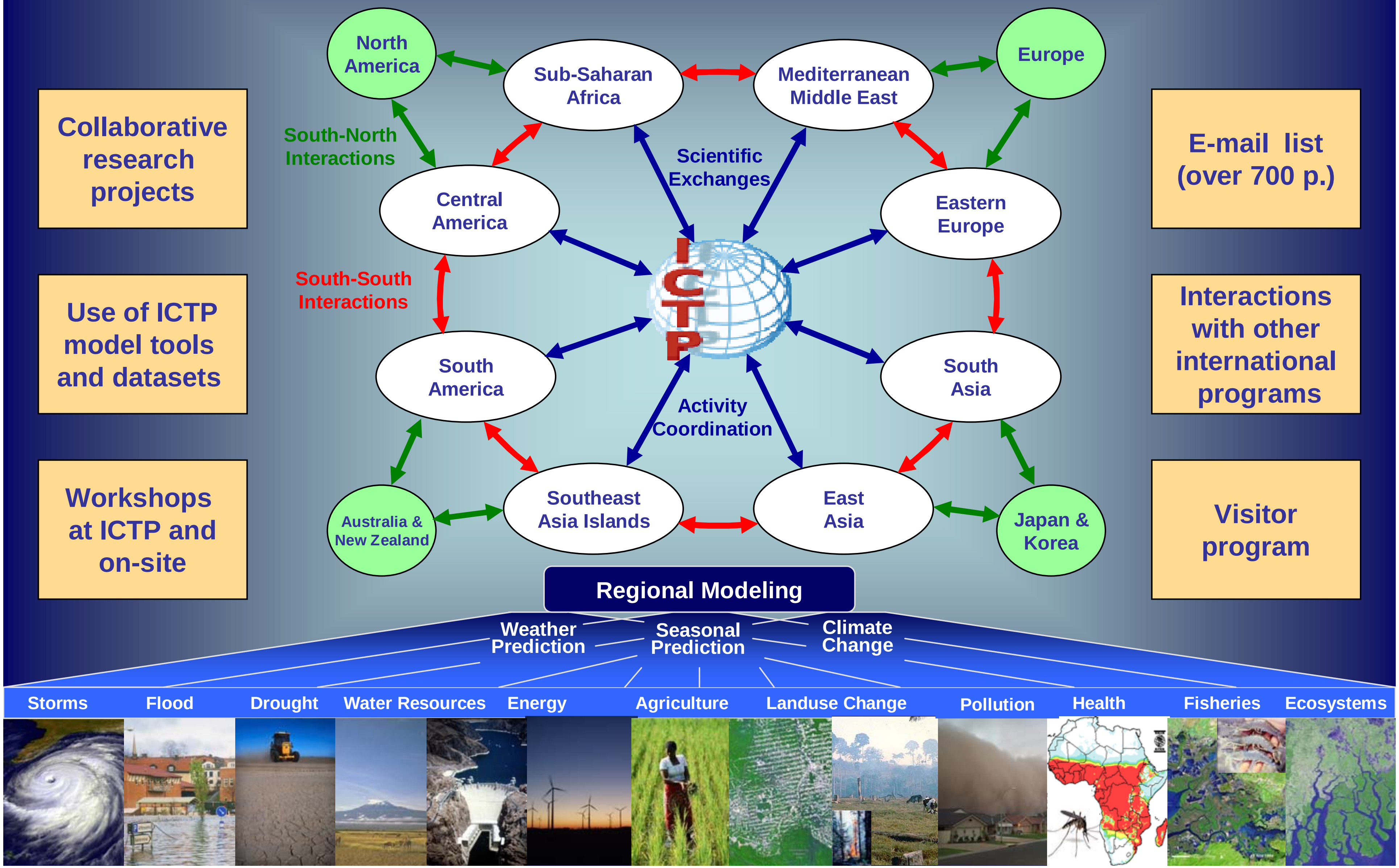




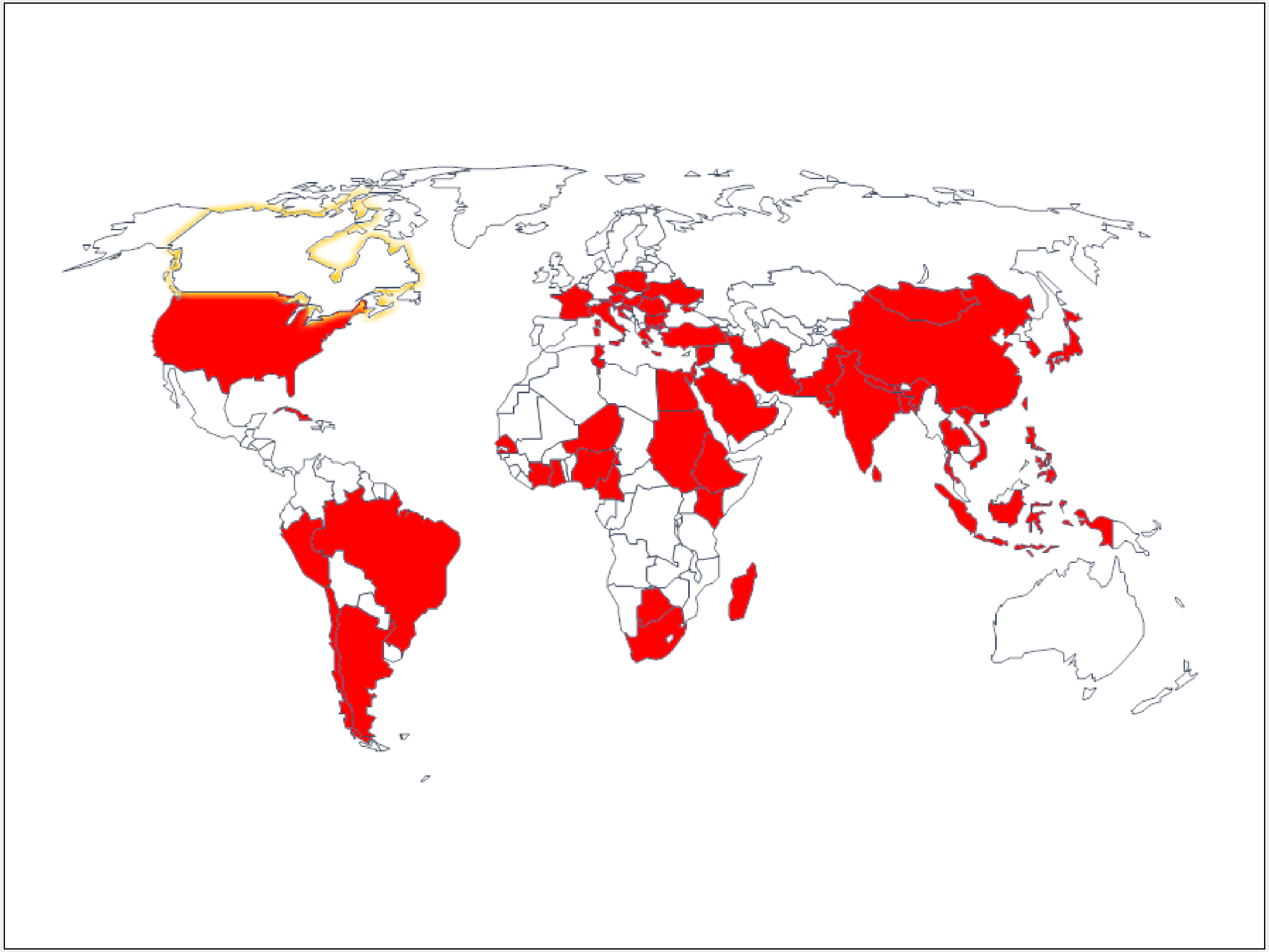




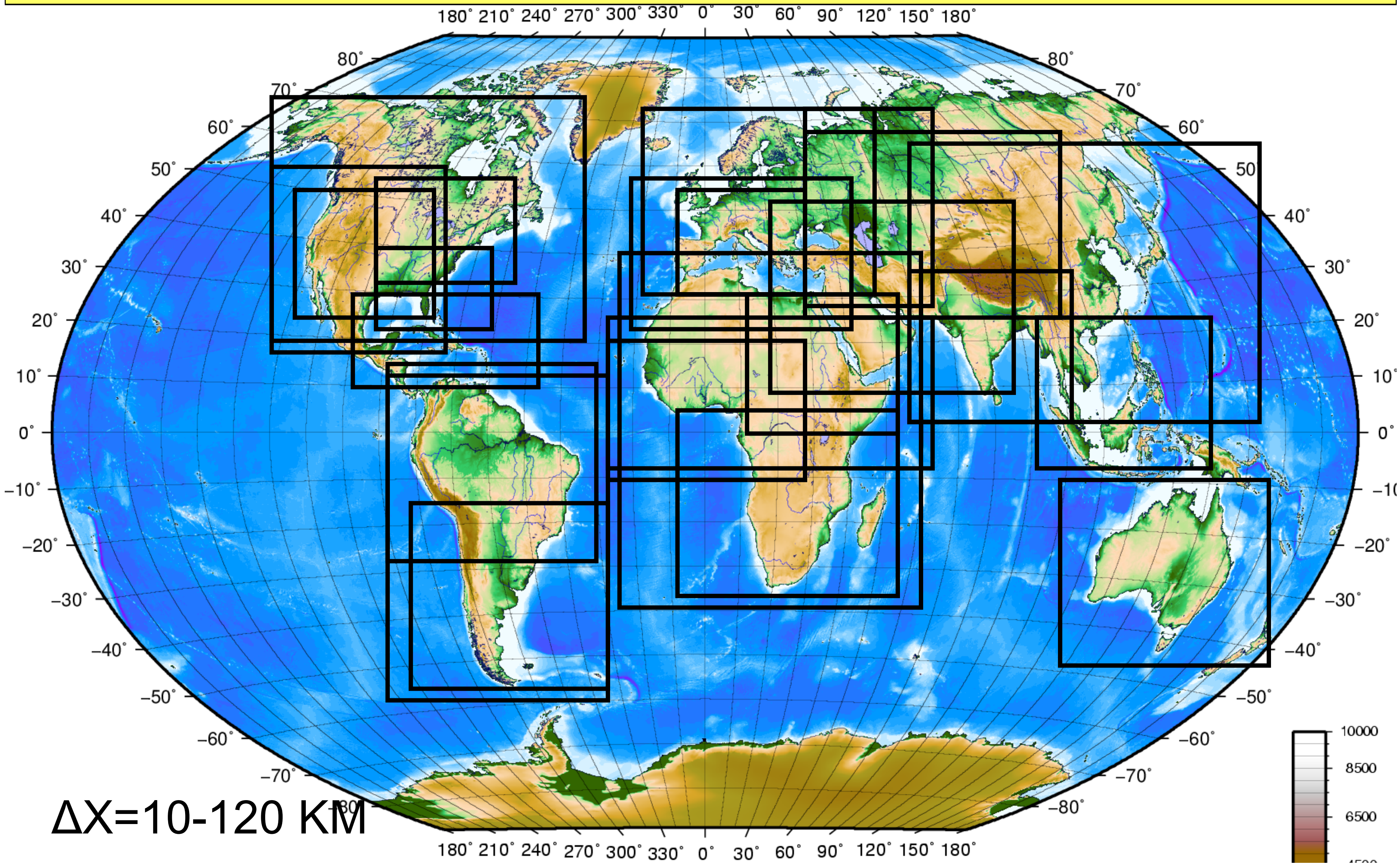
The ESP RegCM and Regional Climate research NETwork, RegCNET



Countries where RegCM is used



Sample of RegCM domains used

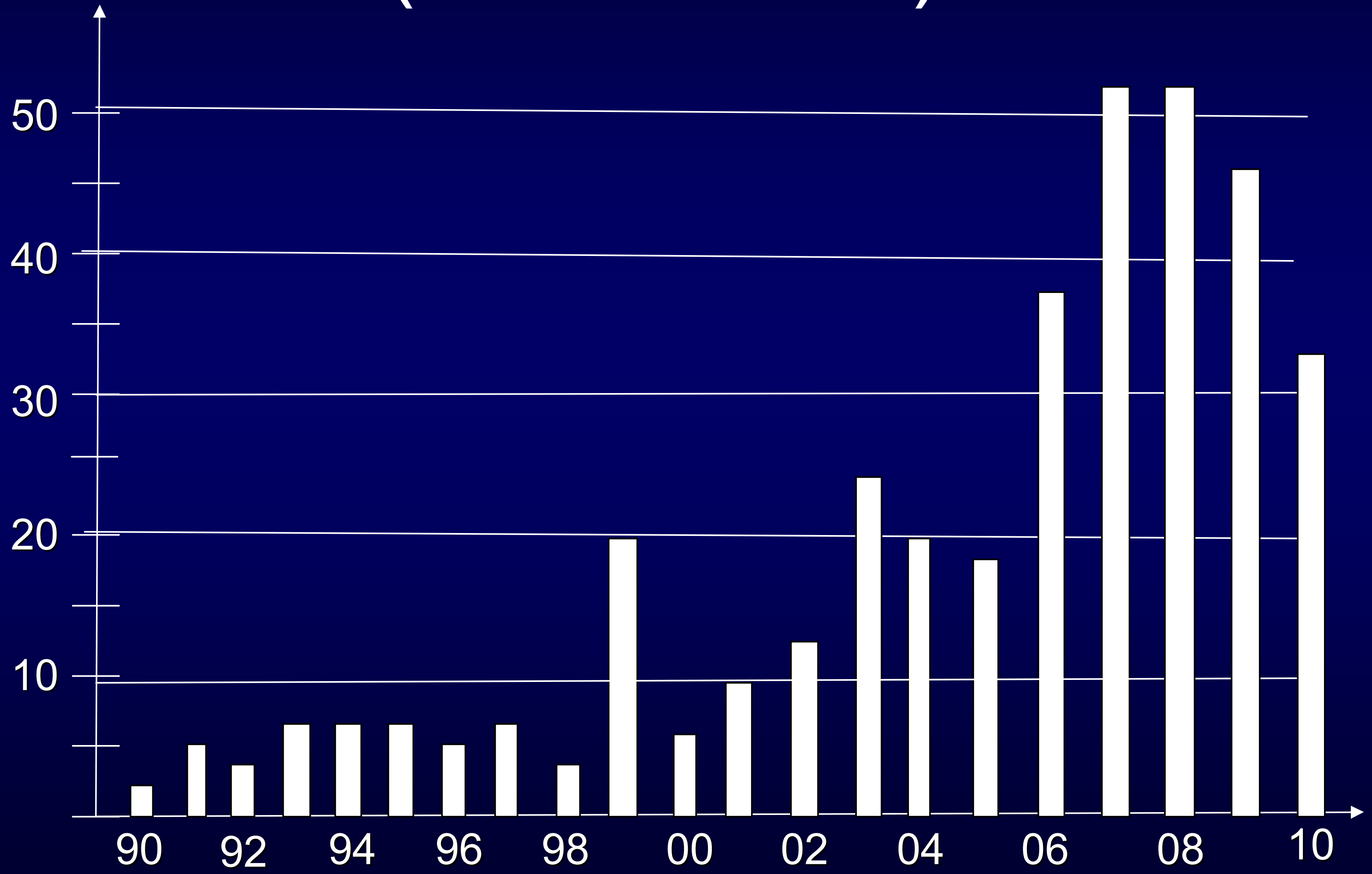


ΔX=10-120 KM

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)

Number of papers using RegCM (from the ISI)



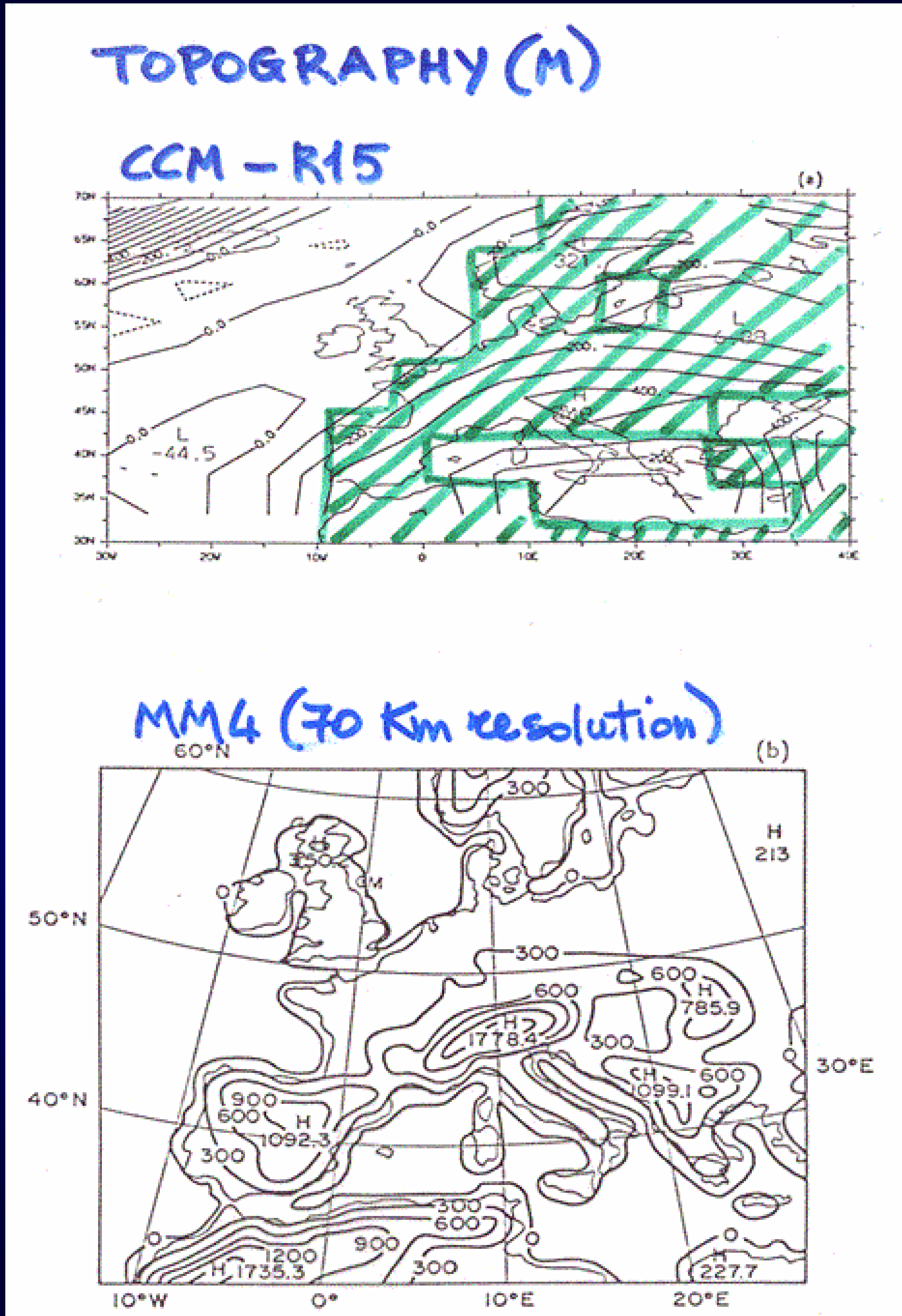
The RegCM regional climate model system
Towards RegCM4

- Documentation
  – Special issue planned in 2010/11, to be discussed here.
- Dynamics essentially unchanged, but …
  – Semi–lagrangian advection in the make (Tefera-Diro)
  – Work towards non-hydrostatic dynamical core started (RegCM5?) (Tumolo-Bonaventura)
- New Physics
  – CLM (Tawfik, Steiner et al.)
  – Diurnal SST scheme (Solmon, Elguindi)
  – Plans to include Tiedtke scheme, improved cloud microphysics and UW PBL scheme (Elguindi, O'Brien)
- Other features
  – Simple aerosol scheme (implemented, Zakey, Solmon)
  – Coupled ocean model ROMS (available in some versions but to be implemented in public RegCM4, Ratnam, Kaginalkar et al.)
  – Gas-phase chemistry schemes (available in some versions but to be implemented in public RegCM4; Zakey, Shalaby et al.)
- Code structure, including pre and post-processors substantially changed to enter the 21st century (Cozzini, Giuliani, Coppola et al.)

My thanks to the people who helped to develop the RegCM4

- X. Bi (ICTP)
- E. Coppola (ICTP)
- S. Cozzini (SISSA)
- N. Elguindi (ICTP)
- G. Giuliani (U. L'Aquila / IMET)
- A. Kaginalkar (CDAC, India)
- L. Mariotti (ICTP)
- A. Messina (ICTP)
- T. O'Brien (UCSC)
- V. Ratnam (CDAC, India)
- M. Scarcia (SISSA)
- F. Solmon (ICTP)
- B. Sylla (ICTP)
- A. Shalaby (Cairo U.)
- A. Steiner (U. Michigan)
- F. Stordal (U. Oslo)
- A. Tawfik (U. Michigan)
- G. Tefera-Diro (ICTP)
- A. Zakey (ICTP/DMI)


THANK YOU

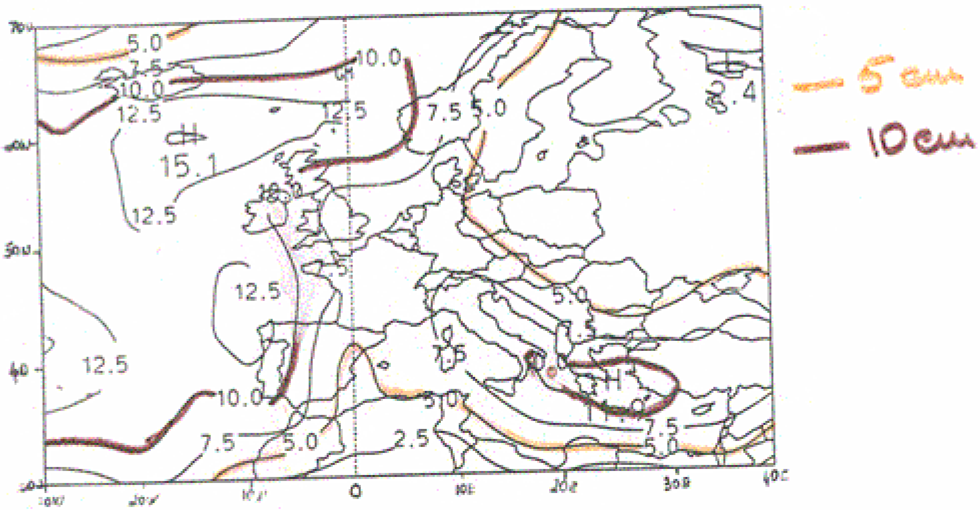


Nested regional climate simulation of the European January climate

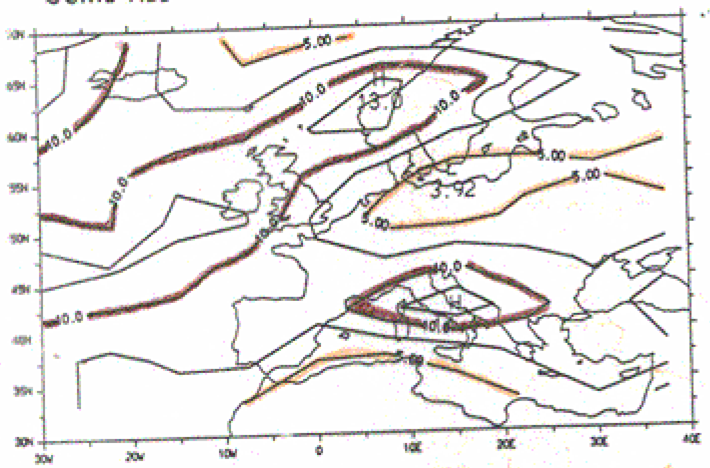
Giorgi, Marinucci, and Visconti (1990)

AVERAGE JANUARY PRECIPITATION (CM)

OBSERVED (2.5°× 2.5° LAT.-LON.)

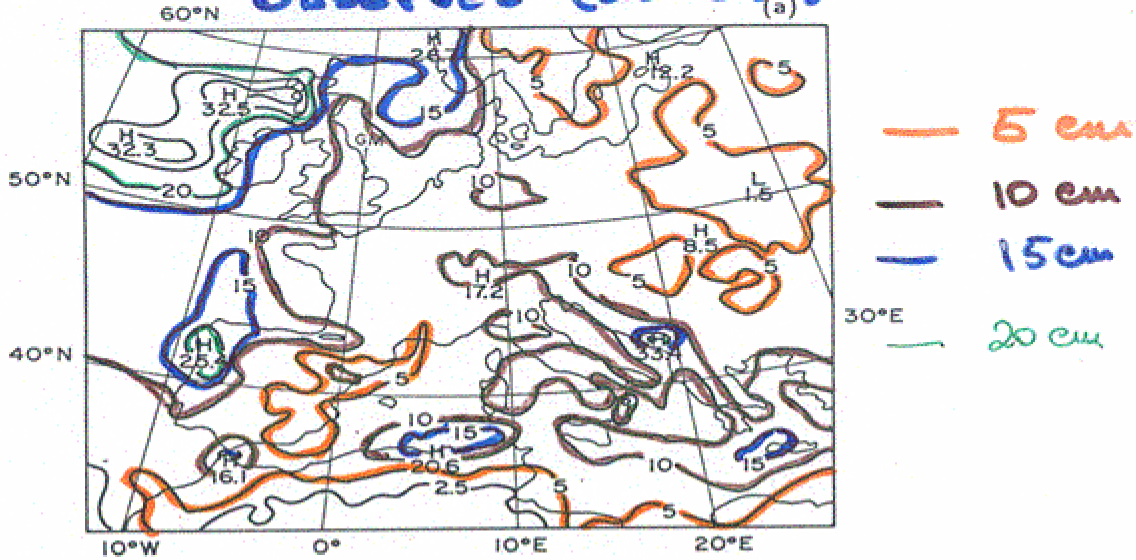


CCM1-R15

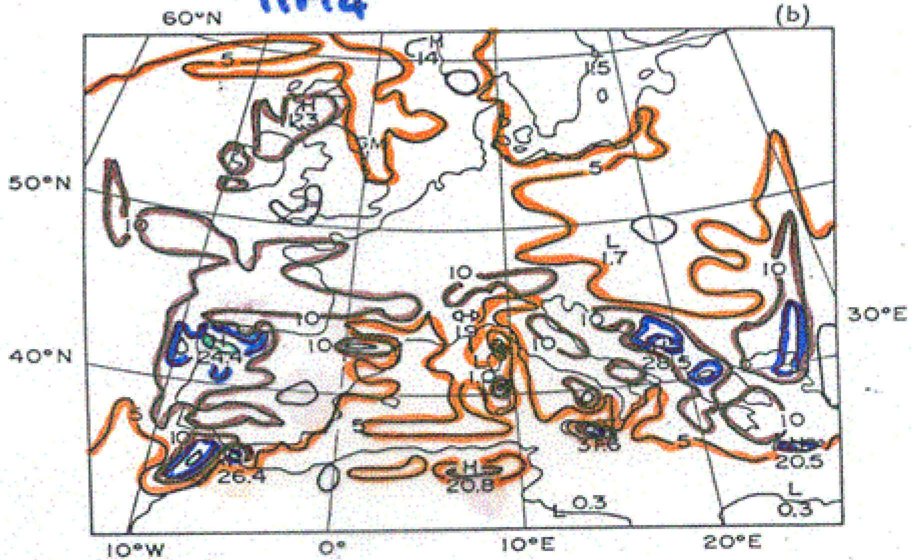


Average January Precipitation (cm)

Observed (0.5°x0.5°)



MM4



Hostetler, Giorgi, Bates, Bartlein (1994)

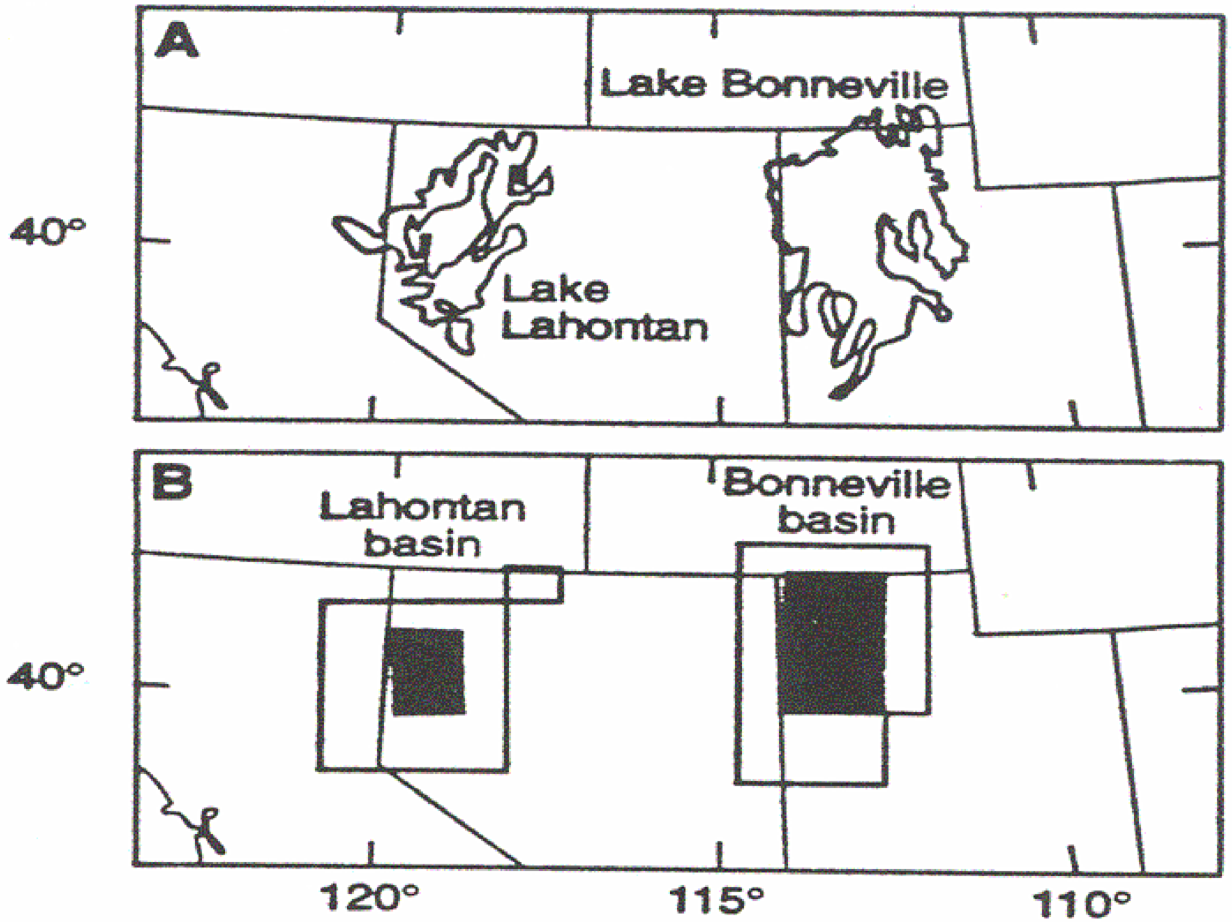
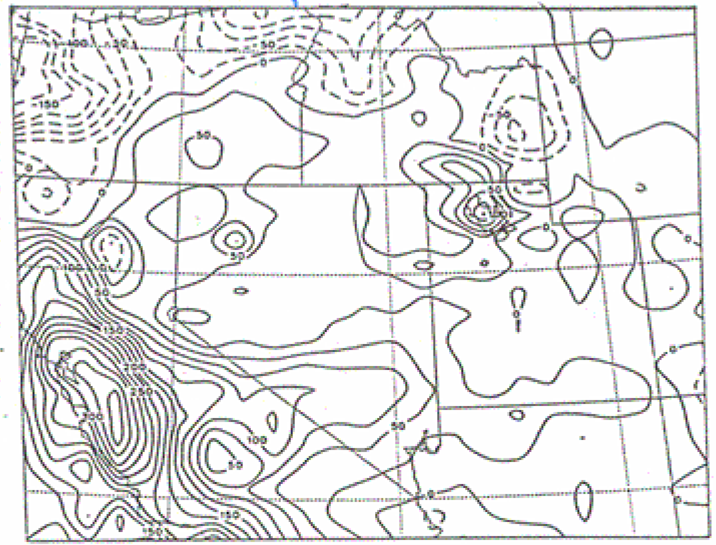


Fig. 1. (**A**) Locations and sizes of lakes Lahontan and Bonneville. Lake extents are for maximum lake sizes. (**B**) Model representation of the 18-ka lake surface areas and the lake basins.

January Precipitation
18K Bp - Present



January Temperature
18KBP - present