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1934-38

Fourth ICTP Workshop on the Theory and Use of Regional Climate Models: Applying RCMs to Developing Nations in Support of Climate Change Assessment and Extended-Range Prediction

3 - 14 March 2008

A review of RCM projects over Africa and suggestions for future coordinated efforts for Regional Climate Simulations over Africa

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Review of Multi-model RCM Projects: Recommendations for a Coordinated RCM Program in Africa & Beyond

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Iowa State University

Ames, Iowa, USA

(with thanks to R. Arritt, J. Christensen, Filppo Giorgi, B. Hewitson, E. Takle & Yongkang Xue)

Outline

1. Early Comparison Projects
2. Current Programs
3. Some African Activities
4. Recommendations for an Integrated Global Program + African Factors

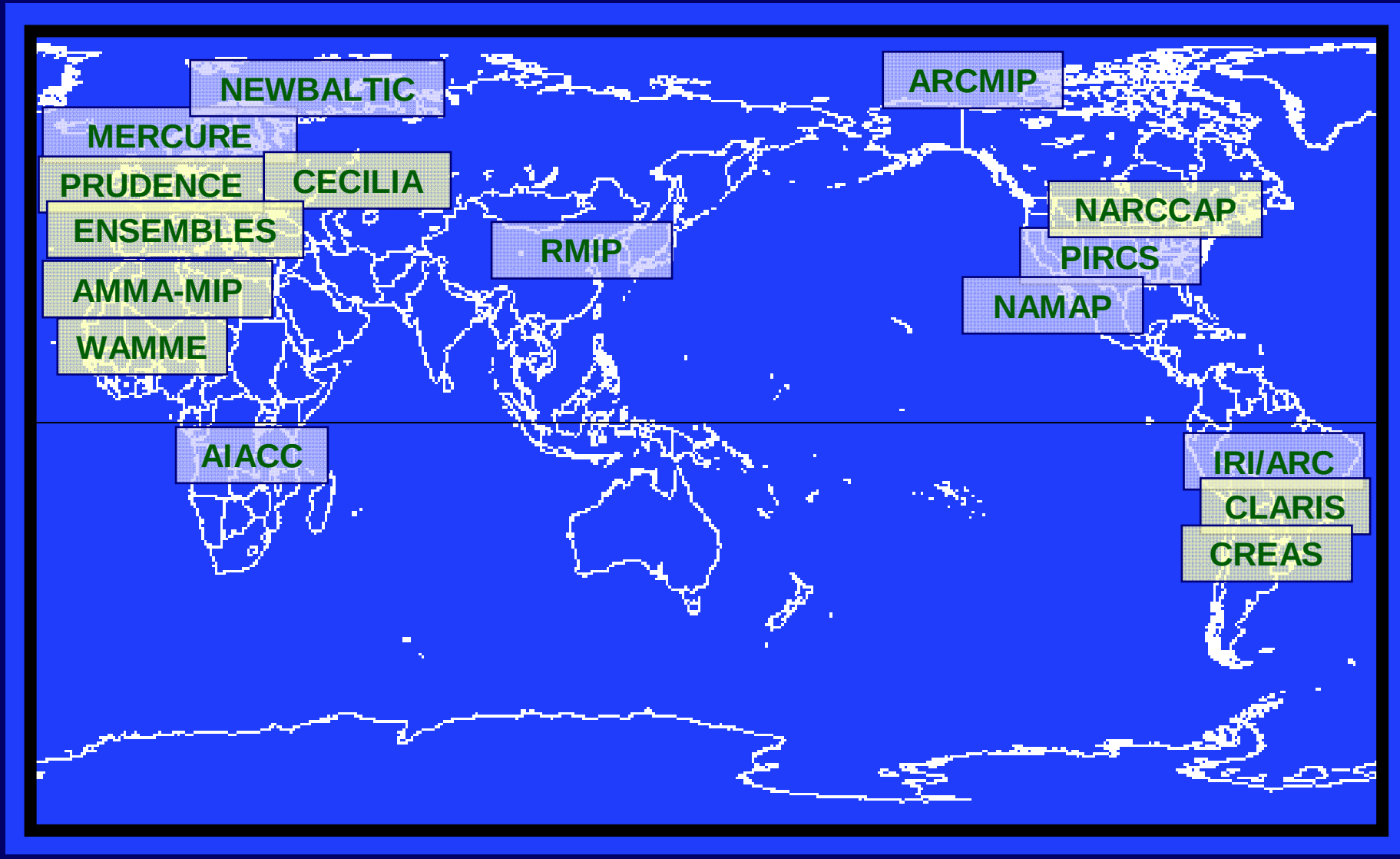
Regional Multi-Model Projects

- PIRCS (Takle et al. 1999; Anderson et al. 2003)
- NEWBALTIC I and II (Graham and Bergström 2000; Jacob et al. 2001)
- PRUDENCE (Christensen et al. 2002, 2005; Déqué et al. 2005)
- IRI/ARC (Roads et al. 2003)
- ARCMIP (Tjernström et al. 2005, Rinke et al. 2006)
- NAMAP (Gutzler et al. 2005)
- RMIP (Fu et al. 2005)
- ENSEMBLES (Hewitt and Griggs 2007)
- NARCCAP (Mearns et al. 2005)

Plus

AIACC	AMMA-MIP	CECILIA
CLARIS	CREAS	GLIMPSE
PLATIN	QUIRCS	SGMIP
WAMME	… … …	

Multi-Model Project Locations



Regional Multi-Model Projects

Early projects:

- Do these models work?
- Side-by-side simulations vs. observations
- Limited time periods (computing power, fine resolution observations)

PIRCS Participating Modelers

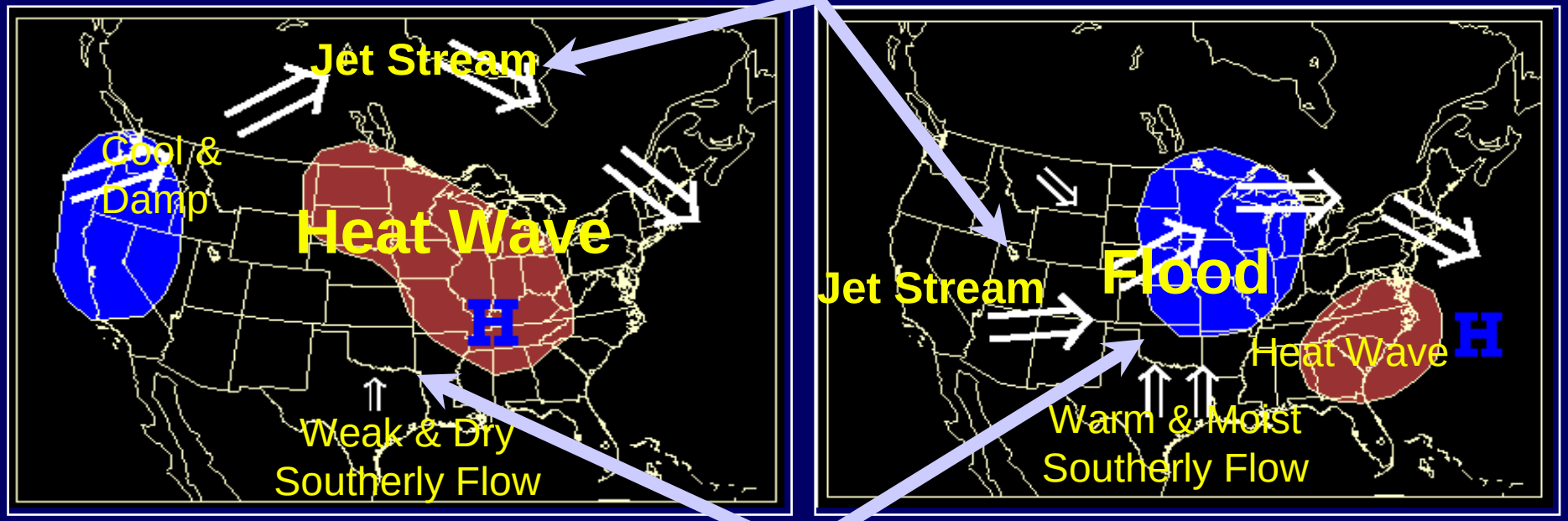
- Danish Met. Inst. (HIRHAM; J.H. Christensen, O.B. Christensen)
- Université du Québec à Montréal (CRCM; D. Caya, S. Biner)
- Scripps Institution of Oceanography (RSM; J. Roads, S. Chen)
- U.S. Nat. Centers Env. Pred. (RSM; S.-Y. Hong)
- NASA - Marshall (MM5-BATS; W. Lapenta)
- Argonne National Lab (MM5-ANL; J. Taylor)
- CSIRO (DARLAM; J. McGregor, J. Katzfey)
- Colorado State University (ClimRAMS; G. Liston, R. Pielke)
- Iowa State University (RegCM2; Z. Pan)
- Swiss Fed. Inst. Tech. (EM; D. Lüthi)
- SMHI / Rossby Centre (SweCLIM; C. Jones)
- Universidad de Castilla-La Mancha (PROMES; M. Gaertner)

PIRCS Experiment 1

Experiment 1a
1988 drought

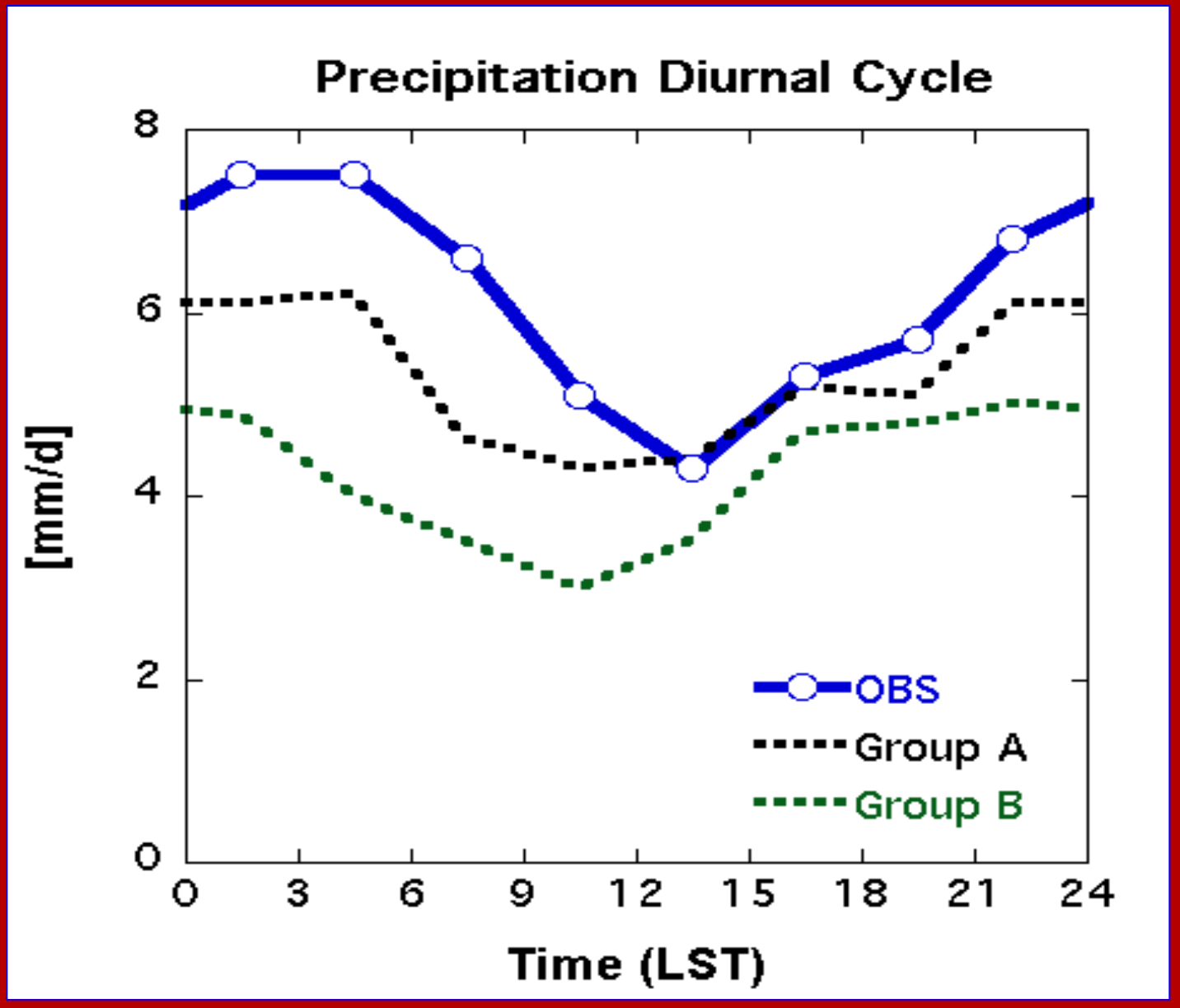
Experiment 1b
1993 flood

Remote Influences



Nocturnal Low-Level Jet

PIRCS Diurnal Cycle

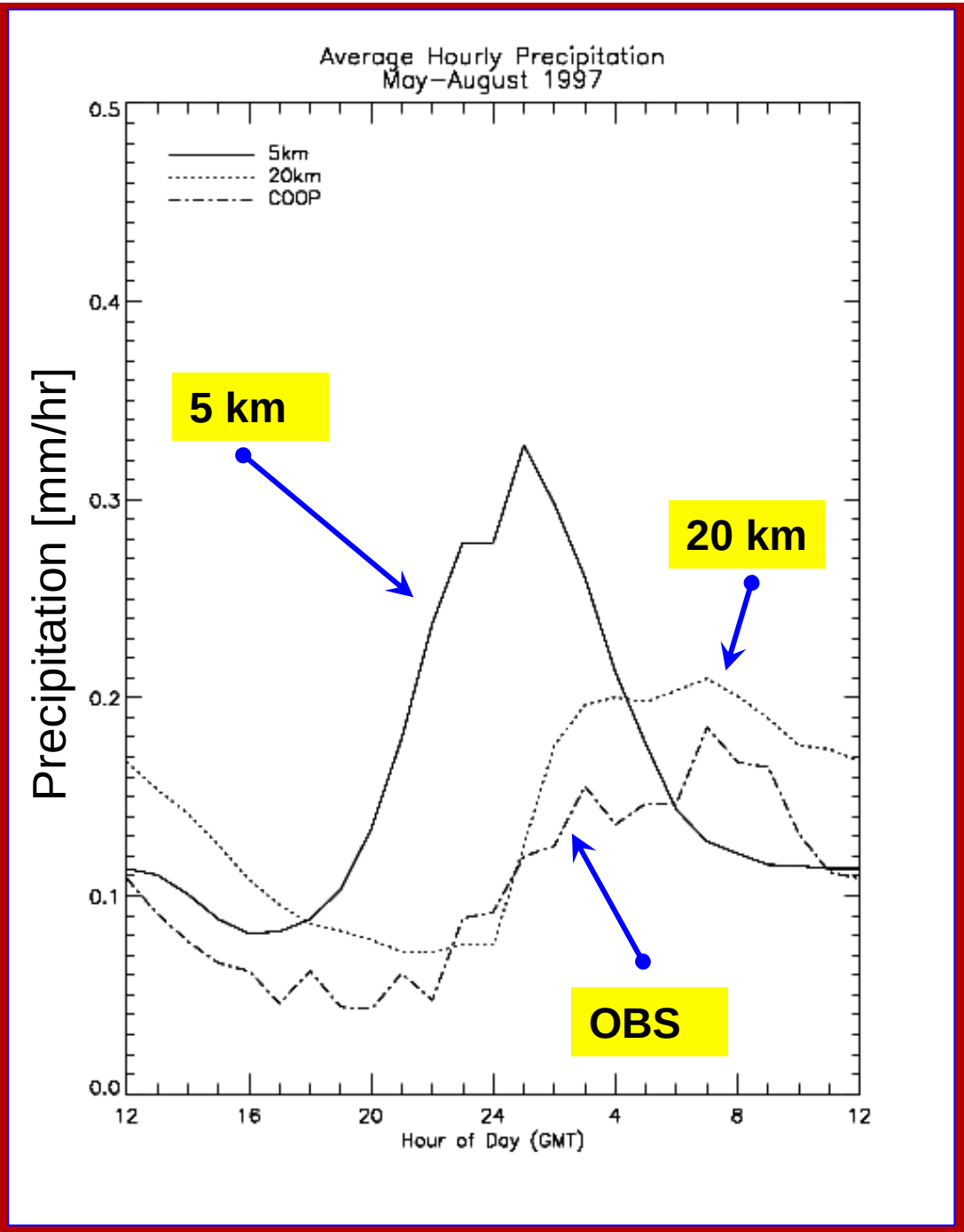


North-Central U.S.

1993

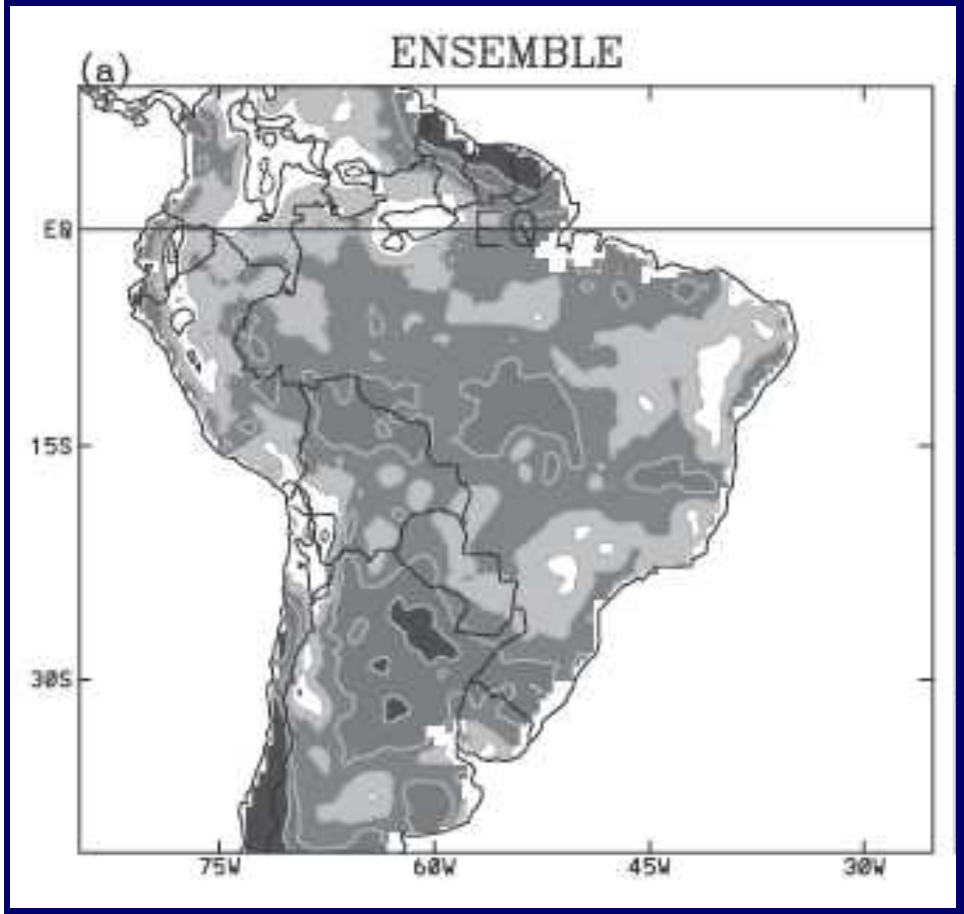
Anderson et al. (2003)

Does higher resolution help?



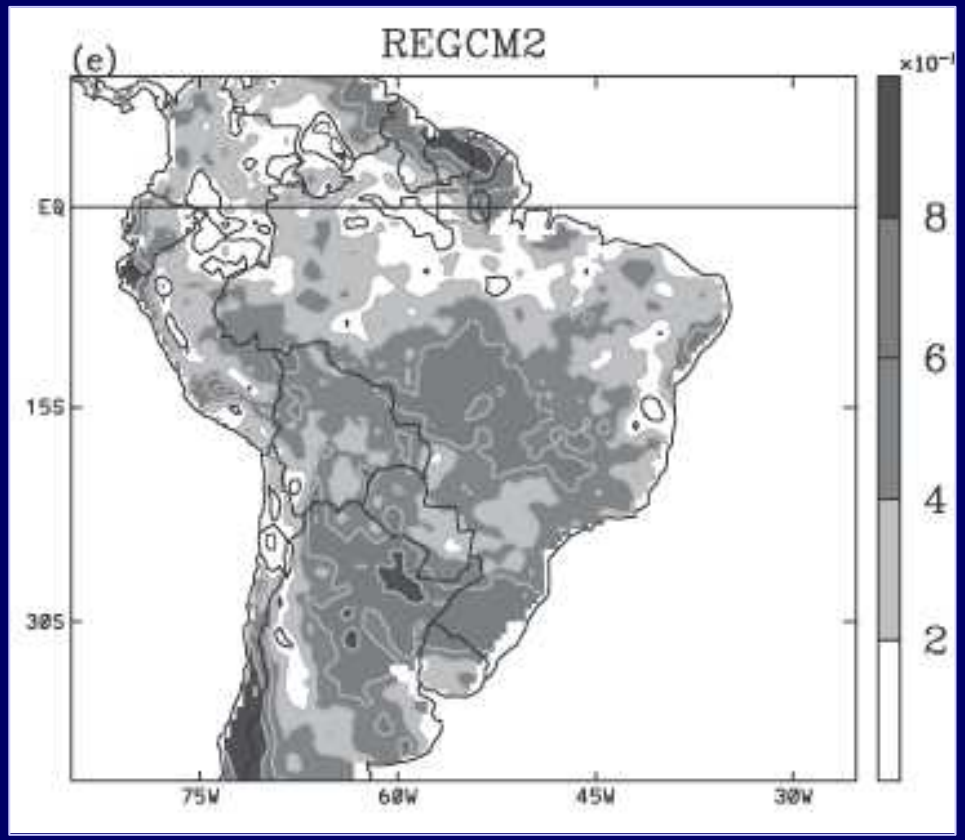
Flory (2003)

Correlation of Daily Precipitation with Observations



Roads et al. (2003)

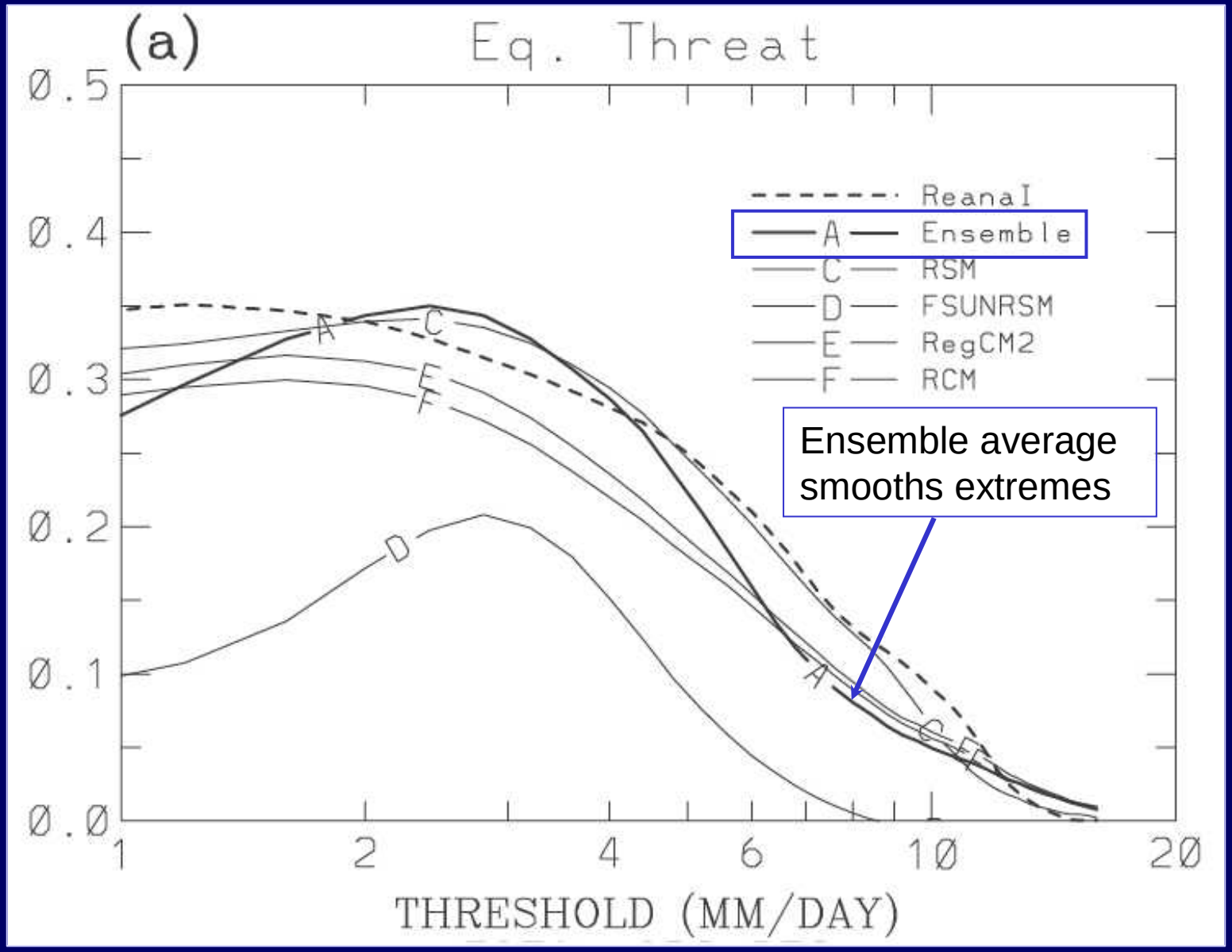
IRI/ARC project



R = 45%

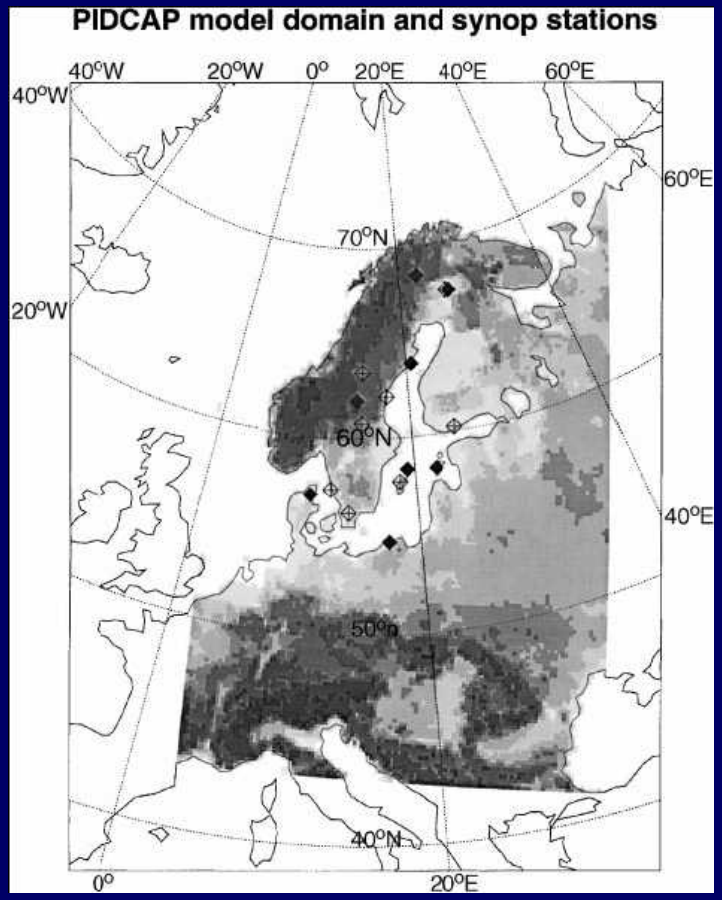
R = 41%

Threat Score: Monthly Precipitation



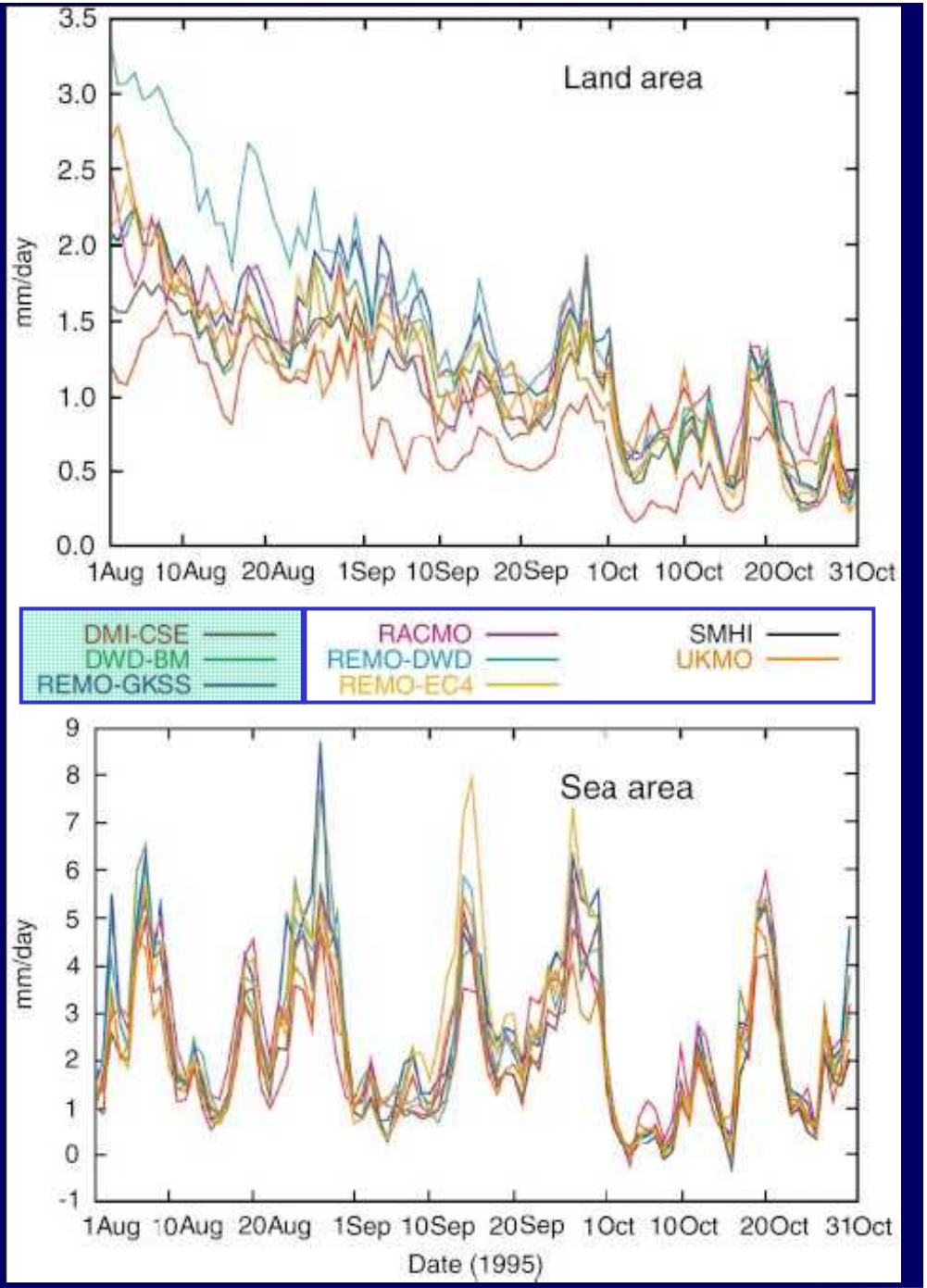
Roads et al. (2003) - IRI/ARC project

Evolution of Evapotranspiration



Jacob et al. (2001)

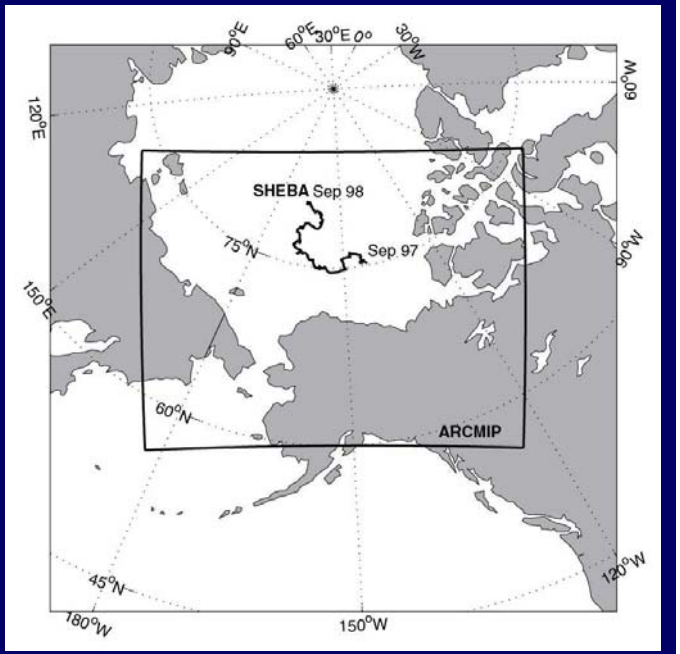
NEWBALTIC Project

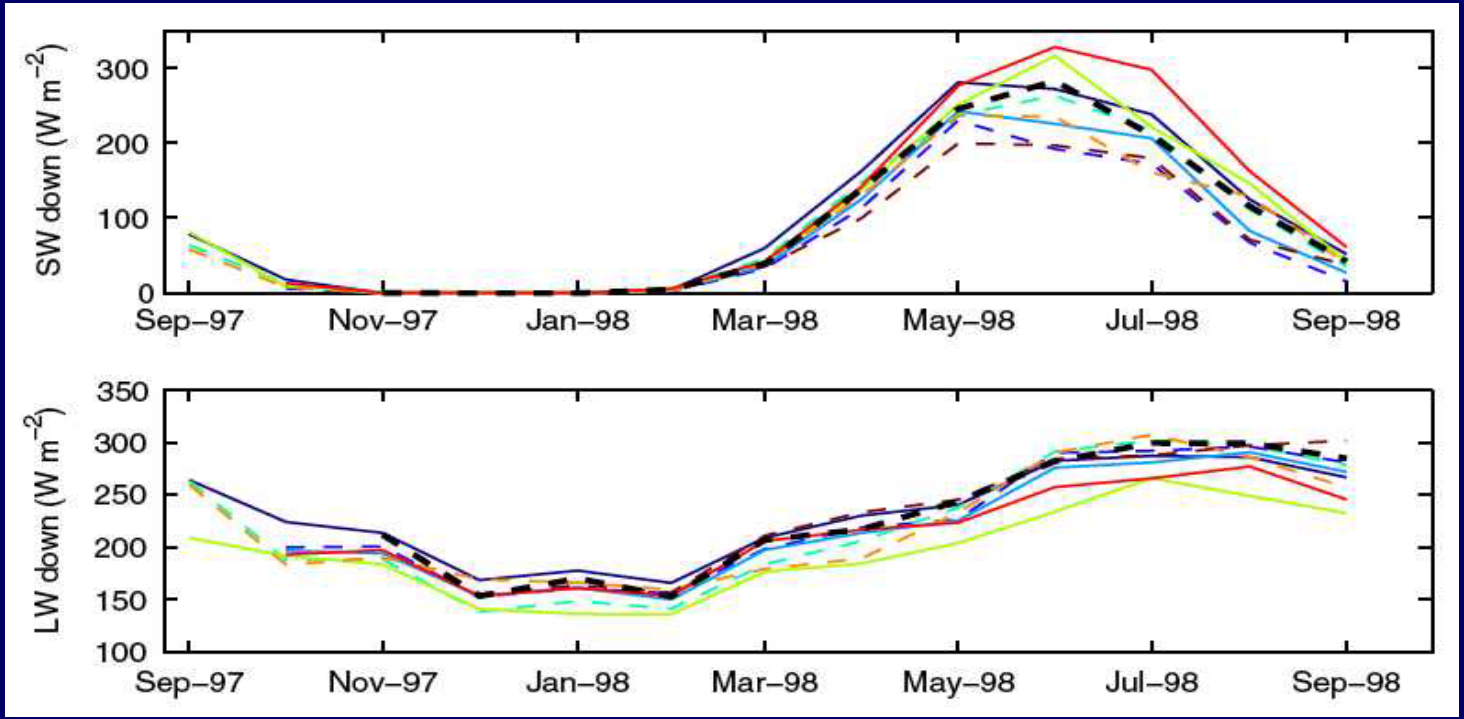


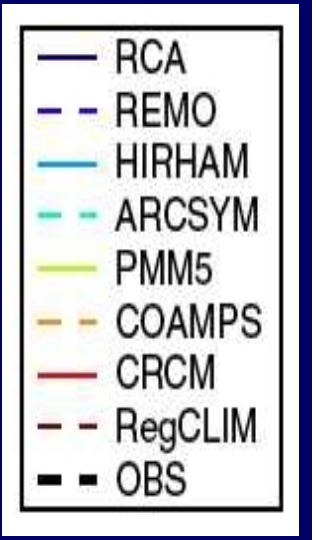
Exploiting Field Campaigns: Non-standard Observations

Wyser et al. (2007)

ARCMIP Project



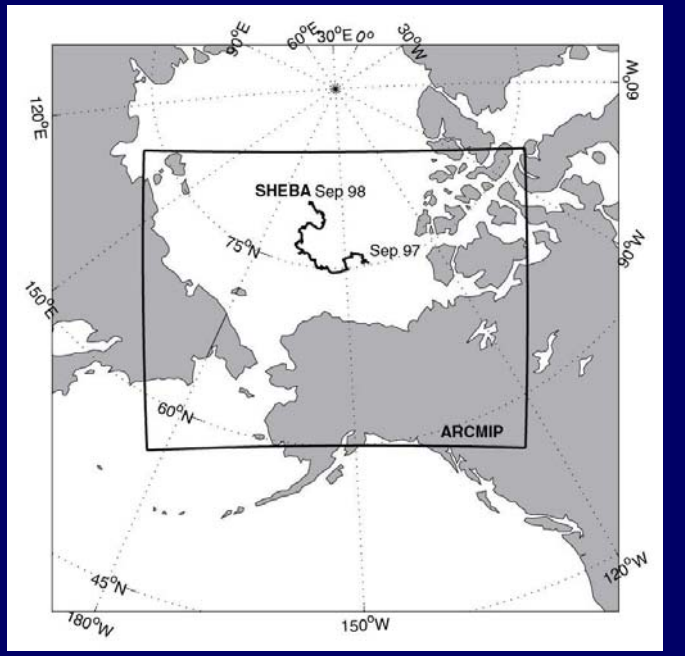


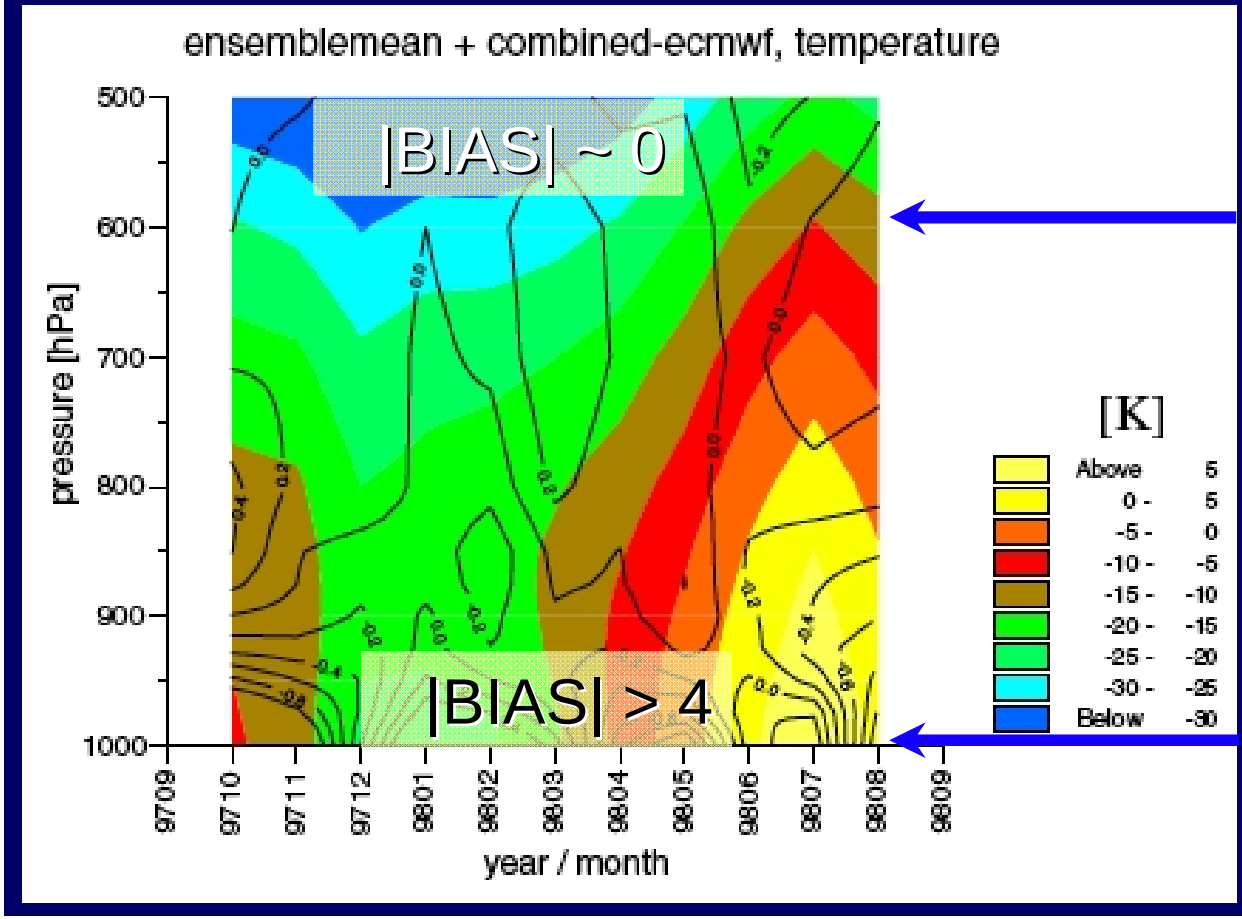


Near-Surface vs. Upper-Air Behavior

Wyser et al. (2007)

ARCMIP Project





Ensemble SDEV < 0.5 K

Ensemble SDEV ~ 2 K

Early Regional Multi-Model Projects

No single model is “best”

- ☞ Must analyze multiple fields

- Models tend diverge more near surface
  - ☞ Partly due to lateral driving
  - ☞ Where higher resolution most important and where we expect added value

- Largely analyses of individual fields
  - ☞ Occasional analyses of relations between fields

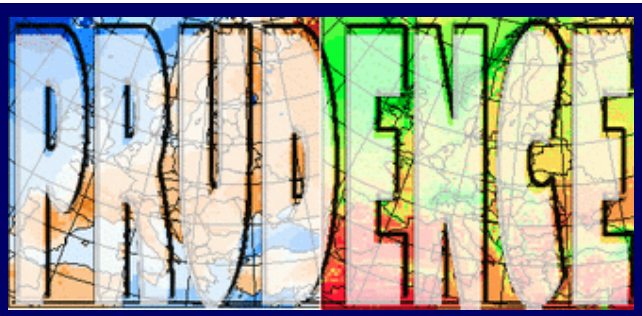
Regional Multi-Model Projects

Early projects:

- Do these models work?
- Side-by-side simulations vs. observations
- Limited time periods

Later projects:

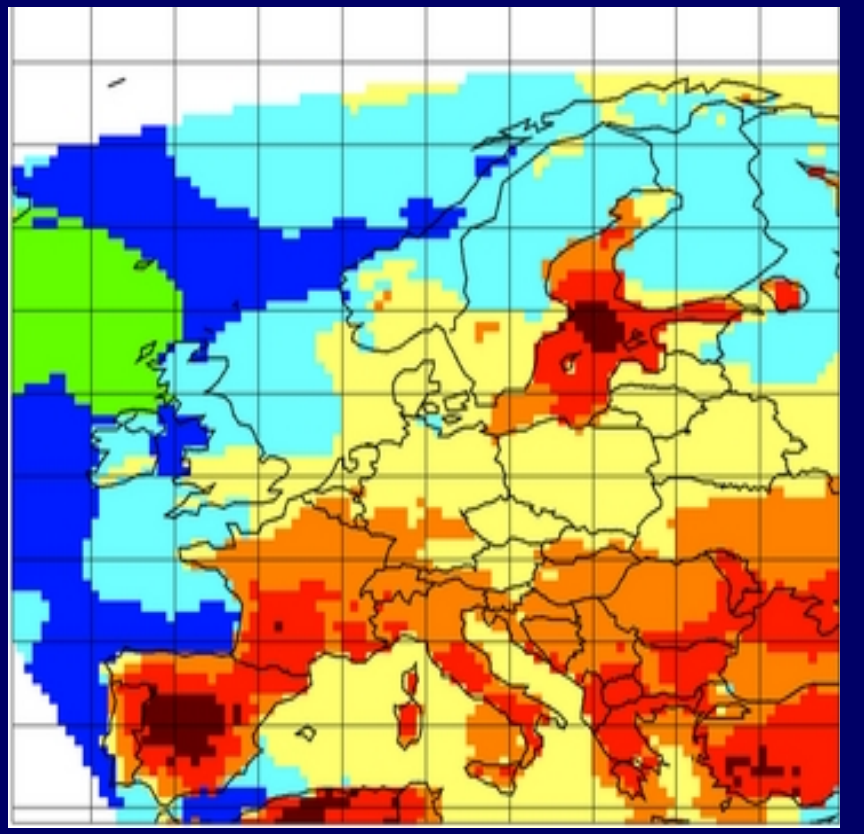
- Coordination with observing campaigns
- Coordination with GCM groups
- Coordination with statisticians
- Coordination with impacts assessments



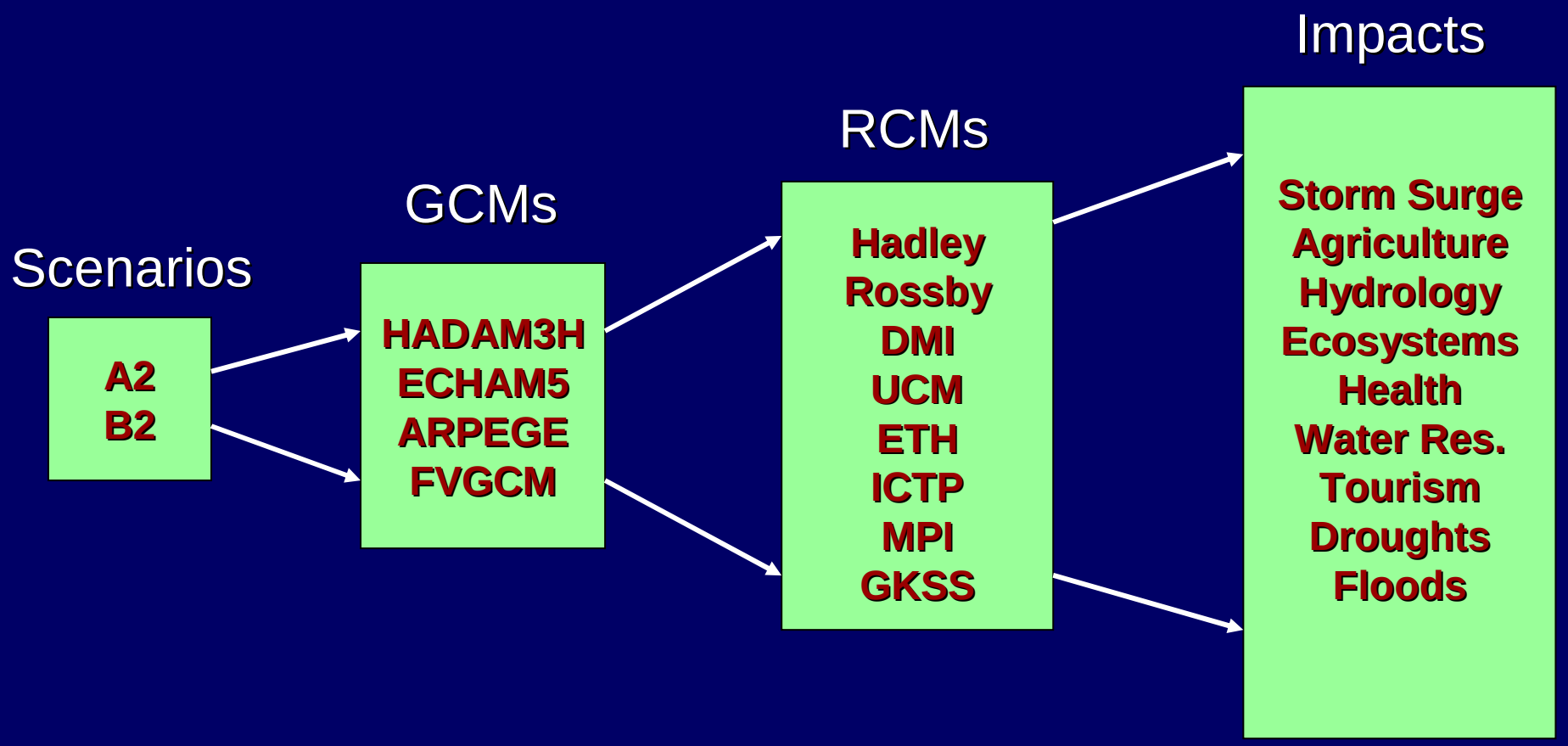
1. address and reduce [resolution] deficiencies in projections;

2. quantify confidence and uncertainties in predictions of future climate and its impacts

3. interpret results in relation to European policies for adapting to or mitigating climate change



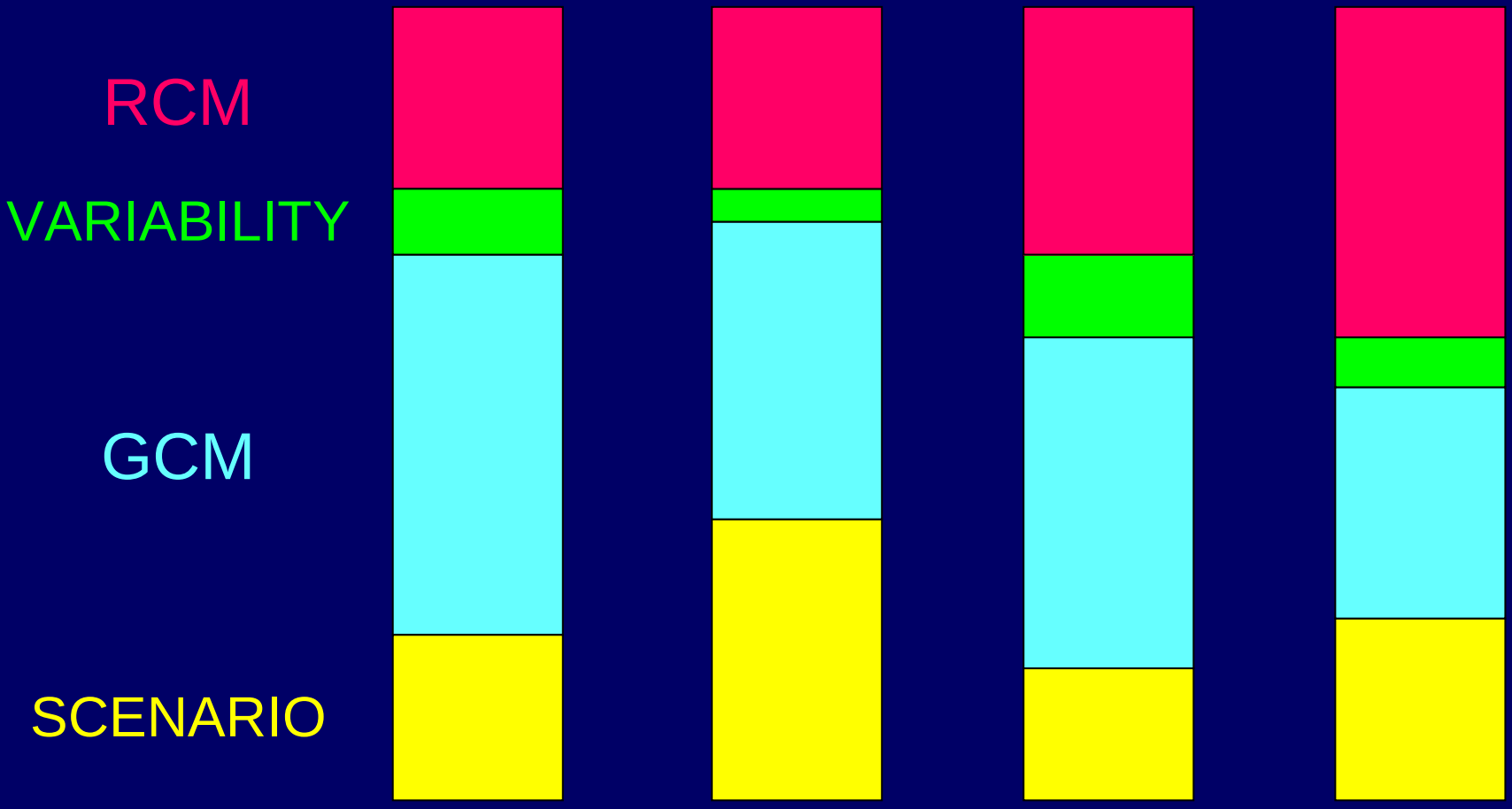
Uncertainties in regional climate change projections: The PRUDENCE strategy



(F. Giorgi, 2008)

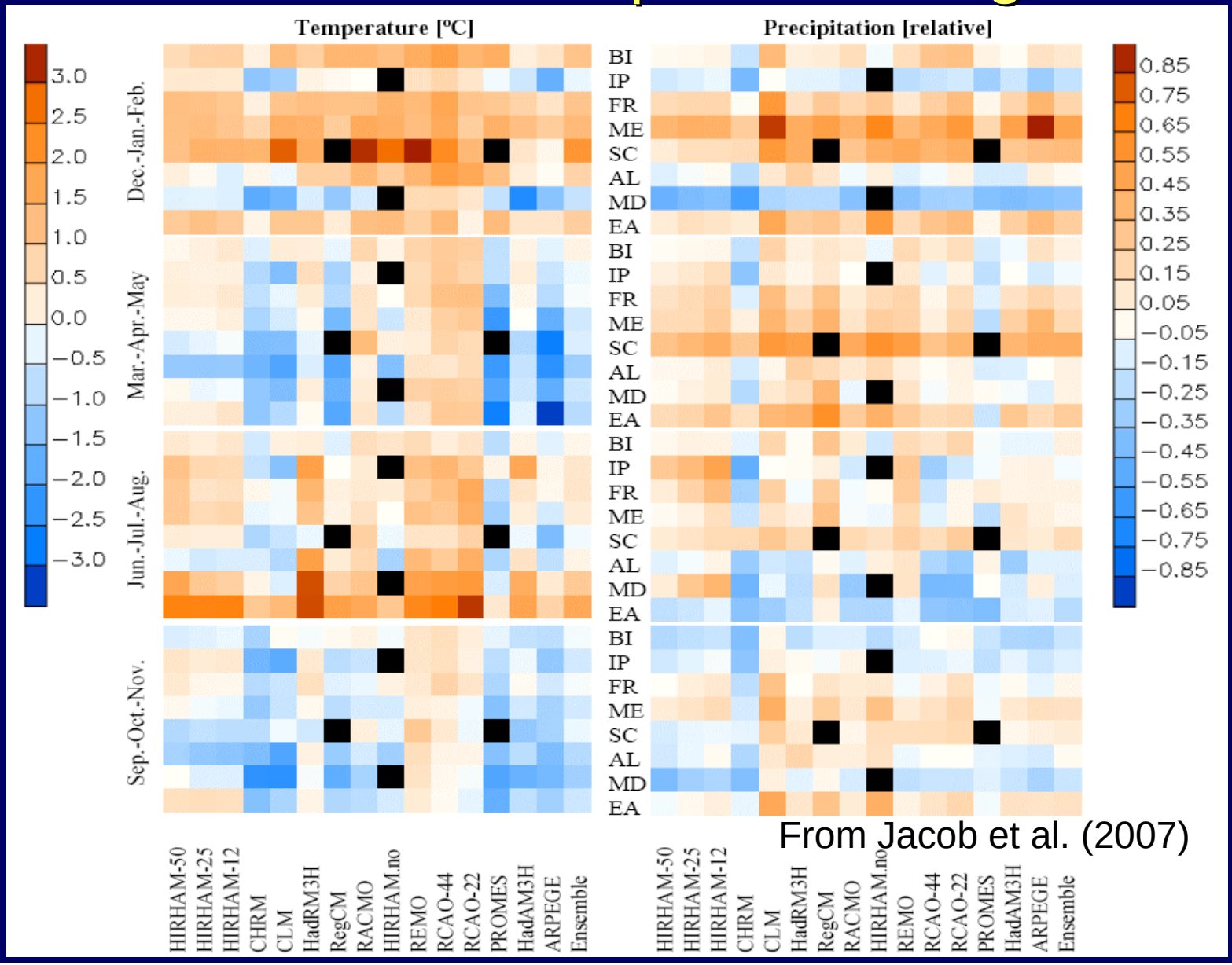
Sources of uncertainty in the simulation of temperature and precipitation change (2071-2100 minus 1961-1990) by the ensemble of PRUDENCE simulations (whole Europe)

(Note: the scenario range is about half of the full IPCC range, the GCM range does not cover the full IPCC range) (Adapted from Deque et al. 2006)



(F. Giorgi, 2008)

Performance of the PRUDENCE models over different European sub-regions



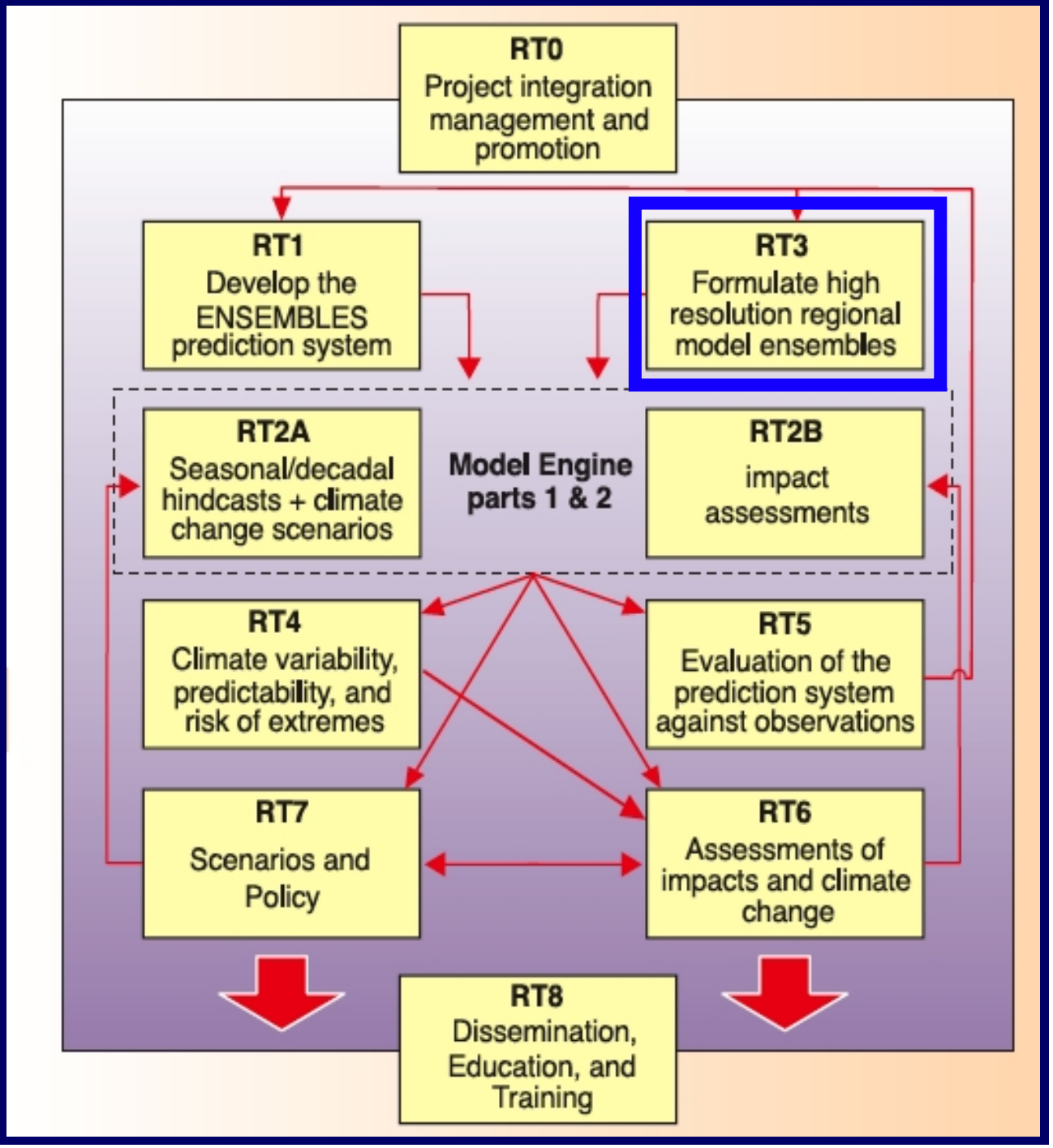
From Jacob et al. (2007)

ENSEMBLES

1. Develop an ensemble prediction system

2. Quantify and reduce uncertainty

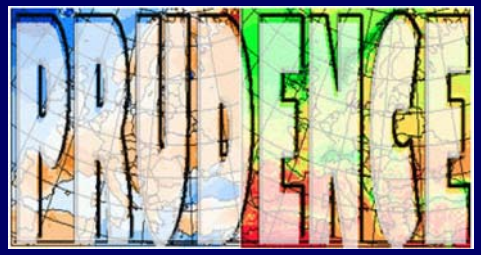
3. Link outputs of ensemble prediction system to a range of applications

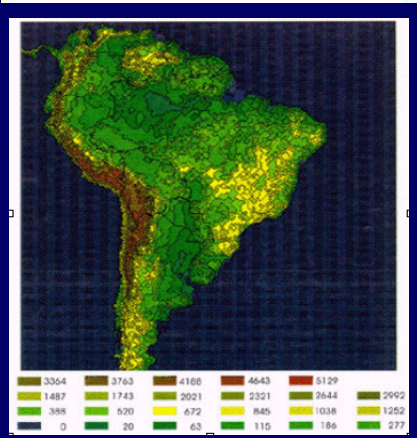


NARCCAP

North American Regional Climate Change Assessment Program

Builds on and complements …





- **PRUDENCE (EU):**

  Reduce deficiencies and quantify uncertainties in predictions of future climate

- **ENSEMBLES (EU):**

  RT2B - probabilistic high-resolution regional climate scenarios

  RT3 - very high resolution regional climate model ensembles for Europe

- **CREAS (South America):**

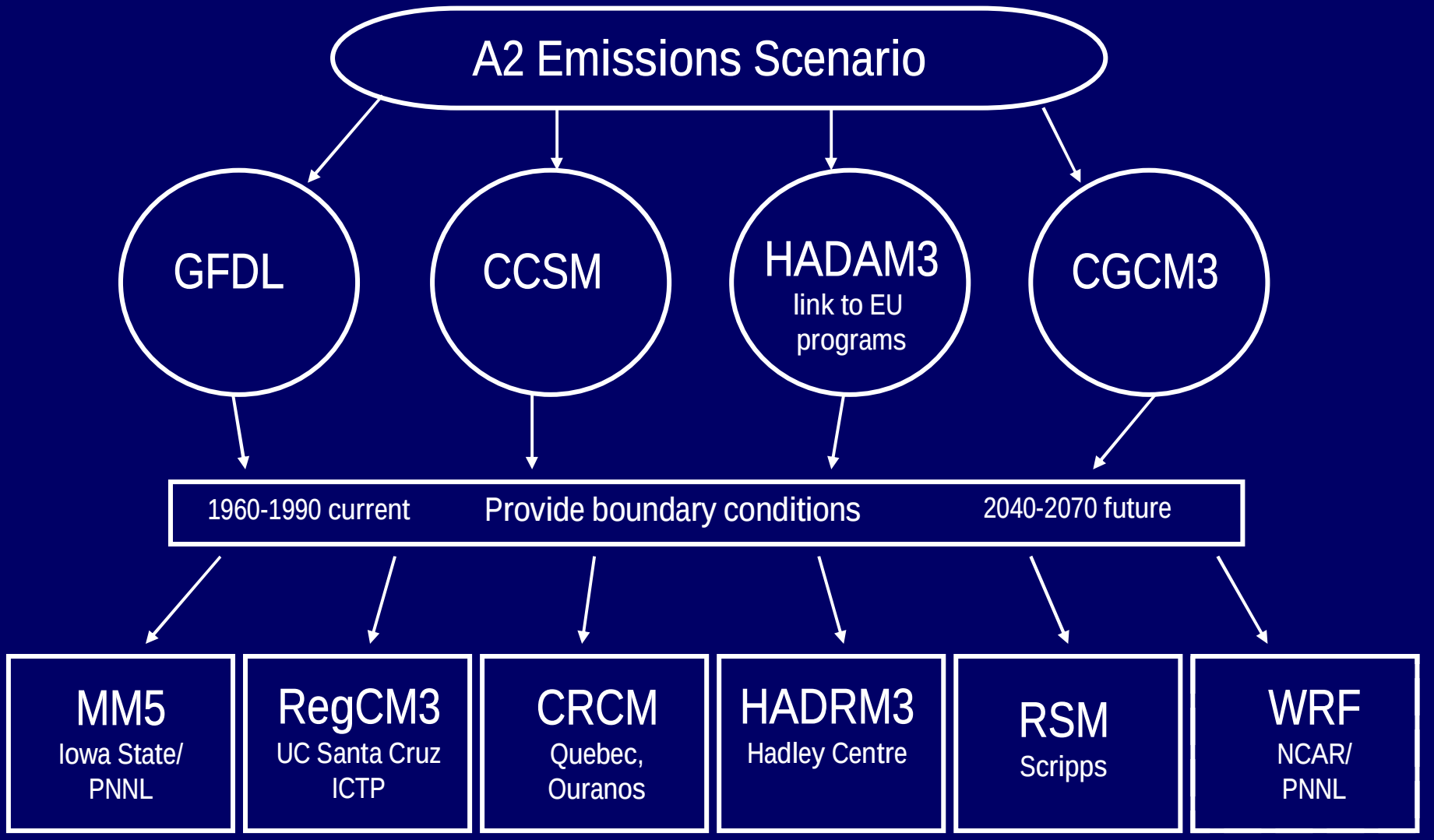
  (Cenários REgionais de Mudança de Clima para América do Sul)

  Downscale climate change scenarios (2 GCMs, 6 RCMs)

NARCCAP Goals

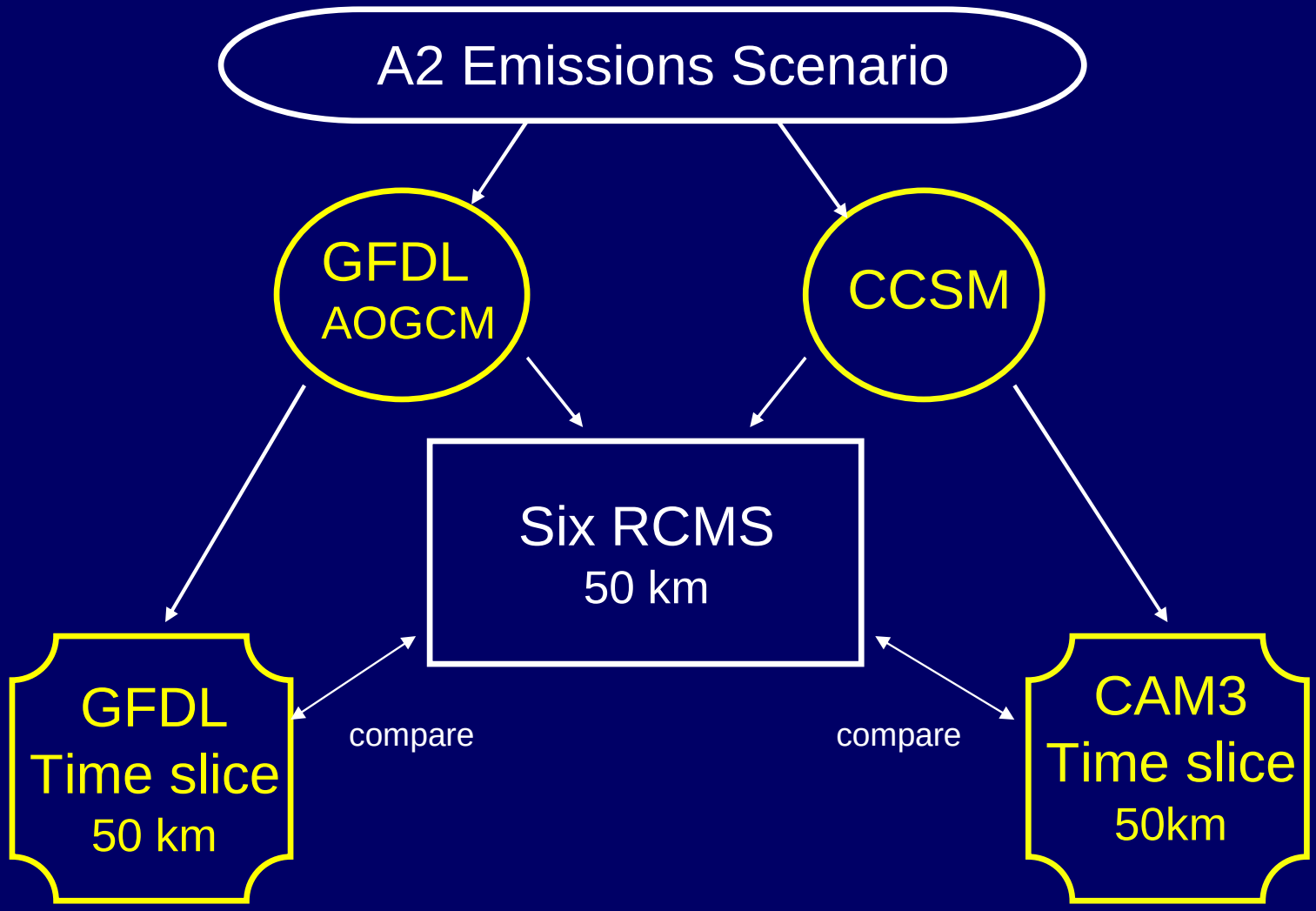
1. Quantify multiple uncertainties in regional model and global climate model future regional projections
2. Develop multiple high resolution regional climate change scenarios for use in impacts and risk assessments
3. Evaluate regional model performance over North America by nesting the RCMs in reanalyses
4. Understand critical regional climate change issues (e.g., effects of increased GHGs on the frequency of extreme weather events)
5. Create greater collaboration between US, Canadian, and European climate modeling groups to leverage the diverse modeling capability across the countries
6. Derive added value from diverse regional and global modeling projects and programs currently underway in the US, Canada, Europe and South America.

NARCCAP PLAN

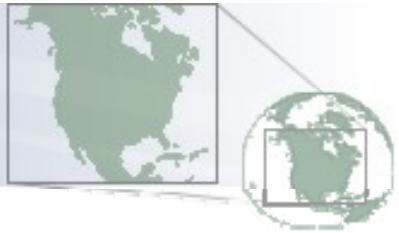


Global Time Slice / RCM Comparison

at same resolution (50km)



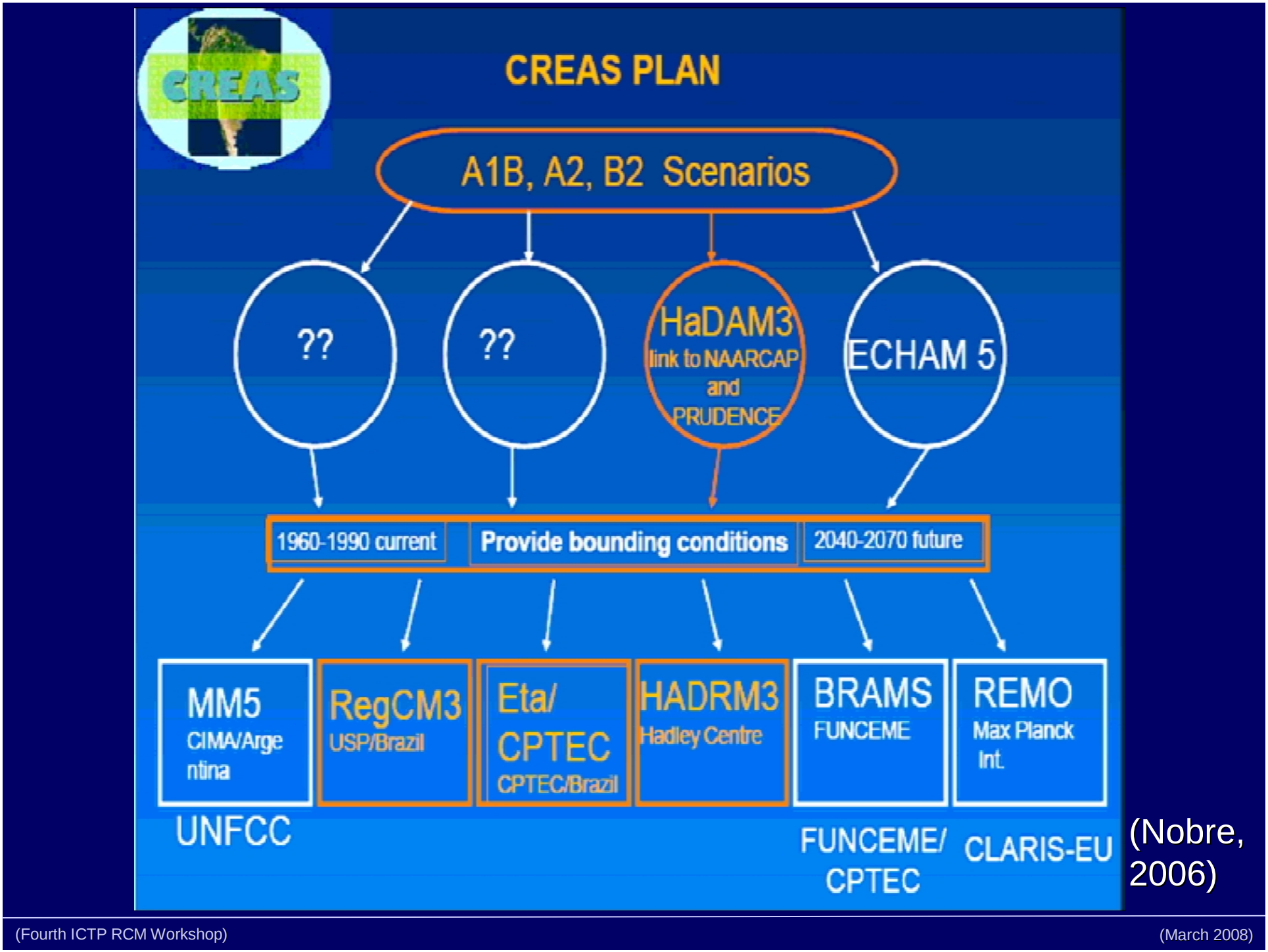
NARCCAP



NARCCAP REGIONAL OUTPUT ARCHIVE

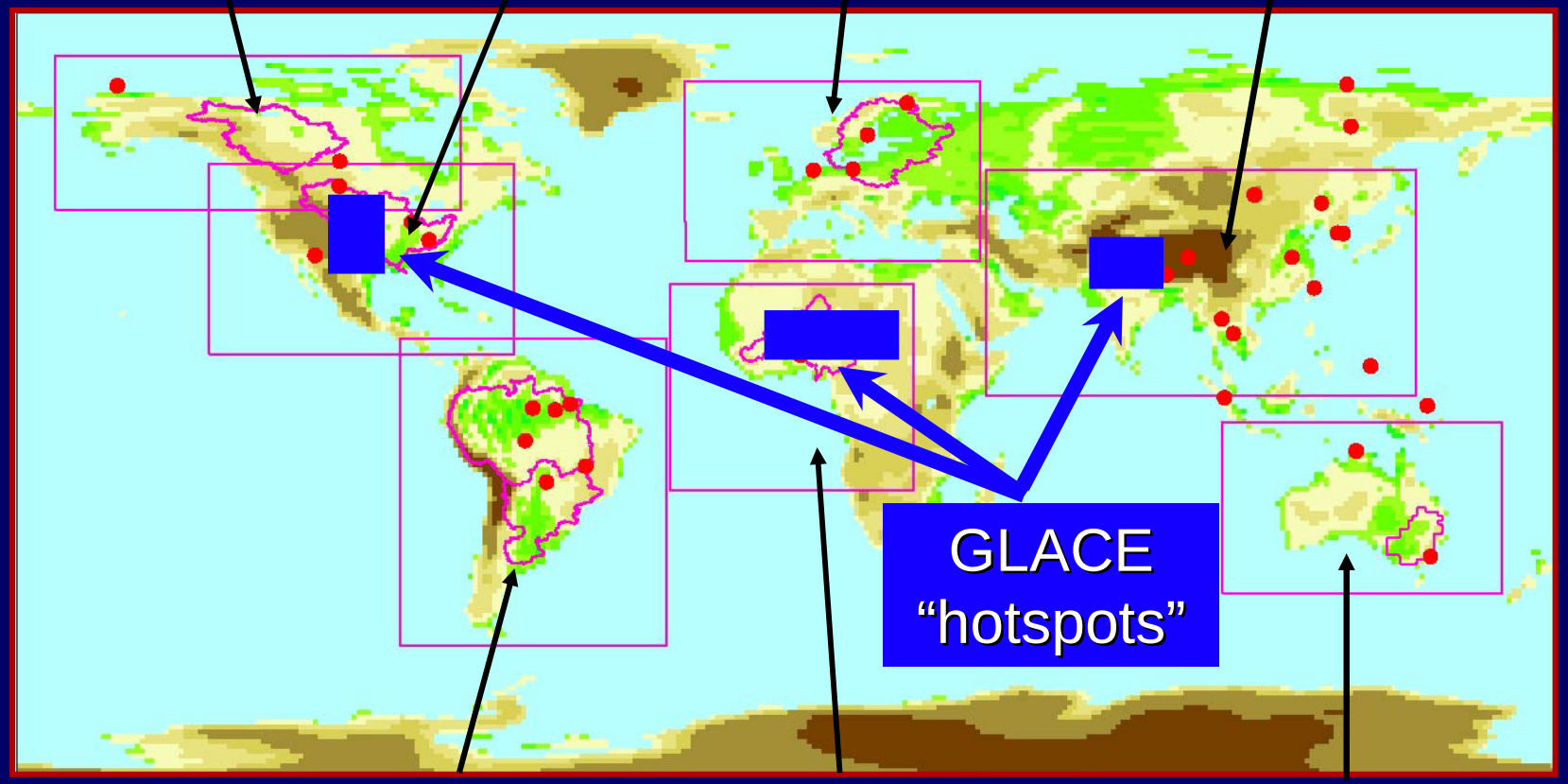
- Modeled after CMIP3 archive at PCMDI
- NetCDF with CF conventions
- 3-hourly output for 31 Two-Dim and 7 Three-Dim fields
- GIS-compatible
- On Earth System Grid - http://www.earthsystemgrid.org

Special thanks to Dave Flory, Seth McGinnis and the modeling and data teams for making this work.


CREAS
CREAS PLAN
A1B, A2, B2 Scenarios
??
??
HaDAM3
link to NAARCAP
and
PRUDENCE
ECHAM 5
1960-1990 current
Provide bounding conditions
2040-2070 future
MM5
CIMA/Argentina
RegCM3
USP/Brazil
Eta/
CPTEC
CPTEC/Brazil
HADRM3
Hadley Centre
BRAMS
FUNCEME
REMO
Max Planck
Int.
UNFCC
FUNCEME/
CPTEC
CLARIS-EU

(Nobre, 2006)

Transferability: A Global Approach to Mulit-Model RCM Simulations

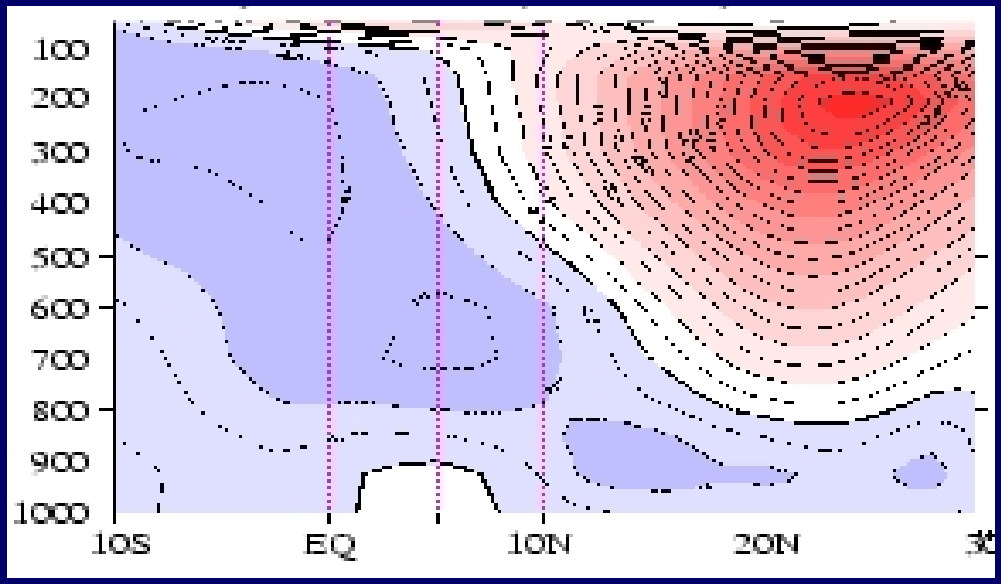


How portable are our models?

African Multi-Institution Activities

- **AIACC - African Climate Simulation:**

  Univ. Cape Town & Cheik Anta Diop University
- **RegCNET & RegCNET-Africa**
- **AFRIMIP (Greater Horn of Africa)**
- **AMMA-MIP**
- **ENSEMBLES**
- **WAMME**

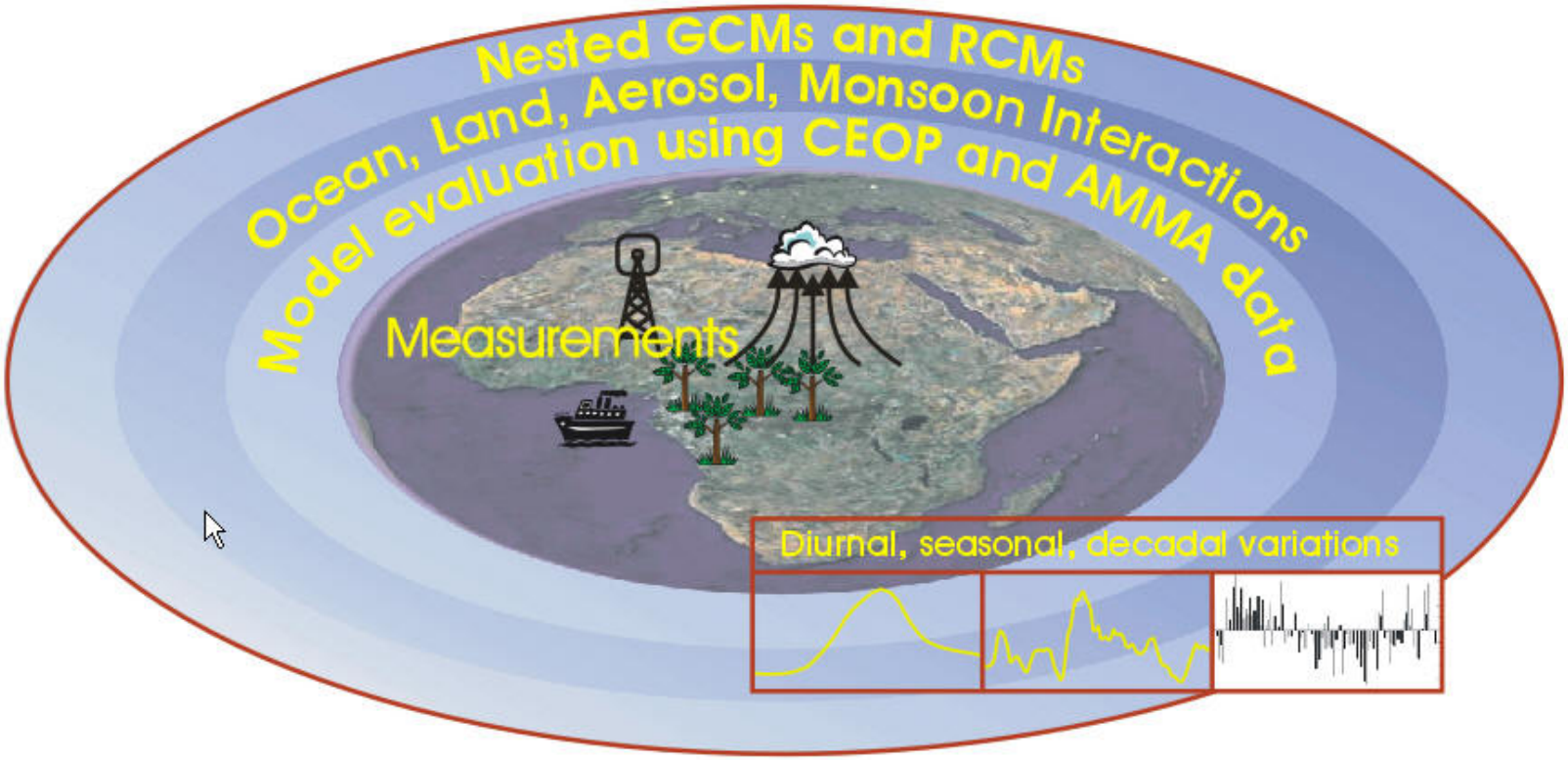


WAMME West African Monsoon Modeling and Evaluation

- Home
- WAMME Initiative
- Experiments
- Documents
- Publications
- Participants
- Forcing and Boundary Data
- Output Data
- Data/Model Output Access
- Models GCM RCM
- Meetings
- Discussions
- Contact Person
- Highlights of new African simulations

WAMME Related:

- CEOP
- AMMA International
- AMMA US
- UCAR Africa Initiative
- ALMIP



WWW.WAMME.Geog.ucla.edu

(Yongkang Xue, 2008)

Implications for African Participation

What does this mean for African participation?

a. Multiple demands on time
b. Weak support infrastructure
c. Many, many demands on time

Need to promote local development of expertise in

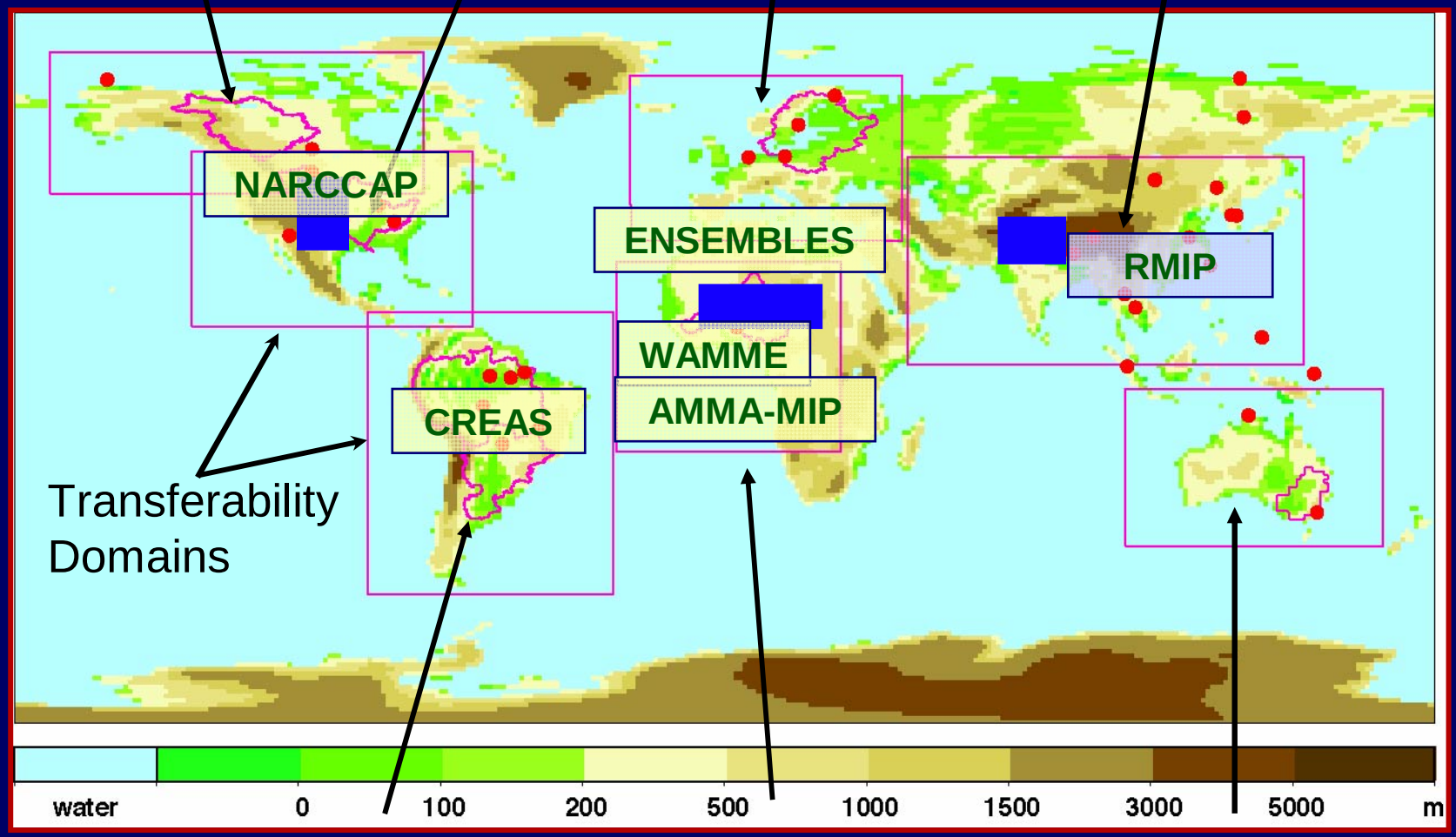
a. Modeling and analysis
b. Supporting infrastructure
c. Education & research environment

Need time to think and escape from other demands.

Recommendations for a Coordinated RCM Program in Africa & Beyond

Regional Coordination of Mullti-Model Projects

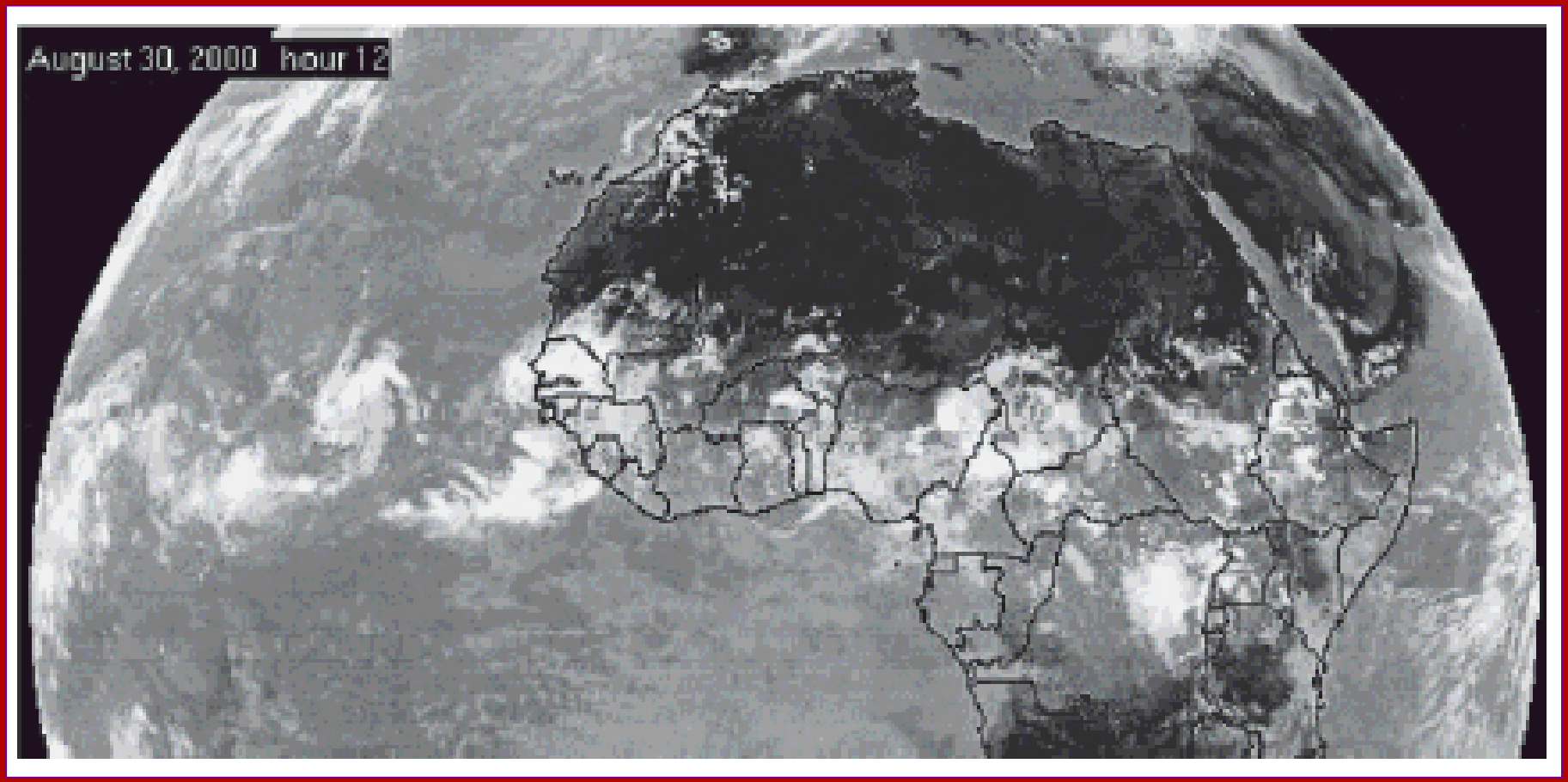
Overlap of Multiple Interests



Recommendation 1:
Create a Globally Coordinated RCM Program

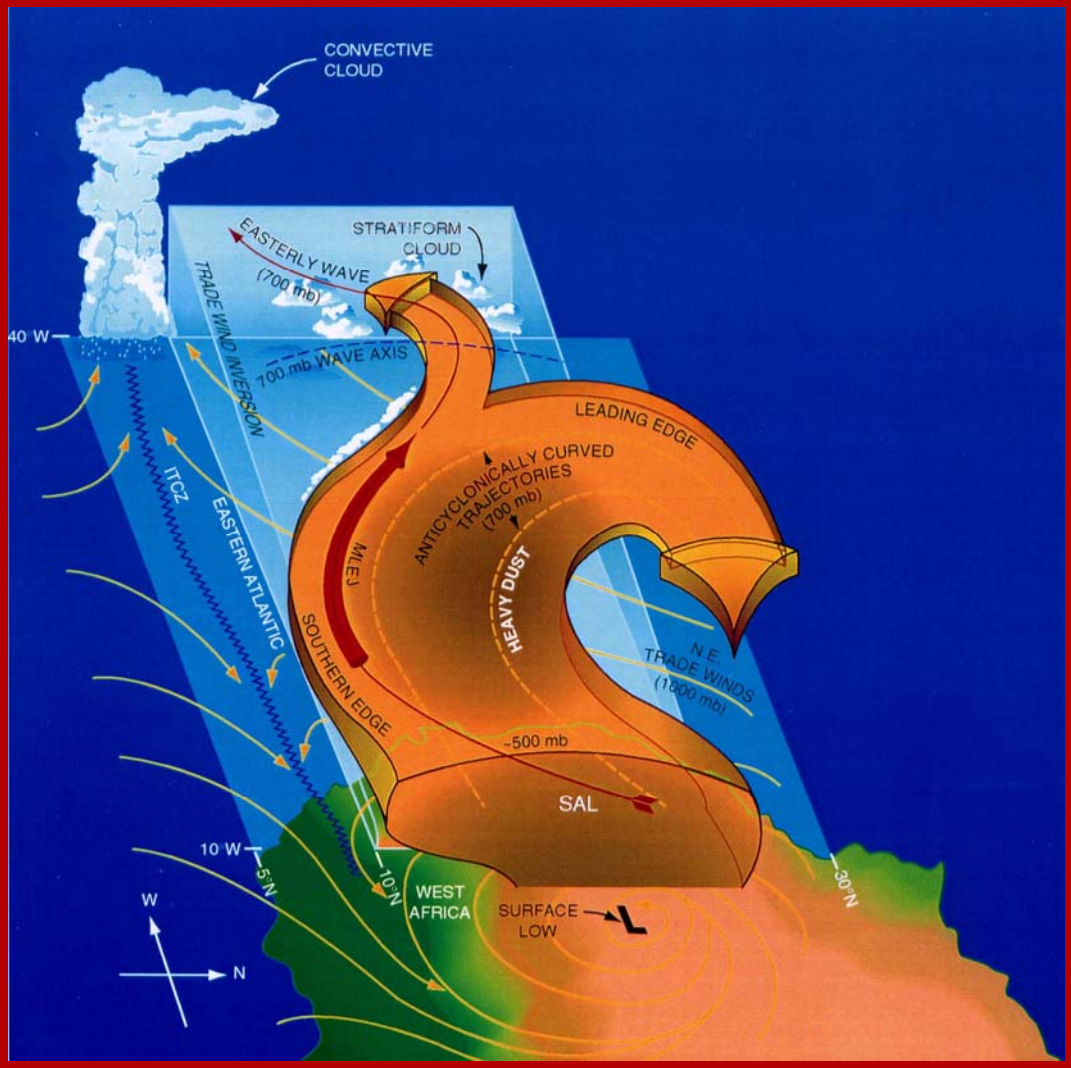
1. Common mesoscale targets (e.g., fronts, convective systems, regional jets, topography, land use, …)
2. Local responses to teleconnections
3. Transferability: Test the generality of models and underlying physical understanding
4. Upscaling

African Easterly Waves



(Thorncroft et al. 2003, Burpee 1972;
from P. Woodworth, 2003, orca.rsmas.miami.edu/~phoebe/myweb3/SALpresentation.ppt)

Saharan Air Layer



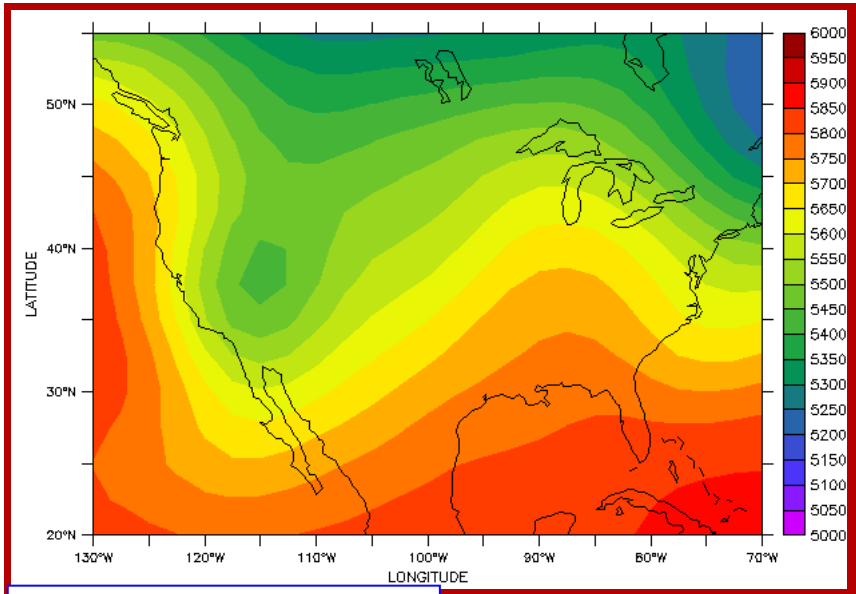
(Karyampudi et al. 1999; from P. Woodworth, 2003, orca.rsmas.miami.edu/~phoebe/myweb3/SALpresentation.ppt))

Recommendation 2: Promote Process-Oriented, Multiple-RCM Analysis

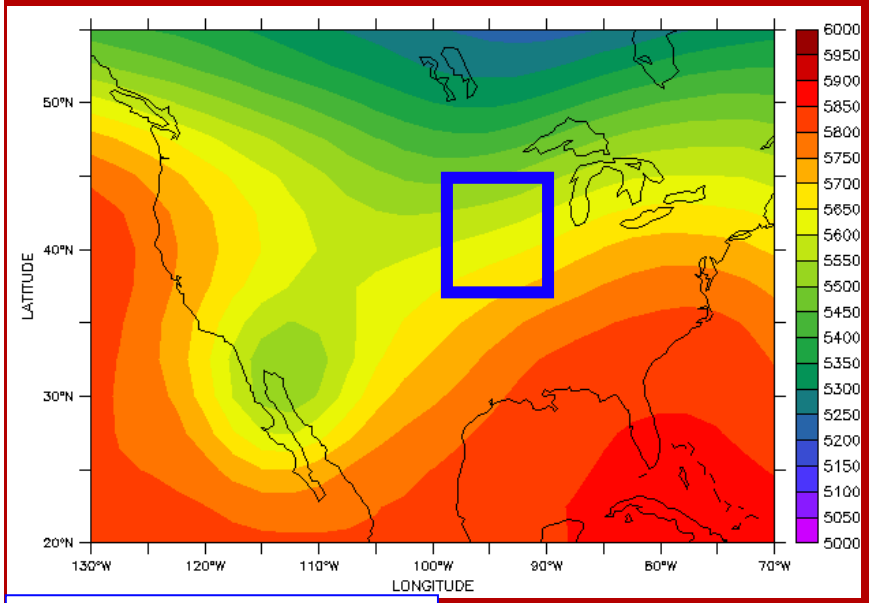
1. Model equations are simulating geophysical fluid flow
2. Evaluate fields linked by processes, especially circulation
3. Need tools to do this with ensemble of models
4. Metrics of accuracy: mesoscale focus, earth-system scope
5. Provide guidance to field campaigns

Observed Circulation

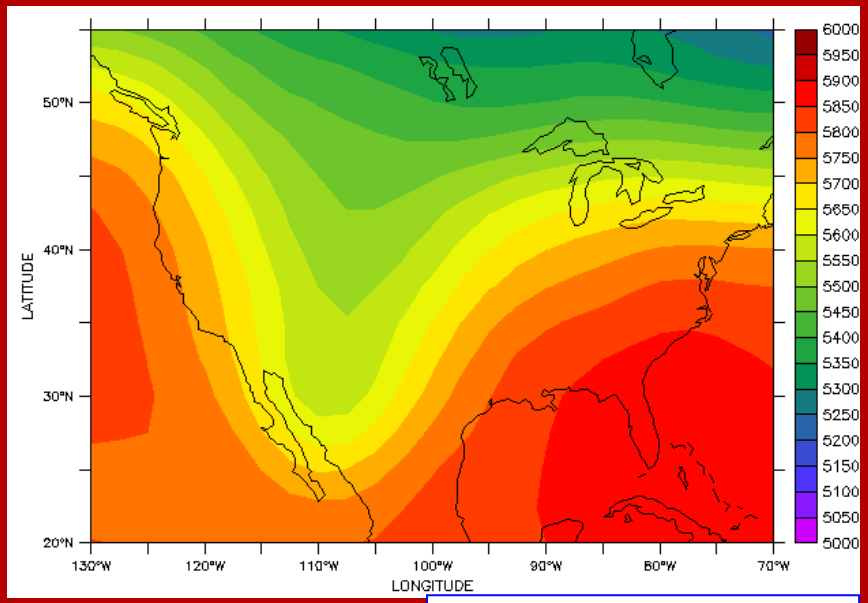
500 hPa Heights during
Extreme Precipitation Event



21 Feb 1985



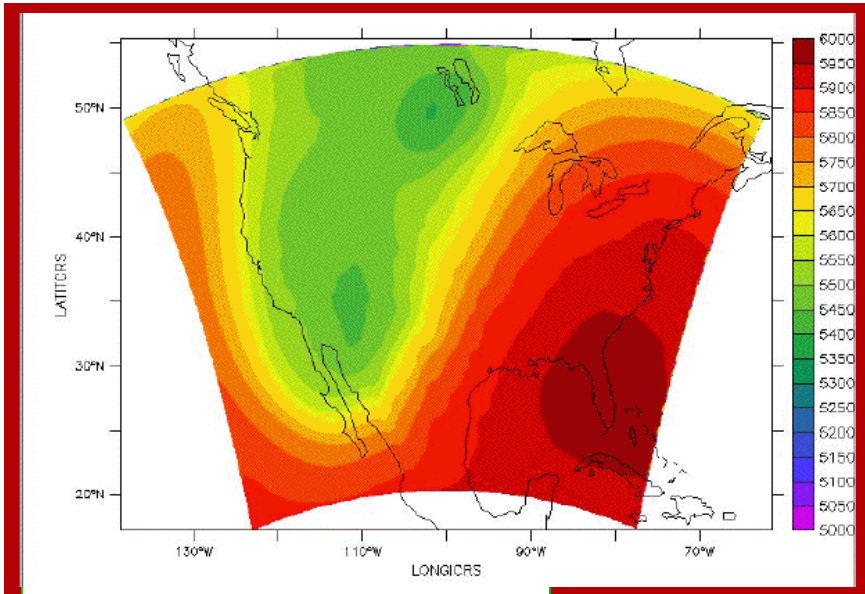
22 Feb 1985



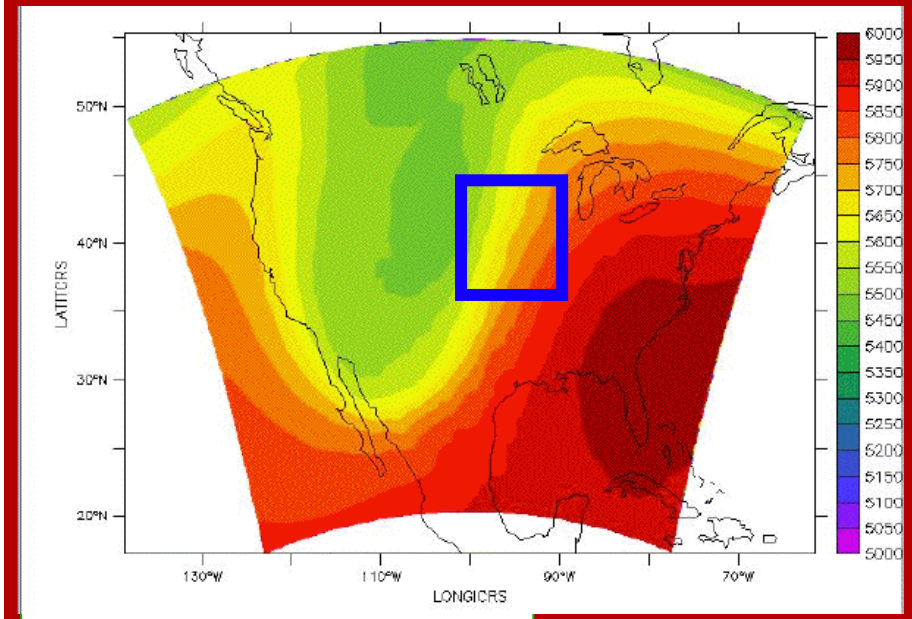
23 Feb 1985

Scenario Circulation

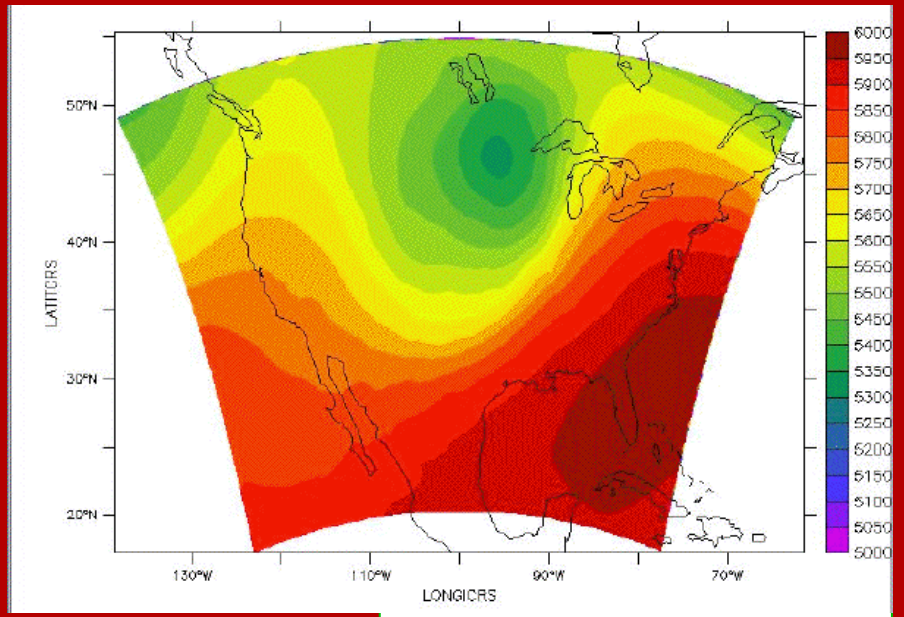
500 hPa Heights during
Extreme Precipitation Event



Day - 1



Day 0

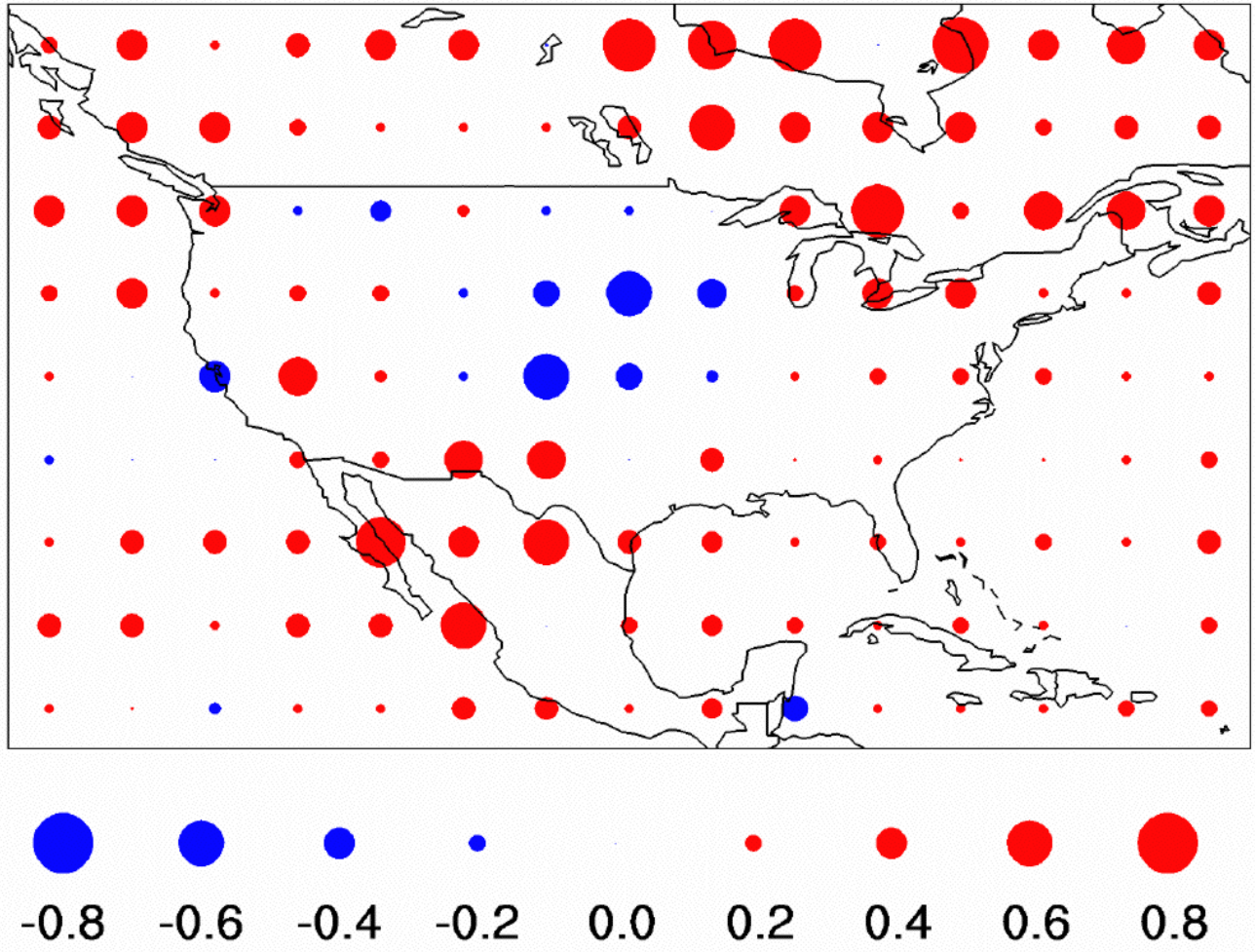


Day + 1

Recommendation 3:
Perform Regional Climate Change Detection and Attribution

1. Build from process-oriented analyses
2. Focus on mesoscale targets

Δ T [K] - JJA (2000-1976)

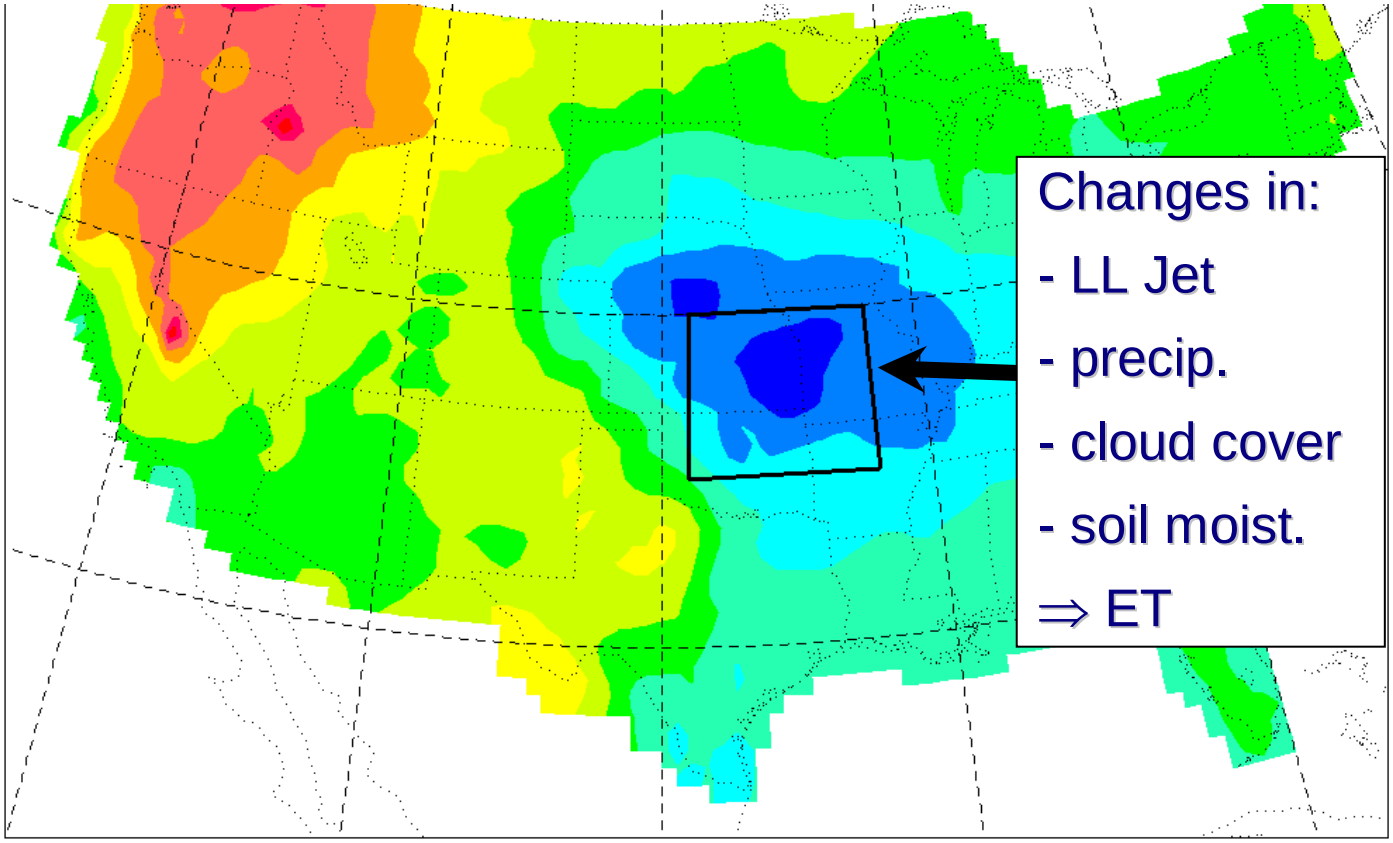


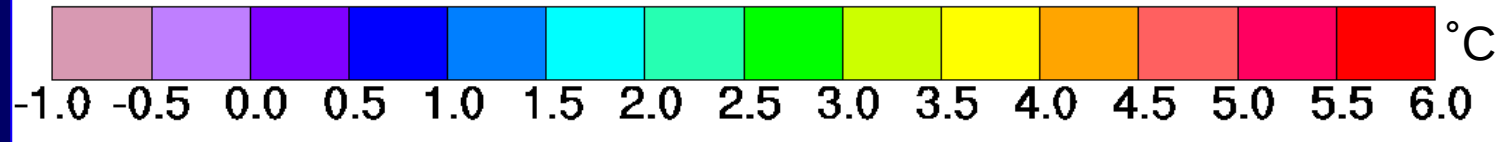
(Adapted from Folland et al. [2001] - IPCC TAR)

“Warming Hole”

Change in Daily max{T} for June-July-August

(RegCM2 simulation: 2040s - 1990s)





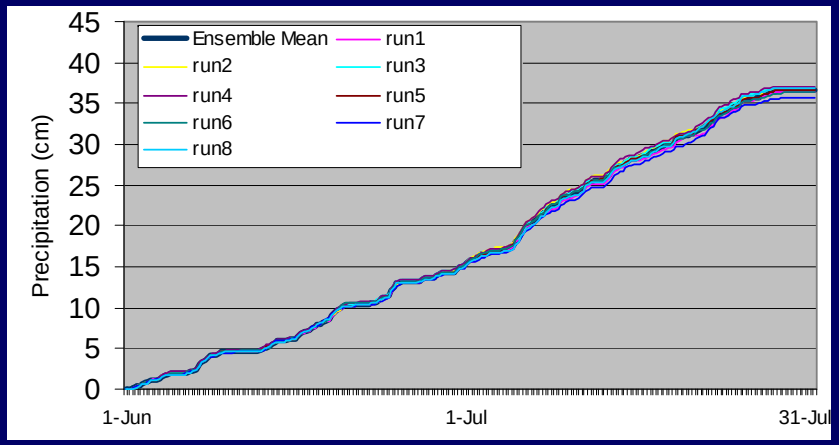
(Pan et al.,2004)

Recommendation 4:
Optimize use of ensembles

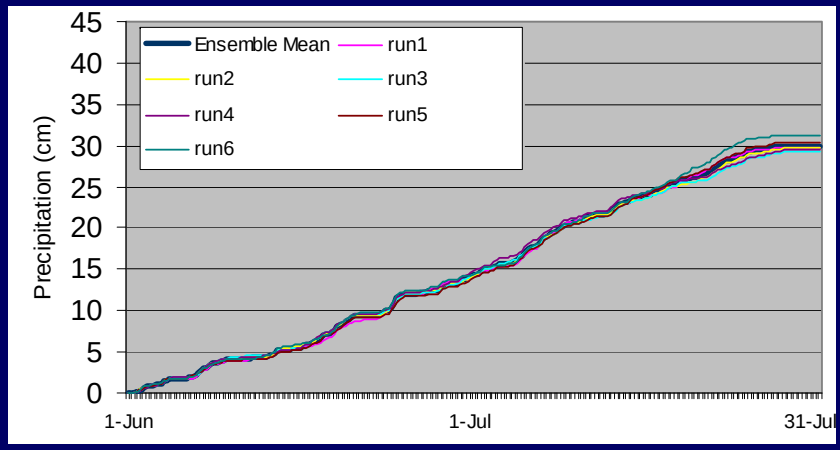
1. Why do ensemble averages work so well for mean fields?
2. What are the best methods for evaluating extremes and their change?
3. How should ensemble spread inform uncertainty?
4. How are time series of linked fields best handled?
5. Are there optimal weightings (e.g., superensemble)?

Area-averaged precipitation in the north-central U.S.

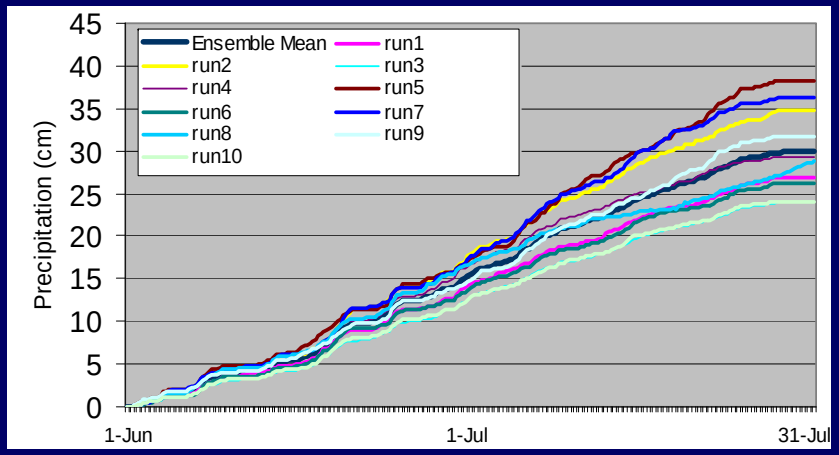
Lagged



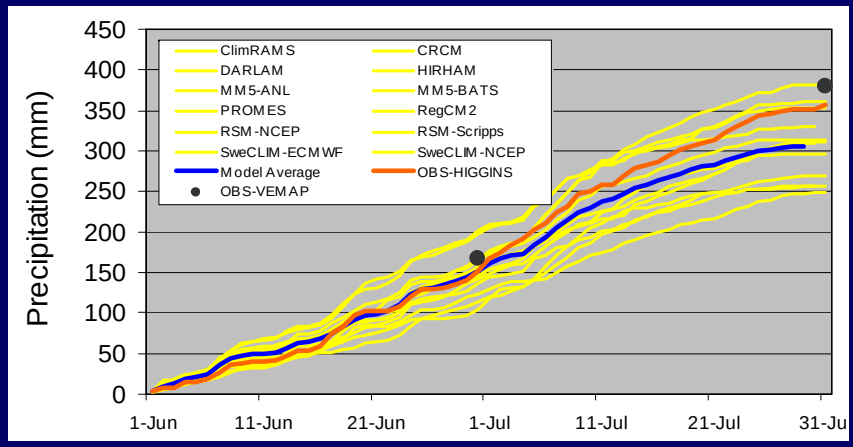
Perturbed Physics



Mixed Physics



Multi-Model (PIRCS 1B)



(R. Arritt, 2002)

Recommendation 5:
Form a global coordination working group

1. Operate under auspices of international governing body (e.g., WCRP, CLIVAR, GEWEX?)

2. Produce RCM simulations for AR5 that link concerns of Working Groups I, II and III.

3. Recognize regional implications in the near term (10-30 years) and long term (30 - … years) for targeting stabilization levels: land use, local aerosol responses.

Recommendation 6: Develop stronger technical coordination among RCMs

1. Common output formatting to ease access and cross comparison
2. Common pool of driving data sets (reanalyses, GCMs, other RCMs?)
3. Core output variables
4. Common names, units, sampling periods, …
5. Central archive for output from major programs?

Recommendation 7: Engage in dialogue with “end users” in the planning stage of a simulation program

1. Target specific output needs
2. Target specific processes
3. May lead to new diagnostics of model performance

Recommendations

1. Create a globally coordinated RCM program
2. Promote process-oriented multiple-RCM analysis
3. Perform regional climate-change detection and attribution
4. Optimize use of ensembles
5. Form a global coordination working group
6. Develop stronger technical coordination among RCMs
7. Engage in dialogue with “end users” from the planning stage of a simulation program

Thank you!

(Camps Bay, South Africa, 2004)

Topics

1. Link with broader community (users) - Andy Robertson's work, NARCCAP: Get dialogue with "end users" - e.g., in IPCC terms link WG-I, WG-II and WG-III. May point to different key diagnostics and targets for model improvement (thresholds like degree-day counts, extreme events, …) Promotes recommendation to engage in more process-based evaluation.
2. Minor: color global map's programs as "early" and "later" and animate the "later" ones to appear later.
3. Metrics of quality of simulation? (Adrian Tompkins)
4. Can RCM programs guide field campaigns?
5. Upscaling (recall Jean-Luc Redelsperger's talk: scale interactions between convective systems from monsoon to shallow convection; also in Jan Polcher's talk) reference in context of AMMA and include my slides
6. "Transferability" - focus on GLACÉ regions? (Colin also talked about ICTS)
7. Physical focus ==> testable hypotheses
8. http://www.envsci.rutgers.edu/~anyah/afrmipindex2.html
9. http://www.wamme.geog.ucla.edu/
10.

Common Features of Regional Projects

Motivations are linked to processes of the targeted region

But there are some common concerns:

- Climate simulation (length of simulation)
- Ecompassing key global events, such as ENSO cycles
- Mesoscale behavior
- Impacts of climate change

$\Rightarrow$ Strongly overlapping physical climate interests

Recommendations: Scientific Coordination

Coordinate science programs:

- Local rendition of common regional processes (e.g. convective systems, mesoscale jets, fronts, …)
- Transferability (common errors?)
- Teleconnection (regional response to remote signals, e.g., ENSO)
- Regional climate change detection and attribution
- Measures of confidence in regional climate projection

Aim for Global Leadership

1. Work through an appropriate governing body (i.e, an appropriate GEWEX, WCRP, etc., panel.
2. WCRP is thinking about a panel similar to WGNE (RJ not sure who is setting it up - contact JSC?)
3. RCM simulations for next round of IPCC? (Don has heard rumor about this) Connecting WG 1,2,3 better via this? Should be similar to WGCM planning. WG 1 simulation framework being established.
4. Common names, definitions, units help a lot. Vertical grid? What is next generation CMOR specification?

Recommendations: Technical Coordination

Coordinate technical aspects of regional programs:

- Output formatting to ease access and cross comparison
- Common pool of driving data sets (reanalyses, GCMs, other RCMs?)
- Common regional models

Further Specifics for an African Program

- Transferability study across Africa
- Why do ensembles work (apparently)? We seem to have empirical evidence, but little theory if any.
  - when errors are “small”, is the problem linear,
  - Work with adjoint?
- Regional attribution - physical attribution

  - physical evaluation of attribution? (use mesoscale targets – e.g., warming hole and physical behavior involving it)
  - pattern analysis (e.g., SOMs? – S.Willis’s work)

Does regional convection affect climatological large-scale circulation?

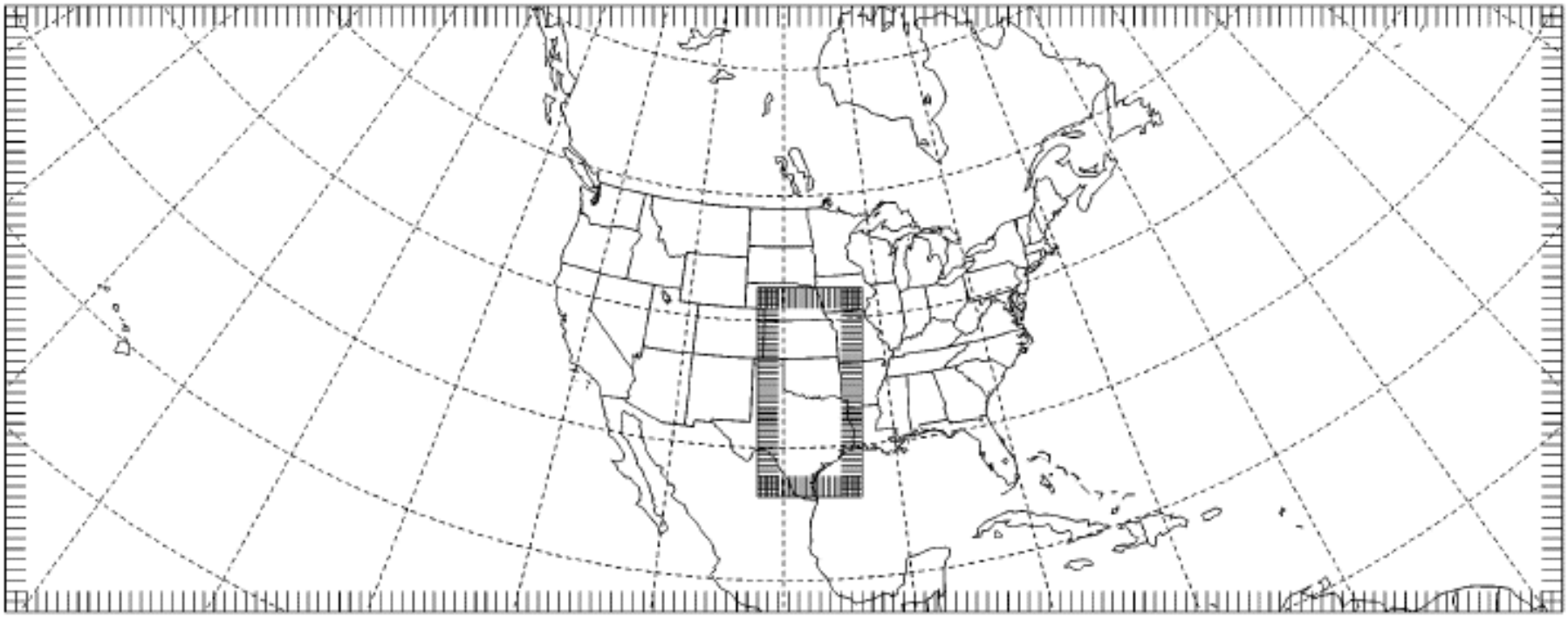
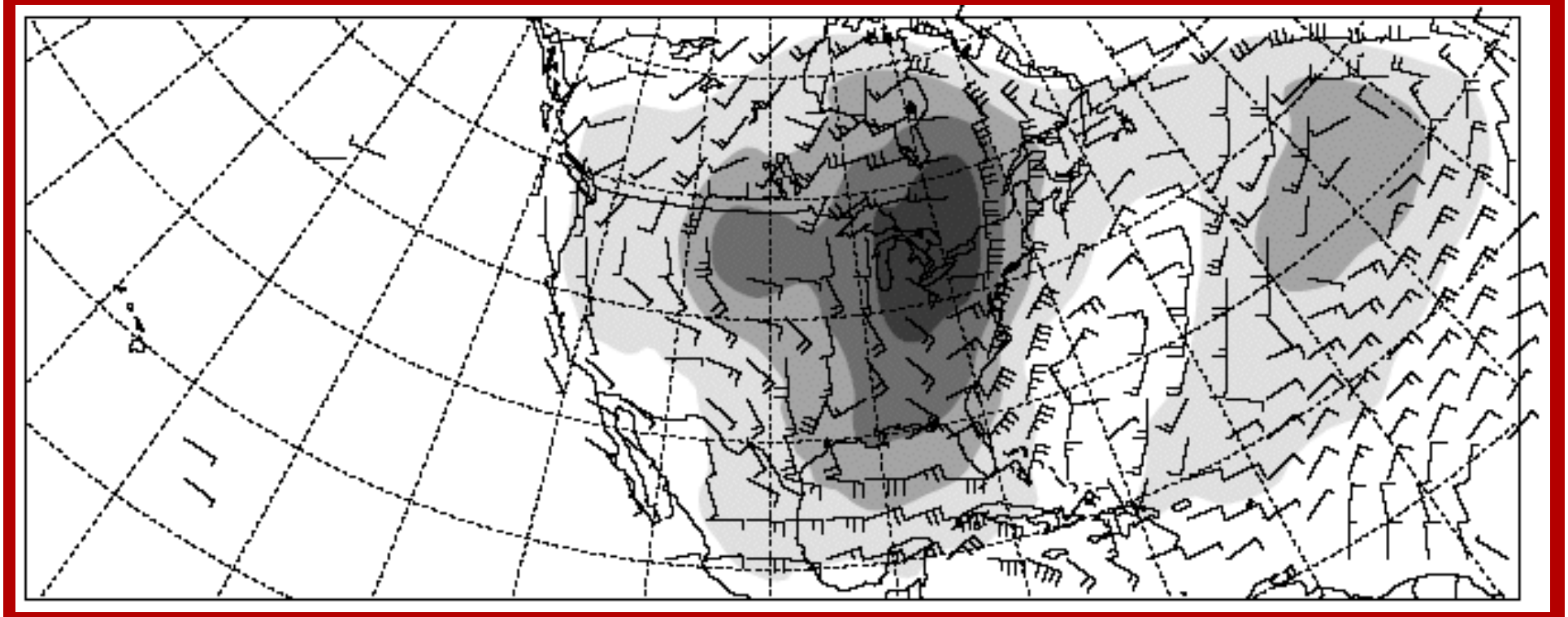


FIG. 5. Mesoscale model coarse grid domain (90 km), with the nested grid domain highlighted (30 km). Tick marks indicate locations of model dot points.

Stensrud (1996)

(Diabatic - No Diabatic) Simulation

200 hPa Heights and Winds



Stensrud (1996)

Contours: 20 m Barbs: 5 m/s

[96 hr from 00 UTC 11 May 1982]