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Regional Climate Models And Linkages to Agricultural Models

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Agriculture and Forestry GHG Modeling Forum

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Outline

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- Uncertainties about Climate Change
- The issue of spatial scale of scenarios - results of NARCCAP
- Applications to Agriculture Models
- Concluding Remarks

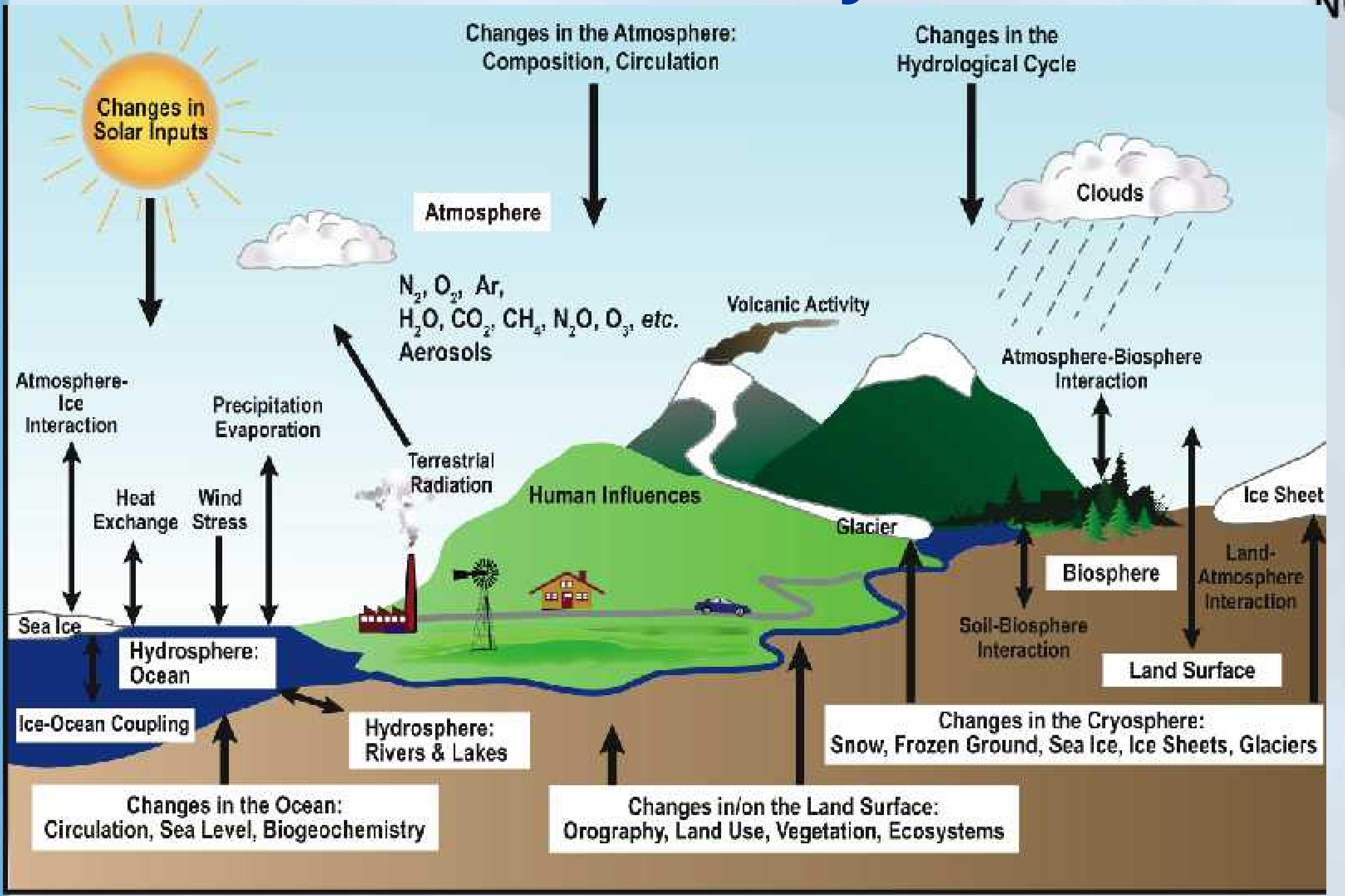
Uncertainties about Future Climate

- The future trajectory of emissions of greenhouse gases (based on uncertainties about how the world will develop economically, socially, politically, technologically)
  - Explored through the development of scenarios of future world development
- How the climate system responds to increasing greenhouse gases.
  - Explored through use of climate models
  - Spatial scale at which climate models are run is an additional source of uncertainty
- The natural internal variability of the climate system

Deep uncertainties we can't readily quantify

- Incomplete knowledge of physical processes
- Model structure (including important feedbacks within the climate system)
- Catastrophic extreme events - e.g., collapse of the Greenland Ice Sheet

The Climate System



System is simulated using climate models

North American Projections

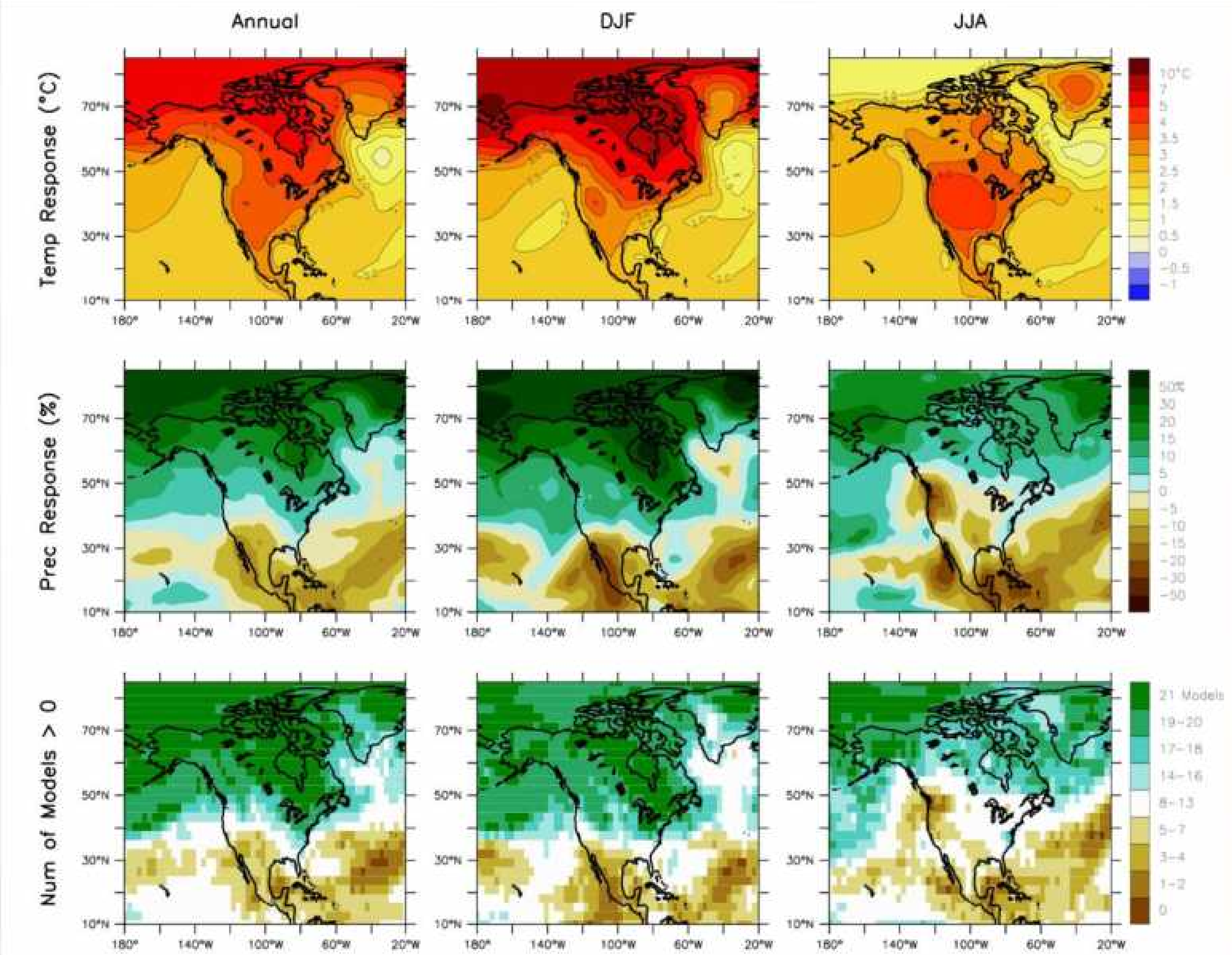
(end of 21st century,
assuming A1B scenario)

- Based on 21 global climate model results – expert judgment of model results
- Note model limitations (e.g., coarse spatial resolution of models, ~ 2 deg.)

IPCC, 2007, Christensen et al. , Chapter 11

Temperature and precipitation changes with model agreement

(2080-2099 minus 1980-1999) A1B Scenario

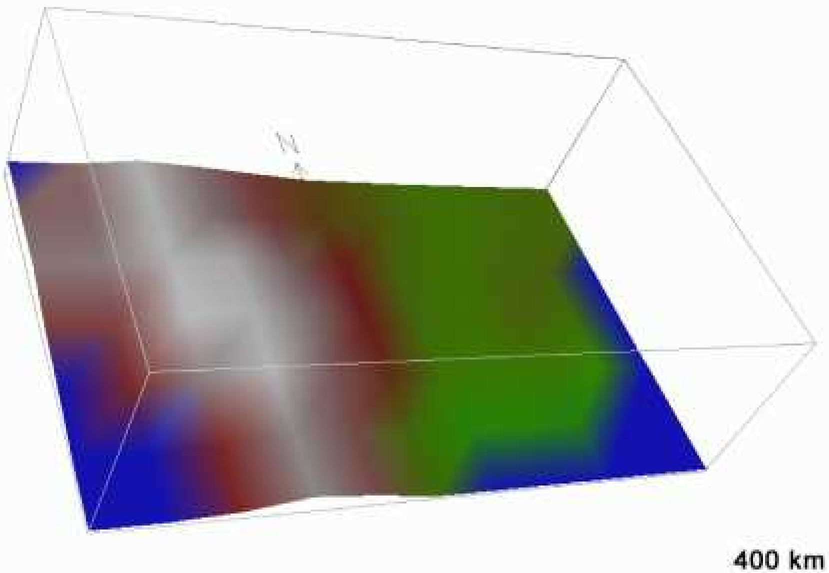


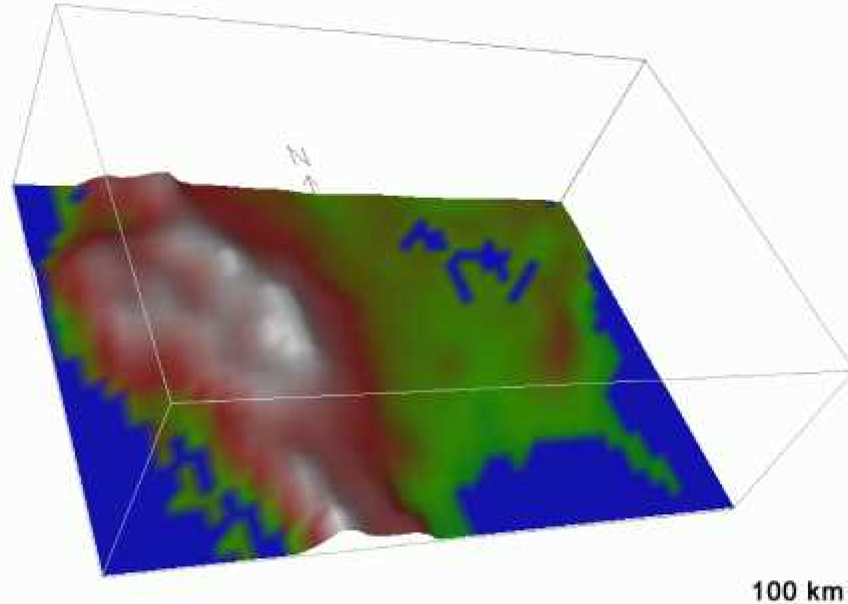
Uncertainty due to Spatial Scale of Climate Simulations

Dynamical Downscaling

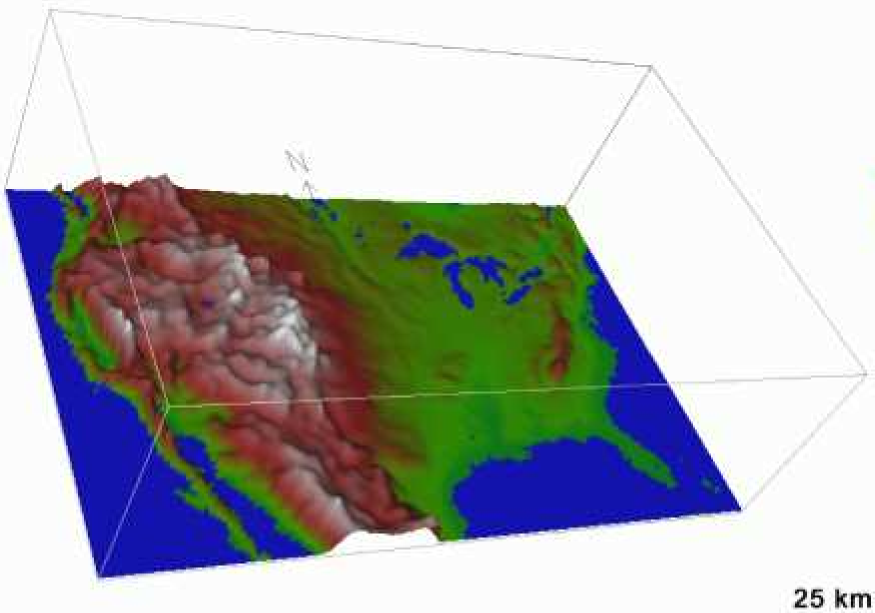
- What about higher resolution information about climate change?
- Global models run at about 200 km (120 mile) spatial resolution - what resolution do we need for adaptation purposes
- How to balance the desire for higher resolution with the other major uncertainties (future emissions, general response of climate system).

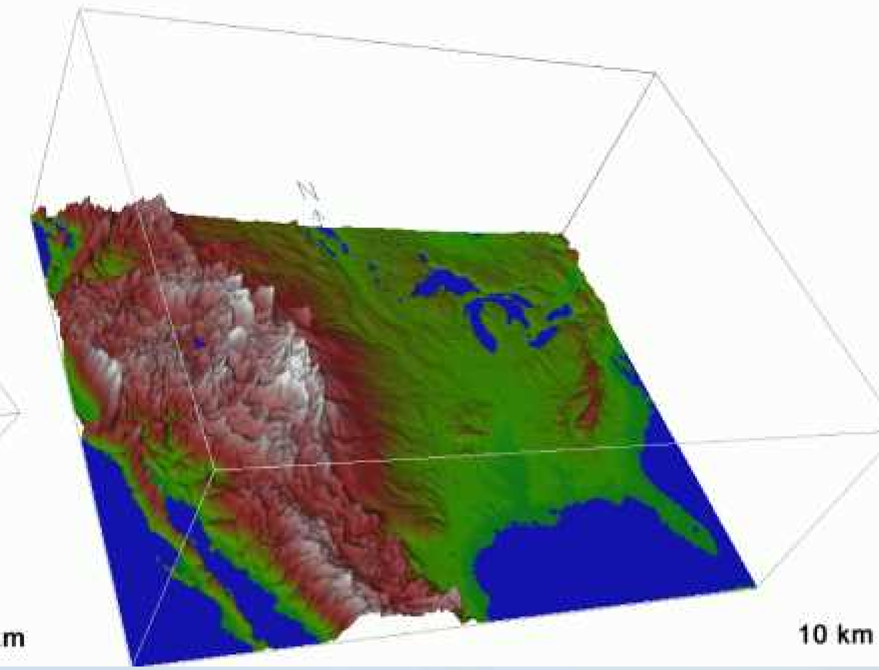
Global Climate Models





Regional models





What high resolution modeling is really useful for

In certain specific contexts, provides insights on realistic climate response to high resolution forcing (e.g. mountains)

Different Kinds of Downscaling

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- Simple (Giorgi and Mearns, 1991)
  - Adding coarse scale climate changes to higher resolution observations (the delta approach)
  - More sophisticated - interpolation of coarser resolution results (Maurer et al. 2002, 2007)
- Statistical
  - Statistically relating large scale climate features (e.g., 500 mb heights), predictors, to local climate (e.g, daily, monthly temperature at a point), predictands
- Dynamical
  - Application of regional climate model using global climate model boundary conditions
- Confusion can arise when the term ‘downscaling’ is used – could mean any of the above

Regional Modeling Strategy

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Nested regional modeling technique

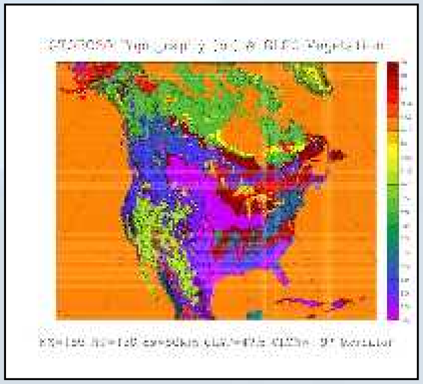
- Global model provides:
  - initial conditions – soil moisture, sea surface temperatures, sea ice
  - lateral meteorological conditions (temperature, pressure, humidity) every 6-8 hours.
  - Large scale response to forcing (100s kms)
- Regional model provides finer scale (10s km) response

The North American Regional Climate Change Assessment Program (NARCCAP)

www.narccap.ucar.edu

- Explores multiple uncertainties in regional and global climate model projections

  4 global climate models x 6 regional climate models



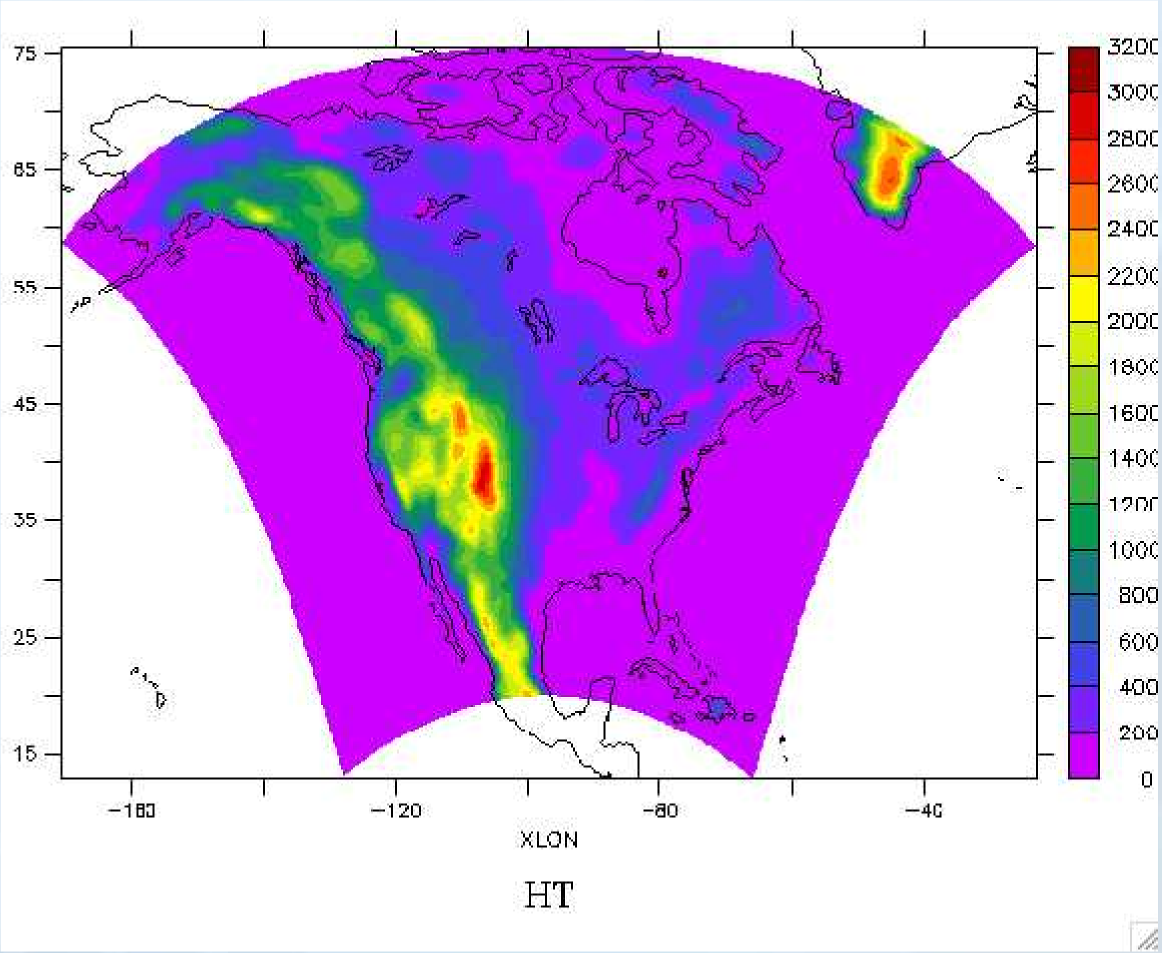
- Develops multiple high resolution regional (50 km, 30 miles) climate scenarios for use in impacts and adaptation assessments

- Evaluates regional model performance to establish credibility of individual simulations for the future

- Participants: Iowa State, PNNL, LNNL, UC Santa Cruz, Ouranos (Canada), UK Hadley Centre, NCAR

- Initiated in 2006, funded by NOAA-OGP, NSF, DOE, USEPA-ORD – 5-year program

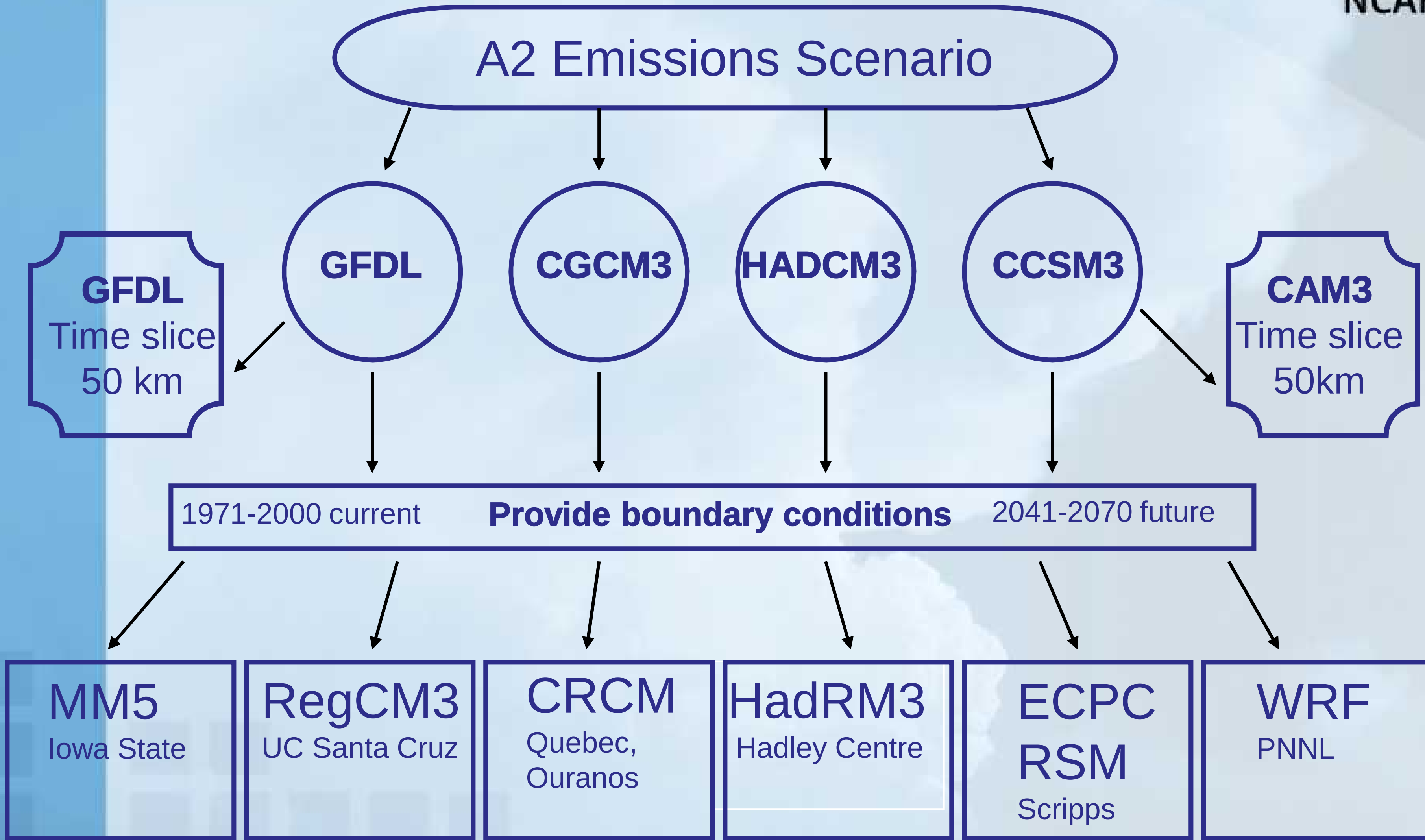
NARCCAP Domain



Organization of Program

- Phase I: 25-year simulations using NCEP-Reanalysis boundary conditions (1980—2004)
- Phase II: Climate Change Simulations
  - Phase IIa: RCM runs (50 km res.) nested in AOGCMs current and future
  - Phase IIb: Time-slice experiments at 50 km res. (GFDL and NCAR CAM3). For comparison with RCM runs.
- Quantification of uncertainty at regional scales – probabilistic approaches
- Scenario formation and provision to impacts community led by NCAR.
- Opportunity for double nesting (over specific regions) to include participation of other RCM groups (e.g., for NOAA OGP RISAs, CEC, New York Climate and Health Project, U. Nebraska).

NARCCAP PLAN – Phase II



AOGCM-RCM Matrix

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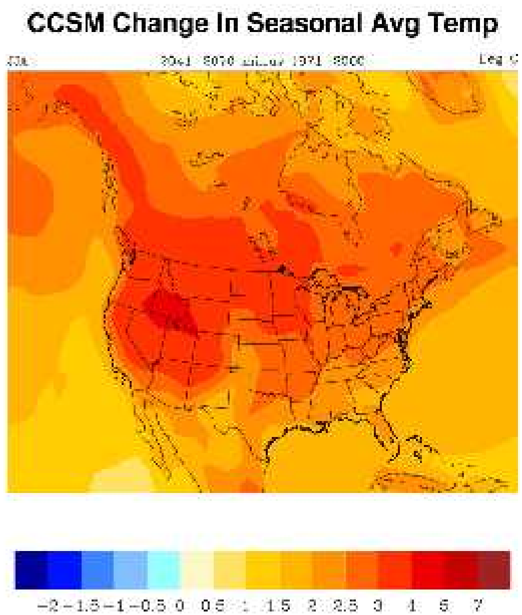
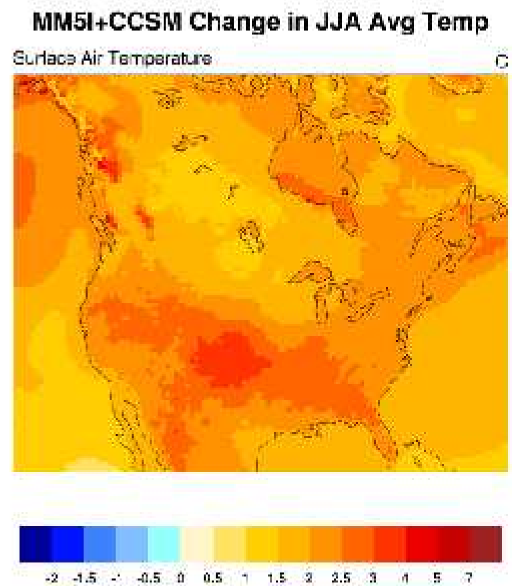
AOGCMS

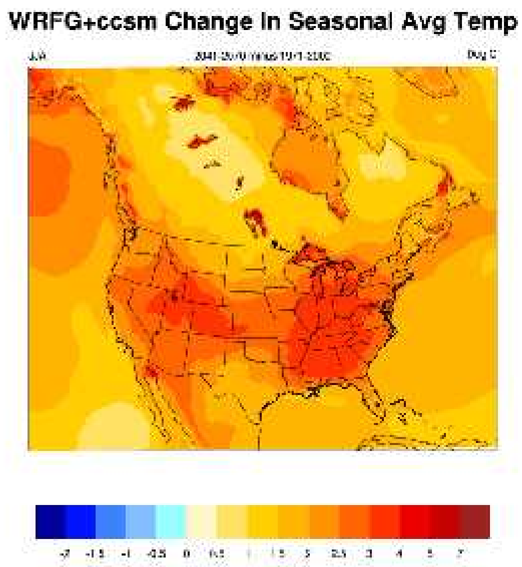
RCMs

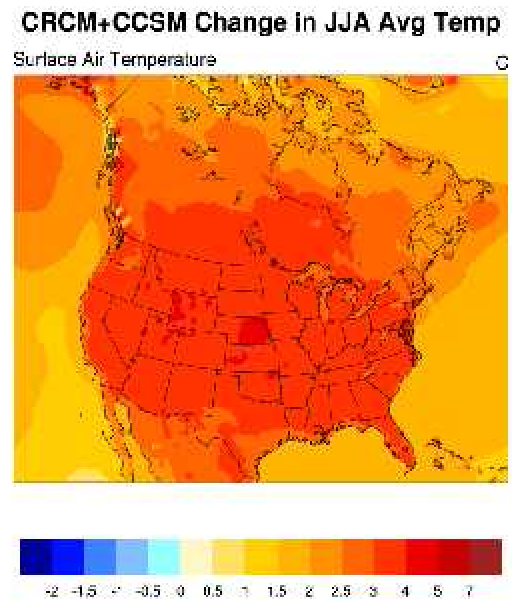
	GFDL	CGCM3	HADCM3	CCSM3
MM5			X	X1**
RegCM	X1**	X**		
CRCM		X1**		X**
HadRM	X		X1**	
RSM	X1		X	
WRF		X**		X1**
*CAM3				X
*GFDL	X**			

1 = chosen first GCM
*= time slice experiments
Red = run completed
** = data loaded



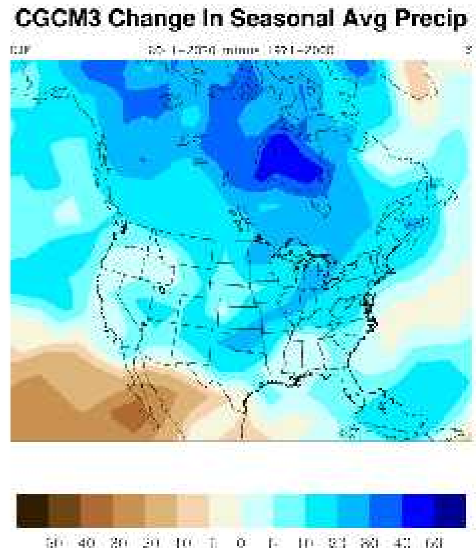




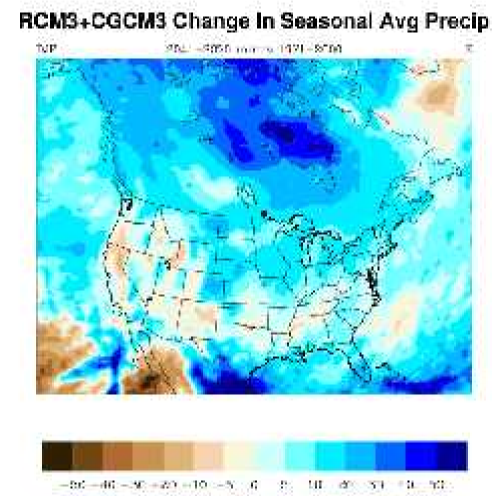


CCSM-driven change in summer temperature

CGCM3 – Global



RegCM3



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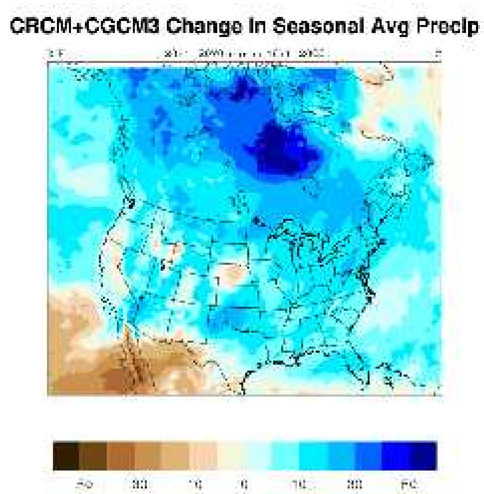
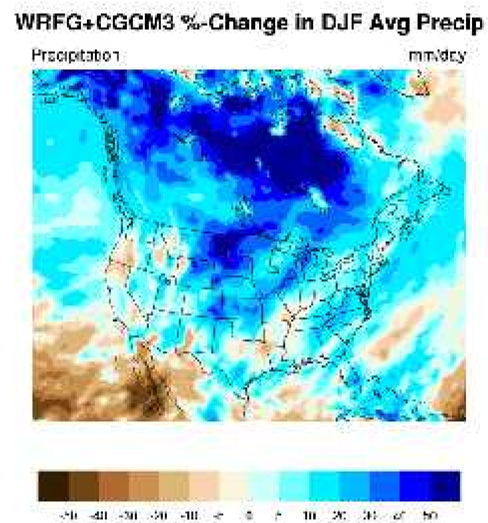
CGCM-driven % Change in Winter Precipitation

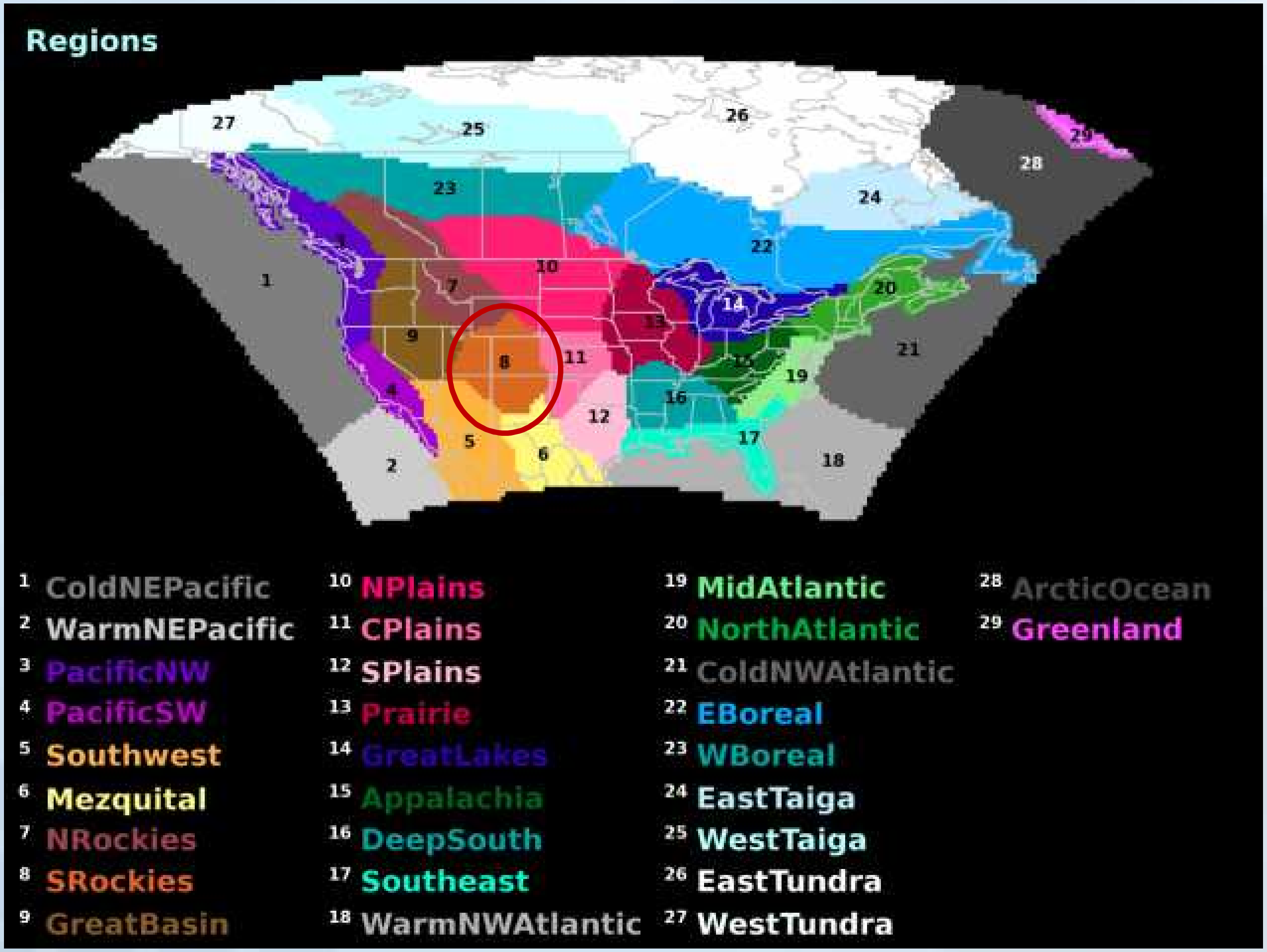
CRCM



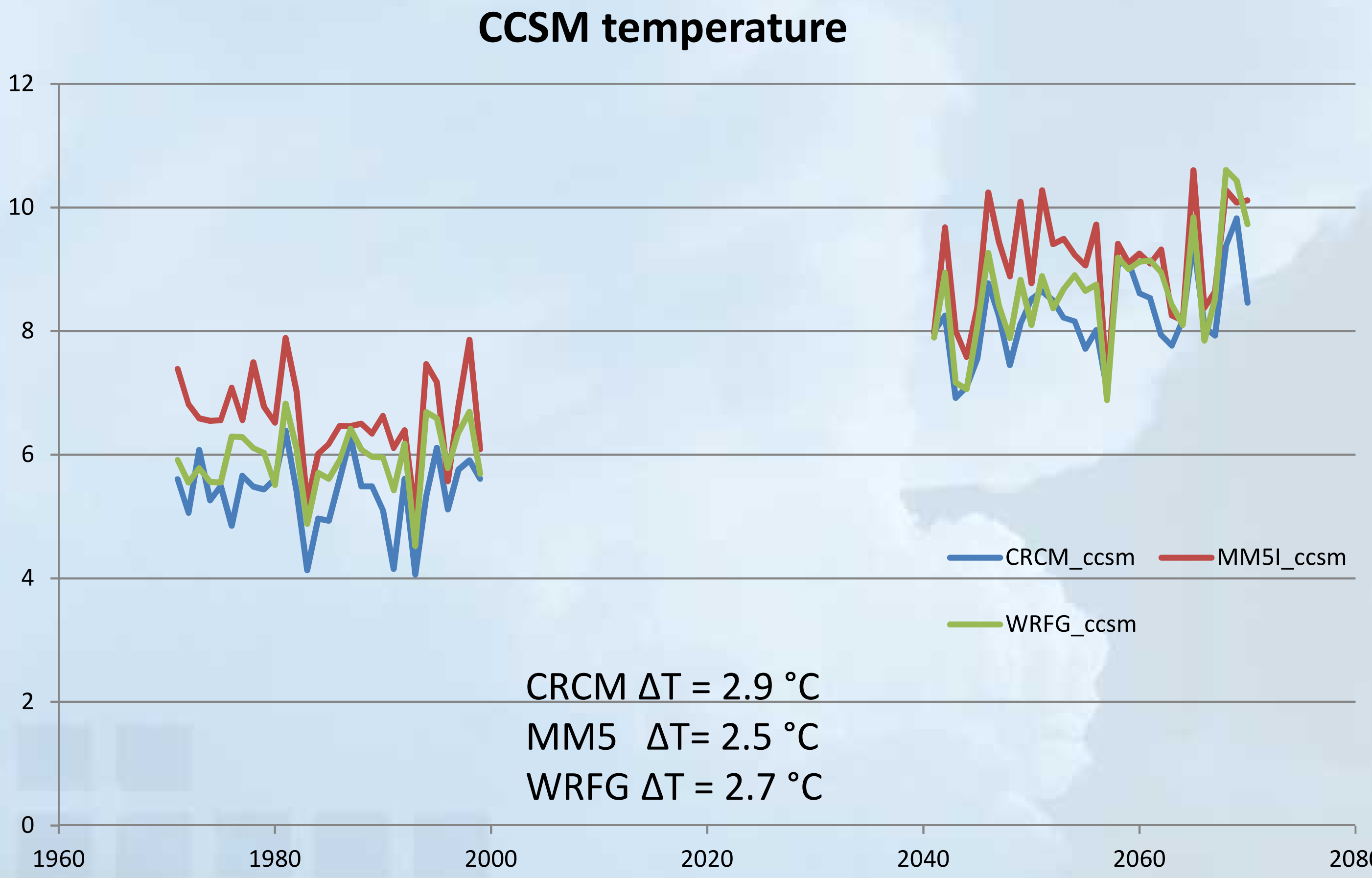


WRFG

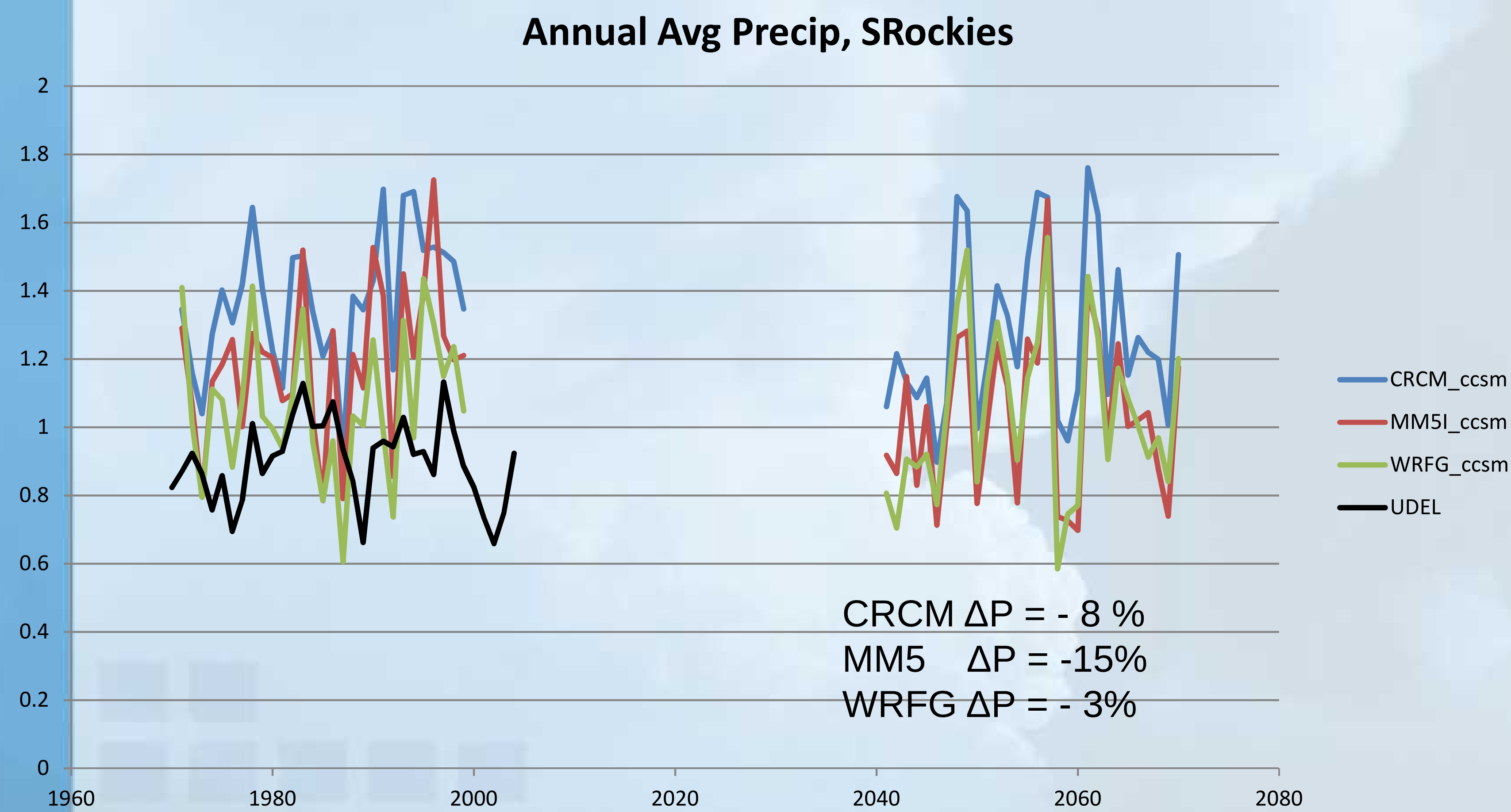
Bukovsky Regions



South Rocky Mountain Region



Southern Rockies



Application to Agricultural Models

The ‘Mismatch’ of Scale Issue

“Most GCMs neither incorporate nor provide information on scales smaller than a few hundred kilometers. The effective size or scale of the ecosystem on which climatic impacts actually occur is usually much smaller than this. We are therefore faced with the problem of estimating climate changes on a local scale from the essentially large-scale results of a GCM.”

Gates (1985)

“One major problem faced in applying GCM projections to regional impact assessments is the coarse spatial scale of the estimates.”

Carter et al. (1994)

‘downscaling techniques are commonly used to address the scale mismatch between coarse resolution GCMs … and the local catchment scales required for … hydrologic modeling’

Fowler and Wilby (2007)

Selected RCM Impacts

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- Mearns et al., 2001 - application to corn, wheat, and soybeans in Great Plains
- Mearns et al., 1999 – Great Plains – comparison of different crop models
- Oleson et al., 2007 – maize suitability – (combined uncertainties)
- Qian et al., 2011 – using regional climate models in crop modeling

Uncertainty due to spatial scale of scenario

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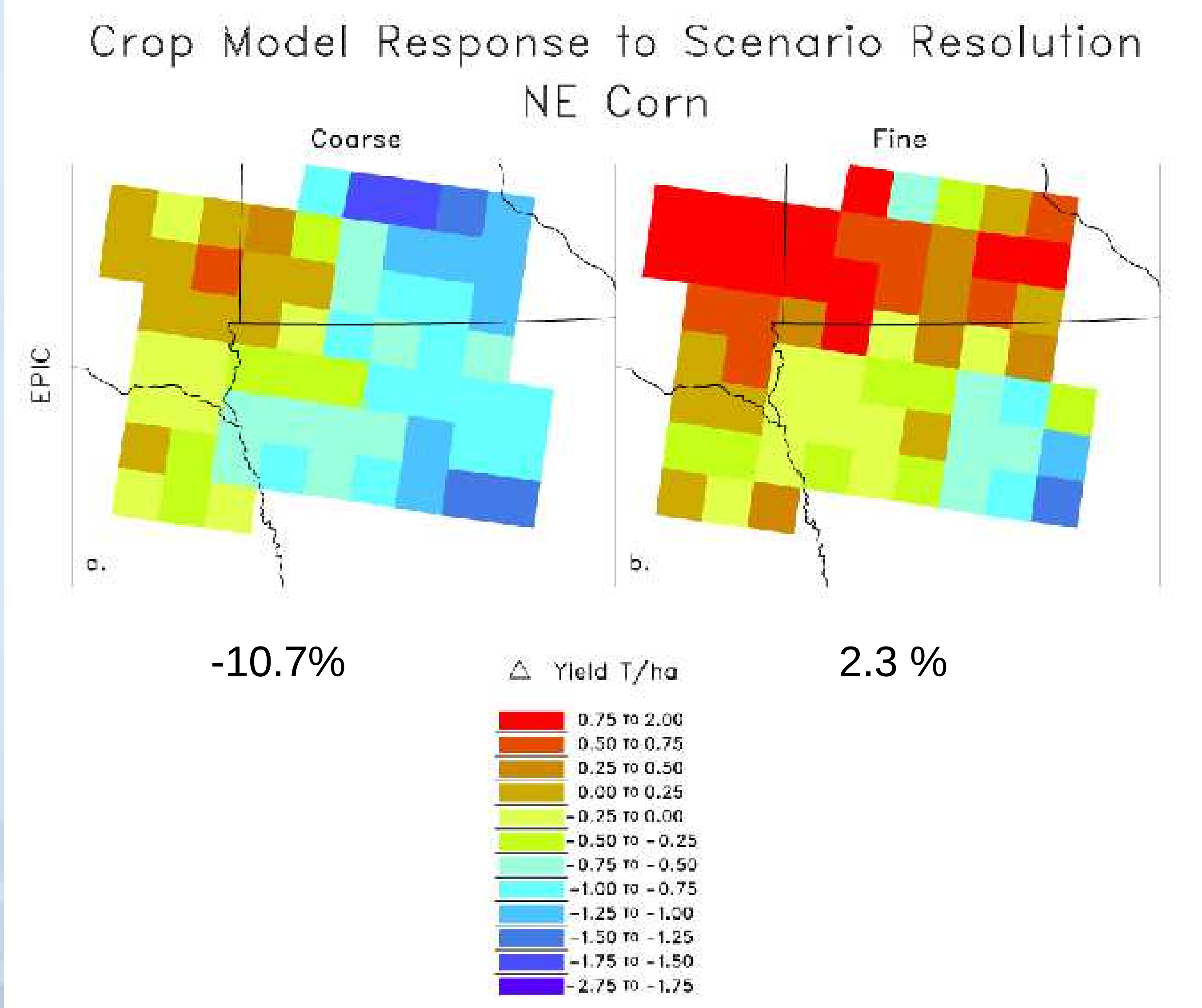
GCM

RCM

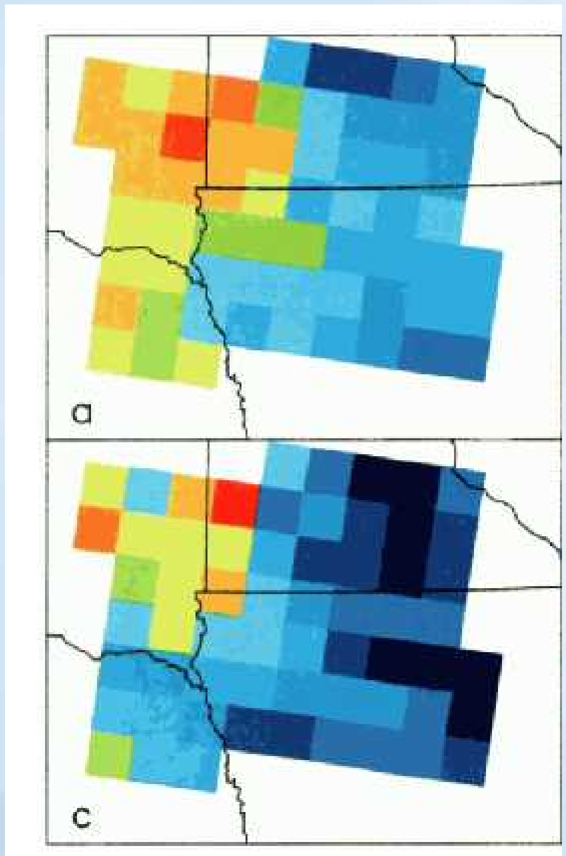


Mearns et al., 2001

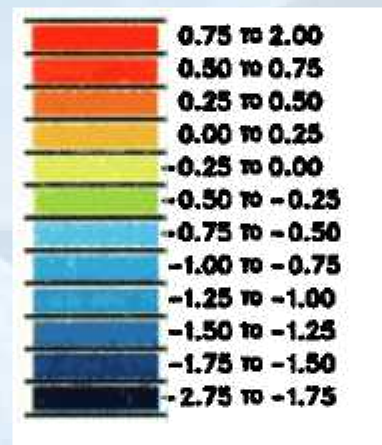
Uncertainty of Impacts Models Agriculture – Corn

EPIC Model

CERES Model



Change in Yield T/ha



CSIRO Coarse Scenario

Mearns et al., 1999

Combined Uncertainties - GCMs, RCMs, Emissions

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Oleson et al., 2007, Suitability for Maize cultivation

Based on PRUDENCE Experiments over Europe

Uncertainties in projected impacts of climate change on European agriculture and terrestrial ecosystems based on scenarios from regional climate models

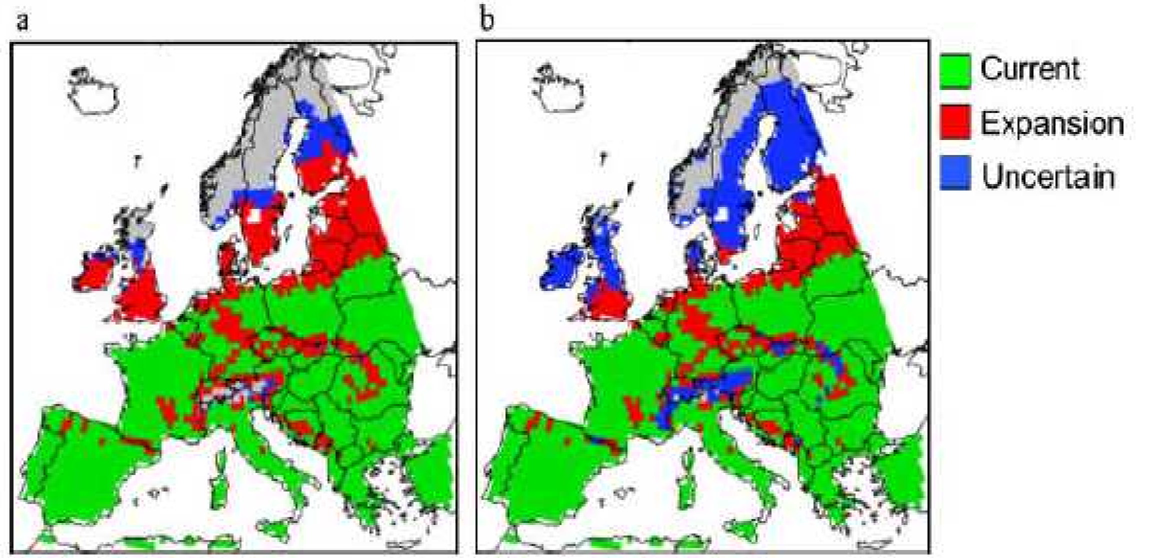

Fig. 4 Modelled suitability for grain maize cultivation during the baseline (1961–1990) and future (2071–2100) periods for: a 7 RCM scenarios driven by HadAM3H for the A2 emissions scenario and b 24 scenarios from 6 GCMs for each of the A1FI, A2, B1 and B2 emissions scenarios. *Green areas* show the suitable area for the baseline, *red* depicts the expansion common under all scenarios and *blue* the uncertainty range of the respective scenario group. *Grey areas* are unsuitable under all scenarios

a. 7 RCMs, one Global model, one emission scenario
b. 24 scenarios, 6 GCMs, 4 emission scenarios

Conclusion: uncertainty across GCMs (considering large number of GCMs) X emissions scenarios larger than across RCMs, BUT uncertainty from RCMs larger than uncertainty from only GCMs used in PRUDENCE

Canadian Crop Model Study

- Uses results from two of the NARCCAP RCMs – CRCM driven by CGCM3; HadRM3 driven by HadCM3
- Applied to DSSAT crop models (cereals, soybeans, potatoes)
- 7 locations in Canada
- Evaluates use of direct RCM output in crop modeling

Qian et al., 2011

Yield Comparisons (T/ha)

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Location	Obs.	C R2	C Raw	C Bias Corr	H R2	H Raw	H Bias Corr
Agassiz (potato)	7.3	6.6	3.8*	7.9	2.9*	3.6*	6.2
Beaver lodge (barley)	3.2	2.0*	1.3*	3.0	2.7	1.3*	2.8
Winnepeg Sp wheat	3.4	3.1	2.1*	3.0	1.8*	3.3	3.2
London soybean	1.9	1.3*	1.4*	1.9	1.9	2.4*	2.0
Montreal (corn)	6.1	7.9*	2.2*	6.2	5.2	6.3	6.2
Charlotte Town (potato)	8.4	10.8*	9.2	8.7	9.5	9.0	8.8

Concluding Remarks

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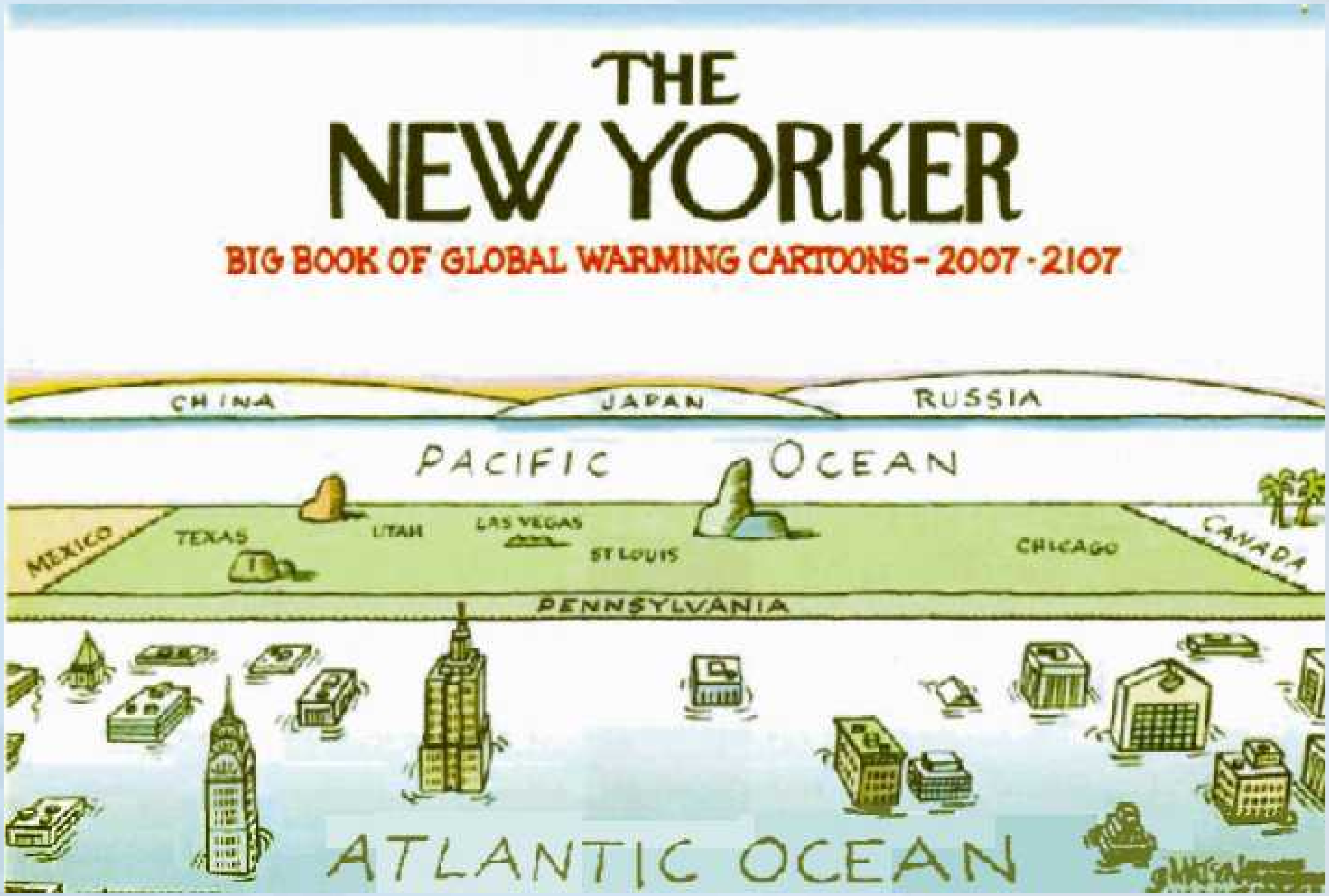
- Spatial scale of climate information about the future is an important factor in determining the impacts of climate change on agriculture
- But, there a number of choices to be made on how one attains higher resolution
- Still a lot of work remains in establishing that higher resolution information from RCMs is more credible than other means of downscaling
- Importance of placing uncertainty related to scale in context of other uncertainties about climate change

The End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