Overview of Coordinated Projects to Develop Regional Climate Change Scenarios

L. Ruby Leung
Pacific Northwest National Laboratory

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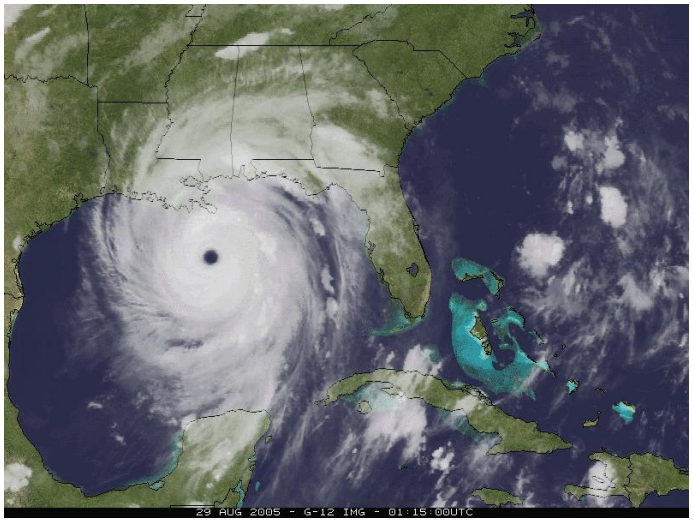
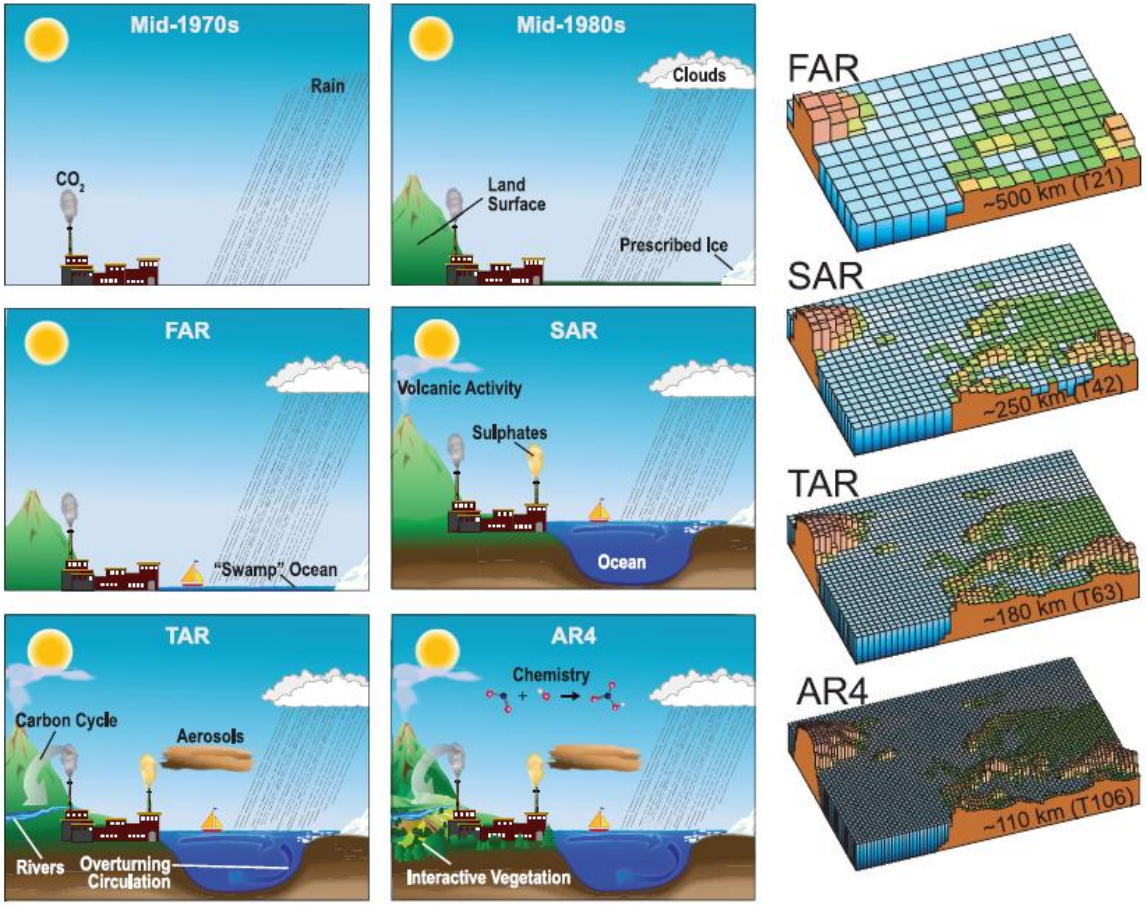
Challenges in predicting regional climate change

- Precipitation is a key variable linking physical, chemical, and biological processes, and a key driver of environmental impacts for assessing climate change impacts

- Precipitation is a result of multi-scale processes (e.g., large scale circulation, cloud, turbulence) - spatial resolution really matters



The Climate Modeling Dilemma:
Complexity vs Resolution



Source: IPCC 2007

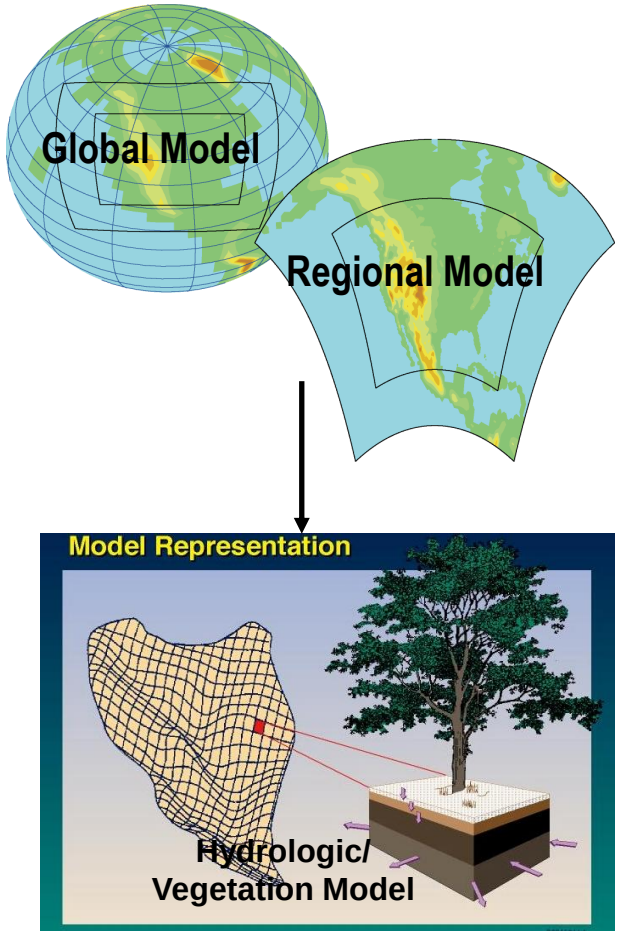
Tianhe-1A (2.57 petaflops)

Jaguar (1.76 petaflops)

Regional Models are used:

- To provide a framework to better integrate measurements that are typically made at the local/regional scale to improve climate models
- To study regional climate processes (e.g., hypothesis testing)
- To dynamically downscale global climate simulations

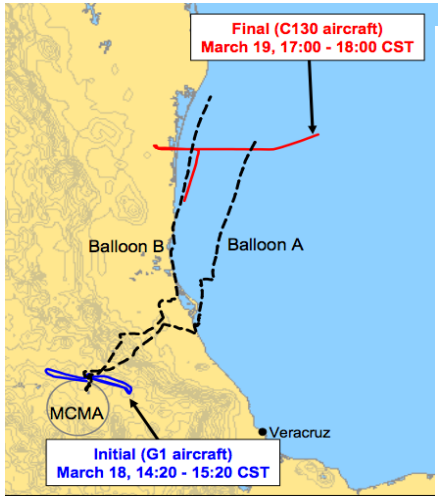
Dynamical Downscaling

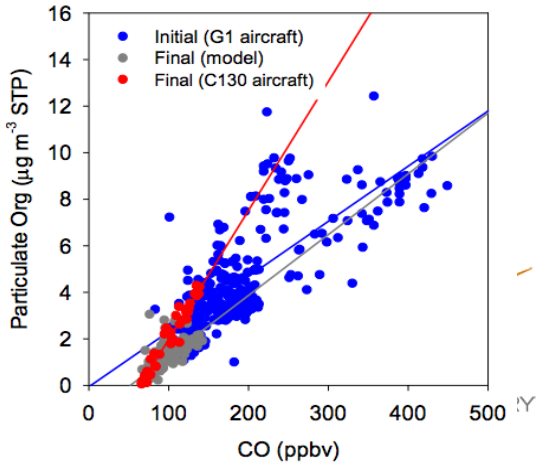


From measurements to modeling

Photo of Particulates over Mexico City

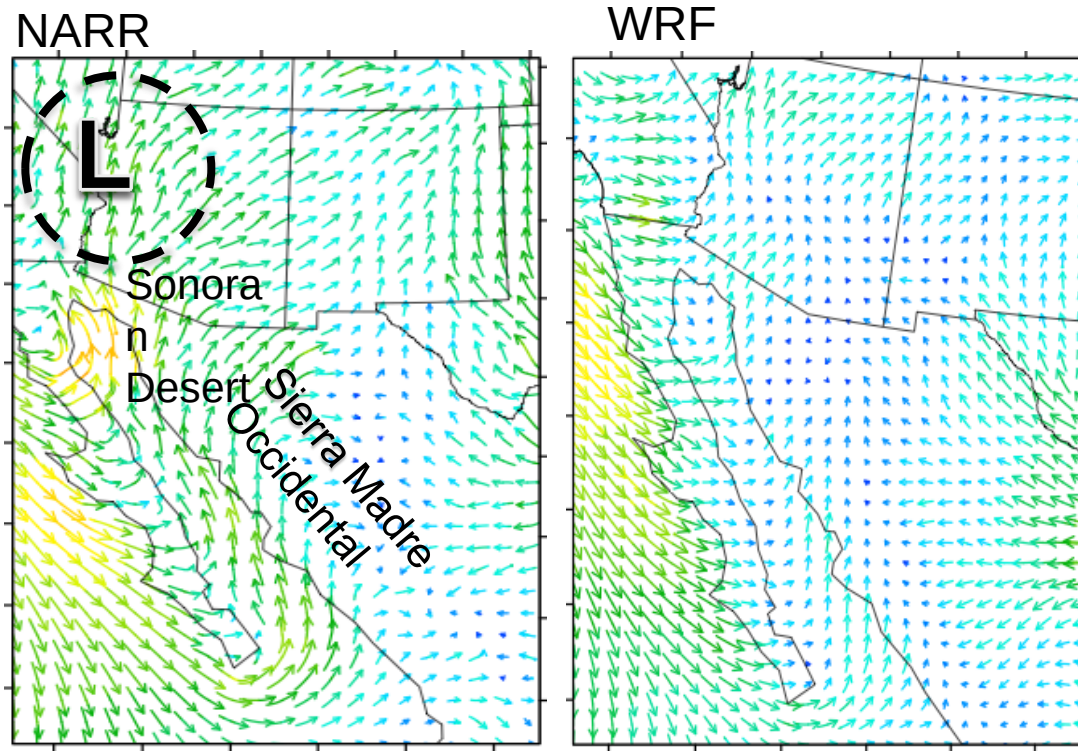
Lagrangian Air Parcel Modeling

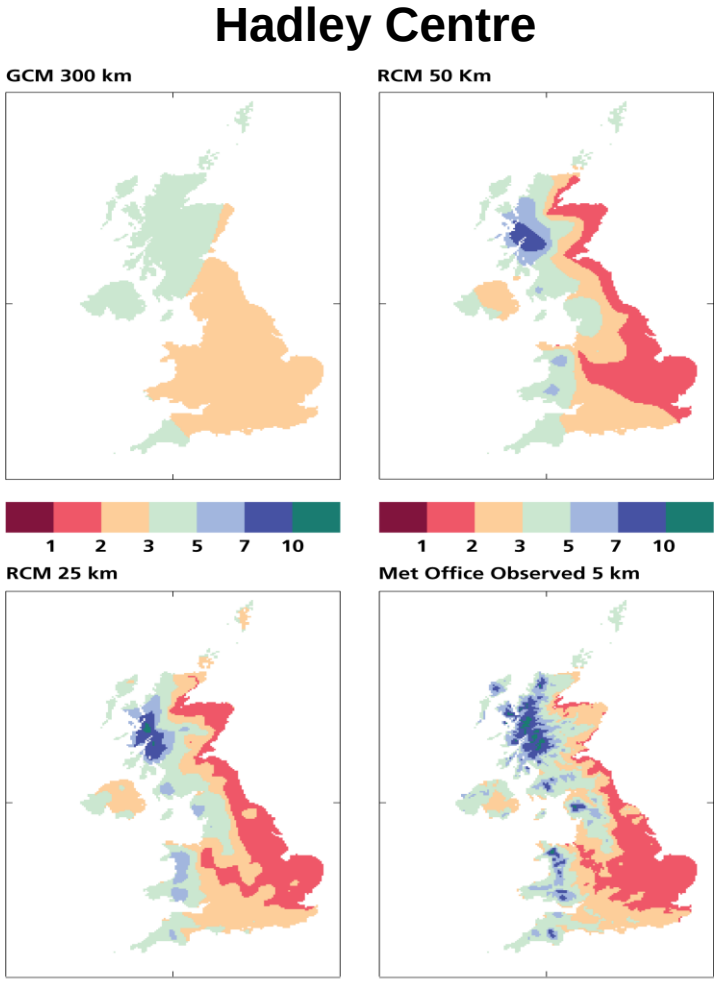




In dynamical downscaling, where do we expect regional models to add value

- Better resolved land surface heterogeneity (e.g., mountains, lakes, and coastlines) and its influence on climate
  - More accurate simulations of spatial variability

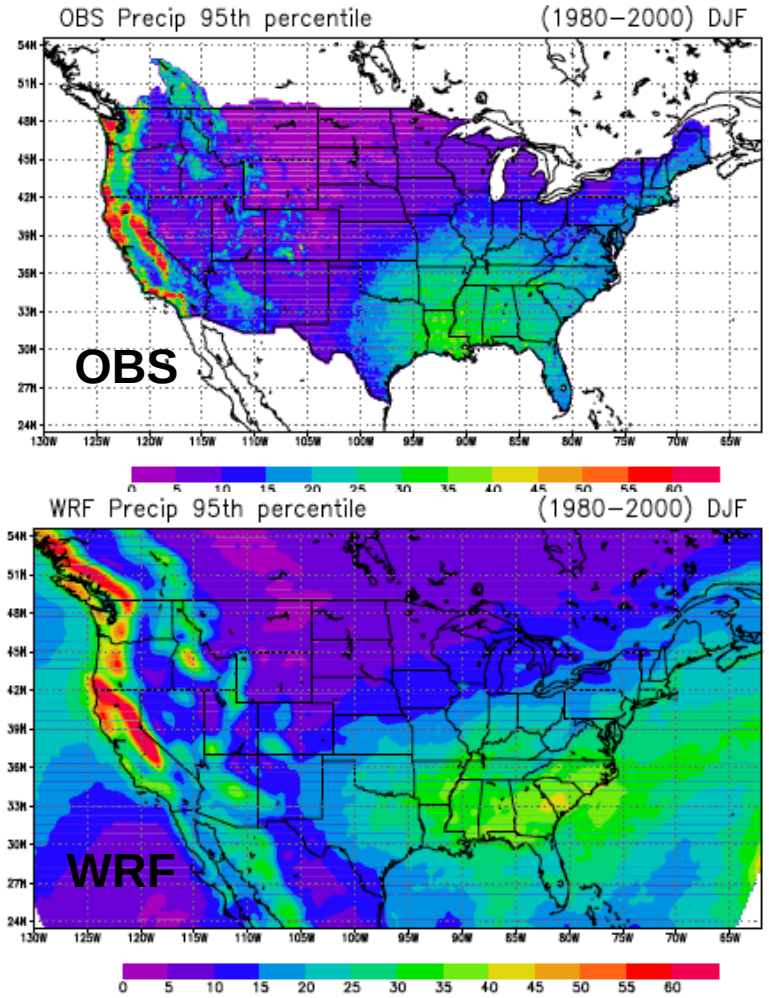




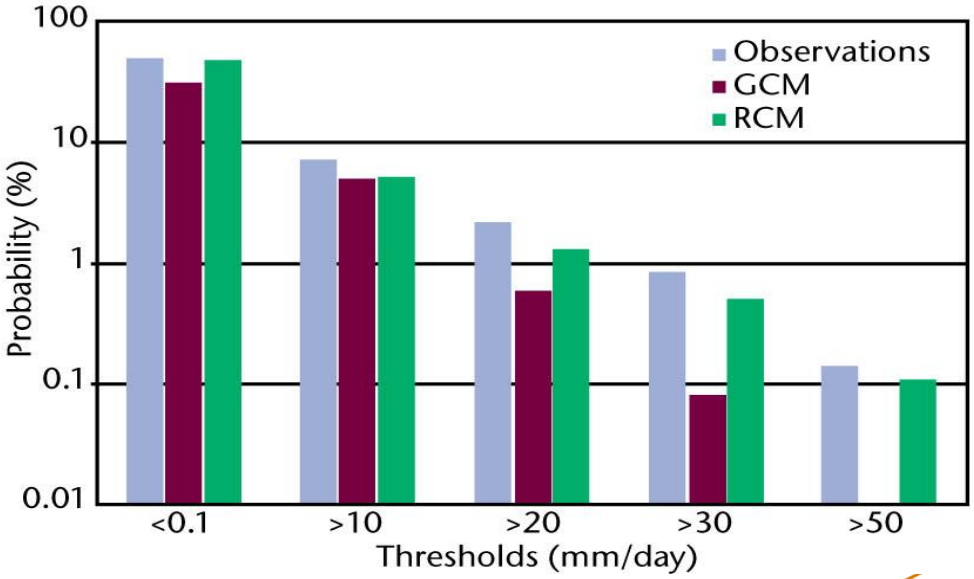
In dynamical downscaling, where do we expect regional models to add value

- Better resolved finer scale processes (e.g., LLJ, hurricane)
  - More accurate simulations of extreme statistics

95th Percentile Daily Precipitation (DJF)



Daily rainfall intensity over the Alps



UKMet: HadCM3

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Coordinated Projects to Develop Regional Climate Change Scenarios

- Climate models have been used to assess climate change for a few decades, but large uncertainties remain in projecting climate change at the regional scale

- Several international projects have been designed to use a multi-model approach to develop regional climate change scenarios

- Programs such as PRUDENCE, ENSEMBLES, NARCCAP, CLARIS address some of the following research questions
  - How do we best assess the quality of models? How should metrics be appropriately defined?
  - How can we make use of the ensembles of projections?

ENSEMBLES A1B GCM-RCM Matrix 30/11/2009 (!)

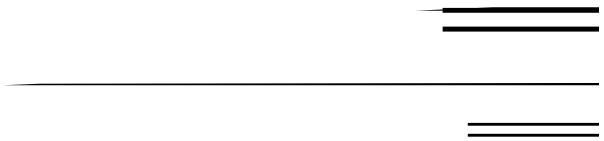
Global model / Regional inst.	METO-HC Standard	METO-HC Low sens.	METO-HC Hi sens.	MPIMET Standard	MPIMET Ens.m. 1	MPIMET Ens.m. 2	IPSL	CNRM	NERSC	MIROC	CGCM3	Total number
METO-HC	2100	2100*	2100*	2100 (??)								4
MPIMET				2100			2050* (06/2009)					2
CNRM								2100				1
DMI				2100*				2100	2100* (01/2010)			3
ETH	2100											1
KNMI				2100* 2100	2100*	2100*				2100*		1+4
ICTP				2100								1
SMHI		2100*		2100* 2100*					2100			3+1
UCLM	2050											1
C4I			2100*	2050 (A2)*								2
GKSS							2050*					1
METNO	2050*								2050*			1
CHMI								2050* (12/2009)				1
OURANOS**											2050*	1
VMGO**	2050*											1
Total (1951-2050)	5	2	2	7+2	0+1	0+1	2	3	3	0+1	1	25+5

Red: Online now; *: non-contractual runs; **:affiliated partners without obligations; underscore: 50km resolution; (in parantheses): Expected date

ERA40 (1958-2002) experiments exists for all models

Methods to Assess Skill and Apply Weighting

- Six metrics were identified based on ERA40-driven runs
  - F1: Large scale circulation and weather regimes (CNRM)
  - F2: Temperature and precipitation mesoscale signal (ICTP)
  - F3: PDFs of daily precipitation and temperature (DMI, UCLM,SHMI)
  - F4: Temperature and precipitation extremes (KNMI; HC)
  - F5: Temperature trends (MPI)
  - F6: Temperature and precipitation annual cycle (CUNI)

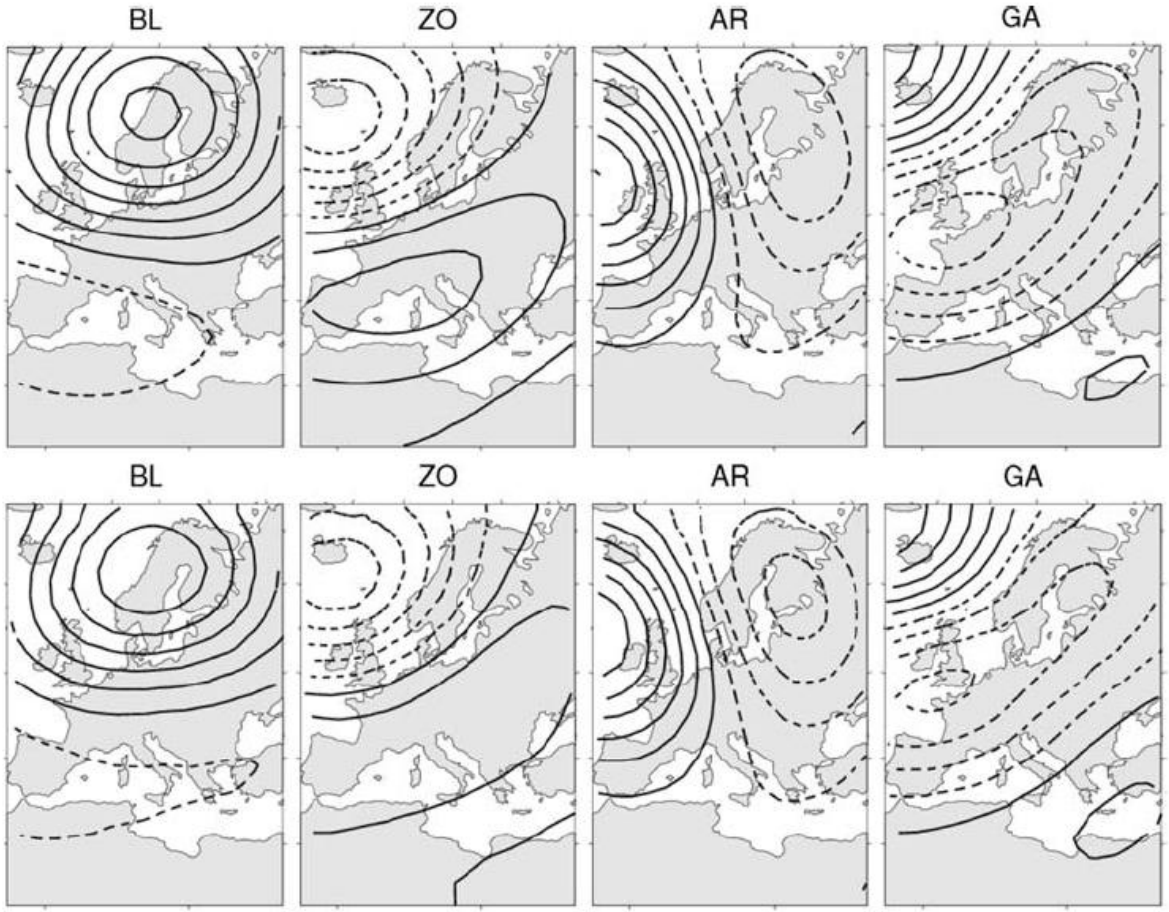


Example: Large-Scale Circulation and Weather Regimes

- The spatial composite, frequency, and persistence of each dominant weather regime in Europe are well simulated by the RCMs driven by global reanalysis

ERA40

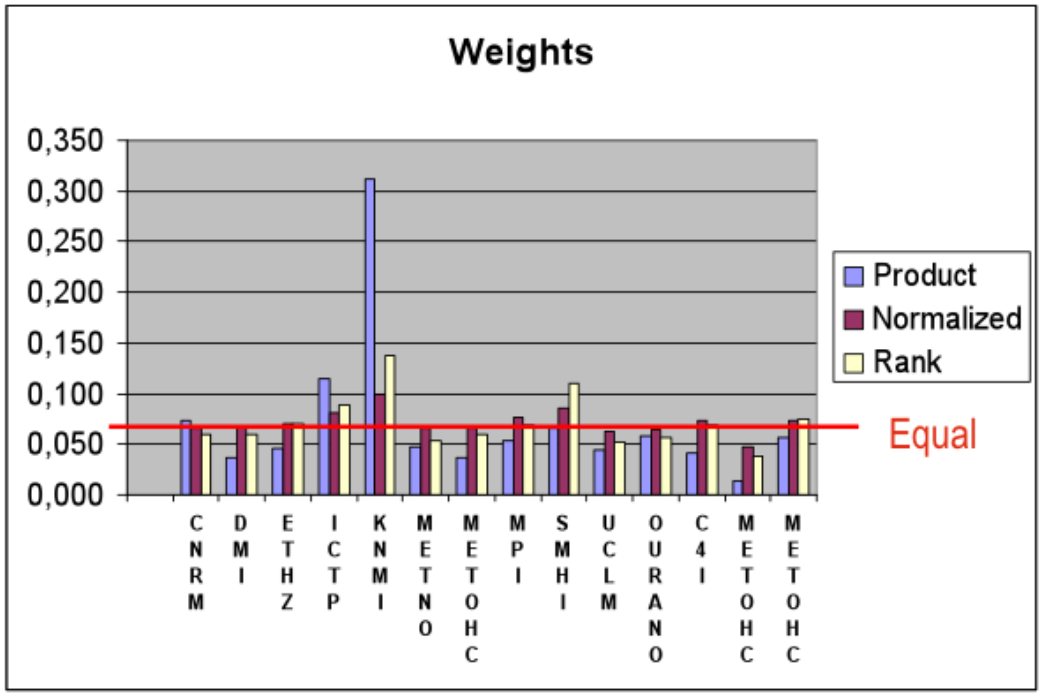
CNRM



Sanchez-Gomez et al. (2009)

Weighting of models

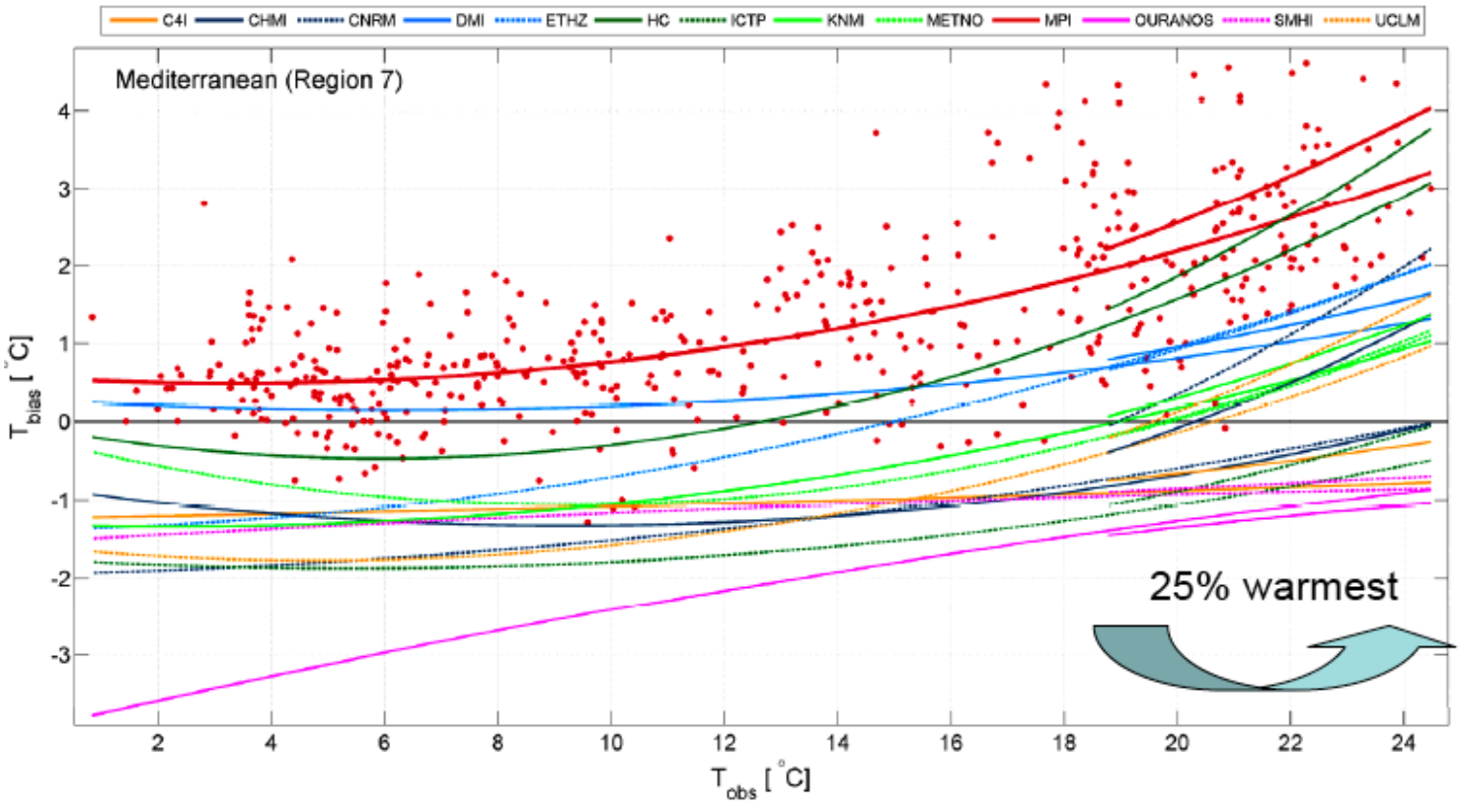
- Contribution from a single metric can dominate the overall weights (e.g., KNMI and DMI); normalization can be done based on inter-model spread in metrics
- Metrics for GCM simulations should be included in the overall GCM/RCM matrix of simulations of current and future climate
- The weighting is inevitably subjective – need to evaluate the sensitivity of the overall weights to the criteria used to derive them



Source: J. Christensen

Nonlinear Bias

- What are the implications of the nonlinear bias for assessing climate change



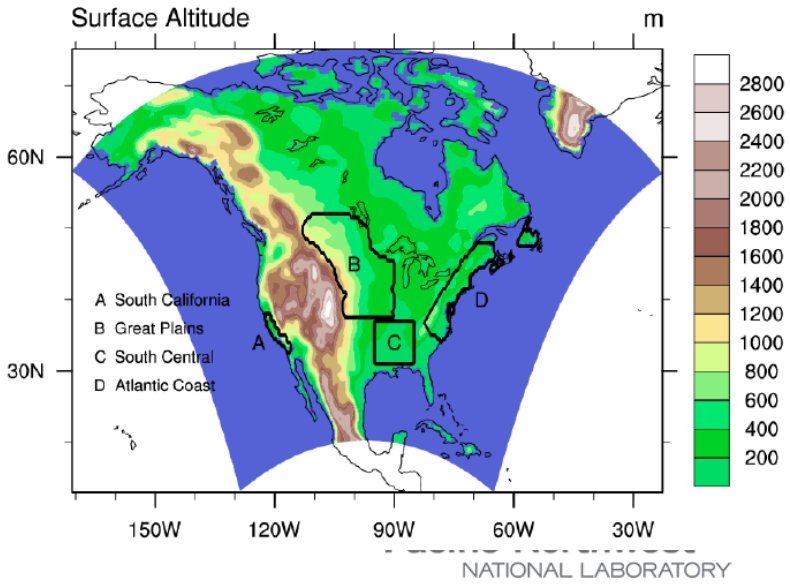
(Christensen *et al.* 2008)

NARCCAP: North American Regional Climate Change Assessment Program

- NARCCAP adopted a balanced fractional factorial design to sample the full 4 × 6 matrix, thus producing 12 different simulations
- Each RCM used one of the GCMs that has a corresponding time slice experiment
- A Bayesian probabilistic approach is used to characterize the joint uncertainty in multi-model ensembles on a regional scale for T and P

Matrix of GCM and RCM experiments

	GFDL	CGCM3	HadCM3	CCSM3
MM5			X	X
RegCM3	X	X		
CRCM		X		X
HadRM3	X		X	
RSM	X		X	
WRF		X		X
CAM3*				X
AM2.1 *	X			



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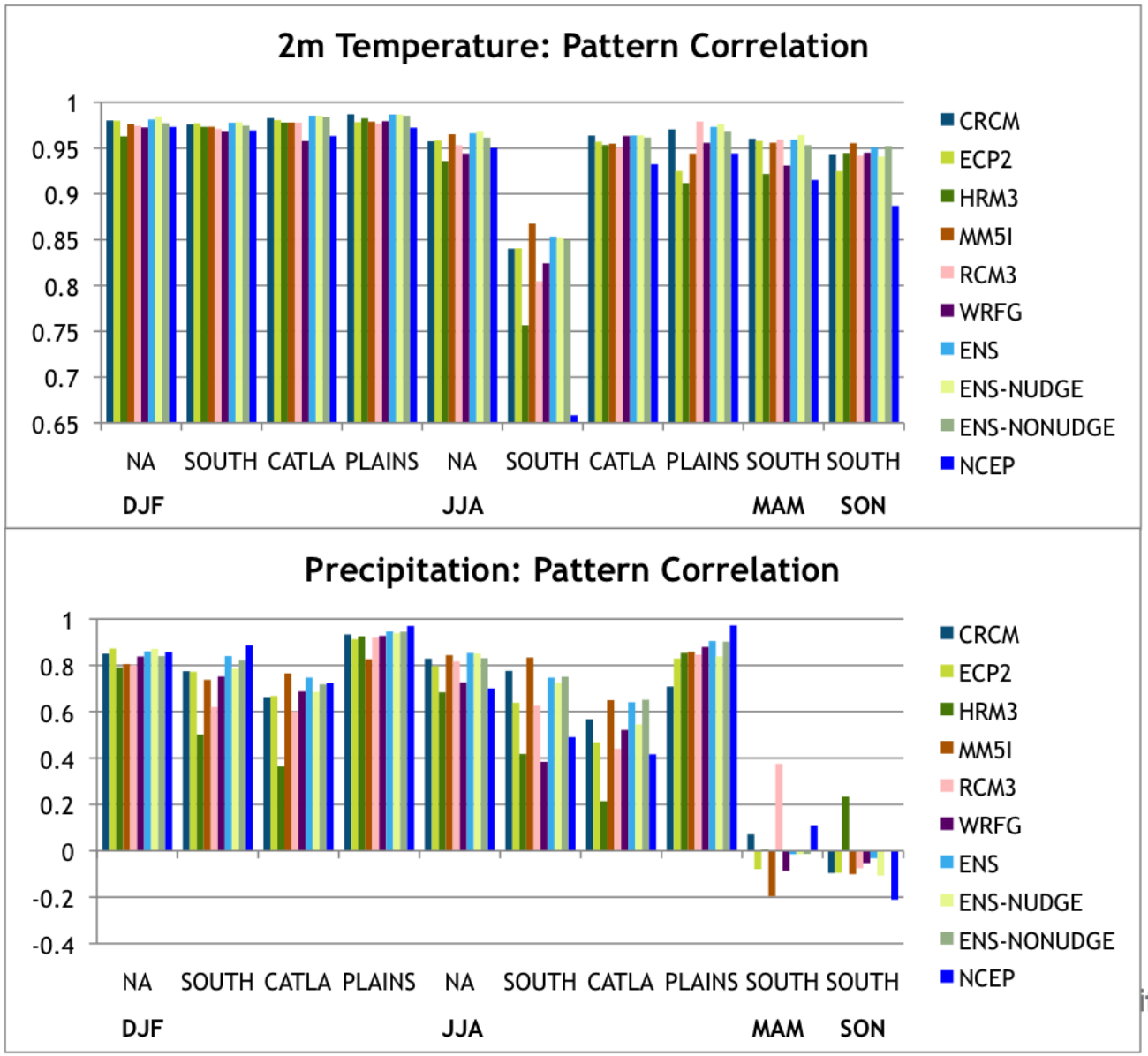
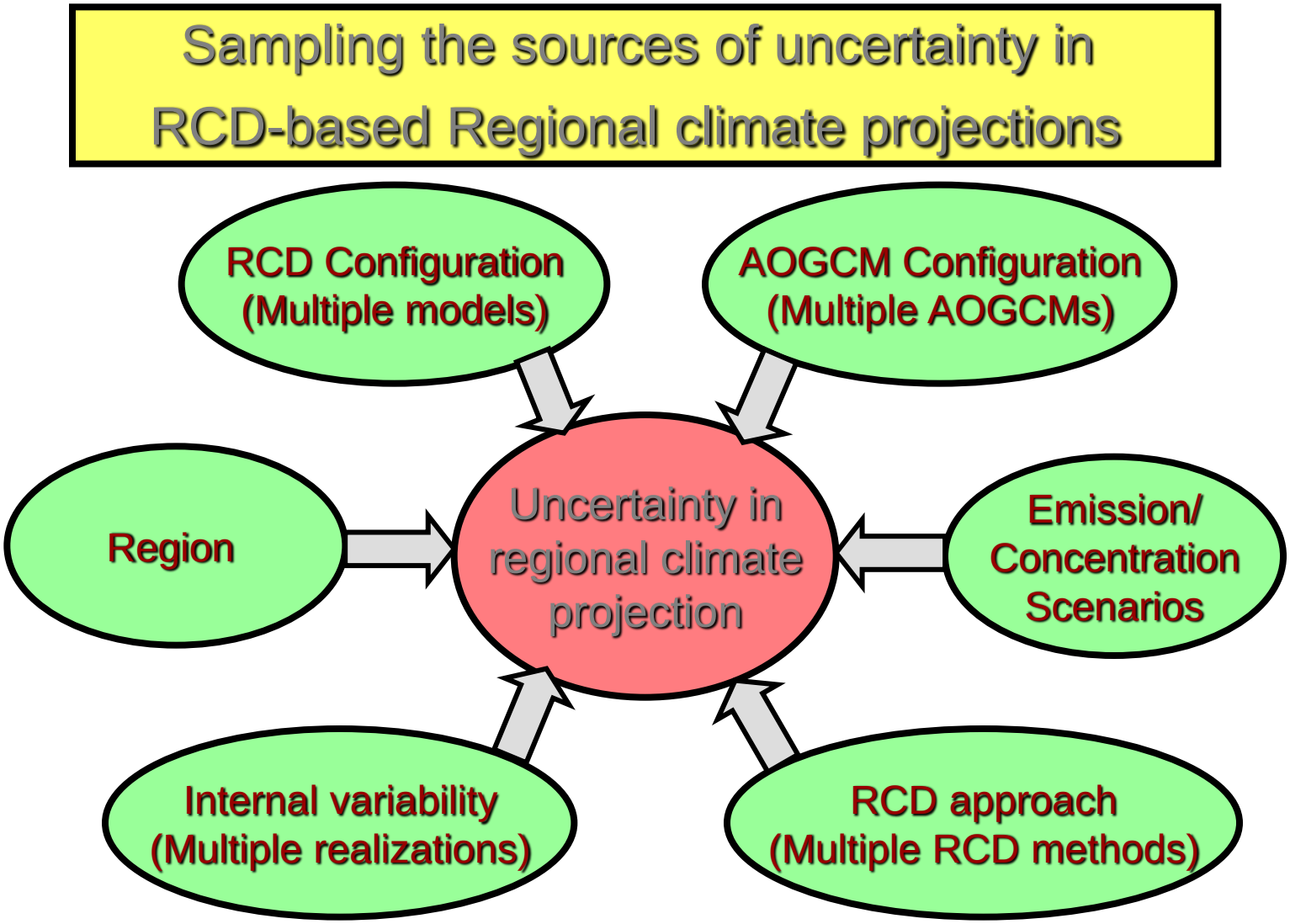
NARCCAP Reanalysis Driven Runs



CORDEX: Coordinated Downscaling Experiment



Co-Leads: Colin Jones and Filippo Giorgi

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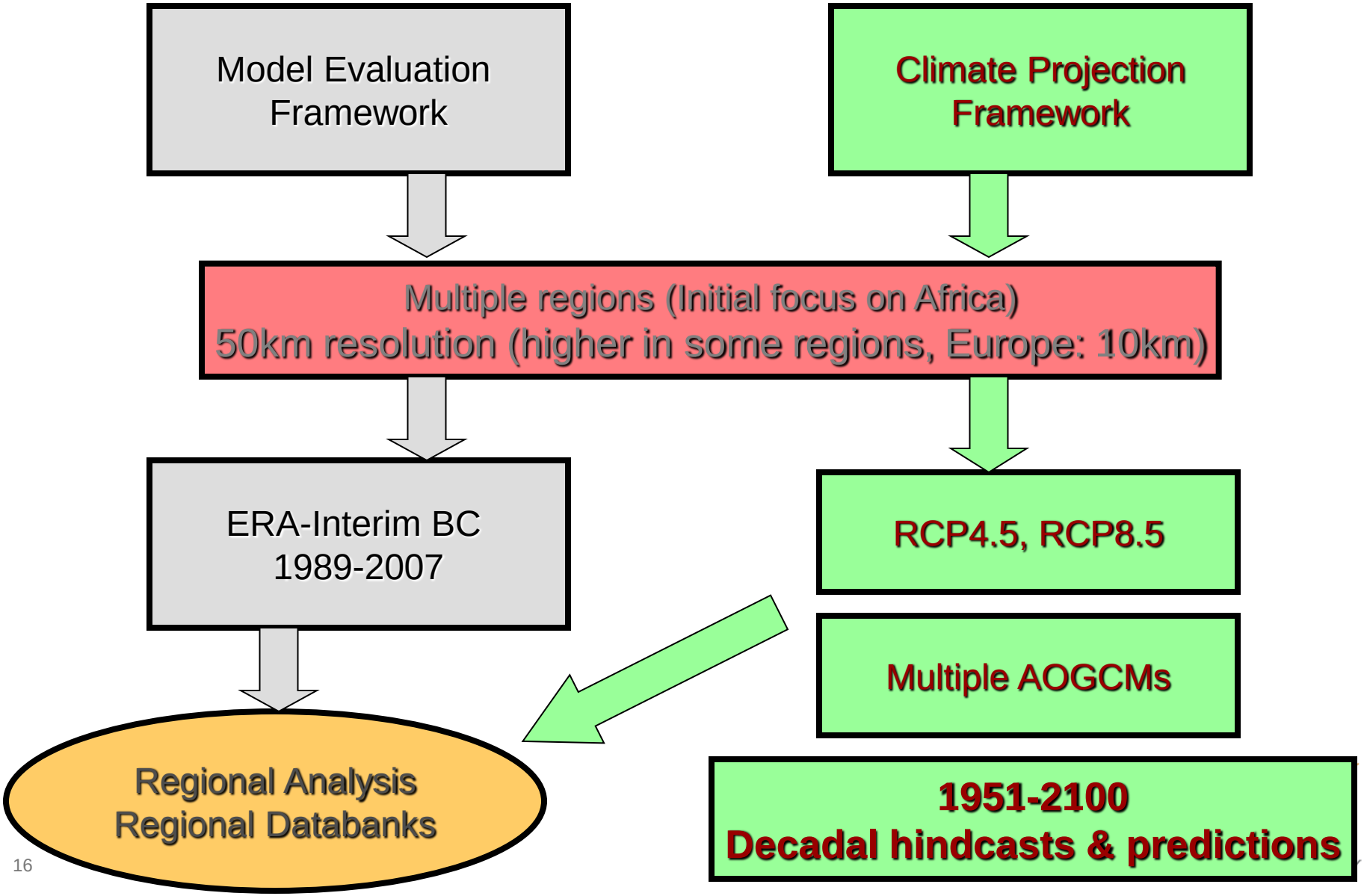
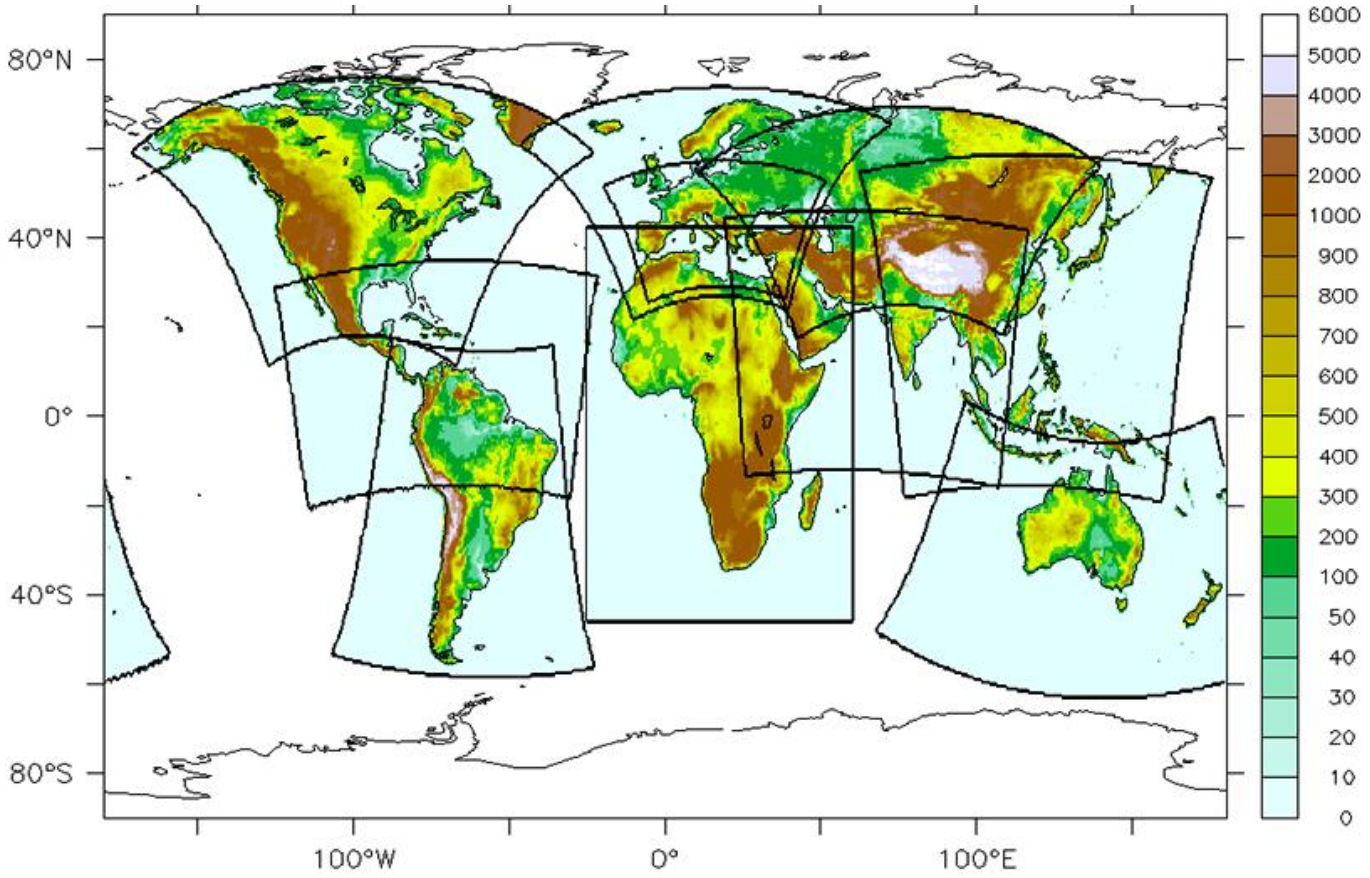
CORDEX Phase I experiment design



CORDEX DOMAINS (except Arctic & Antarctica)



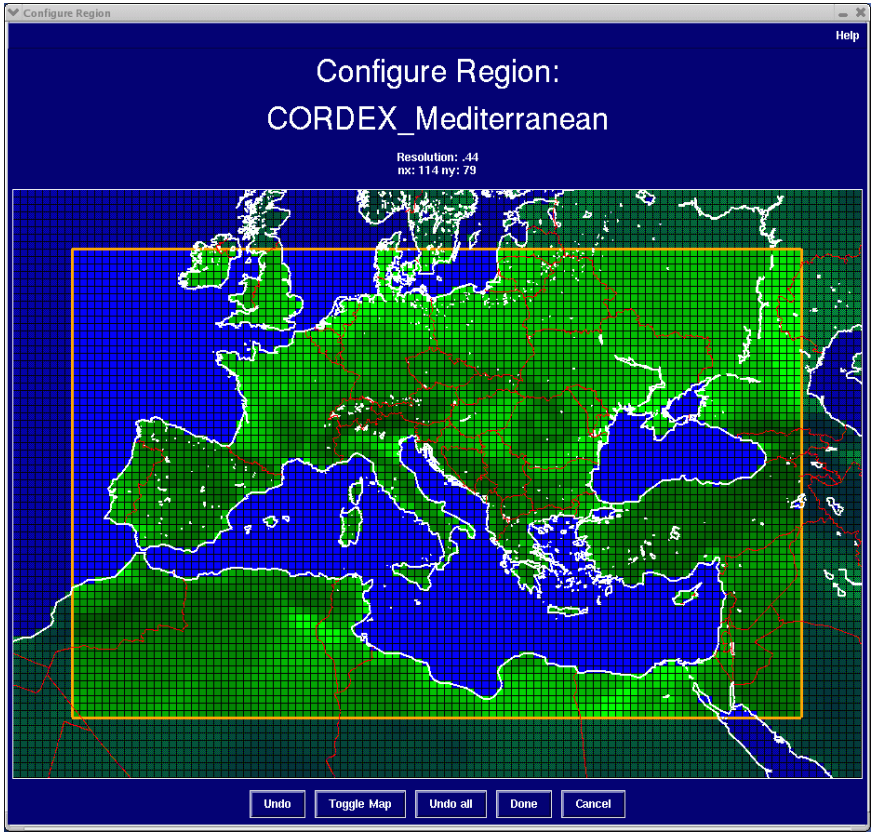
- 12 domains with a resolution of 0.44° (approx. 50x50km²)
- Focus on Africa
- High resolution ~0.11° x0.11° for Europe (by some institutions)

Med-CORDEX (linked to HYMEX)

Groups involved in Med-CORDEX

** Includes a coupled Mediterranean

- LMD (WRF) **
- ICTP-ENEA (RegCM+MIT) **
- CNRM (ALADIN) **
- MPI (REMO) **
- UCLM (PROMES)
- WRF community … SMHI, COSMOS



ARCHIVE:

List of the CORE runs (STAND ALONE + COUPLED):

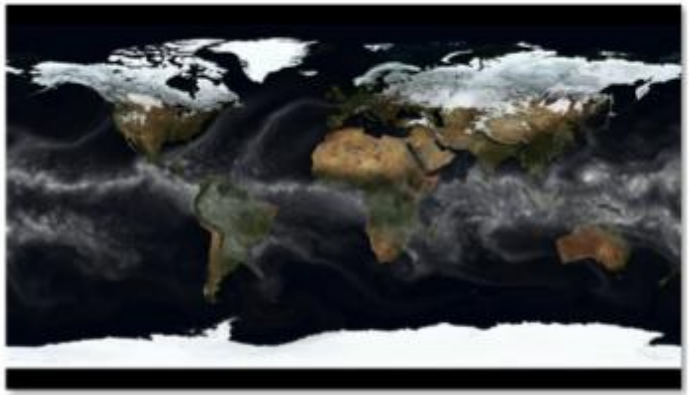
50 km RCM (25 Km)

1989-2008, ERAInterim driven

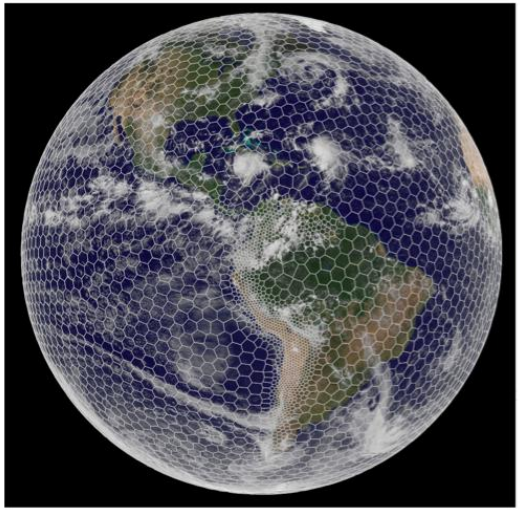
1950-2100, Scenarios RCP4.5 and/or RCP8.5, AR5-GCM driven

Development of Framework For Robust Regional Climate Modeling

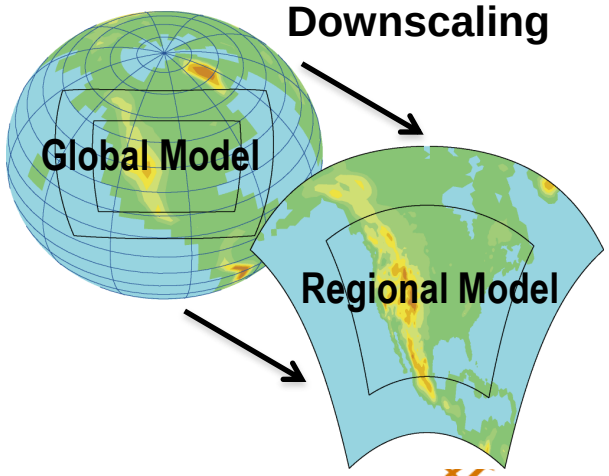
- Systematic and hierarchical evaluation of three modeling approaches to improve understanding of factors contributing to model uncertainties
  - Idealized simulations with no physics (shallow water equation)
  - Idealized simulations with full physics (Aqua-planet simulations)
  - Real world single component (atmosphere-land and ocean) simulations
  - Real world coupled (atmosphere-ocean-land) simulations



Global high resolution model



Global variable resolution model



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Summary

- RCM has been used as a dynamical downscaling tool to develop regional climate change scenarios to assess climate change impacts
- The RCM approach has been demonstrated to “add value” in simulating mesoscale features and extreme statistics
- Several coordinated projects adopt a multi-model approach to sample various sources of uncertainty in regional climate projections
- Systematic and hierarchical evaluation of different approaches will contribute to more robust frameworks for modeling regional climate
- Need continued research on: Model evaluation, metrics to measure model skill, methods to use multi-model scenarios, uncertainty characterization