The Abdus Salam International Centre for Theoretical Physics

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

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CORDEX
A Coordinated Regional Downscaling Experiment

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CORDEX

A Coordinated Regional Downscaling Experiment

Erika Coppola (ICTP)

Giorgi F, Jones C, Asrar G. Addressing climate infor- mation needs at the regional level:
The CORDEX framework.
WMO Bulletin 2009, 58(3):175–183

Pre-CORDEX- how to enhance the RCD input into the IPCC process

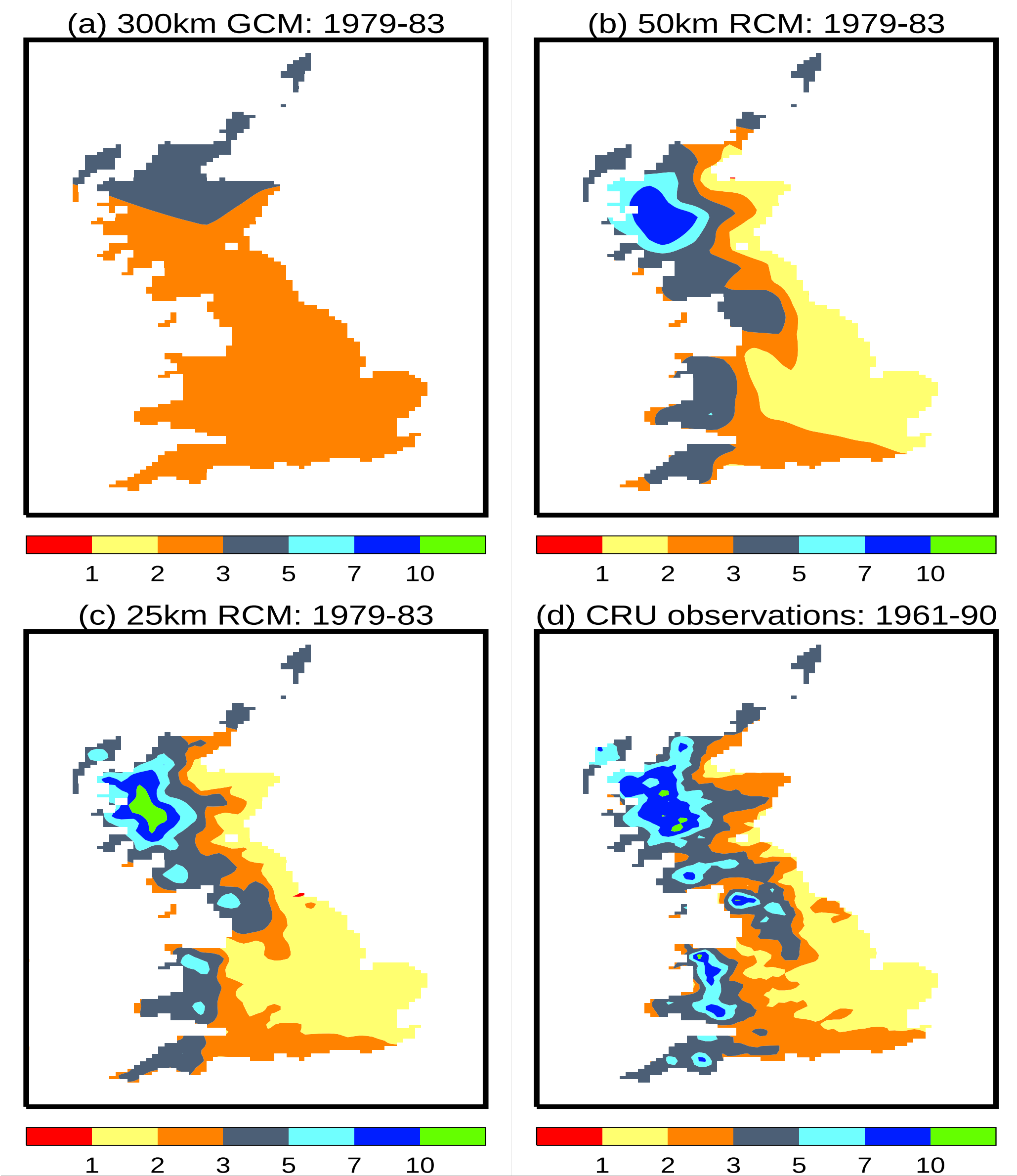
- Design an experiment framework for improving coordination across RCD (RCM and SD) groups
  - Better evaluation and possibly improvement of models and techniques (AMIP-type)
  - More coordinated sets of RCM/SD projections to assess uncertainties (CMIPn-type)
  - Greater involvement of the end-user community and the scientific community from developing countries

Motivating High resolution and Regional Downscaling

Location and intensity of precipitation improves at higher resolution

300km Global Model

50km Regional Model

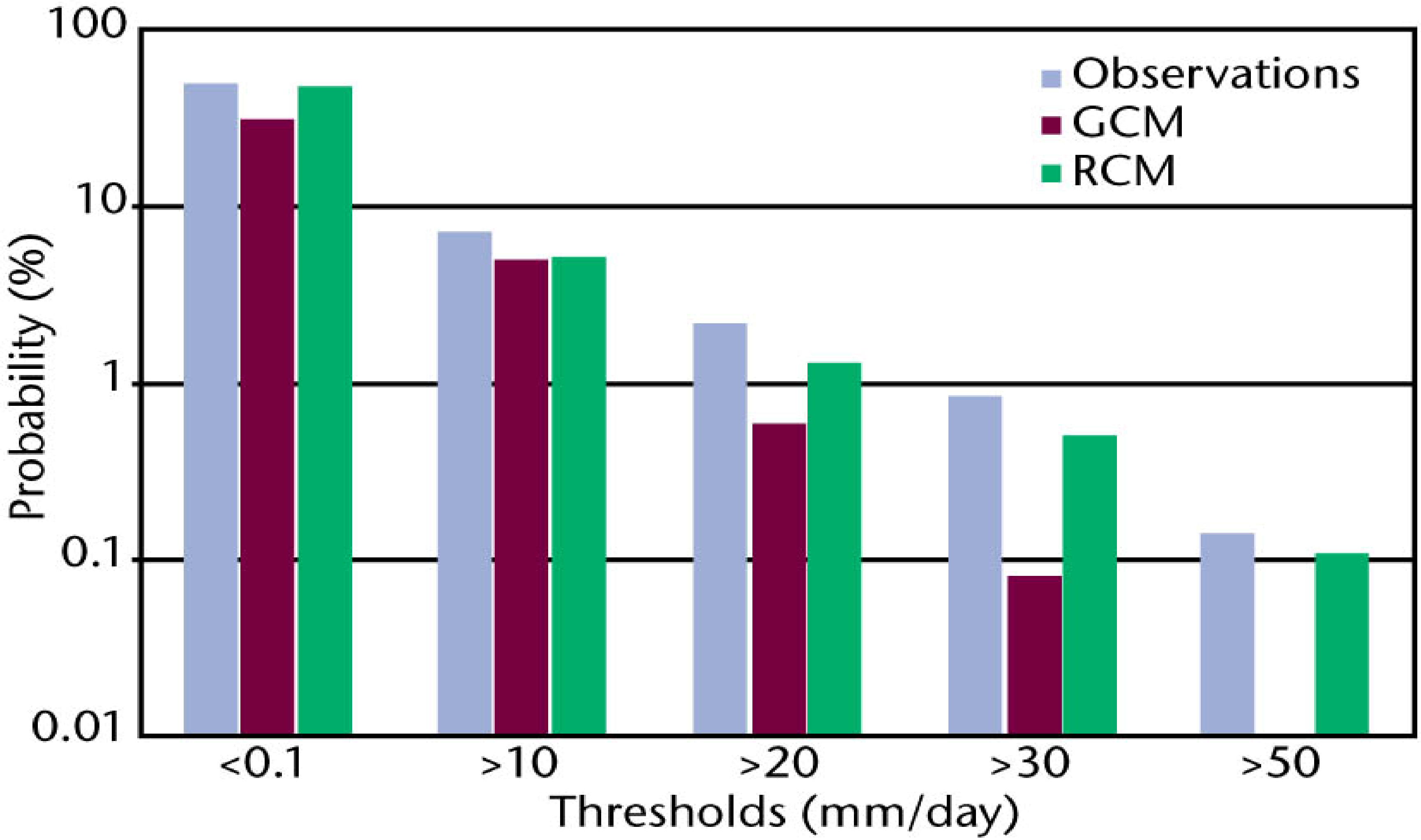


25km Regional Model

Observed

R. Jones : UKMO
(HC models)

DAILY RAINFALL INTENSITY OVER THE ALPS



RCMs simulate extreme rainfall much better than GCMs

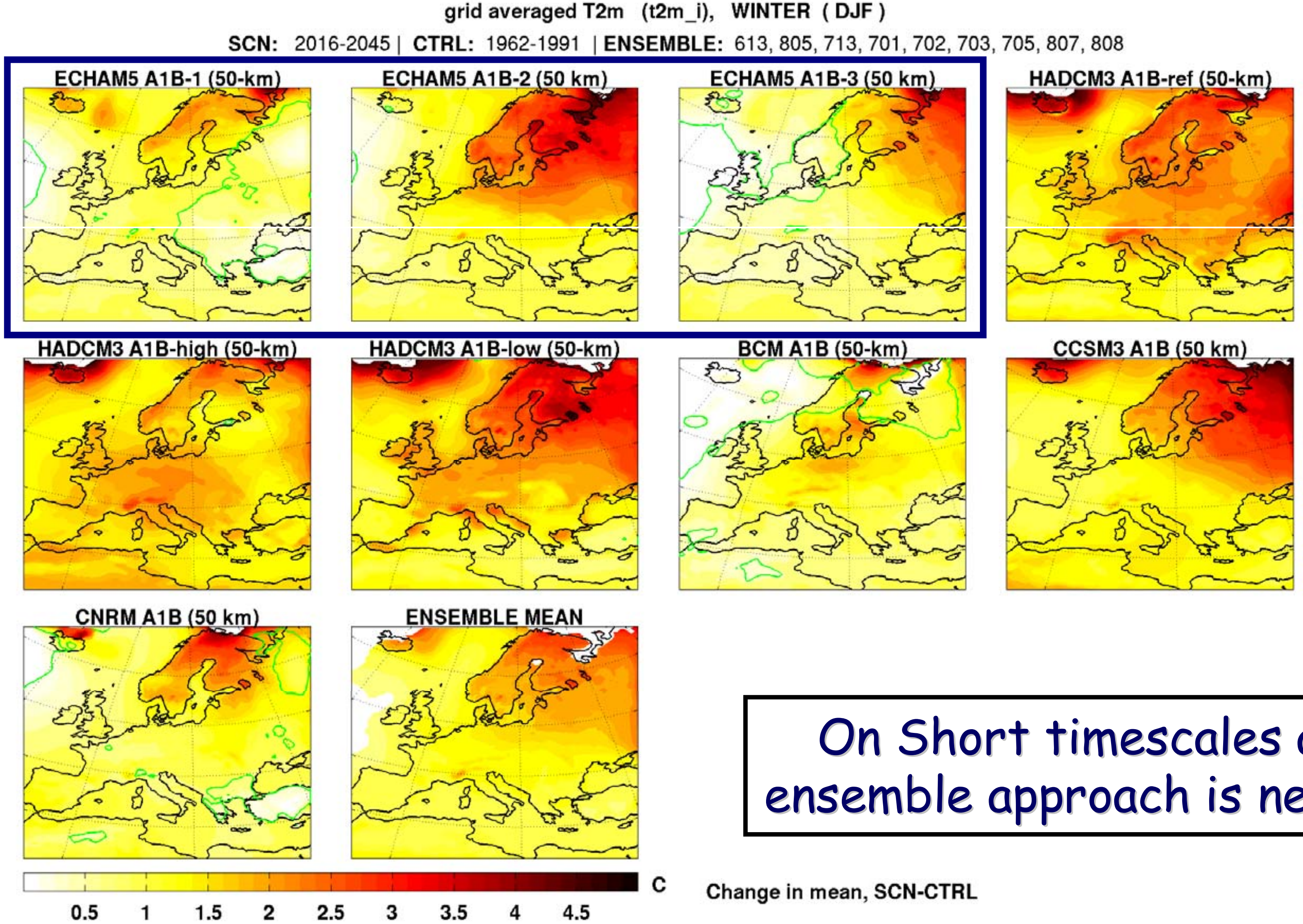
Higher resolution improves the simulation of precipitation extremes

(HC models)

Winter season temperature change (2016-2045)–(1961-1990)

Relatively large differences between simulated climate change signal.

Even between 3 members of the same GCM with same emission scenario (ECHAM5 A1B) but different initial conditions.

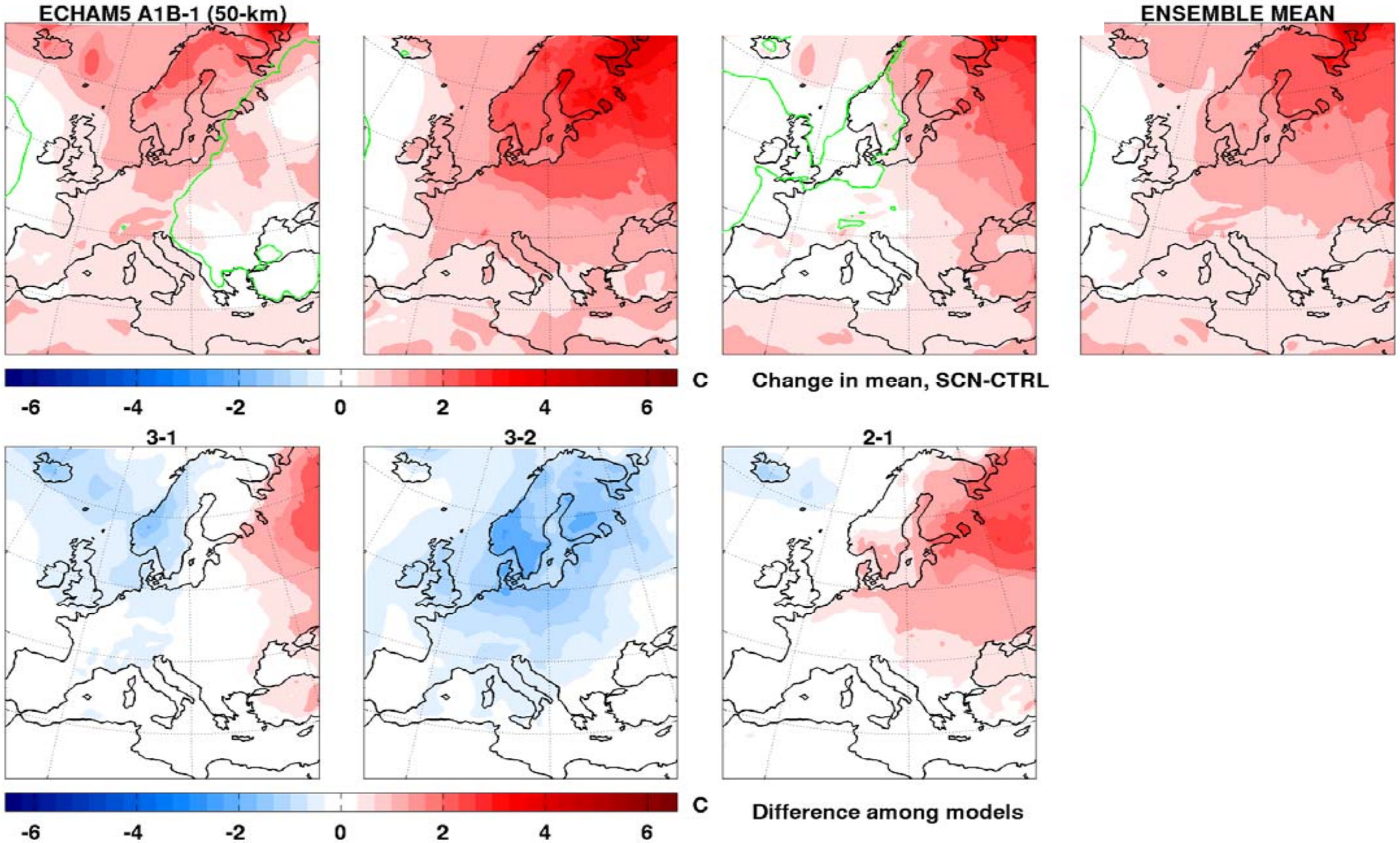


On Short timescales an ensemble approach is needed

From Grigory Nikulin (Rossby Centre)

Winter temperature change from 3 runs of the same ECHAM5 GCM (2016-2045) minus (1962-1991).

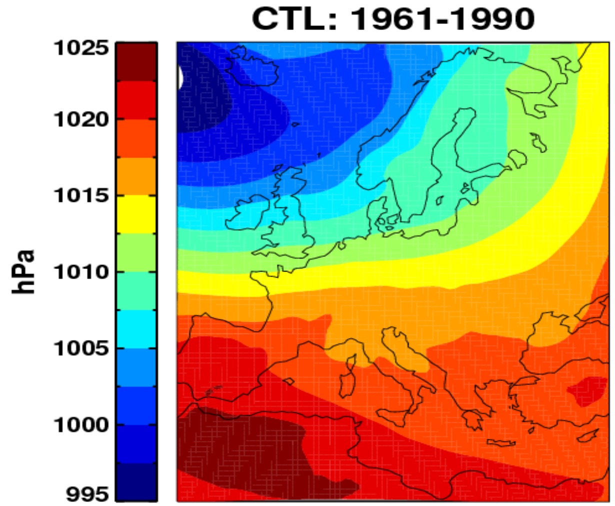
Differences due to using different initial conditions can be of the same magntidue as the simulated climate change signal.



Differences result from different circulation responses in each GCM member

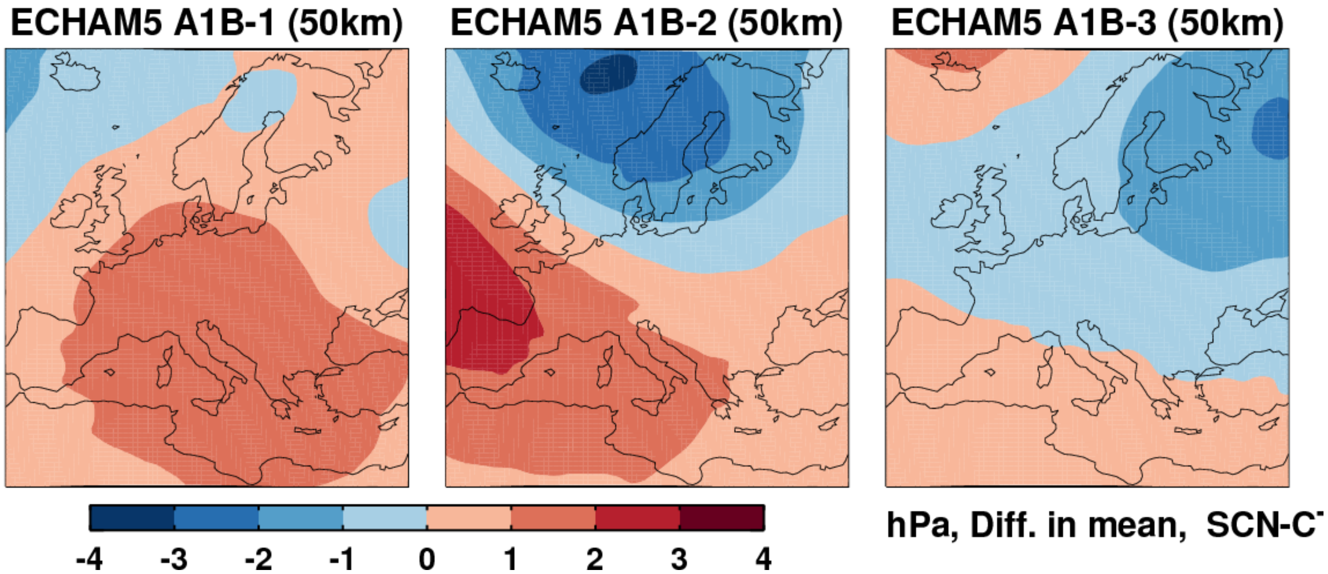
What causes the large differences between ensemble members

Mean sea level pressure
average of 5 simulations with
different AOGCMs on the boundaries
Winter (DJF) control

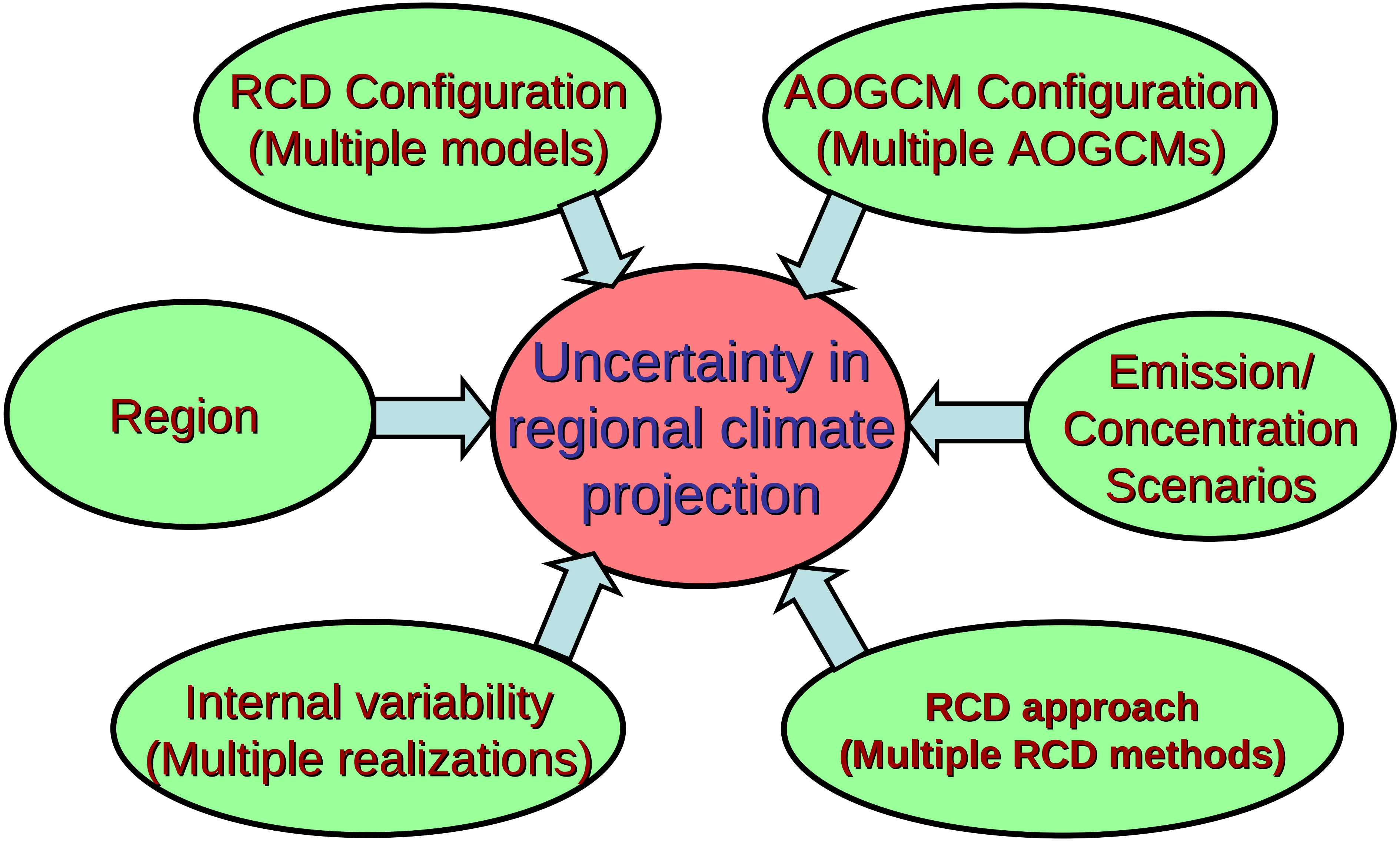


Different changes in
the atmospheric circulation in
the ensemble members.

2011-2040
vs
1961-1990



Sources of uncertainty in RCD-based Regional climate projections



General Aims and Plans for CORDEX

Provide a set of Regional Climate Scenarios for the period 1950-2100, for the majority of the populated land-regions of the globe.

Make these data sets readily available and useable to the impact and adaptation communities.

Provide a generalized framework for testing and applying Regional Climate Models and Downscaling techniques for both the recent past and future scenarios.

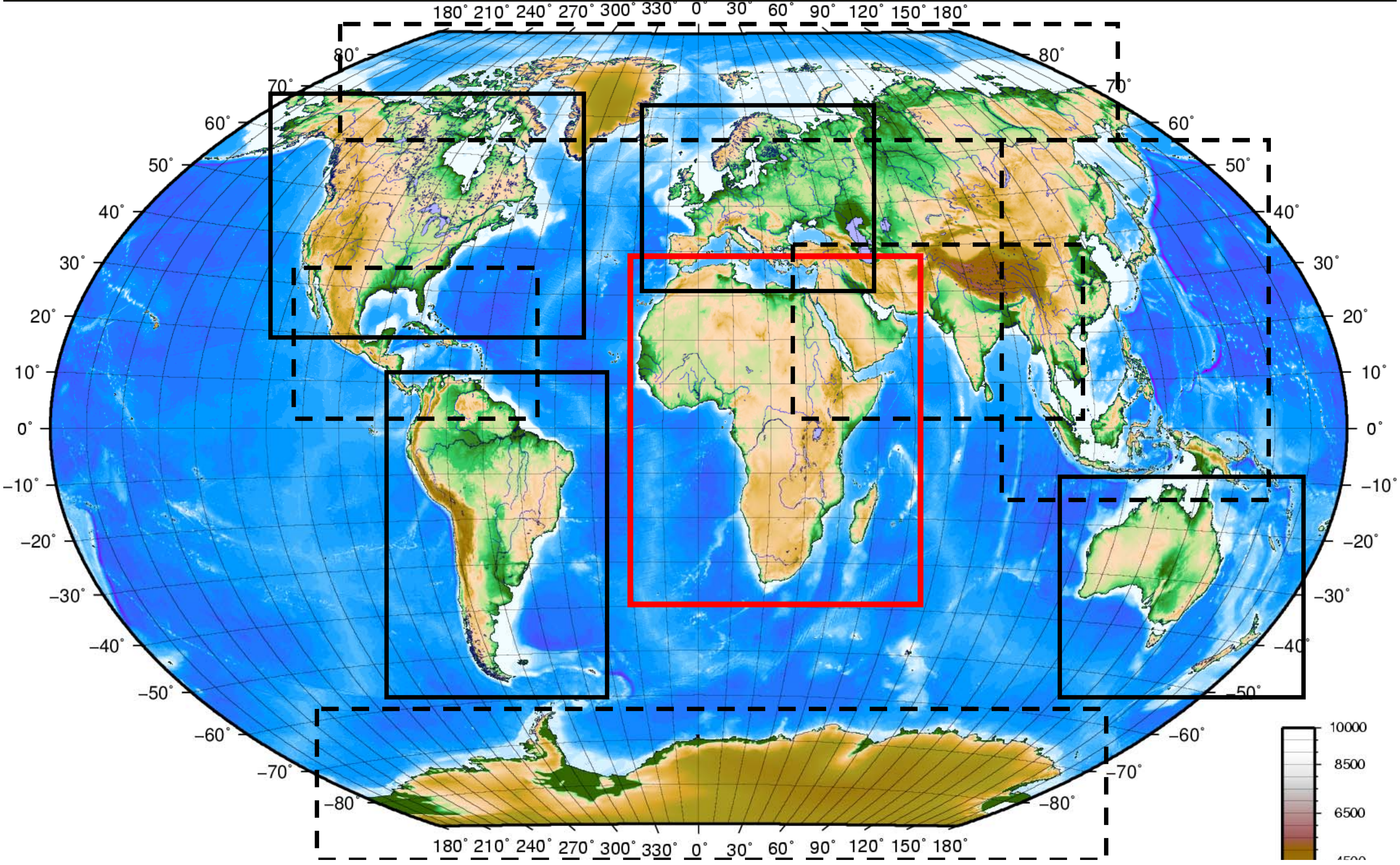
Foster coordination between Regional Downscaling efforts around the world and encourage participation in the downscaling process of local scientists/organizations

Specific aims and plans for CORDEX

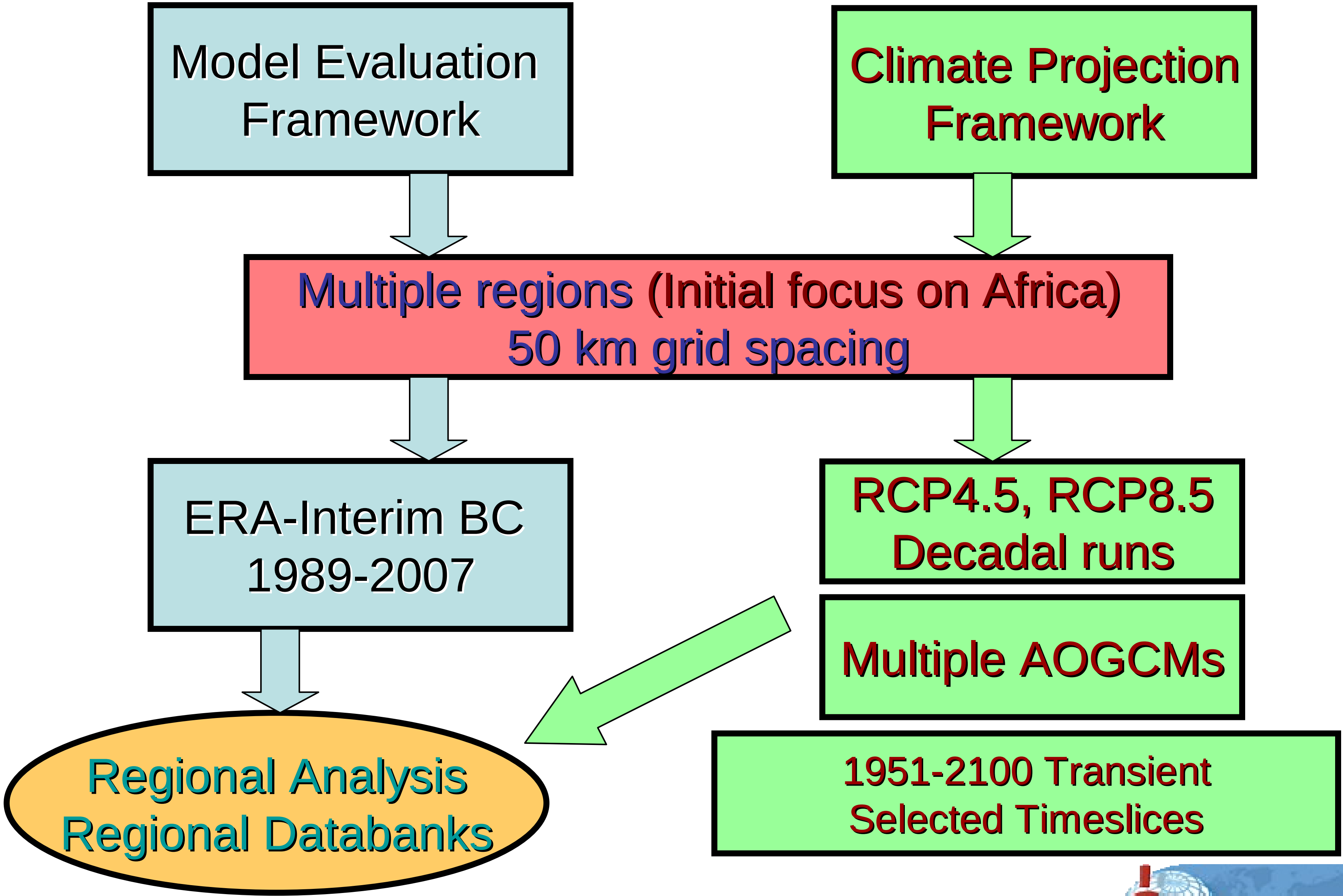
Develop a matrix of RCD simulations that employ:

1. Multiple GCMs as boundary conditions (BCs)
2. Multiple realizations of a given (single) GCM as BCs
3. Multiple RCMs driven by a given GCM over a given domain
4. More than 1 representative greenhouse emission scenario
5. With common RCM domains and resolution
6. With common RCM output variables and frequency
7. In a common format
8. Store the results online for subsequent access and use

Possible CORDEX domains

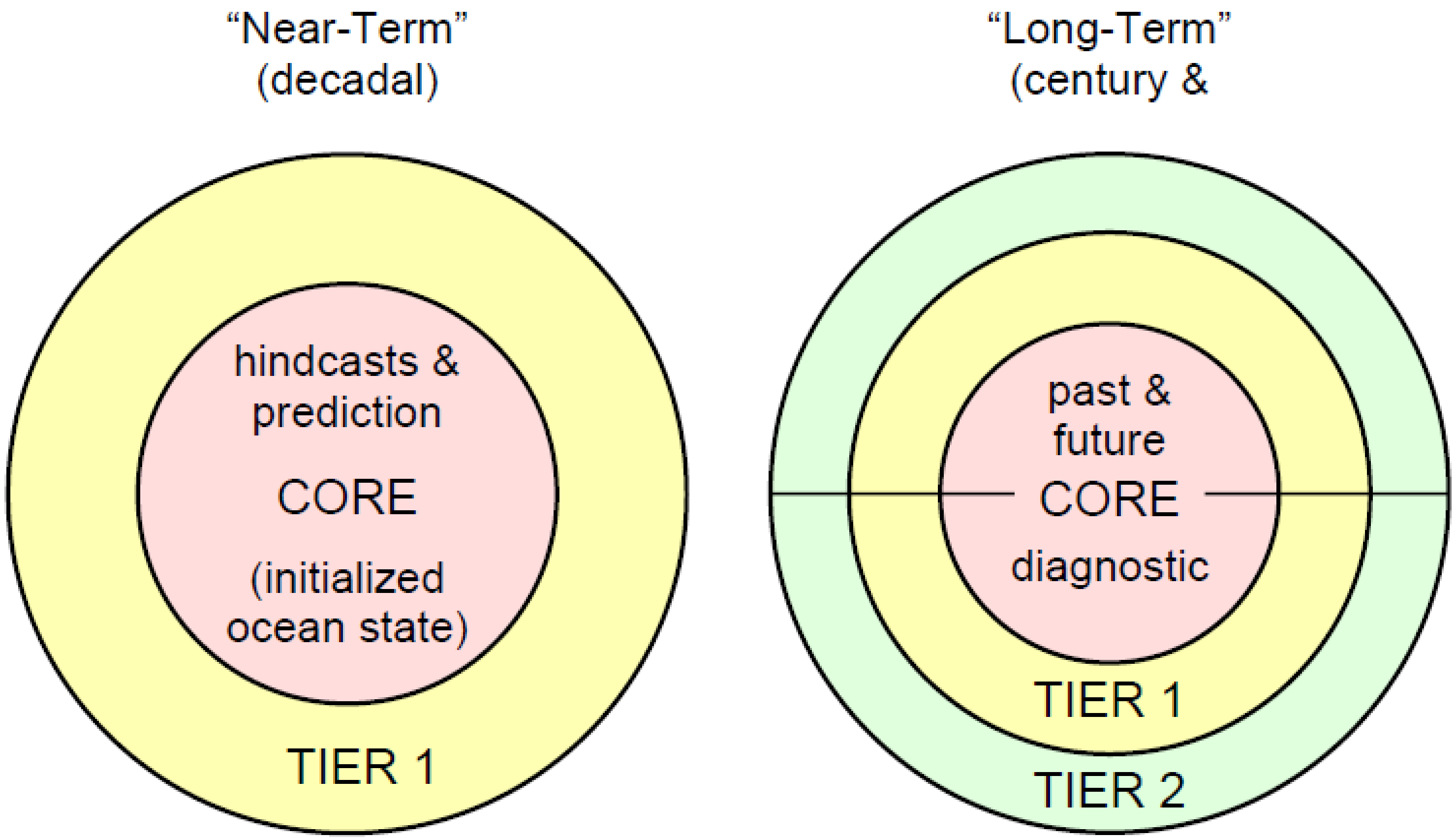


CORDEX Phase I experiment design



Summary of the CMIP5 Experiment Design

Taylor et al, 2009



Near term – decadal prediction

	#	Experiment	Notes	# of years
CORE	1.1	Ensembles of 10-year hindcasts and predictions	With ocean initial conditions in some way representative of the observed anomalies or full fields for the start date, simulations should be initialized towards the end of 1960, 1965, 1970, 1975, 1980, 1985, 1990, 1995 and 2000 and 2005. A minimum ensemble size of 3 should be produced for each start date. The atmospheric composition (and other conditions including volcanic aerosols) should be prescribed as in the historical run (expt. 3.2) and the RCP4.5 scenario (expt. 4.1) of the long-term suite of experiments.	3x10x10
CORE	1.2	Ensembles of 30-year hindcasts and predictions	Extend to 30 years the expt. 1.1 integrations with initial dates near the end of 1960, 1980 and 2005. A minimum ensemble size of 3 should be produced for each start date.	3x3x20
	1.1-E, 1.2-E	Increase ensemble size	Additional runs to expand each ensemble to a size of O(10).	~7x10x10, ~7x3x20
	1.1-I	Initialize 10-year simulations from additional start dates	As in 1.1 and 1.1-E, but initialized near the end of 2001, 2002, 2003, 2004, 2005, 2006 (2007, and beyond) to take advantage of the better ocean data of the Argo float era	≥3x(≥6)x10

TIER 1	3.3	AMIP (1979-at least 2008)	This run is described in Table 3 (expt. 3.3).	≥30
TIER 1	3.1-S	A shortened pre-industrial control	This is a shortened version of the pre-industrial control run described in Table 3 (expt. 3.1).	100
TIER 1	6.1-S	1%/yr CO_2 increase	An- 80 year run with a 1% per year increase in CO_2 (a shortened version of expt. 6.1), initialized at year 20 of the control run (3.1-S).	80
TIER 1	1.3	Hindcasts without volcanoes	Additional runs initialized near end of 1960, 1975, 1980, 1985 and 1990 as in expts. 1.1 and 1.2, but without volcanic eruptions (e.g., without Agung, El Chichon and Pinatubo).	≥3x5x(≥10)
TIER 1	1.4	Predictions with 2010 Pinatubo-like eruption	An additional run initialized near end of 2005 as in expt. 1.1, but with a Pinatubo-like eruption imposed in 2010.	≥3x(≥10)
TIER 1	1.5	Initialize with alternative strategies	Since there is at present no generally accepted "best" way to initialize models, some groups may choose to try different initialization methods.	≥3x(≥10)
TIER 1	1.6	Run with more complete atmos. chemistry	The chemistry/aerosol community plans to put together experiments with short-lived species and pollutants (probably two to three years hence).	≥1x(≥10)

Near term -Time slice experiment 1979 or 2008 and 2026-2035

	#	Experiment	Notes	# of years
TIER 1	3.3	AMIP (1979- at least 2008)	This run is described in Table 3 (expt. 3.3), but is also listed here with the understanding that models doing time-slice experiments with computationally demanding models would not likely be able to complete the core suite of long-term experiments.	≥30
TIER 1	2.1	Future "time-slice" experiment (2026-2035)	Simulation of a future decade covering the years 2026-2035, with prescribed SSTs and sea ice concentration anomalies (relative to expt. 3.3) based on one of the following pairs of coupled atmosphere/ocean climate model runs: 1. the difference in climatology between years 2026-2035 of RCP4.5 (expt. 4.1) and years 1979-2008 of the historical run (expt. 3.2), or 2. the difference in climatology between years 2026-2035 of the RCP4.5 30-year run initialized from observations in the year 2005 (expt. 1.2) and a climatology for years 1979-2008 based on a subset of the years covered in the expt. 1.1 series of 10-year simulations (i.e., 1979-1980, 1981-1985, 1986-1990, 1991-1995, 1996-2000, 2001-2005, and 2006-2008 from the runs initialized near the end of 1975, 1980, …, 2005, respectively)	10
TIER 2	3.3-E	AMIP ensemble	Additional AMIP runs (expt. 3.3, but with different initial conditions imposed on the atmosphere and possibly also the land) yielding an ensemble of size ≥3 (and if practical, much larger).	≥2x30
TIER 2	2.1-E	Future "time-slice" experiment ensemble	Additional expt. 2.1 runs (but with different initial conditions imposed on the atmosphere, sea-ice, and ocean and possibly also the land) yielding an ensemble of size ≥3 (and if practical, much larger). The changes in climatological SSTs and sea-ice used in prescribing the SST and sea-ice in these extended time-slice runs should, when available, be taken from more than one pair of coupled atmosphere/ocean model runs.	≥2x10
TIER 2	6.5-6.8	Cloud diagnostic experiments	Prescribed SST experiments, consistent with CFMIP requirements, described fully in Table 6.	≥105

?

Long term - Baseline simulations for model evaluation

	#	Experiment	Notes	# of years
CORE	3.1	Pre-industrial Control	Impose non-evolving, pre-industrial conditions, which may include: Prescribed atmospheric concentrations of • all well-mixed gases (including CO_2) • some short-lived (reactive) species Prescribed non-evolving emissions or concentrations of • natural aerosols or their precursors • some short-lived (reactive) species. Unperturbed land use.	500 (after spin-up period)
CORE	3.2	Historical (1850-2005)	Impose changing conditions (consistent with observations), which may include: • atmospheric composition (including CO_2), due to both anthropogenic and volcanic influences • solar forcing • emissions or concentrations of short-lived species and natural and anthropogenic aerosols or their precursors • land use	156
CORE	3.3	AMIP (1979- at least 2008)	Impose SSTs & sea ice (from observations), but with other conditions (including CO_2 concentrations and aerosols) as in expt. 3.2. See expt. 6.5 for further recommendations from CFMIP.	≥30
TIER 1	3.2-E	Historical Ensemble	Additional historical runs (expt. 3.2, but initialized at different points in the control) yielding an ensemble of size ≥3.	≥2x156
TIER 1	3.3-E	AMIP Ensemble	Additional AMIP runs (expt. 3.3, but initialized with different atmospheric and possibly land-surface conditions) yielding an ensemble of size ≥3.	≥2x30
TIER 1	3.4	Mid-Holocene (6 kyr ago)	Consistent with PMIP specifications, impose Mid-Holocene conditions, including: • orbital parameters • atmospheric concentrations of well-mixed greenhouse gases	≥100 (after spin-up period)
TIER 1	3.5	Last Glacial Maximum (21 kyr ago)	Consistent with PMIP requirements, impose Last Glacial Maximum conditions, including: • ice sheets • atmospheric concentrations of well-mixed greenhouse gases	≥100 (after spin-up period)
TIER 2	3.6	Last Millennium (850-1850)	Consistent with PMIP requirements, impose evolving conditions, including: • solar variations • volcanic aerosols	1000 (after spin-up period)

1950-2006

Long term - Future climate projections

	#	Experiment	Notes	# of years
CORE	4.1	RCP4.5 (2006-2100)	Radiative forcing stabilizes at ~4.5W m^{-2} after 2100. (if ESM, save CO_2 fluxes from the surface to calculate allowable emissions)	95
CORE	4.2	RCP8.5 (2006-2100)	Radiative forcing reaches ~8.5 W m^{-2} near ~2100. (if ESM, save CO_2 fluxes from the surface to calculate allowable emissions)	95
TIER 1	4.3	RCP2.6 (2006-2100)	Radiative forcing peaks at ~2.6 Wm^{-2} near 2100.	95
TIER 1	4.4	RCP6 (2006-2100)	Radiative forcing stabilizes at ~6 W m^{-2} after ~2100.	95
TIER 1	4.1-L	RCP4.5 extended through year 2300	Extension of expt. 4.1 through the end of the 23rd century.	200
TIER 2	4.2-L & 4.3-L	Extend RCP8.5 & RCP2.6 through year 2300	Extension of expts. 4.2 and 4.3 through the end of the 23rd century.	2x200

CORDEX simulations

- Domains and resolution (50 km).
- Top priority runs (full or time slices):
- ✓ Historical runs for the period Jan 1950 – Dec 2005
- ✓ RCP4.5 and RCP8.5 scenario runs for the period Jan 2006 – Dec 2100
- ✓ AMIP integrations : All years.
- ✓ Decadal hindcasts/forecasts : A minimum of 3 members/GCM for the 3 integrationperiods initialized at the first date and run to the second date: (i) 1980-2010, (ii) 1990-2000, (iii) 2005-2035
- Possible additional runs
  - Emission driven coupled carbon runs
  - Additional DHFG hindcast run
  - Far future RCP4.5 stabilization time slices (2170-2200, 2270-2300)
- Possible sensitivity experiments to assess the importance of regional forcings (aerosol and landuse)

Some Conclusions

The international RCD community is organizing around the CORDEX project:

A coordinated, ensemble approach seems beneficial
(Multi-GCMs, Multi-RCMs, Multi-emissions scenarios)

Aim to provide global (land) coverage of high-resolution RCD data for climate impact and adaptation work based On the CMIP5 GCM integrations

With an emphasis on Africa in the coming 2-3 years.
(Other areas will also be sampled)

What has been decided

1. A request to archive 6-hourly 3D model level fields was included in the CMIP5 GCM output protocol.

   The request was for at least 1 RCP4.5 and 1 RCP8.5 member (1950-2100). Also some limited data from decadal prediction (2005-2035) and hindcast runs.

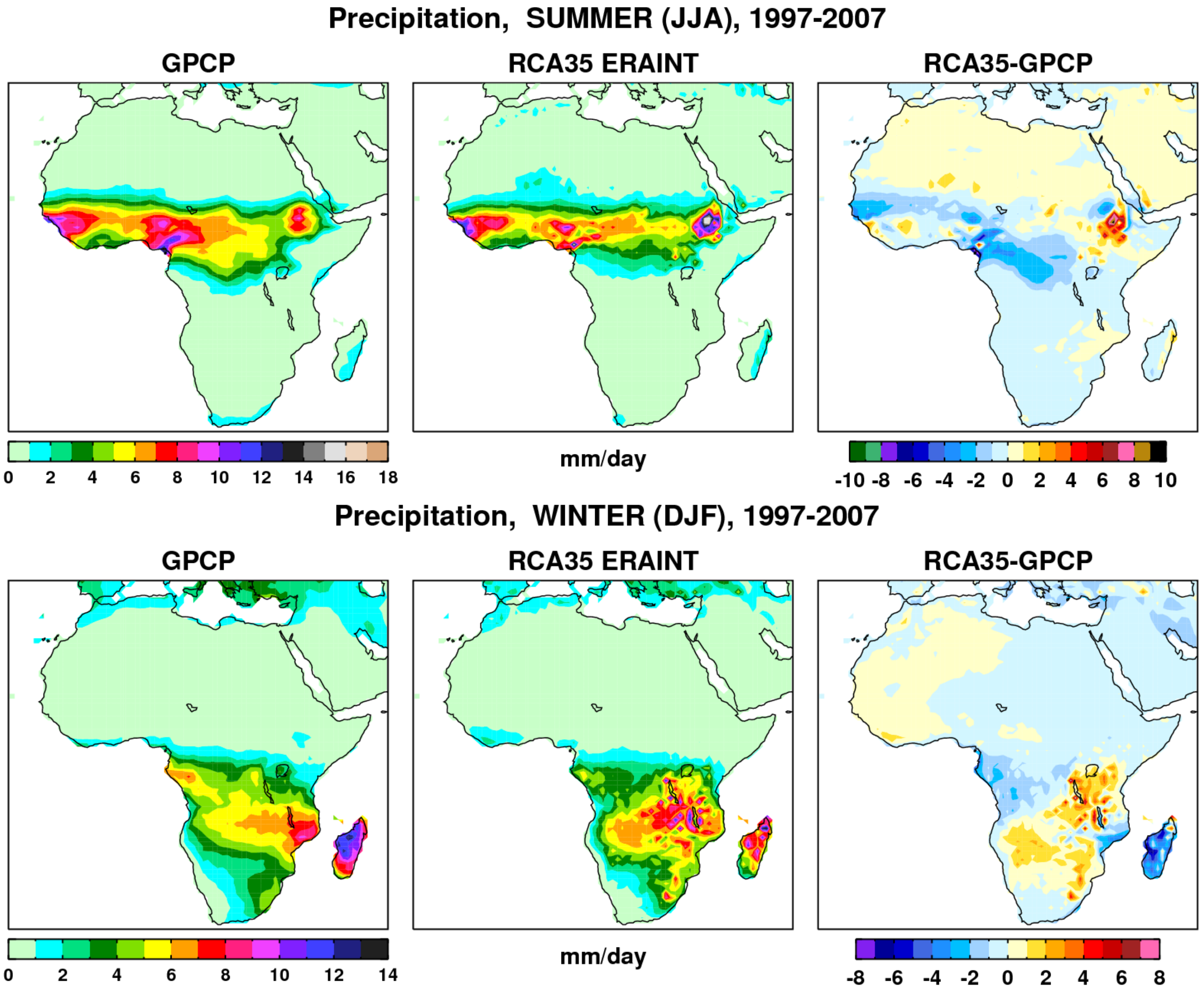
2. The standard RCM resolution is 50km (many groups plan to also run higher resolutions for selected domains)

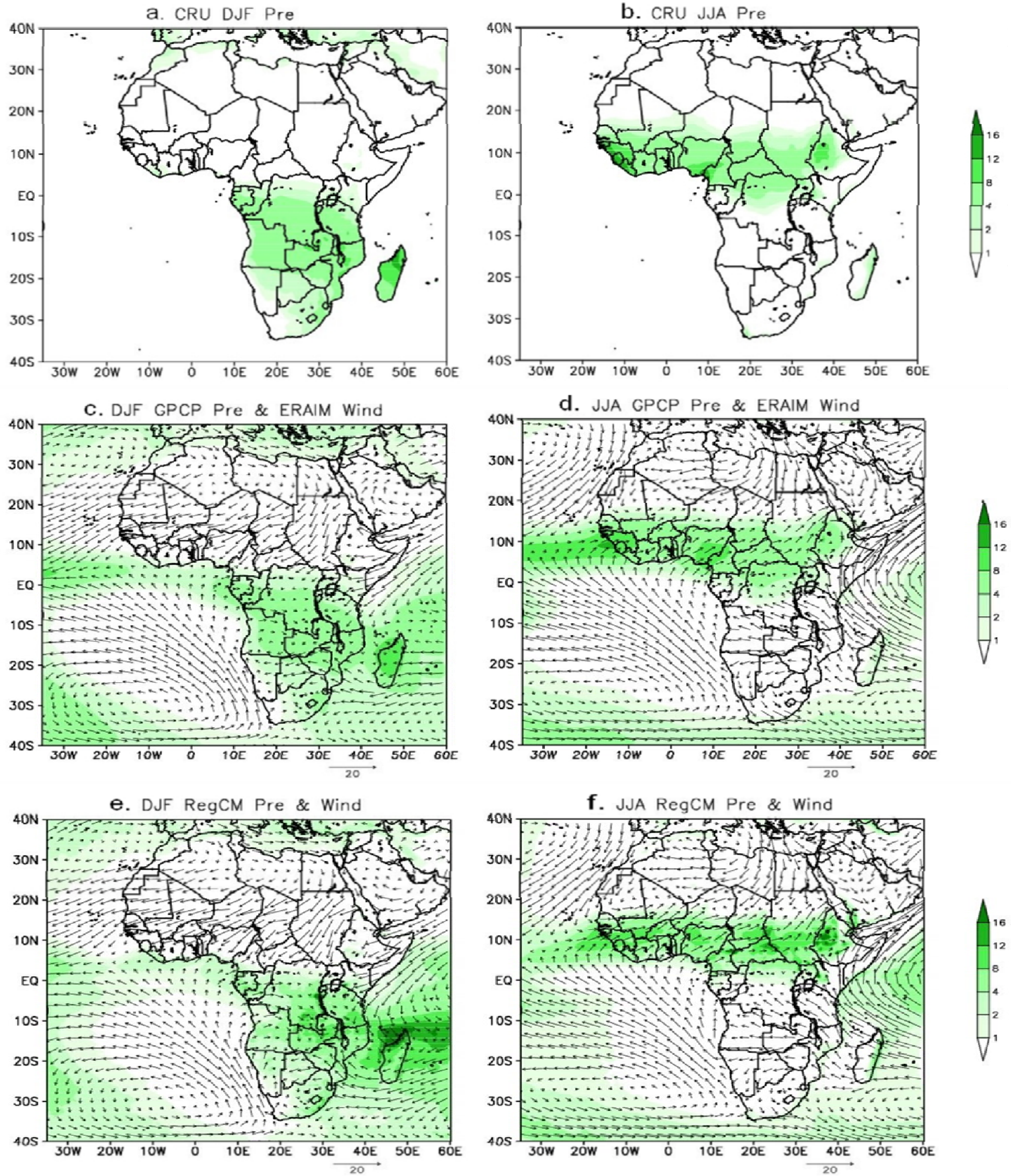
3. Groups are encouraged to run as many of the RCM domains as possible using the ERA-interim data as boundary conditions (1989-2008) for model evaluation

4. An initial focus for future climate scenarios will be Africa with an aim to provide something for IPCC AR5

CORDEX Phase I - preliminary results

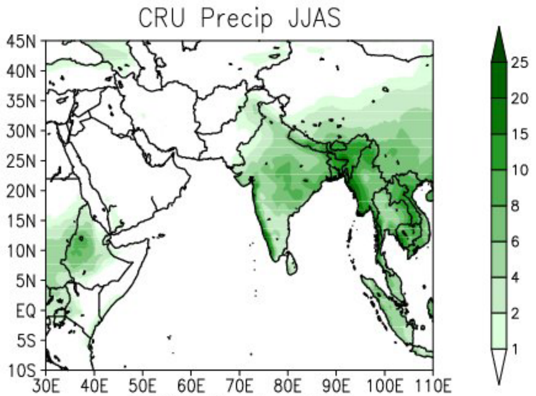
CORDEX ERA-Interim driven experiment: RCA model (SMHI)

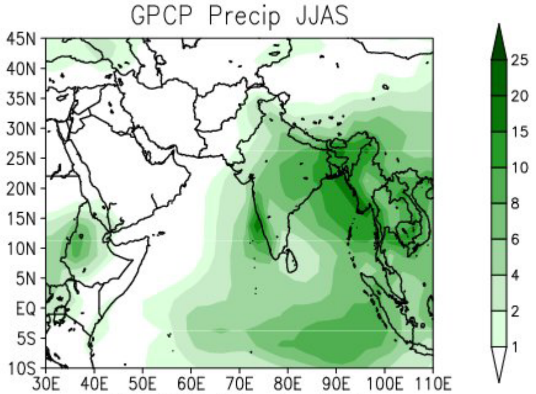




CORDEX ERA-Interim Driven experiment RegCM model (ICTP) 1989-2007

Sylla et al. 2009


CRU Precip JJAS
45N 40N 35N 30N 25N 20N 15N 10N 5N EQ 5S 10S
30E 40E 50E 60E 70E 80E 90E 100E 110E
25 20 15 10 8 6 4 2 1


GPCP Precip JJAS
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30E 40E 50E 60E 70E 80E 90E 100E 110E
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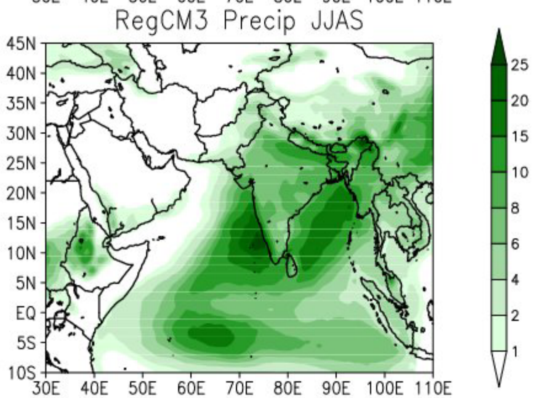
RegCM3 Precip JJAS
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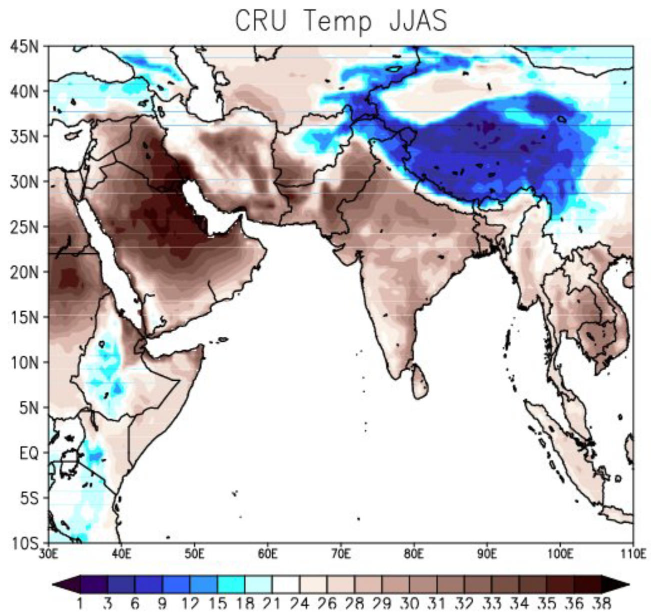
30E 40E 50E 60E 70E 80E 90E 100E 110E
25 20 15 10 8 6 4 2 1


CRU Temp JJAS
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30E 40E 50E 60E 70E 80E 90E 100E 110E
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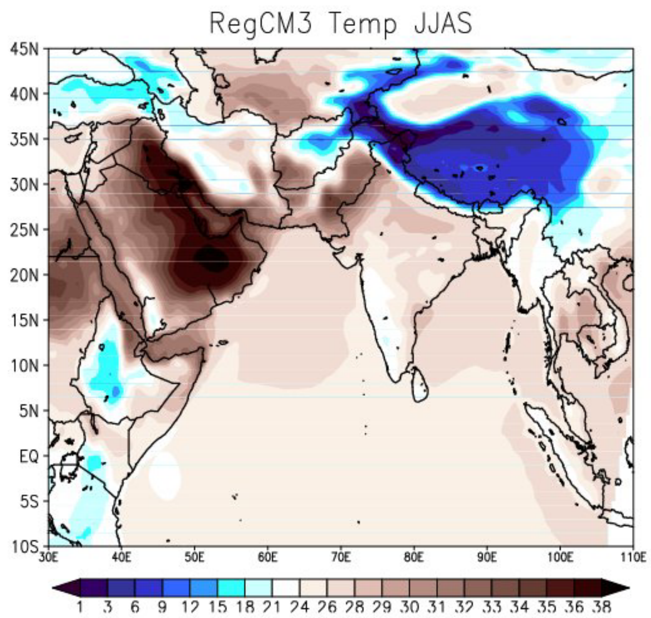
RegCM3 Temp JJAS
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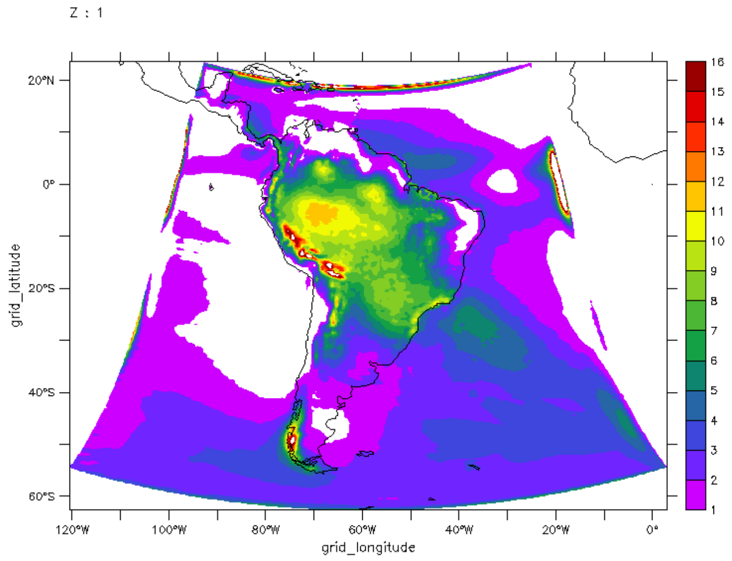
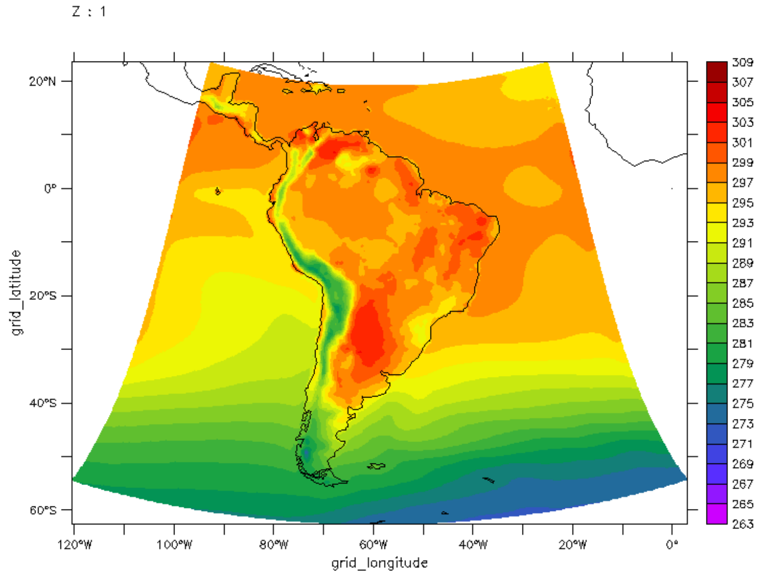
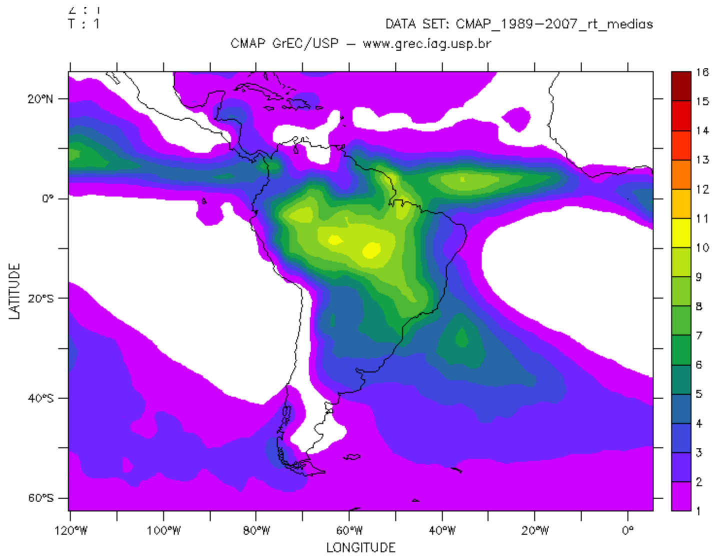


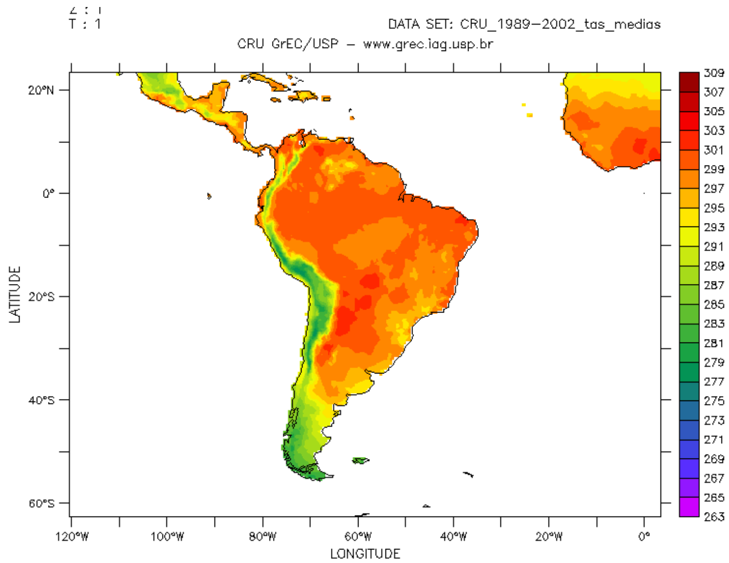
rt_DJF [mm/day] 1989–2008 – RegCM3



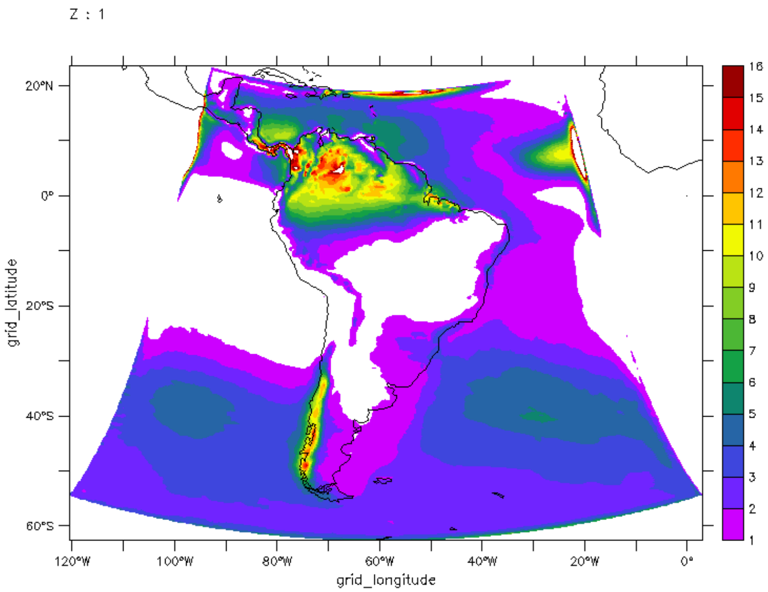
TAS_DJF [K] 1989–2008 – RegCM3



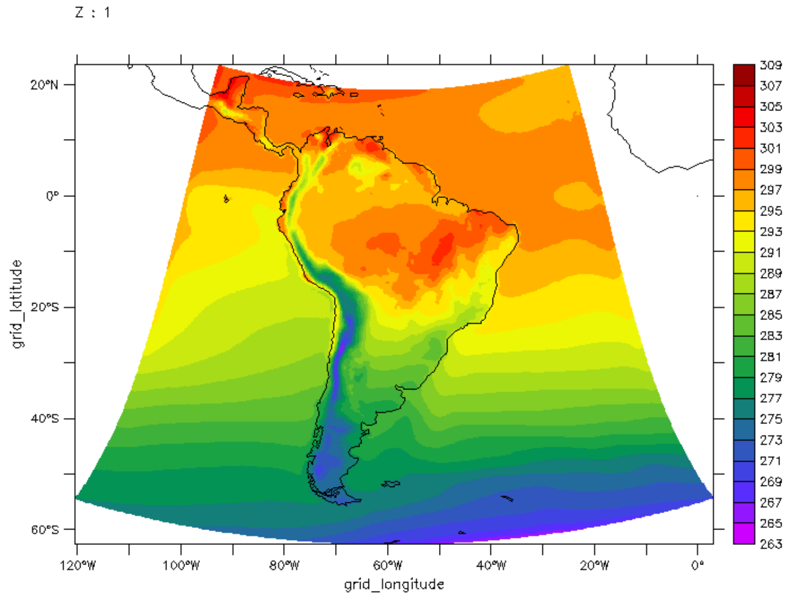
rt_DJF [mm/day] 1989–2007 – CMAP



TAS_DJF [K] 1989–2002 – CRU



rt_JJA [mm/day] 1989–2008 – RegCM3



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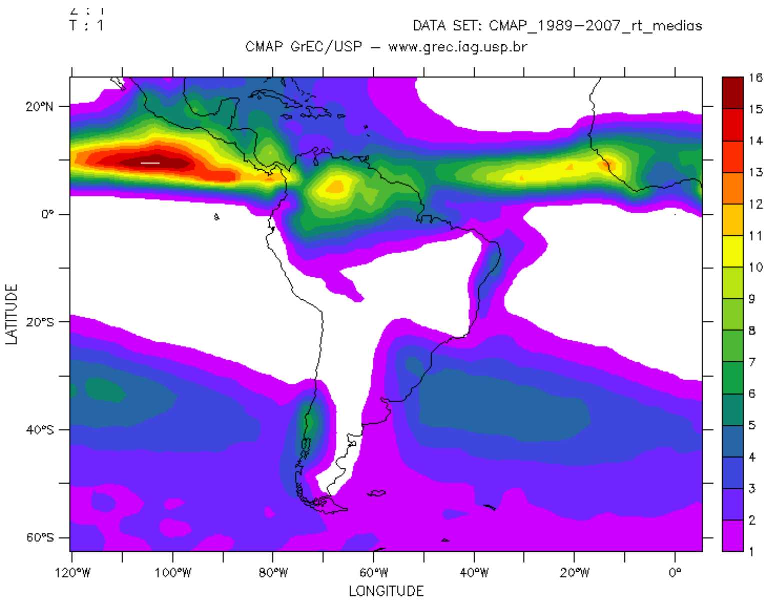
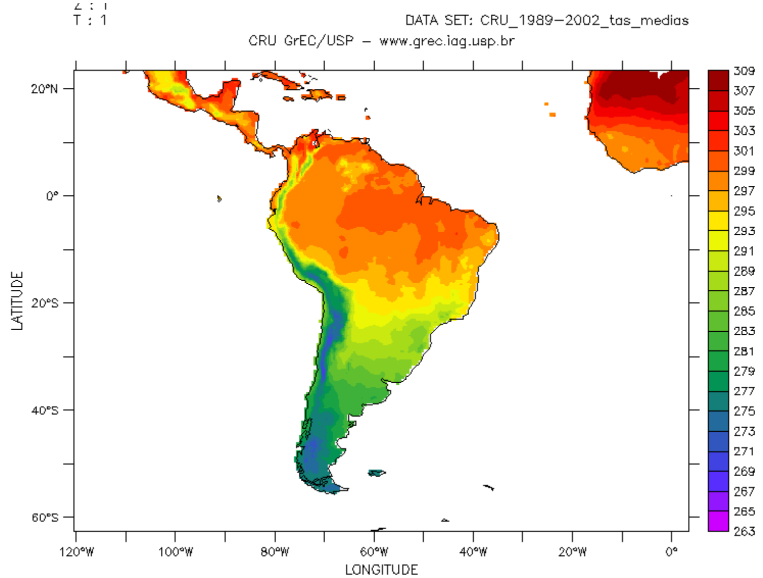
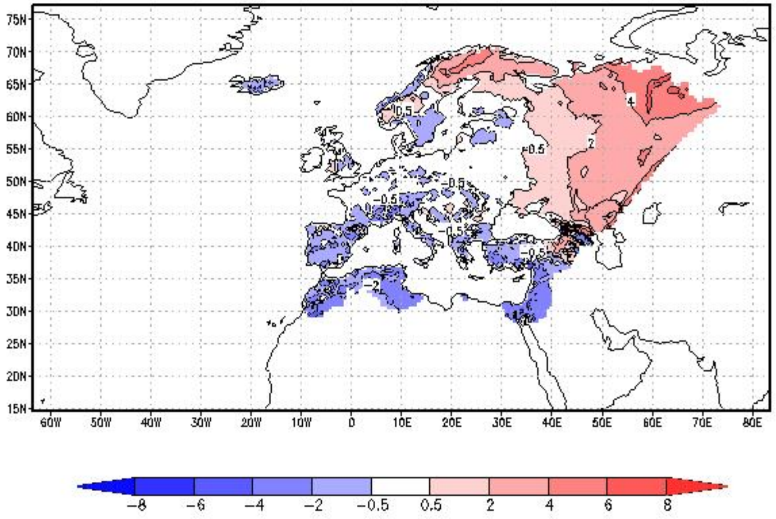


rt_JJA [mm/day] 1989–2007 – CMAP

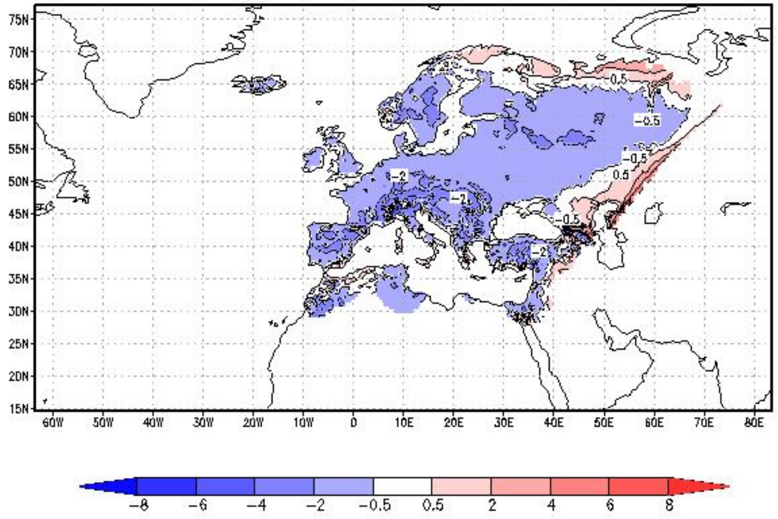


TAS_JJA [K] 1989–2002 – CRU

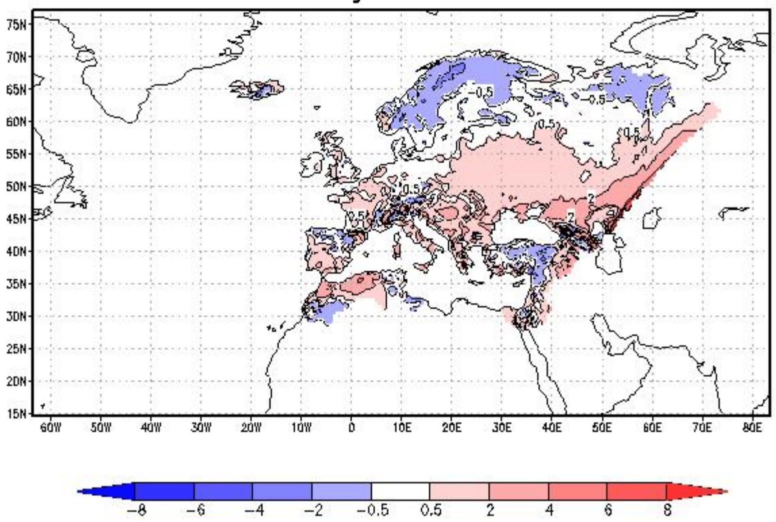
DJF RegCM-EOBS t2m



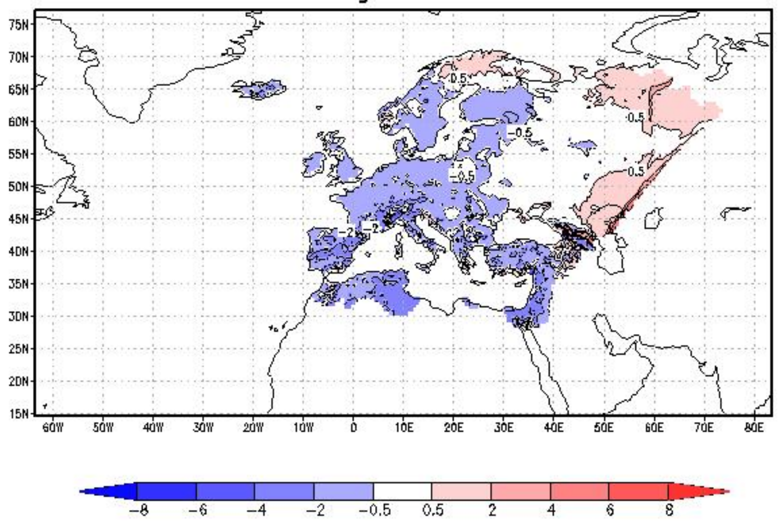
MAM RegCM-EOBS t2m

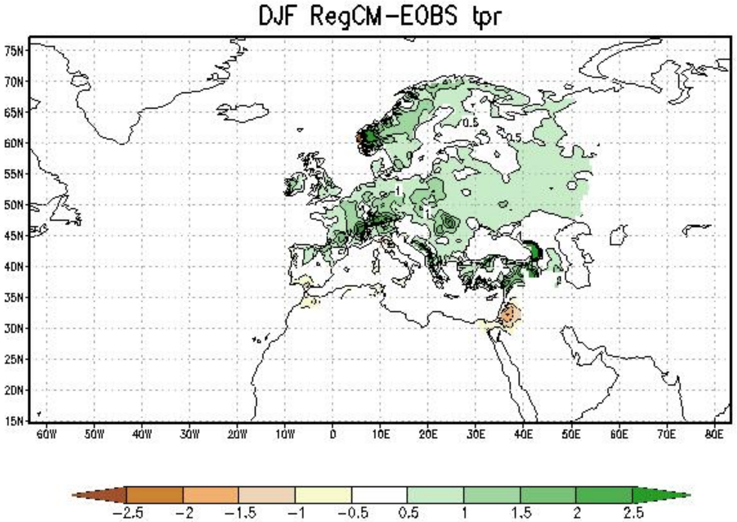


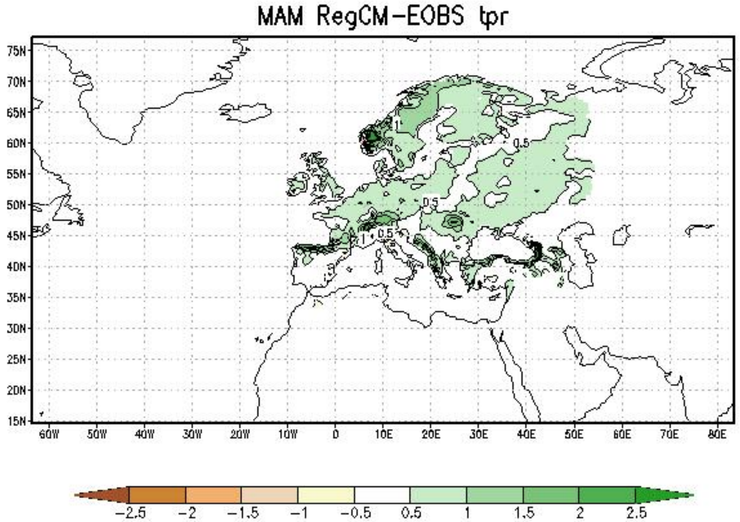
JJA RegCM-EOBS t2m



SON RegCM-EOBS t2m




DJF RegCM-EOBS tpr
−2.5 −2 −1.5 −1 −0.5 0.5 1 1.5 2 2.5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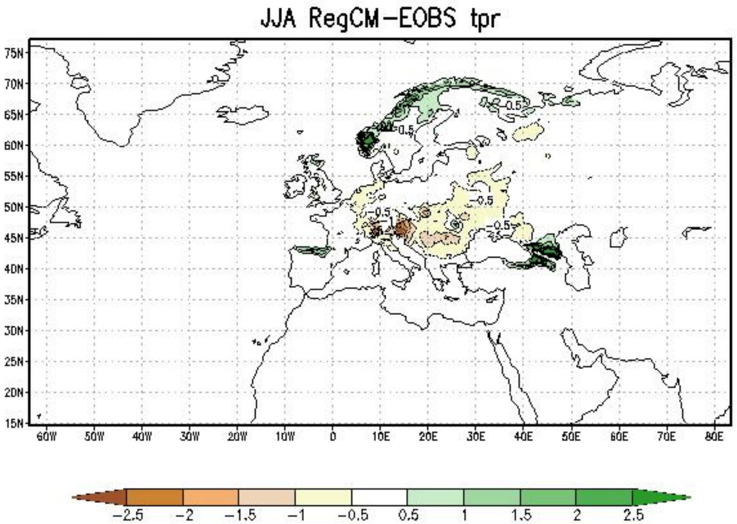
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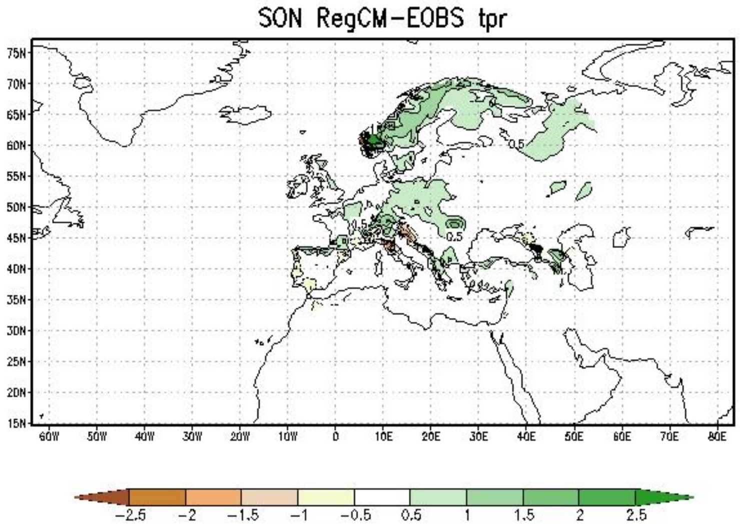
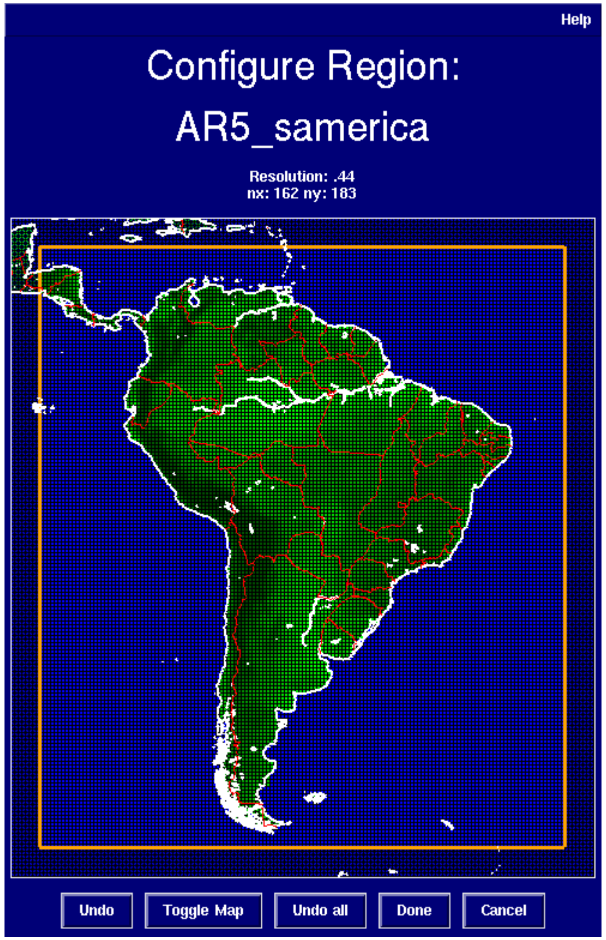

SON RegCM-EOBS tpr
−2.5 −2 −1.5 −1 −0.5 0.5 1 1.5 2 2.5

CORDEX: Some basic information

- Publication describing the CORDEX framework and PHASE I plan.
  - Giorgi, Jones, Asrar, WMO Bulletin, July 2009
- CORDEX web-site and email server (IA State)
  - http://wcrp.ipsl.jussieu.fr/RCD_Projects/CORDEX/CORDEX.html
- CORDEX regional databanks (DMI, KMA)
- Formation of regional diagnostic and evaluation teams (DETs)
  - B. Hewitson (UCT) to lead the Africa DET
- CORDEX sub-projects
  - MED-CORDEX (focus on coupled RCMs)
  - EURO-CORDEX (higher resolution, 10-15 km)

Region 1: South America

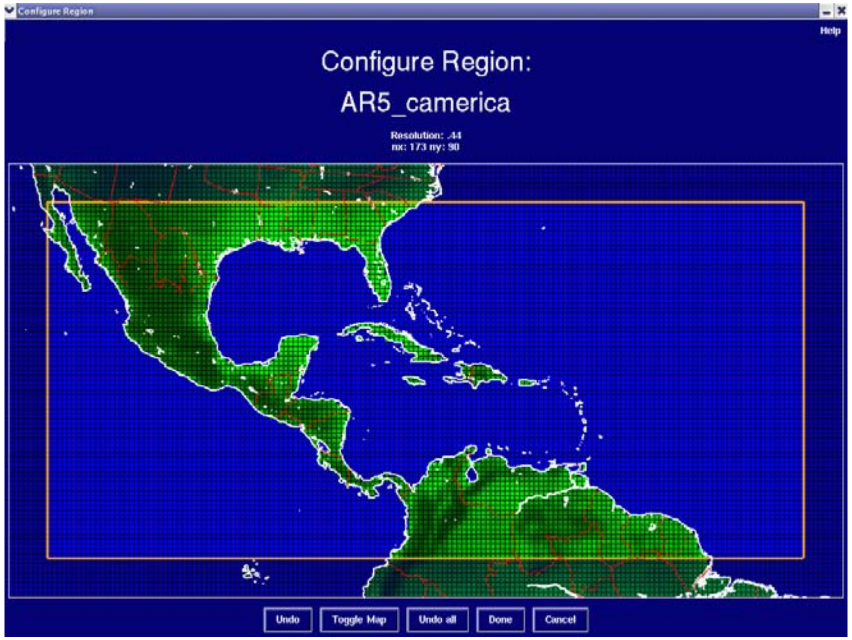
[90W-32W;58S-12N]



162x183

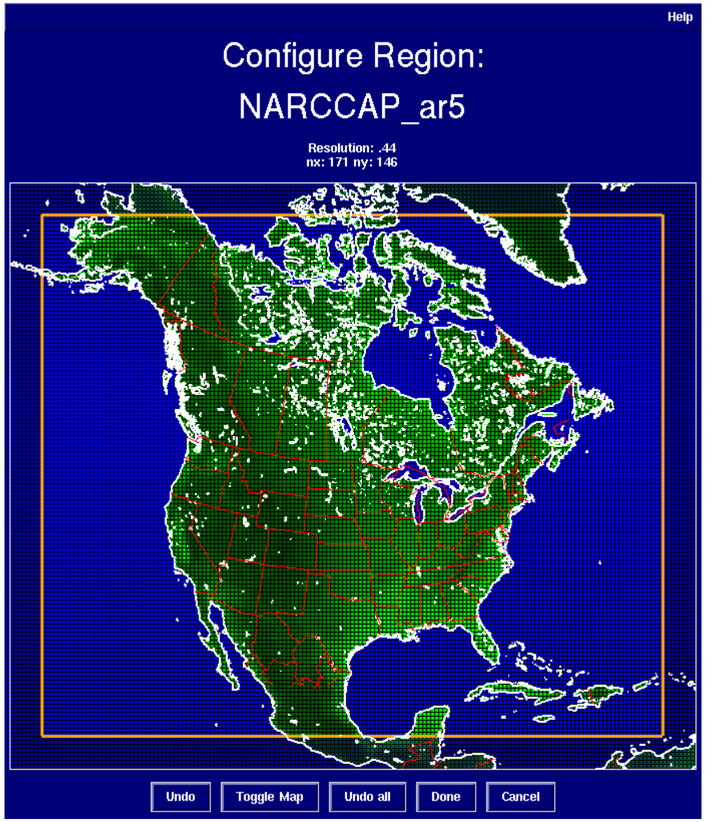
Region 2: Central America

[115W-48W;0-35N]



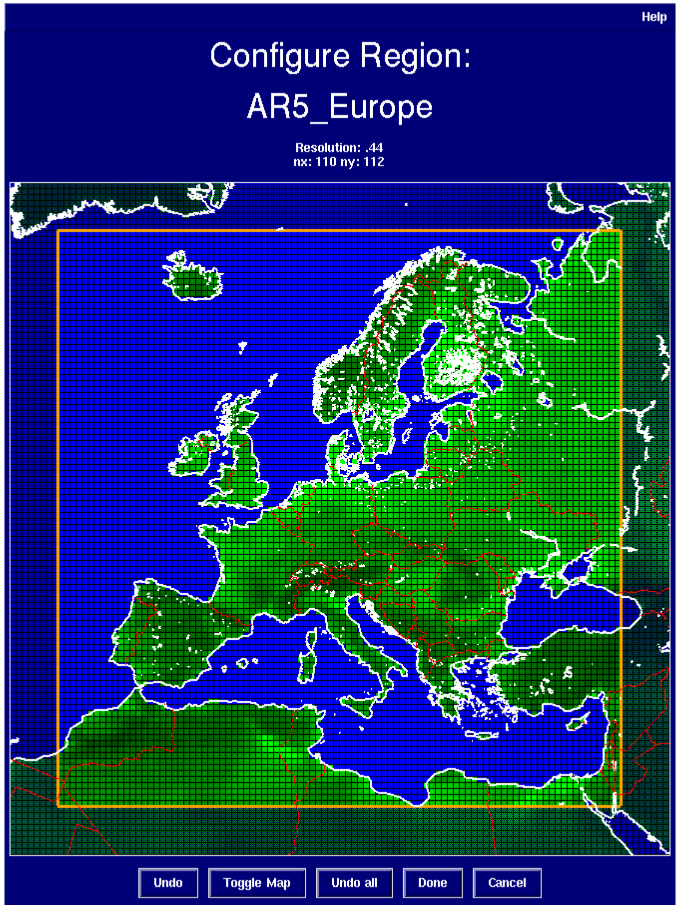
173x90

Region 3: North America (NARCCAP)



171x146

Region 4: Europe (ENSEMBLES)

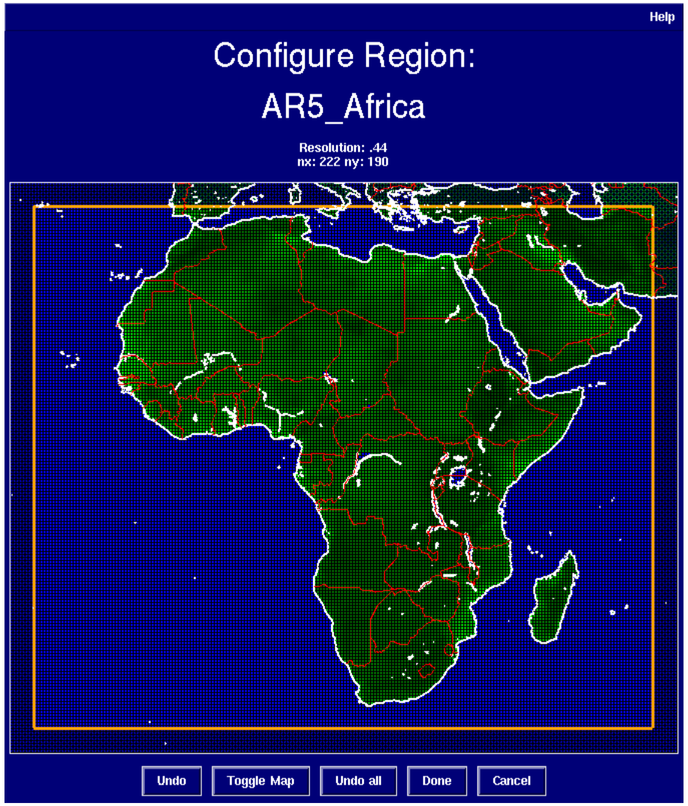


110x112

Region 5: Africa

… or should we split e.g. with a southern region like this

[25W-60E;38S-38N]



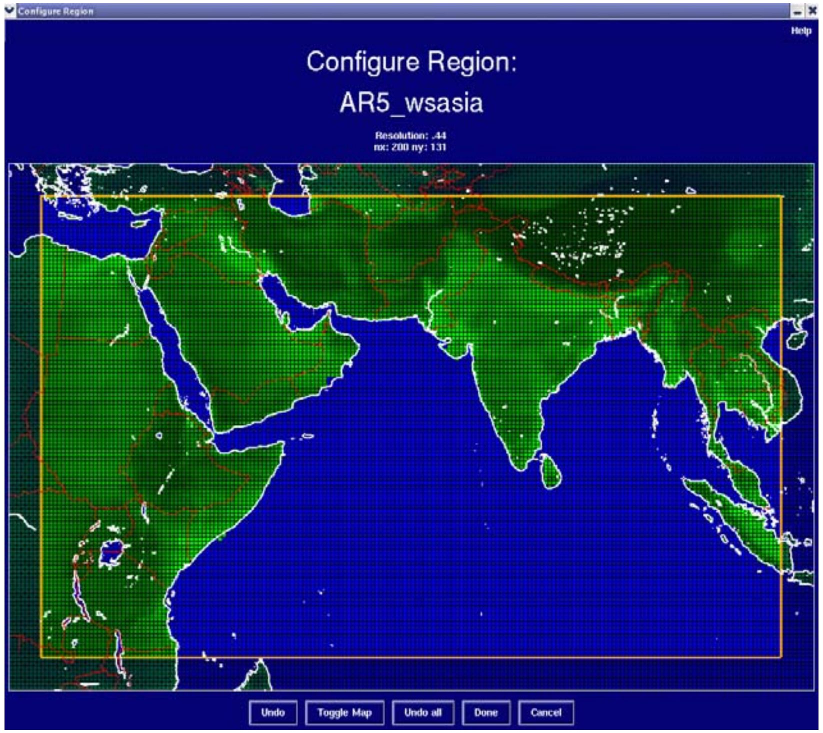
222x190

South Africa [5E-60E;40S-0]

164x116

Region 6: West Asia

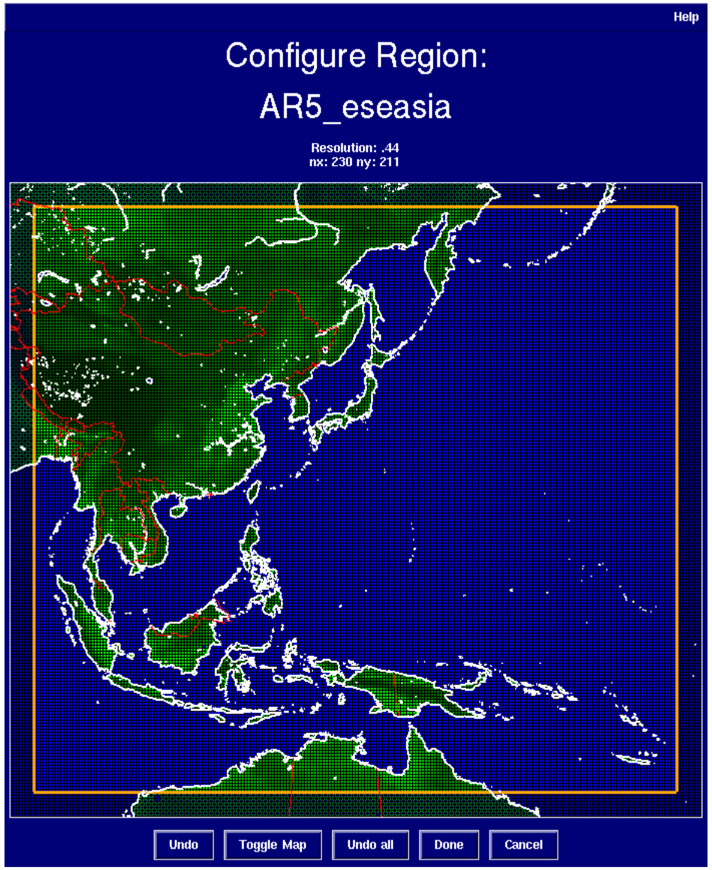
[30E-110E;10S-40N]



200x131

Region 7: East Asia

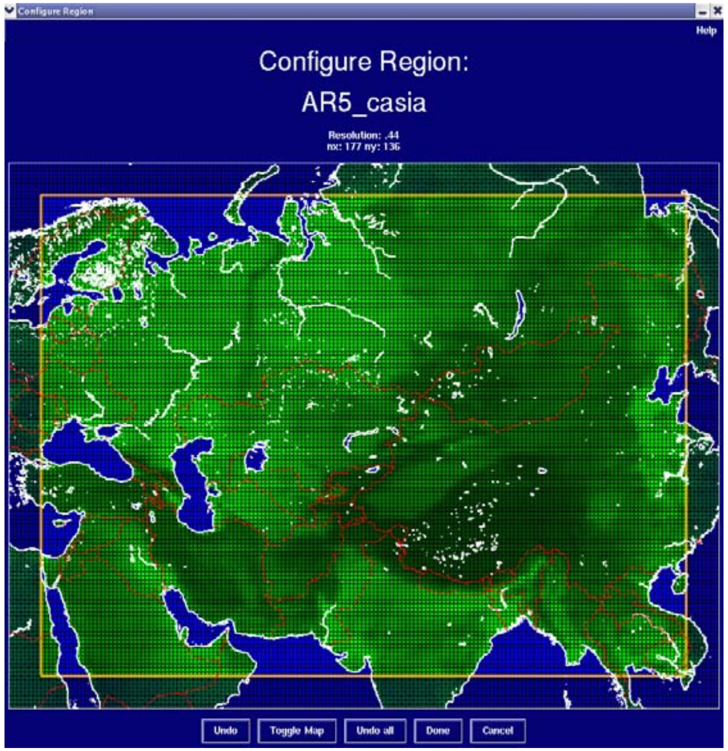
[65E-180E;20S-60N]



230x211

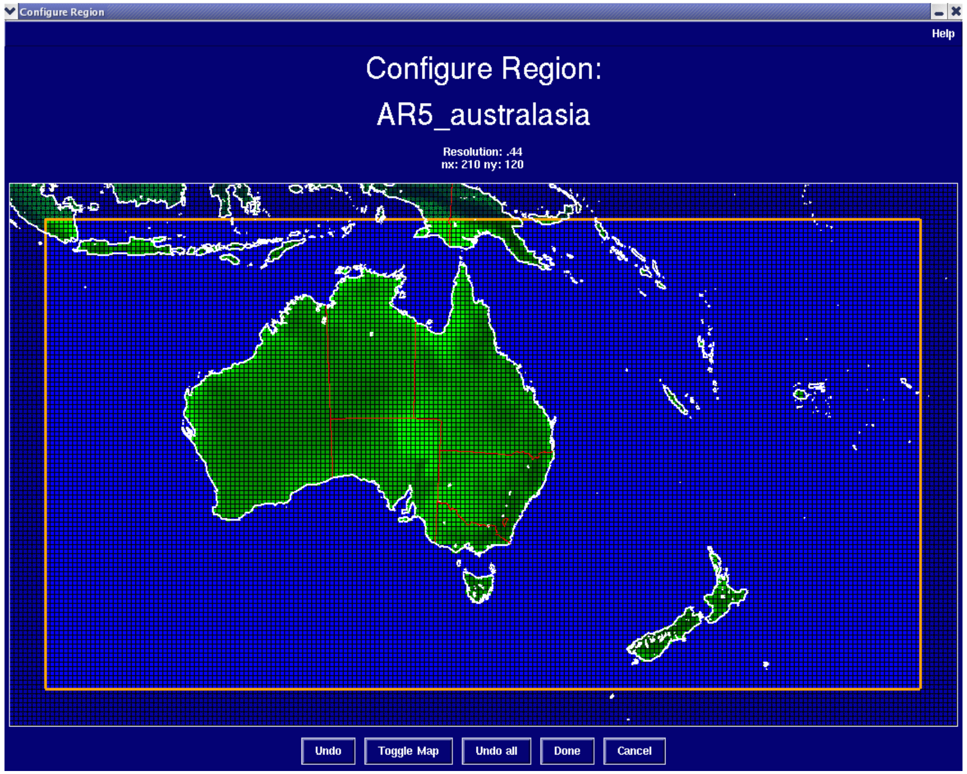
Region 8?: Central Asia

Region 9: Austral Asia



177x136

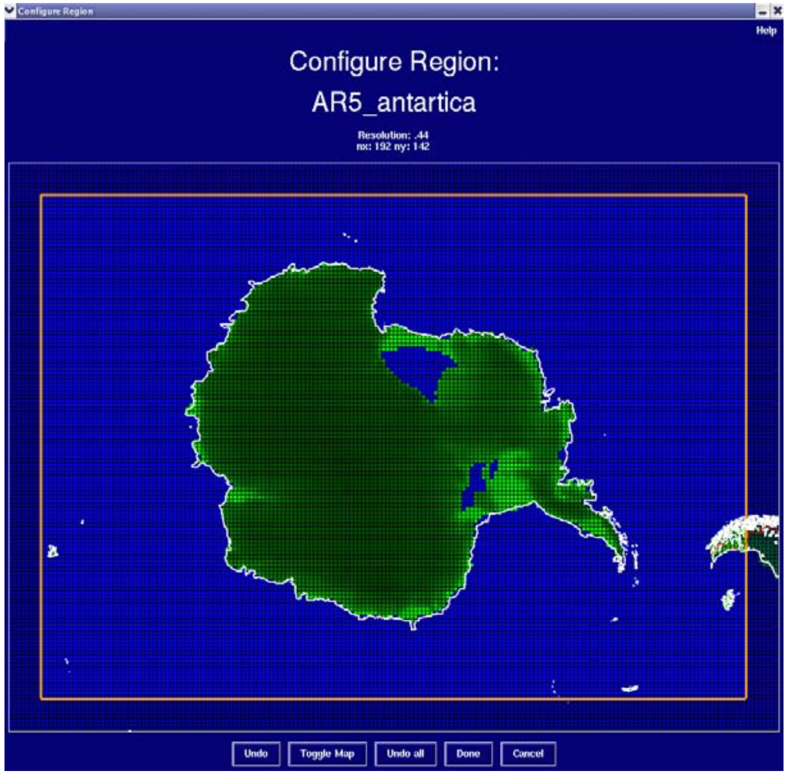
[100E-180E;50S-10S]



210x120

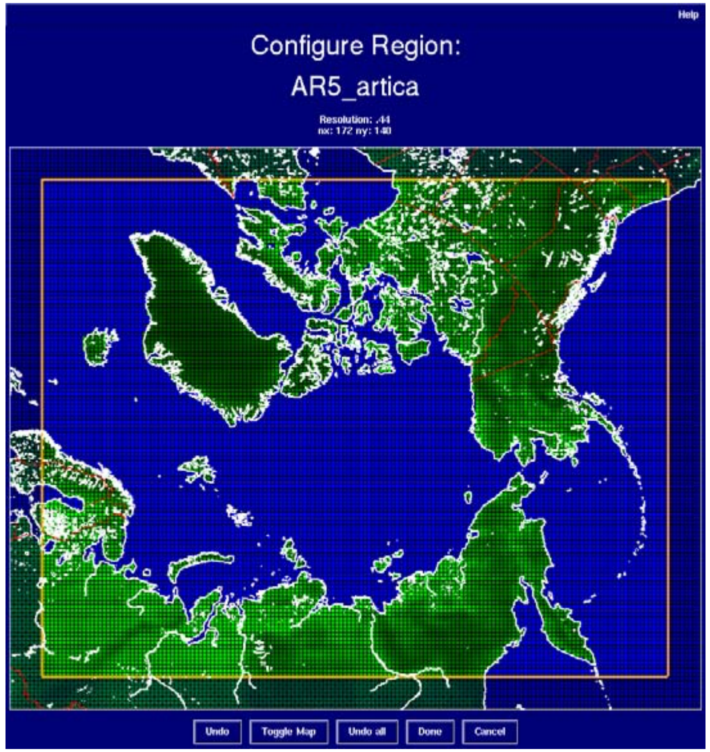
Polar Regions

Antarctica



192x142

Arctic



172x140