Project of Strategic Interest NEXTDATA

Scientific Report for the reference period **01/01/2012-31/12/2012**

Unit ICTP

WP 2.5 - Archive of numerical simulations and projections

1. Scheduled activities, expected results and Milestones (as indicated in the Executive Plan)

During year 1 of the project ICTP is expected to carry out the following activities:

1) Participation to the census of climate simulations and harmonization of the archiving protocols; participation to the definition of the numerical experiment strategy for the project.

   Milestone M2.5.1 (PM12): Completion of the census of climate simulations and harmonization of the data archiving protocol; definition of the "scientific questions" and of the simulation strategy.

2) Participation to the pilot study on the changes in snow cover and hydrologic cycle over the Alps and Apennines, with inclusion of stochastic downscaling technique.

   Milestone M2.6.1 (PM12): preliminary results from the pilot study

2. Deliverables expected for the reference period

1) Contribution to D2.5.1 (PM12): Report on the census of climate simulations

2) Contribution to D2.6.1 (PM12): Report on the preliminary results of the pilot study

3. Activities which have been actually conducted during the reference period

3.1 Research activities

A census of the available simulations that will be included in the NextData archive was completed (WP2.5), and it is reported in the Attachment 1.
The data format decided within the NextData protocol is NetCDF; the previous simulations, reported in Attachment 1 (RegCM3 simulations), will be converted from binary to NetCDF format as requested.

A series of simulations were completed with the regional model RegCM (latest version RegCM4) over different CORDEX domains (WP2.5). Several GCMs were used as boundary conditions from 1970 up to 2100, with greenhouse gas pathways RCP8.5 and RCP4.5. The model domains are Mediterranean, Africa, South Asia, Central America and South America, the model horizontal grid spacing is 50 km (following the CORDEX protocol) and different model configurations were used for the different domains. An analysis of these experiments is currently under way. Data from these simulations will be included in the NextData archive and Attachment 1 provides a list of the model experiments completed this period.

For the Mediterranean and South Asia domains (the latter includes the entire Hymalaya and Tibetan Plateau) an analysis is being carried out of the changes in snow cover for the scenario runs. In addition to providing information on the snow response to global warming, this analysis will provide information on the needs in terms of model development for Alpine environments (WP2.6). Preliminary results indicate that the model tends to overestimate snow cover over the Himalayas, and the reasons for this overestimate are currently being investigated.

3.2 Applications; technological and computational aspects

Substantial development was carried out for the RegCM regional model, including both enhancements in the physics schemes (convection, land surface, radiation, planetary boundary layer) and code optimization. In particular a version of the model was developed which considerably improves parallelization and scaling compared to the previous one. This version allowed us to increase the model resolution while keeping reasonable computation times.
The completion of the CORDEX simulations entailed the intensive use of massively parallel computing resources (about 1 Million CPU hours in a period of three months). The simulations produced about 150 terabytes of data, which are being managed on two storage archives. Post-processing programs to facilitate the analysis of the data was developed.

3.3 Formation

A workshop was conducted in May 2012 on the latest version of the RegCM system, RegCM4. This workshop included both theoretical classes and tutorial/laboratory sessions. About 90 students participated to this workshop. In addition, 4 students from Brazil, India, Mexico and Hungary were invited to ICTP for a period of 6 months to carry out the simulations in 3.1 and the initial phase of the analysis under the supervision of ICTP scientific staff.

3.4 Dissemination

The RegCM model is a free and public code and it is maintained for community use. The output from the simulations in 3.1 will be available for community use, particularly for impact studies.

3.5 Participation in conferences, workshops, meetings

Laura Mariotti attended NextData meetings in Bologna (March 2012), Roma (October 2012) and Bologna (November 2012).

4. Results obtained during the reference period

4.1 Specific results (Data libraries, Measurements, Numerical simulations, etc)

Output from the new set of CORDEX numerical scenario simulations in Attachment 1.

4.2 Publications

A special issue of Climatic Change (including about 10 articles) on the first results and analysis of the CORDEX simulations in Attachment 1 is planned and the papers will be submitted in December 2012 and January 2013.

4.3 Availability of data and model outputs (format, type of library, etc)

Output from the simulations in Attachment 1 are in NetCDF format following the NextData protocol.

4.4 Completed deliverables

D2.5.1
D2.6.1

5. Comment on differences between expected activities/results/deliverables and those which have been actually performed.

Activities were generally in line with expectations. The stochastic downscaling method of CNR-ISAC has not yet been implemented within the RegCM system, and discussions with CNR-ISAC will be needed on how to expedite this implementation.

6. Expected activities for the following reference period (year 2013)

Participation to the "Manifestazione d'Interesse" disseminated by the CNR for continuation of involvement in NextData along the lines indicated in workpackage 2. Transfer of data to the NextData archive once the conversion of the already available data from binary to NetCDF format and the first analysis of the CORDEX simulations are completed.

ATTACHMENT 1

Inventory of climate experiments performed at ICTP

(Please see the appendices for a more detailed description of the models and of the experimental configurations)

1) RegCM3

Model version: RegCM3 (Giorgi et al 1993a,b)
Atmosphere 18 vertical sigma levels.
Raw output files are in binary + netcdf (to be converted)
See appendix 1 for a description of the model.
See appendix 2 for the spatial plots for all the domains.

Completed runs:

- *Alpine Region*
  - Time period: (1951-2050)
  - BC: RegCM3 at 25km of resolution (ECHAM5 boundary, A1B scenario)
  - Horizontal Resolution: 15km
  - Approximate size of the raw output archive (netcdf): 5TB

- *African Region*
  - Time period: (1980-2100)
  - BC: ECHAM5 GCM, A1B scenario
  - Horizontal Resolution: 50km
  - Approximate size of the raw output archive (netcdf): 9TB

2) CORDEX simulations with the regional climate model RegCM4.3

Model: RegCM4.3 (Giorgi et al.2012)
All runs at 50km of horizontal resolution.
See appendix 3 for a description of model.
See appendix 4 for a description of variables for CORDEX archives and of the frequency of the outputs.
See appendix 5 for the spatial plots for all the domains.

The following table summarizes the experiments which have been performed

Domain	Boundary conditions (GCMs)	period	approx. size (Tb)
South Asia	GFDL scenarios: RCP4.5, RCP8.5	1970-2100	3.4
South Asia	MPI ECHAM6 scenario RCP8.5	1970-2100	3.4
Africa	HadGEM scenarios: RCP4.5, RCP8.5	1970-2100	6.3
Africa	MPI ECHAM6 scenario RCP8.5	1970-2100	3.4
Central America	HadGEM scenarios: RCP4.5, RCP8.5	1970-2100	3.8
Central America	MPI ECHAM6 scenario RCP8.5	1970-2100	5.2
South America	HadGEM scenarios: RCP4.5, RCP8.5	1970-2100	6.4
South America	GDFL, scenario RCP8.5	1970-2100	3.5
South America	MPI ECHAM6 scenario RCP8.5	1970-2100	2.6
Mediterranean	HadGEM scenarios: RCP4.5, RCP8.5	1970-2100	6.0
Mediterranean	MPI ECHAM6 scenario RCP8.5	1970-2100	5.0

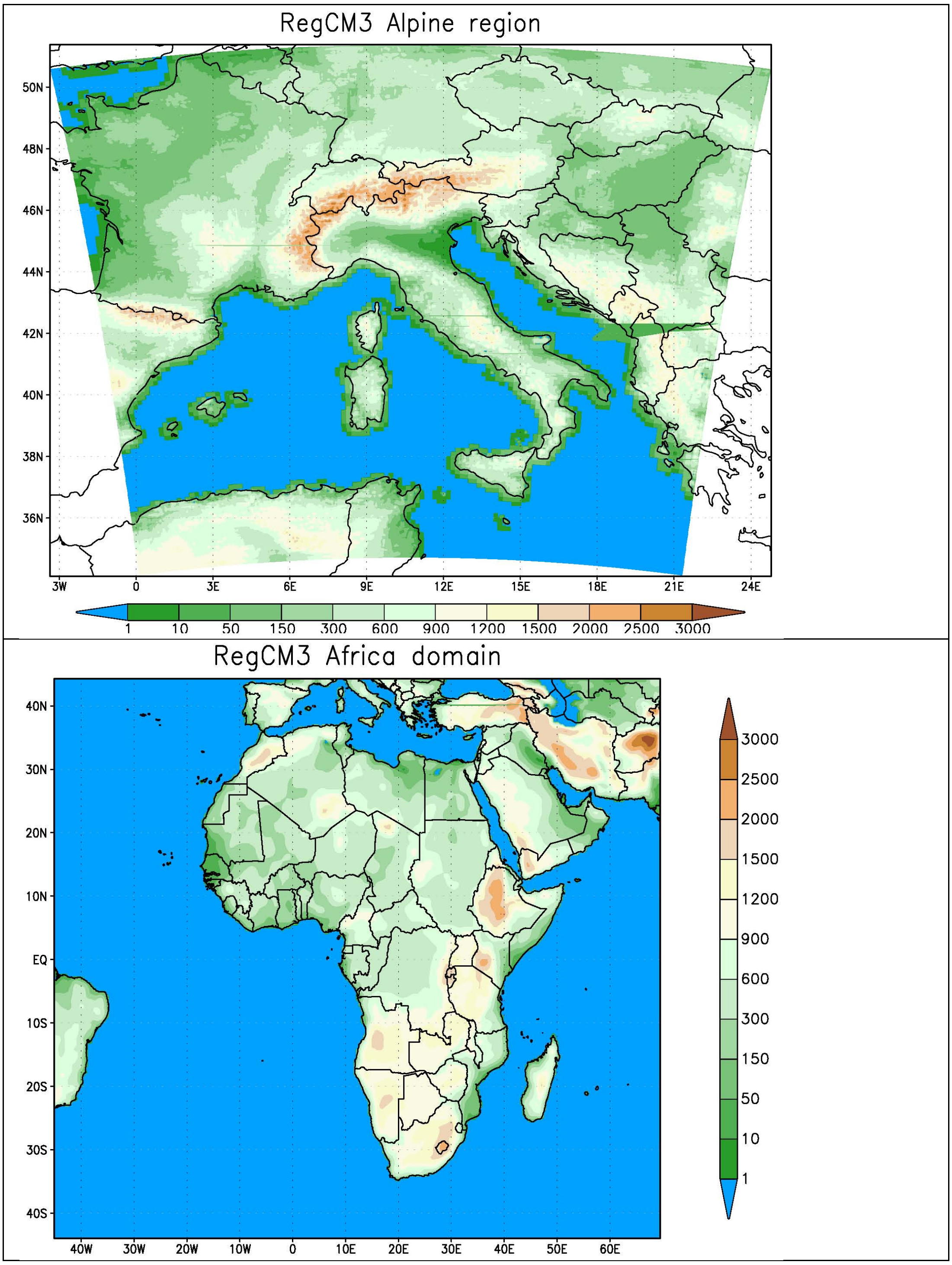
Appendix 1: RegCM3 model description

The ICTP regional climate model, RegCM3, is described in Giorgi et al. 1993a, b; Pal et al. 2007. RegCM3 is a primitive equation, sigma vertical coordinate, regional climate model based on the hydrostatic version of the dynamical core of the NCAR/PSU's mesoscale meteorological model MM5 (Grell et al. 1994). Radiation is represented by the CCM3 parameterization of Kiehl et al. (1996) and the planetary boundary scheme is represented by the scheme of Holtslag et al. (1990) in the implementation of Giorgi et al. (1993a). Interactions between the land surface and the atmosphere are described using the biosphere atmosphere transfer scheme (BATS1E; Dickinson
et al. 1993). For the ocean flux parameterization with two schemes were used: Zeng et al. (1998) and BATS (Dickinson et al. 1993).
Convective precipitation is computed using one of three schemes: (1) Modified-Kuo scheme Anthes (1977); (2) Grell scheme (1993); and (3) MIT-Emanuel scheme (Emanuel, 1991; Emanuel and Zivkovic-Rothman, 1999). In addition, the Grell parameterization is implemented using one of two closure assumptions: (1) the Arakawa and Schubert closure Grell et al. (1994) and (2) the Fritsch and Chappell closure Fritsch and Chappell (1980), hereafter refered to as AS74 and FC80, respectively.
The Large-Scale precipitation scheme Subgrid Explicit Moisture Scheme (SUBEX) is used to handle nonconvective clouds and precipitation resolved by the model. SUBEX accounts for the subgrid variability in clouds by linking the average grid cell relative humidity to the cloud fraction and cloud water following the work of Sundqvist et al. (1989) and it also includes simple formulations for raindrop accretion and evaporation. For a more detailed description of SUBEX and a list of the parameter values refer to Pal et al. (2000).

RegCM Bibliography is in the Appendix 3

Appendix 2: spatial plots for all the domains with RegCM3

Spatial horizontal resolution: 50km for the Africa domain, 15km for Alpine region.



Appendix 3: RegCM4.3 model description

A new version of the regional climate modeling system, RegCM4, has been recently developed in the Abdus Salam International centre for Theoretical Physics (ICTP), described in Giorgi et. al., 2012. Compared to previous versions, RegCM4 includes new land surface, planetary boundary layer, and air–sea flux schemes, a mixed convection and tropical band configuration, modifications to the pre-existing radiative transfer and boundary layer schemes, and a full upgrade of the model code towards improved flexibility, portability, and user friendliness.
The model can be interactively coupled to a 1D lake model, a simplified aerosol scheme (including organic carbon, black carbon, SO4, dust, and sea spray), and a gas phase chemistry module (CBM-Z). The new version RegCM4.3 can be used in multiple 2-way nested mode.
In the table are reported the model options available in RegCM4.

Model aspects	**Available options**
Dynamics	Hydrostatic, σ-vertical coordinate (Giorgi et al. 1993a)
Radiative transfer	Modified CCM3 (Kiehl et al. 1996)
PBL (planetary boundary layer)	Modified Holtslag (Holtslag et al. 1990) UW-PBL (Bretherton et al. 2004)
Cumulus convection	Simplified Kuo (Kuo et al. 1986) Grell (Grell et al. 1993) MIT (Emanuel and Zivkovic-Rothman 1999) Tiedtke (Tiedtke 1989, in progress)
Resolved scale precipitation	SUBEX (Pal et al. 2000)
Land surface	BATS (Dickinson et al. 1993) Sub-grid BATS (Giorgi et al. 2003) CLM (Steiner et al. 2009)
Ocean fluxes	BATS (Dickinson et al. 1993) Zeng (Zeng et al. 2008) Diurnal SST (Zeng and Beljaars 2005)
Interactive aerosols	OC,BC, SO4 (Solmon et al. 2006) Dust (Zakey et al. 2006) Sea salt (Zakey et al. 2008)
Interactive lake	1D diffusion/convection (Hostetler et al. 1993)
Tropical band	Coppola et al. (2011)
Coupled ocean (not in public version)	MIT (Artale et al. 2010) ROMS (Ratnam et al. 2009)

A series of global climate simulations has been completed with RegCM4.3, in coordination with the RegCNET community (Giorgi et al. 2006), to produce climate change projections within the CORDEX framework (Giorgi et al 2009) for at least 6 domains: Africa, Europe, Central America, South America, East Asia, and South Asia. The emissions from the CMIP5 GCMs were used for these experiments. The main reference is the CMIP5 website: http://cmip-pcmdi.llnl.gov/cmip5/forcing.html

RegCM Bibliography

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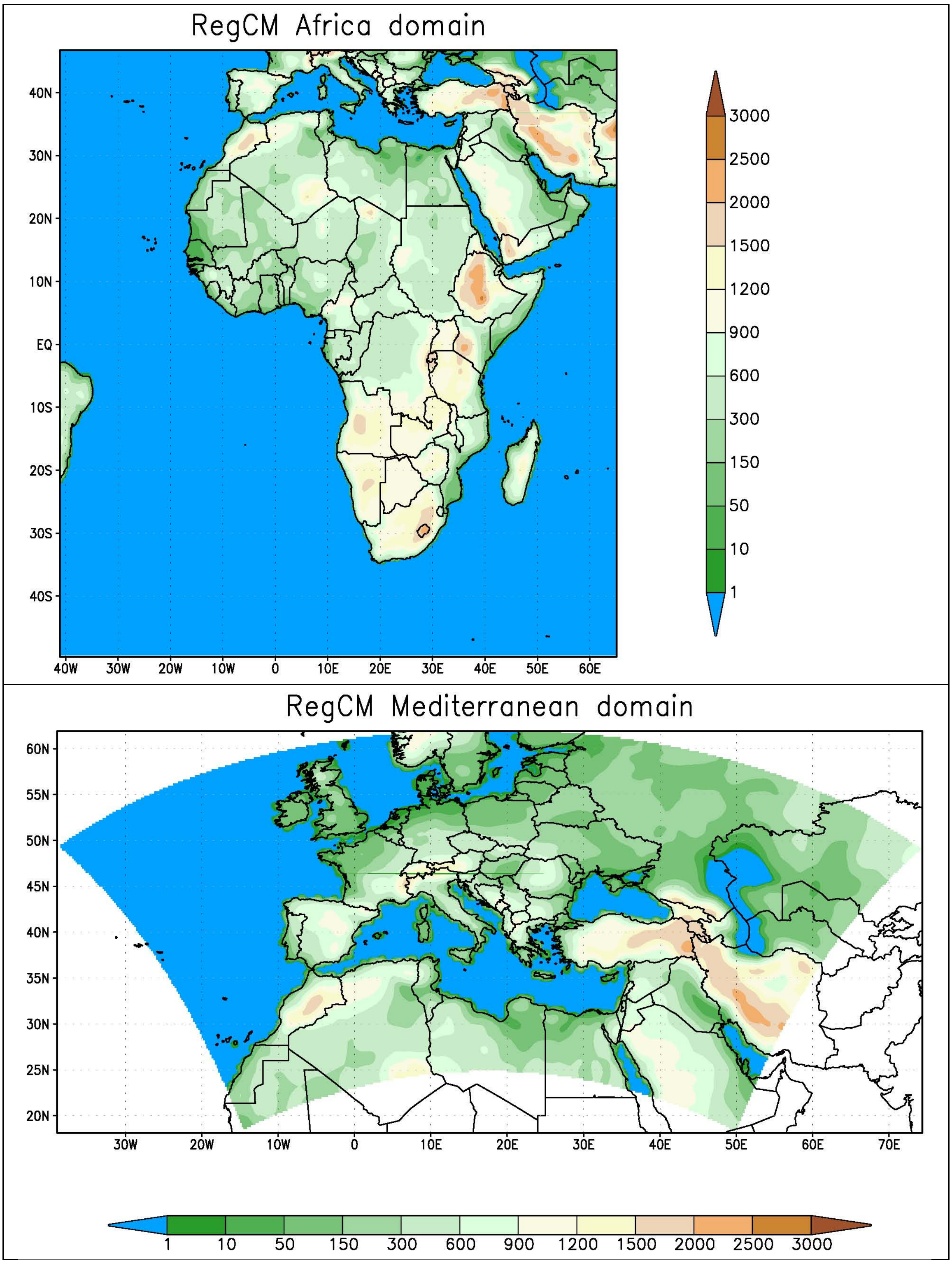
Appendix 4: Summary of variables saved for CORDEX archives

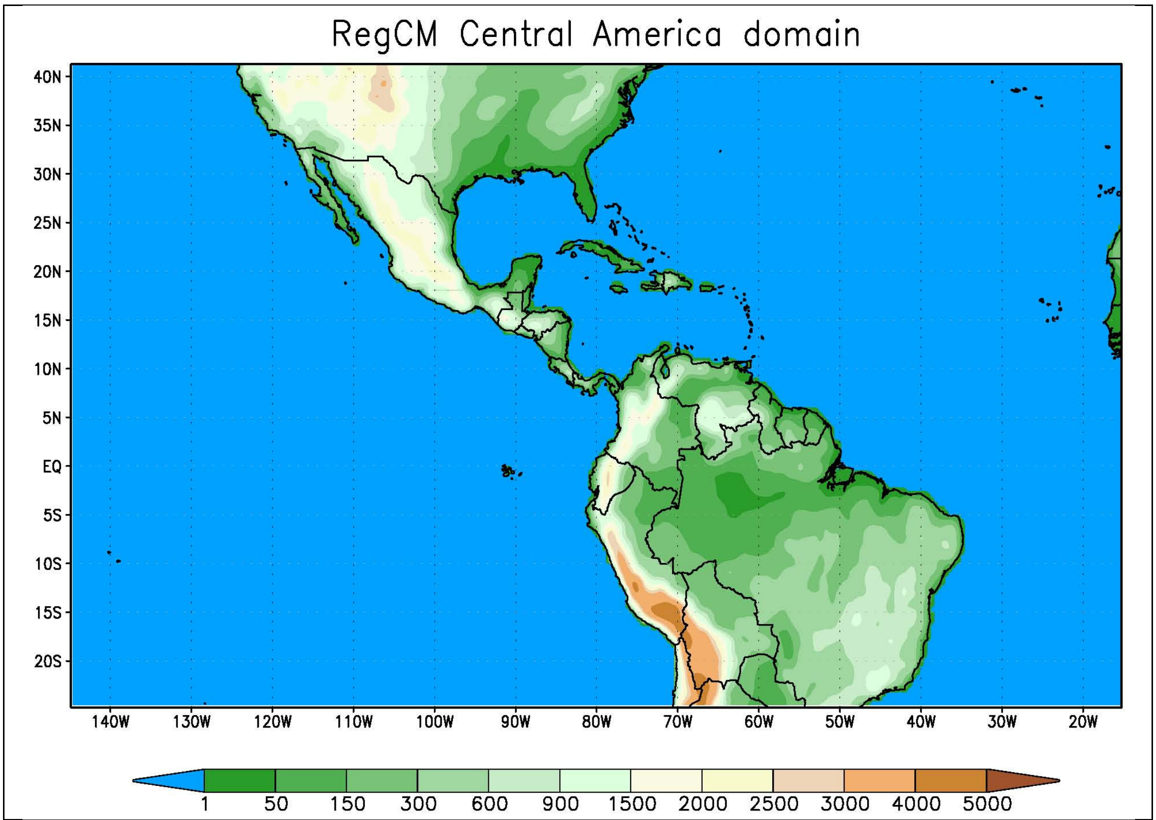
Description	Name	Unit	CORDEX name	CORDEX unit	Freq	Dim.
Atmosphere						
westerly wind	uwind	m/s	ua	m s-1	Daily mean	Height, Lat, Lon
southerly wind	vwind	m/s	va	m s-1	Daily mean	Height, Lat, Lon
omega	omega	hPa s-1	wap	Pa s-1	Daily mean	Height, Lat, Lon
Geopotential height	hgt	m	zg	m	Daily mean	Height, Lat, Lon
Cloud cover	fc	fraction	clt	%	Daily mean	Height, Lat, Lon
air temperature	tk	K	ta	K	Daily mean	Height, Lat, Lon
Relative humidity	th	fraction	hur	%	Daily mean	Height, Lat, Lon
Surface Abs solar	fsw	W/m2			Daily mean	Lat, Lon
LW Cooling of Surf	flw	W/m2			Daily mean	Lat, Lon
Sea Level Pressure	slp	hPa	psl	Pa	Daily mean	Lat, Lon
Surface						
westerly wind at 10m	ua	m/s	uas	m s-1	6hr mean	Lat, Lon
southerly wind at 10m	va	m/s	vas	m s-1	6hr mean	Lat, Lon
ground temperature	tg	K	tslsi	K	6hr mean	Lat, Lon
temperature of foliage	tf	K			6hr mean	Lat, Lon
air temperature at 2m	ta	K	tas	K	6hr mean	Lat, Lon
specific humidity at 2m	qa	kg/kg	huss	1	6hr mean	Lat, Lon
upper layer soil water	smr	mm	mrsos	kg m-2	6hr mean	Lat, Lon
root zone soil water	smu	mm			6hr mean	Lat, Lon
total precipitation	rt	mm/day	pr	kg m-2 s-1	6hr mean	Lat, Lon
evapotranspiration	et	mm/day	evspsbl	kg m-2 s-1	6hr mean	Lat, Lon
total runoff	rnfs	mm/day	mrro	kg m-2 s-1	6hr mean	Lat, Lon
Snow depth	snow	mm H2O	snw	kg m-2	6hr mean	Lat, Lon
sensible heat flux	sh	W/m^2	hfss	W m-2	6hr mean	Lat, Lon
net LW energy surface flux	lwn	W/m^2			6hr mean	Lat, Lon
net solar energy surface flux	swn	W/m^2			6hr mean	Lat, Lon
downward LW energy surface flux	lwd	W/m^2	rlds	W m-2	6hr mean	Lat, Lon
incident solar energy flux	swi	W/m^2	rsds	W m-2	6hr mean	Lat, Lon
convective precipitation	rc	mm/day	prc	kg m-2 s-1	6hr mean	Lat, Lon
surface pressure	psrf	hPa	ps	Pa	6hr mean	Lat, Lon

PBL layer height	zpbl	m			6hr mean	Lat, Lon
maximum 2m air temperature	tamax	K	tasmax	K	Daily mean	Lat, Lon
minimum 2m air temperature	tamin	K	Tasmin	K	Daily mean	Lat, Lon

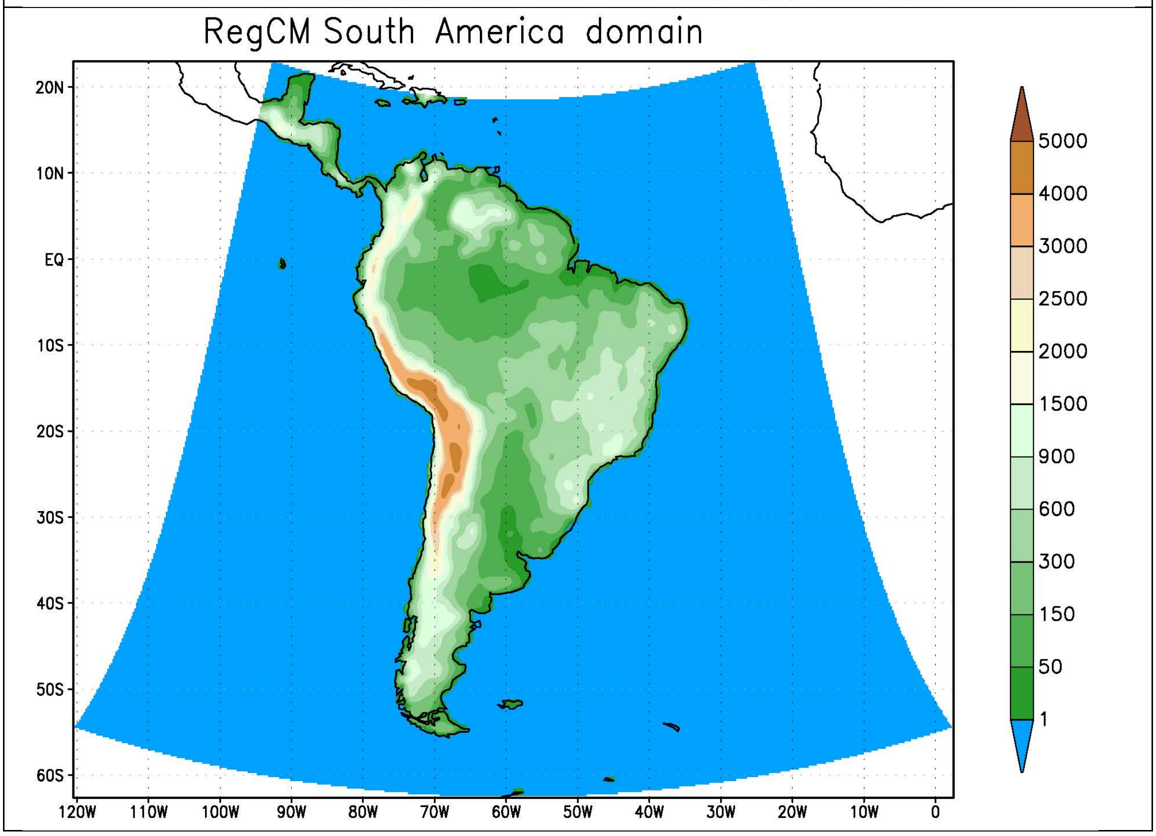
Appendix 5: spatial plots for all the domains

Spatial horizontal resolution 50km

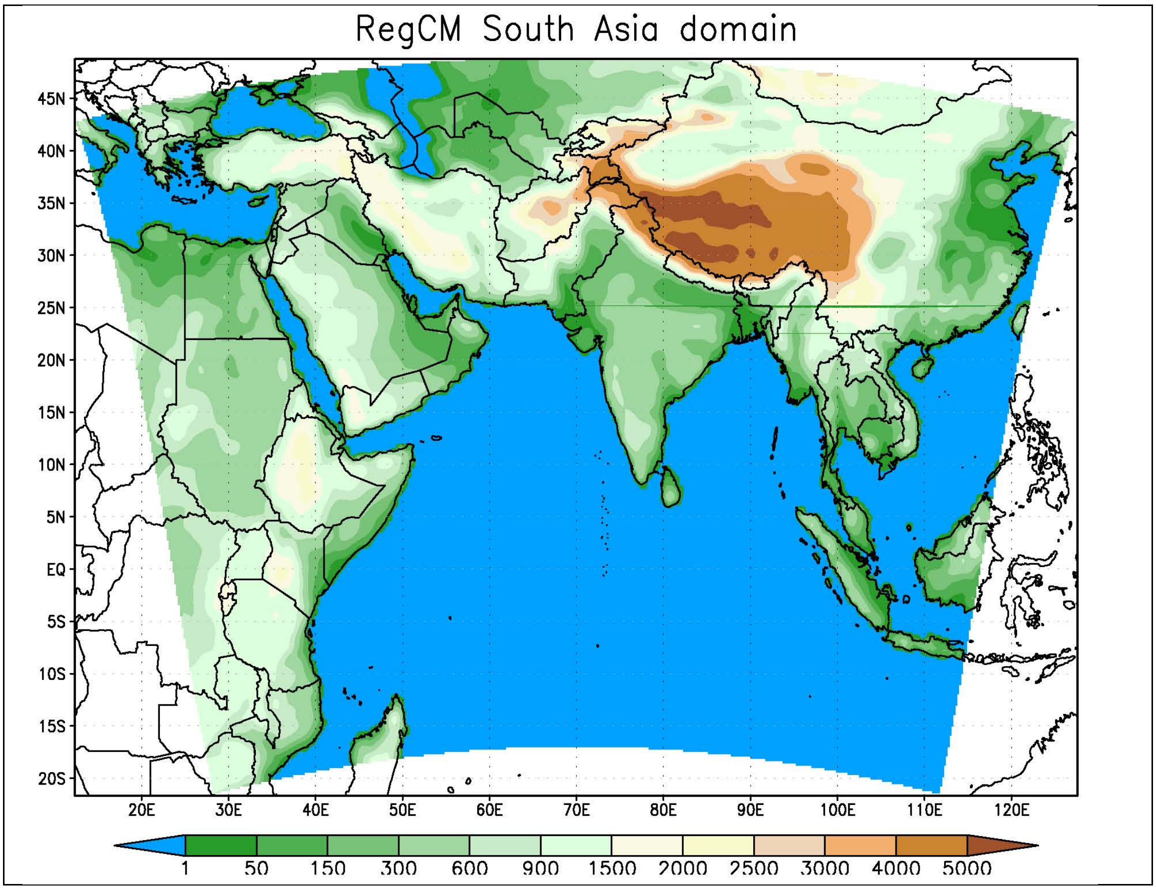




RegCM Central America domain
40N
35N
30N
25N
20N
15N
10N
5N
EQ
5S
10S
15S
20S
140W 130W 120W 110W 100W 90W 80W 70W 60W 50W 40W 30W 20W
1 50 150 300 600 900 1500 2000 2500 3000 4000 5000



RegCM South America domain
20N
10N
EQ
10S
20S
30S
40S
50S
60S
120W 110W 100W 90W 80W 70W 60W 50W 40W 30W 20W 10W 0
5000
4000
3000
2500
2000
1500
900
600
300
150
50
1


RegCM South Asia domain
45N
40N
35N
30N
25N
20N
15N
10N
5N
EQ
5S
10S
15S
20S
20E
30E
40E
50E
60E
70E
80E
90E
100E
110E
120E
1
50
150
300
600
900
1500
2000
2500
3000
4000
5000