Project of Strategic Interest NEXTDATA

Special Project RECCO

Deliverable D2.5.R.1a

includes the internal RECCO Deliverables

RECCO P4.1.1
Description of the data transferred to the NextData Archive

RECCO P4.1.2
Report summarizing the main findings from the analysis of the available simulations.

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1. Introduction

Research activities during the NextData reference period have mostly focused on the analysis of a series of scenario simulations with RegCM4 at 50 km resolution completed over 5 CORDEX domains, and on the completion of a new 12 km resolution scenario run over the Mediterranean region. The CORDEX runs, which are part of the CORDEX RegCM hyper-MAtrix (CREMA) experiment, are a series of scenario simulations over five CORDEX domains completed with the RegCM4 RCM driven by different CMIP5 GCMs on dedicated nodes (for a total of about 1 million CPU hours) in a supercomputer provided by the ARCTUR computing company located in Nova Gorica, Slovenia. The five domains are: Africa, Mediterranean, South America, Central America and West Asia (i.e. the domain centred on India).

Runs were carried out with different driving GCMs, greenhouse gas concentration pathways (RCP4.5 and RCP8.5) and different RegCM physics configurations (convection and land surface schemes). The three GCMs were selected from the CMIP5 ensemble for which 6-hourly fields necessary to run the RegCM4 were available when the CREMA experiment started. The three GCMs are HADGEM2ES, MPI-ESMMR and GFDL-ESM2M. This selection was based on a series of preliminary tests showing that these were the GCMs that provided better performing RegCM4 results over the different domains. We stress, however, that not all CMIP5 GCMs had provided 6-hourly fields when the experiment started, so the choice was within a limited sub-set of CMIP models. In order to provide a first assessment of uncertainty, although necessarily very limited, for each domain mini-ensembles of experiments were carried out with different driving GCMs, different RegCM4 physics configurations and different scenarios. Each simulation extended from 1970 to 2100. The analysis covered different aspects of the simulations. A series of papers was produced as part of this analysis, contributing to a Special Issue of Climatic Change. More specifically, these were the experiments conducted:

Africa domain: Two runs driven by HADGEM2ES for RCP4.5 and RCP8.5 and one RegCM configuration + one run driven by MPI-ESMMR for RCP4.5 driven by a different RegCM configuration. Total: 3 simulations.

South America domain: Four runs driven by HADGEM2ES, with 2 RegCM4 configurations and RCP4.5/8.5 + two runs driven by MPI-ESMMR and GFDL-ESM2M for RCP8.5 and one of the RegCM4 configurations. Total: 6 simulations.

Central America domain: Four runs driven by HADGEM2ES, with 2 RegCM4 configurations and RCP4.5/8.5 + two runs with two RegCM4 configurations, RCP8.5 driven by MPI-ESMMR. Total: 6 simulations.

Mediterranean domain: Six runs driven by HADGEM2ES, with 6 RegCM4 configurations, RCP85 + Seven runs driven by MPI-ESMMR, with 7 RegCM4 configurations, RCP8.5 + one run driven by MPI-ESMMR with one model configuration RCP4.5. Total: 14 simulations.

2. Deliverable RECCO P4.1.1: Description of the data transferred to the NextData Archive

The transfer of the data to the archive is not completed yet; the post-process phase is still on-going. In the following Table 1 a list of the simulations currently available in the NextData archive is reported.

Tab. 1. Summary of the experiments that have been transferred to the NextData archive; all runs at horizontal resolution of 50km.

Domain	Boundary conditions (GCMs)	period
Africa	HadGEM scenarios: RCP4.5, RCP8.5	1970-2100
Africa	MPI ECHAM6 scenario RCP8.5	1970-2100
Central America	HadGEM scenarios: RCP8.5	1970-2100
South America	HadGEM scenarios: RCP8.5	1970-2100
Mediterranean	HadGEM scenarios: RCP8.5	1970-2100
Mediterranean	MPI ECHAM6 scenario RCP8.5	1970-2100

Table 2 reports the variables stored in the NextData archive for each domain:

Tab. 2. Summary of the variables sored in the NextData archive

DAILY MEANS	MONTHLY MEANS
mean temperature (tas) max temperature (tasmax) min temperature (tasmin) precipitation (pr) evaporation (evspsbl) 10m wind (sfcWind)	mean temperature (tas) max temperature (tasmax) min temperature (tasmin) precipitation (pr) evaporation (evspsbl) sea level pressure (psl) total runoff (mrro) specific humidity, and winds at 850mb (hus850,ua850, va850)

3. Deliverable P4.1.2: Report summarizing the main findings from the analysis of the available simulations.

From the analysis of these simulations, we carried out a series of publications whose main results are described here. These papers have been published in the Special Issue of *Climatic Change*, 2014, (vol. 125, issue 1) "The phase I CORDEX RegCM4 hyper-matrix (CREMA) experiment" (all the abstracts are reported in Appendix 1). This special issue of *Climatic Change* gathers a series of papers detailing the first analysis of the Phase I CORDEX RegCM4 hyper-Matrix (or CREMA) experiment. The two papers, Coppola et al. (2014) and Giorgi et al. (2014), provide an overall view of the entire CREMA ensemble of global and corresponding regional model simulations. They serve as basic references for more detailed analyses over individual domains presented in the other papers of the issue and in future papers using this ensemble. Specifically, Coppola et al. (2014) present a baseline analysis of model systematic biases and future changes in temperature and precipitation mean climatologies over the various domains, while Giorgi et al. (2014) provide a corresponding analysis for a range of temperature and hydroclimatic extremes (Figure 1).

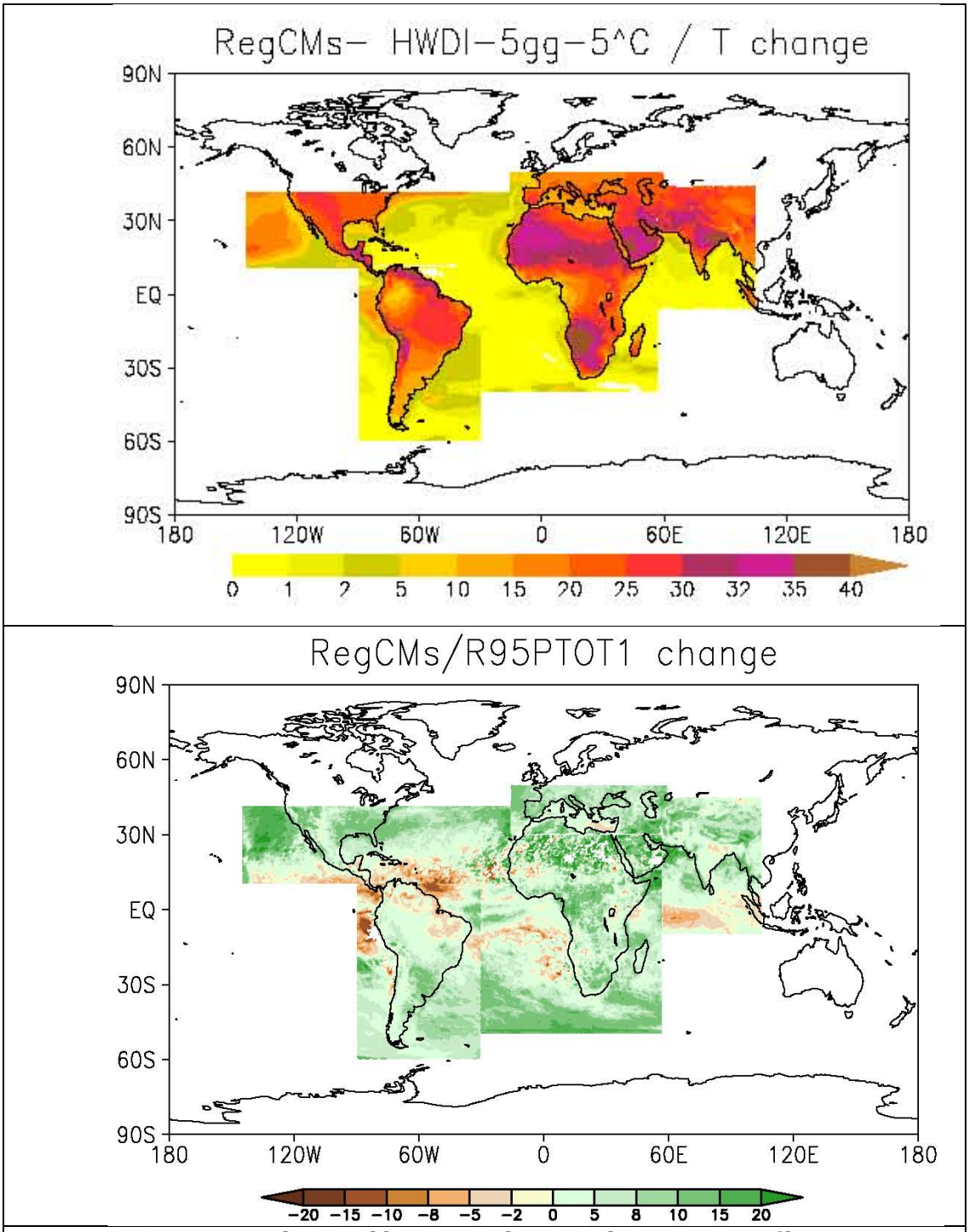

Fig. 1. Upper panel: Ensemble average change in the occurrence of heat waves over the five domains of the CREMA ensemble of RegCM4 scenario simulations (RCP8.5). Units are number of days per year per degree of warming. Lower panel: Ensemble average change in the ninety-five percentile of precipitation over the five domains of the CREMA ensemble of RegCM4 scenario simulations (RCP8.5). Units are % of present day value.

Mariotti et al. (2014) focus on the changes in intra-seasonal and seasonal characteristics of monsoon climates over the Africa domain. This work showed a prevailing late onset and early retreat of the monsoon leading to a narrowing and intensification of the monsoon precipitation season. Diro et al. (2014) report an analysis of changes in different

characteristics of tropical cyclones over the Central America domain (this being the first time that such an analysis is carried out for the RegCM4 system); the papers by da Rocha et al. (2014) and Llopart et al. (2014) examine the model simulations over the South America domain in terms of climate response to el Nino conditions and land-atmosphere interactions. Two papers have been published in other journal (see Appendix 1 for the abstracts):

Fuentes-Franco et al. (2014), showing a strong sensitivity of the model simulation of tropical storms on physics schemes and driving GCM and a decrease in number but an increase in intensity of storms over the Atlantic region.

For the Mediterranen area, a paper by Torma et al. (2014) analysing the application of the Factor Separation (FS) method to a large ensemble of scenarios over the Mediterranean region in order to investigate the relative importance of different aspects of the model configuration in determining the climate change signal. This study illustrated the usefulness of the FS technique to study the importance of different sources of uncertainty in climate projections. In general, these experiments indicated a strong sensitivity of the simulated climate change signals on the model physics schemes, thus providing a substantial contribution to the uncertainty of the simulated signals and further stressing the need of large ensembles to characterize these uncertainties. Finally, during the reference period, the analysis of the high resolution Mediterranean scenario simulation was also initiated and is currently under way.

4. Results obtained during the reference period and discussion

A few general lessons were learned from this first CREMA experiment. The first is that no model physics configuration was found that performed optimally over all domains and for all driving GCMs. In other words, different physics configurations need to be used for the different domains and driving GCM in order to optimize the model performance. This can perhaps be seen as a limitation of the RegCM4 physics schemes but also as an advantage of the flexibility offered by the availability of multiple physics options in the model. It also implies that the off-the-shelf configuration of the model may not be the best for a given application and that careful model validation and customization is needed in order to optimize the model performance.

The second lesson is that not only the model systematic errors but also the change signals were substantially dependent on the model physics configuration. Although the ensemble average large scale patterns of change (e.g. precipitation) were similar in the global and regional model CREMA ensembles (Coppola et al., 2014), in many individual domain cases the sensitivity to model configuration was large, and in some cases even larger than the sensitivity to driving GCM. This was particularly the case for tropical domains, to the point that two different configurations might almost be considered as different RCMs. On the one hand this implies that the internal model physics and variability contributes substantially to the simulation of changes, and on the other it adds an important element of uncertainty in the production of regional projections with RCMs, calling for the large multi-model approach envisioned in the CORDEX framework. The third important lesson concerns the issue of "added value" of using RCMs. This is perhaps the single most important issue in regional climate modelling, which arises virtually in every RCM application. What we found in the CREMA experiments is that the added value is not necessarily to be found when looking at climatological means, which depend more on the physics of the specific models rather than the model resolution, but rather in higher order statistics and regional circulation features/feedbacks. For example, compared to the driving GCMs, the RegCM4 consistently improved the simulation of the tails of the daily (Giorgi et al., 2014) and seasonal (Coppola et al., 2014) precipitation distributions, while not systematically improving the climatological

means (Coppola et al., 2014). As another example, the RegCM4 simulated much more realistic characteristics of African Easterly Wave activity compared to the driving GCMs, and this affected the simulation of precipitation changes over the West Africa region (Mariotti et al., 2014).

References

COPPOLA E. et AL., (2014): Present and future climatologies in the phase I CREMA experiment. *Climatic Change*, 125 (1), 23-28.

DIRO G. T. et AL., (2014): Tropical cyclones in a regional climate change projection with RegCM4 over the CORDEX Central America domain. *Climatic Change*, 125 (1), 79-94.

FUENTES-FRANCO R. et AL.: Inter-annual variability of precipitation over Southern Mexico and Central America and its relationship to sea surface temperature from a set of future projections from CMIP5 GCMs and RegCM4 CORDEX simulations. *Climate Dynamics*, 1-16.

GIORGI F. et AL., (2014): Changes in extremes and hydroclimatic regimes in the CREMA ensemble projections. *Climatic Change*, 125 (1), 39-51.

LLOPART M. et AL., (2014): Climate change impact on precipitation for the Amazon and La Plata basins. *Climatic Change*, 125 (1), 111-125.

MARIOTTI L. et AL., (2014): Seasonal and intraseasonal changes of African monsoon climates in 21st century CORDEX projections. *Climatic Change*, 125 (1), 53-65.

PORFÍRIO DA ROCHA R. et AL., (2014): Interannual variability associated with ENSO: present and future climate projections of RegCM4 for South America-CORDEX domain. *Climatic Change*, 125 (1), 95-109.

TORMA C. and GIORGI F., (2014): Assessing the contribution of different factors in regional climate model projections using the Factor Separation method. *Atmospheric Science Letters*.

APPENDIX 1

COPPOLA E. et AL., (2014): Present and future climatologies in the phase I CREMA experiment. *Climatic Change*, 125 (1), 23-28. DOI 10.1007/s10584-014-1137-9. http://link.springer.com/article/10.1007/s10584-014-1137-9.

Abstract:
We provide an overall assessment of the surface air temperature and precipitation present day (1976–2005) and future (2070–2099) ensemble climatologies in the Phase I CREMA experiment. This consists of simulations performed with different configurations (physics schemes) of the ICTP regional model RegCM4 over five CORDEX domains (Africa, Mediterranean, Central America, South America, South Asia), driven by different combinations of three global climate models (GCMs) and two greenhouse gas (GHG) representative concentration pathways (RCP8.5 and RCP4.5). The biases (1976–2005) in the driving and nested model ensembles compared to observations show a high degree of spatial variability and, when comparing GCMs and RegCM4, similar magnitudes and more similarity for precipitation than for temperature. The large scale patterns of change (2070–2099 minus 1976–2005) are broadly consistent across the GCM and RegCM4 ensembles and with previous analyses of GCM projections, indicating that the GCMs selected in the CREMA experiment are representative of the more general behavior of current GCMs. The RegCM4, however, shows a lower climate sensitivity (reduced warming) than the driving GCMs, especially when using the CLM land surface scheme. While the broad patterns of precipitation change are consistent across the GCM and RegCM4 ensembles, greater differences are found at sub-regional scales over the various domains, evidently tied to the representation of local processes. This paper serves to provide a reference view of the behavior of the CREMA ensemble, while more detailed and process-based analysis of individual domains is left to companion papers of this special issue.

DIRO G. T. et AL., (2014): Tropical cyclones in a regional climate change projection with RegCM4 over the CORDEX Central America domain. *Climatic Change*, 125 (1), 79-94. DOI 10.1007/s10584-014-1155-7. http://link.springer.com/article/10.1007/s10584-014-1155-7.

Abstract:
The characteristics of tropical cyclones (TCs) over the Central America Coordinated Regional Downscaling Experiment (CORDEX) domain are examined for present and future climate conditions using the regional climate model RegCM4. RegCM4 first tested in a 22 year (1982–2003) simulation with boundary forcing from the ERA-Interim reanalysis, showing a generally good performance in reproducing the observed TC climatology and over the Atlantic in reproducing the interannual variations of TC counts. Four scenario simulations (1970-2100) are generated using two model configurations and two driving global models (MPI and HadGEM). The simulations employing the Grell convection scheme produce too few TCs, while those using the Emanuel convection scheme reproduce the observed climatology, especially when driven by the MPI global model. The simulation of TCs is thus sensitive to both the model convection scheme and the forcing GCM. Comparison of future and present day TC statistics indicates that the frequency of future TCs decreases over the tropical Atlantic and the East Pacific coastal areas while it increases over the western areas of the East Pacific and the northern areas of the Atlantic. We also find an increase in the frequency of intense TCs and long lasting TCs, along with a northward shift of TC tracks over the Atlantic. Conclusions on the changes in TC activity are not found to be sensitive to the inclusion of SST thresholds in the detection procedure. These findings provide encouraging indications for the use of the CORDEX framework in the study of TCs and are suggestive of important effects of global warming on the characteristics of TCs in the tropical Atlantic and Pacific basins.

FUENTES-FRANCO R. et AL.: Inter-annual variability of precipitation over Southern Mexico and Central America and its relationship to sea surface temperature from a set of future projections from CMIP5 GCMs and RegCM4 CORDEX simulations. *Climate Dynamics*, 1-16.
DOI:10.1007/s00382-014-2258-6
http://link.springer.com/article/10.1007%2Fs00382-014-2258-6

ABSTRACT:
An ensemble of future climate projections performed with the regional climate model RegCM4 is used to assess changes in inter-annual variability of precipitation over Southern Mexico and Central America (SMECAM). Two different Global Climate Models (GCMs) from the coupled model intercomparison Project phase 5 are used to provide boundary conditions for two different RegCM4 configurations. This results in four regional climate projections extending from 1970 to 2100 for the greenhouse gas representative concentration pathway RCP8.5. The precipitation variability over the SMECAM region and its dependence on the gradient between Atlantic and Pacific sea surface temperature (SST) anomalies are verified by reproducing SST anomaly patterns during wettest and driest years similar to those seen in observational datasets. RegCM4 does a comparably better job than the driving GCMs. This strong relationship between precipitation and SST anomalies does not appear to change substantially under future climate conditions. For the rainy season, June to September, we find a future change in inter-annual variability of precipitation towards a much greater occurrence of very dry seasons over the SMECAM region, with this change being more pronounced in the regional than in the global model projections. A greater warming of the Tropical Northeastern Pacific (TNP) compared to the Tropical North Atlantic (TNA), which causes stronger wind fluxes from the TNA to the TNP through the Caribbean Low Level Jet, is identified as the main process responsible for these drier conditions.

GIORGI F. et AL., (2014): Changes in extremes and hydroclimatic regimes in the CREMA ensemble projections. *Climatic Change*, 125, (1), 39-51.
DOI 10.1007/s10584-014-1117-0
http://link.springer.com/article/10.1007/s10584-014-1117-0

ABSTRACT:
We analyze changes of four extreme hydroclimatic indices in the RCP8.5 projections of the Phase I CREMA experiment, which includes 21st century projections over 5 CORDEX domains (Africa, Central America, South America, South Asia, Mediterranean) with the ICTP regional model RegCM4 driven by three CMIP5 global models. The indices are: Heat Wave Day Index (HWD), Maximum Consecutive Dry Day index (CDD), fraction of precipitation above the 95th intensity percentile (R95) and Hydroclimatic Intensity index (HY-INT). Comparison with coarse (GPCP) and high (TRMM) resolution daily precipitation data for the present day conditions shows that the precipitation intensity distributions from the GCMs are close to the GPCP data, while the RegCM4 ones are closer to TRMM, illustrating the added value of the increased resolution of the regional model. All global and regional model simulations project predominant increases in HWD, CDD, R95 and HY-INT, implying a regime shift towards more intense, less frequent rain events and increasing risk of heat wave, drought and flood with global warming. However, the magnitudes of the changes are generally larger in the global than the regional models, likely because of the relatively low "climate sensitivity" of the RegCM4, especially when using the CLM land surface scheme. In addition, pronounced regional differences in the change signals are found. The data from these simulations are available for use in impact assessment studies.

LLOPART M. et AL., (2014): Climate change impact on precipitation for the Amazon and La Plata basins. *Climatic Change*, 125 (1), 111-125.
DOI 10.1007/s10584-014-1140-1

http://link.springer.com/article/10.1007/s10584-014-1140-1

ABSTRACT:
We analyze the local and remote impacts of climate change on the hydroclimate of the Amazon and La Plata basins of South America (SA) in an ensemble of four 21st century projections (1970–2100, RCP8.5 scenario) with the regional climate model RegCM4 driven by the HadGEM, GFDL and MPI global climate models (GCMs) over the SA CORDEX domain. Two RegCM4 configurations are used, one employing the CLM land surface and the Emanuel convective schemes, and one using the BATS land surface and Grell (over land) convection schemes. First, we find considerable sensitivity of the precipitation change signal to both the driving GCM and the RegCM4 physics schemes (with the latter even greater than the first), highlighting the pronounced uncertainty of regional projections over the region. However, some improvements in the simulation of the annual cycle of precipitation over the Amazon and La Plata basins is found when using RegCM4, and some consistent change signals across the experiments are found. One is a tendency towards an extension of the dry season over central SA deriving from a late onset and an early retreat of the SA monsoon. The second is a dipolar response consisting of reduced precipitation over the broad Amazon and Central Brazil region and increased precipitation over the La Plata basin and central Argentina. An analysis of the relative influence on the change signal of local soil-moisture feedbacks and remote effects of Sea Surface Temperature (SST) over the Niño 3.4 region indicates that the former is prevalent over the Amazon basin while the latter dominates over the La Plata Basin. Also, the soil moisture feedback has a larger role in RegCM4 than in the GCMs.

MARIOTTI L. et AL., (2014): Seasonal and intraseasonal changes of African monsoon climates in 21st century CORDEX projections. *Climatic Change*, 125 (1) 53-65.
DOI 10.1007/s10584-014-1097-0
http://link.springer.com/article/10.1007/s10584-014-1097-0

ABSTRACT:
We analyze a mini ensemble of regional climate projections over the CORDEX Africa domain carried out with RegCM4 model as part of the Phase I CREMA experiment (Giorgi, 2013). RegCM4 is driven by the HadGEM2-ES and MPI-ESM global models for the RCP8.5 and RCP4.5 greenhouse gas and aerosol concentration scenarios. The focus of the analysis is on seasonal and intra-seasonal monsoon characteristics. We find two prominent change signals. Over West Africa and the Sahel MPI produces a forward shift in the monsoon season in line with previous findings, and this shift is also simulated by the RegCM4. Furthermore, the regional model produces a widespread decrease of monsoon precipitation (when driven by both MPI and HadGEM) associated with decreased easterly wave activity in the 6–9 days regime and with soil moisture-precipitation interactions. South of the equator we find an extension of the dry season with delayed onset and anticipated recession of the monsoon and a narrowing and strengthening of the ITCZ precipitation band. This signal is consistent in all global and regional model projections, although with different spatial detail. We plan to enlarge this mini-ensemble as a further contribution to the CORDEX Project to better assess the robustness of the signals found in this paper.

PORFÍRIO DA ROCHA R. et AL., (2014): Interannual variability associated with ENSO: present and future climate projections of RegCM4 for South America-CORDEX domain. *Climatic Change*, 125 (1) 95-109. DOI 10.1007/s10584-014-1119-y.
http://link.springer.com/article/10.1007/s10584-014-1119-y

ABSTRACT:
Interannual variability over South America (SA) is mainly controlled by the El Niño-Southern Oscillation (ENSO) phenomenon. This study investigates the ENSO precipitation signal during

austral spring (September–October–November-SON) over SA. Three global circulation models-GCMs- (MPI, GFDL and HadGEM2) are used for RegCM4 (Regional Climate Model version 4) downscaling of the present (1975–2005) near-future (2020–2050) and far-future (2070–2098) climates using two greenhouse gas stabilization scenarios (RCP4.5 and RCP8.5). For the present climate, only HadGEM2 simulates a frequency of El Niño (EN) and La Niña (LN) years similar to the observations. In terms of ENSO frequency changes, only in the far-future RCP8.5 climate there is greater agreement among GCMs, indicating an increase (decrease) of EN (LN) years. In the present climate, validation indicates that only the RegCM4 ensemble mean provides acceptable precipitation biases (smaller than ±20 %) in the two investigated regions. In this period, the GCMs and RegCM4 agree on the relationship between ENSO and precipitation in SA, i.e., both are able to capture the observed regions of positive/negative rainfall anomalies during EN years, with RegCM4 improving on the GCMs' signal over southeastern SA. For the near and far future climates, in general, the projections indicate an increase (decrease) of precipitation over southeastern SA (northern-northeastern SA). However, the relationship between ENSO and rainfall in most of RegCM4 and GCM members is weaker in the near and far future climates than in the present day climate. This is likely connected with the GCMs' projection of the more intense ENSO signal displaced to the central basin of Pacific Ocean in the far future compared to present climate.

TORMA C. and GIORGI F., (2014): Assessing the contribution of different factors in regional climate model projections using the Factor Separation method. *Atmospheric Science Letters*. DOI: 10.1002/asl2.491.
http://onlinelibrary.wiley.com/doi/10.1002/asl2.491/full

ABSTRACT:
This study applies the factor separation (FS) method to investigate the contributions of different factors, along with their synergy, on a set of regional climate model (RCM) projections for the Mediterranean region. The FS method is applied to six projections for the period 1970–2100 performed with the regional model RegCM4 over the Med-CORDEX domain. Two different sets of factors are intercompared, namely the driving global climate model (GCM) boundary conditions against two model physics settings (convection scheme and irrigation). We demonstrate the usefulness of the FS method to assess different sources of uncertainty in RCM-based regional climate projections.