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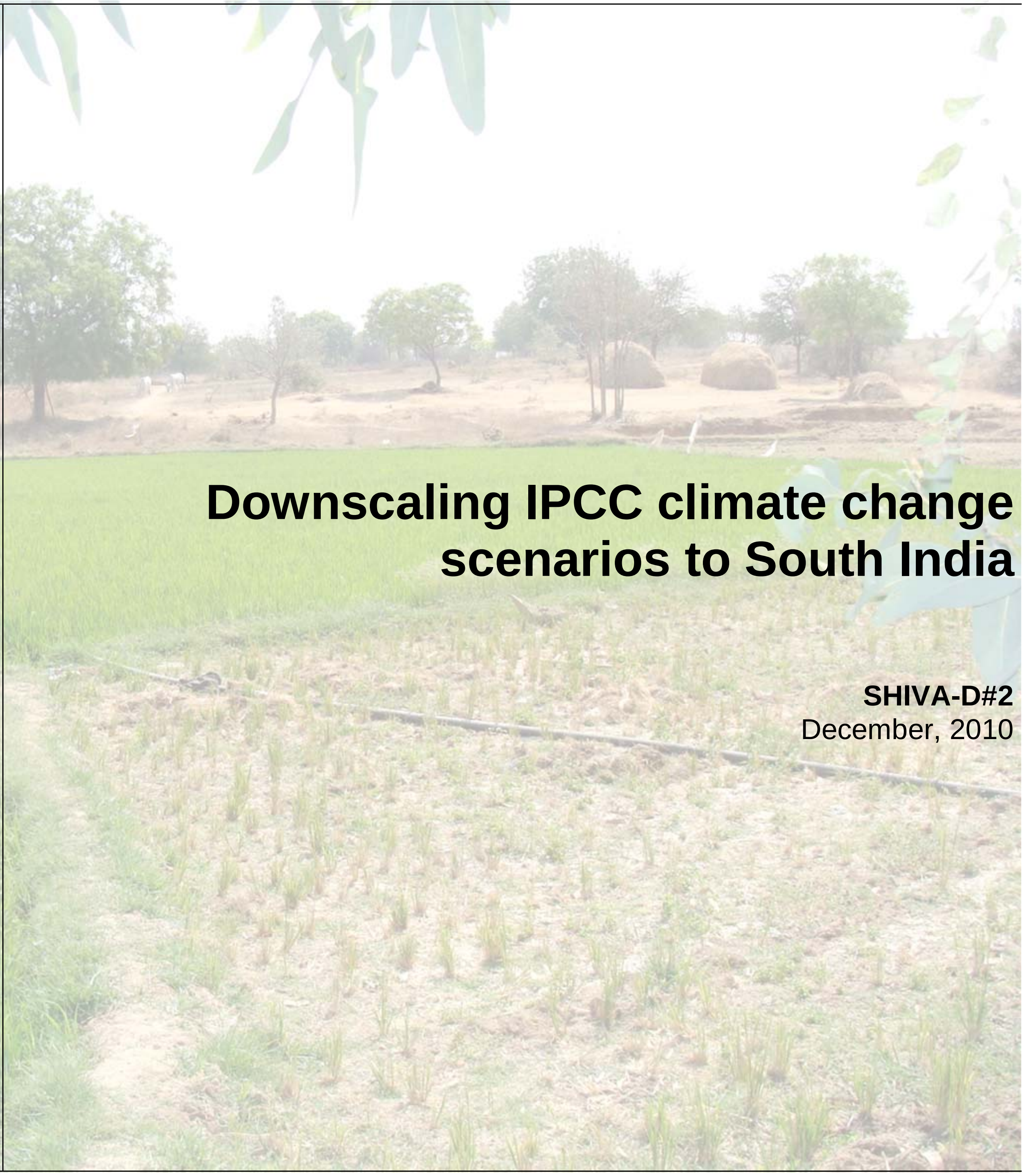
CONVENTION N° ANR-08-VULN-010-01/SHIVA

Socio-economic Assessment of the rural Vulnerability of water users under stressors of global changes in the Hard rock area of South India



Downscaling IPCC climate change scenarios to South India

SHIVA-D#2

December, 2010

With the participation of

A project funded by

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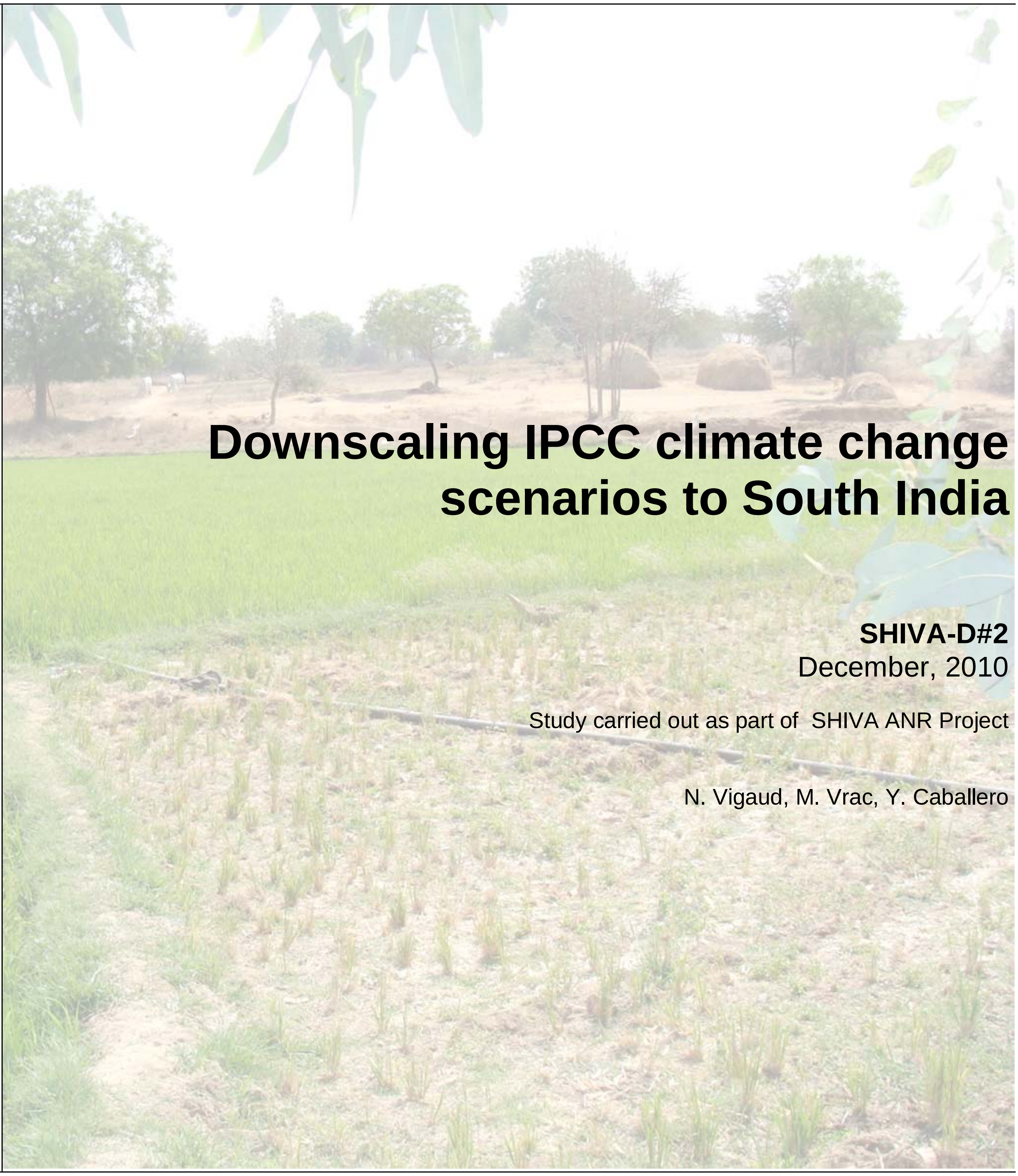

Downscaling IPCC climate change scenarios to South India

SHIVA-D#2

December, 2010

Study carried out as part of SHIVA ANR Project

N. Vigaud, M. Vrac, Y. Caballero

With the participation of

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Keywords: Statistical downscaling; precipitation; temperature; Cumulative Distribution Functions; Climate Change Impact; Monsoon; South-India.

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Synopsis

The Cumulative Distribution Function transform (CDF-t) is used to downscale daily precipitation and surface temperatures from a set of GCMs climatic projections over southern India. To deal with the full annual cycle, the approach has been applied by months, allowing to produce downscaled projections for all seasons. This report presents the main results of this work undertaken in the framework of the Task D#2. Of the ANR-SHIVA research project.

Then CDF-t is applied to GCMs large-scale fields to project rainfall and surface temperature changes for the 21st century under the IPCC SRES A2 scenario. The results obtained show an increase of rainfall most pronounced during the monsoon season while winter precipitation are reduced, and suggest a widespread warming especially in winter and post monsoon season.

This work has been submitted to the “Climatic Change” journal for publication.

Contents

Introduction

The Cumulative Distribution Function transform (CDF-t) is used to downscale future daily precipitation and surface temperatures from a set of GCMs climatic projections over southern India. To deal with the full annual cycle, the approach has been applied by months, allowing to produce downscaled projections for all seasons. First CDF-t is validated over a historical period using observation from the Indian Meteorological Department (IMD). Resulting high resolution fields show substantial improvements compared to original GCMs outputs in terms of distribution, seasonal cycle and monsoon means for arid, semi-arid and wetter regions of the subcontinent. Then CDF-t is applied to GCMs large-scale fields to project rainfall and surface temperature changes for the 21st century under the IPCC SRES A2 scenario. For more details regarding the application of such downscaling method on south of India, in the framework of the SHIVA task 2, the reader can refer to the manuscript *Vigaud et al.* (2010) entitled 'Probabilistic Downscaling of GCMs scenarios over southern India' submitted recently to *Climatic Change*.

No.	Originating Group	Country	IPCC ID	Abbreviation	Reference
1	Canadian Centre for Climate Modelling and Analysis	Canada	CGCM3.1 (t47)	CGCM3	Flato et al. (2000)
2	Meteo-France/Centre National de Recherches Meteorologiques	France	CNRM-CM3	CNRM3	Salas-Melia et al. (2006)
3	Max Planck Institute for Meteorology	Germany	ECHAM5 / MPI-OM	ECHAM5	Jungclaus et al. (2006)
4	Bjerknes Centre for Climate Research	Norway	BCCR-BCM2.0	BCCR2	Furevik et al. (2003)
5	Centre for Climate System Research (The University of Tokyo) National Institute for Environmental Studies and Frontier Research Center for Global Change (JAMSTEC)	Japan	MIROC3.2 (medres)	MIROCMR	K-1 Model Developers (2004)

Table 1: Climate models and their references participating in the IPCC AR4 experiments (adapted from *Kripalani et al.* (2007)). Abbreviated acronyms are used in the text to identify each GCM.

1.DATA & METHOD

1.1.GCM data and observations

In order to investigate climate change impacts on Southern India, several GCMs from the last IPCC AR4 exercise have been used. *Kripalani et al.* (2007) identified a set of 7 GCMs as most reliable regarding Indian monsoon rainfall based on their representation of the mean seasonal cycle in phase and amplitude. Regarding the availability of daily standard output from the Program for Climate Model Diagnosis and Intercomparison (PCMDI) database, 5 GCMs have been retained (see Table 1). More details about models components can be found at :

http://www.pcmdi.llnl.gov/ipcc/model_documentation/

For the purpose of this study,simulated daily rainfall and surface temperatures have been considered from both historical experiments (run 20cm3 for the period 1971- 1999) and future projections in the context of the A2 scenario (run A2 for the period 2046-2065) based on high population and regionally oriented economic growth with significant and widespread decline in fertility (*Nakicenovic et al.*, 2000).

Daily rainfall and surface temperatures for the 2020-2039 period simulated by one GCM (CNRM3, not available on the PCMDI web-site), in the context of the A2 scenario, were obtained thanks to S. Tyteca from CNRM-GAME. As there was no data for this period on the PCMDI site, using the projections of only one GCM allowed to roughly describe the future climatic conditions for the short term, without estimating the associated uncertainty.

In addition, observation from the Indian Meteorological Department (IMD) are also used in this study. IMD daily rainfall are available from 1971 to 2005 on a half a degree grid and surface temperatures from 1969 to 2005 at one degree resolution. It leads to a set of 729 and 210 grid points for rainfall and surface temperatures respectively over a region comprised between 7.5◦ N and 20.5◦ N and 70◦ E and 83◦ E to which we will refer in the following as southern India. Three watersheds are considered more specifically within SHIVA and dedicated diagnostics are presented in the following at Pandam Eru, Kudaliar (semi-arid) and South Gundal (more humid) basins.

More details about the IMD high resolution daily gridded rainfall and surface temperatures dataset can be found in *Rajeevan and Bhate* (2008) and *Srivastava et al.* (2008) respectively.

1.2.CDF-Transform Method

The approach chosen here is the cumulative distribution function transform (CDF-t in the following) offering the advantage to directly deal with and provide CDFs (*Michelangeli et al.*, 2009). Another interest of this method consists in the fact that it does not make any assumption on the shape or family of distribution, and thus can be applied to both rainfall and surface temperatures in the context of this study.

The CDF-t has already been used to downscale GCMs and re-analyses 10 m wind over France by *Michelangeli et al.* (2009). The method is based on the assumption that it exists a transformation T allowing to translate the CDF of a GCM variable (predictor) into the CDF representing local-scale climate variable at a given weather station (predictand).

For more details regarding the CDF-t method the reader can refer to *Michelangeli et al.* (2009).

2.SHORT TERM PROJECTIONS (2020-2039)

2.1.Projected precipitation regimes (2020-2039)

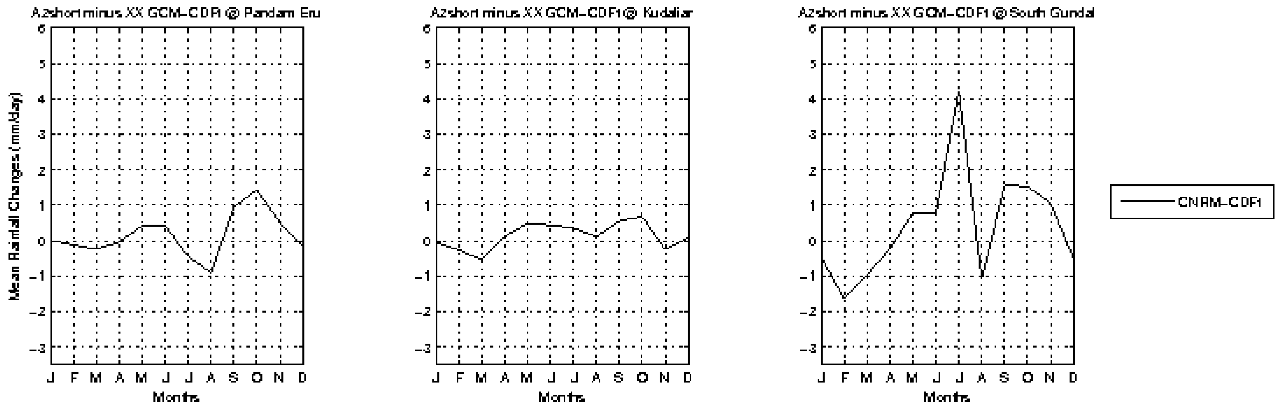

Figure 1: Mean seasonal rainfall differences between A2 short (2020-2039) and XX (1981-1999) periods at Pandam Eru (left), Kudaliar (middle) and South Gundal (right) from CNRM3 downscaled fields using CDF-t with calibration over the 1971-1999 period.

Changes in rainfall seasonal cycle from CNRM3 2020-2039 projections at the three watersheds studied are shown in Figure 1. Most variations are found during the monsoon season (from June to September) when rainfall are due to increase globally, while winter precipitation would tend to be reduced (from November to April mainly). Greatest changes are due to occur over the wettest South Gundal basin with up to 4 mm/day rainfall increase in July and a reduction of about 1.5 mm/day in February.

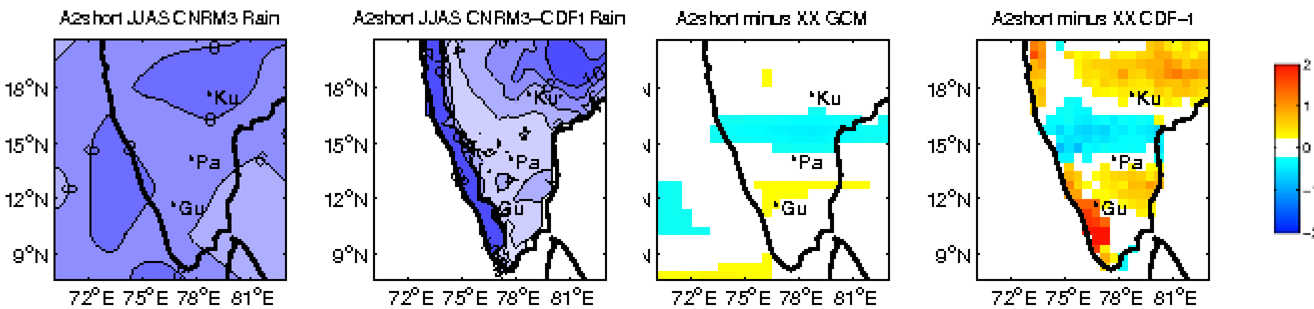

Figure 2: Mean A2 short (2020-2039) JJAS rainfall (leftern panels) and differences with the XX (1981-1999) period (rightern panels) from raw CNRM3 and downscaled output using CDF-t with calibration over the 1971-1999 period.

Mean monsoon rainfall (Figure 2 leftern panels) seem to be more realistic for downscaled fields than for the original GCM output when compared to the observed historical climatology (not shown). The geographical patterns of rainfall differences during the monsoon season (JJAS) between the 2020-2039 and 1981-1999 periods are comparable from both the raw GCM output and the downscaled data (Figure 2 rigthern panels) while their amplitude however differ. Downscaled data suggest rainfall increase most pronounced along the southwestern coast, south and northeastern regions of the subcontinent, while a reduction would characterize central areas of southern India.

2.2.Projected surface temperatures (2020-2039)

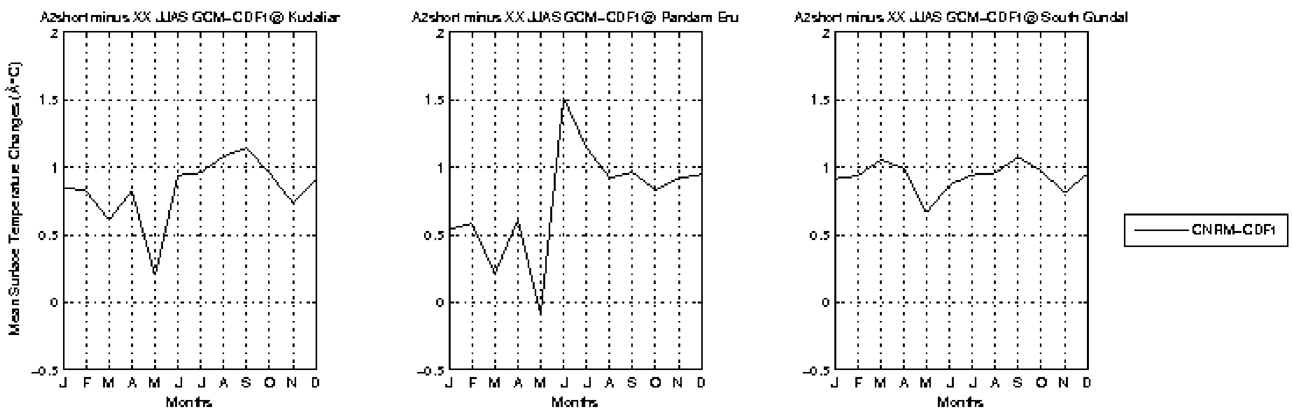

Figure 3: Mean seasonal surface temperatures differences between A2 short (2020-2039) and XX (1981-1999) periods at Pandam Eru (left), Kudaliar (middle) and South Gundal (right) from CNRM3 downscaled fields using CDF-t with calibration over the 1971-1999 period.

Main differences in surface temperatures between the 2020-2039 and 1981-1999 periods over the three watersheds (Figure 3) are characterized by a warming trend most pronounced at the end of the monsoon season and during the post-monsoon period, in particular for the more arid basins (Pandam Eru and Kudaliar).

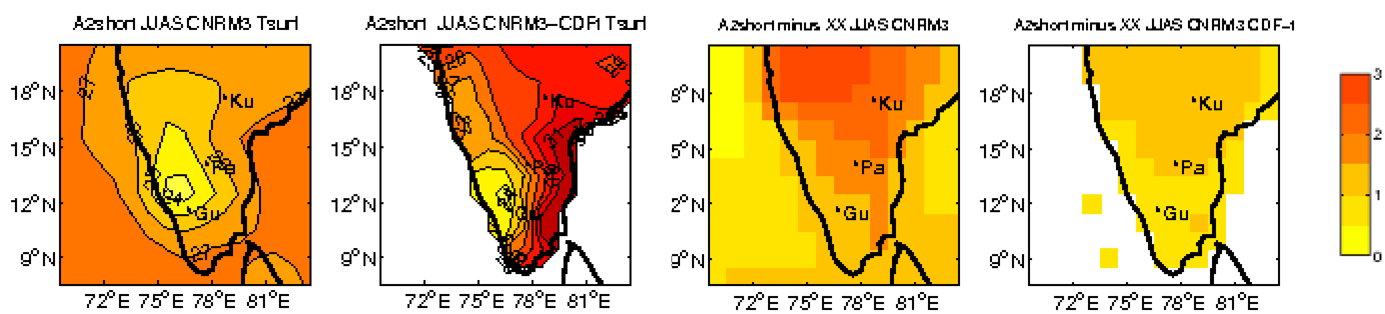

Figure 4: Mean A2 short (2020-2039) JJAS surface temperatures (leftern panels) and differences with the XX (1981-1999) period (rightern panels) from raw CNRM3 and downscaled output using CDF-t with calibration over the 1971-1999 period.

Mean JJAS downscaled surface temperatures (Figure 4 leftern panels) also appear to be more realistic than the original GCM output when compared to the observed historical climatology (not shown). The geographical patterns of surface temperature differences during the monsoon season between the 2020-2039 and 1981-1999 periods are again well comparable between raw GCM output and downscaled data (Figure 4 rigthern panels). However downscaled fields suggest weaker changes than these projected by the GCM, with a maximum warming north of about 15°N.

3.MEDIUM TERM PROJECTIONS (2046-2065)

For medium term projections 5 and 4 GCMs have been used to downscale rainfall and surface temperatures respectively (see section 1.1.) depending on the availability of daily dataset from the PCMDI archive.

3.1.Projected precipitation regimes (2046-2065)

Maximum seasonal rainfall changes at Pandam Eru, Kudaliar and South Gundal watersheds (Figure 5) are found during the monsoon season, most pronounced during May-June and August when rainfall would tend to increase (from 15% to 50%). In addition, weak negative changes are found during the dry season, most particularly from October to April (50 to 80% decrease), from the CDF-t method as well as from raw GCMs data. The amplitude of these variations would tend to be more pronounced over the wetter south Gundal than the other two semi-arid basins (Pandam Eru and Kudaliar).

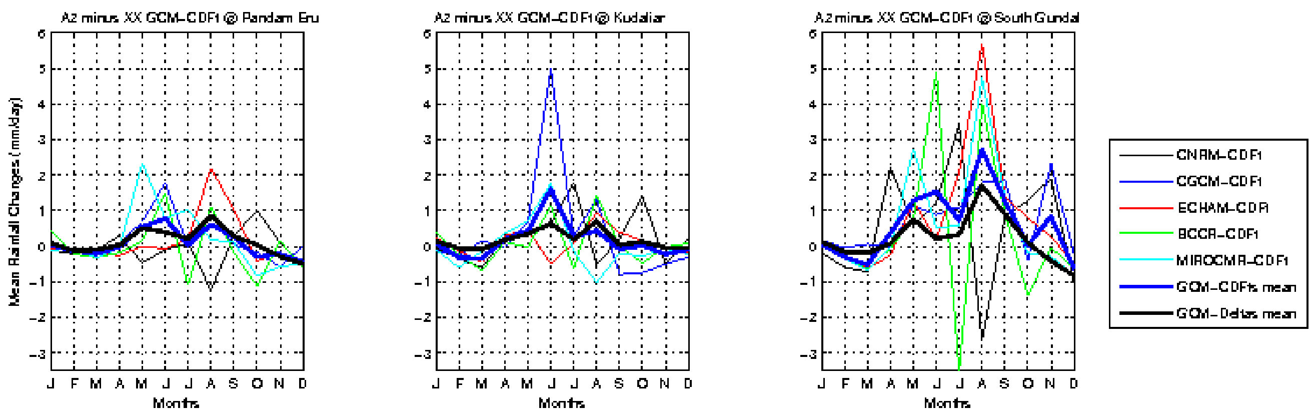

Figure 5: Mean seasonal rainfall cycle changes at Pandam Eru (left), Kudaliar (middle) and South Gundal (right) locations between the A2 (2046-2065) and XX (1980-1999) periods seen by CDF-t compared to results from raw GCMs outputs.

Regarding JJAS rainfall means (Figure 6 two top panels), downscaled fields are more coherent with the known climatology from IMD data for the historical period (not shown) than raw GCMs. In particular, maximum precipitated amounts along the west coast and northeast regions of the subcontinent as well as the central patterns associated to more arid regions, are well represented in the resulting downscaled fields from all GCMs.

Moreover, the spatial changes in JJAS rainfall obtained for individual GCM downscaled data (Figure 6 bottom panels) are systematically comparable to these from their corresponding raw GCM outputs. The amplitudes of these variations however appear to be enhanced for the resulting high resolution fields. In addition, the dispersion of the variations patterns between all GCMs confirms the need to consider ensemble of GCMs projections. However in the case of CNRM3, projected changes from both raw and downscaled GCM output appear to be much more pronounced for the 2046-2065 period than for the shorter term scenario (2020-2039) in particular to the northeast and southwestern of the subcontinent where precipitation increase is enhanced. Interestingly, rainfall decrease over central regions seems to be attenuated from 2040 to 2060 horizons.

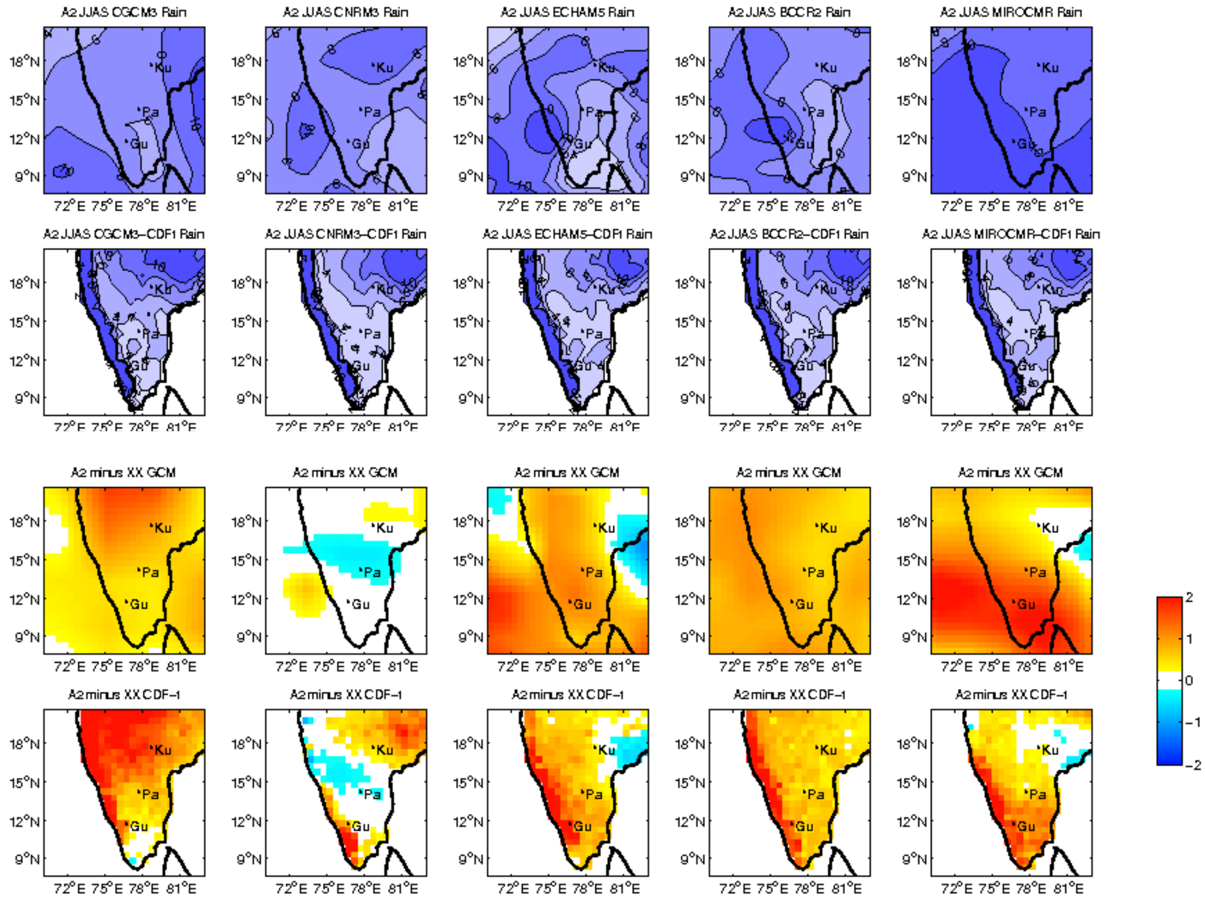

Figure 6: Mean June to September original (top) and downscaled (2nd line) GCMs rainfall for the A2 scenario (2046-2065) over southern India as well as the original GCMs (3rd line) and projected changes (bottom) when compared to the historical XX period (1980-1999).

3.2. Projected surface temperatures (2046-2065)

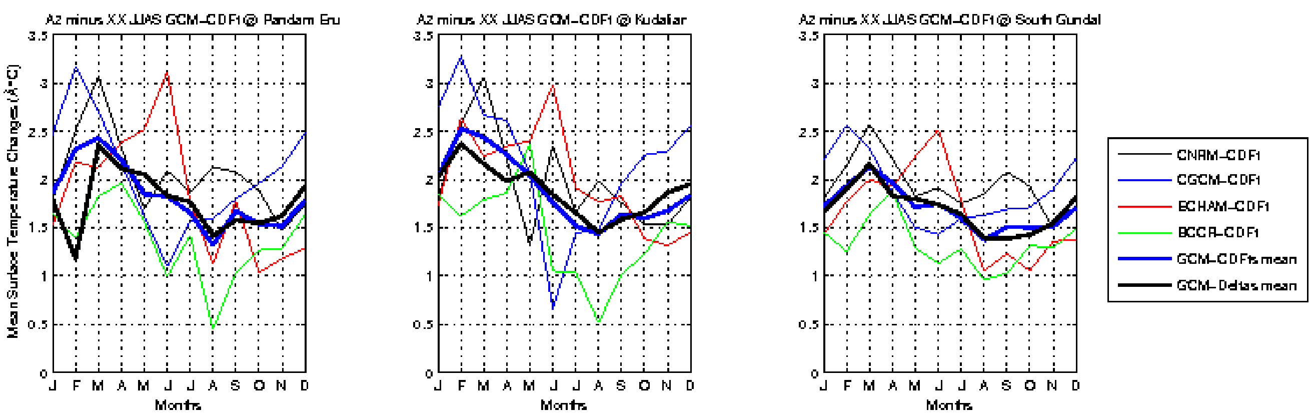

Figure 7: Same as Figure 5 but for surface temperatures.

Maximum surface temperatures changes for all watersheds are found during the dry season (Figure 7), most particularly in February-March (about 2.5◦ C at Pandam Eru and Kudaliar, and 2.2◦ C at South Gundal). Smaller variations are found during the monsoon season with minimum changes in August (about 1.5◦ C for all watersheds). Moreover, it appears that arid and semi-arid areas are places where the seasonal amplitude of surface temperatures projected changes would be maximum.

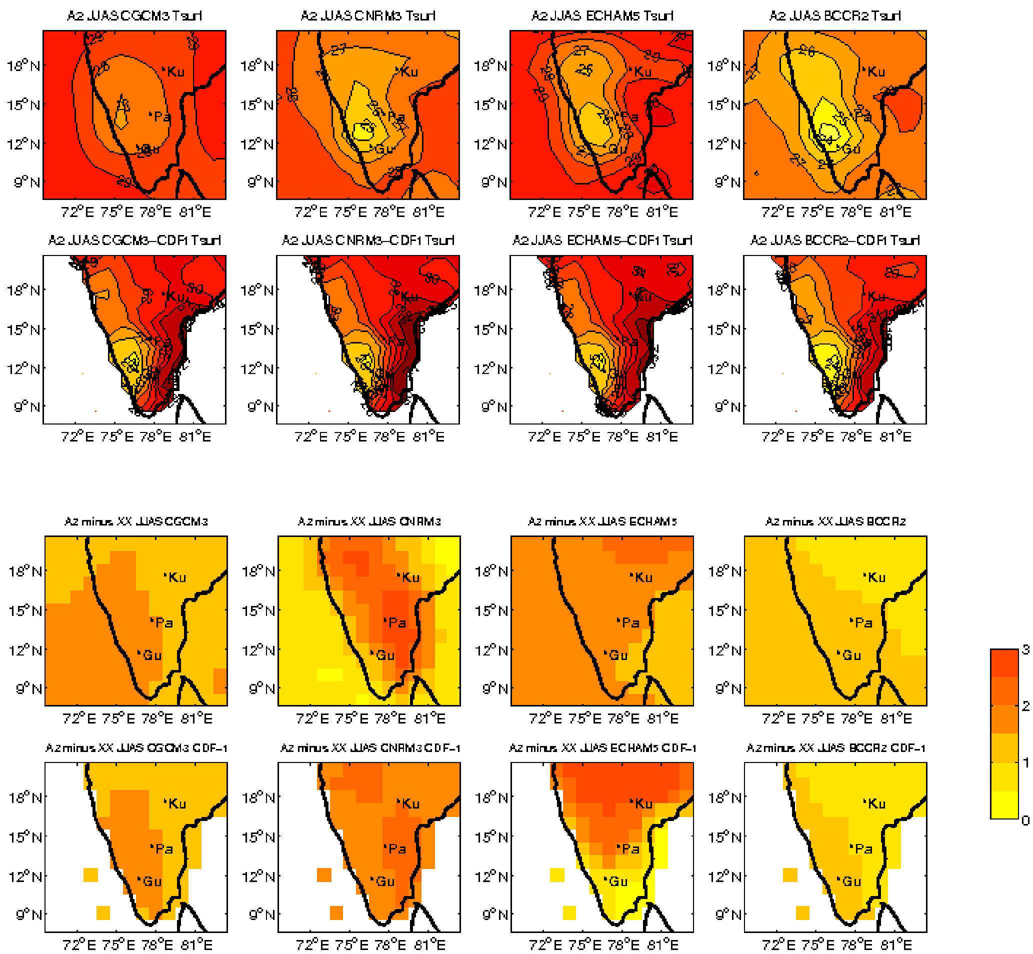

Figure 8: Same as Figure 6 but for surface temperatures.

When compared to the observed climatology (not shown), the projected temperature patterns (Figure 8 top panels) found in all GCMs downscaled data is far more coherent than raw GCMs surface data in particular regarding the latitudinal gradient along the west coast and the meridional gradient inland.

Concerning surface temperature changes between the A2 and XX periods (Figure 8 bottom panels), similar patterns characterize both original and downscaled data. The amplitude of these projected changes are comparable between large-scale and downscaled data, except for ECHAM5 for which downscaled changes are slightly greater. Again, the dispersion between the GCMs projected changes remains substantial even if less pronounced than for precipitation.

Nevertheless, in the case of CNRM3, both raw and downscaled GCM output exhibit larger changes for the 2046-2065 than for the period 2020-2039 when compared to the historical period. Maximum temperature increases are found in both cases from northwestern regions towards the eastern coast.

4.DISCUSSION & CONCLUSIONS

In order to downscale GCMs projections over southern India for the whole annual cycle, the CDF-t method (*Michelangeli et al.*, 2009) has been applied to monthly chronicles of daily large-scale rainfall and surface temperatures, first on a historical period for validation, then for projected scenarios.

Under the A2 gas emission scenario, the results show a substantial increase of rainfall in particular during the monsoon season and for semi-arid and wetter climatic zones (from about 15% to 50%) while winter precipitation are generally reduced (maximum changes of about 50% to 80% for wetter climatic regions) in accordance with previous findings *(Kripalani et al.*, 2007; *Rupa Kumar et al.*, 2006; *Raje and Mujumbar*, 2009). These changes are accompanied by increases in surface temperatures most pronounced during the post-monsoon (up to 2.5◦ C) and winter season at all locations also agreeing with earlier studies (*Rupa Kumar et al.*, 2006; *Bhattacharya*, 2007). From CNRM3 short and medium term projections, it seems that these potential variations in both rainfall and surface temperatures would tend to increase from 2020-2039 to 2046-2065 horizons.

Nevertheless, CDF-t proved to be an interesting and efficient statistical tool, offering substantial perspectives in terms of downscaling and climate change impact studies at local-scale, the low computational cost and flexibility of this approach making it even more attractive.

Finally, deeper research is needed to give further elements of description regarding future climatic projections over southern India and the processes involved. However, the work presented here corresponds to one more step in that direction helping to document medium range future climatic scenarios (2020-2040 and 2040-2060), these horizons being crucial for local adaptation strategies.

This study has been submitted as an article for publication in Climatic Change (*Vigaud et al.,* 2010). More details regarding both the CDF-t method and results would then be available from this paper once published.

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