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Water in the Arabian Peninsula

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ABSTRACT

Increasing temperatures, changes in damaging extreme events, rising costs of energy, heightened environmental consciousness, degraded land productivity, and overburdened water resources are among a variety of stressors that can stem from regional changes in the natural, managed, and built environments. Over the Arabian Peninsula, water can play a multi-faceted role to not only the sustainability but also the vulnerability of prosperity and continued growth across its populated areas. Therefore, simulating future changes in the regional climate – with particular attention to the changing characteristics of precipitation – is key to those adjustments. However, global model projections are too coarse to represent the unique surface and atmospheric features of the region. To help assess changes in regional climate and support regional sustainability efforts, we perform convection permitting regional climate modeling simulations and dynamically downscale Community Earth System Model (CESM) projections under a high-impact emission scenario using the Weather Research and Forecasting (WRF) model to 4 km horizontal resolution. Preliminary results focusing on historical and future changes in the mean and extremes of climate variables are presented here.

1. Introduction

Water consumption in the Kingdom of Saudi Arabia (KSA) has been increasing. As part of Vision 2030 investment activities (https://vision2030.gov.sa/en), several investments have been made and are planned in the region in the near future such as new solar power operated desalinization plants, sustainable infrastructure and touristic areas to attract global attention. Furthermore, recently KSA has been experiencing intense extreme precipitation events: For example, Jeddah floods of 2009, 70 mm of rain was recorded at Jeddah meteorological station. The event led to flooding that cost lives of 122 people while 350 were missing. Damaged businesses created a huge cost ($270 million) to the economy. Hence, structure and infrastructure failure due to intense precipitation events (Ameur, 2016) and the financial and cost associated with recovery have become a main concern for the Kingdom. Particularly of interest is estimating the changes in the intensity and frequency of extreme events (precipitation, heat waves, and dust storms) affecting the region under climate change. For planning new touristic areas, engineering heat withstanding infrastructure, and choosing locations of new infrastructure that will serve the cities, future climate information is needed in local scales. In this study, we are using global model projections to drive a regional climate model

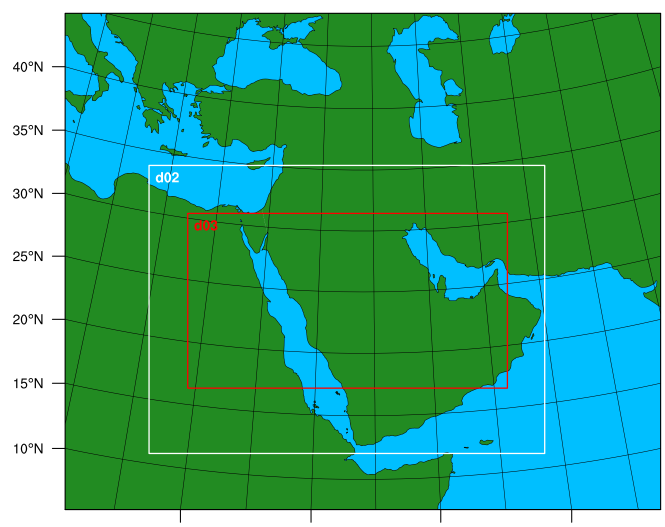

Fig. 1 WRF model domain used in this study.

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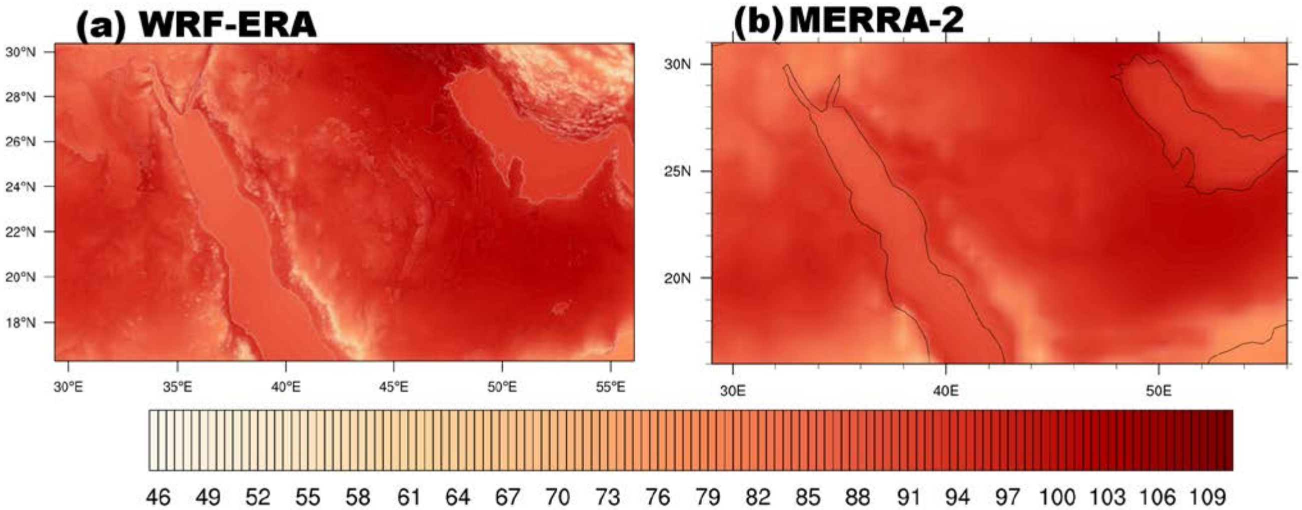

Fig. 2 August mean temperatures at 2 meters [K] from (a) WRF-ERA (b) MERRA-2 averaged over 2008-2017.

to produce high-resolution climate variables under a high impact emissions scenario. We will use these high-resolution projections 1) to study changes in regional climate and climate extremes and 2) as input for hydrological and flood models to assess future changes in water resources, guide sustainable infrastructure design under climate change and help future urban city planning and expansion efforts in the Kingdom of Saudi Arabia.

2. Methods

To obtain high resolution climate projections, we dynamically downscaled the bias corrected CESM projections under Representative Concentration Pathway (RCP) 8.5 (Bruyère *et. al.*, 2014) using the WRF Model v3.6.1. Our methodology and model setup are similar to Komurcu *et al.* (2018). In WRF, we use three nested domains of 36, 12 and 4 km horizontal resolution. Model domain, nesting and parameterization setup were established after a series of sensitivity runs on MIT's Svante High Performance Computing System. The model domain used in this study is shown in Fig. 1. To assess future changes in climate, we perform dynamical downscaling of CESM projections for two time periods representative of present day (2008-2017) and mid-century (2041-2050).

3. Results

Results presented in this paper are preliminary. Figure 2 shows August mean temperatures from WRF-ERA (WRF driven by ERA-Interim data) and MERRA-2 (Modern-Era Retrospective Analysis for Research and Applications version 2) averaged over 2008 to 2017. WRF-ERA is able to simulate similar temperatures

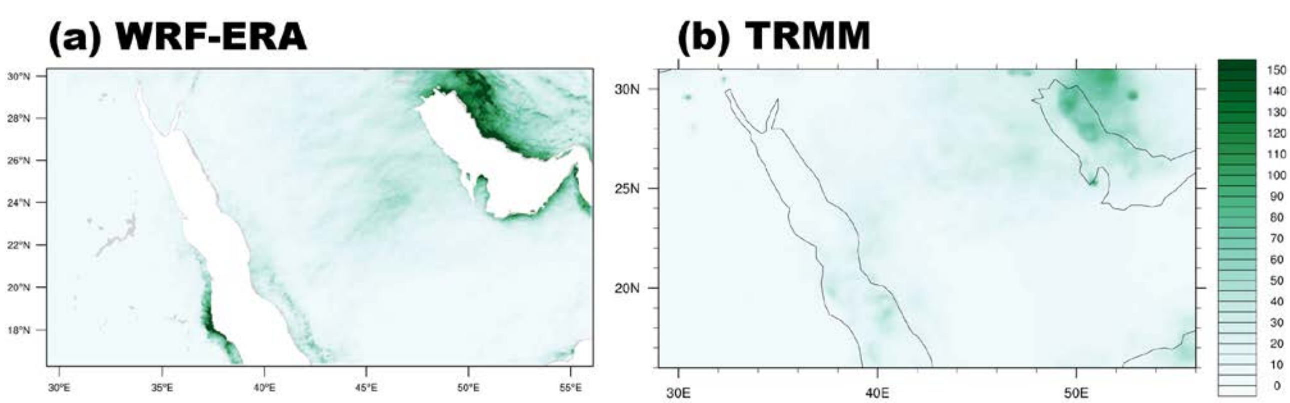

Fig. 3 November precipitation rates [mm/month] averaged over 2008-2017 as simulated from (a) WRF-ERA and observed/retrieved from (b) TRMM.

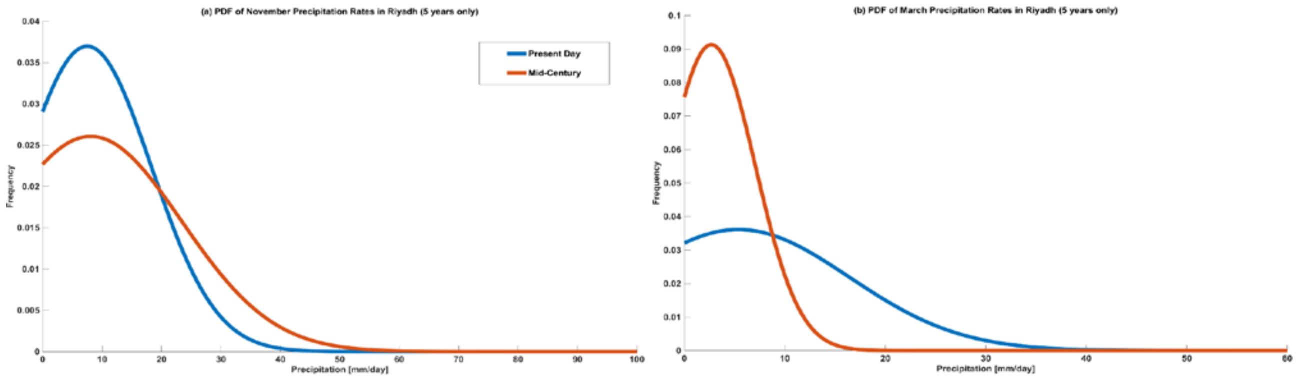

Fig. 4 PDFs of present day (blue) and mid-century (red) precipitation rates (mm/day) in Riyadh for (a) November and (b) March.

to those from (MERRA-2) and provides the detailed, high-resolution temperature data needed for local climate change assessments and sustainability studies.

November precipitation rates from (a) WRF-ERA and (b) TRMM (Tropical Rainfall Measuring Mission) are presented in Fig. 3. WRF-ERA is generally able to capture the observed precipitation structure and locations of increase in precipitation rates. There is a slight positive bias along certain coast lines and in the center of the Kingdom in WRF-ERA compared to TRMM, which may be associated with the higher resolution (hence more detailed representation of the topographical features) in our WRF simulations compared to TRMM. Due to a lack of a dense, homogeneous network of historical observations of precipitation rates, it is difficult to establish the biases beyond a comparison with TRMM. Nevertheless, these biases need to be taken into account while interpreting future projections of precipitation rates.

Figure 4 a and b show the probability density functions (PDFs) of present day and mid-century precipitation rates (mm/day) in Riyadh for November and March respectively for 5 years. We find that while mid-century mean precipitation rates reduce in November compared to present day climate, extreme precipitation events become more intense and frequent. In March, more precipitation events occur mid-century while extreme events become rare compared to present day climate.

In Fig. 5, we present the PDFs of temperatures for November and August for five years of the simulated time period. We find that while temperatures increase for both November and August by mid-century, this rate of increase is more pronounced in August.

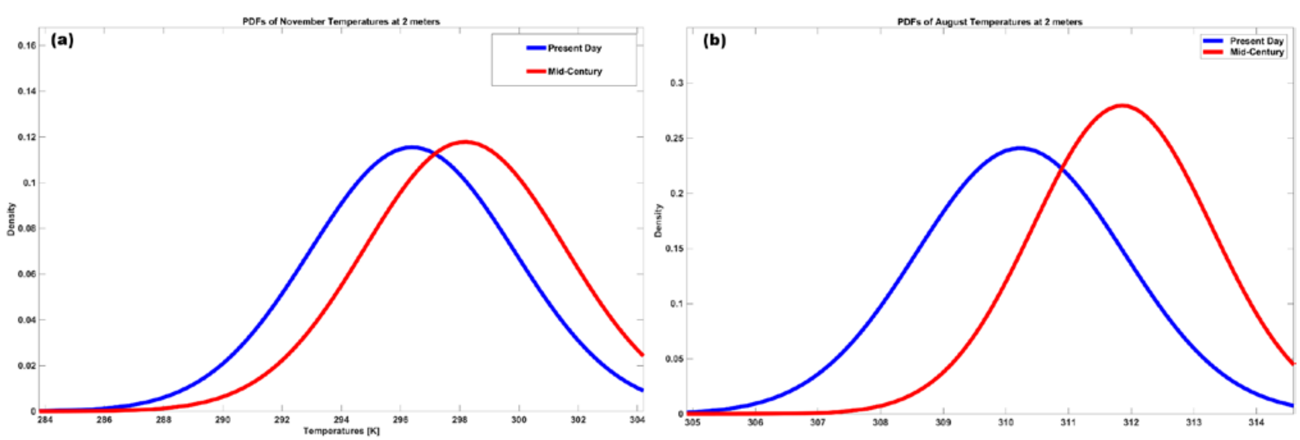

Fig. 5 PDFs of daily temperatures at 2 meters for present day (blue) and mid-century (red) climate for (a) November and (b) August.

4. Conclusions and future work

Our preliminary analysis shows that there are significant differences between mid-century and present-day mean and extreme climate in the Kingdom's capital Riyadh. Work is currently underway to 1) expand the projections to span 20 years in each time period, 2) extend the regions studied 3) use high resolution projections generated in further analysis related to the sustainability of the region.

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