30.5.2019

President and Mintz Foundation 2018-2019 Report

Title: Analysis of Large-Scale Climate Time-Series and their Downscaling over the Eastern Mediterranean

Submitted by: Assaf Hochman

During the past year my colleagues and I have engaged in a number of activities related to the topic of my PhD: 1) Evaluating the state of the art downscaling methodologies[1] and future climate models[2, 3] 3) Developing downscaling procedures for climate models[4, 5] 4) Projecting climatic variables using climate models[3,4,6,7,8,9]. The results of the studies conducted were presented in six published papers, three under review and in seven international conferences and seminars (see below). My main findings so far are summarized in the abstracts of the papers attached below. In addition I have submitted my PhD dissertation to the senate of Tel-Aviv University on 1st May 2019. I was further awarded the Geophysics Department excellence scholarship and the prestigious Minerva Fellowship for a research visit to the Karlsruhe Institute of Technology at Karlsruhe, Germany.

I wholeheartedly thank the President and Mintz Foundation for supporting this research and I hope to continue the collaboration in the near future.

Symposia participation

May 2019: Tel-Aviv, Israel, Porter School of the Environment and Earth Sciences, Atmospheric predictability of eastern Mediterranean weather regimes (Invited talk).

May 2019: Tel-Aviv, Israel, Geography and the human environment department seminar (Invited talk).

May 2019: Beit Dagan, Israel, Israel Meteorological Service, A new dynamical systems perspective on atmospheric predictability: eastern Mediterranean weather regimes as a case study (Invited talk).

December 2018: Tel-Aviv, Israel, Israeli Geographical Association Conference. Eastern Mediterranean climate changes in the 21st century (Invited talk).

September 2018: Karlsruhe, Germany, The predictability of eastern Mediterranean synoptic systems (Invited talk).

June 2018: Lecce, Italy, 11th HyMeX Workshop, The seasons' length in 21st century CMIP5 projections over the eastern Mediterranean (speaker).

May 2018: Capua, Italy, CMCC Euro-Mediterranean Center on Climate Change, Eastern Mediterranean weather regimes in the 21st century (Invited talk).

April 2018: Vienna, Austria, European Geoscience Union (EGU) general assembly.

1) The seasons' length in 21st century CMIP5 projections over the eastern Mediterranean (Speaker).

2) Synoptic classification in 21st Century CMIP5 Predictions over the Eastern Mediterranean with focus on cyclones (Poster)**.**

March 2018: Jerusalem, Israel, Israel Meteorology Society conference. The seasons' length in 21st century CMIP5 projections over the eastern Mediterranean (Speaker).

January 2018: Tel-Aviv, Israel, Israel Center for Disease Control (ICDC). Changing seasons under global warming and potential health hazards (Speaker).

Publications

1. **Hochman A**, Saaroni H, Abramovich F, Alpert P. 2018. Artificial detection of lower frequency periodicities in climatic studies employing Wavelet Analysis demonstrated on synthetic time series. *Journal of Applied Meteorology and Climatology* (Accepted pending minor revisions).
2. **Hochman A**, Bucchignani E, Gershtein G, Krichak SO, Alpert P, Levi Y, Yosef Y, Breitgand J, Mercogliano P. 2018. Evaluation of Regional COSMO-CLM Climate Simulations over the Eastern Mediterranean for the Period 1979 – 2011. *International Journal of Climatology* **38**: 1161-1176. DOI: 10.1002/joc.5232
3. Samuels R, **Hochman A (equally contributed)**, Baharad A, Givati A, Levi Y, Yosef Y, Saaroni H, Ziv B, Harpaz T, Alpert P. 2018. Evaluation and Projection of Extreme Precipitation Indices in the Eastern Mediterranean based on CMIP5 Multi Model Ensemble. *International Journal of Climatology*. **38(5)**, 2280-2297. DOI: 10.1002/joc.5334
4. **Hochman A**, Harpaz T, Saaroni H, Alpert P. 2018. Synoptic classification in 21st century CMIP5 predictions over the Eastern Mediterranean with focus on cyclones. *International Journal of Climatology* **38**: 1476-1483. DOI: 10.1002/joc.5260

5. **Hochman A**, Alpert P, Harpaz T, Saaroni H, Messori G. 2018. A new dynamical systems perspective on atmospheric predictability: eastern Mediterranean weather regimes as a case study. *Science Advances* (in press).
6. **Hochman A**, Harpaz T, Saaroni H, Alpert P. 2018. The seasons' length in 21st century CMIP5 projections over the eastern Mediterranean. *International Journal of Climatology*, **38(6)**, 2627-2637. DOI: 10.1002/joc.5448
7. **Hochman A**, Mercogliano P, Alpert P, Saaroni H, Bucchignani E. 2018. High-resolution projection of climate change and extremity over Israel using COSMO-CLM. *International Journal of Climatology* **38(14)**, 5095-5106. DOI: 10.1002/joc.5714
8. **Hochman A,** Kunin P, Alpert P, Harpaz T, Saaroni H, Rostkier-Edelstein D. 2019. Statistical down-scaling of seasonal precipitation over Israel for the 21st century, using CMIP5 projections. *International Journal of Climatology* (Accepted pending minor revisions).
9. **Hochman A,** Alpert P, Kunin P, Rostkier-Edelstein D, Harpaz T, Saaroni H, Messori G. 2019. The dynamics of eastern Mediterranean cyclones in the 21st century. *Climate Dynamics* (under review).

List of abstracts

Artificial detection of lower frequency periodicities in climatic studies by Wavelet Analysis demonstrated on synthetic time series

Assaf Hochman, Hadas Saaroni, Felix Abramovich, Pinhas Alpert

Abstract

The Continuous Wavelet Transform (CWT) is a frequently used tool to study periodicities in climate and other time series. Periodicity plays a significant role in climate reconstruction and prediction. In several studies the use of CWT revealed Dominant Periodicities (DP) in climatic time series. Several studies suggested that these "natural oscillations" will even reverse global warming. It is shown here that the results of wavelet analysis for detecting DPs are often miss-interpreted in the presence of local singularities that are manifested in lower frequencies and may result in false DPs detection. In CWT analysis of synthetic and a Pacific Decadal Oscillation (PDO) real-data climatic time series with local singularities, CWT indicates on a low-frequency DP with no physical significance. It is argued that this is an inherent general property of CWT. Hence, applying CWT to climatic time series should be re-evaluated and further analysis of the wavelet power spectrum is required, focusing on high frequencies as well. Thus, a cone-like shape in the wavelet power spectrum most likely indicates on the presence of a local singularity in the time series rather than a DP even if the local singularity has an observational or physical basis. It is shown that analyzing the derivatives of the time series may be helpful in interpreting the wavelet power spectrum, but this is only a partial remedy that does not completely neutralize the effects caused by the presence of local singularities.

Evaluation of regional COSMO-CLM climate simulations over the Eastern Mediterranean for the period 1979 - 2011

Assaf Hochman, Edoardo Bucchignani, Giora Gershtein, Simon O. Krichak, Pinhas Alpert, Yoav Levi, Yizhak Yosef, Yizhak Carmona, Joseph Breitgand, Paola Mercogliano, Alessandra L. Zollo

Abstract

The Regional Climate Model (RCM) COSMO-CLM capability to reproduce the climate characteristics, including extreme values, over the Eastern Mediterranean (EM) was tested. Model configuration has been chosen based on a previously performed sensitivity analysis, aimed to ascertain the accuracy of model performances over Israel.

Three simulations driven by ERA Interim reanalysis data for 1979-2011 have been performed using the 0.44°, 0.22° and 0.0715° horizontal resolutions equivalent to about 50 km, 25 km and 8 km, respectively. The CORDEX-MENA domain has been employed for the simulation at resolutions 0.44° and 0.22°. Nested in the 0.22° domain the highest resolution of 0.0715° is performed over Israel. The model response was analyzed for daily precipitation, 2m average temperature, maximum temperature, minimum temperature and a subset of climate indicators defined by the Expert Team on Climate Change Detection and Indices for temperature and precipitation. Results were inter-compared and evaluated against observations.

The increased resolution was found to improve precipitation and temperature results. Extreme precipitation indices were well reproduced compared to observations, with a 13% averaged percentage bias. COSMO-CLM was able to reproduce the EM precipitation gradients, with mostly overestimations in the coastal plains and underestimations in the mountains. Extreme temperature indices related to maximum temperatures were reproduced relatively well with an averaged percentage bias of 5.7%. The ability of the model to reproduce minimum temperature observational values was found to be highly dependent on station location with respect to topography. The results in this study are considered a substantial improvement from earlier RCM evaluation studies.

Evaluation and Projection of Extreme Precipitation Indices in the Eastern Mediterranean based on CMIP5 Multi Model Ensemble

Rana Samuels (deceased), **Assaf Hochman (equally contributed)**, Anat Baharad, Amir Givati, Yoav Levi, Yizhak Yosef, Hadas Saaroni, Baruch Ziv, Tzvika Harpaz Pinhas Alpert

Abstract

An Evaluation of 23 models, participating in the Coupled Model Inter-comparison Project phase 5 (CMIP5), in representing Extreme Precipitation Indices (EPI), over the Eastern Mediterranean (EM) and the Fertile Crescent (FC), was performed. The models ensemble was then used to predict the EPIs evolution in the 21st century under RCP4.5 and RCP8.5 scenarios. Models' performance was determined with respect to gridded precipitation observations from the APHRODITE project. The ensemble mean was found to perform relatively well in capturing the EM steep precipitation gradient, the FC structure and the EPI trends in the observations period (1970-2000).

Over the EM, CMIP5 models agree on a future decrease in the following three EPIs; Total Precipitation, Consecutive Wet Days, and Number of Wet Days by the values of 20-35%, 10-20%, and 20-35%, respectively. In the FC, Extremely Wet Days (P95) are expected to increase by ~25%, except for the south eastern coasts of the Mediterranean Sea, which show significant decreases in P95, particularly for RCP8.5 and at the end of the 21st century. Hence, while total precipitation is expected to decrease, extreme precipitation is expected to increase, at least for the north-eastern part of the FC. This will significantly influence agriculture and floods' potential in a region already suffering from political unrest.

The changes in EPIs are related to changes in the synoptic patterns over the EM, especially the predicted changes in cyclones frequency and intensity in the 21st century, due to changes in storm tracks governed by the phase of the North Atlantic Oscillation and the expected expansion of the Hadley Cell towards the poles in a warmer climate.

Synoptic classification in 21st Century CMIP5 predictions over the Eastern Mediterranean with focus on cyclones

Assaf Hochman, Tzvika Harpaz, Hadas Saaroni, Pinhas Alpert

Abstract

The Mediterranean has been recognized as a 'hot spot', currently influenced by climate change, and predicted to be strongly affected in the future by significant warming and drying. This trend is expected to be expressed in changes in the occurrence and intensity of Mediterranean cyclones, in general, and of East Mediterranean (EM), i.e., Cyprus Lows (CL), in particular, as well as in the occurrence of all other synoptic systems dominating the region.

Here, we have modified the semi-objective synoptic classification (Alpert et al., 2004) to investigate future changes in the occurrence of EM synoptic types, with an emphasis on CLs. The modified classification was applied to eight CMIP5 models for the present (1986-2005), mid-21st century (2046-2065) and end of the century (2081-2100) periods, for both RCP4.5 and RCP8.5 scenarios.

The modified classification captured the synoptic type frequencies for the present period well, and particularly excelled in capturing that of the CLs. For the future period, a ~35% reduction in CL occurrence is found towards the end of the 21st century (RCP8.5). Analysing this reduction for each of the 7 specific types of CLs showed that lows located to the west of Cyprus are the main contributors to this decrease. The reductions in the frequencies of CLs are accompanied by an increase in the frequencies of Red Sea Troughs in winter. The predicted changes in the occurrence of various synoptic types in general and of CLs, in particular, will lead to a more accurate forecast of local potential climatic hazards.

A new dynamical systems perspective on atmospheric predictability: eastern Mediterranean weather regimes as a case study

Assaf Hochman, Pinhas Alpert, Tzvi Harpaz, Hadas Saaroni, Gabriele Messori

Abstract

The atmosphere is a chaotic system displaying recurrent large-scale configurations. Recent developments in dynamical systems theory allow to describe these configurations in terms of local dimension – a proxy for the active number of degrees of freedom – and persistence in phase space, which can be interpreted as persistence in time. These properties provide information on the predictability of a given atmospheric state. Here, this technique was applied to atmospheric configurations in the eastern Mediterranean, grouped into synoptic classifications (SCs). It is shown that local dimension and persistence, derived from reanalysis and CMIP5 models daily sea-level pressure fields, can serve as an objective quantitative method for evaluating the predictability of different SCs. These metrics, combined with the SC transitional probability approach, are shown to be a valuable complement to operational weather forecasts as well as effective tools for climate model evaluation. This new perspective can be easily extended to other geographical regions.

The Seasons' length in 21st Century CMIP5 projections over the Eastern Mediterranean

Assaf Hochman, Tzvi Harpaz, Hadas Saaroni, Pinhas Alpert

Abstract

The eastern Mediterranean (EM) is expected to be influenced by climate changes that will significantly affect ecosystems, human health and socio-economic aspects. One aspect of climate change in this vulnerable area is the length of the seasons especially that of the rainy winter season against the warm and dry summer.

Here, the synoptic seasons' definition of Alpert et al. (2004a) was applied to an ensemble of eight CMIP5 models, under RCP8.5 and RCP4.5 scenarios, to predict the changes in the lengths of EM seasons during the 21st century. It is shown that the ensemble adequately represents the annual cycle of the main synoptic systems over the EM.

The analysis further suggests that at the end of the 21st century, the duration of the synoptic summer, characterized by the occurrence of the Persian Trough, is expected to be lengthened by 49%, while the synoptic winter, characterized by the occurrence of the Cyprus Low, is expected to be shortened by 56% under the RCP8.5 scenario. This may lead to substantial changes in the hydrological regime and water resources, reduce the potential of dry farming, increase the risk of fires and air pollution and change the timing of seasonal health hazards.

High-resolution projection of climate change and extremity over Israel using COSMO-CLM

Assaf Hochman, Paola Mercogliano, Pinhas Alpert, Hadas Saaroni, Edoardo Bucchignani

Abstract

High resolution climate projections over Israel (about 8 km) have been obtained with the regional model COSMO-CLM, nested into the CORDEX-MENA simulations at 25 km resolution. This simulation provides high-resolution spatial variability of total precipitation and precipitation intensity. Projections are presented not only in terms of average properties, but also using a subset of extreme temperature and precipitation indices from the standard Expert Team on Climate Change Detection and Indices (ETCCDI) for the period 2041-2070 with respect to 1981-2010 (RCP4.5).

A general increase in seasonal mean temperature is projected throughout the domain with peaks of ~2.5°C, especially in winter and autumn. Extreme temperature indices show increases, larger in the minimum than in the maximum temperatures. Regarding total seasonal precipitation, decreases were found in the north and central Mediterranean climate parts of Israel, with reductions reaching ~40%, and increases of the same percentage in the most southern arid parts during winter and spring. An increase in precipitation intensity is shown mostly for the southern arid part of the region, with some indications of extremity also in the north. This spatial pattern probably results from a decrease in cyclones' occurrences, which mainly influences the northern and central parts of Israel, and an increase in convective activity in the south.

The outcome of this study can serve as a basis for priority setting and policy formulation towards better climate adaptation.

Statistical down-scaling of seasonal precipitation over Israel for the 21st century, using CMIP5 projections

Assaf Hochman, Pavel Kunin, Pinhas Alpert, Tzvi Harpaz, Hadas Saaroni, Dorita Rostkier-Edelstein

Abstract

Careful planning of water resources is essential for the relatively dry region of the Middle East. The region, located at the border between Mediterranean and dry climates, together with complex terrain exhibits large spatial and inter-annual variability in seasonal precipitation. Global climate models provide only partial information due to their coarse resolution. Statistical downscaling algorithms based both on weather regimes and past analogues are operated for 18 Israeli rain gauges with the altitude range of -200 to ~1000 m ASL. This, by applying the algorithms to six Coupled Model Inter-comparison Project Phase 5 (CMIP5) models for the 21st century in order to project seasonal precipitation over Israel and its hydrologic basins. The downscaled models capture the seasonal precipitation distribution well with correlations over 0.8. All models display a significant reduction of seasonal precipitation for the 21st century RCP8.5/RCP4.5 scenarios. The RCP8.5 ensemble mean precipitation drops by ~30% based on the weather regimes method and by ~50% with the analogues method by the end of the 21st century as compared to historical simulations. It is suggested that the projected reduction in seasonal precipitation is not only the result of a decrease in the rain-bearing systems frequencies, but also the result of a decrease in their average precipitation intensity. The areas with the largest reductions in seasonal precipitation are found over the central mountains, Mediterranean coast and Sea of Galilee influencing the main fresh water aquifers and reservoirs of Israel.

The outcome of this study can serve as a basis for priority and policy setting towards better climate adaptation and regional cooperation.

The dynamics of eastern Mediterranean cyclones in the 21st century

Assaf Hochman, Pinhas Alpert, Pavel Kunin, Dorita Rostkier-Edelstein, Tzvi Harpaz, Hadas Saaroni, Gabriele Messori

Abstract

The Mediterranean region is significantly affected by climate change and is predicted to be influenced by warming and drying. This trend is expected to be expressed in changes of Mediterranean cyclones properties and particularly of East Mediterranean (EM) cyclones, i.e., Cyprus Lows (CL).

Here, a semi-objective synoptic classification was used to study the influence Green-House Gases (GHG) have on the average properties and dynamics of CLs. The classification was applied to NCEP/NCAR reanalysis as well as eight CMIP5 models for the present (1986-2005) and end of the century (2081-2100; RCP8.5) periods. A statistical downscaling algorithm based on past analogues, applied to eighteen stations over Israel, is used to project the changes in CL precipitation yield.

Significant changes in CL properties are found. An increase of ~1-1.5mb and ~0.5-1.5mb in sea-level-pressure and pressure gradients, respectively. A significant decrease in CL persistence (-8%) and an increase in the number of degrees of freedom suggests that the inherent predictability of CLs will be reduced due to global warming. The daily precipitation yield of a CL over Israel will be significantly reduced (-26%) by the end of the 21st century. Thus, the predicted drying over the EM is related to the reductions in CL daily precipitation yield as well as decreases in CL frequency.

The predicted changes in CL dynamics will lead to a more accurate forecast of local potential climatic hazards. The outcome of this study and others can serve as a basis for priority setting and policy formulation towards climate adaptation.