Clim. Past Discuss., doi:10.5194/cp-2016-90, 2016
Manuscript under review for journal Clim. Past
Published: 29 September 2016
© Author(s) 2016. CC-BY 3.0 License.

Climate of the Past Discussions
Open Access

Mid-winter (DJF) temperature reconstruction in Jerusalem since 1750 with some regional implications

Assaf Hochman[1, 2, 5], Hadas Saaroni[2], Miryam Bar-Matthews[3], Baruch Ziv[4], and Pinhas Alpert[1]

[1]Department of Earth Sciences, Tel-Aviv University, Tel-Aviv, Israel.

[2]Department of Geography and the Human Environment, Tel-Aviv University, Tel-Aviv, Israel.

[3]Geological Survey of Israel, Jerusalem, Israel.

[4]Department of Natural Sciences, the Open University of Israel, Ra'nana, Israel.

[5] Porter School of Environmental Studies, Tel-Aviv University, Tel-Aviv, Israel.

Submitted to: Climate of the Past on September 2016

Correspondence author:

Assaf Hochman

E -Mail assafhochman@yahoo.com

© Author(s) 2016. CC-BY 3.0 License.

Abstract

This work presents a statistical reconstruction of average mid-winter (DJF) temperature in Jerusalem since 1750. It is a first comprehensive attempt to reconstruct the temperature in Jerusalem, as a good representation of the Eastern Mediterranean (EM) climate. This representativeness is verified here. The data has been reconstructed by using a statistical model based on Principal Component Regression (PCR), using both instrumental data and high temporal resolution records of proxy data, including tree ring chronologies from Jordan, and records of DJF precipitation and Sea Level Pressure from central and Western Europe. A split validation procedure has resulted in a 0.73 correlation between observed and reconstructed temperature. The warming trend of last decades is well noted in the reconstruction and is in line with other studies. Winters which were cold/warm were historically documented as wet/dry, respectively, consistent with earlier studies pointing a strong relationship between Jerusalem temperatures and precipitation. It is shown here for the first time that the 'First Aliyah' (immigration) to Israel during 1882-1904 initiated during favouring climate conditions (cool and wet) to establish an agricultural community in the region. These conditions were found to be exceptional compared to other periods since 1750.

Keywords: Climate reconstruction; Principal Component Analysis; climate change; First Aliyah; immigration

Clim. Past Discuss., doi:10.5194/cp-2016-90, 2016
Manuscript under review for journal Clim. Past
Published: 29 September 2016
© Author(s) 2016. CC-BY 3.0 License.

1 Introduction

Temperature and precipitation are the most important climatic elements affecting humanity, economy and ecosystems. Warming and drying trends, as well as extreme temperature events, including heat waves, dry spells and droughts have an essential influence on human life, especially in the Eastern Mediterranean (EM) region (Saaroni et al., 2003; Luterbacher et al., 2004; Touchan et al., 2005; Ziv et al., 2005; Luterbacher et al., 2012; Lelieveld et al., 2012; Tanarhte et al., 2012; Saaroni et al., 2015). Several studies suggested that climate change had a decisive impact on societies in the region, at times even bringing about total collapse (Alpert and Neumann, 1989; Weiss and Bradley, 2001; Enzel et al., 2003; Ellenblum, 2012; Torfstein et al., 2013, Kelley et al., 2015). For example, recent studies suggest that Syria and the greater Fertile Crescent, where agriculture had begun some 12,000 years ago, experienced the worst 3-year drought in the instrumental record (Trigo et al., 2010). The drought caused massive agricultural failures. The most significant consequence was the migration of as many as 1.5 million people from rural farming areas to urban centers. It was further suggested that the drought (2007-2010), contributed to the present conflict in Syria (Kelley et al., 2015). The first study to point at global warming as a central contributor to the drying of the Fertile Crescent was Kitoh et al., (2008), see also Alpert et al., (2013).

The EM region has received relatively little attention concerning past multi proxy high resolution climate reconstructions (Finne et al., 2011; Luterbacher et al., 2012; Lelieveld et al., 2012) despite the unique position of the region, as a transition zone between temperate climate in the North and arid climate in the South (Bar-Matthews et al., 1997; Lionello et al., 2014). The EM climate is influenced by subtropical and mid-latitude circulations as well as by tropical intrusions. Fluctuations in the occurrence and intensity of these circulations are known to be controlled by different large-scale oscillations; This leads to complex features in the region's climatic fluctuations (Alpert et al., 2006; Saaroni et al., 2010).

1.1 Recent studies of past climate in the EM

The use of proxy data from natural climate archives in climate reconstruction helps to expand the time scale of the study, and enables investigation of multi-decadal variations (Luterbacher et al., 2012). Various publications deal with European temperature reconstruction at different scales of time and space (Luterbacher et al., 1999; Luterbacher et al., 2004; Casty et al., 2005a; Xoplaki et al., 2005). In Israel and

Clim. Past Discuss., doi:10.5194/cp-2016-90, 2016
Manuscript under review for journal Clim. Past
Published: 29 September 2016
© Author(s) 2016. CC-BY 3.0 License.

nearby areas a few attempts have been made at climate reconstruction with high resolution data, covering the past centuries. Liphschitz and Waisel, (1967) used tree ring data to develop paleo-climate records of the region. Tamari, (1976) has reconstructed rainfall regimes in Northern Sinai and Southern Israel through Dendro-chronological analysis since 1850. Frumkin et al., (1991), Bar-Matthews et al., (1997) and Vaks et al., (2003) have shown isotopic fractionation analysis of speleothems in karstic caves in Israel to infer precipitation at the caves sites. Kuperman, (2005) had reconstructed flood periods during the Holocene by dating speleothems in the Northern Negev, Israel. Touchan and Hughes, (1999) have reconstructed rainfall regimes in Southern Jordan since 1600 using Dendro-chronological analysis. Enzel et al., (2003) exposed the surface levels of the Dead Sea in a resolution of decades to centuries, using it as a proxy for winter rainfall in the region. In a recent study, droughts were reconstructed using Tree-ring chronologies from the Mediterranean region (Cook et al., 2016). They suggested that the recent drought in the Eastern Mediterranean is the worst in 900 years.

No comprehensive attempt has been made to reconstruct the regional climate of Jerusalem, by combining and integrating different proxies, with high temporally resolved records. The various proxies differ widely in their temporal resolutions. Some proxy records have annual or longer time scales. Several works (Pauling et al., 2003; Luterbacher et al., 2012) have reviewed the strengths and potential weaknesses of proxy sources used for seasonal climate reconstructions in the Mediterranean region. They concluded that an optimal combination of high quality natural and documentary proxies can yield better results than using only one of the two types.

1.2 The climate of Jerusalem

Jerusalem is a town located on the Judean Mountains, at an elevation of about 600-800 m. It is situated on the border between temperate climate to its north and west and the semi-arid and arid climate to its east, known as the Judean Desert, which is a 'rain shadow' desert. Jerusalem belongs to the Mediterranean climatic region (according to the Köppen classification) with an average annual precipitation of 537 mm. Precipitation occurs mostly during Oct-May. January is the coldest month of the year with an average temperature of 9.8°C; July and August are the hottest months with and average temperature of 25°C. Temperatures vary widely from day to night (IMS 2016).

© Author(s) 2016. CC-BY 3.0 License.

This study aims to reconstruct the mid-winter (DJF) temperature fluctuation in Jerusalem since 1750. The methodology uses a statistical model based on Principal Component Regression (PCR), combining instrumental data and different documentary and natural proxies.

2 Data

We draw on homogenised mid-winter (DJF) mean temperature of Jerusalem for the period of 1865-2015, as the target of our model; retrieved from the Global Historical Climatology Network (GHCN-adjusted, Lawrimore et al., 2011) and verified as homogenised at the Israel Meteorological Service. Our analysis also compares this record with the precipitation record of Jerusalem for the same period.

Our preliminary data base consisted of 49 long time-series of temperature, precipitation, and Sea Level Pressure (SLP) measurements taken in central and Western Europe, retrieved from the GHCN adjusted station data (Lawrimore et al., 2011). Most of these series start in the mid-18th century with virtually no missing values; some series go further back to the end of the 17th century. The relevance of the above data for the reconstruction of temperature in Jerusalem is established in section 2.3 (Figure 1).

In addition, ten tree-ring site chronologies originating in the Dana Reserve in Jordan and in the Troodos Mountains in Cyprus (Table 1) (www.ncdc.noaa.gov) underwent de-trending and standardization by ARSTAN software (Cook, 1985) in order to eliminate an age trend without losing high and low frequency climatic signals. Furthermore, we have used historically documented data from Jerusalem, since 1750 (Klein, 1985). Brazdil et al., (2005) have suggested that this kind of documentary source can be used to pin point extremes.

The investigation of the synoptic and large-scale patterns that affect Jerusalem was made possible through the use of NCEP/NCAR reanalysis archive (Kalnay et al., 1996; Kistler et al., 2001), along with Kaplan's Global Sea Surface Temperature (SST) reconstructions (http://climexp.knmi.nl). All in all we started with 59 original time-series, which make the full data base. Figure 1 displays a map with the origin of each data source described in this section.

Clim. Past Discuss., doi:10.5194/cp-2016-90, 2016
Manuscript under review for journal Clim. Past
Published: 29 September 2016
© Author(s) 2016. CC-BY 3.0 License.

3 Statistical reconstruction model

Our statistical modelling approach consists of three steps:

1) Reduction of dimensionality – first choosing significant correlated predictors with Jerusalem mean DJF temperature and then Principal Component Analysis (PCA) on the chosen predictors.
2) Temperature reconstruction –Multiple Linear Regression (MLR).
3) Validation – Split Validation (SV).

PCA is a common technique used in statistical modelling, where the number of predictors used in the computation is reduced for the sake of a more robust model. PCA produces artificial predictors, which are uncorrelated to one another, in order to avoid ambiguity in the climatic signal (Mierswa et al., 2006). In this study, significant correlated predictors (95% significant level) to the mean DJF temperature in Jerusalem were found. Before applying PCA we normalised the various proxies in order to avoid dominance of numerically larger attributes over smaller ones (Hsu et al., 2003). Next, PCA was performed, keeping 70% of the variance in the original data while retaining the least number of principal components. The chosen PCs were learned by a MLR model, using the period 1865-1981, for which that proxies can be related to Jerusalem temperature with virtually no missing values. The model produced was applied on the reconstructed period (1750-1864).

Validation of the reconstruction was done by Split Validation, sometimes called rotation estimation, which is the statistical practice of partitioning a sample of data into subsets so that analysis is initially performed on a single subset while the rest of the set is retained for confirmation of the initial analysis (Michaelson, 1987). The initial subset is the training set and the other is validation or testing sets. In this study, the data of 1865-1981 were randomly partitioned into a training set and a validation set.

4 Results

4.1 Jerusalem as a representative of Eastern Mediterranean climate

Studies have shown that the Jerusalem precipitation record is a reliable proxy for the hydro-climatic fluctuations in the EM (Enzel et al., 2003, Kushnir and Stein, 2010). Following this, we applied two tests to evaluate how well the recorded temperature in Jerusalem represents the temperature of the EM. First, we evaluated the coherence among the nine longest records of instrumental surface temperature from stations located in the EM; Jerusalem (Israel), Beirut (Lebanon), Amman (Jordan), Nicosia

© Author(s) 2016. CC-BY 3.0 License.

(Cyprus), Port-Said (Egypt), Abbasiya (Egypt), Antalya (Turkey), Urfa (Turkey) and Adana (Turkey). Using correlation coefficients between every two pairs of these records, each station received a score of "representativeness". The score of each station was calculated as the ratio between the average of all correlation coefficients it has and the average of the significance values for these correlations. This way, a higher average correlation or a lower average significance both contribute to a higher overall score. Jerusalem turned out to be the most representative of them, followed by Nicosia and Amman (Table 2).

The second criterion to evaluate the representativeness of Jerusalem was displaying a comparison of the spatial correlation between the average temperature in Jerusalem and GHCN surface temperature fields in other places in the region and in Europe for DJF, during the period of 1900-1990 (Figure 2). The resulting high significant correlations with other locations in the EM, lead us again to conclude that Jerusalem is a suitable representative for the climate of the region. Accordingly, the reconstruction of temperature variations in Jerusalem is an important first step towards a better understanding of climatic variability in the EM.

To justify our use of both temperature, precipitation and SLP data in Central Europe as good predictors for the temperature in Jerusalem, we analysed the relationship between these variables during the 20^{th} century, using correlation maps, to identify tele-connection patterns. Figure 2 displays correlation maps between mid-winter (DJF) temperature in Jerusalem and temperature, precipitation and SLP in Europe for the same period. The results indicate a strong relationship between the values in the two regions: a positive correlation pattern between precipitation in south Europe and mean temperature in Jerusalem, and a negative one between temperature/SLP in Europe and mean temperature in Jerusalem.

These findings suggest that connection exists between mid-winter (DJF) temperature in Jerusalem and large-scale circulation patterns. Figure 3 presents teleconnection patterns between Jerusalem mid-winter temperature and SST's. A negative relationship ($R<-0.3$) between SST in the North Sea and a positive ($R>0.4$) with the tropical Atlantic and Jerusalem temperature is observed. Figure 4 presents teleconnection patterns between Jerusalem mid-winter temperature and 300mb geopotential heights. A strong negative relationship is observed over central and western Europe. These findings along with the negative SLP relationship with Jerusalem mid-winter temperature (Figure 2) reinforce the statistical relationship between mid-winter precipitation in Europe and

Clim. Past Discuss., doi:10.5194/cp-2016-90, 2016
Manuscript under review for journal Clim. Past
Published: 29 September 2016
© Author(s) 2016. CC-BY 3.0 License.

Climate of the Past Discussions
Open Access

temperature in Jerusalem, with a dynamical one. European high pressure causes northerly winds in Israel which bring cold air from western Russia to the region, in a process governed by the phase configuration of Rossby waves (Ziv et al., 2006).

4.2 The Statistical reconstruction model and validation results

Table 3 shows the final predictors found to be significantly (95% level) correlated to Jerusalem mid- winter (DJF) temperature. 70% of variance in the data was kept by the first **five Principle Components (PC),** while the first PC explained **41%** of the variance. The final regression equation for Jerusalem mid-winter (DJF) temperature is displayed: $0.25*PC1 + 0.16*PC2 + 0.06*PC3 – 0.11 * PC4 + 0.18*PC5 + 8.45$

The split validation has resulted in relatively good performance; with 0.73 correlation coefficient (Table 4 displays performance indicators for the reconstruction model). Figure 5 displays the ability of the statistical model to reconstruct the average winter temperature of Jerusalem. It is shown that the model can simulate relatively well the mid-winter (DJF) temperature fluctuations in Jerusalem.

4.3 Reconstruction results

Final results for the reconstruction of normalised mean Jerusalem mid-winter (DJF) temperatures are displayed in Figure 6. Furthermore, precipitation fluctuations during the instrumental period are super-imposed on the temperature fluctuations. Although a precipitation reconstruction is not the subject of this paper, the variations seen in Fig. 6 indicate the strong negative correlation between temperature and precipitation in the EM in agreement with Striem, (1979), who found that a decrease in 1˚C is equivalent to an increase of 100mm in seasonal precipitation in Jerusalem. To verify this, we compared our reconstructed temperature series with independent historical documents of Klein (1985). The results are in agreement with Striem, (1979); i.e., the winters of 1763/4 1771/2, 1772/3, 1784/5, 1827/8, 1828/9, 1844/5, 1845/6 which were winters with higher than average reconstructed temperature were historically documented as dry winters (Klein, 1985), while the winters 1796/7, 1797/8, 1806/7, 1835/6, 1849/50, 1861/2 with lower than average reconstructed temperature were documented as wet (Klein, 1985). These findings also strengthen the accuracy of our reconstructed series.

It is worth referring to the period 1882-1904 known as the 'First Aliyah' (FA) or the 'Agricultural Aliyah' period. This term is used to describe a large immigration of Jewish Zionists to Israel, ~25,000-35,000, who managed, for the first time, to establish an

© Author(s) 2016. CC-BY 3.0 License.

agricultural community. It is suggested here that this period had favouring climate conditions for dry farming agriculture in the relatively hot and dry conditions of Israel, i.e., below normal temperatures and above normal precipitation. Before the FA, the rainy seasons of 1873/4 and 1877/8 had exceptional high precipitation amounts (~1000mm/year in Jerusalem) as recorded in observations, on the same order of magnitude as 1991/2, which was the most exceptional rainy year on record, related to Mt. Pinatubo eruption (Bookman et al., 2014). Furthermore, 1879/80, 1881/2, 1882/3 and 1883/4 were historically documented as extremely wet years (Klein, 1985). The temperature reconstruction presented here suggests that a partially relief in the hardness, of high temperatures and lack of precipitation, for agriculture probably helped to the success of this agricultural immigration. These conditions have not been seen since 1750. The warming trend of recent years is unprecedented in the last 264 years and is in line with other studies.

5 Summary

The study reconstructed the mid-winter temperatures in Jerusalem since 1750, using data from multiple climate proxies. The hypothesis that Jerusalem is a good representative of the EM climatic fluctuations is proved, based on comparison of the representativeness scores of the nine longest records of instrumental surface temperature in the EM. Also, the high spatial correlations between the temperature in Jerusalem at the 20th century and the surface temperature fields in the EM and in Europe, shown through correlation maps, strengthen this conclusion. The suitability of European station records to serve as highly resolved predictors for the average temperature in Jerusalem is well demonstrated, suggesting they can be used to reconstruct the larger EM climate. Historical documents used pointed at periods of extreme temperatures and therefore, validate the reconstructed values.

The warming trend of recent decades is unprecedented since 1750, in agreement with global and regional studies (IPCC 2013). It is suggested here that the period of the First Aliyah (FA) to Israel coincided with favouring climate conditions for dry faming agriculture in the relatively hot and dry conditions of Israel. These conditions have not been seen since 1750, and probably helped in its success.

© Author(s) 2016. CC-BY 3.0 License.

Acknowledgements

This work was supported in part by Grant from the European Science Foundation in the frame work of Mediterranean Climate Variability and Predictability, the Porter school of Environmental studies, Tel-Aviv University, Tel-Aviv, Israel and GLOWA – Jordan River Project funded by the German Ministry of Science and Education (BMBF), in collaboration with the Israeli Ministry of Science and Technology (MOST).

Finally, we acknowledge the kind hospitality and helpful discussions of Juerg Luterbacher, Heinz Wanner, Elena Xoplaki and the entire klimet GIUB group at Bern University, Bern, Switzerland. Special thanks go to Mrs. Judith Lempert, the linguistic editor of the text.

References

Alpert, P. Jin, F. and Kitoh, A.: The Projected Death of the Fertile Crescent. In: Norwine J, (ed) A World after Climate Change and Culture-Shift, Springer, 193-204, 2013.

Alpert, P. and Coauthors: Relations between climate variability in the Mediterranean region and the Tropics: ENSO, South Asia and African Monsoons, hurricanes and Saharan dust. in: Lionello P, Malanotte-Rizzoli P, Boscollo R (eds) The Mediterranean Climate: an Overview of the Main Characteristics and Issues. Elsevier, 149-177, 2006.

Alpert, P. and Neumann, J.: An ancient "correlation" between streamflow and distant rainfall in the near East. Journal of Near Eastern studies 48: 313-314, 1989.

Bar-Matthews, M. Ayalon, A. Kaufman, A.: Late quaternary paleoclimate in the eastern Mediterranean region from stable isotope analysis of speleothems at Soreq cave, Israel. Quaternary Research 47**:** 155-168, 1997.

Bitan, A. and Rubin, S.: Climatic atlas of Israel for physical and environmental planning and design. Ramot Publishing, Tel Aviv, Israel, 1994.

Bookman, R. Filin, S. Avni, Y. Rosenfeld, D. and Marco, S.: Possible connection between large volcanic eruptions and level rise episodes in the Dead Sea Basin. Quaternary Science Reiews 89: 123-128, 2014.

Brazdil, R. Pfister, C. Wanner, H. Storch, H. V. and Luterbacher, J.: Historical climatology in Europe - The state of the art. Climatic Change 70**:** 363-430, 2005.

Clim. Past Discuss., doi:10.5194/cp-2016-90, 2016
Manuscript under review for journal Clim. Past
Published: 29 September 2016
© Author(s) 2016. CC-BY 3.0 License.

Casty, C. Wanner, H. Luterbacher, J. Esper, J. and Bohm, R.: Temperature and precipitation variability in the European Alps since 1500. International Journal of climatology 25: 1855-1880, 2005a.

Cook, E. R.: A time series analysis approach to tree ring standardization. Dissertation, The University of Arizona, 171 pp, 1985.

Cook, B. I. Anchukaitis, K. J. Touchan, R. Meko, D. M. and Cook, E. R. Spatiotemporal drought variability in the Mediterranean over the last 900 years. Journal of Geophysical Research. doi: 10.1002/2015JD023929, 2016.

Ellenblum, R.: Climate change and the decline of the Eastern-Mediterranean, 950-1072AD. Cambridge university press, New York, 2012.

Enzel, Y. Bookman, R. Sharon, D. Gvirtzman, H. Dayan, U. Ziv, B. and Stein, M.: Late Holocene climates of the near East deduced from Dead Sea level variations in modern regional winter rainfall. Quaternary Research 60: 263-273, 2003.

Finne, M. Holmgren, K. Sundqvist, H. S. Weiberg, E. and Lindblom, M.: Climate in the eastern Mediterranean, and adjacent regions, during the past 6000 years—a review. Journal of Archaeological Science 38: 3153–3173, 2011.

Frumkin, A. Magaritz, M. Carmi, I. and Zak, I.: The Holocene climate record of the salt caves of mount Sedom. Holocene 1**:**191-200, 1991.

Hasanean, H. M.: Fluctuations of surface air temperature in the Eastern Mediterranean. Theoretical and Applied Climatology 68**:** 75-87, 2001.

Hsu, C. W. Chang, C. C. and Ling, C. J.: A Practical Guide to Support Vector Classification, 2003. http://www.csie.ntu.edu.tw/~cjlin/papers/guide/guide.pdf. Accessed 12 January 2014

IPCC Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T. F. Qin, D. Plattner, G. K. Tignor, M. Allen, S. K. Boschung, J. Nauels, A. Xia, Y. Bex, V. and Midgley, P. M. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp. doi: 10.1017/CBO9781107415324, 2013.

Kelley, C. P. Mohtadi, S. Cane, M. A. Seager, R. and Kushnir, Y.: Climate change in the Fertile Crescent and implications of the recent Syrian drought. PNAS 112(11): 3241-3246, 2015.

Kistler, and co-authors. : The NCEP-NCAR 50 year reanalysis: monthly means CD ROM and documentation. BAMS 82: 247-268, 2001.

Clim. Past Discuss., doi:10.5194/cp-2016-90, 2016
Manuscript under review for journal Clim. Past
Published: 29 September 2016
© Author(s) 2016. CC-BY 3.0 License.

Kitoh, A. Yatagai, A. and Alpert, P.: First super-high-resolution model projection that the ancient "Fertile Crescent" will disappear in this century. Hydrological. Research. Letters 2: 1-4, 2008.

Klein, C.: Fluctuations of the level of the Dead Sea and climatic fluctuations in erez Israel during historical times. Dissertation, Hebrew University, 1985.

Kuperman, G.: Reconstruction of flood periods by dating speleothems in Nahal Hazera, Northern Negev. Hebrew University 88, 2005.

Kushnir, Y. and Stein, M.: North Atlantic influence on 19the20th century rainfall in the Dead Sea watershed, teleconnections with the Sahel, and implication for Holocene climate fluctuations. Quaternary Science Reviews 29: 3843-3860, 2010.

Lawrimore, J. H. Menne, M. J. Gleason, B. E. Williams, C. N. Wuertz, D. B. Vose, R. S. and Rennie, J.: An overview of the Global Historical Climatology Network monthly mean temperature data set, version 3. Journal of Geophysical Research 116: D19121, 2011.

Lelieveld, J. Hadjinicolaou, P. Kostopoulou, E. Chenoweth, J. E. Maayar, M. Giannakopoulos, C. Hannides, C. Lange, M. Tanarhte, M. Tyrlis, E. and Xoplaki, E. Climate change and impacts in the eastern Mediterranean and the Middle East. Climatic Change 114, 667–687, 2012.

Lionello, P. Abrantes, F. Gacic, M. Planton, S. Trigo, R. and Ulbrich, U.: The climate of the Mediterranean region: research progress and climate change impacts. Regional Environmental Change 14:1679-1684, 2014.

Liphschitz, N. and Waisel, Y.: Dendrochronological studies in Israel. *Quercus boisseri* of Mt. Meron region. La-Yaaran 17:78–91, 111–115 (In Hebrew), 1967.

Luterbacher, J. and Co-authors.: A review of 2000 years of paleoclimatic evidence in the Mediterranean. in: Lionello P (ed) The Climate of the Mediterranean region: from the past to the future. Elsevier, 87-185, 2012.

Luterbacher, J. Dietrich, D. Xoplaki, E. Grosjean, M. and Wanner, H.: European seasonal and annual temperature variability, trends and extremes since 1500. Science 303: 1499-1503, 2004.

Luterbacher, J. Schmutz, C. Gyalistras, D. Xoplaki, E. and Wanner, H.: Reconstruction of monthly NAO and EU indices back to AD 1675. Geophys Res Let 26:2745-2748, 1999.

Michaelson, J.: Cross-Validation in statistical climate forecasts models. Journal of Climatology and Applied Meteorology 26: 1589-1600, 1987.

Clim. Past Discuss., doi:10.5194/cp-2016-90, 2016
Manuscript under review for journal Clim. Past
Published: 29 September 2016
© Author(s) 2016. CC-BY 3.0 License.

Mierswa, I. and Co-authors.: YALE: Rapid Prototyping for complex data mining tasks. In: Tina ER, Lyle HU, Craven M, Gunopulos D (eds) Proceedings of the 12th ACM SIGKDD international conference of knowledge discovery and data mining (KDD-06). New York, USA, ACM Press 363-368, 2006.

Pauling, A. Luterbacher, J. and Wanner, H.: Evaluation of proxies for European and North Atlantic temperature field reconstructions. GRL 30: 1787, 2003.

Saaroni, H. Ziv, B. Edelson, J. and Alpert, P.: Long term variations in summer temperatures over the Eastern Mediterranean. GRL 30: 1946, 2003.

Saaroni, H. Ziv, B. Osetinsky, I. and Alpert, P.: Factors governing the inter-annual variation and the long-term trend of the 850-hPa temperature over Israel, Quaternary Journal of the Royal Meteorological Society part B 136: 305-318, 2010.

Saaroni, H. Ziv, B. Lempert, J. Gazit, Y. and Morin, E.: Prolonged dry spells in the Levant region: climatological-synoptic analysis. Int J Climatol, 35: 2223-2236, 2015.

Striem, H. L.: Some aspects of the relation between monthly temperatures and rainfall, and its use in evaluating earlier climates in the Middle East. Climatic Change 2(1): 69-74, 1979.

Tanarhte, M. Hadjinicolaou, P. and Lelieveld, J.: Inter-comparison of temperature and precipitation data sets based on observations in the Mediterranean and the Middle East. Journal of Geophysical Research 117: D12102, 2012.

Tamari, A.: Climatic fluctuations in the Eastern basin of the Mediterranean based on dendro-chronological analysis. Dissertation, Tel-Aviv University, 1976.

Torfstein, A. Goldstein, S. L. Stein, M. and Enzel, Y.: Impacts of abrupt climate changes in the Levant from Last Glacial Dead Sea levels. Quaternary Science Review 69: 1-7, 2013.

Touchan, R. Meko, D. M. and Hughes, M. K.: A 396-year reconstruction of precipitation in southern Jordan. Journal of the American Water Resources Association 35(1): 45-55, 1999.

Trigo, R. M. Gouveia, C. M. and Barriopedro, D.: The intense 2007–2009 drought in the Fertile Crescent: Impacts and associated atmospheric circulation. Agricultural Meteorology 150(9): 1245–1257, 2010.

Vaks, A. and Co-authors.: Paleo-climate reconstruction based on the timing of speleothem growth and oxygen and carbon isotope composition in a cave located in the rain shadow in Israel. Quaternary Research 59: 182-193, 2003.

Clim. Past Discuss., doi:10.5194/cp-2016-90, 2016
Manuscript under review for journal Clim. Past
Published: 29 September 2016
© Author(s) 2016. CC-BY 3.0 License.

Weiss, H. and Bradley, R. S.: What drives societal collapse? Science 291: 609-610, 2001.

Xoplaki, E. Luterbacher, J. Paeth, H. Dietrich, D. Steiner, N. Grosjean, M. Wanner, H.: European Spring and Autumn temperature variability and change of extremes over the last half millennium. GRL 32: L15713, 2005.

Ziv, B. Saaroni, H. Baharad, A. Yekutieli, D. and Alpert, P.: Indications of aggravation in summer heat conditions over the Mediterranean basin. GRL 32: L12706, 2005.

Ziv, B. Dayan, U. Kushnir, Y. Roth, C. and Enzel, Y.: Regional and Global Atmospheric Patterns Governing Rainfall in the Southern Levant. International Journal of Climatology 26: 55-73, 2006.

Figure Captions

Fig. 1 Map displaying sites of climate proxies and measurement records used in this work: instrumental records of precipitation temperature and SLP (blue icons), tree rings (green icons), and Jerusalem mean temperature target record (in a black question mark). Additional records used, which do not originate in a single site include, 300 hPa geo-potential heights from NCEP/NCAR Reanalysis, Kaplan global SST reconstructions (http://climexp.knmi.nl), and historic documents (Klein, 1985). These records are represented on the map as red labels.

Fig. 2 Correlations of winter (DJF) temperature in Jerusalem (P<5%) with surface temperature (left column), precipitation (middle column) and SLP fields (right column). The correlations were calculated for the period of 1900-1990 and for three sub periods of 30 years each. Warm colours correspond to positive correlation and cold colours to negative correlation.

Fig. 3 Correlation maps of winter (DJF) temperature in Jerusalem with Kaplan global seasonal SST reconstruction (1856-2003) (http://climexp.knmi.nl). Warm colours indicate positive correlations and cold colours indicate negative correlations. Coloured regions are found to be significant (P<5%).

Fig. 4 Correlation map of winter (DJF) temperature in Jerusalem with NCEP/NCAR 300-hPa geo-potential height (1948-2014). Warm colours indicate positive correlations and cold colours indicate negative correlations. Coloured regions are found to be significant (P<5%).

Clim. Past Discuss., doi:10.5194/cp-2016-90, 2016
Manuscript under review for journal Clim. Past
Published: 29 September 2016
© Author(s) 2016. CC-BY 3.0 License.

Climate of the Past Discussions
Open Access

Fig. 5 The randomly selected validation set of points retained from the 1865-1981 period. Observed vs. Reconstructed mean mid-winter (DJF) temperature of Jerusalem marked in black and red lines, respectively.

Fig. 6 Normalized reconstructed Jerusalem mean winter (DJF) Temperature between 1750 and 2014 (black line), and winter precipitation between 1865 and 1995 (red line). Five year moving average lines are marked in thick black and red, respectively. The reconstructed and observed periods are divided by a black dashed line in the year 1865. The First Aliyah period (1882-1904) is marked by a grey rectangle.

Table 1 Tree ring site chronologies information from Cyprus and Jordan www.ncdc.noaa.gov.

Table 2: Scores of "representativeness" for the nine stations with the longest records of instrumental surface temperature in the Eastern Mediterranean. The score shows how well a station represents all the other stations. Jerusalem received the highest score. The score is calculated as the ratio between the average of the correlations with the other stations and the average of the respective significance scores. The station with the highest score is the best representative of the temperature fluctuations in the region.

Table 3 Predictors found to be significantly (95%) correlated to Jerusalem DJF temperature. The correlations between predictors and Jerusalem mid-winter temperature are indicated in the right column.

Table 4 Split validation results for the statistical reconstruction model.

Clim. Past Discuss., doi:10.5194/cp-2016-90, 2016
Manuscript under review for journal Clim. Past
Published: 29 September 2016
© Author(s) 2016. CC-BY 3.0 License.

Climate of the Past
Discussions

Fig. 1 Map displaying sites of climate proxies and measurement records used in this work: instrumental records of precipitation temperature and SLP (blue icons), tree rings (green icons), and Jerusalem mean temperature target record (in a black question mark). Additional records used, which do not originate in a single site include, 300 hPa geo-potential heights from NCEP/NCAR Reanalysis, Kaplan global SST reconstructions (http://climexp.knmi.nl), and historic documents (Klein, 1985). These records are represented on the map as red labels.

Clim. Past Discuss., doi:10.5194/cp-2016-90, 2016
Manuscript under review for journal Clim. Past
Published: 29 September 2016
© Author(s) 2016. CC-BY 3.0 License.

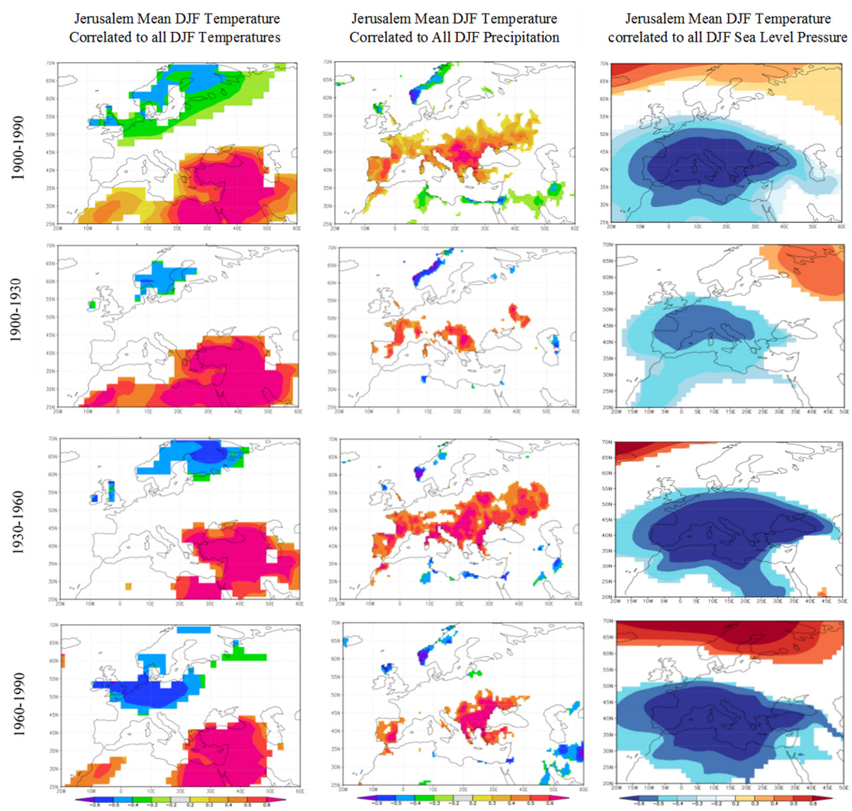

Fig. 2 Correlations of mid-winter (DJF) temperature in Jerusalem (P<5% are coloured) with surface temperature (left column), precipitation (middle column) and SLP fields (right column). The correlations were calculated for the period of 1900-1990 and for three sub periods of 30 years each. Warm colours correspond to positive correlation and cold colours to negative correlation.

Clim. Past Discuss., doi:10.5194/cp-2016-90, 2016
Manuscript under review for journal Clim. Past
Published: 29 September 2016
© Author(s) 2016. CC-BY 3.0 License.

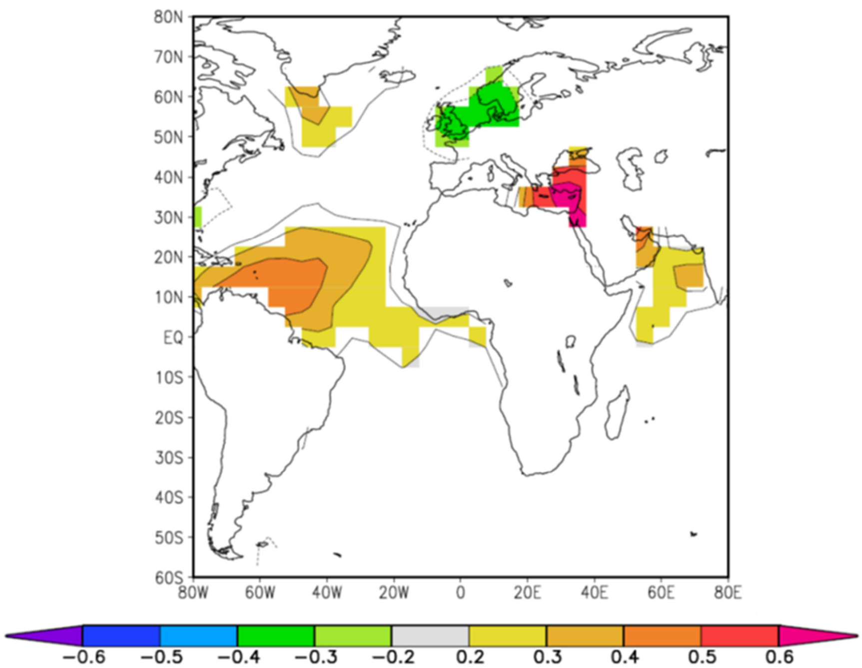

Fig. 3 Correlation maps of winter (DJF) temperature in Jerusalem with Kaplan global seasonal SST reconstruction (1856-2003) (http://climexp.knmi.nl). Warm colours indicate positive correlations and cold colours indicate negative correlations. Coloured regions are found to be significant (P<5%).

Clim. Past Discuss., doi:10.5194/cp-2016-90, 2016
Manuscript under review for journal Clim. Past
Published: 29 September 2016
© Author(s) 2016. CC-BY 3.0 License.

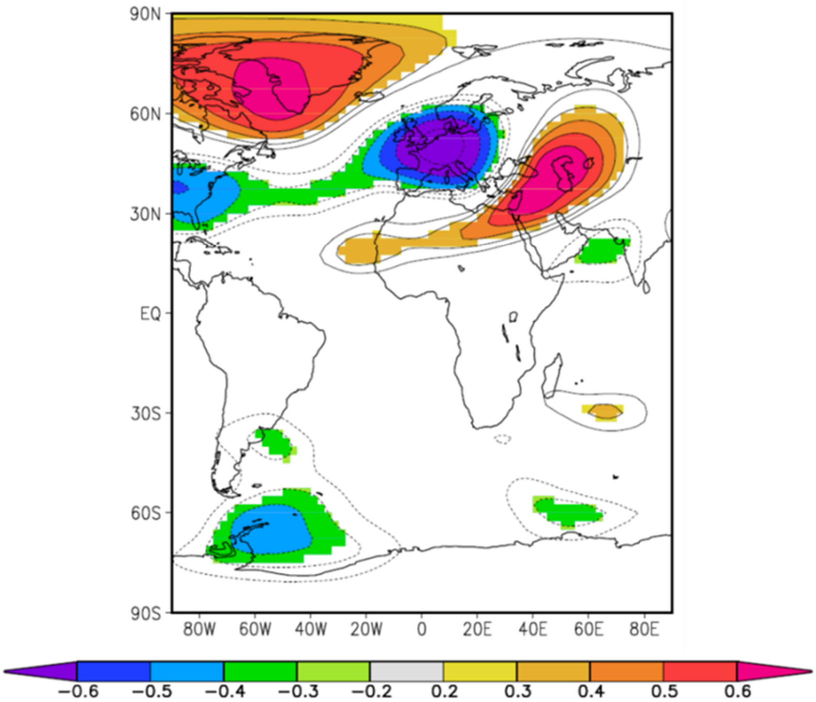

Fig. 4 Correlation map of winter (DJF) temperature in Jerusalem with NCEP/NCAR 300-hPa geo-potential height (1948-2014). Warm colours indicate positive correlations and cold colours indicate negative correlations. Coloured regions are found to be significant (P<5%).

Clim. Past Discuss., doi:10.5194/cp-2016-90, 2016
Manuscript under review for journal Clim. Past
Published: 29 September 2016
© Author(s) 2016. CC-BY 3.0 License.

Climate of the Past
Discussions
Open Access

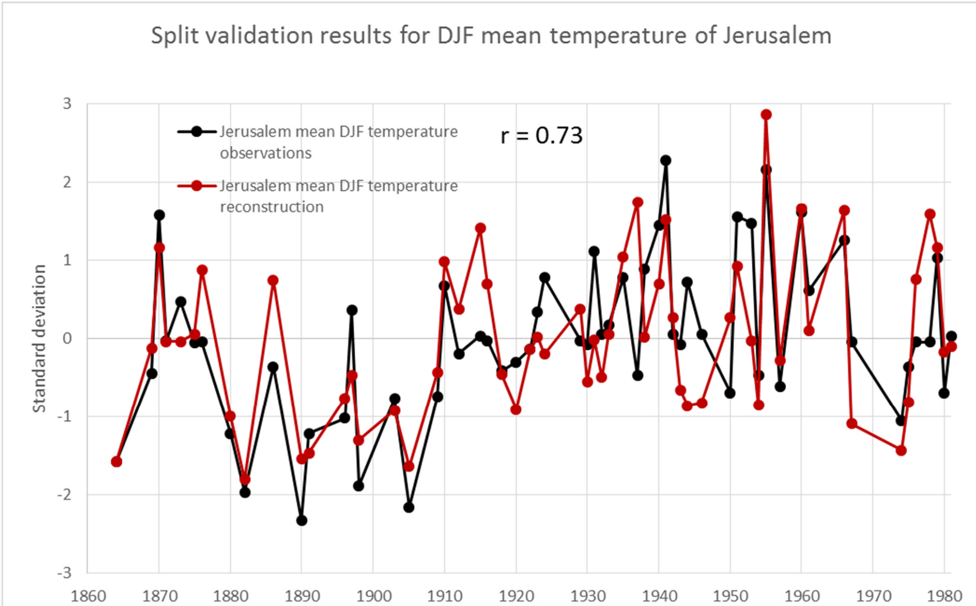

Fig. 5 The randomly selected validation set of points retained from the 1865-1981 period. Observed vs. Reconstructed mean mid-winter (DJF) temperature of Jerusalem marked in black and red lines, respectively.

Clim. Past Discuss., doi:10.5194/cp-2016-90, 2016
Manuscript under review for journal Clim. Past
Published: 29 September 2016
© Author(s) 2016. CC-BY 3.0 License.

Climate of the Past Discussions

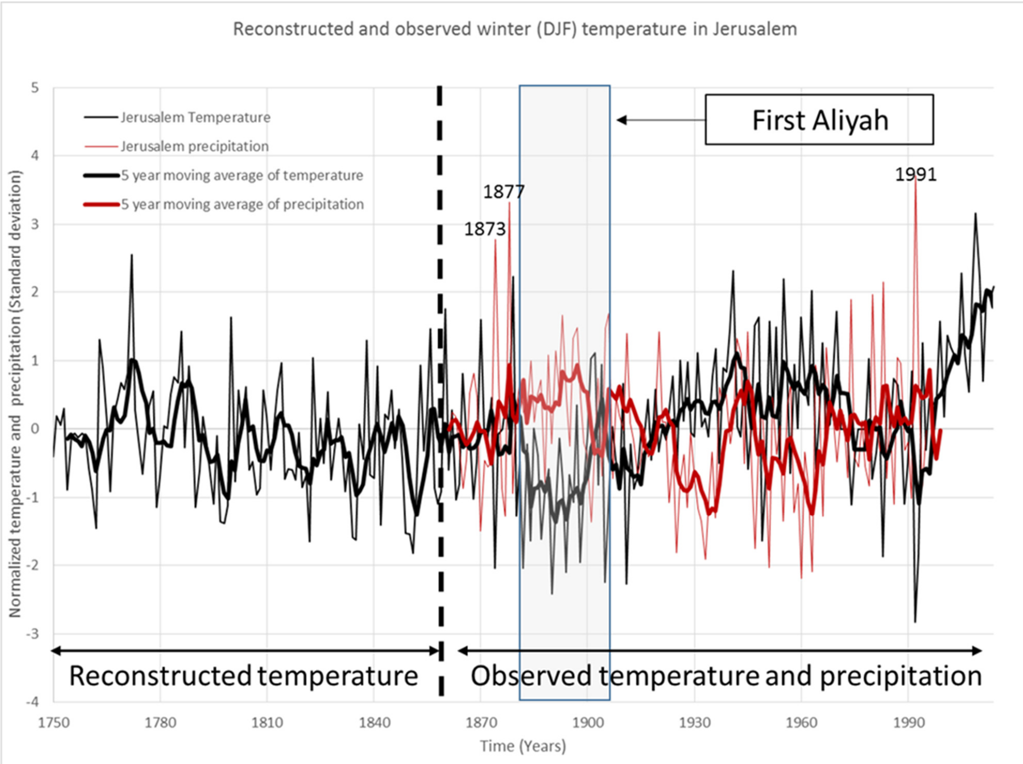

Fig. 6 Normalized reconstructed Jerusalem mean winter (DJF) Temperature between 1750 and 2014 (black line), and winter precipitation between 1865 and 1995 (red line). Five year moving average lines are marked in thick black and red, respectively. The reconstructed and observed periods are divided by a black dashed line in the year 1865. The First Aliyah period (1882-1904) is marked by a grey rectangle.

Clim. Past Discuss., doi:10.5194/cp-2016-90, 2016
Manuscript under review for journal Clim. Past
Published: 29 September 2016
© Author(s) 2016. CC-BY 3.0 License.

Climate of the Past Discussions
Open Access
EGU

Country	Site name	Site elevation	Grid point	Number of trees in chronology	Time	Tree type
Cyprus	Ceader Valley Trocken	1280m	34.59N 32.41S	21	1675-1981	Cyprian Cedar
Cyprus	Ceadar Valley Mittel	1380m	34.59N 32.41S	20	1806-1981	Cyprian Cedar
Cyprus	Plano Platres Feucht	1600m	34.54N 32.54S	22	1742-1981	Austrian Pine, Black Pine
Cyprus	Plano Platres Trocken	1620m	34.54N 32.54S	20	1703-1981	Calbria Pine, Brutia Pine
Cyprus	Trodoos		34.56N 32.52S	32	1628-1981	Austrian Pine, Black Pine
Cyprus	Trodoos Feucht	1900m	34.56N 32.52S	24	1608-1981	Austrian Pine, Black Pine
Cyprus	Trodoos Mittel	1820m	34.56N 32.52S	21	1616-1981	Austrian Pine, Black Pine
Cyprus	Trodoos Mountains	1600m	34.55N 32.53S	13	1594-1981	Austrian Pine
Cyprus	Stavzos Poskas	1050m	35.01N 32.38S	37	1739-2002	Calabrian Pine
Jordan	Dana Resrve and Tor al Iraq	1250m	30.38N 35.30S	17	1469-1995	Phoenician Juniper

Table 1 Tree ring site chronologies information from Cyprus and Jordan (www.ncdc.noaa.gov).

Clim. Past Discuss., doi:10.5194/cp-2016-90, 2016
Manuscript under review for journal Clim. Past
Published: 29 September 2016
© Author(s) 2016. CC-BY 3.0 License.
Climate of the Past Discussions
Open Access

Station	Representative Score for Mean Temperature Records (Mean correlations/Mean Significance)	Mean correlations	Mean Significance
Jerusalem	**381.36**	**0.56**	**0.001**
Nicosia	322.13	0.62	0.002
Amman	102.1	0.69	0.007
Urfa	8.78	0.65	0.074
Adana	7.78	0.56	0.072
Port-Said	6.12	0.51	0.084
Antalya	4.14	0.51	0.122
Abbaisia	4.01	0.66	0.165
Beyrouth	3.09	0.47	0.153

Table 2: Scores of "representativeness" for the nine stations with the longest records of instrumental surface temperature in the Eastern Mediterranean. The score shows how well a station represents all the other stations. Jerusalem received the highest score. The score is calculated as the ratio between the average of the correlations with the other stations and the average of the respective significance scores. The station with the highest score is the best representative of the temperature fluctuations in the region.

Predictors/Correlation	Jerusalem DJF temperature
Gibraltar SLP	0.51
Dana Reserve Tree ring chronology (Jordan)	0.35
Florence DJF precipitation	0.42
Karlsruhe DJF precipitation	0.35
Larochelle DJF precipitation	0.33
Padua DJF precipitation	0.34
Pouilly DJF precipitation	0.34
Frankfurt DJF precipitation	0.3
Paris DJF precipitation	0.37
Strasbourg DJF precipitation	0.33
Lisbon DJF precipitation	0.45
Udine Rivolto DJF precipitation	0.5

Table 3 Predictors found to be significantly (95%) correlated to Jerusalem DJF temperature. The correlations between predictors and Jerusalem mid-winter temperature are indicated in the right column.

Correlation	0.73
Root Mean Squared Error	0.95
Absolute Error	0.76
Relative Error	9%
Prediction Average	8.59

Table 4 Split validation results for the statistical reconstruction model.