ANNEX I
General Response to the Referees Comments and the Revisions

As stated by the Editor, the Referees comments mainly focused on including seasonal trend analysis and as well as detailed comparisons with in-situ data.
Considering that all of the Referees particularly mentioned about the seasonal trend analysis of precipitation (and Referee #2 advising to be selective on variables to include), we added a seasonal trend analysis of precipitation in the revised manuscript as Turkey shows strong seasonality and the precipitation being one of the most critical hydrological variables.

With respect to detailed comparisons with in-situ data, country-wide comparisons of temperature (about 100 stations) and precipitation (about 80 stations) in-situ data were included in the revised manuscript. In addition, comparisons with some ground snow measurements were also added. When in-situ data were non-available (runoff and evapotranspiration), some additional in-direct analysis or explanation was provided in the revised manuscript.

Based on the added seasonal analysis and detailed comparisons with in-situ data, the Results section and the Discussion and Conclusions were also extended and revised.

Below are the point-by-point responses to the reviews presented:

Reflections to the comments of Referee #1
The author would like to thank Referee #1 for his/her valuable and constructive comments. We have considered the comments of Reviewer 1, and hereby try to correspond to them within our knowledge. Based on the comments, we will make the necessary revisions, which will contribute improving the quality of the manuscript. We hope that our replies will satisfy the Referee.

Anonymous Referee #1
Received and published: 22 February 2016

The author analyzed two sets of reanalysis data (ERA-Interim & ERA-Interim/Land), with regards to hydro-climatic variables. The author found that the two reanalysis data have similar patterns over the Turkey, in terms of changes in air temperature. However, for other hydrological variables, the two reanalysis do not have consistent performance. Such kind of assessment of reanalysis products is very much welcomed by the communities. This may help different end-users to understand that the choice of certain reanalysis data is important, as different reanalysis data can lead to different findings and lead to different decision makings. Nevertheless, few concerns arose after reading the manuscript. I suggested a major revision before the further process of this manuscript.

Major concerns:

1. It seems the author used annual value of different hydro-climatic variables to assess the trend and magnitude. On the other hand, certain variable can show strong seasonal behaviors, for example, precipitation. Perhaps, it would be much more useful to investigate precipitation at monthly scale or seasonal scale.

Other than that, at different temporal scales, the hydro-climatic variables may have different errors. How these errors addressed before the analysis over the Turkey is not clear.

Reply of the Author (1):

As suggested by the Rerefee #1, the spatio-temporal trends in precipitation were also analyzed at seasonal scale (for both ERA-Interim and Interim/Land datasets) and the results will be included in the revised manuscript.

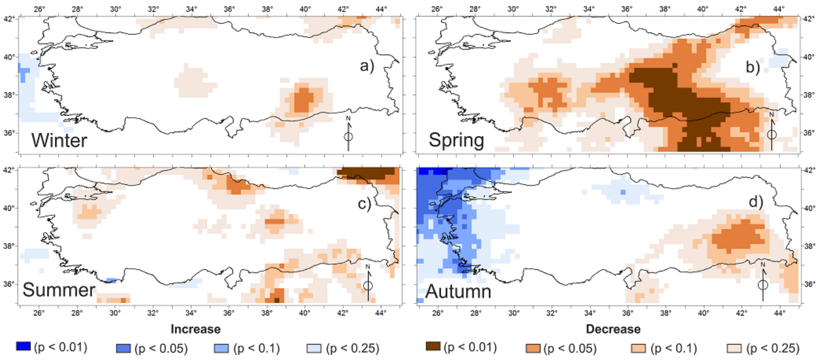

Figure1. The presence and the direction of Total Precipitation trends by ERA-Interim for a) Winter, b) Spring, c) Summer and d) Autumn.

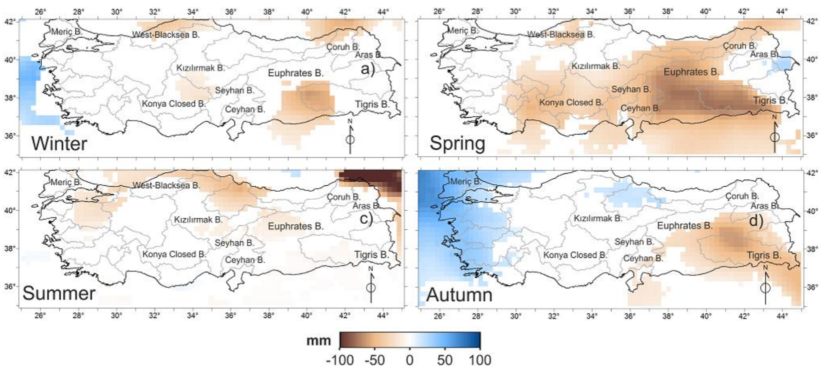

Figure2. The magnitudes of the Total Precipitation trends (32-years total) by ERA-Interim for a) Winter, b) Spring, c) Summer and d) Autumn.

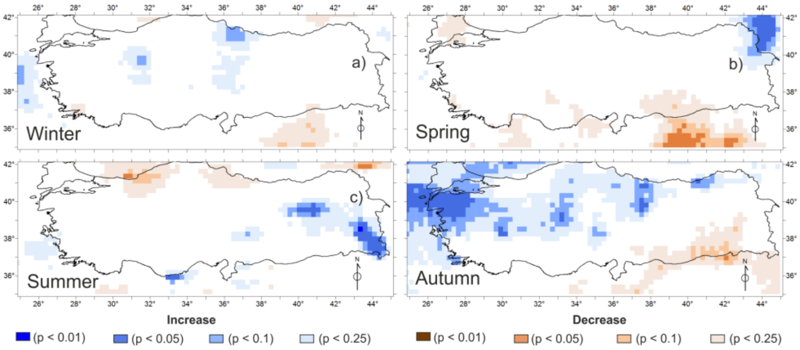

Figure3. The presence and the direction of Total Precipitation trends by Interim/Land for a) Winter, b) Spring, c) Summer and d) Autumn.

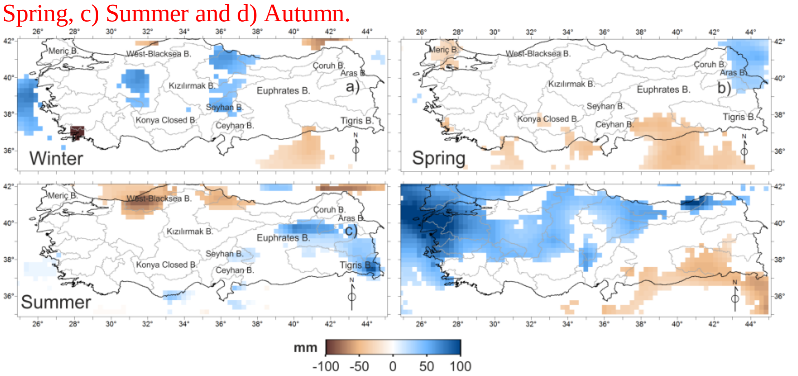

Figure4. The magnitudes of the Total Precipitation trends by Interim/Land for a) Winter, b) Spring, c) Summer and d) Autumn.

With respect to addressing different errors related to the variables, there are dedicated studies which focus on the verification, error analysis o ECMWF Reanalysis datasets (e.g. Szczypta etal2011, Balsamo etal2015) and suitability of them for trend analysis (Dee etal2011).
Here, the main objective of this paper is to investigate and inter-compare the spatiotemporal trends in several hydro-climate variables based on two end-products of ECMWF.
In this regard, rather than characterizing/addressing the possible errors related to ECMWF's reanalysis datasets, here we try to focus to the inter-comparison of the spatio-temporal trends by two products of ECMWF and where possible validate them with ground data.

2. For air temperature, the author used only 11 in-situ stations to compare with reanalysis products, while for precipitation, only 8 in-situ stations used. However, in the text, the author indicated that there are at least 249 stations. I am wondering if it is possible to get those data and interpolate these in-situ observation to get the gridded product of air temperature and precipitation.
Reply of the Author (2):
Previously, the stations temperature data was only available for an in-land basin because that basin was the study area for my (completed) PhD research and the data was available from that. Thanks to the temperature data provided by Dr. Faize Saris from Canakkale 18 Mart University, the comparison now extended to around 100 stations distributed over the country.

The revised Figure 2 (shown below) presents an overlaid comparison of the significance (Fig. 2a) and magnitude (Fig. 2b) of the temperature trends by the ERA-Interim and meteo-stations.

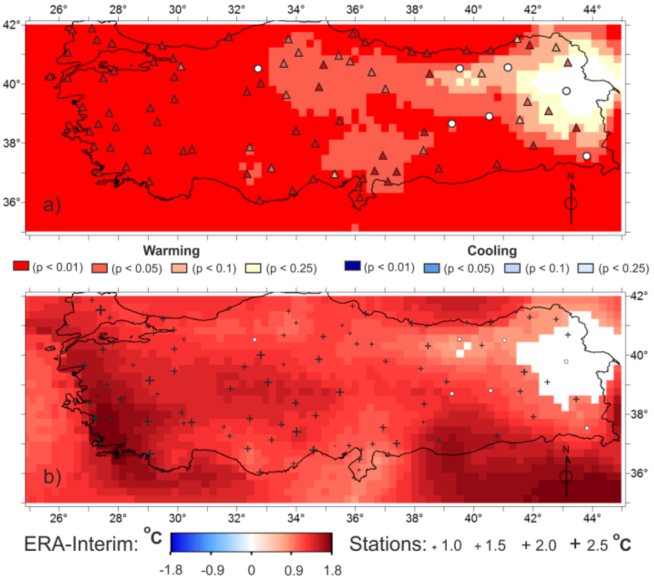

Figure5. The comparison of the (a) presence of the significant Air Temperature trends and (b) the magnitudes of 32-years total Air Temperature trends between the ERA-Interim dataset and the meteo-stations. In Figure (a) upward triangles/circles indicate the presence/absence of increasing trends, while the colors indicate the degree of the significance.

With respect to precipitation in-situ data, Figure 5 was limited with 8 stations due to the readability. Thanks to the availability of yearly precipitation data for 81 provinces freely (source: http://dmi.gov.tr/veridegerlendirme/yillik-toplam-yagis-verileri.aspx#sfU), I applied the trend analysis for the point precipitation data from the 81 meteo-stations and revised Figure 4 accordingly.

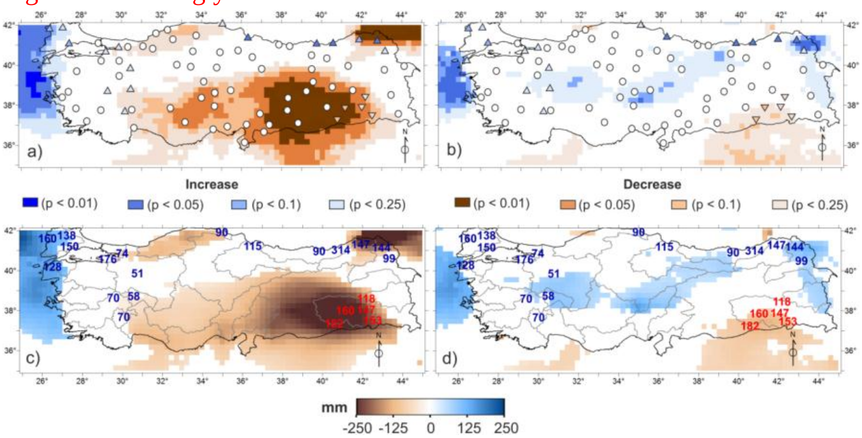

Figure6. The presence of the significant total Precipitation trends by (a) ERA-Interim vs. rain gauges, (b) Interim/Land vs. rain gauges. The magnitudes of 32-years total Precipitation trends by (c) ERA-Interim vs. rain gauges, (d) Interim/Land vs. rain gauges. In figures a-b, the upward/downward triangles indicate the significant increasing/decreasing trends, circles indicate no trend and the colors

indicate the degree of the significance. In figures c-d, the numbers indicate the total increasing/decreasing trends at the stations with significant trends.

The revised figures and the related explanation/discussion will be added in the revised manuscript.

3. For some other variables, you may not have in-situ observation. However, you do can find satellite observation products, for example, for SWE and ET. For runoff, you may find data from GRDC. Without the third independent dataset, it is hard to get the real value of either set of reanalysis data in terms of representing the long-term changes.
Reply of the Author (3):
Thanks to the availability of several snow-gauge data that has been used in Gokmen et al. (2013), Fig 6 was revised as shown below.
The comparison with the SWE stations data reveal that, despite the differences in terms of SWE magnitudes, SWE trends from Interim/Land dataset is quite similar to the in-situ data: both indicate no significant trends during the study period. Although station#6 (and Interim/Land) shows some increasing trend, the time-series is too short for trend detection. For the same locations, ERA-Interim dataset shows significant decreasing trends of SWE.

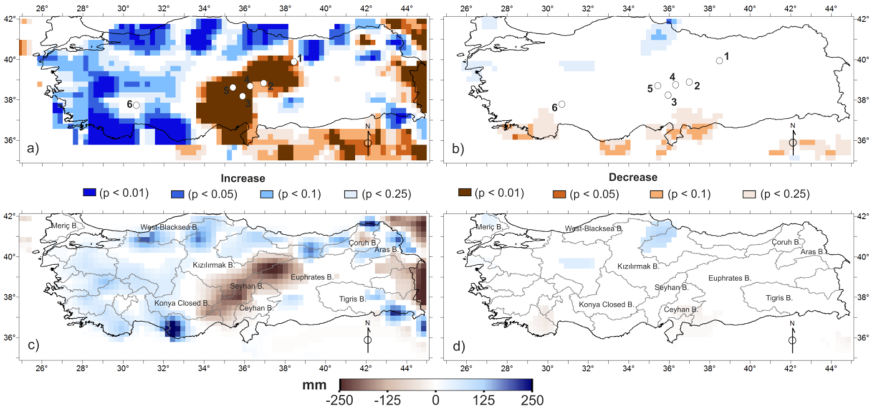

Figure7 The presence of the significant SWE trends by (a) ERA-Interim, (b) Interim/Land. The magnitudes of 32-years total SWE trends by (c) ERA-Interim, (d) Interim/Land.

With respect to ET, a comparison with other independent satellite-based ET datasets could not be carried out because the temporal coverage of freely available datasets do not match with the study period of this study (e.g. MOD16 from MODIS is available year 2000 onwards, LSA-SAF ET from MSG-SEVIRI is available starting 2007). On the other hand, a detailed evaluation of the global terrestrial ET datasets (including ERA-Interim) can be found in Miralles et al., 2016.

With respect to Runoff, I carried out a correlation analysis between Runoff and total Precipitation for both ERA-Interim and Interim/Land datasets. As shown in the below Figure, for both datasets, there is highly significant positive correlation between Runoff and Precipitation. From such high correlations we can deduce that the validations of total P with in-situ data can be assumed valid for Runoff data as well.

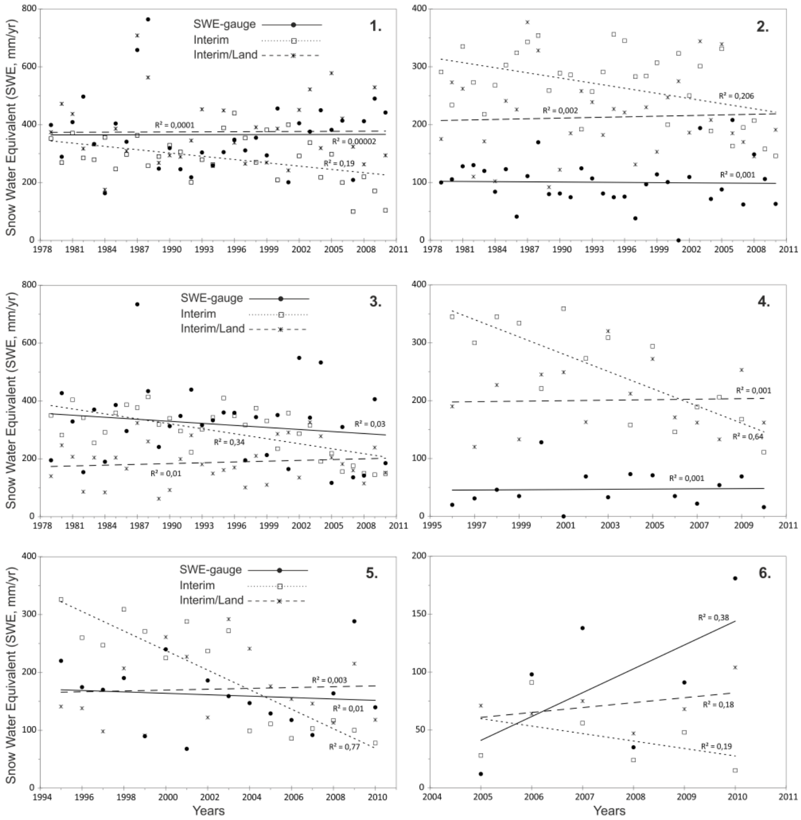

Figure8 The plots 1-6 indicate the comparison of the yearly SWE from the snow-gauges with the corresponding grids from ERA-Interim and Interim/Land. The locations of the stations are shown in figures a-b.

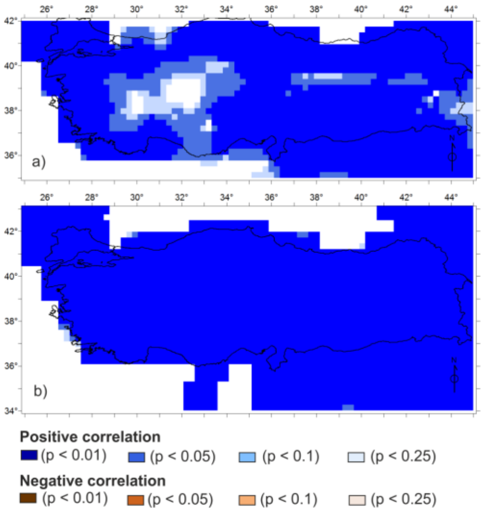

Figure9. The correlation between total Precipitation and Runoff for (a) ERA-Interim, (b) Interim/Land.

Reflections to the comments of Referee #2

The author would like to thank Referee #2 for his/her valuable and constructive comments. We have considered the comments of Reviewer 2, and hereby try to correspond to them within our knowledge. Based on the comments, we will make the necessary revisions, which will contribute improving the quality of the manuscript. We hope that our replies will satisfy the Referee.

Anonymous Referee #2
Received and published: 18 March 2016

This is a well structured and generally well written paper looking into the trends in temperature and several other hydroclimatological variables over Turkey, using two variants of ERA reanalysis data sets. It is useful for assessing both the long term climate change for the country and how this change manifests itself in large scale gridded data sets.
However, the manuscript misses some major points which, in my opinion, should have been included in the analysis and the discussion.

1) As the Anonymous Referee #1 also pointed out, the data should have definitely been analyzed for seasonal trends as well. Turkey is a Mediterranean country that exhibits a distinct seasonality in most of its climatic variables. Therefore, an annual-only trend analysis will obscure possibly stronger seasonal trends, which could have significant implications for climate and hydrology of the country. I advise the author to analyze the data sets for seasonal trends as well (for all variables originally chosen).
This may lengthen the paper quite a bit, so the author should be selective in what he discusses and may feel free not to include every figure produced from the new analyses.

Reply of the Author (1):
i. As suggested by the Referee #2 (and Referee #1), the spatio-temporal trends in precipitation were analyzed at seasonal scale and the results will included in the revised manuscript.

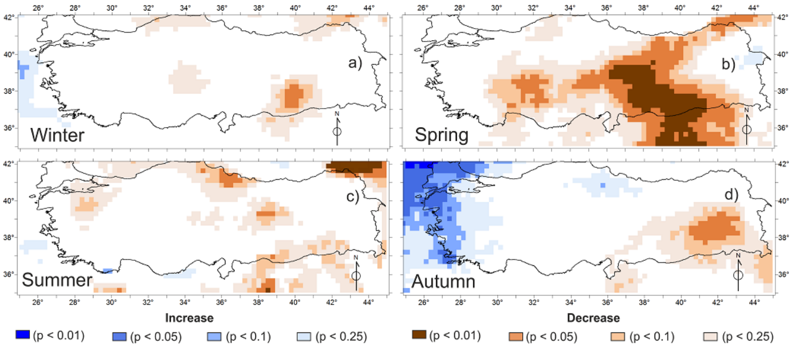

Figure1. The presence and the direction of Total Precipitation trends by ERA-Interim for a) Winter, b) Spring, c) Summer and d) Autumn.

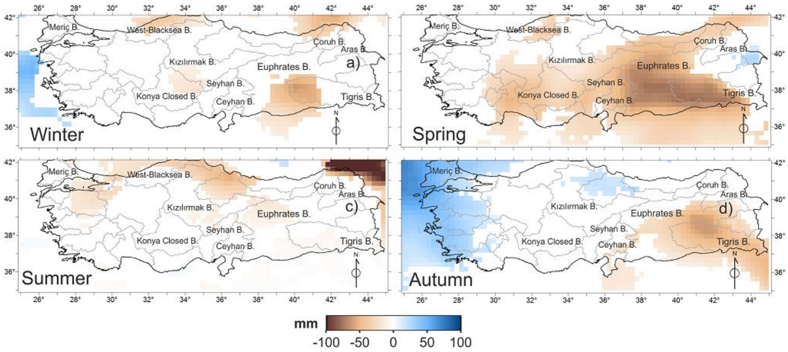

Figure2. The magnitudes of the Total Precipitation trends (32-years total) by ERA-Interim for a) Winter, b) Spring, c) Summer and d) Autumn.

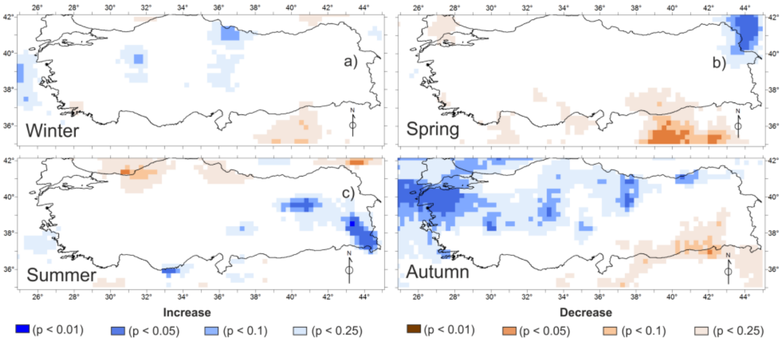

Figure3. The presence and the direction of Total Precipitation trends by Interim/Land for a) Winter, b) Spring, c) Summer and d) Autumn.

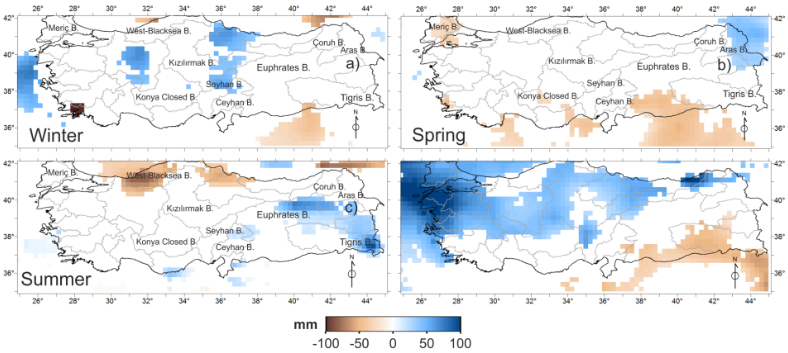

Figure4. The magnitudes of the Total Precipitation trends (32-years total) by Interim/Land for a) Winter, b) Spring, c) Summer and d) Autumn.

As the Reviewer #2 pointed out, to prevent a lengthy paper is an important concern for me. To be selective on including the seasonal analyses of the variables, I assessed the correlations between the variables for both datasets. As the below results reveal, all the hydrological variables (Runoff, SWE and ET over land) are positively correlated with Precipitation for the majority of the study area. Such high correlations also confirm the fact that, land surface models included in Reanalysis datasets (in this case ECMWF) are mainly driven by the atmospheric variables (i.e. Precipitation) rather than land use dynamics (e.g. irrigation).

Therefore, I would rather limit the seasonal trend analysis to the Precipitation, as its seasonal trends would also be expressed especially in seasonal trends of Runoff and ET. With respect to Snow Water Equivalent, as the snow accumulation and melting is mostly taking place in Winter and Spring, a separate seasonal analysis of SWE was considered unnecessary.

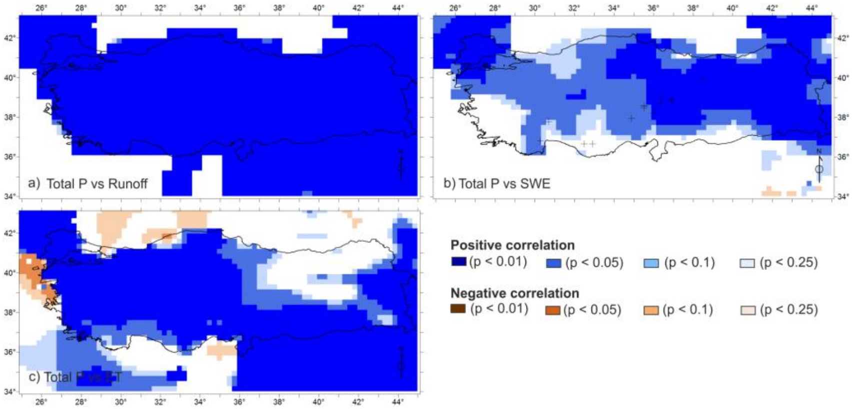

Figure5. The correlation between (a) total Precipitation and Runoff, (b) total Precipitation and SWE, (c) total Precipitation and ET for Interim/Land dataset.

2) Again, as the Anonymous Referee #1 wrote, the comparison with the raw meteorological observations could have been done in a more systematic manner, using as many stations as possible. For instance, I would like to see a map of inconsistencies between station data and renanalysis data sets in terms of their long term trends. Which stations (or, parts of the country) differ from the reanalysis in terms of trends? Should there be regionally coherent inconsistencies, conclusions about long term climate change would perhaps be problematic. Again, the author should focus on significant results only.

Reply of the Author (2):

Thanks to the freely available yearly precipitation data for 81 provinces (source: http://dmi.gov.tr/veridegerlendirme/yillik-toplam-yagis-verileri.aspx#sfU), I applied the trend analysis for the point precipitation data from the 81 meteo-stations and revised Figure 4 accordingly. The overlay of the trends for the in-situ data allowed a better comparison of reanalysis dataset performances geographically, as suggested by the Reviewer #2.

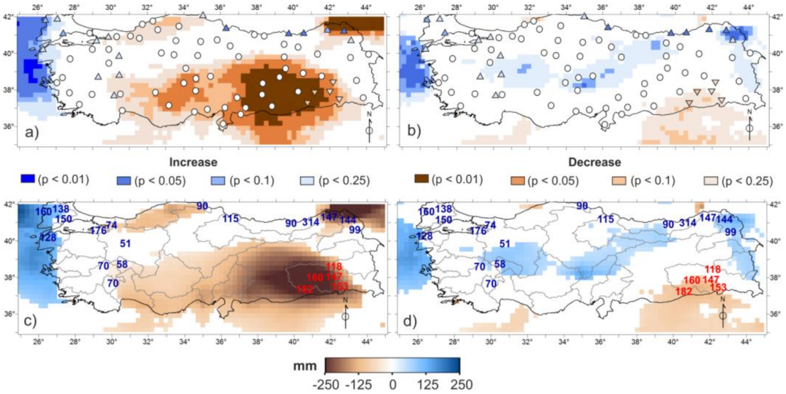

Figure6. The presence of the significant total Precipitation trends by (a) ERA-Interim vs. rain gauges, (b) Interim/Land vs. rain gauges. The magnitudes of 32-years total Precipitation trends by (c) ERA-Interim vs. rain gauges, (d) Interim/Land vs. rain gauges. In figures a-b, the upward/downward triangles indicate the significant increasing/decreasing trends, circles indicate no trend and the colors indicate the degree of the significance. In figures c-d, the numbers indicate the total increasing/decreasing trends at the stations with significant trends.

With respect to temperature, previously the stations data was only available for an in-land basin because that basin was the study area for my (completed) PhD research and the data was available from that. Thanks to the temperature data provided by Dr. Faize Saris from Canakkale 18 Mart University, the comparison now extended to around 100 stations distributed over the country. The revised Figure 2 (shown below) presents an overlaid comparison of the significance (Fig. 2a) and magnitude (Fig. 2b) of the temperature trends by the ERA-Interim and meteo-stations.

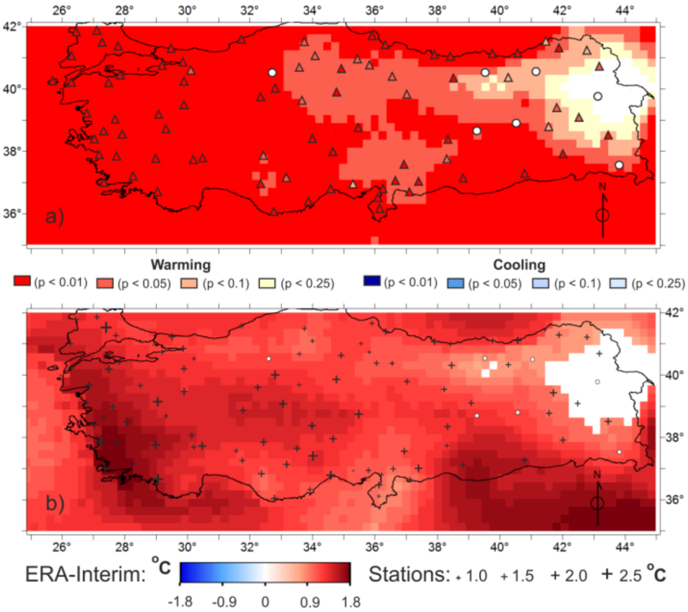

Figure7. The comparison of the (a) presence of the significant Air Temperature trends and (b) the magnitudes of 32-years total Air Temperature trends between the ERA-I dataset and the meteo-stations. In Figure (a) upward triangles/circles indicate the presence/absence of increasing trends, while the colors indicate the degree of the significance.

3) The length of the analysis period can have an effect on the significance of trends. Therefore, I advise to extend the analysis to include recent years as well, if this is possible. Since these are major points and could change the manuscript remarkably, I am not going to comment on the technical issues at this time.

Reply of the Author (3):

Initially I had started the analysis to cover up-to-date data. However, although ERA-Interim dataset is available up-to-date, the recently introduced Interim/Land dataset is available only for 1979-2010 period. Therefore, the study period had to be limited for the 1979-2010 period to allow a consistent comparison of the trends between the two datasets.

Reflections to the comments of Referee #3

The author would like to thank Referee #3 for his/her valuable and constructive comments. We have considered the comments of Reviewer 3, and hereby try to correspond to them within our knowledge. Based on the comments, we will make the necessary revisions, which will contribute improving the quality of the manuscript. We hope that our replies will satisfy the Referee.

Anonymous Referee #3
Received and published: 19 March 2016

The author explored the long-term trends in several hydro-climate variables, in a spatially distributed manner, based on two reanalysis datasets (ERA-Interim and ERAInterim/Land) in Turkey. This kind of research can provide information particularly for the researchers who are interested in the study area, and is therefore welcomed by the community. However, I have to point out this manuscript does not show very much a perspective that would attract the attention of the readers/researchers who are interested in other regions. Therefore, I would suggest that a major revision is required before it can be considered publication in HESS. My major concerns are listed as follows:

1. The author focused on the hydro-climate variables (i.e. air temperature, total precipitation, snowmelt, ET, surface runoff). I wonder why the author selected those variables and ignored others? Whether analyzing those variables is enough to help the author show his/her perspective? I am not very clear. For example, soil moisture is also an important variable, and why the author is not interested in it? Moreover, why the author ignores base flow, which is an important component of runoff?

Reply of the Author (1):
There were mainly two consideration for selecting the hydro-climate variables for the trend analysis: Firstly, to keep the paper as short and simple as possible by considering only the major variables to represent the hydroclimate dynamics. Second, the variables should be present in both ERA-Interim and Interim/Land datasets so that a comparison can be made between the trends revealed by the two datasets.
In this regards, although soil moisture is an important component of the water cycle, it could not be included in the analysis because Interim/Land dataset does not include the soil moisture variable. With respect to the base flow, it was not considered in the analysis due to limiting the analysis to the main components of a surface water balance.

2. The discussion is not deep enough. The author may explain the trends of the variables based on physics for instance. Are those trends of the variables reasonable? Is the phenomenon in Turkey unique? Is there any suggestion? For example, Figure 3b shows the distribution and the histogram of the average temperature increases (over study period) with respect to elevation. Why? Please discuss. I would suggest the author to have a more comprehensive discussion.

Reply of the Author (2):
First of all, thanks to the additional temperature data provided by Dr. Faize Saris from Canakkale 18 Mart University, the comparison could be extended to around 100 stations distributed over the country. The revised Figure (attached Fig1) presents an overlaid comparison of the significance and magnitude of the temperature trends by the ERA-Interim and meteo-stations.

With the availability of more stations data, Figure 3 (in the manuscript) was also revised to compare the observational and reanalysis data in a more systematic manner. In the revised Figure (attached Fig.2), the average yearly temperature of all stations was compared to the yearly average reanalysis data at the same station locations for the study period.

Similar to the previous Figure 3b, the revised Figure also indicate that the total temperature increase during the study period is higher in the lowlands and lower in the higher altitudes by both ERA-Interim and meteo-stations. As it can be seen in the topography map in Figure 1 (in the manuscript), East/North East part of Turkey constitute the mountainous and higher elevation region, where the increasing trend of temperature was less or non-significant. The average height corresponding to this area is about 1850 m.a.s.l. (the average of whole country is 1140 m). Therefore, the region has relatively intense terrestrial climate with shorter summers and longer & harsher winters. As shown in the satellite image (attached Fig.3), the snow also stays longer on the land. Considering that there has not been considerable change in the snow dynamics for the very Eastern region during the study period (Figures 6a and 6b in the manuscript), albedo effect could play a role for relatively less amount of increase in the temperature. Besides, the Eastern region has also significantly less population density in the country, with even considerable population migration to the other regions. So direct urban/land use change contribution to the temperature increase can be less effective. Lastly, the differences in the regional climate system due to the different controlling factors (e.g. the differences in the effective pressure systems, topography, etc) can play a role.

With respect to the observing the largest temperature in the Western coastal areas (which are also lowlands), as referred in lines 21-24 of page 5 (under section 3.1) of the manuscript, Sen et al. (2011) indicated that the largest warming (over 2 oC) occurred over the Aegean Sea and Western Turkey, due to the propagation of warmer air from the Balkans and Aegean Sea toward eastern Anatolia after about 25 February. Further details can be found in Sen et al. (2011).

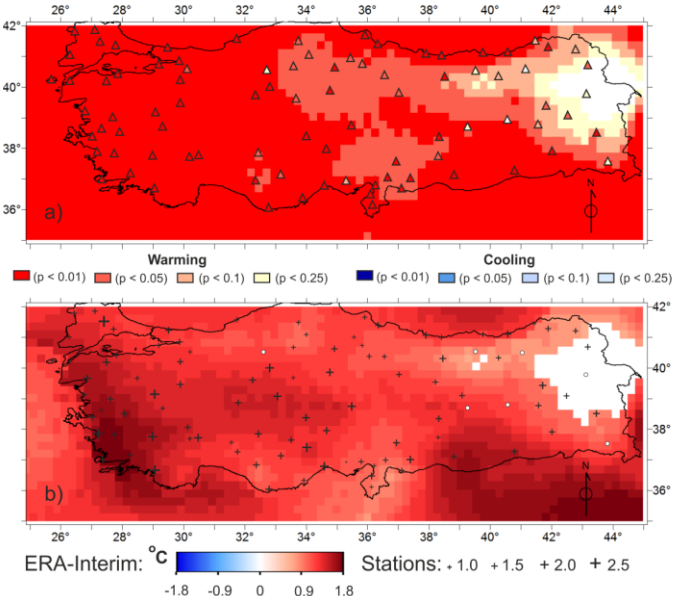

Figure1. The comparison of the (a) presence of the significant Air Temperature trends and (b) the magnitudes of 32-years total Air Temperature trends between the ERA-Interim dataset and the meteo-

stations. In Figure (a) upward triangles/circles indicate the presence/absence of increasing trends, while the colors indicate the degree of the significance.

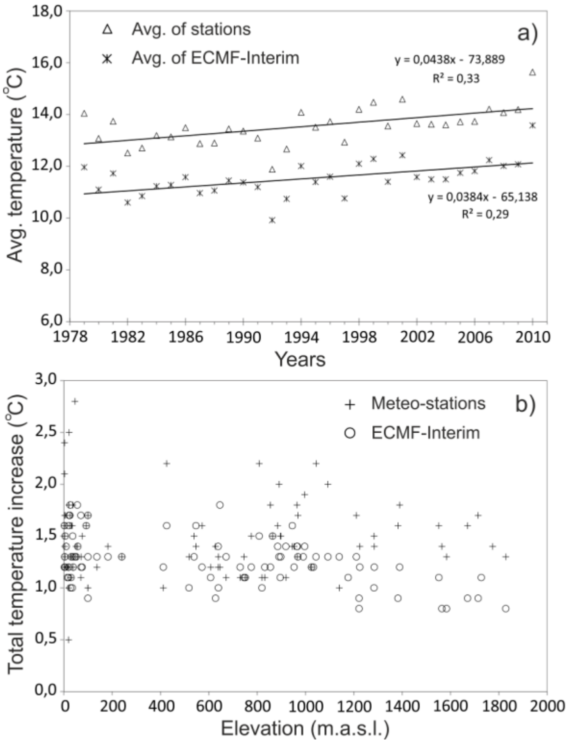

Figure2 a) The comparison of the average yearly T between the (all) stations and the corresponding grids from the ERA-I dataset for the study period b) The comparison of the total 32-years increase of T by meteo-stations and ERA-I with respect to elevation.


Figure3. True color Terra-Modis satellite image on a clear-sky day (April 1, 2016; source: worldview.earthdata.nasa.gov)

3. As pointed out by the Anonymous Referee #1 and # 2, the seasonal variations should be considered since it may strongly affects the intra-annual trends.

Reply of the Author (3):
As suggested by the Reviewer #3 (and Reviewers #1, #2), the spatio-temporal trends in precipitation were analyzed at seasonal scale and the results will be included in the revised manuscript.

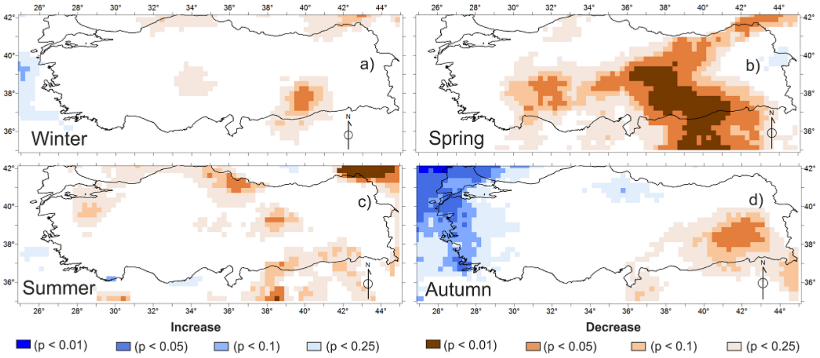

Figure4. The presence and the direction of Total Precipitation trends by ERA-Interim for a) Winter, b) Spring, c) Summer and d) Autumn.

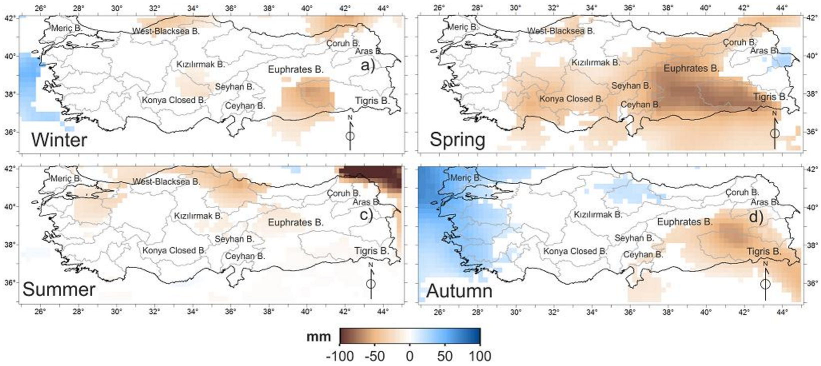

Figure5. The magnitudes of the Total Precipitation trends (32-years total) by ERA-Interim for a) Winter, b) Spring, c) Summer and d) Autumn.

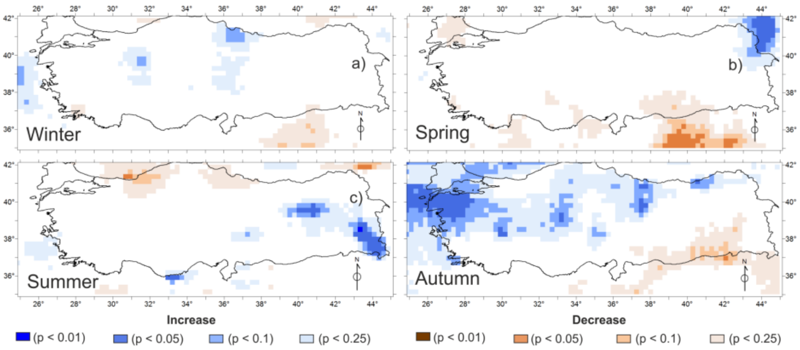

Figure6. The presence and the direction of Total Precipitation trends by Interim/Land for a) Winter, b) Spring, c) Summer and d) Autumn.

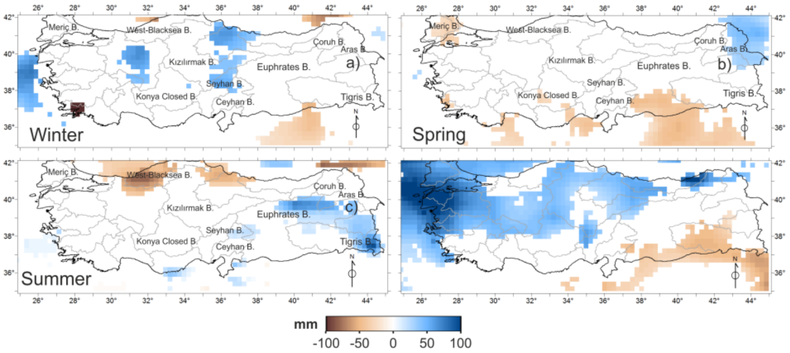

Figure7. The magnitudes of the Total Precipitation trends by Interim/Land for a) Winter, b) Spring, c) Summer and d) Autumn.

On the other hand, to be selective on including the seasonal analyses of the variables, I assessed the correlations between the variables for both datasets. As the correlation maps reveal (attached Fig.8), all the hydrological variables (Runoff, SWE and ET over land) are positively correlated with Precipitation for the majority of the study area. Such high correlations also confirm the fact that, land surface models included in Reanalysis datasets (in this case ECMWF) are mainly driven by the atmospheric variables (i.e. Precipitation) rather than land use dynamics (e.g. irrigation). Therefore, I would rather limit the seasonal trend analysis to the Precipitation, as its seasonal trends would also be expressed especially in seasonal trends of Runoff and ET. With respect to Snow Water Equivalent, as the snow accumulation and melting is mostly taking place in Winter and Spring, a separate seasonal analysis of SWE was considered unnecessary.

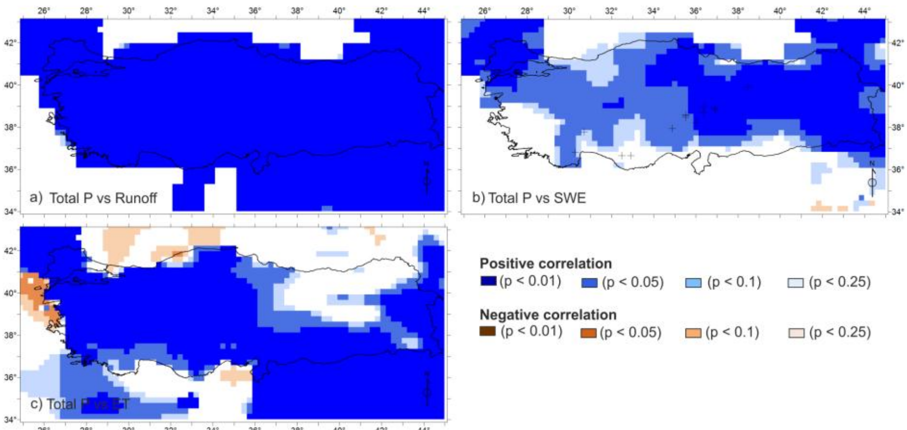

Figure8. The correlation between (a) total Precipitation and Runoff, (b) total Precipitation and SWE, (c) total Precipitation and ET for Interim/Land dataset.

4. The author stated “while over land, ET is mainly water-limited (i.e. precipitation and soil moisture) especially for semiarid regions. ” This statement is not right since, in some humid regions, ET is energy-limited and there are many humid regions over land.
For more information, please see the article “Seneviratne, S. I., T. Corti, E. L. Davin, M. Hirschi, E. B. Jaeger, I. Lehner, B. Orlowsky, and A. J. Teuling (2010), Investigating soil moisture–climate interactions in a changing climate: A review, Earth-Science Reviews,

99(3–4), 125-161.”

Reply of the Author (4):

I think there is misunderstanding possibly caused by the formulation of the sentence, which was meant to refer to not all land areas but only semi-arid regions. Otherwise, I totally agree with Referee #3 that for humid regions over land, ET is mainly energy-limited.

To make it clearer, the related sentence will be revised as follows:

: over sea, ET is generally energy-limited (i.e. temperature and incoming radiation), while over land, ET is mainly water-limited (i.e. precipitation and soil moisture) in semi-arid regions and energy-limited in humid regions.

To support the stament, (attached) Figure9 shows the long term average of the P/ET ratio and the correlation between P and ET for the region. As clearly shown in P/ET ratio map, except for the humid North-East region by the Black Sea, most of the study area has relatively semi-arid conditions with P/ET ratio less than 1. As a result, the correlation map reveals that, for non-humid parts of the country, there is a strong positive correlation between the Precipitation and ET, implying ET is mainly precipitation-controlled in these areas.

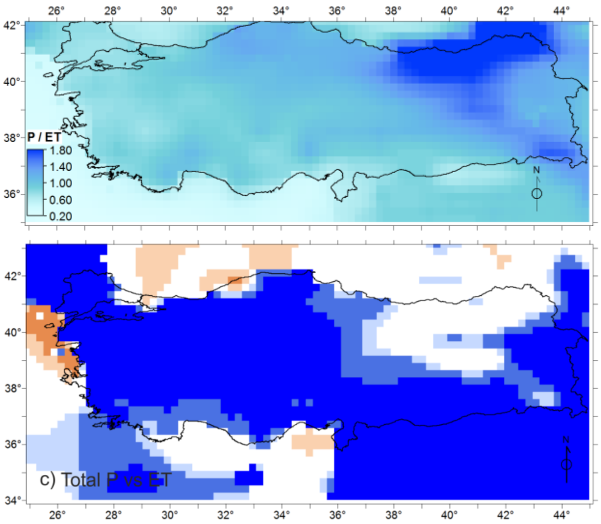

Figure9 a) The distribution of the average P/ET ratio during the study period (1979-2010), b) The correlation between the total Precipitation and ET for Interim/Land dataset.

Reflections to the comments of Referee #4

The author would like to thank Referee #4 for his/her valuable and constructive comments. We have considered the comments of Referee #4, and hereby try to correspond to them within our knowledge. Based on the comments, we will make the necessary revisions, which will contribute improving the quality of the manuscript. We hope that our replies will satisfy the Referee.

Anonymous Referee #4

Received and published: 23 March 2016

In this manuscript the author studied a regional assessment of the spatiotemporal trends in hydro-climate variables in Turkey by using two sets of reanalysis data. This study is important since it could be useful for impact studies. However, I think the paper requires major revision. There are several points that need to be further addressed.

My comments are the following:

1. As the other 3 referees mentioned that, the seasonal and even monthly averages should be investigated by the author to treat also seasonal shift that was indicated by Yucel et al. 2014 (page 12, line 4).

Reply of the Author (1):

As suggested by the Referee #4 (and the other Reviewers), the spatio-temporal trends in precipitation were analyzed at seasonal scale and the results will be included in the revised manuscript.

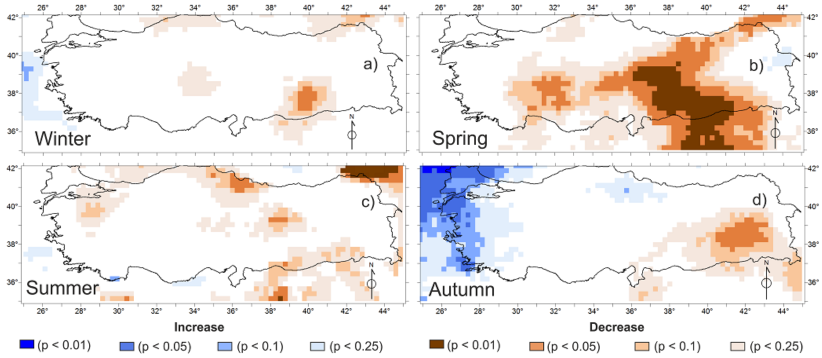

Figure1. The presence and the direction of Total Precipitation trends by ERA-Interim for a) Winter, b) Spring, c) Summer and d) Autumn.

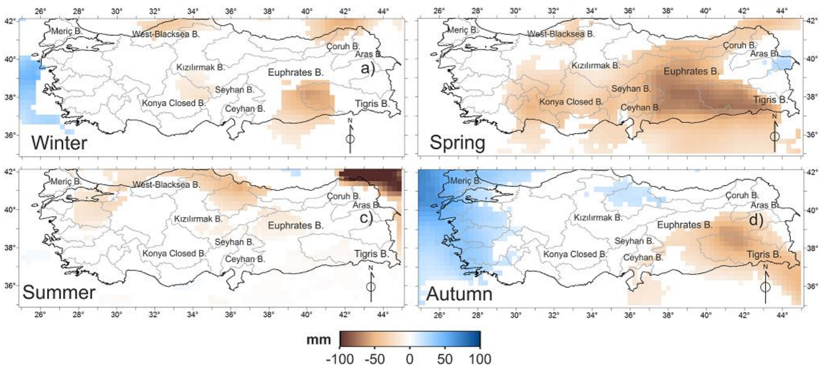

Figure2. The magnitudes of the Total Precipitation trends (32-years total) by ERA-Interim for a) Winter, b) Spring, c) Summer and d) Autumn.

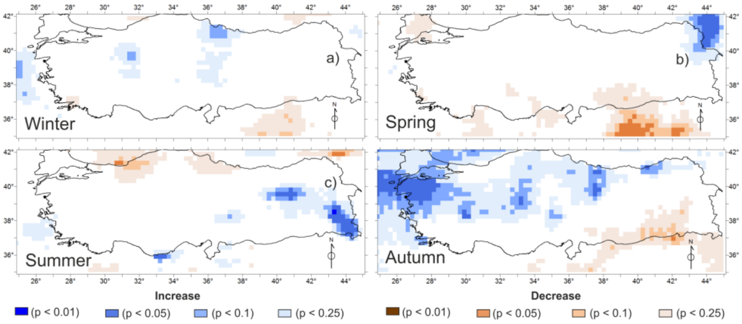

Figure3. The presence and the direction of Total Precipitation trends by Interim/Land for a) Winter, b) Spring, c) Summer and d) Autumn.

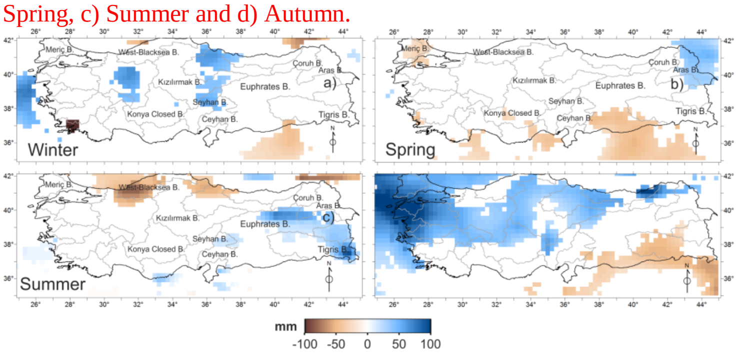

Figure4. The magnitudes of the Total Precipitation trends by Interim/Land for a) Winter, b) Spring, c) Summer and d) Autumn.

On the other hand, to be selective on including the seasonal analyses of the variables, I assessed the correlations between the variables for both datasets. As the below results reveal, all the hydrological variables (Runoff, SWE and ET over land) are positively correlated with Precipitation for the majority of the study area. Such high correlations also confirm the fact that, land surface models included in Reanalysis datasets (in this case ECMWF) are mainly driven by the atmospheric variables (i.e. Precipitation) rather than land use dynamics (e.g. irrigation). Therefore, I would rather limit the seasonal trend analysis to the Precipitation, as its seasonal trends would also be expressed especially in seasonal trends of Runoff and ET. With respect to Snow Water Equivalent, as the snow accumulation and melting is mostly taking place in Winter and Spring, a separate seasonal analysis of SWE was considered unnecessary.

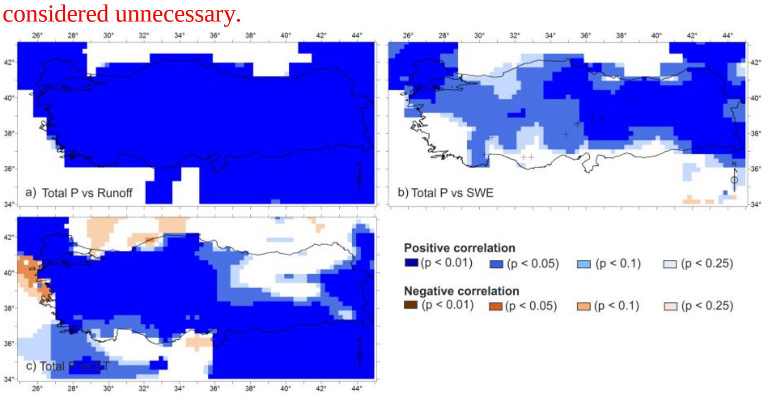

Figure5. The correlation between (a) total Precipitation and Runoff, (b) total Precipitation and SWE, (c) total Precipitation and ET for Interim/Land dataset.

2. Author should provide the map of 249 meteorological stations distributed over the country. The difference between observational and reanalysis data should be investigated in a more systematic manner. For example, author could have explained the main reason behind the statement that the overall increase of air temperature was relatively higher in the lowlands compared to the high mountainous regions.

Reply of the Author (2):

Thanks to the temperature data provided by Dr. Faize Saris from Canakkale 18 Mart University, the comparison could be extended to around 100 stations distributed over the country. The revised Figure (attached Fig.6) presents an overlaid comparison of the significance and magnitude of the temperature trends by the ERA-Interim and meteo-stations.

With the availability of more stations data, Figure 3 (in the manuscript) was also revised to compare the observational and reanalysis data in a more systematic manner. In the revised Fig. 3a (attached Fig.7a), the average yearly temperature of all stations was compared to the yearly average reanalysis data at the same station locations for the study period. While in the revised Figure 3b (attached Fig.7b), the total 32-years increase of temperatures indicated by meteo-stations and Reanalysis were compared for different elevations.

While the attached Fig.6 reveals a general confirmation of the increasing temperature trends in terms of significance and magnitude in the overall country (except the very eastern part), the revised Figure 3 (attached Fig.7a) generally reveals a systematically higher average temperatures and total increasing trends by the meteo-stations compared to Reanalysis data. The systematically higher yearly average temperature by the stations can generally be attributed to the intrinsic problems of point-based vs. grid comparisons: the meteo-station measurements not only represent the local environment (compared to the 80 km resolution original Reanalysis data), they are also usually located in the lower altitudes around the cities due to ease of maintenance. Therefore, for a particular grid, it can be expected that the point measurement of temperature by the station is systematically higher than the overall average of the grid represented by the Reanalysis data. In addition, the growth of urban areas and the related urban heating effect possibly explains the higher increasing trend of temperature indicated by the meteo-stations compared to the Reanalysis data.

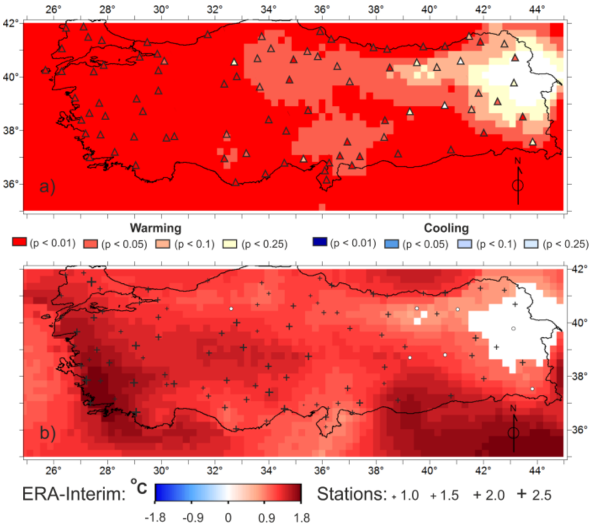

Figure6. The comparison of the (a) presence of the significant Air Temperature trends and (b) the magnitudes of 32-years total Air Temperature trends between the ERA-Interim dataset and the meteo-stations. In Figure (a) upward triangles/circles indicate the presence/absence of increasing trends, while the colors indicate the degree of the significance.

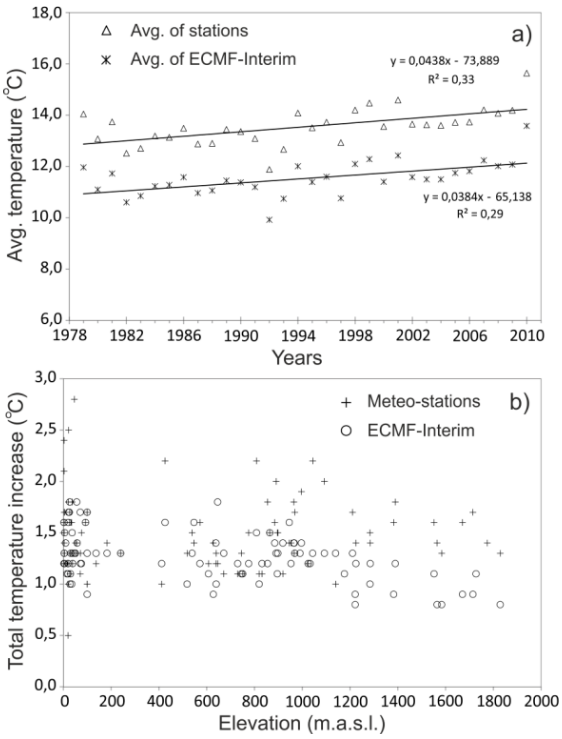

Figure7 a) The comparison of the average yearly temperature between the (all) stations and the corresponding grids from the ERA-Interim dataset for the study period, b) The comparison of the total 32-years increase of temperatures by meteo-stations and ERA-Interim with respect to elevation.

3. I suggest that author discuss the result presented in Figure 2a properly, especially for minor region at the very Eastern border of the country. What could be the reason of this result?

Reply of the Author (3):
That is the non-significant increase of temperature area in the very Eastern border of the country. Several reasons could be contributing for such a result:
The average height corresponding to this area is about 1850 m.a.s.l. (the average of whole country is 1140 m), which is relatively high altitude region of the country with complex topography. Therefore, the region has relatively intense terrestrial climate with shorter summers and longer & harsher winters. As shown in the satellite image (attached Fig.8), the snow also stays longer on the land. Considering that there has not been considerable change in the snow dynamics for the region during the study period (Figures 6a and 6b in the manuscript), albedo effect could play a role for relatively less amount of increase in the temperature.

Figure8. True color Terra-Modis satellite image on a clear-sky day (April 1, 2016; source: worldview.earthdata.nasa.gov)

Besides, the region has also significantly less population density in the country, with even considerable population migration to the other regions. So direct urban/land use change contribution to the temperature increase can be less effective.

Lastly, the differences in the regional climate system due to the different controlling factors (e.g. the differences in the effective pressure systems, topography, etc) can play a role.

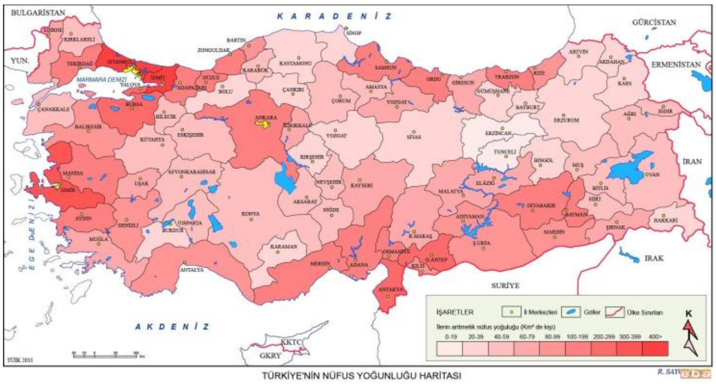

Figure9. Population density map of Turkey based on 2011 data (source. www.eba.gov.tr)

4. I think there are problems in figure captions. b) and c) should be interchanged in Figure 4, Figure 6, Figure 7 and Figure 8.

Reply of the Author (4):
The Figure captions will be checked and corrected in the revised manuscript.

5. Unit of variable (mm) should be indicated in Figure 5.

Reply of the Author (5):
The unit of variables will be indicated in the revised manuscript.

Reflections to the comments of Referee #5

The author would like to thank Referee #5 for his/her valuable and constructive comments. We have considered the comments of Referee #5, and hereby try to correspond to them within our knowledge. Based on the comments, we will make the necessary revisions, which will contribute improving the quality of the manuscript. We hope that our replies will satisfy the Referee.

Anonymous Referee #5

Received and published: 24 March 2016

General Comments:

This manuscript analyzes the trends of hydro-climatic variables (annual precipitation, air temperature, snow water equivalent, runoff and ET) from two reanalyses data (ERA Interim and ERA Interim/land) over Turkey from 1979 to 2010. The magnitude of the variables between these years, direction and different significance levels of the changes are evaluated spatially over the map of Turkey with a particular focus on several important watersheds. Seeing the contradiction and agreement of two reanalyses data for different variables are important as the study potentially provides a good reference for future applications in this semi-arid country where the climate change impacts become vulnerable. The following issues should be considered to make the manuscript in better quality before its publication:

Some Issues:

1. As I agree with other referrers, Turkey shows strong seasonality and therefore it is better to include seasonal changes particularly for precipitation. Other studies show that some important trends are available seasonally but such trend is lost when it is evaluated annually (offsetting).

Reply of the Author (1):

As suggested by the Referee #5 (and the other Reviewers), the spatio-temporal trends in precipitation were analyzed at seasonal scale and the results will be included in the revised manuscript.

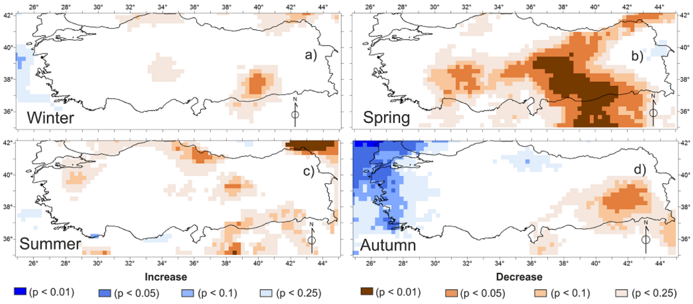

Figure1. The presence and the direction of Total Precipitation trends by ERA-Interim for a) Winter, b) Spring, c) Summer and d) Autumn.

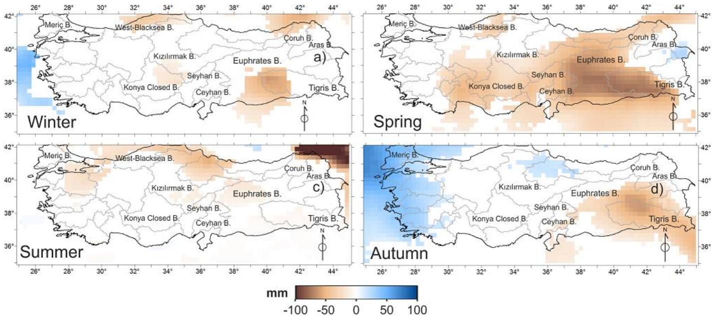

Figure2. The magnitudes of the Total Precipitation trends (32-years total) by ERA-Interim for a) Winter, b) Spring, c) Summer and d) Autumn.

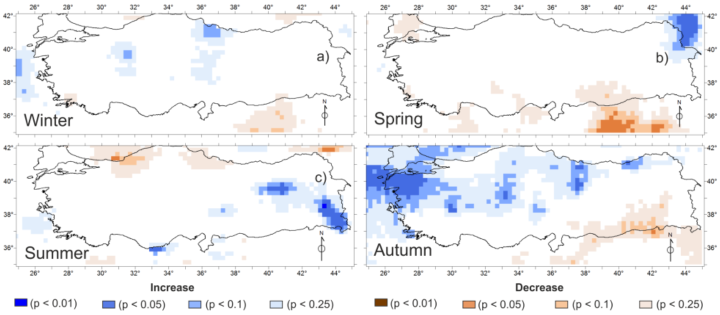

Figure3. The presence and the direction of Total Precipitation trends by Interim/Land for a) Winter, b) Spring, c) Summer and d) Autumn.

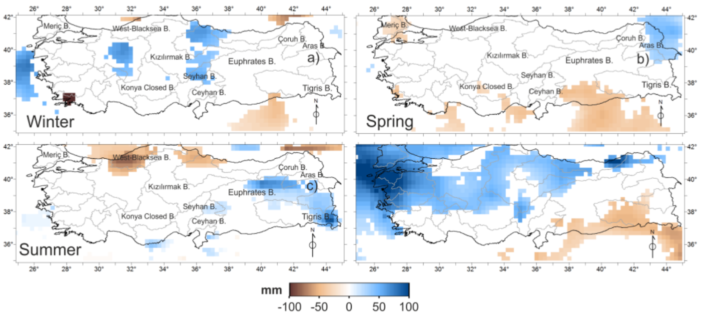

Figure4. The magnitudes of the Total Precipitation trends (32-years total) by Interim/Land for a) Winter, b) Spring, c) Summer and d) Autumn.

2. A more in depth explanations with other findings available in the literature should be given. For example, it is very obvious that there is strong warming and it is very significant on some regions (west, south west), so it should have some impacts on the type and intensity of precipitation. Snow becomes rain and their frequency and intensity are changing. Seasonality analyses can help identfy these results but at least some literature supports can be incorporated to your results.

Reply of the Author (2):

In lines 21-24 of page 5 (under section 3.1) of the manuscript, Sen et al. (2011) is referred from the literature, who indicated that the largest warming (over 2 oC) occurred over the Aegean Sea and Western Turkey, due to the propagation of warmer air from the Balkans and Aegean Sea toward eastern Anatolia after about 25 February.

In addition, the following studies will be mentioned to explain the spatial distribution of the warming in the revised manuscript:

1. Önol B., Bozkurt D., Turuncoglu U.U., Sen O.L., Dalfes H.N., "Evaluation of the twenty-first century RCM simulations driven by multiple GCMs over the Eastern Mediterranean–Black Sea region", Climate Dynamics, Vol. 42, 2014, s. 1949-1965
2. Önol B. , F.H.M Semazzi, "Regionalization of Climate Change Simulations over the Eastern Mediterranean", Journal of Climate, No. 22, 2009, s. 1944-1961

Besides, the seasonal precipitation trends (both by ERA-Interim and Interim/Land) indicate considerable increase of seasonal precipitation especially in Autumn (and partly in Winter) in the western coastal areas. Moreover, a correlation analysis between the yearly Temperature and total Precipitation (attached Fig.5) indicate a significant positive correlation between temperature and precipitation in the western/southwestern coastal areas (both over land and sea). Based on these findings we can suggest that, the strong warming in the western coastal areas is reflected as increased Autumn (and partly Winter) precipitation in the western coastal areas through intensified evapotranspiration and changes in the type and intensity of precipitation.

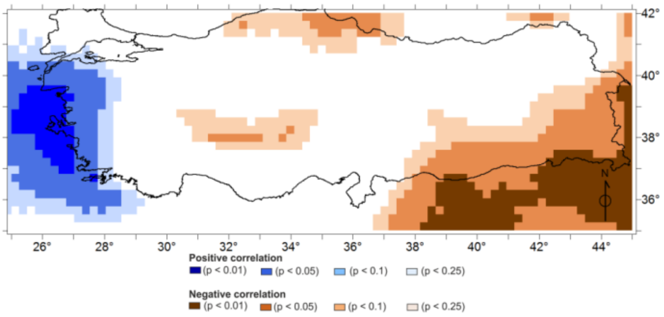

Figure5. The distribution of the correlation between the total Precipitation and the Temperature during the study period

3. Figure 3a, are the station values compared with yearly country-averaged values from ERA Interim data set? You should have compared averaged of observations with averaged of corresponding pixels from dataset (not all country). Make the plots more visible. Why just used temperature data at that location (inland part). As you used precipitation observation from different location across the country you can use the same for temperature to make it more representative spatially. The reason for using these stations should be given (maybe this is the area where very significant increase in temperature but it should be explained).

Reply of the Author (3):

Previously, the stations temperature data was only available for an in-land basin because that basin was the study area for my (completed) PhD research and the data was available from that. Thanks to the temperature data provided by Dr. Faize Saris from Canakkale 18 Mart University, the comparison now extended to around 100 stations distributed over the country. The revised Figure (attached Fig.6) presents an overlaid comparison of the significance and magnitude of the temperature trends by the ERA-Interim and meteo-stations.

With the availability of more stations data, Figure 3 (in the manuscript) was also revised to compare the observational and reanalysis data in a more systematic manner. As suggested by the Reviewer #5, in the revised Fig. 3a (attached Fig.7a), the average yearly temperature of all stations was compared with the average of corresponding pixels from the reanalysis dataset for the study period. While, in the

revised Figure 3b (attached Fig.7b), the total 32-years increase of temperatures indicated by meteo-stations and Reanalysis were compared for different elevations.
The (attached) Fig.7a generally reveals a systematically higher average temperatures and total increasing trends by the meteo-stations compared to Reanalysis data. The systematically higher yearly average temperature by the stations can generally be attributed to the intrinsic problems of point-based vs. grid comparisons: the meteo-station measurements not only represent the local environment (compared to the 80 km resolution original Reanalysis data), they are also usually located in the lower altitudes around the cities due to ease of maintenance. Therefore, for a particular grid, it can be expected that the point measurement of temperature by the station is systematically higher than the overall average of the grid represented by the Reanalysis data. In addition, the growth of urban areas and the related urban heating effect possibly explains the higher increasing trend of temperature indicated by the meteo-stations compared to the Reanalysis data (attached Fig.7b).
The revised figures and the updated results and discussions will be included in the revised manuscript.

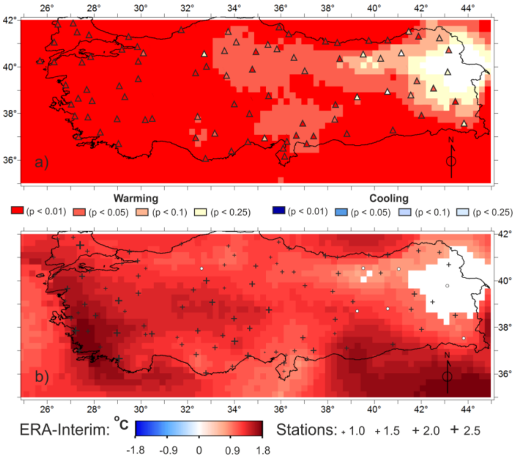

Figure6. The comparison of the (a) presence of the significant Temperature trends and (b) the magnitudes of 32-years total Temperature trends between the ERA-Interim and the stations. In Figure (a) upward triangles/circles indicate the presence/absence of increasing trends, while the colors indicate the degree of the significance.

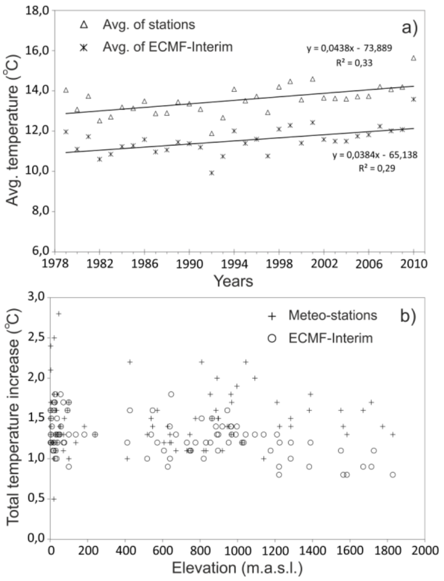

Fig. 7a) The comparison of the average yearly temperature between the (all) stations and the corresponding grids from the ERA-Interim dataset for the study period, 7b) The comparison of the total 32-years increase of temperatures by meteo-stations and ERA-Interim with respect to elevation.

4. Make the plots showing the performance of datasets with observations more visible. Use different legends.

Reply of the Author (4):
Thanks to the availability of extended observations data (for temperature, total precipitation and SWE), all the related trend maps from the Reanalysis datasets were overlaid with the trends of the observations for a better visibility of the comparisons. Besides the revised comparison of the temperature trends (attached Fig.6), Precipitation & SWE trend comparisons were also revised (attached Figs.8, 9 and 10).

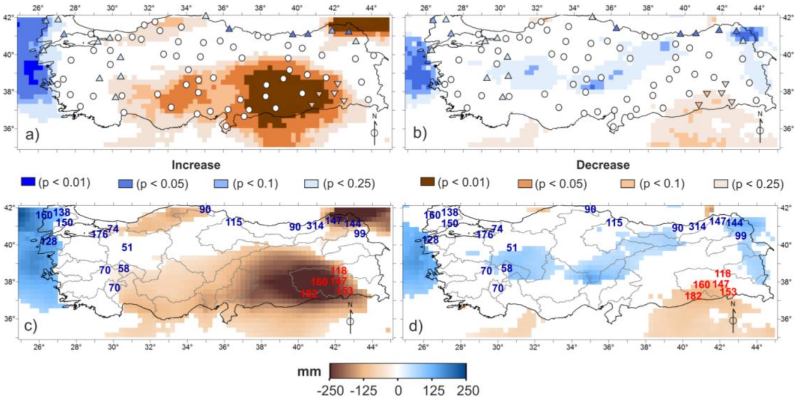

Figure8. The presence of the significant total Precipitation trends by (a) ERA-Interim vs. rain gauges, (b) Interim/Land vs. rain gauges. The magnitudes of 32-years total Precipitation trends by (c) ERA-Interim vs. rain gauges, (d) Interim/Land vs. rain gauges. In figures a-b, the upward/downward triangles indicate the significant increasing/decreasing trends, circles indicate no trend and the colors indicate the degree of the significance. In figures c-d, the numbers indicate the total increasing/decreasing trends at the stations with significant trends.

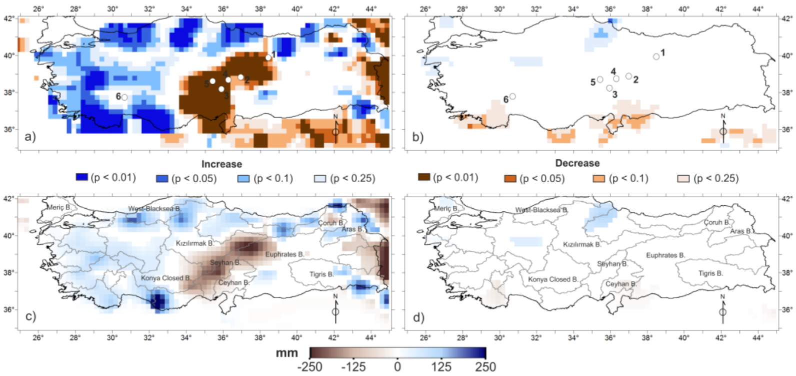

Figure9. The presence of the significant SWE trends by (a) ERA-Interim, (b) Interim/Land. The magnitudes of 32-years total SWE trends by (c) ERA-Interim, (d) Interim/Land.

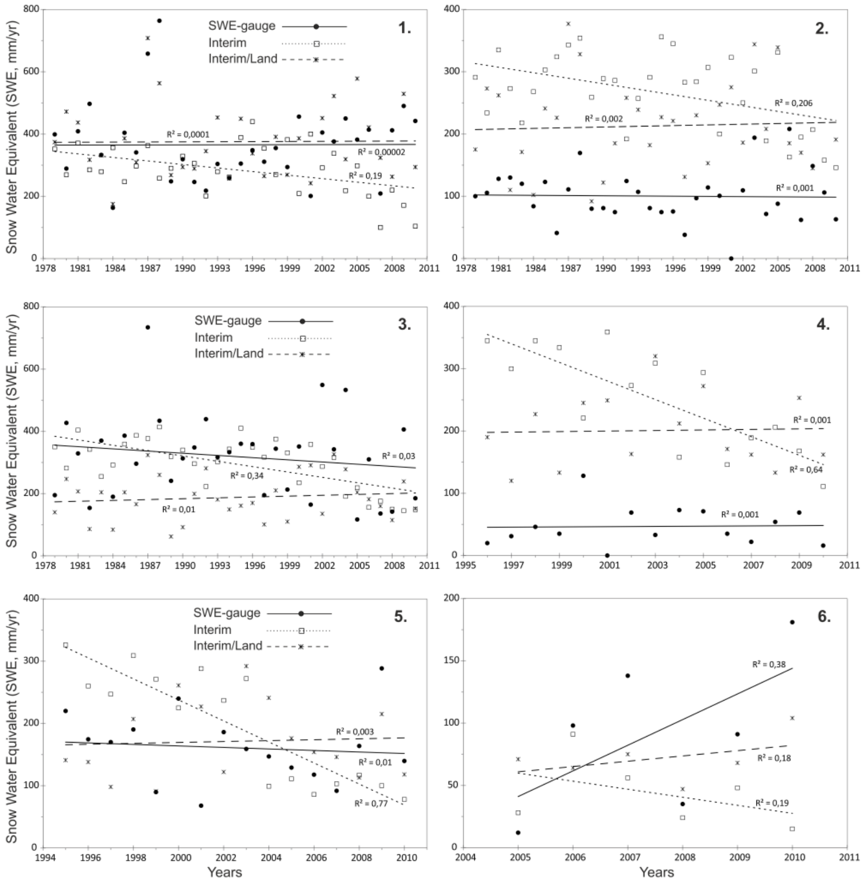

Figure10.The plots 1-6 indicate the comparison of the yearly SWE from the snow-gauges with the corresponding grids from ERA-I and I-L. The locations of the stations are shown in figures 9a-b.

5. All figure captions describing the trend direction and magnitude (except temperature) are wrong. they should be corrected according to figure panels.

Reply of the Author (5):
All the figure captions will be checked and corrected in the revised manuscript.

6. As contradictory results for some areas are obtained for ET, runoff and SWE, a suggestion to readers should be given to which dataset to be used in a possible future studies. Whether the author suggests using ERA Interim Land is more preferable because it uses an updated land surface model.

Reply of the Author (6):
Based on the extended comparisons with observations data (for precipitation and SWE), now it is safer to suggest that Interim/Land dataset reveals hydrological trends closer to the observations. Although no direct comparisons (with observations) were made for Runoff and ET, a correlation analysis revealed (attached Fig.11) that there were strong positive correlations between Precipitation and Runoff, & Precipitation and ET (except the humid North-east). Therefore, improved time-series of Precipitation and SWE by the updated Interim/Land dataset also imply improved Runoff and ET distributions by the Interim/Land.

Such an explanation will be added in the Discussion and Conclusions section of the revised manuscript.

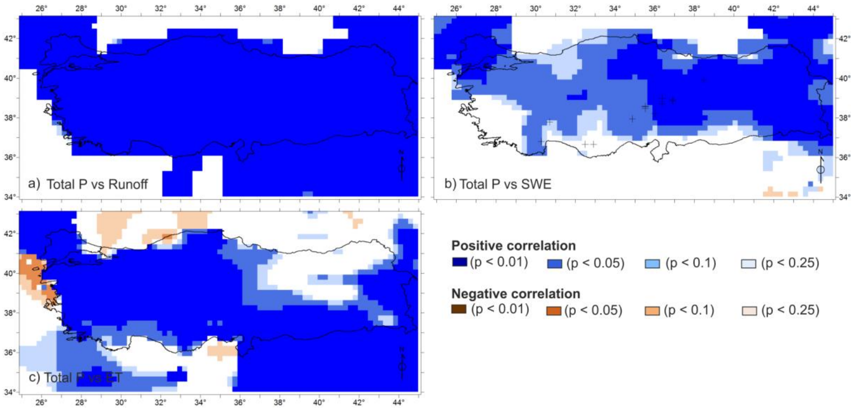

Figure11. The correlation between (a) total Precipitation and Runoff, (b) total Precipitation and SWE, (c) total Precipitation and ET for Interim/Land dataset.

7. Derivation of surface runoff should be given. Does it include contribution from subsurface flow or just an excess water on surface after infiltration? I dont think streamflow on river channels are considered.

Reply of the Author (7):
In the ERA-Interim dataset, which uses TESSEL land surface model, Runoff is estimated based on a single global soil texture, which does not characterize different soil moisture regimes, and a Hortonian runoff scheme which produces hardly any surface runoff (Balsamo et al., 2015). On the other hand, the Interim/Land with the updated HTESSEL model (described in detail in Balsamo et al., 2009), integrates a spatially variable soil hydrological conductivity and diffusivity according to a global soil texture map and the surface runoff is calculated based on the variable infiltration capacity approach. The explanation will be added in the revised manuscript.
In this regard, streamflow on river channels are not considered in the surface runoff by ECMWF models.

8. In text or in figure captions, the basins whose borders are shown in Figures should be explained.

Reply of the Author (8):
An explanation will be added regarding the basins in the revised manuscript.

9. It is explained that ERA Interim is available at 80 km resolution but the author used them at 25 km (0.25) resolution. Have you done a re-scaling (downscaling)? Give explanations

Reply of the Author (9):
In Balsamo et al. (2015), it is mentioned that ERA-Interim is produced at T255 spectral resolution (about 80 km). On the other hand, in the data delivery website of ECMWF (http://apps.ecmwf.int/datasets/), the variables are possible to download from 0.125X0.125 (apprx. 12.5 km) grid to 3X3 degrees grid. In this regard, I directly retrieved 0.25X0.25 grid data from ECMWF and did not apply any re-scaling myself. How ECMWF applies the re-scaling is not unfortunately provided in ECMWF’s website (http://www.ecmwf.int/en/what-horizontal-resolution-data)

ANNEX II- A list of all relevant changes made in the manuscript

1. Abstract section was updated based on the revised Results and, Discussion and Conclusions sections.
2. Önol et al. (2014) and Önol and Semazzi (2009) were added in the Introduction and References.
3. In the Study Area section (2.1), Figure 1b was added to the revised manuscript as an indicator of the climatic conditions of the study area.
4. Under the Data section (2.3), an explanation was added about the in-situ data that were used to compare with the Reanalysis results.
5. In the Results section (3.1 Air temperature), Figures 2a and 2b were revised to include an extensive comparison with in-situ data. The related explanation was also revised in the text.
6. In the Results section (3.1 Air temperature), Figures 3a and 3b were revised to include the additional in-situ data and show a better comparison with the in-situ data. The related explanation was also revised in the text.
7. In the Results section (3.2 Total precipitation), Figures 4a to 4d were revised to include an extensive comparison with in-situ precipitation data and for better representation. The related explanation was also revised in the text.
8. In the Results section (3.2 Total precipitation), the seasonal trends analysis of precipitation was added through the new Figure 5 (ERA-Interim) and Figure 6 (Interim/Land) in the revised manuscript. The related explanation was also added in the text.
9. In the Results section (3.3 Snow water equivalent), Figure 8 was added to show comparisons with in-situ snow water equivalent data. The related explanation was also revised in the text.
10. In the Results section (3.4 Evapotranspiration), the figure caption of Figure 9 was corrected and some explanation was revised based on the comments of Referee #3.
11. In the Results section (3.5 Runoff), the newly Figure 11 was added to contribute for an indirect validation of runoff trends. The related explanation was also revised in the text.
12. Based on the added seasonal analysis and detailed comparisons with in-situ data, the Discussion and Conclusions section was extended and revised.
13. Acknowledgements section was added in the revised manuscript.

Spatio-temporal trends in the hydroclimate of Turkey for the last decades based on two reanalysis datasets

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[2]The Research Association of Rural Environment and Forestry, Ankara, Turkey

Correspondence to: M. Gokmen (mustaf.gokmen@gmail.com)

Abstract. We present a regional assessment of the spatiotemporal trends in several hydro-climate variables from 1979 to 2010 in Turkey, one of the vulnerable countries of the Eastern Mediterranean to climate change, using the two reanalysis products of ECMWF: ERA-Interim and ERA-Interim/Land, namely. The trend analysis revealed that an average warming of 1.26 °C [0.8 to 1.8] occurred in Turkey from 1979 to 2010, with high confidence intervals (95 to 99%) mostly. Geographically, the largest warming (up to 1.8 °C) occurred in the Western coastal areas next to Aegean Sea and in the South-East regions. The air temperature trends were generally confirmed by the in-situ data from about 100 weather stations around the country, though in-situ data indicated slightly higher trends ranging from 1 degree to 2.5 degrees. With respect to the regional trends in hydrological variables, ERA-Interim and ERA-Interim/Land revealed quite different pictures: the ERA-Interim dataset indicated that there have been significant decreasing trends of precipitation, snow water equivalent and runoff in some parts of inner/South-eastern Anatolia (up to 250 mm decrease totally in the upstream of Euphrates, Kizilirmak and Seyhan basins), while ERA-Interim/Land showed none or minor trends in the same areas. Based on the extensive comparisons with precipitation and SWE gauge data we can suggest that the hydrological trends shown by the ERA-Interim/Land dataset, which is said to be a model improvement, are relatively closer to the observations. From the hydrological trends revealed by the ERA-Interim-Land dataset we can conclude that, despite the strong warming trends over Turkey from 1979 to 2010, there have been no widespread and strong hydrological trends for the same period throughout the country. In this regards, we can suggest that the impacts of global warming on the water cycle are not straightforward especially at regional scale and the future climate simulations indicating considerable reductions in precipitation along with the significant increases in temperatures throughout Mediterranean and the Middle East by the end of the twenty-first century need to be dealt with caution.

1 Introduction

The future climate simulations show that the Mediterranean region is one of the most vulnerable zones in the world. The climate models consistently predict that Mediterranean basin will be affected adversely by climate change in the future (Giorgi and Lionello 2008; Lelieveld et al. 2012; Ozturk et al. 2014; Önol et al. 2014; Önol and Semazzi 2009; Türkeş et al. 2011), while IPCC reports (2007, 2014) indicating significant increases in temperatures besides considerable reductions in precipitation throughout Mediterranean and the Middle East by the end of the twenty-first century. Observational records and climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies and ecosystems (Yücel et al., 2014). Milly et al (2005) report 10-30% reductions in runoff in the Middle East by the year 2050.

Apart from the future simulations, several studies show that climate and water cycle of the Mediterranean and the Middle East have already undergoing significant changes in the recent decades whether they are due to climate change and/or direct human influences. Using observations from the Gravity Recovery and Climate Experiment (GRACE) satellite mission, Voss et al. (2013) indicated an alarming rate of decrease in total water storage in the north-central Middle East from 2003 to 2009. Yucel et al. (2014) investigated the regional trends in hydroclimatic variables in the eastern Anatolia, Turkey between 1970 and 2010 based on the streamflow and meteorological point measurements. The seasonal snowmelt runoff in the mountainous basins of eastern Turkey has experienced changes over the past several decades (Sen et al., 2011; Sönmez et al., 2013). Sen et al (2011) indicate that streamflow timings of the Euphrates and Tigris rivers shifted to the earlier days between two consecutive 17-year periods (i.e. 1972-1988 and 1990-2006).

Detection of trends and their significance with confidence generally requires consistent and long-term records of variables considered, especially in the case of detecting climate change driven trends (Gokmen et al., 2013a). As stated by Leroy et al. (2008), it is obvious that the longer the time series, the easier it should be to distinguish a trend from natural variability (and measurement uncertainty), because shorter periods of record generally have small signal-to-noise (S / N) ratios (Allen et al., 1994). Based on a hypothetical data set with certain statistical characteristics, Leroy et al. (2008) determined the minimum detection time as about 33 yr for detecting a global warming signal of 0.2K decade^{-1}. Similarly, assessing the trend consistency over a range of timescales (from 10 to 32 yr), Santer et al. (2011) states that multi-decadal records are required for identifying the human effect on the climate variables (e.g. temperature) with high statistical confidence.

The time series of temperature data from meteorological stations are widely used to assess the historical trends, however, as highlighted by Sen et al (2011), point measurements of temperature come with important shortcomings such as inadequate representation of mountainous areas and contamination by urban heat island effects as most stations are located in cities (e.g. Ezber et al., 2007).

Reanalysis products provide invaluable temporally and spatially continuous information on various atmospheric variables ranging from near-surface temperature, wind and solar radiation components to hydrological parameters including precipitation, evapotranspiration and runoff. Besides the weather forecast services, one of the primary aims of the reanalysis product by The European Centre for Medium-Range Weather Forecasts (ECMWF) is stated to construct a long-term homogeneous record of the atmosphere, which is achieved by systematic assessment, inter-calibration, and integration of the observational record in the context of physical models (Dee et al. 2011). Simmons et al. (2010) show that surface temperature and humidity trends from 45-yr ECMWF Re-Analysis (Era-40; Uppala et al. 2005) and ERA-Interim are in excellent agreement with estimates obtained from climatological land station data from Hadley Centre. Balsamo et al. (2010) evaluated the suitability of ERA-interim precipitation estimates for land applications at various timescales from daily to annual over the conterminous US. Decker et al. (2012) showed that the land surface evaporation of ERA-Interim compared favorably with the flux tower observations and with other reanalysis. The results of the studies based on reanalysis were also used in 5th Assessment Report (IPCC, 2014), which state that adequacy of trend detection using reanalysis data depends on the variable under consideration, the time period and the region of interest. For example, surface air temperature and humidity trends over land in the ERA-Interim reanalysis compare well with observations (Simmons et al., 2010), but polar tropospheric temperature trends in ERA-40 disagree with trends derived from radiosonde and satellite observations (Bitz and Fu, 2008; Grant et al., 2008; Graversen et al., 2008;

Screen and Simmonds, 2011). Recently, ECMWF has introduced a new product, namely ERA-Interim/Land, which incorporates the up-to-date land model developments via combining near-surface meteorological fields from ERA-Interim with the latest version of the HTESSEL land surface model (Hydrological Tiled ECMWF Scheme for Surface Exchanges over Land), which is an extension of the TESSEL scheme (van den Hurk et al., 2000) used in ERA-Interim. Balsamo et al. (2015) states the added-value components of The ERA-Interim/Land as soil, snow and vegetation description upgrades, as well as a bias correction of the ERA-Interim monthly-accumulated precipitation based on GPCP v2.1.

In this study, we utilized reanalysis datasets of ECMWF (both ERA-Interim and ERA-Interim/Land) to analyze the spatiotemporal trends in several hydro-climate variables (i.e. near-surface air temperature, precipitation, snow water equivalent, runoff and evapotranspiration) at regional scale. More specifically, this study aims at;

- determining the significance and magnitude of the hydro-climatic trends over the last decades (from 1979 to 2010) in a spatially distributed manner,
- and comparing the trends detected by ERA-Interim and ERA-Interim/Land datasets with in-situ data (where available),

in Turkey, one of the vulnerable countries of the Eastern Mediterranean to climate change. The Anatolian peninsula not only shows high gradients of topography (from sea level to above 5,000 m) and hydro-climate (yearly average total precipitation ranging from around 400 mm in the semi-arid inner Anatolia plateau to above 2,000 mm in the humid Northeastern Black Sea coast), but also has been undergoing severe human interferences through land use changes due to deforestation, conversion to agricultural lands, expansion of urban lands, building of dams, among others.

2 Materials and Methods

2.1 The study area

Turkey is situated in Anatolia (97%) and the Balkans (3%), bordered by the Black Sea in the North, the Aegean Sea and the Mediterranean Sea in the west and the south (Fig. 1a). Due to its complex terrain and the long land-sea boundary interactions, the climate of the country varies from the Mediterranean (in the coastal areas in the West and South) to the continental climate in the inner Anatolian plateau, while the Black Sea coast in the North is humid due to the orographic effect by the steep topography.

As shown by the long term average of the Precipitation (P) to Evapotranspiration (ET) ratio in Figure 1b, except for the humid North-East region by the Black Sea, most of the study area has relatively semi-arid conditions with P/ET ratio less than 1. Annual precipitation is relatively low (around 400 mm) in the semi-arid Central Anatolia plateau, it varies from 600 to 1,300 mm in the Aegean and Mediterranean coasts, while eastern coast of the Black Sea receives the greatest amount with over 2,000 mm annual rainfall (Bozkurt and Sen, 2011).

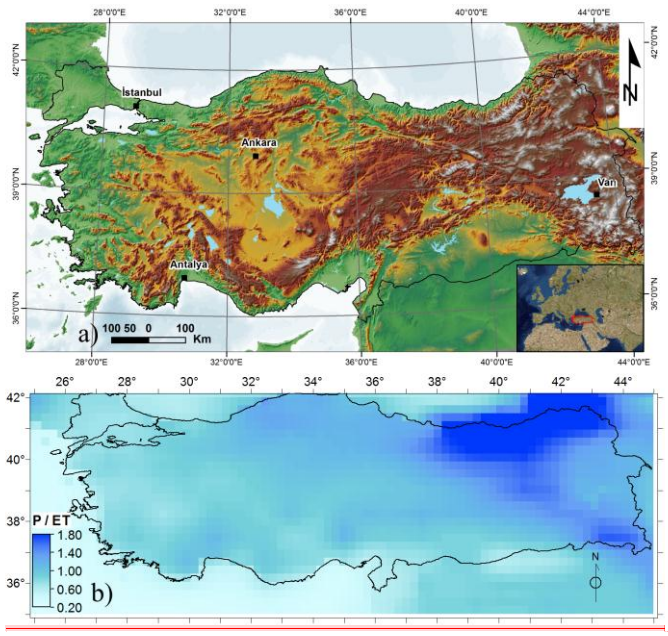


Figure 1a) The geographic location and the topography of the study area, **b)** Distribution of the average of Precipitation to Evapotranspiration ratio as estimated from the ERA-Interim/Land dataset for 1979-2010 period.

Açıklama [MG1]: Figure 1b was added to the Revised Manuscript as an indicator of the climatic conditions of the study area.

2.2 Methods

The time series of temperature and all the hydrologic variables were analysed using the Mann-Kendall non-parametric test for detecting the significance and the direction of the trend. Mann (1945) originally used this test and Kendall (1975) subsequently derived the test statistic distribution. The Mann-Kendall test has two parameters that are of importance for trend detection: the significance level that indicates the trend's strength (p value), and the slope magnitude (Kendall's Tau) estimate that indicates the direction as well as the magnitude of the trend. After detecting the significance level and the direction of trends by the Mann-Kendall test, the magnitude (slope) of trends were determined using linear models.

In order to apply the trend analysis in a spatially distributed manner, the Mann-Kendall test was applied using the R software and the Kendall package for R (http://cran.r-project.org/web/packages/Kendall/Kendall.pdf).

2.3 Data

In this study, we used two different reanalysis products by ECMWF: The ERA-Interim and ERA-Interim/Land (will be mentioned as Interim/Land from hereon), namely. Table 1 provides a summary of the variables that were considered for the trend analyses.

The ERA-Interim atmospheric reanalysis is built upon a consistent assimilation of an extensive set of observations (typically tens of millions daily) distributed worldwide (from satellite remote sensing, in situ, radio sounding, profilers, etc). Besides ERA-Interim, we also used a new product by ECMWF, namely Interim/Land. Balsamo et al. (2015) indicate that the Interim/Land is produced by combining near-surface meteorological fields from ERA-Interim with the latest version of the HTESSEL land surface model. HTESSEL is an extension of the TESSEL scheme (van den Hurk et al., 2000) used in ERA-Interim. HTESSEL includes an improved soil hydrology (Balsamo et al., 2009), a new snow scheme (Dutra et al., 2010), a multiyear satellite-based vegetation climatology (Boussetta et al., 2013), and a revised bare soil evaporation (Balsamo et al., 2011; Albergel et al., 2012).

The original ERA-Interim is produced at T255 spectral resolution (about 80 km) and covers the period from January 1979 to present. While Interim/Land covers the period between 1979 and 2010. To allow comparison, we used 1979-2010 as the study period for both datasets. Also, we used a spatially rescaled version (0.25X0.25 degrees) of the datasets as provided by ECMWF.

In addition to the Reanalysis datasets, in-situ data of air temperature from nearly 100 meteo-stations (unpublished data from Turkish Meteorological Service), precipitation from nearly 80 rain-gauges (unpublished data from Turkish Meteorological Service) and snow measurements from 6 stations (unpublished data from State Hydraulic Works, DSI) were used for necessary comparisons. The details of calculating Snow Water Equivalent (SWE) from in-situ snow measurements are described in Gokmen et al. (2013b).

Table 1. The summary of the Reanalysis data used in the study

Variable	Source	Spatial resolution	Temporal coverage
Air temperature	ERA-Interim	0.25 degrees	1979 – 2010
Total precipitation	ERA-Interim ERA-Interim/Land	0.25 degrees	1979 – 2010
Snowmelt	ERA-Interim ERA-Interim/Land	0.25 degrees	1979 – 2010
Evapotranspiration	ERA-Interim ERA-Interim/Land	0.25 degrees	1979 – 2010
Surface runoff	ERA-Interim ERA-Interim/Land	0.25 degrees	1979 – 2010

3 Hydro-climate trends

3.1 Air temperature

As the Interim/Land product mainly focused model updates related to the hydrological variables and did not include an air temperature output, here only the results from ERA-Interim are presented~~.~~, together with the in-situ data distributed over the country. Figure 2a shows that, apart from the Eastern region, Turkey has experienced significant increases of air temperature from 1979 to 2010, whose distribution is generally confirmed by the trends detected for the in-situ measurements. The significance level for the increasing temperature trends was high ($p<0.01$-0.05) in most of the country. The non-significant trend region in the Eastern Anatolia corresponds to the relatively high altitude region of the country with complex topography (Fig. 1a).

During the 32 years study period, the total temperature increase indicated by ERA-Interim generally ranged between 0.8 degrees (mostly in the Eastern, North-Eastern regions) and 1.8 degrees (Western coastal areas and in the South-East regions), as shown in Figure 2b. While the in-situ data from weather stations generally agree with the distribution of the total warming, the increase was slightly higher ranging from 1 degree to 2.5 degrees.

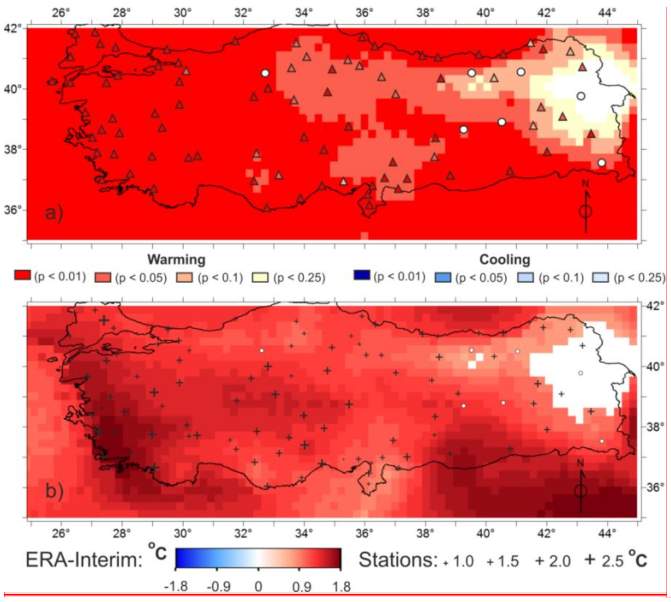


Figure 2. The comparison of the (a) presence of the significant Air Temperature trends at different levels of statistical significance and (b) the magnitudes of 32-years total Air Temperature trends between the ERA-Interim dataset and the meteo-stations. In Figure (a) upward triangles/circles indicate the presence/absence of increasing trends by the stations, while the colors indicate the degree of the significance.

Açıklama [MG2]: Figures 2a and 2b were revised to include an extensive comparison with in-situ data.

Showing the comparison of the yearly average air temperature of (all) the stations with the average of the corresponding grids from the ERA-Interim, Figure 3a indicates systematically higher temperatures by in-situ measurements (about 1.8 degrees) but a similar rate of increase is confirmed by the slope of the fitted trend lines for both in-situ data and ERA-Interim. The higher yearly average temperature by the stations can generally be attributed to the fact that the in-situ measurements not only represent the local environment at lower altitudes inside a grid (as the stations are usually installed at lower altitudes for ease of maintenance) compared to the 80 km original resolution of ERA-Interim, they are also more prone to urban heating effects. Assessing the total temperatures increases by the meteo-stations and the corresponding ERA-Interim grids with respect to elevation, Figure 3b shows that the temperature increases are indicated higher in the lowlands and relatively lower in the higher altitudes by both ERA-Interim and meteo-stations, apart from the generally higher total increase by the in-situ data.

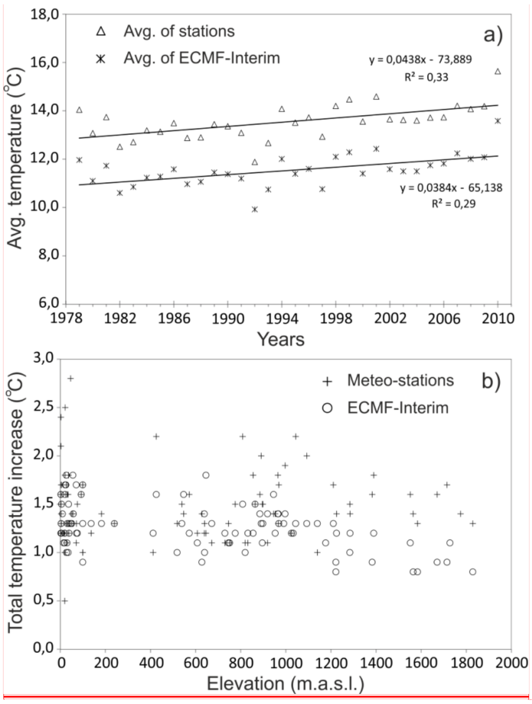


Figure 3a. The comparison of the average yearly temperature between (all) the stations (shown in Figure 2) and the corresponding grids from the ERA-Interim dataset, (b) The comparison of the total 32-years increase of temperatures by the meteo-stations and the corresponding grids from the ERA-Interim with respect to elevation.

3.2 Total precipitation

In ECMWF Reanalysis, total precipitation, which includes rain and snow, is estimated as the sum of convective precipitation and large scale precipitation. With respect to total Precipitation trends, ERA-Interim (Fig. 4a) and Interim/Land (Fig. 4b) reveal quite different pictures: except for the Western part and some of the South-eastern regions, the significance and direction of the precipitation trends are indicated highly different by ERA-Interim and Interim/Land in most of the study area. When these trends are compared with the in-situ measurements, the trends by the in-situ data are relatively closer to the Precipitation trends by Interim/Land rather than ERA-Interim. Especially the widely decreasing trends indicated by ERA-Interim in South/Southeast and North-East regions are not confirmed by the non-significant trends indicated by the stations (Fig. 4a). For these regions there is a general agreement between Interim/Land and the stations (Fig. 4b). The only region where ERA-Interim and Interim/Land both indicate significant increasing Precipitation trends is the Western region, which is confirmed by in-situ data especially in the North-West.

In terms of the magnitude of trends (Figures 4c and 4d), while the in-situ data indicates a range of 50-150 mm total increase/decrease of precipitation (1979-2010 period) at the significant trends locations (except 314 mm increase at Rize station in the North-East), ERA-Interim indicated as high as 250 mm decrease of precipitation totally in some parts of South-East and North-East (Fig. 4c) and, Interim/Land showed a decrease up to 120 mm in the South-East and 50-150 mm total increase in the areas with significant increasing trends.

Açıklama [MG3]: Figures 3a and 3b were revised to include the additional in-situ data and show a better comparison with the in-situ data

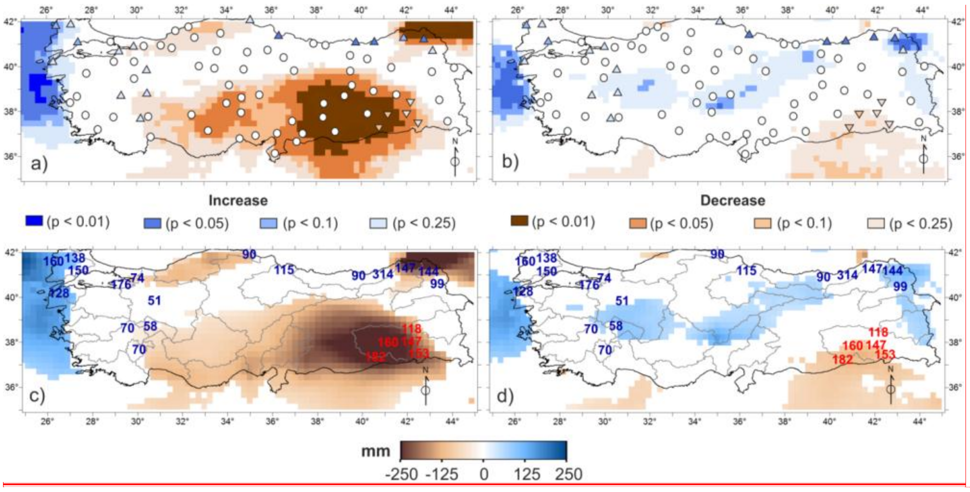


Figure 4. The comparison of the presence of the significant total Precipitation trends by (a) ERA-Interim vs. in-situ data, (b) Interim/Land vs. in-situ data. The comparison of the magnitudes of 32-years total Precipitation trends by (c) ERA-Interim vs. in-situ data, (d) Interim/Land vs. in-situ data. In figures a-b, the upward/downward triangles indicate the significant increasing/decreasing trends, circles indicate no trend and the colors indicate the degree of the significance. In figures c-d, the numbers indicate the total increasing/decreasing trends observed at the stations that have significant trends. The polygons in c-d delineates the 26 water basins in the country.

Considering that Turkey shows strong seasonality and some trends can be lost when evaluated annually, total Precipitation trends were also evaluated at seasonal scale. For ERA-Interim, the decreasing trends in the South and South-East region are observed in winter, spring and autumn but the decrease is most widespread and highlighted in spring (Fig. 5). The increasing trend in the West is the most widespread in autumn but also partly observed in winter. Similarly in autumn (and partly in winter), Interim/Land dataset also indicates widespread increase of Precipitation especially in West/North-West, in parts of inner Anatolia and some areas in the North-East. For Interim/Land, the decrease of Precipitation in South-East region is also observed in winter, spring and autumn but it is relatively local and quantitatively less compared to ERA-Interim. As the stations data was only available in yearly scale, a seasonal comparison with the in-situ data could not be carried out.

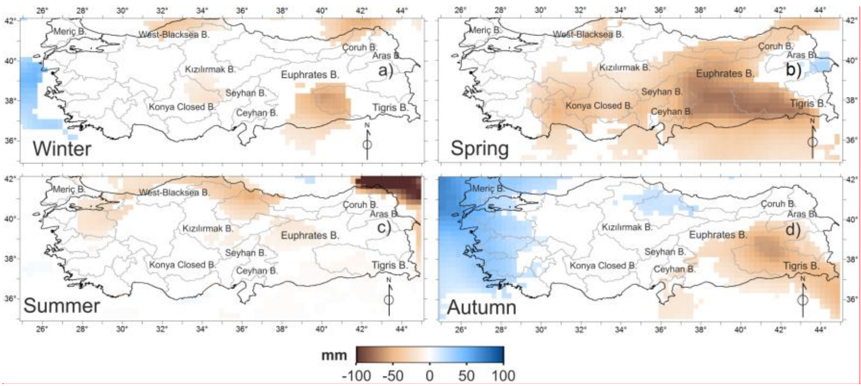


Figure 5. The magnitudes of the Total Precipitation trends (32-years total) by ERA-Interim for **a)** winter, **b)** spring, **c)** summer and **d)** autumn. Only the areas with significant trends (p<0.1) are shown in each map. The polygons in c-d delineates the 26 water basins in the country.

Açıklama [MG4]: Figures 4a to 4d were revised to include an extensive comparison with in-situ precipitation data and for better representation

Açıklama [MG5]: The seasonal trends for precipitation (ERA-Interim) was included in the revised manuscript.

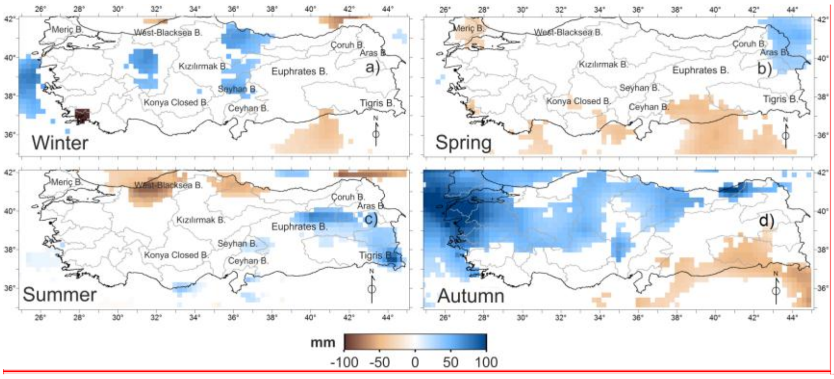
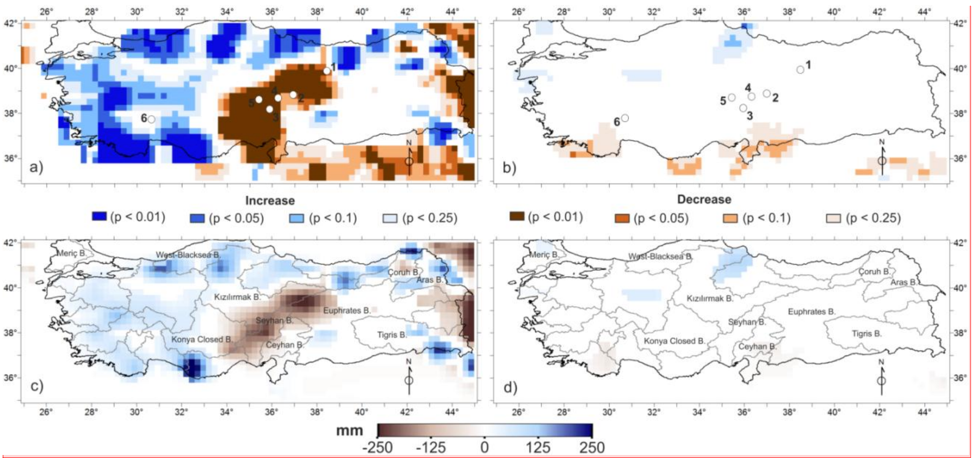


Figure 6. The magnitudes of the Total Precipitation trends (32-years total) by Interim/Land for **a)** winter, **b)** spring, **c)** summer and **d)** autumn. Only the areas with significant trends (p<0.1) are shown in each map. The polygons in c-d delineates the 26 water basins in the country.

Açıklama [MG6]: The seasonal trends for precipitation (Interim/Land) was included in the revised manuscript.

3.3 Snow water equivalent

Runoff from snowmelt-dominated basins in the mountainous and semi-arid regions of eastern Turkey accounts for 60-70% of the total annual runoff for the region (DSI, 2009). Therefore, inter-annual changes of snowfall quantities are especially important for the mountainous regions in Eastern Anatolia. According to the ERA-Interim dataset (Figures 7a and 7c), there has been highly significant decreasing trends ($p<0.01$) of snow water equivalent (SWE) in the upstream parts of Euphrates, Kizilirmak and Seyhan basins up to 250 mm decrease totally for the 32-years study period. Apart from the decreasing trends, ERA-Interim dataset revealed significant increasing trends of SWE in the South-western Turkey, and in various regions along the Black Sea coast. On the other hand, ERA-Interim/Land dataset (Figures 7b and 7d), which is said to be a model improvement integrating a new snow scheme by Dutra et al. (2010), indicated no considerable trends with respect to SWE throughout the country. Indeed, a comparison with data from six SWE gauge stations show that SWE trends from Interim/Land dataset is quite similar to the in-situ data (Figure 8): both indicate no significant trends despite the differences in terms of SWE magnitudes. Although station#6 (and Interim/Land) shows some increasing trend (Figure 8), the time-series is too short for trend detection. In Figure 8, ERA-Interim dataset generally shows significant decreasing trends of SWE for the same locations.



Açıklama [MG7]: Figure 7 was revised to include the locations of six snow gauges.

Figure 7. The distribution of the presence and the direction of Snow Water Equivalent (SWE) trends by **a)** ERA-Interim, **b)** Interim/Land. The magnitudes of 32-years total SWE trends by **c)** ERA-Interim, **d)** Interim/Land. The circles with the numbers indicated the location of snow-gauge stations. The polygons in c-d delineates the 26 water basins in the country.

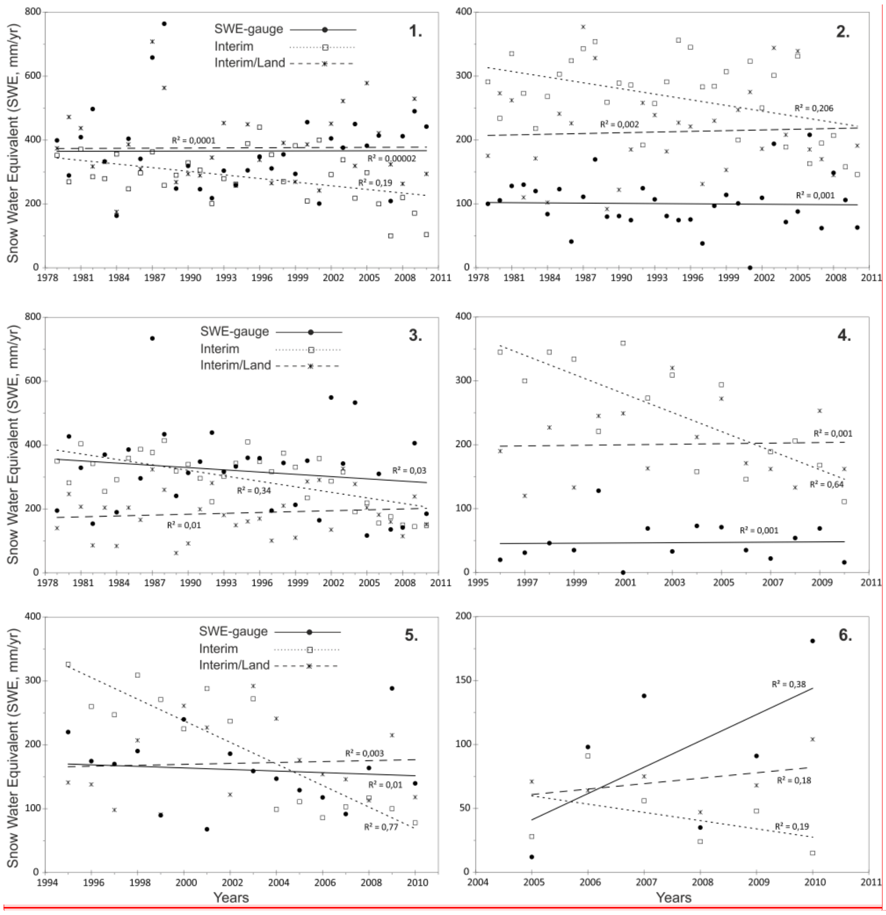


Figure 8. The plots 1-6 indicate the comparison of the yearly SWE from the snow-gauges with the corresponding grids from ERA-Interim and Interim-Land. While the time series of SWE covered whole study period for stations 1 to 3, the stations data was available for a much shorter period for 4 to 6. The locations of the stations are shown in figures 7a-b.

Açıklama [MG8]: Figure 8 was added to show comparisons with in-situ snow water equivalent data.

3.4 Evapotranspiration

With respect to evapotranspiration (ET) trends, while both ERA-Interim and ERA-Interim/Land show similar trends over Mediterranean, Aegean and Black Sea and some areas in the South-east, the two datasets indicate rather contradicting trends over the land along Anatolian peninsula (Figures 9a and 9b). Such a general pattern of consistent ET trends over sea and non-consistent over the land between ERA-Interim and ERA-Interim/Land can possibly be attributed to the different controlling mechanisms of ET (Seneviratne et al., 2010): over sea, ET is mainly energy-limited (i.e. temperature and incoming radiation), while over land, ET is generally water-limited (i.e. precipitation and soil moisture) in semi-arid regions and energy-limited in humid regions. Therefore, clearly increasing trend of air temperature over the entire study area (Fig. 2) mainly explains the increasing trend of ET over sea as detected by both datasets. On the other hand, considering most of the study area has semi-arid conditions (Fig. 1b) and precipitation becomes more controlling than air temperature over semi-arid lands, the contradicting trends of precipitation shown in Figure 4 is reflected similarly for the ET trends detected by ERA-Interim and Interim/Land along the Anatolian peninsula from West to East~~.~~ (Figures 9a and 9b). In terms of magnitude of ET trends (Figures 9c and 9d), both datasets indicate the highest increasing ET trends (up to 250 mm totally) occurred over the Mediterranean coast in the South-west, where the highest rates of temperature increase were experienced too as shown in Figure 2b.

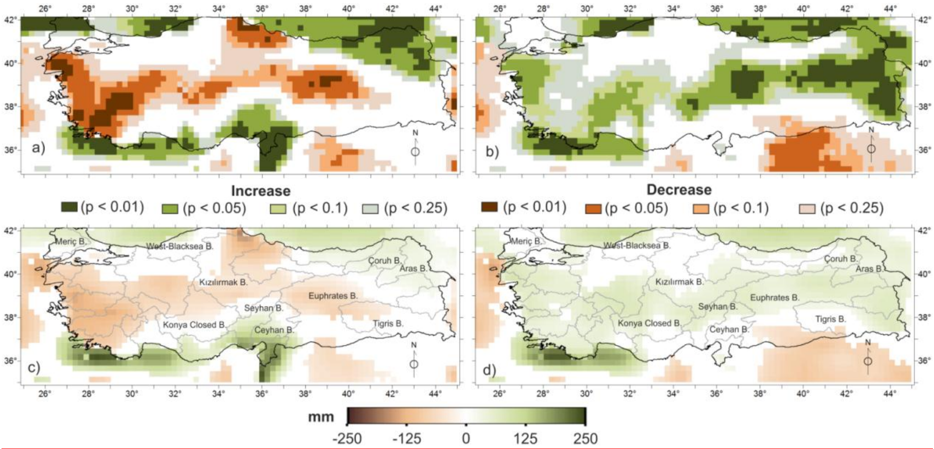


Figure 9. The distribution of the presence and the direction of Evapotranspiration (ET) trends by **a)** ERA-Interim, **b)** Interim/Land. The magnitudes of 32-years total ET trends by **c)** ERA-Interim, **d)** Interim/Land. The polygons in c-d delineate the 26 water basins in the country.

3.5 Runoff

Similar to precipitation and SWE trends, runoff trends were revealed differently by two Reanalysis datasets: while ERA-Interim revealed significantly decreasing trends of runoff at certain regions of Anatolia (Fig. 10a), Interim/Land indicated only minor increasing trends in some limited areas in central Anatolia and the South-east regions. In terms of magnitude, ERA-Interim indicated as high as 250 mm decrease totally in the upstream of Euphrates, Kizilirmak and Seyhan basins (Fig. 10c), but the quantity of increase/decrease indicated by Interim/Land was generally lower than 100 mm for the 32-years period (Fig. 10c). Although no comparison with in-situ or other independent data was carried out, a correlation analysis confirmed that there is highly significant positive correlation between Runoff and Precipitation for both Reanalysis datasets (Fig. 11). From such high correlations we can deduce that the validations of total Precipitation with in-situ data can be assumed valid for Runoff data as well. Indeed, analyzing the streamflow trends in Eastern Anatolia, Yucel et al. (2014) found that only two of the streamflow stations out of fifteen showed evidence for the significant change (both decreasing trends) in the total annual river discharges between 1970 and 2010.

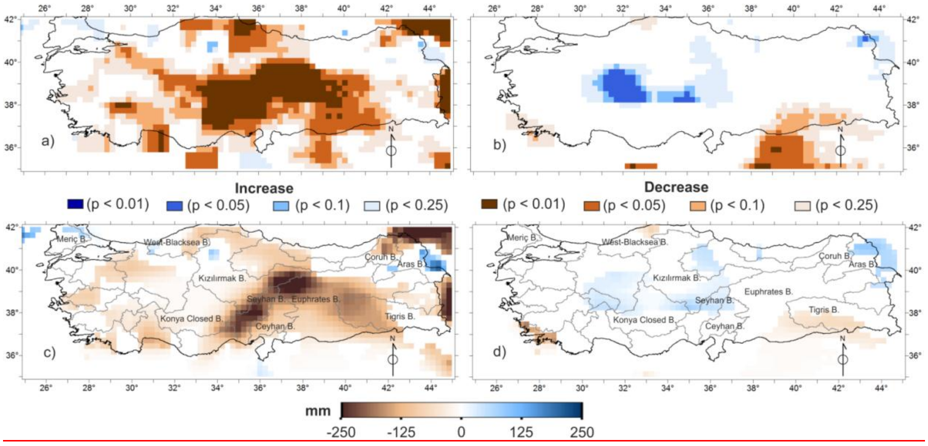


Figure 10. The distribution of the presence and the direction of Runoff trends by **a)** ERA-Interim, **b)** Interim/Land. The magnitudes of 32-years total Runoff trends by **c)** ERA-Interim, **d)** Interim/Land. The polygons in c-d delineates the 26 water basins in the country.

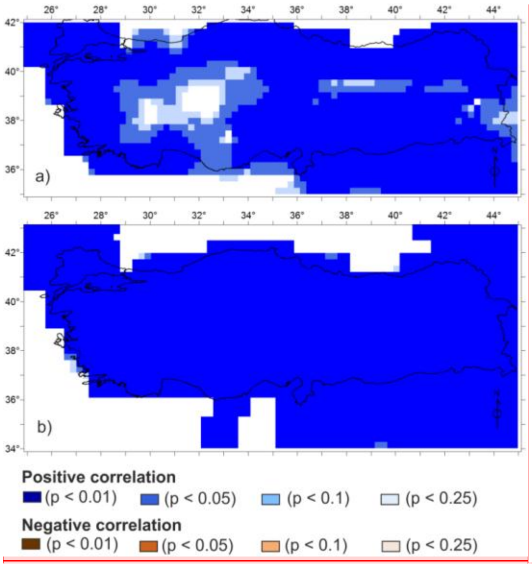


Figure 11. The correlation between total Precipitation and Runoff for **a)** ERA-Interim, **b)** Interim/Land.

Açıklama [MG9]: Figure 11 was added to contribute for an indirect validation of runoff trends.

4 Discussion and Conclusions

In this study, we assessed the spatiotemporal trends in several hydro-climate variables from 1979 to 2010 in Turkey, one of the vulnerable countries of the Eastern Mediterranean to climate change, using the two reanalysis products of ECMWF: ERA-Interim and Interim/Land, namely.

With respect to air temperature, ERA-Interim reanalysis dataset revealed highly significant increasing trends (95 to 99% confidence intervals) with an average warming of 1.26 °C [0.8 to 1.8] in Turkey from 1979 to 2010 (Figures 2a and 2b), which is relatively high compared to the globally averaged increase of 0.72 °C over the period 1951–2012 according to the 5th Assessment Report (IPCC, 2014). The distribution of the significance and the magnitude of the air temperature trends were generally confirmed by the in-situ data from about 100 weather stations around the country, though in-situ data indicated slightly higher trends ranging from 1 degree to 2.5 degrees. The increased exposing of the stations to the urban heat effect during the 32-years study period possibly explains the higher warming detected by the meteo-stations.

Geographically, the largest warming (up to 1.8 °C) occurred in the Western coastal areas next to Aegean Sea and in the South-East regions (and in other Middle East countries including Iraq and Syria), which is also expressed by Sen et al. (2011) who indicated that the largest warming (over 2 °C) occurred over the Aegean Sea and Western Turkey, due to the propagation of warmer air from over the Balkans and Aegean Sea toward eastern Anatolia after about 25 February based on the assessment of 850 hPa temperature differences between 1990-2006 and 1972-1988 periods. Yucel et al. (2014) detected an increasing trend of 1.3 °C between 1970 and 2010 (0.33 °C per decade) in the Eastern Anatolia, where our study also indicated relatively lower warming (about 0.3 °C per decade) or even non-significant changes in some parts. The Eastern Anatolia is the mountainous region of the country (Figure 1a), with a terrestrial climate of shorter summers and longer winters. Considering the relatively less density of population and the non-significant changes in the snow dynamics (Figure 7) in the region, the relatively stationary snow-albedo feedbacks and the less contribution of the direct land use changes to the temperature increase are among the possible explanations to the less and/or non-significant warming in the Eastern Anatolia.

With respect to the regional trends in hydrological variables, ERA-Interim and Interim/Land datasets revealed quite different pictures: while the ERA-Interim dataset indicated significant decreasing trends of precipitation in inner/South-eastern and North-eastern Anatolia, Interim/Land showed none or minor decreasing trends in the South-eastern and increasing trends in the North-eastern parts (Figure 4). When these trends are compared with the rain-gauges data, the trends by the Interim/Land are relatively closer to the Precipitation trends by in-situ data, confirming the minor decreasing precipitation trends in the South-east and some increasing trends in the North-east. The only region where ERA-Interim and Interim/Land both indicate significant increasing Precipitation trends is the Western region, which is also confirmed by in-situ data especially in the North-West.

Similar to precipitation, SWE and runoff trends were revealed differently by the two Reanalysis datasets: while ERA-Interim indicated significant and highly decreasing trends of SWE and runoff in the upstream of Euphrates, Seyhan and Kizilirmak basins (Figs. 7c and 10c), Interim/Land showed none or only minor trends in some limited areas in central Anatolia and the South-east regions (Figs. 7d and 10d). A comparison with data from six SWE gauge stations showed that SWE trends from Interim/Land dataset is quite similar to the in-situ data (Figure 8): both indicate no significant trends despite the differences in terms of SWE magnitudes. Although Sönmez et al. (2013) indicated dominantly negative trends for the snow cover over Turkey, the study period was relatively short (2004-2012) for a reliable trend analysis. Although the validation of the runoff trends could not be carried with in-situ data, a correlation analysis showed that Runoff and Precipitation are positively correlated extensively for both Reanalysis datasets (Fig. 11), implying the validation of precipitation would be valid for runoff as well. Indeed, assessing the river discharges trends in the mountainous Eastern region, Yucel et al. (2014) also indicated that there are generally no statistically meaningful trends in the river discharges (only two of the fifteen stations showed evidence for decreasing trend) over the study period (1970-2010), while the timing of spring streamflow has significantly shifted earlier in the year.

Among the hydrological variables, the only consistent hydrological trend detected by both datasets was the increase of evapotranspiration over Mediterranean and Black Sea, whose magnitude was especially considerable (up to 250 mm totally) over the Mediterranean coast in the South-west Turkey (Figures 9c and 9b). Combining with the strong warming and as well as the increasing precipitation trend in the same region, we can suggest that the warming in the South-western Mediterranean is reflected as increased precipitation (especially in Autumn, Figures 5 and 6) in the western coastal areas through intensified evapotranspiration and changes in the type (i.e. snow becomes rain) and intensity of precipitation. However, such regional temperature-evapotranspiration-precipitation feedbacks are rather absent in the majority of the inland Anatolian peninsula: considering most of the study area has semi-arid conditions (Fig. 1b) and the precipitation becomes more controlling factor for evapotranspiration than air temperature over semi-arid lands, the contradicting trends of precipitation shown in Figures 4a and 4b are reflected similarly for the ET trends detected by ERA-Interim and Interim/Land along the Anatolian peninsula from West to East (Figures 9a and 9b).

Although it should be noted that verification of the grid-based reanalysis data with the point-based station data prone to certain errors as stations may not be representative of a large area especially in mountainous complex terrains, we can still suggest that, based on the extended comparisons with precipitation and SWE gauge data, the hydrological trends from 1979 to 2010~~,~~ in Turkey revealed by the Interim/Land dataset is closer to the observations. Indeed, compared to the ERA-Interim, Interim/Land is said to be a model improvement which includes an improved soil hydrology (Balsamo et al., 2009), a new snow scheme (Dutra et al., 2010), a multiyear satellite-based vegetation climatology (Boussetta et al., 2013), and a revised bare soil evaporation (Balsamo et al., 2011; Albergel et al., 2012).

Finally, considering that Interim-Land dataset revealed no clear and strong hydrological trends over Turkey from 1979 to 2010 despite the strong warming (ERA-Interim) for the same period throughout the country, we can suggest that, the impacts of global warming on the water cycle are not straightforward especially at regional scale. In this regard, the sections of the IPCC reports (2007, 2014) indicating considerable reductions in precipitation along with the significant increases in temperatures throughout Mediterranean and the Middle East by the end of the twenty-first century need to be dealt with caution. Indeed, 5th Assessment Report also declares low confidence for detecting long-term positive or negative trends in hydrological cycle over different latitudinal zones due to data quality, data completeness or disagreement amongst available estimates.

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6 References

Albergel, C., Balsamo, G., de Rosnay, P., Muñoz-Sabater, J., and Boussetta, S.: A bare ground evaporation revision in the ECMWF land-surface scheme: evaluation of its impact using ground soil moisture and satellite microwave data, Hydrol. Earth Syst. Sci., 16, 3607–3620, doi:10.5194/hess-16-3607-2012, 2012.

Allen, M. R., Mutlow, C. T., Blumberg, G. M. C., Christy, J. R., McNider, R. T., and Llewellyn-Jones, D. T.: Global change detection, Nature, 370, 24–25, 1994.

Balsamo, G., Albergel C., Beljaars, A., Boussetta, S., Brun, E., Cloke, H., Dee, D., Dutra, E., Muñoz-Sabater, J., Pappenberger, F., de Rosnay, P., Stockdale, T., and Vitart, F.: ERA-Interim/Land: a global land surface reanalysis data set, Hydrology and Earth System Sciences, 19.1, 389-407, 2015.

Balsamo, G., Boussetta, S., Dutra, E., Beljaars, A., Viterbo, P., and van den Hurk, B.: Evolution of land surface processes in the IFS, ECMWF Newslett., 127, 17–22, 2011.

Balsamo, G., Boussetta, S., Lopez, P., and Ferranti, L.: Evaluation of ERA-Interim and ERA-Interim-GPCP-rescaled precipitation over the U.S.A., ERA Report Series No. 5, ECMWF, Reading, UK, 10 pp., 2010.

Balsamo, G., Beljaars, A., Scipal, K., Viterbo, P., van den Hurk, B., Hirschi, M., and Betts, A.K.: A revised hydrology for the ECMWF model: Verification from field site to terrestrial water storage and impact in the Integrated Forecast System, Journal of hydrometeorology, 10.3, 623-643, 2009.

Bitz, C.M., and Fu, Q.: Arctic warming aloft is data set dependent, Nature, 455.7210, E3-E4, 2008.

Boussetta, S., Balsamo, G., Beljaars, A., and Jarlan, J.: Impact of a satellite-derived Leaf Area Index monthly climatology in a global Numerical Weather Prediction model, Int. J. Remote Sens., 34, 3520–3542, 2013.

Bozkurt, D., and Sen, O.L.: Precipitation in the Anatolian Peninsula: sensitivity to increased SSTs in the surrounding seas, Climate dynamics, 36.3-4, 711-726, 2011.

Decker, M., Brunke, M. A.,Wang, Z., Sakaguchi, K., Zeng, X., and Bosilovich, M. G.: Evaluation of the reanalysis products from GSFC, NCEP, and ECMWF Using Flux Tower Observations, J. Climate, 25, 1916–1944, doi:10.1175/JCLI-D-11-00004.1, 2012.

Dee, D. P., Uppala, S. M., Simmons, A. J., Berrisford, P.. Poli, P., Kobayashi, S., Andrae, U., Balmaseda, M. A., Balsamo, G., Bauer, P., Bechtold, P., Beljaars, A., van de Berg, L., Bidlot, J., Bormann, N., Delsol, C., Dragani, R., Fuentes, M., Geer, A. J., Haimberger, L., Healy, S. B., Hersbach, H., Hólm, E. V., Isaksen, L., Kallberg, P., Köhler, M., Matricardi, M., McNally, A. P., Monge-Sanz, B. M., Morcrette, J.-J., Park, B. K., Peubey, C., de Rosnay, P., Tavolato, C., Thépaut, J.-N., and Vitart, F.: The ERA-Interim reanalysis: configuration and performance of the data assimilation system, Q. J. Roy. Meteorol. Soc., 137, 553– 597, doi:10.1002/qj.828, 2011.

DSI.: Turkey Water Report, Republic of Turkey, Retrieved January 13, 2016. http://www.dsi.gov.tr, 2009.

Dutra, E., Balsamo, G., Viterbo, P., Miranda, P.M. A., Beljaars, A., Schär, C., and Elderet, K.: An improved snow scheme for the ECMWF land surface model: description and offline validation, Journal of Hydrometeorology, 11.4, 899-916, 2010.

Ezber, Y., Sen, O.L., Kindap, T., Karaca, M.: "Climatic effects of urbanization in Istanbul: a statistical and modeling analysis." International Journal of Climatology, 27.5, 667-679, 2007.

Giorgi, F., Lionello, P.: Climate change projections for the Mediterranean region, Global and Planetary Change, 63, 90-104, 2008.

Gokmen, M., Vekerdy, Z., Verhoef, W., and Batelaan, O.: Satellite-based analysis of recent trends in the ecohydrology of a semi-arid region, Hydrology and earth system sciences, 17.10, 3779-3794, 2013a.

Gokmen, M., Vekerdy, Z., Lubczynski, M.W., Timmermans, J., Batelaan, O., and Verhoef, W.: Assessing Groundwater Storage Changes Using Remote Sensing–Based Evapotranspiration and Precipitation at a Large Semiarid Basin Scale, Journal of Hydrometeorology, 14 (6), 1733-1753, 2013b.

Grant, A. N., Brönnimann, S., and Haimberger, L.: Recent Arctic warming vertical structure contested, Nature, 455.7210, E2-E3, 2008.

Graversen, R.G., Mauritsen, T., Tjernström, M., Källén, E., and Svensson, G.: Vertical structure of recent Arctic warming, Nature, 451.7174, 53-56, 2008.

IPCC: Climate Change 2007: Impacts, Adaptation, and Vulnerability, Parry ML, OF Canziani, Palutikof JP, van der Linden PJ, Hanson CE (eds). Cambridge University Press: Cambridge, UK, 2007.

IPCC: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151, 2014.

Kendall, M.G.: Rank Correlation Methods, London, 1975.

Lelieveld, J., Hadjinicolaou, P., Kostopoulou, E., Chenoweth, J., Maayar, M., Giannakopoulos, C., Hannides, C., Lange, M. A., 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.

Leroy, S.S., Anderson, J.G., and Ohring, G.: Climate Signal Detection Times and Constraints on Climate Benchmark Accuracy Requirements, J. Climate, 21, 841–846, doi:10.1175/2007JCLI1946.1, 2008.

Mann, H.B.: Nonparametric Tests against Trend, Econometrica, 13, 245-259, 1945.

Milly, P.CD., Dunne, K.A., and Vecchia, A.V.: Global pattern of trends in streamflow and water availability in a changing climate, Nature, 438.7066, 347-350, 2005.

Önol B., Bozkurt D., Turuncoglu U.U., Sen O.L., Dalfes H.N.: Evaluation of the twenty-first century RCM simulations driven by multiple GCMs over the Eastern Mediterranean–Black Sea region, Climate Dynamics, 42, 1949-1965, 2014.

Önol B., Semazzi, F.H.M.: Regionalization of Climate Change Simulations over the Eastern Mediterranean, Journal of Climate, 22, 1944-1961, 2009.

Ozturk, T., Türkeş, M., Kurnaz, M.L.: Analysing projected changes in future air temperature and precipitation climatology of Turkey by using RegCM4.3.5 climate simulations, Aegean Geographical Journal, 20, 17-27, 2014.

Santer, B. D., Mears, C., Doutriaux, C., Caldwell, P., Gleckler, P. J., Wigley, T. M. L., Solomon, S., Gillett, N. P., Ivanova1, D., Karl, T. R., Lanzante, J. R., Meehl, G. A., Stott, P. A., Taylor, K. E., Thorne, P. W., Wehner, M. F., and Wentz, F. J.: Separating signal and noise in atmospheric temperature changes: The importance of timescale, J. Geophys. Res., 116, D22105, doi:10.1029/2011JD016263, 2011.

Screen, J.A., and Simmonds, I.: Erroneous Arctic temperature trends in the ERA-40 reanalysis: A closer look, Journal of Climate, 24.10, 2620-2627, 2011.

Sen, O.L., Unal, A., Bozkurt, D., and Kindap, T.: Temporal changes in the Euphrates and Tigris discharges and teleconnections, Environmental Research Letters, 6.2, 1-9, 2011.

Seneviratne, S.I., Corti, T., Davin, E.L., Hirschi, M., Jaeger, E.B., Lehner, I., et al.: Investigating soil moisture–climate interactions in a changing climate: A review. Earth-Science Reviews, 99, 125–161, 2010.

Simmons, A. J.,Willett, K. M., Jones, P. D., Thorne, P.W., and Dee, D. P.: Low-frequency variations in surface atmospheric humidity, temperature and precipitation: Inferences from reanalyses and monthly gridded observational datasets, J. Geophys. Res., 115, 1–21, doi:10.1029/2009JD012442, 2010

Sönmez, I., Tekeli, A.E., and Erdi, E.: Snow cover trend analysis using Interactive Multisensor Snow and Ice Mapping System data over Turkey, International Journal of Climatology, 34.7, 2349-2361, 2014.

Türkeş, M., Kurnaz, M.L., Öztürk, T., Altınsoy, H.: Climate changes versus 'security and peace' in the Mediterranean macro climate region: are they correlated? In: Proceedings of International Human Security Conference on Human Security: New Challenges, New Perspectives, CPRS Turkey, 27-28 October 2011: Istanbul, 625-639, 2011.

Uppala, S.M., et al. "The ERA-40 re-analysis." Quarterly Journal of the Royal Meteorological Society 131.612, 2961-3012, 2005.

van den Hurk, B., Viterbo, P., Beljaars, A., and Betts, A. K.: Offline validation of the ERA-40 surface scheme, ECMWF Tech. Memo. No. 295, ECMWF, Reading, UK, 2000.

Voss, K. A., et al.: Groundwater depletion in the Middle East from GRACE with implications for transboundary water management in the Tigris-Euphrates-Western Iran region, Water resources research, 49.2, 904-914, 2013.

Yücel, İ., Güventürk, A., and Sen, O.L.: Climate change impacts of snowmelt runoff for mountainous transboundary basins in eastern Turkey," International Journal of Climatology, 35(2), DOI: 10.1002/joc.3974, 2014.