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

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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).

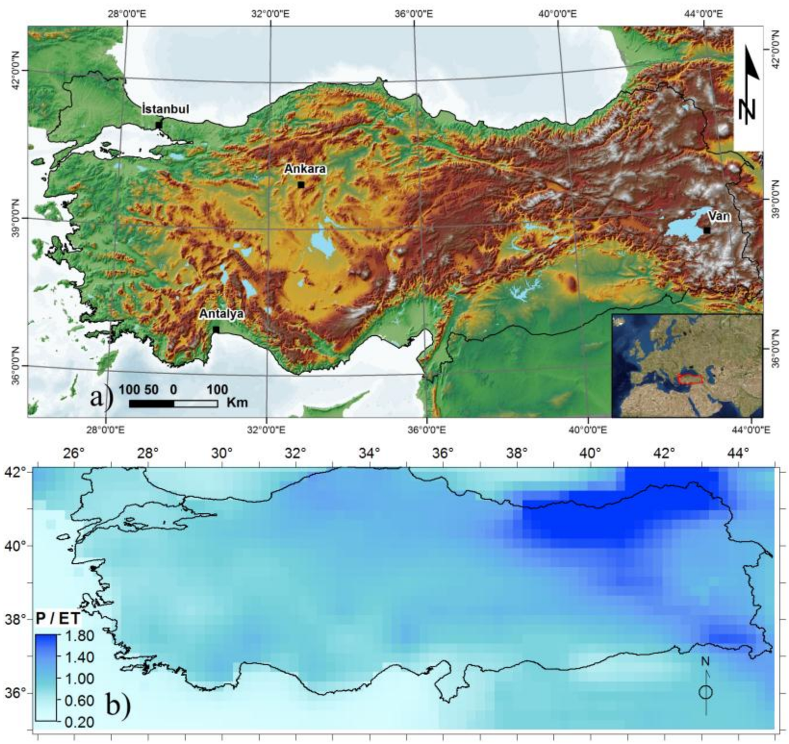

Figure 1a) The geographic location and the topography of the study area, **b)** Distribution of the average of Precipitation to Evapotranspiration ratio as estimated from the ERA-Interim/Land dataset for 1979-2010 period.

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.

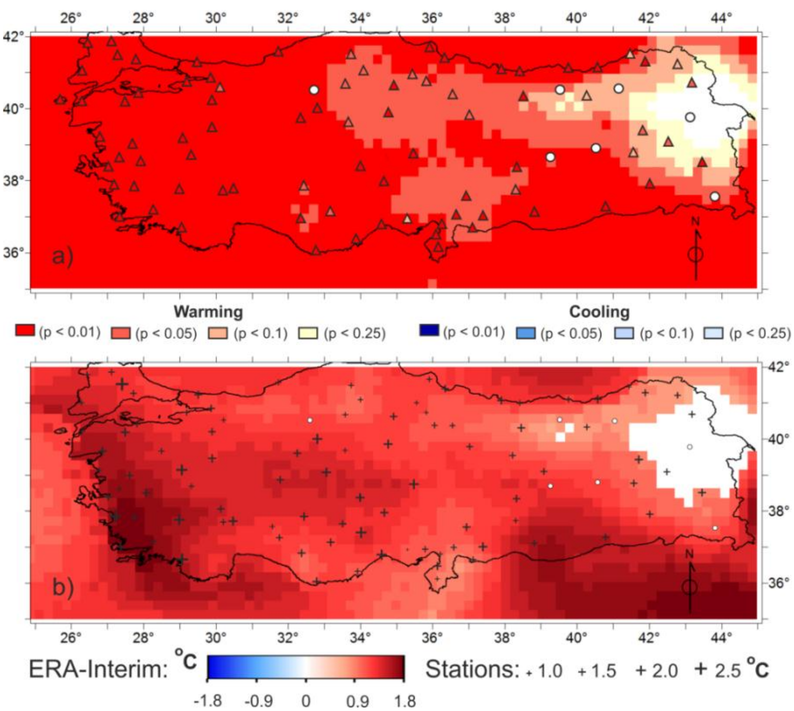

Figure 2. The comparison of the (a) presence of the significant Air Temperature trends at different levels of statistical significance and (b) the magnitudes of 32-years total Air Temperature trends between the ERA-Interim dataset and the meteo-stations. In Figure (a) upward triangles/circles indicate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

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.

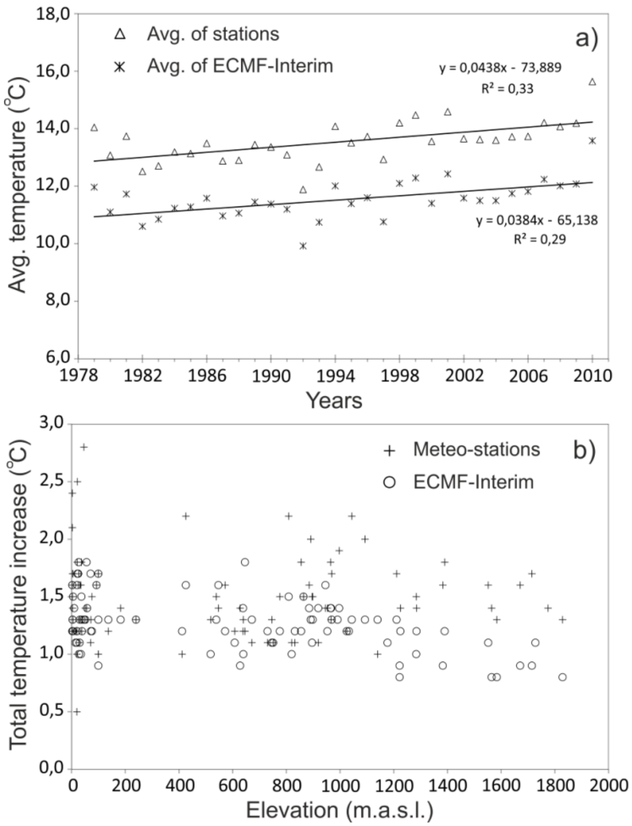

Figure 3a. The comparison of the average yearly temperature between (all) the stations (shown in Figure 2) and the corresponding grids from the ERA-Interim dataset, (b) The comparison of the total 32-years increase of temperatures by the meteo-stations and the corresponding grids from the ERA-Interim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

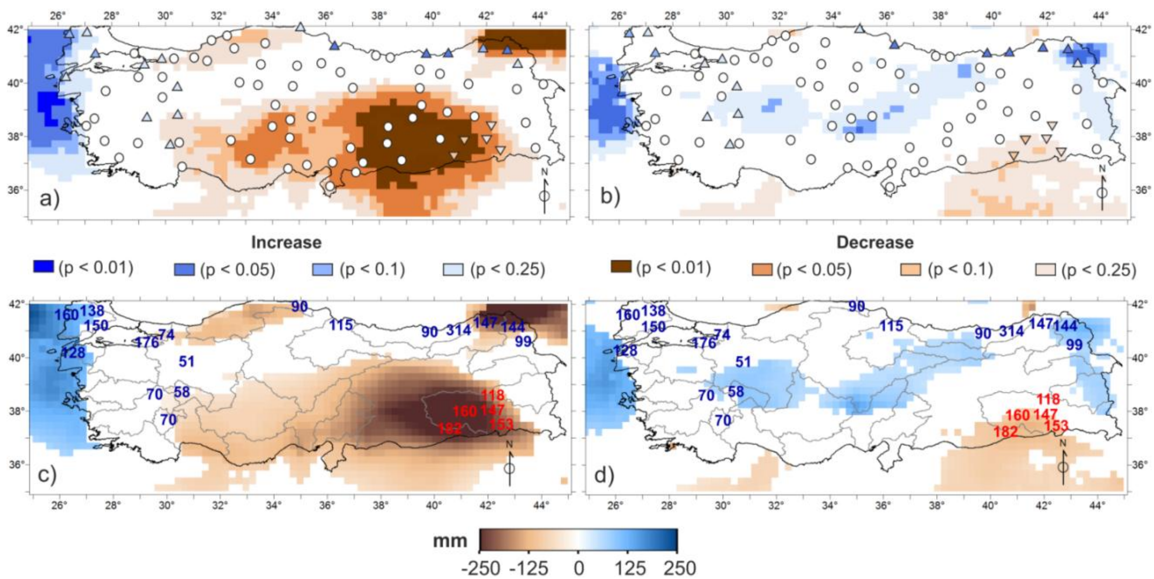

Figure 4. The comparison of the presence of the significant total Precipitation trends by (a) ERA-Interim vs. in-situ data, (b) Interim/Land vs. in-situ data. The comparison of the magnitudes of 32-years total Precipitation trends by (c) ERA-Interim vs. in-situ data, (d) Interim/Land vs. in-situ data. 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.

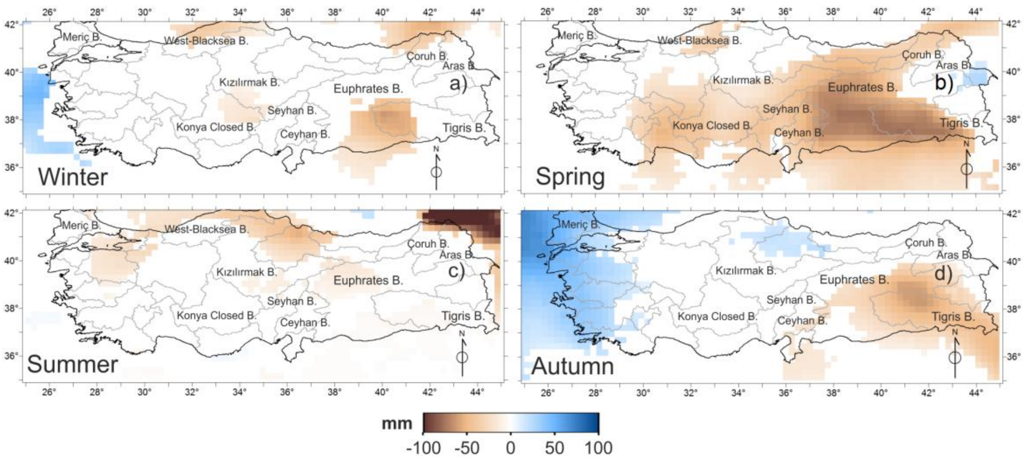

Figure 5. The magnitudes of the Total Precipitation trends (32-years total) by ERA-Interim for **a)** winter, **b)** spring, **c)** summer and **d)** autumn. Only the areas with significant trends (p<0.1) are shown in each map. The polygons in c-d delineates the 26 water basins in the country.

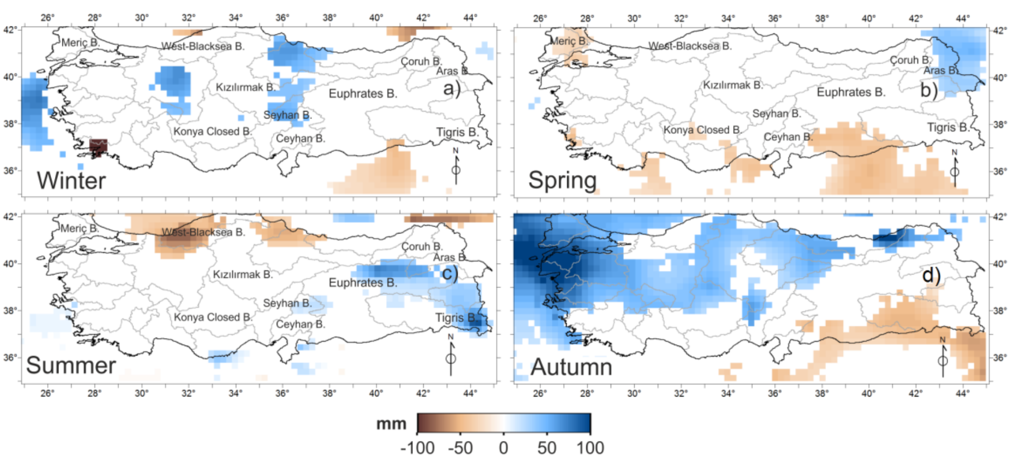

Figure 6. The magnitudes of the Total Precipitation trends (32-years total) by Interim/Land for **a)** winter, **b)** spring, **c)** summer and **d)** autumn. Only the areas with significant trends ($p<0.1$) are shown in each map. The polygons in c-d delineates the 26 water basins in the country.

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.

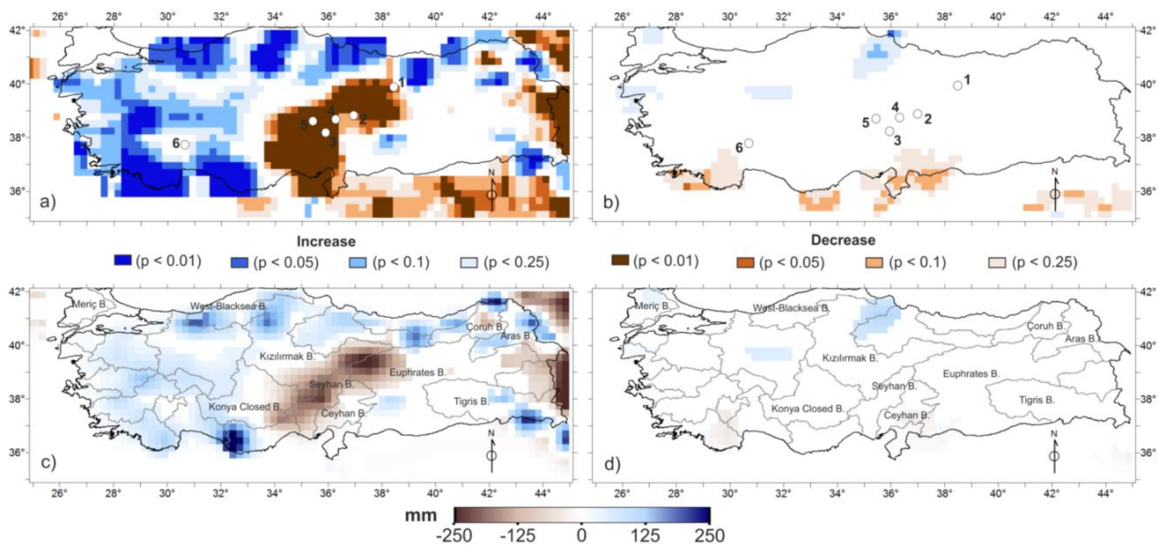

Figure 7. The distribution of the presence and the direction of Snow Water Equivalent (SWE) trends by **a)** ERA-Interim, **b)** Interim/Land. The magnitudes of 32-years total SWE trends by **c)** ERA-Interim, **d)** Interim/Land. The circles with the numbers indicated the location of snow-gauge stations.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

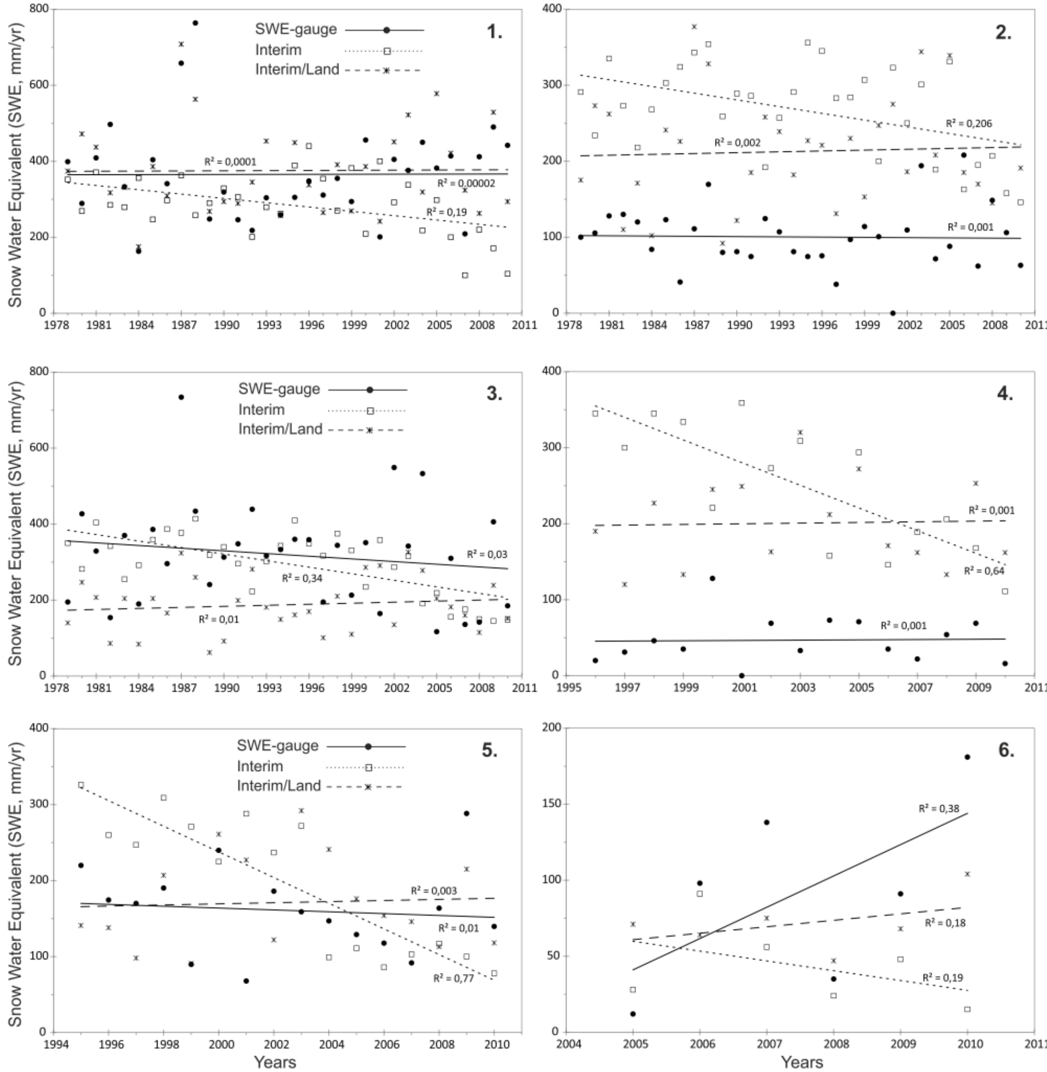

Figure 8. The plots 1-6 indicate the comparison of the yearly SWE from the snow-gauges with the corresponding grids from ERA-Interim and Interim-Land. While the time series of SWE covered whole study period for stations 1 to 3, the stations data was available for a much shorter period for 4 to 6. The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

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.

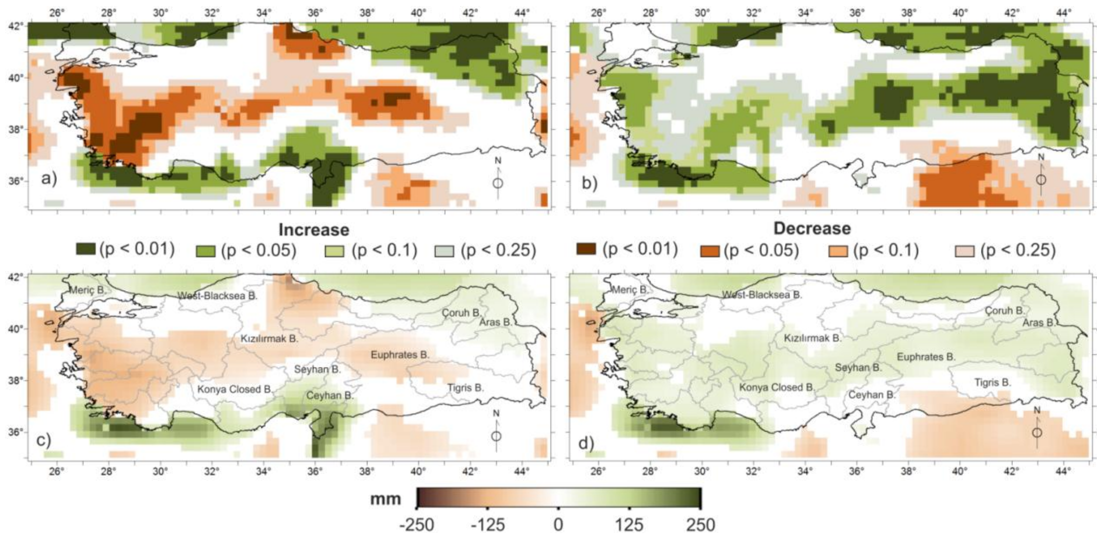

Figure 9. The distribution of the presence and the direction of Evapotranspiration (ET) trends by **a)** ERA-Interim, **b)** Interim/Land. The magnitudes of 32-years total ET trends by **c)** ERA-Interim, **d)** Interim/Land. The polygons in c-d delineate the 26 water basins in the country.

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.

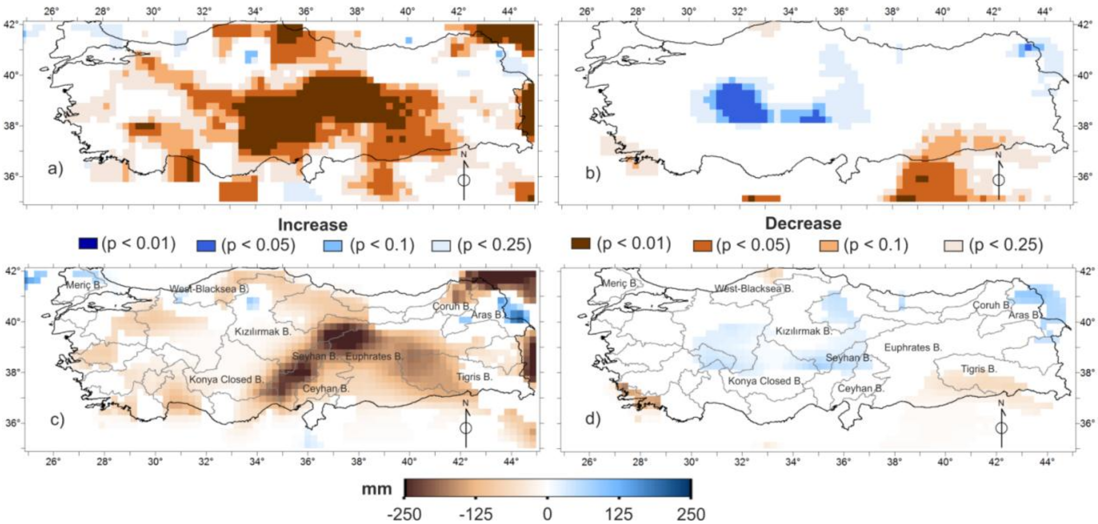

Figure 10. The distribution of the presence and the direction of Runoff trends by **a)** ERA-Interim, **b)** Interim/Land. The magnitudes of 32-years total Runoff trends by **c)** ERA-Interim, **d)** Interim/Land. The polygons in c-d delineates the 26 water basins in the country.

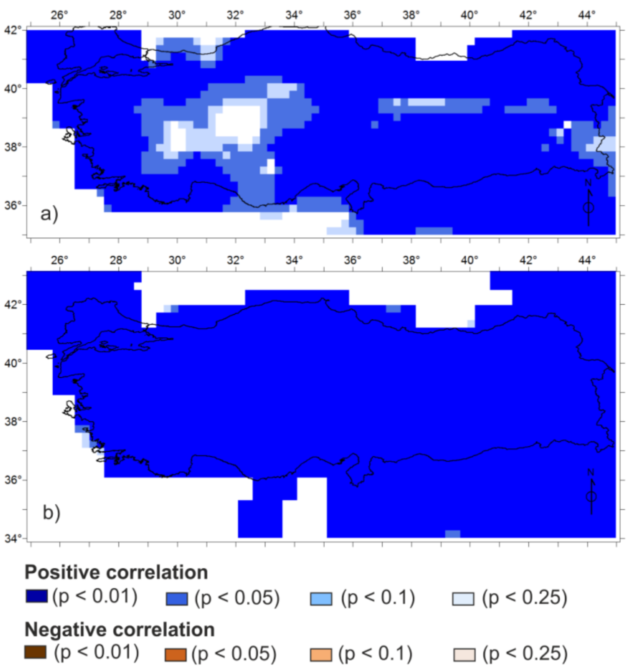

Figure 11. The correlation between total Precipitation and Runoff for **a)** ERA-Interim, **b)** Interim/Land.

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 ^{o}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 ^{o}C between 1970 and 2010 (0.33 ^{o}C per decade) in the Eastern Anatolia, where our study also indicated relatively lower warming (about 0.3 ^{o}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 there are global ET datasets available (e.g. Chen et. al., 2014, among others), a comparison with these independent 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.

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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