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Recent Trends in Global Climate Warming with a Focus on Europe

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Context

Even if the debate on whether we have reached a new epoch, the Anthropocene [1,2] or not, there is no doubt that humanity's impact on Earth has become extremely profound. The new epoch has perhaps begun at about 1950 as a result of economic growth and the resulting accelerating impacts, speeding up climate change [3,4]. Although many in the world are still sceptical about the relative impacts of human-induced climate change and natural climate variability [5], warming nevertheless continues to rise. The recent status of global warming will be described and discussed below.

Global Temperatures

In the last couple of years global CO_2 has surpassed 400ppb and global Methan (CH_4) has increased to over 1800ppb [6]. Combined with the strong El Niño conditions at the beginning of the year 2016, annual pooledglobal land and sea surface temperature deviatedby+0.94 °C on average from the 13.9 °C mean of the 1901 to 2000 base period [7]. The year 2016 consequently became the warmest year on record as third in a consecutive row of years breaking global temperature records. Similarly, global oceans reached a record average temperature anomaly of +0.75 °C.

However, temperatures vary throughout the year in 2016 depending on the region as depicted in Figure 1. Global land temperatures deviate by more than +2 °C from 20_{th} century average in February and March, declining afterwards to anomalies between +1 and +1.29 °C. The smallest difference of +0.8 °C occurs in October resulting in an annual range of 1.58 °C and an annual average of 1.46 °C. Calculated monthly mean temperature anomalies for the Southern Hemisphere were all below +2 °C and less variable (annual average 1.17 °C, max 1.47 °C, min 0.78, range 0.69 °C). Monthly mean temperatures on land in the Northern Hemisphere largely corresponded to the global picture. February to April anomalies were all above +2 °C while all other months were well above +1 °C except October were the minimum of +0.76 °C was reached. Both the annual average of 1.57 °C and the range of 1.97 °C were higher than global. Not surprisingly, the Northern Hemi-sphere contributed more than the Southern Hemisphere to overall climate warming.

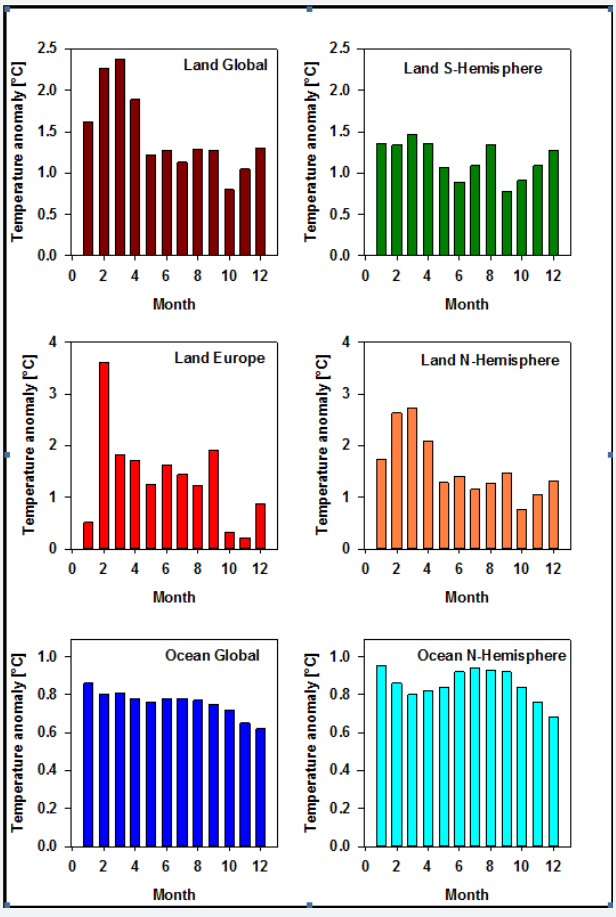

Figure 1: Monthly temperature anomalies for the regions indicated. Note differences in scale. Data for the plots were downloaded from [17].

An even greater variation was observed in monthly mean land temperatures across Europe. February has seen a deviation record of +3.6 °C which was even topped in Austria where temperatures in February were +4 °C above normal [8]. Anomalies for March to September were all well above +1 °C almost reaching +2 °C in September. Mean anomalies below +1 °C prevailed in January and October to December with a minimum of +0.22 °C in November. The resultant range of +3.38 °C was the largest of all the data depicted in Figure 1. With an annual average temperature anomaly of +1.37 °C Europe was below the Northern Hemisphere average.

Similar to other continents, various biogeographical regions in Europe largely differ in the observed impacts [9,10]. Mountain areas, particularly the Alps experienced temperature increase larger than European average. North-western Europe is faced with an increase in winter precipitation and the Mediterranean region is affected by a combination of increasing temperatures and decreasing annual precipitation, to give a few examples.

Oceans and Freshwater Systems

The great variability in monthly temperature anomalies over land surfaces is a consequence of the low heat capacity, which is much larger for the oceans and lakes. As shown in Figure 1, variation of the monthly ocean temperature anomaly is minimal decreasing from +0.85 °C in January to +0.61 °C in December which is a difference of only 0.22 °C. Temperature anomalies in the Oceans of the Northern Hemisphere are slightly more variable (range 0.27 °C). Departures from the 20th century average were greater than +0.9 °C for January and June to September 2016 (Figure 1). As a consequence, annual average temperature anomaly is +0.86° C in the northern oceans which is 0.1 °C above global average and almost 0.2 °C higher than temperatures in the Southern Hemisphere.

Similar to the oceans, climate warming is one of the greatest pressures to freshwater systems. Based on a large global data set of lakes [11], a first worldwide synthesis of in situ and satellite-derived lake data estimates that lake summer surface water temperatures rose rapidly at a global mean of +0.34 °C per decade between 1985 and 2009 [12]. This rate is about 1.4 times that of the global surface air temperature in general [13]. During the hot central European summer of 2015, lake surface water temperatures of many European lakes exceeded their 1991-2010 averages by +1 °C or more. Anomalies up to +1.6 °C were reported from three Austrian lakes. Similarly, high summer surface temperatures were observed in other regions of the world [13]. Over the past twenty years or so, warming of lake surface temperature has been observed reaching abnormal high deviations from the average in 2016 reflecting the observed warming in global surface air temperature [14].

Climate warming is also a major driver in river temperatures worldwide, but long-term investigations are lacking. Over the last century, water temperatures in major European rivers increased by 1-3 °C [15]. River temperatures in several Austrian rivers including the Danube have increased by 1.4-1.7 °C in the 20th century [16,17]. Recently average warming rates of 0.03 °C year^{-1} have been reported from several river sites in northern Germany [18].

Conclusion

Climate warming continues globally and has major implications for land, ocean and freshwater ecosystems. Here we have focused solely on temperature, not discussing the many impacts associated with warming such as ocean acidification, reduced ice-cover in the oceans and on lakes and rivers, prolonged stratification or effects on deeper water strata etc. These changes have major implications for ecosystem functioning and will ultimately affect ecosystem services such as fisheries. Climate warming increases the risk of occurrence of toxic algal blooms in marine and freshwater systems and will subsequently threaten water quality [19,20]. If climate change continues, global and local economies are likely to be increasingly affected.

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