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Temperature trends with reduced impact of ocean air temperature

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Abstract

Temperature data 1900–2010 from meteorological stations across the world have been analyzed and it has been found that all land areas generally have two different valid temperature trends. Coastal stations and hill stations facing ocean winds are normally more warm-trended than the valley stations that are sheltered from dominant oceans winds.

Thus, we found that in any area with variation in the topography, we can divide the stations into the more warm trended ocean air-affected stations, and the more cold-trended ocean air-sheltered stations. We find that the distinction between ocean air-affected and ocean air-sheltered stations can be used to identify the influence of the oceans on land surface. We can then use this knowledge as a tool to better study climate variability on the land surface without the moderating effects of the ocean.

We find a lack of warming in the ocean air sheltered temperature data – with less impact of ocean temperature trends – after 1950. The lack of warming in the ocean air sheltered temperature trends after 1950 should be considered when evaluating the climatic effects of changes in the Earth's atmospheric trace amounts of greenhouse gasses as well as variations in solar conditions.

Keywords

Climate, geography, heat balance, land, ocean, temperature, topography, valley

Introduction

The ocean is the dominating component in the Earth's climate system and all areas of the Earth's surface are to some degree influenced by ocean temperature. On land, the ocean influence depends on a number of parameters such as the distance from the ocean, local

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topography and prevailing wind patterns often exerts a moderating effect on the local land surface temperatures (see, e.g., Sutton and Dong).[1] Coastal areas typically have a smaller annual range of temperatures in comparison with continental locations, and while there are well-known differences in temperature trends for land and ocean surfaces,[2] it is more difficult to separate the influence of the ocean on the land surface temperature trends.

By locating what we have called ocean air sheltered (OAS) areas around the world and utilizing data from temperature stations in these areas, we seek to retrieve temperature data where impact of the ocean temperature trends has been reduced as much as possible. This allows us to study how temperature trends on the Earth surface behave when as much of the ocean influence as possible has been removed. As a contrast to the OAS stations, we compare with what we designate as ocean air affected (OAA) stations, which are more exposed to the influence of the ocean, see Figure 1.

The optimal OAA locations are defined as positions with potential first contact with ocean air. In general, stations where the location offers no shelter in the directions of predominant winds are best categorized as OAA stations.

Conversely, the optimal OAS area is a lower point surrounded by mountains in all directions. In this case, the existence of predominant wind directions is not needed. Only in locations with a predominant wind direction, the leeward side of the mountains can also form an OAS region.

A location far from the ocean but without any topographic shelter is not characterized as optimal OAS location for this analysis.

An example of an OAS region in Scandinavia is shown in Figure 2. Prevailing winds shown in the wind rose for Southern Swedish winds 1901–2008[3] originate from western directions and thus the east side of the Scandinavian Mountains has the characteristics of an OAS region. The prevailing winds from western directions are also typical for the rest of Sweden.[3]

Temperature stations on the northern Swedish east coast are not included in this analysis. These stations are sheltered to some degree from the Atlantic winds due to higher elevations not far from the coast. However, these stations are strongly affected by the ocean winds when the wind turns periodically. These stations are neither optimal OAA nor OAS stations.

Also, stations located near the border between OAA and OAS zones as illustrated in Figure 1 are not included in this analysis. The purpose of this analysis is to examine the temperature trends for the stations best located to show either OAA or OAS characteristics.

Since OAA areas and OAS areas often have a border zone with gradual change from one category to the other, the fraction of a land area that is OAA, OAS, or neither cannot be determined with high precision. However, we can say that an area with many mountains like

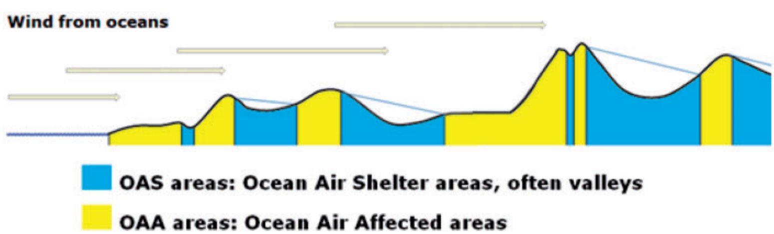

Figure 1. OAA and OAS locations with respect to dominating wind direction.

the Alps or Turkey is dominated by OAS areas, valleys where most locations have shelter against ocean winds in many directions.

The Netherlands has hardly any sheltered locations and is dominated by OAA areas. Hawaii that has mountains but few sheltered locations is also dominated by OAA areas.

Although we look at larger areas than are typically investigated in the study of micro-climate and local climate,[4] our definition of OAS and OAA has similarities in that atmospheric zones are defined by topography and dominant wind directions.

Since OAA sites are typically coasts, islands, hills facing ocean winds etc. and thus to a high degree affected by air from oceans, our OAA data are related to the marine air temperature (MAT) data.[5] In this work, we have not tried to split OAA sites into subcategories since in all our analyses, we found the different types of locations within a region to rather closely show the same temperature trend.

We have also restricted the present analysis to 10 areas distributed over all continents (except Antarctica), but similar results have been found for several other regions covering most of the Worlds land surface.

Data sources

For all individual stations, we have aimed to use yearly averaged unadjusted temperature data. During the work, we encountered the problem that numerous data series for individual stations have been regarded as outliers and thus adjusted to resemble data series from neighbor stations. This is a potential problem for the present work since OAS and OAA temperature stations can often be located just a few kilometers apart depending on the topography. Thus, to evaluate topographic-related differences between neighboring stations, we have to analyze temperature trends without "closest neighbor" homogenization procedures or similar. We need to work with unadjusted originally published temperature data set despite the obvious challenges this gives.

Since we do not expect that temperature adjustments have a bias toward OAS or OAA stations, we do not expect that working with original temperature data will introduce a bias in the present results when evaluating differences between OAS vs. OAA trends.

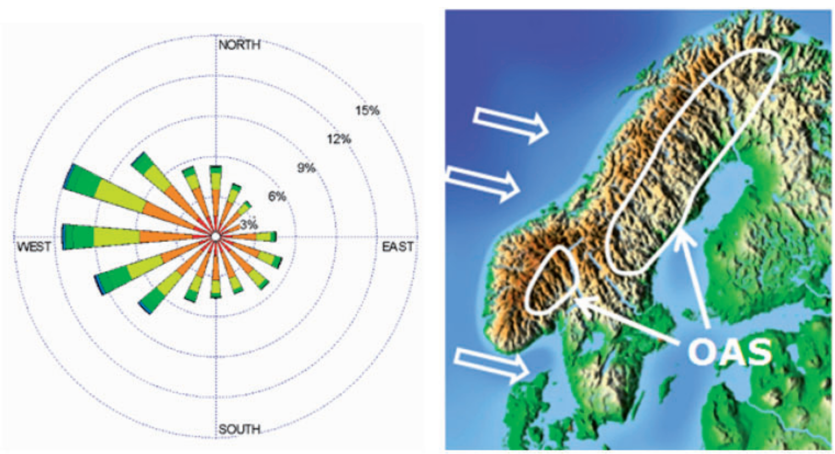

Figure 2. The optimal OAA and OAS locations with respect to dominating wind direction.

To highlight the differences between OAS and OAA temperature trends, we only work with obvious OAS locations and obvious OAA locations determined using topographic maps. Thus, temperature stations located in terrain of mixed OAA/OAS situations were avoided when possible.

Most of the data used are from the National Oceanic and Atmospheric Administration (NOAA) Global Historical Climate Network (GHCN) v2 raw temperature data set.[6] In general data were supplemented with additional data from sources such as Nordklim,[7] ECA&D,[8] BEST raw,[9] etc. to cover more years. For example, we found that NOAA's GHCN data base often cuts of data around 1990 making it necessary to sometimes fill in data from other sources.

For Denmark (1900–1983), Hungary (1934–1993), Poland (1921–2006), Norway (1900–1979), Serbia (1949–2006), Slovakia (1916–1968), Slovenia (1949–2010), and Sweden (1921–1970) some of the data used were collected from meteorological and statistical year-books, and for Denmark also records from the Danish National Archive (1900–1978) was used.

Without the use of multiple data sources, many areas of the present analysis would have few useful data set from temperature stations beginning well before year 1950 and ending after year 2000. In fact, the biggest challenge for this work has been to provide original temperature data sets. For more discussion on the interaction between climate and geography, see Reference section.[10–15]

OAS/OAA areas

A total of 10 areas were chosen for this work to present the temperature trends of OAS areas (typically valley areas) and OAA areas from Scandinavia, Central Siberia, Central Balkan, Midwest USA, Central China, Pakistan/North India, the Sahel Area, Southern Africa, Central South America, and Southeast Australia. In this work, we have only considered an area as "OAS" or "OAA" if it comprises at least eight independent temperature sets. In the following, temperature data 1900–2010 from individual areas are discussed.

As an example, we show in Figure 3 the results for the Scandinavian area where we have used a total of 49 OAS stations and 18 OAA stations. The large number of stations available is due to the use of meteorological yearbooks as supplement to data sources such as ECA&D climate data and Nordklim database.

The upper set of curves is from the OAS areas: Here the blue lines show one-year mean temperature averages for each temperature station, the red lines show the average of all stations of the area, and the thick black line is a five-year running mean of the station average. The reference period is 1951–1980.

The middle set of curves is from the OAA areas. Here the orange lines show one-year mean temperature averages for each temperature station, the red lines show average of the stations of the area, and the thick black line is a five-year running mean of the station average. The reference period is 1951–1980.

On the lower set of curves labeled "OAS vs. OAA areas," a comparison of the two data sets of stations is shown. The blue lines are the one-year average of OAS stations of the area and the red lines are the one-year average of OAA stations of the area. The reference period is 1995–2010.

We note that these Scandinavian OAS stations are not well shielded from easterly winds. Although easterly winds are not frequent (see Figure 2), the OAS area used cannot be characterized as an optimal OAS area. Despite this, we find a difference between the

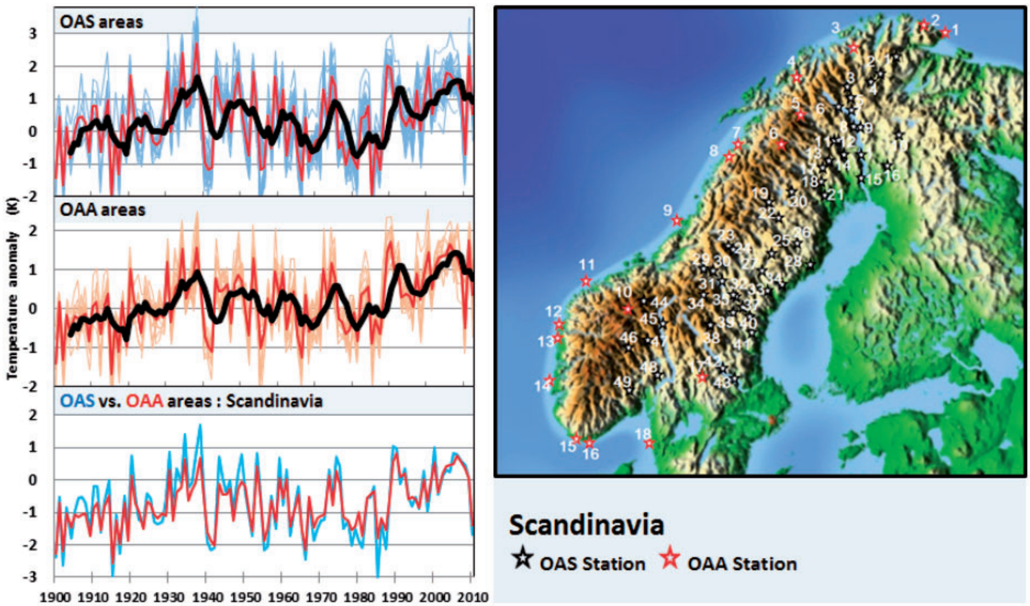

Figure 3. OAS and OAA temperature stations, Scandinavia.

OAS and OAA area temperature data. While the general five-year running mean temperature curves (left panel in Figure 3) show resemblance in warming/cooling cycles, the OAA stations show less variation than the OAS stations. We also find the absolute temperature anomalies for the Scandinavian OAS areas deviate from the OAA area with the OAS stations showing less warming than the OAA stations during the 20th century. For the years 1920–1950, we thus find temperatures in the OAS area to be up to 1 K warmer than temperature in the OAA area. In recent years, there is a closer agreement between OAS and OAA trends and even though the Scandinavian OAS data generally are warmer than OAA data for 1920–1950, we also note that in some very cold years, OAS temperatures are slightly colder than the OAA temperatures.

Another example is from Central Siberia (Figure 4), where a total of 18 OAS stations and 17 OAA stations were used. All data were taken from GHCN v2, raw data. These OAS stations generally appear situated in locations that are sheltered from winds to most or all directions. Thus, we could call this a stronger OAS data set. Again we find that the temperature trends from the OAS area show more warming in the 1920–1950 period with about 0.5–1.5 K higher temperatures than the OAA areas.

In the Central Balkan area (Figure 5), 41 OAS stations and 25 OAA stations were used. The large number of temperature stations analyzed is due to the use of data from meteorological yearbooks and statistical yearbooks supplemented with GHCN v2 raw (NOAA) and BEST raw data. The large central Balkan valley is located with mountains as shelter against winds from almost all directions. Data used originates from Poland, Slovakia, Austria, Hungary, Slovenia, Croatia, Serbia, Rumania, Greece, and Turkey. The temperature trends from the OAS area from the 1925 to 1950 period are found in most years to be around 1 K warmer than temperature trends from the OAA areas.

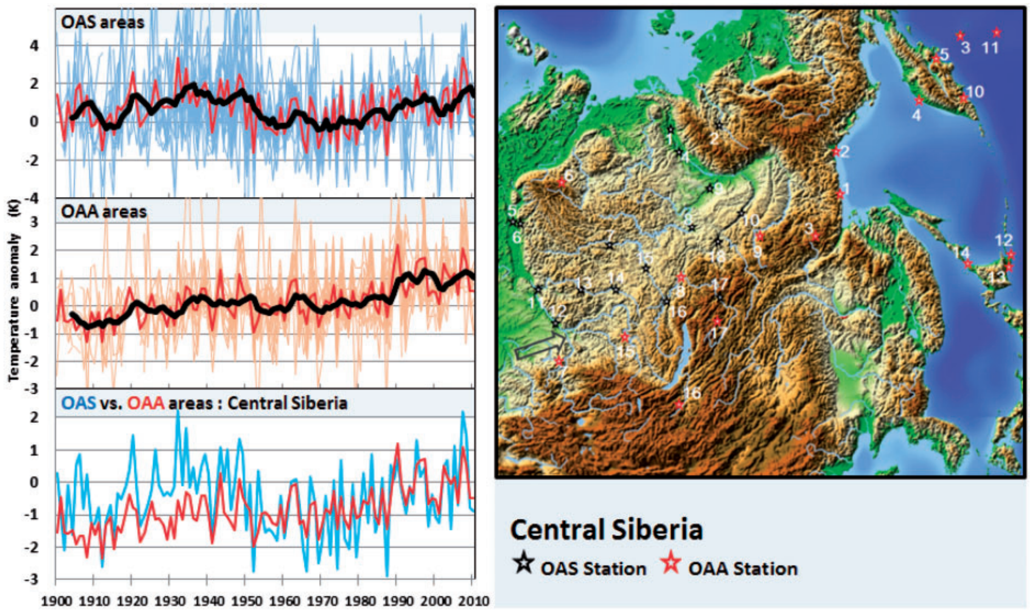

Figure 4. OAS and OAA temperature stations, Central Siberia.

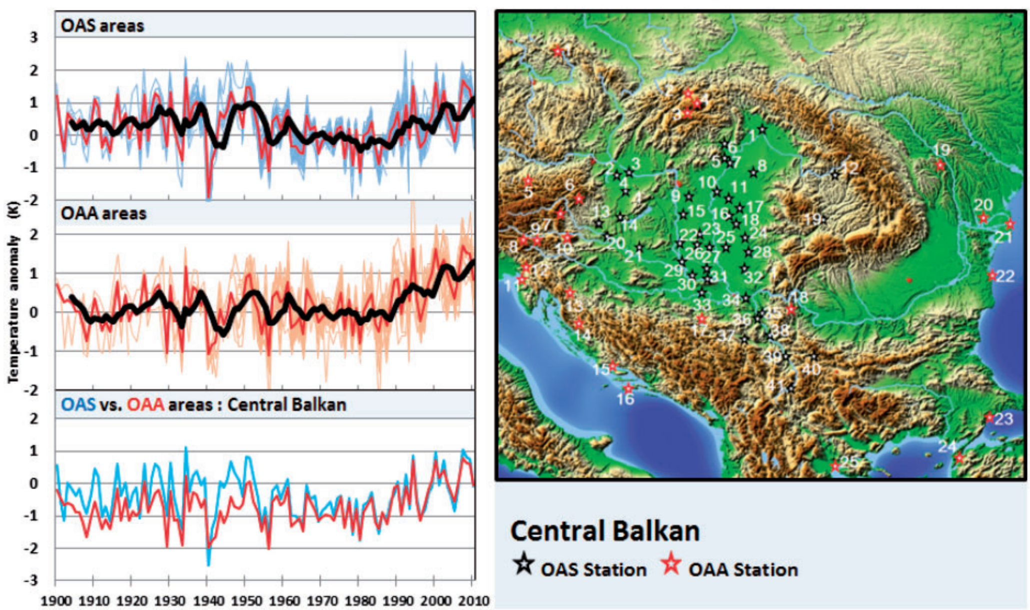

Figure 5. OAS and OAA temperature stations, Central Balkan.

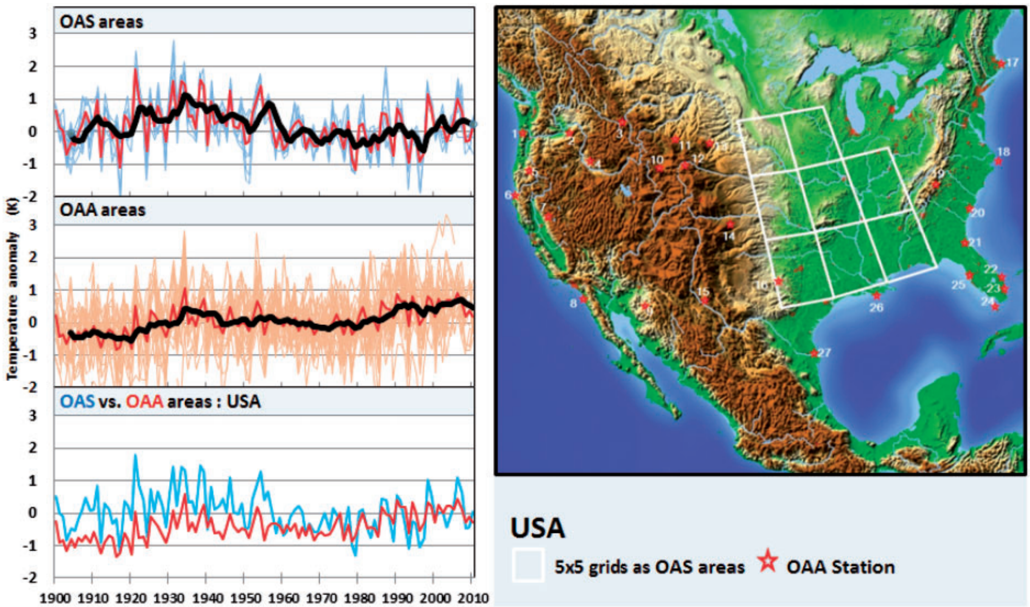

Figure 6. OAS and OAA temperature stations, USA.

For the USA (Figure 6), we defined the OAS area as consisting of eight boxes, each of size 5° × 5°. The boxes were defined as 40°–45°N × 100°–95° W, 40°–45°N × 95°–90°W, 35°–40°N × 100°–95°W, 35°–40°N × 95°–90° W, 35°–40°N × 90°–85°W, 35°–30°N × 100°–95°W, 35°–30°N × 95°–90°W, and 35°–30°N × 90°–85°W. A total of 236 temperature stations were used from this area. Full 5 × 5 grids were not found to be suited as OAA areas, but 27 stations indicated on the map were used for the OAA data set. All data were taken from GHCN v2 raw data. The OAS area in the US Midwest is well protected against westerly oceanic (Pacific) winds due to the Rocky Mountains. The US Midwest is also to some degree sheltered against easterly winds due to the Appalachian mountain range. Again the temperature trends from the OAS area as defined above show the 1920–1955 period in most years to be around 1 K warmer than temperature trends from the OAA areas.

For Central China (Figure 7), 14 OAS stations and 12 OAA stations were used. All data were taken from GHCN v2 raw data. These OAS stations generally appear situated in locations sheltered from winds from all directions and derive mainly from two larger valleys in Central China, and might thus be called a stronger OAS data set. The temperature trends from the OAS area show the 1920–1950 period around 0.5–1.5 K warmer than temperature trends from the OAA areas.

For the Pakistan/NW India area (Figure 8), 10 OAS stations and 8 OAA stations were used. All data were taken from GHCN v2 raw data. On the map, white arrows indicate possible directions from which winds can approach the OAS stations. However, it is a rather narrow range of wind directions that will allow wind from ocean to contact the stations in these OAS areas, and we therefore expect this OAS area to be fairly strong. The temperature trends from the OAS area show the 1930–1955 period to be around 1–1.5 K warmer than temperature trends from the OAA areas.

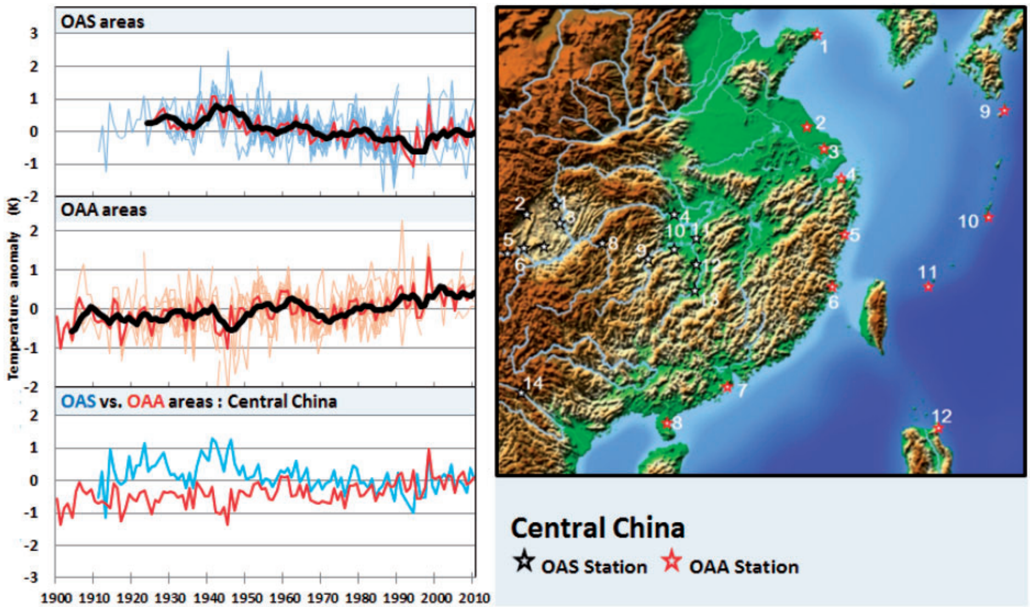

Figure 7. OAS and OAA temperature stations, Central China.

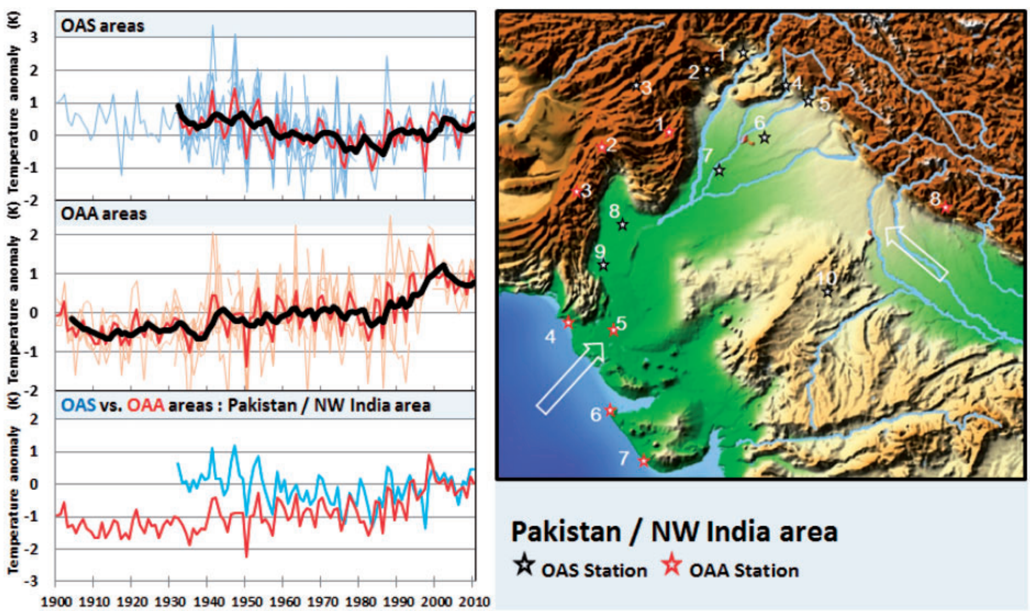

Figure 8. OAS and OAA temperature stations, Pakistan/NW India.

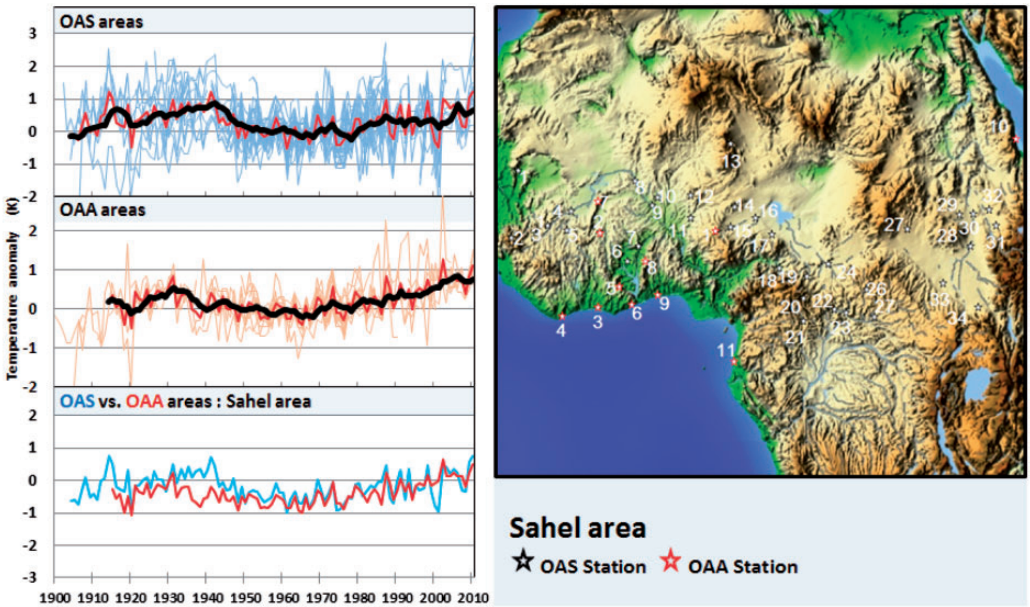

Figure 9. OAS and OAA temperature stations, Sahel area.

In the Sahel area (Figure 9), 34 OAS stations and 11 OAA stations were used. All data were taken from GHCN v2 raw data. The temperature trends from the OAS area show the 1930–1950 period to be around 0.2–1 K warmer than temperature trends from the OAA areas. The OAA datashow a weak warm peak around 1920–1930 and thus in this period OAA data to some degree resemble OAS data.

For Southern Africa (Figure 10), 13 OAS stations and 15 OAA stations were used. All data were taken from GHCN v2 raw data. The temperature trends from the OAS area as defined show the 1920–1945 period to be around 0.2–1.5 K warmer than temperature trends from the OAA areas. 1920–1930 appear quite warm compared to the OAA areas and this warm peak appears to occur earlier than in other areas analyzed. The OAS stations are generally in shelter from ocean air from all directions and thus this OAS area could be considered a stronger OAS area. The GHCN data for specifically the OAS stations in this area all ends in 2003 at the latest, and thus, the base period was set to 1985–2000 for the OAS vs. OAA graph.

For South East Australia (Figure 11), 18 OAS stations and 24 OAA stations were used and all data were taken from GHCN v2 raw data. On the map, the white arrow indicates a possible direction from which oceanic winds can approach the OAS stations. However, OAS stations were chosen in best shelters possible for the area. West of many of the chosen OAS stations, the distance to any shelter is large, thus the OAS stations also can to some degree be affected by westerly winds. Thus this OAS area is not as strong as many other OAS areas we have worked with. The temperature trends from the OAS areas show the 1925–1950 period to be around 0.3–0.5 K warmer than temperature trends from the OAA areas.

Finally, for Central South America (Figure 12), 17 OAS stations and 13 OAA stations were used. Data were taken from GHCN v2 raw data and also from the BEST raw data base. The OAS area chosen in the large valley of Central South America is well shielded

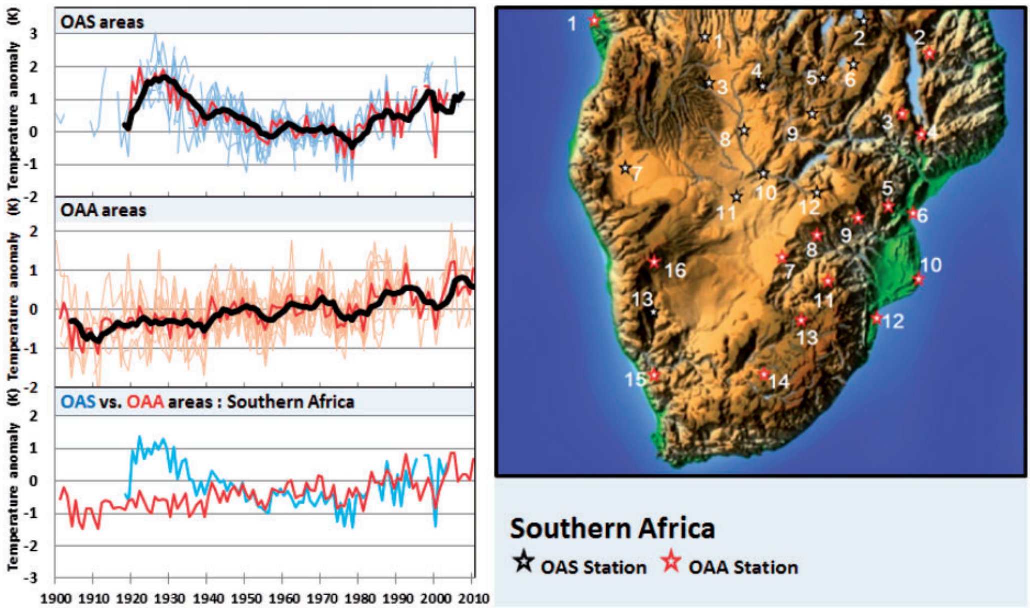

Figure 10. OAS and OAA temperature stations, Southern Africa.

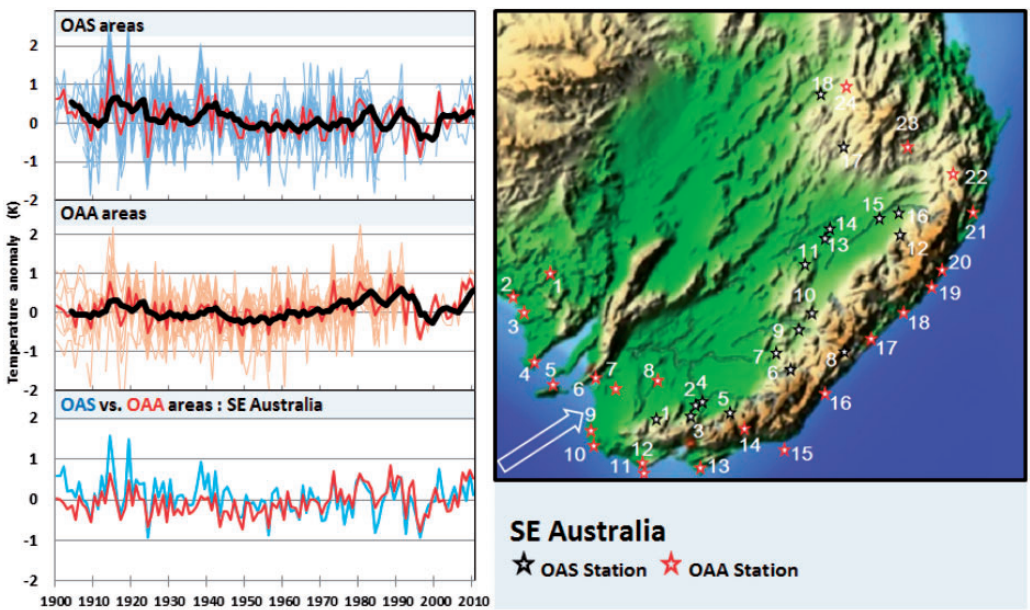

Figure 11. OAS and OAA temperature stations, SE Australia.

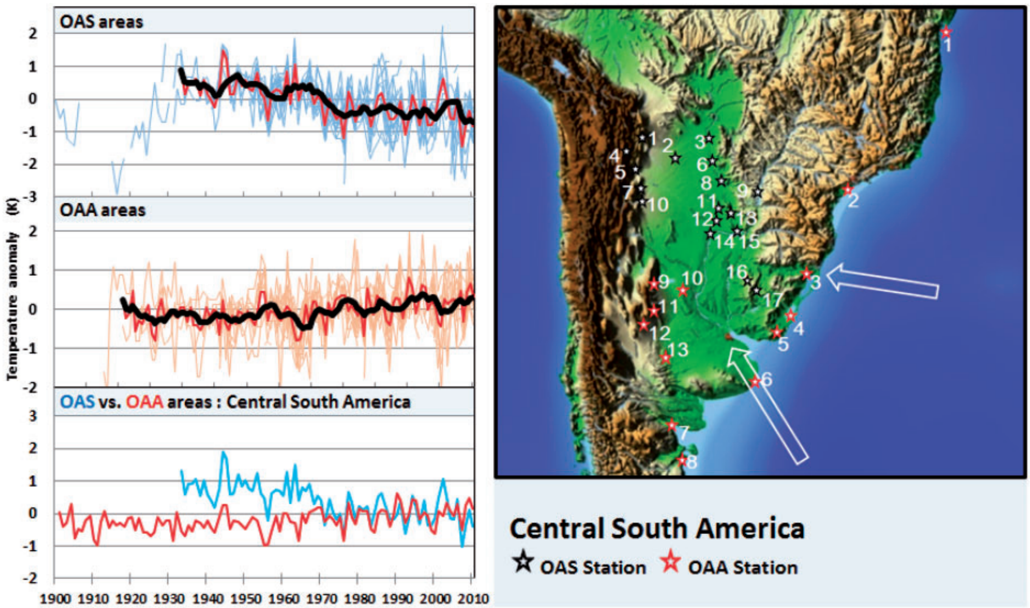

Figure 12. OAS and OAA temperature stations, Central South America.

against winds from most directions except southern and southeastern directions (indicated with arrows on the map) and thus OAS stations were chosen close to the mountain sides with the best possible shelter locations provided by the nuanced topography near the mountain ranges. The temperature trends from the OAS area as defined show the 1930–1965 period to be around 0.5–1 K warmer than temperature trends from the OAA areas. The differences between OAS and OAA areas thus persist longer for Central South America than in other areas shown in this work.

Comparison of area results

In this analysis, we have used a total of seven areas in the Northern Hemisphere (NH) and three areas in the Southern Hemisphere (SH). Although we are cautious to generalize from only three SH areas (with different nature and "strength" of the SH OAS areas), we note that for all SH and NH areas, we see that the OAS areas measured warmer temperatures than the OAA areas in the decades before 1950.

In Figure 13 we have combined average temperature trends for all seven NH OAS areas (blue curves) and OAA areas (brown curves) were areas are divided into low (0°–45°N) and high (45°–90°N) latitudes (dark colors are used for low and light colors for high latitudes). Both for the OAS areas and the OAA areas we see that the seven NH areas have similar development of temperature trends for 1900–2010. The larger variation in data from high latitudes (45°–90°N) is likely to reflect the Arctic amplification of temperature variations. OAS temperature stations further away from the Arctic (0°–45°N) seem to show less temperature increase during 1980–2010 than the OAS areas most affected by the Arctic (45°–90°N). The NH OAS data all reveal a period of heating of the Earth surface 1920–1950 that the OAA data do not reflect well.

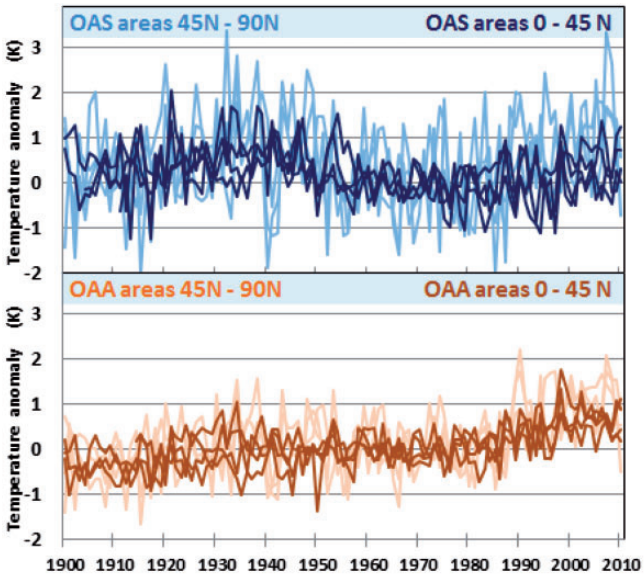

Figure 13. OAS and OAA temperature averages, Northern Hemisphere.

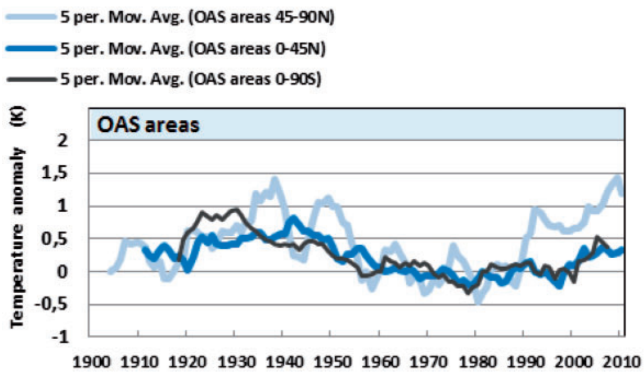

Figure 14. OAS and OAA temperatures, comparison for different latitudes.

In Figure 14 we compare five-year averages of OAS temperature trends for the latitude bands 45°–90°N, 0°–45°N, and 0°–90°S. The 0°–45°N (NH) temperature data – with less impact of Arctic variations – show a good similarity with the 0°–90°S (SH) data although with some discrepancy before 1930. We note that before 1930 the SH data set consists of only two areas and should therefore be interpreted with some caution. All three data sets show a remarkable increase in temperature around 1920. While it is outside the scope of this work to shed light on this, we would like to note that the 1918–1919 El Niño may have been more extraordinary than previously thought.[16]

The areas west of the Central Pacific are compared in Figure 15, and we observe that temperature trends for OAS data are quite similar despite the large distances between the

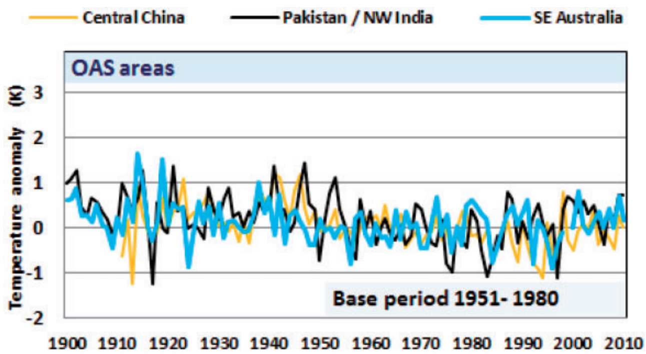

Figure 15. OAS and OAA temperatures, comparison for different regions.

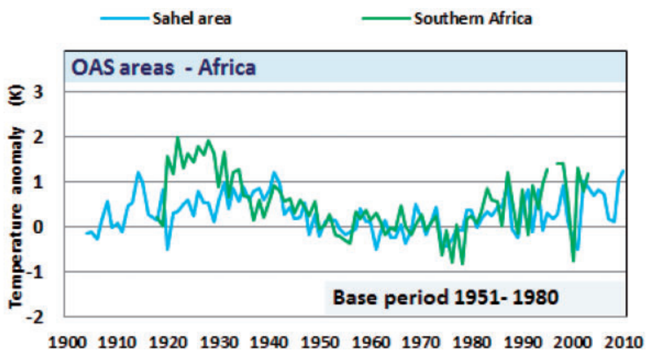

Figure 16. OAS and OAA temperatures, comparison for different regions.

areas. This could be an effect of trade winds generally moving air to the west in the tropics from the El Niño–Southern Oscillation (ENSO) area near the central Pacific Equator region. The 1930s appears globally to be a warm period, but these three areas in Figure 15 experience a relatively cold period during the 1930s. The ENSO activity was low in the 1930s and may play a role that seems to tie OAS temperatures of areas as far apart as Australia, Pakistan, and China.

From 1930 the Sahel and Southern Africa OAS valleys also show some similarity even though they are on opposite sides of the equator (Figure 16). However, the Southern Africa area with its “strong” OAS areas with ocean air shelter (OAS) to all directions shows an early quite warm period 1920–1930. Also in the 1990–2000 period, we see a tendency toward more warming in Southern Africa OAS area than in the Sahel OAS areas.The periods 1920–1930 and 1990–2000 both indicate that the Southern Africa valleys - OAS areas - are more sensitive to warm periods than the Sahel area.

For the Americas (Figure 17), we also see some similarity between the SH and the NH in OAS data until around 1985. Both the SH and NH show a long temperature decline that lasts until around 1970. After 1985, the South American data show a flat temperature trend, while the North American temperature resumes to a new temperature rise. The NH data after 1985 may to some degree be more affected by the Arctic variations.

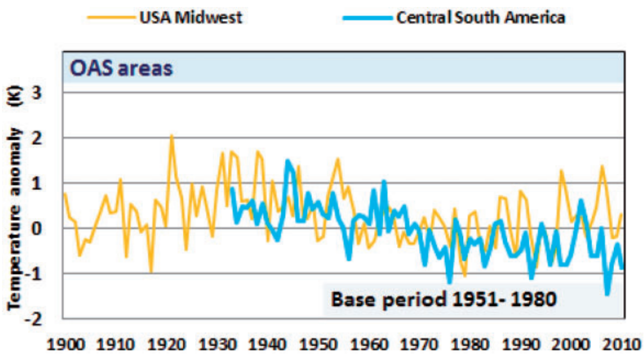

Figure 17. OAS and OAA temperatures, comparison for different regions.

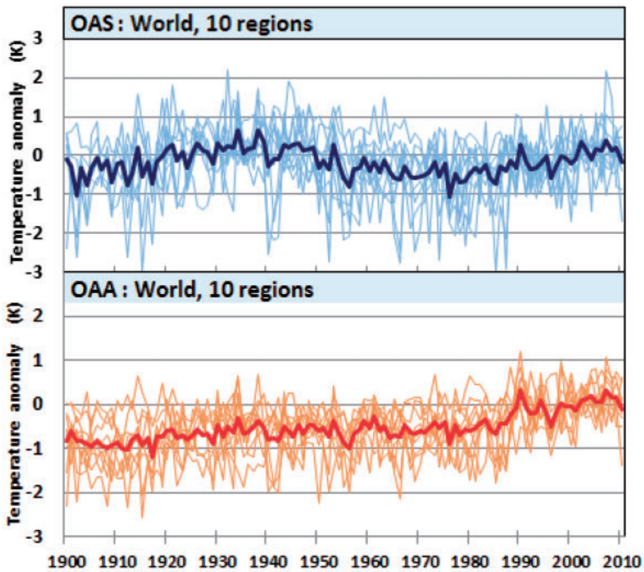

Figure 18. OAS and OAA temperatures, all regions.

Global results

All 10 OAS and OAA areas are shown together in Figure 18 with 1995–2010 as the base period. The light blue curves show the 10 regional yearly averages of OAS temperature data sets and the dark blue line shows yearly world average of the 10 regional OAS temperature trends. The orange curves are the 10 regional yearly averages of OAA temperature data sets and the red curve is the yearly world average of the 10 regional OAA temperature trends.

The global averages for all 10 OAS (blue curve) and OAA (red curve) shown together in Figure 19 to allow comparison. The most significant difference between global OAS and OAA temperature data is found during the period 1920–1950, where the OAS temperatures are generally 0.5–1 K warmer than OAA temperatures. The best agreement between OAS stations and OAA stations begins in 1970 and seems to persist since then.

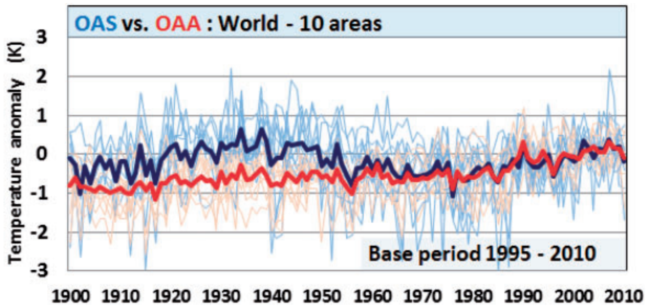

Figure 19. OAS and OAA temperatures, all regions.

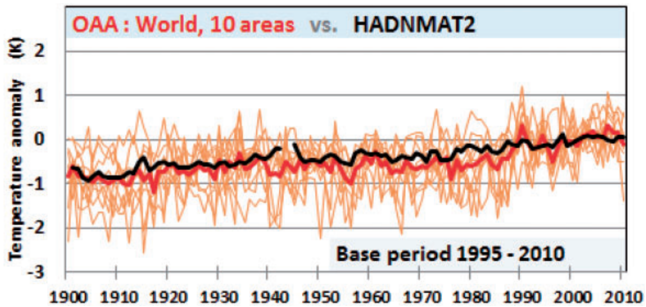

Figure 20. OAA vs. MAT temperatures, worldwide.

The global OAS temperature data reveal a period 1920–1950 with a warmer temperature over the Earths surface than the OAA data affected by ocean air trends show. The warm OAS temperatures during 1920–1950 resemble OAS temperatures of recent decades.

For the OAS areas, we find a linear temperature trend over the whole period from, 1900 to, 2010 of −0.03 K/century whereas we find 0.78 K/century for the OAA areas.

We recognize the remarkable temperature increase in temperature in the years after the 1918/1919 strong El Nino. After this warming, the OAS temperature data appear to have jumped by around 0.5 K to a new level, indicative of a shift to a new climatic regime. The OAA data fail to show this abrupt change.

The OAA data set consists of several types of locations that show similar temperature trends none the less. Some of the OAA temperature data derive from smaller islands and coastal locations and we would therefore expect that temperature trends from OAA stations should have some similarities with the global MAT data.

As seen in Figure 20, we do find such similarities between OAA data and MAT. The linear slope of the HadNMAT2 data over the period 1900–2010 is 0.71 K/century which agrees well with the linear slope for the average global OAA data set of 0.78 K/century.

The resemblance in temperature trends between global unadjusted OAA temperature data and the MAT data supports that the large-scale use of non-adjusted original data is justified for this type of analysis.

Figure 21. OAS and OAA temperature stations, Denmark.

Discussion

The OAS temperature data worldwide reveal the existence of a period from 1920 to 1950 with a temperature over the Earth surface warmer than the OAA data show and resembling temperatures seen in recent decades. We have not found any larger OAS area worldwide with a majority of the stations showing temperature trends in disagreement with this general observation.

In locations best sheltered and protected against ocean air influence, the vast majority of thermometers worldwide trends show temperatures in recent decades rather similar to the 1920–1950 period. This indicates that the present-day atmosphere and heat balance over the Earth cannot warm areas – typically valleys – worldwide in good shelter from ocean trends notably more than the atmosphere could in the 1920–1950 period.

One area not covered well in this work is the Arctic part of North American comprising parts of Alaska, Canada, and Greenland. The number of stations in Alaska with long data sets in optimal OAS areas is limited in the NOAA GHCN v2 data collection, and we have only been able to retrieve limited data from the large Canadian network of temperature stations.

For Greenland, most stations are coastal to some degree, but Bjørk et al. have found that retreat rate for glaciers terminating on land (typically hundreds of kilometers from the ocean

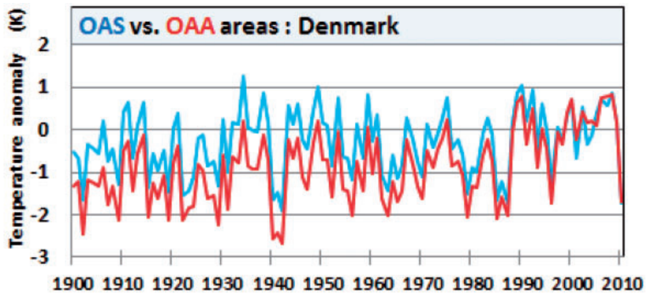

Figure 22. OAS and OAA temperature stations, Scandinavia.

and often in territory with hills and mountains giving some shelter) in the decade 2000–2010 was smaller than the retreat rate in the last warm period 1930–1940.[17] Thus glaciers on Greenland in more OAS-like conditions do not retreat faster in recent years than they did in the 1930s, whereas the opposite is found for marine-terminating glaciers in OAA conditions. In this way the Greenland area also appear to comply with the general differences found for OAS and OAA temperatures in this study.

During our examination of thousands of temperature stations worldwide, we have found many examples that OAS stations and OAA stations even with each their strong typical temperature trends can coexist few kilometers apart when the geography dictates this difference. Such examples can be found in large numbers for example in mountain areas like the Rocky Mountains, the Andes, the European Alps, the Great Dividing Range in Australia, etc.

We also found that often just a small variability in geography affects temperature station data strongly to have more OAS- or OAA-like temperature trends, where in some cases small hills are sufficient to act as a shelter.

As an example hereof, we found (Figure 21) Danish temperature stations located in somewhat OAS-like locations (marked blue on the map) to show more typical OAS temperature trends than stations located in obvious OAA areas (marked red) even though the hills sheltering the OAS stations are often only about 30–70 m in height.

The Danish OAS-like stations (Figure 22) however show slightly warmer trend 1900–2010 and less temperature variation than the other Scandinavian data shown. That is, the Danish OAS-like stations show slightly more OAA characteristics, which is no surprise since Denmark is surrounded by water. The position of the red and blue OAA and OAS areas on the map reflects the prevailing winds from West in Denmark.

Conclusion

We found that in any land area with variation in the topography, for the period 1900-2010 we can divide the meteorological stations into the more warm-trended ocean air-affected OAA-stations, and the more cold-trended ocean air-sheltered OAS-stations. The methods used in this work are meant to give a rough picture of the large differences in temperature trends between OAS and OAA stations. Some might argue against use of original temperature data or use of data from multiple data sources, but using unadjusted temperature data cannot explain the large repeatedly observed differences between OAS areas and OAA areas.

When we isolated temperature trends 1900–2010 with as little ocean influence as possible – the OAS areas – we found a warm period 1920–1950 with temperatures similar to recent decades for all investigated areas worldwide. We have not found any area with numerous OAS/Valley stations available where the majority of temperature stations show a different result.

In contrast, the OAA locations like islands, coasts, hills facing dominating ocean winds, etc., did not reflect the warm period 1920–1950 well.

A question that then calls for further analysis is why temperature stations in best possible contact with ocean air do not exhibit the warming in 1920–1950 and most likely the dampening effect of the ocean with its large heat capacity has an impact.

Around year 1900 - after the little ice age - the oceans had been affected by cold conditions for centuries. The oceans (and thus OAA data) after 1920 responded slowly to the rather sudden strong warming of the Earth 1920–1950 while the warming 1920–1950 was detected well and instantly in OAS data.

The implication from this is therefore that new and fast-changing heat balances over the Earth are better captured in temperature data when no large volume of water as larger lakes or oceans can act as a heat buffer absorbing and delaying faster changes in the heat balance over the surface. The difference between OAA and OAS temperature data may thus help in determining the effect of internal climate variability which appears to be most significant in the ocean-affected stations.

In contrast, we would expect the OAS regions to show a temperature signal which was less affected by internal variations in the climate system. The OAS temperature data are therefore best suited data type we have to reflect variations of the heat balance over the Earth.

Therefore, the lack of warming in the OAS temperature trends after 1950 should be considered when evaluating the climatic effects of changes in the Earth's atmospheric trace amounts of greenhouse gasses as well as variations in solar conditions.

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