GLOBAL AEROLOGICAL DATABASE FROM THE LAST 40 YEARS RADIO SOUNDING

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ABSTRACT. Global aerological database from the last 40 years radio sounding. We have downloaded upper-air observation data over the period of 1973 to 2013 in TEMP reports of all radiosonde stations and pilot-ballon stations from a free American website. WMO keeps register of around 750 radiosonde stations in operation today in the Global Observing System. The purpose of this database is to prepare upper-air case studies and statistical analyses. Not only data of the main isobaric surfaces but of the significant levels (marked points) are available as well, so the whole vertical profile of temperature, humidity and wind can be reconstructed. It enables investigation of climate of isohypses, short and long term variation in the height of tropopause, inversions and isotherms in the future. In the starting phase we can analyse the spatial and temporal variation of data capture that can result interesting outcomes. Since radio sounding is a costly observation method economic considerations of certain countries are reflected in the frequency or even suspending of the measurements. On the other hand several developing countries perform extended upper-air monitoring.

Keywords: upper-air, radiosonde station, aerology.

1. INTRODUCTION

Radiosondes – expendable, balloon-borne devices – are mainly used for measuring pressure, temperature and humidity of the air, as well as wind speed and direction up to heights of 30 km or more. Special sensors can also measure solar and terrestrial radiation, the vertical distribution of ozone, conductivity of the air, radioactivity etc... The name “radiosonde” apparently derived by a German meteorologist, Hugo Hergesell from a combination of the words "radio" for the onboard radio transmitter and "sonde", which is messenger from old English.

Robert Bureau flew his first radiosonde equipped only with thermometer on 7th January 1929 in France (Dubois et al., 2002). According to other sources of literature he was who coined the name “radiosonde”. The first radiosonde measuring both temperature and air pressure was successfully launched by Molchanov in Leningrad on 30th January 1930 reaching 8900 m. In May of the same year in France and Germany were also launched radiosondes. Finland started radio sounding in 1931, Switzerland and Canada in 1934/35, the USA in 1937 (Zaitseva, 1993). Regular radio sounding activity is being carried out since 1949 in Hungary, firstly only in Budapest, later joined Szeged in 1961 as well.

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Since 1957 all stations have made their soundings at the same times: 00.00 and 12.00 UTC (occasionally 06.00 and/or 18.00), although many of them have reduced soundings to one per day because of budgetary constraints. Countries launching operational radiosondes are members of the WMO's World Weather Watch program; as such they freely share their sounding data with each other. Shortly after an operational upper-air sounding is completed, a standard data message is prepared and made available to all nations using the Global Telecommunications System. These TEMP messages are transmitted in a universal format that reports meteorological conditions at various standard or so-called mandatory (pressure) levels as well as at significant levels, which represent levels where prescribed changes in meteorological conditions occurred (Holton et al., 2003).

2. MEASUREMENT TRENDS IN THE WORLD AEROLOGY NETWORK OVER THE PAST 40 YEARS

2.1 In Hungary

According to the most accepted international practice radiosonde observations were carried out in Hungary two times a day both in Budapest and Szeged in the 1970s. In the 1980s Budapest shifted to four radio soundings a day while in Szeged it remained two per day. Similarly to Budapest radiosonde stations launching 4 sondes a day occurred in the region's (Czechoslovakia, Romania, GDR, Soviet Union) cities of emphasized political importance. After 1990 frequency of our measurements decreased to the level in Western Europe that means in Budapest only two radiosondes per day were launched until 2011. Later on in Szeged there was only one ascent a day and for a while only wind measurement was performed at noon and a total sounding at night.

After using German, Finnish and Hungarian radiosondes Soviet RKZ-system was introduced in 1976 and operated until 1991 with Soviet Meteorite-2 radars (Fig. 1). Preparation and carrying out of radiosonde observation required much bigger staff at that time: 3 experts/shift performed this aerological observation, furthermore a radar engineer and a radar technician supported them. Three experts worked in the radiosonde calibration laboratory with calibration and checking of radiosondes and balloons. The former upper-atmospheric measurement technology differed most substantially from the latest one in that targeting of radiosonde was made by a (parabolic) antenna, the radiosonde gave response signal, it was the third coordinate so that pressure sensor was not necessary in the radiosonde. After 1990 Väisälä technology related to the "height-pressure hydrostatic build-up" turned and did not calculate directly the vertical coordinates by polar coordinates, but measured the air pressure and the actual height of the readiosonde is calculated by the hydrostatic principle. Determination method of the horizontal coordinates changed several times along this principle, so until the 1990s Omega navigation system (ultra long waves, VLF) was used then Loran-C that has the same principle, only its wavelength is shorter so its radius is more limited. Certain difficulties occurred in the latter so penetration of the satellite-based GPS (Global Positioning System) came at just the right moment. Three major advantages of the GPS-based techniques are the high accuracy and precision of the wind measurements, the worldwide coverage of GPS and the reasonable price of the receiver inside the radiosonde as consumable supply.

The Väisälä radiosonde operating by GPS is highly prevalent worldwide, however, the newer device is now in the experimental stage has no air pressure sensor, because the spreading of GPS made easier determination of all three coordinates.

Although WMO's metadata base gives some information we do not know which radiosonde in the specific countries applied is. At many radiosonde stations like in Hungary as well other types or brands are used, changes in types cannot be tracked exactly in international bulletins. But pretty graphic picture emerges if we focus on how the frequency of measurements associated with economic systems of a country and how attitude its politics has to natural science, how the government leaders feel important the precise knowledge on the overlying air. The concept of exact knowledge is important here, because according to the present state of metrology, a number of measurements, remote sensing methods are known that in theory, and it is important to stress that so far only with a certain approximation, have the ability to replace radiosonde making direct detection for remote sensing methods.

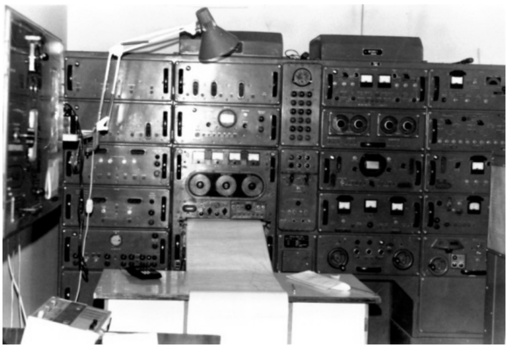

Fig. 1. The indoor unit of Meteorite-2 tracking and receiving radar in Budapest

2.2. International overview

Looking into our 40 years data base (1973-2013) we find that data are starting to come in large quantities from mid-1973. Relatively many radiosonde stations had been working even that time, but display of measurements at this time and for a long time as well has been featured by "significant level centeredness", so that to the curve of temperature or humidity is assigned an intermittently straight curve, which according to its definition aims to cover the least amount of space between this intermittently straight curve (significant level curve) and the original, physically continuous and differentiable measurement curve.

Significant level curve had high importance several decades ago because level of IT did not enable to archive great amount of data or transmit them online. A and C parts of a TEMP message are also derived basically from the significant level curve, and according to a possible approach the significant level curve stretches around the whole ascent, that is the aerological measurement. The standard pressure levels can also be interpolated from that, especially if series of significant levels ends after reaching sufficiently stringent threshold number.

After the modest measurement program of the 1970s, in the 1980s both the daily frequency and spatial density of radiosonde measurements increased. Obviously the development of technology was also present. In the 1980s still existed and even increased the opposition between the Western and Eastern political and military blocks, therefore the northern hemisphere's major powers, as well as smaller states connecting to NATO and Warsaw Treaty operated in both space and time spectacularly dense measurement network for strategic and prestige reasons. It follows the example mentioned earlier that 4 ascents a day were not uncommon in Central and Eastern Europe (Fig. 2.).

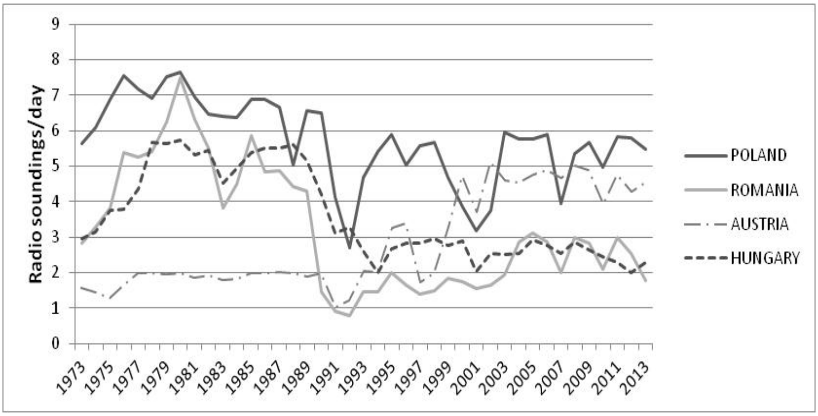

Fig. 2. Trends in the frequency of radio sounding in Central Europe

The third world demonstrated more modest result at that time. Australia, the strongest state of the southern hemisphere only gradually developed the radio sounding program, which reflected both in number of stations and frequency in time. Argentina showed a relatively stable picture in the period under our review, although significant increases and decreases can be seen in measuring program of individual stations over the decades. It is remarkable that although this regional power facing enormous economic crisis and political disturbances, but it paid relatively big attention to this branch of the natural sciences. Similarly to Brazil, who considerably lifted the number of active stations. Mexico also demonstrated big efforts. The picture is substantially less favorable in the smaller Latin American countries, who may think their territory is so small that it is enough if only their neighbour makes radio sounding. What can happen if there are a lot of small countries nearby? It is a big problem in Latin America and even bigger in Africa.

In the black continent only Algeria, South Africa and Egypt carry out serious measuring program while in Central Africa there are “white spots” of several million km^2, one oasis is Nairobi in Kenya and there is certain activity at the equatorial western coasts. Interestingly, Madagascar compared to his similarly developed fellows also shows a pretty good picture, but since 1987 has limited to 'only' two stations.

Considering radio sounding in Asia, it shows differences in the direction of west-east. While in the sparsely populated countries in Western Asia there are only sporadic stations, in Eastern Asia the network is much denser. There are certain exemptions, such as Turkey – located mainly in Asia, partly in Europe – carrying out very good and spatially consistent measurement program. To great surprise the extremes infested Afghanistan for most of the time performed measurements at one-two stations though between 1988 and 2002 there was hardly any measurement (Fig. 4). In 1979, the last year of the Afghan Kingdom frequency of the sounding peaked, then Soviet invasion brought essential drop. On the other hand, Myanmar is the negative example in Eastern Asia having no aerological station at all. Measurements are done in particular way in Indonesia: only at 3-4 stations rhapsodically, as if the psychology of people in this tropical country would be displayed by the way in which they relate to the frequency of upper-atmospheric measurements. In the background we should suppose the Indonesian Meteorological Service may have limited resources comparing with the size of the country on the one hand, on the other hand, in the world of tropical typhoons that is understandable, if upper-air measurement is done depending on the weather situation, whether to launch a radiosonde or not.

The example of the existing socialist countries is remarkable in Asia. They are at the forefront of doing regular observations in wide geographic scope. This applies to China, North Korea, Vietnam, and the former socialist Russia, while the newly independent states separated from the former Soviet Union have drastically decreased their observation (Fig. 3).

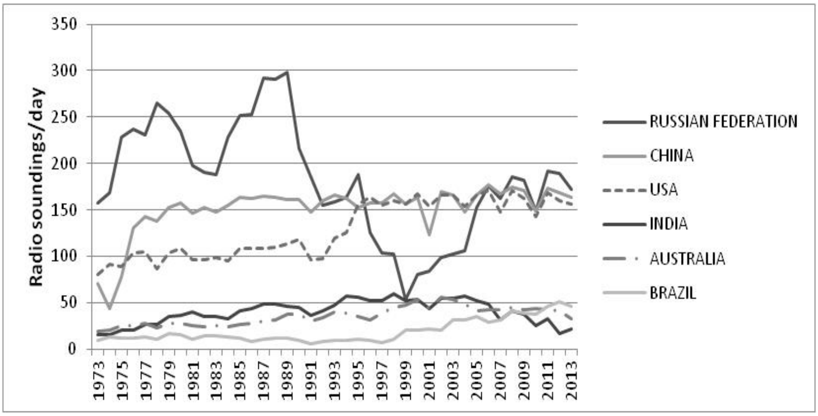

Fig. 3. Trends in the frequency of radio sounding in some large states

Mongolia continues its measurement program with one ascent per day in the capital, though it is less than in the 1980s. However, followers of the state socialism in the Western Hemisphere with respect to their Asian friends show negative examples in the field of aerological measurements. Cuba, their gonfalonier and forerunner stopped the measurements after 1994 and substantially did not restart them even when they found a rich ally: Venezuela. Venezuela totally ceased the aerological measurements between 1998 and 2006 and since then only San Antonio del Tachira launches one radiosonde per 3 days in average. Bolivia performed aerological measurements only until 1995. Colombia – not included in this political circle, but falling in the same weight class as Venezuela – whose oil wealth is only a fraction compared to the eastern neighbour, performs one ascent a day in Bogota, while in Leticia Vasquez in San Antonio only one measurement per two days in average. Mexico is the lead country in Central America, since 1992 it has been performing daily more than one ascent at 10 stations.

Let's look around in the Arab world! The wealthy Saudi Arabia did measurements in the 1970s only rarely, but since 1983 the measurement program has rapidly expanded and is stable for the last 25 years, eight stations perform one-two measurements a day. The Saudis were rich before 1980, too, then why did they not measure? The answer may be that they could have measured, but maybe in this country such demand could not even have conceived to the authorities, or by them. Similar may be the case in several other North and West African countries. So the oil-rich Libya for example measured in the first half of the period examined, however, later on contrasted with the Saudis, no progress has been made, even after 1991 a large descending line occurred, which led to the end of measurements in 2004. Unfortunately, the measurements have not started after the fall of the dictator so far. Jordan, however, shows several decades of stability, while Syria after 1995 even in Damascus has done no meaningful measurement (Fig. 4). During the Iran-Iraq War (1980-1988) the upper-air observation data – if any – were not publicly available.

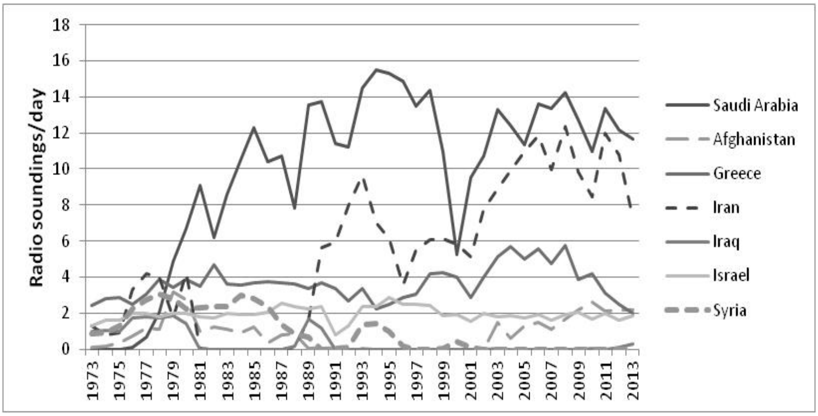

Fig. 4. Trends in the frequency of radio sounding in some countries

In sub-tropical, arid zone of North Africa and in the Near East and Middle East some of the wealthier countries do not measure likely because their weather produce relatively few unusual, stormy moments.

The situation is different in the North and South Pole region. There are many reasons for dense observations and corresponding apparatus is usually available for this purpose. However, the population density is low, so the presence of the countries is limited, and there are huge marine areas. Nevertheless, where stations exist, there in the vast majority of cases, reliable data sets are received.

Same can be said of the seas and oceans as well. The former dependent territory system of the great powers has significance, which has not been eliminated related to the islands with respect to the continental colonial system. The small lands located far from the continents have great significance, as they often represent millions of square kilometers of area, on the other hand radio sounding from a sufficiently small island does not include disturbing effect of land on the climate that is measurements observe the undisturbed climate over the sea! These measurements help to investigate evaporation from the sea surface, track of the water vapor up to the free atmosphere and falling back after condensation. This promises to be not so simple phenomenon. According to some considerations the long-term variation of the temperature at the sea-atmosphere border would be in approximately linear relation with the rate of evaporation. Let's consider the inversion layer formed near the surface is able to restrain the extent of moisture from reaching the higher atmosphere, similarly to the open lid and the lid closed in case of cooked food. All this is of vital importance to us, people living even hundreds of kilometers far from the sea, because the amount of moisture transported by the high flow channels over the sea obviously has an impact on the level of rainfall over the continents.

The stream trends above the sea have been considered as a possible cause of precipitation climate evolution over the continents. Let's consider now another large segment of climatic significance, as how upper-air climate affects the mountain climate. It is obvious that climate of habitats lying in the high grounds is related to upper-atmospheric parameters measured regularly at the respective height. But the situation is somewhat different if we take the undisturbed free atmospheric condition, and a mountain slope is another case, where in the angle of the surface relative to the horizontal has obviously a significant role. But the more we talk about insular terrain elevation, the closer the relationship between the free atmosphere and temperature and wind measured on the hillside. In the case of ridge-type, approximately two-dimensional orographic anomalies the state of the free atmosphere surrounding the luv and lee side that is the rising and falling flow zone is not indifferent. An important task will be to examine the data series in the mountainous areas, such as the variation of temperature compared to the radio sounding data measured geographically not too far at the same time and elevation.

We live at the bottom of the atmospheric ocean that is investigated by climatologists, which thin layer is the border of the Earth and the atmosphere. This boundary surface comprises an ensemble of several impacts, but obviously processes taking place here cannot be separated from processes occurring above, as the vertical currents of short-and long-wave radiation, pulse and other diagnostic parameters in space, especially in the vertical dimension pass of. All these are considered stationary processes at climatic time scale and implement a number of quasi-equilibrium states, however, sometimes lead to surprising exceptions. So the climate in areas around Europe, that is, between the sea and the continent shows several singularities, such as the wet climate in Montenegro comparing with the dry climate of the other Mediterranean coasts. It is obvious, that changes taking place in the whole three-dimensional atmosphere exert significant impact on the climatic variations of a country or geographical area

3. CONCLUSIONS

In this paper we give an overview on the radio sounding in Hungary over the last decades as well as the measurement techniques. Remote sensing methods have also been mentioned. Then we are surfing around the earth reviewing the available radiosonde measurements were performed in the 40-year period and trying to explore the regional characteristics. We tried to find the correlation between the systematic measurements, expanding or shrinking trends, and the economic and political situation or the strategic considerations in the specific states. At the end of the paper some meteorological conclusions, assumptions are written to argue for the importance of upper-air measurements in the present and in the future. In fact, a great variety of remote sensing techniques are developing, but a number of developed countries, which, although can afford operation of the new electronic systems they do not stop the radiosonde measurements so as to obtain sufficient high-quality input data for the forecasting models.

The data base downloaded from the website of University of Wyoming ensured the source of this study. Our further purpose is to carry out aeroclimatological investigation by the help of this data base.

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