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Chapter 9

METEOROLOGICAL MAPS: HOW ARE THEY MADE AND HOW TO READ THEM. A BRIEF HISTORY OF THE SYNOPTIC METEOROLOGY DURING THE LAST THREE CENTURIES

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ABSTRACT

Meteorology is an interdisciplinary science, which uses the laws of physics, mathematics and chemistry to simplify the understanding of the process occurring in the Earth's atmosphere.. One of the most widespread and used ways of representing meteorological products is definitely that of maps. Millions of people consult the different types of existing weather maps on a daily basis. Most of users do not know how the maps are created nor the exact meaning of the symbols represented in it. The purpose of this paper is to try to answer all these questions. In order to better understand the topic, we will start from the description of the history of meteorology during last 300 years, up to the description of the modern methods of production of the maps, by means of computer and specific software.

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1. INTRODUCTION

It is well known that Meteorology is a highly interdisciplinary science that by means of the laws of physics, mathematics and chemistry allows to understand the atmosphere of the Earth together with its processes and its structure.

Since ancient times, ancient civilitazions observed and recordered weather conditions in order to support the agricultural activity and, also, to satisfy own curiosity about the world. In particular, over the centuries the atmosphere has been object of study for different purposes, such as agriculture, military defense and early warnings for severe weather systems like tornadoes and hurricanes. Thanks to the scientific computing development and to an increase of the total number of meteorological observations in a day, it has been possible to improve the forecasts and to better understand the atmosphere [1].

Nowadays, more than a billion people use meteorology by means of countless smartphone apps, which allows them to know with a week in advance, the weather forecast at any location on Earth. Other thousands of people on the ground, on board ships or flying on airplanes, use the most sophisticated and complete meteorological products that are meteorological maps. Apart from rare exceptions, anyone at least once in their life has had to deal with a weather map. The main television channel broadcasting meteorological programs and weather forecasts, do so using and showing to their audience simple meteorological maps, which are able to transmit the information, in an easy and immediate way, to an audience not always sufficiently literate. In the USA there is even a television channel (The Weather Channel) devoted entirely to weather forecasts on which, 24 hours a day, are alternated valid weather forecast for every corner of the World and documentaries on meteorology. This enormous pervasiveness of meteorology and its applications in the life of most of the inhabitants of the planet is opposed to a poor understanding of weather phenomena and the laws that lead the Atmospheric Sciences. The aim of this paper is to explain what a meteorological map is, what information it contains and how it is done. Moreover, it is explained which and how much data are needed to produce a meteorological map, how these data are collected from the various meteorological stations distributed on the earth's surface and finally how these collected data are plotted and represented on the maps.

2. A Little History

2.1. Galileo and the Court of Ferdinand II

In a cultural and political environment dominated by forms of absolutism, the European science of seventeenth century, opened with the extraordinary figure of Galileo Galilei. Astronomer, mathematician and physicist of recognized standing. The great scientist opposed a methodology based on tangible observation of natural phenomena and the consequent verification by means of suitably programmed experiments of the assumptions arose from the observation itself to the conception of science that was until then based on abstract deduction and blind obedience to the authority of the philosophers of which notably Aristotele. It is the beginning of the experimental method and the overcoming of the boundary line between the ancient and modern science. In the field of meteorology, the first relevant result of Galileo innovative quantitative science was undoubtedly the invention, refinement, and the subsequent use of main measuring instruments such as thermometer, barometer, hygrometer and rain gauge. At the school of Galileo, founded in Florence in the seventeenth century under the patronage of the Medici, the instrumental meteorology begins. This science elevates the study of atmospheric phenomena from merely qualitative to quantitative. The interest of Ferdinand II, Duke of Tuscany, for instrumental meteorology, laid the foundation for the subsequent quantitative and systematic study of atmospheric phenomena. The master glassmaker Moriani, built numerous thermometers each other identical, known universally as “small Florentine thermometers.” Their distribution to Italian and foreign observers, gave a further impulse to the establishment of a synchronous meteorological observations service at international scale (Figure 1). At this early stage, the tasks of the observers were to conduct observations and measurements of some general air condition and temperature taken several times a day, but always at the same time. The assignment of observers went to religious since they were used to a very methodical way of life. Early observers arose in Florence, Vallombrosa, Cutignano, Bologna, Parma, Milan, Paris, Innsbruck, Osnabruck and Warsaw. Florence hosted the first historical data recorded: two very short ones, one from 26 November 1657 to 8 May 1658, the other from 12 February to 7 April 1658; a third one, that was much longer covered the period from 15 December 1654 to 31 March 1670 and is known as the Convent of St. Mary of the Angels series. Two years later the observers received also barometers, hygrometers and anemoscopes. Luigi Antinori, court chaplain, was coordinating survey operations from Florence. In addition to measuring instruments, Antinori provided to the observer the operating instructions and the forms to fill with the observations. The National Library of Florence keeps Galilean Manuscripts containing many of these forms reporting the month and the year to which the report was done. The introduction of systematic objective observations instead of discontinuous subjective estimates, is in use until now, and it has represented for meteorology the key moment, the final break from all his previous methodological approach and the consequent recognition of the discipline as a real science [3-4].

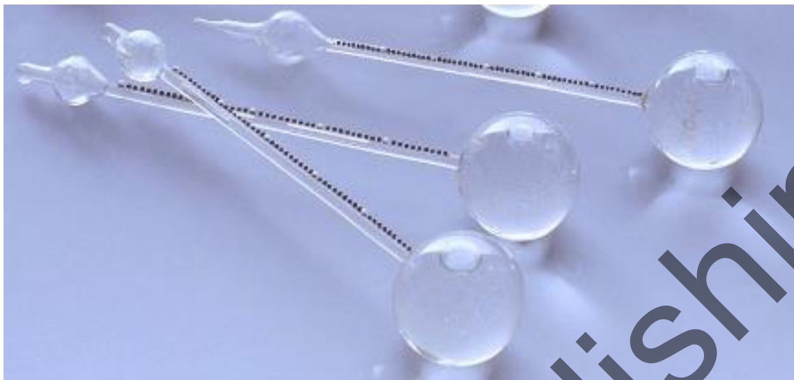


Figure 1. Thermometers designed by the Grand Duke Ferdinando II de 'Medici, the cinquantigradi thermometers were generally used to learn about the mutations of warm and cold air both outdoors and in closed rooms. The academics made wide use of this type of thermometers, which had the advantage of being comparable between them, especially for systematic meteorological observations.

2.2. Meteorology in 1800

From the beginning of XIX century, the atmosphere is investigated from a strictly physical point of view, according to the laws of mechanics and thermodynamics rising.

One of the first contributor was the French physicist Gaspard Gustave de Coriolis (1792-1843). In formulating the acceleration theorem of relative motion for mechanical systems in rotation, he introduced the concept of complementary acceleration and the corresponding force "apparent" that bears his name, force that is acting perpendicular to the motion, resulting in deviant effect on motion itself. Despite such composed force plays a fundamental role in the dynamics of the atmosphere, it should be pointed out that its author is not paid particular attention to the possibility of applying it in such a fluid. The American researcher William Ferrel did so, thus justifying the curvature of the air currents around the centres of high and low pressure and thanks to his studies on the general circulation of the atmosphere, meteorology fully entered into the domain of fluid dynamics. The period that saw very intense theoretical development, was the decade 1880-1890, with the physical and mathematical studies of German Hermann von Helmholtz. Starting from Euler form of the general equations of hydrodynamics, the scientist undertook an analytical study of the equilibrium conditions of the surface of separation between air masses. To explain the origin of the fronts and depressions, he called into question the concept of hydrodynamic instability that will find its application in the theory of the polar front of the Norwegian Meteorological School. Von Helmholtz to formalizes the first law of thermodynamics in 1847, with the publication of a study on this subject. The discovery of the possibility of transforming the work into heat and vice versa, opened a new field of research: the study of the thermodynamic properties of the atmosphere. In parallel with developments of atmospheric physics, the nineteenth century saw significant progresses in statistical studies of the major climatic factors, primarily temperature and pressure, which was followed by studies in the fields of storms and cyclones. The American engineer William Redfield, was the first one to develop the theory of nature swirling and the direction of rotation of the winds in cyclones: counter clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. The Redfield theory of cyclonic storms, was opposed by another theory based on the convection and the centripetal motion formulated by compatriot James Pollard Espy. Unlike Redfield who had preferred not to speculate explanations about the genesis of the cyclones, he hypothesized a strong upward motion at their centre, at minimum pressure, which consequently draws air from all directions. Pollar Espy was not fully knowledgeable on the effect of deflective force due to Earth's rotation while he had fully understood the role of water vapour in atmospheric thermodynamics [5-8]. For a long period this theory was the basis for the later theories formulated in convective cyclones both in America and in Europe. The study on the development of cyclones was deepened by both the German meteorologist Heinrich Wilhelm Dove and the English Admiral Robert Fitzroy. Both reached the conclusion that cyclones develop at the border between the polar currents, cold and dry, and the tropical currents, hot and humid and are that they are organized into families. Instead, only few studies have been done on anticyclones, perhaps related to the fact that they are normally accompanied by sunny and stable weather. In 1863, the Englishman Francis Galton discovers the particular characteristics of the anticyclone and the predominance of light winds at the centre, their clockwise rotation and the subsiding movement of the air column. Other than these two main types of pressure systems, the English meteorologist Ralph Abercromby will add another 5 secondary ones, namely:

- *Ridge*: high pressure area that, with isobars generally rounded or at an acute angle, and protruding from an anticyclone towards a low pressure zone;
- *Trough*: low-pressure corridor with isobars at an acute angle juts out from low pressure area;
- *Secondary cyclone:* low-pressure secondary centre;
- *Saddle*: the relative low-pressure area between two depressions and two anticyclones
- *Slope*: area characterized by pressure regularly decreasing and bounded by isobars almost straight and parallel.

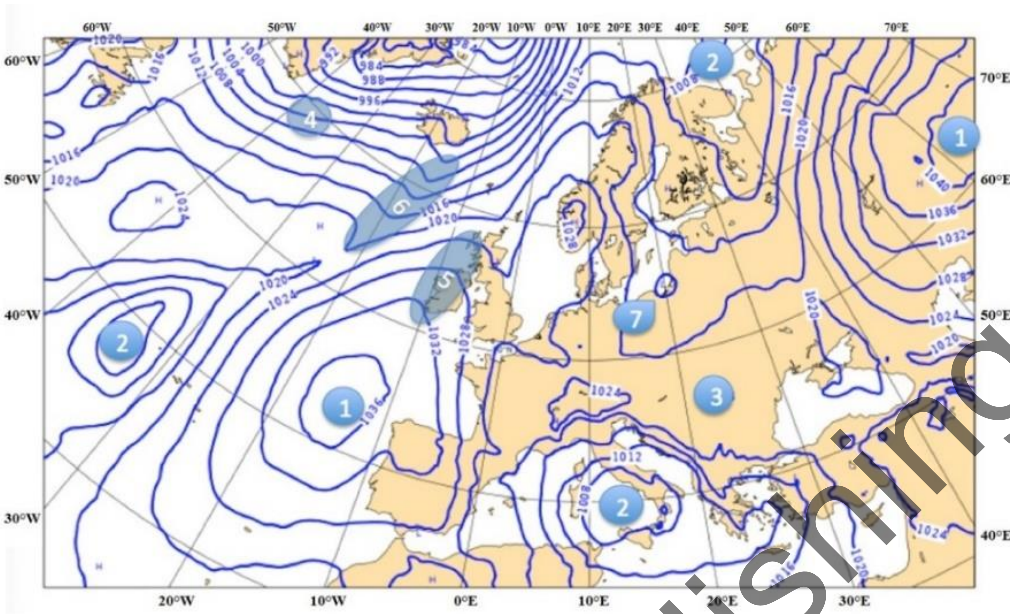


Figure 2. Pressure configurations: 1 Anticyclone; 2 Cyclone; 3 Saddle; 4 Slope; 5 Ridge; 6 Trough; 7 Secondary low.

Introduced by the author in his informational book “Weather,” published in 1888, this classification is, not only of historical interest, but it is still universally adopted (Figure 2).

2.3. Developments in Synoptic Meteorology

Antoine-Laurent de Lavoisier, father of modern chemistry, develops the concepts to represent the meteorological data, in particular the pressure, temperature, wind speed and direction observed synchronously, with great precision, on a geographical map, to forecast 24-48 hours in advance, the likely evolution. He thus laid the basis to the scientific development of a new meteorology: the synoptic meteorology. In October of 1790 he spells out the weather forecast rules based on the variations of the atmospheric pressure later published in the “Literary Magazine.” The scientist worked also to promote a campaign for the creation of a worldwide network of weather stations connected each other and operating in a strictly synchronous way. The worldwide network took over fifty years to be fully operational. The stations were connected each-other with the electric telegraph which allowed to quickly transmit the collected meteorological data and likewise send the weather safety alerts [9-11]. In the U.S.A., the physicist Joseph Henry implemented the weather communications with the telegraph in coordination with the Smithsonian Institution telegraphist proposing to open the daily communications with a weather report like: “clear,” “rainy,” “windy” etc. instead of the usual “okay.” In 1843, the first weather maps were produced (Figure 3).

Further impulse to the development of modern meteorology occurred after the intense storm that affected the Black Sea on 14 November 1854. Both the Brithish and French fleets that were supporting the Turkish fleet in the war between Russia and the Ottoman Empire (Crimean War) suffered serious damages. 38 between vessels and ships including the “Henry IV,” the most prestigious of the British fleet sunked causing the death of about four hundred sailors. Less than a year after the storm, the French, under the guidance of the famous astronomer Jean Joseph Le Verrier, implemented the first meteorological network in the modern sense, made of twenty-four stations connected with the Astronomical Observatory of Paris (thirteen of which by telegraph). Le Verrier, studying the dynamics of the storm in light of atmospheric circulation known laws, was able to extrapolate the future evolution in a logical and rational way providing the first truly scientific approach to the complex issue of weather prediction. In 1873, during the Congress of Wien, participating nations agreed to set up an international organization in order to facilitate the exchange of weather information across national borders. Thus it was born the International Meteorological Organization (I.M.O).

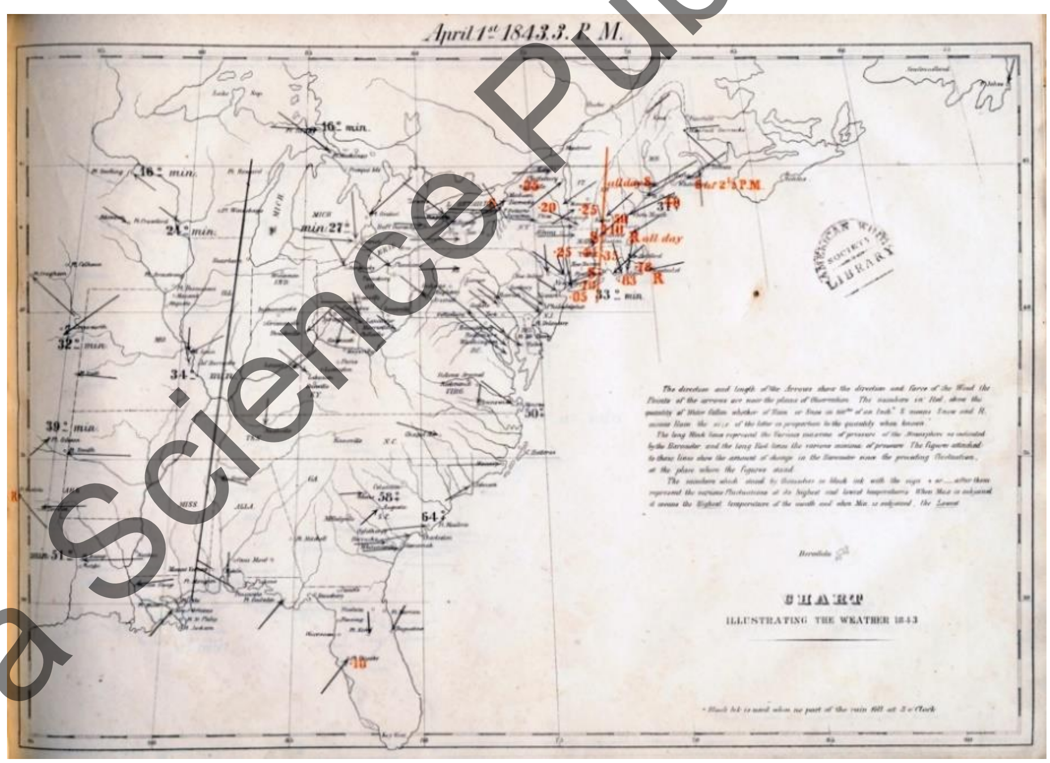


Figure 3. One of the first synoptic maps produced in 1843 from *Espy’s Second Report on Meteorology* (source http://libweb5.princeton.edu/visual_materials/maps/websites/thematic-maps/quantitative/meteorology/meteorology.html).

3. How to Create a Modern Meteorological Map

What then has changed since the first synoptic maps? The modern system of meteorological observations, the fundamental and essential starting point for any meteorological activity, has today a multitude of systems unknown at the time of Le Verrier, that includes super-fast computers, satellites, data networks, electronic meteorological instruments, radar and more other tools(Figure 4).

One thing is, however, remained almost unchanged since the days of Le Verrier: the work of the almost 11.000 observation stations, that promptly make measurements of the main meteorological parameters such as atmospheric pressure, wind direction and speed, temperature, humidity, cloud coverage, on-going phenomena etc.

From their observations it is extrapolated a “snapshot” picture of the current state of the weather across the planet. This network of surface stations contributes significantly to the so-called Global Observing System (GOS) (Figure 5), one of the programs of the World Meteorological Organization (WMO), the specialized agency of the United Nations, created in 1950 and that is mainly involved in international cooperation and coordination in the field of meteorology, the state and behaviour of the atmosphere and its interactions with the oceans and soils and climate and weather that it produces [12].

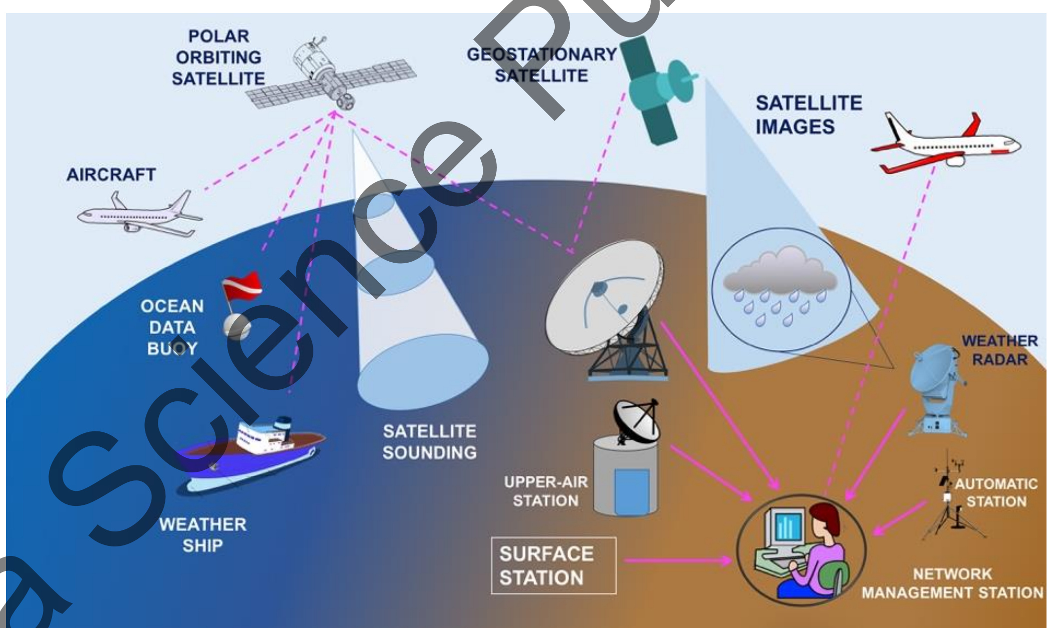
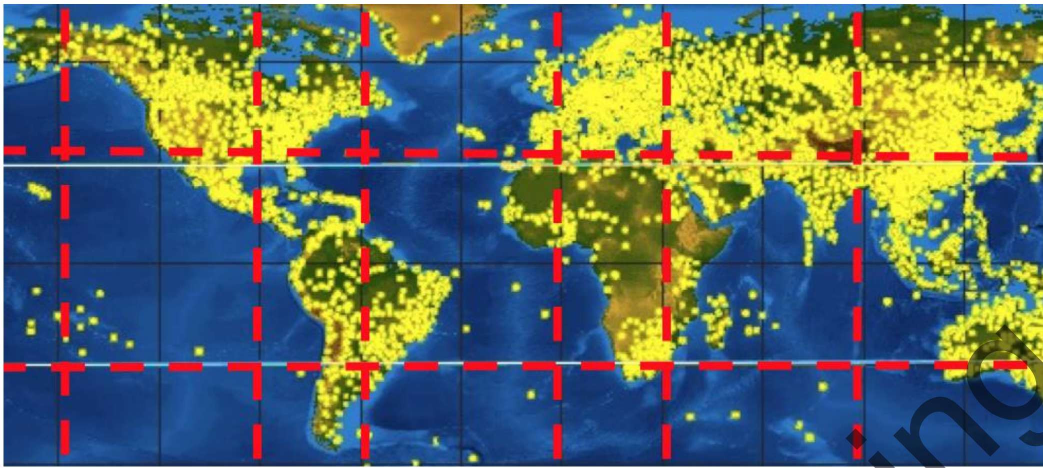


Figure 4. The Global Observing System.



Source: www.meted.ucar.edu.

Figure 5. The Global Surface Meteorological Station Network.

Parallel to the network of surface observation stations, which deal with collecting data in the lower atmosphere, there is a network of upper atmosphere observation stations, consisting of about 1300 stations, which at regular intervals of 6 or 12 hours release a balloons to make measurement of the main atmospheric parameters up to 30 kilometres of altitude. All data is collected by these networks and regularly exchanged data in real time. The exchange and circulation of meteorological data is done through another program of WMO: the Global Telecommunication System (G.T.S.). It is defined as: "The co-ordinated global system of telecommunication facilities and arrangements for the rapid collection, exchange and distribution of observations and processed information within the framework of the World Weather Watch."

4. Overview of Weather Maps and Symbols: Observation and Messages

Each weather station, whether fully automated or with observer staff, must make the meteorological measurements, translate them into a standard meteorological code or message, store them on a suitable base (paper until a few years ago, computer nowadays) and transmit this massage on G.T.S. so that it is available in real time all over the world. For the automatic stations the whole process is almost instantaneous and managed entirely by electronics, while for the stations with personnel it takes place substantially without any significant differences compared to a century ago.

About 10 minutes before the observation time, the observer reads the instrument, taking the data of temperature, air humidity, direction and strength of the wind, pressure etc. He also execute subjective observations such as the quantification of the type, height and the amount of clouds covering the sky in the vicinity of the point of observation, the horizontal visibility and any other visible meteorological phenomena.

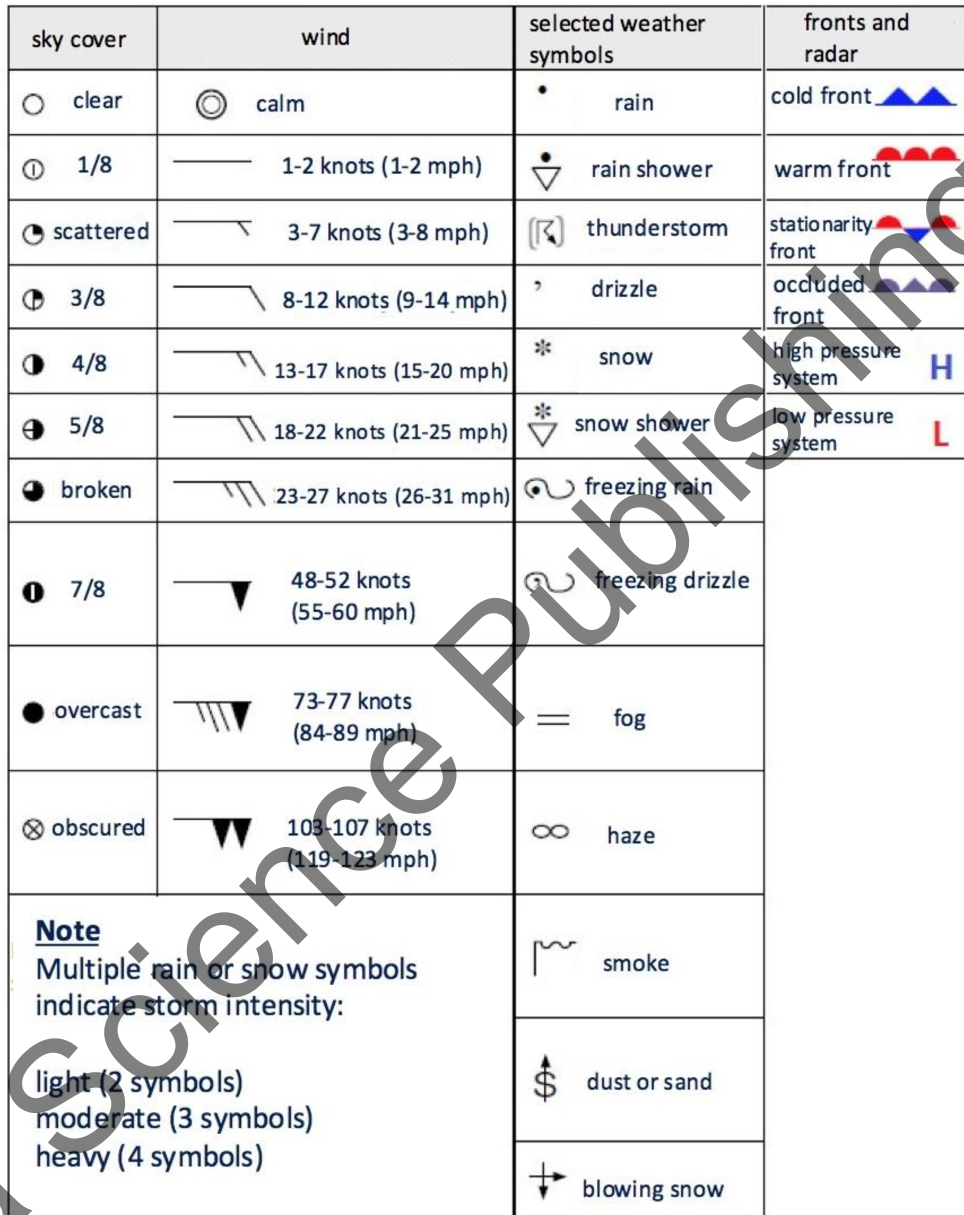


Figure 6. Meteorological Symbols worldwide used.

The next step, until a few decades ago, included the completion of the so-called “station’s book” on which were annotate all measures taken to the instruments. Today, the raw data are inserted on special software that provide the code according to the standards in use. The meteorological code universally adopted is called "SYNOP" and contain in summary form all the data that allow any meteorologist to know exactly the weather observed at any locations of the Earth. The SYNOP message is a numeric code composed by groups of five numbers arranged in such a manner that each group of the code is uniquely a data type. For example, the following code:

"SMIY01 111800 16429 11462 73504 10044 20021 30009 40021 55005 60232 72196 85360 333 20040 32 /// 55005 55300 82915 83818 85356 2 ////"

is the SYNOP message of Sigonella station on day 11 of the current month at 1800 UTC. Each group of the code has a codified meaning. In the example the wind was from 350° 4 knots, the temperature of 4.4°C and so on. For further information, please refer to dedicated publications. SYNOP is a specific message for synoptic meteorology and is produced simultaneously from all the stations around the world with a time step of 3 hours beginning from 00 UTC.

In order to plot the synoptic observations on a map, it was at least necessary to take a number of forms, capable of translate the observed data in graphical symbols (Figure 6).

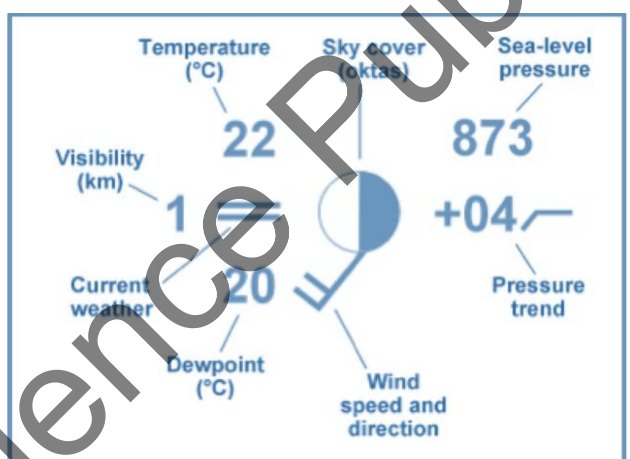


Figure 7. Station Plot.

The result of this process, called "station plot," produce a group of symbols and numbers that can synthesize the whole process of observation, (Figure 7).

In addition to SYNOP, which is the most widespread exchange format of weather data, there are also other types of codes, which are used especially in aviation. It is the case of "METAR" message, an aeronautical meteorological code used for the observation performed by aerodrome meteorological stations. Characteristic of the METAR message is the speed of preparation and dissemination. In this message, the measured data are rounded to the closest unity. It is also an alphanumeric code, more clear than SYNOP, which contains the main meteorological information useful for aircraft pilots.

"METAR LICC 182200Z 35008KT 9999 RA SCT020 BKN035 OVC090 12/10 Q1010" is for example the Metar of Catania aerodrome.

As for the surface observation stations, the stations that measure the upper atmosphere data start the observational activities before the time of observation. Moreover, they have the delicate task of preparing the necessary instruments to collect data, called radiosondes. They consist of small boxes of polystyrene, which enclose internally all the sensors for measurement of temperature, pressure and humidity in addition to the electronics for the transmission of data to the ground station (Figure 8).

Figure 8. Radiosonde.

Such equipment, attached to a balloon inflated with helium and released simultaneously from all the upper observation stations of the world at 00 and 12 UTC, send temperature, humidity and pressure data, in addition to the wind calculated by GPS, to the receiving station (Figure 9).

After the bursting of the balloon, which normally occurs between 20 and 30 km above sea level, and in any case after one hour from the time of launch, the transmitted data are encoded in a message called "TEMP" and forwarded to the appropriate Communication Centre through the G.T.S. network.

Figure 9. Release of balloon at midnight at Mario Zucchelli Station the Italian Base in Antarctica.

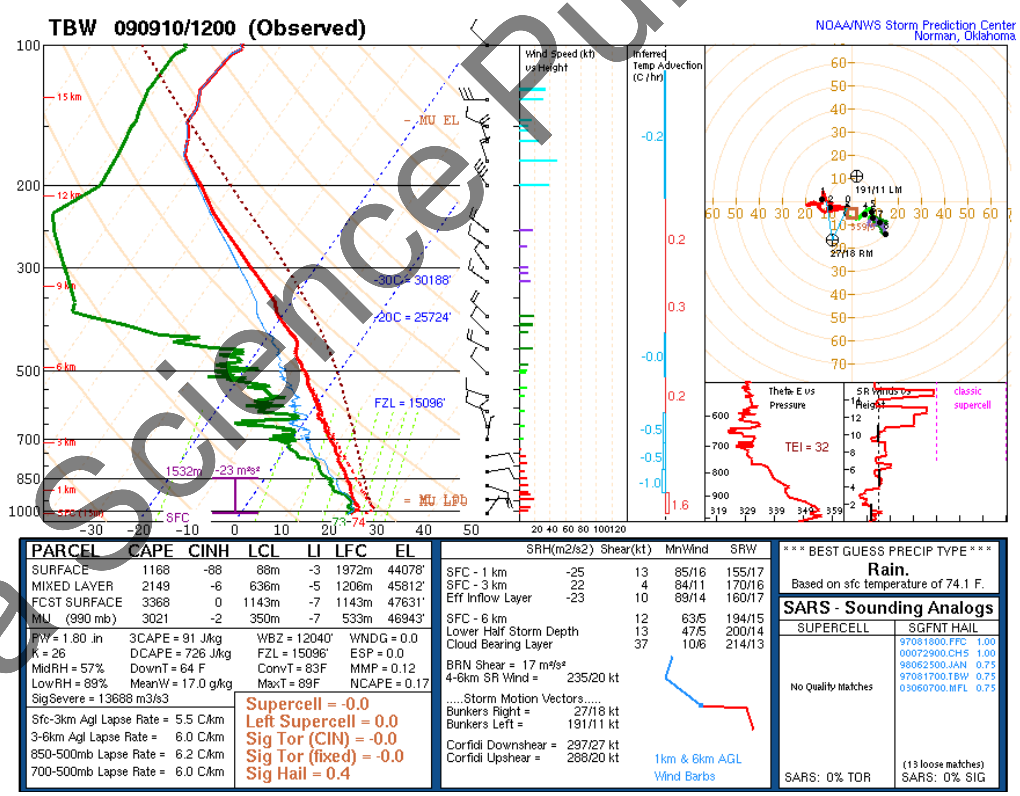


Figure 10. Thermodynamics diagram and data received from radiosonde.

The messages TEMP, in addition to the station identification and the date-time groups, contain data of temperature, humidity and wind to the various pressure altitudes touched by the radiosonde. These data can be plotted on maps or analysed by atmospheric thermodynamic diagrams, which summarize the characteristics of the column of atmosphere crossed by the radiosonde (Figure 10).

5. Surface and Upper Analysis Maps

The enormous amount of data that, through the G.T.S., regularly flow into the main Meteorological Centers around the world, represent the raw material to start the production of any kind of maps. The first step, which will get to the final release of the weather map, is the plot of the graphic symbols - station plot - on a map, in correspondence with the geographical location it's clear, however, due to the excessive crowding of data, that this type of representation does not lend itself to be used for any kind of analysis [13-14]. The next step will therefore be to draw the isolines, using the measured data to the stations, on a map cleaned thinning out most of stations plot and leaving only the most significant (Figure 11).

Similarly, it is possible to draw contour lines of the main data observed: isobars for pressure, isotherms for temperature and so on. The final result will be a map that contains one or more fields, represented by contour lines, easy to read and interpret (Figures 12 and 13).

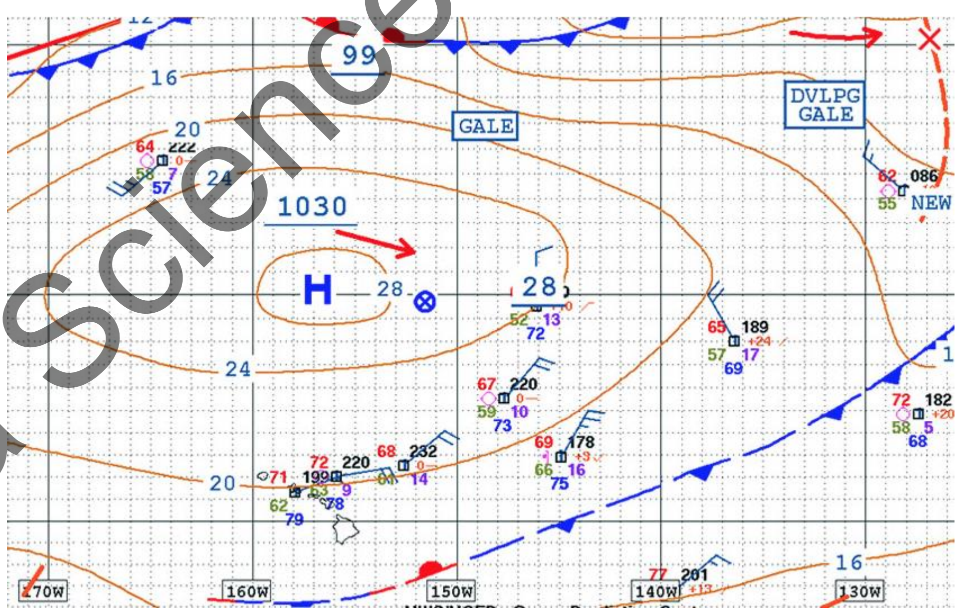


Figure 11. Map of analysis containing the pressure field to the ground, represented by isobars (yellow lines), in which have been left only some station plot.

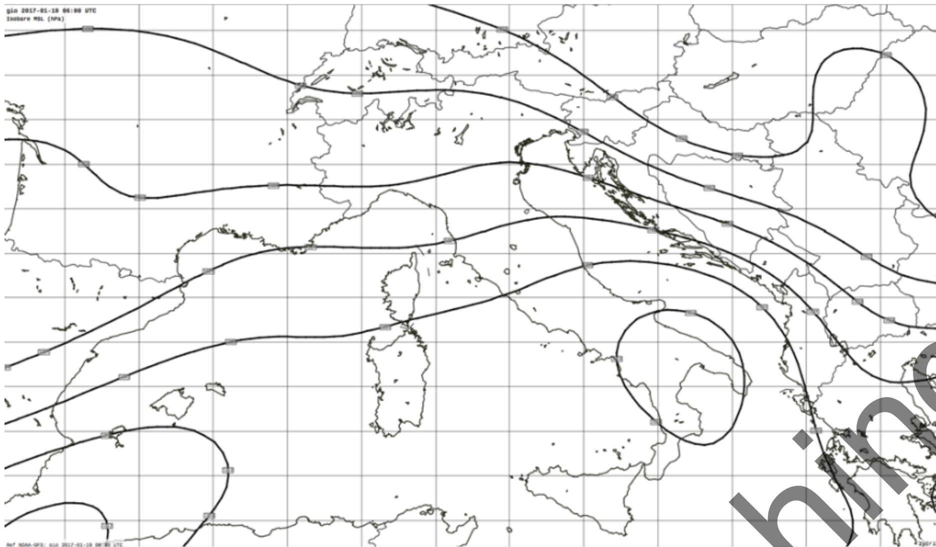


Figure 12. Plot of surface pressure field (ZyGrib freeware).

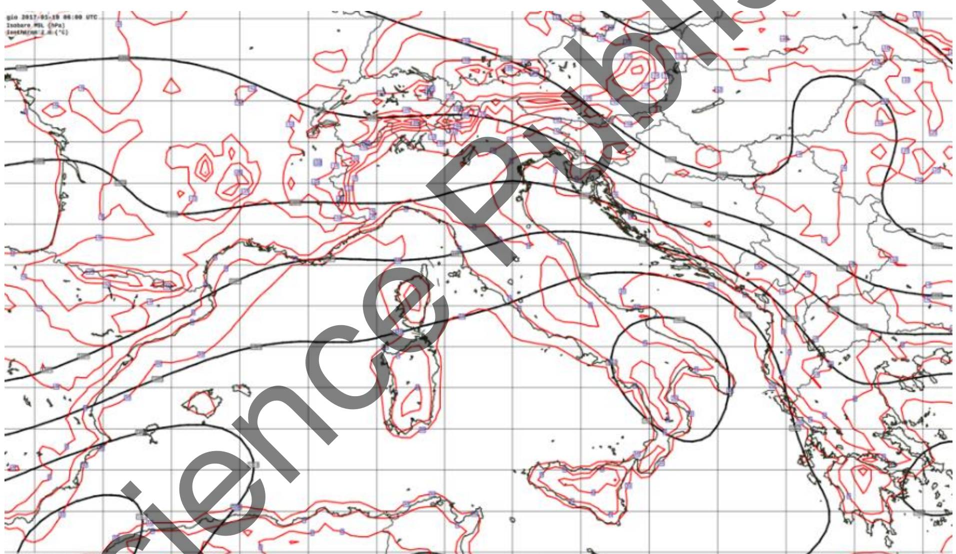


Figure 13. Plot of surface temperature and pressure fields (ZyGrib freeware).

The process of production of maps at high altitude does not differ much from the one to the ground: in place of the surface pressure, the height of the isobaric surfaces are represented. For this reason, the upper maps are also called absolute topographies and altitudes are expressed in geopotential heights, a term that is obtained from the relationship between geopotential (the work necessary to overcome the force of gravity and move upwards, to a certain height), a unit mass of air, and gravity at sea level (Figure 14).

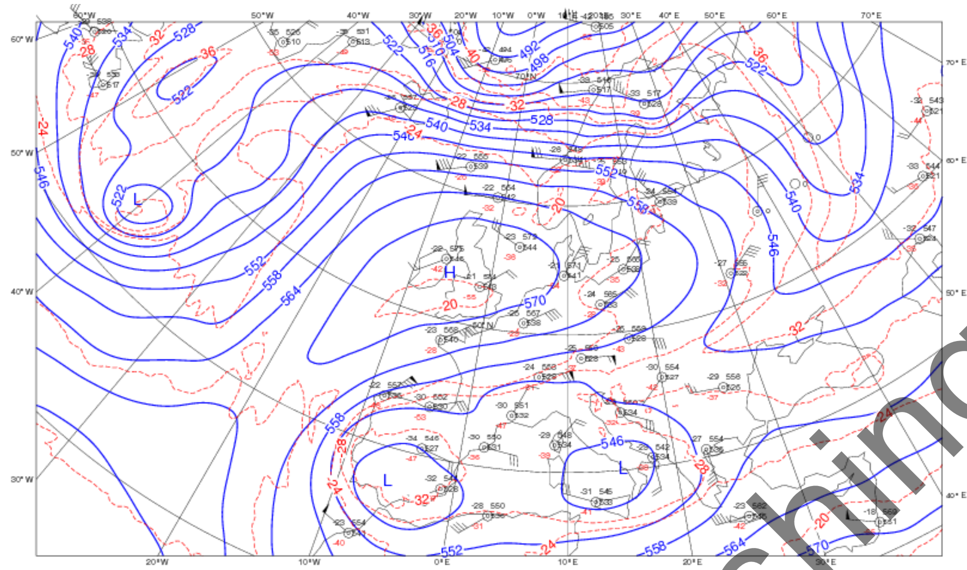


Figure 14 Plot of geopotential height (blue lines) and temperature (dotted red lines) at 500 hPa (source: Italian Air Force Meteorological Service) [Rome Analysis VT: Thursday 19 January 2017 – 00 UTC Geopotenziale 500 hPa + Temperature 500 hPa N.A.].

6. From Analysis to Weather Forecast

Looking at a surface pressure analysis map, it is possible to infer an amount of useful information that can help us to better understand the meteorological phenomena.

Let's analyze, for example, the surface map of Figure 12. The first operation that can accomplish is to locate and mark the high and low pressure centers indicating them with H (high) and L (Low) and highlight the isobar that separates the two areas. In the map we now identified two areas whose pressure values are respectively lower and higher of highlighted isobar. On the maps of the main World Meteorological Centers, the isobars are normally spaced at 4 hPa. Let's make a few comments on the area of low pressure present on Southern Italy. The air will begin to move toward the low pressure (just as a soccer ball to be free to roll on a slope), subject to the force of gradient PGF given by the ratio between the pressure difference AP and the distance between two points ΔX: $PGF = \frac{\Delta P}{\Delta X}$.

This means that, where the isobars are close together (maximum gradient) we will have the maximum wind speed, and where the isobars are widely spaced we will have light winds or absent. In the figure these two situations are respectively present between Bosnia and the Adriatic coast (maximum gradient) and to the south of Sardinia (minimum gradient). However, as understood by Coriolis over two centuries ago, the moving masses on the earth's surface, are subject to the homonymous strength CoF and are thus diverted, in their initial momentum, to the right in our hemisphere and to the left in the southern hemisphere.

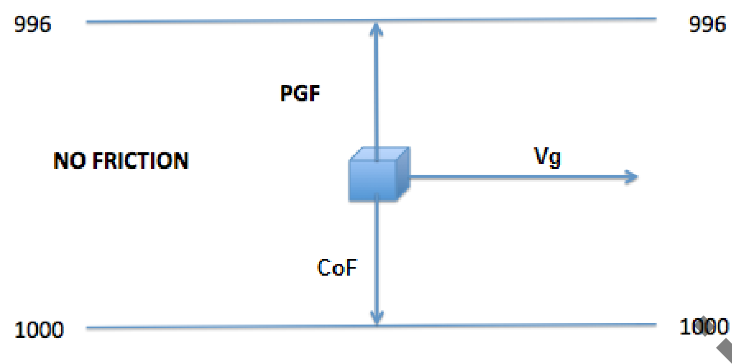


Figure 15. Wind resulting from the balance between the Coriolis force and the pressure gradient force.

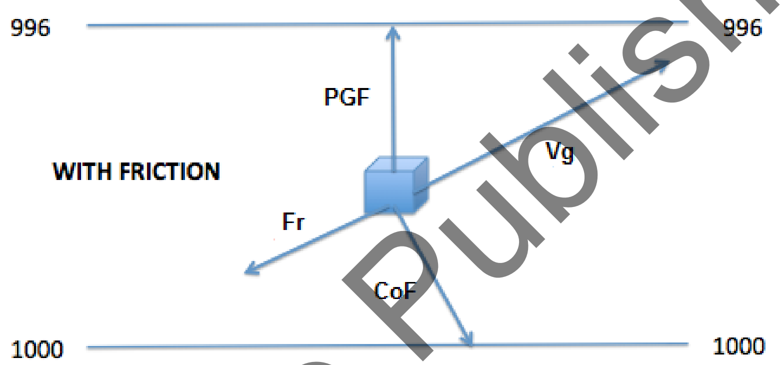


Figure 16. Wind resultant from the balance between Coriolis force, pressure gradient force and friction.

Therefore, in the hypothetical case of straight and parallel isobars and ignoring for the moment all forms of friction, the wind resulting from the balance between the Coriolis force and pressure-gradient force, will give rise to what we call geostrophic wind Vg, as shown in Figure 15.

The geostrophic wind will therefore be parallel to the isobars. However, an air mass moving on a surface such as that of the Earth, will be subject to the resistances of friction F_r that depend upon the roughness of the surface and which act in the opposite direction to the motion. Introducing this force, the new equilibrium will be as follows in Figure 16.

The resultant of this new balance will be a wind (a-geostrophic), which will cut the isobars pointing toward the low pressure, with an angle that will be greater the greater the friction. On the sea or over a very smooth land surfaces this angle is between 10 and 30 degrees, while on rough land or mountain areas you can get to even exceed 60-70 degrees. These considerations help us to understand that the surface wind forecast will follow the isobars, converging, with an angle comprised between 10 and 70 or more degrees, towards the low pressure [15]. Furthermore, the same considerations allow us to establish that in the case of closed circulations of high or low pressure, winds will assume a counterclockwise rotation (or cyclonic) around the low-pressure centers, and clockwise (or anti-cyclonic) around high-pressure centers. For the considerations made on the friction they will tend to diverge from the high pressures and to converge toward the low.

The convergence that occurs around low-pressure centers, is one of the mechanisms which produces the lifting of the air masses.

When the mass of moist air that converges around low-pressure centers begin the lifting process, it expands and cools, condensing the water vapor that contains and giving rise to the typical cloudiness of the low pressure zones. Conversely, the divergence produced by the high pressure center that draws air from the top down dimension is compressed and heated, favoring the dissipation of any present clouds (Figure 17).

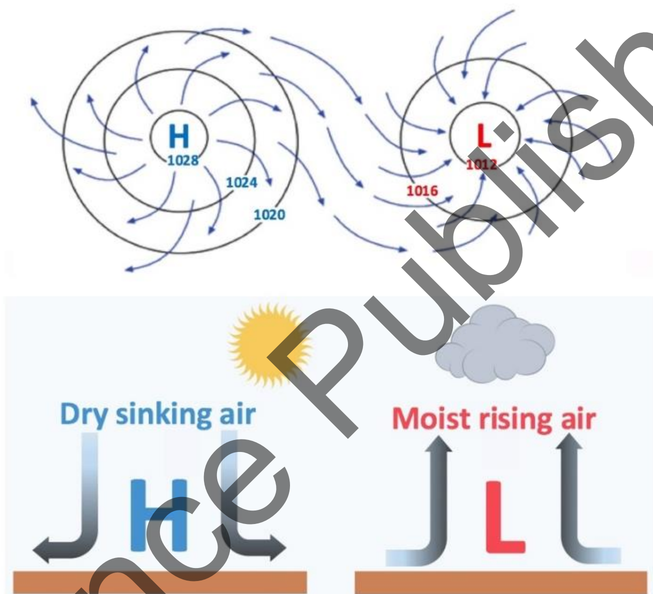


Figure 17. Motion of air around a High and a Low pressure in Northern hemisphere.

7. From Synoptic Meteorology to Climate Analysis

The huge amount of data, continuously observed and archived by weather stations around the world, is one of the most important resources for the development of new branches of meteorology such as the statistical meteorology and climatology. After the invention of the first measuring instruments, one of the key issues was what to do and how to use the data series collected. The first analysis carried out using meteorological data, were simple descriptive statistics, or study about the variability of a phenomenon since the data were collected. This led to the first attempts to classify climates of different places, depending on the temperature and average rainfall occurring during the year.

In 1817 Alexander von Humboldt drew annual-mean temperatures on a world map. Wladimir Koeppen (1846-1940) refined this map and plotted seasonal temperature range in 1884, leading to his climate classification. This classification followed that of plants realized by Linnaeus in 1735, being likewise hierarchical, with major categories subdivided, and then subcategories divided again, and so on. In fact, Koeppen had initially studied botany at St Petersburg, later completing a Ph.D. at Heidelberg on the effect of temperature on plant growth. At the highest level his system is based on five sets of temperature limits. These were developed from his categorization in 1884 of thermal zones suited to various kinds of vegetation (Figure 18).

In 1924 Koeppen became associated at Gradz University with Rudolf Geiger (1894-1981) and collaborated with him in producing the 1936 system of climate classification. Geiger established the discipline of microclimatology as he collected a wealth of observations to understand ‘the climate near the ground’ (to quote the title of his book, translated into English in 1960), and its variations due to topography and land use [16-18].

In the USA, Warren Thornthwaite (1892-1963) developed a hierarchical classification in 1931, essentially in terms of the annual pattern of soil-moisture conditions. These were regarded as depending in a complicated manner on the monthly input as rain, and implicitly on the output as evaporation, indicated by temperature.

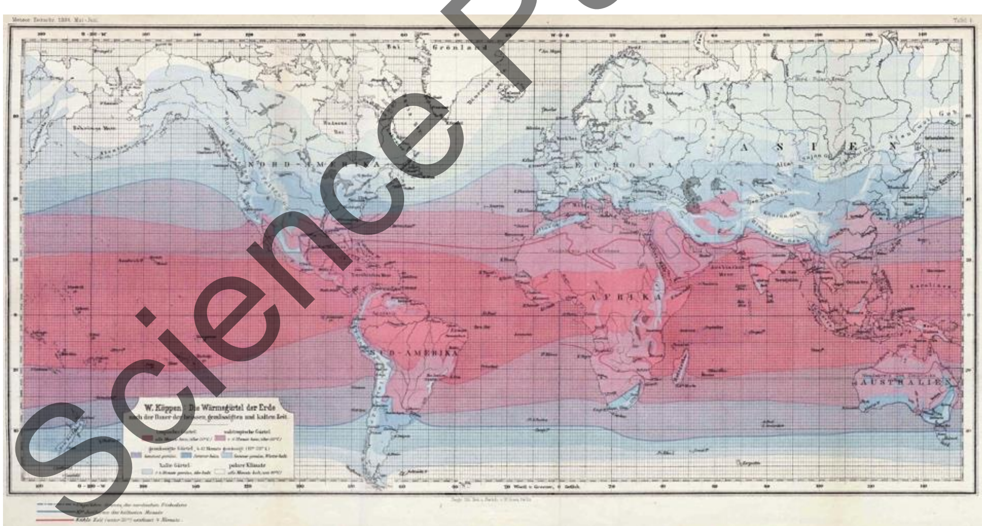


Figure 18. The first Koeppen Climate classification map.

This kind of maps are useful to represent the extreme environments and to explain the effects that make such environment so extreme.

As an example we take into account the Atacama Desert (Chile, USA) that is the most arid place on Earth, where every year falls, on average, no more than 0.08 mm of rain. Its geographical position plays a key role in explaining this negative record. The area is protected by moisture on both sides, with the Andes Cordillera to the East and the coastal mountains to the west. On the desert eastern mountainside, where the peaks reach to over 5000 meters, the Andes Cordillera is a real barrier to the flows coming from the East. The katabatic winds that affect the area are very dry and contribute to heat the air for adiabatic compression (see Figure 19).

These environments are characterized by high aridity, very hot and low temperatures, high salinity and high values of pH and by the fact that many living organisms, the extremophiles, can survive in these conditions thanks to the synthesizing of the trehalose, a disaccharide that is revealed to be a cryptobiotic-activating substances [19-31].

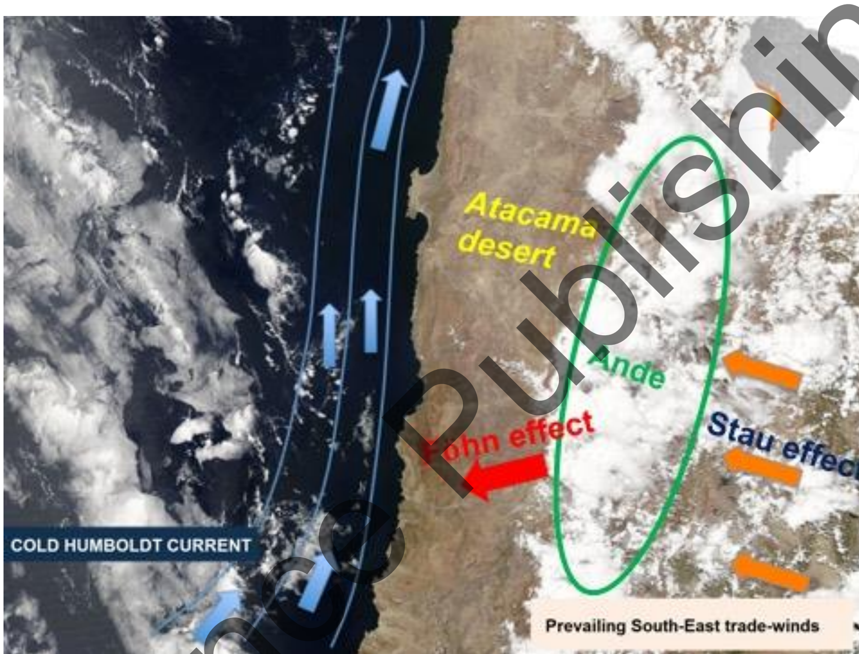


Figure 19. Atacama Desert.

Concerning the extremophile present in the Atacama Desert, it is possible find the plant of resurrection, i.e., *Selaginella lepidophylla* [39-55]. Such a plant that synthesizes trehalose is able to adapt itself at the conditions of prolonged drought in this environment [56-69]. Furthermore, it also lives for 50 years against numerous total dehydration processes without damaging it, and after a process of rehydration, it regenerates [70-81]. This disaccharide is object of many studies with different techniques [82-93].

In parallel to these studies of climate descriptions based primarily on statistical considerations, new techniques of analysis of the time series were developed. The Fourier analysis applied to a time series α (t) is a technique that allows the study of the signal α in the frequency domain, due to the decomposition of the temporal function itself in an infinite number of harmonics (fundamental waves), in which the 'amplitude of each harmonic represents the weight that it has in the original signal [94-102]. The decomposition into harmonics is expressed by the inverse Fourier function, defined as

$$\alpha(t) = \frac{1}{2}\int_{-\infty}^{+\infty} A(\omega)e^{i\omega t}d\omega \tag{1}$$

where the inverse relationship, the Fourier transform, it is defined as:

$$A(\omega) = \frac{1}{\pi}\int_{-\infty}^{+\infty} \alpha(t)e^{-i\omega t}dt \tag{2}$$

with i imaginary unit, ω angular frequency of the harmonic (rad/s), given $\omega = 2\pi/T$ and T period of harmonica in seconds. The analysis in the frequency domain is conducted to highlight certain properties not immediately recognizable in the time representation of a signal. The spectral analysis of climate data is now a widely used technique in the world, and through it many dark sides and little known of the Earth's climate system, were revealed [103-109].

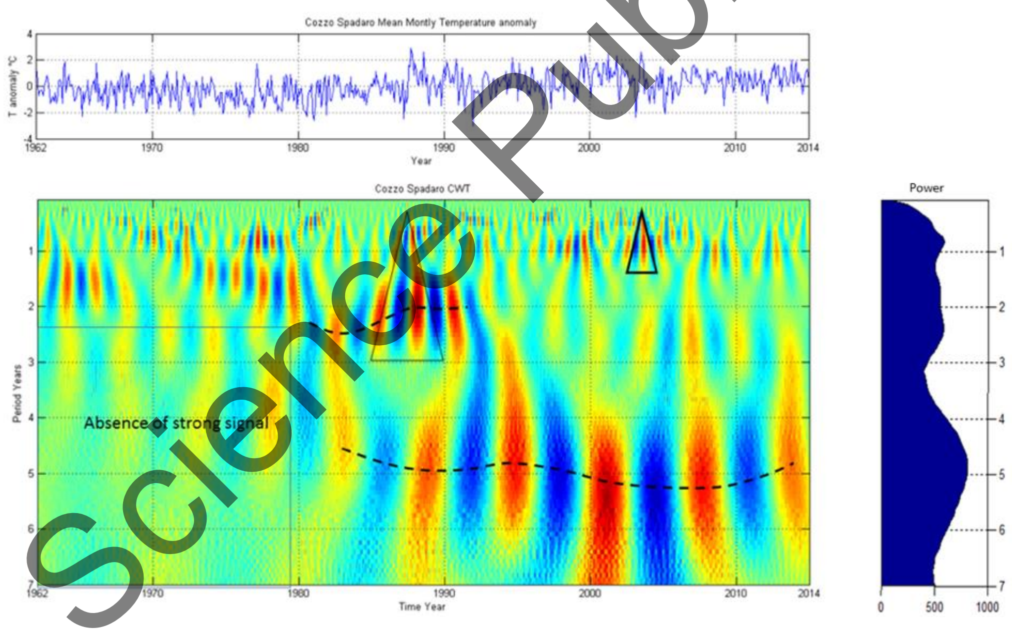


Figure 20. Example of wavelet analysis on a temperature time series.

Thanks to analysis on paleo climatic data was possible, for example, reconstruct and correlate the duration of the astronomical cycles with terrestrial glaciations. Further developments, which benefited Meteorology and Climatology, came undoubtedly from the use of wavelet analysis. The Wavelet analysis is a powerful mathematical tool capable of providing a representation time-frequency of any signal analyzed in the time domain [110-119]. They can be used to analyze time series that contain nonstationary power at many different frequencies. In the case of meteorological and climatological series this type of analysis is particularly appreciated being able to extract valuable information from the signal. Compared for example to the simple Fourier transform, wavelets allow to find not only in the value of certain frequencies present in a non-stationary series, but also to identify the time interval in which these frequencies have been present and predominant. These sophisticated tools have been used in several studies of climatology and the scientific literature is rich of many examples [120-127]. The continuous wavelet transform of a discrete sequence x_n with a scaled and translated version of $\psi_0(\eta)$:

$$W_n(s) = \sum_{n'=0}^{N-1} x_{n'} \psi * \left[\frac{(n'-n)\delta t}{s}\right] \tag{3}$$

where the (*) indicates the complex conjugate. By varying the wavelet scale s and translating along the localized time index *n*, one can construct a picture showing both the amplitude of any features versus the scale and how this amplitude varies with time as reported in Figure 20.

CONCLUSION

In this paper, after a brief history of meteorology during XVIII, XIX and XX centuries, it has been described the evolution of the meteorology as consequence of the evolution of the instruments to measure the main characteristics of the atmosphere such as temperature, pressure and humidity. The invention of the telegraph gave a further strong impetus to the development of modern meteorology and made possible the exchange of the observed data. After the II Word War, the establishment of the World Meteorological Organization (WMO) in March 1950, following the entry into force of its Convention, and the designation of WMO in 1951 as a specialized agency of the United Nations, announced a new era for international cooperation in the field of meteorology, hydrology and related geophysical sciences. Meteorology has had a further impulse thanks to the diffusion of personal computers and the Internet, which have enabled millions of people to be able to consult maps and products previously available only in large computer centers. This possibility of having meteorological products has not been followed by a necessary training and education of users, who often cannot correctly decipher the contents of the meteorological maps available online. The aim of this paper is to help students that approach to meteorology to understand the origin and the evolution of the Science of the Atmosphere and to be able to read and interpret correctly the information contained in the meteorological maps.

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