DAP Service Antarctica Climatology

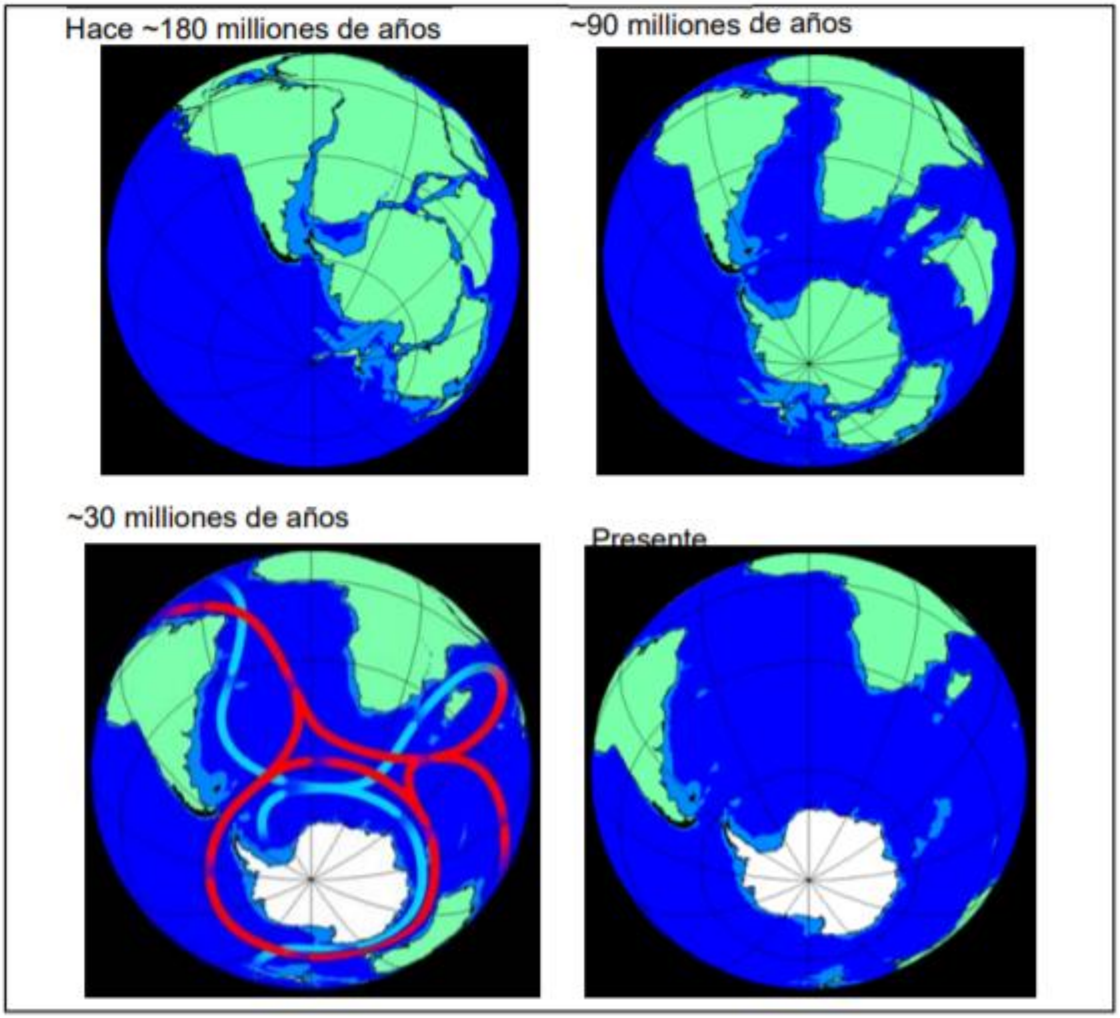

Figure 1.1: Outline of continental drifting

1.1 Antarctica Continent: Origin

200 million years ago, the Earth was formed by a single continent called Pangea which was surrounded by a single ocean: Pantalassa. But before Pangea was formed (280 million years ago), it is believed that on Earth in its 4,500 million years of existence, the continents would have gathered and separated at least twice. Pangea was divided in two giving rise to Laurasia and Godwana, both only continents of the north and south, respectively. 180 million years ago, Godwana began to separate into three large pieces: South America- Africa, Australia-Antarctica and India (Figure 1.1). Then, 45 million years ago Australia and Antarctica separated and moved to the regions where they are located

currently. It is estimated that Antarctica is located around the South Pole since about 40 million years and, in contrast to its counterpart the Arctic, is a continent surrounded by the Pacific, Atlantic and Indian oceans.

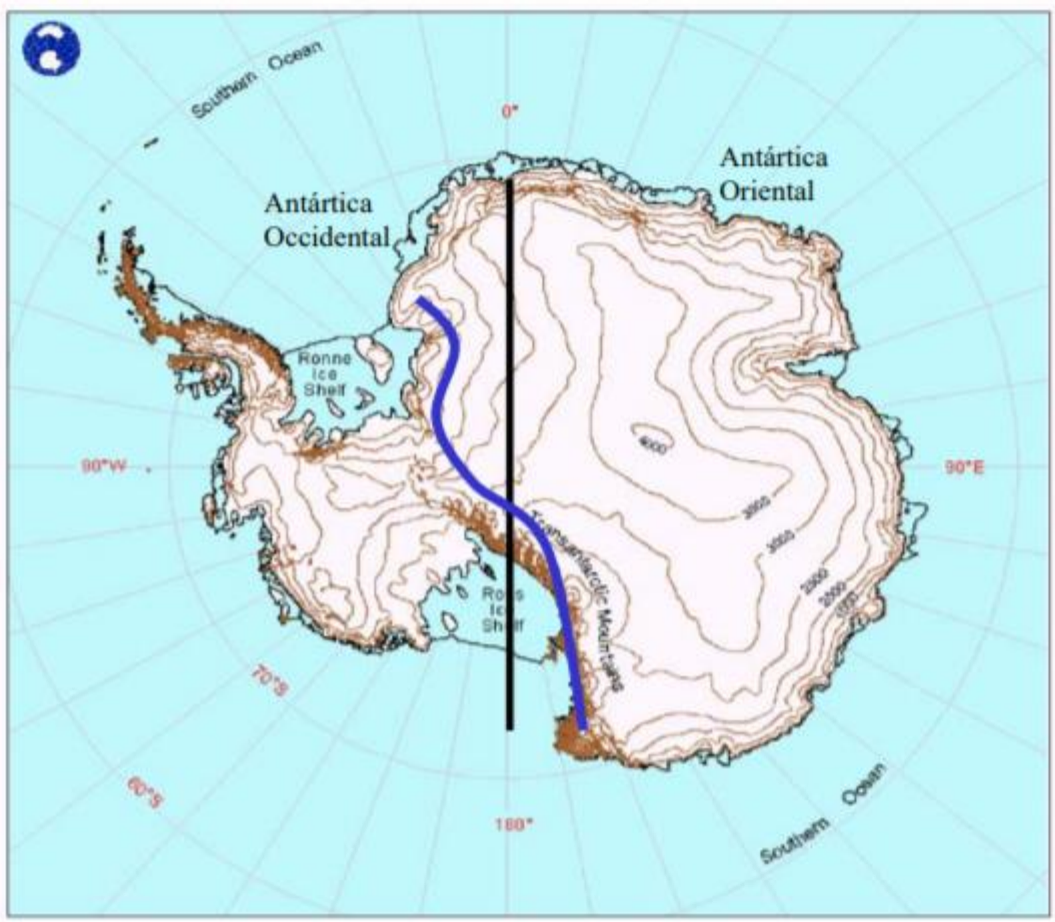

Figure 1.2: Orography of Antarctica

1.2 Orography

The Antarctic continent has an area of 14 million km2 practically covered entirely with ice and snow, including the Ronne, Ross and Amery Ice Platforms (Figure 1.2). In addition, we must add the sea ice surface that fluctuates annually from February (minimum extension) to October (maximum extension) between 4 to 22 million km2. That is, on average the total size of the solid surface doubles from 18 million km2 at the end of summer, to 36 million km2 at the end of winter (Figure 1.3). Its geographical location allows the division of the continent (black line in Figure 1.2) in Eastern Antarctica (from 0 to 180º W) that it faces mostly the Indian Ocean, and in Western Antarctica (from 180º to 360º W) facing the Pacific and Atlantic Oceans.

Another division, according to its topographic characteristics, allows the continent to be divided further by following: the Transantarctic Mountains (blue line in Figure 1.2) West of Antarctica Occidental, as well as Antarctica Oriental. The mountains to the east edge of the Ronne Platform are located in this case Eastern Antarctica and the rest would be Western Antarctica. In both cases, the Antarctic Peninsula is included in Western Antarctica. More than 90% of the Antarctic continent has an elevation above 2000 m. The highest parts of the continent are the plateau located in Eastern Antarctica where about 3.5 million km2 are above 3000 m high, of which 3 million km2 exceed 4000 m.

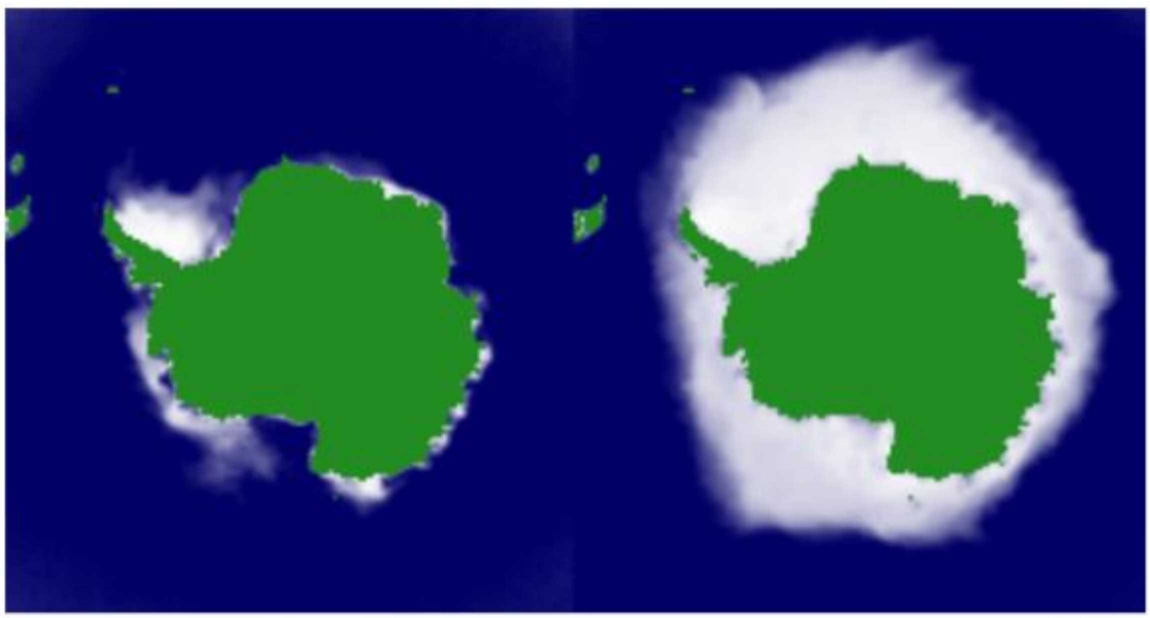

Figure 1.3: Extension of sea ice in a) February and b) September

1.3 General Circulation of the Southern Hemisphere

Seen the atmosphere from an energy point of view, the equatorial zones are of energy gain while the polar ones are of loss. Thus, the Earth and its atmosphere is heated in the tropical strip and cooled in the polar areas. The excess and deficit of heat causes the masses of cold air to travel to the equator and masses of warm air move towards the poles, thus being the atmosphere in constant motion. If the Earth did not rotate, the exchange of air masses would be from the north south and vice versa. In simple terms, there would be a southern circulation with warm air rising in the equatorial zones the one that moves in height towards the poles where it descends, and with cold air that moves in the low levels towards the equator, thus constituting a single cell of southern circulation by hemisphere. However, the effect of the Earth's rotation influences the movement of air masses, so that instead of having a single cell per hemisphere, the circulation of the atmosphere acquires a structure of three southern cells (Figure 1.4). Hadley's direct cell that goes from the area of superficial convergence in the equator, where air ascents occur. Around the tropical latitudes (~ 30º) there are air decreases that give rise to the permanent circulation of high pressure centers. In the middle latitudes (~ 30º to ~ 60º) is an indirect circulation cell called Ferrel with air descent on its equatorial side (~ 30º) and ascent on its polar side (~ 60º), and finally polar cells with ascent of air around 60º and descent in poles, the latter gives rise to permanent highs in the Antarctic and the Arctic. Antarctica is located within the southern polar cell, which climatologically translates into an anticyclonic circulation associated with a permanent region of high pressures in the interior of the continent, low pressures around Antarctica called the circumpolar trough, the polar vortex over the continent in the upper levels of the atmosphere associated with the circulation of the west in height and a regime of east winds in surface.

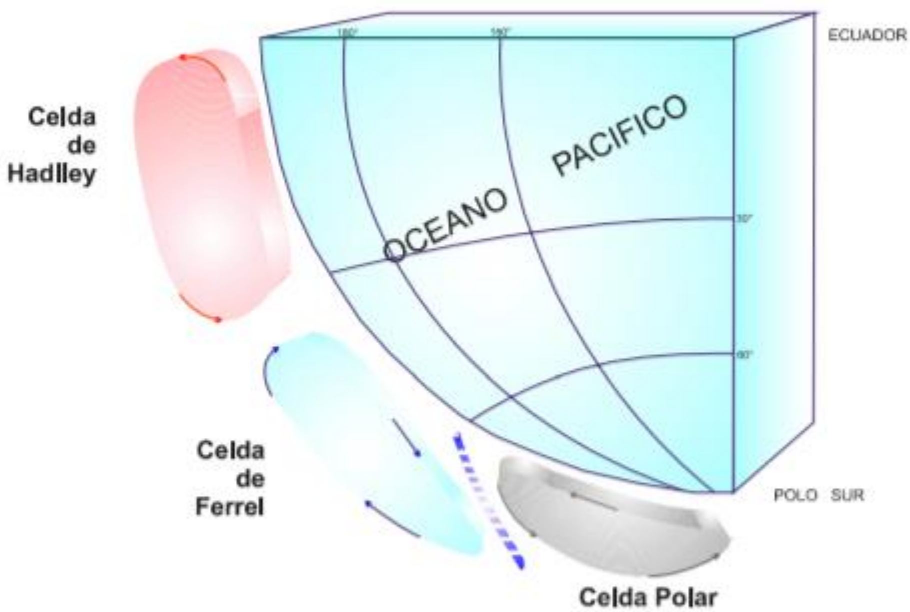

Figure 1.4: Meridional Circulation

1.4: Air Temperature

The surface air temperature shows a distribution influenced by latitude and altitude (Figure 1.5), although the annual average minimum is over the highest region of Eastern Antarctica (Cold Pole displaced from the Geographic Pole). The lowest temperature recorded on the planet was observed at Vostok station (78º 26 ’S, 106º 52’ E) in July 1983 when the thermometer dropped to -89.2º C.

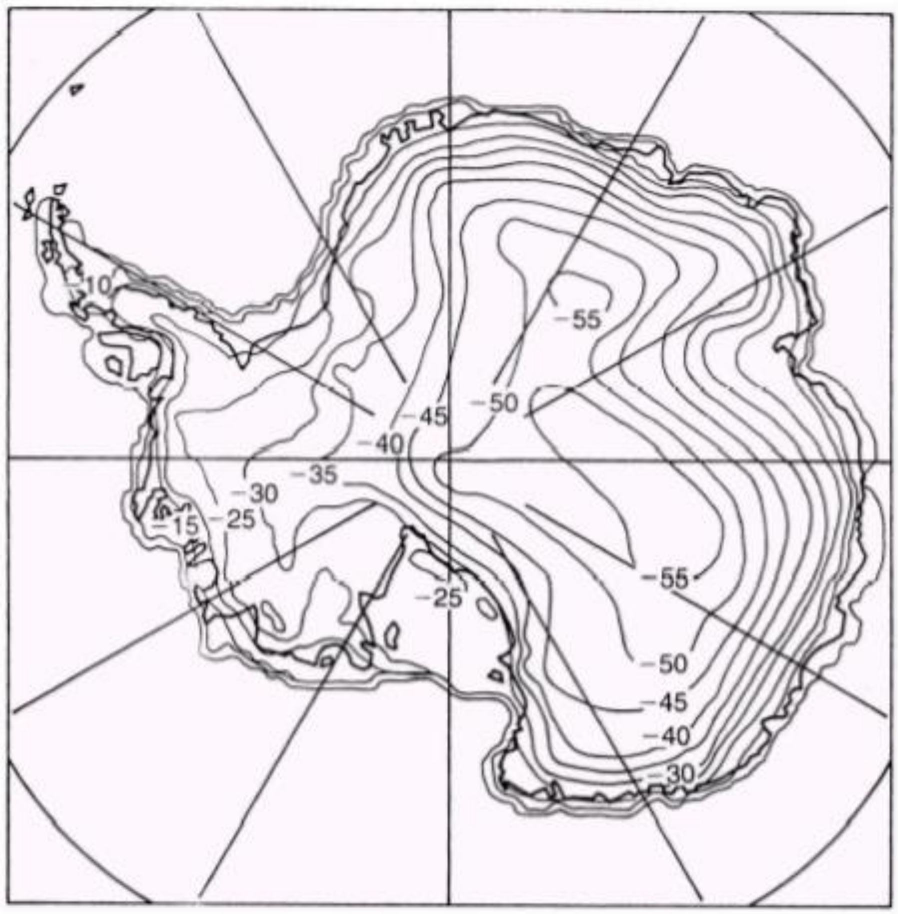

Figure 1.5: Average annual air temperature near the surface (~ 10 m)

Another characteristic of the temperature of the air inside the Antarctic continent is illustrated in Figure 1.5 (Schwerdfeger 1984) where it can be observed that the average monthly temperatures drop rapidly, after the maximum reached in the summer, until the beginning of autumn and then practically remains constant throughout the winter. At the beginning of the spring the temperature experiences a strong increase until reaching the maximum of summer. This temperature behavior is called “winter without minimum” (coreless winter) because the annual cycle does not have a minimum (one colder month). This temperature behavior is directly related to solar radiation. At the end of March until the beginning of September, a large portion of the Antarctic continent (~ south of the 80º S) ceases to receive solar radiation, leaving it completely dark (polar night). In June practically the entire continent is in 24 hours at night (~ south of the 60º S). On the contrary, in the remaining months you have 24 hours of daylight practically throughout the continent.

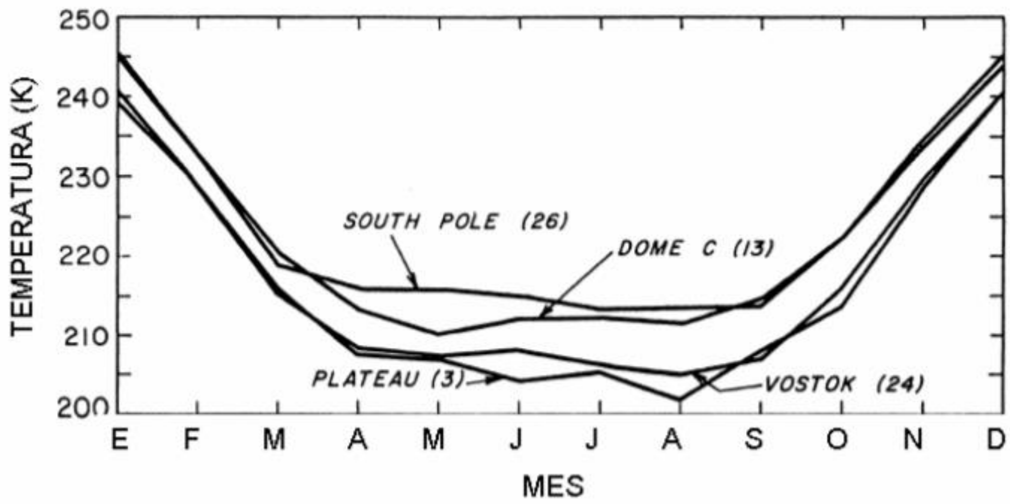

Figure 1.5b: Trend of the surface air temperature in the stations inside the continent: at the South Pole, Dome C, Plateau and Vostok (Schewerdefer 1984).

During the winter months, in absence of solar radiation, the nivosa surface loses terrestrial or infra-red radiation (99% emissivity), thus cooling the atmosphere of immediately adjacent to it (radiative cooling). On the other hand, the atmosphere itself (below 100 to 500 m high) absorbs a good part of the infra-red radiation emitted, which causes it to warm up in this layer. The result is that the temperature of the air in the planetary boundary layer (the portion of the adjacent atmosphere and affected by the earth's surface) in Antarctica increases with height, that is, a thermal inversion occurs. The difference between the temperature of the air near the surface and the top of the investment can reach 25-30º C (Figure 1.6), and this is stronger towards the interior of the continent. The investment weakens in the summer months and may disappear due to the presence of clouds or a mixture caused by strong winds (Warren 1996).

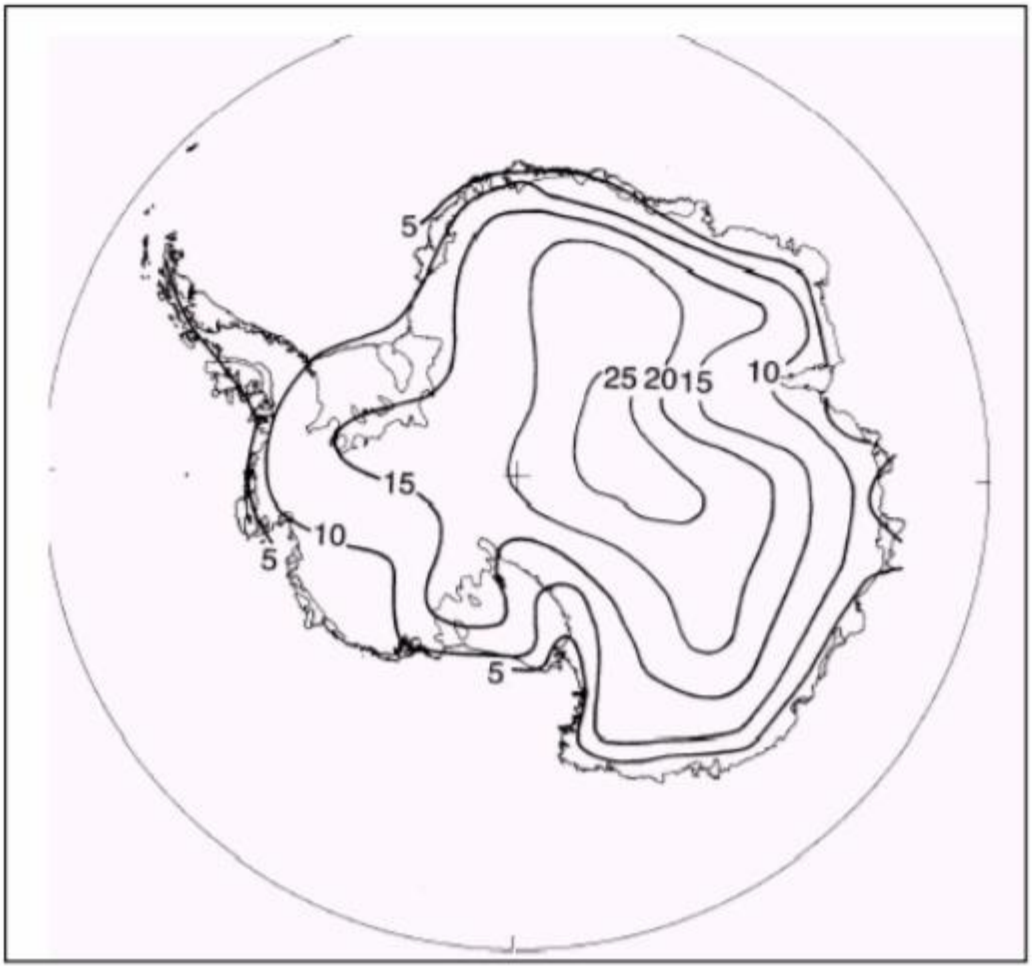

Figure 1.6: Air temperature Inversion (ºC) in winter (June - August) (Schwerdtfeger 1970)

1.5 Wind

The strong radiative cooling in the Antarctic favors the development and persistence of the katabatic wind regime in the boundary layer. These katabatic winds descend on the slopes from the mainland Antarctic plateaus and converge in several areas, especially near the coast (Parish and Bromwich 1987) (Figure 1.7) . This pattern of winds of radiative origin moves cold air towards the equator supporting and contributing to the east winds that surround Antarctica (Schwerdfeger 1984), also contributing to the global heat exchange (Parish and others 1994). An interaction between the katabatic winds from Antarctica and the surface winds from the west and northwest that take place in the southern oceans must take place in the circumpolar trough (Parish and others 1994).

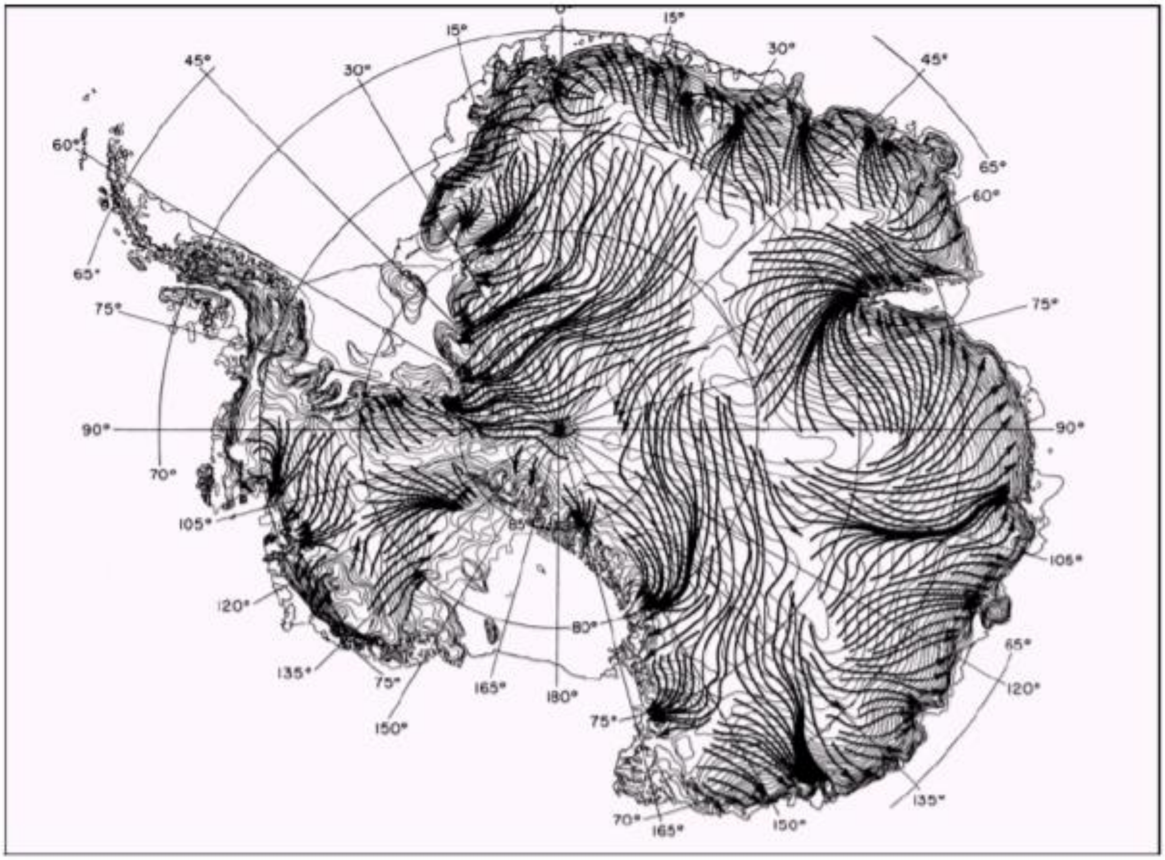

Figure 1.7: Simulation of katabatic winds in Antarctica (Parish and Bromwich 1987)

1.6 Precipitation

Figure 1.8 shows the accumulated net precipitation (Precipitation - Evaporation) annually in the Antarctic continent (Vaughan and others 1999). The interior of Antarctica is extremely dry (icy desert). Most of the continent receives less than 250 millimeters of water equivalent (mm a.eq.). In the central part of Eastern Antarctica the average annual accumulation is less than 50 mm a.eq .; that is, less than what is received. Accumulations over 500 mm a.eq. they take place in the coastal areas of the continent mainly in the sector facing the Pacific Ocean and in particular the western sector of the Antarctic Peninsula, where annual maximums accumulate. This coastal precipitation is associated to frontal systems and to a lesser extent to the activity of cyclones on a subsyptic scale. Within the continent, low rainfall is deposition of ice crystals that occur with clear skies. Precipitation in the Antarctic is mainly of the snow type although in coastal areas, particularly in the Antarctic Peninsula, rain can occur at any time of the year.

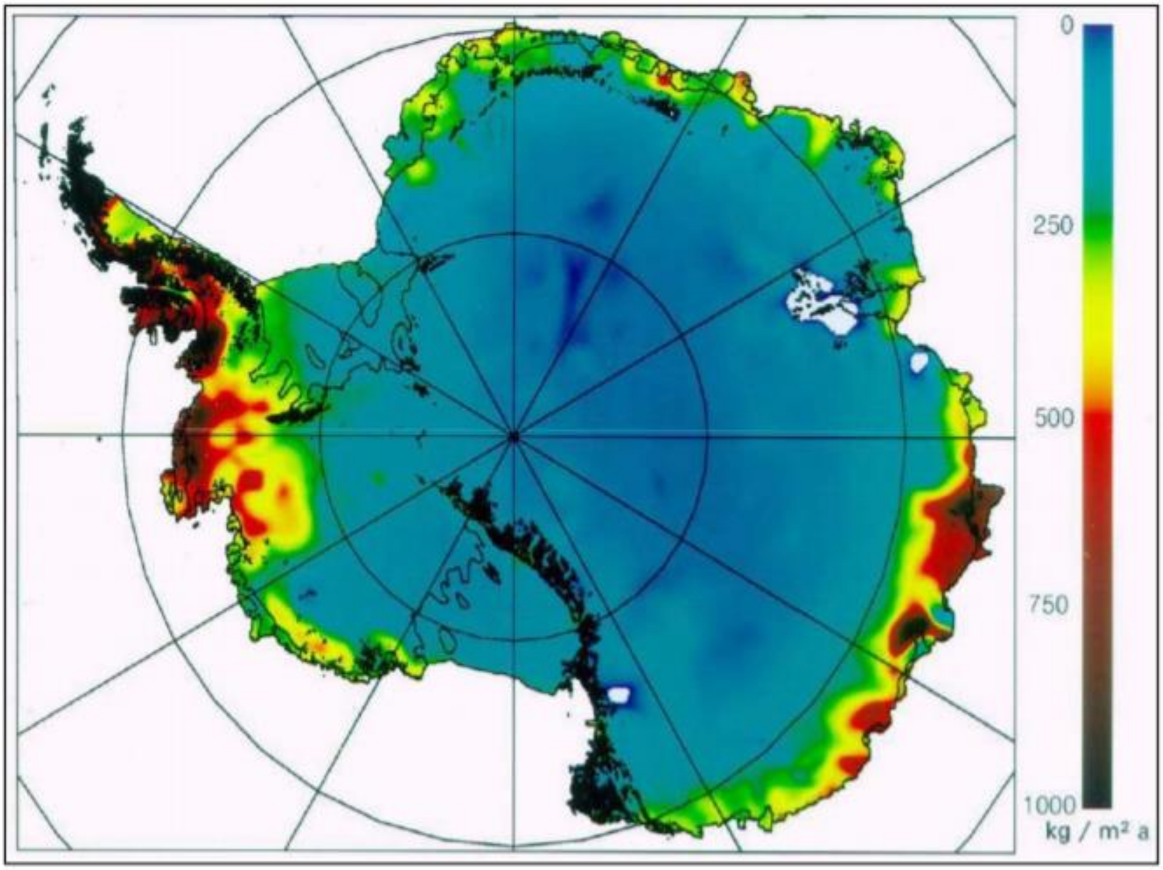

Figure 1.8 Annual net accumulation (P-E) in kg m-2 a-1 (equivalent in water) in the Antarctic continent (Vaughan and others 1999)

1.7 Pressure & Atmospheric Circulation

A significant feature in sub-Antarctic latitudes is the high frequency of frontal systems and their associated low pressure centers (cyclones). These systems determine largely the meteorological and climatic characteristics in Antarctica, particularly in coastal areas including the base.

Antarctica is surrounded by the circumpolar trough which, on average, is between 60º S and 74º S, and is the result of the activity of frontal cyclones that move southeast from the middle latitudes (Figure 1.9). Cyclones mostly dissipate and practically park in the vicinity of the Ross Sea, in the seas of Amundsen and Bellingshausen and in the Weddell Sea sector (Figure 1.10). Cyclonic activity determines the latitudinal position of the circumpolar trough which varies from north to south being more intense and being closer to the continent in January and June, and weaker and displaced to the north in March and September, which reveals the semi behavior -year of the circumpolar trough.

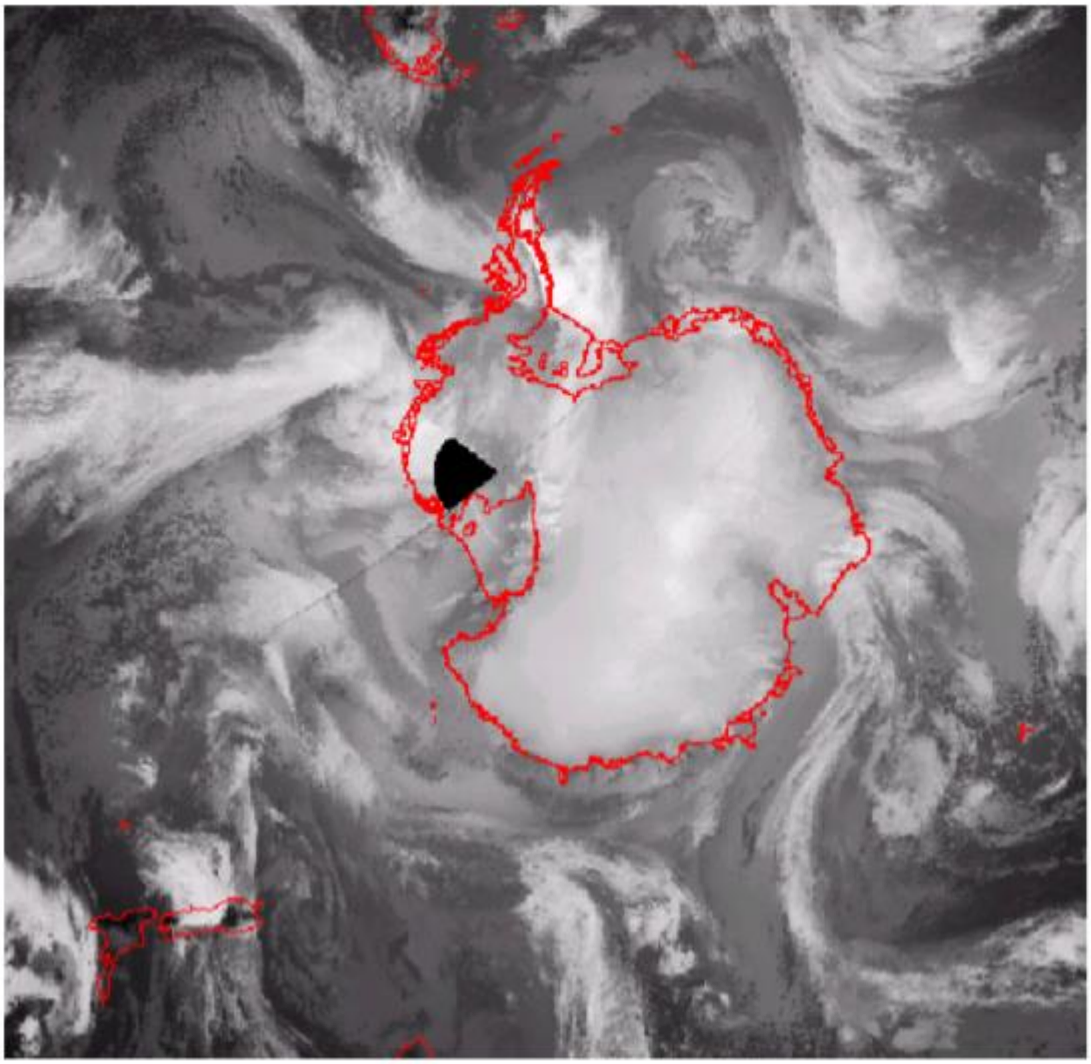

Figure 1.9 Satellite image showing Antarctica and frontal systems and spirals associated with depression centers (cyclones).

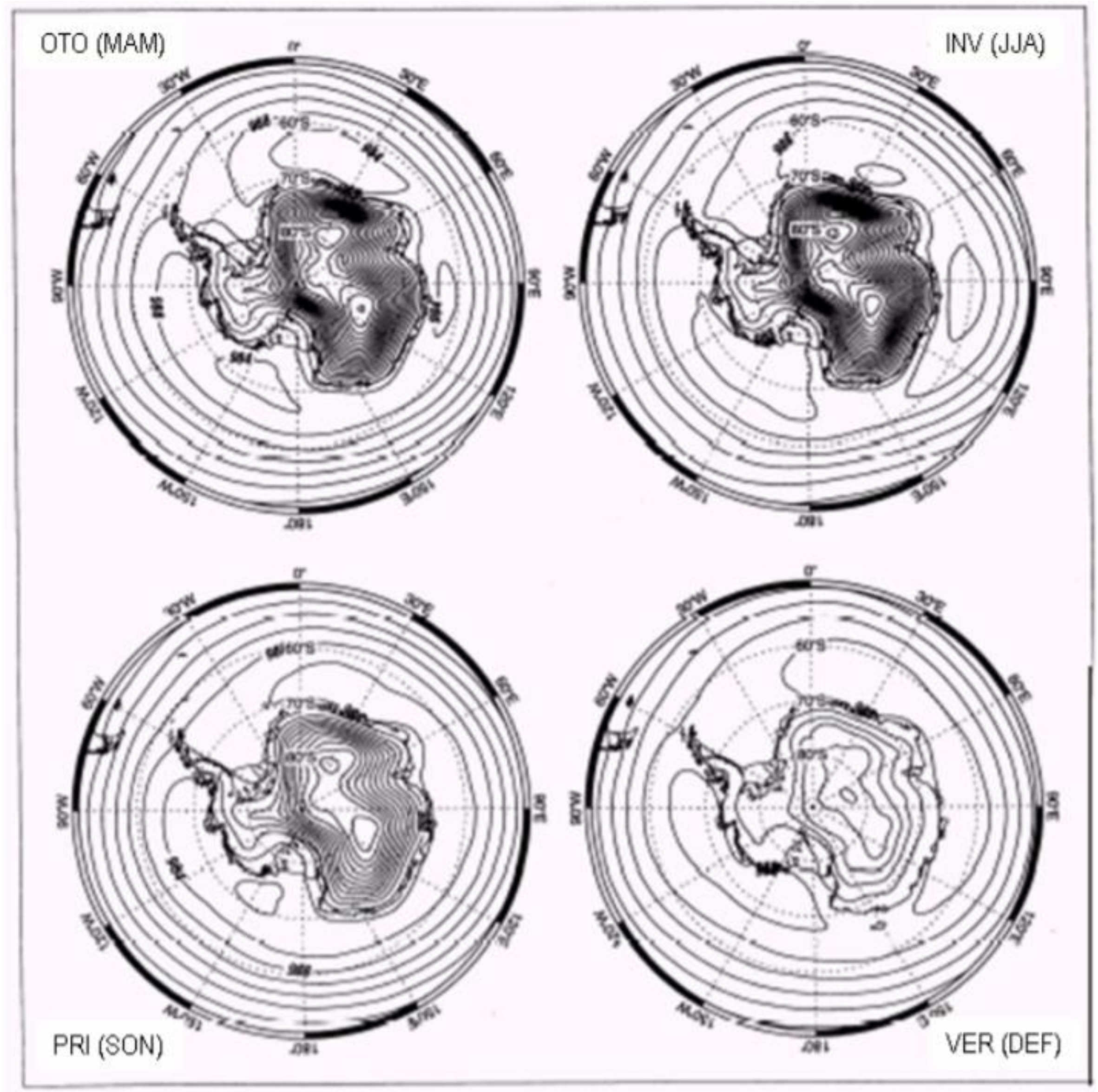

Figure 1.10 Average field of pressure at sea level (1969-98) for four seasons of the year, rebuilt from the re-analysis of the Center for Environmental Prediction (NCEP) in the United States.

The distribution of atmospheric pressure in the polar region also reveals a high pressure center inside the Antarctic. However, in most of Eastern Antarctica the pressure is below 700 hectopascals (hPa), so the first representative level of the free atmosphere (that which is above the boundary layer) is at 500 hPa . At this level, the winds in the atmosphere are from the west with cyclonic circulation centered on the

Ross Platform. On the 500 hPa and in the stratosphere the cyclonic circulation, known as the polar vortex, is more focused on the East Antarctic sector.