Selection of the VLT Site

The readers of the *Messenger* may wonder how the selection of the site for the Very Large Telescope (VLT) is proceeding. The interest in this important matter seems to be rising; hardly a day passes without a corresponding request for information to the ESO Information Service.

Here is a short summary of the current situation.

The Site Selection Working Group (SSWG phase I: Chairman J.-P. Swings) delivered its final report about the meteorological conditions in the Paranal and La Silla areas in early May this year. This report was thoroughly discussed by the Scientific Technical Committee (STC) during its meeting on May 10–11. The STC passed a resolution, which endorsed the SSWG I recommendation to establish the VLT Observatory in the Paranal area and recommended that the ESO Executive work out and present a viable operational model of ESO/Chile with the Observatory on La Silla and the VLT Observatory in the Paranal area to the STC, the Finance Committee and Council in November/December 1990.

In its meeting in Sweden on June 7, the ESO Council passed the following resolution: "Council, taking note of the superior scientific qualities of the Paranal area, asks the ESO Executive to work out financial, technical and research policy implications and operational models of ESO/Chile for the Paranal area option as well as for the Vizcachas option."

This work is now under way at ESO. At the same time, a modified Site Selection Working Group has taken up its work during a first meeting at the ESO Headquarters on July 25. Whereas in the first phase, the SSWG mainly looked into the scientific aspects of the site choice, the terms of reference for SSWG phase II, as defined already in December 1988, also include the operational and financial pros and cons of the site options. J.-P. Swings (Belgium) continues as Chairman; other members are I. Appenzeller (F.R. Germany), A. Ardeberg (Sweden), G. Lelièvre (France) and S. Ortolani (Italy).

The SSWG II will have the important function of providing guidelines for and running criticism of the in-house study by the ESO management, before it is finalized and presented to the ESO Committees and Council later this year.

In this connection, a completely independent line of approach to the question of the long-term climatic stability in Northern Chile has become available. Dr. Michel Grenon of the Geneva Observatory, a regular visiting astronomer to La Silla during the past two decades and a botanist with strong interests in biogeography, has recently submitted a report on the climate in and around the Atacama desert, as deduced from sources, not considered in the SSWG study, but indicative of the climatic conditions in the past and the present around the possible VLT sites.

We are very pleased that Dr. Grenon has agreed to the publication of a popular account of this most interesting biogeographical study in this issue of the *Messenger.* We warmly commend it to the attention of our readers.

In accordance with the original planning, it is hoped that it will be possible to decide about the future VLT site before the end of the current year. In that case, the ground preparation (blasting, etc.) will start on-schedule in early 1991.

The Editor

The Northern Chile Climate and Its Evolution

A Pluridisciplinary Approach to the VLT Site Selection

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1. Introduction

The selection of an optimum astronomical site in northern Chile, undertaken by ESO for several years now, is a very complex task. The location of the VLT will effect the efficiency of the European astronomical community for the next 30 to 50 years. Therefore, it is of prime importance that the selected site optimizes the quality and the quantity of the collected data for the whole range of wavelengths being of interest now and in the future. At least four different parameters have to be considered:

1. the quality of the images (seeing);
2. the quality of the atmospheric transparency, namely the amount of aerosols and of the precipitable water and their time variation;
3. the annual distribution of photometric and spectroscopic nights;
4. the intermediate and long term evolution of climate with local response to global climatic changes.

Several factors complicate the selection of the site. A major problem is the scarcity of meteorological stations in northern Chile, as they are mainly located along the coast, below the inversion layer, or distributed in the main valleys. Little is known about the Andean or the precordillera area climate, south of 23 °S. The rather short duration of continuous records of half a century or less, depending on the measured quantities, make the definition of mean meteorological values and trends uncertain. Another important problem is the vastness of the domain to be investigated, i.e. about 1000 km in latitude and 200 km in longitude in which the potential sites are located in non-populated areas and hence have no meteorological or historical records. In the southern part of the Atacama desert, the occurrence of quasi periodic wet episodes separated by series of dry years, makes the comparison between sites difficult and possibly meaningless unless it is synchronous. With a semi-periodicity of 8 to 12 years, cf. section 3, measurements over 30 to 40 years are necessary to characterize the local mean climatic conditions.

The aim of this report is to provide information on the existing and anticipated sites, complementary to that collected by ESO investigators during the site testing campaign.

The present approach utilizes biogeography as a tool to define with a high spatial resolution the integrated climatic properties over various time scales depending on the life duration and propagation times of living beings considered. The data used here are either compiled from specialized literature or are the results of mainly botanical observations, made by the author in Chile since 1971. The connection with meteorological and climatical parameters will be made in order to define the astronomical properties of northern Chile sites, in comparison with Cerro Tololo and La Silla sites.

The sensitivity of local conditions to small and large amplitude climatic changes will be explored, using data from the fields of palaeobotany, glaciology, and geology.

2. The Origin of the Atacama Desert

The Atacama desert is, geologically speaking, a rather young feature. Its development started during the Miocene, about 12 Myr ago, when the uplifting of the Andes Central Cordillera progressively interrupted the zonal circulation at low altitudes. Erosion and canyon cutting on the western flank ceased at the Miocene-Pliocene boundary, about 5.3 Myr ago, as a consequence of the intensification of the Humboldt current, and of the regression of the counter-running warm current. During the lower Pliocene, the Atacama climate remained warm but not arid. It is only from the lower Pleistocene on, during glacial and interglacial episodes, that the colder humid periods started to alternate with warm and dry ones. The aridity was intensified at each interglacial period as a result of the height increase of the Andes through intense andestic activity (Arroyo et al. 1988). The present day extreme arid condition was reached only at the end of the Pleistocene about 10,000 years ago.

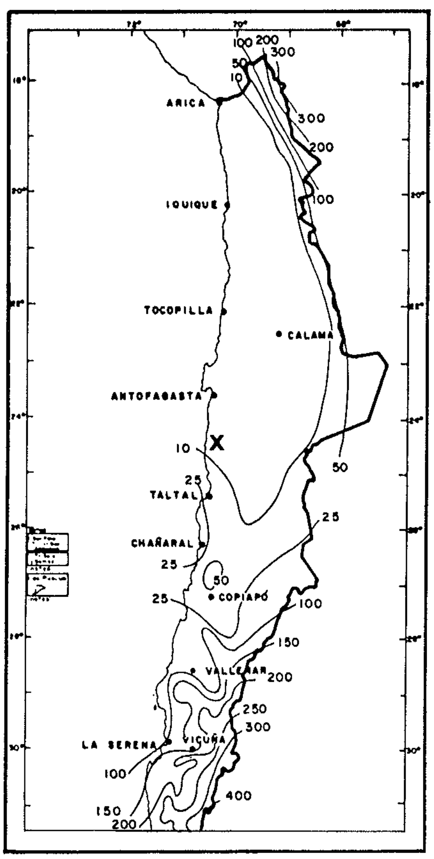

Figure 1: *The distribution of the mean annual precipitation over northern Chile in units of mm H_2O. The cross indicates the site of Paranal (Huber, 1979). The nucleus of the Atacama desert, i.e. the orographic depression between 19° and 25 °S is the most arid desert of the Earth with annual precipitation as low as 3.1 mm at Pintados (20°27 S, 69°29 N) and a daily amplitude of the temperature exceeding 25 °C during more than 9 months per year (Weischet, 1966). Along the northern coast, precipitation is even less, e.g. 0.6 mm at Arica or 2.2 mm at Antofagasta, but the relative humidity is high.*

Nowadays, the wet continental tropical air masses are stopped east of the Andes and may cross the Andes only in southern summer, during the so-called Bolivian winter, when the Pacific anticyclone is moving southwards, cf. Fuenzalida (1983). But even if saturated when crossing the Andes, the adiabatic warming of the air by 10 to 30 degrees leads to a relative humidity of less than 30 % at low altitudes.

On the western side, the Pacific anticyclone prevents the penetration of polar air masses over the continent at latitudes approximately north of 25 °S. The presence of cold waters of the Humbolt current at tropical latitudes induces temperature inversion at an altitude of 900 m near La Serena to 1300–1500 m between Taltal and Antofagasta. This inversion, with its associated quasi-permanent sea of clouds, inhibits the sea evaporation as well as the vertical atmospheric turbulence. The Pacific humid air masses penetrate into the continent only when the coastal Cordillera is depressed, or through the main valleys, pumped by local thermal winds.

Between the latitudes 19°30 S and 25 °S there is no significant discontinuity in the western mountain range and so, for about 600 km, the Pacific air mass is completely blocked over the sea and the narrow coastal strip. As a consequence, one of the most arid deserts of the Earth was able to develop over the coastal Cordillera and in the central depression. In stable conditions, the atmospheric transparency corresponds to the properties of a modified tropical maritime air mass, dry and with a low aerosol content.

3. The Climate of Atacama

Although arid climate prevails from 15 °S to 28 °S in Chile, the climatic conditions are distinct in the northern, eastern and southern borders of the desert. The extension of the extreme arid conditions, defined by precipitation less than 10 mm/y, may be seen in Figure 1. The limits of absolute desert are narrower, with a maximum altitude ranging from 1500 m east of Arica to 3000 m east of Antofagasta.

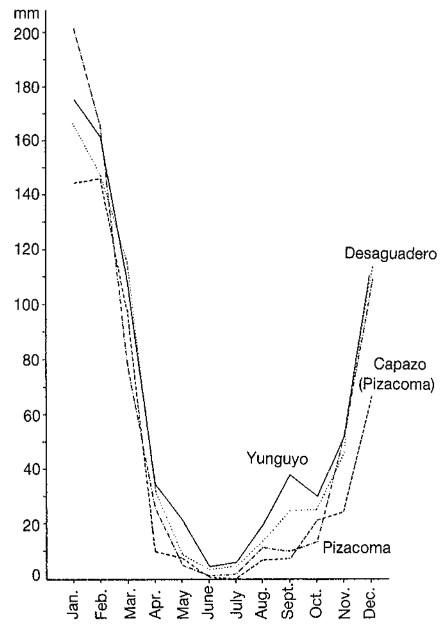

Figure 2: *The annual distribution of precipitations at different sites close to the Chilean-Peruvian border east of the main Cordillera (Rodriguez, 1988). Measurements of annual rain precipitation show that precipitations induced by easterlies are regular, cf. Figure 3, and allow the development of a rich flora and fauna. An increase of moisture in the atmosphere in northern Chile is to be expected from December to March.*

The northern part is a cold air and rain shadow desert with a climate determined by the yearly latitudinal oscillation of the intertropical convergence. The pluviosity shows a steep increase towards the east. Up to 4000 m, regular precipitation as rainfall occurs between November and April with annual maxima reaching 300 mm to 400 mm at the Bolivian border, see Figures 2 and 3.

South of 24–25 °S the precipitations are due to the polar front activity bringing moisture from the south-west. Here, between April and September, the rise of cool moist air produces condensation as rainfall or, if above 3000 m, as snowfall over the precordilleras and cordilleras.

The occurrence of fronts is controlled by the latitudinal yearly oscillation of the South Pacific anticyclone centred at about 27 °S in winter and 30 °S in summer. The virga phenomenon, i.e. the evaporation of rain drops in low altitude dry air layers, is frequent. That is why rain over the central depression and the coastal mountains is so scarce and irregular. The warm tropical desert ends at latitude 27 °S, about 50 km north of Copiapo.

4. The Transition Zone

The transition zone is of particular interest since it contains the three major

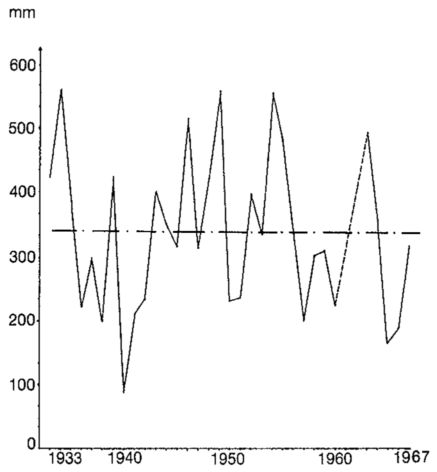

Figure 3: *Annual precipitation at Parinacota station, latitude 18°12, longitude 69°20 W and altitude 4360 m. Notice the limited range of year-to-year variation. Adapted from Niemeyer (1968).*

astronomical sites now operating in Chile. It is also the zone where the biogeography allows a very detailed analysis of the past and present climatic conditions. Since it is a comparison zone for the northern sites of Paranal and Armazoni, its properties will be more extensively described.

This zone, between 27 °S and 34 °S, has a typical Mediterranean climate characterized by sporadic winter rains occurring when the anticyclonic conditions are briefly interrupted by short-lived cyclons, and followed by a dry summer and autumn. The amount of precipitation, as well as the duration of the wet season, steeply declines when moving to the north, see Figure 4 from Caviedes (1990). The number of cyclonic transits also declines towards the North. At the latitude of La Serena, there are about 3 to 4 bad weather episodes with a marked variability in intensity and number per winter.

At La Silla, the frontal activity is the cause of a serious degradation of the observing conditions in winter and spring. The highest percentage of non-photometric nights also occurs when the nights are the longest, it is therefore more realistic to consider the monthly number of lost hours of observation. In Figure 5 we give the total number of hours lost during non-photometric nights at La Silla for the period 1966–1972 which includes only one wet episode, see Figure 7. In Figure 5, lost hours during partially photometric nights, i.e. with at least 6 hours of observation, are not taken into account.

Thus, Figure 5 gives only the lower limits of lost observing hours. Monthly precipitation in central Chile and loss of observing hours show a clear correlation, see Figures 4 and 5, for the greater part of the year, except for spring months when fronts normally produce not rain but only cloudiness at La Silla. The dotted area in Figure 5 is indicative of the number of hours which could be gained by moving the observatory to the North.

Between the Elqui and Copiapo valleys, winter precipitation is highly irregular and, north of Vallenar, totally dry years may occur. The total annual precipitation at La Serena (lat. 29°54 S), Vallenar (lat. 28°34 S) and Copiapo (lat. 27°20 S), for the years 1970–1984, are shown in Figure 6. The decrease of the precipitation, over these 250 km only, is as spectacular as the increase of the variability from year to year.

In order to study the intermediate time scale climatic variations, longer series have to be considered. In the absence of a dense net of nivo- and pluviometers in the transition zone, the mean flux of the major rivers and their affluents are used as indicators of the mean precipitations in their basin. Fluxes are monitored in the area since 1942 and the most relevant data are the hydrograms of Rio Huasco and of its affluent Rio Carmen alimented by precipitation fallen just east of La Silla, see Figure 7.

The most evident pattern is the recurrence of wet episodes with a semi-regular periodicity. Severe winters occur every 7 to 12 years followed by progressive return to dry conditions. The flux distribution is somewhat smoothed by the delay between snowfall and melting at high altitudes about four months later, and by the low velocity of underground water. The volume of water measured in El Carmen correlates very well with the amount of precipitation observed in the Vallenar area. Nevertheless, flux measurement appears to be a better indicator of the winter severity at Las Campanas and La Silla than the pluviosity at Vallenar since it is not affected by the virga effect and thus represents the true frontal cloudiness over La Silla.

The hydrograms of Elqui, Hurtado and Limari rivers, characteristic of the winter

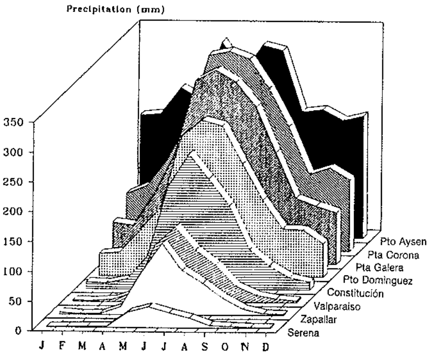

Figure 4: *Monthly precipitation at different coastal stations of central Chile, from Caviedes (1990).*

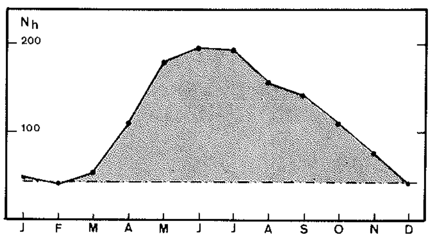

Figure 5: *The monthly number of lost photometric hours during non-photometric nights for the period 1966 to 1972 at La Silla.*

conditions prevailing at Cerro Tololo, show similar patterns but with more pronounced and frequent secondary peaks. The regularity of rainy years is increasing towards the South whereas in the intermediate zone there appears to be a quasi biblical alternance of rich and poor harvests.

When compared during dry years, the mountain sites between Elqui and Copiapo valleys would show little difference in their quality as astronomical sites. This may be the reason why La Silla mountain was selected after a series of tests performed in that area during the dry years 1961–1962. In Figure 7, the peak in 1965 also explains why the first measurements at La Silla that year were somewhat disappointing.

The transition zone is indeed the most sensitive to climatic changes and consequently the southern limit of the Atacama desert is expected to vary by several hundred kilometres.

5. The Biogeography as a Site Testing Tool

The distribution of living beings, in particular that of plants, is the result of geological, biological and climatic evolution. Various time scales are involved, from several million years for the families and genera differentiation, few thousand years for major climatic changes to one year for blossoming of annuals.

At the present time the observed distribution of plants, insects, reptiles, etc., has almost reached a new equilibrium after major changes of the last ice age. Living species develop in well-defined biotopes. Plants in particular are adapted to more or less restricted ranges of temperature, total amount of precipitation, soil acidity, insolation and hygrometry. In the semi-arid and arid zones plants are characterized by their capability to absorb water, to store it for the dry months or years and to resist desiccation. This desiccation, due to low relative humidity, effect of the solar radiation and that of surface evaporation reinforced by wind, is the limiting factor of major importance for the vegetal development.

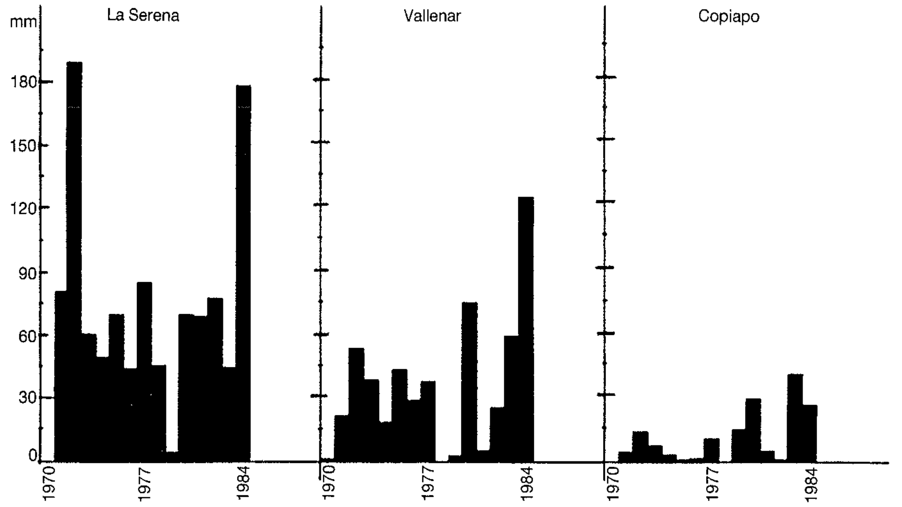

Figure 6: *The total annual rain precipitation at La Serena, Vallenar and Copiapo, between 1970 and 1984.*

Plants or plant associations with well-defined climatic requirements may be used to map the areas where the climatic conditions are within the permitted range for a given species or group. In semi-arid zones, although the plant density is small, botanical surveys may reveal microclimates with a resolution as high as a few metres.

Life cycles are very distinct from species to species. Annuals, with seeds easily dispersed by wind, are tracers of the short time climatic conditions. Perennials are indicative of mean conditions over few years to a century or more, depending on their life time and the time to reach maturity. Species, adapted to restricted climatic conditions and with little efficiency in seed dispersion, are tracers of long term conditions. This is the case with most of the Chilean cactaceae.

Plant distribution, i.e. phytogeography, allows to define the climatic conditions over very extended areas, and to associate to each vegetal group a set of climatological parameters. They are determined by interpolating meteorological data collected in the considered area, if existing, and in adjacent areas. The preselection of astronomical sites, worthy of testing, can indeed be made.

In the semi-arid zone, when the ground coverage is high enough, the location of the domes on a given site may be optimized by using the distribution of plants with distinct sensitivity to the winds, thermal or dominant.

6. The Phytogeographic Zones

Phytogeography reveals a clear zonation in latitude and altitude south of 26 °S. From Elqui Valley to the Santiago area, a Mediterranean vegetation prevails with rare trees, perennial bushes, tree cacti and a rich flora of herbs in blossom at the end of winter. Winter watering is regular as well as humidity, so no special adaptation is required by plants to survive longer than one dry summer. The lower part of Elqui Valley, including Cerro Tololo Observatory, belongs to that climatic zone. The upper Elqui Valley is drier because of rain shadow produced by the precordillera and evapotranspiration due to strong thermal valley winds.

Along the coast, the presence of cold humid Pacific air and fog allows the development of a peculiar floristic association including bromeliaceae and cactaceae.

The transition between the Mediterranean and semi-arid zone occurs north of La Serena, and is completed at Cuesta de Buenos Aires. From there to the north of Copiapo, the winter watering is no longer guaranteed and species have to survive, as seeds or bulbs, succulents or other forms, through one to several dry years. In this area, several cactaceae develop relatively enormous underground water reservoirs, like those of Opuntia archiconoides, a local endemic of Vallenar Cordillera, found at La Silla, see Figure 8.

In the alluvial plains, at intermediate altitude, where the soil is deep enough to retain humidity, a few times per decade, irregular rainy winters produce a spectacular blossoming desert. The typical vegetal association producing this phenomenon extends from Cuesta de Buenos Aires to few pockets, about 50 km north of Copiapo (see map in Figure 9). This is the zone where polar front activity produces at least 20 mm of precipitation semi-regularily. In this zone, tree cactaceae are confined to places invaded by fog during the night. In comparison, similar species are found close to the summit of Cerro Tololo.

North of 26 °S parallel, the zonation becomes East-West. A strip along the

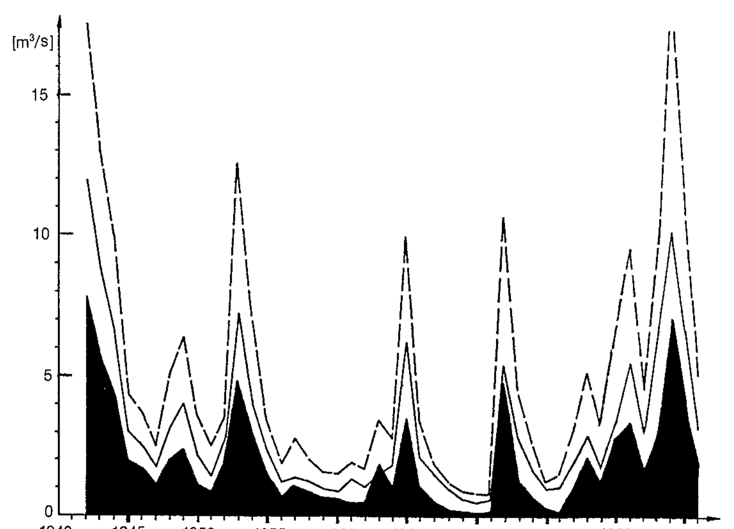

Figure 7: *The hydrogram of Huasco river (upper curve) and (in black) that of Rio Carmen as measured at San Felix, latitude 28°56 S. From Dirección General de Aguas.*

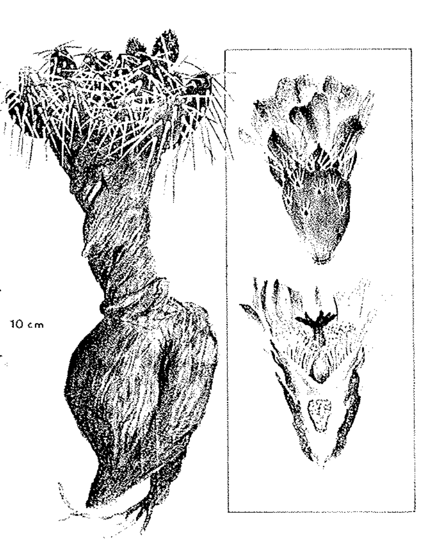

Figure 8: *The root system of Opuntia archiconoides, a La Silla plant adapted to long duration droughts. From Hoffmann (1989).*

coast, narrowing towards the equator, hosts extremely specialized vegetal associations, which in general are able to retain water from fog only. In fog pockets like Paposo, north of Taltal, extremely distinct associations are found. The high rate of endemics indicates that these local climatic conditions are indeed very ancient. Between Taltal and Antofagasta, above the inversion layer, i.e. above about 1300 m, warm desertic conditions prevail, with none to very scarce vegetation. On the western Cordillera, the vegetation is essentially inexistent below 3000 m. At Paranal, only one perennial was found in January 1990, and at Armazoni, two species adapted to extreme conditions have been collected. These are a succulent plant, Philippiamra pachyphylla, and a visquous one, Adesmia atacamensis, which is also found on other summits in the area. At Armazoni, their presence, as well as erosion features near the top, indicate that watering indeed occurs in the area with some regularity. Hoar frost or even snow may be expected at Armazoni. According to Figure 9, the absolute desert stops 80 to 110 km east from the coast, followed by a tropical semi-desert and at higher altitude by an Andean steppe. At the latitude of Paranal, the semi-desert starts at only 30 km from the coast. This is an evidence that, at that latitude, coastal summits are certainly astronomically better than interior ones.

7. Other Biological Evidences

Animals through their food resources can also be used as climatic tracers. As an example, in Figure 10, we give the distribution of reptiles belonging to Iguanidae and Colubridae families. The number of reptile species is limited, not only by the availability of their prey, as insects, and hence of vegetation, but also by temperature. The density of species is 10 to 12 species at maximum between 33 °S to 35 °S, and also shows a relative maximum in the central depression. The density remains constant at 5–6 between Coquimbo and Copiapo and falls to 1 or 0 north of 26 °S.

The only area without reptiles of these families on the western Cordillera is between 24°20 S and about 26°15 S. In the central Andes, the density is small and falls to about 0 at 24 °S, but shows a sharp increase east of Calama where the altiplanic humidity is high because of Bolivian winter.

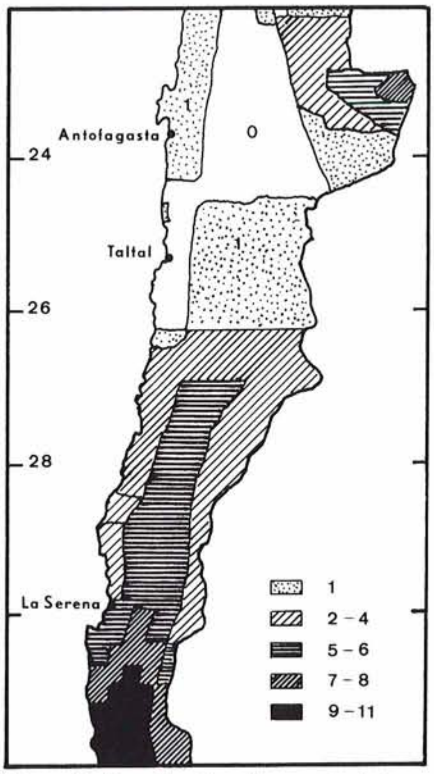

Figure 10: *Density of reptile species belonging to Iguanidae and Colubridae families, mapped according to Donoso-Barros (1966) species distribution.*

8. Phytogeographically the Optimum Latitude

When moving towards the North, the winter conditions improve continuously at least up to 27 °S. At some latitude, the gain in observing time in winter will be compensated by losses during Bolivian "winter" in summer. Bolivian winter is expected to bring moisture in the atmosphere over the whole northern Atacama desert, and for IR and millimetric astronomy, its influence should be minimized. The optimum latitude should then be that which optimizes the yearly distribution of observing time, i.e. by minimizing winter and summer losses.

In the absence of a sufficient number of Andean meteorological stations between 22 °S and 28 °S, the information can again be deduced from phytogeography. Arroyo et al. (1988), have made six transects through the Andes between 18 °S and 29 °S, and have evaluated the richness of species as a function of the altitude and latitude.

The temperature is merely independent on latitude and the richness is essentially controlled by hygrometry. At 26 °S, the richness is independent on altitude up to 4000 m. Closer to the Equator, the maximum species density is found in the altitude range 3000–3500 m, and at lower altitudes south of 26 °.

La Silla mountain with its estimated richness of 130 species, according to the author's collection, is just normal for its altitude and latitude with respect to other Andean sites.

Figure 11 shows the total richness (N_{tot}) per transect and also at an altitude of 2500 m (N_{2500}) as a function of the latitude. North of 24 °S, richness is due to summer precipitation whereas south of 26 °S to winter precipitation. By extrapolating the curves for richness versus latitude for both regimes, we can deduce that Bolivian winter contributes

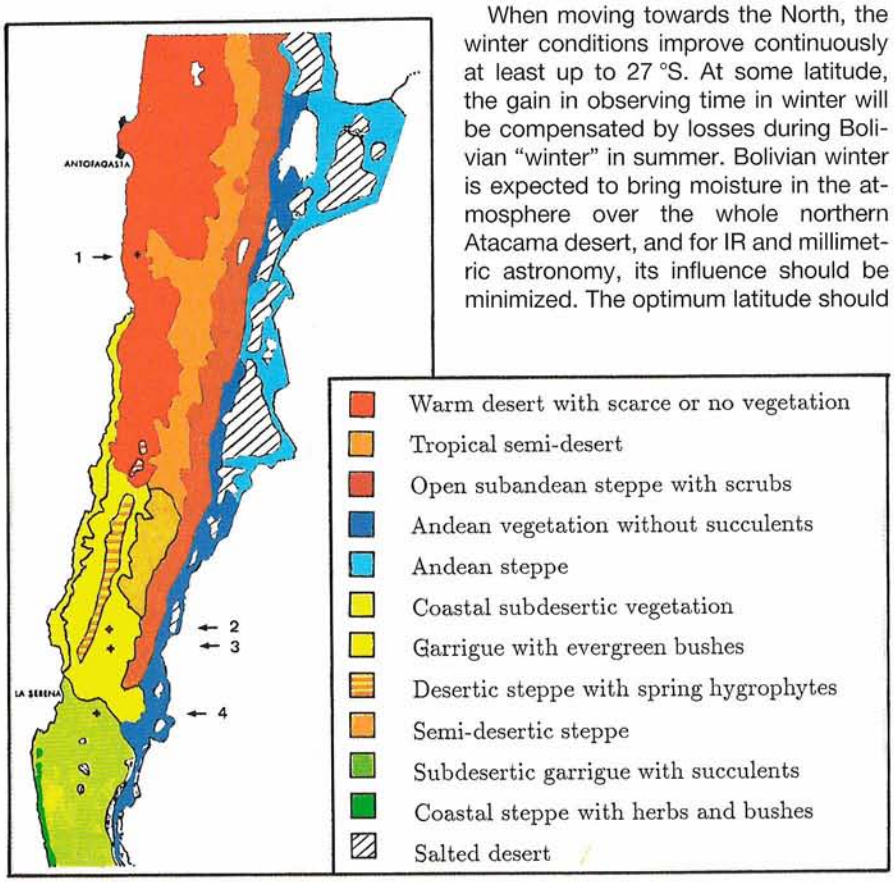

Figure 9: *Map of phytogeographic zones in central and northern Chile (adapted from Geographia de Chile III, Perez (1983). The sites of Paranal (1), Las Campanas (2), La Silla (3) and Cerro Tololo (4) are indicated by crosses.*

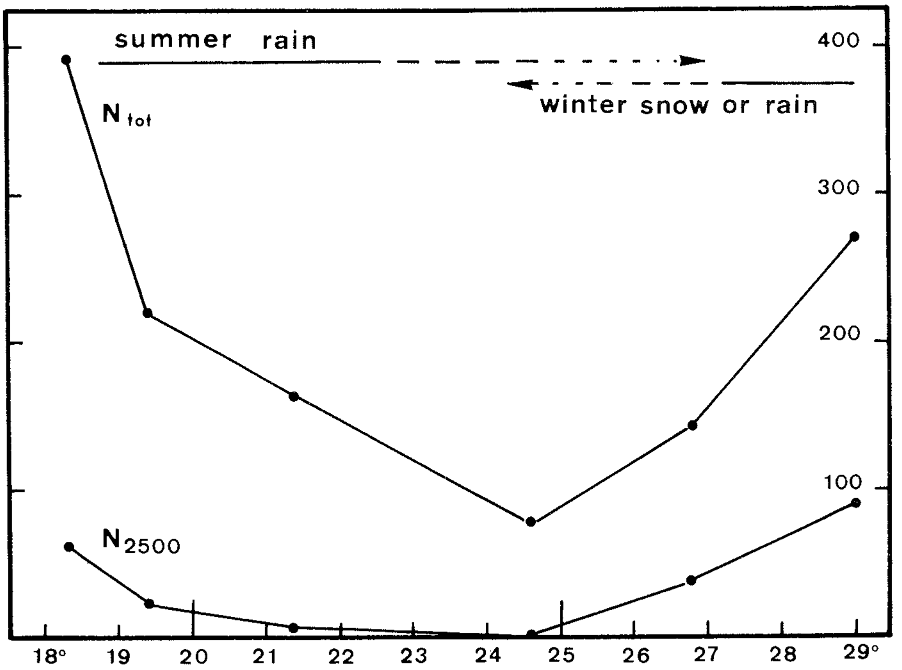

Figure 11: *The dependence of the plant diversity in the Andes, integrated along a transect N_{tot} and at altitude 2500 m (N_{2500}) as a function of latitude, adapted from Arroyo et al. (1988) with an estimate of Bolivian (summer rain) and Chilean winter extensions.*

to plant diversity down to 27 °S, whereas Chilean winter is perceptible up to 24 °S. Thus, the optimum latitude for an astronomical site is somewhere between 24°30 S and 25 °S. Paranal site at latitude 24°37 S, is indeed perfectly located.

9. The Long Term Climatic Variations

In the southern Atacama desert, as stated before, we observe intermediate time scale variations of climatic conditions with a quasi-periodicity of 7 to 12 years. There is some evidence for an intensification of aridity during the past 50 years, partly due to anthropic activity, but more so to real climatic change. At La Silla, the local endemic component of the flora seems to be stable, whereas the part composed of species growing at the northern limit of their natural geographical domain, are in regression. The ground coverage is diminishing, e.g. for the genus Proustia for which very few or no young specimens are found. On the other hand, the discovery of very old Balsamocarpon bushes, in the quebrada west of La Silla, indicates that the local conditions have been quasi stable for centuries. This bush is characteristic of the III^rd and IV^th region, and able to survive during completely dry years in dormant mode by loosing its leaves. The oldest stem shows about 700 growth rings and, depending on the fraction of years without growth, its age possibly exceeds that figure.

Palaeoclimatology indicates little change in temperature and humidity after the end of Pleistocene, 11,400 years B.P.; isotopic datation of underground water in the Antofagasta area confirms the palynological findings, with an age of 10,000 years for this fossil water.

During the moderate climatic optimum following the glacial period, i.e. between 7300 and 3600 years B.P., the temperature in the Andes was higher by 0.6 to 1.2 °C depending on the altitude. The corresponding climates on the western side of the Andes were reconstructed by Lauer (1986).

The temperature rise led to an important regression of the northern limit of the desert, from about 2 ° to 8 °S, but had no noticeable effect on the southern limit at about 26°20 S, see Figure 12. This finding supports the stability of the conditions at Paranal in the case of a moderate greenhouse effect.

The trends in the case of a global planetary cooling are better documented. The changes of snowline, of altiplanic lake shores (now salares), the fossil pollen records in peat bogs, and in particular the presence of relictual floras, belonging to Valdivian type rain forest at the Rio Limari latitude – the Fray Jorge and Talinay woods –, are all convergent indications of an important change of the southern and eastern limits of the Atacama desert.

During the last ice age, the latitudinal shift of the vegetation was about 800 km. At that time, the conditions existing now at La Silla were experienced close to Paranal, and those of Concepción at La Serena.

Multiregressive models by Caviedes (1990) predict the amount of precipitation and the change of snowline for temperature falls. With respect to the present amount of rain, 117 mm at La Serena, a cooling by 1 °, 2 °, 3 °C would produce precipitation of 480, 967 and 1450 mm, respectively. Thus, the zone at latitude 29 °–30 °S appears to be highly sensitive to climatic changes where a temperature drop of just 1 °, induces a precipitation increase by a factor of four.

10. Conclusions

In summary, the La Silla Observatory is located in a transition zone visited by polar fronts which are responsible for a serious degradation of winter observing conditions.

The weather conditions are variable and semi-regular with time-scales in the order of a decade. Although an intensification of the aridity is noticed during the last 50 years, the mean conditions appear to be stable over several centuries. This zone is highly sensitive to global climatic changes where a temperature drop of 1 °C causes an in-

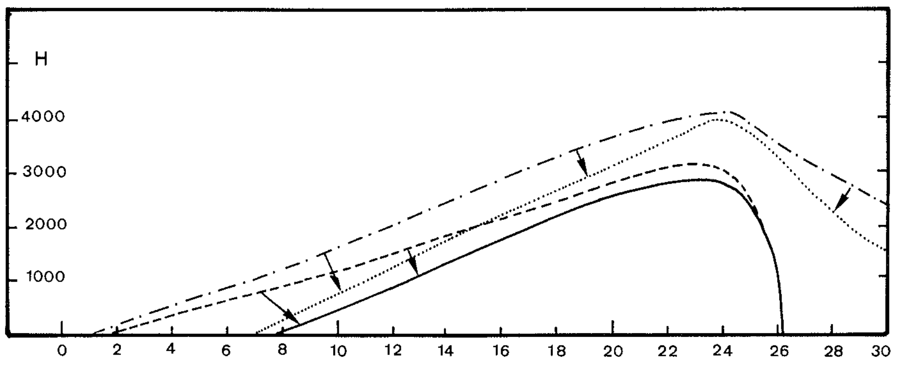

Figure 12: *The limits in latitude and altitude of the absolute desert and semi-arid area, at the present epoch (– – – –) and (– · – · –) respectively, and during the warm episode at the end of the Peistocene. The arrows indicate the effect of a global climatic warming. Adapted from Lauer (1986).*

crease of precipitation by a factor of four or more.

In northern Chile, between latitude 24°30 S and 25 °S, influences of polar fronts and easterlies are at a minimum. Cloudiness and precipitation increase from the west to the east; thus, coastal cordillera summits have to be preferred. On that mountain range, the azoic zone over 1500 m extends from 24°20 S to 26°10 S. Absolute desert is limited to a strip of 80–110 km wide, and possibly due to a purely altitudinal effect, as narrow as 30 km at the latitude of Paranal. The aridity of the western cordillera area, north of 26 °S, appears to be stable, even in case of large amplitude climate changes (warmer or colder). The occurrence of rainfall is barely related to the El Niño phenomenon.

All the climatic indicators considered here, biogeographic and meteorological, lead to the conclusion that Paranal mountain is located in the best possible area of South America for the settlement of a modern astronomical observatory.

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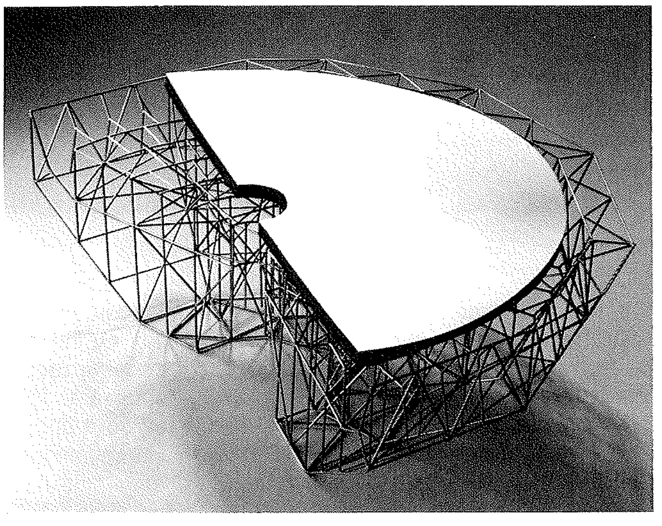
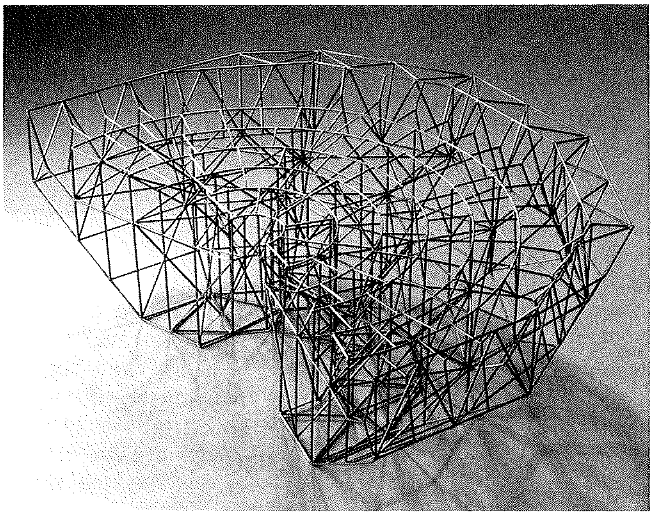
Progress on the VLT Mirror Cell Design





The NOTSA group at Risø (Denmark) is performing, under contract of ESO, the engineering of the VLT primary mirror cell.

A preliminary design has now been produced which however still needs to be optimized through computer modelling and finite element analysis. The NOTSA group thought that a preliminary "hardwire" modelling would be cost- and time-effective and decided to build several models with copper wire which can easily be soldered and rapidly modified. This approach has effectively permitted to discriminate rapidly between several designs, which would have had required much more effort through computer modelling. It also permitted to correct for a few errors which for such a complex structure are almost unavoidable, time consuming and . . . sometimes may reach the manufacturing stage while still undetected.

The two photographs show one of these "hardwire" models, once with a half mirror cardboard model, once without. The actual VLT mirror cell will have a diameter of about 9 metres and it will be 3 metres high.

D. ENARD, ESO

Halley Enters Hibernation

Famous Comet Halley, now receding from the Sun after its perihelion passage in early 1986, has recently entered into a state of hibernation which will last until shortly before the next passage in 2061.

This is the main result of a series of observations in late February 1990, during which the comet was imaged with a CCD camera attached to the Danish 1.5-m telescope at La Silla. The seeing conditions were mediocre, ~ 1.3 arcsec. At this time Halley was 11.6 AU (1735 million km) and 12.5 AU (1870 million km) from the Earth and the Sun, respectively, that is well outside the orbit of the giant planet Saturn.

Exposures totalling 980 min (16 hrs 20 min) were obtained and the "negative" picture shown here is a composite of 23 frames, each individually cleaned. The image of Halley at the centre is pointlike; the straight lines are trails of stars and galaxies in the field, because the telescope was set to follow the com-