
Atacama Large Millimeter Array

# ALMA Environmental Specification

ALMA-80.05.02.00-001-B-SPE

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# Change Record

| Version | Date | Affected Section(s) | Change Request # | Reason/Initiation/Remarks |
|---|---|---|---|---|
| A | 2003-08-22 | All | | First issue. |
| B | 2003-12-14 | AD01 | none | S. Oliver: corrected document number for applicable document number 1. Changed from ALMA-80.10.00.00-002-A-REP To SYSE-80.10.00.00-002-A-REP |
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# Table of Contents

# 1 Description

## 1.1 Purpose

This document specifies the natural and induced environmental conditions expected to be encountered at the ALMA Site in the San Pedro de Atacama area of Northern Chile. Data is presented on various environmental parameters, including: air pressure, temperature, humidity, wind speed, wind direction, solar radiation, precipitation, dust, contamination, and earthquake conditions. These information and data sets are derived from a combination of site testing direct measurement, specific environmental studies as well as other additional reference sources.

From this information a set of requirements is established for the design and construction of the ALMA installations, infrastructure and equipment which will be established at these locations.

## 1.2 Scope

This document covers the environmental specifications and requirements for the buildings, infrastructure and equipment at the ALMA Chile Site in the San Pedro de Atacama area. This includes:

- Chajnantor Array Operations Site (AOS) at an altitude of over 5000m covering the ALMA buildings, antenna stations, roads, connecting utilities and support facilities over the area of the Science Preserve.
- Operations Support Facility (OSF) at an altitude of 2900m and its immediate surroundings.
- Area surrounding the Direct Access Road which leads from the OSF to the AOS.
- Area surrounding the OSF Access Road which connects the San Pedro-Tocano public road to the OSF.
- General conditions in buildings and hangars (temperature, humidity).

This does not include specific sub-system environmental conditions (e.g. Receiver Cabin) which shall be addressed in the sub-system specifications.

# 2 Reference Documents

## 2.1 Applicable Documents

The following Applicable Documents of the exact issue shown form a part of the present document to the extent specified herein. Where no issue or date is indicated, the latest editions/revisions thereof and any amendments or supplements thereto in effect on the date of enforcement of the present document shall be taken as valid. In the event of conflict between the Applicable Documents referenced herein and the contents of the present

document, the contents of the present document shall be considered a superseding requirement.
**AD01**: Seismic Design Specifications for ALMA-AOS and ALMA-OSF Project SYSE-80.10.00.00-002-A-REP

**AD02**: Resolución Exenta No. 0049/2003, Gobierno de Chile, Comision Regional del Medio Ambiente, Segunda Region de Antofagasta, 2003-03-20.

### 2.2 Reference Documents

**RD01** – http://www.tuc.nrao.edu/alma/site/Chajnantor/data.c.html

**RD02** – ALMA Memo #159, Wind Velocities at the Chajnantor and Mauna Kea Sites and the Effect on MMA Pointing - M.A. Holdaway, S.M. Foster, Darrel Emerson, Jingquan Cheng, Fred Schwab – 1996-08

**RD03** – ALMA Memo #250, Seismicity and Seismic Hazard at MMA site, Antofagasta, Chile, S.E. Barrientos – 1996-06

**RD04** – ALMA Memo #251, MMA Site East of San Pedro De Atacama, North Chile Volcanic Hazards Assessment and Geologic SettingM.C. Gardeweg P., 1996-08

**RD05** – ALMA Memo #314, Underground Temperature Fluctuations and Water Drainage at Chajnantor, Laura A. Snyder, Simon J. E. Radford, and Mark A. Holdaway, 2002-06

**RD06** – Very Large Telescope Environmental Specification, Doc. No.: VLT/SPE/ESO/10000/0004, Issue: 6, Date: 12.11.1997

**RD07** – ALMA Memo #322 , Comparison of Meteorological Data at the Pampa La Bola and Llano de Chajnantor Sites, Sakamoto et al.

**RD08** – ALMA Memo, in preparation, 2003-02-12, Lightning near Cerro Chascon, Sakamoto, S., & Radford, S. J. E. 2001

**RD09** – ALMA Memo #446, Levels of radiation exposure near AOS and OSF, Sakamoto et al.

### 2.3 Order of Precedence

In the event of conflict between the text of this document and applicable documents, the following order of precedence shall apply:

1. This document
2. Applicable documents

### 2.4 Abbreviations and Acronyms

| | |
|---|---|
| ALMA | Atacama Large Millimeter Array |
| AOS | Array Operations Site |
| IPT | Integrated Product Team |
| LEMP | Lightning Electromagnetic Pulse |
| MLE | Maximum Likely Earthquake |
| OBE | Operating Basis Earthquake |
| OSF | Operations Support Facility |
| UTM | Universal Transverse Mercator |
| UV | Ultra Violet |

### 2.5 Requirements Numbering

The requirements within the present document are numbered according to the following code

***ENVI-XXXXX-YY/Z(ZZ)***

where

| | |
|---|---|
| ***ENVI*** | stands for 'Environment'; |
| ***XXXXX*** | is the consecutive number 00010, 00020, … (the nine intermediate numbers remaining available for future revisions of this document); |
| ***YY*** | describes the requirement revision and starts with 00; |
| ***Z(ZZ)*** | describes the verification method(s) where T stays for test, I for inspection, R for review of design, A for analysis. |

## 3 Definitions

### 3.1 Operating and Non-Operating Conditions

For the purposes of specifying the requirements for which installations and equipment must be designed to perform under a given set of environmental conditions, the following set of conditions are defined.

#### 3.1.1 Operating Conditions

*[ENVI-00010-00 / R]*

The environmental conditions under which the equipment and installations must fully meet the specified performance.

### 3.1.2 Non Operating Conditions

*[ENVI-00020-00 / R]*
The environmental conditions, which the equipment and installations must survive without damage after safely stowed and/or protected. After return to operating conditions, the equipment and installations must continue to meet all performance specifications with a minimal maintenance adjustment.

## 3.2 Compatibility

When an environmental condition is not specified differently for Operating and Non Operating conditions, the term “compatible” is used.

*[ENVI-00030-00 / R]*
Compatibility with one given environmental condition means:

- Equipment that needs to be exposed to that condition for the operation of the system must meet all its requirements under these conditions.

- Equipment exposed to that condition when not operating (maintenance, transportation…) must survive under these conditions with protective measures (container…) if necessary.

# 4 AOS and OSF Common Environmental Conditions

## 4.1 Earthquakes

*[ENVI-00040-00 / A]*
The levels of earthquake acceleration that are likely to occur at the OSF and AOS [AD01] are specified in
Table 1:

- Operating Basis Earthquake (OBE): an earthquake with a high probability of occurrence during the lifetime of the observatory.
- Maximum Likely Earthquake (MLE): an earthquake of large magnitude but with lower probability of occurrence.

| | **OBE** | **MLE** |
|---|---|---|
| Peak horizontal ground acceleration (g) | 0.17 | 0.28 |
| Probability of excedance (%) | 10 | 10 |
| Reference Time (years) | 10 | 100 |

**Table 1: Earthquake Characteristics for ALMA**

Response spectra are given in Appendix 1.

*[ENVI-00050-00 / R]*
Occurring downtime and time to repair for the equipment must be defined in each sub-system specification.

### 4.2 Lightning and Lightning Electromagnetic Pulse

*[ENVI-00060-00 / R]*
Thunderstorms, lightning and LEMP can occur the entire time of the year, but especially during winter time. Statistical data do not exist.

### 4.3 Sand and Dust/Cleanliness

The site ground surface is principally volcanic soil and gravel with no vegetation of any kind to stabilize the surface, therefore:

*[ENVI-00061-00 / R]*
The system exposed equipment shall be compatible with windblown dust, ashes and grit.

*[ENVI-00062-00 / R]*
The buildings shall be tight enough to prevent penetration of dust and ashes.

### 4.4 Ozone Concentration

Formation of ozone is due to a reaction between dioxygen molecules and UV radiations. This chemical reaction is heavily catalyzed by pollutants such as nitrogen dioxides (NOx). This is why ground level ozone is mainly found in industrial and urban areas and especially in summer.
Two phenomena could contribute to the presence of ground level ozone on the sites:

- High UV radiation
- The movements of the air masses in the atmosphere which can spread out the ozone molecules from remote industrial areas to isolated areas.

However, it is not expected higher levels on the OSF and the AOS than in urban areas. A better quantification requires measurements to be made on the sites.

### 4.5 Fauna

*[ENVI-00063-00 / R]*
Special measures shall be taken to protect the buildings and exposed equipment from fauna intrusion (insects, rodents, llamas, vicuñas …).

### 4.6 Mechanical Shock and Vibration

It is assumed that the highest shock loads are expected either through earthquake (chapter 4), during transport to the OSF or during transport on the antenna transporter (Chapter 8).

## 5 Environmental Conditions at AOS

### 5.1 Geographical Location

The ALMA operation site is located on the Chajnantor altiplano about 40 km east of the historic village of San Pedro de Atacama, 130 km southeast of the mining town of Calama.

AOS position in UTM
N: 7 453 000 m
E: 628 000 m

AOS position in latitude and longitude:
$23^{o}$ 1’ W
$67^{o}$ 45’ S

### 5.2 Altitude

The approximate altitude of the AOS is 5050m. The antenna stations in the current version of the Y+ configuration range from about 4700m to 5125m.

### 5.3 Air Pressure/Air Density

*[ENVI-00070-00 / R]*
All ALMA equipment shall be compatible with an ambient air pressure of 550 mbar ± 60 mbar, which corresponds to an air density of 0.7214 kg/m3 (typical average).

### 5.4 Ambient Temperatures

All ALMA equipment exposed to the natural environment shall be compliant with ambient temperatures given in
Table **2** for the various operating conditions.

| Requirement | Condition | Minimum Temp °C | Maximum Temp °C |
|---|---|---|---|
| *[ENVI-00080-00 / R]* | Operating Conditions | -20.0 | +40.0 |
| *[ENVI-00090-00 / R]* | Non Operating Conditions | -30.0 | +40.0 |

**Table 2: Minimum and maximum temperatures**

For information, the data measured on the site are given in Appendix 2.

### 5.5 Sub-Surface Ground Temperature

The variation in sub-surface ground temperature has been measured in detail as part of the site testing. Any equipment operating underground shall be compatible with these temperatures:

| Requirement | Position | Temp Range [K] |
|---|---|---|
| [ENVI-00100-00 / R] | 100 to 300 mm below ground level | 267 – 271 |

**Table 3: Temperature below ground level**

### 5.6 Solar and Cosmic Radiation

All concerned equipment shall be compatible with the following conditions:

*[ENVI-00110-00 / R]*
For all equipment exposed to the outside environment, a maximum solar flux of 1290W/m2 from 0.3-60 micrometers shall be assumed.

*[ENVI-00120-00 / R]*
For all equipment exposed to the outside environment, a maximum UV radiation (280-400 nm band) of up to 100 W/m$^2$ shall be assumed.

*[ENVI-00121-00 / R]*
Maximum expected Gamma ray dose rates are 3.14 mSv/year

*[ENVI-00122-00 / R]*

Maximum expected neutron dose rates are 0.80 mSv/year

For more information on radiation, it is referred to [RD07] and [RD09].

### 5.7 Relative Humidity

All equipment shall be compatible with the following conditions:

*[ENVI-00140-00 / R]*
The ALMA system will be exposed to an environment of 0 to 30% relative humidity [RD07].

*[ENVI-00150-00 / R]*
The ALMA system will be exposed to an environment of 30% to 95% relative humidity and condensation at the ground surface [RD07].

### 5.8 Precipitations

Annual precipitation on the site is in the range 100 mm to 300 mm. Most of this falls as snow but thunderstorms with rain do occur.

*[ENVI-00160-00 / R]*
Equipment exposed to the natural environment shall be designed to be compatible with brief periods of heavy rain and hail.

#### 5.8.1 Rainfall

The ALMA system will be exposed to a rainfall environment as specified in Table 4 and shall be designed for the given conditions.

| Requirement | Operating Condition | Rainfall Precipitation Event |
|---|---|---|
| *[ENVI-00170-00 / R]* | Operating Conditions | No Precipitation |
| *[ENVI-00180-00 / R]* | Non operating Conditions | < 20 mm/h |

**Table 4: Rainfall**

#### 5.8.2 Ice/Freezing Rain

**The ALMA system will be exposed to an ice and freezing rain environment as specified in**

Table 5 and shall be designed for the given conditions.

| Requirement | Operating Condition | Ice/Freezing Rain Event |
|---|---|---|
| *[ENVI-00190-00 / R]* | Operating Conditions | No Precipitation |
| *[ENVI-00200-00 / R]* | Non operating Conditions | Hailstones <2 cm diameter with velocity 25 m/s<br>radial ice on all exposed surfaces < 1 cm |

**Table 5: Ice and freezing rain**

### 5.8.3 Snowfall

Snow precipitations are expected on the AOS and snow thickness can be up to 1 m (+ drifting factor) for a few weeks.

The following table defines the snowfall events for which the system shall be designed:

| Requirement | Operating Condition | Snowfall Event |
|---|---|---|
| *[ENVI-00210-00 / R]* | Operating Conditions | No Precipitation |
| *[ENVI-00220-00 / R]* | Non operating conditions | Snow load <100 kg/m$^2$ on horizontal surfaces. |

**Table 6: Snowfall**

*[ENVI-00230-00 / R]*
The snow and ice loading and wind conditions have to be survived simultaneously.

## 5.9 Wind

Table 7 specifies the maximum wind speeds from any azimuth angles for which any exposed equipment shall be designed:

| Requirement | Operating Condition | Wind Speed |
|---|---|---|
| [*ENVI-00240-00 / R]* | Operating Conditions | <6 m/s<br>(for quasi static calculations, wind speed shall be 6.4 m/s) |

| | | |
|---|---|---|
| *[ENVI-00250-00 / R]* | Non operating Conditions | < 65 m/s |

**Table 7: Ice and freezing rain**

For information, the data measured on the site are given in Appendix 3.

For more information it is referred to [RD01], [RD02] and [RD07].

# 6 Environmental Conditions at OSF

## 6.1 Geographical Location

The ALMA Operations Support Facility (OSF) is located south-east of San Pedro de Atacama. Its position is approximately 1/3 the way up west facing slope of the main Andean range leading to the 5000m Chajnantor plateau area. A road of approx 45km connects it to the AOS. The OSF and its environs cover an area of approx 100 hectares.

OSF Position in UTM
N: 7 449 088 m
E: 6 041 35 m

## 6.2 Altitude

The altitude at the planned location of the OSF is approximately 2900 m.

## 6.3 Air Pressure/Air Density

*[ENVI-00270-00 / R]*
All ALMA equipment shall be compatible with an ambient air pressure of 750 mbar +/- 100 mbar, which corresponds to an air density of 0.96 kg/m3 (typical average).

## 6.4 Ambient Temperature

*[ENVI-00280-00 / R]*
The OSF and its equipment exposed to the natural environment shall be compatible with a temperature range of -10 to +30°C.

### 6.5 Temperature Shock

*[ENVI-00290-00 / R]*
Equipment which is likely to be brought from indoor to outdoor or outdoor to indoor shall be compatible with a temperature shock of up to 30°C/min.

### 6.6 Solar and Cosmic Radiation

All concerned equipment shall be compatible with the following conditions:

*[ENVI-00300-00 / R]*
For all equipment exposed to the outside environment a maximum solar flux of 1120 W/m2 from 0.28 to 3 micrometers shall be assumed.

*[ENVI-00310-00 / R]*
For all equipment exposed to the outside environment a spectral distribution as specified in table 8 shall be assumed.

| | **Ultraviolet** | **Visible** | **Infrared** |
|---|---|---|---|
| Bandwidth | 0.28-0.32 &<br>0.32-0.40 µm | 0.40-0.78 µm | 0.78-3.00 µm |
| Irradiance | 10 W/ $m^2$ &<br>70 W/$m^2$ | 517-604 W/$m^2$ | 492 W/$m^2$ |
| Tolerance | ±35% ±25% | ±10% | ±20% |

**Table 8: Solar Radiation spectral distribution**

*[ENVI-00311-00 / R]*
Maximum expected Gamma ray dose rates are 1.70 mSv/year.

*[ENVI-00312-00 / R]*
Maximum expected neutron dose rates are 0.25 mSv/year.

For more information, it is referred to [RD09].

### 6.7 Relative Humidity

*[ENVI-00330-00 / R]*
The OSF and its exteriors exposed to the natural environment shall be compatible with an environment of 5% to 30% relative humidity [RD07].

*[ENVI-00340-00 / R]*
The ALMA system will be exposed to an environment of 30% to 95% relative humidity and condensation at the ground surface [RD07].

### 6.8 Precipitations
#### 6.8.1 Rainfall

*[ENVI-00350-00 / R]*
The OSF and its exteriors exposed to the natural environment shall be compatible with a maximum rain of 20mm/h.

#### 6.8.2 Ice/Freezing Rain

*[ENVI-00370-00 / R]*
The OSF and its exteriors exposed to the natural environment shall be compatible with a hard ice requirement of up to 5cm height and a density of up to 0.9kg/dm3.

*[ENVI-00371-00 / R]*
No hail precipitation is expected at the OSF.

#### 6.8.3 Snowfall

*[ENVI-00360-00 / R]*
Up to 50 cm snow (1m with drifting effect) can be expected at the OSF but it stays no longer than one week.

### 6.9 Wind

*[ENVI-00380-00 / R]*
The OSF and its exteriors exposed to the natural environment shall be compatible with a maximum wind speed of 40m/s from any direction.
See data in ch. 5.9

## 7 Building Environmental Conditions

*[ENVI-00390-00 / R]*
Very large equipment which may be stored outside will be subjected to the natural environment conditions defined in paragraphs 4, 5 and 6.
Other equipment will be stored in buildings, warehouses and hangars in which the following environmental conditions shall apply.

Specific storage conditions requirements shall be specified in the dedicated equipment specification.

## 7.1 Temperature

### 7.1.1 Technical Buildings and Living Spaces

*[ENVI-00400-00 / R]*
The computer and control rooms shall be air-conditioned and ventilated with a temperature range of 20°C +/- 2 °C.

*[ENVI-00420-00 / R]*
Offices and living spaces shall be air conditioned or heated and ventilated to nominal 20 °C.

### 7.1.2 Hangars

*[ENVI-00430-00 / R]*
Hangars shall be ventilated and heated to a minimum temperature of 10 °C.

### 7.1.3 Storage areas

#### 7.1.3.1 Basic Storage Area Conditions

*[ENVI-00431-00 / R]*
Storage areas shall be ventilated and heated to a minimum temperature of 15 °C.

#### 7.1.3.2 Special Storage Area Conditions

*[ENVI-00432-00 / R]*
When required by the manufacturer of equipment, storage areas with special required environmental conditions shall be available.

## 7.2 Humidity

*[ENVI-00440-00 / R]*
For the case where people might suffer from the extremely low ambient relative humidity or if it is required also for the proper operation or survivability of some equipment, humidifiers which increase the average relative humidity to 30% shall be used in a few buildings (Offices, storage areas).

## 7.3 Oxygen Enrichment

*[ENVI-00450-00 / R]*
The technical building on the AOS shall be oxygen enriched to a concentration equivalent to the one at 2900 m (OSF).

# 8 Transport Environmental Conditions

This concerns shipment from anywhere to the OSF and transportation on the site (OSF, AOS and between).

## 8.1 General Requirement

*[ENVI-00460-00 / R]*
Each IPT/sub contactor is responsible for the definition of the transportation and shipping specification of the equipment and for the transportation and shipping themselves.

## 8.2 Data for Guideline

The following data are given for information and can be used as guidelines. They are all based on [RD06] except chapter 8.2.8.2.

### 8.2.1 Low Air Pressure

The following table provides minimum cargo compartment air pressures for various aircraft used to transport cargo. These pressures can occur as a result of a failure of the automatic pressurization system:

| Aircraft | Minimum Pressure (kPa) |
|---|---|
| DC10/747/KC-10/L1011/767/DC8/DC9 | 57,2 |
| A300/C | 73,8 |

**Table 9: Minimum Cargo Compartment Pressure**

### 8.2.2 High Temperature

Of interest are the most severe conditions the equipment directly or the shipping container/protective packaging will experience during the transport to the OSF. Since the transportation will be performed by commercial transport agencies, intermediate storage in unprotected areas (solar radiation), in unventilated enclosures and location of the equipment near heat-producing device have to be considered. The following three types of conditions contribute to the maximum hight temperature requirement:

- Ambient air conditions measured in a standard meteorological shelter of a height of 1.2 to 1.8 m.
- Induced conditions which are from the same regions as the ambient temperatures but with an allowance for the effect of solar heating i.e. inside unventilated enclosures, within enclosed vehicle bodies etc.
- Extreme induced conditions with temperatures up to 85°C which occur in enclosed compartment having glazed or transparent panels like vehicle compartments etc.

The following table gives the extreme natural and induced diurnal cycle applicable for the transportation including intermediate storage.

| | Ambient air conditions | | Induced conditions | |
|---|---|---|---|---|
| Time of day | Temperature (°C) | Humidity (% RH) | Temperature (°C) | Humidity (% RH) |
| 0100 | 33 | 36 | 33 | 36 |
| 0200 | 32 | 38 | 32 | 38 |
| 0300 | 32 | 41 | 32 | 41 |
| 0400 | 31 | 44 | 31 | 44 |
| 0500 | 30 | 44 | 30 | 44 |
| 0600 | 30 | 44 | 31 | 43 |
| 0700 | 31 | 41 | 34 | 32 |
| 0800 | 34 | 34 | 38 | 30 |
| 0900 | 37 | 29 | 42 | 23 |
| 1000 | 39 | 24 | 45 | 17 |
| 1100 | 41 | 21 | 51 | 14 |
| 1200 | 42 | 18 | 57 | 8 |
| 1300 | 43 | 16 | 61 | 6 |
| 1400 | 43 | 15 | 63 | 6 |
| 1500 | 43 | 14 | 63 | 5 |
| 1600 | 43 | 14 | 62 | 6 |
| 1700 | 43 | 14 | 60 | 6 |
| 1800 | 42 | 15 | 57 | 6 |
| 1900 | 40 | 17 | 50 | 10 |
| 2000 | 38 | 20 | 44 | 14 |
| 2100 | 36 | 22 | 38 | 19 |
| 2200 | 35 | 25 | 35 | 25 |
| 2300 | 34 | 28 | 34 | 28 |
| 2400 | 33 | 33 | 33 | 33 |

**Table 10: Ambient and induced high temperature conditions**

### 8.2.3 Low Temperature

The most severe diurnal low temperature cycle the equipment is exposed to during the transportation is -25 °C to -33 °C (intermediate storage in unprotected areas).

### 8.2.4 Rain

Blowing rain may be encountered during intermediate storage in unprotected areas with wind velocities from almost calm to extremely high.
The maximum rainfall intensity of 10cm/h has to be considered with a droplet size 0.5 to 4.5 mm and a wind velocity of 18m/s.

### 8.2.5 Temperature – Humidity

Constant high humidity will be encountered during sea transport and intermediate storage in tropical areas of South America. The diurnal temperature-humidity cycles for protected and unprotected areas (i.e. with additional solar radiation) are given in the following table:

| | Protected areas | | Unprotected areas | |
|---|---|---|---|---|
| Time of day | Temperature ($^{o}$C) | Humidity (% RH) | Temperature ($^{o}$C) | Humidity (% RH) |
| 0100 | 27 | 100 | 33 | 69 |
| 0200 | 26 | 100 | 32 | 70 |
| 0300 | 26 | 100 | 32 | 71 |
| 0400 | 26 | 100 | 31 | 72 |
| 0500 | 26 | 100 | 30 | 74 |
| 0600 | 26 | 100 | 31 | 75 |
| 0700 | 27 | 94 | 34 | 64 |
| 0800 | 29 | 88 | 38 | 54 |
| 0900 | 31 | 82 | 42 | 43 |
| 1000 | 32 | 79 | 45 | 36 |
| 1100 | 33 | 77 | 51 | 29 |
| 1200 | 34 | 75 | 57 | 22 |
| 1300 | 34 | 74 | 61 | 21 |
| 1400 | 35 | 74 | 63 | 20 |
| 1500 | 35 | 74 | 63 | 19 |
| 1600 | 34 | 76 | 62 | 20 |
| 1700 | 33 | 79 | 60 | 21 |
| 1800 | 32 | 82 | 57 | 22 |
| 1900 | 31 | 81 | 50 | 32 |
| 2000 | 29 | 91 | 44 | 43 |
| 2100 | 28 | 95 | 38 | 54 |
| 2200 | 28 | 96 | 35 | 59 |
| 2300 | 27 | 100 | 34 | 63 |
| 2400 | 27 | 100 | 33 | 68 |

**Table 11: Diurnal temperature-humidity cycle**

### 8.2.6 Salt Fog

Salt fog is one of the most aggressive chemicals and salt concentration exceeding 20% is not uncommon in coastal regions and maritime environment crossed during transportation. Nevertheless a 5% +/- 1% concentration shall be considered since this has most significant effect on materials.

### 8.2.7 Sand an Dust

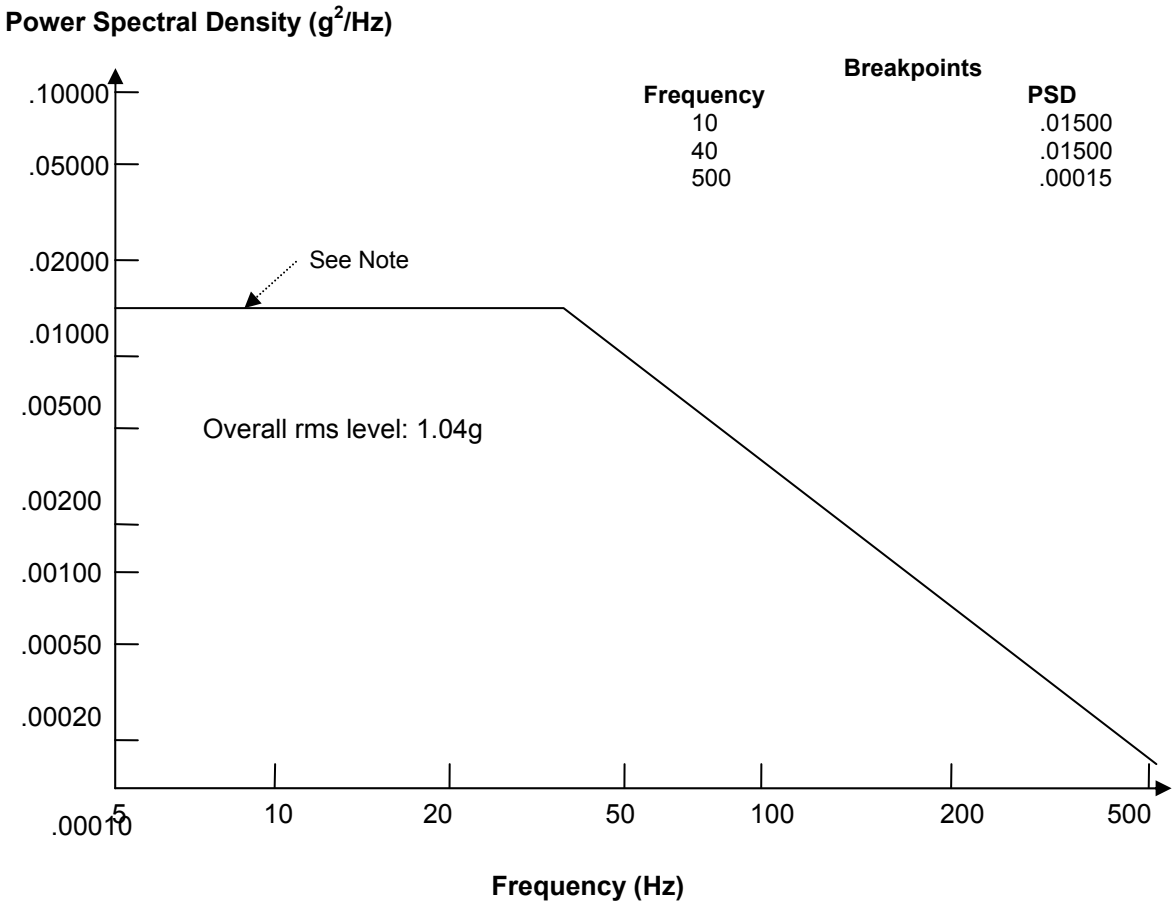
Blowing sand and blowing dust is encountered at many places during the transportation and is very often caused by moving cars etc. Typical data are:

| | | |
|---|---|---|
| Particle size | : | 74 to 1000 micrometers, mostly 74 to 350 micrometers |
| Particle concentration | : | 1.0g/m$^3$ |
| Wind speed | : | 18 to 30 m/s |

### 8.2.8 Vibration

#### 8.2.8.1 Basic Transportation Vibration Levels

All equipment shipped as secured cargo by road, rail, sea or air will encounter the “basic transportation vibration” environment illustrated in figure 1. These levels do not apply to large assembly transports such as transport of pieces of enclosures or main structures.




NOTE: If the item is resonant below 10 Hz, extend the curve to the lowest resonant frequency

Figure 1: basic transportation vibration environment

#### 8.2.8.2 MIL-STD Recommendations

According to MIL-STD-810F (method 514.5, Annex A, 2.4), considering the material resists the levels given in figure 2 provides reasonable assurance that it can withstand transportation and handling including field installation, removal and repair. These vibration levels and duration are based on experience and are valid for a material or subassembly of up to 36 kg.

#### 8.2.8.3 Measures on the Site

*Measurements should be done on equivalent roads in Chile by ESO in September.*

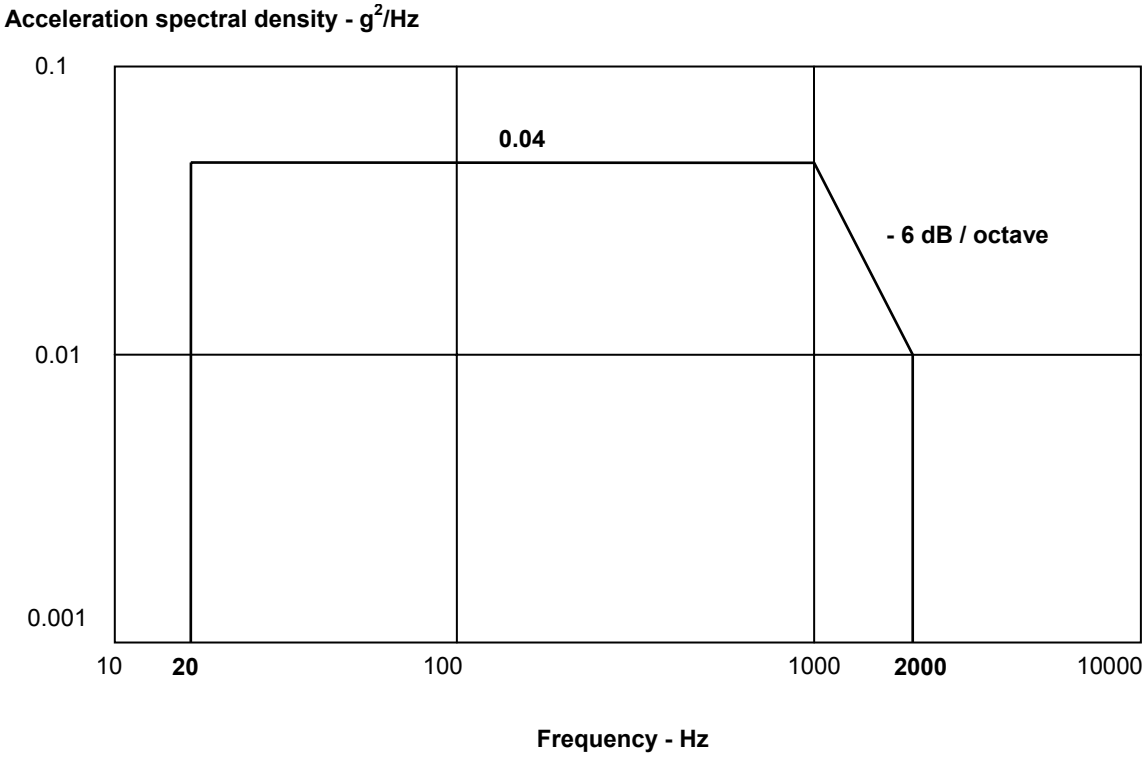



Figure 2: general minimum integrity exposure (MIL-STD810-F, fig. 514.5C-17)

### 8.2.9 Mechanical Shocks

The following table shall serve as guideline to estimate the mechanical shock levels, which might occur during transport and which are mostly caused by handling drops.

| Mass of package | Type of handling | Drop height [cm] |
|---|---|---|
| | | |
| 0 to 9.1kg | Manual Handling | 76 |
| 9.2 to 18.2 | Manual Handling | 66 |
| 18.3 to 27.2 | Manual Handling | 61 |
| 27.4 to 36.3 | Manual Handling | 46 |
| 36.4 to 45.4 | Manual Handling | 38 |
| 45.5 to 68.1 | Mechanical Handling | 31 |
| 68.2 to 113.5 | Mechanical Handling | 26 |
| > 113.5 | Mechanical Handling | 20 |

**Table 12: Shock levels during transport**

# 9 Environmental Impact Study Requirements

*[ENVI-00470-00 / R]*
The construction and operation of the ALMA System must abide by the Chilean resolution on the environmental impact study [AD02].

In particular:

## 9.1 Electrical Power Generation

*[ENVI-00480-00 / R]*
There shall be no soil contamination with fuel or lubrication components.

## 9.2 Waste Disposal

*[ENVI-00490-00 / R]*
Waste material (solid and liquid) shall be handled by registered enterprises.

*[ENVI-00500-00 / R]*
Waste material shall be disposed on authorized dumping sites.

*[ENVI-00510-00 / R]*
A water treatment unit is required.

*[ENVI-00520-00 / R]*
Waste water from the water treatment unit shall be disposed either by road irrigation or by infiltration in Vilama area.

### 9.3 Excavation and Earth movements

*[ENVI-00540-00 / R]*
Excavation material shall be accumulated and leveled near the construction locations.

*[ENVI-00550-00 / R]*
Earth movements that produce hindrance to natural water flows shall be prohibited.

### 9.4 Concrete Work

*[ENVI-00560-00 / R]*
Aggregate extraction shall be authorized by the Chilean authorities.

*[ENVI-00570-00 / R]*
The concrete plant shall be located in situ at the OSF.

### 9.5 Material and Equipment Transport

*[ENVI-00580-00 / R]*
The Baquedano road or the San Pedro by-pass road shall be used for the transport of material and equipment.

### 9.6 Constructions

*[ENVI-00590-00 / R]*
The constructions of buildings and roads shall be adapted to the morphology of the terrain. Natural water flows shall not be interrupted.

### 9.7 Roads

*[ENVI-00600-00 / R]*
Crossings for fauna above and below the roads shall be available.

*[ENVI-00610-00 / R]*
The environmental impact of the construction of the roads shall be limited to the road layout.

*[ENVI-00620-00 / R]*
The access road to the OSF shall be in accordance with the Chilean standards.

*[ENVI-00630-00 / R]*

Light color material shall be used on the surface pavement of the access road to the OSF.

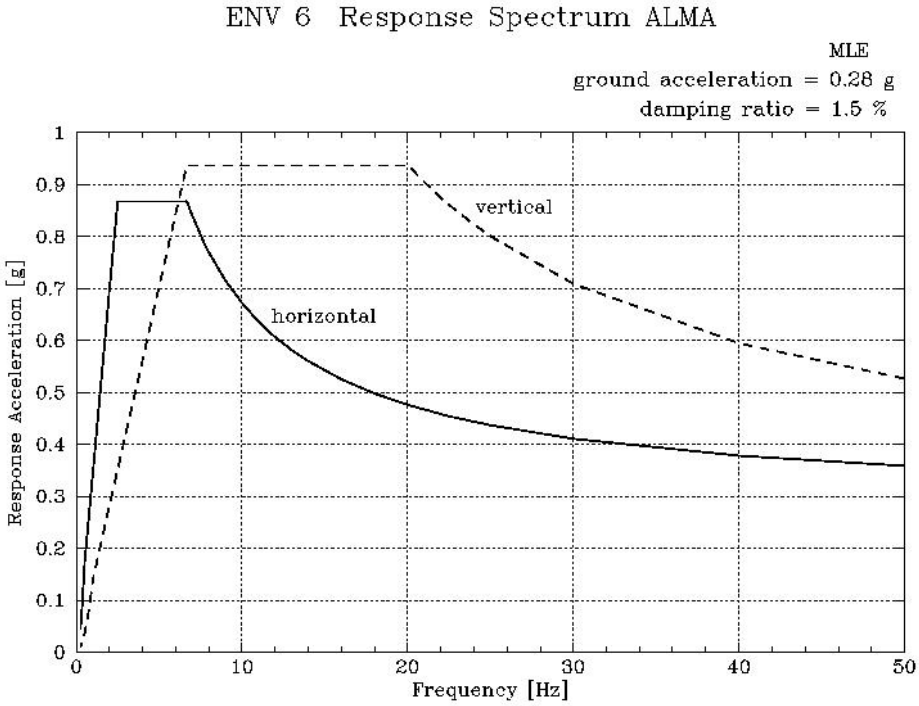
### 9.8 Archaeological Sites

*[ENVI-00640-00 / R]*
Archaeological sites shall be preserved.

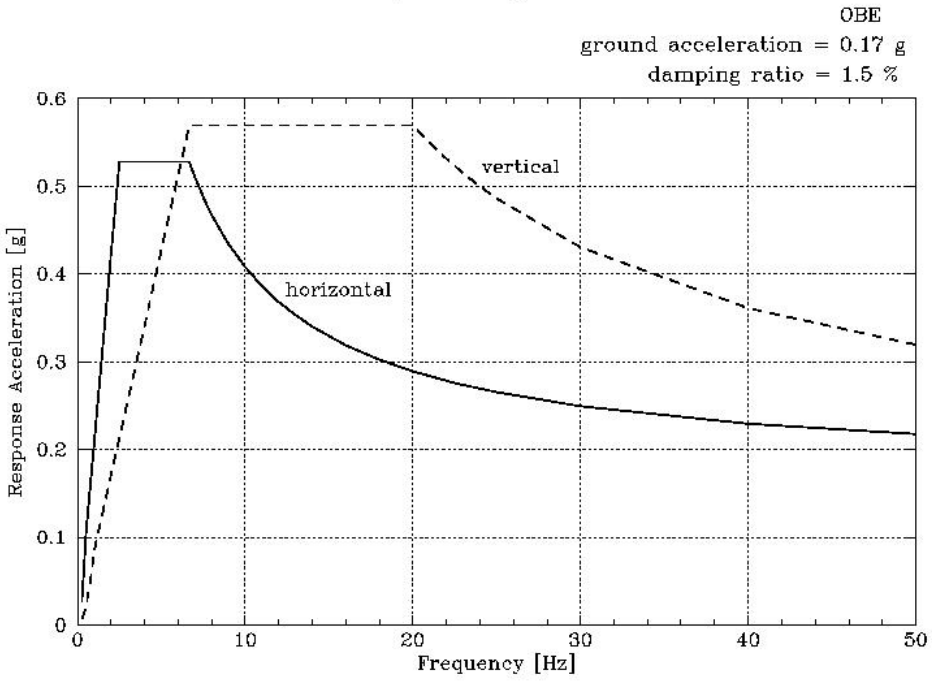
### 9.9 End of the ALMA Operations

*[ENVI-00650-00 / R]*
When ALMA operations are ended, the installations shall be removed and the ALMA sites cleaned up.

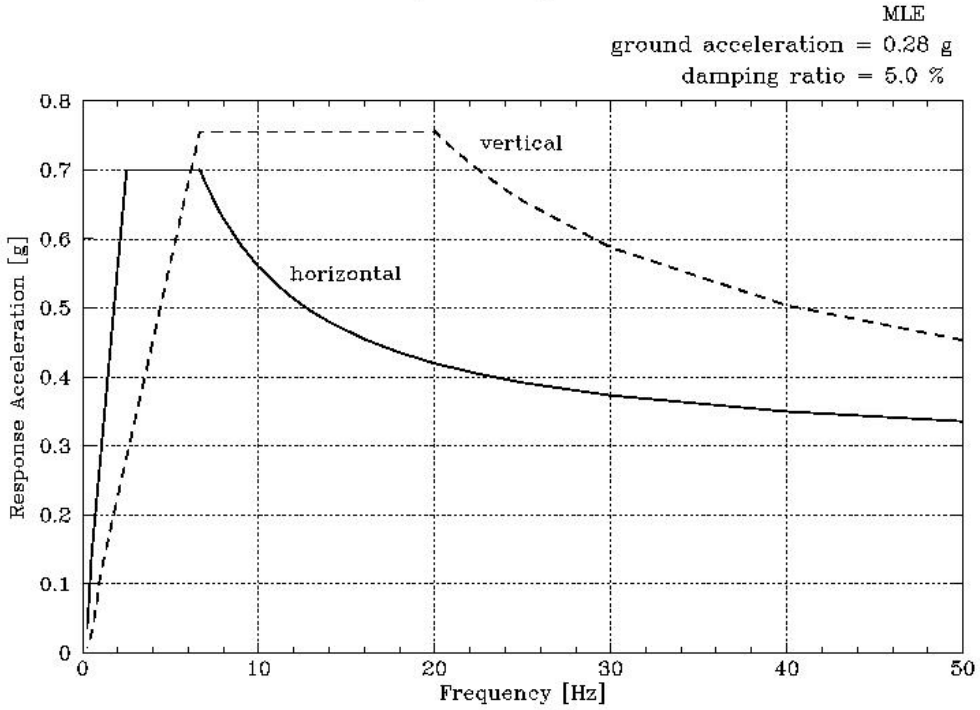
# Appendix 1: Earthquakes response spectra

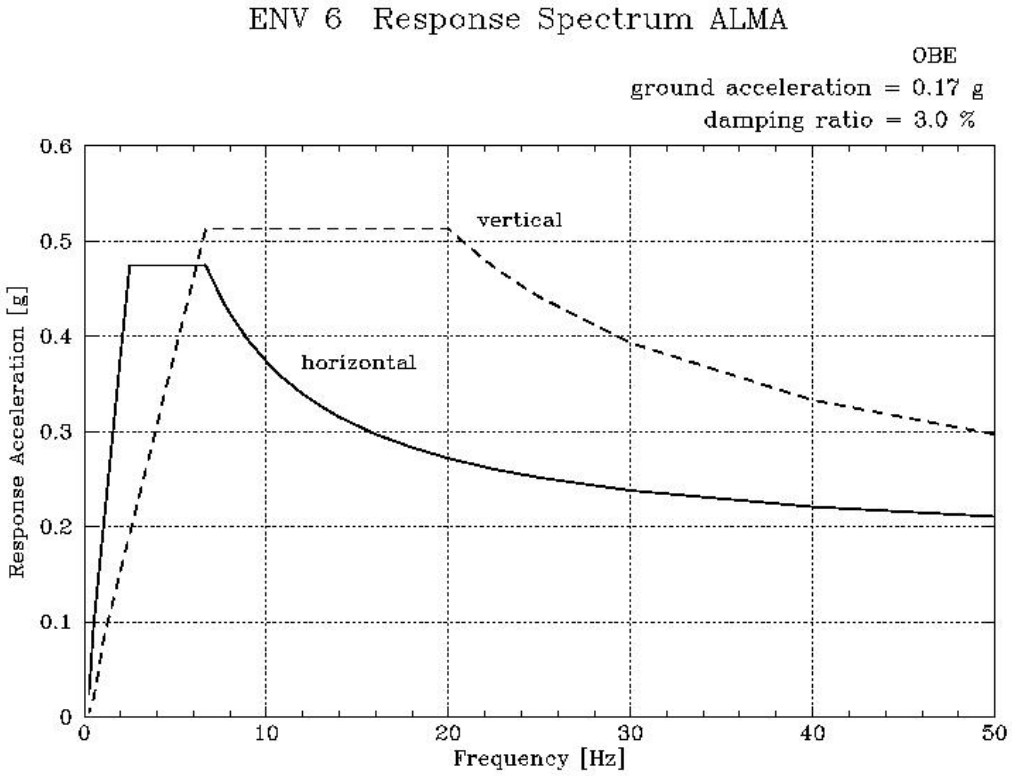


ENV 6 Response Spectrum ALMA



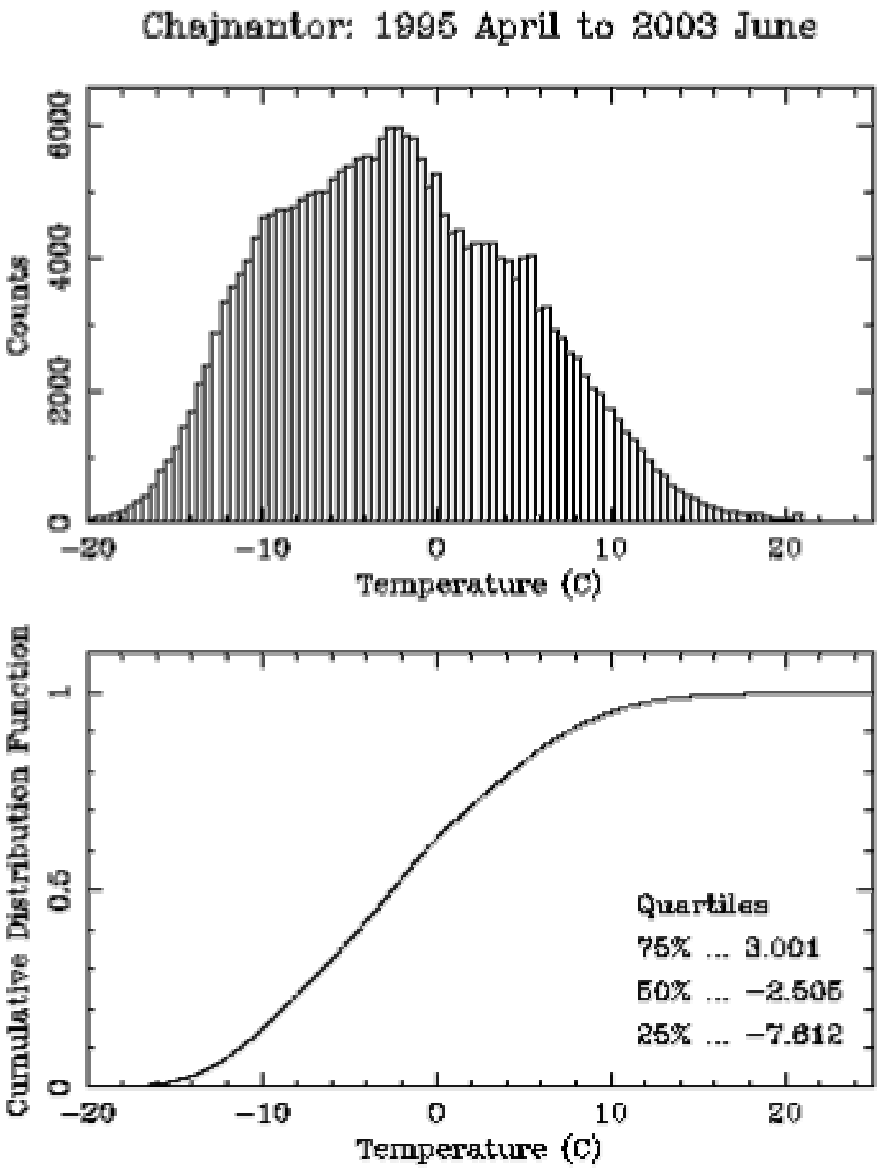

ENV 6 Response Spectrum ALMA





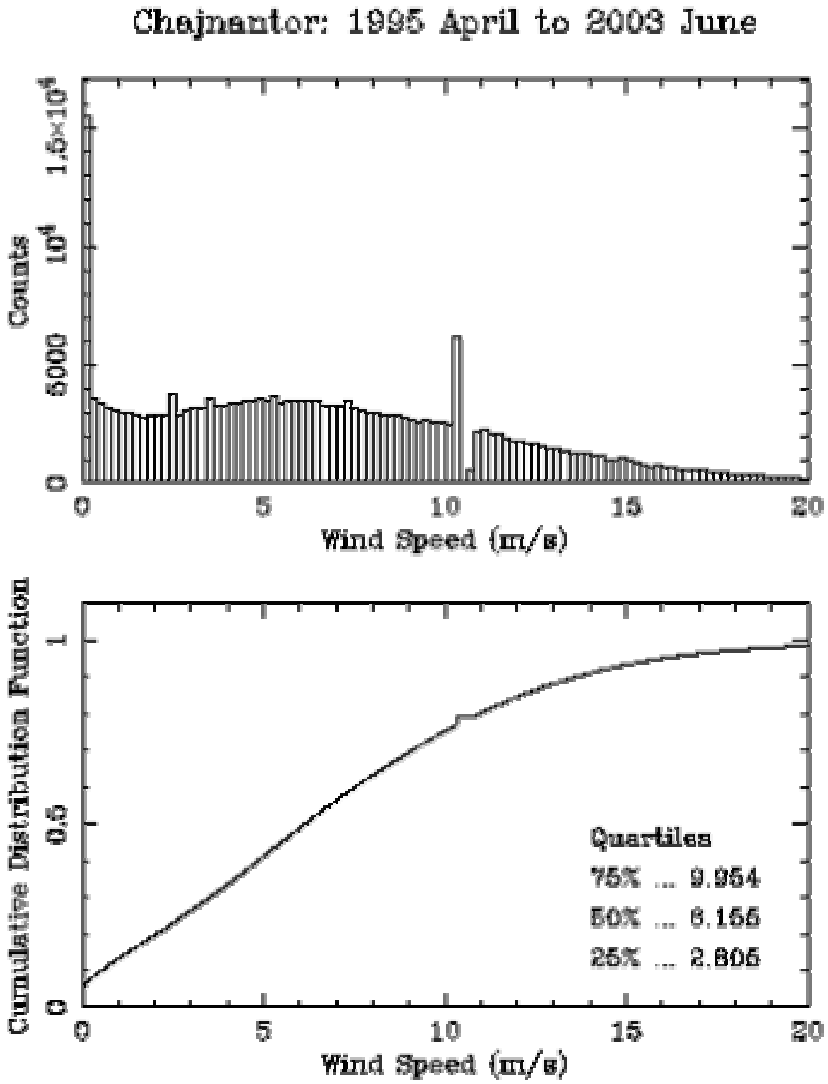

## Appendix 2: Temperature data collected on Chajnantor

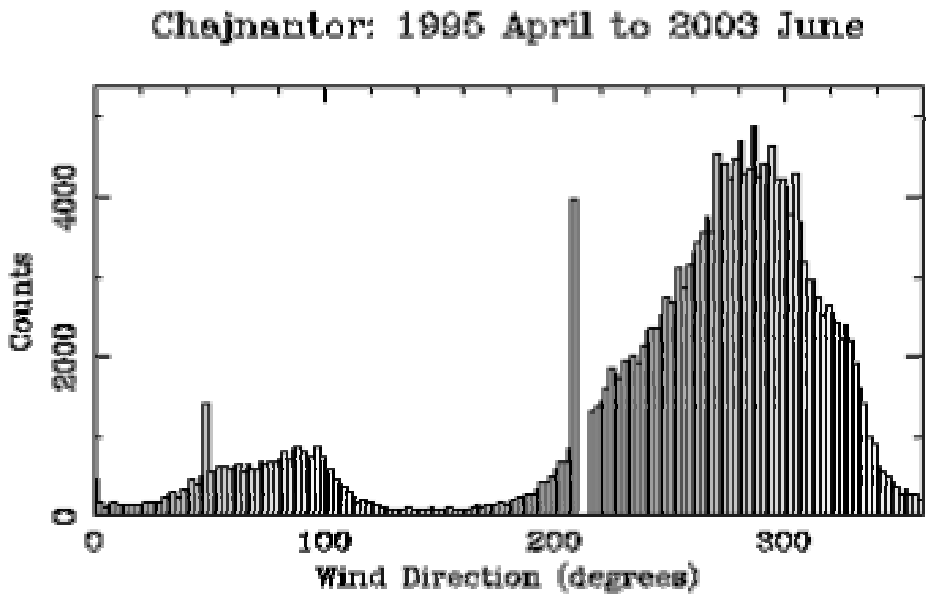
Source: [RD01]


Chajnantor: 1995 April to 2003 June
Counts
0
2000
4000
6000
−20
−10
0
10
20
Temperature (C)
Cumulative Distribution Function
0
0.5
1
Quartiles
75% ... 3.001
50% ... −2.505
25% ... −7.812
−20
−10
0
10
20
Temperature (C)

# Appendix 3: Wind data collected on Chajnantor

Source: [RD01]




Chajnantor: 1995 April to 2003 June
Counts
0
2000
4000
0
100
200
300
Wind Direction (degrees)