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# Status of the Antarctic Base at Dome C and perspectives for Astrophysics

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**Abstract.** We report briefly on the status of the French-Italian base at Dôme C, on the inner Antarctica Plateau, at 3280 m above the sea level. The base is under construction in the framework of the Concordia project, and will permit the development of important astrophysical projects. Thanks to the high altitude, the sky transparency and the exceptionally cold, dry and stable atmospheric conditions, the Antarctica Plateau, is indeed among the best places on the Earth, to perform observations of the sky, at the near infrared, mid infrared, submillimeter and millimetre wavelengths.

**Key words.** Antarctica – site testing - atmospheric effects – infrared: general – submillimeter – millimetre

## 1. Introduction

The French-Italian base of Dôme-C, is sited on the inner Antarctica Plateau (coordinates: 75°06'25"South, 123°23'44"East; altitude 3280 m), at about 1200 km from both the Italian base of Terra Nova Bay and from the French base of Dumont D'Urville, on the coast of Antarctica, and at about 1800 km from the South Pole. The station is under construction in the framework of the Italo-French Concordia project, with the participation of the French IPEV and the Italian PNRA (National Program for Research in Antarctica).

Dômes are regions more elevated, than the rest of the continent (except the Trans-

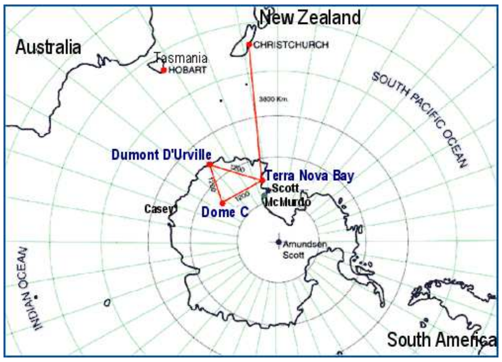


**Fig. 1.** Position of the Dôme C base, Terra Nova Bay (Italy) base and the Dumont D'Urville (France) base.

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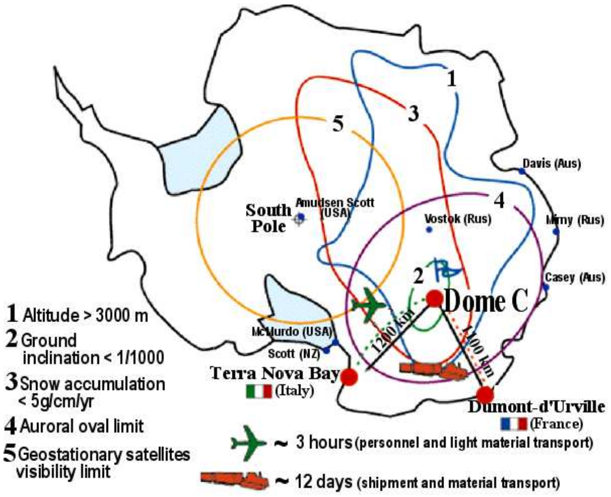


**Fig. 2.** Dôme C is placed on the confluence of several favorable conditions for the astronomical observations, some of which are plotted in the picture. From the Terra Nova Bay base, an air connection with Dôme C is active, for the transport of personnel and light material. From the Dumont D'Urville base, a traverse for caterpillar tractor was established for shipment of heavy material. (Adapted by S. Ciprini. Courtesy of E. Fossat).

Antarctic Mountains). The three major "peaks" of the Antarctic Plateau are Dôme A (Argus, 4100 m) the highest and potentially the best observing site on the planet, but very difficult to reach, Dôme F (Fuji, 3810 m) and Dôme C (Concordia).

A summer camp and the permanent station under construction are presently at Dome Concordia. From the Terra Nova Bay base, air service for the transport of personnel and light material in about four hours is available, and from the Dumont D'Urville base, a traverse for caterpillar tractor was established, for heavy material transport (Figure 2). After shipment from Europe, air and naval connection respectively with the towns of Christchurch (New Zealand) and Hobart (Tasmania, Australia), provides the final crossing to the Antarctica continent (Figure 1). The Italian astrophysical com-

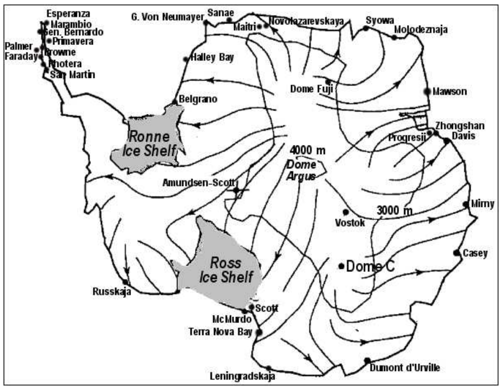


**Fig. 3.** Chart of the wind directions in Antarctica. (Adapted from Marks et al. 1999).

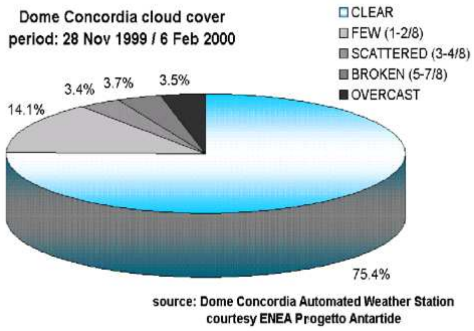


**Fig. 4.** Dôme-C summer time cloud cover.

munity has several projects for facilities to be installed at Dôme C, (e.g. this volume and Candidi et al. 2000; Sironi et al. 2002; Busso et al. 2002; Ferarri-Toniolo et al. 1998; Viotti et al. 2001). The French astrophysical community is involved also in the Concordiastro Programme, with the preparations for an area devoted to the site qualification at about 300 m from the station. Moreover the Australian astrophysical community is proposing large projects of middle-sized and large-sized telescopes to be placed in this site (Burton et al. 2001).

## 2. Why Dôme C

The Antarctica Plateau is assumed to be the best place on Earth, to perform astrophysical observations in the near infrared, mid infrared, submillimeter and millimeter wavelengths, thanks to the high altitude and the extraordinary cold, dry and stable conditions (Figure 2). The Plateau has a mean elevation of about 2.5 km, so the water vapor content of the atmosphere is extremely low. Moreover it is a flat, thick (about 2 km) and large (about 2500 km radius) slab of ice, at constantly low temperature. For these reasons the atmosphere above the Plateau is extremely transparent to the infrared and sub-mm radiation, and the atmospheric noise level produced by turbulence is very low.

Naively Dome Concordia might be thought, as halfway between ground and space conditions, with observing characteristics comparable to what available on stratospheric balloons. For example at South Pole, placed on the plateau at lower altitudes, the opacity is comparable to a stratospheric balloon platform, Mandolesi et al. (1999); Valenziano (2003).

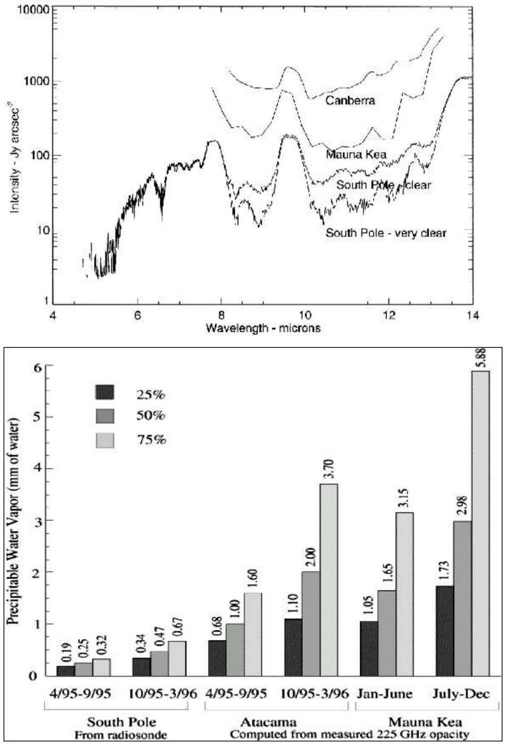


**Fig. 5.** Upper panel: the figure shows a near and mid infrared comparison between South Pole and other sites (Storey et al. 1999; Chamberlain et al. 2000; Marks 2002). Lower panel: precipitable water vapor at South Pole, Atacama and Mauna Kea (Valenziano & Dall'Oglio 1999).

The surface winds in Antarctica are katabatic (Marks et al. 1999). They are the result of of the descent of cold air from the higher regions of the Plateau (Figure 3), consequently these winds are weak at Dôme C. A very low level of atmospheric turbulence is produced in the boundary layer, and there is little mechanical mixing of the different temperature layers, implying a very good seeing from surface level. Therefore a site at which the turbulence occurs only at very low altitudes, offer also large gains in astrometric precision. For an infrared observatory, the ideal conditions

**Table 1.** Conditions at Dôme-C.

| | |
|---|---|
| Geographical coordinates ... | 75°06'25"S<br>123°23'44"E |
| Altitude ............................ | 3280 m |
| Mean summer temp. .......... | -25° C |
| Mean winter temp. ............ | -70° C |
| Maximum wind velocity ..... | 18 m/s |

**Comparison between two Antarctic sites, Mauna Kea (Hawaii Islands) and Atacama desert (Chile)**

| | Dome C | South Pole | Mauna Kea | Atacama |
|---|---|---|---|---|
| Elevation (m) | 3280 | 2836 | 3750 | 5000 |
| Average pressure (hPa) | 644 | 682 | 650 | 550 |
| Median wind speed ($\mathrm{m\,s^{-1}}$) | 2·1 | 3·6 | 4·5 | 6·0 |
| Maximum wind speed ($\mathrm{m\,s^{-1}}$) | 15·9 | 18·5 | 28·8 | 33·0 |

**Fig. 6.** Comparison between Dôme-C and other sites (Valenziano & Dall'Oglio 1999).

on the Plateau, are where the aerosol levels are minimized (Hidas et al. 2000).

The main advantages of Dôme Concordia are summarizable as follows:

- sky background emission $20 - 100$ times lower than temperate sites;
- better atmospheric transmission, especially near water bands;
- exceptionally stability (very low sky noise);
- low temperatures;
- little high-altitude turbulence;
- very large isoplanatic angle;
- low scintillation;
- high astrometric precision;
- continuous observation possible;
- presence of a permanent station.

Preliminary site testing has been performed with good results (Valenziano & Dall'Oglio 1999). A test experiment was run to directly compare the short-term atmospheric stability (the so-called sky noise) between Dôme C and the Terra Nova Bay base on the coast. Data analysis shows good atmospheric stability in terms of sky noise at mm wavelengths and low atmospheric precipitable water vapor (Dall'Oglio 1997; Valenziano & Dall'Oglio 1999). Sub-mm sky routine observations, was performed at 450 $\mu$m, 350 $\mu$m, and in the window at 200 $\mu$m, with an exceptionally low sky noise (Sironi et al. 2002, 1998).

The same good performances are expected for the infrared observations. Figure 5 reports a near and mid infrared comparison between South Pole and other sites. Data on the cloud cover at Dôme C acquired automatically, showed a clear sky during the large part of the winter (Calisse 2002), see e.g. Figure 4. In the next expedition (austral summer of 2002-2003) it is planned to install an automated site testing observatory from the Australian group (like the AASTO at South Pole), and to set-up two high platforms devoted to accommodate telescopes for the qualification of the site, for the French group.

Meteorological radio-sonde balloons, during the last expedition (austral summer 2001-2002), measured an averaged maximum wind speed under the 30 m/s and a mean integrated water vapor content of 0.5 mm above the site (Agabi & Dubourg

**Fig. 7.** Some astrophysical ongoing projects at South Pole and Dôme C.

**Fig. 8.** The Dôme-C base. *Upper panel*: the summer camp. *Lower panel*: the two buildings of the permanent station, with the summer camp on the background.

2002), confirming the hope for values below 0.2 mm in winter, as measured at Vostok base (Russia) 560 km away. The vertical gradient of the potential temperature is a key parameter for the static stability of the air. Depending on the gradient being positive or negative, the air will be stable or unstable. Despite the exceptionally bad conditions in this season with respect to the previous years (for the relatively small number of good weather days, and the large variability of the ground temperature), the low altitude inversion layer of this potential, visible around local noon (and creating local turbulence) disappears at local midnight, even in the summer when the sun stays above the horizon. So the atmosphere mist is expected to be very stable in winter, with a good astronomical seeing (Agabi & Dubourg 2002).

## 3. The Dôme-C Station

The Dôme-C base is composed of a summer camp, with containers and tents, and a permanent station, under construction (Figure 8). The summer camp is composed of a main structure, formed by 7 containers for the sleeping area, and 12 containers for the living area, a power-station, about 10 heated *Weatherhaven* tents, and then caravans, stock tents, containers for laboratories and technical services, underground deposits.

The permanent station is composed of:

- two towers, of three floors each;
- one building is quiet the other is noisy and containing services;
- the total covered square meters are 1500;
- each tower is a structure of 150 tons;
- there are six feet per tower (hydraulic lift);
- the weight on the surface is 100 g/cm$^2$.

In the last Antarctic austral summer (2001-2002), the metallic structure was completed and the floors were laid (plate, sound absorption layer, wood cover), for both the buildings. Moreover the noisy building, was completed with the lateral external panels and the roof. In the next expedition it is planned to install the panelling of the second tower, and the electrical, thermal and hydraulic systems.

The actual logistic capabilities, permit to reach Dôme-C from the Italian base on the coast, in about four-five hours, with *Twin Otter* light airplanes. In the last 2001-2002 summer, 48 flights were done, with 34 tons and 146 passengers carried. A mid point stop (midpoint *Charlie*) for the refuel with *Jet A1* was assembled. The capability of a *Twin Otter* is one ton per flight.

Dôme Concordia is reachable also from the French base with a tractors traverse, done with *Challenger* and *PB330* caterpillars. In the last 2001-2002 campaign, three traverses were done with 130-160 tons of payload each, and 10-12 days needed for the outward trip and 9-10 days for the return. 100 tons of fuel are needed for a round trip. A traverse is composed of about 10 vehicles and 10 person crew. Also for this trip a supply midpoint (midpoint *D80*) was established.

The summer base was opened on November 15, 2001, and after a few days for the operations (opening of the emergency power plant, power station, radio and satellite equipment, snow removal, air track maintenance, water production), the research staff arrived. The mean population of the base reached the value of 50. The scientific activity carried out, included the advance of the *Epica* core sampling (the aim is to reach the bedrock, at a depth greater than 3200 m, under the ice), research about magnetism, seismology, micrometeorites, meteorology, radar survey, preliminary site testing (Calisse

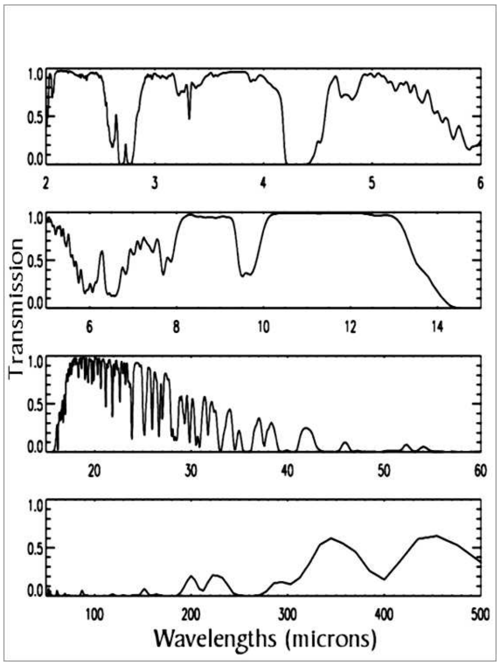


**Fig. 9.** Model calculations of the atmospheric transmission at South Pole across the thermal infrared, from 2 to 500 $\mu$m (Hidas et al. 2000).

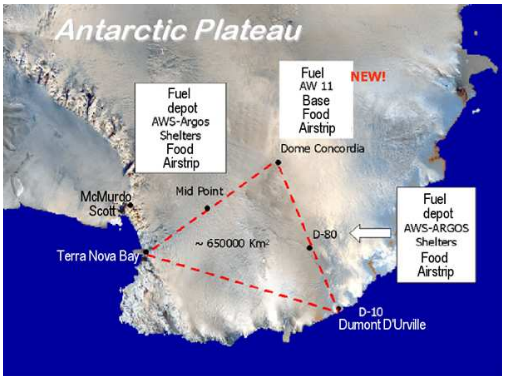


**Fig. 10.** The two routes, air and traverse, for Dôme-C and the midpoint camps.

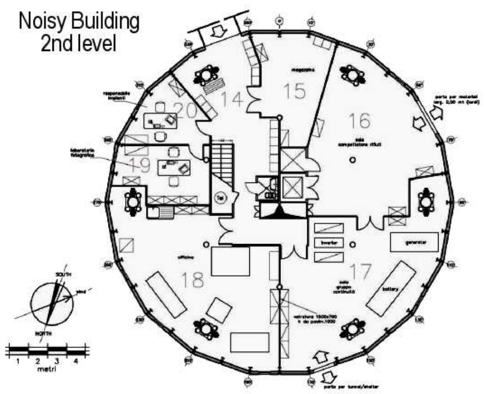


**Fig. 11.** The second level of the noisy tower.

2002), *Concordiastro* site qualification program (Agabi & Dubourg 2002), medical and psychological studies. The main goals achieved in this season are the advances in the towers construction and the *Epica* perforation (reaching the depth of 2872 m). The first expected platform of the *Concordiastro* program, was not mounted for the lack of the material, unloaded from the ship at Dumont D'Urville only after the departure of the last traverse, due to the bad weather conditions. The Base was closed in February 8, 2002.

The stated logistic capabilities are available also for the current and the next projects of astronomy at Dome-C, and the expectations cannot be anything else than very good.

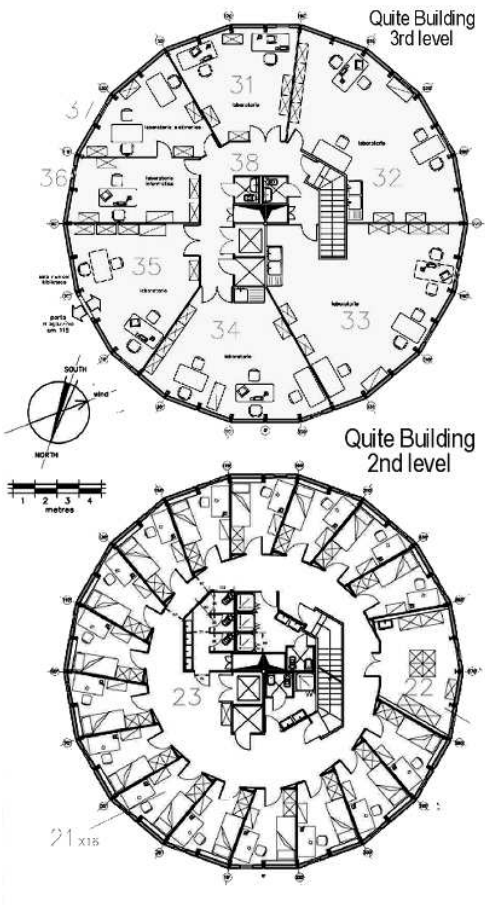


**Fig. 12.** The second level and third level of the quiet tower.

**Fig. 13.** Some phases of the Dôme-C construction.

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**Fig. 14.** A caterpillar and the *Twin Otter* light airplanes, used to reach Dôme C.

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