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Neloy Khare *Editor*

Engineering and Communications in Antarctica

Enabling Technologies in Antarctica

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Foreword

Antarctica is the coldest continent on earth with extreme winds. The continent is snow- and ice-covered, with round the year freezing temperatures. The 'Catabian winds' over the icy continent of Antarctica cause violent snowstorms that can last for days, and sometimes even weeks, making it a very dangerous place not only to humans but also to any engineering structures required to host people or scientific equipment to do scientific research in the Antarctic region.

To mitigate the risk of snow and ice disasters, including snowstorms, the dedicated efforts are needed to create technologies that could withstand the extreme environmental conditions in Antarctica and make the stay of people comfortable in the isolated and inhospitable environment of Antarctica. A successful cost-effective and sustainable operation in a remote, harsh (cold) climate is largely dependent upon the attention given to logistics management and planning. However, being a pristine environment, these technologies need to be nonpolluting. Logistics in this environment is a big challenge. The National Centre for Polar and Ocean Research at Goa has been continuously putting efforts to adopt such technologies and complex logistics.

During the last forty years, India has systematically evolved its cold engineering and green technologies and logistics operations and demonstrated the capability for maintaining year-round two research bases 'Maitri' at Schirmacher Oasis and 'Bharti' at the Larsemann Hills region, with a commitment to preserve the pristine Antarctic environment. With the establishment of the third Indian research station at Larsemann Hills, Indian scientific activities have not only got diversified manifold but also ably covering geographically distinct localities having their own unique scientific significance.

Though we have made reasonable progress in the field of non-conventional energy generation in the Antarctic region through windmills, we have to move further ahead and excel in this highly specialized field. As far as communication is concerned, we have demonstrated our capabilities by establishing a direct 24X7 connectivity with Antarctica using Earth station including video conferencing and transmission of TV channel to Indian research bases in Antarctica. We also support remote sensing satellite data collection from polar orbiting satellites and transfer the data at high speed to India through geostationary satellites.

The present book, *Engineering and Communications in Antarctica—Enabling Technologies* has ably covered most of the relevant engineering, communication, environmental Impact assessment and non-conventional energy generation aspects of Antarctica. I am sure this book will provide a good reference material and encourage the development of newer technologies to support scientific research in the polar region.

Bangalore, India Prem Shankar Goel

Preface

Since the discovery of oil and other mineral resources in the polar regions, significant interest has been generated in exploring these regions in the interest of seeking knowledge and potential resources. To create areas and environments that are essential for human habitat in harsh Antarctic regions that are safe, comfortable and well developed, it is necessary to properly manage various facilities that serve as infrastructure in cold regions, from planning, construction and maintenance to demolition stages. This requires a comprehensive evaluation system that should be capable of centrally managing them all.

Polar regions offer unique opportunities and challenges to face with regard to any engineering structure as, these regions remain below-freezing temperatures regularly occur for months at a time necessitates regular dealing with freeze-thaw effects on building materials or the exchange of moisture through walls of dwellings or any buildings. We need to use proper materials, proper design methods and proper construction methods to have something that can function and last in the unique and harsh polar environment. There is the issue of melting permafrost, which is basically soil with ice particles mixed into its pores, is a pretty good foundation to build on as long as it stays frozen. But when it thaws and the ice in the pores of the soil turns to water, very often the remaining soil will no longer be able to support heavy buildings, pipelines, etc. Many structures built on permafrost were designed with the notion that the permafrost would stay frozen. But now a large number of research bases at Antarctica are being affected with the permafrost thawing due to global warming impacting polar regions coupled with the issue of having a greater number of freeze-thaw cycles as a result of the changing climate.

For this purpose, the establishment of engineering methodologies for technical policies on infrastructure, as well as the introduction of consensus-building support to the formulation of technical-policy processes, is essential. Though India has ably constructed Maitri station indigenously and set up third research base 'Bharti' at Larsemann Hills region, yet the challenges ahead are to foster expertise which can provide solutions to complex environmental and engineering problems common in cold regions like Antarctica. Concerted efforts should be aimed at standardizing the transition of infrastructure policies and internationally promoting infrastructure improvement evaluation methods, as well as their application. We must emphasize on the establishment of environmental policies and waste-management systems, development of methods for planning transportation systems in cold regions, development of technologies and establishment of methodologies for infrastructure systems in cold regions that are safe and reliable.

National Centre for Polar and Ocean Research (NCPOR), as the nodal agency for Indian Antarctic programme, is to support research and development within the field of cold region engineering Various participating organizations like Research and Development Establishment (Engineers), Pune, Defence Electronics Application Laboratory (DEAL), Dehradun, Snow and Avalanche Study Establishment (SASE), Chandigarh, National Aerospace Laboratories (NAL), Bangalore have always been focusing on research and development in cold climate engineering to cater the demands imposed by the Antarctic climate.

Many Indian researchers are involved in research projects concerning cold climate technology/Engineering. Icing is a well-known phenomenon for polar regions. A big problem is the icing of water intakes at power stations, radio masts, power lines and aeroplanes, etc. used for various logistics purposes in Antarctica. De-icing is an expensive process. Therefore, our efforts should be focused on the phenomenon of atmospheric icing to increase understanding as to how ice builds up on different surfaces and how we, through proper choice of materials, can reduce the adhesiveness of the ice. Having spent more than twenty-five years in a cold region, it is most appropriate to collate and evaluate the engineering and technological status from the country’s point of view.

Similarly, Antarctica is one of the few remaining nearly pristine sites in the world and is certainly by far the largest such site. Antarctica is particularly vulnerable to some types of environmental change, notably those that would require biological activity for reversal or amelioration. Pollutants that would be readily biodegradable elsewhere can have very long lifetimes in the Antarctic environment, increasing the possibility of long-term alteration through human activities. Its preservation and well-being is, therefore, vital to the health of the rest of the planet, and impacts to Antarctica's environment could have global effects.

To enhance protection of the Antarctic environment, the Antarctic Treaty parties in 1991 adopted the Protocol on Environmental Protection to the Antarctic Treaty, designating Antarctica as a natural reserve and setting forth environmental protection principles to be applied to all human activities in Antarctica, including the conduct of science, regulated tourism and fishing concerns, but also a position of leadership in the international stewardship of the Antarctic environment. The protection of the Antarctic continent, and the great Southern Ocean surrounding it, is important for every mankind. The discovery of the ozone hole above the Antarctic in 1985 alerted the world to the potentially dangerous changes in the environment caused by human activities. This discovery led to the first measures to control pollution on a global scale. India is committed to preserve the pristine nature of the icy continent, and therefore, undertake regular environmental Impact assessment.

The present book *Engineering and Communications in Antarctica—Enabling Technologies* discusses, in one volume, a wide array of topics that have entered the mainstream of Geotechnical and Geoenvironmental Engineering in the past especially during the initial phase of Indian Antarctic Expeditions, while at the same time not losing sight of the lessons we have learnt in cold engineering technologies during our initial efforts in the contemporary fields of Polar Engineering and communications. It also covers various articles on diversified aspects of environmental science and collates the overall achievements during the last many decades in the fascinating field of Antarctic Engineering and Environmental Impact Assessment.

Accordingly, the present book covers articles on wind energy by **Ramesh et al.** While **Rai** discussed the Engineering aspects in Antarctica, **Pathak** has ably reviewed the engineering details of Dakshin Gangotri and Maitri. An interesting history about Dakshin Gangotri station and its establishment process has ably been provided by **Sharma**. Similarly, communication aspects have been highlighted by **Dhaka** and commercial polymers and their utility in cold region have been discussed by **Dabholker et al.** Besides, **Tiwari and Khare** have reviewed the environmental studies carried out in the past over Indian Antarctic research base 'Maitri'. On the contrary, **Ramchandran and Sathe** have studied the natural radioactivity in Antarctica and fire safety in Antarctica has been ably touched upon by **Chatterjee.** Details on the environmental management services at 'Maitri' station have been provided by **Veerbhadraiah and Jain.** On the other hand, **Tiwari and Da Lima Leitao** have provided a detailed account of the third Indian research station 'Bharti' at Larsemann Hills region. Additionally, the Structural assessment of the second Indian station 'Maitri' in Antarctica is provided by **Raghava and Murthy.**

It is hoped that the present book will serve as a useful reference for young researchers who are fascinated towards cold region engineering and environmental research.

New Delhi, India Neloy Khare
January 2020

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Dr. M. N. Rajeevan, Secretary to the Government of India, Ministry of Earth Sciences, who has shown keen interest and provided valuable guidance and encouragement for reviewing the studies carried out pertaining to Antarctic Engineering and technologies in this book, is gratefully acknowledged.

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Dr. Neloy Khare presently scientist 'G'/adviser to the Government of India at the Ministry of Earth Sciences, has a distinctive acumen of not only handling administration but also quality science. His area of research covers large spectrum of geographically distinct locations like Antarctic, Arctic, Southern Ocean, Bay of Bengal, Arabian Sea, Indian Ocean, etc. He has more than 30 years of experience in the field of paleoclimatic research using paleobiology (Paleontology). Having completed his Ph.D. on tropical marine region and D.Sc. on southern high latitude marine regions towards environmental/climatic implications using various proxies including foraminifera (micro-fossil), he has made significant contributions in the field of paleoclimatology of southern high latitude regions (Antarctic and Southern Ocean) using micropaleontology as a tool. He has been conferred honorary and adjunct professorship by many Indian Universities. He has a very impressive list of publications to his credit (123 research articles in national and international scientific journals; 23 popular science articles). He has authored/edited many books published by international and national publishers. He was awarded the Rajiv Gandhi National Award in 2013 by the President of India. He has made tremendous efforts to popularize ocean and polar science across the country by way of delivering many invited lectures, radio talks and publishing popular science articles. He has sailed in Arctic Ocean as a part of "Science PUB" in 2008 during the International Polar Year campaign for scientific exploration in Arctic Ocean and became the first Indian to sail in the Arctic Ocean.

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Chapter 1
Utilization of Wind Energy at Indian Antarctic Station: Near-Term and Long-Term Objectives

M. P. Ramesh, Kanaka Muthu, T. Ramesh, A. P. Chandran, B. S. Ashoka, I. Rajashekar, N. Jayaraman, G. Nanjunda, and T. K. Lokesh

1.1 Introduction

Winds in the coastal Antarctic region are notorious. As a matter of fact, the instantaneous peaks are known to cross 300 kmph, and with blizzards, the structures built in the Antarctic region must be designs that can withstand extraordinary loads. At the same time, it would make sense to use the winds in Antarctica for a variety of applications. The first experiments with wind power were made by Indian Scientific Antarctic expeditions in 1984 by Bharat Heavy Electricals Limited. R & D E, Pune, also made some rudimentary trials. However, due to the lack of concentrated efforts, these attempts did not make any headway.

Based on the recommendations of the U R Rao's committee (1996), National Aerospace Laboratories, Bangalore, took up the study of the possibilities of using wind as an alternate source of energy at Maitri and other locations used by Indian Antarctic Expedition members for the conduct of scientific experiments. NAL collected invaluable information over the 16th to 21st Antarctic Expeditions and conducted several experiments. A detailed program addressing the following aspects was prepared and implemented:

- Quantification of Wind energy as a usable resource
- Study of energy consumption patterns

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- Identification of available infrastructure facilities available at Maitri for wind turbine installations
- Addressing the energy needs at Maitri.

1.2 Wind Power Potential

Antarctica was able to maintain a pristine environment for so long with the help of unbearable winds that makes living in the Antarctic environment an extremely difficult proposition. In fact, it is the most often quoted difficulty by the early explorers, as well as present-day scientists, involved in the out-door work at Antarctica. Some estimates of peak winds have crossed 250 km/h in the coastal regions. Inland regions, on the continental ice and oases, where stations have been in place have not shown very high values when compared to the coastal regions. The phenomenon of very high winds is generally explained by the occurrence of very frequent cyclones and anti-cyclones that are formed around 55° to 60° South around the continent. This happens very frequently and with great intensities. Apart from this, the presence of strong and sustained Katabatic winds has also been experienced in the coastal zones and glaciers.

1.3 Meteorological Measurements at Indian Stations

Wind speed and Directions were measured at Dakshin Gangotri, as well as at Maitri, as a part of the meteorological measurements that were undertaken by the India Meteorological Department. The readings were taken at Synoptic hours. Apart from this, wind speeds were kept track of using strip chart recorders. Dakshin Gangotri showed exceptionally high average wind speeds. This is understandable, as Dakshin Gangotri was located on the shelf ice. The averages at Maitri were relatively lower and strongly influenced by the time of the year. This is an important point that should be noted as the successful integration of wind energy conversion devices with the existing energy supply system would very largely depend upon a clear understanding of the nature of wind energy availability in the given region. Figure 1.1 shows the measured monthly averages at Maitri over a five-year period.

The pattern of winds is somewhat different from the monsoon-based wind system. Summer months show relatively light winds, which is quite consistent over the years. Mid-winter shows a relatively high wind season, but inter-annual variation is also somewhat high during this period. The wind speeds collected at Maitri by IMD is a part of Synoptic weather observations. The data is being collected as per the standards set by the World Meteorological Organization. But this could not be employed for quantification of wind energy availability for two reasons. First was that the information between two observations was not directly available. The second point was that the sensors are located on the top of Maitri station. In wind energy work,

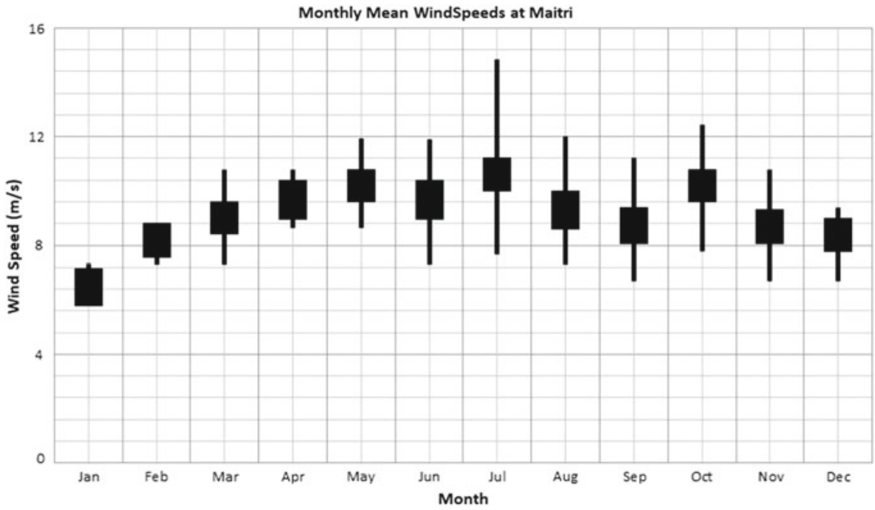


Fig. 1.1 Monthly mean wind speeds and standard deviations (IMD)

it is important to measure the free stream velocities at several elevations from the ground to be able to describe wind energy potential with a good degree of accuracy. There are several other installations on the building, and the building itself can cause difficulty to model type of perturbations into the flow field. It was, therefore, decided to set up an independent microprocessor-based three-level wind-monitoring system. Ice-free wind speed and direction sensors rated at 90 m/s survival speed were fixed on an already existing 28 m tall mast at three levels. Data loggers were housed in summer huts where experiments related to SODAR, Geomagnetism, and other sciences were set up. Data loggers were programmed to store hourly averages of wind speed, direction, and standard deviation. The data collection was initiated in January 1997. Monthly average wind speeds at two levels are shown in Fig. 1.2.

Mid-level wind speed sensor was damaged while being serviced. Although readings were obtained after the repair, the readings could not be taken with much confidence. The wind rose and frequency distribution of winds are given in Fig. 1.3.

1.4 Extreme Winds

The data logger was also recording 2 s gusts and Table 1.1 gives measured gusts during the measurement period. There were two data loggers for data storage. First data logger recorded data from 12 and 28 m level instruments and the second data logger from the 22 m level. The data obtained on peak speeds appear to be reasonable for the 12 m level. As indicated earlier, data from the 22 m level anemometer was somewhat doubtful.

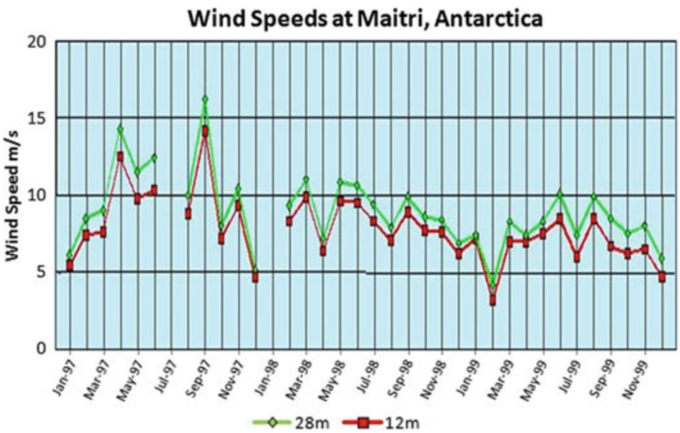
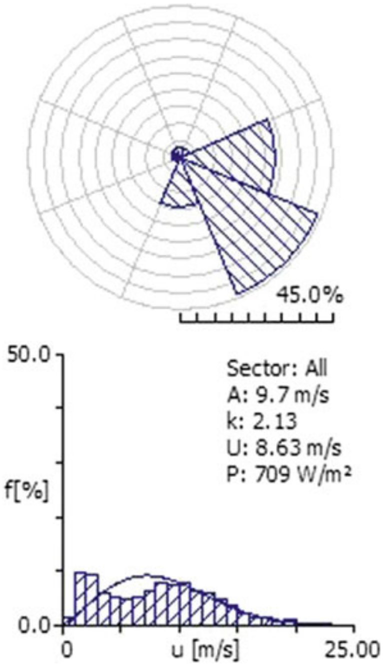


Fig. 1.2 Sensors on 28 m mast and monthly average wind speeds

Fig. 1.3 Wind rose and frequency distribution at Maitri (1998)



There were some breaks in the data for various reasons. From among the data that became available, it was feasible to get continuous records for nearly two years. The Survey of India has published a contour map of Maitri environs. Based on this map a Digital Terrain Model of the area was prepared (Fig. 1.4).

This, in combination with the wind speed and direction information, was used to determine effective wind power availability around Maitri. The calculations were carried out on a 25 m × 25 m grid, and possible energy production levels were determined. To be able to get a good understanding of how this wind potential gets translated into energy production, the annual energy outputs (normalized) from a typical wind turbine has been calculated for the entire region around Maitri and presented in Fig. 1.5. Slightly elevated regions can give better outputs than sheltered regions.

This will be one of the important factors to be considered while setting wind turbines. Depending upon where the new summer facilities would be set up, the location of future wind turbines would be determined. For the existing station, a suitable location could be to the South of the station at about 300 m. The energy that could be expected would be in the range of 4000 to 4500 KWH/year/kW installed. Other locations could be considered as by and large, the area has possible production levels at about 3500 to 4000 KWH/year/kW. Wind turbines are normally designed for withstanding speeds up to 75 m/s which is inadequate in Antarctica. Further, due to sustained higher wind speeds, fatigue damages would result in wind turbines often

Table 1.1 Peak wind speeds (m/s) at Maitri, Antarctica

Month and year	12 m						22 m						28 m		
	Max			Max			Max			Max			Max		
	Hourly	Date	Time	Gust	Date	Time	Hourly	Date	Time	Gust	Date	Time	Hourly	Date	Time
	Avg						Avg						Avg		
Jan-97	11.37	30	05:00	76	22	00:00	12.19	30	05:00	79	22	23:00	12.79	30	05:00
Feb-97	17.88	12	23:00				19.48	12	23:00				20.66	13	01:00
Mar-97	18.69	20	08:00				19.42	20	09:00	107	7	22:00	20.76	20	08:00
Apr-97	24.82	18	22:00				26.58	18	23:00				28.37	18	22:00
May-97	21.73	18	21:00				22.94	18	16:00				24.33	17	21:00
Jun-97	17	2	16:00				32.25	16	23:00	122	3	04:00	19.35	2	16:00
Jul-97							19.18	6	03:00						
Aug-97	24.2	19	04:00	93	3	05:00							27.63	19	04:00
Sep-97	24.41	26	02:00	98	1	01:00							27.59	26	02:00
Oct-97	19.87	2	09:00	82	1	00:23							22.64	2	11:00
Nov-97	22	13	18:00	88	1	17:00							26.19	13	18:00
Dec-97	14.95	2	18:00										16.59	2	18:00
Jan-98															
Feb-98	20.88	12	23:00				21.6	12	23:00	138	5	07:00	22.97	12	23:00
Mar-98	24.01	3	05:00				24.63	3	05:00				26.43	3	05:00
Apr-98	16.94	30	07:00				17.25	30	07:00				18.53	30	07:00
May-98	19.61	27	23:00				19.98	28	00:00	126	1	23:00	21.54	27	23:00
Jun-98	25.01	12	21:00				26.27	12	22:00				28.26	12	22:00

(continued)