HOW TO PREDICT CARGO HANDLING TIMES AT THE SEA PORT AFFECTED BY WEATHER CONDITIONS

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Abstract

Safe implementation of the decisions regarding the potential uncertainties in port loading operations requires the anticipation of all the aspects of loading. However, loading operations that are designed as new maritime projects have not always been supported by extensive practical experience. This paper discusses the case study of Punta Arenas loading terminal, reviewing potential issues related to building such a terminal and providing answers applicable to similar cases. When planning the construction of loading terminals at places exposed to harsh weather conditions, it is necessary to define economic and weather aspects. Building a loading terminal in Punta Arenas represents a demanding venture due to exceptionally hard weather conditions affecting the area.
The quantitative uncertainties in loading operations can be presented by simulations. Probabilistic simulation is a process explicitly presenting the uncertainties by defining the information input as a distribution of probability of error. If the inputs describe an uncertain system, the forecast of future results is necessary. The results are obtained on the basis of the available information that represents the stated distribution.

For the purpose of the probability simulation, the Monte Carlo method is often used, and has therefore been chosen for this research. The main results of the research shall be quantified as the probability of failure in the ship loading operation, with the focus on selected input systems, in the context of difficult weather conditions and unfavourable location of the port of loading. These findings are highly useful to the decision-makers since the latter are able to use the simulation results as a backing for decisions related to the ship loading.

Key words: *terminal construction, Monte Carlo simulation, weather conditions, port aspects*

1. INTRODUCTION

The construction of the new oil terminal in Punta Arenas in the Republic of Chile requires a detailed study which has to take into account numerous economic factors and a variety of weather conditions affecting the port. The study is indispensable also due to insufficient practical experience in building such an infrastructure to be operated within the specific weather and economic environment.

When considering the defined port aspects influencing the design of the Punta Arenas terminal, it is obvious that the weather conditions and the approach to port terminals are the aspects of vital importance. The weather conditions prevailing in the area designated for building the terminal, in particular wind and ice, play an important role during the operations of ship berthing and loading. In order to minimize or reduce the time loss, it is necessary to determine the shore-based storing capacities that would be available at the terminal during production time; this also represents an important safety aspect which implies the ability to store the produced petroleum and gas in the event a ship can not approach the loading terminal. The simulation described in this paper provides the values of the key aspects of the ship loading operation.

It is possible to quantitatively represent uncertainties in simulations. Probabilistic simulation is the process of explicitly representing these uncertainties by specifying inputs as probability distributions. If the inputs describing a system are uncertain, the prediction of future performance is necessarily uncertain. That is, the result of any analysis based on inputs represented by probability distributions is a probability distribution itself.

This type of the probabilistic simulation is often referred to as the Monte Carlo method (Robert and Casella, 2010) and has been selected for the purposes of this study. The main result produced by the study will be the quantified probability of the failure of loading operation based on selected inputs of the system and probabilities of the weather and operational failures. Such findings are greatly useful to decision-makers who can use the simulation results to support their decisions.

2. COMPUTER MODEL OF THE PUNTA ARENAS TERMINAL COMPLEX

The main objective of the availability study is to develop a computer model of the complete terminal complex in Punta Arenas to assess the overall availability of the loading and ship operations at the terminal, and to help understand the contribution of different systems to the overall unavailability. The research findings produced by the simulation that has been carried out in this study can be used for enhancing technical aspects of the loading terminal in harsh weather conditions. The simulation model has defined an adequate approach to the investment plans and the costs involved for building the Punta Arenas terminal. As the terminal is located in a naturally protected area which is exposed to a variety of weather conditions, this paper enables to define potential time delays and the resulting technical shortcomings.

The simulation model for the Punta Arenas terminal includes the following units:

1. Oil production facility,
2. Oil terminal storage, and
3. Loading jetty and arms.

The system has to include the reliability of the units based on general historical data or the best specialist assessment. The operating policies are also built into the model.

2.1. Discrete event model

The computer model can be run though a life-cycle of the terminal (see Fig. 1). As the model includes the events which are set by a random generator, each run yields different results. According to the Monte Carlo method, the system must be run through a sufficient number of times in order to generate a probability function. Typically more than 100 simulations are required.

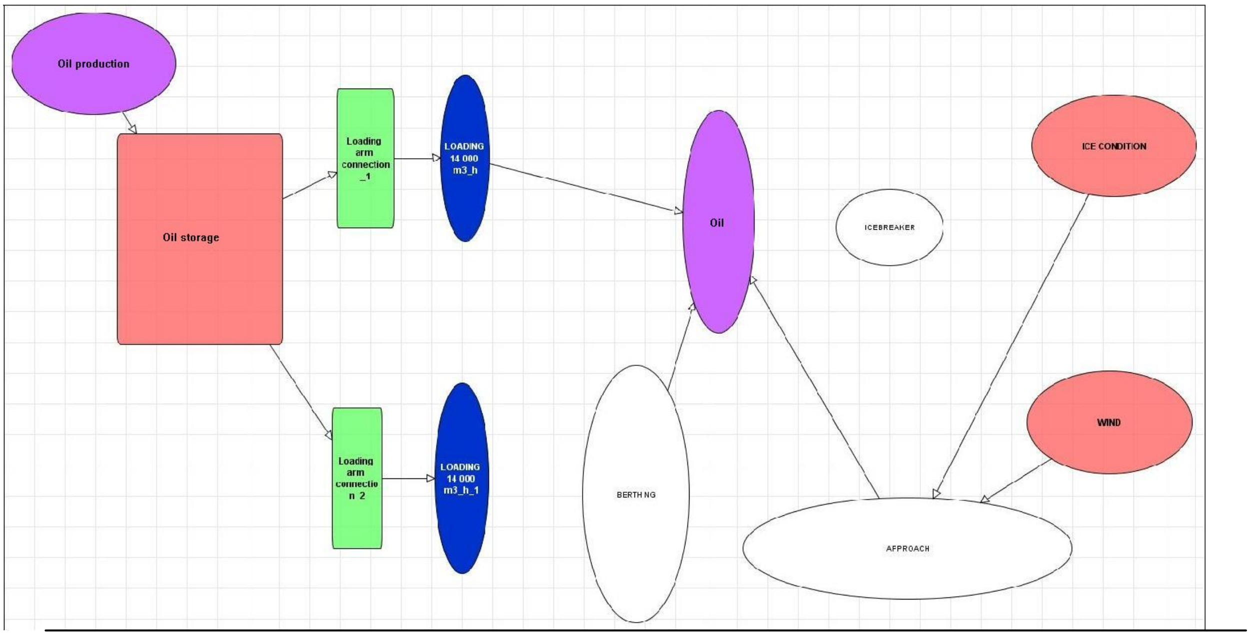


Figure 1: Main elements of the simulation model (simplified).

2.2. Probability density functions

Environmental and failure data contained within the model are described by different distribution functions:

1. exponential,

2. normal,
3. triangular, and
4. rectangular.

In addition to the unscheduled events, all major known activities are included as scheduled events at the required frequency (in years) and duration (in hours). The known weather conditions, maintenance and production parameters which change annually are included into the model as controlling elements. Where complex interactions between the elements of the model are required, conditional logic is used to ensure a good representation of the planned real world operations.

3. BASIC DATA ASSUMPTIONS

The main assumptions in the computer model are:

1. Terminal life-cycle is 25 years,
2. Oil facility input is 35,000 m^3/day,
3. Oil storage tanks capacity amounts to 350,000 m^3,
4. Number of loading jetties (1-3),
5. Oil loading rate is 8,000 m^3/h,
6. Oil tanker is capable of handling all vapour during loading,
7. Connection of the loading arms takes 3 hours,
8. Berthing takes nominally 2-4 hours depending on the season,
9. One line icebreaker is used at entrance, and
10. 4 tug boats in summer time.

Systems or operative functions which do not have a straight influence on the terminal are excluded from the model.

3.1. Weather related influence

3.1.1. Wind speed

Wind information is available from Chile meteorological station and this data is used to represent Punta Arenas conditions at the terminal and offshore, in the approach seaways (see Table 1 and Table 2). The calculation of the availability of the Punta Arenas terminal has been carried out using the available information referring to the geographic position of the terminal and its exposure to the impacts of winds and ice from the Antarctic.

Table 1: Monthly wind speed data

Wind speed													
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Average	6.8	6.3	6.3	6.6	6.8	6.3	5.7	6.1	6.4	7.0	6.9	6.9	6.5
Maximum	34	40	40	40	30	28	30	28	30	34	35	>40	>40

Source: http://weather.noaa.gov/weather/CL_cc.html [from 01/01/09 to 01/12/09]

Table 2: Annual wind speed gradations

Wind speed [m/s]	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-20	21-28	29-40
Frequency [%]	5.0	16.8	20.2	19.6	16.6	8.6	7.4	3.2	1.2	1.2	0.3	0.05

Source: http://weather.noaa.gov/weather/CL_cc.html [from 01/01/09 to 01/12/09]

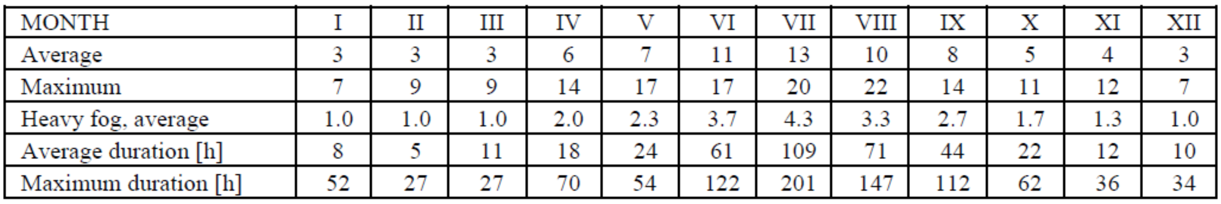
In order to foresee potential events caused by weather conditions, the resulting time loss and material damage, the following wind speed values have been defined:

1. When the wind speed is greater than 15 m/s, delays in sea voyage and limited approach to the port are expected (Schwerdtfeger, 1984).
2. Wind speeds over 12 m/s are expected to delay the sea voyage in the approach channel by 20% due to increased ice compression.
3. When the wind speed is greater than 25 m/s, it is expected to delay sea voyage by 6 hours.
4. When the wind speed is over 15 m/s, the approach to Punta Arenas is prohibited and the oil carrier must wait at a safe position outside the entrance channel. The oil carrier is not allowed to leave the port either.

3.1.2. Fog (visibility)

Fog may considerably impair visibility and, consequently, the safety of navigation, and therefore represents one of the important safety aspects of entering the port and berthing at the terminal. If the visibility is less than 100 m, fog impedes the approach and limits the departure of vessels. Table 3 presents the values defining the approximate number of foggy days per month. Heavy fog is assumed to last for about 1/3 of the average time shown in the Table.

Table 3: Number of days with fog and duration of fog



MONTH	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Average	3	3	3	6	7	11	13	10	8	5	4	3
Maximum	7	9	9	14	17	17	20	22	14	11	12	7
Heavy fog, average	1.0	1.0	1.0	2.0	2.3	3.7	4.3	3.3	2.7	1.7	1.3	1.0
Average duration [h]	8	5	11	18	24	61	109	71	44	22	12	10
Maximum duration [h]	52	27	27	70	54	122	201	147	112	62	36	34

Source: http://weather.noaa.gov/weather/CL_cc.html [from 01/01/09 to 01/12/09]

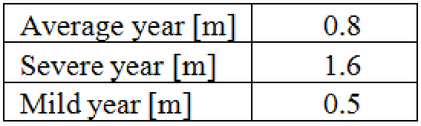
3.1.3. Rain/snow fall

Rain and snow have no effect on the model (Rosenbluth, Fuenzalida and Aceituno, 1997).

3.1.4. Ice

The annual maximum ice thickness (Jones, Wigley and Briffa, 1994; Jones, 1995) is reached from February to April (see Table 4).

Table 4: Annual maximum thickness of ice level



Average year [m]	0.8
Severe year [m]	1.6
Mild year [m]	0.5

Source: http://www-luan.unice.fr/~aristidi/articles/aa_wind.pdf

The delays in sea voyage are difficult to be related to the known data of ice conditions and therefore we used the reference data from the existing ships operating in the same region. It should be mentioned here that all oil carriers which today operate as regular liners in the region, and are supported by the available technical facilities, are able to follow their planned schedules safely (King, 1994).

The following data are generated based on the previous similar vessels voyages data:

1. average speed is 10.35 knots,
2. maximum average speed is 11.45 knots,
3. minimum average speed is 9.64 knots, and
4. distribution type is rectangular.

The speed value has to be converted to time units; the corresponding values based on 45 NM ice distance are:

1. deviation from average max. 3.2 h, and
2. deviation from average min. 4.1 h.

Otherwise it is expected that there are a suitable number of oil carriers so that they are able to arrive with planned schedule towards the oil terminal.

4. STUDY CASES AND RESULTS

The following cases have been analysed:

Case 1.

- Phase 1 production, 1 loading jetty.
- Phase 1 production, 2 loading jetties.

Case 2.

- Phase 2 production, 1 loading jetty.
- Phase 2 production, 2 loading jetties.
- Phase 2 production, 3 loading jetties.

Case 3.

- Phase 3 production, 1 loading jetty.
- Phase 3 production, 2 loading jetties.
- Phase 3 production, 3 loading jetties.

4.1. Computer model simulations

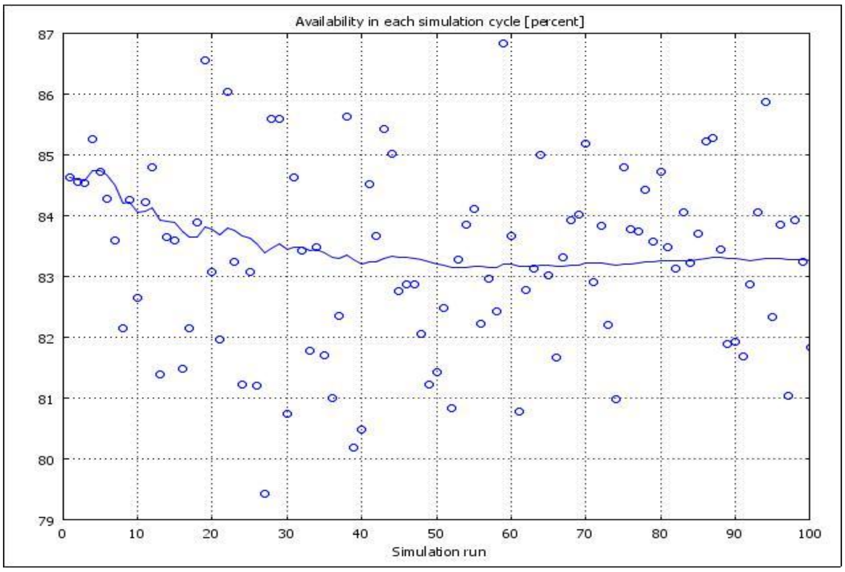


Figure 2: Result of MC-simulations of 100 times. Terminal availability percent (Phase 1)

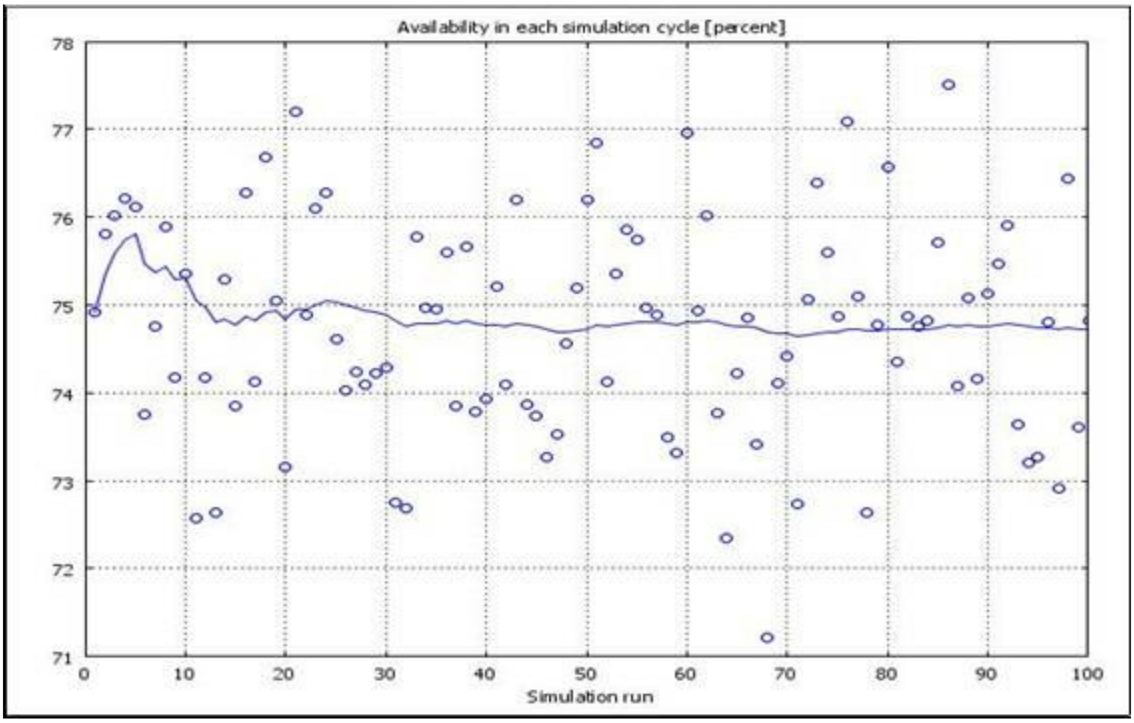


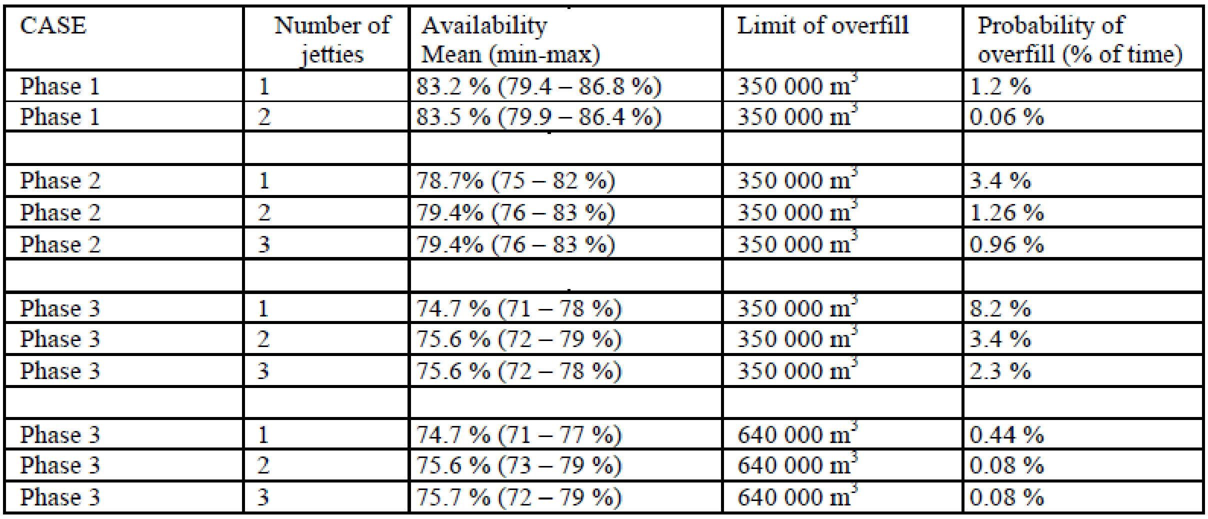
Figure 3: Result of MC-simulations of 100 times. Terminal availability percent (Phase 3)

Regarding the stability of the Monte Carlo simulation for the Punta Arenas terminal complex, by observing the plots from Phase 1 cases it is evident that after 100 simulation runs the result of availability starts to stabilizeThe line in the plot shows the cumulative average of the individual simulation cases. It can be noticed that it stabilizes after 50 simulation runs; therefore it can be concluded that 100 runs should be sufficient (see Fig. 2 and Fig. 3). The availability of the Punta Arenas terminal is expected to have a mean value of 83.2 %. The similar plot is shown also for Phase 3 simulation case.

4.2. Results for the terminal availability and tank overfill

The availability is defined to be the relative time when weather, damage, delay or occupation of the entrance channel limits the approaching or loading operation. The probability of overfill of storage tanks is the time when storage would exceed the given limit value (i.e. 350,000 m^3). Table 5 shows the results from the simulated cases.

Table 5: Availability percent and probability of overloading storage



CASE	Number of jetties	Availability Mean (min-max)	Limit of overfill	Probability of overfill (% of time)
Phase 1	1	83.2 % (79.4 – 86.8 %)	350 000 m^3	1.2 %
Phase 1	2	83.5 % (79.9 – 86.4 %)	350 000 m^3	0.06 %
Phase 2	1	78.7% (75 – 82 %)	350 000 m^3	3.4 %
Phase 2	2	79.4% (76 – 83 %)	350 000 m^3	1.26 %
Phase 2	3	79.4% (76 – 83 %)	350 000 m^3	0.96 %
Phase 3	1	74.7 % (71 – 78 %)	350 000 m^3	8.2 %
Phase 3	2	75.6 % (72 – 79 %)	350 000 m^3	3.4 %
Phase 3	3	75.6 % (72 – 78 %)	350 000 m^3	2.3 %
Phase 3	1	74.7 % (71 – 77 %)	640 000 m^3	0.44 %
Phase 3	2	75.6 % (73 – 79 %)	640 000 m^3	0.08 %
Phase 3	3	75.7 % (72 – 79 %)	640 000 m^3	0.08 %

Source: According to the authors' analysis

A further analysis of the results is required to evaluate the reasons and means of improvement.

5. CONCLUSIONS

The availability of the Punta Arenas terminal heavily depends on the weather conditions. Therefore it does not seem likely that the system might be improved by adding more loading arms or loading jetties. However, the increase in production of petroleum and oil from Phase 1 to Phase 3 clearly implies the need for the increased storage capacity and loading frequency. Delays of vessels caused by bad weather may lead to shutdown of the production and result in additional economic losses.

The analysis of weather conditions in this simulation has defined the probabilities that may arise from these conditions. On the other hand, the number of loading jetties has a clear and positive influence on the probability of the overfilling the storage tanks. The speed of loading the oil onboard ships allows the possibility of faster production and decreased usage of shore-based storage capacities. This would reduce the investment costs by the amount intended for building additional 300,000 m^3 of the storage space.

Important remark: The results of this study show the importance of the weather conditions, namely the ice, wind and fog. However, the reliability of the used information should be crosschecked by using various sources and more specific statistical data should be obtained. For example, fog information does not provide any data on limited visibility and a very rough estimation has been made. Likewise, the available wind data provide controversial information on the probability of high wind speeds over 15 m/s.

The findings produced by this analysis suggest that it would be best to install two loading jetties already in Phase 1 and gradually increase the storage capacity. The 350,000 m^3 capacity does not seem to be sufficient for Phase 3 production; instead, 640,000 m^3 capacity and two loading jetties can be recommended.

The obtained figures and values would improve the safety aspects of the terminal in the event of vessel delay due to weather conditions or unpredictable circumstances. In order to reduce the exposure of storage capacity to loading situations arising from vessel delays, it would be necessary to build additional storage facilities and increase the capacity of storing petroleum and gas. This would prevent the undesirable production shutdown and would allow production operations to resume according to the development plans.

REFERENCES

Aristidi, E., Agabi, K., Azouit, M., Fossat, E., Vernin, J., Travouillon, T., Lawrence, J. S., Meyer, C., Storey, J. W. V., Halter, B., Roth, W. L. and Walden, V. (2004), "An analysis of temperatures and wind speeds above Dome C, Antarctica", available at: http://www-luan.unice.fr/~aristidi/articles/aa_wind.pdf.

Internet Services Group (2007), National Weather Service. Available at: http://weather.noaa.gov/weather/CL_cc.html.

Jones, P. D., Wigley, T. M. L., and Briffa, K. R. (1994), "Global and hemispheric temperature anomalies - land and marine instrumental records", in: Boden, T. A., Kaiser, D. P., Sepanski, R. J. and Stoss, F. W. (eds.), Trends '93; *A Compendium of Data on Global Change*, ORNL / CDIAC-65, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tn, pp. 603–608.

Jones, P. D. (1995), "Recent variation in mean temperature and the diurnal temperature range in the Antarctic", in: *Geophys. Res. Lett*., 22(11), pp. 1345–1348.

King, J. C. (1994), "Recent climate variability in the vicinity of the Antarctic Peninsula", in: *International Journal of Climatology*, Vol. 14, pp. 357–369.

Robert, C. P. and Casella, G. (2010), "*Monte Carlo Statistical Methods*", Springer, USA.

Rosenbluth, B., Fuenzalida, A. and Aceituno, P. (1997), "Recent temperature variations in southern South America", in: *International Journal of Climatology*, Vol. 17, pp. 67–85.

Schwerdtfeger, W. (1984), "Weather and Climate of the Antarctic", Amsterdam, *Elsevier* (Developments in Atmospheric Science: 15), 262p.