Data collected during the FROST project

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An outline is given of the data collected during the winter and summer FROST Special Observing Periods (SOPs) of July 1994 and January 1995. A total of 7,020 (9,582) surface meteorological reports have been obtained from the staffed stations for the winter (summer) periods, representing about 92 per cent of the possible maxima, based on station reporting schedules. The corresponding numbers of radiosonde ascents from winter and summer were 952 and 971 respectively. Today, more observations from automatic weather stations (AWSs) are available for the Antarctic than reports from staffed stations, and the number of AWS observations collected for the two SOPs were 11,721 (13,515) for winter (summer). Forecasts and analyses for the SOPs have been obtained from a number of forecast centres. The FROST data archive also includes ship, drifting buoy, scatterometer surface wind vectors and a wide range of satellite data. Many of the FROST datasets are accessible via the World Wide Web site at http://www.nerc-bas.ac.uk/public/icd/FROST/.

Introduction

The Antarctic FROST project (Turner et al. 1996) provided an excellent opportunity to assemble comprehensive datasets of Antarctic observations for research investigations and the assessment of operational analyses and forecasts. One of the primary goals of the project was to try and acquire as much of the meteorological data as possible for the three one-month special observing periods (SOPs) (July 1994 (SOP-1), 16 October - 15 November 1994 (SOP-2) and January 1995 (SOP-3)), which form the basis of FROST.

Data for these periods were collected via the weather services, national operators who are responsible for the research stations in the Antarctic, data centres who hold data for the continent, and individual scientists or research groups who were operating data collection systems at the time. Much of the routine meteorological data collected at the staffed stations is placed on the WMO Global Telecommunications System (GTS), although, because of communications problems, some observations can become corrupted or not reach certain parts of the system. For these reasons, a number of different sources of Antarctic data were approached during the data collection phase to try and maximise the information for the FROST data archive.

Here we present information on the current (late 1997) holdings of data for the FROST project. Some data are still arriving – in particular, some drifting buoy observations – but it is unlikely that much more will be received in the future.

In the following sections we concentrate on SOPs 1 and 3 since much of the data for SOP-2, and particularly the data received via the GTS, is being held in raw, unprocessed form only until it is shown that there is a requirement for these observations.

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The data collection rationale

The meteorological observations from the staffed research stations were some of the most important observations required for the project and great efforts were made to collect as many of these reports as possible. In real time during the SOPs, two nodes of the GTS (Hobart, Australia, and Cambridge, UK) were used to receive all the Antarctic observations, the data being merged into a combined dataset. This proved to be a very good strategy, since about 25 per cent of the observations arrived at one site but not the other. The merged dataset was supplemented with surface and upper-air observations that were not, for a number of reasons, put onto the GTS.

A similar approach was taken with the AWS observations which were collected at the same two nodes of the GTS and supplemented with observations from the groups who maintain the systems. However, it was found that many of the GTS observations had to be replaced by the corresponding late observations, since many of the AWS operators carry out very thorough quality control checks on their data and the late observations were far superior to the real-time data.

Some other data could be collected in real time, such as the analyses and forecasts produced by the major numerical weather prediction (NWP) centres and distributed via the GTS. However, these data were supplemented by additional products provided by the NWP centres that were prepared a few hours later. These fields included more data or had a higher horizontal resolution. Some very valuable composite satellite images of the whole Antarctic region (Stearns et al. 1995) were also collected in near real-time during the SOPs.

Much of the other data collected for FROST consisted of geophysical parameters derived from satellite measurements and most of these observations were received from the satellite operators or those concerned with processing such data.

Current data holdings

Land-surface SYNOP observations

The number of surface SYNOP reports held is given in Table 1. We currently (late 1997) hold about 92 per cent of the theoretical maximum number that could be assembled if all the stations open during the particular seasons were able to transmit all the observations according to their publicised reporting schedule and no data were lost on the GTS. The number of observations collected during the summer is obviously larger because of the greater number of stations open during that part of the year (38), compared to those that operate year-round (33). In addition, some field camps that are operating during the summer also make meteorological measurements and these can find their way onto the GTS.

The number of surface observations collected from the GTS for the two SOPs represents about 89 per cent of the theoretical total that could be obtained, a testament to the dedication of the observers in the Antarctic who put the data onto the GTS and the efficiency of the communications system. The fact that only 540 observations could be obtained after the event from the national operators suggests that we may have overestimated the reporting frequency of some stations. Of course there will also have been occasions when, for a variety of reasons, the observations could not be made.

Land radiosonde ascents

The number of radiosonde ascents available for the two SOPs is also given in Table 1. These represent about 76 per cent and 75 per cent respectively of the launches that could be carried out, based on the published station programs. The percentages are lower than for the surface meteorological observing programs because of the problems of launching balloons in strong wind conditions. The figures include 91 ascents that were obtained from the national operators after the SOPs.

Table 1. A summary of the *in situ* observations obtained for FROST SOPs 1 and 3.

Type of data	*SOP-1 (July 1994)*	*SOP-3 (January 1995) Total*	
Surface meteorological observations from staffed stations	7,020	9,582	16,602
Radiosonde ascents	952	971	1,923
AWS observations	11,721	13,515	25,236
Drifting buoy observations	7,110	6,416	13,526
Ship reports	81	795	876

During the SOPs, 12 stations had year-round radiosonde programs with, in addition, the Italian Terra Nova Bay station making ascents during the summer only. Eight stations made twice-daily ascents at 0000 and 1200 UTC, while the remainder made a single flight each day at one of the main synoptic hours. During the winter SOP, Halley Station made two rather than the usual single daily ascent.

AWS observations

The changing nature of meteorological observing in the Antarctic is clearly reflected by the fact that for the two SOPs almost 50 per cent more automatic weather station (AWS) observations were received than surface observations from the staffed stations. The AWS reports came from a range of US, Australian, German, Finnish and Italian AWS systems. The number of reports received represent about 74 per cent and 91 per cent of the theoretical maxima.

Although over 25,000 AWS observations were received for the two SOPS, only 38 per cent of this number were collected via the GTS in real time, indicating that comparatively few of the observations are available to the forecast community for use in operational meteorology. Some of the AWSs are research systems and it would not be appropriate to consider the use of their data in operational applications. However, since the vast majority of the AWS observations are sent out of the Antarctic via the ARGOS satellite data collection system, there is clearly great scope for making more use of the observations in analysis and forecasting.

At the time of the SOPS about 51 AWSs were in operation across the Antarctic, the greatest number being operated by the USA.

Drifting buoy data

The total number of drifting buoy observations (see Table 1) collected during the two SOPS is almost as many as the number of reports from staffed stations, indicating the importance of these data for analysis of the southern hemisphere atmospheric circulation. All these observations were collected via the GTS and we still await the arrival of the offline, quality-controlled observations from the data centres holding the buoy data. The split of buoy observations between the two SOPs was 7,110 (6,416) from the winter (summer) SOP. We estimate that these account for 41 per cent and 62 per cent respectively of the data that could be available. However, the relatively low percentages of observations received are thought to arise because of the reliance on there being a satellite overpass at an appropriate time to collect the data.

Ship observations

Relatively few ship reports were received during the winter SOP since at this time of the year there are very few research (and no re-supply) vessels operating in Antarctic waters. During this SOP, therefore, all the reports came from just south of the northern limit of the FROST data collection area at 50°S. However, during the summer period, 795 reports were received from the many ships operating close to the coast of the continent. The location of these reports can be seen in Fig. 1. No late ship reports have been received since the SOPs.

The percentage of possible ship reports cannot be calculated since it is impossible to know how many ships are operating in Antarctic waters at any time.

A few radiosonde ascents from research vessels during SOP-3 are available, but in coded form only.

Satellite imagery

Satellite imagery proved extremely important to the FROST re-analysis exercise (Hutchinson et al., forthcoming) and every effort was made to obtain comprehensive datasets from a variety of sources. Composite satellite images of the whole Antarctic region (Stearns et al. 1995) were collected in near real-time during the SOPs and data for every three hours have been obtained, except for a short period on 4 July 1994 when computer problems were experienced in Madison.

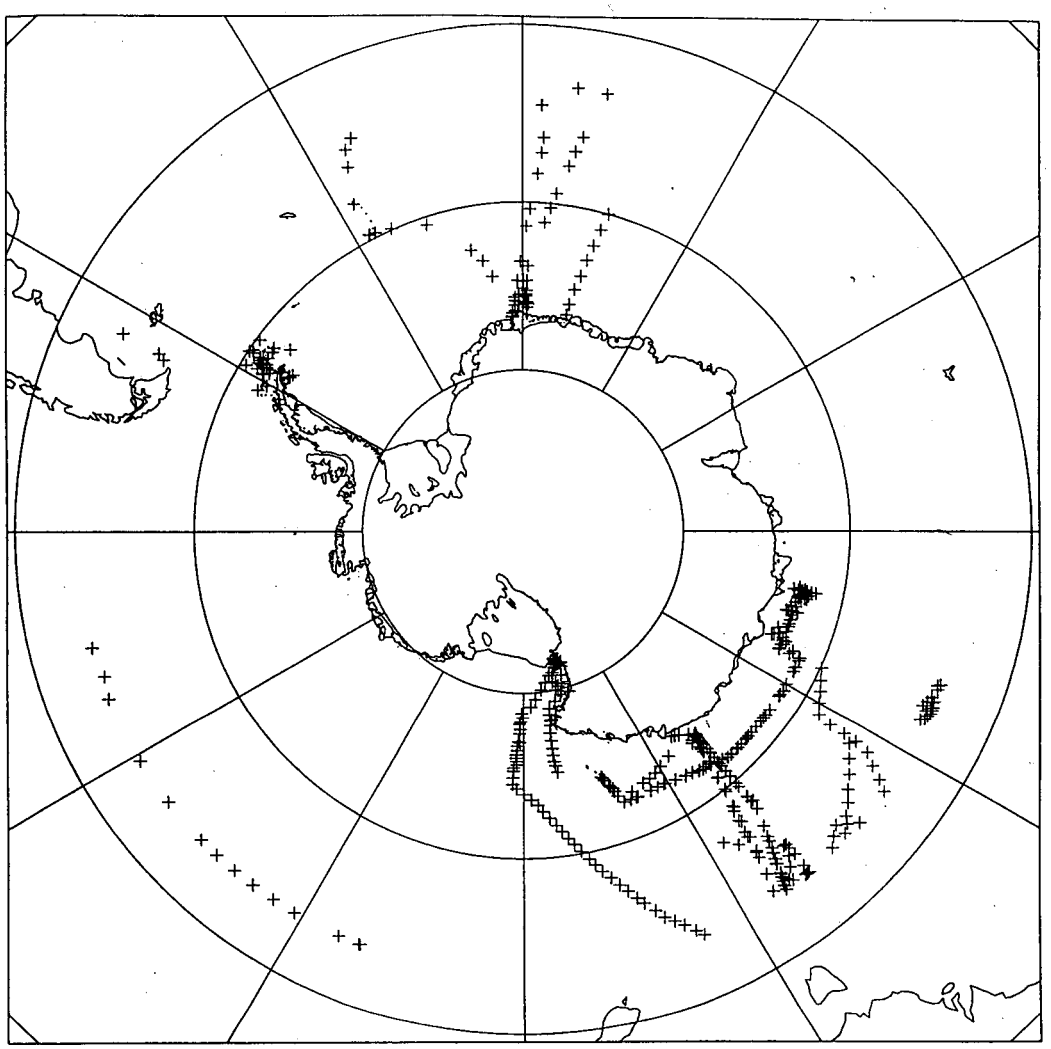
High Resolution Picture Transmission (HRPT) data, containing the full 1 km horizontal resolution NOAA imagery, were collected from the receiving stations in operation during the SOPs. These consisted of Rothera and Palmer on the Antarctic Peninsula, McMurdo to the west of the Ross Ice Shelf and Casey Station on the coast of East Antarctica. Between them these stations provide imagery covering about 90 per cent of the continent and a substantial part of the Southern Ocean. Unfortunately, Casey Station experienced computer problems during the winter SOP and data were lost for that period. However, imagery for the winter period is available from the other stations and all the sites collected imagery during the summer SOP.

To compensate for the loss of the Casey imagery during SOP-1, infrared US Defense Meteorological Satellite Program (DMSP) imagery, with a horizontal resolution of 2.7 km, was obtained for the eastern hemisphere for the period of the second re-analysis (Hutchinson et al., forthcoming) covering the period 22-28 July 1994.

Passive microwave data and derived products

Global brightness temperatures from the Special Sensor Microwave/Imager (SSM/I) on the DMSP

Fig. 1 The locations of all surface ship reports during SOP-3 in January 1995.



satellites were obtained for the SOPs. These data allowed the generation of a number of geophysical products over the ice-free ocean areas, including surface wind speed, integrated water vapour, rain rate and columnar cloud liquid water.

Other satellite data

Surface wind vectors from the scatterometer instrument on the ERS-1 satellite have been obtained for all the SOPs. These data, obtained from the European Space Agency, cover the ice-free ocean areas. The wind vectors are produced every 50 km across a 500 km wide swath, although the swaths are relatively widely spaced so that not all weather systems are observed in these data (Marshall and Turner 1997).

Measurements from the TIROS Operational Vertical Sounder (TOVS) on the NOAA satellites allow the production of temperature and humidity profiles at fairly high horizontal resolution and are therefore very valuable for analysis over the data-sparse Antarctic regions. The HRPT data described above contain the TOVS data, which can therefore be extracted and processed using a number of available software packages.

Numerical model analyses

The numerical analyses produced during the SOPs were obtained from the UK Meteorological Office (UKMO), the Australian Bureau of Meteorology (BOM), the US National Centers for Environmental Prediction (NCEP) and the European Centre for Medium-Range Weather Forecasts (ECMWF). These data were in GRIB code format with the fields having a horizontal resolution of about 250 km, significantly poorer than that of the forecast/analysis systems that produced the fields. Also, we only hold the data at a number of standard levels. NCEP put two different analyses onto the GTS from assimilations that have different data cut-off times, however the analyses that we have are from the earlier aviation (AVN) run. Table 2 lists the analyses that are available to the FROST project.

Numerical model forecasts

Table 3 lists the forecast fields that are available from the UMKO and the ECMWF. Attempts are still being made to obtain additional forecasts for the periods of the SOPs.

Table 2. The analyses available for the SOPs.

Analysis centre	*Analyses available*
UKMO	Every 6 h for all SOPs
BOM	Every 24 h (for 2300 UTC) for July 1994 and every 12 h (1100 & 2300 UTC) for January 1995
NCEP	Every 24 h (for 1200 UTC) throughout July 1994 from the AVN runs
ECMWF	Every 6 h for all the SOPs

Hand-drawn analyses

The basis for the FROST re-analysis effort (Hutchinson et al., forthcoming) was the UKMO hand-drawn surface charts showing the observations and the model pressure at mean sea level (PMSL) analysis, along with modifications made by the analysts. These charts are available in hardcopy form for 0000 and 1200 UTC throughout the three SOPs. The 250 and 500 hPa height fields and the 1000-500 hPa thickness fields are also available in chart form from the UKMO assimilation scheme.

Table 4 lists the manually re-analysed charts produced in Hobart. These are currently all held in hardcopy form, although selected fields are being digitised on a 1.25° by 1.25° latitude/longitude grid.

Appendix

Obtaining FROST data

The British Antarctic Survey (BAS, Cambridge, UK) is the primary data centre for the FROST observations. BAS holds all the surface and upper-air observations from the staffed stations, along with the AWS, ship and buoy data. They also have all the scatterometer and passive microwave satellite raw data and derived products. They have made many of these data available for downloading via their World Wide Web site at http://www.nerc-bas.ac.uk/public/icd/FROST/. There are also some on-line charts of temperature, PMSL and wind speed for all the land stations and AWSs (station-level pressure instead of PMSL) sites. To obtain access to data not on the web site the first author should be contacted at British Antarctic Survey, High Cross, Madingley Road, Cambridge, CB3 0ET, UK.

Although the three-hourly composite satellite images of the Antarctic are available at BAS, it is easiest for interested parties to obtain the images directly from University of Wisconsin-Madison ftp site. Details of this facility can be obtained from http://uwamrc.ssec.wisc.edu/amrc/archive.html.

Table 3. Forecast fields available for FROST.

Centre	*Initial data time*	*Forecast frequency*	*Output frequency*	*Forecast range*	*Fields available*	*Periods covered*
ECMWF	1200 UTC	Daily	Every 24 h	10 days	PMSL and 500 hPa height	All SOPs
UKMO	1200 UTC	Daily	Every 24 h	5 days	PMSL and 500 hPa height	All SOPs

Table 4. Manually re-analysed charts produced in Hobart.

Period	*Frequency*	*Field*	*Area*	*Based on*
SOP-1	Every 6 h	PMSL	South of 50°S	Satellite imagery, model fields and *in situ* data
SOP-1 special week: 22-28 July 1994	Every 12 h	PMSL	Eastern hemisphere	As above, but with DMSP imagery
19-26 Jan 1995 in SOP 3	Every 12 h	PMSL	South of 50°S	Satellite imagery (including DMSP), model fields and *in-situ* data
SOP-1 and SOP 3 (19-26 Jan 1995)	Every 12 h	1000 – 500 hPa thickness	South of 50°S, oceans and ice shelves	TOVS thickness data, plus radiosondes and satellite imagery
SOP-1 and SOP 3	Every 12 h	500 hPa height	East Antarctica	Using the Phillpot (1991) technique
SOP-1 (special week, 22-28 July 1994)	Every 12 h	500 hPa height	South of 50°S	Using the Phillpot (1991) technique over East Antarctica, TOVS and the Phillpot technique over West Antarctica and TOVS and radiosonde data over the ocean, followed by addition of fields
SOP-1 and SOP 3 (19-26 Jan 1995)	Every 12 h	500–250 hPa thickness and 250 hPa height	South of 50°S	Addition of the thickness field derived from TOVS data with the 500 hPa height field
SOP-1 and SOP 3 (19-26 Jan 1995)	Every 12 h	700 hPa height, 700-500 hPa thickness	West Antarctica	700 hPa heights from the Phillpot (1991) method, plus TOVS data for thickness

Because of the very large volumes of HRPT satellite data these files are not held centrally but in a distributed fashion. Details on obtaining HRPT data can be obtained from: Rothera – Ice and Climate Division, British Antarctic Survey, High Cross, Madingley Road, Cambridge, CB3 0ET, UK; Casey – Bureau of Meteorology, GPO Box 1289K, Melbourne, Vic. 3001, Australia; McMurdo and Palmer – Antarctic Research Center, Ocean Research Division, A-014, Scripps Institute of Oceanography, La Jolla, California 92093, USA.

The revised FROST analyses are all held in Hobart, and to obtain copies of these interested parties should contact Bureau of Meteorology, GPO Box 727G, Hobart, Tasmania, 7001 Australia. It is hoped to release the revised FROST analyses on CD-ROM in the near future.

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