1. Data

1.1 Data availability

In January 2009, an automatic weather station (AWS) was erected by BAS and UU/IMAU on the Larsen C ice shelf. This station has been collecting data ever since. The data that is quality-checked and available covers the period 22 January 2009 - 1 May 2011. Coverage has been continuous, apart from a period of 5 hours on 16 January 2011 when the AWS was raised and maintenance was carried out.

In January 2011, additional measurements at the Larsen Camp were carried out in the framework of the OFCAP experiment (Orographic Forcing and Climate on the Antarctic Peninsula). The camp was established on 3 January 2011 at approximately 67°00.8'S 61°28.8'W on Larsen C ice shelf, at approximately 40 m a.s.l. The camp was dismantled on 1 February 2011. A map of the camp is shown in figure 1. The data coverage of the additional radiation measurements extends from 4 to 30 January 2011. Turbulence measurements are available intermittently between 6 and 30 January.

1.2 File description

There are data available for two different periods. Background meteorological data are available from a continuously operating automatic weater station (AWS) that has been installed in January 2009 and has been collecting data up to the present day (2011). As a part of the OFCAP field campaign (Orographic Forcing and Climate on the Antarctic Peninsula), a field camp was set up in January 2011. During this period, additional radiation and turbulence measurements are available. The available data sets are described in sections 1.2.1 - 1.2.8.

1.2.1 AWS14_SEB.txt

The file AWS14_SEB.txt contains meteorological variables and surface energy budget (SEB) components at a 30-minute resolution for the period 22 January 2009 - 1 May 2011. These data have been collected by an autonomously operating weather station (AWS). For the period 22 January 2009 - 16 January 2011, the data have been recovered from the data logger of the UU/IMAU AWS at the site of the OFCAP Larsen Camp. For the remaining period (16 January 2011 - 1 May 2011), the data have been constructed from data transmitted by the ARGOS satellite communication system. As not all data may have been transmitted correctly, some data are interpolated in order to get a continuous data series.

1.2.2 AWS14_dayaver.txt

In the file AWS14_dayaver.txt, most of the variables from AWS14_SEB.txt are compiled to daily means. Daily means are taken from the half-hourly data between 0.30 of that day until 0.00 of the next day.

1.2.3 AWS14_monaver.txt

The file AWS14_monaver.txt contains monthly averages for every month between February 2009 and May 2011, only taking into account the months for which the data coverage is complete.

1.2.4 OFCAP_RADI_05m.txt

During the OFCAP period (3 January 2011 - 1 February 2011), high-quality radiation instruments for broadband incoming and reflected shortwave and longwave radiation have been deployed at the Larsen Camp, close to the site of UU/IMAU AWS 14. Specifications of these instruments are given in section 4. The radiation observations have been corrected for tilt, riming, and spurious values. From the data, 5-minute averages have been compiled from 1-minute data. The time variable is defined such that a data point at 10.30 AM is the mean of the five measurements between 10.26 AM and 10.30 AM.

1.2.5 OFCAP_RADI_30m.txt

The file OFCAP_RADI_30m.txt contains the same data as OFCAP_RADI_05m.txt, but as 30-minute averages, defined in such a way that the data point at 9.00 AM is the mean of the 1-minute data between 8.31 AM and 9.00 AM.

1.2.6 OFCAP_SONIC_05m.txt

The file OFCAP_SONIC_05m.txt contains observations made by the turbulence mast that was also employed during OFCAP. Due to power issues, data coverage is moderate. Missing values are given by -99999 values. The values for specific humidity have been corrected for offsets from the LI-COR gas analyzer. Temperature is taken from the sonic observations itself rather than from the thermocouple, since the latter was misfitted and did not record useful data. The speed of sound measured by the sonic anemometer is corrected for temperature and humidity. Since winds have been coming mostly from the east, the turbulence data should be interpreted with care, as the observations are likely disturbed by the mast construction. A map of the camp is shown in figure 1, on which the location of obstacles and the orientation of the turbulence sensors are indicated. The time variable is defined such that a data point at 10.30 AM is the mean of the measurements between 10.26 AM and 10.30 AM.

1.2.7 OFCAP_SONIC_05m_extended.txt

This file is an extended version of OFCAP_SONIC_05m.txt, containing also the raw data (5-minute means of 20 Hz data), including all the eddy covariances.

1.2.8 OFCAP_SONIC_30m.txt

This file contains the same data as OFCAP_SONIC_05m.txt, compiled to 30-minute averages, defined in such a way that the data point at 9.00 AM is the mean of the 5-minute data between 8.35 AM and 9.00 AM.

1.3 Data description

1.3.1 AWS files

year [-]	The year
day [-]	Day of the year
hour [-]	Time of the day, in decimal 24-h clock (14.5 = 14.30 = 2.30 PM)
Time [-]	Time coordinate in decimal days, where 22.5 = 22 January, 12.00, and 33.75 = 2 February 18.00
Tair [^{o}C]	Radiation-corrected (see xx) air temperature at measurement level
Tair_2m [^{o}C]	Air temperature interpolated to 2 meter above surface
RH [%]	Relative humidity
qair [g kg^{-1}]	Specifif humidity at measurement level
qair_2m [g kg^{-1}]	Specific humidity interpolated to 2 meter above surface
pres [hPa]	Surface air pressure
FF [m s^{-1}]	Wind speed at measurement level
FF_10m [m s^{-1}]	Wind speed at 10 meter above surface
WD [^{o}]	Wind direction, where 0 = N, 90 = E, 180 = S, 270 = W
zenith [-]	solar zenith angle with respect to the surface normal (0 = nadir, 90 = at horizon, >90 is below horizon)
tau_cs [-]	Fraction of top-of-atmosphere radiation that could reach the surface at clear sky
SWglobal [W m^{-2}]	Top-of-atmosphere radiation
SWin_max [W m^{-2}]	Maximum incoming solar radiation at surface (SWglobal * tau_cs)
SWin [W m^{-2}]	Incoming solar radiation
SWin_corr [W m^{-2}]	Incoming solar radiation corrected for tilt and limited sensor field-of-view
SWout [W m^{-2}]	Reflected solar radiation
SWnet_corr [W m^{-2}]	Net solar radiation (= SWin_corr + SWout)

SumDivQ [W m^{-2}]	Solar radiation absorbed below the surface
albedo [-]	Broadband albedo for solar radiation, maximized at 0.95 and put to 0.0 when no sunlight
albrun [-]	Running 24-hour mean albedo with superimposed theoretical daily cycle from Wiscombe and Warren model
Cloudcover [-]	Cloud fraction between 0 and 1 based on longwave radiation balance
DiffFrac [-]	Diffuse fraction of incoming solar radiation, based on Cloudcover
MinDiffFrac [-]	Minimal diffuse fraction due to Rayleigh scattering in clear sky atmosphere
Albwwdir [-]	Theoretical albedo of direct irradiance (Wiscombe and Warren model)
Albwwclear [-]	Theoretical clear-sky albedo (Wiscombe and Warren)
Albwwcloud [-]	Theoretical cloudy-sky albedo (Wiscombe and Warren)
Albww [-]	Theoretical broadband albedo (Wiscombe and Warren)
LWin [W m^{-2}]	Incoming longwave radiation
LWinPara [W m^{-2}]	Incoming longwave radiation, parameterized as function of T2m for riming events
LWout [W m^{-2}]	Outgoing longwave radiation, observed
LWout_corr [W m^{-2}]	Outgoing longwave radiation, observed and maximized at melting surface
LWout_model [W m^{-2}]	Outgoing longwave radiation, computed by model as function of model skin temperature
LWnet_corr [W m^{-2}]	Net longwave radiation from corrected observations (LWin + LWout_corr)
LWnet_model [W m^{-2}]	Net longwave radiation (LWin + LWout_model)
Rnet_corr [W m^{-2}]	Net radiation from observations (SWnet_corr + LWnet_corr)
Rnet_model [W m^{-2}]	Net radiation from model (SWnet_corr + LWnet_model)
Hsen [W m^{-2}]	Sensible heat flux from bulk method and Monin-Obukhov similarity
Hlat [W m^{-2}]	Latent heat flux from bulk method and Monin-Obukhov similarity
Gs [W m^{-2}]	Ground heat flux computed from surface temperature gradient
Gs_integr [W m^{-2}]	Ground heat flux computed from energy content of snowpack (this needs to be used when subsurface radiation is enabled)
qsurf [g kg^{-1}]	Surface specific humidity
Tsurf_calc [^{o}C]	Computed surface temperature
Tsobs [^{o}C]	Observed surface temperature, from LWout_corr
Tsurf-Tsobs [^{o}C]	Difference between Tsurf_calc and Tsobs
rest_energy [W m^{-2}]	Rest energy (residual amount of energy by which the budget is not closed)
melt_energy [W m^{-2}]	Surface melt energy
subsm_nrg [W m^{-2}]	Subsurface melt energy
totm_nrg [W m^{-2}]	Total melt energy (surface and subsurface melt energy)
melt_cum [mm]	Cumulative surface melt
subsmelt_cum [mm]	Cumulative subsurface melt
icemelt_cum [mm]	Cumulative melt when ice is at the surface
totmelt_cum [mm]	Cumulative total melt
refreeze_cum [mm]	Cumulative refreezing
runoff_cum [mm]	Cumulative runoff
sublim_cum [mm]	Cumulative sublimation
depos_cum [mm]	Cumulative deposition
subdep_cum [mm]	Difference of cumulative sublimation and cumulative deposition
water_content [mm]	Water content, vertically integrated over the entire snowpack
Ch [-]	Stability correction coefficient for sensible heat flux
stabcor_h [-]	Stability correction for sensible heat flux
Cq [-]	Stability correction coefficient for latent heat flux
stabcor_q [-]	Stability correction for latent heat flux
u_star [m s^{-1}]	Surface friction velocity
th_star [K]	Turbulent scale of temperature
q_star [g kg^{-1}]	Turbulent scale of specific humidity
psi_m [-]	Vertically integrated stability function for momentum
psi_h [-]	Vertically integrated stability function for heat
hsnow [m]	Height of the snowpack
n_snowlayer [-]	Number of layers in the model snowpack
mwater(Xm) [mm]	Amount of water at X m depth
TsMod(Ym) [K]	Modeled snow temperature at Y m depth

1.3.2 *RADI files*

Year [-]	Year of observation
Doy [-]	Day of year
Hour [-]	Hour, where 1455.0 = 14.55 = 2.55 PM
Time [-]	Decimal time, where 4.75 = 4 January 2011 18.00
SWd [W m^{-2}]	Incoming solar radiation (tilt-corrected)
SWu [W m^{-2}]	Outgoing solar radiation
LWd [W m^{-2}]	Incoming longwave radiation
LWu [W m^{-2}]	Outgoing longwave radiation

1.3.3 *SONIC files*

Year [-]	Year of observation
Doy [-]	Day of year
Hour [-]	Hour, where 1455.0 = 14.55 = 2.55 PM
Time [-]	Decimal time, where 4.75 = 4 January 2011 18.00
Ts [^{o}C]	Air temperature at sonic level, derived from speed of sound
q [g kg^{-1}]	Specific humidity
WindSpeed [m s^{-1}]	Wind speed
WindDir [^{o}]	Wind direction, 0 = N, 90 = E, 180 = S, 270 = W
Hsen [W m^{-2}]	Sensible heat flux
Hlat [W m^{-2}]	Latent heat flux
u [m s^{-1}]	Horizontal wind speed in x-direction
v [m s^{-1}]	Horizontal wind speed in y-direction
w [m s^{-1}]	Vertical wind speed
Ts [^{o}C]	Sound-derived air temperature
Tt [^{o}C]	Thermocouple temperature (corrupt)
CO2 [g m^{-3}]	CO_2 concentration (not calibrated)
H2O [g m^{-3}]	H_2O concentration (not calibrated)
ustar [m s^{-1}]	Surface friction velocity
Ls [m]	Monin Obukhov length derived from sonic temperature
zSonic [m]	Measurement level above surface
z/L [-]	Dimensionless Monin-Obukhov length scale
zoms1 [-]	Not used
All eddy covariances:	
u^2 [m^2 s^{-4}]	u'^2
v^2 [m^2 s^{-4}]	v'^2
w^2 [m^2 s^{-4}]	w'^2
Ts^2 [^{o}C^2]	Ts'^2
Tt^2 [^{o}C^2]	Tt'^2
CO2^2 [g^2 m^{-6}]	CO2'^2
H2O^2 [g^2 m^{-6}]	H2O'^2
uv [m^2 s^{-4}]	u'v'
uw [m^2 s^{-4}]	u'w'
uTs [m ^{o}C s^{-1}]	u'Ts'
uTt [m ^{o}C s^{-1}]	u'Tt'
uCO2 [g m^{-2} s^{-1}]	u'CO2'
uq [g m^{-2} s^{-1}]	u'H2O'
vw [m^2 s^{-4}]	v'w'
vTs [m ^{o}C s^{-1}]	v'Ts'
vTt [m ^{o}C s^{-1}]	v'Tt'
vCO2 [g m^{-2} s^{-1}]	v'CO2'
vq [g m^{-2} s^{-1}]	v'H2O'
wTs [m ^{o}C s^{-1}]	w'Ts'

wTt [m ^{o}C s^{-1}]	w’Tt’
wCO2 [g m^{-2} s^{-1}]	w’CO2’
wq [g m^{-2} s^{-1}]	w’H2O’
TsTt [m ^{o}C s^{-1}]	Ts’Tt’
TsCO2 [g m^{-2} s^{-1}]	Ts’CO2’
Tsq [g m^{-2} s^{-1}]	Ts’H2O’
TtCO2 [g m^{-2} s^{-1}]	Tt’CO2’
Ttq [g m^{-2} s^{-1}]	Tt’H2O’

2. Corrections

2.1 Radiation

2.1.1 AWS

Solar radiation at the AWS is corrected for sensor tilt, using two tilt sensors that continuously monitor the deviation from the horizontal plane in two orthogonal directions. The limited field-of-view (poor cosine response) of the incoming pyranometer makes a correction necessary for high solar zenith angles. For this, the 24-hour running mean albedo is used. Riming of the incoming pyranometer is not taken into account since this only happens when there is very little solar radiation anyway.

Outgoing longwave radiation is capped at the value corresponding to a melting surface. Incoming longwave radiation is manually checked for episodes in which riming occurs. For the 2-year period, a total of 15 days have been identified during which the incoming pyrgeometer is covered with rime. We use a correction algorithm that uses the relation between surface temperature and incoming longwave radiation when there is no rime and when solar radiation is almost zero. During these periods, temperature is strongly correlated to incoming longwave radiation. This correlation is used to compute incoming longwave radiation in periods of riming.

2.1.2 RADI

Measurements of sensor tilt have been made every few days during the OFCAP experiment, and the shortwave fluxes have been corrected for this, assuming a diffuse fraction derived from the longwave radiation balance. Longwave radiation is capped at the value corresponding to a melting surface.

2.2 Temperature

The hut in which the temperature sensor is located, does not get ventilated in order to save energy. In sunny and calm conditions, this leads to overestimation of air temperature. A correction is applied that is a function of wind speed and the sum of incoming and reflected solar radiation fluxes.

2.3 Humidity

When the temperature is below freezing, the relative humidity should be calculated with respect to ice (a sublimating rather than an evaporating surface). This is corrected for, and specific humidity values are calculated using the corrected relative humidity.

2.4 Wind

During a few episodes, the wind sensor is frozen. In those periods, data is takes from neighbouring AWS 15. When this stations is also frozen, a constant wind speed of 1 m s^{-1} is assumed. Wind direction is given with respect to true North.

2.5 Turbulent fluxes

The speed of sound, on which the sonic anemometer turbulence calculations are based, is corrected for temperature and humidity. The air temperature is derived from the speed of sound. The wind direction is given with respect to true North. Care should be taken with interpretation of the sonic anemometer and LI-COR results when the wind is blowing from the eastern sector.

3. SEB model

A part of the data in the AWS14* files is obtained using a surface energy balance (SEB) model, that searches for a surface (skin) temperature for which the energy budget of the surface is closed. When the surface is at the melting point and there is an excess of energy, it is used for melting. This approach ensures that the calculated SEB is consistent and closed. An assessment of the model performance can be made by comparing the calculated skin temperature (Tsurf_calc) with the observed skin temperature (Tsobs), inferred from the upwelling longwave radiation flux (LWout_corr).

The turbulent fluxes are solved by the SEB model using a bulk method, which is a special application of the profile method. It assumes that the turbulent fluxes are constant between the surface and the measurement level. It uses Monin-Obukhov similarity to obtain the vertical profiles of wind, temperature, and moisture. When conditions are non-neutral, stability corrections are applied to these profiles. Using these profiles, temperature, humidity and wind are interpolated to 2 or 10 m above the surface. The critical assumption is a value for z_0, the aerodynamic roughness length.

The SEB model computes the temperature, melt, refreezing, and percolation in a 20-m deep snowpack consisting of 1000 layers of 0.02 m each. The temperature gradient at the bottom of this layer is assumed to vanish. The maximum amount of water stored in the pore space is a function of density.

The ground heat flux is calculated using the snow temperature gradient at the surface - the uppermost two layers are used to computed for this gradient.

The model allows for subsurface absorption of solar radiation. Technically, this is a bit of a compromise to the set-up of the model, which assumes a balance of fluxes at the skin layer. When subsurface absorption of solar radiation is allowed, energy is deposited below the skin layer. In order to restore a balance, the melt energy has to be taken as the sum of surface and subsurface melt energy. Moreover, the ground heat flux should be computed using the change in energy content of the entire snowpack, rather than using the snow temperature gradient.

4. Instrument specifications

Broadband radiation (RADI)

Instrument	Pyranometers (2 x) and pyrgeometers (2 x)
Type	Kipp en Zonen CM21 and Kipp en Zonen CG4
Description	Two pairs of high-precision shortwave and longwave radiation sensors facing North over an undisturbed snowpack.
Sampling period	1 minute
CM21 accuracy	2%
CM21 range	310 - 2800 nm
CG4 accuracy	<1%
CG4 range	4500 - 42000 nm
Measurement height	45 - 65 cm (variable due to sinking of mast)
Control and storage	Campbell CR10X datalogger with internal batteries

Turbulence mast (SONIC)

Instruments	Sonic anemometer and infrared H2O and CO2 analyzer
Type	Campbell CSAT3 anemometer and LI-COR 7500A H2O and CO2 open path analyzer
Description	Fast-sampling eddy covariance measurements of temperature, 3-D wind and water vapour fluxes for the direct measurement of turbulent fluxes.
Sampling frequency	20 Hz
Data storage period	5 minute means
Measurement height	400 cm
Control and storage	Campbell CR23X datalogger on solar power
CSAT3 range	u: 0 - 32 m/s v: 0 - 64 m/s w: 0 - 8 m/s
CSAT3 accuracy	0.5 - 1.0 mm/s
Thermocouple	Campbell Chromel Constantan 75 micron
Thermocouple range	-40 °C to +40 °C
Thermocouple accuracy	0.01 °C
LI-COR range	0 - 42 g per cubic metre
LI-COR accuracy	0.0047 g per cubic metre (at 20 Hz)

AWS 14 sensor specifications (AWS)

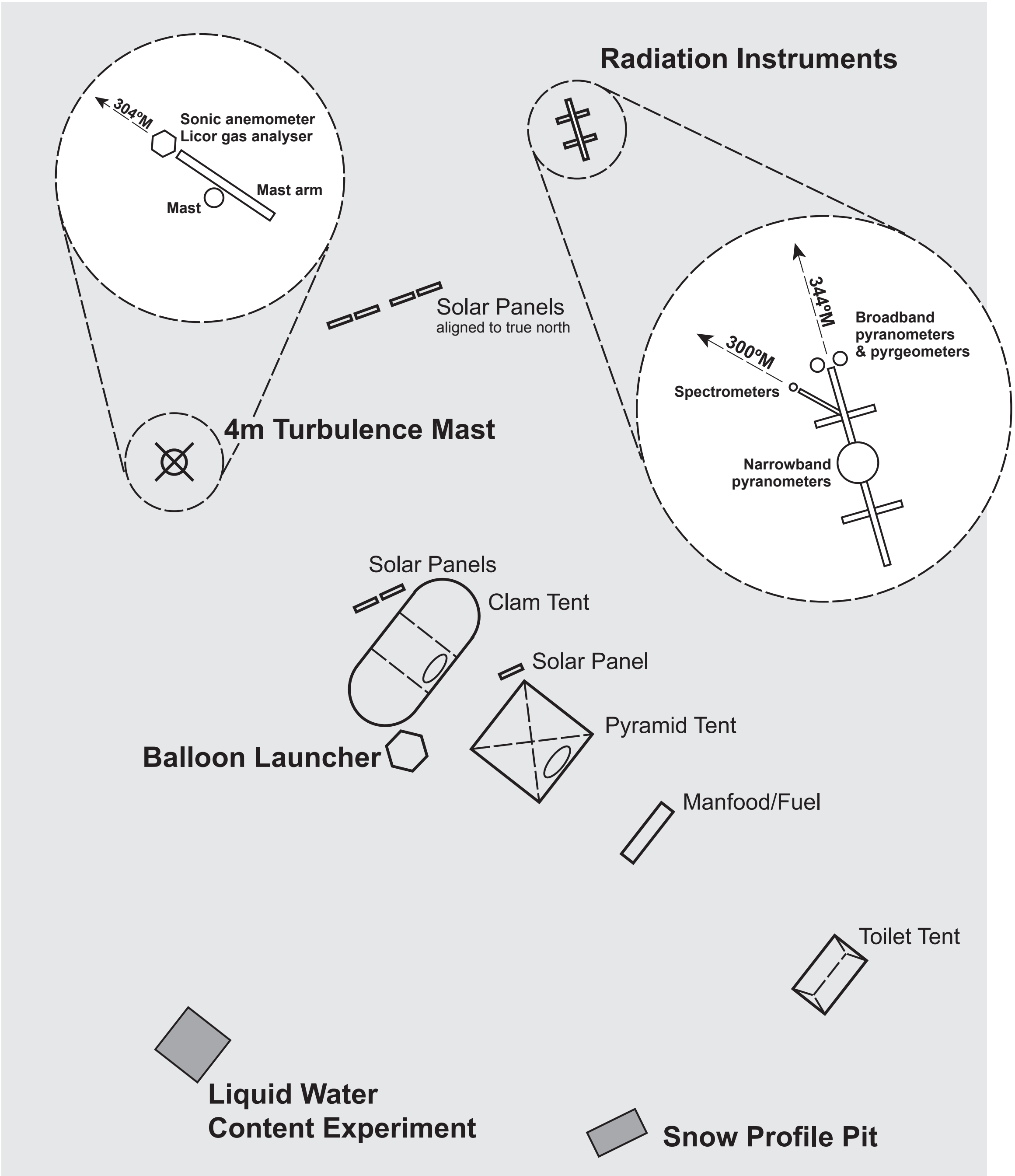
Quantity	Sensor type	Range	Accuracy	Sampling period
Air pressure	Vaisala PTB101B	600 to 1060 hPa	4 hPa	60 min instantaneous
Air temperature	Vaisala HMP35AC	-80 to 56 °C	0.3 °C	6 min, with 60 min means stored
Relative humidity	Vaisala HMP35AC	0 to 100 %	2-3 %	6 min, with 60 min means stored
Wind speed	Young 05103	0 to 60 m/s	0.3 m/s	6 min, with 60 min means stored
Wind direction	Young 05103	0 to 360°	3°	6 min, with 60 min means stored
Solar radiation	Kipp en Zonen CNR1	305 to 2800 nm	2%	6 min, with 60 min means stored
Thermal radiation	Kipp en Zonen CNR1	5,000 to 50,000 nm	15 W/m2	6 min, with 60 min means stored
Snow height	Campbell SR50	0.5 to 10 m	0.01 m or 0.4 %	6 min, with 60 min means stored
Snow temperature	Thermistor strings	...	...	6 min, with 60 min means stored
Mast inclination	Homemade inclinometers	...	...	6 min, with 60 min means stored
Datalogger	Campbell CR10X	-	-	-

SLEDGE OSCAR

Larsen Camp Layout (Enlargement)

S 067° 00.75' W 061° 28.69'

Magnetic North
Magnetic variation is 17°E in 2009. Annual change 0°2'W



Wind Direction
Prevailing strong winds from either the NE or the SW.

0 5 10 15 20 25m

Scale 1:400 2.5cm=10m