COMNAP Fellowship Report 2011/2012

Amelia Marks

Project title

Characterization of the bi-directional reflectance of Antarctic surface for the inter- calibration and validation of satellite remote sensing products

Home Institute

Royal Holloway, University of London

Host Institute

PNRA (Italian National Antarctic Research Programme)

International project collaborators

Dr Nigel Fox, (NPL, UK)
Dr Flavio Parmiggiani, (ISAC-CNR, Bologna, Italy)
Dr Giuseppe Zibordi (Institue for Environment and Sustainability, Ispra, Italy)
Corrado Fragiacomo (PNRA, Italy)
Dr Alasdair Mac Arthur (NERC FSF, UK)
Dr Martin King, (Royal Holloway, University of London, UK)

Scientific objectives of the project

The objective of the project was to take BRDF (bidirectional reflectance distribution function) measurements of the Dome C snow surface for calibration of satellites. Satellites require calibration targets, as the reflectance of natural surfaces is not isotropic; reflectance varies with illumination and viewing geometries. Providing data from calibration sites helps to improve sensor-to-sensor (platform-to-platform) biases present in all global observational systems and Dome C was identified by CEOS (Committee on Earth Observing Satellites) as an excellent calibration site.

Advancement of satellite data collection will allow improved measurements of black carbon concentrations in snow. Black carbon (a component of soot) is a constituent of atmospheric pollution that strongly absorbs solar radiation. Increased black carbon concentration in snow increases absorption of incident solar radiation, causing warming of the snow, exacerbating melting, and lowering planetary albedo [1,2,3,4,5]. The 2007 IPCC report suggested black carbon on snow has a positive forcing of 0.1 ± 0.1 W m^{-2} [6]; there is a great need to reduce uncertainty in this forcing. To ascertain the extent black carbon in snow may affect global climate, data on typical concentrations of black carbon in Polar Regions is essential, but current figures are obtained from fieldwork and consequently limited in scope. Satellite observations provide a method that enables observation of expansive and inaccessible areas.

Measurements of BRDF were obtained using the new Gonio Radiometer Spectrometer System (GRASS) developed at National Physics Laboratory (NPL), UK and loaned by NERC Field Spectroscopy Facility (FSF), UK. Successful preliminary measurements using GRASS in a Polar environment were undertaken by our research group and Italian co-workers in winter 2010/2011 at Terra-Nova Bay, Antarctica. GRASS comprises of two semicircular frames orthogonal to each other forming a hemisphere over the target snow. 16 fibre-optics are mounted on three arms at different azimuth/zenith angles to the target snow, which record the light upwelling from the snow surface at different angles Although BRDF measurements had been previously taken at Dome C, the GRASS equipment was hoped to greatly improve on these previous measurements [7,8]. A photo of the setup of GRASS is shown in figure 1.

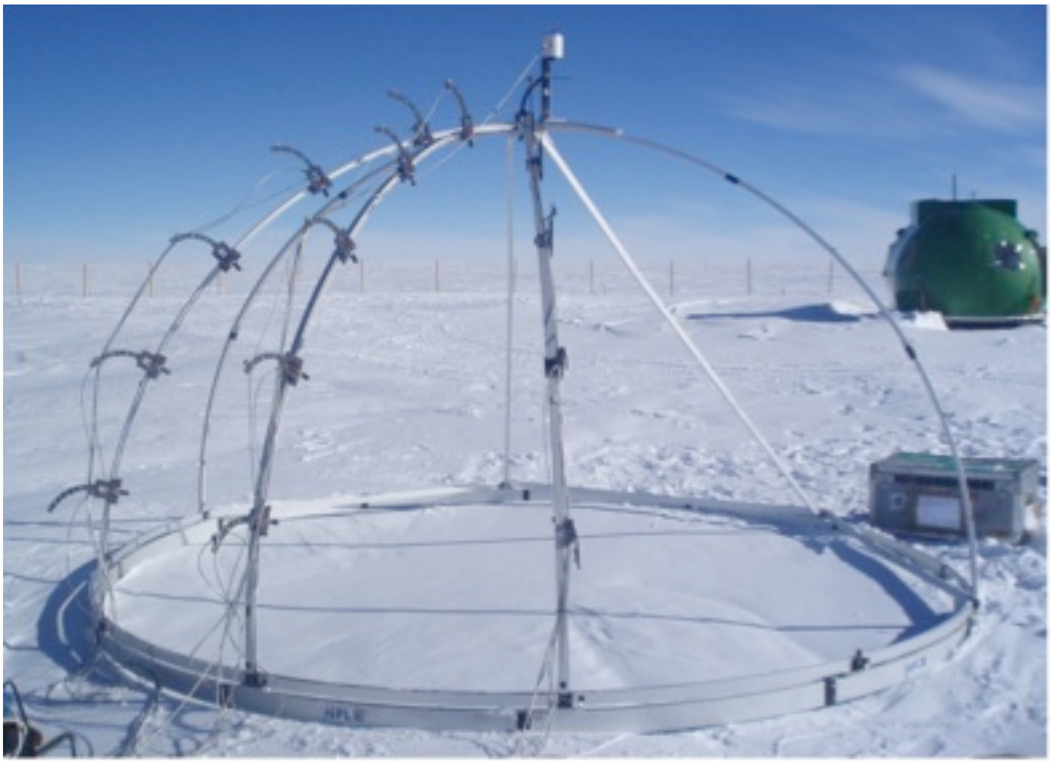

Figure 1- Setup of the Gonio Radiometer Spectrometer System (GRASS) for measuring BRDF of snow surfaces at Dome C. Optics are mounted on three arms at 15° intervals. The structure is then rotated through 360° taking measurements in each 90° segment (4 sets of measurements in total) to provide a 360° image of the surface reflectance at different angles.

Activity conducted in the field

BRDF measurements of snow surfaces were taken at Dome C, Antarctica by myself and Corrado Fragiacomo using GRASS. Measurements were taken at 8 sites along a 100 m transect, in the area shown in figure 2. To take BRDF measurements GRASS was positioned on a suitable snow surface; a suitable surface being one which was as flat as possible and had as few surface inhomogeneties as possible. The GRASS structure was then rotated through 360°, with measurements taken every 90°, thus providing a set of 4 measurements, which provide a 360° surface image. For all measurements the optics on the three arms of GRASS were positioned at 15° intervals from the top (0, 15, 30, 45, 60, 75° solar zenith angles) and 14° optical lenses were used providing a ~30 cm field of view for each optic.

Furthermore at two of the sites optics with 14° optical lenses were spaced 10° apart (0,10,20,30,40,50° solar zenith angles), and optics with 2° optical lenses were spaced 15° and 10° apart and the same snow surface measured. The different lenses and optic positions were used to establish any differences observed using different setups of the equipment. A snow pit to establish the underlying snow characteristics at each site was also made. For each snow pit measurements of change in snow density, snow hardness, snow temperature and grain size and type were recorded 1 m deep into the snow pack.

However due to poor weather for much of the period we were at Dome C we were unfortunately unable to take as many measurements as we hoped, as measurements required clear skies.

Figure 2- Area over which BRDF measurements were taken (inside red box). Measurements were taken at 8 sites spaced at ~10m intervals, each site further towards the base.

Main results obtained

The data from the measurements taken at each site are in the process of being analysed and converted into polar plots. Preliminary polar plots for sites 1–8 for 14° optical lenses spaced 15° apart are shown in figure 3. The plots show the variation in reflectance with different viewing angles, where reds show greatest reflectance, and blues least. Each black dot on the plot represents an optic position after GRASS was rotated 4 times through 360°. The dots nearer the centre represent smaller solar zenith angles, and those around the edges represent the larger solar zenith angles. The sun in each plot is at the base of the plot, therefore in almost all the plots the snow surface appears to be forward scattering i.e when the sunlight hits the snow surface most of the light is transmitted back off the snow away from the sun, not back towards the sun. In the plot from site 9 a clear "hot spot" is seen which occurs where the illumination and viewing angle align, therefore the hot spots occurs where the azimuth and zenith angle are aligned to the sun.

It is noticeable that all the plots differ from one another to some degree, an effect which is partially likely to be due to differences in snow surface features of the snow surfaces measured, for example some surfaces appeared to have more rippled surfaces than others. However the differences could also be due to change in illumination conditions, or other factors that will be investigated in further analysis of the data. After further data analysis is undertaken the results can be used for satellite calibration.

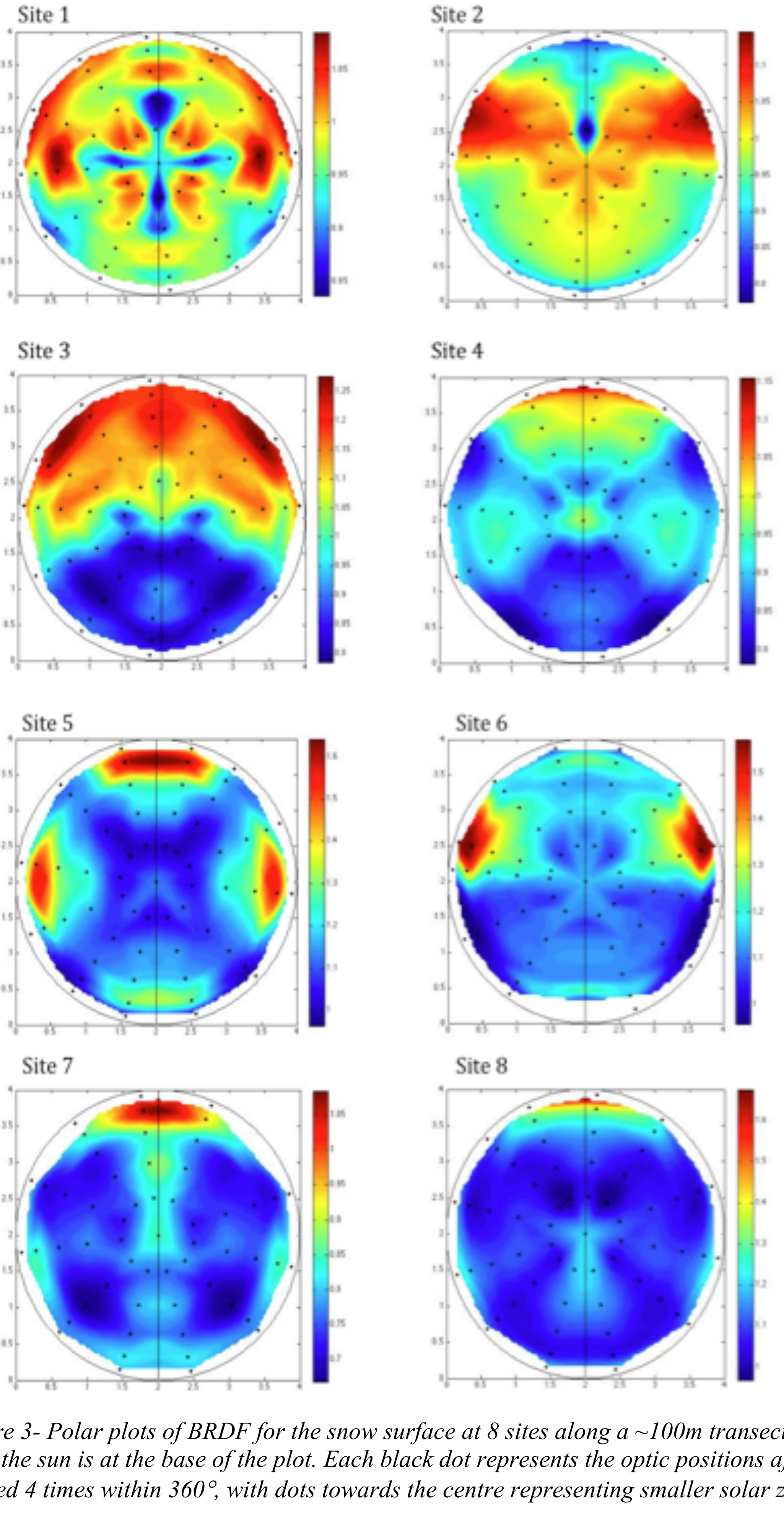

Figure 3- Polar plots of BRDF for the snow surface at 8 sites along a ~100m transect. On each of these plots the sun is at the base of the plot. Each black dot represents the optic positions after GRASS is rotated 4 times within 360°, with dots towards the centre representing smaller solar zenith angles.

References

1) Hansen, J., & Nazarenko, L. (2004). Soot climate forcing via snow and ice albedos. *Proceedings of the National Academy of Sciences of the United States of America*. **101**. 423–428

2) Jacobson, M. (2004). Climate response of fossil fuel and biofuel soot, accounting for soot's feedback to snow and sea-ice albedo and emissivity. *Journal of Geophysical Research*. **109.**

3) Warren, S., & Wiscombe, W. (1985). Dirty snow after nuclear war. *Nature.* **313.** 467–470

4) M.G. Flanner, C.S. Zender, J.T. Randerson, P.J. Rasch, (2007) Present-day climate forcing and response from black carbon in snow. *Journal of Geophysical research.* **112**

5) Clarke, A., & Noone, K. (1985). Soot in the Arctic snowpack: A cause for perturbations in radiative-transfer. *Atmospheric Environment ,* **19**, 2045–2053.

6) Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.). (2007) IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment, Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996

7) Six, D. Fily, M. Alvain, S. Henry, P. Benoist, J. P. (2004) *Remote Sensing of Environment*. **89**. 83, 94.

8) S.R. Hudson, S. R. Warren, S. G. Brandt, R. E. Grenfell, T. C. and Six, D.(2006) *Journal of Geophysical Research*, **111**. 18106.

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