# Analysis of multiscale radiometric data collected during the Cold Land Processes Experiment-1 (CLPX-1)

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[1] Histograms of brightness temperatures collected at 18.7 and 37 GHz over the Fraser and North Park Meso-Scale Areas during the Cold Land Processes Experiment by the NOAA Polarimetric Scanning Radiometer (PSR/A) airborne sensor are modelled by a log-normal distribution (Fraser, forested area) and by a bi-modal distribution (North Park, patchy-snow, non-forested area). The brightness temperatures are re-sampled over a range of resolutions to study the effects of sensor resolution on the shape of the distribution, on the values of the average brightness temperatures and standard deviations. The histograms become more uniform and the spatial information in the initial distribution is lost for a resolution larger than 5000 m, in both areas. The values of brightness temperatures obtained by re-sampling the PSR-A data at 25 km resolution are consistent with those recorded by the Advanced Microwave Scanning Radiometer (AMSR-E) and Special Sensor Microwave/Imager (SSM/I) satellite radiometers at similar resolutions. **Citation:** Tedesco, M., E. J. Kim, A. Gasiewski, M. Klein, and B. Stankov (2005), Analysis of multiscale radiometric data collected during the Cold Land Processes Experiment-1 (CLPX-1), *Geophys. Res. Lett.*, *32*, L18501, doi:10.1029/2005GL023006.

## 1. Introduction

[2] Snow represents a fundamental component of the Earth's water cycle, covering more than the half of the northern hemisphere land surface (around 60%) in mid winter. Over 30% of Earth's total land surface is covered by seasonal snow [*Robinson et al.*, 1993]. Microwaves are sensitive to snow parameters [i.e., *Macelloni et al.*, 2001; *Tedesco*, 2003], which can be estimated using algorithms based on passive microwave remote sensing observations [i.e., *Hallikainen and Jolma*, 1992; *Foster et al.*, 1997; *Tait*, 1998; *Kelly et al.*, 2003; *Tedesco et al.*, 2004a]. The microwave signal of snow covered soil is sensitive to the phase of water, mean grain size, fractional volume and snow depth. In the case of dry snow (the cases considered for this study) the mechanism dominating the microwave signal is the volumetric scattering due to the scatterers (ice particles). The retrieval of snow parameters from microwave remotely-sensed data has many advantages, but a discrepancy exists between the small scale at which many snow parameters are measured and understood and the large-scale footprints of current microwave satellite sensors ($25 \times 25$ km$^2$), as in example discussed in [*Derksen et al.*, 2005; *Jackson*, 2001; *Drusch et al.*, 1999; *Famiglietti et al.*, 1999]. At large scales, the heterogeneity of the terrain within the pixel is a limiting factor for the use of forward radiative transfer models to reproduce the observed brightness temperatures using point scale or area-aggregated snow properties.

[3] In this study, we analyze the brightness temperatures at 18.7 and 37 GHz collected in Colorado, central Rocky Mountain of the western United States, by an airborne passive microwave imager, the NOAA Polarimetric Scanning Radiometer (PSR/A) and by the Advanced Microwave Scanning Radiometer (AMSR-E) and Special Sensor Microwave/Imager (SSM/I) satellite radiometers during the third Intensive Observation Period (IOP3, dry snow, February 19–25, 2003) of the NASA Cold Land Processes Experiment-1 (CLPX-1) (http://www.nohrsc.nws.gov/∼cline/clpx.html). In particular, we concentrate on the data collected over the Fraser and North Park Meso-Scale Areas (MSAs). The brightness temperatures collected by the airborne and space-borne instruments are re-sampled, respectively, at 500 m (PSR/A) and 25 km (SSM/I and AMSR-E) resolutions. Histograms of the brightness temperatures collected by the PSR/A over the Fraser and North Park MSAs are plotted at different resolutions, from 500 m to 25 km. Histograms at 500 m resolution are used to identify distribution functions for both MSAs. The effect of a coarser resolution on the shape of the distribution is studied. At 25 km resolution, microwave brightnesses are also compared with those from the SSM/I and AMSR-E satellite radiometers.

## 2. The Study Areas and the Radiometric Data

[4] The largest study area is the large regional study area (LRSA, $375 \times 375$ Km$^2$) and it is located in northern Colorado and southern Wyoming, U.S.A. The small regional study area (SRSA) is located in north-central Colorado (105°–107.5°W, 39.5°–41°N), and it is approximately 215-km × 170-km. Nested within the SRSA are the Fraser and North Park Meso-cell Study Areas (MSAs, 25-km × 25-km), used for airborne data collection. The Fraser MSA is a topographically complex area with a mean elevation of 3066 m, a range of nearly 1400 m and a maximum elevation of 3962 m. The highest-elevation areas in the south of the MSA are predominantly alpine tundra or bare rock. The mountain areas are dominated by dense coniferous forests. The North Park MSA has a mean elevation of 2499 m. Most of the vegetation is sage-grassland, with willow along riparian areas. Snow-

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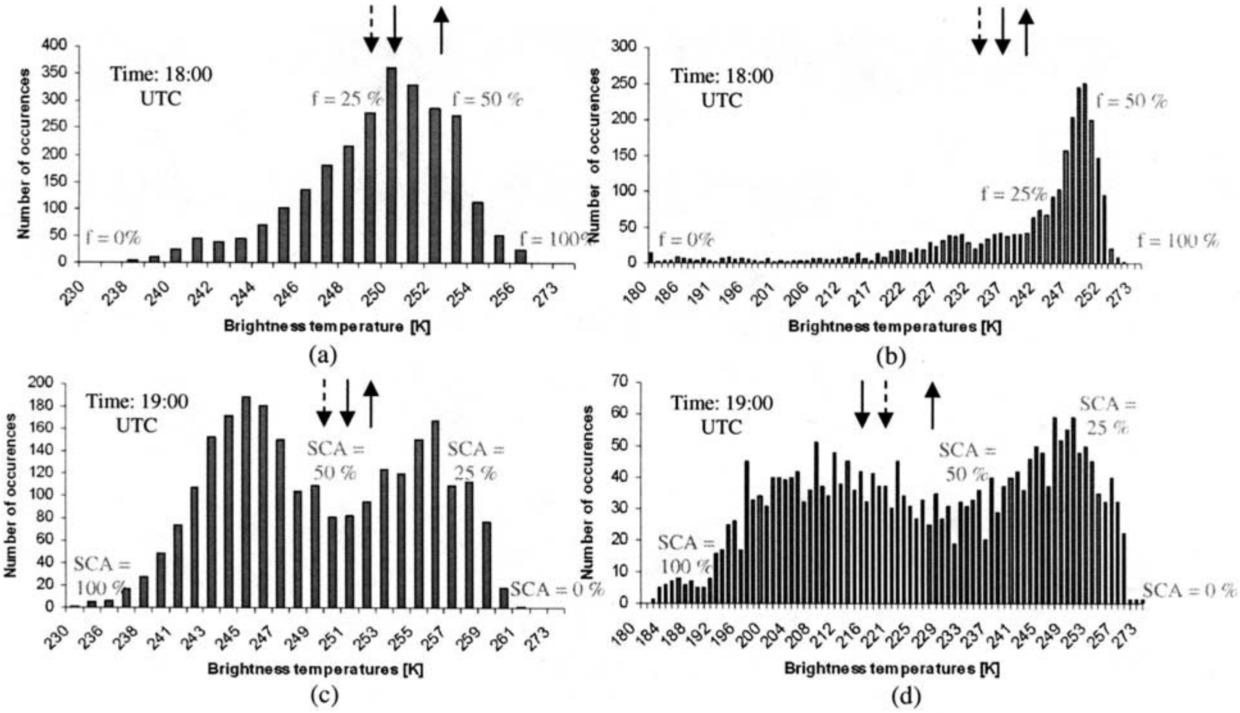


**Figure 1.** Histograms of PSR/A brightness temperatures (vertical polarization) at (left) 18.7 GHz and (right) 37 GHz for the (a,b) Fraser and (c,d) North Park MSAs. The brightness temperatures observed by the AMSR-E (solid arrow) and SSM/I (dotted arrow) are also reported. Upward arrows indicate satellite observations during ascending orbits while downward arrows indicate observations during descending orbits. The values of average brightness temperatures for selected values of forest cover fraction and snow covered area are also indicated.

packs in this area tend to be shallow, and are typical of prairie and arctic- and alpine- tundra snow covers. Further information about the CLPX study areas can be found at http://www. nohrsc.nws.gov/~cline/clpx.html.

[5] Brightness temperatures at fine resolution were collected by means of the NOAA Polarimetric Scanning Radiometer (PSR/A) [*Stankov and Gasiewski*, 2004], an airborne multiband conical-scanned imaging radiometer system [e.g., *Piepmeier and Gasiewski*, 1996]. PSR/A includes a single scanhead that provides imagery at most of the AMSR-E imaging bands, with an observation angle of 53° with respect to nadir. The exact size of the surface footprint is a function of the terrain elevation as the aircraft altitude above sea level was almost constant during the flights. At high frequencies (37 and 89 GHz), the size of the surface footprint ranges between 65 and 229 meters while at 18.7 GHz it ranges between 215 and 749 meters. As the PSR/A is a conical-scanned radiometer, the shape of the footprint on the ground depends on the relative orientation of the scene to the 53° half-cone angle. However, the data collected by the PSR/A used in this study were geo-registered according to terrain height and re-sampled to obtain square pixels with a resolution of 500 m, at all frequencies. This value is selected because it is the minimum value which guarantees complete coverage of the observed areas using a square pixel.

[6] Calibrated and geo-located satellite brightness temperatures, acquired over the LRSA using the SSM/I and AMSR-E radiometers were obtained from the National Snow and Ice Data Center (NSIDC) [*Brodzik*, 2003a, 2003b]. We consider both ascending and descending orbit data, in order to assure the highest number of available observations.

## 4. Conclusions

[12] The brightness temperatures collected using the high-resolution airborne NOAA Polarimetric Scanning Radiometer during the Cold Land Processes Experiment-1 have been aggregated to simulate coarser resolutions. Histograms of the PSR/A brightness temperatures at finest resolution (500 m) display a log-normal distribution in the case of the Fraser forested area and a bi-modal distribution in the case of the patchy-snow non-forested North Park area. The histograms of brightness temperatures at successively coarser resolutions have been studied to understand the effect of the pixel size on the shape of the distribution. For all examined cases, a threshold value of 5000 m resolution has been found after which the histograms of the brightness temperatures become relatively uniform (all brightness temperatures have the same number of occurrences). The values of the brightness temperatures obtained by aggregating the PSR/A data to a 25 km resolution have been compared with the values of the brightness temperatures collected by the AMSR-E and SSM/I radiometers and were found to be within 7.7 K in the case of the Fraser area and 7.1 K in the case of the North Park area. In future studies, we will use the data collected during the Cold Land Processes Experiment during March 2002 and 2003 in order to extend the study to wet snow conditions.