**README**

**PI Product:** Cloud-scale vertical velocity and turbulent dissipation rate retrievals

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**General description:**

This product includes netCDF files that contain time-height fields of retrieved in-cloud vertical wind velocity and turbulent dissipation rate, both retrieved primarily from vertically-pointing, Ka-band cloud radar measurements. These data can be used to determine the vertical extent and magnitude of cloud-driven atmospheric mixing. Files are available for manually-selected, stratiform, mixed-phase cloud cases observed at the US Department of Energy Atmospheric Radiation Measurement (ARM) Program’s North Slope of Alaska (NSA) site in Barrow, Alaska during periods covering the Mixed-Phase Arctic Cloud Experiment (MPACE, late September through early November 2004) and the Indirect and Semi-Direct Aerosol Campaign (ISDAC, April-early May 2008). These time periods will be expanded in a future submission.

**Methods applied:**

Both retrievals included in this product can only be applied to cloud volumes with specific phases that are observed by the cloud radar. The multi-sensor, fixed-threshold, phase classification method of Shupe (2007) is applied to all of these cases and a phase classification mask is included in the output files. The classification is based on phase-specific signatures in radar, lidar, microwave radiometer, and radiosonde measurements.

Vertical velocity is derived in cloud parcels observed by the radar that are classified to contain cloud liquid water droplets using the method described by Shupe et al. (2008). The primary assumption used here is that these liquid droplets, due to their typical small size, have negligible fall speed relative to vertical air motions. A “left edge” radar Doppler spectrum approach is applied, where the slowest falling (or most lifting) edge of the Doppler spectrum, which represents the small liquid droplets in the observation volume, provides an initial estimate of the vertical wind velocity. The radar “stratus” mode is used. Corrections are applied to account for some spectral broadening processes. However, analysis of data sets and comparison with aircraft in situ measurements suggests that this preliminary product is biased by un-corrected broadening processes. To account for this extra broadening a short-pass filter is applied whereby a 30-min running mean at each height is subtracted. The assumption here is that over 30-min periods, due to mass continuity, the vertical air motion will be approximately 0 m/s. The extent to which this assumption is not true, i.e., the larger-scale motions that may exist in reality, contribute to the uncertainty in this product. The uncertainty here is estimated at a fixed value that is at least twice as large as the expected large-scale motions.

Turbulent dissipation rate is derived in cloud parcels that are observed to contain hydrometeors by the cloud radar using the method described by Shupe et al. (2008, 2012). The retrieval is based on the variance of cloud radar mean Doppler velocity measurements over 60-sec time windows, with horizontal wind speeds measured by interpolated radiosondes and/or wind profiler measurements used to characterize the horizontal scales associated with the radar measurements. Only radar measurements with a signal-to-noise ratio greater than -13 dB are used to ensure a strong signal. Fundamental assumptions used in this retrieval are that: 1) the length scales of turbulent eddies observed by the radar between each observation (4-sec) and the 60-sec windows used to compute velocity variance reside within the inertial subrange of the turbulence spectrum, and 2) that turbulent air motions, as opposed to variability in particle terminal fall speeds, are the dominant contribution to variability in the mean Doppler velocity on the scales of interest. Both of these assumptions are shown to hold for the Arctic clouds to which these retrievals are applied by Shupe et al. (2012). That study additionally outlines a theoretical framework for estimating the fractional error in the dissipation rate retrieval, which is included in the product. Lastly, Shupe et al. (2012) also evaluated the dissipation rate product against dissipation rates derived from aircraft measurements during MPACE and against sonic anemometer measurements made from a tethered balloon platform during the Arctic Summer Cloud Ocean Study (ASCOS) over the Arctic sea-ice in late summer 2008. That evaluation shows similar results for these two different comparisons. Furthermore, during ASCOS, dissipation rates were also derived at 15 and 30 m on meteorological towers. Comparisons showed that root mean squared differences between the radar-derived and tethered balloon-derived dissipation rates were no larger than differences between the tethered balloon and met tower derived dissipation rates (both of which were based on the same type of sonic anemometer measurements).

**References:**

Shupe, M.D., 2007: A ground-based multiple remote-sensor cloud phase classifier. Geophysical Research Letters, 34, L22809, doi: 10.1029/2007GL031008.

Shupe, M.D., P. Kollias, M. Poellot, and E. Eloranta, 2008: On deriving vertical air motions from cloud radar Doppler spectra. Journal of Atmospheric and Oceanic Technology, 25, 547-557.

Shupe, M. D., I. Brooks, and G.Canut, 2012: Evaluation of turbulent dissipation rate retrievals from Doppler cloud radar. Atmospheric Measurement Techniques, 5, 1375-1385, doi:10.5194/amt-5-1375-2012.

**File naming convention:**

nsaradardyn1shupeC1.c1.YYYYMMDD.HHMMSS.cdf

Includes the date and time stamps for the first sample in the file.

**Fields:**

Information for each field and the files in general is included in the netCDF header information in each file. A brief introduction to each field is included here.

time: Sample time in decimal hours

height: Sample height in km, these heights are directly from the MMCR heights for the stratus mode

phasemask: Time-height field that specifies the cloud phase. 0=clear sky; 1=ice; 2=snow; 3=liquid cloud; 4=drizzle; 5=liquid cloud + drizzle; 6=rain; 7=liquid cloud + ice (i.e., mixed-phase); 8=haze; 10=not classified.

w: Derived vertical wind velocity, in m/s, with upward being positive. Derived from cloud radar Doppler spectra. Vertical motions are only derived when cloud liquid water is present (phasemask = 3, 5, or 7).

w\_uncertainty: Estimated uncertainty in w retrieval, in m/s. This is an assumed, constant uncertainty value based on expected maximum influence of large-scale vertical motions.

dissipation: Turbulent dissipation rate, in m2/s3, retrieved from cloud radar mean Doppler velocity measurements, and horizontal wind speeds from interpolated radiosonde and/or wind profiler. Dissipation rates can be derived when hydrometeors are present in the radar pulse volume (phasemask = 1-7).

dissipation\_error: The theoretically computed fractional error in dissipation rates (in %) based on the computed error in radar-based velocity variance and an estimated error of 50% for horizontal wind measurements.