

APPENDIX D

GLOSSARY

Aliasing: The process by which frequencies too high to be analyzed with the given sampling interval appear at a frequency less than the Nyquist frequency.

Ambiguous Velocity: See Velocity Aliasing.

Amplitude: The maximum magnitude of a quantity.

Analog: Class of devices in which the output varies continuously as a function of the input.

Anomalous Propagation (AP): When non-standard index-of-refraction distributions prevail, “abnormal” or “anomalous” propagation occurs. When abnormal downward bending occurs, it is called “superrefraction.” The term “subrefraction” is applied when there is abnormal upward bending.

Antenna Gain: The measure of effectiveness of a directional antenna as compared to an isotropic radiator; maximum value is called antenna gain by convection.

Antenna pattern: (Also called radiation pattern, beam pattern, lobe pattern.) A graphical representation of the radiating properties of an antenna as a function of space coordinates.

Attenuation: Any process in which the flux density (power) of a beam of energy is dissipated.

Autocorrelation: A measure of similarity between displaced and undisplaced (in time, space, etc.) versions of the same function.

Automatic Gain Control: Any method of automatically controlling the gain of a receiver, particularly one that holds the output level constant regardless of the input level.

Azimuth: A direction in terms of the 360 degree compass.

Backing Wind: A change in wind direction in a counterclockwise sense representing cold air advection.

Backscatter: That portion of power scattered back in the incident direction.

Bandpass Filter: A filter whose frequencies are between given upper and lower cutoff values, while substantially attenuating all frequencies outside these values (this band).

Band Width: The number of cycles per second between the limits of a frequency band.

Band reject filter: (or notch filters) are used to pass a large operating band of frequencies, while rejecting a narrow band of frequencies.

Baroclinic: The variation with depth of motions associated with variation of density with depth.

Baroclinity: (Or baroclinicity.) The state of stratification in a fluid in which surfaces of constant pressure (isobaric) intersect surfaces of constant density (isosteric).

Base Data: Those digital fields of reflectivity, mean radial velocity, and spectrum width data in spherical coordinates provided at the finest resolution available from the radar.

Base Products: Those products that present some representation of the base data. This representation may not necessarily be either in full resolution or depict the full area of coverage. Base products can be used to generate a graphic display or further processing.

Batch Mode: A radar transmission technique that uses alternating low and high PRFs on each radial of a scanning radar for one full rotation at each elevation angle.

Beam Filling: The measure of variation of hydrometer density throughout the radar sampling volume. If there is no variation in density, the beam is considered to be filled.

Beam Width: Angular width of the antenna pattern. Usually the width where the power density is one-half that of the axis of the beam.

Bias: A systematic difference between an estimate of and the true value of the parameter.

Boundary Layer: The layer of a fluid adjacent to a physical boundary in which the fluid motion is affected by the boundary and has a mean velocity less than the free-stream value.

Bounded Weak Echo Region (BWER): A core of weak equivalent reflectivity in a thunderstorm that identifies the location of an intense updraft. The updraft is so strong that large precipitation particles do not have time to form in the lower and mid-levels of the storm and are prevented from falling back into the updraft core from above. The Weak Echo Region is bounded when, in a horizontal section, the weak echo is completely surrounded or bounded by higher reflectivity values. See also Weak Echo Region.

Bow Echo: Rapidly moving crescent shaped echo that is convex in the direction of motion. Typically associated with strong straight-line winds. See also Line Echo Wave Pattern.

Bright Band: The enhanced radar echo caused by the difference in radar reflectivity of ice and water particles. This echo is interpreted as the delineation on a radar display between frozen and liquid precipitation.

Convective Available Potential Energy: (Abbreviated CAPE.) The maximum energy available to an ascending parcel, according to parcel theory. On a thermodynamic diagram this is called positive area, and can be seen as the region between the lifted parcel process curve and the environmental sounding, from the parcel's level of free convection to its level of neutral buoyancy.

Cell: A compact region of relatively strong vertical air motion (at least 10 ms^{-1} ; 19 knots).

Central Limit Theorem: Statistical theorem showing that averages approach a Gaussian distribution independent of the input distribution.

Centroid: The center of mass of a storm.

Clutter: Echoes that interfere with observations of desired signals on a radar display. Usually applied to ground targets.

Clutter Suppression or rejection: Any of a variety of processes or techniques to eliminate the effects of unwanted signals (clutter) in radar measurements.

Coherence: The property of two or more waves that are in phase both temporally and spatially. Waves are coherent if they have the same wavelength and a fixed phase relationship with each other.

Coherent Radar: A radar that utilizes both signal phase and amplitude to determine target characteristics.

Cokriging: A technique for estimating values of a spatial process (e.g., a precipitation field) given point observations of the process (e.g., rain gage observations) and possibly auxiliary observations (e.g., radar and satellite observations).

Complex Signal: A signal containing both amplitude and phase information.

Conditional Instability: The state of a layer of unsaturated air when its lapse rate of temperature is less than the dry-adiabatic lapse rate but greater than the moist-adiabatic lapse rate.

Convergence: A measure of the contraction of a vector field.

Correlation: A measure of similarity between variables or functions.

Couplet: Adjacent maxima of radial velocities of opposite signs.

Covariance: A measure of the degree of association between two variables. In Doppler radars, the argument (or angle) of the covariance of the complex signal is a measure of the Doppler frequency.

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Dealiasing: Process of correcting for aliases in the velocity measurement. See also Velocity Aliasing.

Deep Convergence Zone (DCZ): A linear region of apparent convergence detected by Doppler weather radar that is occurring over a long, narrow, and deep region of opposing Doppler velocities within some convective storms. The linear region can be up to 100 km or more in

length, up to 13 km in depth, and the interface may be as narrow as ~ 250 m. Similar to the Mid-Altitude Radial Convergence Signature but substantially deeper.

Decibel (dB): A logarithmic expression for ratio of two quantities. dBm is a decibel with respect to 1 milliwatt.

Mathematically: $dB = 10 \text{ Log } (P_1/P_2)$

$$dBm = 10 \text{ Log } (P/10^{-3})$$

$$dBZ = 10 \text{ Log } (Z_e)$$

Deformation: The change in shape of a fluid mass by spatial variations in the velocity field, specifically by stretching or shearing.

Derecho: A widespread convectively induced straight-line windstorm. Specifically, the term is defined as any family of downburst clusters produced by an extratropical mesoscale convective system.

Dielectric Material: A substance that contains no or few free charges and that can support electromagnetic stress.

Dielectric Constant: For a given substance, the ratio of the capacity of a condenser with that substance as dielectric to the capacity of that condenser with a vacuum as dielectric.

Disdrometer: Equipment that measures and records the size distribution of raindrops.

Distortion: Change in a signal resulting in gross non-linearities in signal processing or handling.

Divergence: A measure of the expansion or spreading out in a vector field.

Doppler Shift: The change in frequency at a receiver due to the relative motion of the receiver and the energy source.

Doppler Spectral Moments: Statistical moments of Doppler frequency or Doppler velocity, regarding these quantities as continuously distributed random variables with a probability density function equal to the normalized Doppler spectrum.

Downburst: A strong downdraft that induces an outburst of damaging winds on or near the ground.

Downdraft: Current(s) of air with marked vertical downward motion.

Drop-Size Distribution: The frequency distribution of drop sizes (diameters, volumes) that is characteristic of a given cloud or of a given fall of rain.

Dryline: A mesoscale feature with its own associated vertical circulation. It is a narrow, almost vertical zone, across which a sharp moisture gradient, but little temperature gradient, occurs at the Earth's surface.

Dual-Polarization Radar: A radar capable of transmitting and receiving two orthogonal polarizations.

Ducting: The phenomenon by which the radar signal propagates along the boundary of two dissimilar air masses. The radar ranges with ducted propagation are greatly extended; holes can also appear in the coverage. Ducting occurs when the upper air is exceptionally warm and dry in comparison with the air at the surface. See also Anomalous Propagation.

Dwell Time: Time over which a signal estimate is made. Usually, the time required for the antenna to transverse one degree.

Dynamic Range: The ratio, usually expressed in decibels, or the maximum to the minimum signal that a system can handle. Used to describe limits of receivers.

Echo: Energy backscattered from a target as seen on the radar display.

Elevation Angle: The vertical pointing angle of the antenna (the WSR-88D antenna can vary from -1° to $+60^\circ$).

Equivalent Radar Reflectivity (Z_e): The concentration of uniformly distributed small (diameter one sixteenth wavelength or less) water particles that would return the amount of power received. Typically expressed as: $\text{dBZ} = 10 \text{ Log } Z_e$.

Estimate: A statement of the value of a quantity or function based on a finite number of samples.

Exclusion Zone: A region created to prevent known areas of persistent clutter residue from contaminating the Hybrid Scan Reflectivity.

Feeder Cloud: The flanking lines of developing cumulus congestus clouds that sometimes merge with and appear to intensify supercells.

Folding: See Range Folding.

Frequency: The number of recurrences of a periodic phenomenon per unit time. Electromagnetic energy is usually specified in Hertz (Hz), which is a unit of frequency equal to one cycle per second.

Frequency Carrier: For the WSR-88D, the fundamental transmitted microwave frequency between 2,700 and 3,000 megahertz. It is modulated so that it exists for a few microseconds each pulse repetition time. This limit is called the transmitted pulse.

Gating (Range Gating): The use of electronic circuits in radar to eliminate or discard the target signals from all targets falling outside certain desired range limits.

Gaussian: Refers to the Normal distribution; phenomena whose events are normally distributed are Gaussian distributed. This is the most common distribution encountered in physical processes.

Gravity Wave: (Also called gravitational wave.) A wave disturbance in which buoyancy (or reduced gravity) acts as the restoring force on parcels displaced from hydrostatic equilibrium.

Ground Clutter: The pattern of radar echoes from fixed ground targets.

Gust Front: The boundary between the horizontally propagating cold air outflow from a thunderstorm and the surrounding environmental air.

Helicity: One-half the scalar product of the velocity and vorticity vectors. It is a conserved quantity if the flow is inviscid and homogeneous in density, but is not conserved in more general viscous flows with buoyancy effects. The concept is useful in understanding severe convective storms and tornadoes, since in strong updrafts the velocity and vorticity vectors tend to be aligned, yielding high helicity.

Homodyning: The transfer of signal intelligence from one carrier to another by mixing of signals at different frequencies.

Hook Echo: A pendant of hook on the right side of an echo that often identifies mesocyclones on the radar display. The hook is caused by precipitation drawn into a cyclonic spiral by the winds, and the associated notch in the echo is caused by precipitation-free, warm, moist air flowing into the storm.

Hybrid Scan: An approach in which different elevation angles (normally the lowest four) are used to minimize the effects of ground clutter and data voids on radar based observations such as precipitation estimates.

Incident Power Density: Energy per unit area incident on the radar target.

Inphase: The component of a complex signal along the real axis in the complex plane.

Isodop: Contour of constant Doppler velocity values.

Isolated Storm: An individual cell or group of cells that are identifiable and separate from other cells in a given geographic area.

Instability: A property of the steady state of a system such that certain disturbances or perturbations introduced into the steady state will increase in magnitude, the maximum perturbation amplitude always remaining larger than the initial amplitude.

Klystron: An electron tube used as a low-power oscillator or a high-power amplifier at ultrahigh frequencies. Noted for exceptional stability over long periods of transmission.

Line Echo Wave Pattern (LEWP): A radar echo pattern formed when a segment of a line of thunderstorms surges forward at an accelerated rate. A mesohigh pressure area is usually

present behind the accelerating thunderstorms. A mesolow pressure area is usually present at the crest of the wave.

Macroburst: Large downburst with 4 km (2.2 nmi) or larger outflow size with damaging wind lasting 5 to 20 minutes.

Mainlobe: The envelope of electromagnetic energy along the main axis of the beam.

Master System Control Function (MSCF): A graphical user interface used to set all adjustable parameters that determine pulse repetition frequency, antenna motion, and all processing thresholds and limits, including the setting of adjustable parameters that affect the seasonal and geographical performance of the hydrometeorological algorithms.

Maximum Unambiguous Range: The maximum range to which transmitted pulse wave can travel and return to the radar before the next pulse is transmitted.

Maximum Unambiguous Velocity: The maximum range of radial velocity that can be observed without ambiguity by a Doppler radar. Velocities outside this interval are folded into the interval. *See* Velocity aliasing and Nyquist Frequency.

Mean Doppler Velocity: Reflectivity-weighted average velocity of targets in a given volume sample. Usually determined from a large number of successive pulses. Also called mean radial velocity. Doppler velocity usually refers to spectral density first moment; radial velocity to base data.

Mesocyclone: A 3-dimensional region in a storm that rotates cyclonically and is closely correlated with severe weather.

Mesoscale: Pertaining to atmospheric phenomena having horizontal scales ranging from a few to several hundred kilometers, including thunderstorms, squall lines, fronts, precipitation bands in tropical and extratropical cyclones, and topographically generated weather systems such as mountain waves and sea and land breezes.

Mesoscale Convective Complex (MCC): A quasi-circular conglomeration of thunderstorms having a cloud-top area larger than 100,000 km² (29,000 n mi²) and persisting for more than 6 hours.

Mesoscale Convective System (MCS): Precipitation systems 20 to 500 km (11 to 270 n mi) wide that contain deep convection. Examples in mid-latitudes are large isolated thunderstorms, squall lines, Mesoscale Convective Complexes, and rainbands.

Microburst: Small downburst, 1 to 4 km (0.54 to 2.2 nmi) in outflow size, with peak winds lasting 2 to 15 minutes.

Microwave: Electromagnetic radiation having wavelengths between approximately 1 mm and 1 m (corresponding to 0.3- and 300-GHz frequency). Active systems operating at these wavelengths are called radar, although the definition of radar requires a capability to measure distance that is not always included in active microwave systems.

Mid-Altitude Radial Convergence Signature (MARC): Persistent areas of radial convergence within mid-levels (~ 3 to 7 km AGL) and within the larger zone of convergence along the forward flank of the convective line or storm and appears to be linked to the greatest degree of wind damage. Similar to the Deep Convergence Zone but generally confined to the mid-levels.

Mie Scattering or Region: Radar backscattering by targets having dimensions somewhat greater than 1/10 the wavelength of the radar but less than several radar wavelengths.

Modulation: Variation of the amplitude, frequency, or phase of a wave due to the mixing of two signals.

Monostatic Radar: A radar that uses a common antenna for both transmitting and receiving.

Notch Width: The 3 dB band width of a rejection filter.

Nyquist interval: (Also Nyquist velocity). The maximum time interval between equally spaced samples of a signal that will enable the signal waveform to be completely determined. Also known as the (absolute value) of the maximum unambiguous velocity that can be measured by a Doppler radar, e.g., 50 kts.

Nyquist Co-Interval: The full range of the Nyquist interval, e.g., +/- 50 kts.

Nyquist Frequency: The highest frequency that can be determined in data that have been discretely sampled. For data sampled at frequency f_s , this frequency is $f_s/2$.

Nyquist Sampling Theorem: In order to unambiguously measure a frequency, a sampling rate of at least two times this frequency is required. Doppler radar sampling rate is equal to the pulse repetition frequency (PRF).

Oscillator: The general term for an electric device that generates alternating currents or voltage. The oscillator is classified according to frequency of the generated signal.

Phase: A particular angular stage or point of advancement in a cycle; the fractional part of the angular period through which the wave had advanced, measured from the phase reference.

Phase Shift: The angular difference of two periodic functions.

Polarization: With respect to a transverse electromagnetic wave, the correlation between two orthogonal components of its electric (or, equivalently, magnetic) field.

Propagation: Transmission of electromagnetic energy as waves through or along a medium.

Pulse: A single short duration transmission of electromagnetic energy.

Pulse Duration: Time occupied by a burst of transmitted radio energy. This may also be expressed in units of range (pulse length). Also called pulse width.

Pulse Pair Processing: Name for the technique of mean velocity estimation by calculation of the signal complex covariance argument. The calculation requires two consecutive pulses.

Pulse Radar (or Pulsed Radar): A type of radar, designed to facilitate range measurement, in which the transmitted energy is emitted in periodic brief transmissions.

Pulse Repetition Frequency (PRF): The number of pulses transmitted per second.

Pulse Repetition Rate: See Pulse Repetition Frequency.

Pulse Repetition Time (PRT): The pulse interval from the beginning of one pulse to the beginning of the next succeeding pulse.

Pulse Width: The time occupied by an individual broadcast from a radar.

Quadrature: The component of the complex signal that is 90 degrees out of phase with the inphase component. This component lies along the imaginary axis in the complex plane.

Radar Cross Section: The area of a fictitious perfect reflector of electromagnetic waves that would reflect the same amount of energy back to the radar as the actual target.

Radar Reflectivity Factor: A quantity determined by the drop-size distribution of precipitation, which is proportional to the radar reflectivity if the precipitation particles are spheres small compared with the radar wavelength.

Radar Velocity (v): The component of motion of the target toward or away from the radar.

Random Variable (Variate): A variable characterized by random behavior in assuming its different possible values. Mathematically, it is described by its probability distribution, which specifies the possible values of a random variable together with the probability associated (in an appropriate sense) with each value. A random variable is said to be “continuous” if its possible values extend over a continuum, “discrete” if its possible values are separated by finite intervals.

Range Folding: Apparent range placement of a multiple trip return. A multiple return appears at the difference of the true range and a multiple of the unambiguous range.

Range Gate: A selectable interval of range (or of time delay from transmission) within which returning radar signals are measured. Gating is used to isolate the echoes from different regions of distributed targets.

Range Unfolding: Process of removing range ambiguity in apparent range of a multitrip target.

Rankine Vortex: Velocity profile for a symmetric circulation in which the inner core is in solid rotation, and tangential winds outside the core vary inversely with radial distance from the center.

Rayleigh Scattering: Scattering by spherical particles whose radii are smaller than about one-tenth the radar wavelength.

Receiver: An instrument used to detect the presence of and to determine the information carried by electromagnetic radiation. A receiver includes circuits designed to detect, amplify, rectify, and shape the incoming radio-frequency signals received at the antenna.

Reflectivity (Z): A measure of the fraction of radiation reflected by a given surface; defined as a ratio of the radiant energy reflected to the total that is incident upon that surface.

Refraction: Changes in the direction of energy propagation (due to changes in speed) as a result of density changes within the propagating medium.

Refractive Index: A measure of the amount of refraction. Numerically equal to the ratio of wave velocity in a vacuum to wave speed in the medium.

Scatterer: Any object capable of reflecting the radar signal.

Sectorized Hybrid Scan: A single reflectivity scan composed of data from the lowest four elevation scans. Close to the radar, higher tilts are used to reduce clutter. At further ranges, either the maximum values from the lowest two scans are used or the second scan values are used alone.

Severe Storm: A storm producing a tornado, surface hail $\geq 3/4$ inch, or wind gusts ≥ 50 knots, or all three.

Shear: The rate of change of the vector wind in a specified direction normal to the wind direction. Vertical shear is the variation of the horizontal wind in the vertical direction.

Shelf Cloud: A type of arcus (or roll) cloud. It is a low-level horizontal accessory cloud that appears to be a wedge shape as it approaches as seen along the leading edge of approaching thunderstorms. It is accompanied by gusty straight-line winds and is followed by precipitation.

Sidelobe: Secondary radiated energy maximum other than the radar main beam. Typically contains a small percentage of energy compared to the mainlobe.

Signal Processor: A computer processor used to apply a series of algorithms to the output of the receiver in order to estimate the spectral moments contained in the received backscattered signal.

Signal to Noise Ratio: A ratio that measures the comprehensibility of data, usually expressed as the signal power divided by the noise power.

Slant Range: The line-of-sight distance between two objects.

Slantwise Convection: A form of convection driven by a combination of gravitational and centrifugal forces.

Spearhead Echo: A radar echo associated with a downburst with a pointed appendage extending toward the direction of the echo motion. The appendage moves much faster than the parent echo, which is drawn into the appendage. During the mature stage, the appendage turns into a major echo and the parent echo loses its identity.

Specific Humidity: In a system of moist air, the ratio of the mass of water vapor to the total mass of the system.

Spectral Density: The distribution of power by frequency.

Spectrum Width: A measure of dispersion of velocities within the radar sample volume. Standard deviation of the mean radial velocity spectrum.

Squall Line: A line of active thunderstorms, either continuous or with breaks, including contiguous precipitation areas resulting from the existence of the thunderstorms. The squall line is a type of mesoscale convective system distinguished from other types by a larger length-to-width ratio.

Standard Atmosphere: A hypothetical vertical distribution of atmospheric temperature, pressure, and density that, by international agreement, is taken to be representative of the atmosphere for purposes of pressure altimeter calibrations, aircraft performance calculations, aircraft and missile design, ballistic tables, etc. The air is assumed to obey the perfect gas law and the hydrostatic equation.

Standard Deviation: The positive square root of the signal variance. In the WSR-88D, the velocity standard deviation is called spectrum width.

Storm: Any disturbed state of the atmosphere, especially as affecting the Earth's surface, and strongly implying destructive and otherwise unpleasant weather. Storms range in scale from tornadoes and thunderstorms, through tropical cyclones, to widespread extratropical cyclones.

Storm Motion: The velocity at which a storm travels.

Stratiform: Descriptive of clouds of extensive horizontal development, as contrasted to the vertically developed cumuliform types.

Supercell: An often dangerous convective storm which persists in a quasi-steady state for a period of time longer than it takes an air parcel to rise from the base of the updraft to its summit. It distinguishes itself from ordinary convection in that it contains a mesocyclone and is generally capable of producing the most severe weather (tornadoes, high winds, and giant hail).

Synchronous Detection: Processing that retains the received amplitude and phase but that removes the intermediate frequency carrier.

Target: Precipitation or other phenomena that produce echoes.

Temperature Inversion: A departure from the usual decrease with altitude of the air temperature.

Thin Line Echo: A narrow, elongated non-precipitating echo usually associated with thunderstorm outflow, fronts, or other density discontinuities, also known as a fine line.

Transmitter: The equipment used for generating and amplifying a radio frequency (rf) carrier signal, modulating the carrier signal with intelligence, and feeding the modulated carrier to an antenna for radiation into space as electromagnetic waves.

Unambiguous Range: The range to which a transmitted pulse wave can travel and return to the radar before the next pulse is transmitted.

Updraft: Current(s) of air with marked vertical upward motion.

Unimodal: A distribution having only one localized maximum, i.e., only one peak.

Variance: A measure of variability.

Veering Wind: A change in wind direction in a clockwise sense representing warm air advection.

Velocity Aliasing: Ambiguous detection of radial velocities outside the Nyquist co-interval.

Volume Coverage Pattern: Automatic radar scanning sequence control as it scans the atmospheric volume (from the surface to 70,000 ft and from the radar to 248 nm radius) surrounding the radar providing the data used for meteorological.

Vortex: In its most general use, any flow possessing vorticity. More often the term refers to a flow with closed streamlines.

Vorticity: A vector measure of local rotation in a fluid flow.

Wall Cloud: A local, abrupt lowering of a rain-free cumulonimbus base into a low-hanging accessory cloud, from 1.6 to 6.4 km (1 to 4 n mi) in diameter. The wall cloud is usually located in the southwestern part of a severe thunderstorm in the main updraft to the southwest of the main precipitation region. Rapid upward motion and visible rotation may be seen in wall clouds from several km away. Almost all strong tornadoes develop from wall clouds.

Watershed: The total area drained by a river and its tributaries.

Watt: The unit of power in the meter-kilogram-second (mks) system of units; equal to one joule per second.

Wavelength: The distance a wave will travel in the time required to generate one cycle.

Weak Echo Region (WER): (Abbreviated WER.) A region of weak radar echo that is bounded on one side and above by strong echo. It is located on the low-altitude inflow side of the storm. The WER is produced by strong updraft that carries precipitation particles to midlevels in a convective storm before they grow to radar-detectable sizes. The WER is also, in part, created

when strong mid and upper-level echo is carried horizontally and outward aloft from due to strong divergence from an intense updraft. (e.g., the spreading cumuliform anvil on the updraft flank). *See also* bounded weak echo region (BWER).

Wind Shear: The local variation of the wind vector or any of its components in a given direction.

WSR-88D System: The summation of all hardware, software, facilities, communications, logistics, staffing, training, operations, and procedures specifically associated with the collection, processing, analysis, dissemination, and application of data from the WSR-88D unit.

WSR-88D Unit: The combination of one RDA, one RPG, and all associated OPUPs and interconnecting communications.