# **Proposed CF Standard Names for RADAR and LIDAR data in CfRadial NetCDF-CF format**

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## Introduction

In order for the CfRadial format to be formally recognized by the CF user community, the list of standard names for RADAR and LIDAR must be substantially augmented.

The names proposed in this document cover radar and lidar data. The CfRadial convention is suitable for any instrument that transmits pulses and receives echoes in return. Therefore sonar instruments could be included later.

Since there are a large number of proposed standard names, we separate them into several tables for clarity.

## Table 1 - standard names for sensor geometry and coordinate variables

These names apply to the variables that describe the geometry of the scanning and sampling of the instrument, for orientation in space and distance from the instrument. They are essential for determining the sampling location in space.

| **Proposed standard name** | **Description** | **Units** |
| --- | --- | --- |
| unit\_vector\_component\_x | The component of a unit vector, along the X coordinate axis. | unitless (0-1) |
| unit\_vector\_component\_y | The component of a unit vector, along the Y coordinate axis. | unitless (0-1) |
| unit\_vector\_component\_z | The component of a unit vector, along the Z coordinate axis. | unitless (0-1) |
| line\_of\_sight\_distance\_from\_instrument | The distance, along the line of sight, from the instrument to the location of the observation. | m |
| platform\_heading\_angle | platform\_heading\_angle is the horizontal angle between the reference direction, which is often due north, and the longitudinal axis of the platform. The angle is measured clockwise positive, starting from the reference direction.  If the reference is not north a comment attribute should be added to specify the reference details.  See also standard names platform\_azimuth\_angle, platform\_pitch\_angle and platform\_roll\_angle.  platform\_heading\_angle differs from platform\_azimuth\_angle, in that the former refers to the **orientation of the platform itself**, while the latter refers to the angle **from** an observation point **to** the platform. | degree |
| sensor\_to\_target\_azimuth\_angle | sensor\_to\_target\_azimuth\_angle is the horizontal angle between a reference direction, which is often due north, and the direction of observation from the sensor to the target.  The angle is measured clockwise positive, starting from the reference direction.  If the reference is not north a comment attribute should be added to specify the reference details.  See also standard names sensor\_azimuth\_angle and direction\_of\_radial\_vector\_away\_from\_instrument.  sensor\_to\_target\_azimuth\_angle differs from sensor\_azimuth\_angle in that the former is the angle **from** the sensor **to** the observation point, while the latter is the angle **from** an observation point **to** the sensor. Because of atmospheric path distortion (e.g. from refraction) these are not necessarily reciprocal.  The name direction\_of\_radial\_vector\_away\_from\_instrument is ambiguous in that it does not differentiate between the azimuth and elevation axes.  direction\_of\_radial\_vector\_away\_from\_instrument could be used as a alias for sensor\_to\_target\_azimuth\_angle. | degree |
| sensor\_to\_target\_elevation\_angle | sensor\_to\_target\_elevation\_angle is the vertical angle between the direction from the sensor to the target and the horizontal plane at the sensor location. The angle is measured upward positive, starting from the horizontal plane.  See also the standard name sensor\_view\_angle.  A sensor\_to\_target\_elevation\_angle of -90.0 degrees is equivalent to a sensor\_view\_angle of 0.0 degrees. | degree |
| sensor\_to\_target\_rotation\_angle | sensor\_to\_target\_rotation\_angle is the angle between a reference plane, often the vertical plane, which contains the axis of rotation of the instrument, and the direction of observation from the sensor to the target. The angle is measured clockwise positive, starting from the reference plane.  A comment attribute should be added to specify the reference plane details.  sensor\_to\_target\_rotation\_angle is used in specialized cases, such as aircraft tail radars. | degree |
| sensor\_to\_target\_tilt\_angle | sensor\_to\_target\_tilt\_angle is the angle between the a reference plane that passes through the sensor location and is orthogonal to the plane of rotation, and the direction of observation from the sensor to the target. The angle is measured starting from the reference plane.  A comment attribute should be added to specify the convention for the sign of the angle.  sensor\_to\_target\_tilt\_angle is used in specialized situations, such as aircraft tail radars. | degree |

## Note on weather radar channels and the resulting variables

Modern weather radars can support either single-polarization or dual-polarization operation. Such radars can have up to 4 receive channels: horizontal copolar (Hc), vertical copolar (Vc), horizontal crosspolar (Hx) and vertical crosspolar (Vx).

Single polarization radars generally have just the Hc channel.

This terminology is receiver-centric:

* Hc indicates horizontal transmit and horizontal receive
* Vc indicates vertical transmit and vertical receive
* Hx indicates vertical transmit and horizontal receive
* Vx indicates horizontal transmit and vertical receive.

|  |  |  |
| --- | --- | --- |
|  | **H transmit** | **V Transmit** |
| **H receive** | Hc = H co polar | Hx = H cross polar |
| **V receive** | Vx = V cross polar | Vc = V co polar |

We can compute quantities from signals for a single channel, or for a combination of two channels.

The following table shows the possible channel combinations. For some quantities the result is order dependent:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Hc** | **Vc** | **Hx** | **Vx** |
| **Hc** | HcHc | HcVc | HcHx | HcVx |
| **Vc** | VcHc | VcVc | VcHx | VcVx |
| **Hx** | HxHx | HxVc | HxHx | HxVx |
| **Vx** | VxHc | VxVc | VxHx | VxVx |

## Table 2 - standard names for radar moments variables

To date, the only radar moments fields included in the CF standard names are for radar reflectivity (*equivalent\_reflectivity\_factor*) and radial velocity (*radial\_velocity\_of\_scatterers\_away\_from\_instrument*).

We propose to rename reflectivity to *radar\_equivalent\_reflectivity\_factor*, with an alias to support the existing name (*equivalent\_reflectivity\_factor*).

| **Proposed standard name** | **Description** | **Units** |
| --- | --- | --- |
| radar\_equivalent\_reflectivity\_factor (with alias for backward compatibility: equivalent\_reflectivity\_factor –  this is the existing CF standard name) | "Equivalent reflectivity factor" is the radar reflectivity factor that is calculated from the measured radar backscatter return power assuming the target is composed of liquid water droplets whose diameter is less than one tenth of the radar wavelength, i.e., treating the droplets as Rayleigh scatterers. The actual radar reflectivity factor would depend on the size distribution and composition of the particles within the target volume and these are often unknown. The quantity is corrected for range, radar wavelength and other operating characteristics such as transmit power and pulse length. | dBZ |
| radar\_equivalent\_reflectivity\_factor\_h | This is the radar\_equivalent\_reflectivity\_factor, for the copolar horizontal receive signal. | dBZ |
| radar\_equivalent\_reflectivity\_factor\_v | This is the radar\_equivalent\_reflectivity\_factor, for the copolar vertical receive signal. | dBZ |
| radar\_linear\_equivalent\_reflectivity\_factor | radar\_equivalent\_reflectivity\_factor, in linear units | mm6 m-3 |
| radar\_linear\_equivalent\_reflectivity\_factor\_h | radar\_equivalent\_reflectivity\_factor\_h, in linear units | mm6 m-3 |
| radar\_linear\_equivalent\_reflectivity\_factor\_v | radar\_equivalent\_reflectivity\_factor\_v, in linear units | mm6 m-3 |
| radial\_velocity\_of\_scatterers\_away \_from\_instrument (already in CF) | A velocity is a vector quantity. "Radial velocity away from instrument" means the component of the velocity of the scatterers along the line of sight of the instrument where positive implies movement away from the instrument (i.e. outward). The "instrument" (examples are radar and lidar) is the device used to make the observation, and the "scatterers" are what causes the transmitted signal to be returned to the instrument (examples are aerosols, hydrometeors and refractive index irregularities), of whatever kind the instrument detects. | m s-1 |
| radial\_velocity\_of\_scatterers\_away \_from\_instrument\_h | Radial velocity for the copolar horizontal receive signal. | m s-1 |
| radial\_velocity\_of\_scatterers\_away \_from\_instrument\_v | Radial velocity for the copolar vertical receive signal. | m s-1 |
| radar\_doppler\_spectrum\_width | A measure of the dispersion of radial velocity within the radar measurement volume. This is analogous to the standard deviation of the distribution of velocities for all particles in the measurement volume. | m s-1 |
| radar\_doppler\_spectrum\_width\_h | radar\_doppler\_spectrum\_width for the copolar horizontal receive signal. | m s-1 |
| radar\_doppler\_spectrum\_width\_v | radar\_doppler\_spectrum\_width for the copolar vertical receive signal. | m s-1 |
| radar\_differential\_reflectivity\_hv | The ratio of the copolar horizontal reflectivity to the copolar vertical reflectivity. Commonly referred to as ZDR. | dB |
| radar\_linear\_depolarization\_ratio | The ratio of the received power from one polarization to the received power from the orthogonal polarization, for a pulse transmitted in the orthogonal polarization. Commonly referred to as LDR. | dB |
| radar\_linear\_depolarization\_ratio\_h | radar\_linear\_depolarization\_ratio for horizontal transmit. That is, the ratio of the vertical received power to the horizontal received power, for horizontal transmit. | dB |
| radar\_linear\_depolarization\_ratio\_v | radar\_linear\_depolarization\_ratio for vertical transmit. That is, the ratio of the horizontal received power to the vertical received power, for vertical transmit. | dB |
| radar\_differential\_phase\_hv | The horizontal copolar received phase minus the vertical copolar received phase. Commonly referred to as PHIDP. | degree |
| radar\_specific\_differential\_phase\_hv | The rate of change of radar\_differential\_phase\_hv with distance (i.e. range from the instrument). Commonly referred to as KDP. | degree km-1 |
| radar\_differential\_phase\_copolar\_h\_crosspolar\_v | The horizontal copolar received phase minus the vertical crosspolar received phase. | degree |
| radar\_differential\_phase\_copolar\_v\_crosspolar\_h | The vertical copolar received phase minus the horizontal crosspolar received phase. | degree |
| radar\_correlation\_coefficient\_hv | The complex correlation coefficient between the copolar horizontal received signal and the copolar vertical received signal. | unitless (0-1) |
| radar\_correlation\_coefficient\_copolar\_h\_crosspolar\_v | The complex correlation coefficient between the copolar horizontal received signal and the crosspolar vertical received signal, for horizontal transmit. | unitless (0-1) |
| radar\_correlation\_coefficient\_copolar\_v\_crosspolar\_h | The complex correlation coefficient between the copolar vertical received signal and the crosspolar horizontal received signal, for vertical transmit. | unitless (0-1) |
| radar\_received\_signal\_power | Received power, unspecified channel. | dBm |
| radar\_received\_signal\_power\_copolar\_h | radar\_received\_signal\_power for copolar horizontal receive, for horizontal transmit. | dBm |
| radar\_received\_signal\_power\_copolar\_v | radar\_received\_signal\_power for copolar vertical receive, from vertical transmit. | dBm |
| radar\_received\_signal\_power\_crosspolar\_h | radar\_received\_signal\_power for crosspolar horizontal receive, for vertical transmit. | dBm |
| radar\_received\_signal\_power\_crosspolar\_v | radar\_received\_signal\_power for crosspolar vertical receive, for horizontal transmit. | dBm |
| radar\_signal\_to\_noise\_ratio | The ratio of the signal power to the system noise. The signal power is computed as the total measured power minus the noise power. | dB |
| radar\_signal\_to\_noise\_ratio\_copolar\_h | radar\_signal\_to\_noise\_ratio for copolar horizontal receive, for horizontal transmit. | dB |
| radar\_signal\_to\_noise\_ratio\_copolar\_v | radar\_signal\_to\_noise\_ratio for copolar vertical receive, for vertical transmit. | dB |
| radar\_signal\_to\_noise\_ratio\_crosspolar\_h | radar\_signal\_to\_noise\_ratio for crosspolar horizontal receive, for vertical transmit. | dB |
| radar\_signal\_to\_noise\_ratio\_crosspolar\_v | radar\_signal\_to\_noise\_ratio for crosspolar vertical receive, for horizontal transmit. | dB |
| radar\_clutter\_to\_signal\_ratio | The ratio of the clutter power, as removed by a clutter filter, to the total signal power. | dB |
| radar\_clutter\_to\_signal\_ratio\_copolar\_h | radar\_clutter\_to\_signal\_ratio for copolar horizontal receive, from a horizontal polarization transmit pulse. | dB |
| radar\_clutter\_to\_signal\_ratio\_copolar\_v | radar\_clutter\_to\_signal\_ratio for copolar vertical receive, from a vertical polarization transmit pulse. | dB |
| radar\_normalized\_coherent\_power | The lag1 power of the received signal, divided by the lag0 power of the received signal. | unitless (0-1) |
| radar\_normalized\_coherent\_power\_copolar\_h | radar\_normalized\_coherent\_power for copolar horizontal receive, for horizontal transmit. | unitless  (0-1) |
| radar\_normalized\_coherent\_power\_copolar\_v | radar\_normalized\_coherent\_power for copolar vertical receive, for vertical transmit. | unitless (0-1) |
| radar\_estimated\_precipitation\_rate | Precipitation rate based estimated by radar. | mm/hr |
| radar\_scatterer\_classification | Dominant scatterer type in a radar return for a sample volume. | unitless (0-255) |
| radar\_quality\_mask | A data quality indicator for radar data. Can indicate data quality conditions or data quality processing. See attributes and ancillary data for more details. | unitless (0-255) |

## Table 3 - standard names for radar covariance quantities

This section lists the proposed standard names for radar covariance variables.

These are the fundamental quantities from which many of the radar moments are computed.

Lag0 covariances for a single channel (e.g. horizontal copolar to horizontal copolar) are real.

All other covariances are complex. These are stored as (complex, phase) pairs. Each complex covariance will be represented by two real variables, one for the power in units of dBm, and one for the phase in units of degrees.

| **Proposed standard name** | **Description** | **Units** |
| --- | --- | --- |
|  |  |  |
| **Lag-0 covariances of single channel (real) Used for power-based moments** | | |
| radar\_lag0\_covariance\_of\_copolar\_h \_and copolar\_h | Lag-0 covariance for the horizontal copolar signal. This is the received horizontal copolar power. | dBm |
| radar\_lag0\_covariance\_of\_copolar\_v \_and\_copolar\_v | Lag-0 covariance for the vertical copolar signal. This is the received vertical copolar power. | dBm |
| radar\_lag0\_covariance\_of\_crosspolar\_h \_and\_crosspolar\_h | Lag-0 covariance for the horizontal crosspolar signal. This is the received horizontal crosspolar power. | dBm |
| radar\_lag0\_covariance\_of\_crosspolar\_v \_and\_crosspolar\_v | Lag-0 covariance for the vertical crosspolar signal. This is the received vertical crosspolar power. | dBm |
|  |  |  |
|  |  |  |
| **Lag-0 covariances of 2 channels (complex) stored as (power, phase) Used for correlation moments, differential phase** | | |
| radar\_lag0\_covariance\_of\_copolar\_h \_and\_copolar\_v\_power | Power of the lag-0 covariance of the horizontal copolar signal and the vertical copolar signal. | dBm |
| radar\_lag0\_covariance\_of\_copolar\_h \_and\_copolar\_v\_phase | Phase of the lag-0 covariance of the horizontal copolar signal and the vertical copolar signal. | degree |
|  |  |  |
| radar\_lag0\_covariance\_of\_copolar\_h \_and\_crosspolar\_h\_power | Power of the lag-0 covariance of the horizontal copolar signal and the horizontal crosspolar signal. | dBm |
| radar\_lag0\_covariance\_of\_copolar\_h \_and\_crosspolar\_h\_phase | Phase of the lag-0 covariance of the horizontal copolar signal and the horizontal crosspolar signal. | degree |
|  |  |  |
| radar\_lag0\_covariance\_of\_copolar\_h \_and\_crosspolar\_v\_power | Power of the lag-0 covariance of the horizontal copolar signal and the vertical crosspolar signal. | dBm |
| radar\_lag0\_covariance\_of\_copolar\_h \_and\_crosspolar\_v\_phase | Phase of the lag-0 covariance of the horizontal copolar signal and the vertical crosspolar signal. | degree |
|  |  |  |
| radar\_lag0\_covariance\_of\_copolar\_v \_and\_crosspolar\_h\_power | Power of the lag-0 covariance of the vertical copolar signal and the horizontal crosspolar signal. | dBm |
| radar\_lag0\_covariance\_of\_copolar\_v \_and\_crosspolar\_h\_phase | Phase of the lag-0 covariance of the vertical copolar signal and the horizontal crosspolar signal. | degree |
|  |  |  |
| radar\_lag0\_covariance\_of\_copolar\_v \_and\_crosspolar\_v\_power | Power of the lag-0 covariance of the vertical copolar signal and the vertical crosspolar signal. | dBm |
| radar\_lag0\_covariance\_of\_copolar\_v \_and\_crosspolar\_v\_phase | Phase of the lag-0 covariance of the vertical copolar signal and the vertical crosspolar signal. | degree |
|  |  |  |
| radar\_lag0\_covariance\_of\_crosspolar\_h \_and\_crosspolar\_v\_power | Power of the lag-0 covariance of the horizontal crosspolar signal and the vertical crosspolar signal. | dBm |
| radar\_lag0\_covariance\_of\_crosspolar\_h \_and\_crosspolar\_v\_phase | Phase of the lag-0 covariance of the horizontal crosspolar signal and the vertical crosspolar signal. | degree |
|  |  |  |
| **Lag-1 covariances of 2 channels (complex) stored as (power, phase) Used for velocity, spectrum width, correlations** | | |
| radar\_lag1\_covariance\_of\_copolar\_h \_and\_copolar\_h\_power | Power of the lag-1 covariance of the horizontal copolar and horizontal copolar signal. | dBm |
| radar\_lag1\_covariance\_of\_copolar\_h \_and\_copolar\_h\_phase | Phase of the lag-1 covariance of the horizontal copolar and horizontal copolar signal | degree |
|  |  |  |
| radar\_lag1\_covariance\_of\_copolar\_h \_and\_copolar\_v\_power | Power of the lag-1 covariance of the horizontal copolar and vertical copolar signals. | dBm |
| radar\_lag1\_covariance\_of\_copolar\_h \_and\_copolar\_v\_phase | Phase of the lag-1 covariance of the horizontal copolar and vertical copolar signals. | degree |
|  |  |  |
| radar\_lag1\_covariance\_of\_copolar\_h \_and\_crosspolar\_h\_power | Power of the lag-1 covariance of the horizontal copolar and horizontal crosspolar signals. | dBm |
| radar\_lag1\_covariance\_of\_copolar\_h \_and\_crosspolar\_h\_phase | Phase of the lag-1 covariance of the horizontal copolar and horizontal crosspolar signals. | degree |
|  |  |  |
| radar\_lag1\_covariance\_of\_copolar\_h \_and\_crosspolar\_v\_power | Power of the lag-1 covariance of the horizontal copolar and vertical crosspolar signals. | dBm |
| radar\_lag1\_covariance\_of\_copolar\_h \_and\_crosspolar\_v\_phase | Phase of the lag-1 covariance of the horizontal copolar and vertical crosspolar signals. | degree |
|  |  |  |
| radar\_lag1\_covariance\_of\_copolar\_v \_and\_copolar\_h\_power | Power of the lag-1 covariance of the vertical copolar and horizontal copolar signal. | dBm |
| radar\_lag1\_covariance\_of\_copolar\_v \_and\_copolar\_h\_phase | Phase of the lag-1 covariance of the vertical copolar and horizontal copolar signal | degree |
|  |  |  |
| radar\_lag1\_covariance\_of\_copolar\_v \_and\_copolar\_v\_power | Power of the lag-1 covariance of the vertical copolar and vertical copolar signals. | dBm |
| radar\_lag1\_covariance\_of\_copolar\_v \_and\_copolar\_v\_phase | Phase of the lag-1 covariance of the vertical copolar and vertical copolar signals. | degree |
|  |  |  |
| radar\_lag1\_covariance\_of\_copolar\_v \_and\_crosspolar\_h\_power | Power of the lag-1 covariance of the vertical copolar and horizontal crosspolar signals. | dBm |
| radar\_lag1\_covariance\_of\_copolar\_v \_and\_crosspolar\_h\_phase | Phase of the lag-1 covariance of the vertical copolar and horizontal crosspolar signals. | degree |
|  |  |  |
| radar\_lag1\_covariance\_of\_copolar\_v \_and\_crosspolar\_v\_power | Power of the lag-1 covariance of the vertical copolar and vertical crosspolar signals. | dBm |
| radar\_lag1\_covariance\_of\_copolar\_v \_and\_crosspolar\_v\_phase | Phase of the lag-1 covariance of the vertical copolar and vertical crosspolar signals. | degree |
|  |  |  |
| radar\_lag1\_covariance\_of\_crosspolar\_h \_and\_copolar\_h\_power | Power of the lag-1 covariance of the horizontal crosspolar and horizontal copolar signal. | dBm |
| radar\_lag1\_covariance\_of\_crosspolar\_h \_and\_copolar\_h\_phase | Phase of the lag-1 covariance of the horizontal crosspolar and horizontal copolar signal | degree |
|  |  |  |
| radar\_lag1\_covariance\_of\_crosspolar\_h \_and\_copolar\_v\_power | Power of the lag-1 covariance of the horizontal crosspolar and vertical copolar signals. | dBm |
| radar\_lag1\_covariance\_of\_crosspolar\_h \_and\_copolar\_v\_phase | Phase of the lag-1 covariance of the horizontal crosspolar and vertical copolar signals. | degree |
|  |  |  |
| radar\_lag1\_covariance\_of\_crosspolar\_h \_and\_crosspolar\_h\_power | Power of the lag-1 covariance of the horizontal crosspolar and horizontal crosspolar signals. | dBm |
| radar\_lag1\_covariance\_of\_crosspolar\_h \_and\_crosspolar\_h\_phase | Phase of the lag-1 covariance of the horizontal crosspolar and horizontal crosspolar signals. | degree |
|  |  |  |
| radar\_lag1\_covariance\_of\_crosspolar\_h \_and\_crosspolar\_v\_power | Power of the lag-1 covariance of the horizontal crosspolar and vertical crosspolar signals. | dBm |
| radar\_lag1\_covariance\_of\_crosspolar\_h \_and\_crosspolar\_v\_phase | Phase of the lag-1 covariance of the horizontal crosspolar and vertical crosspolar signals. | degree |
|  |  |  |
| radar\_lag1\_covariance\_of\_crosspolar\_v \_and\_copolar\_h\_power | Power of the lag-1 covariance of the vertical crosspolar and horizontal copolar signal. | dBm |
| radar\_lag1\_covariance\_of\_crosspolar\_v \_and\_copolar\_h\_phase | Phase of the lag-1 covariance of the vertical crosspolar and horizontal copolar signal | degree |
|  |  |  |
| radar\_lag1\_covariance\_of\_crosspolar\_v \_and\_copolar\_v\_power | Power of the lag-1 covariance of the vertical crosspolar and vertical copolar signals. | dBm |
| radar\_lag1\_covariance\_of\_crosspolar\_v \_and\_copolar\_v\_phase | Phase of the lag-1 covariance of the vertical crosspolar and vertical copolar signals. | degree |
|  |  |  |
| radar\_lag1\_covariance\_of\_crosspolar\_v \_and\_crosspolar\_h\_power | Power of the lag-1 covariance of the vertical crosspolar and horizontal crosspolar signals. | dBm |
| radar\_lag1\_covariance\_of\_crosspolar\_v \_and\_crosspolar\_h\_phase | Phase of the lag-1 covariance of the vertical crosspolar and horizontal crosspolar signals. | degree |
|  |  |  |
| radar\_lag1\_covariance\_of\_crosspolar\_v \_and\_crosspolar\_v\_power | Power of the lag-1 covariance of the vertical crosspolar and vertical crosspolar signals. | dBm |
| radar\_lag1\_covariance\_of\_crosspolar\_v \_and\_crosspolar\_v\_phase | Phase of the lag-1 covariance of the vertical crosspolar and vertical crosspolar signals. | degree |
|  |  |  |
| **Lag-2 covariances (complex), stored as (power, phase) Used for spectrum width** | | |
| radar\_lag2\_covariance\_of\_copolar\_h \_and\_copolar\_h\_power | Power of the lag-2 covariance of the horizontal copolar signal. | dBm |
| radar\_lag2\_covariance\_of\_copolar\_h \_and\_copolar\_h\_phase | Phase of the lag-2 covariance of the horizontal copolar signal. | degree |
|  |  |  |
| radar\_lag2\_covariance\_of\_copolar\_v \_and\_copolar\_v\_power | Power of the lag-2 covariance of the vertical copolar signal. | dBm |
| radar\_lag2\_covariance\_of\_copolar\_v \_and\_copolar\_v\_phase | Phase of the lag-2 covariance of the vertical copolar signal. | degree |
|  |  |  |
| **Lag-3 covariances (complex), stored as (power, phase) Used for spectrum width** | | |
| radar\_lag3\_covariance\_of\_copolar\_h \_and\_copolar\_h\_power | Power of the lag-3 covariance of the horizontal copolar signal. | dBm |
| radar\_lag3\_covariance\_of\_copolar\_h \_and\_copolar\_h\_phase | Phase of the lag-3 covariance of the horizontal copolar signal. | degree |
|  |  |  |
| radar\_lag3\_covariance\_of\_copolar\_v \_and\_copolar\_v\_power | Power of the lag-3 covariance of the vertical copolar signal. | dBm |
| radar\_lag3\_covariance\_of\_copolar\_v \_and\_copolar\_v\_phase | Phase of the lag-3 covariance of the vertical copolar signal. | degree |
|  |  |  |
| **Lag-4 covariances (complex), stored as (power, phase)**  **Used for spectrum width** | | |
| radar\_lag4\_covariance\_of\_copolar\_h \_and\_copolar\_h\_power | Power of the lag-4 covariance of the horizontal copolar signal. | dBm |
| radar\_lag4\_covariance\_of\_copolar\_h \_and\_copolar\_h\_phase | Phase of the lag-4 covariance of the horizontal copolar signal. | degree |
|  |  |  |
| radar\_lag4\_covariance\_of\_copolar\_v \_and\_copolar\_v\_power | Power of the lag-4 covariance of the vertical copolar signal. | dBm |
| radar\_lag4\_covariance\_of\_copolar\_v \_and\_copolar\_v\_phase | Phase of the lag-4 covariance of the vertical copolar signal. | degree |
|  |  |  |
| **Lag-5 covariances (complex), stored as (power, phase)**  **Used for spectrum width** | | |
| radar\_lag5\_covariance\_of\_copolar\_h \_and\_copolar\_h\_power | Power of the lag-5 covariance of the horizontal copolar signal. | dBm |
| radar\_lag5\_covariance\_of\_copolar\_h \_and\_copolar\_h\_phase | Phase of the lag-5 covariance of the horizontal copolar signal. | degree |
|  |  |  |
| radar\_lag5\_covariance\_of\_copolar\_v \_and\_copolar\_v\_power | Power of the lag-5 covariance of the vertical copolar signal. | dBm |
| radar\_lag5\_covariance\_of\_copolar\_v \_and\_copolar\_v\_phase | Phase of the lag-5 covariance of the vertical copolar signal. | degree |
|  |  |  |
| **Lag-0 powers for staggered PRT (real) Used for staggered PRT moments** | | |
| radar\_long\_prt\_lag0\_covariance\_of\_copolar\_h \_and\_copolar\_h | Lag-0 covariance for the horizontal copolar signal for long PRT. | dBm |
| radar\_long\_prt\_lag0\_covariance\_of\_copolar\_v \_and\_copolar\_v | Lag-0 covariance for vertical copolar signal for long PRT. | dBm |
| radar\_long\_prt\_lag0\_covariance\_of\_crosspolar\_h \_and\_crosspolar\_h | Lag-0 covariance for horizontal crosspolar signal for long PRT. | dBm |
| radar\_long\_prt\_lag0\_covariance\_of\_crosspolar\_v \_and\_crosspolar\_v | Lag-0 covariance for vertical crosspolar signal for long PRT. | dBm |
| radar\_short\_prt\_lag0\_covariance\_of\_copolar\_h \_and\_copolar\_h | Lag-0 covariance for horizontal copolar signal for short PRT. | dBm |
| radar\_short\_prt\_lag0\_covariance\_of\_copolar\_v \_and\_copolar\_v | Lag-0 covariance for vertical copolar signal for short PRT. | dBm |
| radar\_short\_prt\_lag0\_covariance\_of\_crosspolar\_h \_and\_crosspolar\_h | Lag-0 covariance for horizontal crosspolar signal for short PRT. | dBm |
| radar\_short\_prt\_lag0\_covariance\_of\_crosspolar\_v \_and\_crosspolar\_v | Lag-0 covariance for vertical crosspolar signal for short PRT. | dBm |
|  | | |
| **Lag-1 covariances (complex) for staggered PRT, stored as (power, phase) Used for staggered PRT moments** | | |
| radar\_long\_prt\_lag1\_covariance\_of\_copolar\_h \_and\_copolar\_h\_power | Power of the lag-1 covariance of the horizontal copolar signal for long PRT. | dBm |
| radar\_long\_prt\_lag1\_covariance\_of\_copolar\_h \_and\_copolar\_h\_phase | Phase of the lag-1 covariance of the horizontal copolar signal for long PRT. | degree |
|  |  |  |
| radar\_long\_prt\_lag1\_covariance\_of\_copolar\_v \_and\_copolar\_v\_power | Power of the lag-1 covariance of the vertical copolar signal for long PRT. | dBm |
| radar\_long\_prt\_lag1\_covariance\_of\_copolar\_v \_and\_copolar\_v\_phase | Phase of the lag-1 covariance of the vertical copolar signal for long PRT. | degree |
|  |  |  |
| radar\_short\_prt\_lag1\_covariance\_of\_copolar\_h and\_copolar\_h\_power | Power of the lag-1 covariance of the horizontal copolar signal for short PRT. | dBm |
| radar\_short\_prt\_lag1\_covariance\_of\_copolar\_h and\_copolar\_h\_phase | Phase of the lag-1 covariance of the horizontal copolar signal for short PRT. | degree |
|  |  |  |
| radar\_short\_prt\_lag1\_covariance\_of\_copolar\_v and\_copolar\_v\_power | Power of the lag-1 covariance of the vertical copolar signal for short PRT. | dBm |
| radar\_short\_prt\_lag1\_covariance\_of\_copolar\_v and\_copolar\_v\_phase | Phase of the lag-1 covariance of the vertical copolar signal for short PRT. | degree |
|  |  |  |
| radar\_long\_to\_short\_prt\_lag1\_covariance\_of \_copolar\_h\_to\_copolar\_h\_power | Power of the lag-1 covariance of the horizontal copolar signal for a long-to-short PRT sequence. | dBm |
| radar\_long\_to\_short\_prt\_lag1\_covariance\_of \_copolar\_h\_to\_copolar\_h\_phase | Phase of the lag-1 covariance of the horizontal copolar signal for a long-to-short PRT sequence. | degree |
|  |  |  |
| radar\_long\_to\_short\_prt\_lag1\_covariance\_of \_copolar\_v\_to\_copolar\_v\_power | Power of the lag-1 covariance of the vertical copolar signal for a long-to-short PRT sequence. | dBm |
| radar\_long\_to\_short\_prt\_lag1\_covariance\_of \_copolar\_v\_to\_copolar\_v\_phase | Phase of the lag-1 covariance of the vertical copolar signal for a long-to-short PRT sequence. | degree |
|  |  |  |
| radar\_short\_to\_long\_prt\_lag1\_covariance\_of \_copolar\_h\_to\_copolar\_h\_power | Power of the lag-1 covariance of the horizontal copolar signal for a short-to-long PRT sequence. | dBm |
| radar\_short\_to\_long\_prt\_lag1\_covariance\_of \_copolar\_h\_to\_copolar\_h\_phase | Phase of the lag-1 covariance of the horizontal copolar signal for a short-to-long PRT sequence. | degree |
|  |  |  |
| radar\_short\_to\_long\_prt\_lag1\_covariance\_of \_copolar\_v\_to\_copolar\_v\_power | Power of the lag-1 covariance of the vertical copolar signal for a short-to-long PRT sequence. | dBm |
| radar\_short\_to\_long\_prt\_lag1\_covariance\_of \_copolar\_v\_to\_copolar\_v\_phase | Phase of the lag-1 covariance of the vertical copolar signal for a short-to-long PRT sequence. | degree |
| radar\_long\_prt\_lag1\_covariance\_of\_copolar\_h \_and\_copolar\_h\_power | Power of the lag-1 covariance of the horizontal copolar signal for long PRT. | dBm |

## Table 4 - standard names for radar spectrum variables

We can compute the spectrum for a single channel, or a cross spectrum between two channels.

The following table shows the possible combinations for cross-spectra. These can be computed as the FFT of the first channel multiplied by the conjugate of the FFT of the second channel.

The on-diagonal terms are real – they are the power spectrum for that channel.

The off-diagonal terms are complex.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Hc\*** | **Vc\*** | **Hx\*** | **Vx\*** |
| **Hc** | HcHc\* | HcVc\* | HcHx\* | HcVx\* |
| **Vc** | VcHc\* | VcVc\* | VcHx\* | VcVx\* |
| **Hx** | HxHx\* | HxVc\* | HxHx\* | HxVx\* |
| **Vx** | VxHc\* | VxVc\* | VxHx\* | VxVx\* |

| **Standard name** | **Description** | **Units** |
| --- | --- | --- |
|  |  |  |
| **Power spectrum for a single channel (diagonal terms)** | | |
| radar\_power\_spectrum\_of\_copolar\_h | Power spectrum for the copolar horizontal signal. This is a real value, representing the power only. The phase is discarded. | dBm |
| radar\_power\_spectrum\_of\_copolar\_v | Power spectrum for the copolar vertical signal. This is a real value, representing the power only. The phase is discarded. | dBm |
| radar\_power\_spectrum\_of\_crosspolar\_h | Power spectrum for the crosspolar horizontal signal. This is a real value, representing the power only. The phase is discarded. | dBm |
| radar\_power\_spectrum\_of\_crosspolar\_v | Power spectrum for the crosspolar vertical signal. This is a real value, representing the power only. The phase is discarded. | dBm |
|  |  |  |
| **Complex spectrum for a single channel (diagonal terms, complex FFT)** | | |
| radar\_complex\_spectrum\_of\_copolar\_h\_power | Power of the complex spectrum for the copolar horizontal signal. | dBm |
| radar\_complex\_spectrum\_of\_copolar\_h\_phase | Phase of the complex spectrum for the copolar horizontal signal. | degree |
|  |  |  |
| radar\_complex\_spectrum\_of\_copolar\_v\_power | Power of the complex spectrum for the copolar vertical signal. | dBm |
| radar\_complex\_spectrum\_of\_copolar\_v\_phase | Phase of the complex spectrum for the copolar vertical signal. | degree |
|  |  |  |
| radar\_complex\_spectrum\_of\_crosspolar\_h\_power | Power of the complex spectrum for the crosspolar horizontal signal. | dBm |
| radar\_complex\_spectrum\_of\_crosspolar\_h\_phase | Phase of the complex spectrum for the crosspolar horizontal signal. | degree |
|  |  |  |
| radar\_complex\_spectrum\_of\_crosspolar\_v\_power | Power of the complex spectrum for the crosspolar vertical signal. | dBm |
| radar\_complex\_spectrum\_of\_crosspolar\_v\_phase | Phase of the complex spectrum for the crosspolar vertical signal. | degree |
|  |  |  |
| **Cross spectra of 2 channels (off-diagonal terms, complex FFT)** | | |
| radar\_cross\_spectrum\_of\_copolar\_h\_and\_copolar\_v\_power | Power of the cross spectrum of copolar horizontal signal to copolar vertical signal. | dBm |
| radar\_cross\_spectrum\_of\_copolar\_h\_and\_copolar\_v\_phase | Phase of the cross spectrum of copolar horizontal signal to copolar vertical signal. | degree |
|  |  |  |
| radar\_cross\_spectrum\_of\_copolar\_h\_and\_crosspolar\_h\_power | Power of the cross spectrum of copolar horizontal signal to crosspolar horizontal signal. | dBm |
| radar\_cross\_spectrum\_of\_copolar\_h\_and\_crosspolar\_h\_phase | Phase of the cross spectrum of copolar horizontal signal to crosspolar horizontal signal. | degree |
|  |  |  |
| radar\_cross\_spectrum\_of\_copolar\_h\_and\_crosspolar\_v\_power | Power of the cross spectrum of copolar horizontal signal to crosspolar vertical signal. | dBm |
| radar\_cross\_spectrum\_of\_copolar\_h\_and\_crosspolar\_v\_phase | Phase of the cross spectrum of copolar horizontal signal to crosspolar vertical signal. | degree |
|  |  |  |
| radar\_cross\_spectrum\_of\_copolar\_v\_and\_copolar\_h\_power | Power of the cross spectrum of copolar vertical signal to copolar horizontal signal. | dBm |
| radar\_cross\_spectrum\_of\_copolar\_v\_and\_copolar\_h\_phase | Phase of the cross spectrum of copolar vertical signal to copolar horizontal signal. | degree |
|  |  |  |
| radar\_cross\_spectrum\_of\_copolar\_v\_and\_crosspolar\_h\_power | Power of the cross spectrum of copolar vertical signal to crosspolar horizontal signal. | dBm |
| radar\_cross\_spectrum\_of\_copolar\_v\_and\_crosspolar\_h\_phase | Phase of the cross spectrum of copolar vertical signal to crosspolar horizontal signal. | degree |
|  |  |  |
| radar\_cross\_spectrum\_of\_copolar\_v\_and\_crosspolar\_v\_power | Power of the cross spectrum of copolar vertical signal to crosspolar vertical signal. | dBm |
| radar\_cross\_spectrum\_of\_copolar\_v\_and\_crosspolar\_v\_phase | Phase of the cross spectrum of copolar vertical signal to crosspolar vertical signal. | degree |
|  |  |  |
| radar\_cross\_spectrum\_of\_crosspolar\_h\_and\_copolar\_h\_power | Power of the cross spectrum of crosspolar horizontal signal to copolar horizontal signal. | dBm |
| radar\_cross\_spectrum\_of\_crosspolar\_h\_and\_copolar\_h\_phase | Phase of the cross spectrum of crosspolar horizontal signal to copolar horizontal signal. | degree |
|  |  |  |
| radar\_cross\_spectrum\_of\_crosspolar\_h\_and\_copolar\_v\_power | Power of the cross spectrum of crosspolar horizontal signal to copolar vertical signal. | dBm |
| radar\_cross\_spectrum\_of\_crosspolar\_h\_and\_copolar\_v\_phase | Phase of the cross spectrum of crosspolar horizontal signal to copolar vertical signal. | degree |
|  |  |  |
| radar\_cross\_spectrum\_of\_crosspolar\_h\_and\_crosspolar\_v\_power | Power of the cross spectrum of crosspolar horizontal signal to crosspolar vertical signal. | dBm |
| radar\_cross\_spectrum\_of\_crosspolar\_h\_and\_crosspolar\_v\_phase | Phase of the cross spectrum of crosspolar horizontal signal to crosspolar vertical signal. | degree |
|  |  |  |
| radar\_cross\_spectrum\_of\_crosspolar\_v\_and\_copolar\_h\_power | Power of the cross spectrum of crosspolar vertical signal to copolar horizontal signal. | dBm |
| radar\_cross\_spectrum\_of\_crosspolar\_v\_and\_copolar\_h\_phase | Phase of the cross spectrum of crosspolar vertical signal to copolar horizontal signal. | degree |
|  |  |  |
| radar\_cross\_spectrum\_of\_crosspolar\_v\_and\_copolar\_v\_power | Power of the cross spectrum of crosspolar vertical signal to copolar vertical signal. | dBm |
| radar\_cross\_spectrum\_of\_crosspolar\_v\_and\_copolar\_v\_phase | Phase of the cross spectrum of crosspolar vertical signal to copolar vertical signal. | degree |
|  |  |  |
| radar\_cross\_spectrum\_of\_crosspolar\_v\_and\_crosspolar\_h\_power | Power of the cross spectrum of crosspolar vertical signal to crosspolar horizontal signal. | dBm |
| radar\_cross\_spectrum\_of\_crosspolar\_v\_and\_crosspolar\_h\_phase | Phase of the cross spectrum of crosspolar vertical signal to crosspolar horizontal signal. | degree |

## Table 5 - standard names for Lidar measured quantities

| **Standard name** | **Description** | **Units** |
| --- | --- | --- |
| lidar\_copolar\_combined\_backscatter\_photon\_count | Lidar backscatter photon count from both gas molecules and particles (aerosols plus cloud particles), in the co-polarization (transmit) channel. Backscatter implies a scattering angle of 180 degrees. | unitless (0+) |
| lidar\_crosspolar\_combined\_backscatter\_photon\_count | Lidar backscatter photon count from both gas molecules and particles (aerosols plus cloud particles), in the cross-polarization channel. Backscatter implies a scattering angle of 180 degrees. | unitless (0+) |
| lidar\_colopar\_molecular\_backscatter\_photon\_count | Lidar backscatter photon count from gas molecules only, in the co-polarization (transmit) channel. Backscatter implies a scattering angle of 180 degrees. | unitless (0+) |
| lidar\_volume\_depolarization\_ratio | Ratio of the combined crosspolar signal to the combined copolar signal. | unitless (0-1) |
| lidar\_particle\_depolarization\_ratio | Depolarization ratio caused by particles (aerosols and cloud particles). This is the volume depolarization ratio with the effect of molecular depolarization removed. | unitless (0-1) |
| lidar\_backscatter\_ratio | Ratio of the sum of the combined copolar and crosspolar backscatter signals to the molecular backscatter signal. | unitless (1+) |
| lidar\_backscatter\_coefficient | Probability of 180 degree scattering per unit length per unit solid angle. This is a calibrated value that quantifies the level of backscatter from a sample volume. | m-1sr-1 |
| lidar\_extinction\_coefficient | Rate of power extinction per unit distance. This can also be considered the probability of photon scattering and absorption per unit path length. *(Theory of Lidar, © Springer International Publishing Switzerland 2015)* | m-1 |
| lidar\_optical\_depth | The aerosol optical depth or optical thickness (τ) is defined as the integrated extinction coefficient over a vertical column of unit cross section. Extinction coefficient is the fractional depletion of radiance per unit path length. (*https://www.researchgate.net*) | unitless (0+) |