Newbie's Guide to Atmospheric Sciences

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Research for Personal Gain

1.0 Abstract

The purpose of this paper is to conduct research into Atmospheric Sciences from the point of view of a computer scientist.

2.0 Terminology

Before getting started with any new concepts, a person must learn a "new language" of sorts. If the individual reading this paper right now is unfamiliar with statistics, radar, complex variables, signal theory, polarization, and other aspects of Atmospheric Sciences, they should ensure themselves that the concepts are understood.

2.1 Radar

The radar is one of the tools used by Atmospheric Scientists to measure the variables of a storm.

A *hydrometeor* is any product of condensation or sublimation of atmosphere vapor, whether formed in free atmosphere or at the Earth's surface; also any water particles blown by the wind from the Earth's surface. *Sublimation* is the transformation of a substance from solid phase to gaseous/vapor phase without passing through an intermediate liquid phase.

Pulse Repetition Time (PRT) is the frequency that the radar transmits a pulse.

2.2 Polarimetric Radar

Meteorological Moments

Absolute Reflectivity (Z_h)

Co-polar Reflectivity (Z_{hh})

Differential Reflectivity (Z_{dr})

The differential reflectivity (Z_{dr}) is the ratio of the horizontally polarized reflectivity when the pulse is transmitted horizontally to the vertically polarized reflectivity when the pulse is transmitted vertically

Differential reflectivity, Z_{dr}, is a measure of the difference in reflectivity return in the horizontal and vertical channels. It can be expressed as Z_{dr} (dB) = 10 log (Z_h/Z_v), where Z_h is horizontal reflectivity and Z_v is vertical reflectivity, both in mm^6m^{-3}. This value is dependent upon reflectivity weighted mean axis ratio, therefore, hail that either is approximately spherical or appears spherical to the radar through tumbling will yield a Z_{dr} that approaches zero. Negative Z_{dr} values have been shown to be associated with the presence of large hail (Balakrishnan and Zrnic, 1990a). In rain this value is greater because of the oblate nature of raindrops. In mixed phase precipitation, however, Z_{dr} may not reliably indicate the presence of rain if hail dominates the reflectivity because Z_{dr} is reflectivity weighted (Carey and Rutledge, 1998). [5]

Co-polar Correlation Coefficient (r_{hv})

Different Phase Shift (K_{dp})

Radial Velocity

Radial velocity is

2.3 Statistics

Cumulative density function (CDF)

Joint Density (discrete)

Let X and Y be discrete random variables. The ordered pair(X,Y) is called a two-dimensional discrete random variable. A function f_{XY} such that

$$f_{XY}(x, y) = \text{P[X = x and Y = y]}$$

Is called the joint density for (X,Y).

Bivariate Normal Distribution

A random variable (X, Y) is said to have a bivariate normal distribution if its joint density is given by:

$$F_{XY}(x,y)=\frac{\exp\left\{\frac{1}{-2(1-r^{2}}\left[(\frac{x-m_X}{s_X})^2-2r\left(\frac{x-m_X}{s_X}\right)\left(\frac{y-m_Y}{sy}\right)+\left(\frac{y-m_Y}{s_Y}\right)^2\right]\right\}}{2p\,s_X\,s_Y\sqrt{1-r^2}}$$

Time Series

Correlation

Autocorrelation

Autocorrelation is a signal correlated with itself. The process is a bit more involved in that we are searching for a correlation between a signal at the current time and a signal at a previous time. In a time series, it is the concept that the association between values of the same variable at different time periods is nonrandom – that is, that if autocorrelation does exist in a time series, there is correlation or mutual dependence between the values of the time series at different time periods. [4, p. 292]

The autocorrelation function may be used to detect deterministic components masked in a random background because autocorrelation functions of deterministic data (like sine wave) persist over all time displacements, while autocorrelation functions of stocastic processes tend to zero for large time displacement (for 0-mean time series).

What would we expect an autocorrelation at lag 0 to look like?

Autoregressive Models

2.3 Covariance Matrix

The variance of a random variable x with mean m is defined as E{(x-m)^2}. The covariance of two random variables xi and xj is defined as E{(xi-mi)(xj=mj)}. If the variables are uncorrelated, their covariance is 0.

2.2 Inphase and Quadrature

The inphase and quadrature of a signal are the real and imaginary parts, respectively.

$$\tan(f) = \frac{\text{Im}\,aginary}{real} = \frac{quadrature}{inphase}$$

2.3 Polarization

2.4 Power Spectrum

The power spectrum of a signal demonstrates the measure of

3.0 Simulation

3.1 Random Processes

In probability theory, there is

To describe a random experiment, we ask for three features:

1. The experiment is repeatable.
2. On any trial of the experiment, the outcome in unpredictable.
3. For a large number of trials of the experiment, the outcomes exhibit statistical regularity; that is, a definite average pattern of outcomes is observed if the experiment is repeated a large number of times.

In my opinion, these are all equally important features. You must be able to duplicate your results, and you should always be able to describe many runs of the experiment statistically.

The signal from a radar can be shown to have a normal distribution.

Stationarity

Many random processes have an important property: the statistical characterization of the process is time invariant. This is the definition of stationarity.

StochasticProcesses

A stochastic process $\{X(t), t \in T\}$ is a collection of random variables. That is, for each $t \in T$, X(t) is a random variable [8].

3.1.1 Gaussian Processes

Gaussian (or normal) distribution is the distribution of an m-dimensional random variable $x = (x_1,...,x_n)$ possessing the characteristic function of the form

$$j_e(l) = j_e(l_1,...,l_m) = E\exp\left\{i\sum_{k=1}^{m} l_k e_k\right\} = \exp\left\{i(l,a) - \frac{1}{2}(Al,\,l)\right\}$$

where l and a are column vectors, (a,b) denotes the scalar product of vectors a and b, and A is a symmetrical nonnegatively defined matrix. [7]

3.1.1 Power Spectra

The spectral behaviors of random processes are related to their temporal behaviors through appropriate transforms.

4.0 Raindrop Size Distributions

The raindrop size distribution (or simply DSD) plays an important role in determining the radar parameters considered so far. The reflectivity factor (for spherical drops) is the sixth moment of the DSD. The differential reflectivity is related to the reflectivity-factor weighted mean diameter.

5.0 Doppler Frequency Measurement

Definitions

Bistatic: a radar having transmitter and receiver located at different sites.
Central Limit Theorem:
COHO: Coherent Oscillator
DSD: Raindrop size distribution
Ergodicity:
IF: Intermediate Frequency
LNA: Low noise Amplifier
Monostatic: a radar having both transmitter and receiver located at the same sites (and, generally, sharing the same antenna). The large majority of radars currently in use are Monostatic.
Polarization Agility: refers to the ability to change the transmitted polarization state between any two orthogonal states on a pulse-to-pulse basis
PPI: Plan position indicator. The PPI is
PRF: Pulse Repetition Frequency. 1/PRI.
PRI: Pulse Repetition Interval. For pulsed radar, the interval between transmission pulses.
PRT: pulse repetition time
RHI: Range-height indicator. The RHI displays target altitude (height) on the vertical axis as a function of horizontal range along the horizontal axis. From the viewpoint of a polar plot, the RHI displays radial range with target elevation angle.

STALO: stable local oscillator. RF oscillator used as 1st local oscillator in the receiver (and for up conversion of TX signal in fully-coherent systems)

Wide-sense Stationary:

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