above ground level (AGL), 161
absolute humidity, 207
absorption
  atmospheric, 208
  of electromagnetic energy, 12, 18
  propagation and, 8
  water vapor, 210
absorption bands, 207
absorption lines, 207
accumulated rainfall, 325
active remote sensors, 49
Afternoon Constellation, 432
AGL. See above ground level
air density, 302
airborne radars
  in atmospheric research, 224
  C-band radar on, 386–388
  in hurricane research, 388–389
  NOAA WP-3D, 386–388
  as specialized radar, 43–44
  tropical cyclones studied with, 384–385
  vertically pointing, 58, 60, 208, 415
  WCR as, 224–225
aircraft echo, 196–198
Alberta Clipper, 417–418
algorithms
  legacy unfolding, 239
  multi-PRF dealiasing, 239–240
  for precipitation, 327
  radar, 324
  Sachidananda–Zrnic, 115
alternate transmission and reception, 130
altitude diagram, 373, 375
ambiguity, 52
amplitude, 128
anafront, 368–370
analog to digital converter, 37
angular coordinates, 84
angular frequency, 121
anisotropic turbulence, 201
annual average precipitation, 333
anode, 27
anomalous propagation, 74–77, 184, 188–189
antenna beam pattern, 33, 289–290
antenna section, 32–34
ARM. See Atmospheric Radiation Measurement
A-scope display, 59
ASOS. See Automated Surface Observing System
Atlantic basin, 385
atmosphere, 11, 441–442
atmospheric absorption, 208
atmospheric attenuation, 208–209
atmospheric density, 274
atmospheric gases, 207–212
Atmospheric Radiation Measurement (ARM), 224, 424
atmospheric refraction
  radar ray and, 71
  of radar ray path, 74
  standard, 69
atmospheric research, 224
atmospheric structure, 428–432
A-Train, 432
attenuation, 83
  atmospheric, 208–209
  by atmospheric gases, 207–212
  Beer-Lambert law on, 206
  of C-band radar, 215–216
  by cloud droplets, 212–214
  coefficient, 206
  convective updrafts causing, 225
differential, 133, 139–141, 205–206
  by hail, 219–224
  large-wavelength radars and signal, 24
  liquid coefficient and, 212
  normalized specific, 221
Index

attenuation (Continued)
one-way, 207, 211, 415–416
one-way differential, 207
polarimetric correction and, 217–219
from raindrops, 216
by rainfall, 214–220
reflectivity negative bias causing, 216
short-wavelength radars and, 224–225
specific differential, 207
total, 207
two-way, 207
Australian meteorological radar network, 247
autocorrelation function, 120, 122
Automated Surface Observing System (ASOS), 311
Automated Volume Scan Evaluation and Termination (AVSET), 242
average transmitted power, 55–56
AVSET. See Automated Volume Scan Evaluation and Termination
axis ratio, 135
azimuth ray plot, 157–158, 160
B2 Stealth Bomber, 85
backing, of winds, 256
backscatter differential phase shift, 150, 152–153
backscattered power, 86–87
backscattered waves, 91–92, 133–134
BAMEX. See Bow Echo and Mesoscale Convective Vortex Experiment
band designations, 24
baseline, of radars, 296
BATCH waveform, 240
Battan, 323
beam axis, 84
beam blockage, 287–288
beam pattern, 45, 66
beamwidth, 90, 240
Beer-Lambert law, 206
best-fit curve, 269–270
bilinear interpolation, 291
biological echo, 184, 191–194
biological sources, 191–194
birds, 170–172
birds and bats echo, 193–194
boundary conditions, 305–306
boundary layer, 263
bow echo, 341, 346
Bow Echo and Mesoscale Convective Vortex Experiment (BAMEX), 280, 341
Bragg, William H., 17, 200–201
Bragg, William L., 17, 200–201
Bragg diffraction. See Bragg scattering
Bragg echo, 201
Bragg scattering, 17–18, 184, 415
coherent return of, 201
from crystal lattice, 200–203
layers in, 202
turbulence in, 202
wind profilers and, 261
bright band effect, 342, 377–379
C-130 Hercules aircraft, 316, 365
calibration, 55–56
Canadian operational radar network, 246
canting angle, 135, 137, 141–142
CaPE. See Convection and Precipitation/Electrification Experiment
CAPPI. See Constant Altitude Plan Position Indicator
Cartesian coordinate system, 290–292
VAD technique and, 264
wind components in, 252
Cartesian wind components, 293
cathode, 27
cathode ray tube display, 57
C-band radar
on aircraft, 386–388
attenuation of, 215–216
CSAPR, 160, 168
melting hail on, 222–223
network, 246
observations, 177–180
polarimetric variables of, 169–170
reflectivity factor of, 216
RHI composite of, 217
CD/WO. See continuous Doppler without unfolding
chaff, 184, 196–198
circular polarization, 20
circulators, 31–32
cirrus clouds, 413, 425–426
clear air echo, 183
clear air mode, 237
clear air signal, 105
cloud droplets, 212–214
Cloud Profiling Radar (CPR), 45, 432
cloud radars, 414
applications of, 421–432
atmospheric and storm structure from, 428–432
cirrus clouds and, 426
cloud vertical motions by, 421–424
data from, 417–421
global cloud properties and, 432
pros and cons of, 415–417
Rayleigh scattering and, 416
short-wavelength radars as, 100, 415–416
statistical properties determined by, 424–427
clouds. See also comma head clouds
cirrus, 413, 425–426
comma tail, 363, 367–370
convective, 317, 391–392
dynamics of high, 427
global properties of, 432
radar, 414
trade cumulus, 213–214
trade wind, 322
two-dimensional optical array probe measurements of, 317
vertical motions of, 421–424
vertical radial velocity of high, 427
wall, 352
CloudSat satellite, 415, 420, 432
cloud–top generating cells, 374–376
cloud–top region, 429
clutter filtering, 190
CoCoRaHS. See Community Collaborative Rain, Hail and Snow Network
coherence, 201
coherent oscillator (COHO), 27
cold air advection, 256
cold fronts
radar reflectivity of, 420
synoptic-scale, 346
cold pool, 341, 345
cold-frontal rainband, 368–370
comma head clouds, 363
bright band effect in, 377–379
cloud–top generating cells in, 374–376
cyclones with, 372
elevated convection in, 371
precipitation bands in, 371–374, 376
radar reflectivity of, 372
rain–snow line in, 377–379
vertical radial velocity of, 372
of winter cyclones, 373
comma tail clouds, 363, 367–370
Community Collaborative Rain, Hail and Snow Network (CoCoRaHS), 311–312
complex notation, 7
complex pulse pair, 166
concentric eyewall, 392
conical beam, 90–91
Constant Altitude Plan Position Indicator (CAPPI), 61–62
constructive interference, 11, 201
continuity equation, 303
continuous Doppler without unfolding (CD/WO), 240
continuous surveillance using the Sachidananda-Zrnic (SZ-2) algorithm/continuous Doppler using the SZ algorithm (CS-SZ2/CD-SZ2), 239
continuous surveillance/continuous Doppler-with unfolding (CS-W/CD-W), 238–239
contributing volume, 89–91
Convection and Precipitation/Electrification Experiment (CaPE), 288–289
convective bands, 393
convective bursts, 390, 397–398
convective clouds, 317, 391–392
convective motions, 403
convective scale flow patterns, 259–261
convective storms
azimuth ray plot of, 157–158, 160
correlation coefficient of, 147–148
differential reflectivity of, 147–148, 158
hailstones in, 142–144, 147–148
leading line-trailing stratiform, 156–157
mesoscale, 159
radial velocity of, 147
convective updrafts, 225
conventional radars, 20
convergence updrafts, 225
convergence belt, 430
co-polar channel, 36
co-polar correlation coefficient, 159, 164–168
of cyclones, 167
of S-band observations, 171–172
covariation, 168–170
co-polar power, 128
correlation coefficient
of convective storms, 147–148
of polar, 159, 164–168, 171–172
of hailstorm, 143–144
of Hurricane Arthur, 396
in rain–snow line, 380
sea clutter and, 187
of tornadoes, 353, 355, 410
CPR. See Cloud Profiling Radar
Cressman weighting function, 292
cross-polar channel, 36
cross-polar power, 128
crystal lattice, 201
CSAPR C-band, 160, 168
CS-SZ2/CD-SZ2. See continuous surveillance using the Sachidananda-Zrnic (SZ-2) algorithm/continuous Doppler using the SZ algorithm
CS-W/CD-W. See continuous surveillance/continuous Doppler-with unfolding
Cyclone Detection Radar Network, 247
cyclones. See also tropical cyclones
comma head of, 372
co-polar correlation coefficient of, 167
differential reflectivity of, 167
extratropical, 361–362, 376, 418
marine, 418–419
mesocyclone, 352
mesostructure, 363–367
reflectivity at horizontal polarization of, 167
winter, 362, 364
WSR-88D radar and, 366
cylinder diameter, of conical beam, 90–91
data, 331. See also Doppler data
from cloud radars, 417–421
filtered and unfiltered Doppler data, 287
Level-I, 236
from multiple Doppler syntheses, 290–292
raw, 284–286
single beam Doppler, 285
spectral width, 420, 428
in spherical coordinate system, 290–291
data distribution
of TDWR, 243–245
of WSR-88D, 234–236
debris, dust and smoke echo, 195
debris ball, 353
decorrelation time, 93
Department of Defense (DOD), 233
deployable radars, 41–43
depolarization, 132, 146
destructive interference, 11
dielectric sphere, 95–96
differential attenuation, 133, 139–141, 205–206
differential phase shift
backscatter, 150, 152–153
of leading line-trailing stratiform convective storms, 156–157
positive, 155
propagation, 150–152
specific, 152–155
differential reflectivity, 133–134, 139–140
of convective storms, 147–148, 158
of cyclones, 167
of hailstorm, 143–144, 356
of Hurricane Arthur, 396
in rain-snow line, 380
of S-band observations, 159, 171–172
of tornadoes, 353, 355, 410
diffraction, 33
diffuse reflection, 13
digital receiver, 36
dipole, 3, 68, 95
dipole antenna, 5–6
directional antenna, 90
discrete Fourier transform, 117
disdrometer, 220
impact, 313
Joss-Waldvogel impact, 314
optical, 315
Parsivel optical, 315
precipitation and, 313–315
two-dimensional video, 134, 136–138, 313–314
video, 313–314
distributed target
contributing volume for, 89–91
radar cross section of, 91–94
radar equation for, 94
divergence, 253
DOD. See Department of Defense
Doppler, Hans Christian, 105
Doppler data
ambiguities and editing of, 287–290
filtered and unfiltered radial velocity of, 287
ground clutter and, 287–288
range and velocity ambiguities of, 288–289
range gate locations and, 284
raw, 284–286
Doppler decomposition, 425
Doppler dilemma, 109–113
Doppler frequency shift, 105, 108
Doppler on Wheels (DOW), 164, 165, 185–186
Doppler radar, 105, 190
convective scale flow patterns and, 259–261
dual-Doppler lobes for, 300
frequency, 37
fronts and, 257–259
high PRF of, 110
of Hurricane Olivia, 388
kinematic properties using, 265–271
large-scale flow patterns and, 255–257
network design
  deployment of, 279–281
  meteorological considerations of, 201
  sampling limitations of, 281–283
  siting and logistics of, 283–284
  objectives of, 253–254
  phase shift of, 150
phased-array antenna and, 40–41
polarization-agile and diverse, 131
radial velocity from, 256–259
radial velocity measurements and, 106, 254–255
vertical air motion and, 421
wind field analyzed by, 405
and winter cyclone, 373–374
Doppler radial velocity, 26
Doppler shift, 128
Doppler spectra
  ground clutter contamination and, 191
  ice particles measured by, 118
  and mean radial velocity, 119–120
  measuring, 116, 119–122
  spectral moments and, 117–119
  of targets, 116–117
  of weather, 116–117
  of WSR-88D radar, 115–116
Doppler velocity, 121, 148, 417
double eyewall, 391–392
downbursts, 260, 281, 339, 358
downdrafts, 281, 339, 345
  updrafts and, 115, 117, 349–351, 376, 397, 418, 422–424
downward beam, 419
downward integration, 304–306
downward motion, 425
DPR. See Dual-frequency Precipitation Radar; dual-polarization retrievals
drop oscillations, 136
dryline, 227–228, 430
dual polarization, 326–329
dual-Doppler lobes, 298–299, 300–302
Dual-Frequency Precipitation Radar (DPR), 45–46, 432
dual-polarization Doppler radar, 146, 172
dual-polarization framework, 132
dual-polarization retrievals (DPR), 127–128, 328
dual-polarization variables, 170–172
dual-wavelength radar, 210
dual-wavelength technique, 213
ducting, 75
duty cycle, 55–56
earth
  climate of, 413–414
  curvature of, 67, 72–73
East Pacific basins, 385
echo, 50
  aircraft and chaff, 196–198
  amplitude, 38
  biological sources of, 184, 191–194
  from birds and bats, 193–194
  bow, 341, 346
  Bragg, 201
  clear air, 183
deois, dust and smoke, 195
  flare, 290
ground, 420
  ground clutter, 186
  gust front, 193
  hook, 57, 112, 350
  hydrometeors and radar, 183
  from insects, 191–193
  mean power, 117
  non-meteorological sources of, 170–172, 198–200
  radio interference causing, 200
  receiver noise causing, 199–200
  second-trip, 52–53, 289
  sidelobes and multiple scattering, 289–290
  smoke plumes, 197
  stratiform, 376
  sun spikes causing, 197
  thin line, 418
  tornado debris, 195
  weather, 188–190
ELDORA radar, 399–402
NSF/NCAR, 388–389
  radar reflectivity factor from, 63, 398
  radial velocity from, 63
electric displacement vector, 2
electric field, 4
  of dipole, 3
  intensity, 2
  oppositely charged plates and, 2
  vector, 18–19
electrical currents, 4
Index

electromagnetic radiation, 1–2
electromagnetic spectrum, 9, 11
electromagnetic waves, 2
 absorption and, 12, 18
 Bragg scattering and, 18
 interactions of, 9–11
 linearly polarized, 129
 matter interacting with, 11–12
 oscillation in, 7
 plane of, 128
 polarization of, 18–20
 pulses of, 53–54
 spectrum of, 8–9
 elevated convection, 366, 371
elevation angle, 70, 73, 273
elevation cuts, 236, 244
equations, 302
 continuity, 303
distributed target radar, 94
 Maxwell’s, 6–8
 radar, 82, 87–89, 94
 for ray path, 441–442
 weather radar, 82, 95–100
equivalent radar reflectivity factor, 100, 329
equivalent spherical diameter (ESD), 313
 European weather radar network, 247
 EVAD. See extended velocity-azimuth display
 EVAD technique, 273–274
 exponential size distribution, 318–320
 extended velocity-azimuth display (EVAD), 264, 275
 extratropical cyclones, 361–362, 376, 418
 eye, 391
 eyewall
 concentric, 392
 convective bursts in, 397–398
 double, 391–392
 hot tower in, 400
 of Hurricane Arthur, 395
 radial velocities in, 394
 replacement cycle, 392
 structure, 384, 391
 tropical cyclone and radar structure of, 395–398

Fermat’s principle, 69, 441–442
FFD. See forward flank downdraft
filtered Doppler data, 287
 Finite Impulse Response, 157
 flare echo, 290
 flooding, 407–408
 focus coil, 28
 folded, radial velocity, 113–115
 folded, velocities, 108
 forward flank downdraft (FFD), 350, 352
 forward flank gust front, 350
 Fourier coefficients, 266–268
 frequency, 128
 angular, 121
 band designation and, 24
 Doppler radar, 37
 Doppler shift in, 105, 108
 pulse repetition, 50–51, 108, 110, 130, 236
 radio, 27
 ultra-high, 261
 very high, 261
 wavelength and, 9, 23–25
 frontal boundary, 346–347
 frontal squall lines, 345–349
 frontal zones, 368
 fronts
 anafront, 368–370
 cold, 346, 420
 Doppler radar and, 257–259
 gust, 193, 344, 350
 katafront, 368–370
 radar beams passed through, 258
 radial velocity patterns of, 258–260
 front-to-rear flow, 342, 344
 fuzzification, 176
 fuzzy logic, 173, 175, 190
 gain function, 33, 83, 84
 gamma distribution, 222, 318–320
 Gaussian distribution, 94
 GBVTD. See Ground-Based Velocity Track Display
generating cells, 366
 geographic locations, 284
 geometric optics, 16
 geometry, VAD, 265
 Geostationary Operational Environmental Satellite-East (GOES-E), 401–402
global cloud properties, 432
 Global Precipitation Mission (GPM) satellite,
 46, 386, 415
 FAA. See Federal Aviation Administration
 fall streaks, 366
 Fast Fourier Transform, 117
 Federal Aviation Administration (FAA), 233, 242–243
 feedhorn, 30, 32
hurricane research by, 389–390
precipitation measurement by, 331–334
radar reflectivity measured by, 390
short-wavelength radars and, 224–225
spaceborne radars, 332–334
TRMM and, 432
GOES-E. See Geostationary Operational
Environmental Satellite-East
GPM. See Global Precipitation Mission
satellite
GPM Core Observatory, 332–333
gravity waves, 427
Great Atlantic Hurricane, 383
ground clutter, 74, 183–184
contamination, 191
Doppler data and, 287–288
echo, 186
mitigation, 188–191
radial velocity and, 288
reflectivity and, 288
on RHI, 185
WSR-88D radar suppression of, 240
ground echo, 420
ground reflection, 419
Ground-Based Velocity Track Display
(GBVTD), 406
gust fronts, 193, 344, 350

haboobs (wall of dust), 196
hailstones, 88, 141
attenuation by, 219–224
C-band radar of melting, 222–223
in convective storms, 142–144, 147–148
hydrometeors and melting, 142, 221–223
observations of, 143–144
supercell thunderstorms detection of,
356–358
hailstorms
 correlation coefficient of, 143–144
differential reflectivity of, 143–144, 356
reflectivity factor of, 143–144, 356
harmonic components, 269–270
hazardous mode, 244
hazardous weather, 343–345
HCA. See hydrometeor classification
algorithm
HCIs. See Human Control Interfaces
HCR. See HIAPER Cloud Radar
HIAPER. See High-performance
Instrumented Airborne Platform for
Environmental Research
HIAPER Cloud Radar (HCR), 224, 428
HID. See hydrometeor identification
High Altitude Imaging Wind and Rain
Airborne Profiler (HIWRAP), 389
high-density graupel, 180
High-performance Instrumented Airborne
Platform for Environmental Research
(HIAPER), 428
HIWRAP. See High Altitude Imaging Wind
and Rain Airborne Profiler
hook echo, 57, 112, 350
horizontal air flow, 280
horizontal cross sections, 62–63
horizontal polarization (H), 127, 140
horizontally polarized, 20
hot towers, 390, 398, 400
hotplate, 330–331
Human Control Interfaces (HCIs), 236
humidity, absolute, 207
hurricanes
 airborne radar research on, 388–389
Alice, 384
Andrew, 395, 404
Arthur, 395–397
in Atlantic and Pacific basins, 385
Dennis, 400
with double-eyewall structure, 392
GPM research of, 389–390
Ike, 392, 394, 406, 408
Irene, 408–410
Ivan, 409
Katrina, 385, 405–406
Lili, 399, 404
Matthew, 170–172
Olaf, 390
Olivia, 387
Rita, 397–399, 402
satellite radar systems research on,
389–390
stationary band complex in, 393
three-dimensional depiction of, 390
vortex bands in, 404
hybrid scan, 326
hydrometeor classification algorithm (HCA),
172–180
hydrometeor identification (HID), 172
hydrometeors, 9, 98–99
classifications of, 172–176
fuzzy logic, 175
LDR and properties of, 145–146
melting hail and, 142, 221–223
mixed-phase precipitation and, 166–168
radar echoes from, 183
hydrometeors, (Continued)
  terminal fall velocity of, 274–275
  WSR-88D classification of, 327

ice crystals, 87, 154–155
  ice particles, 376, 422
    Doppler spectra measuring, 118
    rimed and unrimed, 423
    size distribution of, 316–318
    terminal velocity of, 423

ice storm, 274

idealized atmosphere, 69–72

IHOP. See International H₂O project
  Imaging Wind and Rain Profiler (IWRAP), 389

impact disdrometer, 313

inertial subrange, 201

inner-core rainbands, 401, 403

inversion, 201

interference, 11, 184, 200, 201

International H₂O project (IHOP), 227, 429

international operational radar networks, 246–247

International Standard Atmosphere (ISA), 69

intrinsic polarization variables, 127, 129

inversions, 69

ISA. See International Standard Atmosphere

isotropic antenna, 83–84

isotropic turbulence, 201

IWRAP. See Imaging Wind and Rain Profiler

Japan Aerospace Exploration Agency, 332

Joint Polarization Experiment, 327

Joss-Waldvogel impact disdrometer, 314

Kₐ-band magnetron, 39

Kₐ-band radar, 414, 419

KAMA radar, 193

KARX WSR-88D radar, 364–365

katafront, 368–370

K-band radar, 208, 210

KBOX WSR-88D radar, 167

Kₖₛ, see specific differential phase

Kelvin-Helmholz instability, 404

KFFC WSR-88D radar, 345

KFTG WSR-88D radar, 143–144

KFWS WSR-88D radar, 356

KGRK WSR-88D radar, 194

KGSP WSR-88D radar, 291

KHGX WSR-88D radar, 394

KHTX WSR-88D radar, 355

KILX WSR-88D radar, 77

KIND WSR-88D radar, 272

kinematic properties
  Doppler radar used for, 265–271
  Fourier components and, 268
  of wind field, 252–254, 265, 268

KLBB WSR-88D radar, 195–196

KLCH WSR-88D radar, 343

KLOT WSR-88D radar, 379

Klystron transmitter, 25–26

components of, 27–28

as power amplifier, 27

KMIX WSR-88D radar, 410

KMLB WSR-88D radar, 171

KOKX WSR-88D radar, 199, 373

KSLX WSR-88D radar, 346–347

KTLX WSR-88D radar, 157–159, 172

KTVX WSR-88D radar, 97

KVNX WSR-88D radar, 162, 174

lake effect snowband, 187, 429, 431

large-scale flow patterns, 255–257

large-wavelength radars
  power generation of, 55, 417
  short-wavelength and, 55
  signal attenuation of, 24

Lₚₑ, see linear depolarization ratio

leading line-trailing stratiform convective storms, 156–157

leading stratiform, 348–349

least squares regression, 267

legacy relationships, 323

legacy unfolding algorithms, 239

Level-I data, 236

Level-III products, 236

LFR. See lower fuselage radar

lidars, 414, 427

linear depolarization ratio (Lₚₑ), 145–149, 428

linearly polarized, 20

linearly polarized electromagnetic waves, 129

liquid attenuation coefficient, 212

liquid water content (LWC), 154

  from dual-wavelength technique, 213
  vertical cross sections of, 214

LNA. See low-noise amplifier

logistics and siting, 283–284

lossless, 83

low-density graupel, 180

lower fuselage radar (LFR), 386–387

low-level mesocyclone, 352

low-noise amplifier (LNA), 36

low-pass filter, 38
low-pressure centers, 362
LWC. See liquid water content

magnetic field, 4
magnetic permeability, 4
magnetron transmitters, 26, 38–40
main lobe, 33–34
marine cyclone, 418–419
Marshall, J. S., 318
Marshall-Palmer distribution, 303, 319
mass-weighted droplet axis ratio, 154
Master System Control Function (MSCF), 236
matter, 11–12
maximum drop diameter, 138
Maxwell, James Clerk, 6
Maxwell’s equations, 6–8
MCS. See mesoscale convective system
mean echo power, 117
mean phase change, 122
mean radial velocity, 119–120
membership functions, 175
mesoscale convective system (MCS), 159, 274
frontal squall lines and, 345–349
hazardous weather signatures in, 343–345
leading stratiform precipitation in, 348–349
radar reflectivity within, 342
radar-observed life cycle of, 339–341
radial velocities within, 342
research radar observing, 341–343
thunderstorms and, 338–339
trailing stratiform precipitation region, 342
mesoscale convective vortex, 341
mesoscale structures
comma head clouds, 371–380
bright band effect, 377–379
cloud-top generating cells, 374–376
elevated convection, 371
precipitation bands, 371–374, 376
rain-snow line, 377–379
comma tail clouds, 367–370
radar observing, 366–367
mesoscale weather, 361
microbursts, 281, 357
microwave energy, 126, 220
microwave frequencies, 50, 105
mid-level mesocyclone, 352
mid-tropospheric winds, 349–350
Mie, Gustav, 15
Mie scattering theory, 14–17, 217–218, 416
minimum detectable signal, 56
mixed-phase precipitation, 100
hydrometeors and, 166–168
polarimetric variables and, 177–180
in thunderstorms, 149
$Z_{DR}$ measurements in, 141–145
mobile radars, 9, 41–43
modulator, 27
molecules, polarization of, 68
monitor mode, 244
monochromatic, 7
Monopulse Cassegrainian Antenna, 35
MPAR. See Multi-Function Phased-Array Radar
MPDA. See multi-PRF dealiasing algorithm
MSCF. See Master System Control Function
Multi-Function Phased-Array Radar (MPAR), 41
multiple Doppler syntheses
data interpolation from, 290–292
radial velocities transformation and, 292–302
vertical motion retrievals in, 304–306
multiple Doppler wind syntheses, 279, 306
multiple scattering, 289–290
multi-PRF dealiasing algorithm (MPDA), 239–240
narrow cold-frontal rainband (NCFR), 368
NASA. See National Aeronautics and Space Administration
NASA NPOL S-band radar, 130, 140
National Aeronautics and Space Administration (NASA), 389
National Center for Atmospheric Research, 316
National Centers for Environmental Information (NCEI), 236
National Science Foundation/National Center for Atmospheric Research (NSF/NCAR), 25
National Weather Service (NWS), 233, 271
NCAR CP-4 radar, 288–290
NCAR ELDORA, 399
NCAR S-Polka radar, 130
NCEI. See National Centers for Environmental Information
NCFR. See narrow cold-frontal rainband
NCO. See numerically controlled oscillator
network coverage, 233–234
network design
deployment of, 279–281
meteorological considerations of, 201
sampling limitations of, 281–283
network design (Continued)
siting and logistics of, 283–284
neural networks, 190
Next-Generation Radars (NEXRAD), 233
NOAA P-3 aircraft tail radar system, 44, 342, 389
NOAA WP-3D radar systems, 386–388
nocturnal inversion, 189
noise, 56, 288, 305
noise filter, 156
non-meteorologic echo, 170–172, 198–200
normalized specific attenuation, 221
normalized standard deviation, 296
Northrop Grumman B-2 Spirit, 85
NSF/NCAR. See National Science Foundation/National Center for Atmospheric Research
NSF/NCAR ELDORA radar, 388–389
NSF/NCAR Gulfstream V aircraft, 428
numerically controlled oscillator (NCO), 37
NWS. See National Weather Service
Nyquist interval, 108, 284
Nyquist velocity, 108–109, 119, 257

oblate raindrops, 135, 154–155
observation network, 306
one-way attenuation, 207, 211, 415–416
one-way differential attenuation, 207
Operational Program for the Exchange of Weather Radar Information (OPERA), 247–248
operational radars, 100
operational weather radar networks, 232
optical array probes, 315–316
optical disdrometer, 315
optical scattering, 16
orifice manual rain gauge, 312
orthogonal particle motion, 292–302
orthogonal wind components, 302–304
oscillation
  in dipole antenna, 5–6
drop, 136
  in electromagnetic wave, 7
  propagation and, 19
P-3 radar scanning, 45
Palmer, W. Mc K., 318
Parsivel optical disdrometer, 315
particle fall velocity, 273
particle size distribution, 316–317
  exponential, 318–319
gamma, 319

of precipitation, 134
short-wavelength radars and, 93
passive remote sensors, 49
peak transmitted power, 55
Pearson correlation coefficient. See correlation coefficient
permittivity of free space, 3
phase, 149–150
phase angle, 121, 128
phase change, 107, 226
phase measurements, 107–108
phase shift, 25
  backscatter differential, 150, 152–153
differential, 151, 153
  of Doppler radar, 150
  propagation differential, 150–152
phasor sum, 91
photons, 12
plan position indicator (PPI), 57, 113, 200, 324
  of K-band, 210
S-band observations of, 143, 210
supercell thunderstorms shown by, 58
of winter storm, 60
from X-band radar, 220
plane electromagnetic wave, 128
polarimetric attenuation correction, 217–219
polarimetric fields, 149
polarimetric observations, 163
polarimetric radars, 20
  characteristics, 221–223
  quantities measured of, 130–132
polarimetric variables, 127
  covariation of, 168–170
  \( K_{dp} \) and, 169
  mixed-phase precipitation and, 177–180
  reflectivity at horizontal polarization and, 169
S-band and C-band, 169–170
polarization. See also reflectivity at horizontal polarization
circular, 20
depolarization and, 132, 146
Doppler radar and, 131
  of electromagnetic waves, 18–20
horizontal, 127, 140
intrinsc variables, 127
  of molecules, 68
  phase and, 149–150
  plane of, 18–19, 126
propagation variables, 127
vertical, 127
waveguide switches and, 29
polarization diversity radars, 20, 130–131
polarization-agile radars, 20, 25, 130–131
polarization-dependent reflectivity factors, 133
power, 54
amplifier, 27
average transmitted, 55–56
backscattered, 86–87
co-polar, 128
cross-polar, 128
large-wavelength radars generation of, 55, 417
mean echo, 117
peak, 55
power flux density, 15, 83–85
PPI. See plan position indicator
precipitation
annual average, 333
bands, 366
in comma head clouds, 371–374, 376
disdrometers and, 313–315
frontal zones and, 368
gauges measuring, 311–313, 328
hotplate gauge of, 330–331
from Hurricane Ike, 408
from Hurricane Irene, 409
intensity or rate, 311
leading stratiform, 348–349
measuring from space, 330–332
mixed-phase, 141–145
mode, 237
optical array probes measuring, 315–316
particle size distribution of, 134
radar, 332
radar estimation challenges of, 323–326
radar reflectivity factor and, 321
radar remote sensing of, 319–321
as reciprocal media, 129
signal, 105
snow water equivalent, 329–331
storm total, 311
terminal velocity of, 422
total accumulated, 311
trailing stratiform region of, 342
in tropical cyclone, 407–408
using Z-R relationships, 322–323, 325
winter, 329–330
in winter cyclone, 374, 376
WSR-88D and algorithm for, 327
precipitation estimation
by radar, 310–311, 323–326
using dual polarization, 326–329
pressure broadening, 207
PRF. See pulse repetition frequency
primary rays, 209
principal band, 392
product, 331
prolate raindrops, 135, 154–155
propagating wave, 8
propagation, 8
anomalous, 74–77, 184, 188–189
differential phase shift, 150–152
oscillation and, 19
variables with polarization, 127
pulse duration, 51, 54, 89
pulse length, 54
Pulse Pair Processor, 107
pulse period, 50–51
pulse repetition frequency (PRF), 50–51, 108, 110, 130, 236
pulse volume, 72–74, 293–295
pulse-pair processor, 120
purple haze, 113, 115, 239
QLCS. See quasi-linear convective system
quadrature demodulation, 37
quantum mechanics, 12
quasi-linear convective system (QLCS), 341
quasi-vertical profile (QVP), 145–146
radar. See also WSR-88D radar; specific radars
algorithms, 324
baseline of, 296
bright band effects of, 377–379
cloud, 414–415
configuration of, 129–130
cyclone mesostructure monitored by, 363–366
different locations of, 293
frequencies, 417
geometry of two, 301
hazardous weather signatures on, 343–345
K-band and W-band, 414
mesoscale structures observed by, 366–367
precipitation, 332
precipitation estimation by, 310–311, 323–326
PRF and, 50–51
pulse resolution of, 54
rainfall accumulation, 328
range and ambiguity, 50–53
radar. See also WSR-88D radar; specific radars (Continued)
refractivity retrievals, 228–229
remote sensing, 319–321
research, 341–343
sidelobe energy striking, 186
signatures, 354–356, 358
snowflake signatures on, 377–378
spaceborne, 44–45, 330–334
spherical coordinate system data from, 290–291
thunderstorms and geometry of, 294
thunderstorms scanned by, 282–283
transmitted and received signals of, 53–56
tropical cyclone hazards detected by, 405–411
tropical cyclones, 383–386
wave guides for, 29
wavelengths, 126–128, 139–141, 212
W-band, 61
radar antenna, 24, 33
backscattered power collected by, 86–87
effective area of, 86–87
NOAA P-3 aircraft tail, 44
sun spikes and, 199
3-D gain function of, 35
transmitted power of, 55–56
2-D gain function of, 34
radar beams, 258, 283
radar constant, 98
radar cross section, 15–17, 85
of dielectric sphere, 95–96
of distributed target, 91–94
radar reflectivity factor and, 94
Radar Data Acquisition Unit (RDA), 234
radar detection, 85
radar displays, 56–63
radar echo, 429
from hydrometeors, 183
over Florida, 198
sidelobe influencing, 35
smoke plumes in, 197
radar equations, 82, 87–89, 94
radar fine line, 344–345, 358, 429
radar geometry, 56–63
radar images, 77, 361–362
radar networks, 246–248
radar polarimetry, 127–130
Radar Product Generator (RPG), 235–236
radar ray, 13, 66
atmospheric refraction and, 71
water vapor absorption and, 210
radar ray path, 66
atmospheric refraction of, 74
calculating, 75
earth curvature and, 72–73
factors influencing, 67–69
in idealized atmosphere, 69–72
weather conditions and, 76
radar reflectivity
of bow echo squall line, 346
of cold front, 420
of comma head clouds, 372
Doppler decomposition and, 425
from ELDORA radar, 398
GPM measuring, 390
of Hurricane Dennis, 400
of Hurricane Ike, 394
of Hurricane Irene, 409
of Hurricane Olivia, 388
of Hurricane Rita, 399
within MCS, 342
precipitation and, 321
radar frequencies in, 417
rainfall and, 320
Rayleigh scattering and, 319–320
three-dimensional depiction of, 390
of tornadoes, 355
of tropical cyclone, 391
of winter cyclones, 364, 379
$Z_E$–$S$ scatterplot, 330
radar reflectivity factor
from ELDORA radar, 63
equivalent, 100
of Hurricane Ike, 406
of Hurricane Katrina, 406
precipitation and, 321
radar cross section and, 94
rainfall and, 320
second trip echo and, 53
during supercell thunderstorms, 97, 111–112, 409
of tornadoes, 410
WCR and, 365
weather radar equations and, 96–97
of WSR-88D, 111–112
radar remote sensing, 319–321
radar structure
of eyewall, 395–398
of tropical cyclone, 399–404
radar-observed life cycle, 339–341
radial velocities, 49, 105
best-fit curve and, 269–270
of bow echo squall line, 346
cold-frontal rainbands, 369
convective storms, 147
couplet, 260–261
Doppler radar and, 26, 106, 254–255
Doppler radar and winds, 256–259
by ELDORA radar, 63
in eyewall, 394
fields, 347
filtered and unfiltered Doppler data, 287
folded, 113–115
ground clutter and, 288
of Hurricane Arthur, 396
of Hurricane Olivia, 388
insect echo bloom in, 192
within MCS, 342
mean, 119–120
measuring, 106
microburst outflow and, 357
Nyquist velocity and, 109
orthogonal particle motion transformation of, 292–302
patterns, 254–255, 258–260
phase measurements and, 107–108
receiver noise and, 200
reflectivity and, 285–286
sea clutter and, 187
second-trip echoes and, 53
during supercell thunderstorms, 111–112, 260
of tornadoes, 353, 355, 410
unfolded, 114
vertical, 225
wind components and, 297–299
of WSR-88D, 111–112
radiated energy, 5–6
radiation pattern, 17
radio acoustic system, 262
radio frequency (RF), 27, 27n1
radio interference, 184, 200
radio refractivity, 69, 206
radio-acoustic sounding system, 42
radius of influence, 292
radius of maximum winds, 405
radome, 32–33
rainbands, 281, 290
cold-frontal, 368–370
complex, 401
inner-core, 401, 403
spiral, 404
raindrops
attenuation from, 216
axis ratio of, 135
canting angle of, 137
composite spectra of, 317
distortion of, 86
exponential size distribution of, 320
fall speeds of, 212
fall trajectories of, 137
Mie scattering and sizes of, 217–218
oblate and prolate, 135, 154–155
Rayleigh backscattering and, 417
reflectivity and differential reflectivity of, 139
shapes and sizes of, 134–138
size distribution of, 218, 313, 316–318, 322
terminal velocity of, 422
two-dimensional cloud optical array probe measurements of, 317
two-dimensional video disdrometer measurements of, 136–138
\(Z_{DR}\) measurements of, 138–141
rainfall
accumulated, 325
accumulation of, 328
attenuation by, 214–220
radar reflectivity factor and, 320, 324
wind profilers and, 272
rainfall attenuation ratio, 214–215
rain-snow line, 377–380
rain-snow transition, 167
range ambiguities, 288–289
range gate, 284
range gate spacing, 283
range-height indicator (RHI), 289, 339, 388
composite, 217
ground clutter on, 185
polarimetric fields on, 149
scanning strategy of, 59
spherical coordinates used by, 57
of thunderstorms, 110, 113–114
of winter storm, 197
Rapid Scan X-Band dual-Polarization Radar (RAXPOL), 355
Rapid-Scan Doppler on Wheels, 41–43
rawinsondes, 261–262
RAXPOL. See Rapid Scan X-Band dual-Polarization Radar
ray, 66
ray path, 441–442
Rayleigh approximation, 98–100
Rayleigh backscattering, 417
Rayleigh scattering, 16, 132
backscatter differential phase and, 152–153
cloud radars and, 416
Rayleigh scattering. (Continued)
  radar reflectivity factor and, 319–320
  radar wavelengths and, 212
Rayleigh theory, 95
RDA. See Radar Data Acquisition Unit
rear flank, 350
rear flank downdraft (RFD), 350, 352
rear flank gust front, 350
rear-inflow jet, 342, 344
rear-to-front flow, 342
receiver noise, 199–200
receiver section, 36–40
reciprocal media, 129
reconstructed RHI, 59, 61
reflection, 12–14
reflectivity
  ground clutter and, 288
  from NCAR CP-4, 290
  radial velocity and, 285–286
  resolution, 241
  of tornadoes, 353
reflectivity at horizontal polarization, 158, 162
  of cyclones, 167
  polarimetric variables and, 169
  of S-band observations, 159, 171–172, 174
reflectivity factor
  at C-band and S-band radar, 216
  of cold-frontal rainbands, 369
  of cyclone mesostructure, 364–365, 367
differential, 133–134
  in dual-polarization framework, 132
equivalent, 329
  of hailstorm, 143–144, 356
  for high clouds, 427
  at horizontal polarization, 140
  of Hurricane Arthur, 396
  insect echo bloom in, 192
  of K,-band radar, 420
  of lake effect precipitation, 431
  microburst outflow and, 357
  polarization-dependent, 133
  rainfall and, 324
  of stratiform cloud layer, 375
  thunderstorms and, 216
  of winter cyclone, 428
reflectivity-weighted axis ratio, 133
reflection, 12–13, 71
refractive index, 7, 68
refractivity
  principles of, 226–227
  radio, 69, 206
retrievals, 228–229
  surface station, 229
regression, 267
relative humidity, 78
relative permittivity, 3
remote sensing, 49
research radar, 341–343
resolution, 238
  pulse, 54
  reflectivity, 241
  super, 241
  of WSR-88D radar, 240–241
resonance scattering, 221
RF. See radio frequency
RFD. See rear flank downdraft
RHI. See range-height indicator
rotary joints, 29
rotating vortex, 393
RPG. See Radar Product Generator
Sachidananda–Zrnic algorithm, 115
SAILS. See Supplemental Adaptive Intra-Volume Low-Level Scan
sampling limitations, 281–283
satellite images, 369
satellite radar systems, 386–390
saturation, 416
S-band radar
  HCA and, 177–180
  melting hail on, 222–223
  NASA NPOL, 140
  network, 246
  observations, 143, 156, 167, 174
  polarimetric variables of, 169–170
  PPI on, 143, 210
  reflectivity factor at, 216
  RHI composite from, 217
  trade cumulus clouds on, 213–214
  WSR as, 232–233
scanning strategies, 236–240, 387
scattering, 12. See also Bragg scattering; Rayleigh scattering
elements, 66
Mie, 14–17, 217–218, 416
optical, 16
radiation pattern of, 17
resonance, 221
sidelobes and multiple, 289–290
in weather radar equations, 82
scatterplots, 218
scope display, 57–58
sea clutter, 76, 185–188, 287
second moment, 119
secondary rays, 209
second-trip echo, 52–53, 289
sensors, remote, 49
shearing deformation, 253
short-wavelength radars
attenuation and, 224–225
as cloud radars, 100, 415–416
large-wavelength and, 55
particle size distribution and, 93
vertically pointing mode of, 58, 60, 208, 415
doppler, 33–35, 185, 289–290
simultaneous transmit and receive (STAR), 130
sine waves, 282
single polarization retrieval (SPR), 328
siting and logistics, 283–284
size distribution, of raindrops, 218, 313, 316–318, 322
skin paint, 196
slant range, 50, 73
smoke plume echo, 197
Snell's law, 12–13, 69
snow accumulation, 329, 330, 378–379
snow water equivalent precipitation, 329–331
snowbands, 187, 371, 429, 431
snowflake aggregates, 145
snowflakes, 377–378
solid state transmitter, 26
soundings, and radar ray path, 76
space, pulse volume in, 72–74
spaceborne radars, 44–45, 330–331
TRMM, 332–334
GPM, 332–334
S-Pol S-band radar system, 25–27
components of, 32
liquid water content on, 213–214
radar refractivity retrievals from, 228–229
receiver system in, 36
wave guides of, 30
S-PolKa K_a-band radar system, 40
SPR. See single polarization retrieval
squall line, 62–63, 341, 346
stable local oscillator (STALO), 27, 36
standard atmospheric refraction, 69
standard deviation, 297–299, 305
standard rain gauges, 311
STAR. See simultaneous transmit and receive
stationary band complex, 392
storm structure, 428–432
storm surge, 405–407
storm total precipitation, 311
straight-line winds, 344
Strategic Radar Enhancement Project, 246
stratiform cloud layer, 375
stratiform echo, 376
stratiform sector, 402
stratiform winter storm, 59
stretching deformation, 253
Strutt, John William, 16
sun spikes, 199
super resolution, 241
supercell thunderstorms, 339
hail detection in, 356–358
PPI showing, 58
radar reflectivity factor during, 97, 111–112, 409
radar signatures of, 354–356
radial velocity during, 111–112, 260
reflectivity in, 245
storm updraft rotation in, 349–352
structure of, 350
tornado detection in, 352–354
updrafts and downdrafts in, 349–351
Supplemental Adaptive Intra-Volume
Low-Level Scan (SAILS), 242
Supplemental Products Generator (SPG), 243
surface station refractivity, 229
sustained winds, 405
synoptic-scale frontal boundary, 346–347
synoptic-scale surface cold front, 346
tail Doppler radar (TDR), 386–388
targets, 50, 82. See also distributed target
Doppler spectra of, 116–117
power flux density on, 83–85
velocity ambiguities and, 108–115
taurus, 145
Taylor series, 252
TBSS. See three-body scatter spike
TC circulation TREC (T-TREC), 407
TDR. See tail Doppler radar
TDWR. See Terminal Doppler Weather
Radar
temperature, 70, 78, 212
Terminal Doppler Weather Radars (TDWR), 215, 233, 339
data distribution of, 243–245
elevation cuts and, 244
FAA deploying, 242–243
locations of, 242
radar characteristics of, 243–245
reflectivity from, 245
terminal fall velocity, 275, 421, 425
ydrometeors, 274
of ice particles, 423
of precipitation and raindrops, 422
thin line echo, 418
three equation solution, 302
3-D gain function, 35
three-body scatter spike (TBSS), 290, 291
three-point top-hat filter, 285–287
three-radar solution, 294
thundersnow, 371
thunderstorms
four radar geometry of, 294
frontal squall lines in, 345–349
hook echo of, 57
from Hurricane Ike, 408
from Hurricane Irene, 409
MCS and, 338–339
mixed phase in, 149
radar scanning of, 282–283
reflectivity factors and, 216
RHI of, 110, 113–114
training, 348
on X-band radar, 218–219
time to independence, 93
time-height cross section, 58, 60
tipping bucket rain gauges, 311–312
T-matrix simulations, 153
TMI. See TRMM Microwave Image
tornado debris signature, 353
tornadoes, 339, 347
correlation coefficient of, 353, 355, 410
debris signatures and echo of, 195
differential reflectivity of, 353, 355, 410
radar reflectivity factor of, 353–355, 410
radial velocities of, 353, 355, 410
RAXPOL view of, 355
supercell thunderstorms detection of,
352–354
in tropical cyclone, 409–411
updraft rotation, 351
total accumulated precipitation, 311
total attenuation, 207
T-R (transmit-receive) limiters, 31–32
Tracking Radar Echoes by Correlation
(TREC), 407
trade cumulus clouds, 213–214
trade wind clouds, 322
trailing stratiform clouds, 342
trailing stratiform region, 341
training thunderstorms, 348
transformers, 28
translation, 253
transmit-receive (T-R) limiters, 31–32
transmitted signals, 53–56
transmitter section, 26–28
traveling wave tube transmitter, 26
TREC. See Tracking Radar Echoes by
Correlation
TRMM. See Tropical Rainfall Measuring
Mission
TRMM Microwave Image (TMI), 332
tropical cyclones
airborne radars studying, 384–385
concentric eyewall in, 392
convective motions in, 403
eyewall radar structure of, 395–398
inner-core rainbands in, 401, 403
precipitation and flooding from, 407–408
radar detecting hazards in, 405–411
radar depiction of, 383–386
radar reflectivity of, 391
radar structure of, 399–404
rainband complex in, 401
as rotating vortex, 393
stratiform sector of, 401
structure and kinematics of, 390–393
tornadoes in, 409–411
vertical structure of, 397
vortex bands in, 404
winds and storm surge of, 405–407
Tropical Rainfall Measuring Mission (TRMM), 44–45, 224, 331, 386
annual average precipitation measured by, 333
GPM and, 432
spaceborne radars and, 332
tropical trade winds, 202
tropopause, 420
tropopause altitude, 425
T-TREC. See TC circulation TREC
turbulence, 201–202
turbulent eddies, 201
2-D gain function, 34
two-dimensional cloud optical array probe, 317
two-dimensional video disdrometer, 134, 136–138, 313–314
two-radar solution, 295, 299
two-way attenuation, 207, 209
two-way differential attenuation, 207
ultra-high frequency (UHF), 261
unfiltered Doppler data, 287
unfolded, velocities, 110, 114
updraft rotation, 349–352
updraft-downdraft couplet, 282
updrafts
convective, 225
downdrafts and, 115, 117, 349–351, 376, 397, 418, 422–424
upward integration, 304
VAD. See velocity-azimuth display
vapor pressure, 70
variables, list of, 435–440
variational integration, 304
VCPs. See Volume Coverage Patterns
veering, of winds, 256–257
Vehicle Assembly Building, 186
velocity ambiguities, 108–115, 288–289
velocity components, 399
velocity-azimuth display (VAD), 261
Cartesian coordinate system and, 264
extended, 264, 273–275
gametries used by, 265
NWS using, 271
technique of, 264–271
wind properties by, 275
wind recovery of, 270
WSR-88D using, 264
vertical air motion, 421, 425
vertical air velocity, 274, 280
vertical cross sections, 62–63, 214
vertical integration, 305
vertical motion, 273, 302–304
vertical motion retrievals, 304–306
vertical polarization (V), 127
vertical profiles, 209
vertical radial velocity, 225
of comma head clouds, 372
of cyclone mesostructure, 367
of dryline, 430
of extratropical cyclone, 418
for high clouds, 427
of Hurricane Dennis, 400
of Hurricane Rita, 399
of Kα-band radar, 420
of lake effect precipitation, 431
of stratiform cloud layer, 375
terminal fall velocity and, 425
of winter cyclone, 428
vertically pointing mode, 58, 60, 208, 415
vertically polarized, 20
very high frequency (VHF), 261
video disdrometer, 313–314
Visible Infrared Scanner (VIRS), 332
Volume Coverage Patterns (VCPs), 236–238
vortex bands, 404
vortex-scale motions, 403
vorticity, 253
vorticity components, 399
W3-PD aircraft, 389
wall clouds, 352
wall of dust (haboob), 196
warm air advection, 257
water molecules, 68
water vapor, 207
atmospheric absorption and, 208
atmospheric attenuation by, 208–209
density, 209, 211
on dual-wavelength radar, 210
measuring, 227–228
one-way attenuation from, 211
pressure, 68
radar ray and absorption of, 210
wave guide system
peak power in, 55
for radar, 29
of S-Pol S-band radar system, 30
of weather radar system, 28–30
waveforms, 236
waveguide junctions, 31
waveguide switches, 29
wavelength. See also large-wavelength radars; short-wavelength radars
  Doppler dilemma of, 109–113
dual, 210, 213
frequency and, 9, 23–25
one-way attenuation and, 416
radar, 126–128, 139–141, 212
refraction and, 13
short, 224–225, 415–416
sine wave and, 282
temperature and, 212
of WSR-88D radars, 88–89
W-band radar, 61, 225, 414
WCFRs. See wide cold-frontal rainbands
WCR. See Wyoming Cloud Radar
weather
  conditions, 76
    Doppler spectra of, 116–117
echo, 188–190
hazardous, 343–345
mesoscale, 361
weather radar equations, 95
  radar reflectivity factor and, 96–97
Rayleigh approximations in, 98–100
scattering properties in, 82
weather radar system, 25
  antenna section of, 32–34
magnetron transmitters in, 38–40
receiver section of, 36–40
transmitter section of, 26–28
  wave guide system of, 28–30
Weather Service Radar (WSR), 232–233
weighing bucket precipitation gauges, 313
weighting function, 292
wet snow, 179
wide cold-frontal rainbands (WCFRs), 368–369
wind components, 252
wind field
  components of, 253
  Doppler radar analyzing, 405
  kinematic properties of, 252–254, 265, 268
wind gusts, 405
wind profilers
  boundary layer and, 263
Bragg scattering and, 261
  of Doppler radar, 261–264
radio acoustic system of, 262
  of rainfall, 272
three-beam system for, 263
winter cyclones data from, 262–263
wind shear, 358
windowing, 190
winds
  backing of, 256
BAMEX and, 280
  components of, 297–299
  convective scale flow patterns and, 259–261
mid-tropospheric, 349–350
radial velocity and, 256–259
  radius of maximum, 405
storm surge and, 405–407
  straight-line, 344
sustained, 405
tropical trade, 202
VAD and properties of, 275
VAD recovery of, 270
veering of, 256–257
winter cyclones
  cloud-top generating cells in, 374–376
comma head clouds of, 373
  Doppler radar of, 373–374
low-pressure centers of, 362
  precipitation bands in, 374, 376
radar reflectivity of, 364, 379, 428
snow transition in, 378–379
vertical radial velocity of, 428
wind profiler data for, 262–263
winter lightning, 371
winter precipitation, 329–330
winter storm
  dual-polarization Doppler radar and, 146
KDP observations of, 161–162
PPI of, 60
RHI scan of, 197
stratiform, 59
WSR. See Weather Service Radar
WSR-88D radar, 71, 232
  beamwidth of, 90
characteristics of, 234–236, 238
  components of, 235
data distribution of, 234–236
  Doppler spectra of, 115–116
features of, 242
ground clutter suppression of, 240
during Hurricane Matthew, 170–172
hybrid scan constructed for, 326
hydrometeor classification, 327
KARX, 364–365
KFFC, 345
KFWS, 356
KGSP, 291
Index 461

KHGX, 394
KHTX, 355
KIND, 272
KLBB, 195
KLCH, 343
KLOT, 379
KMHX, 410
KOKX, 373
KSLX, 346–347
locations of, 235
microbursts observed by, 357
network coverage of, 233–234
power flux density of, 84–85
precipitation algorithm and, 327
pulse duration of, 89
radar reflectivity factor of, 111–112
radial velocity of, 111–112
reflectivity from, 245
scanning strategies of, 236–240
super resolution of, 240–241
VAD used by, 264
VCPs used by, 237
wavelength of, 88–89

wind profiles from, 272
Z-R relationships for, 323–324
Wyoming Cloud Radar (WCR), 372–373, 375, 415, 418, 430
as airborne radar, 224–225
radar reflectivity factor and, 365

X-band Polarization Radar (XPR), 365–367
X-band radar, 177–180, 208, 355
DOW and, 185–186
PPI images from, 220
thunderstorms on, 218–219

XPR. See X-band Polarization Radar

\( Z_{DR} \) columns, 163
\( Z_{DR} \) measurements
  in mixed-phase precipitation, 141–145
  of raindrops, 138–141
zeroth moment, 117
\( Z_e - S \) relationship, 330
Z-R relationships
  precipitation estimate using, 322–323, 325
  by WSR-88D radars, 323–324