adaptive grids 39-40	land-surface and ice 410-411
adaptive observations 206–209	ocean circulation 411–412
adjoint methods 105–107, 337–338	physical-process parameterization 412
agricultural applications of modeling 386, 399	regional 440–442
air-chemistry modeling 390–391	summary of models 422–427
air-quality modeling 390–391	verification 413–420
aliasing 80–83	cloud-cover parameterizations 166–168
analysis increment 215, 222, 224–225	cloud-microphysics parameterizations 121–128
analysis innovation 217, 224–225	cluster analysis 352–353
analysis residual 217	cold starts 21
analysis, of observations 199–251	composite grid 28–29
Barnes 229	computational fluid-dynamics models 401–406
Cressman 227–228	algorithmic approximations 405
four-dimensional variational 242–244	applications 405
optimal interpolation 230	coupling with mesoscale models 403–404
successive correction 227–230	types 401–402
three-dimensional variational 231–233	
	conformal projection 25
anelastic approximation 11–12	conservation
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	energy 116
background field 210–212	mass 116
balancing, of initial conditions 236–242	consistency, of vertical and horizontal grid increments
Barnes analysis 229	40–42
basis function 42–50	continuous data assimilation 212–215
Big-Brother–Little-Brother experiments 107–108,	convective parameterizations 129–140
329–330	coupled models 378–400
boundary conditions	agricultural 399
introduction 20–21	energy industry 396–398
lateral 96–113	floods 386–389
lower 171–196	infectious disease 382–386
upper 114–116	military applications 399-400
boundary-layer parameterization 140-155	transport, diffusion, transformation 389-393
Boussinesq approximation 11–12	wave height 381–382
Brier score 267–268	wave propagation 394–395
	wildland fire 396
canonical correlation analysis 355	Courant number 19
case studies, methods 321-323	Cressman analysis 227–229
climate modeling, future 407–431	•
anthropogenic landscape impacts 451–453	data assimilation
conservation properties 412	continuous 212–215
deterministic, initial-value prediction 420–422	diabatic (physical) 233–236
downscaling 432–450	ensemble Kalman filter 246–248
ensemble 427–430	extended Kalman filter 244–246
experimental designs 408–410	four-dimensional variational 242–244
flux corrections 413	hybrid 215, 248–249
global 408–431	intermittent 210–212
intercomparison projects 415	relaxation 212–215
mereomparison projects 115	101011011011 212 210

data assimilation (continued)	multi-step 52-53, 78-80
sequential 210–212	semi-implicit 53–54
spinup, relation to 215–216	split explicit 51
statistical framework 216–226	finite-element methods 50
three-dimensional variational 231–233	finite-volume methods 50–51
diabatic initialization 233–236	first-guess field 210–212
differential grid resolution 36–40	flood modeling 386–389
diffusion 84–89	forecaster role, in NWP 364
explicit numerical 85–89	four-dimensional variational data assimilation
grid 89	242–244
implicit numerical 89	Fourier basis function 42–44
physical 84–85	Fourier basis function 42–44
diffusion coefficient 70–71	geostrophic adjustment 236–240
direct numerical simulation models 402	
	grid structure
dispersion, numerical 72–78	consistency of vertical and horizontal grid
downscaling methods 432–450	increments 40–42
current-climate 445–449	differential resolution 36–40
dynamical 439–444	latitude–longitude grids 30–32
future-climate 444–445	map projections 24–30
statistical 435–439	polyhedral gnomonic projections 28–30
dust-transport modeling 391–392	spherical geodesic grids 32–36
dynamic balance 236–242	grid-point methods 23–42
dynamic initialization 21, 199	group-speed errors 76–77
dynamical core 17	
	hot starts 22
energetics analysis 356–357	hydrostatic approximation 11
ensemble Kalman filter 246–248	
ensemble modeling	infectious-disease modeling 382-386
calibration 269–270	initialization 198–251
dispersion 256–257	balancing 236–242
economic benefit 280–282	data-assimilation methods 210–249
graphical displays 273–280	diabatic 233–236
mean 254–256	dynamic 21, 199
rank histogram 265–267	ensemble Kalman filter 246–248
reliability 263–265	extended Kalman filter 244–246
short range 272–273	geostrophic adjustment 236–240
superensemble 258	hot, warm, cold starts 21-22, 215-216
time lagged 271–272	hybrid 215, 248–249
uncertainty sources 257–261	idealized 249–250
variance 256	introduction 21–22
verification 261–269	observations 199–209
error covariances 222–226	physical initialization 233–236
Eulerian analysis framework 343-347	instability, numerical
experimental designs, in modeling 321-342	linear 63–72
extended Kalman filter 244–246	nonlinear 83–84
	intermittent data assimilation 210-212
factor separation 333–337	isochrone analysis 351
finite-difference methods, space 54–58	·
Eulerian 54–55	Lagrangian analysis framework 347–351
introduction 17–19	Lambert conformal map projections 24–27
Lagrangian 55–56	land data-assimilation systems 187–188,
semi-Lagrangian 55–56	190–191
staggering 56–58	land-surface model 187–191
finite-difference methods, time 51–54	land-surface process modeling
explicit 52–53	modeling 187–191
implicit 53–54	processes 172–185
introduction 19–20	urban-canopy modeling 194–196
	aroun canopy modeling 194 190

large-eddy simulation models 401–402	radiation 155–165
lateral-boundary conditions 96–113	stochastic 166
error examples 97–107	perfect-prog method 368
recommendations 110–113	phase-speed errors 72–77
sources of error 96–97	physical initialization 233–236
types 108–110	physical-process studies 321–323
latitude–longitude grids 30–32	plume modeling 389–390
limited-area model 36	polar stereographic map projections 24–27
linear instability 63–72	polyhedral gnomic projections 28–30
advection 63–70	post-processing, statistical
diffusion 70–71	gridded bias correction 374
multiple terms 71–72	Kalman filters 373–375
24.20	model-output statistics 368–373
map projections 24–30 conformal 25	perfect-prog method 368
	weather generators 375–376
Lambert conformal 24–27	predictability 284–293 definition 284
map-scale factor 26–28 Mercator 24–27	error sources 284–287
polar stereographic 24–27	limited-area models 290–293
polyhedral gnomonic 28–30	local-forcing impact 287–288
map-scale factor 26–28	post-processing impact 293
Mercator map projection 24–27	variability causes 288–290
metadata 205–206	predictive-skill studies 338
microphysics parameterizations 121–128	predictor-corrector time differencing 52–53
military applications of models 399–400	primitive equations 7
model-output statistics 368–373	primitive equations 7
conventional 369–371	principal-component analysis 353–355
updatable 371–372	pseudospectral models 46
very-short update 372–373	pseudospeedur models 10
very short apatate 372 373	quality assurance 203–205
nested grids	quality control 203–205
horizontal nesting 36–37	quanty conserved and
stretched grids 36–40	radiation parameterization 155–165
vertical nesting 36–38	rank histograms 265–267
Newtonian relaxation 212–215	rank-probability skill score 269
nonlinear instability 83–84	real-time verification 363
nonlinear normal-mode initialization 242	reanalyses
	global 431–432
objective analysis of observations	regional 445–449
Barnes 229	reduced grid 31–32
Cressman 227–229	reduced-dimension models 339-340
optimal interpolation 230	reduced-physics models 340
successive corrections 227–230	reforecasts 330–331
observations, used for initialization 199-209, 340-341	relaxation 212–215
observing-system experiments 328	reliability diagrams 263–265
observing-system simulation experiments 323-328	Reynolds' averaging 7–10
ocean-surface process modeling 192	Reynolds' equations 7–10
operational NWP 358–365	Reynolds' postulates 7–10
optimal interpolation 230	Reynolds' stresses 9
	Reynolds'-averaged Navier-Stokes equations 401
parameterizations 119–170	rhomboidal truncation 45-46
boundary layer, turbulence 140-155	river-discharge modeling 386-389
cloud cover, cloudiness 166-168	ROC diagrams 267
convective 129–140	
introduction 22–23	self-organizing maps 352–354
land-surface 171–197	sensitivity studies 331–338
microphysics 121–128	sequential data assimilation 210-212

shallow-fluid equations 12-16 upper-boundary conditions 114-116 singular-value decomposition 355 urban-canopy modeling 194-196 skill scores 298-299 spectral analysis 355-356 variational data assimilation four dimensional 242-244 spectral methods 42-50 three dimensional 231-233 advantages, disadvantages 49 basis functions 42 verification 294-320 Fourier basis functions 42-45 accuracy measures 295-298 horizontal resolution 48-49 definition 294 Legendre polynomial basis function 45 dependence on time of day, season, weather regime limited area 50 307-309 pseudospectral 46 ensemble forecasts 261-269 spherical harmonics 45 feature, event, object based 309-312 transform method 46 horizontal-resolution effects 305-306 truncation methods 45-46 probability distribution functions 306-307 spherical geodesic grid 32-36 reasons for verifying 294-295 spherical harmonics 45 reference forecasts 299-300 spinup 215-216 reforecasts, use of 317 static initialization 21 representativeness error 302-304 statistical framework for data assimilation 216-226 scale dependence 312-315 statistical post processing 366-377 skill scores 298-299 toolkits 318 gridded bias correction 374 Kalman filters 373-374 value based 280-282, 317 model-output statistics 368-372 variance 316-317 perfect-prog method 368 vertical coordinates stochastic parameterizations 166 height 89-90 streamline analysis 350-351 hybrid 94 stretched grid 36-40 potential temperature 90-92 successive correction, in analysis 227–230 pressure 90 synthetic initial conditions 339 sigma-height 93-94 sigma-pressure 92 targeted observations 206-209 step-mountain 94-95 volcanic ash modeling 392-393 Taylor diagram 262–263 three-dimensional variational analysis 231-233 time smoothers 95 warm starts 22 time-lagged ensemble 271-272 water-surface process modeling trajectory analysis 347–350 modeling 192 transform method 46 processes 185-187 transport and diffusion modeling 389-393 wave-height modeling 381-382 triangular truncation 45-46 wave-propagation modeling, sound and truncation error 59-63 electromagnetic 394-395 truncation, of spectral basis functions 45-46 weather generators 375-376 turbulence parameterization 140-155 wildland-fire modeling 396