
SUBJECT INDEX

- * , transposed conjugate, 91
- $\hat{\cdot}$, inverse estimate, 277
- β -plane, 2
 - equatorial, 85, 163
- χ^2 -variable, 156, 199, 315
- acoustic tomography, 49, 171, 173
- adiabatic motion, 268
- adjoint operator, 116, 167
- adjoint representer, 119, 242
- adjoint variable, 115, 132, 185
 - discontinuities in, 130
- advection-diffusion equation, 255
- algorithm
 - ideal minimization, 281
 - RTS, 135
 - Simplex, 39
 - sweep, 129, 241, 279
- altimetry, 71, 88, 104
- anisotropy, 54, 85
- annealing parameter, 177
- annealing, simulated, 175, 177, 282, 311
- antenna element, principal, 152, 154, 170
- antenna mode
 - residual, 152, 154
 - solution, 152, 154, 173
- approximation
 - Boussinesq, 2, 273
 - long-wave, 85
- BLUE (best linear unbiased estimate), 48, 61, 65
- behavior
 - asymptotic, 93, 95–6, 133
 - cuspidal, 100
 - high wavenumber, 93
 - local spatial, 63
 - singular, 96
- binomial coefficients, 56
- blurred observations, 19
- bottom velocity, 8
- boundary condition, 77, 80
 - Charney, Fjörtoft & von Neumann, 204, 207, 214
 - classical, 204
 - computational, 313
 - Dirichlet, 203
 - Euler-Lagrange, 279
 - free-surface, 105
 - interpolated 74
 - Judovich, 216–7
 - linear, 260
 - long wave approximation, 85
 - meridional, 85
 - mixed, 203, 241
 - Neumann, 203
 - no-slip, 77
 - number of, 260
 - open, 203, 209, 275
 - perturbation, 270
 - persistent, 72
 - radiation, 172
 - rigid, 77, 172, 205, 261
 - Robin, 203
 - Sommerfeld, 204
 - subcritical, 263–4
 - supercritical, 263–4
 - vanishing zonal transport, 85
- boundary layer, 85, 95, 231, 241
- boundary-value problem, two-point, 131, 186
- buffer-region, 267
- buffer, 308
- calculus of variations, 58, 115, 148, 185, 298
 - fundamental lemma, 299
- canonical decomposition, 152

- characteristic, 207, 223
 - uniformly, 223
- characteristic point, 223, 231, 241
- chi-squared variable, 156, 199, 315
- circulation (integral), 206
- classically well-posed problem, 215
- closure, and linear dynamics, 77
- cmf_random*, 312
- compromises, 246
- conditioning, 153, 179, 284, 290
- Connection Machine, 305
- consistency condition, on inflow
 - boundary, 224, 233
- constraint
 - feasible, 302
 - inconsistent, 30
 - inequality, 27, 29, 137, 286
 - infeasible, 30
 - slack, 30
 - superconsistent, 30
 - strong, 10, 144, 150, 159, 236
 - weak, 10, 150, 199, 316
- continuation, 218
- continuity, 131
- continuity in time, 192
- convection, 301
- convergence, 90, 187, 191, 193, 245, 280, 284, 290–1
- convex function, 39
- convex programming, 39, 286
- cooling, Newton's law of, 302
- coordinates
 - isopycnal, 40, 284, 306
 - Mercator, 248
- correction
 - Cressman, 248
 - successive, 71
 - tropospheric moisture, 110
- Coriolis parameter, 3
- correlation sonar, 284
- covariance
 - field, 50, 61, 71
 - space-time, 72
- CRAY, 304
- crecv*, 311
- Cressman correction, 248
- csend*, 310–1
- cshift* (circular shift operation), 306
- current meters, 40
- damping, Rayleigh, 163
- data-management schemes, 76
- decorrelation length scales, 168
- deformation radius, 77, 248, 297, 316
 - equatorial, 164
- degrees of freedom, 156, 281, 284, 296, 315
- density anomaly (σ_t), 31
- diapycnal mixing, 40, 43
- difference
 - backward, 143
 - centered, 308
 - explicit, 307
 - finite, 140, 227, 271, 288
 - forward, 141
 - implicit, 307
- differentiability, continuous, 64
- diffusive decorrelation time, 161
- direct insertion (nudging), 109
- direct measurement, 49
- discarded field, 59
- discontinuities, 215, 220, 231, 233, 299
- dispersion relation, 222
- distributed parameter system, 90
- distribution
 - bimodal, 74
 - Gaussian, 74, 156
 - non-Gaussian, 174
- domain, 205
- domain decomposition, 308
- drag
 - bottom, 77
 - coefficient, 163, 292
- drifters, 40, 51, 284, 316
- dual
 - eigenvalue problem, 15
 - dual variable, 40
- eclectic modeling, 40
- eigensolution, 166
- eigenvalue, 160, 298
 - decomposition, 153
- Ekman layer, 292
- El Niño, 85, 161
- elements, antenna, 152
- endwhere*, 312
- equation
 - advection-diffusion, 255
 - biharmonic, 65
 - Boolean delay, 299
 - evolution, 92
 - hyperbolic, 223
 - parabolic, 230
 - Riccati, 83, 280
- error covariance, *see also*, p. 342
 - boundary conditions for, 80

Subject index

343

- error covariance (*continuation*)
 cross-spectrum, 93
 estimation by annealing, 313
 explained, 127
 filter, 132
 forecast, 80, 82
 initial, 125, 127
 measurement, 50, 61, 125, 127
 model, 78, 125–6
 posterior, 51, 70, 76, 125
 prior, 70, 76, 125, 315
 relation to Hessian, 147
 requirement for, 81, 127
 smoother, 134
- estimate
 best linear unbiased (BLUE), 48
 climatological, 71
 conditional, 71, 315
 KBF, 107
 linear, 47
 null, 82
 oscillatory, 66
 posterior, 76, 118, 310
 prior, 69, 76, 118, 124, 309
 sequential, 67
 smooth, 45
 smoothing spline, 48
 suboptimal, 132
 unbiased, 48, 70
 uniquely determined, 117
- Euler-Lagrange equations, 114, 116,
 130, 149–50, 236, 240, 251, 276
 iterated, 189
- extrapolation, 51, 74
- feature model, 74
- field
 discarded, 121, 138
 observable, 281
 orthogonal, 60, 122
 pseudo-random, 128
- filter, Shapiro, 231
- filtering, 231
- fine structure, 109
- floats, 40, 51, 284, 316
- forecast, 249, 291
 real time, 72
- FORTRAN-77, 31, 308–11
 FORTRAN-90, 305–8, 311
- Fourier
 integral, 62
 series, 91
- friction, 230
- frozen velocity field, 222
- fudging, 231
- function
 convex, 39
 generalized, 65
 Green's, 206
 Hermite, 85, 164
 influence, 59, 62, 119–20, 125
 phase, 221
- fundamental solution, 137
- generalized function, 65
- geoid, 105, 110
- geometrical construction, 59, 121
- geopotential surface, 71
- geostrophy, 2
- gigaflops, 304
- global minimum, 117, 281
- gradient descent, 140, 146, 177, 281,
 289, 294, 309
- Hessian
 form, 147, 281, 290
 matrix, 124, 129
- hindcast, 72, 249, 291
- homogeneity, statistical, 72, 94,
 157–8, 168
- hydrographic stations, 4
- hydrostatic balance, 2
- hyperplane, 30
- ideal minimization algorithm, 281
- importance sampling, 179
- impulse-response, 19
- inertial oscillation, 296
- inflow, 210
- influence function, 59, 62, 119–20, 125
- information (negative covariance), 104
- infotype*, 311
- inhomogeneity, statistical, 54
- initialization, 69
- inner product, 56, 66, 122, 136,
 165, 244
- instability
 baroclinic, 84, 111, 290
 barotropic, 84, 111, 199, 290
 computational, 84
- integral
 circulation, 206
 energy, 260, 262, 269, 278
- Intel iPSC, 305, 310
- interannual variability, 163
- interference, destructive, 160–1

- interpolation, 51
 - bilinear, 69
 - hodographic, 76
 - linear, 47
- isopycnal coordinates, 40, 284, 306
- isotropy, 52, 72, 168
- iteration
 - bounded, 188, 298
 - naive, 187
- jump condition, 81, 93, 132
- Kalman filter (KF), 76, 80–1, 87, 90, 132, 239, 256
 - algorithm, 80
 - extended, 193
 - gain, 80, 87, 94, 132
- Kalman-Bucy filter (KBF), 82–3
 - gain, 83, 107
- Kalman smoother, 135
 - extended, 193, 298
- kernel, smoothing, 138
- *LISP, 311
- Lagrange multiplier, 10, 13, 144, 149, 236, 286, 289, 297
- Lagrangian
 - derivative, 207
 - history, 214, 267
 - notation, 207
- limit
 - adiabatic flow, 104
 - diffusive, 98, 108
 - non-diffusive, 94, 107
- linear algebra, general problem of, 14
- Local Dynamics Experiment (POLYMODE), 315
- Lorenz cycle, 283
- MIMD (multiple-instruction stream, multiple-data), 305–8
- manager (processor), 307
- mask, logical, 307
- matrix
 - dispersion, 32
 - representer, 60, 119–20, 152
 - resolution, 19, 66
 - square root of, 35
- maximum likelihood, 74, 147, 183
- mean
 - climatological, 69
 - conditional, 125
 - ensemble, 48, 61, 69
- meandering jet, 74
- measurement functional, 48, 69
 - direct or evaluation, 49, 63
 - integral representation of, 49
- Mercator coordinates, 248
- message-passing, 308
- Mid-Ocean Dynamics Experiment, 52
- mode
 - external, 270, 307
 - internal, 270, 307
 - meridional, 84
- model
 - eclectic, 40
 - feature-, 74
 - isopycnal, 268
 - linear quasi-geostrophic, 91, 113
 - nested, 313
 - nonlinear quasi-geostrophic, 183, 248
 - open-ocean, 71, 203, 259, 275–82
 - plane hydrodynamic, 204
 - primitive-equation, 68, 257, 267, 273, 306
 - simple wave, 148, 239
- monotonic sequence, 147
- Monte Carlo simulation, 179
- Moore-Penrose inverse, 14, 16, 154
- mynode*, 310
- NCUBE/ten, 308
- NEWS (North-East-West-South)
 - grid, 306
- nested integration, 313
- networks of workstations, 309
- noise
 - data, 80
 - initial, 80
 - random, 19
 - system, 80, 84
 - white, 78, 80, 82, 106, 130
- nonlinearity, 181
- norm, 56, 63, 188
- nudging, 83, 105, 108, 110, 239, 267
- null
 - hypothesis, 195, 199–200
 - projection, 263
 - space, 44, 66
 - space, right, 17
 - vector, 61
 - vector, left, 17
 - vector, right, 16
- numerical weather prediction, 68, 76, 81
- numnode*, 310
- OUR (Oxygen Utilization Ratio), 40
- objective analysis, 47, 72, 82

- observable, 147
- observation space, 21
- open boundary, Judovich condition at, 216, 217
- operator-splitting, 307
- orthogonal field, 60, 122
- outflow, 210
- PE, *see* model, primitive-equation
- particle path, 207, 219, 223
- penalty function, 286
- penalty functional, 45, 114, 142, 167, 185, 192, 235, 240, 251, 275, 289, 293, 297, 303
 - as inner product, 122
 - mean, 129, 156
 - multiplication by a positive constant, 169
 - posterior, 128, 156
 - prior, 128
- phase function, 221
- physical reality, 90, 104, 214, 231, 233–4, 280
- physically realizable stochastic process, 55, 64
- plankton bloom, 301
- POLYMODE Local Dynamics Experiment, 315
- potential
 - Montgomery, 268, 306
 - velocity, 211
 - vorticity, 3, 183, 191, 248
- preconditioning, 148
- principal component, 250
- programming
 - convex, 39, 286
 - linear, 39
- propagator, 93
- pseudo-random field, 128
- pseudo-stress, 87
- QG, *see* model, quasi-geostrophic
- quantum chromodynamics, 311
- Quaternary glaciation, 299
- quelling, 137–8
- rk, *see* reproducing kernel
- RTS (Rauch-Tung-Streibel) algorithm, 135
- ramp, 66
- reciprocal-shooting, 171
- red cross-spectrum, 93
- redundancy, of observing system, 180
- reference level, 3, 7
- region, 205
 - multiply-connected, 206, 211, 217
 - simply-connected, 205, 213, 217, 230
- representer matrix, 60, 120, 123, 127, 159–60, 309
 - eigenvalues, 129, 153
- representer, 59, 66, 118, 166, 190, 242, 279
 - boundary-value problem for, two-point, 118
 - matrix, 60, 119–20, 152
 - parallel computation of, 309
 - residuals, 120, 138
- reproducing kernel (rk), 59, 61, 62, 66, 122, 126–8, 147, 155
 - computation of, 127
 - decay rate of transform, 63
 - isotropic, 62
 - limiting behavior, 64
 - relation to covariance, 126
 - statistical estimation of, 128
 - translation invariance, 62
 - vector, 58, 118, 243
- reproducing property, 60
- resolution, 18
- rigid lid, 105, 307
- rings
 - cold-core, 74
 - warm-core, 74
- Rossby number, 184
- routing of messages, 308
- SIMD (single-instruction stream, multiple-data), 305–7, 313
- SOP (ship-of-opportunity), 71
- SST (sea surface temperature), 74, 161
- Sv (Sverdrup: $10^6 \text{ m}^3 \text{ s}^{-1}$), 11
- SVD (singular value decomposition), 15–6, 18
- scales, in antenna analysis, 151
- scaling, anisotropic, 62
- sea ice, 284
- searches, during simulated annealing, 179
- separable solution, 104, 269
- sequence
 - bounded, 191–2, 298
 - Cauchy, 188, 191
- sequential estimation, 67, 81, 83, 132, 239
- serial dimension, 313

- shallow-water equations, 162
 linear, 162, 260, 275, 305
 nonlinear, 265
 shooting path, reciprocal, 49
 sigma- t (density anomaly), 31
 simple mixing, 28
 Simplex algorithm, 39
 simulated annealing, 175, 177, 282, 311
 singular value, 15, 176
 singular value decomposition (SVD), 15
 singular vector
 left, 15
 right, 15
 singularity, 281, 288
 smoother
 Gauss-Markov, 47, 74, 128
 Kalman, 135
 RTS, 135
 spline, 56, 61
 suboptimal, 52
 smoothness, 288, 295
 Sobolev space, 189
 solenoidal velocity, 38
 solution space, 21
 solution, multiply-valued, 215
 source type, 31
 specific volume, 267
 square-integrability, 192, 239
 square root (of a matrix), 35
 stability
 computational, 84, 307
 conditional, 307
 criterion, 307, 315
 requirement, 215
 unconditional, 307
 statistical simulation, 128, 147, 179, 194
 statistics
 homogeneous, 85
 inhomogeneous, 85
 nonstationary, 77
 Sturm-Liouville problem, 270, 274
 subcritical, 313
 inflow, 264
 outflow, 263
 subsequence, convergent, 192
 substitution, evaluating gradient by, 145, 281
 successive corrections, method of, 71
 successive over-relaxation, 307
 supercritical, 313
 inflow, 264
 outflow, 262
 surface mixed layers, 284
 Sverdrup (Sv), 11
 vorticity balance, 3
 sweep algorithm, 129, 241, 279
 symmetric g -inverse, 14
 synchronization, 307
 synoptic time scale, 68
 system
 hyperbolic, 262, 274
 symmetric-hyperbolic, 262, 274
 system noise, 80, 84
 homogeneous, 107
 red, 96
 spectrum, 82
 square-integrable, 97
 white, 95, 108, 157
 TCM-90 (Tropical Cyclone Motion Experiment), 248
 TOGA (Tropical-Ocean Global-Atmosphere Experiment), 71
 teraflops, 304
 test, Kolmogorov-Smirnov, 200
 theorem
 central limit, 156
 embedding, 183, 239
 Karush-Kuhn-Tucker, 29, 39
 Kelvin circulation, 206
 Parseval, 63
 thermal wind, 2
 tide, 169
 gauges, 85, 163, 170
 time-like direction, 262
 time-stepping scheme, 307, 315
 tomography, *see* acoustic tomography
 total inversion, 167
 tracer
 conservative, 3
 steady, 37
 transient, 255
 transform
 Bessel, 55
 Fourier, 62
 preconditioning, 290
 travel time equation, 175
 tropospheric moisture correction, 110

Subject index

347

- unbiased estimate, 48, 70
- uniqueness, 116, 120, 131, 146, 193, 199, 212, 214, 226, 261, 263, 265, 277, 289, 304
- unobservable, 123, 147
 - field, 60, 61, 123
 - field, discarded, 61, 123
- unpredictability of real fluid motion, 234
- upstream influence, 239
- upwelling, 37
- vpr (virtual processor ratio), 306
- vector notation, 2
- WOCE (World Ocean Circulation Experiment), 283
- water depth
 - array of, 307
 - behavior of, 267
- water mass
 - analysis, 31
 - classification, 8
- wave
 - barotropic Rossby, 84, 125, 222
 - equatorial Kelvin, 169, 257
 - equatorial Rossby, 84, 169
 - gravity, 68
 - Kelvin, 173
 - Poincaré, 173
 - subtropical Rossby, 84
- wavefront, 221
- waveguide, equatorial, 161
- weight matrix, nondiagonal form, 66
- well-posed problem, classically, 215
- where*, 312
- where-endwhere*, 313
- white noise, 78, 80, 82, 106, 130
- wind stress curl, 5
- workstation networks, 309
- worthless
 - data, 189, 237
 - initial condition, 117, 237
- XBT (expendable bathythermograph), 71, 163