

# Appendix

## List of Acronyms

AATSR:	Advanced Along Track Scanning Radiometer
ACE:	Atmospheric Chemistry Experiment
ACVT-MA:	Atmospheric Chemistry Validation Team – Modelling and Assimilation
ADEOS:	Advanced Earth Observing Satellite
ADM:	Atmospheric Dynamics Mission
AIRS:	Atmospheric InfraRed Sounder
AMSR:	Advanced Microwave Sounding Radiometer (AMSR-E on EOS Aqua, AMSR-2 on GCOM-W)
AMSU:	Advanced Microwave Sounding Unit
ASAR:	Advanced Synthetic Aperture Radar
A-SCOPE:	Advanced Space Carbon and climate Observation of Planet Earth
ASSET:	ASSimilation of Envisat daTa
ASTER:	Advanced Spaceborne Thermal Emission and reflection Radiometer
ATMOS:	Atmospheric Trace MOleculE Spectroscopy
ATOVS:	Advanced TOVS
BASCOE:	Belgian Assimilation System for Chemical ObsERvation (previously the Belgian Assimilation System for Chemical Observations from Envisat)
BIRA-IASB:	Belgisch Instituut voor Ruimte Aeronomie - Institut d’Aeronomie Spatiale de Belgique (Belgian Institute of Space Aeronomy)
BLUE:	Best Linear Unbiased Estimate (also Best Linear Unbiased Estimator)
CALIPSO:	Cloud Aerosol Lidar and Infrared Path finder Satellite Observation
CAMELOT:	Composition of the Atmospheric Mission concEpts and sentinel Observation Techniques
CAPACITY:	Composition of the Atmosphere: Progress to Applications in the user CommuniTY
CCMVal:	Chemistry-Climate Model Validation
CERES:	Clouds and the Earth’s Radiant Energy System
CLAES:	Cryogenic Limb Array Etalon Spectrometer
CMA:	China Meteorological Administration
CMAM:	Canadian Middle Atmosphere Model
CNES:	Centre National d’Études Spatiales
CONAE:	COmisión Nacional de Actividades Espaciales (National Space Activities Commission) – Argentina Space Agency

CoReH <sub>2</sub> O:	Cold REgions Hydrology high-resolution Observatory
CrIS:	Cross-track Infrared Sounder
CRISTA:	CRyogenic Infrared Spectrometers and Telescopes for the Atmosphere
CSA:	Canadian Space Agency
CTM:	Chemistry-Transport Model
DA:	Data Assimilation
DARC:	Data Assimilation Research Centre, UK
DLR:	Deutsches Zentrum für Luft- und Raumfahrt, Germany
DMSF:	Defense Meteorological Satellite Program
DORIS:	Doppler Orbitography and Radiopositioning Integrated by Satellite
DU:	Dobson Units
EarthCARE:	Earth Clouds And Radiation Explorer
EC:	European Commission
ECMWF:	European Centre for Medium-Range Weather Forecasts
ECV:	Essential Climate Variable
EKF:	Extended Kalman Filter
EnKF:	Ensemble Kalman Filter
EOS:	Earth Observing System
EOS MLS:	EOS Microwave Limb Sounder
EP:	Earth Probe
EPS:	EUMETSAT Polar System
ERA:	ECMWF ReAnalysis
ERS:	European Research Satellite
ESA:	European Space Agency
ESSA:	Environmental Survey Satellite
EU:	European Union
EUMETSAT:	EUropean organisation for the exploitation of METeorological SATellites
FCDR:	Fundamental Climate Data Record
FGAT:	First Guess at the Appropriate Time
FLEX:	FLuorescence Explorer
FTIR:	Fourier Transform InfraRed
GCM:	General Circulation Model
GCOM:	Global Change Observation Mission
GCOS:	Global Climate Observing System
GEMS:	Global Earth system Monitoring using Space and in-situ data
GEO:	Group on Earth Observations
GEOS:	Goddard Earth Observing System
GEOS5:	Global Earth Observing System of Systems
GERB:	Geostationary Earth Radiation Budget experiment
GHRSSST:	Global Ocean Data Assimilation Experiment (GODAE) High Resolution SST project
GLI:	GLobal Imager
GMAO:	Global Modeling Assimilation Office (previously the Data Assimilation Office, DAO)
GMES:	Global Monitoring for Environment and Security
GOCE:	Gravity field and steady-state OCEan circulation
GODAE:	Global Ocean Data Assimilation Experiment
GOES:	Geostationary Operational Environmental Satellite
GOME and GOME-2:	Global Ozone Monitoring Experiment
GOMOS:	Global Ozone Monitoring by Occultation of Stars
GOS:	Global Observing System
GOSAT:	Greenhouse gas Observing SATellite

GSI:	Gridpoint Statistical Interpolation
HALOE:	HALogen Occultation Experiment
HIRDLS:	High Resolution Dynamics Limb Sounder
HIRS/4:	High resolution Infrared Radiation Sounder/4
HRDI:	High Resolution Doppler Imager
HSB:	Humidity Sounder for Brazil
IASI:	Infrared Atmospheric Sounding Interferometer
IGACO:	Integrated Global Atmospheric Chemistry Observations
ILAS:	Improved Limb Atmospheric Spectrometer
IR:	InfraRed
ISAMS:	Improved Stratospheric And Mesospheric Sounder
JAXA:	Japan Aerospace space eXploration Agency
KF:	Kalman Filter
KNMI:	Koninklijk Nederlands Meteorologisch Instituut (The Royal Dutch Meteorological Institute)
LEKF:	Local Ensemble Kalman Filter
LETKF:	Local Ensemble Transform Kalman Filter
LIMS:	Limb Infrared Monitor of the Stratosphere
LRR:	Laser RetroReflector
MACC:	Monitoring Atmospheric Composition and Climate
MAESTRO:	Measurements of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation
MERIS:	MEDium Resolution Imaging Spectrometer
MIPAS:	Michelson Interferometer for Passive Atmospheric Sounding
MISR:	Multi-angle Imaging SpectroRadiometer
MLS:	Microwave Limb Sounder
MODIS:	MODerate resolution Imaging Spectroradiometer
MOPITT:	Measurements Of Pollution in The Troposphere
MOZART:	Model of OZone And Related Tracers
MSC:	Met Service Canada
MSG:	Meteosat Second Generation
MTG:	Meteosat Third Generation
MWR:	MicroWave Radiometer
NASA:	National Aeronautics and Space Administration
NCAR:	National Center for Atmospheric Research
NCEP:	National Centers for Environmental Prediction
NCEP GFS:	NCEP Global Forecasting System
NIES:	Japanese National Institute for Environmental Studies
NILU:	Norsk Institutt for Luftforskning (Norwegian Institute for Air Research)
NMC:	National Meteorological Center
NMHCs:	Non-Methane HydroCarbons
NOAA:	National Oceanic and Atmospheric Administration
NPOESS:	National Polar-orbiting Operational Environmental Satellite System
NWP:	Numerical Weather Prediction
OCO:	Orbiting Carbon Observatory
OI:	Optimal Interpolation
OmA:	Observation minus Analysis
OmF:	Observation minus Forecast
OMI:	Ozone Monitoring Instrument
OMPS:	Ozone Mapping and Profiler Suite
OSIRIS:	Optical Spectrograph and InfraRed Imager System
OSE:	Observing System Experiment
OSSE:	Observing System Simulation Experiment

OSTIA:	Operational Sea Surface Temperature and Sea Ice Analysis
PARASOL:	Polarization and Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations from a Lidar
PIRATA:	Prediction and Research Moored Array in the Tropical Atlantic (formerly the Pilot Research Moored Array in the Tropical Atlantic)
POAM:	Polar Ozone and Aerosol Measurement
POLDER:	POLARization and Directionality of the Earth's Reflectance
PREMIER:	PRocess Exploration through Measurements of Infrared and milli-metre wave Emitted Radiation
PROMOTE:	PRotocol for MOnitoring for The GMES service Element
PSAS:	Physical-space Statistical Analysis Scheme
PSC:	Polar Stratospheric Cloud
RA-2:	Radar Altimeter 2
RH:	Relative Humidity
RT:	Radiative Transfer
RTM:	Radiative Transfer Model
SAR:	Synthetic Aperture Radar
SBUS:	Solar Backscatter Ultraviolet Sounder
SBUV/2:	Solar Backscatter Ultra-Violet/2
SCIAMACHY:	Scanning Imaging Absorption spectrometer for Atmospheric CHartography
SEVIRI:	Spinning Enhanced Visible and InfraRed Imager
SGLI:	Second generation GLI
SMAP:	Soil Moisture Active and Passive
SMOS:	Soil Moisture and Ocean Salinity
SMR:	Sub-Millimeter Radiometer
SNSB:	Swedish National Space Board
SPARC:	Stratospheric Processes And their Role in Climate
SPEEDY:	Simplified Parameterizations primitive-Equation Dynamics model
SSM/I:	Special Sensor Microwave Imager
SSMIS:	Special Sensor Microwave Imager/Sounder
SWIFT:	Stratospheric Wind Interferometer For Transport studies
TES:	Tropospheric Emission Spectrometer
TIROS:	Television and InfraRed Observations Satellite
TMI:	TRMM Microwave Imager
TOMS:	Total Ozone Mapping Spectrometer
TOU:	Total Ozone Unit
TOVS:	TIROS Operational Vertical Sounder
TRAQ:	TRopospheric composition and Air Quality
TRMM:	Tropical Rainfall Measuring Mission
UARS:	Upper Atmosphere Research Satellite
UKMO:	UK Meteorological Office (now The Met Office)
UNFCCC:	United Nations Framework Convention on Climate Change
UTLS:	Upper Troposphere / Lower Stratosphere
UV:	UltraViolet
VAR:	VARiational
WMO:	World Meteorological Organization
WMO-GAW:	WMO – Global Atmospheric Watch

# Index

## A

- Active technologies, 274–275, 303
- Adaptive filtering, 563, 577
- Adjoint equations, 25–27, 32, 35, 50, 52–53, 55, 57, 62, 130
- Adjoint method, 25, 37, 50, 53–54, 56, 61–62, 83, 569
- Adjoint model, 26, 53–54, 58, 62, 69, 72, 75–76, 82–83, 88, 388, 391, 464, 497, 505, 559–560, 578, 652
- Adjoint operator, 52, 201, 464, 558, 571
- Advanced Along Track Scanning Radiometer (AATSR), 306, 309
- Advanced Earth Observing Satellite (ADEOS), 310, 318
- Advanced Microwave Sounding Radiometer (AMS-E/EO Aqua, AMSR-2/GCOM-W), 305, 310
- Advanced Microwave Sounding Unit (AMSU), 118, 125, 235, 271–273, 305
- Advanced Spaceborne Thermal Emission and reflection Radiometer (ASTER), 305, 551–552
- Advanced Space Carbon and climate Observation of Planet Earth (A-SCOPE), 307
- Advanced Synthetic Aperture Radar (ASAR), 306, 308
- Advanced TOVS (ATOVS), 118, 279, 456
- Aerosol, 275, 305–307, 309, 313–317, 319, 353, 361, 366, 369, 415, 428, 437, 452, 482, 492, 498, 509–510, 626, 656, 661, 666, 673
- African Easterly Jet, 655
- African Easterly Waves, 655
- Aircraft measurements, 495
- Aleutian high, 341
- $\sigma$ -Algebra, 165, 188–190, 208–209, 211–212
- Altimeter data, 519, 525, 528–529, 531–540
- Analysis correction, 24, 84, 289, 386, 460, 559, 567, 687–688
- Analysis Ensemble System (AES), 652
- Analysis increments, 75, 84–85, 88, 96–97, 104, 106, 108–109, 117–119, 129, 286, 288–290, 357, 360, 373, 391, 558, 590, 631, 638, 662, 669–670
- Analysis states, 20–27, 32, 71, 558–559, 564, 568
- Angular momentum, 325, 328, 331–334, 337
- Antarctic Bottom Water (ABW), 523
- Antarctic Intermediate Water (AIW), 523
- A posteriori* validation, 224
- ARGO floats, 519, 530, 540
- ASSimilation of Envisat data, ASSET, project, 317, 449, 459, 481
- Assimilation time window, 288, 388, 391
- Atmosphere, 3, 6, 12, 50, 63, 95–96, 134, 144–145, 147, 243–244, 247, 263–265, 268–273, 275–276, 278, 283, 285, 290, 296, 302–303, 307, 312–313, 325–328, 330, 332–334, 336–342, 344–347, 353–355, 357–361, 365–371, 373, 375, 381, 383–384, 390, 392, 394–396, 409–411, 413, 416–423, 432, 442, 451, 453–455, 457, 462, 464, 470, 476, 491, 495, 520–521, 523–524, 527, 531, 540, 553, 578, 588–590, 599–601, 603–605, 607, 624, 628–629, 633, 635, 638, 640, 642, 650–651, 653–656, 658–661, 663, 667–668, 672, 674, 681–689, 694–695
- Atmospheric Chemistry Experiment (ACE), 310–311, 315

- Atmospheric circulation, 304, 325–334,  
     337–338, 340, 344, 347, 395, 409,  
     422, 451, 518, 632  
 Atmospheric Dynamics Mission (ADM), 278,  
     307, 316, 666  
 Atmospheric InfraRed Sounder (AIRS), 102,  
     117, 270, 272–274, 305, 312, 453,  
     461, 497, 664  
 Atmospheric temperature, 272, 277,  
     457, 692  
 Atmospheric Trace MOlecule Spectroscopy  
     (ATMOS), 318, 465  
 A-Train, 275, 305–306  
 Augmented data assimilation  
     problem, 34  
 Augmented state system model, 33  
 Automatic differentiation, 26  
 Averaging kernel, 272, 274, 302,  
     470, 508
- B**
- Background  
     error covariance, 22–24, 60, 72–73, 79–81,  
     86–88, 96–101, 106–109, 111–112,  
     134–135, 240, 283, 286, 290, 296,  
     387, 391, 433, 456, 458, 460, 464,  
     468, 474, 476, 496, 504, 566, 568,  
     572, 611  
     estimates, 15, 19, 20, 22, 31, 34, 42, 45,  
     223, 433, 559  
     humidity field, 285–286  
     states, 15–16, 20, 25, 71–72, 76, 95–97, 99,  
     106–111, 285, 384, 386, 558–559,  
     569, 666  
 Banach space, 215–216  
 Baroclinic lifecycles, 336  
 Baroclinic structure, 336  
 Barotropic structure, 392  
 Bayes's theorem, 19, 120  
 Belgisch Instituut voor Ruimte Aeronomie -  
     Institut d'Aeronomie Spatiale de  
     Belgique (Belgian Institute of Space  
     Aeronomy, BIRA), 453, 469, 473,  
     479–480, 482  
 Best linear unbiased estimate/Best linear  
     unbiased estimator (BLUE), 19–20,  
     22, 43–44, 47–48, 117, 219,  
     221–225, 229, 239–240, 468, 494,  
     496, 498–500, 502, 565  
 Bias, 5, 33, 45, 57, 86–88, 95, 115–135,  
     187, 221–222, 225, 227, 229–230,  
     232, 266, 286, 291, 301, 333, 355,  
     357, 371, 373, 378, 384, 398, 431,  
     451, 454, 460, 468, 470, 472–474,  
     477–478, 482, 493, 521–522, 524,  
     530, 533, 543, 556–557, 562–563,  
     565, 573, 575, 580, 583–585,  
     588–589, 611, 625, 627–631, 633,  
     636, 640–642, 660, 665, 667, 675  
     correction, 115, 118–119, 124–127, 129,  
     134, 266, 384, 478, 530, 556, 583,  
     588–589, 625, 630–631, 665, 675  
 Biological ocean assimilation, 530  
 BLUE, *see* Best linear unbiased estimate/Best  
     linear unbiased estimator (BLUE)  
 Borel field, 165, 188, 200, 208–209  
 Box chemical model, 432–437  
 Brewer-Dobson circulation, 340–347, 451,  
     474, 477–478, 633
- C**
- CAMELOT study, 313–314  
 Canadian Middle Atmosphere Model  
     (CMAM), 453, 482  
 Canadian Space Agency (CSA), 304, 306, 308,  
     310–311  
 CAPACITY  
     report, 313–316  
     study, 314, 316  
 Carbon dioxide, 272, 327, 341, 410, 450,  
     497, 684  
 Cariolle scheme, 458–460  
 Cauchy sequence, 202, 215  
 Centre National d'Études Spatiales (CNES),  
     306, 308  
 Channel selection, 271–274  
 Characteristic function, 209–210  
 Characteristics of information, 5–6  
 Charney-Drazin theory, 342  
 Chemistry, 347, 409–429, 431–447, 462–467,  
     492–504  
 Chemistry-climate model (CCM), 432,  
     479, 482  
 Chemistry-Climate Model Validation  
     (CCMVal), 479  
 Chemistry-transport model (CTM), 314, 317,  
     417–421, 424, 429, 432, 442–443,  
     446, 452–453, 459–460, 462–467,  
     471–473, 476–478, 480, 482, 493,  
     496, 504, 509, 639  
 Chi-squared diagnostics, 14–20  
 Clausius-Clapeyron equation, 327  
 Climate, 312–313, 391, 392, 395, 517, 519,  
     522, 582–583, 623–643  
 Cloud Aerosol Lidar and Infrared Path finder  
     Satellite Observation (CALIPSO),  
     275, 305–306, 314, 316

- Cloud(s), 264, 270, 272–273, 275, 278–279, 283, 286, 296, 305–307, 313–316, 327, 344, 359, 361, 363, 365–366, 383–384, 390, 399, 415, 421–422, 428, 451, 455–456, 472, 482, 526, 551–552, 580, 588, 601, 624, 634–635, 651, 653–655, 657, 664–666, 673, 688, 695  
 detection, 102  
 Clouds and the Earth's Radiant Energy System (CERES), 305  
 Cold REgions Hydrology high-resolution Observatory (CoReH<sub>2</sub>O), 307  
 COmisión Nacional de Actividades Espaciales (CONAE), 311  
 Community Land Model (CLM), 553, 583  
 Conditional covariance operator, 141, 148, 154  
 Conditional mean operator, 141, 154  
 Conditional probability, 44, 60, 63, 120  
 Conservation equations, 352–353, 355, 359, 361, 366, 368, 371–373, 446, 606, 608, 625, 633, 641  
 Conservative dynamics, 143  
 Constituent (chemical) data assimilation, 142, 317, 410, 429, 442, 449–451, 453–454, 463–468, 471–472, 478, 481–482, 492–494, 498, 557  
 Continuity equations, 247–250, 353, 360–361, 375, 442–443, 608  
 Continuum system dynamics, 139  
 Control  
 operator, 562  
 run, OSSEs, 87, 493, 505, 585, 647–648, 672  
 space, 49, 60, 387  
 variable, 15, 28–29, 34, 49, 53, 57, 60, 387, 456, 463, 465, 476, 479  
 Convection, 7, 78, 296, 336, 339–340, 363, 397, 410, 420–421, 424, 429, 442  
 Coriolis force, 328–329  
 Coronal mass ejections (CMEs), 599, 601, 604  
 Cost function, 70–72, 74–75, 80–82, 84, 98, 121, 125–126, 130–131, 258–259, 291–294, 385–386, 388–389, 433, 502–503, 571, 578  
 Covariance  
 function, 149, 192, 227–228, 538, 541  
 inflation, 142, 164, 187  
 localization, 142, 158, 577  
 matrices, 19, 22, 27, 31–32, 34–35, 46, 48, 58, 60, 95, 98, 103, 226, 228, 237, 297, 431, 433, 436–437, 446–447, 450, 468, 497, 501–502, 504, 510, 540, 564, 572  
 operator, 141, 144, 146, 148, 152, 154, 167, 169, 180–181, 186, 192–193, 217  
 Critical velocity, 342  
 Cross-correlation, 73, 75  
 Cross-covariance function, 121  
 Cross-track Infrared Sounder (CrIS), 314–315  
 CRyogenic Infrared Spectrometers and Telescopes for the Atmosphere (CRISTA), 318, 465  
 Cryogenic Limb Array Etalon Spectrometer (CLAES), 304, 318, 464  
 Cyclones, 101, 289, 294, 296, 327, 329, 334, 337, 341, 343, 520, 655–656
- D**  
 Data assimilation  
 dual approach, 48, 58–59  
 dual variational problem, 24  
 four dimensional, 25–30  
 in linear systems, 123, 431, 464, 565  
 in non-linear systems, 166, 464  
 sequential, 20–25, 601  
*See also* Kalman filter (KF), variational; Variational assimilation  
 Data Assimilation Research Centre, UK (DARC), 24, 30  
 Data denial experiments, 82, 648, 669  
 Data-minus-analysis difference (DmA), 118, 226–228, 230–231, 237, 239, 241  
 Data space, 43–44, 220–222, 231, 237  
 Data vector, 43–45, 220–223, 227, 233–234  
 Defense Meteorological Satellite Program (DMSP), 272, 274  
 Derived products, 354–355, 360, 363, 366, 623  
 Determinacy condition, 44–46, 48, 221, 223  
 Deutsches Zentrum für Luft-und Raumfahrt (DLR), 308, 479  
 3D-FGAT, 388  
*See also* First guess at the appropriate time (FGAT)  
 Digital filter initialization (DFI), 252–258, 388  
 Digital filters  
 constraint in 4D-Var, 132  
 non-recursive, 253–255  
 recursive, 104, 255  
 Direct circulation, 332, 337–338  
 Direct observer assimilation, 558–559  
 Discharge observations, 581  
 Discrete non-linear equations, 14, 30  
 Discretization, 33, 142, 152, 253, 353, 355, 365–366, 392, 611

- Dissipation, 142–143, 160–161, 163–164, 170, 187, 246, 367, 371, 397, 422, 633, 638
- Divergence, 44, 104, 106–107, 142, 164, 243, 246, 248–250, 256, 290, 359, 366, 371, 374–376, 497, 633–634, 640
- Dolph-Chebyshev filter, 252
- Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS), 306
- Doppler Wind Lidar (DWL), 269, 275, 652, 654, 657, 665–666, 671, 673–674
- Downward control, 347
- Dynamical meteorology, 327
- Dynamical projection, 534, 536
- Dynamic observer assimilation, 558–560, 571–572
- Dynamics, 4, 13, 26, 30–31, 33, 35, 54–57, 78, 86, 100–101, 111, 139–145, 147, 152–153, 155–156, 158, 161, 165–166, 187, 247, 251, 325–348, 353–355, 360, 362–363, 369–370, 373–377, 381, 410–411, 421, 425, 427–429, 443, 451, 453, 457, 462, 467, 482, 492, 498, 509, 521, 554, 557, 559, 571, 573–574, 577, 582, 590, 600–601, 604, 606, 612, 629, 633–634, 640–642, 651, 658, 684, 693, 695
- E**
- Earth Clouds And Radiation Explorer (EarthCARE), 278, 307, 314, 316
- Earth Observation, 7, 11, 269, 302, 304, 307, 454, 467, 491, 508
- Earth Observing System (EOS), 278, 304–307, 309–310, 314, 316, 318, 362, 411, 427, 453, 457, 460–461, 478–480, 495, 624, 641
- Earth Probe (EP), 304
- Earth system, 11–12, 124, 301, 306, 313, 319, 355, 362, 371, 394, 455, 498, 530, 550, 590
- Eddies; stationary, transient, 333–334
- Electron  
density, 599, 601, 605–606, 609–612, 618  
field aligned velocity, 606  
temperature, 606, 609
- El Niño, 339–340, 518, 521–522, 524, 541, 626, 633, 636
- El Niño Southern Oscillation (ENSO), 339–340, 522, 636
- Emission rate estimates, 493, 506–507
- Empirical orthogonal function, 129, 534, 539
- Empirical projection, 534
- Energy  
norm, 84, 139, 142, 396  
total, 139–147, 150, 152, 154, 156, 158–161, 163, 166, 170, 185, 396  
variables, 140, 142, 144–145, 147–148, 152, 155, 163, 185–187
- Ensemble  
assimilation, 390–391, 530  
collapse, 142, 187, 497  
mean, 73, 78, 161, 162–163, 187, 395, 401, 500, 565, 570, 584  
prediction system, 401
- Ensemble Kalman Filter (EnKF), 25, 60, 63, 69–89, 97, 99–100, 104, 107–109, 112, 129, 139–143, 147, 155–165, 186–188, 389–391, 463, 497, 500–501, 530, 559, 569–570, 572, 575–578, 582–584, 688
- Entropy, 9, 497
- Envisat satellite, 8, 275–277, 341
- EOS Aqua satellite, 310
- EOS Aura satellite, 304–306, 309, 316, 318, 411, 427, 453, 457, 460, 479–480, 495
- EOS Microwave Limb Sounder (EOS MLS), 305, 460–461, 478
- EOS Terra satellite, 305, 314
- ERA-15, 624
- ERA-40, 117–118, 454, 460, 478, 482, 625, 631, 633–636, 643
- ERA-interim, 54, 460, 478, 625, 641, 643
- Error  
covariance, 99–101, 103–107  
matrix, 21–25, 47, 60, 96, 98, 100–101, 106, 157, 222–225, 228–231, 233, 238, 240, 286, 433–434, 442, 446, 456, 458, 464–465, 476, 496, 499–502, 560, 565, 568–569, 574, 611  
equation, 33  
of representativeness (or representativity), 10, 302, 665
- Essential climate variables (ECVs), 312–313
- Eulerian picture of motion, 337
- Euler-Lagrange equations, 246
- EUMETSAT Polar System (EPS), 309
- European Centre for Medium-Range Weather Forecasts (ECMWF), 27, 54, 56, 80–81, 100, 127, 132, 231, 270, 273, 279–280, 295–296, 301, 303, 310, 312, 317, 319, 386–387, 391, 393–394, 396–398, 403, 425–426, 453, 456–457, 459–463, 473–476,



- 478–483, 497, 518, 526, 540, 576,  
624–625, 633, 643, 654–655, 671
- EUropean organisation for the exploitation  
of METeorological SATellites  
(EUMETSAT), 269–270, 272, 275,  
308–309
- European Research Satellite (ERS), 270, 275,  
306, 308, 314, 318, 480, 494, 526,  
552, 574
- European Space Agency (ESA), 8, 269, 274,  
275, 278, 304, 306–310, 313, 316,  
469, 479, 482, 528, 694
- Evaluation of data assimilation, 11–12,  
219–241, 467–472
- Expectation operator, 141, 145–146, 153, 167,  
169, 188, 212, 565
- Expendable bathythermographs (XBTs), 524,  
527, 540
- Extended Kalman Filter (EKF), 22, 32, 72, 76,  
80, 187, 389, 391, 442, 445, 465,  
555, 568–570, 574, 576–577, 579,  
582, 587
- F**
- Ferrel cell, 332, 337
- FGAT, *see* First guess at the appropriate time  
(FGAT)
- Filling in gaps, 6–8, 85
- Filter divergence, 142, 164, 497
- Filtered equations, 245, 392
- Final warming, 344
- First guess at the appropriate time (FGAT),  
56–57, 388
- First and second moments, 63
- FLuorescence Explorer (FLEX), 307
- Forecasts, 82–84, 99–101, 127–130, 244,  
294–296, 394–404, 480–481, 529
- Forward model, 115, 319, 457, 504, 590,  
658–660, 662, 669, 682
- Four dimensional variation (4D-Var), 25, 41,  
47–50, 53, 56–60, 69–70, 74–77,  
79–82, 84, 86–89, 100, 102, 109,  
112, 127, 129–130, 132, 134, 139,  
142, 147, 187, 246, 258–260, 279,  
284, 288–291, 294, 303, 388–389,  
391, 403, 457, 460, 463–466,  
473, 478–479, 491, 495–499, 502,  
504–507, 510, 529–530, 571, 578,  
631, 654, 687
- Fourier Transform InfraRed (FTIR), 314–315,  
471–472
- Fraternal twin experiments, 651
- Frèchet space, 202
- Friction torque, 333
- Function of positive type, 144, 155, 185
- Fundamental climate data records  
(FCDRs), 313
- Fundamental control functions, 29–30, 96
- G**
- Gain matrix, 18, 21, 23–24, 72, 82, 84, 117,  
128, 224, 272, 431, 499, 501, 558,  
565, 567, 611, 669, 686
- Gaussian errors, 9, 60, 70, 84, 95, 291–294,  
431, 437, 468–469, 500
- Gauss-markov formula, 571
- General circulation model (GCM), 343, 362,  
374, 377, 393, 423, 425, 452–462,  
473, 477, 480, 482, 521, 552–553,  
639–641, 682, 684–687, 695
- Geoid, 308, 519, 524–526, 528–529, 531–533
- Geopotential, 44, 124, 143–144, 172, 183, 227,  
239, 250, 253, 328, 341, 343, 366,  
457–458, 524, 531, 624, 628, 658,  
669, 671, 673
- Geostationary Earth Radiation Budget  
experiment (GERB), 702
- Geostationary Operational Environmental  
Satellite (GOES), 270, 551–552
- Geostrophic balance, 243–244, 246, 250, 329,  
339, 358, 392, 695
- Geostrophic currents, 518, 524, 528
- Geostrophic wind, 329–330, 358, 371
- Global Change Observation Mission  
(GCOM), 310
- Global Climate Observing System (GCOS),  
312–313
- Global Earth Observing System of Systems  
(GEOSS), 307
- Global Earth system Monitoring using Space  
and in-situ data (GEMS) project,  
319, 482
- GLobal Imager (GLI), 310
- Global Modeling Assimilation Office  
(GMAO), 387, 425–427, 453, 460,  
465, 467, 480, 624
- Global Monitoring for Environment and  
Security (GMES), 307–309, 482
- Global Observing System (GOS), 263–280,  
283, 294–296, 301–303, 311–312,  
317, 319, 368–369, 382–383, 441,  
450–451, 454, 482, 495, 627, 652,  
654, 675–676
- Global Ocean Data Assimilation Experiment  
(GODAE), 526, 531
- Global Ocean Observing System (GOOS),  
519, 521, 531

Global Ozone Monitoring Experiment (GOME, GOME-2), 303, 306, 309, 314–318, 452, 460–461, 478–481, 494, 508

Global Ozone Monitoring by Occultation of Stars (GOMOS), 306, 318, 465, 471, 473, 479

Global Positioning System (GPS), 266, 276–277, 279, 283, 291, 303, 362, 383, 599–618

GMES Sentinels, 309

Goddard Earth Observing System (GEOS), 270–271, 278, 362, 425–427, 453, 460, 467–468, 480, 624, 632, 641

Gradient  
 methods, 24, 49–50  
 minimization procedure, 29  
 optimization method, 25

GRAvity and Climate Experiment (GRACE), 526, 528, 532, 552, 582

Gravity field and steady-state OCEan circulation (GOCE), 307, 526, 528

Gravity  
 wave(s), 243–244, 246, 250–251, 256–258, 260, 333, 361–362, 367, 428  
 drag, 333

Greenhouse gas Observing SATellite (GOSAT), 310, 315

Gridpoint statistical interpolation (GSI), 388, 460

Ground water storage, 582

Group on Earth Observations (GEO), 274, 303, 307, 309

**H**

Hadley cell, 332, 422, 633

HALogen Occultation Experiment (HALOE), 304, 318, 345–346, 465, 470, 473–474, 476–478

Held-Hou model, 332

Hessian, 17–18, 27–29, 464, 571

High impact weather, 301, 401–404

High Resolution Doppler Imager (HRDI), 304

High Resolution Dynamics Limb Sounder (HIRDLS), 305

High resolution Infrared Radiation Sounder/4 (HIRS/4), 272, 702

Hilbert-Schmidt operator, 181, 203–204

Hilbert space, 140–141, 143–147, 152–153, 155, 165–170, 175, 177, 180, 183, 188–207, 214–217

Hilbert space-valued random variables, 141, 143–144, 166–169, 188

HO<sub>x</sub> (=OH+HO<sub>2</sub>), 344, 416, 428, 451

Humidity control variable, 476

Humidity Sounder for Brazil (HSB), 305

Hybrid assimilation methods, 391, 572

Hydrographic, 520, 522, 533–535, 539–540, 543

Hydrological cycle, 278–279, 626, 628

Hydrology, 54, 363, 402, 554–555, 563, 590

Hydrostatic atmospheric dynamics, 144, 153, 156

Hydrostatic balance, 247, 330, 365, 371, 533

Hygropause, 344

Hyperbolic systems, 143, 170, 176, 178–179, 183–184, 187

**I**

Ill-condition index, 23

Imperial College Ocean Model (ICOM), 521

Improved Limb Atmospheric Spectrometer (ILAS), 310, 318, 453

Improved Stratospheric And Mesospheric Sounder (ISAMS), 304

Incremental approach, 27–28, 55–56, 58–59, 388

Independent tests, 468, 470

Indirect circulation, 332, 337–338

Inertia-gravity waves, 428

Infrared Atmospheric Sounding Interferometer (IASI), 272, 309, 312, 314–315, 461

Initialization, 243–260, 355–356, 367, 388, 549, 554, 556, 578, 588, 654

Inner product, 144–145, 152–153, 155, 164–165, 172, 175, 177, 180, 183–184, 188, 190, 195–196, 200–204, 214–217, 469

Innovation vectors, 46, 57–58, 96, 102, 123, 224, 226–227, 239, 291, 384

Integral  
 Lebesgue, 211–213  
 Lebesgue-Stieltjes, 212–213

Integrated Global Atmospheric Chemistry Observations (IGACO), 317, 452

Inverse  
 modelling, 312, 317, 319, 417–418, 420, 450, 453–454, 465, 472, 491–510, 557, 600, 638  
 problems, 13, 23, 28, 417, 419, 440, 582

Ion heating rates, 606

Ion-ion collision frequency, 606

Ion-neutral collision frequency, 606

Ionosphere, 3, 599–601, 603–610, 612–614, 617

Ionosphere data assimilation, 599–601

- Ionospheric processes, 601–606
- Ions  
 density, 600, 608  
 temperature, 608–609
- Iterative algorithm, 16, 49
- J**
- Jacobian, 16–18, 21, 26, 50–53, 55–56, 59, 122, 162–163, 290, 443, 569–570
- Japan Aerospace space eXploration Agency (JAXA), 269, 304, 307, 310
- Japanese National Institute for Environmental Studies (NIES), 310
- Joint probability distribution, 19
- JRA-25 reanalysis, 625, 631, 643
- Jupiter, planet, 681, 695
- K**
- Kalman-Bucy filter, *see* Kalman filter (KF)
- Kalman filter (KF)  
 ensemble, 25, 60, 63, 69–89, 97, 129, 139, 141–142, 155–165, 389–391, 463, 497, 500–501, 530, 559, 570, 572, 576, 582–583, 688  
 extended, 22, 32, 72, 80, 187, 389, 391, 442, 445, 465, 555, 568–570, 576, 587  
 reduced-rank, 100–101  
 variational, 100, 495, 497, 499
- Kalman gain, 72, 83–84, 118, 272, 292, 389, 431, 499, 501, 565, 568, 578, 611
- Kalman smoother, 71, 77, 132, 576, 582
- Kelvin waves, 340, 361
- Koninklijk Nederlands Meteorologisch Instituut (KNMI), The Royal Dutch Meteorological Institute, 453, 460, 479–481, 508–509
- L**
- Lagrangian, 338, 341, 345, 347, 353, 392, 423, 444, 522, 529, 537, 542, 571, 640
- Lagrangian picture of motion, 338
- Land surface  
 data assimilation, 54, 279, 363, 367, 549–590, 635  
 flux, 555, 579–581  
 model, 129, 549–550, 552–555, 557, 564, 572, 577, 579, 582, 586, 588  
 temperature, 308, 579
- La Niña, 340, 626, 633
- Lapse rate, 327, 427
- Laser RetroReflector (LRR), 306
- Leaf Area Index (LAI), 313, 551, 581
- Lebesgue measure, 209, 211–212
- Lebesgue square-integration, 175, 177, 180, 203–204
- Level 0, 1, 2, 3 and 4 data, 302
- Limb Infrared Monitor of the Stratosphere (LIMS), 318
- Limb  
 occultation, 304, 306  
 sounder, 6, 276, 303, 305, 316, 319, 461
- Limited area model, 132, 252, 255, 392, 394
- Linearization matrix, 434–435, 438
- Linear space, 214–217
- Local thermal equilibrium (LTE), 328
- M**
- Mahalanobis scalar product, 221, 231
- Marginal probability density, 403
- Markov property, 132
- Mars data assimilation, 683–694
- Mars, planet, 681–695
- Maximum likelihood, 70–72, 74, 433, 466
- Mean, 16, 78–79, 82, 129, 231, 258, 384, 397–398, 468, 508, 539, 544, 589, 670, 673
- Measurement information, 437–441
- Measurements of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation (MAESTRO), 310, 315
- Measurements Of Pollution in The Troposphere (MOPITT), 305, 418–420, 473, 495
- Measure space, 208–209, 211–212, 216
- MEDium Resolution Imaging Spectrometer (MERIS), 306, 309
- Meridional mean circulation, 423
- Meridional overturning circulation (MOC), 522, 527
- Meridional wind, 109, 140, 333, 636, 673
- Mesopause, 327
- Mesosphere, 304–305, 326–327, 331, 340, 344–345, 362, 457, 473–474, 476
- Meteorological data assimilation, 316–317, 385, 449, 494–495
- Meteorological Office, UK, 54, 640–641, 687
- Meteosat Second Generation (MSG), 308, 314
- Meteosat Third Generation (MTG), 309
- Methane, 310–311, 315, 341, 345, 427, 444, 453, 462, 467
- Met Service Canada (MSC), 482
- Michelson Interferometer for Passive Atmospheric Sounding (MIPAS), 8, 276, 303, 306–307, 318, 460–461, 467, 469, 471–480

- Microwave Limb Sounder (MLS), 6, 276, 304–305, 318, 453, 457, 464, 472, 478–479
- MicroWave Radiometer (MWR), 306, 308, 561, 578, 582
- Minimization, 15–16, 24–26, 28–29, 32, 41–42, 45–57, 59–63, 75, 80–81, 84, 86, 104, 126, 132, 154, 221, 225, 232, 246, 259–260, 285–286, 293, 387–388, 434, 503–504, 568, 571
- Minimum variance, 19–20, 142, 147–151, 186, 572
- Mixing  
   atmosphere, 367, 639  
   ocean, 520, 530
- Model of ozone and related tracers (MOZART), 418–419, 424, 472
- Model(s)  
   equations  
     as strong constraints, 15, 34  
     as weak constraints, 30–31  
   error  
     bias, 33, 132  
     evolving, 33  
     spectral form, 33  
   noise, 643, 660, 665, 668–669  
   operator, 17, 50, 52, 55, 503
- MODerate resolution Imaging Spectroradiometer (MODIS), 274, 305, 418, 551–552, 581–582
- Monitoring, 116, 301, 306–309, 312, 315, 317, 357, 409, 417, 449, 452, 454, 478–480, 482, 498, 527, 531, 661
- Monitoring Atmospheric Composition and Climate (MACC) project, 482
- Monsoon, 338–339, 626
- Monte Carlo methods, 73, 432
- Multi-angle Imaging SpectroRadiometer (MISR), 305
- Multivariate/multivariance, 97, 256, 296, 443, 456, 467, 538, 590
- N**
- Nadir sounder, 276, 303, 305–306
- National Aeronautics and Space Administration (NASA), 6, 269, 272, 274–276, 304–305, 308, 310, 316, 341, 387, 427, 460, 464, 480, 496, 553, 624–625, 632, 641, 643, 666, 685–687
- National Center for Atmospheric Research (NCAR), 86–87, 363, 397, 423–424, 624, 627, 631, 633–634, 636, 643
- National Centers for Environmental Prediction (NCEP), 80, 86, 117, 387, 458, 588, 649, 671
- National Meteorological Center (NMC), 97, 99–100, 106–109, 387, 498, 624
- National Oceanic and Atmospheric Administration (NOAA), 125, 236, 269–274, 279, 308, 311, 403, 460, 468, 479–480, 498, 643
- National Polar-orbiting Operational Environmental Satellite System (NPOESS), 278, 314–316
- Nature run, 79, 83, 87, 648, 650–657, 659–676
- NCEP Global Forecasting System (NCEP GFS), 397, 479
- NCEP/NCAR Reanalysis, 624, 633–634, 636, 643
- NCEP Observing System Simulation Experiment (NCEP OSSE), 649, 654, 664, 669, 671–674
- Necessary optimality condition, 239
- Need for information, 3–4
- Nitrogen dioxide (NO<sub>2</sub>), 304–306, 309–310, 314, 316–318, 411–417, 419, 437, 446–447, 452, 463–465, 471, 473, 480, 494, 496, 504–509
- Nitrous oxide (N<sub>2</sub>O), 310, 315, 317–318, 423, 437, 452, 465–466, 469–472, 480
- NMC method, 99–100, 106–109, 387
- Non-Gaussian errors, 291–294
- Non-Methane HydroCarbons (NMHCs), 315
- Normal mode initialization, 251–252, 257–258, 388
- North Atlantic Deep Water (NADW), 523
- Nowcasting, 270, 599, 601, 612, 617–618
- NO<sub>x</sub> (=NO+NO<sub>2</sub>), 415–416, 421, 428, 465, 504–505
- Nucleus for European Modelling of the Ocean (NEMO), 521
- Nudging, 86, 452, 491, 556, 559, 566–567, 573–574, 580
- Numerical modelling, 50, 363, 392–394, 600–601, 604, 681
- Numerical weather prediction (NWP), 42, 55–57, 61, 63, 99–101, 103, 105, 107, 111–112, 224, 240, 252–253, 263–264, 266, 268–270, 273, 277, 279, 283, 294–296, 301, 303, 305, 310, 312, 314, 316–317, 319, 381–404, 449–456, 458, 460–464, 467, 471–472, 476, 479–482, 529, 576, 580, 600, 611, 623, 650–653,

- 655–656, 660–661, 666–667, 669, 671, 675, 682–684, 686, 695
- NWP, *see* Numerical weather prediction (NWP)
- O**
- Objective  
 analysis, 288, 385  
 function, 15–18, 26–28, 31–32, 34–35, 41, 45–61, 63, 221, 231–234, 236, 502, 557, 559–560, 571, 585–586
- Observational error, 15–16, 19–20, 23, 31, 42, 47, 83, 86–87, 228, 236, 357, 431, 433, 451, 468, 551, 565, 567, 578, 590, 647, 659, 670, 674
- Observation error covariance, 73, 96–98, 103, 285, 659
- Observation gross error, 291–294, 385
- Observation minus analysis (OmA), 357–358, 468, 650, 667, 670
- Observation minus forecast (OmF), 78, 118, 125, 128, 357, 466, 468–469, 473, 478
- Observation operator, 17–18, 20, 22, 25, 32, 45, 47–48, 50, 52–53, 55, 58, 63, 70, 74, 76, 96, 119, 121–122, 140, 147, 159, 186, 223, 272, 283, 285, 290–291, 296, 367, 384, 387, 390, 433, 463, 499, 501, 510, 572, 575, 582, 610, 658
- Observations  
 aircraft, 267–268, 295  
 altimeter, 275, 278  
 asynoptic, 77, 691  
 atmospheric motion vectors, 102  
 dropsonde, 266–267, 269, 278  
*in situ*, 263–264  
 ocean, 519, 521–523  
 ozone, 314, 317, 369, 452, 457  
 ozonesonde, 462, 470, 476, 478  
 radiosonde, 265–267  
 remote sensing, 269–277  
 satellite, 124, 271, 280  
 scatterometer, 274–275, 278  
 surface, 264–265  
 synoptic, 264, 289–290  
 targeted, 268–269  
 wind profilers, 277
- Observing system, 263–280, 312–313, 382–383, 647–676
- Observing system experiment (OSE), 279, 294, 296, 454, 531, 647–648, 652, 670
- Observing system replacement experiment (OSRE), 652
- Observing system simulation experiment (OSSE), 79, 87, 236, 279, 294, 311, 441, 454, 531, 537, 576–577, 647–676
- Ocean  
 colour, 313, 526–527  
 currents, 519, 521, 526, 528, 531  
 data assimilation, 42, 129, 224, 363, 517–543, 554  
 eddies, 333, 518  
 inverse problem, 100–101, 223–224  
 salinity, 278, 313  
 state estimation, 519, 538  
 temperature, 524  
 wave forecasting, 528
- ODIN satellite, 306, 316, 318
- One dimensional variation (1-D Var), 390
- Optical path, 276, 314
- Optical Spectrograph and InfraRed Imager System (OSIRIS), 306
- Optimal analysis, 15, 19, 21–22, 24–25, 31–32, 289, 568
- Optimal filter, 252, 565
- Optimal interpolation (OI), 23–24, 291, 386–387, 463, 498, 530, 540, 556, 559, 567–568, 573–574, 580–581, 687
- Optimality system, 32, 95, 147, 154, 186, 223, 225, 228, 239–241, 431, 576
- Orbiting Carbon Observatory (OCO), 306
- Outgoing radiance, 628–629, 634
- Ozone  
 hole, 8, 307, 347, 409, 458–459, 480–481  
 miniholes, 481
- Ozone Mapping and Profiler Suite (OMPS), 314–316
- Ozone Monitoring Instrument (OMI), 305, 318, 453, 460, 479–480, 494–495
- P**
- Parametrizations, 115, 353, 359, 363–364, 367, 370–371, 373, 378, 382, 392, 396–397, 429, 431, 449, 451, 455, 458–459, 463, 474, 589, 603–605, 624, 626, 629–630, 634, 638, 642, 650–651, 685, 687, 695
- Passive technologies, 271–274, 303
- Passive tracer analysis, 288
- Perturbation run, OSSEs, 647–648
- Photochemical models, 436–437, 442, 444, 471
- Photodissociation, 409, 411–412, 415
- Physical consistency, 351, 355, 365, 370–377, 638–639, 641

- Physical-space statistical analysis scheme (PSAS), 24, 26, 48, 128, 132, 387, 389, 460, 463–465, 467  
 3D, 24, 26, 463  
 4D, 26, 132, 464
- Planetary boundary layer (PBL), 363, 410, 420–421, 629
- Planetary waves, 342, 421, 424–425, 639, 687–688
- Plasma evolution, 607
- Polar cell, 332, 337
- Polarization and Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations from a Lidar (PARASOL), 305–306, 314
- POLarization and Directionality of the Earth's Reflectance (POLDER), 269–270, 310
- Polar Ozone and Aerosol Measurement (POAM), 453, 467, 473
- Polar Stratospheric Cloud (PSC), 314, 344, 347, 451, 455, 474, 479–480
- Polar vortex, 341–345, 347, 425, 474, 481, 693
- Potential vorticity (PV), 85, 336, 354–355, 426–427, 474, 536–538, 542
- Precipitation, 244, 275, 278–279, 283–284, 296, 305, 310, 313, 359–360, 370, 399, 401, 422, 456, 550–551, 576–577, 580, 586, 590, 624–625, 628–629, 632, 634–638, 669
- Preconditioning, 17, 58, 508
- Predictability, 370, 394–395, 397, 457, 649, 667, 685
- Prediction, 4, 127, 160, 244–245, 312, 352, 355–358, 370–371, 381–404, 496, 522, 529–531, 549–551, 553–555, 562, 564, 572–577, 683
- Pressure, 63, 98, 102, 105–107, 144–145, 243–248, 250–253, 255–257, 264–267, 288–291, 326–333, 346, 360, 365–366, 375–376, 384, 387, 392, 397–399, 427, 437, 442, 455, 462, 518, 529, 531, 533–536, 575, 638, 656–657, 682, 684–688, 690, 692–694
- Primary products, 354–355, 359–360, 368
- Primitive equations, 53, 86, 140, 245–247, 392, 535–536, 538, 686
- Princeton Ocean Model (POM), 521
- Principle of energetic consistency (PEC), 139–217
- Probabilistic forecasts, 394, 400–401
- Probability  
 density function, 60, 120–121, 291–292, 385, 433, 437, 445, 496  
 measure, 148–149, 167, 188, 196–197, 212, 214  
 space, 145, 147, 167, 169, 188–189, 199, 212, 214
- PRocess Exploration through Measurements of Infrared and milli-metre wave Emitted Radiation (PREMIER), 307
- PROtocol for MOnitoring for The GMES service Element (PROMOTE), 479, 482
- PSAS, *see* Physical-space statistical analysis system (PSAS)
- Q**
- Quality control, 258, 280, 283, 291–294, 296, 356, 367, 383–385, 469, 474, 476, 505, 560–562, 587, 625–626, 649
- Quasi-linear evolution problem, 178
- R**
- Radar Altimeter 2 (RA-2), 306, 308–309, 625, 631, 643
- Radiance  
 data assimilation, 283–288  
 increments, 286–288  
 residuals, 116–117, 119, 124–125
- Radiation, 117, 235, 244, 271–272, 274, 276, 279, 283, 305, 307, 310, 313, 325, 327, 341, 344, 346–347, 363, 389, 392, 409–411, 422, 451, 457, 459, 522, 574, 599–601, 628–629, 634, 636, 684, 687–688
- Radiative equilibrium, 347
- Radiative transfer, 7, 117, 119, 124, 127, 285, 290, 367, 390, 455, 458, 556, 564, 574, 578, 634, 651, 659, 662, 664  
 equation, 7
- Radiative transfer model (RTM), 117, 127, 290, 367, 390, 458, 556, 574, 577–579, 582, 651, 659, 664–665
- Radiosonde measurements, 236, 271, 627
- Radius of influence, 23, 566
- Random  
 error, 5, 31, 33, 83, 115, 119–120, 225, 291–292, 302, 367, 429, 432, 472, 659–660  
 variable, 29, 31, 141, 143–150, 152–158, 166–172, 180–183, 188–199, 203, 212–214, 220, 233, 469, 563

- Reanalysis, 54, 86–87, 117–118, 355, 370,  
 397, 460, 482, 522, 530, 556, 576,  
 588–589, 623–643, 682
- Relative error growth, 438–441
- Relative humidity, 456, 476, 555, 580, 658
- Remote sensing, 124, 134, 263, 269–277, 315,  
 526, 549–552, 554–555, 561–562,  
 572–575, 578, 581, 586, 590, 686
- Representer, 26, 28, 132
  - accelerated representer algorithm  
 (4D-PSAS), 26, 132, 464
- Residual vector, 376
- Retrieval, 272, 284–286, 302, 314, 316, 390,  
 417, 419–420, 450, 453, 455,  
 460, 468–469, 472, 491, 496,  
 498, 508–510, 550, 574–576, 578,  
 585–587, 629, 682, 685, 688
- Richardson's forecast, 244–245, 392
- Root-mean-square (RMS), 79, 81–82, 85, 129,  
 256, 382, 396, 466, 506, 537, 542,  
 587–588
- Rossby-Haurwitz waves, 243, 249–250
- Rossby radius, 537
- Rossby waves, 251, 334–337, 340–342,  
 361, 542
- S**
- Satellite data/instruments
  - AIRS, 270, 272–274, 305
  - AMSU, 235, 272–273, 305
  - ATOVS, 279, 456
  - AVHRR, 274, 526, 528
  - GPS, 276–277, 303
  - HIRS, 270, 272–274
  - IASI, 272, 309, 312
  - MODIS, 274, 305, 418
  - SBUV, 311
  - SSM/I, 274, 279, 456, 528
  - TOMS, 304–305, 317
  - TOVS, 236, 285, 458
- Satellites
  - ADEOS-II, 310
  - ADM-Aeolus, 278, 307, 316, 666
  - COSMIC, 276–277, 617
  - DMSF, 272, 274
  - Envisat, 8, 270, 275–276, 278, 304,  
 307–309, 314, 316, 318, 341, 419,  
 460, 471–472, 480, 494, 510
  - EOS, 278, 304–306, 309–310, 314, 316,  
 318, 411, 427, 453, 457, 460–461,  
 478–480, 495, 581
  - GEOSAT, 274, 303, 307, 309
  - GOCE, 307, 526, 528
  - GPM, 278, 551
  - GRACE, 526, 528, 532, 552, 582
  - JASON, 308, 524
  - NOAA, 125, 236, 269–274, 279, 308, 311,  
 339–340, 403, 460, 468, 479–480,  
 498, 524, 637, 643, 666
  - non-sun-synchronous, 304
  - operational, 271, 283, 301, 303, 312, 314,  
 393, 461, 629
  - research, 263, 269, 275–276, 278, 283,  
 301–319, 341, 383, 419, 450, 460,  
 464, 495, 526, 528, 627, 661, 666,  
 688
  - sun-synchronous, 304, 308, 310, 685
  - TOPEX/POSEIDON, 524, 552
  - TRMM, 270, 274–275, 279, 310, 528, 551
  - UARS, 6, 269, 304–305, 318, 341, 345,  
 464, 470, 472, 474–475, 478–479
- Saturn, planet, 681, 695
- Scalar invariant, 140, 144, 146–147, 149,  
 151, 166
- Scale analysis, 354, 364
- Scale height
  - Earth, 684
  - Mars, 684–685
- Scanning Imaging Absorption spectrometer  
 for Atmospheric CHartographY  
 (SCIAMACHY), 303, 306–307,  
 318, 453, 460, 479–480, 494, 510
- Seasonal forecasting, 397, 518–519, 521, 530,  
 540, 543
- Second generation GLI (SGLI), 310
- Self-consistency tests, 468, 470
- Sensitivity analysis, 17, 62, 82–84, 285, 522
- Sensitivity observing system experiment  
 (SOSE), 652
- Sequential data assimilation, 14, 20–25, 601
- Set
  - Borel, 165, 188, 200, 208–209
  - bounded, 179, 211
  - closed, 165
  - Lebesgue measurable, 209, 211–212
  - measurable, 167, 208–212
  - open, 155, 165, 170–171, 174, 184, 188,  
 190, 200
  - subset, 165, 167, 189, 208–209
- Shallow-water equations, 143, 147, 172,  
 183–186, 247
- Short-term prediction error, 629
- Singular vector, 62, 100–101, 289, 396, 403
- Skin temperature, 129, 284, 286, 526, 528,  
 551–552, 557, 588–589
  - assimilation, 557, 588–589

- Snow
    - assimilation, 581, 586–588
    - cover, 273, 313, 551–552, 581–582
  - Snow water equivalent (SWE), 551–552, 581–582, 586–588
  - Sobolev space, 166, 177, 180, 184
  - Soil
    - moisture, 274–275, 278, 307, 313, 551, 553–558, 561, 564, 570, 573–581, 583–586
    - temperature, 555, 578–580
  - Soil Moisture Active and Passive (SMAP), 551
  - Soil Moisture and Ocean Salinity (SMOS), 274, 278, 307, 551
  - Solar Backscatter Ultra-Violet (SBUV, SBUV/2), 311, 318, 453, 460–461, 467–468, 479–480
  - Solar Backscatter Ultraviolet Sounder (SBUS), 311
  - Solar system, 681
  - Sources of information, 3–5, 353, 358, 417
  - Spatial error cross-correlation, 578
  - Special Sensor Microwave Imager/Sounder (SSMIS), 272, 274, 278
  - Special Sensor Microwave Imager (SSM/I), 274, 279, 456, 528, 581–582, 632
  - Spectral channel, 103–105, 365
  - Spin-down, 314
  - Spinning Enhanced Visible and InfraRed Imager (SEVIRI), 479
  - Spin-up, 70, 72, 77–80, 82, 88, 244, 296, 468, 470, 510, 577, 629, 638, 666–668
  - State
    - augmentation, 30, 33–35
    - space, 18, 24, 43–45, 51, 59–60, 63, 129, 220–221, 387, 564
    - vector, 20, 44–45, 47, 60, 86, 115, 126, 132, 144, 147, 165, 220, 223, 226, 238, 251, 386, 494, 499, 536–538, 541, 557–560, 563–564, 566, 571, 611
  - Statistical interpolation, 23–24, 386–388, 460, 530, 559, 567
  - Statistical linear estimation, 41–48, 60, 63, 219–224
  - Stochastic field, 73, 143, 203
  - Stochastic prediction, 396–397
  - Stochastic process, 565
  - Stratopause, 327, 346–347, 361, 411, 456–457, 476
  - Stratosphere
    - chemistry, 318, 413–414, 416, 457, 464
    - jets, 331, 342, 344
    - sudden warmings, 342
  - Stratosphere-troposphere exchange (STE), 426–427, 429
  - Stratospheric Processes And their Role in Climate (SPARC), 474, 479
  - Stratospheric Wind Interferometer For Transport studies (SWIFT), 311
  - Streamflow, 575, 584–586, 590
    - assimilation, 584–586
  - Stream function, 248–250, 387, 397, 423–424, 532, 536–538
  - Strong constraint, 15, 34, 47, 50, 53–54, 57–58, 86, 130–132, 135, 388, 560, 578, 580
  - Subjective analysis, 288
  - Sub-Millimeter Radiometer (SMR), 306, 318
  - Successive correction, 23–24, 385–386, 463, 559, 566–567, 687
  - Summertime high, 341
  - Surface
    - emissions, 273, 359, 411, 417–420, 424, 429, 473
    - temperature, 108–109, 273, 286, 306, 308–309, 313, 339, 352–354, 383, 526, 528, 540, 579, 589–590, 631, 634, 653, 689
  - Swedish National Space Board (SNSB), 306
  - Synoptic analysis, 289–290
  - Synoptic waves, 336, 343, 359, 428
  - Synthetic Aperture Radar (SAR), 275, 308–309, 575
  - Systematic error
    - model, 127–128
    - observation, 302
- T**
- Tangent linear equation, 51–52, 55
  - Tangent linear model, 27–28, 54–55, 187, 434, 558, 563, 568, 571
  - Teleconnections, 340, 636
  - Television and InfraRed Observations Satellite, TIROS, Operational Vertical Sounder (TOVS), 118, 236, 279, 285, 456, 458, 664, 671–673
  - Temperature/salinity (ocean), 540–543
    - T/S, 541–542
  - Thermal conductivity, 581, 606
  - Thermal wind, 330, 332, 354, 536
  - Thermocline, 340, 518, 535, 538
  - Thermodynamic equation, 247–248, 372, 374–376, 640
  - Thermosphere, 327, 607



- Three dimensional variation (3D-Var), 24, 46, 53, 56–57, 60, 79–80, 85, 101, 106, 108–109, 128, 134, 259, 387–388, 391, 403, 460, 463, 479, 510, 530, 559, 568
- See also* Variational assimilation
- Tidal/storm surge forecasting, 529
- Titan, satellite, 681
- Total ozone column, 457–459, 461, 481
- Total Ozone Mapping Spectrometer (TOMS), 304–305, 310–311, 317–318, 347, 452, 460–461, 467, 472, 479–480
- Total Ozone Unit (TOU), 311
- Transformed Eulerian mean (TEM), 338, 372, 376, 423–425
- Transmittance function, 616
- Transport, 76, 307, 314, 333–334, 337–338, 341, 344–347, 352–353, 358–359, 364, 366, 369–371, 409–429, 431–447, 477–478, 504, 519, 522, 604–607, 624–625, 633, 638–642, 663
- TRMM Microwave Imager (TMI), 274, 310
- Tropical Atmosphere Ocean, TAO, buoys, 524, 527, 540
- Tropical Rainfall Measuring Mission (TRMM), 270, 274–275, 279, 310, 528, 551
- Tropopause, 128, 268, 290, 314, 327, 330, 336, 344–345, 410–411, 421–422, 424, 426–429, 474, 627, 632–633, 640
- Troposphere, 124, 128, 265, 276–277, 289–290, 304–305, 307, 312, 314–315, 326–327, 330–341, 344–346, 359, 368, 410–411, 413, 415–418, 420–422, 424–426, 428–429, 450–451, 455–456, 458, 461, 472, 476, 478, 493, 495, 506, 600, 604, 629, 639, 686
- Tropospheric chemistry, 414–417, 441, 480, 492–493, 495–496, 499–504
- TRospheric composition and Air Quality (TRAQ), 307
- Tropospheric Emission Spectrometer (TES), 305, 315, 685–689
- Tropospheric jets, 330–331
- Tropospheric pollution, 319, 451, 453, 463–464, 472–473, 482
- Truncated 4D-Var, 29–30
- Twin assimilation experiments, 537
- U**
- Uncertainties
- artificial, 139
  - genuine, 186
- United Nations Framework Convention on Climate Change (UNFCCC), 312
- Univariate, 84, 456, 458, 460, 467, 540
- Upper Atmosphere Research Satellite (UARS), 6, 341, 464
- Upper troposphere / lower stratosphere (UTLS), 305, 314, 316, 344, 425–429, 451, 457, 478
- V**
- Validation, 55, 63, 84, 224–226, 232, 241, 305–307, 311, 362, 462, 471, 479, 496, 527, 557, 562–563, 577, 579, 606, 612, 624, 634, 656
- Value of information, 3–12
- Variance, 9, 19–20, 24, 60, 74, 78, 87, 97–99, 101, 106, 141–143, 146–151, 156, 160–164, 167–168, 170, 186–188, 194, 213, 224–226, 228–229, 231–233, 239, 352, 437–441, 466, 534–535, 541–542, 568, 572, 634, 658–660, 683
- Variational algorithms, 41, 48, 232
- Variational assimilation
- 3D-Var, 391, 460
  - 4D-Var, 246, 258–260, 388
  - incremental 3D-Var, 56
  - incremental 4D-Var, 60, 81, 571
  - strong constraint, 58
  - weak constraint, 57
- Variational quality control, 291–294, 385
- Vegetation, 273, 309, 313, 353, 363, 394, 492, 551–553, 555, 578, 581, 590
- Venus data assimilation, 681, 694–695
- Venus, planet, 681, 694–695
- Vertical modes, 253, 535
- Vertical wind, 290, 329, 331, 359, 374–377, 443, 641
- Vorticity, 44, 85, 104–106, 243, 248–249, 290, 334–336, 354–355, 366, 371, 426, 457–458, 474, 518, 536–538, 542, 673
- W**
- Walker circulation, 338–340, 633–634, 636
- Water
- column, 310, 533, 538, 540–541
  - transformations, 564
  - vapour, 102, 272–274, 277, 288, 304, 306, 310, 312–315, 317, 319, 327, 332, 341, 344–346, 361, 363, 368–369, 421–422
- Wave breaking, 347, 425

Weak constraint formulation of 4D-Var,  
258–259, 388–389

Websites, 24, 30, 304, 402, 411,  
531, 625

Weighting function, 253, 272–273,  
566–567, 574

WMO – Global Atmospheric Watch  
(WMO-GAW), 479–480

World Meteorological Organization (WMO),  
112, 267, 278, 294–295, 317, 383,  
403–404, 452, 478–479, 556

World Ocean Experiment (WOCE), 519–520,  
522–523

**Z**

Zonal wind, 109–110, 331, 343, 426, 636, 673,  
682, 688, 690–691