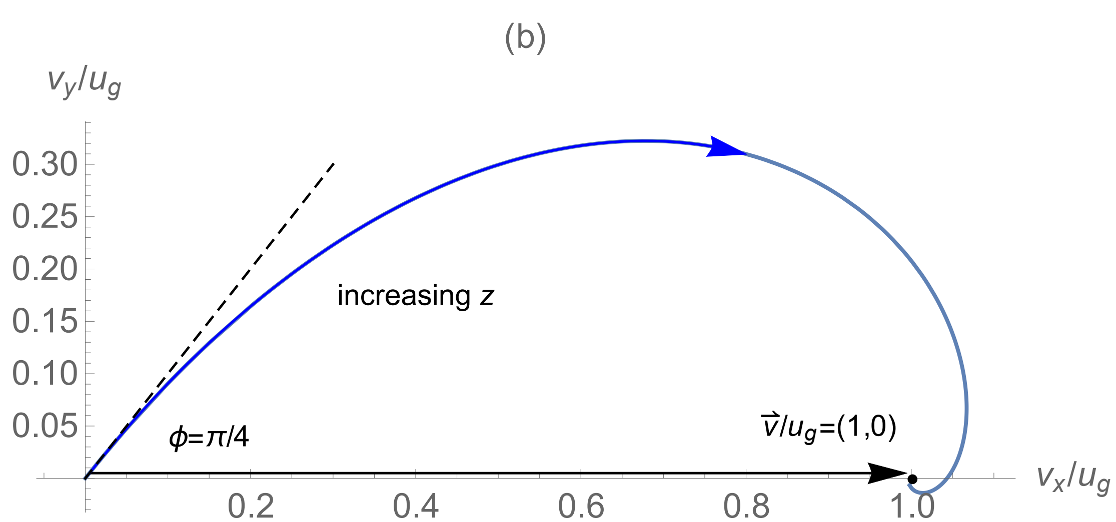
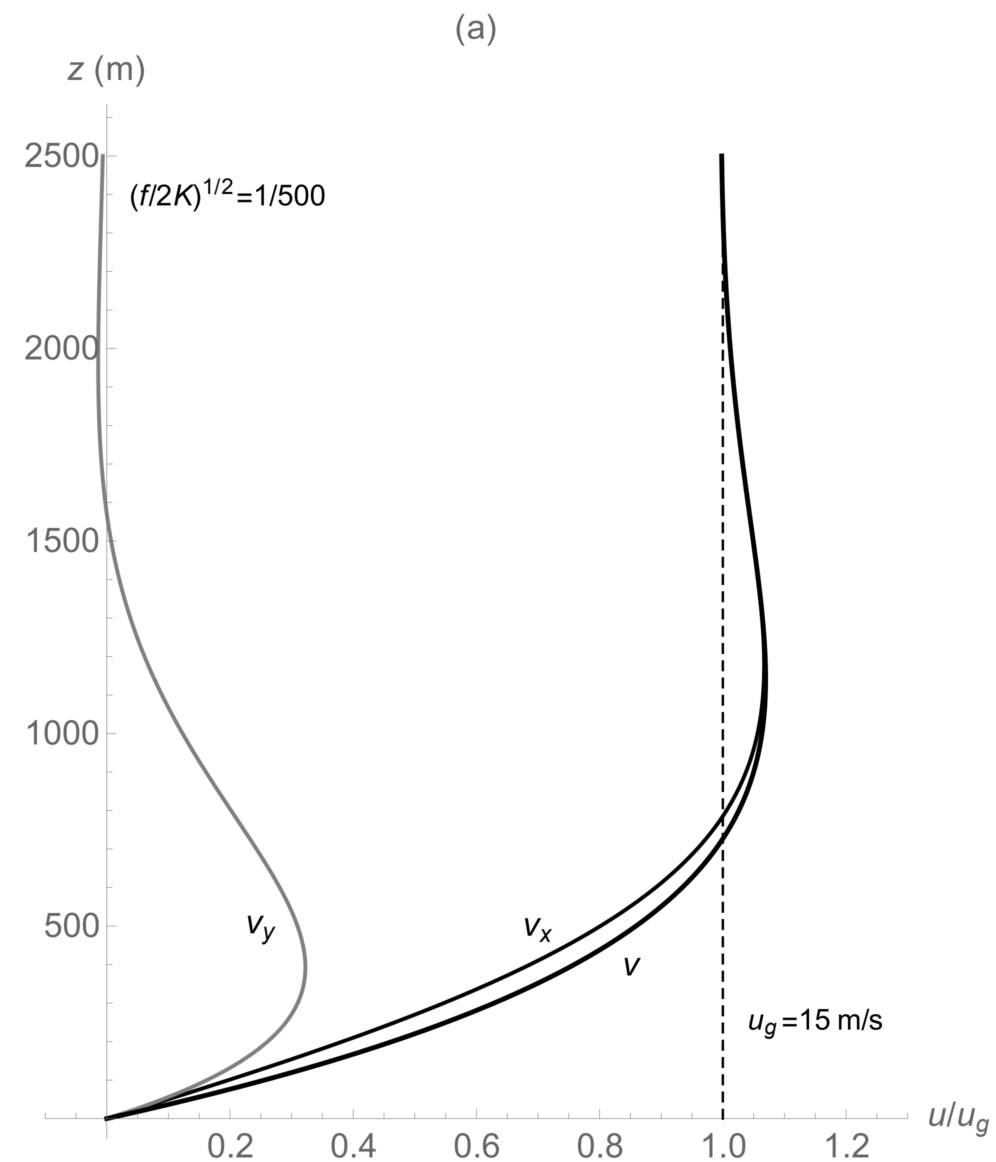
Brief Annotated Bibliography of Applied Mathematics

with relevance to wind sensing radar

Marshall Bradley

November 2021





Ekman spiral wind profiles. a) Vertical variation in speed. b) Hodograph showing change in direction with increasing altitude. f, K and u_g are respectively the Coriolis parameter, eddy diffusivity and geostrophic wind speed. Winds turn 45 deg as they approach the ground. See Garratt for details.

1. A wonderful place to learn the basics of Bayesian probability theory is to read the relevant material in *Scientific Inference,* Third Edition by Sir Harold Jeffreys. Sir Harold led the Bayesian revolution and he is still relevant today. He was one of the great scientists of the 20th century. The book presents his overview of the relationships between what we now call Bayesian probability theory and its application to problems of scientific inference. It provides a wonderful history of the development of important topics in neoclassical physics including statistical mechanics and quantum mechanics.

2. A very readable account of the basics of Bayesian probability theory, selection of prior distributions and the nested sampling algorithm can be found in John Skilling's chapter in the book *Bayesian Methods in Cosmology* edited by Michael P. Hobson and others. Among other things, Skilling places maximum entropy techniques into their proper context to the Bayesian approach.

3. *Bayesian Logical Data Analysis* by Phi Gregory is also very good especially if you like to use Mathematica. Additionally it contains some good discussions on spectral analysis and Fourier analysis.

4. A short, readable introduction to Bayesian techniques is *Practical Bayesian Inference* by Coryn Bailer-Jones.

5. The application of Bayesian probability theory to a variety of complicated physics models can be found in *Bayesian Probability Theory* by Wolfgang von der Linden, Volker Dose and Udo von Toussaint. The development of cubic splines and global smoothing is excellent. Regression in the case of errors in both x and y is also treated.

6. An important application of the use of the Bayesian posterior predictive distribution is given in *Bayesian Statistics in Actuarial Science* by Stuart A. Klugman.

7. Markov chain monte carlo models allow Bayesians to do the necessary computations. A straightforward introduction is in Brendon J. Brewer's chapter "Bayesian Inference and Computation: A Beginners Guide" published in *Bayesian Astrophysics* edited by A. A. Ramos and I. Arregui. Also, Roberto Trotta has a nice chapter in this text entitled "Bayesian Cosmology."

8. An in depth treatment of the theory behind machine learning algorithms is given in *Machine Learning: A Probabilisitic Perspective* by Kevin P. Murphy.

9. Machine learning is also treated in detail in *Bayesian Reasoning and Machine Learning* by David Barber.

10. Selection problems in Bayesian data analysis are treated briefly in *Bayesian Methods for the Physical Sciences: Learning from Examples in Astronomy and Physics* by Stefano Andreon and Brian Weaver.

11. From a historical perspective it is useful to read *Probability Theory: The Logic of Science* by E. T. Jaynes. His treatment of the origins of the Gaussian distribution is very good.

12. Much of probability theory and statistics overuse the Gaussian distribution and related distributions within the exponential family. These distributions all have thin tails making extreme deviations impossible. To break this habit read *Statistical Consequences of Fat Tails* by Nassim Nicholas Taleb.

13. Extreme value distributions arise in many civil engineering applications, e.g floods and extreme storms. The standard introduction is *An Introduction to Statistical Modeling of Extreme Values*. This is a good companion to Taleb's book.

14. A more theoretical treatment of extreme value distributions drawing on examples from the insurance and finance industries is *Modeling Extremal Events* by Paul Embrechts, Claudia Klueppelberg and Thomas Mikosch.

15. Many examples of the application of extreme value theory in civil engineering can be found in *Extreme Value Theory in Engineering* by Enrique Castillo. Extensive use of the Gumbel distributions is made use of in this text.

16. Having a command of dimensional analysis is a great force multiplier in applied mathematics. The place to start is the book *A Students Guide to Dimensional Analysis* by Don S. Lemons. The chapter on heat in this text is outstanding. Lemons makes clear in what circumstance heat can be treated as having its own physical dimension.

17. *The Art of Insight in Science and Engineering* by Sanjoy Mahajan is another great source for learning to apply dimensional analysis in conjunction with simple models. It should be read in parallel with the Don Lemons book.

18. *Scaling* by G. I. Barenblatt covers dimensional analysis, intermediate asymptotic expansions and aspects of turbulence. His lengthier companion book *Scaling, Self-similarity, and Intermediate Asymptotics* has a good treatment of shear flows and the law of the wall.

19. A short but challenging presentation on dimensional analysis is *Dimensional Analysis: Examples of the Use of Symmetry* by Hans G. Hornung. Gas explosions in the atmosphere and the law of the wall are covered. Several important thermodynamic results are derived using only dimensional analysis and the definition of enthalpy.

20. The fractal nature of many different phenomena is treated in *Fractals, Chaos, Power Laws: Minutes from an Infinite Paradise* by Manfred Schroeder. This text contains material useful in unsupervised machine learning and the generation of background noise with a prescribed spectral content (white, pink or brown).

21. The viral theorem is frequently invoked in dimensional analysis. A lovely proof of this theorem can be found in *Physical Mathematics* by Kevin Cahill. This text also contains a simple probabilistic development of the thermodynamic result that internal energy of a gas is $(1/2)kT$ per degree of freedom where k is the Boltzmann constant and T is absolute temperature. Numerous other topics in mathematical physics are covered as well.

22. Fluid mechanics is in many ways a common language for scientists and engineers. A very readable, short introduction is *Fluid Mechanics*, Second Edition by Gregory Falkovich. This text contains 41 exercises with detailed solutions. Solutions emphasize physical insight and dimensional analysis. This is a wonderful place to hone your skills.

23. A book of similar scope to Falkovich's book is *Elementary Fluid Dynamics* by D. J. Acheson.

24. A very nice derivation of Bernoulli's equation is given in *Atmospheric and Oceanic Fluid Dynamics* by Geoffrey K. Vallis.

25. An excellent treatment of fluid dynamics is can be found in *An Introduction to Theoretical Fluid Mechanics* by James Lighthill. The theory of two-dimensional lift is treated in detail.

26. To learn more about ocean surface waves and internal waves read *Waves in Fluids* by James Lighthill.

27. Fluid mechanics is contrasted to solid mechanics in *Flow, Deformation and Fracture* by G. I. Barenblatt. The treatment of stress singularities at the tips of cracks is very good.

28. G. K. Batchelor's book *Fluid Dynamics* presents a very detailed account of classical fluid dynamics and contains many wonderful photographs.

29. A detailed study of the convective boundary layer in which we all reside is given in *The Atmospheric Boundary Layer* by J. R. Garratt. Much information on wind flow near the surface of the earth is presented here.

30. Obukhov models of wind speed profiles in the surface layer are covered in *Turbulence in the Atmosphere* by John C. Wyngaard.

31. The statistical properties of near surface wind profiles are treated in *Wind Power Plants: Fundamentals, Design, Construction and Operation* edited by Robert Gasch and Jochen Twele. This is a good place to learn about the Rayleigh distribution and its generalization the Weibull distribution as they apply to wind speed.

32. Many examples of near surface wind models are given in *Wind Energy Meteorology: Atmospheric Physics for Wind Power Generation,* Second Edition by Stefan Emeis. In particular wind fields in the lee of obstructions are covered.

33. More information on wind fields and atmospheric phenomena in general can be found in *Meteorology for Scientists and Engineers* by Roland B. Stull. The treatment of geostrophic winds is very clarifying.

34. The relationship between solar radiation, the speed of sound and mean winds on the surface of the earth is covered in *From Quarks to the Universe: A Short Physics Course* by Eleftherios N. Economou. The book relies heavily on dimensional analysis.

35. Radiative transfer and black body radiation play an important part in applied mathematics. A good place to learn the basics is in *Physical Principles of Remote Sensing*, Second Edition by W. G. Rees. Numerous other topics are covered here as well.

36. Solving inverse problems in the context of atmospheric remote sensing is addressed in *Inverse Methods for Atmospheric Sounding: Theory and Practice* by Clive D. Rogers. This is a good place to learn about multidimensional Gaussian priors, likelihoods and posteriors.

37. Every applied mathematician should know a little thermodynamics. A very readable account from the perspective of a physicist is *Mere Thermodynamics* by Don S. Lemons.

38. A somewhat similar text on thermodynamics is *Thermodynamics* by Enrico Fermi. An alternate approach is given in *Modern Thermodynamics* by Arieh Ben-Naim and Diego Casadei.

39. A very readable introduction on radar performance analysis is *Radar Range-Performance Analysis* by Lamont V. Blake. His treatment of radar system noise temperature is outstanding.

40. Another treatment of radar range performance prediction is given in *Radar Equations for Modern Radar* by David K. Barton. The presentation of radar system noise temperature is very good in this text.

41. A theoretical treatment of electromagnetic waves is given in *Foundations of Electromagnetic Theory*, Fourth Edition by John R. Reitz, Frededrick J. Milford and Robert W. Christy. This is a good source for electromagnetic wave reflection from planar surfaces and propagation through absorbing media.

42. Radar is viewed in the context of optical systems in *Optical Sources, Detectors and Systems* by Robert H. Kingston. This text contains a nice introduction to black body radiation and radiometry.

43. Radar signal processing is treated in detail in *Fundamentals of Radar Signal Processing* by Mark A. Richards. This is a nice place to learn about the hop and stop approximation in radar signal processing.

44. Sampling, likelihood ratio theory and matched filters are treated in *Detection Theory* by Ivan Selin. Likelihood ratios are contrasted to Bayesian odd ratios.

45. Backscatter of electromagnetic signals from a variety of objects is treated in *Radar Cross Section* by Eugene F. Knott, John F. Shaeffer and Michael T. Tulley.

46. Radar backscatter is treated from a theoretical perspective in *The Scattering of Electromagnetic Waves from Rough Surfaces* by Petr Beckmann and Andre Spizzichino.

47. Scattering from rough surfaces is treated in detail in *Remote Sensing of Planetary Surfaces* by Bruce A. Campbell. Techniques for generating fractal surfaces are presented.

48. The classic text on the subject of geodesy is *Geodesy* by Guy Bomford. There is useful material here on the index of refraction of air at microwave frequencies as a function of environmental conditions.

49. Radar cross section and target strength in underwater acoustics are essentially the same thing. A valuable reference for the latter is *Principles of Underwater Sound,* 3rd Edition by Robert J. Urick.

50. Backscatter in radar and underwater acoustics are based on the same approximations. A more theoretical take on underwater propagation including scattering can be found in *Fundamentals of Ocean Acoustics* by Leonid M. Brekhovskikh and Yury P. Lysanov. This text is a also good place to learn about normal mode propagation and propagation into shadow zones.