STEVEN R. HANNA, PH.D.

Updated to March, 2020

Hanna Consultants
7 Crescent Ave.
Kennebunkport, ME 04046-7235
office: 207 967 4478; cell: 859 351 6524;
E-mail: hannaconsult@roadrunner.com or stevenrogershanna@gmail.com

Adjunct Associate Professor
Exposure, Epidemiology, and Risk Program
Dept. of Environmental Health
Harvard T. H. Chan School of Public Health
Landmark Center, 401 Park Dr.
P.O. Box 15677
Boston, MA 02215-0013

Ph.D., M.S., B.S.,	Meteorology, Penn State University (1967, 1966, 1964)
July 2003-Present:	Adjunct Associate Prof., Harvard School of Public Health, Boston, MA
April 1997-Present:	President, Hanna Consultants, Kennebunkport, ME
July 1997- July 2003	Research Professor, George Mason University, Fairfax, VA
April 1997-Dec. 2000:	Research Associate, Harvard School of Public Health, Boston, MA
1992-April 1997:	Principal Meteorologist, Earth Tech, Inc., Concord, MA
1985-1992:	Founder and Vice President, Sigma Research Corp., Westford, MA
1981-1985:	Principal Meteorologist, Environmental Research & Technology, Inc. (ERT), Concord, MA
1967-1981:	Research Meteorologist and Acting Director (1979-1981) USDOC/ NOAA, Environmental Research Laboratories, Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, TN

AWARDS

Dr. Hanna is the 1994 recipient of the American Meteorological Society's Award for Outstanding Contribution to the Advance of Applied Meteorology, and is a 1996 Centennial Fellow of the College of Earth and Mineral Sciences of Penn State University. In January, 2005, he was named a Fellow of the American Meteorological Society. In January 2010, he received the AMS Helmut E. Landsberg award for "Significant novel and insightful contributions in applied meteorology and urban studies, including field work, data interpretation, model development, and model evaluation". In November 2013, he was elected a Councilor of the AMS. In January 2015, he received the AMS Henry Harrison Award for Certified Consulting Meteorologists. In January 2016, he received the AMS Award for Outstanding Scientific Contributions in Meteorological Aspects of Air Pollution.

PROFESSIONAL SUMMARY

Dr. Hanna is a specialist in atmospheric turbulence and dispersion, in the analysis of meteorological and air quality data, and in the development, evaluation, and application of air quality models. He is an AMS Certified Consulting Meteorologist with over 45 years of experience. He has led several research and development projects involving, for example, the analysis of uncertainties of dispersion models, the statistical evaluations of hazardous gas dispersion models and regional ozone models, the development of models for the dispersion of emissions from tall power plant stacks, from offshore oil platforms, and from accidental and intentional releases of hazardous chemicals, and the analysis of data from large urban and regional field experiments. From 1988-1997, Dr. Hanna was Chief Editor of the *Journal of Applied Meteorology*, and has published 172 articles in refereed journals, and five books in which he is the primary author.

RELATED PROFESSIONAL EXPERIENCE

Model Evaluation, Model Uncertainty, and Concentration Fluctuations

A statistical method for evaluating air quality models was developed by Dr. Hanna and applied to many types of source scenarios, models, and field data sets. This method is now accepted as a standard in international research on dispersion model evaluation (e.g., see www.harmo.org/kit). The U.S. Air Force, the U.S. Army, and the American Petroleum Institute supported the further development of a framework for evaluating and for estimating the uncertainty in environmental models. During the past few years, the Department of Defense, the Department of Energy, the Environmental Protection Agency, and the Department of Homeland Security have sponsored additional studies of model evaluation methods, with emphasis on scenarios where chemical or biological agents might be released.

From 1993 through 2006, the Electric Power Research Institute supported the development of Monte Carlo uncertainty analysis methods for photochemical grid models. The Nuclear Regulatory Commission had Dr. Hanna review their uncertainty analysis methods for linked emissions-dispersion-exposure-risk consequence models.

From 2004 through 2007, Dr. Hanna was a lead scientist in a Defense Threat Reduction Agency (DTRA) study involving improvements of methods to account for mesoscale and regional-scale uncertainties in transport and dispersion estimates.

From 2006 through the present, Dr. Hanna has led model evaluation efforts for the HPAC-SCIPUFF model, for urban dispersion models, and for the JEM model (supported by DOD). From 2014 through 2018, he was part of the scientific advisory team in which many countries' urban puff dispersion models were being compared using the JU2003 tracer observations. The study, UDINEE, was funded by the European Commission. He is presently leading an international model comparison exercise where 17 widely-used hazard response models for dense gases are being tested with the Jack Rabbit II field trial data.

Regional Air Quality Data Analysis and Model Evaluation

Dr. Hanna was the chief scientist for analysis of field data from several regional and urban-scale ozone experiments, including the South Central Coastal Cooperative Aerometric Monitoring Program (SCCCAMP), the Lake Michigan Ozone Study (LMOS), and the Gulf of Mexico Air Quality Study (GMAQS). From 1999 through 2005, Dr. Hanna was the chief scientist on two DOI/MMS-sponsored studies involving boundary layers and air quality in the Gulf of Mexico. He led a ten-year effort in which the effects of uncertainties in input parameters on the uncertainties in predictions of regional air quality models were assessed using Monte Carlo methods. In 2005, Dr. Hanna completed a study of the uncertainties in the BEIS3 model, which is used to estimate biogenic emissions for input to photochemical grid models.

Modeling of Turbulence and Diffusion

Dr. Hanna has developed applied diffusion models for several industrial and governmental clients, including a diffusion model for complex terrain (RTDM), a model for overwater diffusion (OCD), a cooling tower plume model (ATCOOL), a model for diffusion from tall stacks (HPDM), a hazardous gas model for chemical reactions and thermodynamics associated with UF_6 releases, and a baseline urban dispersion model.

In the past ten years, Dr. Hanna's baseline urban dispersion model was further enhanced for use in estimating impacts of possible terrorist attacks with chemical and biological agents. It was evaluated with field data from Los Angeles, Salt Lake City, Oklahoma City, and New York City. He led the evaluation of DTRA's HPAC-Urban model with field data from Oklahoma City and New York City. He was the chief scientist of the Madison Square Garden-2005 (MSG05) tracer experiment in New York City. From 2012-2016, he analyzed the rooftop urban observations during the MID05 field experiment and developed algorithms to better estimate rooftop concentrations in city centers.

Hazardous Gas Model Development and Analyses

The American Institute of Chemical Engineers (AIChE) Center for Chemical Process Safety (CCPS) sponsored the writing of the Guidelines for Use of Vapor Cloud Dispersion Models in 1987, and the preparation of greatly-enhanced second edition in 1996. The AIChE/CCPS also sponsored preparation of the 2002 book entitled Wind Flow and Vapor Cloud Dispersion at Industrial and Urban Sites.

A USAF/API study was completed in which 15 hazardous gas models were evaluated with data from 8 field studies.

An industry-government consortium supported the five-year PERF 93-16 Dispersion Modeling Project, including field and laboratory experiments, in which dense gas models were improved so that they account for high surface roughnesses, short-duration releases, and stable ambient conditions. Dr. Hanna was responsible for the planning and coordination of the technical components of the project and carried out the analysis of the Kit Fox field data and the evaluation of the HGSYSTEM 3+ model.

From 2005 through the present, Dr. Hanna has led DARPA, DHS, DTRA, and Chlorine Chemistry Council studies of emissions and dispersion of chlorine released from railcars. In the

DTRA study, source emission model improvements were made for Toxic Industrial Chemicals (TICs). He analyzed the observations from the DHS Jack Rabbit I chlorine and anhydrous ammonia field experiments, and is a member of the Scientific Advisory Board. He has been a lead scientist for the Jack Rabbit II field experiments (in August 2015 and August 2016), where up to 20 tons of pressurized liquefied chlorine was released in each of nine trials. He continues as the lead scientist in an international model comparison exercise using JR II data, and is guest editor for a special issue of the journal *Atmospheric Environment,* in which the results of the comparison will be presented.

Research on Source Term Estimation

Since 2013, Dr. Hanna has been on the scientific advisory and review panel for several large field experiments intended to improve Source Term Estimation (STE) of methane. In 2015-2016, he led an industry supported technical review of the field (including all pollutants) and published a summary article in *Atmospheric Environment*. He is currently evaluating the STE model in the DOD's JEM 2 model, using several sets of field observations (such as FFT07).

Support of Permitting Activities for Nuclear Reactors

Over the past 15 years, Dr. Hanna has worked on meteorological analyses and report writing as part of permits for several nuclear reactors. The plants include Callaway, Nine Mile Point, Pilgrim, Davis-Besse, Indian Point, and Seabrook. Dr. Hanna testified at the Pilgrim hearing in 2011. In all of these cases, his work focused on support of use of the NRC's MACCS2/ATMOS model. He carried out analyses of plant and other local meteorological data in the SAMA domain (50 mile radius) in order to justify use of the plant data in the ATMOS model. In addition, Dr. Hanna has been supported by BP, Mitsubishi Heavy Industries and the Japan Nuclear Agency in various studies related to the Fukushima accident. He was co-organizer of a March 2015 Workshop at Fukushima University regarding applications of transport and dispersion models to nuclear plant accidents. Since 2018, he has been part of a review team for an NRC project in which NOAA's HYSPLIT model is being implemented in MACCS as an alternative to ATMOS.

Reviews of Diffusion Research

Dr. Hanna has been requested to prepare written reviews of various aspects of diffusion research by many national and international agencies, industries, and universities. He has been a member of peer-review panels for NRC, DOE, EPA, CDC, DHS, CARB, and DOD programs in the US. In March, 1997, he chaired the Peer Review Panel for the Atmospheric Modeling Division of the EPA National Exposure Research Laboratory. In June, 2000, he was a member of the Peer Review Panel for the EPA research program on ozone and air toxics. In November, 1997, he chaired the Peer Review Panel for the U.S. modeling program for the Khamisiyah, Iraq, chemical releases. In 1998 he chaired the Peer Review Panel for the EPA's new AERMOD model. In 2000, he was member of the Peer Review Panel for the Army Research Office's Atmospheric Boundary Layer Program. In 2003, he was a reviewer of the DOE VTMX research program. In 2005, he was a reviewer of the DTRA Chemical/Biological Defense Science Program. In 2009, he gave a keynote address at the Workshop on Evaluations of IMAAC models (for DHS). From 2014 through 2018, he was on the peer-review committee for the Barnett shale methane study and on the EPA CASAC SOx panel. In 2019, he has been a member of a six-

member international peer-review committee for the Swedish FOI (similar to a national laboratory in the US).

Teaching Experiences at Universities

Dr. Hanna has been an adjunct professor and/or research professor at four universities during his career (Vanderbilt University and University of Tennessee while he was in Tennessee), Harvard T. H. Chan School of Public Health from 1983 through the present, and George Mason University from 1997 through 2002). Approximately once each year throughout this period, he has taught graduate-level courses in atmospheric turbulence and dispersion. The Vanderbilt and UT lectures were used as the basis for the Atmospheric Diffusion textbook by Hanna, Briggs, and Hosker (1982), which has been widely adopted as a basic text at other universities. In addition, three or four times a year from 1987-1997, Dr. Hanna taught a two-day short course entitled "Vapor Cloud Dispersion" as part of AIChE/CCPS conferences. Since 2002, he has taught 8 to 16 lectures a year in Air Quality Meteorology graduate-level courses at HSPH in Boston and in their International Institute in Cyprus. The lectures include hands-on training in use of AERMOD.

Business Experience

In 1985, Dr Hanna was a cofounder of Sigma Research Corporation, which carried out basic and applied research on meteorology and air quality issues for a variety of clients. The company grew successfully and was purchased by Earth Tech in 1992. In 1987, Dr. Hanna founded Hanna Consultants, which initially carried out small projects such as EPA peer reviews that did not fall under SRC's scope. Since 1997, he has worked from 50 % to 100% of his time on Hanna Consultants projects. Currently he spends about 95 % of his time on that effort. The other 5 % of his time is spent at Harvard School of Public Health, where he provides several lectures in graduate-level classes. HC's work is sponsored by government agencies, national laboratories, chemical industries, environmental consulting companies, industrial associations, universities, and law firms.

Expert Witness

Dr. Hanna has provided testimony in depositions in several litigation cases and has testified in two trials and at two hearings. In most of these cases, he was required to apply and interpret atmospheric transport and dispersion models. He has modeled releases of methyl mercaptan, anhydrous ammonia and chlorine from rail cars, oleum from valve ruptures, sulfuric acid from a stack, hydrogen sulfide from a missile spill, water vapor and particulates from paper mills and cooling towers, small particles and ozone from power plants over the eastern U.S., pesticide dispersion, wind flows in Manhattan street canyons, and wind patterns and dispersion of potential releases from nuclear power plants.

In January 2018, Dr. Hanna organized and was main speaker and moderator of an American Meteorological Society Short Course on Forensic Meteorology.

PROFESSIONAL ORGANIZATIONS

Member of the American Meteorological Society (AMS), for whom he carried out the following volunteer activities. Certifications and awards are also listed.

Chief Editor, *Journal of Applied Meteorology*, 1988-1997
Chairman, Atmospheric Turbulence and Diffusion Committee, 19771978
Member, AMS/EPA Cooperative Work Group, 19791981
Member, AMS Board on Urban Meteorology, 2002-2009
Member, AMS Board of Certified Consulting Meteorologists, 2015-2019
Chairman, 1974 Atmos. Turb. and Diff. Conference, Santa Barbara
Co-Chairman of Urban Environment Conferences in 2004 (Vancouver) and 2006 (Atlanta)
AMS Certified Consulting Meteorologist (Number 361) 1983
Recipient of 1994 AMS Award for Outstanding Contribution to the Advance of Applied Meteorology
Fellow, 2005
Co-Chairman of 2006 Forum on Managing our Physical and Natural Resources: Successes and Challenges, Annual Meeting, Atlanta
Chairman of F.A. Gifford Memorial Session at AMS Annual Meeting, 2008
Recipient of 2010 AMS Helmut E. Landsberg Award for "Significant novel and insightful contributions in applied meteorology and urban studies, including field work, data interpretation, model development, and model evaluation"
Elected AMS Councilor, December 2013 (one year term)
Recipient of 2015 AMS Henry Harrison Award for Certified Consulting Meteorologists.
Recipient of 2016 AMS Award for Outstanding Scientific Contributions in Meteorological Aspects of Air Pollution.

Member of the Air and Waste Management Association (AWMA)
Member of American Geophysical Union (AGU)

INVITED AUTHOR OF BOOKS

1. Hanna, S.R., 1982: *Review of Atmospheric Diffusion Models for Regulatory Applications*. World Meteorological Organization Technical Note No. 177, WMO No. 581, Geneva, Switzerland.

2. Hanna, S.R., G.A. Briggs and R.P. Hosker, 1982: *Handbook on Atmospheric Diffusion*. DOE/TIC11223, Department of Energy, 102 pp.

3. Hanna, S.R. and P.J. Drivas, 1987: *Guidelines for the Use of Vapor Cloud Dispersion Models*. Published by CCPS/AIChE, 345 East 47th St., New York, NY 10017, 178 pp.

4. Hanna, S.R., and D.G. Strimaitis, 1988: *Workbook of Test Cases for Vapor Cloud Source Emission and Dispersion Models*. Published by CCPS/AIChE, 345 East 47th St., New York, NY 10017, 103 pp.

5. Hanna, S.R., P.J. Drivas, and J.C. Chang, 1996: *Guidelines for Use of Vapor Cloud Dispersion Models (Second Edition)*. Published by AIChE/CCPS, 345 East 47th St., New York, NY 10017, 285 pages + diskette.

6. Hanna, S.R. and R.E. Britter, 2002: *Wind Flow and Vapor Cloud Dispersion at Industrial and Urban Sites.* ISBN No: 0-8169-0863-X, CCPS/AIChE. 3 Park Ave., New York, NY 10016-5901, 140 pages + CD-ROM.

7. Haupt S-E, Hanna S, Askelson M, Shepherd M, Fragomeni M, Debbage N, Johnson B, 100 Years of Progress in Applied Meteorology. Part II: Applications that Address Growing Population. Chapter 23 in the AMS monograph entitled A Century of Progress in Atmospheric and Related Sciences: Celebrating the American Meteorological Society Centennial, 2019: DOI: 10:1175/AMSMONOGRAPHS-D-18-0007.1. https://journals.ametsoc.org/doi/pdf/10.1175/AMSMONOGRAPHS-D-18-0007.1

PUBLICATIONS IN PEER REVIEWED JOURNALS

1. Hanna SR. A method of estimating vertical eddy transport in the planetary boundary layer using characteristics of the vertical velocity spectrum. J Atmos Sci 1968; 25:10261032.

2. Hanna SR. The thickness of the planetary boundary layer. Atmos Environ 1969; 3:519536.

3. Hanna SR. The formation of longitudinal sand dunes by large helical eddies in the atmosphere. J Appl Met 1969; 8:874-883.

4. Hanna SR, Swisher SD. Meteorological effects of the heat and moisture produced by man. Nuclear Safety 1971; 12:114122.

5. Hanna SR, Hoecker WH. The response of constantdensity balloons to sinusoidal variations of vertical wind speeds. J Appl Met 1971; 10: 601604.

6. Hanna SR, Gifford FA. Summary of meeting on mesoscale atmospheric modeling. Bull Am Met Soc 1971; 52:993.

7. Hanna SR. Simple methods of calculating dispersion from urban areas sources. J Air Poll Control Assn 1971; 21:774777.

8. Hanna SR. Depth of boundary layer. Discussion. Atmos Environ 1971; 5:6769.

9. Hanna SR, Swisher SD. A method for calculating the size of cooling tower plumes. Atmos Environ 1972; 6:587588.

10. Hanna SR. Rise and condensation of large cooling tower plumes. J Appl Met 1972: 11:793799.

11. Hanna SR. Comments on a comparison of wet and dry bentover plumes and rebuttal. J Appl Met 1972; 11:13861387.

12. Gifford FA, Hanna SR. Modeling urban air pollution. Atmos Environ 1973; 7:131136.

13. Hanna SR. Description of ATDL computer model for dispersion from multiple sources. In: Noll KE, Duncan JR,eds. Industrial Air Pollution Control: Chapter 4, 1973:2332.

14. Hanna SR. Book review: Fundamentals of Air Pollution, Williamson S. Bull Am Met Soc 1973; 54:957958.

15. Hanna SR. A simple model for the analysis of chemically reactive pollutants. Atmos Environ 1973; 7:803817.

16. Barton CJ, Moore RE, Hanna SR. Radiation doses from hypothetical exposures to Rulison gas. Nuclear Technology 1973; 20:3050.

17. Hosker RP, Nappo CJ, Hanna SR. Diurnal variation of vertical thermal structure in a pine plantation. Agric Met 1974; 13:259265.

18. Hanna SR. Meteorological effects of the mechanical draft cooling towers of the Oak Ridge gaseous diffusion plant. Cooling Tower Environment 1974; ERDA Symposium Series, CONF 740302: 291306.

19. Hanna SR. Fog and drift deposition from evaporative cooling towers. Nuc Saf 1974; 15:190196.

20. Hanna SR. Conference summary. Cooling tower environment1974. Bull Am Met Soc 1974; 55:598.

21. Hanna SR, Gifford FA. Meteorological effects of energy dissipation. Bull Am Met Soc 1975; 56:10691076.

22. Hanna SR, Gifford FA. Part III. Dispersion of sulfur dioxide emissions from area sources. In: Noll K, Davis W, eds. Power Generation, Air Pollution Monitoring and Control. Ann Arbor Science, 1975:7181.

23. Hanna SR, Gifford FA. Discussion of paper by Goumans and Clarenburg, a simple model to calculate the SO_2 concentrations in urban regions. Atmos Environ 1975; 10:564.

24. Hanna SR. Book review: Atmospheric Diffusion, 2nd Edition, Pasquill F. Bull Am Met Soc 1975; 56:693694.

25. Hanna SR. A comparison of observed and predicted cooling tower plume rise and visible plume length. Atmos Environ 1975; 10:10431052.

26. Hanna SR. Relating emissions to air quality in Tennessee. Noll KE, Davis WT, eds. Power Generation. Ann Arbor Science, 1976:107118.

27. Hanna SR. Relative dispersion of tetroon pairs during convective conditions. J Appl Meteorol 1976; 15:588-593.

28. Hanna SR. Predicted and observed cooling tower plume rise and visible plume length at the John E. Amos power plant. Atmos Environ 1976; 10:10431052.

29. Hanna SR. Comments on observations of an industrial cumulus. J Appl Met 1976; 15:12321233.

30. Hanna SR. Symposium review: Third symposium on atmospheric turbulence, diffusion, and air quality. Bull Am Met Soc 1977; 58:242245.

31. Hanna SR. Predicted climatology of cooling tower plume types from energy centers. J Appl Met 1977; 16:880887.

32. Hanna SR. Modeling smog along the Los Angeles-Palm Spring trajectory. Soffet I,ed. Fate of Pollutants in the Air and Water Environments. New York: Wiley J & Sons, 1977:209-295.

33. Hanna SR, Briggs GA, Deardorff J, Egan BA, Gifford FA, Pasquill F. AMS workshop on stability classification schemes and sigma curves. Bull Am Met Soc 1977; 58:13051309.

34. Hanna SR. Diurnal variation of the stability factor in the simple ATDL urban dispersion model. J Air Poll Control Assn 1978; 28:147150.

35. Hanna SR. Accuracy of dispersion models: A position paper of the AMS 1977 committee on atmospheric turbulence and diffusion. Bull Am Met Soc 1978; 59:10251026.

36. Chen N, Hanna SR. Driftmodeling and monitoring comparisons. Atmos Environ 1978; 12:17251734.

37. Hanna SR, Pike M, Seitter K. Observations of vortices in cooling tower plumes. J Appl Met 1978; 17:7, 10681071.

38. Hanna SR. Urban modeling of inert substances. Morris A, Barras R, eds. Air Quality Meteorology and Atmospheric Ozone; ASTM STP 653. Am Soc for Testing and Mat 1978:262-275.

39. Hanna SR. Some statistics of Lagrangian and Eulerian wind fluctuations. J Appl Met 1979; 18:518525.

40. Hanna SR. Measured turbulence in complex terrain near the TVA Widows Creek, Alabama Steam Plant. Atmos Environ 1980; 14:401408.

41. Hanna SR. Lagrangian and Eulerian time scale relations in the daytime boundary layer. J Appl Met 1981; 21:242249.

42. Hanna SR. Diurnal variation of horizontal wind direction fluctuations in complex terrain at Geysers, CA. Bound Lay Meteorol 1981; 18:207213.

43. Hanna SR. Applications in air pollution modeling. Atmospheric Turbulence and Air Pollution Modeling. Boston: D. Reidel 1981:275310.

44. Hanna SR, Briggs GA, Hosker RP. Handbook on Atmospheric Diffusion. DOE/TIC11223, Department of Energy 1982:102pp.

45. Hanna SR. Turbulent diffusion: Chimneys and cooling towers. Ch 10 In: Plate E (ed.), Engineering Meteorology. Elsevier NY: 1982:429480.

46. Hanna SR. Review of atmospheric diffusion models for regulatory applications. World Meteorological Organization Technical Note No 177, WMO No 581. Geneva, Switzerland: 1982.

47. Hanna SR. Natural variability of observed hourly SO_2 and CO concentrations in St. Louis. Atmos Environ 1982; 16:14351441.

48. Hanna SR. Review of Dense Gas Dispersion by Britter and Griffiths. Bull Am Met Soc 1983; 64:645.

49. Hanna SR. Lateral turbulence intensity and plume meandering during stable conditions. J Clim and Appl Meteorol 1983; 22:14241430.

50. Hanna SR, Paine RJ, Schulman LL. Overwater dispersion in coastal regions. Bound Lay Meteorol 1984; 30:389411.

51. Hanna SR, Egan BA, Vaudo CJ, Curreri AJ. A complex terrain dispersion model for regulatory applications at the Westvaco Luke Mill. Atmos Environ 1984; 18:685699.

52. Hanna SR. The exponential PDF and concentration fluctuations in smoke plumes. Boundary Layer Meteorology 1984; 29:361376.

53. Hanna SR. Concentration fluctuations in a smoke plume. Atmos Environ 1984; 18:10911106.

54. Hanna SR. Atmospheric effects of energy generation. In: Randerson D, ed. Chapter 15 in Atmospheric Science and Power Production. DOE/TIC27601, 1984:652684.

55. Hanna SR. Air Pollution. Encyclopedia of Science and Technology: McGrawHill, 1984.

56. Hanna SR, Schulman LL, Paine RJ, Pleim JE, Baer M. Development and evaluation of the Offshore and Coastal Diffusion Model. J Air Poll Control Assoc 1985; 35:10391047.

57. Hanna SR. Groundlevel concentration fluctuations from a buoyant and a nonbuoyant source within a laboratory convectivelymixed layer. Atmos Environ 1985; 19:12101212.

58. Hanna SR. Air quality modeling over short distances. In: Houghton D, Wiley, J and Sons, eds. Handbook of Applied Meteorology. New York,1985:712743.

59. Schulman LL, Hanna SR. Evaluation of downwash modifications to the Industrial Source Complex (ISC) model. J Air Poll Control Assoc 1986; 36:258264.

60. Hanna SR. Spectra of concentration fluctuations: The two time scales of a meandering plume. Atmos Environ 1986; 20:11311137.

61. Hanna SR. Lateral dispersion from tall stacks. J Clim and Appl Met 1986; 25:14261433.

62. Hanna SR. Reply to comments by D. Netterville. Bound-Lay Meteorol 1986: 34: 209.

63. Hanna SR, Paine RJ. Convective scaling applied to diffusion of buoyant plumes from tall stacks. Atmos Environ 1987; 21:21532160.

64. Hanna SR, Drivas PJ. Guidelines for the Use of Vapor Cloud Dispersion Models. Published by CCPS/ AIChE: 1987:178 pp.

65. Hanna SR. Reply to comments on lateral dispersion from tall stacks. J Clim and Appl Met 1987; 26:1781.

66. Hanna SR. The effect of line averaging on concentration fluctuations. Boundary Layer Meteorology 1987; 40:329338.

67. Hanna SR. An empirical formula for the height of the coastal internal boundary layer. Boundary Layer Meteorology 1987; 40:205207.

68. Hanna SR, Strimaitis DG. Workbook of Test Cases for Vapor Cloud Source Emission and Dispersion Models: CCPS/AIChE, 1988; 103 pp.

69. Hanna SR. Air quality model evaluation and uncertainty. J Air Poll Control Assoc 1988; 38:406412.

70. Hanna SR, Paine RJ. Hybrid Plume Dispersion Model (HPDM) development and evaluation. J Appl. Met 1989; 28:206224.

71. Hanna SR, Insley EM. Time series analyses of concentration and wind fluctuations. Boundary Layer Meteorology 1989; 47:131147.

72. Hanna SR. Confidence limits for air quality models, as estimated by bootstrap and jackknife resampling methods. Atmos Environ 1989; 23:1385-1395.

73. Hanna SR. Plume dispersion and concentration fluctuations in the atmosphere. In: Cheremisinoff, ed. Encyclopedia of Environmental Control Technology, Chapter 14, Volume 2. Air Pollution Control, Gulf Publishing Co, Houston: 1989:547582.

74. Hanna SR, Strimaitis DG. Rugged terrain effects on diffusion. Blumen, ed. In: Atmospheric Processes over Complex Terrain, Meteorological Monographs Series, AMS, 45 Beacon St, Boston: 1990:Chapter 6. 109-144.

75. Hanna SR. Lateral dispersion in lightwind stable conditions. Il Nuovo Cimento 1990; 13:889-894.

76. Hanna SR, Chang JC, Strimaitis DG. Uncertainties in source emission rate estimates using dispersion models. Atmos Environ 1990; 24A:2971-2980.

77. Hanna SR, Strimaitis DG, Chang JC. Evaluation of 14 hazardous gas models with ammonia and hydrogen fluoride field data. J Hazardous Materials 1991; 26:127-158.

78. Hanna SR. Characteristics of ozone episodes during SCCCAMP1985. J Appl Met 1991; 30:534-550.

79. Hanna SR, Strimaitis DG, Scire JS, Moore GE, Kessler RC. Overview of results of analysis of data from the South Central Coast Cooperative Aerometric Monitoring Program (SCCCAMP). J Appl Met 1991; 30: 511-533.

80. Schulman LL, Hanna SR. A decision system for selecting a site-specific air quality dispersion model. Ecological Modelling 1992; 64:205-219.

81. Hanna SR, Chatwin P, Chikhliwala E, Londergan R, Spicer T, Weil J. Results from the Model Evaluation Panel. Plant Operations Progress 1992; 11(1):2-5.

82. Hanna SR, Chang JC. Boundary layer parameterizations for applied dispersion modeling over urban areas. Bound Lay Meteorol 1992; 58:229-259.

83. Hanna SR, Chang JC. Representativeness of wind measurements on a mesoscale grid with station separations of 312 m to 10000 m. Bound Lay Meteorol 1992; 60:309-324.

84. Hanna SR, Chang JC, Strimaitis DG. Hazardous gas model evaluation with field observations. Atmos Environ 1993; 27A:2265-2285.

85. Hanna SR, Drivas PJ. Modeling VOC emissions and air concentrations from the Exxon Valdez oil spill. J Air and Waste Management Assoc 1993; 43:298-309.

86. Hanna SR, Chang JC. Hybrid Plume Dispersion Model (HPDM) improvements and testing at three field sites. Atmos Environ 1993; 27A:1491-1508.

87. Hanna SR. Uncertainties in air quality model predictions. Bound Lay Meteorol 1993; 62:3-20.

88. Hanna SR (ed.), Chatwin P, Van Dop H, Poreh M, Sawford B, Stull R. The round table discussion: Interactions and feedback between theory and experiment. Bound Lay Meteorol 1993: 62: 435-448.

89. Wolfe DA, Hameedi MJ, Galt JA, Watabayashi G, Short J, O'Clair C, Rice S, Michel J, Payne JR, Braddock J, Hanna SR, Sale D. Fate of oil spilled from the T/V Exxon Valdez in Prince William Sound, Alaska. Environ Sci and Tech 1994; 28:560A-569A.

90. Hansen DA, Dennis RL, Ebel A, Hanna SR, Kaye J, Thuillier R. The quest for an advanced regional air quality model. Environ Sci and Tech 1994; 28:70A-77A.

91. Hanna SR. Mesoscale meteorological model evaluation techniques, with emphasis on needs of air quality models. In: Pearce R, Pielke R, eds. Chapter in Aspects of Mesoscale Modeling. Meteorological Monographs Series No. 47, AMS, 45 Beacon Street, Boston. 1994.

92. Hanna SR. Hazardous gas model evaluations. Is an equitable comparison possible? J Loss Prev in *the* Process Ind 1994; 7:133-138.

93. Hanna SR, Chang JC, Strimaitis DG. Reply to discussion by J. Davies and D. Heinold et al. on hazardous gas model evaluation with field observations. Atmos Environ 1995; 29:455-460.

94. Hanna SR, Chang JC. Relations between meteorology and ozone in the Lake Michigan region. J Appl Met 1995; 34:670-678.

95. Hanna SR, Chang JC. Comparisons of the Hybrid Plume Dispersion Model (HPDM) with observations at the Kincaid Power Plant. Int J Environ and Pollution 1995; 5:4-6, 323-330.

96. Hanna SR, Fernau ME, Moore GE. Evaluation of photochemical grid models (UAM-IV, UAM-V, and the ROM/UAM-IV Couple) using data from the Lake Michigan Ozone Study (LMOS). Atmos Environ 1996; 30:3265-3279.

97. Hanna SR, Drivas PJ, Chang JC. Guidelines for Use of Vapor Cloud Dispersion Models. 345 East 47th St., New York: AIChE/CCPS . 1996:285 pages

98. Hanna SR, Chang JC, Zhang JX. Modeling accidental releases to the atmosphere of a dense reactive chemical (uranium hexafluoride). Atmos Environ 1997; 31:901-908,

99. Hanna SR, Chang JC, Fernau ME. Monte Carlo estimates of uncertainties in predictions by a photochemical grid model (UAM-IV) due to uncertainties in input variables. Atmos Environ 1998; 32:*3619-3628.*

100. Hanna SR, Briggs GA, Chang JC. Lift-off of buoyant plumes released at ground-level. Journal of Hazardous Materials 1998; 59:123-130.

101. Hanna SR, Davis JM. Use of Monte Carlo uncertainty analysis to evaluate differences in observed and predicted ozone concentrations. Int J Environ and Poll 1999.

102. Hanna SR, Egan BA, Purdum J, Wagler J. Evaluation of the ADMS, AERMOD, and ISC3 Dispersion Models with the OPTEX, Duke Forest, Kincaid, Indianapolis, and Lovett Field Data Sets. Int J Environ and Poll 1999; 16; 301-314.

103. Hanna SR, Yang R, Yin X. Evaluations of Numerical Weather Prediction (NWP) models from the point of view of inputs required by atmospheric dispersion models. Int J Environ. and Poll 2000; 14:98-105.

104. Hanna SR, Franzese P. Along wind dispersion – a simple similarity formula compared with observations at 13 field sites and in one wind tunnel. J Appl Meteorol 2000; 39:1700-1714.

105. Hanna SR, Lu Z, Frey HC, Wheeler N, Vukovich J, Arumachalam S, Fernau M. Uncertainties in predicted ozone concentration due to input uncertainties for the UAM-V photochemical grid model
applied to the July 1995 OTAG domain. Atmos Environ 2001; 35:891-903.

106. Briggs GA, Britter RE, Hanna SR, Havens JA, Robins AG, Snyder WH. Dense gas vertical diffusion over rough surfaces: results of wind-tunnel studies. Atmos Environ 2001; 35:2265-2284.

107. Hanna SR, Chang JC. Kit Fox dense gas dispersion field experiments and HEGADAS model testing. Atmos Environ 2001; 35:2231-2242.

108. Hanna SR, Steinberg KW. Overview of Petroleum Environmental Research Forum (PERF) dense gas dispersion modeling project. Atmos Environ 2001; 35:2223-2230.

109. Hanna SR, Yang R. Evaluations of mesoscale model predictions of near-surface winds, temperature gradients, and mixing depths. J Appl Meteorol 2001; 40:1095-1104.

110. Hanna SR, Davis JM. Evaluation of photochemical grid models using estimates of concentration probability distributions. Atmos Environ 2002; 36:1793-1798.

111. Hanna SR, Tehranian S, Carissimo B, Macdonald RW, Lohner R. Comparisons of model simulations with observations of mean flow and turbulence within simple obstacle arrays. Atmos Environ 2002; 36: 5067-5079.

112. Hanna SR and Britter RE. *Wind Flow and Vapor Cloud Dispersion at Industrial and Urban Sites.* ISBN No: 0-8169-0863-X, CCPS/AIChE. 3 Park Ave., New York, NY 10016-5901, 140 pages + CD-ROM 2002.

113. Chang JC, Franzese P, Chayantrakom K, Hanna SR. Evaluations of CALPUFF, HPAC, and VLSTRACK with two mesoscale field data sets. J Appl Meteorol 2003; 42: 453-466.

114. Britter RE, Hanna SR, Briggs GA, Robins AG. Short-range vertical dispersion from a ground-level source in a turbulent boundary layer. Atmos Environ 2003; 37: 3885-3894.

115. Song CH, Chen G, Hanna SR, Crawford J., Davis DD. Dispersion and chemical evolution of ship plumes in the marine boundary layer. J Geophys Res 2003; 108 (D4): 4143-4153.

116. Britter RE and Hanna SR. Flow and dispersion in urban areas. Ann Rev of Fluid Mech 2003; 35: 469-496.

117. Hanna SR, Britter RE and Franzese P. A baseline urban dispersion model evaluated with Salt Lake City and Los Angeles Tracer data. Atmos Environ 2003; 37: 5069-5082.

118. Dabberdt W, Carroll M, Baumgardner D, Carmichael G, Cohen R, Dye T, Ellis J, Grell G, Grimmond S, Hanna S, Irwin J, Lamb B, Madronich S, McQueen J, Meagher J, Odman T, Pleim J, Schmid HP, Westphal D. Meteorological research needs for improved air quality forecasting. Bull Amer Meteorol Soc 2004; 85 (4): 563-586.

119. Chang JC and Hanna SR. Air quality model performance. Meteorol and Atmos Physics 2004; 87: 167-196.

120. Chang JC, Hanna SR, Boybeyi Z and Franzese P. Use of Salt Lake City Urban 2000 data to evaluate the Urban-HPAC model. J Appl Meteorol 2005; 44 (5): 485-501.

121. Hanna SR, Hansen OR and Dharmavaram S. FLACS air quality CFD model performance evaluation with Kit Fox, MUST, Prairie Grass, and EMU observations. Atmos Environ 2004; 38: 4675-4687.

122. Hanna SR, Wilkinson J, Russell AG, Vukovich J and Hansen DA. Monte Carlo estimation of uncertainties in BEIS3 emission outputs and their effects on uncertainties in Chemical Transport Model predictions. J Geophys Res 2005; 110, D01302, doi: 10.1029/2004JD004986.

123. Hanna SR, MacDonald CP, Lilly M, Knoderer C and Huang CH. Analysis of three years of boundary layer observations over the Gulf of Mexico and its shores. Estuarian, Coastal and Shelf Science 2006; 70: 541-550.

124. Dharmavaram S, Hanna SR and Hansen OR. Consequence analysis – Using a CFD model for industrial sites. Process Safety Progress 2005; 24(4): 316-327.

125. Ma Y, Boybeyi Z, Hanna S and Chayantrakom K. Plume dispersion from the MVP field experiment. Analysis of surface concentration and its fluctuations. Atmos Environ 2005; 39: 3039-3054.

126. Irwin JS and Hanna SR. Characterizing uncertainty in plume dispersion models. Int J Environ and Poll 2005; 25 (1/2/3/4): 16-24

127. Hanna SR, Paine R, Heinold D, Kintigh E and Baker D, Uncertainties in air toxics calculated by the dispersion models AERMOD and ISC in the Houston Ship Channel area. J Appl Meteorol and Climatol 2007: 46; 1372-1382.

128. Hanna SR, Brown MJ, Camelli FE, Chan S., Coirier WJ, Hansen OR, Huber AH, Kim S. and Reynolds RM. Detailed simulations of atmospheric flow and dispersion in urban downtown areas by Computational Fluid Dynamics (CFD) models – An application of five CFD models to Manhattan. Bull Am Meteorol Soc 2006: 87; 1713-1726.

129. Hanna SR. A review of uncertainty and sensitivity analyses of atmospheric transport and dispersion models. Developments in Environmental Science 6, Air Pollution Modeling and Its Application XVIII, Edited by Carlos Borrega and Eberhard Renner, Series Editor: S.V. Krupa, Elsevier Publishing Company, 2007, Chapter 4, 331-351.

130. Hanna SR, White J, Zhou Y. Observed winds, turbulence, and dispersion in built-up downtown areas in Oklahoma City and Manhattan. Bound-Layer Meteorol 2007: 125; 441-468.

131. Zhou Y, Hanna SR. Along-wind dispersion of puffs released in built-up urban areas. Bound-Layer Meteorol 2007: 125; 469-486.

132. Huq P, Carrillo A, White L, Redondo J, Dharmavaram S, Hanna S. Flow within urban canopies. J Applied Meteorol and Climatol 2007: 46; 368-376.

133. Greco SL, Wilson AM, Hanna SR, Levy JI, Factors influencing mobile-source particulate matter emissions-to-exposure relations in the Boston urban area. Environ Sci Tech 2007: 41; 7675-7682.

134. Hanna, SR. Franklin A. Gifford Obituary. Bull Am Meteorol Soc 2007: 88; 1651-1654.

135. Hanna SR, Zhou Y. Space and time variations in turbulence during the Manhattan Midtown 2005 field experiment. J Applied Meteorol and Climatol 2009: 48; 2295-2304.

136. White JM, Bowers JF, Hanna SR, and Lundquist JK. Importance of using observations of mixing depths in order to avoid large prediction errors by a transport and dispersion model. J Atmos and Oceanic Tech 2009: 26; 22-32.

137. Hanna SR, Dharmavaram S, Zhang J, Sykes I, Witlox H, Khajehnajafi S, Koslan K, Comparison of six widely-used dense gas dispersion models for three recent chlorine railcar accidents, Process Safety Progress 2008: 27; 248-259.

138. Hanna SR, Hansen OR, Ichard M, Strimaitis DG, CFD model simulations of dispersion from chlorine railcar releases in industrial and urban areas. Atmos Environ 2009: 43; 262-270.

139. Hanna SR, Baja E, A simple urban dispersion model tested with tracer data from Oklahoma City and New York City. Atmos Environ 2009: 43; 778-786.

140. Hanna SR, Reen B, Hendrick E, Santos L, Stauffer D, Deng AJ, McQueen J, Tsidulko M, Janjic Z, Jovic D, Sykes RI, Comparison of observed, MM5 and WRF-NMM model-simulated, and HPAC-assumed boundary-layer meteorological variables for three days during the IHOP field experiment. Bound-Layer Meteorol 2010: 134 (2); 285-306.

141. Levy JI, Hanna SR, Spatial and temporal variability in urban fine particulate matter concentration. Environ Poll 2011: 159; 2009-2015.

142. Dennis R, Fox T, Gilliland A, Hanna S, Hogrefe C, Irwin J, Scheffe R, Schere K, Steyn D, Venkatram A, A framework for evaluating regional scale numerical photochemical modeling systems. Environ Fluid Mech 2010: 4; 312-329.

143. Britter RE, Weil J, Leung J, Hanna SR, Toxic Industrial Chemical (TIC) source emissions model improvements for pressurized liquefied gases. Atmos Environ 2011:45; 1-26.

144. Marciotto E, Oliveiro A, Hanna S, Modeling study of the aspect ratio influence on urban canopy energy fluxes with a modified wall-canyon energy budget scheme. Building and Environ 2010: 45, 2497-2505.

145. Hanna SR, Marciotto E, Britter R, Urban energy fluxes in built-up downtown areas and variations across the urban area, for use in dispersion models. J Applied Meteorol and Climatol 2011: 50; 1341-1353.

146. Hanna SR, Weil J, Venkatram A, Hosker R, Briggs A, Gary A. Briggs Obituary. Bull Am Meteorol Soc 2010: 91; 506-507.

147. Hanna SR, White J, Trolier J, Vernot R, Brown M, Kaplan H, Alexander Y, Moussafir J, Wang Y, Williamson C, Hannan J, Hendrick E, Comparisons of JU2003 observations with four diagnostic urban wind flow and Lagrangian particle dispersion models. Atmos Environ 2011: 45; 4073-4081.

148. Grimmond CSB, Roth M, Oke T, Au YC, Best M, Betts R, Carmichael G, Cleugh H, Dabberdt W, Emmanuel R, Freitas E, Fortuniak K, Hanna S, Klein P, Kalkstein L, Liu CH, Nickson A, Pearlmutter D, Sailor D, Voogt J, Climate and more sustainable cities: Climate information for improved planning and management of cities (producers/capabilities perspective). Proceedings World Climate Conference 3, Geneva, 31 August-04 September 2009 (ed: M.V.K. Sivakumar) Procedia Environmental Sciences 2010: 1; 247-274.

149. Zwack L, Hanna SR, Spengler JG, Levy JI, Using advanced dispersion models and mobile monitoring to characterize spatial patterns of ultrafine particles in an urban area. Atmos Environ 2011: 45: 4822-4829.

150. Hanna S, Chang J, Acceptance criteria for urban dispersion model evaluation. Meteorol and Atmos Physics 2012: 116 (No. 3); 133-146.

151. Hanna S, Britter R, Argenta E, Chang J, The Jack Rabbit chlorine release experiments; dense gas removal from a depression by crosswinds. J Haz Mat 2012: vol 213-214; 406-412.

152. Pullen S, Chang J and Hanna S, Air/sea transport, dispersion and fate modeling in the vicinity of the Fukushima Nuclear Power Plant: A special conference session summary. Bull Am Meteorol Soc 2013: 94(1); 31-40.

153. Bieringer P, Hanna S, Kosovic B and Hannan J, International Workshop on Methods For Estimating the Atmospheric Radiation Release From the Fukushima Dai-ichi Nuclear Power Plant. Bull Am Meteorol Soc 2013: (online version of vol 94(1) at www.ametsoc.org)

154. Hendrick EM, Tino VR, Hanna SR, Egan BA, Evaluation of NO_2 predictions by the Plume Volume Molar Ratio Method (PVMRM) and Ozone Limiting Method (OLM) in AERMOD using new field observations. J Air Waste Management Assoc 2013: 63(7); 844-854.

155. Hanna SR, Chowdhury B, Minimum turbulence assumptions and u* and L estimation for dispersion models during low-wind stable conditions. J Air Waste Management Assoc 2014: 64(3); 309-321.

156. Hanna SR, Chang JC, Skyscraper rooftop tracer concentration observations in Manhattan and comparisons with urban dispersion models. Atmos Environ 2015: 106; 215-222.

157. Hanna S, Yamada T, Kondo H, Watanabe A, Ohba, R, International workshop at Fukushima, Japan, on dispersion and deposition modeling for nuclear accident releases: Transfer of science from academic to operational models. Bull Am Meteorol Soc 2016. February on-line issue, pp ES31-ES36, DOI:10.1175/BAMS-D-15-00191.I

158. Hanna S, Jaffe D, Porter PS, Blewitt D, Air quality trends in the US Rocky Mountain area. Air Poll Modelling and its Applic XXI (D Steyn and S Trini-Castelli, eds) NATO Science for Peace and Security Series-C: Environmental Security, Springer 2012: Ch 123, 747-751.

159. Hanna S, A 40-year history of a simple urban dispersion model and its evaluation. Air Poll Modelling and its Applic XXIII (D Steyn and R Mathur, eds) Springer Proceedings in Complexity 2014: Ch 54, 329-339.

160. Hanna S, Chang J, Huq P, Observed chlorine concentrations during Jack Rabbit I and Lyme Bay field experiments. Atmos. Environ. 2016: 125:252-256.

161. Hanna S, Chang J, Dependence of maximum concentrations from chemical accidents on release duration. Atmos. Environ. 2017. 148:1-7.

162. Hanna S, Young G, The need for harmonization of methods for finding locations and magnitudes of air pollution sources using observations of concentrations and wind fields. Atmos. Environ. 2017. 148:361-363.

163. Dharmavaram S, Hanna S, CFD modelling of toxic gas dispersion in the vicinity of complex buildings, structures, and topography. I Chem Eng Symp Ser. 2007. No 153, 9 pp.

164. Hanna S, Chang J, Mazzola T, An analytical urban puff dispersion model compared with tracer observations in JU2003. Boundary-Layer Meteorol 2019. 171(3): 377-393. https://doi.org/10.1007/s10546-018-0398-7.

165. Saide P, Steinhoff D, Kosovic B, Weil J, Downey N, Blewitt D, Hanna S, Delle Monache L, Evaluating methods to estimate methane emissions from oil and gas production facilities using LES simulations. Environ. Science and Tech. 2018: 52

166. Hanna S, Chang J, Is a Model's Scatter Really "Very Small" or is Model A Really "Performing Better" than Model B? Air Poll Modelling and its Applic XXVI (C Mensink, W Gong, A Hakami, eds) Springer Proceedings in Complexity 2018: Ch 4.9.

167. Hernández-Ceballos M, Hanna S, Bianconi R., Bellasio R, Chang J, Mazzola T, Andronopoulos S, Armand P, Benbouta N, Čarný P, Ek N, Fojcíková E, Fry R, Huggett L, Kopka P, Korycki M, Lipták L, Millington S, Miner S, Oldrini O, Potempski S, Tinarelli G, Trini Castelli S, Venetsanos A, Galmarini S, UDINEE: Evaluation of Multiple Models with Data from the JU2003 Puff Releases in Oklahoma City. Part I: Comparison of Observed and Predicted Concentrations. Boundary-Layer Meteorol. 2019: https://doi.org/10.1007/s10546-019-00433-8

168. Hernández-Ceballos M, Hanna S, Bianconi R., Bellasio R, Chang J, Mazzola T, Andronopoulos S, Armand P, Benbouta N, Čarný P, Ek N, Fojcíková E, Fry R, Huggett L, Kopka P, Korycki M, Lipták L, Millington S, Miner S, Oldrini O, Potempski S, Tinarelli G, Trini Castelli S, Venetsanos A, Galmarini S, UDINEE: Evaluation of Multiple Models with Data from the JU2003 Puff Releases in Oklahoma City. Part II: Simulation of Puff Parameters. Boundary-Layer Meteorol. 2019: https://doi.org/10.1007/s10546-019-00434-7

169. Haupt S-E, Hanna S, Askelson M, Shepherd M, Fragomeni M, Debbage N, Johnson B, 100 Years of Progress in Applied Meteorology. Part II: Applications that Address Growing Population. Chapter 23 in the AMS monograph entitled A Century of Progress in Atmospheric and Related Sciences: Celebrating the American Meteorological Society Centennial, 2019: DOI: 10:1175/AMSMONOGRAPHS-D-18-0007.1. https://journals.ametsoc.org/doi/pdf/10.1175/AMSMONOGRAPHS-D-18-0007.1

170. Hanna S, Meteorological data recommendations for input to dispersion models applied to JR II trials. To appear in Atmos. Environ. 2020.

171. Hanna S, Britter and McQuaid 1988 Workbook nomograms for dense gas modeling applied to the JR II chlorine release trials. To appear in Atmos. Environ. 2020.

172. Mazzola T, Hanna S, Chang J, Spicer T, Gant S, Results of comparisons of the predictions of 17 dense gas dispersion models with observations from the Jack Rabbit II chlorine field experiment. To appear in Atmos. Environ. 2020.