

## HUGH EDWARD WILLOUGHBY

### Professional Biography

Department of Earth and Environment  
Florida International University  
MMC/AHC5-363  
Miami, FL 33199  
hugh.willoughby@fiu.edu  
(305) 348-0243

7009 SW 66Ave.  
Miami, FL 33143  
(305) 665-4080

### EDUCATION:

Ph.D., 1977. Atmospheric Science. University of Miami, Miami, Florida.

M.S., 1969. Meteorology. United States Naval Postgraduate School, Monterey, California.

B.S. (Distinction), 1967. Geophysics–Geochemistry. University of Arizona, Tucson, Arizona.

### CURRENT POSITION:

**Distinguished Research Professor, Department of Earth and Environment, Florida International University, January 2006-present.** Teaches Meteorology and in the newly established Academic Track in Atmospheric Sciences within FIU's Geosciences Major. Conducts individual research on hurricane motion, structure, intensity, and effects.

### EXPERIENCE:

**Professor and Senior Scientist, International Hurricane Research Center, Florida International University, December 2002-November 2005.** Formulated research programs to study and mitigate hurricane impacts and carried out individual research on hurricane motion, structure, intensity and effects.

**Director, NOAA's Hurricane Research Division, 1995– 2002.** Responsible for scientific, programmatic, and administrative direction of HRD, 30 people, 14 PhDs, annual budget \$4-5M. HRD's mission was improvement of both basic physical understanding and operational forecasting of tropical cyclones and of tropical weather in general. A key aspect of this mission was an annual program of research flights into severe tropical weather.

**Research Meteorologist, HRD, 1975–1995.** Designed and executed observational studies of hurricanes using instrumented research aircraft, formulated theoretical and numerical models of tropical cyclone motion and development, and reported the results of these investigations in the refereed literature and at national and international meetings. Made more than 400 research and reconnaissance flights into the eyes of typhoons and hurricanes. Temporary assignments during this period included:

Chief Aircraft Scientist, TCM93, Guam (June –July 1993)

G. J. Haltiner Visiting Research Chair, Naval Postgraduate School, Monterey, California, (January–July, 1991).

Visiting Research Scientist, Bureau of Meteorology Research Centre, Melbourne, Australia (June –July, 1988).

Visiting Lecturer, Shanghai Typhoon Institute, Shanghai, People's Republic of China (December, 1985)

**Commissioned officer, U. S. Navy, 1968–1974.** Designated Naval Aviation Observer, awarded National Defense Service Medal, Viet Nam Service and Campaign Medals, and Meritorious Unit Commendation. Left active duty as a Lieutenant (O3). Duty stations were:

Military faculty, U. S. Naval Academy, 1971–1974. Taught meteorology, oceanography, geology, and computer science to midshipmen, both at Annapolis and aboard ship during summer cruise.

Flight Meteorologist, Airborne Early Warning Squadron ONE, 1970–1971. Flew as a special crewmember responsible for meteorological aspects of typhoon reconnaissance and other missions throughout the western North Pacific and served as assistant avionics officer for maintenance of the squadron's weather and electronic counter-measures equipment.

Student, Naval Postgraduate School, 1968–1969.

#### **MEMBERSHIPS:**

American Association for the Advancement of Science

American Meteorological Society, past (1995-1997) chair of the AMS committee on Tropical Cyclones and Tropical Meteorology, Member of Program Committees for the 20<sup>th</sup>, 21<sup>st</sup>, 22<sup>nd</sup>, and 26<sup>th</sup> Conferences on Hurricanes and Tropical Meteorology, Program Committee Chair for 20<sup>th</sup> Conference, Member of the Fellows Election Committee, 1999, Associate Editor, *Monthly Weather Review* (1998-2000).

American Geophysical Union

Sigma Xi

#### **AWARDS:**

Mewborne Student Research Award, 1969 (Naval Postgraduate School)

Distinguished Authorship Award, 1985 (Environmental Research Laboratories, NOAA)

U. S. Department of Commerce Gold Medal, 1992 (Group award to HRD)

Fellow of the American Meteorological Society, 1998

Best Paper Award, 2001 (Office of Atmospheric and Oceanic Research, NOAA)

Fellow of the American Association for the Advancement of Science, 2006

Editor's Award, *Bulletin of the American Meteorological Society*, 2008

#### **RECENT SERVICE:**

Member, Advisory Council of the Florida Catastrophic Storm Risk Management Center at FSU.

Meteorology Expert, Florida Commission on Hurricane Loss Projection Methodology.

Participant, National Academies, Summer 2009 Community Workshop, “Progress and Priorities of US Weather Research and Research to Operations Activities.”

CoChair, National Academy’s Committee to Review US Climate Change Science Program’s Synthesis and Assessment Product 3.3, “Weather and Climate Extremes in a Changing Climate.”

Member Joint Hurricane Testbed Steering Committee (NOAA/NWS).

Member WMO/CAS Committee on Tropical Cyclones and Climatic Change.

Member of the NOAA-sponsored Hurricane Forecasting Social and Economic Working Group.

Topic Chair for Hurricane Structure and Structure Change for the WMO-sponsored International Tropical Cyclone Workshop to be held in San Juan Costa Rica, November 2006 (did not attend).

Program Committee 26<sup>th</sup> Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, 3-7 May 2004, Miami FL

Member Science Steering Committee, U. S. Weather Research Program

Member of the following Faculty Search and Screening Committees at FIU: Wind Engineer, Civil and Environmental Engineering; Climatologist, Earth Sciences; Meteorologists (2), Earth Sciences

**TEACHING:**

MET 5016, Physics of Atmospheres I, fall 2014

MET 4993/5994: Planetary Climate Change, Spring 2014

MET 5993, Physics of Atmospheres II, spring 2009, spring 2011

MET 5990, Physics of Atmospheres I, fall 2008, fall 2010

MET 4420, Physical Meteorology, fall 2010

MET 4301, Dynamic Meteorology I, fall 2011-2014

MET 4302, Dynamic Meteorology II, summer 2008, spring 2009-2014

MET 5994, Meteorological Dynamics, spring 2010,

MET 4300, Severe Weather, FIU, fall 2006 and spring 2008 & 2009

MET 3102 Physical Climatology, FIU, spring 2008 & 2009

MET 3502 & 3502L, FIU, Synoptic Meteorology & Lab, fall 2007 & 2009

MET 4532, Hurricanes, FIU, fall 2006--2014

MET 5530, Hurricane Meteorology and Impacts, fall 2009, 2010 & 2011

MET 3003, General Meteorology, FIU, spring 2005, 2006, 2007, 2010, 2011 & 2012.

MET 3993, General Meteorology, FIU, spring 2004

Tropical Meteorology, Naval Postgraduate School, spring 1991

Introduction to Meteorology, The Naval Environment, Physical Geology, BASIC Programming, Synoptic Meteorology, Tropical Meteorology, and Dynamic Meteorology, U. S. Naval Academy, 1971-1974

**FUNDING:**

NOAA CPO through CIMAS: Re-analysis of the Atlantic Basin Tropical Cyclone Database in the Modern Era, \$66K, , 01 JUL 12 through 30 JUN 14, Requesting NCE through 31 DEC 14.

NSF-AGS-1211172. Synthesis of Vortex Rossby Wave Dynamics, \$186K, 1 AUG 2012 – 31 JUL 2015

NSF-ATM- 0454501. Tropical Cyclone Response to Time Dependent Heating and Theory of Tropical Cyclone Motion, \$334,183, 1 April 2005-1April 2011.

Joint NSF-NOAA SWPI Grant: NSF- ATM-9908944 (S. Chen) - \$199,235; NOAA (Willoughby) - \$161,103; A Study of Factors Controlling the Structure and Distribution of Precipitation in Hurricanes. 1 October 2000-30 September 2003

ONR Grant N0014-94-F-0045, Theoretical and Observational Studies of Hurricane Motion and Intensity Change, \$750,000, 3 years, 1994-1996

**PUBLICATIONS:**

**Refereed Journal Articles and Book Chapters:**

Gonzalez, I. III, A. Cotto, and H. E. Willoughby, 2015: Synthesis of Vortex Rossby Waves. Part I: Vortex motion and waves in the outer waveguide. (*J. Atmos. Sci.*, submitted December 2014).

Cotto, A., I. Gonzalez III, and H. E. Willoughby: 2015: Synthesis of Vortex Rossby Waves. Part I: Forced waves in the inner waveguide. (*J. Atmos. Sci.*, submitted December 2014).

Wood, V. T., L. W. White, H. E. Willoughby, and D. P. Jorgensen, 2013: A new parametric tropical cyclone tangential wind profile. *Mon. Wea. Rev.*, **141**, 1884-1909.

Willoughby, H. E., 2012: Distributions and trends of death and destruction from hurricanes in the United States, 1900-2008. *Nat. Haz. Rev.* **13**(1), 57-64.

Willoughby, H. E., 2011: The golden radius in balanced atmospheric flows. *Mon. Wea. Rev.* **139**(4), 1164-1168.

Jones, R. W., H. E. Willoughby, and M. T. Montgomery, 2009: Alignment of hurricane-like vortices on *f*- and *beta*-Planes. *J. Atmos. Sci.*, **66**, 1779-1792.

Pendergrass, A. G., and H. E. Willoughby, 2009: Diabatically-induced secondary flows in tropical cyclones. Part I: Quasi-steady forcing. *Mon. Wea. Rev.*, **137**, 805-821.

Willoughby, H. E., 2009: Diabatically-induced secondary flows in tropical cyclones: Part II: Periodic Forcing. *Mon. Wea. Rev.*, **137**, 822-835.

- Gladwin, H., J.K. Lazo, B.H. Morrow, W.G. Peacock, and H.E. Willoughby, 2009: Social Science Research Needs for the Hurricane Forecast and Warning System. *Bull. Amer. Meteor. Soc.*, **90**, 25–29.
- Price, R. M., P. K. Swart, H. E. Willoughby, 2008: Seasonal and spatial variation in the stable isotopic composition ( $\delta^{18}\text{O}$  and  $\delta\text{D}$ ) of precipitation in south Florida, *J. Hydrology*, **358**, 193-205.
- Willoughby, H. E., E. N. Rappaport, and F. D. Marks, 2007: Hurricane Forecasting: The State of the Art. *Natural Hazards Review*. **8**, 45-49.
- Gladwin, H., J. Lazo, B. Morrow, W. Peacock, H. Willoughby, 2007: Social Science Research Needs for the Hurricane Forecast and Warning System. *Natural Hazards Review*. **8**, 87-95.
- Willoughby, H. E., 2007: Forecasting Hurricane Intensity and Effects (Invited Perspective), *Science*, **315**, 1232-1233.
- Willoughby, H.E., R.W.R. Darling and M.E. Rahn, 2006: Parametric representation of the primary hurricane vortex. Part II: A new family of sectionally continuous profiles. *Mon. Wea. Rev.*, **134**, 1102-1120.
- Carsey, T.P., and H.E. Willoughby, 2005: Ozone measurements from eye wall transects of two Atlantic tropical cyclones. *Mon. Wea. Rev.* **133**, 166-174.
- Willoughby, H.E., and M.E. Rahn, 2004: Parametric representation of the primary hurricane vortex. Part I: Observations and evaluation of the Holland (1980) model. *Mon. Wea. Rev.*, **132**, 3033-3048.
- Rogers, R, S. Chen, J. Tenerelli, and H. E. Willoughby, 2003: A numerical study of vertical shear on the distribution of rainfall in Hurricane Bonnie (1998). *Mon. Wea. Rev.*, **131**, 1577-1599.
- Gedzelman, S., J. Lawrence, J. Gamache, M. Black, E. Hindeman, R. Black, J. Dunion, H. Willoughby, X, Zhang, 2003: Probing hurricanes with stable isotopes of rain and water vapor. *Mon. Wea. Rev.*, **131**, 1112-1127.
- Black, M.L., J.F. Gamache, F.D. Marks, Jr, C.E. Samsury, and H.E. Willoughby, 2002: Eastern–Pacific Hurricanes Jimena of 1991 and Olivia of 1994: The effects of vertical shear on structure and intensity. *Mon. Wea. Rev.*, **130**, 2291-2312.
- Willoughby, H. E., 2002: Chapter 10: Improvements in Observations, Models and Forecasts, in *HURRICANE! Coping with Disaster*, edited by R. H. Simpson, R. A. Anthes, and M. Garstang, American Geophysical Union, pp. 205-216.
- Willoughby, H. E. and R. W. Jones, 2001: Nonlinear motion of a barotropic vortex in still air and in an environmental zonal flow. *J. Atmos. Sci.*, **58**, 1907–1923.
- Willoughby, H. E. 1998: Tropical Cyclone eye thermodynamics. *Mon. Wea. Rev.*, **126**, 3053–3067.
- Willoughby, H. E., 1999: Hurricane heat engines, (News & Views), *Nature*, **401**, 649–650.

- Molainari, J., S. Skubis, D. Vollaro, F. Alsheimer, and H. E. Willoughby, 1998: Potential vorticity analysis of tropical cyclone intensification, *J. Atmos. Sci.*, **55**, 2632–2644.
- Willoughby, H. E., and P. G. Black, 1996: Hurricane Andrew in Florida, Dynamics of a disaster. *Bull. Amer. Meteor. Soc.*, **77**, 543–549.
- Willoughby, H. E., 1995: Normal-mode initialization of barotropic vortex-motion models. *J. Atmos. Sci.*, **52**, 4501–4514.
- Willoughby, H. E., 1994: Nonlinear motion of a shallow-water barotropic vortex. *J. Atmos. Sci.*, **51**, 3722–3744.
- Willoughby, H. E., 1994: Chapter 2: Mature structure and evolution. *Global Perspectives on Tropical Cyclones*, R. L. Elsberry, editor, World Meteorological Organization, Geneva, 21–62.
- Burpee, R. W., S. D. Aberson, P. G. Black, M. DeMaria, J. L. Franklin, J. S. Griffin, S. H. Houston, J. Kaplan, S. J. Lord, F. D. Marks, M. D. Powell, and H. E. Willoughby, 1994: Real-time guidance provided by NOAA's Hurricane Research Division to Forecasters during Emily of 1993. *Bull. Amer. Meteor. Soc.* **75**, 1765–1783.
- Willoughby, H. E., 1992: Linear motion of a shallow-water barotropic vortex as an initial-value problem. *J. Atmos. Sci.*, **49**, 2015–2031.
- Black, M. B. and H. E. Willoughby, 1992: Concentric eyewall cycle of Hurricane Gilbert. *Mon. Wea. Rev.*, **120**, 947–957.
- Willoughby, H. E., 1991: Reply (to W. M. Gray: “Comment on ‘Gradient Balance in Tropical Cyclones’”). *J. Atmos. Sci.*, **48**, 1209–1212.
- Willoughby, H. E., 1990: Linear normal modes of a moving shallow-water barotropic vortex. *J. Atmos. Sci.*, **47**, 2141–2148.
- Willoughby, H. E., 1990: Temporal changes of the primary circulation in tropical cyclones. *J. Atmos. Sci.*, **47**, 242–264.
- Willoughby, H. E., 1990: Gradient balance in tropical cyclones. *J. Atmos. Sci.*, **47**, 265–274.
- Willoughby, H. E., J. M. Masters, and C. W. Landsea, 1989: A record minimum sea level pressure observed in hurricane Gilbert. *Mon. Wea. Rev.*, **117**, 2824–2828.
- Willoughby, H. E., 1988: The dynamics of the tropical cyclone core. *J. Aust Meteor. Soc.*, **36**, 183–191 (text of an invited review paper at the *International Conference on Tropical Meteorology* held at the University of Queensland, 4–8 July 1988).
- Willoughby, H. E., 1988: Linear motion of a shallow-water, barotropic vortex. *J. Atmos. Sci.*, **45**, 1906–1928.
- McBride, J. L., and H. E. Willoughby, 1986: Comment—An interpretation of Kurihara and Kawase's two-dimensional tropical-cyclone model. *J. Atmos. Sci.*, **43**, 3279–3283.

- Willoughby, H. E., D. P. Jorgensen, R. A. Black, and S. L. Rosenthal, 1985: Project STORMFURY: A scientific chronicle 1962–1983. *Bull. Amer. Meteor. Soc.* **66**, 505–514.
- Willoughby, H. E., Frank D. Marks, and R. J. Feinberg, 1985: Stationary and moving convective bands in hurricanes. *J. Atmos. Sci.*, **41**, 3189–3211.
- Lord, S. J., H. E. Willoughby, and J. M. Piotrowicz, 1984: Role of a parameterized ice–phase microphysics in an axisymmetric nonhydrostatic tropical cyclone model. *J. Atmos. Sci.*, **41**, 2836–2848.
- Willoughby, H. E., H.–L. Jin, S. J. Lord, and J. M. Piotrowicz, 1984: Hurricane Structure and evolution as simulated by an axisymmetric, nonhydrostatic numerical model. *J. Atmos. Sci.*, **41**, 1169–1186.
- Willoughby, H. E. and M. B. Chelmon, 1982: Objective determination of hurricane tracks from aircraft observations. *Mon. Wea. Rev.*, **110**, 1299–1305.
- Willoughby, H. E., J. A. Clos, and M. B. Shoreibah, 1982: Concentric eyewalls, secondary wind maxima, and the development of the hurricane vortex. *J. Atmos. Sci.*, **39**, 395–411.
- Shapiro, L. J. and H. E. Willoughby, 1982: Response of balanced hurricanes to local sources of heat and momentum. *J. Atmos. Sci.*, **39**, 378–394.
- Willoughby, H. E., 1979: Excitation of spiral bands in hurricanes by interaction between the symmetric mean vortex and shearing environmental current. *J. Atmos. Sci.*, **36**, 1226–1235.
- Willoughby, H. E., 1979: Forced secondary circulations in hurricanes. *J. Geophys. Res.*, **84**, 3173–3183.
- Willoughby, H. E., 1978: The vertical structure of hurricane rainbands and their interaction with the mean vortex. *J. Atmos. Sci.*, **35**, 849–858.
- Willoughby, H. E., 1978: A possible mechanism for the formation of hurricane rainbands. *J. Atmos. Sci.*, **35**, 838–848.
- Willoughby, H. E., 1977: Inertia–buoyancy waves in hurricanes. *J. Atmos. Sci.*, **34**, 1028–1039.

**Theses:**

- Willoughby, H. E., 1977: *The Dynamics of Inertia–Buoyancy Waves in Hurricanes*. Ph.D. Dissertation, University of Miami, Miami, Florida, 144 pp.
- Willoughby, H. E., 1969: *A Numerical Simulation of Advective and Diffusive Transfer of Trace Substances in the Stratosphere*. Master's Thesis, United States Naval Postgraduate School, Monterey, California, 47 pp.

**Technical reports, conference proceedings, abstracts, and popular writings:**

- Delgado, S., H. E. Willoughby, and C. W. Landsea, 2014: Reanalysis of the 1955–1961 Atlantic Hurricane Seasons, Paper 5C.6, *31<sup>st</sup> AMS Conference on Hurricanes and Tropical Meteorology*, San Diego, CA..

- Gonzalez, I. ,III, and Hugh E. Willoughby, 2014: Linear & Nonlinear Motion of a Barotropic Vortex, Paper 4A.6, *31<sup>st</sup> AMS Conference on Hurricanes and Tropical Meteorology*, San Diego, CA.
- Hernandez, J, and H. E. Willoughby, An Idealized Hurricane Catastrophe Model, Paper 4D.5, *31<sup>st</sup> AMS Conference on Hurricanes and Tropical Meteorology*, San Diego, CA.
- Willoughby, H. E., and J. Hernandez, 2014: Statistics of Hurricane Damage in the US, Paper 4D.4, *31<sup>st</sup> AMS Conference on Hurricanes and Tropical Meteorology*, San Diego, CA.
- Cotto, A., and H. E. Willoughby, 2012: Intermittently forced vortex Rossby waves. *30<sup>th</sup> Conference on Hurricanes and Tropical Meteorology*, 8C6, American Meteorological Society.
- Willoughby, H. E, 2012: Is a trillion-dollar hurricane season possible? *30<sup>th</sup> Conference on Hurricanes and Tropical Meteorology*, 7D5, American Meteorological Society.
- Wood, V. T., L.W. White, D.P. Jorgensen, and H. E. Willoughby, 2012: A new parametric tropical-cyclone wind-pressure model. *30<sup>th</sup> Conference on Hurricanes and Tropical Meteorology*, P2.44, American Meteorological Society.
- Willoughby, H. E., Israel Gonzalez III, and Randall J. Hergert, 2010: Predictability of Hurricane Activity and Impacts. *Preprints, 29<sup>th</sup> Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, Paper 2A.4 in the conference CD.
- Willoughby, H. E, 2008: Tropical Cyclone Response to Periodic Forcing. *28<sup>th</sup> Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, Paper 1.3.
- Willoughby, H. E, 2008: Distributions and trends of death and destruction from hurricanes in the United States, 1900-2006, *88<sup>th</sup> Annual Meeting*, American Meteorological Society, Paper JP3.32.
- Willoughby, H. E., 2006: Tropical Cyclone Response to Time Dependant, Axially Symmetric Heating. *Preprints, 27<sup>th</sup> Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, Paper 4B.1 in the conference CD.
- Willoughby, Hugh E. and Forrest J. Masters, 2005: Early 21<sup>st</sup> Century Hurricane Threats: Maximum Potential Intensity, the Atlantic Multidecadal Oscillation, Global Warming, and Chance, *10<sup>th</sup> Americas Conference on Wind Engineering*, Paper 101 in the conference CD.
- Willoughby, H. E., 2005: Hurricanes of 2004. *Climate Alert*. **15**(1), 1, 5&6.
- Black, M. L., F. D. Marks, R. F. Rogers, L. K. Shay, B. A. Albrecht, and H. E. Willoughby, 2004: The mean structure of vertical velocities and radar reflectivities in the hurricane eyewall as they relate to environmental wind shear. *Preprints, 26<sup>th</sup> Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 94-95.



- Willoughby, H.E., and M.E. Rahn, 2004: The Climatology of Hurricane Wind Profiles *Preprints, 26th Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 264-265.
- Willoughby, H. E., 2004: The P-3 era of airborne hurricane research. *Preprints, 26th Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, (invited), 234-235.
- Jones, R.W., and H.E Willoughby, 2004: Vortex alignment on the  $f$  and beta plane. *Preprints, 26th Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 625-626.
- Willoughby, Hugh E., 2003: *Stormchasers: The Hurricane Hunters and Their Fateful Flight Into Hurricane Janet* (Book Review). *Bull. Amer. Meteor. Soc.*, **84**, 249-251.
- Jones, R. W., and H. E. Willoughby, 2002: Nonlinear motion of a two-layer baroclinic hurricane in shear. *Preprints, 25th Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 134-135.
- Rogers, R., S. Chen, J. Tenerelli, and H. Willoughby, 2002: The role of vertical shear in determining the distribution of accumulated rainfall in high-resolution numerical simulations of tropical cyclones. *Preprints, 25th Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 319-320.
- Gamache, J., P. Reasor, H. Willoughby, M. Black, and F. D. Marks, Jr., 2002: Observations of the evolution of precipitation and kinematic structure in a hurricane as it encountered strong westerly shear. . *Preprints, 25th Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 547-548.
- Willoughby, H. E. and M. E. Rahn, 2002: A new parametric model of hurricane wind profiles. . *Preprints, 25th Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 553-554.
- Willoughby, H. E., and M. E. Rahn, 2002: Realistic Hurricane Profiles, *Bull Amer. Meteor. Soc.*, **83**, 360-361.
- Willoughby, H.E., 2000: People, Property, and Hurricanes. *The Climate Report*, **1**(4), 2-6.
- Jones, R. W., and H. E. Willoughby, 2000: Linear motion of a two-layer baroclinic hurricane in shear. *Preprints, 24th Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 83-84.
- Willoughby, H. E. and R. W. Jones, 2000: Are the Beta Gyres Really Normal Modes? *Preprints, 24th Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 187-188.
- Gamache, J. F., M. L. Black, and H. E. Willoughby, 2000: Radial variation of azimuthally averaged flow across the hurricane core as observed with airborne Doppler radar. *Preprints, 24th Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 416 - 417.

- H. E. Willoughby, 2000: Costs and Benefits of Hurricane Warnings. *Preprints, 24th Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 557–558.
- Willoughby, H. E., 1999: *Isaac's Storm* by Erik Larson (Book Review), *Wall Street Journal*, 3 September, W8.
- Willoughby, H. E., 1998: Vortex tracking semispectral hurricane models. *Preprints, 23rd Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 662–665.
- Jones, R. W., and H. E. Willoughby, 1998: Results of generalizing a semispectral shallow water barotropic hurricane tracking model into a two-layer baroclinic model. *Preprints, 23rd Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 747–750.
- Willoughby, H. E., 1997: More about eye thermodynamics. *Preprints, 22nd Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 96–97.
- Gamache, J. F., H. E. Willoughby, M. L. Black, and C. E. Samsury, 1997: Wind shear, sea surface temperature, and convection in hurricanes observed by airborne Doppler radar. *Preprints, 22nd Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 121–122.
- Jones, R. W., and H. E. Willoughby, 1997: Sensitivity of a spectral shallow-water barotropic vortex to variations of domain size and spectral truncation. *Preprints, 22nd Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 577–578.
- Willoughby, H. E., 1997: Should we expect more Andrews? *Beyond Business—Climatic Change*, Employer's Reinsurance Corp.
- Willoughby, H. E., 1995: Eye thermodynamics. *Preprints, 21st Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 357–358.
- Willoughby, H. E., 1994: Meeting review: 20th Conference on Hurricanes and Tropical Meteorology. *Bull. Amer. Meteor. Soc.* **75**, 601–611.
- Willoughby, H. E., 1993: Nonlinear shallow-water vortex motion. *Preprints, 20th Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, J38–J40.
- Willoughby, H. E., 1991: Semispectral models of moving hurricane-like vortices. *Preprints, 19th Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 383–384.
- Willoughby, H. E., 1989: The dynamics of tropical cyclones. *Program and Abstracts, 23rd Annual Congress, Canadian Meteorological and Oceanographic Society*, 34 (abstract of invited keynote address).
- Willoughby, H. E., W. P. Barry, and M. E. Rahn, 1989: Real-time monitoring of Hurricane Gilbert. *Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 220–221.

- Willoughby, H. E. and W. P. Barry, 1987: Real-time data acquisition and analysis in hurricane Charley of 1986, *Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 341–342.
- Willoughby, H. E., 1987: Tropical-cyclone track prediction: Some theoretical aspects. *Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 262–265 (text of an invited review talk).
- Willoughby, H. E., 1985: Structural changes in Hurricane Diana of 1984 near landfall. (abstract) *AGU Spring Meeting*.
- Willoughby, H. E., 1985: Confirmatory observations of concentric eyes in hurricanes. *Extended Abstracts, 16th Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 1–2.
- Willoughby, H. E., 1984: The wavenumber-one asymmetry of hurricanes. *Postprints, 15th Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 89–94.
- Willoughby, H. E., Jin H.-L., S. J. Lord, and J. M. Piotrowicz, 1983: A nonhydrostatic axisymmetric model of hurricane dynamics with explicit convection and ice microphysics. *Preprints, 6th Conference on Numerical Weather Prediction*, American Meteorological Society, 275–281.
- Willoughby, H. E., 1982: Dynamics of eye formation. (abstract) *14th Technical Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society.
- Willoughby, H. E., 1980: Preliminary results from a time-splitting, nonhydrostatic hurricane model. (abstract) *13th Technical Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society.
- Willoughby, H. E., 1979: Some aspects of the dynamics of Hurricane Anita of 1977. NOAA Technical Memorandum, ERL NHEML-5, 30pp.
- Willoughby, H. E., 1978: Excitation of spiral bands in hurricanes by interaction between the symmetric mean vortex and a shearing environmental steering current. (abstract) *Second Conference on Atmospheric Waves and Stability*, American Meteorological Society.
- Willoughby, H. E., 1978: Some aspects of the dynamics of hurricane Anita of 1977. (abstract) *12th Technical Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society.
- Willoughby, H. E., 1978: Forced secondary circulations in hurricanes. (abstract) *AGU Spring Meeting*.
- Willoughby, H. E., 1977: The role of the Doppler shift in hurricane rainbands. *Papers, 11th Technical Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society, 44–45.
- Willoughby, H. E., 1976: Gravity waves in intense barotropic vortices. (abstract) *10th Technical Conference on Hurricanes and Tropical Meteorology*, American Meteorological Society.

Willoughby, H. E., 1974: The nonlinear growth of hurricanes through CISK. Report E. S. 3, Dept. of Environmental Sciences, U. S. Naval Academy, 22 pp.

Willoughby, H. E., 1973: On the intensity of hurricanes in relation to the sea's temperature. Report E. S. 2, Dept. of Environmental Sciences, U. S. Naval Academy, 8 pp.

Willoughby, H. E., 1972: Computer aided instruction in typhoon evasion tactics. *Proceedings, Symposium on the Use of Computers in the Naval Academy Curriculum*, U. S. Naval Academy, 289–303.

**Students Advised:**

Amaryllis Cotto, MS, 2012

Natacha Galindo-Lopez, Undergraduate Honors, 2013

Sandy Delgado, MS, 2014

Israel Gonzalez III, MS 2014

Javiera Hernandez, MS, 2014

Israel Gonzalez III, PhD in progress