

# RUSSELL SCHNEIDER

## THE MAKING OF A METEOROLOGIST

BY ASHTON ROBINSON-COOK  
*Jackson State University*

**R**ussell Schneider is the chief of science support at the National Weather Service (NWS)'s Storm Prediction Center (SPC) in Norman, Oklahoma. The Science Support Branch supports the SPC forecasters with technology, data sources, and scientific guidance on research projects. The center also leads numerous collaborative efforts.

As a branch chief, Schneider monitors or initiates numerous collaborative research projects in which his direct research contribution is small. One of his responsibilities is to orchestrate improvements in SPC forecast operations through the aggregate effect of research efforts both internal and external to the SPC. Schneider also carries out research projects at home or during the fringes of the day.

Schneider was fortunate that his interest in atmospheric science began early: "I was good at it, and I loved meteorology. It was easy to choose a career in weather." By age 10, Schneider believed that meteorology would be his career of choice. Like many atmospheric scientists, particularly those involved in forecasting, several major weather events piqued his interest in weather. In 1965, when Schneider was 7, there was a major ice storm with over an inch of ice accumulation in the northwest suburbs of Chicago, Illinois. In April of that year, the Palm Sunday tornado outbreak occurred. A giant F4 tornado crossed through Crystal Lake, Illinois, within 10 miles of his home.

These events, combined with the emergence of television meteorology, helped to cement Schneider's love of weather and weather forecasting for life. He always had interests in other sciences, but weather was his passion.

Schneider's childhood experiences with weather also contributed to a deeply held commitment to use science to better warn the public of dangerous weather. This mission inspired his choice to join the NWS after graduate school: "I think the ability to use science to warn people of the threat of severe weather hazards is what my commitment (and many others in atmospheric science) is all about."

One of the most important factors in Schneider's decision to go into a career in meteorology was his

undergraduate and postgraduate work experience. He earned his Ph.D. in atmospheric science from the University of Wisconsin—Madison in 1992, the year before he joined the NWS. His dissertation was titled "A Comparison of Intense Extratropical Cyclone Lifecycles from Diverse Geographical Locations." Another research project that he completed while working on his Ph.D. was titled "Large-Amplitude Mesoscale Wave Disturbances within the Intense Midwest Extratropical Cyclone of 15 December 1987."

As an undergraduate and graduate student, Schneider held several volunteer, internship, and professional positions. To enhance his communications skills, Schneider worked as a disk jockey on a student radio station and directed a student-organized cable television weathercast that was broadcast publicly. He also interned in the University of Wisconsin—Madison Meteorology Department, where he analyzed by hand daily weather-map summaries in support of weekly departmental weather discussions.

Schneider appreciates these experiences because they enabled him to gain invaluable training: "They primarily helped me shape my path within the atmospheric science community rather than [my decision] to be an atmospheric scientist. Through these supplemental activities, I was able to explore atmospheric science subspecialties such as media, education, weather forecasting, and administration in addition to (and prior to) my graduate school research. These experiences were very valuable to making informed decisions."

Schneider enjoys his work at the Science Support Branch. His division is responsible for developing new forecasting techniques and making sure all machinery is functional. This responsibility utilizes the expertise of seven graduates in atmospheric science, two in computer science, and three in electrical engineering. The terminal degrees for employees at the Science Support Branch are diverse. Three hold Ph.D.s, four have an M.S. degree, and three have a B.S. degree.

Work at the SPC and NWS forecast offices is a mix of science and service. Science excellence combined with a passion for service to the public motivates in-

dividuals throughout the organization and is at the heart of the NWS mission. To Schneider, it is the difficult interface between science and service that makes

the NWS both challenging and exciting. This interface is where the purity of research results must meet the reality of day-to-day forecast application.

## GRAD SCHOOL ADVICE A Q&A WITH JOHANNES VERLINDE

BY JESSICA PROUD  
*The Pennsylvania State University*

**J**ohannes Verlinde is an associate professor of meteorology at the Pennsylvania State University and the graduate admissions officer for the Department of Meteorology. The following interview was conducted on 1 May 2003.

*How many graduate schools should you apply to?*

The number of graduate schools you apply to should be based on your GPA. If you have a higher GPA from one of the highly regarded schools, applying to three to four schools is sufficient. However, if your grades are lower, or you have attended a less-established school, you should apply to more schools. In either case, you should apply to both small schools and large schools.

*How important is it to know which area of research you are interested in?*

Knowing the area of meteorology that you want to [do] research in is not critically important. There are two sides to this, though. It may be helpful, as it can narrow down the schools to which you apply. It sometimes can work against you, however, if you apply to a school with a specific interest and that school does not have any professors or funding available for your research interest.

*When applying to graduate school, should you just apply, or should you contact a professor whose research you are interested in?*

If you have a good track record (high GPA, research experience), ask a professor at your institution to contact your prospective professor either by phone or by letter. A prospective professor who receives a letter from a professor with whom you work closely will be much more likely to express interest in you and contact you.

*How important are letters of recommendation and who should write them?*

Letters are extremely important, and they should come from professors only. Also, there is a difference between the professor's title, including assistant, associate, and full professor. This title could make a difference in the weight of the letter since assistant professors tend to be younger and have worked with fewer students that they can compare your performance to. However, establishing a relationship with a faculty member regardless of title by showing initiative and getting to know the faculty member is extremely valuable. Simply taking their class and getting an "A" is not enough for a worthwhile letter.

*How important are Graduate Record Examination (GRE) scores?*

Scores are important, although the interpretation of the GRE varies from school to school. Some schools do not consider the analytical section and focus on the math and verbal sections, while other schools consider all three sections. Although scores are an important part of any application, a number of schools also rank applicants by GRE scores, regardless of GPA. A combined score of 1800 (out of 2400) is considered the minimum for serious consideration at some larger programs.

*What is the minimum GPA considered, and how much weight do math and physics grades carry?*

At many larger programs, a minimum GPA may be



3.5. GPA can be a tricky thing, though, as it is evaluated in the context of the strength of the undergraduate program you are in. Besides hard meteorology classes, math and physics grades are also extremely important, as well as any engineering classes you may have taken. Nonmajor courses (humanities, social sciences, etc.) are not important at most schools.

*How important are professional electives outside of your major?*

Physics, math, engineering, and other technical courses taken in addition to your major courses are very important. Having a strong background in these areas, as opposed to taking only upper-level meteorology courses, makes your application stand out because it shows your willingness to expand your background, which only serves to strengthen your meteorology knowledge.

*How much do research work and other research-oriented internships during the undergraduate years help when being considered for graduate school?*

By completing a research-oriented internship, you have gained valuable research experience that helps prepare you for graduate school and makes your application much more appealing. If you have completed research and submitted a paper to a research journal, you will probably have quite a few offers from graduate schools, since you have shown exemplary research initiative and experience. This research does not necessarily have to be in the specific field you are interested in for graduate work.

*On average, how many applicants are there to graduate school, and how many are accepted?*

At many larger schools, there are usually about 100–200 applicants, and 15–20 are accepted. Over the years, the odds of being accepted have become about 1 in 10.

*Are there any recommended minors for meteorology majors interested in graduate school?*

The two most valuable minors are physics and math.

*On average, how much is a graduate student paid?*

Although it varies from school to school, an incoming graduate student is paid on average \$20,000. This does not take into consideration any fellowships the student has received, and the student's position (teaching assistant or research assistant) does not change this.

*How many years should it take to complete a masters program?*

Two.

*Should a student who knows that he wants to pursue a Ph.D. in atmospheric science go immediately into a Ph.D. program?*

This of course depends on the student. If the student has a good record and has already published a paper in a journal, then this may be a good choice. Not all programs allow for this, though. The student should also take into consideration that he or she will be relatively young when finished with the Ph.D.

*How many credits per semester does a graduate student take?*

During the first two semesters, a graduate student takes a full course load. After this, the student will take one to two classes per semester, and focus is shifted to research. While pursuing a Ph.D., fewer classes are taken in the latter years as the focus shifts toward the research project.

*Is it true that students with a degree in atmospheric sciences or meteorology do not have an advantage over students from other majors when applying to graduate school? What are other popular majors of students who apply to meteorology graduate programs?*

It is true that a meteorology student is not at an advantage when applying to a graduate meteorology program. Because of meteorology's strong dependence on math and physics, graduates of these majors are also strongly considered. Engineering and other majors that require rigorous math are considered as well.

*Is it better to apply early to graduate school rather than waiting until the deadline, and when does a student generally find out if they have been accepted to a school?*

Most deadlines for applications are the end of January. However, applying early can be beneficial because graduate schools will make an offer to a student upon receiving their application if that graduate school is very interested. In general, students who are notified early, as well as students who are not notified until late February, have until April 15 to accept an offer so all offers can be considered. This practice is a courtesy extended by most but not all programs.

*Should a student choose a school based on an advisor or the reputation of the school?*

If you are clear on the subject you would like to pur-

sue, it is better to choose your school based on your advisor; otherwise pick based on reputation.

*Is it important to visit your potential graduate schools?*

A student should try to visit the potential graduate schools and talk to current graduate students. Talking to current graduate students should especially be done

if a student has an offer from a specific faculty member. Speaking with the faculty member's students will help you determine the faculty's style of advising—either hands-on or not. This is an important factor when making your final choice on a school and depends on how independently the student wants to work during their graduate school years.

## DENSE FOG CLIMATOLOGY CHICAGO O'HARE INTERNATIONAL AIRPORT JULY 1996–APRIL 2002

BY MATTHEW T. FRIEDLEIN  
*Northern Illinois University*

UNDERGRADUATE RESEARCH

Different surface and upper-air environments support varying types and densities of fog. The intensity of fog is assessed with visibility observations. Dense fog causes horizontal visibilities at the earth's surface of 5/16 of a statute mile or less [National Weather Service (NWS) 1996]. Chicago, Illinois's, O'Hare International Airport, one of the world's busiest airports, is prone to radiation and advection fog, which may become dense and, thus, be dangerous to flight operations. A map of northeastern Illinois (Fig. 1) shows the proximity of O'Hare to a crucial meteorological factor: Lake Michigan. The airport lies approximately 18 miles northwest of downtown Chicago and is about 15 miles west-southwest of the lake.

In this paper I extend the climatology of dense fog at O'Hare from 1995, the end of a previous study, through the spring of 2002, to ascertain the frequency of these hazardous events. The data, combined with knowledge of area winds, temperatures, and airport location factors, suggest some tentative conclusions about the seasonality and causes of fog at O'Hare.

**METHODOLOGY.** A previous study on dense fog climatology at O'Hare analyzed manual observations



**FIG. 1.** Relationship of O'Hare Airport to downtown Chicago and Lake Michigan.

taken from 1983 through 1995 (Ratzer 1996). Beginning in July 1996, the responsibility of weather reporting at O'Hare was given to the Automated Surface Observing System (ASOS). ASOS at O'Hare reports various aspects of current atmospheric conditions on an hourly basis, with supplemental observations if drastic changes in weather occur. The manual observations from the first half of 1996 were not used in this study, due to time constraints.

Using NWS criteria, horizontal visibilities of less than 5/16 of a statute mile were flagged as dense fog. The transition from a manual to ASOS observing format was believed to be a smooth one in terms of visibility recording. It was found in accuracy testing of the ASOS visibility sensor that 98% of visibilities reported as 1.25 miles or less were accurate to within a

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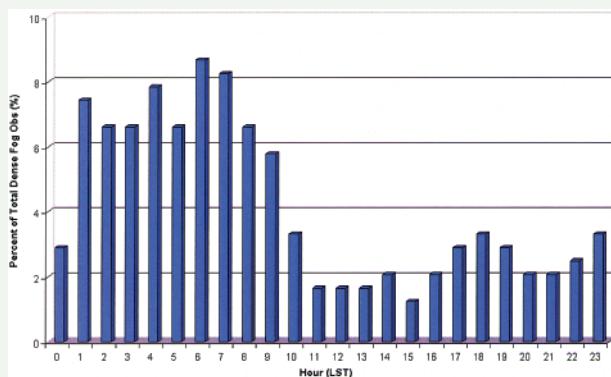
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half mile (AFOTEC 1999, Table 7; NOAA 1998, Table 5). Weather observations from ASOS indicating fog include FG (fog), BCFG (patches of fog), FZFG (freezing fog), and MIFG (shallow or ground fog) (NOAA 1998)—in this study all four of these categories are included where they qualify as dense fog.

In the data used, there was an occasional observation of a form of fog associated with heavy rain or snow and visibilities less than 5/16 of a statute mile. As in Rutzer (1996), it was assumed that the restriction in visibility at these times was due to the combination of the fog *and* heavy precipitation. Therefore, these observations were not included in this analysis.

**RESULTS.** The data suggest that dense fog is typically a cold-season phenomenon at Chicago O’Hare International Airport. Nearly three-quarters of dense fog occurs between 1 November and 31 March; 55.8% of the dense fog observations occur in the December–February time frame. Fall (September–November) had over a quarter (26.0%) of all dense fog observations, followed by spring (10.8% in March–May) and summer (7.4% in June–August), respectively.

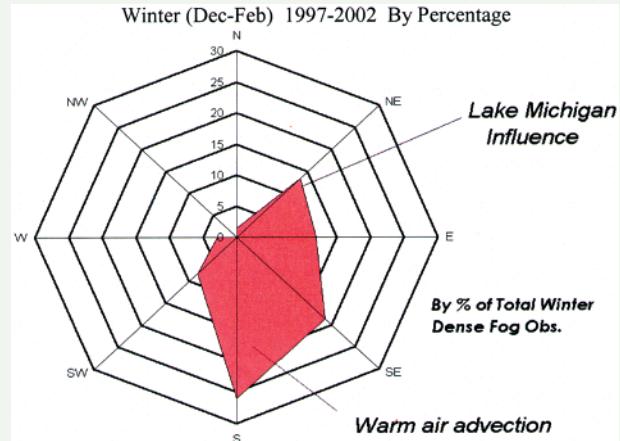
Dense fog for all seasons occurs most often during the nighttime, predawn, and dawn hours, as seen in Fig. 2. There is a peak in the number of observations just after sunrise. Fog is prevalent at all hours during the winter months.



**FIG. 2.** Dense fog observations by hour of day for Jul 1996–Apr 2002 at Chicago O’Hare International Airport.

Winter was expected to contain the most hours of dense fog, considering that long-duration advection fog is quite possible at this time of year. In addition, radiation fog cannot dissipate as readily due to low solar intensity during the winter.

Wind direction data from the times of O’Hare dense fog observations (Fig. 3) support the hypoth-



**FIG. 3.** Radial chart of winds during dense fog observations, ORD.

esis that advection fog is prominent in the winter. Southerly winds during the winter months in the Chicago area tend to be “warm” winds because they have traversed over warmer ground. With other conditions, such as snow cover at O’Hare and synoptic support, dense fog would indeed be very possible with these southerly winds. Throughout all seasons, light winds were found to be important factors as well, with 84% of dense fog observations associated with winds of 7 kn or less.

Lake Michigan has a major influence on fog formation at O’Hare. Both lake temperature and the overriding wind direction are critical. Northeast winds are the most common during dense fog occurrences. Also, the rate of heat loss for the waters of Lake Michigan is less than that of the ground during the fall and winter months. With such close proximity to this feature, O’Hare is susceptible to wind from the east or northeast during the winter that advects air as much as several degrees warmer than the ground. This scenario can again lead to advection fog. It is imperative for area forecasters to take the effects of Lake Michigan into account when making fog forecasts.

Analyses of the various parameters for dense fog observations at O’Hare are similar for spring and fall. Unlike fog during the winter, which occurs in any hour, fog during the spring and fall appears to be restricted to the nighttime or dawn hours. One explanation for this is that north and northeast winds during the spring, or “cold” winds due to typical thermal characteristics of Lake Michigan, prompt the temperature to drop just enough to reach the condensation level.

The data suggest no explicit temperature threshold for dense fog formation at O’Hare (see Table 1). In win-

ter, when dense fog formed, it was found that 90% of the time temperatures were above Chicago's average winter temperature of 25.5°F. A majority of dense fog reports also occurred above

	Winter	Spring & Fall	Summer
>= Avg. Seasonal High Temp.	65%	9%	0%
>= Avg. Seasonal Temp.	90%	39%	0%
< Avg. Seasonal Temp.	10%	61%	100%
<= Avg. Seasonal Low Temp.	4%	6%	67%

**TABLE 1. Percentage of ORD seasonal dense fog observation from July 1996 to April 2002, broken down by temperature.**

the average daily winter high temperature of 32.9°F. In the summer months, dense fog was accompanied by temperatures mainly below normal. For approximately two-thirds of the cases, dense fog occurred during below-average summer low temperatures for Chicago.

**CONCLUSIONS.** The task of forecasting dangerous fog is complex for O'Hare Airport due to Lake Michigan and rapid seasonal swings in Chicago weather. Because of the volume of air traffic, accurate and timely fog forecasts are critical. It is the author's hope that this study sheds some light on this phenomenon for this airport. The findings of this study are relatively similar to those of Ratzer (1996). A difference in March–May dense-fog frequency (decreasing from 41.2% in the previous study to 10.8% in this study) may be due to warmer air and the absence of snow cover in Chicago during the late winters and early springs in the late 1990s and early part of this decade (NWS 2002). The time span of the

study may be an important factor in this difference: the dataset used in this study is based on a period of a little less than 6 yr, whereas the previous study examined a period twice as long.

**ACKNOWLEDGMENTS.** This work was initiated while the author was a student trainee at the NWS Forecast Office, Chicago/Romeoville, Illinois. The author graduates from Northern Illinois University in the spring of 2004.

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## SUMMER INTERNSHIPS HELPING STUDENTS CHART A CAREER PATH

BY SOMER A. ERICKSON  
*University of Miami (Florida)*

**D**uring the summer of 2002, I participated in the University of Oklahoma's Research Experience for Undergraduates (OU REU) program. Funded by the National Science Foundation, this program is made up of 10 students from across the country. It is designed to meet the interest of students who are ma-

joring in meteorology or a related field, such as mathematics or physics.

At OU REU, I met other students, made contacts with established professionals in the field, and acquired knowledge of the different careers in meteorology. My research involved studying the effect that

population growth has on the number of killer tornadoes. At the conclusion of the program, I wrote a 10-page paper and gave an AMS-style presentation.

The internship yielded benefits immediately. During my following semester at the University of Miami, I felt more confident in myself and my studies. I continued the research that I performed at the OU REU program and began other research projects with the University of Miami's Department of Meteorology. I was also ahead of my classmates because of the weather knowledge that I had gained.

Before the program, I was not sure if I wanted to attend graduate school. However, after meeting many professionals in the field, I have decided to pursue graduate school. I also have an idea of the research areas that need more attention.

The only downside of the internship was that it lasted 10 weeks; I wish it had lasted longer. I would definitely apply for internships of another sort in the future to further my experience and knowledge.

I was fortunate to have the added experience of participating in the International H2O Project (IHOP). This was a more active aspect of research, and I was able to experience what field research is like. My experiences encompassed storm chasing, data

collection, teamwork, and survival of the fittest! My "survival" allowed me to gain invaluable knowledge of several different technological devices, such as software programs, citizens-band (CB) radios, and mobile mesonets. One of the most interesting aspects of the experience was meeting and working with international meteorologists.

The field research process really can be tedious and time consuming. Field research is definitely not for everyone, especially those who are less flexible. However, I found it extremely rewarding and hope to do much more in the future. It is evident what the experience gave me, and I will be forever thankful to all those involved.

While I was involved in the OU REU program, I was able to understand the real sense of accomplishment and achievement that comes with research. I enjoyed the entire process of having a problem, finding the data, and analyzing it with the hopes of discovering something new or unknown. Some of the research areas that I would like to explore in the future are tornadogenesis, sea breezes, gravity waves, convection initiation, and cloud formation.

By enhancing my motivation and determination, my summer 2002 internship affirmed my dream of one day becoming a research scientist in meteorology.

## INTERNSHIPS AT TELEVISION AND RADIO STATIONS

The following internships are all unpaid positions, but many colleges and universities provide a mechanism for students to obtain course credit for internship experiences. You should contact your faculty advisor to see if your school allows this opportunity.

This listing, updated 27 January 2004, includes only internships at the stations of AMS sealholders in which the employment period is flexible. Check the "Student Resources" section of the AMS Web site periodically for a more complete and up-to-date listing of employment and internship opportunities for students, including summer jobs.

### ALABAMA

**WKRG-TV, Mobile.** *Period of employment:* Offers unpaid internships each semester, including summer, for juniors or seniors in meteorology. Students must receive college credit and be available at least 2 days per week for 3 hours each day. Specific dates and times of day are flexible. *Contact:* Alan Sealls, Chief Meteorologist, WKRG-TV, 555 Broadcast Dr., Mobile, AL 36606. Phone: 251-662-2996. Fax: 251-662-3071. E-mail: asealls@wkrq.com.

### ARKANSAS

**KAIT-TV, Jonesboro.** *Period of employment:* Negotiable. *Contact:* Ronnie Weston, Box 790, 472 Craig 706, Jonesboro, AR 72403. Phone: 870-931-8888. Fax: 870-933-8058. E-mail: rweston@kait8.com.

## FLORIDA

**WFLA-TV, Tampa.** *Period of employment:* Negotiable, anytime. *Contact:* Mace Michaels, 200 South Parker St., Tampa, FL 33606. Phone: 813-314-5373. E-mail: mmichaels@wfla.com.

**TeleMundo WSCV-TV 51, Miami.** *Period of employment:* Negotiable. In need of an intern who can act as a weather producer in an unpaid capacity, but be able to fill in in case of summer relief, vacation, or illness. This on-air fill-in, when needed, is paid. Must be fluent in Spanish. *Contact:* Felipe Ferro, Chief Meteorologist, 2340 W. 8th Ave., Hialeah, FL 33010. Phone: 305-889-7658. E-mail: wxman@mixmail.com.

## ILLINOIS

**WMBD-TV, Peoria.** *Position(s) available:* Broadcast meteorologist interns. *Period of employment:* All semesters. *Number of positions:* 2 per semester. *Qualifications:* Broadcast meteorologist interest, junior year completed, within 3 hours of Peoria, Illinois. *Applications materials:* Cover letter (e-mail accepted). *Deadline:* Flexible. *Contact:* Chuck Collins, 3131 N. University, Peoria, IL 61604. Phone: 309-686-9487. Fax: 309-686-8658. E-mail: chuckc@wmbd.com.

## INDIANA

**WEHT-TV, Evansville.** *Position(s) available:* Internship. *Period of employment:* Anytime. *Qualifications:* Must be pursuing a B.S. in atmospheric science/meteorology. *Contact:* Wayne Hart, Chief Meteorologist, 800 Marywood Dr., Henderson, KY 42420. Phone: 800-879-8570. E-mail: whart@abc25.com.

## IOWA

**KCAU-TV (ABC), Sioux City. (#144)** Offers unpaid internships each semester, including summer, for juniors or seniors pursuing a degree in meteorology at an accredited college or university. Students must receive college credit for the internship. All three employees in our weather department are meteorologists, and our chief meteorologist has 25 years of experience. Specific dates and times of day for the internship are flexible. *Contact:* Tony Reed, Executive Producer, KCAU-TV, 625 Douglas St., Sioux City, IA 51101. E-mail: treed@kcautv.com. No phone calls, please.

## MICHIGAN

**WLNS-TV, Channel 6, Lansing.** *Position(s) available:* Up to two. *Period of employment:* 4 to 12 weeks (flexible). *Contact:* Pat Michaels, Chief Meteorologist,

WLNS-TV, 2820 East Saginaw St., Lansing, MI 48912. Phone: 517-372-1300 (newsroom), 517-367-2155 (weather office). E-mail: pmichaels@wlms.com.

## MINNESOTA

**KTTC-TV, Rochester.** *Position(s) available:* Internship. *Period of employment:* Any semester. *Number of positions:* 2 per semester. *Qualifications:* Pursuing a degree in meteorology or related field. Should have completed at least sophomore year. Helpful if applicant is from southeast Minnesota, southwest Wisconsin, or northern Iowa. *Application materials:* Cover letter explaining your interest in the internship opportunity. *Contact:* Randy Brook, Chief Meteorologist, 6301 Bandel Rd. NW, Rochester, MN 55901. Phone: 507-280-5124. Fax: 507-288-6278. E-mail: rbrock@kttc.com.

## OREGON

**KPDX-TV, Portland.** *Period of employment:* Year-round. Duties include helping to produce the nightly 10 P.M. weather segment, working alongside the chief meteorologist. Hours and days are negotiable. Must be student and receive credit for internship. *Contact:* Mark Nelsen. Phone: 503-548-6510. E-mail: mark.nelsen@kpdx.com.

**KATU-TV, Portland.** *Period of employment:* Flexible. Applicants should have completed at least 1 year toward their B.S. in meteorology. *Contact:* Rob Marciano, 2153 NE Sandy Blvd., Portland, OR 97232. Phone: 503-231-4269. E-mail: robm@katu.com.

**KPTV TELEVISION, Portland.** *Position(s) available:* One. *Period of employment:* All year long. *Qualifications:* Major in atmospheric science/meteorology or have strong interest in weather. *Application deadline:* Accepted all year. *Contact:* Marv Nelsen, Chief Meteorologist, 14975 NW Greenbrier Pkwy., Beaverton, OR 97006. Phone: 503-572-1233. E-mail: marv.nelsen@cascadeaccess.com.

## PENNSYLVANIA

**NBC-10, Philadelphia.** *Position(s) available:* Meteorology internship. *Period of employment:* Fall, spring, summer. *Qualifications:* Must be a college junior or senior and able to receive academic credit. *Application materials:* Apply on NBC-10 Web site at www.nbc10.com. *Contact:* JoAnne Wilder, NBC 10, 10 Monument Rd., Bala Cynwyd, PA 19004. Phone: 610-668-5793. Fax: 610-668-7092. E-mail: joanne.wilder@nbc.com.

## TENNESSEE

**WHBQ-TV FOX 13, Memphis.** *Position(s) available:* Intern. *Period of employment:* Negotiable. *Number of positions:* Open. *Qualifications:* Must be 21 years old, good academic standing, letter of recommendation. *Contact:* Jim Jagers, 485 South Highland, Memphis, TN 38111. Phone: 901-320-1362. Fax: 901-320-1517. E-mail: whbq-jimjagers@foxtv.com.

## TEXAS

**KEYE TV (CBS), Austin.** Student must receive aca-

ademic credit. *Contact:* Troy Kimmel, Chief Meteorologist, KEYE TV, 10700 Metric Blvd., Austin, TX 78757. E-mail: tkimmel@mail.utexas.edu.

**KBMT-TV, Beaumont.** *Position(s) available:* TV weather internship. *Period of employment:* Any semester. *Number of positions:* One. *Qualifications:* College student enrolled in on-campus B.S. meteorology program. *Contact:* Erik Salna, Chief Meteorologist, KBMT-TV, 525 Interstate 10 South, Beaumont, TX 77704-1550. Phone: 409-833-7512. E-mail: ejsalna@mindspring.com.

# RISE UNDERGRADUATES FIND THAT REGIME CHANGES IN LORENZ'S MODEL ARE PREDICTABLE

BY ERIN EVANS, NADIA BHATTI, JACKI KINNEY, LISA PANN, MALAQUIAS PEÑA, SHU-CHIH YANG, EUGENIA KALNAY, AND JAMES HANSEN

UNDERGRADUATE RESEARCH

*Note from the BAMS editors:* This article was originally reviewed and submitted to BAMS before the student section editorial board was formed, but is included here as an outstanding example of educational opportunities now available to undergraduates.

The summer of 2002 marked the beginning of the Research Internships in Science and Engineering (RISE) program. Funded by the National Science Foundation (NSF), the A. James Clark School of Engineering, and the University of Maryland, and coordinated by the Women in Engineering Program, RISE worked to build an extensive network of women faculty, science and engineering research professionals, graduate students, and undergraduates at all lev-

els. The program built this network through an 8-week summer research experience for “rising” junior and senior undergraduates. The goal was to encourage all participants to remain in the fields of science and engineering and to pursue graduate degrees in these fields.

By engaging 20 undergraduate junior and senior RISE scholars in team-based research projects coordinated by female faculty, the program introduced female students to women mentors and role models while providing high-quality opportunities to enhance their research knowledge and skills. RISE scholars were equipped with advanced training in team skills, interpersonal communication, and project management. They were also able to become a part of the hierarchy of female mentorship by interacting with a group of incoming freshmen students. By sharing their experience as students in science and engineering and as RISE scholars, they became role models to the younger students. The summer’s concluding event was the RISE Research Symposium, where research teams gave oral presentations of the results of their research, as well as a poster exhibit documenting their research activities and results. Coordinating faculty and representatives from the A. James Clark School of Engineering and the College of Mathematics and Physical Sciences, as well as staff from the NSF, were among those attend-

**AFFILIATIONS:** EVANS, BHATTI, AND PANN—RISE scholars at the University of Maryland at College Park, Summer 2002; KINNEY—RISE scholar at the University of Maryland at College Park, Summer 2002, and Texas A&M University, College Station, Texas; PEÑA AND YANG—RISE graduate advisors; KALNAY—RISE faculty mentor, and University of Maryland at College Park; HANSEN—Massachusetts Institute of Technology, Cambridge, Massachusetts

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ing the symposium. R. Colwell, director of the NSF, provided the keynote address.

One of the teams worked on atmospheric predictability. The purpose of this note is to describe the experience and results obtained by this team in order to encourage similar programs to attract women and minorities into graduate studies in the geosciences. One of the RISE scholars described her experience as follows: “As an intern in the RISE program, my main expectation was to gain familiarity with the research process. Without prior research experience, I was unsure if graduate school was a realistic option for me. The RISE program allowed me to make my final decision to pursue a graduate degree and gave me confidence in my ability to contribute to a research project. I was assigned to a project in the field of meteorology, a field about which I had little or no knowledge. Through the guidance of our faculty mentor, Dr. Eugenia Kalnay, and graduate advisors Malaquías Peña and Shu-Chih Yang, my team and I were able to first understand problems involved with weather prediction, and then apply our new knowledge to researching a method of weather prediction. Interpreting results, accepting that actual results may not agree with expected ones, and exploring new paths that the results lead to, are all exciting components of the creative process of research that my team and I had the opportunity to engage in. The fact that we were able to contribute to the discovery of new results

helped me to decide to continue participating in research in graduate school.”

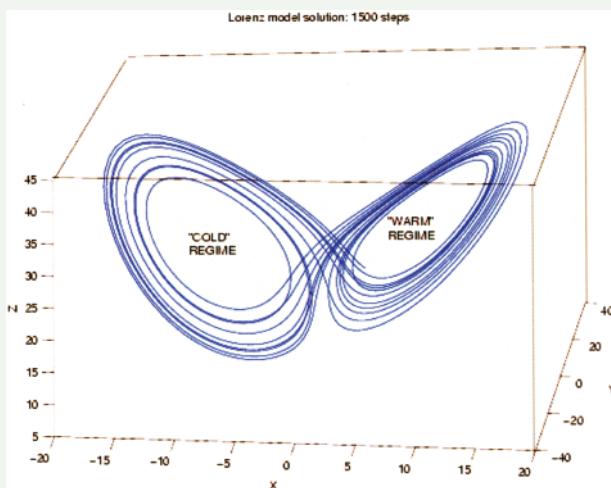
### PREDICTABILITY STUDY OF THE LORENZ (1963) MODEL.

Although the four RISE interns were selected because of their outstanding mathematical, physical, and computer science skills, three of them had no background in meteorology, and the fact that the research internship had to be completed in 8 weeks imposed a significant challenge. The team was given a problem: become familiar with the famous Lorenz (1963) model, and explore its predictability using breeding (Toth and Kalnay 1997; Kalnay 2003), an algorithm chosen for this project because of its simplicity. The Lorenz model equations are

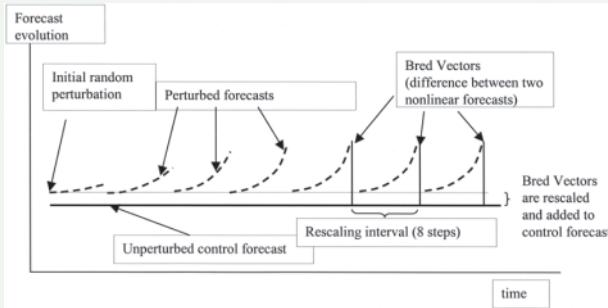
$$\begin{aligned}\frac{dx}{dt} &= \sigma(y - x) \\ \frac{dy}{dt} &= rx - y - yz \\ \frac{dz}{dt} &= xy - bz,\end{aligned}\tag{1}$$

where the parameters  $\sigma = 10$ ,  $b = 8/3$ , and  $r = 28$ , chosen by Lorenz, result in chaotic solutions (Fig. 1). This model has been very widely used as a prototype of chaotic behavior and an example of lack of long-term predictability (e.g., Sparrow 1982; Tsonis 1992; Kalnay et al. 2002). The stability properties and the dependence of the forecast error growth on the initial conditions have been previously studied (e.g., Nicolis et al 1983; Nese 1989; Elsner and Tsonis 1992; Palmer 1993), but we are not aware of studies about the prediction of the occurrence of regime changes and their duration. The students were given as a template a Matrix Laboratory (MATLAB) program of a coupled fast-slow Lorenz model written by J. Hansen, from which they unraveled the classic Lorenz model code and learned how to run and plot its results. They were asked: “Imagine that you are a forecaster living in the Lorenz attractor. Everybody in the attractor knows that there are two weather regimes, which we could denote as ‘Warm’ and ‘Cold’ (see Fig. 1), but the public needs to know *when* changes in regime will happen and *how long* will they last. Can you develop simple forecasting rules to alert people about imminent changes of regime?”

The students implemented breeding, a method used to estimate forecast errors in weather models. Bred vectors are simply the difference between two



**FIG. 1.** Solution of the Lorenz model equations (1) over 1500 time steps, showing a “warm” regime with positive values of  $x$  and  $y$ , and a “cold” regime with negative values of  $x$  and  $y$ . The solution typically remains for several loops in each regime before changing to the other regime.



**FIG. 2. Schematic of the construction of bred vectors, which are the difference between a perturbed and a “control” (unperturbed) solution. Every few (in this case, eight) steps, the difference, rescaled to the original size and added to the control forecast, becomes the initial condition for the perturbed forecast. The ratio between the initial and the final size is the amplification of the bred vector during that interval.**

model runs, the second originating from slightly perturbed initial conditions, periodically rescaled (Fig. 2). The amplification of the bred vectors can be used to identify regions of high error growth within the attractor. The Lorenz model used in this project was integrated using a fourth-order Runge–Kutta time scheme with a time step of  $\Delta t = 0.01$ . The bred vectors were obtained from a second run with the same model started from an initial perturbation  $\delta \mathbf{x}_0 = (\delta x_0, \delta y_0, \delta z_0)$  added to the control at time  $t_0$ . Every eight time steps the vector difference  $\delta \mathbf{x}$  between the perturbed and the control run was rescaled to the initial amplitude

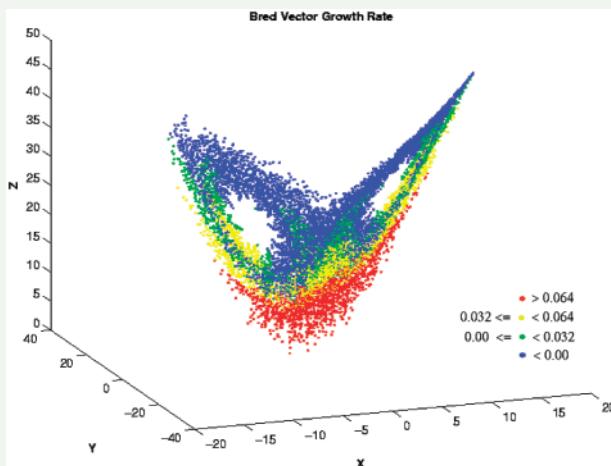
$$|\delta \mathbf{x}_0| = \sqrt{\delta x_0^2 + \delta y_0^2 + \delta z_0^2}$$

and added to the control run (Fig. 2). The bred vector amplification factor was defined as the size of the bred vector after  $n = 8$  steps divided by its original size  $|\delta \mathbf{x}|/|\delta \mathbf{x}_0|$ , and the growth rate as

$$g = \frac{1}{n} \ln(|\delta \mathbf{x}|/|\delta \mathbf{x}_0|).$$

The students plotted the observed bred-vector growth on the Lorenz attractor in order to explore its predictability (Fig. 3). Red indicates that during the last eight steps the perturbation growth rate  $g$  was larger than 0.064 (i.e., the size of the bred vectors grew by a factor of 1.67 or more in eight time steps), whereas blue indicates a negative growth rate, meaning that the perturbations are actually decaying. The results shown in this figure were very promising because they suggested that bred vector growth would allow estimating regions of high and low predictability of the attractor.

The students then examined the bred-vector growth for patterns of predictability. They found that plotting the growth rates on the evolution of the variable  $x(t)$  provides a means to predict when the model will enter a new regime, and also how long the new regime will last. Figure 4 illustrates the “forecasting rules” that the students developed by inspection.



**FIG. 3. The Lorenz “butterfly” attractor with bred-vector growth over eight steps. The table indicates the range of the growth rate corresponding to each color.**

- **Rule 1:** When the growth rate exceeds 0.064 over a period of eight steps, as indicated by the presence of one (or more) red stars, the current regime will end after it completes the current orbit.
- **Rule 2:** The length of the new regime is proportional to the number of red stars. For example, the presence of five or more stars in the old regime, indicating sustained strong growth, implies that the new regime will last four orbits or more (see Fig. 5 for the relationship between number of red stars and the duration of the new regime).

After the RISE internship had been completed, and the results presented at the RISE Research Symposium, Evans (supported by the School of Engineering) and Peña carried out an objective verification of these simple forecasting rules. Table 1 is the contingency table for the categorical Rule 1 that forecasts the occurrence of a regime change during the following orbit. Table 2 is the corresponding contingency table

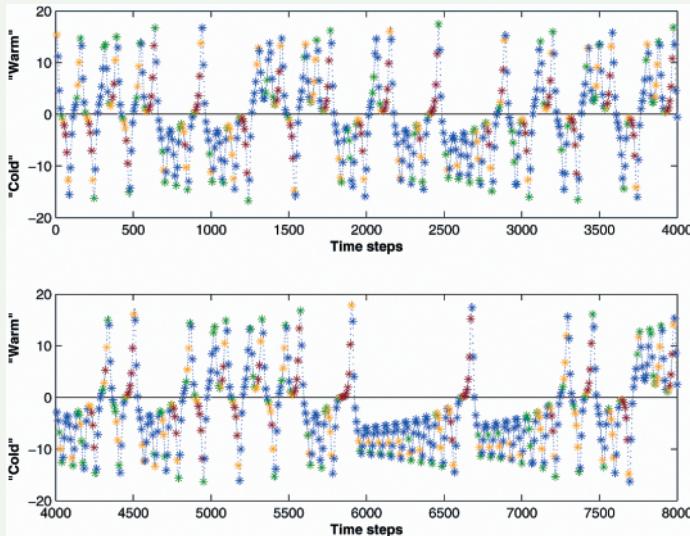


FIG. 4. Time series of the variable  $x$  versus time step, with breeding cycles of eight time steps, with colored stars indicating the bred-vector growth, as in Fig. 3. Each panel shows 4000 steps, corresponding to 500 breeding cycles.

for Rule 2, where the presence of four stars or less indicates that the new regime will only last up to three orbits. Figure 5 shows that there is a strong relationship between the number of red stars in the old regime and the duration of the new regime. The verification scores obtained for the rules, with hit rates over 90%, threat scores over 80%, and false-alarm rates of less than 10%, indicate that both rules provide excellent predictions of regime change and duration.

**TABLE 1. Contingency table for Rule 1 (a change of regime takes place in the orbit after the appearance of a red star), computed over 40,000 time steps, with 187 changes of regime. These numbers correspond to a hit rate (percentage of the forecasts correctly anticipating the subsequent change or lack of change of regime)  $HR = 91.4\%$ , a threat score or critical success index  $TS = 80.3\%$ , and a false-alarm rate, the percentage of forecasts in which a change of regime was forecast but did not occur,  $FAR = 6.5\%$  (Wilks 1995, pp. 238–241).**

OBS	Yes	No	Total
FCST			
Yes	187	13	200
No	33	299	332
Total	220	312	532

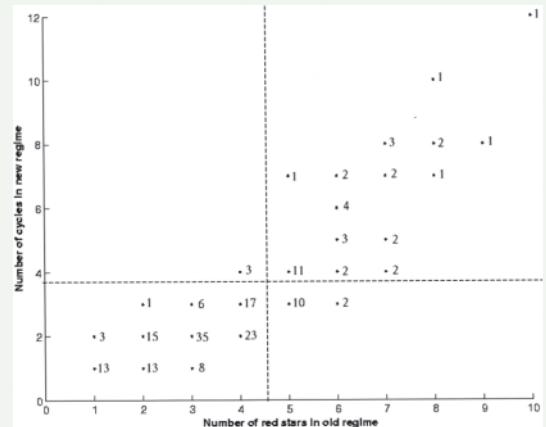


FIG. 5. Observed number of cycles in the new regime for a given number of red stars in the old regime. The numbers indicate the number of pairs observed, with blanks indicating no observed pairs. Dashed lines indicate the specific rule verified in Table 2, although other combinations yield similarly high verification scores.

In summary, the RISE students succeeded in providing the mythical inhabitants of the chaotic Lorenz attractor with robust prediction rules that would allow them to be prepared for changes in regime and indicate how long the new regime would probably last. While in this process, the undergraduate women learned that they were able to both perform and enjoy research, strengthening their motivation to pursue research careers in science and engineering.

**ACKNOWLEDGEMENTS.** We are very grateful to Linda Schmidt, Janet Schmidt, and Paige Smith for conceiving and obtaining funds for the RISE program, for the support of the National Science Foundation and the University

**TABLE 2. Contingency table for Rule 2 (fewer than five red stars in the old regime indicate that the new regime will only last three orbits or less, see Fig. 3), computed over 40,000 steps. These numbers correspond to  $HR = 92.0\%$ ,  $TS = 90.0\%$ , and  $FAR = 2.2\%$ .**

OBS	Yes	No	Total
FCST			
Yes	134	3	137
No	12	38	50
Total	146	41	187

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