Using GEMPAK/GARP in Undergraduate Research

BY RICHARD D. CLARK

This article is part of a continuing series on innovative educational initiatives in the Unidata Community.—THE EDITOR

FIG. 1. A team of Millersville University students prepares to launch the 100-m^3 blimp during an air chemistry field project (NARSTO-NE-OPS).

Operating a mobile tethered atmospheric sounding facility provides Millersville University students a rich opportunity for gaining experience in data collection, boundary layer and air chemistry research, and practical skills that cannot be replicated in the classroom.

The facility features 100-m^3 (Fig. 1) and 7-m^3 helium-filled blimps that tether meteorological sensors and other instruments at altitudes typically around 300 m, although the system is designed to achieve an altitude of 1000 m. The facility is typically used in concert with a variety of other measurement platforms (aircraft, LIDAR, surface chemistry) to provide high-resolution measurements during the development and evolution of the surface and lower-atmospheric boundary layers, and for calibrations and comparisons with other instruments. Most recently, the facility was deployed near Philadelphia in summers 1998, 1999, and 2001 to investigate factors leading to the occurrence of ozone and fine particles in northeastern United States as part of the Environmental Protection Agency–sponsored North American Research Strategy for Tropospheric Ozone–Northeast Oxidant and Particle Study (NARSTO–NE–OPS; Philbrick 1998).

Field experiments can be 24-hour-a-day operations spanning several consecutive days during high-pollution episodes. Students learn to work as a well-honed team to ensure the safety and scientific objectives of the project. When conditions require continuous daytime–nighttime operations, the six students are split into two 3-person groups, with each group working 14-hour shifts including two-hour overlaps during the launch and retrieval of the large blimp. During its shift, each group is responsible for the management of the facility, which includes data collection, short-term weather forecasting, instrument maintenance, and the scientific integrity of the operation.

Within each group, individuals are assigned specific instruments for which they develop expertise in all aspects of instrument operation, and when the instruments are retrieved every 10 h, they are solely re-

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sponsible for downloading and archiving data, performing instrument maintenance and calibration when necessary, and reconfiguring the instruments for subsequent flights. The students work with an extensive array of instruments. In addition to meteorological sensors, airborne instruments include ozone probes, laser-diode scatterometers, particulate impaction samplers, and micro-orifice vacuum samplers. The combined suite of instruments and samplers provides measurements of temperature, pressure, relative humidity, wind speed and direction, and O_3 concentration as a function of time and height. The instruments also yield total scattering coefficient as a proxy of fine particle mass ($PM_{2.5}$), integrated dry particle mass, and air samples later analyzed for 55 volatile toxic compounds. In addition to balloon-borne capabilities, the mobile facility includes a suite of surface-based instruments, including criteria gas analyzers for CO, O_3, SO_2, and $NO/NO_2/NO_X$ and a three-wavelength nephelometer for particle scattering. On-site Internet access to radar and satellite imagery, as well as surface, upper air, and model data, is also available.

The undergraduates assume roles of true research scientists, learning science by doing science. They become intimately familiar and proficient with different instruments and analysis software, and are regularly consulted for project decision-making. As examples, decisions to abort a mission due to deteriorating weather conditions or to coordinate measurements with other platforms (e.g., lidar, aircraft) to provide instrument comparisons and "ground-truthing" are made in consultation between students and project scientists and are based on group consensus.

Field research for undergraduates, more than any other academic exercise, helps students build confidence in their abilities and enhances their scientific maturity. In several cases, the knowledge, understanding, and skills gained by participating in field research have helped students gain employment or acceptance to advanced degree programs. Students return to their coursework more focused and enthusiastic about atmospheric science. The students who have since participated in field research often see it as a capstone experience of their undergraduate training.

The on-site measurements collected during a field intensive project are put into regional and synoptic context by incorporating data and products obtained via Unidata's Internet Data Distribution (IDD) system. Select data are archived for analysis upon completion of the field project. GEMPAK, obtained through the Unidata Program, is the principal application used for visualization, analysis, and interpretation of imagery, observations, and model initializations. GARP (see "Definitions," page 1246) and, more recently, NMAP, provide graphical user interfaces to GEMPAK and facilitate the data display. These applications, along with trajectories from the NOAA Air Resources Laboratory's Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT4) Model, are used to help characterize parcel trajectories and airmass histories in order to integrate point measurements into a regional context.

The hundreds of vertical profiles obtained in ASCII format during a field intensive project are input to a program that converts them to GEMPAK format (GEMPAK output files), and the GEMPAK applications, *sncross* and *snprof*, are then used to create time–height series (Fig. 2) and individual soundings of meteorological variables and O_3 concentrations (Fig. 3).

Upon completion of the field project, GEMPAK applications used with and without the GARP or NMAP graphical user interfaces continue to provide utility for the analysis and visualization of meteorological and trace gas measurements. Once the GEMPAK templates are established, the process can take place rather quickly, which is especially important in field studies that yield literally hundreds of vertical profiles (e.g., 536 profiles in summer 2001).

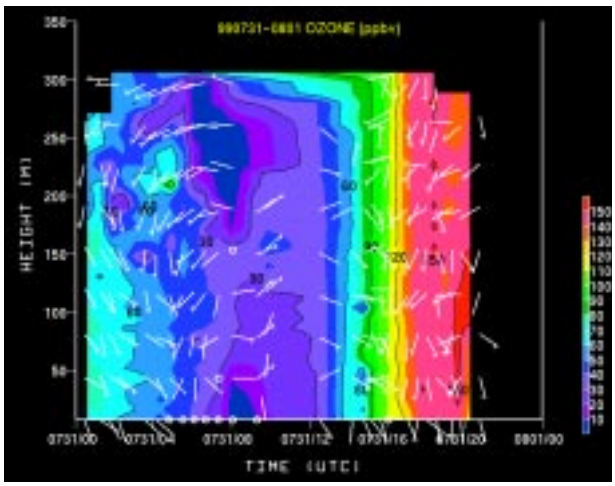

Fig. 2. Time–height series of O_3 concentration created using GEMPAK *sncross*.

Students gain experience in applying their FORTRAN 90 programming skills to create standardized file formats for input into GEMPAK applications, and they learn valuable analysis and interpretative skills

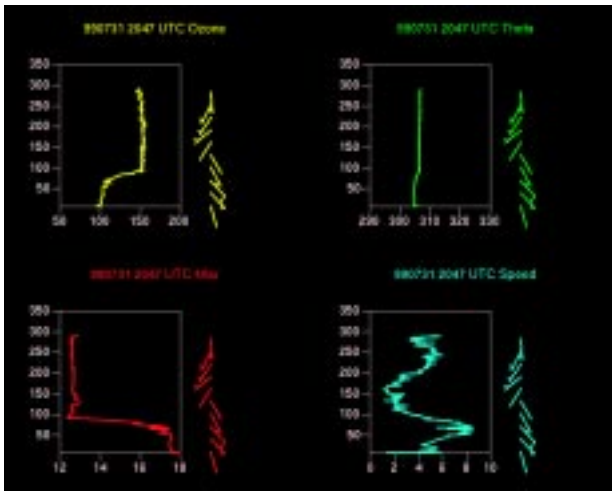

Fig. 3. Vertical profiles of O_3 concentration, potential temperature, water vapor mixing ratio, and wind speed created using GEMPAK *snprof*.

when trying to assimilate the data into the regional context. Students involved in the summer 2001 field project presented the results of their analysis of three case studies at the First AMS Student Conference poster session held in Orlando, Florida, in January 2002 (Walker et al. 2002). Students are also encouraged to mine the data for relationships that may not seem immediately apparent, and in a few cases they have discovered meaningful correlations such as the interesting relationship between high total scattering coefficients (the scattering effect of fine particles) and relative humidity accompanying the propagation of the sea-breeze convergence zone over the field site.

Students are involved in every step of the research process from project logistics and the development of scientific strategies to analysis and quality assurance of data. Postproject self-evaluations by students and the outcome assessments by the faculty researcher indicate quantum leaps in student learning and scientific prowess. In nearly every case, students who have participated in a field project perform at higher levels in upper-division courses in the major than those who do not seek out such opportunities.

DEFINITIONS.

- GARP: GEMPAK Analysis and Rendering Program—a graphical user interface.
- NMAP: A graphical user interface to the GEMPAK library functions with user interactive drawing, looping, and product generation capabilities.

REFERENCES

Philbrick, C. R., 1998: Investigations of factors determining the occurrence of ozone and fine particles in northeastern U.S.A. *Measurement of Toxic and Related Air Pollutants*, Air and Waste Management Association, 248–260.

Walker, R., Jr., A. J. Terry, S. L. Atkins, M. L. Theis, E. D. Carre, and J. M. Barbush, 2002: Measurements of meteorological variables and trace gas concentrations during NE-OPS 2001 using a tethered atmospheric observing system. First AMS Student Conference Poster Session, 82nd Annual Meeting of the AMS, Orlando, FL.