P2.14 REVOLUTIONIZING NAVAL METEOROLOGY TRAINING

Don T. Conlee *[1]

Wendy Schreiber-Abshire
Cooperative Program for Operational Meteorology, Education and Training
Boulder, Colorado

Carl B. Miles, Jr.[1]

Keith G. Blackwell
University of South Alabama, Mobile, Alabama

Thomas F. Lee
Naval Research Laboratory, Monterey, California

Anne G. Carroll[1]

Damon E. Williams[1]

Daniel R. Moreau[1]

[1]Naval Technical Training Unit, Keesler AFB, Mississippi

1. INTRODUCTION

The U.S. Navy has trained enlisted operational weather forecasters for many years and for the past twenty-five side-by-side with the U.S. Air Force and Marine Corps. In concert with a call by the Chief of Naval Operations to "Revolutionize Navy Training", the Navy and Marines have embarked on a project to modernize the Aerographer's Mate (Weather Forecaster) school.

The Navy/Marine (frequently represented by the adjective "Naval") Meteorology and Oceanography (METOC) community must provide support to forces continually deployed around the world in peace and wartime. This support not only includes traditional weather forecasts, but also includes interpreting the environmental impact to military operations and weapons systems. Many of the eventual forecasting environments for the graduates call for highly independent operations with the forecaster forward deployed aboard ships or in the littoral with a Marine Expeditionary Unit.

* Corresponding author address: CDR Don T. Conlee, Commanding Officer, Naval Technical Training Unit, Keesler AFB, MS 39534-2498; email: don.conlee@cnet.navy.mil

The primary challenge of the Naval Technical Training Unit is take a Sailor/Marine with some weather background, typically as an observer for 3-4 years, and prepare them for duty as a qualified forecaster for year-round worldwide military operations via a 7-month course of instruction. The challenge of this effort was to take an outdated and largely paper-based curriculum and laboratory approach, update it with the latest methods and tools, and deliver it in an instructor-led electronic format. This course included over 1240 hours of instruction, over 900 of which needed review, revision and conversion to electronic presentations. With a theme of "scientifically correct, operationally relevant", a vastly modernized course of instruction has been fielded.

2. PARTNERSHIPS

The "scientifically correct" requirement has been addressed by collaborative partnerships with subject-matter experts from the Cooperative Program for Operational Meteorology, Education and Training (COMET), the University of South Alabama and the Naval Research Laboratory. The "operational relevance" has been assured through the involvement of many current Navy and Marine Corps forecasters in both developing and reviewing the actual electronic presentations, laboratory exercises and lesson plans. This unique partnership of military, government and academia has been the key to project success.

2.1 *University of South Alabama Contributions*

The University of South Alabama (USA) has one of the fastest growing undergraduate Meteorology programs in the United States. The program is designed to prepare graduates for employment in both government and industry, and aligns with American Meteorological Society and National Weather Service recommended coursework. USA has assisted extensively in the updating of basic Physics, Physical/Dynamic Meteorology and Forecasting portions of the course.

Atmospheric processes and behavior are governed by physical laws. Conceptual understanding of these laws and how they influence atmospheric behavior is crucial for students to develop into skillful forecasters. The equations which describe these physical laws are very complex. Because advanced mathematics cannot be assumed of the students, the curriculum relies heavily on conceptual explanations including state-of-the-art visualizations.

For instance, the equation describing vertical vorticity generation is shown in Figure 1. Instead of the students understanding vector calculus, it is more important that they grasp the concept of tilting and stretching and its influence on the vertical vorticity. These two processes of stretching and tilting are conceptually demonstrated in Figures 2 and 3, respectively.

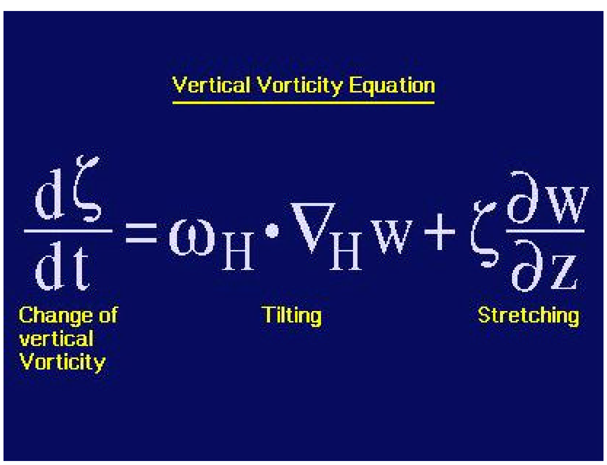

Figure 1. Vertical Vorticity Equation

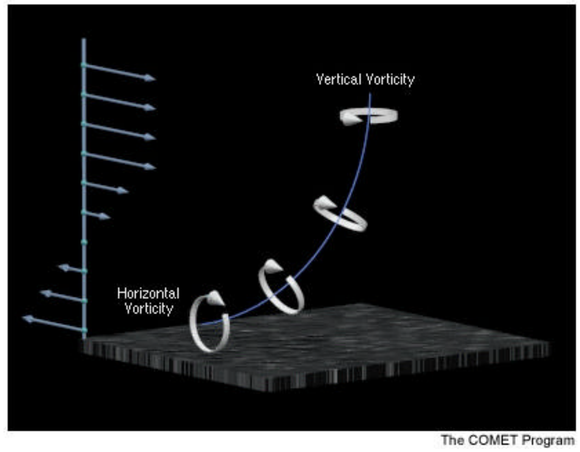

Figure 2. Conceptual illustration of the tilting term from Figure 1.

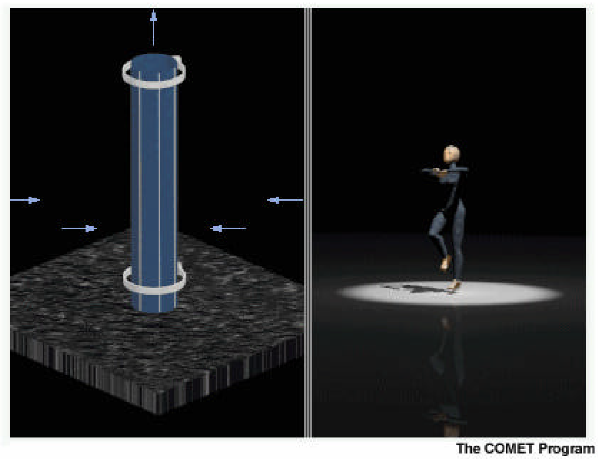

Figure 3. Conceptual illustration of the stretching term from Figure 1.

In another example, a natural coordinate reference frame is used for the basic calculation of vorticity. Then, relative magnitudes of individual components are compared through finite differences to determine the correct sign of the process (i.e., whether the vorticity is cyclonic or anticyclonic). This also provides a quick determination of which term in the equation provides the largest contribution to the process. For example:

Equation: Relative vorticity (ζ) = curvature + shear. Stated mathematically:

Relative Vorticity Equation in Natural Coordinates (Vertical only)

$$\zeta = V \frac{\Delta\alpha}{\Delta s} - \frac{\Delta V}{\Delta n}$$

(A) (B)

where Term A is the curvature vorticity and Term B is the lateral shear vorticity.

A quick numerical estimate of whether Term A has a cyclonic or anticyclonic contribution to ζ may then be accomplished for a particular circumstance:

$$V \frac{\Delta\alpha}{\Delta s} = V \frac{(\alpha_{downstream} - \alpha_{upstream})}{(s_{downstream} - s_{upstream})} =$$

$$\frac{+ \text{ (larger - smaller)}}{\text{(larger - smaller)}} = \frac{+(+)}{(+)} = +$$

Since the result is positive, curvature vorticity provides a cyclonic contribution to the relative vorticity. In addition, this process is conceptually depicted to the students with high-quality graphics. By including the equations, and working through their individual terms, students develop an understanding of the contribution individual terms have on the phenomenon under study.

The heavy use of "rules-of-thumb" in the original course has been de-emphasized. Instead, physical understanding of the underlying processes has been greatly enhanced. This greater conceptual understanding of dynamical structure in atmospheric systems is critically important in today's high-tech computer environment.

Students equipped with meteorological concepts learned in Physics and Dynamics then are required to apply this knowledge to real-world situations. Analysis skills are strongly emphasized. Smart interpretation of numerical model-generated forecasts also is strongly emphasized and represents a big change from earlier emphasis on basic DIFAX charts and rules of thumb. Skillful interpretation of numerical model products often leads to value-added forecasts which are more accurate than model forecasts alone. High-quality graphics and animations are essential to this training process.

Given the new approach to physics and dynamics material, combined with the introduction of many new physical and dynamical concepts and their use in numerical model interpretation, instructor training is essential (i.e., train the trainer). This instructor training takes place in on-site seminars lead by meteorology faculty from USA. In this setting, scientifically-correct lesson plans are presented directly to the Navy and Marine Corps instructors. Lively discussions often develop during these sessions.

2.2 *COMET Contributions*

The COMET Program exists within the University Corporation for Atmospheric Research (UCAR) to serve as a training and education bridge between meteorology research and operations. With 12^{+} years of experience in this role the program has extensive intellectual and graphical resources for supporting meteorology education, especially at and beyond the college level. COMET's contributions to the modernization of the Aerographer's C-school curriculum can be categorized into the following areas:

- Providing instructive graphics and animations
- Sharing expertise in convective severe weather and mesoscale meteorology in general
- Providing historical case data, and
- Networking with the university community to make available an online forecasting competition

Elaborating on several of these areas further, extensive datasets of recent weather events were supplied for use as both lecture examples and in new laboratory exercises throughout the course. Additionally, by taking advantage of COMET's numerous relationships with faculty in the university community we were able to identify the necessary resources for implementing a daily real-time online forecasting exercise developed at Iowa State University that all students will be involved with from the beginning of the course. This activity will immediately motivate students as to the significance of the barrage of information they receive during their seven months of instruction and also serve to develop their forecasting skills from the onset of the course.

2.3 *Naval Research Laboratory Contributions*

The Marine Meteorology directorate of the Naval Research Laboratory (NRL) in Monterey, California has long concentrated on developing applied meteorology in support of Naval interests. In particular, the Remote Sensing branch has specialized in applications in multi-sensor fusion and tropical meteorology, as well as the training required to understand and utilize the applications. The expertise of NRL was tapped for both the specific satellite meteorology training and the support of other sections of the course.

Since surface and upper air observations are nearly absent over huge expanses of oceans, satellite images and products are a crucial aspect of the Navy forecasting operations. Just a few years ago many Navy ships and some Navy shore forecasting facilities had little access to high quality satellite products. However, the communications revolution over about the last decade has meant that even the most remote ship or facility now receives a variety of timely satellite products from a number of sources. However, the ability to interpret these products has not kept pace with their timely delivery. In addition, forecasters must now interpret more than visible, infrared and water vapor images. Microwave ocean surface wind depictions, precipitation charts, cloud height images, and nighttime stratus enhancements are but a few of the many value-added products now available. Unfortunately, few forecasters have been trained to use these products.

Up until recently, the school taught satellite meteorology using dated educational materials. Many of the training images were in hardcopy form, unlike the online images the students now encounter once they arrive at their duty stations. Only basic visible/infrared/vapor skills were emphasized. Often, the images used in instruction were from the GOES satellites over the continental United States (CONUS). While the Schoolhouse must teach satellite interpretation skills over CONUS, overemphasis of this region meant that important overseas regions were not covered. For example, there was little using the European Meteosat or the Japanese GMS satellites. And there was little emphasis on passive microwave satellites that can give important information about tropical marine weather and ocean wind speeds.

Thus, the updated course takes a more global, modernized approach. Electronic lectures now contain examples from around the globe, covering a variety of missions. First, students are introduced to the basic kinds of satellites, including the important distinctions between low-earth orbiting and geostationary satellites. In addition, new multispectral and microwave approaches are covered in detail. Emphasis is given to products which address key Navy problems, for example, tropical cyclones in the Pacific Ocean, marine windflow, low stratus and fog, aviation, cloud properties, blowing dust, etc. While the details of data processing are not discussed, students are introduced to the concept of multi-channel imagers, such as the five-channel GOES satellites and the seven-channel SSM/I satellites. Laboratories feature the same concepts, allowing students to study the products introduced during lectures.

3. REVISED COURSE OVERVIEW

The revised course differs from its predecessor not only in inclusion of updated material, visualizations and presentation format, but also in learning philosophy. The new course flow (Figure 4) is designed to support an approach of "teach, test, build", where more advanced concepts, techniques and tools are introduced earlier in the course. The flow supports continually touching back on earlier concepts, culminating in an expanded laboratory where all of the previous material is exercised and tested. This 147 hour laboratory experience occurs at the 5 month point in the curriculum. Because a student's first forecaster assignment is known at this point, the laboratory includes scenarios tailored to the region most likely to be encountered by the student.

Another major learning strategy shift involves the area of testing. In the previous paper chart-based era, students were frequently graded on similarity to a "schoolhouse solution". Testing in the new curriculum focuses on analytical reasoning, and if a student reaches an analysis or forecast conclusion which is well thought out and scientifically reasonable, credit will be given.

Finally, the numerical weather prediction (NWP) products available today are far superior to times past and these tools are available at sea and in forward locations. Still, the successful graduate (the first of which will emerge in June 2003) will be expected to provide value beyond the skill of the models. This skill is taught by learning to evaluate model performance in a hindcast/nowcast/forecast context. Students are taught how to examine various model tendency summaries, observe and compare model behavior and if necessary to develop tendencies for themselves.

4. CONCLUSIONS

By bringing together the talents and resources from experts from appropriate institutions throughout our field, the Naval Technical Training Unit has successfully modernized the content and delivery of its Aerographer's Mate course. In the process the extensive set of operationally relevant materials has been made more enjoyable for its students while achieving a new standard of rigor.

We can now foresee that the revolution in Naval meteorological training will lead to a revolution in Naval meteorological operations. The communications and computer revolution over the last few years has meant that Sailors and Marines around the world have access to the most advanced and timely information possible. We can now be assured that this capability will be used with confidence and competence by science-savvy Sailors. Furthermore, our hope is that graduates will have been instilled with a desire to learn more, a quality that will serve them well in a world of rapid change.

The meteorology education community may find many aspects of this effort applicable to their own needs. The conceptual, but still rigorous treatment of meteorology concepts may be particularly useful in undergraduate settings as a supplement to traditional mathematical approaches, and in meeting a subset of continuing educational needs of other operational forecasters.

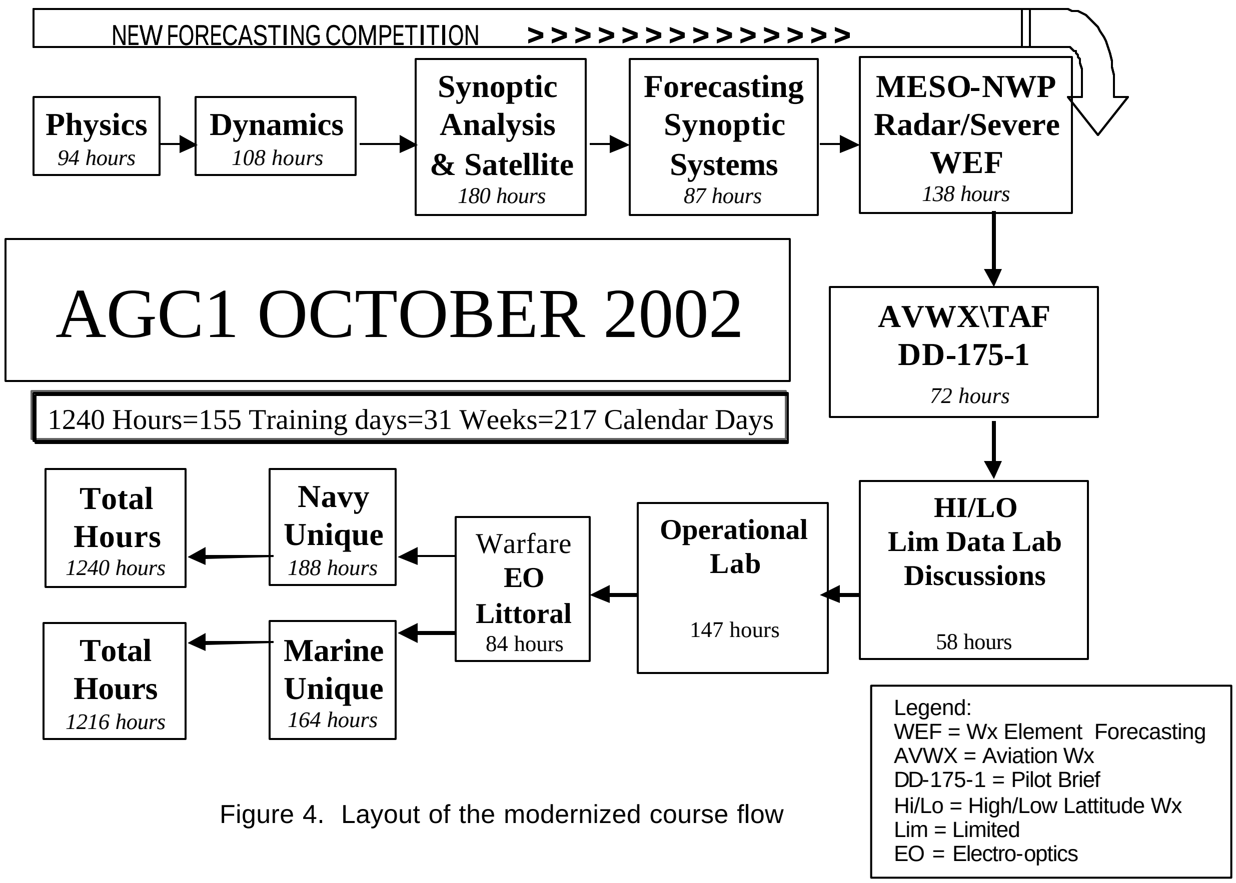

Figure 4. Layout of the modernized course flow