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1. INTRODUCTION

The purpose of this article is to introduce the new COMET NWP distance learning *training series* which is presently comprised of two online courses. Two additional courses are currently at the beginning stage of development and more are planned based on anticipated training needs arising from changes in the operational forecasting environment. This effort was discussed in Bua and Jascourt (2009) when the first two courses were under development and is updated here reflecting what has been published online and an updated view on what will be coming over the next two years.

The Cooperative Program for Operational Meteorology, Education and Training (COMET®) Program has been developing forecaster training on numerical weather prediction for ten years (e.g., see Bua and Jascourt (2005), Jascourt and Bua (2004) and references therein). COMET training on NWP is free and available online. Most items will be listed on the MetEd web page at <http://meted.ucar.edu> under the topic "NWP".

In recent years, the COMET Operational Model Matrix at <http://meted.ucar.edu/nwp/pcu2> and other COMET training, such as webcasts (see <http://meted.ucar.edu> then select NWP from the topics menu) and VISITview teletraining (see http://rammb.cira.colostate.edu/visit/topic_nwp.html) on the ensemble forecast systems and on the NCEP NAM transition from the Eta model to the WRF-NMM model, among others, helped translate model changes into the context of the field forecaster, facilitating better use of the models.

However, most of this training has been focused on particular models and model changes and on new model products. Some of the content has become outdated in details, though many of the principles presented still hold. More importantly, NWP training is needed on integrating the suite of models and products together in the context of the forecast process rather than focusing on specific models or types of products.

Meanwhile, National Weather Service (NWS) forecasters now create grids of sensible weather forecasts at 5-km or 2.5-km grid spacing and some private sector meteorologists and others create gridded forecast products in a similar manner. The application of NWP products has been correspondingly extended from conceiving of the forecast to using a grid editor to create the forecast, but our training has until now considered the former to be the endpoint. A good scientific practice would not allow the mechanics of the gridded forecast process to drive how model data are utilized in creating a forecast. Nonetheless, training must extend through the creation of the end product in order to optimize the use of NWP in the final forecast. These factors led NWS to prioritize development of a new forecast training course on the effective use of NWP in the forecast process. Specific priorities were identified through a survey of NWS Science and Operations Officers working in forecast offices across the United States and by the NWS Regional Scientific Service Divisions (Jascourt and Bua 2009).

The new course was designed to

- be more immersive in the forecast process
- provide more interactivity
- allow COMET to update old material
- address the new training needs identified in the survey
- modernize the online format of COMET NWP training

Note: The operational orientation of COMET NWP training may provide a useful complement to academic courses, and faculty are encouraged to supplement some of their courses with COMET materials as they see fit. However, we have never suggested that COMET NWP materials should substitute for a rigorous curriculum.

2. WHERE TO FIND THE TRAINING

The direct link to the new training series is http://meted.ucar.edu/dl_courses/nwp

The home page has the objectives and philosophy of the series. The introduction tab contains a description of all of the courses. The Course 1 and Course 2 tabs contain the listing of all lessons within each course and the link to each. Additionally, some of the lessons are complemented with cases which can be run on the AWIPS Weather Event Simulator. These cases are available on DVD from the NWS Warning Decision Training Branch.

3. ORGANIZATION

Course 1: NWP Basics and Background covers the fundamental building blocks of NWP as well as specific tools such as downscaling, bias correction, and high-resolution models. Lessons on emerging future tools may also be inserted into the training series in Course 1.

Course 2: Using and Adding Value to NWP in the Forecast Process is more immersive in forecast scenarios and covers the steps of using NWP in making a forecast, beginning with identifying the problem(s) of the day and using observations and models to form a conceptual model. The forecast process described and the individual lessons in this course were developed collaboratively with operational NWS forecasters, including Science and Operations Officers.

Course 3: NWP in the Era of Digital Forecast Preparation will address how NWP can be utilized by a human forecaster whose responsibility is to generate digital forecast grids. NWP-based inputs are crucial and selecting which inputs are to be used is one of the roles of the human but not the only role. This course is being developed now in collaboration with our colleagues in NWS forecast offices and NCEP centers and elsewhere. It is anticipated to become available before the end of 2012.

Course 4: Special Topics will address utilizing NWP in forecasting over complex terrain, in coastal and marine environments, forecasting convection, and a variety of other topics. Each topic will have its own lesson. This course is being developed now in collaboration with our colleagues in NWS forecast offices and NCEP centers and elsewhere. It is anticipated to become available before the end of 2012.


Course 5: Emerging Topics will cover new training needs anticipated to arise a few years further into the future.

4. COURSE 1: NWP BASICS AND BACKGROUND

The first section in Course 1 is comprised of lessons on general basics. This is an update of the COMET online distance learning course from around ten years ago. Some of the material is identical and has simply been reformatted as shown in Figure 1 (old) and Figure 2 (new), while some of the material has been consolidated and streamlined. The material in the old course (Fig. 1) on pages numbered without the white spots on the navigation panel on the left was optional and not tested on the post-module quiz. The optional material in the new version (Fig. 2) is denoted by the faded items in the navigation panel on the left. A small amount of new content was also added as part of the update. An example is shown in Figure 3, part of a section on adaptive analysis methods including ensemble Kalman filter (shown), anisotropic covariances, and 4d-var. Each of the pages on these topics illustrates how the analysis is affected.

The second section in Course 1 contains lessons on various forecast tools. These are all recent additions. Presently, the topics available are:

- Bias Correction of NWP Model Data
- Effective Use of High-resolution Models
- Introduction to the North American Ensemble Forecast System (NAEFS)
- Downscaling of NWP Data



Introduction
DA Process
DA Wizard *
Data
Obs. Increment
Analysis
Operational Tips
Exercises
Summary & Refs.

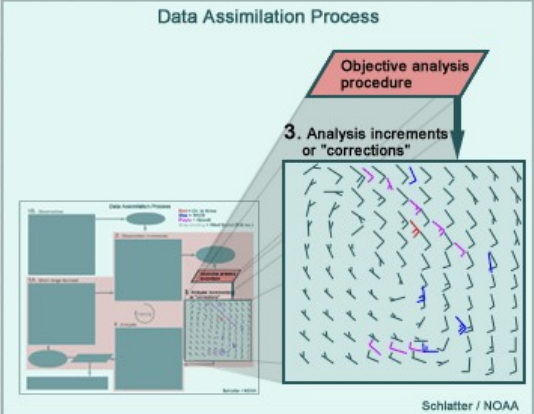
Pages				
1	2	3	4	5
6	7	8		

Op. Models Matrix
NWP Course Homepage
Bookmark Page
Restore Bookmark

Using Observation Increments to Make the Analysis

This step is the core of the analysis process. It's the most complex step and has a very significant impact on the quality of the model forecast.

The objective analysis procedure moves and merges the observation increments at observation times and locations to the grid fields of the model forecast initial conditions (on the model grid). You may have made a Barnes analysis of, for instance, 500-hPa heights from RAOB data in synoptic lab. Your analysis interpolated the height at each station to a grid, weighting the value of each observation by distance so nearby observations contributed far more than distant observations. The operational system does the same thing, using a far more sophisticated analysis method. Instead of analyzing the observations, DA analyzes the observation increments, making a grid of "corrections" to the previous short-range model forecast. These corrections are then added to the short-range forecast to form the



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Figure 1. Sample page from the old COMET NWP distance learning course

U

UNDERSTANDING ASSIMILATION SYSTEMS:

How Models Create Their Initial Conditions

Produced by The COMET® Program

Menu items marked as * are optional

INTRODUCTION

DA PROCESS

*DA WIZARD

*DATA

OBSERVATION INCREMENT

ANALYSIS

Making the Analysis

Weighting Obs, Forecast

Adaptive Analysis Methods

*How 3D-VAR Works

*Major Assumptions...

*Data Use Limitations

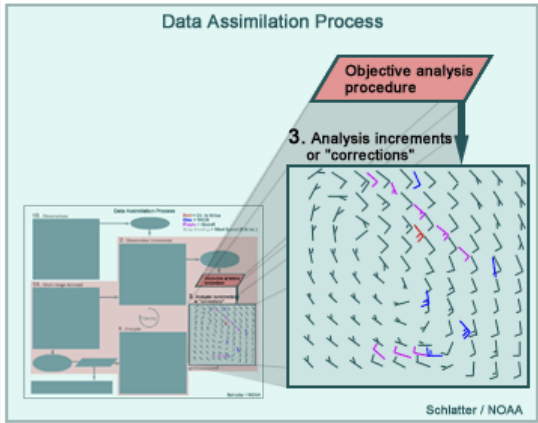
*Variational Quality

Analysis: Using Observation Increments to Make the Analysis

◀ PREVIOUS
|
NEXT ▶

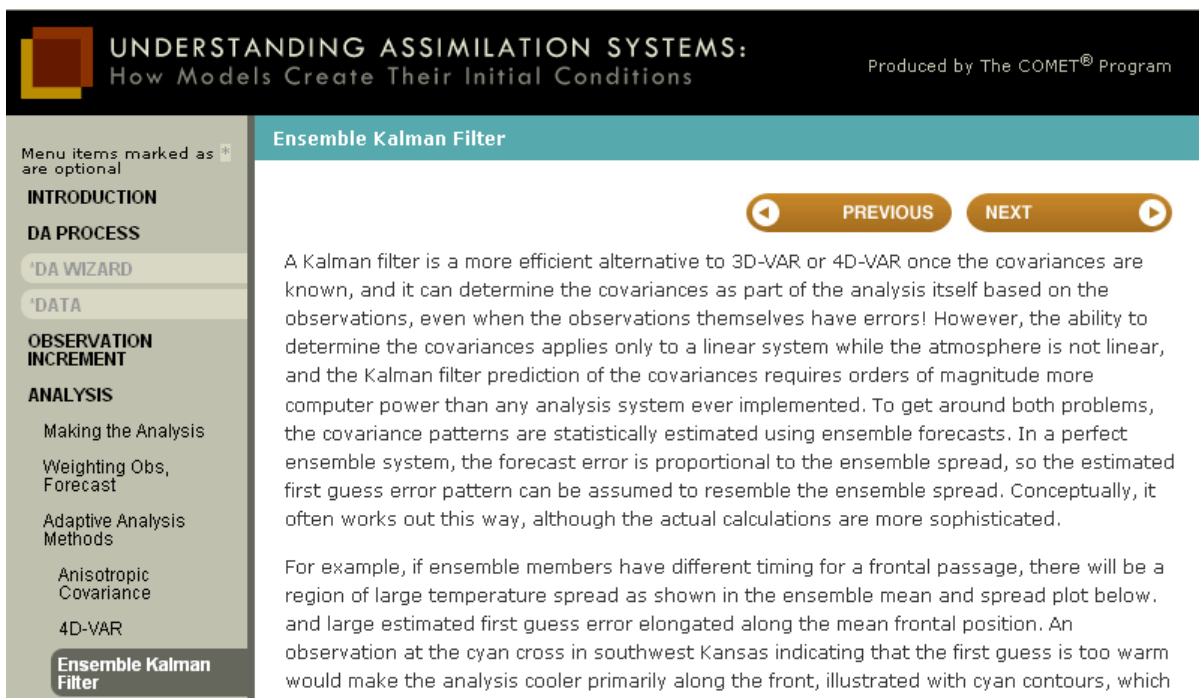
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Figure 2. Sample page of the same content as in Fig. 1 but from Course 1 in the new training series



UNDERSTANDING ASSIMILATION SYSTEMS:
How Models Create Their Initial Conditions

Produced by The COMET® Program

Menu items marked as * are optional

Ensemble Kalman Filter

◀ PREVIOUS NEXT ▶

A Kalman filter is a more efficient alternative to 3D-VAR or 4D-VAR once the covariances are known, and it can determine the covariances as part of the analysis itself based on the observations, even when the observations themselves have errors! However, the ability to determine the covariances applies only to a linear system while the atmosphere is not linear, and the Kalman filter prediction of the covariances requires orders of magnitude more computer power than any analysis system ever implemented. To get around both problems, the covariance patterns are statistically estimated using ensemble forecasts. In a perfect ensemble system, the forecast error is proportional to the ensemble spread, so the estimated first guess error pattern can be assumed to resemble the ensemble spread. Conceptually, it often works out this way, although the actual calculations are more sophisticated.

For example, if ensemble members have different timing for a frontal passage, there will be a region of large temperature spread as shown in the ensemble mean and spread plot below, and large estimated first guess error elongated along the mean frontal position. An observation at the cyan cross in southwest Kansas indicating that the first guess is too warm would make the analysis cooler primarily along the front, illustrated with cyan contours, which

Figure 3. Example of new content on data assimilation in a section on adaptive analysis methods

5. COURSE 2

The emphasis in this course is on how NWP should be used *in the forecast process*. The material in this course is immersed in forecast scenarios and the lessons have accompanying cases the user can run on the AWIPS Weather Event Simulator. There are separate lessons corresponding to each step in the forecast process. Highlights of the lessons are provided below.

The forecast process starts with the lesson “Preparing to Evaluate NWP Models.” This first step involves situational awareness and determining the problem of the day based on current weather and the model forecast scenarios. The page shown in Figure 4 depicts pressure on a model potential vorticity surface overlaid on a water vapor image and discusses evaluating the model initial state and forecast up to the current time. In the left panel, you can see the topics of some of the other pages in this lesson.

Preparing to Evaluate NWP Models

Produced by The COMET® Program

INTRODUCTION

VERTICAL PHENOMENA ANALYSIS FUNNEL

IDENTIFYING TROPOPAUSE ANOMALIES

Evaluating Model Initial Analysis: Lower Stratosphere and Tropopause

Water Vapor and Model PV

The Conceptual Model: Lower Stratosphere and Tropopause

MID-TROPOSPHERE ANALYSIS

LOWER TROPOSPHERE AND BOUNDARY LAYER ANALYSIS

SUMMARIZING THE CONCEPTUAL MODEL

MODEL CAPABILITIES AND ASSESSING ANALYSES AND FORECASTS

Water Vapor and Model PV

PREVIOUS
NEXT

The easiest way to determine how a model is resolving the tropopause-level anomaly is to overlay the imagery with a plot of the pressure (or height) of the 2 PVU (potential vorticity unit) surface. The 2 PVU in the GFS to determine the level of the dynamic tropopause. Compare the 12 UTC initializations from 0 the GFS and NAM models to the closest corresponding water vapor image from 1200 UTC on October 24 the next question. (Click on the GFS or NAM tabs below to see each image.)

GFS
NAM

Water Vapor Imagery and GFS Analysis of Pressure of the 2.0 Potential Vorticity Surface 1200 UTC 24 October 2010

Figure 4. Sample page from Preparing to Evaluate NWP Models

The next lesson is Analysis, Diagnosis, and Short-range Forecast Tools, corresponding to the second step in the forecast process. This discusses diagnosing whether the model solutions are on track and what may be happening which they are missing. For example, after discussing trends in the observed conditions, the black temperature and

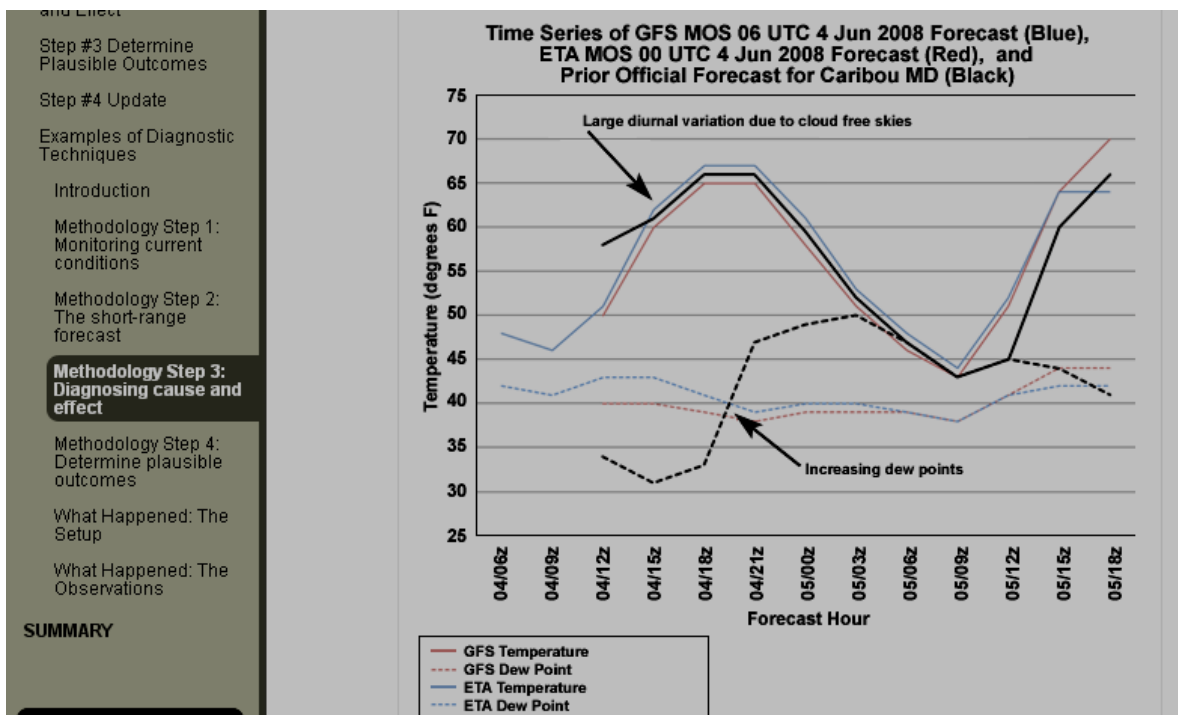


Figure 5. Sample page from Analysis, Diagnosis, and Short-range Forecast Tools

dewpoint curves in Figure 5 show that rising dewpoints may produce saturation and dense fog while numerical guidance shown in the red and blue curves was predicting conditions too dry to even consider a fog threat.

The next three lessons (one of which was still under development as of this writing) address determining which of the possible forecast outcomes are plausible from among the many model and ensemble predictions. The lesson called Determining Plausible Forecast Outcomes runs through this for a couple of different forecast problems. The first

APPLY NWP MODEL PERFORMANCE ASSESSMENTS TO THE FORECAST PROBLEMS OF THE DAY

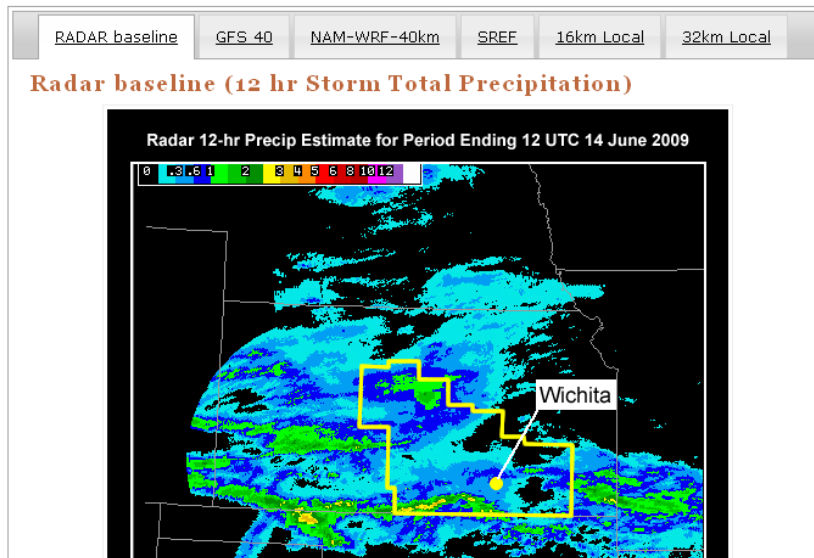
- Situation Briefing
- Evaluate NWP Past Performance**
- Evaluate Current NWP Performance
- Evaluate NWP Prediction

SUMMARY

- HOME
- PRINT VERSION
- REFERENCES
- QUIZ
- SURVEY

of precipitation that fell from evening and overnight convection can be examined by viewing the following data loops. In addition, forecasters should make it common practice to review the previous Area Forecast Discussion (AFD).

Click the tabs to compare the various model QPFs with the previous rainfall total. This is a 12 hour precipitation comparison for the period ending 12 UTC 14 June 2009.



- PRINT VERSION
- REFERENCES
- QUIZ
- SURVEY

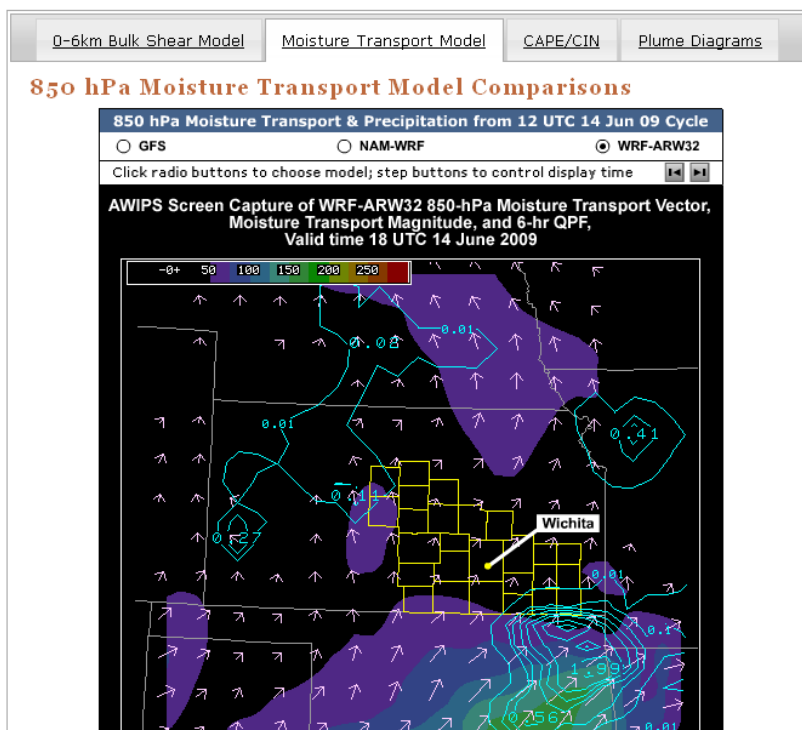


Figure 6. Sample pages from Determining Plausible Forecast Outcomes

image in Figure 6 shows a page on evaluating how the models have handled the situation so far. Other tabs display precipitation over the last 12 hours from the corresponding forecasts from a variety of models and ensembles. The precipitation forecast is then evaluated looking forward in time in the second screen capture. On that page, forecast loops of low-level moisture transport are shown from several models, each selected using the radio button above the data plot.

Also addressing this step in the forecast process is the lesson titled Understanding the Role of Deterministic versus Probabilistic NWP Information. This lesson compares the information from ensembles to that from individual model runs and discusses various ways of viewing ensemble data. On the page shown in Figure 7, there is a question asking the reader what the main forecast problem is based on a plume diagram of QPF color-coded by precipitation type. Many such questions are placed throughout all of the lessons, where the reader is given a little bit of information and learns more by considering the question and reading the feedback discussion.

RESOLUTION MODELS

ADVANTAGES OF EFS

EFS TOOLS USED TO ASSESS UNCERTAINTY AND PROBABILITY

Spaghetti plots

Plume Diagrams

Question: Precipitation Plume Diagrams

Question: Temperature Plume Diagrams

Forecast Uncertainty: Spaghetti and Plume Diagrams

Probability of Exceedance

CURRENT EFS LIMITATIONS

SECTION SUMMARY

HOME

PRINT VERSION

QUIZ

SURVEY

SREF Ensemble Member Forecast Initialized 09 UTC 06Jan2009
Accumulated 3-hour Precipitation Starting 12 UTC 06Jan2009
Green=rain; red=freezing rain; cyan/teal=ice pellets; blue=snow

Precip (inches)

RAIN: Mean: 0.18, Max.: 0.69, Min.: 0.00

SNOW: Mean: 0.09, Max.: 0.20, Min.: 0.03

FZRA: Mean: 0.28, Max.: 0.66, Min.: 0.08

ICEPELL: Mean: 0.24, Max.: 0.56, Min.: 0.00

Total: Mean: 0.85, Max.: 1.14, Min.: 0.52

12 UTC 06Jan 2009 00 UTC 07Jan 12 UTC 07Jan 00 UTC 08Jan 12 UTC 08Jan 00 UTC 09Jan 12 UTC 09Jan

Station Data Plot for State College, PA NOAA/NCEP/NWS

As a forecaster, what is going to be the most significant forecast issue based on this plume diagram? (Choose the best answer.)

a) How much rain will fall?

b) When will the rain fall?

c) What will the precipitation type be?

Figure 7. Sample page from Understanding the Role of Deterministic versus Probabilistic NWP Information

Finally, Course 2 culminates in the lesson titled Adding Value to NWP Guidance. This lesson addresses opportunities for the human to improve over automated guidance at each step in the forecast process. Verification is a key aspect of this and the page shown in Figure 8 is an example of bias in model guidance in a persistent weather pattern. Due to continued persistence of the pattern, the forecaster has an opportunity to use this information to improve over this model guidance.

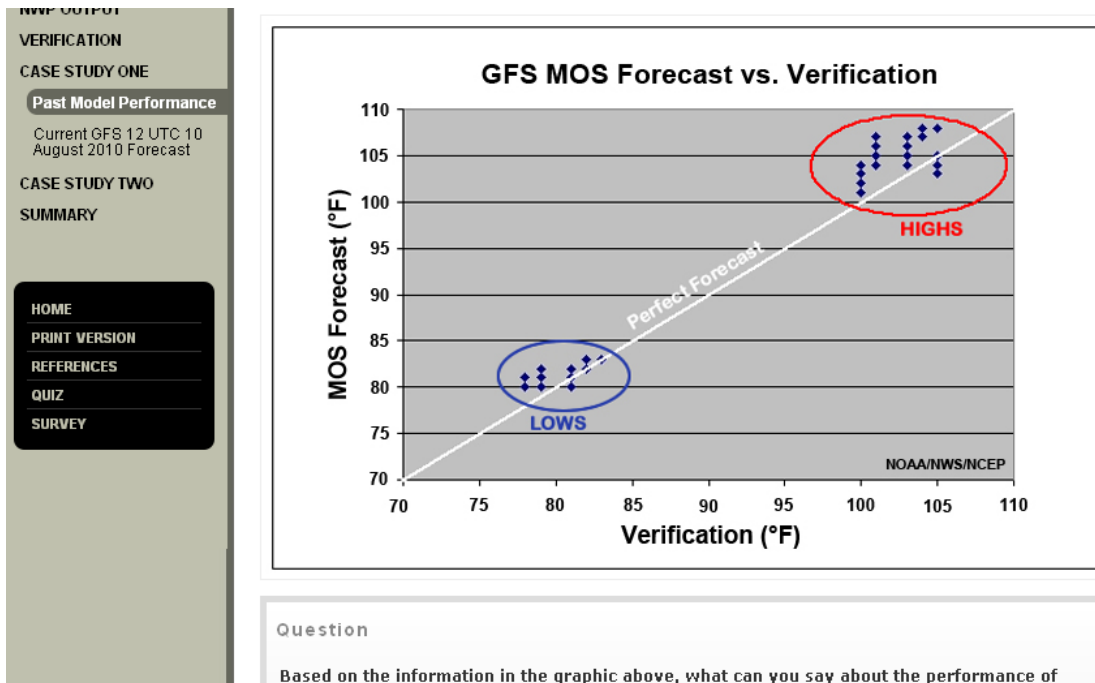


Figure 8. Sample page from Adding Value to NWP Guidance

6. COURSE 3

Course 3 will address how NWP can be put to good use, not blind or automated use, as a forecaster generates gridded products. Topics planned include addressing the time-honored forecast funnel approach to forecasting starting with larger scales and working down to smaller. The difficulty now is that the forecasters are focusing much of their efforts on the small end of the spectrum, while the small scale weather is driven by the larger scale conditions. Other topics include selecting the NWP-based sources for starting points for the grids or when a forecaster should start with the forecast from the previous shift instead of an NWP-based product. Another challenge is forecasting small scales at long lead times. There are some situations when certainty is high enough on the large scale that terrain-driven details, for example, are predictable. Gains made using local models also could be shared more widely and we plan to be working with some forecast offices who have had success.

7. COURSE 4

Course 4 will cover special topics, many of which are geographically limited, but forecasters in any place will find some topics highly pertinent to their challenges. The forecast problem will be presented and a forecast approach will be described using all different types of NWP models and products and observations. The lessons in this course will be immersed in forecast scenarios. Topics planned include convection, complex terrain, coastal environments, predicting excessive rainfall, and arctic environments.

8. COURSE 5

Beyond Courses 3 and 4, we intend to address emerging topics, some of which we can already anticipate. For example, AWIPS will be changing from receiving data pushed over NOAAport to pulling data from servers like NOMADS. Even under current bandwidth limitations, this will greatly increase the variety of NWP data which NWS forecasters will have access to, and they will need some guidance to make the most advantageous selections. Warn-on forecasts, sort of like a long-lead time warning or very detailed watch, will take advantage of high-resolution model forecasts or ensembles. The role of the human in (or over) the loop in the big NextGen aviation project will be crucial to success in what will be largely an automated model-driven system. Future forecasts will be not only for weather but also for various environmental hazards. Meanwhile, NWP data is increasing exponentially and the forecaster needs methods of assessing and making sense of it in real time.

9. ACKNOWLEDGEMENTS

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