J 3.7 A DESCRIPTION OF THE FORECAST SYSTEMS LABORATORY'S REAL-TIME VERIFICATION SYSTEM (RTVS)

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1. INTRODUCTION

The Forecast Systems Laboratory (FSL) is currently involved in a Federal Aviation Administration (FAA) sponsored project aimed at developing analyses and forecasts of state-of-the-atmosphere variables (SAVs) and aviation-impact variables (AIVs) from numerical models (Kraus1993). The Aviation Division of FSL created a Verification Program to evaluate the accuracy of SAVs and AIVs.

The Verification Program conducted two baseline verification exercises (Cairns et al. 1993; Cairns et al. 1994a; Cairns et al. 1994b; Mahoney et al. 1995; Mahoney et al. 1996b) which enabled FSL, the National Centers for Environmental Prediction (NCEP), and National Center for Atmospheric Research scientists to advance the development of models and AIV algorithms through statistical feedback from the verification analyses. However, four specific deficiencies were apparent from these first exercises: 1) output from different models and AIV algorithms were incomparable since the models were run over different time periods, 2) the verification time period was too short for statistically significant results, 3) results were delayed and extremely labor intensive to obtain since the exercises were retrospective and entire data assimilation and modeling systems were required to be rerun on saved data, and 4) model-based forecasts of AIVs could not be compared to National Weather Service (NWS) -issued AIV forecasts, since the NWS forecasts were never ingested or saved.

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Our objective for the development of the Real-Time Verification System (RTVS) is to address the deficiencies found in these previous studies, and to provide a forecast and monitoring tool for the NWS Aviation Weather Center. To this end, the RTVS was designed to ingest NWS-issued AIVs, model-based SAVs and AIVs, in "real-time" (i.e., as soon as they become available), and to store the relevant information in local, long-term storage. Since the NWS issues AIV forecasts on a continuous basis, and different models and AIV algorithms are run (at the NWS and FSL) on a continuous, side-by-side, real-time basis, the simple real-time ingest and local storage of the RTVS allow: 1) different models and AIV algorithms to be easily compared to each other and to NWS forecasts, 2) large sample sizes to be quickly gathered and exploited for statistically significant comparisons and long-term monitoring, and 3) "a quick-look" at, and comparisons of, the accuracy of forecasts valid at the current time.

In addition to the "real-time" capabilities, the RTVS also consists of extensive statistical and visualization capabilities. The combined capabilities stem from the development of six modules: the local data source, data preprocessing (DPP), quality control (QC), local data storage, statistical, and Interactive Verification Visualization System (IVVS) modules, These modules are interconnected and produce an easy-to-use, versatile verification system.

In this paper, we describe the concepts that form the basis of the RTVS, discuss the six modules that make up the RTVS, and present examples of the statistical plots that are available to the user.

2. OPERATIONAL CONCEPT

The RTVS is a real-time data ingest system that also provides user-defined visualization capabilities. Descriptions of the capabilities of the data ingest and the visualization system follow.

2.1 Real-Time Capabilities

The RTVS is a system that accesses and ingests model-based SAVs and AIVs, NWS forecasts, and observation data. It quality controls observation data, interpolates forecasts to observation locations, and archives the forecast/observation pairs in real time. These "real-time" processes are scheduled processes that run when both forecast data and verification observations are available to the system. The processes are transparent to the user and do not require user input.

2.2 Visualization Capabilities

In addition to its real-time capabilities, the RTVS allows users to interact with the data through a series of graphical user interface (GUI) menus. The menu structure allows access to and display of statistical data for any user-defined time period. This capability provides both an immediate and/or long-term view of the statistics.

The GUI allows the user to choose between objective and subjective verification. The objective verification component provides plots of statistical measures (such as probability of detection (POD), bias, etc.) describing the distribution of the data to the user.

The subjective component provides a visual display of forecasts with the verifying observations overlaid. This capability provides an alternate method for evaluating model and/or algorithm performance and will allow access to model-based grids on FSL's local storage system, which stores only 2 to 4 days of data at a time. However, implementation of a mass store system at FSL will greatly increase the number of saved grids available to the RTVS.

3. SYSTEM DESIGN

As previously described, the RTVS is a two-fold system: a real-time data ingest system, as well as a visualization and display system controlled by six computer modules. Each module performs a unique function, but relies on input from the other five. As shown in Fig. 1, observations and model grids enter the RTVS through the local data source module. The observations funnel through the QC module so that the data fields are fully checked for accuracy. From here, the quality controlled "good" observations and forecasts enter the DPP module for processing and interpolation. Selected data are stored in the local storage for access by the IVVS. Once the data are accessed by the IVVS, the statistics are computed "on the fly" for a user-defined time period and displayed through the IVVS. A complete description of the concepts and methods used in each of the modules is described in Mahoney et al. (1996a). The functions of each of the six modules are described in this section.

3.1 Local Data Source

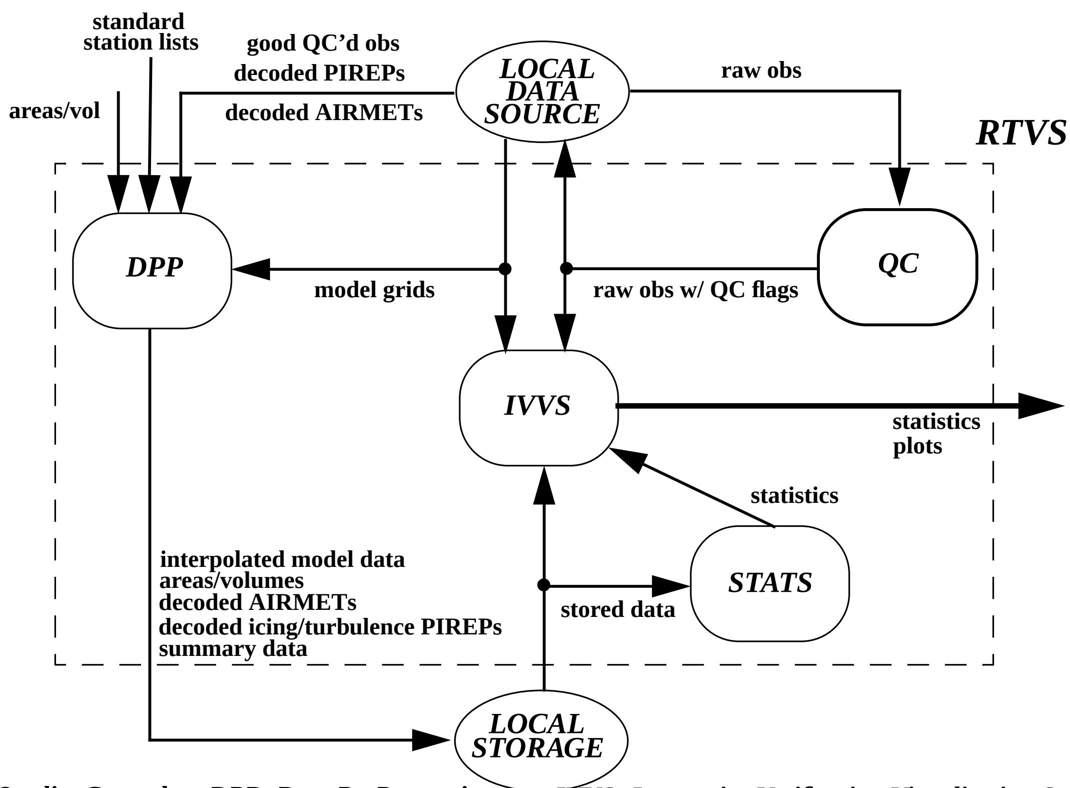
The local data source contains the model-based SAVs and AIVs, NWS forecasts and observation data accessed by the RTVS. For FSL, this location resides on the Networked Information Management client-Based User Service system (NIMBUS) (Pedigo et al. 1994; Wahl et al. 1997), an in-house local storage system developed and maintained by FSL's Facility Division. All gridded fields and observations are available on the NIMBUS system in real time and in netCDF format. Although, netCDF is the current ingest format utilized by the RTVS, other formats are possible and are being planned for. The current data sources accessed by the RTVS include: AIV data from NCEP's Eta and RUC models, such as icing and turbulence forecasts, voice pilot reports (PIREPs), and NWS-issued Airman's Meteorological Advisories (AIRMETs). Planned capabilities include access of: other NWS forecasts such as Significant Meteorological Advisories (SIGMETs), SAV data from the Eta and RUC models, precipitation, radiosonde, and profiler observations, as well as additional AIVs, such as cloud, ceiling, and visibility parameters.

3.2 DPP Module

The DPP module of the RTVS is designed to perform several preprocessing functions in real time that prepare the data for the statistical computations. Currently, these functions include: selection of the valid icing and turbulence PIREPs for verification, interpolation of the model-based AIVs and AIRMETs to PIREP locations, testing PIREPs to determine if they fall within an AIRMET, calculations of the summary data needed to compute the statistics, and computations of the icing, turbulence, and AIRMET areas and volumes. These processes are outlined in the flow diagram shown in Fig. 2. Archived data will become available to the RTVS with the implementation of FSL's Mass Store System (Brundage et al. 1997)

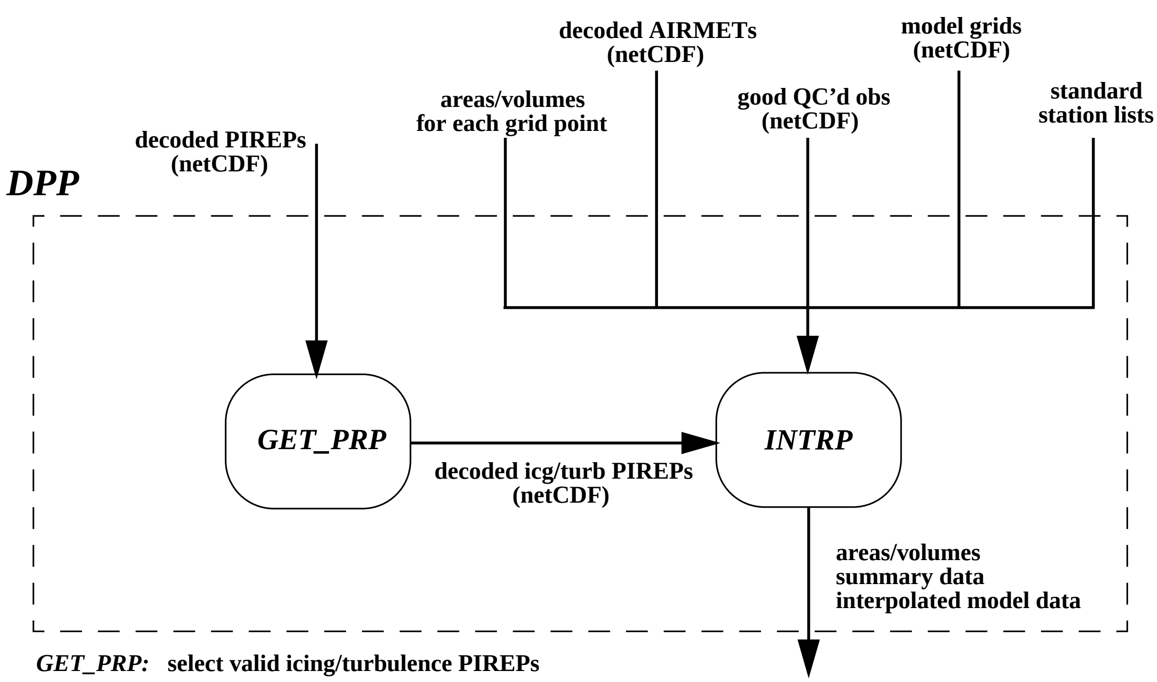
3.3 QC Module

Quality control of observation data is crucial for verification, since the observations are being used as "truth" and are assumed to be correct. Therefore, extensive QC procedures have been developed to check the accuracy of the data (Hartsough et al. 1997, in this vol-



QC: Quality Control ***DPP: Data PreProcessing*** ***IVVS: Interactive Verification Visualization System***

FIGURE 1. Flow diagram for RTVS. Dotted line are modules contained within the RTVS.



GET_PRP: **select valid icing/turbulence PIREPs**
INTRP: **interpolate model grids, score AIRMETs, calculate summary data, areas, volumes**

FIGURE 2. Flow diagram for DPP. Dotted line are modules contained within the DPP.

ume). The QC module is designed to check incoming observations and flag the observations that are found to be “bad.” For the objective verification of the model output, only observations that pass the QC procedures are used. On the subjective side of the RTVS, these observations are to be displayed by colored symbols indicating which procedures the observation failed to pass. This information will also help track stations that that consistently report “bad” data.

3.4 Local Storage

The summary data, interpolated forecasts, areas, volumes, and observations are archived indefinitely in the local storage. Currently, the local storage system for the RTVS comprises several 4 Gb disks. The RTVS users are responsible for their own disk storage, unless they prefer to access the RTVS from the “user’s” account. In that case, users can access local data storage provided by FSL’s Aviation Division.

The local storage consists of a tree of directories and subdirectories which organize the data. The data are stored by model, by variable, and by time. The organization of the directory trees allows easy access to the data through the IVVS menus. The datasets currently archived in local storage available to the RTVS are listed in the Table.

TABLE. Datasets archived in local storage

Dataset	Available Dates
Icing AIRMETs	Jan. 1996- Oct. 1996
Turbulence AIRMETs	Jan. 1996 - Oct. 1996
Icing AIRMETS -no amendments	Jan. 1996 - Oct. 1996
Turbulence AIRMETs - no amendment	Jan. 1996 - Oct. 1996
Eta Turbulence	Jan. 1996 - Oct. 1996
RUC Icing	Oct. 1995 - Oct. 1996
AWC Edited Icing	15 Apr. - 24 May 1996

3.5 Statistical Module

Once the user selects a time period and a statistical plot from the IVVS menu, the statistical module is activated and the statistics are computed on the fly. This allows for maximum flexibility of the system and simplifies the intricate local storage directory structure. The statistic module can accept summary data computed by other users, such as model developers, provided the data are written in RTVS defined formats. This allows the developers to easily compute, display, and compare output from many different models and algorithms.

Currently, statistics for POD*y*, POD*n*, areas, and volumes for Icing, Turbulence, and AIRMETs are available through the RTVS. The system is being developed to include Bias, Root Mean Square Error, and Mean Absolute Error for verification of surface and upper air SAVs and AIVs. Additional statistical measures will be added as they become necessary.

3.6 IVVS

The IVVS is the RTVS’ menu user interface designed to allow users to define, access, and display the statistical plots and/or subjective information. The IVVS is developed using the Interactive Data Language (IDL) software, which provides an efficient way to develop a user-friendly GUI. The IVVS consists of several main-menu and submenu boxes that allow users to specify their data. Fig. 3 shows the main RTVS objective menu where the user defines the data type, time period, geographic location, and statistical plots. The data can be stratified by model valid time, forecast time, or run time.

After choices are implemented through a series of “mouse” clicks, a statistical plot appears on the screen. In addition, a table of data values that make up the sta-

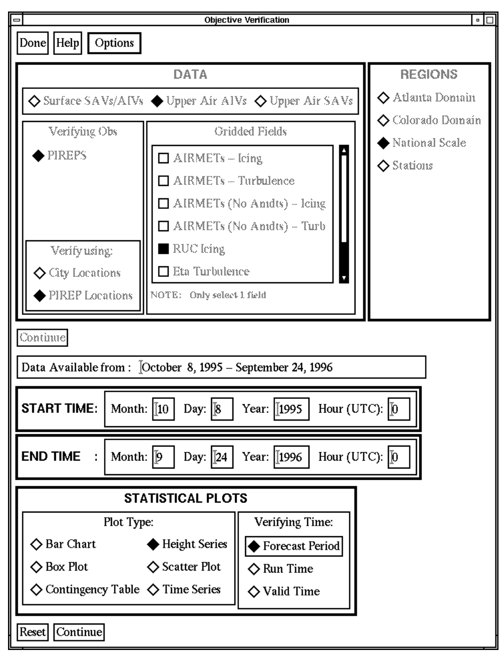


FIGURE 3. Main menu for the RTVS. Users define data type, time period and statistical plot.

tistical parameters can be requested through an “info” button available on the menus. Examples of the plots currently implemented on the RTVS are shown in Figs. 4-6.

Figure 4 shows a time series plot where a statistical measure (in this case, POD) is computed for each day and displayed over a period of time. Note that the graph

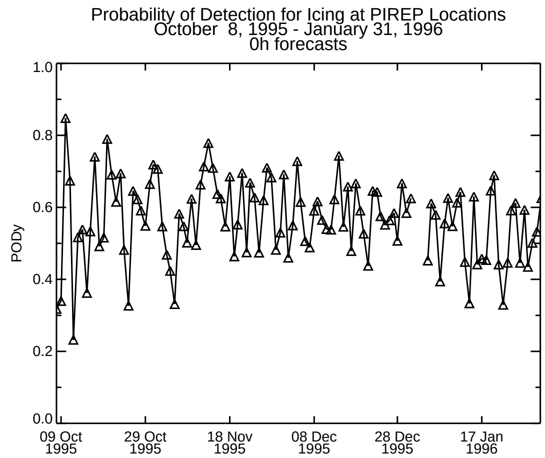


FIGURE 4. Time series plot of POD for icing.

shows only a subset of the years’ worth of data available for model-based forecasts of icing. The IVVS GUI allows the user to easily redefine the time period. The statistics are then quickly recomputed and displayed. This powerful feature allows the user to identify trends and seasonal dependencies in the data and to continually monitor the output. In addition to the daily statistics, the user may choose weekly or monthly accumulations of the particular statistic.

Figs. 5a and 5b show height series plots of turbulence at two different thresholds, another graphic available through the IVVS. This capability allows the developer to quickly compare statistics so that a turbulence threshold producing the best POD value can be determined. The scatterplot, shown in Fig. 6, is a another type of plot. This example displays POD values from icing AIRMETs computed from a single forecast as compared to the area the forecast covers. Forecasters can use this type of plot to make judgements about the accuracy of their forecasts relative to forecast area size.

4. SUMMARY

To summarize, the RTVS is a versatile system designed as a real-time data ingest system, as well as a visualization and display system. The real-time function of the RTVS is transparent to the user, while the

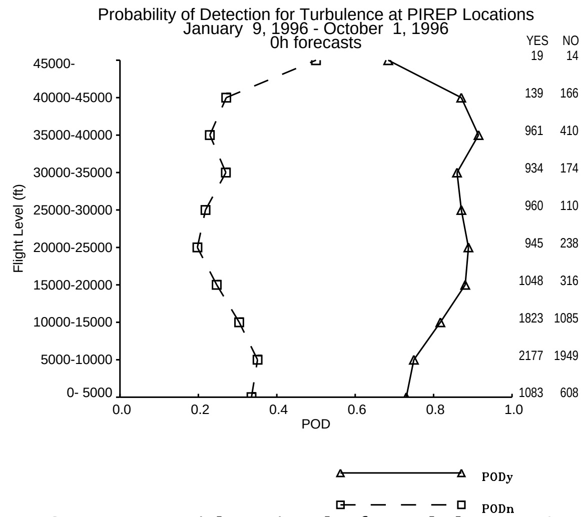


FIGURE 5a. Height series plot for turbulence at 0.5 m^2s^{-2} threshold. Solid line indicates PODy and dashed line is PODn. Height is in 3,000 ft intervals and number of PIREPs are listed along the right side of the figure.

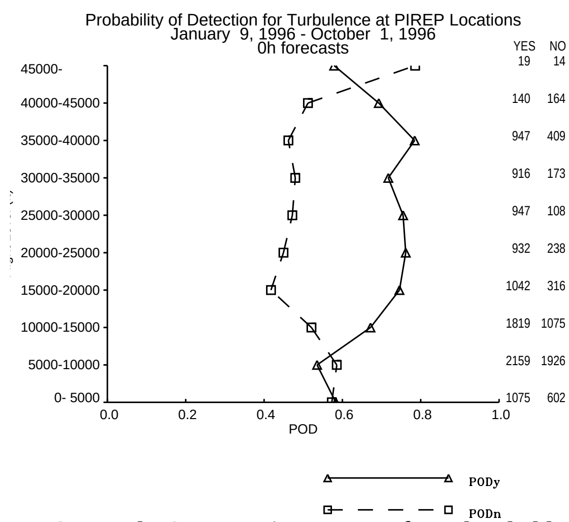


FIGURE 5b. Same as Fig. 5a except for a threshold of

visualization part allows the user to define statistical plots and time periods of interest. The RTVS comprises six modules that are uniquely developed, but work together to produce one easy-to-use verification system. The system is designed to be portable and also to allow outside users to access FSL’s RTVS version, thus enabling access to FSL’s local storage. It provides both development and forecasting verification capabilities.

Current on-line capabilities for the RTVS include: ingest and continuous verification of AIRMETs, RUC and Eta icing and turbulence algorithm grids, and many display features such as height series, time series, and

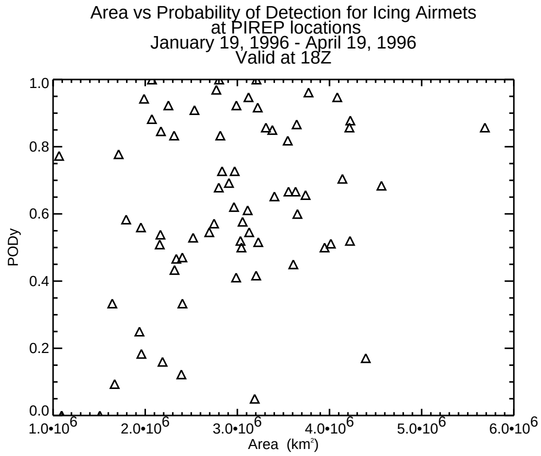


FIGURE 6. Scatterplot of PODy for icing AIRMETs with respect to the area of the AIRMET.

scatterplots. Off-line capabilities or functions not yet fully implemented on to the operational RTVS include: subjective verification such as forecast and verifying observation displays, QC of surface and profiler variables, and additional displays such as boxplots.

Future development includes; verification of SIGMETs and other NWS forecasts, surface and upper-air SAVs, precipitation, ceiling, and visibility. We will also implement the ability to limit statistical calculations to one of several geographic domains or individual stations. Additional IVVS capabilities include: contingency tables, bar charts, and boxplots.

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