P1.10 DEVELOPING TOOLS FOR CALIBRATING FOUR-DIMENSIONAL AVIATION WEATHER FORECASTS

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1. INTRODUCTION

The Federal Aviation Administration estimates that during an average 24-h period the United States air transportation system handles approximately 50,000 flights. This number is expected to double or even triple by the year 2025 (JPDO FAQs 2006). Aviation experts agree that the existing system is not capable of handling such an increase. A Joint Planning and Development Office (JPDO 2006) was commissioned in 2003 to begin the transformation of the air traffic management system. The Next Generation Air Transportation System (NextGen) will reorganize the National Airspace System to meet projected air traffic demands, while improving safety and reducing environmental impacts. NextGen will utilize existing technologies in combination with research and development into new areas, such as advanced weather forecasting techniques.

One critical requirement in NextGen is a Weather-Related Decision-Making capability. In order to provide this capability, a 4-dimensional weather Cube (4D Cube) consisting of real time weather information will be available to pilots, air traffic controllers, and forecasters alike through an efficient and secure data distribution (Souders et al. 2007). The data will improve the decision-making process, minimizing the adverse effects of weather conditions. The data elements associated with the 4D Cube are undecided, but will undoubtedly include a set of high resolution grids that define aviation weather parameters such as aircraft icing and turbulence.

Product Development Teams (PDT) at the National Center for Atmospheric Research have been developing predictive algorithms for aviation weather parameters. These algorithms use Numerical Weather Prediction (NWP) model output and aircraft observations to create digital guidance for each forecast projection on aircraft flight levels. This guidance is operationally available from the National Weather Service's (NWS) Aviation Weather Center. Although PDT post-processing algorithms have undergone continuous improvement over a number of years, it is generally agreed that due to inherent shortcomings within NWP models, value can be added to the guidance by experienced forecasters.

Current plans call for a "Meteorologist-in-the-Loop" (MITL) approach to couple forecaster experience along with the automated guidance. Adjustments include the compensation for known situational drawbacks within the NWP models, as well as "nudging" the digital forecast to reflect the latest available observations. The adjusted aviation guidance will be made available in a

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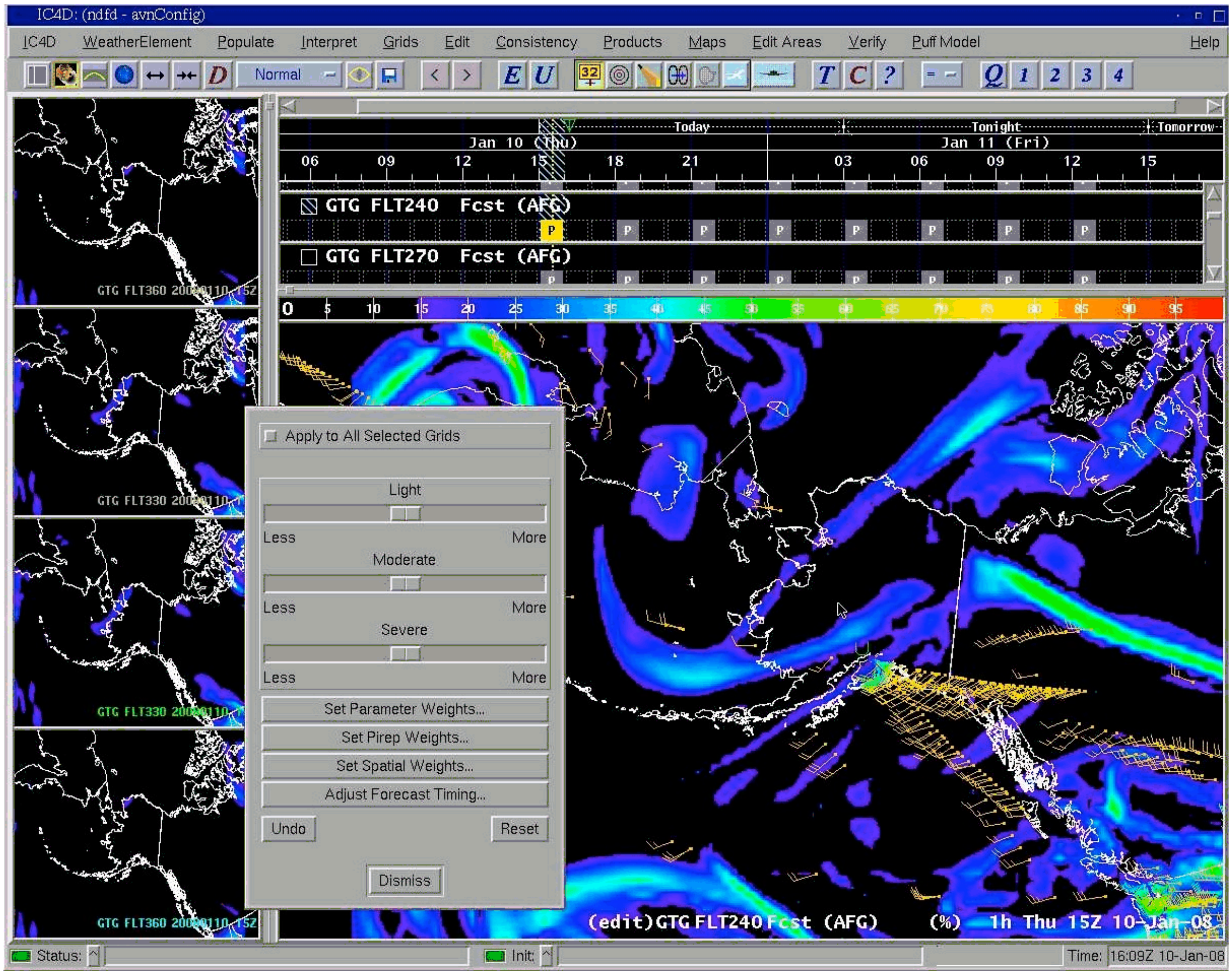


Figure 1: IC4D GUI showing slider bar interface for GTG over Alaska

standardized format that will support products for air traffic decision-assistance applications.

2. THE MITL PROTOTYPE

In early 2004, the NWS Meteorological Development Laboratory (MDL) was tasked with creating a software prototype to support the MITL process. An initial proof-of-concept version of the MITL software was developed based upon an existing package of applications currently implemented at NWS Weather Forecast Offices (WFOs). The WFO version of the software suite allows forecasters to edit a digital data set of sensible surface weather (Ruth 2002; Wier et al. 1998). MDL developers modified the software to adjust aviation weather elements in the vertical. The resultant software package is now called the Interactive Calibration in Four Dimensions (IC4D).

The IC4D encompasses a broad range of functionality, providing forecasters with a highly-configurable graphical user interface (GUI) through which they can display and make adjustments to the digital guidance (Fig. 1). Several display enhancements were added to the original WFO software. A four-panel sidebar display was created so that grids at multiple flight levels could be viewed simultaneously. Real-time aircraft observations, in the form of pilot reports (PIREPs) and Aircraft Communication Addressing and Reporting System (ACARS) observations can be displayed. A mouse-over feature for PIREPS can display the original observation data. Also available is a viewing mode that projects the data in a volumetric display (Fig. 2). Vertical cross-sections and sounding plots can also be viewed.

The software design allows the GUI to be independent of the processes which manage the flow of data through the system. A server process

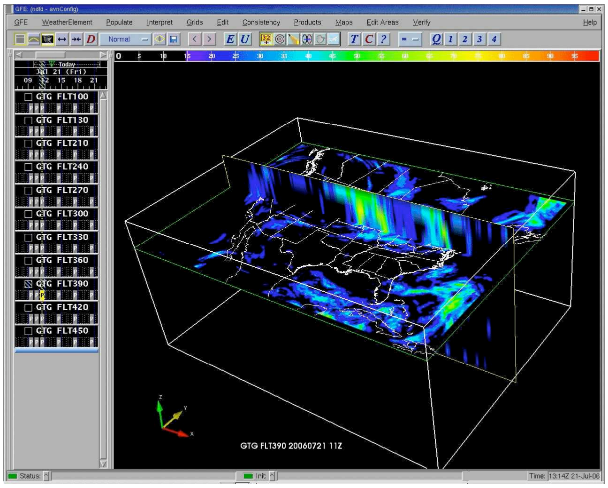


Figure 2: Volume display of turbulence in IC4D

handles the storage, retrieval, and purging of various types of data within IC4D. Model “databases” are created and populated upon receipt of the latest digital aviation guidance. After final calibrations are made to the grids, they are published to an official database. Grids in this database are ready to be disseminated to users and applications downstream of the MITL process.

As new NWP model guidance arrives, the IC4D automatically launches software to run post-processing algorithms and generate aviation parameter grids at aircraft flight levels. Icing and Turbulence output is based on the Rapid Update Cycle model for the conterminous U.S. and defined on a 20 kilometer mesh length grid. Icing guidance consists of both potential and severity fields. In addition, a potential field for supercooled liquid water droplets is generated. Statistical analysis and a fuzzy logic scheme are used to compute the likelihood and severity of icing at flight levels (Wolff et al. 2007; McDonough et al. 2004).

Graphical Turbulence Guidance (GTG) is computed as a severity field from individual NWP-derived indices, such as the Ellrod index. The GTG scheme incorporates PIREPs to gauge NWP-derived index performance (Sharman et al. 2004). Another turbulence parameter in the IC4D package is an algorithm to initialize guidance grids of mountain wave turbulence, computed using the MWAVE algorithm (McCann 1998).

MDL developers have worked with the PDTs to implement the most up to date versions of their software in the IC4D application package. One goal from this effort is to provide the PDTs with feedback from the MITL process to facilitate improvement in subsequent versions of their algorithms.

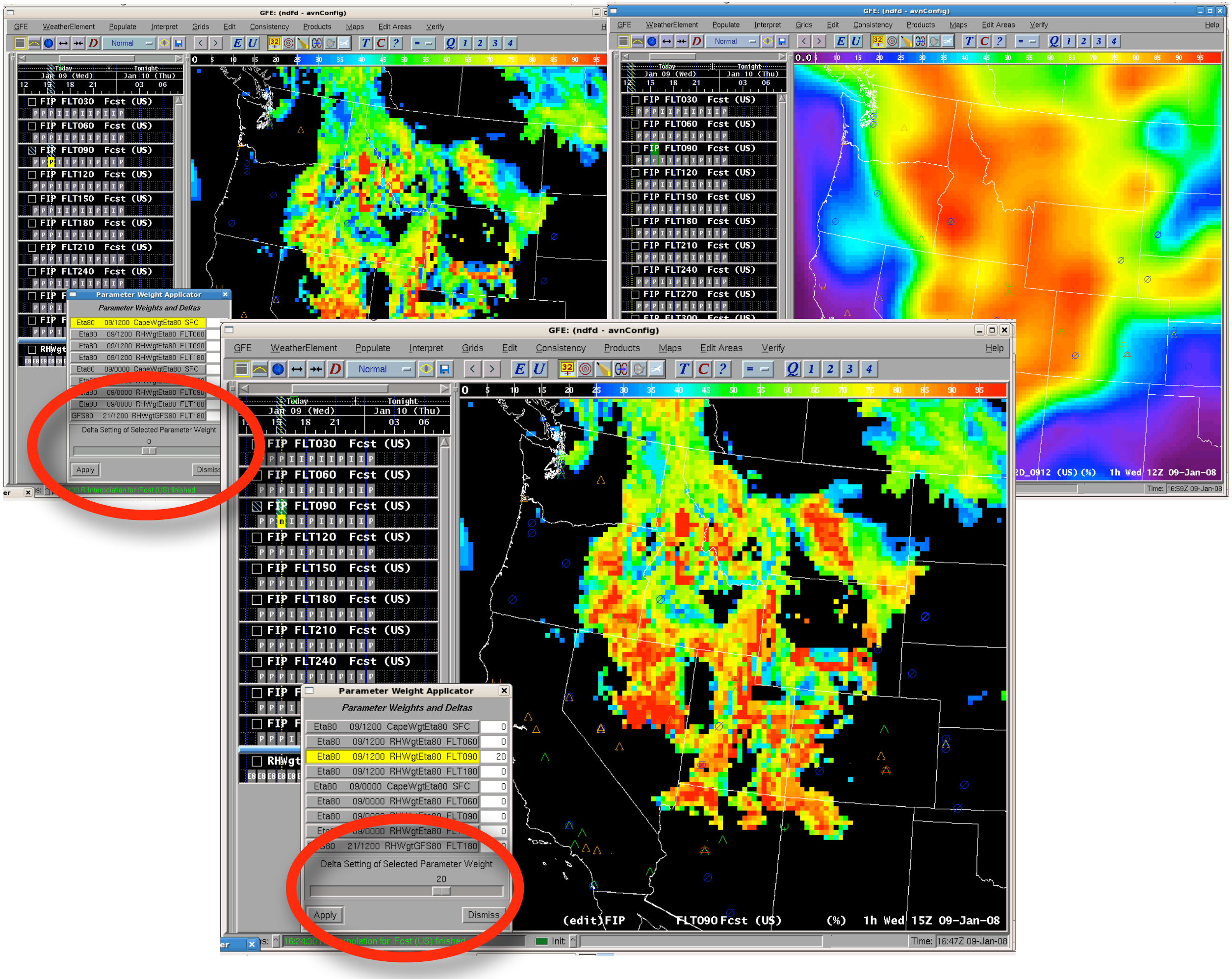
3. AVIATION PARAMETER ADJUSTMENT TECHNIQUES

The NextGen era presents a number of daunting challenges. The foremost of these is the ability to add value to the guidance without being overwhelmed by the avalanche of guidance and observations. MITL tools must give forecasters the ability to make adjustments quickly and in a consistent manner, as well as to prevent temporal and spatial discontinuities from being introduced into the final output. MDL pioneered model interpretation techniques for the Interactive Forecast Preparation System at WFOs in the 1990s (Boyer and Ruth 2002). These techniques were developed to allow the WFO forecasters to prepare an ever-increasing number of high-resolution grids in a limited amount of time. A forecaster with present-day grid editing tools at their disposal would find it nearly impossible to keep up with the rapid updates required by aviation users. Although the final Concept of Operations (CONOPS) for the MITL process has yet to be determined, it is likely that aviation forecasters will be working at regional or even national scales. Model interpretation tools lend themselves to making quick, consistent adjustments to grids at multiple times and across numerous flight levels.

The underlying premise for model interpretation is that a forecaster believes the automated guidance to be either very accurate or at least to closely reflect the projected weather situation. During the process of making adjustments, the underlying guidance is never modified. Rather, sets of instructions in the form of thresholds or weights, are modified interactively by the forecaster and the guidance grids are reinterpreted with the new instructions. The resultant changes on the grid are shown in the IC4D window. Instructions can be modified in any order and still produce the same output result. Typically a session would begin by populating selected times and flight levels with the latest automated guidance. Model interpretation changes are made as necessary according to how well the guidance reflects the current weather situation. When the forecaster is satisfied with the adjustments, the unmodified guidance and instructions can be saved to the working database. When grids are published to the official database the instructions are applied to the original guidance to produce the final output grids.

Model interpretation adjustments in the IC4D are implemented with a series of configurable slider bar GUI tools. Fig. 1 shows an example of categorical slider bars for turbulence forecasts. The slider bars can be repositioned to produce "More" or "Less" turbulence at those grid points that have values just above or below the threshold values for that category. If the slider bar for moderate turbulence is moved to the right ("More"), the lower bounding threshold value for that category is lowered and will have the effect of moving some grid points from the next lower category into the moderate. Threshold changes can be made to the forecast grid currently displayed, or to multiple grids simultaneously. Alternately, slider bar settings can be either copied or interpolated through time or vertically across multiple flight levels. This capability helps to prevent spatial and temporal discontinuities in the final output forecast.

Another interpretation technique is model parameter weighting. Parameter weights allow the forecaster to target guidance adjustments by linking them to forecasts of NWP model variables. For instance, Fig. 3 illustrates an area of icing potential in the western central portion of the United States. The top left grid is the unmodified guidance, while the grid on the top right is the ETA model guidance for relative humidity. By moving a slider bar, the forecaster can raise the potential for aircraft icing where relative humidity is also high. This result is shown in the bottom image in Fig 3. Higher weights are assigned to areas of the grid where the highest relative humidity values are predicted. The changes to the icing forecast will track with the NWP weight field through time and space.



Parameter Weight Applicator

Parameter Weights and Deltas

Eta80 09/1200 CapeWgtEta80 SFC	0
Eta80 09/1200 RHWgtEta80 FLT060	0
Eta80 09/1200 RHWgtEta80 FLT090	20
Eta80 09/1200 RHWgtEta80 FLT180	0
Eta80 09/0000 CapeWgtEta80 SFC	0
Eta80 09/0000 RHWgtEta80 FLT060	0
Eta80 09/0000 [illegible] FLT090	0
Eta[illegible] 09/0000 RHWgtEta80 FL[illegible]	0
[illegible]S80 21/1200 RHWgtGFS80 FLT180	[illegible]

Delta Setting of Selected Parameter Weight: 20

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Figure 3: Model parameter weighting for FIP using relative humidity from the ETA model

PIREP weights allow the forecaster to nudge guidance in the very short term towards recent aircraft observations. As observations are received, an IC4D application creates weight grids at each flight level, based on a pre-defined configuration that controls the spatial and temporal influence of a given PIREP. Slider bar tools nudge the forecast with this weight grid based on the severity of the PIREP. Reports of extreme or severe PIREPS that are less than 30 minutes old have the highest weight. A temporal decay factor is built into the weighting scheme to decrease the influence of an observation as it becomes older.

A temporal shift tool can be used to adjust the timing of events in the automated guidance. Spatial features can be accurately portrayed in cases where the guidance has them occurring too soon or too late in time. Temporal shifting of the guidance blends grids together from different valid times to produce the effect of slowing down or speeding up the model. As with other model interpretation techniques, the degree of blending and the number of hours to look forward or backwards in time are saved as instructions. The actual aviation guidance grids are not modified.

4. TESTING AND FUTURE WORK

MDL began an operational test and evaluation of the IC4D in September 2007 at the NWS Alaska Aviation Weather Unit (AAWU). In addition to working with the IC4D and providing feedback on the software to MDL, forecasters at the AAWU will be taking the first steps in defining a MITL operational concept for the 4D Cube. As a part of the installation of the IC4D at the AAWU, MDL added features unique to the Alaska region. One example (Fig. 4) is the capability to launch a volcanic ash dispersion model from the IC4D that generates grids of particulate concentration within vertical layers. These grids can be loaded for viewing and/or model interpretation adjustments.

One of the main goals of the test and evaluation period is to identify areas for improvement of the IC4D software. AAWU forecasters provide weekly feedback to MDL developers assist in the effort and also make requests for new functionality and data. Planned improvements currently include an upgrade to the latest version of the GTG (v2.4) algorithm, improve model interpretation techniques and tools, and plots of current aircraft positions on the display. The AAWU is beginning a verification analysis project to assess performance of the digital forecasts as well as the MITL overall concept.

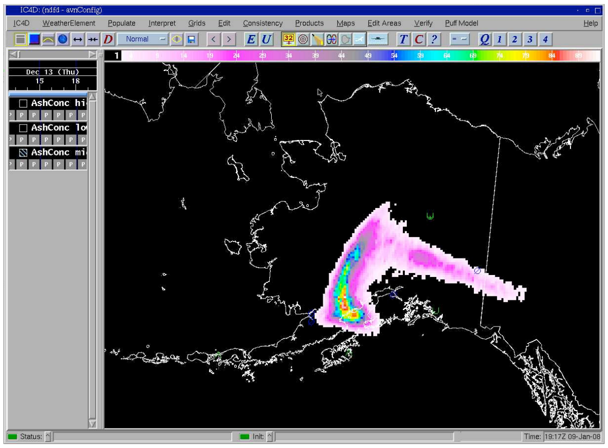

Figure 4: Ash concentration from the Puff model

The IC4D test in Alaska has shown that the software is relatively easy to use and is now assisting forecasters in their operations. The AAWU has plans for generating automated products from the adjusted 4D grids. If successful, the test will show whether and in what ways forecasters can improve the automated guidance. The test will also demonstrate how the 4D Cube can be populated with high-resolution digital aviation forecasts. Thus, one important step will have been taken towards fulfilling the NextGen goal of a more efficient National Airspace System.

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