

## 5.3

# INTERACTIVE FORECAST VISUALIZATION TOOLS FOR THE U.S. ARMED FORCES

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## 1. INTRODUCTION

Headquarters, Air Force Weather Agency (AFWA) at Offutt Air Force Base, Nebraska, declared the Mesoscale Model, Version 5 (MM5) (Chen et al. 2001a; Chen et al. 2001b; Barker 2004) operational on 28 October 1997. This achievement marked the initial operational capability of the Global Theater Weather Analysis and Prediction System (GTWAPS) program. AFWA currently runs the MM5 for seventeen 45 km theaters, eight 15 km nested theaters, and several 5 km nested theaters, dependent upon operational requirements for the Department of Defense (Figure 1). This provides coverage over 98 percent of the world's landmasses. The MM5 is scheduled to transition to the Weather Research and Forecast (WRF) model during 2005.

With the fielding of AFWA's MM5 production line, a huge suite of visualizations was staged for the US Air Force's Joint Air Force & Army Weather Information Network (JAAWIN) (<https://weather.afwa.af.mil>). Over 250,000 visualizations were created every 24 hours, using both Vis5D (from the University of Wisconsin-Madison Space Science and Engineering Center) and the Center for Ocean-Land-Atmosphere Studies' (COLA) Grid Analysis and Display System (GrADS) software visualization tools.

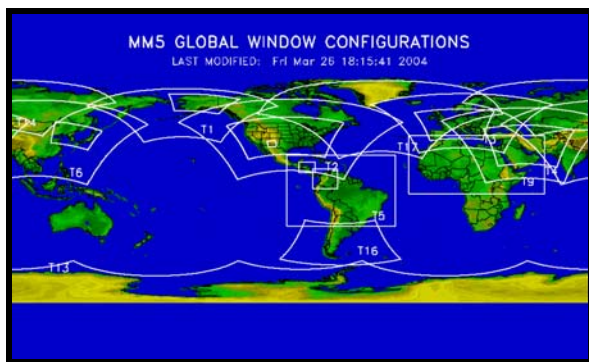


Figure 1. Recent AFWA MM5 theater configuration (March 2004).

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Forecast maps on JAAWIN were grouped in nine separate categories: core, clouds, winds, temperature, contrails, hazards, precipitation, severe weather, and miscellaneous (Figures 2 and 3).

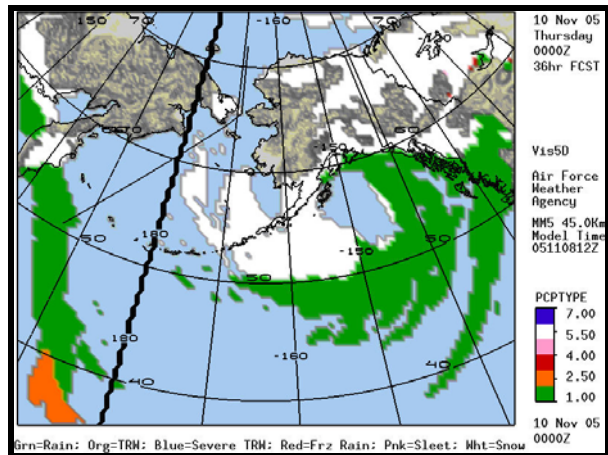


Figure 2. Sample AFWA Vis5D visualization.

In addition, roughly 2,400 meteograms were pre-staged (built with GrADS) based upon AFWA's MM5 and the National Center for Environmental Prediction's (NCEP) Medium Range Forecast (MRF) model, which is now known as the Global Forecast System (GFS) model.

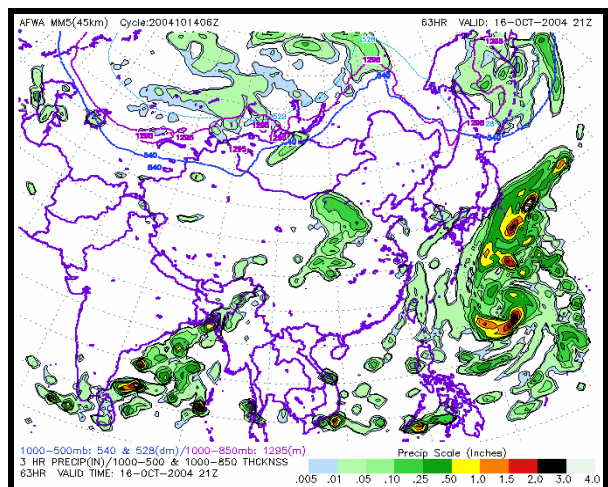


Figure 3. Sample AFWA GrADS visualization.

However, it became apparent that many of the pre-staged forecast charts were not being used frequently enough to warrant the significant associated resource requirements. Consequently, AFWA found it prudent to pre-stage a smaller core product line while still enabling the creation of needed specialized products through the use of an interactive tool, which saved large amounts of mainframe processing resources.

## 2. THE GROWTH OF IGrADS

Customers were clamoring for many new products including capabilities to create vertical cross sections, forecast maps, user-defined meteograms, and numerous alphanumeric products. Therefore, the Visualization Team in AFWA's Technology Exploitation Branch responded by expanding the IMAST capabilities into a new tool that AFWA named Interactive GrADS, or IGrADS. The IGrADS product line has steadily grown so that, at present, it includes the following capabilities (note that all references or capabilities ascribed to MM5 and Eta are scheduled to transition to WRF during 2005):

### 2.1 Map displays (within the GUI) provided by IGrADS:

- World Map centered on Prime Meridian
- World Map centered on International Dateline
- All MM5 theater maps
- United Kingdom Meteorological Office (UKMO) Middle East domain
- Continental United States (CONUS) Eta domain
- Coupled Ocean/Atmospheric Mesoscale Prediction System (COAMPS) domain

### 2.2 Meteorological model output available through IGrADS:

- AFWA MM5
- AFWA Diagnostic Cloud Forecast (DCF) Algorithm (Eylander and Evans 2003; Norquist 2000)
- AFWA Advection Cloud Model
- NCEP GFS
- NCEP Eta
- US Navy NOGAPS
- US Navy COAMPS
- UKMO Middle East Theater
- AFWA Stochastic Cloud Forecasts
- AFWA Worldwide Merged Cloud Analysis

### 2.3 Products offered by IGrADS:

- Meteograms (MM5, Advection Cloud, GFS, Eta, NOGAPS, COAMPS, and UKMO)
- MM5 Army low-level meteograms
- MM5 severe weather meteogram
- GFS (0 to 180 hour and 192-384 hour) meteograms
- GFS and NOGAPS stratospheric meteograms
- User defined meteograms
- Forecast skew-Ts
- Vertical cross-sections
- Multiple leg cross-sections
- Forecast maps (color filled, contoured, both)

- Four-Panel Forecast Maps
- Alphanumeric output products

### 2.4 Alphanumeric output products offered by IGrADS:

- MM5-based
  - Forecast vertical profile
  - "FOUS" bulletin (similar to Eta and NGM output from NCEP)
  - RAOB bulletin
  - Precision airdrop wind profile
  - Chemical downwind message
  - Basic wind message
  - Field artillery forecast
  - Effective downwind message
- GFS-based
  - "FOUS" bulletin (0 to 180 hours at 3 hour intervals)
  - RAOB bulletin
  - Precision airdrop wind profile
  - Chemical downwind message
  - Basic wind message
  - Effective downwind message
- COAMPS-based
  - Basic wind message

Since its initial implementation on the unclassified version of JAAWIN in February 2002, hits on IGrADS have grown to nearly 90,000 per month (statistics courtesy of Mr. Kenneth Smith, HQ AFWA). This statistic reflects numbers of first time entry into IGrADS, not the total number of products generated, which is actually many times larger. IGrADS currently ranks as the tenth most frequently accessed product on JAAWIN. (IGrADS also is available on classified versions of JAAWIN.) Furthermore, the capability for forecasters to make charts tailored to their needs enabled AFWA to reduce the huge amount of pre-staged forecast charts by 25 percent, or from nearly 250,000 charts to 185,000 charts each day.

## 3. IGrADS INTERFACE / PRODUCTS

Access to IGrADS on the unclassified Internet is obtained at the URL within JAAWIN, <https://weather.afwa.af.mil/igrads.html>. This is a password-protected site except from ".mil" accounts. Those working from ".gov" accounts can obtain access to JAAWIN by applying for an account on-line. The opening GUI for IGrADS contains a map for the desired domain (opening default is to a world map) with selection boxes for product, model, image size, location, forecast hour, ICAO designator, and a lookup ICAO search tool. Selection options vary depending on the product selected and the model chosen. In addition, IGrADS allows the user to bookmark frequently needed products and thereby avoid going through the GUI altogether. Many customers find this to be a time-saving technique.

### 3.1 Meteograms



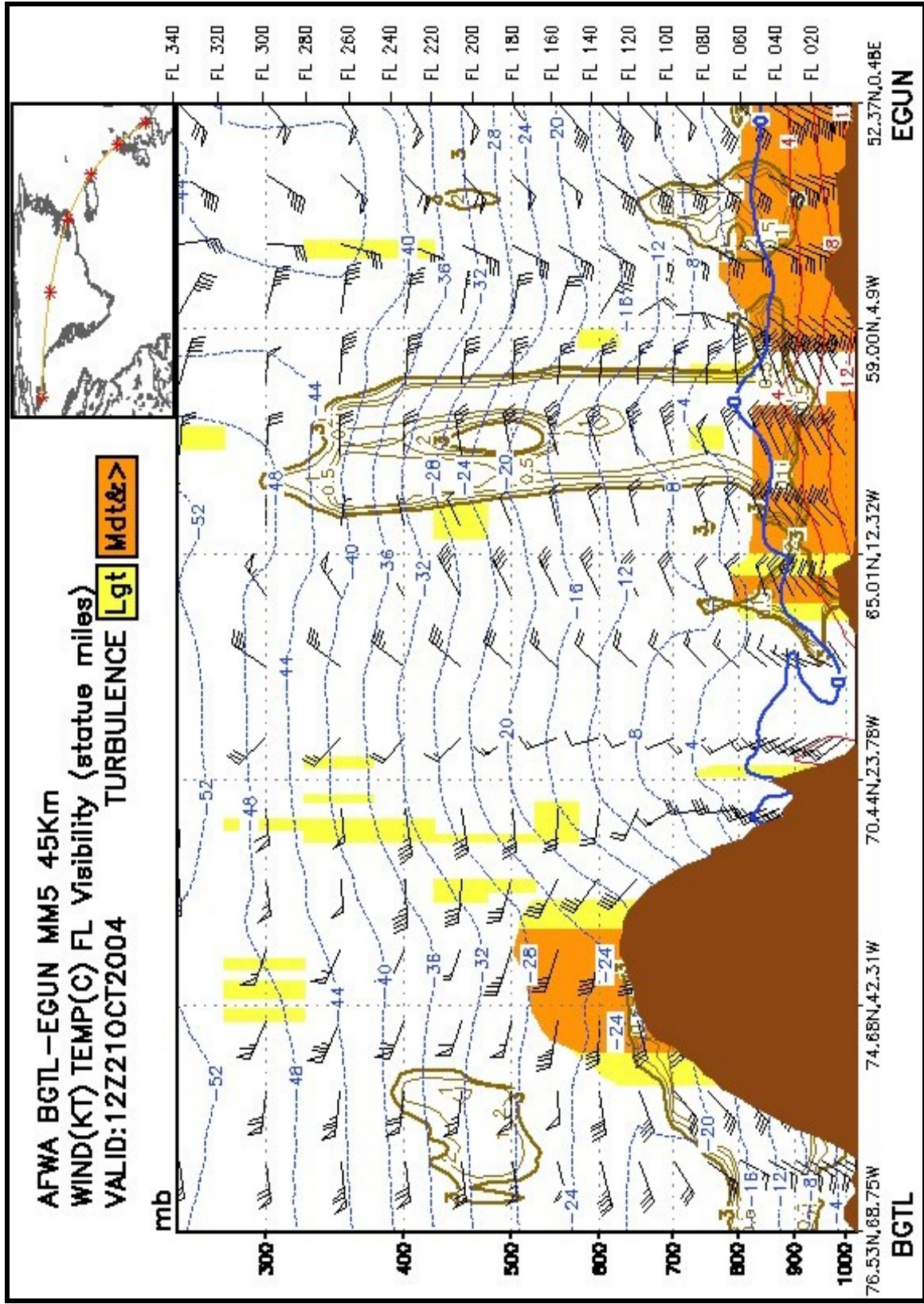


Figure 5. MM5 45 km vertical cross-section from Thule AB to Milledhall AB with brown contours showing forecast flight level visibilities of 3 miles or less. Also shown are forecast wind barbs, temperatures, and turbulence.

The meteogram was previously shown at the 2005 Annual Meeting, as it was available in IMAST. The user-defined IGrADS meteogram (Figure 4) allows the customer to pick among fourteen sets of graphs instead of being limited to the standard five graphs that appear below the time-height cross-section graph at the top of the product. The user also has the option of adding turbulence, icing, potential temperature, and vertical velocity fields to, or in place of, the default temperature, relative humidity, cloud, and wind fields. For example, a user-defined meteogram can have aircraft icing in the time-height cross-section, followed by pressure tendency, temperature, wind, and precipitation amount/type in the accompanying graphs.

### 3.2 Vertical cross-sections

Vertical cross-sections are currently available for the MM5, GFS, Eta, NOGAPS, COAMPS, and UKMO models. This product provides a point in time vertical cross-section between two points within the domain of the model (Figure 9). In addition, the user can choose the layer of the atmosphere to display, from the surface to the top of the model. The forecaster can also choose to display isotherms, isentrops, wind barbs, relative humidity, icing (MM5), turbulence (MM5), and clouds. By choosing more than one valid time, IGrADS will create a Java slideshow that will loop through the selected forecast hours. The visualization includes model surface terrain, the endpoints, with ICAOs (if provided by the requestor), and four intermediate points. An inset map in the upper right portion shows the cross-section route highlighting the path's intermediate points with red asterisks.

A new capability allows the user to display visibility

by making use of an algorithm developed by Stoelinga and Warner (1999) on a vertical cross section (Figure 5). This capability is of great potential value for planning military air refueling operations.

Several Air Force weather stations have reported that they give aircrews a vertical cross-section print out as part of the pre-takeoff briefing. They also report very favorable feedback from aircrews about the product and instances where pilots have asked for the vertical cross section product when it was not offered to them. (E-mail feedback from Mr. Phil Eddy, Thule AB, Greenland.)

### 3.3 Multiple leg vertical cross-sections

The multiple leg cross-section is similar to the vertical cross-section with two enhanced capabilities. Specifically, three terminals (or ICAOs) can be selected and a different valid time chosen for each leg of the cross section. The same set of models and parameters are available for this product (Figure 6).

### 3.4 Forecast maps

On IGrADS, forecast maps allow for display of four parameters, one color filled and three as "contour line" fields. The user can determine the maximum and minimum value for each parameter as well as the interval, the contour color, and line thickness (or wind barb density). Output from seven models (AFWA MM5, AFWA MM5 DCF algorithm, GFS, Eta, NOGAPS, COAMPS, and UKMO) can be visualized. All the model output Grib parameters are available to choose from and with the large number of permutations of models and parameters, literally hundreds of millions of

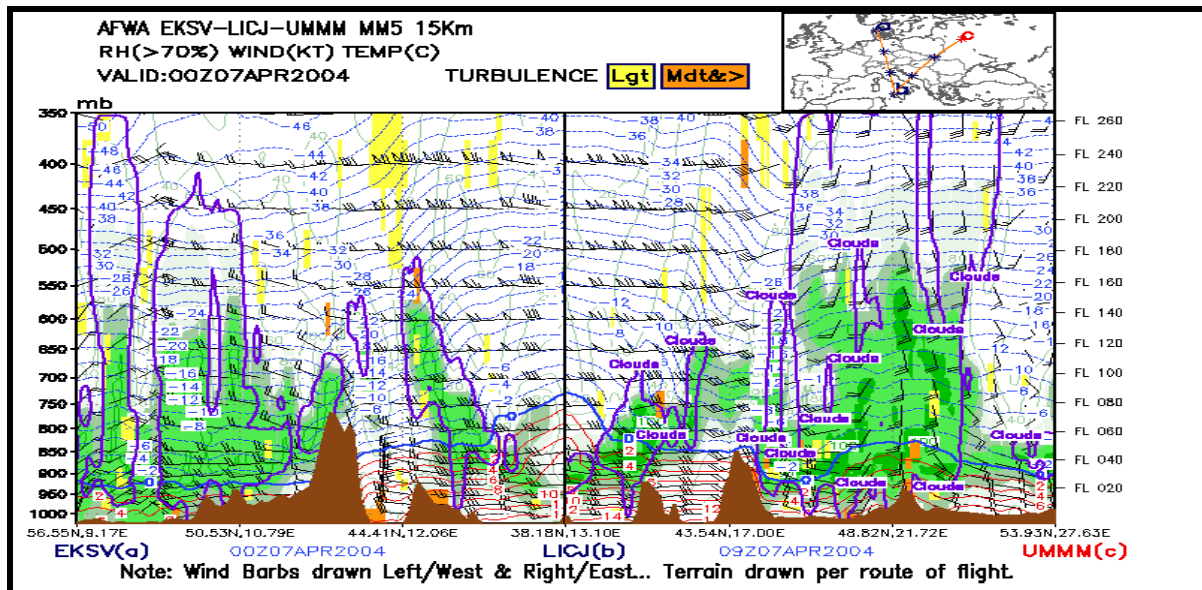
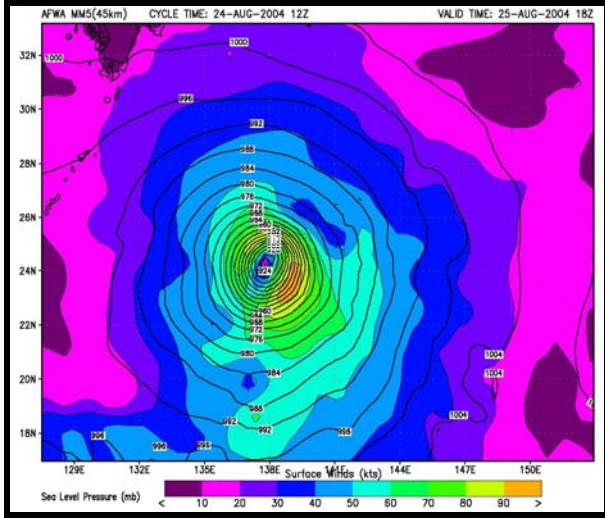
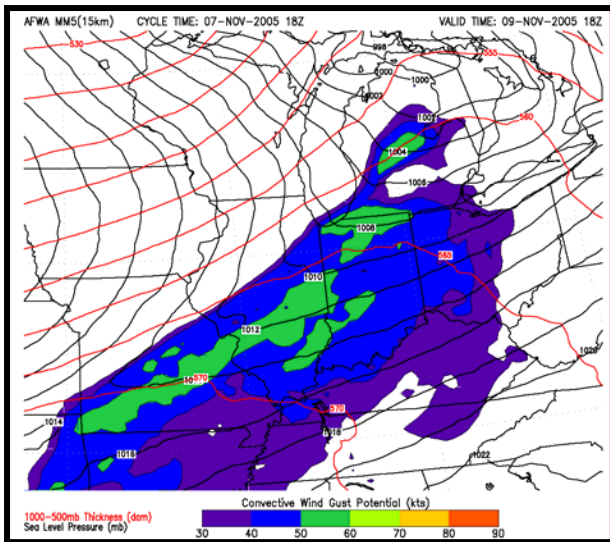


Figure 6. Multi Leg Vertical Cross-Section; Skive, Denmark to Palermo, Italy to Minsk, Belarus, MM5 15 km resolution.



**Figure 7.** Super Typhoon Chaba (30 hr forecast valid 25 Aug 04/1200Z), South of Japan with Sea Level Pressure (black), and surface winds (knots) (color-filled).

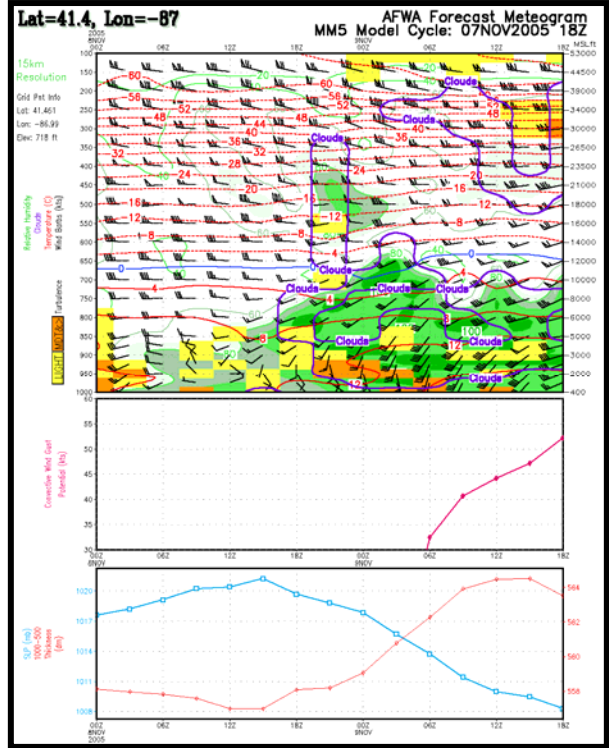


**Figure 8.** Convective wind gust potential, sea level pressure, 1000-500 mb-thickness, AFWA MM5 (15 km).

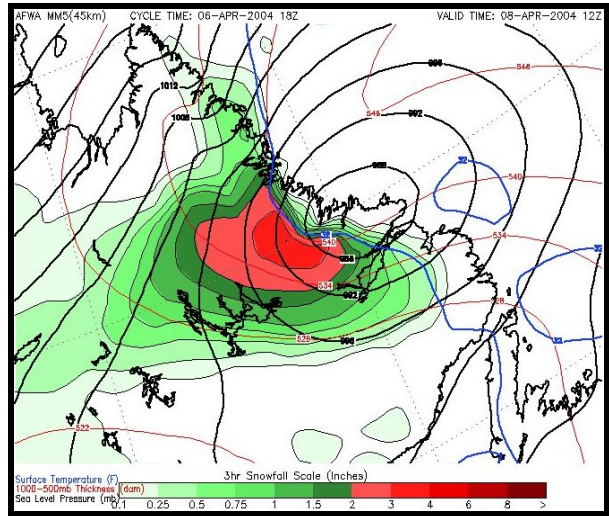
different forecast maps can be created to fit the forecasters' specific needs. Furthermore, the maps can default to display the entire theater, or the forecaster can draw a rectangle within the theater (or enter pairs of coordinates) to define the desired map (Figures 7-12).

### 3.5 Four-Panel Forecast Maps

This function allows customers to create pre-configured four-panel charts that are reminiscent of model output facsimile charts from that era. Presently, there are five types of four-panel charts that forecasters can select:



**Figure 9.** User-defined meteogram for northwest Indiana showing convective wind gust potential as per Figure 13, AFWA MM5 (15 km).



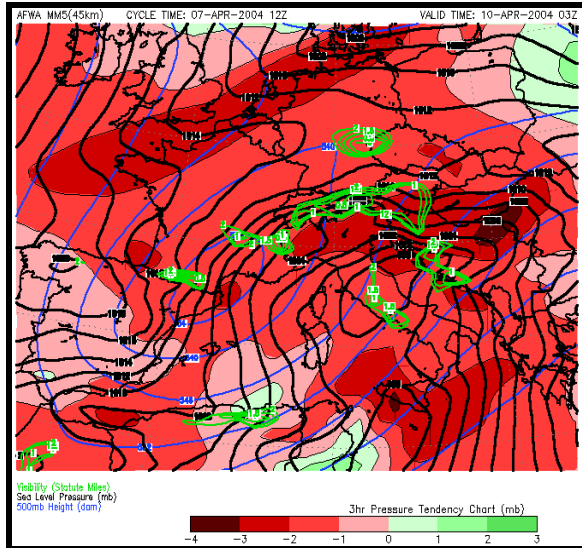
**Figure 10.** Three-hour snowfall accumulation (color filled), sea level pressure (black), 1000-500 mb thickness (red), and surface freezing line (blue), AFWA MM5 (45 km).

- Standard forecast: (1) 500-mb heights, winds, and relative vorticity; (2) 700-mb heights, relative humidity, and vertical velocity; (3) Sea level pressure, 1000-500 mb thickness, and three-hour

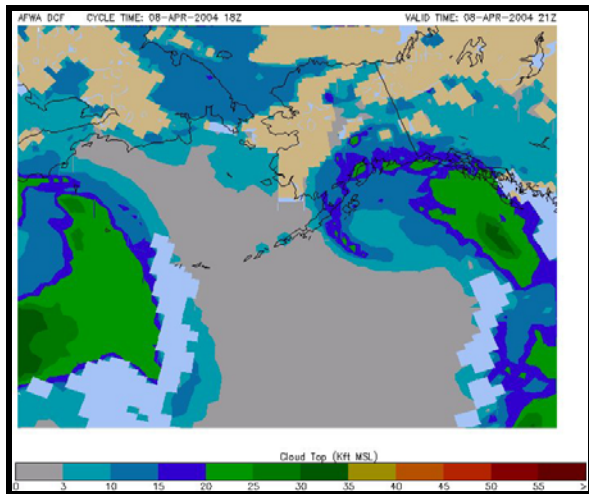
accumulated precipitation; and (4) 825-mb heights, wind barbs, and relative humidity.

- Severe Weather #1: (1) Total totals; (2) SWEAT Index; (3) K-Index; and (4) CAPE.

- Severe Weather #2: (1) Best Lifted Index; (2) Energy Helicity Index; (3) Potential hail size; and (4) Convective inhibition.



**Figure 11.** Three-hour pressure tendency (color filled), sea level pressure (black), 500-mb heights (blue), and surface visibility <= 2 miles (green), AFWA MM5 (45 km).



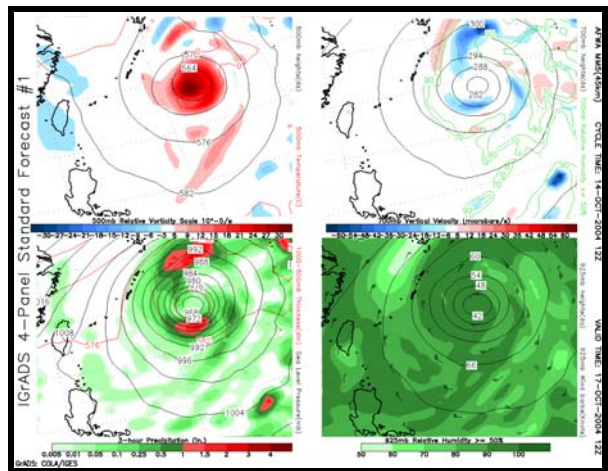
**Figure 12.** Diagnostic cloud forecast cloud top product, AFWA MM5 (45 km).

- Aviation Takeoff/Landing: (1) Surface winds (barbs/colorized velocity); (2) Low level turbulence (surface to 4,500 feet AGL); (3) Three-hour accumulated precipitation, surface freezing contour,

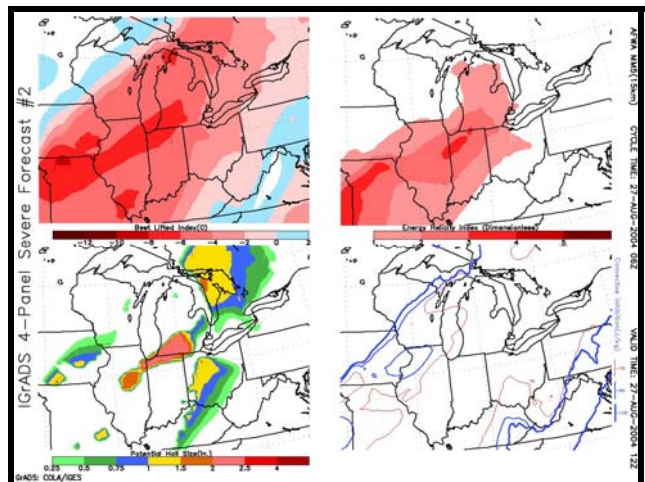
and 1000-500-mb 540-dm contour; and (4) Surface visibility.

- Winter weather: (1) 1000-500-mb thickness, 700-mb wind barbs, and three-hour accumulated precipitation; (2) 1000-850-mb thickness, 925-mb wind barbs, and three-hour accumulated snowfall; (3) Equivalent wind chill temperature, surface wind barbs, and surface visibility, and (4) Surface temperature and color filled surface weather threats (heavy rain, snow, freezing precipitation, strong winds, and severe thunderstorms).

Samples of the four-panel forecast maps appear in Figure 13, 14, and 15.



**Figure 13.** Four-panel "standard forecast" charts depicting Typhoon Tokage at 500-mb, 700-mb, surface, and 925-mb (forecasts valid 17 Oct 04/1200Z), AFWA MM5 (45 km).



**Figure 14.** Four-panel "severe weather forecast #2" charts depicting best lifted index, energy helicity index, potential hail size, and convective inhibition (forecasts valid 27 Aug 04/1200Z), AFWA MM5 (15 km).

### 3.6 Alphanumeric output

Many IGrADS customers shared desires and requirements for alphanumeric meteorological model

output in both existing and newly devised formats. The most significant advantage that IGrADS provides is that the user can specify the location and valid time and not

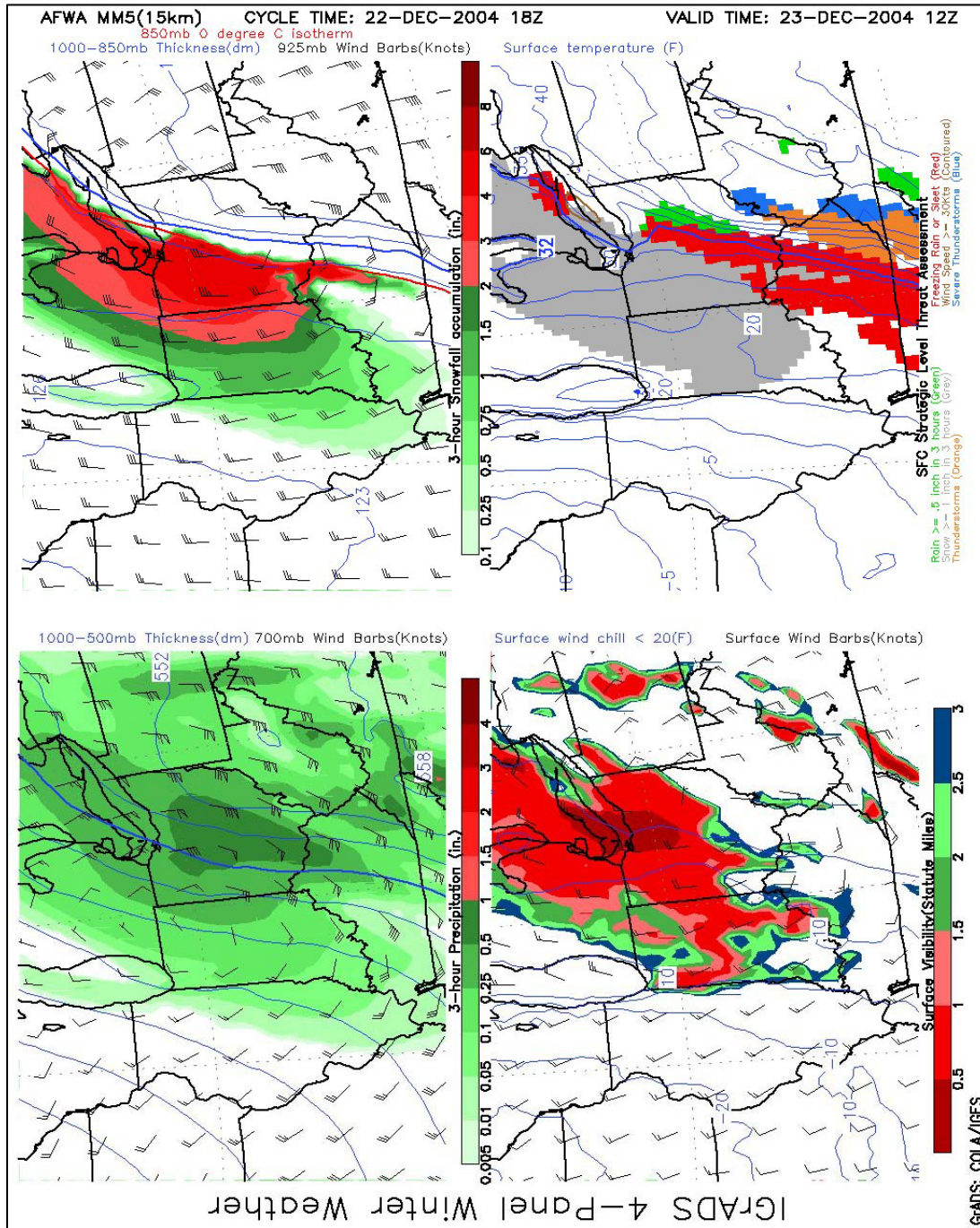


Figure 15. Four-panel "winter weather" charts depicting three-hour accumulated precipitation, 3-hour accumulated snowfall, surface visibility, and surface temperature (forecasts valid 23 Dec 04/1200Z), AFWA MM5 (15 km).



```

38.75N 141.35E
OUTPUT FROM MM5 15KM 06Z Oct 20 04
TTPTTR1R2R3 VVLI PSDDFF HHT1T2T3W CIGVIS
/////999999 18503 990216 68151413 009010
09213969898 38301 910328 73171616R 012028
12135949999 49798 870330 71151615X 006040
15071859398 15103 830133 69151213T 021116
18049848792 11910 903223 62141109R 060083
21007778388 11508 963122 57141108R 044124
24000616771 04404 023015 57161109 ---124
27000625446 -1509 072812 59151109 ---124
30000726951 01910 112809 58131010 ---120
33000869185 -0906 132607 57131008 ---054
36000858177 00306 142409 56141008 ---044
39000889799 05804 151810 55141109 021047
42000839192 -3903 151910 53151210 026098
45000828177 -3602 131813 53151211 069098
48025939596 08300 132010 52141109R 026034

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Model output parameters are based on the 15KM MM5 model.

Bulletin data derived from model Grid Point 38.667N and 141.256E

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TT      # hours past models 00hr; e.g., 03 would be the 3-hour forecast
        from MM5 analysis
PTT     Quantitative precipitation forecast in format x.xx inches. 024
        is 0.24 inches; 123 is 1.23 inches
R1      Relative humidity at 500 ft AGL (100 shown as 99)
R2      Relative humidity at 2000 ft AGL (100 shown as 99)
R3      Relative humidity at 3000 ft AGL (100 shown as 99)
VVV     Vertical velocity at 700 MB in tenths of microbars per second.
        029 is 2.9 microbars per sec. Positive values denote rising
        air; Negative values denote sinking air
LI      Lifted index. Negative values are denoted by "9s"; e.g., 97
        is a LI of -3
PS      Sea Level pressure in millibars. 28 would be 1028mb; 94 would
        be 994mb
DDFF    Wind speed (knots) and direction. 3325 would be winds from 330
        degrees at 25kts
HH      1000-500mb thickness in meters. 52 would be 5520m; 40 would be
        5400m
T1      Temperature in degrees C at 500 ft AGL. Negative values are
        subtracted from 100; e.g. 92 would be -8C
T2      Temperature at 2000 ft AGL
T3      Temperature at 3000 ft AGL
WX      Present weather (prototype capability includes rain (R), snow
        (S), ice pellets (P), freezing rain (Z), thunderstorms (T) and
        severe thunderstorms (X)) Note: This element is not displayed
        for the initial forecast hour.
CIG     Ceiling in hundreds of feet; e.g., 003 is 300 feet; 030 is 3000
        feet, and 100 is 10000 feet.
VIS     Visibility in tenths of statute miles (SM); e.g., 005 is 1/2 SM;
        030 is 3 SM and 100 is 10 SM.

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Figure 16. MM5 FOUS bulletin for Bangor ME. The legend for decoding the bulletin is attached to each product.

be tied to existing pre-staged bulletins. For example, upon customer request, IGrADS will create two products similar to NCEP's Eta and NGM FOUS bulletins. These text products are based upon AFWA's MM5 and NCEP's GFS and can be built for any ICAO or location within the model's domain (world-wide for the GFS) (Figure 16). In creating the bulletins through IGrADS, the software accesses the nearest neighbor gridpoint (in GrADS coordinate space) to the requested location. In addition to the elements typically found in the NCEP bulletins, the FOUS product also has columns for precipitation type, ceiling, and visibility. Instead of relying on existing ICAO locations, the capability to create these products for any desired point within the domain of the model has directly addressed customer requests.

Other alphanumeric products include a forecast RAOB bulletin, a precision airdrop wind profile, and chemical downwind messages (for hazardous releases). AFWA recently added a product tailored specifically for U.S. Army field artillery use, which has resulted in significant reductions of artillery range errors (Mitchell 2003). In fact, range errors decreased by as much as 195 m resulting in substantially more accurate targeting (Mitchell 2003). This product provides temperature, wind, and pressure information in the precise format that Army field artillery is trained to use. Furthermore, the US Army is in the process of incorporating the use of IGrADS into the formal training and doctrine for their field artillery forces. The high resolution and near world-wide land coverage provided by AFWA's MM5 combine to make it a perfect match for both the U.S. Army's and U.S. Air Force's mission requirements.

#### 4. Weather Interactive Data Display System (WIDDS)

The Air Force Weather Agency's (AFWA's) Java-based interactive visualization tool, WIDDS, scheduled to go operational in early 2006, will allow forecasters to interact with both terrestrial and space weather data, enabling them to tailor weather visualizations to fit the needs of their customers. WIDDS was borne out of the warfighter's desire to have interactive display of both weather observations (METARS, SPECIs and Synoptics) and Terminal Aerodrome Forecasts (TAFs) for the entire world (Figure 17). The application will also display data specific to aviation interests, including AIREPS and PIREPS. WIDDS has been expanded to incorporate visualizations of space weather data including lonosonde data and magnetics plus model output from the Parameterized Realtime Ionospheric Specification Model (PRISM) (Figure 18) and, in the future, model output from the Global Assimilation of Ionospheric Measurements (GAIM) model. The WIDDS interface will enable forecasters to not only zoom into an area of interest but also to select parameters such as data density, data fields (such as

altimeter, ceiling, visibility, etc for METARS) and various METWATCH controls to meet specific warfighter needs. Future plans for WIDDS include visualization of forecast model output data, incorporation of the Commercial Joint Mapping Toolkit rendering engine and eventual replacement of the Interactive Grid Analysis Display System (IGrADS), AFWA's current flagship application for interactive visualizations of terrestrial data.

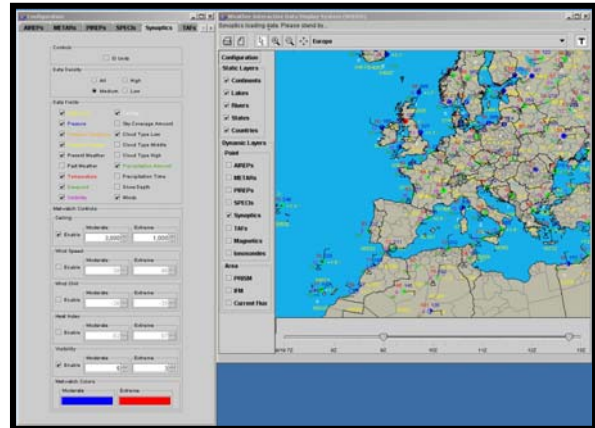


Figure 17. WIDDS TAFS over South America, with mouse over one location and displays raw TAF.

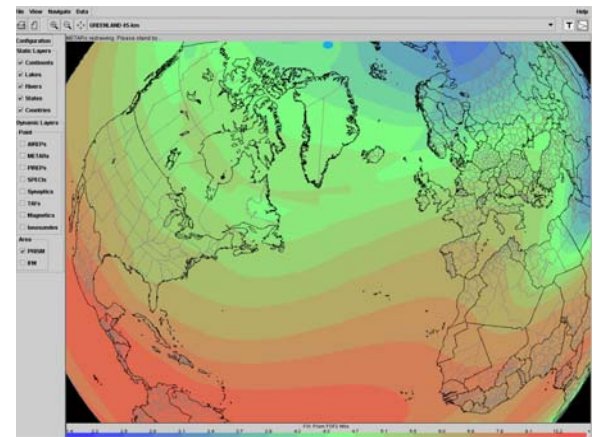


Fig 18. PRISM Model output of FOF2 over the North Atlantic

#### 5. CONCLUSION

IGrADS has proven to be an extremely popular and effective interactive numerical weather forecast visualization tool. It gives forecasters the ability to create products tailored to address their specific mission requirements and deliver the requested product quickly, typically within 30 seconds of making the request. IGrADS is available over the Air Force Weather Agency's webpage, JAAWIN (on three security levels). This interface was developed at HQ AFWA and has been operational since early 2002.

It is available to anyone with “.mil” access to the web and by password through “.gov” accounts for official use.

The interface enables forecasters to create (potentially) many hundreds of millions of varieties of visualized or alphanumeric products designed to meet their customers’ needs. These products range from meteograms, skew-Ts, vertical cross-sections, forecast maps, and seven different types of alphanumeric meteorological output. Forecasters have the option of choosing from among eight different forecast models with worldwide coverage for two. The most extensive product lines are available for AFWA’s MM5. As noted, this will be supplanted with WRF once that model is declared operational.

The AFWA’s Java-based interactive visualization tool, WIDDS will allow forecasters to interact with both terrestrial and space weather data, enabling them to tailor weather visualizations to fit the needs of their customers. It will display observational data, from METARS, SPECIs, Synoptics, AIREPs, PIREPs, and TAFS, to an ever expanding suite of space weather data.

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