THE INTERACTIVE GRID ANALYSIS AND DISPLAY SYSTEM (IGrADS) 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.

With the fielding of AFWA's MM5 production line, a huge suite of visualizations were 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 being 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) (Doty et al. 1995; Doty et al. 1997; COLA 2004) software visualization tools.

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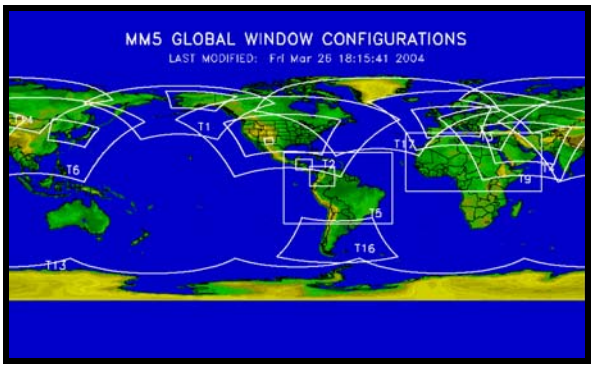

Figure 1. Recent AFWA MM5 theater configuration – March 2004.

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).

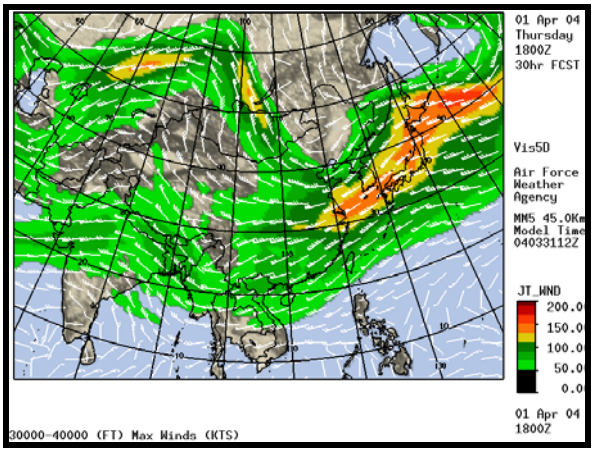

Figure 2. Sample AFWA Vis5D visualization.

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.

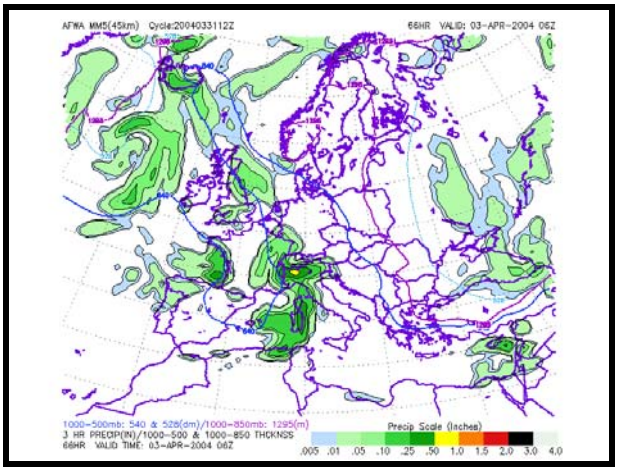

Figure 3. Sample AFWA GrADS visualization.

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. INITIAL EFFORT

AFWA's first interactive tool was known as the Interactive Meteogram and Skew-T (IMaST) program. This interactive tool allowed JAAWIN users to create meteograms and forecast skew-Ts based upon the AFWA MM5, NCEP Eta and MRF, and Fleet Numerical Meteorology and Oceanography Center's (FNMOC) Navy Operational Global Atmospheric Prediction System (NOGAPS) data (Figures 4 and 5).

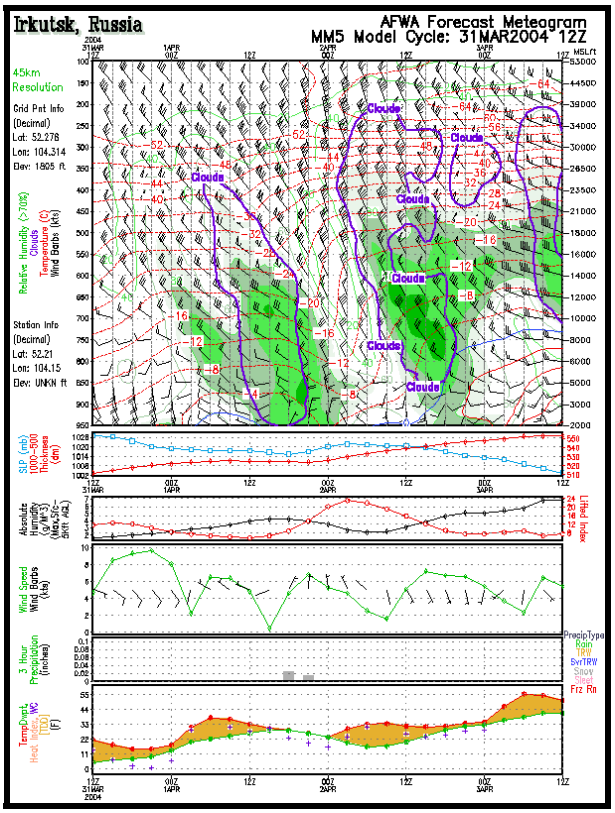

Figure 4. Sample MM5 meteogram created with IMaST (now IGrADS).

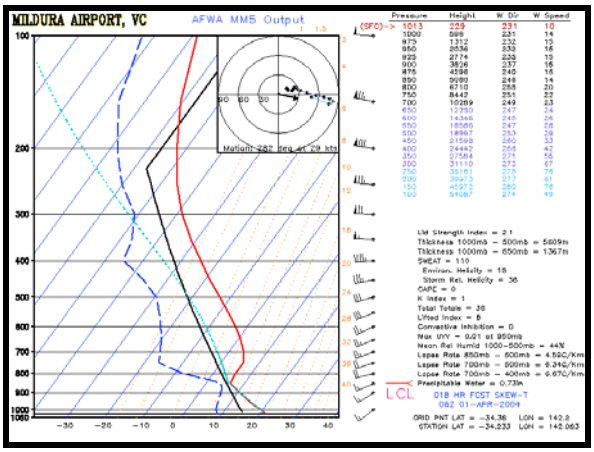

Figure 5: Sample forecast skew-T created with IMaST (now IGrADS).

These applications were created using the GrADS visualization tool (Doty et al. 1995; Doty et al. 1997; COLA 2004) and enabled the user to choose the location by entering the desired ICAO, clicking on a map, or entering the desired latitude and longitude. Through the graphical user interface (GUI), the

customer would also choose the numerical model, product type, forecast hour (for skew-Ts), and select a map projection (either a world map, MM5 theater maps, or the Eta domain). Field forecasters were unanimous in their enthusiasm and praise following IMaST's unveiling on 1 May 2001. An immediate benefit was a cessation of the addition of new pre-staged meteogram locations, as customers could create any location they desired on-the-fly. In addition, requests for new capabilities quickly began arriving and upon completion of the IMaST baselining, AFWA's Technology Exploitation Branch immediately set out to develop a much-expanded interactive tool, which came to be known as IGrADS.

3. 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:

a. 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

b. Meteorological model output available through IGrADS:
- AFWA MM5
- AFWA Diagnostic Cloud Forecast (DCF) Algorithm (Eylander and Evans 2003; Norquist 2000)
- AFWA Advect Cloud Model
- NCEP GFS
- NCEP Eta
- US Navy NOGAPS
- US Navy COAMPS
- UKMO Middle East Theater

c. Products offered by IGrADS:
- Meteograms (MM5, Advect 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)
- Alphanumeric output products

d. 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
- GFS-based
  -- "FOUS" bulletin (0 to 180 hours at 3 hour intervals)
  -- RAOB bulletin
  -- Precision airdrop wind profile
  -- Chemical downwind message
  -- Basic wind 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 14,000 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.

4. 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 (Figure 6) 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, International Civil Aviation Authority (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.

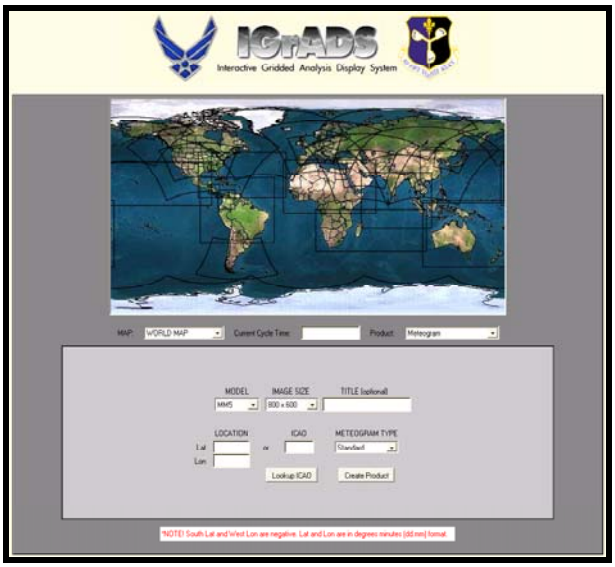

Figure 6: Default IGrADS GUI with world map.

As one begins to use the various selection boxes, the options appear in drop-down menus (Figure 7).

a. Meteograms

The meteogram was previously shown (Figure 4), as it was available in IMaST. The user-defined IGrADS meteogram (Figure 9) 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 (Figure 4). 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 (Figure 9).

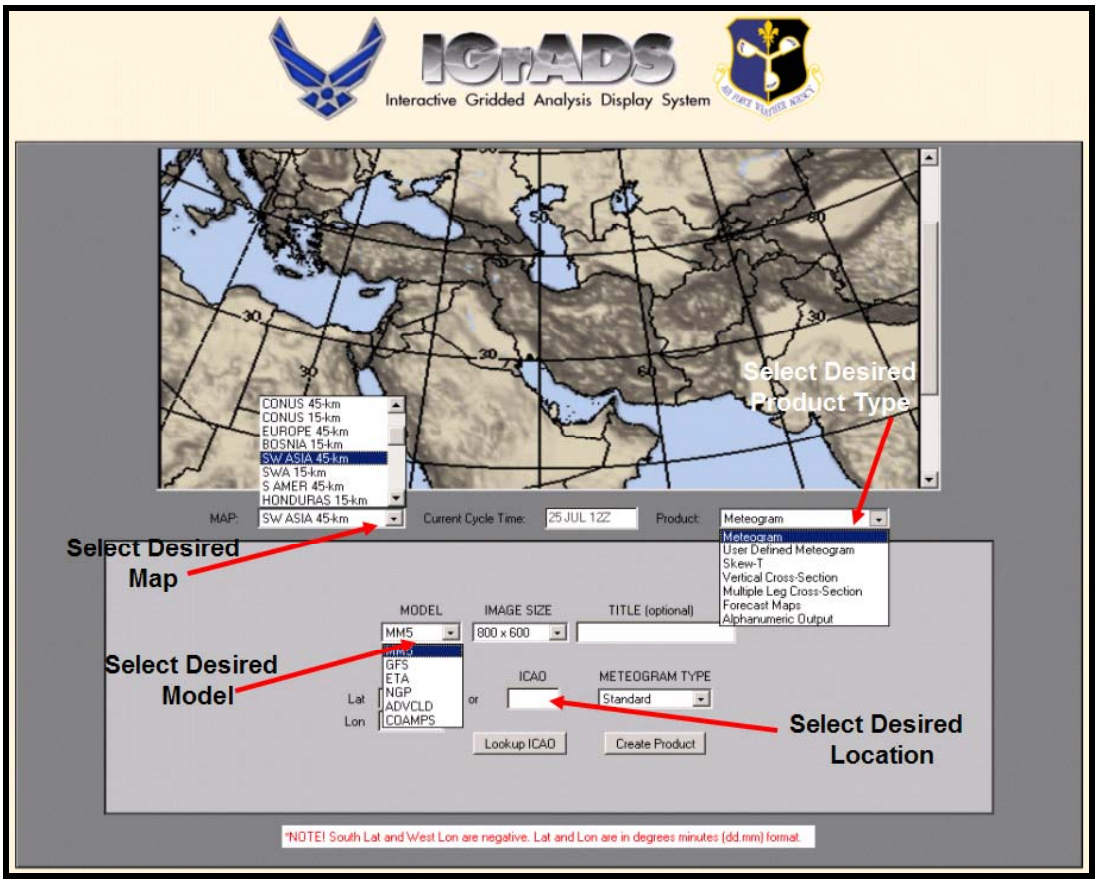

Figure 7: IGrADS GUI with drop-down selection boxes

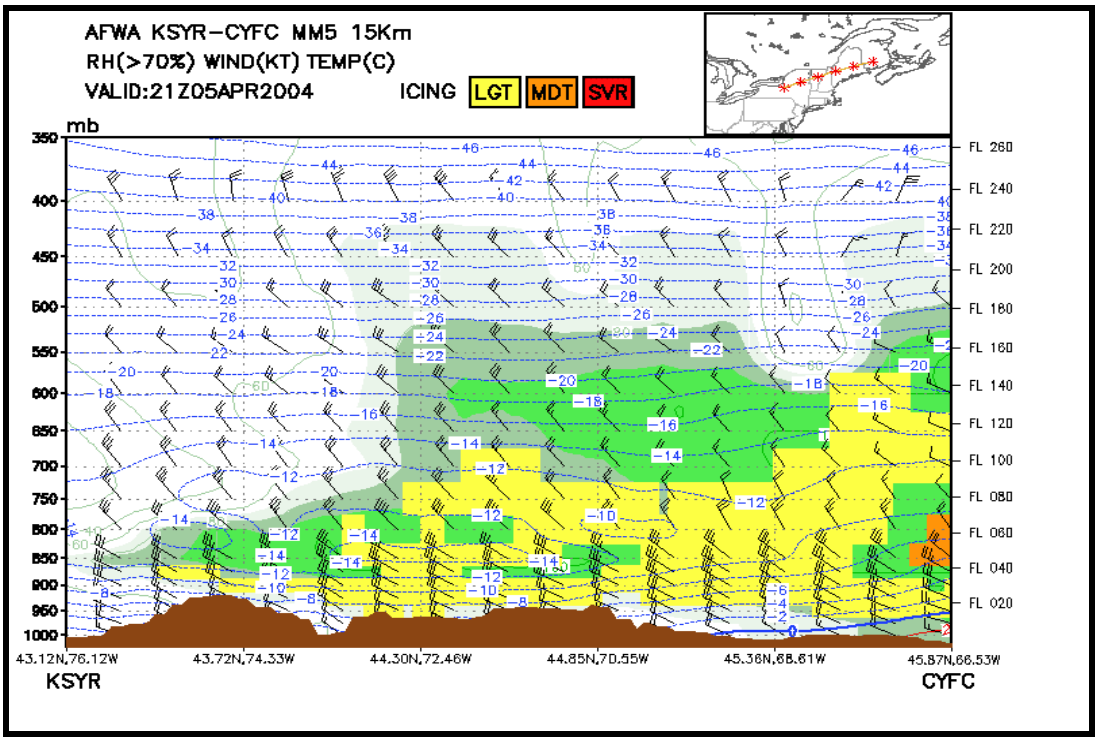

Figure 8. Vertical Cross-Section; Syracuse NY to Fredericton NB, MM5 15 km resolution

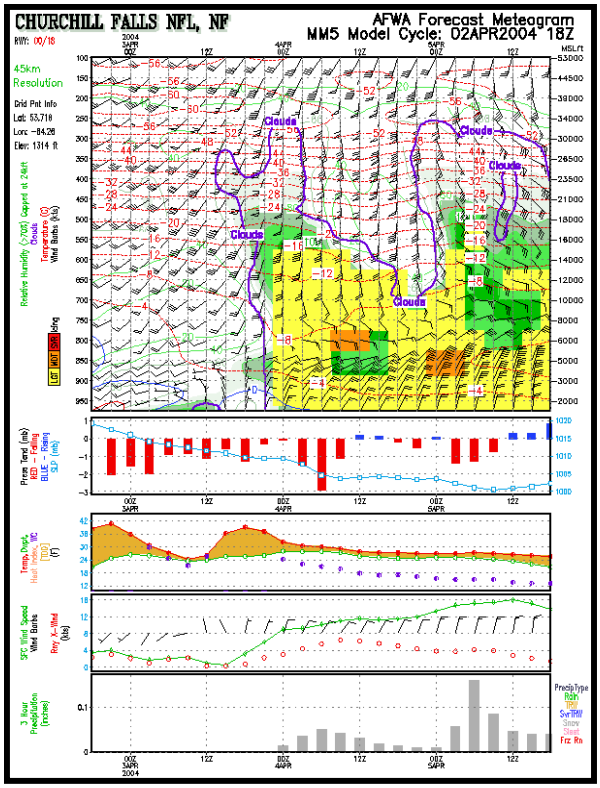

Figure 9. IGrADS user defined meteogram for Churchill Falls, Canada.

b. 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 8). 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.

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.)

c. Multi leg vertical cross-sections

The multi leg cross-section is similar to the vertical cross-section with the added capabilities that three terminals (or ICAOs) can be selected and a different valid time picked for each leg of the cross section. The same set of models and parameters are available for this product (Figure 10).

d. 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 different forecast maps can be created to fit the forecasters' specific needs. Furthermore, the maps can be the default for the entire theater, or the forecaster can draw a rectangle within the theater (or enter pairs of coordinates) to define the desired map (Figures 11-16).

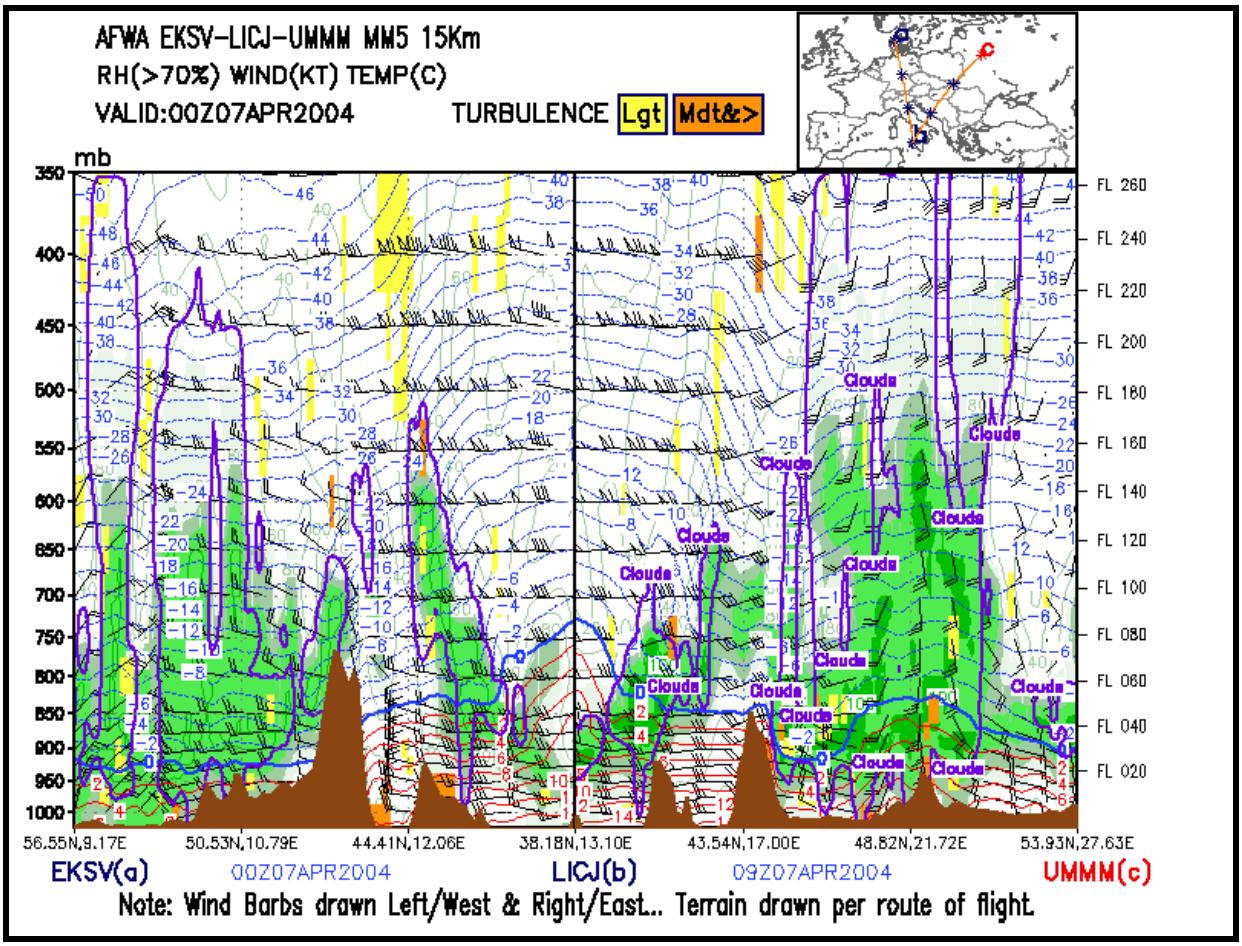

Figure 10. Multi Leg Vertical Cross-Section; Skive, Denmark to Palermo, Italy to Minsk, Belarus, MM5 15 km resolution

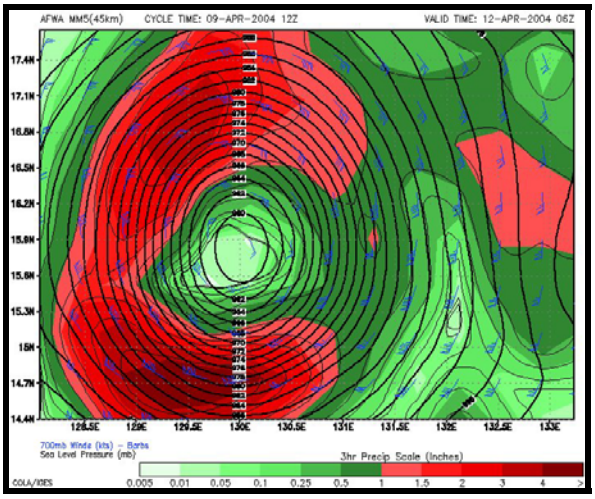

Figure 11. Typhoon Sudal (Apr 04), southwest of Guam with sea level pressure (black), 700 mb winds (blue barbs), and past three-hour precipitation (color-filled).

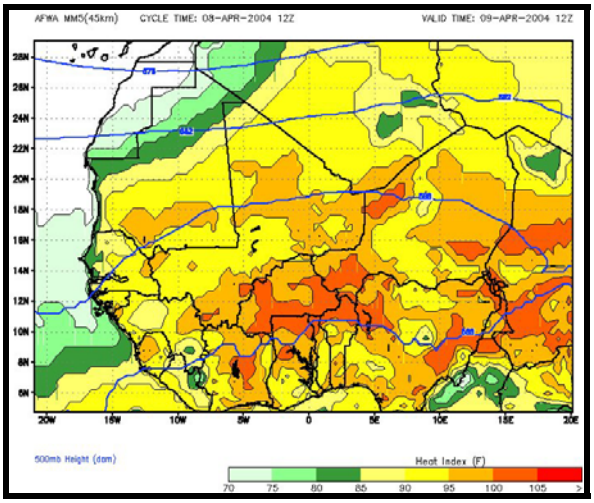

Figure 12. Heat index (^{o}F) and 500mb heights, AFWA MM5 (45 km)

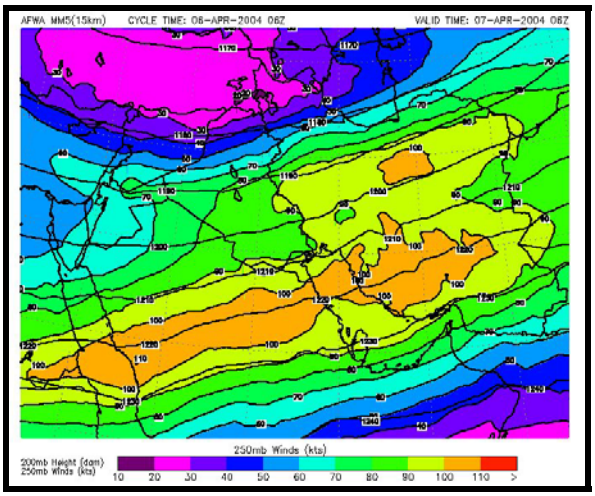

Figure 13. 250 mb wind velocities (color filled) and height contours (black), AFWA MM5 (15 km)

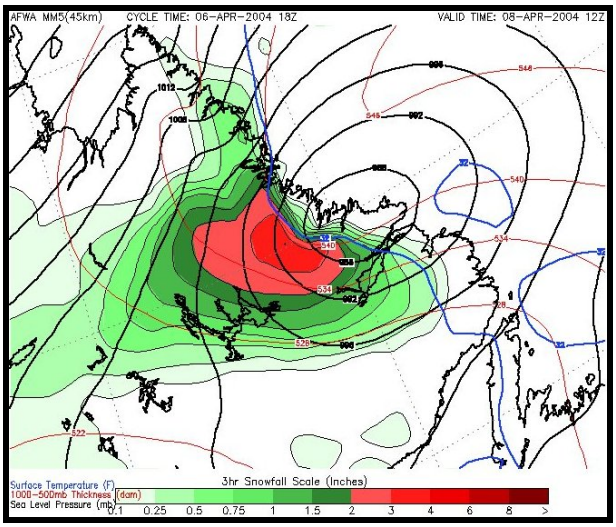

Figure 14. Three-hour snowfall accumulation (color filled), sea level pressure (black), 1000-500 mb thickness (red), and surface freezing line (blue), AFWA MM5 (45 km).

e. Alphanumeric output

Many IGrADS customers shared desires and requirements for alphanumeric meteorological model output in both existing and newly devised formats. The biggest advantage that IGrADS provides is that the user can specify the location and valid time and not be tied to existing pre-staged bulletins.

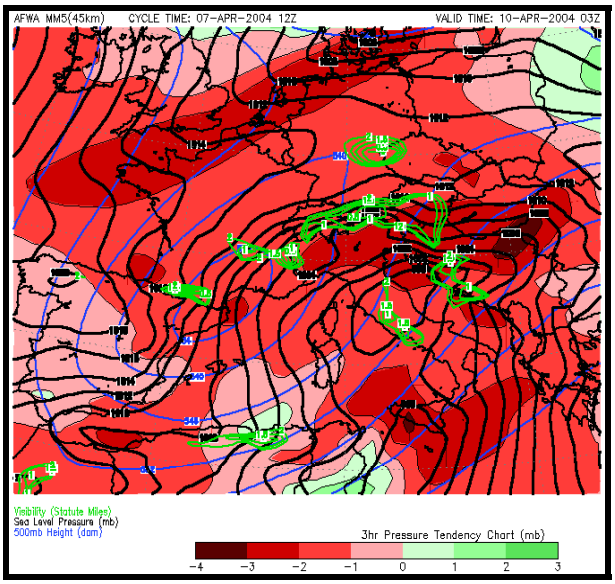

Figure 15. Three-hour pressure tendency (color filled), sea level pressure (black), 500 mb heights (blue), and surface visibility <= 2 miles (green), AFWA MM5 (45 km).

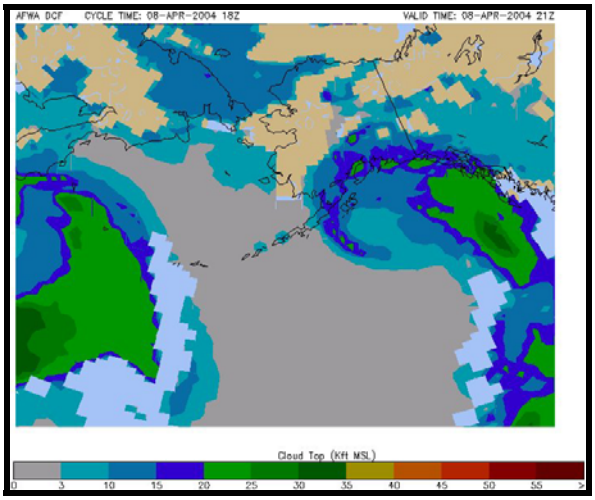

Figure 16. Diagnostic cloud forecast cloud top product, AFWA MM5 (45 km).

There are two products similar to NCEP's Eta and NGM FOUS bulletins. They 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 17). 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. 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 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 195m 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 of AFWA's MM5 and near world-wide land coverage combine to make it a perfect match for the Army's mission requirements.

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44.80N 68.82W
OUTPUT FROM MM5 15KM 06Z Apr 05 04
TTPTTR1R2R3 VVVLI PSDDFF HHT1T2T3W CIGVIS
KBGR/899999 03910 923313 29019795  001012
09012839899 00712 923116 28999694S 001022
12005759399 01413 933116 28999593S 001063
15005759299 -0115 953017 27989492S 001047
18003759299 -2917 962917 26979391S 002073
21001739199 -2718 972916 26979390S 008119
24001749299 -2619 972815 26969290S 003108
27001739199 -3320 972816 27969289S 031100
30000729099 -1421 982816 27959188  031105
33000678698 -2620 992815 28969290  037124
36000628195 -1717 982914 28999592  037124
39000648295 -2016 002916 27999592  037124
42000708798 -3814 022916 25989492  034124
45000739199 -2911 022914 25989492  031108
48000749399 -1710 022812 26989492  031090


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

Bulletin data derived from model Grid Point 44.758N and 68.715W

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

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. This will be supplanted with Weather Research and Forecasting (WRF) Model once it is declared operational.

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